3.10 INVESTIGATING THE ROLE OF AIR-SEA COUPLING ON THE MADDEN JULIAN OSCILLATION

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1. INTRODUCTION

The Madden-Julian Oscillation (MJO; Madden and Julian, 1972) manifests itself as a slow eastward propagation of atmospheric disturbances with maximum amplitudes in the tropical eastern hemisphere (Hendon and Salby, 1994). The oscillation has also been related to precipitation fluctuations in the Indian Ocean, and to active phases of the Indian, Australian and Asian summer monsoons (Wang and Rui, 1990). While the MJO is the strongest signal in the intra-seasonal variability of the tropical atmosphere, the ENSO phenomenon is known to be the single most prominent signal in the inter-annual variability of the earth's climate (Lau and Chan, 1986). Recently scientists have hypothesised possible connections between MJO and ENSO, particularly since the occurrence of extraordinary MJO events recorded in 1996/97 that coincided with the onset of the 1997/98 El Niño (Zhang et al., 2001).

The general performance of general circulation models (GCM) in simulating and forecasting the MJO is well documented (Wang and Xie, 1998; Hendon, 2000). Models with prescribed sea surface temperature (SST) typically produce MJOs that move eastward too fast, are too weak, and have incorrect seasonality. Hendon (2000) recognises that since intra-seasonal SST fluctuations are coherent with the MJO, air-sea interaction may be important for the dynamics of MJO. Furthermore, Watterson (2002) shows that the variability of eastward propagation in the CSIRO GCM at MJO scales is better when coupled to an ocean model than when forced with observed SSTs. This research primarily addresses the question of what role ocean-atmosphere coupling has on the dynamics of the MJO.

Recent studies of zonally propagating waves at the equator have used wavenumber-frequency spectral analysis techniques. The study of Wheeler and Kiladis (1999) used satellite observed OLR on the assumption that it is a reasonably good representation of deep tropical cloudiness. Their technique involved the removal of background noise from tropical cloud spectra, which are "red" in both zonal wavenumber and frequency, revealing statistically significant spectral peaks corresponding to equatorial wave modes. The method of Wheeler and Kiladis (1999) has been adapted here to investigate the performance of model simulations of the MJO using the Bureau of Meteorology Research Centre (BMRC) unified atmosphere model (BAM) in coupled and uncoupled modes.

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2. INTRASEASONAL VARIABILITY IN THE BMRC ATMOSPHERE GENERAL CIRCULATION MODEL (BAM)

The type of convection employed in an atmosphere GCM is likely to play a major role in determining the dynamical structure of the model atmosphere through its interaction with SST and precipitation. The inter-comparison study of Slingo et al. (1996) found that a model's ability to simulate the MJO was improved if the convective parameterisation was closed on buoyancy rather than moisture convergence. The results of Slingo et al. (1996) were tested using two versions of BAM – the standard version that used a moisture convergence convection closure scheme, and a modified version using CAPE closure.

Wavenumber-frequency spectral analyses were performed over all longitudes in the ±10° latitude band using 19 years (1982 – 2000) of satellite-observed outgoing long-wave radiation (OLR) and NCEP-NCAR Reanalysis 10m (surface) zonal wind data. Based on the work of Wheeler and Kiladis (1999), we removed estimated background spectra from the absolute spectra to reveal the Madden-Julian Oscillation (MJO) relative spectral peak.

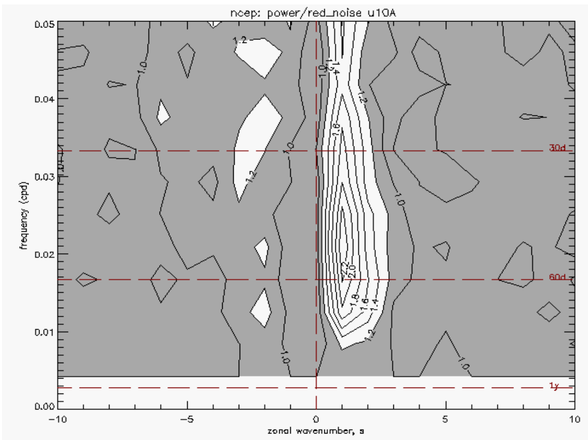

Figure 1. Wavenumber-frequency relative spectra of surface wind anomalies from NCEP observations. Contour interval is 0.2, with grey shaded areas indicating spectral density signal to background noise ratios less than 1.2.

