EXECUTIVE SUMMARY

1. INTRODUCTION

Since the first attempt to utilise numerical methods for predicting weather was made by the British scientist Lewis Fry Richardson (1882-1953), many scientists accepted the challenge to produce improved methods for simulating atmospheric processes and flow. The motivation for these efforts was primarily manifested through the benefits they would hold for short-term planning (daily Numerical Weather Prediction (NWP) and air pollution modelling), seasonal risk analysis (seasonal forecasting) and early warning of the need to adapt to possible variations in the climate system (future climate change projections).

Apart from predicting the day-to-day weather, modern computerised numerical models of the atmospheric circulation have been used for many other purposes. Today numerical atmospheric models are applied in:

- Assimilation of the present state of the atmosphere for use as initial conditions in NWP models and routine air pollution research.
- Short-term NWP that involves day-to-day weather forecasting.
- Climate variability research and product generation that includes sensitivity studies and studies on longer-term forecasting, such as seasonal forecasting.
- Possible future climate change estimations, such as future climate scenarios linked to enhanced greenhouse gas concentrations.

With the training in dynamic meteorology and numerical techniques available at the University of Pretoria, and the capacity existing at South African research institutions to perform their own model simulations, the question was being asked whether South African research institutions should not also become involved in model development. The possibility of developing a unique atmospheric model on African soil by African researchers was also being mentioned. Modern atmospheric models are in an advanced stage with sophisticated numerical approaches and parameterizations. These models had been developed over years, and it would therefore not be easy to start developing a totally new model. South African scientists interested in numerical modeling would, however, benefit significantly from close collaboration with, and involvement in, international modeling efforts. These thoughts inspired the research initiatives and achievements discussed in this report.

2. AIMS OF THE PROJECT

Objectives of the research presented in this report may be summarized as follows:

- To modify the dynamic formulation and physical parameterization schemes of internationally competitive regional atmospheric circulation models in order to improve the simulation of water-related atmospheric variables over South Africa.
- To equip scientists and prospective students from the South Africa and southern African community with the necessary knowledge and skills to develop, maintain and use the regional atmospheric models by means of innovative water research training.

3. RESEARCH APPROACH

The research was conducted in collaboration with international institutions and the objectives were achieved by following two well defined research routes.

3.1 Research route 1

Research route one aimed to improve model simulated rainfall patterns over South Africa. This is in line with the research objective to improve the simulation of water related atmospheric variables over South Africa. The WRC research team performed many simulations on local workstations in order to verify different model versions on a regular basis. Model rainfall biases were identified and CSIRO-AR researchers were notified. Researchers at the CSIRO-AR then adjusted / improved rainfall parameterization schemes in the model code, where after the improved code was sent back to the WRC research team for further verification. This process of code exchange took place for almost three years, meaning that a large number of model simulations were executed on local workstations.

3.2 Research route 2

Research route two consisted of two components. (1) In the first place an unique non-hydrostatic kernel was developed by the WRC research team in South Africa. Many tests were performed in the form of the release of thermal bubbles in the model atmosphere, thereby also opening up the opportunity to add other components (radiation budget, surface characteristics, moisture and rainfall etc.) to the kernel to develop a more comprehensive model. (2) The dynamics developed were used as guideline for making C-CAM non-hydrostatic at the CSIRO-AR. This task was completed during a visit of a WRC researcher to the CSIRO-AR in February 2004.

These two research routes yielded model improvement in simulating rainfall as well as general circulation (dynamics). It also established a sustainable basis for model development in South Africa, both institutional and human related. In concluding the research, the latest version of C-CAM was used and the final simulations were verified. Model development is an ongoing process. Since the WRC project was timerestricted, it was necessary to select a cutoff point for initiating the concluding research. . Nevertheless, the concluding research did not take place before the WRC research team was convinced that significant progress had been made along the two research routes followed.

The achievements of this project, including capacity building, knowledge transfer and sustainable bilateral collaboration, not only between South Africa and the CSIRO-AR but also among African countries, proves that the research approach and routes were greatly successful.

