Science and Technology Infusion Climate Bulletin
NOAA's National Weather Service
41st NOAA Annual Climate Diagnostics and Prediction Workshop
Orono, ME, 3-6 October 2016

An Analysis of the MJO Influence on the Rainfall in Subtropical Coastal Areas of East Asia

Yun-Lan Chen[1,2], Chung-Hsiung Sui[2], Chih-Pei Chang[2] and Wanqiu Wang[3]
[1]*Central Weather Bureau, Taiwan*
[2]*National Taiwan University, Taiwan*
[3]*Climate Prediction Center, NOAA/NWS/NCEP, College Park, Maryland*

1. Introduction

The Madden-Julian Oscillation (MJO) has been found to affect weather and climate over the globe at different time scales, including the tropical cycle, Indian and Australian summer monsoons, North and South American climate, Arctic and North Atlantic Oscillations, and El Nino Southern Oscillation. In this study, we analyze its impact on the rainfall in the subtropical coastal areas of East Asia during northern winter and spring seasons. While previous studies have shown that rainfall over this area is affected by the MJO, locations of the tropical convection that is associated with this influence are not certain. Further, physical processes that link the MJO and the rainfall remain unclear.

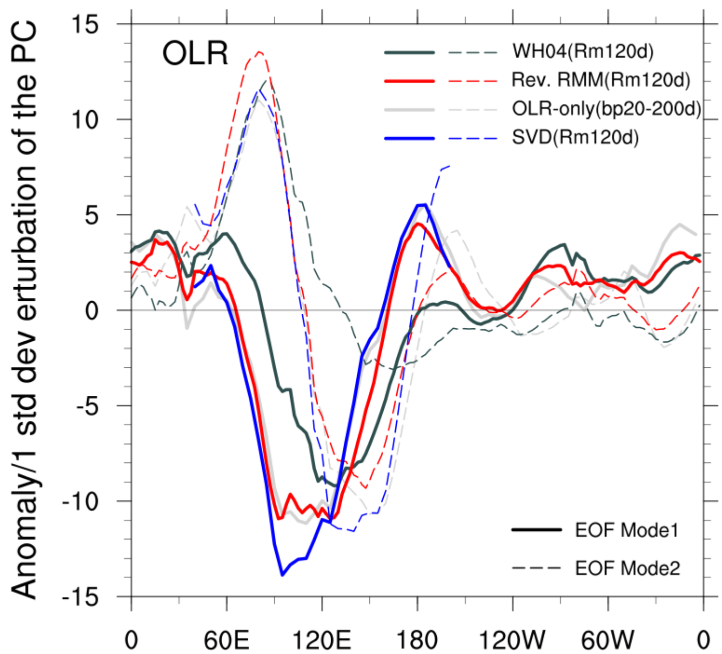

Fig 1 The leading two EOF modes for OLR variable in 4 MJO indices. The comparison shows the revised RMM index and SVD-based index are similar with the OLR-only index, which has two centers of anomaly, while the RMM index more depicts just one center.

Our analysis aims to address the following questions: (1) What is the temporal relationship between evolution of the MJO and the rainfall in the East Asia (EA) subtropical coastal areas; (2) Does such a relationship depend on the use of different MJO indices, and (3) What are the

Table 1 MJO indices used in this study: (1) WH04 RMM index, (2) Revised RMM index, (3) OLR-only index, (4) SVD-based index

	Ref /related Paper	Season	parameter	Data filter	EOF matrix	Domain longitude	Domain latitude
WH04	W&H_RMM (2004)	All-season	OLR+U8U2	Remove 120d_runningM	C-EOF/ Cov scaled	Global Tropics	1D Ave(15S-15N)
Rev. RMM	P. Liu et al. (2016)	All-season	OLR+U8U2	Remove 120d_runningM	C-EOF/ Rev. scaled	Global Tropics	1D Ave(15S-15N)
OLR-only	Matthews (2008)	DJFM	OLR-only	20-200-day filtered	EOF / Cov	Global Tropics	2D (30S-30N)
SVD	Chang et al. (2005)	DJFM	OLR+U8U2	Remove 120d_runningM	SVD/ Cov scaled	IO – MC -WNP	2D (30S-30N)

Correspondence to: Yun-Lan Chen, Central Weather Bureau, Taipei, Taiwan; E-mail: yunlan.chen@cwb.gov.tw

