



Definition of Monsoon ISO Index and Its Predictability

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Content

1. THE RATIONALE FOR DEFINING MISO INDEX

- ◆ Limitation of the **Realtime Multivariate MJO (RMM)** index
(Wheeler and Hendon 2004)
- ◆ Limitation of the **regional monsoon indices**

2. IDENTIFICATION OF THE DOMINANT MODES FOR MISO

- ◆ WNP and East Asian Monsoon Region (MISO-WEM)
: Northward and westward propagating components (2)
- ◆ Indian Monsoon Region (MISO-IM)
: Northward and east-northward propagating components (2)
- ◆ Equatorial Monsoon Region (RMM)
: Eastward propagating component (1)

3. HOW TO DETERMINE THE OPTIMAL MISO INDEX

- ◆ **Fractional variance** explained by the reconstructed field from the MISO index
- ◆ **Forecast skill** of the reconstructed field from the predicted MISO index

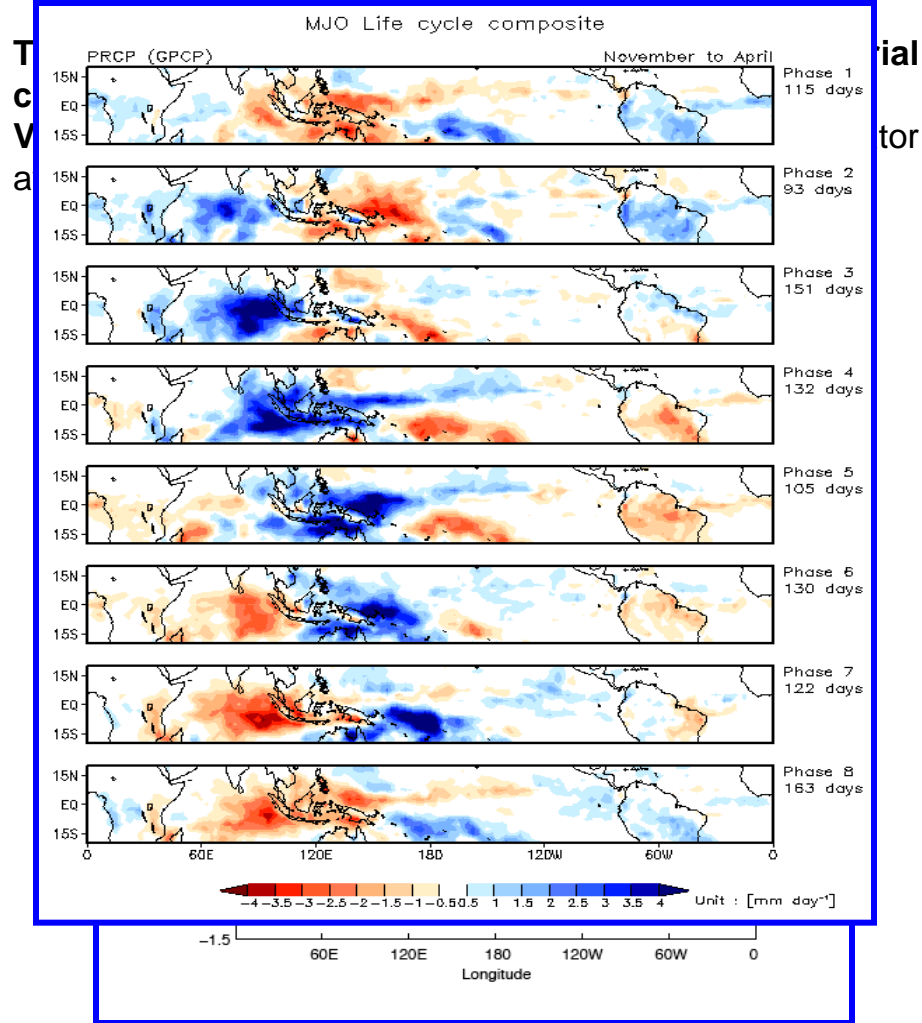
4. STATISTICAL VS DYNAMICAL MISO FORECAST

- ◆ Comparison with UH Hybrid Coupled Model (UH HCM) forecast

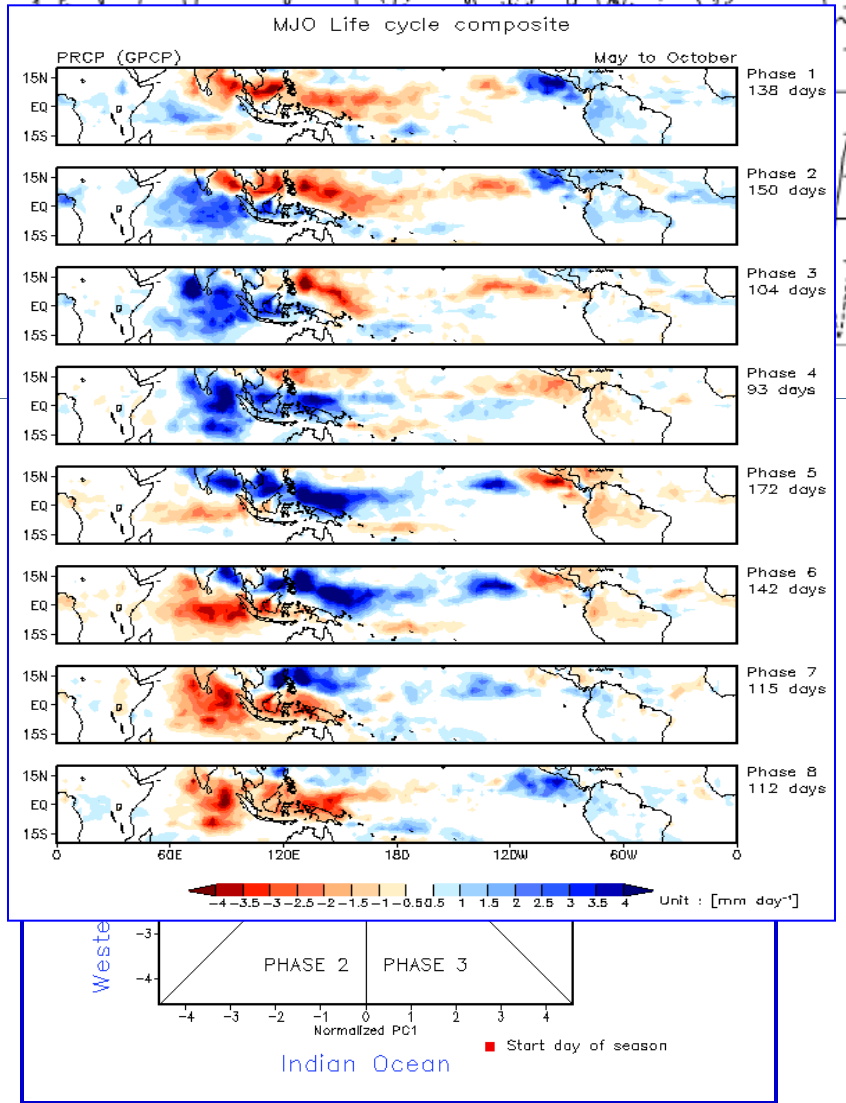
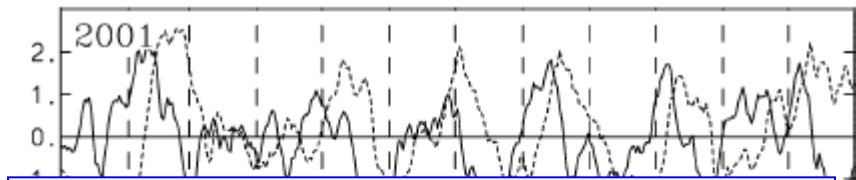


