Regional BSISO over Indian Ocean and Western Pacific

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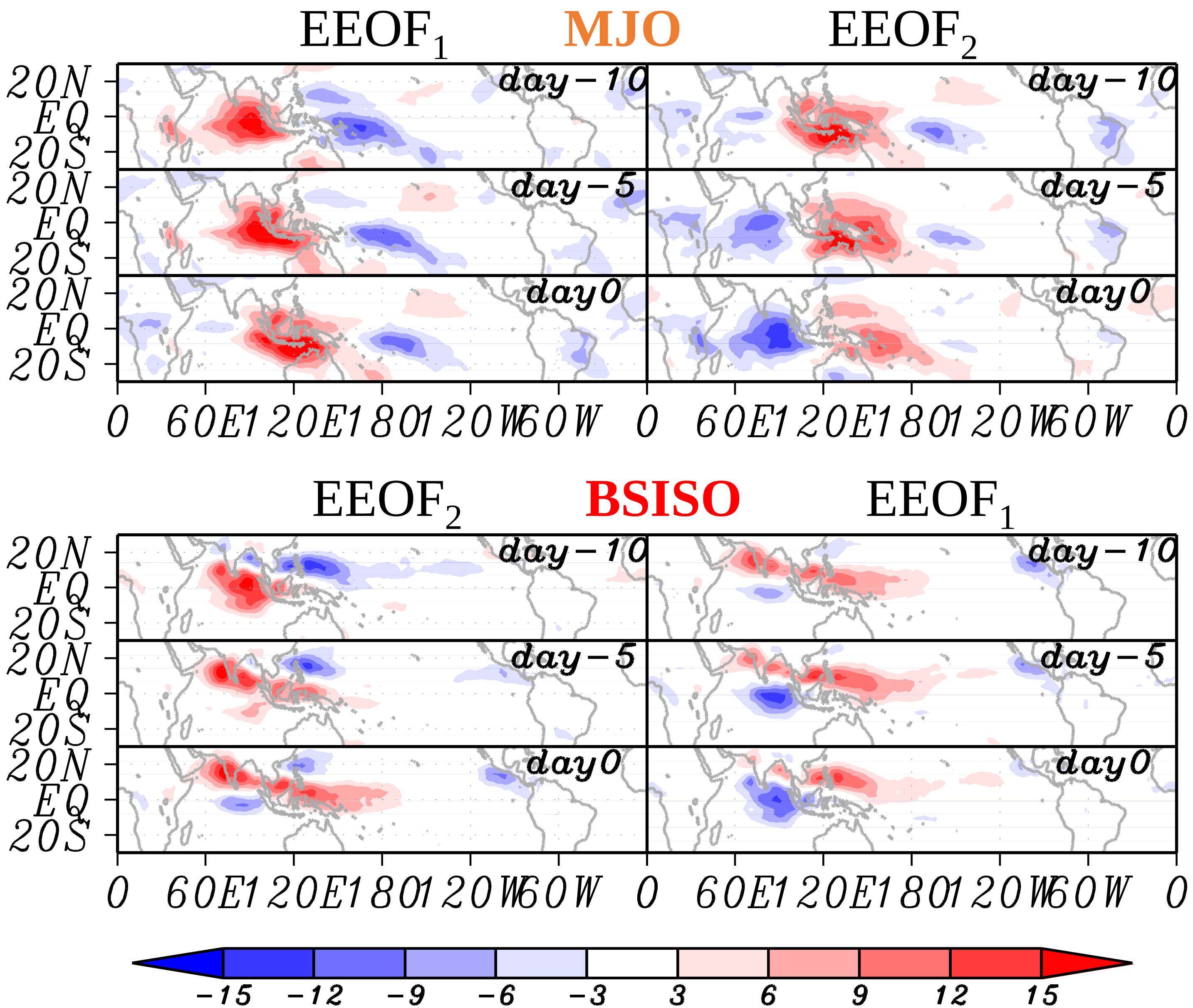
1. Concepts of MJO and BSISO

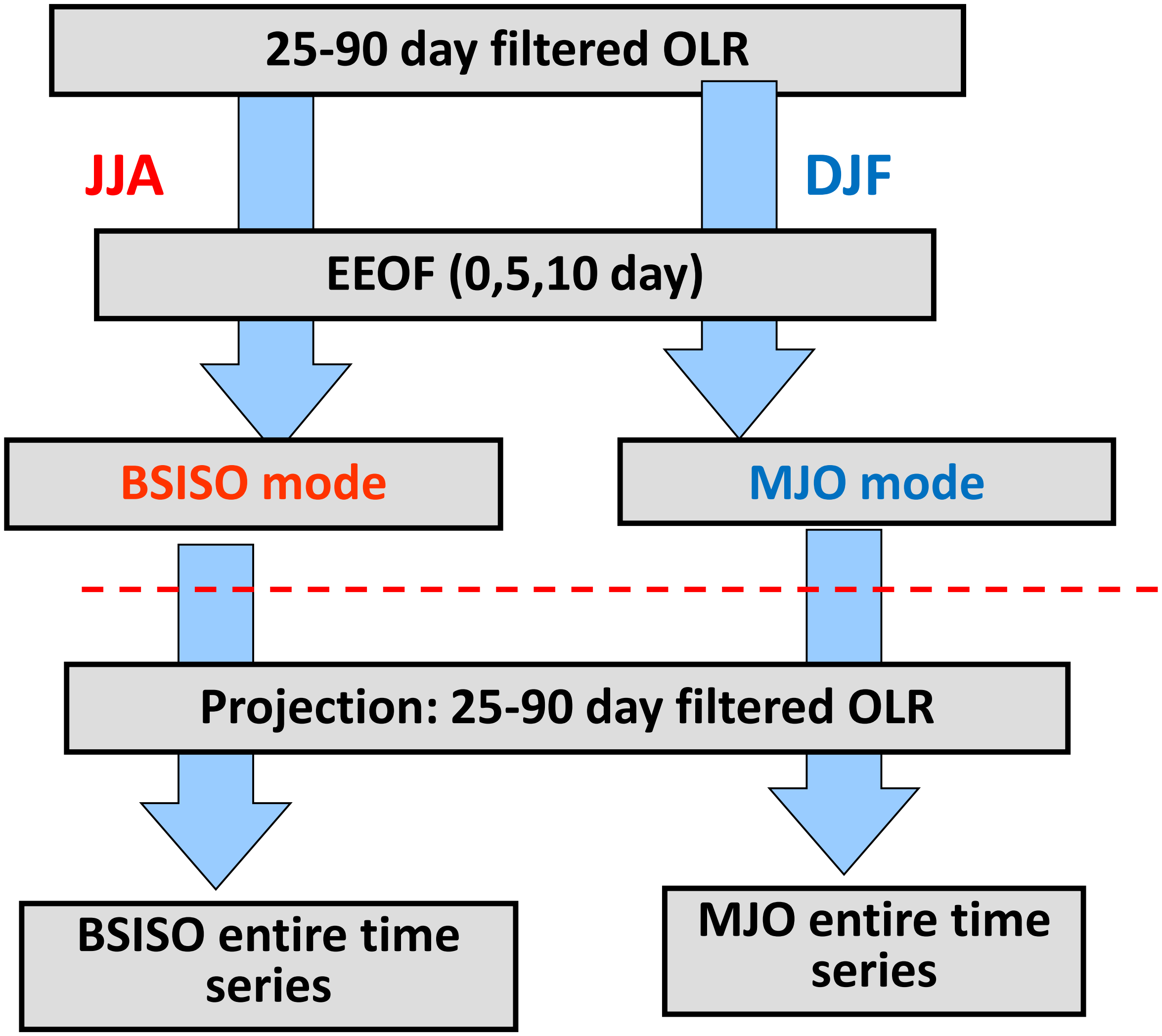
Concept of MJO and BSISO

- One of the fundamental features of ISO is the pronounced seasonal variations in their intensity (Madden 1986), movement (Wang and Rui 1990), and periodicity (Hartmann et al. 1992).
- BSISO was proposed by Wang and Xie (1997): A model for the boreal summer Intraseasonal Oscillation. *JAS*.
- Waliser et al. 2003: The MJO and BSISO have distinct circulation structures, propagation patterns, and life cycles.
- Five distinguished features of BSISO were summarized in Wang, B., P. Webster, K. kikuchi, T. Yasunari, and Y. Qi, 2006: Boreal summer quasi-monthly oscillation in the global tropics. *CD*.
- A Bimodal representation of ISO was proposed in Kikuchi et al. (2012).
- A real time multivariate BSISO indices are proposed to monitor BSISO by Lee et al. (2013).

Bimodal ISO modes: MJO and BSISO

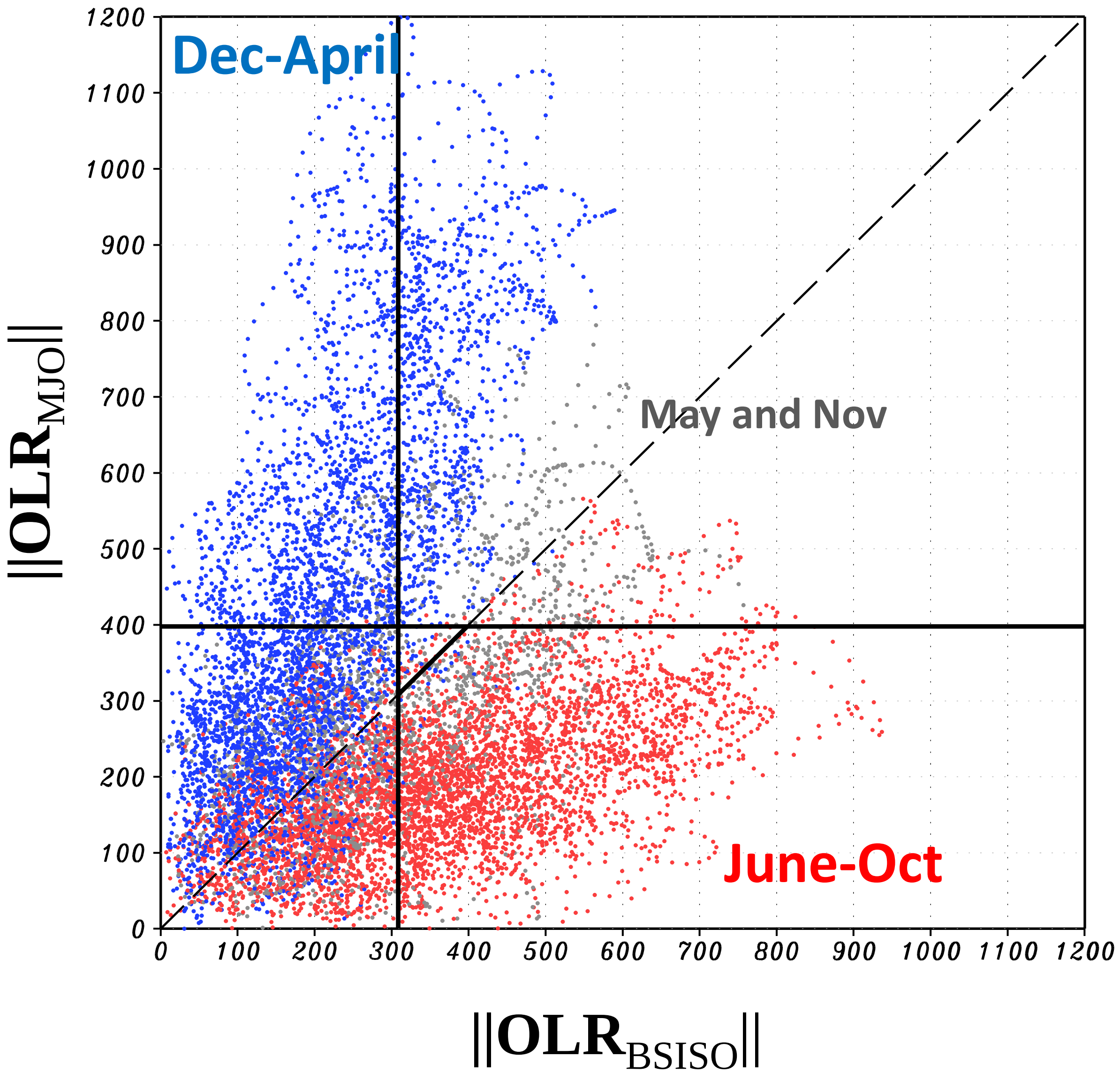


Define MJO and BSISO components

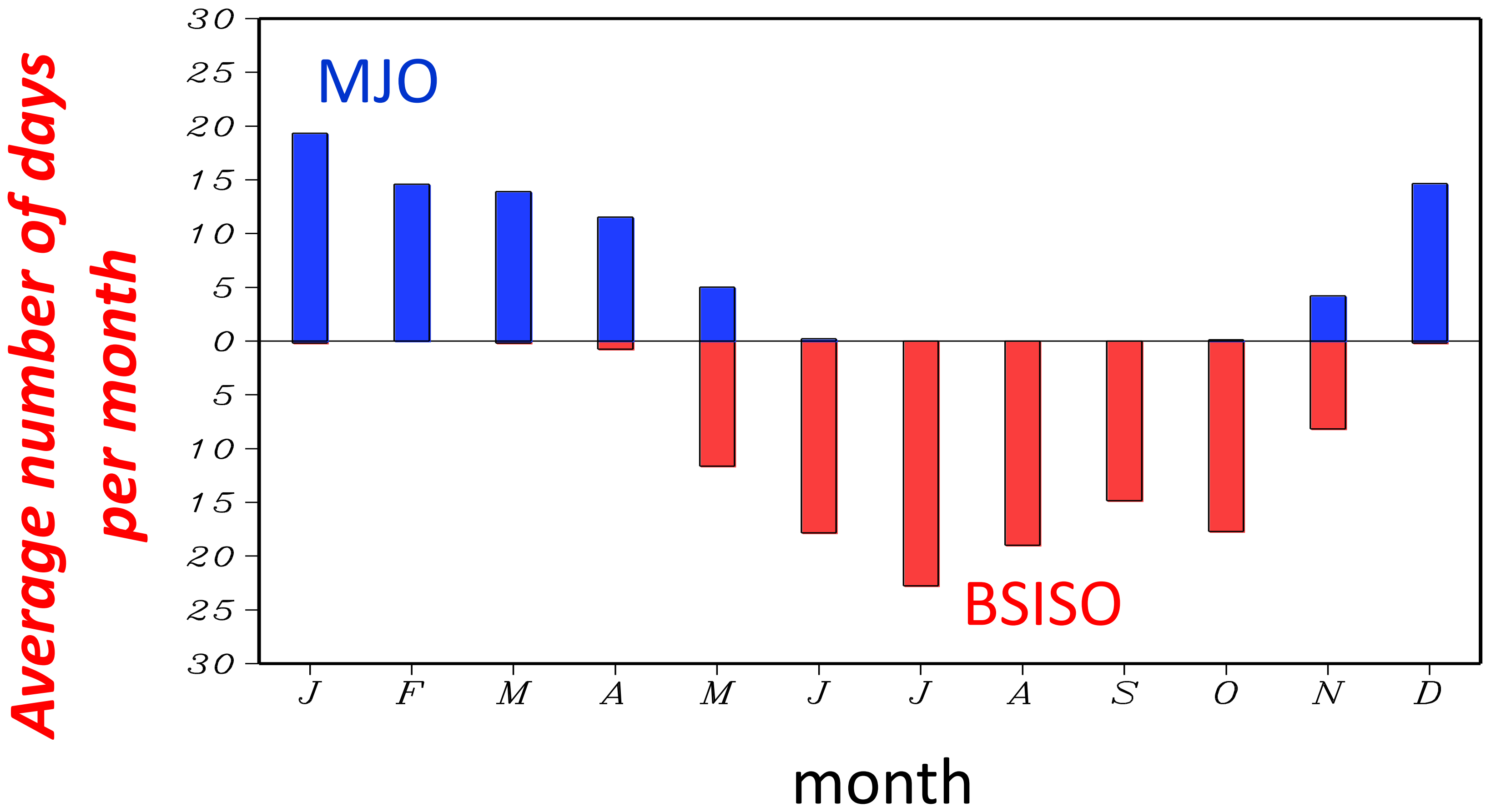


*BSISO: Boreal Summer ISO

MJO vs BSISO: Seasonal Separation



Seasonal variation of MJO and BSISO



Distinctive features of BSISO

Five features of BSISO that distinguishes from MJO.

