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University of the Witwatersrand

School of Geography, Archaeology and Environmental Studies

A Glimpse at the 17th Century Cape Climate of Southern Africa: Documentary Based Evidence from the Jan Van Riebeeck Diaries

A dissertation submitted to the Faculty of Science in fulfilment of the requirements for the degree Master of Science

Ravanya Naidoo

Johannesburg, September 2016

Declaration

I hereby declare that this dissertation is my own, original, work, except where otherwise acknowledged. It is being submitted for the degree Master of Sciences to the University of the Witwatersrand, Johannesburg. I have not submitted this work in part or whole previously, for the purpose of obtaining any degree, qualification, or otherwise, at this or any other university.



02/09/2016

Ravanya Naidoo

Date

Abstract

The diaries of Jan van Riebeeck contains one of the oldest documentary records of weather phenomena for the southwestern Cape. They contain descriptions of daily wind direction and strength and daily rainfall events. The primary aim of this research is to reconstruct a comprehensive weather chronology for the southwestern Cape region from these diaries, spanning the period 1652-1665, and place this in context with the 20th-21st C climate for the region. The study further aims to examine the relationships between the 17th C society and natural environment. All climate and environmental information is extracted from the diaries and tabulated. Qualitative information on wind and rain was classified and transformed into quantitative data. Contemporary data retrieved from the Royal Observatory and the South African Weather Services are used to make comparisons between the historical study period and contemporary conditions. However, due to the qualitative nature of the historical data, statistical analysis demonstrated that such comparisons are limited. Within the historical period, analysis of the number of rain days demonstrated a distinct wet period in the first half followed by progressive drying. Wind data from the diaries reflected distinct seasonality linked to shifts in the position of the ITCZ. Additionally, unusual events including snow, hail, the Black south-easterly and 'dirty rain' are explored. Qualitative data revealed a heavy reliance on climate to support crops and livestock, and a range of environmental stresses to human health, infrastructure and food security.

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List of Acronyms

C: Century

CDD: Consecutive Dry Days

CWD: Consecutive Wet Days

DEA: Department of Environmental Affairs

DEIC: Dutch East India Company

DW: Dryness/Wetness Index

E: Easterly [wind]

ENSO: El Niño Southern Oscillation

ITCZ: Inter-Tropical Convergence Zone

IUCN: International Union for Conservation of Nature

LIA: Little Ice Age

MWP: Medieval Warm Period

N: Northerly [wind]

S: Southerly [wind]

SRZ: Summer Rainfall Zone

UCT: University of Cape Town

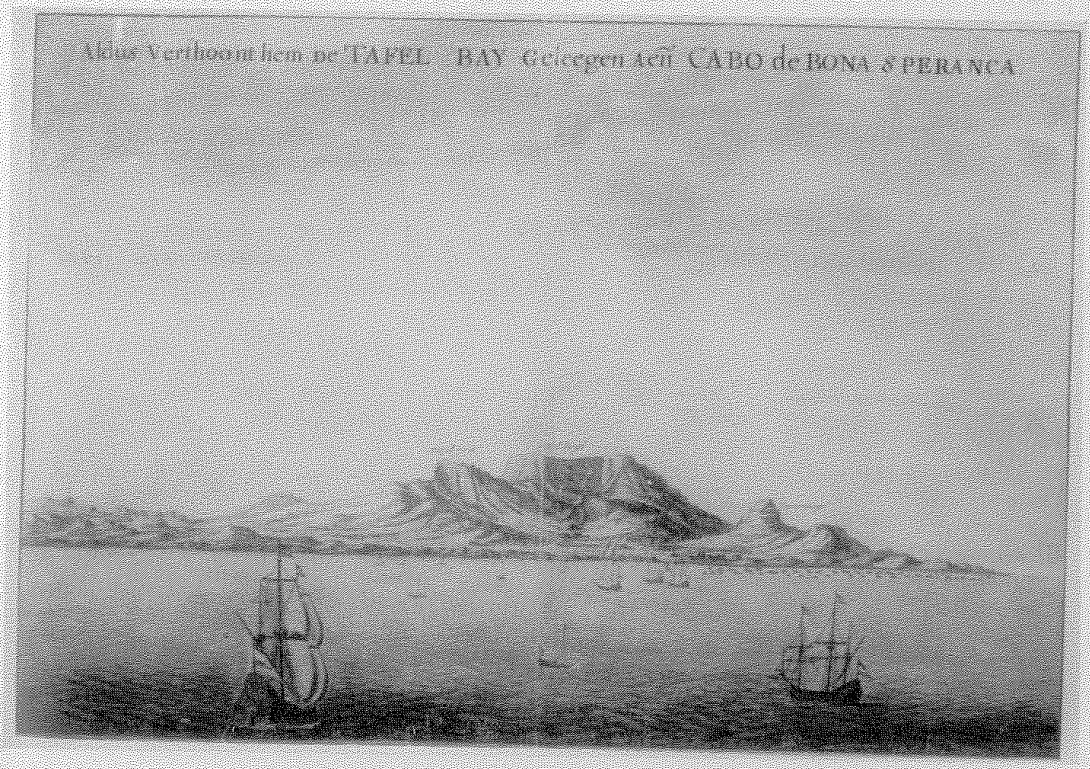
W: Westerly [wind]

WMO: World Meteorological Organization

WRZ: Winter Rainfall Zone

YRZ: Year-Round Rainfall Zone

Chapter 1: Introduction



VIEW OF THE CAPE OF GOOD HOPE, ABOUT 1655

The earliest known picture of Van Riebeeck's settlement. It is reproduced from a water-colour in the State Archives, The Hague.

1.1 Historical Climatology: An Overview

During the past decade, ‘climate change’ has rapidly moving up local and international agendas, based on its ever-increasing impact on poverty, human health and food security. There is a particular focus on climate modeling, so as to better determine likely future climate scenarios. Research on past climates can provide meaningful insights to help improve such modeling. To this end, historical records are a rich source of unexplored data that contain a wealth of weather and climate accounts over periods that may even extend centuries back in time. Globally, and particularly in Africa, the field of historical climatology is still new relative to their more well established counterparts, such as climate science and meteorology.

1.1.1 Definitions

The term historical climatology has various definitions depending on the context in which it is used. It is a term used to perform time series analysis based on historical instrumental data (Brãzdil et al., 2005), and to interpret the climate from historical documentary sources (Ingram et al., 1978; Nash et al., 2015). Although the entire Holocene period has been considered *‘historical’* by Fairbridge (1987), Bradley (1999) argues against this as it then overlaps with palaeoclimatology (Bradley, 1999). The combination of these two terms, ‘historical palaeoclimatology’, seeks to include periods for which written climatic information, in a direct or indirect sense, is available (Hagedorn and Glaser, 1990). However, according to Pfister et al. (2009), historical climatology is not to be confused with palaeoclimatology. Historical climatology entails using mainly documentary sources that present commentary on climate from different time periods, while palaeoclimatology is concerned with reconstructing past climates based on proxy evidence, such as sediments, tree rings, corals and ice sheets, derived from the biophysical environment (Pfister et al., 2009; Quick, 2013). This has more recently been reiterated by Mauelshagen (2014), who articulates that historical climatology should be viewed as intermediary between paleoclimatology and instrumental climatology.

Initially, the sub-discipline of historical climatology was predominantly concerned with a research focus on the analysis of climate variations during historical times. However, historical climatology has rapidly evolved into an interdisciplinary field of research where the natural

sciences and social sciences have been interwoven (von Storch and Stehr, 1997). This has resulted in climate reconstructions that contain both climatic and social and environmental variables. A well-recognised definition for historical climatology, provided by Pfister et al. (2009), states that it is a field of research at the boundary of environmental history and climatology, using primarily documentary evidence and combining climatological and historical methodologies. The following objectives, as outlined by Brázdil et al. (2005), build a framework for this definition:

- To reconstruct weather patterns (spatial and temporal) and climate induced natural disasters before the establishment of national meteorological organizations,
- To assess the vulnerability of historical economies and societies to climate related anomalies and,
- To investigate historical perceptions and representations of the climate

More recently, Mauelshagen (2014) defines the field of historical climatology as one that shares similar methodologies to paleoclimate research, however, where paleoclimatology uses natural proxy archives (those preserved by nature, which provide inferred information about past climates), the field of historical climate uses human archives (preserved human records which directly mention the climate) for climate reconstructions. This definition is based on extensive research of the field of historical climatology, including the critical review of past definitions, methodologies and previous research work producing a contemporary definition that concisely and accurately describes the field of historical climatology (Mauelshagen, 2014). Hence, this was the chosen definition for this research. Scholars within this field of research (cf. Mauelshagen, 2014) have sub-divided this branch of climate science into three major study areas including:

- climate reconstructions
- the impacts of climate on societies
- the dimensions of perception, ritual, knowledge and science between society and their interactions with climate

Through the ages, ancient weather observations have attempted to relate the weather to other factors such as floral and faunal behavioural characteristics and has slowly emerged into a quantifiable science (Kington, 1988). Even in the 1600s when the barometer and thermometer

were invented, travellers and explorers would document weather conditions in diaries, letters and journals (Kington, 1988). In the distant past, archives were the exclusive domain of interest to historians and genealogists (Catchpole and Moodie, 1978). Interest from environmental scientists in climate reconstructions have been prompted by an advancement in scientific methods and global concerns, such as Malthusian's theory of overpopulation, diminishing natural resources and deteriorating environmental conditions (Catchpole and Moodie, 1978). During recent years, researchers have begun using these documentary sources to extract climatic data and reconstruct the climate of the historical past (Table 1.1). Careful examination of documentary sources can reveal detailed weather accounts which may then be used as a substitute where instrumentally recorded weather data are absent. Research in historical climatology has become more prominent in recent years due to the impact changing climate is imposing on global communities and the realization of the value of documentary sources to help reconstruct past weather and climate.

Table 1.1: Prominent early work in scientific historical climatology (after Brázdil et al., 2005).

Scientist/Researcher	**Country**	**Reconstruction**
Louis Dufour	Switzerland	In 1870, discovered that harvest dates may be used in order to reconstruct temperature records in the pre-instrumental period.
Alfred Angot	France	In 1885, created a catalogue of the available documentary evidence for France.
Eduard Brückner	Switzerland	In 1890, used a preferred time scale of 35 years and examined instrumental and historical data from different parts of the world observing climate fluctuations since 1790.
Gustav Hellmann	Germany	In 1921, scientifically compiled historical documents.
Charles Ernest Pelham Brooks	England	In 1926, influenced the work of Hubert H. Lamb (1913-1997) and Gordan Manley (1902-1980).
Emmanual Le Roy Ladurie	France	In 1967, Wrote a prominent monograph on the impacts of climate on historical society over the last millennium.
Hubert Horace Lamb	Britain	Between 1913-1997 produced extensive work analysing climate variations in the 1800s and was the first to develop synoptic charts using documentary data to show pressure distributions.

Table 1.2: Prominent historical documentary based climate reconstructions

Author	Year	Time Period	Location	Other Proxies Used	Reconstruction Type
Catchpole et al.	1976	18th-19th C	Hudson Bay, Canada		Freeze and break-up dates
Vogel	1989	1820-1900	Cape region, South Africa		Changes in dryness/wetness
Wanner et al.	1995	1675-1704	Western Europe		Winter temperature and precipitation indices
Nash	1996	1750-1910	Kalahari region		Hydrological change
Koslowski and Glaser	1999	1501-1995	western Baltic Sea		Winter ice index
Pfister et al.	1999	16th C	Europe		Climate chronology
Rodrigo et al.	1999	19th C	Southern Spain		Precipitation chronology
Alcoforado et al.	2000	AD 1675-1715	Southern Spain		Temperature and precipitation chronology
Song	2000	AD 1470	China		Changes in dryness/wetness
Liu et al.	2001	AD 975-1975	Guangdong, Southern China	Instrumental data	Time series of typhoon landfalls
Nicholson	2001	19th-20th C	Africa		Climate and environmental chronology
Endfield and Nash	2002a	1815-1900	central southern Africa		Changes in dryness/wetness
Endfield and Nash	2002b	1815-1900	central southern Africa		Changes in dryness/wetness
Nash and Endfield	2002	1815-1900	Kalahari region		Rainfall chronology
Chenoweth and Thistlewood	2003	1750-1786	Jamaica		18th C Climate chronology
Dobrovolný and Brázdil	2003	AD 1500	Czech Republic		Chronology of strong winds
Herrera et al.	2003	1750-1920	Santiago del Estero, South America		Precipitation chronology
Guiot et al	2005	mid 18th C	Western Europe	Multiple proxies	Summer temperature variations
Pauling et al.	2006	1500-1900	Europe	Multiple proxies	Precipitation chronology
Gergis and Fowler	2006	AD 1525-2002	China, India, Nile	Multiple proxies	Rainfall chronology
Jones and Briffa	2006	1730-1745	Northwest Europe	Instrumental data	Climate chronology
Tompkins	2007	1842-1852	Southern Yukon, Canada		Seasonal warm/cold index
Kelso and Vogel	2007	19th C	Namaqualand		Changes in dryness/wetness
Rodrigo and Barriendos	2008	16th C	Spain (Iberian Peninsula)		Seasonal and annual rainfall
Cœur and Lang	2008	15th-19th C	Europe		Flood and extreme flood events
Prieto and Herrera	2009	1548-1810	Northwestern Argentina		Precipitation chronology

Gergis et al.	2009	1788-1791	New South Wales		Climate chronology
Holmes et al.	2009	19th C	Western China	Multiple proxies	Climate chronology
Aono and Saito	2010	4th-9th C	Kyoto, Japan	Phenological data	Temperature reconstruction
Battipaglia et al.	2010	1550-2003	Central Europe	Tree-ring density	Temperature extremes
Brázdil et al.	2010	1500-2007	Central Europe	Instrumental data	Temperature series
Gergis et al.	2010	18th C	Australia		Social and environmental chronology
Glaser et al.	2010	AD 1500	Central Europe		Flood variations
Grab and Nash	2010	1833-1900	Lesotho		Cold season chronology
Nash and Grab	2010	1824-1900	Lesotho		Rainfall chronology
Adamson and Nash	2012	1781-1878	western India	Instrumental data	Annual monsoon onset dates
Brázdil et al.	2012	AD 1119-2010	Czech Republic		Tornado chronology
Büntgen et al.	2012	AD 1347-1900	Europe		Plague outbreak chronology
Berland et al.	2013	AD 1770-1890	Antigua, Lesser Antillles		Rainfall chronology
Gergis and Ashcroft	2013	AD 1788-2008	southeastern Australia	Multiple proxies	Rainfall chronology
Neukom et al.	2014	$19^{th} – 20^{th}$ C	southern Africa	Multiple proxies	Winter and summer rainfall chronology
Ashcroft et al.	2014	AD 1788-1859	southeastern Australia	Instrumental data	Inter-annual climate variability chronology
Domínguez-Castro et al.	2014	AD 1855-1856	Iberian Peninsula	Multiple proxies	1 year rainfall chronology
Enzi et al.	2014	$18^{th} – 20^{th}$ C	Italy		Snowfall reconstruction
Hannaford et al.	2015	AD 1796-1854	southern Africa	Instrumental data	Winter and summer rainfall chronology
Domínguez-Castro et al.	2015	AD 711-1010	Iberia		Drought reconstructions
Santos et al.	2015	$17^{th} – 20^{th}$ C	Lisbon, Portugal	Multiple proxies	Temperature series
Prieto and Rajos	2015	$17^{th} – 20^{th}$ C	Bermejo River, Argentina		Drought and flood events reconstruction
Nash et al.	2015	1862 – 1900	Madagascar		Tropical cyclone reconstruction
Norrgård	2015	AD 1750-1800	West Africa		Inter-annual and inter-decadal climate chronology
Nash et al.	2016	1836–1900	KwaZulu-Natal, South Africa		Rainfall seasonality and variability chronology

The sub-discipline of historical climatology has expanded greatly since its early beginnings, with historical documentary-based research now being globally pursued. The field of historical climatology emerged during the 19th C with work restricted to a few prominent scientists as indicated in Table 1.1. European based historical climate chronologies are the most extensive, followed by those in Asia, the Americas, Africa and Australia. These works are proving exceptionally useful in reconstructing global teleconnections of the past. Some of the documentary based case studies are summarised in Table 1.2. Particularly in regions where instrumental data are lacking, these documentary sources provide the only evidence of past climatic impacts on society (Nash and Adamson, 2014).

The study of historical climatology has become important given that the various case studies have shown the impacts of climate on society. These historical reconstructions prior to the industrial revolution have highlighted the minimal impacts of anthropogenic activities on the natural environment, at local or regional scales (Ashcroft et al., 2014). The increasing ability of multi-national corporations to have access to several regions simultaneously, has allowed for the destruction of the natural environment on a global scale over recent decades (Brázdil et al., 2005).

1.2 Documentary Evidence

Proxies in the field of climatology are measurable variables that can be used to quantify changes in another variable; for example flood-marks on structures may provide evidence of past extreme flood events, and their distance may indicate the extent of flood levels (Pfister et al., 2009). Agents such as religious institutions, individuals and private households offer evidence in the form of accounting documents (e.g. tax), weather data (e.g. weather diaries) and observed weather patterns (e.g. written in letters) (Pfister et al., 2009). The reasons given by Pfister et al. (2009) for the different types of record keeping vary from climatic forecasting to diarising a memory of severe natural disasters. According to Glaser (1996), proxy data may be of either a qualitative or quantitative time series. In order for the interpretation to be reliable, a holistic approach must be taken, which will involve an intensive study of historical documentary records, as well as the use of climate proxies (Bradley, 1991; Glaser, 1996; Guiot et al., 2005). For

example, soil type can be used as a measure to assess harvest yields, and agricultural techniques may be a result of biophysical environmental conditions.

A variety of data sources exist which allow for the reconstruction of past climate. The data sources may fall into one of three groups, including descriptive data, proxy data and instrumental data (Glaser, 1996). Descriptive data sources are written accounts that include diaries, letters and chronicles, while proxy data sources include various data types that indirectly contain climatic information. For example, tree ring data can indicate wet and dry periods of a region over time and diatoms can provide evidence for changes in water quality (Nash and Adamson, 2014). Instrumental data sources are those that are recorded numerically from weather instruments such as a barometer that is used to measure atmospheric pressure (Glaser, 1996; Nash and Endfield, 2002). However, according to Dominguez-Castro et al. (2014), documentary sources may have up to a sub-daily data resolution that is very refined given the subjectivity of the data type. These documents are generally found in local archives and if located in international archives, then these need to be retrieved in order to obtain this unique climate data for reconstructing the climate of the past.

Validation of data is required in climate reconstructions, to assess the level of accuracy and usefulness of the reconstruction (Mann et al., 2007; Wahl and Ammann, 2007). The validation process requires the documentary data to be calibrated against instrumental data, which involves advanced mathematical procedures (Mann et al., 2007; Wahl and Ammann, 2007). However, instrumental data are not always available for all regions, even during the instrumental period. The instrumental period is also not always long enough to make complete inferences on climate variability (Jones, 2001). In latter sections of the literature review, various studies on documentary derived climate chronologies will be highlighted, particularly those for Africa.

1.3 Motivation

According to Glaser (1996), the study of historical climatology is particularly important because it allows for the expansion and enhancement of our knowledge of climatic processes and associated human relationships with the environment through recent times. As documentary based climate reconstructions have become more prevalent in academia during recent times, there exists a variety of successful case studies from all over the world (as shown in Table 1.2).

Expansion of the knowledge base in historical climatology throughout various parts of the world is necessary for the production of a thorough global inter-annual climate chronology, prior to the instrumental period (Pant, 2003). A large volume of historical climate/environmental reconstructions has been undertaken for Africa, and southern Africa in particular, for which a brief overview is provided in Table 1.3. Furthermore, in regions where extensive climate reconstructions have been completed for multiple sub-regions, the next step has been to consolidate and reconstruct statistically significant rainfall and/or temperature patterns spanning larger regions. One such southern African study, that is also pertinent to this dissertation, involved collating several documentary derived research works (mentioned in Table 1.3) as well as other proxies (e.g. tree ring studies in Zimbabwe; Therell et al., 2006) to produce a multi-proxy winter and summer precipitation record (Neukom et al., 2014). A more detailed account of the African research work (including East, West and North Africa) is provided in the Literature Review chapter of this dissertation.

The southwestern Cape region was the first in South Africa to be settled by Europeans. There are thus abundant written records of the early Cape settlement, which also offers the oldest South African written sources on historical weather and climate. There are only three published academic articles on historical climatology for the Cape region; these include a 19th C climate chronology for the Western Cape and Eastern Cape regions (Vogel, 1987, 1988, 1989) and a 19th C climate chronology for Namaqualand (Kelso and Vogel, 2007). Aside from the climate reconstructions, further work by Kelso (2010) highlighted the relationships between the Namaqua Khoi people and European settlers, as well as their ability to cope with and adapt to climate stressors within a socio-economic and the social and environmental context (Kelso and Vogel, 2015).

Table 1.3: Southern African case studies using documentary evidence

Reference	Location	Reconstruction	Results	Possible Influences
Vogel (1987, 1988, 1989)	Cape region, South Africa	Climate chronology for the period 1820 – 1900. Objectives of the study: to determine whether the 20th C climate had altered or remained similar to that in the past, and to gauge the frequency of drought episodes	The wet and dry periods were inconsistent, relative to the wet and dry periods first assumed	The results showed a direct relationship where low-phase ENSO events were related to below normal rainfall, whilst high-phase ENSO events were related to above normal rainfall
Nash and Endfield (2002)	Kalahari Region	19th C Climate Chronology: Rainfall record 1815 – 1900	The chronology showed good agreement with the limited instrumental data available for the study period	Incidences of drought or low summer rainfall correspond with low-phase Southern Oscillation events
Nash and Endfield (2008)	Kalahari Region	Rainfall variability reconstruction, 1840–1900.	Sequences of rainfall/drought agree with contemporary seasonal patterns. Heavy rainfall commonly occurred prior to or at the very beginning of an ENSO year, with a drought following in the year after the ENSO event ends.	These were known ENSO warm events that were used to check the rainfall variability before, during and the year following the end of an ENSO warm event.
Kelso and Vogel (2007)	Namaqualand	19th C climate chronology.	Several dry and wet periods were identified.	Several drought or dry years were found to possibly be consistent with low phase ENSO
Grab and Nash (2010)	Lesotho	Climate chronology for cold seasons for the period 1833 – 1900	Relatively more severe cold seasons in the earlier part of the study period and milder conditions during the latter period (except for the 1880s).	When the NH experienced cooler than normal summers after volcanic eruptions, it may be seasonally reversed for the SH which experiences cooler than normal winters.

Nash and Grab (2010)	Lesotho	Climate reconstruction to assess rainfall patterns	Nine wet/flood periods as well as nine drought periods, however, no overall wetting or drying trend could be identified.	Of the nine drought periods, seven have been shown to coincide with low phase ENSO events
Nicholson et al. (2012b)	Southwestern Cape, South Africa	Rainfall reconstruction methodology, 1801 – 1900	Presented the availability of rain gauge and documentary data for 90 regions in Africa for potential research purposes.	Not applicable
Hannaford et al. (2015)	Southern Africa	Rainfall reconstruction, 1796 – 1854 using ships' logbooks evidence.	The 1810s were the wettest decade and the 1820s the driest for the summer rainfall zone (SRZ). For the winter rainfall zone (WRZ), the 1820s were found to be the wettest and the 1830s the driest.	Weak causal links were found between dry summer periods and the documentary reconstructed ENSO that followed. Further research is recommended.
Nash et al. (2015)	Madagascar	Tropical cyclones making landfall on Madagascar, 1862 – 1900.	Twenty tropical cyclones were identified, of which 17 corroborated with the International Best Track Archive for International Stewardship (IBTrACS). There were fewer tropical cyclones in the 19th C relative to the more recent contemporary period.	There was no significant correlation between the number of tropical cyclones making landfall and the Southern Oscillation Index (SOI) and the Dipole Mean Index (DMI). Further research has been suggested.
Nash et al. (2016)	KwaZulu-Natal, South Africa	Rainfall seasonality and variability chronology: 1836 – 1900.	Eight periods of severe drought and six periods of very wet conditions.	Strong connections between these extreme rainfall events and the ENSO cycle.

While several studies have provided detailed 19th C climate chronologies for various parts of southern Africa, thus far no study has attempted to construct detailed inter-annual climate chronologies for the 17th/18th C in the sub-continent. For instance, the diaries of Jan van Riebeeck (Thom, 1952, 1954, 1958) contain one of the oldest, nearly daily, ten year written records of weather phenomena for the southwestern Cape. Such sources provide a good indication of the typical weather over specific periods (i.e. thus an indication of climate), particularly wind strength and direction, as well as rainfall frequency (i.e. rain days). Climate data extracted from documentary sources are the only proxy that can reveal the severity and precise timing of when natural disasters occurred during the pre-instrumental period (Pfister et al., 1999, 2009). This study will provide a useful addition to the 19th C southwestern Cape documentary record (Vogel, 1989) and will also serve as the oldest record of its kind in Africa. It may be used to compare earlier 17th C climate characteristics with those of the more recent 19th – 20th C. Figure 1.1 places this study in context with those climate reconstructions that have been completed for later time periods.

Furthermore, contributing or improving climatological knowledge for the southwestern Cape region is equally as important as contributing to the existing southern African historical climate chronologies database. The climate of the southwestern Cape is distinctive, relative to other parts of southern Africa. Its Mediterranean climate will serve as a good comparison to other Mediterranean regions of the southern Hemisphere, such as that for southwestern Australia (Grab and Craparo, 2011). The region also has high levels of endemism and is globally one of the few biodiversity hotspots, and thus an important region for ascertaining past, present and likely future climate (Goodness and Anderson, 2013).

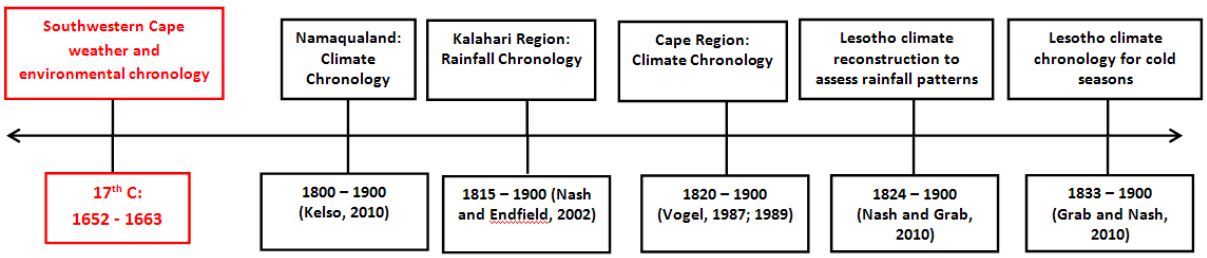


Figure 1.1: Knowledge Gap in the southern African context

1.4 Research Aims

Various South African archives were consulted to retrieve the oldest documents available for the southwestern Cape region. It was established that there is a substantial volume of documents available prior to the 19th C. For the 17th C, however, there are only 13 years of continuous nearly-daily weather entries in the Diaries of Jan van Riebeeck (Thom, 1952, 1954, 1958) and the Precis of the Archives of the Cape of Good Hope (Leibrandt, 1901). This begins from the European settlers' arrival at the Cape of Good Hope. Thereafter, there are several historical documents with scattered and disjointed climatic evidence throughout the 17th C across varying regions of the Cape. Thus, the primary aim of this research is to reconstruct a comprehensive weather chronology for the southwestern Cape region, spanning the period 1652-1665 (13 years), and place this in context with the 20th-21st C climate for the region. A secondary aim is to examine the relationships between the 17th C society and natural environment. This dissertation further aims to build on the existing work by Vogel (1987, 1988, 1989), Kelso (2010) and, Kelso and Vogel (2007; 2015) on documentary-based climate records for the Cape region.

1.5 Research Questions

1.5.1 Primary Question 1

To what extent is it possible to determine historical inter-annual weather patterns/ changes over the southwestern Cape region, based on documentary evidence for the period 1652-1665?

a. Are there distinct wet and dry years for the period 1652-1665?
b. Did the seasonality of rainfall vary between the historical period (1652-1665) and the 20th C?
c. Do the number of rain days differ between the historical period (1652-1665) and the 20th C?
d. What are the dominant patterns in wind direction and strength, and did they vary over the study period?
e. Did the wind patterns influence the extremity of wet and dry periods?
f. Could severe wet or dry periods be attributed to possible ENSO events or other natural environmental anomalies during the period of observation?

1.5.2 Primary Question 2

To what extent have the historical documents assisted in portraying environmental and/or societal changes in the southwestern Cape during the period 1652-1665?

a. What adaptation and coping strategies did the early Cape settlers embrace to overcome weather and environmental stressors?
b. What indigenous flora and fauna existed in the southwestern Cape during 1652-1665?
c. What interactions/relationships existed between society and the natural environment?

1.5.3 Primary Question 3

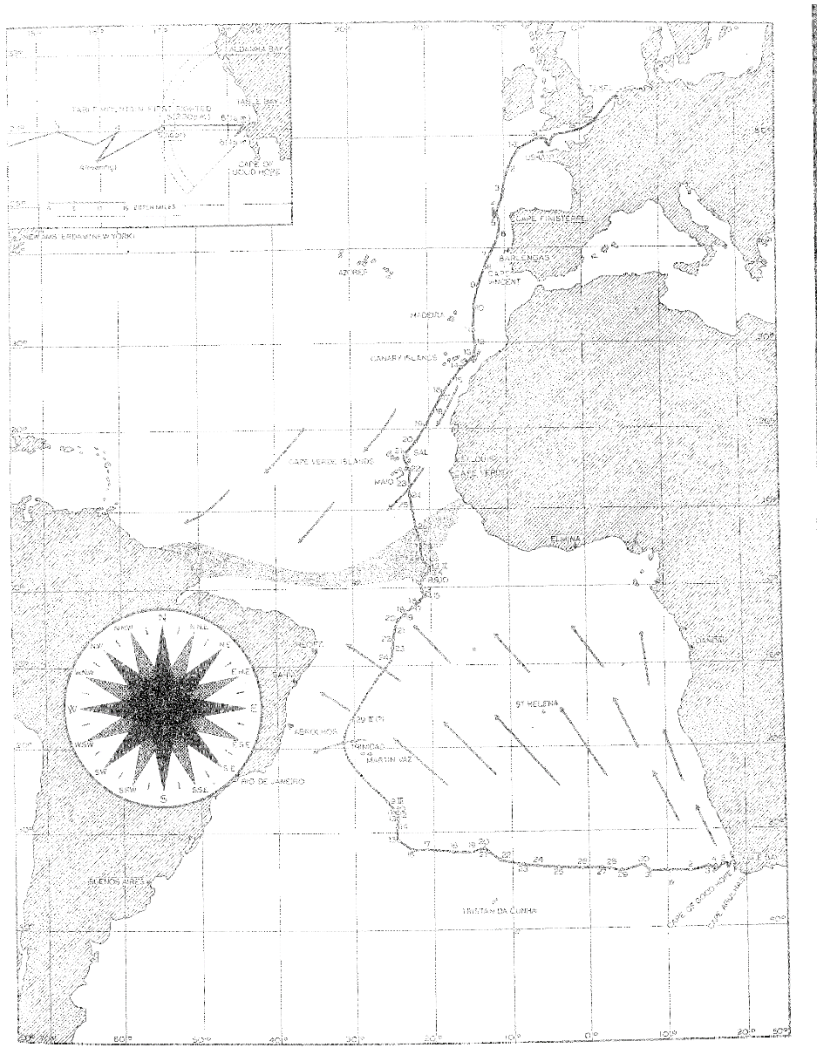
To what extent is it possible to make linkages between inter-annual weather variability over the southwestern Cape region and associated impacts on the natural environment and society for the period 1652-1665?

1.6 Dissertation Outline

This chapter has outlined the scope for a dissertation in historical climatology. The knowledge gap that will be filled should contribute to local environmental history and historical climatology by providing a high resolution record for a region of key importance due to its human habitation, agriculture and endemic biota. Chapter two will focus on the background to the southwestern Cape in a historical and environmental context. It provides an overview on the development of the southwestern Cape through time and discuss the current natural environment, including climate, vegetation and fauna. Chapter three will discuss past work on documentary-based historical climate reconstructions, both at the national and international level. The chapter will also look at drivers of climate change and prominent climate time periods such as the Medieval Warm Period and the Little Ice Age. In a social and environmental context, the chapter will focus on case studies of various historical societal abilities to cope with climate changes and or harsh/extreme environmental conditions, as well as adaptation and coping strategies applied to overcome climate stressors. This literature review chapter further emphasizes the position of this research in addressing a knowledge gap, and the value of such studies to improve the understanding of climate system dynamics. Chapter four details the methodological approach used to obtain the results for this study, situating the approach with those from existing literature

on documentary-based historical climatology. Chapter five discusses the results of the weather chronology component and chapter six focuses on the social and environmental aspects of the research, according to the research questions presented in this chapter. Chapter seven critically examines the results from both the weather chronology and social environmental results chapters, and makes linkages to the literature discussed in chapter three. Chapter eight concludes this research dissertation, reflecting back on the research questions and provides further explanation for those research questions not convincingly answered.

Chapter 2: Historical and Environmental Setting



2.1 Introduction

This chapter will explore the rich history of the southwestern Cape and outlines how it was taken over by the Dutch during the colonial era. The chapter will also discuss the Hottentots – the Cape's indigenous people, as well as prominent foreign role players that created the foundation from which the Cape region expanded and thrived. The initial settlement area of the Cape of Good Hope, now known as Cape Town, will be explored from the 21st C perspective, discussing the extent to which this region has changed since the 17th C. A thorough description of the climate, topography, flora and fauna will also be discussed.

2.2 Cape of Good Hope: The history and cultural Landscape

2.2.1 Discovery of the 'Cabo Tormentoso' – Cape of Storms

Bartolomeu Dias first discovered the 'Cabo Tormentoso' – Cape of Storms in January 1488 (Worden et al., 1998). It was later named 'Cabo de Esparança' – Cape of Good Hope – by Infante Dom Henrique de Avis (who is more commonly known as Henry the Navigator) of Portugal (Figure 2.1; Worden et al., 1998). This location would become a stop-over for Portuguese ships travelling to Asia. However, the Portuguese did not colonise this area as they were concerned about the climate and the Cape's local inhabitants – the Hottentots. The rough seas and turbulent wind storms frequently experienced along the Cape coast posed risks to the safety of the ships. Additionally the Portuguese also had concerns about the temperaments of the Hottentots as they had gotten into altercations with each other on previous occasions (Worden et al., 1998).

Later in 1620, two fleet commanders of the English East India Company, Andrew Shillinge and Humphrey Fitzerherbert took claim of Table Bay in the name of Prince James of Great Britain (Worden et al., 1998). The commanders intended for the tip of Africa to become a refreshment station for the English Company's fleets travelling the spice route to India (Worden et al., 1998). However, this was not implemented and the Cape remained uninhabited by foreigners for another 32 years. The Europeans were always fascinated by Africa, believing that somewhere beyond the desserts on a mountain existed an exotic paradise (Raven-Hart, 1967). The Europeans first gained knowledge of Table Bay in 1503 when Antonio de Saldhana misguidedly sailed into

the bay (Worden et al., 1998). The Cape of Good Hope, and its ever prominent Table Mountain, became symbolic of the exotic paradise of Africa as perceived by Europeans during that time (Raven-Hart, 1967).



Figure 2.1: Historical Map of Southern Africa (Thom, 1952).

2.2.2 Cape Hottentots (Khoi Khoi)

The Khoi Khoi (translated as men of men) arrived at the Cape about 2000 years ago. The Khoi Khoi people belong to the same racial group as the San ('Bushmen'), but are more commonly known as the Hottentots – a name attributed to them by the Dutch settlers (Picard, 1977).

The Hottentots descended from Stone Age man and had yellowish skin and a short, slight build. Unlike the San who were hunter-gatherers, the Hottentots were herdsmen. The Hottentots also knew how to smelt and work metal (Worden et al., 1998). The political structure of the Hottentots was governed by traditional chiefs and tribal councils unlike the San who had no organizational governance (Picard, 1977). It is thought that the Hottentots originated from

Somaliland and migrated south to make the Cape Province (now demarcated as Western Cape and Eastern Cape Provinces) their permanent home (Worden et al., 1998). The wealthiest of the Cape Hottentots were the Namaqua, who had spread across south western Africa (Picard, 1977). In the Eastern Cape, the Inqua, Damaqua and Gonaqua Hottentots herded their cattle (Picard, 1977). Shortly before the arrival of Jan van Riebeeck at the Cape, the Kora Hottentots left the Cape Peninsula and settled on the banks of the Orange River (Picard, 1977).

2.2.3 Dutch Refreshment Station and Settlement

In 1647, a ship named the *Haarlem*, belonging to the Dutch East India Company (DEIC), was shipwrecked at the Cape of Good Hope (Raven-Hart, 1967). Leendert Janzen was made commander, and together with a crew of 60 men, spent a year at the Cape before being shipped back to Batavia (Picard, 1977; Worden et al., 1998). During Leendert Janzen's time at the Cape, the crew survived on venison and fish for the first five months (Picard, 1977; Worden et al., 1998).

Thereafter the Hottentots appeared from inland and fresh meat was obtained through the exchange of iron (Picard, 1977). Following Leendert Janzen's report on the conditions at the Cape, and his opinion that the Hottentots were a docile people, the DEIC decided to set up a refreshment station at the Cape of Good Hope for ships returning from the east (Picard, 1977; Worden et al., 1998). It was Jan van Riebeeck who then suggested a strong fort be built to resist both European enemies and the indigenous people, as he did not share Leendert Janzen's views of the Hottentots.

In May 1651, Jan van Riebeeck was selected as the commander of the Cape of Good Hope and left the Netherlands in December of the same year (Figure 2.2). On 5 April 1652, the Dutch arrived at the Cape to build a settlement, erecting the flag of the Dutch Republic on Table Bay's shore (Picard, 1977; Worden et al., 1998). Jan van Riebeeck followed orders to build a fort for the Company's protection at the Cape, as well as thriving gardens. The envisioned station had a dual purpose: to act as a defensive point against both the indigenous people and European rivals, and to refresh passing ships with fresh food (Worden et al., 1998). Historical engagements within this region were driven by factors such as a natural environment with abundant ecosystem

services, including a variety of wildlife and perennial water (Anderson and O'Farrell 2012). At the end of the first month, both assignments were well underway, which was indicative of Jan van Riebeeck's determination to make the Cape of Good Hope a successful refreshment establishment (Worden et al., 1998).

2.2.4 Jan van Riebeeck: First Governor of the Cape (1652-1662)

Jan van Riebeeck (Figure 2.2) was used as the South African national symbol of apartheid by the white nationalist government post 1994. Due to this, he is perceived in a poor light and as a forefather of racism amongst democratic South Africans (Rassool and Witz, 1993). However, upon the reading of his diaries (Thom, 1952) and autobiographic accounts by historians Dr. C. L. Leipoldt and Dr. E. C. Godée-Molsbergen, there are many positive attributes from this historical icon that helped in the development of the city of Cape Town as it is known today. For the purposes of this research, it was preferred to present Jan van Riebeeck in a neutral way in the context of colonialism, as this is a topic that merits its own investigation. The information presented here was rather used to formulate an opinion around his credibility as a source for historical climate reconstructions. It was not within the scope of this dissertation to engage with socio-political themes.

Jan van Riebeeck was born on 21 April 1618 in Culemborg, Netherlands. Jan van Riebeeck's level of education is not known for certain, but historians assume he had a good level of education relative to other children his age based on his upbringing in the mayor's home and by the neatness of his penmanship (Godée-Molsbergen, 1968). In his youth, Jan van Riebeeck elected to study to become a surgeon and learnt this profession through an apprenticeship, for which he was fully qualified at age 21 (Godée-Molsbergen, 1968; Leipoldt, 1936).

Jan van Riebeeck entered into service with the DEIC in 1639 as a junior surgeon (Godée-Molsbergen, 1968). After a year at the Company, following his arrival at the Headquarters in Batavia, he abandoned his occupation as junior surgeon and took on commercial and administration duties (Godée-Molsbergen, 1968; Leipoldt, 1936). At the time, medical surgeons' salaries were relatively modest compared to those in the commercial departments of the Company. This showed Jan van Riebeeck's ambitious nature, as he had opted to grow his career

in administration and commerce rather than medicine in pursuit of better pay. He started as an assistant in the Batavia office, learning bookkeeping, production, purchase, value and disposal of merchandise (Godée-Molsbergen, 1968; Leipoldt, 1936). He was a quick learner, and in 1642 he was requested to act as secretary on an expedition to Sumatra (Godée-Molsbergen, 1968). It was invaluable experience, and shortly after his arrival back to Batavia, he was promoted to junior merchant (Leipoldt, 1936). He was despatched to Japan where he spent several years trading the Company's silver for silk. In 1646, at age 28, Jan van Riebeeck was promoted to merchant and second-in-command (Leipoldt, 1936). This meant a new service contract as well as an increase in salary (Godée-Molsbergen, 1968; Leipoldt, 1936).



Figure 2.2: Portraits of Jan van Riebeeck (Thom, 1952)

Some merchants of the Company engaged in private trade, either selling off some the goods of the company or using the Company ships to transport the private goods of the merchants (Leipoldt, 1936). Jan van Riebeeck was one such merchant, and was indicted and sent back to Batavia to stand trial as privately trading was against company policy (Godée-Molsbergen, 1968;

Leipoldt, 1936). In 1648, on his way back to Batavia, the fleet stopped at the Cape of Good Hope to rescue those survivors from the shipwrecked *Haarlem*, only a year earlier (see sub-section 2.2.3). He spent 18 days at the Cape which exposed him to the landscape as well as the indigenous peoples, and gave him the opportunity to hear the experiences of the survivors who had spent a year at the Cape (Godée-Molsbergen, 1968). Upon arrival in Batavia, he was found guilty and discharged from the Company (Godée-Molsbergen, 1968). He then left for Amsterdam where he met his future wife, Maria de la Quellerie (Godée-Molsbergen, 1968; Leipoldt, 1936).

Jan van Riebeeck was later asked to give a memorandum on the conditions of the Cape, and based on this, the Directors of the DEIC decided to reinstate him into the Company as the commander of the refreshment station at the Cape of Good Hope (see sub-section 2.2.3; Godée-Molsbergen, 1968; Leipoldt, 1936)**.** Here, he worked very hard for 10 years, and left in May 1662 to return to Batavia (Leipoldt, 1936). Zacharias Wagenaer succeeded him as the next governor at the Cape of Good Hope (Godée-Molsbergen, 1968). According to historians, this was the most important work of Jan van Riebeeck's career, because through his resourcefulness and determined nature, he created the path for the establishment of the European influence in South Africa (Godée-Molsbergen, 1968; Leipoldt, 1936). Later in life, he was a member of the Court of Justice in Batavia and the Commander of Malacca (Godée-Molsbergen, 1968). Jan van Riebeeck died on 18 January 1677 at the age of 58 due to ill health (Godée-Molsbergen, 1968; Leipoldt, 1936).

2.2.5 Zacharias Wagenaer: Second Governor of the Cape (1662 – 1668)

Zacharias Wagenaer was born in Dresden, Saxony on 9 May 1614 (Spohr, 1967). He is one of the most outstanding historical figures from the DEIC serving approximately 35 years (Spohr, 1967). He served seven years in Dutch Brazil where he illustrated much of the exotic flora and fauna as well as the indigenous people of Brazil (Spohr, 1967). He served the DEIC for a total of 28 years, during which four years (1662 – 1666) were committed as second Commander of the Cape of Good Hope (Spohr, 1967). He had a phenomenal career beginning as a small clerk, and thereafter reaching high ambassadorial status at the Royal Courts of China and Japan (Spohr, 1967). He was also the only German Commander at the Cape of Good Hope (Spohr, 1967). One

of his highlights as Commander involved assisting in the construction of a huge water tank in 1664 at the edge of the bay to supply the ships with water (Spohr, 1967). Ill health forced Wagenaer to be relieved of his duties at the Cape and he resigned in September 1666 (Spohr, 1967). Zacharias Wagenaer died on 1 October 1668 in Amsterdam (Spohr, 1967).

2.3 The Development of a City: from the Cape of Good Hope to Cape Town

The Cape of Good Hope, now referred to as the city of Cape Town, is located at the southwestern tip of Africa. It is home to a culturally and linguistically diverse population of approximately 5.8 million of which 49% are Coloured, 33% are African, 17% are White and 1% are Indian or Asian (Statistics South Africa, 2011). The city of Cape Town symbolizes three and a half centuries of urban development. Cape Town's local economy is relatively diversified and the second largest in South Africa (Wilkonson, 2000). This section outlines the urban development of the city which started as a refreshment station and is now an economic tourist hub of activity.

The Cape of Good Hope gained the status of a permanent settlement in 1657 when the "free burghers" were given land for agricultural purposes (James and Simons, 1989). The free burghers were of European descent and considered the middle class in society (businessmen and traders) who were encouraged to immigrate to other countries and settle (James and Simons, 1989; Wilkonson, 2000). Later, in 1674, the permanence of the settlement was reaffirmed by the replacement of the mud and timber fort along the Table Bay shoreline with the completed stone fort (James and Simons, 1989; Wilkonson, 2000). The slave labour population that contributed largely to the physical growth of the settlement comprised indigenous peoples from Madagascar and Mauritius, East and West Africa, the East Indies, as well as indigenous Khoi people (James and Simons, 1989; Wilkonson, 2000). The Khoi had been dispossessed of their livestock, pasture lands and access to water (James and Simons, 1989; Wilkonson, 2000).

At the beginning of the 18th C, the settlers had a total population of approximately 3150, of which 1300 were slaves (Worden et al., 1998; 1999). With time, the settled land extended up to 100 km into the outlying regions which became home to wheat and wine producing farms (Worden et al., 1998; 1999). In the early 19th C, before the British seized control of the Cape, the

culturally and linguistically diverse population had increased to 17000 (Worden et al., 1998; 1999). During the mid-19th C, liberated Muslim slaves undertook artisanal trades as they were skilled craftsmen (Worden et al., 1998; 1999). However, fishing, agriculture and trade remained the central industries in growing the local economy (Worden et al., 1998; 1999). The city of Cape Town developed significantly in the last half of the 19th C due to the construction of rail lines to the southern suburbs of Wynberg, Muizenberg and Simon's Town (Worden et al., 1998; 1999). By 1899 the city had a sufficient water supply, water-borne sanitation, and drainage as well as a professional bureaucracy (Davenport, 1978).

Today, the Cape region attracts people from all walks of life with varying interests of the city which include, myths and legends, philosophical and ideological values, social, environmental and cultural traits, as well as histories and experiences (Booyens and Rogerson, 2016).

2.4 Contemporary Climate of South Africa: An Overview

Continental-scale warming is expected throughout Africa during the 21st C and has been projected to be greater than the global annual mean warming (Engelbrecht and Landman, 2009). The observed temperature trends over subtropical southern Africa result in projections of the dry subtropical regions warming faster than the moister tropics (Kruger and Shongwe, 2004; Kruger and Sekele, 2013). Proxy climatic data such as documentary sources, harvest dates and tree ring analysis, offer opportunities to reconstruct past climates (Pfister et al., 2009). Due to the societal impacts felt as a result of climate change in southern Africa and beyond, it is necessary to understand past and present climates, so as to accurately project future climate trends (Vogel, 1989).

South Africa is located between 25°-30°S latitude, and thus experiences a predominantly sub-tropical climate. The South African climate is largely influenced by the subtropical high pressure system (Engelbrecht and Landman, 2009; Davis, 2010). These high pressure systems result in the subsidence of air over southern Africa, thereby suppressing cloud formation and rainfall. This has resulted in the semi-arid climate that makes up the western half of South Africa (Engelbrecht and Landman, 2009; Davis, 2010).

Rainfall patterns display both inter-annual and intra-annual variability which is characteristic of the subtropics. Total summer rainfall amounts are usually below average during El Niño years and above average in La Niña years (Washington and Todd 1999; Engelbrecht and Landman, 2009). El Niño (La Niña) refers to the large scale phenomenon associated with strong warming (periodic cooling) in sea surface temperatures across the central and east-central equatorial Pacific Ocean, with a paired fluctuation in atmospheric pressure. An El Niño event occurs every 3-7 years. Other climate controls of South Africa include the regional topography and the surrounding oceans. The western, eastern and southern escarpments lead to a high plateau of 1250m above sea level (Engelbrecht and Landman, 2009; Davis, 2010). Hot summers and cold winters are experienced on the plateau, while the climate along the coastal regions is moderated by the oceans that result in milder winters (Tennant and Hewitson, 2002). The eastern and coastal regions of South Africa experience a warm and humid climate due to the warm Agulhas current while the west coast experiences an arid to semi-arid climate due to the cold Benguela current (Roault et al. 2002; Singleton and Reason 2006; Davis, 2010).

There are three principal zones of rainfall seasonality in southern Africa, namely the winter rainfall zone (WRZ), the summer rainfall zone (SRZ) and the year round rainfall zone (YRZ) (Tyson, 1986). The WRZ receives most of its precipitation between April and September (austral winter). It has a Mediterranean climate characteristic of cool, wet winters and warm, dry summers (Schalke, 1973; Tyson and Preston-Whyte 2004; Tadross et al., 2012). However, in contrast to this, the SRZ receives the majority of its precipitation between October and March (austral summer). The SRZ climate is characterised by clear, dry winters and summers with a relatively higher humidity as well as periodic tropical cyclone events and afternoon thundershowers (Fauchereau et al., 2003). The YRZ is a relatively narrow region that lies between the WRZ and SRZ, extending from the northwestern parts to the south coast of South Africa (Taljaard and Phil, 1996; Crimp and Mason, 1999; Weldon and Reason 2014). This zone receives a combination of summer and winter rainfall (Figure 2.3). Absolute rainfall amounts are a main factor used when determining boundary shifts of the YRZ (Quick, 2013). The extents and positions of the three principal rainfall zones are highly variable, both inter-annually and over longer time periods such as the late Quaternary for example (Quick, 2013).

There is a marked climatic seasonality across South Africa, driven by shifts in the position of the Inter-Tropical Convergence Zone (ITCZ). During the summer months, the country experiences a largely sub-tropical climate, with the dominant high pressure cell and high temperatures resulting in precipitation in the form of thunderstorms over the interior. In winter, when the ITCZ shifts north, the southern region of the country is influenced by the westerly belt, receiving rainfall with the landfall of mid-latitude cyclones that develop at the polar front (Taljaard and Phil, 1996; Favre et al. 2013; Weldon and Reason 2014). Winter rainfall is mainly due to storm systems brought in by westerlies, which manifest as mid-latitude cyclones (Buckley & Leslie, 2004; Engelbrecht & Landman, 2015; Figure 2.3). Oceanic (blue arrows) and atmospheric (white arrows) circulation systems and the austral summer positions of the ITCZ and the Congo Air Boundary (CAB) are indicated, all of which influence the meso-scale climatic variability across South Africa (Figure 2.3).

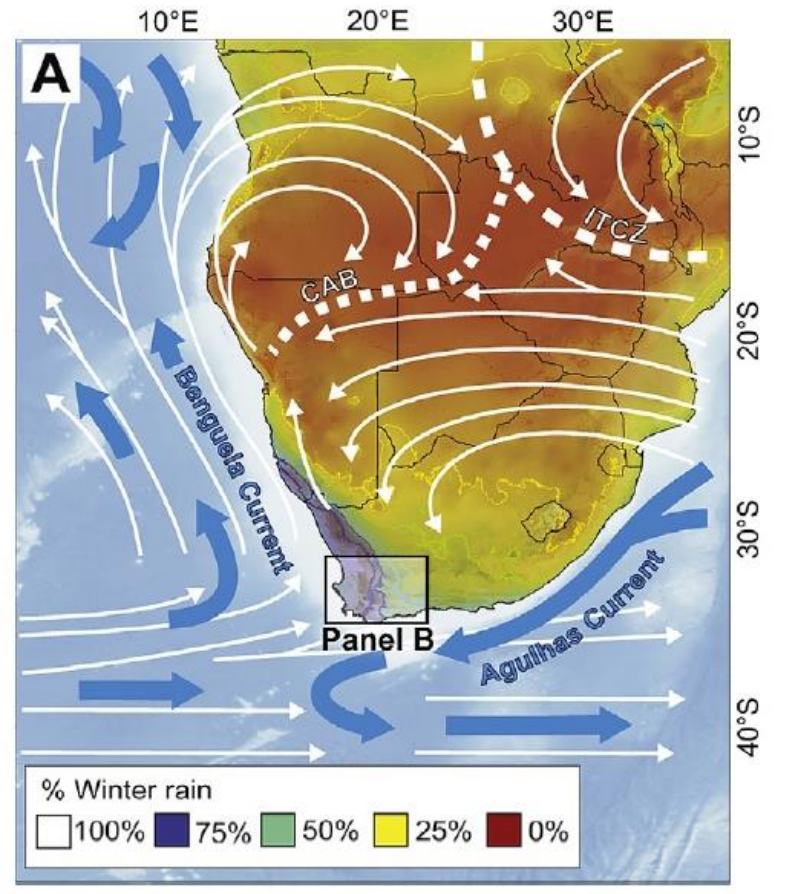


Figure 2.3: Map of southern Africa showing seasonality of rainfall. Dominant summer rainfall (red) and winter rainfall (blue) zones (Chase et al., 2015).

2.4.1 Synoptic Features of South Africa

As the Inter Tropical Convergence Zone (ITCZ) migrates, the continental high pressure cell migrates further north during winter, inducing clear, stable conditions for the entire subcontinent, with the exception of the southwestern Cape region (Tyson and Preston-Whyte, 2000). Coastal lows, as the name suggests, are confined to coastal regions, bringing some precipitation, particularly during winter (Figure 2.4; Engelbrecht et al., 2015). They promote the establishment of 'berg winds' that blow for a few hours to several days, with the subsidence of air downslope, and the associated change in temperature due to lapse rates, causing the highest winter temperatures on the east coast (Van Heerden et al., 1988). With warm offshore airflow ahead, and cool onshore airflow behind, coastal lows typically start on the west coast, circulating through to the south, and then move east and north-east (Van Heerden et al., 1988). The affected coastal regions include those of the Western Cape, Eastern Cape and KwaZulu-Natal. Mid-latitude cyclones with cold fronts are a common occurrence in winter over South Africa, due to the northerly shift of the ITCZ (Taljaard and Phil, 1996; Favre et al. 2013; Weldon and Reason 2014).

These systems are associated with rapid temperature decreases that predominantly affect the eastern regions of South Africa (Weldon and Reason 2014). The westerly waves occur inland of the Western and Eastern Cape escarpment, mostly between October and April, with cloud cover and precipitation behind the wave and subsidence and stable conditions ahead (Tyson, 1969). An intense form of the westerly wave is the cut-off low. Cut-off lows can sometimes result in 24 hour rainfall events that exceed monthly rainfall totals in certain locations (Singleton and Reason 2006, 2007). It is unstable, which results in many flood events over South Africa, with the exception of the Northern and Western Cape (Engelbrecht et al., 2015). In South Africa, these types of flood events are extremely destructive causing damage to infrastructure and on occasion, results in the loss of life (Weldon and Reason 2014). These cut-off lows peak from March to May and again from September to November (Tyson, 1969).

During winter (June to August), rainfall is sparse over the interior of the country due to the presence of the subtropical high pressure belt (Nicholson, 2000). The interior experiences sunny

days, cold nights and clear skies. Frost is also experienced in the higher altitude parts of the interior due to the large diurnal temperature range (Nicholson, 2000). In contrast to this, at the southern boundary of the subtropical high pressure belt, regular cold fronts sweep over the southern parts of the country, bringing winter rain to the southwestern Cape (Van Heerden et al., 1988). The southwestern Cape is a winter rainfall region with the majority of its annual rainfall occurring in the form of frontal rain (Figure 2.4). Snowfalls sometimes occur on the Western and Eastern Cape mountains and Drakensberg due to the passage of such cold fronts (Grab and Linde, 2014). 'Cold snaps' are events that occasionally occur over the interior of South Africa due to the intrusion of a cold front further northwards than usual; in rare cases this leads to snowfalls over the Free State and Highveld regions of Gauteng and Mpumalanga (Tyson and Preston-Whyte, 2004).

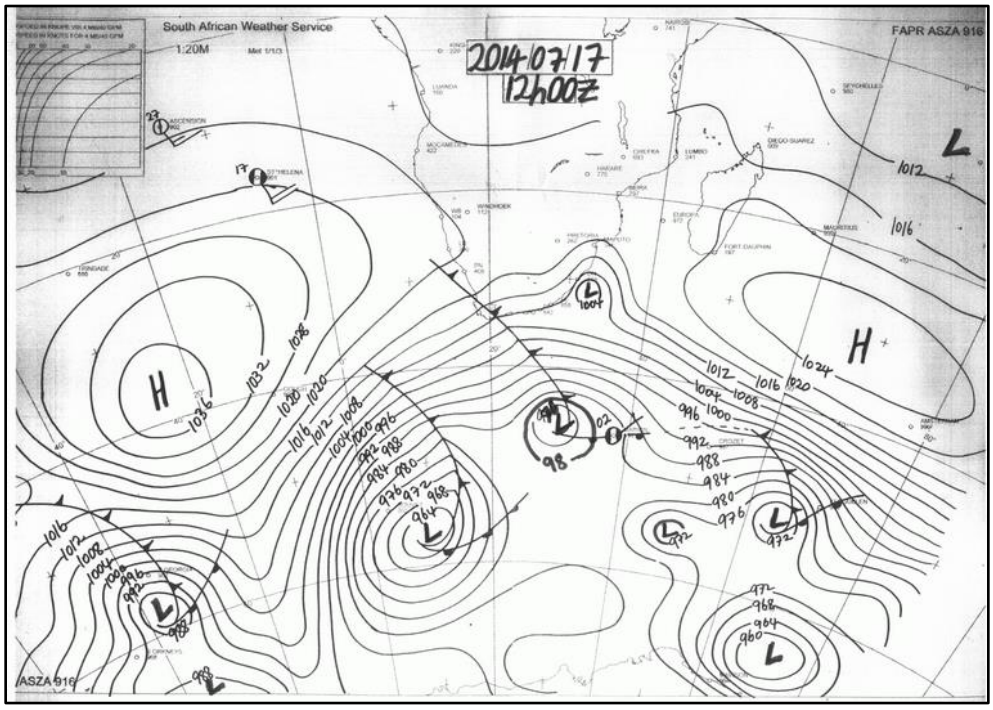


Figure 2.4: Synoptic Chart of South Africa in the winter, demonstrating the frequent passage and landfall of mid-latitude cyclones, and the less dominant high pressure cells over the interior.

Due to enhanced solar radiation in spring (September to November), a heat-low (shallow low pressure system developing in response to the strong heating of the earth's surface) develops over the western parts of South Africa (Figure 2.5; Engelbrecht et al., 2015). From spring

through to autumn the heat low induces the formation of thunderstorms to its east. The onset of rainfall begins in spring over KwaZulu-Natal before spreading to the interior regions of South Africa (Tyson and Preston-Whyte, 2004). The westerly waves together with ridging high pressure systems in the lower levels of the atmosphere are responsible for the rainfall in the interior of the country during spring (Malherbe et al., 2012). The ridging high pressure system is also responsible for transporting moisture into the interior parts of South Africa from the Indian Ocean (Malherbe et al., 2012).

The ITCZ begins to migrate south of the equator and there is strong uplift resulting in summer rainfall through most parts of South Africa, with the exception of the Northern, Eastern and Western Cape regions (Malherbe et al. 2012). There is also a divergence of the high pressure cells which induces the easterly low, resulting in heavy rains over the plateau (Washington and Todd, 1999). The easterly waves and associated low pressure cells peak between December and February, thereby controlling summer rainfall over South Africa (Malherbe et al., 2012). The west-coast trough is formed by the westerly wave in the upper air, resulting in widespread rain over western and central South Africa (Engelbrecht et al., 2015). Regular tropical cyclones form over the Indian Ocean, with a life-span of several days. These occasionally reach South Africa, resulting in heavy rainfall and flood events (Tyson and Preston-Whyte, 2004; Fitchett & Grab, 2014).

During summer (December to February), the central and northern interior parts of South Africa receive summer rainfall (Quick, 2013). The ITCZ reaches its most southern location which results in pockets of moisture from the tropics frequently reaching South Africa (Engelbrecht et al., 2015). In autumn (March to May), the ITCZ advances northwards and subsidence sets in over southern Africa (Quick, 2013). However, it is a rainfall season for the Northern and Eastern Cape interiors due to sub-tropical-temperate troughs (Hart et al., 2013).

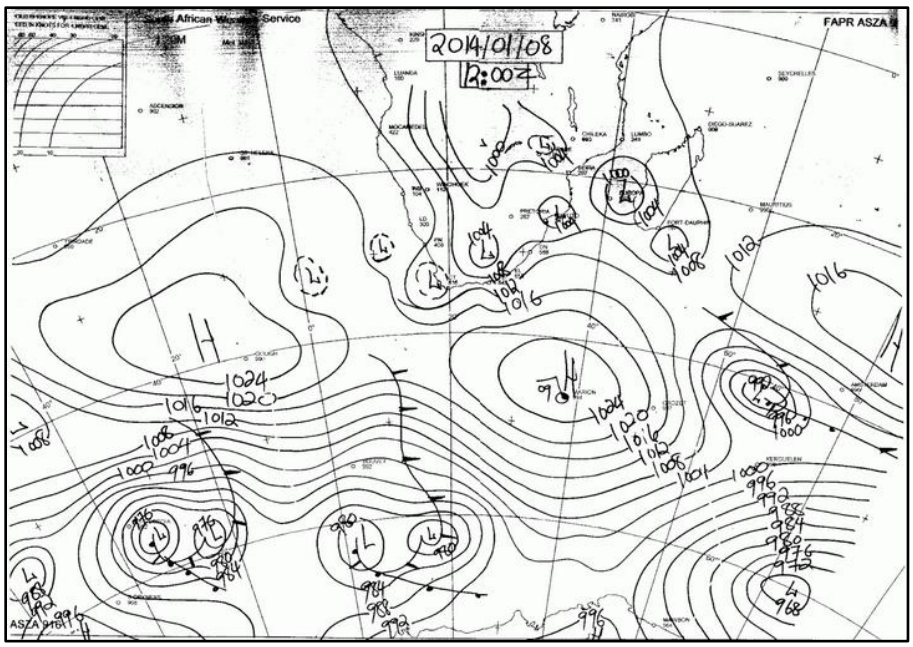


Figure 2.5: Synoptic Chart of South Africa in the summer. Notable are the more southerly location of mid-latitude cyclones, the high pressure system over the interior, and numerous coastal lows.

2.4.2 Temperature Trends

Global climate models (GCMs) are fundamental tools used in making climate projections while taking into account human-induced greenhouse gas forcing as a variable (DEA, 2013). These models work very well in analysing large scale climate predictions, but due to the model's coarse spatial resolution, it does not produce acceptable results at a local scale (MacKellar et al., 2014). However, empirical and dynamical downscaling procedures may be used to represent finer spatial details (Hewitson and Crane, 2006). Long term temperature trends present themselves more accurately than with rainfall indices (MacKellar et al., 2014). The increase in human induced greenhouse gas emissions has resulted in an increase in global mean temperature which is being felt in different regions throughout the world at varying magnitudes (MacKellar et al., 2014).

A review of temperatures over South Africa for the year 2013 (Kruger and Sekele, 2013) provides an indication of contemporary weather conditions. The mean annual air temperature in South Africa was near normal with minimum temperatures 0.5-2°C below average over western South Africa (Kruger and Sekele, 2013). The monthly maximum temperature anomaly was 1-

4°C above normal during the February to March summer months (Kruger and Sekele, 2013). The monthly minimum temperature anomaly was below normal in the winter and spring seasons as well as in April and May, whereas the monthly maximum temperature anomaly was generally positive from September to November (Kruger and Sekele, 2013). Using the reference period of 1961–1990 and preliminary annual mean temperature data from 21 climate stations, the results showed a 0.3°C increase relative to the reference period (Kruger and Sekele, 2013). The results from these climate stations also showed a 0.13°C per decade statistically significant warming trend Kruger and Sekele, 2013). The overall mean temperature over the past 17 years has been above average, relative to the 1961-1990 reference period (Kruger and Sekele, 2013).

In summary, South Africa has a warm climate and much of the country experiences average annual temperatures of above 17°C (Quick, 2013). The southern and eastern escarpments have the lowest temperatures due to decreasing temperatures associated with increasing altitude (Quick, 2013). The warmest regions include KwaZulu-Natal, Mpumalanga, the Limpopo Valley and the interior of the Northern Cape (Quick, 2013). The east coast is significantly warmer than the west coast due given the warm Agulhas current (Rouault et al. 2002; Singleton and Reason 2006). The west coast is subject to the cold Benguela current and upwelling, which results in lower temperatures (Barrable et al., 2002; Chase and Meadows, 2007).

2.4.3 Precipitation Trends

Southern Africa has weak long-term climate trends but climate modelled projections highlight an increase in inter-annual rainfall variability since 1970 (Tadross et al., 2005). Rainfall trends are varied for the summer and winter rainfall zones (Figure 2.6; Barrable et al., 2002). ENSO and the Atlantic and Indian Ocean climates appear to be responsible for intra-decadal fluctuations (Fauchereau et al., 2003). Inter-annually, ENSO, together with other meteorological cycles, has been causing extended summers and winters in the regional climate (Jury, 2013). For southern Africa, rainfall distribution throughout the year may be characterised in terms of:

- the timing of seasonal rainfall onset and cessation;
- more commonly occurring periods of wet and dry and;
- extreme heavy rainfall events

(MacKellar et al., 2013).

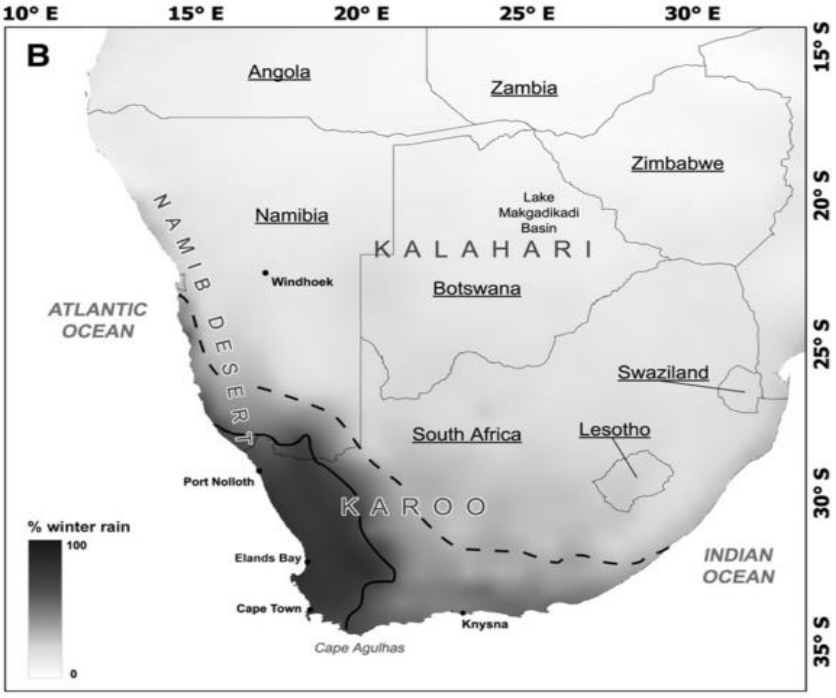


Figure 2.6: The extent of the WRZ (left of the solid black line), SRZ (right of the dotted line) and the YRZ (between the solid and dotted lines) (Chase and Meadows, 2007).

Studies have demonstrated that for most of the 20th C, the southwestern and eastern parts of South Africa had exhibited a tendency for increased extreme heavy rainfall events (Easterling et al., 2000). These heavy rainfall events are confirmed by Groisman et al. (2005) for the period 1906 – 1997. Studies also showed that much of South Africa experienced higher rainfall events for the period 1961–1990 relative to the period 1931–1960 (Mason et al., 1999). The high rainfall events for the period 1961–1990 are also confirmed by New et al. (2006).