The Rationale for Defining MISO Index in Boreal summer

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



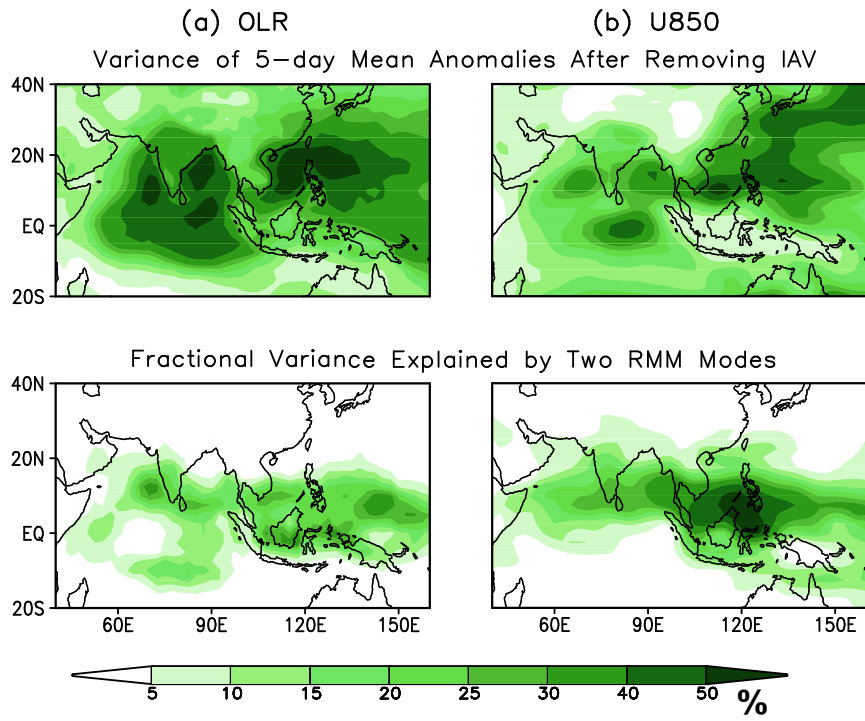
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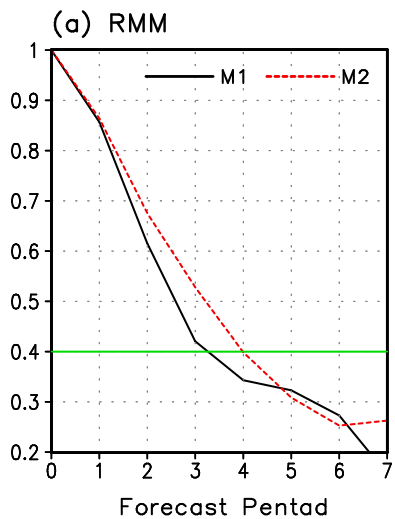
The Rationale for Defining MISO Index in Boreal summer

1. RMM index has limitation to explain ISO variability over major monsoon regions in boreal summer.

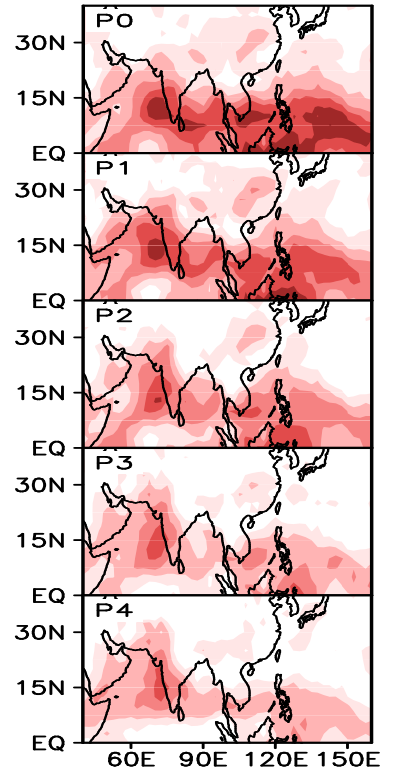


2. Statistical Monsoon ISO prediction based on RMM index has low forecast skills especially over the Western North Pacific and East Asian monsoon region.

Temporal Correlation Skill for two modes of RMM index (5-day mean)



Temporal Correlation Skill for reconstructed OLR anomaly based on predicted RMM Index using statistical model





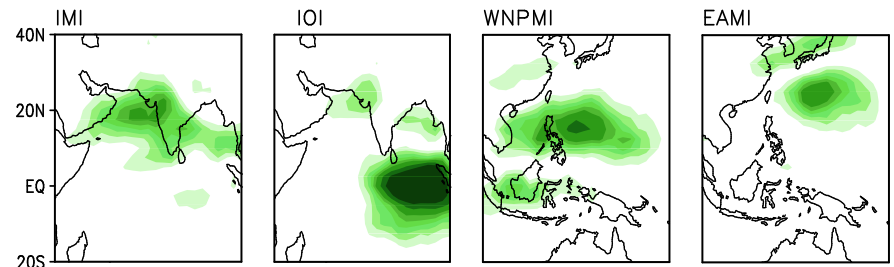
The Rationale for Defining Monsoon Intraseasonal Oscillation (MISO) Index in Boreal summer

Regional Monsoon ISO Indices

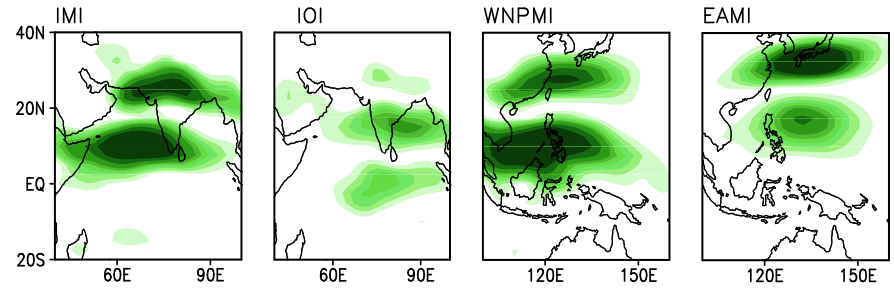
- **IMI** (Indian Monsoon Index, Wang et al. 2001): $U850(40-80E, 5-15N) - U850(60-90E, 20-30N)$
- **IOI** (Indian Ocean Index): $OLR(80-100E, 5S-5N)$
- **WNPMI** (Western North Pacific Monsoon Index, Wang and Fan 1999): $U850(90-130E, 5-15N) - U850(110-140E, 22.5-32.5N)$
- **EAMI** (East Asia Monsoon Index, Ha et al. 2005) : $SQRT(U850^2 + V850^2)$ (125-145E, 30-35N)

Fractional Variance Explained by Each Index

(a) OLR

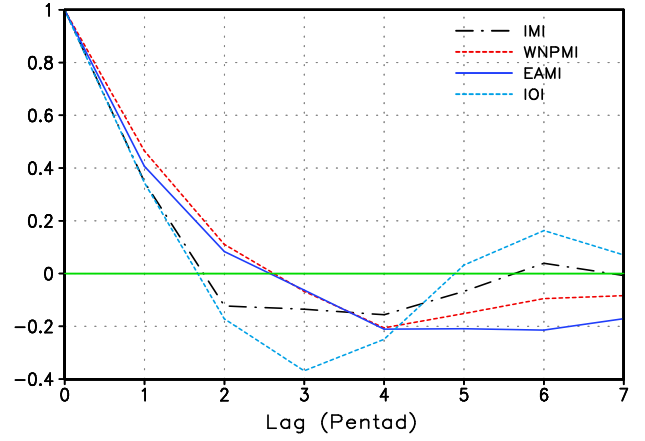


(b) U850



Each regional monsoon index is just capable to explain ISO variability over the region in which the index was defined.

Auto Correlation



Unfiltered pentad-mean anomaly of each monsoon index has low predictability in terms of auto correlation and lag correlation between indices.



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3. HOW TO DETERMINE THE OPTIMAL MISO INDEX

- ◆ Fractional variance explained by the reconstructed field from the MISO index
- ◆ Forecast skill of the reconstructed field from the predicted MISO index

4. STATISTICAL VS DYNAMICAL MISO FORECAST

- ◆ Comparison with UH Hybrid Coupled Model (UH HCM) forecast



Identification of Dominant Modes of MISO

5 Dominant Propagating Components in MISO

(1) 2 components for Western-North Pacific East Asian Monsoon (MISO-WEM)

Method: Multivariate EEOF analysis over the WEM region (100-160E, 10S-40N) using OLR, U850, and V850 (window: 0, -5, -10, -15 pentads)

2 Components: PC 1 & 2 (northward propagation), PC 3 & 4 (westward propagation)

(2) 2 components for Indian Monsoon (MISO-IM)

Method: Multivariate EEOF analysis over the IM region (40-100E, 20S-30N) using OLR, U850, and V850 (window: 0, -5, -10, -15 pentads)

2 Components: PC 1 & 2 (northward propagation), PC 3 & 4 (east-northward propagation)

(3) 1 component for equatorial propagating mode (RMM)

Method: Multivariate EOF analysis using OLR, U850, V850 along the equator averaged between 15S and 15N

