Project 3.1.4

South Eastern Australian
Climate initiative

SST Skill Assessment from the New POAMA-1.5 System

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Abstract

POAMA (Predictive Ocean Atmosphere Model for Australia) is the current operational dynamical seasonal prediction system at the Bureau of Meteorology. The system was developed jointly with CSIRO with support from MCV (Managing Climate Variability). A new version, POAMA-1.5, has been built and is undergoing operational trials. POAMA-1.5 has several enhancements, the most significant of which is a new Atmosphere/Land Initialisation (ALI) system. The introduction of ALI enables the POAMA system to have the same configuration when run in hind-cast mode as in real-time mode, particularly in relation to the initialisation of the ocean, land and atmosphere. A comprehensive set of 10-member monthly ensembles has been completed covering the period 1980-2006.

Investigation of skill from POAMA-1.5 shows promising results. In terms of SST (sea surface temperature) the new system is robustly better than the old one in both the Pacific and Indian Oceans.

The hindcasts from POAMA are freely available for research purposes on an open-Dap server. More information is available at http://poama.bom.gov.au .

Introduction

POAMA is an intra-seasonal to inter-annual climate prediction system based on a coupled ocean and atmosphere general circulation model (Alves et al, 2003). The first version (POAMA-1) was developed jointly between the Bureau of Meteorology Research Centre (BMRC), the former division of CSIRO Marine Research (CMR) and MCV. POAMA-1 became operational in October 2002. The main focus for POAMA-1 was the prediction of SST anomalies associated with the El Niño/Southern Oscillation.

POAMA continues to be developed. Development of core components of the POAMA system is now mostly covered by a new national project called ACCESS (Australian Community Climate and Earth System Simulator). This includes a range of ocean and atmosphere models, assimilation systems and infrastructure systems. A new version of the POAMA system was implemented in the Bureau operations in June 2007, with real-time forecasts produced from July 2007. POAMA-1.5 uses the same coupled model as in POAMA-1 (with some enhancements) and contains a new atmospheric/land initialisation system.

This paper summarises the POAMA-1.5 system and its SST skill performance based on 10 member ensemble hindcasts over the past 27 years. To gain insight into skill improvement in POAMA-1.5 an intercomparison with POAMA-1 is carried out. Finally a medium-to-long term plan for POAMA development is discussed.

POAMA 1.5

(a) The System

The POAMA-1.5 system is an interim version between POAMA-1 and POAMA-2. It uses some modules from POAMA-1 and new modules developed for POAMA-2. The main modules in POAMA-1.5 that have evolved from POAMA-1 include the ocean model ACOM2 (Australian Community Ocean Model version 2), the atmospheric model BAM3 (the Bureau of Meteorology Research Centre Atmospheric Model version 3) and the OASIS2 (Ocean Atmosphere Sea Ice Soil version 2) coupler. These modules include some re-tuning and improvements. One improvement is the inclusion of stress/current coupling i.e. the windstress calculation in the atmospheric model takes into account ocean surface currents from the ocean model. Higher coupling frequency (3 hours now compared with one day previously) has been introduced to resolve the diurnal cycle in coupled processes. Excessive noise was seen in POAMA-1 in the east Pacific SST. The ocean vertical mixing has been re-tuned to reduce this noise. These changes have been individually tested in short experiments and all lead to improvements in the model simulation, particularly smaller model biases. Assessing the impact of each change on forecast skill was not practical as the computational costs would be prohibitive.

A major new component is an Atmosphere-Land Initialisation (ALI) scheme. In this scheme an atmospheric/land re-analysis (initial conditions for the coupled forecasts) is produced by running the atmospheric model from 1980 to present forced with observed SST (AMIP, or Atmospheric Model Intercomparision Project, style) and at the same time nudging the atmospheric 3D to pre-existing analyses (e.g. ERA40, or European Center for Medium range Weather Forecasting 40 Years ReAnalysis, Simmons and Gibson, 2000) in hind-mode or the Bureau NWP (Numerical Weather Prediction) in real-time. The land surface is left to adjust to atmospheric forcing. This allows the same land and atmosphere model to be used for initialisation and coupled forecasts and also allows consistency between real-time forecasts and hind-casts. This overcomes one of the major problems in POAMA-1: the atmosphere and land surface were being initialised directly by the Bureau NWP system, which was not the same model as used for the coupled forecasts.