- Prominent northward propagation prevails in the northern IO, and WNP (Yasunari 1979; Krishnamurti and Subrahmanyam 1982; Chen and Murakami 1988, Jiang and Waliser 2009).

- Major centers of variability in precipitation shifted to Asian-Pacific and North American SM regions (10-20°N) (Kemball-Cook and Wang 2001).

- The leading mode exhibits a NW-SE tilted precipitation band (Ferranti et al. 1997; Wang and Xie 1997).

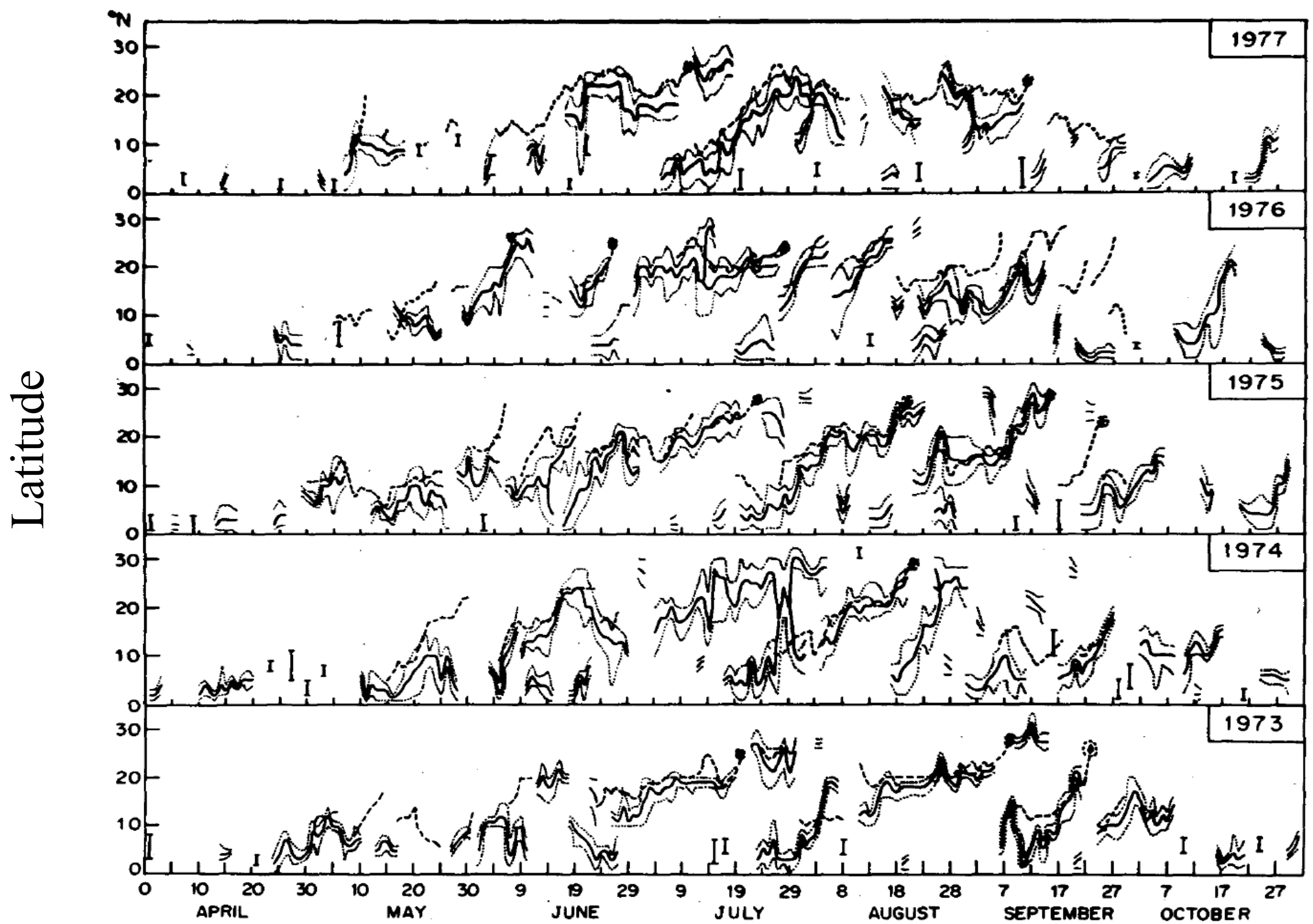
- There exists a considerable stationary component, a convective seesaw between the equatorial IO and the WNP (Lau and Chan 1986, Zhu and Wang 1993).

- Two different periodicities:30-60 days and 10-20 days (e.g., Kikuchi and Wang 2010).

Wang et al. 2006

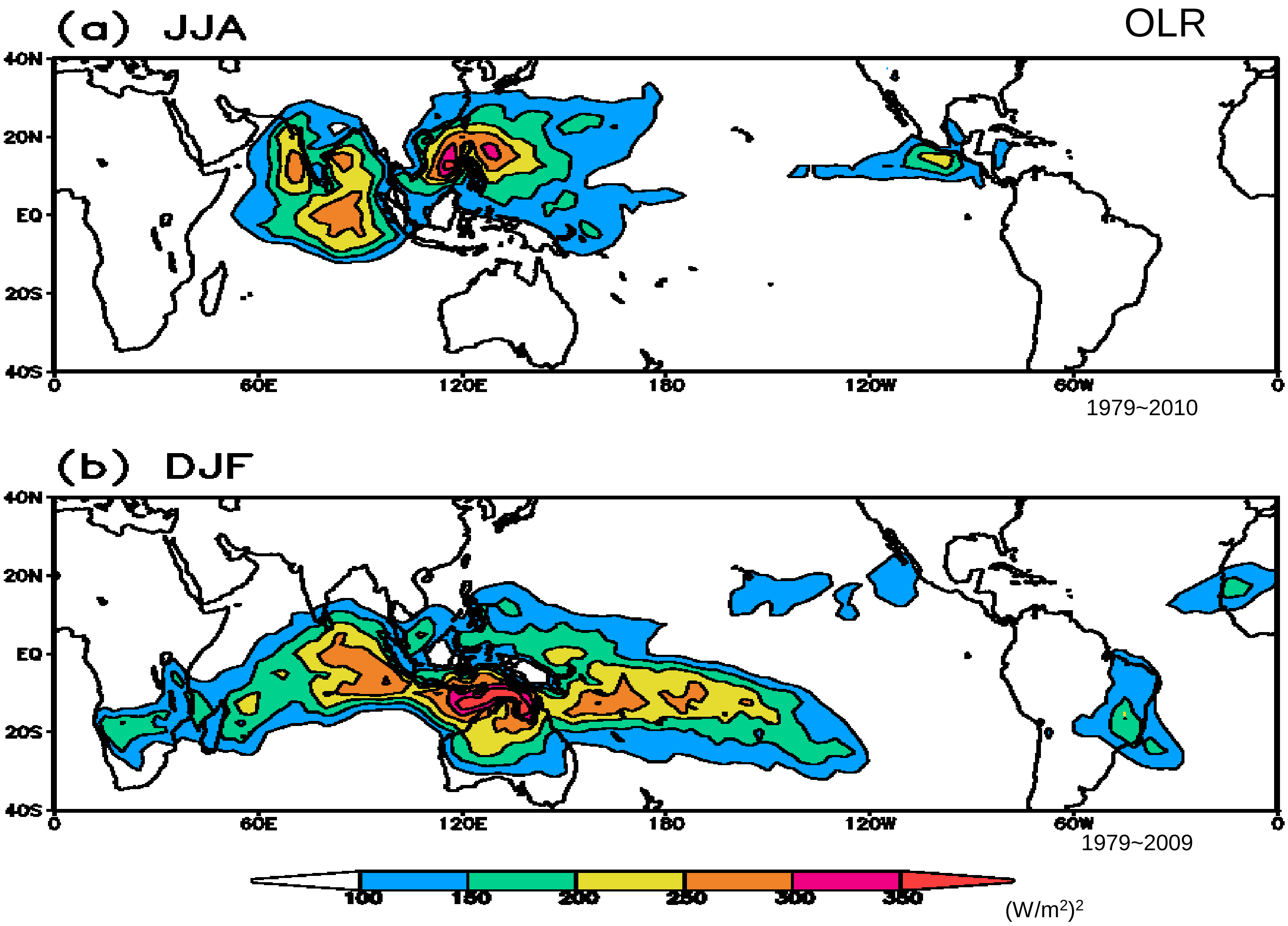
BSISO: Discovery of northward propagation

- Yasunari (1979, *J. Meteorol. Soc. Japan*, 57, 227-242)
- Yasunari (1980, *J. Meteorol. Soc. Japan*, 58, 225-229)
- Sikka and Gadgil (1980, *MWR*, 108, 1840-1853)



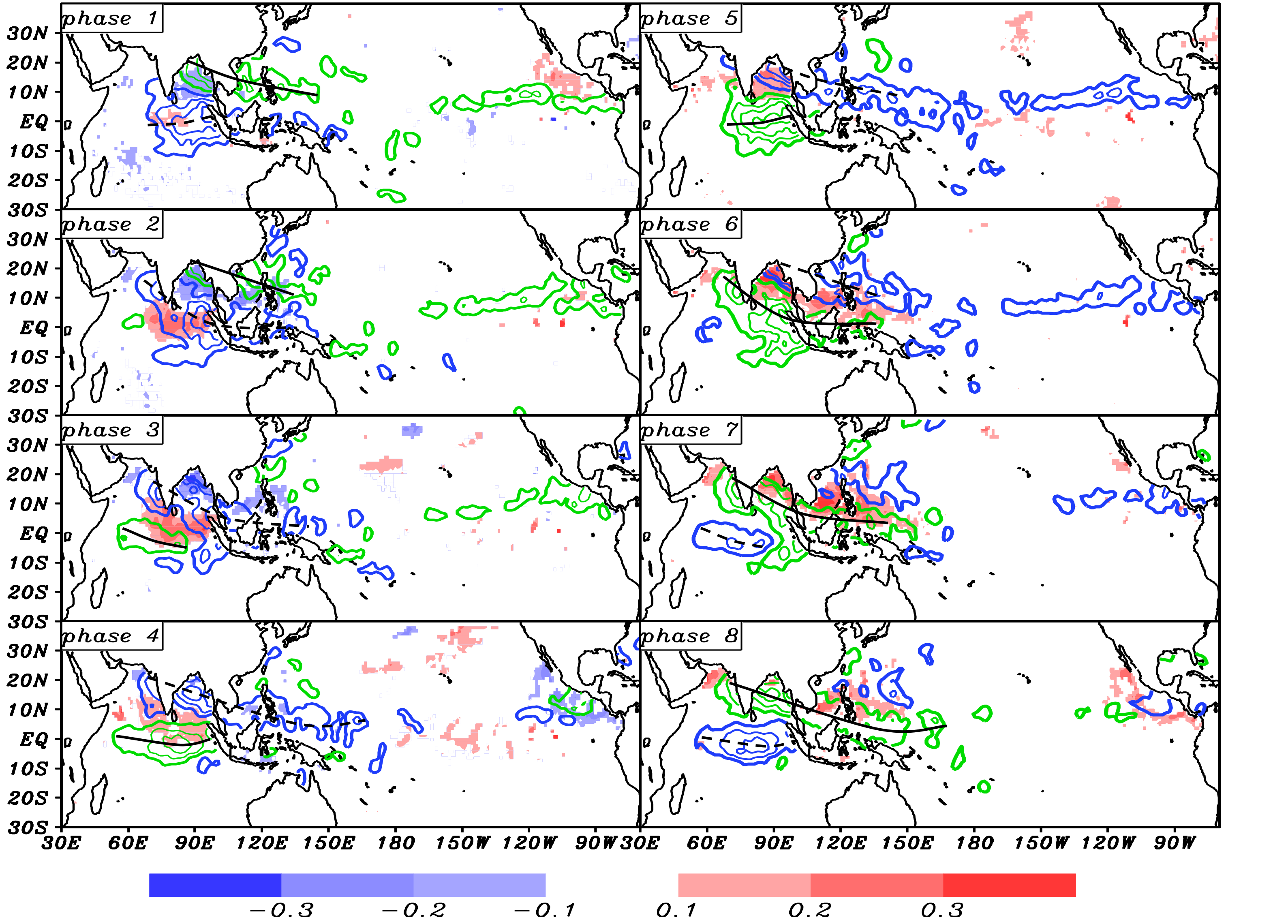
Time-latitude plots of the location and width of the maximum cloud zone at 90°E (after Sikka and Gadgil 1980)