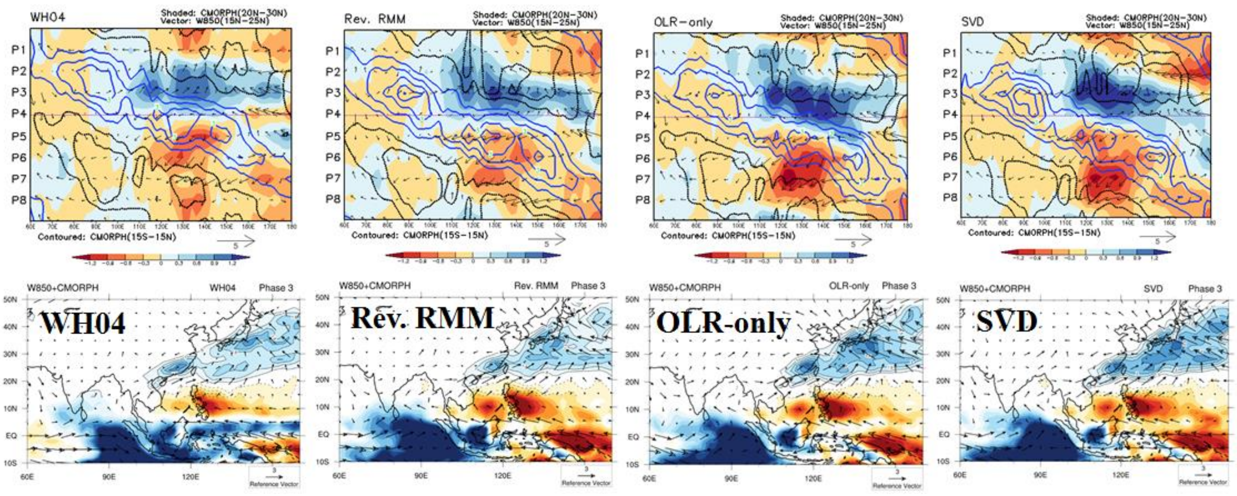

Fig 2 Phase-longitude composite diagram (upper), and 2D composite map for phase3 (lower) for 4 MJO indices, from left to right : (1) WH04 RMM index (2) Revised RMM index (3) OLR-only index (4) SVD-based index.

physical processes that relate the MJO and the rainfall variations and, in particular, what is the role of the convection and atmospheric circulation condition in the tropical western Pacific?

2. Data and approaches

The analysis is based on the NCEP atmospheric reanalysis, outgoing longwave radiation (HIRS OLR, 1979-2015) and satellite rainfall estimation (CPC CMORPH, 1998-2015). We composite rainfall evolution following the tropical MJO phases by 4 MJO indices (Fig. 1): (1) RMM index (Wheeler and Hendon, 2004), which has been shown more dominated by dynamics. (2) Revised RMM index (Liu *et al.* 2016), which was designed to enhance the contribution from OLR, (3) OLR-only index (Matthews 2008), a convection-centric index, (4) SVD-based index, an MJO index proposed by Chang *et al.* (2005) and redesigned in this study to emphasize regional domain and seasonal dependency (Table 1). According to the results from the composite analysis, two types of MJO events are separated to investigate the impact of the detailed spatial convection pattern and its evolution on East Asia rainfall, and the connection between tropical MJO convection and the subtropical responses.

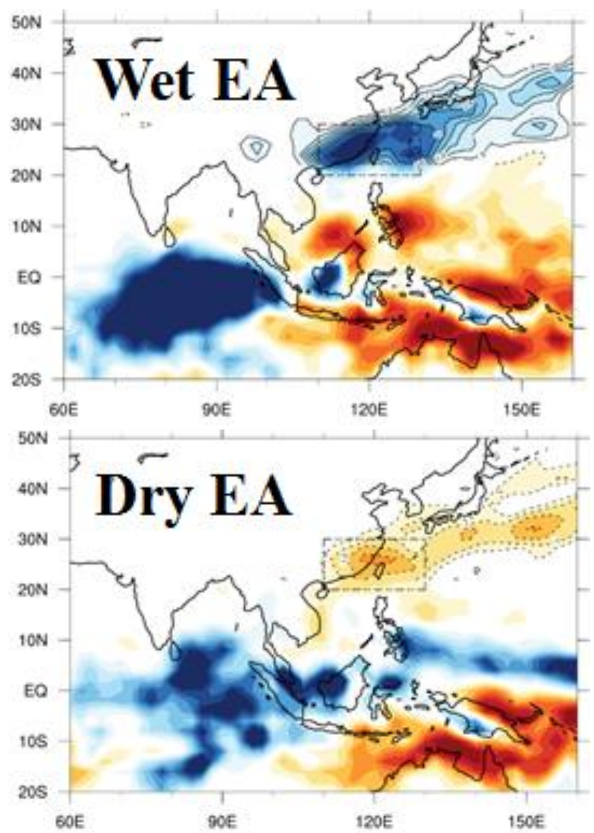

Fig 3 The CMORPH rainfall composite map for RMM MJO phases 2. (upper: the first one-third EA wet cases composite; lower: the first one-third EA dry cases composite)

