Forecasting with the Madden-Julian Oscillation and the applications for risk management

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Abstract

The Madden-Julian Oscillation (MJO) is a tropical atmospheric phenomenon first recognised in the early 1970s. The MJO, also commonly known as the 40-day wave, develops over the Indian Ocean and then travels east across the tropics at 5-10 m/s. With a timescale ranging from 30 to 60 days, the MJO has a frequency of 6-12 events per year. In its active stage, the MJO is associated with increased convective activity. Trailing the active centre is region of suppressed convective activity and mean surface level westerly winds. Statistical analysis shows that the MJO can influence rainfall in Australia and elsewhere in the world, beyond the tropics. As MJO forecasting tends to bridge the gap between synoptic and seasonal forecasting, the potential for on-farm risk management is significant.

Media summary

The Madden-Julian Oscillation can be used for medium-term forecasts of rainfall. These forecasts may improve tactical risk management in agriculture.

Key words

Medium-term rainfall forecasting, MJO, 40-day wave.

The passage of the MJO and its influence on the geographical extent and timing of rainfall.

The Real-Time Multivariate MJO (RMM) index (Wheeler and Hendon, 2004) was used in a statistical analysis of the correlation between the passage of the MJO and rainfall. The RMM index produces a real-time signal describing the MJO, and this can be applied (as a phase space diagram) to divide the evolution and subsequent eastward movement of the MJO into 8 phases, each corresponding with the geographical location of the active phase of the MJO (Figure 1).

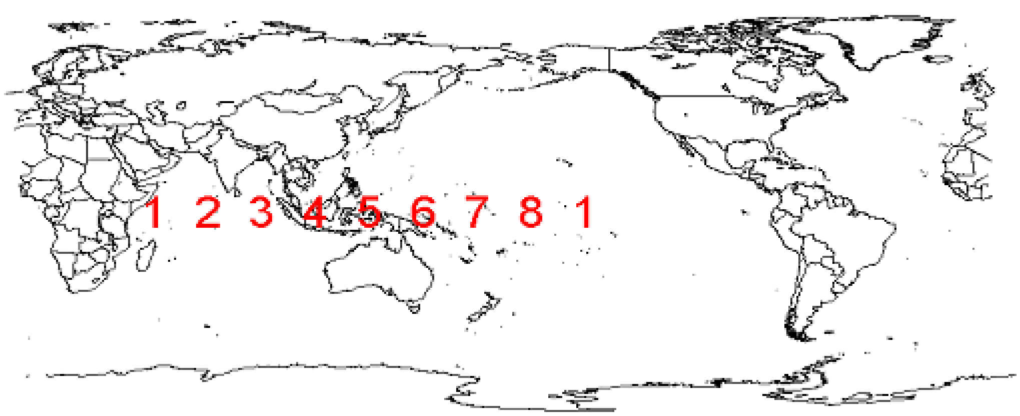

Figure 1: Approximate locations of the MJO centre of convection RMM Index phases 1-8. Phase1 includes signals both from the initiation of an MJO event in the western Indian Ocean basin and

the breakdown of MJO events in the mid-Pacific Ocean. During phases 2 through 8 the MJO travels east at 4-10 days/phase.

The RMM Index phases may be used more or less synonymously with the position of the active centre of convection associated with the MJO. We used statistical distributions (Kolmonogrov-Smirnov) to compare patch point rainfall data (ppd) (Jeffrey et al. 2001) and the RMM Index. Areas of suppressed (significantly below mean at $p < .05$) and enhanced (significantly above mean at $p= .05$) rainfall, dependant on RMM Index phase, were identified (Figure 2). During Phase 1 when the MJO is breaking down in the mid-Pacific Ocean, and/or regenerating in the Indian Ocean, distinct regions of suppression in the north and east and enhancement in the south and west can be observed, and this decayed into some suppression of rainfall over northern and eastern Australia during Phase 2.

