**J1.1** THE IMPACT OF THE MJO – BRIDGING THE GAP BETWEEN WEATHER AND CLIMATE

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## 1. INTRODUCTION

The Madden-Julian Oscillation (MJO) is a tropical atmospheric phenomenon, associated with periods of active convection in (predominantly) the eastern hemisphere tropics. The MJO's temporal scale (events happen at intervals from 22-90 days) coincides with a gap between weather and climate forecasts. Application of knowledge based on MJO events and their evolution addresses this gap. The Real Time Multivariate MJO (RMM) Index is an MJO proxy and reveals the amplitude and location (Phases 1- 8) of MJO active convection and can be ustilised in operational, probabilistic forecasting (Wheeler and Hendon 2004, Donald et al, 2006).

Our research shows that the MJO influences weather well beyond the tropics. We analyse global rainfall data (summer/winter rainfall patterns) with respect to the RMM Index phases of the MJO. Observed MSLP frequencies are at least partially explained by the MJO and advance a causal relationship between the tropical MJO and tropical and extra-tropical rainfall and MSLP anomalies.

The MJO, a high frequency, tropical convective climate system, interacts strongly with other (lower frequency) climate phenomena, most notably El-Nino Southern Oscillation (ENSO). For instance, it is well established that MJO events are often precursors contributing to the development of El Nino events by forcing westerly wind anomalies (Hendon et al 1999, Kessler and Kleeman, 2000; Zhang and Gottschalck, 2002).

In addition, the MJO provides the pulse of the northern Australian Wet Season (NAWS), and governs the timing of dry and wet spells. Often onset as well as termination of the NAWS is associated with the active phase of the MJO. Knowledge of such wet season characteristics is critically important to reduce risks for climate sensitive industries such as agriculture. Hence, we extend our application of MJO information by exploring wet and dry spells with the northern Australian wet season under different ENSO conditions using the Australian grazing industry as a case study.

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Grazing accounts for about 85% of land use in northern Australia (north of 28ºS). Using agriculturally appropriate definitions of the NAWS (Lo et al, in preparation, Lennox et al, in preparation, Donald et al, in preparation) we provide probabilistic forecasts of onset, termination and duration of the NAWS. However it is the ratio of cloud free to rain days and total rainfall that determines seasonal fodder production. A preliminary investigation indicates that MJO/ENSO information, once tailored to the specific needs of decision makers in the Australian pastoral industry, would significantly reduce climate related risks.

Decisions that could be improved through the use of such a climate information range (high to low frequency) include: marketing of stock (eg forward selling) and work scheduling (high frequency decisions made at the intraseasonal time scale); to labour market decisions (hiring of staff, etc) and appropriate stocking rates (lower frequency decisions made seasonally to annually),

## 2. **METHODS**

Donald et al. (2006) applied the RMM Index, which serves as a proxy for the MJO (Wheeler and Hendon, 2004) to quantify MJO impacts on 33 years of daily rainfall (1974-2006; Fig. 1) and mean sea level pressure (MSLP, Fig. 2) (NCEP-NCAR reanalysis Kistler et al , 2000).

Rainfall impacts are calculated by quantifying the maximum vertical distance between the unconditional cumulative distribution function (CDF) for each RMM phase (1-8) and the conditional CDF of all RMM phases. The direction (sign) of the vertical distance indicates a positive or negative anomaly for that RMM phase at each rainfall station.

The observed aggregated standardised MSLP anomalies are calculated, and stochastically generated null distributions of such anomalies are constructed by sampling from a synthetic time series represented by Markov Chain Models (MCM; 2000 runs) that maintain the observed frequency of phase transition. P-values associated with the observed MSLP anomaly are derived from the MCM null distribution (Fig 3).

We determine NAWs onset, termination and duration for a series of biologically relevant thresholds (Lo, in preparation) using a gridded dataset (Mills et al, 1997) of daily rainfall values for 57 years (from 1 August 1948 to 31 July 2005). In order to calculate a NAWS duration both onset and termination thresholds must be met. The NAWS dry spells are defined as short (7-20 days) and long (≥21 days) breaks with 0mm rainfall accumulation. The timing of these dry spells is categorised by RMM Phase.

## 3. **RESULTS**

The results are divided into Austral Summer (1 November - 30 April) and Austral Winter (1 May – 31 October. The low p-values (Fig. 3) derived from the MCM runs provide strong evidence of causal relationship between the passage of the MJO and the demonstrated MSLP patterns. Figure 1 shows patterns of enhanced and suppressed rainfall with respect to the RMM Phase of the MJO. Figure 2 illustrates negative anomalies in standardised MSLP. Negative (positive) - low (high) pressure anomalies correlate with identified areas of enhanced (suppressed) rainfall shown in Figure 1. As expected low pressure MSLP anomalies correspond with rainfall, and with the eastward progression of the MJO.

