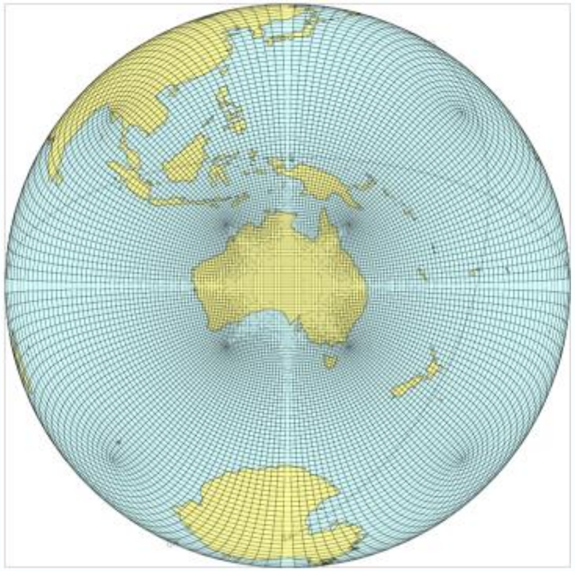


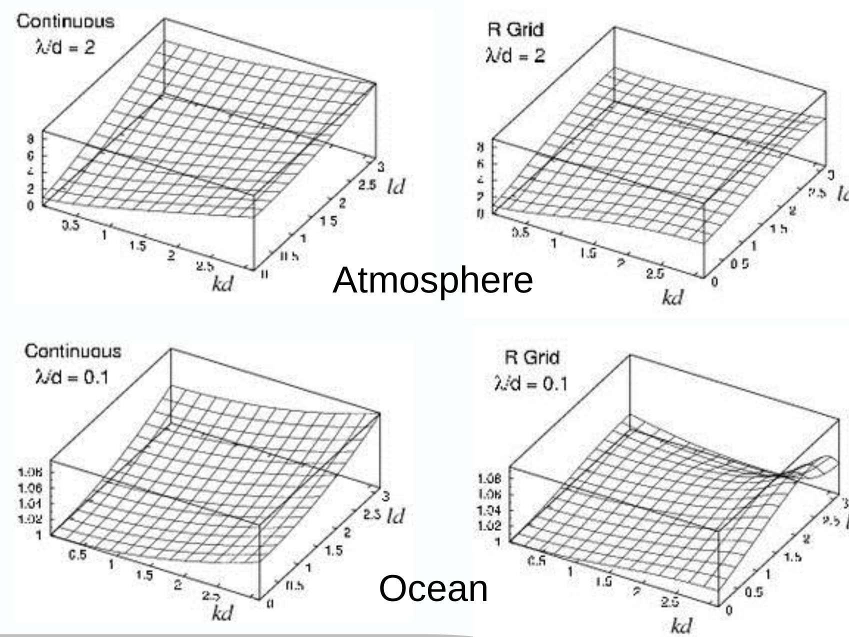
Variable resolution CCAM grid

A reversibly-staggered, atmosphere-ocean regional climate model

Marcus Thatcher and John McGregor

We have developed a reversibly-staggered, atmosphere – ocean coupled global climate model (also for regional applications via the Schmidt transformation) based on the variable-resolution Conformal Cubic Atmospheric Model

Coupling occurs every time step by co-locating the atmosphere and ocean model grids. We use a reversibly- staggered grid that pivots between the Arakawa A and C-grids. The reversibly-staggered grid provides good dispersive behaviour for both the atmosphere and ocean models