1 Component: PC1 & 2 (east-northward propagation)

Data Process

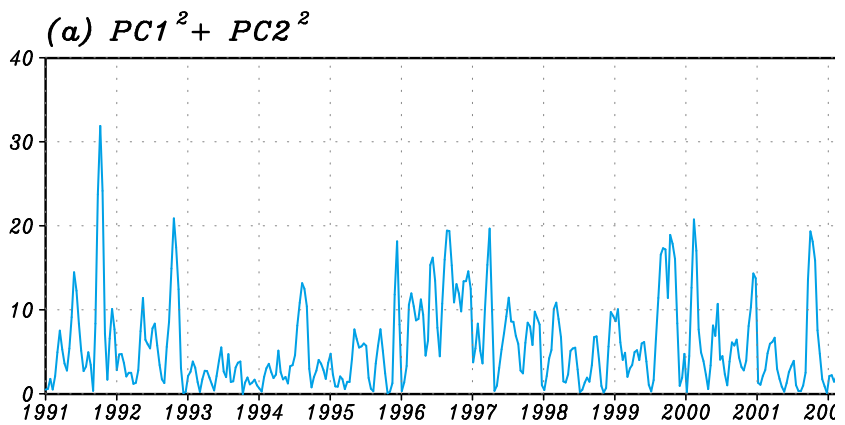
- **Variables :** Pentad mean OLR, U850, V850, and U200
- **Data Period:** MJJAS 1981-2007
- Removal of the first 3 harmonics in climatological annual cycle
- Removal of the effect of ENSO signal through subtracting last 120 day mean and regressed component against Nino 3.4 index
- Normalization of each of three fields by area averaged temporal standard deviation
- ✓ Filtering is not applied to define MISO index for monitor and forecast purpose



Component 1: MISO-WEM [100-160E, 10S-40N]

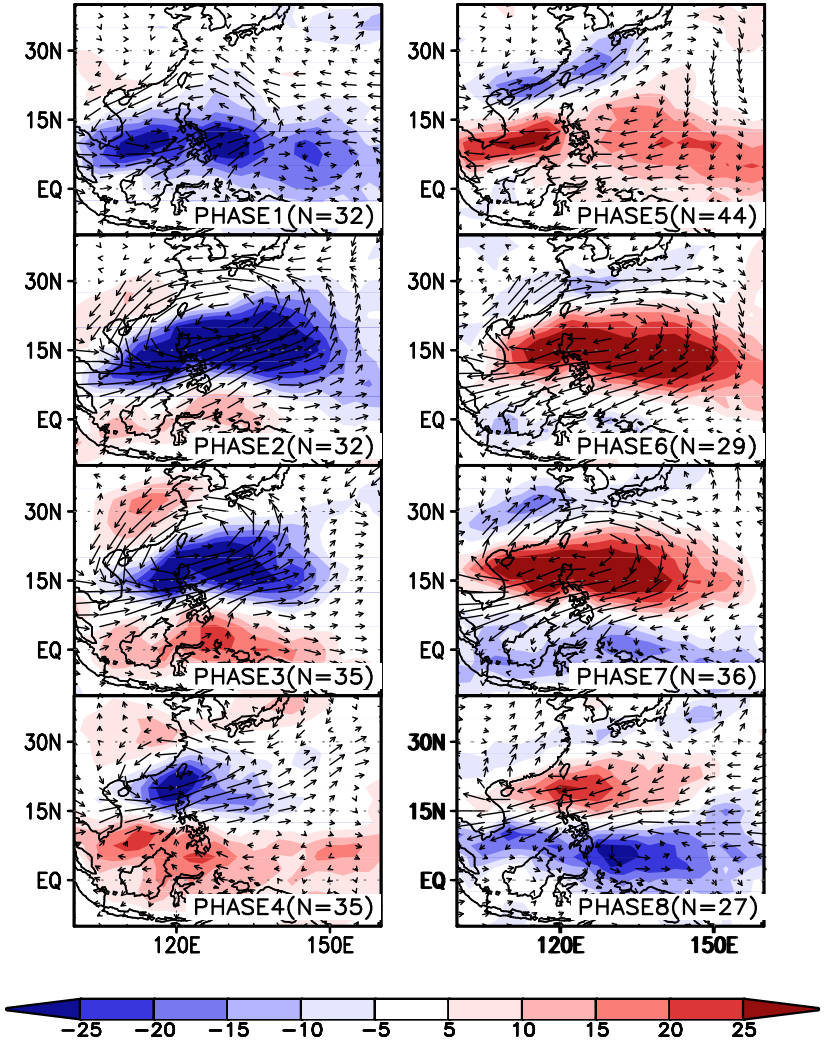
(EEOF Mode 1 and 2 (12.82%), Northward Propagating Modes)

Amplitude of Principal Compor

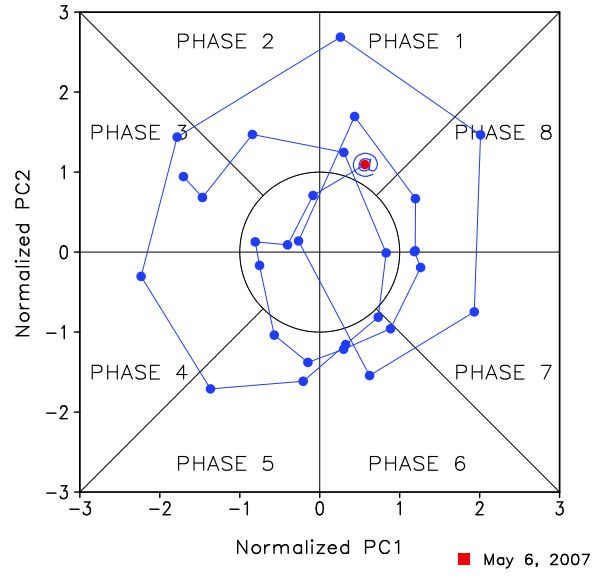


Life Cycle Composite

(a) Mode 1 & 2



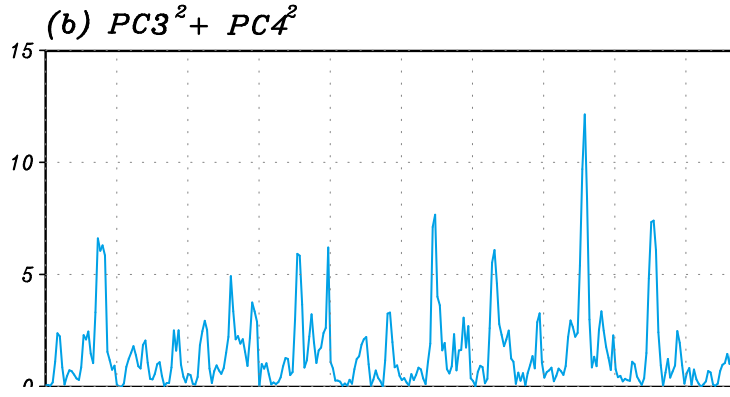
Phase Diagram of PC1 and PC2





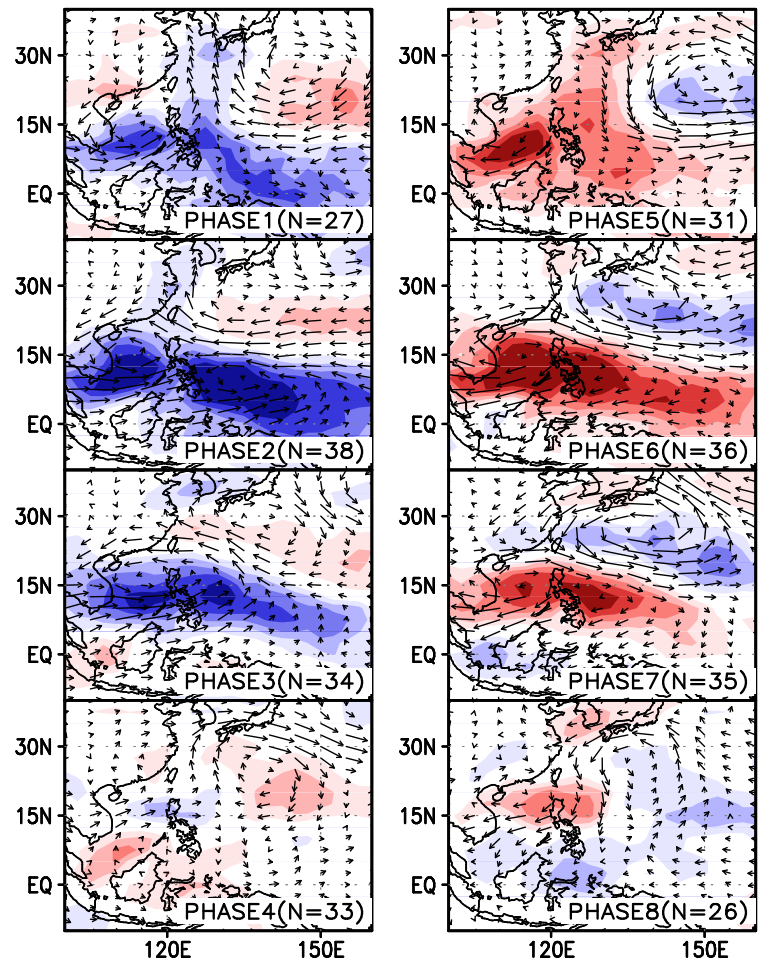
Component 2: MISO-WEM [100-160E, 10S-40N] (EEOF Mode 3 and 4 (6.86%), Westward Propagating Modes)

