MJO verification by JMA Global Ensemble Prediction System

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1. Introduction

- ✓ Madden-Julian Oscillation (MJO) is a dominant mode of intra-seasonal oscillation in the tropics and influences not only in the tropical circulations but also in the extratropical circulations.
- ✓ This study investigates MJO forecast skill of the JMA Global Ensemble Prediction System (GEPS), using its re-forecast dataset, by the algorithm of Wheeler and Hendon (2004; hereafter WH04).
- ✓ This study also focuses on MJO detection methods to demonstrate how some eigenvectors, derived by the Combined Empirical Orthogonal Function (CEOF) of different re-analysis, cause an apparent difference on the MJO phase diagram.

2. Data and GEPS re-forecast configuration

- **Analysis Data :**
- ✓ Japanese 55-year Reanalysis (JRA-55; Kobayashi et al., 2015)
- ✓ NECP/NCAR Re-analysis version 1 (hereafter NN1; Kalnay et al., 1996)
- ✓ NOAA/AVHRR OLR (outgoing longwave radiation) Data (Liebmann and Smith, 1996)
- **Re-forecast Data :** GEPS re-forecast data for 1981-2010
- ✓ All forecast anomaly are calculated using their own model climatology.
- **About GEPS :**
- ✓ GEPS is an integrated system to support for issuing typhoon information, one-week forecasts and one-month forecasts by JMA.
- ✓ JMA replaced the One-month Ensemble Prediction System with GEPS on 23 March 2017.

Table 1: GEPS re-forecast configuration

Atmospheric Model	JMA-GSM **Horizontal resolution :** TL479 (~40 km) up to 18 days, TL319 (~55 km) after 18 days **Vertical levels :** 100 levels up to 0.01hPa
Initial conditions	**Atmosphere :** JRA-55 **Land :** data estimated using the GEPS land-surface model with atmospheric forcing from JRA-55
Sea surface temperature(SST)	Prescribed SSTs using persisted anomaly with daily climatological SST
Ensemble size	5
Initial dates	10^{th}, 20^{th}, and the end of month from 1981 to 2010

3. MJO detection and verification method

- **The method of making eigenvectors by the CEOF analysis (Wheeler and Hendon, 2004 ; WH04)**

1. Compute the daily mean OLR, 850hPa zonal wind (U850), and 200hPa zonal wind (U200).
2. Calculate the long-term mean and the first three harmonic components (i.e. wave number 1-3) from each field at each grid point.
3. Remove the low-frequency component from daily averaged data and remove a 120-day mean of the most recent 120 days at each point and then calculate a zonal mean from 15S to 15N.
4. Normalize each field by the square-root of its global mean variance.
5. Carry out the CEOF analysis.
6. Calculate the principal components (PC1 and PC2) projected the normalized each field data to the first and second eigenvector.

