Introduction to Climate Data

August 21, 2017
Ji-Hyun Oh
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

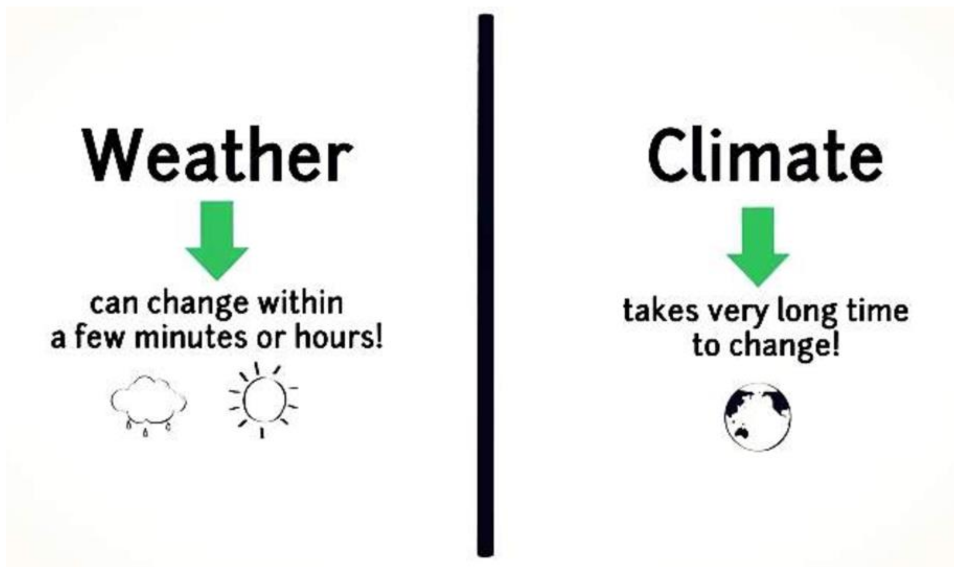
The state of the atmosphere at any given time (Look out the window and view the weather)

"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)

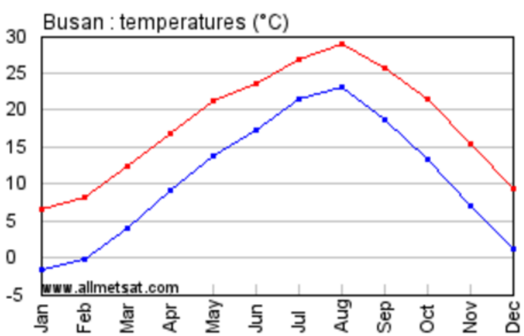
Weather makes up climate

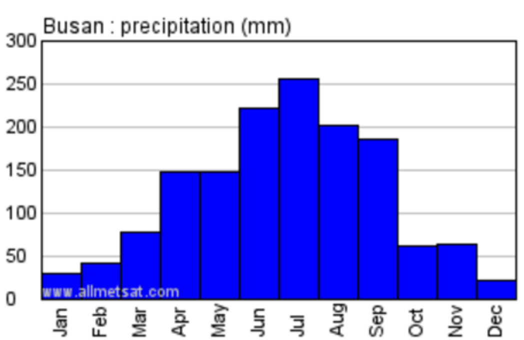


Can you distinguish between weather and climate?

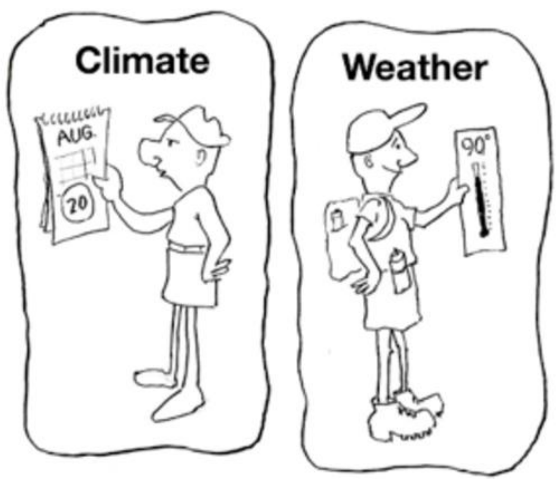
"User-oriented Statistical Downscaling of Climate Information in Agriculture and Water Resources"

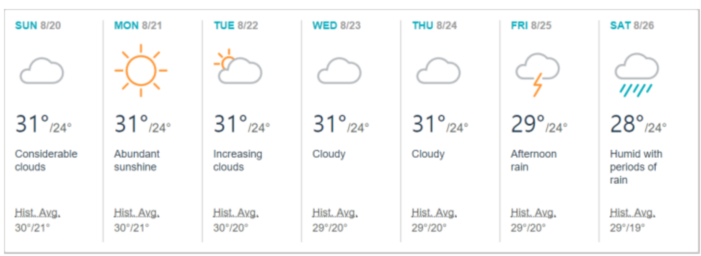
Aug.21-Aug.26, 2017 APEC Climate Center, Busan, South Korea



