Assessment of Communication and Use of Climate Outlooks and Development of Scenarios to Promote Food Security in the Free State Province of South Africa

S. Walker, E. Mukhala, W.J. van den Berg and C.R. Manley

Final Report
Submitted to the
Drought Monitoring Centre (Harare, Zimbabwe)
On the Pilot Project
DMCH/WB/NOAA/OGP
6.02/13/1

University of the Free State
Department of Agrometeorology
P.O. Box 339
Bloemfontein 9300
South Africa

Enviro Vision
P.O. Box 100938
Brandhof
9324
South Africa

September 2001

Acknowledgements

The financing of this project by the Drought Monitoring Center, Harare is gratefully acknowledged. Specific thanks go to Dr. Buruhani S. Nyenzi and other members of DMC for support of the project.

The authors also want to express their thanks for the opportunity to develop new methods and assess the status of the use of seasonal outlooks in the Free State Province. The impact of this project will only be seen in the coming years, as the farming community uses the crop specific seasonal outlooks.

Thanks are due to the following who also made contributions to the project:

- Free State Department of Agriculture
- Agricultural Research Council - Institute of Soil, Climate and Water, Pretoria
- Agricultural Research Council - Grain Crops Institute, Potchefstroom
- Agricultural Research Council - Small Grain Institute, Bethlehem
- Department Communication, University of the Free State
- Dean’s office, Faculty of Natural and Agricultural Sciences, University of the Free State.

Executive Summary

Assessment of Communication and Use of Climate Outlooks and Development of Scenarios to Promote Food Security in the Free State Province of South Africa

S. Walker, E. Mukhala, WJ. van den Berg* & C.R. Manley*

Department of Agrometeorology, University of the Free State, PO Box 339, Bloemfontein, 9300, Republic of South Africa
***** Enviro Vision CC, PO Box 100938, Brandhof, 9301, Republic of South Africa

The need for reliable season climate outlooks is becoming increasingly important for farmers and related agro-industries. Increasing pressure on the cost of fuel, fertilizer, seed and cultivation also increased the risk for production. Although the price of agricultural commodities in South Africa dramatically recovered, farmers are not able to recover from crop failures due to the high input costs. If the farmer knows what type of season to expect in terms of production, he will be able to make better decisions. If a drier season is expected the farmer can adapt some of his practises in order to cut input costs. He can also decide to take out insurance, to use hedging techniques, to contract his commodities at an earlier or later stage, to apply less fertilizer, etc.

The occurrence of the El Niño events since 1982/83 triggered a worldwide awareness of external factors influencing the climate and weather patterns of the world. In retrospect, researchers claimed that if an early warning system had been in place during this season, the negative consequences could have been reduced and mitigated. The chaotic nature of the weather makes is however nearly impossible to forecast with success for periods longer than 10-14 days using dynamic models. A statistical approach (using historical data) or a combination of dynamic and statistical models, have been introduced in most cases. The Southern Oscillation Index (SOI) is an example of a combination of a combined dynamic and historic (statistical) approach, relating expected climate conditions to the current status of the SOI with reference to historic rainfall-SOI relationships. The Pacific Decadal Oscillation (PDO) is another example of a combined approach.

In order for climate outlooks to be useful, there are some basic requirements:

Firstly: Information must be reliable but more important accurate.

Secondly: Information must be applied to specified agricultural practises and commodities.

Thirdly: The end-user must not only be able to have access to the information BUT must be able to interpret, understand and apply information in such a way that he will gain financially.

Fourthly: Information must always be presented and interpreted in terms of financial norms. A high yield can result in low prices and *vice versa*. This study addressed some of the issues mentioned above.

Part A concentrated on the communication of the seasonal outlooks to the end users. For successful communication of the message, there needs to be shared meaning between the farmers as end-users and meteorologists as the senders. Much work is still needed to clarify the concepts and provide simplified explanations of some basic terms used in the seasonal forecasts so as to promote understanding and common ground between the two groups. This task can best be fulfilled by an Agrometeorologist.

The survey showed that less than half the respondents do not receive the seasonal forecast, and this is across both farm size groups. Some of the questions were used to determine the respondents own perception of their understanding of technical terms and then to test the actual understanding of specific meteorological terms. The results show that 93 % of the commercial farmers perceive that they understand, however about half (54 %) of them can not define the technical terms correctly. Two thirds of the small-scale farmers think that they understand while less than a quarter (22 %) of them can successfully define the technical terms. When the farmers understanding of technical terms is related to turnover, those with the highest turnover have a better understanding of the meteorological terms, but it is still low at only 50 % in that category. It appears that further education and training is needed in both sectors of the farming community in the

Free State as actually only about a third of respondents understand the concepts of probability of rainfall occurring.

At the time of the survey, the radio and fax / post were the most frequently used source of seasonal forecasts. The preferred media is first the radio, then e-mail and print media. This can be understood as the radio brings the message when it is released and the printed media enables one to refer back to a diagram or map and refresh ones memory. So dissemination should continue through all of these types of media. It appears that farmers place a high value on the seasonal forecast information. More than half of the respondents also trust the forecasts most of the time and 40 % will make adjustments to their farming practices based on the information received.

Part B of the project provided training seminars for extension and research staff and some small-scale farmers in the Free State. Two training seminars were conducted in October 2000 in Bethlehem and Bloemfontein. They provided a detailed explanation of ENSO and its relationship to the rainfall in South Africa together with the consequences for summer dryland maize production. The seasonal outlook (2000/2001) was also discussed and recommendations were made for changes in various farming practices. As the need for good communication skills had been identified as a critical factor some training was also provided in presentation techniques. These training seminars were overall a success and additional topics and information needed by the farmers was also requested. It is recommended that this type of seminar be held each year as a means of distributing the seasonal outlook and establishing a better understanding of the basis behind the forecast. If the training is given each year, the participants will become more familiar with the technical terms and the applications in their own situation. This type of training should be extended to other provinces also, particularly in the semi-arid region where drought years can be devastating to the farm community.

Part C concentrated in developing and testing seasonal climate outlook models that can be used as climate inputs for the crop growth modeling or simulation process. The aim was to provide more applied or value added seasonal outlook information and to make yield estimates for a specific season.

An analogue year approach, derived from the SOI phases and in current operational use, was evaluated in terms of spatial rainfall distribution but also in terms of spatial yield distribution of maize in the Free State Province of South Africa. From experience, the SOI Phases Analogue (SPA) model, produced inconstent results during the past five years. The most important factor often was the timing of the start of the rainy season. A second model also uses the SPA-model with a training period of three months to relate the current rainfall pattern to analogue years. The best fit analogue years were determined according to the rainfall pattern of the past three months (SPAR-model, SOI Phases Analogue Rainfall). The third alternative was to use the PDO in combination with the SPA-model (SPA-PDO-model).

Results indicate that spatially forecasted rainfall totals (October – March) for the five years that were investigated were in general satisfactory, with an underestimation trend evident in most years. The SPAR-model produced the best results with both the SPA and SPA-PDO-models about 10% adrift. The rainfall on about 58.4% of the area of about 13 million hectares of the Free State, were estimated within a 20% deviation above or below. About the same percentage of the area was under and over estimated in terms of the total rainfall for the six month period. Both SPA and SPA-PDO-models tend to under estimate the rainfall on a larger area of the Free State.

Monthly rainfall distribution forecasts were also evaluated spatially. The seasons with strong signals like the El Niño event of 1997/98 produced near perfect results in forecasting the monthly rainfall pattern. Mixed signals such as during the 1999/2000 year, starting off with near-normal SOI values and later changed to La Niña, produced less accurate monthly rainfall patterns. The SPAR-method on average produced the best results in estimating monthly rainfall patterns.

Spatially correct yield estimates however produced different results. The SPA-PDO-model estimated yield spatially correct within –1000 kg/ha to +1000 kg/ha on about 51% of the area of the Free State. The SPA and SPAR-models were only able to produce correct results within the above mentioned limits on 34.7% and 35.9% of the area. From the rainfall estimates it was expected that the SPAR-model would also give superior results. The SPA-PDO-model however produced a significantly better estimate than the two rival models. The only explanation is that rainfall distribution in time segments smaller than a month were estimated better, providing better estimates of rainfall at critical stages.

Outputs are also used for crop estimate purposes, providing a total tonnage for a geographical area. Rainfall distribution is not only timely erratic, but spatially very unpredictable due to thunderstorm activity and also topographical features. The accuracy of crop estimates for an area is dependant on the accuracy of estimates and also on the normal distribution function, that is that the yield deviations above and below the expected yields are more or less the same. This must be true to cancel out areas with over estimating with areas of under estimation. Results show that although not the most accurate, the SPA-model tends to produce a better distribution of expected yields than the SPAR- and SPA-PDO-models.

A summary of results indicates that the information can be used to advise decision makers. Care must be taken in interpreting and presenting these results on a point scale due to the unpredictability of spatially correct rainfall amounts and timing. It is recommended that there is still a lot of research to be done in refining current climate outlook models to be used as inputs for crop growth models. Spatial measurements and interpolation techniques of rainfall and other climate elements are one of the most important elements with an unknown measure of accuracy. Communication of results and outlooks to end-users and to be able to give crop specific information is still one of the most important challenges.

CONTENTS

List of Tables

Part A

Part C

List of Figures

List of Appendices

Project Proposal as at March 2000

Project Title: Assessment of Communication of Forecast Use, and Development of Climate Outlook Scenarios for Crop Models

Project Manager

Prof. Sue Walker
University of the Orange Free State, Department of Agrometeorology,
P.O. Box 339, Bloemfontein 9300, South Africa.
Tel: +27 51 401 2222, Fax: +27 51 448 0692, Email: walkers@sci.uovs.ac.za

Project Team:

Prof. Sue Walker – Employer: University of the Orange Free State, Department of Agrometeorology
Qualification: PhD (University of California, Davis, USA)
Mr. Johan Van Den Berg – Employer: Free State Department of Agriculture (FSDA)
Qualification: MSc (University of the Orange Free State, RSA)
Dr.Elijah Mukhala – Employer: University of the Orange Free State, Department of Agrometeorology
Qualification: PhD (University of the Orange Free State, RSA)

Project Objectives:

(a) To conduct a survey on the use of weather forecasts for decision making in agriculture
(b) To conduct training seminars to sensitise agricultural extension officers and farmers on the importance of weather forecasts for sustainable agricultural production
(c) To develop techniques for creating climate scenarios

Research Product

A report on the use of weather forecast information and improvements to the methodology of disseminating weather forecasts. The outputs of this work will help in the improvement of the material for dissemination and the methodology for dissemination as well as bring about confidence in the farming community in the use of weather forecasts.

Target Group

The Agribusiness and farming community that has been using the Climate and Agriculture Report and extension officers serving farmers.

Capacity Building

This research work will contribute to the ability of the farming communities and political decision-makers to understand the importance of weather forecasts in farm decision making.

Commencement and Duration
From June 2000 to June 2001

Motivation and background Information
Agricultural Meteorology is a branch of science that concerns itself in a broad sense with the influence of weather and climate on agricultural production. The science of Agrometeorology and its applications is significant in the development of operational knowledge to cope with agricultural drought and its consequences, to obtain sustainable and economically viable agricultural development in the region. Food insecurity among vulnerable and rural households has long been recognised as a serious problem in the SADC region. However, the agricultural systems in the region are heavily dependent on rainfall and therefore slight changes in distribution and amounts can result in serious crop yield reductions.

Food security problems in the region can only be solved if a participatory action research multidisciplinary approach is implemented to address production constraints. Various capabilities for forecasting seasonal rainfall in both national meteorological services and international organisations (Drought Monitoring Centres, Harare and Nairobi) have been established in recent years. These institutions are doing a commendable job. While such forecast information is of potential benefit to the region, many questions still remain: such as how much of this information is actually used and what are the benefits and to which decision-making activities or sectors of society are they given.

Vogel (1999) points out that there is a disconnection between various groups and their efforts for better agricultural drought management which most likely has been transferred into the policy arena. This then becomes imbedded into various methodologies resulting in communities becoming more vulnerable rather than more drought resilient. One of the activities and outputs of the Drought Monitoring Centre (DMC) in Harare and South African Weather Bureau (SAWB) is the preparation and dissemination on a regular and timely basis of relevant products and advisories on drought and other adverse weather patterns including the onset and cessation, its severity and extent (Garanganga, 1999). The Southern African Regional Outlook Forum (SARCOF) of which the DMC's are part, meets annually prior to the start of the growing season and issue a seasonal rainfall forecast for the SADC region. This means that the information regarding the outlook for the coming season is available long before farmers sow the seed. A great deal of time and energy including financial resources is invested in seasonal forecasting and it is ironical that little or no resources are spent on information dissemination to farmers (Mukhala, 1999). There is a need to develop an effective way of disseminating seasonal forecast information to farmers in the region. This role can better be carried out by agrometeorologists who possess expertise to explain the meteorological concepts to farmers and the agricultural concepts to the meteorologists as well as extension officers.

Although several institutions are providing rainfall and climate outlooks for South Africa, there are still a number of limitations in the methods used to qualifying factors of relating climate and rainfall outlooks to agricultural outlooks. At present, the rainfall outlooks most often provide a forecast of the probability of total amount of rainfall for a three or sixth month period. However, from experience it is evident that there is a low inter-dependence between rainfall totals and agricultural conditions due to the sensitivity of crops to timing of rainfall. Crop growth models integrate the climate, plant and soil conditions to simulate a real agricultural situation. However, the current climate outlooks are not in a suitable form for use in the crop growth models, which require daily input data. Currently the FSDA use a system proposed by De Jager, Potgieter and Van den Berg (1997) of identifying different scenarios given lower, median and higher rainfall scenario within a specific phase of the Southern Oscillation Index (SOI). Part of the system was originally developed by the Agricultural Production Systems Research Unit (APSRU) from the Queensland Department of Primary Industries, Toowoomba, Australia and was responsible for kick starting the efforts of the FSDA.

In consultation with researchers from APSRU, a new crop specific outlook system is being developed by refining the phases of the SOI, using indices like the Madden Julian Oscillation, circum polar wave and combine real time data with outlooks. They have established a Climatic Application Centre at the end of 1998 that specialises in climate/agriculture interaction. Because of the interaction since 1995 between the FSDA and APSRU, a good working relationship developed between the two institutions. These new techniques are on the cutting edge of development of science and will address the prediction of specific weather data for scenarios, which can be used as inputs to the crop growth models. It is important that these techniques are used under Southern African conditions so that the results can be applied immediately to the SARCOF outlook process.

During the Eco-region workshop in Potchefstroom in June 1999, contact was also made with researchers from Zimbabwe, Kenya and Uganda who are trying to implement a system for small- scale farmers and use crop modelling and rainfall outlooks for these farmers. Integrating the current commercial crop modelling approach with small-scale farming production will also reduce risk for the small-scale farmer. The dissemination of seasonal forecasts should be accompanied by appropriate small-scale farming technologies that will incorporate impending weather pattern and agricultural practices that suit the weather to sustain agricultural production. Farmers need to be equipped with knowledge to cope effectively with agricultural drought as a normal feature of climate as its recurrence is inevitable. Farmers need to know that no matter how inherently fertile the soil may be, its nutrients cannot be mobilised for plant growth without adequate water. But even with good soil and enough water, crops cannot produce high yields if they are ill-adapted to the climate. It terms of water use efficiency, it has been reported that inter-cropping production systems utilise water more efficiently than mono-cropping systems as the shorter crop in an inter-crop acts as a barrier thereby reducing evaporation from the soil surface (Mukhala, 1998).

Methodology

1. The Free State Department of Agriculture (with contributions from UOFS, SAWB, Australia, Agricultural Research Council) has been issuing monthly climate and agricultural reports to the farming and agribusiness community for many years. Some of the contents of the reports include: rainfall outlooks, sea surface temperatures and

SOI, grazing conditions and rainfall and deviation from normal. Two institutions (UOFS and FSDA) will jointly conduct a survey on the use of weather forecasts for decision making in agriculture with the farming and agribusiness community that is on the mailing list of the report. There are about 400 agricultural clients on the list. The report has been issued for the last 4 years. A questionnaire will be prepared and administered to the respondents during the activities of FSDA.

2. The team will also conduct seminars to sensitise agricultural extension officers, farmers and agribusiness on the importance of using of weather forecasts for decision making and sustainable agricultural production. The research team will also obtain information from users as to how information dissemination can be improved for their own application.

3. Development of climate outlook scenario's for use as input to crop models in order to provide better crop estimates and production technique advice to farmers (Commercial and small- scale farmers) will be done in stages. The first step is to identify possible sources or expertise in this field. Secondly, evaluate currently available technology. Thirdly, apply available technology in the monthly outlook on an operational basis. In this process it is also important to set up a strategy to develop new climate outlook technology.

Evaluation Criteria

The project will be evaluated by using the objectives outlined. The success of the survey will be evaluated by how much information has been obtained and the quality of information and how much this information will be used in developing appropriate methodologies for dissemination of future forecasts. The training programmes will be evaluated by using the objectives of the training programme and using evaluation forms completed by the participants. The improvements in the outlooks will be evaluated by assessing and comparing the previous methodologies to the newly developed methods.

Conclusion

Agriculture in Southern Africa forms the backbone of the economy of many countries, but is highly sensitive to weather variations. Despite the fact that the climate outlooks are distributed to a number of people working in the agricultural sector, including agribusiness, extension workers and farmers, little is known about the degree to which the outlook is actually used in the decision making process. An assessment of the value placed on the outlook will be made during the project. Progress will also be made on the development of future climate scenarios for input to crop models. A report will be given at the SARCOF conference 2000 on the findings to enable other SADC countries also benefit.

References

Climate and Agriculture Report, No 4 of 1999. Issued by the Free State Department of Agriculture, Information Technology Section, Glen.

De Jager, J.M., Potgieter, A.B. & Van den Berg, W.J., 1997. Framework for forecasting the extent and severity of drought in South Africa. Agricultural Systems, 351-366.

Garanganga, B.J. 1999. Role of regional climate system monitoring and prediction in drought management. Proceedings of the International Conference on Integrated Drought Management-Lessons for Sub-Saharan Africa. 20-22 September, Pretoria, South Africa.

Mukhala, E. 1998. Radiation and water utilisation efficiency by mono-culture and inter-crop to suit small-scale irrigation farming. PhD Thesis. University of the Orange Free State, Bloemfontein, South Africa.

Mukhala, E. 1999. Food Security in the SADC Region: An Overview of the role of Agricultural Meteorology. World Development Journal (Submitted)

Vogel, C. 1999. Reflections on drought: Practices, policies and panaceas. Paper at the International Planning Workshop on Integrated Drought Management-Lessons for Sub-Saharan Africa. 16-17 September, Pretoria, South Africa.

Work Plan and Time-table for

Project on Assessment of Forecast use, Communication and Development of Climate Outlook Scenarios for Crop Models.

Objectives	Tasks	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Conduct survey on use of weather forecasts for decision making in agriculture	- Development of questionnaire	.	.										
	- Distribution of questionnaire			.	.								
	- Analysis of data					.	.	.					
	- Writing of report								.	.			
Training seminars to sensitise users on the importance of weather forecasts for sustainable agricultural production	- Designing of programme	.	.	.									
	- Preparation of material		.	.	.								
	- Conduct training seminars				.	.	.	.	.				
	- Participant evaluation				.	.	.	.	.	.			
	- Writing report										.	.	
Development of techniques for creating climate scenarios	- Identify possible expertise	.	.										
	- Trip to Australia			.									
	- Evaluate new technology				.	.	.	.					
	- Application of available tech.								.	.	.	.	
	- Writing report												.
	Project Evaluation											.	.
	Final Project Report											.	.

Part A: Survey of the Use of Seasonal Outlooks

Chapter 1: Orientation to the Research Problem

1.1 Introduction

Seasonal climate information is important for planning and decision making in agricultural production for food security. This information in southern Africa is issued by Meteorological Services or the Weather Bureau in September/October preceding the growing season to provide vital information for farm management purposes to reduce adverse weather effects. The forecasts have been issued for many years, but the benefits on agriculture production and food security appear to be difficult to quantify with respect to increased and/or sustainable agricultural production.

Sub-regional organizations and the United Nations held several meetings to discuss the occurrence of frequent droughts in Africa in the 1980s. These meetings culminated in the establishment of two Drought Monitoring Centers (DMC) one located in Nairobi, Kenya and the other in Harare, Zimbabwe. One of the outputs of the DMCs relevant to this research is that of preparing and disseminating on a regular and timely basis relevant products and advisories on drought including onset and cessation, its severity and extent. This involves the preparation and dissemination in map form or otherwise of relevant parameters such as rainfall and temperature anomalies, drought severity indices, drought risk and moisture stress (Marume and Garanganga, 1997). Preparation and dissemination of drought related products, did not commence until 1991 (Marume and Garanganga, 1997).

In September 1999, a World Bank funded workshop entitled: "Users responses to seasonal climate forecasts in southern Africa; What have we learned" was convened in Dar-es-Salaam, Tanzania (Blench, 1999). The objective was to present, discuss and compare research, primarily in relation to the agricultural sector in southern Africa. Two aspects came out as significant for sustainable agricultural production and food security. The first was that there were communication barriers and that there was a need to develop appropriate information channels. The second was that there were bottlenecks in the effective use of seasonal climate forecasts by farmers (O'Brien, *et al.*, 2000). In any sustainable agricultural development programme, effective communication is a prerequisite for development success. Users of seasonal climate forecasts have not been able to decode the information disseminated. Therefore, the later constraint was as a result of the former constraint. The users cannot make use of information provided if they do not understand the information provided in the first place (O'Brien, *et al.* 2000).

Field studies of the impact of forecasts in southern Africa suggest that there is a considerable gap between information needed by farmers and that provided by meteorological services (Blench, 1999). Again this is a manifestation of communication barriers as the two parties have been interacting for a long time but probably have not been communicating effectively. The farmers know what they want and the meteorological services know what they need to give to the farmers, but there is no "shared meaning". The effectiveness of meteorological communication is determined amongst other things by the extent to which all persons involved in the communication transaction are competent in communicating and interpreting meteorological messages. There are many barriers to effective communication. The main barriers are 'noise' (or interference or competition) during the communication process, differing perceptions, language barriers, inconsistencies in communication, differences in status, distrust, emotional communication, apathy and resistance to change (Adey and Andrew, 1990). At this stage the study will not pinpoint the cause of communication breakdown and therefore, will investigate all possible causes.

This study will investigate and discuss the principles of communication that may help to improve communication between meteorological services (meteorologists) and farmers or other potential users. There is a need to separate the issues of information, dissemination and communication. Meteorological services have been content with using existing channels of communication while ignoring fundamental principles of communication. While appropriate channels of information dissemination have been identified, dissemination does not necessarily guarantee communication. The study concentrates on farmers as users because the agricultural sector makes up a large proportion of the users of climate seasonal forecasts in Southern Africa.

1.2 Motivation for the study

Climate/weather plays an important role in the growth and development of plants in general and crops in particular. Knowledge of impending climate/weather conditions will help in the identification of crop varieties that will perform well in a particular growing season. The responsible government institutions have been issuing seasonal climate forecasts for several years and it is important to establish if the information has been used appropriately or not and if not, then why not. There are definitely various reasons as to why the forecasts are not used some of which could hinge on lack of understanding of the forecasts. This study intends to make an evaluation of the communication process between meteorological staff and the recipients.

1.3 Aims and objectives

Against this background, the researcher intends to conduct a survey in the Free State province with the following objectives:
to investigate if farmers/users receive seasonal climate forecasts
to investigate if farmers/users understand the terminology in the forecasts
to investigate the media that is mostly used to receive seasonal climate forecasts
to investigate characteristics that could influence understanding of seasonal climate forecasts.
The study will start first by defining communication so that the information that will follow will be put in proper perspective. Various definitions of communication will be

reviewed as well as the explanation of the communication process and its various components.

Chapter 2: Communication of Seasonal Climate Forecasts

2.1 Introduction

A variety of information including seasonal climate forecasts is very important in agricultural production as many decisions are based on this information. This imposes a big responsibility on those mandated to disseminate this information through the various mediums available. To communicate information effectively, one needs to understand the principles of communication. It is with this in mind that some principles of communication will be discussed beginning with the definition of communication.

2.2 Definition of communication

While the definition of communication varies according to the theoretical frame of reference employed and the stress placed upon certain aspects of the total process, most definitions include five fundamental factors: an initiator; a recipient; a mode or vehicle, a message and an effect. Simply expressed, the communication process begins when a message is conceived by a sender. It is then encoded and transmitted via a particular medium or channel to a receiver who then decodes it and interprets the message, returning a signal in some way that the message has or has not been understood (Hill and Watson, 1997). This shared understanding, or meaning, is a critical factor to successful communication.

To Marais (1979, in Terblanche and Mulder, 2000), the sharing of meaning can be considered to be the general aim of communication. Tubbs and Moss (1994, in Terblanche and Mulder, 2000) refer to human communication as the process in which meaning is established between two or more persons. Bittner (1985, in Terblanche and Mulder, 2000) defines communication as the action where symbols are shared, while Wenburg and Wilmont (1973, in Terblanche and Mulder, 2000) refer to any attempt to achieve understanding as the crux of communication.

Agricultural communication can therefore be defined as a communication transaction in which agricultural related information is transmitted and interpreted with a view to sharing the meaning thereof (Terblanche and Mulder, 2000). Meteorological communication can be defined as a communication transaction in which meteorological information is transmitted and interpreted with a view to sharing the meaning thereof.

One of the requirements for good encoding and decoding is knowledge. Knowledge in this case includes knowledge of another person's language usage (e.g. scientific terms), knowledge of the subject matter (e.g. meteorology) and general knowledge. If the farmers or users have no knowledge of the subject matter, then encoding of information has to be in such a way that it is not difficult for them to decode.

In Figure 1, a basic communication model is applied to the subject under discussion - seasonal climate forecasts. From this, the following questions arise: Are the meteorological services or meteorologists able to encode climate seasonal forecasts? Is the correct medium or channel being used for the coded message? Are farmers or users able to decode seasonal climate forecasts encoded by meteorological services or meteorologists? Unless the communication model and in particular the importance of shared meanings between encoder and decoder, is understood by those that disseminate information, communication will always be a problem. A brief discussion of the components of a communication model will be given.

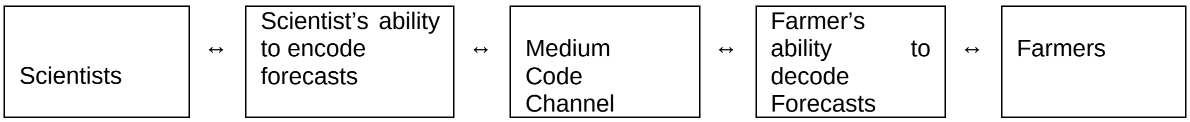


Figure 1 Communication model applied to seasonal climate forecasts

2.3 Communication model

2.3.1 Sender

For communication to take place, there is a need for a sender or source of communication. The sender will encode information and the receiver is supposed to decode this information and respond. In this study, the senders of information are the meteorological scientists and the receivers are the users of seasonal climate forecasts. A communicator needs to be aware of factors which can influence the effectiveness of communication (Terblanche and Mulder, 2000).

2.3.2 The message

Communication events in a meteorological situation focus primarily on the meteorological related messages. The concept of message content essentially suggests, for example, the thoughts, feelings, values, convictions, opinions and scientific facts which the meteorologist wish to covey by means of the linguistic, paralinguistic and non-linguistic codes (Terblanche and Mulder, 2000). The message is thus meteorological information, which the communicator conveys to his/her audience/users in the hope that they will receive it, understand it and accept it and respond to it. The code of the seasonal climate forecasts and the credibility of the meteorologists in the eyes of the users will have a bearing on the success of the meteorologist in the communication transaction (Terblanche and Mulder, 2000).

2.3.3 The receiver

The concept of the receiver refers to the communication partner or participant who receives the message. The communicative involvement of the users of seasonal climate forecasts as receivers, depends on the fact that they not only receive the message, but also have to be able and willing to understand it, decode it and interpret it (Terblanche and Mulder, 2000). Research carried out show that a farmer's socioeconomic status, education level, social participation, age, openness to change, existing knowledge of message, perception of himself, attitude towards the communicator and the message, value orientation, future aspirations, previous experience involving the communicator's message, duration of his farming career and many other factors that may be present, can determine the effectiveness of communication (Terblanche and Mulder, 2000).

2.3.4 The Media

There are several types of media that can be used as channels of communication for seasonal climate forecasts in southern Africa. Both the print media and electronic media are extensively used to disseminate seasonal climate forecasts and other information for agricultural management in southern Africa. In a survey conducted in villages in Phaswana, South Africa, Bembridge and Tshikolomo (1998) found that among the respondents, 92% owned radios, 52% owned television sets and 32% were connected to telephone facilities. With regard to television and telephone facilities, the survey results may not be representative of the situation throughout southern Africa given the relative economic advancement of South Africa. However, the survey provides basic information that target audiences have access to electronic media as indicated in Table 1.

It is important to note however that being in possession of or having access to a television or radio does not guarantee access to information through these media. However, the survey findings show that farmers in South Africa do make use of the electronic media as sources of agricultural information (Bembridge and Tshikolomo, 1998). Electronic media can potentially provide reliable channels to communicate seasonal climate information as long as appropriate terminology is applied to ensure shared meanings. However, the fact that information has been disseminated does not necessarily mean that communication takes place.

Table 1 Availability of communication channels for agricultural information in Phaswanan in rural South Africa (N=50) (Bembridge & Tshikolomo, 1998)

Communication channels	Respondents	
	No.	Percent
Telephone	16	32
Radio	46	92
Television	26	52

The Bembridge and Tshikolomo (1998) survey also ascertained how the respondents obtain information for agricultural management (Table 2). The authors found that 46% of the respondents had access to written information, mainly in the form of popular magazines, pamphlets with little research-based information. The majority of the respondents (76%) claimed to listen to radio broadcasts on farming, but indicated that the information did not contain technical information for farm management implying that the information was of a general nature. The same was claimed regarding information through television. However, these are not the only sources of information for farmers.

Table 2 Distribution of heads of household according to contact with sources of agricultural information (N=50) (Bembridge & Tshikolomo 1998).

Source of Information	Respondents	
	No	Percent
Mass Media		
Printed media	23	46
Radio	38	76
Television	26	52
Group Media		
Farm demonstrations	36	72
Farm discussions	29	58
Farmers' days	24	48
Meetings	21	42
Individual		
Other farmers	28	56
Govt. extension	19	38
Corporate extension	25	50

In Table 2, the researchers showed that farmers obtain information for farm management from both printed media (newspapers, journals, etc.) and electronic media (radio and television). This may be true for meteorological information as well. They also have other sources of information including farm demonstrations, farm discussions, farmers' days, meetings with other farmers, government extension and corporate extension. Among these media, the most popular are radio (76%), farm demonstrations (72%), farm discussions (58%), and other farmers (56%). The least contacted source is government extension officers. The reason for the low level of interest in extension officers as sources of agricultural information could be due to the low level of training of many of the officers (Mukhala & Groenewald, 1998).

2.4 Communication of information

The above findings indicate that appropriate media and channels of communication are already well established to provide agrometeorological information to farmers. If the message or information is not getting through to the target audience, the problem most likely is the way the information is coded or packaged or other factors that create barriers to effective communication. Effective communication is often hampered by various communication barriers, among which are noise, differing perceptions, language barriers, inconsistencies, difference in status, distrust, apathy and resistance to change. The use of jargon in communication often results in failed communication. Meteorologists may tend to assume that potential users understand the meteorological terms (jargon) they use, although, frequently this may not be the case. The use of jargon tends to blur communication and makes the audience feel 'excluded' as they do not understand. Some members of the audience may not be able to attend to the information because they do not understand all or some part of the messages.

Information intended for farmers to improve their farming practices should not be designed in the same way as that intended for scientists. Below (Box 1, Figure 2 and Figure 3) are typical examples of forecasts intended for users of seasonal climate forecasts, including small-scale farmers. The Drought Monitoring Centre (DMC) in Harare, Zimbabwe issues these forecasts for the entire Southern African Development Community (SADC) (Fig. 2). The South African Weather Bureau also issues seasonal climate forecasts for Southern Africa (Appendix II & Fig. 3).

Box 1 SADC Seasonal Climate Forecast for 1999-2000 Growing Season

Seasonal Forecast for the 1999 - 2000 Growing Season

There are high probabilities of normal to above-normal rainfall conditions over much of southern Africa during the period January - March 2000. However, there are high probabilities of below-normal to normal rainfall over the far northern part of the region and over the extreme south-western part of South Africa.

Is it reasonable to assume that all farmers or users of seasonal climate forecasts understand the concept of 'probabilities'? Is this a bottleneck in the effective use of climate forecasts by farmers? The problem could be due to lack of comprehension of the terms used in the forecasts. The term 'probability' may create misunderstanding, resulting in failure to communicate. The mathematical calculation of normal rainfall is known to meteorological services or meteorologists and other scientists. However, it is a rather difficult concept for the uneducated. Normal is a range of rainfall values obtained from a cumulative distribution function of 30 years of rainfall data. Do most farmers share the same meaning of normal? Do most farmers share the same meaning of below normal or above normal? In other words, are farmers able to decode this information? If the answer to these questions is *No*, then effective communication is not taking place. Clearly, the value of the seasonal climate forecasts or any other information depends on the understanding of that information by the involved user.

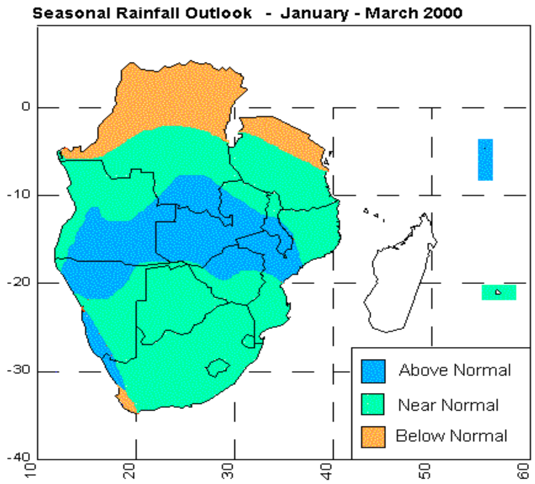


Figure 2 Map of seasonal climate forecasts for January, February and March 2000 (Source: The SADC Food Security Programme. Seasonal Forecast for 1999-2000 Growing Season)

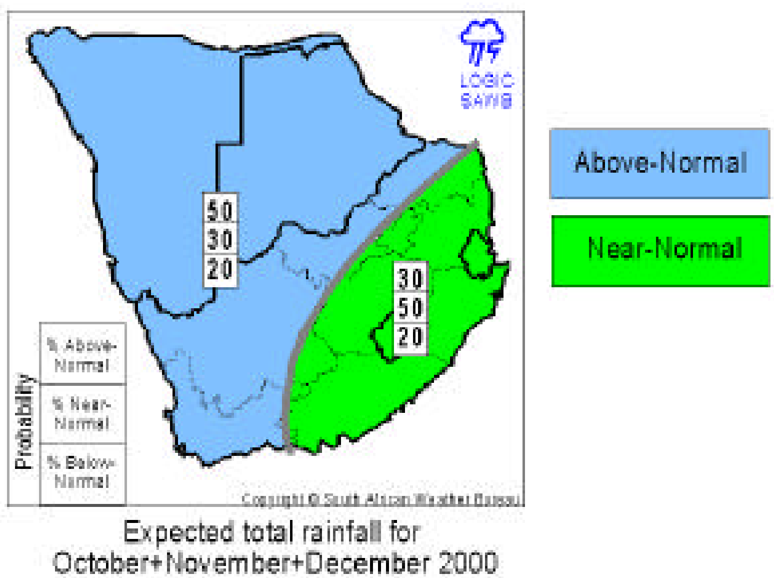


Figure 3 Map of seasonal climate forecasts for South Africa for October, November and December, 2000 (Source: South African Weather Bureau. Forecast for October, November and December 2000)

2.5 Understanding the audience profile

The problem of communication breakdown may be a critical issue in seasonal climate forecasts. To communicate effectively, meteorologists need to recognize the characteristics of the target audience. This helps them to encode information in ways that will be easy for farmers or users to decode. If the information intended for users is to be acceptable and understandable, meteorologists should have a clear profile of their target audience. Meteorological services or meteorologists should ask questions like: What are the characteristics of the target group audience? What type of farming systems do they operate? What are their levels of education and literacy? What is their native language? What is their socioeconomic status? How many are women? What media or channel can be used best to transmit information? Unless such questions are taken into account, effective communication may not take place.

2.6 Use of appropriate language

Language is a basic tool of communication through which simple or complex ideas are conveyed. An effective communicator should be sensitive to the nature of his or her language (Whitman & Boase, 1983). When writing for public consumption, Yopp and McAdams (1999) stress that technical terms should be avoided. The use of technical terms creates a perception that the information is for 'insiders' only, those who are familiar with the jargon. 'Outsiders' or non-experts who could benefit from the information can be estranged both from the source and the message. If jargon is used for farmers with low education levels, technical terms may create a feeling that the information is reserved for elite farmers. As a result, poorly educated farmers may feel excluded or perceive the information as exclusive.

Meteorologists should understand that words do not have the same meaning to all people. To assume that they do, is to ignore a fundamental principle of language - *Words do not have meaning, only people do*. Meteorological services or meteorologists know what they want to convey in seasonal climate forecasts, but farmers may perceive the information differently. A simple anecdote will help explain this problem (Box 2).

Box 2 Communication attempt between a farmer and an extension officer

A farmer offered an agricultural extension officer a banana after a long day's work. Upon recognizing the cultivar of the banana as his favorite type, the extension officer decided to ask for 'another' one. Certainly, affirmed the farmer, leaning forward to where the extension officer was seated and replacing the banana with 'another' one.

Agrometeorologists are scientists that have specialised in meteorology and agriculture. The professionals in this field understand the applications of meteorology to agricultural production. It is therefore important that consultations take place between meteorologists and agrometeorologists during the preparation of forecasts bearing in mind its application in agriculture for food security.

As this simple example shows, a failure in effective communication can occur even when using everyday language. If misunderstanding can take place so easily in everyday language, imagine the problem with scientific or technical language. Information only has value when it is disseminated in such a way that the end-users get the maximum benefit in applying its contents (Weiss, van Crowder & Bernardi, 1999).

2.7 Seasonal climate forecasts

Knowledge of the impending climate situation is an important factor for decision making in agriculture and other water sensitive sectors of the economy. The highly variable rainfall over southern Africa warrants dependable seasonal rainfall forecasts for reliable decision making. In the last decade, southern Africa has experienced droughts and floods affecting many sectors of the economy providing additional motivation for the need for investment in seasonal climate forecasts with clear advice on the implications for sustainable agricultural production. However, seasonal climate forecasts, even if they are perfect and accurate, have limited value if they cannot be understood by those who are supposed to make use of this information for decision making processes (Glantz, 1997; Chagnon, 1992).

Some of the constraints in the optimal use of seasonal climate forecast information include factors such as provision of information that is general. This information may not be specific to any area or particular application or may be received too late for use or often too difficult for the user to decode and apply (Klopper, 1999). To develop user confidence, climate forecasts should be designed and developed for specific user groups. However, this may be very challenging and therefore requires a multi-disciplinary approach. Many seasonal climate forecast users especially small-scale farmers may not realise the value of forecasts. Information on the value of seasonal climate forecast by small-scale farmers is lacking as many studies on the value of forecasts have only been conducted in the developed world (Lyakhov, 1994; Mason, 1996; Mjelde *et al*., 1988; 1997; Mosley, 1994; Nicholls, 1996) while under-developed countries are still trying to ascertain the magnitude of use of forecasts (Klopper, 1999; O'Brien *et al*., 2000).

The users of seasonal climate forecasts are people from various sectors which include energy, water, food industry, farming, nature conservation, construction, policy making and education (Klopper, 1999). This information is used for various purposes which include: management and planning of the energy supply, water management, food processing, crops, dam construction, government policy on agriculture and teaching (Klopper, 1999).

Chapter 3: Research Methodology and Procedure

3.1 Research procedure

In order to appreciate the results of this study, it is important to clearly outline the research procedures that were applied. The research method is therefore divided into the following categories: Questionnaire, respondents, sampling method, measurement instrument, data capturing, statistical analysis and reliability and validity.

3.1.1 Questionnaire

Development of a questionnaire is very important in any survey. An improperly laid out questionnaire can lead respondents to miss a question and can also confuse them about the nature of the data desired (Babbie, 1989). A questionnaire was prepared (Appendix I) addressing the outlined objectives and administered to small-scale, commercial farmers and other users in the Free State Province of South Africa. The questions were prepared in both Afrikaans and English. As a general rule, the questionnaire was prepared in such a way that it was not cluttered and the questions were short (Babbie, 1989). A persuasive introduction explaining the purpose and nature of the study preceded the questionnaire. In order to increase the response rate, the questionnaire was kept as short as possible (Wimmer & Dominick, 1991). The questionnaire had 20 questions of which all were closed-ended questions. Closed-ended questions require that respondents select an answer from a list provided by a researcher. There were about 5 questions at an ordinal level and 15 at the nominal level.

There are several scaling techniques that have been developed for quantitative research (Wimmer & Dominick, 1991). This study used the Likert scales in the preparation of the questions. The basic procedure is that statements are either positively worded or negatively worded. This scale is the most commonly used in mass media research (Wimmer & Dominick, 1991).

3.1.2 Respondents

The study focused on users of seasonal climate forecasts in the Free State Province. The main interest was in users who are directly involved in agricultural production although scientists and extension officers were also included. Therefore, a sample was drawn from users who are directly involved in agricultural production, scientists and extension officers in the Free State Province. The questionnaires were in some cases completed with the help of extension officers while the farmers answered the questions. In other cases, they were posted to commercial farmers to be completed as they were assumed to have a good education. Commercial farmers were selected from an existing list of farmers and small-scale farmers were randomly selected from the farming community in each area. In South Africa, there are many sources of seasonal climate forecasts and this study did not try to find out the use of a particular source of seasonal climate forecasts.

3.1.3 Population and Sampling

The determination of a sample size is one of the most controversial aspects of sampling. How large should a sample be to obtain the desired level of confidence in the results? The size of the sample required for a study depends on at least one or more of the following seven points: (a) project type, (b) project purpose, (c) project complexity, (d) amount of error willing to be tolerated, (e) time constraints, (f) financial constraints, and (g) previous research area (Wimmer & Dominick, 1991). Extension officers were involved in data collection because many small-scale farmers have inadequate education. With regard to the sampling method, respondents were selected at random. Each extension officer was allocated 25 questionnaires for 25 respondents. Small-scale farmers were selected at random by extension officers in their areas of responsibility. Commercial farmers were selected from an existing list of farmers, who have shown interest in the past of receiving seasonal climate forecasts, while extension officers and scientists were selected on the basis of interest in receiving seasonal climate forecasts. The data analysed comprised of 286 respondents of which 189 were involved in full-time farming, 18 were extension and research officers probably involved in farming, 31 were in agribusiness and 49 were involved in farming on part-time basis.

3.1.4 Data capturing

The Director of Extension Services in the Free State Department of Agriculture was approached to assist in the data collection. Extension officers were recruited to assist in the data collection by completing the questionnaires while the farmers answered the questions. Extension officers were trained on how to ask the questions using the local language in their area. The data was collected by completing the questionnaires.

3.1.5 Statistical analysis

The questionnaires were analysed quantitatively and statistical inferences drawn. Each response was coded and the code was entered to compile a database. Frequency tables of all the variables were calculated, some cross tabulations and Pearson-r correlations were done on some of the variables. All the analysis were done on the SPSS Software program of the University of Orange Free State Computer Department.

3.1.6 Reliability and validity

The reliability of a survey deals with the extent to which it consistently gives the same results when the survey is repeated, while validity refers to the measuring device's ability to measure what it is imposed to measure (Wimmer & Dominick, 1991). In order to ensure reliability of the survey, a researcher needs to conduct a pilot study. In this study, a pilot study was not conducted due to financial constraints. However, well-trained professionals were used in the data collection and this gave the researcher some assurance that if the survey was repeated, the results would probably be close to those reported here.

3.2 Terminology

Seasonal climate forecasts - long term predicted weather information as to how the season will perform which is given to the farmers and other users.
Meteorological Scientists or Meteorologists - people involved in forecasting and issuing of weather information in a given country.

Chapter 4: Results and Discussion

4.1 Introduction

Farmers in many countries can be classified as either small-scale or commercial farmers using the following characteristics; size of farm, level of technology, farm turnover and qualified human resource level (Guijt and Thompson, in Turner, 1994). The size of the farm has been used to categorise respondents in this study. Farmers with land under 50 ha were considered small-scale and those with land holding larger than 50 ha were classified as commercial farmers. In South Africa, there was an inequitable distribution of land until the change of government and the redistribution of land is still in progress. Using the mentioned criteria, there were 54 farmers classified as small-scale, 192 as commercial and 40 as other being respondents working as extension or research officers or in agribusiness.

4.2 Analysis with respect to farm size

4.2.1 Access to seasonal climate forecasts with respect to farm size

Table 3 shows that less respondents receive the seasonal climate forecasts (39%), than those who do not (all No categories). Overall, there were 61% that indicated that they do not receive forecasts. However, when the frequencies are broken down into individual categories, the highest percentage of respondents receiving the forecast is amongst those in extension, research and agribusiness (Table 3). There were 65% of the commercial farmers who do not receive forecasts and only 40% of other. The survey revealed that a higher percentage of small-scale farmers than commercial farmers interviewed receive forecasts. At the same time, there were a higher percentage of commercial farmers who do not receive forecasts (Table 3). There are also many commercial farmers (28%) who do not receive seasonal climate forecasts but would like to and with a corresponding percentage of small-scale farmers being 24%. However, the survey shows that 4% of the small-scale farmers have never heard of seasonal climate forecasts while only 2% of the commercial farmers are in this category (Table 3).

Table 3 Comparison of respondents with access to seasonal climate forecasts with respect to farm size (Question 5 and 7)

	Answer	Size of Farm			Percent of total respondents
Receiving seasonal climate forecasts		Small-scale	Commercial	Other	
	Yes	42%	35%	60%	39%
	No	29%	35%	12%	31%
	No But	24%	28%	28%	28%
	No idea	4%	2%	0%	2%
	Total	54	192	40	286
	Percent of total respondents	100	100	100	100

4.2.2 *Technical language in seasonal climate forecasts with respect to farm size*

The use of jargon in communication often results in failed communication. Meteorologists may tend to assume that potential users understand the (meteorological terms) they use, although frequently this may not be the case. The use of standard technical meteorological terms in seasonal climate forecasts tends to result in the receiver not understanding. This tends to make them (users) feel that the forecast is not really meant for them and does not encourage them to use it, as they feel excluded. Some members of the target group may not attend to the information because they do not understand all or part of the message. The next question looked at the understanding by the users of the technical language that is used in seasonal climate forecasts. It is correlated with the size of the farm.

From Table 4 it is clear that information intended for farmers to improve their farming practices should not be presented in the same way as that intended for scientists. The survey revealed that all categories indicated that the terminology used in seasonal climate forecasts was understandable with the highest percentage (75%) being for the extension officers, scientists and those in agri-business. Only 6% of both the small-scale farmers and commercial farmers indicated that it is not understandable (Table 4). It was noted that 27% of the commercial farmers indicated that the technical language is a bit understandable (Table 4). Regarding the need to simplify the terminology, 26% of small-scale farmers indicated that it should be simplified with much lower percentages in the commercial and others categories (Table 4). From this question, it could be deduced that many commercial farmers do understand the terminology adequately to very well. Researchers and extension officers also understand the terminology and this may not be surprising as most of these people have been well educated.

Table 4 Understanding of the technical language used in seasonal climate forecasts with respect to farm size (Question 5 and 12)

		Size of Farm			Percent of total respondents
		Small-scale	Commercial	Other	
Understanding technical Language	Understandable	55%	62%	75%	63%
	Not understandable	6%	6%	0%	5%
	A bit Understandable	13%	27%	12%	22%
	Needs to be simplified	26%	5%	13%	10%
	Total	54	192	40	286
	Percent of total respondents	100	100	100	100

4.2.3 *Understanding of the term "normal rainfall is expected" with respect to farm size*

The methodology applied in the mathematical calculation of normal rainfall is familiar to meteorological services or meteorologists and other scientists. The question that arises is: Do users of seasonal climate forecasts share the same understanding and meaning of normal rainfall? In instances where below normal and above normal are calculated, do most users of seasonal climate forecasts share the same meaning of below normal or above normal? Information is transmitted in codes to the receivers and are farmers able to decode this information? If the information is not properly decoded, then effective communication is not taking place. It has been indicated that the value of the seasonal climate forecasts or any other information depends on the understanding of that information by the receiver. The following question was asked to try and establish if the users of seasonal climate forecasts understand the prevalent statement such as "normal rainfall is expected" that is used in the forecasts.

Actual terminology used in seasonal climate forecasts was quoted in the survey such as "normal rainfall is expected". Do the respondents understand such statements? From Table 5 it is clear that a larger percentage (more than 90%) of the commercial farmers, as well as the extension officers, scientists and those in agri-business understand the statement than the small-scale farmers (67%). Small percentages of the respondents indicated that they do not understand, with the lowest percentage being that of extension officers, scientists and those in agri-business. However, 24% of the small-scale farmers indicated that the terminology used in the seasonal climate forecasts was vague while lower percentages of the commercial farmers shared that sentiment. This indicates that there is need to educate / train the small-scale farmers so that they can understand the terminology and make better use of the information. Some education / training is also necessary for extension officers, scientists and those in agri-business (Table 5). Sometimes people pretend to know something when in actual fact they do not for various reasons one of which is fear of embarrassment. The next question tried to verify if respondents understand the actual statement "normal rainfall is expected" by giving them a choice of meanings.

Table 5 Understanding of the statement "normal rainfall is expected" with respect to farm size (Question 5 and 14)

		Size of Farm			Percent of total respondents
Understanding "normal rainfall is expected"		Small-scale	Commercial	Other	
	Yes	67%	93%	90%	88%
	No	9%	6%	3%	6%
	Vague	24%	1%	7%	6%
	Total	54	192	40	286
	Percent of total respondents	100	100	100	100

4.2.4 Understanding of the definition of normal rainfall

It's one thing to say one understands the terminology but it is another to show or prove that one actually understands the terminology. What is normal rainfall? This question was given to the respondents to verify if they really understand the terminology. Table 6 clearly shows that only 22% of small-scale farmers selected the correct answer - that it is an average of rainfall over a given long period time but more than half of commercial farmers and 80% of the extension officers, scientists and those in agri-business defined the statement correctly. Small percentages (3 – 7%) of respondents indicated that normal rainfall implies the highest rainfall (Table 6). However, 37% of the commercial farmers indicated that normal rainfall implies good rainfall while less than 17% of the extension, researchers and those in agribusiness and 67% small-scale farmers also indicated that normal rainfall implies good rainfall (Table 6). Some respondents even believe the statement “normal rainfall” means low rainfall.

Sometimes people have a tendency not to show that they do not understand issues being presented or what is being discussed. It is important to note from Table 5 that higher percentages of respondents indicated that they think they understand the statement “normal rainfall” but when it came to showing or proving if they really understand the terminology in Table 6, the percentages dropped substantially for all the groups. This is a clear indication that the terminology is not understood by at least half of those who use seasonal climate forecasts. For example, the values decline for small-scale farmers from 67% to 22% and commercial farmers from 93% to 54%. Only the other group showed a smaller decline from 90% to 80%, indicating that most extensionists and researchers do understand the meaning of the technical terms.

Table 6 Table of the actual understanding of the statement “ normal rainfall” with respect to farm size of respondents (Question 5 and 13)

		Size of Farm			Percent of total respondents
		Small-scale	Commercial	Other	
Understanding “what normal rainfall is”	(a)	22%	54%	80%	55%
	(b)	7%	4%	3%	3%
	(c)	67%	37%	17%	38%
	(d)	4%	5%	0%	4%
	Total	54	192	40	286
	Percent of total respondents	100	100	100	100

Average over a long period of time, (b) Highest rainfall, (c) Good rainfall, (d) Low rainfall

As simple as it may look, the statement “normal rainfall” may not be as simple a concept for users of seasonal climate forecasts. Therefore, despite the higher percentages (Table 5) indicating that they thought they knew what normal rainfall is, Table 6 results indicate the opposite, as there were reductions in the knowledge percentages. Again this is a manifestation of the need for further explanation and education among the farmers, if the information provided is to be useful or applied in their farming operations. In this case the education should include commercial farmers as only about half gave the correct answer (Table 6). This shows that there is really a need for the terminology to be explained or simplified, as well as education and training programmes to be conducted for the users so that they could make better use of the information.

4.2.5 Understanding of the term “Probability of normal rainfall is 50%” with respect to farm size

Probability statements are among those that are commonly used in seasonal climate forecasts. Should the meteorological scientists assume that all farmers or users of seasonal climate forecasts share the same meaning when using the term 'probability'? Is it right to assume that this could be a bottleneck in the effective communication and use of climate forecasts by farmers? If problem exists, then it can be due to a lack of comprehension of the terms used in the forecasts. The term 'probability' may create misunderstanding resulting in communication failure. The following question tried to find out if the users basically understand the concept of probability commonly found in the seasonal climate forecasts.

Again the actual terminology used in seasonal climate forecasts was used to ascertain if respondents understand the statement ”probability of normal rainfall is 50%”. From Table 7 it is clear that 54% of small-scale farmers indicated that they think that they understand the statement ”probability of normal rainfall is 50%” while a large percentage (more than 88%) of the commercial farmers and extension, researchers and those in agribusiness think they understand the statement (Table 7). Smaller percentages of the respondents of 15% (small-scale farmers) and less than 7% of commercial farmers and extension, researchers and those in agribusiness indicated that they do not understand. However, 31% of the small-scale farmers indicated that the terminology used in the seasonal climate forecasts was vague while less than 8% of the commercial farmers and extension, researchers and those in agribusiness shared that same opinion. This indicates that there is still a general perception that they understand but that there is still need to educate the small-scale farmers so that they could learn the concepts and understand the terminology and therefore enable them to make better use of the available information (Table 7). The next question tried to find out if respondents can explain what the statement “probability of normal rainfall is 50%” means.