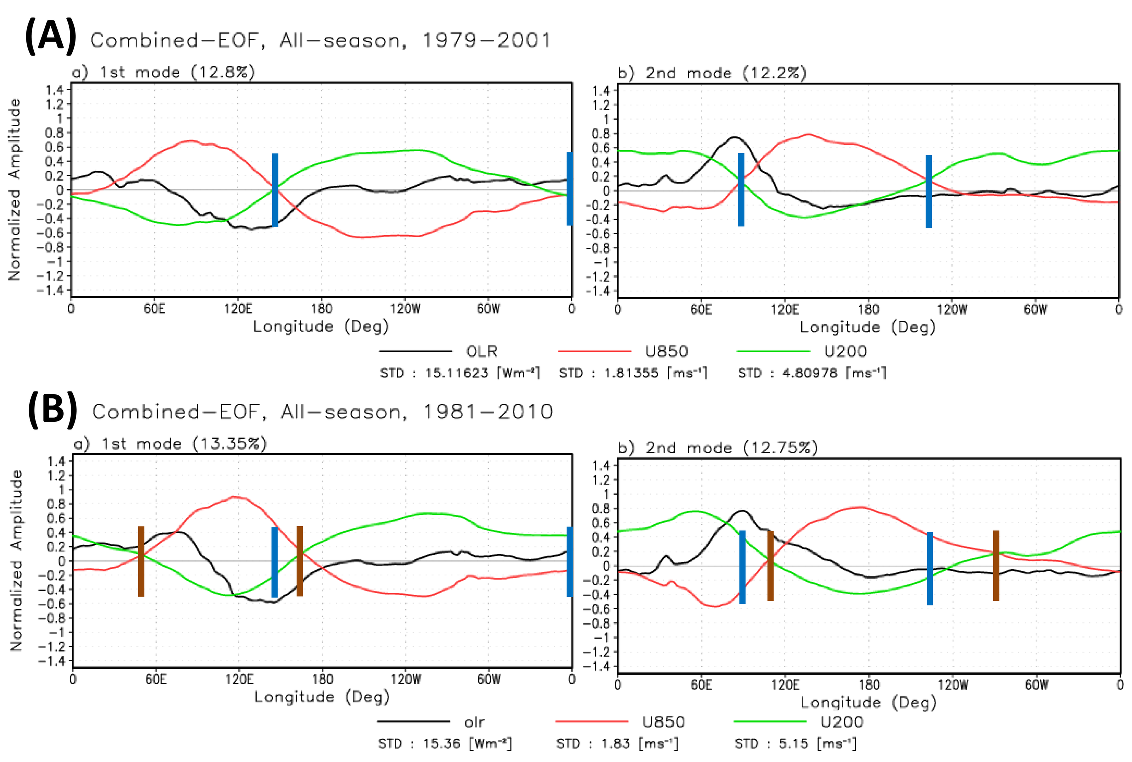
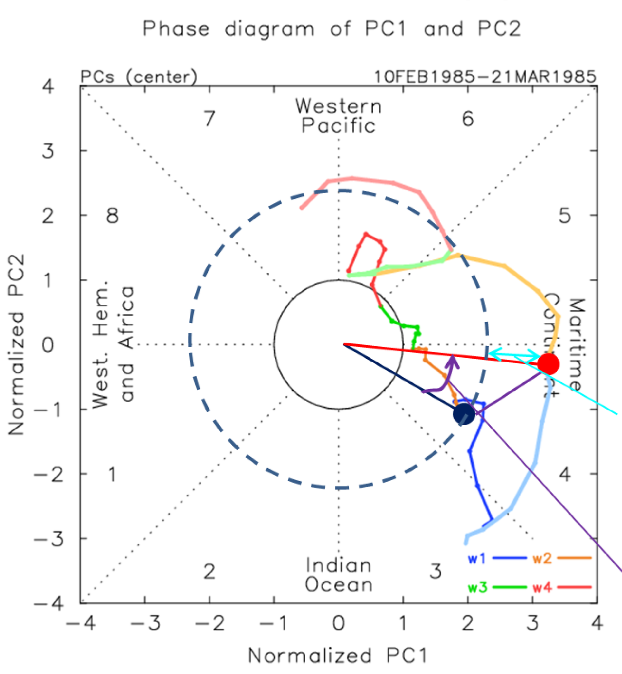


Fig 1: Spatial structures of CEOF1 and 2
(A): results by using the same datasets as WH04 (they used NN1 and NOAA OLR for 1979-2001. we use this CEOFs in section 5).
(B): results by using JRA-55 and NOAA OLR for 1981-2010.

- ✓ When JRA-55 is used as an alternative dataset, the spatial structures of the CEOFs are shifted to the east about 30 degrees compared with that described in WH04 (we discuss in section 4).