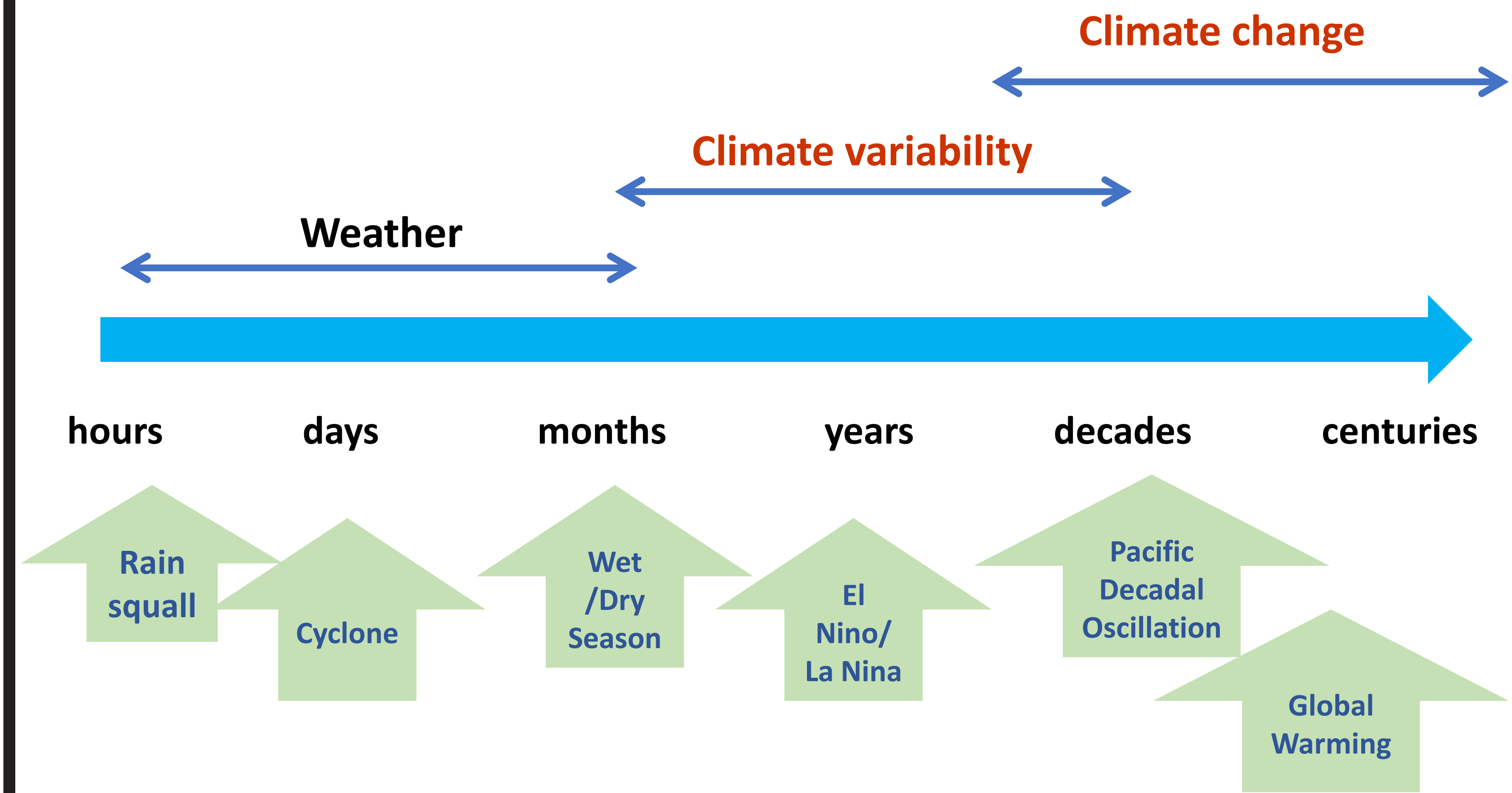


TP Participant





Weather and climate scales



What does APEC Climate Center do?

What does APEC Climte Center do?

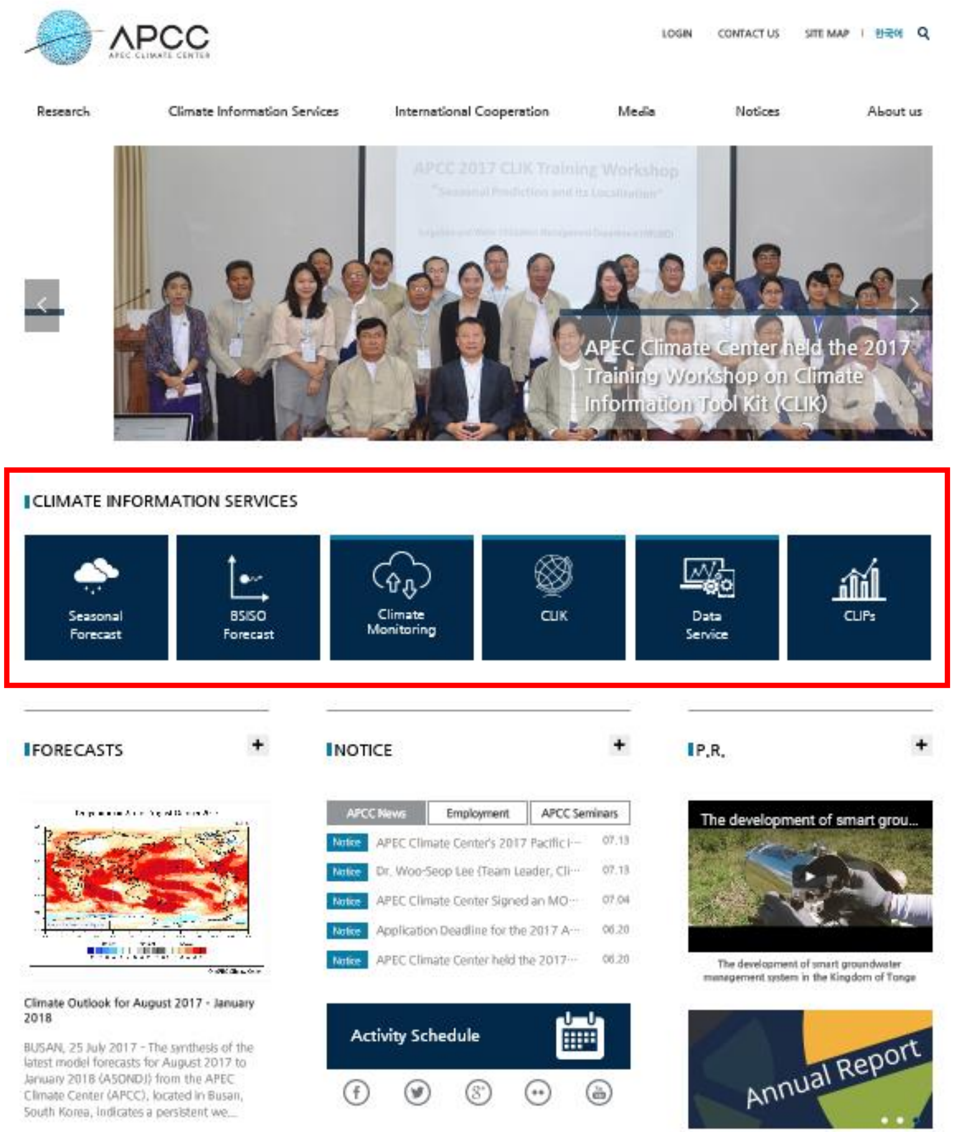
- Established in 2005 as a climate prediction center during the 13th APEC Leaders' Meeting in Busan, South Korea
- Aim: enhance socio-economic wellbeing of APEC countries using climate informati
on

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?