Table 7 Understanding of the statement “Probability of normal rainfall is 50%” with respect to farm size (Question 5 and 15)

		Size of Farm			Percent of total respondents
Understanding of “probability normal rainfall is 50%”		Small-scale	Commercial	Other	
	Yes	54%	88%	90%	82%
	No	15%	7%	2%	8%
	Vague	31%	5%	8%	10%
	Total	54	192	40	286
	Percent of total respondents	100	100	100	100

4.2.6 Explaining probability of normal rainfall is 50% with respect to farm size of respondents

There is a saying that says, “When he/she explains it, then he/she knows it. The next question was: What does the statement “probability of normal rainfall is 50%” imply? In Table 8 it is shown that less than 48% of small-scale and commercial farmers and extension officers, scientists and those in agri-business indicated the correct answer - that it is the chance of getting normal rainfall in 50% of the years (c). Small percentages of respondents of less than 9% indicated that the statement “probability of normal rainfall is 50%” implies the chance of rainfall in 50 years. However, between 32-37% of all the respondents think that probability of normal rainfall is 50% implies the chance of receiving _ the normal rainfall. About a fifth of the respondents indicated that it was the chance of rainfall being 50mm. This confirms that there is a communication breakdown between scientists and users (Table 8). The respondents were not able to explain the terms commonly found in the seasonal climate forecasts. Therefore questions arise as to how they (the users) can possibly use this information if they do not understand it in the first place.

Table 8 Table of actual understanding of the statement " probability of normal rainfall is 50%" with respect to farm sizes (Question 5 and 16)

		Size of Farm			Percent of total respondents
Understanding "what probability of normal rainfall is 50% is"		Small-scale	Commercial	Other	
	(a)	22%	20%	13%	18%
	(b)	32%	35%	37%	35%
	(c)	37%	39%	48%	42%
	(d)	9%	6%	2%	6%
	Total	54	192	40	286
	Percent of total respondents	100	100	100	100

Chance of rainfall being 50mm, (b) Chance of receiving _ the normal rainfall, (c) Chance of getting normal rainfall in 50 % of the years, (d) Chance of rainfall in 50 years

With regard to this statement "probability of normal rainfall is 50%" less than half of all the respondents got it correct implying that there is a need for simplification of these terms as well as detailed simple explanation of the all the terms used in the seasonal climate forecasts.

4.2.7 Conclusion on terminology with respect to farm size

From the results in the tables in this chapter, it has been found that most of the respondents have some difficulty understanding the terminology that is used in the seasonal climate forecasts. The terms: normal rainfall, probability of normal rainfall and the probability of normal rainfall is 50% should be simplified by those that communicate this information. Doubts have arisen as to how users make use of this information when they do not comprehend the meaning of the information. These type of findings have been reported by other scientists dealing with target groups other than farmers in the rest of the world (WMO, 2000).

In a recent survey by WMO, media personnel indicated that one of the problems with meteorological information was unfamiliarity with meteorological jargon, definitions and terminology which are sometimes too technical and unsuitable for public dissemination and understanding (WMO, 2000). Meteorologists should understand that concepts vary in meaning depending on who is using them, although there are concepts that do have a universal meaning. However, to assume that the meaning is the same everywhere is to ignore a fundamental principle of language. Babbie (1981) has stated that meaning is in people and not in words and in this case it would be stated that meaning is in farmers and not in meteorological terms. Scientists involved in the dissemination of information for farming purposes should understand and try to use the language of the intended audience of the information. The use of jargon or technical terms only tends to make the intended audience feel excluded and possibly inferior. Information intended for small-scale farmers should be prepared in a language style that they will be able to be easily understood.

Responses were tested whether farm size or farm turnover had a greater influence on understanding and utilisation of seasonal climate forecasts. There are more commercial farmers who receive seasonal climate forecasts than small-scale farmers. The results indicate that with regard to farm size, small-scale farmers had less understanding of the meteorological concepts than those with larger farms. There are also more commercial farmers who understand the terminology than small-scale farmers, although there are still many who do not understand. There are also more commercial farmers who understand the statement "probability of normal rainfall" than small-scale farmers.

Similar research was conducted by Klopper (1999) on a specific season (1997/98) for the clients of the South African Weather Bureau (SAWB) to determine whether seasonal climate forecasts reached the end users effectively and how decisions were influenced by this information. Klopper (1999) also tried to establish if the users understood the information given to them and if they knew how to apply it. Klopper also found that the terminology was not easily understandable and that it required simplification. However, Kloppers research was restricted to one particular season, that of 1997/1998 rainfall season and the target group was restricted to those with an interest in seasonal climate forecasts for various purposes including energy, food industry, construction and water management.

4.3 Analysis with respect to farm turnover

4.3.1 Access to seasonal climate forecasts with respect to farm turnover of respondents

In many African countries, small-scale farmers have a moderate income from their agricultural activities. Taking this characteristic as a criterion, respondents were divided into three categories with respect to turnover, to ascertain if the turnover had an influence on the use of seasonal climate forecasts. The results show that 49% of the low turnover and high turnover categories indicated that they receive seasonal forecasts (Table 9). However, it is noteworthy that there is a high percentage of those in the medium turnover category indicating that they do not receive forecasts. There is also a high percentage (32%) of those in the medium category that indicated that they do not receive seasonal climate forecasts but they would like to. With regard to knowledge of the existence of seasonal forecasts, they all know that this information exists and less than 3% across all categories have no idea of this type of information (Table 9). This result tends to indicate that the marketing of seasonal forecasts has been effective despite the fact that not all people surveyed actual received the seasonal forecast.

Table 9 Relationship of annual farm turnover to receiving seasonal climate forecasts (Question 6 and 7)

	Answer	Farm Turnover			Percent of total respondents
Receiving seasonal climate forecasts		Low (R0 – 10 000)	Medium (R10 001 – 500 000)	High (above R500 000)	
	Yes	49%	21%	49%	39%
	No	22%	45%	24%	30%
	No But	26%	32%	26%	29%
	No idea	3%	2%	1%	2%
	Total	117	95	74	286
	Percent of total respondents	100	100	100	100

4.3.2 Respondents' understanding of technical language in seasonal climate forecasts with respect to farm turnover

How does the farm turnover influence the understanding of the seasonal climate forecasts? Are those in the high turnover category forced to understand the terminology? The results indicated that more than 67% of the low turnover category and high turnover category understood the terminology (Table 10). Small percentages in all the categories indicated that the terminology is not understandable (Table 10). However, those in the medium category, about 33% indicated that the seasonal climate forecasts need to be simplified while less than 12% of those in the low-income group and high income group would like the terminology to be simplified (Table 10). The results in this case show that one cannot draw a conclusion that the higher the income, the more the understanding by those who use the information.

Table 10 Understanding of the technical language used in seasonal climate forecasts with respect to farm turnover (Question 6 and 12)

	Answer	Farm Turnover			Percent of total respondents
Understanding technical language		Low (R0 – 10 000)	Medium (R10 001 – 500 000)	High (above R500 000)	
	Understandable	67%	49%	74%	63%
	Not understandable	3%	7%	1%	5%
	A bit Understandable	18%	11%	15%	22%
	Needs to be simplified	12%	33%	10%	10%
	Total	117	95	74	286
	Percent of total respondents	100	100	100	100

4.3.3 Understanding of "normal rainfall is expected" with respect to farm turnover

Does the farm turnover influence the understanding of the meteorological language? The results show that more than 80% of the low, medium and high turnover category indicated that think they understand the statement "normal rainfall is expected" (Table 11). Small percentages of less than 7% of the respondents in all categories indicated that they do not understand. However, in Table 11, one can see that 13% of the low turnover farmers indicated that the terminology used in the seasonal climate forecasts was vague, while none of the high category farmers shared that sentiment and only 1% of the medium turnover agreed. The farm turnover appears to have an influence on their own perception of their understanding of the terminology by the users of the seasonal climate forecasts.

Table 11 Understanding of the statement “normal rainfall is expected” with respect to farm turnover

		Farm Turnover			Percent of total respondents
Understanding “normal rainfall is expected”		Low (R0 – 10 000)	Medium (R10 001 – 500 000)	High (above R500 000)	
	Yes	80%	89%	99%	88%
	No	7%	8%	1%	6%
	Vague	13%	3%	0%	6%
	Total	117	95	74	286
	Percent of total respondents	100	100	100	100

The result shows that those who have a high farm turnover, understand the terminology better that those with relatively lower farm turnover. The understanding of terminology by users of seasonal climate forecasts increases as the farm turnover increases (Table 11). Therefore, the farm turnover may have a influence on users regarding the understanding of the terminology used in the seasonal climate forecasts.

4.3.4 Respondents’ definition of “normal rainfall” with respect to farm turnover

The question in this section tried to ascertain if turnover plays a role in understanding terminology by being in a position to know the correct definition or to explain it. In Table 12 it clearly shows that only 34% of low turnover category farmers indicated the correct answer - that the statement “normal rainfall” implies an average over a given time while more than 56% of medium category and high category farmers indicated the same. Small percentages (less than 6%) of respondents in the low turnover category, medium and high category farmers indicated that normal rainfall implies highest rainfall (Table 12). However, 56% of the low turnover category indicated that normal rainfall implies good rainfall while less than 37% of the medium turnover category and high turnover category farmers respectively indicated that normal rainfall implies good rainfall. There were still some respondents who feel normal rainfall implies low rainfall (Table 12).

Table 12 Actual understanding of the statement " normal rainfall" with respect to farm turnover (Question 6 and 14)

		Farm Turnover			Percent of total respondents
Understanding "what normal rainfall is"		Low (R0 – 10 000)	Medium (R10 001 – 500 000)	High (above R500 000)	
	(a)	34%	56%	91%	55%
	(b)	6%	2%	1%	3%
	(c)	56%	37%	8%	38%
	(d)	4%	5%	0%	4%
	Total	117	95	74	286
	Percent of total respondents	100	100	100	100

Average over a long period of time, (b) Highest rainfall, (c) Good rainfall, (d) Low rainfall

Therefore, despite the higher percentages (above 80%) (Table 11) indicating that they thought they knew what normal rainfall is, Table 12 results indicate the opposite as there were major reductions in the actual knowledge percentages. For the low turnover group (changes) from 80% whose own assessment is that they do know the meanings, compared to only 34% who actually indicated the correct definition in question 14. Again this is a manifestation of the need for education / training or even information days among the farmers particularly those not in big business and other users if the information is to be useful (Table 12). However, the trend was the same with respect to understanding, that it is those with a higher turnover who understood the terminology better than those with a lower turnover. While the correct answer is (a), the percentage of those who interpret normal rainfall as good (c) rainfall reduced with an increase in farm turnover (Table 12) showing that the misconception of "normal" = "good" is more prevalent among the small enterprise farmers.

4.3.5 Respondents' understanding of "Probability of normal rainfall is 50%" according to farm turnover

The understanding of the probability of rainfall being 50% was tested using turnover as a possible influencing factor. The results showed that 69% of low turnover farmers indicated that they understand the statement "probability of normal rainfall is 50%" while more than 89% of the medium and high turnover farmers themselves think they understand the statement (Table 13). Small percentages of the respondents of less than 11% of the respondents in all the categories indicated that they do not understand. However, 20% of the low turnover respondents indicated that the terminology used in the seasonal climate forecasts was vague while less than 3% of the medium and high category shared that sentiment. It is clear here that those in the low category are mostly small-scale farmers and these require further support in the form of education/training to enable them make use of seasonal climate forecasts as a practical application on the farming enterprise.

Table 13 Understanding of the statement "Probability of rainfall is 50%" with respect to farm turnover (Question 6 and 15)

	Answer	Farm Turnover			Percent of total respondents
		Low (R0 – 10 000)	Medium (R10 001 – 500 000)	High (above R500 000)	
Understanding "probability of rainfall is 50%"	Yes	69%	89%	96%	82%
	No	11%	8%	1%	8%
	Vague	20%	3%	3%	10%
	Total	117	95	74	286
	Percent of total respondents	100	100	100	100

This again indicated and supports the previous deductions that those with a higher turnover understood the terminology better that those with a lower turnover. This supports the notion that that there is a need to educate the low turnover category (small-scale farmers) so that they could understand the terminology to make better practical application of the information (Table 13).

4.3.6 Explaining probability of normal rainfall is 50% with respect to farm turnover

What does the statement "probability of normal rainfall is 50%" mean? Results attest that 27% of the low turnover category indicated that it is the chance of getting 50 mm rainfall, while 20% of medium turnover category indicated the same and none of the high turnover category (Table 14). Small percentages (less than 8%) of respondents feel probability of normal rainfall is 50% implies chance of rainfall in 50 years. However, 27% of the low turnover category indicated that probability of normal rainfall is 50% implies the chance of receiving _ the normal rainfall and less than 43% of the medium and high turnover category indicated the same. A reasonable percentage (less than 38%) of respondents in the low and medium category indicated the correct answer, that it was the chance of getting normal rainfall 50% of the years and 54% in the high turnover category (Table 14).

Table 14 Actual understanding of the statement " probability of normal rainfall is 50%" with respect to farm turnover

		Farm Turnover			Percent of total respondents
		Low (R0 – 10 000)	Medium (R10 001 – 500 000)	High (above R500 000)	
Understanding of "what probability of normal rainfall is 50% is"	(a)	27%	20%	0%	18%
	(b)	27%	40%	43%	34%
	(c)	38%	35%	54%	42%
	(d)	8%	5%	3%	6%
	Total	117	95	74	286
	Percent of total respondents	100	100	100	100

Chance of rainfall being 50mm, (b) Chance of receiving _ the normal rainfall, (c) Chance of getting normal rainfall in 50 % of the years, (d) Chance of rainfall in 50 years

However, when farm turnover was taken into account, the low (38%) and medium (35%) category had less understanding of the terminology in the seasonal climate forecasts. In the high category turnover, only 54% indicated that they understand the terminology which gives an impression that there are still misconceptions amongst the high turnover group as to the true meaning of a probability when it comes to rainfall (Table 14). This would imply that many of those who invest a lot money in farming had taken the trouble to learn the terminology in seasonal climate forecasts information. However, in the case of seasonal climate forecasts, users frequently have not been able to 'decode' the information disseminated. Clearly, users cannot make use of information provided if they do not understand the information in the first place. Unless the communication model, and in particular the importance of shared meanings between encoder and decoder, is understood and clarified by those that disseminate information, effective communication will always be a problem.

4.3.7 Conclusion on terminology understanding with respect to farm turnover

It has been observed from the survey results that the farm turnover has an influence in the understanding of the seasonal climate forecasts. The results show that those with a higher farm turnover have a better understanding of the seasonal climate forecasts than those with a lower farm turnover. This can be understood in the sense that those who invest much in the farming business have a greater interest in the seasonal forecast as it has a direct effect on the their business. In addition many of the respondents in the higher turnover bracket will be among those with a higher level of education Seasonal climate forecasts help in planning the farming enterprise and ultimately the farm turnover is dependent on how well the planning was done when all variables are considered.

4.4 Media used to receive seasonal climate forecasts

Weather forecasts and warnings have no shelf life and must be disseminated rapidly to the public or else they are worthless. The mass media is the primary means to achieve swift dissemination. They are major stakeholders in the public interest and are both clients and partners of National Meteorological Services (NMSs) where public weather services are concerned (WMO, 2000). As clients they have a keen interest in the quality, format, content and timing of public weather services products, since these must be compatible with their own standards and operational constraints that allow broadcasts during peak audience periods (WMO, 2000). The media can also be effective allies in highlighting the importance of public weather services to the community and in supporting the need for meteorological infrastructure of observing networks, communication systems and forecast offices. The media is a tool which, when used properly can be an efficient means of increasing the visibility of NMSs (WMO, 2000).

4.4.1 Analysis of media used by respondents

The respondents were asked to indicate which media is used to receive seasonal climate forecasts. The media in question were fax / Post, Newspaper / printed pamphlets, television, radio, e-mail and other. There were also combinations of these media. It has already been shown earlier that some respondents receive seasonal climate forecasts while others do not but have an interest in receiving this information. Here it is observed that 59% of the respondents do not receive any seasonal climate forecasts and hence could not indicate which media they use. Of those that are recipient, the radio (12%) was the most commonly used media to receive seasonal climate forecasts. This is because the radio is the most common communication channel which rural communities can afford to purchase.

From figure 4, it was observed that there is a wide range of media used to obtain seasonal climate forecasts. The figure also shows that more than half of the potential users of seasonal climate forecasts do not receive seasonal climate forecasts at present. It can be assumed that these users would make use of the same media as those already receiving the seasonal climate forecasts.

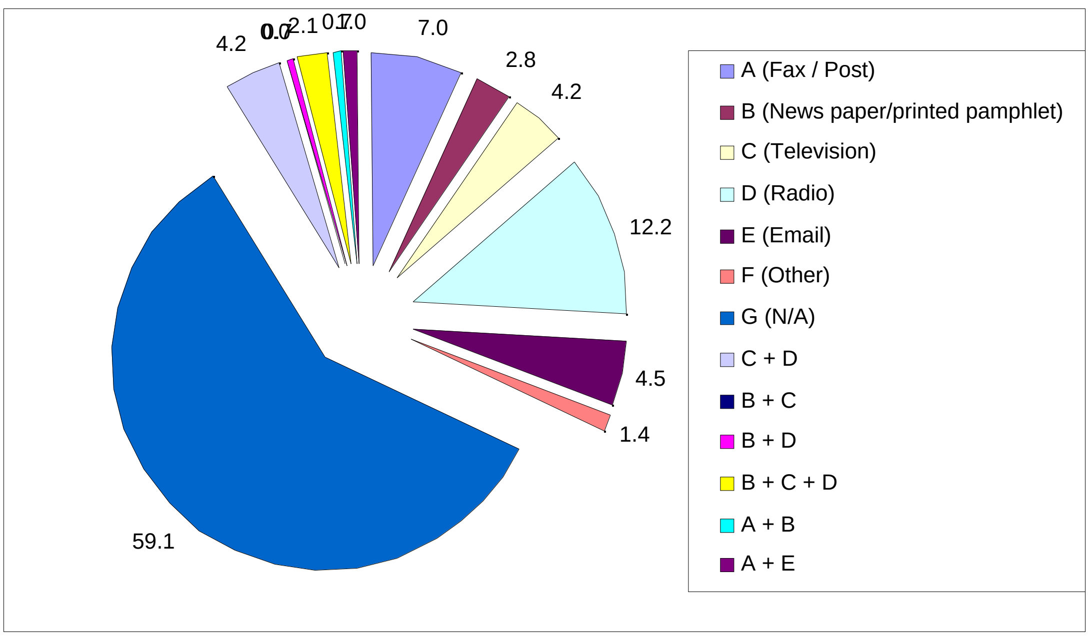


Figure 4 Media through which respondents receive seasonal climate forecasts. N/A – implies do not receive seasonal climate forecasts.

Figure 4 shows that the fax / post were used by 7% of the respondents. Mainly the commercial farmers together with people in agri-business organisations probably used fax, as it requires relatively expensive equipment. The e-mail was also used by 4.5% of the respondents and this was definitely by commercial farmers and those in agribusiness as a computer is expensive equipment to own. Besides the cost of the computer, one needs to subscribe to Internet service providers which is also relatively expensive. Television is one of the most powerful tools of communication, although only 4.2% of the respondents use this medium for receiving seasonal climate forecasts. A combination of television and radio also had 4.2% of respondents using them to receive forecasts. The print media, newspapers and printed pamphlets also had it own share of respondents who use them to obtain seasonal climate forecasts. The combination of other media had percentages of less than 2%.

4.4.2 Preferred media

It was important to establish if the respondents were happy with the existing means of communicating seasonal climate forecasts. Using the media was already discussed in the previous question, then the respondents were asked to indicate media or combination of media that they prefer to receive seasonal climate forecasts. Most respondents (27%) indicated that they prefer receiving seasonal climate forecasts via the radio (Figure 5). Again it is for the simple reason that the radio is generally owned by both poor and well-off respondents. This was followed by the e-mail (22%). This is probably because the e-mail is very fast and can provide much detail. For example, the seasonal climate forecast from the SAWB and DMC was sent to the Department of Agrometeorology, University of the Free State by e-mail. The print media in the third position has 12% of the respondents prefering to use the newspapers / printed pamphlets to receive seasonal climate forecasts (Figure 5). The Fax/Post was preferred as a source of information by 10% of the respondents. A combination of radio and television was preferred by 7% of the respondents. There was also a combination of radio, television and print media, which had a 3% preference. However, the rest of the combinations had less that 3% of the respondents preferring that source of information (Figure 5).

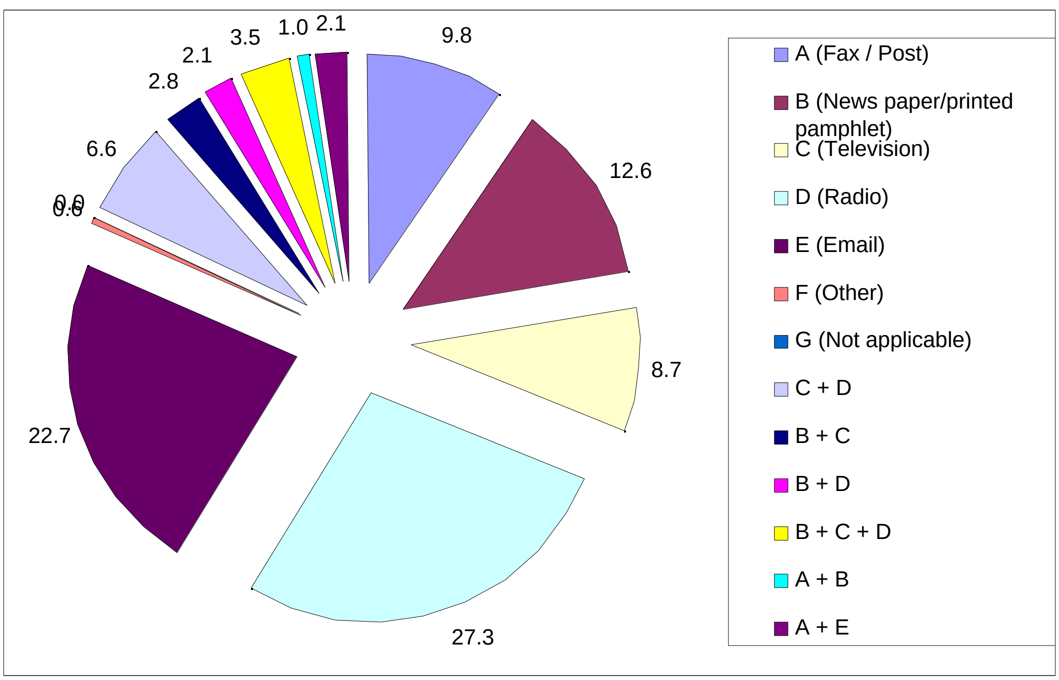


Figure 5 Respondents' preferred media for receiving seasonal climate forecasts

4.4.3 Conclusion on the media use of seasonal climate forecasts

The survey has shown that the both print and electronic media are extensively used in the communication and dissemination of seasonal climate forecasts. In general, currently, the radio, television, newspaper and e-mail are used to communicate forecasts in South Africa. However, the radio ranks top as a preferred media of communicating seasonal climate forecasts. This may be difficult to understand as it is then only stored in the individuals brain and one cannot refresh ones memory from a printed page.

A recent WMO survey to assess the state of Members' public weather service programmes confirmed that the mass media are by far the major communication channels through which the public can receive weather information, forecasts and warnings disseminated by the meteorological services (WMO, 2000). Newspapers, radio and television are all very effective means of informing the public as they reach a maximum number of people. The most common means of reception of weather forecasts, warnings and other information is clearly by radio, (100% world-wide), followed by television (93% world-wide). The picture is similar when analysing the means of dissemination of warnings by NMSs, as survey results indicate global figures of 88% and 79% for radio and television respectively (WMO, 2000).

If the use of various media are compared or contrasted during power outages in the aftermath of severe weather, battery-operated radio is usually the only means of access to critical warning information. Television, with its visual display capability is a high impact medium with very large viewing audiences in most countries (WMO, 2000). Articles in the print media contribute significantly to the education of the community about risks associated with severe weather and ways to mitigate severe weather impacts. Newspapers carry weather forecasts and climate data, as well as interviews on special weather topics, World Meteorological Day themes or post-mortems on recent severe weather episodes (WMO, 2000). However, they cannot cater for the urgency and imminence of a tornado or severe convection. The Internet is a mechanism for worldwide information dissemination and the number of NMSs with access to the Internet has grown from 34% in 1997 to 70 percent in early 1999. The Internet presents both a challenge and opportunity for NMSs. It has limitations as a medium for dissemination of urgent warnings and enables the public to have access to many more information sources, with a potential for public confusion. But at the same time, it allows NMSs to access global and adjacent country’s information to support their public weather services, and to provide information directly to the public (WMO, 2000).

4.5 Decision-making

4.5.1 Value placed on information

Information is of no use unless it can be used. In the survey, the respondents were asked how much value they attached to the seasonal climate forecasts. The results showed that 48% placed high value on the weather information while 38% indicated that the information was important (Figure 6). However, there were about 12% who indicated that they not sure how valuable the information was and 2% categorically indicated that the information was not important (Figure 6). About 48% of the respondents indicated that seasonal climate forecasts are very important for their farming activities. Results from a Pearson correlation with farm size show a positive significant relationship, (r= 0.13, N=286 and p=0.032). This means the farmers with bigger farms consider seasonal climate information more important than the farmers with smaller farms.

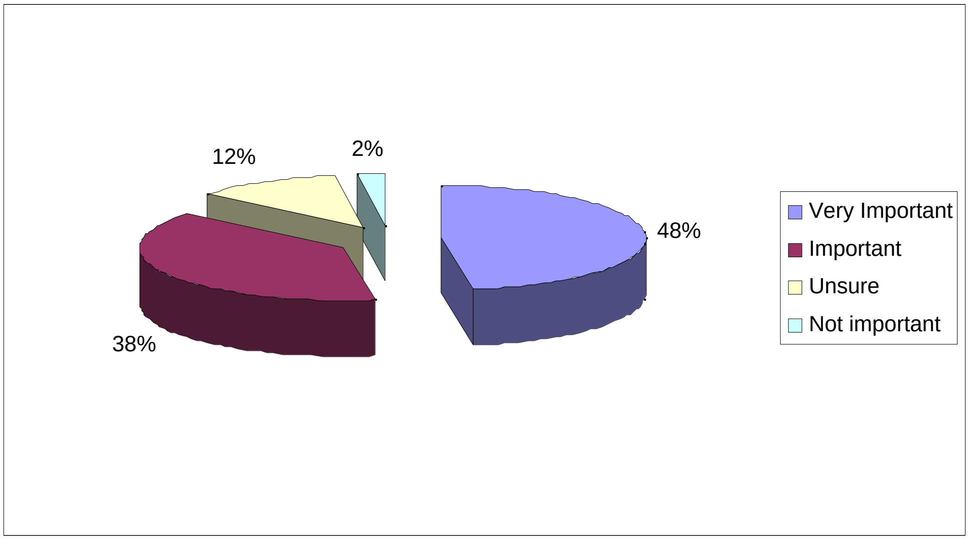


Figure 6 Percentage of respondents that attach value to seasonal climate forecasts

Seasonal climate forecasts are very important for agricultural production, however, it is also important that the information is reliable and valid. The respondents were asked if they trusted the seasonal climate forecasts. The results show that 16% of the respondents trusted the forecasts all the time while 49% trusted the forecasts most of the time. These two categories then show in general that two-thirds of the respondents have confidence in the seasonal climate forecasts. Those that indicated that they some times trust the forecasts were 32% and only 3% indicated that they do not trust the seasonal climate forecasts (Figure 7). From the results, it is shown that the information has enough credibility for people to use. Using Pearson correlation, it was found that the trust in forecasts had a negative relationship (r=-0.17, N=286 and p=0.004) with farm activities (see Appendix I, question 4). It can be concluded that the type of farm activity the respondents are involved in, affect the way they consider and trust the seasonal climate forecasts. There was a positive correlation (r=0.02, N=286 and p=0.73) with the type of occupation (see Appendix I, question 3), however, the relationship was not significant. The lack of significant difference was also observed for many other questions in the survey.

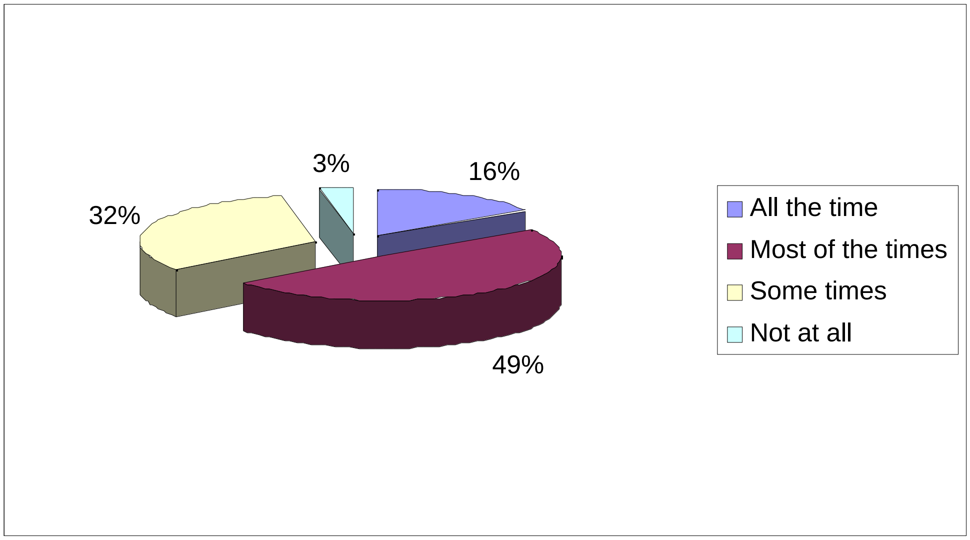


Figure 7 Respondents trust in the seasonal climate forecasts

4.5.2 Usefulness of information

Information is said to be useful if those that it is intend for are able to use it and that they are able to make adjustments to their everyday farming activities. Respondents were asked if they make any adjustments to their activities once they have seasonal climate forecast information. The finding are that 24% make adjustments all the time to their farm activities and 40% do the same most of the time (Figure 8). However, 30% only make adjustments sometimes and 6% never make any adjustments (Figure 8). Considering that reasonable percentages make adjustments all the time and most of the time is an indication that the information is considered important and useful. Using Pearson correlation, it was found that the adjustments to farm activities had a negative correlation (r=-0.02, N=286 and p=0.73) with age of respondents. This means that those who are older do not make adjustments to their farm activities when a drought is forecast while the younger respondents do make adjustments from this information. There was a negative correlation (r= - 0.016, N=286 and p=0.79) with farm activities of respondents. This means that the farm activities may affect the adjustments that could be made, however, the relationship was not significant at 5% level.

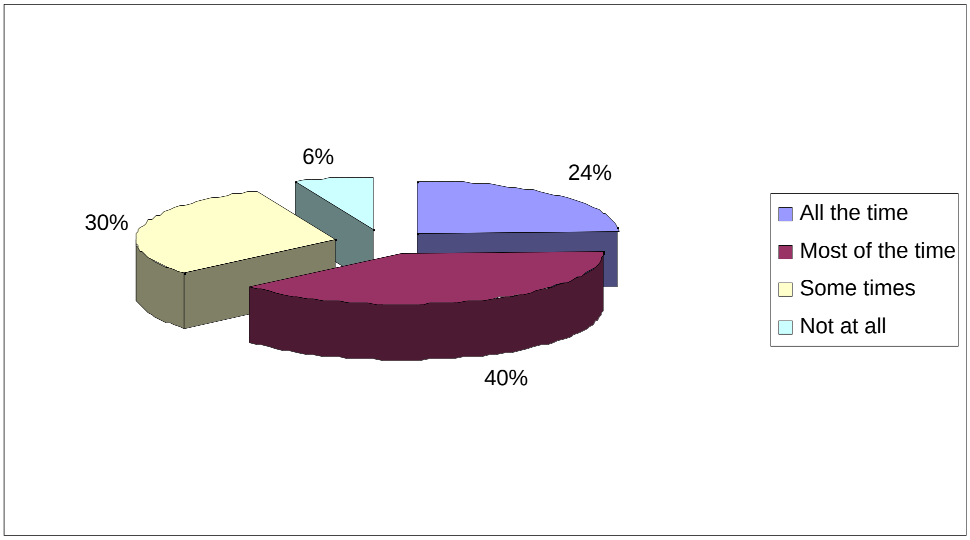


Figure 8 Respondents decision-making after drought is forecast

4.5.3 Effort made to obtain forecasts

When information has been identified as important, users will make every effort to obtain that information for planning purposes. Respondents were asked if they make deliberate effort to obtain seasonal climate forecast information for their planning. The results show that 30% make an effort to obtain forecast information all the time while 37% make an effort most of the time (Figure 9). The survey also revealed that 27% make effort to obtain the forecast sometimes and only 6% do not make any effort to obtain this information at all. In South Africa, it seems that 90% of the farmers will make an effort to get this information if they know it is available. The results show that there is sufficient percentage to indicate that this information is important and users make a deliberate effort to obtain the information. The Pearson correlation calculated indicated that there is negative correlation with farm activities (r= - 0.13, N=286 and p=0.03). This can be interpreted as meaning that depending on the farm activities that the respondents are involved in, they will make an effort to obtain seasonal climate forecast information.

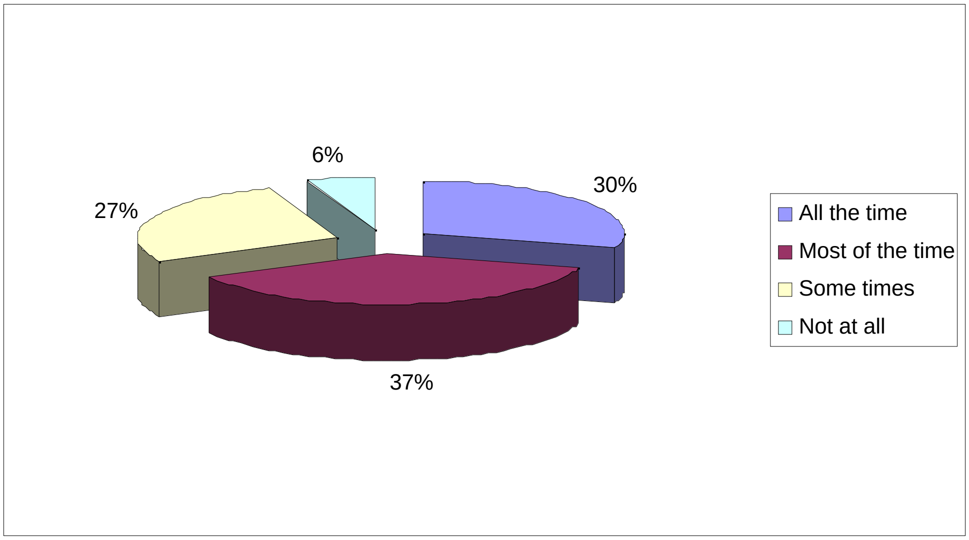


Figure 9 Respondents making deliberate effort to obtain seasonal climate forecasts

The Pearson correlation calculated also indicated that there was negative correlation with farm size (r= - 0.18, N=286 and p=0.003). This can be interpreted as meaning that depending on the farm size of the respondents as the size increase, they make more effort to obtain seasonal climate forecast information. The relationship is significant. The Pearson correlation calculated indicated that there is negative correlation with farm turnover (r= - 0.21, N=286 and p=0.00). This can be interpreted as meaning that depending on the farm turnover of the respondents, they will make an effort to obtain seasonal climate forecast information, this probably because they receive it via fax or e-mail in an automatic fashion. Those with high turnover do not make a lot of effort to obtain the information. This is probably because they receive it via fax or e-mail automatically each month. However, the relationship is highly significant.

4.5.4 Conclusion on decision making

It has been observed that seasonal climate information is regarded as valuable information and that many users trust this information and many of them make adjustments to their farming activities based on this information. The respondents indicated that this information is important for decision making and therefore they make a deliberate effort to obtain this information through the various media channels available to them. However, some negative relationships were also observed where the relationships were found to be highly significant at 1% although some were significant at 5%.

Chapter 5: Conclusion and Recommendations

5.1 Conclusion

This study first identified some problems of communication between meteorological services and farmers or users of seasonal climate forecasts. Communication was defined and a communicating model was used to explain the process. Often, the media or channels for communication of meteorological information are already well established. Therefore, what remains is effective communication of relevant information. Characterization of the target audience is essential for effective communication to occur. Scientists involved in the dissemination of information for farming purposes, should understand the intended audience of the information and their specific needs. The use of jargon or technical terms makes the intended audience feel excluded and possibly inferior. Information intended for small-scale farmers should be prepared in a language style that they will be able to understand.

There is a lack of skill amongst scientists and extension officers to communicate clearly and to make good connection with the general public. There are no regular training programmes for users or farmers so that they are able to understand the information and be able to apply it. Weiss, *et al*. (1999) proposed that in order to facilitate the communication of information to a user community, social scientists should interact with agrometeorologists to provide a message structure that is suited to the target audience. There is limited research on the effectiveness of other channels of communicating meteorological information. These include farm demonstrations, farm discussions, farmers' days, meetings and other farmers. Whatever media or channels are used, the time-tested adage of 'know your audience' is the best starting point.

5.2 Recommendations for possible changes in future

Training programmes for scientists and extension officers in communication skills would help them to understanding the importance of communication. There is also a need to conduct training programmes for users and/or farmers so that they are able to understand the information and able to apply it. If this can be conducted together with a social scientist, then there can be an increase in the efficiency of the transfer of the message to the user groups.

There is also a need to conduct research into the effectiveness of other channels of communicating meteorological information, including farm demonstrations, farm discussions, farmers' days, meetings and other farmers or users. An effort must also be made to identify the needs of the users and the specific farming activities in a certain area, so that these can be addressed.

There is need within the SADC region to allocate the duties of research, dissemination and public relations of meteorological information. The individual would have to conduct research into effective methods of communication and liaise with all the media organisations to try to avoid confusion in the way the media reports on meteorological phenomena.

If the information is effectively communicated and understood correctly by the farmers or users, is it right to assume that the farmers will know how to use the information? In an event of low rainfall or drought, will the farmers know what water conservation practices to use? There is aneed to further develop applications of the seasonal climate forecasts and interpret them into actions at farm level. Agrometeorology professionals are available to help in the practical applications of seasonal climate forecasts. This area requires further research, and should be pursued if agricultural production is to be sustainable in many semi-arid areas.

It is important that agrometeorologists are involved extensively in the communication of seasonal climate forecasts, why? The agrometeorologists have one foot in each camp and they understand meteorological concepts and agricultural principles and can be most useful in translating messages from meteorology specialists into useful and practical information for the agriculture industry.

Part B: Training Seminars

Training Seminars to Sensitize Agricultural Extension Officers and Farmers about the Importance of Weather Forecasts for Sustainable Agricultural Production

1. Introduction

Training has been defined as a learning experience that seeks a relatively permanent change in an individual that will improve his or her understanding of issues relevant to the profession or activity. Training is regarded as a systematic and planned process to change the knowledge, skills and behaviour of an individual to achieve the objectives set by himself or herself and in most cases by the employing organisation.

Meteorology is one of the most difficult sciences especially as it is not very easy to conduct experiments as in other sciences. The nature of the science itself comprises a lot of terms that are difficult to remember, let alone understand the dynamics of the atmosphere. Studying the subject of meteorology demands a sound background in both physics and mathematics. However, not all those who apply the outputs of meteorologists need to understand the dynamics of the atmosphere. It therefore, becomes imperative to expose those who want to or do make use of the meteorological outputs like seasonal climate forecasts, to some simple meteorological concepts.

Extension officers are among the professionals who are in constant contact with farmers providing them with advice on many agricultural related issues. If the seasonal climate forecasts have to be understood by users including farmers, then training must be conducted for extension officers and the farmers themselves to equip them.

It is with this background that training seminars to sensitise agricultural extension officers and farmers on the importance and use of weather forecasts for sustainable agricultural production were conducted.

2. Literature Survey

Among other problems, one of the main challenges facing the rural resource poor farmers in Africa is the unpredictability of weather particularly on a seasonal scale. It is a well known fact that even under traditional farming conditions with no inputs other than labour, resource poor farmers' decisions of crops and varieties to be planted depend on a number of factors of which weather is one. However, diversification is also one of the most basic risk management approaches used at the subsistence level. It should also emphasised that traditional systems can be very robust because of their low water

consumption (as compared with improved varieties) and low input requirements (fertilizers increase water consumption and the risk of agricultural drought) (Gommes, 1999).
Crop insurance can be resorted to only when there is sufficient spatial variability of the environmental stress (e.g. with hail), but remains extremely difficult to implement for some of the major risks, such as drought, which typically affects large areas, sometimes entire countries. It is certainly not feasible without government intervention. One of the techniques that has been adopted by farmers is the practice of risk-reducing techniques, such as early planting.

To reduce the negative impact of weather on agricultural production, users or farmers need to be equipped with some meteorological knowledge so that they will understand the output from the meteorological services (Gommes, 1999). A knowledge in 'Agricultural Meteorology' is essential for extension officers and farmers for sustainable agricultural production. The subject of agricultural meteorology is concerned with defining and applying knowledge of interactions between meteorological and hydrological factors, with biological systems to agriculture, including horticulture, animal husbandry and forestry (WMO, 1981). Agricultural meteorology is concerned with processes that occur from the soil layers of the deepest plant and tree roots, through the air layer near the surface in which crops and forests grow and animals live (WMO, 1981).

3. Materials and Methods

The planning of the training programmes started soon after the finances were remitted. The Director of Extension Services in the Northern and Southern region of the Free State Province were contacted to nominate participants for the training programme. It was suggested that a nominated extension officer attend the training with a farmer who has influence in his or her area so that knowledge acquired can be passed on to the other users. The objective of the training programme was to conduct training seminars to sensitise agricultural extension officers and farmers on the importance of weather forecasts for sustainable agricultural production.

The programme was introduced by a summary of the stated availability of weather information to farmers in the Free State. It was decided to include basic information on the effects of El Nino and how seasonal forecasts are constructed. Additional information was also given on the specific application of the seasonal forecast to summer crop production. As communication of the message is vital a session was included covering some of the communication skills need by extension officers.

Information was given to the participants in form of lectures. There was an exchange of information with the participants concerning real life issues due to their experience in agricultural production. In the last session of the day after the presentations, participants were divided into small groups to discuss issues regarding seasonal climate forecasts as well as to evaluate the presentations of the training programme. After exhausting their group discussions, each group was given an opportunity to make a 5-minute presentation on the evaluation of the training programme and comments on the possible future improvements to be made in the communication of seasonal climate forecasts. The participants also made suggestions as to other relevant information that they felt should be part of the seasonal climate forecasts. Detailed information regarding participants' suggestions is in the section on comments from participants. The printed handout materials that were presented to the participants are in the appendices III to IV. For more effective communication, the materials were also translated into the local language, Sesotho.

4. Training on Communication and Seasonal Climate Forecasts

The information was transferred to the agricultural user community by way of two one-day training sessions held in Bloemfontein and Bethlehem (see appendices VII & VIII). These training session consisted of a full programme including the Dean of the Faculty of Natural and Agricultural Sciences of the University of the Orange Free State and a member of the Free State Department of Agriculture in the particular sub-region. The extension and community workers from the sub-region attended the training sessions and some small-scale farmers were also invited. The main purpose of the training sessions was to introduce the extension officers and farmers to the concepts of the seasonal forecasts. There were four main presentations and an extended time for discussion and feedback via small group discussion lead by Prof Sue Walker. Dr Elijah Mukhala presented a summary of the questionnaire results giving highlights of the areas of little knowledge and contrasting the results according to different farm sizes. Mr Toni Rossouw and Mr Francis Mosetlho from the South African Weather Bureau, Bloemfontein Forecasting Office, gave an illustrated presentation of the methods involved in obtaining the seasonal forecasts from the SST, SOI and GCM outputs. They also presented information about the short-term forecasts, namely 7 and 14-day forecasts. Mr Johan van den Berg presented an informative discussion of the application of the seasonal forecasts for the farmers in the Free State and explained how the probabilities and normal rainfall values are calculated. His presentation included the application to on-farm decisions such as planting dates and cultivar or crop choice. Mr GP van Rheede van Oudtshoorn, of the Department of Communication at UOFS, gave a lively presentation on the use of various communication skills. His presentation was the climax of the day as he broke out into song to illustrate some of his points. Many of the participants said that they had learned much from his alternative method of presentation and would try some of the methods themselves. The feedback from the various groups at both locations will be summarised to highlight the necessity of planning further training workshops of this kind in future.

5. Comments from the Participants

After the presentations of the lectures, the participants had discussions in small groups on relevant topics but also addressing the following four questions:-

1. How can communication be improved?

2. Maps, are they useful or not?

3. What other weather information will be useful to farmers in you area?

4. What additional agricultural information is needed?

See appendices IX & X for list of participants at each seminar.

5.1 Dissemination and communication of seasonal climate forecasts

- The participants suggested that one of the most effective ways of disseminating seasonal climate forecasts would be through the internet although they conceded that not many users had access to the internet. However, extension officers would play a major role in redistribution the seasonal climate forecasts to all clients.
- The participants indicated that at one point seasonal climate forecasts information was posted to some officers and the practice worked well in the past but had been stopped due to budget constraints.
- The participants suggested that seasonal climate forecast information can be saved on diskettes which should be placed at a central research centre like Glen in the Free State. Several extension officers who visit Glen on a regular basis and could make a copy of the diskette and re-distribute in the regions.

5.2 Format of seasonal climate forecasts information

- The participants indicated that the seasonal climate forecast information should contain information relating to specific districts as well as information on the trends of climate for the rest of South Africa.
- The participants indicated that along with seasonal climate forecasts information, there should be information on planting dates for maize, wheat, vegetables and other food and commercial crops.
- The participants suggested that the bulletin should also contain information on the estimation of market prices during different months of the year for planning purposes.
- The participants also suggested that there should be information for farmeres on average rainfall/temperatures together with forecasts.
- With regard to the terminology, the participants indicated that the seasonal climate forecast in its current state was very difficult to understand and therefore could not be used, as the terms are too scientific and not understood by the general public.
- The participants indicated that the seasonal climate forecast information was obtained too late to be applied in the planning of agricultural activities.
- The participants further suggested that there should be experts available to advise farmers or users in distress with regard to late rainfall, floods, extreme cold or snowfall.
- There should also be information on appropriate varieties of seed to be grown in particular areas or regions especially those areas prone to drought.

- Further information on appropriate fertiliser types and amounts for particular soil types in various areas or regions especially those prone to drought should be available.

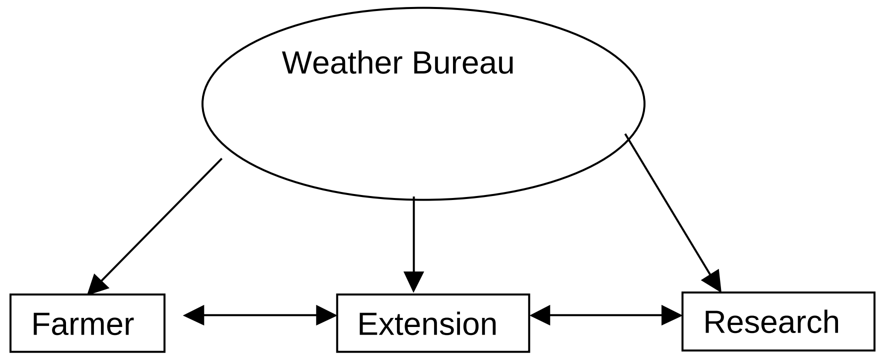


Figure 1 Stakeholders in the operational climate information process

- There is need for collaborative work between all the stakeholders, including the Weather Bureau, Farmers, Extension Officers and Researchers so that appropriate advice can be provided which takes into account both the agronomic and meteorological aspects of production as depicted in the diagram above.
- The use of radio broadcasts to communicate seasonal climate forecasts should be explored, as maximum benefit is not being achieved at the moment.
- The use of computer technology could be improved by further publicizing the location of the WebSite where this information can be found.
- There is need to explore how various agricultural related magazines and newsletters can be used e.g. Farmers Weekly, The Farmer Magazine etc.
- The maps used to present seasonal climate forecasts are extremely effective in communicating information, however the maps presented are not very clear. There is a lot of technical language that is used and this complicates matters and ultimately the information is not understood by all, therefore the present maps need to be simplified.
- The probability concept needs to be explained in detail so that all the users are familiar with the terms and concepts.
- The participants indicated that seasonal climate forecast information should be on a regionally basis.
- There should be better understanding between the South Africa Weather Bureau and the farmers, the seasonal climate forecast information should be made available well in advance so that it can be used for proper planning process for vegetables e.g. Spinach.
- They should give more information on crops other than maize and wheat like spinach etc.
- As a farmer I don't understand why they don't bring back synoptic charts and the time taken for weather forecast presentation on TV must be extended.
- It appears the information is tailored to suit only commercial farmers and small-scale farmers were not considered.
- Continuous training for users should be conducted to equip them.

5.3 Other variables to be included in the forecasts

- Evaporation figures for use in irrigation scheduling by farmers
- Long term maximum temperatures for specific places
- Long term rainfall for particular areas
- Long term first or last frost days
- Current scenarios of El Nino/La Nina

5.4 Further information on the following topics could be to be included in the forecasts

- Wheat Yellow Rust correlations.
- Sheep shearing.
- Fodder making.
- Harvesting risks.
- Scheduling for irrigation.
- Transplanting of sensitive crops.

5.5 Evaluation of the presentations

The presentation on seasonal climate forecasting was highly scientific and too technical for people without meteorological training to understand

6 General Conclusions for Training Seminars

Following the identification of a communication gap between the providers of seasonal forecasts and the users, it was decided to conduct training seminars. The one-day seminars were conducted in both of the sub-regions of the Free State Department of Agriculture, namely in Bethlehem and in Bloemfontein. Extension staff, researchers and some farmers attended the training, which was conducted in English. The printed handout materials were distributed in English and Sesotho to assist the extensionists with the transfer of information to the farmers in their mother tongue. A total of 76 people attended the two training days held during October 2000.

It appears that the detailed explanation of ENSO was too complicated for the audience, however, probably if it is repeated each year they will soon pick up the important points. The use of technical language also hindered the communication, although the use of coloured maps and diagrammes helped the participants to visualize the transformations. The application of the seasonal outlooks for rain and temperature to the production of the summer crops was well received. The extension staff was able to grasp the effect of the various ENSO phases on the maize production, as it is a practical application with which they are familiar. This will enable them to transfer the various recommendations more easily to the farmers.

The seminar on communication techniques was very well received. The participants felt that they had learnt some new techniques that they could easily implement in their own work. Some of the principles of communication may not have been new to them, however, the methods and ideas given provided a new approach to technology transfer.

Overall the training seminars were a great success in many ways – attendance by extension and research staff together with some key farmers. The seminars enabled them to gain insight into the meteorological and statistical terminology used. Particularly the concepts of normal rainfall and probability as related to examples from other walks of life (eg. Lotto). The specific application of the generalized seasonal outlook to maize the predominant summer dry and crop provided a more practical aspect of the seasonal forecast.

It is recommended that these type of training sessions should be conducted each year to disseminate the seasonal forecast or outlook. Thus overtime the participants will build up a better understanding of the concepts and usefulness of the outlook. These training seminars should also be extended to other areas – particularly in the Northern Cape and North-West Provinces where the risk of drought is large and the outlook could provide much assistance each year. Then the actual application of the particular years outlook for that area could be explained in detail together with the options from which the farmers could choose.

Part C: Future Climate Scenario Development for Crop Growth Modeling

Chapter 1: Introduction and Literature Review

1.1 Introduction

Climate and especially rainfall outlooks are increasingly used in agriculture and other related industries in the decision making process. Due to the chaotic nature and therefore unpredictability of weather systems, most seasonal outlooks are of a probabilistic nature using climate statistics (historic data) and not models describing physical processes. Schulze (1989) blames poor predictability of seasonal climate outlooks on the lack of understanding of physical processes. Only in the last decade, scientists are able to treat the ocean and atmosphere as a continuum by realizing the interactions between the components (Allan, Lindesay & Parker, 1996) but were now able for the first time to use powerful computer hard and software to handle the complexity of the system. Currently scientists are able to model and integrate inputs from different components into a more comprehensive system with some success.

1.2. Indices most commonly used for seasonal forecasting

1.2.1 ENSO and Indian Ocean temperatures

In search of periodicities in climate as indicators of seasonal variability, Mitchell (1964) stated that "the atmosphere is essentially a thermally active fluid in motion". Kinetic energy is derived from a conversion of potential energy, mainly produced by differential solar heating of the surface of the earth. In fact, the general circulation is driven by temperature differences caused by unevenly heating of the surface and overlying atmosphere (Partridge, 1994). Schulze (1989) hypothesized that pure physical models will never overcome a two week forecasting limit and that the only viable options are statistical forecasting variables like deviations from climatological means over space and time and secondly the use of slow physical processes in the atmosphere like the ENSO-phenomenon. A combination of the two methods is used by Stone, Hammer & Marcussen (1996) when using the Southern Oscillation Index (SOI) as indicator of sea surface temperatures (SST) in the Pacific Ocean and statistically relating it to rainfall by means of the SOI- phases concept. Figure 1 shows the monthly average SOI since 1900. Appendix XI gives a complete data set since 1876 of monthly average SOI values as well as the phases according to Stone *et al*. (1996).

Stone *et al*. (1996) distinguished 5 phases of the SOI according to the change of the SOI from one month to the next. The five phases are:
Constantly negative phase (Phase 1),
Constantly positive phase (Phase 2)

Rapidly falling phase (Phase 3)
Rapidly rising phase (Phase 4)
Neutral phase (Phase 5).

