Regional climate simulation at 20 km using CCAM with a scale-selective digital filter

John L. McGregor, Kim C. Nguyen and Marcus Thatcher

CSIRO Marine and Atmospheric Research Melbourne 3195 Australia

1 Introduction

The CSIRO Conformal-Cubic Atmospheric Model (CCAM) has been used for a number of years for dynamical climate downscaling, mainly over the Australian region. CCAM is a variable-resolution global model. By using the Schmidt (1977) transformation, fine resolution may be achieved over any part of the globe. We have performed simulations over Australia at 60 km resolution, downscaling from NCEP reanalyses for 1951-2000, and from the CSIRO Mk 3.0 coupled GCM from 1961-2100 (McGregor et al., 2002). We have also performed long simulations at 14 km over Tasmania, Cairns and Rockhampton, and a 10-year simulation at 8 km over Fiji (Lal et al., 2008). Another 10-year simulation over Asia has also been performed (Nguyen and McGregor, 2008), driven by NCEP reanalyses. The simulations employed sea surface temperatures and sea-ice cover from the host model (or reanalysis), and typically used weak nudging from upper-level winds to provide broad similarity of storm tracks with the host model or reanalysis. The present CCAM regional climate simulation uses a C72 global grid (6 x 72 x 72 grid points), with a Schmidt stretching factor of 0.15. CCAM then achieves a fine resolution of 20 km for the central panel which is located over eastern Australia. The grid is illustrated in Figure 1. This report describes downscaling from the CSIRO Mk 3.0 coupled climate model, for model years corresponding to 1961-2000.

CCAM is an hydrostatic model, with two-time-level semi-implicit time differencing. It employs semi-Lagrangian horizontal advection with bi-cubic horizontal interpolation (McGregor, 1996), in conjunction with total-variation-diminishing vertical advection. The grid is unstaggered, but the winds are transformed reversibly to/from C-staggered locations before/after the gravity wave calculations, providing improved dispersion characteristics (McGregor, 2005b). Three-dimensional Cartesian representation is used during the calculation of departure points, and also for the advection or diffusion of vector quantities. Further details of the model dynamical formulation are provided by McGregor (2005a) and McGregor and Dix (2008). CCAM also includes a fairly comprehensive set of physical parameterizations.

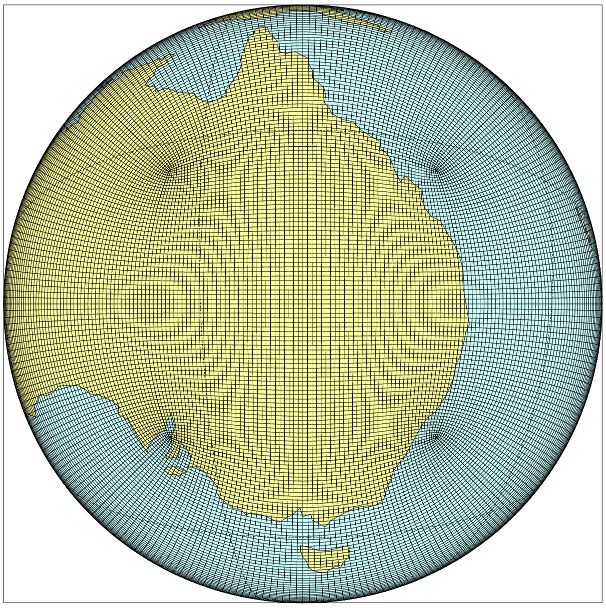

Figure 1. The C72 conformal-cubic grid used for the CCAM simulations over eastern Australia.

2 Simulation design

It should be noted that the Mk 3.0 coupled GCM does not employ flux corrections; hence there are some biases of sea-surface temperatures (SSTs), up to 2 degrees near Australia, compared to observations. The CCAM simulation uses the daily SSTs from Mk 3.0, but with the average monthly two-dimensional biases first subtracted. Sea-ice distributions are interpolated directly from the daily values of Mk 3.0.

For a prior CCAM climate simulation downscaling from NCEP reanalyses for 1951-2000, global nudging of winds above 500 hPa from the large-scale fields was employed, whilst outside the central high-resolution panel, gradually-increasing far-field nudging was also employed for MSL pressures and winds between 900 hPa and 500 hPa. This technique was adopted to help ensure that the north-south shifts of the jet-stream were captured. A new digital-filter technique, applied 12-hourly, is used in the present project, whereby "large-scale" features of MSL pressure and the winds above 500 hPa are similar to those of Mk 3.0; "large-scale" here is specified as a length scale approximately the width of New South Wales.

