Regional climate simulations using a stretched−grid global model

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1. INTRODUCTION

Over the last decade, many Regional Climate Model (RCM) simulations have been performed at CSIRO using the Division of Atmospheric Research Limited−Area Model (DARLAM) nested within CSIRO GCM simulations. DARLAM uses fairly conventional one−way nesting at its lateral boundaries, as described by McGregor et al. (1993). More recently, the conformal−cubic global atmospheric model (CCAM) has been developed. This model can be run either in stand−alone mode, or with extra forcing from another simulation provided by far−field nudging of winds. The CCAM simulation described here is of 30−year duration, and uses forcing from the latest CSIRO Mk3 coupled GCM, which has T63 resolution (about 200 km).

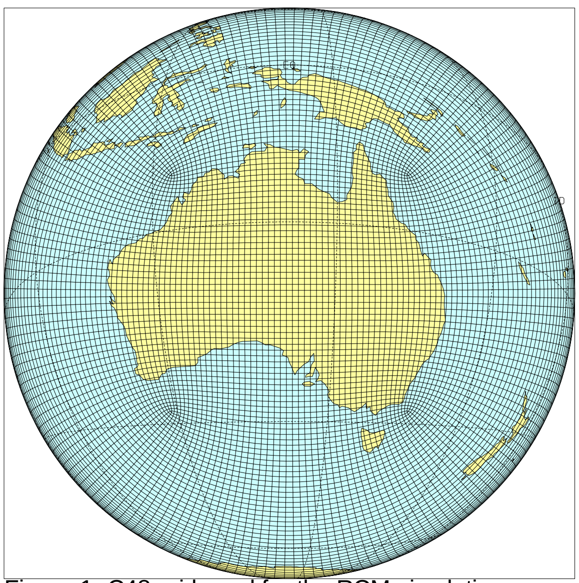

Figure 1. C48 grid used for the RCM simulations.

2. FEATURES OF CCAM

CCAM is formulated on a quasi−uniform grid, derived by projecting the panels of a cube onto the surface of the Earth. CCAM can be run in stretched−grid mode to provide high resolution over any selected region. Compared to the more traditional nested limited−area modelling approach, it provides great flexibility for dynamic downscaling from any global model, essentially requiring only sea−surface temperatures (SSTs) and far−field winds from the host model (McGregor and Dix, 2001). It also avoids other problems that may occur with limited−area models, such as reflections at lateral boundaries.

Distinctive features of the CCAM dynamics include:

- 2−time−level semi−implicit hydrostatic model
- semi−Lagrangian horizontal advection with bi−cubic spatial interpolation
- total−variation−diminishing vertical advection
- unstaggered grid, with winds transformed reversibly to/from C−staggered locations before/after gravity wave calculations
- minimal horizontal diffusion needed:
    - Smagorinsky style used; zero is fine
- Cartesian representation used for:
    - calculation of departure points
    - advection or diffusion of vector quantities
- indirect addressing used to simplify code
- weakly implicit off−centering used to avoid "semi−Lagrangian mountain resonances"
- improved treatment of surface pressure near terrain
- *a posteriori* conservation of mass and moisture.

For the Australian regional climate simulations, the grid shown in Fig. 1 was used, with the following model settings:

- C48 global model (6x48x48 grid points) with 18 vertical levels
- Schmidt stretching factor = 0.3, giving about 65−km resolution over Australia
- nudged by winds from Mk3 CGCM simulation
    - nudged only on furthest panels with e−folding time of at least 24 h.

The latest version of the model includes a new mass−flux cumulus convection scheme, which incorporates downdrafts.

3. RESULTS OF THE SIMULATIONS

Two 30−year RCM simulations were performed with CCAM, with far−field wind forcing supplied by a long transient simulation of the Mk3 CGCM, using the SRES A2 scenario. Sea surface temperatures for the whole domain were supplied twice daily by the CGCM. Results are presented here for the first simulation, which was for present−day greenhouse gas concentrations. The second simulation (not discussed here) was centred around the time of double greenhouse gas concentrations.

The quality of the simulation is illustrated here by showing the average summer rainfall. Fig. 2 displays the observed climatology for December−January−February (DJF) rainfall, as analysed by the Australian Bureau of Meteorology. The high tropical rainfall of the Australian monsoon is evident. Fig. 3 shows the 30−year average of DJF rainfall from the Mk3 CGCM; the broad agreement with the observations is good. Fig. 4 shows the corresponding rainfall from CCAM; the detailed agreement with the observations is even better, with improvements evident over the northern and eastern parts of Australia; the dry interior is also better represented. The CCAM rainfall for the other three seasons (not shown here) also agrees well with the observations.