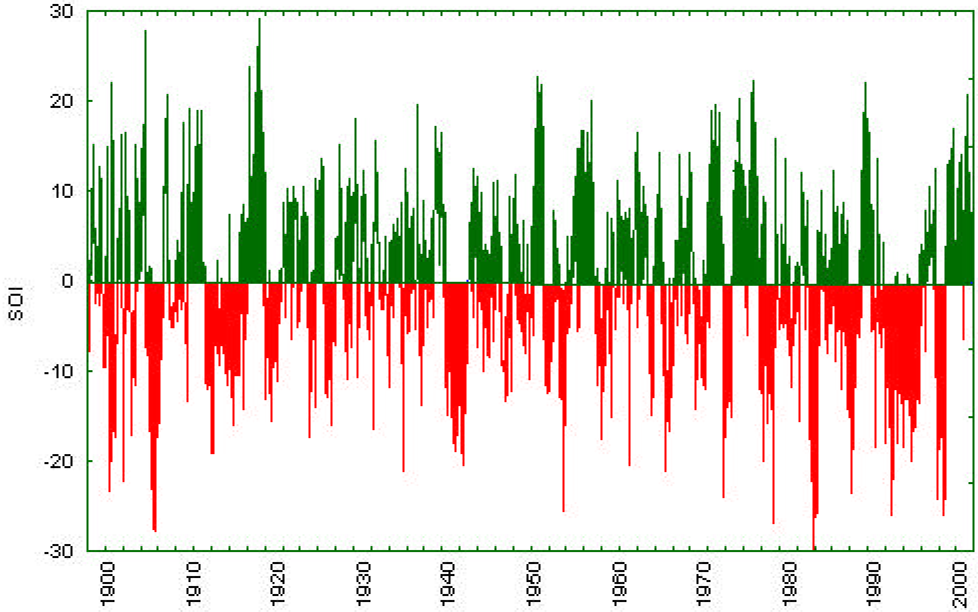


Figure 1 Monthly average SOI for the period 1 January 1900 to 30 April 2001

Using the SOI, the probability of exceeding or not-exceeding a specific amount of rainfall for lead times of one to six months is a method used by Stone *et al*. (1996) and Van den Berg (2000). Landman, Mason, Tyson, & Tennant (2000) however used physically based models to predict global sea surface temperature fields (equatorial Pacific and Indian Ocean) for use as boundary forcing. These SST-fields are then used in forecasting of rainfall.

1.2.2 Pacific Decadal Oscillation (PDO) or Interdecadal Pacific Oscillation (IPO)

Power, Casey, Folland, Colman & Mehta (1999) describes the PDO as the change in SST's in the Pacific Basin or Northern Pacific. Mantua, Hare, Zhang, Wallace & Francis (1997) schematically describe the PDO in Figure 2.

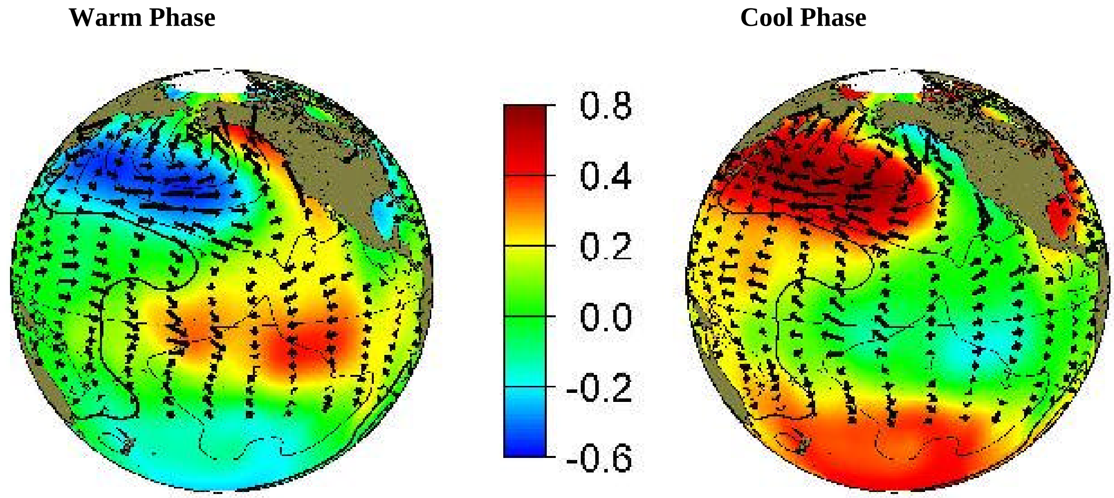


Figure 2. Typical wintertime Sea Surface Temperature (colours), Sea Level Pressure (contours) and surface wind stress (arrows) anomaly patterns during warm and cool phases of PDO (Mantua et al., 1997)

The term "decadal" is used to refer to variability that remains in the data record once periods less than or equal to 8 years have been eliminated, using a filtering method (Power *et al*., 1999b). Power *et al*. (1999a & b) claim that when the PDO raises temperatures in the tropical Pacific Ocean, there is no relationship between year-to-year Australian climate variations and ENSO. The opposite is also found that lower temperatures in the same region resulted in high correlations between year-to-year ENSO-variability and rainfall variability. PDO values are derived from different methods but the method using SST's dated back to 1856. Power *et al* (1999a) found that when the IPO is negative, the seasonal predictability of Australian rainfall deviations is significantly enhanced. Mantua & Hare (2000) graphically provides monthly average values of the PDO for the period January 1900 - July 2000 (Figure 3). The monthly average PDO values for the period since 1900, is included in Appendix XII.

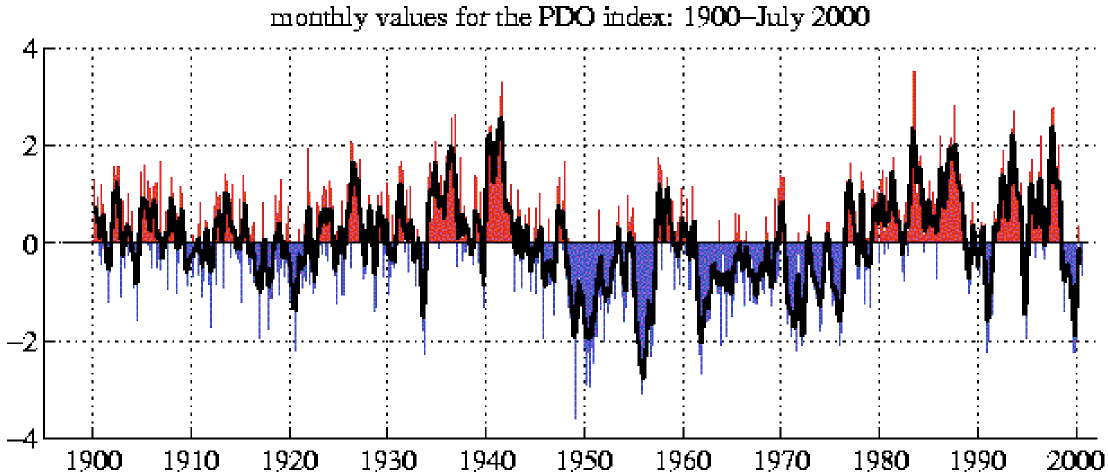


Figure 3 Monthly values of the PDO for the period January 1900 – July 2000 ((Mantua & Hare, 2000)

Power *et al* (1999a) concluded that the contrast in the influence of ENSO between the two phases of the PDO is "quite remarkable" and it opens new avenues to improve climate predictions.

1.2.3 Multi seasonal cycles

Tyson & Dyer cycle

Tyson & Dyer (1978) identified a 16 to 18 year rainfall cycle over the Summer Rainfall Area of South Africa, using a filtering method. The cycle consists of 8 to 9 drier and 8 to 9 wetter years (Appendix XIII). Due to uncertainty about specific seasons (whether it will be wetter or drier in a specific season) it has limited use for agricultural purposes.

1.2.4 Rainfall analogue years

Du Toit (2001, personal communication) used a least square deviation rainfall method to identify two analogue years and train the current rainfall year according to the daily rainfall of these two specified years.

1.3 Use of Seasonal Climate Outlooks

1.3.1 Agricultural production and climate outlooks

Although rainfall is the most important factor in non-irrigation farming, rainfall amount and agricultural production is not highly correlated. Timing of rainfall is often more important as is indicated by the daily time step used in most crop growth models ((Jones, Kiniry, Farmer, Dyke, Godwin, Parker, Ritchie & Spanel, 1986) PUTU-MAIZE (De Jager, 1988) and EPIC (Dumesnil, date unknown). This fact is stressed by De Bruin & Human (1976) where sensitivity of a maize crop to water stress indicates that yield losses of up to 10% per day is possible under severe stress conditions. Already in 1982, Steward & Hash (1982) introduced a mechanism to identify specific seasons according to water adequacy and timing for maize production in Kenya. Three seasons were identified relating onset of the rainy season termed; “early” (implies expectation of high to medium water adequacy), “late” (medium to low expectation) and “too late” to recommend planting. Steward (1990) visited South Africa to introduce the concept of “response farming” with two main principles: Firstly: Risk assessment (estimate potential levels of crop performance associated with different predicted levels of rainfall parameters) and secondly: Risk avoidance and risk minimization. Steward (1990) initially designed response farming as a tool to mitigate the effect of drought and ensure food security. With the introduction of free market trading systems of agricultural products in South Africa, crop estimates became a third important factor depending on climate of a specific season. Mclelland (1994) as well as Du Pisani, Erasmus & Koch (date unknown) identified periods (7-14 or more days) of low rainfall probability (midsummer drought) that coincided with very susceptible growth stages of the maize crop. In order to prevent these periods coinciding with each other, more accurate forecasts of dry and wet spells are necessary to stabilise maize production yields.

Outlooks currently provided and used are only probabilistic of nature and the smallest time steps provided commercially, are one to three months. The effect of other climate elements e.g. temperature, wind, sunshine, etc. and not only rainfall can also affect the agricultural production. By introducing crop growth models (CGM), the soil-plant-atmosphere system is integrated to give an indication of the agricultural condition e.g. the yield potential at a specific growth stage. In order to satisfy this need using the modeling approach, it is therefore necessary to complete a season with daily climate data (using climate forecasts). The end result is a need for a climate outlook that provides daily time steps of weather data up to six months or more in advance to be able to complete the growth cycle of a crop in the model.

1.3.2 Analogue years

It is evident that climate and especially rainfall outlooks for periods longer than two weeks, are problematic. Adding the input frequency requirements of CGMs (daily), no current system can provide information for more specific agricultural decision-making. De Jager (1988) used a rainfall generator to generate site-specific daily rainfall data but it is not able to provide information for a specific season. In order to provide specific season climate data, De Jager, Potgieter and Van den Berg (1998) introduced a system of identifying analogue years from history, using the SOI-phases concept. Stone (Personal communication, 1995) also introduced the analogue year system as the only viable option to identify and characterize specific seasons in terms of real daily climate input values.

Analogue rainfall years are assumed to have more or less the same rainfall distribution and amount as is expected for the current or for a specific season to be forecasted. De Jager *et al.* (1998) used three analogue years after ranking seasonal rainfall totals (25, 50 and 75 percentile years). Daily radiation and temperature data from the three identified years (according to rainfall) are used for the simulation process. The three analogue years are used separately as input for simulations. Simulated yield values of the three runs are then averaged to give a most probable yield for a specific season. Du Toit (2000, personal communication) also used an analogue approach by identifying the two closest analogue years (from all years) and positioning the current or forecasted period according to rainfall already received.

The objective of this study is to develop daily climate scenarios for use in crop growth models using the SOI, PDO and Tyson & Dyer cycles in combination with the analogue type of approach to characterize summer growth seasons as reflected in maize production.

The study will be divided into the following modules:

a. Description of the different scenarios
b. Describe and illustrate the SOI-phases-analogue rainfall (SPAR)-model by using one rainfall point and forecasting for one season of each of the five different phases.
c. Describe SPAR-model to simulate yields data for a point.
d. Describe method to compute and compare actual rainfall with rainfall outlooks generated by SOI-phases and SPAR-models for 1995-2000 for the Free State.
d. Describe model to compute and compare simulated yield estimates from actual climate inputs and inputs generated by the SPA and SPAR-models.

Chapter 2: Materials and Methods (Scenario Description)

2.1. Description of Scenarios

2.1.1 Scenario 1: SOI-phases analogue (SPA) model

The SOI-phases analogue model (SPA) is described by De Jager *et al.* (1998).

1. Analogue years or seasons are identified by using SOI-phases (see Appendix XI).
2. Rainfall totals are then calculated for each of the analogue seasons, ranked and the 25, 50 and 75 percentile seasons identified.
3. The pooled rainfall totals of the 25, 50 and 75 percentile seasons are used to compare to the actual rainfall for the season or period.
4. In determining yield estimates, the CGM was run for the 25, 50 and 75 percentile seasons separately, then using the averaged yield as the yield estimate to compare to the actual simulated yields at the end of the season.

2.1.2 Scenario 2. SOI-phases analogue rainfall model (SPAR)

1. Use SOI phases to identify and extract climate data for same type (analogue) years by using one month (e.g. September Phase 1 months).
2. Compute cumulative rainfall from month n-2 to n [July (n-2), August (n-1), September (n)] for all SOI-analogue years as well as month n-2 to n for year to be forecast (current year).
3. Compare cumulative rainfall of SOI-analogue years with year to forecast using least squares difference (LSD) method and compare on a daily time frame to identify rainfall analogue years.
4. Select 3 nearest years according to least squares difference (LSD) method (i.e. smallest difference).
5. Use 3 nearest years as input for climate data (future scenario) as input to the CGM.
6. Simulate yields with climate data for each of the three nearest years separately.

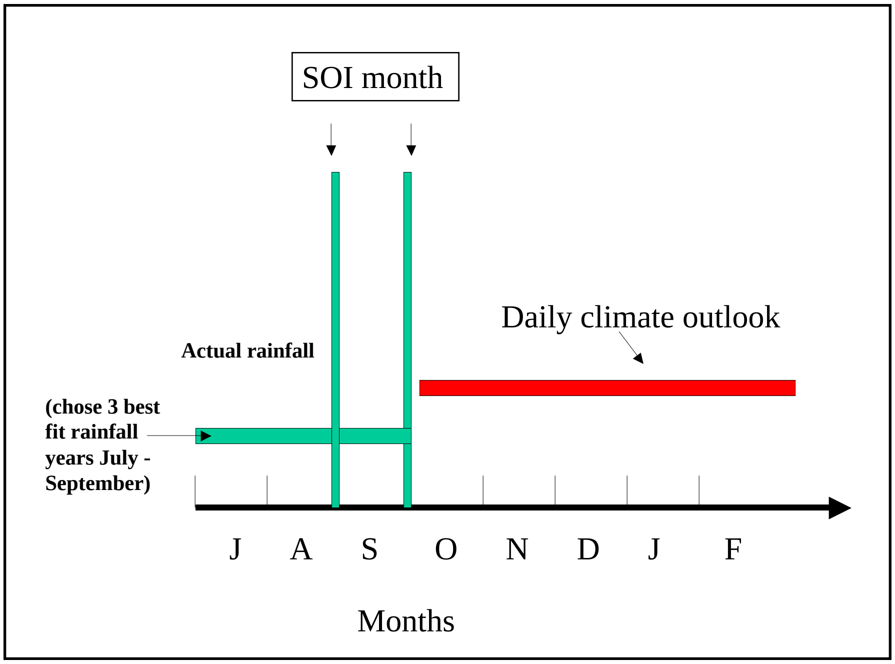


Figure 4 Schematic presentation of scenario 2 using only one SOI month (SPAR-model)

The process of using the SOI-phase year, the "training" or identifying period according to the rainfall of the 3-month period as well as the daily outlook period is illustrated in Figure 4.

2.1.3 Scenario 3. SOI-phases analogue-Pacific Decadal Oscillation (SPA-PDO) model

1. Classify PDO phases into Phase 1 (negative) and Phase 2 (positive) according to Mantua & Hare (2000) (See Appendix XII).
2. Combine SOI and PDO phases e.g. SOI1-PDO1; SOI1-PDO2, etc. and identify analogue years for each paired phases.
3. Select 3 analogue years (25, 50 and 75 percentile year) by ranking seasonal rainfall totals of all analogue years for paired phases.
4. Simulate yields with climate data for three nearest years.

2.2 Point data evaluation SPAR-model

2.2.1 October SOI phases

SOI-analogue years for October are identified in Table 1. The Queensland Department of Primary Industries, Toowoomba, Australia, provides the SOI data set used. Rainfall for the Glen Weather Station: Glen (Lat: 2852 S Lon;2751 E)) was used for the period 1922-2000.

Table 1 Analogue years according to October SOI Phases 1-5 since 1922 (Weather Station: Glen (Lat: 2852 S Lon: 2751 E)) Weather records started in 1922

Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
1923	1922	1925	1929	1926
1932	1924	1941	1930	1927
1939	1928	1944	1934	1931
1940	1935	1947	1948	1933
1946	1938	1963	1950	1936
1951	1942	1981	1952	1937
1965	1943	**1992**	1953	1949
1969	1945		1956	1954
1972	1955		1957	1958
1977	1962		1976	1959
1982	1964		**1986**	1960
1987	1970			1961
1991	1971			1966
1993	1973			1967
1994	1975			1968
	1975			1978
	1983			1979
	1988			1980
	1989			1984
	1996			**1985**

2.2.2 Identifying analogue years

Cumulative rainfall for the September-November period was used as the training period to identify analogue years. The reason for using this period was to accommodate the normal planting date for summer crops at Glen, which is round 1 December. The last date therefore to forecast rainfall for a specific season and still be able to make decisions, is at the end of November. The cumulative rainfall pattern of the September-November period was then compared to the cumulative rainfall pattern of all years within the same phase for a specific month. For example: Cumulative rainfall for the period 1 September – 30 November of 1994 (because October 1994 = SOI phase 1) was compared to the cumulative rainfall for all years in history with October SOI phase 1 (1923, 1932,………..1993). It was done by means of least square errors (LSD), or in other words smallest deviation from the September-November 1994 cumulative rainfall. The LSD-values are then ranked in an ascending order and used to identify analogue years for the period 1 December – 30 March (growing period) by assuming that the best fit analogue years (smallest deviation) for the September-November period will also be the best fit analogue years for the December-March period.

The ranking figures of the September-November period were compared to the ranking figures of the December-March period.

This methodology was repeated for each set of years representing Phases 2, 3, 4 and 5 according to Table 1.

The five years identified to forecast rainfall and yields were:
Phase 1: 1994
Phase 2: 1996
Phase 3: 1992
Phase 4: 1986
Phase 5: 1985

2.2.3 Evaluate SPAR-model with simulated yield data for a point

The CERES-Maize crop growth model (CGM) was used to simulate maize yields for a point, representing the Glen Agricultural Experimental farm near Bloemfontein. Three best fit or best analogue rainfall years according to the LSD-method using the SPAR-method were identified for each of the growing seasons for the period 1980-1997. The average yields of the three analogue years were compared to the actual yields for specific seasons. It was done in attempt to use analogue yields as an indication of what to expect for a specific season in terms of yields. The decision of expected yield according to analogue years in the past is made at the end of November and compared to the actual simulated yield at the end of the season as well as the long term average yields. The hypothesis is that the historic best fit rainfall (LSD) years from the past for a specific Phase of the SOI for a specific season will give a better indication of expected yields than the long term average.

2.3 Geographical evaluation

2.3.1 Evaluating rainfall

Compare actual rainfall with rainfall outlooks generated by SPA-, SPAR- and SPA-PDO models for 1995-2000 for the Free State Province of South Africa

Measured point values of rainfall for the five seasons for the period 1 October – 31 March were interpolated geographically, using the method as is described by De Jager *et al.* (1998). Historic rainfall values were used to determine analogue seasons according to the SPA-, SPAR-and SPA-PDO-models (see scenarios, Materials and Methods). Deviations between actual and expected rainfall according to the SPA-, SPAR- and SPA-PDO-models were geographically determined. Area size or percentage of area deviations was calculated for and grouped into 20% intervals of above and below. The range of between –20% and +20% was assumed to represent a reasonable estimate of actual rainfall totals for the 6-month period.

2.3.2 Evaluating maize yields

Compare simulated yield estimates using actual climate inputs with yield estimates using climate inputs derived from SPA-, SPAR- and SPA-PDO-models

The input components can be grouped into 3 groups (Figure 5): Climate, Soil and Management (plant). Climate consists of daily rainfall, maximum temperature, minimum temperature and a radiation component. Soil physical characteristics are important mainly to determine water holding capacities and water retention. Management is the group of variables that determines the geometry and development stages of the plant. Planting dates, variety, row width, planting density and cultivation are the main crop inputs.

In order to simulate crop yields, it is important to complete a season with daily climate data. As the season progresses, updates of real data is used to substitute “outlook” data. In order to get an estimate of expected crop conditions before the start of the seasonal (to decide on actions before planting), the whole yield estimate is entirely dependent on the outlooks provided. Later in the season, accuracy of yield estimates is improved with the substitution of outlook climate data with actual measured data. It is however too late for decision making and little can be done to alter the initial decisions made before planting. The importance of accurate initial climate outlook data is therefore essential.

Soil depth and soil clay content in GIS-format for the Free State Province is used to derive soil water holding capacities. Cultivation and management practices for maize production will be used according to De Jager *et al*. 1998. The simulation process is schematically presented in Figure 5, describing the different components of the yield and crop estimate process using growth simulation models.

The following seasons were used:
1995/1996
1996/1997
1997/1998
1998/1999
1999/2000

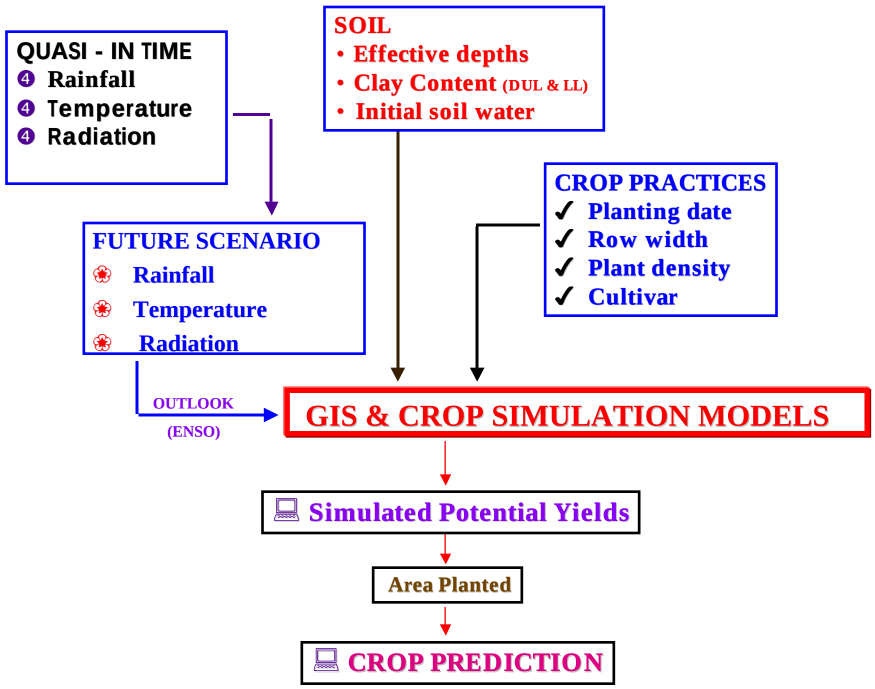


Figure 5 The crop simulation process using crop growth models and GIS-based input data

Step 1: Standard geographical data input sets were used with climate the only variable over time. The same geographical soil depth and clay content, variety, planting date and row width layers were used according to “normal” practices.

Step 2: Yield simulations were geographically executed with actual daily rainfall and associated temperature and radiation data for each of the above seasons for the Free State Province.

Step 3: The SPA- and SPA-PDO-model was used with the SOI phase of September and the SPAR-model with the SOI of September and a training period from 1 July – 30 September in terms of daily rainfall. The process was repeated for each of the 5 seasons

Step 4: Daily climate outlooks derived in Step 3 for each of the five seasons were used as inputs in the simulation process and yields simulated.

Step 5: A weighted average yield is calculated for the Free State according to De Jager *et al*, (1998) and actual simulated yields compared to yields calculated from seasonal climate outlooks.

Step 6: The Free State Province was geographically divided into areas representing specific yields (1000kg/ha intervals). Yield deviations derived from simulated yields of SPA, SPAR- and SPA-PDO climate outlook models and actual climate data were determined geographically.

2.3.3 Testing for significance

2.3.3.1 Skewness:

According to Downie & Heath (1970) is a distribution of measures normal in shape if the sum of cubes of the deviations above the mean is equal to the sum of cubes of deviations below the mean. The total sum of cubes of the deviations will be zero and skewness will also be zero. This test is executed to determine if there is signs of a particular trend of the distribution of frequencies and specifically if there is symmetry in the distribution.

$$\textbf{Skewness} = (\_x^3/N)/(\sqrt{\ }\ \_x^2/N)^3$$

where
x = rainfall or yields
N = the valid number of cases.

The test for skewness provides just a measure of deviation from the mean and in this case the mean is not zero. In this study the interest is in how well the three different models represent the actual rainfall distribution and total. A more useful test is to test for equality of distributions, that is how well is the fit of the distributions of the models in terms of the actual rainfall or yield distribution.

2.3.3.2 Test for equality of multinomial distributions

The test is to determine if the actual rainfall and yields were more or less the same as the simulated values in terms of distributions of rainfall and yield intervals. Mood, Graybill & Boes (1963) proposed a variation of the Chi-square test to test if two distributions are drawn from the same population.

$$Q' = \underset{i=1}{\overset{2}{\_}} \quad \underset{j=1}{\overset{k+1}{\_}} \quad [N_{ij} - n_i(N_{1j} + N_{2j})/(n_1+n_2)]^2 \;/\; n_i(N_{1j}+N_{2j})/(n_1+n_2)$$

2.3.3.3 Model performance

Regression coefficients are widely used to validate predictions made by models. According to Willmott (1981), these coefficients (r and r^2) describe consistent proportional increases or decreases about the respective means of the two variates but there are too few distinctions between the type or magnitudes of possible covariations. In order to circumvent some problems associated with r and r^2, Willmott (1981) proposed an index of agreement (d). The d-value reflects the degree to which the observed value is accurately estimated by the simulated variate. It is a measure of the degree to which the predictions made by the model are error free.

$$d = \frac{1 - [\_(\text{Predicted} - \text{Observed})^2}{\_(|\text{Predicted} - \text{Observed}| + |\text{Observed} - \text{Average observed}|)^2 \;]}$$

Chapter 3: Point Data Evaluation: Spar-Model

3.1 Introduction

This section will illustrate the use of the SOI-phases-analogue rainfall (SPAR)-model by using one rainfall point and forecasting for one season for each of the five different phases. It will also evaluate the SPAR-climate outlook model as input for yield estimation for a point.

3.2 SPAR-model of rainfall outlooks for Glen Experimental Farm

3.2.1 SOI Phase 1 (October)

1994 was selected with October in Phase 1. Normal planting date at Glen is about 1 December. The last date to identify the season is 30 November. The analogue years with October phase 1 are presented in Table 2 column 1. The daily cumulative rainfall for the period 1 September – 30 November 1994 was used to characterize the December 1996 – March 1995-period. The decision which analogue years to be used is taken at the end of November. An example of LSD on the daily cumulative distribution of rainfall is shown in Figure 6 with the best fit and worst fit years for the Sep-Nov period. In Table 2 the least squares deviation or difference of each analogue year (analogue Sep-Nov 1994) can be seen (column 2) ranked in an ascending order (column 3). According to Table 2, the five "best fit" years or least square difference years compared to rainfall for September-November 1994 are 1972, 1965, 1923, 1946 and 1939. The assumption is now that the years 1972, 1965, 1923, 1946 and 1939 will also be the nearest or will give the best fit for the months December 1994 – March 1995.

The LSD for rainfall deviation of analogue years from 1994 is now independently calculated for the December 1994 – March 1995 period and stipulated against the September-November ranking (Table 2, column 4) and also ranked (column 5).

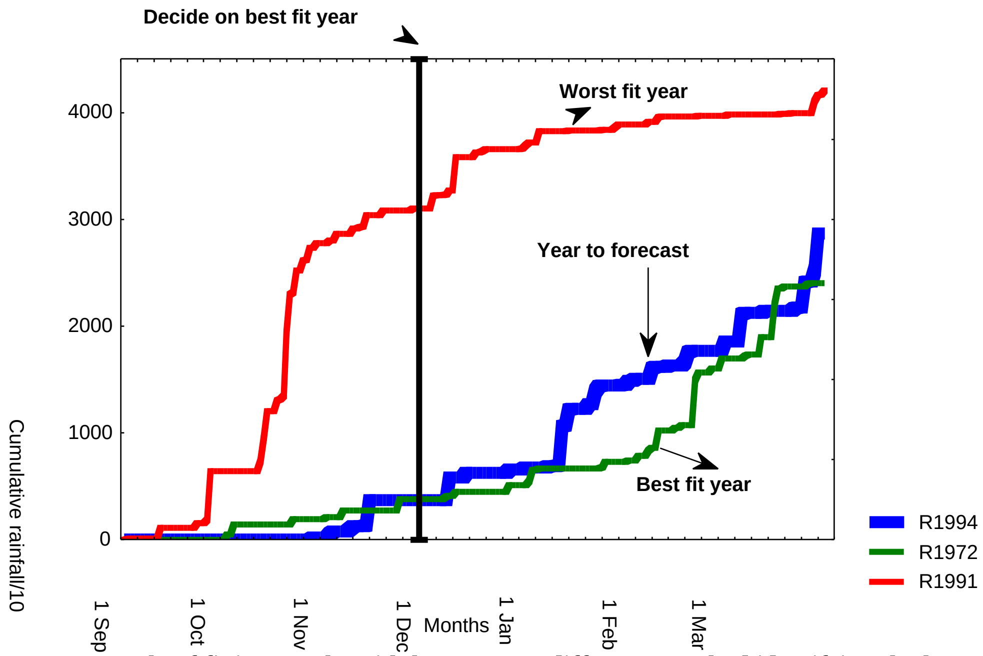


Figure 6 Example of fitting results with least square difference method identifying the best and worst fit years compared to the 1994 year based on the September-November rainfall. The LSD for the rest of the season is also shown indicating the behaviour for the rest of the season.

Table 2 October Phase 1 analogue years, fitting results and ranking of the Sep-Nov and Des-Mar period for Glen weather data

Year	**Mean LSD (Sep-Nov)**	**Rank (Sep-Nov)**	**Mean LSD (Dec-Mar)**	**Rank (Dec-Mar)**
1972	83.2637	1	325.7934	2
1965	124.6923	2	913.9752	7
1923	130.5275	3	789.6446	5
1946	266.0659	4	266.5868	1
1939	436.1319	5	1333.2730	10
1951	459.5165	6	458.3140	3
1932	486.3846	7	742.2314	4
1969	516.8791	8	1073.3800	8
1982	537.4835	9	855.7686	6
1940	623.3626	10	2977.4460	13
1977	692.6484	11	1076.5950	9
1993	989.6813	12	2661.0080	12
1987	1463.1760	13	2977.4460	14
1991	1471.0330	14	3261.2150	11

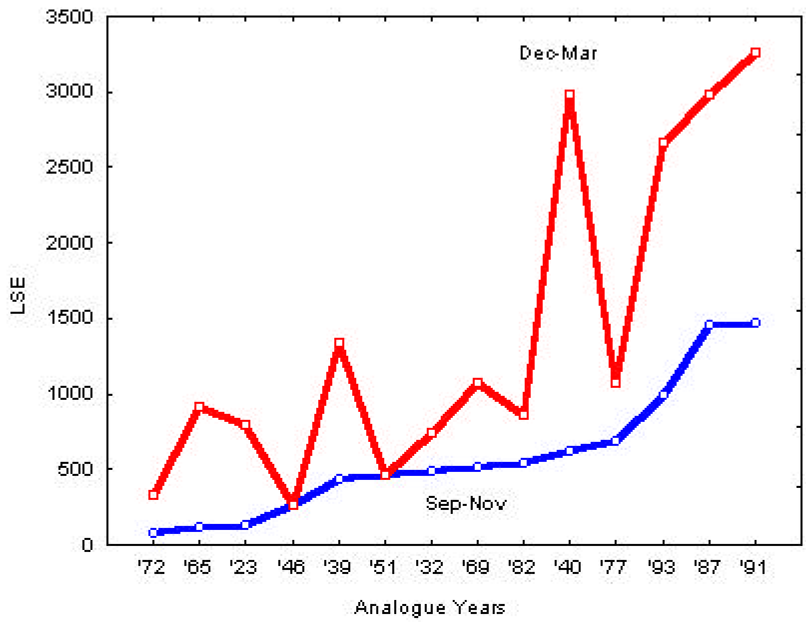


Figure 7 LSD of daily rainfall of SOI analogue years (SOI October Phase 1) from daily rainfall for September-November 1994 in an ascending order (blue line) compared to the LSD for the December 1994 – March 1995 period for rankings based on the LSD for the September-November period

The regression results (Figure 8) show a statistical significant (P = 0.05) correlation of r = 0.84 between the LSD values of September-November and December-March, (n = 14). The implication is that for October SOI-Phase 1, the September-November LSD values is a good indication of the LSD values for the December-March period.

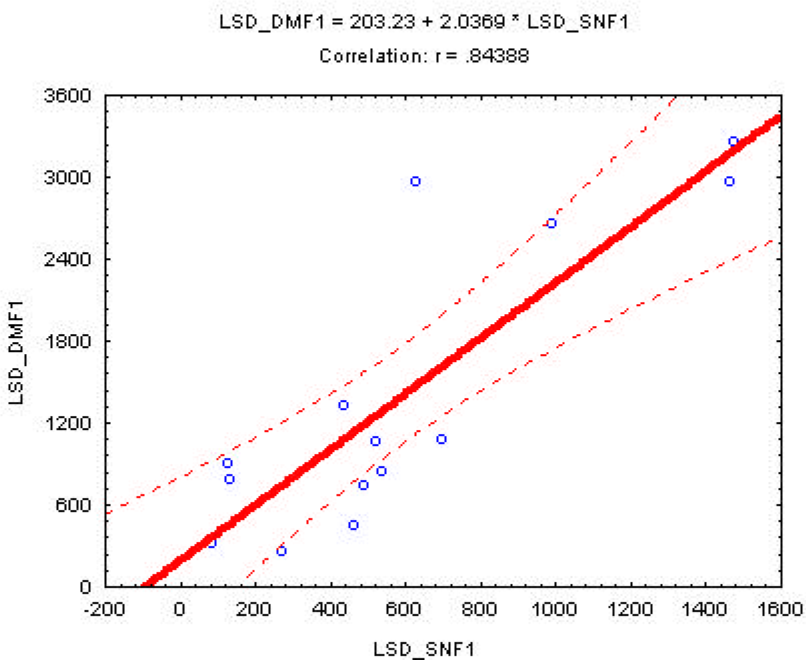


Figure 8 Regression results: LSD of all SOI = October Phase 1 analogue years from 1994/95 for daily rainfall for September-November (LSD_SNF1) vs of daily rainfall for December-March (LSD_DMF1)

3.2.2 SOI phase 2 (October)

Year to test (Example of October Phase 2-years)

1996 was selected with October in Phase 2. The analogue years with October phase 2 are presented in Table 3 column 2. The daily cumulative rainfall for the period 1 September – 30 November is used to characterize the December 1996 – March 1997-period. The decision to determine which analogue years to use is taken at the end of November. In Table 3 the least squares deviation (LSD) of each analogue year for the Sep-Nov 1996 period can be seen (column 2) ranked in an ascending order (column 3). According to Table 3 the five "best fit" years or least square difference years compared to rainfall for September-November 1996 are 1964, 1935, 1973, 1943 and 1942. The assumption is now that the rainfall for the years 1964, 1935, 1973, 1943 and 1942 will also be the nearest or will be the best fit for the months December – March for 1996.

The LSD for rainfall deviation of analogue years from the September-November 1996 daily rainfall situation is now independently calculated for the December-March period and stipulated against the September-November ranking (Table 3, column 4) and also ranked (column 5). Fitting of the best and worst analogue years compared to the 1996-rainfall season can be seen in Figure 9.

Values of ranked LSD (Sep-Nov) are plotted against the independent values of the LSD for the Dec-March period in Figure 10. Regression analysis provided a correlation coefficient of r =0.55 (n = 19).

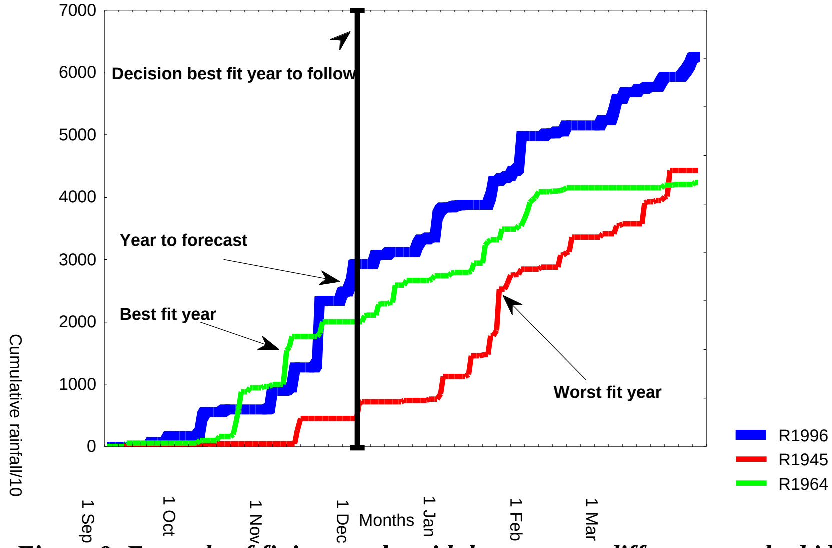


Figure 9 Example of fitting results with least square difference method identifying the best and worst fit years compared to the 1996 year (SOI Phase 2) based on the September-November rainfall. The LSD for the rest of the season is also shown indicating the behaviour of the best and worst fit rainfall year for the rest of the season

Table 3 October Phase 2 analogue years, fitting results and ranking of the Sep-Nov and Des-Mar period for Glen weather data

Year	Mean LSD (Sep-Nov)	Rank (Sep-Nov)	Mean LSD (Dec-Mar)	Rank (Dec-Mar)
1964	283.3846	1	1089.2310	7
1935	293.0110	2	1445.5450	9
1973	296.0549	3	959.0165	6
1943	299.9780	4	270.3636	2
1942	312.6154	5	232.6446	1
1924	348.5165	6	377.1983	4
1922	362.0220	7	1711.4960	13
1962	370.8681	8	1330.2890	8
1970	374.4835	9	1667.5120	12
1989	392.2747	10	1899.2810	15
1975	406.9231	11	586.4132	5
1971	422.8791	12	1574.0830	11
1938	427.7912	13	1943.3060	16
1988	448.1648	14	371.2149	3
1928	465.5824	15	2647.3390	19
1955	476.2308	16	1760.8180	14
1983	484.2747	17	2388.413	18
1974	500.1868	18	1522.281	10
1945	673.8022	19	2129.81	17

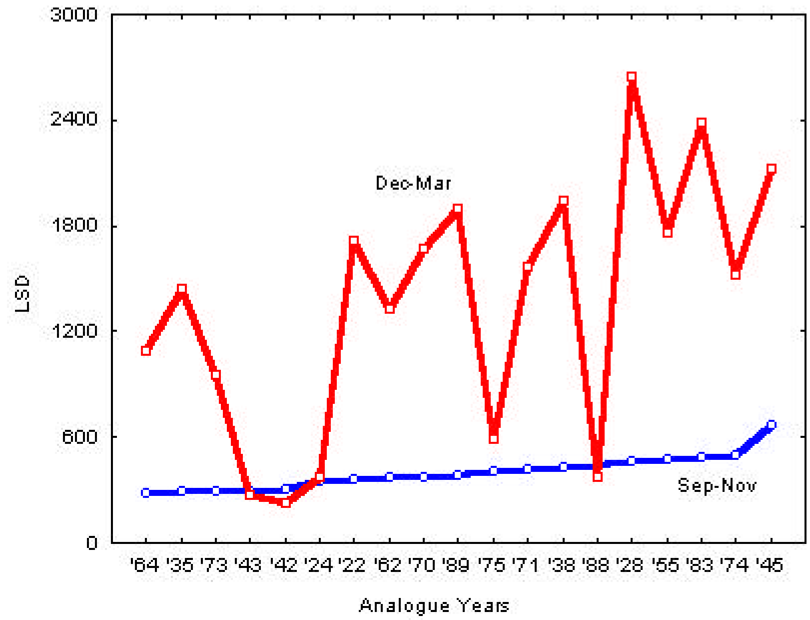


Figure 10 LSD of daily rainfall of SOI analogue years (SOI October Phase 2) from daily rainfall for September-November 1995 in an ascending order (blue line) compared to the LSD for the December 1995 – March 1996 period for rankings based on the LSD for the September-November period

The regression results (Figure 11) show a statistical significant (P = 0.05) correlation of r = 0.55 between die LSD values of September-November and December-March (n = 19). Although not so pronounced as in Phase 1, the positive correlation between LSD values for the two periods in the Phase 2 scenario, support the same trend:

Analogue rainfall years (according to the phase of the SOI in October) chosen for best fit to the daily rainfall for the period September to November, maintains the trend also for the December-March period. In other words: analogue years with a poor performance in Sep-Nov also perform poor in terms of the December-March rainfall.

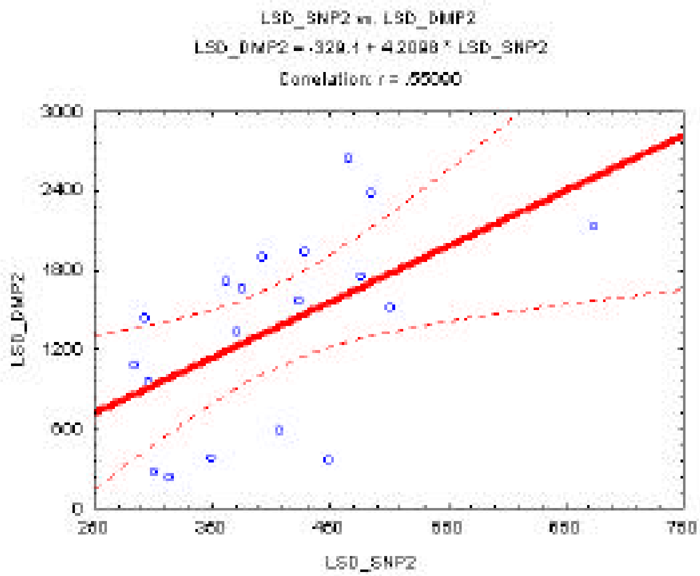


Figure 11 Regression results: LSD of all SOI = October Phase 2 analogue years from 1994/95 for daily rainfall for September-November (LSD_SNP2) vs of daily rainfall for December-March (LSD_DMF2)

3.2.3 SOI Phase 3 (October)

Year to test (Example of October Phase 3-years)

1992 was selected with October in Phase 3. The analogue years with October phase 3 are presented in Table 4, column 1. The years 1963 and 1924 performed the best (least square difference), being the nearest to the daily rainfall of September-November 1992 (Table 4). The same two years were also the nearest to the December 1992 – March 1993 daily rainfall.

Figure 12 presents an example of the LSD fit of all October Phase 3 analogue rainfall years for Glen.

Table 4 October Phase 3 analogue years, fitting results and ranking of the Sep-Nov and Des-Mar period for Glen weather data

Year	Mean LSD (Sep-Nov)	Rank (Sep-Nov)	Mean LSD (Dec-Mar)	Rank (Dec-Mar)
1963	205.5714	1	380.4628	1
1924	254.4066	2	358.7025	2
1941	385.6813	3	1200.8180	6
1981	443.1758	4	718.0165	4
1925	446.9011	5	590.5455	3
1947	448.0000	6	829.4132	5

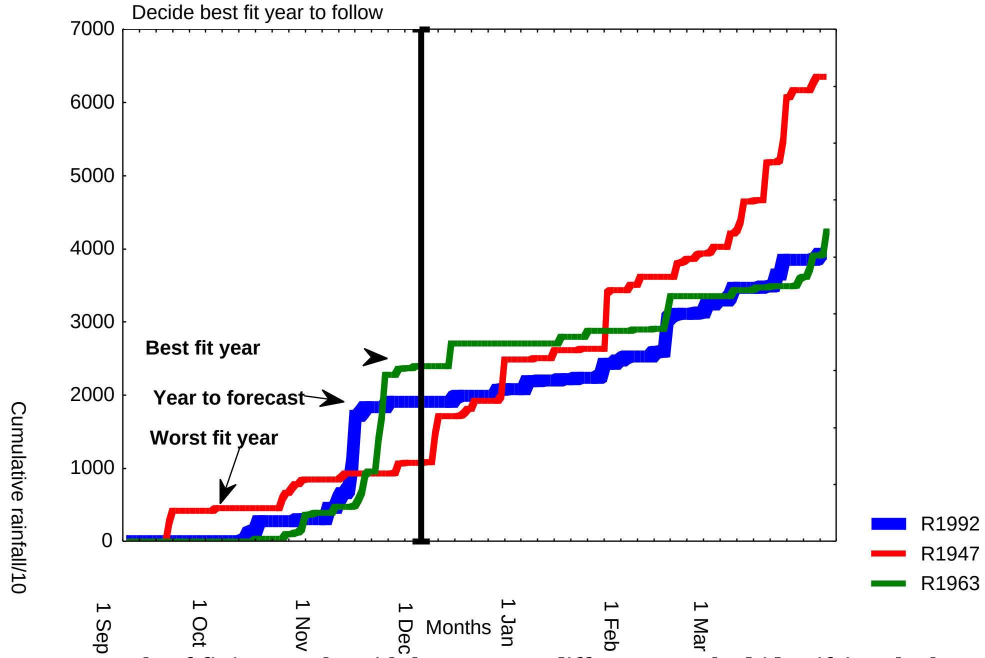


Figure 12 Example of fitting results with least square difference method identifying the best and worst fit years compared to the 1992 year (SOI Phase 3) based on the September-November rainfall. The LSD for the rest of the season is also shown, indicating the behaviour of the best and worst fit rainfall year for the rest of the season

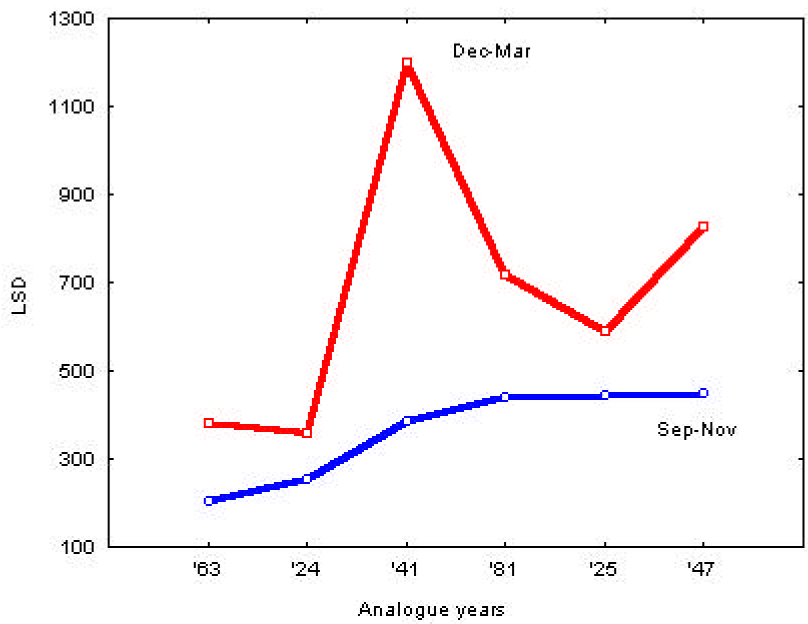


Figure 13 LSD of daily rainfall of SOI analogue years (SOI October Phase 3) from daily rainfall for September-November 1992 in an ascending order (blue line) compared to the LSD for the December 1992 – March 1993 period for rankings based on the LSD for the September-November period

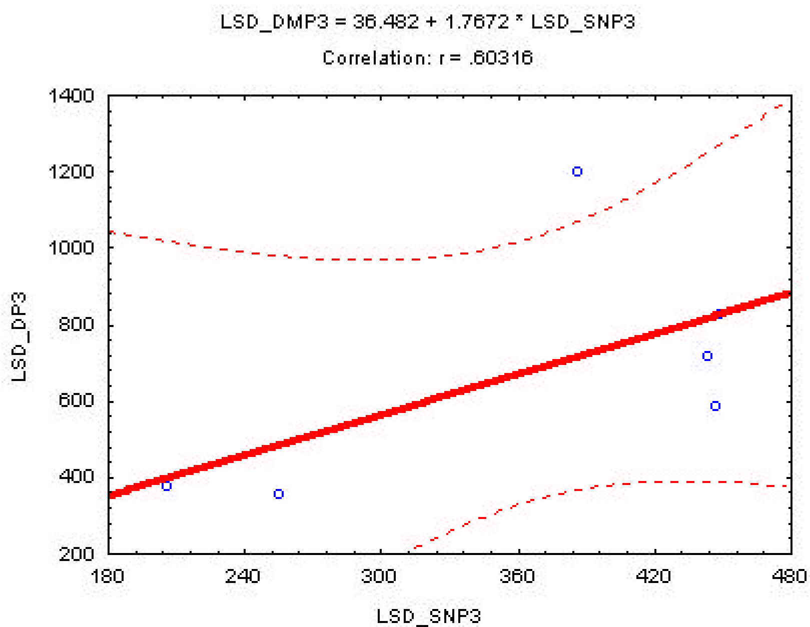


Figure 14 Regression results: LSD of all SOI = October Phase 3 analogue years from 1994/95 for daily rainfall for September-November (LSD_SNP3) vs of daily rainfall for December-March (LSD_DMF3)

Regression analyses for the LSD of October Phase 3 SOI analogue years for the September-November and December-March period for Glen, resulted in a statistical non-significant correlation of r = 0.60 (n = 6). The lack of degrees of freedom with the number of analogue years only six, is responsible for non-significant nature of the relationship. Looking at Figures 13 and 14, it is also evident that there is an outlier, 1941. With exclusion of the LSD of 1941, the correlation improved to 0.9, being statistically significant (P = 0.05).

3.2.4 SOI Phase 4 (October)

1986 was selected with October in Phase 4. The analogue years with October phase 4 are presented in Table 5, column 1. Figure 15 presents an example of the best and least fit analogue years. Comparing the two sets of rankings in Table 5 and Figure 16 and 17, there is some resemblance with a correlation of r = 0.44 (n = 10). Rejection of two outliers (1948 and 1929) provides a significant correlation at P = 0.05, indicating a general lack of a good relationship between the LSD-values of the two data sets.

Table 5 October Phase 4 analogue years, fitting results and ranking of the Sep-Nov and Dec-Mar period for Glen weather data

Year	Mean LSD (Sep-Nov)	Rank (Sep-Nov)	Mean LSD (Dec-Mar)	Rank (Dec-Mar)
1956	260.4835	1	263.8512	2
1952	276.5165	2	529.2562	5
1934	319.7253	3	251.5950	1
1953	325.2747	4	477.1405	4
1976	372.1538	5	954.9008	7
1948	499.7033	6	2028.0330	9
1950	559.1758	7	591.9504	5
1929	565.2198	8	308.2149	3
1957	598.2308	9	856.2645	6
1930	617.8571	10	1244.752	8

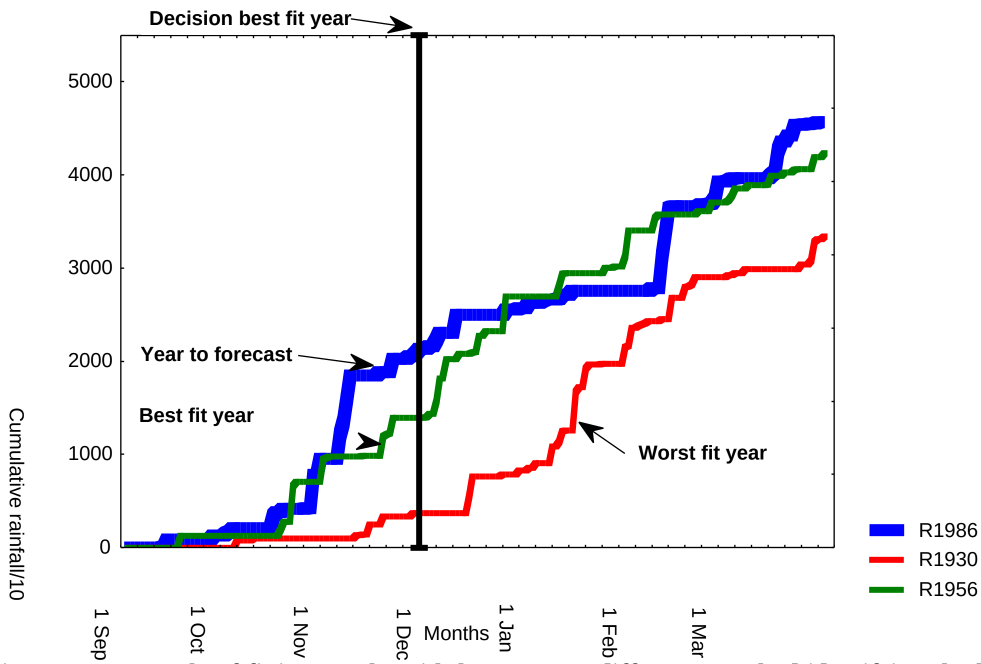


***Figure 15** Example of fitting results with least square difference method identifying the best and worst fit years compared to the 1986 year (SOI Phase 4) based on the September-November rainfall. The LSD for the rest of the season is also shown, indicating the behaviour of the best and worst fit rainfall year for the rest of the season*

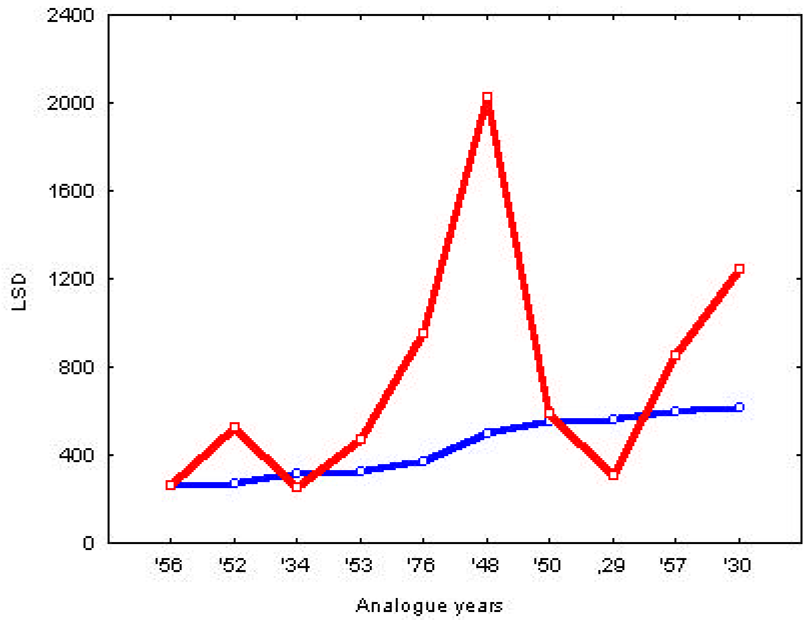


Figure 16 LSD of daily rainfall of SOI analogue years (SOI October Phase 4) from daily rainfall for September-November 1986 in an ascending order (blue line) compared to the LSD for the December 1986 – March 1987 period for rankings based on the LSD for the September-November period

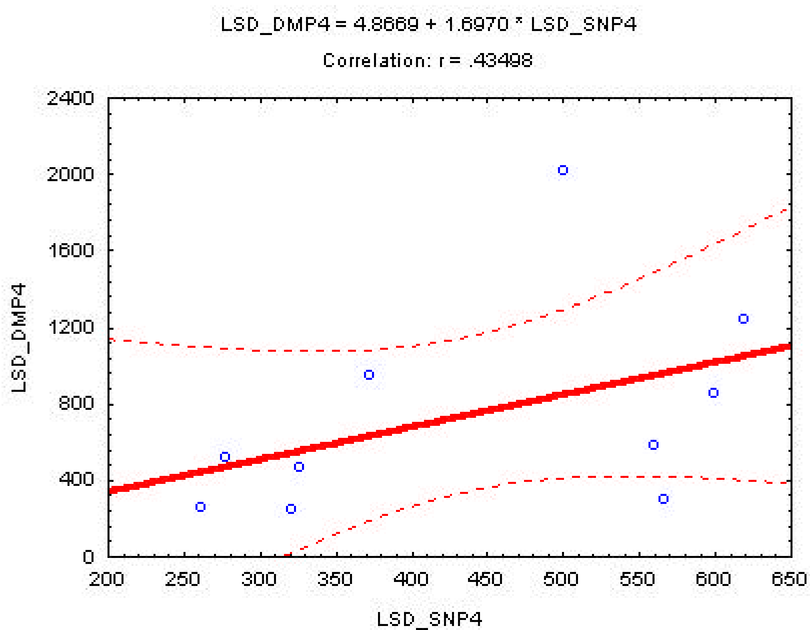


Figure 17 Regression results: LSD of all SOI = October Phase 4 analogue years from 1986/87 for daily rainfall for September-November (LSD_SNP4) vs of daily rainfall for December-March (LSD_DMP4)

3.2.5 SOI Phase 5 (October)

1985 was selected with October in Phase 5. The analogue years with October phase 5 are presented in Table 6, column 1. SOI Phase 5 is per definition the neutral phase of the

SOI. The LSD-values of analogue years for the December-March period (Figure 18, blue line) does seem to follow the same trend as the LSD-values of the September-November period (Figure 18, red line). It is also evident looking at the comparative rankings for the two periods according to Table 6. The regression analyses (Figure 19) of the LSD-values for the analogue years for the September-November and December-March period, resulted in a very low and non-significant correlation of r = 0.29 (n = 17). Rejection of any combination of one or two "outliers" also does not improve the correlation to statistical significance (P = 0.05).