Amplitude of Principal Cc

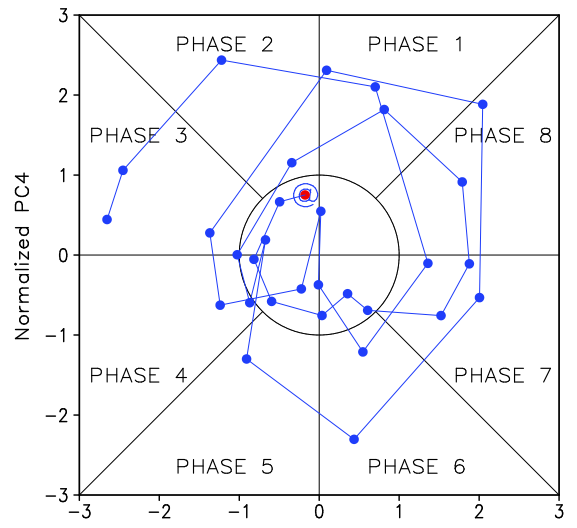


Life Cycle Composite for Strong MISO

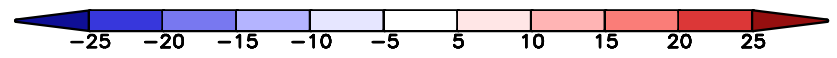
(a) Mode 3 & 4



Phase Diagram of PC3 and PC4



Normalized PC3 ■ May 1, 2007

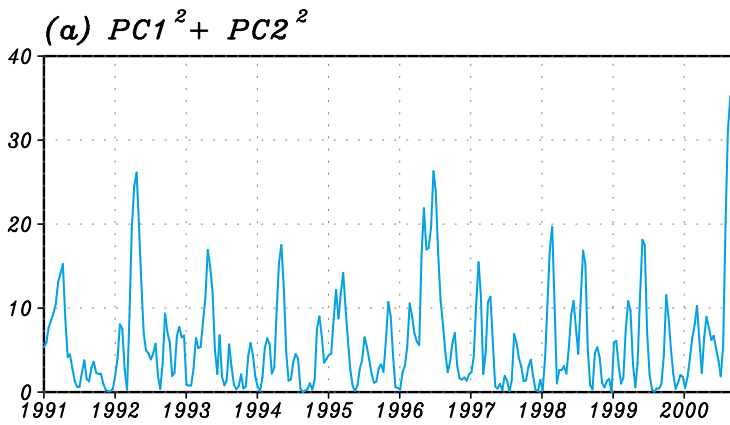




Component 3: MISO-IM [40-100E, 20S-30N]

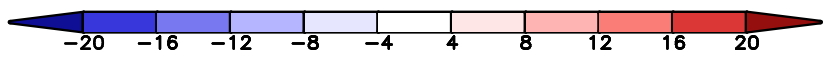
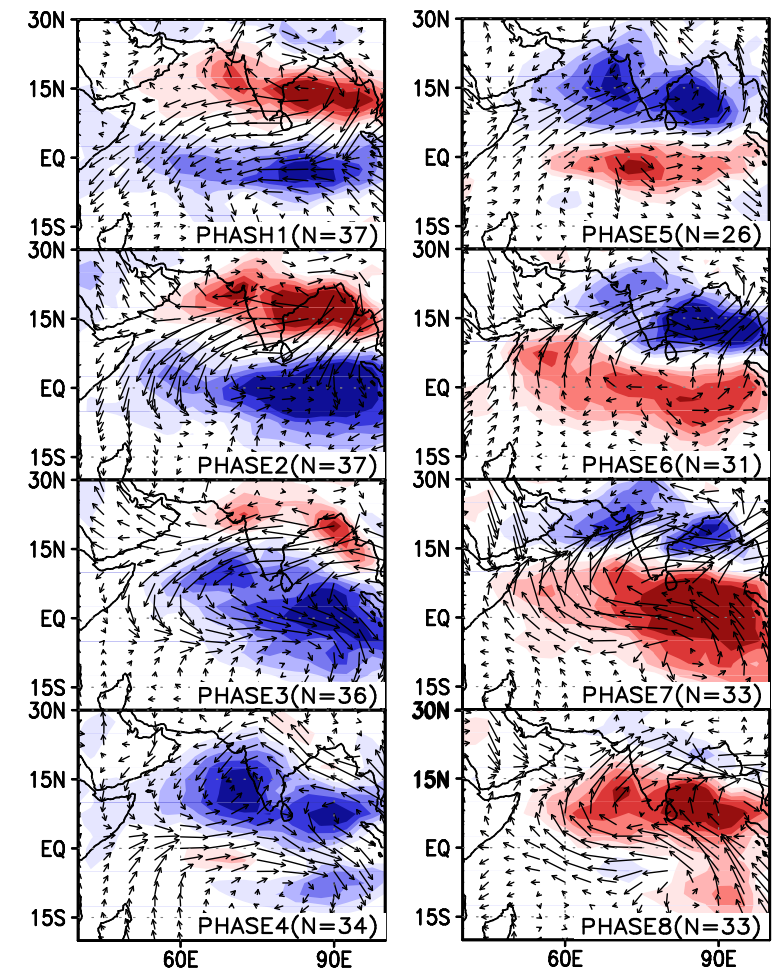
(EEOF Mode 1 and 2 (14.06%), Northward Propagating Modes)

Amplitude of Principal Cc

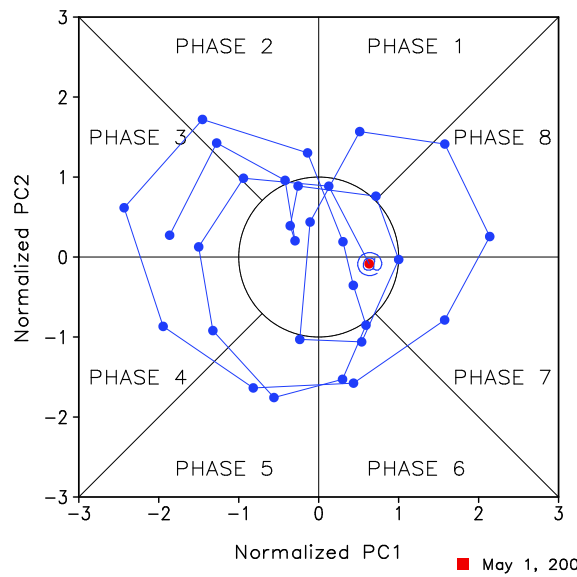


Life Cycle Composite

(a) Mode 1 & 2



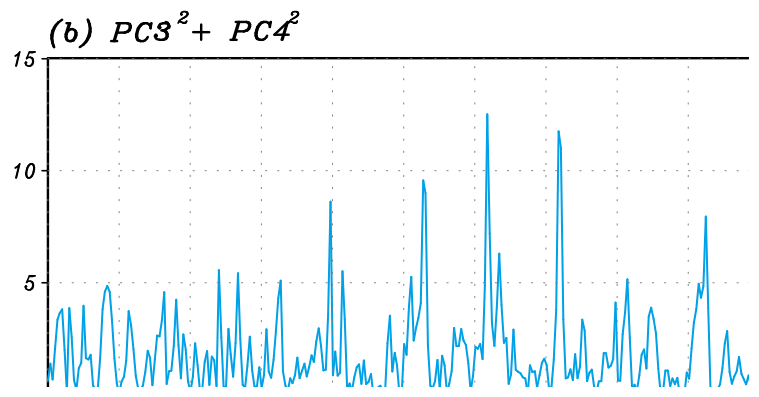
Phase Diagram of PC1 and PC2



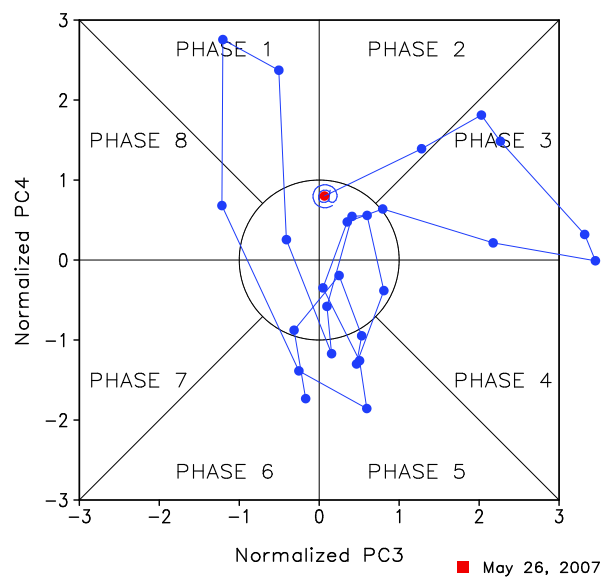


Component 4: MISO-IM [40-100E, 20S-30N] (EOF Mode 3 and 4 (7.86%), East-Northward Propagating Modes)