Add our website to your favorites!

http://www.apcc21.org

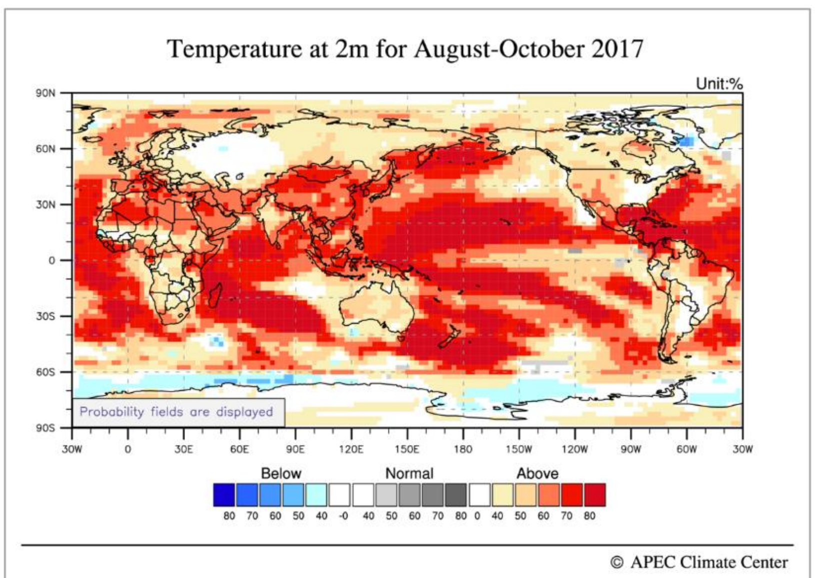
What does APEC Climte Center do?

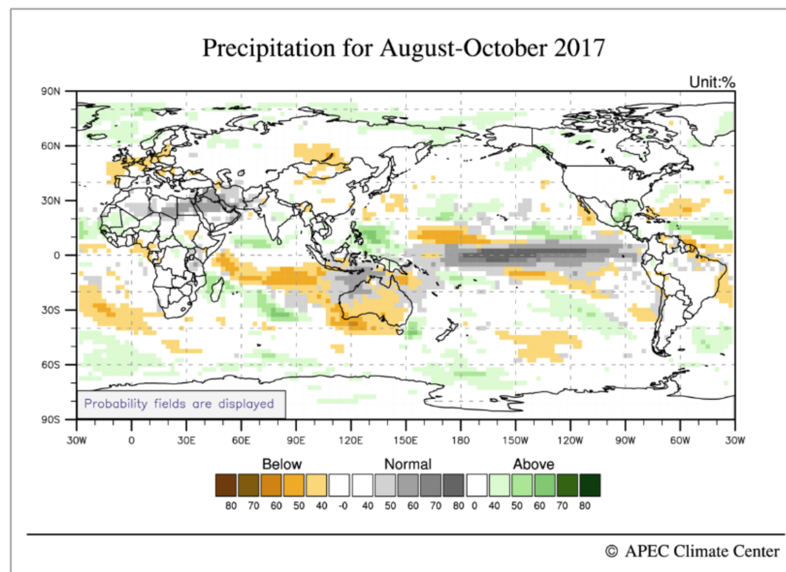
CLIMATE INFORMATION SERVICES

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

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

Forecast for August- October 2017

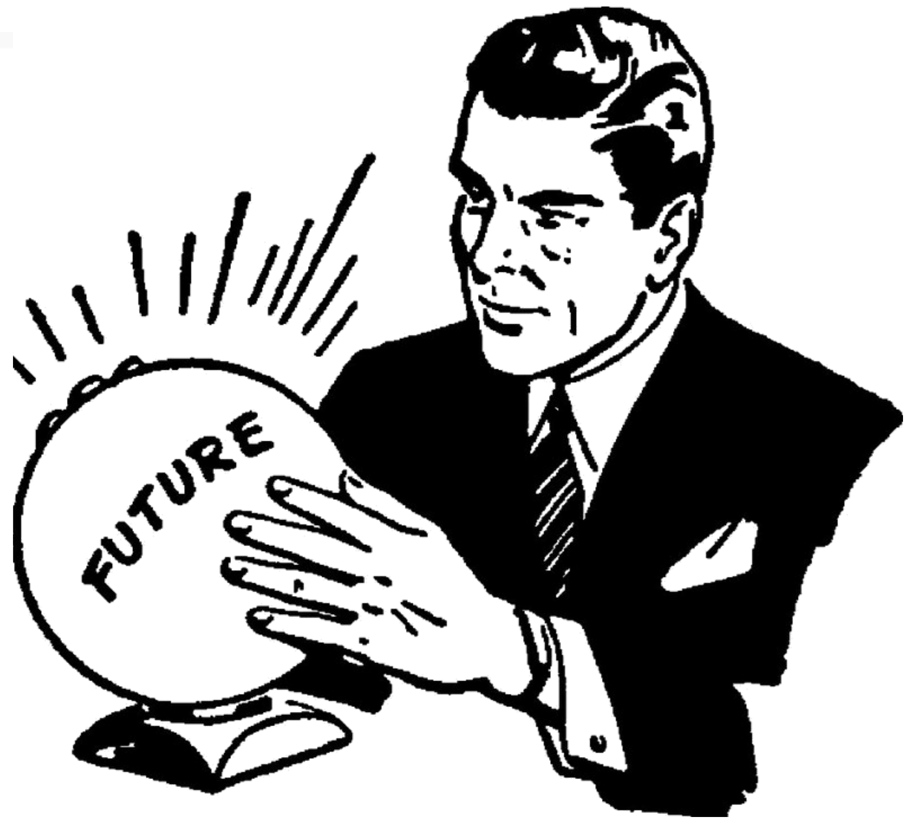




Seasonal forecast: Temperature and Precipitation Outlook (Aug–Oct 2017)

