Multi-model Ensemble Prediction for Boreal Summer Intraseasonal Oscillation (BSISO)

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The World Climate Research Programme (WCRP) – Coordinated Observation and Prediction of the Earth System (COPES)
Identification on Dominant Modes of the BSISO


Multi-model Ensemble Prediction for the BSISO

Summary
Interannual vs Intraseasonal Rainfall Variability during JJAS

The gigantic **Asian summer monsoon** exhibits rich variability with time scales ranging from **synoptic (~ days)** and **intraseasonal (~ weeks)** to **interannual (~ years)** and beyond, which make efficient water management, agricultural planning, and disaster prevention very difficult. For the well-being of the societies affected by the monsoon, the capability of forecasting the Asian monsoon systems with lead times from days and weeks to years and beyond is very desirable.
Bimodal Representation of the Tropical ISO

Spatial-temporal pattern of OLR anomaly associated with the intraseasonal oscillation during (a) boreal winter (DJF, referred to as **Madden-Julian Oscillation (MJO) mode**) and (b) boreal summer (JJA, referred to as **BSISO mode**) by means of the extended EOF (EEOF) analysis.

Kikuch et al. (2011, Clim Dyn)

**Boreal Winter**
Rainfall anomalies propagate in a northeast fashion and mainly affect the Tropical eastern hemisphere.

**Boreal Summer**
Rainfall anomalies propagate in a northeast fashion and mainly affect the Asian summer monsoon region.
Motivation:
Limitation of the RMM index for representing BSISO

As a measure of the strength of the MJO, *Wheeler and Hendon (2004)* Realtime Multivariate MJO (RMM) index used the first two leading multivariate EOF modes of the equatorial mean (between 15S and 15N) OLR, and zonal winds at 850 and 200 hPa. This index captures equatorial eastward propagating mode, the MJO, very well and has been applied all year around to depict MJO activity.

*Can one design a better index to describe boreal summer ISO?*
Process to define the BSISO index

Data Process

- **Variables**: daily OLR and U850
- **Data Period**: MJJASO 1981-2010
- Removal of the first 3 harmonics in climatological annual cycle
- Removal of the effect of ENSO signal through subtracting last 120 day mean
- Normalization of each of two fields by area averaged temporal standard deviation (The ASM standard deviation is 27.58 W m\(^{-2}\) for OLR and 3.62 m s\(^{-1}\) for U850)
- **BSISO index**: The first four leading multivariate EOF modes of daily OLR and U850 over the ASM region (10°S-40°N, 40°-150°E)

Filtering is not applied to define MISO index for monitor and forecast purpose

Criterion for Determining the BSISO Index

1. Fractional variance explained by the reconstructed field from the BSISO index
2. Ability to capture the northward propagating ISO
BSISO1: Canonical Northward Propagating BSISO Mode

- **BSISO1**, consisting of EOF1 and EOF2, represents the canonical northward and north-eastward propagating ISO over the ASM region during the entire warm season from May to October with quasi-oscillating periods of 30-60 days in conjunction with the eastward propagating MJO.

- **Spatial Characteristics**

Rossby wave like pattern with a northwest to southeast slope
**BSISO1: Canonical Northward Propagating BSISO Mode**

- **BSISO1**, consisting of **EOF1 and EOF2**, represents the canonical northward and north-eastward propagating ISO over the ASM region during the entire warm season from May to October with quasi-oscillating periods of 30-60 days in conjunction with the eastward propagating MJO.

- **Spatial Characteristics**

- **Seasonal cycle of variance**

![Seasonal Cycle of Variance of the First Four PCs](image)

*Large overall variance from May to October*
BSISO1: Canonical Northward Propagating BSISO Mode

- **BSISO1**, consisting of **EOF1** and **EOF2**, represents the canonical northward and north-eastward propagating ISO over the ASM region during the entire warm season from May to October with quasi-oscillating periods of 30-60 days in conjunction with the eastward propagating MJO.

- Spatial Characteristics
- Seasonal cycle of variance
- Coherence and lead-lag relationship

The greatest coherence in the 30- to 60-day range with a 90° phase difference

PC1 tends to lead PC2 by about 13 days with a maximum correlation of 0.34 for non-filtered data.

PC1 (PC2) is more significantly correlated with RMM2 (RMM1).
BSISO1: Canonical Northward Propagating BSISO Mode

- **BSISO1, consisting of EOF1 and EOF2**, represents the canonical northward and north-eastward propagating ISO over the ASM region during the entire warm season from May to October with quasi-oscillating periods of 30-60 days in conjunction with the eastward propagating MJO.

- **Spatial Characteristics**
- **Seasonal cycle of variance**
- **Coherence and lead-lag relationship**
- **Phase space composite curves**

Given the strong lead-lag behavior of PC1 and PC2, it is convenient to diagnose the state of BSISO1 as a point in the two-dimensional phase space.
BSISO1: Canonical Northward Propagating BSISO Mode

- BSISO1, consisting of EOF1 and EOF2, represents the canonical northward and north-eastward propagating ISO over the ASM region during the entire warm season from May to October with quasi-oscillating periods of 30-60 days in conjunction with the eastward propagating MJO.

