Mental models of seasonal forecasting outputs among experts and decision-makers

RESEARCH REPORT

BIANCA DE CARVALHO 1091457
SUPERVISOR: PROF. ANDREW THATCHER

A RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MA BY COURSEWORK AND RESEARCH REPORT IN THE FIELD OF ORGANISATIONAL PSYCHOLOGY IN THE FACULTY OF HUMANITIES, UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG,

17 FEBRUARY 2020

PLAGIARISM DECLARATION

Masters in Psychology – Research Report

Surname: De Carvalho

First name/s: Bianca França

Student no.: 1091457

Supervisor: Professor Andrew Thatcher

Title: Mental models of seasonal forecasting outputs among experts and decision-makers

Total Word Count: 37 851 words (excluding Reference List, appendices etc.)

I, Bianca França De Carvalho, declare that this research project is my own, unaided work. It has not been submitted before for any other degree or examination at this or any other university. Consequently, I declare that

- The research proposal is my own work.
- I understand what plagiarism is, and the importance of clearly and appropriately acknowledging my sources.
- I understand that questions about plagiarism can arise in any piece of work I submit, regardless of whether that work is to be formally assessed or not.
- I understand that a proper paraphrase or summary of ideas/ content from a particular source should be written in my own words with my own sentence structure, and be accompanied by an appropriate reference.
- I have correctly acknowledged all direct quotations and paraphrased ideas/ content by way of appropriate, APA-style in-text references.
- I have provided a complete, alphabetized reference list, as required by the APA method of referencing.
- I understand that anti-plagiarism software (e.g. TurnItIn) is a useful resource, but that such software does not provide definitive proof that a document is free of plagiarism.
- I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.
- I am aware of and familiar with the University of the Witwatersrand's policy on plagiarism.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work, or that I failed to acknowledge the source of the ideas or words in my writing.
- The word count (excluding the Reference List, etc.) given above is correct.

Signed: ____________________

Date: 01/06/2020

ABSTRACT

Climate data and change model outputs (such as seasonal forecasting maps as investigated in this study) are important ways in which climate variability and change is communicated. Typically, experts in climate science have used this data, however an increasing number of decision- and policy-makers have been making use of these outputs. A problem arises when climate scientists and decision-makers have different needs in terms of the ways in which these outputs should be composed. Thus, some of the outputs are deemed unusable by decision-makers. Mental models refer to the mental interpretations' individuals have of situations or objects in the external world. These interpretations allow individuals to understand topics, draw conclusions and make predictions for the future. These ideas help individuals decide what sort of decisions they should be making. This study intended on matching the design models of the experts versus the mental models of the users. Non-probability, purposive, convenience sampling was used to draw a sample of experts and users of seasonal forecasting outputs. The study utilised semi-structured in-depth interviews where a set of seasonal forecasting outputs were shown to participants to determine if there were any noteworthy differences and similarities between the two. This was done using Interpretative Phenomenological Analysis (IPA). The sample consisted of four experts and ten users. Users were obtained from various sectors such as the Agricultural, Disaster Management, and Research sectors. It was found that there are considerable differences between the design models of the experts, and the mental models of the users. Major differences were specifically found in the interpretations of the skill maps, as well as a user's ability to accurately decipher the acronyms used in the maps. There were also differences in interpretation found among the experts' design models suggesting that there needs to be some level of correspondence among the seasonal forecasting expert community. This may be due to the fact that a number of organisations produce forecasts which each have their design style and way of interpreting the forecasts. Furthermore, there needs to be more collaboration between the two groups during the development and design of these forecast representations, as well as more opportunities for users to gain some knowledge on the seasonal forecasts and how to accurately utilise them in their decision-making.

Keywords: *Climate variability; Expert design models; Mental models; Seasonal forecasting; User metal model*

ACKNOWLEDGEMENTS

I would like to thank the following people, without whom this research would not have been possible. First of all, to my supervisor, Professor Andrew Thatcher, whose guidance and support has carried me through this entire process. I am truly grateful for all of your help throughout this year.

To Professor Coleen Vogel and Professor Willem Landman, I am so thankful for all the guidance you have given me with regards to the topic, finding a sample, as well as providing me with financial support throughout this year. I am forever grateful and have grown so much from the experience.

I would also like to thank all those who took time out of their extremely busy schedules and agreed to participate in my research.

Without all of you, this research would never have been possible.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

1.1. Introduction

This study aimed to determine whether or not there are differences between the mental models of experts in climate science versus the mental models of users of these seasonal forecasting outputs. The users, in this case, were decision- and/or policy-makers in the field. It is argued that there needs to be an alignment between the cognitive models of the two groups in order to ensure accurate decision-making and problem-solving (Kalantzis, Thatcher, & Sheridan, 2016; Vogel, McNie, & Behar, 2016). This study made use of seasonal forecasts which are currently being developed for the South African context. Currently, there are a number of well-known institutions which develop these forecasts monthly. These are the International Research Institute for Climate and Society (IRI) at Columbia University, the South African Weather Service (SAWS), the Council for Scientific and Industrial Research (CSIR), the Climate Systems Analysis Group (CSAG) at the University of Cape Town, and the University of Pretoria (UP) amongst others. Each of these institutions make use of different methods to develop their outputs which result in differing results and predictions. Furthermore, these outputs are presented to users in slightly different ways. These varying strategies, in turn, have effects on the ways in which users understand and make use of them in their decision-making.

Climate data and climate change model outputs are important ways in which climate variability and change is communicated (Overpeck, Meehl, Bony, & Easterling, 2011). Typically, research scientists and climatologists have used this data, however an increasing number of decision- and policy-makers have been making use of these outputs (Overpeck et al., 2011). A problem arises when the scientists and decision-makers have different needs in terms of the ways in which these outputs should be composed. This particularly refers to the differences in decisions made by each group (Vogel et al., 2016). Thus, there is the possibility that some of the outputs are deemed unusable by decision-makers (Vogel et al., 2016). Furthermore, one of the greatest challenges which those who provide the outputs face is the need to present them in a way which is transparent, understandable, and clearly communicates the uncertainty which is an inherent part of all climate outputs (Taylor, Dessai, & de Bruin, 2015).

This study is important as it provides information on how experts as well as users make use of and interpret seasonal forecasting outputs. Of particular importance are the ways in which these outputs are understood by the participants. Furthermore, the data will provide information on the inferences made and risks perceived by the relative groups. In order for a device or system, such as a seasonal forecasting output, to be used effectively there needs to be an alignment between the design models of the experts and the mental model of the users (Kalantzis et al., 2016). In this case, the users would be those who are in charge of policy- and decision-making. These findings are particularly important due to the impact that changes in climate may have on the supply of natural resources and its overall quality for the general public (Vogel et al., 2016). Water managers at major water sources are at the root of the sorts of decisions needed to combat this. Thus, the improvement of these seasonal forecasting outputs could assist with the clarification of solutions and alternatives for water management (Vogel et al., 2016).

This study intends to match the design models of experts versus the mental models of the users. Here, the experts would identify what the seasonal forecasting outputs should mean which would be compared with the ways in which users (decision- and policy-makers) interpret the outputs. Using this information, gaps in knowledge interpretation and understanding may be identified. This is important because misinterpretations have the potential to lead to incorrect decision-making. Through this research, results may provide data on the kinds of information needed by users to make accurate decisions and how this information should be presented and produced for ease of interpretation. Thus, the overall improvement of seasonal forecasting outputs would be considered through this study.

The following chapter will be discussing the importance of seasonal forecast outputs and the mental models which people develop as a result of these outputs. The focus of this literature will be on seasonal forecasting outputs. Firstly, the concept of climate change, and climate change in the context of South Africa will be discussed. Following this, climate change model outputs along with the requirements and challenges related to creating them will be examined. Following this, mental model theory will be discussed along with their relation to seasonal forecasting outputs. Past studies and their findings will then be examined and discussed. Furthermore, challenges regarding seasonal forecasting outputs will be discussed. This will be examined in relation to the current level of skill to produce accurate and reliable forecasts in the South African context, as well as the current perceptions of usefulness by those who make use of the forecasts in their daily lives. Finally, the chapter will outline a number of research questions this study aims to answer.

1.2. Literature Review

1.2.1. Climate Change

The topic of climate change and the ways in which its effects can be reduced are currently popular discussion points throughout the world. Climate change refers to "an ongoing trend of changes in the earth's general weather conditions as a result of an average rise in the temperature of the earth's surface, often referred to as global warming" (The Department of Environmental Affairs, 2012, p. 8). This has been found to be due to the increase of greenhouse gases (GHGs) in the atmosphere (The Department of Environmental Affairs, 2012). It has been found that climate globally is changing faster than ever before. There are a number of consequences which result from climate change such as the rise of sea levels, melting of glacier ice and polar ice-caps, ocean acidification, changes in patterns of rainfall and snowfall, increased frequency of flooding and droughts, as well as increased extreme weather events (The Department of Environmental Affairs, 2012). Thus, climate change threatens the state of our environment which would, in turn, have an effect on the people and animals inhabiting the various regions being affected. Of particular importance for this study, are the issues regarding water scarcity as a result of climate change (Elum, Modise, & Marr, 2017).

1.2.2. Climate Change in the Context of South Africa

Less than 3% of total greenhouse gas emissions are from the African continent (Hope, 2009). However, it has been estimated that by the year 2020, roughly 250 million people in Africa could be exposed to and at risk of water scarcity (Elum et al., 2017). In the context of South Africa, high vulnerabilities have been found with regards to the potential impacts of climate change despite Africa contributing the least to global climate change (The Department of Environmental Affairs, 2012; Hope, 2009). At the moment, Southern Africa has been found to have had higher temperature changes than other regions of the world (Rogerson, 2016). According to Ziervogel et al. (2014), it has been found that South Africa's annual mean temperatures have multiplied by at least 1.5 times the global average, and there has been an increase in extreme rainfall events. Not only would the impacts of climate change affect the agricultural sector, but it would have lasting effects on the water management, tourism, as well as the economy overall (Elum et al., 2017; Rogerson, 2016). Therefore, there is an increasing need for policies and frameworks which would assist with the adaptation to climate change and its potential effects.

1.2.3. Climate Change Model Outputs

In order to create these frameworks and policies, decision- and policy-makers, such as the government and organisations with the relevant permissions, need information to work from in order to make accurate decisions and informed policies on how to address the potential consequences of climate change. This information is typically shown through visual media called climate change model outputs. Thus, it is particularly important that these outputs communicate and display information which is accurate and easy to interpret (Daron, Lorenz, Wolski, Blamey, & Jack, 2015). Climate scientists and researchers are the developers of these outputs due to their expertise in the field, and thus it is necessary to also take the requirements and abilities of these users into consideration (Porter & Dessai, 2017). This can lead to tension between the groups due to the increased demands received from the different user groups such as presenting the data in visually and aesthetically appealing ways and adapting the data for the use of a specific group of people (Daron et al., 2015). However, these requests and requirements could potentially risk distortions in their interpretation (Daron et al., 2015). Thus, there is a need to determine the needs, requirements, abilities, and usability factors for each group in order to regulate a way in which these climate change model outputs could be created to suit both end-users and experts. This is one of the greatest challenges faced by those creating these outputs. There is a much larger audience which needs to be considered who need to manage risks associated with budgets, livelihoods, as well as decision-making regarding the general public (Overpeck et al., 2011).

Climate change model output maps can vary according to what they represent, however, what is particularly important to look at is the way in which the information is represented and displayed to the user. These maps could vary according to colour (including lightness, hue, and saturation), as well as patterns (including shape, size, spacing, arrangement, and orientation) (Retchless & Brewer, 2016) (see Figures 1, 2, 3, 4 and 5 below). Figure 1 shows the different hues which can represent percentage changes in rainfall over different periods of time. Figure 2 presents the different hues associated with precipitation change, as well as white masking which is explained below. Figure 3 demonstrates different hues indicating temperature change in various regions, as well as a method in which the certainty/uncertainty of those forecasts can be communicated to users. Figure 4 displays a multi-model probability forecast for precipitation in the African region utilising different hues to represent probability, as well as white masking. Finally, Figure 5 uses similar methods as Figure 4, but presents their applicability to temperature forecasting. Some guidelines have been drawn up to ensure that the data have not been distorted to create inaccuracies and that there is a purpose with each output (Tufte, 1983). However, the co-production of outputs has increasingly become a more and more popular way of managing these needs and requirements (Porter & Dessai, 2017; Vogel et al., 2016). This idea has been developed because climate scientists and the users of climate change model outputs have different ideas of what is usable and what is relevant to the job at hand (Porter & Dessai, 2017). Co-production involves a collaboration of the two parties, namely the users and producers of seasonal forecasting outputs, identifying the needs, experiences, and limitations of each party to develop outputs which are relevant and disclose all uncertainties explicitly (Vogel et al., 2016). According to Porter and Dessai (2017), co-production aims at narrowing what is known as the 'usability gap'. These guidelines and recommendations may assist in dealing with a few of these challenges, however the interpretations of these outputs are particularly important as they determine the way in which the individual will use the information provided (Daron et al., 2015). According to Daron et al. (2015), the correct interpretation and use of outputs are extremely important for successful adaptation to climate change effects. Thus, showing the importance of this mental model study.

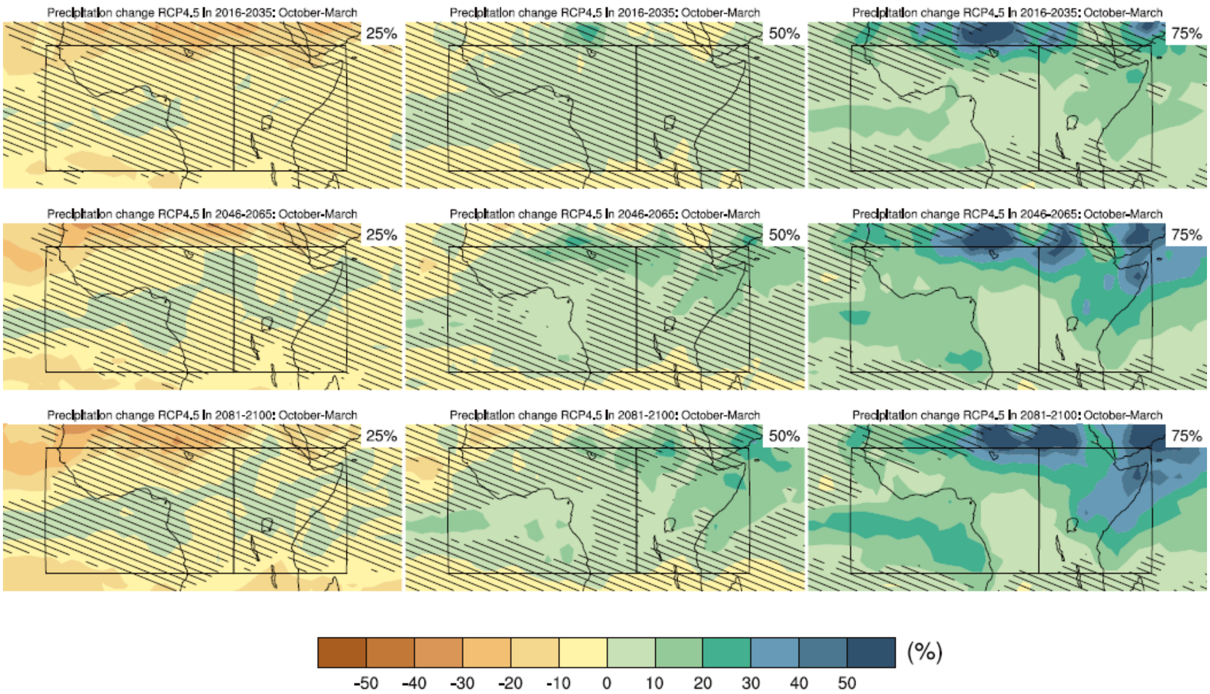


Figure 1: Changes in monthly pattern of rainfall in present and future.

Description of Figure 1: Changes in rainfall for Western and Eastern Africa shown for three periods of time. Figures are presented for different time periods in six-month intervals. The percentage values show the amount of precipitation change compared to the average rainfall in those areas. The black lines in the model represent hatching which means that there is not much variation from current values to projected values. Thus, very little change is projected to occur in these areas (Future Climate for Africa, 2017).

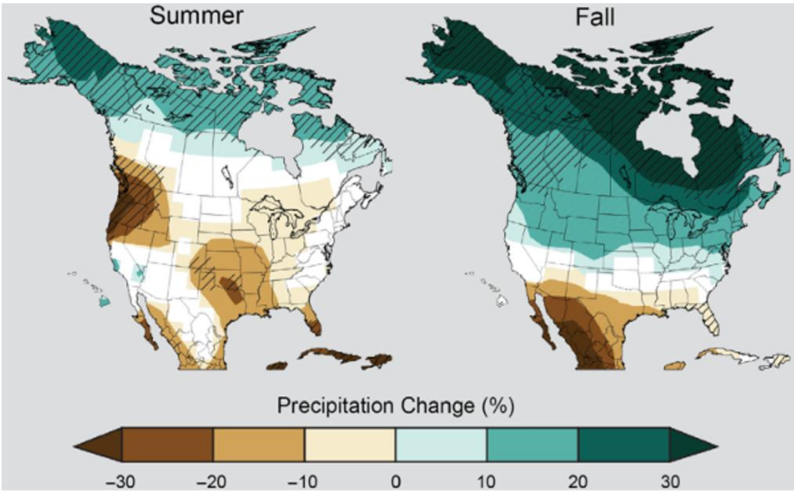


Figure 2: Projected Precipitation Change by Season

Description of Figure 2: Precipitation change refers to the increase or decrease in the amount of rainfall typically received in a particular area, expressed as a percentage change. Hatching patterns are shown for high-certainty areas over the United States. Other areas have been coloured white to show that these are areas of low-certainty. This is called white masking (Retchless & Brewer, 2016).

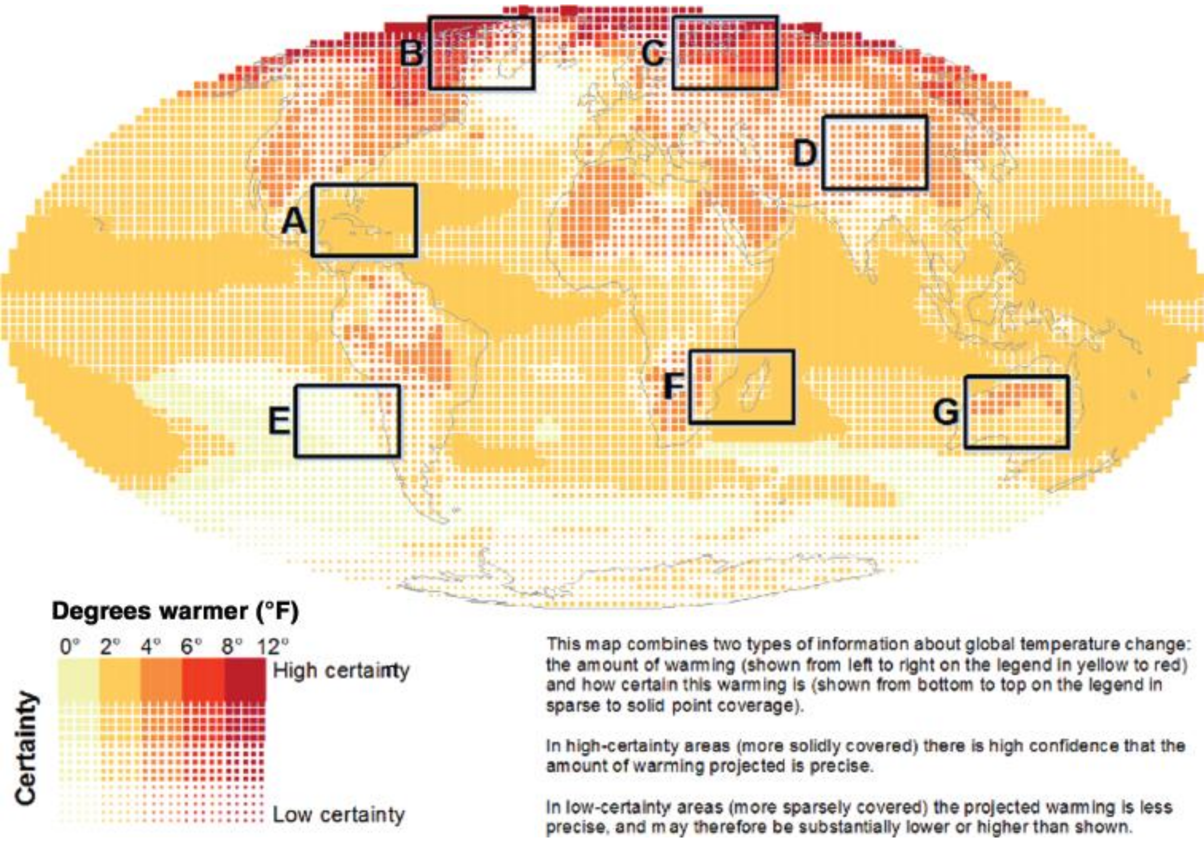


Figure 3: Projection of Surface Temperature Change

Description of Figure 3: This figure presents a Coincident-Bivariate map style which makes use of squares to show change in temperature. The colours, on a spectrum from yellow to red, represent the various temperature changes as per the scale. The squares also symbolise the level of certainty in the areas. The size of the block indicates the percentage certainty of the results. Bigger blocks represent a greater amount of certainty. This map includes some descriptive text and region boxes, A to G, for ranking questions (Retchless & Brewer, 2016).

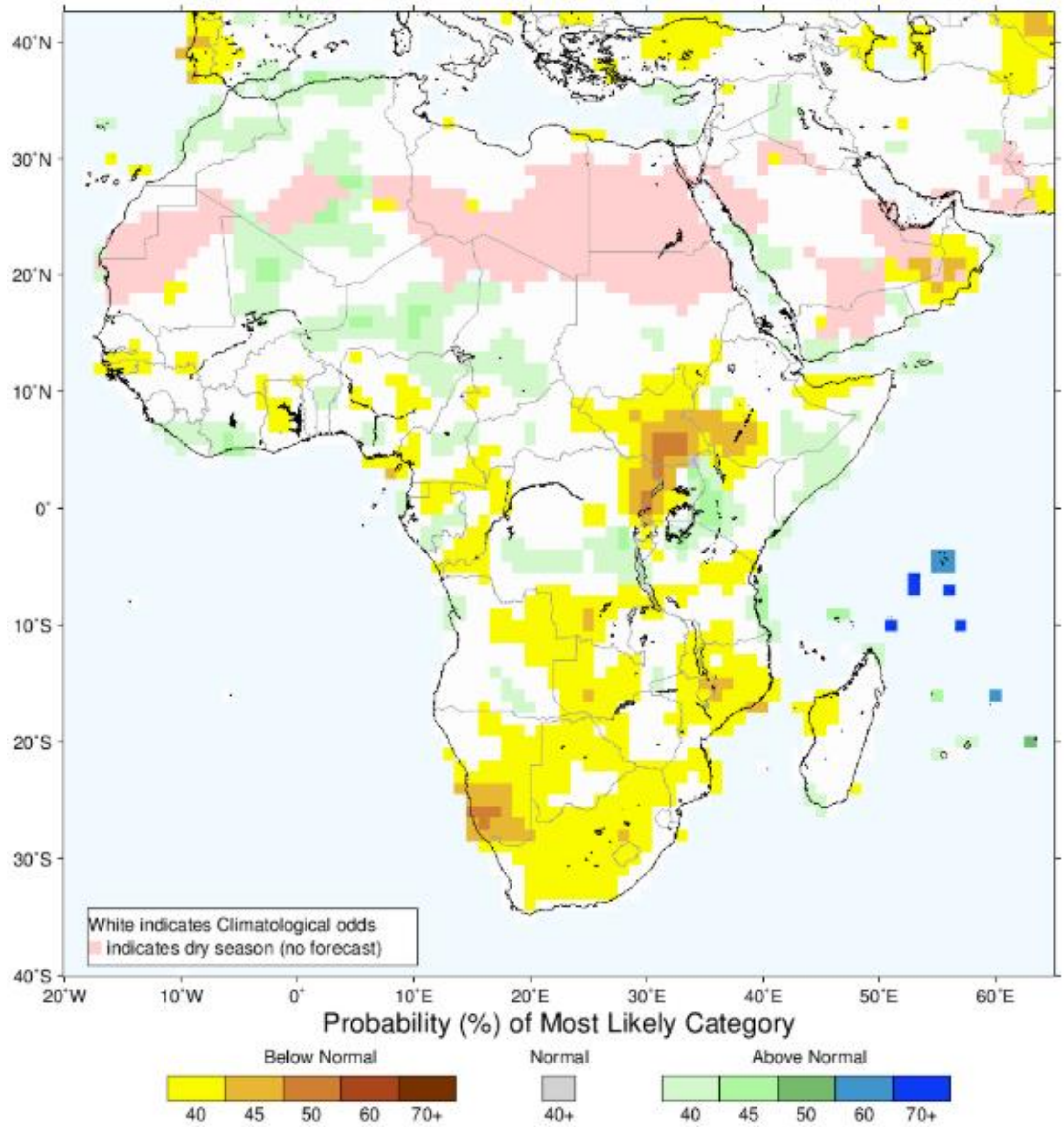


Figure 4: Multi-Model Probability Forecast for Precipitation for April-May-June 2020, Issued December 2019 (International Research Institute for Climate and Society, 2019)

Description of Figure 4: Rainfall probability forecast for April-May-June 2020 in Africa. Various colours represent the below normal and above normal categories, where grey represents normal. Each category has their own set of percentages where 40% has been characterised as the minimum level of significance. White is an indication of climatological odds (i.e. no significance found), and pink is an indication of a dry season (no forecast).

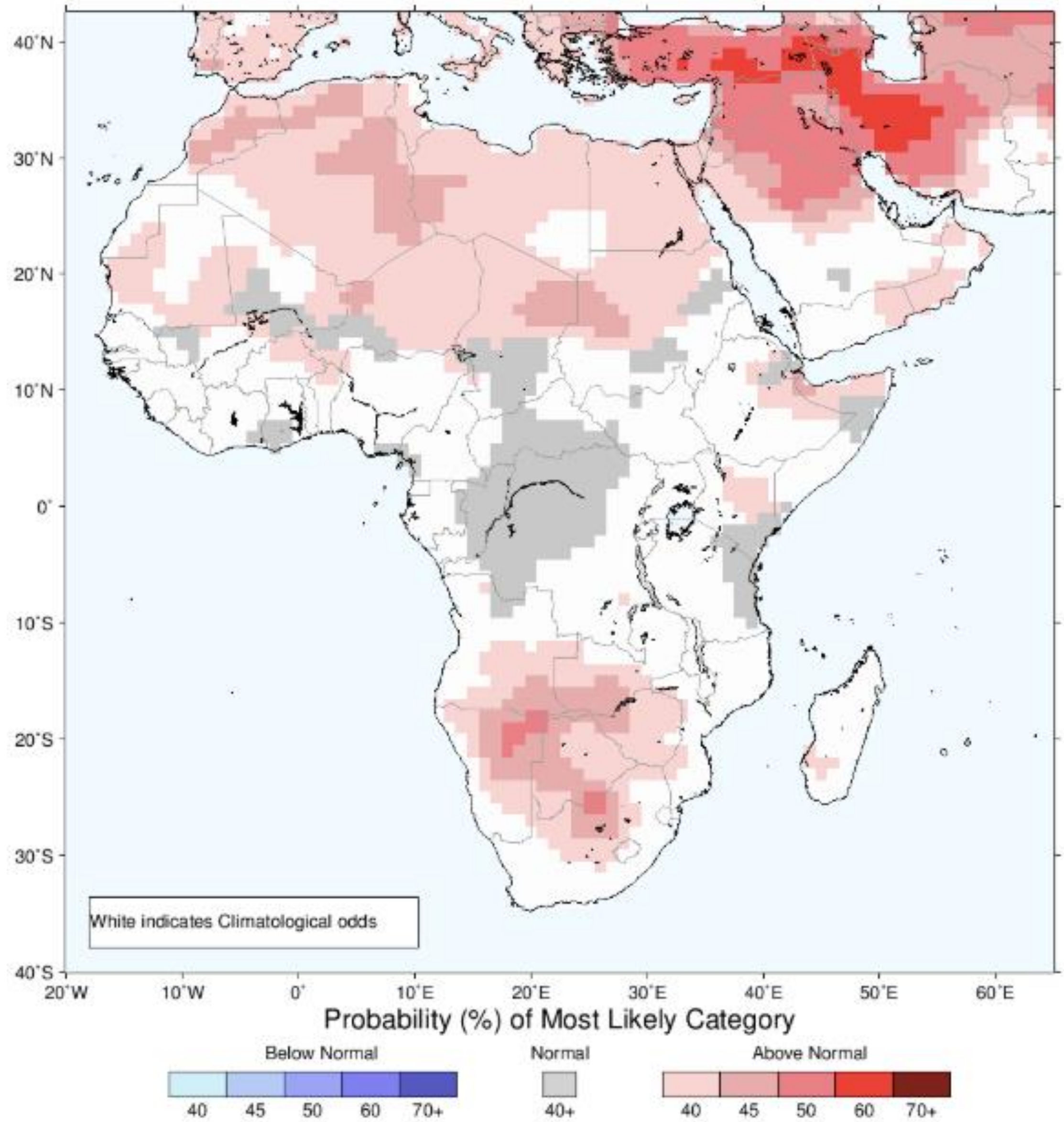


Figure 5: Multi-Model Probability Forecast for Temperature for April-May-June 2020, Issued December 2019 (International Research Institute for Climate and Society, 2019)

Description of Figure 5: Temperature probability forecast for April-May-June 2020 in Africa. Shades of blue represent the below normal categories, while shades of red represent the above normal categories. Each category has their own set of percentages where 40% has been characterised as the minimum level of significance. Grey represents normal. White is an indication of climatological odds, thus there is no significant forecast for these regions.

