# SEASONAL CLIMATE PREDICTIONS WITH A COUPLED ATMOSPHERE-OCEAN GENERAL CIRCULATION MODEL

(CLIPWATER)

by

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# EXECUTIVE SUMMARY

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## 1. INTRODUCTION

Many industrial sectors, especially the agriculture and food production sectors, exhibit a strong seasonal character. In addition, climate variability is factored into the performance of such industries. The availability of relatively accurate seasonal forecasts would therefore be invaluable for production prediction and operational planning. Seasonal climate variability is modulated by atmospheric circulation features, which are considered non-linear of nature.

Progress in the field of seasonal forecasting over the last couple of decades has revealed that the processes involved in seasonal forecasting are complex. Not only do seasonal changes in global Sea Surface Temperatures (SSTs) and land surface characteristics interfere with the conventional El Niño Southern Oscillation (ENSO) signal, but natural variability in the atmosphere (also known as random internal variability or chaos) also appears to be a major contributing factor that prevents forecasters from producing the so called "perfect deterministic seasonal forecast". Since anomalous changes in the ocean circulation evolve over longer periods than in the atmosphere, the response of atmospheric circulation (and therefore rainfall) to the global SST variability is still regarded as a key factor in the process of longer term forecasting. Both statistically and numerically-based (also dynamic) models have shown significant skill in the forecasting of rainfall at many locations on the globe. One benefit of numerically-based models is that natural variability forms part of the general or overall climate variation simulated by these models.

In this study the CSIRO9 Atmospheric Circulation Model (AGCM) with a R21 resolution is used in an effort to produce improved seasonal rainfall forecasts for South Africa. The COCA Coupled Atmosphere Ocean General Circulation Model (CGCM) simulates forecasted SST patterns that serve as boundary forcing for the AGCM. Both the AGCM and CGCM models were developed by the CSIRO Atmospheric Research in Australia. SST forecasts are supplied by Australian collaborators, while AGCM rainfall simulations are performed on a local super computer.

## 2. OBJECTIVES OF THE CLIPWATER PROJECT

The two main objectives of the CLIPWATER project can be summarised as follows:

*a.* *To collaborate with the CSIRO Atmospheric Research in Australia in order to develop a CGCM (referred to as the COCA CGCM) by coupling a dynamic OGCM to the CSIRO9 Mark II global AGCM with a T63 resolution (referred to as the CSIRO9(T63) AGCM). The CSIRO Atmospheric Research has developed both models.*

*b.* *To prescribe the CGSM simulated SST forecasts generated and issued by the CSIRO Atmospheric Research as boundary forcing in a coarser resolution model locally available (CSIRO9 Mark II global AGCM with a R21 resolution or CSIRO9(R21) AGCM) in order to investigate the skill and ability of this model to generate seasonal rainfall forecasts for Southern Africa.*

**The research objectives were successfully achieved:**

Good collaboration was established between the research team and the CSIRO Atmospheric Research in Australia. The CGCM was developed during the research project and the research team as well as students involved benefit significantly in terms of knowledge transfer from an international research organisation. The research team obtained code for the CSIRO9 Mark II AGCM (T63 resolution) and a number of simulations were completed on a local supercomputer.

Monthly SST forecasts generated by the CGCM were acquired from the CSIRO and these forecasts were compared to local SST forecasts. A thourough investigation indicated that CGCM forecasts are superior to persistence and locally generated statistical forecasts. CGCM SST forecasts were prescribed as boundary forcing to the CSIRO Mark II AGCM (R21 resolution). A forecasting technique was developed and probabilistic rainfall forecasts were successfully generated on a local super computer for the 2001/2002 summer season.

## 3. SUMMARY OF RESEARCH

In this study observed rainfall over South Africa was analysed from spatial and temporal perspectives and was compared with the associated AGCM simulated rainfall, where rainfall climatologies were derived in accordance with the CSIRO9(R21) and T(63) spectral resolutions. These climatologies formed the basis from which deviations in forecast rainfall were assessed.

A first numerical rainfall forecast was obtained by using the CSIRO9(R21) AGCM for the 1998/1999 summer season and verified against observations. Instead of CGCM SST forecasts, statistical Canonical Correlation Analysis (CCA) SST forecasts were employed as surface boundary forcing in this first experiment.

The research team collaborated closely with Australian scientists during the development phase of the COCA CGCM. Aspects of anomaly coupling, nudging and the initialisation procedure for forecast simulations were addressed and complex processes involved in ocean-atmosphere coupling as well as forecasting procedures were considered. In this project the COCA CGCM was primarily used for global SST forecasts.

Finally, COCA CGCM SST forecasts were evaluated against persisted SST forecasts and compared with forecasts generated by a statistical model. The CGCM forecasts outscored persistence and statistical forecasts, which motivated why CGCM SST forecasts were used. Spatial anomaly correlation patterns between observations and CGCM SST forecasts were illustrated and ocean regions with significant skill were highlighted.

The CSIRO9(R21) AGCM was forced with CGCM SST forecast fields to in an effort to generate probabilistic seasonal forecasts for the 2001/2002 summer season. An 18-year hindcast simulation was used to determine the skill of the AGCM, and different rainfall categories were defined. Hit rate scores were calculated. CGCM SST forecasts for the October, November, December (OND) 2001 and January, February, March (JFM) 2002 seasons were prescribed as boundary forcing for the AGCM and rainfall simulations were performed. Probabilistic forecasts were prepared for the three rainfall categories.

*The OND 2001 (early-summer) and JFM 2002 (late-summer) forecasts favoured wetter conditions during the early-summer season followed by somewhat drier conditions during the late-summer season.* ***These forecasts agreed with observations during the 2001/2002 summer season.***

The report on capacity building and technology (knowledge) transfer gives an overview on the knowledge that was generated and how it will be applied in future.

## 4. OUTLOOK FOR THE FUTURE

The CLIPWATER project established a firm basis for further research in the field of numerical-based rainfall forecasting. A most challenging prospect is to produce improved seasonal forecasts on the regional scale. The CLIPWATER research team will continue with their efforts to investigate means of improving seasonal forecasts, and will most probably focus on the development of regional scale rainfall forecasting.