Introduction to Climate Data

August 21, 2017
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Climate Research Team, Climate Prediction Department

with support from Drs. Jinho Yoo, Yun-Young Lee, and Wonmoo Kim
Questions to be answered

I. Can you distinguish between weather and climate?
II. What does APEC Climate Center do?
III. How do we predict?
IV. How does APCC predict?
V. How good are they?
VI. What else does APCC provide?
Can you distinguish between weather and climate?

**Weather**
Short term changes in the atmosphere
The state of the atmosphere at any given time (Look out the window and view the weather)
"How hot is it right now?" "What will it be like today?" and "Will we get a snowstorm this week?"

**Climate**
The weather of a place averaged over a period of time (e.g., 30 years)
Weather makes up climate
Can you distinguish between weather and climate?

“User-oriented Statistical Downscaling of Climate Information in Agriculture and Water Resources”

Aug.21-Aug.26, 2017 APEC Climate Center, Busan, South Korea
Weather and climate scales

Weather

- Rain squall
- Cyclone
- Wet /Dry Season
- El Nino/ La Nina

Climate variability

- Pacific Decadal Oscillation
- Global Warming

Climate change

- Hours
- Days
- Months
- Years
- Decades
- Centuries
What does APEC **Climate** Center do?

A: Is it going to rain tomorrow?

B: Why this winter is not that cold?

C: Is global warming real?
What does APEC Climate Center do?

- Established in 2005 as a climate prediction center during the 13th APEC Leaders’ Meeting in Busan, South Korea
- Aim: enhance socio-economic wellbeing of APEC countries using climate information

### MISSION

Use climate science and its applications to contribute to safer, more prosperous, and more resilient communities through four interrelated themes:

- Climate Prediction
- Climate Information Services
- Interdisciplinary Research
- International Cooperation
What does APEC Climte Center do?

http://www.apcc21.org

Add our website to your favorites!
What does APEC Climate Center do?

- Information about the “climate” that can be expected in the coming months

Forecast for August-October 2017

Temperature at 2m for August-October 2017

Precipitation for August-October 2017
Strongly enhanced probability for above normal temperatures is predicted for the western equatorial Pacific, subtropical Pacific, tropical and subtropical Atlantic, Bering Sea, Okhotsk Sea, Chukchi Sea, maritime continent, Tasman Sea, South Pacific east to New Zealand, Arabian Sea, Bay of Bengal, western and southern Indian Ocean including Madagascar, Gulf of Mexico, Caribbean Sea, Mongolia, western China, northern Saudi Arabia, and northwestern Africa. Enhanced probability for above normal temperatures is predicted for most of China, Middle East, North Africa, Mediterranean Sea, western USA, Norwegian Sea, and some parts of the Barents and Kara Seas. A warm tendency is expected for Australia, eastern Russia, Arctic, Greenland, and North America except for the eastern part of it. Enhanced probability for below normal temperatures is predicted in very small areas of Baffin Bay. A below normal tendency is expected for the Antarctic Ocean. Enhanced probability for above normal precipitation is predicted for the Philippian Sea, Mozambique Channel, the off-equatorial North Atlantic, and Gulf of Mexico. A tendency toward above normal precipitation is predicted for the Eastern Siberian Sea, eastern Greenland, Geenland Sea, and Norwegian Sea. Strongly enhanced probability for below normal precipitation is predicted for the central Indian Ocean, Great Australian Bight, and off-equatorial central Pacific. A below normal tendency is predicted for Australia, Russia near Lake Baikal, and the subtropical South Atlantic. Strongly enhanced probability for near normal precipitation is predicted for the central and eastern equatorial Pacific. Enhanced probability for near normal precipitation is expected for the Middle East, North Africa, and the Indian Ocean south to the Greater Sunda Islands.
How do we predict?
## Seasonal forecast: Method

