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POAMA: AN AUSTRALIAN OCEAN-ATMOSPHERE MODEL FOR CLIMATE PREDICTION

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Abstract

The Predictive Ocean Atmosphere Model for Australia (POAMA) is a state-of-the-art seasonal to interannual seasonal forecast system based on a coupled ocean/ atmosphere model. POAMA was developed in a joint project involving the Bureau of Meteorology Research Centre (BMRC) and CSIRO Marine Research. POAMA uses the Bureau of Meteorology atmospheric model and the Australian Community Ocean Model and is initialized with ocean temperature data. The model has been tested and verified over the period since 1987 and a new 8-month forecast is produced every day. The ensemble of forecasts is used to provide guidance for operational climate services. This paper will describe some of the unique characteristics of the POAMA system, including its ability to capture aspects of the Maddern-Julian Oscillation.

1 Introduction

POAMA is a seasonal to interannual climate prediction system based on coupled ocean and atmosphere general circulation models. It was developed in a joint project involving the Bureau of Meteorology Research Centre (BMRC) and CSIRO Marine Research (CMR), with support from the Climate Variability in Agriculture Program (CVAP) of Land and Water Australia.

The POAMA model is a significant improvement over earlier versions of coupled models for seasonal forecasting at BMRC (Kleeman et al., 1995; Wang et al., 2002). It uses the latest state of the art ocean and atmosphere general circulation models. In addition real time oceanic and atmospheric initial states are used to initialise the coupled model in real time forecasting. These are provided by an ocean data assimilation system that is run as part of the POAMA system and by the Bureau of Meteorology operational weather analyses.

The structure of this paper is as follows. Section 2 describes the different components of the POAMA seasonal forecast system. Section 3 describes a set of hindcasts and presents results from these hindcasts, in particular an assessment of model skill. Further skill assessment by examining intraseasonal variability and real-time forecasts of the breakdown of 2002/03 El Niño is also presented in this section. Finally section 4 is a summary.

2 Components of the POAMA system

2.1 Coupled model

The atmospheric component of the coupled model in POAMA is the Bureau of Meteorology unified atmospheric model latest version (BAM3). It has a horizontal spectral resolution of T47 and has 17 vertical levels. A modified convection closure was used based on CAPE closure. This appears to be crucial to better simulate intraseasonal variability, such as the Madden-Julian Oscillation (MJO). BAM3 performance in interannual time scales has been examined through AMIP style experiments where the atmospheric model is forced with the observed SST (Wang et al., 2003)

The ocean model component is the Australian Community Ocean Model version 2 (ACOM2), developed by CMR.

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Improvements with ACOM2 include: a mixing scheme, tidal mixing in areas near Australia where this process influences SST, representation of islands and straits in the Indonesian region to give realistic representation of the Pacific to Indian Ocean throughflow. The grid spacing is 2° in the zonal direction. The merideonal spacing is 0.5° near the equator, increasing gradually to 1.5° near the poles. There are 25 levels in the vertical, with 12 in the top 185 metres. The maximum depth is 5,000m. The level thicknesses range from 15 metres near the surface to almost 1,000 metres near the bottom. Technical details of ACOM2 are given in Schiller et al. (2002).

The models were coupled using the Ocean Atmosphere Sea Ice Soil (OASIS) coupler version 2.4 developed by CERFACS, France. This coupler gives high flexibility for updating model components in the future as models further improve. Atmosphere and ocean models exchange information every day and no flux corrections are used during the exchange.

2.2 Ocean data assimilation

The ocean data assimilation scheme is based on the optimum interpolation (OI) technique described by Smith et al (1991). Only temperature observations are assimilated and only measurements in the top 500m are used. The OI scheme is used to correct the model background field every 3 days using a 3 day observation window, one and a half days either side of the assimilation time. Current corrections are calculated by applying the geostrophic relation to the temperature corrections, similar to the method described by Burgers *et al.* (2002).