Fig. 1 shows a peak spectral maximum with a signal to background noise ratio of 2.2 in the 30 – 90 day period band for anomalous surface wind measurements from the NCEP-NCAR data.

Spectral analyses of surface wind and OLR from AMIP-style uncoupled runs of the standard version of BAM showed no variability in the MJO frequency/wavenumber band comparable with the MJO. Instead they showed anomalous westward propagation (Fig. 2). Coupled model 8-month seasonal forecasts using the same version of BAM also showed no peak in eastward propagating intra-seasonal variability (not shown here).

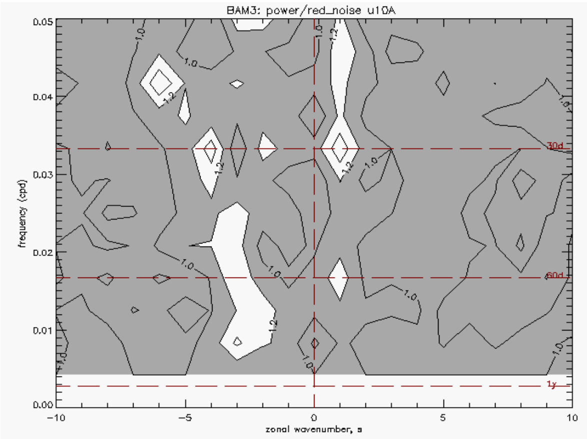

Figure 2. As in Figure 1, except for uncoupled BAM run using moisture convergence convection closure with AMIP monthly SST data.

A modified version of BAM (CAPE version) was used where the convection base mass flux was chosen by relating it to the degree of convective instability present, and evaluated on the assumption that the convection removes convective available potential energy (CAPE) over some characteristic timescale. This version when run in AMIP style produced MJO-like eastward-propagating disturbances on intra-seasonal time scales comparable to the better models examined by Slingo et al (1996). Rather than a broad peak with a period between 30 and 90 days as observed, the model showed multiple peaks – Fig. 3 shows one at about 30 days and another at about 60 days in the anomalous surface wind field, with a power to background noise ratio of 1.4.

In order to investigate the impact of SST on MJO-like activity in BAM further, the atmosphere model was coupled to the ACOM2 global ocean model and run in free mode for 20 years. Coupling appeared to increase the variability at MJO scales in BAM, especially at longer time scales (60-90 days; Fig. 4) At these time scales the peak spectra signal to background noise ratio was increased from around 1.4 to 1.6.

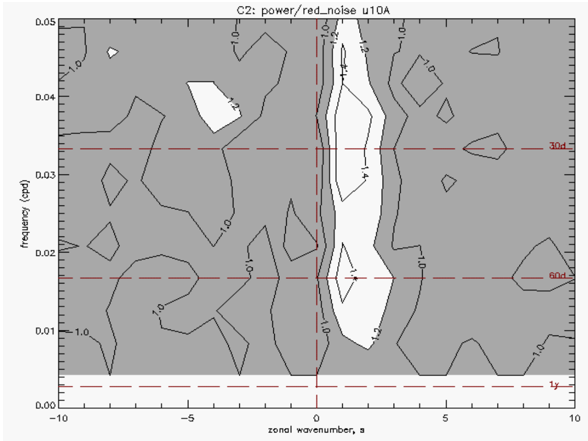

Figure 3. As in Figure 1, except for uncoupled BAM run using CAPE convection closure with AMIP monthly SST data.

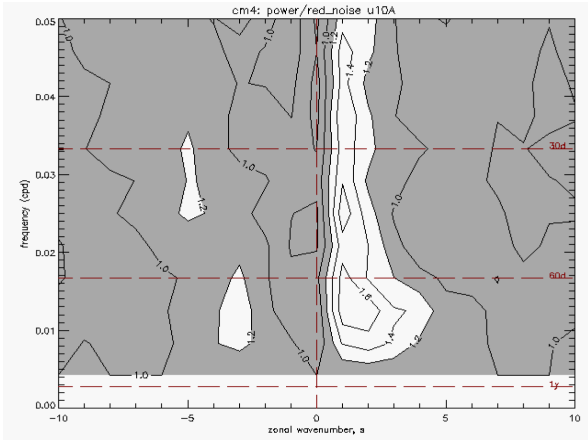

Figure 4. As in Figure 1, except for long coupled BAM run using CAPE convection closure.