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

	Statistical prediction	Dynamical prediction
	▪ Use observed relationship of climate system to predict future	▪ Based on physical laws of the climate system
Pros	▪ Simple ▪ Cheap	▪ Nonlinearity can be considered. ▪ Spatiotemporally coherent variables.
Cons	▪ Stationarity – climate is changing. ▪ Limited data	▪ Complicated & expensive ▪ Not real – biased & need correction.

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)

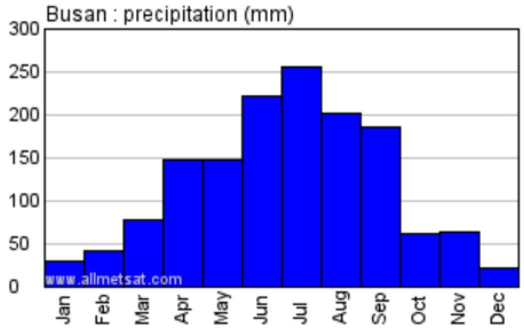
$$x(t+1) = ax(t) + b$$

Seasonal forecast: Statistical prediction

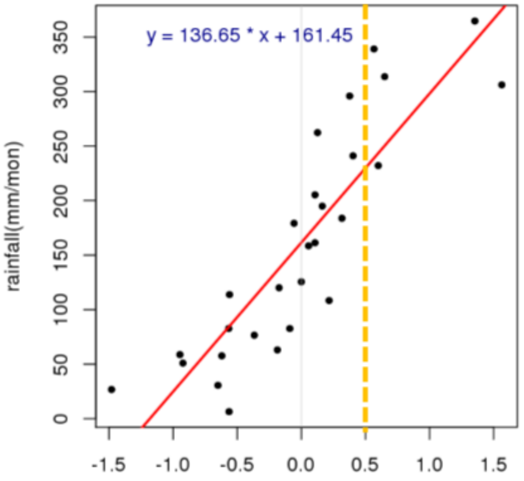
- Predict rainfall in Busan for coming December

(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)

(0)



(2)



