

# **Earth Systems Modelling in the University sector, Contributions to ACCESS**

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## **Introduction**

Some of the largest uncertainties for predicting long term future climate change result from the relatively poor understanding and modelling of the physical and bio-geochemical processes of the slow components of the Earth System. Examples of these slow components are the cryosphere, (including both sea-ice, ice caps, and ice sheets), the oceans, land surfaces and their evolution and the carbon cycle. All of these components are central to understanding variations in climate on decadal to century time scales. The University Sector and other government organisations such as the Australian Government Antarctic Division are deeply involved in the study and modelling of these processes.

## **Some science challenges for ACCESS**

The observational record presents a number of issues that Earth Systems Science models have difficulty in reconciling. These challenges will impact on the ACCESS program. Some examples of these science challenges are:

- Global heat content of the oceans and its variations,
- Global observations of oxygen change in the oceans,
- Global observations of sea-level change and its spatial variations,
- Global observations of the cryosphere and its decadal variations.

The global heat content record of the oceans since 1961, shows that it is increasing at a rate of  $0.21 \pm 0.04 \text{ W m}^{-2}$ . This record also shows that there have been strong decadal variations in the global heat content. For example the period 1980-1983 had a cooling of exceeding  $-1.2 \text{ W m}^{-2}$  while the decade 1993-2003 shows a warming trend of  $0.5 \pm 0.18 \text{ W m}^{-2}$ . These decadal variations in the global heat content are not observed in the oceanic component of Earth Systems Science models used in the IPCC AR4. While there are uncertainties in the ocean heat content record, the recent cooling in 2004 and 2005 with the best data coverage ever adds further evidence that these models are incomplete in simulating the overall energy balance of the Earth System.

There is growing evidence that the oxygen content in some of the key water masses in the 100-1000 metre depth range have decreased. While biological processes cannot be excluded, most of the evidence suggests that the renewal rates of these key waters masses have reduced during the period from the 1970's to 1990's. Current Earth Systems Science models do not

have oxygen carried as formal tracer, or as a biological active component in them, and yet it is one of the best observed variables in the oceanic data sets that can be used for detecting changes in ocean ventilation and bio-geochemical processes.

Sea level is rising. The rate of sea-level rise from 1993-2003 is  $3.1 \pm 0.7 \text{ mm yr}^{-1}$ , the average rate for the period 1961-2003 is  $1.8 \pm 0.5 \text{ mm yr}^{-1}$ . The high rate of sea-level rise in the last decade could be in response to decadal variations or a longer term acceleration of sea-level. In the current range of IPCC models, sea-level projections have a wide uncertainty and a low level of coherence between spatial patterns. The wide uncertainty results, in part, arises from the integrative nature of sea-level (involving the whole water column) and therefore having long response times set by ventilation processes of the ocean interior. The ventilation rate is very model dependent.

The important issue from an Earth System Science modelling perspective is that the sea level rise signal also has large contributions from cryosphere. Current estimates of thermosteric sea-level only contribute 51% of the total observed sea-level (1993-2003) and less than 23% in the 1961-2003 period. Improvements in the observing system for the cryosphere suggest that most of the sea-level rise that is not accounted for by thermal expansion can be accounted for by mass transfer to the oceans from glaciers, ice caps and with a small contribution from ice sheets. This is an important result, because it reduces the uncertainty associated with mass transfer from groundwater and dams to the oceans. Recent observations of ice sheet mass changes and analysis of the past rates of sea-level change and steric height changes show that the ice caps and ice sheets are likely to be more dynamic than previously thought contributing to global sea-level variations. The current ice-sheet and glaciers models are poorly resolved and typically have physics that are not sensitive to climate variations as implied by the observations.

Many of these global processes are linked, in the sense that they cannot be treated independently. Thermal expansion of the water column is inextricably linked to ventilation processes and large scale circulation. Changes in ventilation control carbon sequestration and release, and oxygen content in the oceans. The surface ocean temperature sets a large fraction of the Earth's energy balance. Consequently they need to be considered together, particularly for long term scenarios of future climate.

