Quantifying climate suitability for tourism in Réunion Island.

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Supervisor: Prof Jennifer Fitchett

DECLARATION

I declare that this thesis is my own, unaided work. It is being submitted for the Degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

(Signature of candidate)

19th day of December 2024 at 15:00pm

ABSTRACT

Globally, tourism is dependent on climate. Small islands are the most vulnerable tourism destinations to climate change threats. One such tourism destination is Réunion Island, a French Department located in the southwest Indian Ocean. Tourism climate indices have been used since the 1980s to quantify, classify and compare the climatic suitability of tourism destinations. Most, if not all, have been used in isolation with one specific index being used to quantify a destination's climate in what increasingly appears to be a checkbox exercise. This study does not seek to do this. It looks beyond simple quantification and is one of the first studies to critically assess the use of multiple indices in the southern hemisphere. Réunion Island is particularly well suited for this assessment given its diverse forms of tourism, topography and microclimates. This study presents the first analysis of climatic suitability for tourism for the island over a 33-year time period. Adopting a model inter-comparison approach, the results from the Tourism Climate Index (TCI), Holiday Climate Index for urban tourism (HCI_{Urban}), Holiday Climate Index for beach tourism (HCI_{Beach}) and the Camping Climate Index (CCI) will be presented. Before use, an applicability, suitability and validity assessment is applied, finding all four indices to be appropriate for this context. Data from 11 meteorological weather stations in Réunion for the period ranging between 1991-2023 were used to calculate each index for the available requisite data. Mean annual climatic suitability scores for the TCI range from 50-75.6 classified as 'acceptable' to 'very good' across all available stations. HCI_{Urban} mean annual scores range between 56.9-61.6 classified as 'acceptable' to 'good' while HCI_{Beach} scores range between 69.3-75.4 classified as 'good' to 'very good'. Mean annual scores for the CCI are less favourable ranging between 3.6-5.8 classified as 'unfavourable' to 'acceptable'. Results also show that Réunion offers winter peak seasonality for the TCI and HCI while the CCI shows a bimodal seasonality distribution. Change in climatic suitability over time sees TCI and HCI_{Urban} scores experiencing a greater change in suitability than the HCI_{Beach} and the CCI. A multi-index approach reveals differences in seasonal and overall climatic suitability for the island across the tourism types available. This approach is beneficial in describing the climatic suitability for tourism more accurately, identifying the nuances in suitability for different tourism types and is therefore a valuable approach to use in future studies.

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LIST OF ABBREVIATIONS, ACRONYMS AND KEYWORDS

3S	Sun, sand, surf tourism
AR6	Sixth Assessment Report
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASI	Adaption Strain Index
ATSIT	Acclimatization Thermal Strain Index for Tourism
Austral	Within the southern hemisphere
BCI	Beach Climate Index
BUI	Beach Utility Index
Boreal	Within the northern hemisphere
CCI	Camping Climate Index
CCOHS	Canadian Centre for Occupational Health and Safety
CMIP	Climate Model Intercomparison Project
CTI	Climate Index for Tourism
ECEs	Extreme climate events
EHI	Exertional heat illness
ET	Equivalent temperature
GDP	Gross Domestic Product
GPS	Global Positioning System
HCI_{Beach}	Holiday Climate Index-Beach
HCI_{Urban}	Holiday Climate Index- Urban
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
$km.h^{-1}$	Kilometres per hour
KTCI	Korea Tourism Climate Index

m a.s.l	Metres above sea level
MCIT	Modified Climate Index for Tourism
$m.s^{-1}$	Metres per second
MWCI	Mountainous Winter Climate Index
PET	Physiologically Equivalent Temperature
RCPs	Representative Concentration Pathways
SCI	Ski Climate Index
SIDS	Small Island Developing State
SNIJ	Subnational Island Jurisdiction
SSPs	Shared Socioeconomic Pathways
SST	Sea Surface Temperature
SWIO	Southwest Indian Ocean
RV	Recreational Vehicles
TCI	Tourism Climate Index
UCCI	Urban Climate Comfort Index
USA	United States of America
UTCI	Universal Thermal Comfort Index
VFR	Visiting Friends and Relatives tourism

LIST OF WORKS

The PhD is presented by thesis. However, during the process of the degree, the following works directly related to this research have been published and presented at academic conferences.

Publications:

Fitchett, J.M., Roffe, S.J. and **Prinsloo, A.S**. 2024. Evaluating Sunshine Hour Approximation for Biometeorological Indies. *Theoretical and Applied Climatology*, 156(13), 1-9. https://doi.org/10.1007/s00704-024-05237-6

Prinsloo, A.S. and Fitchett, J.M. 2024. Quantifying climatic suitability for tourism in Southwest Indian Ocean Tropical Islands: Applying the Holiday Climate Index to Réunion Island. International Journal of Biometeorology, 67, 1717-1728.

Academic conferences:

Prinsloo, A.S. and Fitchett, J.M. 2024. Heat stress: Considering climatic components beyond suitability for tourism in the southern hemisphere. Biennial Conference of the Society of South African Geographers, Potchefstroom, South Africa, 16-18 September.

Prinsloo, A.S. and Fitchett, J.M. 2024. Quantifying climatic suitability: The present and future of camping tourism in Réunion Island. 35TH International Geographical Congress, Dublin, Ireland, 24-30 August.

Prinsloo, A.S. and Fitchett, J.M. 2024. Quantifying Climate Suitability for Tourism in Réunion Island through a Multi-Index Approach. Global Indigenous Youth Summit on Climate Change, online, 09 August.

Prinsloo, A.S. and Fitchett, J.M. 2024. Poster- Camping Climate Climatic Suitability: Ideal? Symposium on Climate, Sustainability and Inequality, University of the Witwatersrand, South Africa, 31 July- 01 August.

Prinsloo, A.S. and Fitchett, J.M. 2023. A Multi-index Approach to Quantifying Climate Suitability for Tourism in Réunion Island. International Conference

From Recovery to Resilience in Tourism, Johannesburg, South Africa, 10-12 September.

Prinsloo, A.S. and Fitchett, J.M. 2023. Tourism in Réunion Island: Quantifying Climate Suitability using the Holiday Climate Index (HCI). Symposium on Climate, Sustainability and Inequality, University of the Witwatersrand, South Africa, 23-24 August.

Prinsloo, A.S. and Fitchett, J.M. 2023. Quantifying Climate Suitability for Tourism in Réunion Island through a Multi-Index Approach. International Congress of Biometeorology, Tempe, United States of America, 14-17 May.

Prinsloo, A.S. and Fitchett, J.M. 2022. Assessing the applicability of tourism climate indices to quantify climate suitability and the impacts of climate change for tourism in Réunion Island. Biennial Conference of the Society of South African Geographers, Pretoria (online), South Africa, 12-14 September.

Prinsloo, A.S. and Fitchett, J.M. 2022. Quantifying climate suitability for tourism in Réunion Island. Symposium on Climate, Sustainability and Inequality, University of the Witwatersrand, South Africa, 03-04 August.

Further, please note all photos used in this thesis are taken by the author unless stated otherwise.

CHAPTER 1: INTRODUCTION

1.1 Introduction

Climate is an important component for tourism, globally (Scott *et al.*, 2019). The climate is a significant motivator for destination choice, activities pursued and can affect the seasonality and overall satisfaction with the vacation experience (Amelung *et al.,* 2007; Gössling *et al.*, 2012a; Noome and Fitchett, 2019). Climate change therefore, poses a threat to tourism destinations as temperatures increase, hydroclimatic patterns change, the frequency and intensity of extreme climate events (ECEs) increase, biodiversity declines and other impacts that cause destinations to become increasingly unsuitable for tourism (Hoogendoorn and Fitchett, 2018b). Small islands are popular tourist destinations and often offer ideals of beach holidays where tourist satisfaction relies on 3S tourism (sun, sand, surf) referring to weather of minimal wind, warm temperatures and sunshine (Perch-Nielson *et al.*, 2010; Rutty *et al.*, 2020). For these island destinations, the climate is even more critical in both framing the destination image and creating favourable conditions for spending time on the beach (Fitchett *et al.*, 2020; Rutty *et al.*, 2020). Furthermore, small islands are highly vulnerable to climate change through sea-level rise (SLR), increased ECEs and natural biodiversity loss (Wolf *et al.*, 2021; Mycoo *et al.*, 2022). Islands in the southwest Indian Ocean (SWIO) such as Madagascar, Mauritius and Réunion Island are particularly vulnerable to tropical cyclones (Malan *et al.*, 2013). The site of interest for this study is Réunion Island, a French department located 9,386km from Paris and 2,850km from Johannesburg.

Tourism climate indices are tools used to determine climatic suitability. Using meteorological data, indices can assist in quantifying climatic suitability of destinations for tourism and determine the impacts of climate change over time (Mieczkowski, 1985). Tourism climate indices can also reveal climatic seasonality conditions that are preferred by tourists (Rutty *et al.*, 2020). Three factors are considered when evaluating climatic suitability, namely: thermal, physical and aesthetic components (de Freitas *et al.*, 2008). Over the past four decades, a number of tourism climate indices including the initial tourism climate index (TCI) development by Mieczkowski (1985) have been applied globally. Adapted and modified versions of the TCI have developed over time to account for its perceived limitations and to account for tourism activities that require different climatic conditions (de Freitas *et al.*, 2008; Perch-Nielsen *et al.*, 2010). Perch-Nielson *et al.* (2010) note that activities such as sunbathing, skiing, and surfing require specific conditions and may not be well represented by the TCI, which is formulated for more generic world tourism. Therefore, the development of indices considered more appropriate for particular tourism contexts and activities have been developed, such as the Holiday Climate Index for urban tourism (HCI_{Urban}; Scott *et al.*, 2016a); the Holiday Climate Index for beach or coastal tourism (HCI_{Beach}; Rutty *et al.*, 2020) and the Camping Climate Index (CCI) for nature-based activities such as camping (CCI; Ma *et al.*, 2020). Climate indices were developed to assist tourists in deciding where and when to travel and indirectly promote the sustainable use of climate resources (Mieczkowski, 1985). Understanding the climatic suitability of a tourism destination is important as climate change threatens the availability and quality of climate resources offered (Rutty *et al.*, 2020).

1.2 Rationale

Small islands located in the SWIO are highly dependent on international tourism for their local and national economic stability but are threatened by the impacts of climate change (Gössling, 2006; Mazzola *et al.*, 2019). Mauritius, for example, has experienced a higher frequency of extreme weather events, a shift in the start of summer precipitation and lengthening intermediate dry seasons (Mahadew and Appadoo, 2018). Given the impacts of climate change Réunion Island is set to experience (Mycoo *et al.*, 2022), quantitative data provided by tourism climate indices can detail the changes in climatic suitability for tourism over time which could support tourism planners and marketers in devising more effective infrastructure and programming, more strategic promotions outside of peak seasons and altered destination images (de Freitas *et al.*, 2008). This study will be the first to quantify climatic suitability for Réunion Island and the SWIO, a region that offers a range of tourism destinations that are threatened by the impacts of climate change.

Tourism climate indices are debated, with authors arguing the use of a single index over another (Perch-Nielsen *et al.*, 2010; Scott *et al.*, 2016a). For example, Scott *et al.*, (2016a) and Rutty *et al.* (2020) argue the TCI has inherent limitations in its application and therefore should be replaced by the HCI. Further, tourism climate indices are often used in single-application case studies and modified to align with specific tourism contexts. However, this could result in an infinite amount of indices being developed depending on where and what they are used for. This does not then permit tourism climate index results to be compared broadly across tourism destinations. Given that tourism destinations do not offer only one type of tourism the use of multiple indices is beneficial in identifying the differences in seasonal and total suitability for tourism destinations that offer a range of tourism offerings. This is further supported in heat index research (Matzarakis *et al.*, 2021; Raines and Fitchett, 2024) and the IPCC that argues a single model cannot be used to project the complexity of the Earth's system and therefore utilises hundreds of models to project changing climate systems (Hausfather, 2019). Thus, this research will seek to use four well-established indices (the TCI, both iterations of the HCI and CCI) in the first multi-index approach applied in the southern hemisphere. With this, tourism climate indices are rarely assessed for their applicability, suitability and validity prior to use. Therefore, to ensure the indices are appropriate to use in the study context a critical assessment of the four climate indices will be conducted.

1.3 Study Aim and Objectives

The study aims to provide the first evaluation of the climatic suitability for tourism in Réunion Island and for the southwest Indian Ocean. Through using four tourism climate indices, this study also aims to provide the first assessment of index applicability, suitability and validity in the southern African context, and the first multi-index intercomparison for the tourism-climate nexus in the southern hemisphere. Exploring changes in the output scores over the period of 33 years, this study aims to quantify the impact of climate change on climatic suitability for tourism in Réunion Island. The research aims to achieve this through the following objectives:

1. Assess the validity of four tourism climate indices for tourism in Réunion, specifically, through an evaluation of the availability and completeness of requisite climate data from 1991-2023 followed by validating the index assumptions, and then the mean local climate in comparison to threshold ranges
2. Calculate monthly tourism climate index scores for 11 meteorological stations, for the full study period, of 33 years, using the TCI, HCI_{Beach}, HCI_{Urban} and CCI
3. Calculate the change in climatic suitability over 33 years to assess the impacts of climate change

1.4 Thesis Structure

Chapter 2: Literature Review

This research is situated within the literature on tourism and climate change, tourism climate indices and climate futures. Key themes explored in this chapter include a review of the tourism and climate change landscape, tourism and climate change in the Global South and the SWIO islands. Further, literature around tourism climate indices, modifications of the TCI, and an intercomparison of indices is explored. Specific climate futures for the SWIO are examined, particularly climate threats and adaptation explored in the SWIO region.

Chapter 3: Study Site

The study location in which the research took place is outlined in this chapter. The location geography and topography of Réunion Island are outlined. Given that tourism climate indices are dependent on climate variables, a broad examination of the climate followed by an understanding of the temperature, humidity, precipitation, wind speed, sunshine hours, cloud cover and overall weather variability on the island is explored. Tourism is an important market segment for the island and so the chapter also outlines the economic and tourism landscape.

Chapter 4: Data and Methodology

Quantitative methods were pursued in this study to determine the climatic suitability of tourism for Réunion Island. Prior to the use of an index, an assessment of its applicability, suitability and validity is described. A description of the meteorological and ground-based data acquired for this study is provided followed by an examination of the four tourism climate indices used in this study. The method by which data were analysed is specified.

Chapter 5: Index Applicability, Suitability and Validity

An assessment of the applicability, suitability and validity of the four indices used in this study is provided, with an argument that this should be a precursor step to the use of any tourism climate indices, or indeed any biometeorological indices, in a location different to that where they were developed.

Chapter 6: Results

Results obtained from the application of the four tourism climate indices is unpacked in this chapter. Climatic suitability results are given per index and according to available meteorological stations. Within each station reported, mean annual climatic suitability results are given followed by mean monthly output scores. A spatial comparison between meteorological station scores computed for each index is described comparing mean annual climatic suitability scores and the seasonal distribution results found. Ground-based data results around three camping sites are outlined in relation to meteorological data. The multi-index comparison of the results found for all four indices is described followed by results found for the change in climatic suitability over time.

Chapter 7: Discussion

An evaluation and interpretation of the main findings in relation to the broader literature are discussed in this chapter. The first section of the discussion includes reflections on the comparative climatic suitability of Réunion in relation to other tourism destinations. The implications of acceptable suitability in Réunion for different tourism types, seasonality, types of activity and indoor versus outdoor experiences are outlined. The presence of microclimates is discussed in relation to the results found followed by an examination of the multi-index approach used in this study. The second section of the discussion looks at the link between climatic suitability and safety concerns around thermal stress, extreme events and associated impacts as well as the lexicon of risk and safety. The third section looks forward to the climate future likely given the results found and discusses future considerations for Réunion tourism, the extreme events and sea level rise (SLR), it will experience. The discussion is concluded by highlighting the limitations of the study and how these were addressed.

Chapter 8: Conclusion

A synopsis and the achievement of the study aims and objectives are highlighted in this chapter followed by recommendations for future research.

CHAPTER 2: LITERATURE REVIEW

Moufia- Jace (2017).

2.1 Introduction

Tourism is a climate-sensitive sector (Scott *et al.*, 2012a). Outdoor tourism in particular relies on specific climate characteristics for the provision of services (Nicholls, 2006; Scott *et al.*, 2012a; Craig and Feng, 2018). Climate change will impact the manner in which tourism activities are offered, their availability, and when tourists travel in the future (Pang *et al.*, 2013; Scott *et al.*, 2019). At the same time, tourism is argued to contribute to the increasing impacts of climate change through intensive resource use, infrastructural pressure and pollution and greenhouse gas emissions from travel (Scott *et al.*, 2012a; Pang *et al.*, 2013; Gössling and Scott, 2018). It is with this lens that this chapter outlines the field of tourism and climate change research by first outlining the landscape of global tourism and climate research highlighting gaps from the numerous reviews undertaken, followed by a critical examination of the Global South and the southern hemisphere and to the key area in this research pursuit, the SWIO. Tourism climate indices aim to provide insight into the climatic suitability of tourism destinations but are also highly debated. As such the original TCI and more sector-specific indices will be examined. The literature review will conclude with an examination of the climate futures that are discussed for Réunion Island and the greater SWIO region, including climate threats and adaptation measures.

2.2 Climate Change and Tourism

2.2.1 A Review of the Tourism and Climate Change Landscape

Climate and tourism have been explored in academic literature since at least 1963 with the examination of climate therapy on medical tourism in the Tatara Mountains (Bugyi, 1963). The specific topic of climate change and tourism appeared later in 1986, with a focus on the impacts of climate change on camping activities in Canada (Wall *et al.*, 1986). This was followed by a steady increase in publications from the 1990s (Smith, 1990; Wall and Badke, 1994; Hall and Higham, 2005). Initial papers during this time examined the challenges that climate change posed to the ski industry in North America and wetland areas in Canada (Wall *et al.*, 1986; Wall, 1998; Viner, 2006; Becken, 2013). The scientific basis for the link between tourism and climate change was initially discussed in 2002 around tourism demand and climate preferences (Viner, 2006).

Authors such as Daniel Scott, Geoff Wall and Geoff McBoyle initially sought to describe the evolution of climate change and tourism research (Scott *et al.,* 2005). The field of climate change and tourism was described in four phases, namely 1) *Formative Phase*- alluding to initial research around climate change and tourism, 2) *Period of Stagnation*- a decade of little enquiry around the topic, 3) *Emergence of Climate Change*- where the first peer-reviewed journal article on the implications of climate change on tourism was written in 1986, 4) *Maturation*- the steady increase of publications on the topic from the 1990s to the 2000s. Later, Fang *et al.* (2018: 4-5) built on this insight describing three phases in the growth of climate change and tourism research, namely 1) *Preparation phase (1990-1997),* in which a limited amount of research began to investigate the impact of climate change on tourism, 2) *Development Phase (1998-2006)*, whereby a slow incline in the research and initial theories and empirical research developed and 3) *Rapid Development Phase (2007-2015)*- with an 85.71% increase in published papers around the topic were explored. Although these phase classifications share similarities in both iterations, it is clear that this topic has increased in interest over time.

Given the extent of climate change and tourism knowledge developed over the past 35 years, a number of reviews of the field have emerged (Scott *et al.*, 2012a; Becken, 2013; Pang *et al.*, 2013; Hou *et al.*, 2015; Farid *et al.*, 2016; Fang *et al.*, 2018; Scott and Gössling, 2022). Reviews considered here include published journal articles, conference proceedings and book chapters that have pursued a systematic review of climate change and tourism literature overall and around specific segments of tourism. A total of 36 reviews were identified with the earliest review published in 2005 (Figure 2.1; Scott *et al.*, 2005). This is a relatively short period after the *Development Phase* of tourism and climate change research (Fang *et al.*, 2018). Key themes that emerged from these reviews centred around the climate and tourism research agenda, establishment and reflection of knowledge systems, mitigation, adaptation and policy integration. Most notable is the influx of review papers from 2020 that are linked to the IPCC Fifth and Sixth Assessment Reports (Scott *et al.*, 2016b; Scott and Gössling, 2022; Steiger *et al.*, 2023). Further, while 25 of the review papers examine this field through a global lens, eight investigate the Global North and predominately around sector-specific tourism that would be limited in the Global South such as winter ski tourism (Yang and Wan, 2010; Steiger *et al.*, 2017). As for the Global South, three reviews examine climate change and tourism in Africa and southern Africa (Figure 2.1).

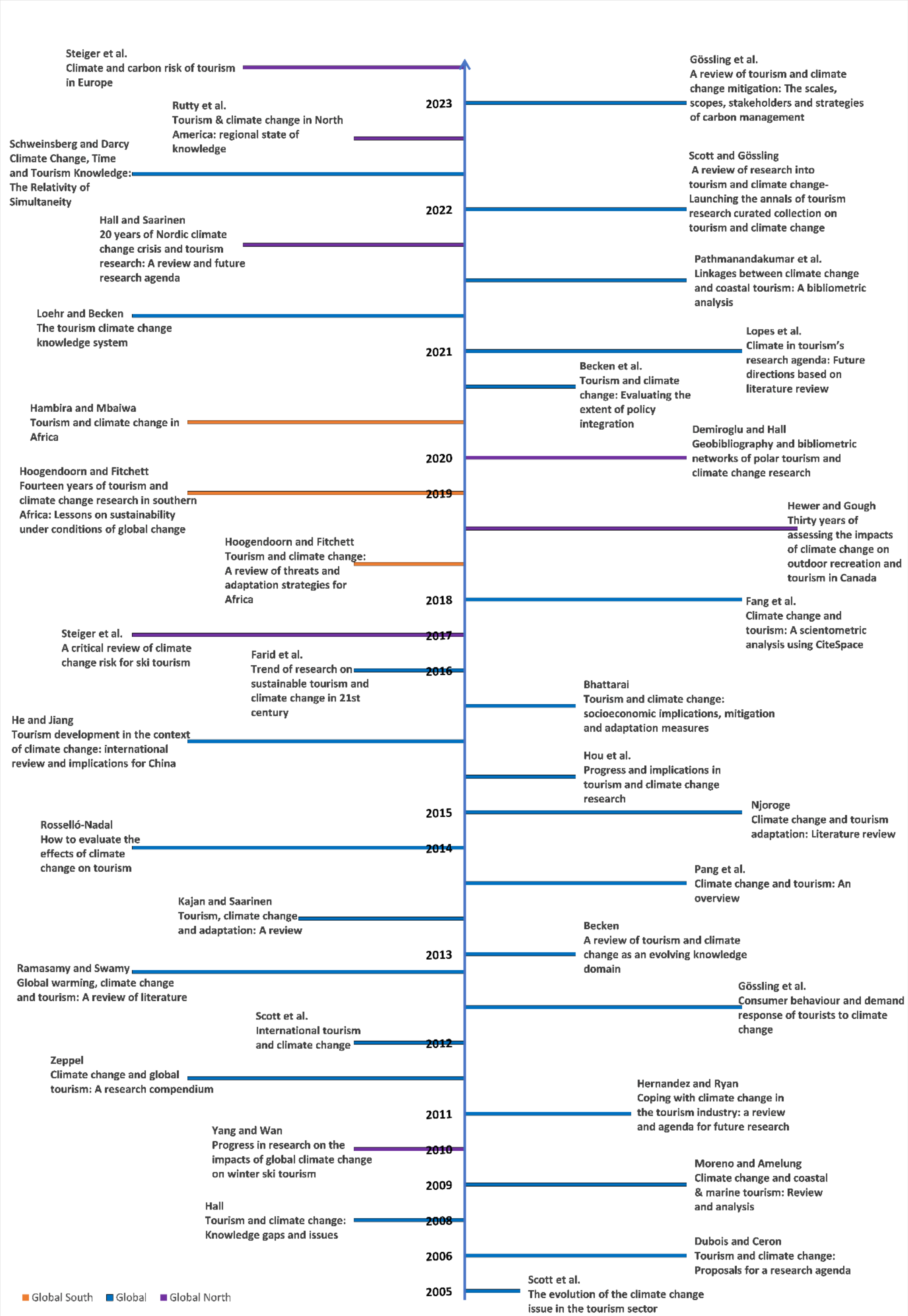


Figure 2.1. Timeline of tourism and climate change review papers around global, Global North and Global South literature from 2005-2023.

Reviews of literature in the field of climate change and tourism allude to the disconnect between research and adaptation or mitigation intervention on the ground through policy or local communities. Loehr and Becken (2021) conducted the first review of research and climate change with a broader review of the knowledge system of this field to determine the limited action of policymakers and the like to tourism and climate change research. Leal Filho (2022) notes that adaptation is a long-term process, however strategic intervention by the tourism sector is required to address short-term impacts.

Reviews have highlighted particular gaps in the knowledge. A geographical gap exists between research hotspots such as Europe, North America, Oceania, the Caribbean and Central America, revealing that the Middle East, South America, Africa and Asia as under researched (Loehr and Becken, 2021; Saarinen *et al.*, 2022; Scott and Gössling, 2022). The latter form part of the Global South, a region that has long been considered under investigated (Hoogendoorn and Fitchett, 2019; Saarinen *et al.*, 2022). This is argued to be a result of the small number of academics that have a stronghold in the field that posit research based on their own contexts, research priorities and biases (Fang *et al.*, 2018, Loehr and Becken, 2021). This is particularly true as seen in extractive studies of the Global South (Haelewaters *et al.*, 2021). Further, review papers around this topic focus on articles written in English (Njoroge, 2015). While this is a common language to present research in, this excludes potentially important research investigations around tourism and climate change in remote or growing tourism spaces (Loehr and Becken, 2021). Conversely, Loehr and Becken (2021) posit that considerable knowledge has been developed for islands and coastal environments and while true, Scott and Gössling (2022) highlight a regional gap in research for small islands. Therefore, further inquiry into the Global South and small islands is required.

2.2.2 The Global South Context

Regions of the Global South are already experiencing, and are projected to experience intensified climate changes, often in excess of the global mean (Engelbrecht *et al.*, 2024). The Global South here will refer to "countries classified by the World Bank as low or middle income that are located in Africa, Asia, Oceania, Latin America and the Caribbean" (Clarke, 2018: n.p.). However, it is noted that this definition has been argued to be problematic as like previous terms such as "developing" or "third world", it encompasses countries that are diverse in economic, cultural, social and political positions (Clarke, 2018; Myers, 2020). Africa in particular, is highly vulnerable to climate change impacts as it depends on tourism as a key economic sector (Rogerson and Rogerson, 2018; Trisos *et al.*, 2022). Tourism attractions, particularly outdoor and nature-based tourism in Africa are a key economic sector (Job and Paesler, 2013). Nature-based tourism is also climate-sensitive and marketed as weather-reliant (Hambira *et al.*, 2013; Coldrey and Turpie, 2020). Understanding weather and climate, and how they have changed over time can provide insight into the extent to which the climate-dependent tourism operations have been affected. This is important for the future of tourism in Africa as the sector expands (Scott *et al.*, 2019). To date, research on the impact of climate change on varied tourism types in Africa has been investigated (Table 2.1). South Africa has been the most extensively researched, followed by Botswana and Zimbabwe (Table 2.1). While these research pursuits are valuable, it is important to note the lack of or lack of access to research in other parts of the continent. This is particularly important as the heterogeneity of the climate and tourism means that results for one location cannot be generalised for the full region.

Table 2.1. Tourism and climate literature in Africa (expanded from Hoogendoorn and Fitchett, 2018b: 746-747).

Year	Country	Climate change threats	Tourism Impact	Method	Authors
1998	South Africa	Rising temperatures	Skin protection and thermally comfortable conditions for beach holidaymakers	Beach comfort index	Becker
1999	Morocco	Increased temperatures	Increased tourism and positive economic and local practices	Literature review	Parish and Funnell
2004	Egypt	SLR	Loss of beaches and historical sites for tourism	Digital elevation model of SLR projections	Agrawala *et al.*
2005	South Africa Lesotho Zimbabwe Zambia Botswana Swaziland	Theoretical: temperature increases Variable precipitation patterns threaten biodiversity	Reduced destination appeal for nature reserves Shortened tourism season	Theoretical discussion of threats to nature-based tourism	Preston-Whyte and Watson
2006	Tanzania	SLR, Increased precipitation, drought increased humidity, more frequent storms	Reduced destination appeal Infrastructure damage Potential for reducing tourism numbers	Interviews with tourists	Gössling *et al.*
2007	Egypt	Theoretical: degradation of coral reefs, SLR, water resource availability	Loss of coastal infrastructure Reduced destination appeal Coral bleaching reduces biodiversity and destination attractiveness	Theoretical discussion of potential threats Scenario-based approach	Ahmed and Hefny
2007	Namibia	Increased temperatures, variable precipitation patterns, desertification and ecosystem shifts have detrimental effects on nature-based tourism	Reduced destination appeal Reduced tourist comfort due to water shortages and increased temperatures	Round table discussions	Reid *et al.*

2008	Kenya	SLR, increased flooding due to increased storm intensity and storm surges, increased temperatures	Decline in key beach attractions Infrastructure damage Biodiversity loss results in reduced destination attractiveness	Theoretical discussion of potential threats on the basis of past disasters Interviews and field observations	Awuor *et al.*
2008	Morocco	SLR, coastal flooding	Decline in beach attractions Tourism infrastructure damage Reduced destination appeal	Digital elevation model SLR projections combined with socio-economic data	Snoussi *et al.*
2009	Nigeria	Increased temperatures Change in precipitation patterns	Reduce tourism revenue Shift tourism destinations Increase costs of running tourism businesses	Survey In-depth interviews Focus groups	Ijeomah and Aiyeloja
2010	Egypt	Rising temperatures inducing greater seasonal differences, coastal degradation, SLR	Reduce beach tourism appeal Threats to diving tourism Summer heat discourages tourists	Interviews with Egyptian policy-makers and tourism managers	Shaaban and Ramzy
2011	Egypt	Coral reef degradation Increased temperature impacting environmental conditions	Reducing tourism attractiveness Dive tourists prioritise sustainability but tourism operators underestimate its importance	Interviews with 150 dive tourists and 35 tourism operators	Marshall *et al.*
2012	South Africa	Increased temperatures Variable precipitation patterns Water availability Increased ECEs	Altered timing and duration of peak tourist seasons Infrastructure damage Decreased visitor satisfaction	Interviews and questionnaires with stakeholders in nature-based tourism	Reddy
2012	South Africa	Increased temperatures, altered precipitation patterns, aridification, loss of fynbos species, changes in wind speed, increased ocean temperatures	Decreased tourist arrivals Impact tourism activities Damage to infrastructure	Theoretical discussion	Steyn

2012	South Africa	Temperature increases, decreased precipitation, shifts in seasonality, increased occurrence of floods and ECEs	Degradation of key natural attractions Reduced local economic activity Reduced visitor satisfaction and enjoyment	Theoretical discussion	Steyn and Spencer
2013	Botswana	Increased temperatures, altered precipitation patterns, degradation of vegetation	No detrimental effects on tourism operators' business, therefore no proactive adaptation strategies were implemented. Future of tourism operations unclear	In-depth interviews with tourism operators	Hambira *et al.*
2013	Botswana	Degradation of natural resources Increased temperature, altered precipitation patterns	Reduced attractiveness of natural attractions Disconnect between local perceptions of climate change and implications for the tourism industry.	Interviews with tourism operators Household survey	Saarinen *et al.*
2013	Ghana	SLR	Damage to infrastructure Reduced destination appeal Economic loss from reduced tourism	Modelled SLR, interviews with tourism operators	Sagoe-Addy and Addo
2014	Botswana	Increased frequency and severity of droughts Variable precipitation patterns Changing flooding patterns	Decreased visitor numbers Loss of income for local communities Reduced attraction attractiveness with biodiversity changes	Interviews with tour operators and lodge managers Focus groups	Mbaiwa and Mmopelwa
2014	Botswana	Increased temperatures Variable weather patterns Increased ECEs	Altered visitor experiences Potential economic losses	Theoretical discussion	Moswete and Dube

2014	South Asia Middle East North Africa Sub-Saharan Africa East Asia Pacific regions	Air pollution negatively impacts tourism through deforestation and natural resource depletion	Reduced investment Less natural resource availability	Multivariate regression analysis Econometric framework	Sajjad *et al.*
2015	Nigeria	Increased temperatures, changes in precipitation patterns, increased frequency and intensity of ECEs, SLR	Decline in tourist attractions and destinations Shifts in tourism activities Reduced tourism visitors	In-depth interviews with tourists	Dillimono and Dickinson
2015	South Africa	Increased temperatures, altered precipitation patterns, changing humidity, SLR, storm surges	Altered visitor experience Economic impact for local businesses reliant on tourism Infrastructure damage	TCI, digital elevation model SLR projections, interviews with tourists and tourism operators	Grant
2015	Botswana	Increased temperatures, altered precipitation patterns, increased ECEs, changing seasonality	Decline in natural attractions Economic impacts for local communities reliant on tourism Altered tourists seasonality	Interviews with key stakeholders and policy-makers	Hambira and Saarinen
2016a	South Africa	Increased temperatures, changes in precipitation patterns, SLR	Altered visitor experience Economic impact for local businesses reliant on tourism Infrastructure damage	TCI, digital elevation model SLR projections Interviews	Fitchett *et al.*
2016b	South Africa	Flooding related to tropical cyclones	Infrastructure damage Loss of revenue for tourism-related businesses Reduced tourist perception of safety and accessibility	Economic assessment of costs of flooding to tourism establishments Interviews and surveys	Fitchett *et al.*

2016	South Africa	Increased temperatures, storm incidence and intensity, SLR	Altered tourist behaviour Economic impact for local businesses reliant on tourism Damage to coastal attractions	Surveys and interviews	Hoogendoorn *et al.*
2016	Tunisia and Italy	Increased temperatures, altered precipitation patterns, increased frequency of ECEs, SLR	Reduced tourism numbers Shift in tourism destination preference Tourism infrastructure at risk Loss of revenue	Sensitivity analysis and linear regression Comparative analysis	Köberl *et al.*
2016	South Africa	Degradation of environmental resources, increase in vector-borne diseases Increased temperatures, altered precipitation patterns, SLR, ECEs	Altered tourist behaviour and preferences Potential for visitor number decline Potential for economic losses	Analysis of public statements, case studies, theoretical discussion	Rogerson
2016	Kenya	Drought events and altered precipitation resulting in flooding risks	Tourist arrivals and reduction of visitors Tourism infrastructure	None mentioned	Nyamwange
2017	South Africa	Change in climate variability	Alter appeal of tourism destinations	TCI	Fitchett *et al.*
2017	Southern Africa	Increased temperatures and altered precipitation, ECEs, SLR	Damage to tourism infrastructure Altered tourist preferences and flows Adaptation costs Ecological changes	Conceptual research	Pandy
2017	Tanzania	Drought and rainfall variability, increasing temperatures, biodiversity changes	Reduced destination appeal Disrupts seasonal patterns of tourists	Land cover assessments and climate data analysis	Kilungu *et al.*
2017a	South Africa Namibia	Extreme climate events (ECEs)	The ability to provide adventure tourism is unpredictable Job and revenue loss concerns	Interviews and surveys- white-water tourism operators	Giddy *et al.*

2017	Africa	Increased temperatures Reduced precipitation and drought Flooding	Change in tourism activities and destination preferences Economic costs for developing countries reliant on tourism	Literature review	Sifolo and Henama
2018	South Africa	Flooding risks for tourism accommodation establishments	Change in tourist demand and decline in bookings and booking patterns Infrastructure damage Reduced business activities	Semi-structured questionnaires and interviews	Southon and van der Merwe
2018	Lesotho	Reduced snow quality and frequency	Future snow availability for tourism	TripAdvisor reviews	Stockigt *et al.*
2018	Zambia	Increased temperatures Extreme rainfall patterns Decline in rainfall Fluctuation in water flow	Decline in tourism products offered Economic losses for local communities	Historical meteorological data analysis Online tourist survey	Dube and Nhamo
2018a	South Africa	SLR, flooding, drought and storms	Second home tourism vulnerable to climate change impacts	Preliminary review	Hoogendoorn and Fitchett
2018	Botswana	ECEs	Change in tourist perceptions and expectations	Online survey	Dube *et al.*
2018	South Africa	Increased temperatures, ECEs, coastal erosion, SLR	Economic losses for tourism providers Changes in tourism offerings	Interviews with key stakeholders	Pandy and Rogerson
2019	Lesotho	Increased temperatures, relative humidity and precipitation	Changes in snow tourism, hiking and sightseeing	TCI	Noome and Fitchett
2019	Zimbabwe	Increased temperatures Increased incidence of extreme rainfall and drought events	Reduce tourists expectations Economic losses for tourism providers	Meteorological and hydrography data analysis Online tourist survey	Dube and Nhamo
2020	South Africa	Reduced precipitation Drought events	Reduced visitor satisfaction, repeat visits and revenue	Semi-structured interviews	Smith and Fitchett

2020a	Zimbabwe	Increased temperatures Altered precipitation causing drought ECEs	Reduced wildlife sightings Reduced destination appeal and repeat visits	Hydrography and meteorological data Interviews and surveys	Dube and Nhamo
2020	Botswana	Drought, increased temperatures, ecological shifts	Reduced destination appeal with changes in wildlife sightings Deter visiting tourists	Interviews with local community and stakeholders	Saarinen *et al.*
2020a	South Africa	SLR, increased temperatures, increased frequency of ECEs	Beach erosion Infrastructure damage Reduced destination appeal	Interviews and surveys	Friedrich *et al.*
2020b	South Africa	SLR, increased ECEs	Future tourism Economic losses	Hazard-activity pair methodology	Friedrich *et al.*
2020b	South Africa	Reduced rainfall ECEs	Loss of infrastructure Disruption to tourism activities	Analysis of archival data Interviews SANParks report reviews	Dube and Nhamo
2020	Africa	Increased temperatures, ECEs, drought, coral bleaching, flooding, poor climatic conditions	Change in market demand Tourists flow Revenue streams	Systematic literature review	Hambira and Mbaiwa
2021	Zimbabwe	Drought, heatwaves and floods	Tourism product offered Tourist arrivals and satisfaction	TCI	Mushawemhuka *et al.*
2021	South Africa	Water scarcity, increased ECEs, biodiversity loss, SLR, increased fire risk	Infrastructure damage Future tourism development	Interviews with 30 tourism stakeholders	Pandy and Rogerson
2021	South Africa	SLR, flooding	Damage to tourism infrastructure Tourism operations and local businesses	Remote sensing, field observations and interviews	Dube *et al.*

2022	Zimbabwe	Drought and water scarcity, tropical cyclones, temperature increases	Storm damage and access to tourist destinations Reduced nature-based tourism resources Disruption to local businesses and tour operations Regional competitiveness of tourist destinations	Thematic and content analysis of semi-structured interviews Survey questionnaires	Mushawemhuka *et al.*
2022	Southern Africa	Increasing temperatures, drought, SLR, ECEs	Losses for the tourism sector	Case studies, discussions on methodologies	Saarinen *et al.*
2022	Southern Africa	ECEs, drought, flooding due to intense rainfall and wildfires	Decline in visitor numbers Sustainable tourism practice challenges Economic losses	Case studies, literature review	Dube
2022	East Africa	Coral bleaching, marine pollution and extreme events impacting dive tourism	Decline in visitor numbers due to biodiversity changes Concern for future destination sustainability	Surveys with 34 dive operators	Dimopoulos *et al.*
2022	South Africa	Increasing temperatures for nature-based tourism, ECEs (heatwaves)	Reduced tourist experience Operational challenges	Assessed archival climate data In-depth interviews with game reserve staff	Sibitane *et al.*
2022	Namibia	Increasing temperatures, changes in precipitation and relative humidity	Employment and local income Tourism infrastructure	TCI	Noome and Fitchett
2022	South Africa	Increased frequency and intensity of drought, altered precipitation patterns, increased temperatures	Decreased visitor numbers Economic losses for tourism-reliant businesses	Interviews Archival data used to review tourism statistics, climate and water usage	Dube *et al.*

2022	South Africa	Increasing temperature, altered precipitation patterns, biodiversity loss and migration, increased frequency and intensity of ECEs	Reduced visitor experiences Shift in available recreational opportunities Economic losses for local tourism-reliant economies	Vulnerability assessment analysis	Coldrey *et al.*
2022	South Africa	Increased risk of tropical cyclones and SLR, drought Disease	Trip cancellation	Questionnaire-based survey	Friedrich *et al.*
2022	South Africa	Increased frequency of ECEs Altered precipitation patterns Increased temperatures	Decline in tourist arrivals Economic losses for tourism-reliant communities	Autoregressive Distributed Lag (ARDL) approach	Jong *et al.*
2023a	Africa	Increased temperatures Increased drought and floods SLR Snow melt Coral bleaching Frequent tropical cyclones	Reduced accessibility Decline in natural attractions resulting in tourist patterns and preferences Economic losses for tourism-reliant communities	Literature review using PRISMA	Dube *et al.*
2023b	South Africa	Flooding ECEs	Damage to infrastructure Economic losses	Interviews, surveys, field observations	Dube *et al.*
2023	Rwanda	Wildfires Flooding Drought	Decrease in tourism revenue	Questionnaire	Mihigo and Lukenangula
2023	South Africa	Increased temperatures, ECEs, drought and water scarcity	Decreased visitor numbers Increased operational costs Reduced wildlife attraction expectations	Semi-structured interviews Energy and water usage analysis	Nhamo *et al.*
2023	South Africa	Drought	Reduced tourism numbers due to the Day Zero drought	Questionnaires, interviews, media and user-profile analysis	Prinsloo and Fitchett
2023	Zimbabwe	Increased temperatures, altered precipitation patterns, drought	Reduced visitor number Reduced attraction expectations	In-depth interviews	Zhou

2023	Africa	Mountain glacier melting Decline in flora and fauna SLR Coral bleaching Increased intensity of tropical cyclones	Decline in African country tourism sectors Increase resilience of tourism sectors	General review	Dube
2024	Zimbabwe	Increased temperatures Altered precipitation patterns Flooding	Changes in tourist patterns and preferences Economic losses for tourism-reliant communities Shifts in seasonality of tourist arrivals	Interviews and surveys Ecological assessment	Makuyana *et al.*
2023	South Africa	Change in temperature and precipitation patterns Increased frequency of ECEs	Reduced camping opportunities Change in camping preferences based on climate Economic impacts to camping sites	Meteorological station data analysis Survey questionnaire	Fitchett and Meyer
2024	South Africa	Increased frequency and intensity of ECEs	Reduced visitor numbers Reduced attraction expectations Economic losses for tourism-reliant businesses	Focus group discussions and field observations	Ramaano
2024	Sub-Saharan Africa	Desertification, increased temperatures	Decline in resources for ecotourism	General review	Mullikin
2024	South Africa	ECEs, changing climate conditions	Shift in camping seasonality and destination choice Tourist safety and satisfaction with the weather	CCI	Mnguni and Fitchett
2024	South Africa	Changes in climate under climate change	Visitors' expectations and satisfaction of the weather	Web-scraping	Mokgehle and Fitchett
2024	Botswana	Altered precipitation patterns Temperature increases Drought and flooding	Change in perception of activities Decline in tourism affects community livelihoods	Cross-sectional survey approach Questionnaires	Hambira *et al.*

Countries in the Global South, and particularly those on the African continent, are highly vulnerable to the impacts of climate change due to lower adaptive capacity, less effective warning systems and infrastructural limitations (Busby *et al.*, 2013; Chirisa *et al.*, 2016; Lumbroso, 2018; Epule *et al.*, 2023). Compared to the Global North, regions of the Global South do not have the necessary capital to invest in effective technological solutions for adaptation while simultaneously addressing pressing socio-economic challenges (Sokona and Denton, 2001).

Urban tourism has gained popularity globally attracting tourists to large urban centres and mega-cities (Rogerson and Rogerson, 2021). Within the Global South, urban tourism has seen rapid growth, particularly in sub-Saharan Africa (Rogerson and Rogerson, 2021). Less focus has been given to urban tourism and climate change because it is part of other tourism subsectors, and it is conflated with other types of tourism that are argued to be less sensitive to climate such as business tourism (Fitchett, 2021). Rogerson and Rogerson (2021) highlight three themes in the urban tourism literature that set the Global South apart from the Global North namely the informality of tourism, the number of tourists who are also poor in the Global South and debates around the rise in slum tourism. Pandy and Rogerson (2019) investigated the perceptions of climate change risk on tourism business stakeholders finding that initiatives to respond to climate change risk are good but not essential to running tourism businesses.

2.2.3 Southwest Indian Ocean Islands

Literature on climate change and tourism in the SWIO is scant. The region consists of small island developing states (SIDS) such as the Comoros, Madagascar, Mauritius, Maldives and Seychelles, along with Réunion Island, which is qualified as a subnational island jurisdiction (SNIJ; Mills and Hancock, 2005; Petzold and Magnan, 2019). The status of Réunion Island as part of the Global South is unclear but in the same way as the SIDS surrounding it, it remains relatively under-researched (World Bank, 2023). The climate threats that are projected to impact the region, such as SLR, will also be similarly experienced by other small islands globally (Mycoo *et al.*, 2022).

Literature on tourism in this region has focussed on sustainable tourism, ecotourism and tourist weather and climatic conditions (Nunkoo and Ramkissoon, 2007; Prayag *et al.* 2010; Picard, 2015). Gössling (2006) describes the growing tourism sector in this region and argues for the need for sustainable tourism as resources will be strained under a growing sector. Similarly, Picard (2015) identified the ecotourism drive in the SWIO but questions its economic viability in the future. Through TripAdvisor, reviews of five islands in the SWIO, Fitchett *et al.* (2020) identified tourists' experiences of the weather during their vacations and highlighted that these reviews can provide insight into tourists' satisfaction and inform better decision-making for future tourists that will ultimately aid the island they are travelling to.

Literature on the SWIO has predominately focused on tropical cyclones as a primary climate change threat (Clayton, 2009; Barthe *et al.*, 2021). Research on tropical cyclones has and continues to determine the characteristics, movement patterns, frequency and intensity of these extreme events over time in the region to understand and better manage the impacts of storm surges (Brand and Cormier, 1971; Chang-Seng and Jury, 2010; Bonnardot *et al.*, 2019; Pillay and Fitchett, 2019; Bousquet *et al.*, 2021). SLR is another climate-induced risk that will be universally experienced but is one of the greatest risks to the territories of the SWIO (Clayton, 2009; Fitchett *et al.*, 2020).

Tourism and climate change literature reveals there has been a lot of progress in the last 35 years, however limited research around the Global South is still significant in comparison. Geographical research gaps for other areas of Africa and smaller regions such as the SWIO and Réunion Island in particular are further under-researched. This is of particular concern given Réunion Islands' reliance on tourism as well as extreme vulnerability to the threat of climate change. This research will seek to contribute to this gap in knowledge as the first study of the climate of Réunion Island, its link to tourism and how it has changed over time.

2.3 Tourism Climate Indices

2.3.1 The Tourism Climate Index

Over the past four decades, a range of tourism climate indices have been developed to determine the suitability of the climate of a location for tourism destinations and activities (Scott *et al.*, 2016a; Rutty *et al.*, 2020). Mieczkowski (1985) developed the initial TCI by integrating a range of pre-existing indices such as the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) scale along with expert opinion on optimal climatic conditions for tourism to produce a five-factor index. The initial TCI aimed to rate a destination’s climate based on the climatic elements tourists seek when travelling and aimed to compare tourism destinations across the globe (Mieczkowski, 1985). This index first considered twelve climatic variables, which were later reduced to seven due to limitations in data availability (Mieczkowski, 1985; Perch-Nielsen *et al.*, 2010). The climatic variables deemed relevant to the tourist experience were maximum and mean daily temperature, minimum and daily relative humidity (the combination of which measured human thermal comfort). In addition, precipitation and wind speed, which were deemed the physical factors, and sunshine hours, formed the aesthetic factor (Mieczkowski, 1985). Thermal comfort is a large consideration for the index and is weighted at 50%, of which 40% comprises daytime comfort, and 10% night-time comfort (Mieczkowski, 1985, Rutty *et al.*, 2020). The remaining variables are weighted at 20% for precipitation, 20% for sunshine hours and 10% for wind (Mieczkowski, 1985). The application of the TCI has increased in the past 10 to 15 years and has been used in research studies globally, with many investigations in the Global North and relatively recently in the Global South (Saarinen *et al.*, 2022). In southern Africa, this index has been applied to South Africa (Fitchett *et al.*, 2017), Lesotho (Noome and Fitchett, 2019), Namibia (Noome and Fitchett, 2022) and Zimbabwe (Mushawemhuka *et al.*, 2021).

In more recent years, a suite of adaptations to the TCI have emerged. On the one hand, more specialised indices were developed as a replacement for the TCI, such as the Climate Index for Tourism (CIT; de Freitas *et al.*, 2008) and, to an extent, the Holiday Climate Index (HCI) for urban settings (Scott *et al.*, 2016a). More recently the latter index has been used in site-specific settings of urban tourism sites such as desert regions in Iran (Hejazizadeh *et al.*, 2019), highly developed cities of Tokyo (Williams, 2021) and China (Yu *et al.*, 2022a) and coastal cities of the Canary Islands (Carrillo *et al.*, 2022) and Sri Lanka (Samarasinghe *et al.*, 2023). On the other hand, adaptations for specific tourist attractions have arisen over time such as the Beach Climate Index (BCI; Morgan *et al.*, 2000) and much later the Holiday Climate Index (HCI) for beach tourism (Scott *et al.,* 2015; Rutty *et al.,* 2020) as well as more sector-specific indices such as the Camping Climate Index (CCI; Ma *et al.,* 2020) and the Ski Climate Index (SCI; Demiroglu *et al.*, 2021).

Currently, the TCI is the most widely applied index and has been applied to calculate climate suitability scores for tourism activities and tourism destinations with vastly different climate conditions (Figure 2.2; Rutty *et al.*, 2020). The index has been used to quantify climatic suitability (Joksimović *et al.*, 2013; Mihăilă and Bistricean, 2018; Noome and Fitchett, 2019; Alonso-Pérez *et al.*, 2021; Fitchett, 2021; Faraj *et al.*, 2023); identify trends in climate change for tourism (Zhong *et al.*, 2019); future tourism climate resource projections (Scott and McBoyle, 2001; Scott *et al.*, 2004; Amelung and Viner, 2006; Perch-Nielsen *et al.*, 2010; Kubokawa *et al.*, 2014; Fang and Yin, 2015; El-Masry *et al.*, 2022; Hidayat, 2022; Nguyen *et al.*, 2020; Li and Chen, 2023); to compare two or more tourism destinations (Amiranashvili *et al.*, 2014, 2017; Grillakis *et al.*, 2016); to compare more than one index (Scott *et al.*, 2016a; Hejazizadeh *et al.*, 2019; Rutty *et al.*, 2020; Matthews *et al.*, 2021; Yu *et al.*, 2021) as well as predict tourism arrivals to tourism destinations (Aygün Oğur and Baycan, 2023; Craig, 2024).

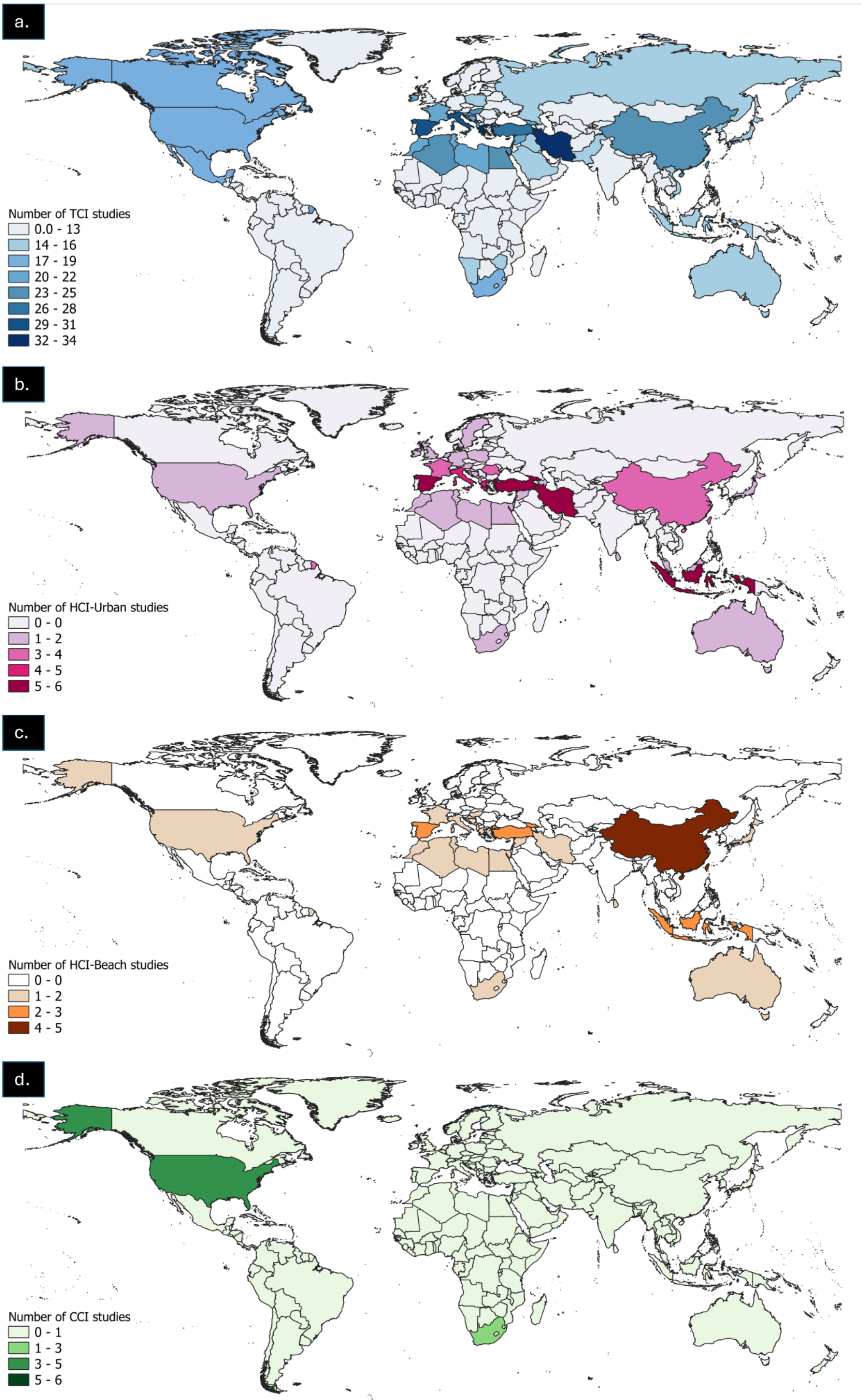


Figure 2.2. Number of studies for the a) TCI b) HCI_{Urban} c) HCI_{Beach} and d) CCI globally from 1986-2024.

Mieczkowski (1985) self-identified two central limitations of the TCI. Both pertain to the subjectivity around the rating system and the weights prescribed. Although based on scientifically applied and objective research, Mieczkowski (1985: 231) used their "own judgment" to ascribe comparative values to the variables of precipitation, sunshine, and wind as well as giving the highest weighting to thermal comfort. In this regard, recent research has tested and found the weightings and thresholds of the TCI to be accurate (Fitchett *et al.*, 2020) in the South African context, and similar to the resultant weightings from the survey questionnaires administered in European cities on which the HCI was developed (Scott *et al.*, 2016a). The second central limitation claims the rating system does not explicitly account for different tourism activities where thermal comfort requirements differ, particularly in varied climatic conditions such as beach and snow activities (Mieczkowski, 1985). The challenges for snow settings are demonstrated in the application of the TCI in Lesotho by Noome and Fitchett (2019), prior to the development of the Snow Climate Index (SCI; Demiroglu *et al.*, 2021). To account for these limitations Mieczkowski (1985) addressed the difficulty in creating set defined thresholds due to the subjective bias humans have for climatic preferences and further emphasised the innate flexibility of the TCI that allows further adaptations. The exact modifications that could be made to the rating and weighting system were not outlined (Matthews *et al.*, 2019). Further, Mieczkowski (1985) states that TCI scores calculated are not absolute but rather provide a comparative assessment of climates.

The TCI has further been critiqued in the literature, predominately around four deficiencies. The first, identified in 2001, is the subjective rating and weighting system based on expert opinion (Scott and McBoyle, 2001; de Freitas *et al.*, 2008; Perch-Nielsen *et al.*, 2010; Demiroglu *et al.*, 2020; Amiranashvili *et al.*, 2021a; Williams, 2021). Later critics of the TCI argue the index negates the tourist experience as a key input in the determination of climate variable thresholds (Scott *et al.,* 2016a; Demiroglu *et al.*, 2020; Rutty *et al.*, 2020). To validate the rating and weighting system, input data from stated tourist preferences through surveys, literature studies, web-based feedback through online platforms such as TripAdvisor and other tourism preference metrics have been included by researchers to better understand tourist experiences of the weather (Morgan *et al.*, 2000; de Freitas *et al.*, 2008; Scott *et al.*, 2016a; Fitchett *et al.*, 2020; Matthews *et al.*, 2021). This is not necessarily a fair critique given the subjective preferences of tourists themselves which are defined by personal and contextual experiences (Mieczkowski,1985; Genç, 2012). Furthermore, thermal comfort, and weightings thereof, can be derived from thermal indices where often there is no user or public perception of comfort as an input in determining physiological comfortability (Jendritzky *et al.*, 2012; de Freitas and Grigorieva, 2015). While it is important to determine the satisfaction of tourists with the weather of a tourism destination, it is not clear whether an accurate reflection of input variables such as maximum temperature can be obtained given the time-of-day respondents are questioned, whether current weather experienced is the norm, and the overall subjectivity of the human experience (Gössling *et al.*, 2016). For example, tourists could remember negative weather events more clearly than positive experiences and an hour of rain could result in them describing an entire day as rainy.

The TCI is also argued to neglect the potential of an overriding influence of physical climate parameters (Scott *et al.*, 2016a). This is to say that precipitation and wind events may cancel out otherwise good weather conditions (Demiroglu *et al.*, 2020). The set thresholds of physical climate parameters may not be transferrable and result in lower input scores where overall TCI scores may be lower from one context relative to another. For example, Fitchett *et al.* (2016c) found sunshine hours to contribute little towards overall TCI output scores where output scores for the reduced version only deviated slightly from the original output score, because for the majority of the year, the scores fell within the largest category for this variable in 'sunny' South Africa.

A third critique of the TCI pertains to the low temporal resolution of climate data. Scott *et al.* (2016a) argue the monthly data used by the TCI has limited relevance for daily or hourly tourist decision-making. Perch-Nielsen *et al.* (2010) addressed this by adjusting the TCI to a daily scale to determine the extent of favourable days in a month. An even higher resolution of hourly climate data has been used and may be ideal to determine the climate for tourism activities as seen by Yu *et al.* (2009) who revised the CIT and developed the Modified Climate Index for Tourism (MCIT). The MCIT considers additional variables of visibility and significant weather such as lightning, snow, and hail as more short-term events in the day (Yu *et al.*, 2009). However, the availability of hourly data has been proven to be a limitation for this and other research (Yu *et al.*, 2009; Demiroglu *et al.*, 2020). Important to consider is the debate around whether higher or lower resolution must be utilized, given that many studies use alternatives due to limited data availability or incomplete datasets, a common challenge particularly in biometeorological studies in Africa (Mieczkowski, 1985; Dinku, 2019; Demiroglu *et al.*, 2020).