- **The definition of MJO verification index (Matsueda and Endo, 2011)**

Root mean square error(RMSE)

$$RMSE(\tau) = \sqrt{\frac{1}{N}\sum_{t=1}^{N}((f_1(t,\tau)-a_1(t))^2 + (f_2(t,\tau)-a_2(t))^2)}$$

Correlation(COR)

$$COR(\tau) = \frac{\sum_{t=1}^{N}(a_1(t)f_1(t,\tau)+a_2(t)f_2(t,\tau))}{\sqrt{\sum_{t=1}^{N}(a_1(t)^2+a_2(t)^2)}\sqrt{\sum_{t=1}^{N}(f_1(t,\tau)^2+f_2(t,\tau)^2)}}$$

Amplitude error(AERR)

$$AERR(\tau) = \frac{1}{N}\sum_{t=1}^{N}\left(\sqrt{f_1(t,\tau)^2+f_2(t,\tau)^2} - \sqrt{(a_1(t)^2+a_2(t)^2}\right)$$

Phase error(PERR)

$$PERR(\tau) = \frac{1}{N}\sum_{t=1}^{N}\tan^{-1}\left(\frac{a_1(t)f_2(t,\tau)-a_2(t)f_1(t,\tau)}{a_1(t)f_1(t,\tau)+a_2(t)f_2(t,\tau)}\right)$$

● analysis $(a_1(t),a_2(t))$ ● forecast $(f_1(t,\tau),f_2(t,\tau))$ τ : lead-time

Fig 2: MJO phase diagram of PC1 and PC2 (10Feb to 21Mar1985) and the definition of MJO verification indices

Acknowledge

- We used a diagnostic package developed by the U.S. Climate Variability and Predictability (U.S. CLIVAR) MJO Working Group (Kim et al., 2009).

References

- Kobayashi, S., Y. Ota, Y. Harada, A. Ebita, M. Moriya, H. Onoda, K. Onogi, H. Kamahori, C. Kobayashi, H. Endo, K. Miyaoka, and K. Takahashi, 2015: The JRA-55 Reanalysis: General Specifications and Basic Characteristics. *J. Meteor. Soc. Japan,* **93,** 5-48.
- Liebmann, B. and C.A. Smith, 1996: Description of a complete (interpolated) outgoing longwave radiation dataset. *Bull. Amer. Meteor. Soc.,* **77,** 1275-1277.
- Kalnay, E., M. Kanamitsu, R. Kirtler, W. Collins, D. Deaven, L. Gandin, M. Iredell, S. Saha, G. White, J. Woollen, Y. Zhu, A. Leetmaa, R. Reynolds, M. Chelliah, W. Ebisuzaki, W. Higgins, J. Janowiak, K. C. Mo, C. Ropelewski, J. Wang, R. Jenne, and D. Joseph, 1996: The NCEP/NCAR 40-year Reanalysis Project. *Bull. Amer. Meteor. Soc.,* **77,** 437-471.
- Kim, D., K. Sperber, W. Stern, D. Waliser, I.-S. Kang, E. Maloney, W. Wang, K. Weickmann, J. Benedict, M. Khairoutdinov, M.-I. Lee, R. Neale, M. Suarez, K. Thayer-Calder, and G. Zhang, 2009: Application of MJO simulation diagnostics to climate models. *J. Climate,* **22,** 6413-6436.
- Matsueda, M., and H. Endo, 2011: Verification of medium-range MJO forecasts with TIGGE. *Geophys. Res. Lett.,* **38,** L11801.
- 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.

Summary

- ✓ With using different re-analysis dataset, MJO shows an apparent difference on the MJO phase diagram. The main cause seems to be a difference on 850hPa zonal wind.
- ✓ JMA Global Ensemble Prediction System (GEPS) has good capability of predicting the amplitude and phase of MJO at about 2-weeks.
- ✓ MJO phase speed of GEPS tends to be a little faster than analyzed phase speed.
- ✓ MJO amplitude of GEPS tends to be smaller than analyzed amplitude.