One of the issues in POAMA-1 was that it was initialised directly by the Bureau NWP system land and atmospheric initial conditions, whereas the hind-casts were initialised from an AMIP style run of the atmospheric and land model used in POAMA-1. This introduced an inconsistency between the hind-casts and real-time forecasts, which is not ideal as the hind-casts are used to bias correct the real-time forecasts. Furthermore, changes in the NWP system could lead to inconsistent initial conditions for POAMA. For example, in 2005 the Bureau NWP system changed its land surface model from a bucket to the new ECMWF (European Center for Medium range Weather Forecasting) multi-layer model. This led to significant changes in the land surface, particularly over South America, and therefore significant differences in the characteristics of the initialisation fields for POAMA. This in turn led to changes to the large scale circulation, which in turn impacted the SST. One of the reasons for introducing the ALI scheme is to provide a buffer between NWP changes and POAMA initial conditions.

The ocean data assimilation scheme is the same as in the POAMA-1. It assimilates temperature measurements into the ACOM2 in the top 500m every 3 days. Current corrections are then calculated by applying the geostrophic relation to the temperature corrections.

A comprehensive hind-cast set has been produced for the past 27 years (1980-2006). For each month, a 10 member, 9-month forecast has been generated.

Statistical calibration and bridging techniques are being developed for forecasts of SST, rainfall and other variables on both intra-seasonal and interannual time scales, as part of the South East Australian Climate Initiative. These results will be reported elsewhere.

(b) Skill

In this section results from POAMA-1.5 (version 1.5b) ten member ensemble mean anomalies that cover January 1980 to December 2006 are used for skill assessment. The model anomalies are formed by subtracting the model climatology from individual hind-casts. By doing this the anomalies are supposedly biases-free. The model climatology is defined as the mean of the hind-casts over all 10 members and over all 27 years for each initial month, calculated as a function of lead time. In the following we define lead one month as the monthly mean of the first month, therefore the forecasts go out to a total lead time of nine months.

Verification data are from the Reynolds OI.v2 Sea Surface Temperatures (Reynolds, et al. 2002) from December 1981 onwards and prior to this they are from HadISST (Rayner et al. 2003).

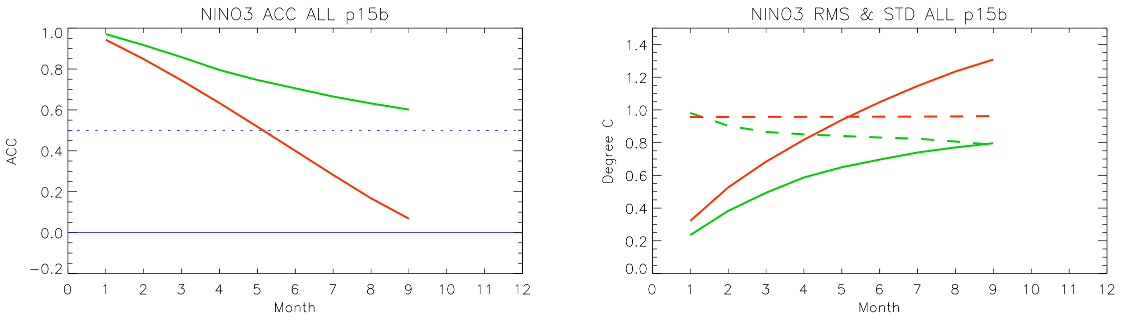

Figure 1. Nino3 anomaly correlation (left panel) and RMS error (right panel), based on the ensemble mean of 10 hind-casts each month from 1980-2006, as a function of lead time. POAMA-1.5 is shown in solid green and persistence is shown in solid red. The dashed lines on right panel show Observed Nino3 SST standard deviation (0.96C) in red and standard deviation from the model in green. The x-axis shows forecast lead time in months.