A fourth critique of the TCI states that the index neglects the different climatic requirements of varied tourism segments and destination types (Scott *et al.*, 2016a). While Mieczkowski (1985) does mention the challenge of using the TCI to rate recreational activities such as beach and mountain tourism, only sightseeing as a common tourist activity was considered. However, the single use of the TCI in determining ‘suitable’ climate becomes more questionable if tourism destinations offer more than one activity that requires varying climate conditions. Grillskis *et al.* (2016) note the difference in climate resource requirements between camping compared to alpine skiing. Similarly, Noome and Fitchett (2019) found that Afriski in Lesotho, a mountainous landlocked country surrounded by South Africa, which offers snow tourism received lower TCI scores than South Africa. This is due to cold and dry weather conditions being ideal for snow tourism but not when considering the more general world tourism that the TCI represents.

Despite the limitations and critique of the TCI, the index remains widely used. Most research applying the TCI has been published in the northern hemisphere with a total of 93 publications since 1985 and a total of 11 publications in the southern hemisphere, while 13 publications take a global perspective. The first publication based in the southern hemisphere was published in Australia in 2011 (Shiue and Matzarakis, 2011) with regional publications only reaching the African continent in 2016 in Cape St Francis, South Africa (Fitchett *et al.*, 2016a). While studies have been pursued in other areas of southern Africa, the TCI is yet to be applied to areas adjacent to the continent, particularly in the SWIO. Following its development in 1985, the TCI was only applied by researchers other than Mieczkowski in the early 2000s, and use of the index peaked in the 2010s with publications ranging from nine to 11 per year (Figure 2.3).

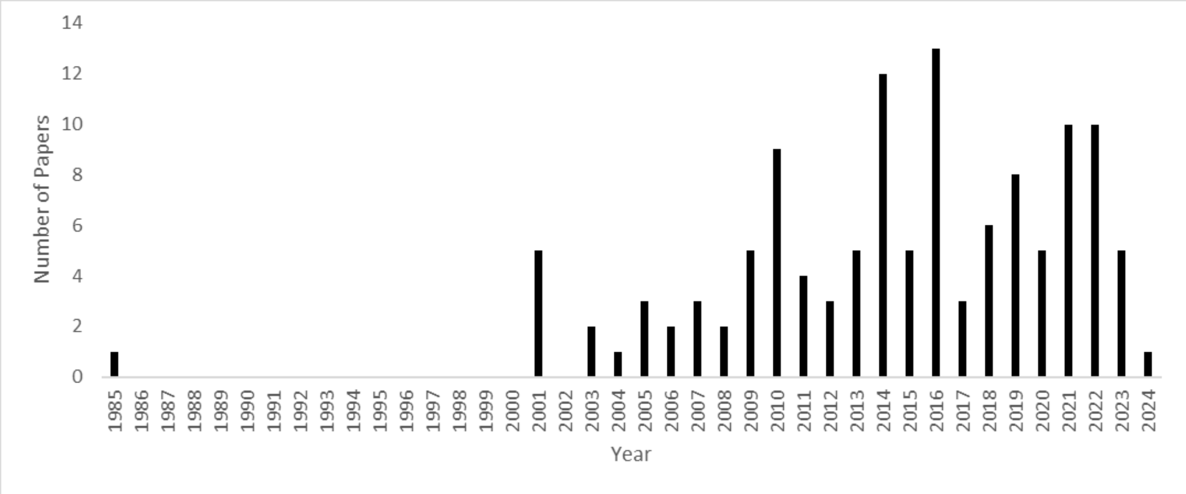


Figure 2.3. The number of publications for the TCI from 1985 to 2024.

2.3.2 Modifications of the TCI

To account for the perceived limitations of the TCI, a range of modified versions of the index have been developed (Kovács and Unger, 2014; de Freitas *et al.*, 2008; Yu *et al.*, 2009). De Freitas *et al.* (2008) modified the TCI to account for weather-sensitive activities such as beach holidays. The modified index was termed the Climate Index for Tourism (CIT) and was verified through 331 surveys from university students (de Freitas *et al.*, 2008). However, the authors predominately set to define the considerations for a comprehensive and universal index, using the CIT. De Freitas *et al.* (2008) argue that a comprehensive and universal index must contain the following features: be theoretically sound, easy to calculate, easy to use and understood by users in the tourism sector and integrate the effects of all facets of climate while recognising the overriding effects of certain weather conditions (de Freitas *et al.*, 2008).

Over time, increased development of sector-specific indices with a narrower focus on tourism activities as compared to general indices such as the TCI have emerged (de Freitas *et al.*, 2008; Matthews *et al.*, 2019; Ma *et al.*, 2020; Demiroglu *et al.*, 2021).

More specific to beach tourism, Morgan *et al.* (2000) developed a slightly modified version of the TCI, the Beach Climate Index (BCI) to evaluate 3S tourism for beach destinations in Wales, Malta, and Turkey. Compared to the TCI, the BCI disregards mean (24-hour) temperature as beach activities are centrally practiced during the day, thus a mean daily maximum temperature with monthly relative humidity was used instead of a 24-hour average (Morgan *et al.*, 2000). Weightings were validated using *in situ* surveys with 1,354 northern European and Mediterranean respondents (Morgan *et al.*, 2000). The BCI has not been widely used since its development but has been applied to studies in the Mediterranean (Moreno and Amelung, 2009a), Indonesia (Haryanto, 2022) and Iran (Lashaki *et al.*, 2022).

As a replacement for the CIT, the HCI_{Urban} was developed by Scott *et al.* (2016a). The HCI_{Urban} is based on tourists' stated preferences for European cities and is used as a climate index for leisure tourism (Scott *et al.*, 2016a). Compared to the TCI, the HCI_{Urban} removes night-time thermal comfort as it was argued that air conditioning had become a universal standard in developed countries and major tourism destinations in developing countries since the inception of the TCI, 30 years prior (Scott *et al.*, 2016a; Rutty *et al.*, 2020). This, however, has not been demonstrated by Scott *et al.* (2016a) or others for those European cities studied, and is unlikely to be the case for all tourism destinations globally. Mushawemhuka (2021) examined the suitability of the use of the TCI and HCI for nature-based tourism in Zimbabwe where a large proportion of tourism accommodation establishments are not air conditioned, resulting in inflated HCI scores. The HCI_{Urban} also places more importance on thermal comfort which is weighted at 40%, with cloud cover weighted at 20%, precipitation at 30% and wind speed at 10% (Scott *et al.*, 2016a).

Similarly, Hejazizadeh *et al.* (2019) compared the use of the TCI and HCI to determine climate suitability for desert regions in Iran and found the TCI more favourable in that it demonstrated a wider range of ideal to not ideal conditions annually compared to the HCI, which revealed little difference in climate conditions. Scott *et al.* (2016a) further argue that the HCI_{Urban} produces a more accurate representation of climatic suitability because it is empirically based on tourist perceptions. However, it is important to note that these perceptions are specific to those respondents within the six European cities, and while the authors argue the importance of the empirical validation that has developed it, it cannot be applied globally without exploring local tourist perceptions. This is problematic in negating the particular offerings of urban sightseeing in smaller contexts or more small-town settings. Further, the HCI_{Urban} is an urban index and should be sector-specific rather than being put forward as the new TCI or CIT, which consider a wider range of tourism activities and offerings.

Comparative studies similar to those explored in Zimbabwe (Mushawemhuka *et al.*, 2021) and Iran (Hejazizadeh *et al.*, 2019) have shown that the argument for the HCI to be used in place of TCI is misrepresentative of destinations both in terms of air conditioning availability and overall representation of the destination. Nonetheless, the HCI_{Urban} has been applied widely (Figure 2.2) to 15 European cities (Tang, 2013; Scott *et al.*, 2016a), Iran (Javan, 2017; Arabi *et al.*, 2018; Mahtabi and Taran, 2018; Hejazizadeh *et al.*, 2019), the Mediterranean (Demiroglu *et al.*, 2020), the Caribbean (Rutty *et al.*, 2020), Indonesia (Hasanah *et al.*, 2020), the United States of America (USA; Ma *et al.*, 2021b), China (Yu *et al.*, 2022a; Xu *et al.*, 2024), Georgia (Amiranashvili *et al.*, 2021a,b, 2024a,b); the Canary Islands (Carrillo *et al.*, 2022), Romania (Velea *et al.*, 2022; 2023), Sri Lanka (Samarasinghe *et al.*, 2023), Malaysia (Jong *et al.*, 2023) Spain (Diaz-Poso *et al.*, 2023), Turkey (Oğur, 2023; Bilgin *et al.*, 2024), Italy (Mazzarano *et al.*, 2024), Australia (Craig, 2024) and South Africa (Kristensen, 2024).

Stemming from the HCI_{Urban} index, the HCI_{Beach} was developed and validated using monthly arrivals data from Canadian tourists', in three Caribbean destinations, namely Antigua and Barbuda, Barbados, and Saint Lucia (Rutty *et al.*, 2020). The HCI_{Beach} differs from the TCI in that it assigns a lower weighting for thermal comfort (20% compared to 50%), because Caribbean tourists rated thermal comfort as the third most important weather variable (Rutty *et al.*, 2020). The percentage of cloud cover is used rather than sunshine hours as a result of limited sunshine hour data from meteorological stations available in the study and has the highest weighting (40%) as it was considered the most important variable based on tourist preferences (Rutty *et al.*, 2020). The precipitation variable assigns a higher score to all amounts greater than 0.5mm with an automatic rating of negative one assigned to rain amounts greater than 25mm to signal an overriding effect of rain (Rutty *et al.*, 2020). The HCI_{Beach} is often used with the HCI_{Urban} although some studies have solely used the beach version (Figure 2.2). It has been applied in the Caribbean (Rutty *et al.*, 2020), the Mediterranean (Demiroglu *et al.*, 2020), China (Yu *et al.*, 2021, 2022a), Georgia (Amiranashvili *et al.*, 2021a,b, 2024b) Indonesia (Sumaja *et al.*, 2023), Iran (Sobani and Danehkar, 2023), Sri Lanka (Samarasinghe *et al.*, 2023), Turkey (Bilgin *et al.*, 2024), Australia (Craig, 2024) and South Africa (Kristensen, 2024).

As a relatively new and sector-specific index, the Camping Climate Index (CCI) was developed in 2020 (Ma *et al.,* 2020). The CCI determines the impacts of weather and climatic variability on optimal camping conditions and occupancy in the USA (Ma *et al.,* 2020). The index was modified from the TCI through its considerations of empirical testing using observed tourist behaviours, addressing the overriding effects of extreme weather conditions, and aimed to better capture seasonality shifts through a methodological approach to better understand optimal camping days by season (Ma *et al.*, 2020). Unlike the HCI_{Urban} and HCI_{Beach}, the CCI retains the initial consideration of night-time thermal comfort as campers sleep outdoors at night (Ma *et al.*, 2020). The definition of outdoors here is contextual given that the authors consider recreational vehicles (RV's) and cabins as part of camping in the USA (Ma *et al.*, 2020). The index considers both mean and extreme weather conditions and provides exception statements that lower the CCI score if particular predefined thresholds are exceeded (Ma *et al.*, 2020). Variable thresholds included minimum and maximum temperature, precipitation, and wind speed and were determined when camping occupancy aligned with unfavourable CCI scores. To date, the index has been predominately applied to nature and camping parks in the USA and posited by the authors of its initial inception through publication in the journals of *Current Issues in Tourism, Tourism Management, Tourism and Hospitality, and Academy of Management Proceedings.* The same group of authors have applied the index globally (Figure 2.2) using gridded data to compare climatic suitability for tourism (Ma *et al.*, 2021a). Within the southern hemisphere, the CCI has only been applied in South Africa (Mnguni and Fitchett, 2024) and has undergone an applicability and suitability assessment prior to use (Figure 2.2; Fitchett and Meyer, 2023).

2.3.3 Intercomparison of Indices

In this thesis, the argument is made that an intercomparison of tourism climate indices is essential to clearly understand the varied climatic suitability that could define a tourism context. Tourism is unique within the sub-theme of biometeorology in trying to argue that each index is a replacement for the former where comparisons are to prove dominance in this field. Within the thermal comfort literature, it is common to see a multi-index approach used (Walls *et al.*, 2015; Kumar and Sharma, 2020; Raines and Fitchett, 2024). Using applicable and multiple tourism climate indices for tourism is not only valuable but necessary for greater accuracy in the determination of climatic suitability for tourism destinations and the varied activities offered. Based on the foundations of the IPCC, interdisciplinary and comparative research is used to "ensure an objective and complete assessment and to reflect a diverse range of views and expertise" (IPCC, 2022: 1). Multi-index comparison is often utilized in the evaluation of heat indices given the many variables influence index scores (Peterson, 1970; Matzarakis *et al.*, 2021).

De Freitas *et al.* (2008: 405) argued that a component of a useful tourism climate index is that "the index is specifically designed for a relevant type of tourism" and requires recalibration to account for varied climatic preferences. A sector-specific index may consider more complexities particular tourism activities may experience, providing more accurate suitability scores as compared to general climate indices. However, as tourism destinations aim to become more competitive, more than one attraction may occupy a space making it necessary to apply more than one index to determine accurate suitability scores (Hoogendoorn *et al.*, 2021). The use of intercomparisons between one or more indices has already been applied in previous research (de Freitas *et al.*, 2008, Scott *et al.*, 2016a, Rutty *et al.*, 2020). However, these intercomparisons aimed to advance one index over another, where the developers of the HCI_{Urban} (Scott *et al.*, 2016a) and HCI_{Beach} (Rutty *et al.*, 2020) argue for the discontinued use of the TCI. This would limit the capacity to calculate the climatic suitability for tourism sectors that do not have specialised indices, such as nature-based and adventure tourism. A multi-index approach recognises the limitations of all indices, allowing the audience to compare the outputs (IPCC, 2021).

The use of multiple tourism climate indices has been used to determine climate resources for camping in the USA (Ma *et al.*, 2021b) and the impacts of climate change on top tourist destination attractiveness in Greece (Lemesios *et al.,* 2024). Ma *et al.* (2021b) applied the TCI, HCI_{Beach}, HCI_{Urban}, Optimised Index and CCI to 11 national parks in the south of the USA. Five indices were used to determine the relative performance of each index, finding the CCI to be most useful in predicting visitation, RV and tent camping compared to the other four indices (Ma *et al.*, 2021b). Lemesios *et al.* (2024) also applied five tourism climate indices, the HCI_{Beach}, HCI_{Urban} and indices customised for Greek climate conditions, the Urban Climate Comfort Index (UCCI), Beach Utility Index (BUI) and Mountainous Winter Climate Index (MWCI). These five indices were used together to determine the change in suitability for summer, sightseeing and skiing tourism (Lemesios *et al.,* 2024). The former study has used a multi-index approach that aims to prove one index is greater than another while the latter has used this approach to determine climatic suitability for varied tourism types specific to Greece. Further, Ma *et al.* (2021b) only apply the indices in a portion of the USA while Lemesios *et al.* (2024) apply the indices broadly in Greece including the mainland and its islands. The use of a multi-index approach in Réunion Island will be of great value given that spatially, the island is small but covers a broad topography and varied tourism types. Further, this study does not aim to determine the best index for climatic suitability for the island but rather uses established tourism climate indices together as they are each valuable in determining potentially varied climatic suitability for the island.

2.4 Climate Futures for the SWIO

Climate change is projected to result in wide-ranging impacts on varied sectors including tourism (Becken and Wilson, 2013). Tourism is one of the most vulnerable sectors to climate change as it relies on climate as a resource (Scott *et al.*, 2012a). Increasing temperatures, heightened frequency and intensity of ECEs, rising sea levels and the shift in the seasonal distribution of resources will impact the functioning and appeal of tourism destinations (Scott *et al.*, 2012a). Climate futures refer to the understanding of scenarios and projections in the literature and the coinciding impacts for tourism and the adaptive strategies to address changes the tourism sector will face.

2.4.1 Climatic Threats in the SWIO

With the projected global increase in temperature of above 1.5°C relative to preindustrial levels under Shared Socioeconomic Pathways (SSP) 1-1.9, the SWIO basin is projected to experience changes in annual temperature and precipitation patterns, SLR and increased intensity and frequency of ECEs, particularly tropical cyclones and heatwaves (Mycoo *et al.*, 2022). The following section explores the climate threats that the SWIO region is projected to experience as well as the adaptation strategies undertaken to address these threats.

Increased temperatures under climate change will impact human thermal comfort, which will be further exacerbated in regions which are concurrently becoming more humid (Vecellio *et al.*, 2023). Equivalent temperature is a metric for assessing thermal comfort and is a measure of temperature, humidity and wind in which the heat budget of the human body is balanced with the external temperature of the environment (Su *et al.*, 2024). Temperature increases under climate change have a potential impact on the thermal comfort of tourists and can dissuade tourists from returning to the destination if they feel too hot to take part in outdoor activities (Matzarakis, 2007; Giddy *et al.*, 2017b). Increased temperatures directly impact the movements and activities of tourists and their overall satisfaction with their experience (Caldeira and Kastenholz, 2018; Yu *et al.*, 2023). This is concerning for island destinations that market good climate conditions to attract tourists (Fitchett *et al.*, 2020), and which are located in the already warm and humid tropics. In the Indian Ocean, Mills and Hancock (2005) note a 1.5°C temperature increase for small islands as per a business-as-usual scenario by 2050, where three years later, Tadross *et al.* (2008) note a uniform increase in temperature across the region. Under particularly high emission modelled scenarios, Leroux *et al.* (2021) project an increase of 1- 2.2°C for the SWIO at the end of the century, with small islands experiencing substantial warming of an increase to 4°C from 2071-2100. Nature-based tourism will be indirectly impacted by rising temperatures as it affects the wildlife viewing experiences, thus reducing destination appeal and future repeat visits by tourists (Agnew and Viner, 2001; Kilungu *et al.*, 2020; Sibitane *et al.*, 2022). In coastal regions and small islands, temperature increases will have an impact on entire ecosystems with coral bleaching, and marine biodiversity loss that will indirectly affect tourists and lead to shifts in demand and competitiveness of tourism destinations (Agnew and Viner, 2001; Gössling and Scott, 2024).

Climate change will impact precipitation patterns through increased precipitation events that will result in flooding or reduced precipitation events such as droughts (IPCC, 2021). Tourists will be directly affected by flooding events through safety concerns, and infrastructure damage (Fitchett *et al.*, 2016a,b; Southon and van der Merwe, 2018; Toubes *et al.*, 2021; Dube *et al.*, 2023b). Conversely, lack of rain through drought results in water restrictions (Martínez-Ibarra, 2015; Drummond, 2019; Dube *et al.*, 2022, Prinsloo and Fitchett, 2023), disruption in adventure and business activities that rely on water (Giddy *et al.*, 2017a; Huddart and Stott, 2020; Pandy and Rogerson, 2021) and negative media coverage that could invoke fear and hesitance to travel (Drummond, 2019; Warner and Meissner, 2021). Precipitation patterns across the region are more challenging to model due to temporal and spatial variability among specific sites (Tadross *et al.*, 2008). Through examination of historical and future changes in rainfall in Madagascar, Tadross *et al.* (2008), argue that there will be an increase in summer rainfall and a decrease in rainfall in autumn months. The southern half of the east coast of Madagascar is projected to become drier in the winter months while the remainder of the country is expected to get wetter (Tadross *et al.*, 2008). As rain is identified as a key component in the satisfaction of tourist experiences, the variability of rainfall is a factor that tourism accommodation providers can prepare for (Gössling *et al.*, 2016; Fitchett *et al.*, 2020). Tourism will be indirectly impacted by flooding and drought where tourism operators and providers will experience revenue loss, reduced visitors and loss of destination appeal resulting in a decline in repeat visits and recommendation intentions (Hamzah *et al.*, 2012; Richardson *et al.*, 2015; Wang *et al.*, 2019).

Increased ECEs are projected to intensify and for some, increase in frequency. ECEs here refer to tropical cyclones, heatwaves, flooding and drought (Stephenson *et al.*, 2008). The frequency and intensity of tropical cyclones impacting the SWIO basin have seen mixed reviews. Tadross *et al.* (2008) project a decrease in tropical cyclones during the early part of the cyclone season, particularly around the region of Madagascar. Five years later, Malherbe *et al.* (2013) similarly projected a decrease in the occurrence of tropical cyclones over the SWIO adjacent to southern Africa at the end of the century. Muthige *et al.* (2018) argue the extent of tropical cyclones making landfall over southern Africa will decrease under global warming. While the occurrence of tropical cyclones may decrease, the intensity with which they impact islands in the SWIO as well as southern Africa will increase and will be distributed more poleward in the future (Pillay and Fitchett, 2019). However, as a result of its land size, Barthe *et al.* (2021) argue that Réunion Island is not often directly impacted by tropical cyclones but experiences the effects of systems passing through. Indirectly, ECEs will impact future tourism flows and are associated with high economic costs that result in the slow rebuild and rebranding of tourism destinations (Rosselló *et al.*, 2020).

SLR is a large concern for island tourism destinations as a result of beach erosion that reduces the attractiveness of beach tourism (Mooser *et al.*, 2020). The resultant impacts of SLR on island destinations include flooding of low-lying coastal and inland areas which impact freshwater availability and sanitation systems that are not only basic rights of locals but a necessity for tourism operations (Seetanah and Fauzel, 2018; Carvalho and Wang, 2019; Hoegh-Guldberg *et al.*, 2019). Becker *et al.* (2019) noted a greater than average increase of around 4mm per year from 1993-2014 in the Indian Ocean, examined near Mauritius. A decade prior, Han *et al.* (2010) describes SLR as globally disproportionate, arguing that the south tropical Indian Ocean has seen a decrease in sea level. Although sea-level rise is not globally uniform, within the SWIO, Li and Su (2021) describe sustained warming in sea-surface temperatures in the SWIO that goes beyond ongoing warming through climate change which will result in greater tropical cyclone intensity.

2.4.2 Climate Change Adaptation in SWIO

Due to their relatively small land area, small islands are highly vulnerable to the impacts of climate change, particularly SLR and extreme events that result in a higher magnitude of losses and recovery demands as opposed to inland areas (Duvat *et al.*, 2016). This section will focus on adaptation to climate change impacts as the impacts of climate change, particularly in the SWIO region are inevitable and will impact the most vulnerable SIDS states which are argued to have lower adaptive capacity (Robinson, 2017). This is not to say that mitigation efforts are not relevant; mitigation strategies are crucial in agricultural and energy production and to avoid further severe climate impacts (Singla, 2024), and tourism does indeed contribute to climate change (Becken, 2002, Pang *et al.*, 2013; Mearns, 2016).

Adaptation strategies for heat stress risk vary according to the context and economic ability of countries, particularly developing regions (Nunfam *et al.*, 2020; Vecellio and Vanos, 2024). Research has investigated infrastructural adaptation strategies through climate-sensitive designs that look to address heat stress including cooling pavements and roofs and green infrastructure (Larsen, 2015; Sun *et al.*, 2021); water-sensitive city designs to support urban cooling (Coutts *et al.*, 2013; Broadbent *et al.*, 2018; Carden *et al.*, 2018; Winker *et al.*, 2019) and smarter energy efficient air conditioning systems (Bruno *et al.*, 2019). Stewart *et al.* (2014), for example, investigate using materials and methods centred around retrofitting, strengthening, enhancing designs and frequent inspections in relation to buildings and ECEs.

Climate change will increase global water demand heightening pressure on water systems. Water shortages and water stress will impact the agricultural sector the most, however, the other sectors including the tourism sector will face great challenges

(Wang *et al.*, 2016). Gössling *et al.* (2012b) highlight that tourism increases global water consumption and water use could be exacerbated at regional levels, particularly in dry and water-scarce regions highlighting the need for proactive water management strategies. Iglesias *et al.* (2007) examined the strategic use of groundwater, irrigation technology and water resource management plans implemented in the Mediterranean to address high tourist water consumption. Desalination plants were implemented in Mykonos, Greece to address water scarcity which holiday stakeholders see as a temporary solution (Atay and Saladié, 2022). Skrimizea and Parra (2020) have evaluated water management adaptation strategies for tourist islands highlighting the need for place-centred and multi-scale approaches to adaptation decision-making. Torres-Bagur *et al.* (2020) found that nature-based tourists engage in water-saving practices better than business or cultural tourists. Citizen engagement with tourists aided in the reduced use of water in Airbnb during the Cape Town Day Zero Drought (Prinsloo and Fitchett, 2023). Within this same context of the Day Zero Drought, Visser and Cloete (2021) found that water management strategies made by guesthouses appeared to become permanent practices rather than temporary solutions but were met with resistance from guests after the drought.

Adaptation to SLR has been implemented through methods of hard protection, raising accommodation establishment infrastructure or land and migration of settlements. Predominately applied to Mauritius and the Maldives, seawalls as a form of hard protection have been installed (Robinson, 2017). However, Betzold and Mohamed (2017) argue the maintenance of these structures is challenging and costly to maintain. Further, these shoreline structures may decrease the aesthetic appeal of tourism destinations where alternative strategies such as managed retreat would be preferred (Rulleau and Rey-Valette, 2017). Raising accommodation establishment infrastructure and land has also been implemented (Nazarnia *et al.*, 2020) but given the economic status of SIDS, it may be too costly. However, as land reclamation is a common result of these processes, Bisaro *et al.* (2020) argue that land raising has the potential to generate revenue through the sale of new land. As another strategy, migration of settlements has been pursued, albeit as a last resort given the social and financial implications (McNamara and Des Combes, 2015; Magnan and Duvat, 2018). In the case of Réunion Island, as it is categorised as a high mountainous island, it would prove to be challenging to relocate the majority of the population who have settled in low-lying coastal areas to more uninhabitable parts of the island which would exacerbate socio-economic issues (Petzold and Ratter, 2019; Ribalaygua *et al.*, 2019). In this regard, the adaption strategy is argued to go beyond a technical solution and considers the socio-political and coping capacities of those involved (Petzold and Ratter, 2019).

Ecosystem-based measures have also been examined to reduce the risks associated with SLR. Mauritius and the Maldives have implemented strategies such as mangrove planting, artificial reefs and beach nourishment (Shaig, 2011, Reguero *et al.*, 2018). Artificial reefs have been developed in Grenada reducing erosion as well as limiting the effects of the 2004 Indian Ocean tsunami for the Maldives (Reguero *et al.*, 2018; Fabian *et al.*, 2013). To reduce beach erosion, beach nourishment has been used to maintain particular beaches in Barbados (Mycoo, 2014). Under higher temperature events, however, Cornwall *et al.* (2021) argue particular biophysical limits will be reached where these ecosystem-based solutions can no longer be a solution, for example, coral reef alternatives which are still sensitive to temperature changes.

Sudden ECEs induced by climate change or risk-prone tourism destinations require strategies around warning systems and evacuations (Tsai and Chen, 2011). Successful early warning systems and comprehensive evacuation plans were seen to prevent loss of life during what is argued by authors to be a climate change-induced landslide in Bolivia (Aparicio-Effen *et al.*, 2018). From examining the great East Japan earthquake and tsunami in Japan, typhoon Yolanda in the Philippines, and Hurricane Maria in Dominica, Faure Walker and Yore (2021) found that the timing of early warning systems is important in informing evacuation decisions and that multiple forms of warning are needed to reach a larger percentage of the population. Similarly, Yi *et al.* (2018) found community-based early warning systems, education and evacuation to reduce risk during the 2013 Kelud volcano eruption in Indonesia. This would be a concern for tourists who travel to destinations for short periods of time and may miss these early warnings. Becken and Hughey (2013) examined the link between disaster risk reduction systems and tourism in New Zealand, finding limited disaster management planning at the time, and stating the importance of this for tourism destinations that are prone to risk. Hall *et al.* (2019) also highlight opportunities for government and tourism providers to disseminate knowledge, warnings and evacuation instructions to tourism hotspot areas such as hotels, airports and through tourism websites when destinations are susceptible to ECEs. Around volcano tourism, Kuri and Suppasri (2018) investigated the use of tourism activities to disseminate disaster information to residents and visitors, finding that evacuation awareness was still limited in areas where knowledge dissemination activities were active and that residents relied heavily on perceptions of eruption frequency and local government guidance.

As a French department, climate change adaptation strategies for Réunion Island are complex. Petzold and Ratter (2019) argue Réunion Island depends on the guidelines set out by the European Union's adaptation strategy and regulatory frameworks and requires support from France. However, while adaptation to climate change in France has been increasingly consistent, Ribalaygua *et al.* (2019) argue the outer regions under its control, such as Réunion Island, do not have specific action plans and require more extensive planning tools for implementation. Therefore, aspects of adaption, asymmetrical governance structures and relationality need to be taken into consideration (Petzold and Ratter, 2019).

2.5 Conclusion

As an island within the SWIO, Réunion Island has been understudied. Limited attention has been paid to islands in the SWIO, particularly around the impacts of climate change on the tourism sector, a key economic sector. Thus, understanding the changes in climate over time and their relation to tourism offerings is imperative. Further, climate indices as tools of investigation into climatic suitability, amongst other motivations, are highly debated. Modified versions of the TCI have been advocated by a small group of authors as a replacement for the original TCI rather than in combination with it. Given the vulnerability of Réunion Island to increased climate risk now and in the future, a thorough investigation into the island's climatic suitability and the tools used to determine it is required.

CHAPTER 3: STUDY SITE

3.1 Introduction

This study is focused on quantifying the climatic suitability for tourism in Réunion Island, a small tropical island in the SWIO. Réunion offers a vast number of tourist attractions centred around its volcanoes, sandy beaches, lush mountainous terrain and urban features that you can see from the island's only public cable car (Figure 3.1). Due to its diverse landscape and tourism offerings, the island is an ideal location to apply a wide range of tourism climate indices. The island was produced from volcanic activity and so is host to relatively flatter low-lying coastal regions as well as more rugged topography that captures the significance of microclimates that provide greater insight into the application of tourism climate indices. This chapter outlines a description of the geographic region and topographic characteristics of Réunion Island as well as the climate and weather of the island. A description of the economic landscape and tourism offerings prevalent in this study will also be outlined in this chapter.

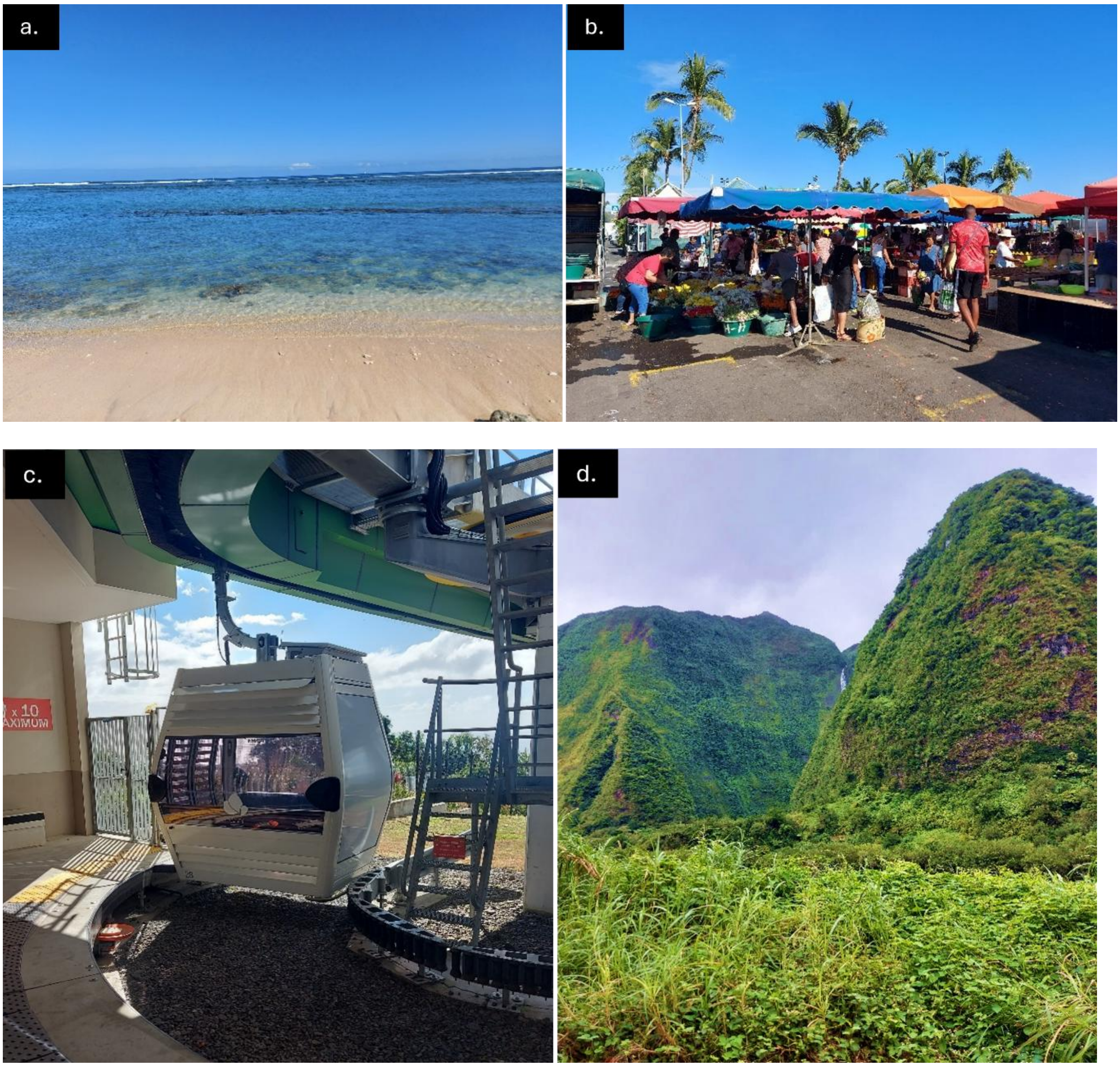


Figure 3.1. Varied tourist attractions include a) beaches, b) markets c) a city cable car and d) many mountainous areas with waterfalls found on the small island of Réunion.

3.2 Geography of Réunion Island

3.2.1 Geography and Topography

Réunion Island or La Réunion, is an island in the SWIO located between the coordinates of 21°22'-20°52'S and 55°16'- 55°47'E, spanning a total terrestrial area of 2,512km^2 (Figure 3.2, Bigot *et al.*, 2019). The island, together with Rodrigues and Mauritius, form part of the Mascarene archipelago, a geographical rather than politically defined region (Bigot *et al.*, 2019). Réunion is located 680km east of

Madagascar and 170km southwest of Mauritius (Bourjon *et al.*, 2019). The island has a coastline of 207km with a 12km^2 fringing reef belt on the west coast of the island (Lemahieu *et al.,* 2017; Île de La Réunion, 2022). The west coast of the island hosts accessible beaches while the east and south coast, aptly named "Wild South Coast" hosts jagged coastlines and experiences rough sea waves (Île de La Réunion, 2022: 1). Waves reach up to 6m heights during tropical cyclone season in this area (Vaxelaire, 2018). Beaches are classified as white and sandy or black consisting of eroded coral and basalt (Vaxelaire, 2018). Beyond the coastline, tourists can enjoy activities such as canoeing, kayaking, scuba diving and boat trips to watch dolphins and whales when in season (Mille Tours, 2020). The island is predominately impacted by the South Equatorial Current (Pous *et al.*, 2014).

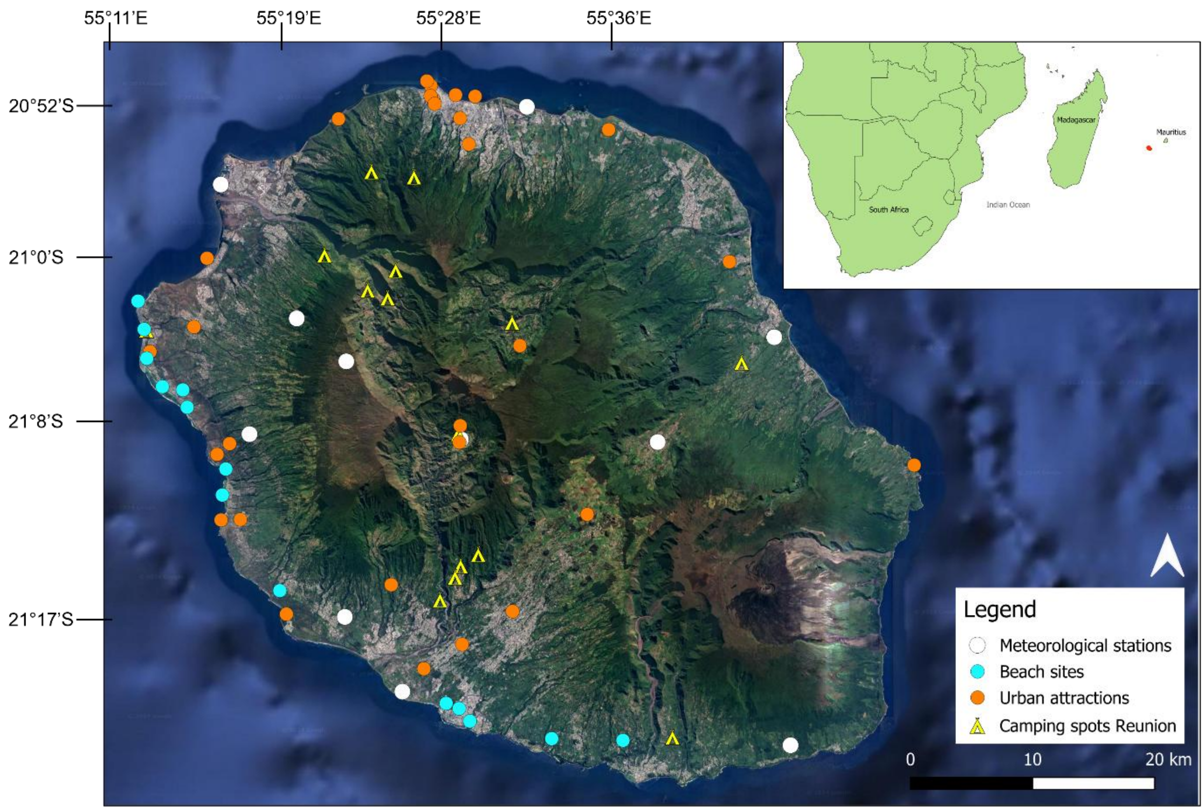


Figure 3.2. Map of the study region of Réunion Island indicating meteorological stations, major cities, beach and camping sites.

Réunion Island formed from volcanic activity over two million years ago and is the youngest of the Mascarene islands (Benard *et al.*, 2016; Forward, 2020). Two volcanos were formed, Piton des Neiges, a dormant stratovolcano for 20,000 years and the highest point of the island at 3,071m.a.s.l. and Piton de la Fournaise, an active volcano at a height of 2,631m.a.s.l (Hawaiian Volcano Observatory, 2001; Lameyer *et al.*, 2015; Vaxelaire, 2018). Piton de la Fournaise is the younger of the two volcanoes, and is considered one of the most active hot spot basaltic shield volcanoes globally (Winckler, 2018; Chevrel *et al.*, 2020). It is also one of the major tourist attractions of the island, which can be viewed from a car drive up to the summit with the option of hiking to the crater (French Bee, 2021). The volcanoes have been part of UNESCO's list of World Heritage Sites since 2010 (La Réunion, 2022). The island contains three natural amphitheatres with vertical slopes greater than 1000m high as a result of collapses from Piton des Neiges, these are termed the Cirques and comprise Salazie, Cilaos and Mafate (Morel *et al.*, 2014; Réunion Island, 2022). Cilaos and Salazie are towns with full road access. Mafate is the most remote amphitheatre containing a secluded village with no entry roads where foot trails are used to enter the village and supplies, and waste removal are executed through helicopters sent by the French government (Quarnstrom, 2023). Lava flows from Piton de la Fournaise are predominately seen in the southeasterly region of the island along a forest road termed 'Lava Road' where six major lava flows that have flowed into the Indian Ocean are visible (Figure 3.4; French Bee, 2021). A resulting feature from one of these lava flows is Tremblet beach, formed in 2007 where it has been identified as the youngest beach in the world (Figure 3.3; Indian-Ocean, 2024).

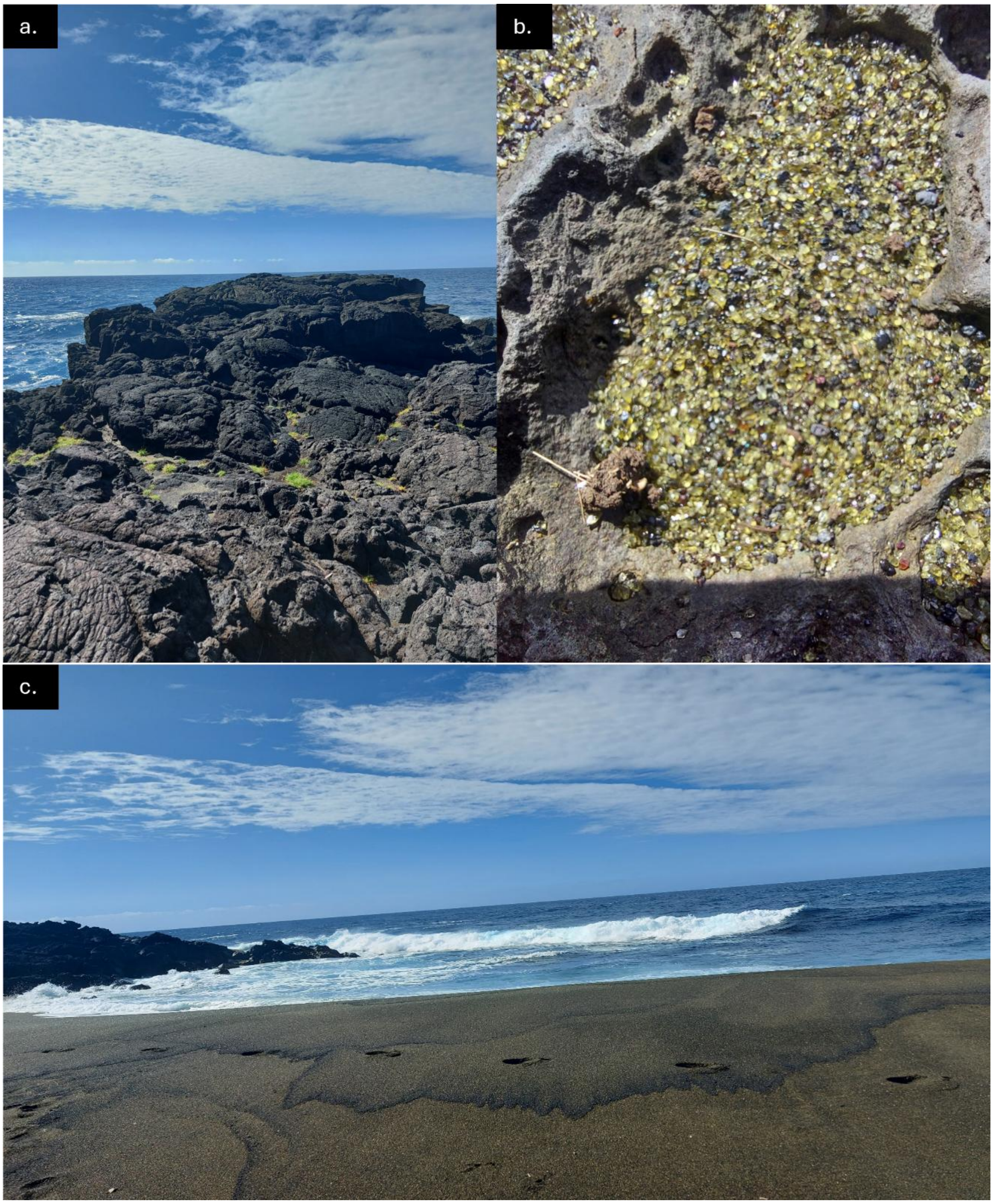


Figure 3.3. Tremblet beach, characterised by a) black-cooled lava b) dark brown sand and consists of c) golden sand particles.

The vegetation on the island ranges from dry to evergreen forests, wetland areas, shrubland, grassland and varied thicket variations and savannah (Figure 3.4). The extent of dry and evergreen forests not only offer aesthetic appeal for tourists but also protection from strong winds and shade from the sun. Hiking activities also take place in the dense natural vegetation of the evergreen forests which offer similar protection (Goursaud, 2016). Savanna vegetation is located in lower elevation areas where most built-up urban spaces are situated resulting in a decline of natural savanna habitats (Strasberg *et al.*, 2005). On the southeast of the island, vegetation regrowth within volcanic lava flows adds to the touristic curiosity of the island (Figure 3.4; French Bee, 2021).

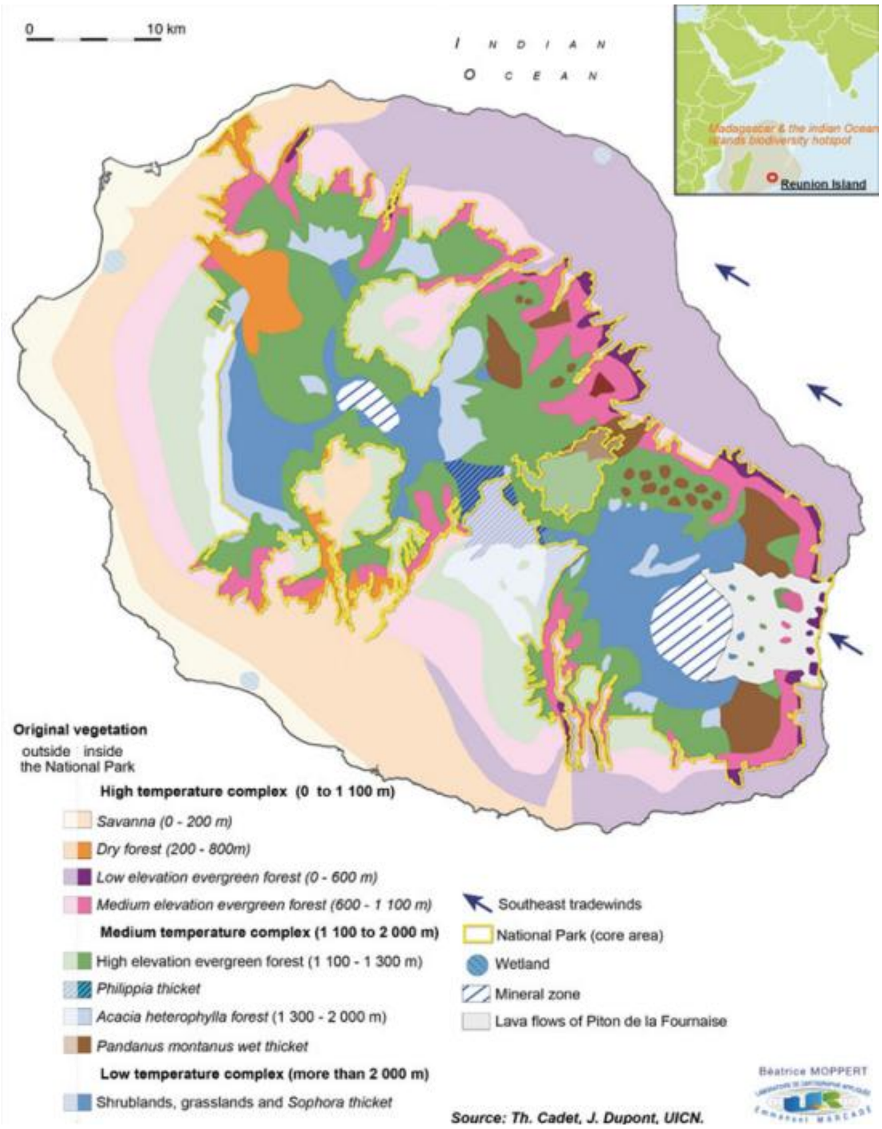


Figure 3.4. Vegetation map of Réunion Island (Brou, 2019).

The urban landscape of Réunion is characterised by 1,000km^2 of liveable areas to support its growing population of 866,000 inhabitants as of 2019 (Vaxelaire, 2018; Forward, 2020). Given increasing population needs, urban regional planning has sought to increase infrastructure in the mid-highlands areas of the island rather than extending within the limited availability of the coastline (Garde *et al.*, 2007). The island contains small coastal towns, hamlets within mountain formations, modern built-up coastal cities and administrative areas, particularly in the northern and western regions of the island (La Réunion, 2024b). Cultural heritage sites are marketed around the history of slavery, colonisation and diverse transformation of the island where tourists can visit functional vanilla plantations, religious sites and Creole-style houses uniquely decorated with bright colours and lambrequins (Figure 3.5; La Réunion, 2024d).

Figure 3.5. Diverse architecture in Réunion from a) historical hotels, b) modern university buildings, c) a church and community centre in Salazie and d) a grand church in Sainte-Anne.

3.2.2 Climate and Weather of Réunion Island

Réunion is characterised by tropical and subtropical climates (Réchou *et al.*, 2014). It is strongly influenced by its wind regime, proximity to the ocean through warm Indian Ocean sea surface temperatures (SST), orographic lift (Meteo1, 2024) and its position in the subtropics that result in Réunion Island exhibiting 200 distinct climates with numerous microclimates (Vaxelaire, 2018). The island is impacted by the Hadley cell and Walker circulation where from May to November during austral winter, steady low-level easterly winds and upper-level westerly winds along with a temperature inversion result in drier conditions (Morel *et al.*, 2014). During austral summer, January to March, Réunion Island experiences wet conditions as trade winds and the inversion weaken. April and December are described as wet or dry transition months (Morel *et al.*, 2014). According to the Köppen Geiger classification, Réunion Island is dominated by a tropical savanna climate (Aw) that receives less rainfall in winter months but also contains areas, particularly on the northern and eastern coast, with an equatorial monsoon climate (Am) as most months of the year experience significant rainfall (Table 3.1; Climate-data Organization, 2023).

Table 3.1. Köppen Geiger climate classification table (Kottek *et al.*, 2006).

Type	Description	Criterion
A	**Equatorial climates**	$T_{min} \geq +18\ °C$
Af	Equatorial rainforest, fully humid	$P_{min} \geq 60$ mm
Am	Equatorial monsoon	$P_{ann} \geq 25\,(100 - P_{min})$
As	Equatorial savannah with dry summer	$P_{min} < 60$ mm in summer
Aw	Equatorial savannah with dry winter	$P_{min} < 60$ mm in winter
B	**Arid climates**	$P_{ann} < 10\,P_{th}$
BS	Steppe climate	$P_{ann} > 5\,P_{th}$
BW	Desert climate	$P_{ann} \leq 5\,P_{th}$
C	**Warm temperate climates**	$-3\ °C < T_{min} < +18\ °C$
Cs	Warm temperate climate with dry summer	$P_{smin} < P_{wmin}, P_{wmax} > 3\,P_{smin}$ and $P_{smin} < 40$ mm
Cw	Warm temperate climate with dry winter	$P_{wmin} < P_{smin}$ and $P_{smax} > 10\,P_{wmin}$
Cf	Warm temperate climate, fully humid	neither Cs nor Cw
D	**Snow climates**	$T_{min} \leq -3\ °C$
Ds	Snow climate with dry summer	$P_{smin} < P_{wmin}, P_{wmax} > 3\,P_{smin}$ and $P_{smin} < 40$ mm
Dw	Snow climate with dry winter	$P_{wmin} < P_{smin}$ and $P_{smax} > 10\,P_{wmin}$
Df	Snow climate, fully humid	neither Ds nor Dw
E	**Polar climates**	$T_{max} < +10\ °C$
ET	Tundra climate	$0\ °C \leq T_{max} < +10\ °C$
EF	Frost climate	$T_{max} < 0\ °C$

Réunion Island experiences warm subtropical temperatures throughout the year (Indian Ocean, 2022). Mean maximum temperatures for the island range from 25-27°C in winter and 30-32°C in summer (Figure 3.6; Li and Li, 2021; Météo-France, 2024). Coastal temperatures range between 18-31°C whereas mountainous areas range between 4-18°C (Meteo1, 2024). Colder temperatures are found at the highest peaks of the island where during winter, mean minimum temperatures range from 2-4°C on the summits and between 8-10°C in areas such as Plaine des Palmistes that lead up to a summit (Météo-France, 2024). Temperatures decrease by 0.6°C with every 100m increment in altitude (Davidson *et al.*, 2023). Localised katabatic winds can create cooler conditions as cool air descends from mountainous areas (El Gdachi *et al.*, 2024). During summer, mean minimum temperatures range between 8-10°C at the summits and 14-16°C in areas that lead up to the summit. Northern and western coastal regions experience the highest mean minimum temperatures, rarely falling below 18°C (Météo-France, 2024).

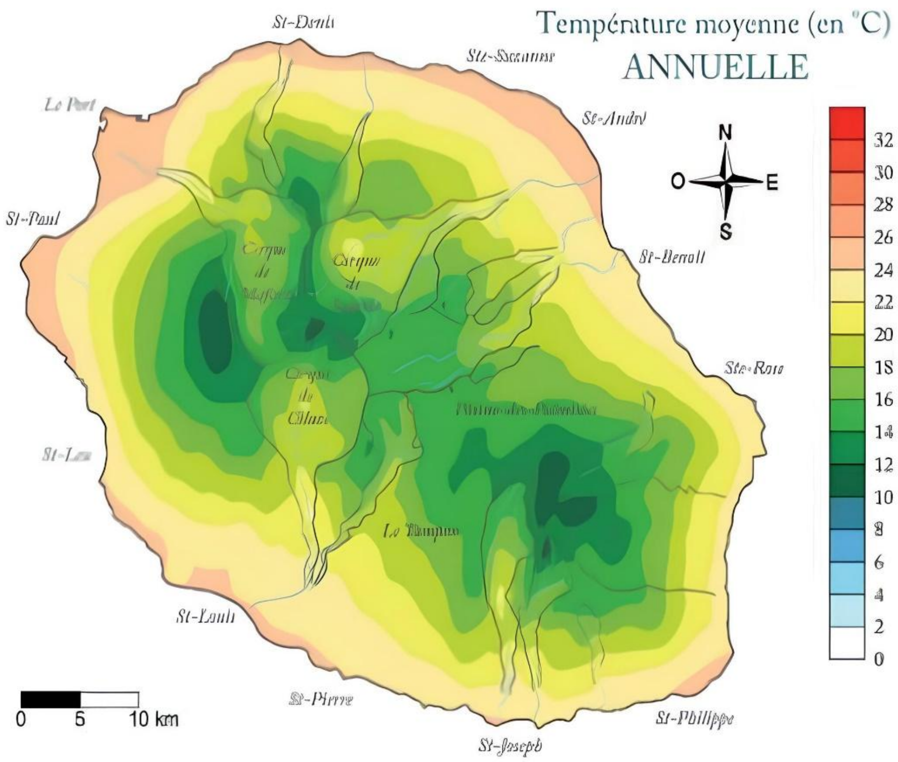


Figure 3.6. Average annual temperature for Réunion Island (Météo-France, 2024).

Southeasterly trade winds transport moist air to the island (Réchou *et al.*, 2019). Seasonal variation in humidity is experienced in Réunion (Weather Spark, 2024). Over seven months of the year from October to June, comfort levels around humidity include classifications ranging from muggy, oppressive or miserable (Weather Spark, 2024). January has the most muggy days (29.7) whereas August has the least number (2.7) of muggy days (Weather Spark, 2024). Due to the proximity to a warm sea, humidity is high and can exacerbate feelings of heat experienced on the island.

Réunion Island is located close to the Tropic of Capricorn and therefore experiences a south-easterly trade wind regime that carries humidity and rainfall throughout the year to the island's eastern side (Réchou *et al.*, 2019). In addition, due to the high relief of both volcanoes and the resultant rain shadow, higher precipitation is experienced on the east coast (windward side) of the island receiving 12,000mm annually with the west coast remaining considerably drier receiving an average of 650mm annually (Figure 3.7; Réchou *et al.*, 2014; Garot *et al.*, 2019; Météo-France, 2024). The island experiences particularly high precipitation between January and March, ranging from 91.7-128.8mm per month due to the Intertropical Convergence Zone (ITCZ) being close to the island resulting in the formation of deep convective systems (Réchou *et al.,* 2014; Météo-France, 2024; Weather Spark, 2024). The dry season in Réunion Island begins in May and ends in November, where on average 14.7mm of rainfall per month is experienced (Météo-France, 2024; Weather Spark, 2024). Intense rainfall has resulted in changes to the topography of the island including the development of deep canyons, steep ridges, calderas and ravines found predominately in the central and eastern regions of the island (Réchou *et al.*, 2019). The island has received snowfall, but it is rare, with two cases experienced in August 2003 and October 2006 on the summit of Piton des Neiges (La Réunion, 2022).

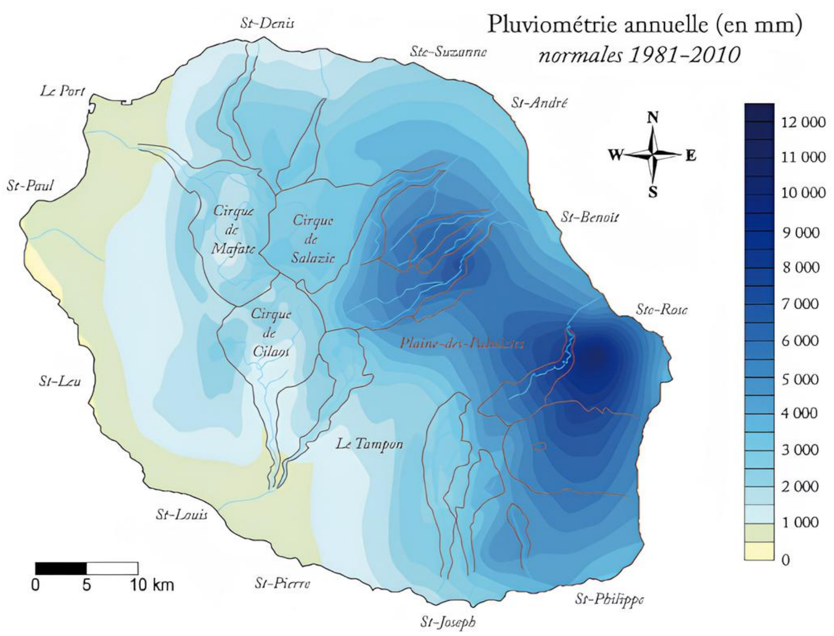


Figure 3.7. Average annual precipitation over a 20-year period from 1981 for Réunion Island (Réchou *et al.*, 2014; Météo-France, 2024).