2.4.4 El Niño Southern Oscillation (ENSO)

ENSO is a predominantly Pacific Ocean phenomena, driven by periodic variations in the barometric pressure, and associated sea level on the eastern and western sides of the Ocean (Wallace et al., 1998; Kao and Yu, 2009). These pressure and height differences induce upwelling, which results in cold sea surface temperatures off the coast of South America, which has been associated with the proliferation of cold water fish (Wallace et al., 1998; Fielder, 2002). However, due to global thermohaline circulation, the impacts of these Pacific Ocean fluctuations are experienced globally (Reason and Roault, 2002; Kao and Yu, 2009). For South Africa, there

is a notable polarity in the weather associated with ENSO events in the winter- and summer-rainfall zones of the country (Reason and Roault, 2002; Mulenga et al., 2003). For north-eastern South Africa, dry summers are experienced during El Niño events, due to a predominance of anomalous westerlies in the upper troposphere of much of the subcontinent preventing moisture-bearing pressure disturbances (Mulenga et al., 2003). These mid-latitude circulation anomalies, by contrast, result in more precipitation occurring in the winter-rainfall zone in the southwest of the country (Reason and Roault, 2002; Mulenga et al., 2003). During La Niña years, the opposite occurs: the winter-rainfall zone experiences drought conditions, while the summer-rainfall zone experiences an increase in rainfall and a greater risk of floods (Reason and Roault, 2002). This pattern is driven by strengthened anticyclonic systems over the interior, driven by a greater pressure differential (Reason and Roault, 2002). El Niño and La Niña events further appear to influence the duration of wet periods in the winter-rainfall zone, with shorter periods of continuous rainfall during La Niña events and longer periods of continuous rainfall during El Niño events (Philippon et al., 2012). This is associated climatologically with shifts between dominant north-westerly and southerly seasonal winds (Philippon et al., 2012). The long-term trend in the strength and frequency of ENSO events is statistically weak (Hewitson and Crane, 2006). However, the intra-decadal oscillation in precipitation is now recognised to be influenced by the ENSO cycles (Jury, 2013).

2.4.5 Future Climate Projections

South Africa is divided by varied climatological regions (Engelbrecht and Landman, 2009; DEA, 2013), which thus makes it difficult to provide both seasonal climate forecasts and long-term climate projections. Some of these examples include thunderstorms on the Highveld, frontal rain over the southwestern Cape, berg winds along the Eastern Cape coast and widespread flooding over north-eastern South Africa when tropical cyclones make landfall over Mozambique (Engelbrecht and Landman, 2009; Nash et al., 2015). High resolution regional modelling over southern Africa using outputs from the AR4 global climate models provide insight to atmospheric circulation changes under climate change scenarios (Tadross et al., 2005; Engelbrecht et al., 2009, 2015; Malherbe et al., 2013). Some of these scenarios include an increased frequency of anti-cyclones during spring and autumn, resulting in drier conditions over southern Africa and the southward displacement of frontal systems which would result in

reduced rainfall over the southwestern Cape during winter (Engelbrecht et al., 2009; Malherbe et al., 2012).

According to Madzwamuse (2010), South Africa is expected to experience a warming of between 1-3˚C over the next 50 years. Prior to this, Engelbrecht and Landman (2009) projected that the interior of South Africa will warm by as much as 3-5˚C by 2015. More recently, the DEA (2013) has made climate change projections for South Africa, under high emission scenarios, that involve extreme warming of between 5-8°C over the interior and less extreme warming over coastal zones. These temperature projections are paired with wetter conditions to the east and drier conditions over the west and south of the country (DEA, 2013). However DEA (2013) also project global emission reduction scenarios that would significantly reduce the risk of extreme warming trends.

South Africa, in general, is expected to experience a reduction in rainfall of 5-10% by 2050, an increased frequency of flood and drought events, and a lower standard of air quality induced by enhanced temperature inversions (Madzwamuse, 2010). Specifically, the winter rainfall areas and western margins of southern Africa are expected to experience decreasing rainfall, while eastern South Africa is projected to experience more intense rainfall episodes during summers (Engelbrecht and Landman, 2009). However, DEA (2013) argues that with effective global emissions reduction, the risk of extreme rainfall changes (increases and decreases) would largely be eliminated by the mid- 21st C.

2.5 Southwestern Cape: a fire-prone Mediterranean type climate

Climatologically, southwestern Africa is at the boundary between tropical and temperate systems located in the southern hemisphere (Tyson, 1986). The southwestern Cape is one of South Africa's most environmentally and floristically biodiverse regions. The region has a Mediterranean climate, receiving the majority of its annual rainfall in the austral winter months (Barrable et al., 2002; Philippon et al., 2012). The natural environments that remain in the city of Cape Town are highly fragmented and in few cases have little connectivity (Goodness and Anderson, 2013). The Cape vegetation requires burning on a 10-15 year rotation using fire as a

management tool. However, this poses many hazardous risks within an urban setting (Goodness and Anderson, 2013).

2.5.1 Rainfall

The southwestern Cape differs from other regions of South Africa as it is characterised for its severe winters due to the frequency of mid-latitude cyclones, frontal depressions, coastal lows and the westerlies bringing cold, wet weather (Quick, 2013; Engelbrecht et al., 2015). Winter rainfall regions such as the southwestern Cape are defined as those having a mean monthly temperature of >0°C and receiving >65% of the regions precipitation during the cooler part of the year, which in this case is from April to September (Barrable et al., 2002). During the rainy season, the westerly winds bring moisture to the region with the northward migration of the dry, anti-cyclonic high pressure systems (Barrable et al., 2002). During summer, a ridging high pressure cell over the Atlantic Ocean influences the Cape climate through the advection of moist air from the south and south-east (Chase and Meadows, 2007). This induces post-frontal conditions which results in 25% of the Cape Peninsula's annual rainfall (Quick, 2013). The high pressure cell also brings on strong south-easterly offshore winds along the southwest coast, which, together with the warm Indian Ocean, results in mist precipitation along the northern sectors of the Cape Folded Mountain Belt (Quick, 2013). The upwelling of the Benguela Current off the west coast, exacerbates summer aridity as it acts as a strong stabiliser for air masses, while the Cape Folded Belt largely prevents the winter rains from passing through into the interior (Barrable et al., 2002; Chase et al., 2015).

The southwestern Cape has a steep rainfall gradient due to altitude and aspect. The rainfall in this region varies from 400-2270mm/year which is unique due to its relatively small extent. Specifically, along the Cape Folded Belt, rainfall totals exceed 1,000 mm while to the north of the mountains less than 200 mm/year is typically recorded over the Karoo (Engelbrecht et al., 2015). Rainfall peaks from March to April are mainly due to the ridging high pressure systems and tropical-temperate troughs, while cut-off lows are associated with a peak in August rainfall (Taljaard and Phil, 1996; Hart et al., 2013; Engelbrecht et al., 2015).

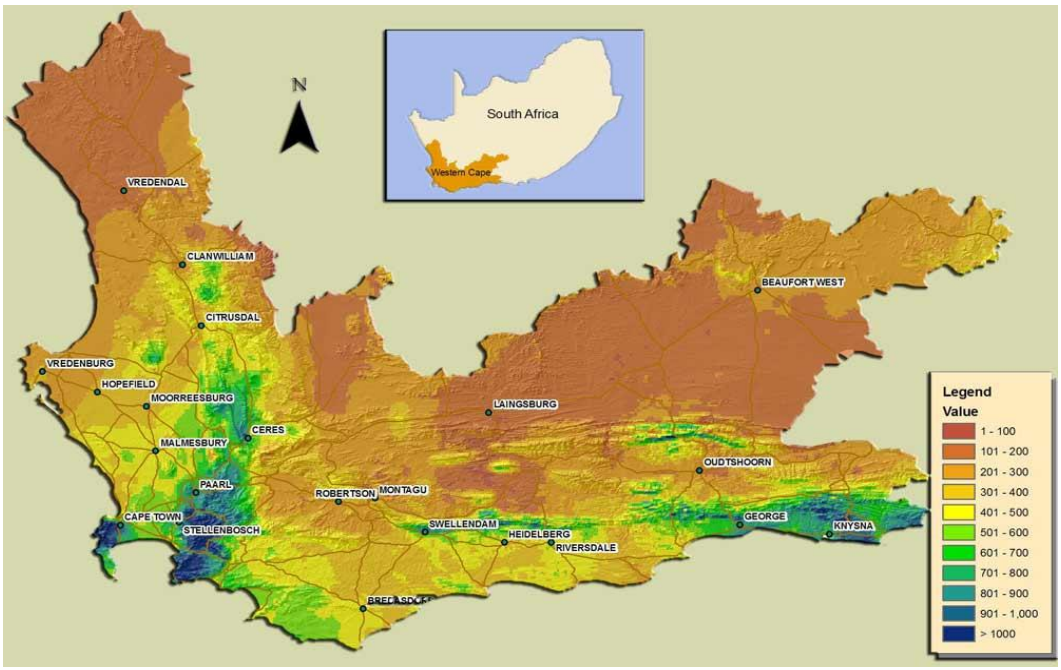


Figure 2.7: Rainfall distribution map of the Western Cape (WC Government Agriculture, 2015).

Frost and snow are not very common and do not generally occur for more than 2 days at a time, mostly on the higher summits of the Cape Folded Mountains (Quick, 2013). Future climate simulations show the displacement of frontal rain bands further southwards, resulting in significantly reduced rainfall over the southwestern Cape. Towards the late 21st C (2080–2099), the southwestern Cape is projected to experience drier conditions through the winter months (Engelbrecht and Landman, 2009).

2.5.2 Temperature

The southern Cape spatial and temporal variations in temperature are not extreme due to abundant cloud cover, frequent rains and the presence of the Agulhas Current which induces a moderating effect on temperatures along the coastline (Roault et al. 2002; Singleton and Reason 2006). The mean annual temperature ranges between 18-20°C and the diurnal temperature range averages between 6-10°C (Quick, 2013). Temperatures average 25 °C in January and 17 °C in July (Mucina and Rutherford, 2006). Temperature projections for the period 2080-2100 for the southwestern Cape region indicate annual average increases of 2 to 4°C and temperature variability of between 1 and 2°C for the period 2040-2060 (DEA, 2013). In the Cape region, the growing season is limited to the austral winter as the dry season (September-March) experiences

on average only ≤15mm per month, combined with high levels of evapotranspiration (Chase et al., 2015). A study by MacKellar et al. (2014) demonstrated significant increases in maximum temperatures for all seasons, ranging from 0.015°C/year to 0.027°C/year with specifically stronger warming occurring in the last 10-12 years of the 1960-2010 record used. Increases in minimum temperatures are relatively smaller, ranging from 0.011°C/year to 0.021°C/year, and are not significant for the winter months of June-August (MacKellar et al., 2014).

2.5.3 Wind

There are several factors that control wind processes, including friction, orographic effects and pressure gradients (Tadross et al., 2012). Along coastlines, land and sea boundaries induce changed wind patterns relative to inland regions (Hsu, 1988). Larger wind systems such as the global wind belts are responsible for seasonal effects as these belts move between longitudes and latitudes over time (Tadross et al., 2012). However, with regard to local wind systems along the coast, land and sea breezes occur diurnally (Schumann and Martin, 1991). Annually, the local wind variability in South Africa is influenced by the country's topography, including the interior escarpment and coastal mountain ranges (Schumann and Martin, 1991). Studies assessing the climate influences on South African wind fields in coastal regions showed that the southwestern Cape has the strongest mean monthly wind strength relative to other coastal regions such as Port Elizabeth and Durban (Schumann and Martin, 1991).

In the southwestern Cape, there are distinctive changes in wind direction and strength with changing seasons. The southward movement of the ITCZ in summer causes the easterly winds to dominate over the southwestern Cape (Engelbrecht et al., 2015). Specifically, the south-easterly dominates between November to January, with wind speeds averaging 20-40km/hour and blowing gale strength for up to a week at a time (Schumann and Martin, 1991; Roberts et al., 2009; Bernard et al., 2011 and Tadross et al., 2012). In contrast, westerly winds dominate over the region during the winter period when the ITCZ shifts north (Tyson and Preston-Whyte, 2004). The position of the westerly wind belt in winter, together with the resulting winds, permits the frequent occurrence of mid-latitude cyclones (Engelbrecht et al., 2015). In particular, the north-westerly wind is dominant during winter over the southwestern Cape region, with mean wind speeds of between 20-30km/hour in August and September, and frequently exceeding gale

force (Schumann and Martin, 1991; Roberts et al., 2009; Bernard et al., 2011; Tadross et al., 2012). The south-easterly winds blow 70% of the time between November and March, but decrease to a mere 40% of the time in June, during which period the north-westerly winds blow 60% of the time (Schumann and Martin, 1991). Relative to other South African coastal regions (i.e. Port Elizabeth and Durban), Cape Town has longer periods of higher energy in both the calm and windy seasons (Schumann and Martin, 1991). The stronger winds at the Cape may be due to relatively less friction over the sea and acceleration by land due to the topography of the region (Schumann and Martin, 1991). According to Nelson and Hutchings (1983), the south-easterly winds that dominate the Cape during summer are essential for the upwelling of the ocean and in turn ensure the successfulness of the Cape fisheries (Chase et al., 2015). Even in the historical past, wind at the Cape has been a powerful controlling force contributing to weather extremes along the coastline (Figure 2.8; Turner, 1988). Where it impacted peoples' livelihoods and well-being in terms of hindering agriculture and construction, today, to a lesser extent, it still impacts livelihoods in the sense of local economies and tourism (Klopper et al., 2006).

Macro-scale processes such as the oscillation of the South Atlantic Anticyclone, together with the circumpolar westerlies that drive mid-latitude cyclones, create the air circulation landscape at the Cape (Roberts *et al.*, 2009). Differences in temperature create on-shore and off-shore breezes on a daily basis over Table Bay, False Bay and the inland areas (Bonnardot *et al.*, 2005). Localised seasonal winds at the Cape occur on a cyclic basis. Offshore hot berg winds are synchronous with coastal lows and occur during late winter and early spring (Tadross *et al.*, 2012). Storm surges and heavy rains that lead to flood conditions are generated by cut off lows from autumn through to winter (Tadross *et al.*, 2012). Table Mountain acts as a natural barrier to seasonal prevailing winds due to its orientation and height, creating wind shadows on the leeward side and promoting cloud formation and orographic rain (Tadross *et al.*, 2012).



Figure 2.8: Painting from 1658 capturing the winds blowing over Table Mountain (Thom, 1952)

2.6 Topography

The southwestern Cape region (Figure 2.9) is a biophysically diverse landmass containing a variety of terrestrial landforms with their accompanying geological substrata as well as a number of hydro-systems including wetlands, rivers and coastal areas (Talbot, 1971; Goodness and Anderson, 2013). There is a strong relationship between the topography of the southwestern Cape and the underlying geology (Meadows and Compton, 2015). It is interspersed with areas of gentle relief, due to more recent geological and aeolian and marine processes (Theron et al., 1992). The diversity of the topography has resulted in diverse habitats that support the large variety of flora and fauna (Goodness and Anderson, 2013). The Table Mountain National Park, a significant conservation entity in the region, is 25,000 ha in size, with three sides of the park enclosed by marine protected area totaling 1000km^2 (Goodness and Anderson, 2013).

Table Mountain, situated in the Cape Peninsula National Park, rises 1000m high and is flanked by Devil's Peak and Lion's Head Mountain (Meadows and Compton, 2015). In order to conserve the Table Mountain chain with its endemic fynbos, the Cape Peninsula National Park was given

World Heritage site status in 2004. In 1998, the Park was renamed ‘Table Mountain National Park’ (Daitz and Myrdal 2009). Table Mountain and Cape Point are two landscape sites that are globally renowned (Goodness and Anderson, 2013). With the warm waters of False Bay and the sand-covered Cape Flats to the east, and the cold waters of the Atlantic Ocean to the west, the mountain chain spreads across the Peninsula and is one of South Africa’s most valued tourism treasures (Figure 2.9; Meadows and Compton, 2015). The mountain is dominantly made up of the sandstone plateau and steep ridges that reach an altitude of 1085m (Meadows and Compton, 2015).

In recent years, urbanization has impacted the river and wetland systems as the upper reaches have been cut off from broader networks due to poor town planning and the lower reaches have become highly polluted (Goodness and Anderson, 2013). The formerly pristine landscape has also been compromised in order to address societal problems. For example, according to Brown and Magoba (2009), canalisation was an inappropriate engineering intervention used to address urban flooding.

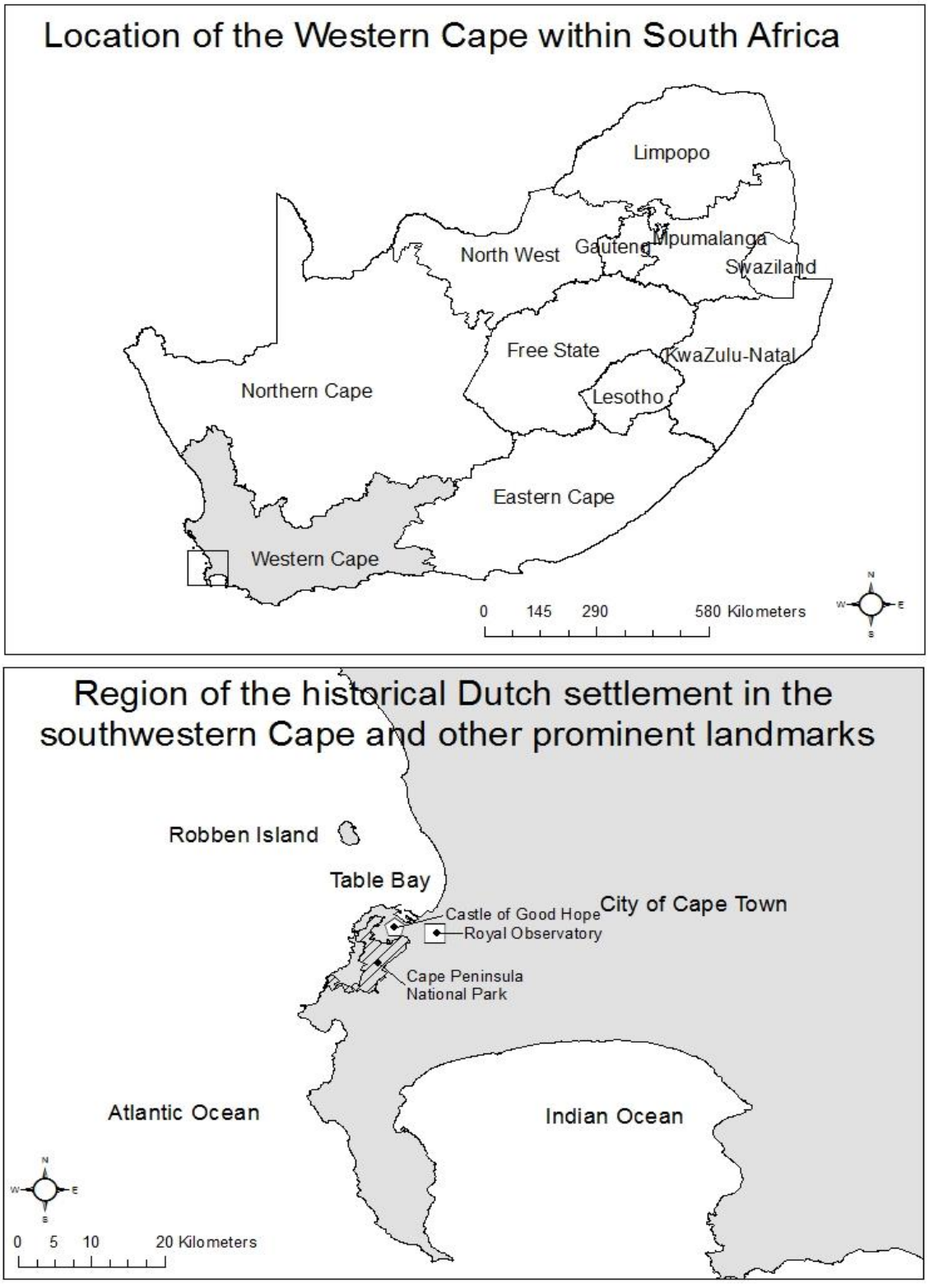


Figure 2.9: Map of Study Region

2.7 Cape Floristic Kingdom and the Fynbos Biome

The Cape Floristic Region is a biodiversity hotspot known for its beautiful natural environment, high percentage of endemic species, and is a large contributing factor for Cape Town's booming tourism industry (Holmes et al. 2008). This floristic kingdom is the smallest out of the six in the country, yet most diverse on earth (Myers et al. 2000). Hosting 9000 plant species on 90,000km^2, the region is home to 44% of all the flora species on the subcontinent and only taking up 4% of the total land area (Mucina and Rutherford, 2006). Of the approximate 3350 indigenous flora in Cape Town, 190 of these species are also endemic to the city itself (Goodness and Anderson, 2013). The ecosystem services are advantageous in that through tourism, it provides the urban poor with opportunities (Goodness and Anderson, 2013). It is also hazardous in the form of flooding in winter due to the high water table (Goodness and Anderson, 2013).

Over time, the biodiversity of the region has become threatened as there are 13 known plant extinctions and approximately 450 indigenous plants that are threatened or near-threatened (Golding 2002; Rebelo et al. 2011). Of the 440 national vegetation types in South Africa, Cape Town is home to 19 and of the 21 critically endangered vegetation types nationally, 11 are located in the city of Cape Town (Rebelo et al., 2011). Primary anthropogenic factors such as urbanization are largely the cause, compounded by secondary anthropogenic factors including the spread of alien invasive species and supressed fire regimes (Anderson and O'Farrell 2012; Meadows and Compton, 2015).

South Africa was one of the few countries in the southern hemisphere that attracted the attention of foreign travellers and explorers due to its natural vegetation (Rycroft, 1966). It was soon discovered that many of the plant species were endemic to the southwestern Cape region and hence botanists and naturalists were visiting the Cape from 300 years ago to study the plant life (Rycroft, 1966). The Fynbos biome and the Cape Floristic region has conservation appeal as it is a biodiversity hotspot and is under constant intensive research in the fields of biogeography, evolutionary biology and ecology (Cowling et al., 1996, 2003; Goldblatt and Manning, 2000; Midgley et al., 2002; Mucina and Rutherford, 2006; Bergh and Compton, 2015). The factors responsible for the distribution and success of fynbos include intensive reoccurring summer fires at 4-40 year intervals, the winter-rainfall climate and soil type and chemistry (Mucina and

Rutherford, 2006; Quick, 2013). Fire was found to be the determining factor for the success of fynbos, as species only release their seeds after fire (Cowling et al., 1996). Changes in fire season are thought to be dependent on the seasonality of rainfall and temperature variations (Deacon et al., 1992).

The fynbos vegetation is found predominantly in regions with nutrient-poor sandstones (Mucina and Rutherford, 2006). The Table Mountain Group geology is home to the mountain fynbos communities due to the shallow and nutrient-poor soils and to Afrotemperate forest patches growing on east-facing gorges or mountain passes (Meadows and Compton, 2015). Table Mountain hosts many microclimates that have given way to diverse fire-adapted plant communities of which many are endemic to the region. It is a globally renowned biodiversity 'hot spot' (Myers et al., 2000). Dotted amongst the fynbos are isolated, small populations of common species such as Restionaceae reeds, Proteaceae and Ericaceae shrubs and *Cyrtanthus ventricosus* family geophytes (Myers et al., 2000). Even with conservation efforts, anthropogenic activities such as agriculture and urban development have significantly impacted the Cape flora (Meadows and Compton, 2015). The fynbos communities are most impacted due to the alien vegetation, fire management problems and the impacts of climate change (Meadows and Compton, 2015). Since the establishment of the colonial settlement, much local vegetation was cleared for agricultural purposes, leaving the land bare and exposed to soil loss due to wind erosion (Baxter and Meadows, 1999). Pine and eucalyptus plantations found on the lower slopes of Table Mountain are now being eradicated as part of the mandate of the government established 'Working for Water' programme (Goodness and Anderson, 2013). The clearing of these plantations has led to increased surface run-off and associated accelerated soil erosion (Meadows and Compton, 2015).

2.8 Fauna

Historical evidence from rock art and fossils show that the Cape region was home to a variety of larger fauna including the Cape lion, leopard and hyena (Kandel and Conard, 2003). Due to hunting and urbanisation, much of the fauna have either been eradicated from the Cape region or have migrated over time to more natural environments (SANParks, 2008). Historically, large

predators such as the Cape lion, black-back jackal, spotted hyena and leopard were reported in this region, as recently as the 1920s (Martins and Martins, 2006). Upon the arrival of the European settlers, black rhinoceros, bush buck, elephant, eland, zebra and other types of antelope species disappeared from the area (Goodness and Anderson, 2013). However, a few antelope species have been reintroduced to a section of the Table Mountain National Park and smaller mammals such as the Cape grysbok, caracal and klipspringer may still be found in the park (SANParks, 2008).

Four hundred years ago, before the Cape leopard (*Panthera pardus*) population was diminished, it was sympatric with the African elephant, buffalo, black rhinoceros, hippopotamus and spotted hyena (Skead, 1980). Today, in the southwestern Cape, the leopard is the only remaining species, from those mentioned previously, and is defined as an apex predator (Skead, 1980). According to conservation studies by Martins and Martins (2006), these leopards have been mistreated for over 350 years by farmers and have now been restricted to inaccessible mountains such as the Cederberg. The Cape leopards are significantly smaller than the northern leopards of South Africa, which could potentially show the extent of the genetic isolation of the Cape leopard population (Martins and Martins, 2006). Further, the results of a density study have shown that these leopards occur in low numbers within the southwestern Cape region. In 1974, the leopard was declared a 'protected wild animal' and action was taken thereafter to minimalize the killing of these animals (Martins and Martins, 2006).

Whaling is a controversial issue in current affairs as the Japanese continue to hunt whales as a source of food (Kandel and Conard, 2003). In recent years, whales have become an endangered species (Vinding et al., 2015), unlike centuries ago when whales were hunted as a source of food and oil (whale blubber). According to Kandel and Conard (2003), the Later Stone Age people scavenged for and processed beached whales given their source of meat and blubber in the Western Cape Province. The results of the study by Kandel and Conard (2003) strongly suggest that the Later Stone Age people obtained meat from beached humpback whales and then took it back to their camps, approximately 4 km inland, where they lit a fire and processed the whale meat and blubber, discarding any remains around the periphery. During the mid-1600s, archival evidence in the form of diary entries explain how indigenous people of the Cape ate whale meat

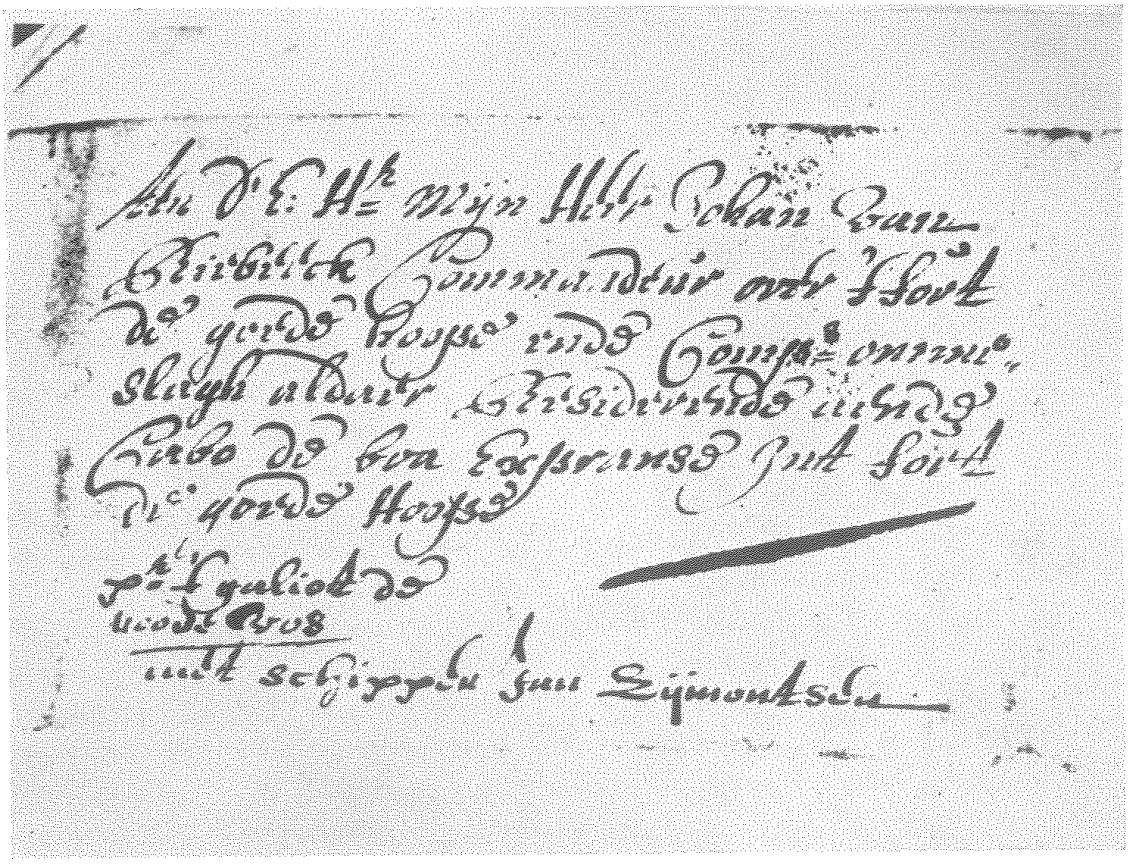
and stored the whale blubber to either drink or smear on their bodies (Raven-Hart, 1967). According to Smith and Kinahan (1984), whale meat was dried and eaten raw or rehydrated and cooked.

Faunal counts, while diverse, do not share the same level of endemism as plant species in the southwestern Cape, with the exception being invertebrates (Goodness and Anderson, 2013). These animal numbers include 364 bird, 83 mammal, 60 reptile, 27 amphibian and eight freshwater fish species (Rebelo et al., 2011). Much conservation efforts exist for amphibians in the city of Cape Town, with ten amphibians listed on the International Union for Conservation of Nature (IUCN) Red list as threatened species. There are also two species of amphibian that are endemic to the city of Cape Town (Goodness and Anderson, 2013). There is a high connectivity between the urban city environment with the conservation areas. Animals from conservation areas often frequent their adjacent neighbourhoods (Rebelo et al., 2011). Chacma baboons are also found in the Table Mountain National Park, but have grown accustomed to human food and pose a threat to people visiting the parks (Hoffman and O'Riain, 2012).

2.9 Summary

The refreshment station at the Cape of Good Hope was initially intended to be a lucrative business venture by the DEIC. However, through the centuries, the Cape of Good Hope quickly evolved into a hub of social, economic and political activity. The biographical information of Jan van Riebeeck and Zacharias Wagenaer is indicative of their credibility as sources for the purposes of this research, with the former being relatively more credible than the latter, based on experience. The contemporary climate of the southwestern Cape was then discussed in some detail. Notably, the region has unique seasonal patterns relative to other regions in South Africa. The southwestern Cape is known for its dry, hot summers brought on by the dominant south easterlies and cool, wet winters due to frequent mid-latitude cyclones. The west coast is also subject to the cold Benguela current and upwelling, which results in lower temperatures. The region is also world renowned for its topological features such as the Cape Fold Belt mountain range and being home to the Cape Floristic Kingdom, a habitat of a multitude of flora and faunal species including those that are endangered and endemic to the region.

Chapter 3: Literature Review



Cape Archives

COVER OF A LETTER ADDRESSED TO JAN VAN RIEBEECK

3.1 Introduction

Mass media such as national newspapers are important mechanisms to transfer national and international information, such as issues including climate change, for the general public at large. A study conducted by addressing the media attention on climate change found that coverage had increased in all 27 countries investigated between 1996 and 2010, however, in some countries more so than others (Schmidt et al., 2013). South Africa's *Sunday Times* had 383 articles and *The Star* had 1066 articles related to climate change, making up 0.95% of the total number of climate change articles worldwide (Schmidt et al., 2013). This is fairly low relative to Australia (15.40%), the United Kingdom (14.74%) and India (2.05%) representing a part of the total number of articles related to climate change worldwide (Schmidt et al., 2013). Overall, the issue of climate change has fast become a widespread global concern.

The field of historical climatology has made important contributions towards developing an understanding of past climate, but could, however, contribute much more towards current debates and discussions concerning climate change and associated impacts and responses (Carey, 2012). Historical climatology has received increasing attention during the last few decades due to discussions and concerns on human induced climate change during recent times (Bradley, 1991; Glaser, 1996; Mann et al., 1998; Jones et al., 2001; Guiot et al., 2005; Kelso and Vogel, 2007; Grab and Nash, 2010). The focus of current climate discussions tends towards the science, with rather too little attention given to the social and cultural dynamics involved (Carey, 2012). It is the extensive anthropogenic processes of the past that have created unequal societies that have to live with the vulnerabilities associated with climate change today, showing again the significance of historical climate records and historical societal interactions with the environment (Liverman, 2009; Carey, 2012). Academics have for a long time been studying and critically questioning the human-climate relationships of the past. This literature review firstly discusses documentary climate reconstructions in detail at an international, continental and local level. Secondly, case studies that show the relationships between past climates and climate anomalies, such as the El Niño Southern Oscillation, droughts, floods and the Little Ice Age, are discussed.

3.2 Climate reconstructions for the historical period – a global overview

Henry Lamb was a pioneer in historical climatology, reconstructing climate changes on a global scale for the past 1000 years using phenological and documentary sources (Kington, 1988). China, Japan and Europe are regions which have extensively used historical documents for past climate reconstructions (Pfister et al., 2009). Several climate time series, based on documentary sources, have been compiled for South America for the period towards the end of the 19th C (Prieto and Herrera, 2009; Villalba, 2009). According to Bradley (1991), North America had limited documentary based climate reconstructions, however, Nash and Adamson (2014) have noted that in recent years, there has been an increase in the reconstructions for the North American region.

3.2.1 Europe

Daily instrumental meteorological data are available for Europe as far back as the 17th C (Pfister et al., 2009). Daily wind and weather records are also available from past documentary sources, but with interruptions in the data and decreasing reliability back to the Middle Ages (Kington, 1988). In central Europe, documentary sources of information with a seasonal temporal resolution go as far back as the year 1500, at a monthly resolution (Glaser, 1996). The main types of climate data used to reconstruct Europe's pre-instrumental climate period include harvest dates, the occurrence and frequency of snowfall, as well as sea-ice occurrence (Pfister et al., 1999). However, phenological data are most abundant and have provided extensive insights into past climate conditions. Comprehensive records of grape harvest dates for different parts of Europe have proven particularly useful for reconstructing climate chronologies for the past few centuries, as well as for corroborating with other studies, as there are several decades of overlap (Le Roy Ladurie and Baulant, 1980; Bradley, 1991; Pfister et al., 1999; Wheeler, 2001; Luterbacher et al., 2002; Pauling et al., 2006; Battipaglia et al., 2010; Büntgen, 2011).

British naval logbooks from the 17th C contained daily weather reports which made no use of meteorological instruments (Kington, 1988). These logbooks contain entries of weather observations which were written daily at noon for the previous 24 hours, and were subdivided

into a first, middle and latter part of the day. Ship logbooks are the most important institutional source as they provide direct observations on wind characteristics and weather on a daily to sub-daily basis (Pfister et al., 2009). The entries were of a spatial nature with a record of the ship's position given each day at noon (either the name of the port if in a harbor, or by the latitude and longitude if at sea) (Kington, 1988). During the 18th C, logbooks would use a standardised set of terms to describe the weather (Kington, 1988 and Pfister et al., 2009); these are illustrated in Table 3.1.

Table 3.1: Terminology used to describe the weather (adapted from Kington, 1988)

State of Sky	Weather	Visibility	Wind (Beaufort wind force scale)
Serene	Drizzle	Haze	Calm
Clear	Rain	Thick haze	Light air
Fine	Snow	Mist	Light breeze
Fair	Sleet	Fog	Moderate breeze
Cloudy	Hail	Thick fog	Fresh breeze
Overcast	Shower		Fresh gale
Thick weather	Rain squalls		Strong gale
	Thunderstorm		Hard gale
	Lightning		

3.2.2 China

Weather and environmental related data have been recorded in China for the past 2200 years, as requested by the government (Pfister et al., 2009). The data were required in order to prevent socio-economic impacts such as famine and riots. The data included information on past and present geography, natural disasters, and agriculture, which in later centuries also included crop yields during harvests and records on precipitation (Bradley, 1991; Pfister et al., 2009). In China, fictional accounts such as poetry contain climatic evidence dating back to approximately 3000 BC (Catchpole and Moodie, 1978). According to Catchpole and Moodie (1978), climatologist Chu K'o-chen extracted climate related data from poetry for the period 1100 BC to 1400 AD. For instance, plum trees were mentioned in poetry from the Yellow River Valley region during the T'ang (618-690 AD) and Sung (969-1126 AD) Dynasties, after which no mention to such fruit trees were made in the years that followed, which may be due to lower temperatures

(Catchpole and Moodie, 1978). Several other Chinese poets wrote about the lychee fruit tree (commonly known as litchi in South Africa) being an economic crop in western China, but appears to be absent from this region since the 12th C, when it is assumed that this region became too cold (lychee trees die at temperatures below -4˚C) (Catchpole and Moodie, 1978).

In recent years, potential climate change was examined for over 100 sites in China using a Dryness/Wetness (DW) Index (Song, 2000). The DW dataset spanned over 529 years and was made up of both historical writings and precipitation records. This was a unique study for China as most historical climatological work assesses past climate using precipitation and other proxies (Song, 2000). Due to the magnitude and extent of the DW Index, it was possible to assess climate change associated with temporal and spatial variations and their extremes. It was found that that dryness was frequent in the early 16th and 17th C, mostly in north-eastern China. Dryness was less frequent during the 18th-19th C (Song, 2000). There was a relatively high increase in dryness for the 20th C. Wetness gradually increased for the 18th and 19th C and there has been little change since then. Overall, the 20th C saw an increase in extreme dryness and wetness (Song, 2000).

A 1000-year time series of typhoon landfalls in Guangdong, southern China, was reconstructed using historical documents in the form of semi-official local gazettes called *Fang Zhi* (Liu et al., 2001). The most active period was 1660-1680, with 28-37 typhoon landfalls occurring per decade. The periods 1660-1680 and 1850-1880 coincided with the coldest and driest periods in northern and central China during the Little Ice Age (Liu et al., 2001). The historical reconstruction was calibrated against the instrumental period (1884-1909) and there was a high correlation ($r = 0.71$) which demonstrates the reliability of such an historical record (Liu et al., 2001).

3.2.3 Japan

As with China, Japan has a rich collection of historical documents that contain information about past climatic conditions (Catchpole and Moodie, 1978). There is an almost continuous daily record of weather conditions for the late 1600s to late 1800s for the region of Hirosaki (Bradley, 1991). These records were carefully studied and it was estimated that the 20th C was relatively

warmer compared to the preceding 250 years (Maejima and Tagami, 1984). Rice harvest dates, snowfall years and lake freezing occurrences are some of the proxies used to reconstruct climate, with a cold period recorded from the 17th to 19th C (Bradley, 1991). Lake freezing dates are available as far back as 1444 (Catchpole and Moodie, 1978). The bloom dates of cherry blossoms were used to determine the commencement of spring from as early as the 9th C (Arakawa, 1955; Aono and Saito, 2010). The date of blooming is controlled by temperature, but more particularly temperature over several days. The bloom dates indicate the arrival of spring, such that a late bloom date would mean a longer cold period and an early spring a warm period (Arakawa, 1955). These blooming dates extend over 10 centuries and therefore serve as an excellent phenological proxy for climate reconstruction. March mean temperature series, spanning 732 years from AD 812-2005, were compiled using the flowering data of cherry trees from chronicles and old diaries (Aono and Kazui, 2008).

3.2.4 India

The regions of Asia that experience monsoons have a variety of proxy climate sources, such as dendroclimatic studies, and are home to some of the oldest civilizations (Pant, 2003). India's monsoons are well recorded in folklores and written documents (Adamson, 2014). Climate related documentary sources mostly make reference to monsoonal rains; examples of this include reference to droughts, floods and poor harvests due to a lack of rain (Pant, 2003; Adamson, 2014). There is an abundance of ancient literature that makes reference to monsoons in India. Historical evidences portray famine conditions due to flood and drought events (Pant, 2003). There was a low frequency of droughts noted for the period AD 900-1600 which may be attributed to limited historical evidence that only addressed severe drought events. The frequency was relatively higher from the 1600s when the drought events were more randomly spread out (Pant, 2003).

Annual monsoon onset dates were reconstructed for western India (in particular, Mumbai) using documentary evidence and newly discovered instrumental data (Adamson and Nash, 2012, 2014). The documentary evidence was comprised of narrative materials written in English and the instrumental data were obtained from weather reports in newspapers (Adamson and Nash, 2012, 2014). The results show that the average monsoon onset date fluctuated from 8th June

during the 18th C and 19th C to later than 13th June between 1955 and 1984. This shift in the late 20th C had not been experienced prior to the last 230 years, thereby demonstrating that the duration and intensity of monsoon onsets have become increasingly delayed (Adamson and Nash, 2012, 2014). The results also show that there is no change in the long-term correlation between El Niño Southern Oscillation (ENSO) and the date of monsoon onset in Mumbai. These results are in agreement with Goswani and Xavier (2005) who detected a stable relationship between the length of the monsoon season and ENSO (Adamson and Nash, 2012, 2014).

3.2.5 Australia and New Zealand

In recent years, Australia and New Zealand have pioneered studies reconstructing climates using documentary based records. An initial short study by Gergis et al. (2009) looked at instrumental daily temperature and barometric pressure records in Sydney Cove, New South Wales, for the period 1788-1791 (Gergis et al., 2009). These observations were comparable with modern day records from Sydney, with similarities in daily, seasonal and inter-annual weather variability (Gergis et al., 2009). The reliability of the data was corroborated against historical documentary evidence and palaeoclimate data and biases associated with the temperature readings were identified (Gergis et al., 2009). The study period happened to coincide with El Niño and La Niña episodes identified by Gergis and Fowler (2009), however, the period under study for Sydney Cove was not conclusive in linking to ENSO conditions (Gergis et al., 2009). However, later studies by Gergis et al. (2010) identified strong La Niña type conditions for the period 1788-1790 using documentary based records and corroborating with palaeoclimatic data. Furthermore, much evidence from the documentary sources demonstrated severe droughts in 1791, which supported the argument of the onset of a strong El Niño after the La Niña (Gergis et al., 2010). These findings were in agreement to those of Gergis and Fowler (2009). Most recently, Fenby and Gergis (2013) extended the historical reconstruction for the pre-instrumental period (from 1788-1860) using secondary sources for five sub-regions in south-eastern Australia (Ashcroft et al., 2014; Fenby and Gergis, 2013). The results of the study identified 14 high rainfall years in New South Wales and 27 years of drought across south-eastern Australia (Ashcroft et al., 2014; Fenby and Gergis, 2013).

A temporally shorter documentary based weather/climate reconstructions has also been produced for northern New Zealand using the missionary diaries of Reverend Richard Davis for the period 1839-1851 (Lorrey and Chappell, 2015). Complementary to the diaries' qualitative description of the daily weather conditions, the Reverend also kept thorough meteorological records (Lorrey and Chappell, 2015). Analysis of the meteorological records indicated relatively more frequent southerly and westerly circulation patterns, and cooler winter temperatures than the contemporary period (Lorrey and Chappel, 2015). Most interestingly, qualitative commentary in the diaries make reference to 'dirty weather' which may be understood as "disturbed conditions with strong winds and driving rainfall" (Lorrey and Chappel, 2015, p.3800).

3.2.6 North America

Historical climatology studies have been undertaken in North America (Bradley, 1991; Burnett and Stahle, 2013). However, thorough reconstructions have been undertaken for Hudson Bay in Canada (Catchpole et al., 1976), and relatively fewer studies on climatic records for New England in the United States (Baron and Gordon, 1985; Burnett and Stahle, 2013). The dates of freezing and break up of ice at Hudson Bay were examined and results show that there was a 2.5°C increase in spring and autumn temperatures from the 19th to 20th C (Catchpole et al., 1976).

A 16th C Spanish Florida historical climate record was reconstructed using documentary sources together with dendrochronology and archaeology (Paar, 2009). The climate of Santa Elena, Florida, was reconstructed for the period 1566-1587 (Paar, 2009). The study aimed to show the impacts drought had on the food reserves of the Native Americans. The dendrochronological data corroborated with the historical documents showing evidence of food shortage (Paar, 2009). Historical droughts were also examined for the year 1860 using instrumental data and supplemented by documentary evidence (Dodds et al., 2009). The reconstruction focused on the drought and hurricane season and the impacts on society. An historical account of a 1771 flood on the southern Atlantic seaboard in Virginia was compiled using documentary evidence such as journals, letters, official records and newspaper articles (Blanton et al., 2009). In addition, ship logbooks, private weather records and instrumental weather records were used to reconstruct a synopsis of the weather conditions (Blanton et al., 2009). The study critiqued the relationship of

floods and human affairs. It was found that major floods are given lower priority in human costs relative to droughts or even hurricanes. This is due to lower income communities existing in lower lying areas along flood zones (Blanton et al., 2009). In 18th C Virginia, the slave houses and lower grade commercial facilities were located on low lying areas which resulted in a 'disproportionate impact' of the flood on the underprivileged (Blanton et al., 2009, 19).

3.2.7 South America

A database of the various climate proxies available for climate reconstruction in South America was produced by Villalba et al. (2009). Relative to the northern hemisphere, the southern hemisphere lacks data going back much beyond the 19th C, which is an unfortunate paradox as it is hypothetically the best place for detecting greenhouse gas signals (Shindell and Schmidt, 2004). Southern Bolivia, Chile and north-western Argentina contain tree-ring records of tree species which provide valuable information on precipitation (Villalba et al., 2009). Although South American documentary evidence is limited to the past 450 years, it has a broad spatial coverage and offers the longest and most comprehensive record for the southern hemisphere. Potential documentary sources are presented for climate reconstructions across several South American countries, but on a regional basis (Prieto and Herrera, 2009). The time scale of these records varied between regions depending on the arrival of the Spanish to any particular region (Prieto and Herrera, 2009). The majority of the documents are made up of temperature, precipitation and/ or stream flow records. The quality of different record types (historical, colonial and republican periods) are also critically assessed by Prieto and Herrera (2009).

3.2.8 Africa

American and European work on documentary records focuses largely on constructing time series and to a lesser extent on anthropogenic indicators, while in Africa the focus is predominantly on drought and its human impact (Anderson, 1984). The importance of research in historical climatology is highlighted by a case study presented by McCann (1999) for West Africa. In 1987, a documentary film entitled "*The Desert Doesn't Bloom Here Anymore*" showed the devastated arid landscapes of West Africa and southward expansion of the Sahelian desert. This was attributed to the poor farming practices of African farmers and overgrazing which

resulted in the 1972-1974 famine. However, the causes have been challenged by Nicholson (1978), who used lake levels from Lake Chad, together with historical landscape descriptions from documentary sources and climate models, to conclude that the Sahel has experienced a sustained decline in rainfall which is more severe than anywhere else in the world. Furthermore, it is suggested that drought periods spanning one or two decades have been a recurrent feature for the Sahel over the last 500 years (Nicholson, 1978; Brooks, 1993; Webb, 1995). The relationship between ENSO and African rainfall was investigated by Nicholson and Kim (1997), who demonstrate that several regions of Africa responded strongly to ENSO in months either preceding or following the rainy season. The ENSO signals also showed teleconnections between the Sahel and southern Africa, as prior to the study it was believed that no relationship between ENSO and the Sahel existed (Nicholson and Kim, 1997). Most recently, Norrgård (2015) has explored the historical climate for West Africa spanning the period 1750-1800 on the basis of travel journals and British documents. The most notable climate events were found for the 1780s and 1790s with periods of very wet conditions and very dry conditions respectively (Norrgård, 2015).

Africa still remains relatively underexplored in terms of utilising climate proxies to reconstruct past climates, particularly from documentary sources (Pfister et al., 2009). However, this excludes southern Africa, as considerable work has been undertaken by a variety of authors, including Nicholson (1979, 1981, 2014), Vogel (1987, 1989), Nash (1996), Endfield and Nash (2002a, b), Nash and Endfield (2002, 2008), Kelso and Vogel (2007, 2015), Grab and Nash (2010), Nash and Grab (2010), Nicholson et al. (2012a, b, 2014), Hannaford et al. (2014, 2015) and Nash et al. (2015, 2016). Temperature trends from documentary records are supported by studies conducted in South Africa and eastern Namibia, which used snowfall occurrences and freezing temperatures as proxies for climate reconstructions (Nicholson, 1979; 1981). For African regions, historical climatologists generally use the amount of rainfall (abundance or absence) to reconstruct past climates (Bradley, 1991). Due to a lack of historical records, there is little hope to accurately reconstruct climates for the southern hemisphere unless a combination of historical evidence including dendrochronology, ice-cores and sedimentary data are used (Bradley, 1991).

A 19th C climate chronology using direct evidence from published and unpublished sources is also available for the Kalahari region (Nash and Endfield, 2002). The documentary sources were used to reconstruct a rainfall record for the period 1815 to 1900. The results from the chronology showed good agreement with the limited instrumental data available for the study period, as well as agreement with Vogel's (1989) study for the Western and Eastern Cape regions (Nash and Endfield, 2002). Furthermore, incidences of drought or low summer rainfall correspond with low-phase Southern Oscillation (SO) events (Nash and Endfield, 2002), which is in agreement with the research work of Lindesay and Vogel (1990). Additional research used documentary evidence to demonstrate a change in the frequency of flow in some hydrological systems (e.g. dry valleys) of the Kalahari (Nash and Endfield, 2002). Later the rainfall variability in Central southern Africa including the Kalahari for the period 1840-1900 was reconstructed using published and unpublished documentary sources to specifically look at the 17 ENSO episodes that occurred during this period (Nash and Endfield, 2008).

The first historical climate chronology assessing cold season conditions in southern Africa was established for Lesotho from 1833 to 1900 (Grab and Nash, 2010). The primary data used in the study were derived from various documentary sources obtained from southern African and British archives. The cold season climate chronology was used to test for connections with global temperature records and volcanic eruptions within the same study period. The results showed relatively more severe cold seasons in the earlier part of the study period and milder conditions during the latter period (except for the 1880s) (Grab and Nash, 2010). The results also corroborated well with air temperatures for the southern hemisphere (Grab and Nash, 2010). Globally, the shifts in regional circulatory patterns that influenced temperatures over the northern hemisphere during the 19th C may have in fact had similar impacts on the southern hemisphere (Grab and Nash, 2010). The study also demonstrated that when the northern hemisphere experienced cooler than normal summers after volcanic eruptions, it may be seasonally reversed for the southern hemisphere which experiences cooler than normal winters subsequent to major eruptions (Grab and Nash, 2010).

A further documentary-based study on Lesotho established past rainfall patterns between 1824 and 1900 (Nash and Grab, 2010). From this study, sequences of annual rainfall variability were

derived and then compared to records in South Africa, Zimbabwe and Botswana. The results show nine wet or flood periods as well as nine drought periods, however, no overall wetting or drying trend could be identified for Lesotho over the study period. The results agree with those from surrounding countries of Botswana and Zimbabwe (Nash and Grab, 2010). Of the nine drought periods, seven have been shown to coincide with low phase ENSO events (Nash and Grab, 2010). For Zimbabwe, the most notable historical climate reconstruction has been based on tree rings, from which rainfall has been reconstructed (Therrell et al. 2006). Tree rings have also been used in climate reconstructions, particularly of rainfall, in the Natal Midlands (Vogel et al., 2001) and the Cederberg (Dunwiddie and LaMarche, 1980).

Most recently, documentary based climate reconstructions have been developed and analysed to establish the past occurrence of tropical cyclones in Madagascar (Nash et al., 2015), and rainfall seasonality in KwaZulu-Natal (Nash et al., 2016). An analysis of the human impacts of climates reconstructed for Namaqualand is detailed by Kelso and Vogel (2015). Notably, the tropical cyclone reconstruction brings together a range of documentary sources together with the NASA IbTracs data presenting a relatively unique multi-proxy approach (Nash et al., 2015). The seasonality reconstruction for KwaZulu-Natal (Nash et al., 2016) is important for the large number of study sites explored and contributes to the discussions on rainfall seasonality in South Africa raised by Neukom et al. (2014).

The documentary based climate reconstructions for southern Africa have been reviewed in detail by Nash and Adamson (2014). Most notable from this review paper is arguably the most comprehensive synthesis of the climatic conditions experienced during simultaneous periods across different regions (Figure 3.1). From the graph developed in this synthesis (Figure 3.1), it is apparent that rainfall chronologies are highly location specific, with simultaneous wet periods in one location and dry in another (Nash and Adamson, 2014). It is notable however, that this synthesis only spans the last two centuries.

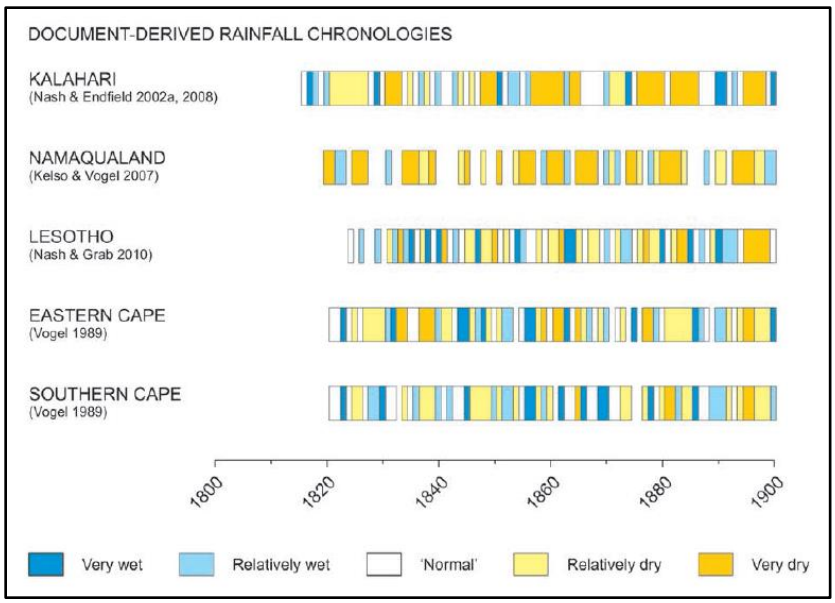


Figure 3.1: Synthesis of documentary based climate reconstructions for southern Africa (Nash and Adamson, 2014).

3.2.9 Local climate reconstructions (Cape Region)

A climate chronology was constructed for the 19th C in the Namaqualand region using documentary derived evidence (Kelso and Vogel, 2007). The chronology is used to discuss drought episodes, as well as extended dry and wet years. The chronology is also compared to the Cape region (Vogel, 1987, 1989) and the Kalahari (Nash and Endfield, 2002, 2008). The climate of Namaqualand was reconstructed to identify how the native rural community (Khoi Khoi) adapted to, and coped with, climate fluctuations at the beginning of the 19th C, as their coping ability had decreased by the end of that century (Kelso and Vogel, 2007). The study outlines several dry and wet periods for 19th C Namaqualand. Of the dry years, the widespread drought years were in agreement with the studies by Vogel (1987) and Nash and Endfield (2002). The drought episodes were also cross-checked for coinciding with low-phase ENSO events. Several drought or dry years were found to possibly be consistent with low phase ENSO events (Kelso and Vogel, 2007).

A 19th C climate chronology for the Cape region for the period 1820-1900 using documentary evidence was compiled by Vogel (1987, 1989). This was the first study of this nature for South Africa. The main objectives of the study were to use the Cape chronology to reconstruct a portion of southern Africa's past climate, to determine whether the 20th C climate had altered or remained similar to that in the past, and to gauge the frequency of drought episodes (Vogel,

1987). A simple method was used to reconstruct the rainfall record of the Cape region; documents that referred to a particular time and included the location were used to extract descriptions of the then current weather conditions (Vogel, 1987). Other documents were used to offer supporting evidence of the climate for a given time period (Vogel, 1987). Through such a methodology, past temporal and spatial rainfall patterns and crop yields could be constructed for the Cape Colony. The study showed that the wet and dry periods were inconsistent, relative to the wet and dry periods first assumed (Vogel, 1987, 1989).

Using the chronology from this research, the relationship between rainfall and early Southern Oscillation (SO) chronologies were investigated by Lindesay and Vogel (1990). The results showed a direct relationship where low-phase ENSO events were related to below normal rainfall, while high-phase ENSO events were related to above normal rainfall (Lindesay and Vogel, 1990). It has been shown that SSTs in El Niño episodes comprise of a cold phase in the first half of the episode and a warm phase in the second half in the Atlantic and Indian Oceans (Nicholson and Kim, 1997). This is reversed during a La Niña episode (first half – warm phase, second half – cold phase; Nicholson and Selato, 2000). Rainfall over southern Africa in the second half of the La Niña episode is in direct contrast to El Niño, as it is abnormally high. However, rainfall is most consistent in the second half of both La Niña and El Niño episodes (Nicholson and Selato, 2000). The results show that SSTs in the Atlantic and Indian Oceans are the dominant factors influencing rainfall variability in Africa, rather than El Niño/La Niña episodes (Nicholson and Kim, 1997; Nicholson and Selato, 2000). This phenomenon has been further explored using regional climate models (Barrable et al., 2002). In recent years, winter precipitation for southern Africa has been reconstructed from multi-proxy records which include documentary sources for the past 200 years (Neukom et al., 2014). This work further explores the variability between the winter and summer rainfall zones (Neukom et al., 2014).

Investigating documentary records for wind in the southwestern Cape, Hannaford et al. (2015) utilized ship log books as a primary source of documentary evidence. Ship log books have been receiving increased focus over recent years for climate reconstructions (cf. Wheeler and García-Herrera, 2008; Fitchett and Grab, 2014; Nash et al., 2015). This study most importantly found a strong relationship between wind and precipitation in Cape Town (Hannaford et al., 2015).

Furthermore, a relationship was found between El Niño and the westerliness of winds for the southwestern Cape (Hannaford et al., 2015).

3.3 Prominent climate oscillations during the Holocene

Climate oscillations are natural processes occurring on earth (Mayewski, et al., 2004). Prominent periods of cooling and warming include the Medieval Warm Period which occurred from about AD 950-1250 and the Little Ice Age (LIA) which occurred from about 1300-1850 AD (Keigwin, 1996; Tyson et al., 2000; Wanner et al., 2015). There is considerable evidence for the LIA in southern Africa, most of which has been recorded from speleothems (cf. Brook et al., 1999; Holmgren et al., 1999, 2001, 2003, 2006; Sundqvist et al., 2013). Further evidence for the LIA is derived from pollen (Ekblom et al., 2008; Neumann et al., 2010), geochemistry (Weldeab et al., 2013) and diatoms (Stager et al., 2011). These climate fluctuations may be due to several factors including changes in the thermohaline circulation, polar cooling, changes in sea level, the hydrological cycle, forest cover and sea ice extent (Keigwin, 1996; Mayewski, et al., 2004). The LIA may be part of the millennial scale cycle with respect to climate variability when the cold North Atlantic Ocean waters move southwards (Bond et al., 1997; Wanner et al., 2015). These cycles, termed Bond Cycles, occur approximately every 1500 years in the North Atlantic and mimic ice age conditions in the Greenland and Iceland regions (Johnson et al., 2001). The period under study for this dissertation falls within the LIA and it is therefore necessary to fully explore these recent climate oscillations further. Even though the MWP does not fall within the study period, it is still necessary to explore this warming period as it is still very recent in geological time scales (Tyson et al., 2000; Esper & Frank, 2009).

3.3.1 Medieval Warm Period (MWP)

Evidence from the MWP does not conclusively show that the period was as warm or warmer than the late 20th C (Crowley and Lowery, 2000; Bradley et al., 2003; Truc et al., 2013). However, there exist studies showing the presence of a relatively warmer period (Tyson et al., 2000). One such study used a combination of proxies including documentary evidence and ice cores to show that favorable conditions existed during AD 800–1100 in the North Atlantic region (Ogilvie et al., 2001). Temperatures were higher for this period relative to the later centuries but

were not more than 2°C. This is what allowed the Vikings to travel to and inhabit Newfoundland, Greenland and Iceland without sea ice posing any danger (Ogilvie et al., 2001).

Similarities in climates during the MWP have been noted across the African continent. Two thousand years ago Bantu agropastorlists moved into southern Africa (Huffman, 1996). The local climate needed to be both warm and wet to permit the growth of grain crops (Huffman, 1996). The study makes a connection between archaeological cultural data and the climate findings by Tyson and Lindesay (1992) that higher temperatures were associated with higher rainfall in summer rainfall areas. The dendroclimatic data showed that grain production and rainfall were important factors in the migration of these Bantu-speaking Iron Age farmers (Huffman, 1996). Carbonized seeds from Mapungubwe, South Africa, show that sorghum was harvested, a grain crop that, in order to be successful, would have required 150mm higher rainfall than what the region experiences today (Huffman, 1996). The climate records show a warmer and wetter period from AD 900-1300 (Tyson and Lindesay, 1992), and together with the archaeological evidence, is indicative of the MWP (Huffman, 1996).

Sediment records were analysed in Lake Naivasha, Kenya, which indicated a relatively dry MWP from 1000-1200AD (Verschuren et al., 2000). In southern Africa, warm episodes occurred at approximately 900-100BC. The stalagmite record taken from Cold Air Cave in the Makapansgat Valley, South Africa, distinctively showed the MWP at approximately 900AD (Holmgren et al., 2001). At the peak of the MWP, temperatures may have been 3°C warmer than today (Holmgren et al., 2001; Tyson et al., 2000). There exists limited evidence showing warming after the mid-19th C using the temperature series derived from the stalagmite record (Holmgren et al., 2001). These conclusions of a mid-Holocene warm phase are supported by *Podocarpus* pollen frequencies which were used to reconstruct forest history in Maputoland, South Africa (Finch and Hill, 2008; Neumann et al., 2008, 2010). The results of this study showed that during the early Holocene, there was a rapid increase in *Podocarpus* pollen frequencies of approximately 60% indicating abundant forests (Finch and Hill, 2008). The mid-Holocene warm phase resulted in temperatures reaching approximately 3°C warmer than the present day, however *Podocarpus* pollen frequencies decreased (Finch and Hill, 2008; Neumann et al., 2014). Furthermore, it was found that several other forest species such as *Acacia*, *Ficus,*

Rosaceae and *Protea* were increasing rapidly (Finch and Hill, 2008). It was then deduced that there was selective forest burning and deforestation of the *Podocarpus* species as other evidence suggests forest growth and expansion during the mid-Holocene warm phase (Finch and Hill, 2008). During this epoch, conditions were relatively wetter and warmer than the present day for the entire eastern region of South Africa (Partridge et al., 1997). More recently, Holocene climate proxy research has included analyses of pollen, diatoms, phytoliths and geochemistry at Braamhoek Wetland in the Free State (Norström et al., 2009, 2014; Finné et al., 2010), an analysis of pollen for Mahwaqa Mountain in KwaZulu-Natal (Neumann et al., 2014) and an analysis of isotopes at Sehonghong in Lesotho (Loftus et al., 2015).

3.3.1 Little Ice Age (LIA)

The term LIA is the recent period from the 16th to mid-19th C when mountain glacier expanded. Throughout the literature, it is noted that even though Europe was impacted during the LIA, other climate conditions were experienced in other parts of the world (Mann, 2002). For instance, North America did not appear unusually cold during the 17th C (the coldest century for Europe), and during the 19th C when Europe was coming out of the LIA, North America experienced some of its coldest temperatures with freezing over of the New York harbour (Bradley and Jones, 1993). In addition, according to documentary records, Russia and China show different temperature variations to those of Europe (Bradley and Jones, 1993; Mann, 2002). The following section specifically looks at the LIA as a result of the outcomes of studies on the northern and southern hemispheres as well as within the local South African context. Most recent work proving the existence of the LIA in southern Africa derives from stalagmites in the interior (Holmgren et al., 2003; Sundqvist et al., 2013) and from coral in Madagascar (Zinke et al., 2014).

3.3.2.1 Northern Hemisphere

During the LIA, the European climate was most strongly impacted by trends towards enhanced glacial conditions. The LIA was not a global synchronous period as previously thought (Wanner et al., 2015). It should instead be defined as a large-scale event of modest cooling in the northern hemisphere with a 0.6°C decrease in temperature within the LIA time period (Bradley and Jones,

1993; Jones et al., 2001, Mann, 2002; Wanner et al., 2015). Aside from documentary evidence, paintings from the LIA capture the large glacial expansion of the French and Swiss Alps (Mann, 2002). To illustrate the impact of the LIA in Europe, Mann (2002) juxtaposed the art works of the LIA era against a contemporary photographic image showing the dramatic climate changes (i.e. glacial advance) in one image and glacial retreat a century later in the next image (Figure 3.1).

The LIA had a large social as well as environmental influence on European society. Many farms and villages were lost in Chamonix, France, due to the glacial advances (Mann, 2002; Wanner et al., 2015). Given the extent of damage, the Bishop of Geneva was summoned by villagers to perform exorcism as the villagers believed that dark forces were responsible for their experiences. As glaciers expanded well beyond previous historical limits, societal hazards were a common occurrence during the late 17th to early 18th C.

Crop failures that prevailed in northern Europe were considered to be the combined result of colder conditions and varying patterns of atmospheric circulation (Mann, 2002). Europe also experienced widespread infant/child mortality and increased famine and disease during the 17th-19th C which was thought to be related to the LIA, partly due to colder temperatures and poor weather conditions (Mann, 2002). Charels Dickens' 'old-fashioned white Christmas' notion was based on the increased frequency of cold, icy winters; Mary Shelley was forced to stay indoors during the 1816 unusually cold summer which resulted in the writing of the novel *Frankenstein* (Le Roy Ladurie, 1971) and the freezing of the Thames River in London resulted in winter carnival celebrations (Mann, 2002; Wanner et al., 2015).



Figure 3.2: The first image is an etching produced between 1850 and 1860 of the Argentiene glacier in the French Alps and the second image is a photograph captured at a similar vantage point in 1966 showing the glacial retreat, Mann (2002).

3.3.2.2 Southern Hemisphere

The sediment record from Lake Naivasha that showed the presence of the MWP also showed that the LIA was relatively wet in Kenya from 1270-1850AD (Verschuren et al., 2000). The abundance (or lack) of biogenic silica in varved sediments was used by Johnson et al. (2001) to reconstruct the past climate in Lake Malawi, East Africa. The biogenic silica was found in high concentrations between 1570-1820AD, coinciding roughly with the LIA and in low concentrations in former and later periods within a 700 year span (Johnson et al., 2001). These results were then compared to global historical periods and it was found that the LIA in the Lake Malawi region coincided with the LIA period in Peru and Antarctica (1550-1990AD), based on ice core records (Thompson et al., 1986). Most recent work for East Africa confirming the LIA includes pollen analysis (Finch et al., 2009; Finch and Marschant, 2011) and diatom based reconstructions (Stager et al., 2003; Panizzo et al., 2008).

3.3.2.3 Local Context

A breakthrough study for southern Africa using a 350 year long stalagmite record from Cold Air Cave (Makapansgat, South Africa) showed that the LIA which was originally recognised in the northern hemisphere had also made a similar impact in the southern hemisphere (Holmgren et al., 2001; Sundqvist et al., 2013). Makapansgat is a summer rainfall region with over 90% precipitation during the summer months (October to March) (Holmgren et al., 2001; Sundqvist et al., 2013). Evidence from the Makapansgat stalagmite record showed that the region was on average 0.9°C colder than today between the years 1690 and 1740, using the 1961 to 1990 mean. The coldest interval was recorded around the 1720s, when it may have been 1.4°C colder than today (Holmgren et al., 2001; Sundqvist et al., 2013). Most recently, a multi-proxy study using pollen, diatoms and sediments has confirmed a LIA cooling period in Eastern Lesotho (Fitchett, 2015).

3.3.3 Contemporary proxy evidence

For periods spanning the last few hundred years, documentary evidence can be supported by and corroborated with more contemporary proxy evidence. For example, to corroborate the evidence from ships' logs and terrestrial missionary diaries for tropical cyclone events in Madagascar and Mozambique, the IbTracs record of storm tracks is used (Fitchett and Grab, 2014; Nash et al., 2015). These types of records are also important for determining the level of accuracy of documentary sources (Nash et al., 2016). The most commonly used contemporary proxy sources are synthesized in Table 3.2.

Table 3.2: Database of Climate Networks utilising research in historical climatology

Acronym	Name	Website	Description (wind, rainfall, pressure, temperature, SST, general climate)
CLIWOC	Climatological Database for the World's Oceans	http://pendientedemigracion.ucm.es/info/cliwoc/	Ship logs and ship climate measurements.
NOAA: National Climatic Data Centre	National Oceanic and Atmospheric Administration	http://www.noaa.gov/	Daily to monthly resolution climate data for the whole of the USA and selected global cities. It's also contains index values (e.g. ENSO)
NCEP/NCAR Reanalysis Data	NOAA Earth System Research Laboratory	http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html	Index values derived from basic climate data.
TAST	Trans-Atlantic Slave Trade Database	http://www.slavevoyages.org/	Can be used to determine human responses to climate e.g. food and water availability.
World Data Centre			Basic meteorological data for each country.
WMO	World Meteorological Organisation	https://www.ncdc.noaa.gov/wdcmet	Monthly meteorological data for most world cities.
IBTrACS	International Best Track Archive for Climate Stewardship	https://www.ncdc.noaa.gov/ibtracs/	Tropical cyclone storm paths.
ACRE	Atmospheric Circulation Reconstructions for the Earth	www.met-acre.org	
IEDRO	International Environmental Data Rescue Organization	www.iedro.org	
	International Surface Temperature Initiative	www.surfacetemperatures.org	
	Old Weather	www.oldweather.org	
	Collaborative research on the meteorological and botanical history of the Indian Ocean, 1600-1900	www.sussex.ac.uk/cweh/	This network is involved in Identifying and digitizing historical documents.