Intraseasonal Variance

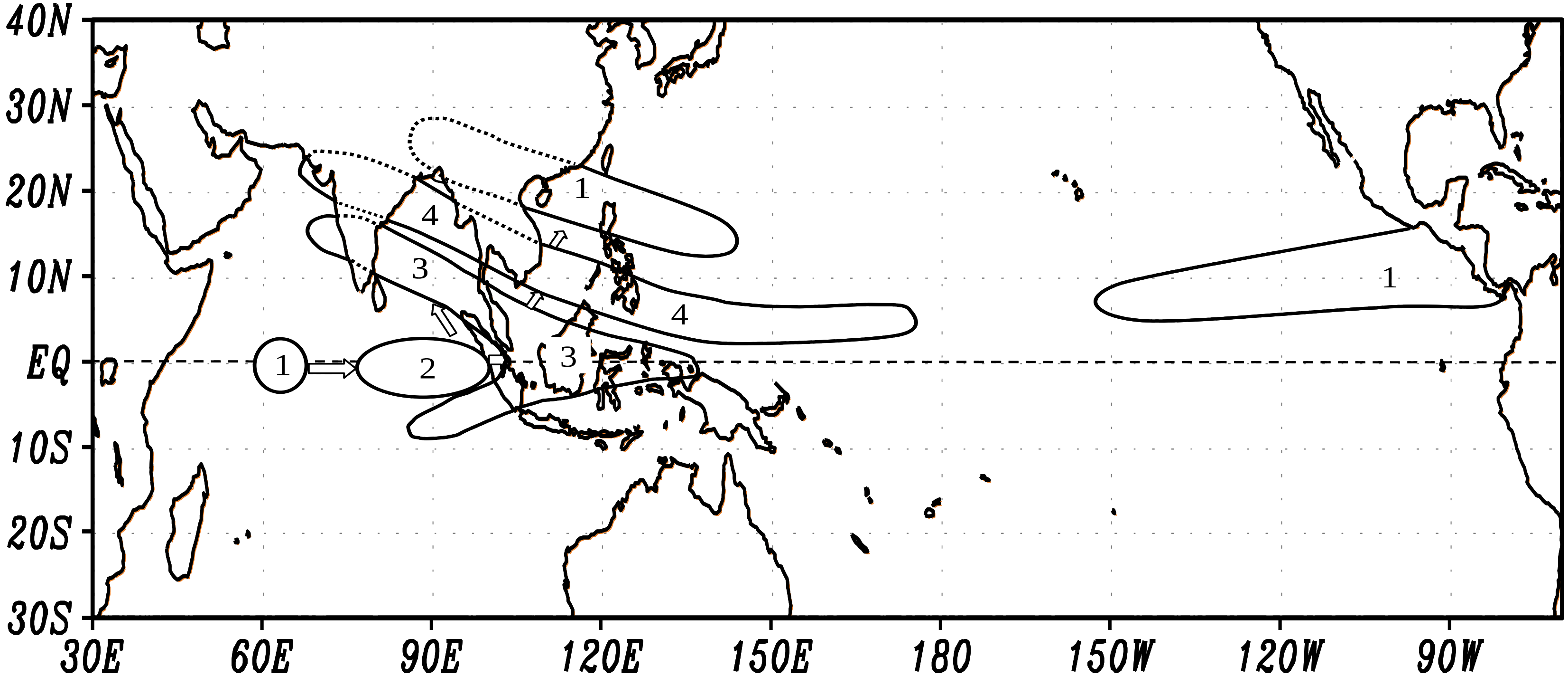


1979-2010

Composite life cycle of ISO rain rate (contour) & SST (shading)



Schematic evolution of tropical ISO rain anomalies



A four-stage evolution

1. The **initial ISO rainfall anomalies** occur in the EIO around 60-70E at Phase 2.

2.After the equatorial rainfall anomalies reach Indonesia, a major rain band extends outward from the convective region of Sumatra-Borneo **tilting northwestward** to eastern Arabian Sea (Phase 6).

3.The slanted rain band then moves **northeastward** (Phase 7-8), 4 Meanwhile the equatorial WP anomalies **rapidly traverse the ITCZ in Pacific and migrate northward slowly to Philippine Sea**.

Wang et al. (2006)

2. Monitoring and measuring MJO and BSISO

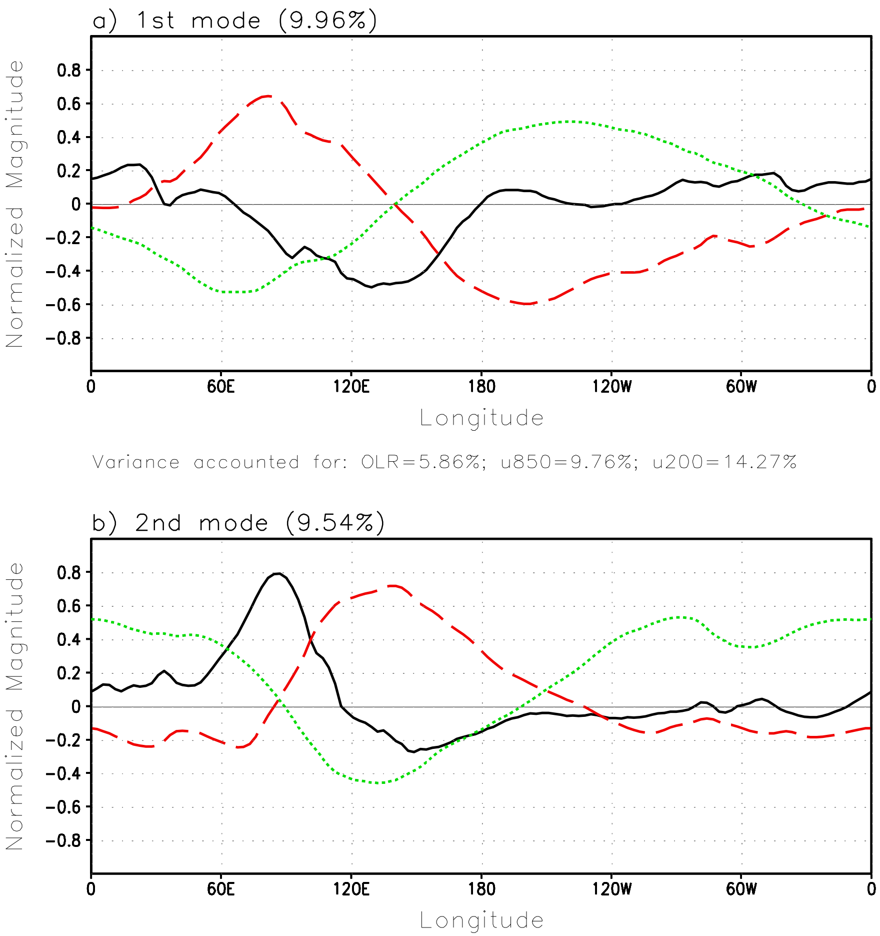
“Real-time multivariate indices for boreal summer intraseasonal oscillation over the Asian summer monsoon region”

J-Y Lee • B Wang • M C. Wheeler • X Fu •
D. E. Waliser • I.-S. Kang

Clim Dyn (2013) 40:493–509

Real-time Multivariate MJO (RMM) (Wheeler and Hendon 2004)

Multi-variable EOF from observation



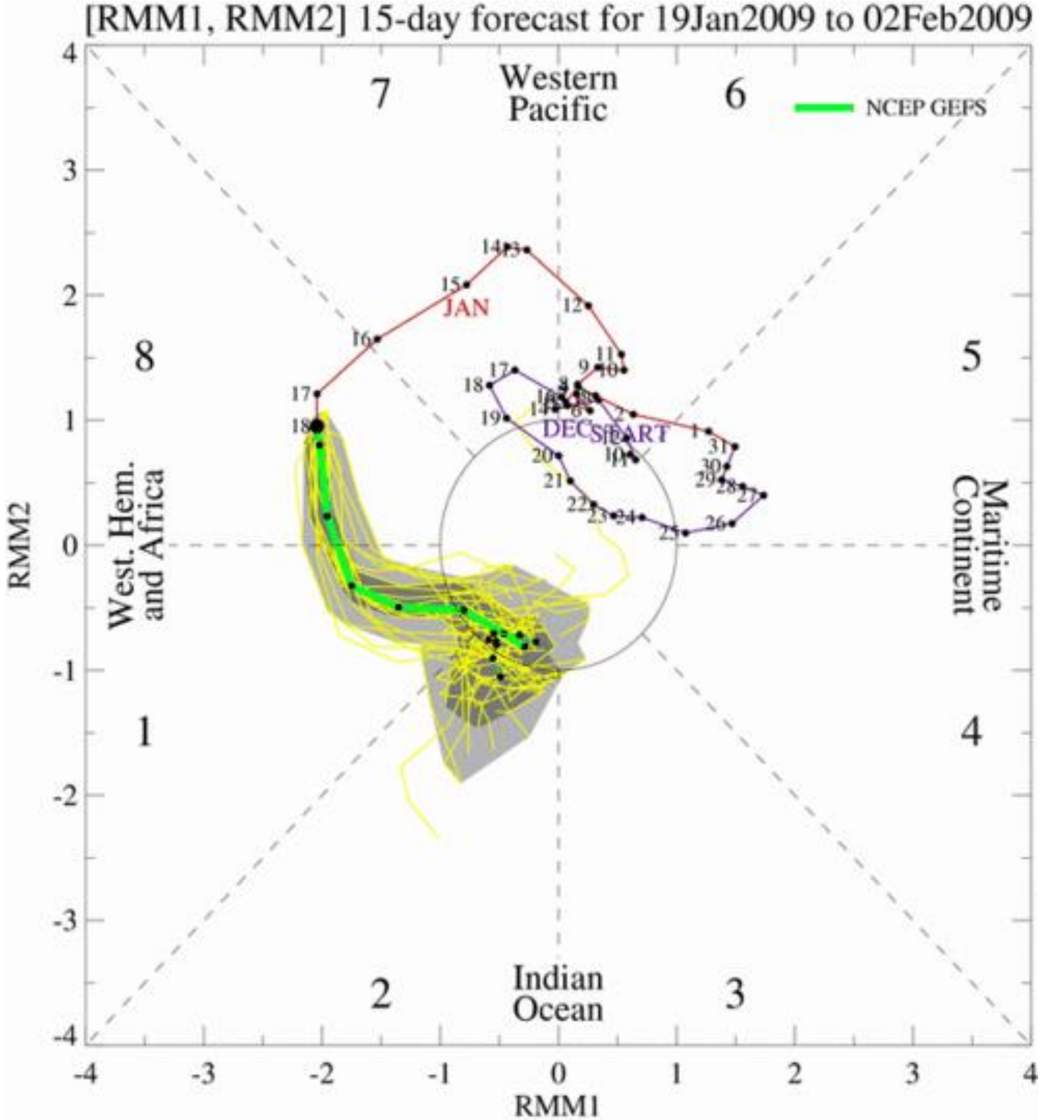
Project the combined eigenvector to predicted variables (OLR, U850,U200)

PC1, PC2 (RMM index)

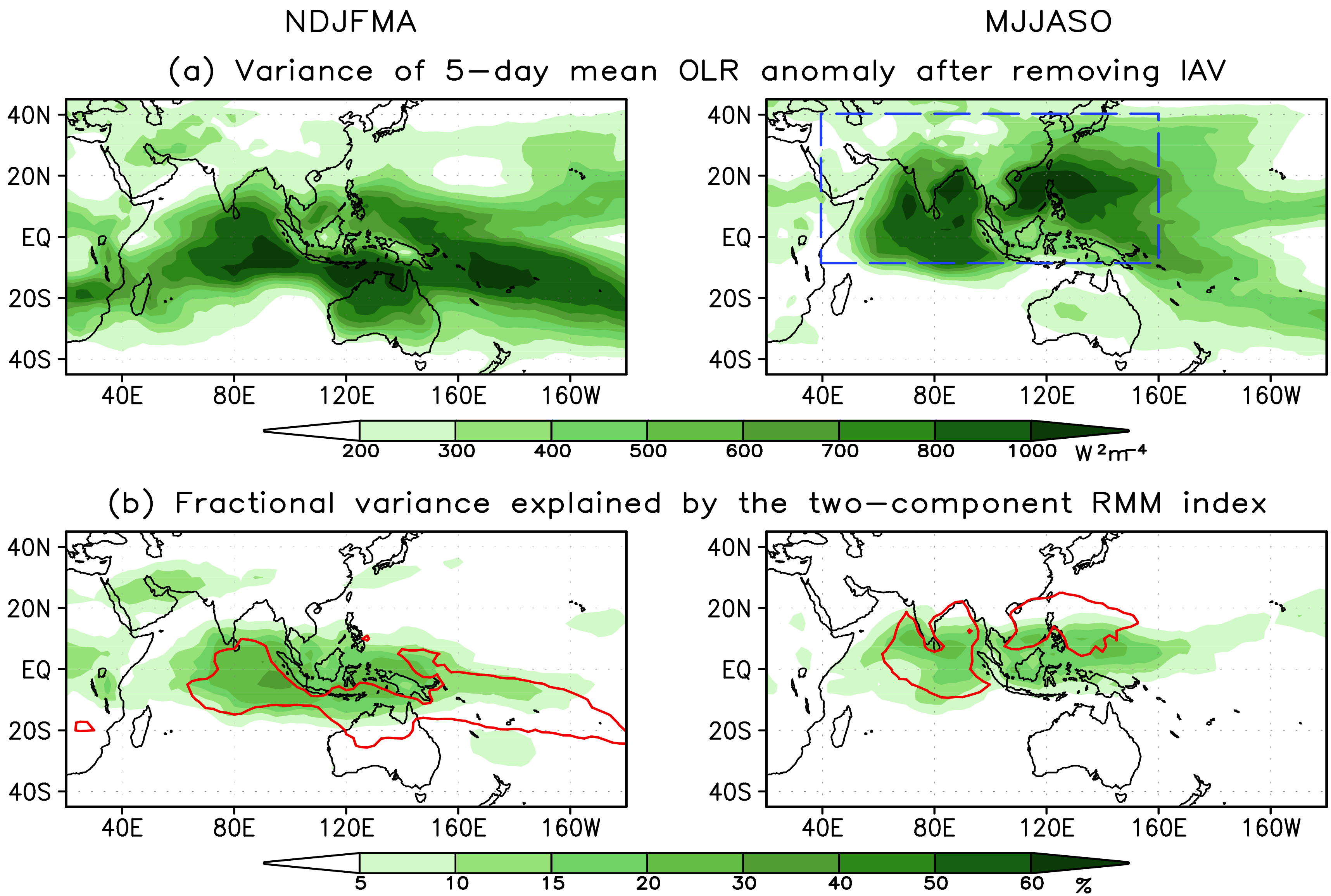
Forecast skill measure

Dynamical Predictions – GEFS

Yellow Lines – 20 Individual Members
Green Line – Ensemble Mean



RMM1 and RMM2 values for the most recent 40 days and forecasts from the ensemble Global Forecast System (GEFS) for the next 15 days



(a) Variance of pentad mean OLR anomaly ($W^2 m^{-4}$) after removing climatological annual cycle and interannual variability during November to April (NDJFMA) and May to October (MJJASO), respectively. (b) Fractional variance (%) of 5-day mean OLR anomaly accounted by the two-component RMM index. Blue dashed line in right-hand side of (a) indicates the Asian summer monsoon (ASM) domain. Red contour in (b) represents OLR variability center with variance larger than 800 $W^2 m^{-4}$ shown in (a).