The background field for one analysis cycle is a three day integration from the previous analysis. During the ocean model integration it is forced with six hourly surface forcing fields. Wind stress zonal and merideonal components are used to force the ocean model momentum equations and to provide an estimate of the wind induced turbulent mixing for the vertical mixing scheme. The net heat flux is used to the top model layer temperature equation. Penetration of the solar radiation is taken into account using the input net solar radiation field. During the data assimilation cycle the model SST is strongly relaxed to an observed SST with an e-folding time scale of 3 days.

2.3 Atmospheric initial conditions

For the real time forecasts the atmospheric component is initialised from the Bureau of Meteorology's operational NWP system (called GASP). This means that the seasonal forecast model knows about the latest intra-seasonal state of the tropical atmosphere.

For the hindcast GASP analyses were not available Instead, the hindcasts used the atmospheric state from an integration of the atmosphere model used in POAMA forced with weekly Reynolds SSTs.

3 Hindcasts and skill assessment

3.1 Hindcast

Testing of the coupled model uses the so-called "hindcast-test". A "prediction" from a given initializing date uses only information available before that date. The test of the model is then based on comparing the prediction to what has actually happened. Hindcast tests initialized at many past dates can be combined into a statistic to evaluate the accuracy of forecasts, and provide a measure of "skill" of the model.

A set of 180 forecasts, one per month for the years 1987 to 2001, have been used to assess the performance of the model. Ocean initial conditions were taken from the ocean assimilation which was carried out from 1982 to 2001 as described in §2.2. The atmosphere state taken from the appropriate date during an integration of the atmosphere model forced with observed SST as described in §2.3.

The coupled model experiences significant coupled model drift during the forecast, a feature characteristic of most climate models. This is taken into account in the products produce from the forecasts by referencing all anomalies relative to the model climatology. A model climatology is defined as an average over hindcast period (1987-2001) of hindcasts according to initial months. Thus the climatology used to calculate each anomaly depends both on start time of the year and also on forecast lead time, as discussed in Wang et al. (2002).

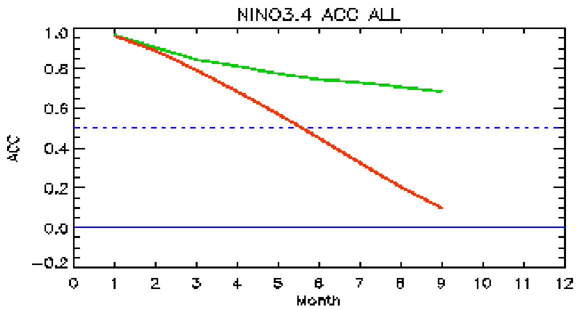

Fig. 1: Nino 3.4 anomaly correlation as a function of lead time for 180 forecasts starting one per month during the period 1987-2001. Red – persistence of initial SST anomalies, Green – POAMA coupled model.

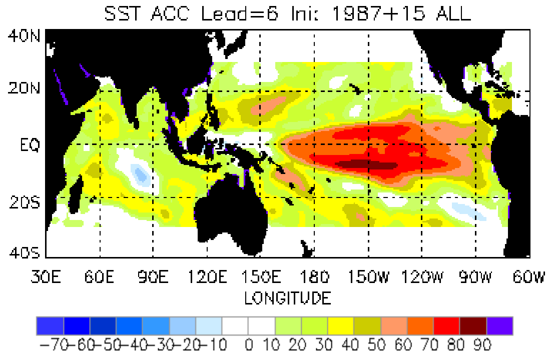

Fig. 2. Spacial distribution of anomaly correlation of SST anomaly (x100) for 180 forecasts starting one per month during the period 1987-2001.

3.2 Hindcast skill

One measure of forecast skill is the anomaly correlation coefficient for NINO3.4 SST anomalies. This is shown in Fig. 1 for both model and persistence, as a function of lead time. The plot shows that the model beats persistence at all lead times. Horizontal patterns of anomaly correlation skill are shown in Fig. 2 for lead time of six months. The peak in skill is concentrated in the central and eastern Pacific, associated with the El Nino phenomenon. It reaches up to 0.8 in the central Pacific south of the equator. These skill measures are at least comparable to other international models.