Figure 1 Global enhanced and suppressed Austral summer rainfall patterns by RMM Phases 1-8 (a-h) (Austral Winter rainfall at http://www.apsru.gov.au/mjo/)

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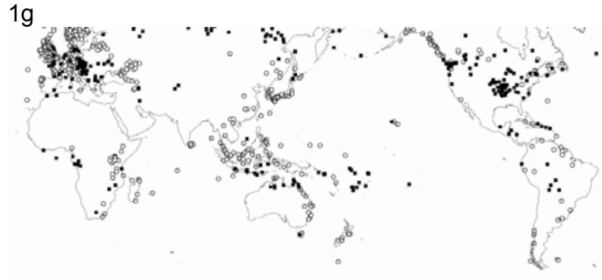

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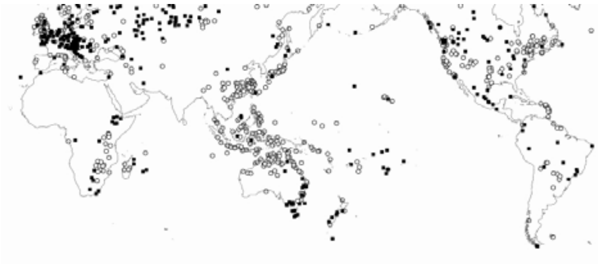

Figure 2 Austral summer low pressure (negative) anomalies in standardised MSLP by RMM Phases 1-8 (a-h) (Austral Winter at http://www.apsru.gov.au/mjo/).

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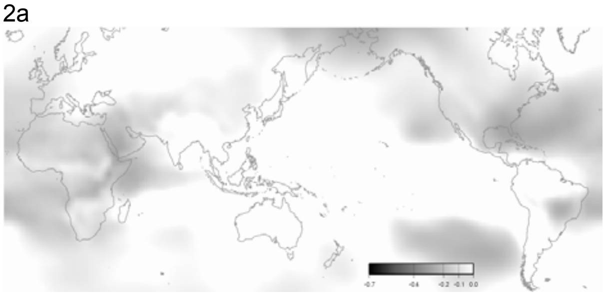

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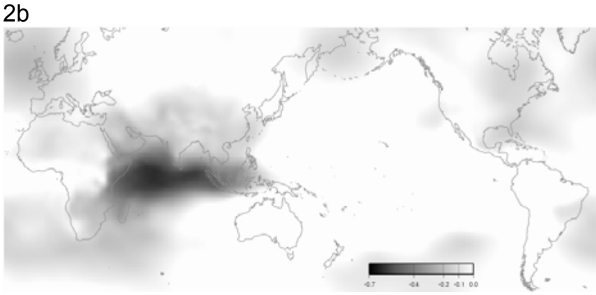

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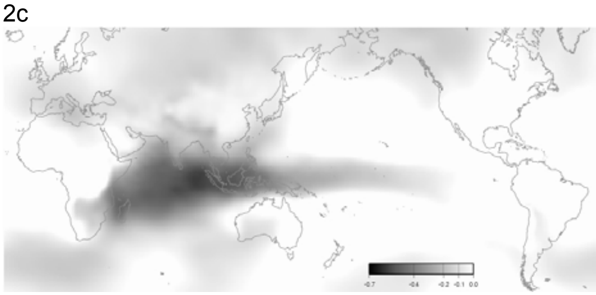

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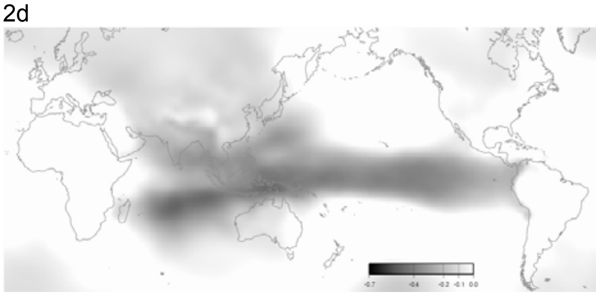

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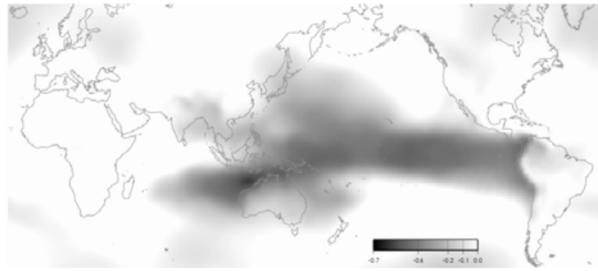