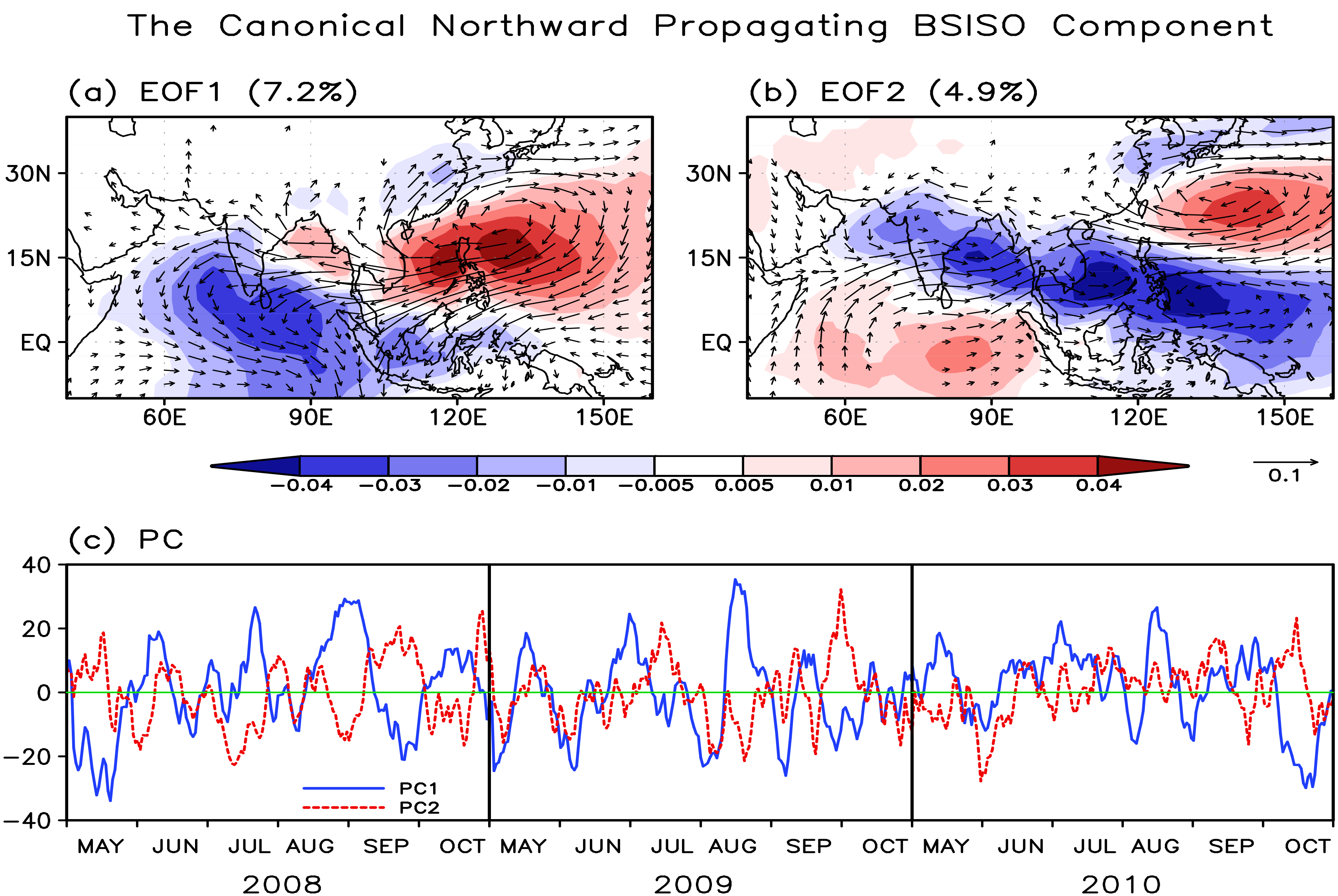


Fig. 2 Spatial structure (a, b) and PC time series (c) of the first two leading MV-EOF modes of daily OLR (shading) and zonal wind at 850 hPa (U850) anomalies normalized by their area averaged temporal standard deviation over the ASM region (33.04 W m^{-2} for OLR and 4.01 m s^{-1} for U850). To display the full horizontal wind vector, the associated meridional wind at 850 hPa (V850) was obtained by regressing V850 anomaly, normalize by its area averaged standard deviation (3.14 m s^{-1}), against each PC. The MV-EOF modes were obtained during MJJASO for the 30 years of 1981-2010.

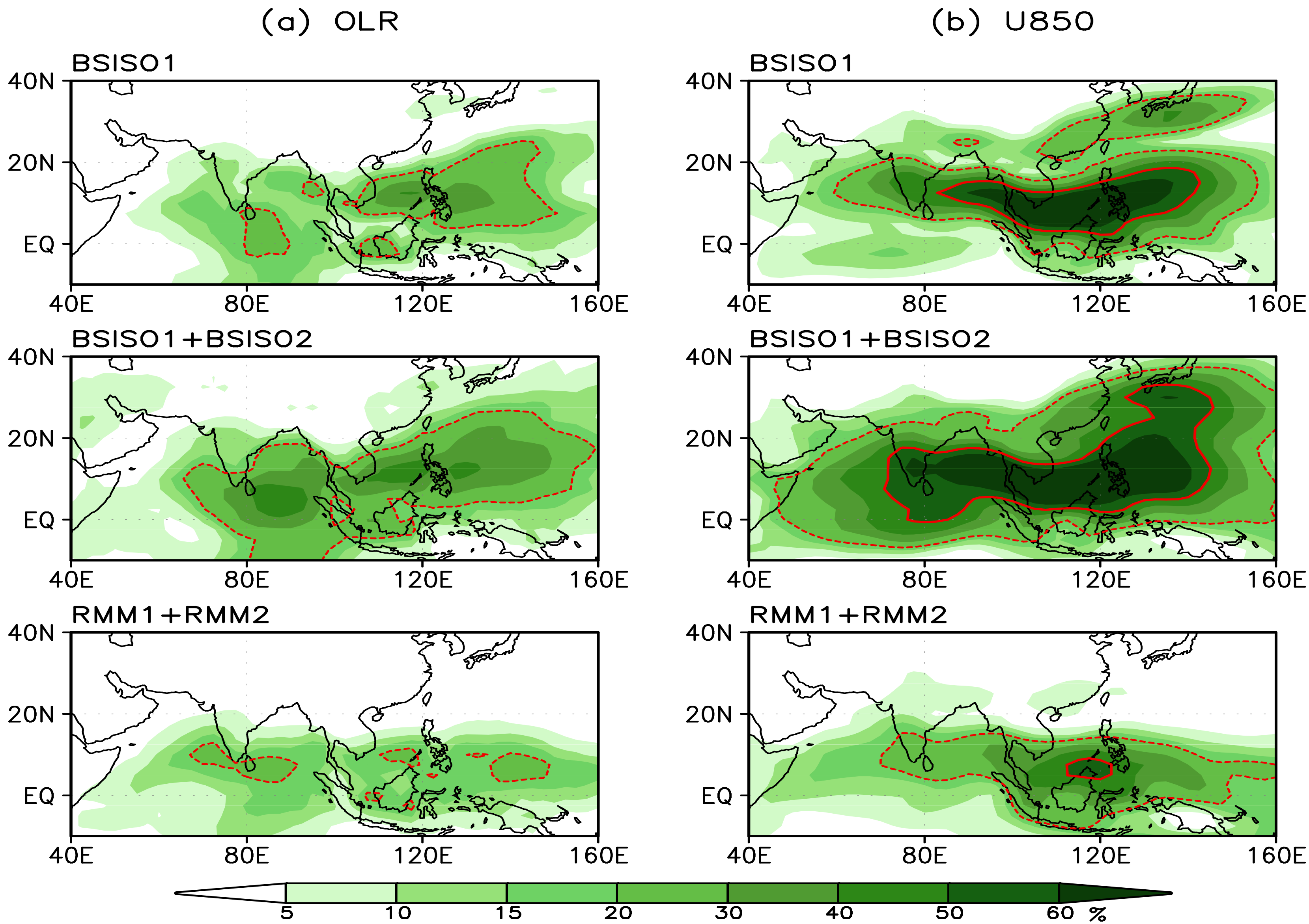


Fig. 11 Spatial distribution of fractional variance of pentad (a) OLR and (b) U850 anomaly that are accounted for by the first two PCs (BSISO1 only in upper panels), the first four PCs (BSISO1 and BSISO2 in middle panels) and the two-component RMM index (lower panels).

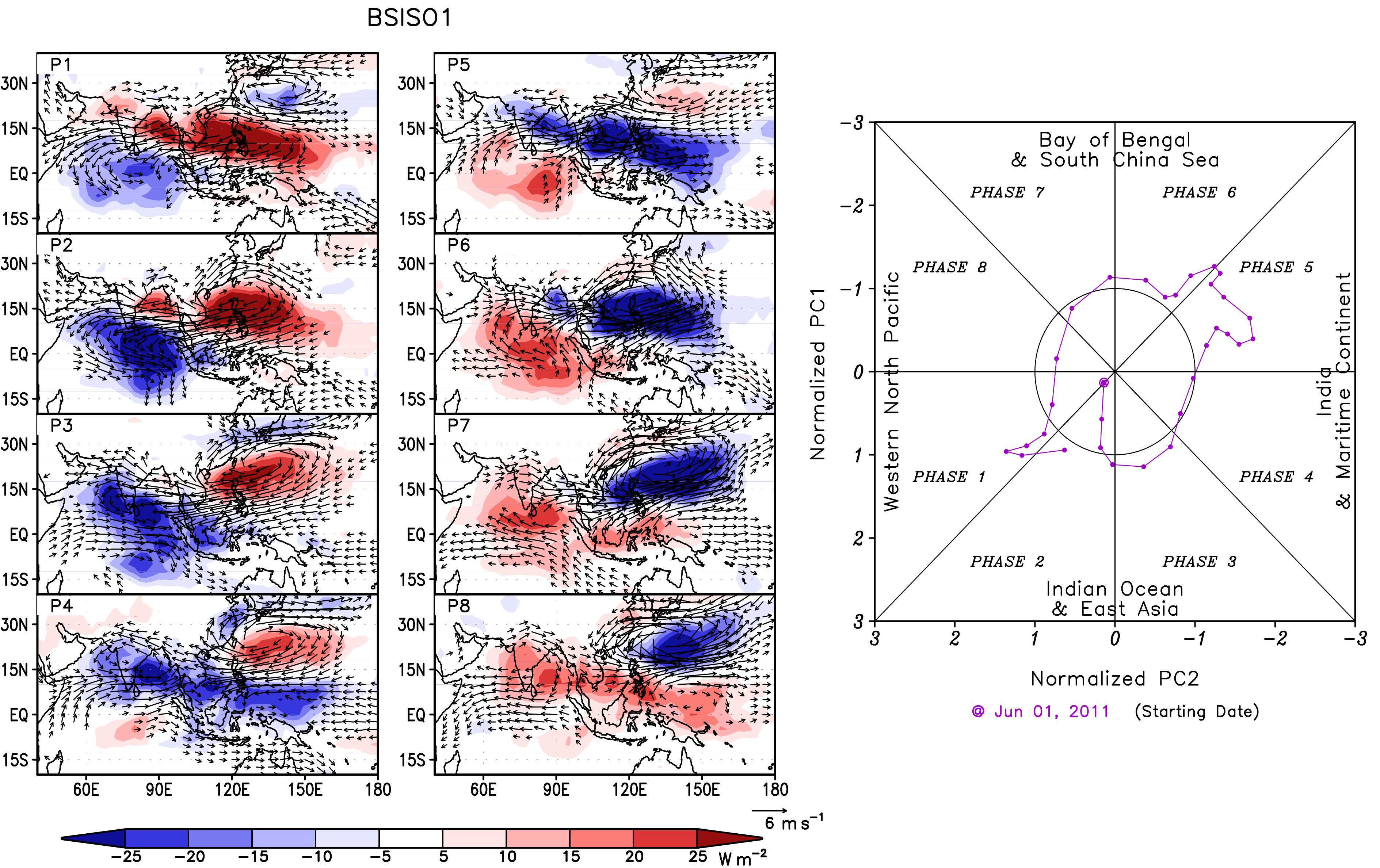


Fig. 9 The life cycle composite of OLR (shading) and 850-hPa wind (vector) anomaly reconstructed based on PC1 and PC2 of BSISO1 in 8 phases.

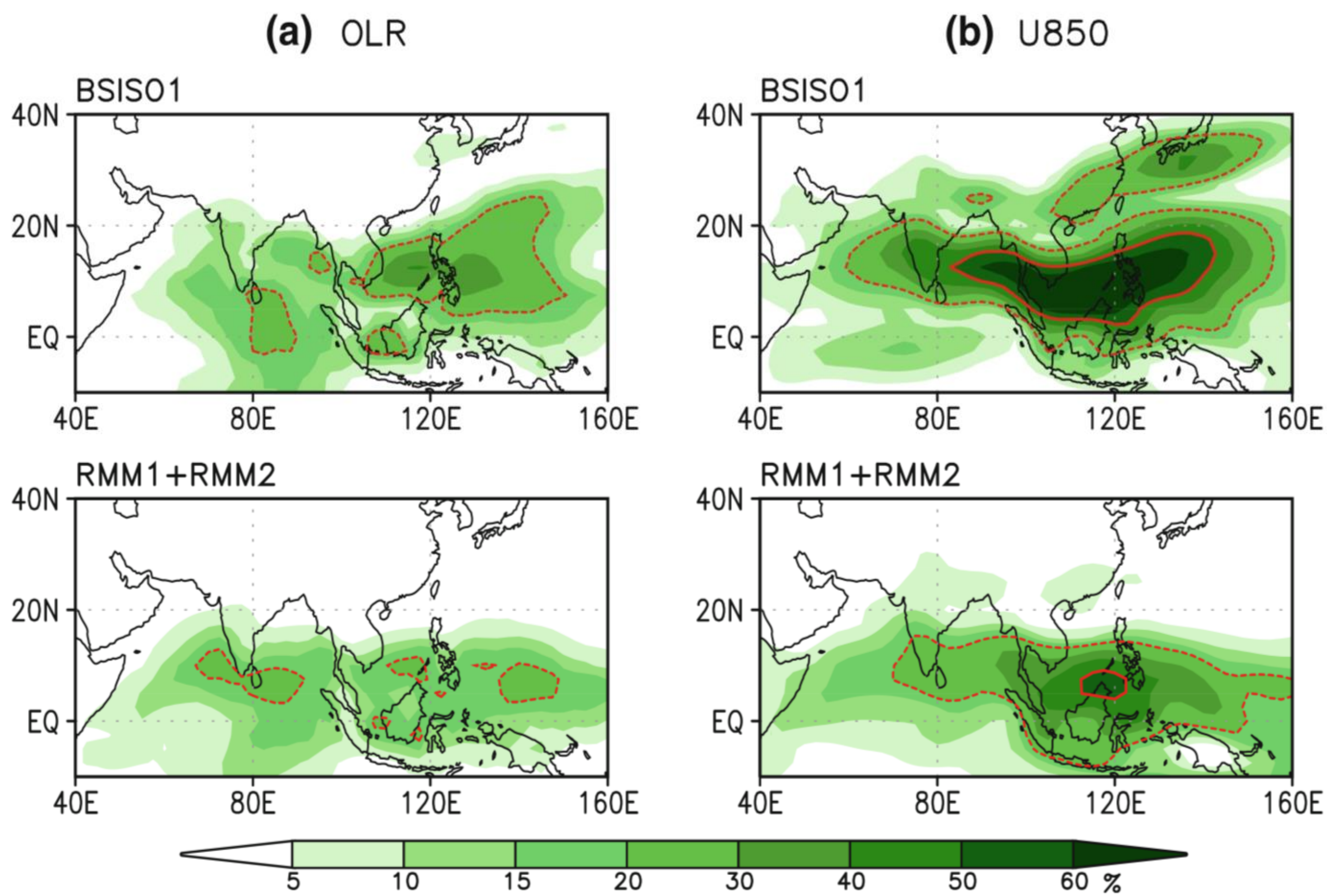
3. Regional BSISO: IO and WNP

References:

Lee, S.-S., and B. Wang, 2016: Regional boreal summer intraseasonal oscillation over Indian Ocean and Western Pacific: Comparison and predictability study. Clim. Dyn., 46, 2213-2229.

Background

- BSISO index (Lee et al. 2013) captures **more fractional variance over the ASM region** than that captured by the MJO index (RMMI) (Wheeler and Hendon 2004).
- However, **due to regional differences between the Indian Ocean (IO) and Western Pacific (WP)**, a uniform BSISO index remains deficient to capture the total variance over the ASM region.