Despite having these guidelines, there are still a number of design challenges which have arisen (Retchless & Brewer, 2016). One aspect is that it is incredibly important to effectively communicate any uncertainties relating to climate change and the outputs produced to predict what may happen to the climate system in the future. Uncertainties are inherent in the field of climatology (Climate-ADAPT, 2017). This is because climate is constantly evolving as a result of human behavioural effects, greenhouse gasses and unpredictable natural processes that are found within the climate system (Climate-ADAPT, 2017). Furthermore, researchers are learning more about the field each day. Retchless and Brewer (2016) identified that the way in which uncertainties are communicated to users as well as their effectiveness had not been evaluated through research. The aims of their study were to determine which mapping techniques affected users' ability to read and understand the variables included, as well as which techniques were the most preferred by the user (Retchless & Brewer, 2016). A number of mapping techniques were shown including maps using pattern and white masking for the uncertainty of temperature-change distributions, maps showing projected change in surface temperature according to greenhouse gas concentrations, maps making use of hatching patterns and white masking to represent precipitation changes, and a number of other map types (Retchless & Brewer, 2016). This study was conducted using survey responses in which they were given two map-reading tasks to complete. Respondents were randomly assigned to one of ten mapping techniques. At the end of the survey, respondents were shown visuals of all mapping techniques and asked which they believed would be the easiest to use (Retchless & Brewer, 2016). According to the study, it was found that the type of mapping used would vary according to the users' goals. For example, if a user would like see where temperature changes may occur, along with the levels of uncertainty, it would be most suitable to make use of a map which uses colour to represent the temperature changes, and patterns to represent uncertainty (Retchless & Brewer, 2016). This shows the importance of the co-production of climate outputs.

In addition to the uncertainties and design challenges which occur, it is also difficult to understand each user's needs and match those to the design of the forecasts (Harold, Lorenzoni, Shipley, & Coventry, 2016). This is especially apparent with regards to experts designing outputs which may be intuitive to them but may not be easy to understand by the users themselves. This may be counter-intuitive because experts may have adhered to the design principles typically used, however, other cognitive principles need to be taken into consideration simultaneously (Harold et al., 2016). Thus, all new designs should be tested on a group of users beforehand to ensure that they are being interpreted correctly, and to ensure that users are accurately utilising them in their work environments. There is, however, the misconception that through making the climate output information more accessible, the scientific background and complexity of the models will be lost (Harold et al., 2016). Although, there are ways in which the outputs can be made more accessible to users through the application of psychological principles which have been gathered through the study of human comprehension (Harold et al., 2016). For instance, instead of inundating users with lots of information on one map which can become overwhelming for users, experts should be finding ways to draw attention to the most important aspects of the forecast through visual cues (Harold et al., 2016). Providing more information apart from the visual details can also assist users in understanding the purpose and usefulness of the outputs. This could be in the form of text (Harold et al., 2016). Along with these two principles, only information which is incredibly vital to the purpose of the forecasts should be included, to reduce any unnecessary complexity attached to the outputs (Harold et al., 2016). Finally, the accommodation of outputs to the various user groups should be considered. This is important due to the different cognitive principles which may be present in each group (Harold et al., 2016). An example of this would be for those who are colour blind. Colour is particularly important for climate model outputs as it is very important that the colours on the map are understood correctly (Harold et al., 2016). Each of these principles requires an understanding of each user group's mental models regarding their interpretation of climate output forecasts. Through the understanding of these mental models, those who develop the outputs would be informed on how they should be setting out and producing these outputs to ensure users are able to use them at their best (Harold et al., 2016).

A study by Porter and Dessai (2017) looked at the ways in which climate scientists and other experts listened to and understood the goals and needs of users. A similar method to the current study was used, namely in-depth interviews. An open-ended, conversational approach was used to allow participants to express their views and experiences freely and in their own words (Porter & Dessai, 2017). Example questions were as follows, "Who was the intended user of the projections?", "What did that user need, or call for?" (Porter & Dessai, 2017, p. 11). Results showed that the climate scientists found it hard to relate to the needs of users and instead assumed the needs, abilities and goals of the users were similar to their own (Porter & Dessai, 2017). This was found to be influenced by their past experiences, the nature and frequency of interactions they had with the users, as well as the institutional setting where the data mapping took place (Porter & Dessai, 2017). Thus, the above studies by Harold et al. (2016) and Porter and Dessai (2017) have highlighted the need for co-production.

Understanding the user's current interpretation of the forecasts, as well as their needs and preferences for the ways in which these forecasts are presented will ensure these forecasts are being used efficiently. However, as shown above, there is a knowledge gap between the users and experts. A study by Lorenz, Dessai, and Paavola (2015) attempted to help close this gap. The aim of their study was to assess the user's level of perceived comprehension of visual climate model outputs versus their actual level of comprehension. Furthermore, the study was aimed at trying to identify user preferences for the information they received, as well as help further understand the complexities which come along with trying to tailor information to those understandings (Lorenz et al., 2015). A sample of 162 climate adaptation specialists who worked in local government from Germany and the United Kingdom was utilised. Surveys were sent out in both German and English to gather data (Lorenz et al., 2015). The survey assessed the individual's decision-making based on the outputs at both an individual and group level, based on their interpretations of the outputs, as well as their visual preferences (Lorenz et al., 2015). It was found that respondents had apparent differences in terms of the preferences and interpretation of the outputs (Lorenz et al., 2015). This was a particularly interesting result because all users of the outputs were from the same user group (i.e. adaptation practitioners) and were from countries in which some of the top leaders in climate change adaptation research live and work (Lorenz et al., 2015). A strong link was found between an individual's perceived comprehension of the models and the way in which the models were presented to users (Lorenz et al., 2015). This may have been a result of participant's being more familiar with a particular representation compared to others. Thus, the way in which outputs are presented visually needs to be investigated further. Specifically, how can the presentation of outputs be matched with the goals of users and the way in which they wish to communicate information to others. Therefore, this study further supports the need for understanding the mental models of users of forecast outputs. This research should be done with a range of user groups, as well as looking within user groups as done in Lorenz et al.'s (2015) study. This information will assist forecasters in developing outputs which will enable users to make better informed decisions.

1.2.4. Mental Models

Mental models refer to the mental interpretations' individuals have of situations or objects in the external world (Kalantzis et al., 2016). This allows an individual to interact with the world around them (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Mental models are varied in terms of their accuracy and congruence. Thus, the accuracy of an individual's mental model has been linked to the effectiveness of an individual's performance (Lim & Klein, 2006). Mental models are built by the individual creating descriptions of a particular system or object from their interactions and experience with the system or object. Examples of this would be the ideas individuals have of computer systems, telephones, electrical circuits, or even a bouncing ball (Payne, 1991). These descriptions would typically be made up of the system or object's purpose, form, and an idea of how the system or object functions. In addition to this, the individual will have an account of previous states of the object or system, as well as ideas regarding the future states of the system or object (Mathieu et al., 2000). These models have the ability to be updated continuously to assist with any knowledge gaps which may be present (Balijepally, Nerur, & Mahapatra, 2012). It should be noted that not all information added to the mental model will be useful as there is the possibility of having an inaccurate mental model. Thus, they are vulnerable to potential errors (Sax & Clack, 2015). Furthermore, individuals who are faced with the same environment and phenomenon may have two different mental models (Sax & Clack, 2015). This is because people may respond to and interpret certain cues that they receive from the environment differently. Therefore, challenges could arise if these two individuals were in a scenario where they were in a team and needed to make a decision regarding a particular phenomenon (Sax & Clack, 2015). These varying mental models would likely be due to the fact that an individual's purview of the world is limited. Thus, a mental model would typically be made up of "the knowledge needed for pursuing a given goal and […] some data extracted from the environment" (Besnard, Greathead, & Baxter, 2004, p. 118). Thus, some information could go unnoticed, in turn, developing an incomplete or incorrect mental model.

Mental models are made up of the design, user, and system models (Kalantzis et al., 2016). The design model refers to how the designer of a system views and conceptualises its features and functionalities (Kalantzis et al., 2016). In the case of this study, this would refer to the expert's design model. The user model refers to the mental model a user has for the way in which a system works (Kalantzis et al., 2016). In this case, the users refer to decision- and policy-makers. It is important to note that these models are concepts which cannot be seen but are "internal representations that are held in [the] working memory" of the individual being interviewed (Kalantzis et al., 2016, p. 37). This mental model typically comes about from interactions with, as well as previous knowledge and current observations of the system (Kalantzis et al., 2016; Wilson & Rutherford, 1989). Finally, the system image is the way in which a system is presented to the user (Kalantzis et al., 2016). However, at times there are disparities between the design model of the researcher or climate scientist and the mental model of the user (Wilson & Rutherford, 1989). Thus, in order for an output to be used to its full potential, there needs to be an alignment between the expert's design model and the user's mental model of the outputs (Kalantzis et al., 2016).

These interpretations allow individuals to "draw inferences, make predictions, understand phenomena, [and] decide which actions to take" (Mathieu et al., 2000, p. 274). Thus, through the subconscious use of mental models, individuals are able to describe, predict, and explain the circumstances around them (Mathieu et al., 2000). Mental models are particularly useful because they allow an individual to gather information regarding a particular phenomenon and store that information so that each time that phenomena is encountered in a new situation, they can draw on past information which may be applicable (Balijepally et al., 2012). In this way, mental models aim to organise knowledge from previous situations to reduce the complexity involved with future situations (Balijepally et al., 2012). These mental models have a large influence on how individuals, whether they are experts in a field or not, perceive, understand, and take action using climate change model outputs. One of the most important parts of interpretation which should have the most attention is risk perception. These interpretations could have detrimental consequences if not interpreted correctly. Thus, the accuracy of one's mental model determines their risk perception performance. In this way, they could also predict whether or not someone was making accurate decision-making and problem-solving (Lim & Klein, 2006).

According to Norman (1983), there are a number of problems which can occur with mental models. For instance, mental models could be incomplete, the individual's mental model does not match up to their ability to carry out the model, or the instability of a mental model could lead to the individual forgetting important details of the system (Norman, 1983). Furthermore, mental models of similar systems or objects could be muddled with one another (Norman, 1983). Another issue is that mental models are "unscientific", meaning that "people maintain 'superstitious' behaviour patterns even when they know they are [unnecessary] because they cost little in physical effort and save mental effort" (Norman, 1983, p. 8). Finally, mental models are considered sparing in terms of the resources used (Norman, 1983). This means that individuals would be willing to take part in extra physical activity to ensure that the task is not as mentally complex (Staggers & Norcio, 1993). Each of these potential issues could lead to erroneous decision-making. Of particular importance is the individual's ability to change their mental models when necessary. For instance, it has been found that individuals would rather continue performing the same erroneous task or decision-making technique, rather than adjust their mental model to ensure it is correct. This is known as a "cognitive lock-up" (Staggers & Norcio, 1993).

When looking at the participants involved in this study, we are able to see that there is some form of team, despite them not working entirely as one unit. This is because the decisions and performance of the expert group directly influences that of the user group. Research looking at team mental model performance suggests that there is a direct relationship between mental model similarity and performance (Lim & Klein, 2006). This suggests that there needs to be a shared understanding between the two groups in order for the two groups to reach optimum performance (Lim & Klein, 2006). More specifically, it was also found that if a team's average mental models were most similar to expert mental models, they were likely to perform better than those who were not (Lim & Klein, 2006). Thus, showing the importance of mental model research on the effective functioning of teams, not only in the sector in which this study was based, but in all sectors. However, the method used by Lim and Klein's (2006) study should be noted as it is different to that of this study. During Lim and Klein's (2006) study, participants were provided with a list of concepts where they were asked to describe the relationships between the lists of concepts and rate them on a 7-point Likert-type scale with 1 signifying unrelated and 7 signifying highly related (Lim & Klein, 2006). Their study looked at the mental models of both users and experts in the Armed Forces and directly assessed the level of overlap of concepts (Lim & Klein, 2006).

In a similar study aimed at describing the shared mental models of water management at a Biosphere Reserve, it was found that overall, participants did not have a shared agreement according to the mental models elicited (Mathevet, Etienne, Lynam, & Calvet, 2011). An approach called Actors, Resources, Dynamics, and Interactions (ARDI) was utilised to elicit the mental models. This involved all participants answering questions using systems diagrams (Mathevet et al., 2011). The overall question asked in the session was "How would you describe the use and management of water in the Central Camargue?" (Mathevet et al., 2011, p. 3). Both Water Board members and non-members were interviewed. Participants ranged from the directors of the park to area managers (Mathevet et al., 2011). Furthermore, with regards to the finding of participants not having a shared model of the water management at the reserve, it was found that there was a difference between the mental models of the Water Board members and that of the non-members (Mathevet et al., 2011). These findings have implications for the way in which the Biosphere Reserve, which is an incredibly complex socio-ecological system, is managed and controlled. Furthermore, the Reserve is under particularly variable and unpredictable states due to seasonal unpredictability of the entire system (Mathevet et al., 2011). In order to ensure that the Reserve has been managed effectively, there needs to be some sort of co-ordination between the groups of individuals who are invested in the Reserve. Furthermore, there should be some sort of shared goal among all groups to ensure that there is (Mathevet et al., 2011). Thus, the way in which this can be done is through the development of a shared or team mental model as discussed in Lim and Klein's (2006) study.

Another study conducted by Daron et al. (2015) was aimed at determining the various interpretations of two sets of climate data on their users. This data differed according to the amount of informational content in the form of visuals and style (Daron et al., 2015). It has been found that issues with regards to the interpretations of climate data visualisations are very common throughout the world (Daron et al., 2015). Their study made use of participants from the African Vulnerability, Impacts, and Adaptation (VIA) community. The survey made use of questions such as "How many models project an increase in annual rainfall of more than 100mm?" and "Estimate the likelihood of changing climate conditions" (Daron et al., 2015, p. 19). Finally, at the end of the survey, the participants were asked about their preferences for outputs (Daron et al., 2015). Their study showed a wide range of interpretations. One of the important findings from the study was the importance that the informational content had on the interpretations of the user. For instance, some models may make use of percentiles versus minimum and maximum values to portray results. Further, the models could make use of colours, such as red or blue, to represent commonly understood information like heat and cold respectively (Daron et al., 2015). Furthermore, specifically for the African Vulnerability, Impacts, and Adaptation (VIA) community, it was found that participants were more likely to interpret a higher likelihood of regions being drier in the future and were quite confident in their interpretations. This was found to potentially be attributed to the participants presenting a confirmation bias of their previous beliefs or hypotheses (Daron et al., 2015). Despite this, the results from the study have suggested that users all over the world commonly misinterpret forecasts in a number of different ways (Daron et al., 2015). This shows the importance of understanding individual mental models. This understanding will enable forecasters to identify what can be changed in the current mappings to ensure effective comprehension and understanding of the complexities of the forecasts.

Another study, despite it not being focused on climate outputs, is a good outline for what this current study proposes to do. In a study by Kalantzis et al. (2016), the design models of experts were compared to users of a water management system. The sample made use of two experts who assisted with the design of the water management system, and six users who interacted with the system on a daily basis (Kalantzis et al., 2016). This is consistent with the recommended number of participants for a qualitative study (Creswell, 1998; Morse, 1994). There may, however, be issues with regards to the applicability of this research to other contexts as a result of the small sample size and relatively specific nature of the study overall. The method also took the form of an in-depth interview but had an additional element of diagramming. In the interview, participants were asked to walk the researchers through how they believed the water management system worked. The diagramming was used to assist participants to work out their ideas by providing a visual aid to their responses (Kalantzis et al., 2016). Results of the study found that there was variability between the mental models of the users compared to the design models of the experts and this could have impacted negatively on the management of the overall system (Kalantzis et al., 2016). This is yet another study which has shown the importance of mental model research and of the need for the alignment of design models and user mental models (Kalantzis et al., 2016).

1.2.5. Seasonal Forecasting

Seasonal forecasts differ compared to mainstream weather forecasts in that they are produced to provide estimations of the future states of seasons (Weisheimer & Palmer, 2014). Specifically, these outputs might show whether the coming seasons will be colder or hotter compared to the norm temperatures in that region. Other sets of outputs will be able to show whether the regions are wetter or drier compared to the usual rainfall levels in that region. This is usually produced on a three-month forecast basis (Weisheimer & Palmer, 2014). In comparison, mainstream weather forecasts would typically provide detailed daily forecasts of the projected weather (Weisheimer & Palmer, 2014). Seasonal forecasts are not to be confused with a climate model forecast which is used to understand what the global climate is projected to be, characterised as a result of global warming in the future (Future Climate for Africa, 2017). There have been a lot of questions regarding the accuracy of seasonal forecasts due to the fact that our daily weather forecasts have not been as predictable and reliable as most would prefer (Hansen, Mason, Sun, & Tall, 2011). This is especially concerning as most weather forecasts have only been found to be accurate for up to a few days from when the forecasts are produced. However, it should be noted that there are different sources which contribute to the predictions made by weather forecasts compared to seasonal forecasts. Weather forecasts are developed through the use of a technique called numerical weather prediction (NWP) which is conducted on computer programmes (Modise & Mphale, 2018). These programmes make use of formulae which take into account the earth’s atmosphere, mathematical equations, and the laws of physics to create predictions which are as accurate as possible (Modise & Mphale, 2018). It should be noted that there is always some level of uncertainty when working with forecasts. Seasonal forecasts are developed using sea-surface temperature (SST) distribution. These values are used to determine whether certain weather systems are more or less likely to occur compared to the typical events which have been recorded historically (Hansen et al., 2011). Sea-surface temperature (SST) is used because the atmosphere, which helps to predict weather patterns, is heated through and receives moisture from the Earth's surface (Hansen et al., 2011). Thus, significant changes in the normal conditions of the Earth's surface can, in turn, have prolonged effects on future weather patterns. Furthermore, the ocean temperatures may offer a method to predict how future weather patterns might be changed (Hansen et al., 2011).

According to Hansen et al. (2011), weather forecasting is found to be harder in the Sub-Saharan African (SSA) region, compared to places in Europe or North America. This is largely due to the uncertainty related to the timing and intensity of weather events (Hansen et al., 2011). Still, weather forecasting in the Sub-Saharan African (SSA) region has been found to be particularly hard due to the "relatively poor density of observations" in the region (Hansen et al., 2011, p. 206). This results in more errors in weather forecasting than in other areas of the world. However, it has been found to be easier to predict seasonal forecast patterns. These predictions are dependent on a number of factors such as location, wind patterns, and the time of year (Hansen et al., 2011). When looking at sea-surface temperature (SST), it is important to consider El Niño and La Niña weather disruptions (Hansen et al., 2011). El Niño refers to when the sea temperatures in the central and Eastern tropical Pacific Ocean are warmer than usual (Philander, 1985). La Niña refers to the opposite, when these areas of the ocean are colder than usual (Philander, 1985). These changes in the Pacific Ocean have a cyclical effect on the overall temperatures in the oceans, and as a result, produce predictable changes in the atmosphere. Thus, they are important for predicting the seasonal climate variations of Sub-Saharan Africa (SSA) (Hansen et al., 2011).

Despite seasonal forecasts making use of sea-surface temperatures (SSTs) to predict future patterns, institutions such as the International Research Institute for Climate and Society (IRI) at Columbia University, the South African Weather Service (SAWS), the Council for Scientific and Industrial Research (CSIR), the Climate Systems Analysis Group (CSAG) at the University of Cape Town, and the University of Pretoria (UP) still have different methods of using this data to create their seasonal forecast outputs. For the purposes of this study, these will be briefly discussed. Most commonly an empirical or numerical approach is used. The empirical approach makes use of historical data to develop predictive models for the future of a particular region. This method is the oldest known technique for producing seasonal forecasts (Stockdale, 2000). The numerical approach is relatively new and has some challenges which emerge. It is employed through the use of calculations of first order physical principles or approximations of how the climate system is usually thought to perform (Stockdale, 2000). However, a combined multi-model approach of the two commonly used methods could be considered to be the most powerful technique (Stockdale, 2000). These various techniques will ultimately produce different forecasts which will require different kinds of mental models from the user in order to interpret them efficiently.

In the case of this study, a seasonal forecast output was shown to participants to elicit the mental models. The outputs shown to participants were developed using a multi-modal approach. Specifically, the North American Multi-Model Ensemble (NMME) approach was used (Seasonal Forecast Worx, 2019). This approach has been found to be effective in the prediction of uncertainties due to the way in which its formula has been developed (Kirtman et al., 2014). Seasonal forecasts allow users to view and understand the potential unpredictability of climate (Klopper, Vogel, & Landman, 2006). These outputs can predict rainfall and temperature changes in ranges of one to six months. The output shown to participants was a three-category rainfall climate forecast map similar to that of the November-December-January 2018/2019 period in a particular region (as shown in Appendix G). These maps show the probability that either temperatures or rainfall in a specific region will identify with one of three categories. Namely, above-normal (“wet”/“hot”, rainfall totals higher than the 75th percentile of the climatological record), near-normal (“average” season), or below-normal (“wet”/“hot”, rainfall totals lower than the 25th percentile of the climatological record) (Grieser, 2014; Seasonal Forecast Worx, 2018). This is particularly useful for decision- and policy-makers in all sectors, including those in the water management, natural disaster and agricultural sector as in this study, because of their interest in potential extreme outcomes (Grieser, 2014). Specifically, for this study, questions relating to the likelihood that the three months depicted in the seasonal forecasts are to be extremely wet or extremely dry months compared to a 32-year historical period (Klopper et al., 2006; Seasonal Forecast Worx, 2019). Thus, the preparation and implementation of adaptation policies for these potential extreme outcomes is possible (Klopper et al., 2006). This, in turn, attempts to reduce negative outcomes as much as possible (Grieser, 2014).

1.2.6. Forecasting Skill in the South African Context

There are several factors which need to be considered when interpreting a seasonal forecast. In particular, the skill, reliability, resolution, sharpness, and uncertainty around the seasonal forecast outputs. For the purposes of this study, the skill, reliability, and uncertainty of forecasts will be discussed. Skill is a measure of the quality of a set of forecasts. Quality would be measured through comparing the forecast to an alternative approach to forecasting (Troccoli, Harrison, Anderson, & Mason, 2008). The comparison approach is usually one that is much simpler such as the use of guessing, climatology (average weather patterns over time), or recent data. These approaches would be known as having 0% skill (Troccoli et al., 2008). The reliability of the forecast is measured by comparing the predicted forecast for the season versus the observed values of the season. This is then made into a mean value (Johnston et al., 2004). Finally, uncertainty relates to the difficulty the forecasters had in making a prediction for a particular time period or region (Johnston et al., 2004). These factors assist with determining the usefulness of the forecasts for users (Johnston et al., 2004). This level of usefulness differs widely according to the region in which the forecasts are being used, as well as the sector in which they are being used. This can be shown in a study where reliability categories (where 1 = dangerous, 2 = not useful, 3 = marginally useful, 4 = still useful, and 5 = perfect) were created and were shown through seasonal rainfall and temperature forecasts in regions all over the world (Weisheimer & Palmer, 2014). Results for both rainfall and temperature forecasts were quite varied. The study found that most seasonal temperature forecasts were usually placed in the 4th Category (i.e. still useful), thus these forecasts were found to have good reliability and as a result were useful for decision making (Weisheimer & Palmer, 2014). However, most seasonal rainfall forecasts were found to fall in Category 3 (i.e. marginally useful) which implies that they are not very reliable but could be slightly useful in some cases (Weisheimer & Palmer, 2014). It should be noted however, that some of the seasonal rainfall forecasts were placed into Category 1 which is considered to be dangerous if used. Seasonal temperature forecasts were found to be generally more reliable. This is supported by a study conducted by Landman, Barnston and Vogel (2015), where seasonal rainfall forecasts from a number of regions including South America, Asia, Africa, and others were compared to determine the predictability of various regions. The levels of predictability were ranked in order from most reliable to least reliable. Results showed that rainfall forecasts for Southern Africa were ranked low together with other developing regions and countries such as Brazil, India, and Chile (Landman et al., 2015). This was found to be the case due to the poor level of predictability in these regions (Landman et al., 2015). As a consequence, forecasts for these regions may not be able to effectively identify extreme seasons and their reliability may be reduced as a result. This may have a negative effect on a user's mental model of the forecasts as they are seen as being not reliable, and thus are not deemed useful and will ultimately reduce the uptake of the forecasts.

Seasonal forecasts are considered to be extremely valuable for decision- and policy-makers (Taylor et al., 2015). However, this information can only be valuable to users who are able to understand the information provided, and in turn make use of this information along with other tools and methods to ensure the accuracy of their decision-making and risk management (Klopper et al., 2006). As with climate change model outputs, the challenges facing seasonal forecasting outputs are similar. According to Taylor et al. (2015), these seasonal forecasts have been found to be useful, but are often hard for users to understand. For instance, one of the greatest challenges faced by experts is the way in which uncertainty within the outputs should be communicated (Taylor et al., 2015). This issue could have a number of implications on the user of the output due to false ideas of certainty regarding the output which could lead to misinformed decision-making. The results of these actions could lead users to have reduced levels of trust in the experts as a result of the potentially harmful outcomes attributed to the inaccurate interpretations of the outputs (Taylor et al., 2015). Therefore, there is a need to ensure that these seasonal forecasts are suitable for both experts and users (Taylor et al., 2015). When looking specifically at the context of South Africa, it can be said that forecasting skill will be directly influenced by climate systems in the tropical and extra-tropical regions. This therefore creates greater variability in climate compared to other areas of the world and as a result lower forecast skill (Mason, Joubert, Cosijn, & Crimp, 1996). This leads to the question of whether or not seasonal forecasts will ever be able to reach the point of being accurate and precise. This should be evaluated in terms of the goals set out for seasonal forecasting outputs.

The accuracy and reliability of seasonal forecasts has a number of implications for the users of the forecast outputs. As discussed briefly above, if a seasonal forecast is unreliable, poor decisions could be made as a result (Weisheimer & Palmer, 2014). It should be noted however, that there will always be an aspect of uncertainty in the seasonal forecasts (Johnston et al., 2004). Forecasts are presented to users through the use of probabilities. Thus, the skill of a particular area over a particular time period is expressed through levels of the likelihood of a particular climate system (e.g. rainfall or temperature) occurring (Johnston et al., 2004). Therefore, seasonal forecasts can never be entirely wrong as they are developed with the assumption that there is an inherent amount of uncertainty in terms of the predictions they make. However, users of these forecasts tend to misinterpret these forecasts as being entirely wrong if the prediction made is not the observed result which can create negative opinions of seasonal forecasts overall (Johnston et al., 2004). While this is clearly an instance of poor interpretation on the users' side, there are instances where the opinions brought about by seasonal forecasts can be erroneous. For instance, if a forecast were to have a high level of probability for the prediction of low rainfall this would imply that farmers may need to prepare for a drought (Johnston et al., 2004). If this were to be inaccurate there would be considerable economic effects on farmers as a result of them having prepared their land for the state of a drought which didn't actually happen. The lowered efficacy of the land may be devastating to the farmer (Hansen et al., 2011). This therefore brings about an important question regarding the way in which this uncertainty is presented and communicated to users of seasonal forecasts. Furthermore, how can users more accurately utilise these outputs so that their decision-making benefits from the seasonal forecasts. This is supported through Johnston et al. (2004), who state that it is the responsibility of those producing the forecasts to explicitly state the skill and uncertainty levels of the existing forecasts so as to present the relevant risks to the users of the forecasts.