4. MJO apparent difference caused by eigenvectors

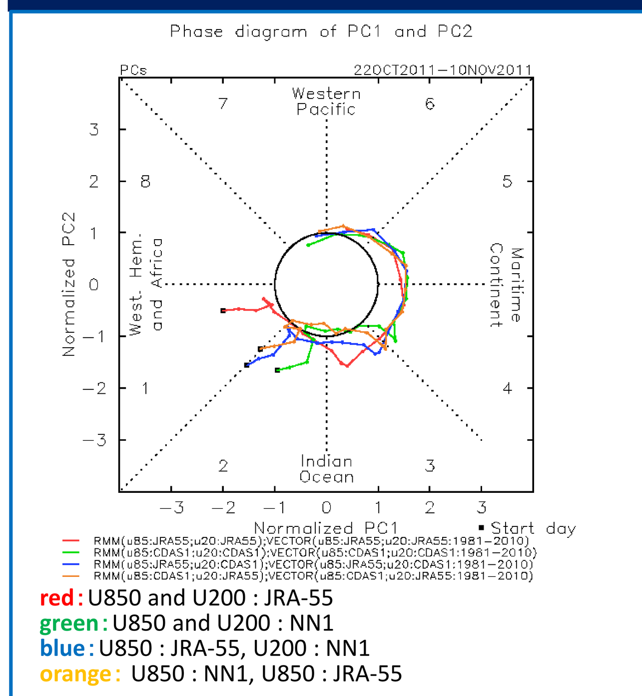


Fig 3: MJO phase diagram (22Oct to 10Nov2011) defined by the four types of eigenvectors by using JRA-55 and NN1 for 1981-2010

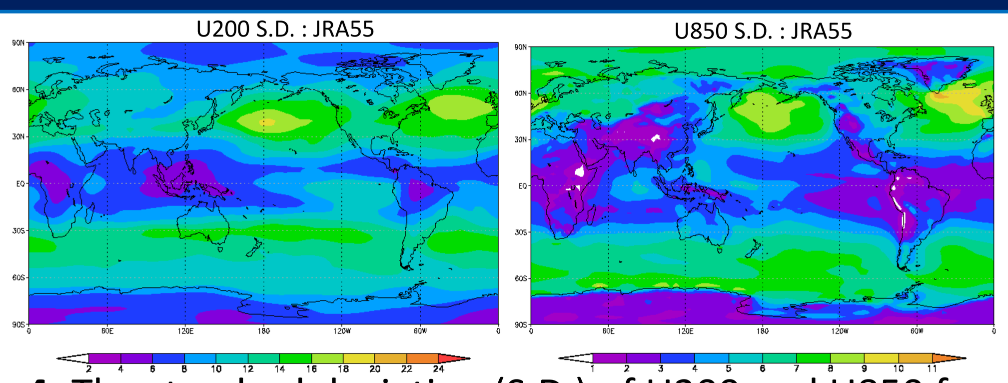


Fig 4: The standard deviation (S.D.) of U200 and U850 for 1981-2010

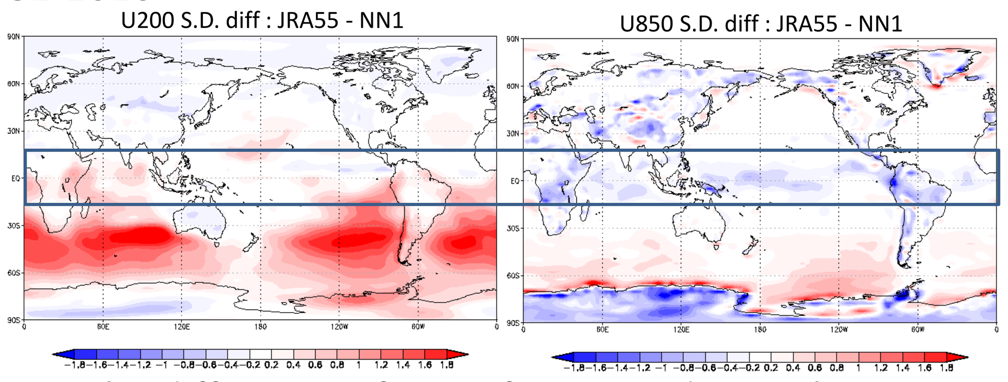


Fig 5: The difference of S.D. of U200 and U850 between JRA-55 and NN1
Box: the zonal averaged range to calculate PC1 and PC2

- ✓ Results on the MJO phase diagram are compared by only changing U850 or/and U200 re-analysis data.
- ✓ The different of zonal averaged U850 S.D. between JRA-55 and NN1 is larger than that of U200 S.D in the tropics.
- ✓ The difference of U850 between JRA-55 and NN1 seems to make the biggest difference on the MJO phase diagram.