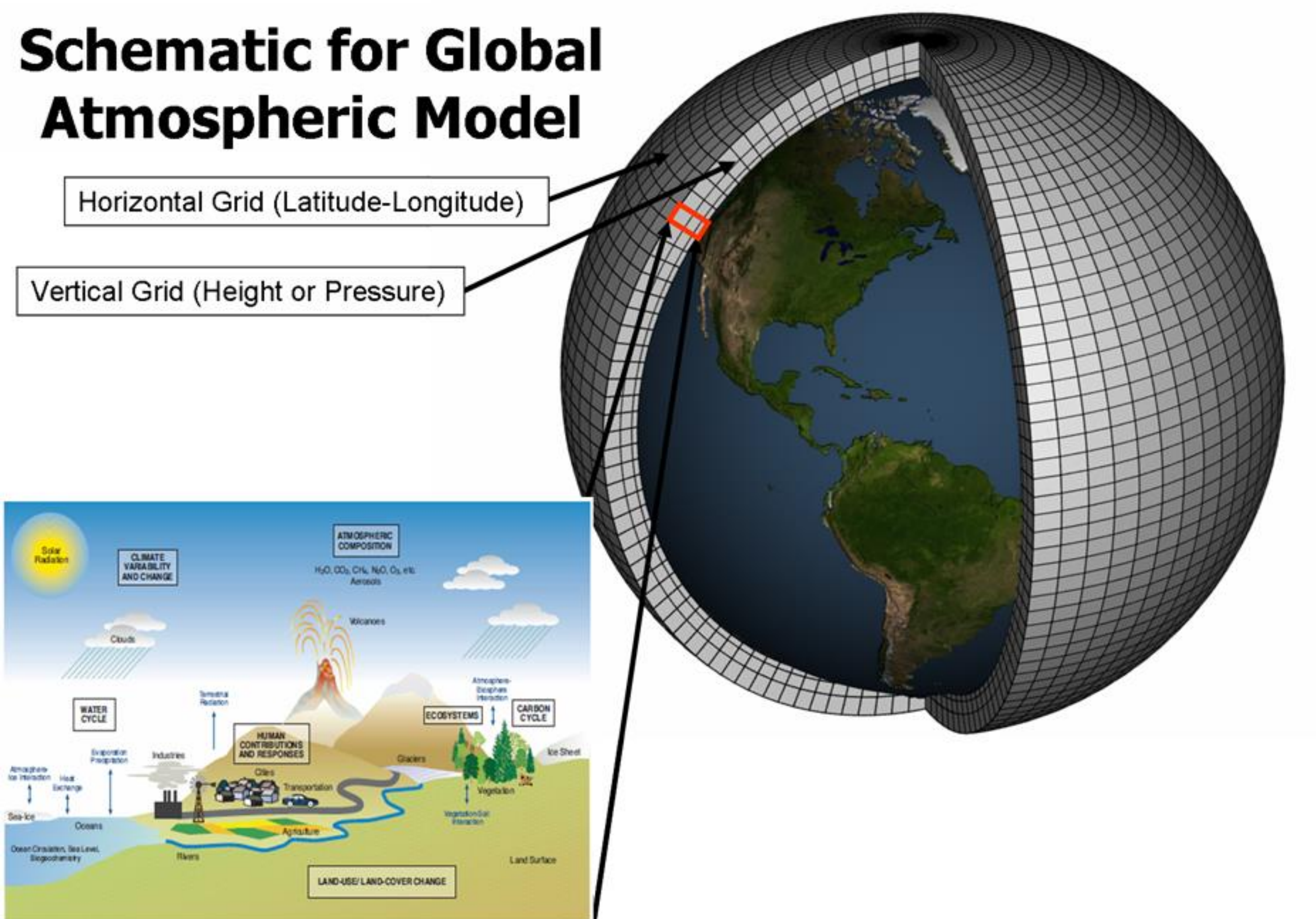
Sea surface temperature in Pacific

Seasonal forecast: Dynamical prediction

- Use GCM : Global Climate Model

Atmosphere
Ocean
Sea-Ice
Land surface
Chemistry
Biosphere

Seasonal forecast: Dynamical prediction



Seasonal forecast: Dynamical prediction

$$r:\rho\left(\frac{\partial u_r}{\partial t}+u_r\frac{\partial u_r}{\partial r}+\frac{u_\phi}{r\sin(\theta)}\frac{\partial u_r}{\partial \phi}+\frac{u_\theta}{r}\frac{\partial u_r}{\partial \theta}-\frac{u_\phi^2+u_\theta^2}{r}\right)=-\frac{\partial p}{\partial r}+\rho g_r+$$

$$\mu\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial u_r}{\partial r}\right)+\frac{1}{r^2\sin(\theta)^2}\frac{\partial^2 u_r}{\partial \phi^2}+\frac{1}{r^2\sin(\theta)}\frac{\partial}{\partial \theta}\left(\sin(\theta)\frac{\partial u_r}{\partial \theta}\right)-2\frac{u_r+\frac{\partial u_\theta}{\partial \theta}+u_\theta\cot(\theta)}{r^2}-\frac{2}{r^2\sin(\theta)}\frac{\partial u_\phi}{\partial \phi}\right]$$

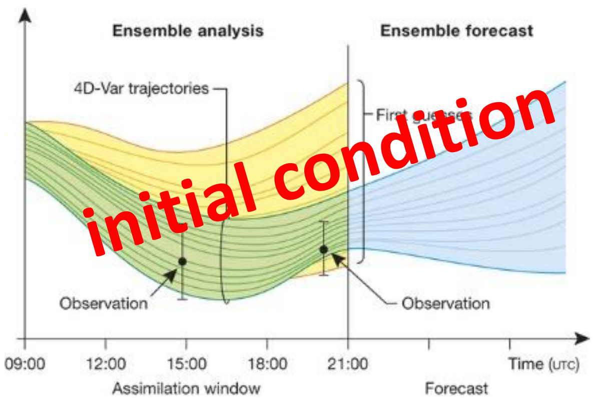
$$\phi:\rho\left(\frac{\partial u_\phi}{\partial t}+u_r\frac{\partial u_\phi}{\partial r}+\frac{u_\phi}{r\sin(\theta)}\frac{\partial u_\phi}{\partial \phi}+\frac{u_\theta}{r}\frac{\partial u_\phi}{\partial \theta}+u_r u_\phi+u_\phi u_\theta\cot(\theta)\right)-\frac{1}{r\sin(\theta)}\frac{\partial p}{\partial \phi}+\rho g_\phi+$$

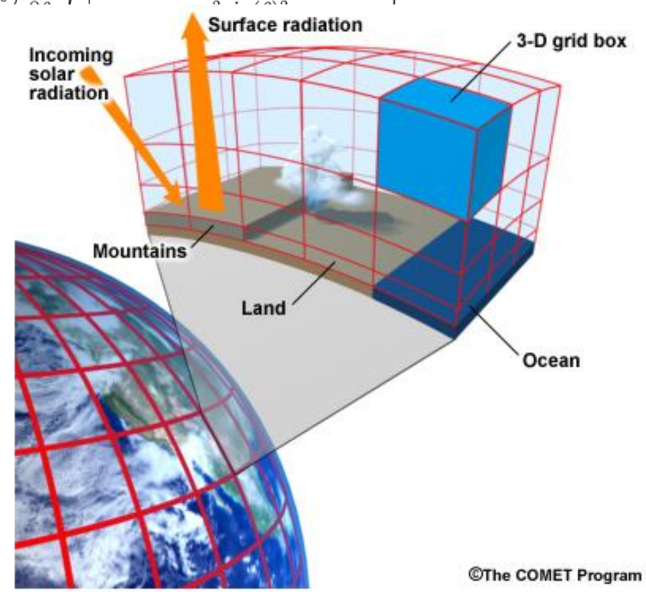
$$\mu\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial u_\phi}{\partial r}\right)+\frac{1}{r^2\sin(\theta)^2}\frac{\partial^2 u_\phi}{\partial \phi^2}+\frac{1}{r^2\sin(\theta)}\frac{\partial}{\partial \theta}\left(\sin(\theta)\frac{\partial u_\phi}{\partial \theta}\right)+2\sin(\theta)\frac{\partial u_r}{\partial \phi}+2\cos(\theta)\frac{\partial u_\theta}{\partial \phi}-u_\phi\right]$$

