MADDEN-JULIAN OSCILLATION OVER MALAY PENINSULA

Yudha S. Djamil[1], Koh Tieh-Yong[1,2,3], Janaki Chandimala[2], Teo Chee-Kiat[3]
[1]Earth Observatory of Singapore, Nanyang Technological University, [2]School of Physical and Mathematical Sciences, Nanyang Technological University [3]Temasek Laboratories, Nanyang Technological University

1. INTRODUCTION

Madden-Julian Oscillation (MJO) as the dominant weather pattern in intraseasonal time scale in the equatorial tropics (Maden & Julian 1972) was shown to be weakened when it propagates over the western Maritime Continent (Zhang & Hendon 1997, Kemball-Cook & Weare 2001).

The topography in the western Maritime Continent (Northern Sumatra, Malay Peninsula and Borneo) was suggested to modify the detailed structure during the eastward propagation of MJO (Wu & Hsu 2009). Such modification would imply inhomogeneous spatial weather pattern at smaller scales during active MJO events (Kiladis et al 2005).

Therefore, detailed study of in-situ observational records of MJO manifestation at small scales such as represented by Malay Peninsula may help us understand MJO behavior over the western Maritime Continent.

2. LOCAL MULTIVARIATE MJO (LMM) INDEX

Weather signals in the intraseasonal time scale were extracted using Extended Empirical Orthogonal Function (EEOF) method from climatology-removed bandpass-filtered daily radiosonde observations at five locations in Malay Peninsula for the period 1981-2000 (Fig.1.A). The radiosonde-derived parameters are : zonal (U) and meridional (V) wind at 850 and 250 mb; temperature (T) at 500 mb; specific humidty (SH) at 850 and 500 mb; temperature difference (dT) between 250 and 850 mb; wind shear between 500 and 850 mb.

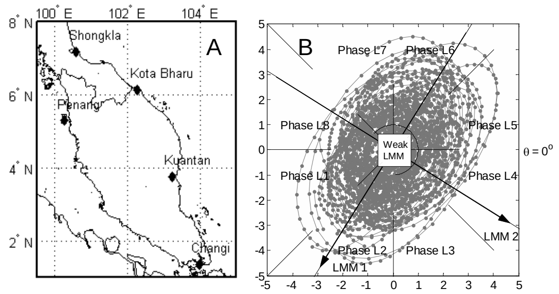

Fig.1. Panel A shows the location of radiosonde stations in Malay Peninsula used in this study. Panel B shows the phase diagram of the LMM1 & 2.

* *Corresponding author address:* Koh Tieh-Yong, Nanyang Technological University, Singapore; e-mail : KohTY@ntu.edu.sg.

Using a time window of 17 days, the first two EEOFs are retained to reconstruct the intraseasonal signal in the radiosonde data which is then subjected to the conventional Empirical Orthogonal Function (EOF) analysis. The principal component scores (PCs) of the first two EOFs thus obtained have maximal correlation of ~0.6 with projections of the Real-time Multivariate MJO index (RMM, Wheeler & Hendon, 2004) in phase directions that are orthogonal. Thus, the two PCs together can act as a vector MJO index and are labeled henceforth as Local Multivariate MJO (LMM) index 1 and 2. The phases of LMM (Fig.1.B) are defined such as to align with the phases of RMM in Fig. 7 of Wheeler and Hendon (2004).

Further confirmation of MJO signature captured by the LMM indices can be seen from the composite of Outgoing Longwave Radiation (OLR) in Fig.2, which is comparable with the composite made from RMM-phases (see Fig. 8 of Wheeler & Hendon, 2004).

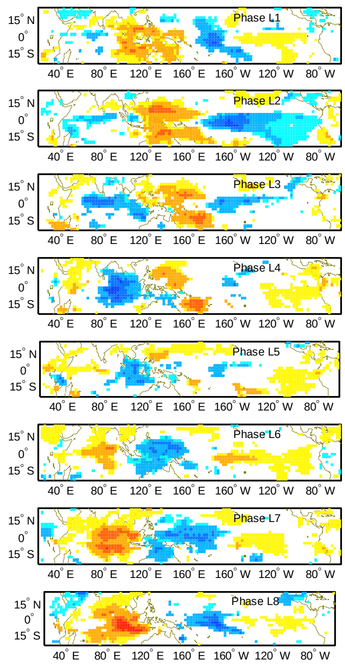

Fig.2. Composite of OLR anomaly (W/m^2) in the eight phases of LMM in December-January-February (1981-2000) where the shades denote statistically significant anomalies at 95% confidence level.

3. ATMOSPHERIC STRUCTURE OF LMM

The phase evolution of the atmospheric structure associated with MJO over Malay Peninsula can be seen from the direction-vectors on LMM's phase diagram and from composites of other parameters not included in LMM's eigenvectors. The latter are: geo-potential height (H); lifting condensation level (LCL); convective inhibition (CINS); surface pressure (SFP); OLR and gauge rainfall. The phase relation of these parameters is shown in LMM phase-space in Fig.3.