4. CONCLUDING COMMENTS

Long RCM simulations have been performed for the first time with a stretched global atmospheric model, with far−field nudging supplied by a prior CGCM simulation. The technique is very robust and is capable of providing realistic and detailed climatologies. The technique requires less consistency with the host model, in regard to physical parameterizations, than the traditional one−way nested approach.

REFERENCES

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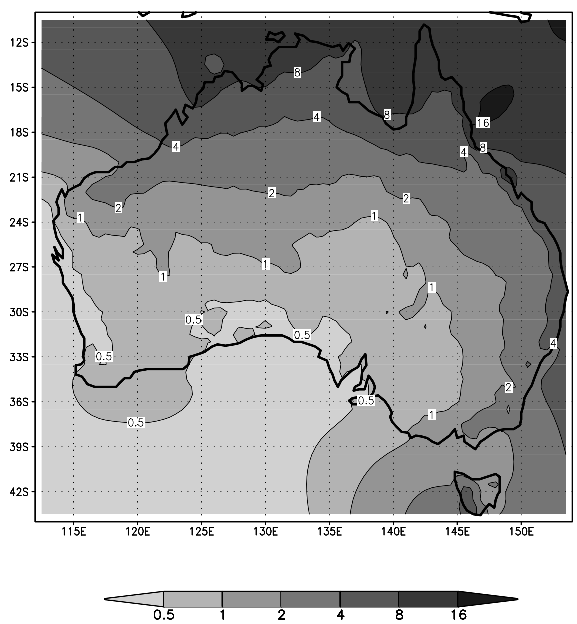

Figure 2. Observed DJF precipitation (mm/day) from the Australian Bureau of Meteorology; all values over the sea should be ignored.

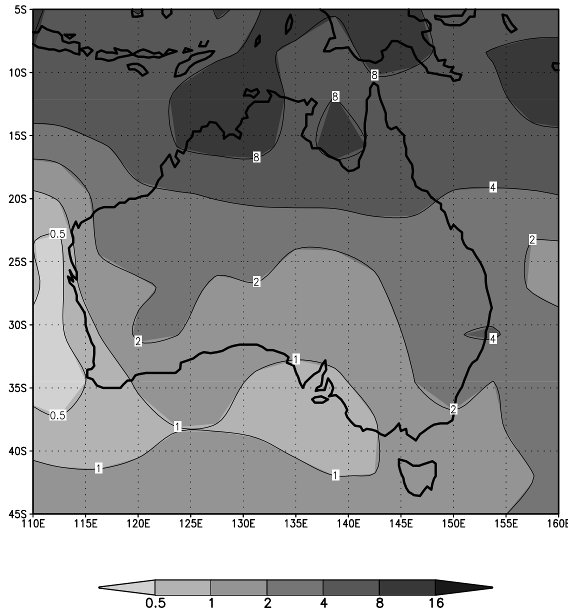

Figure 3. DJF precipitation (mm/day) from the 30−year Mk3 CGCM simulation.

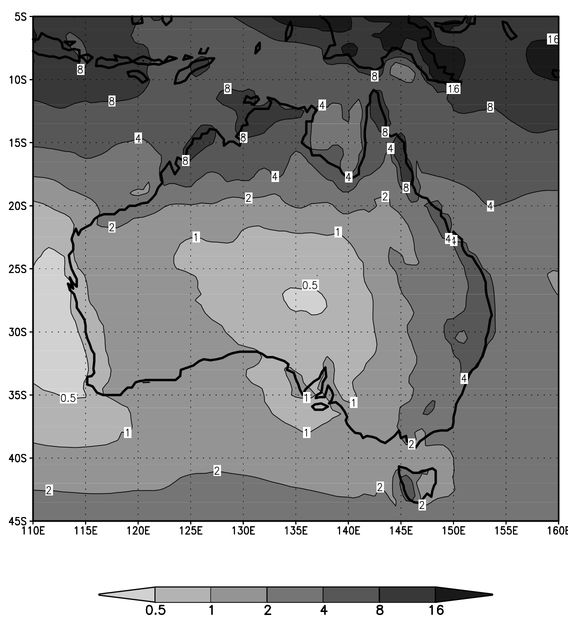

Figure 4. DJF precipitation (mm/day) from the 30−year CCAM simulation.