<table>
<thead>
<tr>
<th></th>
<th>Statistical prediction</th>
<th>Dynamical prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pros</strong></td>
<td>Use observed relationship of climate system to predict future</td>
<td>Based on physical laws of the climate system</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Simple</td>
<td>Nonlinearity can be considered.</td>
</tr>
<tr>
<td></td>
<td>Cheap</td>
<td>Spatiotemporally coherent variables.</td>
</tr>
<tr>
<td><strong>Cons</strong></td>
<td>Stationarity – climate is changing.</td>
<td>Complicated &amp; expensive</td>
</tr>
<tr>
<td></td>
<td>Limited data</td>
<td>Not real – biased &amp; need correction.</td>
</tr>
</tbody>
</table>

- **Use observed relationship of climate system to predict future**: This method relies on the observed relationship between climate variables and future conditions. It is simple and cheap, but it does not consider the changing nature of the climate system.
- **Based on physical laws of the climate system**: This method is based on the fundamental laws governing the climate system, which allows for the consideration of nonlinearity and spatiotemporally coherent variables. However, it is more complicated and expensive, and the results need correction to account for biases.
Seasonal forecast: Statistical prediction

- Use past observational record and statistical methods

(0) Climatology (use 30 year average as a baseline)
\[ x(t + 1) = \bar{x} \]

(1) Persistence (Assume that future will be same as it is now)
\[ x(t + 1) = x(t) \]

(2) Regression (The most popular method and many variations)
\[ x(t + 1) = ax(t) + b \]
Seasonal forecast: Statistical prediction

- Predict rainfall in Busan for coming December

(0) Climatology (use 30 year average as a baseline)
(1) Persistence (Assume that future will be same as it is now)
(2) Regression (The most popular method and many variations)
Seasonal forecast: Dynamical prediction

- Use GCM: Global Climate Model

- Atmosphere
- Ocean
- Sea-Ice
- Land surface
- Chemistry
- Biosphere
Seasonal forecast: Dynamical prediction

Schematic for Global Atmospheric Model

- Horizontal Grid (Latitude-Longitude)
- Vertical Grid (Height or Pressure)
Seasonal forecast: Dynamical prediction

\[ r : \rho \left( \frac{\partial u_r}{\partial t} + u_r \frac{\partial u_r}{\partial r} + \frac{u_\theta}{r} \frac{\partial u_r}{\partial \theta} \right) - \frac{u_r^2 + u_\theta^2}{r} \right) = - \frac{\partial p}{\partial r} + \rho g \nabla \cdot + \nabla \cdot \left[ \frac{1}{r^2} \frac{\partial}{\partial r} \left( r^2 \frac{\partial u_r}{\partial r} \right) + \frac{1}{r^2 \sin(\theta)} \frac{\partial}{\partial \theta} \left( \sin(\theta) \frac{\partial u_r}{\partial \theta} \right) \right] - 2 \frac{u_r + \frac{u_\theta}{\cos(\theta)} + u_\theta \cot(\theta)}{r^2} - \frac{2}{r^2 \sin(\theta)} \frac{\partial u_\phi}{\partial \phi} \nabla \cdot \left[ \frac{1}{r^2} \frac{\partial}{\partial r} \left( r^2 \frac{\partial u_\phi}{\partial r} \right) + \frac{1}{r^2 \sin(\theta)} \frac{\partial}{\partial \theta} \left( \sin(\theta) \frac{\partial u_\phi}{\partial \theta} \right) \right] - \frac{2 \sin(\theta) \frac{\partial u_\phi}{\partial \phi} + 2 \cos(\theta) \frac{\partial u_\theta}{\partial \phi}}{r^2 \sin(\theta)} \nabla \cdot \left[ \frac{1}{r^2} \frac{\partial}{\partial r} \left( r^2 \frac{\partial u_\theta}{\partial r} \right) + \frac{1}{r^2 \sin(\theta)} \frac{\partial}{\partial \theta} \left( \sin(\theta) \frac{\partial u_\theta}{\partial \theta} \right) \right] - \frac{1}{r^2 \sin(\theta)} \frac{\partial}{\partial \phi} \left( \sin(\theta) \frac{\partial u_\theta}{\partial \phi} \right) \right] + \frac{1}{r^2 \sin(\theta)} \frac{\partial}{\partial \theta} \left( \sin(\theta) \frac{\partial u_\theta}{\partial \theta} \right) \right] \]
Which approach does APCC take for Seasonal forecast?
Multi-model ensemble (use many GCMs)
# Seasonal forecast: Predictability