Table 6 October Phase 5 analogue years, fitting results and ranking of the Sep-Nov and Des-Mar period for Glen weather data 1985

Year	Mean LSD (Sep-Nov)	Rank (Sep-Nov)	Mean LSD (Dec-Mar)	Rank (Dec-Mar)
1959	137.33	1	915.42	15
1931	165.68	2	598.98	10
1936	178.97	3	751.66	13
1979	213.09	4	683.80	11
1958	214.76	5	406.30	3
1967	242.79	6	460.40	6
1949	260.01	7	536.40	9
1960	265.04	8	451.99	5
1933	280.32	9	1211.27	16
1968	311.38	10	412.68	4
1966	321.10	11	694.43	12
1937	333.21	12	465.47	7
1954	342.38	13	830.00	14
1927	361.62	14	398.30	2
1978	366.41	15	514.74	8
1961	393.73	16	394.06	1
1980	460.87	17	2041.84	17

Pooling the values of the five examples of years as is discussed above resulted in a significant correlation (r = 0.67, Figure 20) between the LSD values of the September-November and the LSD of December-March. Removing two outliers still resulted in a correlation of r = 0.54.

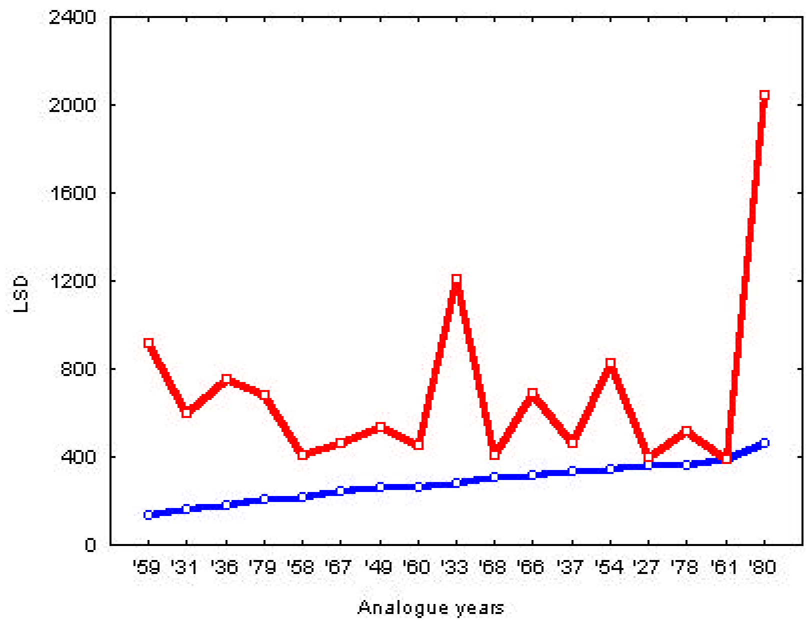


Figure 18 LSD of daily rainfall of SOI analogue years (SOI October Phase 5) from daily rainfall for September-November 1985 in an ascending order (blue line) compared to the LSD for the December 1985 – March 1986 period for rankings based on the LSD for the September-November period

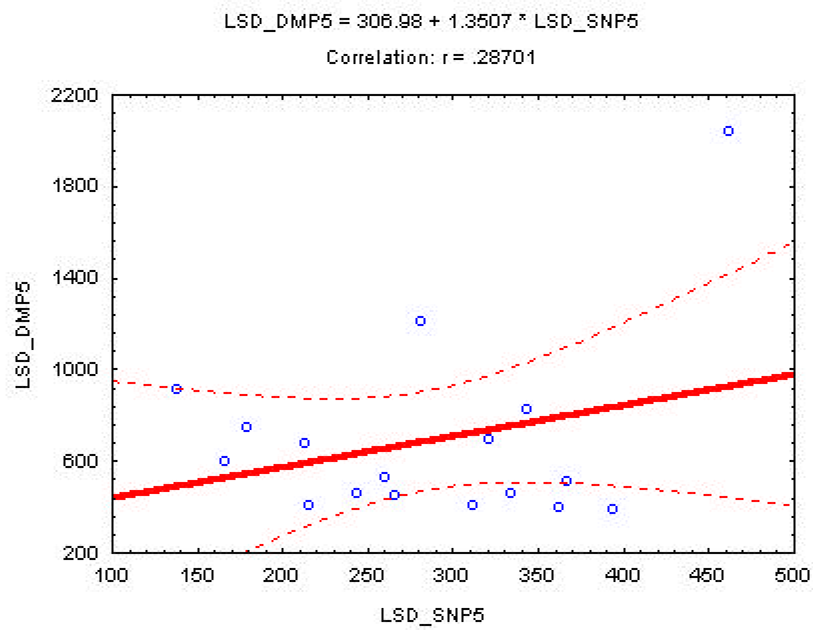


Figure 19 Regression results: LSD of all SOI = October Phase 5 analogue years from 1985/86 for daily rainfall for September-November (LSD_SNP5) vs of daily rainfall for December-March (LSD_DMP5)

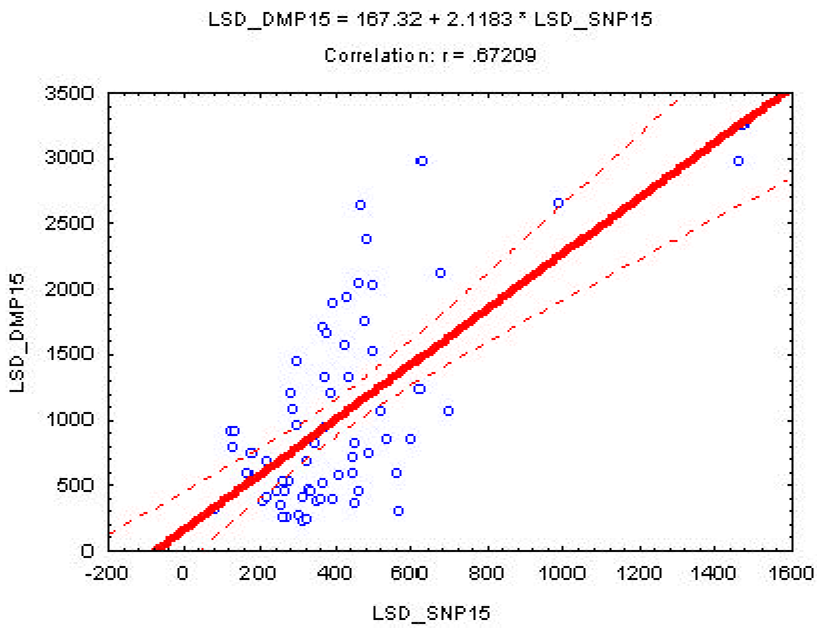


Figure 20 Regression results: LSD of SOI = October All Phase analogue years for daily rainfall for September-November (LSD_SNP15) vs of daily rainfall for December-March (LSD_DMP15) for the five examples discussed

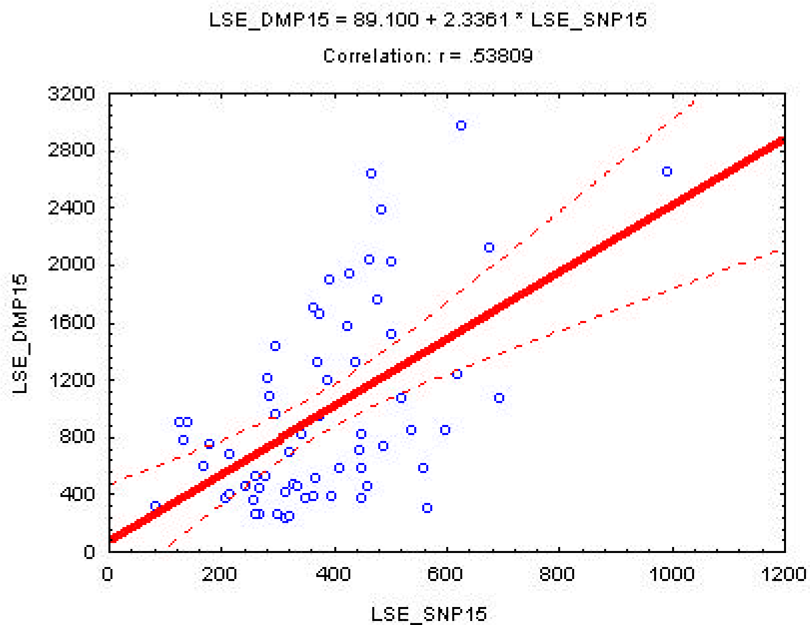


Figure 21 Regression results:LSD of SOI = October All Phase analogue years for daily rainfall for September-November (LSD_SNP15) vs of daily rainfall for December-March (LSD_DMP15) for the five examples discussed (two extreme values rejected)

3.2.6 Discussion

Taking the five examples for the Glen weather data into account, some skill is present in the LSD values of the preseason (September-November) with regards to the LSD values of the growing season (December-March).

Of importance however is the fact that there seem to be more skill in SOI Phase 1 (El Niño and Phase 2 (La Niña) than the neutral (Phase 5) and intermediate phases (Phases 3 and 4).

3.3 Evaluate simulated yields using SPAR-model of climate outlooks with simulated yields using actual climate data for a point

Yields were simulated using historic climate data for the Glen weather station with standard inputs for soil and management (already discussed under material and methods).

3.3.1 Yield estimates (actual climate data)

The CERES-Maize crop growth model is used to simulate yields for the same site (Glen) for the period 1915 – 2001.

Table 7 Simulated yields for Glen Experimental Farm, Bloemfontein, Free State Province, RSA, using CERES-MAIZE crop growth model with historic daily climate data and standard or normal management inputs for the area

Year (harvest)	Yield (kg/ha)	Year (harvest)	Yield (kg/ha)	Year (harvest)	Yield (kg/ha)
1915	554	1945	1982	1975	1254
1916	269	1946	2390	1976	2320
1917	2346	1947	488	1977	2467
1918	1051	1948	2764	1978	1170
1919	1302	1949	1001	1979	975
1920	2304	1950	1708	1980	1456
1921	1128	1951	959	1981	2433
1922	365	1952	1267	1982	2345
1923	2335	1953	1261	1983	1468
1924	2756	1954	2220	1984	589
1925	2397	1955	1619	1985	1739
1926	1355	1956	1906	1986	1128
1927	460	1957	852	1987	162
1928	1265	1958	1221	1988	457
1929	384	1959	1179	1989	2285
1930	935	1960	1847	1990	2761
1931	1471	1961	1017	1991	1282
1932	2588	1962	1742	1992	396
1933	196	1963	1016	1993	1080
1934	922	1964	1120	1994	1978
1935	1275	1965	599	1995	457
1936	2563	1966	1581	1996	3056
1937	1598	1967	3532	1997	923
1938	986	1968	962	1998	1450
1939	1016	1969	838	1999	767
1940	1582	1970	1005	2000	1080
1941	1854	1971	1036	**Average**	**1430.5**
1942	1707	1972	811		
1943	1754	1973	1275		
1944	686	1974	2964		

3.3.2 Use SPAR-model to identify analogue yields

Simulated yields for Glen for the period 1915 till 2000 (Table 7) are used as an indicator of expected yields for a specific season. It was done using the method of least squares deviation from a specific year (year to forecast the yield) in terms of rainfall (SPAR).

To test this hypothesis, yields from 1980-1997 were forecasted using the three best fit analogue yields years (according to the rainfall deviation, using the SPAR-model) before 1980. The estimate of the expected yield according to analogue years in the past is made at the end of November (last day before planting) and compared to the actual simulated yield at the end of the season as well as the long term average yields (Table 8). The three best analogue years (BAY) according to the SPAR-model gives an average yield of 89.2 kg/ha higher than the actual simulated yields (ASY) while the long term average (LTA) yield is on average 13.3 kg/ha lower than the ASY. The standard deviation (SD) is however 879.6 kg/ha for the ASY (in terms of the LTA) and 745.9 kg/ha for the ASY (in terms of the BAY).

The use of the SPAR-model in identifying BAY decreased the SD with more than 15% from 879.6 kg/ha to 745.9 kg/ha compared to the LTA-method of yield estimation.

Table 8 Using simulated yields (CERES-MAIZE) for Glen Experimental Farm, Bloemfontein, Free State Province, RSA, with SPAR-input data to determine the use of analogue yield years as an estimate of yields for a specific season compared to the long term average yield

Year (Plant year)	**Long term average yield (LTA) (kg/ha)**	**Average yield 3 best analogue years (BAY) (kg/ha)**	**Actual simulated yields (ASY) (kg/ha)**	**Deviation of ASY from LTA (kg/ha)**	**Deviation of ASY from BAY (kg/ha)**
1980	1430.5	1890	2433	1002.5	543
1981	1430.5	2034	2345	914.5	311
1982	1430.5	1285	1468	37.5	183
1983	1430.5	1092	589	-841.5	-503
1984	1430.5	1144	1739	308.5	595
1985	1430.5	1214	1128	-302.5	-86
1986	1430.5	1129	162	-1268.5	-967
1987	1430.5	1343	457	-973.5	-886
1988	1430.5	1583	2285	854.5	702
1989	1430.5	1752	2761	1330.5	1009
1990	1430.5	1474	1282	-148.5	-192
1991	1430.5	1343	396	-1034.5	-947
1992	1430.5	1603	1080	-350.5	-523
1993	1430.5	1287	1978	547.5	691
1994	1430.5	1730	457	-973.5	-1273
1995	1430.5	2177	3056	1625.5	879
1996	1430.5	2042	923	-507.5	-1119
1997	1430.5	1474	1450	19.5	-24
Ave	**1430.5**	**1533.1**	**1443.8**	**13.3**	**-89.2**

3.3.3 Discussion

The results show some skill in using analogue years in estimating yields before the planting season. The effect of different soil moisture regimes is not taken into account in estimating analogue yield seasons but will play an important roll in the simulation process. The next step is to use the analogue climate data as model input and to extrapolate it for more than one point, which was the case in this study up till now.

Chapter 4: Results of Different Rainfall Outlook Scenarios

4.1 Introduction

Actual rainfall, interpolated from rainfall point data is assumed to be the actual rainfall that geographically occurred over the Free State Province. Daily rainfall is accumulated for the 6-month period October – March. The accumulated rainfall from the SPA-, SPAR- and SPA-PDO-models for the same period is interpolated similarly and compared geographically with actual rainfall for the seasons 1995/96, 1996/97, 1997/98, 1998/99 and 1999/2000.

4.2 Rainfall for the 1995/96 season

The actual rainfall total for the period 1 October 1995 - 31 March 1996 ranging from less than 200mm in the extreme southwest of the Free State to more than 1000mm in the east (Figure 22a). The rainfall outlook using the phases of the SOI (SPA-model) provided on general lower rainfall amounts (Figure 22b) as is the case with the SOI-phases analogue rainfall (SPAR) model (Figure 22c) and the SOI-Phases-PDO (SPA-PDO) model (Figure 22d).

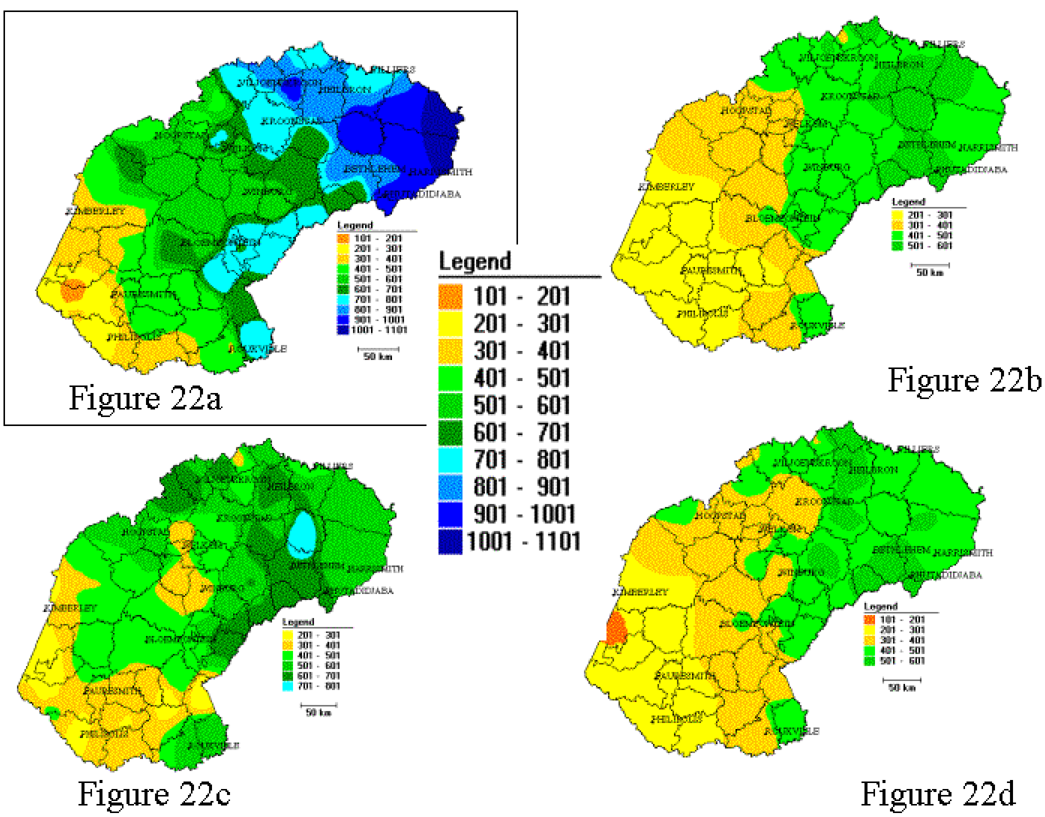


Figure 22 Interpolated rainfall amounts for the 1995/96 season (October – March) for actual rainfall (Figure 22a), rainfall amount outlook provided by the SOI-phases (SPA) model (Figure 22b), the rainfall amount outlook provided by the SOI-phases analogue rainfall (SPAR) model (Figure 22c) and rainfall amount outlook provided by the SPA-PDO-model (Figure 22d)

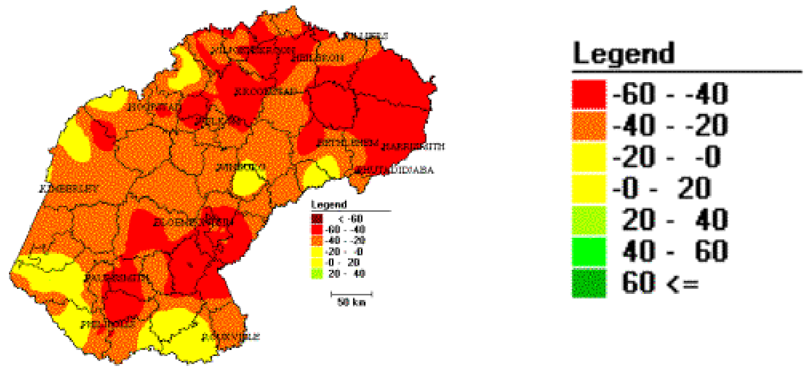


Figure 23a

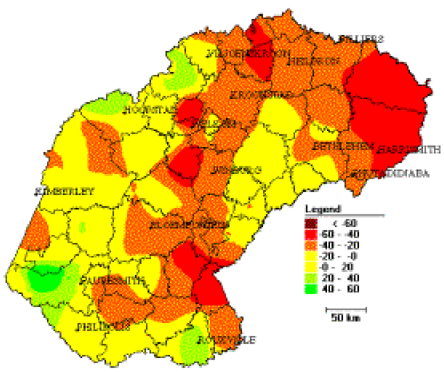


Figure 23b

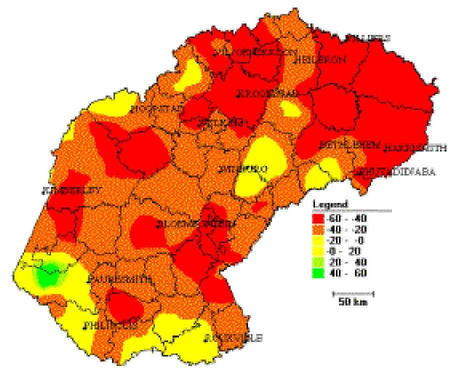


Figure 23c

Figure 23 Percentage deviation of total rainfall: Rainfall outlooks from actual rainfall for 1 October 1995 – 31 March 1996 for the SPA- (Figure 23a), SPAR- (Figure 23b) and SPA-PDO-model (Figure 23c)

The deviation from the actual rainfall is evident in Figures 23a-c where there was on average an underestimation (brown) of the actual rainfall of between 20% and 60%. The SPA-model under estimates the rainfall on (more than 20% under estimation) about 87% of the area of the Free State (Table 9, 34% + 53%), the SPAR-model under estimates the rainfall on about 53% (Table 9, 14% + 39%) of the area of the Free State and the SPA-PDO-model about 85% (Table 9, 39% + 46%) of the area. Only about 13% (11% + 2%) of the area of the Free State estimates the rainfall within the –20% to +20% deviation from actual rainfall (yellow) for the SPA-model while the SPAR-model estimated correctly on about 41% (29% + 12%) and the SPA-PDO-model on only about 14% (12% + 2%) of the area. Only small, localized areas were overestimated (green).

According to Figures 23a-c, the eastern and central parts of the Free State was on general underestimated (brown) while the western to southern parts was on general estimated correctly (yellow) to overestimated (green)

Table 9 Geographical percentage area of the Free State Province covered by different percentage deviations from actual rainfall (SPA-, SPAR- and SPA-PDO-model of seasonal rainfall outlook) for 1995/96.

% deviation from actual	**% area of the Free State**		
	SPA	**SPAR**	**SPA-PDO**
< -40	34	14	39
-20 to -40	53	39	46
0 to -20	**11**	**29**	**12**
0 to +20	**2**	**12**	**2**
+20 to +40	0	5	1
> 40	0	1	0

The bottom line is that the actual rainfall for the 1 October 1995 – 31 March 1996 period was on general better than expected by all three models. The SPAR-model performed the best with about 41% of the area estimated correctly.

4.3 Rainfall for the 1996/97 season:

The actual rainfall amount for 1996/97-season varies between 200mm -300mm in the southwest to small areas in the northeast receiving between 900 and 1000mm for this period (Figure 24a). Rainfall outlooks were also more conservative than the actual rainfall and totals vary between 200mm and 700mm for the SPA-model (Figure 24b) and SPA-PDO-model (Figure 24d) and between 200mm and 900mm for the SPAR-model (Figure 24c).

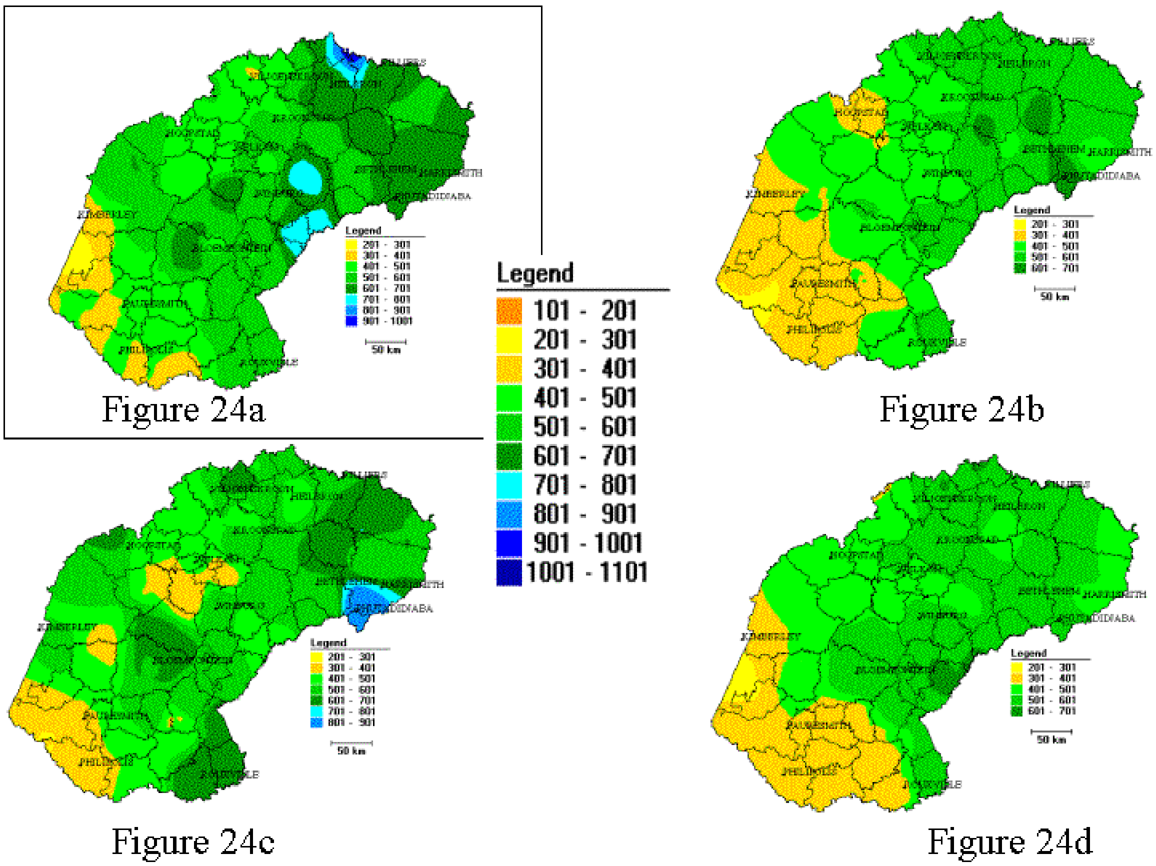


Figure 24 Interpolated rainfall amounts for the 1996/97 season (October – March) for actual rainfall (Fig 24a), rainfall amount outlook provided by the SPA-model (Figure 24b), rainfall amount outlook provided by the SPAR-model (Figure 24c) and rainfall amount outlook provided by the SPA-PDO-model (Figure 24d)

The differences between actual and expected rainfall are much less pronounced than in the 1995/96-season as can be seen in Figures 25a-c. Table 10 gives percentage deviation of the area estimates (SPA-, SPAR- and SPA-PDO-model) for the October-March period.

Table 10 Geographical percentage area of the Free State Province covered by different percentage deviations from actual rainfall (SPA-, SPAR- and SPA-PDO-model of seasonal rainfall outlook) for 1996/97 season

% deviation	**% of area of the Free State**		
	SPA	**SPAR**	**SPA-PDO**
< -40	0	1	0
-20 to -40	29	10	26
0 to -20	**61**	**51**	**58**
0 to +20	**8**	**27**	**14**
+20 to +40	2	9	2
> 40	0	2	0

As can be seen from Table 10, about 69% of the area received within the –20% to +20% range of the actual rainfall for the SPA-model, 78% for the SPAR- and 72% for the SPA-PDO-model. There was an under estimation of rainfall of more than 20% (Figure 25a-c, brown and Table 10) on about 29% of the area of the Free State for the SPA-model, 11% for the SPAR-model and 26% for the SPA-PDO-model.

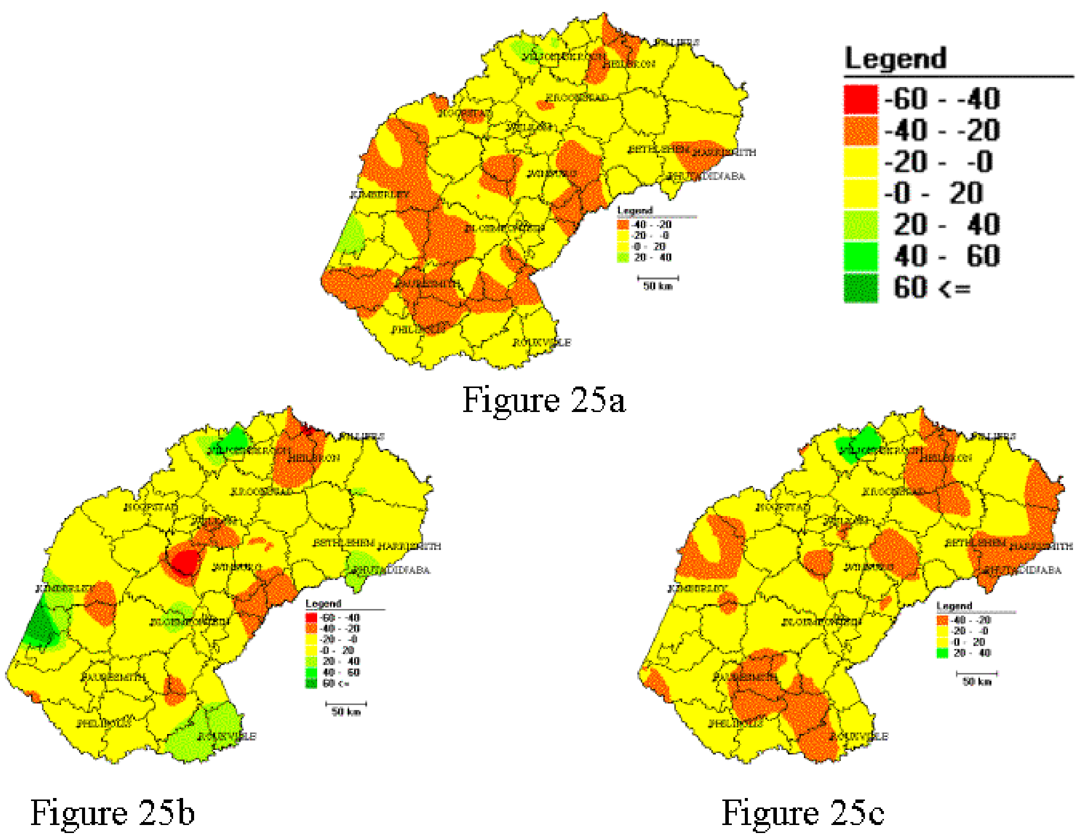


Figure 25 Percentage deviation of total rainfall: Rainfall outlooks from actual rainfall for 1 October 1996 – 31 March 1997 for the SPA- (Figure 25a), SPAR- (Figure 25b) and SPA-PDO-model (Figure 25c)

The SPA-model estimated the rainfall totals correctly (-20% to + 20% deviation range) for about 68% (Figure 25a, yellow) of the area of the Free State for the 1996/97 season, the SPAR-model about 78% correct (Figure 25b, yellow) and the SPA-PDO-model about 72% (Figure 25c, yellow) correct (Table 10). Looking at Figures 25a-c, representing the differences between actual and expected rainfall according to the three models, it can be seen that the deviations outside the -20 to +20% range are isolated areas with little or no trend for a specific area. This can be attributed to localized extreme rainfall events, caused by thunderstorm activity.

According to Table 10, about 29% of the area of the Free State was again underestimated by the SPA-model with the SPAR-model about 10% and the SPA-PDO-model about 26%. Overestimation on about 2% of the area occurred with both the SPA- and SPA-PDO-models while the SPAR-model overestimated the 11% of the area.

The expected rainfall according to the three models was well within the expected range. The SPAR-model was about 10% more accurate in terms of area than the other two models, with a much more even distribution of area for the different categories.

4.4 Rainfall for the 1997/98 season

The actual rainfall totals for the 1997/98 season varies between less than 200mm in the west to a small area in the east receiving more than 800mm (blue area) for the October-March 1997/98 period (Figure 26a). The 1997/98 season was characterized by a very strong El Niño event. All three models provided relative good estimates looking in retrospect. The SPA- (Figure 26b), SPAR- (Figure 26c) and SPA-PDO-model (Figure 27d) gave good estimates of the actual total rainfall for this 6-month period ranging between more or less within the same limits as the actual rainfall totals according to Figure 26a. There is also some geographical resemblance of extreme rainfall events like the areas of more than 600mm (dark green and blue, Figures 26a and 26c) in the eastern Free State, the brown areas of less than 200mm in the west (Figures 26a and 26d).

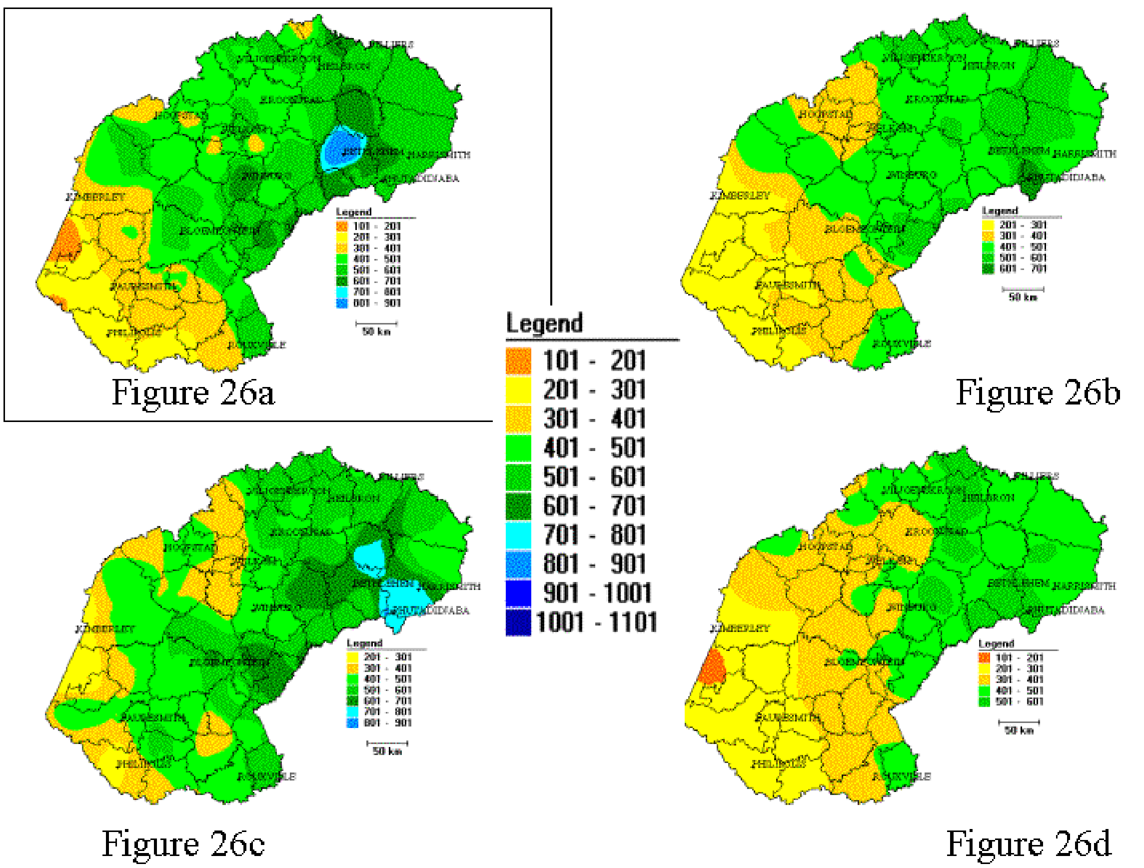


Figure 26 Interpolated rainfall amounts for the 1997/98 season (October – March) for actual rainfall (Fig 26a), rainfall amount outlook provided be the SOI-phases (SPA) model (Figure 26b), the rainfall amount outlook provided by the SOI-phases analogue rainfall (SPAR) model (Figure 26c) and rainfall amount outlook provided by the SPA-PDO-model (Figure 26d)

Table 11 Geographical percentage area of the Free State Province covered by different percentage deviations from actual rainfall (SPA, SPAR-and SPA-PDO-model of seasonal rainfall outlook) for 1997/98 season

% deviation	**% of area of the Free State**		
	SPA	**SPAR**	**SPA-PDO**
< -40	1	0	0
-20 to -40	16	9	26
0 to -20	**60**	**27**	**58**
0 to +20	**18**	**44**	**10**
+20 to +40	5	11	5
> 40	0	9	1

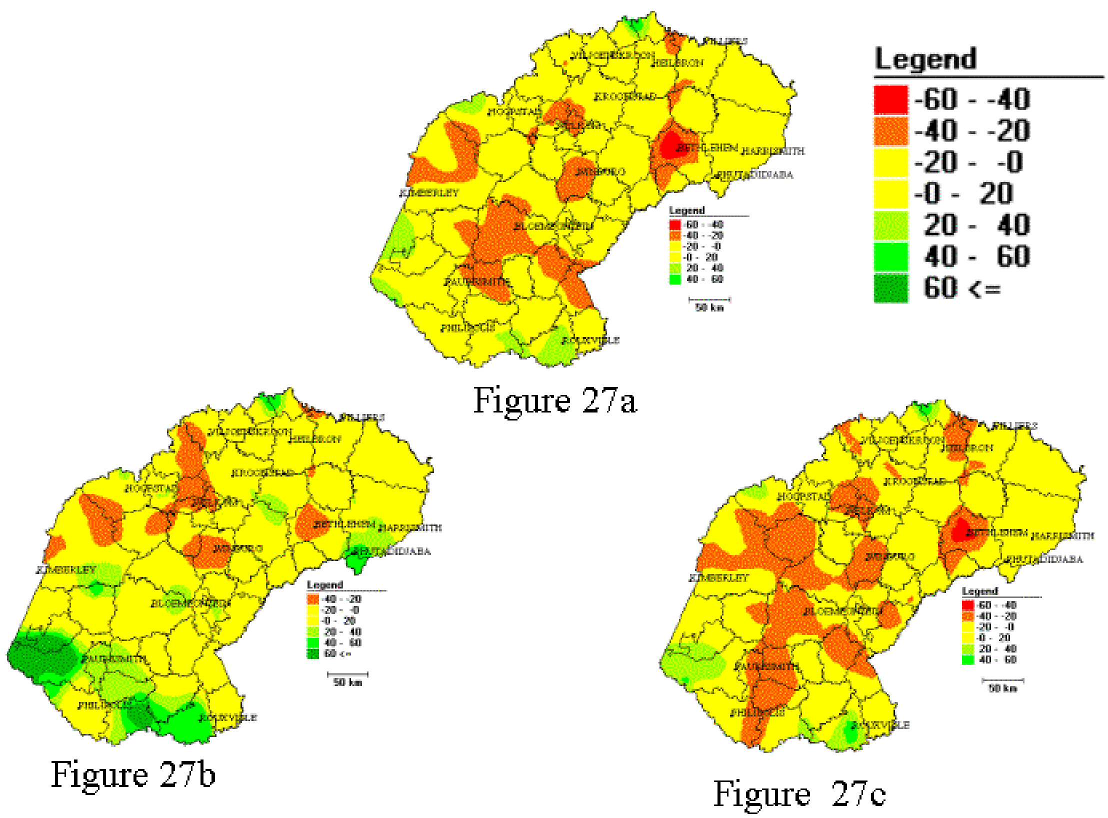


Figure 27 Percentage deviation of total rainfall: Rainfall outlooks from actual rainfall for 1 October 1997 – 31 March 1998 for the SPA- (Figure 27a), SPAR- (Figure 27b) and SPA-PDO-model (Figure 27c)

The area that received within the –20% and +20% deviation limit according to Table 11, is about 78% for the SPA-model, 71% for the SPAR-model and 68% for the SPAR-PDO-model. Figures 27a-c, representing percentage deviations from actual rainfall for the

SPA-, SPAR- and SPA-PDO-models for the 1997/98 season, indicate that only small areas, 17%, 9% and 26% of the total area for the SPA and SPAR-model, respectively, were under estimated (brown). About 20% of the area was over estimated (green) in terms of rainfall with the SPAR-model with about 5% and 6% respectively for the SPA- and SPA-PDO-model.

The overestimation (green) was concentrated towards the southern and southwestern parts (Figures 27a-c).

The good results in estimating rainfall amounts for a six-month period in advance for extreme events like the El Niño, is encouraging. A strong El Niño signal was present already in September 1997. The SPA-model performed the best.

4.5 Rainfall for the 1998/99 season

Actual rainfall for the October 1998 – March 1999 period (Figure 28a) varies from less than 200mm for the districts in the southwestern Free State to more than 700mm in small areas of the southeastern Free State. The bulk of the area received between 300 and 600mm. Rainfall outlooks produced by the SPA- and SPA-PDO-model (Figure 28b and 28d) varies between 200mm and 700mm and the SPAR-model between 200mm and 800mm (Figures 28c).

The area within the –20% to +20% deviation range, according to the estimates with the three models are respectively 56%, 47% and 25% for the SPA-, SPAR- and SPA-PDO-model (Table 12 and Figures 29a-c). **About 38% and 53 % of the area (mainly in the south western Free State) was overestimated (rainfall more than 20% overestimated) for the SPA- and SPAR-model respectively.**

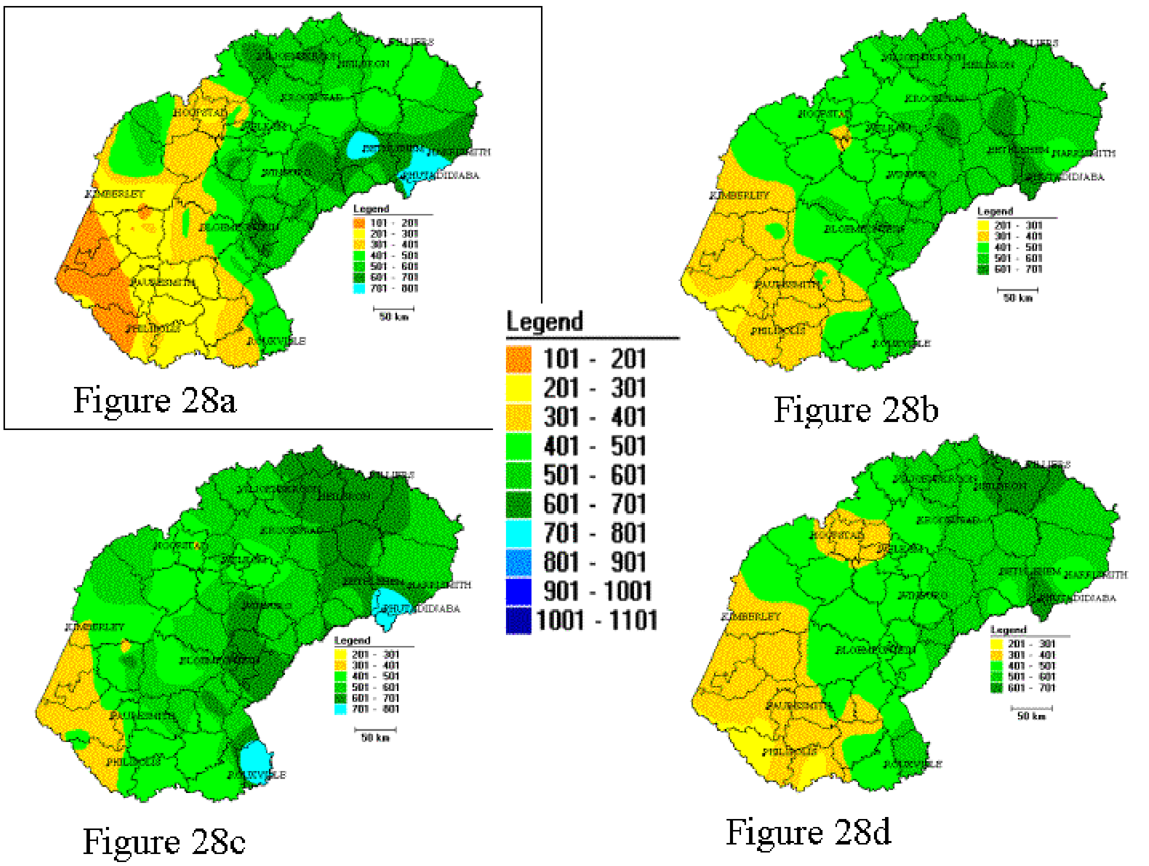


Figure 28 Interpolated rainfall amounts for the 1998/99 season (October – March) for actual rainfall (Fig 28a), rainfall amount outlook provided be the SOI-phases (SPA) model (Figure 28b), the rainfall amount outlook provided by the SOI-phases analogue rainfall (SPAR) model (Figure 28c) and rainfall amount outlook provided by the SPA-PDO-model (Figure 28d)

Table 12 Geographical percentage area of the Free State Province covered by different percentage deviations from actual rainfall (SPA, SPAR- and SPA-PDO-model of seasonal rainfall outlook) for 1998/99 season

% deviation	**% of area of the Free State**		
	SPA	**SPAR**	**SPA-PDO**
< -40	0	0	0
-20 to -40	5	0	6
0 to -20	**33**	**20**	**35**
0 to +20	**24**	**27**	**26**
+20 to +40	21	21	16
> 40	17	32	17

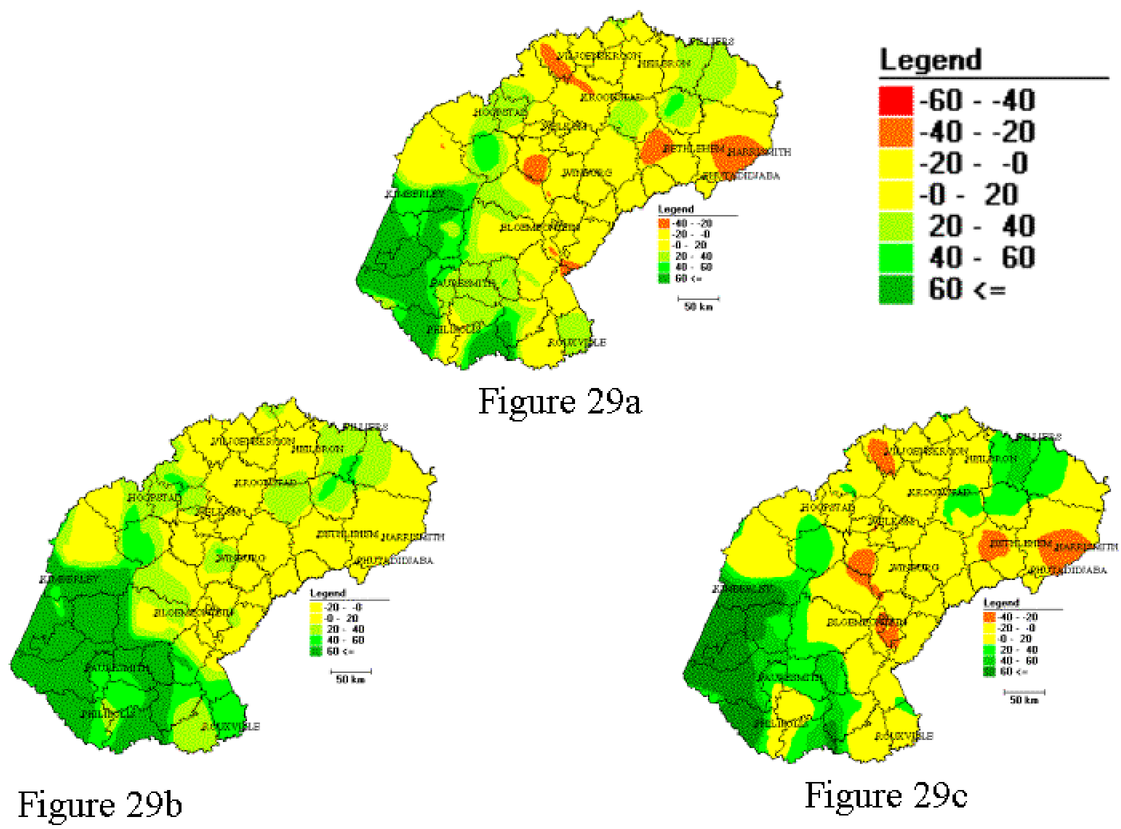


Figure 29 Percentage deviation of total rainfall: Rainfall outlooks from actual rainfall for 1 October 1998 – 31 March 1999 for the SPA- (Figure 29a), SPAR- (Figure 29b) and SPA-PDO-model (Figure 29c)

The areas within the accepted range deviation (-20% to +20%) are 57%, 47% and 61% for the SPA-, SPAR- and SPA-PDO-model respectively.

4.6 Rainfall for the 1999/2000 season

The actual measured rainfall for the 1999/2000-season varies between 200mm and 1000mm (Figure 30a). Expected rainfall totals range from 200mm to 600mm for the SPA-model (Figure 30b) and between 200mm and 800mm for the SPAR- and SPA-PDO-model (Figure 30c and 30d). Comparing the actual rainfall (Figure 30a) to the predicted rainfall from the SPA-, SPAR- and SPA-PDO-model, there was in general an under estimation of rainfall totals for the 1999/2000 season. Table 13 indicates that about 81% of the area of the Free State was under estimated by 20% or more by the SPA-model compared to the actual rainfall. Only 19% of the area was in the –20% to +20% range. The SPAR-model also under estimates the actual rainfall and 39% of the area of the Free State received more than 20% more than the predicted amount by the SPAR-model. About 55% of the area received rainfall within the –20% to +20% range (SPAR-model).