Figure 1 compares the anomaly correlation (ACC) skill and root-mean-square (RMS) error for Nino3 SST anomaly from POAMA-1.5 and from persistence. POAMA-1.5 forecasts beat persistence at all lead times. The anomaly correlation is above 0.6 and the RMS error is less than 0.8C for all lead times. The correlations are even higher for

SST anomaly indices for the Nino3.4 and Nino4 regions (Figures not shown). The correlation of 0.6 is often used as a threshold value for a forecast being useful, the result in Fig. 1 indicates that the POAMA 1.5 has useful SST prediction skill across central to east Equatorial regions for lead times up to 9 months.

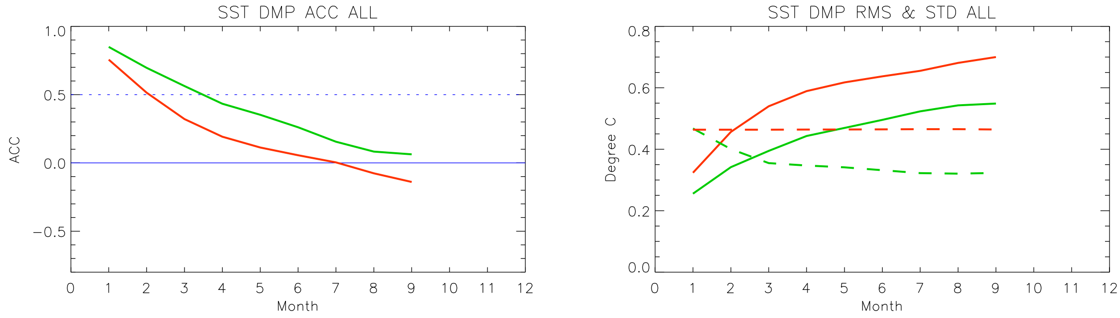

Figure 2. As Figure 1 except for the Indian Ocean Dipole mode index (DPI)

Figure 2 shows the ACC skill and RMS error for the Indian Ocean dipole mode index (IOD). The DPI is constructed as the SST anomaly difference between the west and east poles across the tropical Indian Ocean. Although the forecast correlation skill is higher and the RMS error is smaller than persistence for all lead times, the forecast correlation drops to below 0.6 within the first four months, and the RMS error at the first lead month is already substantial, at more than 50% of its standard deviation. By lead month 3 the RMS exceeds the model standard deviation. The lower skill for IOD is the result of lower skill over the both poles (see Fig. 3).

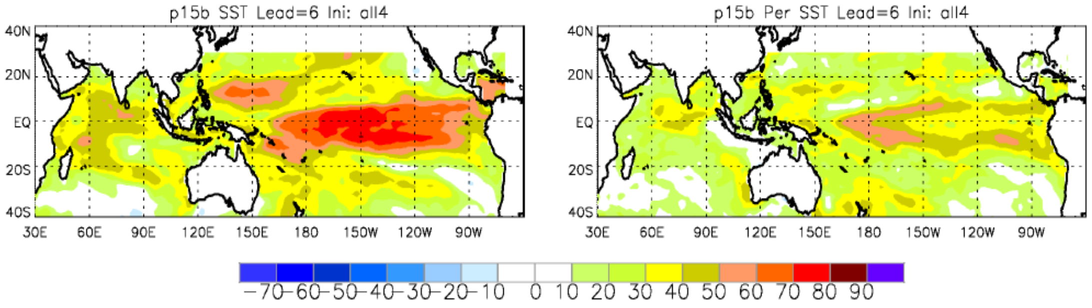

Figure 3. SST anomaly correlation skill at 6 month lead time for POAMA-1.5 forecasts (left) and persistence (right).

SST skill at lead time 6 months for the forecasts and persistence is displayed in Fig. 3. At this lead time POAMA1.5 skill clearly beats persistence almost everywhere within the tropical and subtropical Pacific and Indian Oceans. However, the forecast skill varies regionally. The highest skill is in the central and eastern Pacific, with the POAMA values reaching over 0.7. This skill is mainly associated with the prediction of El Niño/La Niña. In the western Pacific there are two distinct regions of skill reaching over 0.6 correlation: one near the Solomon Islands, and the other in the northwest Pacific east of the Phillipines. Elsewhere the skill is relatively lower, including in the tropical Indian Ocean.