3.4 Background: Social and Environmental Historical Theme

3.4.1 Introduction

Historical climate events reconstructed from documentary sources have considerable similarities between different regions of the world due to the atmospheric and oceanic teleconnections (Wanner et al., 2015). Therefore, it is likely for records from different continents to each provide evidence for the LIA or to demonstrate variability linked to ENSO cycles (Nash and Adamson, 2014; Wanner et al., 2015). By contrast, human responses to climate and the environment, adaptation strategies, and ultimately human survival, relies far more on the adaptive capacity of a group of people and the specific selection of stressors from the natural environment (Ziervogel and Calder, 2003; Kelso and Vogel, 2015). In particular, the adaptation strategies adopted in the southwestern Cape under van Riebeeck's time would be very different to simultaneous strategies in Europe. First, these were the first settlers in southern Africa and would therefore have been very unfamiliar with the climate and environmental conditions, whereas these were well documented at this stage for Europe. Second, the indigenous populations would have had their own adaptation strategies which would have developed specific to those conditions (Butzer, 2012). Therefore, this chapter section is limited to an exploration of the literature on social and environmental responses to climate in southern Africa. This approach to the literature is similar to the historical vulnerability analysis compiled by Kelso and Vogel (2015), which was investigated at the local scale, or more specifically at a community level.

3.4.2 Links between the environment, society and the economy

Aside from reconstructing a climate chronology for the 19th century Namaqualand region, Kelso (2010) also examined socio-economic changes with the Khoi Khoi community. The climate of Namaqualand was reconstructed to identify how the native rural community (Khoi Khoi) adapted to, and coped with, climate fluctuations at the beginning of the 19th C, as their coping ability had decreased by the end of that century (Kelso and Vogel, 2007, 2015; Kelso, 2010). In addition to the climate, other drivers of change between 1800-1853 occurred. These include the introduction of agriculture, the encroachment of Dutch farmers in the Namaqualand area, the direct and indirect effects of missionaries play an influential role in the muted prosperity of the Namaquas (Kelso, 2010; Kelso and Vogel, 2015). Table 3.3 illustrates the Namaqua peoples' journey through time, beginning before the arrival of the

missionaries, during the establishment of the Dutch, as well as the changes after adapting to the surrounding changes. The results showed an improvement through time of the Namaqua peoples' circumstances, with livestock numbers having drastically increased, and high agricultural yields in some years showing effective adaptation (Kelso and Vogel, 2007, 2015).

Table 3.3: Changes through time of the Namaqua people – Coping and Adaptation (after Kelso, 2010)

Before the settlers and missionaries	**Stresses from the settlers and missionaries**	**Adaptation and Coping Mechanisms**
During a drought the Namaqua's travelled to the coast where they lived of fish. Did not conduct agriculture. Diet: Milk, cow; sheep; and goat meat, other game, roots, honey, ants, etc. Economy: Traded cattle, skins and other items with nearby groups. Wore sheep and goat skins. Lived in mat huts. Primary language: Namaqua	Namaquas under multiple threats: - Influx of Basters and the trekboers settling in the Leliefontein area. - Intensified copper mining. - Trade exploitation and cattle raids	Most Namaquas attempted to recover livestock by working as herdsmen for the Dutch farmers. Those that opted to stay in Namaqualand, obtained a missionary and sought to retain control over their livelihoods. Through the missionary the Namaqua people: - embraced activities such as agriculture - kept nomadic pastrolism as their highest priority - were offered protection from the missionaries - preserve traditional livelihoods

3.4.3 Adaptation and coping strategies of historical communities due to climate

Adaptation during historical times is most clearly illustrated by Kelso and Vogel (2015) through the Namaqua KhoiKhoi case study. The Namaqua KhoiKhoi were originally nomadic groups that left the Kamiesburg at the beginning of winter (May) and moved back at the approach of summer (October), as this allowed for the preservation of their grazing lands (Kelso and Vogel, 2015). In years of severe drought, these nomads would move to the coastal regions as they could fish for an alternative food source (Kelso and Vogel, 2007, 2015). Other strategies, employed by the Namaqua, to adapt to severe drought conditions, involved dispersing with their cattle (Kelso and Vogel, 2015). Their resilience together with their

adaptation strategies allowed the Namaqua to recover quickly and still maintain good harvests (Kelso and Vogel, 2015).

According to Kelso (2010), the coping strategies employed help to limit their exposure to risk. The impacts of the severe droughts that occurred between 1820 and 1827 were lessened as Leliefontein was already a mission station and the Namaqua were involved in agricultural practices (Kelso and Vogel, 2015). A combination of this and transhumance grazing resulted in shorter periods of recovery with reports of good harvests and good well-being only a year later (Kelso, 2010). Although not coastal, archaeological records from eastern Lesotho reflect a similar pattern of shifting reliance to fish (in this case freshwater) under climatic conditions unfavourable to support sufficient quantities of the ordinary food groups (Plug et al., 2010).

Research conducted by Prieto and Rojas (2013) question the coping strategies of agrarian societies during periods of long term drought and other climate stressors. In Alto Peru, Bolivia, the native demographic decline during the late 18th to early 19th C was investigated using archival records, in association to climatic stresses and epidemic events. According to Prieto and Rojas (2013), the results showed that during the beginning of the 1750s, there were extreme shifts in precipitation which significantly impacted the native population. Due to the increased climate stress, the vulnerability of the people increased resulting in a higher health risk. The analysis showed a strong association between climatic and epidemic events (Prieto and Rojas, 2013). Comprehensive documentary sources such as diaries and travelogues may be used to create long-term vulnerability assessments that identify successful adaptations to drivers of social and environmental change (Kelso and Vogel, 2015).

3.4.4 Impacts of climate on the natural environment

3.4.4.1 Human health: disease and death

In contemporary times, environmental and health challenges are argued to be one of the largest challenges when underpinned by climate change (Patz and Kovats, 2002). This is because climate change, especially from an increasing temperature perspective, can exacerbate infectious influencing pathogens, vectors and habitat (Patz et al., 2005). Climate change is a main factor in the re-emergence of vector-borne disease, only that it is now redistributed across the world. ENSO episodes together with other extreme weather events may influence the intensity and timing of infectious diseases (Epstein, 2002; Pascual et al., 2006). However, there are complexities involved in the relationship between climate and

human susceptibility to disease (Endfield et al., 2009). Even though vector distribution and abundance may be influenced by changes in land use and vegetation cover, there are also the effects of political and socio-economic factors to consider as these may also exacerbate the occurrence and dissemination of diseases (Rogers et al., 2002; Endfield et al., 2009).

Understanding the contemporary relationships between human health, climate change, socio-economic and political variables could be improved through gaining an understanding of historical epidemics that plagued various societies (Parmenter et al., 1999). Diseases and epidemics are the result of long term climate anomalies, especially in agrarian societies (Prieto and Rojas, 2013) as well as societies which are forced to adapt due to land encroachment by new settlers (Kelso, 2010). Studies using published and unpublished documentary sources in East Africa and Uganda investigated the history of epidemic diseases in the late 19th to early 20th C (Endfield et al., 2009). This region was selected due to climate variability over time and the time period was selected based on social, political and economic reordering of East Africa at that time (Endfield et al., 2009). Also during this time period, the region experienced a host of ecological, climatic and disease challenges (Endfield et al., 2009). The study argued that the sleeping sickness epidemic for the period 1900-1920 ensued due to the merging of various social and environmental factors (Endfield et al., 2009). This disease continues to be a significant public health risk in the region (Steverding, 2008).

According to relatively recent historical climate literature, various naturally occurring weather and environmental phenomena resulted in the death of people. Weather extremes such as prolonged snow events impacted the health of humans and livestock, even leading to death in 19th C Lesotho (Grab and Nash, 2010). Prolonged droughts have in some cases been attributed to volcanic eruptions. In the case of the of the 1883 Tambora eruption, Garstang et al., (2014) demonstrated that this lead to a prolonged drought, resulting in famine that then caused the loss of life in 19th C KwaZulu-Natal and the Eastern Cape. Additionally, the smallpox epidemics of 1724 and 1755 caused a large number of deaths, weakened the Namaqua Khoikhoi population (Kelso and Vogel, 2015).

3.4.1.2 Livestock wellbeing: disease and death

Aside from human deaths, droughts also negatively impact livestock. One particular drought in 1863 in Lesotho was classified as significantly severe based on the description from

historical documentary sources (Nash and Grab, 2010). The authors describe the severity of the drought with key phrases such as ‘pastures are missing’, ‘hunger everywhere’, ‘famine ahead’, ‘ground cracked’, as well as make reference to dried up water bodies (Nash and Grab, 2010). Similarly, the extremity of the drought can be noted based on the descriptive account to relay which animals in particular had died and in what quantity. The animals included goats, oxen, cows, calves and horses. Additionally, due to the lack of rainfall, the drought of 1895-1900 in KwaZulu-Natal resulted in a loss of pastureland that led to the death of livestock (Nash et al., 2016).

Grab and Nash (2010) found death of livestock in three consecutive years (1847-1850) due to prolonged snow and extreme cold conditions in the Lesotho Lowlands. Thereafter, relatively less frequent, severe snow events caused livestock perish, specifically in the years 1852, 1854 and 1857 (Grab and Nash, 2010). Furthermore, mentions to livestock loss became more infrequent in later years but were still due to snow, frost and cold (1881 and 1871; Grab and Nash, 2010).

Other than weather, the documentary records reflect other extremities resulting in the loss of livestock through death. Even though death may not have occurred, indigenous tribes in Africa also experienced loss of livestock due to tribal raids by other ethnic tribes (Kelso, 2010). In 18th C Namaqualand, the Namaqua Khoi Khoi people lost their livestock due to increased raids by the San (Kelso and Vogel, 2015). This resulted in a substantial decline in the number of livestock (Kelso and Vogel, 2015).

3.4.1.3 Crop Damage

During pre-industrial times, there was a greater reliance placed on agricultural crops as this was one of the few major sources of food, together with livestock and aquatic life (cf. Kelso and Vogel, 2015). In historical climate studies, many historical documentary based studies indicate the emphasis placed on loss of/ or damage to crops due to weather extremes. In the historical climate reconstruction for Lesotho, snow and severe frost ruined crops, specifically in the early 1850s and 1860s (Grab and Nash, 2010). In some instances vegetables were found to be frost bitten and prolonged frost events destroyed fruit trees (Grab and Nash, 2010). In the late 1800s, the indigenous population of Namaqualand were sensitive to climate fluctuations as this impacted negatively on their agriculture for when drought years

dominated, harvests would fail and the society would face food shortages (Kelso and Vogel, 2015).

Excessive rainfall or lack thereof can also be detrimental to crop growth and increase the risk for damage or loss. The heavy rains in KwaZulu-Natal in 1891 led to the damage of crops whilst the early rains that didn't arrive in 1895 resulted in the loss of pastureland (Nash et al., 2016). Similarly in Basutoland, the stalks of the corn were completely scorched by the sun while other crops were stunted and wilted due to drought (Nash and Grab, 2010). In other instances the crops were spoilt due to hail (Nash and Grab, 2010). Similarly, two towns in India, Thane and Colaba, experienced severe flooding of their crops in 1853 (Nash and Adamson, 2014).

Additionally, factors other than weather extremes, such as pests and wild animals could destroy or contribute to crop damage. The crop damage (and resultant food shortages) caused by the relatively dry conditions in KwaZulu-Natal in the 1896-1897 rainy season, were exacerbated by swarms of locusts and the rinderpest epidemic (Nash et al., 2016). Other factors that would negatively impact crops were a combination of drought and over-farming (cf. south eastern South Africa; Garstang et al., 2014).

3.4.1.4 Harvest times and general phenology

In historical climatology, harvest and sowing dates are a good proxy for reconstructing past climates as they will indicate years with early/late harvest/sowing dates which could be a result of weather extremes such as floods and droughts (Fitchett et al., 2015). For example, in Lesotho, due to the prevailing drought conditions in 1862, local people worried that sowing the lands would be delayed as the earth was dry and hard. Similarly, in 1866, sowing was done earlier than usual as local people were expecting drought conditions to soon prevail (Nash and Grab, 2010). During 1895 in KwaZulu-Natal the ploughing of fields and sowing of crops were delayed as the expected rains were late (Nash et al., 2016). From these examples, it is noted that many historical authors whose documents are used for historical climate research potentially could have frequently mentioned harvest/sowing dates, however, not many academics in this field often reflect on these writings from a social environmental context.

3.4.1.5 General Food Shortages

Much of the literature makes reference to food shortages in the 1800s, brought on specifically by drought conditions (Nash and Grab, 2010; Kelso and Vogel, 2015; Nash et al., 2016). For example, in Lesotho in 1862, food prices doubled and tripled in price and famine conditions were predicted (Nash and Grab, 2010). Similar predictions were described in 1884, as rain had not fallen in three months (Nash and Grab, 2010). For the local Namaqualand community, their food shortages and famine were most significant in drought conditions particularly when they became more dependent on agriculture (Kelso and Vogel, 2015). The severity of crop damage during the 1896-1897 relatively dry conditions in KwaZulu-Natal resulted in significant food shortages which then led to population dispersal (Nash et al., 2016).

3.4.1.6 Pests

It is noted that with historical climatology, past societies would record only those events that would have caused them loss or harm (Carey, 2012). From the literature, it was determined that locusts plagued historical societies, resulting in the loss of their crops. Studies by Brazdil et al. (2014) investigated locust outbreak in the Czech Lands during the 16th-18th C. Results indicated that the locust outbreaks were most severe in the 17th C, followed by the 1800s and lastly 1600s (Brazdil et al., 2014). For the Czech Lands, the largest outbreaks recorded occurred in 1542-1546, 1693, 1712 and 1748-1749 (Brazdil et al., 2014). During 19th C Lesotho, locusts were noted to cause destruction to crops in 1866 (Nash and Grab, 2010). Similarly, in KwaZulu-Natal, Nash et al. (2016) noted swarms of locust in October-November 1895 as well as during the years 1896-1897.

3.4.1.7 Infrastructure damage

Documentary records indicate that the greatest hardships through infrastructural damage are experienced when settlers first arrived in a new location. Furthermore, they were affected far more at this stage than the local indigenous people. This is primarily because they did not know what stresses they were likely to encounter, and didn't have a solid adaptation plan (Kelso and Vogel, 2015). In India, banks were destroyed in flood events in 1853 (Nash and Adamson, 2014). During the 19th C in Lesotho, the missionaries suffered much damage to their infrastructure (Nash and Grab, 2010). In 1841, several partition walls were struck down

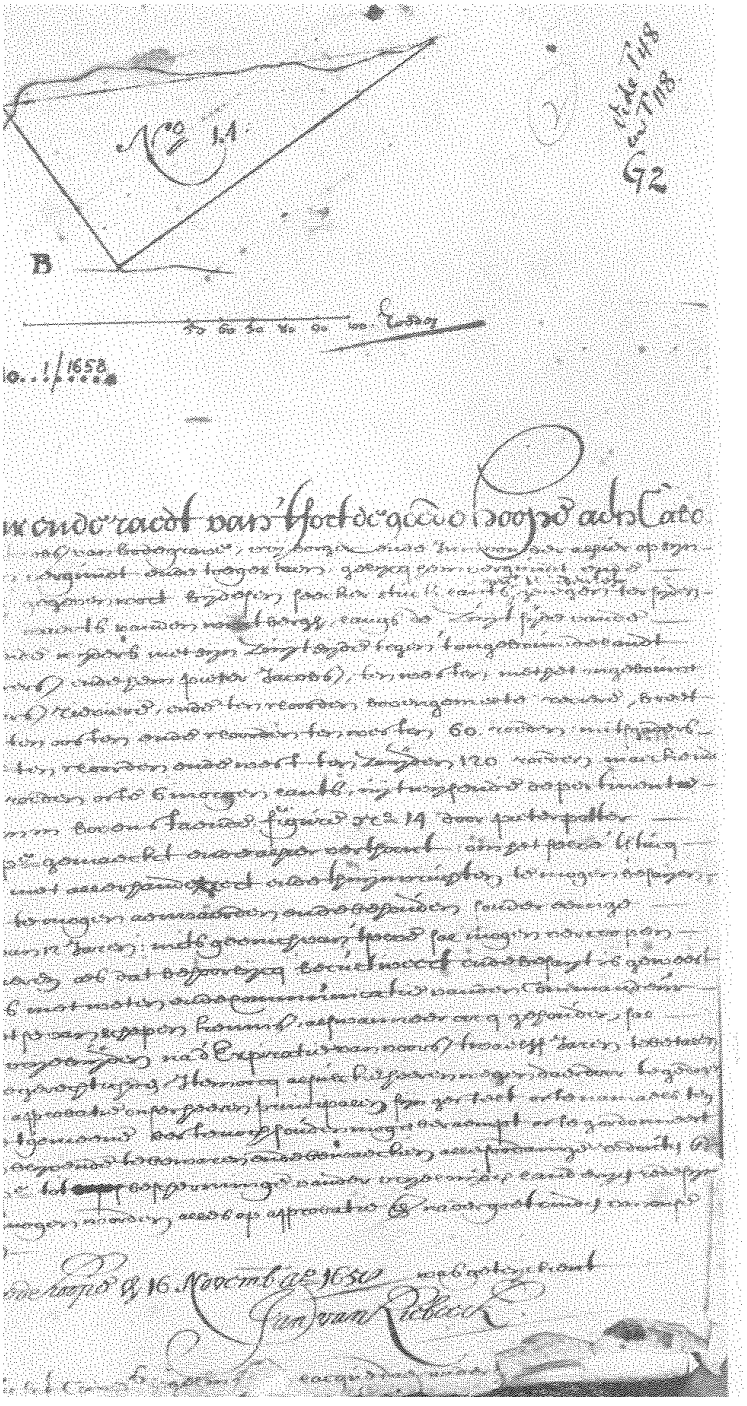
by lightning and continuous floods, including walls (and trees) in the garden (Nash and Grab, 2010). In later years, specifically 1893, the Bishop had mobility difficulties as the excessive rains had caused much damage to the roads (Nash and Grab, 2010). Nearing Pietermaritzburg in KwaZulu-Natal, heavy landslides on the railway line, brought on by several weeks of continuous rainfall, resulted in the damage of houses in 1893 (Nash et al., 2016).

3.4.2 Summary

It is interesting to note that some of the literature used to discuss local, historical climate reconstructions did not make reference to social environmental reflections in the historical context, as their primary aim was a climate reconstruction (e.g. Neukom et al., 2014, Nicholson, 2014, 2015; Nicholson et al., 2012a, b, 2014). Other studies such as Kelso and Vogel (2015) focus only on the social environmental context of the historical documents. Focussed studies such as these have merit for their specificity and thoroughness but are limited in their holistic description of the study period. However, other studies, similar to this dissertation (cf. Vogel, 1987, 1989; Kelso and Vogel, 2007; Grab and Nash, 2010; Nash and Grab, 2010; Nash and Adamson, 2014; Nash et al., 2016) look at the historical documentary evidence from two perspectives, i.e. climate reconstruction and from a social and environmental context. This allows for a richer description of the study period and more importantly uses the qualitative information from the historical documents used to support the climate reconstruction produced.

The relationships and their resulting stressors between historical society and the natural environment have been discussed in the section above. According to Prieto and Rojas (2013), climate plays an integral role as a natural factor on society and the economy. In some cases, adaptation strategies, if applied early enough, may help lessen the impact and effects of climate anomalies together with the introduction of new settlers.

Chapter 4: Methodology



4.1 Introduction

The study involved reading the journals of Jan Van Riebeeck and producing two sets of results. One is the weather chronology and the other is the social environmental aspect. This

methodology is loosely based on those employed previously by others working in southern Africa (cf. Vogel, 1989; Kelso and Vogel, 2007, 2015; Kelso, 2010; Nash and Grab, 2010; Grab and Nash, 2010; Hannaford et al., 2015; Nash et al., 2016), but had to be adapted to suit this research. This is due to the fact that previous 19th C work in the sub-continent spread efforts across multiple decades per study, whereas this Masters study focusses on a more detailed but fine-scaled thirteen year period during the 17th C. While several studies have provided detailed 19th C climate chronologies for various parts of southern Africa, thus far no study has attempted to construct detailed inter-annual climate chronologies for the 17th-18th C in the sub-continent. The diaries of Jan van Riebeeck (Thom, 1952, 1954, 1958) provide a good indication of the typical weather over specific time periods (an indication of climate), particularly wind strength and direction, as well as rainfall frequency (rain days). Climate data extracted from documentary sources are the only proxy which can reveal the severity and precise timing of when natural disasters occurred during the pre-instrumental period (Pfister et al., 1999, 2009; Nash et al., 2015). This study will provide a useful addition to the 19th C southwestern Cape documentary record (Vogel, 1989) and will also serve as the oldest record of its kind for Africa. It may be used to compare earlier 17th C climate characteristics with those of the more recent 19th-20th C.

4.2 Conceptual Framework

This conceptual framework section discusses the various approaches used by prominent researchers in the field of historical climatology. This is important as a hybrid approach was used in the development of the methodology for this dissertation, combining several techniques. A hybrid approach was required due to the nature of the documentary sources available. Many of the accounts of daily weather were descriptive in nature and occasionally involved terms that are no longer in use. Moreover, unlike for much of Europe, meteorological readings were only recorded and stored from the 1800s.

4.2.1 Documentary Evidence (Descriptive Sources)

Historical documentary evidence is generally scattered across different places and written in varied languages with many interpretations (Pant, 2003; Nash and Grab, 2010; Nash et al., 2016). At times, evidence may also be vague and fragmented; therefore, a systematic and logical approach should be applied when interpreting historical documentary sources (Pant, 2003; Nash et al., 2015). Historical climatology employs a hybrid approach, combining

elements of natural science with historical elements (Adamson, 2015; Hannaford et al., 2015). The historical elements include critically evaluating the sources of information, while the natural science approach occurs when numerical methods are applied after an explanatory/interpretive approach is taken to analyse data sources which can help create a level of objectivity (Glaser, 1996; Nash et al., 2015). Descriptive sources of information should be systematically separated; firstly into those sources which represent single or occasional instances of weather events such as floods, and secondly into daily diary entries that account for the weather (Kelso, 2010). The latter (which is also the primary source of information for this research) also allows for descriptive statistical analysis (Glaser, 1996; Nash et al., 2016). Weather recorded events in diaries generally refer to climatic elements such as temperature, rainfall, wind and weather phenomena such as thunderstorms and severe flood events (Grab and Nash, 2010).

Content analysis is described by Catchpole et al. (1976) and reviewed by Nash and Adamson (2014) as a method designed to eliminate subjectivity from the interpretation of source documents. In this method, a frequency count is used, which in the case of this research will sum the frequency of climate, weather and environmental related words, phrases and themes (Catchpole et al., 1976; Nash and Adamson, 2014; Kelso and Vogel, 2007). However, even with objective methods, subjectivity may still pose a problem. For example, Vogel (1988) categorically ranged rainfall between extremely dry and extremely wet, depending on percentage of rainfall. The findings showed more extremely wet areas for both the southern and eastern Cape over the 19th and 20th centuries (Vogel, 1988). This is increasingly being adopted as a primary research methodology (cf. Kelso and Vogel, 2007; Berland et al., 2013; Gergis and Ashcroft., 2013; Domínguez-Castro et al., 2014; Prieto and Rajos, 2015). However, it is not indicative of long term changes, but rather of the subjective nature of documentary sources (Vogel, 1988; Nash and Grab, 2010; Hannaford et al., 2015). This was assumed because sources may place a higher importance on extremely wet events that are relatively shorter and more destructive, as opposed to drought episodes that are more common, occurring frequently in both the southern and eastern Cape (Vogel, 1988).

An author of historical documentation, specifically journals and diaries, will document a weather related incident based on personal experience as well as their knowledge on these subjects (Adamson, 2015). For example, if droughts were unusual events from the author's homeland then they may be more descriptive and exaggerate a dry period in an arid region

where this would be a relatively common occurrence (Grab and Nash, 2010; Nash and Grab, 2010). It is therefore imperative to separate the subjective and objective parts within any given text (Glaser et al., 2010). Diaries also often contain wind direction which is useful in the analysis of weather dynamics (Glaser, 1996; Nash and Adamson, 2014; Hannaford et al., 2015). Fictional accounts as well as artistic evidence should be used as fragments to fill in gaps of unavailable information, as well as to help verify and validate data from other proxies (Catchpole and Moodie, 1978; Domínguez-Castro et al., 2014).

Hermeneutics is a method suggested by Glaser et al. (2010), which involves firstly conducting a background check about the original author in order to adequately interpret the accounts related to the text. Alternatively, the time period of the author's life may be indicative of education and social background, which may then influence their choice of words when describing certain events (Glaser et al., 2010; Nash and Adamson, 2014). The measure of bias will be based on the extent to which the author was affected personally by an event (Adamson, 2015). For example, Glaser et al. (2010) suggest that a person who has lost someone would describe an event more severely than a journalist.

Flood data from historical documentary sources are very useful in determining flood intensity, information on the impacts on society during extreme flood events, and adaptation strategies developed to cope with and overcome consequences of flood events (Glaser et al., 2010; Nash et al., 2015). For example, the floods associated with tropical cyclones in Madagascar (Nash et al., 2015) and floods in KwaZulu-Natal (Nash et al., 2016) have been reconstructed over historical periods with a particular focus on coping and adaptation strategies. Although there are inaccuracies associated with this type of data source, it allows for frequency counts (Glaser et al., 2010; Nash et al., 2015). Frequency counts of wet/dry years are a common method for climate reconstructions in many parts of the world. For example, Song (2000) noted the dryness/wetness in China for the past 529 years. However, in other parts of the world, relative temperature (warm/cold) is a more suitable variable that has been measured, and particularly so for Europe and North America (Tompkins, 2007; Battipaglia et al., 2010).

4.3 Data Acquisition

4.3.1 Step-wise Flow Process

The process followed in the initial acquisition of data and throughout the methodological stages of this study can be summarised with an adaptation of a flow diagram developed by Kelso (2010). The flow diagram for this study is presented in figure 4.1.

4.3.1.1 Step 1: Selection of documents

Archival searches were conducted to determine availability of relevant documentation that would be able to provide evidence for a historical climate reconstruction. There are a substantial number of documents relating to the Cape region from various historical time periods. These documents are housed in several archives across South Africa (as noted in Table 4.1) and internationally. A database of the complete set of records was developed in the preliminary stages of this study and can be found in Appendix A. The sources deemed to be most useful in providing accurate information and spanning an understudied time period for southern Africa were then selected from this database for use in this project.

Table 4.1: List of local archives that were consulted

Archive Consulted	Location
Pretoria Archives	Pretoria, Gauteng
Cape Town Archives	Cape Town, Western Cape
Killie Campbell Library	Durban, KwaZulu-Natal
William Cullen Library	University of the Witwatersrand, Johannesburg, Gauteng
Jan van Riebeeck Society	Cape Town, Western Cape

STEP 1
Archival Work

ARCHIVES CONSULTED

- Jan van Riebeeck Society
- Library collections, WITS
- National Library South Africa, PTA
- National Archives, PTA and CT
- Killie Campbell Library, DBN

KEYWORD SEARCHES

- Cape of Good Hope
- Jan van Riebeeck
- Names of governors

POSSIBLE CATEGORIES OF SOURCES

- Explorers, travellers, governors journals/diaries
- Government reports
- Private correspondence
- Historical maps
- Drawings and paintings

STEP 2A
Weather related quotes extracted

INDICATORS USED

- Rain, Wet, Muddy
- Floods
- Snow
- Crop failure/ Good crop yields
- Excessive heat
- Dry
- Drought
- Wind (speed, direction)

STEP 2B

Weather record to be constructed focussing on the relevant research questions.

Statistical Analysis of Data:

1. Rain Days
2. Periods of Wet/Dry

STEP 3A
Social-environmental quotes extracted

INDICATORS USED

- Farming techniques
- Presence of various flora and fauna
- Diseases – death due to climate related disease
- Crop failure due to pests
- Presence of natural resources
- Climate related damage to settlement

STEP 3B

17th century society chapter will be written discussing the environmental conditions that were faced as well as adaptation strategies to overcome natural extremes/phenomena.

Figure 4.1: Steps to be followed for methodology (after Kelso, 2010)

Many historical documents pertaining to the Cape Region and South Africa at large are also available for online reading from the Internet Archive website (2001). These online documents assisted in reducing the number of physical visits to the various libraries and archives. Keyword searches were conducted in the various archives and through library online catalogues in order to refine the results and find the relevant documents (i.e. pertaining to the 17th and 18th C). From Appendix A, it can be noted that there are a variety of texts available that date back to the mid-1600s, which in several instances include translated bibliographies (journals, travelogues, letters, diaries, letters and graphics – paintings, maps, etc.). The text documents were separated into primary and secondary sources (Kelso, 2010; Nash et al., 2015). The primary sources (Appendix A: Tables A1, A3, A5, A7) are original texts where the authors give first-hand accounts of their experiences and observations while the secondary sources (Appendix A: Tables A2, A4, A6, A8) are texts that relate the experiences of others in order to provide a more comprehensive account of that for the given time period (Adamson, 2015). Secondary sources are written using reference material from primary sources (Kelso, 2010). Furthermore, international archives also house historical documents referring to the Cape in historical times (Appendix A: Tables A9-10).

Through the archival searches it was discovered that the first comprehensive daily weather accounts were reported in the diaries of Jan van Riebeeck together with descriptions of the surrounding biophysical environment. Due to the fine-scaled resolution of results that could be obtained from such a manuscript, it was decided to comprehensively analyse the qualitative texts from these diaries as well as any other sources that could corroborate or extend this record within a close time range and with similar detail. Hence, a new search within the archives was conducted using names of the governors of the Cape that succeeded Jan van Riebeeck as keywords. From these searches, the results showed that many of the governors to follow did in fact keep diaries. However, only Jan van Riebeeck's immediate successor, Zacharias Wagenaer included weather and environmental accounts in his diaries on a nearly daily basis. Of the four years that he lived at the Cape, the first three years of his diary entries were sufficiently frequent and detailed to provide an acceptable extension to Jan van Riebeeck's work. It was therefore decided to focus on a total of these 13 years (including 10 years from the diaries of Jan van Riebeeck from 1652-1662 and 3 years from Zacharias Wagenaer from 1662-1665) and provide a detailed weather reconstruction for the period 1652-1665 as well as a social and environmental

account during this time period. Hence, Appendix A provides a database of the available historical documents that may be used for future research in historical climatology for the Cape region.

4.3.1.2 Step 2: Text Extraction and Reconstruction

The diaries of Jan van Riebeeck and Zacharias Wagenaer were read and the relevant texts pertaining to the weather and natural environment were extracted verbatim. Information was recorded on spreadsheets in Microsoft Excel 2010 (Table 4.2). An example of these extractions may be found in Appendix B. The year, month and date (and day of the week if available) were noted in all instances. Thereafter the comments pertaining to wind (speed and direction), temperature descriptions (for example hot or cold), and rain (including intensity) were noted. There were several different keywords that could be easily identified in the diaries in order to ascertain the intensity of the wind speed, temperature and rainfall as listed in Table 4.3.

Table 4.2: Descriptive words used due to lack of instrumental equipment

Weather Variable	**Descriptive Words**
Wind Speed	'calm',
	'breeze',
	'windy',
	'strong',
	'gale'
Temperature	'mild',
	'warm',
	'hot',
	'cold',
	'icy'
Rainfall	'drizzle'
	'rainy'
	'hail'
	'heavy downpours'

Not much mention was made to different locations (besides Robben Island), so it was assumed that the diary entries referred to the Table Bay vicinity (as the settlement was situated there) unless stated otherwise (Goodwin, 1952). Not all of the various categories contained information

on a daily or frequent basis. For example, wind recordings were almost daily while temperature recordings (in terms of descriptive words as there was no instrumentation available) were relatively less frequent.

Lastly, a column for general comments was included. This was to capture information on social and environmental related themes such as damages from weather related phenomena, observations of various fauna and flora, adaptation and coping strategies applied to overcome various environmental stressors. It was also used to record any weather related incidents that were stressed by the writer. For example, if it was just a calm wind that brought no extreme rainfall conditions, then the wind and rain entries were noted separately in the individual columns, however, if the wind and rain were closely associated, resulting in a fairly severe weather event, then this was again noted in the individual columns (rain and wind). In such instances the whole excerpt was recorded verbatim under the general comments column. This was done for easy access to quotations that illustrated the linkages between weather variables and other relationships which assisted in data analysis.

After the text extraction process, the data were separated into those variables that related to the weather specifically, i.e. indicating the weather in a quantifiable, non-biased approach and those variables that illustrated the environmental setting of the period. The quantifiable weather variables could be easily identified as ‘wind’, ‘temperature’ and ‘rainfall’ while the social and environmental settings were less easy to navigate. The spreadsheets containing the diary extracts had to be read several times in order to identify key themes and frequently occurring incidents in order to analyse the social and environmental extracts. Due to differences in the weather reconstruction and social and environmental data, separate approaches were used in order to produce the results. The weather results produced a weather reconstruction while the social and environmental results led to a discussion portraying the historical society’s responses to weather and the natural environment.

4.3.2 Further data consulted

To corroborate and further explore the climate and day to day weather in the southwestern Cape, and to determine whether the information from the journals is consistent with events today, two

further datasets were consulted: The Royal Observatory and the South Africa Weather Services data for the period 1840-2013. The South African Weather Service data were obtained directly from this organisation. Minimal data clean-up was required for the South African Weather Service records and all data were quality checked by the organisation.

The Royal Observatory records were considerably more difficult to work with. Unlike the South African Weather Services data which is digital, these records were handwritten and scanned. In addition to handwriting that was difficult to read, in some instances unusual terminologies were used to describe weather events. A subset of this dataset was therefore selected for initial analysis. To perform statistics analysis on these data, information had to be digitized from these records. This involved considerable data clean-up.

4.4 Quantitative data analysis

This section describes the quantitative methods used to analyse the weather data extracted from the documentary sources and those obtained from the South African Weather Service and the Royal Observatory. All methods are described in the order in which they are applied in Chapter 5. If a particular statistical method is used more than once, on all subsequent mentions reference will be made back to the first description. All statistical analysis was performed using Microsoft Excel 2013 unless otherwise stated. The quantitative methodology is based on existing literature in the field of documentary climatology, synoptic climatology and climate change science.

4.4.1 Rainfall days

As the diaries did not make reference to exact rainfall amounts, rain days became an important climate variable used in this study. It is unclear whether rainfall volumes were ever measured at that time or whether they were omitted from the commentary presented from the diary. Rain days provided a relatively good substitute from which the frequency of rainfall and the seasonality of rainfall could be determined (Easterling et al., 2003; New et al., 2006). A ‘rain day’ was defined for the purpose of this study as any day for which a diary entry made mention of rain occurring. This includes light rain and drizzle in addition to more substantial heavy rains. Monthly and annual totals were made of the number of days for which there were mentions of rain. These

totals were then explored for broad patterns in wet and dry periods. Thereafter, rain days were explored in their subdivisions of types of rain which were selected on the basis of most commonly used terms in the diaries. These are later explored to determine whether they coincide with known climate events such as El Niño (Vogel, 1989; Nash and Grab, 2010; Grab and Nash, 2010; Nash et al., 2015).

Seasonal rainfall days were then explored by totalling the rainfall day counts for the months May-September, representing the wet period and October-March, representing the dry period. The separation of months into the wet and dry seasons for the southwestern Cape was categorised on the basis of existing literature (Keigwin, 1996; Grab and Craparo, 2011). These seasonal averages were also further explored in terms of the more specific rainfall type categories from the diaries.

The counts of contemporary rainfall days were then explored in relation to contemporary measured rainfall amounts to determine whether the journals accurately capture rain day events. For this data set, rainfall values were used for defining a rain day, rather than mentions of rainfall, as such qualitative data do not exist in the South African Weather Service records. Therefore, a rain day was classified as a day with greater than zero rainfall. To explore trends in rainfall days over varied temporal periods to ascertain the reliability of the diaries in capturing rainfall events, the following time periods were explored in the South African Weather Services data;

- 173 Years (1841 - 2013)
- Last 50 Years (1964 - 2013)
- Last 50 Years of 19th C (1850 -1899)
- 20th C (1900 - 1999)
- Last 30 Years (1984 -2013)
- Last 13 Years (2001 - 2013)

These time periods were selected due to their value in exploring climate change trends with the minimum period of 30 years required (WMO in Ahas et al,. 2002), for equivalent in the 19th and 20th C and for a 13 year period to compare directly with the diary records. To explore very long

term patterns, a complete dataset of 173 years from 1841-2013 was used, in addition to a record spanning the whole of the 20th C.

Trends in the number of rain days in both the documentary records and in each of the temporally segregated datasets from the South African Weather Services were statistically determined using linear univariate regression, as per Fitchett and Grab (2014):

$$y = ax + b$$

$$b = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sum x^2 - \frac{(\sum x)^2}{n}}$$

$$a = \frac{\sum y - b \sum x}{n}$$

Equation 1; Linear univariate regression (Underhill and Bradfield, 2009)

$$R^2 = \frac{b\left(\sum xy - \frac{\sum x \sum y}{n}\right)}{\sum y^2 - \frac{(\sum y)^2}{n}}$$

Equation 2; Co-efficient of determination (Underhill and Bradfield, 2009)

The strength of any time trends calculated were determined using Pearson's correlation coefficient. As there were no abrupt changes in the time series; there was no need for change point analysis. The significance of the correlation was determined on the basis of the p-value at the 95% confidence level, a function of the number of data points (N) and the strength of the relationship.

$$|r| = \left| \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \right|$$

Equation 3; Pearson's correlation coefficient (Underhill and Bradfield, 2009)

In addition to exploring the number of rain days, the contemporary record allowed for the relationship between rain days and rainfall amount to be explored. The time series for rainfall amount was explored for the period 1841-2013 using equations 1, 2 and 3. Thereafter, the number of rainfall days and the rainfall amount both totaled annually for the period 1841-2013 were correlated using equation 3. These variables were further plotted using a scatterplot to determine visually whether there was a range of rainfall amounts and total rainfall days which were most closely correlated. On the basis of this a very tentative estimate could be made regarding the rainfall volumes associated with a given number of rainfall days in the historical record.

4.4.2 Rainfall onset and termination

To explore inter-annual variability in the timing of seasons, the dates of rainfall onset and termination in the historical record were explored. Rainfall onset may be defined as the beginning of the rainy season and when the distribution of rain is sufficient to promote crop growth (Odekunle, 2005; Fitchett et al., 2015). Rainfall termination, cessation or retreat may be defined as the period when the rainy season is coming to an end. This is not necessarily the date beyond which no further rainfall will fall, but rather represents the date beyond which the amount and distribution of rainfall will no longer support crop development (Odekunle, 2005). Ordinarily, rainfall onset and termination are calculated on the basis of rainfall amounts, with either a large total rainfall for a particular day or a minimum of three days with above zero rainfall (Odekunle, 2005; Fitchett, 2013). However this was not possible as no rainfall amounts were recorded or reported in these journals. Therefore, the first mention of rainfall classified as stronger than drizzle was taken as the onset and the last day in a season with rainfall stronger than drizzle taken as cessation or termination. These dates were then explored for any clear trend that would suggest a progressive seasonal shift. Moreover, years with anomalous rainfall days or other climate anomalies could be compared with this rainfall onset and cessation date record.

4.4.3 Extreme rainfall events

Extreme rainfall events were of particular interest given the considerable impact that they have on human life, and the requirements they pose for successful adaptation (Nash et al., 2015).

Direct mentions to floods and indirect mentions to excessive rain in the diaries were therefore recorded. These daily mentions were totalled monthly and annually allowing for the seasonal pattern of floods to be explored and to detect years with particularly high counts of flooding. As this is qualitative in nature, direct quotes were captured and explored to determine whether particular classes of flood event could be categorised.

Similar to flood events, mentions to drought and dry weather were recorded and totaled monthly and annually. This allowed for seasonal patterns in the timing of drought and dry weather to be detected and for years with particularly severe drought or dry weather to be identified.

4.4.4 Wind

Wind is of particular interest in the southwestern Cape as it is considerably stronger than for most of southern Africa (Chase and Meadows, 2007). The primary information on wind presented in the journals related to the direction of wind. The total number of mentions of each wind direction was summed per year to determine whether there was inter-annual variability in predominant wind direction (Hannaford et al., 2015). These data were represented visually using a cumulative bar chart to visually explore these changes. To represent the predominant wind directions web graphs were produced for each year.

The journals additionally provided descriptive information on wind strength. This was divided into categories on the basis of most commonly used terms in the diaries and includes;

- breeze
- wind
- strong
- squall

For each month of each year the dominant and secondary wind directions were compared to the dominant and secondary wind strengths in order to determine whether a particular wind direction was related to a threshold strength. This would provide insight into the underlying synoptic conditions.

4.4.5 Royal Observatory Records

The Royal Observatory weather records were used in an attempt to better quantify rainfall quantity during the historical period. This record represents the first quantified information of rainfall amount and allows for further exploration into the relationships between rainfall amount and the rainfall days. More importantly, as this record includes descriptions, it was hypothesised that some of these may be common to those in the journals, again allowing for better quantification of the climate conditions.

The total dataset available from the Royal Observatory spans the period 1858-1873 and 1872-1977. A random five year set (1843-1847) was used to determine whether there were unique relationships between rainfall descriptions and quantitative rainfall amounts. Should this hypothesis be found true, the following methodology would be repeated on data for all of the years. The categories of rainfall mentioned in these records were selected as frequent terms from the Royal Observatory records and do not necessarily correspond directly to this study's historical period. These recorded the rainfall in inches instead of the more recently used millimeters, and so the results displayed in Chapter 5 are for both inches and millimeters, using a standard metric conversion. This was done so that all statistical analysis applied to the data was performed from the original data in inches, thus minimising possible errors. In particular, the data analysis intended to determine whether there were any unique ranges of rainfall amount associated with any given category of rainfall terminology.

The exploration of unique ranges involved recording ten categories of rainfall descriptions, namely;

- heavy rain
- light rain
- occasional showers
- rain
- morning rain
- afternoon rain
- night rain
- showers

- squalls
- rain with hail

The rainfall amounts on each day that corresponded with a particular classification were then recoded for each year throughout the five year subset. From this information, a collection of exploratory statistics was used to determine whether a category of a description was associated with an amount of rainfall that no other category contained in part or in full. These exploratory statistics include; the maximum amount of rain in both inches and millimeters, the minimum amount of rain in both inches and millimeters, the mean and the standard deviation.

$$A = \frac{1}{n}\sum_{i=1}^{n} a_i$$

Equation 4; The arithmetic mean (Underhill and Bradfield, 2009)

$$\sigma_{est} = RMSE = \sqrt{\frac{\sum(y - y_{est})^2}{N}}$$

Equation 5; The standard deviation of the mean, or root mean squared error (Underhill and Bradfield, 2009)

In order to determine whether unique ranges in rainfall amount existed for each rainfall classification, a box and whisker plot was produced using Stata 11. This plot allows for all categories to simultaneously be visually compared, presenting the maximum and minimum, the mean and the inter-quartile range on a common y-axis.

A similar approach was used to determine whether there were unique rainfall amount ranges associated with any given wind direction. All rainfall amounts for each day of a particular dominant wind direction was summed with the minimum and maximum extracted, and equations 4 and 5 calculated. Conversely, tests were performed using particular rainfall intervals to determine the dominant wind direction. Testing by the converse, for particular rainfall intervals the dominant wind direction was determined.

4.4.6 Climate events identified in the journals

In addition to the very standard weather variables of wind and precipitation, there were notable mentions in the journals of what could be classified as unusual climate events which are characteristic of the southwestern Cape. The variables that were mentioned most frequently in the journals were therefore explored in this study- these include:

- dirty rain
- black south-easterlies
- hail
- snow

As for the more standard climate variables, the frequency and seasonal timing of mentions of these events is both quantitatively and qualitatively explored.

4.4.6.1 'Dirty rain'

There are numerous mentions of 'dirty rain' in the diaries. These were of interest as this is no longer a commonly used term relating to weather in the southwestern Cape. The dates of each mention of 'dirty rain' were captured. These were then totalled monthly and annually to determine whether there were any seasonal patterns which could be related to known synoptic events. Inter-annual variability in total mentions of dirty rain was also explored to determine whether any particular year had anomalously high or low counts which in turn could be related to an event such as El Niño. Furthermore, if mentions of 'dirty rain' were associated with marked commentary about simultaneous weather events, this was captured.

4.4.6.2 'Black south-easterlies'

Unlike 'dirty rain', the term 'black south-easterly' is used in contemporary language to describe a particular weather event in the southwestern Cape. There is no categorical definition for this event in the peer-reviewed literature, however, many websites link this event to the contemporary 'Cape Doctor' (Hepworth, 2013). Today this is described as a very strong wind from the south east which clears all of the city smog, hence the term 'the Doctor' (Hepworth, 2013). The dates of each mention of the 'black south-easterly' were captured and totaled

monthly and annually. The quotes associated with these mentions were captured in order to determine whether there were predominant associated weather phenomena. From this, a flow diagram was developed to segregate the number of mentions according to the associated climatic conditions on that day, and thus determine whether they are uniquely related to easterly wind directions and/ or rain.

4.4.6.3 Hail

It was surprising to see mentions of hail in the diaries as it is not a common weather occurrence in the contemporary climate of Cape Town (Harris et al., 2010). Therefore all mentions of hail were recorded, with a complete quote and the date of the diary entry. The number of hail occurrences was totaled monthly and annually to explore seasonal and inter-annual patterns. The quotes were examined to determine whether there were any clear weather patterns and associated phenomena.

4.4.6.4 Snow

In the contemporary climate of the southwestern Cape, snow is common in winter on the high mountain peaks (Harris et al., 2010). The same methodology was followed as for mentions of hail. The quotes were particularly important here as they allowed for differentiation between different types of snow, such as sleet or light snow. For both hail and snow, the monthly counts were presented in graphical format for seasonal patterns to be easily distinguished.

4.5 Qualitative data analysis

The diaries revealed considerable richness in their description of social and environmental conditions during the period 1652-1655. These were analysed with an aim to determine the influence of weather on these features. Moreover, these diaries provided very valuable information regarding adaptation and coping strategies to climate that was very different to what the settlers were used to in Europe. It is necessary to differentiate between adaptation and coping as these terms should not be used inter-changeably. Pauline et al. (2016) provide a thorough review of the concepts ‘adaptation’ and ‘coping’. Their review elaborates that coping is a task orientated mechanism that deals with stress (i.e. short-term), whereas adaptation is a social

change that occurs unconsciously over time (i.e. long-term). Hence, Pauline et al. (2016, 3) defined coping as, "*short-term responses to a crisis*" and adaptation as "*long-term responses*" and these definitions are applied throughout this dissertation. This is important under contemporary climate change where adaptation is becoming critical (Ziervogel and Calder, 2003). The social and environmental component of this project is necessarily more qualitative in nature as it is based on subjective experiences and interpretations. The methodology adopted in this section of the project is adapted primarily from existing published research on climate patterns in southern Africa based on documentary sources (Grab and Nash, 2010; Nash and Grab, 2010; Nash and Adamson, 2014; Nash et al., 2015, 2016).

4.5.1 Frequency counts

For environmental consequences which occurred relatively frequently throughout the period 1652-1665, it is of interest to explore the seasonal and inter-annual patterns in the frequency of their occurrence. This follows a similar methodology to that adopted for many of the climate variables, and included recording all mentions of an event, capturing quotes, and making monthly and annual totals (Nash and Adamson, 2014). The following environmental consequences fall into this category;

- Floral damage
- Infrastructure/goods damage
- Crop damage
- Wildlife
- Wildlife attacks
- Fish abundance
- Livestock illness, disease and/ death
- Human health

This list of social and environmental themes was selected having read the diaries and was therefore captured through an iterative process, capturing information that was originally stored in the 'general comments' column (see Appendix B). Therefore, this column was examined to select the themes, and thereafter all comments in this column had to be reread to make counts of mentions of each theme.

The monthly and annual totals of mentions of each theme were plotted on a matrix to visually demonstrate temporal patterns (Nash and Adamson, 2014). In some instances, additional information concerning the climatic drivers of these environmental consequences were recorded and plotted in the matrix (Grab and Nash, 2010). For example, for floral damage categorisations of heat-drought, flooding and wind were used. In other instances, such an approach was used to separate climate and non-climate drivers. For example, for crop damage categorisations of pests, weather, or both, were used. In some instances, categorisations separated the nature of damage. For example, infrastructure/ goods damage was separated into settlement, goods, or both. In no cases would data captured for one matrix be represented a second time on a different matrix, so as to prevent double counting or exaggeration of the severity of a particular event.

4.6.2 Quotes

Due to the richness of descriptions of social and environmental conditions, it was often insufficient to capture only a count of each mention. These descriptions included the severity of the event, how common the event was, but more importantly the social response. A detailed analysis of quotes also allows for events which could be perceived to be similar, to be differentiated from one another. For example, two cases of poor human health could be segregated on the basis of symptoms, recovery time, or the severity.

An analysis of quotes further assist in understanding and compensating for any biases which may have arisen due to either language differences or prejudices from a particular author. This was particularly relevant for this study as the diaries for two different governors were used. In particular, biases relating to the severity of events could be identified.

Quotes were extracted for the themes outlined in section 4.6.1 as the aim was to provide greater detail on these phenomena. From the general comments section, each mention of an event was identified together with the date of the journal entry. The journal was then consulted for those particular days to extract the exact quote verbatim. Quotes that provided detail greater than a simple mention of the event were retained for use in the results chapter, while those that lacked any specific detail were excluded. No specific limit was given to the length of the quote, however, an effort was made to ensure that the quote only contained information necessary to

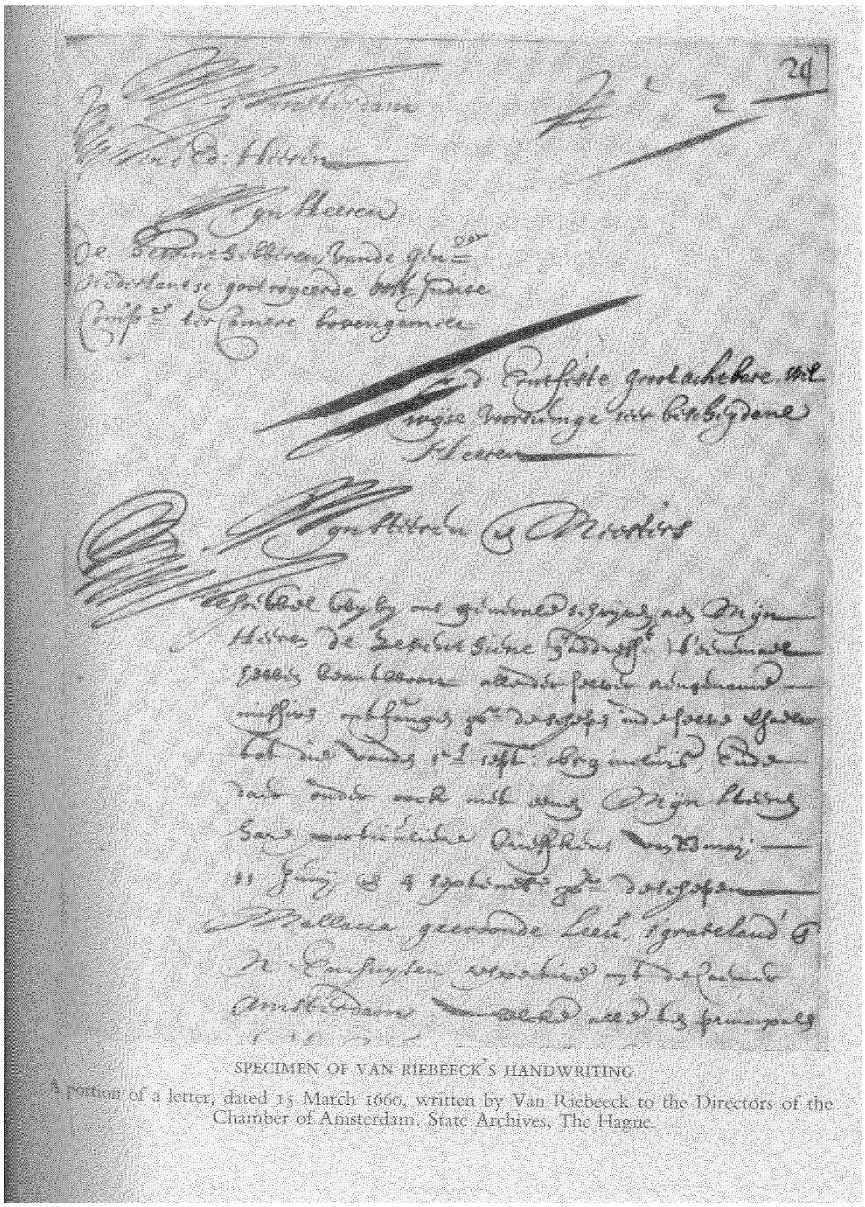
understand the social and environmental effects of the weather on a particular day. As a translated version of these diaries was used in this study, the author used this translated version only and made no efforts to correct for words or terminology that seemed out of place. In no instances were quotes obtained from the original untranslated diaries and independently translated to maintain consistency in the biases inherent in translation. Limitations relating to these translations are explored in more detail in Chapter 7 (Discussion).

Once all of the quotes had been captured, the nuances of these descriptions of these social and environmental events were related back to the climate data extracted from the diaries. In most instances this involved referring back to the weather on the specific day of an event. In cases where mentions of an event were clustered in a particular year, month or season, the broader climate patterns for those periods were examined to determine whether there was an anomaly. For example, if a particular year had an unusual number of mentions of pests, the climate data from the diaries would be consulted for any anomalies which might explain it.

4.6 Summary

Where possible, the methodology used was adapted from similar studies (cf. Vogel, 1989; Kelso and Vogel, 2007; Kelso, 2010; Grab and Nash, 2010; Nash and Grab, 2010; Nash and Adamson, 2014; Hannaford et al., 2014, 2015; Nash et al., 2015, 2016). Due to the age of the diaries, the lack of meteorological readings being undertaken, and the Eurocentric bias of the authors, in many cases the methods had to be developed further through an iterative trial and error approach. Importantly, the methodology for this study is divided by the type of information captured, with more quantitative methods used in analysing the climate data, and qualitative methods to explore the social and environmental conditions. Finally, supporting data were obtained from the South African Weather Service and the Royal Observatory to corroborate the findings from the diaries.

Chapter 5: An analysis of the weather from 1652-1665



SPECIMEN OF VAN RIEBEECK'S HANDWRITING

A portion of a letter, dated 15 March 1660, written by Van Riebeeck to the Directors of the Chamber of Amsterdam. State Archives, The Hague.

5.1 Introduction

This section presents results of the weather chronology that has been quantified from the documentary sources. First, the rainfall days are explored for the historical record (1652-1665) and then compared with more recent records (1841-2013). Thereafter, potential seasonal patterns for the historical record are presented using rainfall onset and termination dates. Next, the historical wind patterns are discussed in terms of dominant wind direction and strength. Lastly, anomalous climate events and the inter-relationships between the different climate variables are discussed.

5.2 Historical Record

The primary aim of the study was to extract documentary climate data from historical diaries for weather reconstructions. The following climate data were collected:

- Daily wind direction and wind strength
- Frequent mentions to rainfall and relatively less frequent mentions to temperature
- Mentions to extreme conditions (floods, drought, hail and snow)
- The natural environmental setting of the Cape of Good Hope in the 1600s

There are no similar journals (with daily weather entries) to those of Jan van Riebeeck and Zacharias Wagenaer before or after the historical period (<1652-1665), hence the restriction of this study to these 13 years. However, in an attempt to corroborate the data, the Royal Observatory weather records from the 1800s and the South African Weather Services data for the contemporary period were used. Due to the qualitative nature of the diaries (no measurements of rainfall), the Royal Observatory weather records from the 1800s were tested as a potential data set to tentatively indicate the rainfall amounts of the 1600s.

Each of the records used contains and omits certain climate variables. The availability of these variables is outlined in Table 5.1. Due to the lack of instrumentation, historical information from the 1600s does not contain quantified measurements of rainfall amounts, exact temperatures in degrees Celsius, or measurements of wind strength. However, the diaries are very rich sources of information as they contain nearly-daily mentions of wind direction and descriptions of strength,

relative temperature descriptions, and thorough descriptions on precipitation incidents. Additionally, comprehensive remarks on the natural environment and societal implications are made throughout the diaries (Table 5.1). These descriptions of the natural environment and human interaction with the environment are discussed further in Chapter 6.

Table 5.1: Availability of information from historical sources

Dataset	Mention to rainfall	Measurement of rainfall (inches or mm)	Mention of Temperature	Measurement of Temperature (°C)	Mention of wind direction & strength	Measurement of wind strength (knots/hr)	Mention to the natural environment
Diaries of Jan van Riebeeck	✓	×	✓	×	✓	×	✓
Diaries of Zacharias Wagenaer	✓	×	✓	×	✓	×	✓
Royal Observatory weather journals	✓	✓	×	×	✓	×	×
South African Weather Services	✓	✓	×	×	×	×	×

The captured data span 4745 days over a 13 year period from 1652-1665. The diaries are translated English versions and comprise of three volumes. As the diaries were hard copies, it was not possible to attempt keyword searches so everything had to be read to ensure a thorough data extraction process. Each quote that made mention to climate or environmental variables was captured. From the data, 707 mentions were made to precipitation (Table 5.2), with the highest number in 1655 (80) and the lowest in 1661 (43). Wind had the highest number of total mentions at approximately 2426, whilst temperature had the lowest at approximately 383 mentions over the 13 year period (Table 5.2). The highest number of mentions of wind occurred in 1658 (252) whilst the lowest occurred in 1664 (65; Table 5.2). For temperature, the most number of mentions occurred in 1652 (85) whilst the lowest was in 1663 (8; Table 5.2). It is interesting to note that for all of the climate variables, the least number of mentions was recorded for the 1660s which was part Jan van Riebeeck's time at the Cape of Good Hope and all of Zacharias Wagenaer's time as governor. There are two possible reasons for the low number of mentions to these climate variables during Jan van Riebeeck's time. One is that as the Dutch settlement was

expanding, Jan van Riebeeck became increasingly interested in political matters such as developing business relationships with the Hottentots, and thus became less focused on commenting on weather conditions. In addition, it is evident from the very start of Zacharias Wagenaer's diaries, that he was not as thorough on documenting weather and/or environmental conditions as was his predecessor.

Table 5.2: Number of mentions of each climate variable

Year	Annual		
	Precipitation	**Temperature**	**Wind**
1652	61	85	178
1653	55	43	213
1654	58	26	224
1655	80	37	243
1656	58	45	232
1657	67	24	207
1658	47	36	252
1659	45	23	188
1660	52	9	174
1661	43	23	192
1662	49	11	180
1663	44	8	78
1664	48	13	65
Total	**707**	**383**	**2426**

5.3 Rainfall Days

There is a large emphasis placed on rainfall days (i.e. the number of days that rain fell) in this study as the exact rainfall amounts are not known, and therefore this is the best possible or permissible quantification. Additionally, in studies where there was an availability of rainfall amounts, the number of rain days were also used in the analysis, especially as a basis for determining rainfall frequency and seasonality; there is thus value in establishing this climate variable (Easterling et al., 2003; New et al., 2006). The RClimDex software package was used by New et al., (2006) to calculate precipitation indices, with the use of rain days (Table 5.3) further highlighting the importance of rain days as a climate variable.

Table 5.3: Precipitation Indices using the number of rain days (New et al., 2006)

Index	Descriptive name	Definition	Units
CDD	consecutive dry days	max number of consecutive dry days (dry day = daily rainfall rate <1mm)	Days
CWD	consecutive wet days	max number of consecutive wet days (wet day = daily rainfall rate ≥1mm)	
R10mm	heavy precipitation days	annual count of days when the daily rainfall rate ≥10mm	
R20mm	very heavy precipitation days	annual count of days when the daily rainfall rate ≥20mm	

5.3.1 Historical Rain Days

The years 1652 and 1665 are incomplete years due to the unavailability of the historical documentation. The year 1665 provides insufficient data for an annual analysis as it is only two out of twelve months complete. However, 1652 has ten complete months, yet with an annual total number of rain days greater than those years with complete monthly data, and was therefore included in the annual analysis.

The average annual number of rain days for the full 13 year historical period was 54 days. For the period 1652 to 1664, the year 1663 had the least number of annual rain days (43 rain days) closely followed by 1664 (45 rain days) whilst 1655 had the highest (77 rain days; Table 5.4). All other years fell between 47 and 67 (inclusive) annual rain days (Table 5.4). In all years, the majority of days with rain occur between May and August, with a noteworthy recording of 12 rain days in September which was much higher than the mean for Septembers between 1652-1664. (Table 5.4). The month of February generally has the least number of rain days and several years (1652, 1655, 1659, 1660, 1662, 1663, 1664) have no mention to rainfall in this month (Table 5.4). Notably, although the data from 1665 are limited, February had a relatively high number of rain days relative to most other years. The month of May recorded the highest number of total rain days over the 13 year period, followed by July and June (Table 5.4).

Table 5.4: Monthly rain day historical record

Month	Number of Rain Days per Month for the period March 1652 - February 1665													
	Year													
	1652	**1653**	**1654**	**1655**	**1656**	**1657**	**1658**	**1659**	**1660**	**1661**	**1662**	**1663**	**1664**	**1665**
January	-	3	0	3	3	3	1	3	2	4	3	0	3	1
February	-	3	6	0	1	2	1	0	0	1	0	0	0	3
March	5	1	5	2	1	4	4	5	2	3	1	0	3	
April	2	4	5	5	5	4	4	5	6	1	7	5	3	
May	10	5	7	9	10	8	5	7	15	3	8	5	6	
June	8	6	9	9	4	10	5	12	4	5	2	7	6	
July	7	8	11	9	10	5	7	3	5	7	6	4	8	
August	11	6	6	8	3	7	4	3	9	1	4	8	4	
September	3	5	4	12	5	5	6	3	3	7	0	2	4	
October	6	5	3	4	5	8	5	3	6	3	4	4	1	
November	2	3	1	8	5	5	0	4	2	5	9	7	2	
December	4	5	3	8	2	6	5	1	2	2	5	1	5	
Total	58	54	60	77	54	67	47	49	56	42	49	43	45	4
Mean	4.8	4.5	5	6.4	4.5	5.6	3.9	4.1	4.7	3.5	4.1	3.6	3.8	-

The diaries provided information on the *type* of rain. This assisted in better interpreting the *relative* quantity of rainfall, in the absence of quantity having been measured. For example, a rain day with ‘drizzle’ would accumulate less rainfall than a rain day with ‘heavy downpours’. Additionally, the type of rainfall relates to the synoptic conditions that caused it. The category with the most number of mentions is ‘rain’ (54 times in 1655) and the category with the least mentions is ‘light shower’ (1 time in 1657, 1662 and 1664; figure 5.1). The highest recorded number of mentions to 'heavy downpour’ was in both 1652 and 1660 (22 days in each year), whilst the lowest was recorded in 1658 (4 days; figure 5.1). Inter-annually, ‘rain’ registered the most number of mentions in 1655 (54 days) and the least in 1652 with 17 days (Figure 5.1). The category 'light shower' had the highest number of mentions in both 1659 and 1660 with four days and no mentions from 1653-1655 as well as 1661 (Figure 5.1). The lowest rainfall amount category, 'drizzle' had the most number of mentions in 1652 (16 days) and the least in both 1661 and 1664 (2 days; figure 5.1). Notably, the years with the highest annual rainfall, 1654, 1655 and

1657, were those that had the ‘rain’ category with the most number of mentions overall for each of those years (Figure 5.1).

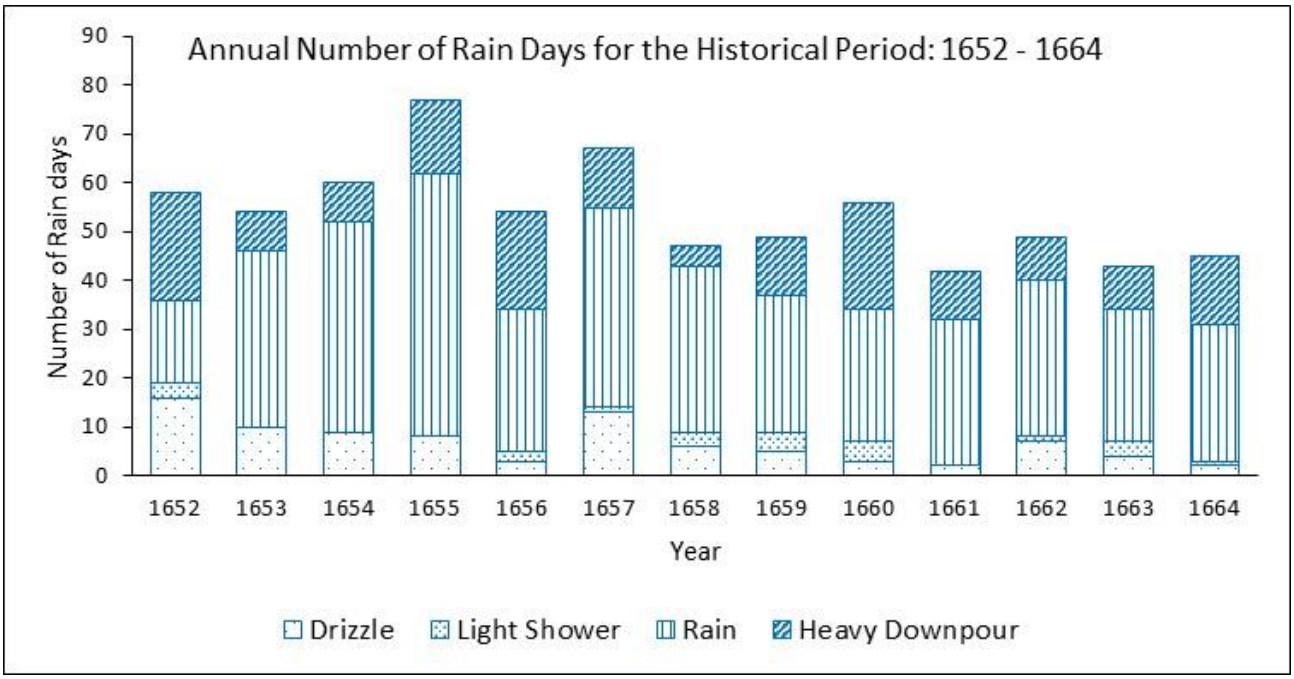


Figure 5.1: Annual Number of Rain Days 1652-1665

In addition to the broad annual patterns in rainfall type, it is interesting to explore the difference between wet and dry seasons. As mentioned in Chapter 2, the Cape region has a climate that is different from the summer rainfall regions of South Africa (Quick, 2013). For the historical period, it was found that there was much more inter-annual rainfall variability in the wet season than dry season (Figure 5.2). The most prominent pattern noted in the historical period are the peaks in the number of rain days during the wet season (May to September), followed by a relatively noticeable dip during the contemporary dry season (October to March; figure 5.2). It is also interesting to note that when there is a relatively higher peak in monthly totals inter-annually for a given wet season, it will follow with a relatively lower number of rain days in the dry season. This trend is distinct for the following periods: 1652-1653, 1654-1655, 1655-1665 and 1660-1661(Figure 5.2). The periods 1654-1655 and 1660-1661 are particularly interesting as the wet seasons are above and the dry seasons are below their respective 13 year averages (Figure 5.2). This follows on Barrable et al. (1998) that when wet seasons are relatively wetter then dry seasons are relatively much drier.