- **Predictability**: How well we can predict?
  -> depends on what to predict

| Lead time ($\tau$) | 1. *Temperature of this room tomorrow*  
|                   | 2. *Temperature of this room in 30 days later*  
|                   | 3. *Temperature of this room in 30 years later* |

| Location | 1. *Temperature of Seoul (Korea)*  
|          | 2. *Temperature of Jakarta (Indonesia)*  
|          | 3. *Temperature of Villa Las Estrellas (Antarctica)* |

| Physical variables | 1. *Temperature*  
|                   | 2. *rainfall*  
|                   | 3. *wind speed* |
Seasonal forecast: Predictability

- Assume you want to predict $X = X_{\text{signal}} + X_{\text{noise}}$

  Signal $>>$ Noise: more predictable

  Signal $<<$ Noise: less predictable

Trying to reach potential predictability with state-of-art prediction system
Seasonal forecast: Multi-model ensemble

- Averaging across a number of models
- To reduce noise by averaging large ensemble members
  (The Earth’s atmosphere is chaotic, and GCM is not perfect)
Seasonal forecast: Multi-model ensemble

An example of a MME outperforming individual models in forecasting
(Jin et al. (2008))
Seasonal forecast: Multi-model ensemble

- Collect Global climate forecast data from 17 institutes and disseminate MME forecast

APCC website: apcc21.org

APCC Data Service System website (ADSS): adss.apcc21.org
Seasonal forecast: Multi-model ensemble

- Methodology of the APCC MME Prediction System (Min et al. 2014)

- Deterministic method
  - Simple Composite Method (SCM)
  - Stepwise Pattern Projection Method (SPM)
  - Multiple Regression Method (MRG)
  - Synthetic Superensemble Method (SSE)

- Probabilistic method

- ✔ 2m temperature
- ✔ Precipitation
- ✔ 850hPa temperature
- ✔ 500hPa geopotential height
- ✔ sea surface temperature
Seasonal forecast: Multi-model ensemble

- **Deterministic**
- **Probabilistic**

Map showing probability of rainfall falling in one of three categories (with respect to climatology): BN vs NN vs AN
# How good are they?

## What makes a good forecast?
1. Consistency
2. Quality
3. Value

*(Murphy AH 1993; Wea. Forecasting 8, 281)*

### Verification for Deterministic MME method

<table>
<thead>
<tr>
<th>Anomaly Correlation Coefficient</th>
<th>Root Mean Square Error</th>
</tr>
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</table>

### Verification for Probabilistic MME method

<table>
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<tr>
<th>Reliability Diagram</th>
<th>Relative Operating Characteristics Curve</th>
<th>Heidke Skill Score</th>
<th>Ranked Probability Skill Score</th>
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</table>
How good are they?

**Verification for Deterministic MME method**

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<th>Anomaly Correlation Coefficient</th>
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</table>

\[ G(t) = F(t) + 100 \]

Correlation coefficient? RMSE?

**Sunspot Number**

\[ F(t) \]

**Year**

1700 1750 1800 1850 1900 1950
### Verification for Probabilistic MME method

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How good are they?

- APCC operational forecast

Realtime rainfall forecast for last 4 years (12-15)
ROC score: Perfect = 1, Meaningless (no skill) = 0.5,
How good are they?

The skill of the APCC forecasts strongly depends on seasons and regions that it is higher for the tropics and boreal winter than for the extratropics and boreal summer.

- forecast skill for precipitation is more seasonally and regionally dependent than that for temperature.
- The skill of both temperature and precipitation forecasts strongly depends upon the ENSO strength. (the highest forecast skill noted in 2015/2016 boreal winter is associated with the strong forcing of an extreme El Nino event)
What else does APCC provide?