Fractional variance of pentad OLR and U850 anomalies that are explained by the BSISO index and MJO index

------ 20%

—— 50%

Lee et al. (2013)

Question:

Can 'regional ISO modes' capture a more significant portion of total variance over the ASM region than the BSISO's leading modes?

- The **IO and WP are major IS convective activity centers during boreal summer.**
- Maximum IS OLR variance is found over the IO in May-June while it moves to the WP during Aug-Oct. (Kemball-Cook and Wang 2001; Bellenger and Duvel 2007), indicating **different seasonal cycle of ISO over the IO and WP during boreal summer**.
- **ISOs in the IO and WP (IOISO and WPISO) have not been systematically compared based on the well-designed metrics.**

This work aims to

- 1) Establish the regional BSISO measures over the IO and WP in order to improve monitoring and prediction of BSISO.
- 2) Compare regional features of ISO over the IO and WP;
- 3) Examine prediction skill in the current climate models
- 4) Estimate their predictability

How to objectively measure IOISO and WPISO?

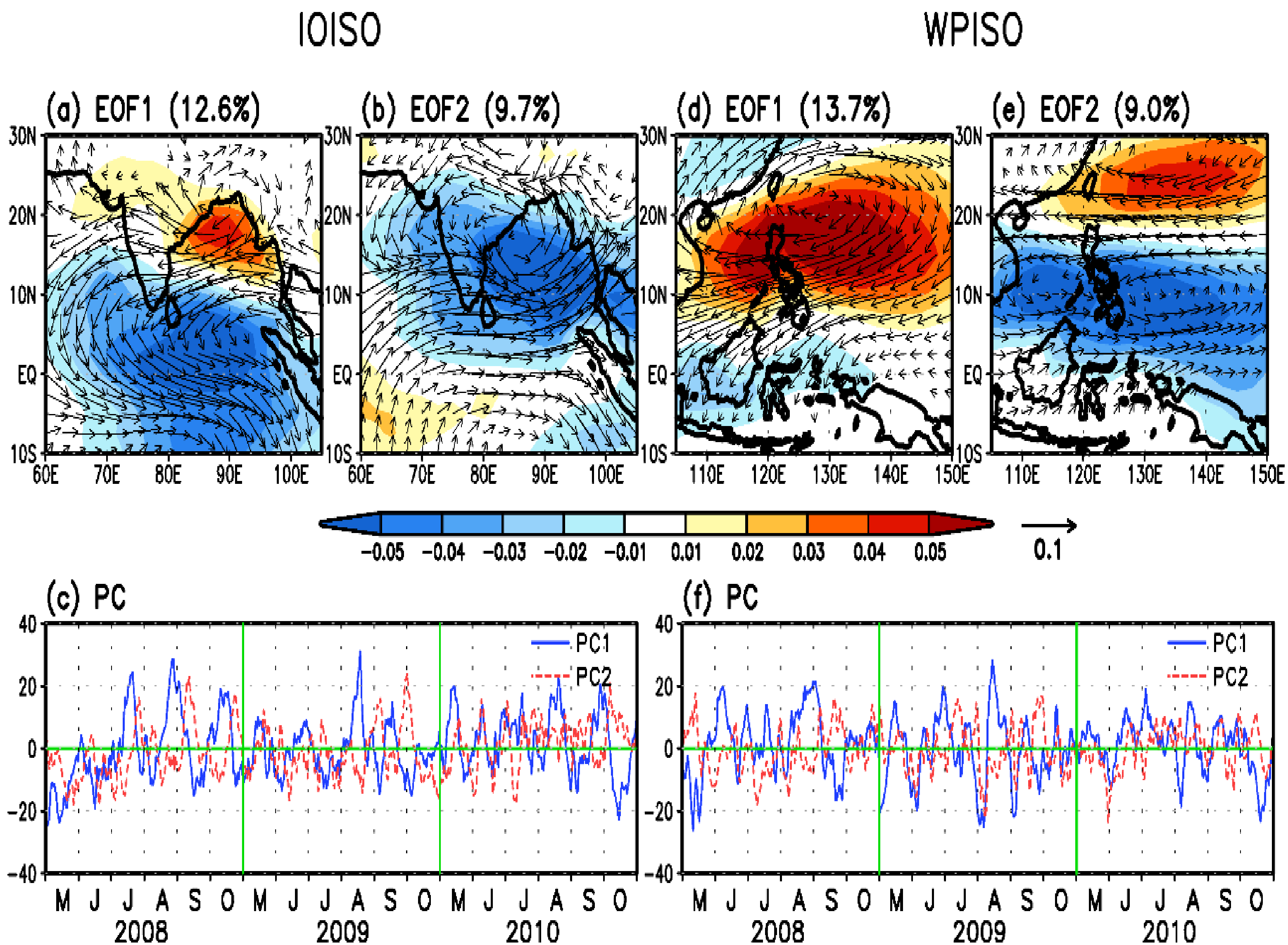
Focus on regional leading mode of BSISO

MV-EOF using daily OLR and U850 anomalies (MJJASO, 1981-2010)

↓ ↓

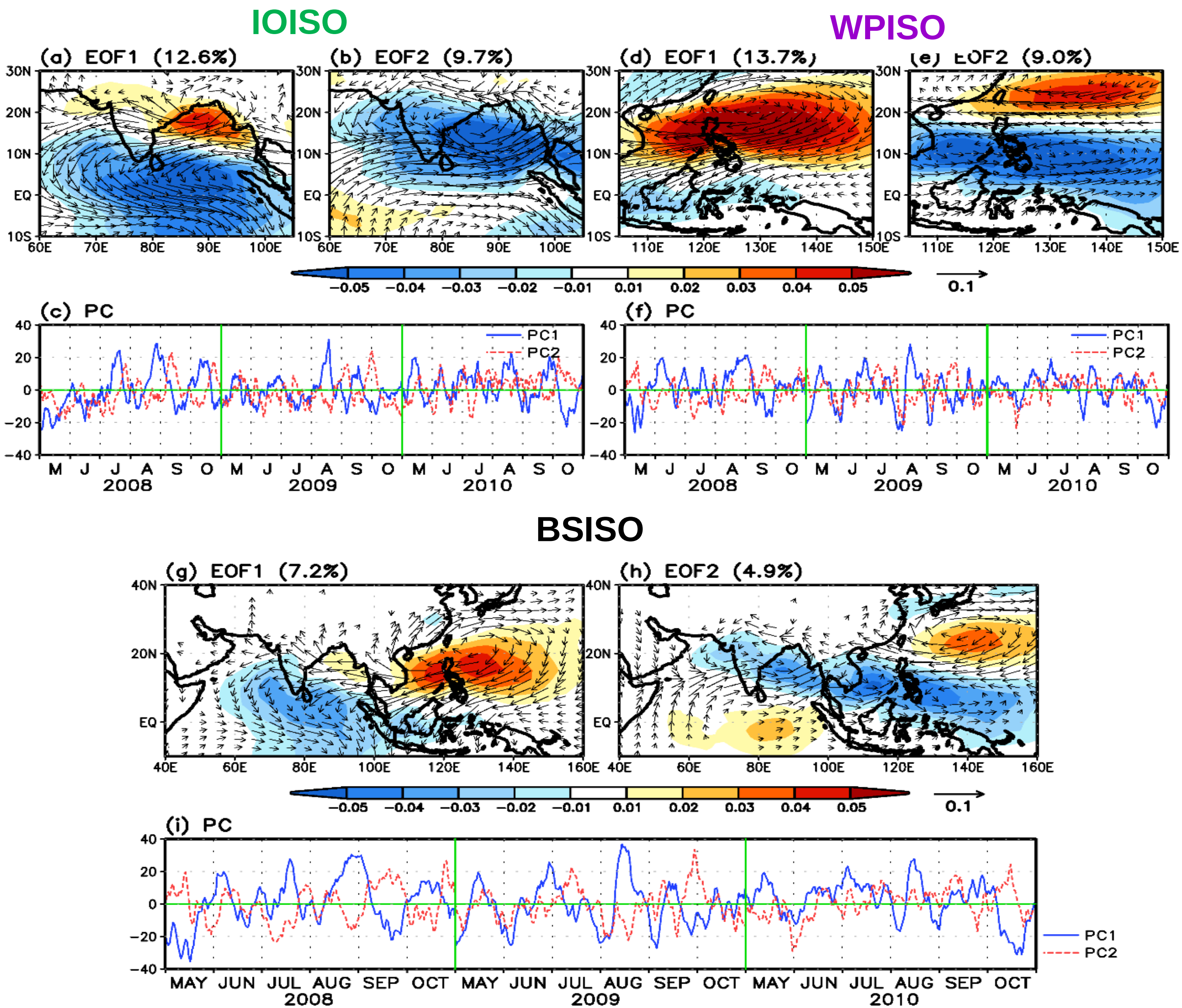
IO domain (10S-30N, 60-105E)	**WP domain (10S-30N, 105-150E)**
↓	↓
Principal modes of IOISO	**Principal modes of WPISO**

Principal modes of IOISO and WPISO



CC (IOISO PC1, WPISO PC1)=0.41 at 0-day lag

→ Out-of-phase pulse **of convection between the IO and WP**

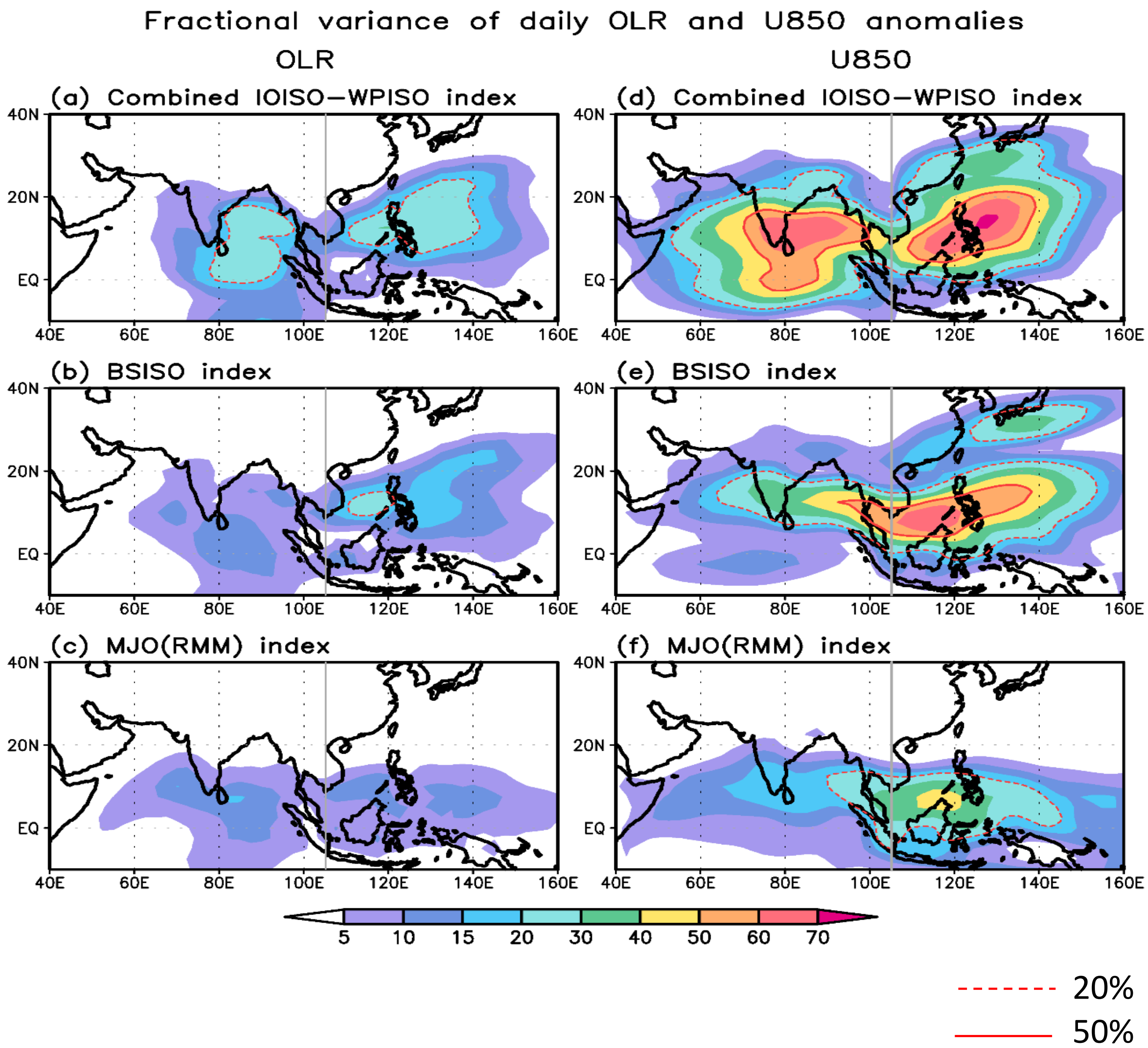


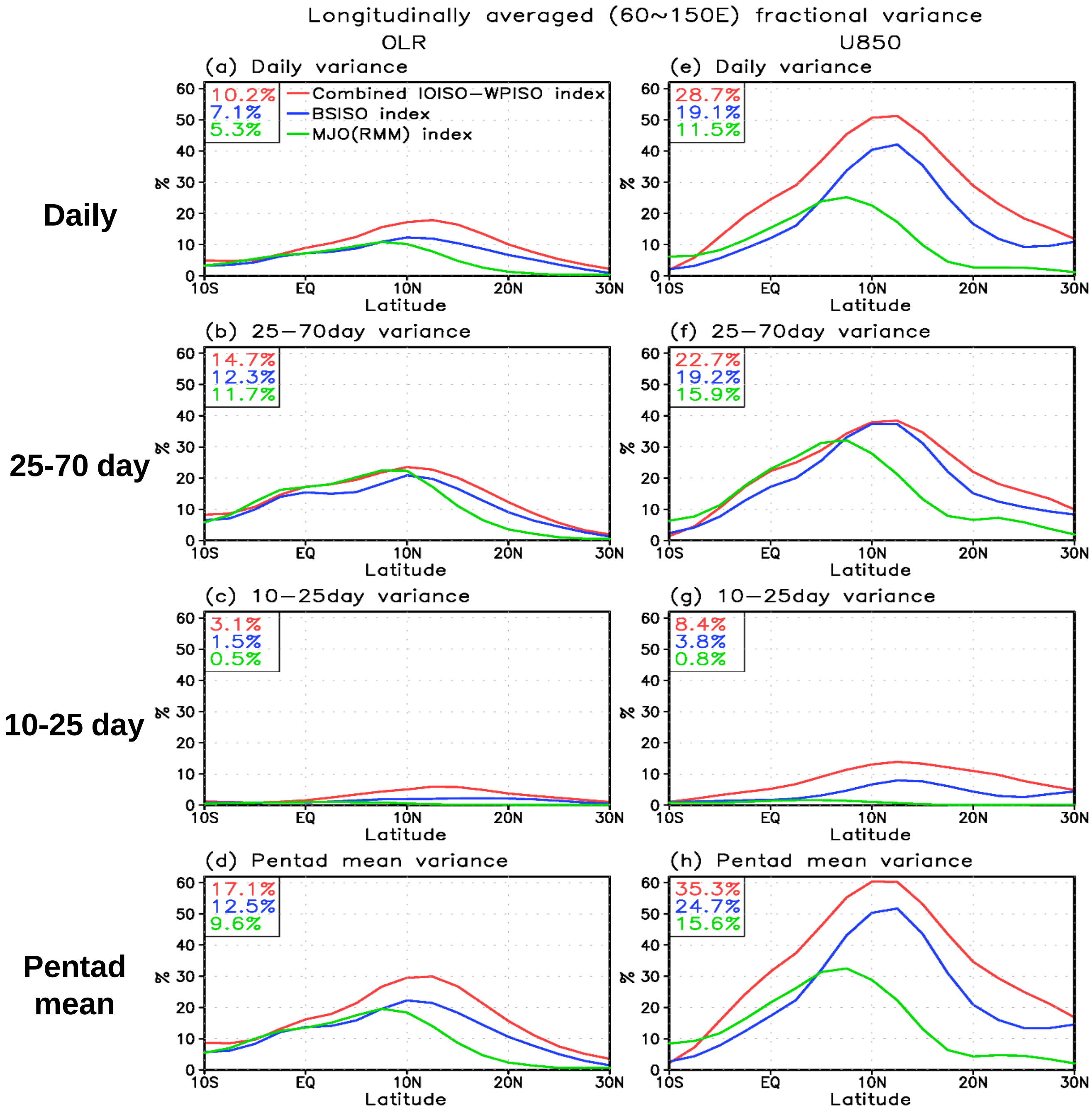
IOISO
WPISO
(a) EOF1 (12.6%)
(b) EOF2 (9.7%)
(d) EOF1 (13.7%)
(e) EOF2 (9.0%)
−0.05 −0.04 −0.03 −0.02 −0.01 0.01 0.02 0.03 0.04 0.05
0.1
(c) PC
(f) PC
PC1
PC2
M J J A S O M J J A S O M J J A S O
2008 2009 2010
BSISO
(g) EOF1 (7.2%)
(h) EOF2 (4.9%)
(i) PC
MAY JUN JUL AUG SEP OCT MAY JUN JUL AUG SEP OCT MAY JUN JUL AUG SEP OCT
2008 2009 2010