Réunion Island receives approximately 2,500 sunshine hours per year in coastal areas (Selosse *et al.*, 2018; Vaxelaire, 2018). Sunshine hours range on average around 10 hours and 51 minutes in winter months to 13 hours and 25 minutes in summer months (Weather Spark, 2024). The average time between sunrise and sunset is 12 hours and 13 minutes (Weather Spark, 2024). There is seasonal variation in cloud cover throughout the year on the island with the clearest month of the year being August where average cloud cover is clear, mostly clear or partly cloudy for 91% of the time (Weather Spark, 2024). The cloudiest month of the year is January where average cloud cover varies from overcast to mostly cloudy 61% of the time (Weather Spark, 2024).

The SWIO experiences 10-15% of global tropical cyclone activity (Barthe *et al.*, 2021). Tropical cyclones are commonly experienced between November and April (Mavume *et al.*, 2009). Although only two tropical cyclones have made landfall in its history, Category 1 Tropical Cyclone Beryl in 1961 and Category 2 Tropical Cyclone Firinga in 1989, tropical cyclones passing through the archipelago hundreds of kilometres away can have an impact on the island (Barthe *et al.*, 2021). Réunion Island has extremely high rainfall amounts during tropical cyclone season with average rainfall ranging from 12 hours to 15 days (Morel *et al.*, 2014).

Within an individual day, the weather can be quite varied depending on where you are on the island. On the western coast, mild temperatures and sunny conditions could be experienced in the morning with temperatures becoming increasingly warm until the afternoon. The eastern coast could experience similar conditions, but clouds gather quickly, resulting in sudden downpours. Within higher altitude areas, cooler temperatures could become warmer where mist could develop throughout the day. The weather throughout the day is relatively unpredictable and localised to particular areas.

3.3 Réunion Island Economy and Tourism

3.3.1 Economy of Réunion Island

In 1946, Réunion Island formally integrated with the French Republic gaining status as an overseas region in 1974 thereby influencing the structure of the economy (Forward, 2020; Cole and Cabestan, 2024). The island is supported through financial aid and subsidies from the European Union and French Government (European Commission, 2017). Given the close ties to mainland France, it is described as a developed island nation, but there is little consensus in the literature as to what constitutes its economic activities, or the economic independence of the island (Cole and Cabestan, 2024).

Economic activities in Réunion are perceived to be predominately driven by agriculture, particularly sugar cane (Stanziani, 2018). Over time, the country has aimed to move away from a single economy based on agriculture to a more service-based economy with tourism only recently becoming an important contributor to the economy (Forward, 2020). A range of sources (Thomassin *et al.*, 2010; Magnan and Duvat, 2018, Forward, 2020) therefore describe the distribution of the economy as market and non-market services (67%), transport and distribution (16%), construction (7%), industry (8%), and only a 1.4% contribution from agriculture and fisheries. Tourism contributed 8% or €1.9 billion to the Gross Domestic Product (GDP) of the island in 2023 and is projected to increase to 8.4% or €2.1 billion by the end of 2024 (World Travel and Tourism Council, 2024). The economy is also slowly incorporating what it calls a 'tropical bio-economy' with a drive for ecotourism and digital knowledge development of clean energy consumption (European Commission, 2017).

The island experiences challenges of economic dependency, high rates of unemployment and poverty, with 37% of citizens living below the poverty line in 2019, which is higher than in mainland France (Outermost Region: Conference of Presidents, 2023). The public sector is a major employer but with the island importing 67% of its food supply and 57% of its livestock feed, the cost of living is expensive (Billen *et al.*, 2024). However, the island is increasing its economic independence through local food markets and fairs (Seychelles Nation, 2017), the growth of alternative tourism accommodation establishments such as Airbnb (Okoronkwo, 2024) and its operation of local airline Air Austral (Odhiambo, 2021). The airline was founded in 1974 with the primary aim of increasing the inter-island connections of travellers in the Indian Ocean (Iles Vanille, 2024).

3.3.2 Tourism in Réunion Island

Réunion Island welcomed 556,089 tourists in 2023 (Île de Réunion Tourisme, 2024). Before COVID-19 travel restrictions, the island received approximately 574,000 international tourists in 2018, with many travellers visiting the island through cruise ships or as an alternate destination to Mauritius (St Agne, 2019). The French market represents 80% of foreign tourists with 445,208 visiting the island in 2023 (Île de Réunion Tourisme, 2024). The second largest external visitors to Réunion, 12.2%, are from the Indian Ocean. The largest cohort of these travellers, 34,608, come from Mayotte, 23,022 from Mauritius and 5,349 from Madagascar (Île de Réunion Tourisme, 2024). Tourists from Europe comprise 5.9% of tourists, who come predominately from Belgium, Switzerland and Germany (Île de Réunion Tourisme, 2024). The remaining 1.8% of tourists are from other regions of the world. In 2023, the largest proportion of tourists arrived in Réunion between November and January as well as in August (Île de Réunion Tourisme, 2024). Domestic tourism is an important market for the island where in 2019, it was estimated that €1.2 billion was contributed by tourism spending from Réunion residents compared to the €600 million from external tourists (Île de Réunion Tourisme, 2022). Local tourism is comprised of day trips around the island, purchasing from local markets, catering and eating at local restaurants and stays in camping, guesthouse and hotel accommodation establishments (Île de Réunion Tourisme, 2022).

The average duration of stay varies according to accommodation type. The highest duration of stay is 24 days, with tourists staying with relatives and friends, followed by short-term rentals and tourism residences of 20 and 19 days respectively (Île de Réunion Tourisme, 2024). Hotels have shorter stay duration between 10-11 days and rustic guesthouses and rooms are stayed in for nine days. Camping site stays average approximately seven days (Île de Réunion Tourisme, 2024). As of 2022, there are a total of 1,128 tourist accommodation establishments on Réunion Island (Figure 3.8; Île de Réunion Tourisme, 2024). Tourism accommodation types available include seasonal rentals (64.5%), guesthouses (17.3%), stop-over and hiking lodges (8.6%), hotels (8.1%) and 1.5% are classified as camping sites (Île de Réunion Tourisme, 2024).

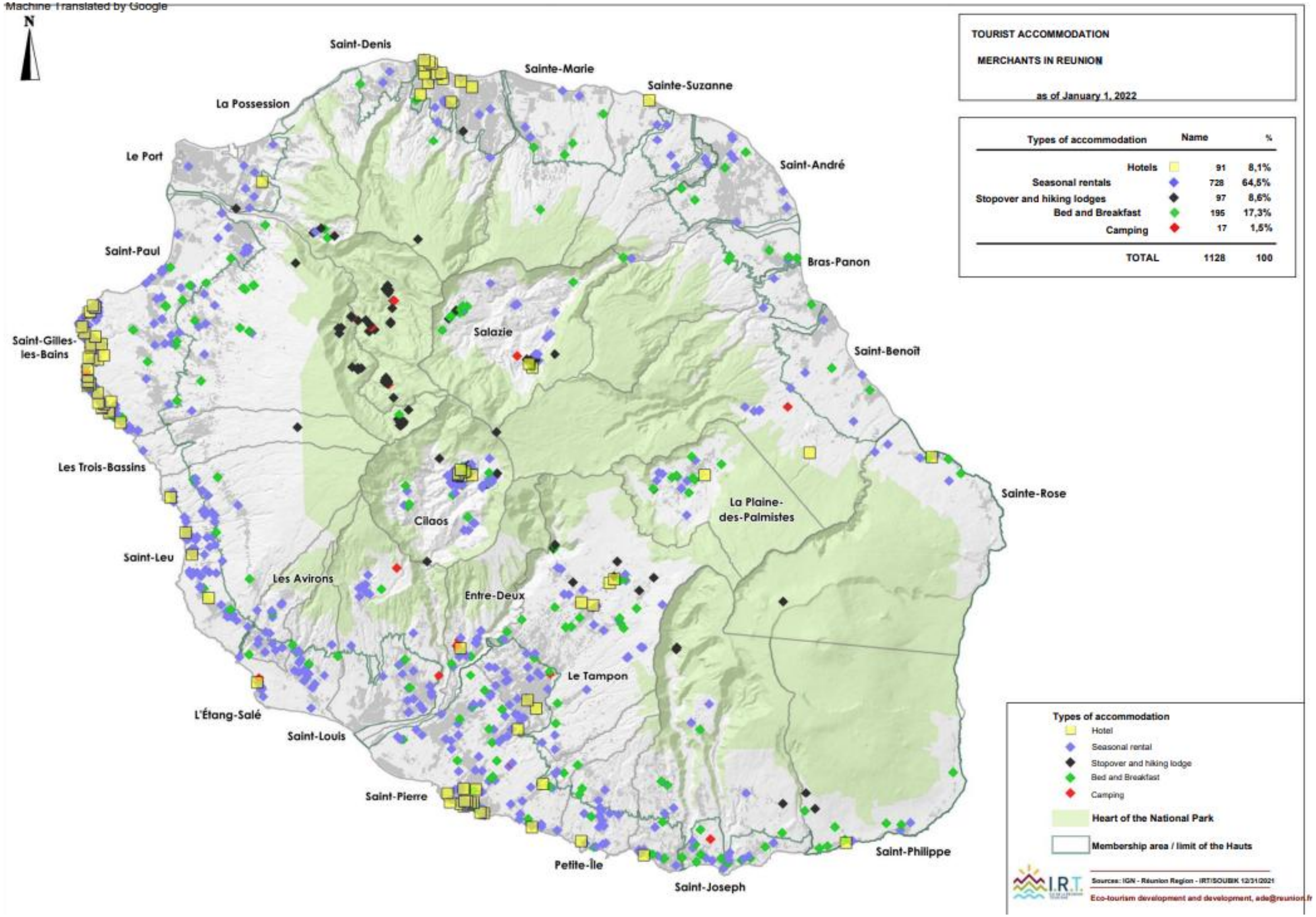


Figure 3.8. Map of tourism accommodation types offered across the island (Île de Réunion Tourisme, 2024).

The island is marketed around four tourism offerings namely marine, mountain, culture/traditions and volcano tourism (Île de Réunion Tourisme, 2018). Lava flow tunnel tours are offered as a form of adventure tourism, allowing tourists to explore the underground galleries that have formed over time (French Bee, 2021). Popular water activities include swimming with dolphins, kayaking in the lagoons, star gazing at sea, snorkelling and deep-sea diving but are forbidden within a 300m perimeter around the island as a result of a protected marine wildlife area and due to increased shark risk (La Réunion, 2024 c, e). The island is also marketed around hiking. It hosts many hiking trails paced at varied levels of hiking ability (Goursaud, 2016). Hiking trails vary in length from hours to up to six days and are situated in both mountainous areas as well as the coastline. Accommodation establishments include 30 mountain lodges around the island that have been made available for hikers (Vaxelaire, 2018). Two coastline hiking trails located on the eastern side of the island are along Sainte-Rose and Saint Benoit (Goursaud, 2016). Some hiking trails start from urban towns such as Le Piton de l'Entomoir which starts in the town of Saint-Joseph located on the south of the island (Goursaud, 2016).

The Réunion Island Tourism Board, Observatoire Regional du Tourisme*,* aims to promote the island to the European market, countries within the Indian Ocean, southern Africa as well as India and China (Île de Réunion Tourisme, 2018). Challenges in reaching these tourism markets include limited visibility outside of mainland France; limited information to inform marketing strategies to other markets, accessibility, language and cost barriers, competition with Mauritius, remoteness to world tourism markets and high shark risk labels that are associated with the island (Île de Réunion Tourisme, 2018). One case study of the South African tourist market found that tourists from South Africa prefer the island destinations of Mauritius and

Thailand with Madagascar and Réunion remaining marginal destinations despite a visa exception introduced in 2013 (Horwath HTL, 2016). Réunion is highly marketed around outdoor activities, however, a 2016 report found that only a small segment of South African travellers are motivated by these activities, and so marketing to South Africa has been challenging (Horwath HTL, 2016).

To address these challenges, the Observatoire Regional du Tourisme has developed several strategies to increase the positioning of the island (Île de Réunion Tourisme, 2018). To differentiate from competing destinations, Observatoire Regional du Tourisme is aiming to increase qualitative and contributory tourism by branding itself as an ecotourism island. They aim to economise on its unique history and position as a French department and develop experiential and differentiating marketing strategies (Île de Réunion Tourisme, 2018). A strategy to create networks with South African tourism professionals is ongoing that includes workshops, educational tours in Réunion and training sessions for tour operators to assist this aim (Horwath HTL, 2016). Further, Observatoire Regional du Tourisme, is aiming to reassure tourists about the minimal risk of shark attacks, create joined tourism offerings between the island and Mauritius as well as expand the tourism seasonality of the island (Île de Réunion Tourisme, 2018).

3.4 Conclusion

Réunion Island is a diverse tropical island with settings that range from sandy to rocky beaches, mountainous areas, two UNESCO volcano sites and urban attractions linked to modern and historical French and Creole culture. The type of tourism attractions offered correspond well with the tourism climate indices aimed to be applied in this study. The tourism sector is relatively new compared to other economic sectors and aims to increase its tourism market and become a popular tourism destination as neighbouring Mauritius. The climate of the island is also distinctive as a result of its position in the SWIO and topography that results in a drier western side of the island and a wetter eastern side. The climate also results in the presence of microclimates that presents a unique lens through which to test tourism climate indices.

CHAPTER 4: DATA AND METHODOLOGY

4.1 Introduction

This chapter outlines the data and methods used to quantify the climatic suitability of tourism for Réunion Island. The methods in this study draw from a number of previously developed tourism climate index studies and their application in a range of locations globally. The scale of global studies includes for example, a global investigation from TCI Mieczkowski (1985) and CCI (Ma *et al.*, 2021a), European and North American perspectives of both iterations of the HCI (Scott *et al.*, 2016a; Rutty *et al.*, 2020) and the CCI in the USA (Ma *et al.*, 2020, 2021b) and South Africa (Mnguni and Fitchett, 2024). Each index has valuably aided in the identification of climatic suitability and seasonal variation for tourism in particular locations. However, when computed and presented at a global scale, these index outputs have insufficient resolution for small islands such as Réunion. Further, global estimations based on gridded data do not pick up the level of variability in topographically complex regions (van der Walt *et al.*, 2023; Fitchett and Mackay, 2024). Importantly, at the time of writing, this study is the first to bring these indices together in a multi-index approach in the southern hemisphere. In addition to putting forward this multi-index approach, it is also the first of any tourism climate index quantification of climatic suitability for tourism in the SWIO.

In line with the research objectives highlighted in *Chapter 1*, this chapter will first describe the assessment of applicability, suitability and validity pursued prior to the application of any of the tourism climate indices used. Once highlighted that the use of all four indices is indeed appropriate, a description of meteorological and field-based data acquisition is provided. The meteorological input variables required for each index are highlighted followed by a description of each equation, rating and classification system. Scores are calculated for the longest period annually, monthly and daily. The seasonal distribution was determined followed by the change in climatic suitability over time.

The decision to assess the TCI, both iterations of the HCI and CCI to be used in this study is based on whether the indices are theoretically, contextually and activity-appropriate (Figure 4.1). Réunion Island offers a range of tourism activities that include general sightseeing, beach activities, urban activities, hiking and camping. Modifications of the TCI were not pursued because the CIT was designed for 3S tourism (de Freitas *et al.*, 2008) and the MCIT aims to identify visibility and significant weather events using hourly weather data (Yu *et al.*, 2009). Apart from the lack of higher-resolution data available, both have been applied in limited settings compared to the widely used TCI (Figure 4.1). Similarly, the HCI_{Urban} was chosen over the UCCI (Kapetanakis *et al.*, 2022) as the former has been applied to multiple tourism destinations where the UCCI is specific to the context of Greece. The HCI_{Beach} was chosen over the BCI, as the latter replaced the HCI_{Beach} because it was not validated using beach tourists' preferences and needed greater empirical testing (Rutty *et al.*, 2020). The CCI was chosen as, to date, it is the only camping-specific index and has been applied globally (Ma *et al.*, 2021a), in the USA (Ma *et al.*, 2020,2021) and in South Africa (Mnguni and Fitchett, 2024) and aligns with the marketing of camping activities in Réunion. Other indices that do exist but are not applicable in this context are, for example, the SCI (Demiroglu *et al.*, 2021). It cannot be used given the limited snow cover and lack of skiing tourism. It is noted that in higher mountain areas of the island, snow has been known to occur (La Réunion, 2024a), however, it is not enough to propose ski tourism activities. The Korea Tourism Climate Index (KTCI) would also not be applicable in this context as it was developed to account for Korean tourist preferences for the country's particular tourism market (Park, 2015; Kim *et al.*, 2019).

As the four tourism climate indices have been broadly applied and align to the types of tourism found in Réunion, they are argued to be applicable in this research context.

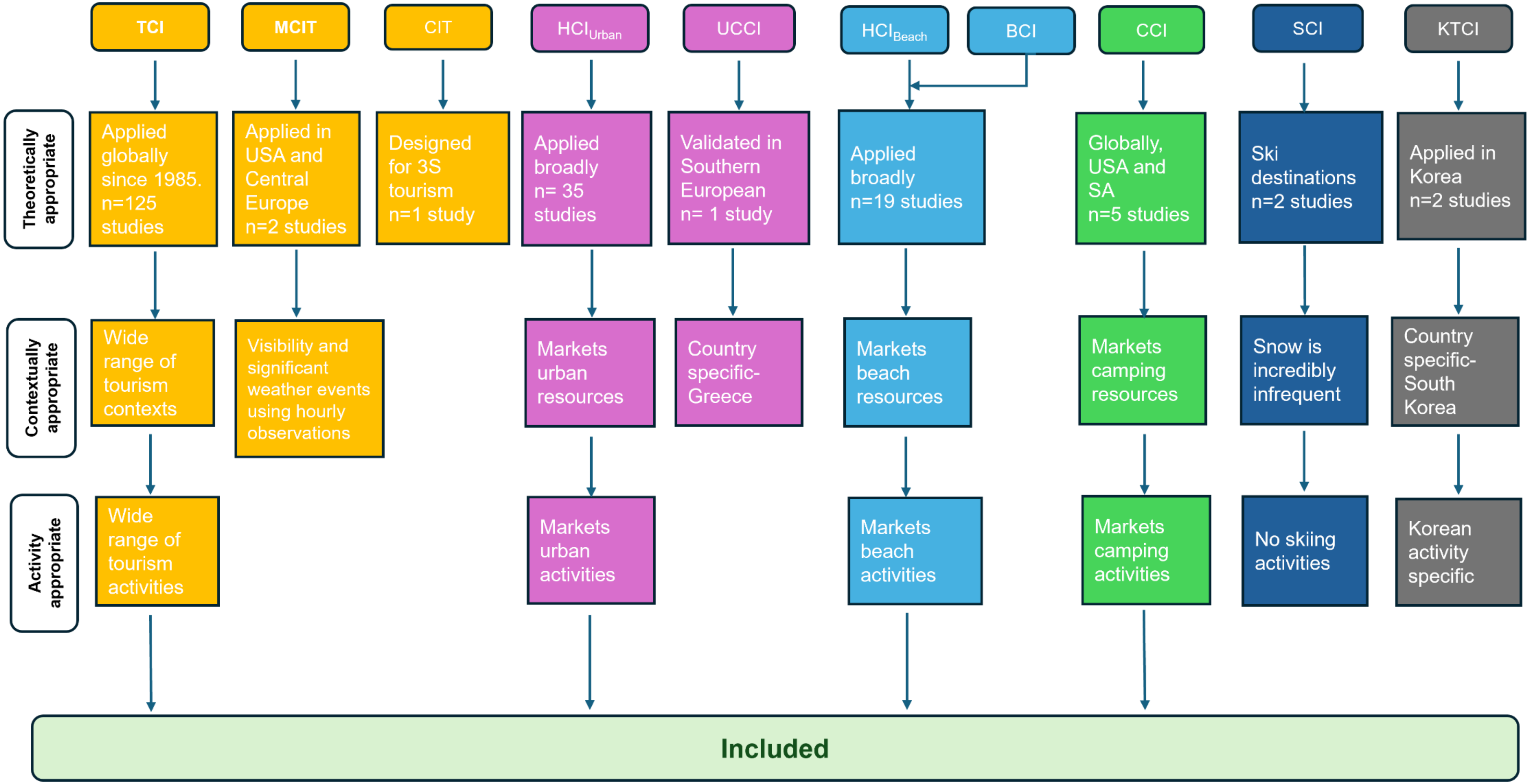


Figure 4.1. Prisma-type diagram describing tourism climate index selection.

4.2 Applicability, Suitability and Validity Assessment

Tourism climate indices have been developed, applied and validated within varied contexts. Very few studies determine whether an index is applicable, suitable or valid to use before it is used. The universal thermal comfort index (UTCI), for example, was applied to determine a date when heat stress levels would impact athletes competing during the Comrades marathon (Havenga *et al.*, 2022), but was later critiqued because the index considers moderate physical activity such as walking and not running, as the main physical component of this marathon, which underestimates heat stress (Simpson *et al.*, 2024). The HCI has been critiqued for its use in southern Africa because a lack of air conditioning and stable access to electricity results in nighttime thermal comfort becoming a concern for tourists, which the index does not account for (Mushawemhuka, 2021; Noome and Fitchett, 2022). Fitchett and Meyer (2023) determined whether the CCI is applicable and suitable for application in South Africa, prior to its local application (Mnguni and Fitchett, 2024). This provided a clear approach to evaluating these components of an index, which can be applied more broadly. To determine applicability, Fitchett and Meyer (2023) explored the availability of meteorological data, finding that sunshine hour data were limited but other required data of temperature and wind speed are available, so it is applicable but with limited spatial coverage. Fitchett and Meyer (2023) explored the suitability of the index using questionnaire data, finding thermal comfort and sunshine to be factors of importance to tourists and therefore consistent with the primary input variables of the CCI. Based on the importance of the pre-assessment highlighted by Fitchett and Meyer (2023), this research sought to carefully interrogate all indices used before their application.

4.2.1 Applicability

Applicability, in the context of this research, refers to the assessment of whether a tourism climate index can practically be applied to the setting in question. The applicability is dependent on two criteria. First, whether the index aligns with the tourism offerings within the study context. To accomplish this, the types of tourism offered in Réunion were investigated through an online search using La Réunion (2024a,b,c,d,e,f) marketing websites and TripAdvisor (TripAdvisor, 2024) as well as through two fieldwork campaigns.

Second, whether the requisite input data used to compute an index at the appropriate resolution is available. Daily input variables of T_{min}, T_{max}, T_{mean}, minimum relative humidity, mean relative humidity, precipitation, and wind speed were identified for all four indices. Cloud cover data were identified for the HCI and sunshine hour data for the TCI and CCI. The level of completeness of data per station was evaluated and substitutions for incomplete data were determined.

4.2.2 Suitability

The suitability of an index refers to whether an index should be used in a specific location based on its inherent assumptions. If an assumption holds true, the index can be deemed suitable to use (Fitchett and Meyer, 2023). The TCI has been built from pre-existing indices assumed to be used broadly (Mieczkowski, 1985). This assumes the index can be used to describe all tourism attractions, activities and destinations, however, the climatic requirements for suitability may differ according to the context of a tourism destination, for example, a destination that provides desert or skiing tourism. These assumptions will be unpacked in relation to the context of Réunion Island. A large concern of the HCI is that it negates nighttime thermal comfort with the assumption that air conditioning is "almost universal" (Scott *et al.*, 2016a: 85). To determine the extent of air conditioning availability, popular tourism accommodation booking sites (Booking.com, TripAdvisor, Hotels.com, Trivago and Kayak) were examined for flexible input travel dates. For each site, air conditioning amenities were searched for using a filter function, from which a total number of accommodation establishments that provide air conditioning was calculated. The CCI was built in the USA using camping occupancy data and the suitability for the CCI has been assessed in a South African context and tested with specific thresholds. Therefore, locational contexts will be compared to determine if the CCI will be suitable in Réunion. This will be unpacked further in *Chapter 5*.

4.2.3 Validity

The validity of an index is dependent on whether its results align with on-the-ground experiences in a local setting. The TCI, HCIs and CCI have been validated through expert opinion (Mieczkowski, 1985), tourist preferences (Scott *et al.*, 2016a) and occupancy data (Ma *et al.*, 2020; Rutty *et al.*, 2020), respectively. Whether these validated indices hold true for a context like Réunion Island was considered. The weightings and variable thresholds for each index were developed based on the validation techniques mentioned. Therefore, to determine whether the four indices are valid for the context of Réunion, tourists' self-reported preferences and reports by Observatoire Regional du Tourisme collected from literature and online research will be examined in relation to the weightings and thresholds of each index. The collection of in-person tourist preference data was not pursued in this study.

4.3 Meteorological and Field-based Data Acquisition

To calculate tourism climate index scores and thus quantify climatic suitability, meteorological data were acquired from Météo-France. No tourism data were collected for this study, but information from the Observatoire Regional du Tourisme, was compiled from online reports and literature and reflected on in the discussion (Chapter 7). Data for 11 meteorological stations located across the island were obtained at a daily resolution, spanning periods ranging from 1991-2023. Roland Garros Airport contained the longest and most complete period of data (33 years), followed by Cilaos (15 years), Colimacons (14 years), Le Port (12 years), and Plaine des Palmistes (10 years). Le Baril, Pont Mathurin, Saint-Benoit and Pierrefonds Airport contained eight years of data while Piton-Maido and Petite-France contained only seven years of useable data (Figure 4.2).

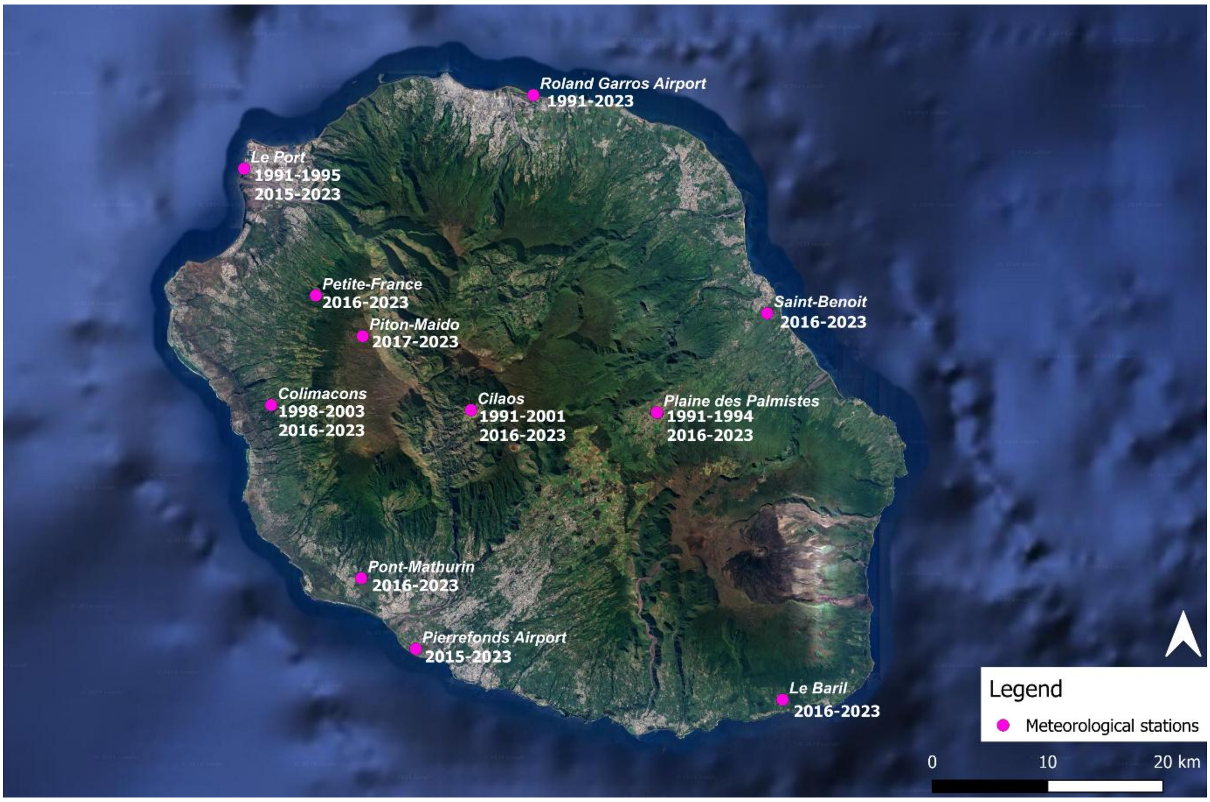


Figure 4.2. Data availability in year ranges for each of the 11 meteorological stations in Réunion Island.

Each index considers climatic factors that are relevant to tourism including a thermal component that is calculated from temperature and relative humidity, a physical component, that includes precipitation and wind speed, and an aesthetic component of either sunshine or cloud cover (de Freitas *et al.*, 2008; Perch-Nielsen *et al.*, 2010; Scott *et al.*, 2016a; Ma *et al.*, 2020). Data variables in each dataset included the date of measurement, minimum temperature ($T_{min;}$ °C) and maximum temperature (T_{max}; °C), maximum and mean relative humidity (%), precipitation (mm), sunshine hours (min), wind speed ($m.s^{-1}$), and cloud cover (oktas). To fulfil the input requirements of each index, sunshine hours, wind speed and cloud cover needed to be converted into the appropriate format. Sunshine minutes were converted to hours and wind speed was adjusted from metres per second ($m.s^{-1}$) to kilometres per hour ($km.h^{-1}$). Cloud cover is measured in oktas and is required to be in a percentage format to be input into tourism index equations (Table 4.1). The TCI and CCI require T_{mean} and minimum relative humidity (%), where values were calculated from the existing data.

Table 4.1. Sunshine, wind speed and cloud cover variables conversion equation and units.

Input variable	Raw unit	Converted unit	Equation
Sunshine (S)	m	hrs	$S = \frac{Minutes}{60}$
Wind speed (WS)	$m.s^{-1}$	$km.h^{-1}$	$WS \times 3.6$
Cloud cover (CC)	oktas	%	$\frac{CC}{8} \times 100$

Data were checked and cleaned, identifying gaps in the data. Meteorological station data were incomplete, with greater gaps in sunshine hour and cloud cover data than other input variables. One solution explored for the substitution of sunshine hour data would be to exclude the sunshine hour variable. Fitchett *et al.* (2016c) found that excluding sunshine hours in a reduced version of the TCI results in significantly similar results to the outputs of the full TCI, ultimately finding that this variable could be excluded in a South African context without compromising index accuracy or comparability. This is due to relatively consistent year-round day length at that latitude, and the predominance of cloud cover in summer rather than winter for much of the country (Fitchett *et al.*, 2016c). As Réunion is situated at a similar latitudinal range to the interior of South Africa, where this approach was most effective, this may have been an option (Fitchett *et al.,* 2016c). This approach was tested for one full station, Roland Garros Airport, in Réunion but it was found that it resulted in notably different TCI scores and therefore was not pursued. Another method explored for the substitution of sunshine hour data determined estimated sunshine hours compared to measured sunshine hours using solar radiation data in a South African context (Fitchett *et al.*, 2024). A statistically significant difference was found between measured and estimated sunshine hours and an estimation of sunshine hours in South Africa was cautioned against (Fitchett *et al.*, 2024). As Réunion Island is within a similar latitudinal range, the substitution of sunshine hours using this method similarly was not pursued. Gridded data were not used because Réunion Island is mountainous, limiting the accuracy of a gridded approach, especially over such a small geographic area (van der Walt *et al.*, 2023; Fitchett and Mackay, 2024). Cloud cover was also less ubiquitous. Noome and Fitchett (2019) experienced this limitation in calculating climatic suitability in the Lesotho highlands with the use of remote sensing imagery. The use of remote sensing was not used as it is time-consuming and also has accuracy limitations (Mushawemhuka *et al.*, 2021). Therefore, this study used the data that were available and where data were incomplete, no substitutions were made.

Ground-based climate measurements were taken in two one-week field visits in June 2023 and 2024 to compare to meteorological station data to determine how suitability may differ *in situ* (Heise *et al.*, 2009). The ground-based measurements taken in June

2023 were used in this study while data from June 2024 will not be referred to in this study as they could not be compared with 2024 meteorological data because data could not be acquired from Météo-France. Similar meteorological variables to the station data were collected including location information. Meteorological data including the date, time, location, latitude and longitude coordinates, elevation, air temperature (°C), relative humidity (%), wind speed (km.h^{-1}), and wet bulb temperature (°C) were collected. Ground-based data in both fieldwork campaigns were collected using a global positioning system (GPS) and Kestrel 3000 (Chung and Meyer, 2017). Observations of location characteristics, precipitation, cloud cover and fog were noted. Data were collected every 15 minutes to account for changes in location and weather throughout the day (Kothapalli and Totad, 2017). Further, a base station was set up at the fieldwork accommodation establishment chosen, recording weather data using a data logger (Burt, 2012). In June 2023, the accommodation establishment or base station was located on the west of the island, while in June 2024 it was located on the east of the island. This was chosen as a means of determining weather conditions on each side of the island. The device captured temperature and relative humidity every 15 minutes and was used because it is inexpensive and convenient to position while providing relatively accurate weather information (Burt, 2012). *In situ* measurements across a range of touristic locations were later cross-referenced to the base station during both field visits.

4.4 Calculation of Indices

4.4.1 Effective temperature

Tourism climate indices consider thermal comfort as an important variable in climatic suitability (Matzarakis, 2007; Perch-Nielsen *et al.*, 2010; Scott *et al.*, 2016a; Rutty *et* *al.*, 2020). Thermal comfort refers to "the condition of mind that expresses satisfaction with the thermal environment" (Gosling *et al.*, 2014: 24). Effective temperature can be measured using a range of methods from the ASHRAE scale, Humidex, and the UTCI. The initial TCI used the ASHRAE scale to determine thermal comfort using manual observations from the thermal comfort chart (Mieczkowski, 1985). A more computationally simple method to determine equivalent temperature, with low data requirements is the Humidex (Equation 1). The HCI and CCI use the Humidex to determine thermal comfort (Scott *et al.*, 2016a; Ma *et al.*, 2020).

$$Humidex = Air\ temperature + \frac{5}{9} \times \left(6.112 \times 10^{7.5 \times \frac{T}{237.7+T}} \times \frac{H}{100} - 10\right) \qquad [1]$$

Humidex is a measure of effective temperature based on temperature and humidity (CCOHS, 2024). The equation output produces a thermal sensation as a temperature in °C (CCOHS, 2024). From this, the temperature is classified according to Humidex 1 for unacclimatized workers/moderate work scenarios and Humidex 2 for acclimatized workers/light work scenarios (Figure 4.3; AWS, 2023). Humidex is calculated and classified from one to six (light yellow to red) corresponding to a suggested response recommended by the Canadian Centre for Occupational Health (CCOHS, 2024). Tourism climate indices do not use this classification scheme and each use their own thresholds and scoring to determine effective temperature levels associated with each level of climatic suitability for tourism.

Humidex 1 – Moderate physical work, unacclimatized worker, OR Heavy physical work, acclimatized worker	Response	Humidex 2 – Moderate physical work, acclimatized worker, OR Light physical work, unacclimatized worker
25 - 29	• supply water to workers on an "as needed" basis	32 - 35
30 - 33	• post Heat Stress Alert notice • encourage workers to drink extra water • start recording hourly temperature and relative humidity	36 - 39
34 - 37	• post Heat Stress Warning notice • notify workers that they need to drink extra water • ensure workers are trained to recognize symptoms	40 - 42
38 - 39	• work with 15 minutes relief per hour can continue • provide adequate cool (10 - 15°C) water • at least 1 cup (240 mL) of water every 20 minutes • workers with symptoms should seek medical attention	43 - 44
40 - 41	• work with 30 minutes relief per hour can continue in addition to the provisions listed previously	45 - 46*
42 - 44	• if feasible, work with 45 minutes relief per hour can continue in addition to the provisions listed above	47 - 49
45 or over	• only medically supervised work can continue	50* and over

Source: Occupational Health Clinics for Ontario Workers (OHCOW) – "Humidex Based Heat Response Plan"

Figure 4.3. Humidex classifications for acclimatised and unacclimatised workers.

All of the tourism climate indices require the effective temperature to be determined. Therefore, the effective temperature is calculated using Humidex. Humidex output scores are the input data for the thermal comfort component of each index.

4.4.2 Tourism Climate Index (TCI)

The TCI was calculated using the equation developed by Mieczkowski (1985) and refined by Perch-Nielsen *et al.* (2010). The original TCI used 12 climate variables but was later reduced to seven variables to account for the restrictions in commonly available data (Perch-Nielsen *et al.*, 2010). The TCI was calculated at a daily resolution using Equation 2:

$$TCI = 2(4CID + CIA + 2R + 2S + W) \qquad [2]$$

For the TCI, there are two thermal comfort measures: daytime thermal comfort (CID) computed from T_{max} and minimum relative humidity, and daily thermal comfort (CIA), which includes nighttime conditions and is computed from T_{mean} and mean relative humidity (Perch-Nielsen *et al.*, 2010). Weightings are given according to their perceived importance for tourists (Mieczkowski,1985). The thermal component is weighted at 40% for CID and 10% for CIA. Precipitation (R) is weighted at 20%, sunshine hours (S) at 20% and wind speed (WS) at 10%. Each variable is rated according to the TCI ranking table with ratings that range from -3 to 5 (Table 4.2).

Table 4.2. Rating system for each climatic variable input into the TCI (after Roshan *et al.*, 2016).

Rating	Effective Temperature (°C)	Mean Monthly Precipitation (mm)	Mean monthly sunshine hours (hrs)	Wind speed (km.h^{-1})
5.0	20-26	0.0-14.9	>10	<2.88-5.75
4.5	19 27	15.0-29.9	9	5.76-9.03
4.0	18 28	30.0-44.9	8	9.04-12.23
3.5	17 29	45.0-59.9	7	12.24-19.79
3.0	16 30	60.0-74.9	6	19.80-24.29
2.5	10-15 31	75.0-89.9	5	24.30-28.79
2.0	5-9 32	90.0-104.9	4	28.8-38.52
1.5	0-4 33	105.0-119.9	3	
1.0	(-)5-(-)1 34	120.0-134.9	2	
0.5	35	135.0-149.9	1	

0.25				
0	>36	>150.0	<1	>38.53
	(-)10-(-)6			
-1.0	(-)15-(-)11			
-2.0	(-)20-(-)16			
-3.0	<(-)20			

Ratings for each variable are input into the TCI equation producing an output score that can range from -30 to 100 (Table 4.3). Descriptive categories describe the preferred conditions experienced by tourists and range from <10 classified as 'impossible' suitability to 100 classified as 'ideal' suitability. This however is generalised and represents average world tourists. Therefore, an 'impossible' score for a category such as wind speed >38.53km.h^{-1} would be given a score of 0 and classified as detrimental, reducing the overall TCI score. However, those particular conditions may benefit a particular type of tourist seeking 'adverse' conditions such as storm watching or high winds needed for windsurfing (Scott *et al.*, 2016a). A similar case would occur where cold temperatures and precipitation are considered 'adverse' yet are what tourists look for when travelling to a skiing destination (Stockigt *et al.*, 2018; Noome and Fitchett, 2019). Daily output scores were computed for all available data and classified according to the descriptive categories (Table 4.3).

Table 4.3. Classification for output scores for the TCI (after Perch-Nielsen *et al.*, 2010).

Descriptive Rating	
<10	Impossible
10-19	Extremely unfavourable
20-29	Very uncomfortable
30-39	Unfavourable
40-49	Marginal
50-59	Acceptable
60-69	Good
70-79	Very Good
80-89	Excellent
90-100	Ideal

4.4.3 Holiday Climate Index- Urban and Beach

The HCI_{Urban} developed by Scott *et al.* (2016a) and HCI_{Beach}, developed by Rutty *et al.* (2020) consider the climatic suitability in line with urban activities and beach or leisure activities respectively. The HCI_{Urban} index is represented using Equation 3 and the HCI_{Beach} is represented using Equation 4:

$$HCI - Urban = 4(TC) + 2(A) + (3(P) + W) \quad [3]$$

$$HCI - Beach = 2(TC) + 4(A) + 3(P) + W \quad [4]$$

For Equations 3 and 4, thermal comfort (TC) is computed using Humidex with daily T_{max} and mean relative humidity as input variables (Scott *et al.*, 2016a; Rutty *et al.*, 2020). Thermal comfort is weighted at 40% for the HCI_{Urban} and 20% for the HCI_{Beach}. The aesthetic (A) component includes cloud cover (%) which is weighted at 20% for the HCI_{Urban} and 40% for the HCI_{Beach}. Therefore, the thermal component has greater importance for the HCI_{Urban} while the aesthetic component has greater importance for the HCI_{Beach}. The physical component includes rainfall (P) which is weighted at 30% and wind speed (W) weighted at 10% for both iterations of the HCI. Each input variable is ranked according to the HCI ratings ranging from -10 to 10 (Table 4.4). The ratings for each variable are input into the equation producing an output that can range from 0-100. A negative score may be possible however descriptive categories for the HCI do not describe conditions lower than 0 (Scott *et al.*, 2016a).

Table 4.4. HCI ratings for TC, A, P and W variables (adapted from Scott *et al.*, 2016a; Rutty *et al.*, 2020; Matthews *et al.*, 2021).

Ratin	Thermal		Aesthetic		Physical			
	Thermal Comfort (°C)		Cloud Cover (%)		Precipitation (mm)		Wind (km.h^{-1})	
	HCI_{Urban}	HCI_{Beach}	HCI_{Urban}	HCI_{Beach}	HCI_{Urban}	HCI_{Beach}	HCI_{Urban}	HCI_{Beach}
-10		≤9.9					≥70.0	≥70.0
-5		10.0-14.9						

-1					≥25.00	≥25.00		
0	≥39.0	≥39.0; 15.0-16.9			12.00-24.99	12.00-24.99	50.0-69.9	50.0-69.9
1	≤ -6.0	17.0-17.9	100.0					
2	37.0-38.9; -0.1- -5.9	38.0-38.9; 18.0-18.9	91.0-99.9	≥96.0	9.00-11.99			
3	0-6.9	19.0-19.9	81.0-90.9	86.0-95.9			40.0-49.9	40.0-49.9
4	35.0-36.9; 7.0-10.9	37.0-37.9; 20.0-20.9	71.0-80.9	76.0-85.9		9.00-11.99		
5	33.0-34.9; 11.0-14.9	36.0-36.9; 21.0-21.9	61.0-70.9	66.0-75.9	6.00-8.99			
6	31.0-32.9; 15.0-17.9	35.0-35.9; 22.0-22.9	51.0-60.9	56.0-65.9		6.00-8.99	30.0-39.9	30.0-39.9
7	29.0-30.9; 18.0-19.9	34.0-34.9	41.0-50.9	46.0-55.9				
8	27.0-28.9	33.0-33.9	0.0-0.9; 31.0-40.9	0-0.9; 36.0-45.9	3.00-5.99	3.0-5.99	0; 20.0-29.9	0-0.05; 20.0-29.9
9	26.0-26.9; 20.0-22.9	31.0-32.9; 26.0-27.9	1.0-10.9; 21.0-30.9	1.0-14.9; 26.0-35.9	<3.00	0.01-2.99	10.0-19.9	10.0-19.9
10	23.0-25.9	28.0-30.9	11.0-20.9	15.0-25.9	0.00	0	0.1-9.9	0.6-9.9

Calculated output scores were classified according to HCI descriptive categories (Table 4.5). Output scores can range from 0-100, where 0 is classified as 'dangerous' and 100 is classified as 'ideal'. Scores between 10-29 are classified as 'unacceptable', 30-49 as 'marginal', 50-59 as 'acceptable', 60-69 as 'good' and 70-79 as 'excellent'.

Table 4.5. HCI scores descriptive categories (after Scott *et al.*, 2016a).

Descriptive Rating	
9-0	Dangerous
10-19	Unacceptable
20-29	
30-39	Marginal
40-49	
50-59	Acceptable
60-69	Good
70-79	Very Good
80-89	Excellent
90-100	Ideal

4.4.4 Camping Climate Index (CCI)

The CCI, developed by Ma *et al.* (2020) was used to determine the climatic suitability of camping activities. The index is represented using Equation 5:

$$CCI = \left\{ \begin{array}{c} 0.5 \times TC + 0.5 \times S \\ \\ Min(CCI, 3) \\ IF\ Tmin < 8^{\circ}\ or\ Tmax > 34^{\circ} \\ or\ P > 10mm, or\ W > 23km/h \end{array} \right\} \qquad [5]$$

The CCI primarily considers the climatic suitability for camping as a function of two variables, thermal comfort (TC) and sunshine hours (S). Thermal comfort is computed using Humidex which is calculated using T_{mean} and mean relative humidity. Thermal comfort and sunshine hours are weighted at 50% respectively. Each variable is ranked according to CCI ratings from 0-10 (Table 4.6). Rated variables are input into the equation producing output scores that range from 0-10.

Table 4.6. Rating system for thermal comfort (TC) and sunshine hours (S) variables for the CCI (after Ma *et al.*, 2020).

Thermal Comfort (TC)		Sunshine (S)	
Humidex (˚C)	Rating	Hours	Rating
≥42	0	≥14	10
35-41.9	7	13-13.9	9
29-34.9	10	10-12	8
25-28.9	9	7-9	4
21-24.9	8	4-6	2
17-20.9	7	<4	0
13-16.9	6		
9-12.9	5		
5-8.9	4		
2-4.9	3		
<2	0		

Output scores are classified according to Ma *et al.* (2020) classification categories ranging from 0-10, with 0 being classified as 'unfavourable', 4-5 classified as 'acceptable', 6-7 classified as 'good' and 8-10 classified as 'optimal' suitability for camping (Table 4.7).

Table 4.7. CCI descriptive rating classifications for output scores (after Ma *et al.*, 2020).

Descriptive Rating	
0-3	Unfavourable
4-5	Acceptable
6-7	Good
8-10	Optimal

A notable difference from the three other indices used is the exception thresholds to account for adverse weather events. To account for adverse weather events while camping, an exception statement is applied and if the requirement is met, an automatic low score of 3 ('unfavourable') is applied (Ma *et al.*, 2020). The exception statements include instances where T_{min} is less than 8°C; T_{max} is greater than 34°C, precipitation (P) is greater than 10mm per day, or wind speed (W) is greater than 23 km.h^{-1} (Equation 5; Ma *et al.*, 2020). These exception statements were checked before the CCI was calculated. If any input variables exceeded the maximum exception threshold, a score of 3 was given. The CCI was calculated for all available data to determine scores lower than 3 as there is a possibility of thermal comfort and sunshine hours yielding a score lower than 3, even when exception statements occurred. When scores of lower than 3 were found, they were maintained.

4.5 Data Analysis

Output scores for each index were averaged monthly and annually. Monthly score means were calculated from daily values to identify the climatic suitability per month for all available years. Annual score means were calculated to determine the climatic suitability per year for each index for the available period. Both monthly and annual scores were classified per index for each station.

4.5.1 Seasonal Distribution

Seasonal tourism climate distributions, developed by Scott and McBoyle (2001), were used to classify the suitable times of year for each tourism climate index. Tourism climate distributions were conceptually developed in North America and used to determine how tourism climate resources are expected to change seasonally and how this will impact the length of the tourism season (Scott and McBoyle, 2001). Typology distributions are classified into six categories: year-round optimal, poor, summer peak, winter peak, bimodal shoulder peak, and dry season peak (Figure 4.4; Scott and McBoyle, 2001). This type of seasonal classification has been applied to TCI calculations both in the northern (Farajzadeh and Matzarakis, 2009; Bakhtiari and Bakhtiari, 2013; Fang and Yin, 2015; Roshan *et al.*, 2016) and southern hemisphere (Mushawemhuka *et al.*, 2021; Noome and Fitchett, 2019, 2022; Kristensen, 2024), and beyond to the HCI (Scott *et al.*, 2016a; Yu *et al.*, 2022a) and the CCI (Mnguni and Fitchett, 2024). The use of these typologies has been and will be applied to all indices to determine the variations in seasonal distributions for the different types of tourism. This will assist in identifying when particular tourism would be most suitable to pursue.

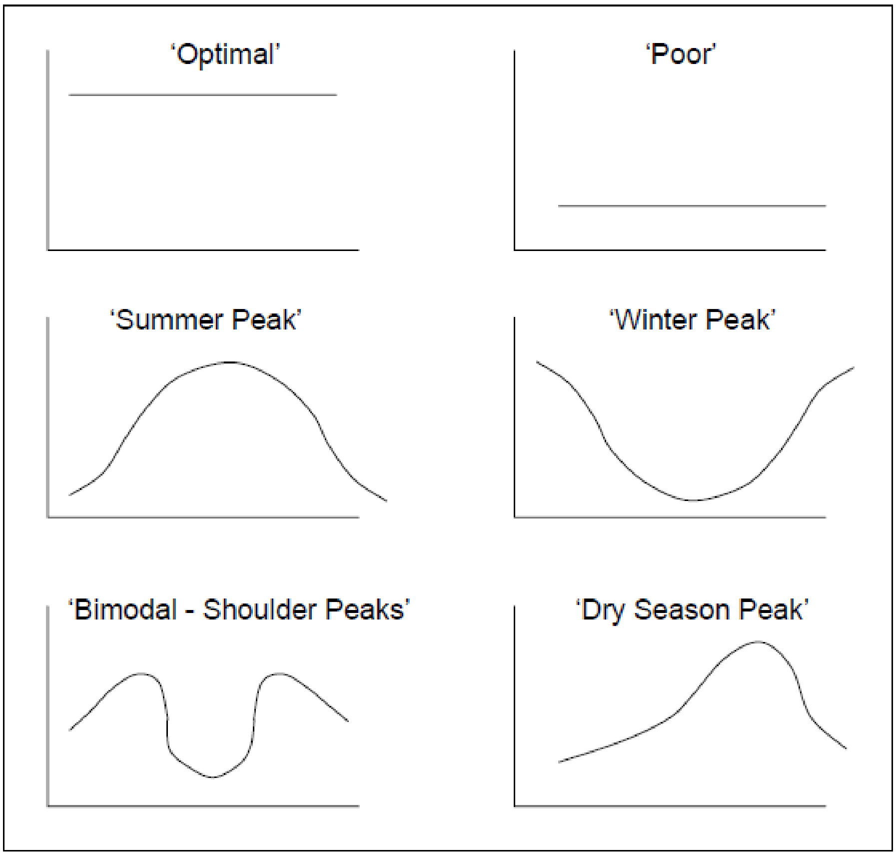


Figure 4.4. Six seasonal distribution classifications developed by Scott and McBoyle (2001).

4.5.2 A multi-index approach

The four tourism climate indices used in this study are valuable in that they can each reveal a different image of climatic suitability that is specific to different tourism offerings on the island. To compare the climatic suitability of each index, mean annual scores for each station for the TCI, HCI_{Urban}, HCI_{Beach} and CCI were mapped using QGIS. From this, the mean annual climate suitability could be seen according to station and index, making it easier to compare suitability across the entire island. Mean monthly suitability scores were analysed for the best score and correlating month and the worst score and correlating month. The best and worst suitability scores and their associated months were tabulated according to each index and meteorological station.

This assisted in visually determining the overall best and worst month according to each index.

4.5.3 Change of Suitability Over Time

Once climatic suitability has been calculated, seasonal distribution determined and an intercomparison between indices made, the rate of change in suitability over time needs to be determined. While climatic suitability may appear acceptable in the present, understanding how it has changed in the past can provide insight into how it may change in the future. Tourism climate index scores were observed for the longest available period, 33 years to determine the rate the suitability score changed over time. Linear regression is used as the mode of time trend analysis (Manly, 2000; Paolella, 2018). Regression analysis is a frequently used statistical tool, that describes a mathematical relationship between the independent and dependent variable describing a quantitative response between two variables, in this case, the rate of change of the dependent variable (Manly, 2000, Lomax and Hahs-Vaughn, 2012; James *et al.*, 2013). Through this, the rate by which the index score changes over time per unit time (unit is per year) is determined (Lomax and Hahs-Vaughn, 2012). The regression equation is calculated using Equation 6:

$$y = mx + c \qquad [6]$$

This is taken as our time trend, where the independent variable x represents time which will be calculated as years, y is the tourism climate index score, and m, the rate coefficient of x, represents the rate of change over time. The term c is the error variable, representing the component not influenced by time (Lomax and Hahs-Vaughn, 2012). The linear regression analyses between single dependent and independent variables were undertaken using GraphPad Prism (Motulsky, 2007). From the calculated outputs, R^2 is the amount of change in *y*, which can be explained by a change in *x* (Motulsky, 2007). For example, an R^2 value of 0.85 means there is an 85% change in suitability scores because of change through time. The *r value* is the correlation coefficient and refers to the spread of data relative to the trend line (Lomax and Hahs-Vaughn, 2012). The extent of statistical significance is measured by the *p-value* (Manly, 2000). Statistical significance refers to the probability that results could have occurred as a result of the coincidence of random sampling (Motulsky, 2007). Taking the threshold *p-value* at 0.05, the statistical significance of the rate of change is determined (Manly, 2000).

4.6 Conclusion

The results of the methods outlined in this chapter will be presented in *Chapter 5* (Index Applicability, Suitability and Validity) and *Chapter 6* (Results). A pre-assessment of the indices used in this study was described followed by a description of the meteorological and field-based data acquisition. A description of the effective temperature considered for each index was outlined followed by a description of the four tourism climate indices (TCI, HCI_{Urban}, HCI_{Beach} and CCI) applied to the study context of Réunion Island. Tourism climate index scores were analysed for seasonal distribution. A key component of this research is the multi-index approach to quantifying climatic suitability where the steps to achieve this were highlighted. Finally, a description of the method used to determine the change in climatic suitability over time was outlined.

CHAPTER 5: INDEX APPLICABILITY, SUITABILITY AND VALIDITY

5.1 Introduction

Many tourism climate indices have been developed over time, varying in what they are used for in specific touristic contexts. Authors generally apply a given index to their location of interest without an explicit or thorough evaluation of its applicability, suitability and validity prior to use (Fitchett and Meyer, 2023). The method to achieve this assessment is outlined in *Chapter 4 Data and Methodology*. This chapter seeks to assess the applicability, suitability and validity of the four tourism climate indices identified for use in this study to confirm their appropriateness for inclusion in this multi-index approach in quantifying the climatic suitability of tourism for Réunion Island.

5.2 Index Applicability Assessment

An online search using TripAdvisor and a key tourism site for Réunion highlighted key towns and attractions (La Réunion, 2024a,b,c,d,e,f; TripAdvisor, 2024). Key attractions of general sightseeing, urban, beach and camping tourism are confirmed as dominant forms of tourism for the island (Table 5.1).

Table 5.1. List of key tourism types and attractions found in Réunion Island.

Tourism type	Key attractions	
General sightseeing	Piton de Fournaise Cascade de Grand Galet Jardin des Parfums et des Epices Anse des Cascades Bassin des Aigrettes Jardin d'Eden Route des Laves Cascade de trou noir Grand Bassin Pont Suspendu de la Riviére de l'Est	
Urban tourism	City	Attraction
	Saint-Gilles-Les Bains	Kélonia aquarium
	Saint-Pierre	La Saga du Rhum
	La Plaine des Cafres	Volcano House
	Saint-Denis	Jardin de l'Etat
	Salazie	Museum for music and instruments

	Saint-Pierre	Marche Forain
	Saint-Leu	Museé Stella Matutina
	Saint-Benoit	Distillerie Riviére du Mât
	Saint-Gilles-les Hauts	Musée de Villéle
	Sainte-Rose	Notre-Dame des Laves
	Saint-Pierre	Temple Tamoul Narassingua Perournal
	Saint-Denis	Musée Léon Dierx
	Saint-Denis	Grand Marche
	Saint-Leu	Marché de Saint-Leu
	Sainte-Clotilde	Marché Forain du Chaudron
	Saint-Denis	Muséum d'Histoire Naturelle de La Réunion
	Saint-Denis	Cathédrale de Saint-Denis de La Réunion
	Sainte-Anne	Église Sainte-Anne
	Saint-Denis	Urban Ropeway Cable car
	Sainte-Denis	Grand Nord Shopping Centre
	Le Port	Cap Sacré-Coeur
	Sainte-Marie	E.Leclerc La Réserve
	Saint-Benoit	Centre Commercial Beaulieu
	Saint-Pierre	Happy Galerie-Les Francolins
Beach tourism	Plage des Roches Noires Plage de Boucan Canot Plage de L'Hermitage, La Passe Plage de L'Etang-Salé Plage de La Saline-Les-Bains Plage de Saint-Leu Plage de Saint-Pierre Plage de Grande Anse Plage de Trou d'Eau Plage Grand Bois	
Camping tourism	Bubble Dome Village Camping de L'Etang-Salé Camping Ermitage Lagon Camping Chez Gigi Camping Pré vert entre 2 songes Camping et Table d'hôte les Filaos Kaz Insolite Ferme Lou-Cachet Pause Mafate Camping Chez Julien Camping le Relax	

The availability of requisite data for each index was determined (Table 5.2). Each meteorological station was assessed for similar variables including T_{min}, T_{max} and T_{mean}, daily minimum and mean relative humidity, precipitation and wind speed. Cloud cover and sunshine hours data were of particular interest as they differ between indices, where the TCI and CCI require sunshine hours and both iterations of the HCI require cloud over. From this initial assessment, only one station, Roland Garros Airport had complete data for the 33 years with limited periods of one day, a week and one month having no data. It was also the only station for which all four indices could be applied as it contained both sunshine hour and cloud cover data (Table 5.2). Pierrefonds Airport contained variables where the HCI could be calculated but not the TCI or CCI. Likewise, the remaining nine stations contained data where the TCI and CCI could be calculated by not the HCI. Substitutions for sunshine hours and cloud cover were examined but ultimately not explored in this study, as highlighted in *Chapter 4*.

Table 5.2. Data availability within the 11 meteorological stations.

Station	TCI	HCI_{Urban}	HCI_{Beach}	CCI	Years
Roland Garros Airport	Yes	Yes	Yes	Yes	1991- 2023
Cilaos	Yes	No	No	Yes	1991-2001 2016-2023
Colimacons	Yes	No	No	Yes	1998-2003 2016-2023
Le Baril	Yes	No	No	Yes	2016-2023
Le Port	Yes	No	No	Yes	1991-1995 2015-2023
Petite-France	Yes	No	No	Yes	2016-2023
Pierrefonds Airport	No	Yes	Yes	No	2015-2023
Piton-Maido	Yes	No	No	Yes	2017-2023
Plaine des Palmistes	Yes	No	No	Yes	1991-1994 2016-2023
Pont-Mathurin	Yes	No	No	Yes	2016-2023
Saint Benoit	Yes	No	No	Yes	2016-2023

Therefore, the four selected indices can be confirmed as applicable for use in Réunion Island.