**CLIMATE INFORMATION SERVICES**

- Seasonal Forecast
- BSISO Forecast
- Climate Monitoring
- CLIK
- Data Service

The APEC Climate Center Data Service System was developed for real-time climate monitoring and provision of digital data service to APEC member economies. This system underscores the role of APCC in playing an important role as a hub of climate data and services in the region. The main objective of the ADSS is to provide a comprehensive set of models and observational climate data to various researchers and users to establish a scientific basis for climate prediction. ADSS also aims to monitor climate information using near real-time in-situ observation and prediction data in a standardized and accessible format for various users.
### What else does APCC provide?

<table>
<thead>
<tr>
<th>DataSet</th>
<th>Area Coverage</th>
<th>Grid Size</th>
<th>Time Step</th>
<th>Access</th>
<th>Source</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>APCC-MME(6-MON)</td>
<td>Global</td>
<td>2.5 x 2.5 (degree)</td>
<td>Monthly</td>
<td></td>
<td>APCC</td>
<td>Login</td>
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<td>APCC-JMRI(6-MON)</td>
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<td>INDIVIDUAL MODEL(6-MON)</td>
<td>Global</td>
<td>2.5 x 2.5 (degree)</td>
<td>Monthly</td>
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<td>Login</td>
</tr>
<tr>
<td>INDIVIDUAL MODEL(3-MON)</td>
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<td>2.5 x 2.5 (degree)</td>
<td>Monthly</td>
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</tr>
<tr>
<td>CORDEX-SEA25</td>
<td>Regional</td>
<td>25km</td>
<td>Daily</td>
<td></td>
<td>APCC</td>
<td></td>
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<tr>
<td>CORDEX-SWAN</td>
<td>Regional</td>
<td>25km</td>
<td>Daily</td>
<td></td>
<td>APCC</td>
<td></td>
</tr>
<tr>
<td>Glopal GMPS</td>
<td>National level (22 Countries)</td>
<td>Depending on GISGM</td>
<td>Daily</td>
<td></td>
<td>ESGF</td>
<td></td>
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<tr>
<td>IRI DATA_LIBRARY</td>
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<tr>
<td>NCEP</td>
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<td>2.5 x 2.5 (degree)</td>
<td>Daily</td>
<td></td>
<td>NOAA</td>
<td></td>
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<tr>
<td>NCEP-IRFC</td>
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<td>Daily</td>
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<td>NOAA</td>
<td></td>
</tr>
<tr>
<td>NOAM-CLR</td>
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<td>NOAA</td>
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<tr>
<td>TM3</td>
<td>Global</td>
<td>2.5 x 2.5 (degree)</td>
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<td></td>
<td>REMS</td>
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<td>QUICKSCAT</td>
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<td>0.25 x 0.25 (degree)</td>
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<td></td>
<td>REMS</td>
<td></td>
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<tr>
<td>GPCP</td>
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<td>1.0 x 1.0 (degree)</td>
<td>Daily</td>
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<td>NASA</td>
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<tr>
<td>GHCN</td>
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<td>Monthly</td>
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<td>NOAA</td>
<td></td>
</tr>
<tr>
<td>UO</td>
<td>Global</td>
<td>3.5 x 3.5 (degree)</td>
<td>Monthly</td>
<td></td>
<td>University of Delaware</td>
<td></td>
</tr>
</tbody>
</table>
What else does APCC provide?

Climate change scenario data

- **Coupled Model Intercomparison Project (CMIP) Phase 5**

20 climate modeling groups from around the world involved to

1) Assess the mechanisms responsible for model differences in poorly understood feedbacks associated with the carbon cycle and with clouds
2) Examine climate “predictability” and exploring the ability of models to predict climate on decadal time scales
3) Determine why similarly forced models produce a range of responses

Realistic scenarios of climate forcing for both historical, paleoclimate and future scenarios

Provide simulations for assessment in the Assessment Report (AR)5 of IPCC (Intergovernmental Panel on Climate Change)
What else does APCC provide?