5. MJO verification of GEPS prediction

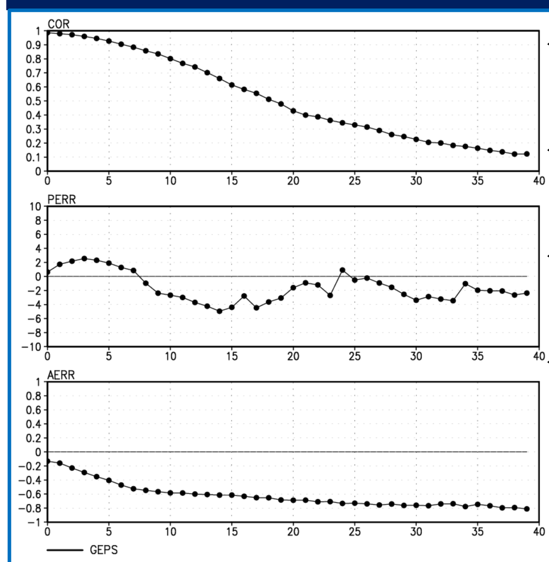


Fig 6: MJO verification score of GEPS for JRA-55

- ✓ The predicted MJO phase speed tends to be a little faster than analyzed phase speed, especially phase 3 (Fig 6 and 8).
- ✓ The predicted MJO amplitude tends to be smaller than analyzed amplitude (Fig 6, 7 and 8).
- ✓ Seeing phase 2-3 composite map, the negative OLR anomaly accompanied by MJO is weak (Fig 7).
- ✓ The tropical circulation in response to MJO and the following extratropical circulation by teleconnection mechanism are also reproduced at a lead time of about 2 weeks in terms of composite analysis (Fig 9).