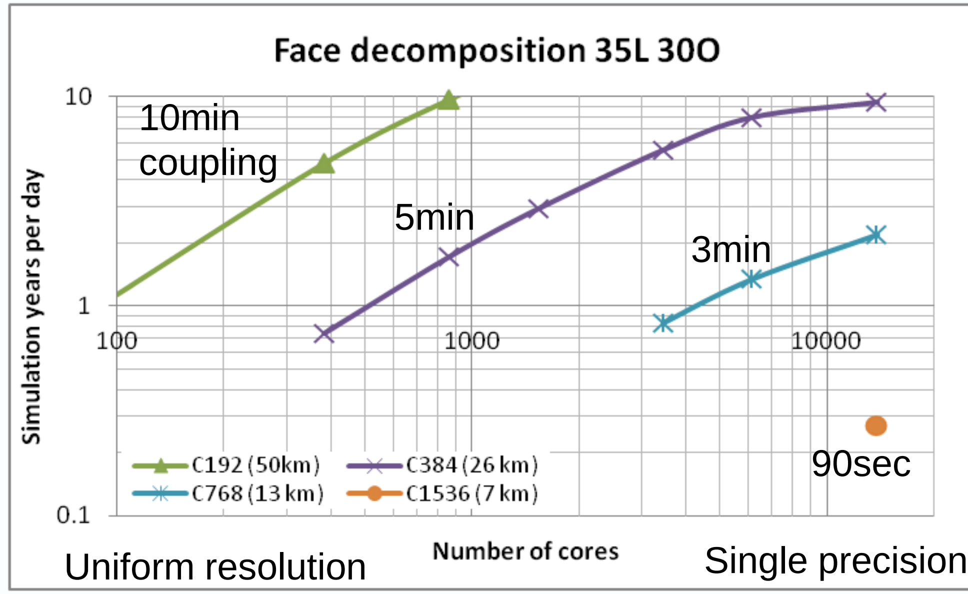


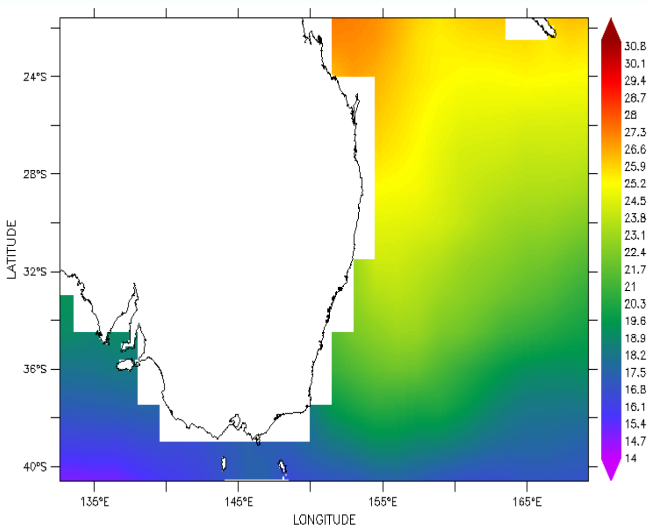
A reversibly-staggered, atmosphere – ocean regional climate model

Marcus Thatcher and John McGregor

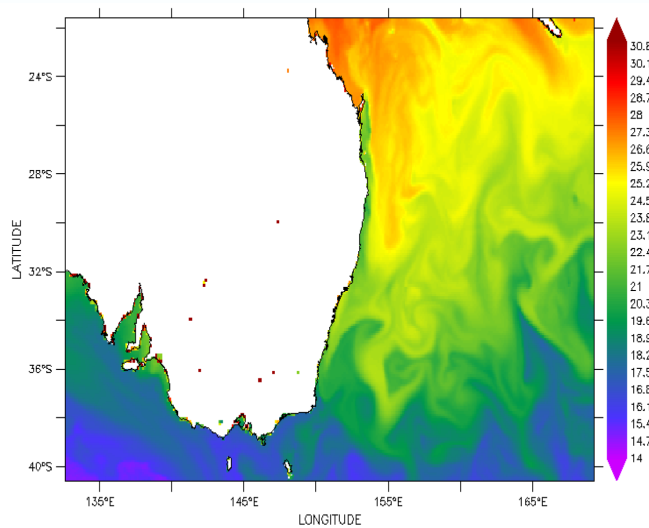
Walltimes are competitive with atmosphere-only models, producing 2 sypd with 13,824 cores at 13 km resolution in single precision mode 35 atmosphere levels and 30 ocean levels.