Climate change scenario data

**Coupled Model Intercomparison Project (CMIP) Phase 5**
Representative Concentration Pathways (RCPs) scenarios

<table>
<thead>
<tr>
<th>RCPs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCP8.5</td>
<td>Rising radiative forcing pathway leading to 8.5 W/m² in 2100.</td>
</tr>
<tr>
<td>RCP6.0</td>
<td>Stabilization without overshoot pathway to 6 W/m² at stabilization after 2100</td>
</tr>
<tr>
<td>RCP4.5</td>
<td>Stabilization without overshoot pathway to 4.5 W/m² at stabilization after 2100</td>
</tr>
<tr>
<td>RCP2.6</td>
<td>Peak in radiative forcing at ~ 3 W/m² before 2100 and decline</td>
</tr>
</tbody>
</table>

**Total radiative forcing**
cumulative measure of human emissions of GHGs from all sources expressed in Watts per square meter

Source: IPCC
What else does APCC provide?

Climate change scenario data

Coupled Model Intercomparison Project (CMIP) Phase 5
Representative Concentration Pathways (RCPs) scenarios

Knutti & Sedlacek (2012)

change in global surface temperature relative to 1951-1980 average temperatures

Data source: NASA’s Goddard Institute for Space Studies (GISS).
Credit: NASA/GISS

Annual mean
6 year mean

relativeto1986–2005
What else does APCC provide?

National level data based on clipped CMIP5 data (29 GCMs)

<table>
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<tr>
<th>DataSet</th>
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<td>CORDEX-SEA25</td>
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<td>APCC</td>
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<td>CORDEX-SEA20</td>
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<td></td>
<td>APCC</td>
<td></td>
</tr>
</tbody>
</table>

Clipped CMIP5

National level data based on clipped CMIP5 data (29 GCMs)

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Countries</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical</td>
<td>Bangladesh, Burma, Chile, Cuba, Egypt, Ethiopia, Federated States of Micronesia, India, Indonesia, Kenya, Malaysia, Marshall Islands, Mongolia, Nepal, Philippines, Pakistan, Samoa, Tanzania, Thailand, Tonga, Vietnam, Zambia</td>
<td>Precipitation, max/min temperature, wind speed, relative humidity, solar radiation</td>
</tr>
<tr>
<td>RCP4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCP8.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What else?

**CLIMATE INFORMATION SERVICES**

- Seasonal Forecast
- BSISO Forecast
- Climate Monitoring
- CLIK
- Data Service
- CLIPs

**Current Climate Conditions**

- Climate Highlight
- Climate Indices
- Global Drought / Flood Monitoring

<table>
<thead>
<tr>
<th>Pacific SST</th>
<th>Atlantic SST</th>
<th>Atmosphere</th>
<th>Monsoon</th>
<th>Index Forecast</th>
</tr>
</thead>
</table>

Slowly (w.r.t. atmosphere) varying ocean, land surface, sea ice conditions may provide some predictable signals...

Assume you want to predict $X = X_{signal} + X_{noise}$

Signal $>>$ Noise : more predictable

Signal $<<$ Noise : less predictable
Can you answer all the questions?

I. Can you distinguish between weather and climate?
II. What does APEC Climate Center do?
III. How do we predict?
IV. How does APCC predict?
V. How good are they?
VI. What else does APCC provide?
Climate variability

I. What drives atmospheric circulation?
II. Monsoon
III. ENSO
IV. IOD
V. BSISO
What drives atmospheric circulation?

Towards energy balance!
To compensate for the surplus and deficit of radiation in different regions of the globe, atmospheric and oceanic transport processes distribute the energy equally around the earth. This transport is accomplished by atmospheric winds and oceanic currents.
Monsoon

- Most of the world's population live in monsoon regions
- While the global monsoon system responds to net heating on planetary scales, the evolution of the regional monsoons depends on the distribution of land and ocean as well as SST gradients and topography.

