The impact of land-atmosphere initialisation on dynamical seasonal prediction

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Introduction

This study presents a new Atmosphere and Land Initialisation scheme (ALI) for POAMA (Predictive Ocean Atmosphere Model for Australia). POAMA is a coupled ocean/atmosphere model seasonal forecast system, and the first version, POAMA-1 (Alves et al., 2003), has been run operationally by the Bureau of Meteorology since 2002. For atmospheric initialisation, the POAMA-1 system uses data directly from the NWP forecast system for the real-time forecasts, and data from an AMIP-style atmosphere-only simulation (referred to here as BAM AMIP) for hindcasts. The initial conditions for the hindcasts thus contain observed atmospheric information which is related to sea-surface temperature, but they do not capture the true intra-seasonal state. This is true also for the initialisation of the land surface, which uses an AMIP-style climatology for both the hindcasts and forecasts.

A new version of POAMA, POAMA1.5, is currently undergoing operational trials and uses atmospheric and land initialization from the ALI scheme. ALI involves the creation of a new reanalysis dataset using the atmospheric model of POAMA. This dataset is then used for the initial conditions of the hindcasts and forecasts. This process means that real atmospheric information, as well as land surface conditions that are in balance with this atmospheric forcing, are incorporated into the initial conditions. This has lead to improvements in skill at both seasonal and intra-seasonal scales.

Atmosphere-Land Initialisation Scheme (ALI)

Motivation for developing ALI

The rationale behind developing a new initialisation scheme is that, firstly, real atmospheric initial conditions are important for intra-seasonal forecasting. Results from the current POAMA system appear to support this hypothesis. The MJO is important for Australian climate variations primarily through impacts on the onset and breaks of the summer monsoon and tropical cyclone genesis (e.g. Hendon and Liebmann 1990; Hall et al. 2001; Wheeler and Hendon 2004). Secondly, real atmospheric initial conditions may be important for seasonal forecasting. There are indications that the MJO may affect the development of ENSO events, interannual variability of monsoon rainfall, as well as rainfall over higher latitudes via teleconnections (e.g. Hendon et al. 1999, Zhang et al. 2001; Hendon et al. 2007). Information of the MJO in the initial conditions thus has the potential to improve our ability to forecast these events. There may also be benefits for intra-seasonal/seasonal forecasting from improving the initialisation of the land surface, primarily due to soil moisture memory in the earth-atmosphere system (e.g. Zhang and Frederiksen 2003; Koster et al. 2004).

Description of ALI

ALI uses a forecast-analysis (or nudging) scheme to produce the atmospheric and land surface initial conditions for the hindcasts and real-time forecasts. In this approach, an offline version of the POAMA atmospheric model (BAM) is nudged towards "reality", or an "analysis", provided by ERA-40 for the hindcasts and the NWP forecast system in real-time. The model's forecast of u-wind, v-wind, atmospheric temperature and humidity is compared directly to the analysis at six-hour intervals, and a fractional difference between the forecast and the analysis is added repeatedly to the evolving model atmospheric state. The land surface is initialised indirectly via the nudged atmosphere, such that the soil moisture and temperature evolve to become consistent with the atmospheric forcing. (This approach has also been used by the Climate Change Prediction Program, CCPP, and Atmospheric Radiation Measurement, ARM, Program in the CCPP-ARM Parametrization Testbed to provide initial conditions for the evaluation of climate models in NWP-mode.) The atmospheric model (forced by observed weekly sea-surface temperatures) is run in forecast-analysis mode from 1980 to real-time, allowing an initial spin-up year for the land surface. The output from this simulation, called BAM-reanalysis, is used as initial conditions for the hindcasts and forecasts. This approach of initialising the land surface does not attempt to correct biases in the land surface model, but it may offer improvements over using climatological land initial conditions.

Advantages of ALI

- ALI introduces more realistic atmosphere and land initial conditions into the hindcasts. Hindcasts will now capture true intra-seasonal atmospheric states.
- ALI allows greater consistency between the hindcasts and real-time forecasts, thus allowing better use of the hindcasts to assess intra-seasonal and seasonal forecast skill.
- ALI reduces the shock to the system compared to using ERA-40 directly for the hindcasts (also, the use of ERA-40 directly reduces consistency between hindcasts and real-time forecasts).
- ALI reduces the sensitivity to changes in the NWP forecast system (acts as a buffer).