3. Results

3.1 Relationship between tropical MJO and East Asian rainfall

Composite of CMORPH data show the rainfall variation in the EA subtropical coastal is modulated by MJO, consistent with previous studies (Jia *et al.* 2011, Hung 2014). All 4 MJO indices show robust wet/dry flip sign over EA during the MJO cycle. Although the main feature is similar among the 4 MJO indices, rainfall variation over subtropical EA is better captured by OLR-only index and regional SVD-based index (Fig. 2). Taking phase 3 composite value for example, the rainfall variance over subtropical EA (20°-30°N, 110°-130°E) are 1.46 and 1.54 (mm/hr)2 for WH04 and Revised RMM indices, and are 2.63, 2.93 $(mm/hr)^2$ for OLR-only and SVD-based indices. Differences in the spatial tropical convection pattern are found between the WH04 index and the other three, which are more convection-centric. The 4 indices all show clear wetness over Indian Ocean (IO) during the MJO phase 3, while only the WH04 index produces wetness over the equatorial west Pacific (WP).

Composite maps for abnormal conditions of subtropical EA rainfall are also calculated to study its connection with the tropical convection pattern. For the same MJO phase, a dry or wet pattern over EA can exist. One such an example is shown in Fig. 3 for RMM phase 2 which also show some differences in tropical area. This suggests an analysis of more detailed spatial convection pattern is needed to understand the connection between tropical convection and subtropical rainfall.

3.2 Connection between tropical convection and subtropical responses

The fact that the subtropical rainfall variance is better captured by convection-centric MJO indices suggests that detailed tropical convection patterns may be crucial in determining the impact on EA rainfall from the MJO. We separate MJO events that correspond to strong convection into 2 groups: ISO-A and ISO-B. Group ISO-A is for cases with significant dry condition over Maritime Continent (MC), and ISO-B is for the others. We use OLR-only index for the selection of MJO cases and define the day0 as the time when active convection is over IO. The phase diagram (Fig. 4) and the time evolution of the tropical convection (Fig. 5) show the ISO-A type cases correspond to successive MJO events, while ISO-B type cases belong more to primary events.

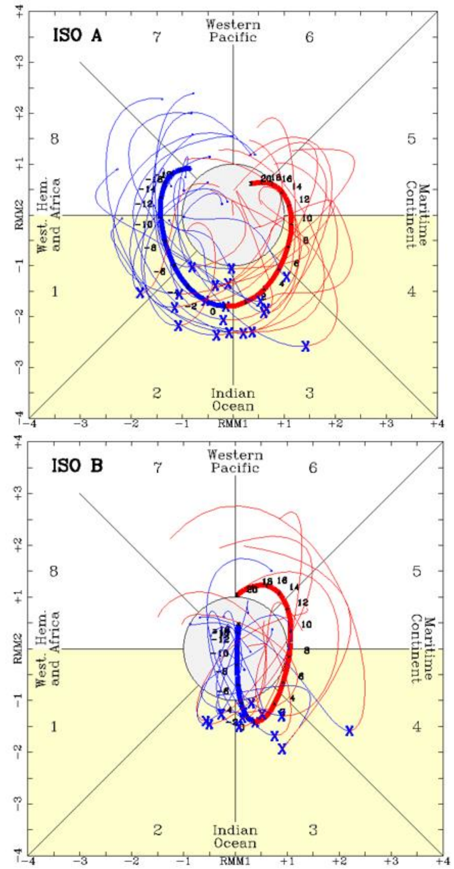

Fig 4 The MJO phase diagram for ISO-A (upper, 19 cases) and ISO-B (lower, 12 cases).