3 Digital filter

Thatcher and McGregor (2008) have devised an efficient approximation to the two-dimensional convolution procedure for a scale-selective Gaussian digital filter on the surface of a sphere. This approximation consists of a sequence of one-dimensional passes on the six panels of the conformal-cubic grid. The orientation of the one-dimensional passes is illustrated schematically in Figure 2.

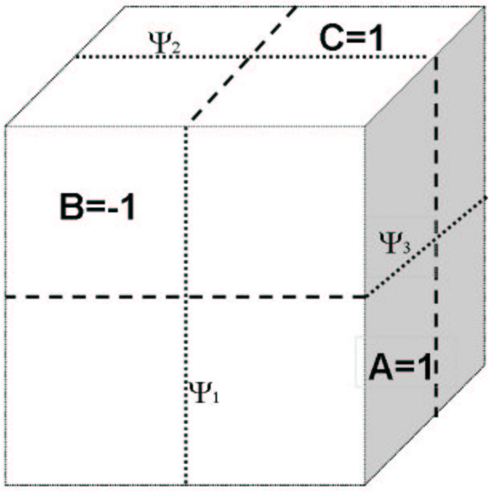

Figure 2. Schematic illustrating one-dimensional passes of the Gaussian digital-filter. Passes corresponding to the short dashed lines are performed before those with long dashed lines. A, B, and C refer to coordinate axes of the cubic geometry.

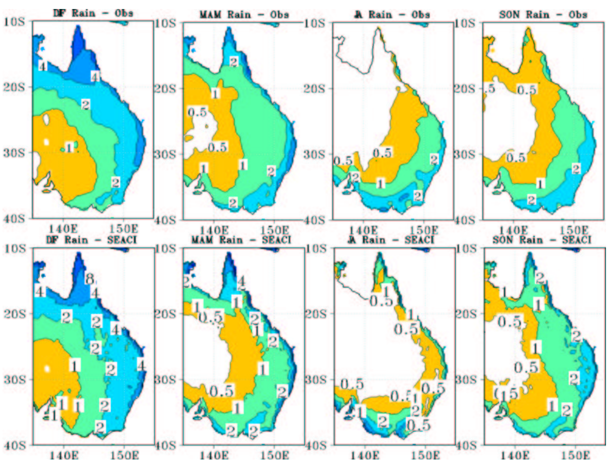

Figure 3. Seasonally-averaged rainfall (mm/day), with observations (top) and CCAM (downscaled from Mk 3.0, bottom).

4 Seasonal-mean rainfall results

The 40-year (1961-2000) monthly-mean CCAM rainfall was averaged to produce seasonal averages for December, January and February (DJF), March, April and May (MAM), June, July and August (JJA) and September, October and November (SON). These averages are compared against the observed seasonal rainfall provided by the Australian Bureau of Meteorology.

In general, CCAM reproduces the mean seasonal rainfall patterns (Figure 3). The large rainfall along the eastern coast is well captured for all seasons. The large rainfall along the Great Dividing Range and the eastern coast is also reproduced, except in winter when it is deficient. Inland of the Great Dividing Range, summer rainfall is well captured, autumn and winter are somewhat lower than observed, whereas spring rainfall is somewhat larger than observed over inland New South Wales and Queensland.

Acknowledgement

This work was supported by the South Eastern Australian Climate Initiative.

References

Lal, M., J. L. McGregor, and K. C. Nguyen, 2008: Simulation of surface air temperature and rainfall and its temporal and spatial distribution over Fiji. *Climate Dynamics*, **30**, 293–305.

McGregor, J. L., 1996: Semi-Lagrangian advection on conformal-cubic grids. *Mon. Wea. Rev.*, **124**, 1311–1322.

McGregor, J. L., 2005a: C-CAM: Geometric aspects and dynamical formulation [electronic publication]. Technical Report 70, CSIRO Atmospheric Research, 43 pp.

McGregor, J. L., 2005b: Geostrophic adjustment for reversibly staggered grids. *Mon. Wea. Rev.*, **133**, 1119–1128.

McGregor, J. L., and M. R. Dix, 2008: An updated description of the Conformal-Cubic Atmospheric Model. *High Resolution Simulation of the Atmosphere and Ocean*, K. Hamilton and W. Ohfuchi, Eds., Springer, 51–76.

McGregor, J. L., K. C. Nguyen, and J. J. Katzfey, 2002: Regional climate simulations using a stretched-grid global model. *Research Activities in Atmospheric and Oceanic Modelling Rep. 32, WMO Tech. Doc. 1105*, H. Ritchie, Ed., 3.15–3.16.

Nguyen, K. C., and J. L. McGregor, 2008: Modelling Asian summer monsoons using CCAM. *Climate Dynamics*, submitted.

Thatcher, M., and J. L. McGregor, 2008: Using a scale-selective filter for dynamical downscaling with the conformal cubic atmospheric model. *Mon. Wea. Rev.*, submitted.