Capture more Fractional variance (10S-40N, 40-160E)

- **BSISO index:** PC1/2
  MJO (RMM) index: RMM1/2
- **IOISO index:** PC1/2
  WPISO index: PC1/2
- **Combined IOISO-WPISO index**: Combination of the IOISO and WPISO index

- For the calculation of fractional variance, **IOISO index** was applied only for the region of **west of 105E** and **WPISO index** was used only for the region of **east of 105E.**



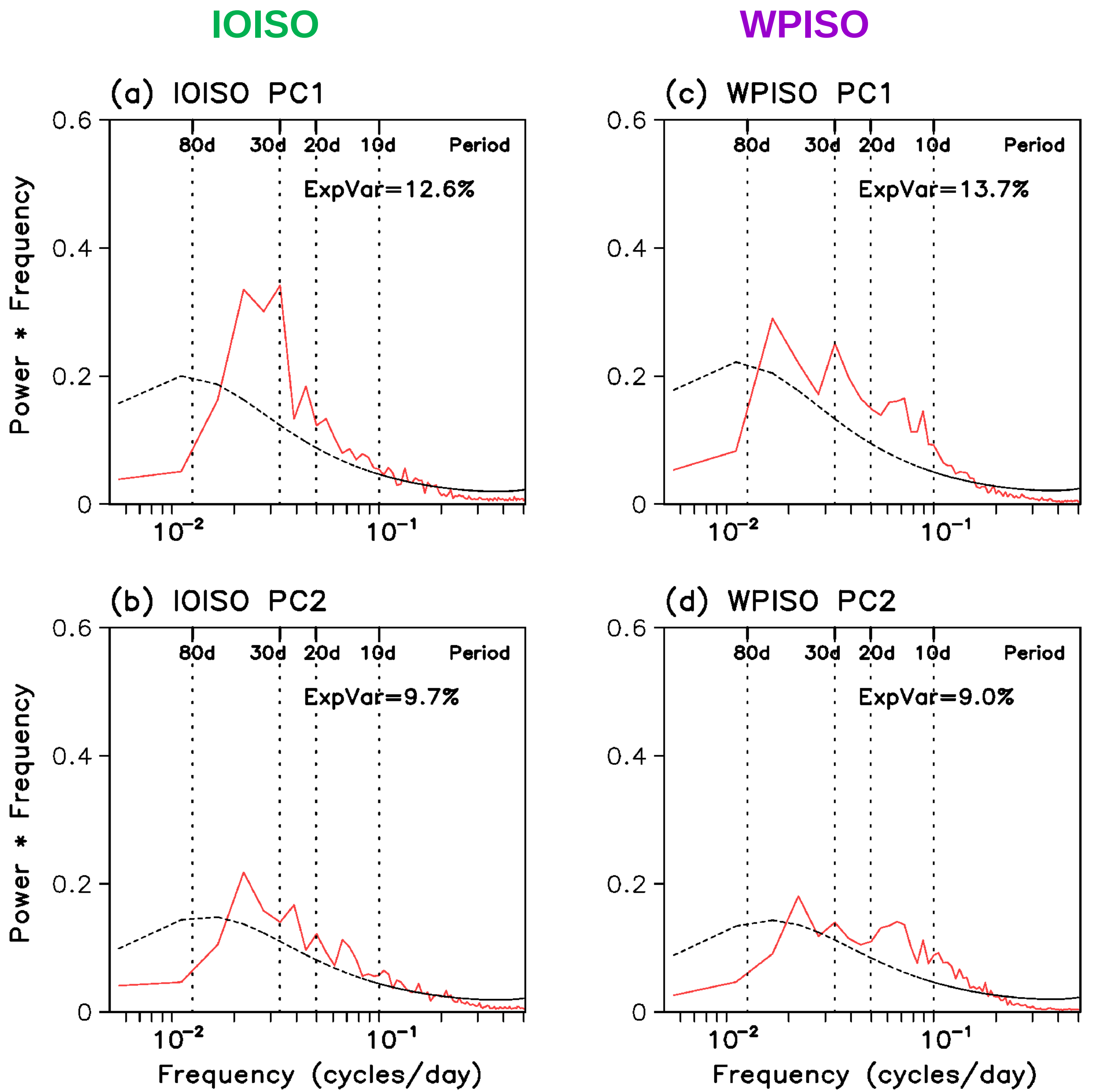


Capture more fractional variance: 10S-30N,60-150E

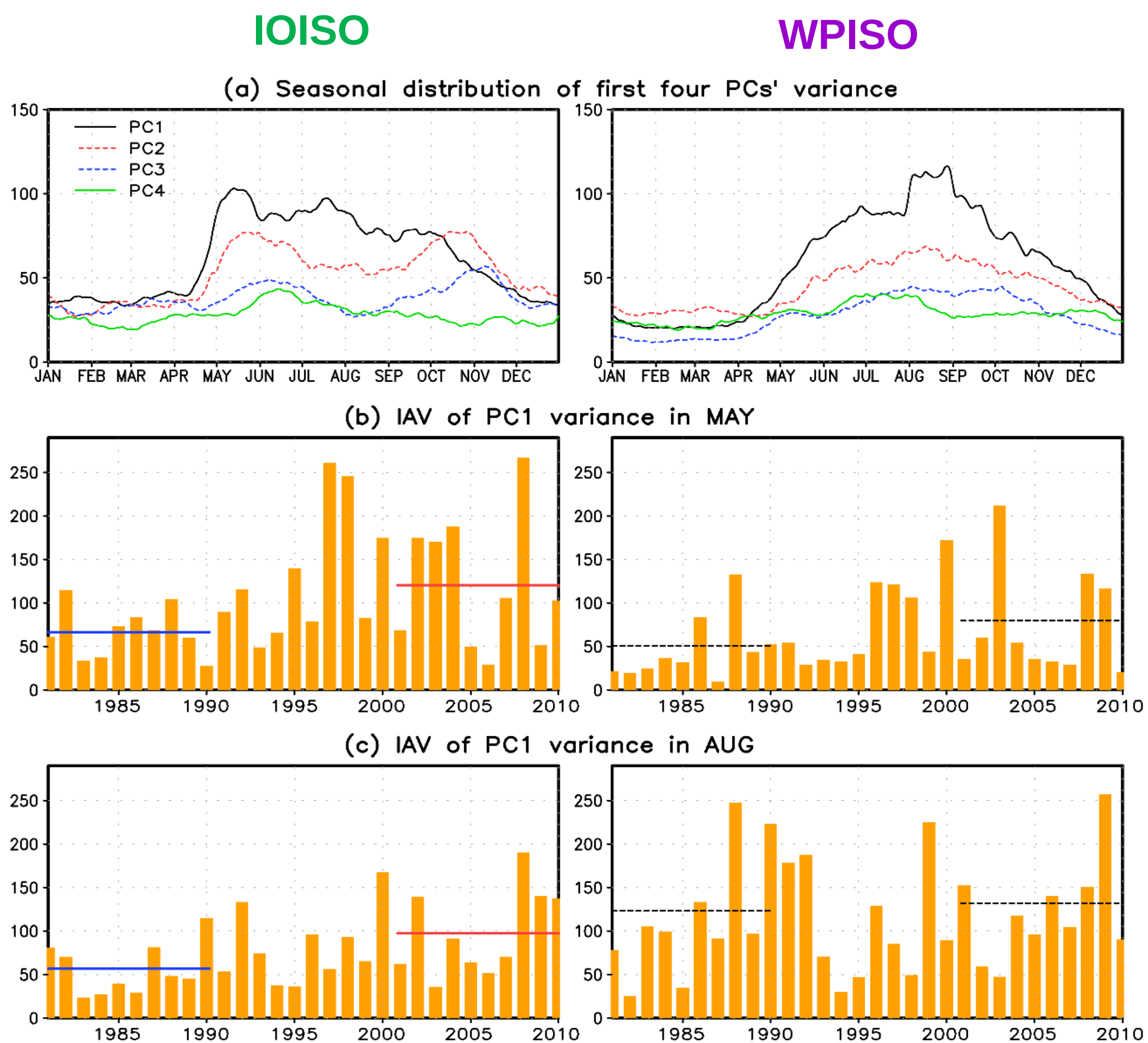
- **The combined IOISO-WPISO index captures about 30% (10%) of daily U850 (OLR) variance**, which doubles that captured by the MJO index and is 50% higher than that captured by the BSISO index.
- The combined index also shows **superior performance in representing biweekly and pentad-mean variations in the Asian-Pacific summer monsoon region (north of 10N)**.

Comparison of IO and WP ISO: Periodicity

- **IOISO: 30-45 days periodicity**
- **WPISO: multi-time scale variability including biweekly, 30 day, and 60 day**



Comparison: Seasonality and interannual variability



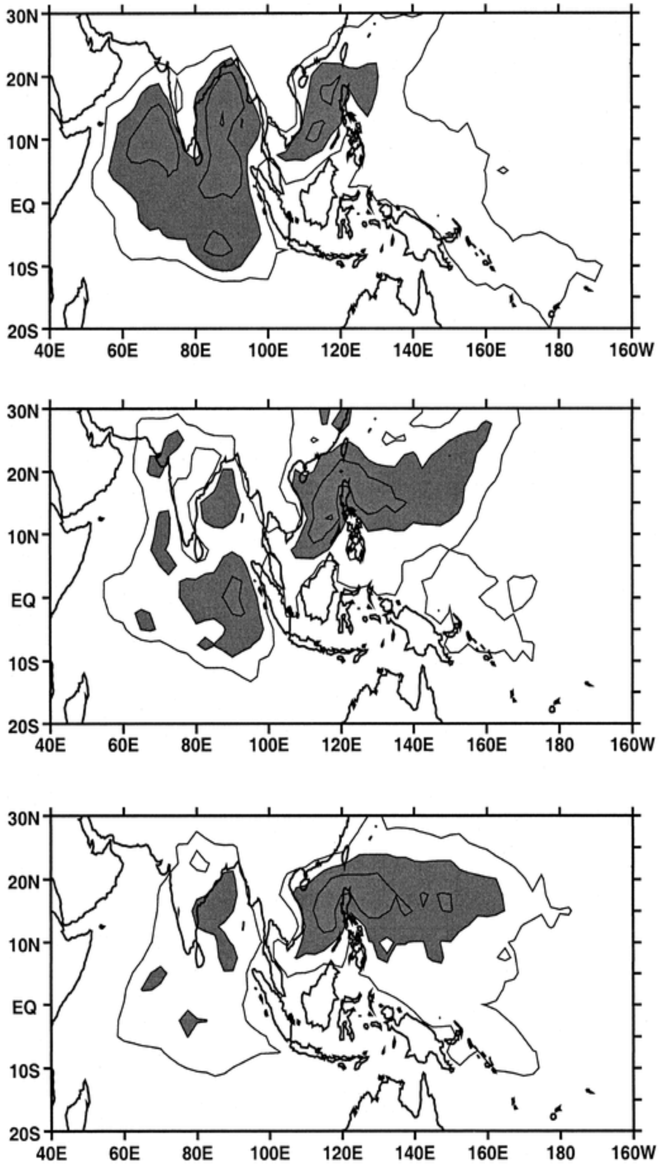
- PC1 peak in May- Double peaks of PC2 & PC3

- Significant interdecadal trend

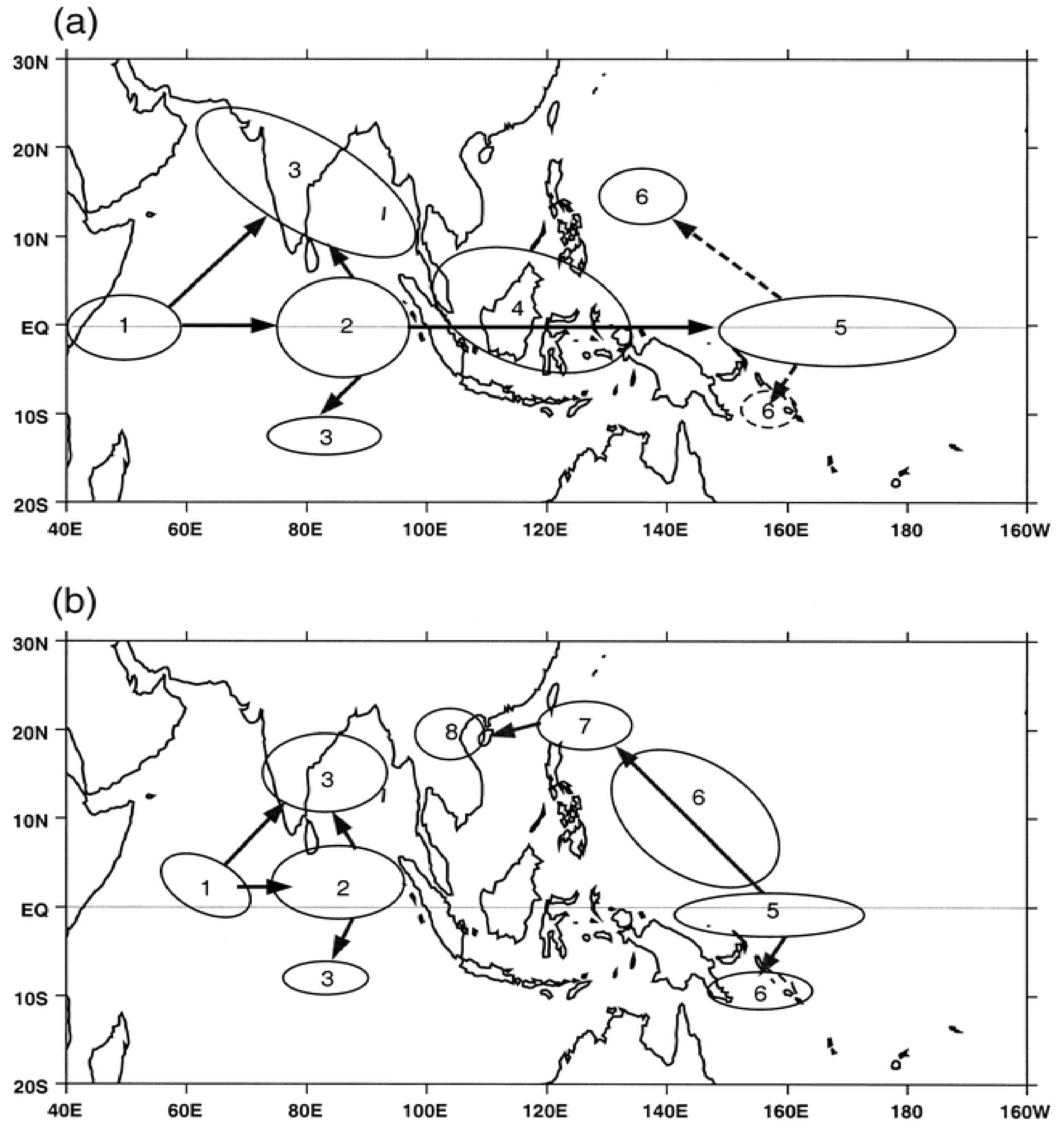
- PC1 peak in Aug.