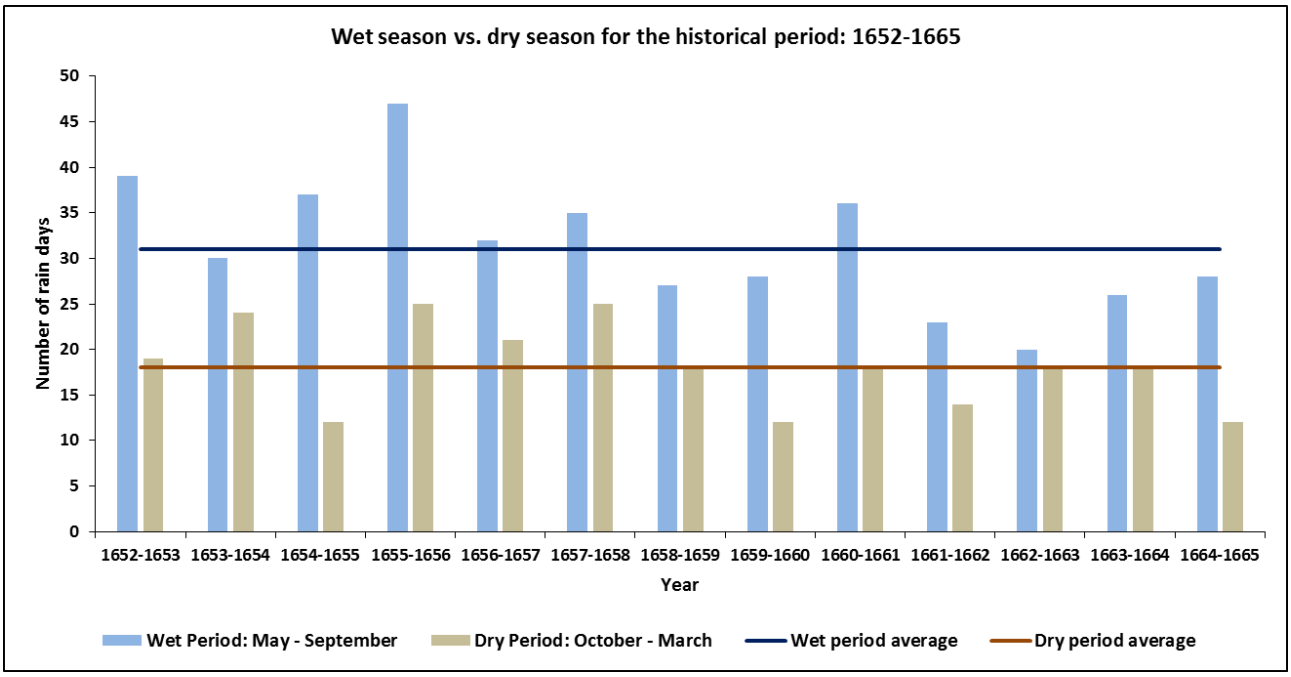


Figure 5.2: Graph showing Wet Periods and Dry Periods for 1652-1665

Due to the differences found in the number of rainfall days for wet and dry seasons, it is interesting to examine rainfall category type for each of these seasons. In the dry period, it was noted that the 'rain' category makes up a larger proportion of the number of rain days within each year relative to the other categories (Figure 5.3). This is followed by 'heavy downpour' and 'light shower' with drizzle making up the smallest proportion. The most number of mentions to 'heavy downpours' (6 days) were within the period 1655-1656 together with the second largest mentions to 'rain' (18 days; Figure 5.3). Interestingly, there were no 'light showers' recorded for this period which is rare during the 13 year dry seasons as the only other year with no mention to 'light showers' was 1664-1665 (Figure 5.3). However, the 1664-1665 recordings were documented by Zacharias Wagenaer and are relatively less comprehensive to those of Jan van Riebeeck. Hence, through closer inspection of the more reliable 1655-1656 dry period data, it was noted that it follows a similar trend of a wet season as very little 'light shower' number of rain days were recorded over a few individual years (Figure 5.3; 5.4). This is also interesting as the 1665 year recorded the most number of rain days out of the entire 13 year historical period (Table 5.4). Of the 13 year historical period, four years had no mention to 'heavy downpours' and four years had no mention to 'drizzle'. Two of these four years, the periods beginning 1654

and 1661 had no mention to both the ‘heavy downpours’ and ‘drizzle’. The dry seasons with the lowest number of rain days recorded were 1654-1655, 1659-1660 and 1664-1665. The periods 1655-1656 (no mention to ‘light shower’) and 1657-1658 (no mention to ‘drizzle’) were the highest number of rain days for the dry period (25 days; Figure 5.3).

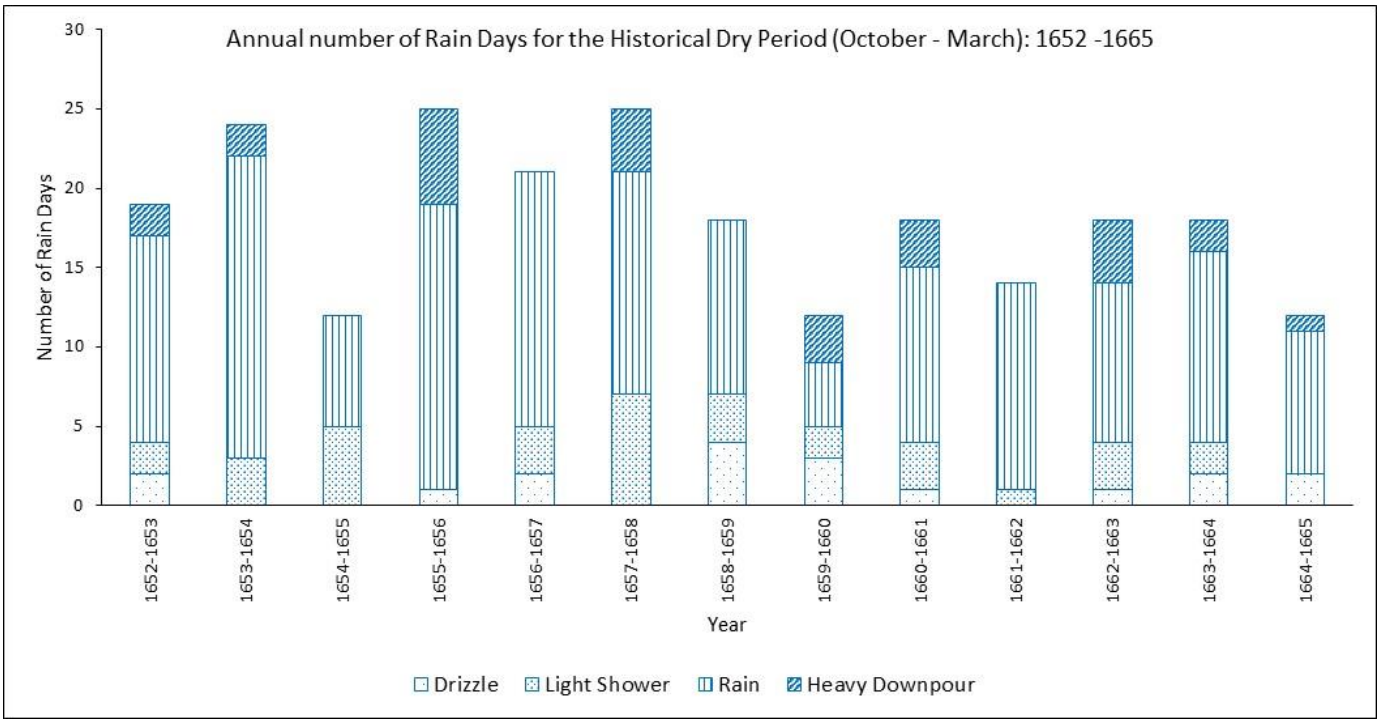


Figure 5.3: Annual dry periods according to rainfall intensity for the period 1652-1665

During the wet season it was noted that 'rain' and 'heavy downpours' predominate throughout the 13 year historical period (Figure 5.4). The year with the highest number of rain days was 1655 (47 days), followed by 1652 with 39 mentions to rain days (Figure 5.4). However, 1652 comprises 11 days of 'drizzle' whilst 1654 (37 rain days) only comprises 3 days of 'drizzle' and 1660 (36 rain days) with one 'light shower' and no mention to 'drizzle' (Figure 5.4). Based on this, it can be noted that 1654 and 1660 may have tentatively received equivalent or more rain for their respective periods than for 1652 (Figure 5.4). The lowest number of rain days captured was in 1662 and was comprised of five 'heavy downpour' days, 13 'rain' days and two 'drizzle' days (Figure 5.4). All years for the 13 year period comprised of 'heavy downpour' and 'rain' whilst only four years made mention to 'light shower' and only two years made no mention to 'drizzle' (Figure 5.4).

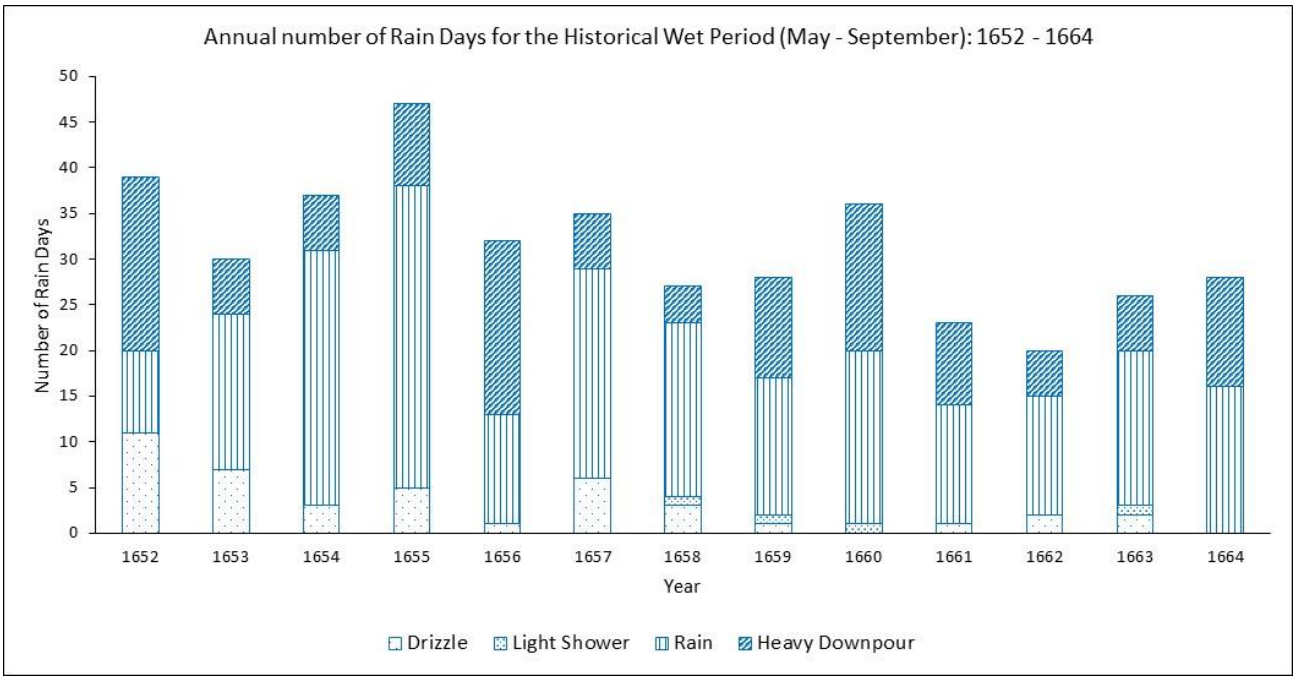


Figure 5.4: Annual wet period according to rainfall intensity for the period 1652-1664

5.3.2 Contemporary Rain Days

As data from the historical period is limited to rain days and no rainfall amounts, it is interesting to see how it compares to the contemporary data for which there were rainfall amounts. The contemporary data set is also used to test if a given number of rain days with known rainfall type could broadly represent specific quantities of rain, and thus tentatively be used as a proxy indicator of relative rainfall amounts (mm) during the historical period.

The long term contemporary rainfall record retrieved from the South African Weather Services was for the period 1841-2013 and is therefore interesting to explore the rain days over this very long period especially for potential comparison purposes to the 13 year historical period. It is observed that the long-term climate change trend is a decrease in the number of rainfall days at a rate of 0.19 days per year (Figure 5.5). There is also a considerable amount of inter-annual variability to that of the 13 year historical period. The mid-1900s indicated higher number of rain days relative to the rest of the period (Figure 5.5). Overall, the lowest number of rain days was recorded from the late 1900s to the early 2000s (Figure 5.5).

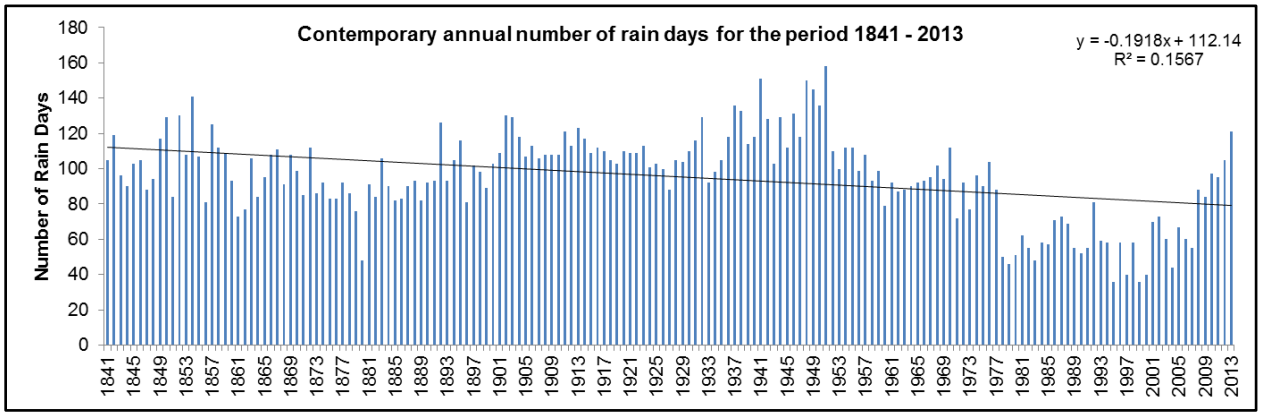


Figure 5.5: Annual number of rain days for the contemporary period: 1841-2013

The average number of rain days for the full 173 years is 96 rain days/annum and the average for the historical period was 54 rain days/annum (Table 5.5). This indicates that on average the historical period (1652-1665) only received ca 56% the number of rain days compared to that of the last 173 years (Table 5.5). However, when compared to the contemporary Cape climate (i.e. last 30 years), the historical period received ca 82% the number of rain days, thus still relatively less than that during recent decades. When the contemporary period was sub-divided into shorter periods, more variability is noted (Table 5.5). The last 50 years (1964-2013) and the last 13 years (2001-2013) have a similar number of mean rain days (72 and 78 days respectively; table 5.5). The last 50 years of the 19th C and the 20th C in its entirety showed similarities with the entire contemporary period with 96 and 97 rain days respectively (Table 5.5). Closest to the 13 year historical period rain day average was the last 30 years (1984-2013) with 66 days resulting in a difference of 12 days on average (Table 5.5). The results presented here, highlights the variability of rain days amongst randomly selected rain day sets for the contemporary period.

There is considerable variation in rainfall amounts for different time periods. For example, the last 50 years with an average of 72 rain days resulted in a lower rainfall average of 596.6mm relative to the prior 30 years that had a 66 rain day average but a slightly higher rainfall average of 614.6mm (Table 5.5). Additionally, even when the number of average rain days are constant, at 96 rain days for both the 173 years contemporary period and the last 50 years of the 19th C, the average rainfall differed by 45.2mm. Hence, it appears that a direct link cannot be made between

the number of rain days and rainfall amounts. It was found that almost no change occurred across the long term period for the annual total rainfall as shown by the statistically insignificant trendline.

Table 5.5: Rainfall (mm) and rain day averages for the contemporary and historical period

Average Period	Total Annual Rainfall Amount (mm)	Total Annual Rain Days
Historical Record	no data	54
173 Years (1841 - 2013)	619.2	96
Last 50 Years (1964 - 2013)	596.6	72
Last 50 Years of 19th C (1850 -1899)	664.4	96
20th C (1900 - 1999)	603	97
Last 30 Years (1984 -2013)	614.6	66
Last 13 Years (2001 - 2013)	622.3	78

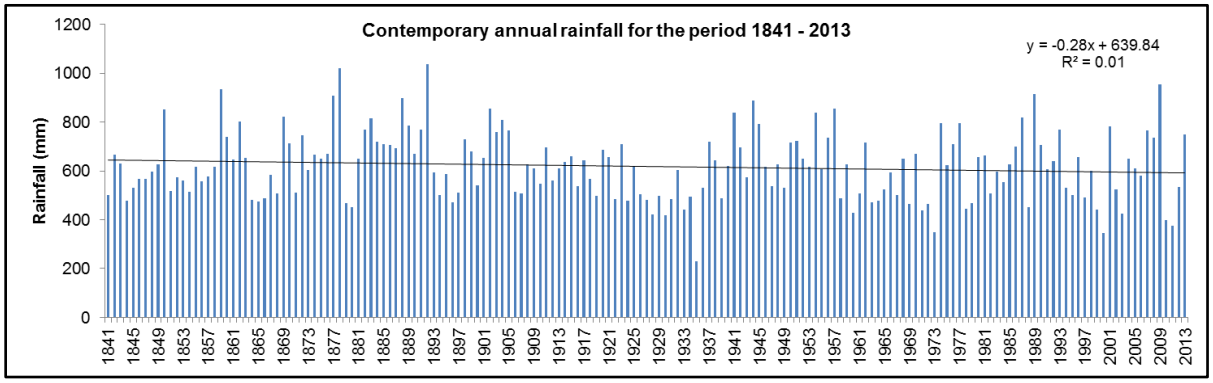


Figure 5.6: Annual rainfall for the contemporary period: 1841-2013

Rain days and rainfall amounts were correlated to statistically test whether a relationship can be inferred between the two variables for the purposes of the historical record. They reflected a poor correlation (r = 0.02), indicating a statistically insignificant reduction of 0.28mm/year (Figure 5.6). Furthermore, rainfall amounts for any given number of rainfall days spans a 400mm range and thus rainfall days cannot be used as a proxy for rainfall amount. It is only useful as an independent climate variable. However, given that the maximum rain days during the historical record was 77 days for 1655, tentatively the regression output suggests that based on the contemporary results there is a 69.9% chance that rainfall was between 400-800mm (Figure 5.7).

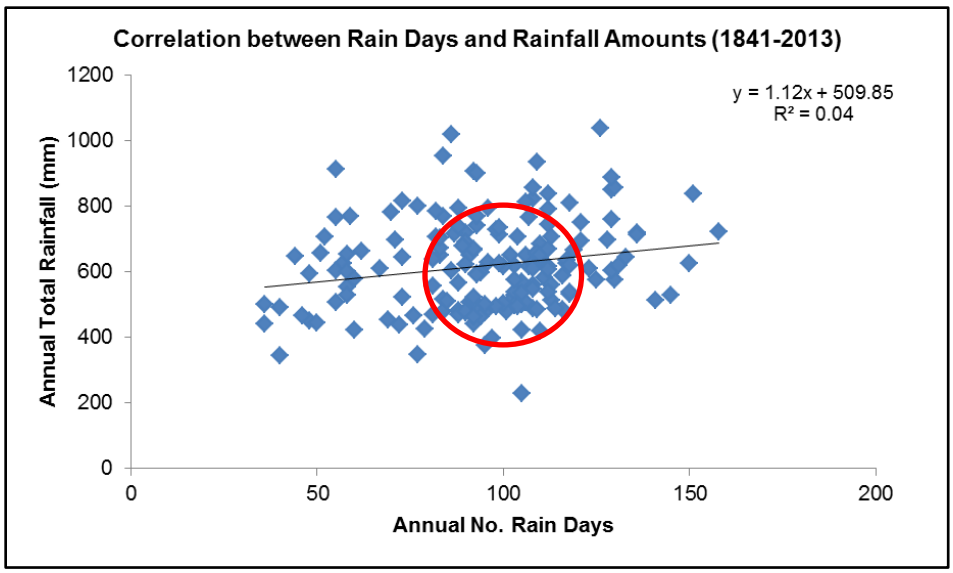


Figure 5.7: Scatterplot showing the relationship between rain days and rainfall for the contemporary period (1841-2013).

The historical record is further valuable in facilitating tests to determine the level of variability within a 13 year period. Although the 13 year historical period used in this study was the longest period available and must certainly be explored for its climate value, it is important to acknowledge potential errors and limitations. Two sets of graphs are presented using annual rainfall days for groups of 13 years which commence and terminate in different years (Figure 5.8). In both cases, they are compared to the average annual rain days from the historical record, termed the 'historical mean' (Figure 5.8).

The variations between these two graphs are notable, it is noted that the last two year sets, (1984-2006; 1997-2009) for the first graph were both below the 'historical mean'. For the second graph, values below the mean are recorded for the second last two periods (1975-1987; 1988-2000) with a greater deviation from the mean (Figure 5.8). The 2001-2013 data period was then found to be above the historical record. This is an important test as had the diaries commenced a year later, the data would have likely been very different, especially as the first year (1652) had a relatively high number of rain days (Figure 5.8). The trends noted for the entire contemporary period links back to earlier commentary where it was found that the number of rain days have decreased during the more recent past, with values either equivalent to or less than the historical mean (Figure 5.8).

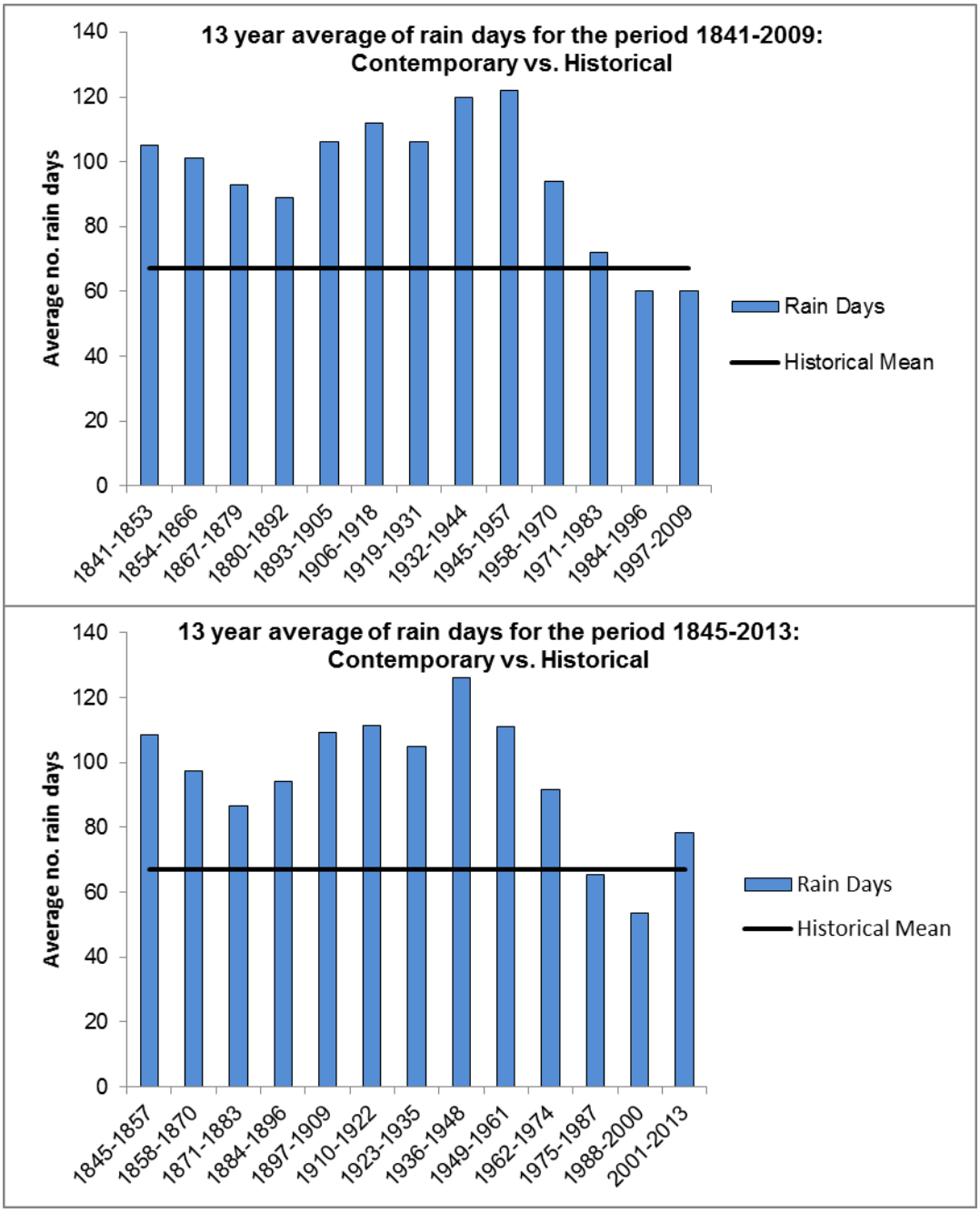


Figure 5.8: Thirteen year average rain day sets for the contemporary period: 1841-2009 and 1845-2013

5.4 Rainfall Seasonality (Onset/ Termination)

Rainfall seasonality can be determined using rainfall onset and termination. Rainfall onset may be defined as the beginning of the rainy season and when the distribution of rain is sufficient to promote crop growth (Odekunle, 2005). Rainfall termination/cessation/retreat may be defined as

the period when the rainy season is coming to an end and is not necessarily that no rainfall will fall but rather that the amount of rainfall and its distribution will no longer promote crop development (Odekunle, 2005). Quantitative measures of the onset and termination of rainfall is important as it shows shifts in seasons and is also indicative of the strength and position of the westerly belt which drives winter rainfall in the southwestern Cape region (Fitchett, 2013; Le Roux, 2015). The onset of rainfall also directly influences biodiversity (flora and fauna) by determining the beginning of spring phenophase events (Fitchett et al., 2015). Ordinarily, rainfall onset and cessation is based on specific threshold values of rainfall over a specific time period, and is often adjusted based on the seasonality of rainfall for a particular location (Odekunle, 2005; Fontaine and Louvet, 2006). Again, due to a lack of such data for the historical period, the descriptive rain records will be used instead. 'Light showers' and 'drizzle' categories are not considered as an onset or termination day as they are indicative of very little rainfall and not appropriate for promoting crop growth. Furthermore, in Cape Town the rain season is driven by the passage of mid-latitude cyclones, which are characterised by rain conditions rather than drizzle (Buckley and Leslie, 2004). Instead, only the 'heavy downpour' and 'rain' categories are used.

Table 5.6: Rainfall Onset and Termination dates for the Historical Period

Year	Onset Date	Termination Date
1652	03-May	08-Nov
1653	06-Apr	29-Nov
1654	29-Mar	23-Sep
1655	04-Apr	31-Dec
1656	04-Apr	22-Nov
1657	30-Mar	24-Oct
1658	23-Mar	17-Oct
1659	26-Mar	17-Oct
1660	11-Apr	11-Oct
1661	20-May	12-Nov
1662	01-Apr	23-Nov
1663	11-Apr	22-Nov
1664	19-Mar	17-Sep

Through disregarding the 'light showers' and 'drizzle' categories, interesting patterns were noted. When the rainfall onset occurred during April and May, the termination days always

occurred during November and one time in December and one in April (Table 5.6). The termination in December occurred in 1655 which also happened to be the year with the most number of annual rain days for the 13 year period (Table 5.6). When the onset occurred in March, the termination months were always in October and in two cases September (Table 5.6). At the beginning and the end of the 13 year period, it was predominantly an April/May onset date but in the middle of the period, for three consecutive years it was always a March onset date ceasing in October for all three years.

5.5 Flood Events

All mentions to flooding and/ or excessive rains were made during the wet period (May – September; figure 5.9). During the first three years, there were two mentions to these events, occurring in consecutive months (Figure 5.9). In 1652, it was during July and August, 1653 in May and June and again in July and August in 1654. Thereafter, it was mentioned once a year in 1655 (June), 1656 (July) and 657 (June; figure 5.9). There was no mention made to flood events for two years and then two mentions in the following year, thereafter a similar pattern of two years with no mention and then two mentions in the following year (Figure 5.9). From the diaries, the vocabulary chosen to describe flood-like conditions are very different to that of a normal rain event. Some of the words and/ or terms used to describe extreme rainfall include 'heavy', 'never before experienced', 'unusually heavy rains', 'overflowed their banks', The following quotes illustrate the descriptive choice vocabulary used to indicate excessively wet conditions:

> In the morning it began to blow very hard from the N.N.W. with fairly heavy hail an drain showers. … During the night stormy weather increased, with the heaviest downpour imaginable… (22 July 1652, p. 51).

> … Towards nightfall extraordinarily heavy rain continuing almost throughout the night. We have never before experienced the like of it here (26 July 1654, p. 252).

> [speaking of the Hottentots that barter with the Dutch]: "At the moment it is hardly possible for them to cross with their cattle because of the unusually heavy rains which had inundated the country in all directions during this season" (22 September 1660, p. 261).

> Rain the whole night, so that all the rivulets in Table Valley overflowed their banks, and with great noise rushed towards the sea (2 June 1663, p. 57).

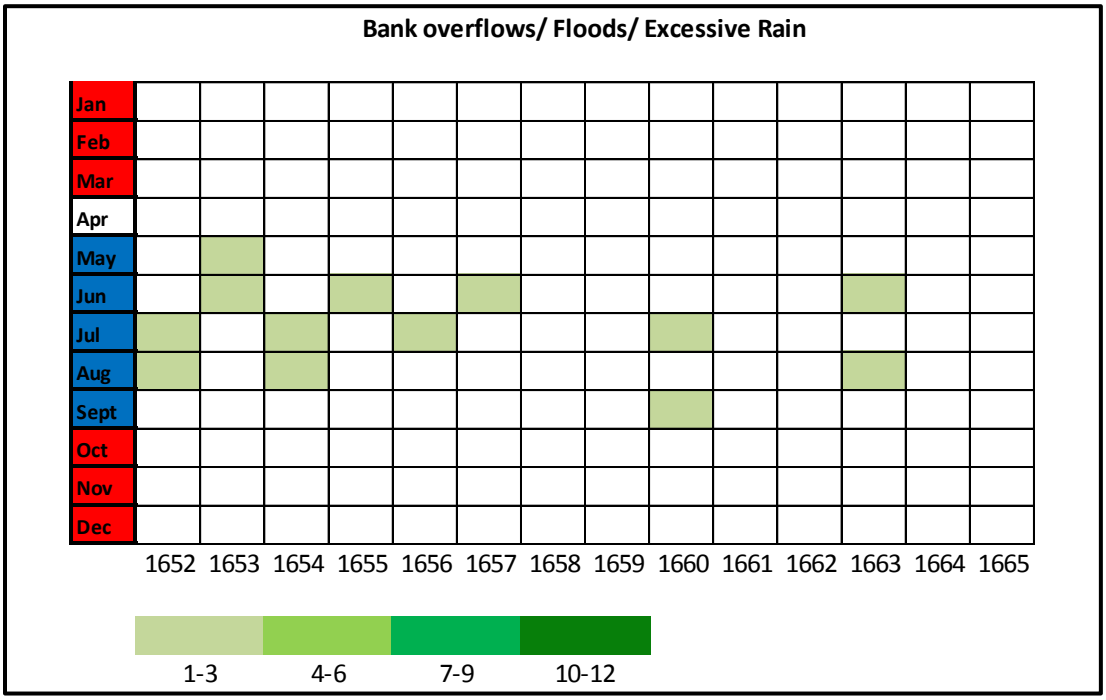


Figure 5.9: Mentions of wet weather incidents

5.6 Drought and Dry Weather

The term drought is usually made with reference to depletion of fresh water sources as well as poor harvests and the death of livestock. At this early stage of the settlement it would not have been necessary to make use of these terms unless in reference to the water sources as little or no establishment was made with regards to crops and livestock. These social environmental factors in relation to drought and/ or dry weather are discussed in greater detail in sections 6.2 and 6.4.3.

The contextual setting of the physical environments at these times, i.e. the beginning of the time period and the end of the time period, may potentially be the reason for the infrequent mentions to dry weather. Initially upon settlement (April 1652), references to ‘drought’ or ‘dry weather’ was mentioned scarcely (the years 1652-1653) with a steady increase in annual frequency but a similar frequency regarding the number of times ‘drought’ or ‘dry weather’ references were made within a month (the years 1654-1655; figure 5.10). The year 1656 had the most number of

mentions whilst 1652, 1663 and 1664 had the least. The years 1657 and 1658 were quite similar in that there was no reference to drought or dry weather between the months of March to August of those years (Figure 5.10). In the years 1663 and 1664, it must be noted that the settlement was being governed by the newly instated, Zacharias Wagenaer, who did not emphasis on the weather and environmental conditions at the Cape as frequently or as comprehensive as his predecessor, Jan Van Riebeeck.

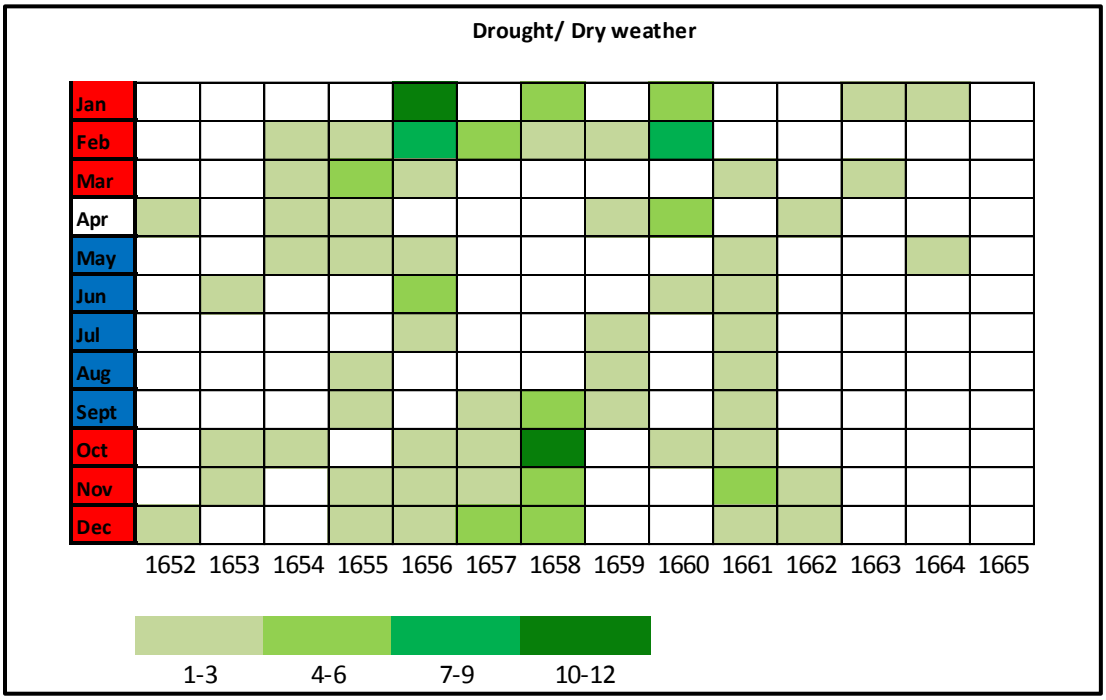


Figure 5.10: Mentions of drought or dry weather incidents

5.7 Wind

As discussed in Chapter 2, the south Atlantic anticyclone and westerlies are the macro-scale processes determining air circulation over the southwestern Cape. The convergence of the tropical easterly and westerly belts results in seasonal shifts and determines changes in dominant wind direction (Figure 5.11). During winter, the north-westerlies dominate, bringing cold, rainy weather, whilst in summer the south-easterlies bring dry conditions (Tadross et al., 2012). Inter-annual differences in wind strength are interesting because they reflect competing synoptic patterns (Chase and Meadows, 2007; Chase et al., 2015).

Throughout the 13 year historical period, it is noted that the dominant wind directions were north-westerlies, westerlies, south-easterlies and south south-easterlies (Figure 5.12). Limited mention is made to west north-westerlies in 1652, 1653, 1656 and 1662 (Figure 5.12). Similarly, west south-westerlies, south south-westerlies, southerlies, north-easterlies, north north-easterlies and northerlies are only occasionally mentioned throughout the historical period (Figure 5.12). There were only two mentions to east south-easterlies and no mentions to east north-easterlies (Figure 5.12; Table 5.7). The north-westerlies were particularly frequent during 1655 and 1656, of which 1655 was the year with the most rain days. It is also interesting to note that in the first two years at the Cape of Good Hope, Jan van Riebeeck made reference to predominantly south-easterlies during the summer months and then in years that follow he changed to making reference to the south south-easterlies wind direction instead. However, from 1662, there is a return to the use of south-easterlies instead of south south-easterlies (Figure 5.12). This was about the same time that Zacharias Wagenaer took over as governor at the Cape, and thus these changes may reflect personal preferences in describing dominant wind directions.

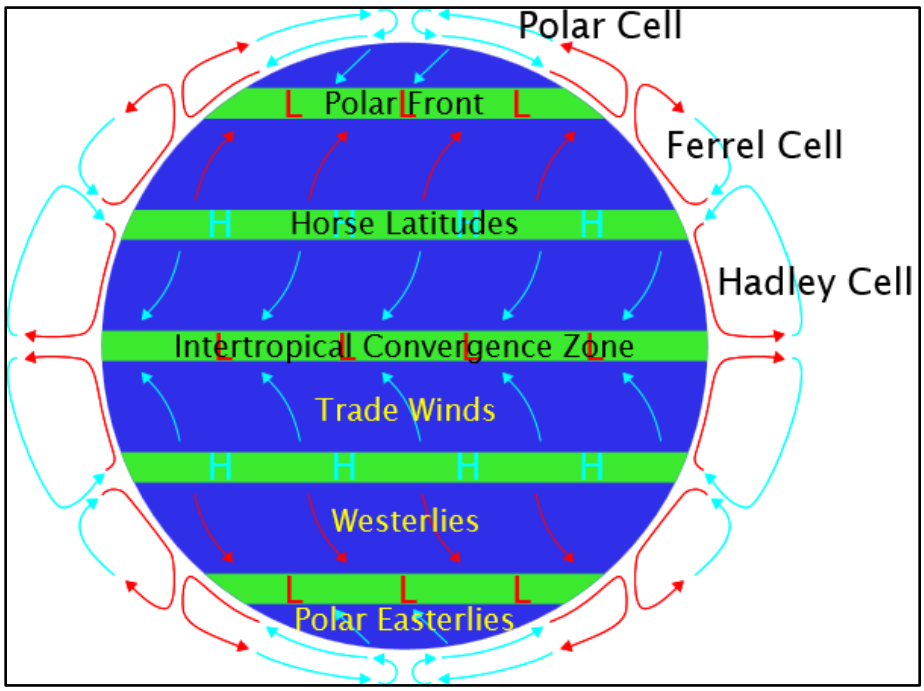


Figure 5.11: The Global Atmospheric Circulation and resultant wind bands (Windrum, 2004)

As the north-westerly and south-easterly groups (south-easterlies and south south-easterlies) were the dominant wind directions, these variations are explored further as web graphs (Figure 5.13). In 1652, the north-westerlies and south-easterlies equally dominated whilst in 1653 the south-easterlies dominated with a small presence of a combination of winds from the west (Figure 5.12; Table 5.7). These south-easterlies and south south-easterlies also dominated during 1653-1654, 1659-1661 and 1663-1664 (Figure 5.12; Table 5.7). It is interesting that this trend seems to occur in two and three year trends. The other years where both south-easterlies/ south south-easterlies and north-westerlies dominated include 1655, 1657 and 1658 (Figure 5.12; Table 5.7). The north-westerlies dominated in 1656, and 1662 (Figure 5.12; Table 5.7). Aside from the north-westerlies, south-easterlies and south south-easterlies, the other wind direction would be west (Table 5.7). Most rains during the winter months are brought with the westerlies. From this perspective, it can be noted that in years with the most number of mentions to rain days, the combined winds from all westerly directions, such as north-westerlies, north north-westerlies, west north-westerlies, south-westerlies, south south-westerlies, west south-westerlies and westerlies were relatively higher than other years with fewer mentions of rain days (Figure 5.12).

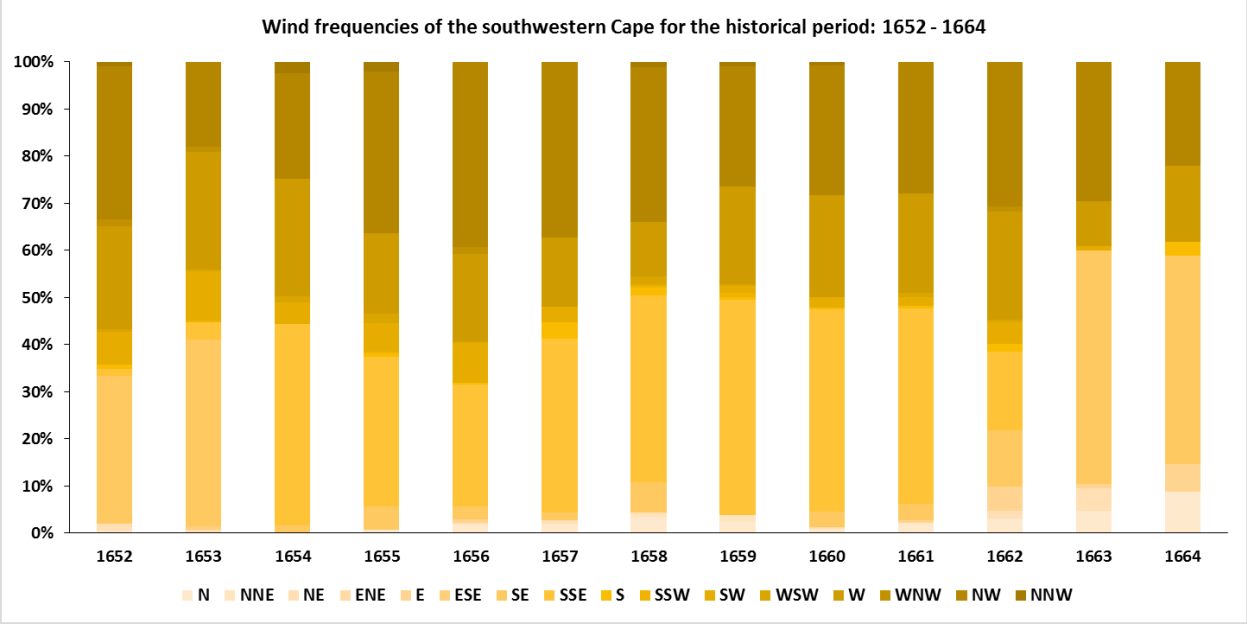


Figure 5.12: Wind frequencies at the Cape during Historical times

The nearly-daily wind direction and wind strength data were fairly comprehensive, relative to other categories (such as temperature). This allowed for detailed analysis of the relationship between wind direction and wind strength on an annual and monthly basis (Table 5.7). The common theme noted is that the south-easterlies and south south-easterlies were experienced at the beginning and later parts of each year, whilst the north-westerlies and westerly winds were noted mid-year (May - September; Table 5.7). In some cases where the south-easterlies and north-westerly winds are equal in the secondary wind direction category, then in most cases the westerlies will be the dominant wind direction (see yellow highlight in Table 5.7). The dominant and secondary wind strengths for each wind direction is highly variable but is pre-dominantly 'wind', 'breeze', 'strong' and then 'squall' respectively (Table 5.7). However it must be noted that no further quantification can be made from these descriptions as there would have been some degree of inconsistency in their categorisation of winds based on the level of damage or inconvenience that winds on a particular day caused. Furthermore, there is also a level of difficulty segregating categories, as for example it would be difficult to differentiate the wind strengths associated with a 'strong breeze' relative to a 'light wind'. The winds were westerly and not specifically north-westerly in 1653, which differed from the norm for the winter season trends (Table 5.7). It was also noted that in 1656 westerly winds dominated, with west and north-west as both dominant and secondary categories (Table 5.7).

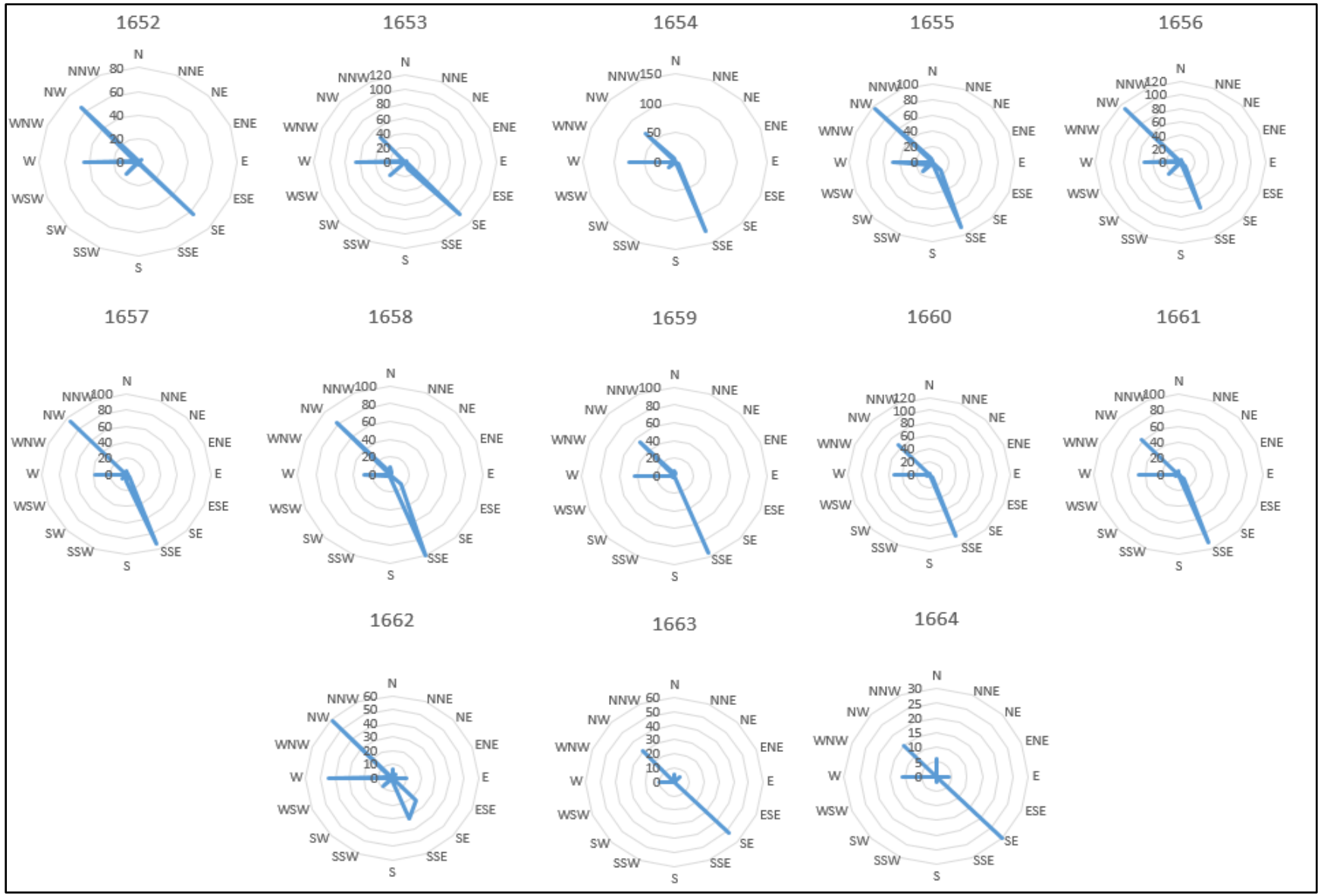


Figure 5.13: Web graphs depicting annual dominant wind directions for the historical period: 1652-1664

Table 5.7: Major Wind Directions and Wind Strengths for the first 12 years of the historical period: 1652-1663

Month	DWD	SWD	DWS	SWS	DWD	SWD	DWS	SWS	DWD	SWD	DWS	SWS	DWD	SWD	DWS	SWS
	1652				1653				1654				1655			
Jan	Not Applicable: Travelling to the Cape of Good Hope				SE	NW	Sq	B	SSE	NNW	Sq	B	SSE	W*	B	Wi
Feb					SE	W	Sq	St	SSE	NW	St	B	SSE	NW	B	St
Mar					SE	W	St	Wi	SSE	W&NW	Sq	B	SSE	W	St	Wi
Apr	SE	W	Wi	B	SE	SW	B	St	SSE	NW	Sq	B	NW	SSE	B	Wi
May	W	SE	Wi	St	W	SW	Wi	B	NW	W	B	Wi	NW	SSE	W	St&B
Jun	NW	SE	St	W	W	NW	Wi	B	W	WSW	B	Wi	NW	W	W	B
Jul	W	NW	Wi	B	W	SE&NW	Wi	St	NW	SSE	Wi	Sq	SSE	NW	B	Wi
Aug	W	SE	Wi	St	W	NW	Wi	B	NW	W	Wi	Sq	SSE	W&NW	Wi	St
Sep	SW	SE	Wi	Sq	SE	W	Wi	B	W	SSE	B	Wi	NW	SSE	Wi	Sq&St
Oct	NW	SE	Wi	St	SE	W	Wi	St	SSE	W	Wi	Sq	SSE	NW	Wi	St
Nov	NW	SE	Wi	Sq	SE	NW	Sq	B	SSE	W	B	Wi	SSE	NW*	Wi	B
Dec	SE	WNW	St	W	SE	S	St	Wi	SSE	W	B	St	NW	W	B	Wi
	1656				1657				1658				1659			
Jan	NW	SSE&W	Wi	B	SSE	NW	B	Wi	SSE	NW	St	B	SSE	NW*	Wi	B
Feb	SSE	W	B	St	SSE	W	B	St	SSE	NW	St	B	SSE	N	St	B
Mar	SSE	NW	B	Wi&St	SSE	NW*	B	St	NW	SSE	B	Wi	SSE	W	B	St
Apr	NW	SSE,SE&W	Wi	B	SSE	NW	B	Wi	SSE	NW	St	B*	SSE	NW	St	B*
May	NW	SSE&W	Wi	B	NW	SSE	Wi	B	NW	SE	Wi	B	NW	W	B	Wi
Jun	NW	W	B	Wi&St	W	NW*	Wi	St	NW	SSE	B	Wi	NW	SSE	St	B*
Jul	NW	W	B	Wi	SSE	NW	B	St	NW	SSE	Wi	St	NW	SSE	St	B
Aug	NW	SE&W	Wi	St*	NW	W	St	Wi	NW	SSE	Wi	B	SSE	W	St	B
Sep	SSE	NW	St	Wi	NW	SSE	Wi	B*	SSE	W	Wi	B	W	SSE	Wi	St&B
Oct	NW	SW	B	Wi	SSE	NW	Wi	St&B	SSE	W	St	B	SSE	NW	St	B
Nov	SSE	NW	B	Wi&St	SSE	NW	St	B	SSE	W	St	B	SSE	W	St	B
Dec	SW	SSE	B	St	NW	SSE	Wi	B*	SSE	NW	Wi	B	W	SSE	B	St
	1660				1661				1662				1663			
Jan	SSE	W	St	B	W	SE&NW	B	Wi	NW	SSE	B	St	SE	NW	St	Sq
Feb	SSE	W	St	B	SSE	W	B	St	SSE	NW	B	St	SE	N/A	Wi	St
Mar	SSE	NW	St	Wi&B	SSE	W	St	B*	SSE	W	B	St	SE	N/A	St	N/A
Apr	W	SSE	B	St	W	SSE	B	St	W	NW	B	Wi&St	W	SE	St	B
May	NW	SSE	Wi	B*	SSE	NW*	B	Wi&St	W	SE	Wi	B	W	NW	B	Wi&St
Jun	NW	W	Wi	B	NW	SSE	Wi	St*	NW	W	B	Sq	NW	N/A	St	N/A
Jul	W	SE	B	Wi	NW	SSE	Wi	St&B	NW	SW	St	B	SE	NW&NE	Wi	St
Aug	NW	N/A	St	Sq	NW	SSE	B	Wi	NW	W	B	St	NW	W	St	Wi
Sep	NW	SSE&W	St	B	NW	SSE	St	B*	NW	SE	Wi	B	SE	NE	Sq	St
Oct	W	SSE	B	Wi	SSE	NW	St	B	SE	NW	Wi	B*	NW	SE	Wi	St&B
Nov	SSE	NW	St	Wi	SSE	W	St	B	W	SE	B	Wi	NW	SE	Wi	St
Dec	SSE	NW	St	B	SSE	NW	St	Wi	SE	W	St	B	SE	N	St	B

Legend	
DWD	Dominant Wind Direction
SWD	Secondary Wind Direction
DWS	Dominant Wind Strength
SWS	Secondary Wind Strength
	dominant easterlies
	dominant westerlies
	contians easterly and/ westerly winds
*	denotes equal DWD/DWS.
B	Breeze
Wi	Wind
St	Strong
Sq	Squall

5.8 Royal Observatory Data Set

As explained in Chapter four, the Royal Observatory weather records were used in an attempt to better quantify rainfall quantity during the historical period. A random five year set (1843-1847) was used to determine the validity of this dataset as a proxy for a rainfall amount. The categories of rainfall mentioned in these records are frequent terms from the Royal Observatory and don't directly correspond to this study's historical period. These recorded the rainfall in inches instead of the more recently used millimeters, and so the results displayed are for both inches and millimeters. This was done so that all statistical analysis applied to the data was performed from the original data in inches, thus minimising possible errors. Within the random first five year set, no unique ranges were identified for the various descriptions of rainfall. The ranges were highly variable as illustrated by the very high standard deviations relative to the mean (Table 5.8). Hence, no distinct categories were identified. Examples of this would be the 'rain' category where the maximum was 53.59mm and the minimum was 0.05mm from a total of 169 mentions. This resulted in a mean of 0.26 inches and a standard deviation higher than the mean of 0.36 (Table 5.8).

Table 5.8: Descriptive statistics on rainfall amounts according to category types

Category	Max (inches)	Max (mm)	Min (inches)	Min (mm)	Mean	Std. Dev	No. of mentions
heavy rain	1.25	31.75	0.026	0.66	0.42	0.37	9
light rain	1.03	26.16	0.14	3.56	0.41	0.36	6
occasional showers	1.17	29.72	0.012	0.30	0.29	0.35	9
rain	2.11	53.59	0.002	0.05	0.26	0.36	169
morning rain	0.19	4.83	0.015	0.38	0.14	0.06	7
afternoon rain	0.19	4.83	0.06	1.52	0.13	0.07	5
night rain	2.12	53.85	0.016	0.41	0.42	0.5	22
showers	0.19	4.83	0.0001	0.00	0.11	0.07	13
squalls	0.35	8.89	0.009	0.23	0.12	0.14	6
rain with hail	0.35	8.89	0.018	0.46	0.11	0.11	7

Box and whisker plots were used to graphically display the variance for each category from the Royal Observatory data. There is much overlap between categories. For example, 'heavy rain', 'light rain', 'rain' and 'night rain' all overlap (Figure 5.14). Therefore, for a given rainfall quantity, descriptions in the Royal Observatory data have fallen into at least three categories.

This becomes problematic as maximum and minimum rainfall for one category could easily describe the maximum and minimum rainfall for another category. Therefore, the dataset cannot be used as a proxy for rainfall quantity on the basis of rainfall description, as many category descriptions would have no unique rainfall amounts. Following on the categories from the previous example, these all include 0.3 inches of rainfall. Here again, rainfall type for rainfall amount, could not be proven to be an accurate proxy for the purposes of this study, that is the category type cannot be used to infer rainfall quantity.

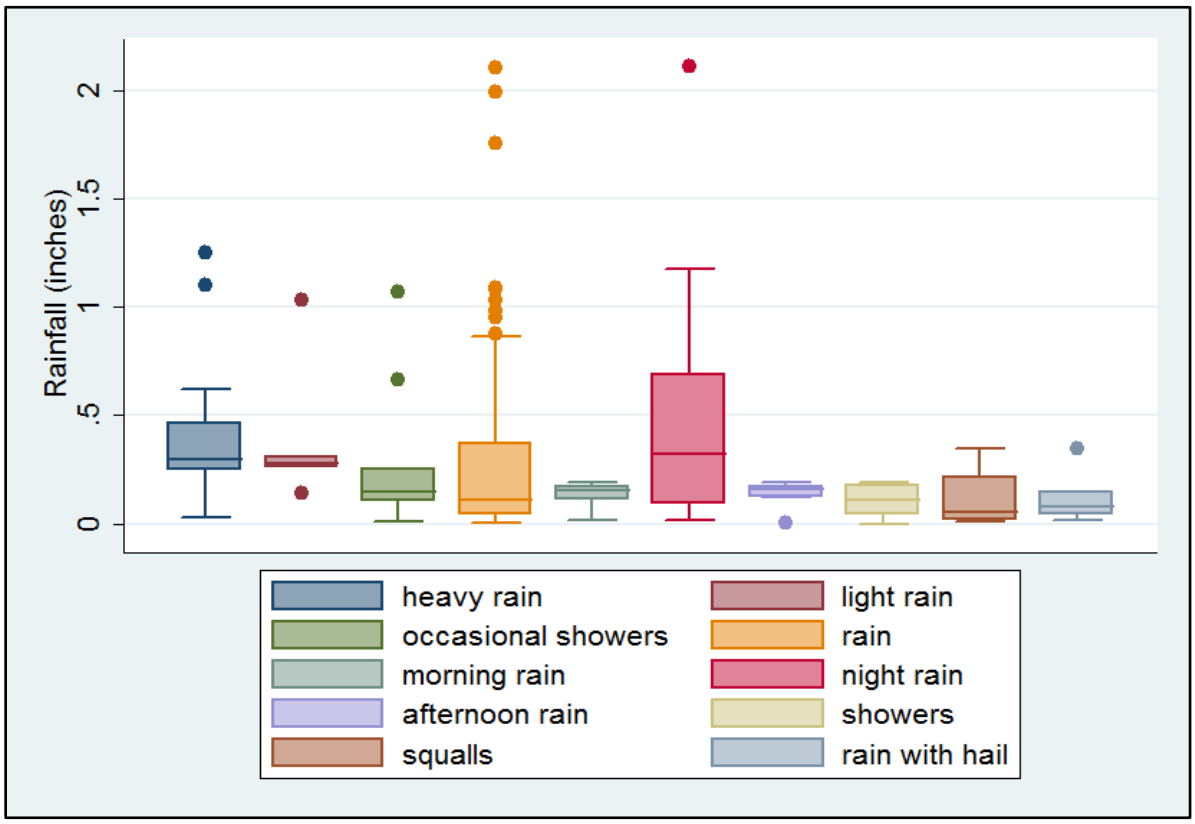


Figure 5.14: Box and whisker plots representing variance of rainfall categories for the Royal Observatory data: 1843-1847

The wind direction was also captured from the Royal Observatory data set, for the five random years selected for the previous tests of rainfall quantity. While not useful in finding a relationship between rainfall type and amount, the Royal Observatory data may be useful in exploring the relationships between wind direction and rainfall quantity. It could be noted that north-westerly winds predominate during rainfall conditions, as most frequently they coincide directly with

rainfall events (235), while southerly winds are associated with the second highest number of rain counts, at 34 mentions (Table 5.8). Upon inspection of the maximum and minimum rainfall values for the different wind directions, there are very prominent overlaps for both specific wind directions (for example west north-westerlies and north north-westerlies) and for broad wind direction groups (for example westerlies, northerlies and southerlies). There is also much variance within each rainfall amount for a given wind direction relationship as shown by the standard deviation relative to the mean, indicating considerable noise in the data (Table 5.9). Hence, no clear relationship between wind direction and rainfall amounts could be determined, and therefore wind direction cannot be used as a proxy for rainfall amount in the historical data (Table 5.9).

Table 5.9: Descriptive statistics on rainfall amounts according to wind direction

Wind direction	Max (inches)	Max (mm)	Min (inches)	Min (mm)	Mean (inches)	Std. Dev	No of appearances
easterlies	0.10	2.59	0.00	0.08	0.05	0.04	4
northerlies	1.16	29.39	0.11	2.82	0.49	0.37	6
north-easterlies	0.95	24.13	0.02	0.46	0.59	0.50	3
north north-easterlies	0.13	3.35	0.13	3.35	0.13	0	1
north north-westerlies	1.08	27.46	0.01	0.20	0.32	0.33	19
north-westerlies	2.11	53.71	0.00	0.05	0.26	0.33	235
southerlies	0.81	20.50	0.00	0.01	0.18	0.23	34
south-easterlies	0.82	20.75	0.00	0.10	0.19	0.28	12
south south-easterlies	0.11	2.74	0.01	0.23	0.04	0.04	5
south south-westerlies	1.25	31.75	0.01	0.30	0.32	0.44	7
south-westerlies	0.68	17.25	0.00	0.08	0.15	0.17	22
westerlies	0.97	24.54	0.03	0.76	0.26	0.33	7
west north-westerlies	1.29	32.82	0.01	0.30	0.25	0.34	22
west south-westerlies	0.17	4.39	0.17	4.39	0.17	0	1

The final test performed on the Royal Observatory random five year data set was to determine if there were different dominant wind directions for pre-determined ranges of daily rainfall amount. North-westerly winds were found for all categories, and so these results showed that no distinct rainfall range (in inches) could be identified, relating to a unique category wind direction (Table 5.10). Hence no clear relationship between rainfall volumes and dominant wind direction was

observed for this data set. The dominant wind direction could thus not be used as a proxy for rainfall amount or a category amount of daily rainfall. While Hannaford et al. (2015) found correlations between rainfall and wind, this relied on a dataset with quantified rainfall amounts and wind speeds.

Table 5.10: Wind direction per a threshold of rainfall

Range(inches)	Dominant Wind Direction	Count of the Dominant Wind Direction	Count of all other wind directions
0.001-0.02	north-westerlies	24	8
0.021-0.035	north-westerlies	20	8
0.036-0.055	north-westerlies	23	9
0.056-0.099	north-westerlies	24	7
0.1-0.139	north-westerlies	24	10
0.14-0.199	north-westerlies	23	8
0.2-0.299	north-westerlies	19	11
0.3-0.439	north-westerlies	33	5
0.44-0.799	north-westerlies	26	9
0.8-end	north-westerlies	15	9

Through the several tests performed on the five year Royal Observatory data, it has been demonstrated that neither rainfall description nor wind direction can be used a proxy for rainfall amount. Similarly, no relationship could be found between wind direction and rainfall volumes nor could a relationship be determined between the rainfall categories and rainfall volume. It was valuable to test these relationships as if there were a significant link between these variables there inference of rainfall amount would greatly improve the value of the historical data. Therefore the Royal Observatory data does not provide useful additional information in interpreting the historical record therefore no further Royal Observatory data will be used in this study. It was however important to test all of these variables, as the potential to better quantify the weather records from 1662-1665 would have vastly increased the applicability of this data to climate models.

5.9 Inter-relationships between climate variables

This section will discuss the key inter-relationships in the climate record that refer to specific events and anomalies. This has in no way been imposed on the data but instead presented itself during the data extraction processes of this study. There have been references to ‘dirty rain’, which will be explored further. It was also noted that in some instances rainfall would occur simultaneously to south-easterly winds. Through investigation of the Royal Observatory data, it was identified that these are in fact specific events that are related to certain weather conditions and are termed ‘Black south Easter’ (see Figure 5.15 for example). Relative to rainfall, infrequent events such as hail and snow will be explored in greater detail in this section. Lastly, individual years or periods of time during the 13 year historical period will be addressed and tentatively linked back to other weather phenomena such as El Niño Southern Oscillation.

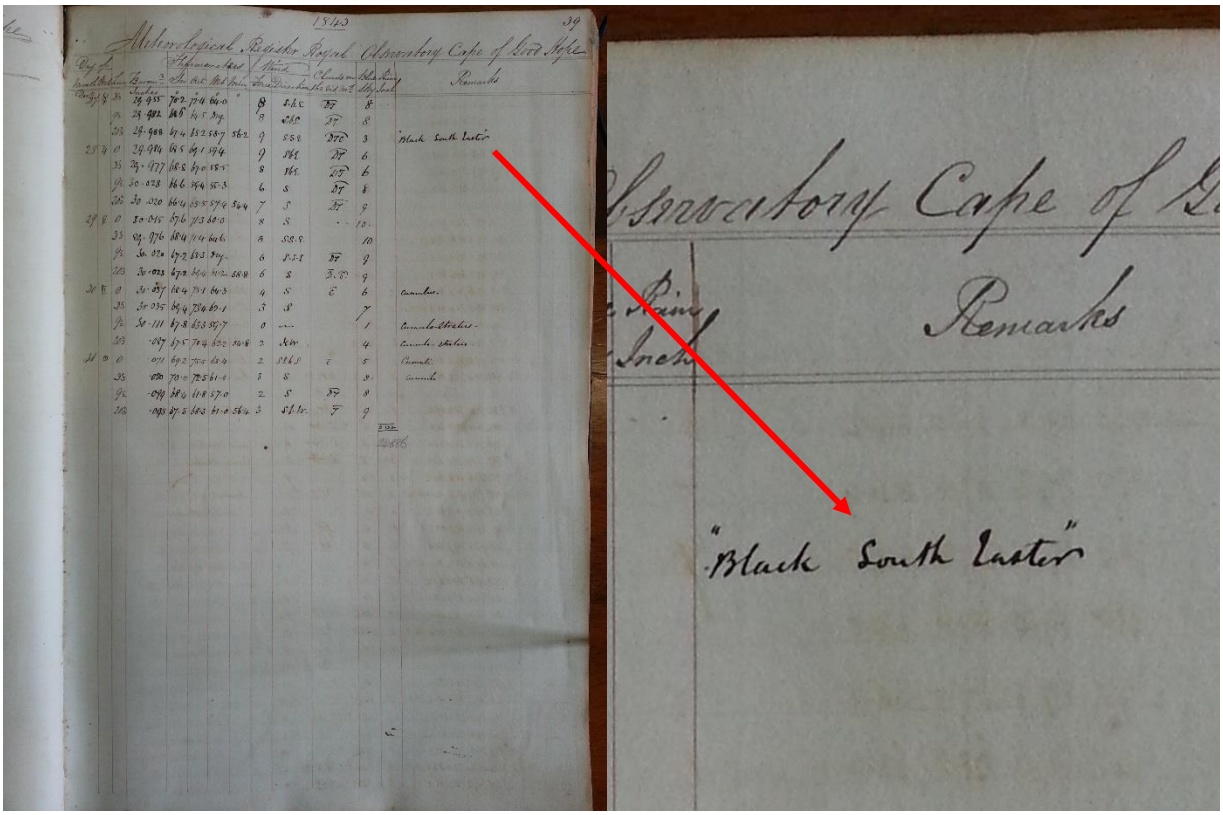


Figure 5.15: Example of mention of ‘Black south Easter’ winds in the Royal Observatory records (27 December 1843).

5.9.1 References to 'dirty rain'

The term 'dirty rain' appears throughout the diaries. The analysis of Richard Davis' weather diaries provides a definition for 'dirty weather' as: "comments scattered throughout the diary [that] describe disturbed conditions with strong winds and driving rainfall" (Lorrey and Chappell, 2015, p. 3800). Similarly, mentions to 'dirty rain' from the Jan van Riebeeck diaries can be described as those occasions when the rain was particularly heavy and accompanied by strong winds from the west with storm-like conditions. Aside from the work of Lorrey and Chappell (2015), not much else is commonly known about the terms 'dirty weather' or 'dirty rain'. It is important to gain an understanding of these conditions as it may refer to a particular set of environmental conditions that explorers of the past deemed 'dirty'. Furthermore, it is not clear whether such events still occur today but under a different name.

As for many of the other tests, but unlike the Black south-easterly, the wind direction is not unique for these events and includes the typically north-westerly winds observed predominantly throughout the record and the broader westerly group (Table 5.11). General comments relating to these events extracted from the documentary evidence include the words 'boisterous', 'violent', 'stormy', 'heavy rains' and are juxtaposed against prior 'calm' conditions (Table 5.11). A contemporary understanding of a 'dirty storm' would involve large amounts of dust and debris but this does not seem to be the case. Rather these seem to be very large and severe storms.