## **University sector activities in Earth Systems Science**

There are a number of important contributors to the Earth Systems Science in Australia within the University Sector and also within Federal and State Government departments. They focus around a number of groups at:

- Antarctic Climate Ecosystems CRC
- Australian Government Antarctic Division
- ANSTO
- University of New South Wales
- University of Tasmania
- Macquarie University
- Monash University
- University of Wollongong
- Queensland DNR

These groups cover a broad range of themes in Earth System Science. They cover land surfaces models, terrestrial carbon cycle, atmospheric chemistry, cryosphere and coupled ocean-atmosphere modelling. Each group operates models that they have enhanced and configured themselves and used to address specific science questions on a variety of time-scales. Most of these groups have international recognition, and have played significant roles

in Earth Systems Science, the IPCC Third and Fourth Assessments of the Climate Change Science and Impacts.

The problems that confront this group in participating in ACCESS can be summarised as:

- access to block funding that supports analysis Earth System Science
- agreed collaborative frameworks that can be sustained over long periods of time
- infrastructure support that can contribute significantly and sustained way to the building of Earth Systems Science capabilities
- diffused efforts that are only aligned scientifically (rather than at infrastructure level)
- different organisational foci and timelines that mean that alignment is difficult to achieve or coordinate.

## **Mechanisms for supporting Earth Systems Research**

There have been a number of important developments at a national level which have the potential to enhance the participation of Australian researchers within the University Sector (and from other Federal and State Organisations).

- These can be summarised as follows:
- development of ARC funded Network for Earth Systems Science (ARCNESS),
- development of APAC and in particular the APAC funded Earth Systems Science Project (lead by TPAC),
- development of the NCRIS Platforms for Collaboration
- and ACCESS ( as a CSIRO and Bureaus of Meteorology joint venture)
- new initiatives and appointments within the Univeristy Sectors (eg Australian National University, Macquarie University, University of New South Wales and Monash University, and Melbourne University)

The NCRIS process (and its forerunner, Systemic Infrastructure Initiative) has meant that new infrastructure capacity and capabilities have been or are being developed for Australian Researchers. These national infrastructure projects under the “Platforms for Collaboration” stream is very likely to provide resources for Australian ESS researchers with compute, storage and expertise in the use of facilities. These resources are likely to be delivered through the Australian Partnership for Advanced Computing (APAC). APAC partially funds an Earth Systems Science Project lead by TPAC. The TPAC Earth Systems Science project has specifically supported the joint development of AusCOM ocean model (see paper on Australian Community Ocean Model) and also in the creation of an Earth Systems Science Digital Library ([digitallibrary.tpac.org.au](http://digitallibrary.tpac.org.au)). This project has now been supported for 3 years, and is planned to be a specific APAC application area for the next 5 years.

Although indirectly relevant to ACCESS, the NCRIS process has also funded an Integrated Marine Observing System and a Terrestrial Observing system is proposed in the next NCRIS round. These two streams will provide important observational infrastructure for the testing and development of aspects of the ACCESS system. The current “Platforms for Collaboration” stream (currently in planning and to be funded from July 2007) is also a key element in the infrastructure required to support the compute, storage and generic IT expertise that meet ESS requirements.

The successful establishment of ARC NESS is also pivotal to the University contributions to the ACCESS. ARC NESS provides the ESS community a mechanism for representing this community within ACCESS both at a technical and scientific level. ARC NESS also helps to support collaborative activities, such as workshops, winter schools, access to models such as

the CSIRO Mk3L model and in the negotiation of licenses for use of and distribution of Earth Systems Science Models. This network is funded until 2009.

Within the University Sector, the climate research profile has been further enhanced by community having three Federation Fellows, and by the new investment initiatives at the University's supporting new appointments in Climate research and also in the building of postgraduate courses and programs that include Earth Systems Science. All of these activities represent a growth of resources for climate research within Australia.

The challenge now is harness these new and established resources so that the community as a whole can develop synergies that enhance the collaboration and impact of the research in Earth Systems Science at a national and international level.

## **Recommendation**

The key steps to be taken now are:

- focus on the science challenges and further develop the implementation plan and timetable of the ACCESS vision
- complete the development of collaborative mechanisms between ACCESS partners (perhaps similar to NCRIS principles)
- further plan how to exploit resources provided through NCRIS streams to the benefit of ACCESS and Australian ESS research
- continue to adopt standards common to this community
- continue to adopt and participate in international efforts