Load balancing is not noticeably exacerbated.





ERAI Sea surface temperature (C)



CCAM Sea surface temperature (C)

For regional runs, SSTs are assimilated with a convolution-based scale-selective filter that can accommodate irregular coastlines

CSIRO

A prototype reversibly-staggered atmosphere–ocean coupled model for regional climate simulations

Marcus Thatcher and John McGregor

CSIRO MARINE AND ATMOSPHERIC RESEARCH
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A prototype atmosphere-ocean coupled climate model has been developed based on the variable-resolution Conformal Cubic Atmospheric Model (CCAM). This approach exploits the reversible staggering property of the CCAM dynamical core to produce an ocean model with good dispersive properties, while facilitating coupling between the atmosphere and ocean every timestep.

A variable resolution coupled model

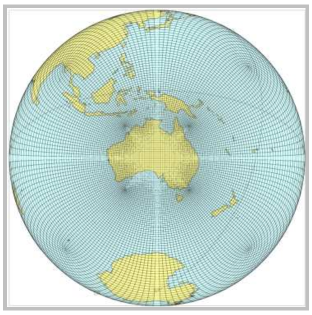

Figure 1: Example of a variable-resolution conformal cubic grid focused over Australia, using the Schmidt transformation with Schmidt factor S=3.

CCAM is a semi-implicit, semi-Lagrangian, non-hydrostatic climate model based on a conformal cubic grid (McGregor, 2005a). The variable resolution CCAM grid can be focused over an area of interest using the Schmidt transformation (Schmidt 1977), thereby avoiding lateral boundary conditions (see Figure 1). CCAM uses an MPI-only model for message passing (McGregor and Dix, 2008) and a geometric multi-grid method to improve scaling when solving the implicit Helmholtz equation.

The reversibly-staggered grid and coupling approach

CCAM employs a reversibly-staggered grid where the winds and currents 'pivot' reversibly between Arakawa A and C-grids. This fully reversible method has excellent dispersive properties for both the atmosphere and ocean, as shown by McGregor (2005b) (see Figure 2). Atmosphere – ocean coupling is performed when the reversibly-staggered grid is in the A-grid configuration used for the single column physics parameterizations and for calculating mixed Corilois terms. This avoids additional message passing since the corresponding atmosphere and ocean grid points are located on the same core, but constrains the ocean to use the atmosphere grid. Hence the approach is particularly suited to eddy-resolving regional models.

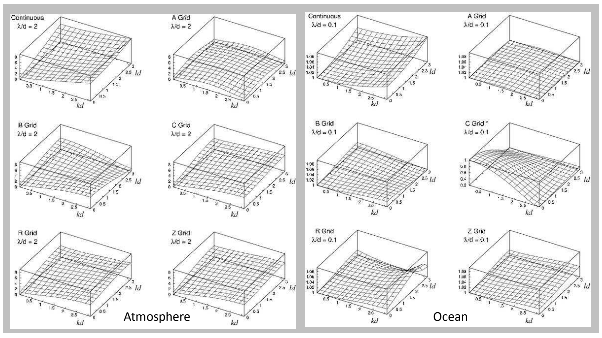

Figure 2: Plot of dispersive properties of the reversibly-staggered grid (denoted as R-grid) using shallow water equations (McGregor 2005b). Typical cases for the atmosphere (left) and ocean (right) are shown.

Scaling properties of the implicit dynamical core

The scaling of the single precision version of the coupled CCAM is shown in Figure 3 for global simulations of various spatial resolutions and atmosphere - ocean coupling frequency. CCAM's scaling properties are competitive with modern atmosphere-only models (e.g., two simulation years per day at 13 km resolution), although achieved with a relatively small number of cores and with a rapid coupling frequency (e.g., three minute coupling). The main limitation on scaling is load imbalance between processors, although this could be improved with an explicit dynamical core.