Table 5.11: Extracts from the diaries: References to 'dirty rain'

Year	Wind	Rain	General Comments
21-22/05/1652			Dirty, rainy and windy weather from the West, p. 41
23/05/1652			Dirty, violent, stormy weather with intermittent hard showers of hail from the south-westerlies, p. 41
11/06/1652	Fairly strong north-westerlies wind	Dirty, wet, drizzly weather and heavy downpours	Suffering severe cold and discomfort which is contributing to the daily spreading sickness. No more progress in the work can be expected due to the incessant rain and the weakness of the men, pp. 44-45
28/08/1652		Drizzly, dirty, rainy	cold weather…, p. 57
29/08/1652	Veered N.	heavy rain and hail showers	"If we had not dug a ditch and made a little dike round the new garden, it would once more have been submerged and all the crops spoilt; these have now been saved by this measure, p. 57
30/08/1652	Strong W. Wind	Still the same wet and dirty weather, p. 57	

13/10/1652	windy	Dirty, rainy	Dirty, rainy and windy weather from the W., p. 73
24/05/1653	Wind still W.	wet and dirty, rainy weather	…the ground will be sufficiently softened by the rain for sods to be cut; for some time it has been too dry to raise the said bastions any further and make them strong and permanent…, pp. 156-157
08/06/1653	S.W. wind	Wet, dirty, rainy weather, p. 159	
6-7/07/1653	westerly wind	dirty, drizzly, rainy	Cold, dirty, drizzly, rainy weather and westerly wind, p. 162
24/05/1654	W. breeze	dirty, rainy weather	Dirty, rainy weather and W. breeze, p. 237
27/06/1654	W. wind	Dirty, wet, rainy weather, p. 244	
28/06/1654			*Idem*, p. 244
29/06/1654			Wet weather and wind as before, p. 244
30/06/1654		Wet and dirty, rainy weather continuing, p. 244-245	
01/07/1654	strong westerly windstorms,	Very wet, dirty, rainy weather	Very wet, dirty, rainy weather and strong westerly windstorms, which blew so violently last night, accompanied by such heavy downpours, that all the gardens were inundated…, p. 245
02/07/1654	wind from the N.W.	Wet, rainy weather as before, p. 245	
03/07/1654	wind from the N.W.	Wet, rainy, stormy weather continuing, p. 245	
24/07/1654	wind continuing	Wet, boisterous, dirty weather	preventing work as before, p. 252
25/07/1654			*Idem*, p. 252
26/07/1654		…extraordinarily heavy rain continuing almost throughout the night. We have never before experienced the like of it here.	Weather and wind as above, p. 252
28/07/1654		Wet, dirty, stormy weather	Wet, dirty, stormy weather and wind, preventing work as before, p. 252
29/07/1654			*Idem*, p. 252
31/07/1654	wind W.	Very wet and dirty, rainy weather, p. 253	
16/03/1655		dirty, rainy	calm weather, p. 301
21/04/1655	S.S.E. breezes	dirty, rainy weather, p. 309	
03/05/1655		weather still wet, dirty and boisterous as before	wind unchanged, p. 310
22/04/1656	N.W. wind	Dirty, rainy weather, p. 31	
08/05/1656	fairly strong N.W. breeze interfering with daily work	Dirty, rainy weather in the morning, p. 33	
13/05/1656		Dirty, stormy, wet	Idem. Dirty, stormy, wet weather with wind as

		weather	before, pp. 33-34
20/05/1656	strong N.W. wind as before	Wet, dirty, stormy weather in the morning, p. 35	
09/07/1656		Same dirty, rainy weather in the morning, but calm, p. 39	
15/07/1656		Very wet, dirty, boisterous weather, p. 40	
16/07/1656	N.W. wind	Same wet, dirty, rainy weather, p. 41	
31/08/1656	S.E. wind	Dirty rainy weather, p. 58	
06/09/1656	N.W. wind	dirty, rainy weather, p. 59	
05/10/1656		dirty, wet weather, p. 63	In the morning dirty, wet weather and wind as above.
06/10/1656	N.W. wind		Calm weather and overcast sky in the morning… the weather became dirty and rainy, p. 64
12/05/1657	fairly strong N.W. wind	Dirty, wet weather, p. 118	
19/05/1657	strong N.W. wind	Dirty, rainy weather, p. 119	
26/05/1657	N.W. wind	Dirty, rainy weather, p. 121	
27/05/1657	wind as before	Dirty, boisterous, wet weather, p. 121	
03/06/1657	W. wind	Dirty, rainy weather, p. 122	
07/06/1657	N.W. wind	In the morning the same dirty, rainy weather, pp. 123-124	
17/06/1657	variable wind	Dirty, rainy weather, p.125	
18/06/1657	strong W. wind	Dirty, wet weather, p. 125	
27/06/1657	wind as above	Stormy, dirty, wet weather, p. 126	
02/07/1657			In the morning dirty, cold, rainy weather with wind as before, though less strong, p. 127.
08/08/1657			In the morning stormy, dirty, wet weather and strong W. wind which had last night caused the Provintie to part from two anchors and to be driven right up to the shore. The ship is busy towing up to the anchorage again, p. 141
14/08/1657		see general comments	In the afternoon heavy rain set in, with the result that the Commander and the skipper with their men returned home thoroughly wet and dirty, p. 142
08/10/1657	N.W. wind	Dirty, rainy weather, p. 156	
19/10/1657	S. wind	wet, dirty weather, pp. 160-162	

02/11/1657	westerly wind	dirty, rainy weather , p. 173	
01/12/1657	N.W. wind	Wet, dirty weather	Wet, dirty weather with N.W. wind as before, p. 190
18/05/1658		Same wet, dirty, rainy weather, p. 272	
18/06/1658		Dirty, rainy, stormy weather from the N.W., p. 285	
17/07/1658	N.W. gale		The same stormy, dirty, cold weather and N.W. gale, p. 314
05/08/1658	N.W. wind	Dirty, wet weather, p. 323	
10/08/1658	N.W. wind		Dirty weather, p. 324
21/05/1662	variable breezes	Dirty, rainy weather, p. 2	
30/05/1662	W. winds	Wet, dirty weather, p. 3	
28/06/1662			Dirty N.W. weather, pp. 8-9
25/06/1663		Dirty boisterous weather, p. 59	
26/07/1663		see general comments	Dirty, wet, windy weather, p. 64
05/07/1664	see general comments		S.E. breeze in the morning, which blew the dirty, misty weather away, p. 114
09/07/1664		Dirty wet weather, p. 115	
22/07/1664	Violent N. Winds	Cold, windy, dirty wet weather, nearly the whole day..., pp. 115-116	
29/07/1664	N.W. Winds	Wet, dirty weather, p. 116	

Whether these were just large storms or additionally associated with debris and dust, it is of interest to determine whether there is any seasonal pattern in the mention of these events in the historical record. Altogether, there were 70 references to ‘dirty rain’ between 1652 and 1664 (Table 5.12). Exploring the number of mentions of such events for each month of each year, it becomes apparent that they were most frequent in July (21) followed by May (16; Table 5.12). These are therefore winter events. Synoptically they therefore are most likely related to the landfall or passing of mid-latitude cyclones which are more prevalent in winter when the ITCZ moves north. Inter-annually, the largest number of mentions of this event was in 1657 (16) followed by 1656 (11; Table 5.12). This is notable as 1655 was the year with the highest number of rain days (Table 5.4), followed by two years of reduced numbers of rain days. This suggests that the subsequent reduction in rain days was compensated by a greater severity in storm events. It is therefore possible that similar amounts of rainfall occurred in 1655, 1656 and 1657.

Table 5.12: Numerical summary of mentions to ‘dirty rain’

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1652					3	1		3		1			8
1653					1	1	2						4
1654					1	4	9						14
1655			1	1	1								3
1656				1	3		3	1	1	2			11
1657					4	5	1	2		2	1	1	16
1658					1	1	1	2					5
1659													0
1660													0
1661													0
1662					2	1							3
1663						1	1						2
1664							4						4
1665													0
Monthly Total	0	0	1	2	16	14	21	8	1	5	1	1	70

5.9.2 Black south-easterlies

As demonstrated in Figure 5.13, the term Black south-easterlies was firmly established by the time the Royal Observatory was recording the weather of Cape Town. However, the historical records provide evidence for the use long before this. There is no categorical definition for this event in the peer-reviewed literature, however, many websites link this event to the contemporary ‘Cape Doctor’ (Hepworth, 2013). Today this is described as a very strong wind from the south east which clears all of the city smog, hence the term ‘the Doctor’ (Hepworth, 2013). Synoptically, the event is associated with cut-off lows along the Cape coast, with a resultant increase in pressure gradient and wind direction induced by the cyclonic circulation which are characteristic of this term (Hepworth, 2013). It is very interesting that there are mentions of it in the historical records as it suggests relatively unchanged synoptic conditions over the last 400 years.

The greatest number of mentions of this event were recorded for 1655 and 1660, with six mentions each (Table 5.13). There were no mentions of this event in 1664 (Table 5.13).

Additionally, 1664 had a relatively average number of rain days (Table 5.4), hence this would appear rather to reflect a decline in the quality of weather commentary provided by Zacharias Wagenaer.

While the specifics from the day-to-day climate are not clear from the documentary records, the relationship between Black south-easterlies and rain days are of interest. The number of days classified as a Black south-easterlies (including days with east south-easterlies, south-easterlies and south south-easterlies due to variability in the classification of wind direction over the historical period) over the historical period were 1155, while the remaining 1711 days had other wind directions and are therefore not of interest to this section (Figure 5.16). Therefore a greater number of days did not have Black south-easterly type conditions, confirming that this is an unusual event. Of the south-easterlies wind days, 40 were concurrent with rainfall and 1117 were not (Figure 5.16). Therefore, south-easterlies winds are more commonly associated with no rainfall. However, when rainfall did occur, 25 were categorised as ‘rain’, 10 as ‘heavy downpour’, three as ‘drizzle’ and two as ‘light shower’ (Figure 5.16). This provides greater information about the specifics of the weather associated with, and potentially driven by the south-easterlies winds.

Table 5.13: Extracts from the diaries: Black south-easterly type conditions

YEAR	WIND	RAIN	GENERAL COMMENTS
28/08/1652		Drizzly, dirty, rainy	
	blow very hard from the S.E.		
	but at night it calmed down	heavy downpours, p. 57	
23/10/1652	S.E. wind	Few light showers	… reasonably fine weather. The sky was a little overcast, however, with a few light showers., p. 77
10/02/1653		Calm, rainy weather, most welcome for our gardens	
	it started blowing quite hard from the S.E.	the rain continuing, p. 142	
07/04/1653	slight S.E. breeze during the day	Rainy	Calm, rainy weather, p. 149
25/07/1653	N.W. wind		Fine, warm, sunny weather, p. 164
26/07/1653		Began to rain very heavily, much water pouring down and this continued unabatedly on 27th…	Weather and wind as before with an overcast sky over the mountains, p. 164
27/07/1653	…with a S.E. wind, p. 164		
19/04/1654	heavy squalls from the S.S.E.	Stormy, rainy weather, p. 231	
20/04/1654			Stormy weather continues, p. 231
21-23/04/1654	violent gusts of wind	heavy showers of rain	Likewise, indeed worse than it has ever been throughout the year, with heavy showers of rain and violent gusts of wind, pp. 231-232
24/04/1654	strong S.S.E. wind continuing, p. 232		
13/12/1654	S.S.E. breeze	began raining, p. 277	
21/04/1655	S.S.E. breezes	dirty, rainy weather, p. 309	
30/05/1655		Rainy	dark, rainy, calm weather, p. 313-314

31/05/1655	started blowing quite strongly from the S.S.E.	rain showers	Weather and wind as before, fairly favourable, pp. 314-315
16/08/1655	strong S.S.E. winds with rain and violent squalls over the Table Mountain	rain, p. 336	
04/09/1655	wind gusty - but not very strong - from the S.S.E.	dark, rainy weather, p. 339	
09/09/1655	wind S.S.E.	the same unsteady, rainy weather, p. 341	
18/01/1656	windy weather from the S.S.E.	Rain-shower of short duration. It was soon blown away by the strong wind, which also dried the ground, p. 5	
31/08/1656	S.E. wind	Dirty rainy weather, p. 58	
24/10/1657	strong S.S.E. wind with gusts	rain showers	In the morning boisterous weather and strong S.S.E. wind with gusts and rain showers, p. 164
06/11/1657	breeze from the S.S.E.	slight rain	fine weather, p. 180
08/04/1658	S.S.E. breeze		Fine morning, p. 256
09/04/1658		Rainy morning	Same breeze as yesterday, p. 256
19/06/1658	strong S.S.E. wind	occasional rain showers	drifting clouds, p. 285
25/07/1658			Overcast, calm weather in the morning, p. 316
	the breeze was S.S.E.	drizzling, p. 316	
12/10/1658	stormy weather with strong S.S.E. wind	driving drizzle, p. 350	
21/10/1659	The strong S.S.E. winds continued…	…some rain in the morning…	…sky overcast…, p. 148
27/01/1660	The same strong winds and dry weather continued this morning, the air being as hot as before, p. 178		
28-31/01/1660	The wind was as fierce as we ever experienced.	...and was accompanied by most unusual downpours…, p. 178	

18/04/1660	Violent, dry S.S.E. winds		
19/04/1660	The same wind...	...with rain…, p. 195	
12-13/10/1660	A S.S.E. wind which sprang up suddenly forced her to drop anchor there, p. 272		
14/10/1660	see general comments	Slight rain	The same wind with overcast sky. Slight rain and stronger winds followed, p. 272
19/11/1660	strong S.S.E. winds	A drizzle	The rain stopped in the afternoon but the winds continued to blow even more strongly, p. 290
8-9/04/1661	wind...S.S.E.	occasional rain	Idem, with occasional rain until noon, when the wind began to blow rather strongly from the S.S.E., p. 372
18/12/1661	stiff S.S.E. winds,…blew up once more	…accompanied by rain	the sky was overcast …, p. 449
16/08/1662	Heavy S.E. wind…	…accompanied by rain…, p. 14	
04/10/1662	Heavy S.E. winds	rains…, p. 20	
27/05/1663	Heavy S.E. winds...which is seldom experienced at this time of year.	rain…, p. 56	
04/12/1663	The S. Easter goes down somewhat...	…so that we had a slight shower in the morning..., p. 84	

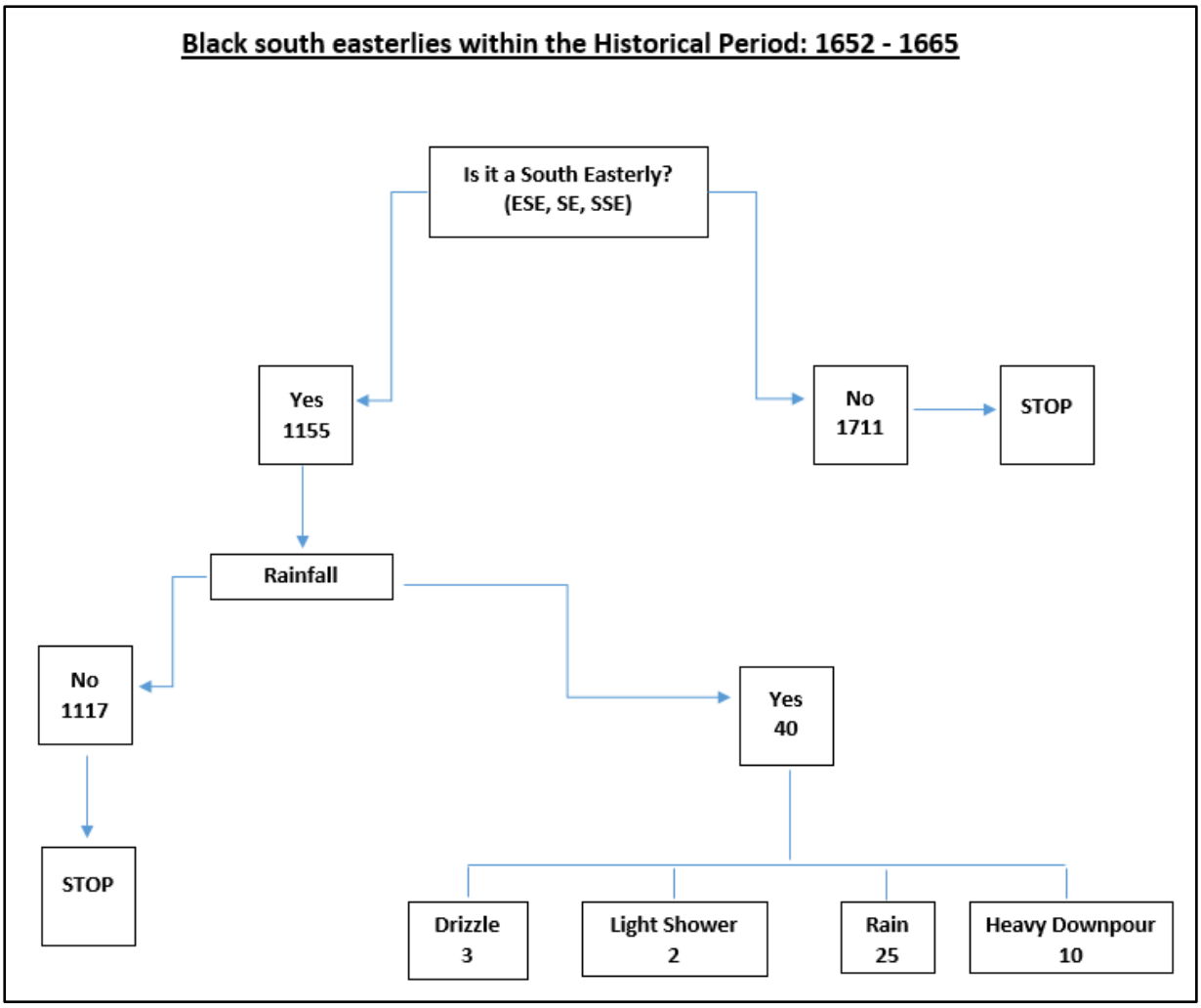


Figure 5.16: Flow diagram indicating weather patterns which coincide with south-easterlies winds. Numbers indicated reflect the number of mentions of each weather condition.

5.10.3 Infrequent climate events

Here, infrequent climate events are defined as those meteorological conditions that were scattered intermittently across the 13 year historical period. These events include hail, snow, frost and ice. These various events are interesting as they assist to develop an understanding of seasonal and inter-annual extreme weather events.

5.10.3.1 Hail

Hail events occurred infrequently throughout the 13 year period. When it did occur within a specific period of time it would occur a few times within a month. It would usually occur during stormy rain events that were accompanied with severe heavy downpours (Table 5.14). It was noted that fiercely strong westerly, north-westerly or south-westerly winds occurred

during hail events (Table 5.14). Mention was also made to thunder in some cases, illustrating that these were almost certainly storm-like events with accompanying hail (Table 5.14). In some instances, damage to crops was noted after hail storms (see the 07/10/1656 in Table 5.14). Once the Cape settlement became more established, episodes of hail became more of a hindrance as it deterred the labourers from completing their work (see the 03/07/1664 in Table 5.14).

Table 5.14: Commentary on hail events throughout the 13 year historical period: 1652-1665

Hail	
Year	**Description**
23/05/1652	Dirty, violent, stormy weather with intermittent hard showers of hail from the south-westerlies, p. 41
25/05/1652	Heavy showers of hail and rain, pp. 41-42
26/05/1652	Weather from previous night continued throughout today, p. 42
11/06/1652	Dirty, wet drizzly weather and heavy downpours… …Heavy showers of hail and rain, pp. 44-45
12/06/1652	Heavy showers of hail and rain, p. 45
22/07/1652	Fairly heavy rain and hail showers… …Stormy weather increased with the heaviest downpour imaginable, p. 51
23/07/1652	Heavy hail and rain…, pp. 51-52
17-18/08/1652	…with very stormy weather and many heavy hail showers, so that there was little progress with the fortification works as the men could not really work in the rain and hail, p. 55
15/07/1653	During the night the wind veered right round to the S.W., with exceptionally hard hail and rain showers, swirling so vehemently over the head of the Lion Mountain that it appeared as if everything would be blown down. It continued with undiminished force on the 16th..., p. 163
04/08/1653	In the afternoon wind shifted to the S.W. From this direction stormy weather developed with hail and rain showers which continued throughout the night so vehemently that it appeared as if everything would be blown down, p. 166
05/08/1653	Still continuing, with intermittent hail showers and sleet from the W.S.W., pp. 166-167
29/03/1654	…quite heavy thunder, lightning, rain and hail showers, p. 220
06/071656	Full moon. In the morning strong N.W. gale with heavy rain and cold hail showers, pp. 38-39
06/09/1656	Towards night the weather became exceptionally stormy, with mainly W.S.W. wind and heavy hail and rain showers, p. 59
07/10/1656	Fine, calm morning. A beginning was made with the reaping of the barley behind the fort, sown on 4 May. It appears that it was sown too early, as many of the ears have been destroyed by the heavy hail and rain which we are still experiencing, p. 64
04/09/1657	…accompanied by fierce showers of rain and hail, with the result that the ships were hard put to it to ride out the storm, p. 149
02/10/1657	Boisterous weather and N.W. wind, accompanied by heavy rain, lightning and thunder, although at its loudest the latter is here about equal to the mildest form in the Fatherland. Since the Company established the settlement here, no earthquake has been experienced, glory be to God. This is very cheering as few places in India are exempt from it, p. 156

	Towards evening hailstones fell. These were on an average the size of the joints of the thumb, while the biggest were the size of pigeon eggs or small tennis-balls, p. 156
16/07/1658	Heavy rain accompanied by hail, p. 313
17/06/1659	Very stormy weather this morning with heavy rain, hail, and a strong N.W. wind. …a very heavy downpour which was so blinding that one could not see 5 roods before one, p. 100.
27/07/1659	In the morning the weather improved slightly, but the wind still N.W., accompanied by hail and showers,, p. 105.
24/08/1660	Showers of rain, and hail, p. 251.
12/09/1660	Windy weather as before, with heavy showers of hail and rain, p. 256.
19/09/1660	There were hailstorms, too, which destroyed all the peas on the farms of the free burghers, p. 257.
11/10/1660	…fierce showers of hail and rain, pp. 271-272.
13/02/1661	Fine, lovely weather in the morning, but later in the day squally weather blew up from the west with hail and showers, p. 332.
19-20/07/1661	Violent, stormy weather with many downpours of rain and hail, p. 404 .
22/07/1661	…there was another most violent storm accompanied by hail and rain, p. 405.
27/08/1661	The weather was better but still rather unsettled with wind from the W. accompanied by rain and hail, p. 413-414.
28/06/1662	[Dassen Island] Return of the freemen's vessels, having encountered last night a heavy N.W. storm with thunder and hail at Dassen Island, p. 8-9.
21/07/1662	…hard rain, unusual thunder and hail (which in this country is seldom loud or striking hard). No damages were suffered, p. 11.
17/07/1663	Last night and during the whole of this day, the weather has been so cold and boisterous that nothing like it has been felt for many years. The result was that a N.W. Gale brought on such an immense quantity of hail and snow that Table Mountain was covered right to the top, p. 63.
01/08/1663	Same weather, with big hailstones and some thunderclaps, continuing the whole day, so that no workman or slaves could do anything..., p. 65.
09/08/1663	rain and hail
03/07/1664	The cold weather growing intense, so that to-day with the rain, also much snow and hail fell, and no one could do any work in the open air either in the veld, gardens or at the buildings. This hinders us and causes much damage..., p. 114.
17/08/1664	A heavy N.W. Storm with rain and big hailstones. At midnight, when the weather appeared to moderate a little, many heavy thunderclaps were heard..., pp. 119-120.

Numerical counts of the number of hail events were tabulated to determine monthly, seasonal and annual trends. The results showed that there were 35 mentions to hail in total over the 13 year period, of which 31 mentions occurred during winter (Table 5.15). The highest number of mentions were noted in mid-winter (July:11 mentions; August: 10 mentions) for the 13 year period (Table 5.15). Upon inspection of contemporary records of hail events, it was noted that four hail events at the University of Cape Town (UCT) occurred in July, one in August and one in October for the period 1995 – 2008 (Harris et al., 2010; Table 5.16). This corroborates well with the historical record for July and August hail events. Annually, 1652

had the most number of mentions to hail events (11) whilst 1655 was the only year with no mentions to hail (Table 5.15).

Table 5.15: Counts of monthly and annual mentions of hail in the historical record

	Hail												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1652					3	3	2	3					11
1653							1	1					2
1654			1										1
1655													0
1656							1		1				2
1657									1	1			2
1658							1						1
1659						1	1						2
1660								2	1	1			4
1661		1					2	1					4
1662							1						1
1663							1	3					4
1664							1						1
Monthly Total	0	1	1	0	3	4	11	10	3	2	0	0	35

Table 5.16: Extract of contemporary snow and hail events from Harris et al (2010)

Type	Location	Date
Snow	N1 highway, Matroosberg	15/7/2000
Snow	N1 highway, Matroosberg	15/7/2000
Snow	Gydo Pass	July 2000
*Snow	Theronsberg Pass	July 1996
*Snow	Waaihoek	July 1996
Hail	UCT	19/7/2000
Hail	UCT	August 2004
Hail	UCT	October 2008
Hail	Pinelands	31/8/08
*Hail	UCT	July 1995
*Hail	UCT	July 1996
*Hail	UCT	July 1996

*1995-6 data from Diamond and Harris (1997); d = deuterium excess

The historical hail events were graphed in order to determine patterns of when the number of mentions were high and low and to link this back to the number of annual rain days. As mentioned previously, 1652 had the highest number of mentions to hail events followed by 1660, 1661 and 1663 (with four mentions each; figure 5.17). Upon inspection of the total number of annual rain days, no significant pattern was noted (Table 5.4). However, the year with no mentions to hail (1655), was also the year with the highest number of annual rain days. Furthermore, it was noted that those years with a relatively higher number of mentions to annual hail events did not have particularly high number of rainfall days. From this, it can be tentatively concluded that the years with lower than normal rain days would have resulted in more extreme precipitation events.

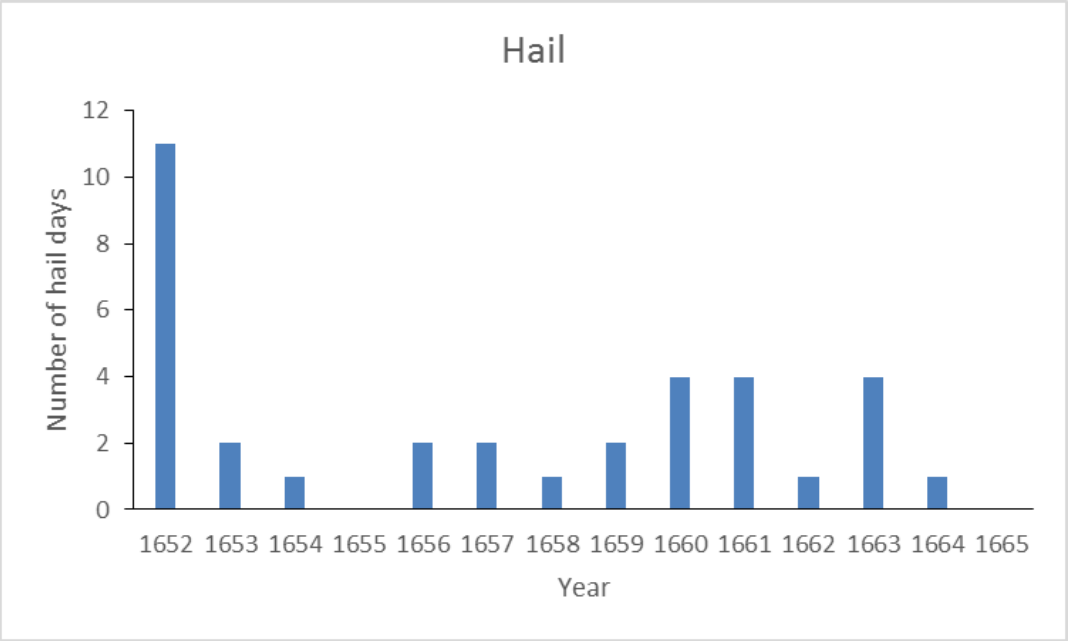


Figure 5.17: Number of hail days for the historical period: 1652-1665

5.10.3.2 Snow

Relative to all other meteorological phenomena, snow, frost and ice were the least mentioned during the 13 years at the Cape of Good Hope. References to 'ice' conditions would only be made the morning after a cold night (see the 17/07/1652 from Table 5.17). From this, the severity of the cold could be deduced relative to winter nights in other years with no mention to ice or frost-like condition during the next morning. Similarly, descriptions of 'ice' or 'frost' would be specific to water bodies (see 28/07/1658 from Table 5.17). This would be another example of rich descriptions that would allow the reader to determine the severity of

the cold. In several of the snow incidents, hail would accompany these events (see 03/07/1664 from Table 5.17).

Interestingly, the nine mentions to snow, frost and or ice are only referred to in the wet period (winter months; Figure 5.18). Within the historical study period they appear to occur in two consecutive year sets, that is 1652 and 1653, five years later in 1658 and 1659, and then four years later in 1663 and 1664 (Figure 5.18). The mentions are specifically noted in only July and August, which corroborates well with the contemporary records, as all snow events listed occurred only in July for 1996 and 2000 (Table 5.16; Harris et al., 2010).

Table 5.17: Commentary on snow events throughout the 13 year historical period: 1652-1665

Snow	
Year	**Description**
17/07/1652	Strong surf on the beach. It was so cold during the night that ice had formed, p. 50.
28-30/07/1652	Much snow has melted…, pp. 52-53
07/07/1654	Fine, sunny weather; calm. Quite frosty last night as well as the night before, p. 246.
28/07/1658	Lovely, dry weather in the morning but so cold that in some marshes and pools there was ice the thickness of half a finger, p. 321.
13/08/1659	In the morning lovely, calm and sunny weather, but very cold, since there was a sharp frost last night and ice had formed in some of the puddles, p. 117-119.
17/07/1663	Last night and during the whole of this day, the weather has been so cold and boisterous that nothing like it has been felt for many years. The result was that a N.W. Gale brought on such an immense quantity of hail and snow that Table Mountain was covered right to the top, p. 63.
25/07/1663	...On the way they had to leave behind 1 pack ox and 14 sheep, which perished on the high, steep, stony and snow covered (besneude) mountains, and in the deep, rapidly running rivers. During the journey they had not want of cold, snow, hail or rain, but thank God! All returned in good health. Sousoa's kraal is about 4 (Dutch) miles distant from the sea shore... Their camp is on and behind the mountains behind the high False Cape range, now mostly covered with snow, p. 64.
20/08/1663	Calm and very cold during the night, and when we got up in the morning we saw that the Table and Tiger Mountains were white, and thickly covered with snow. This had never been witnessed during the 12 years that the Company has been in possession here, p. 68.
03/07/1664	The cold weather growing intense, so that to-day with the rain, also much snow and hail fell, and no one could do any work in the open air either in the veld, gardens or at the buildings. This hinders us and causes much damage..., p. 114

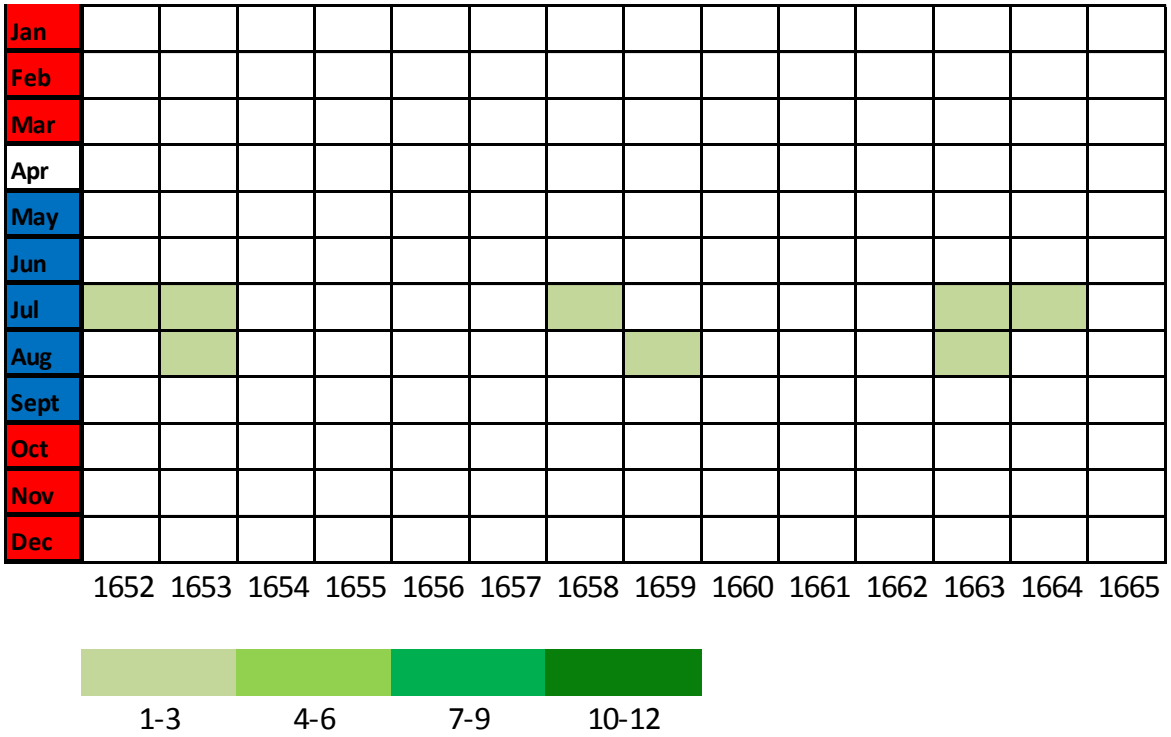


Figure 5.18: Snow, frost and ice grid for the historical period: 1652-1665

5.10.3.3 The first year at the Cape: 1652 – Biases or El Niño?

The most outstanding year noted was 1652 for the relatively high number of hail events compared to all other years. Upon further inspection, it was found that the number of rain days for 1652 (58) were very high relative to other years (Table 5.4). It was the fourth highest number of rain days for the 13 year period. Notably, May and August in 1652 were particularly high with 10 and 11 rain days respectively (Table 5.4). This was the second highest recorded for May (1660 recorded 15) and the highest for August (the second highest was 9 rain days for August 1660; Table 5.4). When dividing 1652 into the wet and dry period, it was found that the number of rain days for both seasons were above the 13 year averages for the historical period (Figure 5.2). Further exploration of the wet period found that 1652 had the second highest number of rain days between May and October. However, it was identified that the rainfall onset occurred in May which is rare as only one other year had this and all other years had their onset earlier in either March or April. The termination month occurred in November which was quite 'normal', however this would mean that in 1652, the rainy season had shifted to more than a month later. It is deduced that rainfall occurring on days closer together relative to other years when it was more spread out. Regarding rainfall, this year had a relatively high number of mentions to 'dirty rain' (8; Table 5.11).

Through the considerable high number of rain days, wind direction and strength was explored for 1652 to determine potential relationships. It was found that the westerly wind group, which included south-westerly, westerly, and north-westerly, dominated during the year (Figure 5.12). This trend was confirmed in Table 5.7 for 1652 as westerly type winds dominated from May through to November. South-easterly winds dominated only for April and December, and from January to March no data was available as the settlers were still travelling to Cape of Good Hope (Table 5.7). However, even with the lack of data taken into account it was found that in other years from the historical period, the south-easterlies winds would dominate between October and December, but here it is noted that the south-easterlies winds were only dominating in December (Table 5.7).

This trend of dominant westerlies was confirmed with the Black south-easterlies as only two mentions were made to this phenomena in 1652, which was low relative to the other years from the historical period (Table 5.13). Three counts of hail were noted for May, June and August. This was a notably high count for one year as August 1663 was the only other time that three mentions to hail was recorded (Table 5.15). Additionally, of the nine mentions to snow, frost or ice over the 13 year historical period, two occurred in 1652 (Table 5.17).

From the extraction of 1652 from the different results presented in this chapter, it was deduced that this year appeared to be relatively severe as it was the settlers first year at the Cape and so events may have been spoken about in excess, relative to the years that followed (a clear example being that of hail; Table 5.15). These limitations are commonly mentioned in the literature, with explorers demonstrate an element of subjectivity in their descriptions of weather conditions, due to other stresses (such as not having regular food supplies and medical treatment) and not being familiar with the new weather conditions. Hence, it was assumed these factors contributed to 1652 appearing as an anomalous year. However, upon the review of pertinent literature (Gergis and Fowler 2009; Nash and Adamson, 2014), it was noted that in fact 1652 was deemed an El Niño year that occurred over a three year period starting in 1650. Based on the proxies that this year was tested against, 1652 resulted in a weak El Niño year (Gergis and Fowler, 2009). Similarly, 1659-1661 were also classified as El Niño years and 1654, 1658 and 1663 were categorised as La Niña years. These events shall be further explored in the Chapter 7, the discussion section of this dissertation.

5.11 Key Findings

In this chapter, weather data extracted from diaries, spanning 4745 days over a 13 year period from 1652-1665, were explored. The historical weather variables included rain days, wind strength and wind direction and mentions to extreme weather phenomena. Notably, the richness of descriptions dwindled towards the end of the period which coincided with the end of Jan van Riebeeck's term and the beginning of Zacharias Wagenaer's term as governor. This is thought to be due to decreasing interest in weather and environmental factors as the physical settlement became more established and an increasing interest in social-political issues.

There was a large emphasis placed on the quantification of rain days in this study, as the exact rainfall amounts were not known, and therefore this was the most acceptable method. February recorded the least number of rain days with several years having no mention to rainfall in this month, and the month of May recorded the highest number of total rain days over the 13 year period. For the historical period, it was found that there was much more inter-annual rainfall variability in the wet season than dry season. The average number of rain days for the wet period and separately for the dry period were established using the 13 year historical data set. The periods 1654-1655 and 1660-1661 had wet seasons that were above the 13 year wet period average coinciding with dry seasons that were below the 13 year dry period average. This corroborates well with Barrable et al. (1998), namely that when wet seasons are relatively wetter then dry seasons are drier than usual.

Attempts were made to compare these results against those of the contemporary period using data from the South African Weather Services. Relationships between number of rain days and rainfall amounts proved to be statistically insignificant and no strong results emerged from this. Further attempts were then made to corroborate the historical data with the weather records from the Royal Observatory for the 1800s, however, a similarly poor result emerged from this and was thus not further tested. Through the several tests performed on the five year Royal Observatory data, it has been demonstrated that neither rainfall description nor wind direction can be used as a proxy for rainfall amount. Similarly, no relationship could be found between wind direction and rainfall volumes nor could a relationship be determined between the rainfall categories and rainfall volume. However, it was valuable to test these

relationships as the inclusion of the rainfall amount variable would have greatly improved the value of the historical data analysis and subsequent findings.

Rainfall onset and termination showed that there were predominately March/April onsets that would cease in October during the historical period. Synoptically, all mentions to flooding and/ or excessive rains were made during the wet period (May – September). The year 1656 had the most number of mentions to drought or dry weather. Additionally, the dominant wind directions were north-westerlies and westerlies which were commonly experienced during the wet seasons, and south-easterlies and south south-easterlies which frequented the dry seasons.

The results showed that 'dirty rain' events were associated with winter and the landfall or passing of mid-latitude cyclones which are more prevalent in winter when the ITCZ moves north. Of interest were the occurrence of black south easterlies in 40 out of a total mention of 1157 south easterly winds. Of these 40, a total of 35 were associated with either 'rain' or 'heavy downpour' rain type events. Hail events were usually accompanied by severe heavy downpours. Seasonally, hail and snow events for the historical period corroborated well with the contemporary period. Lastly, 1652 was assessed in further detail in order to decipher whether it was subjected to 'first-year-settlement' bias or was in fact due to an El Niño year as described by Gergis and Fowler (2009). This, together with potential La Niña events, is discussed further in Chapter 7.

Chapter 6: Social and Environmental Results



ARQUEBUSIER

After taking aim the soldier placed his heavy arquebus on the forked rest. The burning match was then applied to the powder. Towards the beginning of the seventeenth century the arquebus was considerably improved and the matchlock could be applied more swiftly and surely.
Plate and Collection of Prints, Amsterdam

6.1 Introduction

There is value in examining the social-environmental commentary from the southwestern Cape during the 17th C for various reasons. Firstly, the Dutch were the first long-term settlers to arrive at the Cape and their documentation of the environmental conditions would have been the earliest in existence for this region. This documentation serves as a source to understand past weather when instrumental records were lacking. Secondly, their responses to harsh weather conditions would have been a first recorded for this region, and would have also been the foundation for others to apply the same or similar coping (and longer-term adaptive) strategies in years to come. Thereafter, potential patterns and trends between the historical and contemporary period are discussed. The results are also discussed within seasonal and annual periods.

6.2. Settlers' understanding of weather conditions

6.2.1 Understanding of the difference between a 'drought' and the 'normal' dry season

Jan van Riebeeck was able to immediately identify that they had arrived in the dry season, which indicated his understanding of climate/ weather conditions. He was able to identify streams and rivulets that had dried up, realising that these flowed during the rainy seasons. During the first month of arrival, Jan van Riebeeck explored the Table Bay region and discovered contrasts in soil types. He found dry and stony slopes on the leeward side of the Lion Mountain and found fertile soil in the Table Valley. He was able to determine that the Table Valley soil would be suitable for cultivation in the wet season, as he identified dried cattle tracks in the ground and several dried up rivulets. Through reading the diaries and developing an understanding of how Jan van Riebeeck wrote, it became evident that the term 'drought' was used interchangeably with the word 'dry', demonstrating that they did not clearly differentiate between these two terms. The severity of the drought or dry season can only be assessed when the events are comprehensively described by Jan van Riebeeck or Zacharias Wagenaer as this would give a clear indication of a potential drought that occurred.

> It appears to be the dry season at present. The ground is cracked everywhere on account of the drought as well as many side streams and rivulets are found to be quite dry. The fortification site was selected next to the principal Fresh River (8 April 1652, p. 19).

> …Crossing the Lion Mountain on the seaward side of the head found the slopes on the other side dry and stony. Down into the Table Valley, once again found the finest clay soil in the world, watered by several rivulets during the rainy season. The rivulets are quite dry and now because of the dry season the earth is rather hard but due to the cattle tracks in the ground, it should be suitable for cultivation in the wet season (27 April 1652, p. 35).

6.2.2 Evidence of drought conditions from the soil/plant life

Given the predominantly semi-arid climate, drought (or long dry seasons) in southern Africa exacerbates environmental, social and economic conditions. Severe drought dries up water resources, and not infrequently destroys crops and pasture lands for cattle. During contemporary times, the effects of drought have left poor communities without potable water, resulting in the culling of several hundred livestock, and severely impacting crop yields. Despite all the technologies available today (e.g. downscaled climate forecasts), the phenomena of drought still has the ability to cripple nations, in part due to a lack of adequate adaptive and preparatory mechanisms. It is thus interesting and important to study past drought conditions and their impacts on society in order to understand how early inhabitants coped under such scenarios, but with much less technology available to them.

Jan van Riebeeck shows how he would have to adapt the dry soil in order to prepare it for planting before the rainy season:

> Slightly better weather. The loose soil will have to be made firm with sods for the rainy season. Due to the dryness of the land, it is still too hard to cut them (13 April 1652, p. 31).

This is odd for July, which is the middle of the rainy season; there had been no rain for a week and the ground is drying up:

> 7-8 days of dry weather have again made the ground so hard that picks and mattocks can hardly penetrate the surface (8 July 1652, p. 49).

The following quote indicates the severity of the dry season at its peak in December as the strong south-easterly winds ruin the young crops:

> On visiting the gardens to-day, we found that as a result of the strong winds which have blown with extreme severity during the past 5 or 6 days, our young green peas (which were blossoming beautifully and promised to be ripe by the arrival of the return fleet) had been blown to shreds…On account of the drought it seems as if we shall not be able to sow again before February or March, and the return ships from India will find all our potherbs run to seed - except carrots, turnips, radish and beetroot (30 December 1652, p. 121-122).

The dry season beginning in October 1654 made the settlers realise that due to the severity of the dry season in the Cape, certain types of plants would not come to harvest due to the harsh winds and dryness:

> …In our opinion, this was mainly due to the dry, sandy soil and the incipient drought. We are therefore gradually discovering that neither grain nor rice (which does not even come up) can be grown here, but there are plenty of cabbages, beetroot, carrot, turnips and all other potherbs and garden fruits which grow under and just above the ground (2 October 1654, p. 262).

> …and exceptionally dry, as a result of which many crops, particularly watermelons and other melons, are getting damaged and spoilt in their thousands, the foliage being blown to bits and shrivelling up before the plants have reached full maturity. This is a pity, as there was such an abundance that would have ripened and would have come in useful for the next return fleet (12 – 13 February 1655, p. 293-294).

Similarly, the settlers showed an awareness of the impacts of the wind on the crops, specifically the damage brought on by the south-easterlies:

> …dry, cold, strong S.S.E. winds were still blowing, which was detrimental to the crops (8 October 1658, p.349).

> Heavy S.E. the whole day now blowing eight days in succession, so that the ground everywhere cracks in consequence of the drought (14 January 1663, pp. 33-34).

At the beginning of the 1664 dry season, it is found that the settlers are still attempting to grow wheat crops, which are not thriving due to the harsh winds and lack of rain during the dry months:

> The freemen... Bitterly complained of the drought which had set in so early this year. The young crops had been burnt in the earth by the hot manure and scorched above it by the powerful heat of the sun. But where the soil was moist, the lands looked fairly well (1 November 1664, pp. 126-127).

> This day the freemen commenced to harvest all the barley saved from drought. No crops of wheat, rye or oats, worth mentioning, expected this summer, as the grain has been burnt up in the ground to such an extent that in some places hardly the quantity sown, and in others a little more will be gathered, which again causes much lamentation and groaning among the agriculturists (1 December 1664, pp. 131-132).

6.2.3 Evidence of unexpected rainfall during dry/drought conditions

In some instances, there was no direct reference to dry/drought conditions but, based on the commentary of unexpected rainfall, it could be inferred that it was dry prior to the rainfall. Even with unexpected rainfall in the dry season, Jan van Riebeeck would pray to God to send down more rain as the earth was so dry. In one instance, there was unanticipated rainfall in the middle of the dry season in 1656:

> A beautiful rain began to fall in the afternoon. It was very good for the lands and gardens as everything had been almost scorched during the recent severe drought. We could get no cabbage to grow, whatever trouble we took with it, so that we fear we shall have only a limited supply available for the next return ships. The caterpillars and worms have also done much damage as everything which was sown or planted here has for some time been repeatedly destroyed by them and scorched by the heat (27 November 1656, p.76).

In September and October 1658, Jan van Riebeeck commented on the rains in late September through to October 1658 (beginning of the dry season), which was very much required as the crops were withering. It would appear that the rains arrived late in 1658 and that not much had fallen:

> To-day excellent rains fell, very serviceable for the grain and other crops, which were beginning to wither in consequence of the long, dry spell (25 September 1658, p. 343).

> It is a pity that the rain did not continue somewhat longer, as the fruit and the grain crops on the land were badly in need of rain. It became dry and it began to blow strongly from the S.S.E (7 October 1658, pp. 348-349).

> In the morning cloudy sky and fairly strong N.W. breeze from the sea without rain which is badly needed, but the Lord God does not seem to give much this year (20 October 1658, pp. 354-355).

In March 1662, towards the end of the dry season that began in the previous year, there was unexpected rainfall:

> At about 3 o' clock this afternoon there were some claps of thunder and it began to rain. This is the first rain we have had for 4 months, so it will be most welcome on our plantations everywhere (29 March 1662, p. 485).

There was also unexpected rain at the beginning of the next dry season in late November and early December 1662:

> Heavy rains nearly the whole day… These rains have been longed for, for some time, in order to refresh the parched earth (26 November 1662, p. 28).

> Soft rain towards evening (thank God), something rare at this time of the year, which is very dry, so that all earth fruits sown or planted perish from drought (3 December 1662, p. 29).

At the beginning of the dry season in mid-October 1663 and towards the end of the dry season in January 1664, there were mentions of rain that would have been unexpected:

> Fine rain early this morning on the parched earth. It was very much longed for (15 October 1663, p. 76).

> A warm summer rain during the night and nearly the whole of this day. It will do the dry earth no harm (13 January 1664, p. 91).

> Fine drizzling rain, which has thoroughly wetted the dry earth (18 January 1664, p. 92).

An hour-long rain was documented towards the end of the dry season in February 1665:

> Rain in the morning about 3 o'clock, lasting an hour, so that the thirsty soil was well drenched and refreshed (27 February 1665, p. 140).

6.2.4 Comparison of inter-annual dry periods

In this section, the basic commentary concerning the dry season is presented in Table 6.1 below. It provides the descriptive words used by Jan van Riebeeck to highlight the various dry seasons. This table contributes as additional support to differentiate between normal dry seasons and longer or more severe dry seasons, together with the various sections presented above.

Table 6.1: General commentary on the dry season, represented inter-annually

Dry season		**Quote**
Beginning	**End**	
Oct-1653	Mar-1654	Strong S.S.E. winds continuing; very dry, more so than last year… (7 November 1653, p. 188).
		Stormy, strong S.S.E. winds still continue with stiff squalls over the Table Mountain; extremely dry (15 March 1654, p. 219).
		Intense heat and dryness (4 April 1654, p. 225).
Oct-1654	Mar-1655	…stiff S.S.E. wind continuing, and extremely dry weather (18 February 1655, p. 295).
		Windy from the S.S.E. winds continuing throughout the day and night; very dry…(20 March 1655, p. 302).
		…extremely hot, dry sunshine… (21 March 1655, p. 302).
Oct-1655	Mar-1656	…rain shower of short duration. It was soon blown away by the strong wind, which also dried the ground (18 January 1656, p. 5).
Oct-1657	Mar-1658	Strong S.S.E. wind and severe drought (20 January 1658, p. 216).
		Heavy S.S.E. wind and drought (26 January 1658, p. 221).
Oct-1658	Mar-1659	Warm, calm, sunny weather in the morning with great heat and drought (25 December 1658, p. 402).
		…the exceptionally hot and dry weather of the previous days continued (10 February 1659, pp. 17-18).
Oct-1659	Mar-1660	Dry weather with the usual S.S.E. winds of summer (14 – 15 January 1660, pp. 175-176).
		Equally strong S.S.E. winds in the morning, bleak and dry (1 November 1661, p. 425).
		Same weather (2 November 1661, p. 425).
Oct-1661	Mar-1662	…the weather changed when strong, dry S.S.E. winds sprang up (13 November 1661, p. 429).
		Dry, sunny weather (14 November 1661, p. 429).
		Dry, windy weather in the morning; wind S.S.E. (4 December 1661, p. 446).

		The same weather (5 December 1661, pp. 446-447).
		The same fine weather (6 – 7 December 1661, p. 447).
		Strong, dry S.S.E. winds (8 December 1661, p. 448).
		The same strong, sharp, dry S.S.E. winds continued (25 December 1661, p. 450).
		The same weather (26 December 1661, p. 450).
		Cool, dry weather (15 April (1662, p. 487).
		Dry weather (25 April 1662, p. 491).
Oct-1663	Mar-1664	Dry easterly breezes (15 May 1664, p. 109).
		Continuation of the dry S.E. winds (19 May 1664, 109).
		Westerly winds and drought (23 May 1664, p. 110).

As mentioned previously, for the southwestern Cape, the dry season begins in October in each year and ends in March of the following year (Tyson, 1986; Keigwin, 1996; Grab and Craparo, 2011). Sometimes it was found that the dry season would extend into April and in some instances to May (Table 6.1). Jan van Riebeeck would also describe the current year in relation to the previous year, which would provide a good indication of the intensity of the heat and dryness, as well as the strength of the winds. (Table 6.1)

6.2.5 Wet/flood conditions affecting the land and crops

It can be noted that the first two initial years at the Dutch settlement did not have flood like conditions relative to 1654. This is inferred from the comments made at the beginning of July 1654. The settlers experienced much adversity as the large volumes of rain were inundating their seedlings in the gardens:

> Very wet, dirty, rainy weather and strong westerly windstorms, which blew so violently last night, accompanied by such heavy downpours, that all the gardens were inundated, as the rivers and the ditches made by us could not hold all the water. We therefore had great trouble and adversity before we could get the land dry again; many young plants have been washed away and spoilt, causing not a little loss (1 July 1654, p. 245).
>
> Wet, rainy weather as before (2 July 1654, p. 245).
>
> Wet, rainy, stormy weather continuing (3 July 1654, p. 245).

Two years later in the early parts of July 1656, similar conditions to that of July 1654 were noted:

> Idem. Stormy weather and wind as before. Such continuous and extremely heavy rain fell that the whole Table Valley looked like an open sea, the lands and gardens being all inundated and much of them washed away (7-8 July 1656, p. 48).

6.3 Damage to the settlement and / or goods

This section discusses environmental and climate stressors that have affected society through damaged settlement infrastructure and/or goods. Infrastructure of the settlement refers to all building activities conducted by the Dutch settlers over the 13 year period, while goods refer to supplies of food and equipment, etc. There were several mentions to settlement infrastructure being damaged throughout the 13 year period, while only two instances are mentioned concerning damage to goods (1652; 1660), and one event when both goods and infrastructure were damaged (1653).



Figure 6.1: Grid showing weather induced damage to settlement and/ or goods

Initially arriving at the Cape, the settlers were understandably not very well protected from the harsh cold and wet conditions. As they arrived at the beginning of winter, it was noted that the winter rains were responsible for the damage of their goods. In this instance, the various dry goods are damaged by rain. The food stores going bad would have severely affected the settlers as they had relatively little other sources of food:

> Bread and other dry goods not well protected from the rain hence becoming wet and bad (6 June 1652, p. 43).

Here, the severity of the winter rains are well depicted as it is noted that the rains did not only ruin the crops but also the settlement infrastructure:

> The downpour was so heavy that at several places the land looked like sea as the rivers flooded. A strong wall of clay and heavy stone (about 2.5 feet thick and 8 ft. high has completely collapsed due to the excessive and heavy infiltration of water (23 July 1652, pp. 51-52).

During the following winter (1653), the severity of the season is again noted over the following two days. Here, the people, cattle and settlement infrastructure are all impacted by heavy rains:

> During the night the wind veered right round to the S.W., with exceptionally hard hail and rain showers, swirling so vehemently over the head of the Lion Mountain that it appeared as if everything would be blown down. It continued with undiminished force on the 16th... (15 July 1653, p. 163).
>
> …retarding our work and completely blowing away and to shreds the tents in which the sheep are kept at night to protect them against cold. The gardener's house at the gardens, outside the fort, still without its roof, was completely blown over. The galiot also had enough to do to ride out the storm (16 July 1653, p. 163).
>
> Fine weather and wind as before. To-day the point Walvis fell in on one side and also the embankments at a few other places, as a result of the excessively heavy rains we have had for some days now (2 August 1654, p. 253).

During the fourth winter at the Cape, Jan van Riebeeck realised that current materials being used to build up the settlement were inappropriate given the winter climate of the Cape. He knew that they would eventually need to use materials that are more durable on the fort in order to withstand these severe winters:

> Idem; exceptionally heavy downpours during the night; yet nowhere did our embankments give way or fall in, although on account of the mighty rain, this was what we had greatly feared (8 June 1655, p. 317).
>
> Idem, as a result of which five roods of the embankment at the hind curtain of the fort caved in and subsided. Apparently this is going to be an annual occurrence, as the immense quantity of water that falls here during such extraordinarily heavy downpours threatens to wash away almost everything that stands upright. In the course of time it will become necessary to build a stone fort... (10 – 12 June 1655, pp. 317-318).
>
> Idem, with exceptionally heavy downpours, as a result of which the back curtain of the fort (a part of which caved in on the 12th instant) has entirely collapsed from the one point to the other. We now intend to rebuild it with laths, interwoven with rushes, two or three feet high. We fully realise that otherwise it would hardly remain firm as the weather is too severe on it, and much rain beats on it, coming with extraordinary violence from the S.W.... (19 June 1655, pp. 318-319).

Early in 1656, the boat, *Schapenjacht*, had suffered damage to its sail due to the heavy stormy winds:

> [With regards to going by boat to Robben Island to Table Bay] Scarcely was the boat out in the bay when the wind increased in force, with such heavy squalls that the foresail was torn to pieces. The wind became more and more contrary and rapidly increased in violence, so that the boat was obliged to return without accomplishing its purpose (3 January 1656, p. 1).

By mention of the length of time it would take to repair the damage, this provides an indication of the relative severity of the damage. Again, this occurred during the winter months and was due to heavy rainfall:

> The embankment of the old works of the fort has also collapsed in three places as a result of the rain, and it will take at least two months to repair the damage. But we shall then raise it with stakes and fencing, interweaving it with grass, as was done last year with the back curtain, which is firmly overgrown and has remained standing (7-8 July 1656, p. 48).

Similar to the storm impact upon the boat, *Schapenjacht*, in 1655, at the beginning of the dry season of 1657, harsh SSE winds blew and caused much damage to the settlement. From the previous mention to more durable building materials, it is noted that the stronger materials are assisting to somewhat improve the situation of coping with harsh weather conditions, but not entirely:

> Violent weather. The strong S.S.E., though not as violent as the wind that rolled like thunder over the Table Mountain on the preceding days…The hospital built from the wood of the old houses which had previously stood inside the fort was also completely blown down, three beams simply snapped, and if a strong stone wall had not been built at the back, it would have gone altogether (26 October 1657, p. 164).

It was only three years later in 1660, that any form of damage to the settlement or goods was again noted. The ships are once again damaged in the bay due to heavy north-westerly winds. The weather is described as violent:

> To-day the wind blew so strongly from the N.W. into the bay that the flute Vogelesangh several times dragged her anchors, and ran foul of the Loenen, smashing her spritsail yard. Afterwards the Loenenalso broke away from her anchorage, and, running foul of the flute Hilversum, smashed her own beakhead and snapped off the Hilversum's bowsprit. What further damage these ships may have suffered it is impossible to tell, since the violent weather prevents any of the ships' boats from coming ashore (23 April 1660, pp. 203-204).

At this point, it seems that damage to the settlement became a yearly occurrence during winter seasons on account of the violent weather. In these instances, it is a combination of both the heavy rains and the age of certain parts of the settlement that is contributing to damage, specifically in August in 1660 and 1663:

> ...work went on apace daily on the rebuilding of the ramparts of the fort, which are old and have collapsed as the result of the heavy rains this season (17-20 August 1660, p. 250).
>
> The wet, foul, stormy weather continues. This caused the southern end of the Walvis bastion also to cave in and collapse completely (25-26 August 1660, pp. 251-253).
>
> The aforesaid heavy rains having continued half through the night, we heard about three o'clock in the morning a dreadful crashing noise, as if a heavy building was falling. ...discovered that the gable of the office... Had completely collapsed with 6 window-frames which were in it, but that no one had been hurt (thank God!).... The accident was caused by continuous rains, which were violently forced against it by the N.W. gales and the mason work, consisting of half-baked bricks and clay, as soft as pap, so that the collapse was inevitable (19 August 1663, pp. 67-68).
>
> We also discovered that the rain had greatly injured our newly begun reservoir, as all the rivulets which rapidly run through this Table Valley into the sea, had overflown their banks during the night, so that the immense volume of water pressing heavily against the new wall, which was not even dry, had not only overthrown about two roods length of it, but also pierced and washed away the wall on the one side of the commenced sluice, which had already been built up on both sides about three feet, with baked bricks, so that the whole has to be broken down and rebuilt. We further observed that during the past night the earthen walls of the fort had tumbled down in three places, so that we shall have our hands full to repair what is not a little thing (20 August 1663, p. 68).

Much damage took place in different forms during 1660, ending in September, with damage to roads because of the rain. The greater the damage to settlement, the more this was indicative of the development and expansion of the settlers at the Cape:

> The weather somewhat calmer. Early this morning the Commander went out with some men with shovels and spades to repair the road at those places where it had been badly damaged by the heavy rains; at the same time he went to survey the lands for the new free farmers (18 September 1660, p. 257).

6.4 Crop Damage

Upon reading the diaries of Jan van Riebeeck, it became apparent that he was a keen agriculturalist. He started the company gardens as well as attempted to grow many different crops and orchards including wheat, barley, almonds and grapes. The gardens mainly comprised of root vegetables and herbs. As much as the produce reaped from these various crops were enjoyed by the settlement population, there were many adverse influences that many a time affected the quality and quantity of the grain, fruits, herbs and vegetables. This section first explains the factors that caused the resultant crop damage which included weather and / or pests (Figure 6.2), focussing specifically on instances where both weather and pests were factors of crop damage. Thereafter, the weather factor is further sub-divided into the following sub-categories:

- heat-drought
- flooding/ severe wet weather
- wind
- combination of weather (Figure 6.3).

It can be noted that the damage to crops from flooding was only indicated in the wet season while wind was a factor for crop damage predominantly in the dry season. Similarly, heat or drought events connected to damaged crops were only mentioned in the dry season.

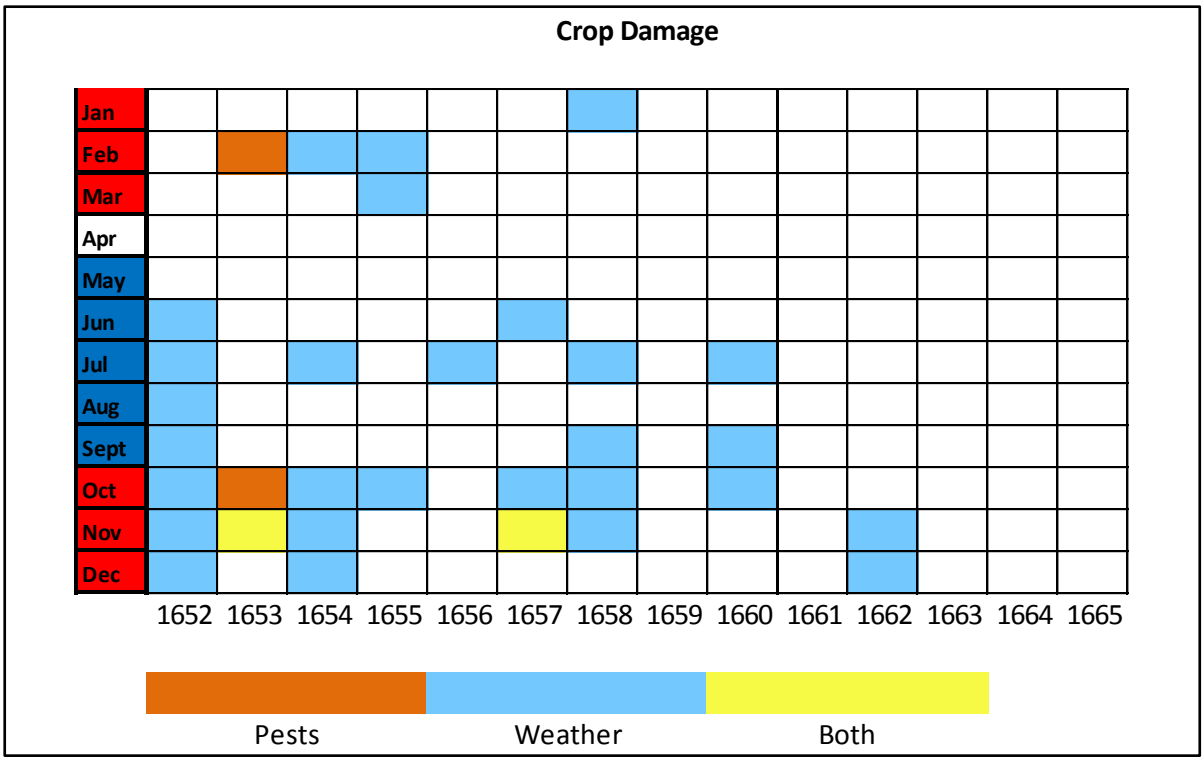


Figure 6.2: Grid showing damage to crops due to the weather and or pests

6.4.1 Mentions to Crop damage due to both weather conditions and pests

During the dry season of 1653, particularly in November, Jan van Riebeeck noted the effect that both dry conditions and worms were having on the crops:

> Weather and wind as before with some rain, most welcome for our gardens, as the fine crops have been burnt and parched considerably by the recent drought and the hot sun. Item also the turnips, carrots and cabbages have been largely destroyed by the surprisingly great number of worms in the gardens (18 November 1653, p. 192).

Similarly, in November 1657, Jan van Riebeeck comments on the drought and worms that are destroying the crops:

> A beautiful rain began to fall in the afternoon. It was very good for the lands and gardens as everything had been almost scorched during the recent severe drought. We could get no cabbage to grow, whatever trouble we took with it, so that we fear we shall have only a limited supply available for the next return ships. The caterpillars and worms have also done much damage as everything which was sown or planted here has for some time been repeatedly destroyed by them and scorched by the heat (27 November 1657, pp. 187-188).

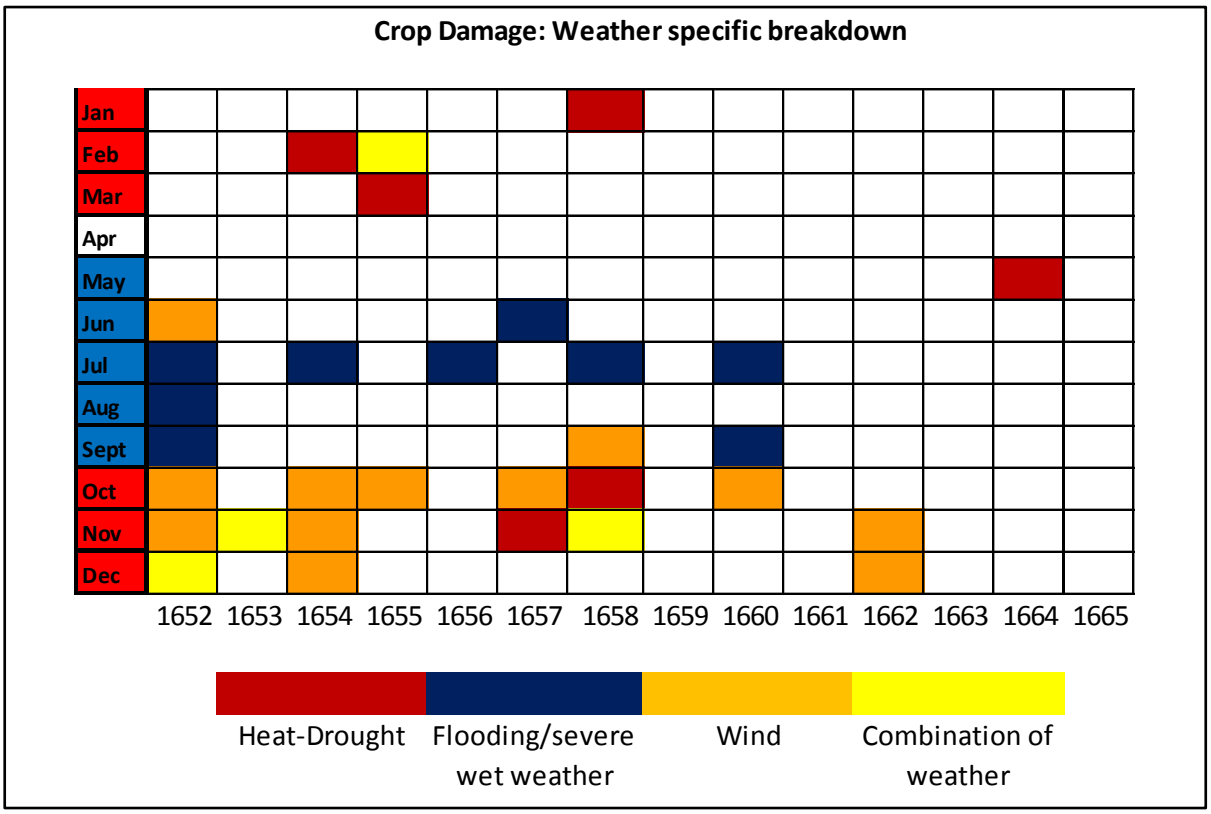


Figure 6.3: Grid showing the breakdown of weather conditions resulting in crop damage

6.4.2 Mentions to Crop damage due to weather conditions: Cold/Wet Season (May – September)

There are four comments discussing the severe weather damaging or destroying crops in four consecutive winter months, i.e. from June to September 1652. The effects from the heavy wind conditions were first reported in mid-June 1652 whilst the first reported flood event causing crop damage occurred in late July 1652. This was during the first year of Dutch settlement at the Cape:

> All young cabbages and many other Dutch fruit and veg that were thriving have been blown to bits and completely ruined (12 June 1652, p. 45).

> [The poor weather from the previous day] found all our hard work done in the new garden being completely flooded and all the crops submerged and spoilt… There had been such a heavy downpour that at several places the land looked like sea as the rivers could not hold all the water. (23 July 1652, pp. 51-52).

> [In the night] This rain beat down and destroyed the remainder of the growth of potherbs and crops (23 July 1652, pp. 51-52).

As the wet season progressed during the first year at the Cape, hail and cold weather were mentioned as being factors deterring crop growth. However, Jan van Riebeeck indicated that they were still in an experimental phase, planting different plants, in small quantities, to determine the seasonal crops:

> …the blossoms of the large beans are all falling off, apparently the result of the hail and the continuing cold weather, so we intend planting more and experimenting throughout the year with a little of all the crops in different months in order ultimately to gain experience of the best season for each (19-20 August 1652, pp. 55-56).

However, even with experimentation, a few years later in 1657, it was noted that a new garden was under water due to the severity of the rains:

> Wet weather and stronger wind than on the preceding days with the result that the rivers overflowed in all directions…The Company's new garden behind the fort, at least 4 morgen in extent, cultivated this season and sown with carrots, is almost completely under water and has been washed away by the overflow of the rivers (28 June 1657, p. 126).

Additionally, in later years at the Cape, almost a decade later, it was noted that heavy rainfall still caused havoc with regards to damaging crops:

> A westerly wind and a heavy downpour such as we have never experienced since the Hon. Company took possession of the Cape. Many private gardens and also gardens of the Company were inundated by the sudden and violent flood of storm water which washed away some of the sown lands (19-21 July 1660, p.245).

> There were hailstorms, too, which destroyed all the peas on the farms of the free burghers. The only peas belonging to the Company were a few sown as an experiment in the Company's vineyard, together with some other crops. (19 September 1660, p. 257).

6.4.3 Mentions to Crop damage due to weather conditions: Warm/Dry Season (October-March)

6.4.3.1 Wind damage:

Throughout the 13 years at the Cape, the wind played havoc with the settlers' crops and gardens. It seemed to occur more specifically from October to December. The commonly mentioned crops throughout the years during this three month time period included peas,

beans, barley, wheat and cabbages. It is assumed that these crops may be the ones most affected by wind:

> Stormy weather continuing and wind as before, blowing so terribly that all our beans, peas and barley, standing beautifully in pod and ear, were blown to pieces. It is feared that hardly anything that grows fairly high will attain full growth, and the S.E. wind is so strong that the plants cannot stand up to it; and we shall thus get our best results from turnips and carrots. In time we shall gain more knowledge about this (31 October 1652, p. 78).