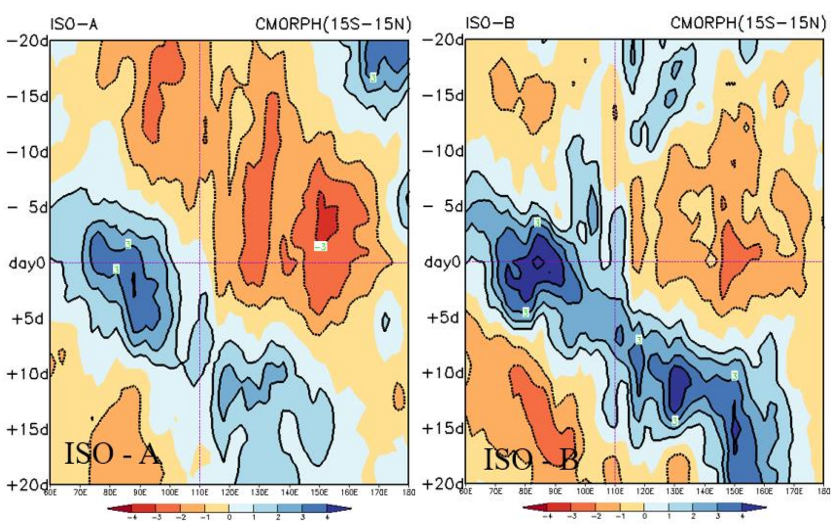

Fig 5 The propagation of tropical convection for ISO-A (left) and ISO-B (right).

Comparison of the evolution of the two MJO types shows the ISO-A type has much stronger wet response over EA than ISO-B (Fig. 6 and Fig. 7). A significant local high-level trough was established before the day0 for ISO-A in association with the evolution of the tropical convection. We speculate that this is the dynamical reason for favoring the EA wetness. Another interesting finding for ISO-A is the southward movement of the EA wetness after the day0, which is in association with the getting-stronger southwest flow near 15°-25°N (Fig. 7). It looks like the high-level trough and the southwest flow together form a long period of unstable weather and cause