Spatial Characteristics

Seasonal cycle of variance

Coherence and lead-lag relationship

Phase space composite curves

Composite life cycle

Life cycle composite of OLR (shading) and 850-hPa wind anomalies
BSISO2: The ASM pre-monsoon and onset mode

- **BSISO2**, consisting of EOF3 and EOF4, captures the northward/northwestward propagating variability with periods of 10-30 days during primarily the pre-monsoon and monsoon-onset season.

- **Spatial Characteristics**

  Elongated and front-like pattern with a southwest to northeast slope
BSISO2: The ASM pre-monsoon and onset mode

- BSISO2, consisting of EOF3 and EOF4, captures the northward/northwestward propagating variability with periods of 10-30 days during primarily the pre-monsoon and monsoon-onset season.

- Spatial Characteristics

- Seasonal cycle of variance

![Graph showing seasonal cycle of variance of the first four PCs](image)

Maximum variance from late May to early July, corresponding to the pre-monsoon and onset period
BSISO2: The ASM pre-monsoon and onset mode

- BSISO2, consisting of EOF3 and EOF4, captures the northward/northwestward propagating variability with periods of 10-30 days during primarily the pre-monsoon and monsoon-onset season.

- Spatial Characteristics

- Seasonal cycle of variance

- Coherence and lead-lag relationship

PC3 tends to lead PC4 by about 3-4 days for 10-20 period and 7-8 days for 30 day period.

BSISO2 is not correlated with MJO

High coherence in the 10-20 day range and at ~30 days, with 90° phase difference
BSISO2: The ASM pre-monsoon and onset mode

- **BSISO2**, consisting of EOF3 and EOF4, captures the northward/northwestward propagating variability with periods of 10-30 days during primarily the pre-monsoon and monsoon-onset season.

- Spatial Characteristics
- Seasonal cycle of variance
- Coherence and lead-lag relationship
- Phase space composite curves

![PC3 and PC4 phase space composite curves](image)
BSISO2: The ASM pre-monsoon and onset mode

- **BSISO2**, consisting of EOF3 and EOF4, captures the northward/northwestward propagating variability with periods of 10-30 days during primarily the pre-monsoon and monsoon-onset season.

- Spatial Characteristics
- Seasonal cycle of variance
- Coherence and lead-lag relationship
- Phase space composite curves
- Composite life cycle

Life cycle composite of OLR (shading) and 850-hPa wind anomalies
BSISO1 and BSISO2 capture a significant portion of the total variance particularly over the WNP-EA region during boreal summer while the RMM describes the variance primarily in the equatorial region and only moderately captures variability over the ISM region.
BSISO Real-time Monitoring
http://iprc.soest.hawaii.edu/users/jylee/bsiso

Boreal Summer Intraseasonal Oscillation (BSISO)

Daily time series of the BSISO and other regional monsoon ISO indices

(a) BSISO1
Normalized Amplitude
-3 -2 -1 0 1 2 3
MAY 2012 JUN JUL AUG SEP OCT

(b) BSISO2
Normalized Amplitude
-3 -2 -1 0 1 2 3
MAY 2012 JUN JUL AUG SEP OCT

Daily time series of the first four BSISO modes and Indian summer monsoon index

Normalized PC1
 normalized PC2
 normalized PC3
 normalized PC4

(a) BSISO1

(b) BSISO2

Map of phases for BSISO1 and BSISO2

Legend:
- May 24, 2011 (Starting Date)
- May 20, 2012 (Starting Date)
The ISVHE Project
Intraseasonal Variability Hindcast Experiment

The ISVHE is a coordinated multi-institutional ISV hindcast experiment supported by APCC, NOAA CTB, CLIVAR/AAMP & MJO TF, and AMY.

Supporters

http://iprc.soest.hawaii.edu/users/jylee/clipas.htm
## Description of Models and Experiments

### One-Tier System

<table>
<thead>
<tr>
<th>Model</th>
<th>Control Run</th>
<th>ISO Hindcast</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABOM</td>
<td>CMIP (100yrs)</td>
<td>1980-2006</td>
</tr>
<tr>
<td>CMCC</td>
<td>CMIP (20yrs)</td>
<td>1989-2008</td>
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<tr>
<td>ECMWF</td>
<td>CMIP(11yrs)</td>
<td>1989-2008</td>
</tr>
<tr>
<td>GFDL</td>
<td>CMIP (50yrs)</td>
<td>1982-2008</td>
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<tr>
<td>JMA</td>
<td>CMIP (20yrs)</td>
<td>1989-2008</td>
</tr>
<tr>
<td>NCEP/CPC</td>
<td>CMIP 100yrs</td>
<td>1981-2008</td>
</tr>
<tr>
<td>PNU</td>
<td>CMIP (13yrs)</td>
<td>1981-2008</td>
</tr>
<tr>
<td>SNU</td>
<td>CMIP (20yrs)</td>
<td>1989-2008</td>
</tr>
<tr>
<td>UH/IPRC</td>
<td>CMIP (20yrs)</td>
<td>1994-2008</td>
</tr>
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</table>