Some caution is necessary in interpreting these plots since only one ensemble member has been run. Ideally a large ensemble would be produced, but this requires enormous computing resources. Instead we select several dates from 1997/98 event and make a 20 member enesemble hindcasts. These hindcasts starts from slightly different atmosphere initial conditions but identical ocean initial conditions. Fig. 3 shows Nino3.4 plumes of the 20 hindcasts initiated on 1st March 1997, together with the observed estimates from POAMA assimilation. Clearly all curves go to warm conditions and several members catch up with the observed strength of about 2.5°C at the end of the hindcasts. Similar results are found for other cases initiated at different phase of the event. This implies that the skill of POAMA shown in Figs. 1 and 2 are likely underestimated because only single ensemble member has been used in the skill assessment.

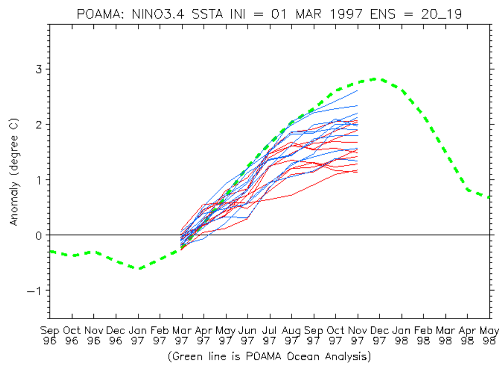

Fig. 3. Nino 3.4 SST anomaly curves. Green – observed, short curves – model forecasts starting on the 1st March 1997.

3.3 Intraseasonal variability

Another method of assessing the quality of the forecast system is to find ways of analysing how well the model represents the physical processes of relevance to seasonal prediction. For example, how well can the model represent intraseasonal variability, such as the MJO. There is growing evidence of the importance of the MJO for triggering the development of El Nino.

Fig. 4 is the relative power spectra in frequency/wave number space of surface zonal wind averaged between 10ºS and

10ºN from the hindcasts. The result shows that there is a maximum power at eastward propagating wave number 1-2 and frequency 30 days to 100 days. Although there is a slight shift towards the lower frequency compared with the observation, the POAMA model generates MJO-like oscillation.

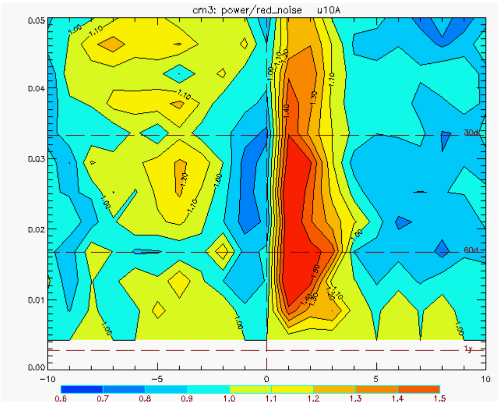

Fig. 4. Relative power spectra in frequency / wave number space of surface zonal wind averaged between 10ºS and 10 º N using the daily data from the hindcasts.

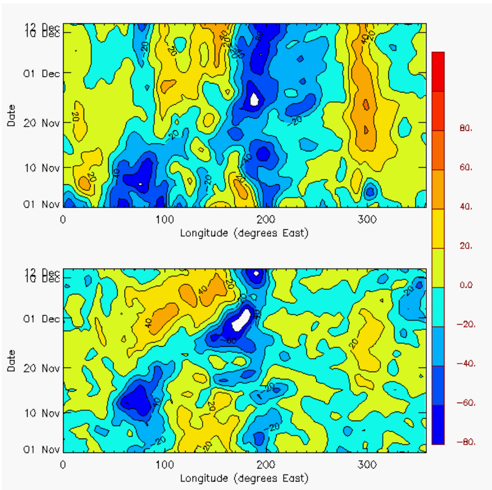

Fig. 5. Longitude-time section of OLR anomalies averaged between 10ºS-10ºN from observation (lower panel) and real-time coupled model forecasts initiated at 1st Nov 2002. Contour interval is 20W/m^2.