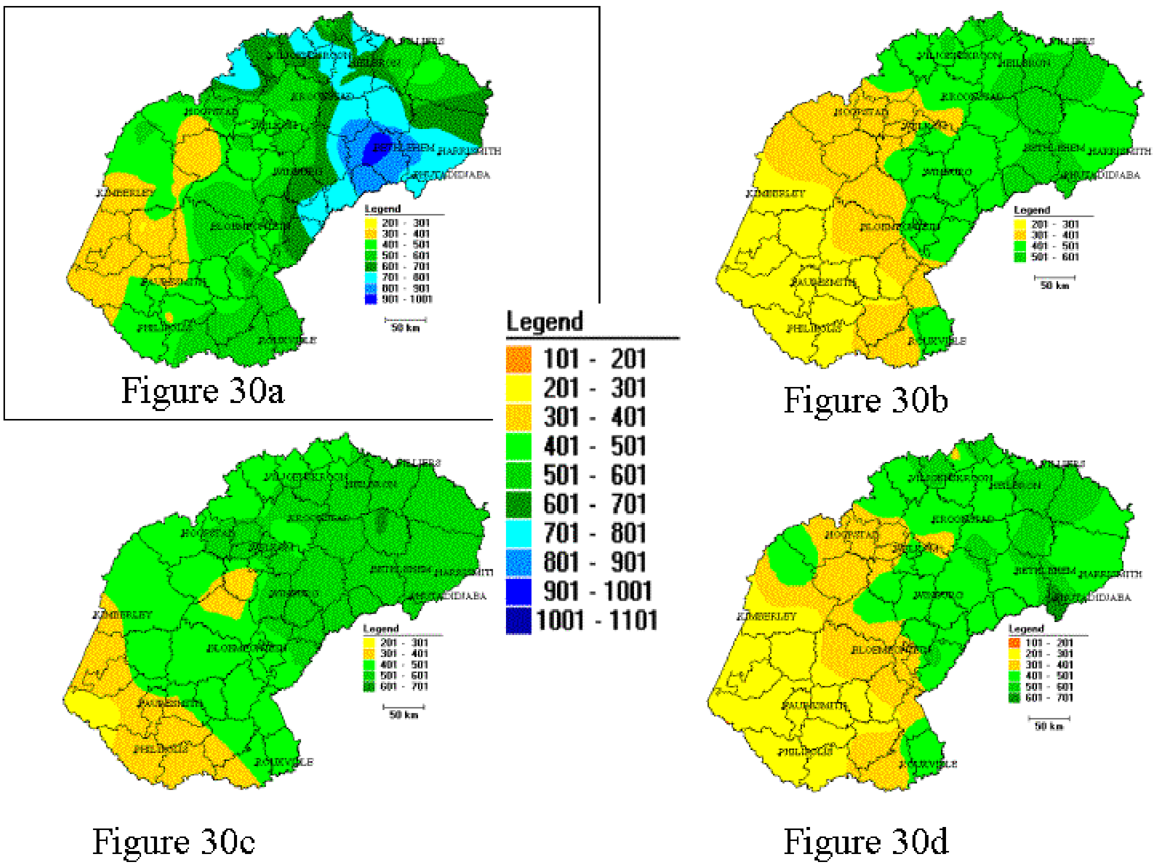


Figure 30 Interpolated rainfall amounts for the 1999/2000 season (October – March) for actual rainfall (Fig 30a), rainfall amount outlook provided be the SOI-phases (SPA) model (Figure 30b), the rainfall amount outlook provided by the SOI-phases analogue rainfall (SPAR) model (Figure 30c) and rainfall amount outlook provided by the SPA-PDO-model (Figure 30d)

Table 13 Geographical percentage area of the Free State Province covered by different percentage deviations from actual rainfall (SPA, SPAR- and SPA-PDO-model of seasonal rainfall outlook) for 1999/2000 season

% deviation	**% of area of the Free State**		
	SPA	**SPAR**	**SPA-PDO**
< -40	16	1	18
-20 to -40	65	38	56
0 to -20	**15**	**37**	**21**
0 to +20	**4**	**18**	**4**
+20 to +40	0	5	1
> 40	0	1	0

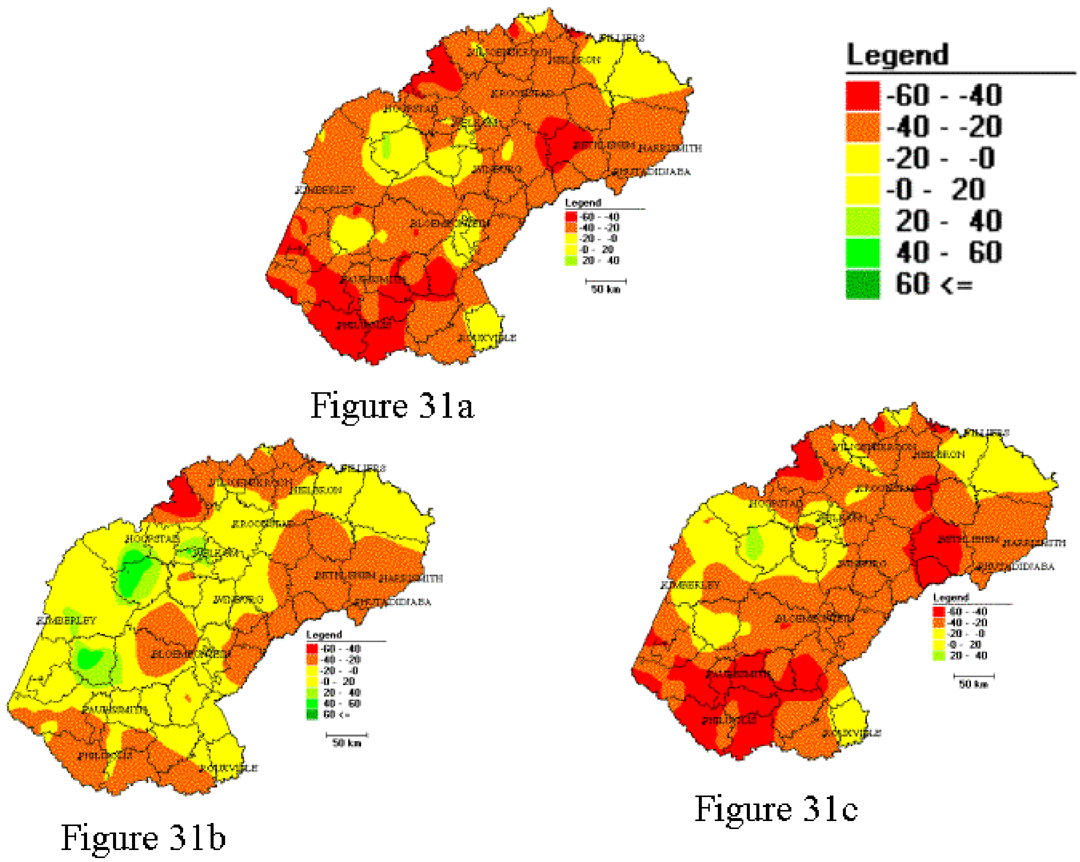


Figure 31 Percentage deviation of total rainfall: Rainfall outlooks from actual rainfall for 1 October 1999 – 31 March 2000 for the SPA- (Figure 31a), SPAR- (Figure 31b) and SPA-PDO-model (Figure 31c)

The SPA-PDO-model also seriously underestimated the rainfall totals for this specific season. About 74% of the area was underestimated (brown) with 25% of the area within the correct or -20% to +20% range (yellow). Only about 1% of the area was over estimated (green).

4.7 Summary and Discussion

4.7.1 Average deviations

Two of the five years under estimated the actual rainfall, namely 1995/96 and 1999/2000. The "buffering" effect of three analogue years in both models hampered the estimation of outliers. The El Niño season of 1997/98 was relatively well predicted in terms of rainfall totals with about 78% of area estimated within the –20% to + 20% range from the actual rainfall for the SPA-model, 71% of the area "correct" with the SPAR-model and 68% correct with the SPAR-PDO-model.

Table 14 Summary of geographical percentage area of the Free State Province covered by different percentage deviations from actual rainfall (SPA-, SPAR- and SPA-PDO-model of seasonal rainfall outlook)

Season	*% area "correct" (-20% to + 20%)*			*% area under estimated (> 20%)*			*% of area over estimated (< 20%)*		
	SPA	*SPAR*	*PDO*	*SPA*	*SPAR*	*PDO*	*SPA*	*SPAR*	*PDO*
1995/96	13	41	14	87	53	85	0	6	1
1996/97	69	78	72	29	11	26	2	11	2
1997/98	78	71	68	17	9	26	5	20	6
1998/99	57	47	61	5	0	41	38	53	17
1999/00	19	55	25	81	39	74	0	6	1
Average	**47.2**	**58.4**	**48.0**	**43.8**	**22.4**	**50.4**	**9.0**	**19.2**	**5.4**

The poorly estimated years were the 1995/96 and the 1999/2000-season (Table 14) where under estimation of the area took place. Comparing the values as well as the phases of the SOI (Stone *et al*, 1996), for each of the months under discussion in the five years, an interesting trend is evident. September (used as the SOI indicator month) of 1995 was in SOI phase 5 (Table 15, neutral phase) but was unstable during the season having a rapidly falling phase in December followed by a rapidly rising phase in January as well as in March. The 1999/2000-season started with a neutral phase in the SOI indicator month (September) but was in fact a phase 2 (constantly positive phase) -season. September was too early to characterize the season for 1999/2000 while 1995/96 was an unstable SOI season with no strong trend.

According to Table 14, about 47.2% of the area received the expected rainfall using the SPA-model, 58.4% using the SPAR-model and 48.0% using the SPA-PDO-model.

The seasons with stronger trends (1996/97; 1997/98 and 1998/99) were the SOI seasons with relatively strong signals (Table 15), either phase 2 (1996/97 and 1998/99) or phase 1 (1997/98).

Table 15 Monthly average SOI as well as phases of SOI for the months September till March for the seasons 1995/96, 1996/97, 1997/98, 1998/99 and 1999/2000

Month	**1995/96**		**1996/97**		**1997/98**		**1998/99**		**1999/2000**	
	SOI	**Phase**	**SOI**	**Phase**	**SOI**	**Phase**	**SOI**	**Phase**	**SOI**	**Phase**
Sep	3.4	5	6.2	2	-14.1	1	12.1	2	0.15	5
Oct	-0.6	5	6.2	2	-17.4	1	11.2	2	9.2	2
Nov	1.7	5	-0.8	5	-13.9	1	13.3	2	11.6	2
Dec	-7.8	3	7.3	4	-10.8	1	10.0	2	13.2	2
Jan	7.7	4	3.5	3	-22.1	3	14.7	2	3.0	2
Feb	-0.1	5	12.4	2	-22.2	1	7.1	2	14.0	2
Mar	5.3	4	-7.0	3	-26.1	1	7.8	2	7.2	2

Chapter 5: Distribution of Monthly Rainfall

5.1 Comparing monthly rainfall totals

The average rainfall totals for (a) actual rainfall, (b) median rainfall, (c) the SPA- as well as for (d) the SPAR-models, (e) the standard deviation as the upper (SD UPPER) and lower (SD LOWER) limits were computed for the Free State Province for the seasons 1995/96, 1996/97, 1997/98, 1998/99 and 1999/2000. Rainfall totals were calculated as a monthly total for the summer months from October through to March.

5.2 Median rainfall

Figure 32 compares the actual rainfall totals with the median monthly rainfall, Figure 33 the actual with the SPA-model and Figure 34 the actual with the SPAR-model.

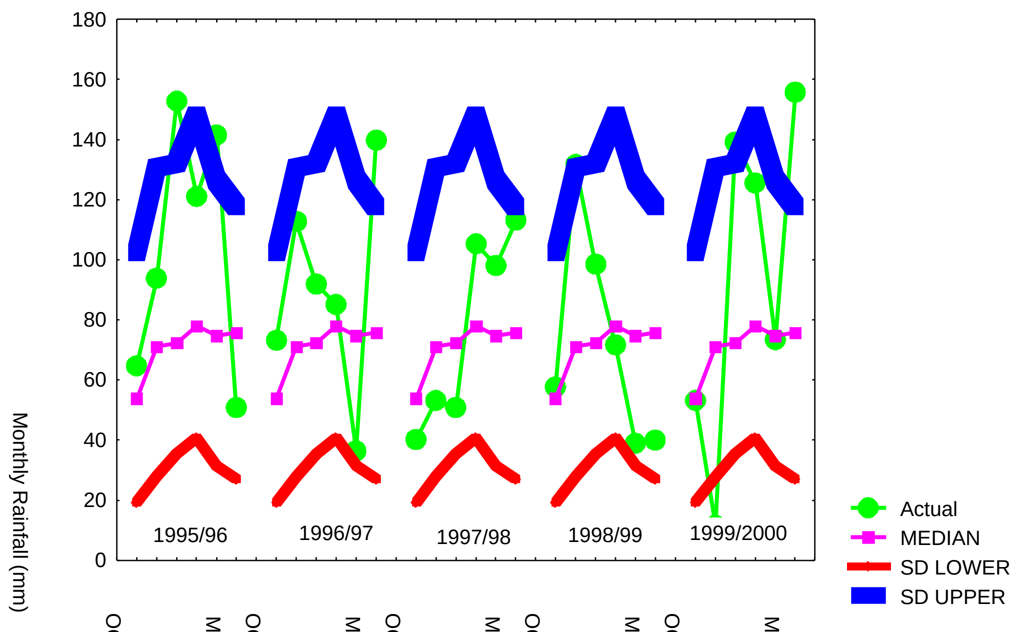


***Figure 32** Monthly rainfall totals for the Free State for the summer months (October-April) for the 1995/96, 1996/97, 1997/98, 1998/99 and 1999/2000 season for actual rainfall (green lines) and median rainfall (purple lines) with the standard deviation added to (thick blue line) and deducted (thick red line) from the monthly long term average rainfall*

As can be seen from Figure 32, the long term median rainfall shows nearly no resemblance to the actual total monthly rainfall for the Free State. In the t-test for evaluating median rainfall totals with actual totals for the 5 seasons, the two sets of data shows significant differences at the 95% level.

5.3 SPA-model

Comparing rainfall outlooks using the SPA-model (Figure 33, light blue line).

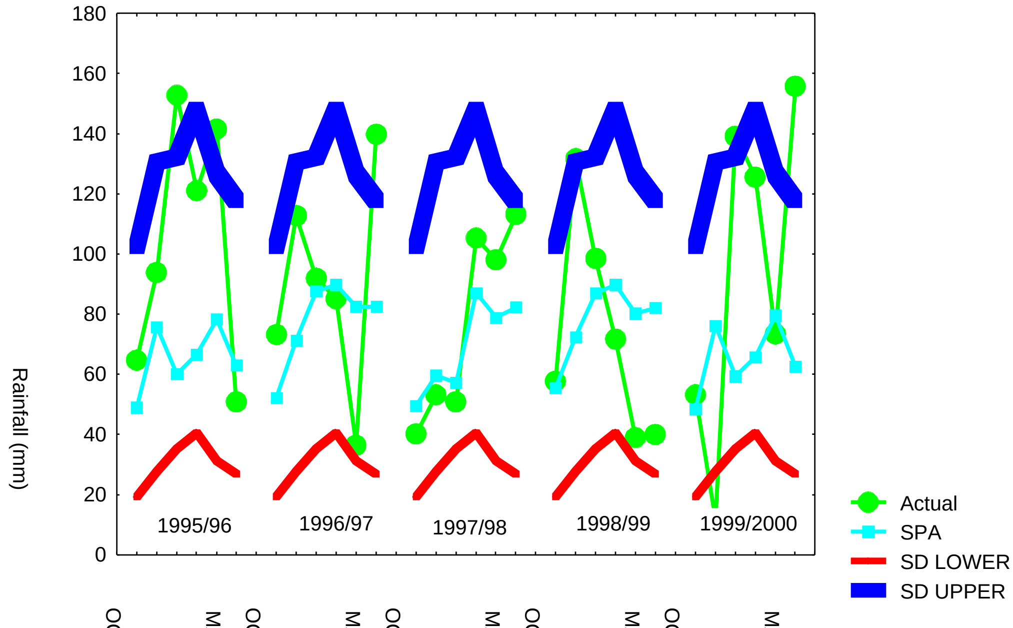


Figure 33 Rainfall totals for the Free State for the summer months (October-April) for the 1995/96, 1996/97, 1997/98, 1998/99 and 1999/2000 season for actual rainfall (green lines) and rainfall from SPA-model (light blue) with the standard deviation added to (thick blue line) and deducted (thick red line) from the monthly long term average rainfall

There are some visual similarities between actual rainfall and rainfall outlooks provided by the SPA-model for the 5 seasons (Figure 33). Interesting was the close relationship between actual and forecast rainfall totals for the 1997/98 season (the El Niño season). Little or no trend for the five seasons pooled together, was evident and the two sets of data significantly differ at the 95% level.

5.4 SPAR-model

Comparing rainfall outlooks using the SPAR-model (Figure 34, black line).

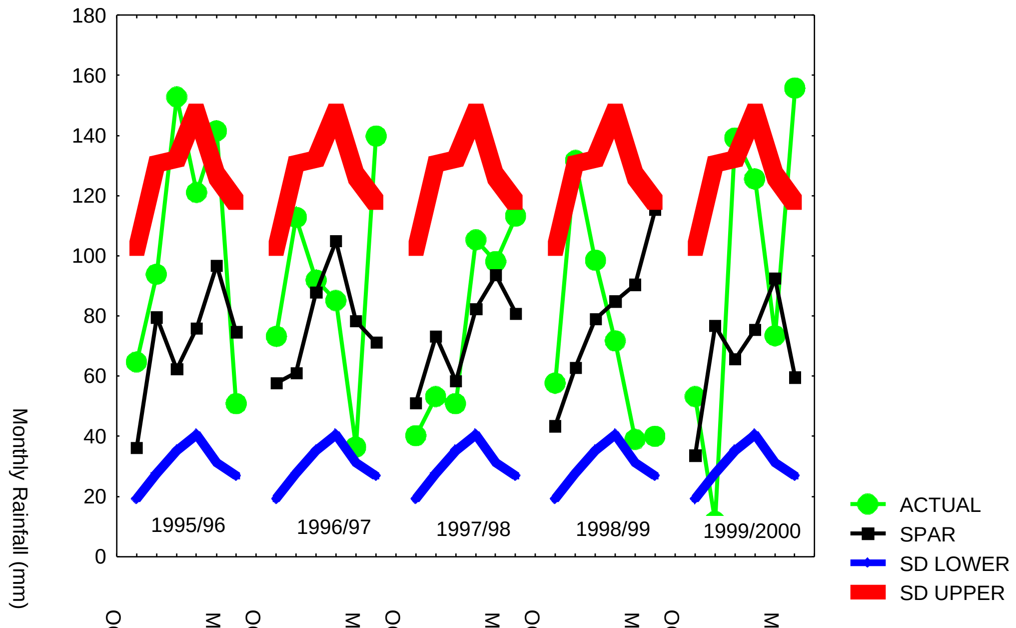


Figure 34 Monthly rainfall totals for the Free State for the summer months (October-April) for the 1995/96, 1996/97, 1997/98, 1998/99 and 1999/2000 season for actual rainfall (green lines) and rainfall from SPAR-model (black) with the standard deviation added to (thick blue line) and deducted (thick red line) from the monthly long term average rainfall

The SPAR-model provided the best similarity with actual monthly rainfall totals (Figure 34), not differing significantly at the 95% level.

5.5 SPA-PDO-model

The SPA-PDO-model describe the 1996/97 as well as 1997/98 seasons very well in terms of the actual monthly rainfall totals (Figure 35).

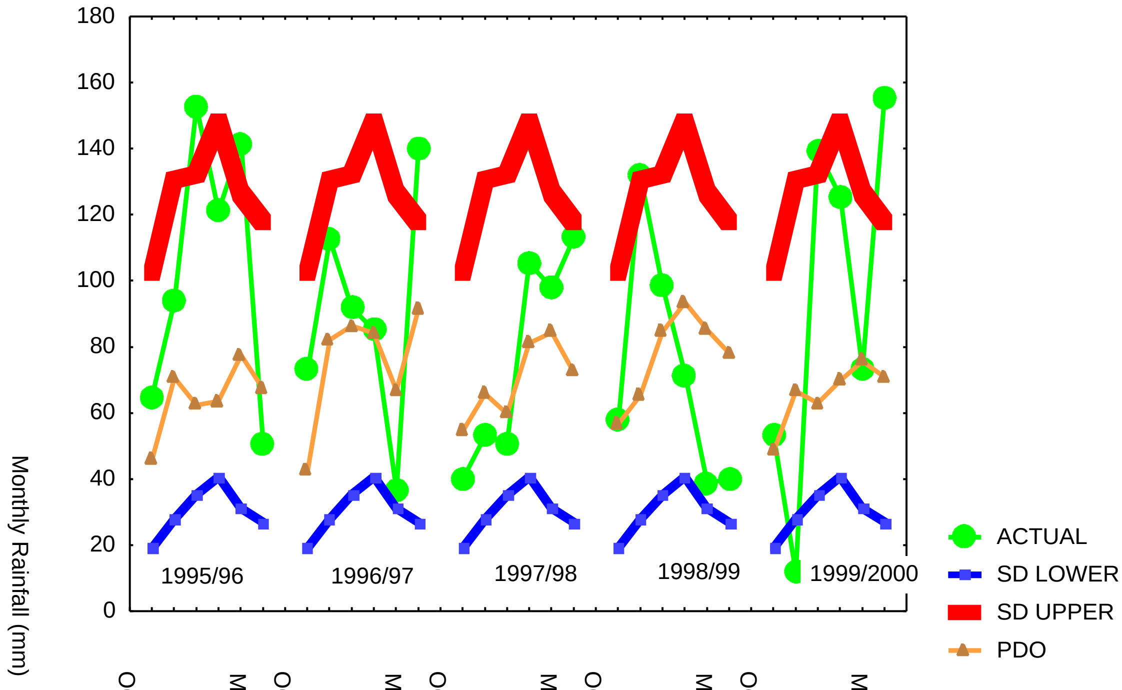


Figure 35 Monthly rainfall totals for the Free State for the summer months (October-April) for the 1995/96, 1996/97, 1997/98, 1998/99 and 1999/2000 season for actual rainfall (green lines) and rainfall from SPA_PDO-model (yellow) with the standard deviation added to (thick blue line) and deducted (thick red line) from the monthly long term average rainfall

5.6 Discussion and Summary

The standard deviation (SD UPPER and SD LOWER) calculated for the long term average monthly rainfall totals shows the extend of variability of rainfall for the Free State. Both the SPA and SPAR models of generating daily rainfall totals for a specific season try to break away from the averaged situation as is indicated by the median rainfall (Figure 32, purple line). Both SPA and SPAR are using three analogue years to combine as a single figure, thus eliminating extreme values to a large extent but also decrease the ability to follow extreme rainfall events. Analyzing the actual rainfall for the five seasons under discussion, it is evident that seasons with monthly rainfall totals within the standard deviation limit (SD UPPER and SD LOWER, Figures 32, 33 and 34), the SPA and SPAR model gave a relative good estimate, for example 1997/98. It is however evident that both models are not able to forecast extreme events.

The occurrence of extreme high and extreme low rainfall events (where the actual rainfall exceeds the SD UPPER limit or SD LOWER limit) can occur in about 10-20% of years (both high and low) for a place like Kroonstad in the central Free State.

Measured rainfall totals for the 1995/96 and 1999/2000-seasons were in general higher than anticipated by the three models (Figures 22 and 30) as is also evident from the maps indicating deviations from the actual rainfall (Figures 23 and 31). The actual rainfall totals for the 1996/97-, 1997/98- as well as 1998/99-seasons were estimated relatively good by all three models (Figures 24,26 and 28) with the SPAR-model the best Table 14 (See also Figures 25, 27 and 29 representing deviations of rainfall totals from actual totals).

Chapter 6: Comparing Simulated Yields for The Free State Using Actual Climate Data and Climate Data Provided by the SOI-Phases (SPA), SOI-Rainfall Analogue (SPAR) and SOI-Phases-PDO (SPA-PDO)-Models

6.1 Introduction

Using standard inputs for soil, management and plant factors in the simulation process, varying only climate inputs, provides a measure of sensitivity of the different climate outlooks in terms of maize yields. Actual daily climate data (rainfall, temperature and radiation) interpolated from measured point data is assumed to be the actual climate that occurred geographically over the Free State Province and used as input data for the CERES-MAIZE crop growth simulation model. Rainfall data is used to identify analogue years using the SPA, SPAR- and SPA-PDO-models for the same period. Temperature and radiation for the rainfall analogue years is interpolated similarly and used together with rainfall as input data for the simulation process for the seasons 1995/96, 1996/97, 1997/98, 1998/99 and 1999/2000.

6.2 Simulated yields for 1995/96

The rainfall analyses for the 1995/96 season (Figures 23a-c) indicates that the actual rainfall was considerably higher than the rainfall provided by all three models. It is also clear from Figure 36 that the maize yields simulated with actual rainfall and associated climate elements were higher than the simulated yields provided by all three rainfall outlook models. The differences between simulated yields using actual climate inputs and simulated yields using climate outlooks provided by the three models (Figure 37a-c), show the same trend as the rainfall analyses by under estimating the actual yields.

All three models under estimate the actual yields (Table 16) and only about 15.8% of the area was estimated within the +1000kg to -1000kg from the actual yields with the SPA-model, 26.3% by the SPAR-model with the SPA-PDO the best with 33.0%. The -20% to +20% deviation range provided correctly estimated areas of 12.2%, 23.4% and 14.8% respectively for the SPA-, SPAR- and SPA-PDO-models (Table 17).

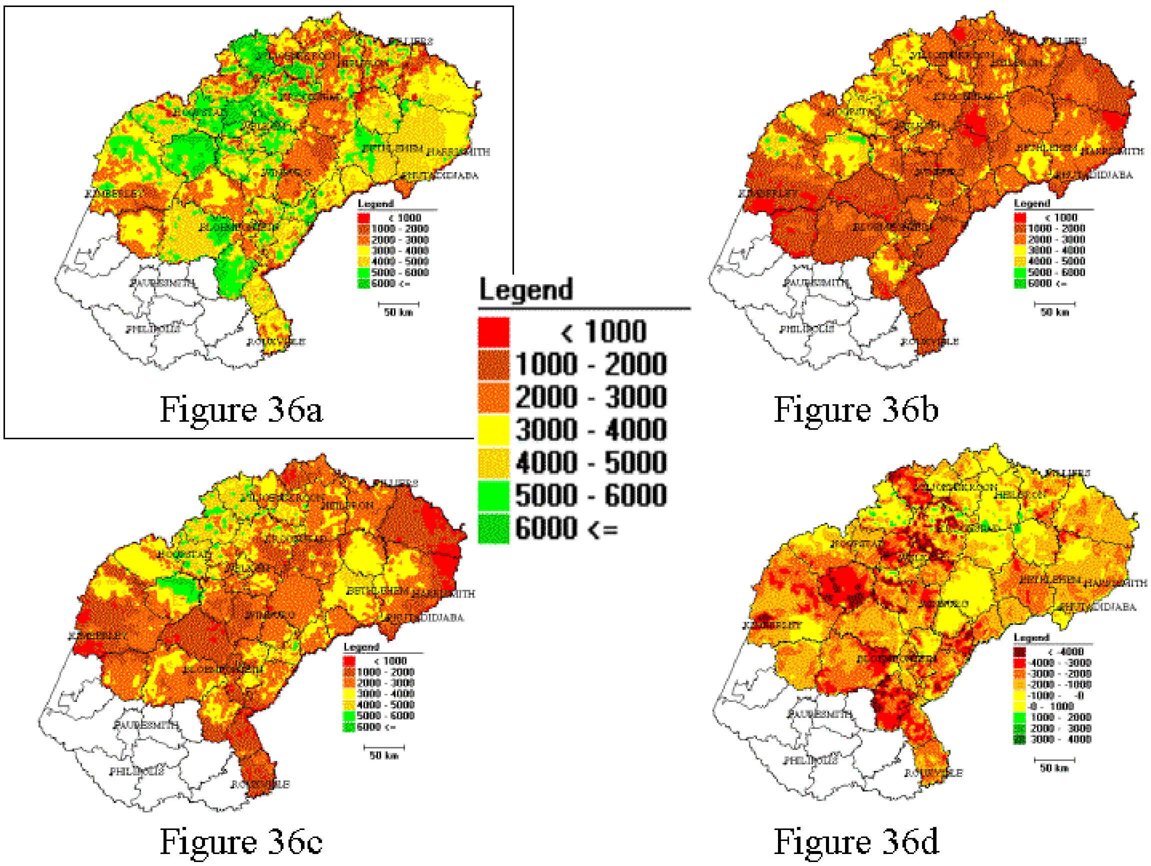


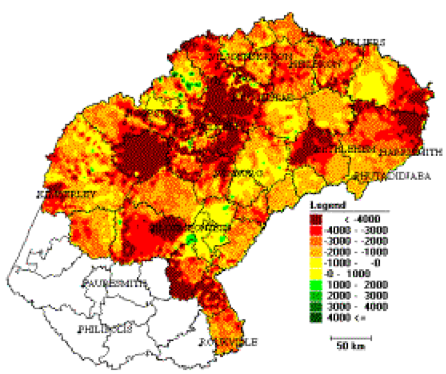
Figure 36 Maize yields (kg/ha) simulated by the CERES-MAIZE model for the 1995/96 season for the Free State using actual rainfall and associated climate elements (Figure 36a), rainfall and associated climate elements provided by the SPA-model (Figure 36b), rainfall and associated climate elements using the SPAR-model (Figure 36c) and rainfall and associated climate elements using the SPA-PDO-model (Figure 36d)

Table 16 Geographical area (percentage of total area) of the Free State Province covered by deviations (kg/ha) from actual simulated yields (SPA- SPAR- and SPA-PDO-model) for the 1995/96 season

Deviation from actual simulated yields (kg/ha)	**% of area of the Free State SPA**	**% of area of the Free State SPAR**	**% area of the Free State SPA-PDO**
< -4001	16.23	12.05	3.61
-4000 to -3001	17.58	13.23	7.17
-3000 to -2001	24.05	22.22	15.32
-2000 to -1001	25.40	23.79	27.20
-1000 to –1	**12.27**	**18.55**	**19.67**
0 to 1999	**3.56**	**7.75**	**13.28**
1000 to 1999	0.67	1.79	8.62
2000 to 2999	0.15	0.41	3.42
3000 to 3999	0.07	0.11	1.27
4000<=	0.03	0.08	0.45

Table 17 Geographical area (percentage of the total area) of the Free State Province covered by different percentage deviations from actual simulated yields using the SPA-, SPAR- and SPA-PDO-climate outlook models for the 1995/96-season

Deviation from actual simulated yields (%)	% of area of the Free State SPA	% of area of the Free State SPAR	% area of the Free State SPA-PDO
< -60	21.14	15.70	21.49
-60 to -41	40.04	28.76	37.55
-40 to -21	24.96	27.67	23.18
-20 to -1	**9.46**	**17.34**	**10.42**
-0 to 19	**2.78**	**6.02**	**4.42**
20 to 39	0.78	2.32	1.63
40 to 59	0.27	0.95	0.76
60 <=	0.58	1.24	0.55



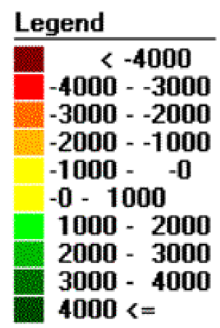


Figure 37a

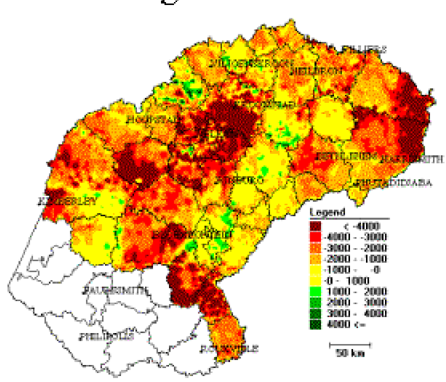


Figure 37b

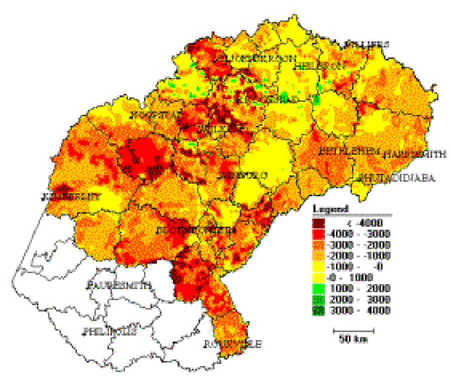


Figure 37c

***Figure 37** Differences in simulated maize yields (kg/ha) from actual climate inputs and climate inputs provided by the SPA-model (Figure 37a), SPAR-model (Figure 37b) and the SPA-PDO-model (Figure 37c) for the 1995/96 season*

6.3 Simulated yields for 1996/97

The 1996/97-season (Figure 38a) in general shows lower yields than the 1995/96 season (Figure 36a).

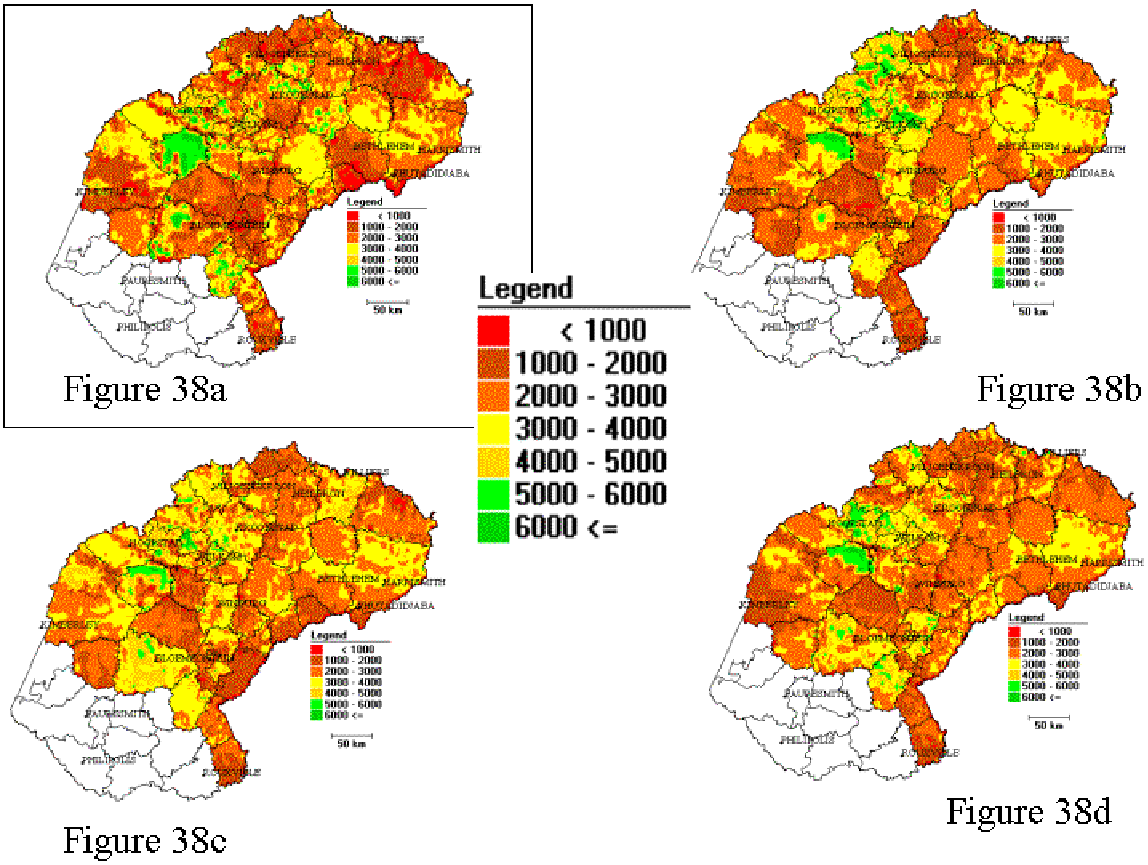


Figure 38 Maize yields (kg/ha) simulated by the CERES-MAIZE model for the 1996/97 season for the Free State using actual rainfall and associated climate elements (Figure 38a), rainfall and associated climate elements provided by the SPA-model (Figure 38b), rainfall and associated climate elements using the SPAR-model (Figure 38c) and rainfall and associated climate elements using the SPA-PDO-model (Figure 38d)

The SPA-PDO-model provided the best results in estimating maize yields on about 71.7% (35.08% + 36.64%) of the area of the Free State within the -1000kg to +1000 kg deviation range (Table 18). The SPA- and SPAR-models estimate the yields within the -1000kg to +1000kg on about 46.7% and 53.8% of the area of the Free State respectively.

The percentage deviation (from actual yields) within the -20% to +20% range is 32.4% for the SPA-model, 39.2% for the SPAR-model and 41.0% for the SPAR-PDO-model (Table 19). The deviations in both kg/ha and percentage (for all three models) follow more or less a normal distribution.

Table 18 Geographical area (percentage of total area) of the Free State Province covered by deviations (kg/ha) from actual simulated yields (SPA- SPAR- and SPA-PDO-model) for the 1996/97 season

Deviation from actual simulated yields (kg/ha)	**% of area of the Free State SPA**	**% of area of the Free State SPAR**	**% of area of the Free State SPA-PDO**
< -4001	0.6	1.33	0.15
-4000 to -3001	1.67	2.65	0.60
-3000 to -2001	6.99	6.24	1.67
-2000 to -1001	18.42	12.79	9.88
-1000 to –1	**25.59**	**24.48**	**35.08**
0 to 1999	**21.15**	**29.27**	**36.64**
1000 to 1999	16.12	14.94	13.15
2000 to 2999	6.01	6.11	2.43
3000 to 3999	2.26	1.69	0.38
4000<=	1.20	0.50	0.00

Table 19 Geographical area (percentage of the total area) of the Free State Province covered by different percentage deviations from actual simulated yields using the SPA-, SPAR-and SPA-PDO-climate outlook models for the 1996/97 season

Deviation from actual simulated yields (%)	**% of area of the Free State SPA**	**% of area of the Free State SPAR**	**% of area of the Free State SPA-PDO**
< -60	2.96	2.46	1.22
-60 to -41	8.90	8.26	6.36
-40 to -21	21.11	15.68	16.36
-20 to -1	**19.39**	**20.56**	**22.98**
-0 to 19	**13.00**	**18.62**	**18.03**
20 to 39	9.34	10.89	10.06
40 to 59	6.19	6.44	7.30
60 <=	19.11	17.09	17.68

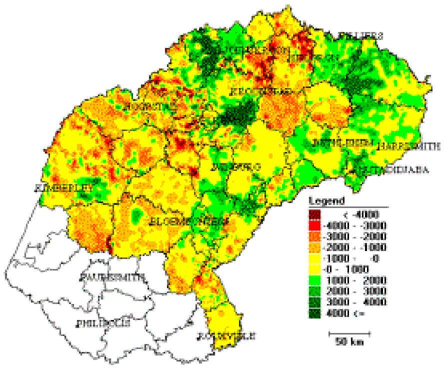
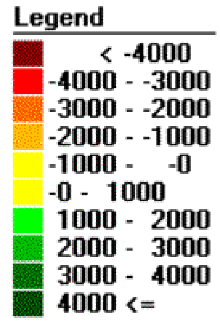


Figure 39a



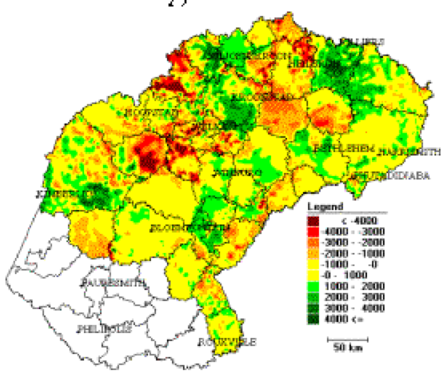


Figure 39b

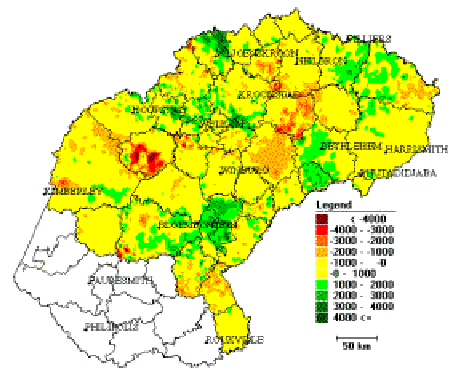


Figure 39c

Figure 39 Differences in simulated maize yields (kg/ha) from actual climate inputs and climate inputs provided by the SPA-model (Figure 39a), SPAR-model (Figure 39b) and the SPA-PDO-model (Figure 39c) for the 1996/97 season

6.4 Simulated yields for 1997/98

The 1997/98 season was characterized by a very intense El Niño event. Rainfall was however not so severely inhibited as expected by many people. Maize yields were on general about normal to above normal. Yields of more than 3000 kg/ha were recorded in most of the maize producing areas of the Free State (Figure 40a). Generated climate outlook data provided by the three models (SPA-, SPAR and SPA-PDO) tended to underestimate the actual yields (Figure 40b, 40c and 40d). It is in contrast to the relative good estimate of total rainfall given by the three models (Figures 22 and 27). This illustrates the importance of timing of rainfall where small amounts of rain at critical stages of development (like the flowering stage of maize) can have a huge positive effect on yields or on the other hand lack of water during these stages can have serious negative consequences on yields. The climate data generated by the SPA-model, estimated the actual yields correctly (within the -1000kg/ha to +1000kg/ha range) on about 40% (25.67% + 14.12%) of the area (Table 20, and Figures 41a, 41b and 41c (yellow areas)), the SPAR-model about 32.54% (19.63% + 12.91%) and the SPA-PDO-model about 49.77% (34.10% + 15.67%) of the total area.

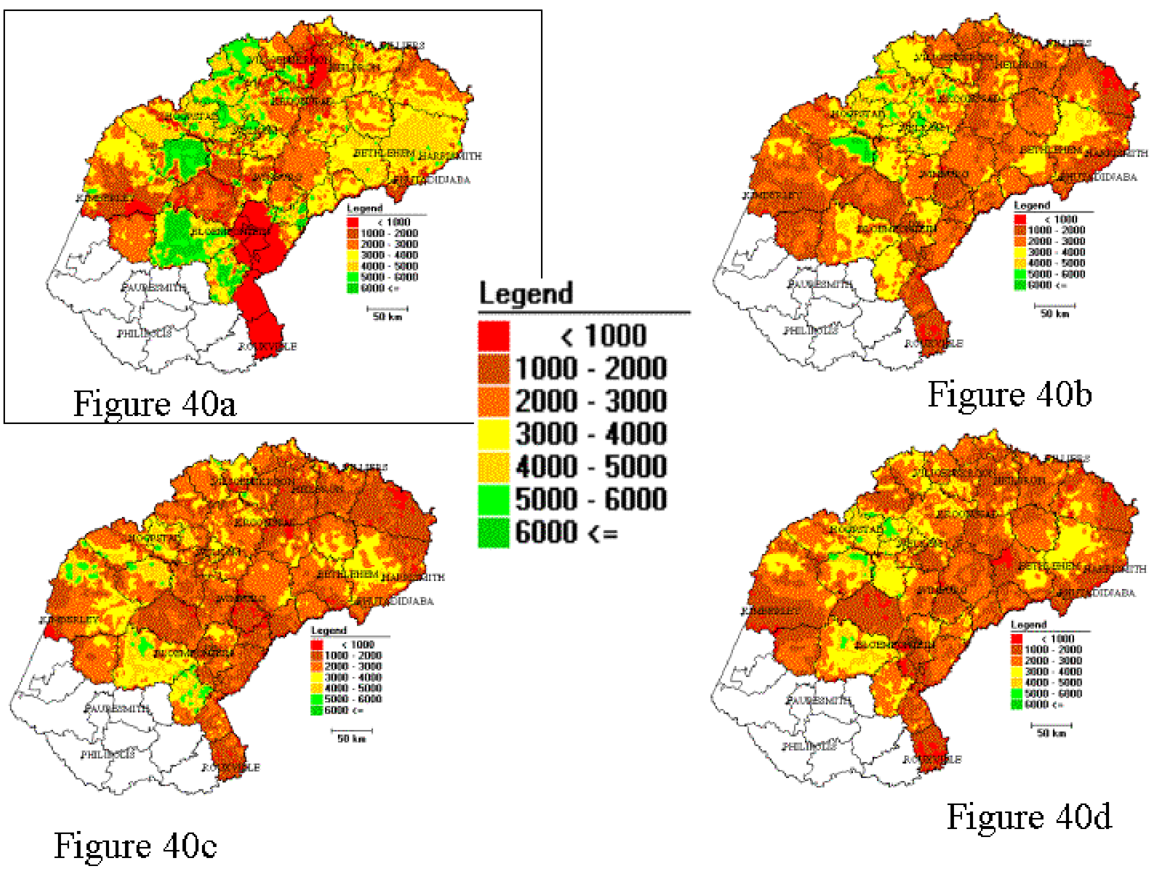


Figure 40 Maize yields (kg/ha) simulated by the CERES-MAIZE model for the 1997/98 season for the Free State using actual rainfall and associated climate elements (Figure 40a), rainfall and associated climate elements provided by the SPA-model (Figure 40b), rainfall and associated climate elements using the SPAR-model (Figure 40c) and rainfall and associated climate elements using the SPA-PDO-model (Figure 40d)

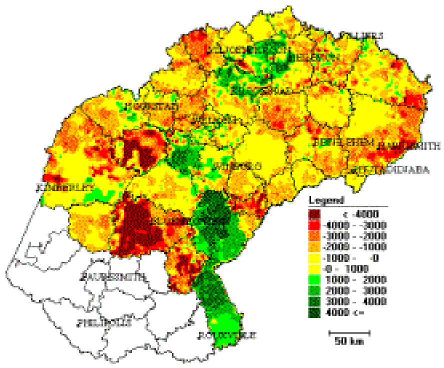
Table 20 Geographical percentage area of the Free State Province covered by deviations (kg/ha) from actual simulated yields (SPA-, SPAR- and SPA-PDO-model of seasonal rainfall outlook) model for the 1997/98 season

Deviation from actual simulated yields (kg/ha)	**% of area of the Free State SPA**	**% of area of the Free State SPAR**	**% of area of the Free State SPA-PDO**
< -4001	4.21	4.66	0.62
-4000 to -3001	5.10	9.00	3.27
-3000 to -2001	12.47	17.21	10.34
-2000 to -1001	23.17	22.99	25.99
-1000 to –1	**25.67**	**19.63**	**34.10**
0 to 1999	**14.12**	**12.91**	**15.67**
1000 to 1999	6.58	5.92	7.24
2000 to 2999	4.92	4.77	2.46
3000 to 3999	2.82	2.15	0.30
4000<=	0.94	0.78	0.00

Table 21 Geographical area (percentage of the total area) of the Free State Province covered by different percentage deviations from actual simulated yields using the SPA-, SPAR-and SPA-PDO-climate outlook models for the 1997/98 summer season

Deviation from actual simulated yields (%)	**% of area of the Free State SPA**	**% of area of the Free State SPAR**	**% of area of the Free State SPA-PDO**
< -60	6.74	8.21	6.89
-60 to -41	14.27	21.32	18.11
-40 to -21	26.10	27.11	27.91
-20 to -1	**22.36**	**15.58**	**20.10**
-0 to 19	**9.38**	**7.94**	**7.72**
20 to 39	4.29	4.46	3.56
40 to 59	2.38	2.56	2.05
60 <=	14.47	12.82	13.66

In terms of percentage deviation from actual yields (within the -20% to +20% range), the SPA-model estimates about 31.74% of the area correct, the SPAR-model about 23.52% and the SPA-PDO-model about 27.82% (Table 21) correct.



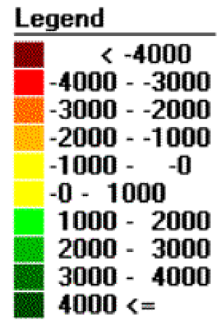


Figure 41a

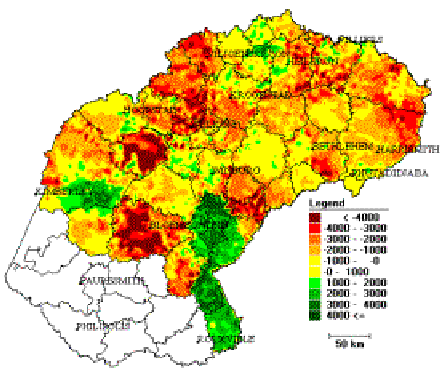


Figure 41b

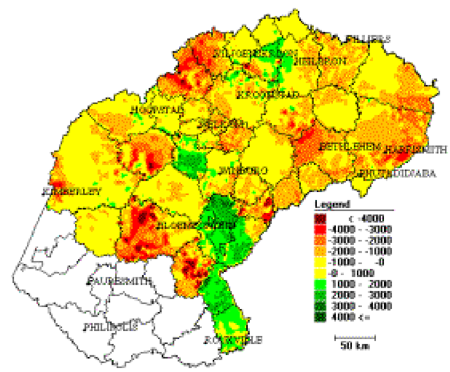


Figure 41c

Figure 41 Differences in simulated maize yields (kg/ha) from actual climate inputs and climate inputs provided by the SPA-model (Figure 41a), SPAR-model (Figure 41b) and the SPA-PDO-model (Figure 41c) for the 1997/98 season

6.5 Simulated yields for 1998/99

The actual simulated maize yields for 1998/99 (Figure 42a) were in general low with only small areas exceeding 3000 kg/ha (yellow and green, Figure 42a). All three models over estimated the yields to a certain extent (Tables 22 and 23; Figures 43a, 43b and 43c). The -1000kg/ha to +1000kg/ha deviation from actual yields range were reached on about 39.36% (16.23% + 23.13%, Table 22) by climate input data generated by the SPA-model, about 33.85% (12.48% + 21.37%, Table 22) by the SPAR-model and about 54.65% (16.98% + 37.67%, Table 22). In terms of percentage deviation from actual yields, about 23.38% (Table 23) of the area was estimated correctly or within the -20% to +20% range by the SPA-model, 19.44% by the SPAR-model and about 26.22% by the SPAR-PDO-model.

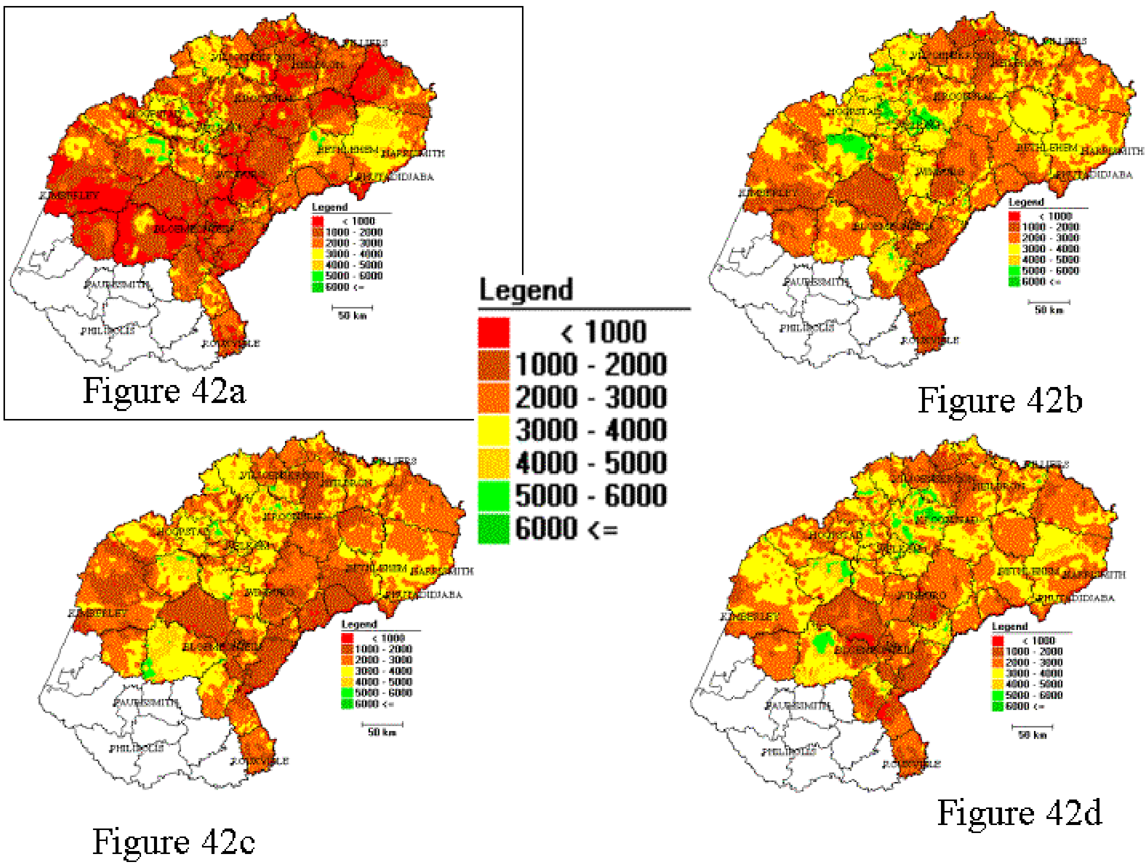


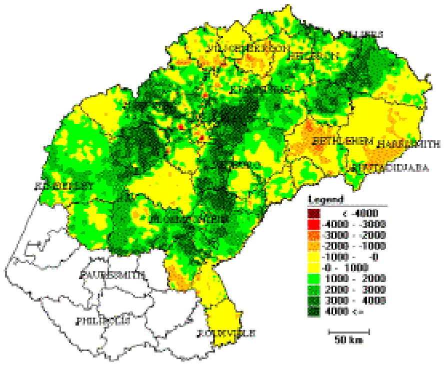
Figure 42 Maize yields (kg/ha) simulated by the CERES-MAIZE model for the 1998/99 season for the Free State using actual rainfall and associated climate elements (Figure 42a), rainfall and associated climate elements provided by the SPA-model (Figure 42b), rainfall and associated climate elements using the SPAR-model (Figure 42c) and rainfall and associated climate elements using the SPA-PDO-model (Figure 42d)

Table 22 Geographical percentage area of the Free State Province covered by deviations (kg/ha) from actual simulated yields (SPA-, SPAR- and SPA-PDO-model of seasonal rainfall outlook) for 1998/99 season

Deviation from actual simulated yields (kg/ha)	**% of area of the Free State SPA**	**% of area of the Free State SPAR**	**% of area of the Free State SPA-PDO**
< -4001	0.01	0.06	0.00
-4000 to -3001	0.04	0.39	0.00
-3000 to -2001	0.46	2.03	0.21
-2000 to -1001	4.51	5.46	3.65
-1000 to –1	**16.23**	**12.48**	**16.98**
0 to 1999	**23.13**	**21.37**	**37.67**
1000 to 1999	25.67	27.03	28.29
2000 to 2999	18.33	18.94	11.28
3000 to 3999	8.40	9.13	1.75
4000<=	3.20	3.12	0.17

Table 23 Geographical area (percentage of the total area) of the Free State Province covered by different percentage deviations from actual simulated yields using the SPA-, SPAR-and SPA-PDO-climate outlook models for the 1998/99 summer season

Deviation from actual simulated yields (%)	**% of area of the Free State SPA**	**% of area of the Free State SPAR**	**% of area of the Free State SPA-PDO**
< -60	1.53	2.81	1.62
-60 to -41	1.89	3.37	1.96
-40 to -21	7.36	6.34	7.54
-20 to -1	**12.69**	**9.68**	**11.99**
-0 to 19	**10.69**	**9.76**	**14.23**
20 to 39	8.45	8.41	10.36
40 to 59	6.81	6.57	8.02
60 <=	50.57	53.07	44.28



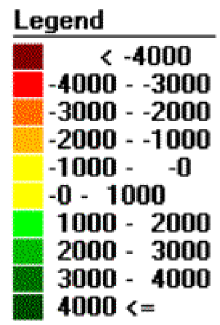
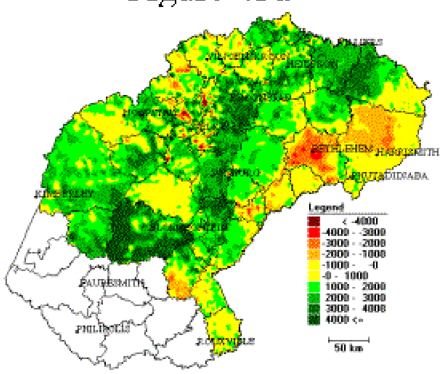


Figure 43a



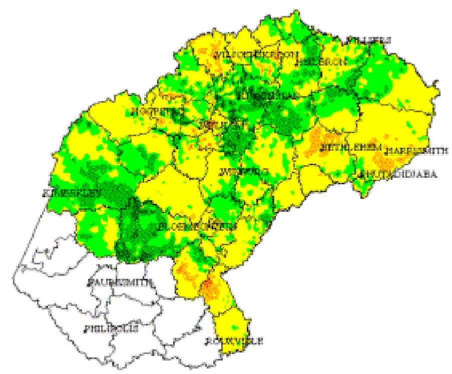


Figure 43b

Figure 43c

Figure 43 Differences in simulated maize yields (kg/ha) from actual climate inputs and climate inputs provided by the SPA-model (Figure 43a), SPAR-model (Figure 43b) and the SPA-PDO-model (Figure 43c) for the 1998/99 season

6.6 Simulated yields for 1999/2000

The 1999/2000 season was characterized by yields of more than 3000 kg/ha (Figure 44a, yellow and green) for the entire northern and eastern parts of the Free State (Figure 44a). There was on average an under estimation of yields by all three models (compare Figure 44a with Figures 44b, 44c and 44d). The SPA-model underestimated (brown, Figure 45a) the yields with more than 1000kg/ha on about 58.04% of the area and about 31.67% within the -1000 kg/ha to +1000 kg/ha range (Table 24 and Figure 45a, yellow). On only about 10.3% of the area the yields were over estimated (Table 24 and Figure 45a, green) The SPAR-model under estimated the yields on about 53.3% of the area, correctly on about 32.95% of the area and overestimated on about 13.76% of the area (Table 24 and Figure 45b). The SPA-PDO-model estimated the yields within the -1000kg to +1000 kg correctly on about 45.29% of the area, under estimated yields on about 48.03% of the area and over estimated it on less than 7% of the area (Table 24 and Figure 45c).