As the MJO approaches northern Australia during Phase 3, the east coast of Australia experiences some enhancement of rainfall, whereas the south and west experience some suppression. In Phase 4, rainfall throughout the north and east of the Australian continent is statistically correlated with the MJO. During Phase 5, as the MJO continues east over the Maritime Continent and the Coral Sea, the impact on rainfall has progressed southward, and is apparent across southern and western Australia. In Phase 6, the pattern of enhanced rainfall has contracted into 2 distinct regions, one through the north, and the other along the south-eastern coast. By Phase 7, the area of enhanced rainfall covers much of the Northern Territory, northern Queensland and the extreme north of Western Australia, while Southern Australia experiences intermittent suppression. As the MJO moves into the mid-Pacific during Phase 8 the rainfall impact signal weakens, but with some areas of suppressed rainfall along the Queensland coast.

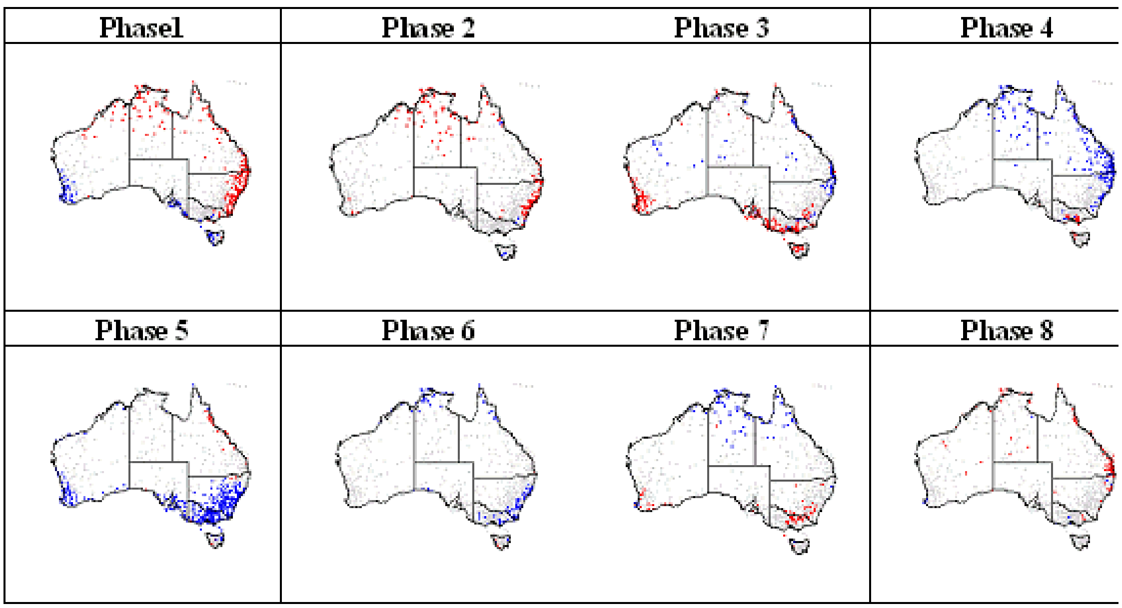

Figure 2 Australian rainfall enhancement and suppression patterns, based on the correlation of rainfall data and the RMM Index phases of the MJO.

The same statistical processes were applied to world rainfall data (Figure 3) from NOAA/National Climatic Data Centre, Asheville, North Carolina USA. The results for this data set were comparable and consistent, but not the same as for Australia. The differences may be accounted for by differences in the number of rainfall stations and the quality of the data. As the MJO moves east, accompanying patterns in suppression and enhancement of rainfall have been identified. Many of these patterns are consistent with previous findings on the geographical extent and nature of 30-60 -day variations in climate data (Chen and Murakmai, 1988, Goswami and Ajayamohan, 2001, Bond and Vecchi, 2003, Barlow et al., in publication).

While the precise teleconnections between MJO events and Australian rainfall have not been established, mean sea level pressure (mslp) anomalies reveal broad-scale MJO influences on synoptic patterns. The mslp was selected as a simple measure of the synoptics, and anomalies determined for each RMM Index phase. Anomalies were established by calculating the mean of each phase, and subtracting the mean of every other phase. The anomalies revealed the synoptic patterns associated with the MJO that result in the rainfall patterns observed in the statistical analyses of Australian and world rainfall data. The mslp data was divided simply into Lows (<1000hPa) or Highs (>1020hPa). When correlations indicate rainfall will be suppressed, there is an accompanying high pressure anomaly in the region or off-shore (dry) winds resulting from the circulation about the anomalous pressure cell. When regions receive enhanced rainfall with respect to the RMM Index phase, low pressure anomalies or on-shore winds can be identified.