Another important challenge to consider is the complexity of the outputs and the effects that they may have on users attempting to interpret them. It has been found that individuals are more likely to ignore what they perceive as too complex (Taylor et al., 2015). Thus, users may ignore certain forecast information while focusing on what they are more familiar with (Taylor et al., 2015). This could lead to the user missing out on vital information which could have contributed to their informed decision-making. It can be argued that if these seasonal forecasts are developed with the user in mind, they can be of immense value to the user's decision-making. In a paper by Hansen et al. (2011) seasonal forecasting in the Sub-Saharan African (SSA) agricultural sector was reviewed. It was found that after having had forecasting workshops in which it was explained to farmers how to interpret and utilise the forecasts as part of agricultural management, 91% of participants stated that they had changed at least one strategy in the management of their land based on the information they had uncovered in the outputs. After participants passed on this information to other individuals in the agricultural sector, 78% of non-participants stated that they had done the same (Hansen et al., 2011). The adaptation of strategies can be attributed to their having had the workshop in which they were able to further understand the applicability of the seasonal forecasts to their everyday lives and decision-making. Thus, they were able to develop their mental models of the forecasts to further understand the "probabilistic nature" of the seasonal forecasts which is usually thought of as a challenge to those who have not had exposure to such forecasts beforehand (Hansen et al., 2011, p. 224). Furthermore, it was found that the more experience famers had with the forecasts, the better they were able to use them (Hansen et al., 2011).

In order to ensure that these seasonal forecasts are utilised in a way where their value and reliability is understood, seasonal forecasts should be delivered to users with either some form of education on the outputs or a manual in which the technical aspects of the outputs are carefully explained to the users (Hansen et al., 2011). These educational workshops or manuals should be co-developed by both users and modellers to ensure all the relevant information is provided in a way which will be understandable to those who do not have a background in climate science (Landman et al., 2015). Thus, the risk of misinterpretation is significantly reduced. Through the co-production of forecasts, as well as further education of forecasts regarding their capabilities and how to interpret them, the design models of experts and the mental models of users will become a shared mental model. These provisions to ensuring that there are shared mental models among experts and users will ensure that the forecasts are interpreted accurately and ensure that correct and effective decisions are made as a result.

1.2.7. Uptake of Seasonal Forecasts

Seasonal forecasts have a number of applications for users in various sectors which are weather-sensitive. Not only can these forecasts assist farmers in making agricultural decisions, but it can also assist organisations in anticipating food shortages as a result of droughts (Weisheimer & Palmer, 2014). Further, these forecasts can be useful during the planning stages for water provision services, as well as emergency services in the case of perceived danger of floods or droughts. It should be noted that this information will only be useful in these sectors if the outputs are skilful as discussed above. This brings about an important question regarding the maximum amount of skill that can be expected from forecasts currently being produced and whether these levels can be improved. Furthermore, what goals regarding skilfulness are unobtainable, and what are more realistic goals for the future of seasonal forecasting? These are extremely important considerations due to the volatility of the climate system (Weisheimer & Palmer, 2014). Currently, seasonal forecasts are distributed to users as seasonal guidelines only, however users tend to use them as though they are developed for their specific application (Johnston et al., 2004). This leads to frustrations on both the part of the user as well as the modeller (Johnston et al., 2004). It could be worth investigating whether the adaptation of forecasts to the specific needs of its various users is feasible.

When looking at the current uptake of seasonal forecasts in Africa, a study conducted by Change, Yanda and Ngana (2010) found that indigenous knowledge was used historically to determine when there may be incidents of drought and flood. This was an important way in which communities would adapt their environment to suit the predicted climate forecast. This was done through the analysis of plants, birds, animals, and insects (Change et al., 2010). Change, Yanda and Ngana (2010) explain that past research has found that there has been a slow disappearance or breakdown of this indigenous knowledge in Zimbabwe. In order to combat this, communities in Zimbabwe have been combining their indigenous knowledge of climate with scientific seasonal forecasts more frequently. Change et al. (2010) discovered that regions in Tanzania also rely on indigenous knowledge. Thus, previous studies were adapted to suit the Tanzanian context. Change et al. (2010) found that the certain areas of Tanzania were also found to use a combination of indigenous knowledge with seasonal forecasts to assist with their increased climate variability (Change et al., 2010). Typically, this has been helpful in adaptation and recovery from floods and droughts in the area (Change et al., 2010). Their study had a total of 53 participants who were interviewed. These participants were from a number of Tanzanian villages and more than 90% of participants used agricultural and livestock farming as their source of income. An important finding from the study was that 96% of participants were aware of seasonal forecasts which were issued by the Tanzania Meteorological Agency (TMA) however, it was found that only 58% of respondents utilised these forecasts for agricultural planning and management (Change et al., 2010). Furthermore, only 17% of participants had the opinion that these forecasts were reliable, while for 58% of participants they were “somehow” reliable. Finally, 17% and 8% of participants believed they were not reliable, or were unsure of their reliability respectively (Change et al., 2010). Change et al. (2010) argued for the benefit that combining or adding indigenous knowledge could have on the improvement of the reliability of seasonal forecasts if it were to be further researched and documented. This is supported through 94% of participants acknowledging the presence of mixed method predictive forecasting. This was followed by 92% of participants who said that they made use of this method in their work. It should be noted, however, that only 64% of participants were confident in the reliability of indigenous knowledge for the purposes of predicting seasonal events (Change et al., 2010). This was found to be reduced mainly because of the increasing unpredictability of climate systems (Change et al., 2010).

Another study conducted by Klopper et al. (2006), sent out questionnaires to seven farmers involved in the commercial farming sector in South Africa. All participants were selected from the North-Eastern interior of South Africa where they had all participated in the commercial farming industry (Klopper et al., 2006). Here, the sample should be of particular note since it would have limited applicability to other contexts since the sample size was quite small and all participants were gathered from a particular region in South Africa. Despite this, some interesting information was uncovered from the sample that did participate in the study and is useful to consider as similar questions have been asked in this study. The questionnaire consisted of four sections, one of which tested how the individual would utilise seasonal forecasts during a particular time of year. Specifically, the mid-summer rainfall season (December, January February – DJF) (Klopper et al., 2006). A number of important findings were found from these questionnaires. All respondents indicated that the seasonal rainfall forecast is an important factor which is taken into consideration at the beginning of a rainy season. This includes the onset and timing of rainfall in a particular region (Klopper et al., 2006). It should be noted that it was generally found that the participants did not perceive the indication of 'below normal' rainfall as being a sign of a drought (Klopper et al., 2006). This was a common misconception among users because of the way in which it has been presented on the maps. More specifically, the shades of red were used to show below normal rainfall probabilities. The darker the shade of red, the more likely an individual is to perceive the danger of a drought regardless of the average amount of rainfall received in a particular area. It was also found that participants were unsure of what measures they could personally take to ease the effects of droughts (Klopper et al., 2006). An observation noted by the authors was that the participants did not make mention of forecasts being related to an ENSO (El Niño-Southern Oscillation) versus a non-ENSO year. This is important as seasonal forecast skill has been found to typically be higher during an ENSO year (Klopper et al., 2006). Forecasts are also of more value to the farmers during those periods. This may be an indication that users of the forecasts need to be educated further with regards to the finer details of the forecasts which would ultimately result in better decision-making.

Finally, all participants indicated that they benefited from the forecasts in some way or another, and that they were considered as being "potentially useful" in their planning processes (Klopper et al., 2006, p. 84). It was stated that further climate information was used in addition to the forecasts to enhance the overall value of the information. In addition to this, information relating to winds, hail, frost-events, and soil moisture were indicated as a potential option to add to the usefulness of future forecasts (Klopper et al., 2006). According to Klopper et al. (2006), an important aspect to note is that traditional beliefs and theories regarding the weather and climate science influence the way in which the seasonal forecasts are perceived and interpreted by users. This, in turn, influences their decision-making. These preconceived notions regarding forecasts may be reduced to purely background facts if the forecasts were to be accompanied by a workshop or training course in which the users can gain more insight into the application of these forecasts. Despite yielding positive results, as stated above, the study did have a small sample size which means that the results should be interpreted with caution.

As a result of some of the challenges discussed above, seasonal forecasts are only beneficial to a small number of the total users in the industry. This is often due to users' lack of experience interacting with and interpreting this kind of information (Klopper et al., 2006). However, in a study conducted by Taylor et al. (2015), it was found that even with participants who had technical and/or statistical expertise in the area, there were still misinterpretations of the forecaster's design model. Thus, there is not always an alignment between the forecaster's design model and the user's mental model of the output. Experts within the forecasting community are constantly developing new ways in which forecasts can be presented in order to make the information more understandable and flexible for user needs (Grieser, 2014). However, as shown above, it is particularly important that the users are part of this development process to ensure users are equipped with the information needed to make informed decisions (Klopper et al., 2006; Dilling & Lemos, 2011). In addition, this information needs to be presented in a way which is understandable for the users (Taylor et al., 2015). This responsibility should not only fall on the experts creating the outputs, but also the organisations, specifically the users, who benefit from the production of usable science (Dilling & Lemos, 2011).

1.2.8. Opportunities for Seasonal Forecasting

As shown through the literature discussed above, there is a limited group of users for seasonal forecasts. This includes individuals in the agricultural sector. There are a number of other groups of users who could benefit greatly from the use of seasonal forecasts, including water, health, disaster management, and natural resource management people (Johnston et al., 2004). However, these groups are not always seen as utilising this sort of information in their decision-making processes. In order to address why this may be the case, problems in uptake and the influences that the societal context may have to utilising these forecasts should be investigated (Johnston et al., 2004).

In a study conducted by Klopper (1999), the usefulness of rainfall seasonal forecasts during the years 1997-1998 in South Africa was investigated. The participants were sourced from the seasonal forecast email list at the South African Weather Bureau (SAWB). A questionnaire was sent out to these users and responses were received from individuals in several sectors. This included individuals from the farming, climatology and meteorology sectors, energy and water management sectors, policy-making industries such as agricultural government department, and the disaster management and strategic planning industries. Some responses were also received from the education, nature conservation, food, and construction industries (Klopper, 1999). Due to various institutions developing and issuing their own seasonal forecasts, a section of the questionnaire asked if any conflicting information had been received from multiple institutions. It was found that 75% of participants stated that they had not received any conflicting information, while the remainder of participants claimed that they had (Klopper, 1999). These results may be attributed to the various methods utilised by these institutions to develop these forecasts. Furthermore, the reason for the development of these forecasts could also produce different outputs. Klopper (1999) stated that some institutions developed their outputs purely for the use of farmers, whereas others produced them for the use of the country as a whole (i.e. without a specific user in mind). This indicates a need for further collaboration and standardisation within the field with regards to how the seasonal forecasts are developed. Another influencing factor on the presence of conflicting results is the influence that media outlets have on the mental models of the users. There may be differences in the interpretations from different portions the media which is translated to the users and this creates pre-conceived notions of how to interpret the outputs. This is supported by the results from the questionnaire where some participants indicated that they considered the newspapers, radio, and television outlets to be more reliable than the forecasts themselves (Klopper, 1999). Thus, education needs not only to be focused on the users of the forecasts, but also on the media which report on them.

Furthermore, an important finding was that 75% of participants noted that their decisions had been influenced as a result of the seasonal forecasts given to them (Klopper, 1999). Others noted that the seasonal forecast had indicated that their current decisions would not need to be adjusted and one participant indicated that he had hoped the seasonal forecast would be incorrect in its prediction (Klopper, 1999). There has been limited research on this, specifically in the African region, however this finding has been supported by Klopper's (2006) and Hansen et al.'s (2011) studies which found similar results. Although, it has been noted that this was found with a small sample group. In addition to this, Change et al.'s (2010) study provides some support for these findings since there has been an increase in forecasting use since the slow loss of indigenous knowledge. Finally, 80% of respondents indicated that they felt they were better off having had the seasonal forecast information given to them. Thus, the importance of these forecasts was reinforced. Moreover, 97% of participants indicated that the outputs were understandable and were able to apply the probabilistic information to their decision-making. This was a surprising finding as there have been a number of studies which have contradicted this finding (e.g. Hansen et al., 2011; Klopper, et al., 2006; Landman et al., 2015; Taylor, et al., 2015). When investigating further into the study, it was found that three of the questions on the questionnaire addressed this theme. Specifically, "Are the outlooks understandable?", "Were you able to interpret the information?", "The Weather Bureau uses probabilistic forecasts – in other words a probability (or percentage) is coupled to the chance of above-normal, near-normal or below-normal rainfall or temperature occurring. Do you understand the concept of probability forecasts and how to apply it?" Participants are asked to circle 'Yes' or 'No' for all questions (Klopper, 1999, p. 315). Participants were not asked to elaborate on their answers to provide reasons for their answers and were not asked to interpret the model provided to them. A potential reason for this result may have been as a result of the participants responding in a socially desirable manner, or there may be incongruence between an individual's level of perceived comprehension versus their actual intention as shown in the study by Lorenz et al. (2015). Therefore, further investigation into the mental models of users is needed to ensure there are accurate results. Specifically, how do they interpret forecasts and are their interpretations equal to that of experts in the field?

When participants were asked how the forecasts could be improved, it was requested that wider areas should be represented on the maps, while others asked for specific areas to be narrowed down. Other users asked for more technical information such as historical rainfall records, wind speed and direction, flood risk, cold, and heatwaves (Klopper, 1999). While some of these suggestions are understandable, it should be noted that there are some aspects of the maps which cannot be adjusted due to the long-term nature of the prediction which does not allow for this information to be added (Klopper, 1999). This may indicate another aspect of education which needs to be addressed with users. In addition, participants expressed the need for explanations of difficult terms to be placed alongside the maps (Klopper, 1999). This may assist with an increase in understanding, as well as the further development of user mental models. Thus, as shown in the study above, these seasonal forecasts have the ability to be useful in various sectors, but as discussed above, the way in which this information is communicated to the users' needs to be developed further. It should be noted, however, that this study was published 21 years ago. Thus, the technology and way in which the outputs have been presented may have changed quite a bit. Furthermore, the users may have become more knowledgeable in the area of seasonal forecasting.

There are also aspects of seasonal forecasts which can be developed to reach a wider range of users specifically in the context of South Africa. In particular, Vogel (2000) conducted a study in which the use of seasonal forecasts by farmers was examined. During the pilot study, a focus group was conducted with agricultural extension officers in the North West province of South Africa. Extension officers refer to individuals who help farmers make appropriate decisions regarding agricultural production and development of the area. They make use of various information including, seasonal forecasts. During this study it was found that the extension officers had shown interest in obtaining seasonal forecasts which provided more information and simpler charts (Vogel, 2000). Furthermore, it was found that the extension officers would like to receive regular updates of the forecasts during the relevant period of time (Vogel, 2000). Whether or not these changes have been made cannot be confirmed. Finally, an important finding particularly for the South African context is the call for seasonal forecasts to be translated into other languages, for example SeTswana, to ensure the accessibility of these forecasts (Vogel, 2000).

In conclusion, this study will attempt to add to the currently limited body of knowledge by making use of mental model theory by analysing the interpretations and perceptions of seasonal forecasts by two groups (novices and experts) and determining if there are any discrepancies among them. This is particularly helpful as it will allow us to develop ideas of what each group would potentially need – in terms of visuals, data, etc. – from an output to ensure its usefulness when creating informed adaptation behaviours and policies, as well as overall decision-making accuracy by the users of the outputs. Furthermore, it will also allow the exploration of the idea of co-producing outputs to determine if it is the best possible solution to support the accurate distribution of information. Despite there being some studies looking at the interpretations of experts or users on certain climate model outputs, the current body of knowledge is lacking in studies which look at both expert and user mental models on the same seasonal forecasting model output. This study will add to closing that gap.

1.3. Research Questions

1. How are seasonal forecasting outputs viewed by experts and users?
2. How are risk predictions and solutions thought of by each group?
3. Do the perceptions align between the two groups?
4. How are seasonal forecasting outputs utilised by users?
5. How should seasonal forecasting outputs be presented in order for decision-makers to make accurate predictions and, ultimately, correct decisions?

CHAPTER 2 – METHODS

This study follows a qualitative, phenomenological design. This allows for the motivations which underpin an individual's actions and decision-making to be identified. This research will also follow a cross-sectional design. Semi-structured interviews were used as the method of data collection. The questions were developed with the help of the supervisor of the study, as well as experts in the field from the Global Change Institute (GCI) and the University of Pretoria (UP). These questions were open-ended to allow for the participants to explore any topics they wished to discuss. These interview questions were piloted beforehand to ensure the appropriateness of the research questions. In this chapter, the methods used to conduct the study will be discussed. Firstly, the research design of this study will be discussed, followed by the procedures used during the data collection. Following this, the methods of analysis, as well as the final sample will be discussed. Next the data collection instrument used will be examined. Finally, the ethical considerations taken during the completion of the study will be examined, as well as the reflexivity needed to ensure validity of the study.

2.1. Research Design

This study is a qualitative, phenomenological design. Qualitative research aims to examine the complexities of a specific phenomenon which mostly cannot be made into numerical values (Leedy & Ormrod, 2013). Phenomenological research attempts to identify an individual's perception, perspective, and meaning of a specific situation (Leedy & Ormrod, 2013). This type of research can provide insight into the motivations of an individual's actions or decisions. This is particularly relevant for this study as it is trying to understand user perceptions of seasonal forecast outputs and the decisions they make as a result of them. Furthermore, it makes use of a cross-sectional research design, which refers to when groups are studied at one point in time (Salkin, 2012).

2.2. Data Collection and Procedure

Ethics approval was first be obtained from the Human Research Ethics Committee at the University of the Witwatersrand (non-medical – clearance number: MORG/19/003 IH) (see Appendix A). With assistance from the Global Change Institute (GCI), potential experts and users were contacted via email and telephonically. Most of the participants were drawn from a

WhatsApp group with individuals who were either in the seasonal forecasting field or had been exposed to seasonal forecasts as part of their normal work. Thus, non-probability, purposive, convenience sampling was utilised. Other participants were drawn through snowball sampling, where individuals in the WhatsApp group provided details of other individuals in the field who could act as potential participants. The potential participants were informed of the purpose of the study and the way in which data were proposed to be collected. Individuals then let the researcher know if they were interested in participating either via email or telephonically. Arrangements were then made in terms of mutually convenient times and venues to conduct the interviews. Due to varying schedules, data collection took place between August 2019 and November 2019. Overall, sixteen interviews were conducted, two of which were part of the pilot study.

Data collection took place through the use of in-depth, face-to-face interviews. The interview was semi-structured and the schedule was developed by the researcher along with the help of experts in the field and past research discussed in the literature review (see Appendix F) (Daron et al., 2015; Payne, 1991; Porter & Dessai, 2017). The pilot study was conducted to determine if the interview schedule explored all aspects of the research questions sufficiently and if they needed to be adjusted. After the completion of the pilot interviews, it was found that the interview schedule was suitable for the study without any adjustments being necessary. Participants in the pilot study were not included in the final sample, however. In order to ensure consistency all interviews were conducted by the researcher, under the supervision of her supervisor. Interviews were conducted in environments which participants perceived as comfortable and convenient to them. Most of the time this was in their work building or at the University of the Witwatersrand. Some interviews did, however, take place through the use of Skype due to them being in a different part of the country. The same procedure was followed during the Skype interviews as with the face-to-face interviews, and participants were only shown the seasonal forecast outputs at a specific time during the interview by sending an attachment with the outputs to them at the relevant time.

Before the start of the interview, participants were provided with the Participant Information Sheet and the Consent Forms and were given time to read through them before the start (see Appendix C, D, and E). Participants who were interviewed via Skype were sent the Participant Information Sheet and the Consent Forms via email prior to the interview and were asked to either fax or email the signed copies before the interview. This could have been done electronically or by hand. All Consent Forms were received prior to the interviews.

Furthermore, before the start of the interview a few important aspects of the participant information sheet and consent forms were restated, and participants were asked if they had any further questions. The interview began once the interviewer verbally asked whether or not the participants were comfortable with the interview being recorded. Both groups were asked the same set of questions, and the experts were not told of the users' responses. Participants were then thanked for their participation in the research and were reminded that they may ask to receive a short summary copy of the findings from the research after submission. Participants were asked if there were any further questions after the interview and were reminded that the interviewer's, as well as their supervisor's contact details were on the Participant Information Sheet for any further queries. The interviews were then transcribed verbatim. Once this was completed, a neutral third party reviewed the accuracy of the transcription by conducting a random check on five of the transcriptions. This third party was an Organisational Psychology Honours student from the University of South Africa. The third party had no involvement in the research. These transcripts were then analysed using Interpretive Phenomenological Analysis (IPA).

2.3. Instrument

A semi-structured interview with open-ended questions was developed for the purposes of this study. A semi-structured interview schedule allows the interviewer to be guided by an interview schedule, but not restricted by it (Smith & Osborn, 2009). This allows the researcher to follow the participant's thought patterns and probe into more interesting topics which may arise. Specifically, for the purposes of this research, a semi-structured interview allows the interviewer to produce more detailed data according to the design/mental models of the participants. This schedule has been developed with the help of the supervisor for the study, as well as a Professor from the Global Change Institute (GCI), and a Professor in meteorology from the University of Pretoria who each have professional background knowledge on these topics. Along with this, the literature review and previous studies were consulted to develop the interview schedule (Daron et al., 2015; Payne, 1991; Porter & Dessai, 2017). The interview schedule (as shown in Appendix F) consisted of sixteen questions in total. These questions are made up of four sub-sections, starting with a section regarding the background information of each participant. In particular, individuals were asked about their gender, age, highest education level, number of years in the current field, job title, role in their current position, and their experience in seasonal forecasting. The participants were then presented with a seasonal forecasting output which they were asked to interpret in the remaining sub-sections (as shown in Appendix G). The next set of questions allowed the researcher to probe the participant's mental or design model of the seasonal forecast model output. Examples of these questions include, 'What do you understand by the outputs?', and 'What do you perceive in terms of risks?' Following this, the remaining two sub-sections looked at identifying the participant's perceived risk factors as a result of the output, as well as the actions they would consider taking to mitigate those risks. Overall, there were sixteen interview questions with a few prompts in between to allow the interviewer to clarify the question or probe more into the participants' responses. The semi-structured nature allowed participants to explore different topics within these categories that they would like to discuss.

The interview schedule was piloted beforehand with two interviewees to determine if the questions, along with the outputs, were understandable and appropriate for this research study. For the purposes of the pilot study, two experts in climate science were interviewed. Once these interviews were completed, they were transcribed. Feedback from the experts were also considered, and it was found that the questions were not found to be ambiguous where all questions were answered adequately. Where individuals may have difficulty, prompts were added to further assist the researcher and interviewees. Thus, the interview schedule worked well in the context of the study and did not need to be adjusted. For the purposes of the study, four experts and ten users were interviewed. Each interview typically took between fifteen and fifty minutes. Generally, it was found that the interviews with experts ran longer than with the users. On average, each interview was twenty-five minutes long.

2.4. Materials

Figure 6: Rainfall probabilities for November, December and January 2018/2019

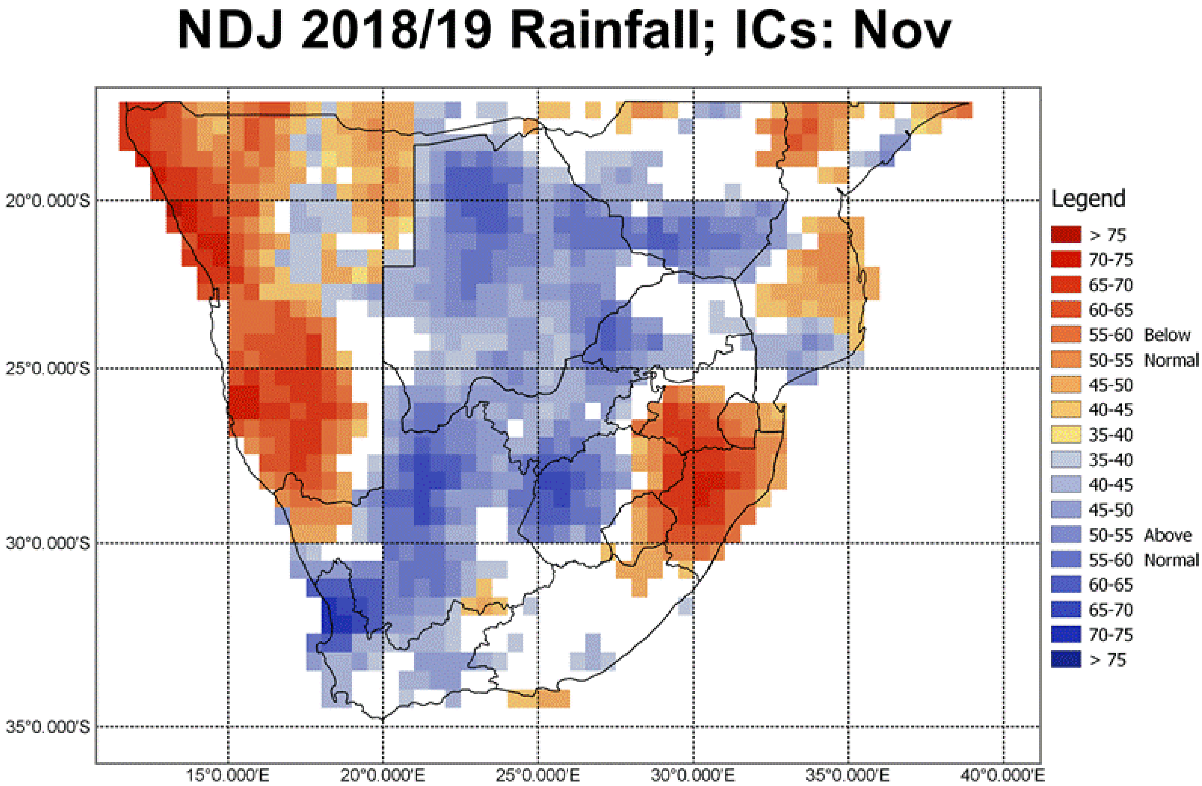


Figure 7: Above-Normal Rainfall Probability Skill Maps for November, December, January 2018/2019

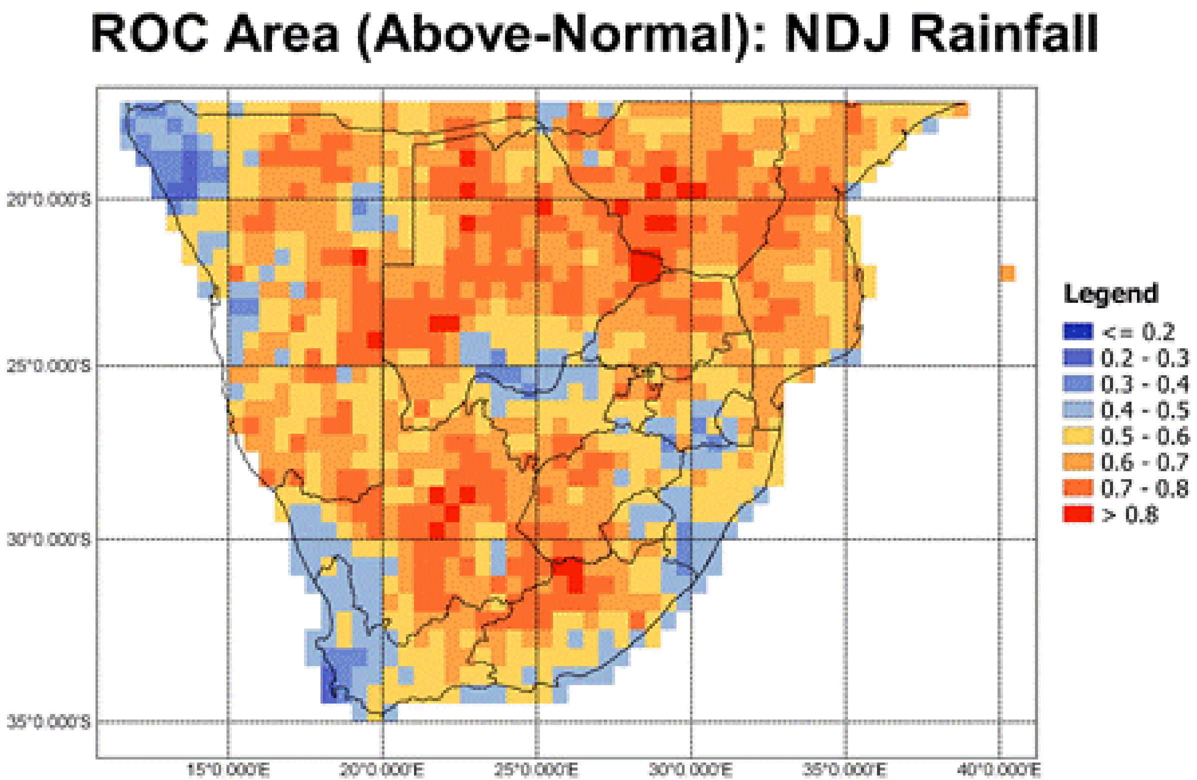
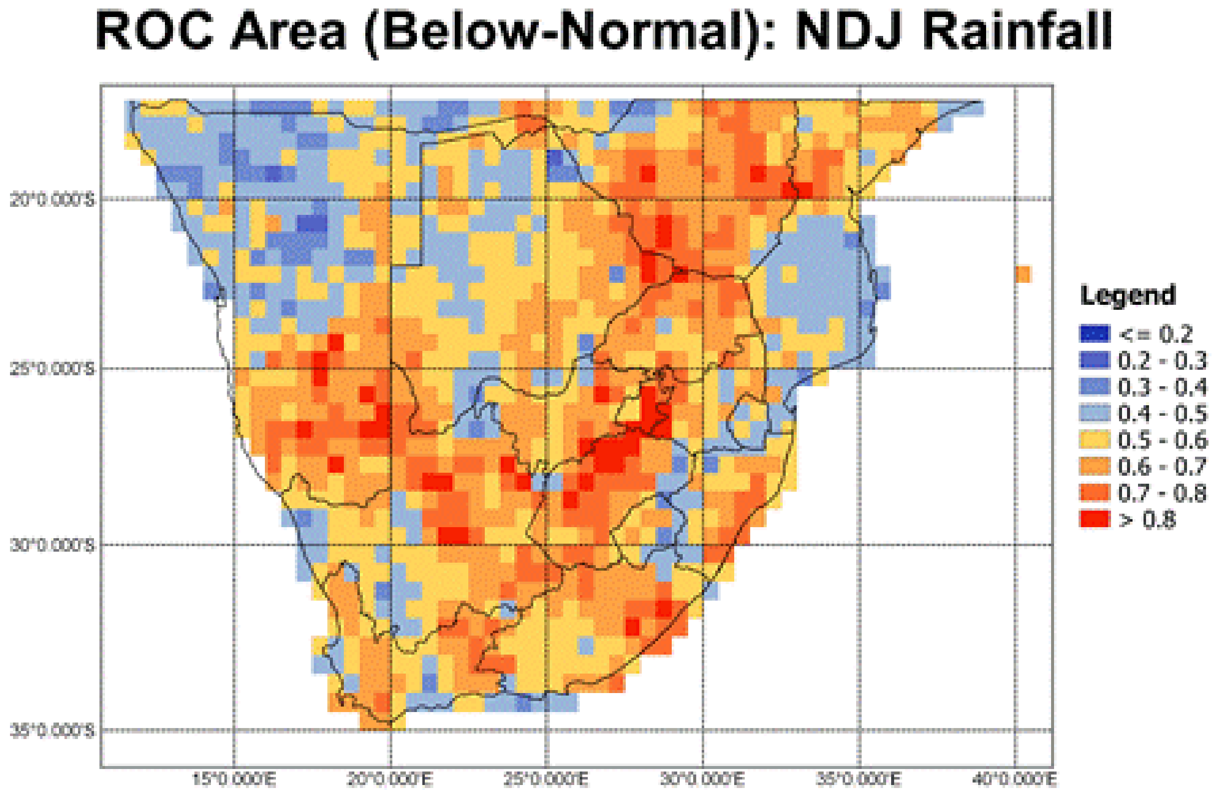


Figure 8: Below-Normal Rainfall Probability Skill Maps for November, December, January 2018/2019



2.4. Sample and Sampling

Non-probability, purposive, convenience sampling was utilised for the purpose of this study. These methods were utilised as only individuals who were considered representative of the proposed sample, as well as matched up to the specific criteria required were interviewed (Laher & Botha, 2012). Specifically, these criteria involved only individuals who were considered as experts in the field of climate science (and seasonal forecasting specifically) for the expert set of participants, and the second set of participants (i.e. the users) required individuals who were decision- and/or policy-makers in their particular field. An expert in this case would refer to someone who had extensive knowledge and experience in the field, and potentially produced seasonal forecasts for the use of others. A user would be classified as someone who made use of seasonal forecasting outputs in their work to inform their decisions. Furthermore, only participants who were available and willing to take part in the study were used. Thus, this study was made up of a volunteer sample (Laher & Botha, 2012). An invitation to participate was sent on the WhatsApp group with my email address for them to contact if they were willing to participate. The WhatsApp group led to snowball sampling to produce a greater number of individuals being contacted to participate.