Assessment of ALI: BAM Reanalysis compared to BAM AMIP

This section evaluates the BAM Reanalysis simulation, described above, and compares it to the BAM AMIP simulation, which is used to initialise the hindcasts of the current operational system (POAMA-1). As expected, BAM Reanalysis is able to capture the intra-seasonal variability of the MJO, as given by the ERA-40 reanalysis (where BAM AMIP is unable). In general, BAM Reanalysis exhibits higher spatial and temporal correlations and smaller temporal RMSE than BAM AMIP (for example, see Table 1). Note that the variables in Table 1 are not directly nudged in the creation of BAM Reanalysis. The nudging process to create BAM Reanalysis worked well and produces more realistic initial conditions than BAM AMIP.

Table 1: Correlations (r), bias and RMSE over Australia for BAM AMIP and BAM Reanalysis for monthly data from 1980 to 2002. For the bias, the units are hPa for mean sea level pressure, K for 2m-temperature and mm/day for precipitation. Soil moisture is normalized. The observed data are the ERA-40 reanalysis, except for precipitation where Global Precipitation Climatology Project (GPCP) data are used. The ± values shown for the spatial correlations represent 1 standard deviation of the monthly data for the analysis period.

		MSLP	2m TEMP	PRECIP	NORMALISED SOIL MOISTURE
SPATIAL CORRELATION	BAM AMIP	0.81±0.20	0.95±0.02	0.53±0.19	0.20±0.26
	BAM REANALYSIS	0.98±0.01	0.98±0.01	0.74±0.11	0.53±0.21
TEMPORAL CORRELATION	BAM AMIP	0.78	0.968	0.56	0.33
	BAM REANALYSIS	0.996	0.999	0.96	0.82
TEMPORAL BIAS	BAM AMIP	-1.13	0.52	-0.37	-
	BAM REANALYSIS	-2.3	0.59	-0.76	-
TEMPORAL RMSE	BAM AMIP	2.03	1.16	0.97	0.49
	BAM REANALYSIS	0.29	0.28	0.36	0.27

Will the use of ALI produce improved skill?

The hindcast dataset extends from 1980-2006, with 9 month forecasts starting on the 1st of every month. There are two experiments considered here:

- p15a: BAM AMIP initial conditions (3 member ensemble)
- p15b: ALI (BAM Reanalysis) initial conditions (10 member ensemble)

Improved skill at seasonal and intra-seasonal scales

Initial results indicate improvements in skill at both seasonal (e.g. Figures 1 and 2) and intra-seasonal (e.g. Figure 3) scales. Skill varies a great deal as a function of forecast start month and region of analysis (e.g. Figure 3). Initial investigations of the simulation of the MJO in p15b are promising (e.g. Figure 4).

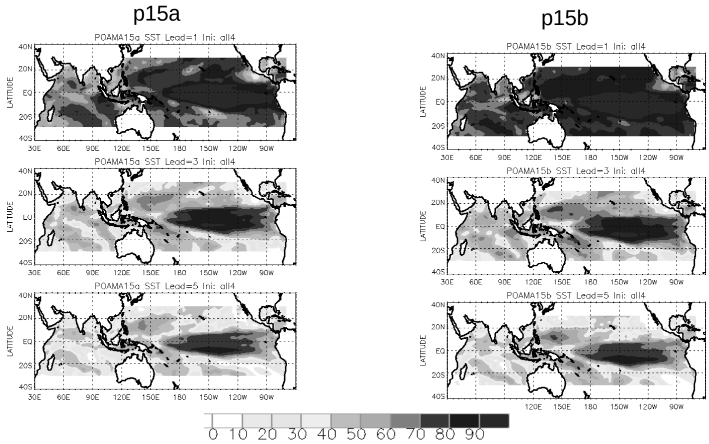

Fig. 1: Sea-surface temperature anomaly correlation skill from p15a (left) and p15b (right) for lead times of 1 (top), 2 (middle) and 3 months (bottom).