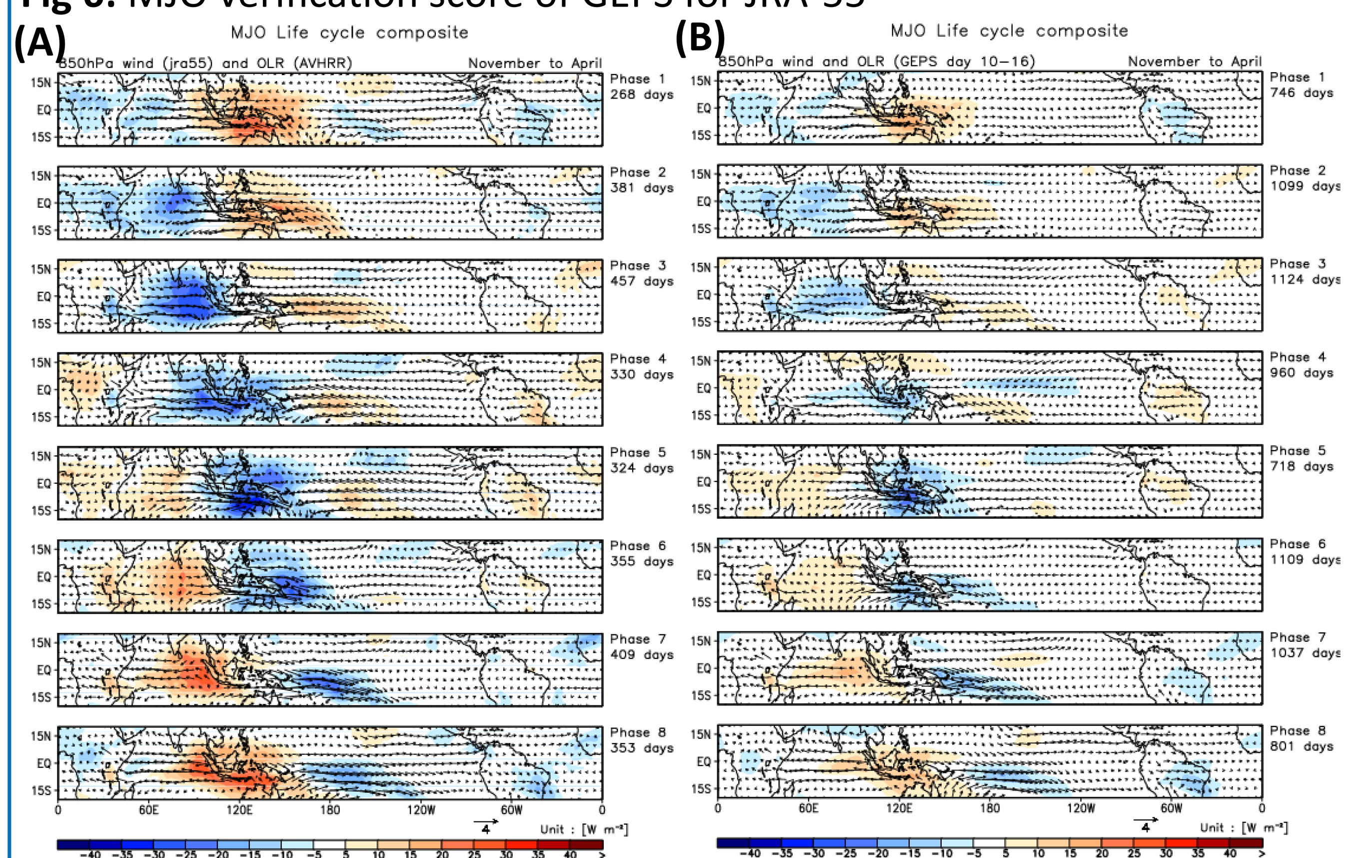


Fig 7: The composite map of OLR and 850hPa wind each MJO phase during the boreal winter
Shaded: OLR anomaly
Vector: 850hPa wind anomaly
Days: total number of days averaged at each MJO phase
(A): NOAA OLR/JRA-55
(B): GEPS for the 2-week lead-time

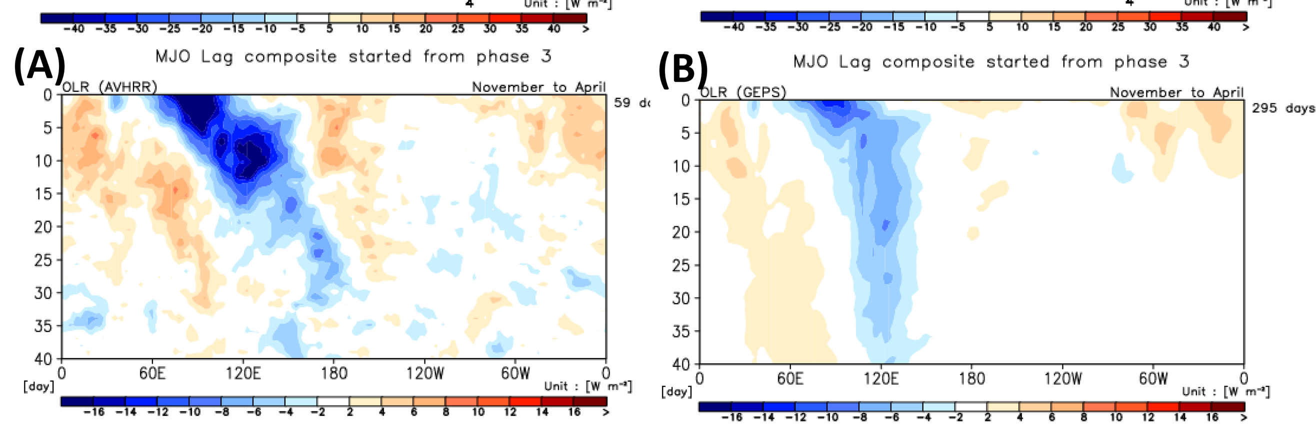


Fig 8: The hovmöller composite map averaged OLR 15S-15N for phase 3 during the boreal winter
Shaded: OLR anomaly
(A): NOAA OLR
(B): GEPS