Other models also have skill levels in the Indian Ocean considerably lower than in the Pacific. Possibly many factors are contributing to lower skill in Indian Ocean. For instance the monsoonal flow is very active in Indian Ocean. Another important factor is the ocean data used to initialise the forecasts is more sparse and is less reliable over this region, both surfacing terms of SST and ocean subsurface. This impacts the quality of the ocean data assimilation on one hand, and cast doubt on the validity of the skill assessment on the other hand.

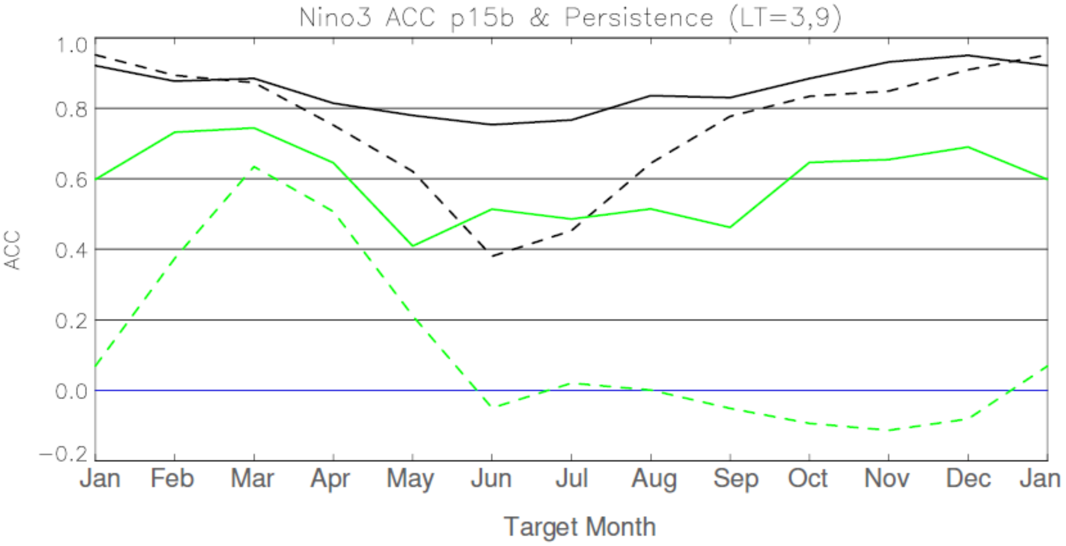

Figure 4: Nino 3 anomaly correlation skill for each target month (x-axis) at 3 (black) and 9 (green) months lead. POAMA-1.5 10 member ensemble in solid and persistence in dashed lines. Based on hindcasts from 1980-2006.

Skill maps given in Figs. 1-3 are based on hindcasts started from all initial months and are a useful way of assessing the overall skill level, whereas in practice a forecast is always attached to a particular time of year. To assess seasonal skill variation, shown in Fig. 4 is skill in the form of anomaly correlation for Nino 3 at lead times 3 and 9 months for each target month, where the anomaly correlation skill and the corresponding persistence skill (y-axis) are displayed according to target calendar month (x-axis). Persistence skill drops from April/May or boreal spring, i.e. a lack of persistence across northern hemisphere spring, the so called "spring predictability barrier". For example at three months lead the skill of persistence has a peak value of around 0.95 for forecasts for November –January, and a minimum skill of around 0.4 for forecasts for June/July. The model hindcasts do not show the same predictability barrier, although there is a slight decrease in skill across the boreal spring. The skill of persistence is very high from November to January, and similar to that of the model predictions. However, for June/July the model skill is around 0.75 correlation, which is substantially larger than that from persistence, but still the least skill target period. The dynamical forecasts are able to overcome a large part of the persistence northern spring predictability barrier, probably because of information contained in the ocean sub-surface initial conditions.