5.3 Index Suitability

Tourism climate indices have inherent assumptions due to the nature of how they were developed. An index is suitable to use when its assumptions hold true in a particular context. The TCI was initially developed from pre-existing indices, such as ASHRAE to determine the climatic suitability at a broad scale for humans (Mieczkowski, 1985). This assumes that the same conditions are true while on holiday. A holiday however is not isolated to one location or activity. The TCI has been tested against a wide range of tourism globally as identified in *Chapter 2* (*Section 2.3.1 Tourism Climate Index*). It has been used to determine the climatic suitability in urban (Adiguzel *et al.*, 2022; Fitchett, 2021), beach (El-Masry *et al.*, 2022; Li and Chen, 2023), desert (Heydari Alamdarloo *et al.*, 2019; Faraj *et al.*, 2023), island contexts (Georgopoulou *et al.*, 2019; Nguyen *et al.*, 2020; Alonso-Pérez *et al.*, 2021) and within tourism destinations that have a large range of tourism offerings such as the USA (Ma *et al.*, 2020, 2021b), South Africa (Fitchett *et al.*, 2017), and China (Wang *et al.*, 2022). The TCI weightings and output scores have also been tested against tourist experiences in South Africa using TripAdvisor reviews (Fitchett and Hoogendoorn, 2019). A sample of 5,898 TripAdvisor reviews were used to determine climate mentions relative to TCI results for 19 destinations in South Africa, of which, 7.9% mentioned climate conditions and largely aligned with the TCI (Fitchett and Hoogendoorn, 2019). A subsequent study using a web-scraping approach to compile a considerable 26,687 reviews, found consistent results (Mokgehle and Fitchett, 2024). Therefore, given the wide range of tourism the TCI has been applied to and validated using tourist preferences in the

South African context, it is argued to be suitable to use in Réunion Island given the latitudinal similarity and the climatic similarity to the more subtropical coastal regions of South Africa such as Durban and St Lucia, and mountainous regions of the Drakensberg.

The HCI was developed to "overcome…noted limitations of the TCI...and to more accurately assess the climatic suitability of destinations for tourism" (Scott *et al.*, 2016a: 2). In its modification, it removes nighttime thermal comfort as air conditioning is assumed to be ubiquitous in accommodation establishments (Scott *et al.*, 2016a). To determine the availability of air conditioning in Réunion Island, popular booking sites were identified that include a list of amenities within the accommodation establishments. Booking.com, TripAdvisor, Kayak, Hotels.com and Trivago were examined. The total number of accommodation establishments was searched for and filtered for air conditioning amenities (Prinsloo and Fitchett, 2024). The proportion of establishments that offer air conditioning was calculated (Table 5.3). Of the 2,694 accommodation establishments listed on Booking.com, 69.2% listed air conditioning. This does not reveal a true image of all accommodation establishments in Réunion and does not account for Airbnb listings which are becoming increasingly popular. At 69.2%, air conditioning cannot accurately be described as ubiquitous. However, it is arguably sufficient to warrant the use of the HCI due to the low diurnal temperature range on the low-lying and mostly populated areas of the island, and the cool temperatures at the higher altitude locations inland (Prinsloo and Fitchett, 2024).

Table 5.3. Accommodation booking sites reveal total listings available and percentage of listings containing air conditioning (Prinsloo and Fitchett, 2024).

Accommodation site	Total listed	Total (Air conditioning)	%
Booking.com	2,694	1,808	69.2

TripAdvisor	644	57	8.9
Kayak	885	654	73.9
Hotels.com	187	106	56.7
Trivago	216	140	64.8

The CCI was developed in the USA from camping occupancy and gridded meteorological data (Ma *et al.*, 2020). The locations it has been applied to are broad given the size of the USA. However, particular locations in the southeast of the country such as Miami and Florida align with the tropical climate of Réunion Island. Furthermore, specific climatic thresholds have been tested in South Africa where the CCI has been assessed. Specific suitability of climate thresholds is discussed in the next section (5.4 Validity). The CCI was found to be suitable in a South African context (Fitchett and Meyer, 2023) and thus applied (Mnguni and Fitchett, 2024). Similarly to the USA, South African locations cannot be directly compared to Réunion, however, as argued for the TCI, locations such as Durban have a subtropical climate that is similar to Réunion Island. Therefore, if these assumptions are true in tourism destinations as disparate as South Africa and the USA, the CCI can be used in the context of Réunion Island.

Therefore, the four chosen indices are deemed as suitable for the application in Réunion.

5.4 Index Validation

Tourism climate indices have been built on expert opinion (Mieczkowski, 1985), survey questionnaire data on tourism preferences for European cities (Scott *et al.*, 2016a), arrivals data from the Caribbean (Rutty *et al.*, 2020), and camping occupancy data

(Ma *et al.*, 2020). These approaches inform the climate preference weightings and thresholds used in each index. To assess whether these four indices are also valid for the context of Réunion, the weightings and thresholds of the indices need to be examined.

To determine the climate requirements that tourists may consider important when visiting Réunion, online reports, travel guides and literature were examined. Despite the limitations identified for the TCI, particularly its lack of self-reported data, the HCI has been built on self-reported experiences in the context of Europe (Scott *et al.*, 2016a) and the Caribbean (Rutty *et al.*, 2020), and arguably do not hold true more widely. The merits of obtaining self-reported climatic preferences for Réunion Island will not be debated in this study. Travel guides revealed little information about climate preferences for tourists, however mention the island is popular for hiking (Goursaud, 2016). Climate preferences in the region of the study were found in a paper by Fitchett *et al.* (2020) on TripAdvisor tourist reviews of weather for five islands in SWIO. Self-reported sensitivity and satisfaction with the weather were examined and analysed through 13,618 TripAdvisor reviews where 31 reviews were found for Réunion Island (Fitchett *et al.*, 2020). TripAdvisor reviews found that temperature both hot and cold, humidity, sunshine, rain and wind were important climate factors for tourists (Fitchett *et al.*, 2020). The 31 weather mentions found are compared to the weightings for each index and it is argued that the weightings align with the climate preferences for Réunion (Table 5.4). The marketing around hiking for the island also aligns with the weighting of the indices as hiking is often linked to camping activities. Further, there is enough variation in the weightings of the indices that a multi-index approach is ideal because each index reflects specific climatic components well. For example, the TCI and HCI_{Urban} represent the thermal comfort component while the HCI_{Beach} and CCI represent aesthetic features.

Table 5.4. Index variable weighting comparison.

Variable	Index	Weighting	Tripadvisor weather mentions
TC- Daytime thermal comfort	TCI	40%	Hot (8 reviews) Cold (7 reviews) Humid (2 reviews)
	HCI_{Urban}	40%	
	HCI_{Beach}	20%	
	CCI	50%	
TC- Nighttime thermal comfort	TCI	10%	None mentioned
	HCI_{Urban}	0%	
	HCI_{Beach}	0%	
	CCI	0%	
Aesthetic-including Sunshine hours and cloud cover)	TCI	20%	Sunshine (2 reviews)
	HCI_{Urban}	20%	
	HCI_{Beach}	40%	
	CCI	50%	
Physical-Precipitation	TCI	20%	Rain (2 reviews) Mist (briefly mentioned)
	HCI_{Urban}	30%	
	HCI_{Beach}	30%	
	CCI	0% *exception factors	
Physical- Wind speed	TCI	10%	Wind (10 reviews)
	HCI_{Urban}	10%	
	HCI_{Beach}	10%	
	CCI	0% *exception factors	

The threshold values previously identified and built into each index need to be assessed to determine whether these thresholds would be appropriate for Réunion by capturing the potential range of experiences and capturing tourists' expectations versus reality. Thermal comfort is one of the most important climate components for tourists. Optimal thresholds for each index include the highest favourable score of 5 for the TCI with an effective temperature range of 20-26°C, 10 for the HCI_{Urban} and HCI_{Beach} with a temperature range of 23-25°C and 28.0-30.9°C respectively, and 10 for the CCI with an effective temperature range of 29-34°C (Table 5.5). Warmer effective temperature ranges align with the context of Réunion, as these would result in uncomfortable conditions or potential heat stress. Lower effective temperature ranges for the HCI_{Beach} and CCI also align with the cooler conditions experienced in Réunion. The TCI and HCI_{Urban} include negative temperatures that are rare but could be experienced in the higher altitudes of the island (Table 5.5). The CCI usefully includes exception thresholds to account for adverse weather conditions. The temperature thresholds for each index vary considering a broad range of contexts and activities which further supports the use of a multi-index approach.

Table 5.5. Optimal and unfavourable thermal comfort ranges.

Index	Optimal (highest score)	Effective Temperature Range	Unfavourable (lowest score)	Warm Effective Temperature Range	Cold Effective Temperature Range
TCI	5.0	20-26°C	0	>36°C	(-)10-(-)6°C
HCI_{Urban}	10	23-25°C	0/1	≥39°C	≤-6°C
HCI_{Beach}	10	28.0-30.9°C	0	≥39°C	15.0-16.9°C
CCI	10	29-34°C	0	>42°C	<2°C

The thresholds prescribed by the initial developers are intuitive where optimal temperatures for beach activities are warmer than urban activities, whereby suitable clothing and activities are pursued by tourists. For example, wearing beach attire such as a bikini to an urban area will result in a different thermal comfort experience. In urban experiences, appropriate clothing is worn and tourists tend to walk in between markets and shops, so lower temperatures are preferred. For camping, the temperature range is relatively high, considering a tent would not be much protection from high temperatures (Table 5.5). However, the overriding thresholds that return a maximum score of 3 account for high temperatures that could result in unpleasant or even harmful experiences. The TCI has a bigger range because it is aimed at a wide range of attractions and so while the lower temperature thresholds would be too cold for tourists going to the beach, they would be appropriate temperatures for hiking. Thresholds do not need to be changed and will be applied as is. By using four indices in a multi-index approach and applying them with their original equations, weightings and thresholds, results are comparable to the rest of the world where it has been applied and further supports the approach used in this study.

The applicability, suitability and validity of the four indices is therefore confirmed, enabling the study to proceed.

CHAPTER 6: RESULTS

6.1 Introduction

To determine the climatic suitability for tourism, data from 11 meteorological stations across Réunion Island for a period ranging from 1991-2023 were acquired from Météo-France. These data were used to compute the four selected tourism climate indices, namely the TCI, HCI_{Urban}, HCI_{Beach} and CCI. The input variables for these indices included T_{min}, T_{max} and T_{mean}, minimum and mean relative humidity, precipitation, wind speed, sunshine hours and cloud cover. Typical to common constraints of data availability (Fitchett *et al.*, 2016; Noome and Fitchett, 2019; Mushwemhuka *et al.*, 2021), cloud cover and sunshine hour data were limited for 10 of the 11 stations. Cloud cover is required to calculate the HCI, while sunshine hours are required for the TCI and CCI. Further, *in situ,* ground-based data were obtained for the first week of June in both 2023 and 2024 to augment the data. This chapter presents the results of the calculation and classification of scores for each of the four indices for available data from the 11 meteorological stations. Ground-based data collected from two field trips will also be presented. A comparison of climate classifications between stations for each index will be examined followed by a comparative examination of seasonal variation between stations for each index. The chapter concludes with results for the determination of the change in climatic suitability over time.

6.2 Tourism Climate Index (TCI)

The TCI, developed by Mieczkowski (1985) allowed the climatic suitability for general tourism, such as sightseeing, suitability to be determined at a global level and so can be calculated for any location with the available requisite data. As the TCI utilizes sunshine as an input variable, only data from 10 out of the 11 stations could be used to calculate the TCI. The TCI was calculated for Roland Garros Airport followed by

Cilaos, Colimacons, Le Baril, Le Port, Petite-France, Piton Maido, Plaine des Palmistes, Pont-Mathurin and Saint-Benoit (Figure 6.1).

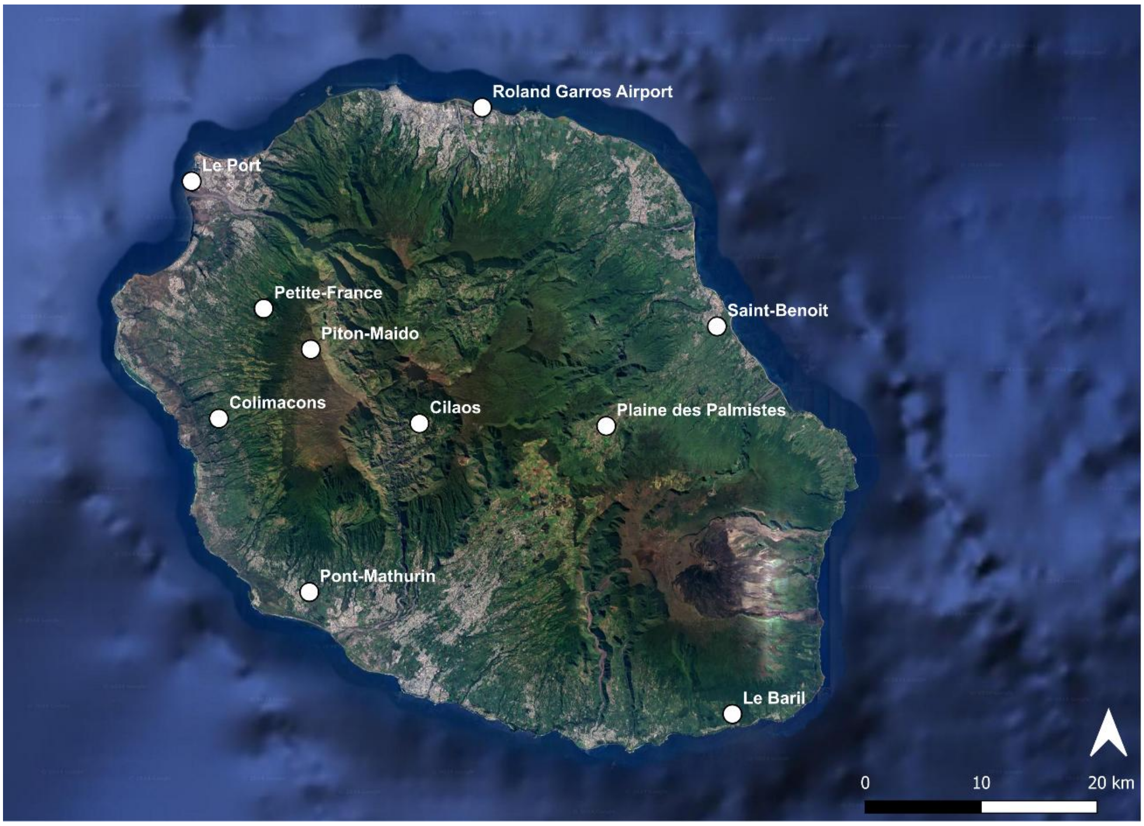


Figure 6.1. Meteorological stations where the TCI could be calculated.

6.2.1 Roland Garros Airport

Climatic suitability scores for Roland Garros Airport, located in a coastal city centre north of the island, were calculated for 33 years from 1991-2023 using the TCI (Table 6.1). Mean annual scores ranged from 43.4 ('marginal', 2023) to 57.2 ('acceptable', 1992). Annual scores are classified as 'acceptable' for 90% of the data period from 1991-2023 and decrease to a 'marginal' classification by 0.4 unit scores from 2021-2022. Mean annual climate suitability decreases further from 2022-2023 by 4.2 unit scores. The annual average for the period of data is 54.0 classified as 'acceptable'.

Table 6.1. Mean annual and monthly TCI climate suitability scores for Roland Garros Airport from 1991-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
1991	42.5	39.5	39.9	40.7	51.0	64.9	79.5	72.7	67.0	55.5	49.1	46.3	54.0
1992	41.5	40.3	42.3	49.6	58.8	66.0	76.9	80.2	72.9	59.4	50.6	48.4	57.2
1993	42.7	36.8	39.1	41.3	50.0	68.6	77.4	75.2	75.3	64.5	55.3	45.6	56.0
1994	39.4	38.5	37.7	47.8	52.7	69.2	69.7	72.1	73.9	58.9	59.5	43.0	55.2
1995	38.4	39.9	39.4	41.9	60.4	68.2	77.1	73.8	69.5	65.8	53.9	38.5	55.6
1996	37.3	40.6	40.7	43.8	60.1	69.8	77.2	73.5	76.0	62.1	51.2	43.3	56.3
1997	39.8	39.7	43.5	48.3	52.0	68.8	76.6	77.2	74.1	65.9	53.4	45.5	57.1
1998	42.1	31.8	40.5	41.0	50.9	66.4	73.8	74.6	67.8	61.6	55.1	42.2	54.0
1999	43.2	39.8	39.2	45.8	54.9	66.9	79.1	76.8	67.4	66.5	54.6	43.1	56.4
2000	39.6	38.6	43.4	45.7	51.4	71.2	74.1	77.0	77.9	65.8	57.0	43.5	57.1
2001	38.4	41.6	42.0	45.1	58.0	75.3	74.9	70.6	68.9	59.1	51.4	42.2	55.6
2002	39.0	42.7	39.6	44.0	50.5	69.6	68.9	74.4	75.2	64.1	51.0	40.4	55.0
2003	38.6	40.1	41.1	38.6	45.5	77.9	81.0	79.9	71.0	63.0	51.7	43.0	55.9
2004	40.4	39.5	40.0	43.0	60.0	77.9	73.7	71.0	66.3	61.8	49.5	37.9	55.1
2005	38.9	36.2	36.2	44.0	55.6	67.3	80.5	78.1	68.4	67.3	50.9	46.5	55.8
2006	40.3	39.3	37.6	42.0	49.8	62.0	72.3	78.5	72.7	66.5	47.0	42.9	54.2
2007	35.8	34.3	43.1	42.9	51.8	69.0	70.2	75.6	73.7	64.2	54.0	43.6	54.8
2008	37.9	36.2	41.0	45.9	57.5	71.6	78.4	75.3	64.0	58.0	46.2	44.8	54.7
2009	41.1	40.5	39.5	41.5	51.6	61.2	74.5	74.2	71.6	57.7	48.6	42.3	53.7
2010	37.3	40.0	35.4	44.0	46.4	61.3	74.5	71.7	64.4	58.5	51.7	44.7	52.5
2011	38.8	39.3	40.9	40.7	48.7	57.3	69.2	68.8	69.8	59.2	48.0	41.6	51.9
2012	40.3	40.3	37.8	44.1	54.8	71.4	71.6	74.5	70.6	61.4	49.6	41.5	54.8
2013	38.8	37.0	41.6	44.8	54.5	73.3	77.0	77.6	69.4	58.2	46.2	42.8	55.1
2014	38.1	39.9	43.2	46.1	55.9	66.0	69.1	73.8	69.7	50.8	47.8	39.4	53.3
2015	36.6	39.1	39.9	43.6	51.7	58.0	76.0	72.6	71.3	56.4	48.1	41.5	52.9
2016	40.7	36.7	39.8	44.0	63.5	71.8	77.5	70.6	73.1	55.5	47.3	45.3	55.5
2017	43.9	38.7	37.1	41.6	54.2	66.9	72.1	72.2	67.6	58.4	47.0	44.3	53.7
2018	35.5	41.7	36.8	42.6	55.0	63.7	77.5	71.3	65.0	59.8	46.6	45.3	53.4
2019	40.8	42.9	42.7	39.9	50.7	64.8	66.5	70.0	62.5	50.3	44.4	42.1	51.5
2020	37.1	39.2	38.0	43.7	56.0	71.3	74.1	77.1	68.6	54.5	53.6	42.0	54.6
2021	39.3	39.8	40.6	33.7	47.4	56.3	63.2	61.1	59.8	44.1	41.8	39.6	47.2
2022	36.7	35.7	39.7	36.6	47.7	58.5	64.9	59.5	56.9	51.3	44.8	39.0	47.6
2023	35.6	39.7	39.5	39.7	43.0	49.7	55.1	49.0	48.0	43.1	39.0	39.1	43.4
Avg	39.3	39.0	40.0	43.0	53.1	66.7	73.5	72.7	68.8	59.1	49.9	42.8	**54.0**

Legend

10-19	Extremely unfavourable	40-49	Marginal	70-79	Very Good
20-29	Very unfavourable	50-59	Acceptable	80-89	Excellent
30-39	Unfavourable	60-69	Good	90-100	Ideal

Exploring scores at a more granular monthly scale, a greater variance in the quantified scores and qualified classifications emerge. Mean monthly TCI scores range from extremes of 31.8 ('unfavourable') in February 1998 to 81.0 ('excellent') in July 2003 (Table 6.1). There are only three instances of 'excellent' climate suitability computed at a monthly scale over the 33-year period, 80.2 (August, 1992), 81.5 (July, 2003) and 80.5 (July, 2005). There are no instances of 'ideal' climate suitability classifications at a monthly scale. Notably, suitability scores range from 'unfavourable', 'marginal', 'acceptable' and 'good' from January to May and October to December, while more favourable climate suitability classifications of 'good', 'very good' and 'excellent' are calculated for the months June to September. During the aforementioned favourable months, climate suitability decreases from 2021.

6.2.2 Cilaos

The TCI was calculated for Cilaos, located in a central mountainous region, for the 15 years of requisite data available, spanning 1991-2001 and 2017-2023 (Table 6.2). Mean annual climatic suitability scores ranged from 60.5 ('good', 2023) to 81.5 ('excellent', 1999). The annual average for the period of data is 75.5 classified as 'very good'. Annual scores reduce in climatic suitability from 2021 changing from 'excellent' and 'very good' to 'good'. Mean monthly climatic suitability scores range from 45.1 ('marginal') in March 2022 to 90.5 ('ideal') in October 1995. The highest mean monthly climate suitability score is also the only score with an 'ideal' classification. The months of May through September generally do not have a lower classification than 'good'. The first 'acceptable' monthly score was recorded in February 1998 and became more common in 2017 from January through April and in 2019 from October through December.

Table 6.2. Mean annual and monthly TCI climate suitability scores for Cilaos from 1991-2001 and 2017-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
1991	66.9	63.3	67.1	74.4	83.1	83.7	83.1	82.2	88.9	84.5	83.5	79.1	78.3
1992	66.4	67.4	76.7	85.9	85.6	86.3	81.8	80.1	87.5	87.2	85.3	85.0	81.3
1993	69.0	69.3	76.6	81.2	86.5	80.3	82.5	78.9	84.0	87.6	87.9	80.3	80.4
1994	71.2	64.3	71.7	80.1	86.8	84.7	85.6	86.2	87.6	86.9	87.9	77.1	80.8
1995	72.2	66.4	74.4	82.9	87.5	85.4	85.8	84.6	85.4	90.5	86.7	71.1	81.1
1996	66.3	71.1	68.7	76.3	88.4	85.6	83.3	85.1	88.4	86.1	83.6	71.6	79.5
1997	68.8	72.3	73.2	78.1	83.2	85.6	83.2	84.3	85.6	82.4	77.1	72.8	78.9
1998	65.0	51.8	71.7	76.9	89.5	86.2	82.1	86.4	87.1	87.4	88.0	76.7	79.1
1999	76.4	70.6	72.5	84.6	87.1	86.0	82.7	86.4	84.1	85.0	88.3	74.7	81.5
2000	68.0	71.5	80.7	83.1	86.8	85.4	82.9	84.4	89.2	83.3	84.2	71.6	80.9
2001	62.9	65.7	72.5	79.5	85.3	85.0	83.8	87.5	87.0	83.2	79.8	66.0	78.2
2017	63.6	53.8	54.5	63.2	79.4	85.7	85.0	84.7	85.3	76.7	70.2	60.0	71.8
2018	51.2	52.3	62.2	66.6	81.4	85.4	84.4	88.0	87.9	82.5	74.4	68.3	73.7
2019	53.5	56.1	53.7	59.5	76.5	84.7	83.6	87.0	82.9	79.1	67.4	58.5	70.2
2020	58.6	59.3	53.2	70.5	81.3	85.9	84.5	87.4	84.5	76.7	78.9	61.3	73.5
2021	49.7	49.5	46.2	54.6	70.1	79.0	83.0	79.9	79.6	68.5	57.9	52.9	64.2
2022	51.6	49.8	45.1	54.7	70.5	81.1	82.8	82.2	82.5	73.2	63.8	52.0	65.8
2023	49.0	48.2	50.1	50.6	60.2	75.0	80.7	76.1	73.1	58.2	55.2	50.1	60.5
Avg	62.8	61.3	65.1	72.4	81.6	84.0	83.4	84.0	85.0	81.1	77.8	68.3	**75.5**

Legend

10-19	Extremely unfavourable	40-49	Marginal	70-79	Very good
20-29	Very unfavourable	50-59	Acceptable	80-89	Excellent
30-39	Unfavourable	60-69	Good	90-100	Ideal

6.2.3 Colimacons

The TCI was calculated for Colimacons, located inland on the western side of the island, for 14 years of requisite data available, spanning 1998-2003 and 2016-2023 (Table 6.3). Mean annual climate suitability scores ranged from 67.2 ('good', 2003) to 78.5 ('very good', 1999). The annual average for the period of data is 72.7 classified as 'very good'. The annual scores are predominantly classified as 'very good' for this station with a slight decline in suitability seen from 2021. Mean monthly climate suitability scores range from 43.5 ('marginal') in February 1998 to 90.2 ('ideal') in June 2000 (Table 6.3). There are two instances of 'ideal' climate suitability with 90.0 (June, 1999) and 90.2 (June, 2000). In the months of January to April suitability score classifications ranged from 'marginal', 'acceptable', 'good' and 'very good'. Climate suitability classifications in the months of May and October through December predominately range from 'good', 'very good' and 'excellent'. The months of June through September had the most favourable climate suitability scores with 'excellent' and 'ideal' classifications.

Table 6.3. Mean annual and monthly TCI climate suitability scores for Colimacons from 1998-2003 to 2016-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
1998	50.2	43.5	64.1	72.0	85.2	86.8	88.4	86.6	85.0	84.8	81.8	68.5	74.7
1999	65.7	57.6	63.2	76.9	87.5	90.0	88.8	88.0	86.5	85.2	82.9	69.7	78.5
2000	61.4	58.7	64.2	71.4	79.5	90.2	87.9	86.4	85.7	84.0	82.2	64.5	76.3
2001	51.2	57.8	57.2	64.5	80.2	88.1	88.5	87.5	87.8	81.7	81.2	60.9	73.9
2002	56.6	56.5	55.3	68.4	73.9	88.0	86.4	89.2	85.7	81.9	64.7	53.8	71.7
2003	43.8	47.1	53.0	49.3	63.6	89.2	87.9	85.1	84.2	76.3	70.4	57.0	67.2
2016	50.4	51.7	59.3	71.2	86.9	87.4	84.3	84.8	82.9	83.3	75.9	75.3	74.4
2017	65.5	54.8	52.7	65.4	80.8	87.0	88.1	84.1	83.4	81.8	74.3	68.1	73.8
2018	49.3	56.4	59.2	67.7	85.4	86.3	86.2	84.9	85.2	83.8	78.4	69.5	74.4
2019	49.5	56.7	60.1	59.7	78.4	85.6	85.9	86.9	85.3	81.3	74.2	61.0	72.0
2020	60.6	59.2	55.4	71.8	85.1	86.6	81.6	81.5	82.7	81.7	82.7	66.6	74.6
2021	51.6	52.9	50.1	52.8	76.4	83.4	85.8	84.2	84.8	79.6	72.7	57.2	69.3
2022	51.8	46.7	44.6	55.8	76.7	84.9	84.2	83.6	83.0	81.3	76.5	61.9	69.2
2023	53.0	52.4	52.5	57.5	70.1	81.6	86.0	84.3	83.2	73.3	67.6	57.8	68.3
Avg	54.3	53.7	56.5	64.6	79.3	86.8	86.4	85.5	84.7	81.4	76.1	63.7	**72.7**

Legend

10-19	Extremely unfavourable	40-49	Marginal	70-79	Very good
20-29	Very unfavourable	50-59	Acceptable	80-89	Excellent
30-39	Unfavourable	60-69	Good	90-100	Ideal

6.2.4 Le Baril

The TCI for Le Baril, located on the southeast coast of the island, could be calculated for eight years from 2016-2023 (Table 6.4). Mean annual climate suitability scores ranged from 46.3 ('marginal', 2023) to 55.5 ('acceptable', 2020). The annual average for the period of data is 52.2 classified as 'acceptable'. Annual scores are predominately 'acceptable' with two years, 2021 and 2023 reducing in suitability and classified as 'marginal'. Mean monthly climate suitability scores ranged from 30.0 ('unfavourable') in April 2021 to 80.5 ('excellent') in August 2020. The highest mean monthly score is also the only 'excellent' suitability classification. The months of January to April had very low climatic suitability with classifications of 'unfavourable' and 'marginal'. The months of May, October through December vary in suitability with classifications of 'marginal', 'acceptable' and 'good'. June through September have the most favourable climate suitability with classifications ranging from 'acceptable' to 'excellent'.

Table 6.4. Mean annual and monthly TCI climate suitability scores for Le Baril from 2016-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Avg
2016	35.6	31.6	36.0	39.4	63.3	74.7	76.0	71.8	75.5	59.3	49.9	44.9	54.8
2017	45.8	39.1	35.3	41.0	50.6	63.8	67.6	67.9	68.3	57.5	46.9	43.5	52.3
2018	32.2	36.3	34.3	36.8	54.5	66.3	77.3	76.0	72.8	62.7	44.5	46.1	53.3
2019	39.0	40.6	39.9	40.4	53.0	66.7	70.1	75.4	69.3	60.3	50.7	40.9	53.8
2020	34.9	38.6	31.8	41.5	57.8	71.0	73.6	80.5	72.9	60.2	59.9	43.1	55.5
2021	41.0	41.2	35.6	30.0	47.6	59.9	68.1	66.4	65.9	51.3	45.7	42.3	49.6
2022	37.9	35.5	34.5	33.7	50.9	64.0	72.1	70.5	67.7	61.3	53.2	44.3	52.1
2023	38.8	41.7	38.1	35.1	41.3	55.4	60.1	57.2	57.4	47.9	42.0	40.1	46.3
Avg	38.1	38.1	35.7	37.2	52.4	65.2	70.6	70.7	68.7	57.6	49.1	43.1	**52.2**

Legend					
10-19	Extremely unfavourable	40-49	Marginal	70-79	Very good
20-29	Very unfavourable	50-59	Acceptable	80-89	Excellent
30-39	Unfavourable	60-69	Good	90-100	Ideal

6.2.5 Le Port

The TCI could be calculated for Le Port, a coastal city located on the northwest of the island, for 12 years of requisite data available, spanning 1991-1994 and 2016-2023 (Table 6.5). Mean annual climate suitability scores ranged from 46.6 ('marginal', 2023) to 56.3 ('acceptable', 2016). The annual average for the period of data is 51.2 classified as 'acceptable'. Classifications of mean annual scores are 'acceptable' and 'marginal'. Mean monthly climate suitability scores ranged from 36.1 ('unfavourable') in March 2018 to 82.0 ('excellent') in September 1994. The highest mean monthly climate suitability score is also the only 'excellent' classification for this station. The months of January through May have reduced climatic suitability with classifications of 'unfavourable' and 'marginal' with one 'acceptable' in May 2020 and a 'good' classification in May 2016. The months of October through December vary in climate suitability with 'marginal' and 'acceptable' classifications, two instances of 'good' classifications and one instance of 'unfavourable'. The month of June is predominantly classified as 'acceptable' with one instance of a 'very good' classification and two instances of 'good' classifications. July through September are the most favourable months with 'good' and 'very good' classifications and few 'acceptable' classifications.

Table 6.5. Mean annual and monthly TCI climate suitability scores for Le Port from 1991-1994 and 2016-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
1991	44.0	41.3	40.1	40.3	46.6	56.9	70.5	66.8	56.7	50.1	46.9	44.6	50.4
1992	43.5	43.5	42.9	44.6	47.9	56.9	71.6	69.2	63.6	48.9	43.4	45.1	51.8
1993	41.8	38.4	40.2	42.3	45.2	57.3	65.0	66.0	67.0	56.2	47.6	43.9	50.9
1994	41.0	40.4	39.4	45.5	48.5	59.7	60.6	54.1	82.0	60.4	64.7	48.6	53.7
2016	41.0	37.5	40.0	42.9	60.3	74.1	78.1	73.5	74.2	59.2	49.4	45.2	56.3
2017	42.1	37.8	36.4	38.5	46.2	55.0	63.3	65.6	61.3	52.9	44.7	39.7	48.6
2018	37.4	39.3	36.1	41.5	49.5	58.8	70.7	67.4	61.8	59.2	45.6	47.2	51.2
2019	41.3	43.8	44.0	41.2	49.0	60.8	66.0	67.7	60.6	52.3	47.5	45.1	51.6
2020	39.4	42.6	40.7	44.4	52.2	65.2	69.4	72.9	66.7	53.1	54.2	43.7	53.7
2021	42.4	40.8	41.0	36.2	47.2	55.4	62.5	63.8	62.4	49.5	44.8	43.6	49.1

2022	40.8	36.9	40.8	41.5	46.5	55.5	64.4	63.9	60.7	55.8	47.8	44.2	50.0
2023	41.4	42.8	41.4	40.5	44.5	52.7	59.8	52.6	51.6	47.3	42.3	42.7	46.6
Avg	41.3	40.6	40.2	41.6	48.6	59.0	66.8	65.3	64.1	53.7	48.2	44.5	**51.2**

Legend					
10-19	Extremely unfavourable	40-49	Marginal	70-79	Very good
20-29	Very unfavourable	50-59	Acceptable	80-89	Excellent
30-39	Unfavourable	60-69	Good	90-100	Ideal

6.2.6 Petite-France

The TCI could be calculated for Petite-France, a mountainous region located on the western side of the island, for seven years spanning 2017-2023 (Table 6.6). Mean annual climate suitability scores ranged from 72.6 (‘very good’, 2020) to 76.6 (‘very good’, 2017). The annual average for the period of data is 74.4 classified as ‘very good’. Mean monthly climate suitability scores ranged from 62.4 (‘good’) in March 2020 to 82.7 (‘excellent’) in November 2018 and December 2016. Within the winter months, two ‘good’ classifications were found one in August 2020 and one in July 2022. Eight ‘excellent’ classifications are found in January 2017, May 2017, 2018 and 2022, October 2019 and November 2017, 2018 and 2022. Although a short data period, notably climatic suitability is ‘good’ year-round.

Table 6.6. Mean annual and monthly TCI climate suitability scores for Petite-France from 2017-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
2017	82.6	72.3	68.9	78.3	80.6	77.0	77.4	72.6	73.0	77.3	80.0	79.9	76.6
2018	64.8	70.9	69.0	73.2	81.7	77.8	73.8	74.8	77.8	79.2	82.7	78.9	75.4
2019	63.0	71.4	75.5	73.9	79.5	77.2	77.6	74.9	74.7	80.2	79.5	70.6	74.8
2020	68.3	70.2	62.4	74.0	78.0	74.4	70.6	68.9	73.5	79.0	76.8	75.4	72.6
2021	67.5	66.7	66.7	68.6	79.0	76.4	75.8	74.1	75.5	78.5	79.6	74.2	73.6
2022	64.7	63.1	64.1	74.1	80.7	75.2	69.9	72.6	73.7	76.9	81.2	78.1	72.9
2023	70.1	68.9	70.3	71.8	78.2	78.6	77.9	76.8	79.0	78.8	78.5	72.7	75.1
Avg	68.7	69.1	68.1	73.4	79.7	76.7	74.7	73.5	75.3	78.5	79.8	75.7	**74.4**

Legend					
10-19	Extremely unfavourable	40-49	Marginal	70-79	Very Good
20-29	Very unfavourable	50-59	Acceptable	80-89	Excellent

30-39	Unfavourable	60-69	Good	90-100	Ideal

6.2.7 Piton Maido

The TCI could be calculated for Piton Maido, a mountainous region located on the western side of the island, with seven years of requisite data available spanning 2017-2023 (Table 6.7). Mean annual climate suitability scores ranged from 72.4 ('very good', 2018) to 78.6 ('very good', 2023). The annual mean for the period of data is 75.6 classified as 'very good'. Mean monthly climate suitability scores ranged from 62.7 ('good') in August 2017 to 87.9 ('excellent') in November 2021. Higher suitability scores are found from October to April for all years, whereas lower suitability scores classified as 'good' are found in the winter months of June to August with slight improvement in September. Higher climate suitability scores are driven by cooler temperatures because it is located at a higher altitude at one of the mountainous peaks in Réunion.

Table 6.7. Mean annual and monthly TCI climate suitability scores for Piton Maido from 2017-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
2017	78.5	77.7	81.8	77.7	73.0	66.4	65.5	62.7	69.3	72.5	73.7	78.5	73.1
2018	77.6	82.5	73.8	78.0	69.5	66.7	64.8	67.9	66.8	66.7	75.6	79.5	72.4
2019	86.1	85.8	85.8	81.7	73.4	65.8	68.9	67.1	67.7	77.1	77.0	85.0	76.8
2020	79.0	83.6	82.0	78.2	72.0	67.1	66.9	68.9	66.6	73.8	77.3	83.5	74.9
2021	83.4	83.6	84.4	80.4	75.4	67.1	65.6	67.6	70.8	77.9	87.9	84.1	77.3
2022	81.7	74.9	85.8	82.8	76.7	68.2	66.7	67.8	65.7	75.0	81.9	82.4	75.8
2023	80.2	83.7	84.8	82.9	79.9	69.2	67.6	68.7	71.6	86.1	83.8	84.2	78.6
Avg	80.9	81.7	82.6	80.2	74.3	67.2	66.6	67.2	68.4	75.6	79.6	82.5	**75.6**

Legend

10-19	Extremely unfavourable	40-49	Marginal	70-79	Very good
20-29	Very unfavourable	50-59	Acceptable	80-89	Excellent
30-39	Unfavourable	60-69	Good	90-100	Ideal

6.2.8 Plaine des Palmistes

The TCI could be calculated for Plaine des Palmistes, a mountainous region located central east of the island, for 10 years of requisite data available spanning 1991-1993 and 2017-2023 (Table 6.8). Mean annual climatic suitability scores ranged from 71.6 ('very good', 1991) and 77.4 ('very good', 2017). The annual mean for the period of data is 74.8 classified as 'very good'. Mean monthly climatic suitability scores range from 52.1 ('acceptable') in March 2022 and 85.5 ('excellent') in July 2017. The months of January through April are the only months with 'acceptable' classifications with 1993, 2017, 2019-2020 and 2023 having no 'acceptable' classifications. 'Excellent' classifications are found in May through November and August is 'excellent' in all calculated years.

Table 6.8. Mean annual and monthly TCI climate suitability scores for Plaine des Palmistes from 1991-1993 and 2017-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
1991	52.3	54.9	54.2	66.6	78.6	78.2	77.1	80.9	84.6	78.8	79.7	73.5	71.6
1992	59.3	63.7	68.2	79.4	82.5	81.6	80.5	80.5	79.1	85.3	82.7	78.0	76.7
1993	74.9	67.7	66.0	70.8	79.1	83.8	80.9	82.8	78.6	82.0	81.9	72.7	76.8
2017	76.1	65.3	62.7	71.8	82.1	83.3	85.5	81.4	83.7	83.7	77.8	74.9	77.4
2018	59.4	60.1	63.1	71.2	84.7	84.9	81.3	82.8	81.2	82.6	80.0	78.3	75.8
2019	63.4	64.3	65.2	69.7	79.9	80.2	83.5	81.2	80.5	83.1	78.1	67.6	74.7
2020	67.2	70.9	61.8	76.9	83.0	82.1	79.3	80.0	81.2	83.5	84.7	74.5	77.1
2021	61.2	59.4	57.1	59.5	78.0	81.6	80.6	81.0	84.8	81.0	76.0	66.6	72.2
2022	55.4	55.6	52.1	66.6	80.0	83.9	76.7	80.8	80.4	83.7	83.0	75.4	72.8
2023	62.5	65.4	63.9	61.6	73.8	82.0	83.8	80.9	83.7	78.0	72.6	62.5	72.6
Avg	63.2	62.7	61.4	69.4	80.2	82.2	80.9	81.2	81.8	82.2	79.6	72.4	**74.8**

Legend					
10-19	Extremely unfavourable	40-49	Marginal	70-79	Very good
20-29	Very unfavourable	50-59	Acceptable	80-89	Excellent
30-39	Unfavourable	60-69	Good	90-100	Ideal

6.2.9 Pont-Mathurin

The TCI could be calculated for Pont-Mathurin, a coastal town located on the southwest of the island, for eight years of requisite data available, spanning 2016-2023 (Table 6.9). Mean annual climatic suitability scores ranged from 49.9 ('marginal', 2023) to 55.6 ('acceptable', 2016). The annual mean for the period of data is 53.1 classified as 'acceptable'. Scores for this time period are predominately classified as 'acceptable' apart from 2023 with reduced suitability being classified as 'marginal'. Mean monthly climatic suitability scores ranged from 36.4 ('unfavourable') in April 2021 and 75.9 ('very good') in July 2016. In the months of January through April, climate suitability is classified as 'unfavourable' and 'marginal'. The months of May and October are classified as 'good', 'acceptable' and 'marginal' across all years. November and December are classified as 'marginal' and 'acceptable'. The months of June through September reveal the most favourable instances of classifications ranging from 'acceptable', 'good' and 'very good'.

Table 6.9. Mean annual and monthly TCI climate suitability scores for Piton Mathurin from 2016-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
2016	40.5	38.0	39.8	43.2	61.2	70.6	75.9	70.5	75.4	56.6	48.3	47.8	55.6
2017	46.1	39.9	38.8	42.6	52.0	66.0	68.9	68.2	68.0	54.5	51.4	43.2	53.3
2018	36.6	39.4	40.1	41.6	51.6	64.6	75.3	67.7	64.2	58.3	46.1	47.6	52.8
2019	41.2	43.4	45.2	42.4	49.7	62.0	64.0	68.7	63.0	53.5	47.0	44.8	52.1
2020	38.9	42.3	37.7	44.8	54.8	67.2	69.1	73.0	67.1	53.7	55.6	45.0	54.1
2021	45.0	43.9	41.4	36.4	51.7	62.0	67.8	67.0	70.3	51.6	46.5	45.0	52.4
2022	41.2	39.5	39.0	40.9	54.1	68.5	74.7	68.3	69.3	61.7	53.9	46.7	54.8
2023	43.5	45.0	42.9	39.9	46.9	59.8	67.0	57.7	58.1	48.7	46.2	43.4	49.9
Avg	41.6	41.4	40.6	41.5	52.8	65.1	70.3	67.6	66.9	54.8	49.4	45.4	**53.1**

Legend					
10-19	Extremely unfavourable	40-49	Marginal	70-79	Very good
20-29	Very unfavourable	50-59	Acceptable	80-89	Excellent
30-39	Unfavourable	60-69	Good	90-100	Ideal

6.2.10 Saint-Benoit

The TCI could be calculated for Saint-Benoit, a coastal town located on the eastern side of the island, for eight years of requisite data available spanning 2016-2023 (Table 6.10). Mean annual climatic suitability scores range from 43.1 ('marginal', 2023) to 53.1 ('acceptable', 2020). The annual mean for the period of data is 50.0 classified as 'acceptable'. Classifications for the mean annual average are 'acceptable' but decrease to a 'marginal' classification from 2021-2023. Mean monthly climatic suitability scores range from 31.9 ('unfavourable') in April 2021 to 76.0 ('very good') in July 2018. The months of January through April are classified as 'unfavourable' and 'marginal'. May and October are classified as 'marginal', 'acceptable' and 'good' whereas November and December are predominantly classified as 'marginal'. June through September reveal more favourable suitability with 'good' and 'very good' classifications from 2016-2020 but noticeably, suitability decreases to classifications of 'good', 'acceptable' and 'marginal' towards 2023.

Table 6.10. Mean annual and monthly TCI climate suitability scores for Saint-Benoit from 2016-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
2016	39.7	34.1	39.0	42.6	60.5	64.3	72.5	65.9	69.9	54.3	45.7	43.2	52.6
2017	44.6	38.3	35.8	39.7	49.6	63.4	68.5	68.7	69.8	61.2	48.3	46.1	52.8
2018	35.9	39.1	35.5	40.1	51.5	63.6	76.0	70.7	64.9	58.3	44.1	47.1	52.2
2019	42.7	44.1	42.7	39.3	48.5	61.0	66.0	72.5	65.7	55.1	48.1	42.7	52.4
2020	38.9	41.3	38.1	41.7	53.0	65.3	69.3	72.4	66.7	53.5	54.4	42.6	53.1
2021	41.5	39.2	39.0	31.9	45.3	50.8	56.9	59.8	59.4	44.6	44.6	41.0	46.2
2022	38.1	37.0	38.6	34.8	47.0	54.9	61.0	58.6	57.3	55.7	49.2	41.7	47.8
2023	38.0	42.6	39.6	39.3	40.4	48.7	51.1	46.1	47.2	43.8	40.7	40.2	43.1
Avg	39.9	39.5	38.5	38.7	49.5	59.0	65.1	64.3	62.6	53.3	46.9	43.1	**50.0**

Legend

10-19	Extremely unfavourable	40-49	Marginal	70-79	Very good
20-29	Very unfavourable	50-59	Acceptable	80-89	Excellent
30-39	Unfavourable	60-69	Good	90-100	Ideal

6.2.11 Inter-Station Comparison

Mean annual TCI scores across all 10 available stations revealed five stations classified as 'acceptable' and five stations as 'very good' (Figure 6.2). Stations located on the outer side of the island, Le Port (51.2), Roland Garros Airport (54), Saint Benoit (50), Le Baril (52.2) and Pont-Mathurin (53.1) have 'acceptable' classifications. Stations located relatively central of the island, Petite-France (74.4), Piton-Maido (75.6), Colimacons (72.7), Cilaos (75.5) and Plaine des Palmistes (74.8) were classified as 'very good'.

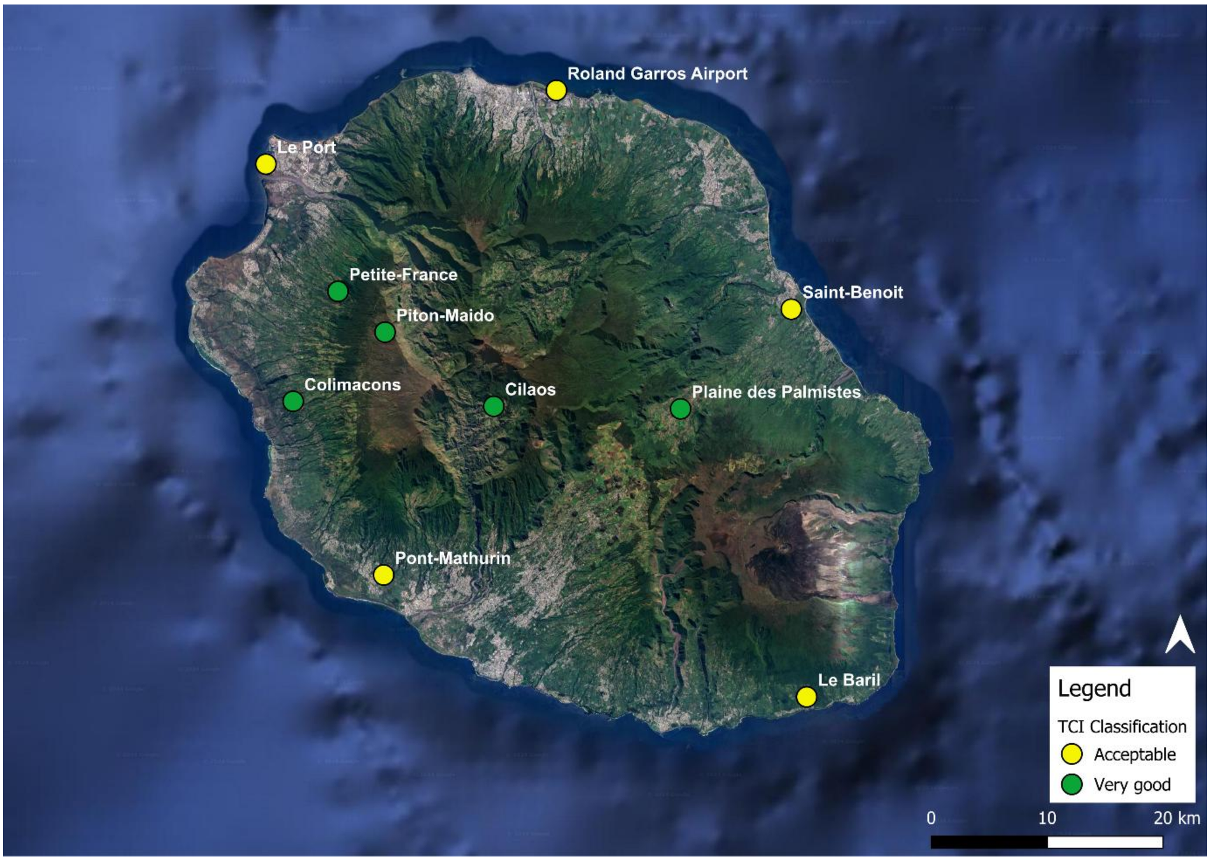


Figure 6.2. Mean annual TCI classifications.

The TCI scores were classified according to Scott and McBoyles's (2001) six seasonal classifications (Figure 6.3). A winter peak seasonal classification was found for Roland Garros Airport, Le Baril, Saint-Benoit, and Pont-Mathurin and Le Port (Figure 6.3a). A winter peak classification was also found for Colimacons, Plaine des Palmistes and Cilaos, although it is a relatively late one compared to the previous four stations (Figure 6.3a). A bimodal shoulder peak seasonal classification was found for Petite-France (Figure 6.3b). A summer peak seasonal classification was found for Piton-Maido (Figure 6.3c).

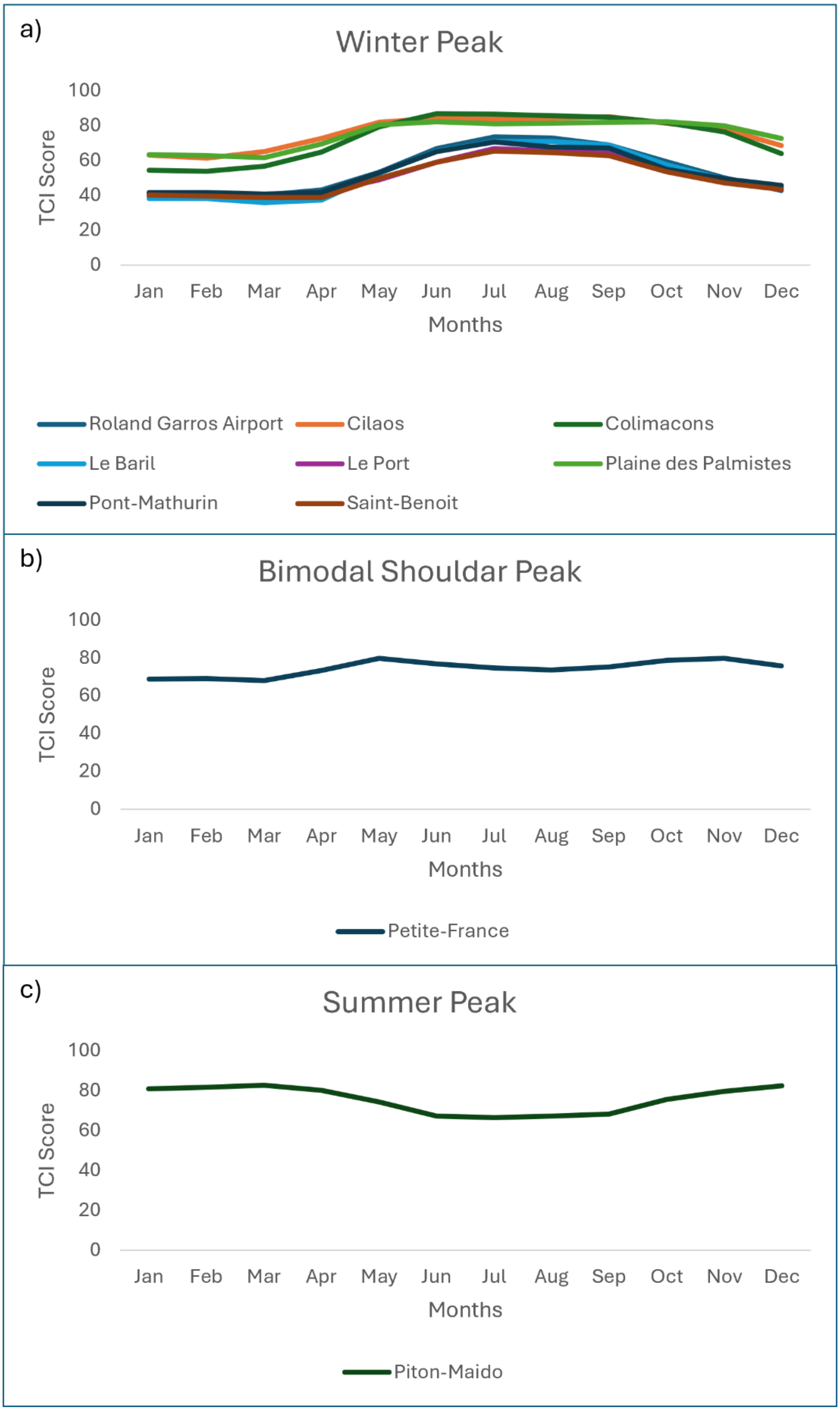


Figure 6.3. The seasonal distribution of climatic suitability for the TCI for 10 meteorological stations is characterised by a) winter b) bimodal shoulder and c) summer peak distribution.

6.3 Holiday Climate Index: Urban (HCI_{Urban})

The HCI_{Urban}, developed by Scott *et al.* (2016a) is used to determine the climatic suitability of tourism attractions within urban contexts. The HCI_{Urban} uses variables of T_{mean}, relative humidity, precipitation, wind speed and cloud cover. Cloud cover data were only partially available and therefore only stations that contained cloud cover data could be calculated. These stations included Roland Garros Airport and Pierrefonds Airport (Figure 6.4). Roland Garros itself is an airport and not in the centre of a city, however, it is located 6-10km from the capital city Saint-Denis, a city centre that hosts varied urban attractions such as museums (TripAdvisor, 2024). The urban sprawl of Saint-Denis which has a suburban area that is now indistinct from the adjacent town of Sainte-Rose prescribes the airport to be within and representative of an urban area (TripAdvisor, 2024). Pierrefonds Airport is located in the urban area of Saint-Pierre on the western coast of the island (TripAdvisor, 2024).

Figure 6.4. Meteorological stations applicable for the calculation of both the HCI_{Urban} and HCI_{Beach}.

6.3.1 Roland Garros Airport

The HCI_{Urban} was calculated for Roland Garros Airport for 33 years from 1991-2023 (Table 6.11). Mean annual climatic suitability scores range from 52.0 ('acceptable', 2023) to 60.2 ('good', 1992). The annual mean for the period of data is 56.9 classified as 'acceptable'. Classifications for mean annual scores are predominately classified as 'acceptable' with only two 'good' classifications identified in 1992 and 1994.

Table 6.11. Mean annual and monthly HCI_{Urban} climate suitability scores for Roland Garros Airport from 1991-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
1991	45.6	44.4	41.7	42.7	56.5	62.7	76.0	74.3	61.9	56.6	51.4	49.4	55.3
1992	46.5	45.4	45.9	55.9	63.8	69.6	74.3	76.1	72.9	64.3	58.7	48.5	60.2
1993	48.0	32.7	42.1	43.1	57.1	71.5	72.6	68.8	71.8	67.9	61.9	47.5	57.1
1994	41.0	40.1	39.0	51.1	57.9	69.9	76.8	85.0	76.1	65.2	67.6	51.5	60.1
1995	41.2	44.3	43.5	48.3	60.4	71.7	72.5	69.3	67.7	68.9	61.5	35.1	57.0
1996	34.4	42.5	46.8	48.1	63.4	70.5	71.9	71.2	76.0	64.5	57.7	48.2	57.9
1997	41.3	41.4	46.8	52.6	53.6	65.5	72.9	72.6	72.8	65.8	58.0	50.4	57.8
1998	44.5	27.5	48.1	46.2	54.2	67.8	67.4	72.0	65.3	65.0	59.1	45.7	55.2
1999	44.8	39.4	40.5	50.9	62.2	70.4	74.6	71.9	65.1	69.6	59.4	49.1	58.2
2000	41.3	36.0	43.6	52.1	59.3	70.8	71.3	71.1	74.6	65.0	62.0	48.8	58.0
2001	39.1	45.6	45.4	47.1	60.7	73.6	70.1	70.6	72.3	61.5	59.9	41.5	57.3
2002	42.7	49.5	43.0	49.3	55.7	68.9	67.6	69.7	73.6	69.5	60.2	44.2	57.8
2003	38.0	41.9	46.1	37.6	47.0	75.3	75.7	77.3	66.3	68.9	58.0	49.1	56.8
2004	42.9	39.7	40.7	44.3	61.9	74.3	72.8	72.1	65.2	66.6	59.3	43.3	56.9
2005	37.6	38.1	40.2	50.2	60.5	68.5	78.0	70.5	66.0	67.8	58.4	53.0	57.4
2006	42.1	39.1	37.9	48.9	56.8	67.3	67.0	73.7	72.1	69.7	54.9	45.8	56.3
2007	33.6	35.0	48.9	46.2	57.3	71.6	66.3	73.9	72.7	65.5	65.5	51.0	57.3
2008	38.8	38.6	43.2	55.4	59.4	70.2	73.5	75.3	65.8	64.7	55.2	50.5	57.5
2009	42.6	45.5	41.3	47.9	58.0	62.7	73.2	72.5	72.5	62.5	55.8	47.3	56.8
2010	43.6	40.7	35.8	49.3	48.6	66.6	73.7	67.3	68.0	65.9	61.2	55.5	56.4
2011	45.4	43.0	43.5	45.8	57.2	63.6	69.7	67.1	69.9	66.5	56.5	48.9	56.4
2012	47.1	42.2	40.5	47.6	59.5	69.9	71.3	73.1	68.4	67.2	58.6	48.7	57.8
2013	37.5	39.6	43.5	50.2	61.8	74.4	75.0	73.0	72.2	66.8	51.7	48.9	57.9
2014	35.5	45.5	47.6	50.9	60.4	71.8	72.3	71.7	70.7	59.3	54.4	44.7	57.1
2015	34.4	40.9	43.8	50.3	56.0	59.8	75.3	69.5	68.8	61.6	58.6	46.7	55.5
2016	46.9	35.9	45.8	51.6	66.0	71.4	72.0	71.0	71.6	63.8	52.8	49.1	58.2
2017	49.0	39.8	36.3	48.4	58.3	65.2	72.4	66.8	67.8	64.3	53.3	50.6	56.0
2018	36.4	46.7	38.1	45.9	61.6	66.6	71.9	74.4	68.4	61.6	53.1	52.9	56.5
2019	42.7	49.4	55.3	46.5	56.2	63.2	69.9	70.6	66.8	58.1	52.7	47.6	56.6
2020	41.6	44.6	43.1	51.2	61.9	72.5	74.7	75.1	69.9	64.0	59.5	46.7	58.7
2021	44.4	42.6	45.6	34.7	58.6	64.0	65.5	67.8	67.3	50.3	49.8	44.8	52.9

2022	40.9	38.7	46.2	37.8	56.9	65.6	66.6	66.4	62.9	62.3	55.4	46.1	53.8
2023	42.7	47.3	47.5	49.4	49.6	59.6	66.3	56.5	61.5	54.4	42.6	46.6	52.0
Avg	41.6	41.3	43.6	47.8	58.1	68.4	71.9	71.5	69.2	64.1	57.1	47.8	**56.9**
Legend													
9-0	Dangerous			30-39	Marginal	60-69	Good		90-100	Ideal			
10-19	Unacceptable			40-49	Marginal	70-79	Very Good						
20-29	Unacceptable			50-59	Acceptable	80-89	Excellent						

Mean monthly climatic suitability scores range from 27.5 (‘unacceptable’) in February 1998 and 85.0 (‘excellent’) in August 1994. The lowest mean monthly climate score is also the only ‘unacceptable’ classification. There is only one instance of an ‘excellent’ classification 85.0 (August, 1994). January through April classifications are predominately ‘marginal’. May and November classifications vary between ‘marginal’, ‘acceptable’, and ‘good’. Classifications from June through October are more favourable months with classifications including ‘acceptable’, ‘good’, ‘very good’ and ‘excellent’.