The final sample consisted of fourteen participants. These individuals were from a range of sectors. An additional two participants were part of the pilot study. As shown in *Table 2.1* below, the average age for the pilot participants was 58 years old with a standard deviation of 3, and there was an equal split between the number of men and women in the sample. Furthermore, both participants' highest education level was a PhD and worked in the field of research.

Table 2. 1: Descriptive Data for Pilot Sample

Variables		**Frequency (N)**	**Proportion of Sample (%)**
Age (Mean; SD)	58; 3	2	100
Gender			
	Female	1	50
	Male	1	50
Highest Education Level			
	PhD	2	100
Current Field of Work			
	Research	2	100

Of the total number of participants in the study, four were part of the expert sample. As shown in *Table 2.2* below, the average age of the expert sample was 47 years old (SD = 8.337). The majority of participants were male with 75% (N = 3) and 25% being female. Similarly, 75% (N = 3) of participants held a PhD, while one participant (25%) held an Honours degree. All experts were in the field of research.

Table 2. 2: Descriptive Data for Expert Sample

Variables		**Frequency (N)**	**Proportion of Sample (%)**
Age (Mean; SD)	47; 8.337	4	100
Gender			
	Female	1	25
	Male	3	75
Highest Education Level			
	PhD	3	75
	Honours	1	25
Current Field of Work			
	Research	4	100

For the user sample, the average age was 52 years old (SD = 10.46) as shown in *Table 2.3*. In *Table 2.3* 70% (N = 7) of participants were male and 30% (N = 3) of participants were female. The majority of participants (N=7) obtained Masters' degrees (i.e. 70%). This was followed by two (20%) participants having PhDs and one participant (10%) with a Diploma. Users were from a range of sectors with the majority being from the Agricultural sector (N = 6; Users 1, 3, 4, 5, 6, and 8). The remainder of participants were from the Disaster Management (N = 2; Users 2, and 9) and Research sectors (N = 2; Users 7, and 10). Users in the research sector differed from experts in the research sector as their main field of study was not in climate science. However, the users did make use of seasonal forecasts as part of their studies or their daily work. The number of participants in this study was suitable when analysing data with the Interpretive Phenomenological Analysis (IPA) as this method is typically used on small sample sizes (Smith & Osborn, 2009).

Table 2. 3: Descriptive Data for User Sample

Variables		Frequency (N)	Proportion of Sample (%)
Age (Mean; SD)	52.3; 10.46	10	100
Gender			
	Female	3	30
	Male	7	70
Highest Education Level			
	PhD	2	20
	Masters	7	70
	Diploma	1	10
Current Field of Work			
	Agriculture	6	60
	Disaster Management	2	20
	Research	2	20

2.5. Data Analysis

The data collected from the interviews were analysed through the use of Interpretative Phenomenological Analysis (IPA). Interpretative Phenomenological Analysis (IPA) is mostly used when researchers want to determine how individuals interpret objects, events, as well as people (Pietkiewicz & Smith, 2012). In order to do this, the analysis method makes use of the principles of hermeneutics, phenomenology, and ideography (Pietkiewicz & Smith, 2012). The

Interpretive Phenomenological Analysis (IPA) framework can be used flexibly according to a study's specific research objectives (Pietkiewicz & Smith, 2012). According to Pietkiewicz and Smith (2012), typically a researcher would immerse themselves in the data by reading the transcripts, and listening to recordings if possible, as much as possible while making notes of any distinct phrases and ideas. These notes are then transformed into emergent themes (Pietkiewicz & Smith, 2012). From these emergent themes, relationships and conceptual similarities are found to create a list of major themes and subthemes (Pietkiewicz & Smith, 2012).

Below is a thorough understanding of the way in which an Interpretive Phenomenological Analysis (IPA) was conducted with the help of a text by Smith and Osborn (2009). Smith and Osborn (2009) state that this method should be adapted slightly to suit the needs of the research at hand:

- Printed transcripts were read a number of times along with the margin being used to note down any interesting or significant responses said by the participant. The re-reading of the transcripts allowed the researcher to become close to and familiar with the data (Smith & Osborn, 2009). This is important, as through the different readings of the transcripts, new and unnoticed observations may occur.
- Following this, the other margin was used to identify emergent themes from the notes taken. This was done through the use of short phrases which are meant to capture the core of what the participant has said (Smith & Osborn, 2009).
- These themes were then measured against what the participant had actually said in the transcript (Smith & Osborn, 2009). This allowed the researcher to ensure that the content of the transcript was adequately summarised in the theme identified without distortion of what the participant had said.
- The above was repeated for all transcripts.
- Next, the themes were connected. Some themes were grouped together, others were discovered as sub-themes of larger themes (Smith & Osborn, 2009).
- Following this, a table of themes was produced (Smith & Osborn, 2009). All themes and sub-themes were ordered here.
- Identifiers were placed alongside this table to ensure that corresponding quotes were easily identifiable in the transcripts (Smith & Osborn, 2009). During this process, it was found that some themes needed to be discarded since they did not fit the transcripts.
- A final table of themes was then created.

Any noteworthy similarities or differences between the design models of the experts compared to the users understanding of the climate change model outputs were identified, and any potential consequences of those themes were discussed. Furthermore, future directions for seasonal forecast production have been discussed.

2.6. Ethical Considerations

Ethical clearance was obtained from the Human Research Ethics Committee at the University of the Witwatersrand (non-medical – clearance number: MORG/19/003 IH) (see Appendix A). Any individual who participated in the study did so voluntarily. There were no benefits to participating in the study. Participant information sheets detailing the purpose of the study, and two consent forms were provided to each participant to be signed prior to the interview. The first consent form was consent to participate in the interview, and the second consent form was consent to record the interview and to use direct quotes. Along with this, participants were also informed verbally of the details of the study and of the finer ethical details at the time of the interview. The interview recordings are only accessible to the researcher and her research supervisor. These interview recordings and transcriptions are being kept in an encrypted folder on the researcher's computer. Participants were instructed that they could choose to not answer any questions they felt uncomfortable with. Further, it was explained that participants could withdraw their responses at any time. Anonymity could not be ensured during the data collection phase due to the method of data collection, namely face-to-face interviews. Demographic information was collected to help describe the sample. All identifiable characteristics have been left out of the final write-up of the research and participants have been referred to by a pseudonym; for example, Participants 1 and 2. Therefore, the confidentiality of all responses has been maintained. Participants were provided with contact details on the participant information sheet, which they kept, should they have any further questions. Participants were advised that they could also be provided with a brief summary of the findings of the study upon request. Finally, any major discrepancies between the expert and user knowledge were addressed in the form of a debriefing.

2.7. Reflexivity

Reflexivity is a method commonly used during qualitative research to ensure the legitimacy and validity of the research practices (Pillow, 2010). To do this, reflexivity acts as a method of quality control for qualitative research (Berger, 2015). This is done through the acknowledgement of subjectivity and the affects that subjectivity may inevitably have on the research (Pillow, 2010). Thus, it is particularly important to take into account the potential influences a researcher's personal experiences, social position, or beliefs may have on the interpretation of qualitative data (Berger, 2015). Reflexivity is important throughout the research process (Berger, 2015). Therefore, researchers make use of reflexivity to detect the potential effects these characteristics may have on the collection, interpretation and reporting of the data, thus improving the rigor and ethics of the study (Berger, 2015).

During this study, the researcher acted as the primary instrument for data collection. This may have had an influence on the interpretation of the responses from participants due to a number of factors discussed above (Berger, 2015). Thus, during the study, the researcher made herself aware of any potential biases or pre-conceived notions she may have had with regards to the responses she received. In the case of this study, her knowledge background was made up mostly of psychological concepts, whereas, the topic of her study focused on climate change model outputs (specifically seasonal forecast models), in conjunction with the psychological concept of mental models. This placed the participants in the "expert position" where the interviewer was unable to lead or influence their responses. There are a number of ways in which researchers practice reflexivity including writing self-critical accounts, keeping a journal or field diary, or reflecting on their writing style. In this study, a self-reflexive journal was kept where the researcher made note of any potential biases she may have had and how these could have impacted the research.

CHAPTER 3 – RESULTS

This chapter aims to explore the themes identified during the analysis of the interviews conducted. The chapter will begin discussing the themes and design models which arose with the experts, followed by the themes and mental models of the users. It can be seen that a lot of these themes overlap between the experts and users with some slight differences. Themes discussed in each question will be presented at the start of each section in the form of a table. Some quotations have been used to show support for the themes identified. It should be noted that certain identifiable characteristics have been removed from the quotations of participants to ensure confidentiality.

3.1. How are seasonal forecasting outputs viewed by experts and users?

The following section is divided into the views of the experts and the views of the users. Table 3.1 below shows the various themes discussed in this section.

Table 3. 1: Themes Captured During Data Analysis

Experts	Users
Combined Design Model	Mental Models of Seasonal Forecasting Outputs
Perceived Uncertainty in Seasonal Forecasting	Perceived Uncertainty in Seasonal Forecasting
Reliability and Skill of Seasonal Forecasts	Reliability and Skill of Seasonal Forecasts

3.1.1. Experts

3.1.1.1. Combined Experts' Design Model

During the interviews, experts were asked to explain the three maps they had in front of them (see *Figures 6, 7, and 8* on pages 42 and 43). *Table 3.2* on page 51 shows which expert identified particular features of the output, as well as which features were identified incorrectly and those they did not identify at all. It should be noted that none of these experts were from the organisation where these outputs were produced. For the first map, it was identified that the Initial Conditions (ICs) were used to run the models in August. This was a three-month lead forecast with a rainfall forecast produced for November, December, January (NDJ) 2019/2020. In the case of this forecast, red symbolised the higher probability for below normal rainfall conditions and blue symbolised a higher probability for above normal rainfall conditions. It was noted that these would not be the only categories when considering rainfall conditions, as typically there are three categories. Namely above normal, normal, and below normal. It was also identified that there would be masked-out areas, or white areas, which would indicate that there is no forecast being shown due to the skill of the forecasts having been identified as being very low in those areas and should not be used for decision-making. Thus, there is a lack of significance. Expert 2 identified that the resolution of the map would most likely be 50 km by 50 km. It was discussed that users would need to be wary of this due to spatial variation when it comes to mountains and other terrain characteristics.

It was explained that the next set of maps would cover how well the system would perform. These are known as skill maps. Specifically, the measure used for this map was the Relative Operating Characteristics (ROC) Curve Area. In the case of these maps, red was symbolic for good. The moment you get to your warmer colours or the warmer it is (colours in the red range), the more reliable the forecast is for that area. This can be good or bad news depending on the results of the first map.

When using these maps, it is important to look at the forecast as is. Then, look at the set of skill maps to determine which are the useful areas on the map. This would be due to the level of skill of the model. After this has been investigated, extra information should be considered. Specifically, the climatological information which shows what happens during that season generally. This is important because if certain areas have been shown to typically not have rain occur during those months, then a below average result does not have much of an effect on the region.

It is important to note that some of the experts were unable to define some of the acronyms on the maps. This is an important finding as it alludes to the fact that there may be an inconsistency in terms of the way in which these forecasts are produced by different organisations. This may lead to potential confusion among users. In particular, Experts 2 and 4 were unable to identify what the acronym ‘ICs’ (Initial Conditions) stood for. Furthermore, Expert 1 was unable to correctly identify when this output had been issued from looking at the information on the map.

Table 3. 2: Summary of experts' design models

Features	**Experts' Design Model**	**E1**	**E2**	**E3**	**E4**
Feature 1: Time periods	Forecast was produced in August for November, December, January (NDJ) 2019/2020	✗✓	✓	✓	✓
Feature 2: Acronyms	ICs = Initial Conditions; ROC = Relative Operating Characteristics	✗✓	✗✓	✓	✗
Feature 3: Map 1 – Categories	Red = higher probability for below normal rainfall conditions; Blue = higher probability for above normal rainfall conditions	✓	✓	✓	✓
Feature 4: Map 1 – Masked-Out Areas	White areas which indicate that there is no forecast being shown due to low skill in those regions	●	✓	✓	✗
Feature 5: Maps 2 & 3 – Skill Maps	Explains how well the system performs in a particular region	✓	✓	✓	●
Feature 6: Maps 2 & 3 - Categories	Red = good level of skill; The warmer the colours, the better the forecast is for that area. Can be good or bad depending on the results of the first map	✓	✓	✓	●
Feature 7: Combination of maps	When using these maps, it is important to look at the first map which shows the forecast. Following this, the skill maps should be consulted to determine which are the useful areas on the map.	✓	✓	✓	●
Feature 8: Other Information to be Consulted	After Theme 7 has been completed, extra information should be considered. Specifically, the climatological information which shows what occurs in the season generally.	●	✓	✓	●

E1-E4 = Expert 1 to Expert 4; ✓ = correct conceptualisation of feature; ✗ = incorrect conceptualisation of feature; ● = didn't address the feature at all; ✗✓ = some aspects of the feature are correct

3.1.1.2. Experts' Perceived Uncertainty in Seasonal Forecasting

When asked about whether or not there was any uncertainty apparent in the models, all experts were in agreement. Expert 1 stated that there was definitely a degree of uncertainty in the forecasts. Expert 2 explained the uncertainty in relation to how users may perceive it, "*The uncertainty around the whole process is high. People don't know what it means.*" Expert 2 states that users would likely trust the forecasts because it is believed that they were developed by reliable people, namely scientists. Thus, most users were not trying to understand what goes into the forecasts to develop them but were assuming that there were good reasons for the results being shown. Expert 2 did, however, express, "*uncertainty is a tricky word. farmers would much rather use the word reliability. That's what they want to know.*" This is likely because weather was always considered to be uncertain. "*you have to explain to them that this is all based on probabilities. There's certain conditions in the atmosphere at this time of year that are leading us to believe that there's a certain probability of wetter or drier conditions.*" (Expert 2). They further stated that the most difficult part of forecast production is the prediction of normal conditions. When looking at the uncertainty in relation to the forecast provided, Expert 4 stated that there definitely was a level of uncertainty due to the way in which the legend was presented, "*The maximum probability is more or less 75%... even then you don't get that high for above normal by the looks of it. All the rest of it, you know there's less than 70% probability of it happening for all of it. There's always a risk it's not going to happen.*"

Expert 2 explained, "*The forecast uncertainty relates to the ROC scores*." However, it was stated that more information is needed with regards to the skill scores provided on the maps. "*There's no definition of a ROC score, there's no indication of how the ROC scores are actually calculated, or what it actually means… and that to me is a huge problem.*" Expert 2 went on to explain that they understood what the Relative Operating Characteristics (ROC) meant, however it may be difficult for a farmer to relate it to their context, "*he's going to say, 'What the heck is that? How does that relate to me?' Is it skilful in that 13% or 60% of the years or 100% of the years when you said it was going to rain, it didn't rain? That communication is not given.*" It should be noted that there is some explanation of how these scores are reached in the information booklet which comes along with the maps. However, for the purposes of this study, only the maps were shown to help understand the mental models of experts and users.

Expert 3 did note, however, that it may be difficult to represent the uncertainty on the forecasts. "*it's to some extent presented more in the skill maps. Both of these would have a different type of uncertainty.*" (Expert 3). They did express that the forecasts are unable to guarantee the results, "*It's not 100% chance, so there's uncertainty inherently from the model or from the statistical downscaling here. But then there's also uncertainty on whether the model is correct or not.*" It was further discussed that individuals who are able to read the outputs correctly would be able to identify the uncertainties present. "*The uncertainties are pretty much baked into these two maps if you know how to read them.*" (Expert 3).

3.1.1.3. Reliability and Skill of Seasonal Forecasts According to Experts

During the interviews with experts, it was very much apparent that the usefulness of the forecasts for users was all dependent on the reliability of the forecasts. Expert 1 stated, "*I think if these forecasts are reliable, it can be extremely useful.*" The reliability of these forecasts also had an influence on the mental models of users. Expert 1 elaborated that, "*The outcome of the forecasts, and the fact that it doesn't work every single season… sometimes it goes wrong… so then in the back of their minds they will think, 'Oh okay, but maybe it will be like that and that year, because we also had that forecast but then we had that rainfall event.... and I had some good yield on that piece of land.'*" This is supported by Expert 3 who stated that, "*The question people usually ask is not, 'Well if you forecast this probability, how often is it correct?' They ask you, 'How good is your system percentage wise throughout the years?' 'Give a sort of a score of 50%, 60%, 70% in general for this specific area.'*"

Another aspect which brings about questions regarding the reliability of the forecasts are the number of forecasts produced by different organisations. Each of these forecasts have the potential to show different forecasts, whether big or small. Expert 2 explained what a user expressed their opinion would be if they received differing forecasts, "*One farmer said to me, 'You know what we do? We hope that the forecast is wrong.'*"

Expert 2 also discussed the issue of forecasting skill and the kinds of information that were being provided to users. With regards to the information provided, they explained that "*it's not always going to be good news [and] it is not always going to be accurate.*" This brings about questions from users regarding how an individual can judge whether or not a forecast will be accurate. Expert 2 explained the concept of verification schemes, "*they will look at past forecasts for specific regions, specific times and say that on average that forecast was only 50% skilful. Which means that really… you could've just guessed.*" When looking at most forecasting skill, Expert 2 explained that they typically had 60% maximum skill, "*It's marginally, in the long run, sixty years over a hundred… it's alright, but forty years out of a hundred it will be wrong. So, there's a huge ethical question around that.*" Thus, experts try to make the forecasts useful for users by explaining, "*'Under conditions like this… because this is an El Niño year, the likelihood of having drought has increased or elevated… and because it's elevated, the chances are, no guarantee, the chances are, for the coming season, are more likely to be drier than wet.'*" (Expert 2). As a response, Expert 2 explained that a farmer's actions would likely be to reduce the amount of fertiliser bought and choose seeds that are not long-growing and are drought or heat resistant because they would need less irrigation, "*in that way the forecast is now useful. It wasn't 100% accurate, 100% skill, but was useful.*"

3.1.2. Users

3.1.2.1. Mental Models

As with the experts, the users were asked to explain the three seasonal forecast outputs they had in front of them (see Figures 6, 7, and 8). In this section, each user will be reported separately and then the final results will be put into a *Table 3.3*. *Table 3.3* turns the expert design model into eight themes which will be related to the mental model of each user. It should be noted that at times participants did not reflect on certain parts of the model even with prompts, which makes it difficult to determine if they knew exactly what they were interpreting. However, from their answers it was easier to deduce if they did or did not know the interpretation of the outputs.

User 1 was unable to provide a lot of detail about the seasonal forecast. They focused more on the colour symbols and disregarded the skill maps completely. "*Normally the yellow and red and so on is showing you where the lower rainfall is. And then the blue, is it right, I think in our… is the blue the less rainfall? Or is it? No, it's more. So above normal.*" (User 1). Thus, User 1 was able to accurately identify the colour codes and their usage after some studying of the maps. Furthermore, the user did not attempt to identify which set of months the forecast was predicting for, the masked-out areas, and the usage of external information.

User 2 was able to identify what the legend represented, "*The colours normally mean the level of severity and how that severity happens to change over time.*" The user was unable to identify when the forecast was set for and was unsure of the skill maps, "*It doesn't necessarily give me a future date… this is the present rainfall probability just for the season. […] What is ROC? Alright well, I am not familiar with this, so I would have to study it a bit longer to get a sense of it.*" After having had a bit of time to study the maps, User 2 was able to partly identify the relationship between the maps, "*I assume this is the prediction, and this is the level of certainty of this prediction.*" However, User 2 was still a bit uneasy with the interpretation, "*exactly what above normal and below normal is… […] I am not too clear on what this says, other than the fact that it is obviously presenting a quite a different pattern for certain areas. A substantially different pattern. It possibly means that the models that they are using to do this are less secure* *in the drier areas than the wetter areas.*" (User 2). The user also did not address the masked-out areas of the maps, as well as the use of other information to interpret the maps.

User 3 found it easy to interpret the outputs and place it in the context of specific regions. In particular, the maize growing regions. "*I would say from the first chart we're probably looking at a standard to below average season for the maize growing regions in the country. There are other regions where we expect there to be probably a bit of a higher rainfall, but we're probably looking at a normal season in terms of rainfall. Normal to below average.*" (User 3). These conclusions are consistent with the experts' interpretations. Thus, it can be inferred that the user is able to understand the legend. When analysing the skill maps, the user found it a lot more difficult to understand exactly what it was trying to tell them. Instead they interpreted them as forecast maps for above normal and below normal rainfall conditions respectively, "*If I look at the other one.... I would say that probably backs up what I was suspecting because for the above normal, it doesn't look like we're going to get a lot of above normal rain, and for below normal, it doesn't look like we're going to get a lot of below normal rain. So, a fairly neutral seating.*" (User 3). Furthermore, the user was unable to determine the correct timeframe this forecast was predicting: "*the Rainfall for August, along the coastal regions we expect above average, on the interior we're expecting below.*" (User 3). Here, the user incorrectly identified that the production date of the forecasts as the month in which this forecast was predicting. Thus, August was actually the month in which the forecasts were produced, but the forecasts were predicting for November, December, and January (NDJ). The user also did not attempt to define the acronyms, as well as what the masked-out areas were meant to indicate. This being a trend among most users.

User 4 was able to interpret the legend, "*it's interesting that the blue colour shows an above normal. I'm guessing that that's the rainfall probability, so that was the above normal probability of rainfall which is the coastline which kind of makes sense. The yellow and lighter blues will be above normal. Then below normal will be the red portions. So, I guess the red colour will be in this case if you don't want rain. An indication of risk… the red areas will be the drier areas.*" The user also found it hard to interpret the skill maps, "*These [referring to maps 2 and 3] are a bit more tricky… The patterns are more scattered.*" The user was also unable to identify what the acronyms meant, "*I have no idea what ROC stands for… that would be the first thing that would throw me. Rainfall occurrence area? It seems like?*" When trying to interpret the second and third maps, User 4 expressed that it was found to be more difficult because the two categories were separated, "*It's more difficult because this has a nice above* *average, below average. This one does have a legend. It gives you a good indication of higher and lower… but whether it means that you've got a significant higher chance of rain,* or a *significant…*" (User 4). After having been given a bit of time to study the maps, the user was able to correctly identify the function of the maps, "*well the top says ROC area above normal rainfall, and then the one is below normal rainfall. So, would this then be interpreted that the below normal rainfall the higher would be the highest potential of below normal rainfall… the red colour? That would be my interpretation, and then the opposite would then be true for the top one that the higher percentage is then linked to the higher occurrence or higher likelihood of above normal rainfall.*" The User went on to say that more clarification on the skill mappings would be needed for ease of interpretation. Finally, the user was unable to identify when the forecasts were prepared for, despite having had the information on the map, "*what I'm missing, I would say, that probably date brackets… when they are estimating.*" (User 4). The user, was unable to identify what the masked-out areas meant, as well as the use of other information to supplement the predictions

User 5 admitted to struggling with all of the outputs. "*Acronyms. Again, I spend an enormous amount of time working with acronyms. I'm not even sure… and I'm trying to… those are the ones… again… so what I'm seeing from this is rainfall probability.*" (User 5). When asked about the legend, the participant was able to correctly map the legend to the output, "*These are likely to be wetter and those are likely to be below average. Again, there's a variability element within this. So those are going to be below what the normal is, it doesn't necessarily mean it's going to be dry which often what a red colour thinks. So above average, below average, for the next year… for this year.*" (User 5). However, as is shown with the last quotation, the user was able to identify the years the forecasts were predicting for, but was unable to determine which months. Once again, they had an issue with acronyms as stated previously. When looking at the skill maps, User 5 admitted to being unable to interpret the outputs. "*Yeah these ones are confusing me completely. And this is the kind of thing that I was leading to at the beginning. The complexity of this stuff, and they appreciate the richness of the science behind this but for me as a person…*" (User 5). Here, User 5 was implying that they had understood the complexity which goes into producing forecasts such as these, however, they were not made clear in the presentation of these forecasts. Specifically, with regards to the skill maps, the user understood that there was a level of uncertainty in the forecasts, but was not provided with the means to identify those uncertainties and complexities clearly in the forecasts without the requirement of a discussion with experts. Thus, the forecasts were not easily comprehensible to users.

User 6 stated that they had seen these forecasts on a regular basis, however it was immediately apparent that some of their interpretations were incorrect. This is particularly concerning in terms of the dates these outputs were predicting. "*So, I've got the 2019 rainfall ICs for August. I see these on a regular basis.*" (User 6). This is concerning as the user disregarded that there are two years which have been outlined on this map, namely 2019 and 2020, which may be an indicator that these forecasts were not only for one month. The user was, however, able to correctly interpret the legend for the particular region relevant to their work, "*it shows me trends for our area. So, it might not be able to ascertain very specifically for our farm, but I mean you can see the whole of Swaziland going across into the lowveld it is definitely below normal.*" (User 6). It should be noted that the user disregarded the skill maps completely. Furthermore, the masked-out areas were not addressed.

User 7 had experience with other forecasts and was unsure about the manner of the layout being presented. Specifically, there were issues with regards to the legend and acronyms, "*This is wrong. You're talking about below normal being greater than 75%... See I would say that that actually is… it suggests that this graph has… So, it's a summer rainfall story… I don't know what ICs means… it could mean all sorts of things…*" When referring to the skill maps, User 7 expressed, "*I don't know what ROC is… What I can tell you that if you ask them to tell me how much… I'm not sure what percent they use for what's significant, if they produce a map which was significant it would be largely white. So, all this colour I know is largely meaningless.*" This was an incorrect interpretation. The user was also able to correctly identify that the masked-out areas represented areas which are of no significance.