These results indicate that the new operational POAMA-1.5 system has higher than practically useful SST prediction skill for lead times up to three seasons across large areas of tropical Pacific Ocean. The spring predictability barrier is much reduced in the model. Over the Indian Ocean skill from POAMA-1.5 beats the persistence but is lower than the skill level in the Pacific.

Other variables, such as regional rainfall and temperature, and products on intra-seasonal timescales have also been investigated. However, they are beyond the scope of this report and will be described elsewhere.

Comparison with POAMA-1

POAMA-1 was the first version of the POAMA model and its hindcast period is shorter (1987-2001). In addition, there is only one hindcast ensemble member available for POAMA-1. It is well known that simply increasing an ensemble size improves hindcast skill as the ensemble mean is usually a more accurate predictor than individual ensemble members.

To make comparison compatible between the two versions we restrict data from POAMA-1.5 to the same time period as POAMA-1, i.e., use those hindcasts from 1987-2001 only. In addition to avoid ambiguity in dealing with single member and multi-member hindcasts in this section skill is assessed based on a single ensemble member.

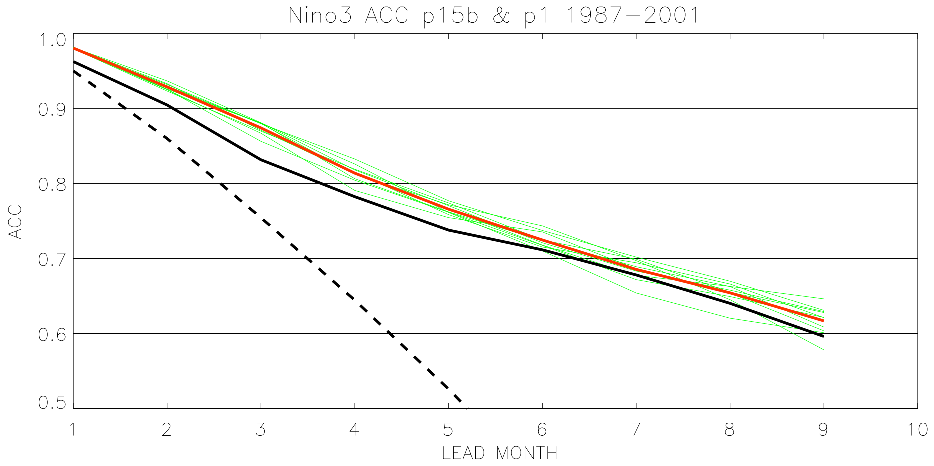

Figure 5. Nino3 SST anomaly correlation for POAMA-1 (black solid) and POAMA-1.5 each ensemble member (green) and their mean (red). Persistence is dashed.

Fig.5 summarises Nino3 SST anomaly correlation skill from POAMA-1 and POAMA-1.5. The skill of POAMA-1.5 for all members for lead times up to 6 months and most members for lead time up to 9 months is higher than that of POAMA-1. As a result the skill averaged over the ten one-member-hindcasts (ie the average of the skill of each member rather than the skill of the ensemble mean) of POAMA-1.5 beats the skill of one member hindcast of POAMA-1 for all lead times, most noticeably in the fist five months.

Looking at the skill spatial distribution at a lead time of 3 months, as shown in Fig. 6, the skill is generally higher for POAMA-1.5 than for POAM-1. The regions with ACC above 0.5 are closer to northwest and northern Australia in the new version, which can potentially increase application scope in the short lead time range for these regions, such as for Great Barrier Reef bleaching forecasting.