6.3.2 Pierrefonds Airport

The HCI_{Urban} could be calculated for Pierrefonds Airport, for eight years of requisite data available spanning 2016-2023 (Table 6.12). Mean annual climate index scores range from 60.1 (‘good’, 2023) and 63.1 (‘good’, 2022). The annual mean for the period of data is 61.6 classified as ‘good’. Mean monthly climatic suitability scores range from 38.5 (‘marginal’) in January 2018 to 80.4 (‘excellent’) in August 2018. December and January through April range between classifications of ‘marginal’ and ‘acceptable’. May and November have classifications of ‘acceptable’ and ‘good’ with May being the more suitable month of the two. Classification from June through to October are more favourable months with classifications including ‘good’, ‘very good’ and the only ‘excellent’ score calculated in August 2018.

Table 6.12. Mean annual and monthly HCI_{Urban} climate suitability scores for Pierrefonds Airport from 2016-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
2016	50.2	42.7	47.8	51.1	64.7	75.7	77.3	75.6	77.3	70.6	59.2	55.5	62.3
2017	56.4	51.9	49.7	51.6	65.3	69.0	71.2	72.1	72.0	64.5	58.0	54.5	61.4
2018	38.5	45.9	48.6	51.1	70.6	73.5	77.3	80.4	76.8	69.4	59.2	57.1	62.4
2019	50.9	54.1	55.9	56.8	62.1	67.7	67.3	76.6	71.2	65.4	58.0	48.6	61.2
2020	45.8	49.4	43.2	53.4	65.9	71.9	72.0	78.2	74.6	64.9	64.1	51.7	61.3
2021	53.6	52.9	51.1	48.1	63.5	67.0	75.9	72.5	75.9	66.5	58.9	51.4	61.4
2022	49.8	46.0	50.1	49.7	65.2	71.5	77.5	77.7	73.0	73.4	67.4	56.0	63.1
2023	51.9	53.3	49.2	53.1	56.5	69.7	71.8	72.3	71.7	62.5	54.3	55.3	60.1
Avg	49.6	49.5	49.5	51.9	64.2	70.7	73.8	75.7	74.1	67.1	59.9	53.8	**61.6**

Legend							
0-9	Dangerous	30-39	Marginal	60-69	Good	90-100	Ideal
10-19	Unacceptable	40-49	Marginal	70-79	Very good		
20-29	Unacceptable	50-59	Acceptable	80-89	Excellent		

6.3.3 Inter-Station Comparison

Mean annual HCI_{Urban} classifications were found to be ‘acceptable’ and ‘good’ (Figure 6.5). Roland Garros Airport had a calculated score of 56.9 (‘acceptable’) and Pierrefonds Airport, had a calculated score of 61.6 (‘good’).

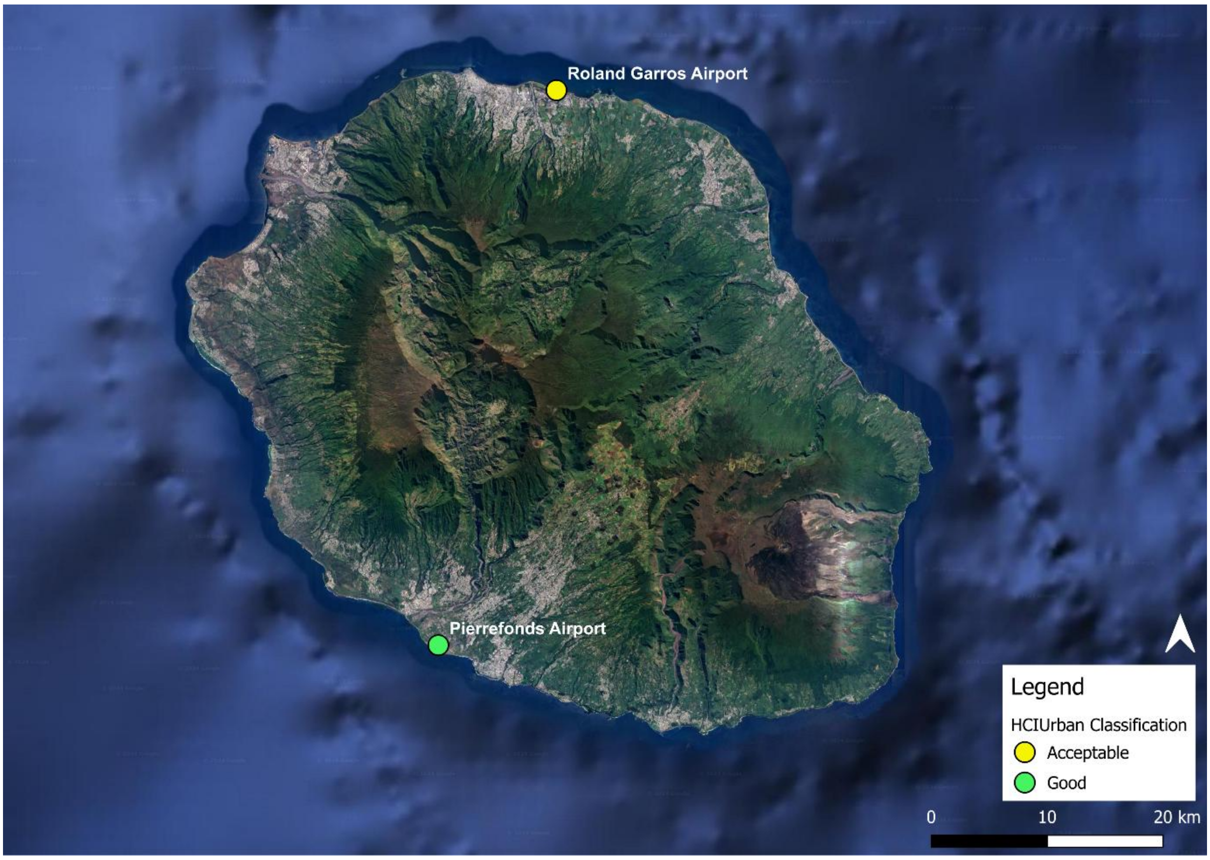


Figure 6.5. Mean annual HCI_{Urban} classifications.

According to Scott and McBoyles's (2001) six seasonal classifications, a winter peak seasonal classification was found for Roland Garros Airport and Pierrefonds Airport (Figure 6.6). Urban activities are generally suitable throughout the year but improve from May, becoming particularly suitable during the winter months from June to August.

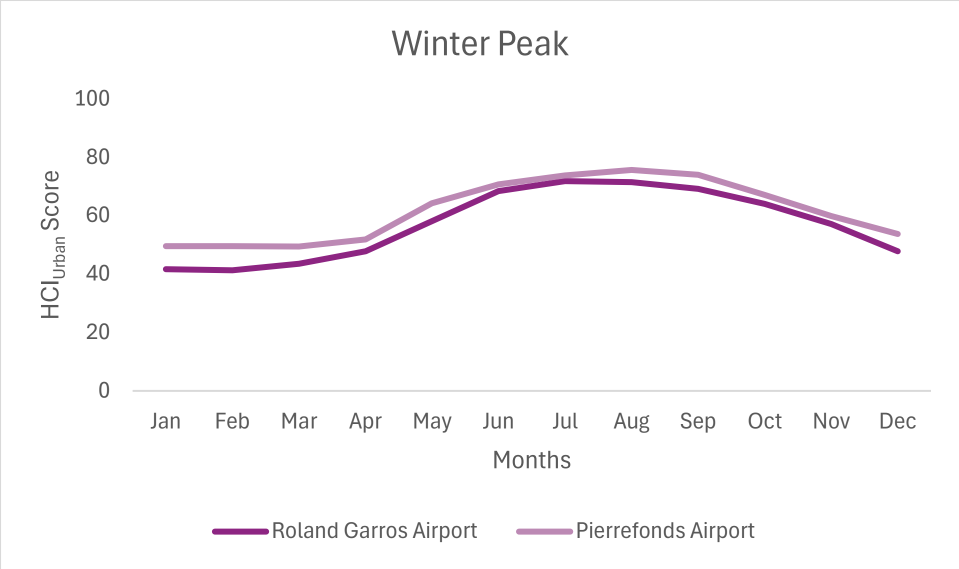


Figure 6.6. The seasonal distribution of climatic suitability for the HCI_{Urban} for Roland Garros Airport and Pierrefonds Airport is characterised by winter peak distribution.

6.4 Holiday Climate Index- Beach (HCI_{Beach})

The HCI_{Beach} was developed to determine the climate suitability of tourism activities in relation to beach environments (Rutty *et al.*, 2020). The HCI_{Beach} uses variables of T_{mean}, relative humidity, precipitation, wind speed and cloud cover. Cloud cover data were only partially available and therefore only stations that contained cloud cover data could be calculated. These stations included Roland Garros Airport and Pierrefonds Airport (Figure 6.4). While data for Roland Garros Airport were captured within an airport, it is within the coastal region of Sainte-Marie, 2.5km from the nearest beach. Pierrefonds Airport is located within the coastal region of Sainte-Pierre, less than 5km from the nearest beach. This airport is also located on the western coast of the island which hosts most of the island's beach sites (TripAdvisor, 2024).

6.4.1 Roland Garros Airport

The HCI_{Beach} was calculated for Roland Garros Airport for 33 years spanning 1991-2023 (Table 6.13). Mean annual climatic suitability scores range from 66.1 ('good', 2021) and 72.3 ('very good', 1992). The annual mean for the period of data is 69.3 classified as 'good'. Classifications for mean annual scores vary between 'good' and 'very good' from 1991- 2023 but decrease to a 'good' classification from 2021.

Table 6.13. Mean annual and monthly HCI_{Beach} climate suitability scores for Roland Garros Airport from 1991-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
1991	60.9	57.9	54.6	52.6	66.7	71.8	84.9	84.1	82.3	67.4	65.5	60.4	67.4
1992	59.1	58.7	60.6	69.2	76.9	81.5	83.0	84.3	83.2	76.9	72.3	62.4	72.3
1993	62.6	44.5	53.7	55.4	71.4	82.9	82.7	77.9	81.2	78.1	71.5	63.2	68.8
1994	53.4	52.6	52.1	67.2	70.7	82.2	78.1	73.9	82.7	73.8	79.7	63.2	69.1
1995	53.3	56.9	56.6	60.9	70.4	81.3	84.1	76.8	77.1	80.1	71.9	44.5	67.8
1996	45.0	56.1	60.9	60.7	74.0	81.6	79.7	79.4	85.2	75.5	70.4	60.7	69.1
1997	53.4	55.0	60.0	65.3	62.2	75.0	80.5	81.1	79.7	71.9	67.9	61.8	67.8
1998	58.1	36.9	62.4	58.8	66.6	77.8	75.8	80.3	75.2	77.7	71.3	56.8	66.5
1999	58.7	52.6	53.2	67.9	73.4	81.7	83.1	81.7	74.7	80.1	71.2	60.6	69.9
2000	53.1	49.6	57.2	67.3	71.3	81.7	82.0	79.2	83.2	74.4	71.9	62.2	69.4
2001	50.6	60.3	59.5	60.9	74.9	83.4	79.2	81.0	84.0	71.9	74.4	56.5	69.7
2002	55.9	64.9	57.3	64.8	65.4	80.1	77.0	81.4	82.8	81.7	72.9	57.1	70.1
2003	51.0	54.0	62.5	49.6	59.7	59.7	85.6	85.5	78.2	80.6	73.2	64.7	67.0
2004	55.7	52.6	56.3	58.1	72.3	85.5	84.3	82.7	76.9	76.9	71.8	55.1	69.0
2005	52.1	51.0	53.4	67.7	72.2	81.5	89.3	81.2	77.9	78.6	70.4	70.6	70.5
2006	55.6	55.4	52.0	65.8	70.4	80.8	79.0	83.2	83.1	81.2	64.8	61.5	69.4
2007	45.8	47.0	64.5	61.8	71.4	82.8	75.8	83.5	84.1	74.9	80.4	66.2	69.9
2008	53.3	51.0	58.6	72.9	72.2	79.5	84.3	87.0	77.5	77.5	71.7	64.4	70.8
2009	58.5	62.6	57.3	61.8	73.1	75.3	83.5	83.4	85.5	75.5	69.8	64.4	70.9
2010	56.1	56.2	48.8	68.5	66.4	78.8	85.4	78.4	80.0	79.9	75.7	72.7	70.6
2011	61.8	57.8	58.9	60.5	73.4	77.0	80.8	76.8	81.1	76.9	72.0	62.0	69.9
2012	61.8	60.3	53.9	62.2	70.8	80.3	82.3	85.0	78.1	78.3	72.4	65.5	70.9
2013	52.7	50.4	59.2	63.0	74.6	86.6	87.0	84.7	83.7	78.9	66.6	62.9	70.8
2014	50.1	59.2	65.5	66.6	76.0	83.6	83.5	83.5	84.0	71.6	69.9	59.5	71.1
2015	46.7	54.9	59.2	68.4	68.8	69.1	85.0	79.0	78.7	73.1	72.3	64.0	68.3
2016	60.1	49.7	60.1	68.4	80.2	81.0	81.9	80.4	81.9	76.3	65.4	64.0	70.8
2017	66.9	53.8	51.5	62.2	70.5	77.4	83.5	76.6	76.9	76.9	65.4	66.8	69.0
2018	49.8	61.7	52.8	60.9	74.5	78.5	82.3	86.4	81.7	73.5	64.7	71.0	69.8
2019	59.3	65.4	72.7	62.3	67.7	73.6	82.6	81.7	76.0	69.6	65.1	65.1	70.1
2020	53.8	59.9	58.8	66.0	73.9	85.0	82.5	84.3	79.4	74.7	70.7	61.0	70.8
2021	59.1	58.8	62.2	47.5	75.4	75.6	76.6	76.8	80.4	59.7	62.0	58.8	66.1

2022	55.9	53.0	62.2	51.3	72.9	76.7	75.0	76.8	72.7	73.8	68.9	61.1	66.7
2023	57.0	64.3	64.8	65.6	65.8	72.1	78.0	67.6	74.9	68.5	57.2	61.5	66.4
Avg	55.4	55.3	58.3	62.5	71.1	78.8	81.8	80.8	80.1	75.3	70.0	62.2	**69.3**

Legend							
0-9	Dangerous	30-39	Marginal	60-69	Good	90-100	Ideal
10-19	Unacceptable	40-49	Marginal	70-79	Very good		
20-29	Unacceptable	50-59	Acceptable	80-89	Excellent		

Mean monthly climatic suitability scores range from 36.9 (‘marginal’) in February 1998 and 89.3 (‘excellent’) in July 2005 (Table 6.13). The climate suitability in May through November is more favourable with classifications of ‘acceptable’, ‘good’, ‘very good’ and ‘excellent’. No ‘ideal’ classifications were calculated. January to March include varied suitability with classifications of ‘acceptable’ and a few ‘good’ and ‘marginal’. April and December are generally favourable with one ‘marginal’ classification found in December 1995 and two found in April 2003 and 2021.

6.4.2 Pierrefonds Airport

The HCI_{Beach} was calculated for Pierrefonds Airport for eight years of requisite data available spanning 2016-2023 (Table 6.14). Mean annual climatic suitability scores range from 74.0 (‘very good’, 2020) to 77.0 (‘very good’, 2022). The annual mean for the period of data is 75.4 classified as ‘very good’. Classifications for mean annual scores are all classified as ‘very good’. Mean monthly climatic suitability scores range from 53.0 (‘acceptable’) in January 2018 to 91.7 (‘ideal’) in August 2018. Three classifications of ‘acceptable’ are found in January through March with remaining classifications of ‘good’ and ‘very good’. April through December reveal favourable climate suitability with June through October revealing ‘excellent’ and one ‘ideal’ classification.

Table 6.14. Mean annual and monthly HCI_{Beach} climate suitability scores for Pierrefonds Airport from 2016-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
2016	66.8	58.7	64.1	65.7	75.3	86.5	85.9	85.5	87.9	83.2	73.1	72.6	75.4
2017	75.2	69.4	66.5	67.1	77.3	81.0	81.5	81.3	81.8	78.2	70.6	72.7	75.2
2018	53.0	63.3	63.9	65.7	84.2	83.4	87.0	91.7	89.4	81.1	72.4	75.0	75.8
2019	67.8	70.1	74.6	73.4	76.0	79.3	77.1	86.6	82.1	79.7	71.7	65.4	75.3
2020	59.5	66.3	57.8	70.6	78.8	83.5	78.1	86.6	86.0	77.8	75.7	67.6	74.0
2021	71.3	70.3	68.0	60.1	75.2	76.9	87.1	82.1	88.3	77.5	74.7	68.8	75.0
2022	65.1	61.7	66.1	65.5	79.9	81.6	88.5	89.3	83.8	86.1	82.3	73.9	77.0
2023	68.6	70.8	66.0	69.7	70.7	80.6	83.1	85.3	85.2	78.6	70.0	73.4	75.2
Avg	65.9	66.3	65.9	67.2	77.2	81.6	83.5	86.0	85.6	80.3	73.8	71.2	**75.4**

Legend							
0-9	Dangerous	30-39	Marginal	60-69	Good	90-100	Ideal
10-19	Unacceptable	40-49	Marginal	70-79	Very good		
20-29	Unacceptable	50-59	Acceptable	80-89	Excellent		

6.4.3 Inter-Station Comparison

Mean annual scores for the HCI_{Beach} for Roland Garros Airport and Pierrefonds Airport were classified as 'good' and 'very good' (Figure 6.7). A mean annual score of 69.3 was calculated for Roland Garros Airport whereas a score of 75.4 was calculated for Pierrefonds Airport.

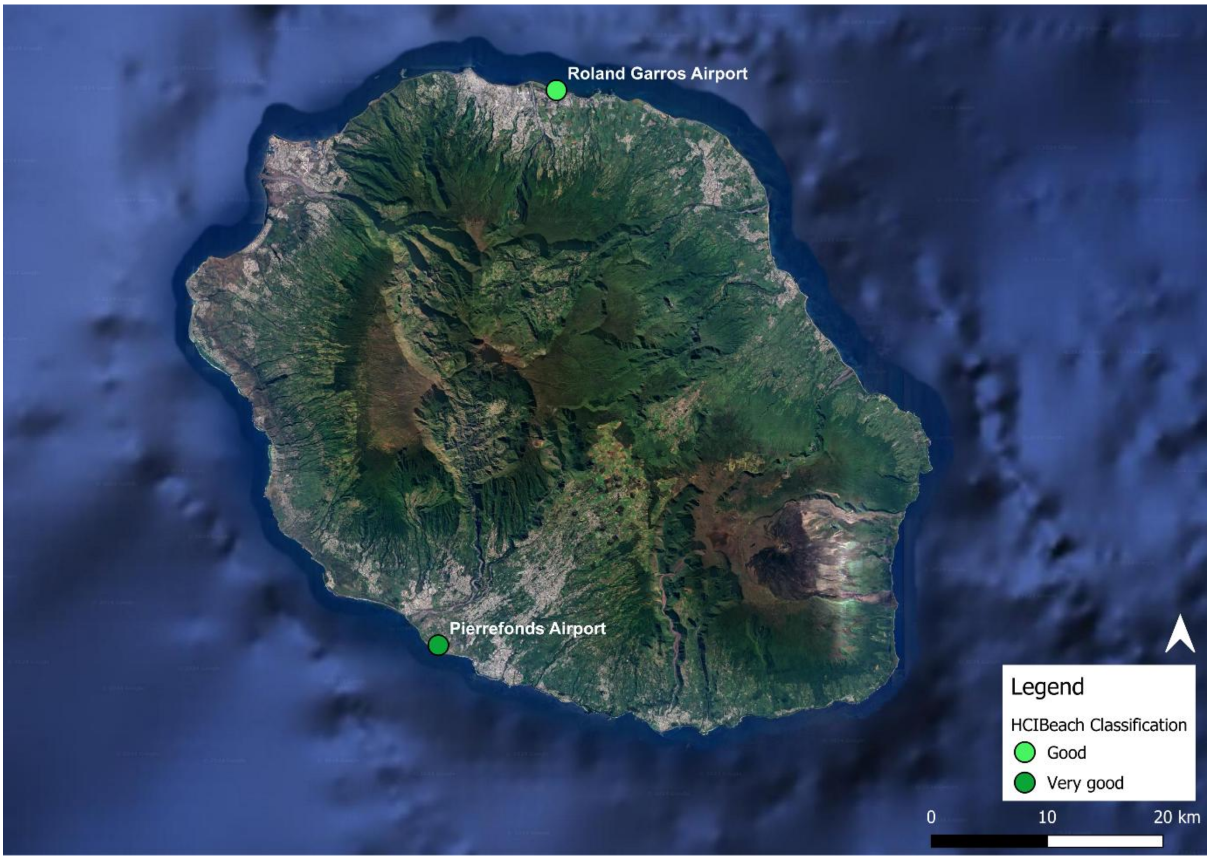


Figure 6.7. Mean annual HCI_{Beach} classifications.

A winter peak seasonal classification was calculated for the HCI_{Beach} for Roland Garros Airport and Pierrefonds Airport (Figure 6.8). Climatic suitability is generally acceptable year-round where higher climatic suitability to pursue beach activities can be seen from the end of May and remains suitable until the middle of September. Pierrefonds Airport shows higher seasonal suitability compared to Roland Garros Airport, located in the most northern region of the island which has relatively lower suitability and fewer beach sites. Pierrefonds Airport is located on the western side of the island, which hosts many beach sites and so is an ideal region for a beach holiday.

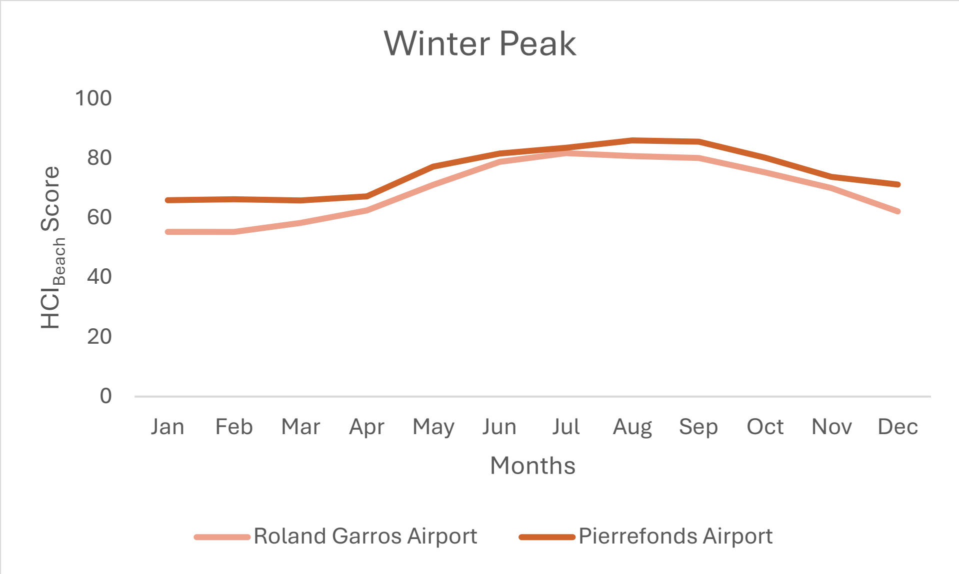


Figure 6.8. The seasonal distribution of climatic suitability for the HCI_{Beach} for Roland Garros Airport and Pierrefonds Airport is characterised by winter peak distribution.

6.5 Camping Climate Index (CCI)

The CCI, developed by Ma *et al.* (2020), was used to determine the climatic suitability for camping, considered both an activity and accommodation. The CCI is one of the only tourism climate indices to include extreme climate thresholds that when exceeded, scores received an automatic low score of 3. The CCI uses variables of T_{max}, T_{min}, T_{mean}, precipitation, wind speed, mean relative humidity and sunshine hours. Stations for which the requisite data were available and for which the CCI was calculated included Roland Garros Airport, Cilaos, Colimacons, Le Baril, Le Port, Petite-France, Piton Maido, Plaine des Palmistes, Pont-Mathurin and Saint-Benoit (Figure 6.9). Camping sites and activities are predominately found on the western half of the island and the higher mountainous areas as identified by Google locations (Figure 6.9). It is noted that while there are identified designated camping sites, camping may hypothetically occur near any of the meteorological stations, although some locations do specifically prohibit camping.

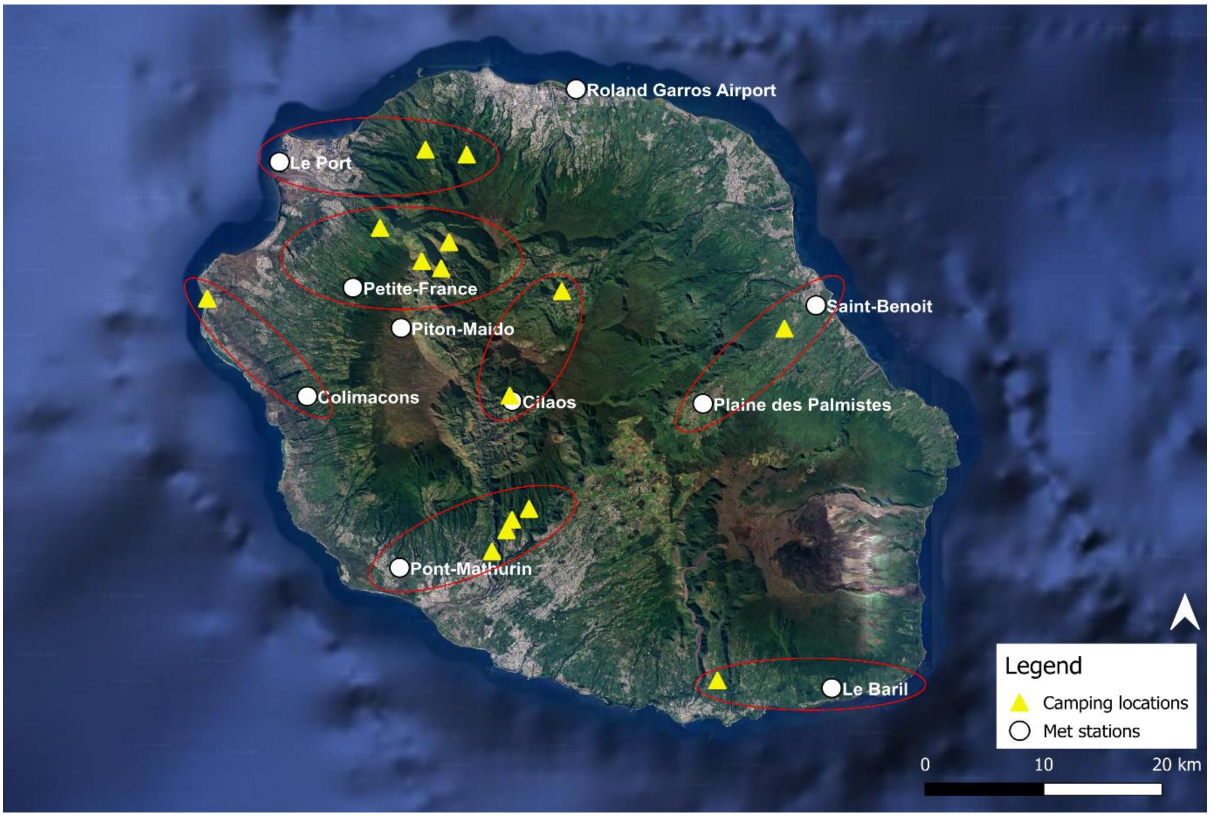


Figure 6.9. Camping locations in relation to meteorological stations for which the requisite data were available for the CCI.

6.5.1 Roland Garros Airport

The CCI was calculated for Roland Garros Airport for 33 years spanning 1991-2023 (Table 6.15). Mean annual climate suitability scores ranged from 4.2 ('acceptable', 2004) to 5.5 ('acceptable', 1991). The annual mean for the period of data is 4.7 classified as 'acceptable'. There is less variation in climatic suitability for camping annually over the entire period of data. It is not clear whether scores may be in decline or improving annually.

Table 6.15. Mean annual and monthly CCI climate suitability scores for Roland Garros Airport from 1991-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
1991	4.7	5.1	4.8	5.2	5.5	5.0	5.7	6.2	6.1	5.9	5.3	6.2	5.5
1992	5.4	4.3	5.5	5.9	5.8	5.7	5.3	4.6	4.3	6.1	6.6	5.8	5.4
1993	5.9	4.9	5.1	4.5	6.7	5.3	4.7	4.5	4.1	4.4	5.0	5.6	5.1

1994	3.9	4.8	4.6	6.5	5.8	5.0	4.9	4.9	5.0	4.5	4.5	4.9	4.9
1995	4.2	4.6	4.8	5.4	4.0	5.9	3.9	3.6	4.0	3.9	5.3	4.4	4.5
1996	3.9	3.7	4.9	5.2	4.1	5.0	4.5	4.6	4.5	4.1	5.3	5.1	4.6
1997	3.8	4.4	6.0	6.1	4.2	4.0	4.0	4.6	5.3	4.2	5.6	5.2	4.8
1998	4.0	3.8	4.9	3.6	4.6	5.2	4.0	3.8	3.8	4.7	4.3	5.3	4.3
1999	4.9	4.4	4.7	6.2	6.2	5.5	3.9	3.5	4.1	5.4	3.8	4.3	4.7
2000	4.8	3.7	3.7	5.3	5.6	4.6	3.8	4.1	3.8	4.2	4.2	4.7	4.4
2001	4.4	5.2	4.5	5.7	5.5	4.6	4.6	3.9	5.0	4.4	4.5	4.9	4.8
2002	5.3	5.0	4.3	5.0	4.6	4.0	3.6	3.0	4.5	4.2	4.9	4.8	4.4
2003	4.4	4.8	4.5	4.8	4.2	4.7	4.4	4.5	3.8	4.5	5.1	4.5	4.5
2004	5.0	4.2	3.9	4.7	4.1	4.2	3.9	3.8	4.7	4.4	3.8	4.1	4.2
2005	4.6	4.2	4.4	5.6	4.1	4.2	4.7	3.8	3.5	4.4	4.3	5.4	4.4
2006	4.0	3.7	4.0	5.4	6.3	4.7	4.0	4.2	4.2	4.1	4.7	4.0	4.4
2007	4.2	4.3	5.3	4.0	5.8	5.6	4.0	4.2	4.2	3.6	5.4	4.5	4.6
2008	4.5	4.1	3.8	6.6	6.0	4.9	4.4	4.4	3.7	3.9	5.5	5.1	4.7
2009	4.5	4.4	4.6	5.1	6.0	5.2	4.5	4.5	4.2	5.0	5.0	5.0	4.8
2010	4.4	4.4	4.0	4.8	4.8	5.2	4.6	3.6	4.5	4.8	4.7	5.7	4.6
2011	4.7	4.5	4.6	5.0	6.6	5.8	5.4	4.6	4.4	5.2	6.1	5.0	5.1
2012	4.5	5.0	4.0	4.6	4.5	4.9	4.4	4.4	4.1	4.9	5.8	4.5	4.6
2013	3.9	4.4	4.7	4.8	5.5	5.2	5.1	4.6	4.4	4.7	6.3	5.4	4.9
2014	4.5	4.3	4.4	5.1	5.7	5.7	4.3	4.8	4.8	5.7	5.7	4.7	5.0
2015	3.9	5.1	5.2	5.8	4.8	4.7	4.9	4.7	4.1	4.0	5.5	4.8	4.8
2016	4.7	4.4	4.7	5.5	4.6	4.0	4.1	4.5	3.7	5.4	4.8	4.9	4.6
2017	4.0	4.7	3.6	4.7	4.7	4.7	5.0	4.4	5.5	4.5	5.7	5.6	4.8
2018	4.5	5.2	4.2	5.2	5.5	5.1	4.1	4.6	3.7	5.5	5.7	5.4	4.9
2019	5.0	5.2	4.9	4.4	5.0	4.0	4.8	5.0	4.9	4.6	4.9	4.8	4.8
2020	4.3	4.6	4.3	3.9	5.5	4.2	4.0	4.1	4.4	4.9	4.5	4.0	4.4
2021	3.9	3.6	4.6	3.8	5.5	4.4	3.6	4.7	3.9	4.7	5.2	4.2	4.4
2022	4.1	4.0	4.4	3.7	4.9	5.0	3.4	4.7	4.0	4.5	5.3	4.0	4.3
2023	3.8	4.0	4.6	4.9	5.1	5.6	5.1	4.5	4.4	5.6	4.6	4.8	4.8
Avg	4.4	4.4	4.6	5.1	5.2	4.9	4.4	4.4	4.3	4.7	5.1	4.9	**4.7**
Legend													
0-3	Unfavourable	4-5	Acceptable	6-7	Good	8-10	Optimal						

Mean monthly climate suitability scores ranged from 3.0 (‘unfavourable’) in August 2002 to 6.7 (‘good’) in May 1993 (Table 6.15). June is an entirely ‘acceptable’ month. December is also almost all ‘acceptable’ with the exception of a ‘good’ classification seen in December 1991. No ‘good’ mean monthly scores were found in January, February and July. Further, no ‘optimal’ classifications were found over the 33 years for camping.

6.5.2 Cilaos

The CCI was calculated for Cilaos using 18 years of requisite data available spanning 1991-2001 and 2017-2023 (Table 6.16). Two known camping sites are located in proximity to Cilaos (Figure 6.9). Mean annual climatic suitability scores ranged from 4.1 ('acceptable') for 1993 and 1996 to 4.6 ('acceptable') for 2019 and 2021. The annual mean for the period of data is 4.3 classified as 'acceptable'. Classifications for mean annual scores are only classified as 'acceptable'. Mean monthly climatic suitability scores range from 2.9 ('unfavourable') in August 1992 and 6.2 ('good') in December 1992. Only one score for the 'good' classification was calculated for the 18-year period. February has one instance of an 'unfavourable' classification (3.9, 1993). June through October are revealed to be the least suitable months with predominately 'unfavourable' classifications. The remainder of the year (January through May and November through December) are classified as 'acceptable'.

Table 6.16. Mean annual and monthly CCI climate suitability scores for Cilaos from 1991-2001 and 2017-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
1991	5.9	5.4	4.8	4.8	4.1	3.7	3.4	3.5	4.0	4.5	5.0	4.7	4.5
1992	5.2	4.9	4.8	4.5	4.1	3.3	3.1	2.9	3.3	4.2	4.5	6.2	4.3
1993	5.0	3.9	4.7	4.8	4.0	3.3	3.2	3.3	3.2	3.8	4.6	5.1	4.1
1994	4.4	4.4	4.9	4.8	4.5	3.3	3.6	3.6	3.4	4.1	4.8	5.1	4.2
1995	5.2	4.9	4.8	4.8	4.1	3.4	3.5	3.2	3.5	4.3	4.6	4.1	4.2
1996	4.5	5.2	5.2	4.6	4.3	3.4	3.2	3.2	3.5	3.7	4.7	4.2	4.1
1997	4.8	4.9	5.2	4.7	4.2	3.7	3.5	3.3	3.5	3.5	4.8	4.5	4.2
1998	5.6	4.3	5.5	4.8	4.9	3.5	3.4	3.1	3.6	4.1	5.0	4.5	4.4
1999	5.2	4.9	4.9	4.9	4.3	3.2	3.2	3.2	3.5	3.8	4.8	5.0	4.2
2000	4.8	4.8	5.5	5.2	4.5	3.7	3.5	3.5	3.5	3.9	4.4	5.1	4.4
2001	5.0	5.2	4.9	5.0	4.8	3.2	3.4	3.5	3.7	3.9	4.8	4.7	4.3
2017	5.2	4.9	5.2	5.0	4.5	4.5	3.8	3.8	4.0	4.2	4.6	4.8	4.5
2018	4.2	4.8	4.2	4.9	4.8	4.5	3.5	3.4	3.8	4.1	4.3	4.9	4.3
2019	5.1	4.6	5.1	5.3	4.8	4.0	3.7	3.8	3.3	4.5	5.2	5.3	4.6
2020	4.6	4.7	4.9	4.9	4.6	3.7	4.0	3.2	3.4	4.1	4.9	5.2	4.4
2021	5.7	5.3	4.8	4.6	4.7	3.7	3.4	3.2	3.9	4.7	5.4	5.3	4.6
2022	4.9	4.7	4.5	4.8	4.1	3.6	3.3	3.3	3.8	4.4	5.3	5.3	4.3

2023	4.7	5.1	5.0	4.7	4.7	3.8	3.4	3.8	4.0	5.0	4.6	5.0	4.5
Avg	5.0	4.8	4.9	4.8	4.4	3.6	3.4	3.4	3.6	4.2	4.8	4.9	**4.3**
Legend													
0-3	Unfavourable	4-5		Acceptable		6-7	Good		8-10	Optimal			

6.5.3 Colimacons

The CCI was calculated for Colimacons for the 14 years of requisite data available, spanning 1998-2003 and 2016-2023 (Table 6.17). One campsite is located the closest to this station (Figure 6.9). Mean annual climate suitability scores ranged from 4.5 ('acceptable', 2016) to 4.9 ('acceptable', 2001, 2002 and 2019). The annual mean for the period of data is 4.7 classified as 'acceptable'. Classifications for mean annual scores are only classified as 'acceptable'. Mean monthly climate suitability scores ranged from 3.9 ('unfavourable') in August 2017 and 2020, September 2016 and October 2022 to 5.7 ('acceptable') in January 1998 and December 2019. The majority of the year is classified as 'acceptable' with only four instances of 'unfavourable' classifications with a 3.9 score.

Table 6.17. Mean annual and monthly CCI climate suitability scores for Colimacons from 1998-2003 and 2016-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
1998	5.7	4.6	5.4	5.1	5.0	4.6	4.6	4.4	4.1	4.1	4.3	4.8	4.7
1999	4.7	4.8	5.1	5.0	5.4	4.8	4.6	4.5	4.2	4.5	4.8	4.5	4.7
2000	5.5	5.3	5.4	5.1	5.0	5.0	4.4	4.3	4.2	4.5	4.8	4.8	4.8
2001	5.0	5.6	5.3	5.4	5.2	4.6	4.6	4.6	4.6	4.3	4.7	5.0	4.9
2002	5.5	5.6	5.4	5.2	4.8	4.5	4.4	4.5	4.1	4.5	4.8	5.0	4.9
2003	5.0	5.3	4.6	5.0	5.0	5.0	4.5	4.4	4.4	4.2	4.9	5.0	4.8
2016	5.0	4.5	5.0	5.1	4.8	4.6	4.3	4.2	3.9	4.2	4.2	4.5	4.5
2017	4.8	4.1	5.3	4.6	5.0	4.7	4.8	3.9	4.1	4.4	4.6	4.4	4.6
2018	4.4	4.7	4.7	4.9	5.1	4.6	4.3	4.2	4.1	4.4	4.4	5.0	4.6
2019	5.0	5.4	5.4	5.2	4.9	4.5	4.5	4.5	4.2	4.6	5.3	5.7	4.9
2020	4.9	5.4	4.6	5.3	4.7	4.5	4.0	3.9	4.0	4.3	4.5	5.1	4.6
2021	4.8	4.9	5.0	4.8	4.9	4.6	4.2	4.2	4.2	4.4	4.8	5.3	4.7
2022	5.1	4.9	5.0	4.7	5.1	4.7	4.0	4.0	4.0	3.9	4.6	4.9	4.6

2023	5.0	5.2	5.0	4.5	4.9	4.7	4.5	4.2	4.5	4.8	4.8	5.2	4.8
Avg	5.0	5.0	5.1	5.0	5.0	4.6	4.4	4.3	4.2	4.4	4.7	4.9	**4.7**
Legend													
0-3	Unfavourable	4-5	Acceptable	6-7	Good	8-10	Optimal						

6.5.4 Le Baril

The CCI was calculated for Le Baril for eight years of requisite data available spanning 2016-2023 (Table 6.18). One known campsite is located in proximity to this station (Figure 6.9). Mean annual climate suitability scores ranged from 4.6 ('acceptable', 2016) to 5.0 ('acceptable', 2017). The annual mean for the period of data is 4.8 classified as 'acceptable'. Mean monthly climate suitability scores range from 3.3 ('unfavourable') in April 2021 to 7.0 ('good') in November 2022. May, June, August and September are entirely classified as 'acceptable' for the data period. February and April have one 'unfavourable' classification each, 3.6 in February 2016 and 3.3 in April 2021. January is mostly 'acceptable' with one score of 6.6 classified as 'good' in 2017.

Table 6.18. Mean annual and monthly CCI climate suitability scores for Le Baril from 2016-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
2016	4.4	3.6	4.0	4.6	4.3	4.2	3.8	4.1	4.4	5.8	5.5	6.3	4.6
2017	6.6	5.2	3.8	5.0	4.7	4.5	4.4	4.3	5.0	5.7	5.1	6.2	5.0
2018	4.1	4.3	4.1	4.0	4.7	4.4	4.1	5.0	5.4	5.0	5.3	6.4	4.7
2019	4.7	4.7	5.1	4.6	4.6	4.4	4.4	5.0	5.0	6.0	5.7	5.0	4.9
2020	4.5	4.9	3.7	4.2	4.8	4.3	4.1	4.9	4.9	6.2	5.2	4.8	4.7
2021	4.8	4.6	4.1	3.3	5.2	4.2	4.0	4.5	5.2	5.5	6.8	6.1	4.9
2022	4.7	4.3	4.0	4.1	4.7	4.0	4.0	4.8	4.6	6.0	7.0	6.0	4.8
2023	5.1	5.2	4.8	4.3	4.7	4.4	4.2	4.5	5.8	5.7	4.4	4.9	4.8
Avg	4.9	4.6	4.2	4.3	4.7	4.3	4.1	4.6	5.0	5.7	5.6	5.7	**4.8**
Legend													
0-3	Unfavourable	4-5	Acceptable	6-7	Good	8-10	Optimal						

6.5.5 Le Port

The CCI was calculated for Le Port for 12 years of requisite data available spanning 1991-1994 and 2016-2023 (Table 6.19). Two known campsites are located in close proximity to this station (Figure 6.9). Mean annual climate suitability scores ranged from 5.6 ('acceptable', 2017 and 2018) to 6.0 ('acceptable', 1991 and 1992). The annual mean for the period of data is 5.8 classified as 'acceptable'. Apart from 1991 and 1992 which are classified as 'good', all remaining mean annual scores are classified as 'acceptable'. Mean monthly climate suitability scores ranged from 3.8 ('unfavourable') in February 1993 to 7.1 ('good') in June 2020 and November 2019. The lowest score is also the only score classified as 'unfavourable'. June and July are the most favourable months with all scores being classified as 'good'.

Table 6.19. Mean annual and monthly CCI climate suitability scores for Le Port from 1991-1994 and 2016-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
1991	5.4	5.1	4.7	5.1	6.0	6.3	6.6	6.9	6.6	7.0	6.8	5.7	6.0
1992	5.1	4.9	5.1	6.0	6.2	6.5	6.2	6.5	6.6	6.8	6.0	5.9	6.0
1993	4.8	3.8	4.7	5.2	5.8	6.0	6.4	6.6	6.3	6.7	6.1	5.6	5.7
1994	4.2	4.3	4.4	5.3	6.2	6.8	6.9	6.5	6.1	6.2	6.1	5.6	5.7
2016	5.3	4.6	4.4	5.2	6.1	6.8	6.2	6.1	5.9	5.9	6.1	6.3	5.7
2017	6.1	4.9	4.6	4.5	4.9	6.4	6.5	6.3	5.9	5.8	6.1	5.3	5.6
2018	4.0	5.0	4.4	4.6	5.6	6.2	6.5	6.2	5.8	5.9	6.4	6.5	5.6
2019	6.0	4.8	5.5	4.9	5.5	6.3	6.1	6.1	6.1	6.0	7.1	5.6	5.8
2020	5.4	5.7	4.2	5.0	6.2	7.1	6.3	5.5	6.0	6.1	6.4	6.6	5.9
2021	5.4	4.1	5.2	4.1	6.8	6.7	6.3	6.5	6.3	6.3	6.6	5.7	5.8
2022	4.8	4.1	4.3	5.1	6.6	6.7	5.8	6.0	6.0	5.9	6.6	6.2	5.7
2023	5.1	5.1	4.9	5.3	6.3	6.2	6.6	6.3	6.4	6.2	5.8	5.3	5.8
Avg	5.1	4.7	4.7	5.0	6.0	6.5	6.4	6.3	6.2	6.2	6.3	5.9	**5.8**

Legend							
0-3	Unfavourable	4-5	Acceptable	6-7	Good	8-10	Optimal

6.5.6 Petite-France

The CCI was calculated for Petite-France for seven years of requisite data available, spanning 2017-2023 (Table 6.20). Four known campsites are located in proximity to this station (Figure 6.9). Mean annual climate suitability scores ranged from 3.5 ('unfavourable', 2020 and 2022) to 3.9 ('unfavourable', 2019). Classifications for mean annual scores were all classified as 'unfavourable'. The annual mean for the period of data is 3.7 classified as 'unfavourable'. Mean monthly climate suitability scores ranged from 2.8 ('unfavourable') in July 2022 to 5.0 ('acceptable') in December 2019. April through November are revealed to be the least suitable months for camping with 'unfavourable' and 'acceptable' classifications. January through March and December have improved suitability with 'acceptable' and 'unfavourable' classifications.

Table 6.20. Mean annual and monthly CCI climate suitability scores for Petite-France from 2017-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
2017	4.0	4.0	4.0	3.9	3.5	3.3	3.3	3.1	3.1	3.3	3.6	3.8	3.6
2018	4.0	4.0	4.0	4.0	3.7	3.3	3.0	3.1	3.2	3.3	3.8	4.6	3.7
2019	4.6	4.7	4.6	3.9	3.6	3.2	3.2	2.9	3.1	3.7	4.3	5.0	3.9
2020	4.1	4.1	4.3	4.0	3.5	2.9	2.9	2.9	3.0	3.4	3.3	3.9	3.5
2021	4.1	4.1	4.1	4.1	3.7	3.1	3.0	2.9	3.0	3.5	3.9	4.1	3.6
2022	4.0	3.9	4.4	3.9	3.6	3.1	2.8	2.9	3.0	3.1	3.6	4.0	3.5
2023	4.0	4.0	4.2	3.8	3.9	3.4	3.1	3.2	3.2	3.9	4.0	4.4	3.8
Avg	4.1	4.1	4.2	3.9	3.6	3.2	3.0	3.0	3.1	3.5	3.8	4.3	**3.7**

Legend							
0-3	Unfavourable	4-5	Acceptable	6-7	Good	8-10	Optimal

6.5.7 Piton Maido

The CCI was calculated for Piton Maido for seven years of requisite data available spanning 2017-2023 (Table 6.21). Piton Maido is located between Petite-France and Cilaos where six stations are in proximity to this station (Figure 6.9). Mean annual climatic suitability scores range from 3.4 ('unfavourable', 2017) and 3.9 ('unfavourable', 2021). Classifications for mean annual scores were all classified as 'unfavourable'. The annual mean for the period of data is 3.6 classified as 'unfavourable'. Mean monthly climatic suitability scores range from 2.9 ('unfavourable') in August 2017; September 2019; June and July 2021 and June 2022 to 5.2 ('acceptable') in November 2021. May through September are the least suitable months for camping with only 'unfavourable' classifications.

Table 6.21. Mean annual and monthly CCI climate suitability scores for Piton Maido from 2017-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
2017	3.6	4.0	4.0	3.8	3.3	3.1	3.0	2.9	3.2	3.6	3.3	3.5	3.4
2018	3.8	3.9	3.8	3.9	3.3	3.0	3.0	3.5	3.5	3.1	3.3	3.8	3.5
2019	4.6	4.4	4.2	4.2	3.3	3.0	3.1	3.2	2.9	4.0	3.9	4.4	3.8
2020	4.0	4.1	4.4	3.8	3.4	3.0	3.1	3.1	3.2	3.6	3.9	4.0	3.6
2021	4.5	4.4	4.3	3.9	3.7	2.9	2.9	3.0	3.4	4.1	5.2	4.0	3.9
2022	4.1	3.6	4.6	4.0	3.6	2.9	3.0	3.2	3.0	3.4	3.6	3.3	3.5
2023	3.5	3.7	4.1	4.0	3.6	3.3	3.0	3.1	3.1	4.6	3.5	4.1	3.6
Avg	4.0	4.0	4.2	3.9	3.4	3.0	3.0	3.1	3.2	3.8	3.8	3.9	**3.6**
Legend													
0-3	Unfavourable	4-5	Acceptable	6-7	Good	8-10	Optimal						

6.5.8 Plaine des Palmistes

The CCI was calculated for Plaine des Palmistes for 10 years of requisite data available, spanning 1991-1993 and 2017-2023 (Table 6.22). One known campsite is located in proximity to this station (Figure 6.9). Mean annual climatic suitability ranged from 4.1 ('acceptable') for 1991 and 2020-2023 and 4.4 ('acceptable') in 2019. The annual mean for the period of data is 4.2 classified as 'acceptable'. Classifications for mean annual scores are all classified as 'acceptable'. Mean monthly climatic suitability ranged from 3.2 ('unfavourable') in July 2022 and 5.6 ('acceptable') in January 1993.

Classifications for November through May are ‘acceptable’ with suitability declining in the months of June through October.

Table 6.22. Mean annual and monthly CCI climate suitability scores for Plaine des Palmistes from 1991-1993 and 2017-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
1991	5.0	4.4	4.5	4.0	4.0	3.8	3.4	3.6	4.1	3.8	4.6	4.4	4.1
1992	4.5	4.5	5.2	4.5	4.3	4.0	3.5	3.6	3.7	4.5	5.0	4.6	4.3
1993	5.6	4.4	4.6	4.3	4.5	4.2	3.6	3.8	3.7	3.9	4.3	4.6	4.3
2017	4.7	4.3	4.5	4.3	4.0	4.1	4.1	4.1	4.1	4.0	4.1	4.0	4.2
2018	4.0	5.0	4.3	4.1	4.4	4.4	4.3	3.7	3.5	3.6	4.3	4.4	4.2
2019	4.8	5.4	5.0	5.0	4.3	4.1	3.8	3.7	3.6	3.9	4.4	4.6	4.4
2020	4.5	4.6	4.1	4.6	4.1	4.0	3.7	3.4	3.5	3.6	4.1	4.6	4.1
2021	5.1	4.2	4.7	4.2	4.8	4.0	3.6	3.8	3.9	4.0	5.3	4.7	4.1
2022	4.8	4.5	4.4	4.0	4.3	3.9	3.2	3.5	3.5	3.7	4.6	4.2	4.1
2023	4.4	4.6	4.7	4.5	4.5	4.0	4.0	3.7	4.1	4.4	4.7	5.2	4.1
Avg	4.7	4.6	4.6	4.3	4.3	4.0	3.7	3.7	3.8	3.9	4.5	4.5	**4.2**

Legend							
0-3	Unfavourable	4-5	Acceptable	6-7	Good	8-10	Optimal

6.5.9 Pont-Mathurin

The CCI was calculated for Pont-Mathurin for eight years of requisite data available, spanning 2016-2023 (Table 6.23). Four known campsites are located in proximity to this station (Figure 6.9). Mean annual climatic suitability scores ranged from 5.6 (‘acceptable’) for 2016, 2018-2020 and 2022 to 5.7 (‘acceptable’) for 2017, 2021 and 2023. Classifications for mean annual scores are all classified as ‘acceptable’. The annual mean for the period of data is 5.6 classified as ‘acceptable’. Mean monthly climatic suitability scores range from 4.2 (‘acceptable’) in March 2020 and 7.4 (‘good’) in December 2016. September through December are more favourable months for camping with ‘acceptable’ and ‘good’ classifications while May, April, June and August are only ‘acceptable’.

Table 6.23. Mean annual and monthly CCI climate suitability scores for Pont-Mathurin from 2016-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
2016	5.2	4.4	4.9	5.7	5.3	5.3	5.4	5.4	6.2	6.3	6.1	7.4	5.6
2017	6.3	4.9	4.8	5.4	6.0	5.7	6.0	5.3	5.7	6.1	6.3	5.6	5.7
2018	4.5	4.4	5.0	5.1	6.2	5.5	5.4	5.8	6.6	5.8	6.8	6.4	5.6
2019	4.5	5.3	5.8	5.1	5.7	5.6	5.3	5.4	5.7	6.8	6.5	6.0	5.6
2020	5.0	5.7	4.2	5.9	5.9	5.5	5.0	5.3	5.6	6.7	6.5	6.3	5.6
2021	6.2	5.3	5.3	4.3	5.7	5.5	5.5	5.2	6.3	6.0	6.9	6.3	5.7
2022	5.4	5.2	4.5	5.4	5.9	5.0	5.3	5.3	5.9	6.0	6.7	6.8	5.6
2023	5.8	6.3	5.5	4.7	5.8	5.4	5.5	5.3	6.6	6.3	5.6	5.5	5.7
Avg	5.4	5.2	5.0	5.2	5.8	5.4	5.4	5.4	6.1	6.3	6.4	6.3	**5.6**

Legend							
0-3	Unfavourable	4-5	Acceptable	6-7	Good	8-10	Optimal

6.5.10 Saint-Benoit

The CCI was calculated for Saint-Benoit for eight years of requisite data available, spanning 2016-2023 (Table 6.24). One known campsite is located in proximity to this station (Figure 6.9). Mean annual climate suitability scores ranged from 5.2 ('acceptable', 2016-2018, 2020-2021 and 2023) to 5.3 ('acceptable', 2019 and 2022). Classifications for mean annual scores are all classified as 'acceptable'. The annual mean for the period of data is 5.2 classified as 'acceptable'. Mean monthly climate suitability scores ranged from 3.5 ('unfavourable') in April 2021 to 6.7 ('good') in November 2021 and 2022. There are only three instances of 'unfavourable' classifications in March 2017 (3.7), February 2021 (3.9) and April 2021 (3.5). January, June, July and August are entirely classified as 'acceptable' for the data period. May, September, November and December are mostly classified as 'acceptable' but have two 'good' classifications each.

Table 6.24. Mean annual and monthly CCI climate suitability scores for Saint-Benoit from 2017-2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg
2016	4.9	4.3	4.5	5.5	5.9	5.0	4.8	5.0	5.5	5.7	5.4	5.7	5.2
2017	5.9	4.4	3.7	5.0	5.3	5.2	5.4	5.3	5.7	5.6	5.2	6.4	5.2
2018	4.4	4.7	4.4	5.0	5.1	5.3	5.1	5.8	5.6	5.1	5.8	6.3	5.2
2019	5.1	5.5	5.0	4.5	5.1	4.9	5.3	5.7	5.2	6.1	5.5	5.2	5.3
2020	4.8	5.0	4.6	4.7	5.6	5.2	5.0	5.5	5.6	6.0	5.7	5.4	5.2
2021	4.9	3.9	4.3	3.5	6.0	5.2	4.8	5.1	6.2	5.6	6.7	5.5	5.2
2022	4.6	4.2	4.5	4.4	6.1	5.4	5.1	5.6	5.4	6.1	6.7	5.6	5.3
2023	4.4	5.0	4.9	4.6	4.9	5.7	5.4	5.2	6.3	5.9	5.2	5.0	5.2
Avg	4.9	4.6	4.5	4.7	5.5	5.2	5.1	5.4	5.7	5.8	5.7	5.6	**5.2**

Legend							
0-3	Unfavourable	4-5	Acceptable	6-7	Good	8-10	Optimal

6.5.11 Inter-Station Comparison

Mean annual CCI scores reveal two ‘unfavourable’ and eight ‘acceptable’ classifications (Figure 6.10). Mean annual ‘acceptable’ scores were calculated for Roland Garros Airport (4.7), Saint-Benoit (5.2), Le Baril (4.8), Pont-Mathurin (5.6), Colimacons (4.7), Le Port (5.8), Cilaos (4.3) and Plaine des Palmistes (4.2). Mean annual ‘unfavourable’ scores were calculated for Petite-France (3.7) and Piton-Maido (3.6). No ‘optimal’ scores were found across all stations for any period of time.

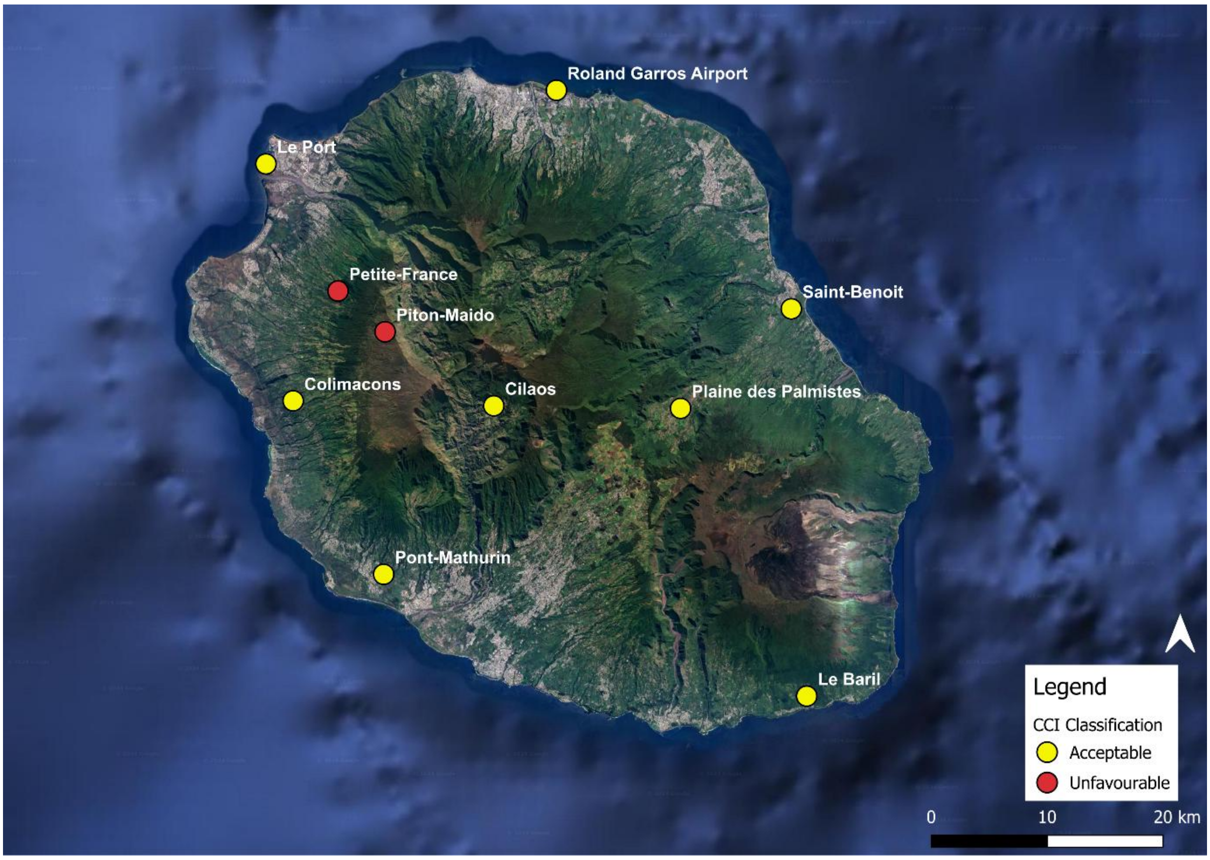


Figure 6.10. Mean annual CCI classifications.