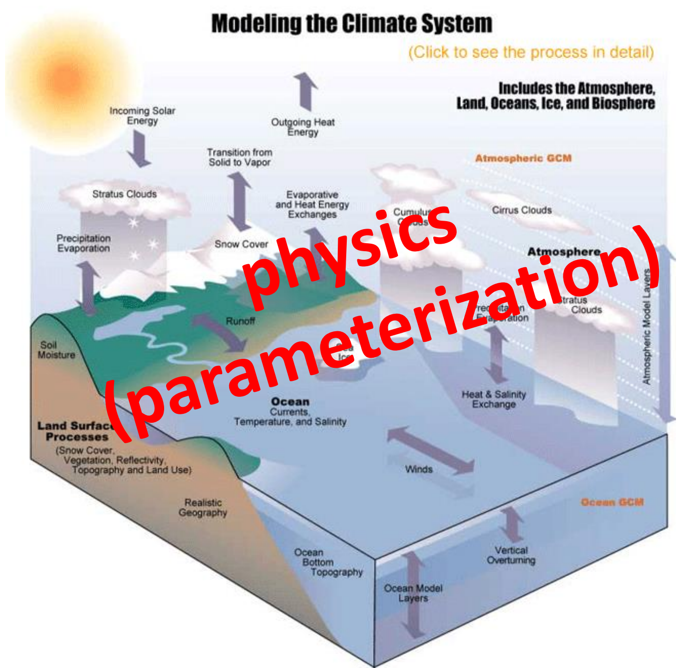
$$\theta:\rho\left(\frac{\partial u_\theta}{\partial t}+u_r\frac{\partial u_\theta}{\partial r}+\frac{u_\phi}{r\sin(\theta)}\frac{\partial u_\theta}{\partial \phi}+\frac{u_\theta}{r}\frac{\partial u_\theta}{\partial \theta}+\frac{u_r u_\theta-u_\phi^2 \cot}{r}\right.$$

$$\mu\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial u_\theta}{\partial r}\right)+\frac{1}{r^2\sin(\theta)^2}\frac{\partial^2 u_\theta}{\partial \phi^2}+\frac{1}{r^2\sin(\theta)}\frac{\partial}{\partial \theta}\left(\sin\right.\right.$$

dynamics







Which approach does APCC take for Seasonal forecast:? Multi-model ensemble (use many GCMs)

APCC
APEC CLIMATE CENTER

Seasonal forecast: Predictability

- **Predictability: How well we can predict?**

-> depends on what to predict

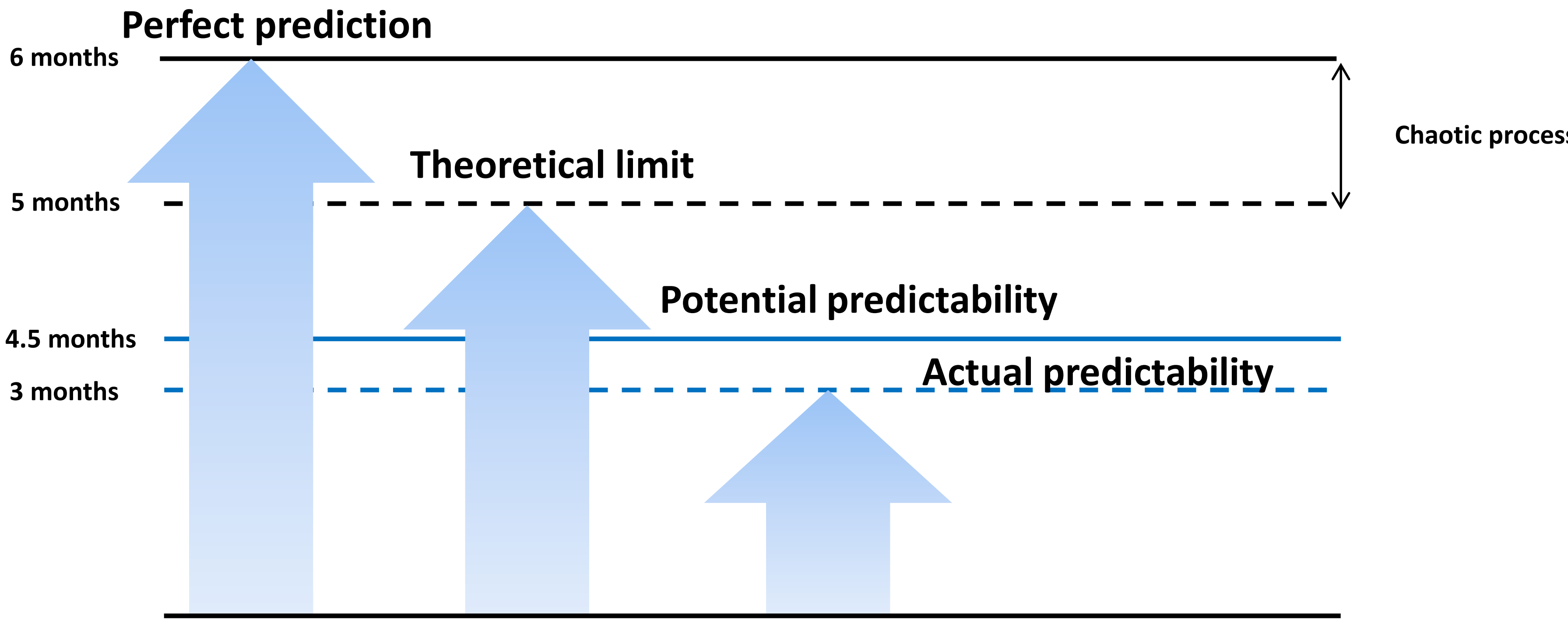
Lead time(τ)	***1. Temperature of this room tomorrow*** ***2. Temperature of this room in 30days later*** ***3. Temperature of this room in 30years later***
Location	***1. Temperature of Seoul (Korea)*** ***2. Temperature of Jakarta (Indonesia)*** ***3. Temperature of Villa Las Estrellas (Antarctica)***
Physical variables	***1. Temperature*** ***2. rainfall*** ***3. wind speed***