User 8 incorrectly identified that the red signifying below normal which in the legend represented drought. This is a common misconception as discussed in my literature review, "*The red part that shows that this is a bit of drought. There will be less rainfall in here… and then here the greener one… that's where there will be more rainfall.*" (User 8) (Klopper et al., 2006). It should be noted that the user also interpreted the blue colours as green. This may be an indication of a form of colour-blindness or an issue relating to language barriers. In the case of colour-blindness, outputs which make use of a range of colours to present their information as shown in Figures 1 and 4 in Chapter One, may need to take this into consideration during the production of forecasting outputs. User 8 did not discuss when these forecasts were produced for, but did make mention of the dates as shown. When looking at the skill maps, User 8 identified them as historical data maps, despite acknowledging that there was no indication of this. "*Now this one is sort of more zoomed in… so the scale… This one is above* *normal… okay… interesting. Yeah, this looks like a historic map… it doesn't look like a forecast. I'm looking into the pattern here, even though there's nothing mentioned of the year or anything.*" (User 8). Interestingly, User 8 identified that the skill map mimicked that of a historical data map which led to their conclusion, "*This is more consistent with what we do see from the previous years. It might not be the picture that we will see this year. I will have to check the forecast this year. But this is more like it happened last year.*"

User 9 did not make mention of when the following forecast was produced or for what time period the predictions were developed for. User 9 made particular note of the colours in the legend, however, it was hard to identify where the values they were discussing were coming from based on the outputs given. During further discussion it seemed as though the current output was being compared to that of previous outputs they had previously made reference to in their work. "*One firstly looks at the colours, […] the red colours are the areas where you see where the rainfall is going to be quite negatively impacted in terms of 0.8.*" (User 9). Interestingly, User 9 came to the conclusion that there would be a higher probability of above normal rainfall despite the maps showing largely below normal probabilities. Furthermore, the user began talking about the psychology of colours and what individuals would normally identify certain colours as being, "*Red will, without looking at the legend, people will intuitively think that red colours means bad, and blue colours mean good. So, one needs to be careful that the legend and the image match.*" The previous quote may be an indication that the user is unaware that the legend provides information regarding the probabilities of receiving a certain category of rainfall, rather than the actual amount of rainfall received in a particular period of time. The interpretation of the output was not similar to that of the experts. After having studied the outputs a bit more, User 9 explained, "*I just want to make sure of this legend in terms of rainfall probability… bigger than… so below normal is 75 […] So it is not a very positive forecast for the grain producing areas. Should be quite careful.*" After a taking a second look at the skill maps, the user matched that of the experts' interpretations. When referring to the skill maps the user noted, "*I am also aware that we need to know about what is the skill score of this specific forecast. So, the forecast itself is saying something, but how reliable is this forecast?*" (User 9). However, the user did not attempt to combine the two maps to determine if his initial interpretation was correct, and did not make mention of the masked-out areas.

User 10 was able to correctly identify the time period in which the forecast was set, as well as understand the legend correctly. "*NDJ 2019/20… the blue is obviously above normal rainfall and the red is below normal rainfall.*" The interpretation of the outputs was also correct and in line with the experts' perceptions, "*Here, I will see along the KwaZulu coast and in midlands it will be about 60% change of above normal, so it's the chance of getting above normal and that could mean that there's remainder of the chance to be different. Then all along the coast, North of Cape Town, there's a very thin line of above normal, but not very high above normal. Most of the Highveld, across the Free State and Gauteng and it's all below normal… maybe 60% chance of below normal.*" (User 10). In addition, User 10 was able to identify the masked-out areas and their significance in the overall prediction, "*Then there are a few white patches along the Eastern Cape and the central part of Limpopo. And the white patches are saying that there is no skill.*" Finally, when referring to the skill maps, the user was unable to determine what the relevance of the maps were and also acknowledged that there were difficulties with the acronyms. "*It doesn't tell me what ROC is… I mean, if I don't know what this is, so to me these maps are useless because I don't know what ROC is… I know that the blank areas are the ones where there is poorer predictability, but what the difference between these two above normal and below normal, and who knows what ROC… […] what ROC is, is gibberish. I just have to guess that ROC has something to do with R^2, and there are hardly any red parts, so we are not sure of anything.*" (User 10). Furthermore, User 10 indicated that along with these forecasts they would be making use of long-term data for a particular area during the required season to ensure that they are able to understand the climatological impacts of the probabilities being shown on the forecasts, "*I would work out what that curve is and say okay so above normal is above this amount of millimetres over the three month period. […] For the Highveld, I would have the long-term rainfall and therefore have the cut off value for the below normal at 33% probability would be below this many millimetres for this many months.*"

Table 3. 3: Summary of differences & similarities in experts' design model & users' mental models

Features	Experts' Design Model	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10
Feature 1: Time periods	Forecast was produced in August for November, December, January (NDJ) 2019/2020	●	✗	✗	✗	✗✓	✗	✓	✗	●	✓
Feature 2: Acronyms	ICs = Initial Conditions; ROC = Relative Operating Characteristics	●	✗	●	✗	✗	✗✓	✗	●	✗	✗
Feature 3: Map 1 – Categories	Red = higher probability for below normal rainfall conditions; Blue = higher probability for above normal rainfall conditions	✓	✓	✓	✓	✓	✓	●	✗✓	✗✓	✓
Feature 4: Map 1 – Masked-Out Areas	White areas which indicate that there is no forecast being shown due to low skill in those regions	●	●	●	●	●	●	✓	●	●	✓
Feature 5: Maps 2 & 3 – Skill Maps	Explains how well the system performs in a particular region	●	✗✓	✗	✗✓	✗	●	✓	✗	✓	✓
Feature 6: Maps 2 & 3 - Categories	Red = good level of skill; The warmer the colours, the better the forecast is for that area. Can be good or bad depending on the results of the first map	●	✗	✗	✓	✗	●	✓	✗	●	✓
Feature 7: Combination of maps	When using these maps, it is important to look at the first map which shows the forecast. Following this, the skill maps should be consulted to determine which are the useful areas on the map.	●	✗✓	✗	✗✓	✗	●	✓	✗	✗	✓
Feature 8: Other Information to be Consulted	After Theme 7 has been completed, extra information should be considered. Specifically, the climatological information which shows what occurs in the season generally.	●	●	●	●	●	●	●	✓	●	✓

U1-U10 = User 1 to User 10; ✓ = correct conceptualisation of feature; ✗ = incorrect conceptualisation of feature; ● = didn't address the feature at all; ✗✓ = some aspects of the feature are correct

3.1.2.2. Users' Perception of Uncertainty in Seasonal Forecasting

When asked about whether or not there was any uncertainty in the outputs and their projections, user responses were unanimous in that all users understood the uncertainty related to this kind of information. User 2 stated, "*I don't necessarily believe the work that comes out of it. I think it's good work, but I think it's too uncertain.*" This is supported by User 7 who said, "*Uncertainty is almost as good as tossing a coin and simply reflects the limits of climate science at the moment.*" While User 6 explained, "*I look at that and use that but with the full understanding that that could be different next week and the week after, and the following month. But at least I'm basing my decisions on something, rather than nothing. For me that gives me value, it guides me.*"

Furthermore, a danger which Users 2 and 5 discussed was related to how individuals interpret this information without the consideration of its uncertainty. User 2 stated, "*I think projections are dangerous in the sense that people tend to believe what those projections say, rather than use it as a measure of uncertainty.*" Furthermore, User 5 explained that those who produce forecasts should not try to simplify these outputs to the level that the complexity becomes ignored. "*That's pointless because you ignore the complexity and the uncertainty of this, which is also important to communicate. So, the trick for me I think is finding a way of maintaining that this is… there's no complete sure science in here… but this is an easier way of trying to communicate it.*" (User 5). This shows the dangers which may occur if users do not consider the fact that the forecasts are based on probabilities, thus, there is no guarantee of any particular outcome. It is also the responsibility of the forecast producers to make this clear to users when they make use of the outputs.

3.1.2.3. Users' Perception of the Reliability and Skill of Seasonal Forecasts

Some of the users brought up issues relating to the reliability of forecasts. User 3 explained that it can be hard to trust the outputs because of the varied and extremely specific forecasts throughout the country. "*That leaves me questioning how we can forecast at that kind of level of detail, cause from, and this is where the kind of scientist in me starts to think a little differently and say well… if I think back to what I remember from previous seasons, higher rainfall is typically widespread across the country.*" (User 3). Expert 3 was concerned about the manner in which these are interpreted.

Another issue at hand, which User 7 discussed, is with regards to multiple forecasts being produced by different organisations and the differences between them which can become overwhelming for the user. "*In one they use colour tones whereas the other one they're using different colours. So, you choose your model, and you get your forecast and they're all so different, so which one do you believe? If they're all so different and no one has confidence?*" (User 7).

Some users also discussed skill when asked about uncertainty of seasonal forecasts. For instance, User 1 stated that the science of forecasting has bettered over the years, "*When I started out forecasting was not so good. At least now we know that it will be El Niño or La Niña, so the farmers can use that information to really look at what they need to do.*" However, User 1 did express that in certain regions of the world the forecasting science is a lot more specific and is a lot more advanced, "*If you look at the US, they can really tell you exactly how many millimetres you are going to get today and tomorrow. It seems like their weather patterns are just more reliable than us… so I understand why our predictions are not so good.*" They went on to explain, "*I think our predictions are not very stable. Sometimes they predict El Niño and predict that it's not going to rain, but then there are smaller locations and other areas that get above normal rain, so the farmer would want to know that. You need to look at a much smaller location, and I think that's where we are lacking.*" (User 1). In support of this, User 7 stated that a central question in seasonal forecasting is which systems you are using to make predictions, and how predictable they are? "*One thing which I do know is that in Africa the weather systems are such that if you just want to measure how much rain falls… you've got to have more rain gauges or more observation, and ten times more than in Europe to get the same level of accuracy because it's so variable.*" (User 7). Thus, in any region of the world, you will either be more or less able to produce a reliable forecast, "*I think Southern Africa is not an easy place to forecast, but there are other places that are just as difficult. And then there are places which are easy. It's a function of what particular weather system you live in, rather than your skill levels.*"

3.2. How are seasonal forecasting outputs utilised by users?

The following section provides a comparison of the way in which users utilise seasonal forecasts versus how experts perceive they make use of them. *Table 3.4* below outlines the themes uncovered in this section.

Table 3. 4: Themes Captured During Data Analysis

Difficulty in Assessing Usefulness of Seasonal Forecasts for Users
Usefulness of Seasonal Forecasts
Information Used from Seasonal Forecasts
Expectations of Seasonal Forecasts
Unreasonable User Expectations of Seasonal Forecasts
Experts Uncertain of Required Timeframes
Required Timeframes
Other Information Used

3.2.1. Difficulty in Assessing Usefulness of Seasonal Forecasts for Users

During the interviews, the experts expressed that their main aim through the production of seasonal forecast outputs was to provide value to those who make use of them for decision-making purposes. Expert 1 expressed, "*One of my biggest aims here now since joining [name of organisation] is for us to produce seasonal forecasts that can be very useful and helpful.*" They went on to say that they were unsure about whether or not users relied on the information they received from the forecasts, "*What I can definitely say is that they do want to see it… whether it influences their decisions is another question.*" (Expert 1).

Furthermore, the experts expressed that they often tried to take the information and make it more accessible and understandable for the use of participants. Expert 2 stated that he did this through "*…advising farmers, writing up reviews of those forecasts*". Expert 4 also stated that he too provided advice to individuals who may find it useful in their work.

Expert 2, however, expressed that it can be a quite hard when trying to define usefulness for users themselves. They stated, "*It all depends how you define usefulness. […] it's useful to farmers and other people who want them because […] they're accessible, and they're available. But when it comes to usefulness one has to ask more questions. Is it useful to a specific user requirement? Is it something that they can act on? And is it likely to be useful again?*" (Expert 2).

3.2.2. Usefulness of Seasonal Forecasts

When users were asked whether or not they had felt as though seasonal forecasts have been useful to them in the past, a range of answers were uncovered. Some users found them to be very helpful. User 6 explained, "*I've been able to summarise this data year by year and start* *identifying weather trends which guide us in terms of what we, when we should be planting and availability of water and things like that.*" This was supported by User 9 who stated that they found them very helpful and tried to make use of them as often as possible. User 9 explained, "*because I work in the insurance field what is the anticipation of the number of storms you can expect. So, if they anticipate say below normal rates, it usually relates. Not always directly correlated to a lower frequency of convector storms and therefore you can have probably a lower frequency of hail.*" User 9 also explained that the forecasts had an impact on the dates farmers would decide to plant. This was supported by User 10 who stated that they had been helpful for planning in Southern Africa and other countries such as Indonesia. User 10 expressed that this information is mostly used for planning decisions. "*Maybe plant spacing, plant population, what kind of weather they should plant at all, whether it's a totally dry season with below normal for both the seasons. Then obviously you have to consider changing crops or something like that.*" (User 10). User 8 also stated that they found them very helpful, however they did express some concern while saying that the forecasts can be quite challenging, but necessary for the work done. Specifically, this was plant mapping.

There were, however, some users who found the forecasts helpful only on occasion. For instance, User 1 said, "*we do use them, but not as prescription for what we are going to do.*" They elaborated "*We will use it just to see are we going to get rain or not. But it's not really, as I say, it's not that important for us.*" (User 1). User 1 did note that they are very important for farmers, however. User 2 indicated that through the recent improvement of the science behind forecasting, they had recently begun using the forecasts more frequently. "*We wanted to refine what was done before [...]. The downscaling [the act of taking information from climate models and generating information which is useful at the local scale] has improved, and that makes more difference to me. The broader scaling that they used to work on was too broad for me. I can't make much out of it because I work on a much more micro-scale than they do. But the downscaling now is much better and actually might give us good insight into how things have changed.*" (User 2). Now User 2 has begun using the forecasts to determine the risks which may be of concern during different climate scenarios. Similarly, User 5 explained that forecasts are a large part of the industry in which they work, namely disaster management and urban planning, however it has not been something used directly by the user. "*I'm aware of them, I use the outputs from a lot of the discussions I have in the research with government decision makers, but it's not something I use myself.*" (User 5). They elaborated that the lack of predictability of the forecasts posed a challenge to their usefulness, "*Where they* *become un-useful is just by the nature of what that science is. It's unpredictable.*" Furthermore, there are challenges in terms of how they are presented which also pose a challenge for their usefulness, "*they're presented in a way that's very difficult for someone who's not a forecaster to be able to interpret in a way that matters for planners.*" (User 5). Interestingly, User 3 stated that the forecasts were useful for an aspect of forecasting which may not have been considered before. User 3 explained that the forecasts were used to assist individuals in preparing themselves psychologically with regards to what may potentially occur. However, large decision-making processes would not be based on the forecasts themselves. User 3 said, "*in terms of taking action on the forecasts, they are not accurate enough.*"

One user did mention that they found the forecasts to be not particularly useful. "*You have to know what they say, and they are important pieces of information if only to explain to people how little use they are.*" (User 7). They elaborated that there is very little information provided in seasonal forecasts, "*They are mainly about how little information there is, and as a consequence they have very, very little applicability or usefulness but it's very important that they be done, because they do provide occasionally maybe once every ten or twenty years, they might provide some operational information. What they also do is they just remind people of the extent of uncertainty in which we live.*" (User 7). User 7 did however note that it may be of slight use to farmers or those in the agricultural sector because the forecasts cover large regions. However, they added that they were curious to know if users based their decisions on them, and whether or not they had positive results. "*the only time I'm aware of a seasonal forecast having been used and affecting people's decisions about management, it turns out the seasonal forecast was wrong, and it had really quite bad effects.*" (User 7).

3.2.3. Information Used from Seasonal Forecasts

When asked about what kind of information users look for from forecasts, and what specific information from the forecasts they used to make decisions it was clear that there was a mismatch between the information which can be produced compared to what users expect of the forecast. When looking at the information used from the forecasts, User 1 expressed that they would mostly be looking at the rainfall forecasts. Specifically, "*We are looking at the locations we are selecting. We would look at long-term rainfall figures.*" (User 1). Users 3, 5, and 9 were trying to determine if there were any trends or patterns to be identified. "*A general trend. Are we expecting a really wet season? Or are we expecting a dry season? Further than that, not much.*" (User 3). This was supported by User 9 who stated, "*I am trying to see if I can* *pick up a trend of what's going to happen especially in terms of the coming season, mainly for agricultural purposes.*" In agreement with User 3, User 6 stated that they were trying to identify signs of "*drought, but equally, flooding. Both of them have very significant consequences for us.*" This was the same for User 10, who stated that their main concern would be the rainfall, as there is not much one can do to help the temperature. Interestingly, User 4 identified that what a user would look for may differ according to the sector in which they were in, "*From a marketing perspective, they would like to have a seasonal forecast at least for the whole growing season because they will then be able to estimate how much seed farmers would probably buy because of the risk in the environment. What type of seed, right? Because farmers would swing from one seed to the other because of the farming practices, and that will ultimately result in higher or lower sales.*"

3.2.4. Expectations of Seasonal Forecasts

Despite users understanding what information can be gathered from the forecasts, there was a trend in terms of users identifying what information they would like the forecasts to show in addition to the information discussed above. User 1 expressed the need for "*the history of rainfall and the prediction for that year as well.*" In support of this, User 2 said that the provision of the historical data would allow users to gain a sense of "*how well the models are working now.*" In addition to this, User 8 explained, "*We normally look into the onset of the rain, and if we're going to have enough for the season or not.*" Interestingly, User 5 stated that they understood the limitations of the science of forecasting, but ideally would like to know information regarding extreme climate events. "*How can we start having a better understanding of extreme events which is on a more short-term format? Then those forecasts become important… not just for flooding, but for drought, for fires when it's going to be dry and so forth.*" (User 5).

3.2.5. Unreasonable User Expectations of Seasonal Forecasts

Another theme which appeared frequently during interviews was that experts felt as though the expectations of the forecasts, as well as those who produce the forecasts were unrealistic in terms of what the science can produce at the moment. "*I've done probably ten or fifteen workshops where you ask farmers what they want, and we just have to say… 'Right, the state of the art of forecasting is such that we cannot possibly give you that kind of information, so we are going to try and tailor what we have to best fit your requirements'*" (Expert 2). Thus, there has been incongruence between what the experts can provide to the users, versus what the users would actually want from the forecasts they receive. Expert 1 stated that users were seen to be "*a bit fragmented in how they approach using it*". Thus, there were varied needs and uses for each forecast.

Furthermore, Expert 1 expressed that users have asked for quite specific information with regards to the coming season to assist their decision-making processes. This was supported by Expert 2 and 4 who stated that there were five main points of information which users, specifically farmers, would ideally want. Firstly, they would want to know when the rain was going to start "*on time, late, or earlier than norma*l" (Expert 2)". Secondly, they want to know whether the rainfall would be higher or lower than the average rainfall in their region. Thirdly, they would like to know if the rainfall would be spread evenly across the season. Fourth, they would like to know if they would be expecting any intense rainfall events at any point during the season. Finally, they would like to know when the rainfall season was expected to end, whether it was early, late, or normal. Additionally, Expert 1 expressed that the kinds of information users were looking for changed throughout the year which is unreasonable in terms of what the forecasts were developed to provide and what they can produce as expressed by Expert 2. Additional information should be utilised to supplement this information.

There were, however, some of the expectations which could be met. As discussed by Expert 2, "*of all those, we can tell them about the average rainfall for the three months. We can infer that the rainfall onset might be late if we can forecast for the first period being dry and the later period being wetter then we can infer that they are going to start early, and we can make the same inference for the end of the season.*"

3.2.6. Experts Uncertain of Required Timeframes

When looking at the production of these forecasts, it is also important to understand expert perceptions of the needs of users. An important aspect of this would be regarding when users would require the information in order to have ample time to utilise it in a way which will be beneficial for their work. During the interviews it was found that there were slight differences in opinions about whether or not these outputs would be needed sooner or later. Expert 1 expressed that "*farmers… most of them, I think, generally a season ahead. When there is some climatic challenge their focus can shift a bit. […] If things are not starting as they expected, then they immediately want to know what the end part of the season will look like because that will influence what they do.*" This is compared to Expert 2, 3, and 4 who were of the view that a month in advance would be sufficient. Expert 2 stated that "*They don't need it that far in* *advance to be honest… because there are a couple of decisions that they need to make ahead of time. One is ordering seed. One is ordering implements and ordering fertiliser, pesticides and so on. […] They can do it on a shorter timescale, but we've found that about a month is usually sufficient.*" This was supported by Expert 4 who said, "*If I'm putting myself in the position of a farmer then ideally you would need them as sort of a one to two months in advance I would say.*"

3.2.7. Required Timeframes

Users were also asked about the timeframes in which they would like the forecasts to be distributed. Most users (Users 3, 5, 6, and 8) were in agreement that this information should be received about a season or two ahead. "*We talk about a growing season which would be Spring/ Summer and a little bit of Autumn. So, in Spring, you would want to understand what your Summer is going… or in the previous winter you want to try and understand what your summer is going to look like.*" (User 3). User 8 noted, "*Since I'm in the research side, three months is more ideal. But I think for farmers it should be more than that.*" This was supported by User 10 who explained, "*Usually the decisions for planting and for ordering the seeds are being made more than six months before. […] if you are planting in October, you want that information in April or something, but if you talk to the seed suppliers, and they say they want it in the previous October because they want to multiply the correct seed.*" User 10 did note that it was understood that forecasts could not be produced a year ahead because of the nature of the science. This was also supported by User 5 who explained from a water planning perspective it is necessary to ensure there is sufficient water provisioned for the particular season ahead. "*Normally at the end of the wet season there'll be a discussion around what's happened, how much water is within the system. We know that that amount of water that has to last us through the drought, through that dry season, into the next wet season… and then the question is, how wet is the next wet season going to be? […] Are we going to have a drier summer? With more flash flooding events? […] It's not something that's a big immediate need of mine, but it's something that certainly helps the conversations when I go and talk to the city around sustainable drainage, or around water management and scarcity and so on.*" (User 5).

Importantly, User 9, as discussed briefly by User 10, noted the reliability which is attached to any predictions made too far in advance which needs to be taken into consideration, "*from a statistical point of view one should not put too much value on anything further than six months ahead in any case.*" They went on to explain that they have a more realistic view of the validity of the forecasts if they are produced too far ahead, thus have realistic expectations of forecasting ability.

3.2.8. Other Information Used

During the interpretation of the outputs, some users indicated that during decision-making, they made use of other information either alongside the seasonal forecasts or instead of them. Interestingly, this was mainly the case for users in the disaster management or urban planning sectors. User 2 explained that in the case of a flood scenario they would make use of terrain, land coverage, and soil information, as well as typical climate data, specifically actual rainfall and evaporation. They went on further to say, "*It varies from site to site. So, there is quite a bit of investigation that has to go into the kinds of analysis that I do and it's all site specific. So, I might choose different information from one area to another just because of the levels of sensitivity from one case to another or whatever the case may be.*" This is similar to that of User 5 who stated, "*My job is integrating a whole range of factors… so, from the planning infrastructural context, the rainfall climate variability information, the soils information, a whole range of things.*" Other than this, User 9 makes use of "*exposure information or economical information, or something like that where I can actually see that this is where the impact is. […] I sit with other information that needs to be integrated with this to reach a conclusion.*"

3.3. How are risk predictions and solutions thought of by each group?

Once the mental models of the outputs were identified, participants were asked questions relating to the risks that they would identify from these maps, and how they may approach dealing with these risks. In this section, expert responses will first be discussed, followed by that of the users. *Table 3.5* below highlights the themes addressed in the following section by comparing themes which arose from the expert pool versus those which arose from the user pool. This will assist in identifying whether or not both groups of individuals have similar ideas regarding the application of seasonal forecasts.

Table 3. 5: Themes Captured During Data Analysis

Experts	Users
Rainfall Profile is Risky	Rainfall Pattern Will Result in Significant Risks
Experts Would Seek More Information	Call to Action
	No Action Due to Uncertainty in the Predictions
	Risk in Trusting the Seasonal Forecasts

3.3.1. Rainfall Profile is Risky

From looking at the map, Expert 1 noted that it may be difficult for those producing maize in the next coming season. "*this doesn't look good for them. This is unfortunately a higher chance of not getting the needed rainfall… below normal rainfall.*" (Expert 1). They noted that it may be difficult for a farmer to identify what action they should take as a result of this forecast, "*I think the challenge one has is that… I mean, the farmers… […] if they're not planting, they're definitely not going to have any yield… and no cash flow. So the question to them is, 'Do I take a risk with this kind of situation?'*" They further expressed that it seemed as though it would be a very risky season for all users.

In the case of those in higher policy-making positions in the country, Expert 1 stated that their organisation would be in communication with the Department of Agriculture, Forestry, and Fisheries. "*Through extension officers, the message is then conveyed, 'Be conservative in your planning this coming season.' This is the message is that's going to be conveyed. It's not going to say, 'Don't plant.' but, 'Be conservative, it's a higher risk season based on what we see here.'*" (Expert 1). This was supported by Expert 3 who also stated that risks should not be taken during the season especially with regards to decisions which require water availability. They did note, however, "*This does not mean you will never get any rainfall in this area, it just means you're going to get less. How much less? We don't know.*" [Expert 3]. Thus, highlighting the uncertainties related to seasonal forecasting. Expert 4 explained that in terms of risk there would be little to no risk in the Western Cape during the season reported as typically there is very little rainfall, "*so those above normal probabilities probably don't mean much…*" This showed the manner in which the forecasts are interpreted. In particular, the forecast was examined and then mapped against the expected amount of rainfall in a certain region. This allowed users to identify whether the forecast was significant in a particular area or not. "*Maybe over KZN there's a risk of flooding there…*" This was determined due to the above normal rainfall prediction on the map. "*Maybe there's a risk of planting maize somewhere around the*

Free State and similar to southern Zimbabwe for subsistence farmers in Southern Zim." This was found because those areas were predicted to have below normal rainfall which users should take note of and be cautioned against. Thus, Expert 4 discovered some risk may be prevalent for maize farmers. The language used here should be taken note of, particularly the use of the word "*maybe*" as it reiterates Expert 2's statement which says that users cannot expect the predictions to be correct each and every time and there are levels of uncertainty associated with these maps. Expert 4 expressed that if the forecasts were confirmed to be correct after having consulted more information, they would be concerned about potential flooding in the Southern Mozambique and KwaZulu Natal regions. As a result, "*my recommendation [is to put out] a warning for Southern Zim and probably the Free State.*" (Expert 4). This echoes the responses of the other experts who state that only once the forecasts are confirmed, can actions be taken.

3.3.2. Experts Would Seek More Information

Expert 2 stated that before making any decisions, they would refer to other forecasts to determine if they had similar outlooks. This was supported by Expert 4 who said, "*My action would be to consult more forecasts […]. I'd also look at what some of the climate drivers are doing. […] Just to have a sort of overview of what the SSTs [Sea Surface Temperatures] are doing, and to see whether you can get a consistent message really, for these areas.*" Thus, the experts would not rely on only one forecast to assist with their decision-making. Furthermore Expert 4 expressed that they would make use of other climatological information such as Sea Surface Temperatures, and El Niño and La Niña trends. Along with this, Expert 2 stated that they would look at past predictions versus the actual rainfall during those time periods to determine which is the most accurate. Expert 2 expressed that the forecast which has been found to be the most accurate in the relevant region they are looking at, would likely be the forecast which the expert would utilise in their decision-making. They went on to say the typical actions of a farmer having had this information would be to, "*internalise it, discuss it with your friends, and make limited decisions based on this.*" (Expert 2). Thus, showing that the forecasts are not the only source in which individuals would evaluate risks for the coming season. With regards to the solutions or decisions being made as a result of the forecasts, Expert 2 stated, "*When you look at the kind of decisions they make, it's when to plant, how much to plant, what cultivar to plant.*" They did note however that farmers were aware that when they make a decision based on these forecasts, it is a risk that they understand they themselves as the users are taking. "*They could not expect us to be right every time.*" (Expert 2).

3.3.2. Users

3.3.2.1. Rainfall Pattern Will Result in Significant Risks

After having had the users interpret the seasonal forecast outputs, participants were asked about the risks which emerged from having interpreted the forecasts, and what their solutions or actions might have been as a result. User 2 stated that from looking at the forecasts it seemed as though, "*The wet areas are getting wetter and the dry areas are getting drier.*" User 8 reflected that by looking at the current forecast it was found that there may be difficulties in the season depending on where you would like to plant. Overall User 4 noted that, "*if you know that you are in the darker red, in other words like a 70 to 75 or higher probability of below normal rainfall, and that is across three months predicted… then that's definitely a risk, right?*" The language used here, specifically when they look for a form of validation in the use of the word "*right*", suggests that the user was not entirely confident in the conclusion that they have drawn here. This turned their statement of risk analysis into a question.