Amplitude of Principal Cc

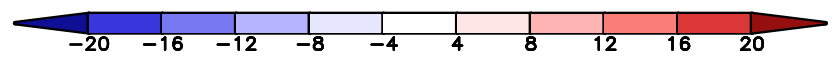
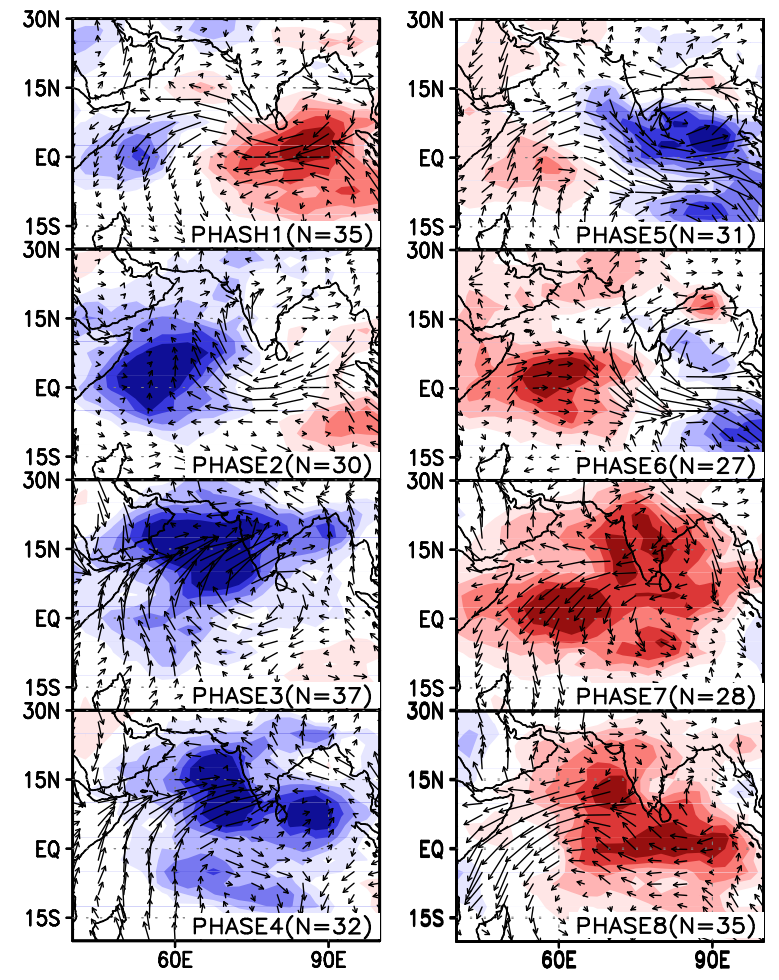


Phase Diagram of PC3 and PC4



Life Cycle Composite

(a) Mode 3 & 4





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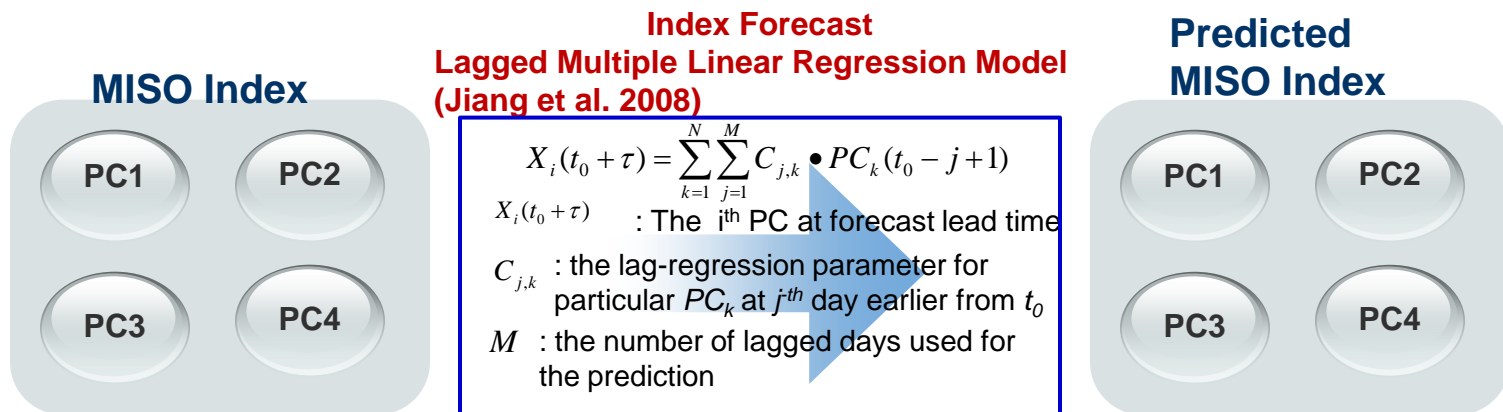
- ◆ Comparison with UH Hybrid Coupled Model (UH HCM) forecast



Determination of the Optimal MISO Index

Criterion for Determining the MISO Index

1. Fractional variance explained by the reconstructed field from the MISO index
2. Forecast skill of the reconstructed field from the predicted MISO index



Reconstruction of OLR and other variables from PCs Multiple Linear Regression Model

$$Y(lon, lat, t_0 + \tau) = \sum_{i=1}^N \alpha_i(lon, lat) \cdot X_i(t_0 + \tau)$$

$Y(lon, lat, t_0 + \tau)$: Reconstructed field from predicted PCs at $t_0 + \tau$

$X_i(t_0 + \tau)$: The i^{th} PC at forecast lead time

N : the number of selected PCs

$\alpha_i(lon, lat)$: Weighing coefficients determined by the least square fitting

Reconstruction of 5-day mean OLR and U850 anomalies over the Asian monsoon region
(Fractional Variance)

Reconstruction of OLR and other variables from predicted PCs

$$Y(lon, lat, t_0 + \tau) = \sum_{i=1}^N \alpha_i(lon, lat) \cdot X_i(t_0 + \tau)$$

Prediction of 5-day mean OLR and U850 anomalies over the Asian monsoon region
(Forecast Skill as a function of forecast lead time)



Predictability of MISO Index

Statistical Model for MISO Index

Lagged Multiple Linear Regression Model (Jiang et al. 2008)

$$X(t_0 + \tau) = \sum_{k=1}^N \sum_{j=1}^M C_{j,k} \bullet PC_k(t_0 - j + 1)$$

$X(t_0 + \tau)$: Predictant X at forecast lead time

t_0 : the time at the forecast point τ : the forecast lead

N : the number of total PCs included in the model

M : the number of lagged days used for the prediction

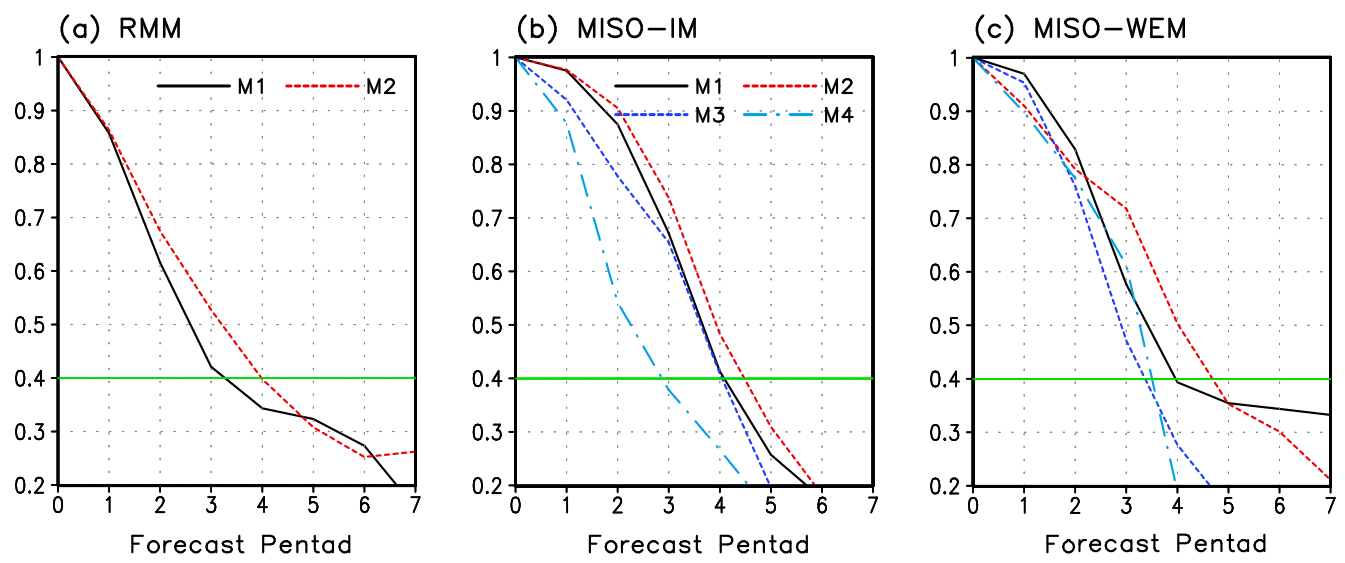
$C_{j,k}$: the lag-regression parameter for particular PC_k at j^{th} day earlier from t_0

Forecast Period : 1996 – 2007

Training Period : Last 10 years from target year

Target Months : MJJAS

Temporal Correlation Skill



The modes of MISO index are predictable up to 3-4 pentad.