4. FINE RESOLUTION OBSERVED RAINFALL OVER SOUTH AFRICA

Model performance is evaluated by comparing model results with observations. Many global observational fields are currently available for model verification. Coarse resolution observational fields (here regarded as coarser than 1° x 1°) might be useful to verify general large-scale atmospheric patterns as well as averaged climate fields, but they are not suitable for verification use in fine-resolution model-development studies where the sensitivity of the atmosphere to fine-resolution initial and boundary fields are evaluated. Global fine-resolution observational fields are not commonly available.

Many internationally available observational data sets have a relatively coarse grid resolution and important fine resolution features such as the influence of high topography on observed rainfall is smoothed out significantly. Apart from this, observed summer rainfall is significantly underestimated by some of these fields. The research team therefore decided to produce fine resolution observational data fields interpolated from 1027 South African rainfall stations. These fields were used in model verification.

5. THE STRETCHED GRID MODEL C-CAM

The research team decided to focus on the regional model C-CAM that was developed by the CSIRO Atmospheric Research (CSIRO-AR) in Australia. The advantage of C-CAM is that it is a global stretched grid model and problems related to nested modeling are therefore avoided. C-CAM employs a conformal cubic projection over a sphere instead of a traditional longitudinal-latitudinal projection. In the conformal cubic projection the model grids are expressed on six panels of a cube, which is then radially projected onto a sphere. Each panel has a user prescribed number of grid points. The grid may then be stretched with a stretch factor ranging from 0 to 1 (Schmidt factor) for full-stretch and non-stretch modes, respectively. Many model climate and sensitivity simulations were performed with C-CAM in order to improve rainfall over South Africa. The model was improved bilaterally during close collaboration with the CSIRO-AR. The latest results are a remarkable improvement on those produced at the beginning of the project.

6. A LOCALLY DEVELOPED ATMOSPHERIC MODEL

Apart from improving an international model (C-CAM), the project research also focused on the development of a unique non-hydrostatic model (equations and the associated numerical solution procedures). The aim was to develop a non-hydrostatic kernel for the hydrostatic C-CAM, which employs a semi-implicit semi-Lagrangian solution procedure. The research also focused on the development of a nonhydrostatic dynamic kernel for a new split semi-Lagrangian atmospheric model that is unique to South Africa. Significant progress has been made in the development of these models.

7. AN IMPROVED C-CAM FOR NUMERICAL WEATHER PREDICTION

In the final phase of the project a licence agreement was obtained to employ the improved C-CAM as a NWP model. NETSYS International provided office space and networking for downloading initial conditions on a daily basis. The first predictions were generated at the beginning of December 2004, and since then the model is producing predictions of four days in advance on a daily basis. Data are archived for verification purposes, and according to the license agreement predictions will be issued until December 2005. C-CAM appears to perform well as a NWP model. Model predictions are available on the following web page: **http://www.up.ac.za/academic/geog/meteo**

8. CONCLUSIONS

On the local front the project contributed significantly in capacity building. The two workshops that were presented as part of the project were well attended by local scientists, and the student seminar drew a lot of interest. The Laboratory for Research into Atmosheric Modelling (LRAM) was established and has served as a basis for research in atmospheric modelling over the past two years. The availability of infrastructure and models led to other modelling research activities that include:

- Long-range climate change scenario simulations for other Water Research Commission and ESKOM research projects.
- Air quality modelling with the emphasis on wind trajectory modelling for ESKOM.
- Weather forecasts for the Southern Ocean as part of research for the South African National Antarctic Programme (SANAP) funded by the Department of Environmental Affairs and Tourism (DEAT).
- Seasonal forecasting simulations with the South African Weather Service (SAWS).
- Student research as part of under and post-graduate studies.
- School projects with UP@Science

The project has assisted in establishing a strong and sustainable relationship between the project team and the CSIRO-AR. Regular contributions from the CSIRO-AR and feedback from the research team took place during the project. A number of visits strengthened this bilateral relationship. The research team and LRAM are internationally recognised as capable of performing complex atmospheric modelling simulations and of contributing to model development. The research on our own dynamic kernel has put South Africa on a higher level in the discipline of atmospheric modelling than it occupied previously.

It is recommended that the project team continue to expand the knowledge and facilities established by this project to encourage further capacity building and international recognition. The data generated through the project is available for future research.