Fig. 5 shows an example of OLR real-time forecast started on 1st Nov 2002. The OLR has been subject to a simple filtering on intraseasonal time scales. Initially a convection develops over the Indian Ocean and it propagates eastward and reaches central Pacific one month later in the observation (lower panel). This MJO event is forecasted very well as shown in Fig. 5 (upper panel).

3.4 Breakdown of the 2002 El Niño

The POAMA system has been run in real-time every day by the Bureau of Meteorology operations branch since 1st October 2002. At that time the 2002/03 El Niño was close to its peak. Most coupled model forecasts available during Nov/Dec 2002 showed a continuation of warmer than average conditions in the central and eastern equatorial Pacific for the subsequent 5 to 7 months. In addition westerly wind anomalies associated with an MJO event led several centres to issue forecasts that stated that warm conditions would continue into the middle half of 2003.

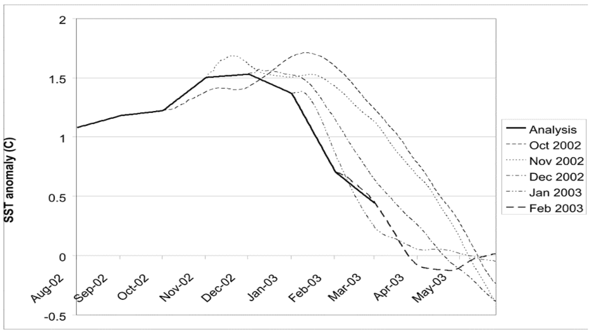

Fig. 6. Dashed lines: monthly ensemble means of Nino3 SSTA from POAMA real-time forecasts, each ensemble starting at different months during the peak period of the 2002/03 El Niño. Solid line is observed Nino3 SSTA.

However, the El Niño event declined rapidly in the first few months of 2003, as shown in figure 6. Also shown in Fig. 6 are the monthly ensemble means of Nino3 SSTA from POAMA real-time forecasts, each ensemble starting at different months during the peak period of the 2002/03 El Niño. The POAMA coupled model successfully predicted the breakdown of the event. The POAMA model forecasts included the impact of the westerly wind bursts that occurred towards the end of 2002 in its initial conditions and the model behave as in nature, i.e., the westerly wind bursts did not lead to the maintenance of warm conditions.

We are currently diagnosing what causes the breakdown of the 2002 El Niño in POAMA model.

4. Summary

The new Bureau of Meteorology seasonal forecast system called POAMA is now run in real-time and produces an eight month forecast every day using the very latest ocean and atmosphere initial conditions. The ocean state is taken from an ocean analyses system also running in real time, based on optimum interpolation and using all sub-surface ocean observations received over the GTS. Atmospheric initial conditions are taken from the Bureau of Meteorology operational NWP system.

The skill assessment in terms of NINO 3.4 anomaly correlation based on 15 years of hindcasts is very promising. The model beats persistence at all lead times. In the central Pacific skill reaches over 0.8 after six months. The hindcast of strong 1997/98 El Nino event was also a success.

One of the notable features of the model is its ability to represent intraseasonal variability characteristic of the MJO. This is one of the measures of the ability of the model to represent the physical mechanisms relevant to seasonal prediction; many models have difficulty simulating realistic intraseasonal variability.

While this first version of the POAMA system shows that the model is performing at least comparable to other international models several issues still remain. These form the core of research at BMRC towards understanding climate variability on intra-seasonal to interannual time scales and towards improving the POAMA seasonal forecasting system.

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Appendix: POAMA website and products

The main product for ENSO is the forecast plume of NINO3, 3.4 and 4 anomalies. Many other plots are available on the POAMA web site at

http://www.bom.gov.au/bmrc/ocean/JAFOOS/POAMA/index.htm

These include horizontal plots of SST anomalies as for each lead time as well as equatorial/time plots with daily resolution of SST, 20ºC isotherm depth and surface zonal wind anomalies. These are produced for means of monthly ensembles, mean of last 30 forecasts and also individual forecasts. These plots are updated each day as a new 8-month model forecast is produced.