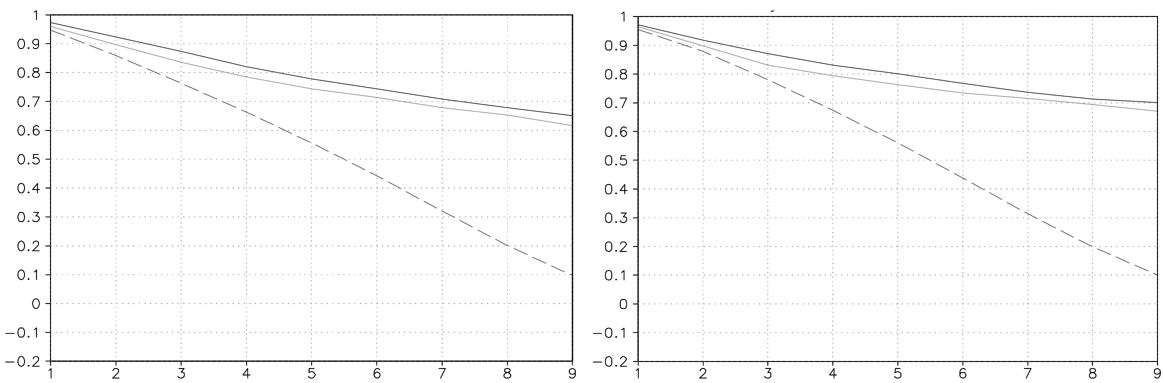

Fig. 2: NINO3 (left) and NINO3.4 (right) sea-surface temperature anomaly correlation skill as a function of lead time (months) for all forecast start months (1980-2001). The dashed line is for persistence, the grey line for p15a and the black line for p15b.

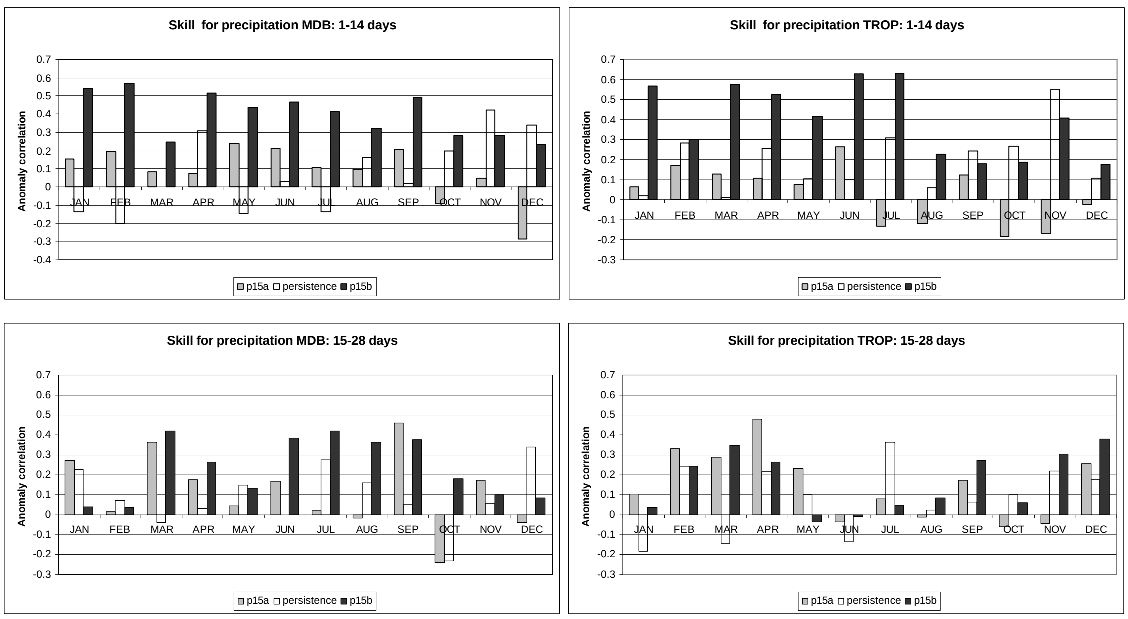

Fig. 3: Precipitation anomaly correlation skill for SE Australia (left) and Tropical Australia (right) based on forecast start month for the average of the first 2 fortnights of the forecast (1-14 days and 15-28 days), for persistence (clear), p15a (grey) and p15b (black).

