# Modelling of Weather and Climate at the Bureau
# A Brief History

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A brief review of development and application of atmosphere/ocean models at the Bureau of Meteorology and the rationale for development of ACCESS

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# Introduction

Australia has a proud history in all aspects of atmospheric/oceanic research and modelling

- Has had a prominent profile and impact in international circles
- Bureau and CSIRO models have been very well represented internationally in:
  - Numerical Weather Prediction (NWP) and climate/climate change communities
  - Major model intercomparison projects such as AMIP, CMIP, C20C and in assessment reports of IPCC
  - Australian modelling experts have been invited to spend extended periods at major modelling Centres

The presentation will briefly touch on some key highlights in this history

# Some organisational aspects


| 1969-1974 | 1974-1984 | 1985-2007 | 2007-2013 | 2013- |
|---|---|---|---|---|
| BoM/CSIRO | BoM/CSIRO | BoM | Bom/CSIRO | BoM |

CMRC: Commonwealth Meteorology Research Centre

ANMRC: Australian Numerical Meteorology Research Centre

BMRC: Bureau of Meteorology Research Centre

CAWCR: Centre for Australian Weather and Climate Research

BoM: Bureau of Meteorology

# History of Bureau's computing

| DATE | Computer | Nodes | CPUs | GFLOPS |
|---|---|---|---|---|
| 1985 | FACOM | 1 | 1 | 0.01 |
| 1988 | Eta10P | 1 | 0.5 | 0.16 |
| 1990 | XMP | 1 | 2 | 0.23 |
| 1992 | YMP | 1 | 2 | 0.5 |
| 1994 | YMP | 1 | 3 | 0.75 |
| 1995 | YMP | 1 | 4 | 1.0 |
| 1997 | SX4 | 16 | 128 | 32 |
| 1998 | SX4 | 32 | 256 | 64 |
| 2000 | SX5 | 13 | 104 | 104 |
| 2001 | SX5 | 16 | 128 | 128 |
| 2004 | SX6 | 18 | 144 | 1152 |
| 2005 | SX6 | 28 | 224 | 1792 |

# Limited area modelling

- The use of limited area models for weather prediction over Australia by the Bureau of Meteorology (BoM) has a long history
- **The first real time forecasts started in 1969 using a quasi-geostrophic model (Maine 1967)**
- **First operational primitive equation model was implemented in 1977 (McGregor et al. 1978)** - Australian Region Primitive Equation (ARPE) model
  - Lambert conformal projection, Resolution: 250km, 6 vertical levels
  - Domain: $55^0$S – 10S, $85^0$E – $185^0$E
- The RASP system was designed specifically for **extratropical** numerical prediction. However approximately half of the area of the Australian continent lies in the tropics
- In response, **the Tropical Analysis and Prediction System TAPS** (Puri et al. 1992, Davidson and Puri 1992) was developed and implemented operationally in November 1992

# Limited area modelling

In the early 1990s it was clear that RASP needed to undergo a significant upgrade. There was also a need to run RASP and TAPS under a single system

The above considerations resulted in a totally new limited area suite called the Limited Area Prediction System (LAPS)

**LAPS became operational on 3 July 1996** (Puri et al.1998) after extensive testing from February 1995 to June 1996

- Resolution: $0.75^0$, 19 levels, period: 48 hours

Implementation of LAPS resulted in **major increase in forecast skill** relative to the previously operational RASP

A significant new development in the LAPS suite was **development of a relocatable TC model TCLAPS**

# Limited area modelling, LAPS

- The capability of the Cray YMP allowed implementation of a mesoscale version of LAPS, called MesoLAPS
- Initially limited to two domains covering SE and SW Australia, run at $0.25^0$ .
  - **Upgraded in 1999 to a horizontal resolution of $0.125^0$ over the whole Australian domain**
- Collaboration between BMRC and CSIRO led to the development of the Australian Air Quality Forecasting System (AAQFS) to be used by the Environmental Prediction Agencies (EPAs)
- The system required a a fine resolution ($0.05^0$) LAPS model over Sydney and Melbourne to drive the CSIRO Chemical Transport Model
- The city scale system was run in real time each day in research mode from 1999. Output was made available to the NSW and VIC Regional Offices. **Used by forecasters during the Sydney Olympics**.