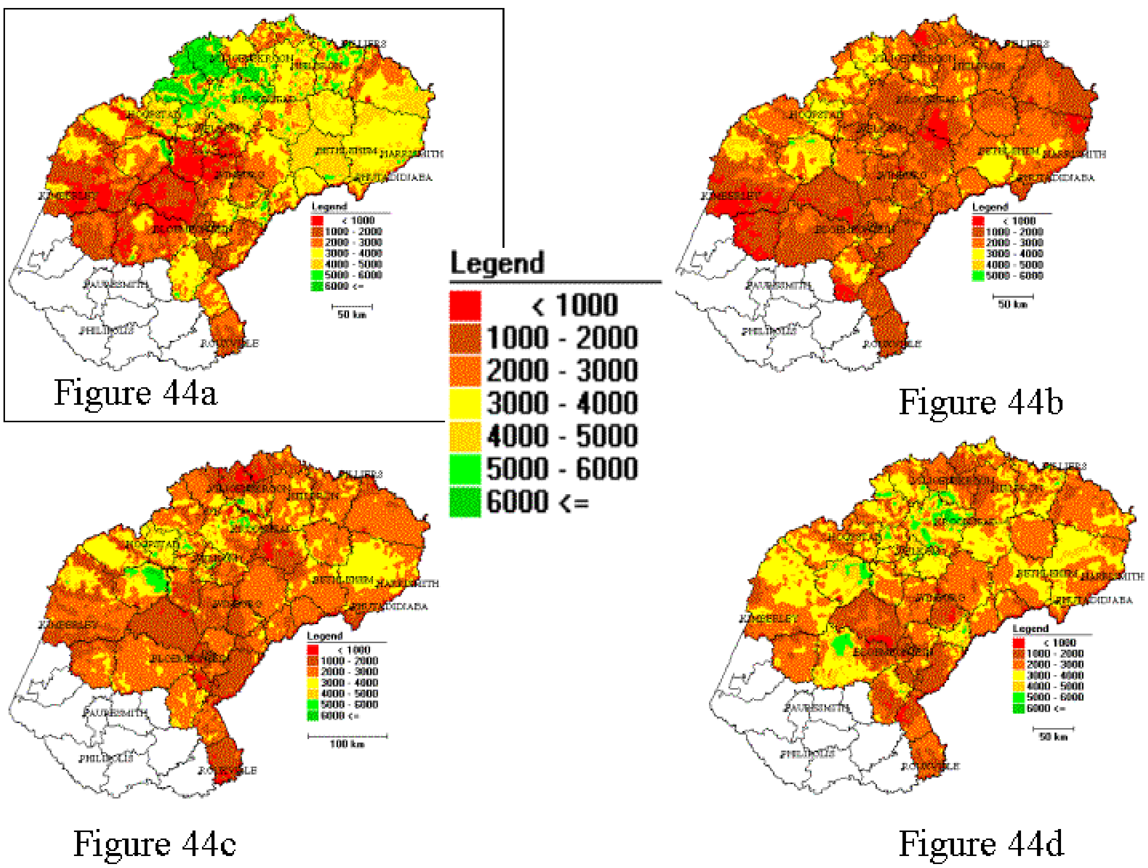


Figure 44 Maize yields (kg/ha) simulated by the CERES-MAIZE model for the 1999/2000 season for the Free State using actual rainfall and associated climate elements (Figure 44a), rainfall and associated climate elements provided by the SPA-model (Figure 44b), rainfall and associated climate elements using the SPAR-model (Figure 44c) and rainfall and associated climate elements using the SPA-PDO-model (Figure 44d)

Table 24 Geographical percentage area of the Free State Province covered by deviations (kg/ha) from actual simulated yields (SPA-, SPAR- and SPA-PDO-model of seasonal rainfall outlook) for the 1999/2000 season

Deviation from actual simulated yields (kg/ha)	% of area of the Free State SPA	% of area of the Free State SPAR	% of area of the Free State SPA-PDO
< -4001	6.94	3.61	0.54
-4000 to -3001	11.10	7.17	4.03
-3000 to -2001	15.84	15.32	15.75
-2000 to -1001	24.16	27.20	27.71
-1000 to –1	**20.28**	**19.67**	**28.84**
0 to 1999	**11.39**	**13.28**	**16.45**
1000 to 1999	6.28	8.62	5.91
2000 to 2999	2.78	3.42	0.75
3000 to 3999	0.82	1.27	0.00
4000<=	0.41	0.45	0.00

Table 25 Geographical area (percentage of the total area) of the Free State Province covered by different percentage deviations from actual simulated yields using the SPA-, SPAR-and SPA-PDO-climate outlook models for the 1999/2000 summer season

Deviation from actual simulated yields (%)	% of area of the Free State SPA	% of area of the Free State SPAR	% of area of the Free State SPA-PDO
< -60	14.12	8.05	7.90
-60 to -41	25.92	19.51	29.82
-40 to -21	25.49	31.28	26.49
-20 to -1	**12.46**	**14.09**	**12.90**
-0 to 19	**5.55**	**6.56**	**6.46**
20 to 39	2.81	3.48	4.00
40 to 59	1.97	2.68	2.37
60 <=	11.69	14.36	10.07

The estimates in terms of percentage deviation from actual yields, provided areas correctly (within the -20% to +20% range) estimated on about 18.01% of the area using the SPA-model, 20.65% using the SPAR-model and 19.36% of the area using the SPAR-PDO-model (Table 25). All three models tend to under estimate yields with the SPA-model under estimating 65.53% of the area, the SPAR-model about 58.84% and the SPA-PDO-model about 64.21% of the area.

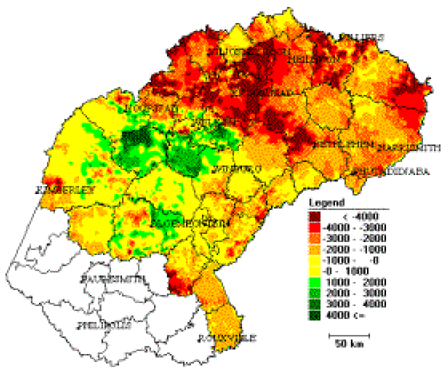
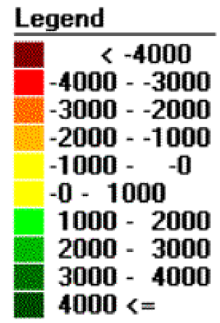


Figure 45a



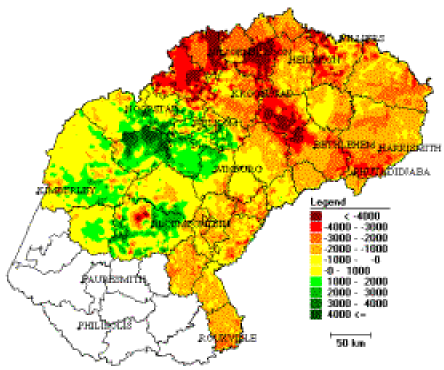


Figure 45b

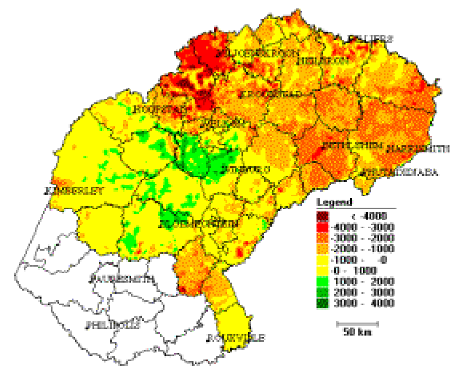


Figure 45c

Figure 45 Differences in simulated maize yields (kg/ha) from actual climate inputs and climate inputs provided by the SPA-model (Figure 45a), SPAR-model (Figure 45b) and the SPA-PDO-model (Figure 45c) for the 1998/99 season

6.7 Summary of results

6.7.1 Average deviations

According to Table 26, the SPA-PDO-model estimated on average about 50% of the area correct (within the –1000kg/ha to +1000 kg/ha deviation range) for the five seasons while both the SPA- and SPAR-models estimated smaller areas correctly. The 1997/98-season was characterised by an El Niño event. Although all three models estimated the total rainfall for the six month period satisfactorily, the yield estimates were not of the same level of accuracy. The 1997/98-season was characterised by very low rainfall totals (Figures 32, 33, 34 and 35, green line) during the first part of the summer (October – December) and very high totals for the January-March 1998 period, averaging more or less normal for the six months. This same trend does not reflect in the simulated yield values. The SPA-PDO-model of providing climate outlooks estimated the area within the limits of –1000kg to +1000kg deviation much better than the other two models (Table

26). The only explanation is a better distribution of rainfall over time, most probably within months, which corresponds with sensitive growth and development stages.

The 1995/96-season was in general seriously underestimated by all three models. From Figure 22 it is however evident that the rainfall totals were underestimated, especially in the midsummer months (Figures 33, 34 and 35, compare green lines (actual) and estimated by the three models (blue, black and yellow)).

Table 26 Geographical percentage area of the Free State Province covered by deviations between –1000kg/ha and +1000kg/ha (area correct), deviations of more than +1000kg/ha (under estimated) and deviations less than –1000kg/ha (over estimated) of the SPA-, SPAR- and SPA-PDO-model of climate inputs used in simulations compared to actual simulated yields

Season	***% area "correct" (-1000kg to + 1000kg)***			***% area under estimated (> 1000kg)***			***% of area over estimated (< 1000kg)***		
	SPA	***SPAR***	***PDO***	***SPA***	***SPAR***	***PDO***	***SPA***	***SPAR***	***PDO***
1995/96	15.8	26.3	**33.0**	83.3	71.3	53.2	0.9	2.4	13.8
1996/97	46.7	53.8	**71.7**	27.7	23.0	23.2	25.6	23.2	16.0
1997/98	40.0	32.5	**49.8**	45.0	53.9	13.6	15.0	13.6	10.0
1998/99	39.4	33.9	**54.7**	5.0	7.9	58.2	55.6	58.2	41.5
1999/00	31.7	33.0	**45.3**	58.0	53.3	13.8	10.3	13.8	6.7
Average	**34.7**	**35.9**	**50.9**	**43.8**	**41.9**	**32.0**	**21.5**	**22.1**	**17.0**

Chapter 7: Testing for Significance

7.1 Introduction

Visual differences between results generated by the different models are evident but is it statistically significant to distinguish between the different models. The chaotic nature of geographic distribution of rainfall due to thunderstorm activity and topographical features, will always impose “unexplained” variability. It is however important to determine the extent of rainfall variability in terms of the normal distribution and skewness (in other words to determine if there is reliability in the forecasts and secondly to test for a constant under or over estimation of the measured values).

7.2 Skewness

A distribution of measures is normal in shape if the sum of cubes of the deviations above the mean is equal to the sum of cubes of deviations below the mean (Downie & Heath, 1970). The total sum of cubes of the deviations will be zero and skewness will also be zero. This test is included to give a measure of the character of the distribution of rainfall and yields. The importance however is that it just gives a measure of the shape of the distribution in terms of the mean of each individual data set and not in terms of the deviation from the general mean.

7.2.1 Rainfall (October – March totals)

Rainfall totals derived from different outlook models, described in Chapter 6, are evaluated against actual rainfall. The extent of areas covered by deviations from actual rainfall is grouped into 20% deviation intervals. In Table 27 the skewness of deviations is computed. It is expected to have a normal distribution to accommodate rainfall deviations with below and above normal rainfall due to the chaotic character of rainfall. Skewness in terms of rainfall deviations from normal for each of the three models indicates that the SPA-model were significant different from zero (skew) in four of the five years. Only the 1998/99 season produced a significant normal distribution (bold figures) taking the standard error of skewness into account (Table 27) for the SPA-model. The SPAR-model produced a much better distribution with only two of the five seasons producing significant skewness of rainfall with rainfall of three seasons more or less normally distributed. The SPA-PDO-model also produced skew results in four of the five seasons. The SPAR-model produced the lowest average skewness figure of 0.869 followed by the SPA-PDO-model with 1.150 and the SPA-model with 1.366.

Table 27 Test for skewness of rainfall deviation intervals (mm) from actual rainfall for rainfall totals provided by the SPA-, SPAR- and SPA-PDO-rainfall outlook models for the five summer seasons form 1995/96 to 1999/2000

Season	**Skewness SPA**	**Skewness SPAR**	**Skewness SPA-PDO**	**Standard error of skewness**
1995/1996	1.141	**0.724**	0.847	0.845
1996/1997	1.579	1.427	1.516	0.845
1997/1998	1.869	1.156	1.639	0.845
1998/1999	**-0.225**	**-0.526**	**0.163**	0.845
1999/2000	2.018	**0.512**	1.583	0.845
Average	**1.366**	**0.869**	**1.150**	**0.845**

Figures 46, 47 and 48 give graphic indications of the skewness of deviations for the three models. The SPAR-model (Figure 47) visually also gives a less skew distribution of deviations than the SPA- (Figure 46) and the SPA-PDO- (Figure 48) models. The average skewness over the five seasons is plotted in Figure 49, indicating more clearly the more normal distribution of deviations by the SPAR-model compared to both the SPA- and SPA-PDO-models.

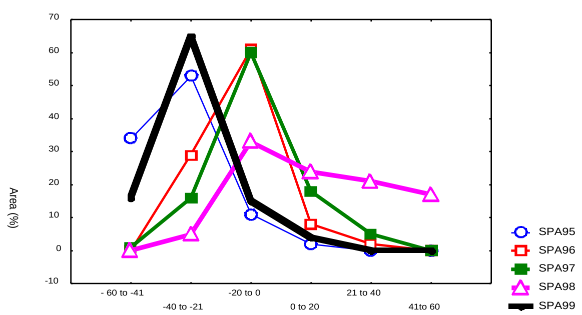


Figure 46 Percentage area covered by percentage deviation intervals from actual rainfall for the SPA-model for the summer seasons 1995/96 to 1999/2000 for the Free State

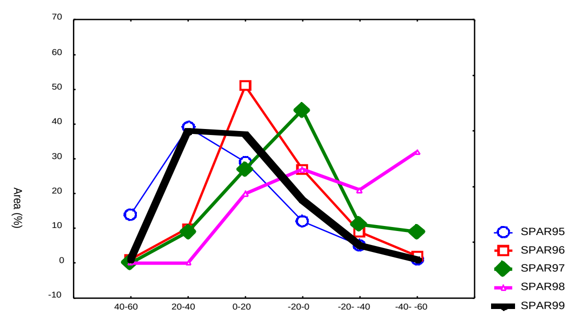


Figure 47 Percentage area covered by percentage deviation intervals from actual rainfall for the SPAR-model for the summer seasons 1995/96 to 1999/2000 for the Free State

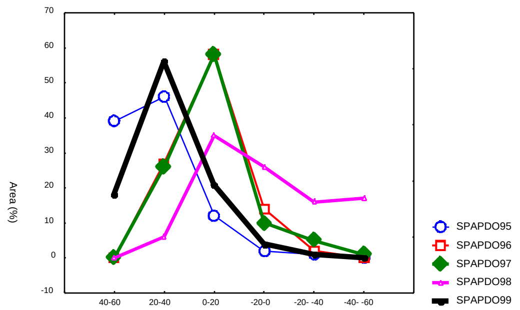


Figure 48 Percentage area covered by percentage deviation intervals from actual rainfall for the SPA-PDO-model for the summer seasons 1995/96 to 1999/2000 for the Free State

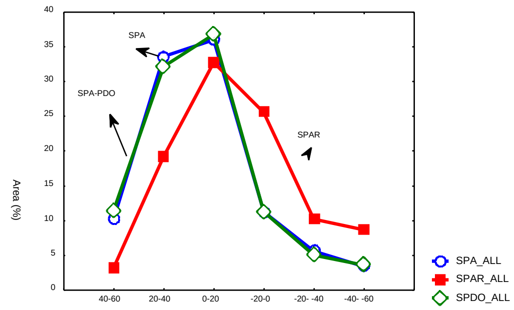


Figure 49 Percentage area covered by average percentage deviation intervals from actual rainfall for the SPA-, SPAR- and SPA-PDO-model for the summer seasons 1995/96 to 1999/2000 for the Free State

Figure 49 also indicates that there is a general tendency of positive skewness (tail extending to the right), indicating a longer tail or more extended range of intervals towards the right . The SPAR-model estimates the actual rainfall the least skew, meaning the intervals on both sides of the mean are more or less equal.

7.2.2 Simulated maize yields

Geographically simulated maize yields, using climate data produced by the different climate outlook scenarios and actual climate, produced some contrasting results compared to total season rainfall for the same situation. In Table 28, the SPA-model produced non-skew results in four out of the five seasons with only the 1997/98 season being skew (under estimating, Figure 50).

Table 28 Test for skewness of rainfall deviation intervals (mm) from actual rainfall for rainfall totals provided by the SPA-, SPAR- and SPA-PDO- rainfall outlook models for the five summer seasons form 1995/96 to 1999/2000

Season	**Skewness SPA**	**Skewness SPAR**	**Skewness SPA-PDO**	**Standard error of skewness**
1995/1996	**0.392**	**0.293**	0.842	0.687
1996/1997	**0.560**	1.022	1.412	0.687
1997/1998	0.997	**0.550**	1.238	0.687
1998/1999	**0.504**	**0.682**	1.282	0.687
1999/2000	**0.521**	0.823	0.823	0.687
Average	0.595	0.674	1.119	0.687

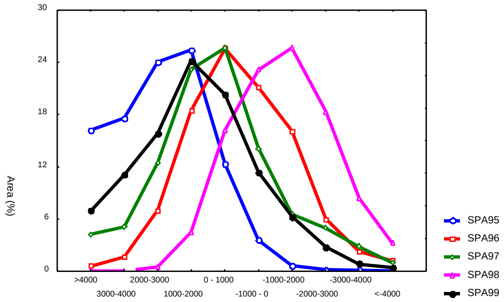


Figure 50 Percentage area covered by percentage deviation intervals from actual yields for the SPA-model for the summer seasons 1995/96 to 1999/2000 for the Free State

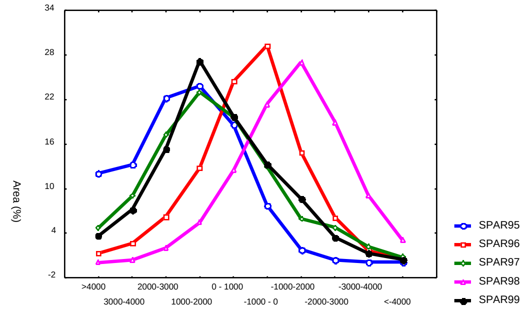


Figure 51 Percentage area covered by percentage deviation intervals from actual yields for the SPAR—model for the summer seasons 1995/96 to 1999/2000 for the Free State

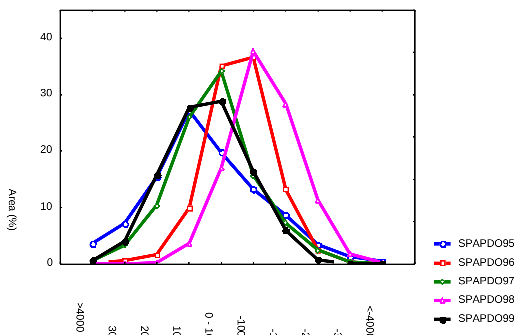


Figure 52 Percentage area covered by percentage deviation intervals from actual yields for the SPA-PDO-model for the summer seasons 1995/96 to 1999/2000 for the Free State

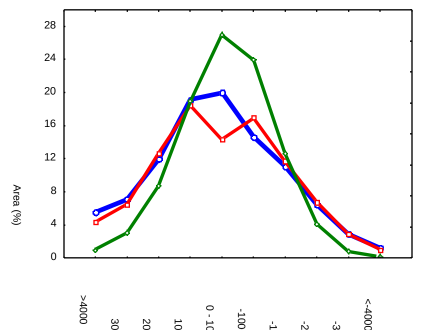


Figure 53 Percentage area covered by average percentage deviation intervals from actual rainfall for the SPA-, SPAR- and SPA-PDO-model for the summer seasons 1995/96 to 1999/2000 for the Free State

7.3 Equality of two multinomial distributions

7.3.1 Rainfall (October – March totals)

The assumption is made that the rainfall outlook intervals received on specific areas of the Free State were more or less the same as the actual rainfall during the five seasons. The use of the test for equality of two multinomial distributions does not take spatial distribution into account. Rainfall amounts were independent of geographical distribution and only compare the percentage area covered by a specific rainfall interval. For example: A specific rainfall interval (say 400-500mm) taken from the actual rainfall of the Free State may cover an area of 30% of the total area. The area covered by the interval in concentrated in the eastern part of the Free State. The rainfall provided by the outlooks may also cover an area of 30% with rainfall between 400-500mm, but in the western Free State. In terms of the distribution trend, it appears to have a 100% agreement BUT in terms of geographical distribution it totally disagrees.

Testing for equality of two distributions is done by using a variation of the Chi-square test (Q) as proposed by Mood *et al*, 1963, resulting statistics can be seen in Table 29. Figure 54 also indicates that the rainfall distributions provided by the outlooks in general were non representative of the active distribution as is also evident in Table 29 with high non significance of following the distribution of the actual rainfall.

The actual rainfall interval distribution of 1996/97 season (Figure 55) were estimated very well by the SPAR-model being significant at P = 0.25 level. The rainfall interval distribution of the 1997/98 season also were estimated best by the SPAR-model (Figure 56) and being significant at P=0.05 level while the 1998/99 season (Figure 57) were best estimated by the SPAR-PDO-model being significant at the P=0.1 level. The 1999/2000 season (Figure 57) saw a relative skew actual rainfall interval distribution and none of the three models were able to follow the actual trend significantly.

Table 29 Chi-square test results for testing equality of two multinomial distributions of rainfall amounts in 100mm intervals for rainfall provided by the SPA-, SPAR-, and SPA-PDO-models in terms of the actual rainfall

	SPA		**SPAR**		**SPAR-PDO**	
Season	**Q**	**P**	**Q**	**P**	**Q**	**P**
1995/96	100.13	ns	196.30	ns	106.62	ns
1996/97	39.70	ns	8.48	0.250	37.17	ns
1997/98	25.56	0.995	5.46	0.050	37.88	ns
1998/99	11.29	0.500	22.03	0.975	6.92	0.100
1999/2000	57.00	ns	52.77	ns	56.55	ns

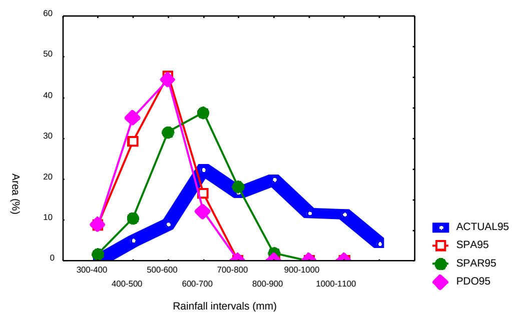


Figure 54 Distribution of percentage areas receiving specific rainfall intervals (100mm intervals) for the 1995/96-season for actual rainfall (blue line), SPA- (red line), SPAR- (green line) and SPA-PDO (purple line) rain outlooks

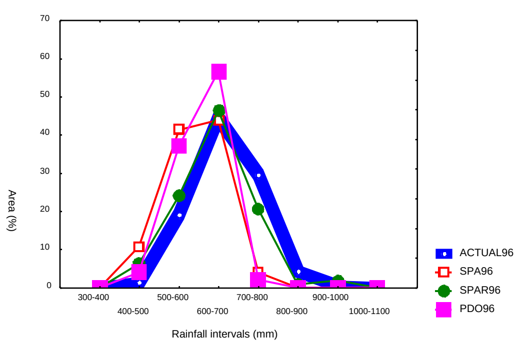


Figure 55 Distribution of percentage areas receiving specific rainfall intervals (100mm intervals) for the 1996/97 season for actual rainfall (blue line), SPA- (red line), SPAR- (green line) and SPA-PDO (purple line) rain outlooks

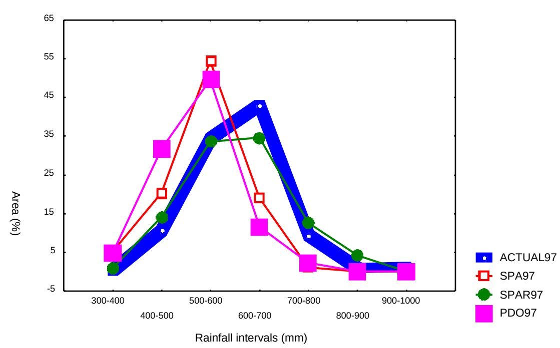


Figure 56 Distribution of percentage areas receiving specific rainfall intervals (100mm intervals) for the 1997/98 season for actual rainfall (blue line), SPA- (red line), SPAR- (green line) and SPA-PDO (purple line) rain outlooks

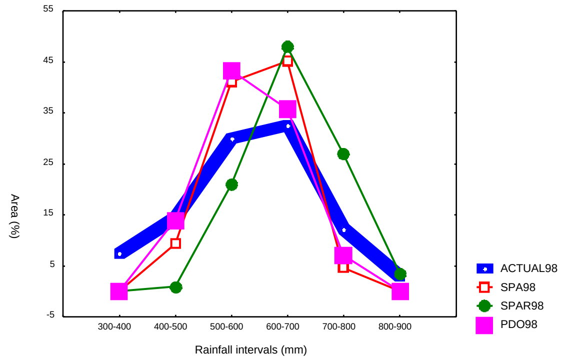


Figure 57 Distribution of percentage areas receiving specific rainfall intervals (100mm intervals) for the 1998/99 season for actual rainfall (blue line), SPA- (red line), SPAR- (green line) and SPA-PDO (purple line) rain outlooks

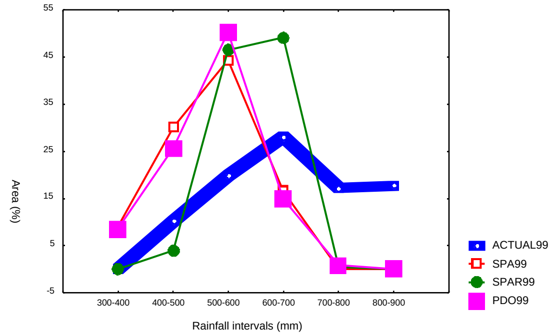


Figure 58 Distribution of percentage areas receiving specific rainfall intervals (100mm intervals) for the 1999/2000 season for actual rainfall (blue line), SPA- (red line), SPAR- (green line) and SPA-PDO (purple line) rain outlooks

7.3.2 Yield intervals

The same assumptions are made as with testing the rainfall intervals. Table 30 provides the statistics.

The yield intervals for the 1995/96 season were poorly estimated by all three models with the SPAR-model making the best attempt (although non-significant) to estimate the yield interval of actual yields (Table 30 and Figure 59). The 1996/97-season was estimated very good by all three models with the SPA-model gives highest significance (Table 30 and Figure 60). Figure 61 indicates that the 1997/98 season were not estimated good in terms of the actual yield interval distribution with only the SPA-model significantly representative of actual intervals at the P = 0.995 level (Table 30). The 1998/99 season were estimated relatively good (Figure 62) with the actual yields given a relative skew distribution with peak between 1000 and 2000kg/ha. The 1999/2000 season were also not estimated within significant range (Table 30 and Figure 63).

Table 30 Chi-square test results for testing equality of two multinomial distributions of maize yield intervals provided simulation of yield by the SPA-, SPAR-, and SPA-PDO-models in terms of the actual simulated yields over all years

	SPA		SPAR		SPAR-PDO	
Season	**Q**	**P**	**Q**	**P**	**Q**	**P**
1995/96	62.70	ns	34.23	ns	66.60	ns
1996/97	1.83	0.050	4.73	0.250	3.10	0.100
1997/98	18.03	0.995	23.50	ns	25.28	ns
1998/99	14.65	0.975	10.10	0.750	18.78	ns
1999/2000	38.46	ns	28.72	ns	45.17	ns

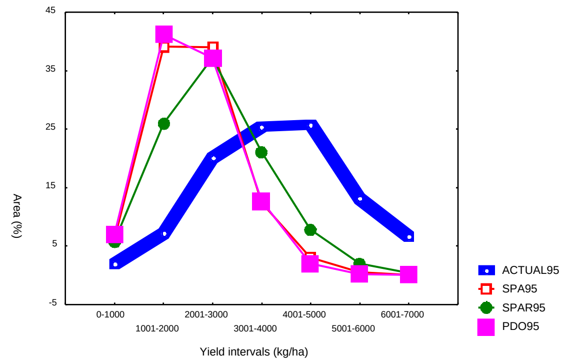


Figure 59 Distribution of percentage areas with specific yield intervals (1000 kg/ha intervals) for the 1995/1996 season for actual yields (blue line), SPA- (red line), SPAR- (green line) and SPA-PDO (purple line) yields from climate outlooks

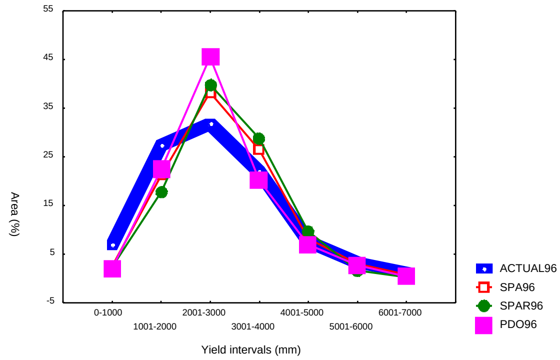


Figure 60 Distribution of percentage areas with specific yield intervals (1000 kg/ha intervals) for the 1996/1997 season for actual yields (blue line), SPA- (red line), SPAR- (green line) and SPA-PDO (purple line) yields from climate outlooks

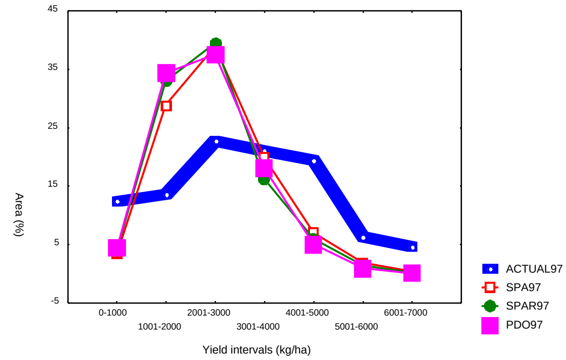


Figure 61 Distribution of percentage areas with specific yield intervals (1000 kg/ha intervals) for the 1997/1998 season for actual yields (blue line), SPA- (red line), SPAR- (green line) and SPA-PDO (purple line) yields from climate outlooks

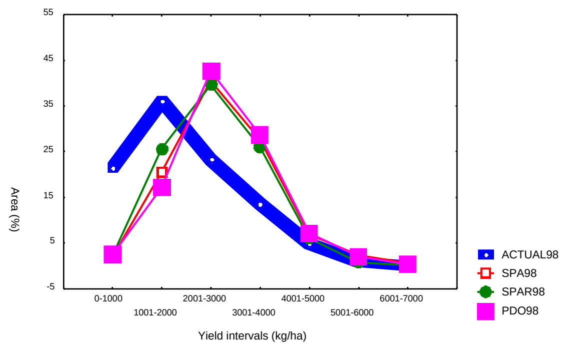


Figure 62 Distribution of percentage areas with specific yield intervals (1000 kg/ha intervals) for the 1998/1999 season for actual yields (blue line), SPA- (red line), SPAR- (green line) and SPA-PDO (purple line) yields from climate outlooks

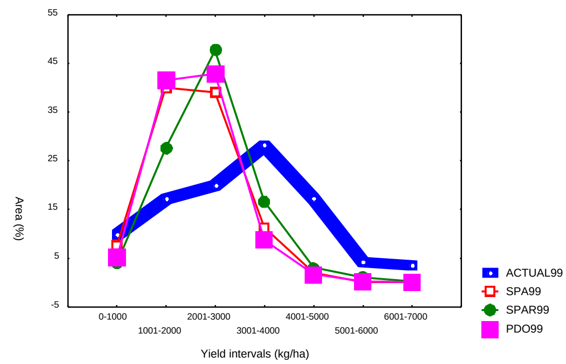


Figure 63 Distribution of percentage areas with specific yield intervals (1000 kg/ha intervals) for the 1999/2000 season for actual yields (blue line), SPA- (red line), SPAR- (green line) and SPA-PDO (purple line) yields from climate outlooks

7.4 Model fit

7.4.1 Seasonal total Rainfall

The geographically averaged rainfall totals for the 6 month periods for the five seasons for the actual as well as rainfall generated by the SPA-, SPAR- and SPA-PDO-models is calculated and can be seen in Table 31.

The Willmott index of agreement for the rainfall generated by the three models compared to the actual rainfall gives:

d(SPA) = 0.347
d(SPAR) = 0.348
d(SPA-PDO) = 0.340

Table 31 Geographically averaged rainfall totals for the Free State for the period 1 October – 31 March for 5 seasons provided by actual rainfall and rainfall totals generated by the SPA-, SPAR- and SPA-PDO-models

Season	Actual rainfall	SPA	SPAR	SPA-PDO
95/96	624.8	392.9	425.8	387.2
96/97	539.5	465.8	461.0	453.9
97/98	460.9	414.8	439.6	418.4
98/99	438.4	466.9	476.0	463.8
99/00	558.7	392.2	403.8	394.9
Average	**524.5**	**426.5**	**441.2**	**423.6**

The index of agreement is about the same for all 3 models, yielding a d-value of between 0.34 and 0.35.

7.4.2 Yield estimates for the Free State

Using the method of De Jager *et al.* (1998), the average yield estimate for the Free State is simulated for the 5 seasons using the actual climate data as well as the daily climate data generated by the SPA-, SPAR- and SPA-PDO-models. The actual yields for the Free State were taken as the values given by the Crop Estimates Committee of the RSA and the actual simulated values were also compared to the actual yields.

Table 32 Average yields of maize (kg/ha) for the Free State for the seasons 1995/96 till 1999/2000 using actual yields given by the Crop Estimates Committee, simulated yields using actual daily climate data, simulated yields using climate data generated by both the SPA- and SPAR-models as well as deviations from actual yields

Harvest Year	Actual yields (kg/ha)	Actual climate simulated yield (kg/ha)	SPA-climate simulated yield (kg/ha)	SPAR-climate simulated yield (kg/ha)	SPA-PDO climate simulated yield (kg/ha)
1996	2971	4052.789	2289.038	2714.863	2177.936
1997	2267	2627.596	2905.161	2805.661	2802.688
1998	2433	3077.851	2691.019	2427.428	2482.250
1999	2523	2115.218	2846.405	2644.655	2801.578
2000	3219	3153.350	2190.977	2396.787	2132.416
Average	**2682**	**3005.361**	**2584.52**	**2597.879**	**2479.374**

The Willmott index of agreement for the average yields for the Free State generated by the three models compared to the actual yields (simulated) and measured give:

d(SPA)	=	0.130	(simulated) and actual(observed)	=	0.000
d(SPAR)	=	0.339	(simulated) and actual(observed)	=	0.231
d(SPA-PDO)	=	0.160	(simulated) and actual (observed)	=	0.084

The index of agreement between actual yields and actual simulated yields is d = 0.61. The SPAR-model of climate outlooks seems to give higher agreement values than either the SPA- and the SPA-PDO-model.

Chapter 8: Conclusion

8.1 Rainfall

The SPAR-model provided the least skew rainfall interval estimates and also tends to follow more closely the rainfall interval distribution of the actual rainfall for the Free State than both the SPA- and SPA-PDO-models. Estimates of rainfall totals however were more or less the same for all three models. The SPAR-model also gives the highest geographically correct estimates of rainfall with an average of about 58% of the area within a –20% to +20% deviation from actual rainfall over the season. All three models tend to underestimate rainfall totals for the season except for the 1999/2000 season.

Strong signals in terms of the SOI or sea surface temperature deviations from normal, tends to give more stable rainfall outlooks.

8.2 Yields

The SPA-model seems to have an advantage over the other two models in terms of estimating similar yield intervals (of actual simulated yields) as well as the lowest degree of skewness. The Willmott index of agreement however indicates that the SPA-model estimates the actual yields with the lowest index of agreement.

The bottom line is that the yield interval estimates were estimated the best by the SPA-model but the model is unable to estimate actual yields geographically correct.

The SPA-model therefore is the best in estimating yield interval distribution but the SPAR-model are the best in estimating yields geographically correct.

8.3 Conclusion

The modeling approach must be used with discretion. Strong external signals, like the SOI and sea surface temperatures, tend to give better estimates but geographically still lacking in exact estimates. The SPAR-model seems to have an advantage in forecasting geographically specific but the SPA-model can be used with greater ease due to a more normal distribution and a better indication of yield intervals.

8.4 Recommendations

The need for reliable climate (and especially rainfall) outlooks as indicators of expected agricultural conditions is becoming more important. The South African farmer relies on his own financial resources to secure a crop and with the increasing pressure of higher input or cost of production, the risk for the farmer also is becoming higher. It is of vital importance to have information regarding the expected climate conditions for a specific season at hand before the final decision making process, that is before the planting process. The farmers must decide between different options:

- Is it viable to plant at all?
- Which kind of crop must he plant?
- Within a crop, which variety will be best suited for a specific season? For example if the farmer decided to grow maize must he plant short or long season varieties?
- What will be the optimum planting density, fertilizer application rate and planting date?

Timing of rainfall is of utmost importance in securing a crop. A few days can mean the difference between crop failure and a record yield.

Future research must be focused more towards forecasting timing of rainfall events than forecasting of rainfall totals.

Crop specific climate outlooks must get more attention. It is of little value to the decision maker to accurately forecast “correctly” for a only part of the growing season. An example is a three month outlook which only covers part of a growing season. The climate requirements of a crop like soya beans differs from the requirements for a crop like maize. Of importance however is that timing of rainfall and extreme events like frost or heat conditions must be quantified before the start of the season.

A very important part of the early warning process is the accurate assessment or monitoring of farming conditions. Spatial interpolation of rainfall and climate information is very important to get the status of initial conditions as well as progress during the season. Construction a more representative rainfall collection network is very important.

The most important part of an early warning or preseason information system is the communication to the end user. If a two way flow between the farmer (rainfall co worker) and the operation centre is established, the farmer will also take ownership of the information.

References

Adey, A.D. and Andrew, M.G. 1990. Getting it right. The managers guide to business communication. p. 1-9. Juta & Co. Ltd.

Allan, R., Lindesay, J. & Parker, D., 1996. El Niño Southern Oscillation & Climate Variability. CSIRO Publishing, Collingwood, Australia.

Anon, 2000. Forecasts of Tropical Pacific SST Using Ensemble Neural Network Models. http://www.ocgy.ubc.ca/projects/clim.pred/past/model_2.2.html.

Babbie, E. 1989. The practice of social research. Wadsworth Publishing company, Belmont, California.

Bembridge, T.J. and Tshikolomo, K.A. 1998. Communication and decision making among fruit growers in the Phaswana area of Northern province. *S. Afr. J. Agric. Ext. 27:19-29.*

Bittner, J.R. 1985. Fundamentals of communication. Englewood Cliffs, New Jersey: Prentice-Hall.

Blench, R. 1999. Seasonal climate forecasting: Who can use it and how should it be disseminated? September, World Bank funded workshop titled "Users responses to seasonal climate forecasts in southern Africa: what have we learned" was convened in Dar es Salaam, Tanzania.

Chagnon, S.A. 1992. Contents of climate predictions desired by agricultural decision makers. *J. Appl. Meteorol. 31: 1488-1491.*

De Bruin, L.P.& Human, J.J., 1976. Die gevoelige periodes vir interne plantvogstremming tydens die groei en ontwikkeling van *Zea mays. Agroplantea*, 8:77-82

De Jager, J.M., 1988. PUTU12-8 Maize growth simulation model. Unpublished source code. Department of Agrometeorology, University of the Orange Free State, Bloemfontein.

De Jager, J.M., Potgieter, A.B. & Van den Berg, W.J., 1998. Framework for forecasting the extent and severity of drought in maize in the Free State province of South Africa. *Agric. Systems* 57: 351-365.

Downie, N.M. & Heath, R.W., 1970. Basic statistical methods. Third edition. Harper & Row Publishers, London.

Dumesnil, D., 19??. Epic User's Guide – Draft. Unpublished report. United States Department Of Agriculture Research Service and Grassland, Soil and Water Research Laboratory, Texas.

Du Pisani, L.J., Erasmus, J.F. & Koch, F.G.L., (19??). Best planting dates for maize. Unpublished Report. Institute for Soil, Climate & Water. Pretoria.

Glantz, M.H. 1977. The value of long-range weather forecast for the West African Sahel. *Bull Am. Meteorol. Soc. 58: 150-158.*

Gommes, R. 1999. Special Agroclimatic concepts: Climate Risk Management.

http://www.fao.org/sd/eidirect/agroclim/riskman.htm

Hill, A. and Watson, J. 1997. A Dictionary of Communication and Media Studies. Arnold, London, 4. ed. p. 251 ISBN 0-340-67635-3 , 09/97

Jones, C.A., Kiniry, J.R., Farmer, D.B., Dyke, P.T., Godwin, D.C., Parker, S.H., Ritchie, J.T. & Spanel, D.A., 1986. CERES-MAIZE: A simulation model of maize growth and development.

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

Landman, W.A., Mason, S.J., Tyson, P.D. & Tennant, W.J., 2001. Retro-active skill of multi-tiered forecasts of summer rainfall over Southern Africa. *International Journal of Climatology*: 21: 1: 1-19.

Lomus, J., Milford, J.R. and Mukhala, E. 2000. Education and training in agricultural meteorology: current status and future needs. *Agric. Forest Meteorol. 103 197-208.*

Lyakhov, A.A. 1994. Analysis of economic benefits of short term, medium term and long term forecasts. WMO/TD – No 630 Geneva 278-280.

Mantua, N.J. & Hare, S.R., 2000. The Pacific Decadal Oscillation.. http://tao.atmos.washington.edu/pdo/

Marais, H.C. 1979. Kommunikasie in kleingroepe. Bloemfontein: P.J. De Villiers.

Marume, W. and Garanganga, B.J. 1997. Drought monitoring centers (Activities, outputs, and linkages into other early warning systems). In Drought Preparedness and Management for Western African Countries, Banjul, The Gambia.

Mason, B.J. 1996. The role of meteorology in national economy. *Weather* (November) 382 – 393.

Mclelland, L., 1994. Climatic variability and outlooks for maize production in South Africa. Project Summary for the National Maize Producers Organisation.

Mitchell, J.M., 1964. A critical appraisal of periodicities in climate. CAED, Report No.2. Iowa State.

Mjelde, J.W., Sonka, S.T., Dixon, B.L. and Lamb, P.J. 1988. Valuing forecast characteristics in a dynamic agricultural production system. *Am. J. Agric. Econ. 70: 674 – 684.*

Mjelde, J.W., Thompson, T.N., Nixon, C.J. and Lamb, P.J. 1997. Utilising a farm level decision model to help priotise future climate prediction research needs. *Meteorol. Appl. 4: 161 – 170.*

Mood, A.M., Graybill, F.A. & Boes, D.C., 1963. Introduction into the theory of statistics. McGraw-Hill International Bok Company, Third Edition.

Mosley, M.P. 1994. Economic and social benefits of meteorological and hydrological services to the water sector. WMO/TD – No 630 Geneva 78-82.

Mukhala, E. and Groenewald, D.C. 1998. Experiences and perceptions of Black small-scale irrigation farmers in the Free State. *S. Afr. J. Agric. Ext., 27:1-18.*

Nicholls, J.M. 1996. Economic and social benefits of climatological information and services: A review of existing assessments. WCASP – 38, WMO/TD 78: 37pp.

O'Brien, K. Sygna, L., Otto Naess, L., Kingamkono, R. and Hochobeb, B. 2000. Is information enough? User responses to seasonal climate forecasts in southern Africa. Report to the World Bank, AFTE1-ENVGC. Adaptation to climate change and variability in sub-saharan Africa, Phase II. Report 2000:3 ISSN: 0804-4562.

Partridge, I.J., 1994. Will it rain? The effects of the Southern Oscillation and El Niño on Australia. Information Series Q194015. Department of Primary Industries, Queensland, Australia.

Power, S., Casey, T, Folland, C., Colman, A & Mehta, V., 1999. Inter-decadal modulation of the impact of Enso on Australia. *Climate Dynamics* 15:319-324.

Power, S., Tseitkin, F., Mehta, V., Lavery, B., Torok, S. & Holbrook, N., 1999. Decadal climate variability in Australia during the twentieth century. *Int. J. Climate* 19: 169-184.

SADC, 2000. SADC Food Security Programme. www.zimbabwe.net/sadc-fanr/intro.htm
.

SAWB, 2000. South African Weather Bureau. Forecast for October, November and December. www.weathersa.co.za

Schulze, G.C., 1989. Seisoensvariasies van reënval oor die somerreënvalstreke van Suid-Afrika. Unpublished M.Sc. Thesis. University of Pretoria.

Steward, J.I., 1990. Response farming in rainfed agriculture. Abstract. Wharf foundation press. Davis, California.

Steward, J.I. & Hash, C.T., 1982. Impact of weather analysis on agricultural production and planning decisions for the semi-arid areas of Kenya. *J. Applied Meteorol*., 21. 477-494.

Stone, R.C., Hammer, G.L. & Marcussen, T., 1996. Prediction of global rainfall probabilities using phases of the Southern Oscillation Index. *Nature*, 384, 252- 255.

Terblanche, F.H. and Mulder, D. 2000. Communication and Technology Transfer. *MVL 712 Lecture Notes. 60pp*

Tubbs, S.L. and Moss, S. 1994. Human Communication. New York: McGraw-Hill.

Turner, B., 1994. Small-scale irrigation in developing countries. *J. Land Use Policy 11 (4) 251-261.*

Tyson, P.D., & Dyer, T.G.J., 1978. The predicted above-normal rains of the seventies and likelihood of drought in the eighties. *S.A. J. Sc.* 74, 312-377.

Van den Berg, W.J., 2000. Climate and Agriculture report 1 of 2000. Unpublished report, Free State Department of Agriculture, Glen.

Weiss, A., Crowder, L. Van and Bernardi, M. 1999. Communicating agrometeorological information to farming communities: The role of the new information technologies. In Proceedings of the International Workshop on Agrometeorology in the 21st Century: Needs and Perspectives. Accra, Ghana, 15-17 February 1999.

Wenburg, J.R. and Wilmont, W.W. 1973. The personal communication process. New York: John Wiley & Sons.

Whitman, R.F. and Boase, P.H. 1983. Speech communication. Principles and context. Macmillan Publishing Co., inc. New York.

Willmott, C.J., 1981. On the validation of models. *Physical Geography, 1981, 2,2 : 184-194.*

Wimmer, R.D. and Dominick, J.R., 1991. Mass media research: An introduction. Wadsworth Publishing company, Belmont, California.

WMO. 2000. Media Issues. http://www.wmo.ch

Yopp, J.J. and McAdams, K.C., 1999. Reaching Audiences. A Guide to Media Writing. 2nd ed. ISBN 0-205-28622-4.

Appendix I

QUESTIONNAIRE ON COMMUNICATION OF SEASONAL CLIMATE FORECASTS

VRAELYS IN VERBAND MET KOMMUNIKASIE VAN SEISOENALE KLIMAAT VOORSPELLINGS

COMPLETE AND RETURN IN ADDRESSED ENVELOPE (NO POSTAGE NEEDED)
VOLTOOI EN STUUR TERUG IN GEFRANKEERDE KOEVERT (GEEN POSGELD NODIG)

MARK IN THE BLOCKS MARKED 1, 2, 3 …
MERK IN DIE BLOKKIES GEMERK 1, 2, 3 …

1 Gender/*Geslag*

(a) Male/*Manlik*	1
(b) Female/*Vroulik*	2

2 What is your age/*Ouderdom*

(a) under 25 years/*onder 25 jaar*	1
(b) 26 – 46 years/*26 – 46 jaar*	2
(c) 47 – 59 years/*47 – 59 jaar*	3
(d) Above 60 years/*Bo 60 jaar*	4

3 What is your occupation?/*Beroep*

(a) Farmer – full-time/*Boer – voltyds*	1
(b) Extension / Researcher/*Voorligtingsbeampte / Navorser*	2
(c) Agribusiness/*Agri-besigheid*	3
(d) Farmer – part-time/*Boer – deeltyds*	4

4 What farm activities are you involved in?/*By watter boerderybedrywighede is u betrokke?*

(a) Crops/Akkerbou	1
(b) Livestock/*Vee*	2
(c) Mixed farming/*Gemengde boerdery*	3
(d) Other/*Ander:* Specify/*Spesifiseer:*	4

5 What is the size of your farm?/*Wat is die grootte van u plaas?*

(a) 0 – 49 ha/*0 – 49 ha*	1
(b) 50 – 499 ha/*50 – 499 ha*	2
(c) Above 500 ha/*Bo 500 ha*	3
(d) Not applicable/*Nie van toepassing*	4

6 What is your turnover in rands per year?/*Wat is u omset in rand per jaar?*

(a) R0 – 10 000	1
(b) R10 001 – 100 000	2
(c) R100 001 – 500 000	3
(d) Above/*Bo* – R500 000	4

7 Do you receive any seasonal climate forecasts?/*Ontvang u tans enige seisoenale klimaat voorspellings?*

(a) Yes/*Ja*	1
(b) No/*Nee*	2
(c) No but I would like to/*Nee, maar ek sal graag wou*	3
(d)I don't know anything about seasonal climate forecasts/*Ek weet niks omtrent seisoenale klimaat voorspellings*	4

8 Through which media do you receive the seasonal climate forecasts?/*Deur middel van watter media ontvang u die seisoenale klimaatsvoorspellings?*

(a) Fax / Post/*Faks / Pos*	1
(b) News paper/printed pamphlet/*Koerant / Gedrukte pamflet*	2
(c) Television/*Televisie*	3
(d) Radio/*Radio*	4
(e) E-mail/*E-pos*	5
(f) Other/*Ander* Specify/*Spesifiseer*	6

9 Through what media would you prefer to receive the seasonal forecasts?/*Deur middel van watter media sou u graag die seisoenale klimaatsvoorspellings wou ontvang?*

(a) Fax / Post/*Faks / Pos*	1
(b) News paper/printed pamphlet/*Koerant / Gedrukte pamflet*	2
(c) Television/*Televisie*	3
(d) Radio/*Radio*	4
(e) E-mail/*E-pos*	5
(f) Other/*Ander* Specify/*Spesifiseer*	6

10 How much value do you put on the seasonal climate forecast information?/*Hoeveel waarde heg u aan die seisoenale klimaatsvoorspellings inligting?*

(a) Very important/*Baie belangrik*	1
(b) Important/*Belangrik*	2
(c) Unsure/*Onseker*	3
(d) Not important/*Nie belangrik*	4

11 Do you trust seasonal climate forecasts?/*Vertrou u die seisoenale klimaatsvoorspellings?*

(a) All the time/*Altyd*	1
(b) Most of the times/*Meestal*	2
(c) Some times/*Somtyds*	3
(d) Not at all/*Geensins*	4

12 Do you understand the terminology in which the seasonal climate forecasts are presented?*Verstaan u die waarin die seisoenale klimaatsvoorspellings aangebied word?*

(a) Understandable/*Verstaanbaar*	1
(b) Not understandable/*Nie verstaanbaar*	2
(c) A bit understandable/*Gedeeltelik verstaanbaar*	3
(d) Needs to be simplified/*Moet eenvoudiger gemaak word*	4

[redacted]

13 "Normal rainfall is expected." Do you understand the above statement?/*"Normale reënval word verwag." Verstaan u die bogenoemde stelling*?

(a) Yes/*Ja*	1
(b) No/*Nee*	2
(c) Vaguely/*Vaagweg*	3

14 The meaning of normal rainfall is/*Die betekenis van normale reënval is*

(a) Average over a long period of time/*Gemiddeld oor 'n lang Tydperk*	1
(b) Highest rainfall/*Hoogste reënval*	2
(c) Good rainfall/*Goeie reënval*	3
(d) Low rainfall/*Lae reënval*	4

15 "The probability of normal rainfall is 50%" Do you understand the above statement?/*"Die waarskynlikheid vir normale reënval is 50 %." Verstaan u bogenoemde stelling?*

(a) Yes/*Ja*	1
(b) No/*Nee*	2
(c) Vaguely/*Vaagweg*	3

16 What is the meaning of the following "probability of normal rainfall is 50%"/*Wat beteken die volgende "die waarskynlikheid vir normale reënval is 50 %"*

(a) Chance of rainfall being 50mm/*Kanse vir reënval 50mm*	1
(b) Chance of receiving _ the normal rainfall/*Kans om die helfte van die normale reënval te kry*	2
(c) Chance of getting normal rainfall in 50 % of the years/*Kanse om normale reënval te kry in 50 % van die jare*	3
(d) Chance of rainfall in 50 years/*Kanse vir reënval in 50 jaar*	4

17 Are you able to use the seasonal climate forecasts in planning your farm activities?/*Kan u die seisoenale klimaatsvoorspellings in die beplanning van u boerderybedrywighede gebruik?*

(a) For some activities/*Vir sommige aktiwiteite*	1
(b) For all activities/*Vir alle aktiwiteite*	2
(c) I don't know how/*Weet nie hoe nie*	3
(d) I don't use it/*Gebruik dit nie*	4

18 If a drought is forecast, do you make adjustments to your activities?/*As 'n droogte voorspel word, maak u veranderings in u aktiwiteite?*

(a) All the time/*Altyd*	1
(b) Most of the times/*Meestal*	2
(c) Some times/*Somtyds*	3
(d) Not at all/*Geensins*	4

19 Do you make a deliberate effort to obtain forecast information ?/*Poog u om voorspellingsinligting te bekom?*

(a) All the time/*Altyd*	1
(b) Most of the times/*Meestal*	2
(c) Some times/*Somtyds*	3
(d) Not at all/*Geensins*	4

20 Would you consider paying for seasonal climate forecasts?/*Sal u dit oorweeg om te betaal vir seisoenale klimaatsvoorspellings?*

(a) Yes/*Ja*	1
(b) No/*Nee*	2
(c) Will consider/*Sal dit oorweeg*	3
(d) Depends on cost/*Hang af van koste*	4

Thank you very much for your time in completing the questionnaire

Baie dankie vir u tyd om die vraelys te voltooi

Appendix II

Seasonal Outlook for Southern Africa
September 2000

Issued by the LOGIC, SA Weather Bureau, 22-09-2000

The **AIM** of this seasonal outlook is to provide the best possible information on future rainfall and temperature conditions (on a seasonal time scale) to reduce the risk in economic and social decisions.

