CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The climate of the SADC region is fundamentally influenced by mesoscale circulation patterns that are not adequately simulated by AGCMs. The main reason for this is the coarse horizontal resolution of AGCMs. Computational requirements prevent AGCMs running at mesoscale resolutions of a few kilometres to about 100km. As a computationally feasible alternative, the technique of nested climate modelling utilises high-resolution LAMs to obtain climate simulations on the mesoscale. An appropriate range of synoptic situations is obtained by integrating an AGCM forward in time for an extended period. The lower resolution output of the AGCM is then used to force the lateral boundaries of the LAM. The LAM, with a horizontal resolution in the order of 100km, can simulate some of the mesoscale features which leads to a more accurate, detailed and realistic depiction of the region's climate.

A NCM domain over the SADC region should be sufficiently small to ensure that simulated circulation of the NCM does not depart from that of the driving AGCM on the synoptic scale. The domain however, has to be large enough to prevent the coarse scale lateral boundary conditions from dominating the solution over the area of interest. Full development by the NCM of features having a finer scale than those skilfully resolved by the AGCM should be possible. The horizontal resolution of the nested model should be fine enough to capture forcing and circulation on the mesoscale.

The model domain should encompass, to the extent feasible, all regions that include forcing and circulation that directly influence climate over the area of interest. For example, a domain over southern Africa should include the Agulhas retroflection region in the south and Madagascar in the east. Such a domain will also need to extend far enough over the Atlantic ocean to adequately capture the development and movement of mid-latitude cyclones and far enough northwards to capture tropical features like the semi-stationary tropical surface trough.

The nested model DARLAM has been developed for both mesoscale studies and for climate change experiments. The model is a two-time level, semi-implicit, hydrostatic primitive equations model. It uses an Arakawa C-grid and semi-Lagrangian horizontal advection with bicubic spatial interpolation. The model includes a full range of physical parameterisations. Many simulations have been performed (primarily over Australia) by one-way nesting DARLAM within the CSIRO9 AGCM or within observational analyses. Generally the finer resolution of the nested simulations provides significantly improved simulations near topographic features, in particular precipitation and near surface values.

The characteristic feature of the dynamical formulation of DARLAM is the semi-Lagrangian method used to solve the advective part of the primitive meteorological equations. The essential feature of semi-Lagrangian schemes is that the total or material derivatives in the equations of motion are treated directly by calculating the departure points of fluid parcels. The upstream values of the required fields are then usually evaluated by spatial interpolation. The main advantage of the semi-Lagrangian technique is that it allows for the relaxation of the CFL criterion. Theoretical analysis of the semi-Lagrangian scheme used in DARLAM reveals that this method offers unconditionally stable integrations with a high degree of advection accuracy. Numerical experiments involving a case of non-linear but uniform flow and a case of non-linear but strong deformational flow confirm that the semi-Lagrangian scheme used in DARLAM has excellent amplitude, phase and conservation properties. The scheme is shown to be superior to the well-known and widely used modified Lax-Wendrof finite difference scheme.

The nested climate model DARLAM has been nested within the output from the CSIRO9 AGCM to provide high-resolution simulations of present January and July climate over the SADC region. DARLAM provides a more accurate and detailed simulation of particularly January climate over southern Africa than is available from the AGCM. This is largely due to the fact that the regional topographical features which influence the climate of the SADC region, such as the steep escarpment of south-eastern South Africa and the Great East African Valley, are more clearly resolved at 60 km resolution of the NCM than they are by the CSIRO9 Mark II AGCM. Over regions of steep topographic gradients such as the South African escarpment and Madagascar, DARLAM simulates in excess of twice as much daily rainfall as observed. The nested model's mountain wave response possibly contributes to this over estimation.

Results from the first nested climate modelling simulations over the SADC region indicate that DARLAM is capable of simulating the details of regional climate with greater skill than the AGCM. The nested modelling approach to applications such as projecting the regional response to global climate change therefore holds significant promise.

There remain theoretical and scientific problems to be solved in the use of limited-area climate models. Tropical domains pose additional difficulties for the one-way nested modelling approach, relating to the weaker boundary forcing in such domains and the greater necessity for the physical parameterisation schemes of the LAM and AGCM to be compatible. This problem is of particular importance for the SADC region, which includes extensive regions north and south of the equator. Another aspect of nested climate modelling still needing improvement is the tendency for the occurrence of excessive precipitation in NCM simulations over regions of steep topography. The cause for these over estimations is not fully understood. In some NCMs the over estimation may be related to the model's mountain wave response, while in others the dynamical effects of the cumulus parameterisation scheme used may contribute to the over estimation. This unresolved issue needs to be investigated in future nested climate modelling experiments over the SADC region.