Fig.3 shows a baroclinic structure (U, H & SFP) that is consistent with the previous reports (Madden & Juilan 1972, Kemball-Cook & Weare 2001). The westward phase tilt with height in SH is well-captured by LMM. However, the temperature profile shows a unique boomerang feature that is also noted by Kiladis et al. (2005) for Medan station in Sumatra. This is likely a local feature of the MJO in western Maritime Continent.

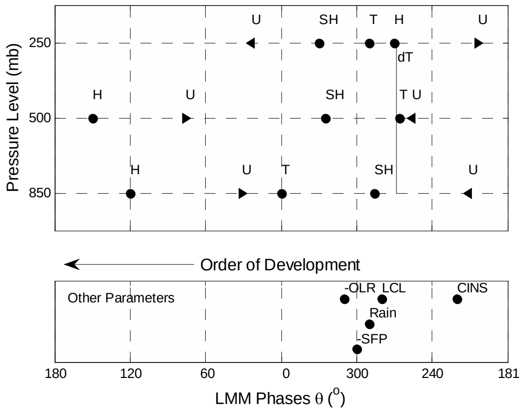

Fig.3. Phase evolution of the vertical structure of the atmosphere over Malay Peninsula in a complete MJO cycle. The circular markers (•) denote the maxima of T, H, SH, Rainfall, LCL (in mb) and CINS, and the minima of OLR and SFP. dT represented by a vertical line from 850mb to 250mb denote T250 minus T850. The direction of the zonal wind (U) extrema is given by the direction of the triangular marker.

The vertical profile of temperature at Fig.3 shows the atmosphere is most stable (marked by the maximum dT anomaly) just before the peak in MJO convection indicated by the highest rainfall followed by the lowest OLR. The near-coincidence of the highest LCL (in mb) and the greatest 850mb-humidity when the atmosphere begins to destabilize (i.e. dT decreasing from the maximum) seems important for achieving the peak in MJO convection. The maximum convective inhibition occurs before the atmosphere is most stable.

4. MJO INDICES AND LOCAL RAINFALL

We carried out lag-correlation between the total rainfall on the five Malay Peninsula stations and the projections of RMM and LMM indices projected along all phase directions to find the highest correlation for each lag. The time series were five-day accumulations for rainfall and pentad means for MJO indices.

Fig. 4 shows that the LMM index has non-zero correlation with the local rainfall 3 to 4 pentads ahead of time but RMM index does not (at the 95% confidence level). Such result suggests the merit of using LMM over RMM in investigating the relationship to local rainfall. The reason is clearly based on the local and in-situ nature of the radiosonde dataset used to derive the LMM index. Note that rainfall is excluded in this dataset to ensure the independent validity of this result.

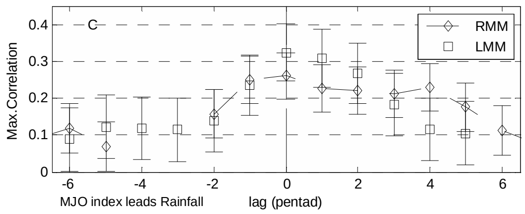

Fig.4. Maximum correlation of the MJO indices with rainfall on each time lag. The uncertainty limits are obtained at 95% confidence level. Only non-zero correlation scores (at 95% confidence level) are plotted.

5. CONCLUSION

The definition of a vector Local Multivariate MJO (LMM) index based on in-situ radiosonde observations allows a closer relation to be established with rainfall in Malay Peninsula that manifests itself even 3 to 4 pentads ahead. The RMM index does not manifest this relation. But more importantly, the structure of the MJO identified by LMM has a temperature profile that is perhaps unique to the western Maritime Continent. The phase relation between circulation (U, H, SPR, SH) and convective parameters (CINS, LCL, dT, OLR, rain) in Malay Peninsula warrants further investigation.

6. REFERENCES

Kemball-Cook, S. R., and Weare, B. C., 2001: The Onset of Convection in the Madden–Julian Oscillation. *J. Climate*, **14**, 780–793.

Kiladis, G. N., Straub, K. H., and Haertel, P. T., 2005: Zonal and Vertical Structure of the Madden–Julian Oscillation. *J. Atmos. Sci.*, **62**, 2790–2809.

Madden, R. A., and Julian, P. R., 1972: Description of Global-Scale Circulation Cells in the Tropics with a 40–50 Day Period. *J. Atmos. Sci*., **29**, 1109–1123.

Wheeler, M. C., and Hendon, H. H., 2004: An All-Season Real Time Multivariate MJO index: Development of an Index for Monitoring and Prediction, *Mon. Wea. Rev.,* **32**, 1917-1932.

Wu, C. -H., and Hsu, H. -H., 2009: Topographic Influence on the MJO in the Maritime Continent. *J. Climate*, **22**, 5433–5448.

Zhang, C., and Hendon, H. H., 1997: Propagating and Standing Components of the Intraseasonal Oscillation in Tropical Convection. *J. Atmos. Sci.*, **54**, 741–752.