![Monsoon Regions Map](image1)

![Planetary-Scale Monsoon Circulation](image2)

*Fig. 3.29. The monsoon regions as defined by Ramage (1971).*
Monsoon
Monsoon

Division of Asia-Pacific Monsoon

Monsoon indices Monitoring

<table>
<thead>
<tr>
<th>WYI</th>
<th>AUSMI</th>
<th>SAMI</th>
<th>IMI</th>
<th>WNPMI</th>
</tr>
</thead>
</table>

South Asian monsoon index (SAMI)

Time: Aug 2007 - Jul 2017

© APEC Climate Center
ENSO

- El Nino Southern Oscillation: the biggest signal on the globe
- Strong couplings between the ocean and atmosphere
- Interannual times scale occurs in the tropical Pacific
- Has three states: El Nino vs La Nina vs Neutral
- Perturbing Walker circulation

( = ENSO neutral)
ENSO

El Niño

La Niña
ENSO

- Why do we care ENSO?
**ENSO**

- **ENSO monitoring**

  - Strongest in the boreal winter
  - 3-7 years of period
ENSO

- ENSO prediction

The skill of both temperature and precipitation forecasts strongly depends upon the ENSO strength (Min et al., 2017)

- ENSO can be predicted even 6 months ahead
- ENSO forecast is difficult from Feb-Apr, called the “spring predictability barrier”
IOD

- Indian Ocean Dipole

**Positive**

Indian Ocean Dipole (IOD): **Positive phase**

- Increased convection
- Warmer than normal
- Reduced chance of rain

**Negative**

Indian Ocean Dipole (IOD): **Negative phase**

- Increased convection
- Cooler than normal
- Increased chance of rain
IOD

- IOD develops rapidly in boreal summer and reaches its mature phase in October.

- IOD tends to have a biennial tendency, that is, the zonal wind and SST gradient anomalies change the sign from one year to the following year (i.e., A negative IOD usually follows a positive IOD).

- Co-evolution of El Niño (La Niña) with positive (negative) IOD.

- Dipole Mode Index
  \[ \text{Dipole Mode Index} = \text{SST}_{\text{WIO}} - \text{SST}_{\text{EIO}} \]
Dipole Mode Index

\[ \text{DMI} = \text{SST}_{WIO} - \text{SST}_{EIO} \]

Monitoring

Forecast

Fig. 2. Predicted Indian Ocean Dipole mode index (IODMI) from individual models (A, B, C, D, E, F and G) and the SCM.
Last but not least

- Don’t forget our BSISO forecast!

**CLIMATE INFORMATION SERVICES**

- Boreal Summer *Intraseasonal* Oscillation (2 weeks upto a season = *subseasonal*)
BSISO Life cycle composite

- Phase 1: 121 days
- Phase 2: 145 days
- Phase 3: 94 days
- Phase 4: 71 days
- Phase 5: 181 days
- Phase 6: 133 days
- Phase 7: 105 days
- Phase 8: 106 days

- Intraseasonal: 2 weeks up to a season (20-90 days)
- OLR: Outgoing Longwave radiation
In northern summer, signal maximizes in the northern Indian Ocean and South China Sea.

Propagation is both northward and eastward.

Northward propagation is related to the onset/break of Asia Monsoon.
Lau et al (1988) found that the 40-day & 20-day Oscillations are related to rainfall fluctuations over East Asia.
BSISO

- BSISO indices: Multivariate EOF (A statistical tool)

Feasible for real-time ISO monitoring
Consist of BSISO1 & BSISO2:
daily time series (phase, amplitude)

extracting important spatial pattern & how they change with time
BSISO

Reconstructed OLR anomaly based on the BSISO indices (13Aug2017)

BSISO Monitoring for 05Jul2017~13Aug2017

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**BSISO1**

- Consists of EOF1 and EOF2
- Represent canonical northward and northeastward propagating ISO
- Periods of 30-60 days

Lee et al (2013)
BSISO2

- Consists of EOF3 and EOF4
- Represent northward/northwestward propagating variability
- Periods of 10-30 days

Lee et al (2013)
Periods of BSISO1 & BSISO2

Lee et al (2013)
BSISO

Changma onset in Korea

Changma: long rainy period of over Korea within EASM
The rainfall during Changma accounts for 30% of annual precipitation in Korea
18 out of 28 cases of Indian monsoon onset occur in phases 2-4
19 out of 29 cases of South China Sea monsoon onset occur in phases 2-4
The BSISO forecast activity has been initiated in 2013 with the goal of improving our ability to understand and forecast the BSISO based on numerical models.

