Australian Community Ocean Model (AusCOM)

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Introduction

AusCOM (Australian Climate Ocean Model) is an ocean and sea ice model being developed and tested by the Australian climate modelling community. This model will form the core ocean model for climate applications developed under the ACCESS project.

The main applications driving the development of AusCOM are:

- Climate change projections and studies, including biogeochemistry
- Interannual to decadal variability and predictability studies
- Seasonal prediction
- Downscaling of climate change in the marine environment
- Input to ecosystem models

A basic rationale for the development of AusCOM is that a single model configuration will serve most climate applications. Organisations involved in the AusCOM project include: BMRC, CSIRO, TPAC, ACE-CRC and several universities.

The following section provides a summary of scientific focus areas as of October 2006. Details of the model configuration are still an area of active scientific debate among participating institutions and are subject to changes in the future.

Applications and research drivers

(a) Climate change projections

AusCOM will form part of the ACCESS coupled model to be used for long term predictions of climate out to 2100 and beyond as part of 5AR and 6AR IPCC assessments. This application requires the model to maintain realistic water masses and density structure with no drift in the coupled model. The strength of major currents (ACC, EAC, Kuroshio, Gulf Stream, Indonesian Throughflow) needs to be correct and major north/south transports of heat and salt throughout the water column realistic. The vertical structure in the tropics must be sufficient strength to main a realistic ENSO and the stratification in the North Atlantic and Ross and Weddell Seas must allow for the development of deep and bottom waters which drive the thermohaline circulation of the ocean. The choice of subgrid-scale parameters in the ocean model must be sufficient to maintain realistic present day conditions and be sufficiently physically based that they respond correctly to changes in conditions imposed during future projections.

The model is the physical bases for the bio-geochemical and carbon cycle ocean models, so conditions of realistic water masses, stratification and no drift on coupling are essential for the success of these models.

Some climate variability modes e.g. NAO, SAM are driven by the atmosphere, ENSO is a true coupled mode, and requires realistic stratification in the Eastern Pacific, appropriate temperatures in the western warm pool, no excessive cold tongue and correct representation of Kelvin and Rossby waves dynamics. The dynamics of links between ENSO and the IOD are still under investigation worldwide, but appear to require appropriate upwelling and jets along Java and Sumatra coastline and a realistic Indonesian Troughflow that transmits waves along the Australian continental shelf.

The gyre scale circulations in the North Pacific and North Atlantic as well as the North Atlantic thermohaline circulation exert control over the timescale of decadal signals in the North Pacific and North Atlantic and allow some predictability based on ocean dynamics (Inter-decadal Pacific Oscillation (IPO)).There are also decadal time scale anomalies in the Southern ocean with long-term coherent sub-surface anomalies about which less is known; the deep winter mixed layers allows the signals to be retained over many seasons.

Initialising these slowly varying anomalies with data assimilation (ARGO and altimeter data) may provide some predictive skill on these time scales. Predictions from short time scales out to decadal time scale are a focus of the new WCRP programme COPES.

(b) Southern Ocean

The ACCESS ocean model is built on the AusCOM model which was being built in conjunction with TPAC and colleagues at the ACE-CRC in Hobart. The model has deliberately been given enhanced Southern Ocean resolution equivalent to 1/3 degree cosine latitudes. The model will be used to produce realistic representations of Southern ocean water masses which are important throughout the global ocean (AABW, AAIW, SAMW). With the inclusion of an ice model at this high resolution for a global climate model, it should be able to realistically represent the ice production in coastal polynias and bottom waters on the Antarctic continental shelves. The inclusion of fluxes from under ice shelves as a boundary condition at sub-depth at the edge of the model domain, allows representation of processes of Intermediate Subantarctic Water in the model and permits to model how this may change under future projections of climate.

(c) Intraseasonal, seasonal and interannual prediction and predictability

The POAMA system has been developed jointly by BMRC and the former CSIRO Marine Research Division. Future effort will divert to implementing the POAMA system within the ACCESS framework with the aim that the ACCESS coupled model will be the core system in the POAMA-3 system on a time scale of 2-4 years. It is likely that the atmospheric configuration used for POAMA-3 will be different to that used, for example, for climate change studies (e.g. POAMA will use higher resolution).

Key issues for ocean model development focus on improving the simulation of the tropical oceans, in particular, the Indonesian Throughflow, the Indian Ocean and the Eastern Pacific need attention. These issues are equally important for simulation of tropical variability in climate change studies. There may also be some predictability from the mid and high latitude oceans and sea ice variability.

Critical to dynamical seasonal prediction is the development of advanced ocean data assimilation techniques. The focus of the developments in ocean data assimilation will be led by the joint requirements of seasonal prediction and operational ocean forecasting (Bluelink project).

The major modes of inter-annual climate variability and predictability and their interactions are still not fully understood, e.g., ENSO, Indian Ocean variability, SAM. Understanding these modes of variability and limits to their predictability needs to progress hand-in-hand with development of coupled models for seasonal prediction. Furthermore, due to limited past observations, coupled models provide the main tools for understanding these modes and for providing estimates of potential predictability. Key questions that need to be answered include:

- role of stochastic noise on ENSO evolution (e.g. MJO),
- why each ENSO different and different impact on Australian climate,
- relation between ENSO and Indian Ocean variability,
- impact of Indian Ocean variability on Australian Climate,
- how predictable is Indian Ocean variability,
- how predictable is SAM, etc.

Some of these questions are being tackled using existing models (BAM/ACOM2 model used in POAMA-1 system and CSIRO MK3 coupled model). This work will gradually evolve to using the new ACCESS model (AusCOM Ocean and Ice model coupled UKMO atmospheric model).

Baseline configuration for AusCOM-1

(a) Ocean model grid

AusCOM is based on the GFDL MOM4 code. A review was carried out to document configurations and resolutions used by other key international modelling centres (Rashid, pers. comm.). A workshop held in 2004 decided on a configuration based on a 1 degree background grid but incorporating regional enhancements as follows:

- Enhanced equatorial resolution with the N/S resolution increased to 1/3 degree in the equatorial wave strip
- Enhanced resolution in the Southern Ocean by increasing meridional resolution as meridians converge (up to approx. 30km x 30km)
- A shifting of the North Pole over land.

The vertical resolution involves 46 levels, with high resolution of up to 5m in the near surface layers.

(b) Ocean model physics

The first version will use physics already tested in Mk3 or ACOM2. Physics options used are summarised in the table below:

Scheme
Explicit non-linear free surface
Chen et al mixed layer (as coded by CMR)
ACOM2 solar penetration (as coded by CMR)
Ramstorf (1993) convection
Wilson (2000) Ri vertical mixing
Griffies et al (1998) Isoneutral diffusion (uniform)
Griffies (1998) implementation of Gent and McWilliams
Horizontal viscosity – probably grid-length dependent
Horizontal diffusion – lowest values that maintains numerical stability
Horizontal viscosity – probably Smagorinski
Quick 3rd order tracer advection
Variable bottom cells

(c) Sea-ice model

The sea-ice model developed by TPAC/ACE CRC (based on the Hibler viscous rheology model, implemented as Hunk's Elasto-Viscous-Plastic formulation and TPAC Sea Ice thermodynamics) forms the core ice model in AusCOM. To maintain realistic water-masses in Arctic and Antarctic waters, including ice and fresh-water fluxes into North Pacific and Atlantic a mass-conserving coupling between ocean, sea-ice and atmospheric component models is required. This is achieved by using the Ocean Atmosphere Sea-Ice Soil coupler (OASIS; developed by CERFACS, France).