Candidates for MISO Index

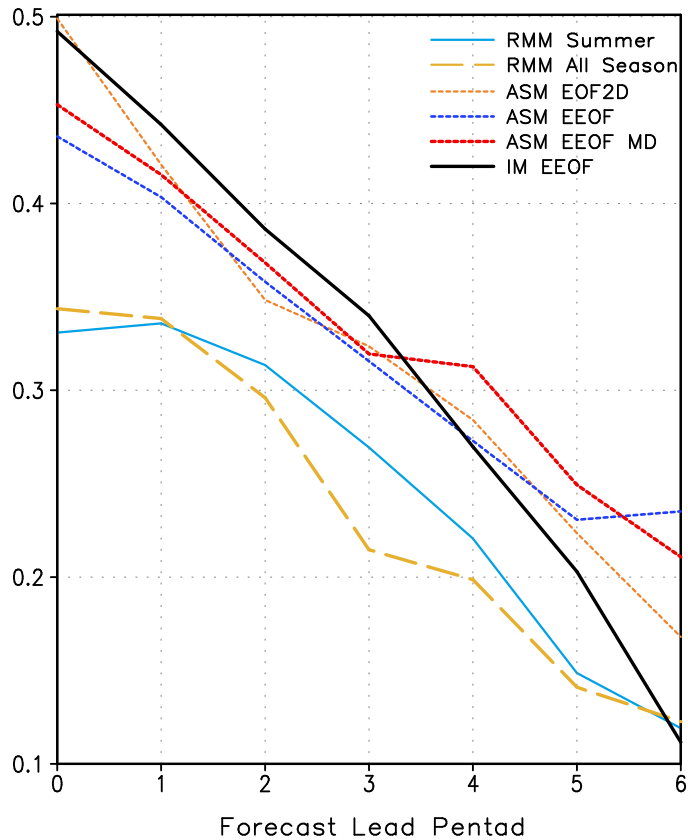
Region	EOF 1D	EOF 2D	EEOF
Equatorial Region (15S–15N)	RMM (latitudinal mean)		
Asian Summer Monsoon Region (ASM) (40-160E, 10S-40N)		ASM EOF	ASM EEOF
Indian Monsoon Region (IM) (40-100E, 10S-30N)	IM EOF1D (longitudinal mean)	IM EOF2D	IM EEOF
Western North Pacific – East Asian Region (WEM) (100-160E, 0-40N)	WEM EOF1D (longitudinal mean)	WEM EOF2D	WEM EEOF



Determination of MISO Index

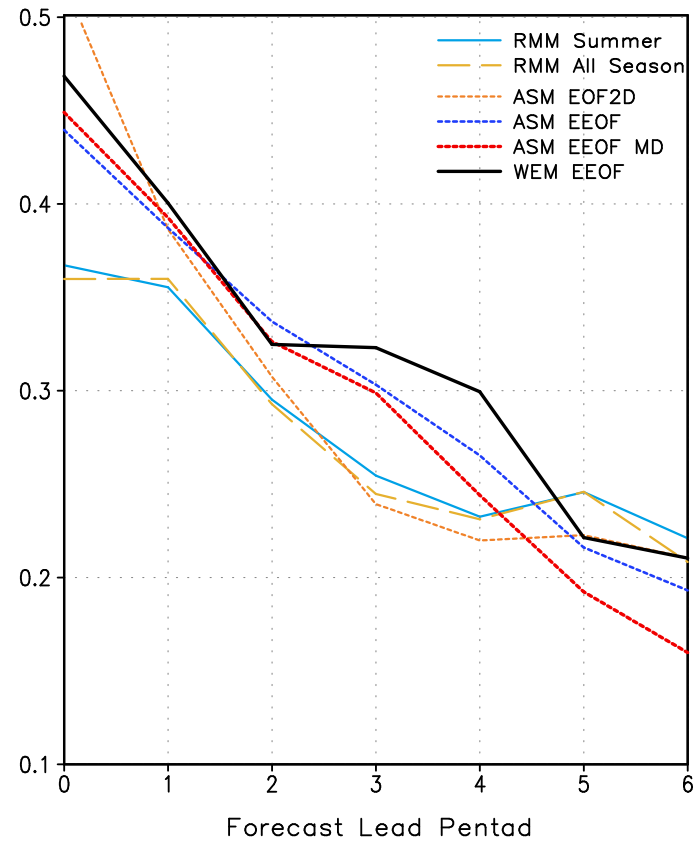
Anomaly Pattern Correlation Skill

Indian Monsoon Region



ASM EEOF MD or IM EEOF

WNP-EA Monsoon Region

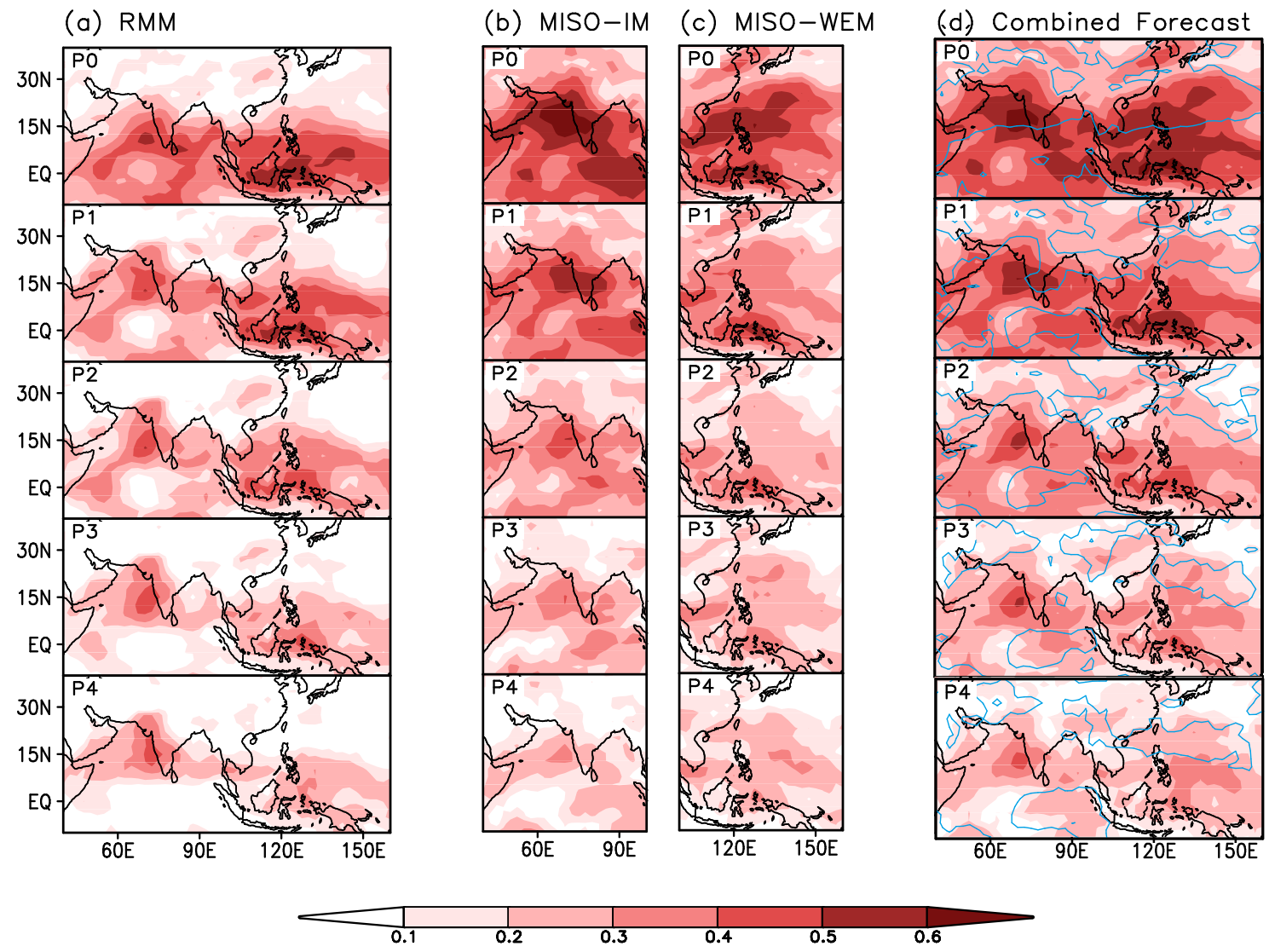


ASM EEOF or WEM EEOF



Anomaly Correlation Skill of Reconstructed OLR Anomalies using each Index/ 1996-2007