The forecast is updated everyday with the latest information and is available from May to October.
# BSISO forecast

## Participating models

<table>
<thead>
<tr>
<th>Institute</th>
<th>Model</th>
<th>Ensemble Size</th>
<th>Forecast Period</th>
<th>Update frequency</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCEP</td>
<td>Climate Forecast System</td>
<td>4</td>
<td>40 days</td>
<td>Once a day</td>
<td>T126 L64</td>
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<tr>
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<td>Global Forecast System</td>
<td>1</td>
<td>16 days</td>
<td>Once a day</td>
<td>T574, T190 L64</td>
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<tr>
<td>Australia</td>
<td>POAMA 2.4 multi-week model</td>
<td>33</td>
<td>40 days</td>
<td>Twice per week</td>
<td>T47 L17</td>
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<tr>
<td>ECMWF</td>
<td>ECMWF Ensemble Prediction System</td>
<td>51</td>
<td>32 days</td>
<td>Twice per week</td>
<td>T639, T319 L62</td>
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<tr>
<td>Taiwan CWB</td>
<td>CWB EPS T119</td>
<td>1</td>
<td>40 days</td>
<td>Every 5 days</td>
<td>T119 L30</td>
</tr>
</tbody>
</table>
Welcome to the Boreal Summer Intraseasonal Oscillation (BSISO) monitoring website. The BSISO, one of the dominant phenomena over the Asian summer monsoon region, is characterized by northward/northeastward propagation over the Indian summer monsoon region and northward/northwestward propagation over the Western North Pacific-East Asian region, including equatorial eastward propagation. This monitoring information is available from May to October.

Text file of Normalized Time Series for the BSISO1 and BSISO2 index

Reconstructed OLR anomaly based on the BSISO indices (31Oct2016)
BSISO forecast

- Monitoring

Welcome to the Boreal Summer Intraseasonal Oscillation (BSISO) monitoring website. The BSISO, one of the dominant phenomena over the Asian summer monsoon region, is characterized by northward/northeastward propagation over the Indian summer monsoon region and northward/northwestward propagation over the Western North Pacific-East Asian region, including equatorial eastward propagation. **This monitoring information is available from May to October.**

Text file of Normalized Time Series for the BSISO1 and BSISO2 index
BSISO forecast

- Forecast

| Phase Diagram | Spatial OLR Anomalies | Heavy Rainfall Probability | Verification | Participation |

Phase Plots of BSISO Index Forecasts

| BOM | CFS | GFS | ECM | CWB |

BSISO Forecast for 14Aug2017-2Sep2017
BSISO forecast

- Forecast

<table>
<thead>
<tr>
<th>Phase Diagram</th>
<th>Spatial OLR Anomalies</th>
<th>Heavy Rainfall Probability</th>
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</tr>
</thead>
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<tr>
<th>BOM</th>
<th>CFS</th>
<th>GFS</th>
<th>ECM</th>
<th>CWB</th>
</tr>
</thead>
</table>

Initial Date (14/08/2017)
Days 1–5 Ave forecast
Days 6–10 Ave forecast
Days 11–15 Ave forecast
Days 16–20 Ave forecast

Probability of heavy rainfall determined by predicted BSISO

WEEK 1

WEEK 2

Probability of occurrence for heavy rainfall event as defined by daily rainfall exceeding the 90th percentile value (22.6 mm/day) for Aug during 1981-2010.

© APEC Climate Center
BSISO forecast

- **Forecast**

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</tr>
</thead>
</table>

- **Correlation coefficient**
  - Perfect score: 1
  - Skill in forecasting the phase of the BSISO

- **Root Mean Square Error (RMSE)**
  - Perfect score: 0
  - Errors in both phase & amplitude

- **Phase amplitude**
  - Perfect score: 0
  - Relative amplitude difference btw observation and forecast
  - Positive: forecast amplitude is larger than the observed

- **Phase error**
  - Perfect score: 0
  - Positive: phase speed of the forecast is faster than that of the observation

- **Mean square skill score (MSSS)**
  - Perfect score: 1
  - Relative level of skill of forecast compared to a climatological forecast that predict no BSISO signal