User 4 was able to express the risks and actions from multiple perspectives. From a farming perspective, some risks were identified. "*If you plant in October it's going to take February before you might get your normal rainfall. That's three months of plants starting to grow and germinate. If your soil moisture is not significant enough, you're going to have an issue with plants suffering. So, if you don't have supplementary irrigation really for that time you're going to be in trouble.*" (User 4). From a disaster management perspective, the user indicated that fire risks may be an issue, "*the fields are drier, so you have a significant fire risk*" (User 4). From the perspective of a pathologist, "*if we now have an above normal rainfall expected in some of these areas and we overlap that with some of the big commercial farmers depending on the varieties or the cultivar that they plant, this could potentially pose a risk for disease outbreak.*" (User 4). Finally, they noted that cattle farmers would also have potential risks to look out for, "*if it's below average rainfall it would mean that they would have to get feed supplement in, and of course if you now can stock up before the demand is high you can probably stock up on a lower price.*" (User 4). The responses from User 4 are particularly interesting as they show how the forecasts are useful to multiple users. In particular, it has shown how the decision-making processes which occur as a result of the seasonal forecasts can have domino effects on other aspects of a users' end goal.

3.3.2.2. Call to Action

User 1 stated that the predictions from the seasonal forecasts would not deter them from operating as usual. "*As a researcher, […] if you go into a period of low rainfall, then you can do good selections. You need to know which locations are still going to give you data. If you have marginal locations with marginal soils, the chances are that you are not going to get data from those locations.*" However, they did explain that from the perspective of a farmer, "*they will go and determine what moisture they have in their soils and then according to that they will then plan what is their potential. If they just get a little bit less rain than normal or normal rain, and then if they get more rain, then if the prediction is for more rain then they will maybe plan for a better potential. So, they can either plant higher densities or they can put more fertiliser or more inputs.*" (User 1).

From the perspective of someone who assists with developing policy for governmental use, User 5 explained that the predicted risks are extremely important to mention as part of policy documents. "*If I'm doing a report on water security, and there's longer-term information availability and if that risk is going to be higher or lower… that's an incredibly important part for me to put into a policy document, because that means that whoever is making decisions around water scarcity needs to know that their responses may need to be far more adaptive because there's a higher level of risk. If there's a lower level of risk, then what we can do is… You could put a lot more certainty and confidence in the type of policy documents that you are putting out.*" (User 5). Thus, showing the importance that seasonal forecasts can have on policy documents which have ultimately long-term effects. The policies can be received with more or less confidence because of the predicted forecast. This also needs to take into consideration the reliability of forecasts, however.

User 6 explained that it is very helpful in the work that they do, specifically in terms of awareness and any maintenance that needs to be done on the plot. "*[…] Driekoppies dam which is a source for irrigation. It is currently at I think 62%... if it was at 32% this map that you've sent me would actually cause me… it would spur me into action because we actually dug boreholes here, in 2005 we became aware that the dam had dropped to dangerously low levels and we received maps similar to this saying that there was drought conditions, so we responded by sinking boreholes, and we were actually the first to respond in the area. […] It was a very distinct advantage in terms of awareness.*" (User 6). Thus, the following user had found the seasonal forecasts along with information regarding dam levels extremely helpful in determining how to proceed onwards. User 6 went on to further discuss how the seasonal forecasts would assist them in deciding when to conduct maintenance services on the borehole equipment. "*to give you a bit of background the boreholes deteriorate whether you're using them or not because ground water is high in minerals, salts and calcium and so on… So, you get deposits building up on the pumps and they need maintenance. I'm not going to do maintenance on the pumps if the dam is at 62% but… and I'm also not going to do maintenance on them if I receive a forecast which is positive. But I will have to spend R20 000 on them if you send me a map like this and the dam is empty. So most certainly it would spur me into action at the appropriate time.*" (User 6). Thus, showing that the forecasts can be helpful for users in determining which actions to take and when.

User 3 interpreted that this would be a forecast for the month of August. This was inaccurate, but their interpretation of risks was still useful. "*This is short term… so I am not quite concerned about this cause it's August and in August we expect very low rainfall. So, the average is less than very little*." (User 3). As a result, User 3 expressed that they would continue as normal and their advice to farmers would be "*'Take it as it comes. Be quite careful with your plantings. If you get an early rain don't go plant your whole farm, plant a portion of it. If you just take the season as it comes and keep a little bit of it in a reserve because there is a significant level of risk.'*" This is quite interesting as it shows that the forecasts are not clear with regards to the period of time they are intended for. This has implications for the manner in which these forecasts are understood and utilised. Specifically, individuals are using information based on forecasts for another time period. This may have implications for the user and their decision-making, as well as their opinion of the forecasts due to their decision-making likely being inappropriate for the conditions at the time.

3.3.2.3. No Action Due to Uncertainty in the Predictions

There are, however, trickle effects which may occur in certain areas of business as a result of famers taking a slightly more cautious approach. This was discussed by User 9. "*There is an income reduction in terms of premium for this specific region. […] The implication is that farmers could be because of poor planting conditions, there will not be any crop to insure, and therefore it will impact on the revenue of the company.*" (User 9). Thus, there are not only risks for the farmers and their land, but also for businesses whose clientele is mostly farmers. However, they did note that the information received from the forecasts will not alter any policies or business strategies much due to the uncertainty related to the forecasts. "*Because* *there is so much uncertainty in terms of this forecast, and you cannot work with a 20 to 25% uncertainty in that business because there are other issues which are just as uncertain. So, people live with this environment of uncertainty.*" (User 9). As a result, User 9 stated that the organisation may look at the decisions they are making with slightly more caution due to the increased risk attached. This is similar to what was discussed with User 4. "*if they had to make a call on something, if it was a judgement call… [they] will be a bit more conservative. […] But it will be more subtle decisions, than something that is gone dramatically changing the whole direction of the whole ship. I don't think it will disrupt something, but I think it will be more cautious.*" (User 9).

In contrast to most other users, User 7 stated, "*It could not help me identify risks.*" They added, "*I've actually made a whole lot of policy recommendations, for agriculture, for energy and for water, based on my understanding of the region… I didn't use any of this.*" (User 7).

3.3.2.4. Risk in Trusting the Seasonal Forecasts

Interestingly, some participants also discussed "risk" in terms of the risk attached to them relying on the forecasts. This was discovered to be them either placing too much or too little emphasis on the forecasts in terms of their decision-making. For instance, User 8 expressed that due to the maps being a forecast, the risks were limited. These outputs would act as a form of advice in terms of how much inputs (e.g. seeds) to place. "*the risk will be that you will under-plan. But if you over-plan, and then they were proper and they were correct, then you lose. So that's the risk. It's minimal.*" (User 8). This was also discussed by User 9 who stated that it could be difficult to make decisions when relying on the predictions of the forecasts because there were a number of domino effects. "*what can happen, if you get earlier rain, in October, and then the planters and the merging of those crops is going to be quite poor. So, it could happen that a lot of the crops are not going to germinate effectively. So therefore, this region might be put under stress. What it will also mean in terms of our own company, the insurance company, if the farmers don't plant, they also don't take out insurance.*" (User 9).

User 10 further expressed that this information would never be used on its own, "*I would use it together with the rainfall that has been received. […] I would have to have the long-term rainfall and also the current amount of rainfall since the first of July*." Furthermore, it was explained that it can be confusing at times with regards to how to interpret the information, for instance, "*we are on the 15th of November and we have already received above normal for November so I don't know what to do then with this information… because then it will tell me* *that then that means that December and January are going to be extremely dry because I've had more than my fair share in half of November. Or what? I'm not sure.*" (User 10).

3.4. Do the perceptions align between the two groups?

During interviews, some experts explained where they believed the alignment between user and expert understanding of seasonal forecasting maps were not congruent and the potential reasons for this. *Table 3.6* below outlines the themes that emerged.

Table 3. 6: Themes Captured During Data Analysis

User Understanding According to Experts
Misinterpretation of Information by Third Parties

3.4.1. User Understanding According to Experts

Experts explained that the lack of understanding of these models is mostly attributed to poor user understanding of the science upon which it is based. For instance, Expert 1 stated that "*Seasonal forecasting science is not very well understood by, I think, most of the users out there… which is to be expected.*" An example of an area which may be most misunderstood is the skill maps. During the interpretation of the models, Expert 1 stated that "*Farmers won't know what these ROC [Relative Operating Characteristics] scores are… but we here know how it works.*" Furthermore, Expert 2 explained that the forecasts were able to provide users with details on the percentage probability of getting a particular category of rainfall; for instance, above normal rainfall. However, some users become confused with regards to the interpretation of the forecasts. "*that's not the percentage probability of getting normal rainfall or the percentage of normal that I'm going to get, and many people get confused with that… but it's the percentage probability of receiving a certain category.*" (Expert 2). This was further supported by Expert 3 who stated that "*The problem we have is the people out there that don't know this system. They tend to struggle to do what I just did. Really struggle. […] People tend to struggle to take this information with this… combine it.*" Here, Expert 3 was referring to the act of combining the first map provided with the set of skill maps to determine whether or not the prediction can be relied on or not. They went on to say that "*in the back of your head you know that there are people that do understand it and use it correctly, but there are probably people that just look at this and take that as a certain forecast and just run with it. Which is also very wrong, and then they don't even take skill into account.*" (Expert 3).

According to Expert 3, this lack of understanding may be attributed to the lack of statistical knowledge. They stated that "*For seasonal forecasting, statistics kind of takes the cake. You really need to understand that to understand seasonal forecasting.*" (Expert 3). In addition to this, poor understanding of how this information could be tailored for a specific user was discussed. Expert 3 noted that "*something people tend to do… is they go and zoom into a very specific spot, and they tend to look at that little blue spot and say okay well this model is not good at performing for that very specific area… and that's not really how you should be looking at a seasonal forecast. That's also one of the things that's very difficult to explain to people.*" Unfamiliarity with the sorts of information may also be a contributing factor to poor user understanding as explained by Expert 4 who stated that the rainfall probability legend may be confusing to most users. "*the fact that it goes from greater than 75 at the bottom and greater than 75 at the top in blue. So, you've got the same numbers associated with… and they me meet at 35 to 40. That would be confusing for someone who is used to seeing a scale that goes from either negative to positive or at least individual numbers. How do you get 65 as both a red and a blue?*" (Expert 4).

3.4.2. Misinterpretation of Information by Third Parties

It was also expressed by two of the experts that there were third parties, including journalists, insurance brokers, and companies who provide farmers with raw materials, who make use of seasonal forecasts but report on them inaccurately. These third parties are considered to be trustworthy by most. This then gets communicated to the users who thus make use of incorrect information or begin to develop incorrect mental models on how to interpret the forecasts themselves. Expert 2 explained that third parties should be basing this information on two factors, "*one they must know what they are talking about ... The second one is that they must be using the most skilful forecast cause if they are using a forecast that is likely to be wrong, you are now expecting people to react in specific ways based on that information. Like, 'Don't plant.', or 'Plant more.', or 'Plant less.' And those that have got significant impacts in the long run to that farmers income.*" However, Expert 3 stated that most of the time third parties had the intention of writing articles based on the information from the forecasts, but did not consult those who had produced the forecasts to ensure they were understanding the information correctly and as a result they were conveying the correct information to the public. "*they just write the news article saying that the weather service or the university is expecting above normal rainfall in the Western Cape. Then they would talk about sometimes there's potential* *for flooding and… but if you were just to have a look at the climatological map you would know that that's highly unlikely.*" (Expert 3).

Furthermore, users should also be aware of third parties who may be biased in terms of the information they distribute. Expert 2 stated that farmers may "*phone up the insurance companies, they might phone up the fertiliser companies and say, 'What do you guys think?' They must realise that the fertiliser companies want to sell a lot of fertiliser, and the seed companies want to sell the most expensive seeds.*"

3.5. How should seasonal forecasting outputs be presented in order for decision-makers to make accurate predictions and, ultimately, correct decisions?

During interviews, some experts and users provided recommendations for the future of seasonal forecasting production as a whole, as well as suggestions for this particular forecast. *Table 3.7* below outlines the themes discussed.

Table 3. 7: Themes Captured During Data Analysis

Uncertainty in the Level of Detail According to Experts
Users' Perceived Lack of Detail
Expert Recommendations

3.5.1. Uncertainty in the Level of Detail According to Experts

With regards to the level of detail on the forecast there were a range of opinions. When asked about the level of detail provided to users, Expert 1 stated that the seasonal forecast provided was quite general. While Expert 2 said that the maps provided a good amount of information. They went on to explain, "*the scale is good, and the intervals are good, but I think it lacks information in that it doesn't tell me that exactly what the definition of what below normal and above normal is.*" (Expert 2). To explain this, they focused on the representation of information on the first map, the expert focused particularly on the legend. "*What information is it actually telling me? It's telling me within a 5% interval, which I think is ridiculous because what is the difference between 55% chance of being below normal and 50% chance of being below normal… there's no difference there.*" (Expert 2). Similarly, they explained what the information on the map would be translated into in real life according to average climatological statistics, "*What do you mean by below normal? Is it going to be 100mm below normal? 50mm below normal? 5mm below normal? That's not defined, so that's a problem already.*" (Expert

2). Furthermore, they went on to explain that the legend which shows above and below normal probabilities for rainfall was unclear. Specifically, in terms of where the "normal" probabilities are presented. "*Where does the above normal and the below normal end? I can only presume that the blue is above normal, and the yellow and orange is below normal. […] It doesn't give any indication of what's the possibility of normal*" (Expert 2). Thus, Expert 2 had a mixed opinion regarding the level of detail of the seasonal forecast outputs. They stated that on the one hand they were quite detailed in terms of the legend showing the percentage probability of receiving a particular category, however, they did state that there would be a problem in terms of how this information was received by users. *"Orange says 55-60% chance of below normal. Now that would mean that there's a 40% chance of something else, but it's not showing blue it's showing orange… so my question is what is that 40% chance of something else? What is it? Is it the chance of normal? It's clearly not of being above normal.*" (Expert 2). Thus, there is some level of uncertainty, particularly for users who do not have an extensive background in climatological science.

In comparison, Expert 3 said that the forecasts provided "*Too much detail, probably, especially the skill scores… because again, our perception has been that people tend to not know how to use these with this. […] For someone that knows seasonal forecasts and knows how these things are calculated this is great, because I can really get information from this. […] For example, for people that have been working with seasonal forecasts in weather services, if they get access to it, I'd say this is great. This going out to the public is not going to be useful.*" They added instead of information, such as skill maps, which may not be understandable to the average person, could potentially be reworked and replaced with other information. "*I think what's missing from this specific one… is the indication of what happens climatologically. […] What's very useful is what actually happens normally, because people tend to not know this.*" (Expert 3). Expert 4 agreed with Expert 3 with regards to the level of detail and added that, "*It needs to be much more simpler… title... so that you know exactly what it is 2019/20 rainfall that's made in August.*" Along with this, "*It would be nice to have, maybe for someone else, November, December, January, or November to January or something.*"

3.5.2. Users' Perceived Lack of Detail

When users were asked about the level of detail in these forecasts, it was found that users either felt as though the outputs were somewhat detailed or they felt that certain information was missing. User 1 stated, "*I think this is detailed enough, but if you go onto certain areas in like* *a farm or a county or a province, and then countries then this is not good enough.*" However, User 7 expressed that additional information should be provided alongside these forecasts. If not, they could be deemed "meaningless" (User 7). Users 2, 9, and 10 stated that it is important to be able to relate this information to what "normal" in a particular area might be. This information was not provided currently. "*This just gives me above and below. […] I need to understand what the normal is, because if it's 20% drier in the part of the country that only gets 50 mm of rain per annum on average, I really need to understand what that difference means. […] 60 below zero is still nothing, and it may not be significant to what people need in this area. Whereas, this may be more significant because the risks may be more immediate. The percentage of 50 or 60% on top of a high rainfall area may be far more damaging*." (User 2). This echoes what Expert 2 had said in the previous section. User 9 added, "*For example, the blue here along the West Coast is insignificant because it doesn't rain really in the West. From an agricultural point of view, it is insignificant. While [in a maize producing area] it is important to have more detail in terms of what is the underlying meaning of it for that specific region.*"

Another aspect which was thought of as not detailed enough was the graduations of colours in each category in the legend. User 6 expressed that they are unsure how this could be adjusted, however, "*From 45 to 50, and 50 to 55, and 55 to 60, those three oranges are actually identical on a map like this. It's almost pointless having a differentiation between them because you won't pick that up easily on the map.*" Furthermore, User 10 expressed that the masked-out areas have not been identified on the map and could be hard for a user who has not come across other forecasts of this type to understand what the white areas on a map mean.

Interestingly, however, Users 7 and 10 agreed that the level of detail required would differ between the kinds of users making use of the outputs. User 7 explained that the provision of extra information may not help overall user understand simply because each user would like their own set of information specific to their needs. User 7 elaborated, "*I think they do provide for farmers, but I think the agricultural sector has their own process for taking whatever is said and trying to understand it. And the same for the disaster management sectors.*"

During the interpretation of outputs, some users voiced concerns around the ease of use of these outputs. User 2, for instance, stated, "*the messages are not necessarily immediate. I think one has to get a fairly sound understanding of what the person who prepared this was actually trying to say.*" They went on to explain, "*When you've got projections which say it could be* *wetter or it could be drier, what does that really mean? I think it takes quite a lot of interpretation by the people who have prepared the data to explain it to not just the lay person, but professionals as well.*" (User 2). User 2 further expressed that understanding how these forecasts were developed may better assist users in understanding the forecasts.

User 2 also expressed the dangers of producing outputs or providing outputs which were not user friendly. In particular, users may have decided that these were too complicated to understand, or not enough information was provided and may deter users from making use of them. "*if this was quite well explained, and I could tap into it quite quickly and believe it or understand it, then I might use it a lot more quickly than I would any other pattern.*" (User 2). They went on to say that this is a key matter because a lot of users were still trying to understand what these projections really said. This is further explained by User 5 who stated that having to understand multiple forms of information from multiple sources could be difficult when trying to make use of them in a helpful way without having some basis to understand them. "*Each specialist gives me something like this. What it means is I need to know a little bit about everything, […] I kind of want to pull my hair out in frustration with them because I see you, I hear, I understand this was complex to develop… but help me out a little bit.*" The user also expressed that developers should take into consideration the different sets of information provided to a user as well as their time constraints which may be upon them, *"for me then to go and take twelve sets of specialist inputs that have depth and to a decision-maker… I don't have the time to do the half an hour technical explanation for each of them that this would require… so I kind of want to know the one map message.*" (User 5). Thus, producing a forecast which was easy to understand, did not diminish the complexity of the science, and provided a bit of extra information with regards to the important aspects of the map may assist users to better utilise the seasonal forecast outputs.

According to User 5, this was not to be confused with simplifying, but rather providing an understandable way in which these are produced and relayed to users. "*Detail and complexity matters. I'm really not in the favour of trying to dumb-down messages, which is often what scientists tend to do."* User 5 elaborated that merely providing the end results for users to interpret takes away from the complexity and uncertainty of the science that is seasonal forecasting. To further assist with the understanding of these forecasts User 5 stated, "*For me its stuff like using the colours, explaining the links between them… rather than trying to simplify them. That complexity and that uncertainty is incredibly important, and I think particularly as climate scientists we're trying to convey something as certain when we are* *uncertain.*" (User 5). Thus, making the information understandable for those not characterised as specialists in the field was emphasised as key to ensuring accurate user understanding.

One aspect of the current output which has been expressed as being unclear was the division lines which represent provinces, catchment areas, rivers and so on. For instance, User 6 expressed, "*the lines for the provinces and for Swaziland need to be more bold so that you can more easily identify where you are on it. The catchment areas are very clearly bolded but to the average Joe, how the hell do we know what catchment we are in if we can't see the province lines?*" This is supported by User 5 who said, "*please help make maps clearer. So, the lines and the… I mean the rivers are important […] easily identify… bring up the provincial boundaries, identify towns and places a little bit more… pick different colours. The psychology of colours matters.*"

3.5.3. Expert Recommendations

Having seen the forecast provided, there were a few recommendations on how to make the forecasts more useful for the users. Specifically, Expert 1 stated that it might be helpful to include "*rainfall characteristics within this period. […] there are going to be frequent days… or the frequency of days is not going to be below normal… it's the amount of rainfall per event.*" Furthermore, Expert 1 explained that, "*Heat can also be a factor. They can compromise the outcome of the season in terms of yield. I think together with something like… with the rainfall forecasts and maybe a measure of […] heat attributes within the season can be helpful.*" This would likely be in the form of the temperature forecasts which are provided alongside the rainfall forecasts. Although this study aimed to focus on rainfall forecasts for the purposes of understanding user and expert mental models, it has shown that weather is a complex phenomenon which cannot be seen in isolation from other aspects, such as temperature.

Finally, Expert 3 expressed that what was found to be missing from the current forecast presented was that, "*There isn't a presentation, a short synopsis on what is expected that accompanies it.*" They explained that providing an expert view first may have assisted with the usability and understanding of the forecasts, "*We've found it very helpful to have an overview statement accompanying that. In fact, you start with that. […] start with an expert's view – what we think is the important part to highlight and then you could look at the maps for further information.*" It should be noted that this information is provided on a monthly basis along with the maps shown, however it was omitted for research purposes to determine whether the maps were understandable and useful without the need for accompanying information.

CHAPTER 4 – DISCUSSION

This chapter will make use of the results and literature discussed in Chapter 3 and Chapter 1 respectively. This section will combine the results of both the experts and the users. Once this has been completed, the results will be discussed in comparison to previous studies. Following this, the theoretical and practical implications of the results, as well as the limitations of the study will be examined. Finally, the directions for future research will be explored.

4.1. Do the perceptions of seasonal forecasting outputs align between experts and users?

In answering Research Question 1, the results show that there is some disparity between how users view the seasonal forecasts versus how the experts view them. Interestingly, however, there also are some disparities within each group. This is shown in *Table 3.2* where only two of the four experts had identified all the relevant features during their interviews. Experts 2 and 3 were found to have covered all the relevant features, while Experts 1 and 4 were found to have had some aspects that were not correctly identified. Expert 1 did not discuss certain features such as the masked-out areas, and the use of additional information in the interpretation of seasonal forecasting outputs. Furthermore, some of the acronyms were found to be hard to decipher for all experts except Expert 3. Expert 4 found it particularly difficult to decode the acronyms and interpreted the representation of the masked-out areas incorrectly. In addition to this, Expert 4 did not discuss the purpose of the skill maps or the introduction of additional information.

With regards to user mental models, there were a range of interpretations found during the interviews, as outlined in *Table 3.3*. This is a similar result to the study by Daron et al. (2015) who found that most users had varying mental models of the same concept. This may be the case due to users' having incomplete mental models for the seasonal forecasts as discussed by Norman (1983). Another issue highlighted by Norman (1983) includes users having mismatched mental models about seasonal forecasts. This may be the case in seasonal forecasting due to the different organisations which produce seasonal forecasts with different ways of interpreting them. This may lead to incorrect decision-making or decision-making which is not accurately supported by the data. Interestingly, almost all users were able to correctly understand the red and blue categories for the first map provided. However, most users, except Users 7 and 10, were unsure about the relevance of the skill maps. As a result, these users were unable to interpret the skill maps almost entirely. Two users (Users 1 and 6) disregarded the two maps completely, while others tried to interpret them unsuccessfully or with partial success. Another interesting fact is that almost all users disregarded the masked-out areas in their interpretation, as well as the use of additional information when interpreting the models. This may be explained by Stagger and Norcio's (1993) "cognitive lock-up" where individuals would rather continue interpreting a concept incorrectly instead of making the effort to change or adjust their mental model because this task has been seen as being too complex. Furthermore, two of the ten users were able to correctly identify the time period for which the forecasts are valid, while the rest were unable to identify the validity period (i.e. November to January). In addition to this, only one participant (User 6) was able to partially identify what the acronyms on the forecasts stood for while the rest either disregarded them completely or were unable to provide the correct answer. Notably, Users 1, 3, 5, 6, and 8 were found to have the most limited knowledge about the seasonal forecasts and were each from the Agricultural sector. User 9, who was from the Disaster Management sector, was also found to have a limited amount of understanding of the seasonal forecast outputs.

With regards to the uncertainty of the seasonal forecasting outputs experts believed that there were high degrees of uncertainty due to the nature of the science. This finding was supported by all users who understood that there was a lot of uncertainty which is inherent in this kind of information which is difficult to represent. However, the experts explained that they believed that most users were unaware of what exactly the uncertainty means and how they should go about using the forecasts. In particular, Expert 2 stated that it was hard to explain to users how they could make use of and adequately understand the probabilities seen in the forecasts. Users 2 and 5 discussed the dangers associated with seasonal forecasting outputs if the uncertainties and the complexities of the science were not taken into consideration. Thus, it was found to be important to find a way in which this could be communicated easily to users. Furthermore, Expert 2 and 3 both explained that the addition of the skill maps created more confusion for users as they were unaware of how the three maps related and how to identify the uncertainty inherent in the maps.

The uncertainties have an effect on the way in which a user views the reliability of the forecasts. During years in which the forecasts were not correct, users were found to view the forecasts as being unreliable because the uncertainties inherent in the forecasts had not been considered. This was supported by User 3 who stated that it was difficult to understand the distribution of the predicted rainfall over a particular period of time, usually three months. This may be an indication that further research is needed to understand how this information can be communicated to the various user groups, as supported by Harold et al. (2016), as well as Retchless and Brewer (2016). Furthermore, having had a number of forecasts released from various organisations with differing predictions the tendency was to reduce the perceived reliability of the forecasts for users (Expert 2). Along with this are the various ways in which these organisations represented their forecasts which could be confusing when users were receiving forecasts from multiple organisations (User 7).

With regards to the seasonal forecasting skill, users had expressed that the skill of the science had bettered over the past couple of years, however there were still other areas of the world where forecasting skill was much more advanced (Users 1 and 7).

To answer Research Question 3, after having compared *Tables 3.2* and *3.3* in Chapter 3 which outline the experts' design models and the users' mental models respectively, it is clear that eight of the ten users have significantly different mental models from that of the experts. There were two users, namely Users 7 and 10 who had similar mental models to the design models of the experts. There were, however, still some differences present in their mental models of the seasonal forecasting outputs. User 10 was found to have had the most accurate mental model of the user group with the exception of being unable to correctly decipher the acronyms on the forecasting maps.

These results are not surprising because they follow the trend of previous studies where the design models and mental models do not match (Daron et al., 2015; Kalantzis et al., 2016; Mathevet et al., 2011; Taylor et al., 2015). These differences and similarities are extremely important as they affect the way in which a user makes use of the forecasts in their decision-making. It also affects their perception of the science of seasonal forecasting as a whole and how reliable they believe the information they are being given is. If an individual were to have misconceptions regarding a particular seasonal forecast, they may use their interpretations as part of their decision-making and ultimately result in negative outcomes for the user because the probabilistic predictions on the forecasts have not been utilised correctly. An important aspect of this study is that most users, except for two, ignored the relevance of the skill maps. This could lead to misinterpretations regarding the reliability of the outputs, as well as a misinformed understanding of the total amount of skill contained in the outputs. As a result, if a user were to have a negative outcome after having consulted the outputs, the user would likely develop negative opinions of the outputs overall. However, the user was unable to interpret the model correctly from the beginning and thus did not have adequate understanding to make decisions based upon this.

4.2. Do each groups' risk predictions and solutions align?

In answering Research Question 2, there were three different kinds of risk predictions and solutions thought of by experts. Firstly, Experts 1 and 3 stated that the season did not seem to have a favourable outlook for those in maize producing areas, and users in those areas would likely not get the required rainfall for the season. The experts explained that this would bring about questions regarding the level of risk about planting or not planting for farmers. Their recommendations were to be conservative for the coming season as it was perceived to be a higher risk season. They were unsure of how much less/more rainfall would be received, thus highlighting the uncertainties related to seasonal forecasting.

Experts 2 and 4 stated that their action before making any major decisions would be to consult more forecasts to determine if they had presented similar outlooks. They would also make use of other climatological information to determine exactly what the predictions would mean, and to determine which forecasts had been the most reliable in the past. This finding was also found in a study by Klopper (1999) in which the users who were studied had asked for more technical information including historical records rainfall events, as well as extreme events. For instance, Expert 4 had identified that in the Western Cape there was typically very little rainfall during the November, December, January period, thus there was little to no risk in that area. However, the experts maintained the view that the forecasts would not always be correct, and it is at the risk of the user to make decisions based upon this information. Expert 4 did, however, state that if the forecasts were deemed to be correct, they would be concerned about potential flooding in the Southern Mozambique and KwaZulu Natal regions.