> …when the stormy weather abated considerably and changed to fine, warm sunshine. Many of our crops standing high above the ground, such as peas, beans, barley and wheat, have, much to our regret, been blown to the ground by the strong wind and totally ruined (4 November 1652, p. 79).

> …with a clear, bright sky, but the Table Mountain quite covered in clouds. From it the wind comes falling down as if from a bag, blowing ripe corn from the ears; we shall be able to reap hardly a quarter of it. It is a pity that the corn has been so spoilt by the hard winds, otherwise we should have had a good harvest. It grows so extraordinarily well here that it is a joy to behold; on the other hand it is a pity that, as stated before, it is so much damaged by the wind (28 December 1652, p. 120).

Following from the previous discussion around wind in 1652, the year 1654 was quite similar making mention to wind damage from October to December and affecting cabbage and grain crops. It is interesting to note the resilience of the settlers to continue to attempt to grow grain crops in the Cape even though they did not appear to agree with the weather conditions:

> It caused much damage to the young cabbage plants and other crops, which were blown down completely by the strong winds. If such winds were to blow when the corn ripened, there would hardly be a grain left to gather (19-21 October 1654, p. 267).

> At times these came with such violence over the mountain that everything standing appeared to be in danger of being blown down, and the crops, such as cabbages and grain, suffered quite an amount of damage (18 November 1654, p. 273).

> Most of the wheat, which was almost ripe, was beaten out by the strong wind, with the result that there will hardly be a fourth part left to be garnered. This is a pity, for otherwise it would have been exceptionally fine grain (10 December 1654, 275).

Even in later years (1657; 1660), the settlers were still complaining about the winds destroying their gardens, specifically peas and beans as well as their grain crops. In 1657 specifically, Jan van Riebeeck makes mention to having attempted to shelter the garden crops with protective materials but to no avail:

> Violent weather. The strong S.S.E., though not as violent as the wind that rolled like thunder over the Table Mountain on the preceding days, is destroying much of the young fruit in the garden, especially the Roman and Turkish beans and the green peas, because however well they are protected with branches and mats, many shelters and fences were blown down (26 October 1657, pp. 164-165).

> To-day reaping started of the first crop of barley in the new fields of the Commander's estate, called the Uytwijck. It is exceptionally fine, fat grain but it was badly beaten out last night by the S.S.E. winds (25-26 October 1660, pp. 274-275).

6.4.3.2 Heat and Drought

In February 1654, the drought, heat and dryness are spoken of being 'extreme' on two different occasions. This gives an indication to the possible severity of the drought relative to other times mentioned:

> The garden fruits have also been so scorched by the extreme drought and prolonged heat that we are afraid that the crops will be rather poor (2 February 1654, p. 211).

> Still continuing, with extreme heat and dryness, most injurious to the crops in the gardens which are being badly spoilt and burnt (23 February 1654, p. 216).

In March 1655, in one diary entry, the word 'scorched' is mentioned twice while the word 'hot sunshine' mentioned once. This choice of vocabulary in this instance may also give an indication of the severity of the dry season as it is also mentioned that rain has not fallen in the last 3 months:

> Idem. Particularly hot sunshine and very dry. As a result the cabbages and other vegetables in the gardens were quite scorched, so much so that there is at present hardly a good cabbage or other vegetable left in the beds. Scarcely any rain has fallen for three months, and if it remains so dry much longer there is no doubt that everything will be scorched and destroyed and we shall then have nothing to give to the return fleet except carrots, turnips, radishes, melons, watermelons, cucumbers, etc., which are still fairly plentiful (3-4 March 1655, p. 297).

Here again in January and October 1658, the word 'scorched' is used to describe the state of the garden crops. Specifically in January 1658, a plea to God to send rain is also stated:

> Calm weather with dark, cloudy sky in the morning. We hope that the Lord will be pleased to send some rain to refresh the garden crops, which have been badly scorched and parched by the long spell of heat and the bleak S.S.E. winds (14 January 1658, pp. 214-215).

> Calm, hot weather, scorching much of the young fruit (25 October 1658, p. 361).

6.4.3.3 Combination of both Heat-Drought and Wind

One interesting case referred to the watermelons being destroyed in different ways depending on the weather factor. In the first instance, the actual crop was being damaged due to the severe dryness given the time of year, while in the second instance the crop's foliage was also being destroyed due to the heavy winds:

> …exceptionally dry, as a result of which many crops, particularly watermelons and other melons, are getting damaged and spoilt in their thousands, the foliage being blown to bits and

> shrivelling up before the plants have reached full maturity. This is a pity, as there was such an abundance that would have ripened and would have come in useful for the next return fleet (12-13 February 1655, pp. 293-294).

In some cases, crop damage may have occurred due to different factors at different times in the month. These were highlighted as a 'combination of weather' on the grid (Figure 6.3):

> Fine, calm weather in the morning, but too hot for the fruit and grain (9 November 1658, pp. 372-373).

> In the morning the same strong S.S.E. wind. This is very bad for the grain, which ripens at this time of the year. It is suffering much damage, so that it cannot be left on the land until it is thoroughly rip but will have to be cut sooner (15 November 1658, pp. 377-378).

6.4.4 Mentions to Crop damage due to pests

Relative to crop damage caused by weather extremes, crop damage due solely to pests were commented on three times in 1653. Initially, there were two mentions to pests in February and then later a single entry in October. It is interesting to note that all these occurred during the dry season. The first two incidents in February refer to swarms of locusts attacking the crops:

> …having gone about 2 miles behind Table Mountain, found so many locusts there that the earth and sky were hardly distinguishable - as when the air is filled with flying snowflakes. If we judge from the grass, which they devour so completely that the earth is left quite denuded, then we must fear that all our crops will be ruined if they come near the fort and in the gardens (9 February 1653,pp 141-142). (Editor's note: Swarms of locusts in the vicinity of Cape Town are unknown to-day, p. 142).

> As a result of this calm weather the country around here and our gardens are full of locusts, causing much damage to the cabbage and other crops (15 February 1653, p. 143).

Relative to locusts, mentions to worms were more frequent. Although not mentioned in 1652, Jan van Riebeeck recalls the worms being a problem in the gardens:

> Better weather with cloudy sky. To-day sowed some watermelon and cucumber seed in the new garden. The fine herbs sown this month and last month and which have come up well, as well as the young cabbages, carrots, turnips, radishes and most of the garden fruits, are all being eaten by worms in the ground. Whether this will always occur at this time of the year experience will show; in any case, last year we also had trouble with them, *pro memoria* (24 October 1653, pp. 183-184).

6.5 Wildlife

Upon arriving at the Cape, wildlife was mentioned frequently from 1652-1665 (Figure 6.4). Thereafter, there was a long period with no mentions to wildlife from 1657-1661 and then

sporadic single-event mentions in 1662 and 1664 (Figure 6.4). Whales were the most frequently mentioned type of wildlife spotted in the Table Bay area and all other wildlife were mostly mentioned on single occasions. Besides whales, other aquatic life included seals, while land based animals mentioned included a host of mammals and a few types of birds.

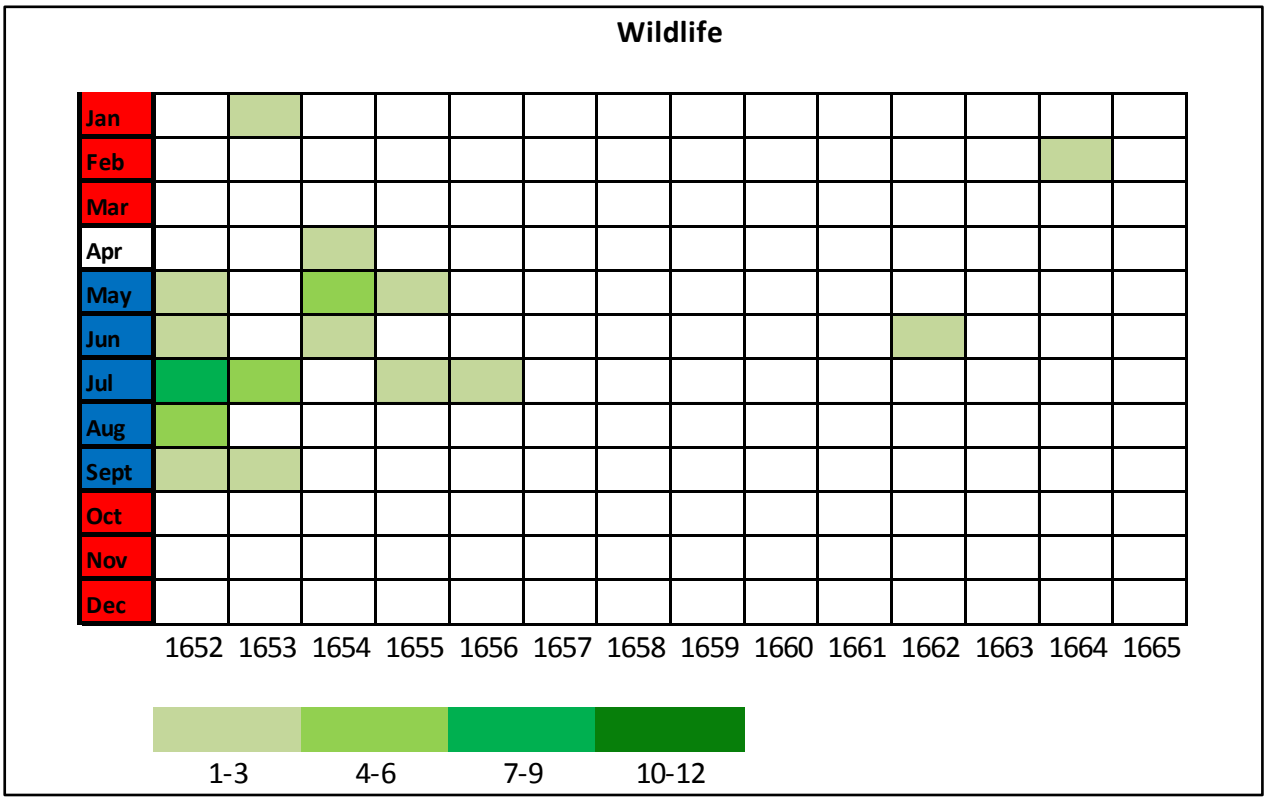


Figure 6.4: Presence of wildlife in the region

The majority mentions of wildlife could be grouped into a few key species that are mentioned frequently (Table 6.2). These animal species are very indicative of the coastal environment and include marine species such as whales. Occasionally, mentions of animals are coupled with climate commentary which demonstrates inter-relationships between climate and the natural environment. It is possible that there was a greater range of wild species than was recorded in the diaries, as some species may have been too common or boring to be worth mentioning.

Table 6.2: Wildlife according to species and corresponding related weather commentary

Wildlife	Date of mention	Related weather commentary
Whales	14 May 1652	…lying in the sun…, p. 39
	27 June 1652	Hazy but good weather, pp. 47-48
	3 July 1652	-

	4 July 1652	-
	9 July 1652	…calm…, p. 49
	11 July 1652	-
	14 – 15 July 1652	-
	31 July 1652	Mostly drizzly weather today with quiet, variable but mostly N.W. winds…, p.53
	1 August 1652	
	3 August 1652	Wind in the bay S.E. as before, with quite pleasant weather…, p. 54
	5 – 7 August 1652	Fine, calm, sunny weather…,p.54
	13 August 1652	-
	21 August 1652	Fine, warm, sunny, calm weather. …, p. 56
	5 – 6 September 1652	Fine, warm weather as before…, p. 57
	9 – 10 September 1652	-
	2 July 1653	Cold, windy weather from the S.W. and occasional light showers. …, p. 161
	9 July 1653	Very fine, lovely, calm, warm, sunny weather. …, p. 162
	13 May 1654	Calm, warm, sunny weather…, p. 236
	15 – 16 May 1654	Having had suitable weather this week, …, p. 236
	22 – 23 May 1654	…the weather has been favourable every day… cold weather…, p. 237
	31 May 1654	Calm, fine, bright, sunny weather…, p. 239
	3 – 5 June 1654	-
	11 July 1655	Calm weather with occasional sunshine, also sometimes rain;…, p. 330
Baboons	24 July 1652	Severe, rainy weather with heavy rain showers and intense cold, …, p. 52
	27 July 1652	the weather was exceptionally fine, with bright warm sunshine, but bitterly cold at night, and quite calm. …, p. 52
Deer	11 August 1652	…the land was so flooded by the rain … necessary to wait for the dry season, …, pp. 54-55
Hart (Deer)	25 August 1652	
Duikers	13 September 1652	no fresh water* …, p. 58
Penguins	13 September 1652	no fresh water* …, p. 58
Birds	14 September 1652	-
Seals	15 September 1652	-
Various game	18 September 1652	-
Civet cat	11 October 1653	Strong S.S.W winds with warm sunshine. …, p. 174
Orang-utan	24 April 1654	In the morning strong S.S.E. wind continuing,…, pp. 231-232
'Tigers'	2 May 1655	Boisterous, rainy weather and wind…, p. 310
Porcupine	31 July 1656	Fine weather with wind…, p. 54
Wild dogs	6 June 1662	
Ostrich	18 February 1664	
Rams	3 April 1654	In the morning the S.S.E. wind still continued…, p. 224
Ewes	4 April 1654	clear, calm, sunny weather with intense heat and dryness. …, p. 224
Rabbits	3 April 1654	In the morning the S.S.E. wind still continued…, p. 224

* These observations were made on Robben Island, all other observations were made in the Table Bay area.

Of interest are instances where the settlers were prevented from either catching wildlife or processing the by-products due to the weather on the particular day. This illustrates the impact of variable weather on settler livelihoods.

> This morning our men, who had been on watch at the Soete River to catch deer, returned home to report that as the land was so flooded by the rain there was no chance of getting anything, but that it was necessary to wait for the dry season (11 August 1652, pp. 54-55).

> In any case, the rainy season now setting in, it is not the right time for catching seals and drying their skins. This can only be done in the dry season, beginning about October (12-13 May 1653, p. 156).

Weather conditions, however, were not the only factor that hindered their ability to catch and process wildlife. The wildlife itself and the tools available to them were mentioned as limitations.

> …Also found everywhere, the finest flat meadows in the world, most suitable for planting and cultivating, full of game, namely harts, hinds, roes, steenbok, eland, shelducks, geese, partridges, pheasants, and all kinds of finches, snipe and small animals, but all so wild that it is almost impossible to catch them. Rock-rabbits and hares were also seen in great abundance higher up in the mountains, but they knew how to hide so deeply in the caverns under the rocks that they were beyond reach (29 July 1653, p.165).

> The bay has also been full of whales all the time; a pity that we have neither the equipment nor the people to catch them, as the weather has been favourable every day and, because of the cold weather, it is now also the best time for it (22-23 May 1654, p. 237).

> The Hottentots brought us two more porcupines, a male and a female; both were examined but again nothing was found. It is a wonderful animal as regards its means of defence, for it uses its long sharp quills so cleverly that it is almost impossible to catch; when chased, it shoots its quills backwards, driving them into the body of the enemy a span deep or more. This was evident in the last lion killed, in whose body many quills were found which had penetrated the skin and had lodged deep in the flesh, and particularly in the case of the porcupine caught yesterday by our men, who saw it shoot its quills backwards, wounding the dog that chased it in its open jaws, and later, when it had already been caught, the dog would have been compelled to let it go again if some of our men had not come to its assistance and smashed the porcupine's head with the butt-end of the musket, though they hardly dared to come near it for fear of having their legs riddled with quills (31 July 1656, p. 54).

In some cases, the weather was particularly favourable for the acquisition of wildlife. This was most likely a combination of good weather encouraging wildlife to remain in the open, and it facilitated easy conditions for catching and transporting wildlife.

> The yacht that returned from Robben Island brought back about 100 duikers, some penguins and about 3000 eggs. It was reported that there was no fresh water available but penguins and black duikers in abundance (13 September 1652, p. 58).

> 6 seals killed and flayed. Contained thick blubber (for train-oil) and fine thick skins (15 September 1652, p. 59).

> To-day a bush manikin, called orangh-outangh in Batavia, was found dead on the mountain. It was as big as a small calf, having distinct hands and feet like a human being, with long arms and hands, very hairy and dark grey colour. Our men ate it, so hungry were they, for the greens do not provide much nourishment (24 April 1654, pp. 231-232).

> This morning an ostrich was shot near the large Salt Pans; the legs were brought home (they were as much as a horse could carry), prepared and tasted like young beef, very nice (18 February 1664, p. 100).

6.6 Wildlife Attacks

There are occasional mentions in the diaries of wildlife attacking humans or livestock or both (Figure 6.5). These attacks do not seem particularly related to the coinciding weather. This may, however, be due to the small number of mentions.

In some cases, wildlife attacks on man were not very severe, as the greatest damage they inflicted was eating the settlers' food. However, in some cases this was more severe as it included attacking and eating livestock, compromising their food supplies in the long-term:

> The carpenter, returning home from the forest in the afternoon, brought a young civet-cat which they had shot at the tent and of which many were seen daily, eating the men's meat and bacon whenever possible (11 October 1653, p. 174).

> During the night the remaining ox, a young calf and a sheep perished in the cold rain owing to the lack of stabling, which cannot yet be provided on account of the want for timber; many cattle are dying daily from cold and exposure, or are dragged away by night under the noses of the guards and devoured by wild animals (21 October 1653, pp. 181-182).

In the most severe cases, wildlife attacked the settlers themselves when trying to defend their livestock. This was particularly a problem due to the poor quality of the fences and walls to exclude the wild animals. In this case, a coping response of building walls that were more effective served multiple purposes in keeping wild animals away from crops and livestock and protecting the humans inside:

> Last night the tigers killed 6 of our Dutch sheep in the enclosure... The animals had made several holes in the two-foot thick wall made of sods and entered without the watchmen being able to prevent them. In the evening the tigers had also been in the hen-house, killing the only 3 geese we had left and biting a certain person severely in the arm when he tried to scare them away. It seems as if the wild animals will again be worrying us often in the rainy season (2 May 1655, p. 310).

> Fine, calm, sunny weather. Began clearing another stretch of land for cultivation, fully 44 Rhineland roods long and 10 wide. Ditches 8 feet wide have already been dug around it and planted with thorn. All the gardens are being planted this way with the said thorn trees which were found wild here and are growing well. When they have become intertwined they will soon be impenetrable even to wild animals, which are at times doing considerable damage to the crops (10 September 1655, p. 341).

In one instance, it was noted that due to the rapid population growth of domestic dogs, they had grown wild and began attacking other animals brought by the Dutch:

> …pigs were scarce, for the dogs left there by the ships having greatly multiplied and grown wild, had destroyed and chased them away, so that within a short time this species of refreshment may fail entirely (6 June 1662, pp. 4-5).

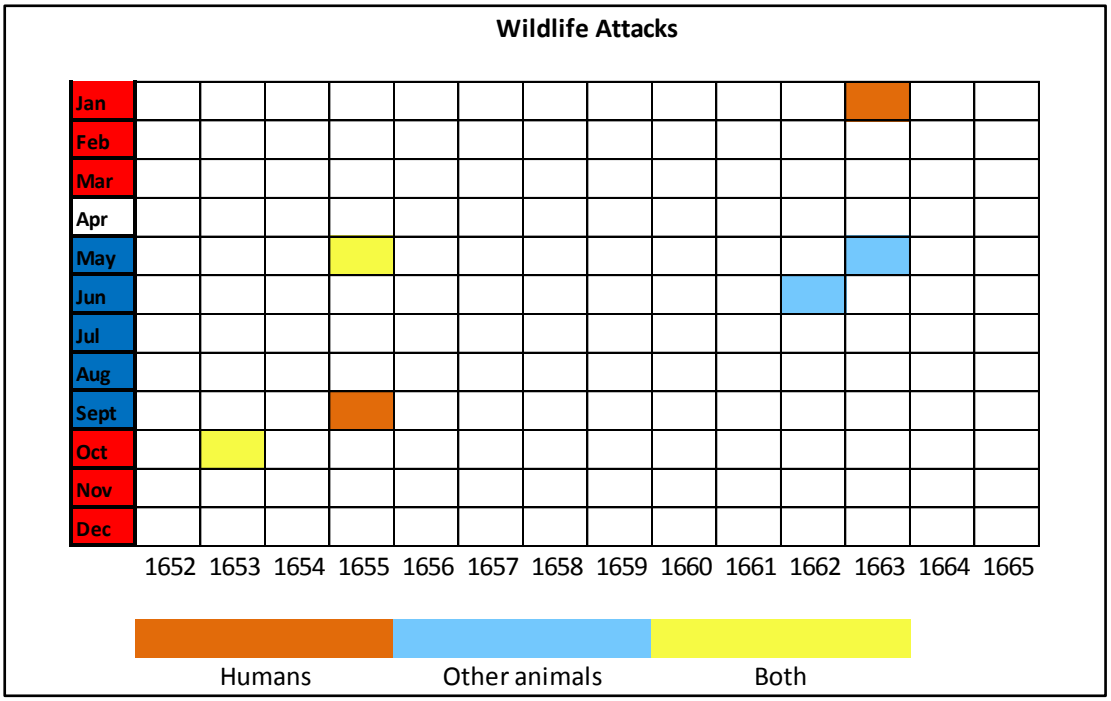


Figure 6.5: Grid representing wildlife attacks on the Dutch settlement and or on other animals

6.7 Fish Abundance

Fish stocks were a major contributor to the food supplies when the settlers first arrived at the Cape. The abundance of fish was frequently commented on in 1652, 1654, and only a few times in 1653 and 1660 (Figure 6.6). Fish abundance was mostly noted in the dry season with a few mentioned in June and August (wet season). It appears that more importance was placed on fish abundance during the first three years at the Cape, as the settlers had not yet had access to cattle as a source of meat. Hence, initially fish abundance was commented on frequently and then tapered off as the Dutch settlers bartered (traded) more and more goods with the dominant native tribes for cattle (meat). Steenbras and Harder fish species were caught in large quantities while eels, sand sharks and herrings were mentioned once each (Table 6.3).

Fish were one of the first things noticed by Jan van Riebeeck when he arrived at the Cape. This is most likely because it gave him confidence that he would have a sustainable supply of food:

> [On Board the ship, on the Table Mountain shore]. Sent soldiers early in the morning to procure greens for refreshments as well as sweep the sea once or twice with seines (nets) for fresh fish. Been at sea 3.5 months without stopping for refreshments and therefore the health of men have been undermined. Shortly after 8am, they returned with a reasonable amount of fish (7 April 1652, pp. 21-25).

Mentions of fish included commentary about the variety, size and quantity caught, as also their taste. It would appear that the settlers fished excessively (Table 6.3), which was at least in part due to the good tasting fish:

> A fishing excursion to the Salt River resulted in 4 bags of beautiful mustard leaves and sorrel and also a catch of about 750 lovely Steenbras including 4 other delicate fish more tasty than any other in the Fatherland could be. one was similar to haddock and quite as good and tasty (10 April 1652, pp. 29-30).

> Fine lovely weather. Went fishing with boats to the Salt River and with 3 sweeps of the net 900-1000 Steenbras were caught as well as some other fish and harders (Mullet or Cape Herring). The Steenbras were on average 1.5 ft. long (14 April 1652, p. 31).

There was a notable absence of mentions of fishing for much of 1653 (Figure 6.6). This appears to be a result of the deterioration of fishing equipment:

> Weather and wind as yesterday. The bay again full of fish, but the seines could not be used, as they are quite broken on account of age, and are being repaired (26 January 1653, p. 140).

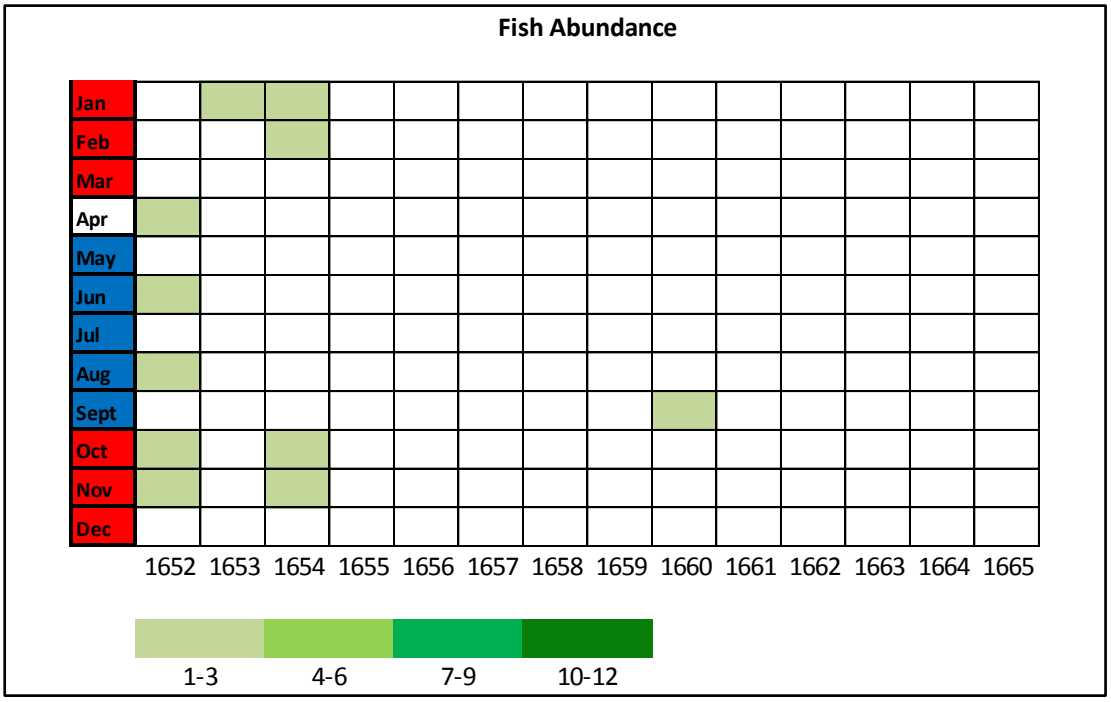


Figure 6.6: Grid showing the abundance of fish populations

Table 6.3: Variety of fish species, quantity caught and corresponding weather conditions

Date	Numbers	Species	Weather conditions
10 April 1652	750	Steenbras	
	4	?	
14 April 1652	900-1000	Steenbras	Fine lovely weather, p. 31
26 June 1652	10 000	?	Fine calm weather, p. 47
22 – 24 August 1652	400	Steenbras	
	2000	Harders	
6 October 1652	2000	Harders	
	200	spotted sand-sharks	
25 October 1652	500	Harders	
29 October 1652	1 600	?	…sky slightly overcast, p. 78
5 November 1652	800	?	
25 January 1653	1 700	Harders	
29 January 1653	1 400 - 1 500	Harders	
15 January 1654	4000 – 5000	Harders	
24 February 1654	half a boat-full	Herrings	
14 October 1654	8,000	Harders	Calm, warm weather and wind, p. 264
14 November 1654	10 000	Harders	
14 September 1660	1	Eel	

6.8 Livestock wellbeing

Throughout intervals in the 13 year period, the extremity of weather could be denoted by the health and well-being of livestock and in a few instances the settlers' domestic animals. The livestock wellbeing grid used death, illness and growing populations as factors to indicate the weather conditions (Figure 6.7). For example, if the weather conditions were conducive for vegetation growth (i.e. the livestock having plenty food supplies), this would be indicative of healthy animals with the likelihood to increase in population size.

6.8.1 Livestock disease and/or death due to extreme weather conditions

This section addresses a very critical aspect of the effects droughts or dry seasons had on livestock, which were an important food source for settlers. It also indicates the years in

which a drought may actually have occurred. For example, in January 1653, it was mentioned that one Dutch pig, a calf and a sheep died. The cause of death was not given in this particular diary entry, only that the pigs may not thrive well in the region:

> One of the Dutch pigs died; they do not seem to thrive here at all. *Idem* one calf and one sheep (2 January 1653, pp. 123-124).

However, on the same day in the evening, a second diary entry was made indicating the dry conditions that the researcher inferred as being indicative of poor weather conditions were not the best for rearing animals:

> …and as a result of the dry wind, the earth is becoming as hard and as difficult to dig up as real rock (2 January 1653, pp. 123-124).

However, in later years, the cause of death of livestock due to particular weather conditions was made clear with the first being noted at the beginning of 1656:

> The severe drought has made the pasture lands so bare that there is almost nothing for the cattle to feed on, with the result that some old cows have become very thin and remain lying on the veld, to weak to rise. We are consequently obliged to slaughter them at once in order to be able to use the meat. The effect of the drought is especially shown by the milch cows; they dry up completely, giving less milk daily. Every year it becomes more apparent that little can be obtained from the milch cows during the dry season, but from June to October they give a fair yield (17 January 1656, p. 5).

> New moon. … The severe drought continues, in consequence of which the grazing is becoming so extremely parched and sparse that the animals are getting little to eat and are therefore becoming very thin (26 January 1656, p. 6).

> …still fine, warm weather, which is not favourable for the stock as it makes the pastures very dry and the cattle very thin (7 February 1656, p. 11).

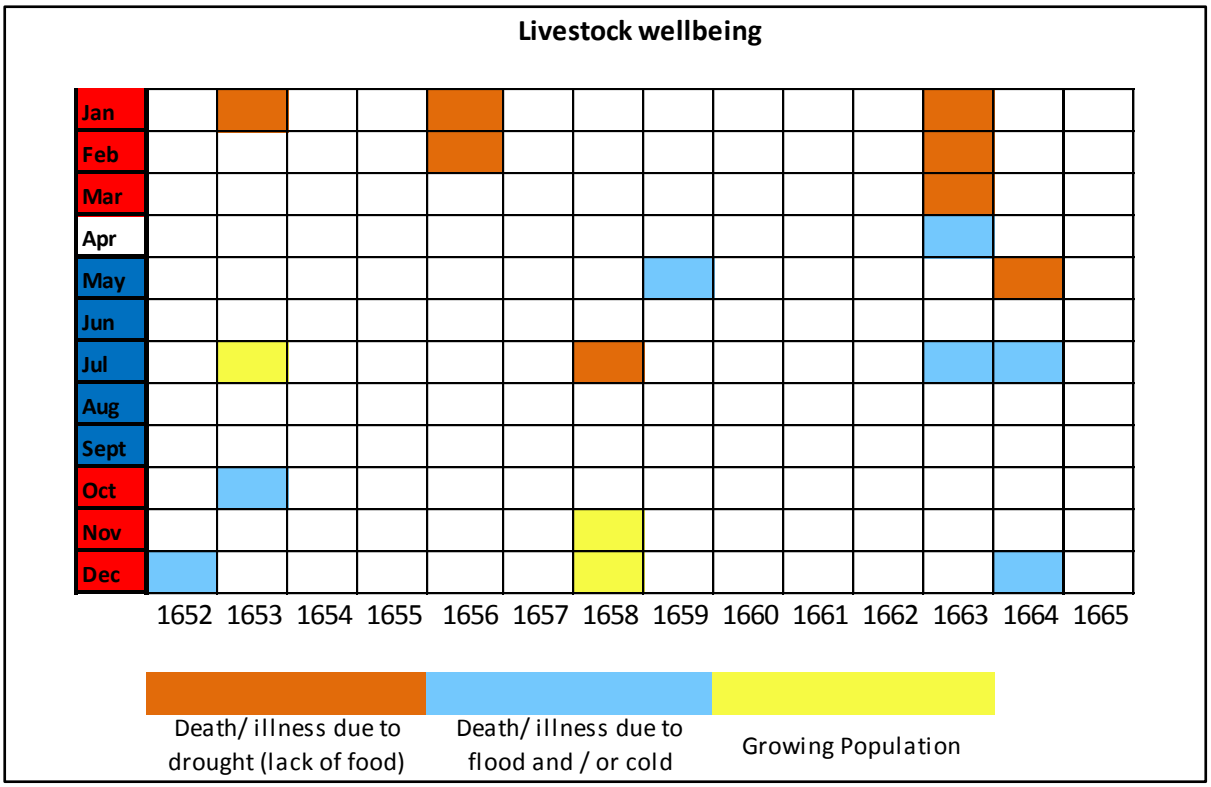


Figure 6.7: Changes in the health of livestock due to extreme weather

By 1658, Robben Island had become a home for livestock, as they fared better there than on the mainland. These thriving conditions were indicative of increasing livestock populations:

> During the dry season, the animals find more to eat here than at the Cape in the form of dry grass and bushes, which are always green (Extract from a letter by Rijck Overhagen: 13 July 1658, pp. 311-312).

> It was astonishing to see in what good condition the 489 sheep were, for there was no grass anywhere on the island but only some green bushes growing here and there. As it was the dry season, the island was for the rest as dry as the most barren sand dune, though in winter or in the rainy season it is covered with grass, wild sorrel, spinach, etc. (18 December 1658, p. 390).

However, even with better vegetation conditions, they were not exempt from the cold, wet conditions during the severe winters:

> The recent severe weather has killed many sheep. Now another 31 or 32 have died.... The new grass causes them to purge, and when the rains come they die in great numbers from the wet and cold, and we see and fear that there will be no end to this (Extract from a letter by Rijck Overhagen: 13 July 1658, pp. 311-312).

In order to provide food for the sheep during winter months, a specific plant, which is unfortunately not named, but which grows even during the dry season, was planted throughout Robben Island for the sheep to graze. Through further investigation of the literature around Robben Island, no information on past plants could be identified:

> She [referring to the Company's ship going to Robben Island] also carried some seed of a kind of plant which grows in the open on sandy soil during the dry season and which, it has been found, the sheep eat very readily. For this reason the seed will be sown all over the island so that the sheep will have more pasture when there is no grass during the dry season (15 February 1659, p. 20).

It is noted that the dry season from the previous year, ending at the beginning of 1663, may have been a drought year as the cattle were dying in large numbers:

> In the meanwhile we greatly fear that half the young ewes, through want of food, will perish [these ewes were to be dispatched to Robben Island but ship could not leave the bay due to contrary N.W. wind blowing.] (29 January 1663, p. 36).

> Obtained 22 lean sheep from the Hottentots for tobacco and copper. On the other hand 5 were left to die on the veldt, through want of food (9 March 1663, p. 44).

However, other diary entries in January 1663 indicated death of cattle in dry seasons in general:

> ...chief Sousoa [Hottentot], brought us a good number of cows and sheep. We bought 8 of each, and let them keep the rest, as they were extremely decrepit and lean, so that they could hardly stand on their legs. At present we are burdened with too many of such lean, old and toothless cattle, of which in the dry season nearly every day two or three die (25 January 1663, pp. 35-36).

In May 1664, a prolonged drought is indicated for the 1663/1664 dry season based on the vegetation drying up, the resultant lack of food for the livestock and ultimately livestock death:

> In consequence of the continuous drought, so very unusual at this time of the year, the ground can hardly be entered by the plough, at the same time the grass is drying and dying away so fast that the cattle can hardly obtain food, so that many of them are growing sick. At Schuur, 24 of the best cattle of the Company are ill, suffering from costiveness, and unfit for work (17 May 1664, p. 109).

During the winter of 1663, travels were undertaken by some of the settlers to barter for cattle with Chief Sousoa's, a Hottentot. Upon the return journey, mention is made to the inclement cold weather conditions that resulted in some livestock being left behind on snowy mountains:

> On the way they had to leave behind 1 pack ox and 14 sheep, which perished on the high, steep, stony and snow covered (besneude) mountains, and in the deep, rapidly running rivers. During the journey they had not want of cold, snow, hail or rain, but thank God! All returned in good health. Sousoa's kraal is about 4 (Dutch) miles distant from the sea shore... Their camp is on and behind the mountains behind the high False Cape range, now mostly covered with snow (25 July 1663, p. 64).

6.9 Human Health

Interestingly, mention to human health predominantly occurred in 1652 and 1653, with only one mention in 1656 and two mentions in 1661. There are two possible reasons for the lack of commentary to human health for later years at the Cape. Firstly, it may have been such a common occurrence for people to get sick at a particular time of year (for example with a change of seasons) that the authors felt it was not important to continue mentioning society's health on a frequent basis. Secondly, it should be noted that in the first two years at the Cape (1652 – 1653), Jan van Riebeeck and his men were only just beginning to build a settlement and vegetable garden and lacked protein and fresh food supplies. To this end, it would be understandable that the earlier years were harsher for the settlers, given the lack of fresh food and adequate shelter; thus, people were more frequently sick relative to later years.

There were several types of illnesses and diseases recorded in the diaries due to environmental and weather conditions; these included influenza, fever, dropsy, dysentery, starvation as well as generally poor health. Dysentery was regularly referred to as 'bloody flux' by Jan van Riebeeck, which is commonly known as diarrhoea today (Haycock, 2002). Dropsy is defined as the accumulation of water in the soft tissue. It can be noted that these illnesses and diseases varied in severity but most resulted in death. The number of deaths were exceptionally high in May/June 1652, and then began to taper off by September (Figure 6.8). Mention to death due to an illness was only mentioned again in January 1653 (Figure 6.8). The most frequent cause of death was dysentery, followed by 'disease' (type not specified) and general poor health, which could include a multitude of symptoms because of a combination of environmental and weather impacts. For example, a labourer would initially be suffering from hunger and develop dysentery from a lack of nourishment. This condition would be exacerbated by the cold, wet winter and he would then develop influenza and fever.

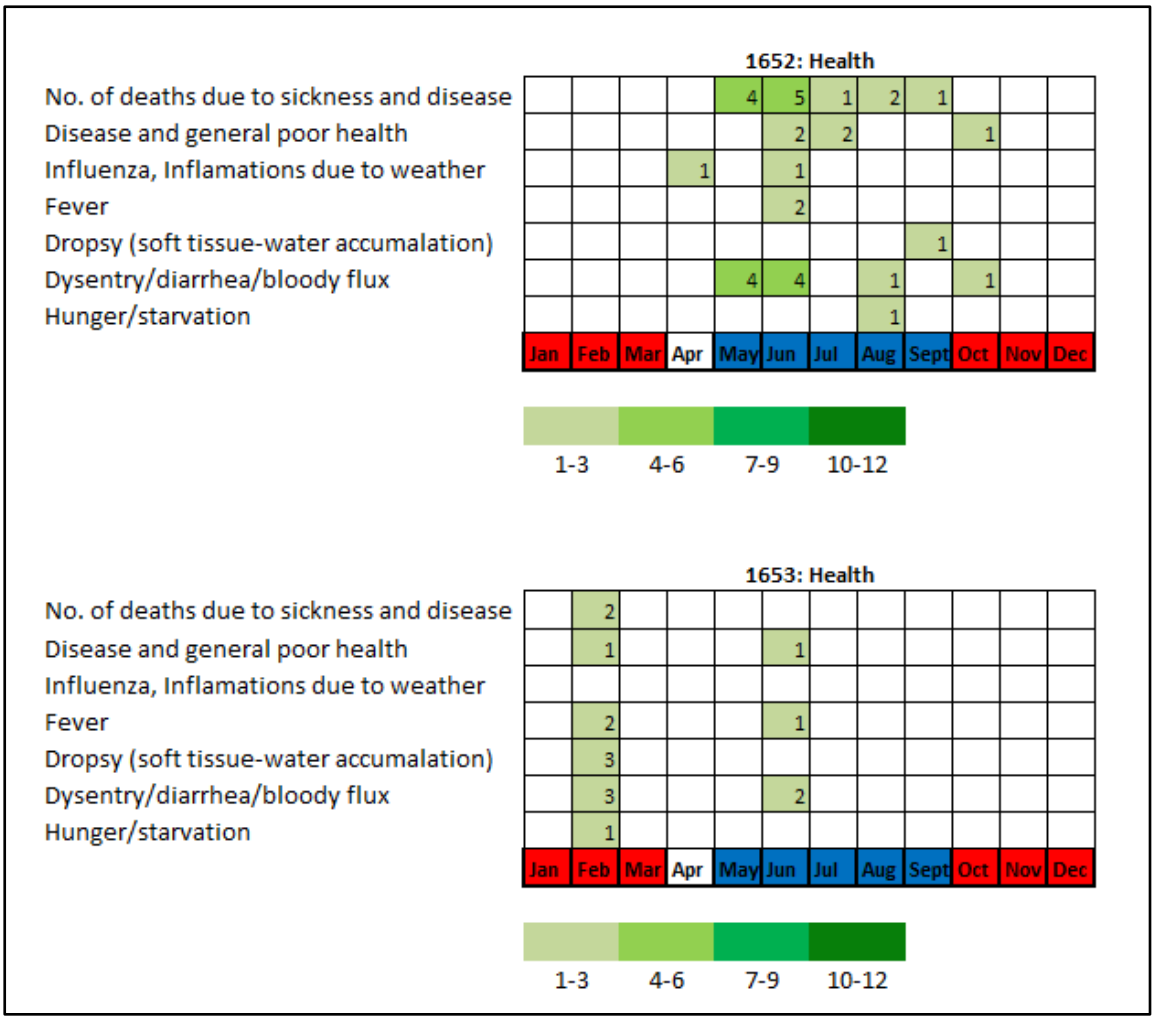


Figure 6.8: Mentions to poor health of the human population: 1652-1653

Initially, upon settlement at the Cape, it is noted that the labourers have taken ill. At this point, Jan van Riebeeck is not certain of the cause but attributes it to the current weather conditions. At the time, people travelling to the Cape would have also been at sea for several months and would thus have had weak immune systems before settling at the Cape. As the ship arrived in April, the cusp of winter, all pre-existing health conditions would have been exacerbated by the cold, wet winters endured at the Cape:

> …very little progress could be made owing to the small number of labourers, of whom several are still ill (15 April 1652, pp. 31-32).

> Fine, bright sunshine and lovely calm weather… Quite a number of the men here on shore are going down with bloody flux as well as other diseases and fevers, evidently from the cold and discomfort they suffer here in the scanty dwellings…To-day a seaman … died after suffering from the bloody flux for some days (25 May 1652, pp. 41-42).

In some instances, medical professionals such as the chief surgeon had contracted dysentery. This would have had serious implications for settlers as the chief surgeon would have been unable to assist others in sickness:

> Last night our chief carpenter, …, [and soldier] died from the bloody flux, the chief surgeon has also gone down with this disease… past 6 or 7 days at least 7 or 8 men have been struck down [by bloody flux] (28 May 1652, p. 42).
>
> Clear bright weather. Assistant surgeon and gunner have also fallen very sick (29 May 1652, p. 42).
>
> Fine, clear, calm weather. The surgeon reported another 8 person shad come under his treatment for dropsy, dysentery, fevers and pains in the joints. Furthermore, the chief carpenter, the chief surgeon (who is our only surgeon) and the gardener have fallen ill to-day, and the corporal or provisional sergeant of the soldiers also had the fever last night (12 February 1653, p. 142).

Throughout June 1652, the prevalence of poor health is rife amongst the settlers. Sickness spreads quickly and Jan van Riebeeck indicates that nearly 50% of the labour force is unfit for work. The illnesses vary from dysentery to fevers. In one instance, mention is made to the inclement weather illustrating the cold conditions the settlers are faced with while trying to establish a settlement with vegetable and herb garden. :

> Gunner dies of fever. This disease together with red flux is becoming more prevalent among men and labour forces are weakened (1 June 1652, p. 43).
>
> Clear weather. Sickness is rapidly increasing. Out of 116 men, not more than 60 are fit for work (3 June 1652, p. 43).
>
> Variable weather. The past 3-4 days another 7 to 8 persons have gone down with red flux and other forms of dysentery and also violent fevers and some are on the point of dying (7 June 1652, pp. 43-44).
> 3 others have come down with red flux (8 June 1652, p. 44).
>
> Hardly 50 men that are fairly well, the rest being laid up with bloody flux and heavy fevers (10 June 1652, p. 44).
>
> Suffering severe cold and discomfort which is contributing to the daily spreading sickness. No more progress in the work can be expected due to the incessant rain and the weakness of the men (11 June 1652, pp. 44-45).
>
> Weather and wind as before but less rain. The past two days have seen another 8-10 men go down with dysentery and other complaints (13 June 1652, p. 45).
>
> Hazy but good weather. In the last 3-4 days, another 7-8 people have contracted severe fever (27 June 1652, pp. 47-48).
>
> In the past few days, due to the inclement weather, 8-10 persons have again taken ill (28-30 July 1652, p. 48).

All comments describing the weather noted calm and bright days, hence the illnesses were due to lack of nourishing food.

> Another soldier has died due to red flux. Many others are going down with this disease on a daily basis due to eating greens and not having any fresh meat. Still have to eat stale food (21 August 1652, p. 56).

> Found to-day that there were again more than 20 persons quite sick with fever, dropsy and dysentery… evidentially from the continual labour and the fact that they hardly have enough to eat, owing to the scarcity of victuals [food provisions] (11 February 1653, p. 142).

The settlers are able to gain cow and sheep milk which they use as a source of nourishment for the sick. This highlights the prior lack of nourishment:

> …Have also for the first time drunk the milk of the cows and sheep; from this the sick have already received much nourishment and they will be able to enjoy more every day (9 December 1652, pp. 109-110).

By June 1653, Jan van Riebeeck is able to establish that it is a common occurrence for people to fall sick during the wet season:

> During the past 3 or 4 days another 7 or 8 sick have been taken into hospital. This time of the year seems to be somewhat unhealthy, especially for the newcomers; many are going down with fever and dysentery (11 June 1653, p. 160).

> Since the day before yesterday 5 or 6 more persons have contracted fever and dysentery. These illnesses are rapidly beginning to become rampant among the men (13 June 1653, p. 160).

The most number of deaths at the Cape were recorded in 1652. This large number of lives lost would have severely affected the initial start-up of the settlement. Table 6.4 illustrates some of the occupations of those that died in 1652. These would have been crucial as these professions would have been necessary at the beginning phases of the settlement. On many occasions, Jan van Riebeeck noted that the sickness of people causing delays in the development of the settlement:

> Wind and weather as yesterday. … In the meantime we are still doing our best to bring the fortifications into a better state of defence, but the sickness is again proving a great hindrance (10 October 1652, pp. 71-72).

> Full moon. Same weather. The sickness among the men continues, greatly delaying the works…, as the master carpenter and the best assistants, apart from others, fell seriously ill about 2 or 3 days ago, while most of the others are still very weak and the rest are complaining. Every day men are falling ill one after another, so that we are already in difficulties (5 August 1656).

In some instances, Jan van Riebeeck indicated that the workforce was also irresponsible when it came to their health, knowing no moderation in their eating habits which resulted in them getting sick:

> For the last 2 or 3 days some of our men (including 4 carpenters) have again been laid up with dysentery, apparently caused by wild figs which grow here and are eaten by natives. Our men had gathered bags full and feasted so excessively that many have now contracted dysentery. It is annoying that the men are so indifferent about their health and know no moderation before they have to take to their beds (7-10 January 1653, p. 133).

Table 6.4: Human deaths showing the cause and weather/seasonal association

Date	Cause	Occupation
25 May 1652	Bloody flux	Seaman
27 May 1652	Bloody flux	Chief carpenter and soldier
1 June 1652	Fever	Gunner
18 June 1652		Carpenter
20 June 1652		Cadet
22 July 1652	Severe illness	Chiefs surgeon's son
1 August 1652		Soldier
3 August 1652		Soldier
21 August 1652	red flux	Soldier
23 September 1652	dropsy	Cadet
5 February 1653	dysentery	Soldier

6.10 Key Findings

Through the interrogation of the social environmental diary entries, it became evident that the Dutch settlers were faced with many challenges mainly due to weather related constraints. In some instances, temporary solutions were implemented, however in most, especially strong flood/drought events, the settlers were at a loss to how they would overcome these. In most of these instances, they would pray to God for help.

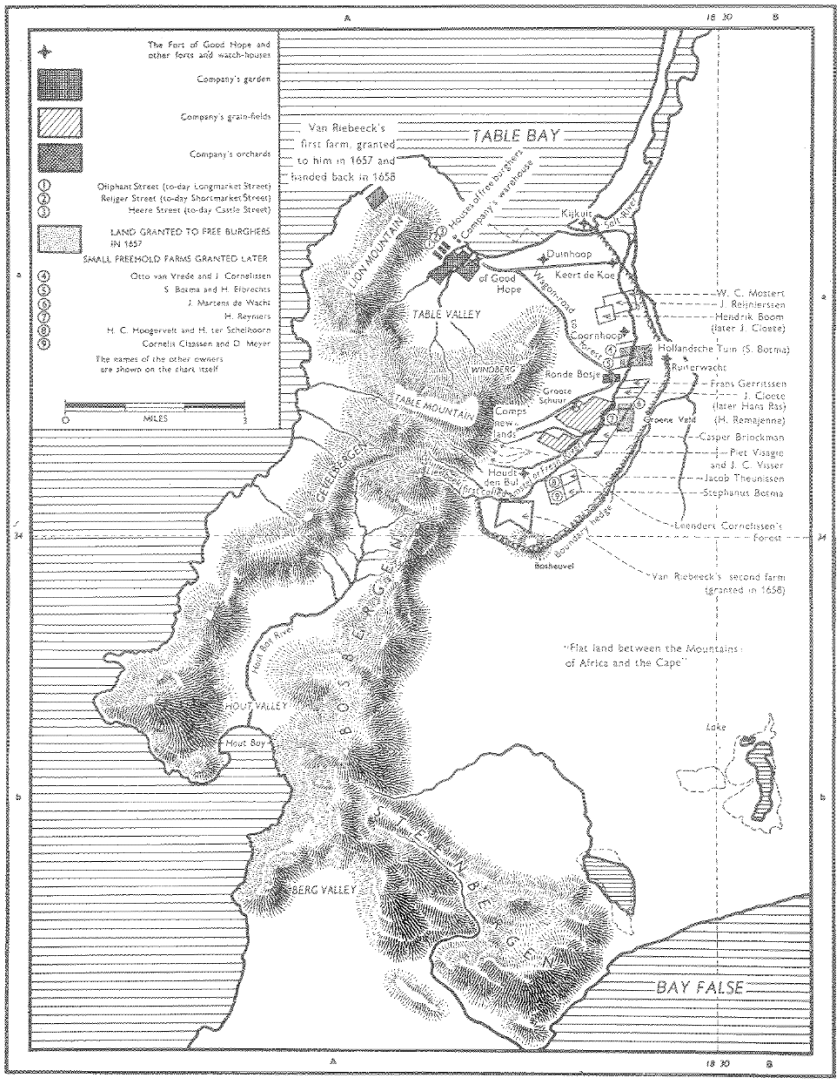
Cold, wet season struggles included the flooding of vegetable and herb gardens, crop damage and the ill health of livestock. In earlier years, diary entries noted frequent poor health of the settlers, predominantly in the wet season. However, in later years, mentions to poor health became scarce or simply not diarised. Practical solutions included the development of trenches to divert excess water and the building of a shed to house the livestock during cold spells. However, infrequent weather phenomena such as snow and hail exacerbated poor livestock health and crop damage. Heavy winter rains also hindered settlement development and in most instances damaged infrastructure that was only a few years old.

Severe dry periods presented its own unique challenges including the drying out of garden herbs and vegetables, and the desiccation of grain crops due to extreme temperatures and harsh, dry south-easterly winds. In most cases the crop damage was due to the unsuitable crop selection for the Cape climate however, the settler only realised this in later years. Solutions to overcome these challenges included the harvesting of grains before maturity and praying to God for rain. The sowing of crops during the dry season was also a problem due to the dryness of the ground and the inadequate farming implements. Furthermore, livestock would be left in the fields to perish due to the lack of vegetation and fresh water during the harsh dry seasons.

Jan van Riebeeck and the settlers encountered a variety of different fauna during the historical period, including tigers (Cape leopards), horses (quaggas), baboons and deer. In some instances heavy rainfall events would prevent hunting expeditions and in other instances these wild animals would pose a threat by attacking both the settlers and their livestock. Pests such as locusts and worms were also mentioned sporadically during the 13 year period, yet no coping strategies were implemented to overcome the resulting crop damage.

Notably, fish abundance was mentioned more frequently in earlier settlement times and thereafter almost no further mention. Possible reasons for the increasing lack of mention are further discussed in Chapter 7. Whales and seals were also frequently sighted in the 13 year period and penguin eggs were often collected on Robben Island. The relationships between the natural environment and settlers are explored in greater detail in Chapter 7.

Chapter 7: Discussion



THE FREE BURGHER SETTLEMENT

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7.1 Introduction

The primary aim of this study was to develop a weather and environmental reconstruction for the southwestern Cape for the period 1652-1665. This contributes to the current research gap,

first in analysing a record which has not previously been explored for its value in weather commentary, second for producing a reconstruction for the southwestern Cape for a period that has not previously been addressed, and third in contributing to the southern African climate reconstruction chronology. The results of quantitative analyses of weather records and qualitative analyses of social and environmental records are presented in Chapters 5 and 6 respectively. This chapter integrates these results within the context of existing literature on documentary based climate reconstructions for southern Africa and the contemporary understanding of human adaptation and coping to climate and environmental challenges. This chapter also critically explores the limitations of this study, and where possible outlines measures that were taken to mitigate these.

7.2 Documentary weather reconstruction

The primary objective of this study was to reconstruct weather for a time period (i.e. 17th Century) and location for which no previous information exists. This contributes first to the growing body of literature on documentary based climate reconstructions for southern Africa. Second, it improves our understanding of the dynamics of long term climate patterns in the southwestern Cape by providing a benchmark from the 1600s. Third, as is an aim for many documentary based climate reconstructions, there is the potential that this information could be used towards the purposes of climate modelling and thus future projections. Therefore, an important output of this research is a weather reconstruction.

7.2.1 Characteristics of the weather in the Cape from 1652-1665

The nature of the diaries used in this research is such that a reconstruction made would be of a high temporal resolution, but would not span sufficient time to comment on any climate trends or repetitive cycles in precipitation. The primary output of this reconstruction is thus to focus on inter-annual and seasonal patterns. As temperature could not be quantified from the information provided in the diaries, this does not constitute part of this reconstruction. The greatest focus is placed on precipitation and wind, for which there is an almost daily record.

7.2.1.1 Inter-annual characteristics

From the documentary-based reconstruction, the year with the most mentions of rain days was 1655, with the first half of the record being much wetter than the second half. The most

common rainfall category for both the dry and wet period was ‘rain’. The addition to existing chronologies showed that there was a distinct wet period at the beginning half of the 13 years followed by a distinct dry period (see section 7.2.5 and Figure 7.2). Annually, for the wet period, the category ‘rain’ was the most commonly occurring rainfall type in 1655; ‘heavy downpour’ for 1652 and 1656 and the category ‘drizzle’ was most mentioned in 1652. Additionally, there were relatively more mentions to drizzle in the first half than second half of the 13 year period. Mentions of flood type conditions and excessive rain were more common in the first half than the second half which would be consistent with progressive drying over the 13 year period (Figure 7.2). Notably, this reduction in mention of rainfall and flood is not replaced directly in an increase in mentions of drought. The most frequent mentions of drought was from 1655-1661 across the wet and dry seasons, whereas below average number of rainfall days persisted through 1663-1665. For the dry season,, mentions to ‘heavy downpours’ was highest in 1652 and 1656, while drizzle was the highest in 1652 and 1657.

Inter-annual wind patterns for the historical period demonstrated dominant south-easterlies (including south south-easterlies) from 1653-1654, 1659-1661 and 1663-1664. 1652 was dominated by north-westerlies (Table 7.1). In all other years there was a relatively equal spread between dominant wind directions. Throughout the period, south-easterlies were a dominant feature followed by north-westerlies (Table 7.1). The mentions of the lowest wind strengths were in 1656-1657 and 1661-1662 as the dominant wind strength was ‘breeze’ in many months. Very strong winds were noted in 1659-1661 and this also coincided with a period of dominant south-easterlies. These years corresponded with those for which drought is most commonly mentioned, i.e. from 1655-1661.

With regards to weather extreme events, the most mentions of ‘dirty rain’ were in 1656 and 1657 (Table 7.1). Furthermore, mentions to ‘dirty rain’ ceased between the years 1659-1661 (Table 7.1). The phenomena ‘black south-easterlies’ was not a term used by Jan van Riebeeck or Zacharias Wagenaer. However, there were many instances when rain would occur during the presence of a south-easterly wind (Table 5.13). The literature demonstrated that black south-easterlies were termed as such, based on their ability to bring on rainfall which is uncommon as the south-easterlies are a dry wind in the southwestern Cape, known to bring on drought conditions (Hepworth, 2013). The most frequent mentions to south-easterlies that resulted in rainfall were from 1653-1665 and also in 1668 (Table 5.13). Eleven of the 35

mentions to hail throughout the 13 year period occurred in 1652. Throughout the period there was an average of three hail days per year. Mentions to snow or similar events occurred in two year sets, namely 1652-1653, 1658-1659, 1663-1664.

Table 7.1: Most extreme mentions of rain and wind variables for each year in the 13 year period

Year	Relative Wetness	Rain type	Rain days	Wind Direction	Wind Strength	Extreme events
1652	Relatively wet	Rain	58	NW	Wind	Dirty rain, Hail
1653	Relatively wet	Rain	54	SE	Wind	Black south-easterly, Snow
1654	Relatively wet	Rain	60	SSE	Breeze	Dirty Rain, Black south-easterly
1655	Relatively dry	Rain	77	SSE	Wind	Black south-easterly
1656	Relatively dry	Rain	54	NW	Breeze	Dirty Rain
1657	Relatively dry	Rain	67	SSE	Breeze	Dirty Rain
1658	Relatively dry	Rain	47	SSE	Strong	Black south-easterly
1659	Relatively dry	Rain	49	SSE	Strong	
1660	Relatively dry	Rain	56	SSE	Strong	Black south-easterly, Hail
1661	Relatively dry	Rain	42	SSE	Breeze	Hail
1662	-	Rain	49	NW	Breeze	
1663	Relatively wet	Rain	43	SSE	Strong	Hail, Snow
1664	-	Rain	45	-	-	
1665	-	Rain	4	-	-	

7.2.1.2 Seasonal characteristics

Throughout the 13 year period, January and February was a distinct dry period as there were many years during this period that had zero rain days and only one year (1661) with four or more rain days in the month. Similarly, a distinct wet season is noted from May to August observed as all of the years had at least a month with 10 rain days or more during this selection. Seasonally, south-easterlies are predominantly summer winds and north-westerlies are winter winds in the southwestern Cape. Using wind direction, it was noted that across the 13 year study period, south-easterlies were dominant in October/November in one year to March/April the following year. Additionally, based on mentions of north-westerlies over the 13 year period, winter was from May to August but sometimes even April to September. The strongest winds were typically in summer from December through to February and then late winter in August and/or September.

Mentions to ‘dirty rain’ from the Jan van Riebeeck diaries can be described as those occasions when the rain was particularly heavy and accompanied by strong winds from the

west with storm-like conditions. This generally occurred from May to August with occasional mentions from September to December and March to April, but never in January and February. Seasonally, 'black south-easterlies' were mostly mentioned in late winter (August and September) but also had a notable number in April (8 of the 40 mentions). Hail occurred predominantly in July and August. Similarly, snow also occurred in the winter months with seven of the nine mentions made in July and the other two mentions made in August.

In order to determine the most favourable and unfavourable conditions at the Cape, depending on the time of the year, maximum rainfall and wind variables were tabulated (Table 7.2) On the basis of these data, the most favourable conditions in the southwestern Cape in the 1600s were April, September and October. During April there were generally variable breezes with a moderate number of rain days. During September and October conditions are similar to that of April with dominant north-westerly and south-easterly winds respectively. Particularly unpleasant conditions were noted for January and February as there are relatively less rain days and dominating dry south-easterly winds that ensue. Conversely, May to July is generally pleasant for the relatively high number of rain days with cold north-westerly winds.

Jan van Riebeeck arrived in April 1652, a more favourable time of year. He understood that they had arrived at the Cape during the end of the dry season but that they could expect a rainy season that would bring more favourable conditions. Based on the tone of his initial commentary, it could be sensed that he was very positive about cultivation due to the wet season and good soil:

> Between the Lion Mountain and the downs was the most beautiful land for sowing and grazing cattle that one could desire (several miles long and about one mile wide). Crossing the Lion Mountain on the seaward side of the head found the slopes on the other side dry and stony. Down into the Table Valley, once again found the finest clay soil in the world, watered by several rivulets during the rainy season. The rivulets are quite dry and now because of the dry season the earth is rather hard but due to the cattle tracks in the ground, it should be suitable for cultivation in the wet season (27 April 1652, p. 35).

Table 7.2: Monthly maximum mentions of rain and wind variables for the 13 year period

Month	Rain days	Rain type	Wind strength	Wind type	Extreme Events
January	29	Rain	Breeze	SE	
February	17	Rain	Breeze	SE	
March	36	Rain	Breeze	SE	
April	56	Rain	Breeze	SE/NW	Black south-easterly
May	98	Rain	Wind	NW	Dirty Rain
June	87	Rain	Wind	NW	Dirty Rain
July	90	Rain	Wind	NW	Dirty Rain, Black south-easterly, Hail, Snow
August	74	Rain	Wind	NW	Dirty Rain, Black south-easterly, Hail, Snow
September	59	Rain	Wind	NW	
October	57	Rain	Wind	SE	Black south-easterly
November	53	Rain	Strong	SE	
December	49	Rain	Strong	SE	

7.2.2 Comparison with contemporary weather

It is of interest to determine whether the climatic conditions experienced in the southwestern Cape from 1652-1665 are consistent with weather conditions today. This is of particular interest, given that since this time, considerable urbanization has taken place (Ziervogel et al., 2010), and in the last few decades climate change has altered seasonal patterns (Grab and Craparo, 2011). This section will therefore explore the weather reconstruction presented in 7.2.1 and critically analyse whether these conditions reflect a significantly varied climate to that experienced in the contemporary southwestern Cape environment.

From a seasonal perspective, conditions are tentatively similar to the contemporary weather. The southwestern Cape is still characterised by a seasonal divide of the south-easterly and north-westerly winds, with marked winter precipitation (Chase and Meadows, 2007; Phillipon and Roualt, 2012). Notably, Cape Town is known for very strong winds in late summer and relatively mid-winters (Schumann and Martin, 1991). The documentary records reflect the same seasonal pattern of peaks in wind strength. However, it is of interest that for many years the dominant wind strength is ‘breeze’. Even though the counts reflect this, it was more a case of always noting the weather, especially wind strength and direction as opposed to nothing. It could be argued that some or all of the mentions of very strong wind may have been an exaggeration due to the large impacts that these winds had on their settlement. There is also likely some degree of bias that comes from the words used to describe wind (Table 7.3).

Table 7.3: Words used to describe winds from an example of tropical cyclones (Chenoweth, 2007)

Tropical depression	Tropical storm	Hurricane
blew pretty fresh	blew severely, fierce gusts	blew with great and destructive fury
blew rather heavily	fearful gale, frequent gusts	blew with indescribable violence
blew heavy (hard)	furious gale, hard squalls	fierce roaring
blowing half a gale	gale, heavy gusts	hurricane
brisk wind	heavy gale, severe blasts	indescribable force
inclining to a gale	heavy storm, severe gusts	mere hurricane
nearly a gale	not a hurricane, severe squalls	roared and howled most terribly
stiff breeze	regular gale, strong blasts	terrific hurricane
strong breeze (wind)	severe gale, strong puffs	violent hurricane
very fresh and variable	smart gale, strong squalls	
wind whistled loudly	stormy, tremendous gusts	
wind unsteady	strong gale, violent gusts	
(very) high wind	violent gale, wind raged	

With regards to the extreme events, black south-easterlies are still a common occurrence in the southwestern Cape and are now termed the 'Cape Doctor' (Hepworth, 2013). The seasonality in the documentary records is not as clearly defined as in the contemporary conditions, with mentions in almost all of the months of the year. However, the highest number of mentions is in autumn and mid-winter, which showed tentatively similar consistency with contemporary conditions (Schumann and Martin, 1991; Hepworth, 2013).

'Dirty rain' is difficult to associate with any contemporary conditions. In the 'Dirty Weather' diaries of Reverend Richard Davis, it is defined as "disturbed conditions with strong winds and driving rainfall" (Lorrey and Chappell, 2015, pp. 3800). Within the Cape context it is unclear whether this relates to storms which may be associated with the movement of a large amount of dust leaving the city dirty, or whether the term 'dirty' may have been a loose translation of terms such as 'bad' and refer to severe storms with large sea swell. Both of these conditions occur in the contemporary environment of the southwestern Cape. However, it may also potentially refer to a weather event that no longer occurs.

There are notably considerably more mentions of hail than snow in the documentary record. Hail is very uncommon in the contemporary climate of the southwestern Cape, whereas snow does still occur most winters, particularly in the Cape Fold Mountains (Worden et al., 1998; Harris et al., 2010). This is of interest due to the cloud formation conditions for each of these

phenomena. Hail is associated with strong convection clouds, and requires a very strong uplift in continued unstable conditions for its formation (Huanbin and Ying, 2001). This phenomena is most common during the summer months in the Highveld, where heating throughout the day results in uplift of unstable moisture of the Indian Ocean (Carte and Held, 1978; Garstang et al., 1987). By contrast, snow forms under conditions of frontal uplift, and is associated with particularly strong mid-latitude cyclones, or mid-latitude cyclones that arrive in quick succession (Barrie, 1991; Grab and Linde, 2014). It is unclear why so few mentions of snow are made, but this is possibly because most of the snow falls in the high mountains beyond the coastal colony from which , most reporting took place (Worden et al., 1998). Furthermore, unlike hail, snow would not have impacted on their settlement (Wicht, 1943).

Comparing the counts of rain days from the documentary record to contemporary weather station recordings (Table 5.5), the historical record tentatively reflects less annual numbers of rain days than for the period 1841-2013, at 54 and 96 days respectively. Notably weather station records for the last three decades (1984-2013) are relatively more similar to the historical record at 66 total annual rain days. However, with any subset of contemporary meteorological data, the number of rain days in the documentary period are notably undercounted. It is possible that not every rainfall event was mentioned in the diaries, particularly if a storm were short lived or did no damage. By contrast meteorological stations record each day with a non-zero rainfall amount. It is therefore difficult to determine whether the climate has changed since the documentary period to one with more frequent rain, or whether contemporary measurements are just more accurate (Fitchett and Grab, 2014; Nash et al., 2016). This makes it particularly difficult to infer rainfall amount from the number of rain days, if the number of rain days themselves may be inaccurate.

7.2.3 Climate drivers for the weather experienced in the southwestern Cape from 1652-1665

7.2.3.1 Inter-annual drivers: The ENSO event

According to the reconstruction of El Niño and La Niña years from 1525-2002 presented by Gergis and Fowler (2009), El Niño events occurred from 1659-1661. Additionally, within the study period of this research, El Niño events also occurred in 1652 and 1655. However, in both years, incomplete weather records exist as Jan van Riebeeck arrived in April of 1652

and from 1665, weather related commentary made by Zacharias Wagenaer became too sparse to be accurately quantified. Therefore, changes in counts for weather events for these years cannot be attributed to El Niño conditions.

Upon closer inspection of the 1659-1661 period, several anomalous findings were observed. For 1659-1661, it was noted that south-easterlies and south-south-easterlies dominated. Also, of the seven Februaries that registered zero rain days, two of these occurred in 1659 and 1660. The year 1660, in particular, had the lowest number of mentions to rain days throughout the 13 year period. Additionally with regards to the number of rain days, the category 'light shower' (which had the lowest number of mentions overall relative to the other categories) had the highest number of mentions in both 1659 and 1660 with four days and no mentions in 1661 (Figure 5.1). The 'drizzle' rainfall category had the least number of mentions in 1661 (and 1664) with two days (Figure 5.1). For the dry seasons, 1659-1660 was one of two two-year sets that recorded the lowest number of rain days. Interestingly, the rainfall onset and termination registered the year 1661 as the only one having an onset date in May (Table 5.6) Most interestingly, 1659-1661 were the only years with no mention to ‘dirty rain’ type conditions. With regard to weather extremes, hail was most mentioned in 1652, however thereafter 1660-1661 had four mentions each, only equal with 1663 and snow occurred in 1659. Based on these conditions, there is a strong argument to support the finding of global ENSO periods by Gergis and Fowler (2009) that occurred from 1659-1661. This is consistent with contemporary conditions in the southwestern Cape during El Niño years, characterised by severe weather of this kind, as outlined by Phillipon and Roualt (2012).

The time of shipwrecks along the Cape of Good Hope together with the occurrence of ENSO events were used to determine the extent of the teleconnections between southern Africa and the Pacific Ocean (Caviedes, 2001). During the 17th C, 1660, 1668 and 1696 correlate strongly with El Niño episodes in the southern Pacific. This was also true for several years in the 18th C and 19th C (Caviedes, 2001). However, shipwrecks also occurred in ‘normal’ non-ENSO years. Hence, further statistical tests were conducted which showed that Cape Town had a higher probability of no shipwrecks in non-ENSO years than in ENSO years (Caviedes, 2001). Furthermore, the rainfall in Cape Town was grouped within the non-ENSO and ENSO years to determine whether Cape Town experienced above normal rainfall for the winter months during an El Niño year. The results showed that of the 146 years of available data, 26 of the rainiest years corresponded with El Niño events (Caviedes, 2001).