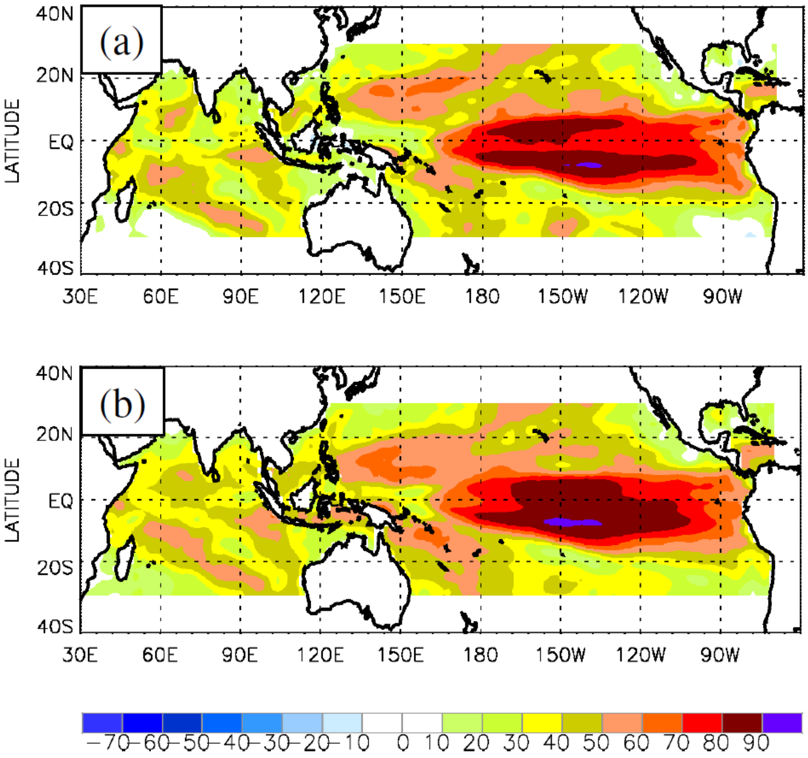

Figure 6. SST anomaly correlation at lead time of 3 month for (a) POAMA-1 and (b) POAMA-1.5. The POAMA-1.5 skill is the average of the skill of the individual ensemble members to facilitate comparison.

The short-time period and single member ensemble from POAMA-1 make it difficult to get a reliable skill comparison. However, since Nino3 skill in POAMA-1 is lower than every single member (measured individually) of POAMA-1.5 in the first 5 months, it is likely that POAMA-1.5 skill improvement is statistically significant. In addition, some aspects of POAMA-1.5 were clearly improved. For instance, better defined atmospheric initial conditions in POAMA-1.5 through the use of ALI will certainly have positive impact on skill at short to medium lead times. On the other hand, the introduction of ocean current feedback in surface windstress calculation could be another factor influencing skill at medium to longer lead times by reducing model SST biases. Fig. 7 shows that the SST bias in POAMA-1.5 is smaller than POAMA-1. The SST difference between model climatology of the hindcasts initialized in January and the corresponding observed climatology grows with lead time. For lead times up to 5 month the difference in SST biases between POAMA-1 and 1.5 is insignificant. However, by

July-September (lead 7-9) when the climatological equatorial easterlies are strongest, the cold SST biases along the equatorial Pacific in POAMA-1.5 is much smaller than that in PAOMA-1. Similar improvement can be found along the west coast of Sumatra and eastern Indian Ocean.