When looking at users' perceptions, there were a number of different responses and resulting actions. User 2 stated that it seemed as though the areas which are typically wet would be getting more wet, and those which are typically dry would become drier. User 8 stated that certain areas may have difficulty planting due to the upcoming forecast. This was supported by User 4 who said that farmers may have an issue with their plants if the soil moisture is not able to make up for the reduced amount of rainfall. This was a similar response to that of User 1.

User 6 mentioned that the forecast received each month allows them to determine how they would like to maintain their farm. Particularly when it comes to boreholes. They have been deemed extremely useful. From the current map along with information regarding dam water levels, the user would begin to perform maintenance on their boreholes and start to prepare for reduced amounts of water. This is in contrast with User 9 who stated that the current forecast would merely make them be a lot more cautious in their decision-making, but no major actions would take place immediately. These responses are in contrast to that of User 7 who stated that they would be unable to identify risks from the seasonal forecasting outputs and would not take any actions as a result.

Another perspective which arose from the interviews with users were related to the amount of risk involved when choosing to trust the seasonal forecasting outputs. For instance, User 8 expressed the risk involved with either trusting the forecasts too much or too little and which could result in either under-planning or over-planning for the coming season. User 9 touched on this concept too but added that there are various factors which also need to be taken into consideration. This included the actions of other agents and their effect on the user's business. This theme was also touched upon in a study by Taylor et al. (2015) which found that there may be false ideas of certainty which reduce the level of trust in these forecasts. Thus, users need to be educated on the correct way to interpret the forecasts to ensure that there is a good level of trust with regards to the reliability of the forecasts. Finally, User 10 also expressed that they would never make a decision based purely upon the information received in a forecast, there would be other information such as long-term and current rainfall levels which would need to be consulted before any actions have taken place.

From the interpretation of the models, participants were asked to identify any potential risks and their resulting actions from the perceived risks to minimise negative consequences. As outlined above, when determining risks and solutions from the seasonal forecasts it seems as though most users' mental models align with the design models of the experts. Users 6 and 9 had the most similar perceptions to the experts with User 6 explaining that they would make use of additional information to determine their actions, and User 9 saying that they would be cautious in their decision-making. User 7 interestingly adopted an entirely different perspective and said that they would not make use of the seasonal forecasting predictions.

To answer Research Question 3, in terms of users' alignment with experts in terms of the risk involved in the trusting of seasonal forecasts, User 8 matches the design models of the experts in that the risk that users take is their own. This is an opinion shared by the experts. Users 9 and 10 also agree with the experts in that they will not base their decisions purely on the forecasts themselves but will ensure that other information is consulted beforehand. Overall, the results have shown that despite the user mental models of the outputs being mostly incorrect, users were still able to identify the recommended actions to take as a result of the forecasts. These findings contrast research by Lim and Klein (2006), who found that in order for two groups to perform well, there needs to be a shared understanding between the two. However, their study did take the levels of performance into consideration. Thus, the mental models of the users in this study could be adjusted through further education to ensure that they reach optimum performance levels. Mathevet et al. (2011) also found that there were differences in the way in which users and experts managed the Reserve (in their study) as a result of the two groups not having mental models which aligned. However, the different findings found in this study may be attributed to the experts and users in this study having a shared goal, as discussed by Mathevet et al. (2011) and Lim and Klein (2006). Currently, there is limited research on mental models in the context of climate science. Further research in the particular area of climatology is required to determine exactly why this may be. A potential hypothesis may be that the legend for the probabilities of rainfall is easily understandable which resulted in users being able to clearly identify the risks present in the outputs. However, it should be noted that users had the tendency to ignore the complexities that came along with the forecasts and thus, ignored that there were uncertainties which were inherent in the outputs. It was noted in the results chapter, however, that at times users seemed unsure of themselves in relation to their solution planning. It should be noted that with the correct training and education of the forecasts, users may be more confident in their decision-making abilities.

According to experts, there were two main reasons which may form part of the lack of understanding some users may have. Firstly, there is a poor understanding of the science overall (Expert 1). This was found to be particularly the case when looking at the skill maps. Interestingly, this was predicted by the experts (Experts 1, 2, and 3). Expert 3 attributed this lack of understanding of the skill maps to poor knowledge of how statistics are utilised. Furthermore, Expert 3 noted that the forecasts were being used incorrectly as individuals are purely looking at them for the particular area relevant to their work. Instead, individuals should be looking at the seasonal forecasting outputs as a whole. Thus, this may be attributed to incomplete mental models as discussed by Norman (1983). This may result in individuals interpreting the models as they have done before without the introduction on the new and relevant information because it is seen as being too complex (Staggers & Norcio, 1993). Furthermore, the introduction of new information may seem like a task which is too time-consuming and effortful, that users would rather interpret the outputs using incorrect mental models instead of developing them further (Staggers & Norcio, 1993). This all could lead to negative consequences as a result of inaccurate decision-making if not all features of the outputs are considered.

Another reason is the misinterpretation of information by third parties. Experts 2 and 3 explained that third parties, such as news outlets, are also guilty of providing incorrect information to the public because most do not consult with the research scientists to ensure that their understanding of the seasonal forecasting outputs are correct. Instead, they interpret them themselves and then translate this information to the public, including to users who may make the incorrect decision as a result. These news outlets are considered to be trustworthy sources and thus, users would not question their interpretations. These outlets and other third parties may also be biased in terms of the information they want to put out to users and thus cannot always be trusted. Ultimately, this would have an impact on the users' views of the outputs and seasonal forecasting science rather than the third party itself, as discussed by Taylor et al. (2015). Inaccurate information from a source which is considered to be reputable may lead to negative consequences for the science overall, as well as create distrust between users and experts in the field due to the false level of certainty provided by misinformed third parties (Taylor et al., 2015).

4.3. How are seasonal forecasting outputs utilised by users?

During interviews, participants were asked how they made use of the seasonal forecasting outputs, and whether or not they found them useful. Experts stated that they would like for the outputs to be as useful as possible, but it is difficult to determine whether or not it is actually useful for all users. They did discuss that they were attempting to make them as accessible and understandable as possible for all users. Expert 2 specifically mentioned that usefulness may differ from user to user. They mentioned that merely having the outputs available may increase the perceived usefulness of the outputs as it is some kind of information to work with. When evaluating the users' responses, there were a range of answers. Some users found the outputs to be very useful and made use of them as often as possible. Furthermore, other users had found them helpful for management decisions in areas such as Southern Africa and Indonesia. It was mentioned, however, that although they are helpful and are necessary for users to make informed decisions, they can be quite challenging.

Other users discussed that the forecasts are helpful on occasion. In a study by Weisheimer and Palmer (2014), it was shown that mostly temporal seasonal forecasts were found to have good reliability and thus were useful in decision-making. However, seasonal rainfall forecasts were found to have a lesser reliability but could be considered to be slightly useful in some cases. These findings correspond with the findings of this study. Seasonal forecasts were found to be particularly useful for one category of users, namely those in the farming community. As the science has been developed, forecasts are increasingly being found to be more and more useful to other communities. However, it was stated that beforehand, the scaling was too broad, and the predictability of the outputs was a challenge for most of the users. It was also found that these forecasts could be useful for preparing the user's mindset. Those participants who found it to be somewhat useful stated that the outputs would not be their only source of reference when making decisions. On the other hand, there was one participant who stated that they did not find it useful whatsoever because they believe there is very little information provided in the outputs. These ideas have been found to have negative consequences for the mental models of users (Johnston et al., 2004). They found that the misinterpretation of the forecasts, or lack of reliability were found to have a negative impact on the overall mental model of the user (Johnston et al., 2004).

Users were also asked about the kind of information users look for from forecasts, and what kind of information is needed to make decisions. Users indicated that rainfall forecasts would be used mostly. Through this information, trends and patterns were identified to assist users in determining their following actions to prevent any negative consequences that may be imminent. Specifically, rainfall probabilities were of importance as there is not much one can do regarding temperature probabilities. There were, however, some expectations which users had regarding the seasonal forecast. Specifically, the provision of historical data along with the current predictions for the year. Another expectation was probabilities relating to the onset of rainfall, as well as extreme climate events. Experts did note, however, that users needed to have reasonable expectations of what the outputs were able to produce with the current level of the science. Users have indicated that they would like extremely specific information, however it has not been understood by the users that this information is not possible according to the current level of the science. Instead, users should make use of additional information to supplement the gaps in their understanding. Examples of the kind of information that can be used would be terrain, land coverage, and soil information, as well as typical climate data relating to the actual rainfall and other characteristics of rainfall.

Another aspect which experts need to consider are the required timeframes by users so that they are able to make the important decisions in the correct amount of time. Overall, it was found that experts were generally uncertain about the needs of users as there were a lot of varied answers. Some believed that they should generally plan a season ahead, where others believed that a month in advance or even shorter would be sufficient. Despite this, most users believed that a season or two ahead would be important due to the planning which needs to be done with regards to farming correct seeds and assigning the various resources needed to accommodate the seeds amongst other planning activities. This was also found to be important for natural resources planning. However, some users were able to understand that due to the nature of the science, this would not always be possible. In addition to this, some users have acknowledged that because the forecasts are using statistical analysis, predictions of more than six months ahead could not have much value placed upon them. However, this might be a misconception which contributes to the mental models of the users because it may not be the statistical ability of the science which contributes to its variability, but rather the erratic nature of the raw data which feeds into the statistical models. This includes information such as sea-surface temperatures (SSTs), El Niño patterns, and so on. These issues could be addressed through the introduction of the co-production of seasonal forecasting outputs (Porter & Dessai, 2017; Vogel et al., 2016). This may allow users to accurately understand what is relevant and what can be produced by seasonal forecasts. Further, it will allow producers of forecasts to identify what is usable in a user's daily life.

4.4. How should seasonal forecasting outputs be presented in order for decision-makers to make accurate predictions and, ultimately, correct decisions?

With regards to the level of detail there were some conflicting views when looking at experts' versus users' perceptions. Some experts and users agreed that the forecasts contained a good amount of information and were detailed enough, however, a few participants had a few questions regarding the detail of the outputs. One question which was brought up by both groups was with regards to the categories on the legend of Figure 6. They were specifically concerned with what above normal and below normal really meant, as well as where the normal probabilities would fit within that. Along with this, users were unsure of what "normal" really meant (in terms of actual rainfall in millimetres) in relation to the below normal and above normal probabilities. Thus, these should be made more clear or additional information should be provided to users for ease of understanding. Some experts advised that climatological information could be provided to users so they can refer to this information during interpretation. Additionally, Expert 2 explained that using intervals of 5% was not entirely helpful as the difference between a 50% chance of being below normal rainfall and 55% chance of being below normal rainfall does not change much. Furthermore, User 6 had expressed that it was hard to identify what intervals are being shown on the map as they are using the very similar colours which are not distinguishable.

Moreover, Expert 3 believed that the skill maps were too detailed for the average user who has not had quite a bit of background on the science of skill scores. This is supported by Harold et al. (2016) who stated that providing too much information to users may become overwhelming for the user and as a result the key features of the outputs were lost. Thus, experts in the field need to try to find ways in which this can be communicated so that the key aspects of the outputs are made clear to users. This kind of information would include explicitly explaining the meanings of the various colours of the maps, providing greater detail on the maps regarding the demarcation lines showing provinces, providing a synopsis for the maps – especially with regards to the skill maps and how they relate to one another. Furthermore, any uncertainties present in the maps should be made explicit. Thus, making the forecasts more accessible to all types of users. Furthermore, another expert identified that the titles should be a lot simpler for users to be able to interpret. This is supported by users being unable to identify when the forecasts were valid for as shown in *Table 3.3*. In addition to this, User 10 identified that the masked-out areas have not been represented in the legend which could be difficult for users to interpret who have never had any background on these maps. Finally, some users acknowledged that the level of detail required may differ between the kinds of users utilising the outputs. Thus, it may be difficult to accommodate all user needs. This is supported by Daron et al. (2015) who states that the guidelines and recommendations which assist experts with the development of the outputs can only help to a limited extent. The remainder of the development needs to take into consideration the needs of the individual users (Daron et al., 2015). Despite this being a particularly difficult task, it is extremely important to the concept of mental models, as well as the uptake of seasonal forecasts. An important question arises from this analysis concerning the level at which experts understand their users and their needs. Furthermore, do the experts have the means to educate users, as well as the ability to design the various outputs needed from users? Additional research on these topics are required for these questions to be effectively answered.

Another theme which came about during interviews was the perceived ease of use of the outputs by users. Firstly, User 2 stated that the messages the forecasts were trying to portray were not immediate which could lead to other users finding it too difficult to interpret and, as a result, finding other sources of information to assist with their decision-making. This conclusion was supported by a study by Taylor et al. (2015) which found that seasonal forecasts were found to be useful, however they were found to be difficult to understand in terms of how they have been communicated to users. In particular, the uncertainty related to seasonal forecasting was most difficult to understand (Taylor et al., 2015). User 5 also explained that users were not expecting these messages to be overly simplified, but rather just more understandable for the lay person through the use of symbols and colours which were easily understandable. In addition to this, Users 5 and 6 expressed the need for clear division lines in provinces, catchment areas and rivers. This would assist in making the maps as clear as possible so that users are able to clearly identify what is relevant to them.

During interviews some of the experts provided ways in which the current seasonal forecasting outputs could be improved to make them easier to use. Some of the recommendations consisted of providing more information on the rainfall characteristics within particular periods, such as frequency and intensity of rainfall events (Expert 1). It should be noted however, that this may not be possible because of the level the science is currently at versus the level of science needed to produce such forecasts. Another suggestion is to provide temperature forecasts alongside the rainfall forecasts. As mentioned previously, these are available, but for the purposes of this study only the rainfall forecasts were utilised. Another example would be to provide short expert views along with all forecasts for users to see what the general outlook is for the three-month period which users could then use to outline their views for their own decision-making. This is supported by Harold et al. (2016) who stated that providing information apart from visual cues may assist in understanding and overall usefulness of the outputs.

All in all, there is a clear trend that can be identified from the above, there needs to be some kind of collaboration between the users of the forecasts and the experts of the forecasts. This has been supported by a number of studies (Porter & Dessai, 2017; Vogel et al., 2016). There has been shown to be a clear lack of knowledge in terms of the needs and requirements of users, versus what the experts believe users already have knowledge of. An example of this is the assumption that users would be able to clearly understand the purpose of, as well as, how to use the skill maps. Another example includes the omission of a legend which describes what the masked-out areas represent and how they can be interpreted by users. These are all aspects of the design process which need to be addressed in order to help close the 'usability gap' of the forecasting science (Porter & Dessai, 2017).

4.5. Theoretical Contributions and Practical Implications

The following study has added to the body of knowledge of mental model research. Specifically, there has not been a lot of research conducted on the mental models of seasonal forecasting outputs, so this study provides a good framework which other researchers can build upon. Another important theoretical implication this study has brought about is the importance that coherent expert design models may have in influencing the mental models of users. Specifically, there needs to be some understanding among the experts in this community regarding what kinds of information they are presenting to users and how they are doing so. Furthermore, this research added to that of Kalantzis et al. (2016) as it supported their findings in showing that there are significant differences in the mental models of users and experts. However, it also showed that there may also be significant differences among experts as a group due to the different institutions generating these outputs which have been shown to develop slightly different mental models regarding the outputs and how they should be presented.

A key practical implication this study has reflected is the importance of educating users on the seasonal forecasting outputs being distributed. It is critical that users are able to understand all aspects of the outputs and how they would relate to the work they engage in on a daily basis. It is also important to take into consideration aspects discussed in Section 4.5 regarding the ease of use of the outputs and how this can be bettered to assist users' understanding. Finally, the kind of extra information being provided to users should be understandable not only to the experts in the community, but also to the users. Thus, the outputs should try to explain the complexities of the science in a way which is understandable in layman's terms. Finally, this study has emphasised the need for the co-production of seasonal forecasting outputs. This has been shown through the comments made by users regarding their ease of use and the complexities inherent in these outputs, but it has also been shown through the lack of congruence between the design models of experts and the mental models of its users. The co-production of the forecasts may help to reduce these gaps.

4.6. Limitations

As with all qualitative studies, there are some limitations which should be considered. Most importantly, a researcher's inherent biases may have an effect on the interpretation of participant responses due to the subjective nature of qualitative studies (Adams & Cox, 2008). However, a reflexive journal was kept ensuring that these biases were not present in the interpretation of the results. Another important aspect to consider in qualitative studies is the reduced number of participants due to the time-consuming nature of in-depth interviews and the evaluation of those responses (Adams & Cox, 2008). This may influence the generalisability of the findings as the individuals interviewed were not an accurate representation of the entire seasonal forecasting community. Rather, the information gathered is particularly relevant only to the South African context, as well as a very select group of individuals. The majority of these individuals would be for those in the agricultural sector. Further research is required to develop this body of knowledge in order for it to be generalisable to more populations.

With regards to this study, the following limitations should be taken into consideration. Firstly, the same interview schedule was used for both experts and users. Upon the evaluation of responses, it was found that this interview schedule should be slightly different as some of the questions were orientated more towards the needs of a user rather than what experts' perceptions were. The reworking of the interview schedule may have been helpful in gathering more clear and insightful information from experts. For example, instead of asking experts what their perceived risks are from the information on the outputs, asking what they would recommend to users based on the information in the forecasts would be a more appropriate question for the nature of their work.

Another limitation of the above study is that the concept of mental models are not visible to the human eye. They are cognitive processes which contribute to the ideas an individual has about a particular topic or object. Thus, these mental models were not easily accessible and could only be understood through an individual's explanation of them. Therefore, there are a number of factors which can influence these mental models. Kalantzis et al. (2016) stated that the results of a mental model study can be influenced by any biased questions asked by interviewers, as well as the potential for spontaneous construction of a mental model through the use of long-term memory instead of working memory. Furthermore, the time an individual has to contemplate the mental models used to interpret seasonal forecasting outputs may bring about a change to those original mental models because they are having the time to think through their mental models when they normally wouldn’t in daily life.

Another limitation of the study was that participants were able to choose which part of the seasonal forecasting output they wished to interpret. This was likely to be a result of them being more familiar with certain regions of the maps compared to others, as well as having had certain parts of the map being more relevant to their ongoing work. Thus, it was hard to identify if all participants had the same mental model of the map overall. To make the contrasting views more distinctive, researchers may want to ask participants to interpret the entire map where participants would likely focus on regions relevant to their daily working life. Along with this, researchers may want to block off or highlight a particular section of the maps where they can ask all participants, including experts, to interpret that particular area. This will provide researchers with a solid idea of whether or not the participant is able to understand and make use of the information provided. This can also be compared to other users to determine where the faults in interpretation may lie. Thus, correct and incorrect mental models and resulting actions would be more easily identified.

4.7. Directions for Future Research

The concept of mental models is extremely complex and needs to be evaluated further, especially within the seasonal forecasting context. There are a number of recommendations and directions which future research could take. For instance, interviewing experts who have produced the outputs versus those who have not. This could be particularly interesting as my study only looked at experts within the field and not those who had produced the outputs being used. This may identify any disparities between experts in the community which may be attributing to the misunderstanding of outputs by users. Furthermore, this study made use of a range of users which assisted in identifying overall trends for users in terms of their mental models for seasonal forecasting outputs. Further research should look at identifying a particular group of users to study. This may assist in mental model research as it may assist with identifying the specific needs in terms of seasonal forecasting education, as well as the way in which seasonal forecasting outputs are presented to that category of users. An example of this may be individuals in governmental and municipal positions, or those who advise individuals in those positions about seasonal forecasting.

Additionally, it may be worthwhile to provide more information to users during the interview. The reason being is that individuals are provided with a lot more information when receiving seasonal forecasting outputs on a monthly basis. It may be of use to understand whether or not additional information, within reason, would assist users in understanding the forecasts more. An example of the kind of information which could be provided is the method used to produce the outputs, as well as the various significance levels which were used to map the output. This may assist in identifying whether providing additional information to individuals would be more or less helpful for the mental models of users. Finally, conducting research where both rainfall and temperature forecasts are shown may be interesting to determine how users make use of the two sets of information, and if they are able to combine the information given to them effectively.

4.8. Conclusion

This study has provided more information regarding the make up of mental models, specifically in the field of climate science. Important findings regarding the misalignment between experts' design models and users' mental models have been identified. More importantly, this study has highlighted the negative effects that this mismatch can have on a user's overall mental model of the seasonal forecasting science. This calls for experts in the field to re-evaluate the way in which their science is presented to users to ensure that they are as valuable and useful as possible. This study has been a valuable addition to the current body of knowledge, but there is still a call for further research to be done along with the recommendations for future research discussed.

REFERENCE LIST

Adams, A., & Cox, A. L. (2008). Questionnaires, in-depth interviews and focus groups. In P. Cairns, & A. L. Cox (Eds.), *Research Methods for Human Computer Interaction* (pp. 17-34). Cambridge, UK: Cambridge University Press.

Balijepally, V. G., Nerur, S., & Mahapatra, R. K. (2012). Effect of task mental models on software developer's performance: An experimental investigation. *45th Hawaii International Conference on System Sciences* (pp. 5442-5451). Institute of Electrical and Electronics Engineers.

Berger, R. (2015). Now I see it, now I don't: researcher's position and reflexivity in qualitative research. *Qualitative Research, 15*(2), 219-234.

Besnard, D., Greathead, D., & Baxter, G. (2004). When mental models go wrong. Co-occurrences in dynamic, critical systems. *International Journal of Human Computer Studies, 60*(1), 117-128.

Change, L. B., Yanda, P. Z., & Ngana. (2010). Indigenous knowledge in seasonal rainfall prediction in Tanzania: A case of the South-western Highland of Tanzania. *Journal of Geography and Regional Planning, 3*(4), 66-72.

Climate-ADAPT. (2017). *Uncertainty guidance.* Retrieved from Climate-ADAPT - Sharing Adaptation Information Across Europe: https://climate-adapt.eea.europa.eu/knowledge/tools/uncertainty-guidance/topic1

Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions.* Thousand Oaks, CA: Sage Publications.

Daron, J. D., Lorenz, S., Wolski, P., Blamey, R. C., & Jack, C. (2015). Interpreting climate data visualisations to inform adaptation decisions. *Climate Risk Management, 10*, 17-26.

Dilling, L., & Lemos, M. C. (2011). Creating usable science: Opportunities and constraints for climate knowlede use and their implications for science policy. *Global Environmental Change, 21*, 680-689.

Elum, Z. A., Modise, D. M., & Marr, A. (2017). Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa. *Climate Risk Management, 16*, 246-257.

Future Climate for Africa. (2017). *How to understand and interpret global climate model results.* Cape Town: Climate & Develoment Knowledge Network.

Grieser, J. (2014, September 10). *Flexible forecasts: Responding to user needs*. (Columbia University) Retrieved May 2, 2019, from International Research Institute for Climate and Society: https://iri.columbia.edu/news/flexible-forecasts-for-decision-makers/

Hansen, J. W., Mason, S. J., Sun, L., & Tall, A. (2011). Review of seasonal climate forecasting for agriculture in Sub-Saharan Africa. *Experimental Agriculture, 42*(2), 205-240.

Harold, J., Lorenzoni, I., Shipley, T. F., & Coventry, K. R. (2016). Cognitive and psychological science insights to improve climate change data visualization. *Nature Climate Change, 6*, 1080-1089.

Hope, S. K. (2009). Climate change and poverty in Africa. *International Journal of Sustainable Development & World Ecology, 16*(6), 451-461.

International Research Institute for Climate and Society. (2019, December). *Seasonal Climate Forecast.* Retrieved from International Research Institute for Climate and Society: https://iri.columbia.edu/our-expertise/climate/forecasts/seasonal-climate-forecasts/

Johnston, P. A., Archer, E. R., Vogel, C. H., Bezuidenhout, C. N., Tennant, W. J., & Kuschke, R. (2004). Review of seasonal forecasting in South Africa: producer to end-user. *Climate Research, 28*, 67-82.

Kalantzis, A., Thatcher, A., & Sheridan, C. (2016). Mental models of a water management system in a green building. *Applied Ergonomics, 57*, 36-47.

Kirtman, B. P., Min, D., Infanti, J. M., Kinter III, J. L., Paolino, D. A., Zhang, Q., . . . Suarez, M. (2014). The North American multimodel ensemble: Phase-1 seasonal-to-interannual prediction; Phase-2 toward developing intraseasonal prediction. *Bulletin of the American Meteorological Society, 95*(4), 585-601. Retrieved from NOAA.

Klopper, E. (1999). The use of seasonal forecasts in South Africa during the 1997/98 rainfall season. *Water SA, 25*(3), 311-316.

Klopper, E., Vogel, C. H., & Landman, W. A. (2006). Seasonal climate forecasts - potential agricultural-risk management tools? *Climatic Change, 76*, 73-90.

Laher, S., & Botha, A. (2012). Chapter 7: Methods of Sampling. In C. Wagner, B. Kawulich, & M. Garner, *Doing social research: A global context* (pp. 86-100). London: McGraw-Hill.

Landman, W. A., Barnston, A. G., & Vogel, C. (2015). Ranking seasonal rainfall forecast skill of emerging and developing economies. *31st Conference of the South African Society for Atmospheric Science: Apply the weather* (pp. 112-116). Centurion: Council for Scientific and Industrial Research.

Leedy, P. D., & Ormrod, J. E. (2013). *Practical research: Planning and design.* New Jersey: Pearson Education, Inc.

Lim, B.-C., & Klein, K. J. (2006). Team mental models and team performance: A field study of the effects of team mental model similarity and accuracy. *Journal of Organizational Behaviour, 27*, 403-418.

Lorenz, S., Dessai, S. F., & Paavola, J. (2015). Tailoring the visual communication of climate projections for local adaptation practitioners in Germany and the UK. *Philosophical Transactions of the Royal Society A, 373,* 1-17.

Mason, S. J., Joubert, A. M., Cosijn, C., & Crimp, S. J. (1996). Review of seasonal forecasting techniques and their applicability to Southern Africa. *Water SA, 22*(3), 203-209.

Mathevet, R., Etienne, M., Lynam, T., & Calvet, C. (2011). Water management in the Camargue Biosphere Reserve: Insights from comparative mental models analysis. *Ecology and Society, 16*(1), 1-20.

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team progress and performance. *Journal of Applied Psychology, 85*(2), 273-283.

Modise, W., & Mphale, K. M. (2018). Weather forecasting: From the early weather wizards to modern-day weather predictions. *Journal of Climatology & Weather Forecasting, 6*(2), 1-9.

Morse, J. M. (1994). Designing funded qualitative research. In N. K. Denizin, & Y. S. Lincoln, *Handbook of qualitative research.* Thousand Oaks, CA: Sage Publications.

Norman, D. A. (1983). Some observations on mental models. In D. Genter, & A. L. Stevens, *Mental models* (pp. 7-14). New York: Psychology Press.

Overpeck, J. T., Meehl, G. A., Bony, S., & Easterling, D. R. (2011). Climate data challenges in the 21st Century. *Science, 331*, 700-702.

Payne, S. J. (1991). A descriptive study of mental models. *Behaviour & Information Technology*, *10*(1), 3-21.

Philander, S. G. (1985). El Niño and La Niña. *Journal of the Atmospheric Sciences, 42*(23), 2652-2662.

Pietkiewicz, I., & Smith, J. A. (2012). A practical guide to using Interpretative Phenomenological Analysis in qualitative research psychology. *Czasopismo Psychologiczne - Psychological Journal*, *18*(2), 361-369.

Pillow, W. (2010). Confession, catharsis, or cure? Rethinking the uses of reflexivity as methodological power in qualitative research. *International Journal of Qualitative Studies in Education, 16*(2), 175-196.

Porter, J. J., & Dessai, S. (2017). Mini-me: Why do climate scientists' misunderstand users and their needs? *Environmental Science and Policy, 77,* 9-14.

Retchless, D. P., & Brewer, C. A. (2016). Guidance for representing uncertainty on global temperature change maps. *International Journal of Climatology*, *36*, 1143-1159.

Rogerson, C. M. (2016). Climate change, tourism and local economic development in South Africa. *Local Economy*, *3*, 322-331.

Salkin, N. J. (2012). *Exploring research.* New Jersey: Pearson Education, Inc.

Sax, H., & Clack, L. (2015). Mental models: a basic concept for human factors design in infection prevention. *Journal of Hospital Infection, 89*, 335-339.

Seasonal Forecast Worx. (2018). Seasonal forecasts. University of Pretoria.

Seasonal Forecast Worx. (2019). Seasonal forecasts. University of Pretoria.

Smith, J. A., & Osborn, M. (2009). Interpretative Phenomenological Analysis. In J. A. Smith, P. Flowers, & M. Larkin, *Interpretative Phenomenological Analysis: theory, method and research* (pp. 53-80). Los Angeles: SAGE.

Staggers, N., & Norcio, A. F. (1993). Mental models: concepts for human-computer interaction research. *International Journal of Man-Machine Studies, 38*, 587-605.

Stockdale, T. N. (2000). An overview of techniques for seasonal forecasting. *Stochastic Environmental Research and Risk Assessment, 14*, 305-318.