La Niña events are recorded to have occurred in 1654, 1658 and 1663 (Gergis and Fowler, 2009). La Niña years were found to bring on drier than normal conditions to Cape Town, resulting in fewer mid-latitude cyclones and less rainfall, and therefore fewer shipwrecks in those years (Caviedes, 2001). Revisiting the results for the years 1654, 1658 and 1663, it was found that no specific 'La Niña' type conditions took place. The year 1654 was one of three years that had had the 'rain' category with the most number of mentions (Figure 5.1). The period 1654-1655 was interesting as the wet season was above and the dry season was below its 13 year average (Figure 5.2). This follows from Barrable et al (2002), who found that when wet seasons are relatively wetter than normal, then dry seasons are typically much drier. Interestingly, 1654 had no mention to both 'heavy downpours' and 'drizzle', while 1658 had the least number of mentions to 'heavy downpours' (4; Figure 5.1). The periods 1655-1656 (no mention to 'light shower') and 1657-1658 (no mention to 'drizzle') had the highest number of rain days for the dry period (25 days; Figure 5.3). Furthermore, 1654 only comprised 3 days of 'drizzle' (Figure 5.4). Based on the results presented in section 5.2.1 for rainfall categories, it is tentatively argued that the year 1654 may have received equivalent to or more rain than for 1652 (Figure 5.4).

The period 1654-1655 was one of three dry seasons with the lowest number of rain days recorded. Additionally, 1654 had a relatively early rainfall termination date on 23 September, the only other year with this early termination date was 1664 (17 September; Table 5.6). All other rainfall termination dates were from October-December (Table 5.6). This tentatively indicates that the dry season started earlier in 1654. The year 1663 along with two non-El Niño years had the least mentions to drought while 1658 (and 1657) were relatively similar in that there was no reference to drought or dry weather between the months of March to August of those years. The dry south-easterlies dominated during 1653-1654 and 1663-1664.

Out of the 70 mentions to 'dirty rain' type conditions, 14 were mentioned in 1654, five in 1658 and two in 1663. Additionally, July 1654 had the highest monthly total (9 mentions to 'dirty rain') throughout the 13 year period. Of the 40 'black south-easterlies', a total of 12 were counted for the tentative La Niña years 1654, 1658 and 1663. Hail occurred once in each of the years 1654 and 1658 while 1663 had four mentions. Relevant to El Niño, there was a mention to frost in 1654, a mention to ice in 1658 and three mentions to snow in 1663. In the years 1663 and 1664, it must be noted that the settlement was being governed by the

newly instated Zacharias Wagenaer, who did not emphasise on the weather and environmental conditions at the Cape as frequently or as comprehensively as his predecessor, Jan Van Riebeeck. Often, El Niño events correlate more strongly with climate anomalies than La Niña events, which are difficult to detect in the climate record (see Gergis and Fowler, 2006; Nash and Grab, 2010; Fitchett and Grab, 2014; Nash et al., 2015).

7.2.3.2 Synoptic climate drivers of seasonal and inter-annual weather

The progressive drying sometimes noted at the southwestern Cape during the historical period could suggest that this was due to a reduction in the frequency of mid-latitude cyclones passing over the Cape as they are the primary cause of winter rainfall and are associated with at least one day of light rainfall or drizzle. Dirty rain predominantly happened in winter and was therefore associated with mid latitude cyclones.

Synoptically this can be explained by a southward shift in the ITCZ (Chase and Meadows, 2007; Weldon and Reason, 2014). With regards to wind, the north-westerlies in winter versus the south-easterlies in summer are due to the seasonal shift in the westerlies which affects both the dominant wind direction (i.e. being in the westerly belt in winter when the ITCZ shifts north and being in the tropical easterly belt in summer when the ITCZ moves south). It also affects the secondary wind directions in winter because this is mostly affected by the passing of the mid-latitude cyclones due to the cyclonic wind movement in the system (Weldon and Reason, 2014). Seasonally, wind strength is driven by two different factors. In winter, wind strength is due to the passing of mid latitude cyclones and the associated greater pressure differential between the warm and the cold sectors (Tyson and Preston-Whyte, 2000; Weldon and Reason, 2014). In summer, wind strength is driven predominantly by the difference in temperature between the land and the sea that often induces berg winds.

7.2.4 Comparison of the weather in the southwestern Cape with global phenomena

Although this study presents the only weather reconstruction for the 1600s in southern Africa, there is information on weather conditions in this period for places elsewhere in the world. Most of this stems from Europe where, by this time, weather recording was already well established and frequent records of climatic conditions were reported. This would be why Jan van Riebeeck placed a significant focus on weather commentary in his diaries, as he had been

trained in Europe. A small selection of commentary on weather conditions during the pre-18th C in other regions of the world is presented in Table 7.4.

Table 7.4: A selection of records of climate during the 16th - 17th Century

Publication reference	Region	Time period	Notable weather phenomena
Camuffo and Enzi, 1992	Italy	1570 to 1614	increase in the frequency of cold harsh winters
Brázdil et al., 1999	Europe	end of the 16th C	Increase winter rainfall and frequent floods
Rodrigo et al., 2000	Andalusia, southern Spain	last decades of 16th C to first half of 17th C	increase in rainfall
Benito et al., 2003	Tagus river basin, central Spain	1590-1640	increase in flood frequency
Chuine et al. 2004	France	~1650	coldest and wettest in the historical period
Dom´ınguez-Castro et al, 2010	Iberia, Spain	1600-1750	first half of the period had very local droughts, second half had regional droughts; 1664 and 1680 were two prolonged droughts
Dobrovolnỳ et al., 2015	Czech Lands (contemporary Czechoslovakia and the Czech Republic)	1501-2010	Second half of the 16th C had the highest rainfall values
Niedźwiedź et al., 2015	Baltic Sea	past 1000 years	second half of the 16th C was very cold and progressing to mild, two phases of cold winters, 1597–1629 and 1663–1706

It is difficult to make direct comparisons between the northern and southern hemisphere, as it is known that climate events were not necessarily synchronous due to the greater proportion of land mass over the northern hemisphere (Wanner et al., 2015). However, it is notable that the majority of these records speak to very wet conditions during this period, with very cold temperatures. The implications are twofold. First, Cape Town would by comparison have been a very pleasant location for these settlers who had just arrived from Europe. Second, it aligns somewhat with the wet conditions in the first half of the southwestern Cape historical record presented in this study (Figure 7.2), which is of interest given debates of historical connections between northern and southern Hemisphere events throughout the Holocene (Fitchett, 2015). However, the majority of these records speak to persistently wet conditions, and do not reflect rapid cycles of dry and wet conditions experienced in the southwestern Cape. Notably, Domínguez-Castro et al. (2010) speak of drought conditions in Spain during

this period, and so it is possible that these fluctuations did exist but were masked by longer term cold and wet conditions.

One would also hope that global records from this period would assist in clarifying uncertainties raised from the diaries. Of greatest interest were mentions of a very red sky:

> In the evening, between light and darkness, a brightly flaming ray, like a burning torch, was clearly seen in the sky before the stars were visible. It shot straight from the East to the West, and left a fiery red streak behind it about 9 or 10 roods in length, which remained visible for some time, and afterwards changed into a white cloud. All the people in the street beheld it with fear and surprise (20 July 1664, p. 115).

In other documentary records for the 1800s in southern Africa, bright red skies have been linked to volcanic eruptions (Grab and Nash, 2010). However, as there is no global record of a volcanic eruption during this period, and as no other documentary record spanning this period (Table 7.4) mentions particularly red skies, hence this assumption cannot be made for the 1652-1665 period. However, the description more suitably fits that of a meteorite event. The meteor pictured in Figure 7.1 illustrates the description given by Zacharias Wagenaer. Alternatively, contemporary sunsets in Cape Town are a dark orange colour due to the latitudinal position and together with less cloudy conditions than the settlers would have experienced in Europe, these conditions may just have been very exciting and therefore exaggerated.



Figure 7.1: Example of a meteor (Mckinnell, 2011)

7.2.5 Extending the southern African climate chronology

The majority of documentary based weather and climate reconstructions for southern Africa have spanned the period 1800s to present (Nash and Adamson, 2014). This is predominantly

because the major period of occupation of southern Africa by colonial groups only commenced in the 1800s (Worden et al., 1998). In a review of documentary based climate reconstructions of southern Africa, Nash and Adamson (2014) graphically represented the coinciding weather reconstructed for different regions in South Africa (Figure 3.1). The contribution that this study makes to this chronology for southern Africa is presented in an amendment of this figure (Figure 7.2). As Nash and Adamson (2014) classify periods into very wet, relatively wet, normal, relatively dry and very dry, these classifications were applied to the results in this study. The most reliable quantitative data obtained were the total annual number of rain days, grouping all types of rainfall to overcome biases and inconsistencies in the classification of rainfall type in the diaries. The mean was calculated with a five year boundary placed around this, and then taken as 'normal'. This bracket spanned 50-55 rain days per annum. Thereafter, relatively wet was classified as years with an average of 56-60 rain days per annum and very wet was greater than 61 rain days per annum. Relatively dry years were classified as having between 45 and 49 rain days per annum while very dry years had less than 44 rain days per annum. The last year was omitted because it was incomplete. From Figure 7.2 it is apparent that the first half of the period was wetter than the second half of the period. It should however be noted that this may in part be explained by Zacharias Wagenaer's comparatively poor attention to recording weather phenomena. His records only span the last three years, of which one has been excluded.

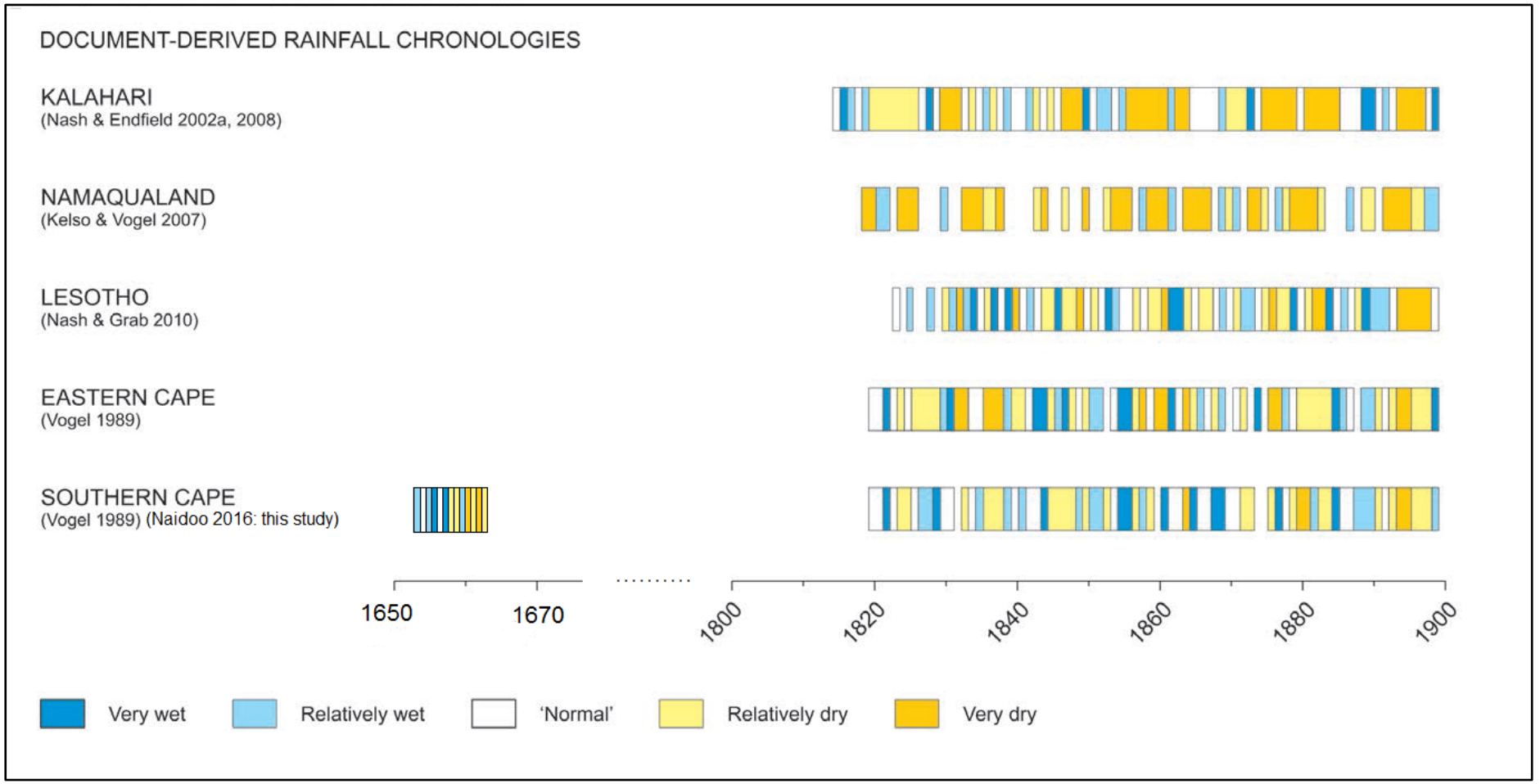


Figure 7.2: Graphical display extending the rainfall chronology for southern Africa including the results from this study with relative wetness inferred from numbers of mentions of rainfall (after Nash and Adamson, 2014).

7.3 Social responses to the climate of the 1600s

7.3.1 Historical solutions to climate and environmental stressors

During historical times, the Dutch settlers faced many problems driven by the surrounding climate and environmental setting. This section discusses the challenges faced as well as those instances where no solutions were implemented but that the settlers merely "lived with it". There will also be a focus on the instances where solutions were implemented. Lastly, attention will be drawn to the contemporary period and what has been done in modern times to overcome climate and environmental stressors. The wet and dry seasons came with their own specific set of climate and environmental challenges but some were also year round struggles.

7.3.1.1 Wet period (May – September)

The daily struggles during the wet season were owing to the cold, driving rain brought on by mid-latitude cyclones. The floods experienced at the Cape fluctuated in severity throughout the 13 years studied resulting in the inundation of the settlers' gardens, damaging their crops and in a few instances causing livestock to perish. Solutions to ameliorate or all together avoid flood damage to crops included digging trenches and ditches to redirect the excess water away from the gardens. Additionally, the cold north-westerly winds that dominate the southwestern Cape coast during winter contributed to crop damage, in many instances completely eradicating specific garden crops such as cabbages and potherbs, and field crops including wheat and barley. However, this made very little impact as even a decade later the flooding of the gardens was a persistent concern throughout the time period studied. Furthermore, in the first few years, the icy winds and wet conditions of winter resulted in the death of livestock in large numbers due to the lack of shelter. In later years, this was ameliorated as a shed was built to house the livestock during trying weather conditions. The poor health of livestock and damage to crops during the wet period were exacerbated by anomalous weather phenomena such as hail and snow.

During the first two years at the Cape (1652-1653), sickness and general poor health prevailed amongst the settler population, especially in the wet season. However, in later years, mentions to poor health became scarce or all together non-diarised. Even though the reasons for this may not have been mentioned, it can be assumed that the development of the

settlement and increasing nutritious food supply (livestock increased with time) that death and disease became less prevalent. Alternatively, death and disease may have been such a common and ongoing occurrence that it was not worth mentioning. However, this is an unlikely assumption as, should people from specific professions (cf. labourers, carpenters, brick-makers, etc.) have continued to get sick and possibly died, then this would have hindered settlement development which would then have been significant enough to mention.

7.3.1.2 Dry period (October – March)

Droughts or severe dry periods were brought on predominantly by the high pressure cell over the southwestern Cape and in a few instances the effects from El Niño. The lack of or limited rainfall in the Cape over this period presented its own unique challenges, relative to those experienced in the wet period. The severity of the dry periods was made up of several contributing factors. These included the lack of rainfall, the dominant, strong and dry south-easterlies and scorching temperatures resulted in the withering of some garden crops and the obliteration of grain crops such as wheat, barley, etc. To overcome the wind stress, the grain-type crops would be harvested before those plants reached full maturity. In the gardens, attempts to use protective materials such as branches and mats were implemented but to no avail as the winds were more powerful.

As for the sporadic rainfall, there was not much that the settlers believed they could have done, aside from praying to God for rain as well as thanking God for when rain did fall. Sowing crops was also faced with much difficulties during this time of year owing to the dryness and hardness of the earth. The settlers' equipment was unable to penetrate the earth during this time and only one solution in the first year at the Cape was presented to overcome such an adversity. When the settlers arrived, in the rainy season, at the Cape, they noted the looseness of the soil to be a problem (the settlers realising that this could easily be washed away), so a solution to grow 'sods' (i.e. turf) to hold the soil in place was implemented.

> Slightly better weather. The loose soil will have to be made firm with sods for the rainy season. Due to the dryness of the land, it is still too hard to cut them (13 April 1652, p. 31).

In addition to livestock related challenges during the wet period, in dry periods, the livestock would be left in the fields to perish due to the lack of vegetation and fresh water. Poor human health was not a significant issue in the dry period relative to wet period with only a few mentions in 1652 and slightly more in 1653. This indicates that it was poor shelter from the

cold and a lack of nourishing food upon arrival at the settlement that made the settlers ill and disease prone during the winter months.

7.3.1.3 Contemporary climate and environmental solutions for the southwestern Cape

Many of the adversities faced by the Dutch settlers during the historical study period have become obsolete in contemporary times. This is mainly due to changes of the social environmental setting of the region over time. The Table Bay region (mainly the city of Cape Town) has become urban centric with strategic farming areas that optimize on appropriate climate conditions and suitable topographical landscapes situated on the outlying areas of the southwestern Cape (For example, there is no agriculture, viticulture or cultivation that takes place in snow prone areas such as on mountain peaks). All crops that are unsuitable for the Cape's Mediterranean-type climate (such as wheat and rice) are no longer grown in the Cape. Similarly, animal rearing for human consumption is not done on a macro-economic scale. Man-made dams and reservoirs are built to supply farm crops and citizens with water respectively during times of drought and water shortages. Additionally, aquifers and other ground water sources are used during very trying conditions.

Today, fruit farming (citrus, cherries and peaches) and viticulture are large-scale commercial activities in the southwestern Cape. Much of the fruit grown here are of an export quality and are shipped to developed nations. This indicates that the farming technologies implemented to deal with harsh climate stressors (for example, the strong winds and heavy rainfall during the winter months) are state-of-the-art and work effectively. This illustrates the leaps in adaptation with respect to fruit farming and viticulture through the centuries in the southwestern Cape.

7.3.2 Historical coping strategies to weather extremes

Weather extremes negatively impacted many aspects of the settlers lives from shelter to food to development impairment. The crops were one of the settlers biggest problems at the Cape, be it the dry winds and lack of rain during the summer months or the inundation of rain and sometimes hail events in the winter. Initially, realising that they were to experience a different climate for cultivation purposes than what they were used to, the settlers experimented with many different types of crops in order to determine what would grow under the southwestern Cape weather conditions:

> …the blossoms of the large beans are all falling off, apparently the result of the hail and the continuing cold weather, so we intend planting more and experimenting throughout the year with a little of all the crops in different months in order ultimately to gain experience of the best season for each (19-20 August 1652, p. 55).

> The beans seem to be completely spoilt. Making tests, however, to see whether they will come up. The endive is also growing so well that it is a pleasure to see. Item also the Roman or large beans which are beginning to freshen with the warm weather. Turkish beans were destroyed by the heavy rains (5-6 September 1652, p. 57).

However with time, they found that the weather was very difficult and adopted several different coping strategies in order to minimise or eliminate crop damage. The settlers used techniques that are still common to farming today, in order to adapt to weather stressors, but the materials implemented varied and changed over time. As this was a pre-industrial period, coping strategies were rustic. Regarding the inundation of the gardens, the settlers decided to employ drainage systems to overcome the future inundation of their gardens:

> …all the sown lands of the freeman are submerged, seemingly a regular inundation. It is feared that they will suffer considerable damage. The Company's new garden behind the fort…is almost completely under water and has been washed away by the overflow of the rivers. Much of the work done this year is therefore wasted, but a recurrence next year will be prevented by making embankments and digging wider trenches around it. The Company's ploughed and sown grain-fields, about 20 morgen in extent, are however still reasonably dry and undamaged as a result of the trenches constructed through them which provide adequate drainage to the rivers (28 June 1657, p. 126).

The wind at the Cape always wreaked havoc throughout the 13 year study period. It damaged their grain crops and destroyed their young seedlings in the Company gardens. In most cases it was that inappropriate crops such as wheat were selected for cultivation, but in order to protect all of their crops, many different coping strategies were employed. In 1657, specifically Jan van Riebeeck makes mention to having attempted to shelter the garden crops with protective materials, but to no avail:

> On account of the heavy winds we shall, however, not have much success with the grain and perhaps also with trees, of which we shall have more experience later. This applies especially to the St. Helena citrus trees, still growing fairly well, which were brought here by the *Tulp*, as well as to some hazelnut trees which are growing from nuts received from the Fatherland. Time will show, however, whether they will be able to stand up to the severe squalls which come over the Table Mountain. The alder tree seed has not come up (9 October 1654, pp. 263-264).

> Violent weather. The strong S.S.E., though not as violent as the wind that rolled like thunder over the Table Mountain on the preceding days, is destroying much of the young fruit in the garden, especially the Roman and Turkish beans and the green peas, because however well they are protected with branches and mats, many shelters and fences were blown down (26 October 1657, pp. 164-165).

With time, it became evident that the settlers knew what to expect with regards to their crops and the common seasonal extremes. In this instance, Rijck Overhagen (second in command at Robben Island) writes to Jan van Riebeeck with prior years' wisdom about his expectations for the crops:

> [extract from letter to Commander from Rijck Overhagen] The seed, after being sown, will in the dry season be exposed to the strong S.E. winds. as the island is only sand, whatever does come up will be scorched by the extreme heat (13 July 1658, pp. 311-313).

Heavy winter rains and all-year round harsh wind conditions also hindered settlement development and in most instances damaged infrastructure that was only a few years old. Similarly, with crop damage brought on with weather extremes, Jan van Riebeeck was able to proactively identify negative impacts on certain projects, specifically in certain locations. In one instance, it was noted that he cancelled a project to build a canal on the Cape Flats due to the impacts of heavy rainfall:

> Commander Riebeeck went out early in the morning to inspect the state of the lands after the heavy rains and to find a means of draining off water… He further proceeded into the country into the country, a distance of two hours travelling, to carry out an inspection on the flats where the Hon. Van Goens wished to have a canal dug together with the projected redoubts and ravelins, in order to check the Hottentots. All over the flats we found strong torrents of water coming from the mountain. These would flood and wash away not only the aforementioned canal, but all the redoubts as well, for at many places on the flats there were stretches of water looking like lakes. The labour would therefore be wasted, and the project is best left in abeyance (29 June 1657, pp. 126-127).

7.4 Social responses to the environmental conditions of the 1600s

7.4.1 Mythical Animals

Throughout Jan van Riebeeck's time as governor at the Cape, he sporadically makes mention to certain animals that he obviously had never seen before and so names them closest to what he thinks they may be. Specifically he calls the Cape leopards tigers, and refers to the quaggas as horses. It is most interesting to note that quaggas were a very common animal in the Cape region:

> Last night the tigers killed 6 of our Dutch sheep in the enclosure... In the evening the tigers had also been in the hen-house... (2 May 1655, p. 310).

> …catch some young horses, which are so extraordinarily coloured or marked as is seen nowhere else in the world, and as rarities would be above price (16 November 1658, pp. 378-379).

There were also terms used to describe animals accurately, however these were outdated terms that had to be further researched in order to determine what exactly they were. In this

instance the animal 'hart' was a medieval word for a stag older than 5 years old (Internet Archive 2001: Turbervile, 1575):

> Caught a young hart with the dog today. Tasted like a young lambkin (25 August 1652, p. 56).



Figure 7.3: Picture from the 16th C depicting the hunting of the hart (La Venerie de Jaques du Fouilloux: George Turbervile, 1575 in Internet Archive, 2001)

7.4.2 Coping strategies for crop damage: The case of pests and wild animals

Locusts and worms were pests that were seldom mentioned during the 13 year historical study period. The settlers offered no strategies that were implemented to overcome these pests. Studies on historical locust events in Hung Ho and Huai Ho regions in China found that locust outbreaks would occur 1-2 years after an El Niño episode (Zhang and Li, 1999). Earlier in the chapter (section 7.2.3.1), it was mentioned that Gergis and Fowler (2009) identified El Niño episodes in 1652, 1655 and the period 1659-1661. It was ascertained that 1652 and 1655 could not be related back to the southwestern Cape due to data limitations. However, following from Zhang and Li (1999), the locust outbreak in the southwestern Cape in 1653, a year after an El Niño episode (Gergis and Fowler, 2009), could be used to support the argument that there was an El Niño episode in 1652:

> …having gone about 2 miles behind Table Mountain, found so many locusts there that the earth and sky were hardly distinguishable - as when the air is filled with flying snowflakes. If we judge from the grass which they devour so completely that the earth is left quite denuded, then we must fear that all our crops will be ruined if they come near the fort and in the gardens (9 February 1653, p. 147).

> As a result of this calm weather the country around here and our gardens are full of locusts, causing much damage to the cabbage and other crops (15 February 1653, p. 148).

Although not really mentioned throughout both governors diaries, from the next quote, it would seem that, like weather extremes, wild animals also posed a threat to the destruction of crops. Thorn trees were planted to act as a deterrent:

> Ditches 8 feet wide have already been dug around it and planted with thorn. All the gardens are being planted this way with the said thorn trees which were found wild here and are growing well. When they have become intertwined they will soon be impenetrable even to wild animals, which are at times doing considerable damage to the crops (10 September 1655, p. 341).

7.4.3 Coping strategies to support improved livestock wellbeing

In order to provide food for the sheep during the winter months, a specific plant, which is unfortunately not named, but which grows even during the dry season, was planted throughout Robben Island for the sheep to graze. Through further investigation of the literature around Robben Island, no information on past plants could be identified:

> She [referring to the Company's ship going to Robben Island] also carried some seed of a kind of plant which grows in the open on sandy soil during the dry season and which, it has been found, the sheep eat very readily. For this reason the seed will be sown all over the island so that the sheep will have more pasture when there is no grass during the dry season (15 February 1659, p. 20).

7.4.3.1 Harvest/ sowing dates

In most instances harvest and or reaping of crops are mentioned due to weather extremes (Table 7.5). Throughout the study period it was noted that the settlers would frequently have early harvests, especially of the grain crops, as the wind would be so destructive to crops. If the crops were not being harvested early, then Jan van Riebeeck would mention a large fraction of the crop yield would not make it to harvest:

> …with a clear, bright sky, but the Table Mountain quite covered in clouds. From it the wind comes falling down as if from a bag, blowing ripe corn from the ears; we shall be able to reap hardly a quarter of it. It is a pity that the corn has been so spoilt by the hard winds, otherwise we should have had a good harvest. It grows so extraordinarily well here that it is a joy to behold; on the other hand it is a pity that, as stated before, it is so much damaged by the wind (28 December 1652, pp. 120-121).

> To-day the barley sown on 15 May was reaped, although not fully ripe. We dared not wait any longer, as the squalls from the Table Mountain totally destroy the ears as soon as they are ripe, so that we shall again get nothing from it if we allow it to stand any longer (16 October 1655, p. 352).

Table 7.5: Examples of harvest or sowing times months

Time of Year	Harvest/ Sowing
28 December 1652	Harvesting corn (see quote below)
6 January 1653	reaping the seeds of lettuce, radish, endive, spinach, green peas, wheat
12 December 1653	Harvesting cabbage and turnip
17 July 1654	Sowing wheat (see quote below)
11, 16, 28 December 1654	Harvesting wheat
15 May 1655	Sowed barley (see quote below)
10 December 1658	Harvesting grain
16 October 1655	Harvesting barley (see quote below)

At other times, Jan van Riebeeck would be aware that weather conditions would not be permissible for sowing new crops. On the 30th December 1652, a drought prevented sowing until the following year:

> On account of the drought it seems as if we shall not be able to sow again before February or March, and the return ships from India will find all our potherbs run to seed - except carrots, turnips, radish and beetroot (30 December 1652, pp. 121-122).

Additionally, the common weather extremes in the Table Bay region, forced the settlers to move some of their cultivation activities over to Robben Island. This demonstrates their ability to adapt to their climate environment and shows their determination of making a successful crop out of wheat:

> weather and wind as before. Sent our boat to Robben Island to-day with provisions for the men there, as well as a few shovels and spades for preparing some land to be sown with wheat and other seed by the way of further experiment. As the S.E. winds do not blow so strongly there, we surmise that one would have greater success with harvesting of wheat over there than here (17 July 1654, pp. 250-251).

The next quote demonstrates the settlers' vast experience in cultivating the land. In September 1660, they identified fertile soil and ploughed it for sowing in their next sowing season (May of the following year). They were also cautious to not over-farm the lands and employed fallow techniques to help the soil recover. They also lacked manure for sowing purposes. Furthermore, this can be noted as adaptation as the European settlers were farming for many decades and had knowledge and experience of how to cultivate the land:

> At the foot of this vineyard some very fertile soil has been found, so the Company's farming-superintendent has been ordered to start ploughing it to-morrow so as to have it ready for sowing with wheat in the next sowing season, which is May of next year. A great deal of the old ground has been exhausted so that we shall not sow on all of it but let some of it lie fallow through lack of manure (19 September 1660, p. 257).

7.5 Human drivers of environmental conditions

7.5.1 Human induced damage/ alteration to the natural environment

Crops were very important to the settlers in the southwestern Cape as they provided them with a more reliable and consistent food supply than they could get from fishing or trading livestock. Crop damage from climate factors was therefore a major threat to their survival. However, by contrast, the relatively intensive farming in an otherwise pristine environment is argued to have been the first step in removing many of the native plant species and threatening the endemics such as many of the Protea species (Joubert, 2009). The following quote is one indication of the exertion placed on the land:

> A great deal of the old ground has been exhausted so that we shall not sow on all of it but let some of it lie fallow through lack of manure (19 September 1660, p. 257).

Fish abundance was looked at in great detail in this research (see section 6.7). The quantity of fish caught was tabulated in Table 6.3. Three hypotheses are put forward to explain the abrupt reduction in the number of mentions of fish populations after the settlers' initial years at the Cape (Figure 6.6):

1. The settlers were improving their bartering skills for red meat. Even though fish is referred to being delicious by the settlers, much commentary demonstrated their preference to red meat as it was a more nutritional source, especially for the labourers:

   > To-day the farmer Tielman Hendricxsen of Utrecht caught an eel in his bow net. This is the first one to be caught in the Fresh River. It was twice as thick as a man's arm, fleshy and tasty (14 September 1660, pp. 256-257).

2. Mention was made to large quantities of fish being caught in seines in the beginning years at the Cape (Table 6.3). This tentatively indicates that the settlers could have easily overfished the area in a short space of time:

   > Made a good haul of fish on the beach to-day, about 800, which can supply us for 2 days (5 November 1652, p. 79).

   In contemporary times, overfishing is a huge concern globally and along the South African coastline (Attwood and Bennett, 1995; Shelton et al., 2015). To support continued biodiversity and progress away from overfishing the International Union for Conservation of Nature (IUCN) has created several red lists for species, including fish

species, that should be protected and conserved as they are most susceptible to extinction (Carizzo et al., 2013).

3. Lastly, the fish abundance and the process of catching the fish may have become such a regular occurrence that over time, it became unnecessary or boring to mention.

In addition to aquatic life, the movement of whales over time is interesting to note. During the 13 year period, Jan van Riebeeck would on a regular basis note 'Whales in the bay' (Table 6.2), referring to Table Bay as this is where the original settlement was made:

> Once more many whales in the bay; last night, close to the shore, they made a great hubbub, blowing and behaving noisily (3 August 1652, p. 54).

The timing of the whales' presence in the historical period aligns with the whale season during contemporary times. However, the location of the whales has shifted over time as in the present, tourists will go to Hermanus to see the whales from June to September and they are seldom seen in Cape Town (Findlay, 1997; Finkler and Highman, 2004). This may possibly be due to urbanization.

However, some animals that were present in the Table Bay region are still present today, for example baboons:

> Saw large baboons in various troops on the lower slopes of the Table Mountain (24 July 1652, p. 52)
>
> Saw many baboons feeding at the foot of the Lion Mountain (27 July 1652, p. 52).

7.6 Uses of wildlife:

The seals were used for their skins, whales for their blubber to produce train oil for export, penguin eggs were collected by the hundreds to feed the labourers and other settlers, many attempts were made to hunt game for human consumption but in most instances, the game proved to be very fast moving which made hunting difficult. In contemporary times, much conservation efforts exist for seals, whales and penguins on a global scale. For example, through conservation campaigning, the fur seal industry collapsed worldwide in the mid-19th C (Wickens et al., 1991). Similarly for whales, given the nutritional value of their meat, they are continuously fished especially for Asian markets (Vinding et al., 2015). International sea patrols exist to impose penalties and in some instances imprison those offenders that continue to fish whales (Vinding et al, 2015). Given their size and beauty, whales are continuously

marked as species to conserve and in some instances used as flagship species (Carizzo et al., 2013; Vinding et al., 2015).

7.7 Validity of both diaries as a data source

This study relies predominantly on the diaries of two governors of the Cape as sources of meteorological information. These diaries were selected as their entries spanned a period for which no previous climate reconstructions for southern Africa had been performed, and due to the detailed daily accounts of the weather that they provided. This section is explores the validity of these diaries in specific, and documentary sources in general, in applications of climate and weather reconstructions.

7.7.1 Validity of documentary sources

Documentary sources are used where meteorological records are not available (Nash and Grab, 2010; Nicholson et al., 2012). These include a large range of sources, such as diaries, missionary reports, ship logs and travel journals (Nicholson et al., 2012). Due to the relatively late development of meteorological networks in much of the developing world, there has been a considerable research output for countries such as India (cf. Pant, 2003; Adamson and Nash, 2012), and the countries of southern Africa (Nicholson, 1979, 1981, 2014; Vogel, 1987, 1989; Nash and Endfield, 2002, 2008; Kelso and Vogel, 2007, 2015; Grab and Nash, 2010; Nash and Grab, 2010; Nicholson et al., 2012a, b, 2014; Hannaford et al., 2014, 2015; Nash et al., 2015, 2016). While it could be argued that some information is better than nothing, particularly with the need for long climate records for modelling and projection purposes, it is important to query the validity of these sources. Documentary sources are inherently less accurate than meteorological records as they are subjective and include biases of the author (Kelso, 2010). However, the descriptive nature of these sources potentially adds greater value than meteorological records particularly in descriptive details of a weather phenomenon, such as a type of rain (Nash and Adamson, 2014). Furthermore, these records capture first-hand the human responses to a particular climate event which is not captured by any meteorological record (Nash and Adamson, 2014).

The first advantage of documentary sources is the high temporal resolution of the weather records, with daily to sub-daily information (Nash and Adamson, 2014; Norrgård, 2015). This is particularly valuable when compared to other climate proxies that offer at best an

annual resolution (in the case of tree rings) to decadal and longer (in the case of pollen and diatoms; Fitchett et al., 2016). In further comparison to frequently used Holocene climate proxies, documentary sources also provide clearer evidence of specific climate variables. These also span a greater range than most proxies can provide, often giving accounts of the wind, precipitation, temperature and events such as flooding and drought (Nash and Adamson, 2014).

The greatest limitation of documentary sources of climate information is that because they are often compiled by a single individual, they seldom span more than a few years (Nash and Adamson, 2014). This is particularly problematic as any analysis of climate change requires a continuous record of at least 30 years in length (Parmesan, 2007). In some cases a collection of different documentary records for a particular place may in combination span this minimum period, but in these cases issues of bias and shifts in positionality pose further limitation (Nash and Adamson, 2014). Further limitations can be found summarised in Table 7.6.

Table 7.6: Description of the relative advantages and limitations of documentary evidence as a source for reconstructing past weather and climate (Nash and Adamson, 2014)

Advantages	Limitations
Excellent dating control and high temporal resolution.	Discontinuous nature of many records (e.g., due to partial preservation of material or the death of observers).
Clear identification of different meteorological elements (e.g., temperature, precipitation, snow cover, wind).	Positionality of individual observers may influence their attitudes, biases, and environmental awareness.
Emphasis of observations on climate anomalies and natural disasters.	Emphasis of observations is often short-term, so long-term trends may go unrecognized.
Generally good coverage of months and seasons (although evidence may be biased toward months of sowing and harvest).	Mathematical analysis is simple but robust (although this may be a drawback for the acceptance of results by the scientific community).
Descriptions of conditions are often accompanied by accounts of associated impacts.	Geographical coverage of evidence is often incomplete, as it depends upon (a) the sedentary presence of literate individuals, (b) a tradition of recording eyewitness accounts of extraordinary events, and (c) the existence of appropriate institutional and cultural frameworks to preserve documents.

For southern Africa, robust meteorological records only commenced in the 1800s at the Royal Observatory, and accredited climate records from the South African Weather Service span less than the past 100 years. Consequently, there exists little information regarding the climate or human responses to it in the time prior to this. From an adaptation and coping perspective, it is important to understand these patterns to inform planning and mitigation.

Therefore, if used with caution and with an understanding of the limitations, documentary evidence serves a valuable source in reconstructing past weather and climate.

7.7.2 Validity of diaries as a data source

Accepting that documentary sources are a valid repository of accurate weather and climate information, it is important to determine whether diaries specifically are acceptable. The greatest source of evidence regarding the validity of diaries as a source in documentary based climate, weather and environmental reconstructions is the prevalence of their use by other established academics engaging in documentary based climate research as this establishes this source as an accepted methodology (Nicholson et al., 2012; Nash and Adamson, 2014). As is demonstrated in Table 7.7, diaries have been used as a source of climate and weather information in documentary climate research extensively.

Table 7.7: Historical weather reconstructions based on evidence from diaries since the 18th C

Reference	Time period	Location	Author of the diary	Profession
Lorrey and Chappel, 2015	1839-1851	Northern New Zealand	Richard Davis	Reverend
Roche, 1984	1849-1858	New Zealand	Charles Torlesse	Surveyor
Nash et al., 2015*	19th C	Madagascar	?	?
Miller-Rushing and Primack, 2008	1852-1858	Massachusetts	Henry David Thoreau	Naturalist
Sparks and Carey, 1995	1736-1777	UK	Marsham	Property owner
Norrgård, 2015	1777-1778	Guinea coast	?	?
Endfield et al., 2009	1893-1894	UK	Colvile	Local county official
Adamson and Nash, 2012	1787-1788	India	Dr. Anton Pantaleon Hove	Doctor
Nash et al., 2016	1895	KwaZulu-Natal, South Africa	Thomas Groom	?
Grab and Nash, 2010*	1833-1900	Lesotho, southern Africa	Sir Godfrey Lagden	colonial government official
Nash and Grab, 2010	1824-1900	Lesotho, southern Africa	Sir Godfrey Lagden; ?	colonial government official; Resident Commissioner

* Diaries used as one of many data sources; ? = author name and/ or profession not indicated

Diaries have the benefit of relatively regular daily accounts of features of interest to the author (Norrgård, 2015). This allows for regular climate and weather records to be captured. However, the positionality and bias of the author is of particular concern because as they were not writing for a specific audience, they did not have to edit out or obscure their personal feelings from day-to-day (Nash and Adamson, 2014). The level of education and

occupation of the author of the diaries can to a certain extent mitigate this; one would expect a more accurate account of day-to-day weather from a well-educated person in a position of responsibility. As demonstrated in Table 7.7, the majority of diaries that have been used in the literature on documentary based climate reconstructions have been written by people in positions of responsibility, many of which have had to study to have reached these positions. It can therefore be concluded that should a diary contain regular daily accounts of weather and climate variables, and be written by a person of acceptable educational level and professional standing, that this would be a valid data source for documentary based climate and weather reconstructions.

7.7.3 Validity of Jan van Riebeeck's and Zacharias Wagenaer's diaries

7.7.3.1 Translated diaries

The diaries of Jan van Riebeeck and Zacharias Wagenaer are translated versions from Old Dutch to English (Thom, 1952). There are many biases and exaggerations that may be associated with translated documents for use in historical climate research (Pfister, 2014). In order to make sentences flow, some words will be the choice of the translator but should only be within reason (Jones, 2008). Exaggerations from the original, untranslated works should come through even though it is a translation. For example, for the term 'dirty weather', describing wet, windy, and disturbed conditions, demonstrates that the translator interpreted the words exactly as this gives the reader a more real understanding of what the settlers meant. It also assisted in corroborating to other studies that found the term 'dirty weather' in the diaries used for climate reconstruction (Lorrey and Chappel, 2015).

Despite these limitations, the use of the translations of the diaries rather than the original text can be justified on a number of grounds and is arguably the only scientifically consistent approach. Firstly, accurate translation would require one to have complete fluency of both Dutch and English. Working from a dictionary alone, many of the nuances would be lost, and inconsistencies in meaning would arise. Secondly, translating only portions but otherwise relying on the diaries would result in even further linguistic inconsistencies. Third, the translations used in this study were not the work of one person alone, but rather a team of assistants with one overall editor (Thom, 1952, 1954, 1958). This prevented any biases in interpretation of meaning, particularly for adjectives, deriving from one specific translator, as these would be moderated by the rest of the team (Thom, 1952, 1954, 1958). Details of those

responsible for translation are detailed in Table 7.8. Finally, by using published translations, the reader can refer back to the translated version to gain further detail on information portrayed in any of the selected quotes presented in this dissertation.

Table 7.8: Listed translators of each of the volumes of Thom (1952, 1954, 1958)

Volume	**Translators**
Volume 1: 1652-1655	Prof. H. B. Thom Mr L. C. Van Oordt Mr W. P. L. Van Zyl Mr V. de Kock Mr D. H. Varley Dr. E. E. Mossop Mr V. Walpole
Volume 2: 1656-1658	Prof. H. B. Thom Mr. J. Smuts Mr V. de Kock Mr D. H. Varley Dr. E. E. Mossop Mr V. Walpole
Volume 3: 1659-1662	Prof. H. B. Thom C. K. Johnman A. Ravenscroft Mr W. P. L. Van Zyl Mr V. de Kock Mr D. H. Varley Dr. E. E. Mossop Mr V. Walpole

7.7.3.2 The use of diaries from two different sources

In their capacity as governor, both Jan van Riebeeck and Zacharias Wagenaer met the criteria for holding a position of responsibility, and both were well-educated. Both sets of diaries contained daily entries, with daily accounts of weather conditions. The greatest concern with this record is that it comprised the diaries of two different people. While this allowed for a longer time period to be covered, it incurred errors and inaccuracies due to differences in bias and personal preference of the two authors (Nash and Adamson, 2014). Jan van Riebeeck had a keen eye for the natural environment and agriculture. Because of this, his diary entries were, for the most part, thorough and observation centred. Throughout Jan van Riebeeck's 10 years at the Cape, he recorded the all climate variables on a nearly-daily basis and Zacharias

Wagenaer, began in this vein. However, Zacharias Wagenaer demonstrated more passion for the Cape's socio-political landscape and chose to write instead, in great detail, about the settlers' relationship with the indigenous people. This resulted in the weather chronology results becoming increasingly unreliable due to the lack of detail and inconsistent recording.

Reflecting on the total counts of mentions of both climate and environmental events, a sudden reduction (and in cases absence) of mentions following the handover in 1662 can be observed for the following variables:

- Crop damage
- Drought
- Floods
- Wildlife

Similarly, there were topics that received a greater number of mentions from Zacharias Wagenaer relative to Jan van Riebeeck, namely:

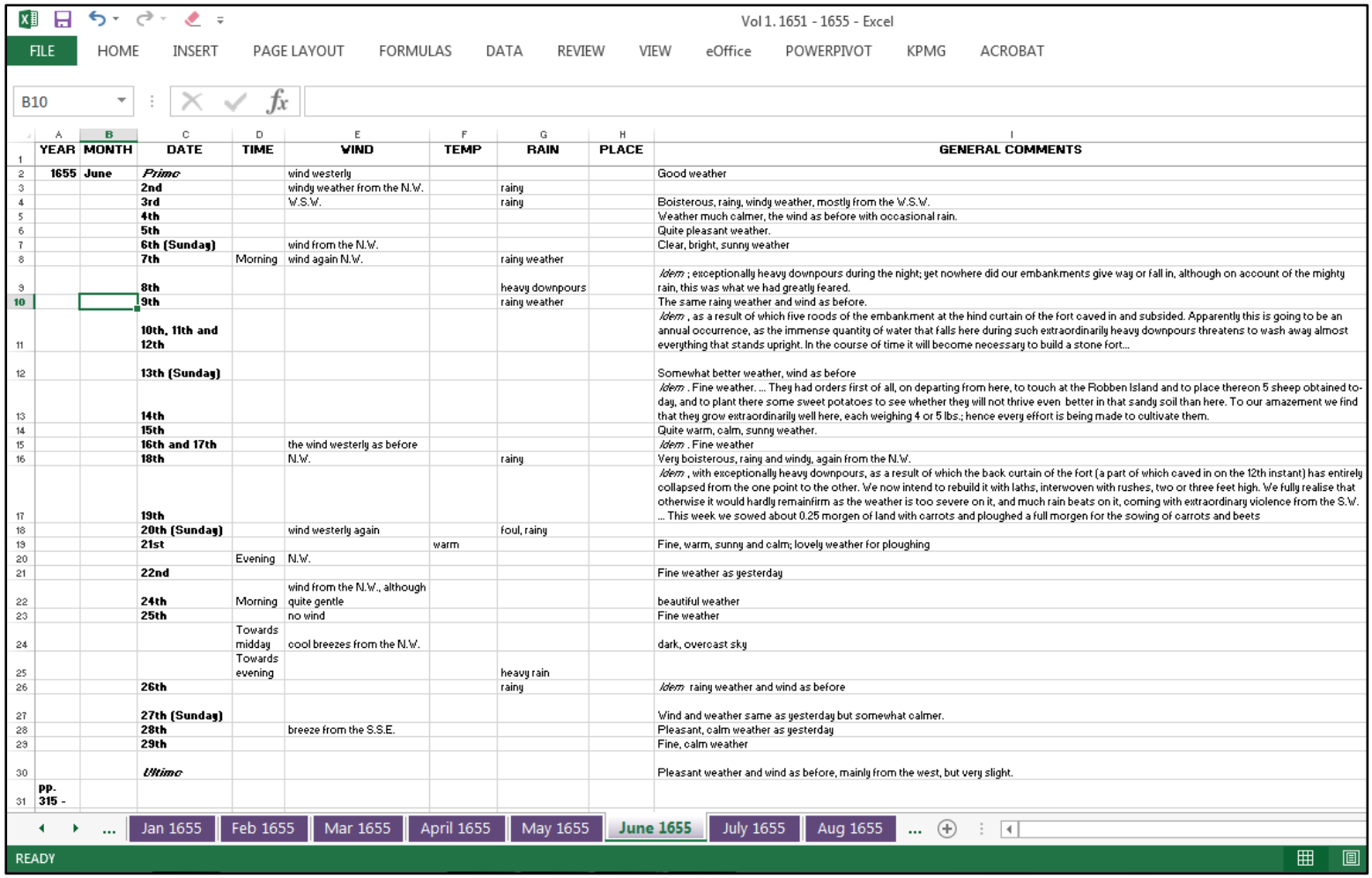
- Livestock well-being
- Damage to settlement

For variables such as drought and flood, it could be argued that these events did not occur during the last three years of the period and that in turn this explains the decrease in mentions of crop damage. However, from the wording of the diaries and the proportional focus on social issues, it is apparent that this is rather a case of a lack of interest in these meteorological variables.

This is well demonstrated when comparing excerpts from the diaries of each author from dates from the same month. A winter month was selected as this period is characterised by persistent rain and strong winds, which are notable climate variables. In July 1655, during Jan van Riebeeck's time, it can be noted that he recorded the weather nearly every day with only two data gaps (the 23rd and 30th) for the month (Figure 7.4).

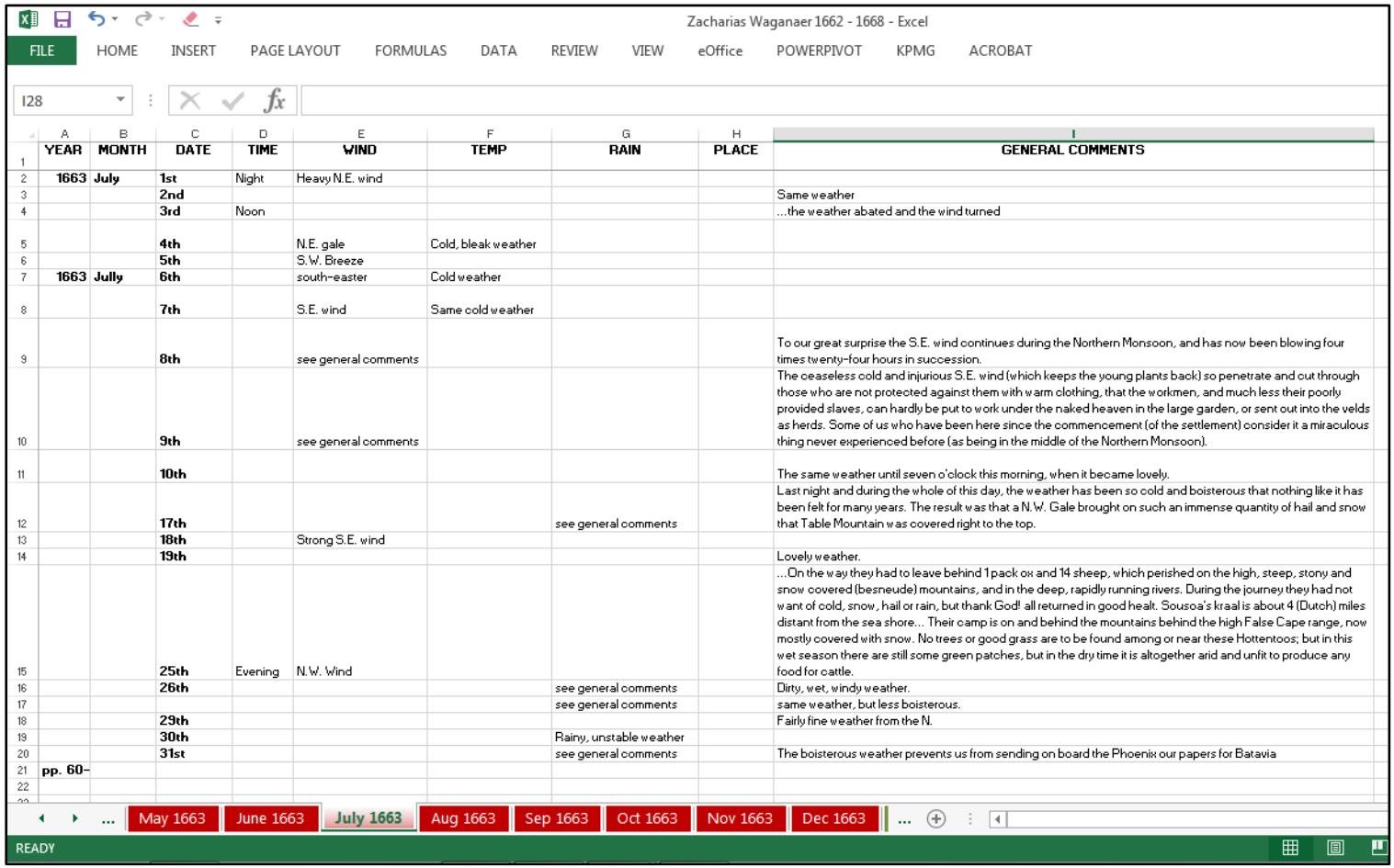
Jan van Riebeeck was thorough in his descriptions, frequently recording the wind direction and strength, the type of rain and also further descriptions for other environmental related activities happening on a particular day (Figure 7.4). Conversely, for Zacharias Wagenaer's recordings for July 1663, two large data gaps are recorded (11th-16th ; 20th-24th; Figure 7.5). It

can also be noted from his general commentary, that he described extreme events and not necessarily the day-to-day daily activities (Figure 7.5).



	A	B	C	D	E	F	G	H	I
1	YEAR	MONTH	DATE	TIME	WIND	TEMP	RAIN	PLACE	GENERAL COMMENTS
2	1655	June	*Primo*		wind westerly				Good weather
3			2nd		windy weather from the N.W.		rainy		
4			3rd		W.S.W.		rainy		Boisterous, rainy, windy weather, mostly from the W.S.W.
5			4th						Weather much calmer, the wind as before with occasional rain.
6			5th						Quite pleasant weather.
7			6th (Sunday)		wind from the N.W.				Clear, bright, sunny weather
8			7th	Morning	wind again N.W.		rainy weather		
9			8th				heavy downpours		*Idem* ; exceptionally heavy downpours during the night; yet nowhere did our embankments give way or fall in, although on account of the mighty rain, this was what we had greatly feared.
10			9th				rainy weather		The same rainy weather and wind as before.
11			10th, 11th and 12th						*Idem* , as a result of which five roods of the embankment at the hind curtain of the fort caved in and subsided. Apparently this is going to be an annual occurrence, as the immense quantity of water that falls here during such extraordinarily heavy downpours threatens to wash away almost everything that stands upright. In the course of time it will become necessary to build a stone fort...
12			13th (Sunday)						Somewhat better weather, wind as before
13			14th						*Idem* . Fine weather. ... They had orders first of all, on departing from here, to touch at the Robben Island and to place thereon 5 sheep obtained to-day, and to plant there some sweet potatoes to see whether they will not thrive even better in that sandy soil than here. To our amazement we find that they grow extraordinarily well here, each weighing 4 or 5 lbs.; hence every effort is being made to cultivate them.
14			15th						Quite warm, calm, sunny weather.
15			16th and 17th		the wind westerly as before				*Idem* . Fine weather
16			18th		N.W.		rainy		Very boisterous, rainy and windy, again from the N.W.
17			19th						*Idem* , with exceptionally heavy downpours, as a result of which the back curtain of the fort (a part of which caved in on the 12th instant) has entirely collapsed from the one point to the other. We now intend to rebuild it with laths, interwoven with rushes, two or three feet high. We fully realise that otherwise it would hardly remainfirm as the weather is too severe on it, and much rain beats on it, coming with extraordinary violence from the S.W. ... This week we sowed about 0.25 morgen of land with carrots and ploughed a full morgen for the sowing of carrots and beets
18			20th (Sunday)		wind westerly again		foul, rainy		
19			21st			warm			Fine, warm, sunny and calm; lovely weather for ploughing
20				Evening	N.W.				
21			22nd						Fine weather as yesterday
22			24th	Morning	wind from the N.W., although quite gentle				beautiful weather
23			25th		no wind				Fine weather
24				Towards midday	cool breezes from the N.W.				dark, overcast sky
25				Towards evening			heavy rain		
26			26th				rainy		*Idem* rainy weather and wind as before
27			27th (Sunday)						Wind and weather same as yesterday but somewhat calmer.
28			28th		breeze from the S.S.E.				Pleasant, calm weather as yesterday
29			29th						Fine, calm weather
30			*Ultimo*						Pleasant weather and wind as before, mainly from the west, but very slight.
31	pp. 315 -								

Figure 7.4: Screen shot from the extraction process of Jan van Riebeeck's diaries, July 1655



	A YEAR	B MONTH	C DATE	D TIME	E WIND	F TEMP	G RAIN	H PLACE	GENERAL COMMENTS
2	1663	July	1st	Night	Heavy N.E. wind				
3			2nd						Same weather
4			3rd	Noon					...the weather abated and the wind turned
5			4th		N.E. gale	Cold, bleak weather			
6			5th		S.W. Breeze				
7	1663	Jully	6th		south-easter	Cold weather			
8			7th		S.E. wind	Same cold weather			
9			8th		see general comments				To our great surprise the S.E. wind continues during the Northern Monsoon, and has now been blowing four times twenty-four hours in succession.
10			9th		see general comments				The ceaseless cold and injurious S.E. wind (which keeps the young plants back) so penetrate and cut through those who are not protected against them with warm clothing, that the workmen, and much less their poorly provided slaves, can hardly be put to work under the naked heaven in the large garden, or sent out into the velds as herds. Some of us who have been here since the commencement (of the settlement) consider it a miraculous thing never experienced before (as being in the middle of the Northern Monsoon).
11			10th						The same weather until seven o'clock this morning, when it became lovely.
12			17th				see general comments		Last night and during the whole of this day, the weather has been so cold and boisterous that nothing like it has been felt for many years. The result was that a N.W. Gale brought on such an immense quantity of hail and snow that Table Mountain was covered right to the top.
13			18th		Strong S.E. wind				
14			19th						Lovely weather.
15			25th	Evening	N.W. Wind				...On the way they had to leave behind 1 pack ox and 14 sheep, which perished on the high, steep, stony and snow covered (besneude) mountains, and in the deep, rapidly running rivers. During the journey they had not want of cold, snow, hail or rain, but thank God! all returned in good healt. Sousoa's kraal is about 4 (Dutch) miles distant from the sea shore... Their camp is on and behind the mountains behind the high False Cape range, now mostly covered with snow. No trees or good grass are to be found among or near these Hottentoos; but in this wet season there are still some green patches, but in the dry time it is altogether arid and unfit to produce any food for cattle.
16			26th				see general comments		Dirty, wet, windy weather.
17							see general comments		same weather, but less boisterous.
18			29th						Fairly fine weather from the N.
19			30th				Rainy, unstable weather		
20			31st				see general comments		The boisterous weather prevents us from sending on board the Phoenix our papers for Batavia
21	pp. 60-								
22									

Figure 7.5: Screen shot from the extraction process of Zacharias Wagenaer's diaries, July 1663

The differences in the level of detail recorded by the two governors are demonstrated in the example demonstrated in Table 7.9 depicting the two wind directions used in this study:

- dominant wind direction (DWD)
- secondary wind direction (SWD)

Table 7.9: Example of the difference in recordings between the two governors for randomly selected years

Jan van Riebeeck: 1658			**Zacharias Wagenaer: 1664**		
Month	**DWD**	**SWD**	**Month**	**DWD**	**SWD**
Jan	SSE	NW	Jan	SE	N/A
Feb	SSE	NW	Feb	SE	N/A
Mar	NW	SSE	Mar	SE	NW
Apr	SSE	NW	Apr	SE	W
May	NW	SE	May	SE	W
Jun	NW	SSE	Jun	W	NW
Jul	NW	SSE	Jul	NW	N
Aug	NW	SSE	Aug	NW	N
Sep	SSE	W	Sep	NW	S
Oct	SSE	W	Oct	SE	N/A
Nov	SSE	W	Nov	SE	N/A
Dec	SSE	NW	Dec	N, E, SE, S	N/A

Notably, Jan van Riebeeck was very thorough in his descriptions of all the wind variables, specifically noting a south south-easterly wind from a south-easterly. Conversely, Zacharias Wagenaer would only note a south-easterly and nothing more and also had many instances where no wind was noted, i.e. N/A (Table 7.9). Although Zacharias Wagenaer did not care much about the day-to-day weather, the variables that had increased in mention demonstrate his keen interest in social dynamics. It was noted that Zacharias Wagenaer cared much about the politics between the Hottentots and the European settlers. He also frequently recorded the abundance of livestock and procurements from bartering with the indigenous people.

Despite the variation of the information recorded across the two diaries, there is, however, additional value of the diaries when combined. Firstly, it allowed for extending the period of study from 10 to 13 years. This was really useful as it was difficult to use other source

documents to extend the record as they were not as comprehensive. Although three years is not a particularly long period, it first, represents a 30% increase in the length of the record and second, allowed for inter-annual variability to be examined, such as El Niño-type conditions during the ENSO year identified by Gergis and Fowler (2009) to be confirmed. Furthermore, considerable development of the Cape took place during this period and it is of interest to observe human responses to climate and the environment in such a context of development and change.

Using two different diaries from within a short time period also offered an opportunity to corroborate the descriptions of seasonal patterns and social environmental experiences made by each of the authors. It also allowed for strong perceptions and unusual diary entries to be interrogated and to be critiqued based on how realistic they were relative to accounts from the other author. One key example would be that of 'dirty rain' as this helped corroborate the use of the term as well as the accuracy of the translation for key terms (refer to Table 5.11).

7.7.3.3 Jan van Riebeeck diaries

Jan van Riebeeck's biography was discussed in great detail in Section 2.2.4. He was a keen traveller and had explored many different regions before becoming governor at the Cape. More so, he also spent a few months at the Cape, when he was part of a rescue trip to collect those stranded from a shipwreck. In this time, he spent time with the indigenous people of the Cape and grew to know the landscape. He reported back to his superiors about going ahead with the refreshment station. He also studied in the medical profession through apprenticeship in his youth. Therefore it could be argued that Jan van Riebeeck was a particularly reliable source of climate information. He had sufficient education, knowledge and experience of climate patterns and the region to understand what was happening and provide a consistent account.

Through the diary entries, one can establish that Jan van Riebeeck had a particularly keen interest for the weather and environment. He also had very scientific mind in the way he observed and documented his finding. He was thorough in his diary entries which assisted in reconstructing the weather for this period and more especially for providing commentary

within a social and environmental context. He would also document any coping strategies that he would wish to implement to overcome weather and other environmental adversities:

> The bay again full of whales; calm weather, favourable to growth and of great benefit to the seed now being put into the soil. In the garden, which we are beginning to restore, the soil is so extraordinarily fine and rich, and is so suitable for being entrenched with the ditches we propose making, that with God's blessing there is no doubt it will prove to be exceedingly fertile. This is already shown to some extent by the fact that the seeds, which had been sown there previously and had been inundated and scattered by water, are coming up at random in several places. Those especially that remained at the corners of some beds, such as cabbage and marrow-peas, are sprouting beautifully, and some of it can still be saved. We hope that the turnips and carrots sown in the dry, sandy soil near the fort will also thrive and mature, which seems fairly likely at present (1 August 1652, p. 53).

Jan van Riebeeck, assumedly through his many travels, was well experienced in understanding the local weather dynamics (for example, he was able to identify that they had docked into Table Bay when the wet season was fast approaching). He was very interested in growing crops and a vegetable and herb garden as many of his accounts were centred around this. In terms of crop damage, the strong winds, hot, dry conditions in the summer and cold, wet conditions in the winter frustrated him as all his efforts to protect his crops were more often than not unsuccessful. He was also able to identify many different types of species such as baboons and deer. In some instances, it could be assumed that he had never come across a particular type of animal species in which case he would use a name of an animal that most closely represented what he saw (for example, he wrote about a ‘small tiger’ when in fact he had meant a Cape Leopard).

In terms of Jan van Riebeeck’s relationships with the indigenous people, he was initially the one to suggest that a fort must be built during the initial settlement at the Cape as he had very little trust in the Hottentots. However, in later years his perceptions of this group of people changed to reflect the following:

> A Hottentot had been bitten by an adder in the foot, which caused it to swell considerably; to prevent the poison spreading, they had bound the leg tightly in two places under the knee and scarified the foot as the bloodletters do, and covered it with warm, fresh cow dung. A man and a woman, kneeling down, sucked the blood from the cuts and spat it out on the cow dung, with all the eagerness of a child at the breast. From this it is evident that these people felt a great affection for one another, especially as all were equally busy contributing to the cure and preservation of this man (20 February 1657, pp. 88-89).

From this, we see that Jan van Riebeeck had the ability to change his perception based on new experiences. This then questions, what other things from his perception may have been changed. Upon further investigation of the weather related quotes, it can be noted that through time he would use phrases such 'usual for this time of year' or '…which is to be expected for this time of the year' which referred to the seasonality changes in the weather. However, on the whole, it can be concluded that Jan van Riebeeck was a reliable weather information source and that based on the comprehensiveness of his entries, more reliance could be placed on him rather than his successors.

7.7.3.4 Zacharias Wagenaer

Zacharias Wagenaer was Jan van Riebeeck's successor at the Dutch settlement at the Cape. From the literature that currently exists, not much is known of him. He spent a shorter time at the Cape than his predecessor (6 years) due to poor health. He was responsible for the building of the water trough and the completion of the settlement. Zacharias Wagenaer's initial diary entries of life at the Cape were in great detail, similar to that by Jan van Riebeeck. However, with time, his interests diverted to the relationships between the settlers and local people. He was more concerned with the trading of European goods for cattle and the socio-economic development of the settlement. This was not a bad use of his time, however, it did somewhat break the consistency in daily recordings as well the variables that were recorded.

As Zacharias Wagenaer was not as frequent in his recordings of the Cape weather as Jan van Riebeeck, a holistic understanding of his awareness of the weather could not be fully ascertained unless individual quotes were used. He would, however, still comment on the major events that would affect society at large (for example, damage to the settlement caused by heavy winds).

His inconsistency in reporting on weather events becomes apparent with regard to mentions of drought and flood. As described in section 7.2.1, there is a progressive decrease in the number of mentions of rain, drizzle type rain in particular, and of floods throughout the study period. This is paired with an increase in the number of mentions of drought, supported by

below average counts of rainfall days, throughout the rest of Jan van Riebeeck's time. However, there are almost no mentions of drought in the three years of Zacharias Wagenaer's governance, despite rainfall counts that were considerably below average. It is therefore possible that either rainfall had increased again but was not mentioned, or that drought persisted and was not mentioned. With no corroborating evidence from meteorological measurements there is no way to validate this, and therefore the results can only be taken at face value.

In some cases, Zacharias Wagenaer was relatively consistent in recording weather events. In the case of 'dirty rain', there was no discernible decrease in the number of mentions from when he took over. He also mentioned hail and snow with the same consistency as Jan van Riebeeck. In both cases these are relatively extreme climate events and so it is possible that he was more aware of these.

7.8 Limitations: problem, solution, what limitation remains

7.8.1 Overcoming biases and exaggerations

The limitations pertaining to the diaries and their translations have already been discussed in this chapter. Another limitation is around the level of bias and exaggeration of weather related events. Extreme weather events are over emphasised in documentary sources and were most likely captured due to the impact it had on society; for example, severe flood events that destroy crops (Kelso and Vogel, 2007; Pfister et al., 2009). For example, because the settlers were dependent on their vegetable garden and grain crops as a large source of their food, when there was a lack of rain in the dry period, it have been a normal event that may have been exaggerated based on their dependence of gaining a good harvest from all their crops. This may also be due less to the 'drought' and more to their inappropriate crop selection (for example wheat and rice) given the climate and topographical setting. The exaggeration of extreme climatic events may also be due to the 'foreigner' not being accustomed to the new climatic conditions now being faced within his/her new environment. An example of this would be the Dutch explorers from the northern hemisphere travelling to the southern hemisphere. The abrupt end of the mentions of certain variables (for example fish abundance

and human health) is noted. Initially human health was reported frequently in the first two years at the Cape, thereafter almost not at all. The potential reasons for this have already been discussed in section 7.3.1.1 above. Similarly, fish abundance is given a decreasing importance over time for reasons explained in section 6.7.

7.8.2 Limitations in extracting quantitative information from qualitative sources

As there was no weather instrumentation available to the settlers for the historical period, they only noted the days that there was rain in most instances the type of rain (drizzle, heavy downpour, etc.). The lack of rainfall amounts restricted the statistical analysis possible. Instead, only rain days and types were used with limited statistics applied and compared to the Royal Observatory and South African Weather Services datasets. These comparisons were done in an attempt to convert the rain days to rainfall amounts and only tentative results were produced. There was also a possibility of the diaries being incomplete in that if rain did fall but the settlers forgot to record it.

Rainfall indices initially used by Vogel (1987, 1989) for South Africa is one of the most accurate methods to quantify the qualitative information found in historical documentary sources. This method has since been used frequently in historical climate studies particularly for southern Africa (cf. Kelso, 2010, Grab and Nash, 2010, Nash and Grab, 2010). The rainfall index methodology does not rely solely on qualitative data and also depends on rainfall amounts. All studies that have used this methodology successfully were able to acquire historical instrumental data, for the time period, to corroborate against. Both the South African Weather Services and Royal Observatory datasets were analysed however, the datasets proved that it wasn't possible to infer an amount. Importantly, description of rainfall type could only be subjectively coded if:

1. Delineations between each rainfall type could be guaranteed to be clear cut and consistently made throughout the study period
2. If there were information regarding the duration of the rainfall event
3. If there were information regarding whether there was more than one occurrence of rain in a given day

4. If there was some way of directing relating rainfall type to a threshold amount of rainfall

Table 7.10: Data requirements to construct a rainfall index

Data Type	Data Availability in this study
Measured rainfall amounts	✗
Measured rainfall days	✗
Accounts of rainfall days	✓
Rainfall type	✓
Rainfall duration	✗
Subjective and consistent delineation in descriptions	✗

The above criteria could not be met, despite efforts to integrate the Royal Observatory and the South African Weather Services data. From Vogel (1989), a rainfall index would require all of the categories reflected in Table 7.10, or else objective instrumental meteorological measurements. Using the combination of rain days and descriptions of rainfall type alone would be inaccurate because it is impossible to tell how much rain would have fallen in a day of drizzle relative to an hour of a heavy storm. Often the diaries didn't mention how long a specific rainfall type persisted for. Even where duration was mentioned, the level of subjectivity is such that it is impossible to differentiate between for example 'heavy drizzle' and 'light rain'. Therefore in an effort to compare these results to the existing literature and to extend the climate chronology for southern Africa (Figure 7.2), rain days were used as a measure of relative rainfall amount, as a year with significantly greater number of rain days is likely to have a greater amount of rainfall (Le Roux, 2015). This has been proven from the contemporary South African Weather Services data for the southwestern Cape (Figure 5.7), which demonstrate a positive relationship between rain days and total annual rainfall. .