Weather and Climate

The potential of climate prediction arises not from timing and location of individual weather events, but for averages over months and seasons. Climate forecasts are distinctly different from weather forecasts, because they cover relatively large regions over longer time-spans. The weather at particular points and at specific times may sometimes appear to contradict the climate forecast.

Limitations of Seasonal Forecasts

Probabilities: The forecast is given as the probability (in percent) for each of the three categories (above, normal, below) to occur over a certain region. Probability forecasts can only be useful or less useful, but never right or wrong. The category with the highest probability (see in the example) is the most likely to occur, although there are also lesser probabilities for each of the other two categories.

50*
30
20

Normal: The normal is NOT the seasonal average, but an interval for a particular region. For instance, the normal interval (rainfall) for Gauteng during January is between 95 and 129 mm. In the example, there is a 50% chance that the rainfall will be more than 129 mm (above-normal), a 30% chance that it will be between 95 and 129 mm (near-normal) and a 20% chance that the rainfall will be less than 95 mm (below-normal). These normal intervals are available from the LOGIC.

Confidence: The higher the confidence in the forecast, the higher the assigned probability will be for that specific category to occur.

Area: It is NOT possible to make useful seasonal forecasts for small, localised areas, because local climate variations and topography cannot be simulated accurately with global climate models. Furthermore, it should be remembered that the boundary between forecast regions should be considered as a transition zone.

Good or bad season? A forecast of above-normal rainfall does not necessarily mean it will be a “good year”, because the distribution of rainfall over time (WHEN it rains) makes a difference. The same argument is valid for below-normal rainfall and a “bad year”. At present seasonal forecasts do not incorporate the distribution of rainfall over time.

The climate of Southern Africa is influenced, amongst other, by the variability in sea-surface temperature (SST) in the region of the equatorial Pacific Ocean. El Niño is associated with anomalously high SSTs in this region, and La Niña with anomalously low SSTs.

SSTs during the past month (observed):	**SSTs during the coming months (forecast):**
No significant changes. SSTs in the equatorial Pacific near the date line are still near-normal to slightly below-normal, depicting a weak La Niña.	The weak La Niña is expected to persist up to the end of 2000, while near-normal SST anomalies in the equatorial Pacific can be expected to continue into autumn. A warming in the Agulhas SSTs are expected during the coming months.

The Southern Oscillation Index (SOI) for August: 0.4

TEMPERATURE OUTLOOK for South Africa, Namibia, Lesotho, Swaziland and Botswana

Mean for October to December 2000:
Over the western half of the forecast region (see map) the mean temperature during this period is expected to be near-normal to above-normal (40% probability each). The eastern parts of the forecast region (see map) can expect below-normal temperatures (50% probability, with a 30% chance of near-normal).

Mean for January to March 2001:
The western parts of Namibia and South Africa (see map) can expect the mean temperature during this period to be above-normal (50% probability, with a 30% chance of near-normal), while the remainder of the forecast region can expect below-normal temperatures (50% probability, with a 30% chance of near-normal).

RAINFALL OUTLOOK for South Africa, Namibia, Lesotho, Swaziland and Botswana

Total: October+November+December 2000
The eastern parts of South Africa (see map) can expect near-normal rainfall conditions (50% probability, with a 30% chance of above-normal) during the forecast period. Above-normal rainfall conditions (50% probability, with a 30% chance of near-normal) are expected over the remainder of the forecast region.

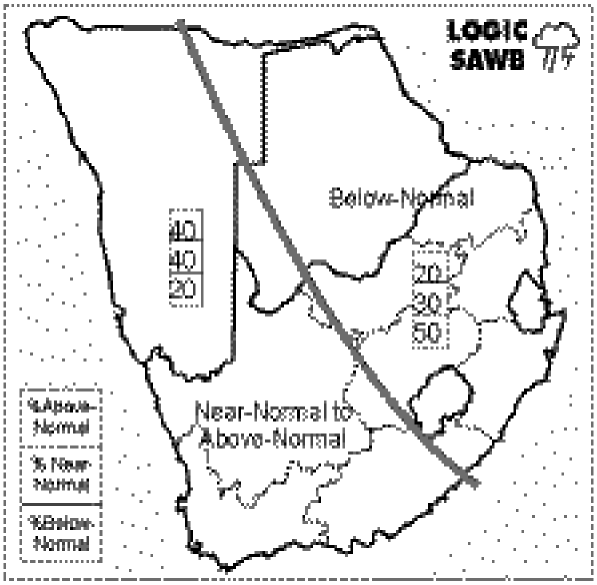
Total: January+February+March 2001
The southeastern and central parts of the forecast region (see map) can expect near-normal to below-normal rainfall conditions (40% probability each) during this period, while near-normal to above-normal rainfall conditions (40% probability each) can occur over the remainder of the region.

DISCLAIMER

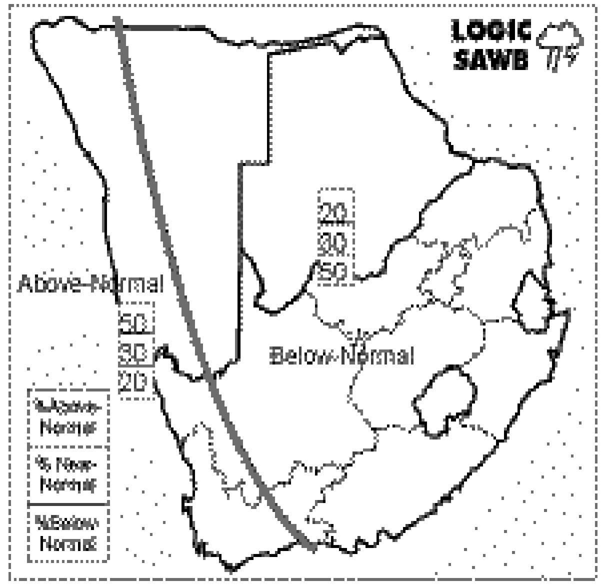
(Next update: 22 September 2000)
Most of the forecast products of the SAWB are available from Travelphone's fax-on-demand system: phone 082-232-5600 from your fax machine.
If you experience problems with this system, please contact the LOGIC.

For more information on seasonal outlooks, or for an interim 4-week outlook, feel free to contact the Long-term Operational Group Information Centre (LOGIC) at tel **082-233-9000** (**08:00 - 12:00**) or fax (012) 323-4518.
A pamphlet on how this outlook is compiled is available on request.
Address: LOGIC, Room 5057, SA Weather Bureau, Private Bag X097, Pretoria, 0001
E-mail: logic@sawb.gov.za
Internet Homepage: **http://www.sawb.gov.za/rgscs/index.htm**
For a **daily weather forecast (1-7 days)** contact the forecaster on duty: 082-233-9800

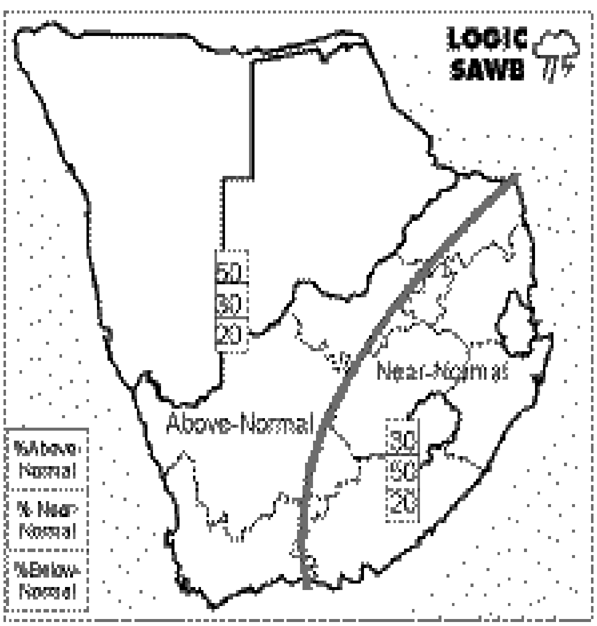
This product is compiled by using model output from models developed at the SA Weather Bureau and the University of the Witwatersrand, as well as at the International Research Institute for climate prediction (IRI).



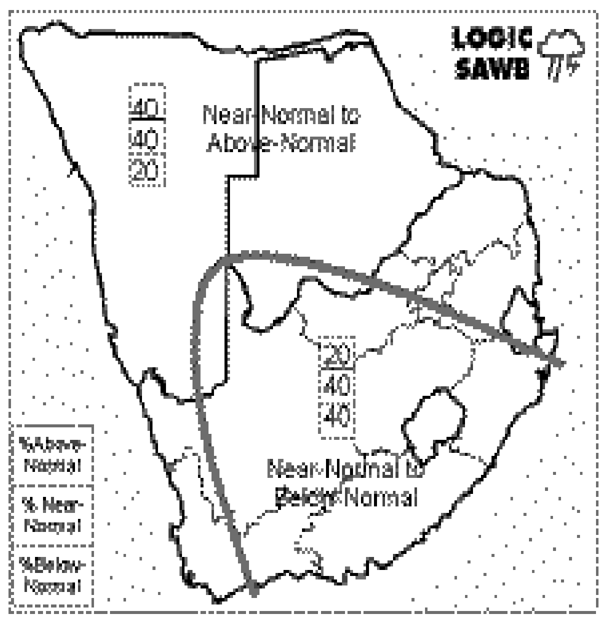
Expected mean temperature
for October to December 2000



Expected mean temperature
for January to March 2001



Expected total rainfall for
October-November-December 2000



Expected total rainfall for
January-February-March 2001

Appendix III (a)

Communication of seasonal climate forecasts between meteorological scientists and farmers in the Free State Province

Mukhala, E., Walker, S. and Van Den Berg, W.J.
University of the Orange Free State, Department of Agrometeorology, P.O. Box 339, Bloemfontein 9300, South Africa.

Summary
The effectiveness of meteorological communication is determined by the extent to which all persons involved in the communication transaction are competent in communicating and interpreting meteorological messages. The aims of the research were to investigate if farmers receive seasonal climate forecasts, if farmers understand the terminology in the forecasts and characteristics that could influence the understanding of seasonal climate forecasts. A questionnaire was prepared addressing the aims and administered to small-scale and commercial farmers in the Free State province of South Africa. The questionnaires were in some cases completed with the help of extension officers as the respondents answered the questions. They were posted to commercial farmers and other users to complete. They were analysed quantitatively and statistical inferences drawn. The data analysed comprised of 286 respondents of which 189 were involved in full-time farming, 18 were extension and research officers probably involved in farming, 31 were in agribusiness and 49 were involved in farming on part-time basis. Respondents were put to a test to ascertain whether farm size or farm turnover had an influence on understanding and utilisation of seasonal climate forecasts. The results indicate that with regard to farm size, small-scale farmers had less understanding abilities than those with larger farms did. However, when farm turnover was taken into account, the low and medium category had less understanding of the terminology in the seasonal climate forecasts but those with a turnover over R500 000 had not problems with the terminology. This implies that those who invest a lot money in farming had a lot of interest in seasonal climate forecasts information. However, it is important that small-scale farmers are educated with regard to interpretation of seasonal climate forecasts for sustainable food security. Unless the communication model, and in particular the importance of shared meanings between encoder and decoder, is understood by those that disseminate information, communication will always be a stumbling block.

Appendix III (b)

Puisano ka tjhebelopele ya maemo a lehodimo mahare ha boramatlhe le balemi profensing ya Foreisetata

Mukhala, E., Walker, S and Van Den Berg, W.J.
University of the Orange Free State, Department of Agrometeorology, P.O. Box 339, Bloemfontein 9300, South Africa.

Khutsufatso
Ho atleha ha puisano ka bolepi ho fihlellwe ha bohle ba amehang puisanong ya ho qaqabolla molaetsa o tlhahiswawa wa maemo a lehodimo. Maikemisetso maholo a dipatisiso ke hore a balemi dohle ba amohela tjhebelopele ya maemoa a lehodimo le ho ananela se bolelwang. Patlo-maikutlo ena e entswe ele ho fihlella balemi ba potlana profensing ya Foreisetata mon Afrike Borwa. Dipotso tsena, karolong tse itseng di arakibilwe ka thuso ya balemisi. Dipotso tsena di rometswe ho balemi le badirisi ba dikuno tsa temo ho di araba. Ba arabileng ebile ba 286, ho bona 189 e nnile balemi ba nako e tletseng, ba 18 ya ba balemisi, ba 31 e bile bagwebi ka dikuno tsa temo mme ba 49 ebile ba lemang mme bana le tiro tse itseng tse ba di etsang ntle le temo. Ho botsiwe dipotso jwalo ele ho leka ho netehatsa hore a boholo ba polasi kgotsa ditjheho di na le kamano mo ho ananela le ho sebedisa tjhebelopele ya maemo a lehodimo. Ditlamoraho di supa hore boholo ba polasi, molemi e monyane hona le molemi e moholo ona le tsebo e nyane mme fa ho ananelwa ditjheho, balemi ba ba nyane ba tlhoka tsebo ya puo e sebediswang tjhebelongpele ya maemo a lehodimo, mme ho ba ditjheho tse hodima ha R500 000 ha ho bothata ho ananeleng. Sena se bolela hore ba beeletsang haholo mo temong ba na le tjheseho ho tseba tjhebelopele ya maemo a lehodimo.
Jwale ho tlhokohalo hore molemi e monyane a rutwe ho anananela tjhebelopele ya maem a lehodimo ho tiisetsa hore ha hona tlhokeho ya dijo. Ntle le hore mogwa wa puisano e bebefatswe, bothata botla tswelele ho ba teng.

Appendix IV (a)

Seasonal Climate Forecasts

Rossouw, A. and Mosetlho, F.
South African Weather Bureau, Bloemfontein Forecasting Office, South Africa.

Introduction

The potential of climate prediction arises not from timing and location of individual weather events, but from averages over months, seasons and beyond. The climate forecasts are distinctly different from weather forecasts because they cover relatively large regions over longer time-spans. The weather at particular points and at specific times may sometimes appear to contradict the climate forecast.

Different models and the products they produce:

The S A Weather Bureau (SAWB) operates two supercomputers, a J-90 (Since September 1996) and SV-1 (Since November 1999). This computing powers permits running a general circulation model (GCM) for extended-rage applications. The two used are the COLA (Center for Ocean-Land-Atmosphere Studies) and the NCEP (National Centers for Environmetal Prediction), implemented locally as the Global Spectral Model (GSM).

14 Day Forecasts

The GSM model:

Update two-week forecasts is available every Monday.
-Rainfall is mapped as a probability of the amount exceeding a threshold.
-Maximum and minimum forecast for each cluster
-Windspeeds and direction
-Cloud cover output in % for low, middle and high cloud.
(Monthly forecasts)

The COLA model:

This model is used mainly to study ocean-atmosphere processes and to produce monthly forecasts. Monthly forecasts based on the COLA have been produced by the SAWB since 1995. The GCM is initialized over weekends to produce a monthly forecast on every Sunday.

Seasonal forecasts:

Alternative (cheaper) ways to fully use GCM's has been adopted by the RGSCS. The multi-tiered system consists of four tiers. The first is predicting sea-surface temperatures using statistical method, next the GCM is integrated using the predicted SST"S as a lower boundary forcing, then large scale circulation fields forecast by the GCM are downscaled to regional rainfall using a statistical method and finally forecast guidance from various models are combined to produce a probability forecast.

A GCM that is used to forecast the atmosphere for periods longer than a month requires predicted sea-surface temperatures (SSTs). Studies have shown that seasonal forecast skill may be largely attributed to slowly varying lower boundary forcing (Shukla, 1981). Near-global SST anomalies are shown to be predictable, using Canonical Correlation Analysis (CCA) (Barnett and Preisendorfer, 1987), up to several seasons in advance.

The first tier involves preparing the forecast SSTs for the GCM. In the second tier the COLA GCM is integrated forward 8 months from initial conditions. The third tier utilizes statistical methods where large-scale circulation fields generated by the GCM are downscaled to specific rainfall regions. CCA (Canonical Correlation Analysis) is used to perform the downscaling process in a "perfect prognosis" approach. CCA regression equations are trained using observed circulation and regional rainfall.
The final tier comprises a monthly discussion between the long-term forecasters in the RGSCS, Inputs from various statistical and dynamical models both locally and around the world are gathered and a probability forecast is generated.

ENSO Parameters:
Measuring oceans: Sea-surface temperature (SST)
El Nino events are associated with positive SST anomalies.

The Walker circulation:
Measuring the atmosphere: (Southern Oscillation).
The Southern Oscillation index (SOI) gives a simple measure of the strength and phase of the anomalous sea-level pressure difference between Tahiti (mid-Pacific) and Darwin (Australia).

Global impact:
Impact on southern Africa:
El Nino seasons below rainfall.. La Nina normal to above normal rainfall over southern parts of Africa. It cannot be accepted as a rule. One should be careful not to make a general rule for rainfall and temperature changes in ENSO years over Southern Africa. Note how not all El Nino seasons gave rise to below-normal rainfall, and not all La Nina seasons to above-normal rainfall.

Forecasting El Nino:
Scientists use statistical and general circulation models to see how the climate is expected to behave in coming months. The tendency of the ENSO parameters is therefore important. The SOI (The Southern Oscillation Index) and the SST (Sea-Surface Temperature).

Sea-Surface Temperature forecasts:- SST Forecasts:
The Global Ocean Principal Oscillation Pattern (POP) forecast:

Global Ocean POP model output:
The Global Ocean Canonical Correlation Analysis (CCA) Forecast:
Global ocean CCA model output:
Seasonal Predictions of Rainfall:
The SA Weather Bureau Canonical Correlation analysis (CCA) Rainfall Model:

The IRI/CRG Quadratic Discriminant Analysis Model (QDA) Rainfall Forecast:
Principal components of sea-surface temperature in the Atlantic and Pacific ocean south 20 south, and in the Indian Ocean are calculated.

QDA Model Output Maps:

Forecasts available: What and where

There are quite a few products available to the consumer. Some products being use and value added by people outside weather forecasting centers. The South African Weather Service in association with the RGSCS (Research Group for Seasonal Climate Studies) is responsible for the RGSCS bulletin. These products are disseminating through the LOGIC (Long-term Operational Group Information Centre) at the South African Weather Bureau. (Weather Services in future) This supports the goals of the IRI (International Research Institute) and the WMO CLIPS (Climate Information and Prediction Services) programme, which are to construct information products in support to the end-user community.

The RGSCS bulletin includes the following:

*Discussion of the ENSO parameters; *Sea Surface Temperature Forecasts; *Seasonal rainfall predictions over southern Africa; *Seasonal temperature predictions over South Africa

Appendix IV (b)

Tjhebelopele ya selemo ya maemo a lehodimo

Rossouw, T and Mosetlho, F.
South African Weather Bureau, Bloemfontein Forecasting Office, South Africa.

Kakaretso

Tjhebelopele ya maemo a lehodimo ha e etswe ka ho lebella ntla e nngwe fela ya bosa mme ho sebediswa tshobokanyo ya maemo a lehodimo nakong e telele jwale ka dikgwedi le ho ya ho dilemomg. Ena e farohana le bolepi ba tsatsi le letsatsi ho bane boleping ba tsatsi le letsatsi ho sbediswa maemo a bosa nakong ya hona jwale.

Mekgwa e sebediswang ho fana ka tjhebelopele ya nako e telele

Ho sebediswa mefuta e farohane ya dimotele jwale ka COLA (center for ocean-land-atmosphere study) le NCEP (national centers for enviromental prediction) le GSM (global spectral model) ho hlahisa tjhebelopele. Ho tjhebelopele ya malatsi a 14 e bong dibeke tse pedi ho sedishwa GSM model, ho bolepi ba kwedi ho sebedishwa COLA model. Tjhebelopeleng ya selemo ho sebediswa GCM, mona ho etswa tjhebelopele ya motjheso ka SST model mme ka mora mona ho sebediswe COLA, GCM ho etsa ponelopele ya paka e telele.

ENSO:

Ho lekanyetswa ha motjheso hodimo ha lewatle ho fana ka tsebo ya maemo a ka tlhahellang, mo re amohelang motjheso o hodimo re bolela ka EL NINO mme mo maemo a motjheso a leng tlase re bolela ka LA NINA

EL NINO ke nako e re lemohana maemo a komello kampotsi pula e tsase ha tlwaelo mme La NINA ke nako eo pula e leng hodimo ha tlwaelo mona Afrika Borwa.

Ponelopele ya el nino

Bo ramahlale ba lebello maemo a bosa ho bona se tla dirahale dikgweding tse latelang mme hape ba lebello seo se etsahalang lewatleng le borwa. Ka ho sebedisa SST model ho lepa motjheso. Ha balemoho nyoloho motjhesong ba fana ka tlhahiso ya hore maemo a loketse ho etsahala ha EL NINO.

Ponelopele ya pula selemong

Bero bosa Afrika Borwa e sebdisa dimodele tse fapafapaneng jwalo ka CCA model, OCN model le QDA model ho lepa pula.

Mefuta e fapafaneng ya ponelopele e ka fumanwa ho kae

RGSCS eleng (research group for seasonal climate studies) e fana ke mefuta e farolohameng ya ponelopele.Ho kafumana dikwalo ho tshwana le :-

Kopa le le kantoro ena:
Logic, (Room 5057), South African Weather Service, Private Bag x097, Pretoria, 0001
Mohala : 0822339000 fax : 012-3234835 www.weathersa.co.za
HA O TLHOKA HO KA AMOHELA KA FAX: 0822325600

Ponelopele ya matsatsi a supa

Ho sebediswa maemo a lehoding a nako eo ho simollwang, mme a bapisiwe le seo dimodele di se bontshang. Ho tlhoha moo ho latelwa seo dimodele jwalo ka ECMWF le EGRR di se supang.

Appendix V (a)

Presentation skills: What does it take to communicate effectively?

Van Rheede van Oudtshoorn, G.P.
University of the Orange Free State, Department of Communication and Information Studies , P.O. Box 339, Bloemfontein 9300, South Africa.

---

1. INTRODUCTION

To communicate is one of the most basic behavioural components of human interaction. Without the human communication that we have grown to know, we would not be able to understand each other or convey necessary information regarding our everyday activities. But even though communication is one of the basic components of our society and human existence, it has become one of the most complex societal components. I daresay that if you want to make sure that you communicate effectively, you will find that the communication process becomes even more complex and that you need to work hard at getting your message across in the way that you intended to get it across. But I do not mean to discourage any communicator – speech anxiety is hard enough to deal with (to name one interference). What I want to make clear is that in order to make sure that you communicate effectively, you have to understand the communication process in the context in which it takes place to make sure that you actually share meaning.

Now, we can ask the question: "When do I communicate effectively?" The answer is not a simple one. I am sure that effectiveness cannot merely be defined in terms of making sure that the receiver of your message received the message without distortion. When we communicate we do more than just convey information. We try our utmost to share meaning with our communication partners. The problem lies in the understanding of the message that we transmitted to the receiver. Sometimes the receiver gives a whole different meaning to the message that the sender of the message intended it to have. We call this phenomenon miscommunication and it is a great danger in our communication with others, especially during intercultural communication. That is why it is so important to communicate effectively: we want the receiver of our messages to not only understand the words that we wanted to convey, but also the unsaid meaning that accompanies the words (like for instance our friendly intentions, or perhaps even our anger). To become the type of communicator that achieves this goal, you need awareness of the nature of communication and have some form of experience in excellent effective communication.

2. THE DYNAMIC COMMUNICATION PROCESS

You might have noticed that I not only stated that you need to gain experience as an effective communicator, but as an excellent effective communicator. Do not be afraid: it is not as difficult as you think. You do not need to attend a hundred workshops to be an excellent communicator. If you have the basic understanding of what it takes to communicate effectively and you keep it in mind, you can practice it every time you come in contact with another person. But effective communication is not only an activity to be practised, it is a dynamic process that constantly needs adaptation to make sure that you share the meaning that you intended to share with the receiver.

Let us very briefly have a look at the process before we carry on with the discussion. The communication process consists of specific components. First of all the message starts at the speaker as source. It is the responsibility of the speaker to try and transmit a message. He starts the whole communication process and, simply put, he is the one trying to say something to someone. At the same time he is also receiving messages from the person that he is communicating with. The sender communicates by means of transmitting a message to his communication partner. This message can be one of four things: unintentional verbal, intentional verbal, unintentional nonverbal or intentional nonverbal. We consciously use the intentional verbal message if we want to communicate with others by using words to give meaning to our messages. Sometimes we say things without meaning to (like stuttering or mispronouncing words); those messages are unintentional. The same principle applies to nonverbal communication (all the messages we transmit without words or over and above the words we use). Controlling nonverbal messages is a very difficult task. In communication we use certain channels (like the telephone, the radio, your voice or even our bodily sensory organs) to act as vehicles to carry the message to the recipient. Hopefully your message will reach the recipient via these channels, who will in turn give you feedback on the message that he received.

The problem with our communication process is that interference can step in that will distort the information transmitted to the receiver or distract him from receiving it. The interference can either be technical or semantic by nature. Technical interference is the easiest to sort out, because, more often than not, it can be cancelled or eliminated. Semantic interference has to do with the attribution of a different meaning by the receiver to the message sent by the sender to the receiver.

Do you now realise why it is important to have a good understanding of the communication process? The sharing of meaning is such a simple process on the one hand, but on the other hand you can easily share a totally different meaning without intending to do so. By concentrating on what you communicate, you will lessen the impact of possible interferences on your communication. You should always remember that we communicate to share meaning, and without empathy for the recipient of that message, we can easily share the wrong meaning!

So now that we have dealt with the basics, let us look at a few ways in which you can use this knowledge to be an excellent effective communicator. The first thing I always tell myself while communicating with others is “find out what their communication code is, and use that code to communicate with them”. A communication code is a system of letters or symbols used to form a message – I used the English language as the code to communicate to you as the reader; an actor will use animation or action to communicate to the viewers; we would use a lot of gestures and facial expressions when telling children a story. I want to use the code that the recipient uses and knows well to better my chances at canceling the interference that will make it difficult for the recipient to understand my message the way I wanted him to understand it. If he will understand my message better if I use visual aids, then let me use visual aids! If the recipient will understand me better, or will get the feeling that I am a more credible communicator if I make eye contact with him, then let me do just that. What is important here is to get the message across effectively. To summarize my golden rule, I can say that you should first of all create and establish some common ground between yourself and the recipient, and then carry on communicating.

Perhaps you will tell me now that you understand what I am trying to say to you, but when you communicate you still feel anxious and end up transmitting more unintentional messages than intentional messages. If that is the case, I have a bit of bad news and good news for you: the bad news is that speech anxiety will always be there no matter how experienced you get in the communicative world; the good news is that you can use that anxiety to your advantage. Speech anxiety makes you sharper and keeps you on your toes. You will only have to learn to control it. If you can control speech anxiety, get your message across as you intended it to be received and make the receiver believe that you are a credible and skilful communicator, then you have become an excellent effective communicator.

3. DELIVERY: MAKING AN IMPRESSION

I would like to write more on the communication process and exactly how we can use it to communicate effectively and persuasively, but time does not allow it. I am, however, going to list a few reminders to the future excellent effective communicator. At no time do I claim the following to be complete – the list is merely a support to the memory and an aid to the preparation of the communicator.

In order to make an impression with the delivery of your message; you need to put a little extra effort into the communicative activities that you engage in. To deliver excellently, you need to focus on the total image that you portray as a communicator as well as your message content. Remember the following:

- Prepare very well. Find out what you can about your audience. Perhaps you will find something that will make it easier for you and the recipient to share meaning.
- Use supporting material like statistics to support your message, but remember that the statistics support – you still need to make up the message to help in the effective sharing of meaning.
- Keep your speech short and sweet. If you talk too much after the recipient understood the message, you will do more harm than good.
- Try to hold the attention of the recipient with the use of humour, visual aids (however small and insignificant), eye contact, movement of your body and involving the audience in your presentation (with the help of questions or practical examples).
- Admit your mistakes; if you stutter a little, use humour to relieve the tension. Joke with yourself but do not offend your recipient. Make sure that you use humour that the recipient will understand and find funny.
- Articulate your words so that no one struggles to understand or hear what you are saying. Use enough volume to make sure that it is easy for people to listen to you.

- Concentrate on your use of language. Through good language you can make the recipient see, arouse emotions, bring the members of the audience together, encourage action and help the recipient to remember.
- Vivid and exciting language will help in the motivation of the recipient because that will help you to seem more confident about the information that you are conveying.

4. CONCLUSION

I posed the question "What does it take to communicate effectively?" at the beginning of this retort. The answer is simple: it takes a communicator that has the will to share meaning and plans to practice the art of communicating to become a better communicator. The art of communication lies in the dynamic sharing of meaning through the use of a common code. If we as human beings realise that communication can solve so many problems, bridge so many gaps and overcome so many barriers, the world would be a better place for all. Hopefully the realisation will evolve into the actual phenomenon of sharing meaning.

Appendix V (b)

Moqoqo ka hongwe puisano

Van Rheede van Oudtshoorn, G.P.
University of the Orange Free State, Department of Communication and Information Studies , P.O. Box 339, Bloemfontein 9300, South Africa.

Moqoqo ke karolo ya bohlokwa dikamanong tsa batho. Re ka tsebana hantle hela ha re buisana.. Jwalo he, ho bohlokwa ho bua ka makgethe osa ikgantse.
Re kare puisano ke e makgwethe ha hole jwang. Fela fa e a mametseng a ananelwe se molaetsa o rometsweng o se bolelang. E se hela ho ka bala mafoko a ngotsweng mme o anananelwa molaetsa.

PUISANO E MAKGETHE
E a bolelang ke ena sesosa sa molaetsa, o qala puisano. Molaetsa o ka romelwa ka ho ngola kgotsa ka ho bua. E le ka maikemisetse kgotsa tjhe. Ho tsela tse ngata tse sebediswang ho romela molaetsa, jwale ka telefono, seyalemoya(radio), ditho tsa mmele, jwalojwalo. Karabo e kguhla ka tsona tselana tsena. Ho nepahatsa hore ha ho kgohleleho molaetseng, beya ka matla dintla tse sehlohong molaetseng wa hao. Sebedisa puo e itsahalang ho motheletsi. Sena se ka netefatsa hore ha ho be le ho seutlwane.
PUO HO ETSA PHAPANG
Ho etsa phapang ha o fana ka molaetse tlhokomela dinhla tse latelanga:-

1. Itukise hantle (netehatsa hore momamedi ke mang)
2. Sebedisa ntho tse tshehetsang se o bolelang ka sona.
3. Se be moleele puong, tota ntla ya bohlokwa.
4. Netefatsa hore bamamedi ba utlweletse se o se bolelang jwale ka ho sebedisa metlae Mona le mane, ba lebe mahlong, se sebedisa ditshwantsho tse maleba se o se bolelang.
5. Se etse diphoso puong.
6. Bua ka makgethe.
7. Dirisa puo ele nngwe.
8. Ba le boitshepo ka se o se bolelang. Jwalajwalo..

KHUTSOFATSO
Potso ke ena, ho hlokofalang eng ho ba sebui se tlhwatlhwa. Sebui se lokelwa ho ikemisetsa ho arona kitso e ho ena. Mokgwa wa puo o itshetlehile ho faneng ka puo ka maatla, o sebedisa mokgwa o tlwaelehileng wa puo. He batho ba ka lemoha maatla a puisang ho rarolleng mathata, ha ho se ka ba fenyang.

Appendix VI (a)

Climate outlooks

Van den Berg, W.J.
University of the Orange Free State, Department of Agrometeorology, P.O. Box 339, Bloemfontein 9300, South Africa.

GENERAL

Agricultural production, especially in South Africa, is mainly determined by climatic conditions. For rain fed or dry land production, rainfall is the single most important factor that determines the outcome of a crop. In the past, with highly regulated prices for commodities, production risk (tonnage per hectare) was the only external factor that determined the financial success of the farmer. With the introduction of a total free market system (demand and supply), financial success for the producer is determined by both production and market related factors. A high production often resulted in low prices and vice versa which means a producer will sometimes be able to profit more from lower yields than from a bumper crop. The rapid increase in the cost of input to produce a commodity also increased the financial risk for the producer. The producer as well as input providers and commodity traders, heavily rely on climate outlook information for decision making. Reliable information is the name of the game.

Different institutions and people are currently providing climate outlook information. Due to the chaotic state of the atmosphere and low predictability of weather patterns, the best outlook only can provide some assistance in decreasing the risk for the user. There is no single outlook that can provide in the format and accuracy required by different production systems and users. There are two main categories of outlooks namely a forecast to determine the probability of a specific amount of rainfall for a part of a season (3-6 months) and the second to identify the distribution characteristic of rainfall for a specific season. The latter is more agricultural related due to the sensitivity of agricultural crops to short term weather related factors. Total amount of rainfall for a 3 to 6 month period often shows no correlation with agricultural production. With an indication of the probability of wet and dry spells, the producer now can decide on best planting dates, best varieties, cultivation practices, etc.

WHAT IS EXPECTED FOR THE 2000/2001 SEASON?

Sea surface temperatures

The sea surface temperatures in the Pacific Ocean are near normal, indicating neither an El Niño (warmer than normal) nor a La Niña (cooler than normal) temperatures.

Rainfall

In terms of rainfall outlooks, using Pacific Ocean sea surface temperatures as forecaster, it seams that the rainfall outlook for the next six months is near normal using a monthly calendar time step. Breaking it up into smaller time steps, more skill is however obtained to obtain indications of drier and wetter spells.

Possible dry spells

Little or no effective rainfall is expected up to the middle part of October. It is expected that we can experience a midsummer drought from the second part of December till the last part of January. It is also expected to have a second dry spell, especially in the central to eastern parts in the second part of February.

Possible wet spells

The highest probabilities for good rainfall is expected in the first week of December but especially in the period towards the end of January and first part of February. It is also expected to get enough rain to ensure good planting conditions for summer crops.

Summer crops

It seems that the best planting dates for maize is the "normal" planting dates ranging from the period around 15 October in the extreme east to as late as 15 December in the extreme west. Bearing in mind the current surplus stock of maize in South Africa, the good prospects for a record high maize crop in the USA and the expected midsummer drought, farmers are advised to use only their high potential fields for maize production. Alternative crops for the eastern parts are soya, dry bean and sunflower while alternatives for the drier and warmer central to western parts are a fallow system for part of the production area, sunflower, ground nuts and to a certain extent cotton. It is however not advisable to change on large scale to alternative crops, especially if the farmer does not have the necessary knowledge and equipment to produce an alternative commodity.

Live stock production

Although current conditions are relatively good for this time of the year, low temperatures and the time needed for reproduction after rain, the first real veld production is expected towards the end of the year. Farmers are there for advised not to regard spring rain as "high production veld production". With probable drier conditions in the autumn of 2001, farmers are also advised to sell of unproductive and old animals in time.

SUMMARY

Expected rainfall conditions are on general more or less normal, meaning drier and wetter spells on the traditional times of the year. Due to relative good initial agricultural production conditions, normal rainfall conditions can still mean above normal agricultural conditions. Farmers are therefor advised to ensure that marketing of products and commodities will need special attention in order to manage his farming enterprise as an economically viable unit.

Appendix VI (b)

Ponelopele ya tsa maemo a lehodimo a paka etelele

Van den Berg, W.J.
University of the Orange Free State, Department of Agrometeorology, P.O. Box 339, Bloemfontein 9300, South Africa.

KAKARETSO

Ho hlahiswa ha dikuno tsa temo, haholo-holo Afrika Borwa, ho itshehlehile maemong a lehodimo. Temo mafelong a omeletseng le mafelong a a fumanang pula e ngata, pula ke ntho ya bohlokwa e ka hlahisang ditlamoraho tsa dimela. Nakong ya ho feta, moo hlwahlwa ya dikuno e neng e laolwa haholo, mathata hlahisong ya dikuno ene ele ntlha ele nngwe e ka ntle ee neng e ka bontsha katleho ya ditjhelete ho balemi. Ditlamoraho tsa hlahiso dikuno e feteletseng, ke hlwahlwa tse tlase mme hlahiso e nyane ditjeho ke tse hodimo. Ka selelekela sa hlahiso ee felletseng ya ditlhoko le ya ho fetisa dihlahiswa, katleho ya ditjhelete bakeng sa mohlhise e bontshahatswa ho ya ka metjha e mmedi, e leng ya hlahiso le e ikamahantseng le ditheko. Hlahiso e ngata e baka hore ditjeho di be tlase mme hlahiso e nyane e baka hore ditjeho di be hodimo. Ho bolela hore mohlahisi ka nako tse ding o kgona a etse phaello e ngata ho tswa ditlhahisong tse tlase hona le hlahisong tse ngata. Nyollo e eleng tene kgafetsakgafetsa ditjehong tsa disebediswa tse bileng teng tlhahisong ya dikuno e nyollotse mathata a ditjelete ho bahlahisi. Mohlahisi jwalo fela ka batho ba fanang ka dintho tse thusang tlhahisong mmoho le barekisi, ba itshetlehile haholo maenong a lehodimo bakeng sa ho nka diqeto. Bopaki bo tshepahalang ke se tlhokahalang.

Ditheo tse fapaneng le batho ba fana ka bopaki bakeng sa maemo a lehodimo. Ho latela maemo a a hlobaetsang a lehodimo le tjhebelopele e e sa itshetlehang hantle ya maemo a lehodimo.tjhebelopele e ntle e ka fan ka tshehetso ho fokoseng mathata bakeng sa mosebedisi. Ha hona tjhebelopele le fa ele nngwe e ka kgonang ho ananela ka nepahalo metjha ya tlhahiso e fapaneng mmoho le ho basebedisi. Ho na le mekgahlelo e mmedi ya tjhebelopele e sebediswang e leng ho labella kgoneho ya palo e e nepahetseng ya pula sehleng se itseng.(kgwedi tse 3 B 6) mme ya bobedi ke ho labella ka moo pula e tlhahellang sehleng se itseng. Ena ya bobedi e amahangwa ha hole le dimele ho ya ka boikgeto tsona ha ya ka maemo a lehodimo. Palo ya pula bakeng sa kgwedi tse tharo ho ya ho tse tshelela, ha ngata ha di bontshe kamano le dihlhiswa tsa dimela. Ka pontsahatso ya ho kgonahala ha maemo a mongobo le maemo a komello, mohlahisi o ka nka qeto ho jaleng ka matsatsi a a lokileng, le ho jala mofuta o lokileng wa dimele, jwalajwalo..

KE ENG SE LEBELETSWENG SEHLENG SA 2000/2001

THEMPERETJHA HO DIMO HA LEWATLE

Dithemperetjha lewatleng la Pacific ke tse atamelang tsa tlwaelo, moo ho bontsha hore ELNINO (Dithemperetjha tse feteletseng) kappa LA NINA (Dithemperetjha tse tlase ha tsa kahale) ha di a lebellwa.

DIPULA

Bakeng sa tjhebelopele ya pula, ho sebediswa ditemperetjha lewatleng la Pacific. Ho bonala eka dipula tse lebeletsweng e le tse tlwaelehileng kgweding tse thataro tse lateng ka ho arola tsamaiso ya nako ka dikotwana, mme tsebo e ngata ya tlhokahala ho fihlella matshwao a nako tse mongobo le nako tsa komello.

NAKO EO KOMELLO E KA LEBELLWANG

Ho lebeletswe pula e nnyane ho fihla bohareng ba kgwedi ya mphalane. Ho lebelletswe hape hore re ka fumana komello mahareng a lehlabula ho tloha karolong ya bobedi ya kgewdi ya tshitwe ho fihlella qetelong ya pherekgong. Ho bile hape ho lebeletswe hore re ka ba le komello ya bobedi, ha holo dikarolo tse ka hare tsa naha karolong ya bobedi ya tlhakole.

NAKO TSE HO TLABA MONGOBO

Kgonahalo e hodimo en nepahetseng ya pula e lebelletswe bekeng ya pele ya tshitwe, empa e lebelletswe haholo nakong e lebileng mafelong a Pherekgong le karolo ya pele ya Hlakola. Ho bile ho lebeletswe ho fumana pula e lekaneng ho nepahatsa maemo a ho jala dimela tsa lehlabula.

DIMELA TSA LEHLABULA

Ho bonahala eka dinako tse nepahetseng tsa ho jala poone ke matsatsi a jalo a tlwaelehileng a tlohang ho 15 Mphalane mo tjhabela ho fihlela 15 Tshitwe bophirima. Re ntse re hoopla hore phaello e eleng teng ya poone Afrika Borwa, katleho entle ya dimela tsa poone ho la Amerika le komello e lebeletsweng mahareng a lehlabula, balemi ba eletswa ho sebedisa masimo a maemo a loketseng poone. Dimela tse amanang ka tshebetso bakeng sa botjhabela ke soya, dinawa tse omeletseng le sonobolomo mme dijalo tse amanang bakeng sa komello le motjheso o leng mahareng ho ela dikarolong tse bophirima ho ka jalwa sonobolomo, matokomane le boboya. Ha se keletso e ntle ho fetola dimela ha ngata, ha holo ha molemi a sena tsebo e tebileng le didiriswa tse nepahetseng tsa temo.

TLHAHISO YA LERUO

Le haeba maemo maemo a ha jwale a lokile karolong ena ya selemo, motjheso o tlase le nako e hlokahalang bakeng sa ho hlahisa hape ka mora pula, tlhahiso ya pel ya nnete ya naha e lebeletswe ho ya mafelong a selomo. Balemi jwale eletswa ho se elellwe pula ya lehlbula jwaka ka monyetla wa ditlhhiswa e kgolo ya naha. Ka kgoneho maemo a komello ka hwetla ya 2001, boradipolasi/ balemi ba eletswa hape ho rekisa diphoofolo tse tsofetseng le tse sa kgone ho tswala.

KGUTSUFATSO

Maemo a lebeletsweng a pula a akaretsa haholo kapa ha nyenyane ho tlwaelo, komello le mongobo nakong tse tlwelehileng tsa selemo. Ho ya ka maemo a tlhahiso ya dimela, maemo a pula a tlwaelehile. Balemi ba bile ba eletswa ho nepahatsa hore thekiso ya ditlhahiswa di ka tlhoka tlhokomelo e ikgethileng hore ho ka batswellisa kgwebo ya bolemi e leng ntho e tla fanang ka botsitso ikonoming ya naha.

Appendix VII

University of Orange Free State
Faculty of Natural and Agricultural Sciences
Department of Agrometeorology

TRAINING ON COMMUNICATION OF SEASONAL CLIMATE FORECASTS

Bethlehem 5 October 2000
Venue: Small Grain Institute

Chairperson: Prof. Sue Walker, UOFS

08:00 – 08:30	Registration and tea/coffee
08:30 – 09:00	Contribution of basic science to agrometeorology Prof. G.N. van Wyk, Dean – Faculty of Natural and Agricultural Sciences, UOFS
09:00 – 09:15	Welcome Speech - Department of Agriculture, Free State. Mr. A. Munnik
	P R E S E N T A T I O N S
09:15 – 10:00	An evaluation of communication effectiveness between meteorological scientists and Farmers in the Free State Province. Dr. Elijah Mukhala, UOFS
10:00 – 10:30	T E A B R E A K
10:30 – 11:15	Seasonal Climate Forecasts and operational forecasts Mr. Tony Rossouw and Mr. Francis Mosetlho SA Weather Bureau
11:15 – 12:00	Applications of seasonal climate forecasts Mr. Johan van den Berg, UOFS
12:00 – 13:00	Presentation skills Mr. G.P. van Rheede van Oudtshoorn, UOFS
13:00 – 14:00	L U N C H
14:00 – 15:00	Discussion and closing remarks Chairperson - Prof Sue Walker
15:00	T E A B R E A K

Contact: Department of Agrometeorology, UOFS.
Tel: (051) 401 2222 Fax: (051) 448 0692

Appendix VIII

University of Orange Free State
Faculty of Natural and Agricultural Sciences
Department of Agrometeorology

TRAINING ON COMMUNICATION OF SEASONAL CLIMATE FORECASTS

Bloemfontein 10 October 2000
Venue: Civic Centre

Chairperson: Prof. Sue Walker, UOFS

08:00 – 08:30	Registration and tea/coffee
08:30 – 09:00	Contribution of basic science to agrometeorology Prof. G.N. van Wyk, Dean – Faculty of Natural and Agricultural Sciences, UOFS
09:00 – 09:15	Welcome Speech - Department of Agriculture, Free State. Mr. Jeanne du Rand
	P R E S E N T A T I O N S
09:15 – 10:00	An evaluation of communication effectiveness between meteorological scientists and Farmers in the Free State Province. Dr. Elijah Mukhala, UOFS
10:00 – 10:30	T E A B R E A K
10:30 – 11:15	Seasonal Climate Forecasts and operational forecasts Mr. Tony Rossouw and Mr. Francis Mosetlho SA Weather Bureau
11:15 – 12:00	Presentation skills Mr. G.P. van Rheede van Oudtshoorn, UOFS
12:00 – 13:00	L U N C H
13:00 – 14:00	Applications of seasonal climate forecasts Mr. Johan van den Berg, UOFS
14:00 – 15:00	Discussion and closing remarks Chairperson - Prof Sue Walker
15:00	T E A B R E A K

Contact: Department of Agrometeorology, UOFS.
Tel: (051) 401 2222 Fax: (051) 448 0692

Appendix IX

List of Participants (Bethlehem)

NAME	ADDRESS
Lucky Lesufi	Private Bag X29, Bethlehem Lucky@kgs1.agric.za
Alta Meyer	P.O. Box 171, Harrismith
Sarel Bester	P.O. Box 15, Reitz 9810
Willem Otto	Private Bag X29, Bethlehem Willem2@kgs1.agric.za
Thom Steyn	Private Bag X29, Bethlehem Thom@kgs1.agric.za
Samuel Nyambe	Box 108, Paul Roux 9800
S. Naidoo	Box 6, Ficksburg 9730
Mavis Nohlakoana	5366 Rosendal 9720
M.J. Malete	Private Bag X816 Agricultural Department
T.J. Tlaoi	Private Bag 698 Senekal
M.J. Sebakamotse	P.O. Box 24, Clocolan 9755
K.S. Moeketsane	Box 5642, Marquard 9610
T.H. Keele	Private Bag X816, Windhoek 9870
Daniël Zwane	P.O. Box 13422, Windhoek 9826
Lucas Serage	Small Grain Institute Lucas@kgs1.agric.za
Mantoabi Mbupo	Box 585, Bethlehem 9700
Simon Motsima	Box 108, Paul Roux 9800
Gerrie van der Westhuizen	Posbus 242, Fouriesburg 9725
Danie Taljaard	Tozenstraat 15, Bethlehem 9701
Ivan De Kock	Posbus 2006 Sasolburg
Rantai Manfumelo	P.O. Box 10893 Mokodumela
Eric Serabele	P.O. Box 15497, Windhoek 9870
Thabo Motsoenery	P.O. Box 15497, Windhoek 9870
Abednigo Nhlapo	18 Park Street, Warden 9890
Samson Sebakamotse	P.O. Box 98, Senekal 9600
Davis Mashinini	P.O. Box 13422, Windhoek 9870
T.L. Machaka	Small Grain Institute Bethlehem
Pieter Craven	Small Grain Institute Bethlehem
Anri Barnard	Small Grain Institute, Bethlehem
T.L. Mapla	Department of Agriculture Box 151, Lindley, 9630
Una Aucamp	Small Grain Institute Bethlehem
Kobus van Zyl	Small Grain Institute Bethlehem
Fred van Niekerk	Small Grain Institute Bethlehem
Trudie Marais	Department of Agriculture P.O. Box 60782, Vaalpark
Lelanie Metaxas	Department of Agriculture P.O. Box 151, Vrede 9835
Meshack Petlane	DELTAI, Department of Agriculture Weltevrede, Qwaqwa
Chester Mhlanga	DELTAI, Department of Agriculture Weltevrede, Qwaqwa
L.L. De Jager	Department of Agriculture Harrismith
L.J. Viljoen	Department of Agriculture Harrismith
M.A. Letuisa	P.O. Box 367 Ilestell
John Tolmay	ARC-Small Grain Institute 058-3073422
Thabiso Mojaje	Marquard
A.M. Masiza	3642/6 Ficksburg

Appendix X

List of Participants (Bloemfontein)

Lebohang Bulane	Bulane@lesoff.co.za
Mafa Mokoano (Farmer)	Private Bag X13 Kroonstad 9300
Dimilatso Hlapi (Farmer)	P.O. Box 308 Ventersburg 9450
Robert Ntoampe (Farmer)	P.O. Box 5163 Kroonstad
George Madiba (Extension)	P.O. Box 990 Thaba Nchu 9780
Sam R. Mokhua (Extension)	Box 990 Thaba Nchu 9780
Serf van Schalkwyk (Exten)	Box 529 Bloemfontein
Mabafokeng Mahahabisa	Lesotho Meteorology Office, Box 14515, Maseru 100, Lesotho
Molemo Molapo (Extension)	Department of Agriculture Free State province.
J. Tsonodibane (Farmer)	Box 41 Welkom 9460
Mahlomola Lenka	P.O. Box 772 Maseru 100
Stephen Mofoka	P.O. Box 772 Maseru 100
Isaac Moloi (Extension)	Private Bag X13 Kroonstad 9500
Lydia Mshlotsi (Farmer)	P.O. Box 2428 Kroonstad 9500
Marumo, M.T.D. (Extension)	P.O. Box 402 Thaba Nchu 9780
Du Rand, D.J.	Department of Agriculture, Glen.
Kotzé, C.D. (Extension)	Box 529 Bloemfontein, 9300
J.T. Ntholeng (Farmer)	456 Masilo Theunissen
M.S. Kotola (Extension)	P.O. Box 92 Theunissen
M.E. Rantoa (Extension)	P.O. Box Box 92 Theunissen
K Morebotsane	Lesotho Meteorology Office, Box 14515, Maseru 100
M. Maletjane	Lesotho Meteorology Office, P.O. Box 14515, Maseru 100
J. van Tonder (Extension)	98 Zastronstreet Bloemfontein
K.J. Booysen (Extension)	98 Zastronstreet Bloemfontein
G. Ziervogel	University of Oxford, Department of Geography
David Mokgoetsi (Extension)	48 D'A lmeda street Dagbreek, Welkom
T.M. Lebentlele (Farmer)	B.O. Box 12948 Maseru
N. Mamis (Farmer)	P.O. Box 1424 Kroonstad 9500
Joel Sentane (Farmer)	P.O. Box 5193 Parys 9585
E.M. Likole (Farmer)	P.O. Box 63, Ventersburg 9450
D. Nketsi	4181 Constantia, Kroonstad 5163
M.F. Fantiri (Farmer)	43 Lefakane Street, Mokyyallo Vredefort, 9595
M.G. Ramotsoika	287 Seeisoville Kroonstad

Appendix XI

Monthly average values of the Southern Oscillation as well as phases according to Stone *et al.* (1996) starting January 1900.