Considering the seasonal variability, a bimodal shoulder peak seasonal distribution was found at Roland Garros Airport, Le Baril, Pont-Mathurin, Colimacons, Plaine des Palmistes and Saint-Benoit (Figure 6.11a). A winter peak, although relatively late in the season, was identified for Le Port (Figure 6.11b). A summer peak was classified for Petite-France, Petite-Maido and Cilaos which indicate suitable conditions for camping during December through February (Figure 6.11c).

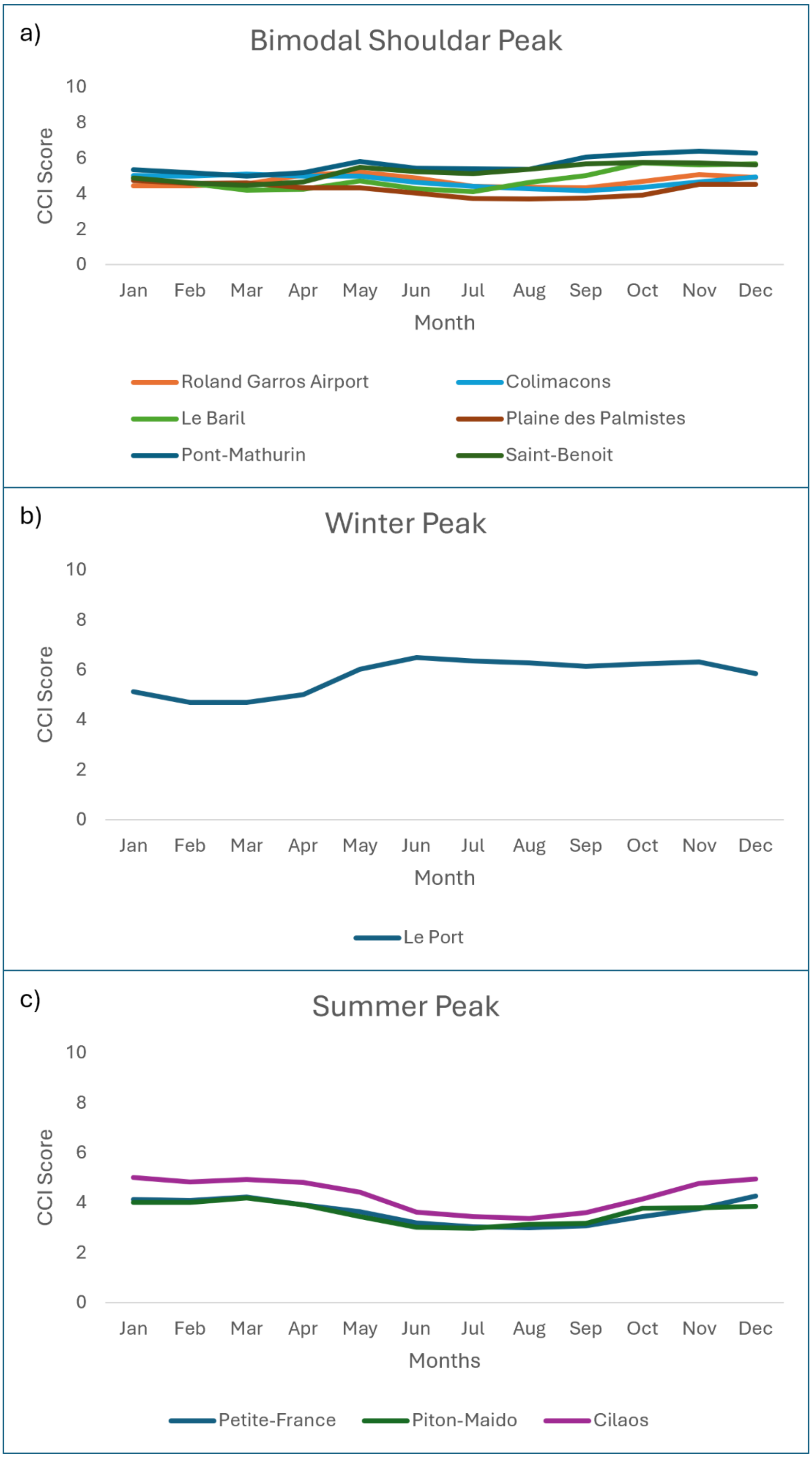


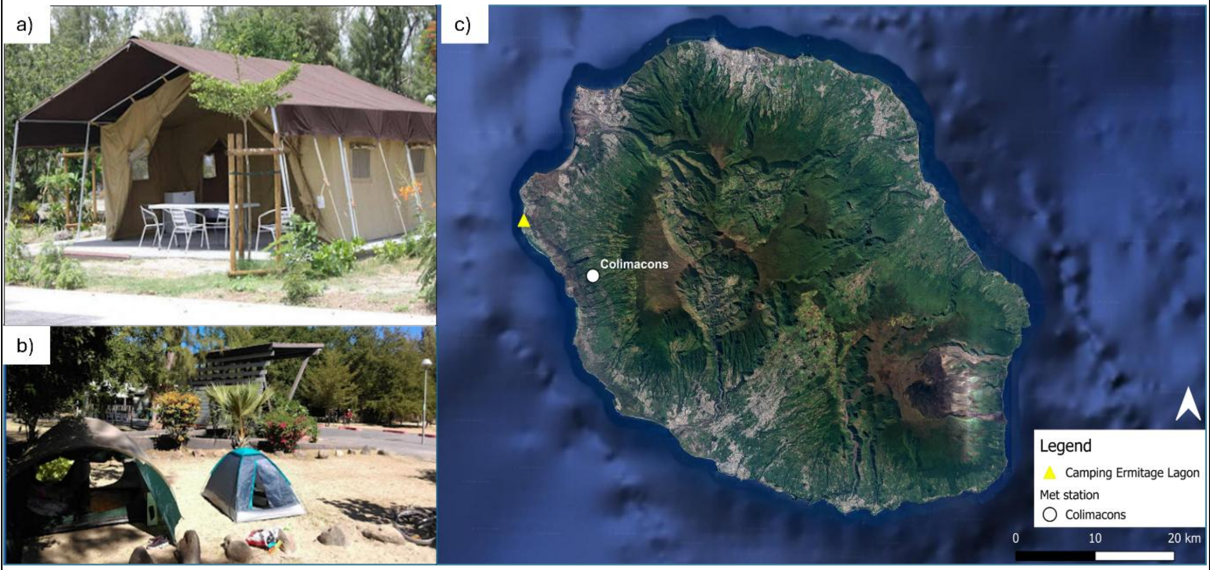
Figure 6.11. The seasonal distribution of climatic suitability for the CCI for 10 meteorological stations is characterised by a) bimodal-shoulder b) winter and c) summer peak distribution.

6.6 Ground-based Camping Evaluation

Using the CCI to determine the climatic suitability of camping had shown that, as a result of the exception thresholds included in the calculation of the index, precipitation and predominantly wind speed were variables where thresholds were exceeded and subsequently resulted in automatic lower 3 scores. Ground-based measurements were therefore recorded to determine whether *in situ* instances produced different CCI scores and whether microclimate variations could be seen.

In situ data were measured for three types of camping accommodation types. Ground-based measurements were recorded at particular times of the day in 2023 for a beach campsite in Saint-Paul, a farm campsite in La Possession and a glamping site in Saint-Joesph. A beach campsite, *Camping Ermitage* in the coastal town of Saint-Paul was examined in relation to the closest meteorological station, Colimacons (Table 6.25). Ground-based measurements taken on 12 June 2023 observed air temperature at 27.8°C and relative humidity at 64.0% at the time recorded. Humidex was calculated to be 35.5°C. Comparatively, humidex was higher at the beach campsite than the recorded meteorological station data on the same day and the average recorded for the month of June in 2023. Sunshine hours could not be determined during the day of ground-based recordings where known measurements for the day were recorded after fieldwork took place. CCI scores calculated for the meteorological station on the day was 4 classified as ‘acceptable’, the average score for June 2023 was 5 classified as ‘acceptable’ and the beach campsite received a calculated score of 7.5 classified as ‘good’. No exceptions were applicable as T_{max}, T_{min}, precipitation and wind speed thresholds were not exceeded (Table 6.25).

Table 6.25. Comparative table for beach campsite Camping Ermitage.

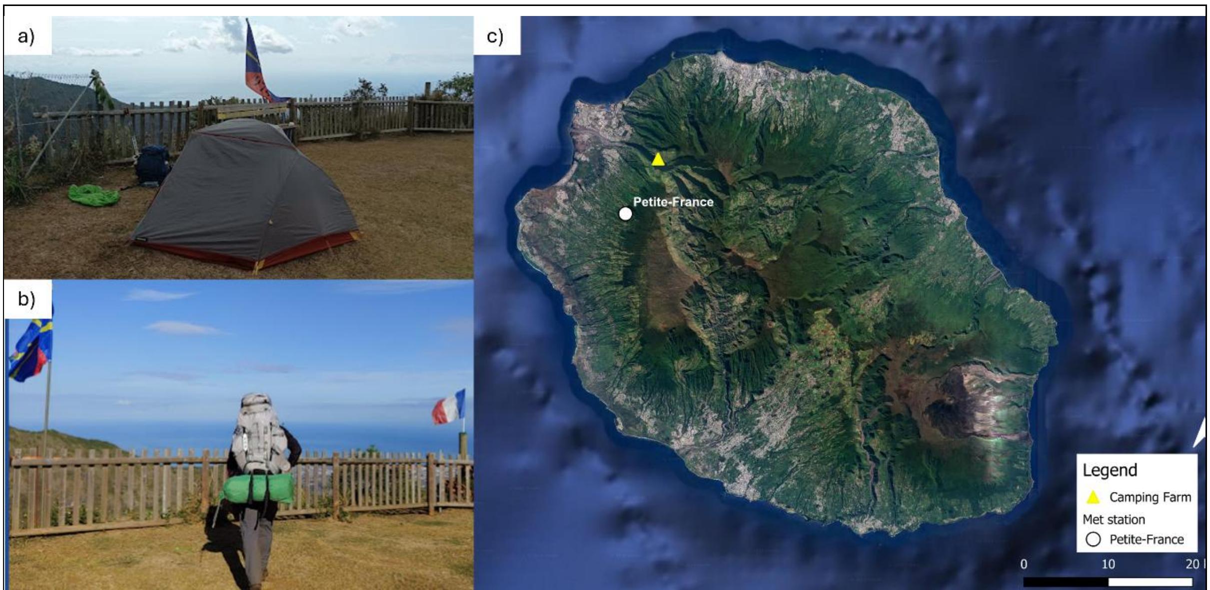


Picture sources: a) Témoignages, 2012 b) Bertrand Payet, 2018 c) Own map

Category	Meteorological Day measurement	Average conditions in June 2023	Ground-based Day measurement
Site	Colimacons	Colimacons	Camping Ermitage
T_{max}	21.6	21.3	-
T_{min}	15.0	14.3	-
Precipitation	0.0	0.3	No rain
Wind speed	6.1	7.4	1.5
Air temperature	18.3	17.8	27.8
Relative humidity	86.8	84.1	64.0
Humidex	22.9	21.8	35.5
Sunshine hours	3.9	4.9	11.0
CCI Score	4 No exceptions applicable	5 No exceptions applicable	7.5 No exceptions applicable

A farm campsite, *Table D'Hote La Ferme Bellevu* located in the suburb of La Possession and in close proximity to the meteorological station Petite-France was examined (Table 6.26). Ground-based measurements taken on 12 June 2023 observed air temperature at 23.7°C and relative humidity at 64.6% at the time recorded. Humidex calculated for the farm campsite was 28.6°C, comparatively higher than the Humidex calculated for the same day by the meteorological station (17.6°C) and the average for the month of June 2023 (16.7°C). Similar to the beach campsite, known sunshine hours were recorded after fieldwork was completed. Known sunshine hours for the campsite were higher than the meteorological station data and the average recorded for June 2023. The CCI score calculated for the farm campsite was 8.5 classified as 'optimal' whereas the meteorological station data for the same day yielded a score of 3.5 classified as 'unfavourable' where the average CCI score for the month of June 2023 was 3 also classified as 'unfavourable'. Notably, fog and rain were experienced as *in situ* measurements were taken (Table 6.26). Given that the average rain experienced in June 2023 and the meteorological station on the day of recording do not exceed 10mm, it can be assumed that the precipitation threshold was not exceeded during the recording of the measurement at this campsite. No other exceptions were applicable as no thresholds were exceeded.

Table 6.26. Comparative table for a farm campsite *Table D'Hote La Ferme Bellevu*.



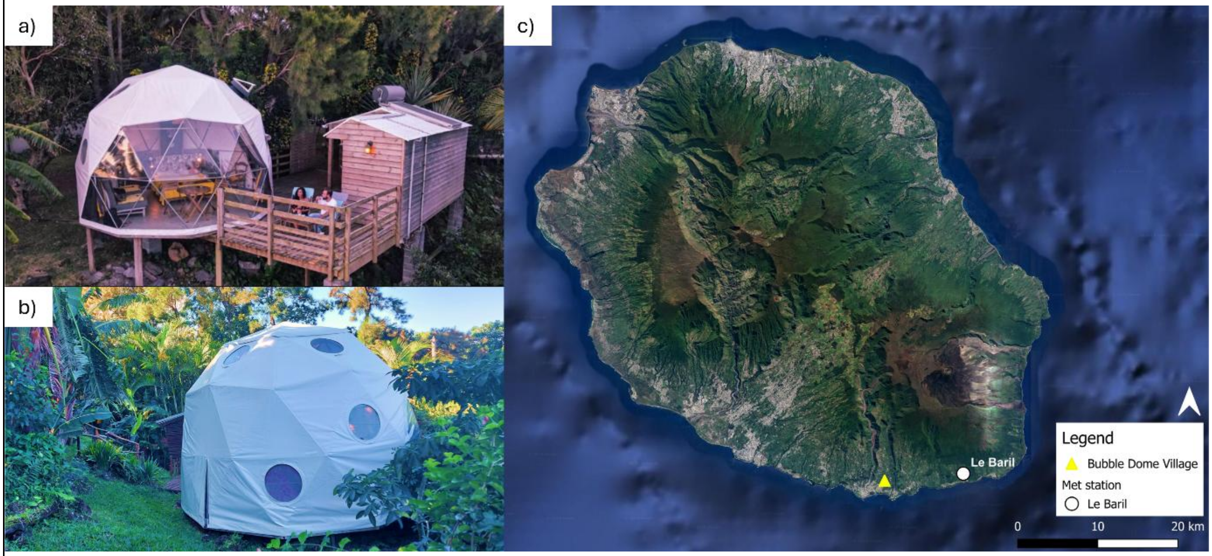
Picture sources: a) Jonathan Reisch, 2022 b) Karoline Meador, 2019 c) Own map

Category	Meteorological Day measurement	Average conditions in June 2023	Ground-based Day measurement
Site	Petite-France	Petite-France	Camping Farm (Table D'Hote La Ferme Bellevue)

T_{max}	18.3	18.5	-
T_{min}	10.5	9.7	-
Precipitation	1.6	0.9	Fog and rain
Wind speed	5.4	7.1	0.0
Air temperature	14.4	14.1	23.7
Relative humidity	95.9	90.7	64.6
Humidex	17.6	16.7	28.6
Sunshine hours	1.9	2.7	11
CCI Score	3.5 No exceptions applicable	3 No exceptions applicable	8.5 No exceptions applicable

A glamping site, *Bubble Dome Village*, located in Saint-Joseph and in close proximity to the meteorological station Le Baril was examined (Table 6.27). Ground-based measurements taken on 16 June 2023 observed air temperature at 28.0°C and relative humidity at 60.9% at the time recorded. Humidex for this site was calculated at 35.2°C and is relatively close to the Humidex calculated for the nearest meteorological station at 31.3°C. Known sunshine hours were recorded at 10.5 hours compared to 6.8 recorded by Le Baril. CCI scores for the glamping campsite are relatively close compared to Le Baril with 7.5 classified as 'good' calculated at the campsite and 6 classified as 'good' calculated for the meteorological station (Table 6.27). No exceptions were applicable because no thresholds for the four variables were exceeded.

Table 6.27. Comparative table for a glamping campsite *Bubble Dome Village*.



Picture sources: a) Agoda.com, 2024 b) Own picture c) Own map

Category	Meteorological Day measurement	Average conditions in June 2023	Ground-based Day measurement
Site	Le Baril	Le Baril	Bubble Dome Village
T_{max}	27.5	25.1	-
T_{min}	20.2	19.4	-
Precipitation	0.0	9.0	No rain
Wind speed	10.1	10.9	0.0
Air temperature	23.9	22.3	28.0
Relative humidity	78.9	81.1	60.9
Humidex	31.3	28.8	35.2
Sunshine hours	6.8	3.2	10.5
CCI Score	6 No exceptions applicable	4.5 No exceptions applicable	7.5 No exceptions applicable

6.7 Multi-index Comparison

The four tourism climate indices produced varied outcomes across all 11 meteorological stations (Figure 6.12). Roland Garros Airport was the only station for which all four indices could be calculated. Mean annual score classifications of ‘acceptable’ were found for the TCI, HCI_{Urban} and the CCI. The HCI_{Beach} was classified as ‘good’ for Roland Garros Airport. While the HCI_{Beach} indicates more favourable climatic suitability compared to the remaining indices, this does not necessarily indicate that one index is better to use over another. Rather, it highlights the most appropriate tourism activity or accommodation type a tourist could pursue near or around that station. These results indicate that beach activities would be better to pursue than urban, camping or general sightseeing near or around Roland Garros Airport.

Comparing the HCI_{Beach} and the HCI_{Urban}, for both Roland Garros Airport and Pierrefonds Airport, the HCI_{Urban} indicates slightly reduced climatic suitability (Figure 6.12). Roland Garros Airport is classified as ‘acceptable’ according to the HCI_{Urban} and ‘good’ according to the HCI_{Beach} while Pierrefonds Airport is classified as ‘good’ according to the HCI_{Urban} and ‘very good’ according to the HCI_{Beach}. The HCI_{Beach} shows more favourable climatic suitability in both locations.

Mean annual classifications for Petite-France and Piton-Maido show vast differences between the TCI and CCI (Figure 6.12). For the TCI, Petite-France and Piton-Maido are classified as ‘very good’ for the TCI, while the CCI indicates lower climatic suitability with an ‘unfavourable’ classification. Camping activities take place in close proximity to these two stations (Figure 6.9) showing that camping activities may not be ideal and general sightseeing would be more suitable for tourists.

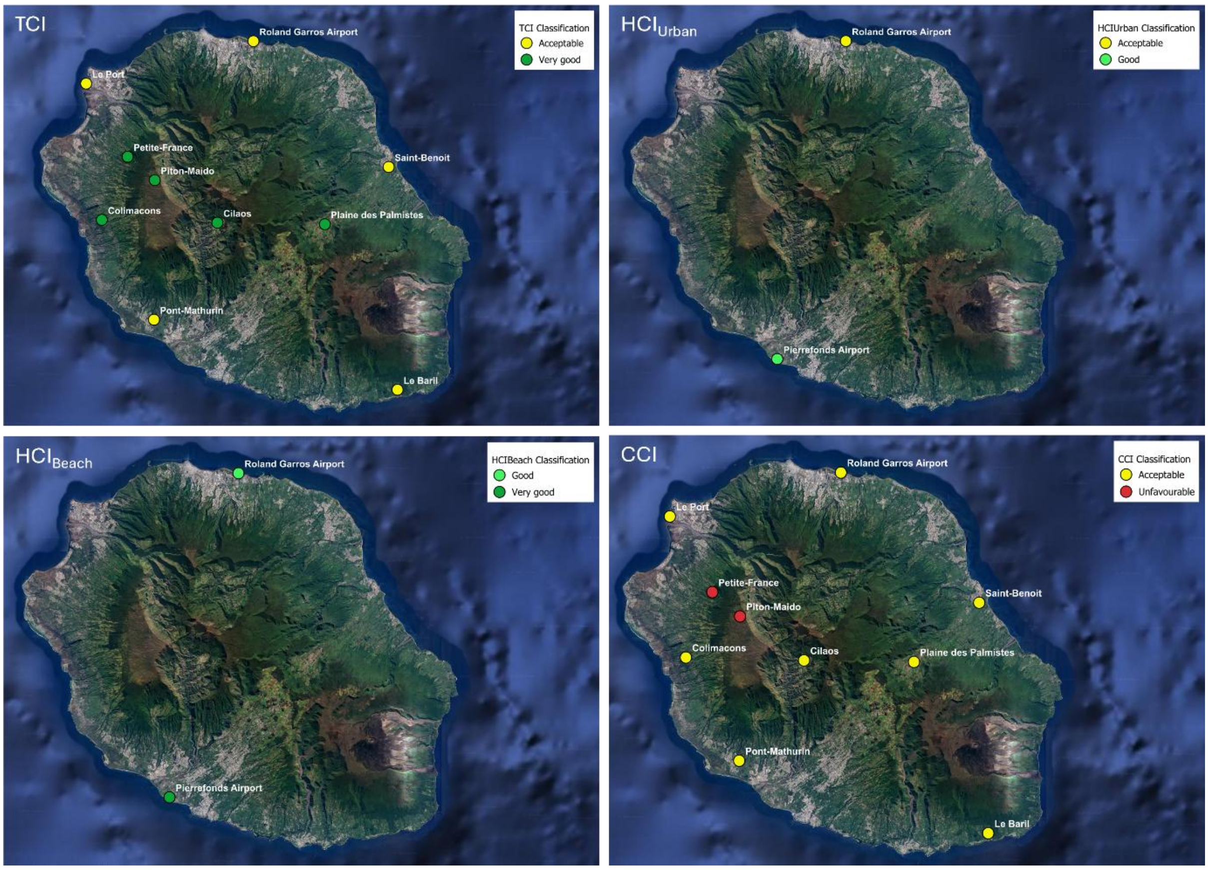


Figure 6.12. Multi-index comparison of mean annual climate classifications across all four indices.

Climatic suitability scores within certain months of the year could be used to inform when travellers should travel to particular locations on the island (Table 6.28). The best scores were identified for the month of July for Roland Garros Airport for the TCI, HCI_{Beach} and the HCI_{Urban} whereas the worst scores were identified for the month of February. The CCI demonstrated dissimilar best and worst months with May indicating the best scores and September as the worst score. For Pierrefonds Airport, the month of August is the best time of year for the HCI_{Beach} and HCI_{Urban} with the worst times of the year being February through March for the HCI_{Urban} and January and March for the HCI_{Beach}.

Table 6.28. Best (green) and worst (red)scores per month per location across the four indices

Station	TCI	HCI_{Urban}	HCI_{Beach}	CCI
Cilaos	Sep			Jan
	Feb			Jul and Aug
Colimacons	Jun			Mar
	Feb			Sep
Le Baril	Aug			Oct and Dec
	Mar			Jul
Le Port	Jul			Jun
	Mar			Feb and Mar
Petite-France	Nov			Dec
	Mar			Jul and Aug
Piton Maido	Mar			Mar
	Jul			Jun and Jul
Plaine des Palmistes	Jun and Oct			Jan
	Mar			Jul and Aug
Pierrefonds Airport		Aug	Aug	
		Feb and Mar	Jan and Mar	
Pont-Mathurin	Jul			Nov
	Mar			Mar
Saint Benoit	Jul			Oct
	Mar			Mar
Roland Garros Airport	Jul	Jul	Jul	May
	Feb	Feb	Feb	Sep

Comparing across indices, beach and urban activities are the most favourable to experience in July and August (Table 6.28). Months with the least favourable climatic conditions that are likely to affect tourist enjoyment are February and March. Camping activities are more likely to be enjoyed in January and March, May and June and later in the year, around October through December. Varied periods of good and bad suitability throughout the year are seen for the TCI, with all months accounted for apart from January, April, May and December.

6.7.1 Change in Climate Suitability Over Time

The change in climatic suitability over time was only calculated for Roland Garros Airport as the only station with a minimum of 30 years of data (Table 6.29). TCI climatic suitability declines per decade by a score of 0.9 (January), 1.5 (April), 2.8 (June), 3.1 (July), 3.5 (August), 3.7 (September), 4.2 (October) and 1.0 (December). No statistically significant changes in suitability for the TCI were calculated for February, March and May. Climatic suitability for the TCI declines overall by 2.1 unit scores per decade. HCI_{Urban} climatic suitability declines per decade by 1.2 (July), 2.1 (August), 2.1 (October) and 2.8 (November). Overall, climatic suitability for the HCI_{Urban} declines by 0.09 unit scores per decade. Only one instance of significant change was found for the HCI_{Beach} with a decline in climatic suitability of 2.3 unit scores per decade in November. Overall climatic suitability for the HCI_{Beach} changes very little over time. A decline in climatic suitability for the CCI per decade of 0.3 in April and 0.2 in December was identified. Similar to the HCI_{Beach}, the overall climatic suitability of the CCI changes very little over time with a decline in suitability by 0.1 unit scores per decade (Table 6.29).

Table 6.29. Regression analysis for the TCI, HCI_{Urban}, HCI_{Beach} and CCI scores for Roland Garros Airport, 1991–2023. Grey shading indicates statistically significant trends.

	TCI			HCI_{Urban}			HCI_{Beach}			CCI		
Month	r-value	p-value	Rate of Change (score/per year)	r-value	p-value	Rate of Change (score/per year)	r-value	p-value	Rate of Change (score/per year)	r-value	p-value	Rate of Change (score/per year)
January	0.42	0.0161	-0.09	0.08	0.6397	-0.04	0.00	0.7134	0.03	0.32	0.0711	-0.02
February	0.05	0.7869	0.01	0.23	0.1942	0.11	0.33	0.0575	0.21	0.04	0.8337	0.00
March	0.16	0.3691	-0.04	0.11	0.5543	0.04	0.30	0.0925	0.15	0.33	0.0599	-0.02
April	0.45	0.0079	-0.15	0.19	0.2923	-0.09	0.02	0.8964	-0.01	0.43	0.0135	-0.03
May	0.00	0.1813	-0.12	0.06	0.7478	-0.03	0.20	0.2662	0.09	0.00	0.9263	0.00
June	0.43	0.0133	-0.28	0.34	0.0507	-0.15	0.14	0.4243	-0.08	0.17	0.3359	-0.01
July	0.55	0.0010	-0.31	0.35	0.0480	-0.12	0.08	0.6546	-0.03	0.13	0.4583	-0.01
August	0.55	0.0010	-0.35	0.45	0.0090	-0.21	0.13	0.4881	-0.05	0.09	0.6363	0.00
September	0.60	0.0002	-0.37	0.32	0.0708	-0.13	0.29	0.1013	-0.10	0.20	0.2693	-0.01
October	0.67	<0.0001	-0.42	0.46	0.0077	-0.21	0.32	0.0701	-0.15	0.12	0.4997	0.01
November	0.73	<0.0001	-0.33	0.57	0.0005	-0.28	0.48	0.0044	-0.23	0.12	0.4957	0.01
December	0.38	0.0285	-0.10	0.09	0.6244	0.03	0.32	0.0679	0.17	0.34	0.0494	-0.02
Annual	0.42	0.14	-0.21	0.27	0.2700	-0.09	0.22	0.3197	0.00	0.19	0.39	-0.01

6.8 Conclusion

The results of calculating the scores for four tourism climate indices to quantify the climatic suitability for tourism in Réunion Island are presented in this chapter. Overall, climatic suitability for Réunion Island ranges from 50.0-75.6 ('acceptable' to 'very good') for the TCI and 3.6-5.8 ('unfavourable' to 'acceptable') for the CCI. Only two stations contained requisite data appropriate for calculating the HCI where overall climatic suitability was 56.9-61.6 ('acceptable' to 'good) for the HCI_{Urban} and 69.3-75.4 ('good' to 'very good') for the HCI_{Beach}. A winter peak seasonal distribution is found for the TCI and both iterations of the HCI while a bimodal shoulder peak is present for the CCI. Over time, results show statistical significance in the rate of climatic suitability change over the 33-year period where the TCI and HCI_{Urban} show greater change than the HCI_{Beach} and CCI. Overall, the four tourism climate indices show variation in climatic suitability for the island, further supporting a multi-index approach. The application and implications of the results found are discussed in *Chapter 7 Discussion*.

CHAPTER 7: DISCUSSION

7.1 Introduction

Through the use and application of four tourism climate indices, this study aims to quantify the climatic suitability of Réunion Island for tourism. Foundational to this, is the initial assessment of the applicability, suitability and validity of using each of these four indices prior to their use for this study site from which broader considerations have been made for future studies. The importance of quantifying the climatic suitability for tourism in Réunion Island, particularly using a multi-index approach was highlighted in *Chapter 2* (Literature Review). This discussion chapter presents a critical evaluation of the results found in this study considering the literature previously reviewed and considers implications for future research and the limitations encountered. First, the overall climatic suitability of the island is explored, comparing and considering the implications of this suitability in relation to that of destinations in southern Africa, and across other island and European tourism destinations. Second, the quantified and classified level of climatic suitability of Réunion Island has implications for tourists and tourism providers in terms of not only comfort and suitability but more crucially their safety. Therefore climate-related threats and risks are examined. Third, the current climate and its implications for tourists will be discussed followed by an interrogation of future climate considerations for the island and beyond with the increase in changing climate. Finally, limitations associated with the study in terms of data availability and spatial variation of meteorological instruments will be explored.

7.2 Tourism Climate Indices

7.2.1 The Comparative Climatic Suitability of Réunion Island

Réunion aims to increase its standing globally as a competitive tourism market (Île de Réunion Tourisme, 2018). In comparing destinations to travel, tourists may decide between Réunion, other islands in the SWIO, southern Africa, global islands or Europe (Figure 7.1). In comparing destinations, tourist operators would also compete with the popularity, pricing, distance and other factors when selling tourism products (Ioannides, 1998). Réunion Island offers a range of climatic suitability. Each of the four indices demonstrates a distinctly different picture of climatic suitability for tourism for Réunion Island. Mean annual scores for the HCI_{Beach} range from 69.3-75.4 with classifications of 'good' and 'very good', particularly in winter, whereas the CCI scores range from 3.6-5.6 with classifications of 'unfavourable' and at best 'acceptable' conditions with no distinct seasonality. TCI scores range from 50-75.6 and HCI_{Urban} from 56.9-61.6 showing a more moderate set of scores with classifications of 'acceptable', 'good' and 'very good', confirming winter suitability. From this it is seen that beach camping is favourable, urban activities would be less favourable and camping would be the least climatically favourable.

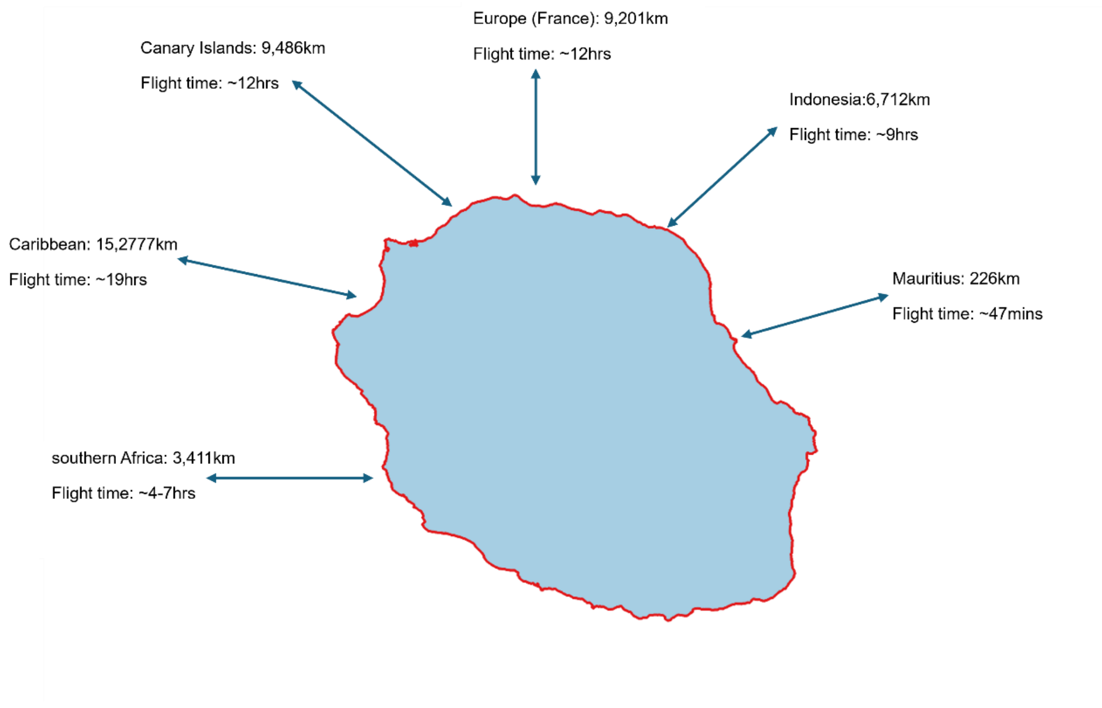


Figure 7.1. The distance and approximate flight time for tourism destinations in Europe, islands, southern Africa and an island in the SWIO.

As climate is a consideration for tourists when choosing a tourism destination (Scott *et al.*, 2012a), it is useful to compare the climatic suitability of international and regional destinations, and of geographically similar destinations like islands. International comparisons to the island are comparable as no changes have been made to the indices. Tourism climate indices applied in European contexts are comparable to Réunion in that while the location and climate of the island are different to Europe, the infrastructure and way of life are similar because it is a French department. As a French department, Réunion Island may be convenient for European travellers, particularly its predominant external tourists from France than for example, travelling to southern African countries. This is due to the island having the same language, currency and transport systems (Île de Réunion Tourisme, 2018; La Réunion, 2022). Further, direct flights are available from Paris, Lyon and Marseille in France to the island which eases accessibility (Île de Réunion Tourisme, 2018; Africa News, 2024).

A tourism destination that is in close proximity to Réunion Island is southern Africa. Climatic suitability has been calculated for popular tourism destinations of South Africa (Fitchett *et al.*, 2017), Lesotho (Noome and Fitchett, 2019), Namibia (Noome and Fitchett, 2022) and Zimbabwe (Mushawemhuka *et al.*, 2021) and are comparable tourism destinations in that they are similar long-haul destination flights for international travellers. The island does, however, offer more logistical challenges for non-European travellers given its Euro currency, language barriers and transportation differences (Île de Réunion Tourisme, 2018). Regarding comparable tourism activities, South Africa also offers urban, beach and general sightseeing but extends to include offerings for nature-based tourism such as game viewing (Saarinen *et al.*, 2022). Namibia and Zimbabwe offer more sector-specific tourism through dune tourism in Namibia, Victoria Falls in Zimbabwe, and wildlife experiences in both (Mushawemhuka, 2021). Lesotho offers unique outdoor tourism experiences such as cultural sites, mountain biking and hiking and most notably ski tourism at the Afriski Mountain Resort (Noome and Fitchett, 2019).

The Initial TCI was applied globally revealing a range of climatic suitability for tourism destinations across the globe (Mieczkowski, 1985). This application of the TCI revealed 'good' and 'very good' classifications for January for the eastern region of Madagascar. Réunion Island is too small to be identified in this original work but assuming suitability is within a similar sub-region, over time the region appears to have reduced in suitability in January as mean monthly climatic suitability scores range between 38.1-80.9 ('unfavourable' to 'excellent') for the TCI. However, for a single month, this shows a large amount of spatial variation between meteorological stations and across the island, which is missed in the original iteration of the index. The CCI has also been applied globally from 1948-2016 using gridded datasets (Ma *et al.*, 2021a). Results reveal that tropical and subtropical regions have the highest CCI scores that reduce polewards (Ma *et al.*, 2021a). Mean annual climatic suitability scores differ for Réunion Island in that very few high scores with no 'optimal' classifications and very few 'good' classifications were found. While gridded data at a global scale is too coarse to reveal camping suitability for smaller islands, it is useful in identifying the spatial variation of climatic resources and highlights the need for localised applications of the CCI.

Tourism climate indices have been widely applied to European contexts for a range of purposes (Scott and McBoyle, 2001; Amelung and Viner, 2006). The TCI has been applied to determine the level of weather and bioclimatic resources in the Mediterranean (Matzarakis, 2001, 2006), Italy (Mereu *et al.*, 2016) and Poland (Derkowska and Araźny, 2022); risk analysis for tourism in Northern Cyprus (Olya and Alipour, 2015); climate change impacts for the Mediterranean (Perry, 2001, 2005, 2009; Amelung and Viner, 2007; Moreno and Amelung, 2009b; Moreno, 2010) Spain (Hein *et al.*, 2009) and central and Eastern Europe (Mishev and Mochurova, 2008), and Europe in general (Grillakis *et al.*, 2016). The TCI has also been used to determine future projections for European tourism (Perch-Nielsen *et al.*, 2010), specifically for the Mediterranean (Roson and Sartori, 2014), Greece (Matzarakis *et al.*, 2014) and Italy (Köberl *et al.*, 2016). Joksimović *et al.* (2013) applied the TCI in Montenegro from 1961-1990 where mean monthly scores ranged from 10-86 ('extremely unfavourable' to 'excellent') and found that geographic factors influence the suitability for tourism activities. Kovács and Unger (2014) applied a modified version of the TCI to Hungary, Prague and Greece. The TCI was modified by using Physiologically Equivalent Temperature (PET) instead of effective temperature and adjusted temporal scale from a monthly average to a 10-day scale (Kovács and Unger, 2014). Kovács and Unger

(2014) found that general sightseeing activities in summer are ‘unfavourable’ due to high heat conditions. The HCI_{Urban} and TCI have been applied to six European cities (Barcelona, Istanbul, London, Paris, Rome and Stockholm) between 1961-1990 (Tang, 2013; Scott *et al.*, 2016a). Compared to these European cities and according to TCI scores, Réunion Island has higher annual climatic suitability than Paris, London and Stockholm (Table 7.1). Annual TCI scores are less suitable than Barcelona, Istanbul and Rome. A comparison of HCI_{Urban} scores reveals that Réunion cities are less suitable than Barcelona, Istanbul and Rome while suitability is similar for Paris, London and Stockholm (Table 7.1).

Table 7.1. Tourism climate index scores in Réunion relative to those of European cities for which they have been calculated.

Place		TCI	HCI_B	HCI_U	CCI
Barcelona	DJF	↑		↓	
	MAM	↓		↓	
	JJA	↓		↓	
	SON	↑		↓	
	Annual	↓		↓	
Paris	DJF	↑		↓	
	MAM	↑		↓	
	JJA	↑		⇆	
	SON	↑		⇆	
	Annual	↑		⇆	
Istanbul	DJF	↑		↓	
	MAM	⇆		↓	
	JJA	↓		↓	
	SON	⇆		↓	

	Annual	↓		↓	
Rome	DJF	↑		↓	
	MAM	⇆		↓	
	JJA	↓		↓	
	SON	⇆		↓	
	Annual	↓		↓	
London	DJF	↑		↑	
	MAM	↑		↓	
	JJA	↑		⇆	
	SON	↑		↑	
	Annual	↑		⇆	
Stockholm	DJF	↑		↑	
	MAM	↑		↓	
	JJA	↑		⇆	
	SON	↑		↑	
	Annual	↑		⇆	
Legend	↑ (higher) ↓ (lower) ⇆ (same)				

At the time of writing, tourism climate indices have not been calculated for any other islands and have yet to be published in the southern hemisphere. While global-scale applications of the TCI (Mieczkowski, 1985) and CCI (Ma *et al.*, 2021a) have been pursued, the resolution may be too coarse to represent small islands adequately. Within the northern hemisphere, tourism climate indices have been applied to multiple island destinations. Both beach and urban iterations of the HCI have been calculated for Sri Lanka from 2010-2018 (Samarasinghe *et al.*, 2023), reporting HCI scores for beach attractions ranging from 39-62 ('marginal' to 'good') and urban attractions ranging from 27-86 ('unfavourable' to 'excellent'). The study did not engage in a suitability assessment prior to use yet argued that the HCI is useful for predicting future tourism arrivals and that the HCI is a more appropriate update for the TCI (Samarasinghe *et al.*, 2023). This argument was claimed to be supported by the work of Noome and Fitchett (2022), who argued the opposite when applying the TCI due to the paucity of air conditioning availability in Namibia. Samarasinghe *et al.* (2023) reported challenges relating to data availability and avoided ground-based meteorological data, instead using monthly climate data downscaled from the global circulation model. A comparison of the HCI study results for Sri Lanka were compared to calculations for the TCI but were negated because of a level of uncertainty due to unavailable long-term daily data and data required to calculate CIA and CID (Samarasinghe *et al.*, 2023). Comparatively, Sri Lanka offers varied beach experiences of 1600km of sandy "palm-fringed beautiful beaches" (Samarasinghe *et al.*, 2023: 50) whereas beaches in Réunion are composed of eroded coral and basalt (Vaxelaire, 2018). Comparing the HCI scores computed for Réunion and Sri Lanka, Réunion has higher climatic suitability annually and seasonally for both beach and urban activities (Table 7.2).

Table 7.2. Tourism climate index scores in Réunion relative to island locations for which they have been calculated.

Place		TCI	HCI_B	HCI_U	CCI
Canary Islands	DJF	↓			
	MAM	↓			
	JJA	⇆			
	SON	↓			
	Annual	↓			
Sri Lanka	DJF		↑	↑	
	MAM		↑	↑	

	JJA		↑	↑	
	SON		↑	↑	
	Annual		↑	↑	
Caribbean	DJF	↑	↓		
	MAM	↑	↓		
	JJA	↑	↑		
	SON	↑	↑		
	Annual	↑	↓		
Puerto Rico	DJF	↓			
	MAM	↓			
	JJA	↑			
	SON	↑			
	Annual	↑			
Indonesia	DJF				
	MAM				
	JJA	↑		↑	
	SON				
	Annual				
Legend	↑ (higher) ↓ (lower) ⇆ (same)				

The TCI and HCI have been applied to Indonesia from 2010-2019, to determine a climate comfort assessment for tourism in Borobudur Temple (Hasanah *et al.*, 2020). Using the TCI, where values were averaged over a 10-year period for the same month, the TCI score was 62.8 (‘good’) in July and 65.3 (‘good’) in August and therefore determined to be comfortable months (Hasanah *et al.*, 2020). Using the HCI_{Urban}, scores range from 53-70 (‘acceptable’ to ‘good’) where the months of July-October were considered comfortable (Hasanah *et al.*, 2020). Compared to Réunion, which also hosts religious sites for tourism on the northeast, northern and western coasts of the island, general sightseeing during July and August is slightly more suitable with mean monthly scores for four stations in proximity to temple sites ranging from 65.3-86.4 and classified as 'good' to 'excellent' (Table 7.2). Suitability scores for the HCI_{Urban} in Réunion were also found to be slightly more suitable ranging from 64.1-75.7 and classified as 'good' to 'very good' (Table 7.2). While focused on religious tourism, output scores have broader relevance to the island and speak to the comparative suitability of Indonesia to Réunion Island.

Within the Caribbean, the TCI and HCI were calculated and compared to mean monthly tourism arrivals data (Rutty *et al.*, 2020). For the period spanning 2008-2017, TCI scores ranged from 32-63 ('unfavourable' to 'good') while HCI scores ranged from 60-87 ('good' to 'excellent'). Similar to results found for Réunion, no 'excellent' scores were found for the TCI whereas the HCI did produce 'excellent' score classifications. Réunion Island has more favourable suitability for the TCI and less favourable suitability for the HCI when compared to the Caribbean (Table 7.2). Favourable months to travel to the Caribbean were found to be from December to March (less favourable for Réunion), whereas the boreal summer months (June to September) were found to be less suitable while more suitable for Réunion (Table 7.2; Rutty *et al.*, 2020). Similar findings were explored in the application of the TCI, prior to the development of the HCI, in Puerto Rico for the period spanning 2000-2010, where favourable months were found to be in February and March and unsuitable months were the end of August to the beginning of September (Méndez-Lázaro *et al.*, 2014). In the case of Réunion Island, similarly, lower suitability scores were found during the tropical cyclone season from November to April, with higher climatic suitability for tourism in the austral autumn and winter months (Table 7.2).

The TCI has been applied to determine the climatic suitability for tourism in the Canary Islands (Alonso-Perez *et al.*, 2021). While a subtropical destination with many beach locations, the TCI was used instead of a beach sector-specific index like the HCI_{Beach} because the TCI aligned with the wide variety of tourism types offered across the archipelago (Alonso-Perez *et al.*, 2021). TCI scores, ranging from 1985-2018, produced calculated mean monthly scores for all locations between 58-84 ('acceptable' and 'excellent'), and the best period for tourists was found to be in April, during the boreal spring (Alonso-Perez *et al.*, 2021). Mean annual TCI scores for Réunion are indicative of lower climatic suitability than the Canary Islands, with lower climatic suitability in summer, autumn and spring months and approximately the same climatic suitability in the winter months of June, July and August (Table 7.2).

Southern Africa is located close to Réunion, offering an alternative tourism destination. The TCI has been applied to South Africa (Fitchett *et al.*, 2016c, 2017), Lesotho (Noome and Fitchett, 2019), Namibia (Noome and Fitchett, 2022) and Zimbabwe (Mushawemhuka *et al.*, 2021). The overall climatic suitability of South Africa calculated from 1995-2015 using the TCI ranged from 76.5-93, with resultant classifications of 'very good' to 'excellent' (Fitchett *et al.*, 2017). Similarly, climatic suitability for Zimbabwe using the TCI reveals scores spanning 75.5-83 for the period 1989-2014, classified as ranging from 'very good' to 'excellent' (Mushawemhuka *et al.*, 2021). Mean annual TCI scores show that Réunion Island is less climatically suitable than South Africa and Zimbabwe (Table 7.3). Seasonal distribution is similar, with Réunion having lower climatic suitability year-round, with the exception of austral spring which is relatively the same when compared to South Africa and Zimbabwe (Table 7.3). Although, South Africa and Zimbabwe offer higher climatic suitability than Réunion, TCI scores for the island display a winter peak seasonal distribution with suitability scores ranging from 50-80 classified as ‘acceptable’ to ‘excellent’. Thus, the island can offer tropical tourism offerings during the winter period and become a competitor for southern Africa during these months, if marketed well.

Table 7.3. Tourism climate index scores in Réunion relative to southern African locations for which they have been calculated.

Place		TCI	HCI_B	HCI_U	CCI
South Africa	DJF	↓	↓	↓	↓
	MAM	↓	⇆	↓	⇆
	JJA	↓	↑	↓	↑
	SON	↓	⇆	↓	⇆
	Annual	↓	↓	↓	⇆
Namibia	DJF	⇆			
	MAM	↓			
	JJA	↓			
	SON	⇆			
	Annual	↓			
Zimbabwe	DJF	↓			
	MAM	↓			
	JJA	↓			
	SON	⇆			
	Annual	↓			
Lesotho	DJF	⇆			
	MAM	↑			
	JJA	↑			
	SON	↑			
	Annual	↑			
Legend	↑ (higher) ↓ (lower) ⇆ (same)				

Mean annual TCI scores for Namibia range from 62-80 for the period 2008-2018 with classifications from ‘good’ to ‘excellent’ (Noome and Fitchett, 2022). Compared to Réunion Island, South Africa and Namibia have a comparatively higher level of climatic suitability for tourism annually (Table 7.3). Although, Réunion and Namibia have similar climatic suitability during austral summer and spring (Table 7.3). Within southern

Africa, Lesotho received lower climatic suitability with an overall score of 64 and a classification of ‘good’ for the period 2012-2017. While climatic suitability overall is higher for Réunion, it is less comparable given that the key tourism attraction depends on snow availability (Noome and Fitchett, 2019).

The HCI and CCI have been used less extensively in southern Africa. The HCI has been applied to Zimbabwe but found to overestimate climatic suitability through the omission of nighttime thermal comfort in a region with very sparse air conditioning, and was thus deemed inappropriate (Mushawemhuka, 2021). Within South Africa, the suitability and applicability of the HCI have been assessed by identifying the availability of air conditioning and applying the index to 13 destinations (Kristensen, 2024). The assumption of air conditioning was partially met with only 50% of accommodation establishments having access to air conditioning and tourism climatic suitability was found to be ‘very good’ with scores ranging between 70-79, for most destinations (Kristensen, 2024). In comparing HCI scores with TCI scores calculated for South Africa (Fitchett *et al.*, 2017), TCI scores were higher, potentially due to a higher weighting for thermal comfort given to the TCI compared to the HCI (Kristensen, 2024). Therefore, HCI scores were not over-estimated as they were in Zimbabwe. Compared to Réunion Island, HCI scores were relatively more favourable compared to the TCI and CCI. The over-estimation of HCI scores is more similar to Zimbabwe than HCI scores calculated for South Africa. HCI scores for Réunion Island, particularly the HCI_{Beach}, were potentially higher because the thermal component favours warmer temperatures on a tropical island with the highest rating of 10 being awarded to temperatures between 28-30.9°C. Compared to South Africa, HCI scores for Réunion are lower, where the HCI_{Urban} is lower year-round for Réunion, while HCI_{Beach} scores are higher in winter months and relatively the same in austral spring and autumn (Table

7.3). Therefore, while there may be lower suitability, Réunion could become a competitive destination for beach holidays to the South African market during winter periods.

The CCI has been applied in South Africa where, its application and suitability have been assessed and found to be feasible to apply (Fitchett and Meyer, 2023). Mean annual scores range from 3.5-5.3 for the period 1990-2022 with classifications of 'unfavourable' to 'acceptable' (Mnguni and Fitchett, 2024). Similar scores were found for the CCI in Réunion with mean annual scores between 3.6-5.8 also with 'unfavourable' to 'acceptable' classifications (Table 7.3). Similarly, no classifications of 'optimal' were found for South Africa and Réunion (Mnguni and Fitchett, 2024). Seasonally, camping in South Africa is similar to Réunion, however, camping has higher suitability in winter months which similar to beach tourism could be marketed to the South African market during winter periods (Table 7.3).

7.2.2 Implications for Acceptable Suitability

The quantification of the climatic suitability of Réunion Island can be used to maximise the optimisation of climate resources for tourism (Ma *et al.*, 2021a). Réunion Island currently attracts Visiting Friends and Relatives (VFR) tourism, leisure, adventure and business tourism (Île de Réunion Tourisme, 2024). In 2023, 43.2% of tourists to Réunion were VFR travellers, staying an average of 21 days (Île de Réunion Tourisme, 2024). VFR travellers are by definition on a holiday that is determined by the location of friends and family they are visiting (Zanni and Ryley, 2015; Backer *et al.*, 2020). The climate, therefore, does not determine their choice of destination, however, it could influence the timing of their visit, their length of stay, and their enjoyment (Backer, 2008). VFR travellers are also likely to have access to a wider range of local amenities, such as a car, and a range of household items such as bedding, to maximise their comfort in the friend and family space (Darar and Ismail, 2016). Therefore, the role of climate is reduced, and thresholds for bad climate are minimised.

Beach tourism is a popular attraction for Réunion as it is marketed around its tropical location (Île de La Réunion, 2022). Tourists going to the beach have expectations of warm and sunny weather, often characterised by 3S tourism (Rutty *et al.*, 2020). HCI_{Beach} results confirm that beach activities are the most favourable to experience in July and August. However, given that only two stations contained requisite data, the HCI_{Beach} is not fully representative of beach tourism in Réunion. Scores for one of the stations calculated using the TCI and CCI, Colimacons, is closely located to Pierrefonds Airport, a station used to calculate the HCI_{Beach} on the western part of the island. Mean monthly TCI scores for Colimacons are similar to the HCI_{Beach} calculated for Pierrefonds Airport from June to August with scores between 85.5-86.8 classified as 'excellent'. Climatic suitability extends into the month of September with a score of 84.7 classified as 'excellent'. This may not truly align with beach expectations set out by the HCI_{Beach}, but Réunion hosts sandy and rocky beaches, where a tourist may not be able to partake in sunbathing, beach sports and swimming, but instead enjoy general sightseeing on the beach. The CCI for the same station from June to August scored between 4.3-4.6 classified as 'acceptable' highlighting that should beach tourists also want to camp at the beach it would be suitable.

Réunion Island is marketed as being an outdoor tourism destination, offering adventure tourism around its mountainous areas and surrounding ocean (Vaxelaire, 2018). Popular adventure tourism on the island includes hiking, scuba diving the

Hermitage underwater trail, whitewater rafting, aquatic hiking, canoe-rafting, kayaking, canyoning, paragliding, bungee jumping, parachute jumping and crawling in the lava flow tunnels (La Réunion, 2024f). None of the tourism climate indices in this study explicitly represent the climate requirements for adventure tourism. However, it is often coupled with camping where the thresholds may also apply (Ma *et al.*, 2021a). Therefore, climatic suitability around adventure tourism is ‘acceptable’ but not ideal. The exception thresholds apply well to the adventure activities in Réunion because if the temperature, precipitation and wind speed thresholds are met, it will create unfavourable conditions to pursue those activities. Cut-off thresholds may even allow a level of safety when rain conditions reduce visibility, or temperatures get too hot for hikers. Moreno and Amelung (2009b) note, however, that further studies are required to determine the climate requirement while accounting for varied levels of physical activity. Further Wang *et al.* (2024) used hiking big data to determine the sensitivity of hiking activities to the climate requirements of tourists, finding that climate zones impact threshold ranges for tourists and need to be considered in future evaluations of climate suitability.

Business tourism is becoming increasingly popular, but there are misconceptions about its link to the weather (Fitchett, 2021). This type of tourism is described as travel for governmental, educational or commercial purposes with secondary leisure or recreational activities (Nicula and Elena, 2014). Business tourism predominately takes place in urban settings and inside buildings and cars that are climate-controlled (Fitchett, 2021). Over time, urban spaces and subsequently urban tourism offerings have diversified to include a variety of urban types of tourism such as cultural and heritage as well as coastal tourism which due to the functioning of these offerings, are sensitive to climate change (Fitchett, 2021). However, as leisure is also pursued during business trips, an individual may explore urban areas after work or explore the offerings of their destination. In Réunion this may result in a visit to the beach, a walk or hike, shopping in a local urban area or if staying over a weekend, visiting the volcano.

A winter peak tourism climate seasonality is experienced by most stations for the TCI, HCI_{Urban} and HCI_{Beach} due to moderate temperatures and little rainfall which, overall make the weather pleasant during June, July and August. Therefore, general sightseeing, beach and urban activities would be ideal during these months. Less ideal meteorological conditions for tourism on the island are experienced during the summer months from November to January, which also coincides with the tropical cyclone season. Tropical cyclones are not clearly detectable in month-averaged index scores. In this research, it is fortuitous that the worst time of the year based on mean ambient climate conditions coincides with the time of the year with the greatest tropical cyclone risk. Due to compounding bad weather creating low suitability in summer months, marketing for austral winter tourism would be beneficial.

For camping, a bimodal shoulder peak was identified for most stations for the CCI as a result of exception thresholds for maximum temperature, precipitation and wind speed resulting in a large number of days with automatic ‘unfavourable’ scores, and thus reducing mean monthly scores in the summer and winter. A summer peak was identified for three stations: Petite-France, Piton-Maido and Cilaos. These regions are popular for camping containing many camping sites (Figure 6.9) and have good weather for it, especially in summer when the rest of the island is less suitable. This is due to the elevation of these areas and a result of lapse rates decreasing higher temperatures found in the summer months. Réunion Island has the opportunity to economise during periods of favourable climatic suitability for example, during summer when camping is more suitable in mountain areas and during winter when camping is more suitable in beach locations. The June through August summer break in Europe results in many travellers, including universities and schools who are on a long semester break, taking advantage of good weather in Europe (Jacobs, 2009). Réunion is an ideal long-haul travel opportunity during this time for European travellers given the lack of visa requirements, good weather, and the European culture. Located geographically within the southern hemisphere and only a four-hour flight from South Africa, Réunion simultaneously offers an escape from cold winter conditions for regional tourists, which also coincides with a three-week school and university holidays in June and July (Buswell, 2024). Apart from school and university holidays, December is peak season in many destinations and is a popular period for tourists to travel (Ma *et al.*, 2008; Goulding, 2024). For European travellers, Réunion could offer a reprieve from colder conditions, however, travel and enjoyment will be impacted by warm temperatures and the risks of adverse and potentially dangerous weather during tropical cyclone season.

The climate of a destination influences the type of activity available to tourists, and their likelihood to take part in them (Gössling *et al.*, 2012a; Pröbstl-Haider *et al.*, 2021). Tourists seldom operate in isolation, and a holiday could include a combination of beach, urban and camping activities. Hence the importance of using a multi-index approach. For example, overlapping tourism forms such as beach camping where camping would be more favourable in beach settings. Similarly, if camping were to occur in an urban area, it would have better climatic suitability and would potentially be more enjoyable but could also be affected by pollution, noise and privacy and security concerns (Nkanjeni, 2018). The inverse is also true whereby climatic expectations for beach activities could be less enjoyable in camping locations such as the mountainous area of Petite-France. It is for this reason the use of a multi-index approach is further supported.

The proportion and nature of indoor versus outdoor environments is a factor in the tourist experience. Indoor spaces such as shopping malls and museums offer tourists more climate-controlled experiences and can be explored throughout the year (Marvin and Rutherford, 2018). These spaces also offer greater protection from the elements of heat, wind and rain. However, indoor spaces in hot and humid conditions become unbearable if thermal regulating facilities of fans and air conditioning, insufficient insulation and other thermoregulating building materials are not available, particularly in summer (Kenny *et al.*, 2019). While the HCI_{Urban} classification ranges from ‘acceptable’ to ‘good’, it is dependent on indoor spaces having available amenities such as air conditioning for the HCI to be representative but also a consideration for a range of appealing indoor activities to encourage tourists to spend their time inside without feeling they are missing out on potential outdoor experiences such as hiking, going to the beach or visiting the volcano.