Similarly, due to the qualitative nature of wind data extracted, there were limits in the ability to quantify these. Wind directions and wind strengths were analysed on a primary and secondary basis. That is, the most number of wind directions were noted as the 'dominant' wind direction and the second highest number of mentions for a 'secondary wind direction for a given year. The same was applied for wind strength. However, due to the lack of wind

speed related information, the speed of winds at the Cape could not be computed. Furthermore, the dominant wind strengths (DWS) and secondary wind strengths (SWS) may have contained biases and exaggerations as in most cases either a 'breeze' or a 'wind' was mentioned as opposed to a 'squall' or a 'strong' wind (Table 7.11). Due to these limitations, the focus of the research was shifted to seasonal and inter-annual variability patterns. The grids (cf. Figures 5.9; 5.10) were used to identify and depict these patterns.

Table 7.11: Example of dominant and secondary wind strengths between the two governors

Jan van Riebeeck: 1658			**Zacharias Wagenaer: 1664**		
Month	**DWS**	**SWS**	**Month**	**DWS**	**SWS**
Jan	St	B	Jan	B	N/A
Feb	St	B	Feb	St	Sq & Wi
Mar	B	Wi	Mar	B	St
Apr	St&B	Wi	Apr	Wi	B
May	Wi	B	May	Wi	St&B
Jun	B	Wi	Jun	B	N/A
Jul	Wi	St	Jul	Wi	St
Aug	Wi	B	Aug	Sq, Wi & St	N/A
Sep	Wi	B	Sep	St	B
Oct	St	B	Oct	St	N/A
Nov	St	B	Nov	St	N/A
Dec	Wi	B	Dec	B	St

7.8.3 Statistical limitations

7.8.3.1 Length of the data set

The length of the data set used for this study was limited to 13 years. This was due to the lack of continuity of weather related comments by Zacharias Wagenaer. It was also due to lack of comprehensive documentary sources before and after the historical period studied. According to the WMO, data spanning less than 30 years cannot be used for the exploration of climate change trend analysis (Ahas et al. 2002; Parmesan, 2007). This created limitations in calculating the weather changes over time for the historical record. Thus, changes could only

be tentatively determined using the South African Weather Services dataset for comparative purposes.

7.8.3.2 Data Gaps

Manually collected data are inevitable for having missing data. The strength of the statistical analyses and being able to detect patterns accurately is therefore limited (Ahas et al., 2002; Ledneva et al., 2004). As the historical data used for this study worked specifically on when actual mentions were made, interpolation was not used to fill in data gaps as this would skew the relationships with the weather variables (Ledneva et al., 2004; Croitoru et al., 2012). The limitation is that the missing values were distinctly different to the existing data (for example, no mentions made to rain when there may have been rain), this may have produced different weather patterns and relationships. For the Royal Observatory data and South African Weather Service data, all data gaps were stated explicitly by the organisation. For consistency of comparison with the documentary record, interpolation was not performed here either. When exploring long term trends in the Royal Observatory and South African Weather Service data, p-values were calculated to determine whether these relationships were statistically significant despite missing data.

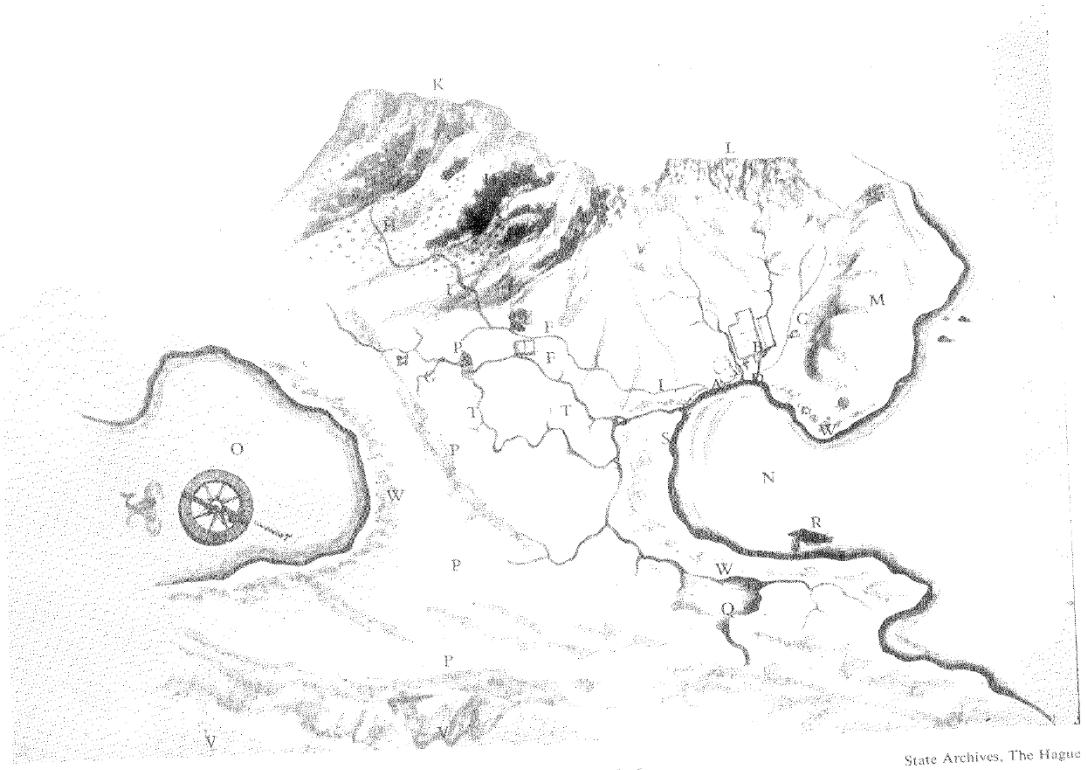
7.8.3.3 Statistical accuracy of averages

Averages were often used to explore inter-annual and inter seasonal patterns in weather mentioned in the diaries. The statistical accuracy of these averages is inherently a function of the number of data points. As a result of data gaps and the short time period, in some cases an average would be made of only a few mentions. This average would be less accurate than an average made from a large number of mentions. For this reason, no averages were taken for the year 1655 as there were only three months of data to work with. In cases where the average was of statistical importance, the standard deviation of the mean was calculated and presented to quantify the accuracy of this mean.

7.8.4 Limitations in the interpretation of qualitative information on the social and environmental conditions

Due to the subjective nature of the data extracted, as well as the subjectivity of the researcher's interpretations, the results produced will be subject to interpretation limitations. The use of the grids and quotes assisted in overcoming these limitations as they offered a method to convey the results objectively. After the quotes were extracted into the general comments data capturing table, it was reread to identify common themes and frequently mentioned social and environmental factors. This easily assisted in creating narrow themes to then sub-categorise the quotes.

Chapter 8: Conclusion



State Archives, The Hague

THE COLONY IN 1656

State Archives, The Hague (Key translated and symbols transcribed)

A THE FORT OF GOOD HOPE.
B COMPANY'S GARDENS.
C BRICK-KILN.
D GARDENER'S HOUSE.
E REDOUBT DUIJNHOOP.
F TWO PLOTS OF LAND AT RONDEBOSCH, SOWN FOR A TRIAL . . . . WITH A SMALL WATCH-HOUSE.
G PROJECTED REDOUBT.
H FOREST BEHIND TABLE MOUNTAIN. . . .
I WAGON ROAD TO THE FOREST FROM WHICH THE COMPANY OBTAINS ITS TIMBER . . . .
K BEHIND TABLE MOUNTAIN — THE SOUTHERN SIDE.
L THE FRONT OF TABLE MOUNTAIN — THE NORTHERN SIDE.
M LION MOUNTAIN.
N TABLE BAY.
O FALSE BAY.
P THE CAPE FLATS.
Q SALT-PANS.
R WRECK OF THE HAERLEM.
S SALT RIVER.
T FRESH RIVERS.
V THE MOUNTAINS OF AFRICA.
W DUNES.

8.1 Introduction

This research dissertation used the historical diaries of Jan van Riebeeck and Zacharias Wagenaer to reconstruct the weather of the southwestern Cape for the period 1652-1665. Furthermore, the rich quotes in the diaries were used to understand the social and environmental variable present at the Cape during this period and the interaction between them and with the European society. This study adds value on several different platforms. It contributes to the ever-expanding regional and local chronology for southern Africa and the southwestern Cape respectively. The findings from the historical synoptic conditions assisted in an improved understanding of the weather in the Cape. Additionally, it will complement

international documentary climate and weather reconstructions produced for the 17th C, and in general the period prior to the instrumental age. These translated diaries were used for purposes that may not have been its original intent, showcasing the versatility of archival documents for contemporary research purposes. As Jan van Riebeeck is a prominent historical figure in South Africa, this study may also supplement local history studies with a social and environmental element.

8.2 Achievement of study aims

The aim of this study was twofold. The primary aim sought to reconstruct a comprehensive weather chronology for the southwestern Cape region, spanning the period 1652-1665 (13 years), and place this in context with the 20th-21st C climate for the region. The diaries addressed the historical component of this aim, while the Royal Observatory data and the South African Weather Services records were used to reconstruct the contemporary period. The weather chronology was broken down into two main variables, i.e. rainfall and wind, statistically analysing both the historical and contemporary data sets. Additionally, anomalous weather phenomena, such as 'dirty rain' and 'black south-easterlies' were identified during the reading of the diaries and data extraction of the Royal Observatory records respectively. Furthermore, weather extremes such as snow and hail events were also presented in great detail. Furthermore, within the weather chronology context, the dissertation aimed to expand on existing chronologies for southern Africa (Nash and Endfield, 2002; 2008; Kelso and Vogel, 2007; Grab and Nash, 2010; Kelso, 2010; Nash and Grab, 2010; Nash et al., 2016; Hannaford et al., 2014) and more specifically the existing southwestern Cape climate record (Vogel, 1989) using documentary-based records.

A secondary aim examined the relationships between the 17th C society and natural environment. The rich qualitative nature of the diaries lent itself to writing a full social and environmental reconstruction supported by quotes from the diaries throughout. In this reconstruction, relationships between the weather and environment; environment and society and; weather and society were explored. The output of this aim was a full descriptive social and environmental chapter (Chapter 6). The discussion chapter (Chapter 7) further investigated the coping strategies employed by the settlers to overcome harsh weather

extremes especially those that were a common occurrence such as excessive winter rain and damaging strong winds. For the social and environmental context, the dissertation aimed to build on the existing work by Kelso (2010) and Kelso and Vogel (2007; 2015) on documentary-based records for the Cape region.

There were three primary research questions for this dissertation, each question consisting of several sub-questions noted in order to fully answer the primary question. In this section, only the primary question will be presented but the answers will take into consideration all sub-questions. The sub-questions can be found in section 1.5.

Primary Question 1

To what extent is it possible to determine historical inter-annual weather patterns/ changes over the southwestern Cape region, based on documentary evidence for the period 1652-1665?

Two methods were employed to determine if distinct wet and dry periods existed for the historical period. First, grids relating to drought and flood conditions individually were produced by counting mentions of each variable. The results showed distinct wet years and dry years based on these mentions alone. A second method involved aggregating the count of historical rain days per year and creating bands of rainfall amounts. From this, each year was allotted into a band (dry, relatively dry, normal, relatively wet and wet) based on its average rain days for the period. Both methods indicated different findings. In the grid method, the years start off relatively wet (for the first three years) and then progress into relative dryness. In the second method using aggregation, similar results are found, however, there are more 'wet' type years at the beginning of the period followed by the 'dry'.

The historical reconstruction of rainfall was based on a count of rain days, and with no mention of rainfall amounts, it was difficult to determine statistical patterns between the historical and contemporary period. Only tentative patterns could be determined on an annual basis. However, inter-annually, for the historical period, many rainfall patterns were found to support the qualitative texts. The rain days differed significantly between the two periods. The historical period had fewer rain days relative to the contemporary. This may be that the

rain days have increased over time or that the authors of the diaries did not record every single rain event.

While rainfall patterns were difficult to interpret, synoptic wind patterns showed much agreement between the historical and contemporary periods, specifically with seasonal variations. The dominant wind directions have not differed much between the 1650s and that during the 20th C. Seasonally, the south-easterlies dominated in the summer and the north-westerlies in the winter. No distinct variations were noted. The dryness of the south-easterlies exacerbated the drought conditions in the dry season and similarly for the north-westerlies that brought on cold, wet conditions during the winter months.

An El Niño episode from 1659 to 1661 is mentioned by Gergis and Fowler (2009). Using the weather conditions for these years from this study El Niño type conditions are detected for periods simultaneous with those presented by Gergis and Fowler (2009). La Niña episodes were not as easy to detect which is in agreement with much of the literature (cf. Gergis and Fowler, 2006; Fitchett and Grab, 2014).

Primary Question 2

To what extent have the historical documents assisted in portraying environmental and/or societal changes in the southwestern Cape during the period 1652-1665?

The richness of the qualitative information presented in the diaries allowed for the presentation of a very descriptive 13 year historical scene. Initially, the settlers struggled with the harsh wet winters that would flood their gardens and the hot, dry summers that would scorch their parched crops along with the strong winds that would severely damage their crops. The settlers were able to adopt many different strategies, especially in their cultivation methods, in order to adapt to the intense weather events. Key coping strategies included the digging of trenches and the building of embankments to redirect excess rain water in the winter months. To overcome the strong winds damaging their crops, the settlers used branches and mats to offer the garden plants protection while in the fields, harvesting was sometimes done slightly earlier (before the grain was ripe) to gain a bigger yield. The livestock gained from the local tribes through bartering suffered at times in both the wet and

dry seasons. In the dry season they would perish due to the heat, lack of vegetation and rainfall. In the wet season they would die of being exposed to the cold and rain. The settlers built a shelter for the livestock to prevent against the winter elements.

The indigenous flora was mentioned very seldom between 1652-1665, and only wild mustard and sorrel leaves were once documented. The settlers collected the seeds from these wild herbs to grow them in their Company's gardens. Relative to indigenous flora, indigenous animals were more frequently mentioned. Wild game such as deer/hart, ostrich, penguins, whales, seals, quaggas, baboons and orang-utan were all mentioned at least one time during the 13 year period. Some animals such as the Cape leopard was mistaken as a tiger by Jan van Riebeeck, who had never in his experience seen a leopard before and so identified to the closest thing he knew. The settlers found much use for the aquatic life available at the Cape. Initially, they would often mention the abundance of fish, catching them in large quantities and describing it to be delicious. They also collected the eggs from the penguins for human consumption, the whales for blubber to produce train-oil for export, the seals for their skins and the deer for game meat.

Upon reflection of the diary entries, it would appear that the settlers did enjoy living at the Cape albeit all their hardships with the harsh weather conditions. The impression one creates of the settlers is that they were a hard-working society with innovative ideas in attempts to combat against weather stressors. Through the writings of Jan van Riebeeck, it is noted that he had a keen interest in cultivation and the natural environment, while Zacharias Wagenaer wrote more on the settlers' relationships with the local tribes.

Primary Question 3

To what extent is it possible to make linkages between inter-annual weather variability over the southwestern Cape region and associated impacts on the natural environment and society for the period 1652-1665?

Due to the comprehensiveness of the qualitative information and given that there were no instrumental data available for the study period, the relationships between the weather, natural environment and society could be easily reconstructed. No matter how small or large, Jan van Riebeeck always recorded the happenings of the natural environment and society,

while Zacharias Wagenaer recorded mostly only large events. Key weather related words such as ‘drought’, ‘flood’, ‘hail’, ‘snow’, ‘wet’, ‘cold’, ‘scorching’, ‘strong winds’ would almost always be used when describing a negative, social environmental impact as a result of the weather extremes. Therefore, linking environmental impacts on society back to the weather could be done with ease. Biases and exaggerations of the authors as well the subjectivity of the interpretations should be taken into account when examining the results of this research.

8.3 Implications of my findings

Much of the literature talks around historical climate work from documentary sources being useful in assisting to understand future climate scenarios (Carey, 2012). However, in the case of this study, its usefulness as an input for climate scenarios is very limited. From a climate science perspective, it can be used (with other similar studies conducted in the region) to understand the seasonality of time periods going forward. It will also assist in the expansion of the southern African chronology. As a secondary outcome, more was learnt about the past society and how they would struggle but persevere through the harshest of weather extremes. This study demonstrated the resilience of the settlers, which can relate to current climate debates. The more detrimental climate is to society, the more innovative humans are to mitigate the negative impacts of climate change. Lastly, considerably more has been understood about Jan van Riebeeck, and the climatic, social and environmental conditions at the time, than was originally anticipated, which could contribute to knowledge gaps in South Africa. Furthermore, given the limited biographical accounts available for Zacharias Wagenaer, this study offers more socially and environmentally inclined accounts on this governor of the Cape.

8.4 Future work

Various South African archives were consulted to retrieve the oldest documents available for the southwestern Cape region. It was established that there is a substantial volume of documents available prior to the 19th C. For the 17th C, however, there are only 13 years of continuous nearly-daily weather entries in the Diaries of Jan van Riebeeck (Thom, 1952,

1954, 1958) and the Precis of the Archives of the Cape of Good Hope (Leibrandt, 1901). This begins from the European settlers' arrival at the Cape. Thereafter, there are several historical documents with scattered and disjointed climatic evidence throughout the 17th C across varying regions of the Cape.

This study explored a glimpse in time of the Dutch settlers in the southwestern Cape. These 13 years offer a basis to expand the chronology further, using the primary and secondary documentary records tabulated in Appendix A. As this study looked at both the weather and social environmental aspects, it will allow future researchers the scope to explore one or both of these topics. The aim should be to fill the gap between the 1600s to the 1820s, as Vogel (1989) addresses the southwestern Cape thereafter. The diary entries of Zacharias Wagenaer could be further researched from a historical social studies perspective, particularly historical relationships between the European settlers and the indigenous people.

More specifically, this study has exposed climatic themes in southern African historical period, which require greater research to be more clearly understood. From this work, conditions associated with a Black south Easter have now been clearly defined, and from this, traces of this event both in the Western Cape and the broader southern African region for more recent historical times can be explored. This research has also raised questions of whether the 'dirty rains' mentioned in the diaries are a phenomenon experienced today. To address this, future work should involve interrogating the translation of this term, and exploring contemporary climate records for events that fit this description. Relating to translation, this study emphasises the reliance on translated works, and exposes the limitations in the length of period covered when only English translated records can be used. Future work should therefore be collaborative in nature and include teams of people with a range of native languages.

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Appendices

Appendix A

CATALOGUE: Potential Sources of Information for Data Collection

University of the Witwatersrand: William Cullen Library

Table A.1: Primary Sources

Title	Author	Location (# denotes that text is available online)	Year	Document Type	Shelf Information (* denotes library use only)
Precis of the archives of the Cape of Good Hope, December 1651 - December 1653	[compiled by] H. C. V. Leibrandt	WITS: William Cullen Library; Durban: Killie Campbell Library; #	1651-1653		Cullen Africa Closed, CD 2355.C2 CAP*; KCAL, 968.71 PRE*
The Khoikhoi at the Cape of Good Hope: seventeenth-century drawings in the South African Library	Smith, Andrew B	WITS: William Cullen Library	Late 17th C.	Drawings	Cullen Africa, DT 1768.K56 SMI*
Scenes from the Cape of Good Hope in 1741 as drawn by Johann Wolffgang Heydt	Heydt, Johann Wolfgang	WITS: William Cullen Library; Durban: Killie Campbell Library	1741		Cullen Africa 4, DT 1813 HEY; KCAL, F 916.871 HEY*
Travels at the Cape, 1751-53 : an annotated translation of Journal historique du voyage fait au Cap de Bonne-Esperance into which has been interpolated relevant passages from Memoires de l'Academie Royale des Sciences	La Caille, Nicolas Louis de/ translated and edited by R. Raven-Hart	WITS: William Cullen Library; Durban: Killie Campbell Library	1751-1753	Journal	Cullen Africa, DT 826 LAC; KCAL, 916.871 LAC*

New travels into the interior parts of Africa : by way of the Cape of Good Hope ; in the years 1783, 84 and 85	Le Vaillant, François	WITS: William Cullen Library; Durban: Killie Campbell Library; #	1780-1785	Cullen Africa Closed, DT 1730 LEV V 1, 2 and 3*; KCAL, XA 916.87 LEV*
Military Mails At The Cape Of Good Hope, 1795-1870	Baker, Ken	WITS: William Cullen Library	1795-1870	Cullen Africa Pam, HE 7351 BAK*
Walks and sketches at the Cape of Good Hope / a facsimile edition with new introduction by Frank R. Bradlow	Semple, Robert	WITS: William Cullen Library; Durban: Killie Campbell Library; #	Starts 5 September 1800	Cullen Africa, DT 2020 SEM; KCAL, 916.87 SEM; PAM 916.871 SEM*
History of Southern Africa : comprising the Cape of Good Hope, Mauritius, Seychelles	Martin, Robert Montgomery	WITS: William Cullen Library; Durban: Killie Campbell Library; #	Early 1800s	Cullen Africa Closed, DA 11 MAR*; KCAL, SR 916.8 MAR*
Adventures at the Cape of Good Hope in 1806	Nahuys van Burgst H. G. 1782-1858	WITS: William Cullen Library	1806	Cullen Africa, DT 2044 NAH
CAPE OF GOOD HOPE. Accounts and receipts: The documents relate to taxes, land, rent, tuition, goods.		WITS: William Cullen Library	1812 - 1878	Historical Papers, A224f*
CAPE COLONY, Commercial document, Dutch 1814 : Relates to a public auction held by the Orphan Masters in respect of a house and adjoining property at the foot of Table Mountain.		WITS: William Cullen Library	1814	Historical Papers, A380f*
The Present State Of The Cape Of Good Hope	Kolb, Peter	Cape Town Campus & Pretoria Campus; WITS: William Cullen Library; Durban: Killie Campbell Library		Cape Town General Colle FB.5480-5481; Cape Town General Colle G.26.a.12, 12a Second ed. of v; Cape Town General Colle G.16.b.1 Second ed. of v.1 onl; Cape Town Special colle AZ.986.7024T/KOL; Pretoria Foreign SA Mat missing; Cullen Africa, DT 826 KOL V. 1 and V. 2; KCAL, XA 916.871 KOL*

Table A2: Secondary Sources

Title	Author	Location (# denotes that text is available online)	Year	Document Type	Shelf Information (* denotes library use only)
Seven Khoi lives : Cape biographies of the seventeenth century	Schoeman, Karel, 1939	WITS: William Cullen Library	1600s		Cullen Africa, DT 1768.K56 SCH
Jan van Riebeeck, 1618-1677	Pelzer, A. N. (Adriaan Nicolaas Petrus), 1915-	Cape Town Campus & National Library SANB & Pretoria Campus; WITS: William Cullen Library	1618-1677	Biography	Cape Town General Colle A.920.PEL ; Cape Town General Colle A.Dup.13682 ; Pretoria SANB, 54-20589 968.03 RIE; Cullen Africa Closed, DT 843.2 RIE P*
Cape Good Hope 1652-1702 : the first fifty years of Dutch colonisation as seen by callers / translated with notes by R. Raven-Hart.	Raven-Hart, Rowland	WITS: William Cullen Library, Durban: Killie Campbell Library	1652-1702		Cullen Africa 4, DT 1813 RAV V 1 and V 2; KCAL, F 916.871 CAP*
Early slavery at the Cape of Good Hope, 1652-1717	Schoeman, Karel	WITS: William Cullen Library	1652-1717		Cullen Africa Overnight, HT 1394.C1 SCH
The Swiss at the Cape of Good Hope 1652-1971	Linder, Adolphe	WITS: William Cullen Library	1652-1971		Cullen Africa, DT 1768.S95 LIN
The Cape Of Good Hope And Foreign Contacts 1735-1755	Boucher, Maurice	WITS: William Cullen Library; Durban: Killie Campbell Library	1735-1755		Cullen Africa, DT 843 BOU; KCAL, 968.7 BOU*
The Reconstruction Of The Nineteenth Century Cape Climate Using Documentary Evidence	Vogel Coleen Heather	WITS: William Cullen Library	1820-1900	Masters Dissertation	Cullen Thesis, QC 991.S7.C1 VOG
Cape Town : city of good hope	Honikman, A. H.	WITS: William Cullen Library	1966		Cullen Africa 4, DT 2405.C5 CAP
The Cape Of Good Hope: A Maritime History	Knox-Johnston, Robin	WITS: William Cullen Library			Cullen Africa, HE 903.4 KNO
A history of Southern Africa	Walker, Eric A. (Eric Anderson), 1886-	WITS: William Cullen Library & Wartenweiler Library			Cullen Africa Closed, DT 732 WAL, DT 732 WAL*; Main Library. Short loan Section, DT 732 WAL c.2
Maps of the South Western Cape of Good Hope: a bibliography		WITS: William Cullen Library			Cullen Africa, Z 6027.W82 MAP

Pretoria Archives

Table A3: Primary Sources

Title	Author	Location (# denotes that text is available online)	Year	Document Type	Shelf Information (* denotes library use only)
Journals of the expeditions of Olof Bergh (1682 and 1683) and Isaq Schrijver (1689)		Cape Town Campus & National Library SANB & Pretoria Campus	1682-1683, 1689		Pretoria SANB, 54-19563 916.87 BER
Guillaume Chenu de Chalezac, the French boy : the narrative of his experiences as a Hugenot refugee, as a castaway among the Xhosa, his rescue with the Stavenisse survivors by the Centaurus, his service at the Cape and return to Europe, 1686-9	Vigne, Randolph, 1928-	Cape Town Campus & National Library SANB & Pretoria Campus	1686-1689		Cape Town General Colle 575.e.1233(II,22) c.3; Cape Town General Colle A.1994-282; Cape Town General Colle PZ.1011; Pretoria SANB, 93-3584 B29 4918
The early Cape Hottentots	O. Dapper, W. T. Rhyne and J. G. De Grevenbreek	National Library SANB & Pretoria Campus; Van Riebeeck Society	1686-1695		Pretoria SANB, 54-9105 572.9687 DAP
A bibliography of personal accounts of the Cape of Good Hope in printed books : 1715-1850 (compilation)	Schmidt, K. L. M. (Käthe Luise Margaret)	Cape Town Campus & National Library SANB & Pretoria Campus	1715-1850	bibliography	Pretoria SANB, 54-0147 016.91687 SCHMIDT
Vol. 2: Natural history of the Cape. Present State of the Cape of Good-Hope	Kolb, Peter	Pretoria Campus	1731		Pretoria Foreign SA Mat, G173625 PP (Val)
Briefwisseling van Hendrik Swellengrebel Jr oor Kaapse sake 1778-1792	Swellengrebel, Hendrik, 1734-1803	Cape Town Campus & Msunduzi Legal Deposit & National Library SANB & Pretoria Campus; Van Riebeeck Society	1778-1792		Cape Town General Colle 575.e.1233(II,13) c.3, ON SHELF; Cape Town General Colle A.1984-700, ON SHELF; Cape Town General Colle PZ.1011, ON SHELF; Pretoria General, G171847, ON SHELF; Pretoria SANB, 83-3536 B48 4776, ON SHELF
The Journal of Hendrik Jacob Wikar (1779)		Cape Town Campus & National Library SANB & Pretoria Campus	1779		Pretoria SANB, 54-19256 916.08 WIK

Life at the Cape in mid-eighteenth century : being the biography of Rudolf Siegfried Allemann, captain of the military forces and commander of the castle in the service of the Dutch East India Company at the Cape of Good Hope	Mentzel, Otto Friedrich	Cape Town Campus & Msunduzi Legal Deposit & National Library SANB & Pretoria Campus; Durban: Killie Campbell Library	1781		Pretoria General, G185995; Pretoria SANB, CR 968.7 MENTZEL; KCAL, 968.71 ALL/MEN*
A Geographical and topographical description of the Cape of Good Hope. Pt. 3 / by O.F. Mentzel ; translated from the original German by G.V. Marais and J. Hoge ; revised and edited with an introduction and footnotes by H.J. Mandelbrote	Mentzel, O. F. (Otto Frederick)	National Library SANB & Pretoria Campus, Durban: Killie Campbell Library; Van Riebeeck Society; #	1787 (original in German)		Pretoria SANB, 54-19620 916.87 MRN; KCAL, 916.871 MEN PT.1*
The Cape diaries of Lady Anne Barnard, 1799-1800	Barnard, Anne Lindsay, Lady, 1750-1825	Cape Town Campus & Msunduzi Legal Deposit & Msunduzi Reference & National Library SANB & Pretoria Campus; Van Riebeeck Society	1799-1800		Cape Town General Colle 575.e.1233; Cape Town General Colle A.DUP.32217; Cape Town General Colle PZ.1011; Pretoria SANB, 99-2927 B40 4682 v. 1; Pretoria SANB, 99-2928 B40 4682 v. 2
Travels in Southern Africa in the years 1803, 1804, 1805 and 1806	Lichtenstein, Hinrich, 1780-1857	National Library SANB & Pretoria Campus; #	1803-1806		Pretoria SANB, 916.87 LICHTENSTEIN
Cape Almanac of 1829, Cape of Good Hope Annual register		Pretoria Campus	1829		
Life at the Cape a hundred years ago / by a Lady ; with contemporary illustrations selected from the work of Thomas Bowler	Lady (S.G.B.)	Cape Town Campus & National Library SANB & Pretoria Campus	1854-1872		Pretoria SANB, 85-0019 B01 0051
The reports of Chavonnes and his Council, and of Van Imhoff, on the Cape : with incidental correspondence	Translated by Margaret Ralling	Cape Town Campus & Msunduzi Legal Deposit & National Library SANB & Pretoria Campus		English version of the extracts from a letter, two reports…	Pretoria General, G185994; Pretoria SANB, CR 968.7 CHAVONNES
Travels and adventures in southern Africa. Part 1, 2 and 3	Thompson, George, 1796-1889	National Library SANB & Pretoria Campus; Van Riebeeck Society			Pretoria SANB, CR 916.804 THOMPSON
Cape of Good Hope official gazette		Pretoria Campus		microfilm	Pretoria General, MS00171 1957-1970*

Table A4: Secondary Sources

Title	Author	Location (# denotes that text is available online)	Year	Document Type	Shelf Information (* denotes library use only)
Old Cape Colony : a chronicle of her men and houses from 1625 to 1806	Trotter, Alys Fane	National Library SANB & Pretoria Campus	1625 - 1806		Pretoria SANB, CR 968.7 TROTTER
Jan van Riebeeck and the Hottentots, 1652-1662	Goodwin, A. J. H.	National Library SANB & Pretoria Campus	1652-1662		Pretoria SANB, missing
Dutch South Africa : early settlers at the Cape, 1652-1708	Hunt, John	Cape Town Campus & Pretoria Campus	1652-1708		Cape Town Campus, A.2006-867*; Pretoria Reference, G302961 R968.703 HUN
The Silversmiths and goldsmiths of the Cape of Good Hope, 1652-1850	Morrison, Mollie N.	National Library SANB & Pretoria Campus	1652-1850		Pretoria SANB, 739.237687 MORRISON; 54-11641 739.2109687 MOR; CR 739.23 MORRISON
Jan van Riebeeck, 1652-1952 : souvenir brochure	O'Connell, T	National Library SANB & Pretoria Campus	1652-1952		Pretoria SANB, 54-20530 968 CON
South Africa's heritage (1652-1952) : the story of white civilisation in South Africa from the landing of the first Dutch settlers with Jan van Riebeeck to the present day	South Africa. State Information Office	Cape Town Campus & National Library SANB & Pretoria Campus	1652-1952		Cape Town General Colle A.Q.968 UNI; Cape Town General Colle A.dup.22082; Cape Town General Colle A.Q.968 UNI French; Pretoria General,G188699; Pretoria SANB, OP 06368
The Wreck of the Grosvenor		Cape Town Campus & National Library SANB & Pretoria Campus; Durban: Killie Campbell Library	1790-1791		Pretoria SANB, 54-19122 910.453 CAR; KCAL, 910.45 WRE*
The First British occupation of the Cape of Good Hope, 1795 -1803 : a bibliography	Wagner, Mary St. Clair.	National Library SANB & Pretoria Campus; Durban: Killie Campbell Library	1795 -1803	bibliography	Pretoria SANB, 54-0171 016.9687 WAGNER; KCAL, R 016.96871 WAG*
Memorial of certain farmers, landholders, and others of the district of Peddie / Cape of Good Hope	Cape of Good Hope (South Africa)	Cape Town Campus & National Library SANB & Pretoria Campus			Cape Town General Colle CGP.A 53-1863*; Pretoria SANB, OP 08595
Cape of Good Hope Western Province Exhibit	Empire Exhibition (1936-1937 : Johannesburg, South Africa)	National Library SANB & Pretoria Campus	1936-1937		Pretoria SANB, 54-9606 708.968 CAT; 54-11449 708.968 CAT; 54-11467 708.968 CAT

Jan van Riebeeck and the Dutch Settlement at the Cape	Johnson Barker, Brian, 1939-	Cape Town Campus & National Library SANB & Pretoria Campus			Cape Town General Colle AQ.1990-325; Cape Town General Colle AQ.1990-325(missing); Pretoria SANB, A 89-1993 B39 6787
Owning the land : history of South Africa from Jan van Riebeeck to John Balthazar Vorster	Lekhela, Simon McDover Mohau	National Library SANB & Pretoria Campus			Pretoria SANB, 2008-0456 B18 SANB copy: sign
History, productions, and resources of the Cape of Good Hope : official handbook	Noble, John, 1837-1898	National Library SANB & Pretoria Campus; Durban: Killie Campbell Library; #			Pretoria SANB, OP 08978; KCAL, 916.87 HIS*
The story of Jan van Riebeeck	Worm, Piet.	Cape Town Campus & National Library SANB & Pretoria Campus			Cape Town General Colle AJ.823 WOR; Pretoria SANB, 54-20972 968.7 WOR

Durban: Killie Campbell Library

Table A5: Primary Sources

Title	Author	Location (# denotes that text is available online)	Year	Document Type	Shelf Information (* denotes library use only)
The Cape of adventure : being strange and notable discoveries, perils, shipwrecks, battles upon sea and land, with pleasant and interesting observations up the country and the natives of the Cape of Good Hope	extracted from the writings of the early travellers by Ian D. Colvin	Durban Killie Campbell Library; #	starting in the 1400s		916.8 CAP*
Roteiro da Africa do Sul e sueste desde o Cabo da Boa Esperanca ate ao das Correntes, 1576 = Roteiro of the south and south-east Africa from the Cape of Good Hope to Cape Corrientes, 1576	Mesquita Perestrelo, Manuel de	Durban Killie Campbell Library	1576		500 MES*
An account of the Cape of Good Hope and the Hottentotes [i.e. Hottentots], the natives of that	Rhijne, Willem ten	Durban Killie Campbell Library	1600s		F 916.871 RHI*

country

Precis of the Archives of the Cape of Good Hope. Letters and documents received, 1649-1662	H.C.V. Leibbrandt	Durban Killie Campbell Library; #	1649-1662	Letters and documents	968.71 PRE*
Precis of the Archives of the Cape of Good Hope. Riebeeck's Journal, etc.	H.C.V. Leibbrandt	Durban Killie Campbell Library; #	pt. 1. 1652-1655, pt. 2. 1656-1658, pt. 3. 1659-1662	Diaries	968.71 PRE*
Personal accounts of the Cape of Good Hope written between 1652 and 1715	Engels, Louise J.	Durban: Killie Campbell Library	1652-1715		R 016.96871 ENG*
Adventure at the Cape of Good Hope in December 1672 /by Jan Pietersz Cortemunde	Henning Henningsen and translated and annotated by Douglas and Vera Varley	Durban: Killie Campbell Library	1672		968.71 COR*
Rambles through the Archives of the Colony of the Cape of Good Hope, 1688-1700, First series	H.C.V. Leibbrandt	Durban Killie Campbell Library; #	1688-1700		968.71 LEI*
A new voyage round the world : describing particularly the isthmus of America… the Cape of Good Hope and Santa Hellena ... (Cape of Good Hope: v. 1, p. 528-544)	Dampier, William	Durban Killie Campbell Library	1697		SR 910.4 DAM*
Precis of the Archives of the Cape of Good Hope. Letters despatched, 1696-1708	H.C.V. Leibbrandt	Durban Killie Campbell Library; #	1696-1708	Letters	968.71 PRE*
Historico-geographical dissertation concerning the kaffirs living in the vicinity of the Cape of Good Hope	Beulwitz, Anton Friedrich von	Durban: Killie Campbell Library	1707	Dissertation	PAM 306.0896867 BEU*
Description of the Cape of Good Hope with the matters concerning it…	Valentyn, François	National Library SANB & Pretoria Campus, Durban: Killie Campbell Library; Van Riebeeck Society	1726		Pretoria SANB, 74-1871; KCAL, 916.87 VAL*
A chart of the western coast of Africa [map] : from the eleventh degree south latitude to the Cape of Good Hope	G. Child sculpt	Durban Killie Campbell Library	1738	Map	Housed in map cabinet in numerical sequence according to accession no ("No. XIV Chart III. Vol:1" below bottom border)*

An account of the astronomical, geographical and physical observations made at the Cape of Good Hope in 1751, 1752 and 1753 by order of the French King	La Caille, Nicolas Louis de	Durban Killie Campbell Library	1751-1753		520 LAC*
A map of the Cape of Good Hope & the country adjacent, 1752	Gibson, J.	Durban Killie Campbell Library	1752	Map	MAPS*
The observations of the internal contact of venus with the sun's limb in the late transit made in different places of Europe, compared with the time of the same contact observed at the Cape of Good Hope, and the parallax of the sun from thence determined	Short, James	Durban Killie Campbell Library	1761-1762		520 SHO*
A voyage round the world performed by order of His Most Christian Majesty in the years 1766, 1767, 1768 and 1769	Bougainville, Louis de	Durban Killie Campbell Library; #	1766-1769		SR 910.4 BOU*
A voyage to the Isle of Mauritius, (or, Isle of France), the Isle of Bourbon and the Cape of Good Hope & C. with observations and reflections upon nature and mankind	Saint-Pierre, Bernardin de	Durban Killie Campbell Library; #	At Cape from 1768, 1734-1814		XA 916.982 BER*
Travels in Europe, Africa and Asia performed between the years 1770 and 1779	Thunberg, Carl Peter	Durban Killie Campbell Library	1770-1779		XA 910.4 THU*
Travels at the Cape of Good Hope 1772-1775	Thunberg, Carl Peter, 1743-1828	Cape Town Campus & Msunduzi Legal Deposit & National Library SANB & Pretoria Campus; Durban: Killie Campbell Library	1772-1775		Cape Town General Colle A.1989-203; Cape Town General Colle A.Dup.25109; Cape Town General Colle 575.e.1233(II,17); Pretoria Foreign SA Mat G176344; Pretoria SANB, 87-3626 B45 4864; KCAL, 916.87 THU*
A voyage to the Cape of Good Hope, towards the Antarctic Polar Circle, round the world and to the country of the Hottentots and the Caffres, from the year 1772-1776	Sparrman, Anders, 1748-1820	Cape Town Campus & Msunduzi Legal Deposit & National Library SANB & Pretoria Campus; Durban: Killie Campbell Library; #	1772-1776		Cape Town General Colle A.968.7025.T/SPA; Cape Town General Colle 575.e.1233 (II, 6-7); Pretoria SANB, 76-1690 Vol. 1; Pretoria SANB, 77-1498 Vol. 2; KCAL, 916.87 SPA/ XA 916.87 SPA*
Natural history and description of the tyger-cat of the Cape of Good Hope	Forster, John Reinhold	Durban: Killie Campbell Library	1780		PAM 599 FOR*

An account of the Cape of Good Hope : containing an historical view of its original settlement by the Dutch, its capture by the British in 1795 and the different policy pursued there by the Dutch and British governments : also a sketch of its geography, productions, the manners and customs of the inhabitants, &c. &c. : with a view of the political and commercial advantages which might be derived from its possession by Great Britain	Percival, Robert	Durban Killie Campbell Library; #	Starts 1796		XA 916.87 PER/ PAM 916.87 PER/ACC*
The loss of the ship Hercules, 16th June, 1796	Stout, Benjamin	Durban: Killie Campbell Library	1796		910.45 STO*
An account of travels into the interior of Southern Africa in the years 1797 and 1798 : including cursory observations on the geology and geography ... the natural history ... the animal, vegetable and mineral kingdoms and sketches of the physical and moral characters of the various tribes ...	Barrow, John, Sir, 1764-1848	Cape Town Campus; Durban: Killie Campbell Library; #	1797-1798		Cape Town General Colle AZ.1991-10*; Cape Town General Colle Hof.d.19*; Cape Town General Colle A.968.7031.T/BAR*; KCAL, 916.87 BAR / XA 916.87 BAR*
The Cape journals of Lady Anne Barnard, 1797-1798	edited by A.M. Lewin Robinson, with Margaret Lenta and Dorothy Driver	Durban: Killie Campbell Library; Van Riebeeck Society	1797-1798	Journals	968.71 BAR*
South Africa a century ago, 1797-1801	Barnard, Anne, Lady	Durban Killie Campbell Library; #	1797-1801	Letters written from the Cape of Good Hope	968.71 BAR*
Diary of a journey to the Cape of Good Hope and the interior of Africa in 1802 and 1803	De Mist, Augusta Uitenhage	Durban: Killie Campbell Library	1802-1803	Diary	916.87 DEM*
General remarks on the Cape of Good Hope	Pallandt, A. van	Durban Killie Campbell Library	1803		968.71 PAL*
Gleanings in Africa : exhibiting a faithful and correct view of the manners and customs of the inhabitants of the Cape of Good Hope, and surrounding country with a full and comprehensive account of the system of agriculture adopted by the colonists, soil, climate, natural products etc, interspersed with observationa and reflections on the state of slavery in the southern extremity of the African continent in a series of letters from an English officer during the period in	Anonymous	Cape Town Campus; Durban: Killie Campbell Library	1806		Cape Town General Colle AZ968.7031T/GLE; Cape Town General Colle A dup 2002, 2003, 2004; KCAL, 916.8 GLE*

which that colony was under the protection of British government ; illustrated with engravings.					
A century ago : the S.C.A. in 1807 : a letter from George Middlemiss, a soldier in the 72nd regiment, dated Cape Town, Cape of Good Hope, Sept. 16, 1807	Middlemiss, George	Durban Killie Campbell Library	1807	Letter	PAM 248 MID*
Travels in the interior of Southern Africa	Burchell, William J.	Durban Killie Campbell Library; #	1810		F 916.87 BUR*
Narrative of a voyage in the Indian seas, in the Nisus frigate, to the Cape of Good Hope, Isles of Bourbon, France, and Seychelles [i.e. Seychelles] ... during the years 1810 and 1811	Prior, James	Durban Killie Campbell Library	1810-1811		916 PRI*
James Ewart's journal : covering his stay at the Cape of Good Hope, 1811-1814, and his part in the expedition to Florida and New Orleans, 1814-1815	Ewart, James, 1791-1823	Durban: Killie Campbell Library	1811-1814	Journals	916.871 EWA*
Management of crown forests at the Cape of Good Hope under the old regime and under the new	Brown, John Croumbie	Durban Killie Campbell Library; #	1812		630 BRO*
Voyages to and from the Cape of Good Hope in the years 1812 and 1814 : for the entertainment of young people	Campbell, John	Durban Killie Campbell Library	1812-1814		SR 910.4 CAM*
Journal of a visit to South Africa in 1815 and 1816 : with some account of the missionary settlements of the United Brethren near the Cape of Good Hope	Latrobe, C. I. 1758-1836	Durban: Killie Campbell Library; #	1815-1816	Journal	F 916.87 LAT / SR 916.87 LAT*
The journals of Sophia Pigot, 1819-1821	Pigot, Sophia	Durban: Killie Campbell Library	1819-1821	Journals	968.75 PIG*
Sketches of some of the various classes and tribes inhabiting the colony of the Cape of Good Hope and the interior of Southern Africa : with a brief account descriptive of the manners and customs of each	W. R. and L. Dickinson	Durban Killie Campbell Library	1820s	Sketches	F 760 JW*
The Cape of Good Hope and the Eastern Province of Algoa Bay	Chase, John Centlivres	Durban: Killie Campbell Library; #	1820		916.87 CHA*
The Royal Observatory at the Cape of Good Hope 1820-1970 : a sesquicentennial offering	edited by J.D. Laing	Durban: Killie Campbell Library	1820-1970		520 ROY*
Maclear & Herschel : letters & diaries at the Cape of Good Hope, 1834- 1838	Maclear, Thomas	Durban: Killie Campbell Library	1834-1838	Letters and diaries	520 MACL*
The voyage of Peter Kolben, A.M. to the Cape of Good Hope	Kolb, Peter	Durban Killie Campbell Library			SR 916.871 KOL*

The method of hunting the elephant at the Cape of Good Hope. An authentic account of the manners and customs of the Hottentots : taken from the Abbe de la Caille's Journal to the Cape of Good Hope	La Caille, Nicolas Louis De	Durban Killie Campbell Library			PAM 799 MET*
Travels from the Cape of Good Hope into the interior parts of Africa : including many interesting anecdotes... descriptive of the country and inhabitants	Le Vaillant, Francois	Durban Killie Campbell Library; #	Published 1790		916.87 LEV / XA 916.87 LEV*
Scenery of Africa: a series of views of the most remarkable localities, celebrated for picturesque beauty or historical and other associations	Drawn by S. Owen, Esqr. (From Milbert). Engraved by George Cooke	Durban Killie Campbell Library		Drawings	SR 916 SCE*
A brief account of Bushman folk-lore and other texts	Bleek, Wilhelm Heinrich Immanuel	Durban Killie Campbell Library; #	1875		SR 306.0896819 BLE*
Narrative of an exploratory tour to the north-east of the colony of the Cape of Good Hope	Arbousset, Thomas and F. Daumus	Durban: Killie Campbell Library			916.85 ARB*
The Cape of Good Hope	Blundell, J. W. F.	Durban Killie Campbell Library			PAM 916.871 BLU*
Cape of Good Hope	Cary, John	Durban Killie Campbell Library		Map	MAPS*
Lectures on the emigration of the Dutch farmers	Cloete, Henry	Durban: Killie Campbell Library; #			968.033 CLO, SR 968.4 CLO*
Cape of Good Hope	drawn and engraved by John Cooke under the direction of A. Arrowsmith	Durban Killie Campbell Library		Map	MAPS*
The Huguenot settlement at the Cape of Good Hope	Hinde, W. H.	Durban Killie Campbell Library			968.71 HIN*
Klare besgryving van Cabo de Bona Esperanca = A Clear description of the Cape of Good Hope	Hondius, Jodocus 1563-1611	Durban: Killie Campbell Library			916.8 HON*
The far interior : a narrative of travel and adventurefrom the Cape of Good Hope across the Zambesi to the lake regions of Central Africa	Kerr, Walter Montagu	Durban Killie Campbell Library; #			916.8 KER*
Icebergs near the Cape of Good Hope	Sir Hudson Lowe	Durban Killie Campbell Library			PAM 969.82 SIR*
Cape of Good Hope		Durban Killie Campbell Library		Map	Housed in map cabinet no 39 marked on bottom right hand corner)*

Table A6: Secondary Sources

Title	Author	Location (# denotes that text is available online)	Year	Document Type	Shelf Information (* denotes library use only)
The Portuguese in South Africa : with a description of the native races between the River Zambesi and the Cape of Good Hope during the sixteenth century	Theal, George McCall, 1837-1919	Durban Killie Campbell Library; #	1500s		968 THE*
Natal, Cape of Good Hope : a grazing, agricultural and cotton-growing country : comprising descriptions of this well-endowed colony, from the year 1575 to the present time, by government officials and travellers	Christopher, J. S.	Durban Killie Campbell Library; #	1575 to present		916.84 CHR*
Fortifications of the Cape of Good Hope prior to the first settlement and during the governership of Van Riebeeck	Emms, Mervyn	Durban: Killie Campbell Library	Prior to 1652		F 968.71 EMM*
Masters of the castle : a portrait of the Dutch commanders and governors of the Cape of Good Hope, 1652-1795, 1803-1806	Picard, Hymen Willem Johannes	Durban: Killie Campbell Library	1652-1795, 1803-1806		968.71 PIC*
The Cape of Good Hope, 1652-1833 : an account of its buildings and the life of its people	Pearse, G. E.	Durban: Killie Campbell Library	1652-1833		720 PEA*
Children of bondage : a social history of the slave society at the Cape of Good Hope, 1652-1838	Shell, Robert Carl-Heinz	Durban: Killie Campbell Library	1652-1838		326 SHE*
The parliament of the Cape : being a narrative of the parliament and councils of the Cape of Good Hope from the founding of the colony by Van Riebeeck in 1652 to the Union of South Africa in 1910 : to which is added a list of governors from 1652 to 1910 and a complete list of members from 1825 to 1910	Kilpin, Ralph	Durban: Killie Campbell Library	1652-1910		328 KIL*
Slaves and free blacks at the Cape, 1658-1700	Böeseken, A. J.	Durban: Killie Campbell Library	1658-1700		968.7 BOE*
Birds of passage : distinguished travellers to the Cape of Good Hope from 1710-1896.	Masson, Madeleine	Durban: Killie Campbell Library	1710-1896		916.87 MAS*
Louis Michel Thibault, 1750-1815; his official life at the Cape of Good Hope	Puyfontaine, Huguette Roy de	Durban: Killie Campbell Library	1750-1815		F 720 THI/PUY*
Enlightment and emancipation: Southern African perspectives on the eighteenth and early nineteenth centuries	Durban: University of Natal, 1989	Durban: Killie Campbell Library	1700 - 1800s		F 968 ENL*

The great treks : the transformation of southern Africa, 1815-1854	Etherington, Norman	Durban: Killie Campbell Library	1815-1854		968 ETH*
Settlers to the Cape of Good Hope : organisation of the Nottinghamshire party, 1819-1820	Burton, Clive	Durban: Killie Campbell Library	1819-1820		PAM 968.75 BUR*
French speakers at the Cape in the first hundred years of Dutch East India Company rule : the European background	Boucher, M. (Maurice)	Durban: Killie Campbell Library			968.71 BOU*
The results of veld-burning	Compton, R. H.	Durban Killie Campbell Library			PAM 574 COM*
Maps and diagrams of human migration and the settlement and expansion of the Cape of Good Hope	Evans, Stanley 1916-2004	Durban Killie Campbell Library		Maps and diagrams	EF 325.687 EVA*
Along Cape roads : being the wanderings of a stranger at the Cape of Good Hope	Fairbridge, Dorothea 1862-1931	Durban Killie Campbell Library	1928		823 FAI*
A list of South African indigenous plants used as remedies by the colonists of the Cape of Good Hope	Pappe, L.	Durban Killie Campbell Library			SR 580 PAP*
Lords of Stalplein : biographical miniatures of the British Governors of the Cape of Good Hope	Picard, Hymen W. J.	Durban: Killie Campbell Library			968.7 PIC*
Wild flowers of the Cape of Good Hope	Rice, Elsie Garrett	Durban Killie Campbell Library			580 RIC*
Liberated Africans and labour at the Cape of Good Hope in the first half of the nineteenth century	Saunders, Christopher	Durban: Killie Campbell Library			F 968.7 SAU*
The forests and forest flora of the Colony of the Cape of Good Hope	Sim, Thomas R.	Durban Killie Campbell Library			SRF 630 SIM*
History of the colony of the Cape of Good Hope…	Wilmot, Alexander	Cape Town Campus; Durban: Killie Campbell Library; #	? - 1819		Cape Town Fairbridge, FB.5790; KCAL, 968.7 WIL*
Breaking the chains : slavery and its legacy in the nineteenth-century Cape Colony	edited by Nigel Worden & Clifton Crais.	Durban: Killie Campbell Library			326 BRE*

Cape Town Archives

Table A7: Primary Sources

Title	Author	Location (# denotes that text is available online)	Year	Document Type	Shelf Information (* denotes library use only)
The voyage of François Leguat of Bresse, to Rodriguez, Mauritius, Java and Capo of Good Hope, 1637-1735	François Leguat	#	1637-1735		Internet Archive
Journal of jan van riebeeck : v.1 1651-1655, v.2 1656-1658 and v.3 1659- 1662	Thom H B (ed.)	Cape Town Campus	1651-1662		Cape Town General Colle
"Dagboek" of Van Riebeeck's time for 11th June, 1654 (Orig. Transcript)[picture]		Cape Town Campus & National Library Visual Collection	1654		Cape Town Pictures, POR (11126)
[Letters and placcaten, 1654-1700, from the Dutch East India Company and from Governors of the Cape]	Generale Nederlandsche Geoctroyeerde Oost-Indische Compagnie	Cape Town Campus	1654-1700	Letters	Cape Town Grey Collecti G.38.b.20
Simon van der Stel's journey to Namaqualand in 1685 / with a revised introduction by Maria Waterhouse ; transcription of the original text by G. C. de Wet ; English translation by R. H. Pheiffer	Van der Stel, Simon	Cape Town Campus & Msunduzi Legal Deposit	1685		Cape Town Special colle AZF.1979-3
Simon van der Stel's journal [in Dutch with English tr.] of his expedition to Namaqualand, 1685-6	Van der Stel, Simon	Cape Town Campus	1685-6		Cape Town General Colle AZQ.968.7023TVAND
The Diary of Adam Tas (1705-1706)	Tas, Adam (1668-1722)	#	1705-1706	Diary	Internet Archive
The Cape of Good Hope and Its Dependancies	Benjamin Stout	#	1785		Internet Archive
Records of the Cape Colony from February 1793 (Volumn 1-35)	Great Britian Public Record Office	#	1793		Internet Archive

Catalogue of documents from 16th September 1795 to 21st February 1803, in the collection of colonial archives at Cape Town	Compiled by Theal, George McCall	#	1795-1803	Letters and Journals	Internet Archive
A voyage to South America and the Cape of Good Hope: in His Majesty's gui brig The Protector	Keith, George Mouat, Sir	#	Starting 1806	Journal	Internet Archive
'A WEST VIEW OF THE FAMOUS PASS NEAR THE CAPE OF GOOD HOPE, CALLED HOTTENTOT HOLLANDS KLOFFE	PRATTENT, T	Cape Town Campus & National Library Visual Collection		Picture	Cape Town Pictures, ARA (8446)
'THE CAPE OF GOOD HOPE' - TABLE BAY WITH SHIPS [picture]		Cape Town Campus & National Library Visual Collection			Cape Town Pictures, ARB (8450)
REPROD OF 'A WINE FARM, CAPE OF GOOD HOPE', DRG BY C E PEERS WITH PAN VIEW OF CAPE DUTCH HOMESTEAD [picture]		Cape Town Campus & National Library Visual Collection			Cape Town Pictures, PHC (7761)
Jan van Riebeeck Collection		Cape Town Campus		Manuscript	Cape Town Manuscripts, MSC 28
A map of the Cape of Good Hope with its true situation		Cape Town Campus			Cape Town Maps, KHA CPA 1704

Table A8: Secondary Sources

Title	Author	Location (# denotes that text is available online)	Year	Document Type	Shelf Information (* denotes library use only)
Jan van Riebeeck : a biographical study	Leipoldt, C. Louis (Christiaan Louis), 1880-1947	Cape Town Campus	1619-1677		Cape Town General Colle Mss.S.A.C.24 ; Cape Town General Colle A.Dup.6213
Jan van Riebeeck en die vestiging van die eerste blankes 1652-1662	Schoeman, Karel, 1939-	Cape Town Campus & Msunduzi Legal Deposit	1652-1662		Cape Town General Colle AQ.2010-263
Cape of Good Hope ..: a place of refuge : the Cape of Good Hope 1688-2025?	Robin M. Pinard	Cape Town Campus	1688-2025?		Cape Town General Colle RES.A.9878
Furniture from European trading posts at the Cape of Good Hope and in South-east Asia 17th - 19th centuries		Cape Town Campus	17th - 19th C		Cape Town General Colle AQ.2004-330
Smallpox at the Cape of Good Hope in the eighteenth century	Ross, R. J. (Robert John), 1949-	Cape Town Campus; #	1700s		Cape Town General Colle AP.1997-205
Footprints in time : Cape	Perry, J. G. (John Godwin), 1909-	Cape Town Campus & Msunduzi Legal Deposit			Cape Town General Colle A.920.0687 PER; Pretoria SANB, 74-1378

International Archives

United Kingdom, England

University of London: School of Oriental and African Studies Archives

Table A9

Title	Year	Document Type	Shelf Information/ Ref. No.
Home, 1799 (Joint letter by Joseph Hardcastle and John Eyre, London to Capt. Thomas Robson George Lmabert, Hull – Dr Johannes Vanderkamp's arrival at the CoGH)	1799	Letters	CWM/LMS/01/06/01/005
Home, 1834 (Letter by William Reeve, CoGH – returning from Madras)	1834	Letter	CWM/LMS/01/06/01/043
Portraits of Livingstone's Friends and Relations (engraving of Rev J. C. Brown, missionary, Cape of Good Hope)	n.d.	Engraving	CWM/LMS/01/09/04/08
Society Islands, 1799 (Peter Hodges, Cape of Good Hope)	1799	Letters	CWM/LMS/02/02/004
Australia, 1848 (Captain Robert Morgan, on board John Williams, Cape of Good Hope)	1848	Letters	CWM/LMS/03/02/052
South Africa,1799 (Thomas Haweis, Bath Joseph Hardcastle, London, Dr Johannes Vanderkemp, Cape of Good Hope)	1799	Letters	CWM/LMS/05/02/02/003
South Africa,1800 (25 letters from Cape Town written by various people)	1800 – 1801	Letters	CWM/LMS/05/02/02/004
South Africa,1801 (26 letters from Cape Town/ Cape of Good Hope written by various people)	1801	Letters	CWM/LMS/05/02/02/005
South Africa,1802 (41 letters – many of these written in the Cape region)	1802	Letters	CWM/LMS/05/02/02/006
South Africa,1803(25 letters from Cape Town written by various people)	1803	Letters	CWM/LMS/05/02/02/007
South Africa,1804 (31 letters – many of these written in the Cape region)	1804	Letters	CWM/LMS/05/02/02/008
South Africa,additional (1801-11) (8 letters- some regarding the Cape of Good Hope)	1801 – 1811	Letters	CWM/LMS/05/02/02/009
South Africa,1805 (26 letters- some regarding the Cape of Good Hope)	1804 – 1805	Letters	CWM/LMS/05/02/02/010
South Africa,1806 (50 letters- some regarding the Cape of Good Hope)	1806	Letters	CWM/LMS/05/02/02/011

South Africa,1807 (27 letters- some regarding the Cape of Good Hope)	1807	Letters	CWM/LMS/05/02/02/012
South Africa,1808 (18 letters- some regarding the Cape of Good Hope)	1808	Letters	CWM/LMS/05/02/02/013
South Africa,1809 (33 letters- some regarding the Cape of Good Hope)	1809	Letters	CWM/LMS/05/02/02/014
South Africa,1810 (34 letters- some regarding the Cape of Good Hope)	1810	Letters	CWM/LMS/05/02/02/015
South Africa,1811 (51 letters- some regarding the Cape of Good Hope)	1811	Letters	CWM/LMS/05/02/02/016
South Africa,1812 (40 letters- some regarding the Cape of Good Hope)	1812	Letters	CWM/LMS/05/02/02/017
South Africa,1813 (36 letters- some regarding the Cape of Good Hope)	1813	Letters	CWM/LMS/05/02/02/018
South Africa,1817 (82 letters- some regarding the Cape of Good Hope)	1817	Letters	CWM/LMS/05/02/02/022
Holland,1802 (9 letters- some regarding the Cape of Good Hope)	1802	Letters	CWM/LMS/07/02/01/005
Holland,1807 (8 letters- some regarding the Cape of Good Hope)	1807	Letters	CWM/LMS/07/02/01/010
South India (General),1809 (John Hands, near Cape of Good Hope, South Africa)	1809	Letters	CWM/LMS/10/02/01/009
South India (General),1816 (Richard Knill, on board the Moira [Deal, England], at Cape of Good Hope)	1816	Letters	CWM/LMS/10/02/01/016
South India (Tamil),1818 (Cornelius Traveller, Funchal, Madeira and Cape [of Good Hope, South Africa])	1818	Letters	CWM/LMS/10/02/04/002
North India (Bengal),1816 (Henry Townley, Cape of Good Hope)	1816	Letters	CWM/LMS/11/02/01/009
Madagascar,1812 (John Campbell, Cape of Good Hope)	1812	Letters	CWM/LMS/13/02/02/003
John Campbell Papers (John Campbell, Travels in South Africa, undertaken at the request of the Missionary Society [London: 1815])	1772-1840	Various	CWM/LMS/20/02/05
Rev Barnabas Shaw	1816	Various	MMS/17/02/04/08

University of Oxford: Rhodes House Archives

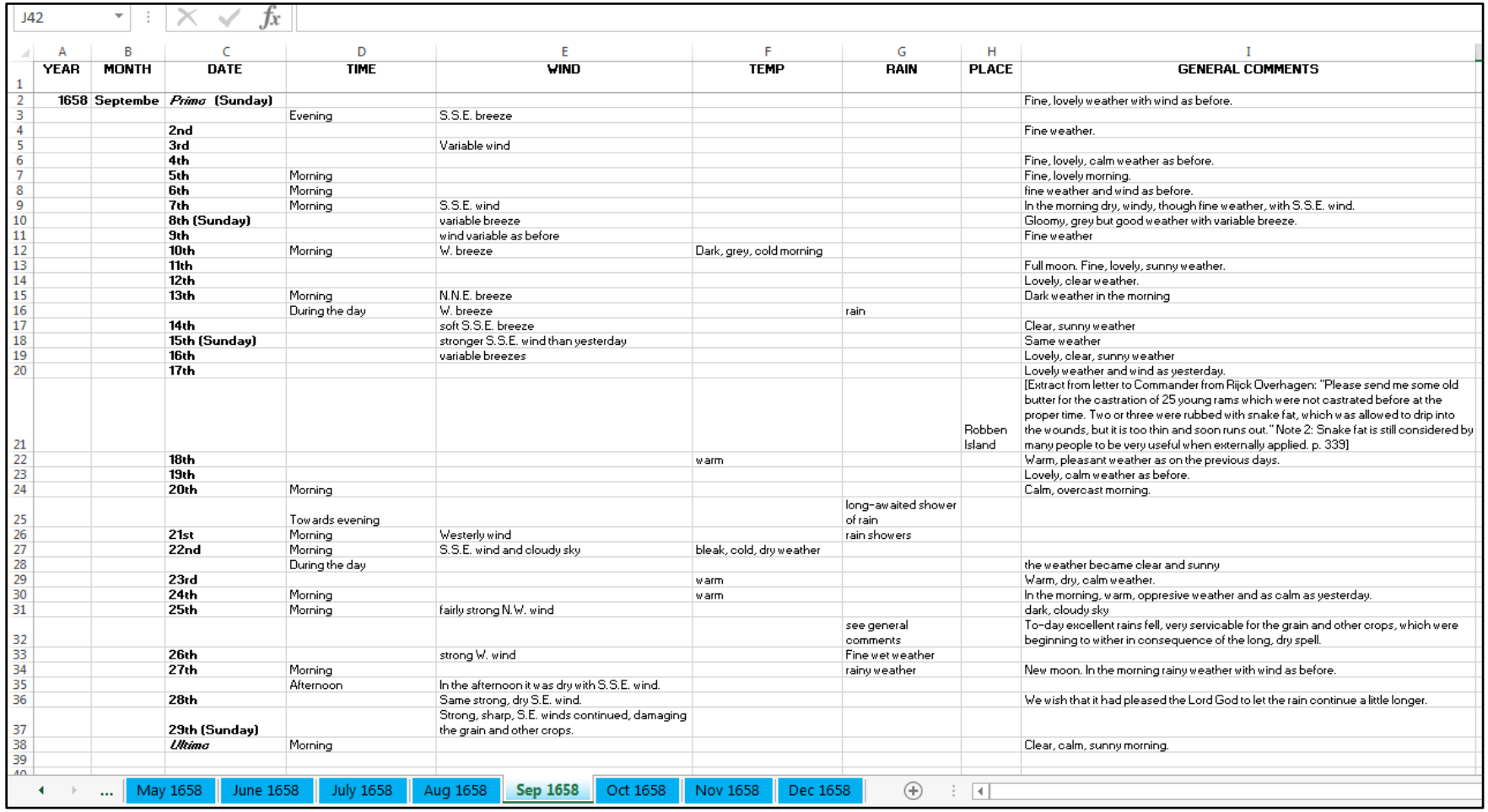
University of Cambridge: Scott Polar Research Institute

Table A.10

Title	Author	Location	Year	Document Type	Shelf Information (* denotes library use only)
Correspondence of George Macartney, 1st Earl Macartney, whilst Governor of the Cape of Good Hope	George Macartney	The Bodleian Library of Commonwealth and African Studies at Rhodes House	1797-1798, 1801	Various	GB 162 MSS.Afr.t.2-4
Cape Colony Letters	Robert White and others	The Bodleian Library of Commonwealth and African Studies at Rhodes House	1795-1880	Letters	GB 162 MSS.Afr.s.1,2
Papers of General Sir Richard Bourke	Richard Bourke	The Bodleian Library of Commonwealth and African Studies at Rhodes House	1816-1845	Letters, papers and correspondence	GB 162 MSS.Afr.t.7
Sir John Barrow collection	Sir John Barrow	Scott Polar Research Institute, University of Cambridge	1818-1843	Correspondence	GB 15 Sir John Barrow
Robert Hood collection	Robert Hood	Scott Polar Research Institute, University of Cambridge	1811-1821	Expedition material on microfilm	GB 15 Robert Hood
Papers of William Sherard	William Sherard	Sherardian Library of Plant Taxonomy, Bodleian Libraries, University of Oxford.	17th-early 18th century	Drawings of Cape of Good Hope Plants	GB 1046 MSS. Sherard 44-201

Appendix B:

Example of the database created in Excel for extracting weather and, social and environmental information



	A	B	C	D	E	F	G	H	I
1	YEAR	MONTH	DATE	TIME	WIND	TEMP	RAIN	PLACE	GENERAL COMMENTS
2	1658	Septembe	*Primo* (Sunday)						Fine, lovely weather with wind as before.
3				Evening	S.S.E. breeze				
4			2nd						Fine weather.
5			3rd		Variable wind				
6			4th						Fine, lovely, calm weather as before.
7			5th	Morning					Fine, lovely morning.
8			6th	Morning					fine weather and wind as before.
9			7th	Morning	S.S.E. wind				In the morning dry, windy, though fine weather, with S.S.E. wind.
10			8th (Sunday)		variable breeze				Gloomy, grey but good weather with variable breeze.
11			9th		wind variable as before				Fine weather
12			10th	Morning	W. breeze	Dark, grey, cold morning			
13			11th						Full moon. Fine, lovely, sunny weather.
14			12th						Lovely, clear weather.
15			13th	Morning	N.N.E. breeze				Dark weather in the morning
16				During the day	W. breeze		rain		
17			14th		soft S.S.E. breeze				Clear, sunny weather
18			15th (Sunday)		stronger S.S.E. wind than yesterday				Same weather
19			16th		variable breezes				Lovely, clear, sunny weather
20			17th						Lovely weather and wind as yesterday.
21								Robben Island	[Extract from letter to Commander from Rijck Overhagen: "Please send me some old butter for the castration of 25 young rams which were not castrated before at the proper time. Two or three were rubbed with snake fat, which was allowed to drip into the wounds, but it is too thin and soon runs out." Note 2: Snake fat is still considered by many people to be very useful when externally applied. p. 339]
22			18th			warm			Warm, pleasant weather as on the previous days.
23			19th						Lovely, calm weather as before.
24			20th	Morning					Calm, overcast morning.
25				Towards evening			long-awaited shower of rain		
26			21st	Morning	Westerly wind		rain showers		
27			22nd	Morning	S.S.E. wind and cloudy sky	bleak, cold, dry weather			
28				During the day					the weather became clear and sunny
29			23rd			warm			Warm, dry, calm weather.
30			24th	Morning		warm			In the morning, warm, oppresive weather and as calm as yesterday.
31			25th	Morning	fairly strong N.W. wind				dark, cloudy sky
32							see general comments		To-day excellent rains fell, very servicable for the grain and other crops, which were beginning to wither in consequence of the long, dry spell.
33			26th		strong W. wind		Fine wet weather		
34			27th	Morning			rainy weather		New moon. In the morning rainy weather with wind as before.
35				Afternoon	In the afternoon it was dry with S.S.E. wind.				
36			28th		Same strong, dry S.E. wind.				We wish that it had pleased the Lord God to let the rain continue a little longer.
37			29th (Sunday)		Strong, sharp, S.E. winds continued, damaging the grain and other crops.				
38			*Ultimo*	Morning					Clear, calm, sunny morning.
39									