Year	Month	Month	SOI	PHASE	Year	Month	Month	SOI	PHASE
1900	1	jan	-7.9	5	1951	1	jan	12.7	2
1900	2	feb	-7.6	1	1951	2	feb	5.7	2
1900	3	mar	-23.3	3	1951	3	mar	-5.5	3
1900	4	apr	-16.9	1	1951	4	apr	-7.4	5
1900	5	may	-6.3	1	1951	5	may	-11.5	1
1900	6	jun	21.9	4	1951	6	jun	-1.8	4
1900	7	jul	9.3	2	1951	7	jul	-12.5	3
1900	8	aug	7.5	2	1951	8	aug	-5.2	1
1900	9	sep	-15.9	3	1951	9	sep	-11.2	3
1900	10	oct	-17.3	1	1951	10	oct	-12.3	1
1900	11	nov	-5.9	1	1951	11	nov	-8.5	1
1900	12	dec	-6.8	5	1951	12	dec	-8.3	1
1901	1	jan	-0.8	4	1952	1	jan	-8.9	1
1901	2	feb	2.2	5	1952	2	feb	-8.1	1
1901	3	mar	7.4	4	1952	3	mar	0.2	4
1901	4	apr	3.5	2	1952	4	apr	-6.7	3
1901	5	may	0.3	5	1952	5	may	7.7	4
1901	6	jun	16.3	4	1952	6	jun	5.8	2
1901	7	jul	3.6	2	1952	7	jul	4.5	2
1901	8	aug	9.4	4	1952	8	aug	-2.2	5
1901	9	sep	-15.3	3	1952	9	sep	-1.8	5
1901	10	oct	-22.3	1	1952	10	oct	3.5	4
1901	11	nov	-8.5	1	1952	11	nov	0.4	5
1901	12	dec	-3.2	1	1952	12	dec	-12.8	3
1902	1	jan	16.5	4	1953	1	jan	1.6	4
1902	2	feb	-3.2	3	1953	2	feb	-7.1	3
1902	3	mar	9.4	4	1953	3	mar	-6	5
1902	4	apr	6.5	2	1953	4	apr	-0.8	5
1902	5	may	7.7	2	1953	5	may	-25.5	3
1902	6	jun	1.7	2	1953	6	jun	-2.5	4
1902	7	jul	1.4	5	1953	7	jul	-1	5
1902	8	aug	-8.2	3	1953	8	aug	-16.1	3
1902	9	sep	-17.1	3	1953	9	sep	-13	1
1902	10	oct	-7.2	1	1953	10	oct	-0.3	4
1902	11	nov	-3.4	5	1953	11	nov	-2.7	5
1902	12	dec	-4.3	5	1953	12	dec	-5.8	5
1903	1	jan	-9.9	5	1954	1	jan	5	4
1903	2	feb	-11.6	1	1954	2	feb	-5.2	3
1903	3	mar	14.6	4	1954	3	mar	-2.2	5
1903	4	apr	15.2	2	1954	4	apr	5	4
1903	5	may	7.7	2	1954	5	may	4	5
1903	6	jun	-1.1	3	1954	6	jun	-2.5	5
1903	7	jul	5.7	4	1954	7	jul	3.3	4
1903	8	aug	0.3	5	1954	8	aug	9.4	4
1903	9	sep	8.7	4	1954	9	sep	2.3	2
1903	10	oct	4.7	2	1954	10	oct	2.2	5
1903	11	nov	1.1	5	1954	11	nov	2.3	5
1903	12	dec	14.6	4	1954	12	dec	11.5	4
1904	1	jan	13.6	2	1955	1	jan	-5.5	3
1904	2	feb	16	2	1955	2	feb	14.6	4
1904	3	mar	7.4	2	1955	3	mar	1.2	3
1904	4	apr	27.7	4	1955	4	apr	-5.2	5
1904	5	may	9.2	2	1955	5	may	11.4	4
1904	6	jun	-6.7	3	1955	6	jun	12.8	2
1904	7	jul	-8.2	5	1955	7	jul	16.6	2
1904	8	aug	0.9	4	1955	8	aug	13.6	2
1904	9	sep	0.5	5	1955	9	sep	14.6	2
1904	10	oct	1.6	5	1955	10	oct	16.7	2
1904	11	nov	-16.7	3	1955	11	nov	15	2

Year	Month	Month	SOI	PHASE	Year	Month	Month	SOI	PHASE
1904	12	dec	1.3	4	1955	12	dec	7.9	2
1905	1	jan	-9.9	3	1956	1	jan	10.8	2
1905	2	feb	-18.5	3	1956	2	feb	12.1	2
1905	3	mar	-27.7	1	1956	3	mar	7.4	2
1905	4	apr	-38.2	1	1956	4	apr	8.7	2
1905	5	may	-34.3	1	1956	5	may	16.5	2
1905	6	jun	-27.7	1	1956	6	jun	10	2
1905	7	jul	-19.8	1	1956	7	jul	11.1	2
1905	8	aug	-7	1	1956	8	aug	10.6	2
1905	9	sep	-6.5	5	1956	9	sep	1.1	2
1905	10	oct	-5.3	5	1956	10	oct	19.9	4
1905	11	nov	-17.3	3	1956	11	nov	2.3	3
1905	12	dec	-14.4	1	1956	12	dec	8.5	4
1906	1	jan	-4.1	1	1957	1	jan	4.5	2
1906	2	feb	-8.6	5	1957	2	feb	-3.2	3
1906	3	mar	-4.3	1	1957	3	mar	-2.7	5
1906	4	apr	-6.2	5	1957	4	apr	-0.1	5
1906	5	may	4.3	4	1957	5	may	-11.5	3
1906	6	jun	-3.9	3	1957	6	jun	-1.8	4
1906	7	jul	6.3	4	1957	7	jul	1.4	5
1906	8	aug	14.8	4	1957	8	aug	-8.2	3
1906	9	sep	18.1	2	1957	9	sep	-9.4	1
1906	10	oct	9.8	2	1957	10	oct	-0.3	4
1906	11	nov	20.7	4	1957	11	nov	-11	3
1906	12	dec	5.5	2	1957	12	dec	-4.3	1
1907	1	jan	2.6	5	1958	1	jan	-17.5	3
1907	2	feb	-2.8	5	1958	2	feb	-7.1	1
1907	3	mar	2.3	4	1958	3	mar	-2.2	5
1907	4	apr	-3.3	5	1958	4	apr	1.3	5
1907	5	may	-5	5	1958	5	may	-9.3	3
1907	6	jun	-2.9	5	1958	6	jun	-0.4	4
1907	7	jul	-5.1	5	1958	7	jul	3.3	5
1907	8	aug	-4.2	5	1958	8	aug	7.5	2
1907	9	sep	-3.4	5	1958	9	sep	-3	3
1907	10	oct	-1.1	5	1958	10	oct	-0.3	5
1907	11	nov	2.2	5	1958	11	nov	-4.6	5
1907	12	dec	-2.4	5	1958	12	dec	-7.3	5
1908	1	jan	-4.4	5	1959	1	jan	-8.9	1
1908	2	feb	-1	5	1959	2	feb	-15	1
1908	3	mar	4.4	4	1959	3	mar	7	4
1908	4	apr	2.3	5	1959	4	apr	4.3	2
1908	5	may	1.1	5	1959	5	may	4	5
1908	6	jun	-1.1	5	1959	6	jun	-5.3	3
1908	7	jul	-3.2	5	1959	7	jul	-4	5
1908	8	aug	2.2	4	1959	8	aug	-4	5
1908	9	sep	17.5	4	1959	9	sep	0.5	5
1908	10	oct	8.5	2	1959	10	oct	4.7	5
1908	11	nov	2.3	2	1959	11	nov	11.2	4
1908	12	dec	-6.8	3	1959	12	dec	6.9	2
1909	1	jan	-3.1	5	1960	1	jan	0.2	5
1909	2	feb	-4.2	5	1960	2	feb	-1.7	5
1909	3	mar	-1.2	5	1960	3	mar	4.5	4
1909	4	apr	-13.3	3	1960	4	apr	7.2	2
1909	5	may	2.5	4	1960	5	may	4.7	2
1909	6	jun	19.1	4	1960	6	jun	-2.5	5
1909	7	jul	9.9	2	1960	7	jul	4.5	4
1909	8	aug	9.4	2	1960	8	aug	6.3	2
1909	9	sep	1.1	2	1960	9	sep	7.6	2
1909	10	oct	4.7	5	1960	10	oct	0.3	5
1909	11	nov	8.7	2	1960	11	nov	6.8	4
1909	12	dec	3.4	2	1960	12	dec	5.9	2
1910	1	jan	5	5	1961	1	jan	-3.1	3
1910	2	feb	15	4	1961	2	feb	5.7	4

Year	Month	Month	SOI	PHASE	Year	Month	Month	SOI	PHASE
1910	3	mar	10.3	2	1961	3	mar	-20.5	3
1910	4	apr	4.3	2	1961	4	apr	7.9	4
1910	5	may	1.1	5	1961	5	may	1.8	2
1910	6	jun	18.4	4	1961	6	jun	-2.5	5
1910	7	jul	19	2	1961	7	jul	-0.4	5
1910	8	aug	9.4	2	1961	8	aug	-0.3	5
1910	9	sep	15.2	2	1961	9	sep	1.1	5
1910	10	oct	11	2	1961	10	oct	4.7	5
1910	11	nov	18.8	2	1961	11	nov	6.8	2
1910	12	dec	14.6	2	1961	12	dec	12.5	2
1911	1	jan	2.6	2	1962	1	jan	16.5	2
1911	2	feb	0.7	5	1962	2	feb	-5.2	3
1911	3	mar	2.1	5	1962	3	mar	-3.1	5
1911	4	apr	1.3	5	1962	4	apr	-0.8	5
1911	5	may	-7.1	3	1962	5	may	12.1	4
1911	6	jun	-10.9	1	1962	6	jun	5.1	2
1911	7	jul	-11.9	1	1962	7	jul	-0.4	5
1911	8	aug	-11.3	1	1962	8	aug	4.5	4
1911	9	sep	-8.3	1	1962	9	sep	5.2	2
1911	10	oct	-11.6	1	1962	10	oct	10.4	2
1911	11	nov	-7.2	1	1962	11	nov	4.2	2
1911	12	dec	-2.7	5	1962	12	dec	0.3	5
1912	1	jan	-10.3	3	1963	1	jan	8.4	4
1912	2	feb	-19	3	1963	2	feb	2.7	2
1912	3	mar	-8.9	1	1963	3	mar	5.5	5
1912	4	apr	-19.1	3	1963	4	apr	7.2	2
1912	5	may	-11.5	1	1963	5	may	2.5	2
1912	6	jun	-6	1	1963	6	jun	-10.2	3
1912	7	jul	-0.4	4	1963	7	jul	-2.2	4
1912	8	aug	-7	5	1963	8	aug	-2.8	5
1912	9	sep	-3.6	5	1963	9	sep	-5.9	5
1912	10	oct	-7.9	5	1963	10	oct	-14.8	3
1912	11	nov	2.3	4	1963	11	nov	-9.1	1
1912	12	dec	-9.4	3	1963	12	dec	-12.9	1
1913	1	jan	-4.1	1	1964	1	jan	-4.1	1
1913	2	feb	-6.2	5	1964	2	feb	-2.2	5
1913	3	mar	0.2	4	1964	3	mar	5.5	4
1913	4	apr	-6	5	1964	4	apr	1.3	5
1913	5	may	-7.1	5	1964	5	may	6.9	4
1913	6	jun	-3.9	5	1964	6	jun	5.8	2
1913	7	jul	-1.6	5	1964	7	jul	5.1	2
1913	8	aug	-7	5	1964	8	aug	14.2	4
1913	9	sep	-8.8	5	1964	9	sep	14	2
1913	10	oct	-9.1	1	1964	10	oct	14.2	2
1913	11	nov	-11.6	1	1964	11	nov	2.3	2
1913	12	dec	-8.3	1	1964	12	dec	-4.3	5
1914	1	jan	-6	1	1965	1	jan	-4.6	5
1914	2	feb	1.2	4	1965	2	feb	1.2	4
1914	3	mar	7.4	4	1965	3	mar	2.1	5
1914	4	apr	-9.7	3	1965	4	apr	-10.4	3
1914	5	may	-9.7	1	1965	5	may	-0.4	4
1914	6	jun	-9.7	1	1965	6	jun	-10.9	3
1914	7	jul	-9.7	1	1965	7	jul	-21	3
1914	8	aug	-16.1	1	1965	8	aug	-10.1	1
1914	9	sep	-16.1	1	1965	9	sep	-13.5	1
1914	10	oct	-14.2	1	1965	10	oct	-11	1
1914	11	nov	-6.9	1	1965	11	nov	-16.7	1
1914	12	dec	-6.9	1	1965	12	dec	0.3	4
1915	1	jan	-6.9	1	1966	1	jan	-4.6	5
1915	2	feb	-10.5	1	1966	2	feb	-4.7	5
1915	3	mar	-10.5	1	1966	3	mar	-12.8	3
1915	4	apr	-10.5	1	1966	4	apr	-6	1
1915	5	May	5.4	4	1966	5	may	-7.8	5

Year	Month	Month	SOI	PHASE	Year	Month	Month	SOI	PHASE
1915	6	jun	5.4	5	1966	6	jun	0.3	4
1915	7	jul	5.4	5	1966	7	jul	-0.4	5
1915	8	aug	7.4	2	1966	8	aug	4.5	4
1915	9	sep	-0.2	5	1966	9	sep	-1.8	5
1915	10	oct	-7	3	1966	10	oct	-2.2	5
1915	11	nov	-14.2	3	1966	11	nov	0.4	5
1915	12	dec	8.5	4	1966	12	dec	-4.8	5
1916	1	jan	5	2	1967	1	jan	14.1	4
1916	2	feb	-4.7	3	1967	2	feb	12.6	2
1916	3	mar	-6.5	5	1967	3	mar	6.5	2
1916	4	apr	-0.8	4	1967	4	apr	-3.8	3
1916	5	may	6.9	4	1967	5	may	-2.6	5
1916	6	jun	7.2	2	1967	6	jun	4.5	4
1916	7	jul	23.8	4	1967	7	jul	0.8	5
1916	8	aug	15.4	2	1967	8	aug	5.7	4
1916	9	sep	4.6	2	1967	9	sep	5.8	2
1916	10	oct	6.6	2	1967	10	oct	-0.3	5
1916	11	nov	9.3	2	1967	11	nov	-4.6	5
1916	12	dec	14.1	2	1967	12	dec	-6.8	5
1917	1	jan	4.5	2	1968	1	jan	3.6	4
1917	2	feb	9.6	2	1968	2	feb	9.1	4
1917	3	mar	15.1	2	1968	3	mar	-3.6	3
1917	4	apr	18.9	2	1968	4	apr	-3	5
1917	5	may	21	2	1968	5	may	14.3	4
1917	6	jun	17.7	2	1968	6	jun	10	2
1917	7	jul	26.3	2	1968	7	jul	6.3	2
1917	8	aug	33.1	2	1968	8	aug	0.3	5
1917	9	sep	29.2	2	1968	9	sep	-2.4	5
1917	10	oct	16.1	2	1968	10	oct	-1.6	5
1917	11	nov	20.1	2	1968	11	nov	-3.4	5
1917	12	dec	21.2	2	1968	12	dec	0.3	5
1918	1	jan	14.1	2	1969	1	jan	-14.2	3
1918	2	feb	16.5	2	1969	2	feb	-7.6	1
1918	3	mar	-2.7	3	1969	3	mar	-0.7	4
1918	4	apr	14.5	4	1969	4	apr	-8.2	3
1918	5	may	9.9	2	1969	5	may	-5.6	1
1918	6	jun	-4.6	3	1969	6	jun	-1.1	5
1918	7	jul	-13.1	3	1969	7	jul	-6.4	5
1918	8	aug	-4	1	1969	8	aug	-4	5
1918	9	sep	-7.7	5	1969	9	sep	-10	3
1918	10	oct	-4.7	5	1969	10	oct	-11.6	1
1918	11	nov	1.1	4	1969	11	nov	-0.2	4
1918	12	dec	-9.4	3	1969	12	dec	2.3	5
1919	1	jan	-15.6	1	1970	1	jan	-10.8	3
1919	2	feb	-12.6	1	1970	2	feb	-12.1	1
1919	3	mar	-12.3	1	1970	3	mar	0.7	4
1919	4	apr	-3	4	1970	4	apr	-4.5	5
1919	5	may	-6.3	5	1970	5	may	2.5	4
1919	6	jun	-9.5	5	1970	6	jun	8.6	4
1919	7	jul	-8.2	1	1970	7	jul	-5.2	3
1919	8	aug	-6.4	1	1970	8	aug	3.9	4
1919	9	sep	-5.3	5	1970	9	sep	12.8	4
1919	10	oct	-10.4	5	1970	10	oct	11	2
1919	11	nov	-11	1	1970	11	nov	18.8	2
1919	12	dec	-10.4	1	1970	12	dec	16.1	2
1920	1	jan	1.2	4	1971	1	jan	2.1	3
1920	2	feb	-2.7	5	1971	2	feb	15.5	4
1920	3	mar	-4.6	5	1971	3	mar	16.1	2
1920	4	apr	-0.1	5	1971	4	apr	19.6	2
1920	5	may	-1.9	5	1971	5	may	9.2	2
1920	6	jun	5.1	4	1971	6	jun	1.7	2
1920	7	jul	8.7	2	1971	7	jul	1.4	5
1920	8	aug	5.1	2	1971	8	aug	14.2	4

Year	Month	Month	SOI	PHASE	Year	Month	Month	SOI	PHASE
1920	9	sep	5.2	2	1971	9	sep	15.8	2
1920	10	oct	-4.1	3	1971	10	oct	18.6	2
1920	11	nov	-0.2	5	1971	11	nov	6.8	2
1920	12	dec	8.5	4	1971	12	dec	0.8	5
1921	1	jan	10.3	2	1972	1	jan	3.1	5
1921	2	feb	6.2	2	1972	2	feb	7.2	2
1921	3	mar	6.8	2	1972	3	mar	1.2	5
1921	4	apr	6.8	2	1972	4	apr	-5.2	5
1921	5	may	8.6	2	1972	5	may	-24	3
1921	6	jun	8.6	2	1972	6	jun	-10.9	1
1921	7	jul	2.7	2	1972	7	jul	-17.3	1
1921	8	aug	-6.4	3	1972	8	aug	-8.2	1
1921	9	sep	5.2	4	1972	9	sep	-14.1	1
1921	10	oct	10.4	2	1972	10	oct	-11	1
1921	11	nov	8	2	1972	11	nov	-3.4	1
1921	12	dec	6.9	2	1972	12	dec	-13.4	3
1922	1	jan	7.4	2	1973	1	jan	-3.6	1
1922	2	feb	8.6	2	1973	2	feb	-15	3
1922	3	mar	4.1	2	1973	3	mar	-0.3	4
1922	4	apr	-5.2	3	1973	4	apr	-2.3	5
1922	5	may	-4.1	5	1973	5	may	3.3	4
1922	6	jun	4.5	4	1973	6	jun	10	4
1922	7	jul	2	5	1973	7	jul	5.7	2
1922	8	aug	-1	5	1973	8	aug	11.8	2
1922	9	sep	5.2	4	1973	9	sep	13.4	2
1922	10	oct	6.6	2	1973	10	oct	10.4	2
1922	11	nov	8	2	1973	11	nov	31.5	4
1922	12	dec	10.5	2	1973	12	dec	15.6	2
1923	1	jan	5	2	1974	1	jan	20.3	2
1923	2	feb	3.7	5	1974	2	feb	16	2
1923	3	mar	7	2	1974	3	mar	17	2
1923	4	apr	7.2	2	1974	4	apr	9.4	2
1923	5	may	2.5	2	1974	5	may	10.6	2
1923	6	jun	0.3	5	1974	6	jun	1.7	2
1923	7	jul	-10.7	3	1974	7	jul	11.1	4
1923	8	aug	-17.4	1	1974	8	aug	6.3	2
1923	9	sep	-14.1	1	1974	9	sep	12.2	2
1923	10	oct	-6	1	1974	10	oct	9.2	2
1923	11	nov	-12.3	3	1974	11	nov	-1.5	3
1923	12	dec	0.8	4	1974	12	dec	0.3	5
1924	1	jan	-6	5	1975	1	jan	-6	5
1924	2	feb	0.3	4	1975	2	feb	4.7	4
1924	3	mar	1.2	5	1975	3	mar	9.4	2
1924	4	apr	-14	3	1975	4	apr	12.3	2
1924	5	may	11.4	4	1975	5	may	6.2	2
1924	6	jun	6.5	2	1975	6	jun	12.8	2
1924	7	jul	6.9	2	1975	7	jul	19.6	2
1924	8	aug	10	2	1975	8	aug	19.7	2
1924	9	sep	8.1	2	1975	9	sep	22.2	2
1924	10	oct	8.5	2	1975	10	oct	18.6	2
1924	11	nov	11.2	2	1975	11	nov	13.1	2
1924	12	dec	3.9	2	1975	12	dec	17.6	2
1925	1	jan	5	5	1976	1	jan	11.2	2
1925	2	feb	13.6	4	1976	2	feb	12.6	2
1925	3	mar	12.2	2	1976	3	mar	10.8	2
1925	4	apr	12.3	2	1976	4	apr	0.6	3
1925	5	may	-0.4	3	1976	5	may	2.5	5
1925	6	jun	-4.6	5	1976	6	jun	0.3	5
1925	7	jul	-12.5	3	1976	7	jul	-11.9	3
1925	8	aug	-10.1	1	1976	8	aug	-11.3	1
1925	9	sep	-5.9	1	1976	9	sep	-12.4	1
1925	10	oct	-12.9	3	1976	10	oct	3.5	4
1925	11	nov	-9.1	1	1976	11	nov	9.3	4

Year	Month	Month	SOI	PHASE	Year	Month	Month	SOI	PHASE
1925	12	dec	-8.3	1	1976	12	dec	-20	3
1926	1	jan	-6	1	1977	1	jan	-4.1	4
1926	2	feb	-16	3	1977	2	feb	8.6	4
1926	3	mar	-12.8	1	1977	3	mar	-9.4	3
1926	4	apr	-6.7	1	1977	4	apr	-8.2	1
1926	5	may	-1.9	5	1977	5	may	-9.3	1
1926	6	jun	-6.7	5	1977	6	jun	-15.8	1
1926	7	jul	-1	4	1977	7	jul	-13.7	1
1926	8	aug	-7	5	1977	8	aug	-11.3	1
1926	9	sep	1.7	4	1977	9	sep	-8.8	1
1926	10	oct	4.7	5	1977	10	oct	-12.9	1
1926	11	nov	1.3	5	1977	11	nov	-14.2	1
1926	12	dec	4.9	5	1977	12	dec	-11.4	1
1927	1	jan	4.5	5	1978	1	jan	-3.6	1
1927	2	feb	0.3	5	1978	2	feb	-26.9	3
1927	3	mar	15.1	4	1978	3	mar	-6	1
1927	4	apr	5.7	2	1978	4	apr	-7.4	5
1927	5	may	6.2	2	1978	5	may	15.8	4
1927	6	jun	0.6	5	1978	6	jun	4.5	2
1927	7	jul	0.6	5	1978	7	jul	5.1	5
1927	8	aug	-1.6	5	1978	8	aug	2.1	5
1927	9	sep	-0.1	5	1978	9	sep	1.1	5
1927	10	oct	-4.1	5	1978	10	oct	-5.3	5
1927	11	nov	-7.8	5	1978	11	nov	-2.1	5
1927	12	dec	6.4	4	1978	12	dec	-2.2	5
1928	1	jan	-10.8	3	1979	1	jan	-4.6	5
1928	2	feb	10.1	4	1979	2	feb	6.2	4
1928	3	mar	11.3	2	1979	3	mar	-3.6	3
1928	4	apr	10.1	2	1979	4	apr	-5.2	5
1928	5	may	-1.9	3	1979	5	may	4	4
1928	6	jun	-7.4	5	1979	6	jun	4.5	5
1928	7	jul	-0.4	4	1979	7	jul	13.6	4
1928	8	aug	9.4	4	1979	8	aug	-4.6	3
1928	9	sep	8.1	2	1979	9	sep	1.7	4
1928	10	oct	9.8	2	1979	10	oct	-2.2	5
1928	11	nov	2.3	2	1979	11	nov	-4.6	5
1928	12	dec	10.5	4	1979	12	dec	-8.3	5
1929	1	jan	15.6	2	1980	1	jan	2.6	4
1929	2	feb	18	2	1980	2	feb	0.3	5
1929	3	mar	3.6	2	1980	3	mar	-8.4	3
1929	4	apr	3.5	5	1980	4	apr	-11.8	1
1929	5	may	-10.7	3	1980	5	may	-2.6	4
1929	6	jun	0.3	4	1980	6	jun	-3.9	5
1929	7	jul	1.4	5	1980	7	jul	-1.6	5
1929	8	aug	0.3	5	1980	8	aug	1.5	5
1929	9	sep	-0.1	5	1980	9	sep	-4.7	5
1929	10	oct	8.5	4	1980	10	oct	-0.9	5
1929	11	nov	10.6	2	1980	11	nov	-3.4	5
1929	12	dec	4.4	2	1980	12	dec	-2.2	5
1930	1	jan	12.2	4	1981	1	jan	2.1	5
1930	2	feb	7.2	2	1981	2	feb	-4.2	5
1930	3	mar	0.7	5	1981	3	mar	-15.6	3
1930	4	apr	-3.8	5	1981	4	apr	-5.2	1
1930	5	may	2.5	4	1981	5	may	8.4	4
1930	6	jun	-5.3	3	1981	6	jun	12.1	2
1930	7	jul	-4	5	1981	7	jul	8.1	2
1930	8	aug	-1.6	5	1981	8	aug	5.1	2
1930	9	sep	-6.5	5	1981	9	sep	6.4	2
1930	10	oct	4.1	4	1981	10	oct	-5.3	3
1930	11	nov	1.7	5	1981	11	nov	2.3	4
1930	12	dec	-2.7	5	1981	12	dec	3.4	5
1931	1	jan	6.4	4	1982	1	jan	8.8	4
1931	2	feb	-16.5	3	1982	2	feb	-0.2	3

Year	Month	Month	SOI	PHASE	Year	Month	Month	SOI	PHASE
1931	3	mar	4.1	4	1982	3	mar	0.7	5
1931	4	apr	7.2	2	1982	4	apr	-2.3	5
1931	5	may	12.8	2	1982	5	may	-7.1	5
1931	6	jun	15.6	2	1982	6	Jun	-17.2	3
1931	7	jul	8.7	2	1982	7	jul	-17.9	1
1931	8	aug	4.3	5	1982	8	aug	-22.2	1
1931	9	sep	4.3	5	1982	9	sep	-20	1
1931	10	oct	4.3	5	1982	10	oct	-20.5	1
1931	11	nov	-1.1	5	1982	11	nov	-30	1
1931	12	dec	-1.1	5	1982	12	dec	-22.6	1
1932	1	jan	-3.2	5	1983	1	jan	-31.4	1
1932	2	feb	-3.2	5	1983	2	feb	-35.7	1
1932	3	mar	-3.2	5	1983	3	mar	-25.7	1
1932	4	apr	-3.2	5	1983	4	apr	-15.5	1
1932	5	may	1.1	5	1983	5	may	5.5	4
1932	6	jun	1.1	5	1983	6	jun	-3.2	3
1932	7	jul	1.1	5	1983	7	jul	-7	5
1932	8	aug	4.9	5	1983	8	aug	0.9	4
1932	9	sep	-8.3	3	1983	9	sep	9.9	4
1932	10	oct	-4.1	1	1983	10	oct	4.7	2
1932	11	nov	-4.6	5	1983	11	nov	-0.8	5
1932	12	dec	1.8	4	1983	12	dec	-1.2	5
1933	1	jan	-11.8	3	1984	1	jan	0.7	5
1933	2	feb	4.2	4	1984	2	feb	5.2	4
1933	3	mar	-2.7	5	1984	3	mar	-6.5	3
1933	4	apr	2.8	4	1984	4	apr	1.3	4
1933	5	may	6.2	5	1984	5	may	0.3	5
1933	6	jun	-3.9	3	1984	6	jun	-8.1	3
1933	7	jul	3.3	4	1984	7	jul	0.8	4
1933	8	aug	-0.3	5	1984	8	aug	2.1	5
1933	9	sep	2.3	5	1984	9	sep	2.3	5
1933	10	oct	4.1	5	1984	10	oct	-4.7	5
1933	11	nov	6.8	2	1984	11	nov	3.6	4
1933	12	dec	6.9	2	1984	12	dec	-2.7	5
1934	1	jan	6	2	1985	1	jan	-4.6	5
1934	2	feb	-0.7	5	1985	2	feb	6.2	4
1934	3	mar	-0.7	5	1985	3	mar	-2.7	3
1934	4	apr	5	4	1985	4	apr	12.3	4
1934	5	may	-6.3	3	1985	5	may	3.3	2
1934	6	jun	8.6	4	1985	6	jun	-8.8	3
1934	7	jul	2.7	2	1985	7	jul	-2.2	4
1934	8	aug	-21	3	1985	8	aug	8.2	4
1934	9	sep	-5.9	1	1985	9	sep	0.5	5
1934	10	oct	4.7	4	1985	10	oct	-5.3	5
1934	11	nov	12.5	4	1985	11	nov	-1.5	5
1934	12	dec	-3.8	3	1985	12	dec	0.8	5
1935	1	jan	6	4	1986	1	jan	7.4	4
1935	2	feb	-5.7	3	1986	2	feb	-12.1	3
1935	3	mar	9.8	4	1986	3	mar	-0.3	4
1935	4	apr	2.1	2	1986	4	apr	0.6	5
1935	5	may	-5.6	3	1986	5	may	-5.6	5
1935	6	jun	-2.5	5	1986	6	jun	8.6	4
1935	7	jul	-0.4	5	1986	7	jul	2	2
1935	8	aug	2.1	5	1986	8	aug	-7	3
1935	9	sep	6.4	4	1986	9	sep	-4.7	5
1935	10	oct	7.9	2	1986	10	oct	6.6	4
1935	11	nov	3.6	2	1986	11	nov	-13.5	3
1935	12	dec	-5.3	3	1986	12	dec	-15	1
1936	1	jan	-2.7	5	1987	1	jan	-7	1
1936	2	feb	-0.2	5	1987	2	feb	-14	3
1936	3	mar	0.7	5	1987	3	mar	-16.1	1
1936	4	apr	19.6	4	1987	4	apr	-23.5	1
1936	5	may	4.7	2	1987	5	may	-19.6	1

Year	Month	Month	SOI	PHASE	Year	Month	Month	SOI	PHASE
1936	6	jun	-1.8	5	1987	6	jun	-17.9	1
1936	7	jul	3.9	4	1987	7	jul	-17.3	1
1936	8	aug	-8.2	3	1987	8	aug	-13.1	1
1936	9	sep	2.9	4	1987	9	sep	-10.6	1
1936	10	oct	0.3	5	1987	10	oct	-5.3	1
1936	11	nov	-13.8	3	1987	11	nov	-1.5	5
1936	12	dec	-0.7	4	1987	12	dec	-5.8	5
1937	1	jan	8.8	4	1988	1	jan	-1.5	5
1937	2	feb	-6.2	3	1988	2	feb	-6.2	5
1937	3	mar	4.5	4	1988	3	mar	1.2	4
1937	4	apr	1.3	5	1988	4	apr	-3	5
1937	5	may	0.3	5	1988	5	may	9.9	4
1937	6	jun	2.4	5	1988	6	jun	-3.9	3
1937	7	jul	-5.2	3	1988	7	jul	10.5	4
1937	8	aug	3.3	4	1988	8	aug	14.2	2
1937	9	sep	1.1	5	1988	9	sep	18.7	2
1937	10	oct	-2.2	5	1988	10	oct	15.5	2
1937	11	nov	-2.1	5	1988	11	nov	22	2
1937	12	dec	5.4	4	1988	12	dec	9.5	2
1938	1	jan	6.9	2	1989	1	jan	12.7	2
1938	2	feb	2.7	2	1989	2	feb	8.5	2
1938	3	mar	-4.1	5	1989	3	mar	5.5	2
1938	4	apr	2.8	4	1989	4	apr	18.1	4
1938	5	may	12.8	4	1989	5	may	15.1	2
1938	6	jun	14.9	2	1989	6	jun	6.1	2
1938	7	jul	17.2	2	1989	7	jul	8.5	2
1938	8	aug	12.4	2	1989	8	aug	-5.6	3
1938	9	sep	7.6	2	1989	9	sep	5.8	4
1938	10	oct	13.6	2	1989	10	oct	7.8	2
1938	11	nov	1.7	2	1989	11	nov	-1.8	3
1938	12	dec	12.5	4	1989	12	dec	-5.3	5
1939	1	jan	16.5	2	1990	1	jan	-1.9	5
1939	2	feb	7.2	2	1990	2	feb	-18.4	3
1939	3	mar	9.4	2	1990	3	mar	-8.2	4
1939	4	apr	7.9	2	1990	4	apr	-0.7	4
1939	5	may	-0.4	5	1990	5	may	13.6	4
1939	6	jun	-1.8	5	1990	6	jun	0	3
1939	7	jul	7.5	4	1990	7	jul	5.2	5
1939	8	aug	-0.3	5	1990	8	aug	-4.4	5
1939	9	sep	-8.8	3	1990	9	sep	-7.3	1
1939	10	oct	-14.8	1	1990	10	oct	-1.2	5
1939	11	nov	-7.8	1	1990	11	nov	-5	5
1939	12	dec	-9.9	1	1990	12	dec	-3.7	5
1940	1	jan	-0.8	4	1991	1	jan	4.2	5
1940	2	feb	-5.2	5	1991	2	feb	-0.2	5
1940	3	mar	-10.4	5	1991	3	mar	-10.1	3
1940	4	apr	-8.9	1	1991	4	apr	-11.5	1
1940	5	may	-13	1	1991	5	may	-17.9	1
1940	6	jun	-17.2	1	1991	6	jun	-5.5	5
1940	7	jul	-14.3	1	1991	7	jul	-1.5	5
1940	8	aug	-17.4	1	1991	8	aug	-6.8	3
1940	9	sep	-18.8	1	1991	9	sep	-16.2	3
1940	10	oct	-18.6	1	1991	10	oct	-13.5	1
1940	11	nov	-6.5	1	1991	11	nov	-6.9	1
1940	12	dec	-30.7	3	1991	12	dec	-18.3	1
1941	1	jan	-10.3	1	1992	1	jan	-26	1
1941	2	feb	-17	1	1992	2	feb	-10.3	1
1941	3	mar	-10.4	1	1992	3	mar	-22.1	1
1941	4	apr	-10.4	1	1992	4	apr	-16.5	1
1941	5	may	-5.6	1	1992	5	may	0.4	4
1941	6	jun	-13	3	1992	6	jun	-11.9	3
1941	7	jul	-19.1	1	1992	7	jul	-6.5	1
1941	8	aug	-18	1	1992	8	aug	0.8	5

Year	Month	Month	SOI	PHASE	Year	Month	Month	SOI	PHASE
1941	9	sep	-7.7	1	1992	9	sep	0.7	5
1941	10	oct	-20.5	3	1992	10	oct	-18	3
1941	11	nov	-9.1	1	1992	11	nov	-6.9	1
1941	12	dec	-9.9	1	1992	12	dec	-6.6	1
1942	1	jan	-13.7	1	1993	1	jan	-9.2	1
1942	2	feb	-4.7	1	1993	2	feb	-8.7	1
1942	3	mar	-6	5	1993	3	mar	-8.8	1
1942	4	apr	-5.2	5	1993	4	apr	-18.5	3
1942	5	may	5.5	4	1993	5	may	-7.3	1
1942	6	jun	6.5	2	1993	6	jun	-14.4	1
1942	7	jul	-1	5	1993	7	jul	-10.1	1
1942	8	aug	3.9	4	1993	8	aug	-13	1
1942	9	sep	8.7	2	1993	9	sep	-7	1
1942	10	oct	9.2	2	1993	10	oct	-13	1
1942	11	nov	-4	3	1993	11	nov	0.4	4
1942	12	dec	12.5	4	1993	12	dec	0.7	5
1943	1	jan	8.8	2	1994	1	jan	-2.1	5
1943	2	feb	10.1	2	1994	2	feb	0.3	5
1943	3	mar	2.6	2	1994	3	mar	-10	3
1943	4	apr	11.6	4	1994	4	apr	-19.9	3
1943	5	may	3.3	2	1994	5	may	-11.6	1
1943	6	jun	-7.4	3	1994	6	jun	-9.4	1
1943	7	jul	2.7	4	1994	7	jul	-16.7	1
1943	8	aug	7.5	4	1994	8	aug	-15.7	1
1943	9	sep	5.8	2	1994	9	sep	-16.2	1
1943	10	oct	9.8	2	1994	10	oct	-13.5	1
1943	11	nov	3.6	2	1994	11	nov	-7.3	1
1943	12	dec	-9.9	3	1994	12	dec	-13.1	1
1944	1	jan	-8.9	1	1995	1	jan	-5.8	5
1944	2	feb	3.2	4	1995	2	feb	-3.3	5
1944	3	mar	4.1	5	1995	3	mar	2.8	5
1944	4	apr	-5.2	3	1995	4	apr	-13.5	3
1944	5	may	-0.4	5	1995	5	may	-8.2	1
1944	6	jun	-3.9	5	1995	6	jun	-1.7	5
1944	7	jul	-8.2	5	1995	7	jul	4	5
1944	8	aug	3.3	4	1995	8	aug	1.2	5
1944	9	sep	2.9	5	1995	9	sep	3.4	5
1944	10	oct	-8.5	3	1995	10	oct	-0.6	5
1944	11	nov	-6.5	1	1995	11	nov	1.7	5
1944	12	dec	2.9	4	1995	12	dec	-7.8	3
1945	1	jan	4.5	5	1996	1	jan	7.7	4
1945	2	feb	5.7	2	1996	2	feb	-0.1	5
1945	3	mar	10.8	2	1996	3	mar	5.3	4
1945	4	apr	-6.7	3	1996	4	apr	5.3	2
1945	5	may	0.3	4	1996	5	may	1.7	5
1945	6	jun	6.5	4	1996	6	jun	10.5	4
1945	7	jul	3.3	2	1996	7	jul	6.7	2
1945	8	aug	11.2	4	1996	8	aug	5.3	2
1945	9	sep	8.7	2	1996	9	sep	6.2	2
1945	10	oct	2.9	2	1996	10	oct	6.2	2
1945	11	nov	-3.4	5	1996	11	nov	-0.8	5
1945	12	dec	5.4	4	1996	12	dec	7.3	4
1946	1	jan	-3.1	3	1997	1	jan	3.5	2
1946	2	feb	3.7	4	1997	2	feb	12.4	2
1946	3	mar	-2.7	5	1997	3	mar	-7	3
1946	4	apr	-8.9	5	1997	4	apr	-14.4	3
1946	5	may	-10	1	1997	5	may	-18.7	1
1946	6	jun	-8.8	1	1997	6	jun	-24.3	1
1946	7	jul	-9.5	1	1997	7	jul	-8.9	1
1946	8	aug	-4	1	1997	8	aug	-18.7	3
1946	9	sep	-13.3	3	1997	9	sep	-14.1	1
1946	10	oct	-12.3	1	1997	10	oct	-17.4	1
1946	11	nov	-1.5	4	1997	11	nov	-13.9	1

Year	Month	Month	SOI	PHASE
1946	12	dec	-6.8	5
1947	1	jan	-5.5	5
1947	2	feb	-5.2	5
1947	3	mar	9.4	4
1947	4	apr	-4.5	3
1947	5	may	-12.2	3
1947	6	jun	1.7	4
1947	7	jul	8.7	4
1947	8	aug	6.9	2
1947	9	sep	11.7	2
1947	10	oct	-1.6	3
1947	11	nov	8.7	4
1947	12	dec	3.9	2
1948	1	jan	-3.6	5
1948	2	feb	-3.7	5
1948	3	mar	-4.6	5
1948	4	apr	2.1	4
1948	5	may	4	5
1948	6	jun	-4.6	3
1948	7	jul	0.8	4
1948	8	aug	-4	5
1948	9	sep	-7.1	5
1948	10	oct	6.6	4
1948	11	nov	4.2	2
1948	12	dec	-6.8	3
1949	1	jan	-7.9	5
1949	2	feb	1.2	4
1949	3	mar	4.1	5
1949	4	apr	0.6	5
1949	5	may	-4.8	5
1949	6	jun	-10.9	3
1949	7	jul	-1.6	4
1949	8	aug	-4	5
1949	9	sep	2.3	4
1949	10	oct	6	5
1949	11	nov	-5.9	3
1949	12	dec	6.4	4
1950	1	jan	4.5	2
1950	2	feb	17	4
1950	3	mar	14.6	2
1950	4	apr	13.8	2
1950	5	may	7.7	2
1950	6	jun	22.6	4
1950	7	jul	19.6	2
1950	8	aug	11.8	2
1950	9	sep	7	2
1950	10	oct	18	4
1950	11	nov	11.8	2
1950	12	dec	21.7	2

Year	Month	Month	SOI	PHASE
1997	12	dec	-10.8	1
1998	1	jan	-22.1	3
1998	2	feb	-22.2	1
1998	3	mar	-26.1	1
1998	4	apr	-22.5	1
1998	5	may	-0.4	4
1998	6	jun	8.2	4
1998	7	jul	12.9	2
1998	8	aug	9.8	2
1998	9	sep	12.1	2
1998	10	oct	11.2	2
1998	11	nov	13.3	2
1998	12	des	10	2
1999	1	jan	14.7	2
1999	2	feb	7.1	2
1999	3	mar	7.8	2
1999	4	apr	16.8	2
1999	5	may	0.9	3
1999	6	jun	-0.5	5
1999	7	jul	4.37	5
1999	8	aug	3.3	2
1999	9	sep	0.15	5
1999	10	oct	9.2	2
1999	11	nov	11.6	2
1999	12	dec	13.2	2
2000	1	jan	2.97	2
2000	2	feb	13.98	2
2000	3	mar	7.16	2
2000	4	apr	10.06	2
2000	5	may	6.03	2
2000	6	jun	-6.54	5
2000	7	jul	-4.02	5
2000	8	aug	4.85	4
2000	9	sep	10.14	2
2000	10	oct	11.55	2
2000	11	nov	20.68	2
2000	12	des	7.75	2
2001	1	jan	7.39	2
2001	2	feb	12.01	2
2001	3	mar	4.7	2
2001	4	apr	1.39	5
2001	5	may	-9.8	3
2001	6	Jun	2.39	4

Appendix XII

Interdecadal Pacific Oscillation (IPO).

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1900	0.04	1.32	0.49	0.35	0.77	0.65	0.95	0.14	-0.24	0.23	-0.44	1.19
1901	0.79	-0.12	0.35	0.61	-0.42	-0.05	-0.6	-1.2	-0.33	0.16	-0.6	-0.14
1902	0.82	1.58	0.48	1.37	1.09	0.52	1.58	1.57	0.44	0.7	0.16	-1.1
1903	0.86	-0.24	-0.22	-0.5	0.43	0.23	0.4	1.01	-0.24	0.18	0.08	-0.03
1904	0.63	-0.91	-0.71	-0.07	-0.22	-1.53	-1.58	-0.64	0.06	0.43	1.45	0.06
1905	0.73	0.91	1.31	1.59	-0.07	0.69	0.85	1.26	-0.03	-0.15	1.11	-0.5
1906	0.92	1.18	0.83	0.74	0.44	1.24	0.09	-0.53	-0.31	0.08	1.69	-0.54
1907	-0.3	-0.32	-0.19	-0.16	0.16	0.57	0.63	-0.96	-0.23	0.84	0.66	0.72
1908	1.36	1.02	0.67	0.23	0.23	0.41	0.6	-1.04	-0.16	-0.41	0.47	1.16
1909	0.23	1.01	0.54	0.24	-0.39	-0.64	-0.39	-0.68	-0.89	-0.02	-0.4	-0.01
1910	-0.25	-0.7	0.18	-0.37	-0.06	-0.28	0.03	-0.06	0.4	-0.66	0.02	0.84
1911	-1.11	0	-0.78	-0.73	0.17	0.02	0.48	0.43	0.29	0.2	-0.86	0.01
1912	-1.72	-0.23	-0.04	-0.38	-0.02	0.77	1.07	-0.84	0.94	0.56	0.74	0.98
1913	-0.03	0.34	0.06	-0.92	0.66	1.43	1.06	1.29	0.73	0.62	0.75	0.9
1914	0.34	-0.29	0.08	1.2	0.11	0.11	-0.21	0.11	-0.34	-0.11	0.03	0.89
1915	-0.41	0.14	-1.22	1.4	0.32	0.99	1.07	0.27	-0.05	-0.43	-0.12	0.17
1916	-0.64	-0.19	-0.11	0.35	0.42	-0.82	-0.78	-0.73	-0.77	-0.22	-0.68	-1.94
1917	-0.79	-0.84	-0.71	-0.34	0.82	-0.03	0.1	-0.22	-0.4	-1.75	-0.34	-0.6
1918	-1.13	-0.66	-1.15	-0.32	-0.33	0.07	0.98	-0.31	-0.59	0.61	0.34	0.86
1919	-1.07	1.31	-0.5	0.08	0.17	-0.71	-0.47	0.38	0.06	-0.42	-0.8	0.76
1920	-1.18	0.06	-0.78	-1.29	-0.97	-1.3	-0.9	-2.21	-1.28	-1.06	-0.26	0.29
1921	-0.66	-0.61	-0.01	-0.93	-0.42	0.4	-0.58	-0.69	-0.78	-0.23	1.92	1.42
1922	1.05	-0.85	0.08	0.43	-0.19	-1.04	-0.82	-0.93	-0.81	0.84	-0.6	0.48
1923	0.75	-0.04	0.49	0.99	-0.2	0.68	1.16	0.84	-0.24	1.1	0.62	-0.36
1924	1.29	0.73	1.13	-0.02	0.36	0.75	-0.55	-0.67	-0.48	-1.25	0.24	0.11
1925	-0.05	-0.14	0.2	0.86	0.79	-1.08	-0.06	-0.86	0.52	0.04	0.88	1.19
1926	0.3	0.98	-0.5	2.1	1.43	2.03	1.05	1.64	1.18	1.65	1	1.06
1927	1.07	1.73	0.15	-0.18	0.3	0.69	-0.31	-0.73	-0.41	-0.62	-0.07	0.07
1928	0.96	0.79	0.52	0.81	0.66	0.15	0.3	-0.72	-1.41	-1.31	0.14	0.98
1929	0.97	0.52	0.5	0.55	1.07	0.5	-0.06	-0.69	0.45	-0.21	1.24	-0.03
1930	0.97	-1.06	-0.43	-0.7	0.06	0.58	-0.45	-0.53	-0.2	-0.38	-0.31	1.2
1931	0.08	1.56	1.13	1.28	1.66	0.39	1.49	0.02	-0.01	-0.17	0.34	1.09
1932	-0.26	-0.58	0.51	1.15	0.64	0.1	-0.12	-0.14	-0.4	-0.29	-0.88	0.02
1933	0.29	0.02	0.15	-0.05	-0.5	-0.68	-1.81	-1.56	-2.28	-1.19	0.55	-1.1
1934	0.17	0.68	1.34	1.63	1.23	0.51	0.44	1.54	1.25	2.1	1.63	1.67
1935	1.01	0.79	-0.11	1.1	0.99	1.39	0.68	0.63	0.98	0.21	0.13	1.78
1936	1.79	1.75	1.36	1.32	1.83	2.37	2.57	1.71	0.04	2.1	2.65	1.28
1937	0	-0.49	0.38	0.2	0.53	1.75	0.11	-0.35	0.63	0.76	-0.18	0.55
1938	0.5	0.02	0.24	0.27	-0.25	-0.2	-0.21	-0.45	-0.01	0.07	0.48	1.4
1939	1.36	0.07	-0.39	0.45	0.98	1.04	-0.21	-0.74	-1.1	-1.31	-0.88	1.51
1940	2.03	1.74	1.89	2.37	2.32	2.43	2.12	1.4	1.1	1.19	0.68	1.96
1941	2.14	2.07	2.41	1.89	2.25	3.01	2.33	3.31	1.99	1.22	0.4	0.91
1942	1.01	0.79	0.29	0.79	0.84	1.19	0.12	0.44	0.68	0.54	-0.1	-1

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1943	-0.18	0.02	0.26	1.08	0.43	0.68	-0.36	-0.9	-0.49	-0.04	0.29	0.58
1944	0.18	0.17	0.08	0.72	-0.35	-0.98	-0.4	-0.51	-0.56	-0.4	0.33	0.2
1945	-1.02	0.72	-0.42	-0.4	-0.07	0.56	1.02	0.18	-0.27	0.1	-1.94	-0.74
1946	-0.91	-0.32	-0.41	-0.78	0.5	-0.86	-0.84	-0.36	-0.22	-0.36	-1.48	-0.96
1947	-0.73	-0.29	1.17	0.7	0.37	1.36	0.16	0.3	0.58	0.85	-0.14	1.67
1948	-0.11	-0.74	-0.03	-1.33	-0.23	0.08	-0.92	-1.56	-1.74	-1.32	-0.89	-1.7
1949	-2.01	-3.6	-1	-0.53	-1.07	-0.7	-0.56	-1.3	-0.93	-1.41	-0.83	-0.8
1950	-2.13	-2.91	-1.13	-1.2	-2.23	-1.77	-2.93	-0.7	-2.14	-1.36	-2.46	-0.76
1951	-1.54	-1.06	-1.9	-0.36	-0.25	-1.09	0.7	-1.37	-0.08	-0.32	-0.28	-1.68
1952	-2.01	-0.46	-0.63	-1.05	-1	-1.43	-1.25	-0.6	-0.89	-0.35	-0.76	0.04
1953	-0.57	-0.07	-1.12	0.05	0.43	0.29	0.74	0.05	-0.63	-1.09	-0.03	0.07
1954	-1.32	-1.61	-0.52	-1.33	0.01	0.97	0.43	0.08	-0.94	0.52	0.72	-0.5
1955	0.2	-1.52	-1.26	-1.97	-1.21	-2.44	-2.35	-2.25	-1.95	-2.8	-3.08	-2.75
1956	-2.48	-2.74	-2.56	-2.17	-1.41	-1.7	-1.03	-1.16	-0.71	-2.3	-2.11	-1.28
1957	-1.82	-0.68	0.03	-0.58	0.57	1.76	0.72	0.51	1.59	1.5	-0.32	-0.55
1958	0.25	0.62	0.25	1.06	1.28	1.33	0.89	1.06	0.29	0.01	-0.18	0.86
1959	0.69	-0.43	-0.95	-0.02	0.23	0.44	-0.5	-0.62	-0.85	0.52	1.11	0.06
1960	0.3	0.52	-0.21	0.09	0.91	0.64	-0.27	-0.38	-0.94	0.09	-0.23	0.17
1961	1.18	0.43	0.09	0.34	-0.06	-0.61	-1.22	-1.13	-2.01	-2.28	-1.85	-2.69
1962	-1.29	-1.15	-1.42	-0.8	-1.22	-1.62	-1.46	-0.48	-1.58	-1.55	-0.37	-0.96
1963	-0.33	-0.16	-0.54	-0.41	-0.65	-0.88	-1	-1.03	0.45	-0.52	-2.08	-1.08
1964	0.01	-0.21	-0.87	-1.03	-1.91	-0.32	-0.51	-1.03	-0.68	-0.37	-0.8	-1.52
1965	-1.24	-1.16	0.04	0.62	-0.66	-0.8	-0.47	0.2	0.59	-0.36	-0.59	0.06
1966	-0.82	-0.03	-1.29	0.06	-0.53	0.16	0.26	-0.35	-0.33	-1.17	-1.15	-0.32
1967	-0.2	-0.18	-1.2	-0.89	-1.24	-1.16	-0.89	-1.24	-0.72	-0.64	-0.05	-0.4
1968	-0.95	-0.4	-0.31	-1.03	-0.53	-0.35	0.53	0.19	0.06	-0.34	-0.44	-1.27
1969	-1.26	-0.95	-0.5	-0.44	-0.2	0.89	0.1	-0.81	-0.66	1.12	0.15	1.38
1970	0.61	0.43	1.33	0.43	-0.49	0.06	-0.68	-1.63	-1.67	-1.39	-0.8	-0.97
1971	-1.9	-1.74	-1.68	-1.59	-1.55	-1.55	-2.2	-0.15	0.21	-0.22	-1.25	-1.87
1972	-1.99	-1.83	-2.09	-1.65	-1.57	-1.87	-0.83	0.25	0.17	0.11	0.57	-0.33
1973	-0.46	-0.61	-0.5	-0.69	-0.76	-0.97	-0.57	-1.14	-0.51	-0.87	-1.81	-0.76
1974	-1.22	-1.65	-0.9	-0.52	-0.28	-0.31	-0.08	0.27	0.44	-0.1	0.43	-0.12
1975	-0.84	-0.71	-0.51	-1.3	-1.02	-1.16	-0.4	-1.07	-1.23	-1.29	-2.08	-1.61
1976	-1.14	-1.85	-0.96	-0.89	-0.68	-0.67	0.61	1.28	0.82	1.11	1.25	1.22
1977	1.65	1.11	0.72	0.3	0.31	0.42	0.19	0.64	-0.55	-0.61	-0.72	-0.69
1978	0.34	1.45	1.34	1.29	0.9	0.15	-1.24	-0.56	-0.44	0.1	-0.07	-0.43
1979	-0.58	-1.33	0.3	0.89	1.09	0.17	0.84	0.52	1	1.06	0.48	-0.42
1980	-0.11	1.32	1.09	1.49	1.2	-0.22	0.23	0.51	0.1	1.35	0.37	-0.1
1981	0.59	1.46	0.99	1.45	1.75	1.69	0.84	0.18	0.42	0.18	0.8	0.67
1982	0.34	0.2	0.19	-0.19	-0.58	-0.78	0.58	0.39	0.84	0.37	-0.25	0.26
1983	0.56	1.14	2.11	1.87	1.8	2.36	3.51	1.85	0.91	0.96	1.02	1.69
1984	1.5	1.21	1.77	1.52	1.3	0.18	-0.18	-0.03	0.67	0.58	0.71	0.82
1985	1.27	0.94	0.57	0.19	0	0.18	1.07	0.81	0.44	0.29	-0.75	0.38
1986	1.12	1.61	2.18	1.55	1.16	0.89	1.38	0.22	0.22	1	1.77	1.77
1987	1.88	1.75	2.1	2.16	1.85	0.73	2.01	2.83	2.44	1.36	1.47	1.27
1988	0.93	1.24	1.42	0.94	1.2	0.74	0.64	0.19	-0.37	-0.1	-0.02	-0.43
1989	-0.95	-1.02	-0.83	-0.32	0.47	0.36	0.83	0.09	0.05	-0.12	-0.5	-0.21
1990	-0.3	-0.65	-0.62	0.27	0.44	0.44	0.27	0.11	0.38	-0.69	-1.69	-2.23
1991	-2.02	-1.19	-0.74	-1.01	-0.51	-1.47	-0.1	0.36	0.65	0.49	0.42	0.09

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1992	0.05	0.31	0.67	0.75	1.54	1.26	1.9	1.44	0.83	0.93	0.93	0.53
1993	0.05	0.19	0.76	1.21	2.13	2.34	2.35	2.69	1.56	1.41	1.24	1.07
1994	1.21	0.59	0.8	1.05	1.23	0.46	0.06	-0.79	-1.36	-1.32	-1.96	-1.79
1995	-0.49	0.46	0.75	0.83	1.46	1.27	1.71	0.21	1.16	0.47	-0.28	0.16
1996	0.59	0.75	1.01	1.46	2.18	1.1	0.77	-0.14	0.24	-0.33	0.09	-0.03
1997	0.23	0.28	0.65	1.05	1.83	2.76	2.35	2.79	2.19	1.61	1.12	0.67
1998	0.83	1.56	2.01	1.27	0.7	0.4	-0.04	-0.22	-1.21	-1.39	-0.52	-0.44
1999	-0.32	-0.66	-0.33	-0.41	-0.68	-1.3	-0.66	-0.96	-1.53	-2.23	-2.05	-1.63
2000	-1.99	-0.82	0.29	0.35	-0.05	-0.43	-0.66	-1.19	-1.24	-1.3	-0.53	0.52
2001	0.61	0.30										

Appendix XIII

Dry and wet cycles

Tyson & Dyer Wet- and dry cycles (Tyson & Dyer, 1978).

Years	Wet/Dry
1916-1925	Wet
1926-1934	Dry
1935-1943	Wet
1944-1953	Dry
1954-1962	Wet
1963-1972	Dry
1973-1981	Wet
1982-1991	Dry
1992-2001	Wet