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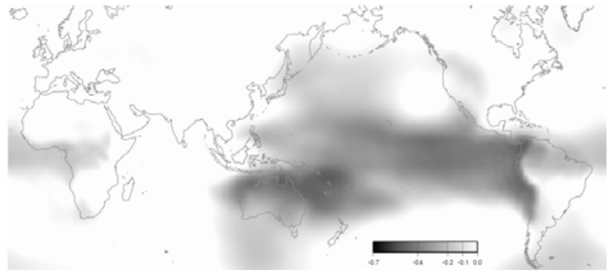

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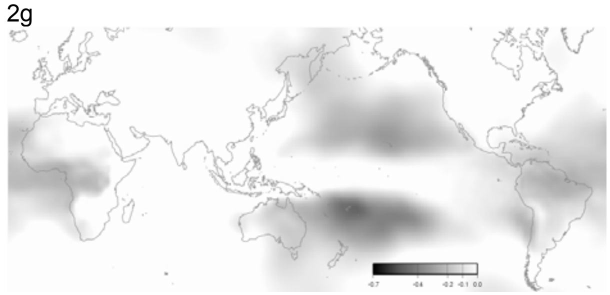

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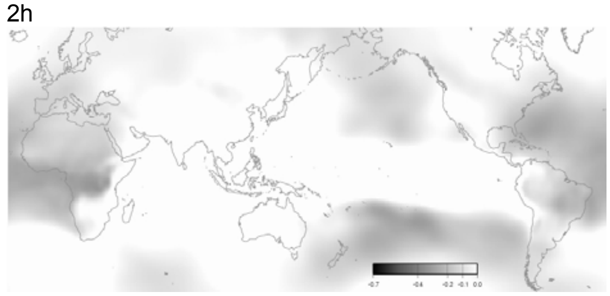

Figure 3 Austral summer null distributions of aggregated MSLP anomalies generated using a first order MCM for RMM phases 1-8 (a-h) (Austral Winter at http://www.apsru.gov.au/mjo/).

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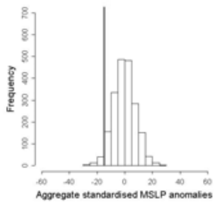


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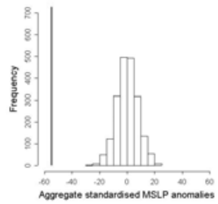


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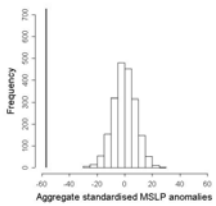


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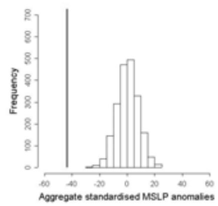


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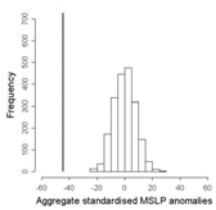


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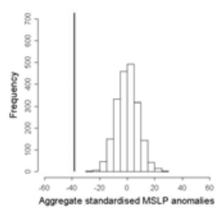


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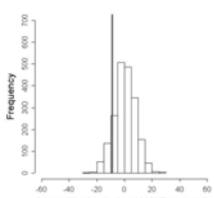


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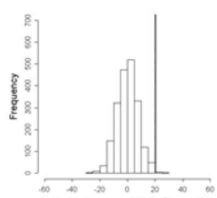


Donald et al. (2006) showed that the MJO acts like a ‘pulse’ for the NAWS by providing quasi-regular burst of convective activity interspersed by dry spells. To better understand the role of the MJO as a driver of sub-seasonal variability, the analysis investigates the timing of dry spells. Forecasting dry spells potentially improves areas of risk management like resource allocation. Armed with the knowledge of an upcoming long dry spell, managers might purchase sufficient supplements (phosphorus licks) and timetable staff and vehicles to deploy them.

We can define the probability of short or long dry spells at location, using the RMM Phase. The RMM Phase of the MJO can be forecast up to 20 days in advance (Wheeler and Hendon, 2004), the likelihood of upcoming dry spells can be assessed. For example, at Palmerville (16.00ºS, 144.08º E) (Figure 4) managers might plan around the high probability of a dry spell (0mm accumulation of rainfall of equal to or more than 7 days) starting from the occurrence of RMM Phase 3.