Seasonal forecast: Predictability

- Assume you want to predict X = Xsignal + Xnoise

Signal >> Noise : more predictable

Signal << Noise : less predictable

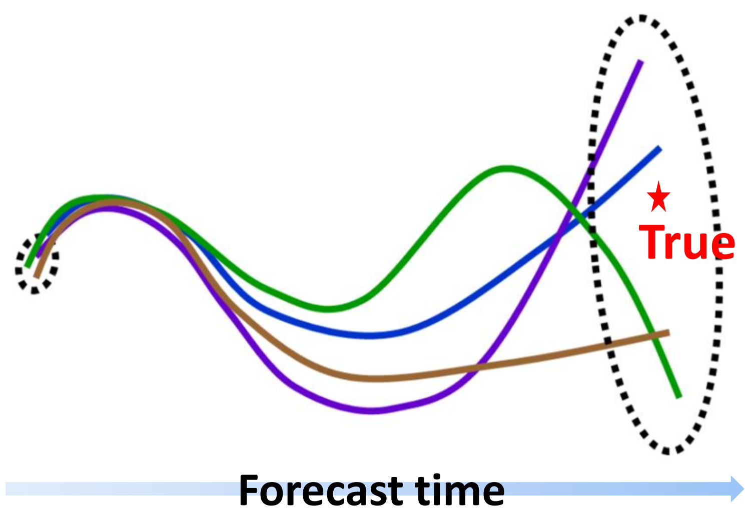


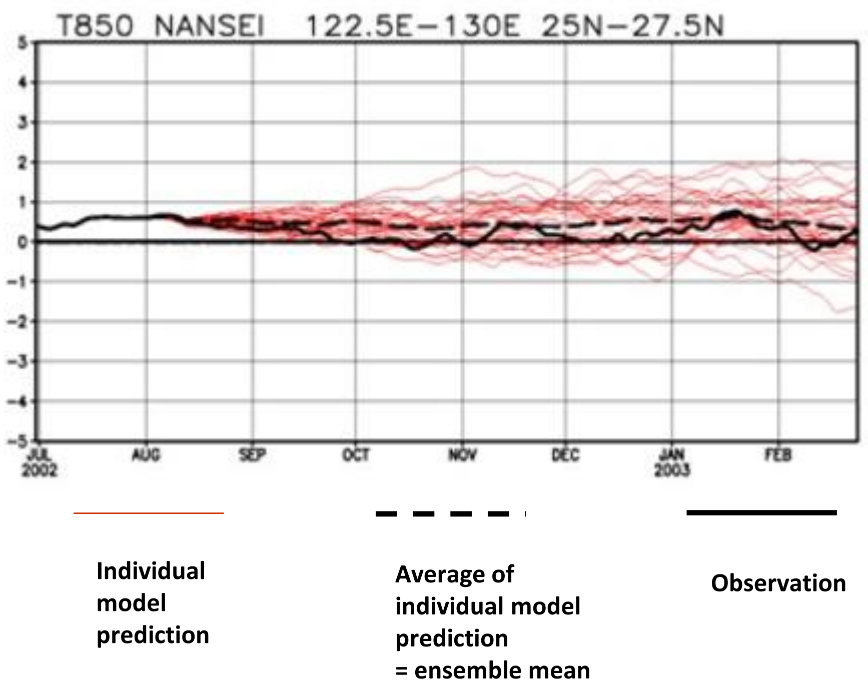
Trying to reach potential predictability with state-of-art prediction system

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)