Coupled model seasonal forecasts from the POAMA (Predictive Ocean Atmosphere Model for Australia – see www.bom.gov.au/bmrc/ocean/JAFOOS/POAMA) were also analysed. This is the same version of the model as used for the long coupled model integration discussed above. We calculated the power spectra by performing an FFT on each of 60 eight-month forecasts, one per season from 1987 to 2001, and averaging over all forecasts. The model anomalies were calculated relative to the model mean state and a linear drift was removed. The resulting spectral plot is shown in Fig. 5. These forecasts have a power spectrum closest to that observed. There is a spectral peak with relative values of over 1.6 between 30 and 90 days.

The results above raise the question of whether the better simulation of MJO-like activity in coupled model seasonal forecasts was due to the coupling itself, or due to different mean states of the model integrations performed. This is currently being investigated using a simple ocean slab model that produces SST anomalies such that variations in the slab layer depth can be investigated while keeping the mean state of the model constant.

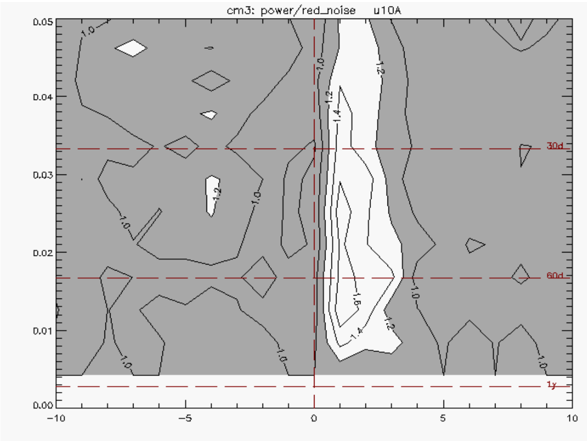

Figure 5. As in Figure 1, except for coupled BAM forecasts using CAPE convection closure.

A sample forecast form the POAMA seasonal forecasting system starting on 10th November 2002 is shown in Fig. 6. This model is initialised with both true ocean and atmospheric analyses. The plot shows that the model evolves an MJO event during November from the Indian Ocean into the Pacific Ocean. (Note: A similar event was observed in reality.) A second MJO event is seen to evolve during December/January.

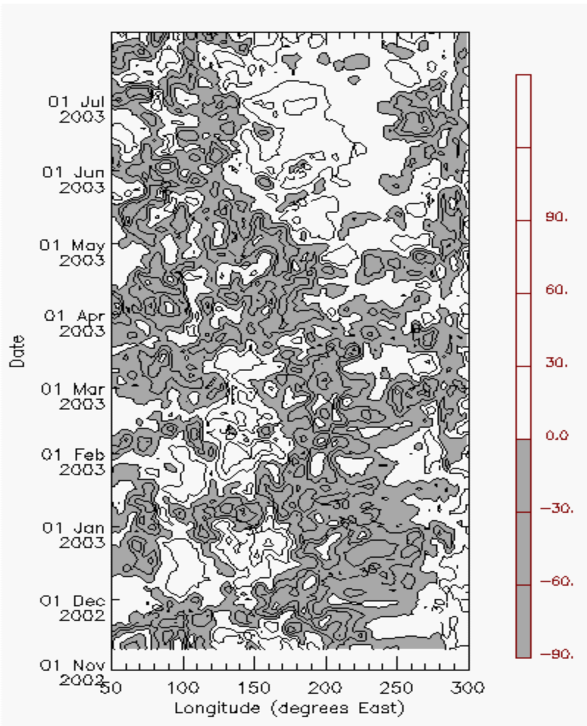

Figure 6. OLR forecast from the POAMA seasonal forecasting system starting on 10th November 2002 showing evolution of MJO events in November and December. Contour interval is 30Wm^{-2}, with grey shaded areas indicating negative OLR values.

(For further examples Hovmöller plots of all daily forecasts are available at: http://www.bom.gov.au/bmrc/ocean/JAFOOS/POAMA/exproducts/poama_v10/fc_rt_hov_in.htm)

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