Taylor, A. L., Dessai, S., & de Bruin, W. B. (2015). Communicating uncertainty in seasonal and interannual climate forecasts in Europe. *Philosophical Transactions of the Royal Society A, 373*, 1-16.

The Department of Environmental Affairs. (2012). *National climate change response: white paper.* Republic of South Africa. Retrieved from https://www.environment.gov.za/sites/default/files/legislations/national_climatechange_response_whitepaper.pdf

Troccoli, A., Harrison, M., Anderson, D. L., & Mason, S. J. (Eds.). (2008). *Seasonal climate: Forecasting and managing risk.* Dordrecht: Springer.

Tufte, E. (1983). *The visual display of quantitative information.* Chershire, CT: Graphic Press.

Vogel, C. (2000). Usable science: an assessment of long-term seasonal forecasts amongst farmers in rural areas of South Africa. *South African Geographical Journal, 82*(2), 107-116.

Vogel, J., McNie, E., & Behar, D. (2016). Co-producing actionable science for water utilities. *Climate Services, 2*(3), 30-40.

Weisheimer, A., & Palmer, T. N. (2014). On the reliability of seasonal climate forecasts. *Journal of the Royal Society Interface, 11*, 1-10.

Wilson, J. R., & Rutherford, A. (1989). Mental models: Theory and application in human factors. *Human Factors, 31*(6), 617-634.

Ziervogel, G., New, M., Archer van Garderen, E., Midgley, G., Taylor, A., Hamann, R., . . . Warburton, M. (2014). Climate change impacts and adaptation in South Africa. *Wiley Interdisciplinary Reviews: Climate Change, 5*(5), 605-620.

APPENDIX A – ETHICAL CLEARANCE CERTIFICATE

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (SCHOOL OF HUMAN & COMMUNITY DEVELOPMENT

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: MORG/19/003 IH**
PROJECT TITLE:	Mental models of seasonal forecasting outputs among experts and decision-makers
INVESTIGATORS	De Carvalho Bianca
DEPARTMENT	Psychology
DATE CONSIDERED	01/07/19
DECISION OF COMMITTEE*	Approved

This ethical clearance is valid for 2 years and may be renewed upon application

DATE: 01 July 2019

CHAIRPERSON
(Dr Colleen Bernstein)

cc Supervisor:

Prof. Andrew Thatcher
Psychology

DECLARATION OF INVESTIGATOR (S)

To be completed in duplicate and **one copy** returned to the Secretary, Room 100015, 10th floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure be contemplated from the research procedure, as approved, I/we undertake to submit a revised protocol to the Committee.

This ethical clearance will expire on 31 December 2021

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX B – SUPERVISOR-SUPERVISEE CONTRACT

16. STATEMENT OF PRINCIPLES FOR POSTGRADUATE SUPERVISION

IN A CONTEXT OF ACADEMIC FREEDOM AND WITHIN A FRAMEWORK OF INDIVIDUAL AUTONOMY AND THE PURSUIT OF KNOWLEDGE THIS AGREEMENT IS WRITTEN IN THE BELIEF THAT THERE IS A RECIPROCAL RELATIONSHIP AND MUTUAL ACCOUNTABILITY BETWEEN SUPERVISOR AND STUDENT.

THE SUPERVISOR AND THE STUDENT:

1. Will establish agreed roles and clear processes to be maintained by both parties. In the case of joint supervision everyone's role needs to be clarified.
2. Will meet regularly and as frequently as is reasonable to ensure steady progress towards the completion of the proposal, research report, or dissertation or thesis. This time varies but the normal minimum requirement for face-to- face contact, spread across each year of registration is: 10 contact hours for an Honours project, 15 contact hours for a Masters by research report and 24 contact hours for a Masters by dissertation and a PhD.
3. Will keep appointments, be punctual and respond timeously to messages.
4. Will keep one another informed of any planned vacations or absences as well as changes in his or her personal circumstances that might impact on the work schedule. Unplanned absences or delays should be discussed as soon as possible and arrangements should be made to catch up lost time.
5. Will ensure that research on animal or human subjects is conducted according to the procedures and the requirements of the relevant University Ethics committee.
6. Will together complete progress reports on the research project, as requested by each Faculty Graduate Studies Committee.

THE SUPERVISOR:

1. Undertakes to provide guidance for the student's research project in relation to the design and scope of the project, the relevant literature and information sources, research methods and techniques and methods of data analysis.
2. Has a responsibility to be accessible to the student.
3. Will be prepared for meetings with the student. This includes being up-to-date on the latest work in his/her area of expertise.
4. Will expect written work as jointly agreed, and will return that work with constructive criticism within a timeframe (a suggestion of 2-4 weeks) jointly agreed at the outset of the research.
5. Will provide advice that can help the student to improve his/her writing. This may include referrals for language training and academic writing. The supervisor will provide guidance on technical aspects of writing such as referencing as well as on discipline specific requirements. Detailed correction of drafts and instruction in aspects of language and style are not the responsibility of the supervisor.
6. Will support the student in the production of a research report, dissertation or thesis. Provision should be allowed for adequate, mutually respectful, discussion around recommendations made.
7. Will assist with the construction of a written time schedule which outlines the expected completion dates of successive stages of the work.
8. Will ensure the student has the opportunity to present work at postgraduate/staff seminars/national/international conferences as appropriate.
9. Will assist with the publication of research articles as appropriate.
10. Will discuss the ownership of research conducted by the student in accordance with the University guidelines and rules on intellectual property, co-authorship and copyright.
11. Will ensure that the research is conducted in accordance with the University's policy on plagiarism.
12. Will ensure that the student is made aware in writing of the inadequacy of progress and/or of any work where the standard is below par. Acceptability will be according to criteria previously supplied to the student.
13. Has a duty to refuse to allow the submission of sub-standard work for examination, regardless of the circumstances. If the student chooses to submit without the consent of the supervisor, then this should be clearly recorded and the appropriate procedures followed.

THE STUDENT:

1. Undertakes to work independently under the guidance of the supervisor. This includes reading widely to ensure that the literature pertinent to his/her chosen topic has been identified and consulted.
2. Is obliged to make appointments to see the supervisor and will arrange meeting times well in advance.
3. Will think carefully about how to derive maximum benefit from these contact sessions by planning what he/she wants in these sessions.
4. Should submit written work for discussion with the supervisor well in advance of a scheduled meeting. The kind and frequency of written work should be agreed with the supervisor at the outset of the research.
5. Undertakes to submit written work that is relatively free of basic spelling mistakes, incorrect punctuation and grammatical errors. Responsibility for the accuracy of language, the overall structure and coherence of the final research report, dissertation or thesis rests with the student.
6. Undertakes to heed the advice given by the supervisor and to engage in discussion around suggestions made. Ultimately the student has to take responsibility for the quality and presentation of the work.
7. Should strive, within reasonable bounds, to maintain a focus on his/her research area and to work within the agreed time schedule.
8. Will prepare material for presentations at seminars and conferences.
9. Undertakes to submit papers for publication.
10. Agrees to honour agreements about ownership of the research and in accordance with the University's guidelines and rules in relation to co-authorship, copyright and intellectual property.
11. Will ensure that the work contains no instances of plagiarism and that all citations are properly referenced and that the list of references is accurate, complete and consistent.
12. Agrees to work in accordance with the criteria of acceptability as supplied by the supervisor.
13. Undertakes not to place the supervisor under undue pressure to submit work for examination until the supervisor is satisfied that it has reached an acceptable level of quality.

I confirm that I have read and understood this statement and agree to be guided by its principles

Name of student : BIANCA DE CARVALHO

Student's signature :

Name of Supervisor : ANDREW THATCHER

Supervisor's signature :

Name of Co-Supervisor :

Co-Supervisor's signature :

The broad area of study is : ORGANISATIONAL PSYCHOLOGY

Provisional submission date is: 14 FEB 2020

Degree : MA Org Psych

School : HUMAN + COMMUNITY DEVELOPMENT

Faculty : HUMANITIES

Date : 21/06/2019

Specific agreements pertaining to: ownership and joint publication, funding, etc. may be attached and signed.

GRIEVANCE PROCEDURES. It should be acknowledged that during the course of the research, both students and supervisors can feel aggrieved. In this event, matters should be dealt with as swiftly as possible by the parties involved and, if necessary, the appropriate Postgraduate Coordinators and Committees. There is, in addition, a University Grievance Policy to help guide deliberations. It is available on www.wits.ac.za/prospective/postgraduate.

APPENDIX C – PARTICIPANT INFORMATION SHEET

Psychology

School of Human &
Community Development

University of the Witwatersrand

Private Bag 3, Wits, 2050

Tel: 011 717 4503
Fax: 086 553 4913

Dear Sir/Madam

My name is Bianca De Carvalho. I am currently completing my Masters degree in Industrial/Organisational Psychology at the University of the Witwatersrand. As part of the degree I am required to carry out a research project. I have chosen to look at the different mental models of experts and decision- and/or policy-makers regarding climate change model outputs. I would like to invite you to volunteer to participate in my study. Participation in this study would involve an interview of approximately 45 minutes. All information provided will be confidential. These interviews will be recorded, however only I and my supervisor will have access to these recordings. These recordings will be kept in an encrypted folder on my computer. You may only answer the questions which you feel most comfortable in answering and you may withdraw from the study at any time without consequence. There are no benefits or disadvantages associated with participation in the study. Demographic variables will be collected to help describe the sample, however no identifiable characteristics will be discussed in the write-up of the study. Participants will be given pseudonyms to ensure confidentiality. Therefore, anonymity and confidentiality of all participants and responses will be kept.

If you have any further questions or need any results of the study, please contact me or my supervisor on the details bellow. If requested, a summary of the study and results can be provided approximately six months after the completion of the interview.

Thank you for considering to take part in this research. Please detach and keep this sheet for future reference.

Kind regards,

Miss Bianca De Carvalho

Cell: +27 73 214 4847

E-mail: 1091457@students.wits.ac.za

Professor Andrew Thatcher (supervisor)

Tel: +27 11 717 4533

E-mail: Andrew.Thatcher@wits.ac.za

For any information regarding the ethics of this study you may contact Shaun Schoeman from the University's Ethics Committee (HREC):

Tel: +27 11 717 1408

E-mail: shaun.schoeman@wits.ac.za

APPENDIX D – CONSENT FORM (Interview)

Psychology

School of Human & Community Development

University of the Witwatersrand

Private Bag 3, Wits, 2050

Tel: 011 717 4503
Fax: 086 553 4913

I, ____ (insert name here), consent to be interviewed by Bianca De Carvalho for the study looking at mental models of climate change model outputs. I understand that my participation is entirely voluntary, I may choose to not answer any questions, and I am able to withdraw from the study at any time. I understand that my identity, as well as any information disclosed will remain confidential. I understand that the write-up of my responses will make use of a pseudonym, for example Participant A or B. I am aware that there are no benefits or disadvantages associated with participating in the study. I recognise that the results of this study will be reported in a research report required for the completion of a Masters degree in Industrial/Organisational Psychology. I understand that direct quotations may be used from this interview. Finally, I understand that this research may be presented at any local/international conferences and/or published in a journal or book.

Name: __________________________ Signature: __________________________

Date: _______________

APPENDIX E – CONSENT FORM (Recording)

Psychology

School of Human &
Community Development

University of the Witwatersrand

Private Bag 3, Wits, 2050

Tel: 011 717 4503
Fax: 086 553 4913

I, ____ (insert name here), give consent for this interview with Bianca De Carvalho to be recorded for the study looking at mental models of climate change model outputs. I understand that this recording will be confidential where only Miss De Carvalho and her supervisor will be able to access. I understand that the write-up of my responses will make use of a pseudonym, for example Participant A or B, and no identifiable characteristics will be discussed. I understand that the transcripts and recordings of my interview will be stored in an encrypted folder on Miss De Carvalho's computer.

Name: _________________________ Signature: _________________________

Date: _______________

APPENDIX F – INTERVIEW SCHEDULE

Dear participant,

My name is Bianca. We have communicated via email. Thank you for agreeing to participate in my study. I would like to record the interview, but would like to receive your permission beforehand. Everything said during this interview will be kept confidential and the recordings will only be accessed by my supervisor and I. The tapes and transcripts will be kept on an encrypted folder on my laptop for the duration of the study. Thereafter, they will be destroyed. Any identifiable characteristics will not be disclosed in the final write-up of the report, thus your anonymity will remain intact. When your responses are referred to in the report, a pseudonym will be used, for example Participant 1 or Participant 2.

Please be reminded that you may withdraw from the study at any time during the interview. You may also choose to refrain from answering any specific questions if you wish. Upon your request, a summary sheet of the research findings will be mailed to you. My contact details, as well as my supervisor's, have been provided on the participant information sheet given to you. You may contact us to request the summary sheet. Feedback will be available roughly 6 months after the collection of data.

Please ensure that you have read and understood all of the above information, as well as the information provided on the participant information sheet before the start of the interview. Once this is complete, please sign the two consent forms for the interview and recording. These forms confirm that you have understood everything discussed above.

Once you are ready, we may begin the interview. There are no right or wrong answers. Please discuss everything you think about the following topics.

Background information

1. Gender?
2. Age?
3. Highest education level?
4. Number of years in current field?
5. What is your job title?
6. How long have you been practising as a …?

7. What is your role in this position?
8. What has been your experience in seasonal forecasting?
9. Do you use seasonal forecasting outputs?
    a. If yes, what do you use them for? Do you find them helpful?
    b. If no, would you ever consider using them? What would you use them for?
10. What information do you look for in seasonal forecasting outputs?

    Prompts

    i. How would you use these outputs?
11. How far in advance would these forecasts be needed?

    Prompts

    i. When is the time when decisions are being made?

Mental or conceptual model of a seasonal forecasting output (seasonal forecasting output will be shown, as seen in Appendix I)

12. What do you perceive? What are you looking at?

    Prompts

    i. What do the different colours mean to you?
    ii. What area/region are you looking at?
    iii. Why are you looking at these? What are you trying to see?
    iv. Why is that an important indicator?
13. What do you understand? What does it mean? What does it tell you?

    Prompts

    i. Is it too detailed?
    ii. Is it not detailed enough?
14. Why have you not made use of … (specific information)? (optional question)

Perceived risk factors as a result of the output

15. What do you perceive in terms of risks?

    Prompts

    i. Is this model based on a particular season?
    ii. Is there enough information?
    iii. Is there any degree of uncertainty?
    iv. What is the degree of risk?

Actions to prevent risks

16. What would you do with this information?

General prompts

"Can you tell me more about…?"

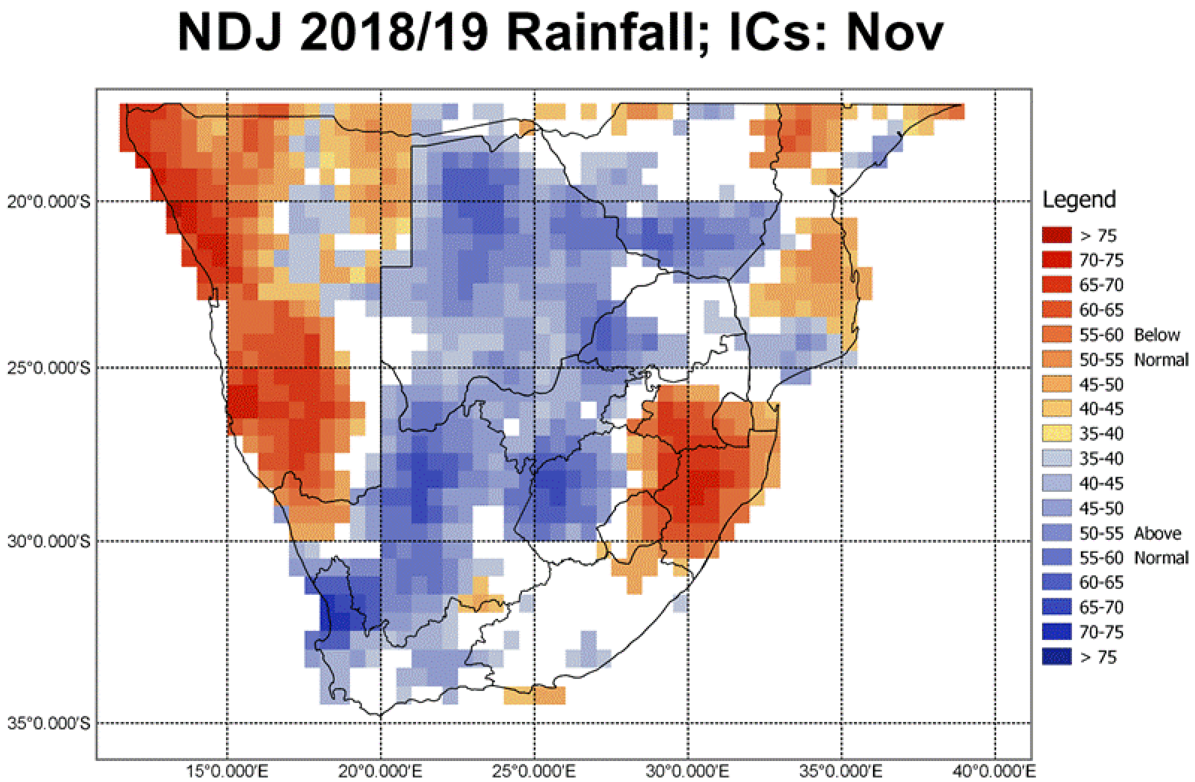
"Can you explain how…?"

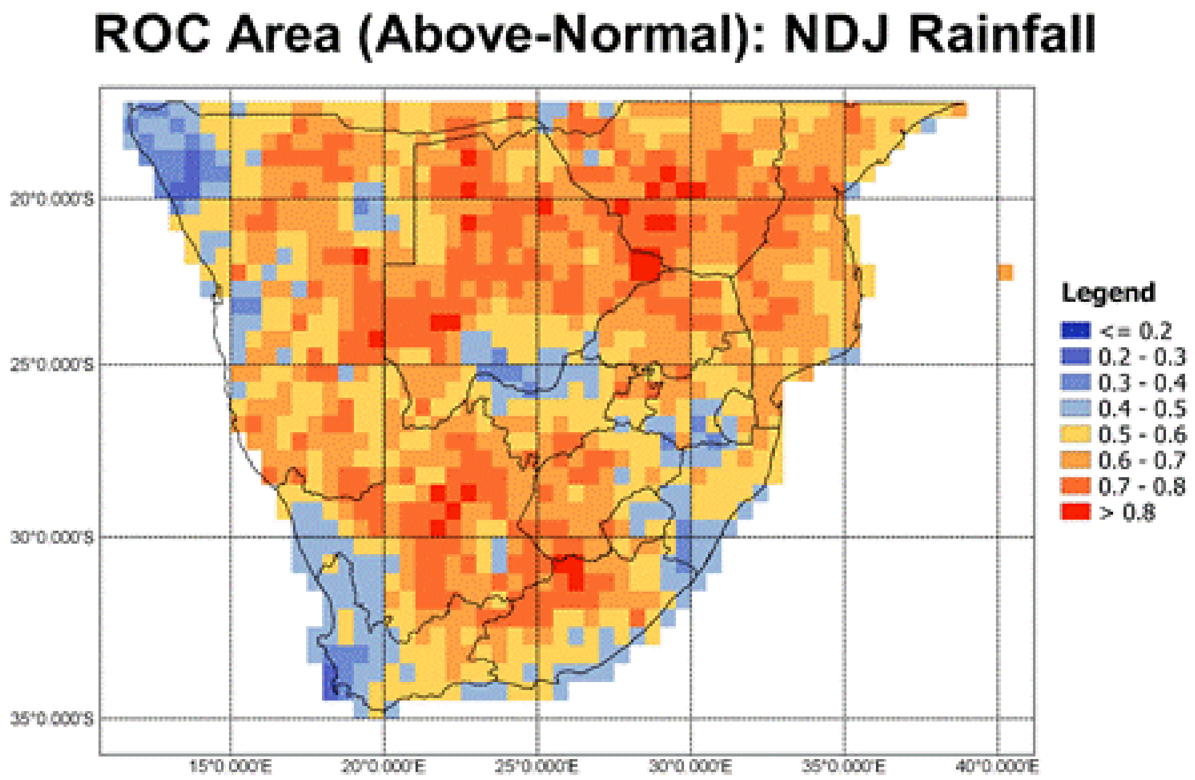
"Is there anything you'd like to add?"

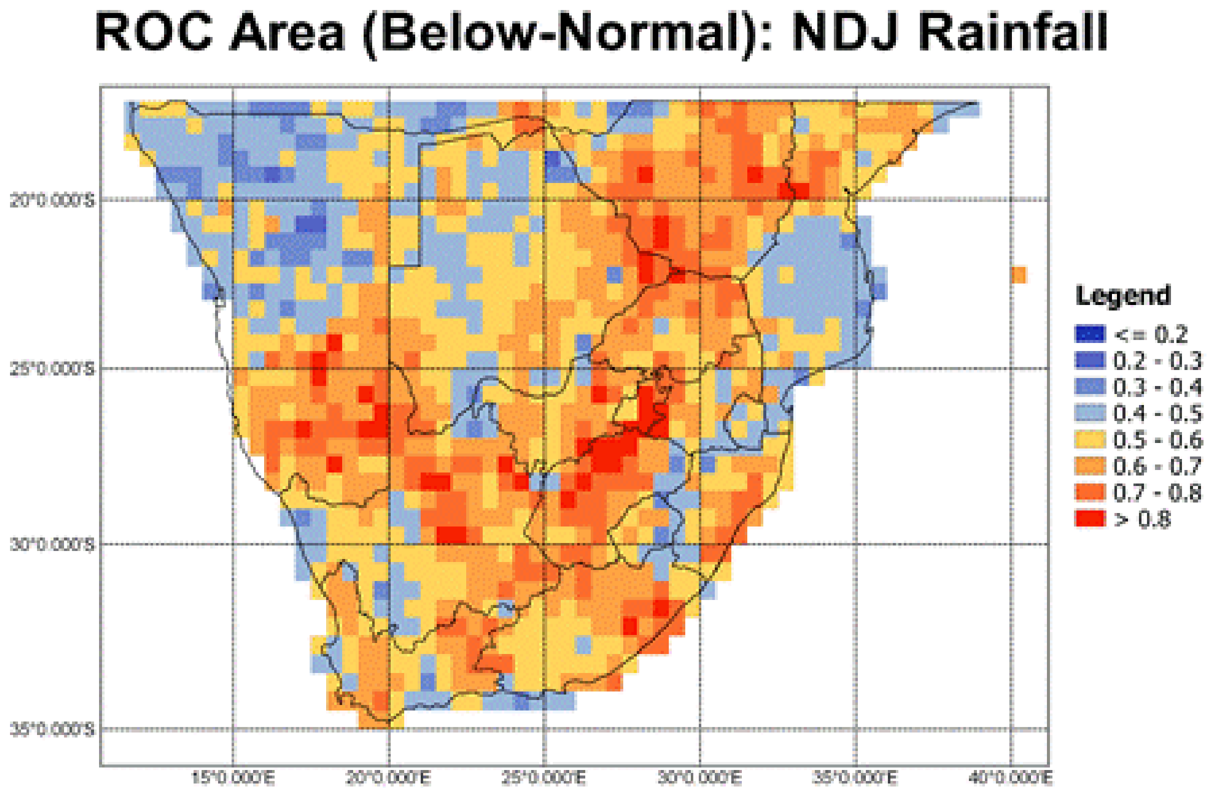
"Does anything else come to mind?"

Thank you for your participation!

APPENDIX G – SEASONAL FORECASTING OUTPUTS






ROC Area (Below-Normal): NDJ Rainfall
20°0.000'S
25°0.000'S
30°0.000'S
35°0.000'S
15°0.000'E
20°0.000'E
25°0.000'E
30°0.000'E
35°0.000'E
40°0.000'E
Legend
<= 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
> 0.8

APPENDIX H – TurnItIn REPORT

1091457:FULL_REPORT_-_TURNITIN_VERSION.docx

ORIGINALITY REPORT

2%	1%	1%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Kalantzis, Anastasia, Andrew Thatcher, and Craig Sheridan. "Mental models of a water management system in a green building", Applied Ergonomics, 2016. Publication	<1%
2	sanbi.org Internet Source	<1%
3	Joseph D. Daron, Susanne Lorenz, Piotr Wolski, Ross C. Blamey, Christopher Jack. "Interpreting climate data visualisations to inform adaptation decisions", Climate Risk Management, 2015 Publication	<1%
4	Submitted to Middle East Technical University Student Paper	<1%
5	Submitted to University of Witwatersrand Student Paper	<1%
6	Retchless, David P., and Cynthia A. Brewer. "Guidance for representing uncertainty on global temperature change maps : GUIDANCE FOR MAPPING UNCERTAINTY OF GLOBAL TEMPERATURE CHANGE", International Journal of Climatology, 2015. Publication	<1%
7	www.thediplomaticsociety.co.za Internet Source	<1%

8	ajlmonline.org Internet Source	<1%
9	Submitted to The University of Manchester Student Paper	<1%
10	www.wrc.org.za Internet Source	<1%
11	Oladele, Idowu. "Borich Needs Model Analysis of Professional Competence Among Extension Officers in North West Province, South Africa", Journal of Agricultural & Food Information, 2015. Publication	<1%
12	issuu.com Internet Source	<1%
13	Mxolisi E. Shongwe, Willem A. Landman, Simon J. Mason. "Performance of recalibration systems for GCM forecasts for southern Africa", International Journal of Climatology, 2006 Publication	<1%
14	Submitted to Rhodes University Student Paper	<1%
15	Submitted to Middlesex University Student Paper	<1%
16	Submitted to Laureate Higher Education Group Student Paper	<1%
17	www.mdpi.com Internet Source	<1%
18	www.channelnewsasia.com Internet Source	<1%
19	Submitted to City University Student Paper	<1%

20	satida.net Internet Source	<1%
21	www.arcipreste.org Internet Source	<1%
22	Submitted to Chapman University Student Paper	<1%
23	Submitted to UC, Irvine Student Paper	<1%
24	slidelegend.com Internet Source	<1%
25	www.journalofnaturestudies.org Internet Source	<1%
26	Juerg Schwitter. "Myocardial perfusion", Journal of Magnetic Resonance Imaging, 2006 Publication	<1%
27	www.safehomealabama.gov Internet Source	<1%
28	Sara Börjesson, Petra K. Boström. ""I want to know what it is used for": Clients' perspectives on completing a routine outcome measure (ROM) while undergoing psychotherapy", Psychotherapy Research, 2019 Publication	<1%
29	www.dtic.mil Internet Source	<1%
30	Submitted to University of Exeter Student Paper	<1%
31	www.ideals.illinois.edu Internet Source	<1%

32	archive.org Internet Source	<1%
33	naturaloceanhazardsmar110.umassd.wikispaces.net Internet Source	<1%
34	Submitted to University of Northampton Student Paper	<1%
35	Submitted to Kenyatta University Student Paper	<1%
36	bmcpublichealth.biomedcentral.com Internet Source	<1%
37	www.bpa.gov Internet Source	<1%
38	Submitted to The Robert Gordon University Student Paper	<1%
39	Submitted to Creighton University Student Paper	<1%
40	Submitted to University of Newcastle Student Paper	<1%
41	shura.shu.ac.uk Internet Source	<1%
42	www.gwp.org Internet Source	<1%
43	Submitted to University of Bath Student Paper	<1%
44	Submitted to 8779 Student Paper	<1%

45	Pietro Ceccato, Keith Cressman, Alessandra Giannini, Sylwia Trzaska. "The desert locust upsurge in West Africa (2003 – 2005): Information on the desert locust early warning system and the prospects for seasonal climate forecasting", International Journal of Pest Management, 2007 Publication	<1%
46	Anastasia Kalantzis, Andrew Thatcher, Craig Sheridan. "Mental models of a water management system in a green building", Applied Ergonomics, 2016 Publication	<1%
47	"Interactive Governance for Small-Scale Fisheries", Springer Science and Business Media LLC, 2015 Publication	<1%
48	Submitted to Edith Cowan University Student Paper	<1%
49	José Maria Brabo Alves, José Nilson B. Campos, Jacques Servain. "Reservoir Management Using Coupled Atmospheric and Hydrological Models: The Brazilian Semi-Arid Case", Water Resources Management, 2012 Publication	<1%
50	DEBORAH A. BOEHM-DAVIS. "Knowledge Elicitation and Representation", Elsevier BV, 1990 Publication	<1%
51	Submitted to Colorado Technical University Online Student Paper	<1%

52	Miranda Jane Cunningham, Anita Slade. "Exploring the lived experience of homelessness from an occupational perspective", Scandinavian Journal of Occupational Therapy, 2017 Publication	<1%
53	Submitted to Scottish Agricultural College Student Paper	<1%
54	"Climate Change and Its Impacts", Springer Science and Business Media LLC, 2018 Publication	<1%
55	Submitted to University of Stellenbosch, South Africa Student Paper	<1%
56	www.environment.gov.za Internet Source	<1%

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		