- No significant interdecadal trend

ISO variance pattern



Sub-seasonal variation

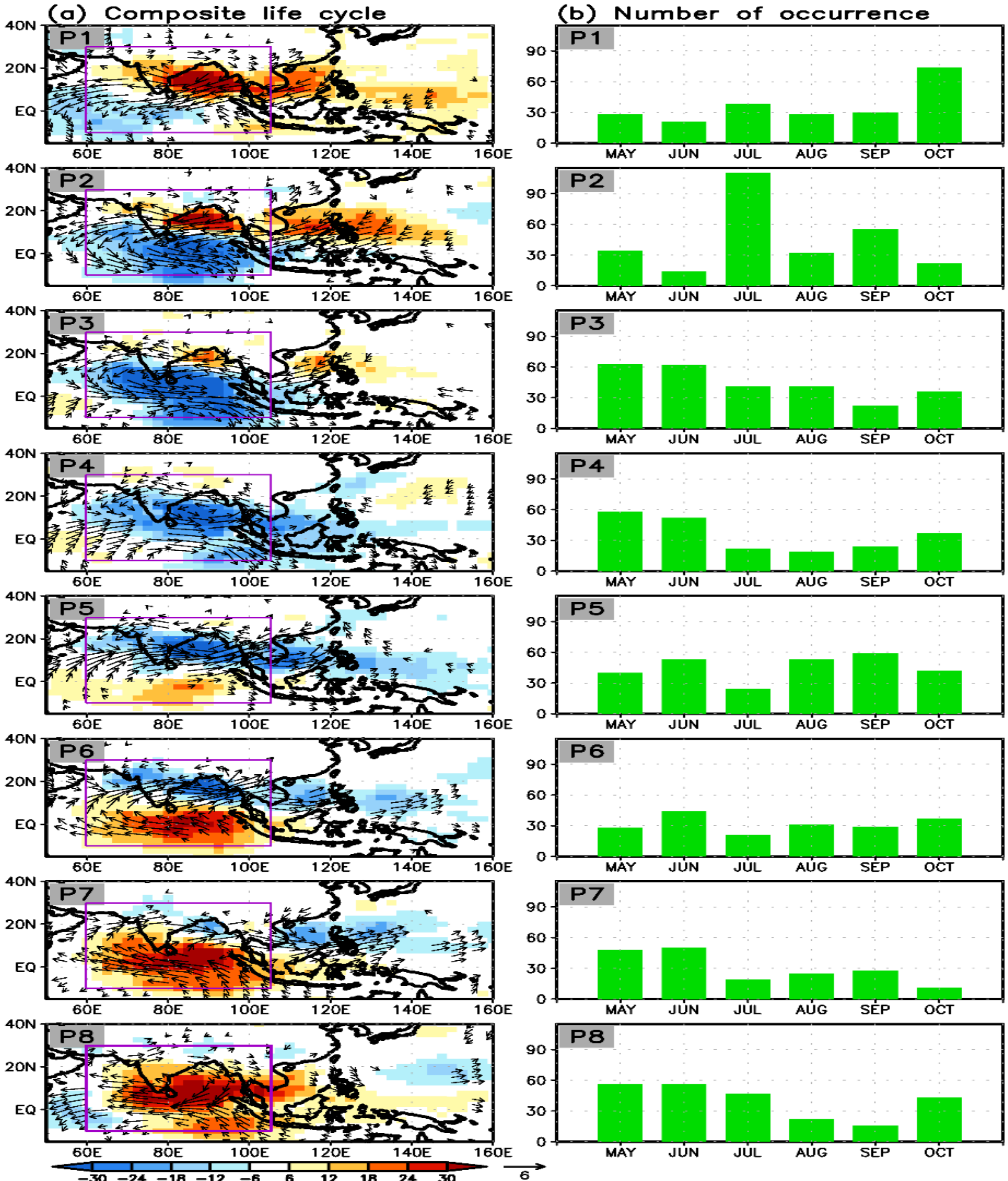


Camball-Cook and Wang 2001

IOISO life cycle

NE-propagation

Composite life cycles with strong amplitude [$(PC1^2 + PC2^2)^{1/2} > 1.50$] and its occurrence →



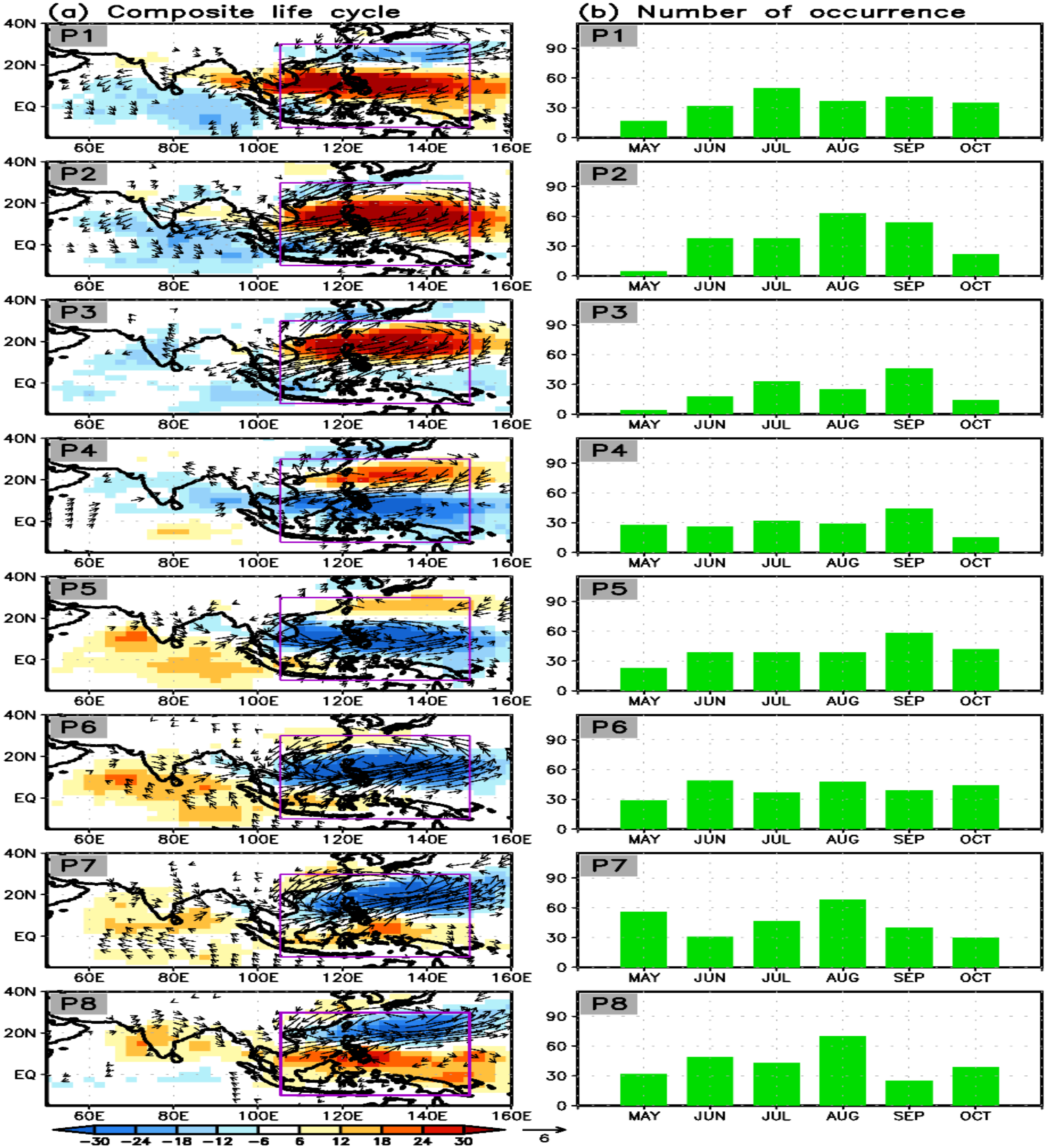
Season Reliant

-- Higher frequency of strong events in May, June, Oct.

WPISO life cycle season-Reliant

N-propagation - High frequency of strong events in August and September

Composite life cycles with strong amplitude [$(PC1^2 + PC2^2)^{1/2} > 1.50$] and its occurrence →



4. Predictability study of regional BSISO

Lee, S.-S., B. Wang, D. Waliser, J.M. Neena, and J.-Y. Lee, 2015: Predictability and prediction skill of the boreal summer intraseasonal oscillation in the Intraseasonal Variability Hindcast Experiment. Clim. Dyn., published online

Lee, S.-S. and B. Wang, 2015: Regional boreal summer intraseasonal oscillation over Indian Ocean and Western Pacific: Comparison and predictability study. Clim. Dyn., in revision

Methodology

Calculation of BSISO index in observation and hindcast

- Following Lee et al. (2013)

- MV-EOF analysis of daily anomalies of OLR and U850 over [10°S-40°N, 40°E-160°E]

-In present study, focusing on BSISO1 (PC1 & PC2)

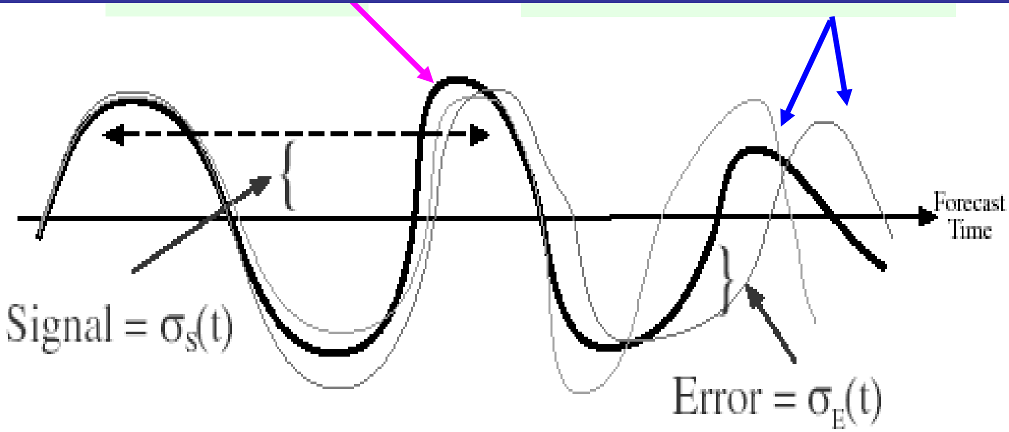
Estimation of predictability and prediction skill

- Single member method and ensemble mean method (Mani et al. 2014)

- Perfect model assumption

- Predictability of BSISO is defined as forecast lead day when mean forecast error becomes as large as the mean signal.

Signal to Error ratio estimate of MJO/ISV predictability



Initial Condition Differences Based On Forecasts 1 Day Apart

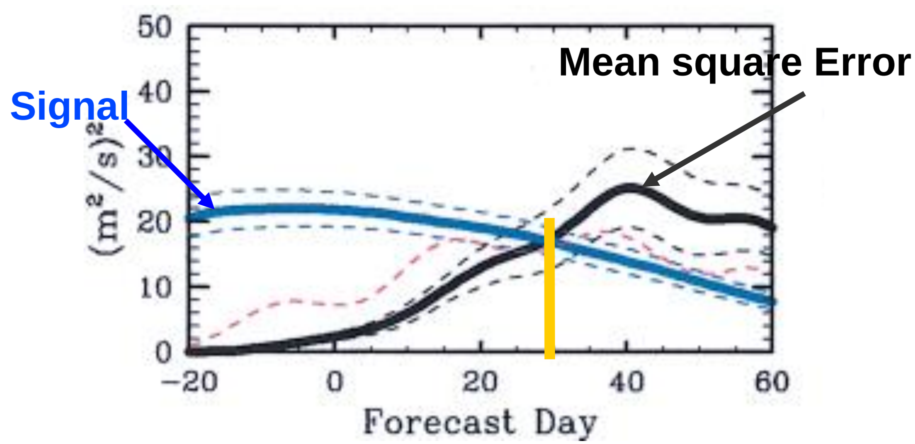
Signal (L=25 days)

$$\sigma^2_{S_{ij}} = \frac{1}{2L+1}\sum_{\tau=-L}^{L}(X^0_{i,j+\tau})^2$$

Error

$$\sigma^2_{E_{ijk}} = (X^k_{ij} - X^0_{ij})^2$$

$$X^0_{ij} = \begin{cases} \text{Predictability = Model Control} \\ \text{Prediction Skill = Observations} \end{cases}$$



As in
Waliser et al. (2003, 2004);
Liess et al. (2005); Fu et al. (2007)
Except using a modern indices
(e.g. RMM1 & RMM2 for MJO)

Bivariate estimates of Signal and Error

$$E^2_{ij} = (RMM1^{k1}_{ij} - RMM1^{k2}_{ij})^2 + (RMM2^{k1}_{ij} - RMM2^{k2}_{ij})^2$$

$$S^2_{ijk} = 1/51 \times \sum_{t=-L}^{L}(RMM1_{ik\,j+t})^2 + (RMM2_{ik\,j+t})^2$$

Predictability and prediction skill of IOISO & WPISO

* **Strong IOISO/WPISO initial condition**:
sqrt(OBS PC1^2 + OBS PC^2) at forecast lead day 0 > 1.5