Anomaly Correlation Skill of Reconstructed 5-Day Mean OLR Anomalies





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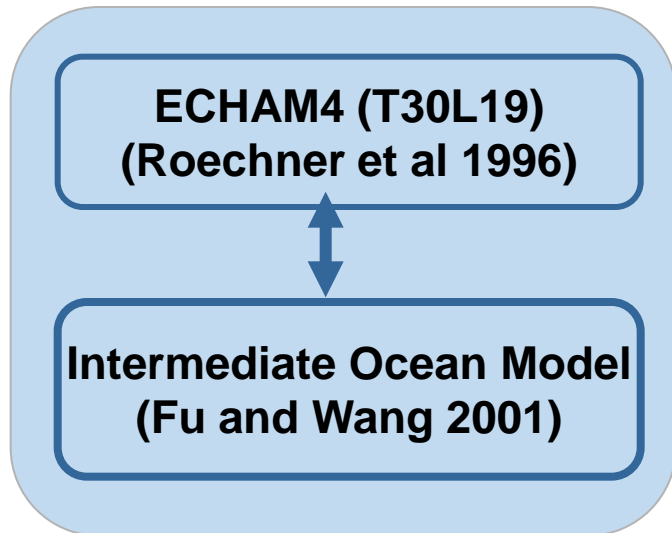
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ISO Hindcast Experiment / UH Model

UH Hybrid Coupled Model



➤ The UH hybrid coupled model is a capable of simulating Boreal summer monsoon ISO (Fu et al. 2003; Kemball-Cook et al. 2002) with the potential predictability of ISO up to 24 days (Fu et al. 2007; 2008).

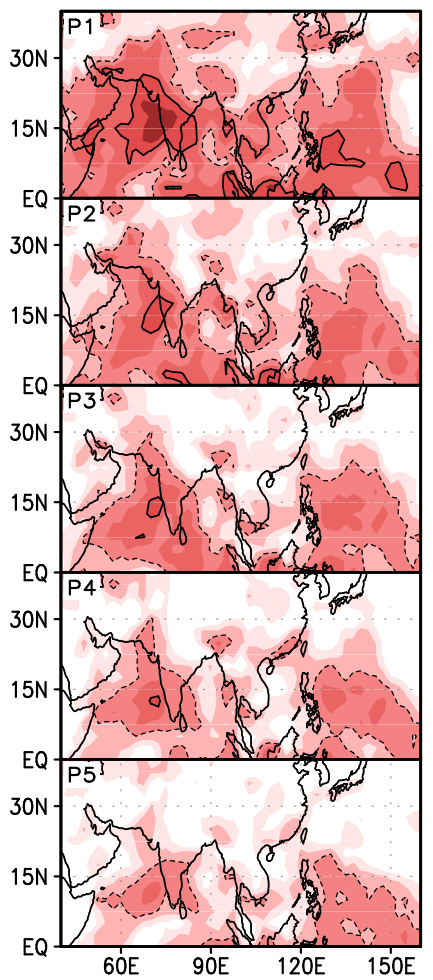
Experimental Design

Retrospective Forecast Period	20 summers from 1988 to 2007
Ensemble Member	6 member
Initial Date	Every 5 days from May 1 to Aug 26
The Length of Integration	45 days

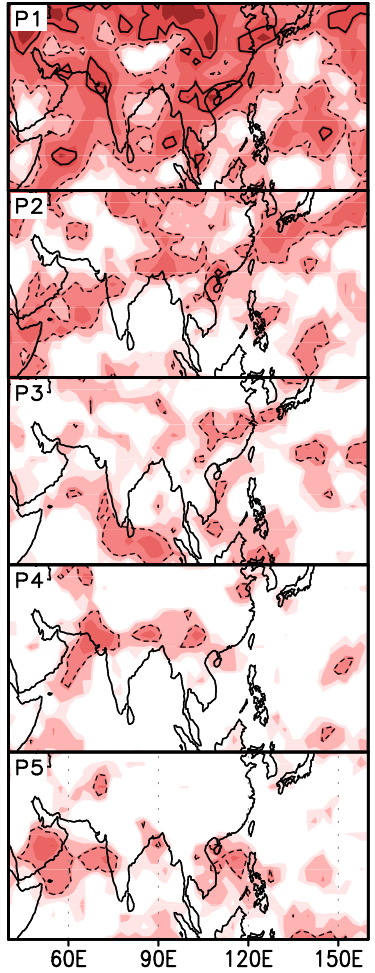


Statistical vs Dynamical ISO Forecast/ OLR Anomaly Temporal Correlation Skill/ 2004-2007

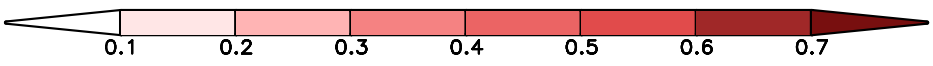
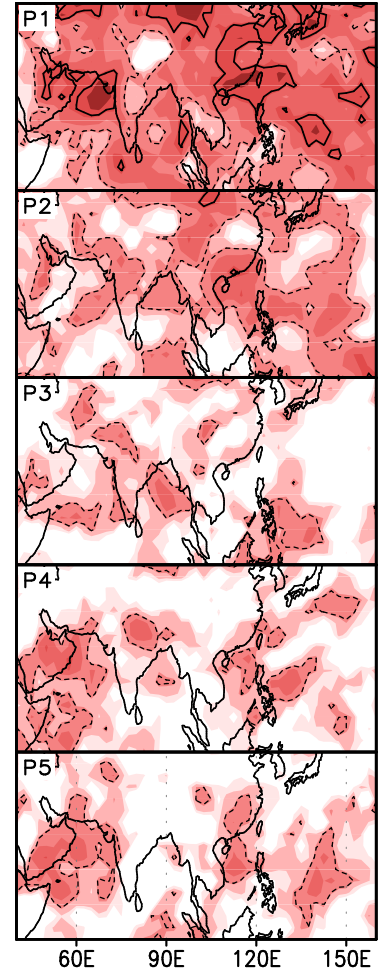
Statistical Forecast