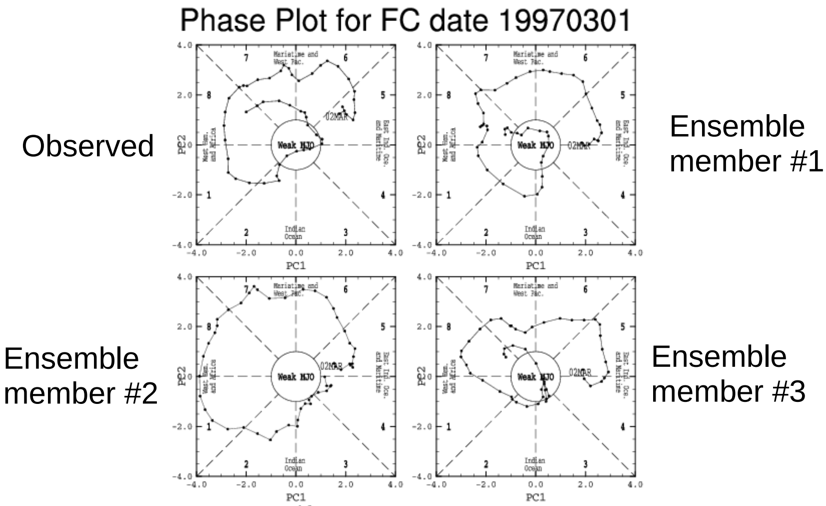

Fig. 4: Case study showing the phase diagrams (Wheeler and Hendon, 2004) of MJO propagation for a forecast start date of 1/3/1997 for the observations and 3 ensemble members of p15b (Figure courtesy of Harun Rashid).

References

Alves, O., Wang, G., Zhong, A., Smith, N., Tzeitkin, F., Warren, G., Shiller, A., Godfrey, S., and Meyers, G. 2003. POAMA: Bureau of Meteorology Operational Coupled Model Forecast System. National Drought Forum, 15/16 April, Brisbane.

Hall, J.D., Matthews, A.J. and Karoly, D.J. 2001. The modulation of tropical cyclone activity in the Australian region by the Madden-Julian oscillation. *Monthly Weather Review*, 129,2970-2982.

Hendon, H.H., Zhang, C. and Glick, J.D. 1999. Interannual Variation of the Madden–Julian Oscillation during Austral Summer. *Journal of Climate*, 12,2538-2550.

Zhang, C., Hendon, H.H., Kessler, W.S. and Rosati, A.J. 2001. Meeting summary: A workshop on the MJO and ENSO. *Bulletin of the American Meteorological Society*, 82,971–976.

Hendon, H.H., and Liebmann, B. 1990. A composite study of onset of the Australian summer monsoon. *Journal of the Atmospheric Sciences*, 47,2227–2240.

Wheeler, M.C. and Hendon, H.H. 2004. An all-season real-time multivariate MJO Index: Development of an index for monitoring and prediction. *Monthly Weather Review*, 132,1917-1932

Hendon, H.H., Wheeler, M.C. and Zhang, C. 2007. Seasonal dependence of the MJO-ENSO relationship. *Journal of Climate*, 20,531-543

Fennessy, M.J. and Shukla, J. 1999. Impact of initial soil wetness on seasonal atmospheric prediction. *Journal of Climate*, 12,3167-3180.

Zhang, H. and Frederiksen, C.S. 2003. Local and nonlocal impacts of soil moisture initialization on AGCM seasonal forecasts: A model sensitivity study. *Journal of Climate*, 16,2117-2137.

Koster, R.D., Suarez, M.J., Liu, P., Jambor, U., Berg, A., Kistler, M., Reichle, R., Rodell, M. and Famiglietti, J. 2004. Realistic initialisation of land surface states: Impacts on subseasonal forecast skill. *Journal of Hydrometeorology*, 5, 1049-1063.