When conditions are climatically optimal, tourists would still have the option to be indoors. If weather conditions decline, tourists may have been able to see the sights but have accommodation that offers protection as well as a space to thermoregulate and recover from a bad or unexpected weather experience. Outdoor activities of hiking and going to the beach are more dependent on weather conditions and the time of year. Hiking, camping and going to the beach during the summer season in Réunion results in tourists experiencing high temperatures, wind speeds and rainfall events where indoor environments such as an Airbnb would offer relief from adverse conditions. Compared to traditional hotels, Airbnb offers a wider range of types of accommodations such as an entire house or flat that could offer a greater range of movement and space if tourists needed to recover from a prolonged rainfall event. Airbnb has and is fast becoming an accessible and alternative tourism accommodation provider to more traditional hotel and guesthouse establishments (Guttentag, 2015; Xifilidou *et al.*, 2018; Yu *et al.*, 2022b). However, it does rely on tourists anticipating their needs and preferences prior to booking.

7.2.3 Microclimate Analysis

The output scores of the TCI, HCIs and CCI, calculated from 11 meteorological stations, reveal the differences in the seasonality of suitability and that total suitability ranges considerably across the island. Microclimates across the island can be influenced by topographical features such as forested and mountainous areas and their related effects such as providing windbreaks (Baker *et al.*, 2021), windward and leeward wind regions (Nullet *et al.*, 1995), valley winds (Banta *et al.*, 1990), lapse rates (Bell *et al.*, 2022), and orographic cloud formation (Roe *et al.*, 2003). The calculated tourism climate scores and climatic suitability could be influenced by the microclimates on the island depending on where meteorological stations are situated. For example, CCI scores may be impacted by high winds, however, *in situ,* camping sites may be forested, alleviating harsh winds with windbreaks. Scores calculated on the eastern side of the island compared to the western, drier side of the island will vary between meteorological stations and across the TCI and HCI indices. The CCI has more capability to adapt to microclimates given the exception thresholds it includes.

The meteorological stations that could be used to calculate the HCI are limited due to a lack of cloud cover data. Both stations for which cloud cover data are recorded, Roland Garros Airport and Pierrefonds Airport, are close to both beach and urban locations and therefore both iterations of the index can be applied, providing initial insight for this index. For the HCI_{Beach}, available stations are situated on the north and southwestern sides of the island. Many beaches are located in between these sites, and certain beach sites, such as Plage du Tremblet and lagoons such as Basin Bleu Aire De Pique Nique are located on the east coast where weather is more variable. The HCI_{Urban} accounts for two urban sites but does not include cities such as Salazie and Cilaos which are located at higher elevations. Therefore, we cannot assume scores for Pierrefonds and Roland Garros Airport are accurately representative of the island as a whole. TCI scores vary across the island, and it would be reasonable to assume that the HCI would have similar fluctuations. However, as the HCI excludes nighttime temperatures, it may not quite capture the different diurnal regimes between coastal and inland areas.

There are also implications for wind and precipitation variables. On the southwestern, leeward side of the island, winds have a relatively lower speed and are drier. This produces favourable suitability scores for the HCI_{Beach}, which is consistent with the popular beach attractions located on this side of the island. More stations would need to be situated on the western side of the island, particularly further north, to get a more accurate representation of beach climate suitability. The easterly trade winds experience orographic uplift when encountering the mountains, specifically Piton de la Fournaise, leading to high wind speeds and precipitation on the windward side of the island. Only one station, Saint-Benoit, is situated on the eastern side of the island, and does not contain cloud cover data. Therefore, more stations with requisite data would need to be situated on the eastern side to be able to determine potential beach implications.

Ground-based measurements show variations in suitability from ‘optimal’ suitability calculated for the camping farm and ‘good’ suitability for the beach and glamping sites (Figure 7.2). Ground-based measurements for the CCI indicate that microclimates influence the suitability of camping tourism beyond what is demonstrated for the 10 stations for which the index has been calculated. Meteorological data and ground-based data were compared on the same day during 2023 fieldwork (Figure 7.2). *In situ* meteorological readings at a glamping site, called the *Bubble Dome Village*, and its nearest meteorological station Le Baril were compared. The CCI scores with no applicable exceptions were calculated to be 6 (‘good’) for Le Baril and 7.5 (‘good’) for the glamping site; while this is a large difference in scores, it importantly does not change the output classification. Both the meteorological station and the glamping site are in forested areas and similar suitability may be due to wind cover, resulting in lower wind speeds. The CCI score was 3.5 (‘unfavourable’) for the nearest meteorological station Petite-France and 8.5 (‘optimal’) when calculated from *in situ* meteorological readings taken at the camping farm (Figure 7.2). For a beach camping site, the CCI score was 4 (‘acceptable’) for the nearest meteorological station, Colimacons, and 7.5 (‘good’) *in situ*. The meteorological station for the beach camp shows a lower suitability score because Colimacons is located at a higher elevation and therefore experiences cooler temperatures. The large difference between the camping farm could be due to the difference in elevation where the camping farm is located at 1000m.a.s.l, where Petite-France is at 749m.asl. Greater similarities would be expected for campsites in much closer proximity to meteorological stations, such as at Cilaos. Observations *in situ* revealed that camping takes place surrounded by farm buildings and some trees which could be protected from wind and high temperatures. Meteorological stations therefore would be better situated within camping sites as tourists are not camping at the meteorological station, and given the exposure to the elements, campsites are often carefully selected for their microclimates and microenvironments.

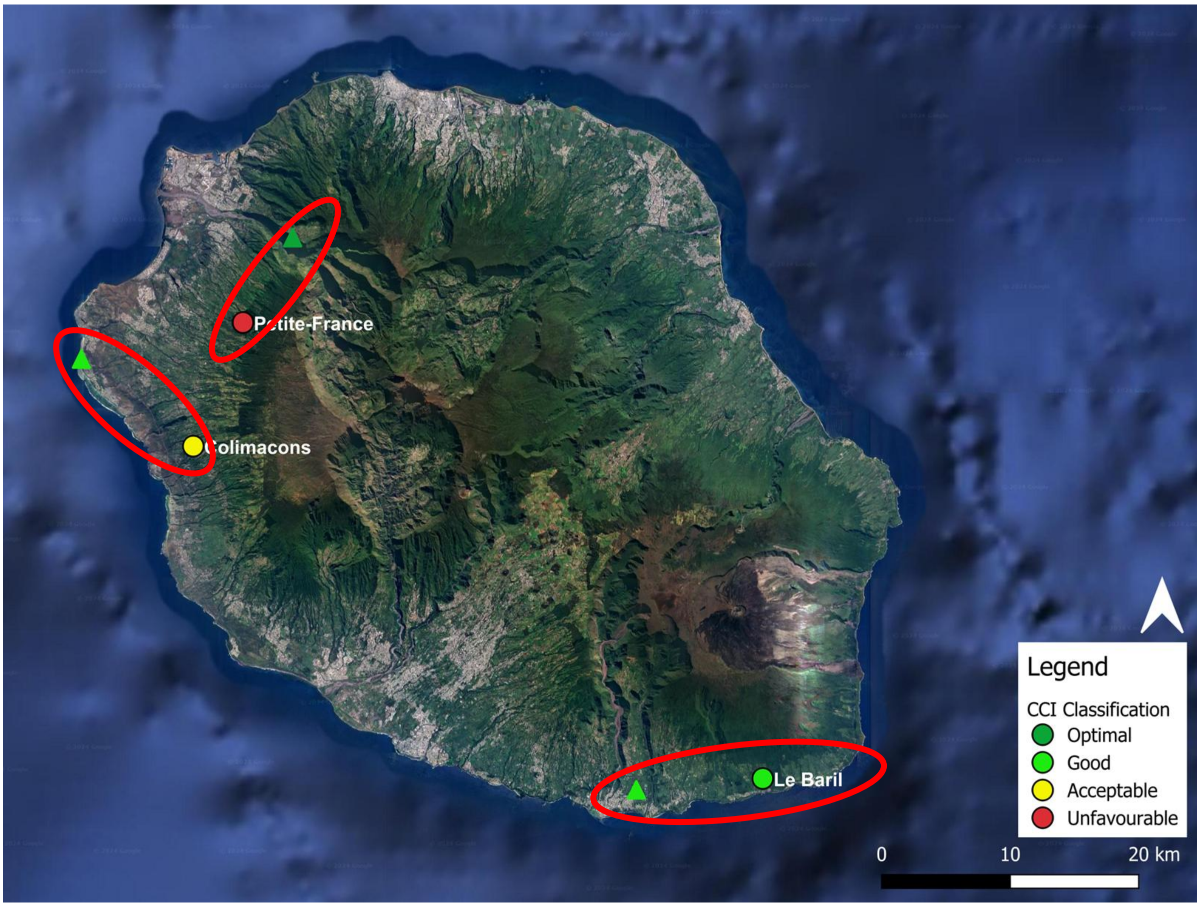


Figure 7.2. Meteorological station measurements compared to ground-based measurements for the CCI for three camping sites.

Similar to the spatial variation induced by microclimates, there is also a micro-temporal influence on climatic suitability for tourism. Tourism climate indices use input meteorological variables at a daily resolution for the TCI, HCIs and CCI to produce suitability scores. Mean conditions for the day do not encapsulate the best and worst weather conditions experienced within a 12-24 hour period. A negative experience, such as a sudden downpour, even for a few minutes, could negatively affect a tourist (Coghlan and Prideaux, 2009). Through TripAdvisor reviews of Indian Ocean tropical islands, rain was identified as a meteorological variable that was frequently mentioned and viewed as a negative experience (Fitchett *et al.*, 2020). Similarly, if an hour of ideal weather conditions coincides with a planned outdoor activity, a tourist's experience could be considerably improved (Becken and Wilson, 2013). Sunshine, warm temperatures, clear skies and wind were identified to be associated with a positive experience for tourists from TripAdvisor reviews of the SWIO (Fitchett *et al.*, 2020). A neutral experience was noted for rain when it occurred in short durations (Fitchett *et al.*, 2020). Therefore, short-lived experiences may have a greater impact on overall tourist satisfaction than the mean score of that day. This is demonstrated through a hypothetical series of occurrences throughout the day whereby the mean conditions start with a TCI score of 63 classified as 'good', followed by sunshine conditions that become too hot, reducing the score to 53 classified as 'acceptable' and ending the day with cooler conditions that increase suitability to 61 classified as 'good' (Figure 7.3). Conversely, the day could start with the same mean conditions but reduce in suitability due to rain, ending the day with a TCI score of 33 classified as 'unfavourable' (Figure 7.3).

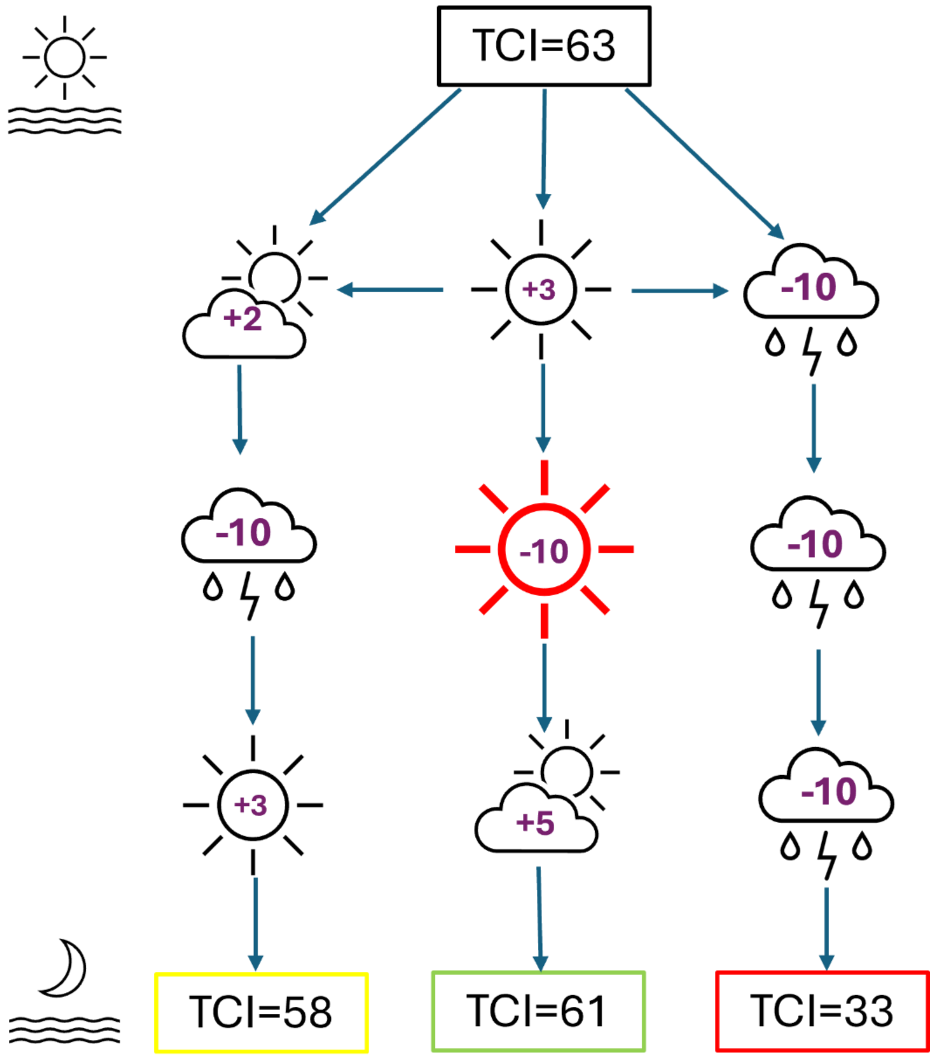


Figure 7.3. Diagram depicting the change in climatic suitability throughout the day depending on weather conditions experienced.

Tourism climate index scores are a good representation of climatic suitability for tourism in general and sector-specific tourism. However, weather changes throughout the day and on an island can be even more variable (Shea, 2003; Gough and Li, 2024). Thus, tourism climate indices do not give an absolute view of what is being experienced *in situ.*

7.2.4 Multi-index Approach

Tourism climate indices are not perfect representations of tourist experiences of weather and climate (Fitchett and Hoogendoorn, 2019). The purpose of a tourism climate index is to provide a multifactorial measure of climate well-being (Mieczkowski, 1985). With this comes the consideration of the multiple variables of weather that impact the tourism experience, but also the context of tourism destinations. Thus, one index that only partially considers these aspects will inherently have limited value in its output, and bringing together and comparing the outputs of a range of indices would provide a more comprehensive representation of the climatic suitability for tourism. Within the biometeorological sub-field of thermal comfort, over 162 indices have been developed with particular research needs in mind, varying according to context and use where seldom only one index is used (de Freitas and Grigorieva, 2015). The Climate Model Intercomparison Project (CMIP6) used in the IPCC AR6 report incorporates 100 models from 49 modelling groups, because it is argued that the use of a single model cannot accurately represent the workings of Earth's complex system (Hausfather, 2019).

The development of sector-specific tourism climate indices is ideal for identifying climatic suitability through a broad lens of the activity. Rutty *et al.* (2020: 3) argue that the purpose of using one index is to “reflect the specific needs and preferences of travellers”, and while this could provide a clear indication of suitability for that activity, tourists seldom visit a destination for only one form of tourism. For example, a beach tourist seldom only sits on the beach but is likely to visit shops and markets, eat out at a range of restaurants, and may take part in a range of beach-situated adventure tourism activities. Similarly, a tourist who is camping instead of staying in a hotel or Airbnb is unlikely to spend their entire vacation in their tent and is likely to couple this form of accommodation with tourist activities as widely diverse as hiking through to days on the beach or cultural visits in a city.

Kovác and Unger (2014) modified the original TCI using PET over effective temperature because of perceived subjective, physiological and thermal limitations of using effective temperature, and calculated output scores over 10 days rather than at monthly resolution because it was argued the time scale aligns more with tourists' short-term visits to a destination. Park (2015) developed the KTCI to determine changes in the climate for tourism specifically for South Korea as it was argued the original TCI did not consider global warming in its determination of suitability. The UCCI was developed to address the perceived limitations of tourism climate indices not including empirical data "collected exclusively for urban tourism destinations" (Kapetanakis *et al.*, 2022: 283). Tourism climate index research is increasingly becoming similar to the work on thermal comfort indices where many versions of an index are being developed for specific contextual purposes and motivations. However, the modification of indices to fit particular tourism destinations and attractions is not ideal because it could become infinite. A cross-comparison of destinations' suitability that also captures a range of tourism attractions is more appropriate for future work. The multi-index approach in this study captured a range of tourism activities from general sightseeing, urban tourism, beach tourism and camping tourism. If a singular index, such as the TCI, were to have been used, it would reveal a less suitable tourism destination and not accurately depict camping, beach and urban tourism that are also available as tourism offerings in this tourism context. Similar to the IPCC (2021), results have shown that each index has value and contributes to the different tourism climate suitability information in totality.

Further, the output scores of tourism climate indices are often kept within academic spaces in journals that are often paywalled with language inaccessible to tourists or tourism operators. For climatic suitability information to become accessible to the tourism sector and the public, meteorological data could be measured on-site in hotels and other tourism accommodations, for index scores to be calculated and classified *in situ,* and smartphone applications could be developed to be used by tourists prior to travel. The calculation of an index could be programmed into or linked to weather data loggers situated within tourism accommodations and would require little training besides the interpretation of the score output. The development of an application with this programme and related information would be ideal. From this, hotel and tourism accommodation establishments could run their own tourism climate indices to have locational information that could be integrated into the reporting for Météo-France. Further, while a higher resolution of data would provide valuable insight, the results from this study do reveal inter-spatial, inter-temporal and inter-index variability.

7.3 Climatic Suitability versus Climatic Safety for Tourists

Identifying the climatic suitability of a destination is useful, particularly as many tourism destinations rely on good tourism for their economy (Curtis *et al.*, 2011; Scott *et al.*, 2012a). The calculated scores, patterns of seasonality and change over time present a broad picture of suitability, but the lived reality, particularly around safety concerns needs greater consideration. This is seen in temperature thresholds that may be deemed as suitable but could pose the potential threat of thermal stress, or climate events such as tropical cyclones and associated geohazards that could be experienced even if a 'suitable' score is returned from a cumulative index. While tourism climate indices were not developed to address potential risk, consideration of incorporating exception thresholds into tourism climate indices, similar to the CCI and lexicon of risk should be investigated.

7.3.1 Thermal stress

The outputs of tourism climate indices were developed for a range of purposes including the ability to compare the relative climate suitability of comparable destinations (Perch-Nielsen *et al.*, 2010; Mihăilă and Bistricean, 2018; Alonso-Pérez *et al.*, 2021). The classifications of their output scores, developed by authors within a specific context, are useful in describing the expected climatic suitability of a destination (Mieczkowski, 1985; Scott *et al.*, 2016a; Ma *et al.*, 2020). However, they do not explicitly consider the level of climatic risk and safety considerations that tourists may need at that destination. Olya and Alipour (2015) have used the TCI to determine the risk related to excessive precipitation, highlighting that the index is useful, however the study does not investigate the implications of this further. Tourism climate indices are additive in that relatively high scores could be comprised of only a few variables representative of ‘good’ weather, such as clear skies, low windspeed, and no rain. However individual component variables such as temperature, precipitation and wind speed may indicate circumstances that are not only uncomfortable for tourists but also considered dangerous (Scott *et al.*, 2008). For example, on a day with clear skies, low wind speeds and no rain, all of which additively contribute to a strong TCI score, the low thermal comfort score during thermally risky conditions, would not reduce the overall score outside of ‘good’ to ‘excellent’ conditions. Further, indirect climate change impacts such as an increase in vector-borne diseases or geohazards that will directly impact tourists are overlooked by these indices.

The tourism climate indices used in this study include equivalent temperature as an input variable with threshold scoring to represent thermal comfort, they do not, however, express the shift to thermal stress when equivalent temperature thresholds are exceeded. Heat or cold stress results from the failure of the body's physiological mechanism to regulate temperature or compensate for the rise or fall in temperature (Hosokawa *et al.*, 2021). Without these regulatory mechanisms and ease of access to healthcare services, heat illnesses can develop with prolonged exposure (Hosokawa *et al.*, 2021). Humidex, developed by the Canadian Centre for Occupational Health and Safety (CCOHS), measures how hot one feels in hot and humid conditions (CCOHS, 2024). It also takes into consideration the level to which individuals exert themselves through physical activity and how acclimatized they are to the local environment (AWS, 2023). Tourists generally visit holiday destinations for short periods of time, but are still at risk of experiencing heat stress, particularly if they are unprepared or unacclimatized (Skinner *et al.*, 2001). Further, if they partake in activities that require exertion or physical activity such as hiking, beach walking or shopping, they are even more at risk of heat stress and related illness.

For Réunion Island, the percentage of days with zero scores for daytime thermal comfort (CID) at Roland Garros Airport for the period 1991-2023 were calculated at 46.4% for the TCI, 42.7% for the HCI_{Beach}, 42.1% for the HCI_{Urban} and 0.02% for the CCI. The equivalent temperature value, calculated using Humidex, for which a thermal factor of zero is scored, is >36°C for the TCI, ≥39°C for both iterations of the HCI and ≥42°C for the CCI (Table 7.4). Humidex classifications range from 2-3 for Humidex 1 (unacclimatised) and 1-2 for Humidex 2 (acclimatized). The CCI has a Humidex score of 5 for Humidex 1 (unacclimatised) but contains an exception threshold that reduces the risk of thermal stress because of an automatic low score (Table 7.4). This reveals that these days have the potential for heat risk given that the Humidex was so high. These thresholds for the thermal component of the TCI, HCIs and CCI have all been exceeded for Réunion Island. Despite this, no scores for the TCI were classified with the lowest classification of 'extremely unfavourable' at a score of 10-19. Similarly, no scores for the HCI_{Urban} or HCI_{Beach} have scored the lowest score of 0-9 with a classification of 'dangerous'. The CCI produced many low scores between 0-3, but the classification category is simply 'unfavourable', which does not explicitly convey a risk to safety and wellbeing.

Table 7.4. The highest thermal comfort value with a thermal factor of zero is classified according to Humidex 1 and 2.

Index	TC threshold value when thermal factor= zero	Humidex 1 Unacclimatized or heavy exertion	Humidex 2 Acclimatized or low exertion
TCI	>36°C	**2**: 34-37°C	**1**: 36-39°C
HCI_{Beach}	≥39°C	**3**: 38-39°C	**1**: 36-39°C
HCI_{Urban}	≥39°C	**3**: 38-39°C	**1**: 36-39°C
CCI	≥42°C (BUT exception thresholds)	**5**: 42-44°C	**2**: 40-42°C
Response	**1**: Post Heat stress Alert notice and encourage workers to drink water. Some discomfort. **2**: Heat stress Warning notice- extra water needed. Some discomfort. **3**: 15-minute relief needed; provide water, 1 cup water every 20 mins, present heat stress should seek medical attention. **4**: Work with 30 minutes of relief per hour can continue in addition to the provisions listed previously. Great discomfort avoid exertion. **5**: If feasible, work with 45 minutes of relief per hour can continue in addition to the provisions listed previously. Great discomfort avoid exertion.		

For the TCI, the highest score with a CID input of 0 is 54 which is classified as 'acceptable'. For HCI_{Urban} the highest score when TC is 0 is 60 which is classified as 'good'. The highest score for the HCI_{Beach} with a TC score of 0 is 89 and classified as 'excellent'. These scores present relatively good climatic suitability conditions, despite including thermal conditions that pose a risk to human health. According to Humidex classification, with scores from three of the four indices spanning 54-89, tourists would be at a high level of risk for Humidex 1 where a tourist could be exerting moderate physical movement and be unacclimatized or be highly exerted and acclimatized. Humidex 2 shows a similar level of risk for tourists who are acclimatized and performing moderate movement or being unacclimatized doing light physical movement (Figure 4.3; AWS, 2023).

The aspect of acclimatisation becomes particularly important when considering the location of origin of tourists, and the time of year of travel. Acclimatisation is defined as "an adaptive process which results in a reduction in the physiological strain produced by the application of a constant environmental stress" (Hellon *et al.*, 1956: 570). Acclimatisation is important for travellers not only in terms of comfort but as it reduces the threshold effective temperature at which a risk of thermal comfort is posed (Savourey and Bittel, 1997). According to a 2023 Tourism report (Île de Réunion Tourisme, 2024), the most popular time of travel to the island is from November to January. As the largest proportion of tourists who visit Réunion are from mainland France, they would be travelling from the coldest conditions of the year in the boreal winter to the hottest conditions of the austral summer, with artificially controlled temperatures during the long-haul flight. There would be no acclimatisation in these cases, as those tourists would alight from a temperature-controlled airplane after half a day of travel (Salata *et al.*, 2017). Bleunven *et al.* (2023) found that while not a common occurrence, during competitive running, most cases of exertional heat stroke occur during the hot and wet season in Réunion. In the remaining parts of the southern hemisphere, these months experience the highest temperatures of the year where travelling from a winter to a summer destination to experience a warmer climate could increase thermal risk.

Grigorieva (2018) developed a relative index, termed the Acclimatization Thermal Strain Index for Tourism (ATSIT), to determine the physiological cost of acclimatisation experienced by tourists, but note that climatic conditions are not the only factors that impact acclimatisation to a tourism destination. Within the context of Réunion Island, if travellers are not from France or a European context, navigating a Eurocentric landscape would be challenging from a social acclimatisation perspective. Tourists who are from France may adapt easily to the French culture and currency but would still be faced with challenges such as predominately spoken Creole French (Forward, 2020). Even within the same hemisphere, there is spatial variability in climate. Błażejczyk and Vinogradova (2014) note using the Adaption Strain Index (ASI) with tourists travelling from central and northern Europe to the Mediterranean, particularly to Athens that in the summer, tourists experience a high adaptation strain.

Tourists travelling within the southern hemisphere would benefit from consistent seasonality but may not be well acclimatised to the tropical climate and environment. Skinner *et al.* (2001) found that tourists are generally unprepared for the thermal environment when visiting Australia from unspecified locations. The potential of heat stress on tourists travelling to Réunion has implications for their destination choice, time of travel and activity pursued. Hiking is a popular activity in Réunion (Goursaud, 2016) and the physical exertion coupled with the remote nature of the activity could result in higher risk for safety and wellbeing. Linsell *et al.* (2020) note that heat stress when hiking reduces performance, water availability is essential to reduce risk and exertional heat illness (EHI) is a common cause of mountain rescues in warm environments. According to Humidex, the threshold for heat stress is lower when there is high exertion (CCOHS, 2024). In Réunion, hiking occurs in mountain areas where it is cooler (Goursaud, 2016), but introduces risks of cold stress, particularly if tourists are ill-prepared for the cold.

Prolonged exposure to and experience of heat stress can be dangerous, particularly for tourism operators working continuously within a single location. Experienced tourism operators in Australia experienced conflict with government institutions when refusing to do guided tours during hot days, stating safety concerns (Skinner *et al.*, 2001). Inversely, the potential for cold stress has been evident in cases of tourism operators providing Antarctic tour excursions, where although assumed to be acclimatised, experienced varied levels of occupational cold stress according to the level of exposure and activity in this case (Morris *et al.*, 2017). While Réunion Island does not experience the same level of extreme cold conditions as the Antarctic, there is the potential for cold stress to be experienced as tourists hike or visit higher mountainous terrain with insufficient thermal clothing. From 02-03 August 2003, snow was experienced in the high mountains of Réunion, and frost can occur at night in winter in the high altitudes (Vaxelaire, 2018). Lépy *et al.* (2016) found that tourists entering Finland who are unfamiliar with the level of cold conditions are unprepared for Nordic environments and are at risk of accidents such as slipping. In Réunion, where tourists' expectations are for a tropical environment, unpreparedness around clothing choices, especially for exercise would be a concern. Further, tourists who are unfamiliar with the island or do not hike in guided groups could get lost and stuck in the mountains, experiencing unpleasant cold conditions, particularly overnight.

Improved thermal comfort warning systems are needed in Réunion Island. Tourism climate indices should ideally be adapted to incorporate a CCI-type cut-off threshold for thermally unsafe conditions (or indeed unsafe wind or rain). Classifications need to be adjusted to not just 'unfavourable' but 'dangerous' if particular thresholds are exceeded. The HCI does contain a 'dangerous' descriptive category and argues that to achieve the lowest category "dangerous thermal conditions (heat/cold stress, very high winds or high precipitation) must occur…conditions rarely last for more than one or two days at a destination" (Scott *et al.*, 2016a: 5). This is problematic as index scores are cumulative and therefore is unclear what the danger is referring to and does not take into account the physical risk that may be present as conditions normalise.

7.3.2 Climate Events and Associated Impacts

Tropical cyclones are intense short-lived storms that form over warm tropical waters between 5-22° latitude (Liu, 2010). They form under specific conditions such as SST above 26°C, atmospheric instability and weak vertical wind shear (Lighthill *et al.*, 1994; Liu, 2010). In the SWIO, tropical cyclones have been identified to form with an SST of as low as 24°C (Pillay and Fitchett, 2021). The Saffir-Simpson scale is used to categorise the wind intensity of tropical cyclones and from this used to determine the potential damage wind could cause (Table 7.5; Wehner and Kossin, 2024). The SWIO region experiences a tropical cyclone season spanning November to April (Mavume *et al.*, 2009). Tropical cyclones are destructive to humans and the built and physical environment where secondary events such as flooding, storm surges and landslides cause the greatest amount of damage (World Health Organisation, 2024). For tourist destinations, tropical cyclones cause damage to infrastructure, tourist attractions and disrupt essential services during and in the aftermath of the storm (Nhamo *et al.*, 2021).

Table 7.5. Wind speeds associated with Category tropical cyclones, storms and depressions (after Geography in the News, 2024).

Category	Wind speeds
Five	≥157mph; ≥252km/h
Four	130-156mph; 209-251km/h
Three	111-129mph; 178-208km/h
Two	96-110mph; 154-177km/h
One	74-95mph; 119-153km/h
Tropical storm	39-73mph; 63-118km/h
Tropical depression	≤38mph; ≤62km/h

Réunion Island has only experienced the landfall of two tropical cyclones in recorded history, Category 1 Tropical Cyclone Beryl in 1961 and Category 2 Tropical Cyclone Firinga in 1989 and is less directly impacted by tropical cyclones than Madagascar or Mauritius (NOAA, 2024). However, tropical cyclones can range from a diameter size of 80-100km for Category 1 tropical cyclones to up to a 500km radius for Category 5 tropical cyclones, therefore the island is impacted by heavy rainfall events and strong winds as tropical cyclones move through the region (Pillay and Fitchett, 2020). Tropical cyclones have, however, tracked within close proximity of the island, including Category 2 Tropical Cyclones Florine in 1981 and Coline in 1993; Category 3 Tropical Cyclone Florine in 1981, Hollanda in 1994; Bejisa in 2013 and Category 4 Tropical Cyclone Dina in 2002. No Category 5 tropical cyclones have passed near Réunion (NOAA, 2024). For example, the eye of Category 4 Tropical Cyclone Batsirai passed approximately 200km from the coast on 03 February 2022, confining Réunion residents to their homes with disruptions in water and electrical services leaving 12 injured (Figure 7.4; News Wires, 2022).

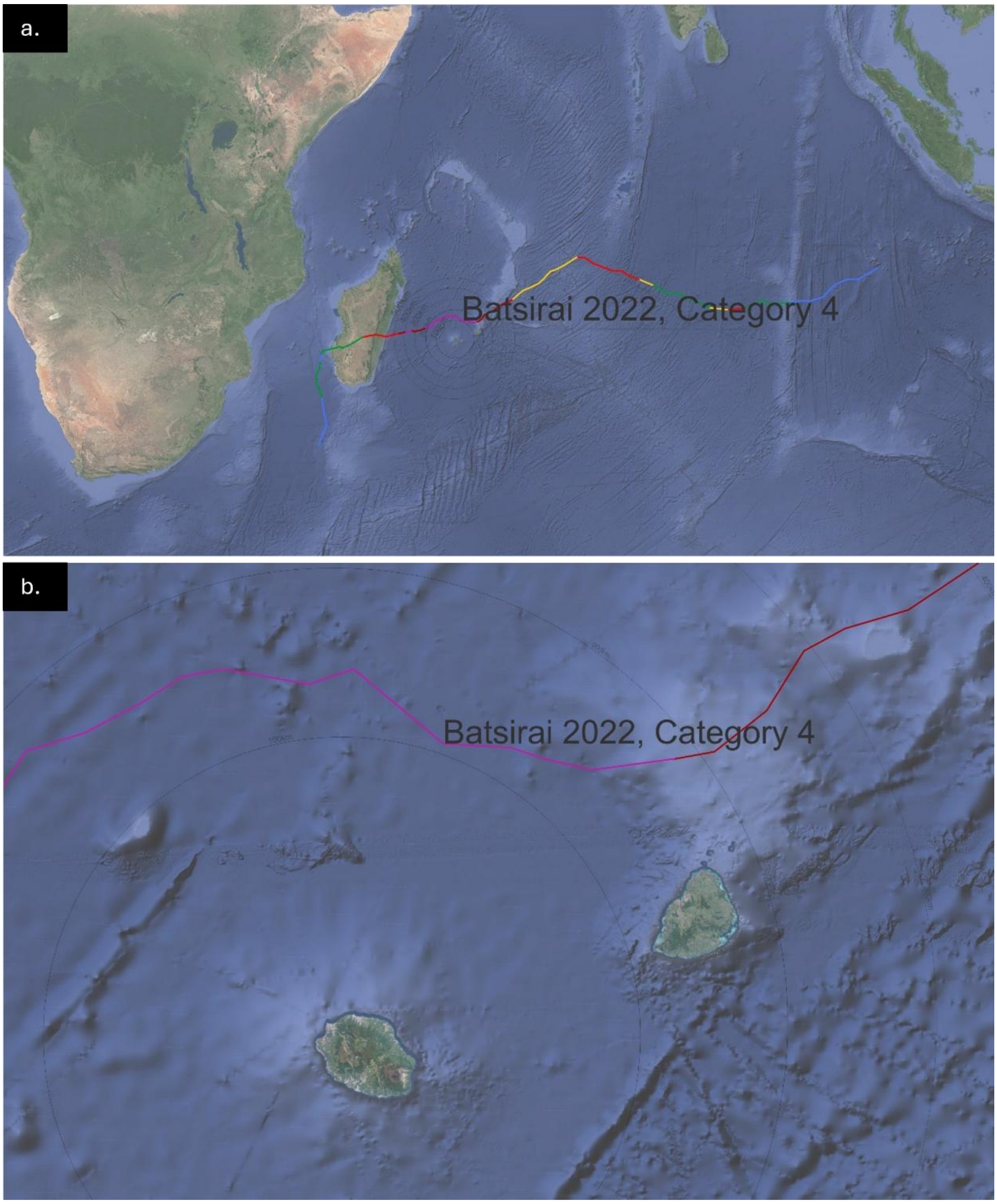


Figure 7.4. Movement of Category 4 Tropical Cyclone Batsirai in early February 2022 a) within the greater SWIO and b) zoomed closer to Reunion and Mauritius.

Tropical cyclones influence the temperature, precipitation and wind variables of tourism climate index scores. During the days surrounding the passage of a tropical cyclone, wind and rain scores could be classified as 0 while temperatures may only drop slightly. Depending on how far the storm is and its location to the eye of the storm, sunshine hours could be rated at zero for the full days the storm passes, or the passage of the outer cloud bands could reduce to half the potential sunshine hours. These scores would be averaged into a month as the tourism climate indices are computed. For the period of study, corresponding to the 2022 and 2023 tropical cyclone period, three tropical cyclones in 2022 and 2023, one tropical storm and one tropical depression in 2022 considerably impacted Réunion Island (Table 7.6; WorldData.info, 2024). The most affected areas were Saint-Denis and Le Port (WorldData.info, 2024). During Tropical Cyclone Batsirai the lowest score for the TCI was 6 classified as 'impossible' and 1 for the HCI_{Urban} and 9 for the HCI_{Beach} classified as 'dangerous' (Table 7.6). Low scores were also found for Tropical Cyclone Emnati in February of 2022 where the TCI scored 18 classified as 'extremely unfavourable', the HCI_{Urban} scored 1.5 classified as 'impossible' and the HCI_{Beach} scored 12 classified as 'unacceptable' (Table 7.6). The TCI scored 28 classified as 'very unfavourable', the HCI_{Urban} scored 18 classified as 'unacceptable' and the HCI_{Beach} scored 32 classified as 'marginal' for Tropical Cyclone Freddy (Table 7.6). Classifications for the TCI and HCI are appropriate for describing the dangerous conditions tourists could experience during this particular tropical cyclone, but this is not always the case. Mean monthly scores for January and February in 2022 and 2023 for the TCI are classified as 'unfavourable' and the HCI_{Urban} is 'marginal' while the HCI_{Beach} is 'acceptable' in 2022 and 'good' in 2023 (Table 7.6). The monthly classifications represent the low climatic suitability for general and urban tourism well while beach tourism is less representative. Mean monthly scores for the CCI also do not represent tropical cyclones well as for all tropical cyclone conditions, climactic suitability for camping is classified as ‘acceptable’. This reveals that the cumulative nature of tourism climate indices misses adverse and potentially dangerous climate conditions that will impact tourism activities.

Table 7.6. Tropical storms and cyclones that correspond to the lowest index scores and monthly index scores for 2022 and 2023.

Tropical cyclones 2022-2023				Lowest Index score				Month Index Average			
Name	Type	Year	Date	TCI	HCI_U	HCI_B	CCI	TCI	HCI_U	HCI_B	CCI
Batsirai	C4	2022	27-08 Feb	6	1	9	3*	36.2	39.8	54.5	4.1
Dumako	TS	2022	13-16 Feb	41	43	60	3*	35.7	38.7	53.0	4.0
Emnati	C4	2022	16-24 Feb	18	1.5	12	3*	35.7	38.7	53.0	4.0
Jasmine	TD	2022	24-28 Apr	41	50	67	3*	36.6	37.8	51.3	3.7
Freddy	C4	2023	6-24 Feb	28	18	32	3*	39.7	47.3	64.3	4.0

The CCI scored an automatic score of 3 for all events with the exception threshold for wind speed and precipitation being met (Table 7.6). The exception thresholds used for the CCI are valuable in describing low suitability for tropical cyclones but given that rainfall values are higher than 10mm and wind speeds exceed 24km.h^{-1}, the cut-off thresholds are missing potentially dangerous conditions. The classification of ‘unfavourable’ does not aptly describe the conditions during tropical cyclones as camping conditions are not only unfavourable but should be completely impossible. Similarly, the HCI considers 25mm of rainfall as an overriding factor and is scored -1. This is insufficient given the extent of rainfall during tropical cyclone events generally in excess of six inches or 150mm in a day (NOAA, 2011). An adjusted threshold should be added to account for severely adverse conditions that could be described as dangerous.

Following the passage of a tropical storm, variables may return to ‘normal’ conditions producing favourable suitability categories, but the impacts of tropical cyclones will still be felt. Following Tropical Cyclone Belal in January of 2024, coastal cities were flooded, and several boats were damaged with media coverage stating that “the winds hit hardest on the higher, inland areas, but roads to reach them remained impassable” (Africa News, 2024: 1). Besides the economic losses taken by local governments during and after these storm events, personal costs to the tourists could be implicated. During Storm Eleanor in February 2024, Mauritius grounded flights and closed public transportation lines to reduce the impacts of the storm (Agence France-Presse, 2024). In the long-term, as tropical cyclones are projected to become more intense under climate change (Seneviratne *et al.*, 2021), the addition of an exception threshold for tropical cyclone and storm events would be valuable to include in quantifying climatic suitability given the implications for human safety during these events.

Isolated heavy rainfall events risk resultant landslides in Réunion (Mycoo *et al.*, 2022; Rault *et al.*, 2022). Volcanic islands such as Réunion are “typically high and distant from other landmasses” (Mycoo *et al.*, 2022: 2051) where erosional rock falls have the potential to cause road closures or physical harm to tourists. The risk of mudslides or landslides as a result of heavy rainfall or flooding is not typically conveyed to tourists, especially as these can happen a few days after rain has subsided. These geohazard events could occur when there are otherwise good TCI and HCI scores because rain might only be heavy for a few days and could occur when thermal comfort is classified as ‘very good’.

Volcanoes offer unique opportunities through adventure tourism and ecotourism (Erfurt-Cooper, 2011; Putra *et al.*, 2023). Réunion Island is a volcanic island with two volcanoes, one dormant and the other active, one of the main tourist attractions for the island. Volcanic eruptions can result in short-term global cooling as a result of eruptions forming a stratospheric sulphate aerosol layer and can reduce regional temperatures with global cooling effects of 0.2-0.3°C (Zielinski, 2002; Hopcroft *et al.*, 2018). While slight cooling induced by the emission of particulate matter into the lower stratosphere may be beneficial for tourism destinations, the impacts on ecosystems and society will increase from large eruptions because the precipitation changes, as a result, are complex and projected to intensify (Hopcroft *et al.*, 2018).

The presence of volcanoes is not directly linked to climate but has an impact on the potential experience and safety of tourists. Mount Etna located in Sicily, Italy and Mount Stromboli located on a nearby on Aeolian Island, are active volcanoes and have become increasingly hazardous in the last few years (O'Donoghue, 2024). Mount Etna is known to erupt frequently where local authorities are not concerned for tourists stating "Mount Etna erupts so frequently; tourist's activities are rarely disrupted. The volcano has more than 200 craters so even when one of them is erupting, there are many other areas where visitors can safely hike" (O'Donoghue, 2024: 1). Conversely, in 2019 Mount Stromboli erupted resulting in one death and 30 tourists needing to escape in the ocean for safety (O'Donoghue, 2024). The level of safety concern appears to be different for an island location. While Réunion Island does have extensive monitoring systems in use (Richter and Froger, 2020) it is unclear what the warning signals would be should a volcanic eruption become hazardously active, particularly for tourists who are unfamiliar with the island. Tourism climate indices in this case would be irrelevant as eruptions can occur during perfect weather. Eruptions from the volcano Piton de la Fournaise have resulted in lava flows on the east side of the island that have impacted urban areas and infrastructure (Côté Est Réunion, 2024). These lava flows provide unique tourist attractions with geological evidence of past eruptions (Figure 7.5). However, they also place significant risks to tourism infrastructure and to tourists' safety.

Figure 7.5. The Church of Notre Dame des Laves in Sainte-Rose, a church impacted by the lava flow of 1977.

The Indian Ocean that surrounds Réunion is home to many fish species and megafauna such as dolphins, whales and sharks that are a key attraction for tourists (La Réunion, 2024e). Réunion Island also has one of the highest rates of shark attacks globally (Figure 7.6; Midway *et al.*, 2019). Tiger and bull sharks are primarily responsible for these attacks, occurring seasonally on the western coast of the island, where most beach sites are located (Blaison *et al.*, 2015). Fewer sharks are recorded near Mauritius, where it is hypothesised that sharks are deterred by the coral reefs surrounding the island, however, research to understand the specific reason behind this shark behaviour is ongoing (Schuetze, 2015). With the imagery of a tropical island, Réunion markets coastal activities such as surfing, windsurfing, bodyboarding, sea kayaking and outrigger canoeing where 61% of attacks were centred around boarding activities, particularly surfing because these activities tend to occur further away from the coastline Taglioni *et al.*, 2019). While conditions may be suitable for beach tourism, including beach activities, and a key marketing point for the island to increase its tourism input, the risk of sharks is still of great concern (Île de Réunion Tourisme, 2018).

Figure 7.6. Shark warning located at a beach in Saint-Paul.

Entering a tourism destination exposes tourists to vector-borne diseases. Indirectly linked to climatic suitability is the distribution of vector-borne diseases in tourism destinations. The presence of mosquitoes and other disease-carrying insects and animals becomes more prevalent under warm and wet conditions that are typical of tropical island contexts (Mavian *et al.*, 2018). Within the Indian Ocean, malaria is a risk factor in the Comoros and Madagascar, while cases of Chikungunya, dengue fever and West Nile virus are found in Réunion Island (Renault *et al.*, 2012; Vincent *et al.*, 2023). A Chikungunya epidemic occurred between 2005-2006, and more recently a case was experienced in April 2016 but was not mentioned in the media in Réunion or France (Soumahoro *et al.*, 2011; Île de Réunion Tourisme, 2018). Chikungunya is transmitted through day-biting mosquitoes resulting in symptoms of fever, joint pains and flu-like symptoms (World Health Organisation, 2022). Although there is a winter peak in the seasonal climatic suitability, peak tourism season occurs in summer from November to January (Île de Réunion Tourisme, 2024). Warmer conditions could exacerbate and spread the presence of vector-borne diseases, especially under climate warming (Endo and Amarasekare, 2022; Pillay *et al.*, 2023). Further, CCI seasonality indicates three meteorological stations with summer peaks where suitability is found to be 'acceptable'. These stations are located close to where many camping activities are found (Figure 6.9). Therefore, while the suitability for camping is relatively acceptable, the presence of insects and mosquitoes could result in an unpleasant experience and one with risk if Chikungunya is caught. The risk of vector-borne diseases is not diminished with cooler temperatures in high altitude areas, particularly seen in the increased risk of dengue fever and Chikungunya that have been found to thrive in central Nepal, due and attributed to climate and environmental changes (Dhimal *et al.*, 2015).

7.3.3 Lexicon of Risk and Safety Warning Communication

The lexicon used in the classification of index output scores conceals greater issues of risk and safety where communication of this information to tourists requires caution. Classifications of 'marginal' or 'acceptable' do not convey that there is an inherent risk within. For example, it may rain every single day or, worse, there could be a risk of heat stress that is hidden as previously shown. Therefore, the lexicon does not adequately convey risk.

This leads to the warning signals and communication around safety for tourists. The use of applications and online communication portals such as *Xenios* have been used to inform and warn tourists of natural disasters or life-threatening events in Greece (Psaroudakis *et al.,* 2021). Dinkoksung *et al.* (2023) have developed a mobile application to be able to alert tourists of heat warnings in warm and humid environments. Such an application is in development in the Kerambitan District in Bali due to an identified need to have precautions in place given its natural tourism base and topography that is prone to flooding and landslides during high rainfall events (Partama *et al.*, 2024). For popular accommodation establishments such as Airbnb, the application makes it easy to communicate warnings and information to tourists in the absence of a front desk service or centralised messaging. The sharing economy and its associated applications like Airbnb have been seen to take two roles in disaster management (Seddighi and Baharmand, 2020). The first is a direct role in pre-mitigating the impact of disaster from an economic perspective and how to use the Airbnb space, the other is an ad hoc indirect role by providing information for responders and affected people that are not necessarily in their shared spaces (Seddighi and Baharmand, 2020). For example, during the Cape Town Day Zero Drought, Airbnb hosts were found to share water-saving methods and changes in the

Day Zero end date as well as changes made by the government (Prinsloo and Fitchett, 2023). The disadvantage of this is that tourists may not have roaming internet access, may not be able to translate warnings if they are given in a foreign language, or may miss out on timeous information if a host is unresponsive or outside of the island during their stay.

With respect to VFR travel, a popular form of tourism on Réunion Island, risk awareness may take two forms. The first is identified in second-home tourism, as frequent visitors to a destination who may own property in another location where concerns for these warnings may be taken less seriously due to being desensitised over time. This has been seen in the example of Finland where environmental challenges from second-home tourism are recognised but cause less concern for property owners (Hiltunen *et al.*, 2016). Further, VFR travellers have been identified to have a reduced level of risk awareness when visiting familiar locations, particularly around disease and health (Behrens *et al.*, 2010). Conversely, Kozak *et al.* (2007) found that international tourists visiting Hong Kong for varied tourism purposes were sensitive to perceived risk and likely to change travel plans to destinations with elevated risk. Therefore, depending on the purpose of travel, risk is perceived differently.

There is limited inclusion to no consideration of risk and safety linked to tourism climate indices which have an impact on the lived experience of tourists and the likelihood of returning to a destination based on their experience. Including exception thresholds and the approach used by the CCI would be a valuable addition to creating future segment-specific indices or adjusted indices to include overarching factors that account for less suitable and unsafe conditions (Ma *et al.*, 2020). The use of multiple exception statements for temperature, precipitation and wind can also be used to assist in contextual adaptation where for example, high temperatures are considered ideal if there is the presence of shaded areas, water availability and other heat adaptation strategies within that specific tourism context.

7.4 Climate Futures

The increasing impacts of climate change will result in a shift in the time of year tourists travel, where they go, the type of accommodation sought, and activities pursued. Summer destinations may become too hot or tourism accommodations not eco-friendly enough, for instance. This allows for the planning of tourism destinations globally. However, some destinations have greater access to adaptation resources and are better socio-economically situated to address the changing climate, creating climate ‘winners’ and ‘losers’ (O'Brien and Leichenko, 2003). North American countries will see a redistribution of climate resources for tourism where southern USA countries will provide better suitability in the winter months and the summer months in Canada (Scott *et al.*, 2004). Southern and Central America, including the Caribbean, are considered climate ‘losers’ as the future will see a deterioration in climatic features (Moore *et al.*, 2009). Within Europe, the Mediterranean will be most impacted due to higher temperatures which will impact water resources, while some regions such as France and Italy are projected to benefit from the changing climate (Ehmer and Heymann, 2008). Asia, the South Pacific and the Indian Ocean are considered climate ‘losers’ as they will be negatively impacted given the high economic dependence on tourism and the risk of ECEs (Ehmer and Heymann, 2008). African countries are extremely vulnerable due to low adaptive capacity (Ziervogel and Zermoglio, 2009; Epule *et al.*, 2023) but also as the continent is warming 1.5 times the global rate, particularly in the subtropics (Engelbrecht *et al.*, 2015). These ‘winner’ and ‘loser scenarios’ are short-term and as the world has already surpassed the 1.5°C scenario, averaging 1.64°C above preindustrial levels globally, all tourism destinations are climate ‘losers’ (Beament, 2024).

Scenarios within the IPCC AR6 are based on SSPs that are used to describe climate change projected impacts rather than RCPs that were assessed in AR5 (Pathak *et al.*, 2022). Representative Concentration Pathways (RCPs) are scenarios and outcomes that result in climate changes based on atmospheric models (IPCC, 2014). Shared Socioeconomic Pathways (SSPs) were first published in 2017 and are alternative projections that describe challenges to mitigation and adaptation through socio-economic factors such as inequality (Pathak *et al.*, 2022). SSP1-1.9 refers to limiting warming to 1.5°C with no or limited overshoot (Pathak *et al.*, 2022). Through engagement with the literature, however, it is clear that continued engagement and reflections on RCP-based projections are needed. In the forthcoming discussion section as part of *7.4 Climate Futures*, RCPs will be used as there is more engagement with these pathways than the described SSPs.

7.4.1 Future considerations for tourism in Réunion

Climate and biodiversity are key resources for many small tropical islands including Réunion in terms of attracting tourists (Saarinen *et al.*, 2022). Small islands are known to be some of the most vulnerable regions to climate change risk and are often described as being on the “frontlines of climate change” (Thomas *et al.*, 2020: 2). Increased warming, SLR and exposure to ECEs is projected at high confidence in the latter half of the century (Mycoo *et al.*, 2022). Globally, the air temperature of small islands is projected for the period 2040-2060 to increase by 1°C under RCP4.5, 1.5°C under RCP8.5 and further increase for the period 2080-2100 by 1.3°C under RCP4.5 and 2.8°C under RCP8.5 (Harter *et al.*, 2015). Mauritius, a popular tourism destination in the SWIO and neighbour to Réunion has been warming at a rate of 0.02°C/year over the period 1971–2020 (Doorga, 2022). Compared to South Africa, another competitive tourism destination within the region, temperatures are projected to be twice the global average rate where Réunion Island is at similar risk (Scott *et al.*, 2019; Scholes and Engelbrecht, 2021). The climatic suitability for general tourism and sightseeing, represented by the TCI, is declining at a rate of 2.1 unit scores per decade (Table 7.7). Should this rate of change continue linearly, this would result in a category classification change from 'marginal' in 2023 to 'unfavourable' by approximately 2043 and becoming 'very unfavourable' by approximately 2093, assuming change continues at a current rate (Table 7.7). For other locations that may be appealing to tourists in southern Africa, average temperatures are projected to increase at 2-4°C per century over the interior region, particularly northern Botswana and southern Zambia where many nature-based tourism activities are based (Dube and Nhamo, 2018; Engelbrecht *et al.*, 2024).

Globally, small islands are projected to become slightly wetter, and precipitation is likely to become increasingly variable (Harter *et al.*, 2015). In the SWIO, islands are projected to become drier during wet seasons, particularly countries south of 10°S latitude, which include Madagascar and Réunion Island (Lazenby *et al.*, 2018). HCI_{Beach} suitability has almost no change per decade over the next century (Table 7.7). Lower rainfall may result in higher suitability for the HCI as lower precipitation is rated a higher score. However, warmer and humid conditions could result in higher thermal comfort scores reducing suitability, even though thermal comfort is weighted less than precipitation. The thermal comfort component could be exacerbated if air conditioning is not available or if water resources are impacted. Climatic suitability for urban tourism represented by the HCI_{Urban} has declined by 0.9 unit scores per decade over the period 1991-2023. Should this trend perpetuate, the classification categories would reduce from 'acceptable' in 2023 to 'marginal' in approximately 2053, assuming the rate of change is consistent. The decrease in suitability would be due to an increase in temperature, potentially because of urban heating (Velea *et al.*, 2023).

Table 7.7. Projected trends in the change in suitability until the end of the century across tourism climate indices.

Projected decade	TCI -2.1/decade	HCI_{Urban} -0.9/decade	HCI_{Beach} 0.0/decade	CCI -0.1/decade
2023	~43.4	~52.0	~66.4	~4.8
2033	~41.3	~51.1	~66.4	~4.7
2043	~39.2	~50.2	~66.4	~4.6
2053	~37.1	~49.3	~66.4	~4.5
2063	~35.0	~48.4	~66.4	~4.4
2073	~32.9	~47.5	~66.4	~4.3
2083	~30.8	~46.6	~66.4	~4.2
2093	~28.7	~45.7	~66.4	~4.1

A lower rate of change has been calculated for the CCI over the period 1991-2023 at a rate of 0.1 unit scores per decade, assuming change continues at a current rate (Table 7.7). Projected resources for camping reveal that climate resources in Europe and North America have a positive outlook under climate change conditions whereas sub-Saharan Africa and tropical islands see a decline in suitability due to ECEs under climate change (Ma *et al.*, 2021a). The number of days that exceed temperature, precipitation and wind speed thresholds accounts for this decline (Ma *et al.*, 2021a). The reason for this may be due to the inherent nature of the index accounting for thresholds that would result in unfavourable suitability. Accounting for this accumulation of exceptions over a long period suggests that it has accounted for negative change. However, these results are a best-case scenario where classification may decline sooner given the acceleration of climate change (Scott *et al.*, 2004; Parks, 2009). Given that tourism climate indices do not account for climate change phenomena, beach and camping tourism will be impacted by other extreme changes such as SLR and the disappearance of coastlines (Spencer *et al.*, 2022).

7.4.2 Extreme Climate Events

Due to human-induced greenhouse gas emissions, ECEs are increasing in frequency and severity globally (Seneviratne *et al.*, 2021). ECEs include temperature extremes in the form of heatwaves, flooding, drought, tropical cyclones and other storms (Bell *et al.*, 2018). Regional projections from the IPCC AR6, project that tropical cyclones, heatwaves, drought, heavy precipitation and SLR will continue to have a serious impact on small tropical islands like Réunion (Mycoo *et al.*, 2022). These will have consequences for human safety, infrastructure and resource management and therefore adaptation measures need to be considered (Bell *et al.*, 2018).

Globally, heatwaves are projected to increase in frequency and duration, including within the Indian Ocean and Réunion Island. Marine heatwaves are also projected to increase where warmer oceans have implications for ecosystems (Holbrook *et al.*, 2022; Azarian *et al.*, 2023). For Réunion, the percentage of days with the highest score when the thermal comfort factor is rated a zero was determined (Table 7.8). The zeros largely represent heatwave events. Of these days, 46.4% were identified for the TCI, where the highest score with a zero rating was 54 classified as ‘acceptable’. For the HCI_{Beach} 42.7% of days were identified where the highest score with a zero rating was

89 classified as 'excellent'. The percentage of days for the HCI_{Urban} was 42.1% where the highest score with a zero rating was 60 classified as 'good'. The CCI contains an accumulation of exception scores that result in a low percentage of potential heat stress days (Table 7.8). No scores for the TCI were classified with the lowest classification of 'extremely unfavourable' (10-19) or between 0-9 with a classification of 'dangerous' for the HCI_{Beach} and HCI_{Urban}, despite these heatwave conditions. This highlights the risk of potential heat waves missed by tourism climate indices.

Table 7.8. Percentage of days with a thermal factor of zero with acceptable suitability per index.

Index	Annual Average from 1991-2023	Annual Average classification	Highest score when thermal factor= zero	Percentage of days
TCI	54.0	Acceptable	54 ('acceptable')	46.4%
HCI_{Beach}	69.3	Good	89 ('excellent')	42.7%
HCI_{Urban}	56.9	Acceptable	60 ('good')	42.1%
CCI	4.7	Acceptable	Exception thresholds	0.02%

Under climate change, SSTs have increased and there has been an expansion of the Hadley Cell, resulting in a poleward shift in SSTs (Sharmila and Walsh, 2018; Pillay and Fitchett, 2019). The poleward shift results in tropical cyclones tracking further south and due to higher SSTs, the intensity of tropical cyclones will increase resulting in more destructive winds and rainfall periods that will cause increased flooding. An increase in tropical cyclone intensity will result in considerable damage if they make landfall (Pillay and Fitchett, 2019). Importantly, storms passing within 250-500km of the coastline of the island can still have a marked impact on the weather of Réunion Island (Barbary *et al.*, 2019). With a projected move polewards and Réunion located relatively far south in the region, tropical cyclones will be a greater risk.

7.4.3 Sea Level Rise

The impacts of climate change on small islands will be exacerbated by socio-economic factors, particularly an increase in population where increased coastal inundation by 2100 under RCP4.5, threatens populations living close to sea level (Kulp and Strauss, 2019). In the Indian Ocean, relative SLR is projected to increase at 4-6mm.y^{-2} in the Mauritius region (Becker *et al.*, 2019). Urban centres, including hotel and guest house accommodations, are in the low-lying areas of Réunion and will be heavily threatened by SLR. Under the one metre SLR risk scenario in the Caribbean, 29% of resorts are projected to be partially or fully inundated while 49-60% of tourism properties would experience the risk of beach erosion damage (Scott *et al.*, 2012b). Sandy coastlines will experience a greater risk of erosion than rocky coastlines with half the world's sandy beaches projected to disappear by 2100 (Ferreira *et al.*, 2008; Vousdoukas *et al.*, 2020). Pacific Ocean islands will be impacted by SLR through flooding, beach erosion, inundation and saltwater intrusion; most remarkably, Tuvalu, has experienced SLR at a rate of 5.9mm/year, four times higher than the global average (Mimura, 1999; Aung *et al.*, 2009). Sea levels at Tuvalu are projected to rise by 150mm and Kiribati by 80mm by 2040 when estimated from 2001 (Raj, 2022). SLR will most impact residents and businesses that rely on tourism that is located near coastal low-lying regions of Réunion where the Observatoire Regional du Tourisme must work with local government and these local stakeholders to determine the level of awareness and strategies to adapt to climate changes (Fitchett *et al.*, 2016a).