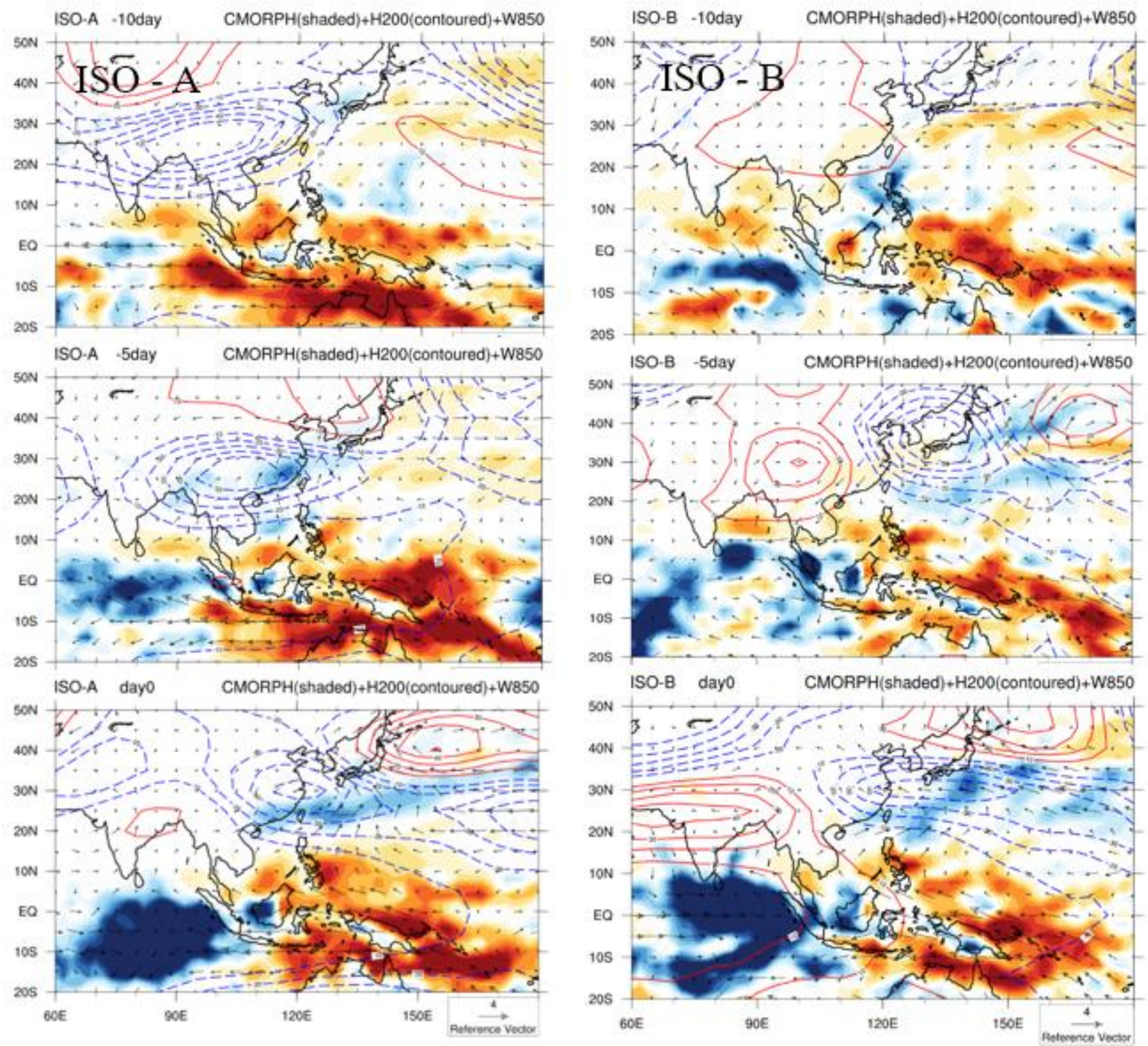

Fig 6 Evolution for ISO-A (left) and ISO-B (right): 10-day before (upper), 5-day before (middle), day 0 (lower).

rainfall over EA, and they both could be related to the MJO tropical heating and its eastward movement. From the evolution of ISO-A, the high-level trough over EA is after the eastward of cyclonic circulation anomalies, which is consistent with a response of dry phase MJO over IO-MC. The increased southwest flow is a feature frequent seen when a low-level anticyclone sits over Philippines. With a dry phase in advance, the ISO-A type tends to have a low-level anticyclone lingering Philippines area while the tropical convection over IO moves eastward into WP.

4. Summary

This study analyzes East Asia rainfall variation related to the MJO during northern winter and spring seasons. The robustness of wet/dry flip sign show EA rainfall variation is clearly modulated by MJO, suggesting that it is a source of the predictability for EA intraseasonal variations. Among the MJO indices, the convection-centric MJO index and reginal SVD MJO index are found to better capture the connection between the MJO and its subtropical rainfall responses. Our results suggest the EA rainfall response depends on the detailed spatial pattern of tropical convection. Development of a high-level trough corresponding to MC dry condition may be a key component for the EA wetness, suggesting the importance of the MC dry phase before the active convection over the IO.

References

Chang, C.-P., P. A. Harr, and H.-J. Chen, 2005: Synoptic disturbances over the equatorial South China Sea and western maritime continent during boreal winter. *Mon. Wea. Rev.*, **133**, 489–503.

Hung, Chih-Wen, Ho-Jiunn Lin, Huang-Hsiung Hsu, 2014: Madden–Julian Oscillation and the winter rainfall in Taiwan. *J. Climate*, **27**, 4521-4530.

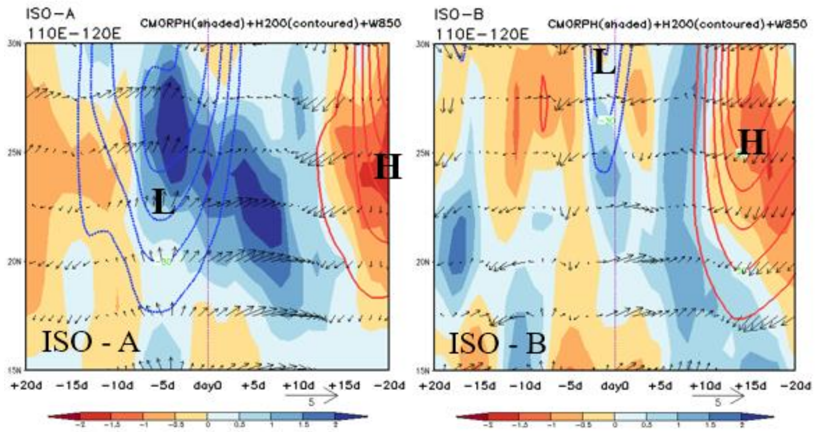

Fig 7 Time-longitude section over 110°-120°E for ISO-A (left) and ISO-B (right).

Jia, X., L. J. Chen, F. M. Ren, and C. Y. Li, 2011: Impacts of the MJO on winter rainfall and circulation in China. *Adv. Atmos. Sci.*, **28**, 521–533

Liu, P., Q. Zhang, C. Zhang, Y. Zhu, M. Khairoutdinov, H.-M. Kim, C. Schumacher, and M. Zhang, 2016: A revised real-time multivariate MJO index. *Mon. Wea. Rev.*, **144**, 627–642.

Matthews, A. J., 2008: Primary and successive events in the Madden-Julian Oscillation. *Quart. J. Roy. Meteor. Soc.*, **134**, 439–453.

Wheeler, M. C., and H. H. Hendon, 2004: An all-season real-time multivariate MJO index: Development of an index for monitoring and prediction. *Mon. Wea. Rev.*, **132**, 1917–1932.