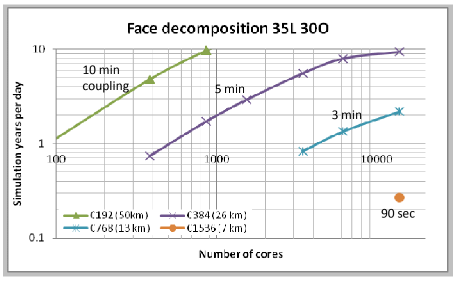

Figure 3: Example of scaling of global atmosphere – ocean coupled CCAM simulations in single precision mode. This configuration employed 35 vertical atmosphere levels and 30 ocean levels, with coupling every time step.

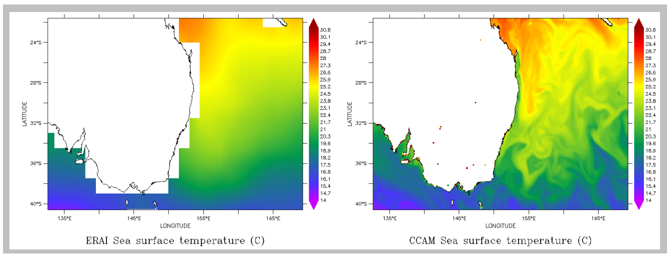

Figure 4: Comparison of prescribed Sea Surface Temperatures (SSTs) from ERA-Interim reanalyses (left) with the 10 km resolution coupled model prediction (right) after assimilating SSTs with length scales greater than 500 km. Note the coupled regional model spins-up SSTs variation that is not represented in the ERA-Interim reanalyses.

Scale-selective assimilation of large-scale circulation

CCAM can assimilate large-scale behaviour of prognostic variables including winds, temperature surface pressure and water vapour from a host model (e.g., atmosphere reanalysis) using a convolution-based scale-selective filter (Thatcher and McGregor 2009). This approach has been generalised to assimilating ocean currents, potential temperature, salinity and surface height, since the convolution can accommodate irregular coastlines that otherwise cannot be processed with a Discrete Fourier Transform. Figure 4 compares the prescribed Sea Surface Temperatures (SSTs) from ERA-Interim with the predictions of the coupled model after assimilating large scale SSTs. In this experiment, SST perturbations are applied to the potential temperature in the ocean mixed layer. Currents and salinity are left unperturbed. The results show the complex variations in SSTs arising from the simulation of eddies that are not represented in the ERA-Interim reanalysis. Atmosphere and ocean mixed layer are spun-up within one simulation year when using the scale-selective filter.

Coupled regional model performance

Simulated Tropical Cyclone Like Vortices in the Atlantic are found to be significantly improved in the coupled simulation (Figure 5), although the number density is still small compared to observations. Currents are too strong compared to OSCAR when assimilating SSTs with the scale-selective filter, although assimilating salinity is expected to correct this problem.

Simulated rainfall over Australia is not noticeably changed at meso-scales in the coupled simulations, although changes in coastal regions are still being investigated. We are also exploring the impact of the coupled simulation on sea-ice in regionally focused simulations.

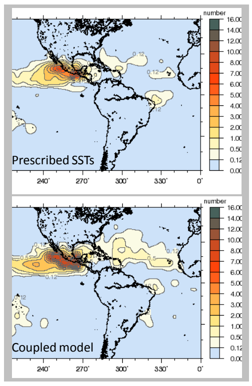

Figure 5: Simulated number of Tropical-Cyclone-Like-Vortices per year per 5º x 5º box with prescribed SSTs (top) and coupled model (bottom).

FOR FURTHER INFORMATION

Dr Marcus Thatcher
e marcus.thatcher@csiro.au
w www.csiro.au/cmar

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