UH HCM



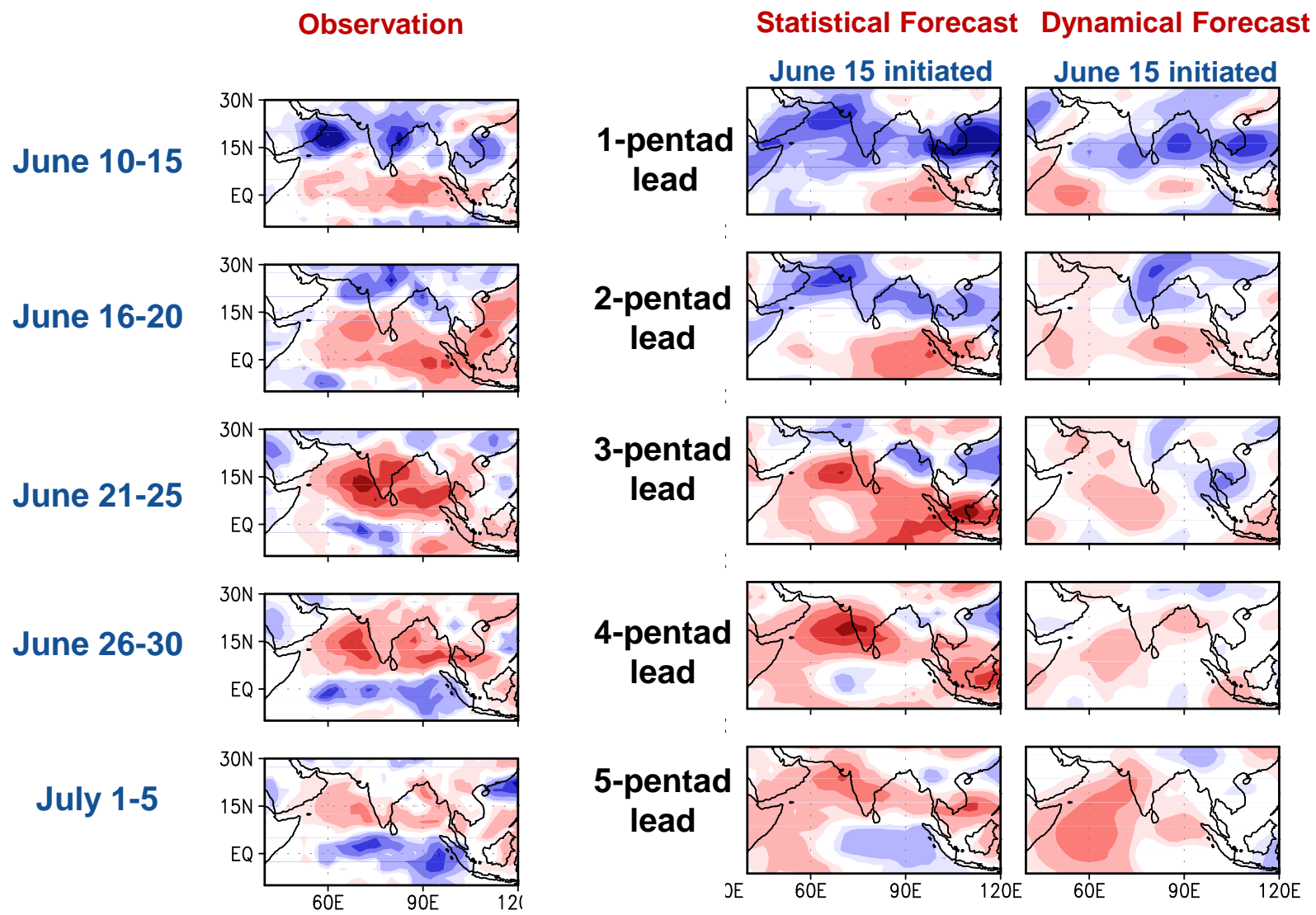
UH HCM Enhanced ISO Initialization





Observed and Predicted OLR Anomaly in 2004

Observed and Predicted Pentad Mean OLR Anomalies in 2004





Summary

- The real-time multivariate Monsoon ISO (**MISO**) has been defined to monitor and predict MISO in boreal summer.
- The MISO index consists of 3 components; **MISO-WEM** (the first four multivariate EEOF modes over WNP-EA monsoon region), **MISO-IM** (the first four multivariate EEOF modes over Indian monsoon region), and **RMM** (the first two modes of multivariate EOF over equatorial).
- The three components of MISO index are complementary each other in capturing the dominant ISO over entire monsoon domain with 30-60 time scales.
- A statistical forecast model for the MISO index has been developed based on multivariate lag-regression model. The statistical model has useful skill up to lead time of 3-4 pentads for each modes in the MISO index.



Summary

- The combined forecast using the reconstructed OLR and circulation fields from the predicted three MISO components has a useful skill up to 15-20 days depending on region. In particular, 850 hPa zonal wind anomalies are well predicted up to 20 days over India, Bay of Bengal, the South China Sea, WNP, and the some part of East Asia.
- A set of hindcast experiment for MISO are performed for the period of 1988-2007 using UH HCM initiated every 5 days from May 1st.
- The UH HCM is capable to forecast strong ISO events but the averaged forecast skill drops after 2 pentads for non-filtered pentad-mean OLR and circulation anomalies.
- The statistical MISO prediction has a better skill than dynamical prediction using UH HCM after forecast lead time of 10 days while the UH HCM is much better at a short forecast leadtime.



APCC/CIIPAS ISO Hindcast Experiment

1. Purpose

- Better understanding of the physical basis for intraseasonal prediction. To determine potential and practical predictability of ISO in a multi-model frame work.
- Developing optimal strategies for multi-model ensemble (MME) ISO prediction system, including effective initialization schemes and quantification of the MME's ISO prediction skills with forecast metrics under operational conditions.
- Identifying model deficiencies in predicting ISO and finding ways to improve models' convective and other physical parameterizations relevant to the ISO through development of model process diagnostics.

2. Experimental Type

- **Global dynamical models with either one-tier or two-tier setting**
- **Statistical forecast models will be developed and serve as benchmarks**

3. Experimental Design

Retrospective Forecast Period	20 years from 1989 to 2008
Ensemble Member	at least 6 member
Initial Date	Every 10 days
The Length of Integration	at least 45 days

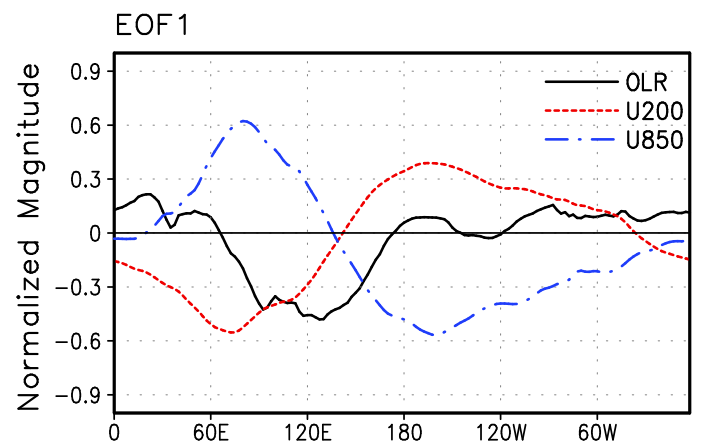
4. Potential Participating Groups

BMRC, ECMWF, GFDL, GMU/COLA, IAP/LASG, JAMSTEC/APL, NASA/GMAO, NCEP/CPC, SNU, UH/IPRC, UM, FSU, INGV, CWB, BCC/CMA

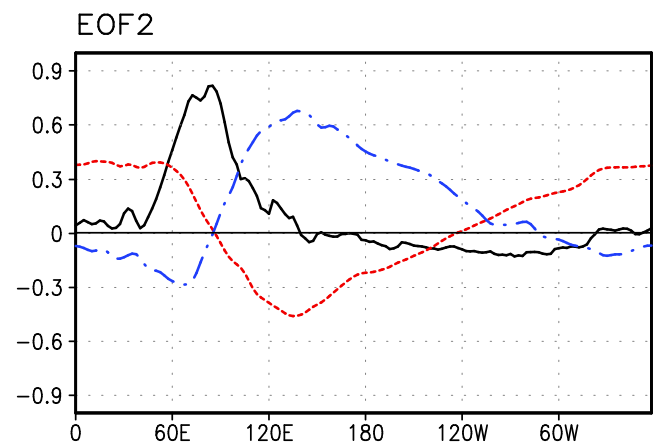
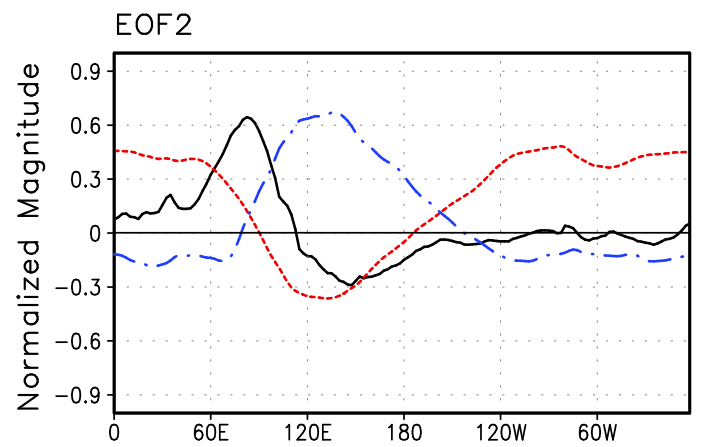
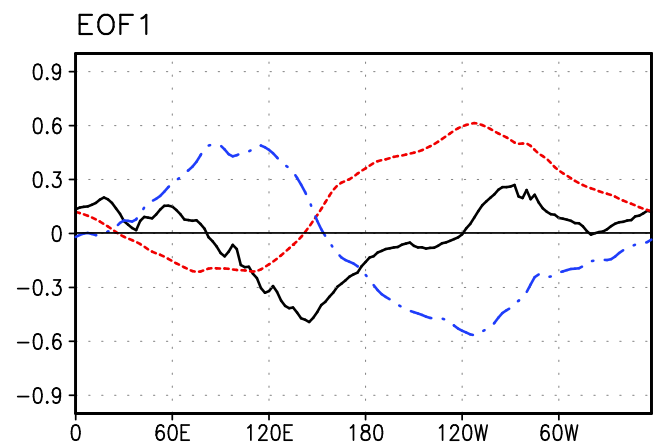


RMM: Spatial Characteristics

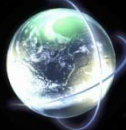
All Seasons



MJJAS



- ✓ The 1st and 2nd combined EOF's capture the equatorial convective and baroclinic structure of the MJO
- ✓ Seasonal Stratification is needed!



Fractional Variance by Explained by MISO Index

- The multivariate EEOF analysis applied separately between Indian and WNP-EA monsoon region for better results.
- The reconstructed fields from the first four modes of EEOF for both monsoon domains can explain monsoon ISO variability better than those from RMM.
- It is found that **the MISO-WEM, MISO-IM, and RMM are complement each other to capture monsoon ISO variability in boreal summer.** The ensemble mean of the reconstructed fields from each components can explain large portion of monsoon ISO variability over Asian monsoon domain.

Fractional Variance of OLR and U850 anomalies explained by the MISO index JJA 1996-2007