7.5 Limitations

Spatial and temporal variation in meteorological data, data availability challenges, and inherent limitations of tourism climate indices should be considered in tourism climate research, and their impacts on this study have been carefully considered. In assessing the applicability, suitability and validity of using a multi-index approach in *Chapter 5*, some of these limitations have already been outlined and addressed, particularly the use of each index included in this study. Data availability, spatial and temporal variation and the overall limitation of using a tourism climate index in assessing a tourism context are discussed.

For this study, meteorological data from Météo-France were obtained for 11 ground-based weather stations across the island. Roland Garros Airport was the only station for which all requisite meteorological variables had been measured and for which data spanned the optimal minimum period of over 30 years for calculating means and trends. Despite the challenges relating to variables measured and the duration of the record, the number and distribution of these stations fulfil the threshold criteria of ground-based meteorological station network density per km^2 (van der Walt and Fitchett 2022). Considering the thresholds of Jones and Trewin (2002) and Vose and Menne (2004) 100-200 stations are sufficient for both Australia (7,692,024 km^2) and the USA (9,826,675km^2) respectively. This threshold, when applied to South Africa indicated that 20 stations were sufficient for the 1,221,037km^2 terrestrial area of the country (van der Walt and Fitchett, 2022). Applying this same logical approach to the context of Réunion, from its 2,511km^2 terrestrial surface area, 3-6 stations would provide sufficient meteorological coverage. The 11 meteorological stations can therefore be considered as well-representative of the mesoclimate variation across the island.

However, due to the complex topography and issues of data paucity, a concern remained around the level to which meteorological station data could represent the microclimate differences across the island. Therefore, although not a key aim of the study or a component of the original methodology, we conducted ground-based micrometeorological data logging in Réunion in two fieldwork campaigns during June of 2023 and June 2024 respectively. The differentials between base-point temperatures (with a base point in western Réunion in 2023 and in eastern Réunion in 2024) and site readings are plotted together with the mean June temperatures for each meteorological station (Figure 7.7). While the ground-based *in situ* data collected on fieldwork confirmed that there are microclimatic differences across the island, these are subtle relative to the mesoscale climatic differences captured by the 11 meteorological stations, and consistent with the variation in meteorological station values. With the granularity of the ranking, scoring and classification of the tourism climate indices, these subtle differences in microclimate would be aggregated. Therefore, while it would be ideal, particularly for campsites, to have a longer-term measure of local meteorological conditions and the shading effect of trees from sun and wind, this limitation does not profoundly compromise the validity or representativity of the results obtained.

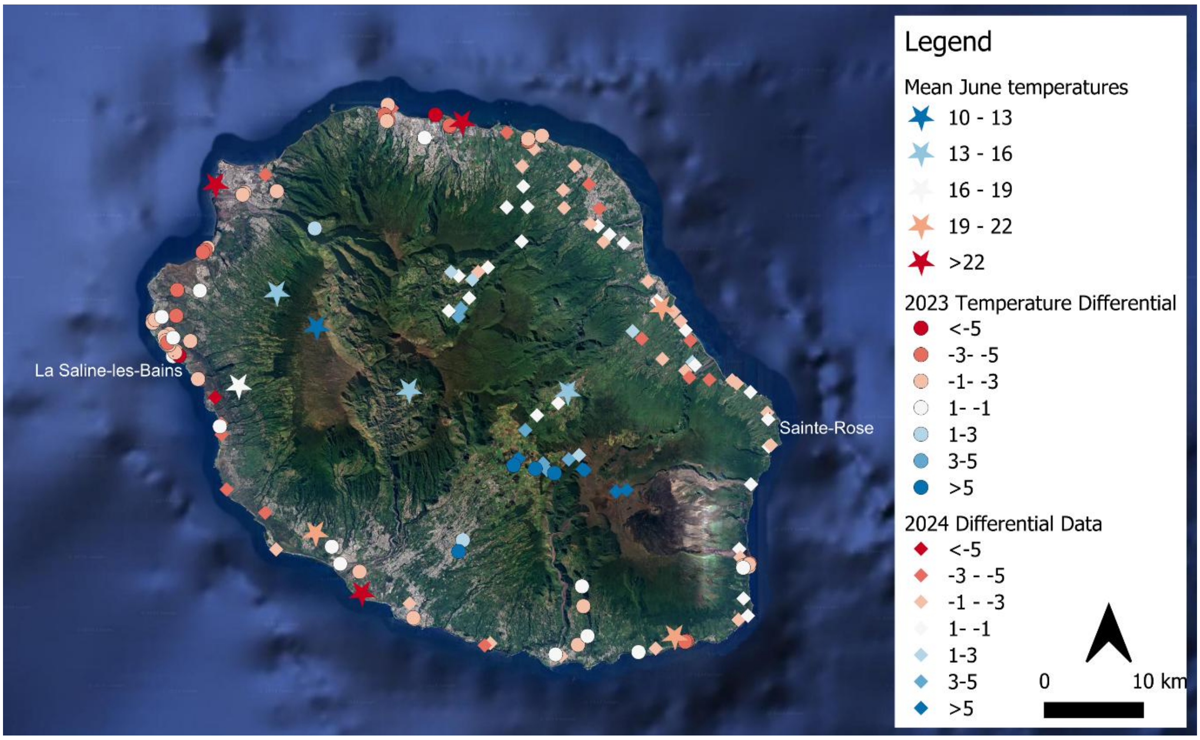


Figure 7.7. Temperature differential data for June 2023 and 2024 compared to June mean temperature from meteorological data.

The exception to this may arguably be for the CCI where if a meteorological station measured conditions that met an exception condition and resulted in an automatic low score of 3 or less, it is possible that the same threshold would not be exceeded at a specific camping site, particularly if it was well sheltered from the wind, or at higher altitude than the meteorological station. One way to address this inaccuracy would be to encourage campsites, and indeed other tourism accommodation establishments, to erect their own meteorological stations on site. This, however, would be costly, and require expertise in the analysis of the recorded data, and is thus most likely not a viable option for most campsites. Gridded data may be an option in addressing site-specific data; however, the presence of mountainous topography is often a challenge for using such data (Daly, 2006; van der Walt *et al.*, 2023; Fitchett and Mackay, 2024), and the grid cell size of the gridded data may be of a coarser resolution than the existing ground-based network. Furthermore, while climate data is available at a higher resolution, data storage capacity is an additional challenge to consider (Mangal *et al.*, 2020).

The data used to calculate the climatic suitability of Réunion Island was limited particularly for sunshine hour and cloud cover data (as mentioned in *Chapter 5*). The only station with 33 years of meteorological data was Roland Garros Airport. The remaining 10 stations varied in the level of completeness of data. Cloud cover was the main variable with limited data followed by sunshine hour data. As cloud cover is the main aesthetic component in the calculation of the HCI, this index could only be calculated for the two stations for which data were available, Roland Garros Airport and Pierrefonds Airport. The latter only had eight years of cloud cover available. The accuracy of representation for Pierrefonds not only limits the representation of beach and urban sites but the HCI across the island is also limited.

Finally, the inherent assumptions of tourism climate indices have been discussed in *Chapter 5*. As the HCI excludes nighttime thermal comfort on the assumption that air conditioning is universal (Scott *et al.*, 2016a), it also assumes that tourists spend the evening within their air-conditioned accommodations. Tourists can venture to bars and nightclubs, restaurants, live art and dance venues, or simply walk around the city at night (Nofre, 2021). These spaces do not necessarily have air conditioning, particularly where they include open spaces outside. Réunion Island is host to 116 nighttime activities ranging from popular restaurants, wine bars, casinos and nightclubs, some of which are located on the beach (La Réunion, 2024b). Further, it is noted that tourism climate indices are applied within varied environmental and socio-political contexts. While tourism climate indices indicate climatic suitability the overall enjoyment of a tourism destination may be reduced by the presence of pollution (Dyson, 2010), crime and safety concerns (Malleka, 2020) overcrowding (Dodds and Butler, 2019), poor infrastructure and environmental quality (Giannoni and Maupertuis, 2007) amongst other factors. This study aimed to understand the climatic suitability of tourism for the island through a primarily desktop approach.

CHAPTER 8: CONCLUSION

Le Port Graffiti- Jace (2017).

8.1 Synopsis

Understanding the climatic suitability of tourism destinations assists in maximising climate resources for tourism. The tools to determine climatic suitability are tourism climate indices. Much of the literature argues for a singular-use index or modified index. However, each index is valuable in presenting a particular image of climatic suitability. The study sought to quantify the climatic suitability of tourism for Réunion Island. It used this context to critically evaluate the application of tourism climate indices using a multi-index approach.

Key tourism and climate change literature was reviewed from global inputs to research being investigated in the SWIO. This was followed by a thorough review of the development, application and intercomparison of the tourism climate indices. Like all small islands, Réunion Island will be highly impacted by climate change which not only has implications for its future but for the future of tourism, an economic sector it relies on. The climatic threats to the SWIO region and adaptation strategies in the literature were outlined.

A description of the study site was outlined in *Chapter 3*. The geography and diverse topography were examined, outlining its position in the world and the beach, urban and mountainous areas it markets towards tourists. Given this study is focused on the climatic suitability of the island, the climate and weather of Réunion Island were outlined. The economy of the island was described followed by the tourism landscape and strategies the island has for its tourism development.

The methods used to conduct this quantitative study were outlined in *Chapter 4*. An assessment of the applicability, suitability and validity of using the four tourism climate indices was conducted. The methods for this assessment were outlined in *Chapter 4* and explored in *Chapter 5*. The acquisition of meteorological station and field-based data were provided followed by a descriptive outline of each of the four tourism climate indices used in this study namely the TCI, HCI_{Urban}, HCI_{Beach} and the CCI. The methods of data analysis including determining the seasonal distribution, multi-index approach as well as the change in suitability over time were outlined.

The results found in this study are provided in *Chapter 6*. The mean annual and mean monthly climatic suitability scores are given for each tourism climate index for meteorological stations that contained the available requisite data. Mean annual scores range between 50-75.6 classified as ‘acceptable’ to ‘very good’ for the TCI, 56.9-61.6 classified as ‘acceptable’ to ‘good’ for the HCI_{Urban}, 69.3-75.4 classified as ‘good’ to ‘very good’ for the HCI_{Beach} and 3.6-5.8 classified as ‘unfavourable’ to ‘acceptable’ for the CCI. A station comparison was conducted for each index and the seasonal distribution determined. A winter peak seasonal distribution is found for the TCI and both iterations of the HCI while a bimodal shoulder peak is present for the CCI. A ground-based data comparison was conducted between three campsites and compared to meteorological station data finding that scores differed *in situ*. The four tourism climate indices show variation in monthly and overall climatic suitability for the island, further supporting a multi-index approach. Over time, results show statistical significance in the rate of climatic suitability change over the 33-year period where the TCI and HCI_{Urban} show greater change than the HCI_{Beach} and CCI.

The study is the first quantification of the climatic suitability of climate for tourism in the SWIO. Tourism climate indices have predominately been applied in the Global North with few studies and relatively recently applied indices in the Global South. Previous tourism studies in the SWIO have also investigated TripAdvisor reviews of tourists visiting the region (Fitchett *et al.*, 2020) where this study confirms climatic suitability for these self-reported reviews. Further, and most importantly, tourism climate indices are often applied in isolated tourism case studies. Within the literature, research has tended to focus on simply applying an index to quantify the climatic suitability or determine the future climate resources of a region amongst other purposes. This study is one of the few studies to conduct an applicability, suitability and validity assessment of tourism climate indices prior to their application. Once deemed appropriate the study sought to critically assess the climatic suitability of Réunion Island. As one of the first multi-index approaches to be used in the southern hemisphere, the use of four tourism climate indices was found to be valuable given the diverse range of tourism offerings and the complex topography of the island. The scores computed from the tourism climate indices (TCI, HCI_{Urban}, HCI_{Beach} and CCI) have revealed that each index contains individual strengths in revealing the varied climatic suitability of the island and future work involving these indices should utilise these strengths and use them together to get a clearer image of climatic suitability.

8.2 Achievement of Study Aims and Objectives

The primary aim of this study, to quantify the climatic suitability of tourism in Réunion Island using multiple tourism climate indices over a 33-year period, was achieved through the three research objectives outlined in *Chapter 1*, *Section 1.2*. Limitations discussed in *Chapter 7* (*Section 7.5*) address challenges that arose during this study and how these challenges were overcome, thereby not compromising the objectives set out in this research. A more detailed summary of how the research objectives were achieved is outlined in the order they appear in *Chapter 1*.

1. *Assess the validity of four tourism climate indices through an evaluation of the availability and completeness of requisite climate data from 1991-2023, and validity of the index assumptions, and the mean local climate in comparison to threshold ranges*

Tourism climate indices rarely assess whether an index is applicable to use in a given context. An assessment of the applicability, suitability and validity of using the four tourism climate indices is detailed in *Chapter 5*. In determining the applicability of the indices, tourism offerings and data availability needed to be assessed. An assessment of available tourism offerings for Réunion Island was conducted and the completeness of requisite data were examined. The island was found to have varied tourism offerings from general sightseeing, beach tourism, urban tourism and camping. These align with what the tourism climate indices were developed to quantify. Data were incomplete with sunshine hours and cloud cover data being limited. Substitutions for sunshine hours and cloud cover data were examined but found not to work in the context of the study. Much of the data could be used to calculate the TCI and CCI while only two stations, one fully complete contained enough requisite data to calculate the HCI. The four indices were found to be applicable to use on the island.

The suitability of using the four tourism climate indices was determined. The inherent assumptions for each index were examined. The TCI was developed from pre-existing biometeorological indices and measures of climatic suitability for humans to capture a range of tourism types and contexts, built on particular thermal comfort methods and incorporates variables based on expert opinion. Given the wide range of tourism the TCI has been applied to and validated using tourist preferences in the South African context (Fitchett and Hoogendoorn, 2019; Mokgehle and Fitchett, 2024), it was argued to be suitable to use in Réunion Island given the latitudinal similarity and the climatic similarity to the more subtropical coastal and mountainous regions of South Africa. A key assumption of the HCI is its removal of nighttime thermal comfort as it is assumed that air conditioning is ubiquitous. Therefore, an assessment of air conditioning availability on the island was conducted, finding from one popular booking site, that 69.2% of the 2,694 accommodation establishments listed have air conditioning available. While not completely ubiquitous, it was argued to be sufficient to warrant the use of the HCI due to the low diurnal temperature range on the low-lying and populated areas of the island, and given the cool temperatures at the higher altitude locations. Although the CCI was developed for the USA and applied globally, its suitability for Réunion was questioned. The CCI was found to be suitable in a South African context and given the similarities of locations in South Africa and the USA such as Durban and Florida to Réunion, the CCI was found suitable to apply.

2. *Calculate monthly tourism climate index scores for 11 meteorological stations, for the full study period, of three years, using the TCI, HCI_{Beach}, HCI_{Urban} and CCI*

Data from 11 meteorological stations ranging from 1991-2023 were checked and cleaned. Of the 11 stations, one was found to contain the complete 33 years of data, whereas the remaining 10 contained 7-15 years of data. The results of the calculated indices are presented in *Chapter 6* (*section 6.2 Tourism Climate Index (TCI), 6.3 Holiday Climate Index-Urban (HCI_{Urban}), 6.4 Holiday Climate Index-Beach (HCI_{Beach}) and 6.5 Camping Climate Index (CCI)*. The methods used to achieve these calculations are provided in *Chapter 4*. Mean monthly and mean annual climatic suitability scores were calculated for each tourism climate index. Mean annual TCI scores range between 50-75.6 classified as 'acceptable' to 'very good', HCI_{Urban} scores range between 56.9-61.6 classified as 'acceptable' to 'good', HCI_{Beach} scores range between 69.3-75.4 classified as 'good' to 'very good' and CCI scores range between 3.6-5.8 classified as 'unfavourable' to 'acceptable'. A station comparison and the seasonal distribution were determined for each index revealing that the TCI and HCI have predominately winter peak seasonal distributions while the CCI has a bimodal should peak seasonality. A key component of this research was using a multi-index approach to understand the climatic suitability of the island. Results show there is varied climatic suitability according to each index, proving that a multi-index approach is valuable in quantifying the climate of a tourism destination.

3. *Calculate the change in climatic suitability over 33 years to assess the impacts of climate change*

The rate of change in climatic suitability was determined for a 33-year period for each tourism climate index. Linear regression was used as a mode of time trend analysis and is outlined in *Chapter 4*. The results for this change over time are outlined in *Chapter 6* (S*ection 6.7.1 Change in climatic suitability over time).* The change in climatic suitability over time was only calculated for Roland Garros Airport as the only station with a minimum of 30 years of data. Climatic suitability for the TCI declines overall by 2.1 unit scores per decade with statistically significant declines per decade by a score of 0.9 (January), 1.5 (April), 2.8 (June), 3.1 (July), 3.5 (August), 3.7 (September), 4.2 (October) and 1.0 (December). Climatic suitability for the HCI_{Urban} declines by 0.09 per decade with significant declines in suitability per decade by 1.2 (July), 2.1 (August), 2.1 (October) and 2.8 (November). Only one instance of significant change was found for the HCI_{Beach} with a decline in climatic suitability of 2.3 unit scores per decade in November. The climatic suitability of the CCI changes very little over time with a decline in suitability by 0.1 unit scores per decade with a significant decline per decade of 0.3 in April and 0.2 in December.

8.3 Future Research Trajectories

Given the time and resources to pursue this study, there are multiple avenues of research that could be taken beyond this research. Ground-based data at all major beach, urban and camping sites could be obtained and compared to meteorological station data. Further data could be acquired from Météo-France for 2024 to compare to *in situ* ground-based measurements taken during a 2024 field trip. Given the implication of heat stress identified in *Chapter 7*, further research needs to investigate the actual instances of heat stress experienced in the island and within the greater SWIO region. As the southern African region is projected to experience intense heat, greater future projections of heat and precipitation cycles need to be examined. Future research could look to obtain more perception data of climate variables from French and local tourists to get a context-specific understanding of climatic preferences for Réunion Island contributing both to this work and previous work using TripAdvisor reviews (Fitchett *et al.*, 2020). Policy implications for climatic suitability over time should be examined. As a French department and part of the European Union (EU), Réunion Island is implicated in broader policies overseas while experiencing particular changes in the southern hemisphere context. The examination of policies and the inclusion of overseas departments could assist in necessary policy changes to assist small islands that will experience great climatic change in the future.

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APPENDIX A: PERCENTAGE OF DATA AVAILABILITY PER METEOROLOGICAL STATION

Cilaos Station-1197												
Year	Precip	Tmin	Tmax	Sunshine hours	Wind speed	Max Humidity	Mean Humidity	Cloud Cover	TCI	HCI-U	HCI-B	CCI
1991	100.0	100.0	100.0	100.0	96.4	89.6	89.6	0.0	Yes	No	No	Yes
1992	100.0	100.0	100.0	100.0	100.0	99.5	99.5	0.0	Yes	No	No	Yes
1993	100.0	100.0	100.0	84.1	99.5	99.5	99.5	0.0	Yes	No	No	Yes
1994	100.0	100.0	100.0	100.0	98.9	98.9	98.9	0.0	Yes	No	No	Yes
1995	100.0	100.0	100.0	100.0	100.0	98.6	98.6	0.0	Yes	No	No	Yes
1996	100.0	100.0	100.0	100.0	98.6	100.0	100.0	0.0	Yes	No	No	Yes
1997	100.0	100.0	100.0	100.0	98.9	98.9	98.9	0.0	Yes	No	No	Yes
1998	100.0	100.0	100.0	100.0	99.7	100.0	100.0	0.0	Yes	No	No	Yes
1999	100.0	100.0	100.0	100.0	99.7	99.7	99.7	0.0	Yes	No	No	Yes
2000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2001	100.0	100.0	100.0	100.0	100.0	77.0	77.0	0.0	Yes	No	No	Yes
2002	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
2003	100.0	100.0	100.0	100.0	98.1	0.0	0.0	0.0	No	No	No	No
2004	100.0	100.0	100.0	100.0	98.6	0.0	0.0	0.0	No	No	No	No
2005	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
2006	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
2007	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
2008	100.0	100.0	100.0	0.0	98.6	0.0	0.0	0.0	No	No	No	No
2009	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2010	100.0	100.0	100.0	0.0	96.7	0.0	0.0	0.0	No	No	No	No
2011	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2012	100.0	100.0	100.0	0.0	98.6	73.5	73.5	0.0	No	No	No	Yes
2013	100.0	100.0	100.0	0.0	97.8	100.0	100.0	0.0	No	No	No	Yes
2014	100.0	100.0	100.0	0.0	96.2	98.9	98.9	0.0	No	No	No	Yes
2015	100.0	100.0	100.0	0.0	94.0	95.9	95.9	0.0	No	No	No	Yes
2016	100.0	100.0	100.0	54.1	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2017	100.0	100.0	100.0	95.3	99.7	100.0	100.0	0.0	Yes	No	No	Yes
2018	100.0	100.0	100.0	99.5	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2019	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2020	100.0	100.0	100.0	99.7	99.7	100.0	100.0	0.0	Yes	No	No	Yes
2021	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2022	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2023	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes

Colimacons Station-798												
Year	Precip	Tmin	Tmax	Sunshine hours	Wind speed	Max Humidity	Mean Humidity	Cloud Cover	TCI	HCI-U	HCI-B	CCI
1991	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	No	No	No	No
1992	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	No	No	No	No
1993	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	No	No	No	No
1994	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	No	No	No	No
1995	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	No	No	No	No
1996	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	No	No	No	No
1997	100.0	100.0	100.0	100.0	0.0	70.7	70.7	0.0	No	No	No	No
1998	100.0	100.0	100.0	100.0	0.0	80.5	80.5	0.0	No	No	No	No
1999	100.0	100.0	100.0	100.0	0.0	100.0	100.0	0.0	No	No	No	No
2000	100.0	100.0	100.0	100.0	0.0	99.2	99.2	0.0	No	No	No	No
2001	100.0	100.0	100.0	100.0	0.0	100.0	100.0	0.0	No	No	No	No
2002	100.0	100.0	100.0	100.0	0.0	99.5	99.5	0.0	No	No	No	No
2003	100.0	100.0	100.0	100.0	0.0	89.3	89.3	0.0	No	No	No	No
2004	100.0	100.0	100.0	100.0	0.0	4.4	4.4	0.0	No	No	No	No
2005	100.0	100.0	100.0	32.6	0.0	0.0	0.0	0.0	No	No	No	No
2006	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	No	No	No	No
2007	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	No	No	No	No
2008	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	No	No	No	No
2009	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	No	No	No	No
2010	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	No	No	No	No
2011	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	No	No	No	No
2012	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	No	No	No	No
2013	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	No	No	No	No
2014	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	No	No	No	No
2015	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	No	No	No	No
2016	100.0	100.0	100.0	94.5	94.3	94.8	94.8	0.0	Yes	No	No	Yes
2017	100.0	100.0	100.0	97.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2018	100.0	100.0	100.0	99.2	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2019	100.0	100.0	100.0	99.7	99.5	100.0	100.0	0.0	Yes	No	No	Yes
2020	100.0	100.0	100.0	99.7	99.7	100.0	100.0	0.0	Yes	No	No	Yes
2021	100.0	100.0	100.0	98.9	99.1	99.5	100.0	0.0	Yes	No	No	Yes
2022	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2023	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes

Le Baril Station-115												
Year	Precip	Tmin	Tmax	Sunshine hours	Wind speed	Max Humidity	Mean Humidity	Cloud Cover	TCI	HCI-U	HCI-B	CCI
1991	100.0	100.0	100.0	0.0	96.7	89.6	89.6	0.0	No	No	No	No
1992	100.0	100.0	100.0	0.0	95.9	80.3	80.3	0.0	No	No	No	No
1993	100.0	100.0	100.0	0.0	96.4	0.5	0.5	0.0	No	No	No	No
1994	100.0	100.0	100.0	0.0	97.8	0.0	0.0	0.0	No	No	No	No
1995	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
1996	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
1997	100.0	100.0	100.0	0.0	99.7	0.0	0.0	0.0	No	No	No	No
1998	100.0	100.0	100.0	0.0	98.6	0.0	0.0	0.0	No	No	No	No
1999	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2000	100.0	100.0	100.0	0.0	99.5	0.0	0.0	0.0	No	No	No	No
2001	100.0	100.0	100.0	0.0	99.2	0.0	0.0	0.0	No	No	No	No
2002	100.0	100.0	100.0	0.0	97.3	0.0	0.0	0.0	No	No	No	No
2003	100.0	100.0	100.0	0.0	99.5	0.0	0.0	0.0	No	No	No	No
2004	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2005	100.0	100.0	100.0	0.0	98.4	0.0	0.0	0.0	No	No	No	No
2006	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2007	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2008	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2009	100.0	100.0	100.0	0.0	98.6	0.0	0.0	0.0	No	No	No	No
2010	100.0	100.0	100.0	0.0	95.3	0.0	0.0	0.0	No	No	No	No
2011	100.0	100.0	100.0	0.0	95.9	0.0	0.0	0.0	No	No	No	No
2012	100.0	100.0	100.0	0.0	98.6	0.0	0.0	0.0	No	No	No	No
2013	100.0	100.0	100.0	0.0	98.1	0.0	0.0	0.0	No	No	No	No
2014	100.0	100.0	100.0	0.0	95.3	0.0	0.0	0.0	No	No	No	No
2015	100.0	100.0	100.0	3.8	97.5	4.1	4.1	0.0	Yes	No	No	Yes
2016	100.0	100.0	100.0	99.7	100.0	98.4	98.4	0.0	Yes	No	No	Yes
2017	100.0	100.0	100.0	97.8	98.9	99.7	99.7	0.0	Yes	No	No	Yes
2018	100.0	100.0	100.0	99.2	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2019	100.0	100.0	100.0	99.7	98.6	100.0	100.0	0.0	Yes	No	No	Yes
2020	100.0	100.0	100.0	99.7	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2021	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2022	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2023	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes

Le Port Station-115												
Year	Precip	Tmin	Tmax	Sunshine hours	Wind speed	Max Humidity	Mean Humidity	Cloud Cover	TCI	HCI-U	HCI-B	CCI
1991	100.0	100.0	100.0	100.0	89.9	90.1	90.1	0.0	Yes	No	No	Yes
1992	100.0	100.0	100.0	100.0	99.7	100.0	100.0	0.0	Yes	No	No	Yes
1993	100.0	100.0	100.0	100.0	99.5	94.0	94.0	0.0	Yes	No	No	Yes
1994	100.0	100.0	100.0	100.0	100.0	92.6	92.6	0.0	Yes	No	No	Yes
1995	100.0	100.0	100.0	100.0	100.0	14.8	14.8	0.0	Yes	No	No	Yes
1996	100.0	100.0	100.0	100.0	99.7	0.0	0.0	0.0	No	No	No	No
1997	100.0	100.0	100.0	100.0	99.5	0.0	0.0	0.0	No	No	No	No
1998	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
1999	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
2000	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
2001	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
2002	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
2003	100.0	100.0	100.0	100.0	99.7	0.0	0.0	0.0	No	No	No	No
2004	100.0	100.0	100.0	24.9	100.0	0.0	0.0	0.0	No	No	No	No
2005	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2006	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2007	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2008	100.0	100.0	100.0	0.0	99.2	0.0	0.0	0.0	No	No	No	No
2009	100.0	100.0	100.0	0.0	99.5	0.0	0.0	0.0	No	No	No	No
2010	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2011	100.0	100.0	100.0	0.0	96.7	0.0	0.0	0.0	No	No	No	No
2012	100.0	100.0	100.0	0.0	98.6	0.3	0.3	0.3	No	Yes	Yes	No
2013	100.0	100.0	100.0	0.0	94.5	0.0	0.0	0.0	No	No	No	No
2014	100.0	100.0	100.0	0.0	96.7	0.0	0.0	0.0	No	No	No	No
2015	100.0	100.0	100.0	5.5	97.0	5.8	5.8	0.0	Yes	No	No	Yes
2016	100.0	100.0	100.0	99.5	99.5	100.0	100.0	0.0	Yes	No	No	Yes
2017	100.0	100.0	100.0	95.6	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2018	100.0	100.0	100.0	99.5	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2019	100.0	100.0	100.0	99.7	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2020	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2021	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2022	100.0	100.0	100.0	100.0	98.6	99.5	99.7	0.0	Yes	No	No	Yes
2023	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes

Petite France Station-1200												
Year	Precip	Tmin	Tmax	Sunshine hours	Wind speed	Max Humidity	Mean Humidity	Cloud Cover	TCI	HCI-U	HCI-B	CCI
1991												
1992												
1993												
1994												
1995												
1996												
1997												
1998												
1999	100.0	94.0	94.2	66.6	92.9	93.4	93.4	0.0	Yes	No	No	Yes
2000	100.0	100.0	100.0	0.0	96.2	96.4	96.4	0.0	No	No	No	No
2001	100.0	100.0	100.0	0.0	99.7	99.7	99.7	0.0	No	No	No	No
2002	100.0	100.0	100.0	0.0	92.3	91.0	91.0	0.0	No	No	No	No
2003	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	No	No	No	No
2004	100.0	100.0	100.0	0.0	98.4	8.5	8.5	0.0	No	No	No	No
2005	100.0	100.0	100.0	0.0	89.6	0.0	0.0	0.0	No	No	No	No
2006	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2007	100.0	100.0	100.0	0.0	95.3	0.0	0.0	0.0	No	No	No	No
2008	100.0	100.0	100.0	0.0	85.8	0.0	0.0	0.0	No	No	No	No
2009	100.0	100.0	100.0	0.0	93.4	0.0	0.0	0.0	No	No	No	No
2010	100.0	100.0	100.0	0.0	91.5	0.0	0.0	0.0	No	No	No	No
2011	100.0	100.0	100.0	0.0	93.2	34.0	34.0	0.0	No	No	No	No
2012	100.0	100.0	100.0	0.0	97.8	99.2	99.2	0.0	No	No	No	No
2013	100.0	100.0	100.0	0.0	81.9	87.9	87.9	0.0	No	No	No	No
2014	100.0	100.0	100.0	0.0	59.5	69.3	69.3	0.0	No	No	No	No
2015	100.0	100.0	100.0	0.0	87.7	93.2	93.2	0.0	No	No	No	No
2016	100.0	100.0	100.0	67.8	92.3	92.9	92.9	0.0	Yes	No	No	Yes
2017	100.0	100.0	100.0	91.8	95.9	98.1	98.1	0.0	Yes	No	No	Yes
2018	100.0	100.0	100.0	98.6	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2019	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2020	100.0	100.0	100.0	99.5	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2021	100.0	100.0	100.0	93.2	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2022	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2023	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes

Pierrefonds-Airport Station-21												
Year	Precip	Tmin	Tmax	Sunshine hours	Wind speed	Max Humidity	Mean Humidity	Cloud Cover	TCI	HCI-U	HCI-B	CCI
1991												
1992												
1993												
1994												
1995												
1996												
1997												
1998												
1999	0.0	98.8	100.0	0.0	98.8	100.0	100.0	0.0	No	No	No	No
2000	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	No	No	No	No
2001	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	No	No	No	No
2002	100.0	100.0	100.0	0.0	100.0	98.6	98.6	0.0	No	No	No	No
2003	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	No	No	No	No
2004	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	No	No	No	No
2005	100.0	100.0	100.0	0.0	99.2	99.7	99.7	0.0	No	No	No	No
2006	100.0	100.0	100.0	0.0	100.0	100.0	100.0	22.2	No	Yes	Yes	No
2007	100.0	100.0	100.0	0.0	99.2	98.1	98.1	31.2	No	Yes	Yes	No
2008	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	No	No	No	No
2009	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	No	No	No	No
2010	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	No	No	No	No
2011	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	No	No	No	No
2012	100.0	100.0	100.0	0.0	99.5	100.0	100.0	0.0	No	No	No	No
2013	100.0	100.0	100.0	0.0	99.5	100.0	100.0	0.0	No	No	No	No
2014	100.0	100.0	100.0	0.0	98.1	100.0	100.0	0.0	No	No	No	No
2015	100.0	100.0	100.0	0.0	98.6	99.7	99.7	62.2	No	Yes	Yes	No
2016	100.0	100.0	100.0	0.0	100.0	100.0	100.0	100.0	No	Yes	Yes	No
2017	100.0	100.0	100.0	0.0	100.0	100.0	100.0	100.0	No	Yes	Yes	No
2018	100.0	100.0	100.0	0.0	100.0	99.7	99.7	100.0	No	Yes	Yes	No
2019	100.0	100.0	100.0	0.0	100.0	100.0	100.0	100.0	No	Yes	Yes	No
2020	100.0	100.0	100.0	0.0	100.0	100.0	100.0	100.0	No	Yes	Yes	No
2021	100.0	100.0	100.0	0.0	100.0	100.0	100.0	100.0	No	Yes	Yes	No
2022	100.0	100.0	100.0	0.0	100.0	100.0	100.0	100.0	No	Yes	Yes	No
2023	100.0	100.0	100.0	0.0	100.0	100.0	100.0	69.9	No	Yes	Yes	No

Piton-Maido Station-2150												
Year	Precip	Tmin	Tmax	Sunshine hours	Wind speed	Max Humidity	Mean Humidity	Cloud Cover	TCI	HCI-U	HCI-B	CCI
1991												
1992												
1993												
1994												
1995												
1996												
1997												
1998	100.0	100.0	100.0	0.0	97.7	100.0	100.0	0.0	No	No	No	No
1999	100.0	100.0	100.0	0.0	97.8	100.0	100.0	0.0	No	No	No	No
2000	100.0	100.0	100.0	0.0	100.0	71.3	71.3	0.0	No	No	No	No
2001	100.0	100.0	100.0	0.0	97.8	100.0	100.0	0.0	No	No	No	No
2002	100.0	92.3	92.3	0.0	87.4	6.0	6.0	0.0	No	No	No	No
2003	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2004	100.0	100.0	100.0	0.0	95.1	0.0	0.0	0.0	No	No	No	No
2005	100.0	100.0	100.0	0.0	97.8	0.0	0.0	0.0	No	No	No	No
2006	100.0	100.0	100.0	0.0	97.0	0.0	0.0	0.0	No	No	No	No
2007	100.0	100.0	100.0	0.0	83.8	0.0	0.0	0.0	No	No	No	No
2008	100.0	100.0	100.0	0.0	20.5	0.0	0.0	0.0	No	No	No	No
2009	100.0	100.0	100.0	0.0	46.0	0.0	0.0	0.0	No	No	No	No
2010	100.0	100.0	100.0	0.0	99.2	0.0	0.0	0.0	No	No	No	No
2011	100.0	100.0	100.0	0.0	98.9	37.0	37.0	0.0	No	No	No	No
2012	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	No	No	No	No
2013	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	No	No	No	No
2014	100.0	100.0	100.0	0.0	95.6	96.2	96.2	0.0	No	No	No	No
2015	100.0	100.0	100.0	0.0	98.4	100.0	100.0	0.0	No	No	No	No
2016	100.0	100.0	100.0	1.1	93.7	98.9	98.9	0.0	Yes	No	No	Yes
2017	100.0	100.0	100.0	96.4	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2018	100.0	100.0	100.0	98.6	99.7	100.0	100.0	0.0	Yes	No	No	Yes
2019	100.0	100.0	100.0	99.7	99.7	100.0	100.0	0.0	Yes	No	No	Yes
2020	100.0	100.0	100.0	98.1	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2021	100.0	100.0	100.0	99.5	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2022	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2023	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes

Plaine des Palmistes Station-1032												
Year	Precip	Tmin	Tmax	Sunshine hours	Wind speed	Max Humidity	Mean Humidity	Cloud Cover	TCI	HCI-U	HCI-B	CCI
1991	100.0	100.0	100.0	100.0	93.7	90.7	90.7	0.0	Yes	No	No	Yes
1992	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
1993	100.0	100.0	100.0	100.0	96.7	88.8	88.8	0.0	Yes	No	No	Yes
1994	100.0	100.0	100.0	100.0	97.5	64.4	64.4	0.0	Yes	No	No	Yes
1995	100.0	100.0	100.0	100.0	99.5	0.0	0.0	0.0	No	No	No	No
1996	100.0	100.0	100.0	100.0	96.7	0.0	0.0	0.0	No	No	No	No
1997	100.0	100.0	100.0	91.5	99.5	0.0	0.0	0.0	No	No	No	No
1998	100.0	100.0	100.0	100.0	99.5	0.0	0.0	0.0	No	No	No	No
1999	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
2000	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
2001	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
2002	100.0	100.0	100.0	100.0	98.9	0.0	0.0	0.0	No	No	No	No
2003	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	No	No	No	No
2004	100.0	100.0	100.0	0.0	98.9	0.0	0.0	0.0	No	No	No	No
2005	100.0	100.0	100.0	0.0	98.9	0.0	0.0	0.0	No	No	No	No
2006	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2007	100.0	100.0	100.0	0.0	98.6	0.0	0.0	0.0	No	No	No	No
2008	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2009	100.0	100.0	100.0	0.0	98.6	0.0	0.0	0.0	No	No	No	No
2010	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2011	100.0	100.0	100.0	0.0	75.3	0.0	0.0	0.0	No	No	No	No
2012	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2013	100.0	100.0	100.0	0.0	99.7	0.0	0.0	0.0	No	No	No	No
2014	100.0	100.0	100.0	0.0	95.3	0.0	0.0	0.0	No	No	No	No
2015	100.0	100.0	100.0	0.0	97.8	0.0	0.0	0.0	No	No	No	No
2016	100.0	100.0	100.0	76.2	93.7	80.9	80.9	0.0	Yes	No	No	Yes
2017	100.0	100.0	100.0	94.8	100.0	98.4	98.4	0.0	Yes	No	No	Yes
2018	100.0	100.0	100.0	99.5	99.7	100.0	100.0	0.0	Yes	No	No	Yes
2019	100.0	100.0	100.0	100.0	99.7	100.0	100.0	0.0	Yes	No	No	Yes
2020	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2021	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2022	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2023	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes

Pont Mathurin Station-19												
Year	Precip	Tmin	Tmax	Sunshine hours	Wind speed	Max Humidity	Mean Humidity	Cloud Cover	TCI	HCI-U	HCI-B	CCI
1991	100.0	100.0	100.0	0.0	98.4	0.0	0.0	0.0	No	No	No	No
1992	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
1993	100.0	100.0	100.0	0.0	99.2	0.0	0.0	0.0	No	No	No	No
1994	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
1995	100.0	100.0	100.0	0.0	98.4	0.0	0.0	0.0	No	No	No	No
1996	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
1997	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
1998	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
1999	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2000	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2001	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2002	100.0	100.0	100.0	0.0	99.5	0.0	0.0	0.0	No	No	No	No
2003	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2004	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2005	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2006	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2007	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2008	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2009	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2010	100.0	100.0	100.0	0.0	98.6	0.0	0.0	0.0	No	No	No	No
2011	100.0	100.0	100.0	0.0	99.7	0.0	0.0	0.0	No	No	No	No
2012	100.0	100.0	100.0	0.0	99.5	0.0	0.0	0.0	No	No	No	No
2013	100.0	100.0	100.0	0.0	98.4	0.0	0.0	0.0	No	No	No	No
2014	100.0	100.0	100.0	0.0	98.9	0.0	0.0	0.0	No	No	No	No
2015	100.0	100.0	100.0	17.3	94.8	17.5	17.5	0.0	Yes	No	No	Yes
2016	100.0	100.0	100.0	99.7	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2017	100.0	100.0	100.0	92.6	100.0	99.7	99.7	0.0	Yes	No	No	Yes
2018	100.0	100.0	100.0	99.5	100.0	99.7	99.7	0.0	Yes	No	No	Yes
2019	100.0	100.0	100.0	100.0	99.7	100.0	100.0	0.0	Yes	No	No	Yes
2020	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2021	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2022	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2023	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes

Roland Garros Airport Station-8												
Year	Precip	Tmin	Tmax	Sunshine hours	Wind speed	Max Humidity	Mean Humidity	Cloud Cover	TCI	HCI-U	HCI-B	CCI
1991	100.0	100.0	100.0	100.0	91.8	100.0	100.0	100.0	Yes	Yes	Yes	Yes
1992	100.0	100.0	100.0	100.0	98.9	99.7	99.7	99.5	Yes	Yes	Yes	Yes
1993	100.0	100.0	100.0	100.0	98.1	100.0	100.0	100.0	Yes	Yes	Yes	Yes
1994	100.0	100.0	100.0	100.0	99.5	86.0	86.0	86.0	Yes	Yes	Yes	Yes
1995	100.0	100.0	100.0	100.0	99.7	100.0	100.0	100.0	Yes	Yes	Yes	Yes
1996	100.0	100.0	100.0	100.0	100.0	100.0	100.0	75.1	Yes	Yes	Yes	Yes
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
1998	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
1999	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.4	Yes	Yes	Yes	Yes
2000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2001	100.0	100.0	100.0	100.0	99.7	100.0	100.0	98.6	Yes	Yes	Yes	Yes
2002	100.0	100.0	100.0	100.0	99.5	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2003	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2004	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2005	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2006	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2007	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2008	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2009	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2010	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2011	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2012	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2013	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2014	100.0	100.0	100.0	100.0	99.7	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2015	100.0	100.0	100.0	100.0	99.5	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2016	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2017	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2018	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2019	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2020	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2021	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2022	100.0	100.0	100.0	100.0	98.9	100.0	100.0	100.0	Yes	Yes	Yes	Yes
2023	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	Yes	Yes	Yes	Yes

Saint Benoit Station-43												
Year	Precip	Tmin	Tmax	Sunshine hours	Wind speed	Max Humidity	Mean Humidity	Cloud Cover	TCI	HCI-U	HCI-B	CCI
1991	100.0	100.0	100.0	0.0	70.1	0.0	0.0	0.0	No	No	No	No
1992	100.0	100.0	100.0	0.0	46.7	0.0	0.0	0.0	No	No	No	No
1993	100.0	100.0	100.0	0.0	96.4	0.0	0.0	0.0	No	No	No	No
1994	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	No	No	No	No
1995	100.0	100.0	100.0	0.0	93.7	0.0	0.0	0.0	No	No	No	No
1996	100.0	100.0	100.0	0.0	98.6	0.0	0.0	0.0	No	No	No	No
1997	100.0	100.0	100.0	0.0	99.5	0.0	0.0	0.0	No	No	No	No
1998	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
1999	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2000	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2001	100.0	100.0	100.0	0.0	98.6	0.0	0.0	0.0	No	No	No	No
2002	100.0	100.0	100.0	0.0	98.4	0.0	0.0	0.0	No	No	No	No
2003	100.0	100.0	100.0	0.0	95.9	0.0	0.0	0.0	No	No	No	No
2004	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2005	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2006	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2007	100.0	100.0	100.0	0.0	99.2	0.0	0.0	0.0	No	No	No	No
2008	100.0	100.0	100.0	0.0	100.0	0.0	0.0	0.0	No	No	No	No
2009	100.0	100.0	100.0	0.0	97.3	0.0	0.0	0.0	No	No	No	No
2010	100.0	100.0	100.0	0.0	93.7	0.0	0.0	0.0	No	No	No	No
2011	100.0	100.0	100.0	0.0	95.9	0.0	0.0	0.0	No	No	No	No
2012	100.0	100.0	100.0	0.0	92.3	0.0	0.0	0.0	No	No	No	No
2013	100.0	100.0	100.0	0.0	95.3	0.0	0.0	0.0	No	No	No	No
2014	100.0	100.0	100.0	0.0	93.4	0.0	0.0	0.0	No	No	No	No
2015	100.0	100.0	100.0	0.0	17.3	17.8	17.8	0.0	No	No	No	No
2016	100.0	100.0	100.0	98.6	99.2	100.0	100.0	0.0	Yes	No	No	Yes
2017	100.0	100.0	100.0	95.6	98.4	98.9	98.9	0.0	Yes	No	No	Yes
2018	100.0	100.0	100.0	99.2	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2019	100.0	100.0	100.0	99.7	99.7	100.0	100.0	0.0	Yes	No	No	Yes
2020	100.0	100.0	100.0	99.7	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2021	100.0	100.0	100.0	99.2	99.5	100.0	100.0	0.0	Yes	No	No	Yes
2022	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	Yes	No	No	Yes
2023	100.0	100.0	100.0	98.6	100.0	100.0	100.0	0.0	Yes	No	No	Yes

APPENDIX B: TCI LITERATURE REVIEW TABLE

Date	Author	Journal	Location
1985	Mieczkowski	Canadian Geographer/Le Géographe Canadien	Global
2001	Matzarakis	Proceedings of the First International Workshop on Climate, Tourism and Recreation	Greece
2001	Scott and McBoyle	First International Workshop on Climate, Tourism and Recreation	North America, Canada, USA
2001	de Freitas	Proceedings of the First International Workshop on Climate, Tourism and Recreation	Global
2001	Perry	Proceedings of the First International Workshop on Climate, Tourism and Recreation	Mediterranean
2003	Scott *et al.*	First International Conference on Climate Change and Tourism	North America, Canada, USA
2003	de Freitas	International Journal of Biometeorology	Global
2004	Scott *et al.*	Climate Research	North America, Canada, USA, Mexico
2005	de Freitas	Tourism, Recreation and Climate Change: International Perspectives	Global
2005	Perry	Tourism, recreation and climate change	Mediterranean
2005	Scott *et al.*	Tourism, recreation and climate change	North America, Canada, USA, Mexico
2006	Amelung and Viner	Journal of Sustainable Tourism	Mediterranean
2006	Matzarakis	Tourism and Hospitality Planning & Development	Greece
2007	Amelung *et al.*	Journal of Travel Research	Global
2007	Matzarakis *et al.*	Developments in Tourism Climatology	Global
2007	Amelung and Viner	Institute of Geography and Spatial Organization	Mediterranean
2008	Amiranashvili *et al.*	Transactions of the Georgian Institute of Hydrometeorology	Georgia
2008	Mishev and Mochurova	International conference "global environmental change: challenges to science and society in south-eastern Europe"	Central and Eastern Europe
2009	Hain et al.	Current Opinion in Environmental Sustainability	Spain
2009	Farajzadeh and Matzarakis	Meteorological Applications	Northwest Iran
2009	Perry	Journal of Sustainable Tourism	Mediterranean
2009	Moreno and Amelung	Coastal Management	Europe
2009	Roshan *et al.*	Journal of Geography and Regional Planning	Iran, Tehran city
2010	Amiranashvili *et al.*	Collection of Scientific Works of International Conference	Batumi, Georgia
2010	Farajzadeh and Ahmadabadi	Physical Geography Research Quarterly	Iran
2010	Moore	Current Issues in Tourism	Carribean
2010	Moreno	Tourism and Hospitality Planning and Development	Mediterranean
2010	Perch-Nielsen	Climate Change	Global
2010	Perch-Nielsen *et al.*	Climate Change	Europe
2010	Gandomkar	Journal of Physical Geography	Isfahan, Iran
2010	Eugenio-Martin and Campos-Soria	Tourism Management	Global
2010	Becken	(Monograph) Research Archive Lincoln	Global
2011	Shakoor	International Journal of the Physical Sciences	Yazd Province, Iran
2011	Lin and Matzarakis	Tourism Management	Taiwan, Eastern China
2011	Shiue and Matzarakis	International Journal of Biometeorology	Australia
2011	Gandomkar and Mohseni	Economics and Tourism Management	Iran,Mazandaran Province
2012	Cashman et al.	Tourism Review	Barbados

2012	Gourabi and Palic	Acta Geographica Debrecina Landscape and Environment	Iran
2012	Kulendran and Dwyer	Tourism Analysis	Global
2013	Bakhtiari and Bakhtiari	Desert	Iran, Kerman Province
2013	Németh	Journal of Environmental Geography	Hungary
2013	Yazdanpanah *et al.*	Geography and Environmental Planning	Iran
2013	Omrani and Yazdanpanah	Geographic Space	Iran
2013	Joksimović *et al.*	Glasnik Srpskog Geografskog Društva - DOAJ	Montenegro
2014	Mailly *et al.*	Journal of Multi-Criteria Decision Analysis	Global
2014	Rosselló-Nadal	Tourism Management	Global
2014	Amelung and Nicholls	Tourism Management	Australia
2014	Kovács and Unger	Quarterly Journal of the Hungarian Meteorological Service	Central Europe
2014	Amiranashvili *et al.*	Journal of the Georgian Geophyscial Society	Baku, Tbilisi, Yerevan
2014	Ghanbari and Karimi	Journal of Regional Planning	Isfahan, Iran
2014	Matzarakis	Sustainable Environment	Global
2014	Matzarakis *et al.*	Global NEST Journal	Athens, Greece
2014	Kubokawa *et al.*	Journal of the Meteorological Society of Japan	Japan
2014	Méndez-Lázaro *et al.*	Ecology and Society	Puerto Rico
2014	Roson *et al.*	International Journal of Climate Change Strategies and Management	Mediterranean
2014	Kovács and Unger	Acta Climatologica et Chorologic	Hungary
2015	Olya and Alipour	Tourism Management	North Cyprus
2015	Amiranashvili *et al.*	International Scientific Conference “Sustainable Mountain Regions: Make Them Work”	Georgia
2015	Fang and Yin	Atmosphere	China
2015	Mokhtari and Anvari	Journal of Novel Applied Sciences	Iran
2015	Olya and Alipour	Fresenius Environmental Bulletin	Mediterranean
2016	Lorde *et al.*	Journal of Travel Research	Carribean
2016	Kovác *et al.*	Theorectical and Applied Climatology	Hungary
2016	Grillakis *et al.*	International Journal of Biometeorology	Europe
2016	Grillakis *et al.*	Climate Services	Europe
2016	Scott *et al.*	Atmosphere	Europe
2016	Roshan *et al.*	International Journal of Biometeorology	Iran
2016	Fitchett *et al.*	South African Journal of Science	South Africa
2016	Fitchett *et al.*	Tourism: an International Scientific-Professional Journal	South Africa
2016	Mereu *et al.*	Science of the Total Environment	Sardinia, Italy
2016	Zhang and Kulendran	Journal of Travel Research	Hong Kong, China
2016	Köberl *et al.*	Science of the Total Environment	Tunisia, Italy
2016	Amiranashvili *et al.*	Actual Problems of Pathology, Therapy and Medical Rehabilitation	Eastern Georgia
2016	Dubois *et al.*	Earth Perspectives	Mediterranean
2017	Li *et al.*	Journal of Travel Research	Hong Kong, China

2017	Fitchett *et al.*	Journal of Sustainable Tourism	South Africa
2017	Amiranashvili *et al.*	Journal of Georgian Geophysical Society	Georgia and North Caucasus (Russia)
2018	Hoogendoorn and Fitchett	(Book) Handbook of Research Methods for Tourism and Hospitality Management	South Africa
2018	Om *et al.*	Asia Pacific Journal of Tourism Research	PDR Korea
2018	Ahmadi *et al.*	Modeling Earth Systems and Environment	Iran
2018	Amiranashvili *et al.*	Journal of the Georgian Geophysical Society	Georgia
2018	Huang *et al.*	Theoretical and Applied Climatology	China
2018	Mihăilă and Bistricean	Present Environment and Sustainable Development	Moldova
2019	Georgopoulou *et al.*	Theoretical and Applied Climatology	Georgia
2019	Heydari Alamdarloo *et al.*	Scientific Journals Management System	Yazd Province, Iran
2019	Razzaq and Abbood	Transylvanian Review	Iraq
2019	Mahmoud *et al.*	GeoJournal of Tourism and Geosites	Egypt
2019	Noome and Fitchett	Journal of Mountian Science	Lesotho
2019	Zhong *et al.*	Journal of Geographical Sciences	China
2019	Abbasnia *et al.*	Journal of Research in Atmospheric Science	Turkey
2019	Hejazizadeh *et al.*	Arabian Journal of Geosciences	Iran
2020	Rutty *et al.*	Atmosphere	Carribean
2020	Derradji *et al.*	International Journal of Innovation and Applied Studies	Algeria
2020	Qiang	Current Issues in Tourism	China
2020	Sobhani and Safarian Zengir	Modeling Earth Systems and Environment	Iran
2020	Nguyen *et al.*	Vietnam Journal of Marine Science and Technolohy	Vietnam
2020	Hasanah *et al.*	Heliyon	Indonesia
2021	Yu *et al.*	International Journal of Biometeorology	China
2021	Noome and Fitchett	Environment, Development and Sustainability	Namibia
2021	Mushawemhuka *et al.*	South African Geographical Journal	Zimbabwe
2021	Alonso-Pérez *et al.*	Sustainability	Canary Islands
2021	Masoudi	Arabian Journal of Geosciences	Iran
2021	Dong and Xia	Geographica Pannonica	China
2021	Ma *et al.*	Tourism Recreation Research	United States of America
2021	Matthews *et al.*	International Journal of Biometeorology	Canada
2021	Matthews *et al.*	Current Issues in Tourism	Carribean
2021	Fitchett	(Book)Urban Tourism in the Global South	South Africa
2021	Ma *et al.*	Tourism Recreation Research	United States of America
2022	Wang *et al.*	Atmospheric Research	China
2022	Hidayat	Jurnal Meteorologi dan Geofisika	Indonesia
2022	Adiguzel *et al.*	Theoretical and Applied Climatology	Turkey
2022	Derkowska and Araźny	Bulletin of Geography- Physical Geography Series	Poland
2022	El-Masry *et al.*	Environment, Development and Sustainability	Egypt

2022	Shahzad *et al.*	Environment, Development and Sustainability	Pakistan
2022	Abedi *et al.*	Social Studies in Tourism	Iran
2022	Aygün Oğur and Baycan	Environment, Development and Sustainability	Turkey
2022	Joudaki	Geography (Regional Planning)	Isfahan, Iran
2022	Efe *et al.*	Climate	Turkey
2022	Sobhani and Danehkar	Journal of Natural Environment	Iran
2023	Faraj *et al.*	International Journal of Environmental Science and Technology	Saudia Arabia
2023	Li and Chen	SHS Web of Conferences	China
2023	Faraj *et al.*	International Journal of Environmental Science and Technology	Saudia Arabia
2023	Li *et al.*	Current Issues in Tourism	China
2023	Aygün Oğur and Baycan	Environment, Development and Sustainability	Turkey
2024	Ullah *et al.*	Heliyon	Pakistan

APPENDIX C: HCI_{Urban} LITERATURE REVIEW TABLE

Date	Author	Journal	Location
2013	Tang	Masters thesis	15 European cities
2016	Scott *et al.*	Atmosphere	6 European cities
2017	Javan	Physical Geography Research Quarterly	Iran
2018	Mahtabi and Taran	Desert	Iran
2018	Öztürk and Göral	Global Journal of Emerging Trends in e-Business	Turkey
2018	Arbabi *et al.*	Regional Planning	Iran
2019	Hejazizadeh *et al.*	Arabian Journal of Geosciences	Iran
2020	Demiroglu *et al.*	Atmosphere	Mediterranean
2020	Hasanah *et al.*	Heliyon	Indonesia
2020	Rutty *et al.*	Atmosphere	Caribbean (Antigua and Barbuda, Barbados, Saint Lucia)
2021	Amiranashvili *et al.*	Journal of the Georgian Geophysical Society	Georgia
2021	Williams	Josei International University Bulletin	Japan
2021	Amiranashvili and Kartvelishvili	Journals of Georgian Geophysical Society	Georgia
2022	Velea *et al.*	Atmosphere	Romania
2022	Yu *et al.*	Current Issues in Tourism	China
2022	Motahari *et al.*	Journal of Natural Environment	Iran
2022	Carillo *et al.*	Regional Environmental Change	Canary Islands
2023	Samarasinghe *et al.*	Climate	Sri Lanka
2023	Oğur	Current Urban Studies	Turkey
2023	Díaz-Poso *et al.*	Investigaciones Turísticas	Spain
2023	Velea *et al.*	Atmosphere	Romania
2023	Ma *et al.*	Tourism Recreation Research	USA
2023	Sudiar *et al.*	Journal of Climate Change Society	Indonesia
2023	Jong *et al.*	Asian Journal of Business Research Volume	Malaysia
2023	Akmal *et al.*	Buletin Meteorologi, Klimatologi dan Geofisika	Indonesia
2024	Mazzarano *et al.*	Tourism Economics	Italy
2024	Amiranashvili *et al.*	Georgian Geographical Journal	Georgia
2024	Bilgin *et al.*	International Journal of Biometeorology	Turkey
2024	Xu et al.	International Journal of Biometeorology	China
2024	Craig	International Journal of Tourism Citites	Australia
2024	Lemesios *et al.*	Atmosphere	Greece
2024	Hidayat *et al.*	Jurnal Meteorologi dan Geofisika	Indonesia
2024	Hemmati and Taghiloo	Geography and Human Relationships	Azerbaijan
2024	Amiranashvili *et al.*	Journals of Georgian Geophysical Society	Georgia
2024	Kristensen	Masters thesis	South Africa

APPENDIX D: HCI_{Beach} LITERATURE REVIEW TABLE

Date	Author	Journal	Location
2020	Rutty *et al.*	Atmosphere	Caribbean (Antigua and Barbuda, Barbados, Saint Lucia)
2020	Demiroglu *et al.*	Atmosphere	Mediterranean
2021	Amiranashvili *et al.*	Journal of the Georgian Geophysical Society	Georgia
2021	Yu *et al.*	International Journal of Biometeorology	China
2021	Ma *et al.*	Tourism Recreation Research	USA
2022	Yu *et al.*	Current Issues in Tourism	China
2022	Carillo *et al.*	Regional Environmental Change	Canary Islands
2022	Gao *et al.*	Sustainability	China
2022	Zajch *et al.*	Regional Environmental Change	Japan
2023	Sumaja *et al.*	Proceedings of the International Conference on Radioscience, Equatorial Atmospheric Science and Environment and Humanosphere Science	Indonesia
2023	Sobani and Danehkar	Journal of Natural Environment	Iran
2023	Samarasinghe *et al.*	Climate	Sri Lanka
2023	Magyari-sáska and Magyari-sáska	Geographia Technica	Hungary
2023	Sudiar *et al.*	Journal of Climate Change Society	Indonesia
2024	Bilgin *et al.*	International Journal of Biometeorology	Turkey
2024	Craig	International Journal of Tourism Citites	Australia
2024	Lemesios *et al.*	Atmosphere	Greece
2024	Amiranashvili *et al.*	Journals of Georgian Geophysical Society	Georgia
2024	Kristensen	Masters thesis	South Africa

APPENDIX E: CCI LITERATURE REVIEW TABLE

Date	Author	Journal	Location
2020	Ma *et al.*	Tourism Management	USA
2021	Ma *et al.*	Tourism Recreation Research	USA
2021	Ma *et al.*	Current Issues in Tourism	USA
2023	Ma *et al.*	Tourism and Hospitality	Global
2024	Mnguni and Fitchett	South African Geographical Journal	South Africa