*Kim (2014) APCC Research report*
Boreal winter ISO: MJO

- Madden-Julian Oscillation: Eastward propagation of rainfall
- Discovered by Roland Madden and Paul Julian in early 1970’s
Winter ISO = MJO

- An eastward moving 'pulse' of clouds, rainfall, winds and pressure near the equator.
- It’s a traversing phenomenon and is most prominent over the Indian and Pacific Oceans.
MJO index

- MJO index: RMM index (Real-time Multivariate MJO index)
  - Designed by Wheeler and Hendon (2004) considering observed features of the MJO (use of OLR, zonal wind at 850hPa & 200hPa)
  - Phase (where is MJO?) & amplitude (how strong is it?)
MJO impact

- Cold surge
- Storm track
- Extreme rain
- AO/NAO
- ENSO
- O₃, CO₂, aerosol
- Tropical cyclone (TC)
- Asian monsoon
- Australian monsoon

TC: tropical cyclone
AO: Arctic oscillation
NAO: North Atlantic oscillation
MJO forecast

MJO operational prediction:


NCPO: National Centers for Environmental Prediction - Operational Global Forecast System
NCPE: National Centers for Environmental Prediction - Ensemble Global Forecast System
NCPB: National Centers for Environmental Prediction - Bias-Corrected Ensemble Global Forecast System
NCFS: National Centers for Environmental Prediction - Climate Forecast System

UKMA: UK Met Office - MOGREPS-G Operational Control Run
UKME: UK Met Office - MOGREPS-G Ensemble System

CMET: Canadian Meteorology Centre - Ensemble System
ECMF: European Centre for Medium Range Weather Forecasts - Ensemble System
ECMM: European Centre for Medium Range Weather Forecasts - Ensemble System (anomalies based on lead dependent model climatology)

BOMM: Australian Bureau of Meteorology - POAMA Coupled System
CPTC: Brazil Center for Weather and Climate Studies - Ensemble System
JMAN: Japan Meteorology Agency - Global Spectral Model Ensemble System
TCWB: Taiwan Central Weather Bureau - Operational Prediction System
IMDO: India Meteorology Department - Operational Global Forecast System
EMON: European Centre for Medium Range Weather Forecasts - Seasonal Prediction Ensemble Forecast System
EMOM: European Centre for Medium Range Weather Forecasts - Seasonal Prediction Ensemble Forecast System (anomalies based on lead dependent model climatology, weekly - Thursday only)
Seasonality of ISO

MJO Life cycle composite

BSISO Life cycle composite
S2S: Subseasonal to seasonal

White et al., 2017
S2S: Subseasonal to seasonal

- We are progressing!

Dynamical MJO prediction skill

<table>
<thead>
<tr>
<th>Lead time (weeks)</th>
<th>Predictability</th>
<th>After 2010</th>
<th>2000~2010</th>
<th>Before 2000</th>
<th>Statistical models</th>
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<tr>
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</tbody>
</table>


Courtesy of Hyemi Kim (SUNY/stony brook)
Decision making process based on S2S information

USER NEEDS
Reliable and actionable information for decision-making

SHORT RANGE 1–3 DAYS
- issue warnings
- distribute humanitarian aid
- evacuation

MEDIUM RANGE 3–10 DAYS

EXTENDED RANGE (S2S) 10–30 DAYS

LONG RANGE >30 DAYS

SHORT-TO MEDIUM-RANGE WEATHER-INFLUENCED ACTIONS
- issue warnings
- distribute humanitarian aid
- evacuation

LONG-RANGE WEATHER-INFLUENCED ACTIONS
- start monitoring forecasts
- update contingency plans
- inform strategic planning decisions

S2S WEATHER-INFLUENCED ACTIONS
- continue monitoring forecasts
- update community warnings
- initiate preparedness activities
- revise water allocations
- activate water conservation practices
- supplement financial risk strategies
- inform loss scenarios
- update peak energy demand scenarios
- pre-positioning of disaster response materials
- implement irrigation, pesticide or fertilizer schedules

White et al., 2017
THANK YOU