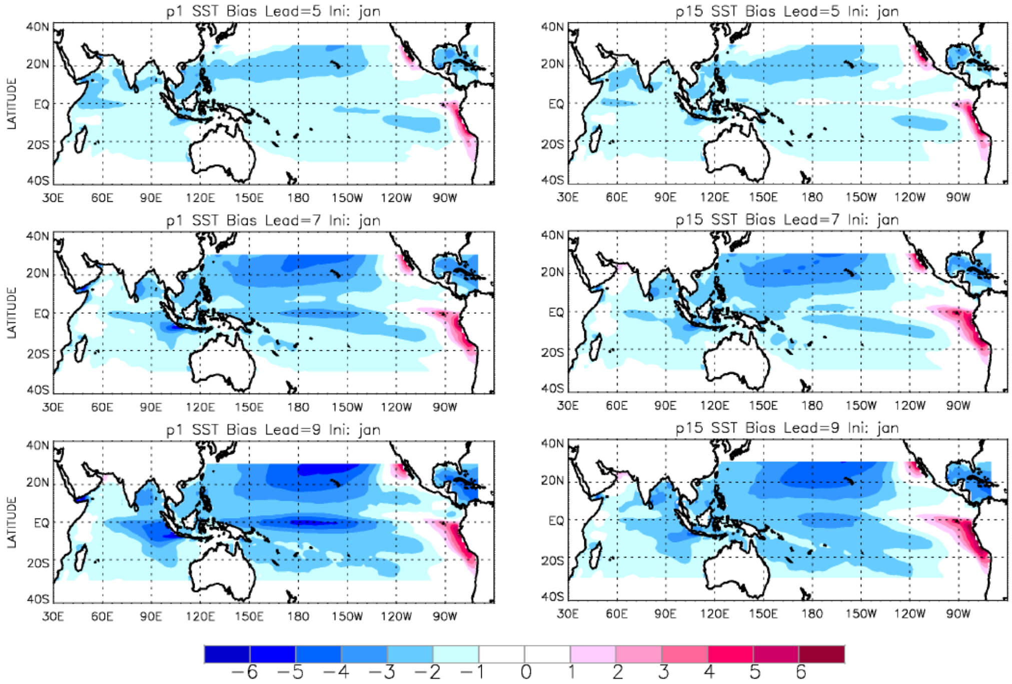

Fig. 7. SST biases for hindcasts started in January at lead times of 5 (top), 7 (middle), and 9 (bottom) months, for POAMA-1 (one member, left) and POAMA-1.5 (10 members average, right).

Longer-term Development

(a) POAMA-2 System

A major new version, POAMA-2, will become operational in 2008. POAMA-2 will use a new higher-resolution version of the atmospheric model, a new ocean data assimilation system and enhanced versions of the atmospheric/land initialisation systems.

A timeline for the development of different versions of the POAMA system is shown in Figure 8. The diagram also shows the development of the POAMA-3 system, which will be built from new modules developed as part of the ACCESS system. The models used in the various versions of the system are also used for a range of climate variability and predictability studies that underpin the development of future systems.

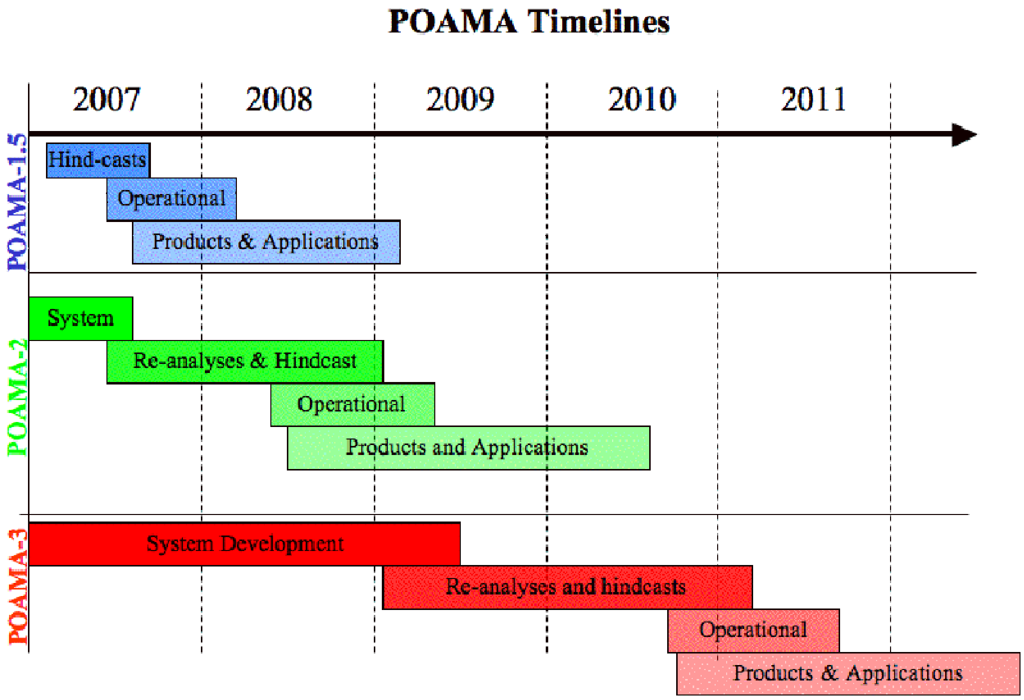

Figure8: POAMA timelines

POAMA-2 builds on POAMA-1.5, and will include improvements to the ALI atmosphere/land initialisation system based on experience gained using POAMA-1.5. The resolution of the atmospheric model will be extended from T47L17 (spectral truncation at wavenumber 47 and 17 vertical levels) to T63L17. Trials have been conducted with a T95L60 version, but there were no significant improvements that justified the significant additional computational cost.