Figure 4 Probability of being in a dry spell (≥ 7 days 0 mm rain/day) for each RMM Phase 1-8 during a NAWS

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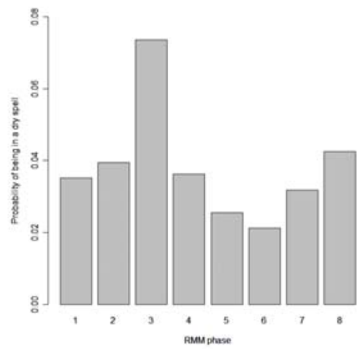


## 4. **DISCUSSION and CONCLUSIONS**

Global weather patterns well beyond the tropics are influenced by the MJO via teleconnections. We have quantified the impact of the MJO, however of the exact nature of these teleconnections is yet to be determined. Extra-tropical links with the MJO are well established (Chen and Murakami, 1988; Goswami et al, 2003; Bond and Vecchi, 2003; Barlow et al 2006), and this analysis, similar to Donald et al (2006), illustrates the global scale of these impacts, with respect to the timing and movement of the MJO, at least in the eastern hemisphere and possibly beyond. The analysis represents a valuable tactical tool applicable to operational climate risk management in many (rural) industries.

Many of the strategic and tactical decisions for agricultural climate risk management are made at the temporal scale of MJO impact. For example, the cotton planting window in southern Queensland is quite narrow - early October to mid-November, and preferentially late October (Salmond, 2006), and starting soil moisture is an important determinant. A ‘no regret’ approach can be adopted where ground preparations are finalised with the approach of an Austral summer Phase 4 MJO event. If that passage of the MJO does not result in (sufficient) rain, then irrigated water can be applied. In the long term, this reduces reliance on stored water, reducing cost and spreads risk across two complementary strategies.

Better understanding and forecasts of intra-seasonal weather/climate variability will improve weather/climate risk management for sensitive industries. Here we provide wet season forecasts based in the MJO and ENSO signals (Southern Oscillation Index (SOI) and/or Sea Surface Temperatures (SST)) Using a higher frequency weather /climate phenomena such as, the MJO, additional knowledge of the likely intensity and temporal distribution of rainfall within a wet season. In addition it allows probabilistic forecasting of onset, decline and duration based on lower frequency, larger scale climate episodes such as ENSO and SST.

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**References**

Barlow, M., Wheeler, M., Lyon, B. and Cullen H. 2006: Modulation of daily precipitation over southwest Asia by the Madden-Julian Oscillation. Mon Weather Rev, 133, 3579-3594

Bond Vecchi 2003: The influence of the Madden-Julian Oscillation on Precipitation in Oregon and Washington. Weather and Forecasting, 18, 600-613.

Chen, T.C. and Murakami, M. 1988: The 30-50 day variation of convective activity over the Western Pacific Ocean with emphasis on the northwestern region 116, 892-906

Donald, A., Meinke, H., Power, B., Wheeler, M. C., Maia A de H. N , Stone, R. C., Ribbe J. and White N. 2006: Near-Global Impact of the Madden-Julian Oscillation on Rainfall, Geophys. Res. Lett., 33, L09704

Donald, A., Lennox, S.M., Meinke, H., White, N. A., Wheeler, M.C., Lo, F. in preparation: MJO and ENSO interactions and applications for Australian grazing systems management.

Goswami, B.N., Ajayamohan, P.K., Xavier, P.K. and Sengupta, D. 2003: Clustering of synoptic activity by Indian summer monsoon intraseasonal oscillations Geophys. Res. Lett. 30(8)1431.

Hendon, H. H. Zhang, C., and Glick, J. 1999: Interannual variation of the Madden-Julian oscillation during austral summer. Journal of Climate, 12, 2538-2550.

Kessler, W.S. and Kleeman, R. 2000: Rectification of the Madden-Julian oscillation into the ENSO cycle. Journal of Climate, 13, 3560-3575.

Kistler, R. et al 2000: The NCEP-NCAR 50-year reanalysis: Monthly means CD ROM and documentation, Bull. Am. Meteorol. Soc., 82. 247-268

Lennox, S.M, Donald, A., Meinke, H., White, N. A., Wheeler, M.C., Lo, F. in preparation: The Northern Australian Wet Season Rainfall: Onset, Decline and Duration and its relationship with ENSO.

Lo, F., Wheeler, M.C. and Meinke, H. In preparation: Probabilistic Forecasts of the Onset of the North Australian Wet Season

Mills, G. A., G. Weymouth, D. Jones, E.E. Ebert, M. Manton, J. Lorkin, J. Kelly, 1997: A national objective daily rainfall analysis system. BMRC Techniques Development Report No. 1, Bureau of Meteorology, Melbourne, Australia, 30 pp.

Salmond, G. January 2006: Cotton Planting http://www2.dpi.qld.gov.au/fieldcrops/8306.html

Wheeler, M. and Hendon, H. H. 2004: An All-Season Real-time Multivariate MJO Index: Development of the index for monitoring and prediction in Australia. Mon. Weather Rev., 132, 1917-1932

Zhang, C. and Gottschalck, J. 2002: SST Anomalies of ENSO and the Madden Julian Oscillation in the Equatorial Pacific. Journal of Climate, 15, 2965-2997.