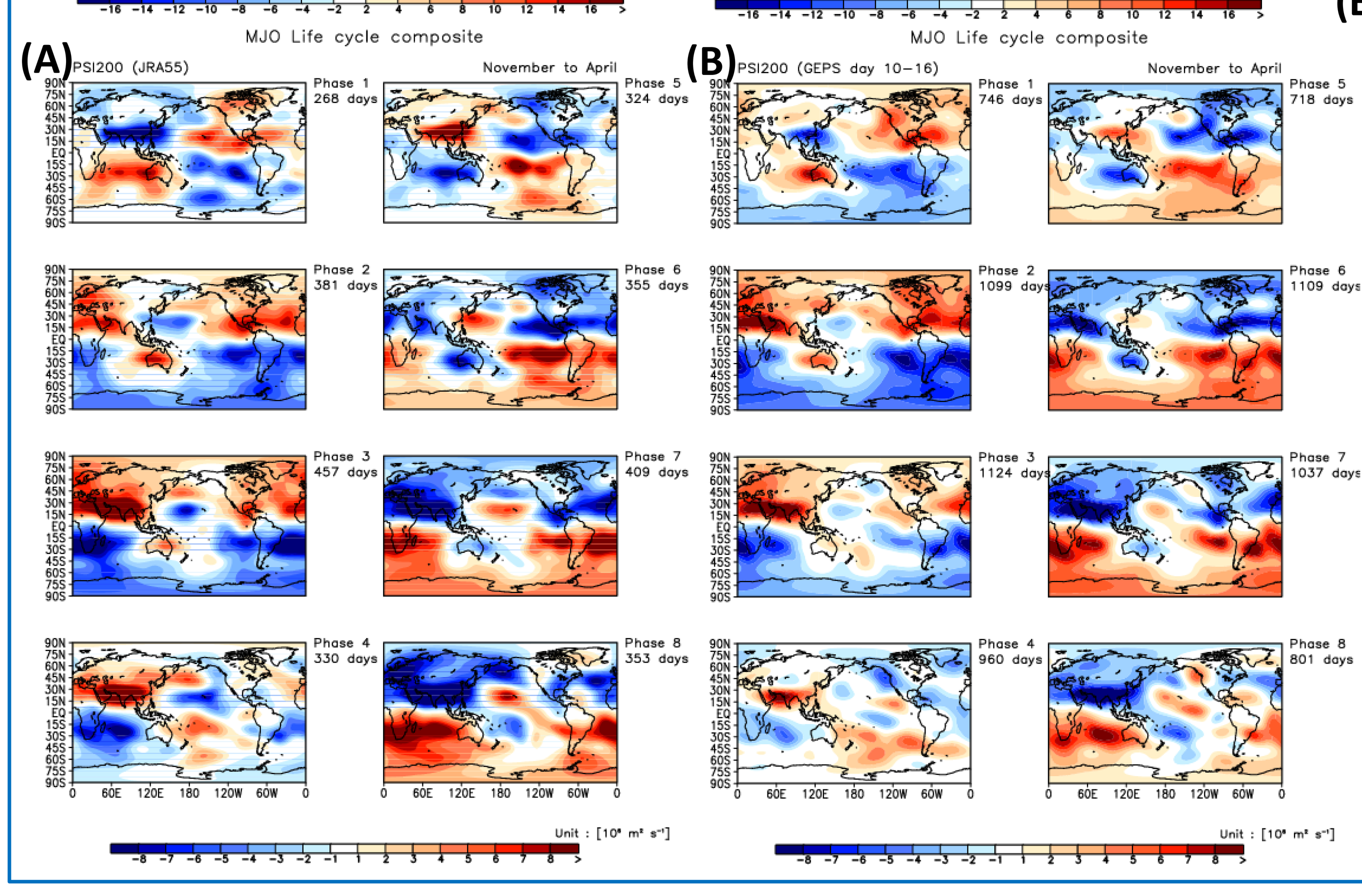


Fig 9: The composite map of the 200hPa stream function anomaly during the boreal winter for each MJO phase
(A): JRA-55
(B): GEPS for the 2-week lead-time