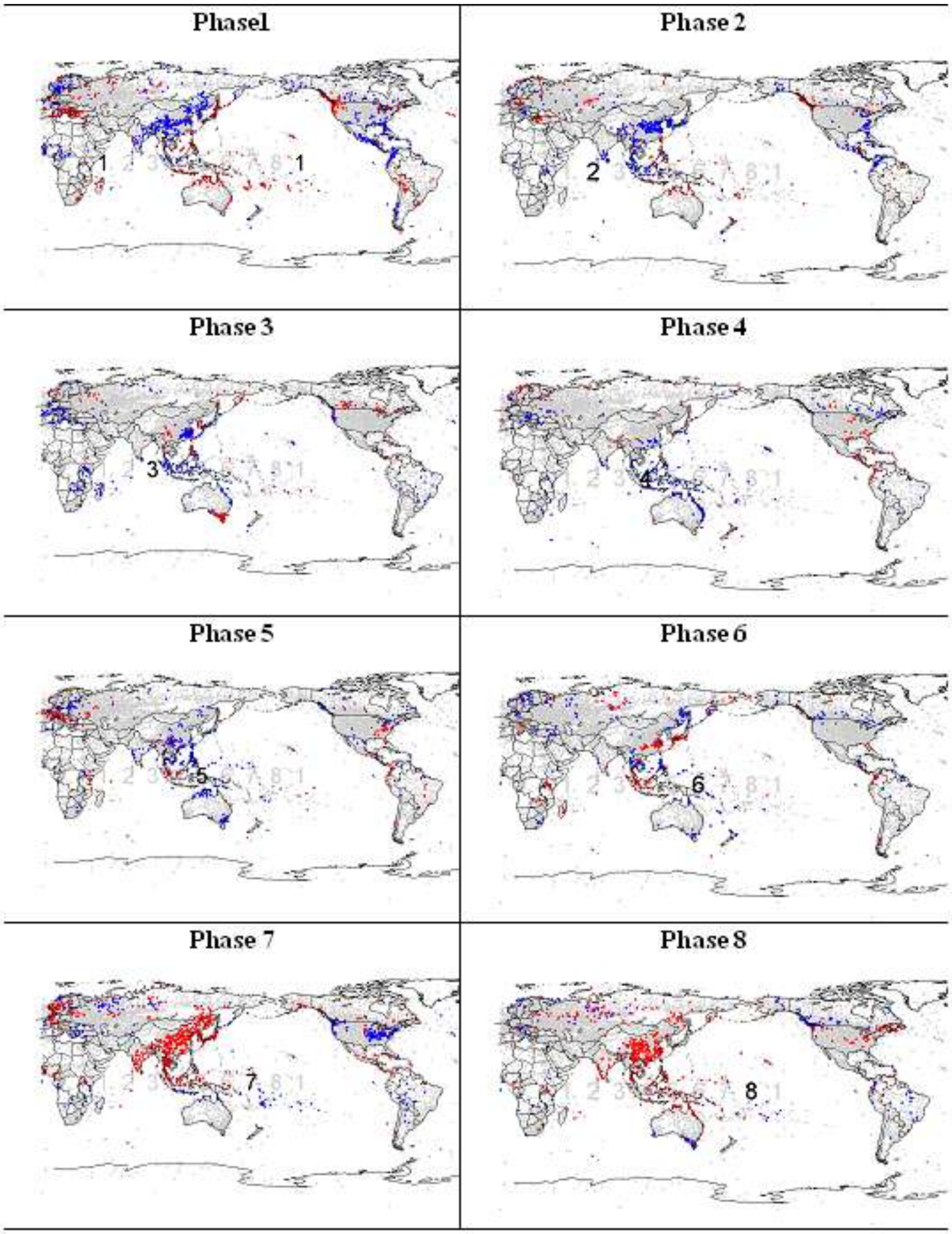

Figure 3 World-wide patterns of enhancement and suppression of rainfall, based on the correlation of rainfall data and the RMM Index phases of the MJO.