A new ocean data assimilation system, called POAMA Ensemble Ocean Data Assimilation System (PEODAS), had been developed as the ACCESS ocean data assimilation system for seasonal prediction and is based on an extension of the BlueLink system (Oke et al 2005) into a pseudo-ensemble Kalman Filter. In this system a multi-variate three dimension OI approach is used and takes covariances from a time evolving ensemble (Alves and Robert, 2005). For the first time salinity data will be assimilated. A

PEODAS ocean re-analyses starting in 1977, is almost complete. Preliminary hind-casts using the new PEODAS ocean initial conditions show skill improvement in the Pacific. The PEODAS systems also produces an ensemble of initial conditions, which provides a new way of perturbing the coupled forecasts.

A comprehensive hind-cast set will be produced similar to that for POAMA-1.5. However, the increase in atmospheric resolution comes with an increase in computational cost. Production of the hind-casts will take place during 2008. The expectation is that operational trials will start in the second half of 2008.

(b) POAMA 3/full ACCESS system

POAMA-3 will be built solely from components being developed as part of ACCESS. The ACCESS earth system model will form the core coupled model used in POAMA. This will involve a new atmospheric model based on the UK Met Office (UKMO) atmospheric model and the CSIRO Atmosphere Biosphere Land Exchange (CABLE) land-surface model. The exact configuration of these systems remains to be decided and will depend on computational costs and scientific performance.

In 2003/04, scientists from the Bureau of Meteorology, CSIRO and several universities agreed to the joint development of the next generation ocean and sea-ice components of a coupled climate model. The Australian Climate Ocean Model (AusCOM), the first version of which is based on Geophysical Fluid Dynamics Laboratory (GFDL) Modular Ocean Model version 4 (MOM4) code with enhancements by Australian researchers, is the result of a Workshop at the BMRC in March 2004. AusCOM will form the core ocean model for climate applications within the ACCESS project and will be the core ocean model for POAMA-3.

The PEODAS ocean and ALI atmosphere/land initialisation schemes will be further developed under ACCESS. These two approaches will be combined to form the POAMA Ensemble Coupled Data Assimilation System (PECDAS). Assimilation will be performed directly in the coupled model, with ocean observations assimilated into the ocean component through the PEODAS approach and atmospheric fields assimilated (nudged) into the atmosphere/land component using the ALI approach. In this first version there will be no cross-covariance information between ocean and atmosphere. This will be explored for systems beyond POAMA-3.

Conclusion

This paper describes the new POAMA-1.5 system, assesses its forecast skill performance for SST, and compares skill with the earlier version POAMA-1.

The result demonstrates that SST skill measured by anomaly correlation from the new system is higher than 0.6 up to 9 months lead time over a large part of the equatorial Pacific Ocean. SST skill is likely useful at shorter lead times over the Indian Ocean. This conclusion is based on 10 member hindcasts initialized every month over 27 yrs, and therefore can be considered as highly robust.

The comparison with an early POAMA-1 version suggests that the skill improvement seen in the new version is possibly the combined result of improved initialization and improved coupling physics. This reinforces the notion that with the continuing efforts into the development of better data assimilation and better climate models seasonal prediction skill will get steady improvement.

The POAMA-1.5 system shows higher skill for El Nino SST, even when looking at individual ensemble members. Furthermore, the new ALI initialisation scheme for atmosphere and land introduces a buffer between the Bureau's NWP system and the initial conditions for atmosphere and land required by POAMA. The real-time forecasts are therefore much more consistent with the hind-casts and the system as a whole will be more robust.

Note also the POAMA-1.5 system will be using the same ocean assimilation system as POAMA-1 and the new PEODAS ocean assimilation system will only be implemented in POAMA-2.

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