### Two-Tier System

<table>
<thead>
<tr>
<th>Model</th>
<th>Control Run</th>
<th>ISO Hindcast</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWB</td>
<td>CWB AGCM</td>
<td>1981-2005</td>
</tr>
<tr>
<td>MRD/EC</td>
<td>GEM</td>
<td>1985-2008</td>
</tr>
</tbody>
</table>
The MME’s Skill for 5-day mean OLR and U850 Anomalies

Anomaly Correlation Coefficients (1989-2008, MJJASO)
The MME and Individual Models’ Skill for BSISO

Anomaly Correlation Coefficients (1989-2008, MJJASO)

**BSISO1**

- Common Period: 1989-2008
- Initial Condition: 1st day of each month from Oct to March
- MME: Simple composite with all models

Using the MME, forecast skill for BSISO1 reaches 0.5 at 15 to 20-day forecast lead and for BSISO2 at 10- to 15-day forecast lead.
The MME and Individual Model Skills for MJO

Common Period: 1989-2008
Initial Condition: 1st day of each month from Oct to March
MME1: Simple composite with all models
MMEB2: Simple composite using the best two models
MMEB3: Simple composite using the best three models

Anomaly Correlation Coefficients (1989-2008, NDJFMA)
Phase Dependency of BSISO Forecast Skills

Temporal Correlation Coefficient Skill of the MME for BSISO1

Life cycle composite of OLR (shading) and 850-hPa wind anomalies
Summary

- Given the extreme importance of the BSISO, we have made an effort to define new indices to assist in real-time monitoring and forecast applications of the BSISO. The BSISO indices proposed in this study were designed to better represent fractional variance and the observed northward/northwestward propagating ISO over the ASM region than the RMM index.

- **BSISO1**, consisting of EOF1 and EOF2, represents **the canonical northward and north-eastward propagating ISO over the ASM region** during the entire warm season from May to October with quasi-oscillating periods of 30-60 days in conjunction with the eastward propagating MJO.

- **BSISO2**, consisting of EOF3 and EOF4, captures **the northward/northwestward propagating variability with periods of 10-30 days** during primarily the pre-monsoon and monsoon-onset season.

- The ISVHE has been coordinated **to better understand the physical basis for prediction and determine predictability of ISO**.

- **11 climate models’ hindcast for ISO** have been collected from research institutions in North America, Europe, Asia, and Australia.

- Using the all models’ MME, ACC skill for BSISO1 and BSISO2 reaches **0.5 at 15-20-day and 10-15-day forecast lead, respectively.**
Thank You!
Motivation:
Limitation of the regional indices for representing BS MISO

Regional Monsoon ISO Indices
- IOI (Indian Ocean Index): OLR(80-100E, 5S-5N)
- EWNPI (Equatorial WNP Index): OLR(125-140E, Eq-7.5N)
- WNPMI (Western North Pacific Monsoon Index, Wang and Fan 1999): U850 (90-130E, 5-15N) - U850 (110-140E, 22.5-32.5N)

Can one design a better index to describe boreal summer MISO?
The conceptualization of the predictability of precipitation (Courtesy of Paul Dirmeyer).
Factors for Limiting Monsoon Prediction: Predictability Limit

The MME Hindcast Skill (1981-2005)

Theoretical Limit of TCC Skill by MSE

Theoretical Limit of TCC Skill by PMA
Wang, 2004

Physical Processes

Fundamental Components

Important Feedbacks

Annual/Seasonal Modulation

Moisture Distribution

Land-Sea Distribution  Climatological SST  Surface Heat Fluxes

Lower Boundary Forcing

Background Circulation (Monsoon, Hadley, Walker)

Low Freq. Equatorial Waves

Convective Latent Heating

Boundary Layer Dynamics

Cloud-Radiation

Ocean Mixed Layer Processes

(1) (2) (3) (4) (5)
We suggest a new MISO index that is defined by the first four multivariate EOF modes of daily OLR and U850 anomaly over the ASM region (10°S-40°N, 40°-160°E).

The RMM index captures the OLR variability primarily in the equatorial region whereas the MISO index captures large portion of the variability in the off-equatorial region, yielding more realistic variance pattern.

The MISO index describes better ISO variability center and represents better northward as well as eastward propagating pattern in the ASM domain than the RMM index.

The northward-propagating MISO component can be monitored using the phase diagram between the first and second PC similar as the eastward-propagating MJO. Taking into account distinct regional characteristics of MISO with smaller horizontal scale than MJO, the reconstructed field from the first four modes may provide more useful information.