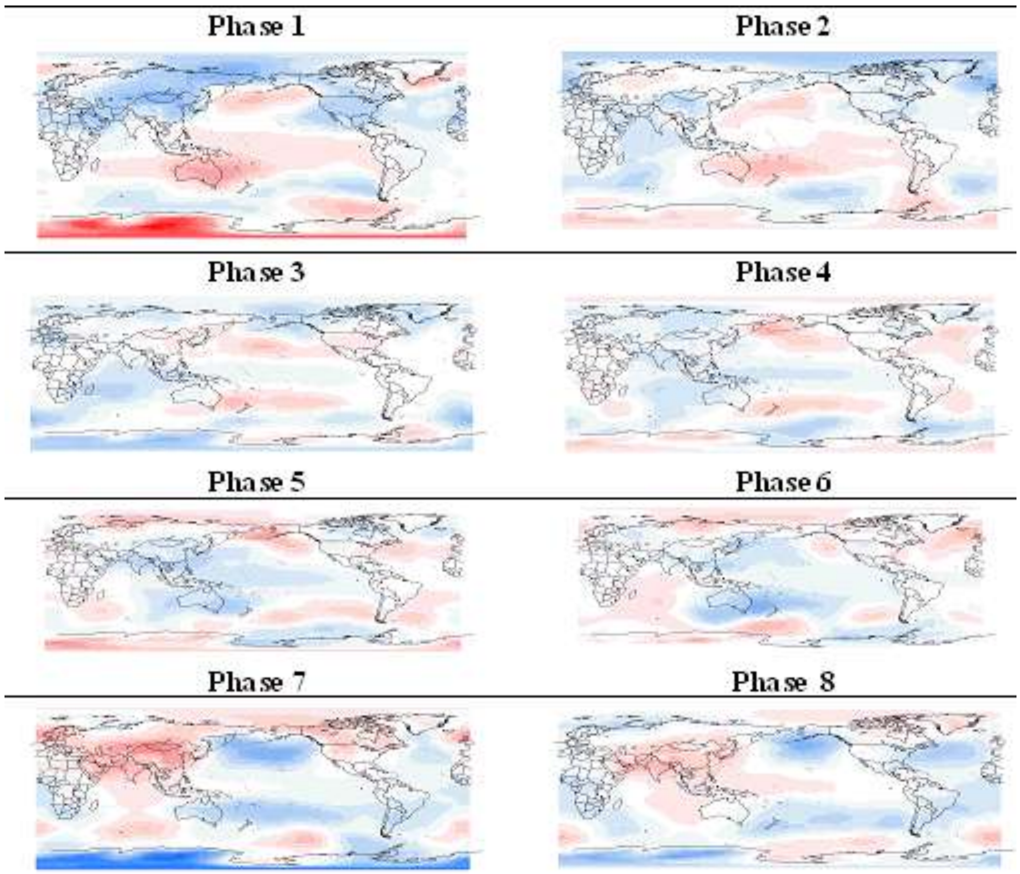

Figure 4. Mean sea level pressure anomalies with respect to the RMM Index phase of the MJO.

Risk management applications

Intra-seasonal climate variability impacts heavily on the agricultural sector. Current forecasts supplied to rural industries are dominated by seasonal forecasts even though many rain-related risk decisions are made at higher frequencies. Intra-seasonal forecasting (short-term climate forecasting or long-term weather forecasting) has the potential to modify strategies that reduce vulnerability for individuals and businesses. How often have we heard of high quality wheat, sorghum, peanut or cotton crops destroyed or downgraded due to rain just before harvest? The economic losses and environmental impacts of these events are substantial and affect all of primary production. Based on the RMM Index, the passage of the MJO can be predicted, allowing patterns of suppression and/or enhancement of rainfall to be forecast beyond the synoptic scale. Tactical risk management can be improved through the application of an MJO-based forecasting capability that will allow Australian producers to assess timing and likelihood of rainfall events and temperature fluctuations at time-scales of up to six weeks. This has the potential to improve the economic return for both the individuals and the rural companies (e.g. grain traders, sugar mills, cotton gins). Improved intra-seasonal forecasting may also allow the rural sector to better consider the environmental aspects of their operations. Such improved risk management practices contribute to increasing the self-reliance abilities of rural industries.

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