# Global Modelling

- The Bureau and CSIRO were at the forefront of global modelling in the early days
- This started with the formulation of spectral equations in terms of vorticity and divergence and expressing u and v in terms of ucos(latitude) and vcos(latitude) by Bourke (Bourke, 1972)
- This was followed by the development of a spectral shallow water model
- The next step was development of a full primitive equations spectral model.
- **This led to a number of significant milestones in global modelling**

# Global Modelling
# Some key milestones

- The Bourke formulation for spectral equations was adopted internationally.
- In January 1976 SPECPROG was implemented operationally by NMOC (Bourke et al., 1977). **This was the the first spectral model to go operational anywhere in the world.**
  - Hemispheric, horizontal resolution **R15 (~600km), 7** levels.
- ANMRC scientists (McAvaney, Bourke, Puri) conducted a 130 day 'climate' run with the model. This was the **first 'climate' run conducted with a spectral model anywhere in the world**.
  - Doubts had been raised about ability to conduct long integrations with a spectral model. The run showed the doubts were unfounded
- Following an extended (12-month) visit by Puri to NCAR in 1978, the **ANMRC spectral model was implemented by NCAR as its Community Climate Model CCM0, marking a significant landmark**

# Global modelling

- SPECPROG was replaced by the Hemispheric Assimilation and Prediction (HASP) system in 1985. Used a univariate SI analysis.
- The domain was extended to global (Global Assimilation and Prediction (GASP) system) in 1990.
- MVSI replaced univariate SI in 1995.
- The spectral truncation was changed from rhomboidal to triangular in 1995 to capitalise on important positive features of the latter truncation.
- The model was used as the basis for BMRC's submissions to the early AMIP, CMIP (AR) assessments
- In collaboration with CSIRO Marine Research (CMAR), the BMRC coupled model for seasonal forecasting, called POAMA (Predictive Ocean Atmosphere Model for Australia) was developed (Wang et. Al 2002, Alves et.al 2003) and transferred to NMOC in October 2002

# Global Modelling

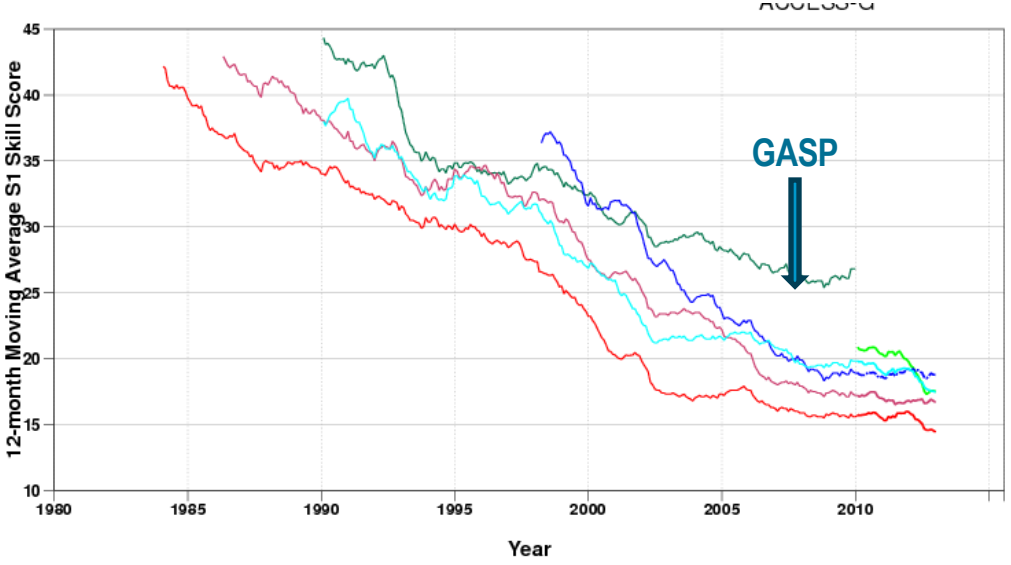
- Both Regional and Global models had upgrades over the years in
  - Resolution
  - Physical parameterisations
  - Data Assimilation
  - Use of increased variety of data, particularly satellite data in DA
- By 2007:
  - Resolutions: Global Model T239 (~75km), 33 levels, LAPS $0.375^0$, 51 levels, MesoLAPS $0.125^0$, 29 levels, TLAPS $0.375^0$, 51 levels, TCLAPS $0.15^0$ (relocatable), 19 levels
  - Both systems had similar physical parameterisations
  - Both systems used GenSI for data assimilation