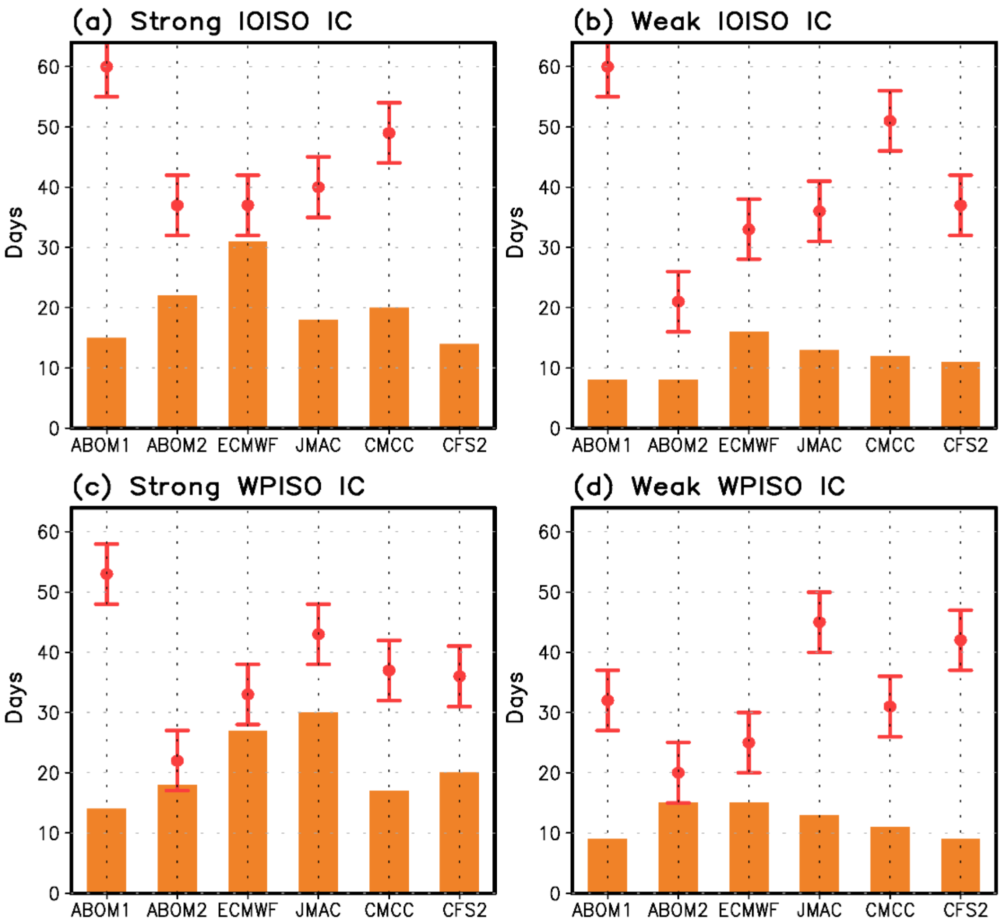
* **Weak IOISO/WPISO initial condition**:
sqrt(OBS PC1^2 + OBS PC^2) at forecast lead day 0 < 0.8

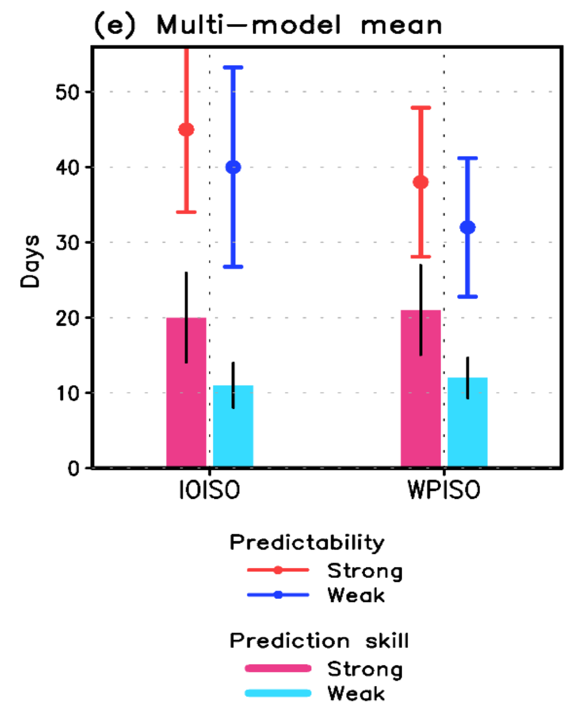
Multi-model mean

Predictability	Strong	Weak
IOISO	45 days	40 days
WPISO	37 days	33 days

Prediction skill	Strong	Weak
IOISO	20 days	11 days
WPISO	21 days	12 days

Predictability and prediction skill by ensemble-mean method



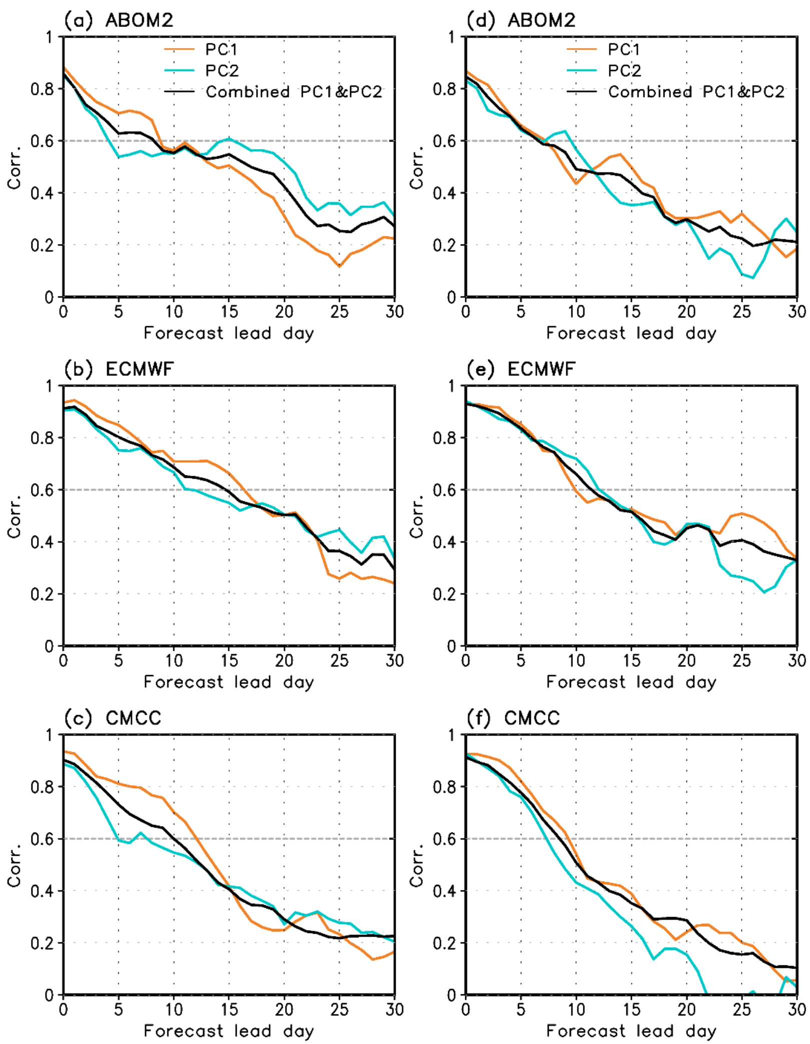


Dependence of initial season: Correlation skill

* Selected 3 models: Initialized 1st day of every month

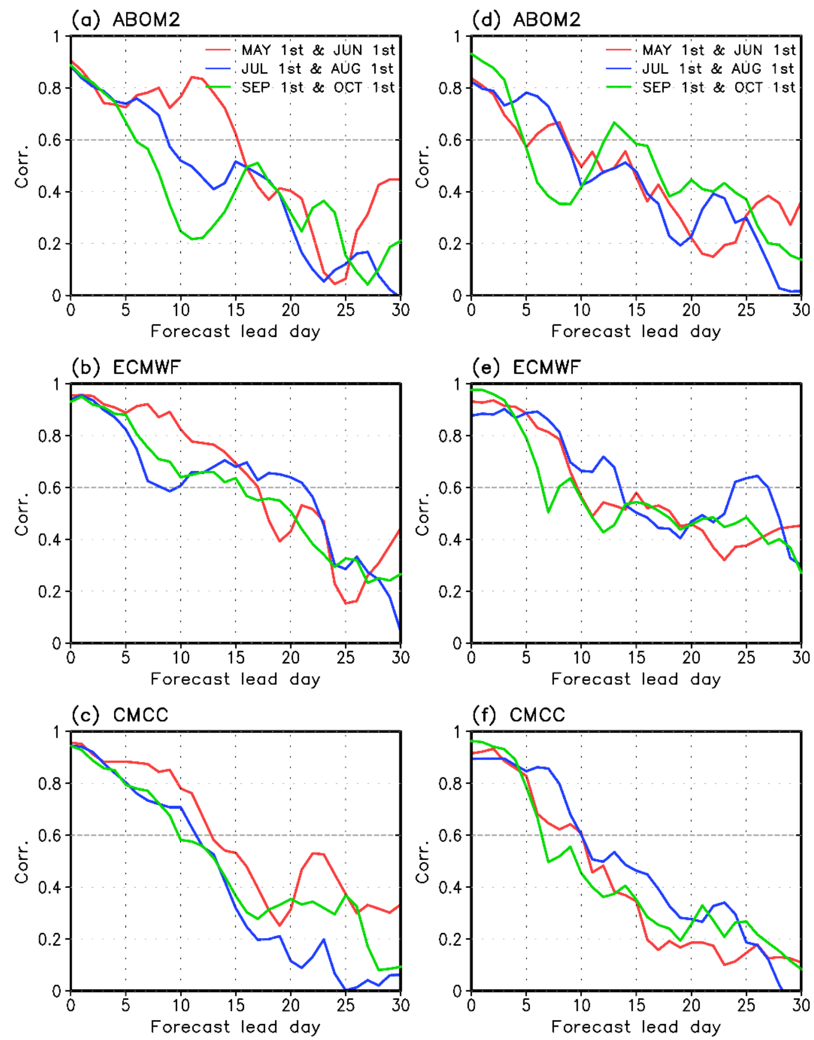
All summer initial conditions (PC1 & PC2)

IOISO **WPISO**



Different initial conditions (PC1)

IOISO **WPISO**

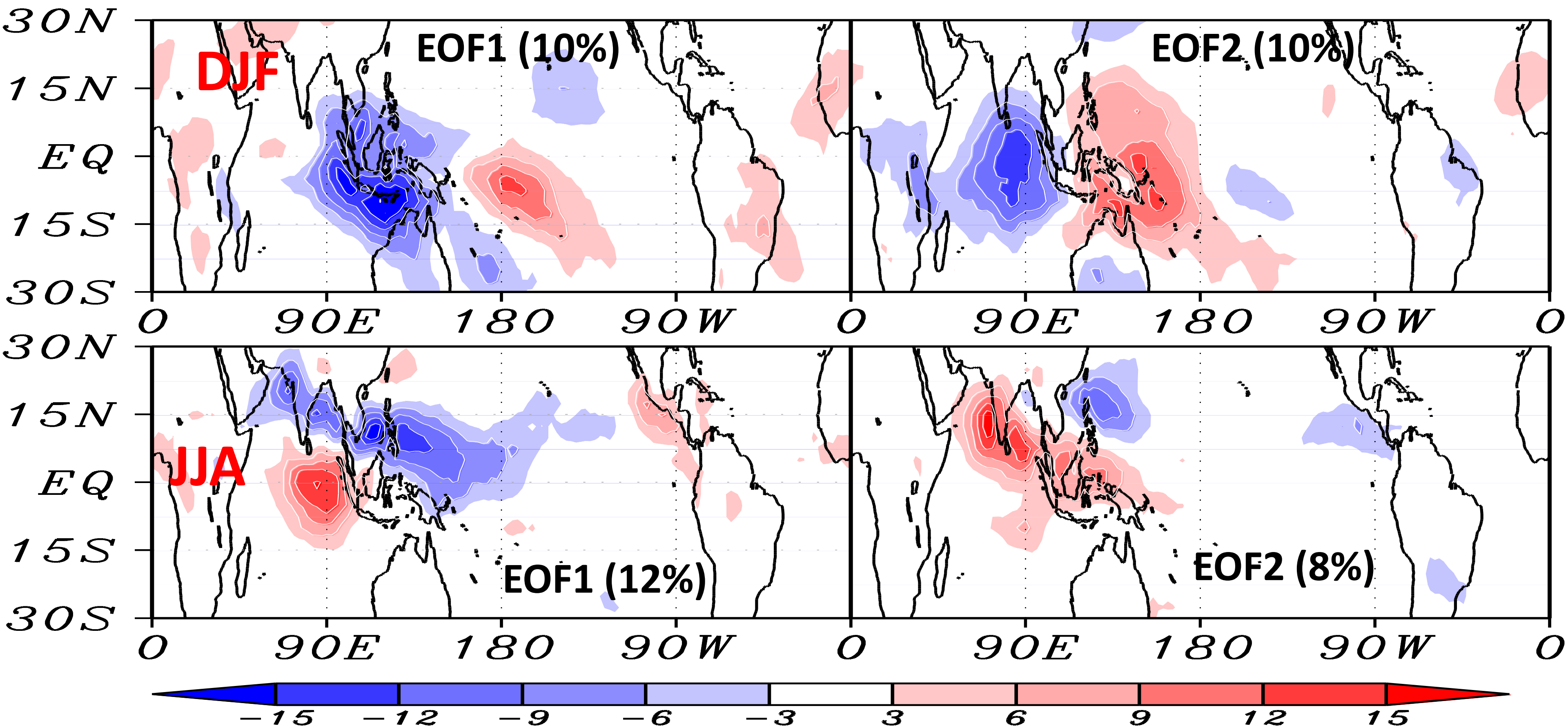


Summary

- To better capture BSISOs, we investigate **spatial-temporal structures of IOISO and WPISO individually by examining the corresponding leading modes (OLR & U850)**.
- The **combined IOISO-WPISO index captures about 30% (10%) of daily U850 (OLR) variance over the entire IO-WP region (10S-30N, 60-150E)**, which doubles that by the MJO index and is 50% higher than that by the BSISO index.
- The **IOISO** features a **NE propagation** with a **30-45 day energy peak** and the **PC1 has maximum variance in May**, while the **WPISO** propagates **northward** with a broad spectral peak on **10-60 days** and the **PC1 has maximum variance in August**.
- The **IOISO PC1** variance in May and August exhibits **a significant interdecadal trend**.
- Several phases of the IOISO and WPISO show **different seasonal preference** for their occurrences.
- The **multi-model mean estimate of the predictability is 40-45 days for the IOISO index, whereas 33-37 days for the WPISO index**, depending on the initial amplitude.
- The **multi-model mean prediction skill is significantly higher with large initial amplitude** (~20 days for two indices) than that with small initial amplitude (~11 days).

THANK YOU !

Principal Modes of ISO (30-60 day) during DJF and JJA, 1979-2010



Do we need a bimodal representation of Tropical ISO?

Kikuchi, et al., 2011 Climate Dyn