# Considerations for development of ACCESS

In the mid to late 1990s, there were clear signs that Australia was in serious risk of falling behind in NWP and climate/climate change modelling. Signs included:

- GASP performance was significantly short of performance of major overseas operational models
- Reduced contributions to international climate/climate change intercomparisons

**In response, the Bureau and CSIRO decided in 2005 to jointly develop the Australian Community Climate and Earth System Simulator**



# Considerations for development of ACCESS

Australian Community Climate and Earth system Simulator

- Fully coupled system
  - Provide a *national* approach to climate and weather prediction model development
- Joint initiative
  - Bureau of Meteorology
  - CSIRO
  - Australian universities > access to common system
  - DCCEE
- Focus on the needs of a wide range of stakeholders:
  - Providing the best possible services
  - Analysing climate impacts and adaptation
  - Linkages with relevant University research
  - Meeting policy needs in natural resource management

# Considerations for development of ACCESS

- ACCESS planning started in May 2005 with appointment of K.Puri as ACCESS Scientist
- Tasked by ACCESS Executive Board to develop two key documents describing (i) the Scope of ACCESS, and (ii) a Project Plan for development of ACCESS
- Visits by Puri to MPI Hamburg, ECMWF, MetOffice, GFDL and UK, resulted in two documents:
  - Blueprint for ACCESS, K. Puri, June 2005
  - Project Plan for ACCESS, K. Puri, September 2005
- The Blueprint provided the scope for the fully coupled ACCESS
- The Project Plan made recommendations for all modules to be used in ACCESS

# Considerations for development of ACCESS

- Following the visits to the key international modelling Centres, particularly the operational Centres ECMWF and the MetOffice and a detailed analysis of local modelling systems, it became clear that;
- Our dynamical models were competitive
- Our key weakness was in data assimilation
  - The major Centres were using four-dimensional variational algorithms (4DVAR) and were working on Kalman Filter assimilation
  - Unfortunately, owing to lack of resources, we were still using essentially 1DVAR

# Considerations for development of ACCESS

- The above considerations led to two key recommendations in the Project Plan:
  - The MetOffice model HadGEM1 (UM) should be imported to provide the initial atmospheric model for ACCESS
  - The MetOffice 4DVAR scheme should be imported to form the atmospheric data assimilation module in ACCESS
- **Following detailed discussions at a special Workshop. all recommendations made in the Project Plan were accepted**
- **A formal agreement to acquire the MO systems was signed in 2008, and work on ACCESS development commenced**

# Development of collaboration Science Plan

- It was also decided to develop a Science Plan to clarify the mode of collaborations between the MetOffice, BoM and CSIRO
- The first phase of the Science Plan was framed by Pankiewicz and Puri and accepted by all sides. Plan included:
  - Concept of full and associate membership
  - Annual fees to be paid by full and associate members
- The money collected to be used to (i) hire scientists at MO to aid partners in use of MO modelling infrastructure, (ii) to fund holding of Workshops, particularly the Annual Workshop, (iii) to facilitate agreed visits

➢ **From this modest beginning it is highly satisfying to see how much the Partnership has flourished and grown**.

# Thank you

## Questions?