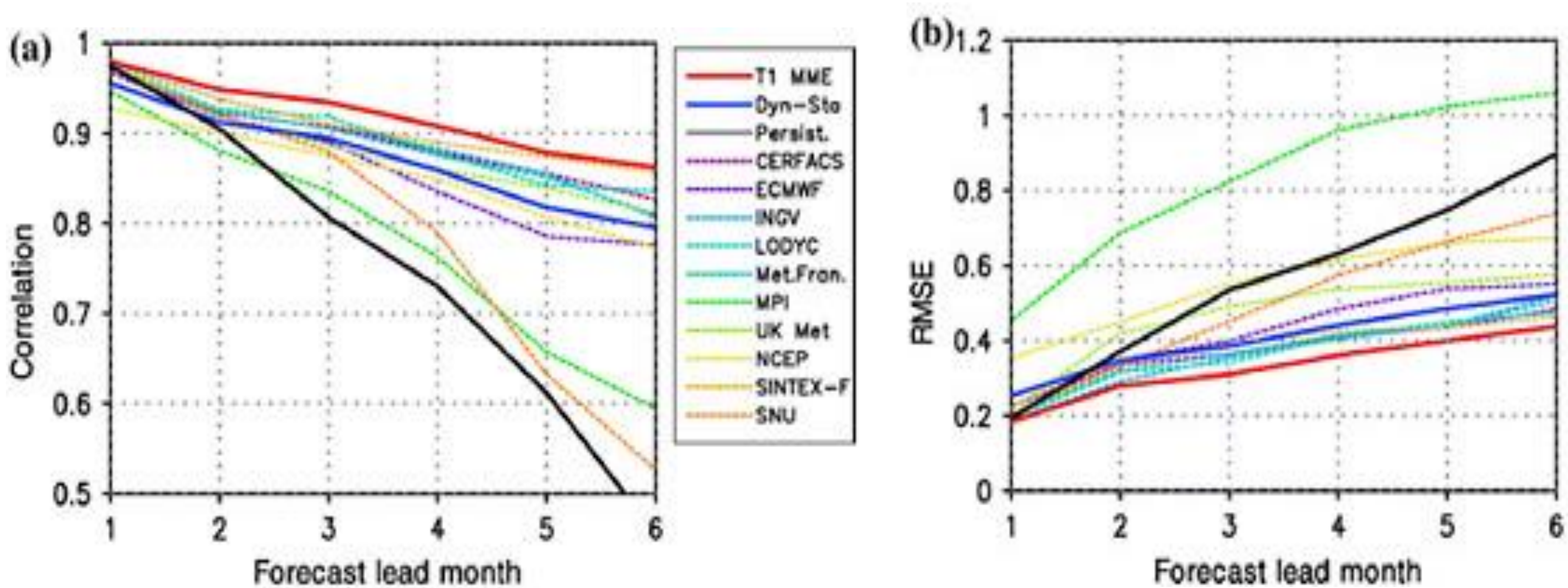




Seasonal forecast: Multi-model ensemble

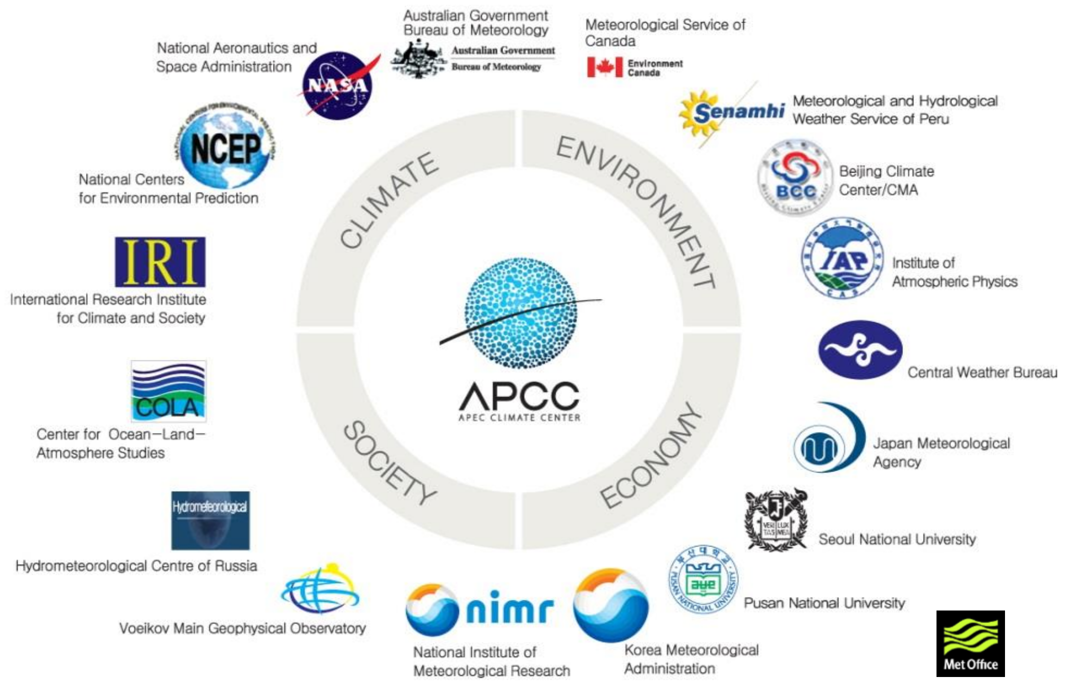
An example of a MME outperforming individual modesl in forecasting

(Jin et al. (2008)



Seasonal forecast: Multi-model ensemble

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



Graphical products	APCC website: apcc21.org
Digital products	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)

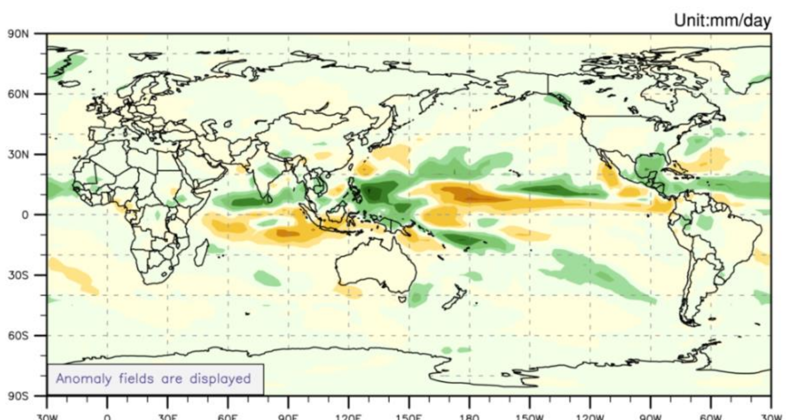
Probabilistic method

- ✓ 2m temperature
- ✓ Precipitation
- ✓ 850hPa temperature
- ✓ 500hPa geopotential height
- ✓ sea surface temperature

Seasonal forecast: Multi-model ensemble

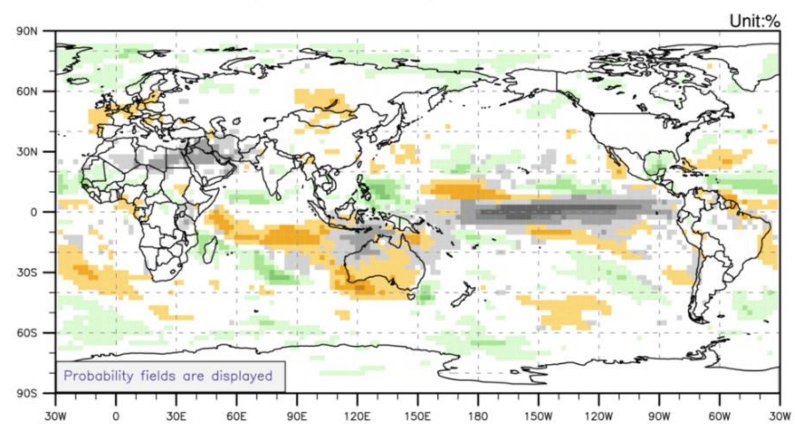
Deterministic

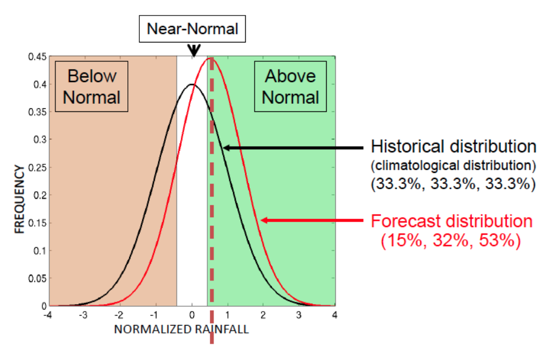
Precipitation for August-October 2017



Probabilisitc

Precipitation for August-October 2017





Map showing probility 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

Anomaly Correlation Coefficient	Root Mean Square Error

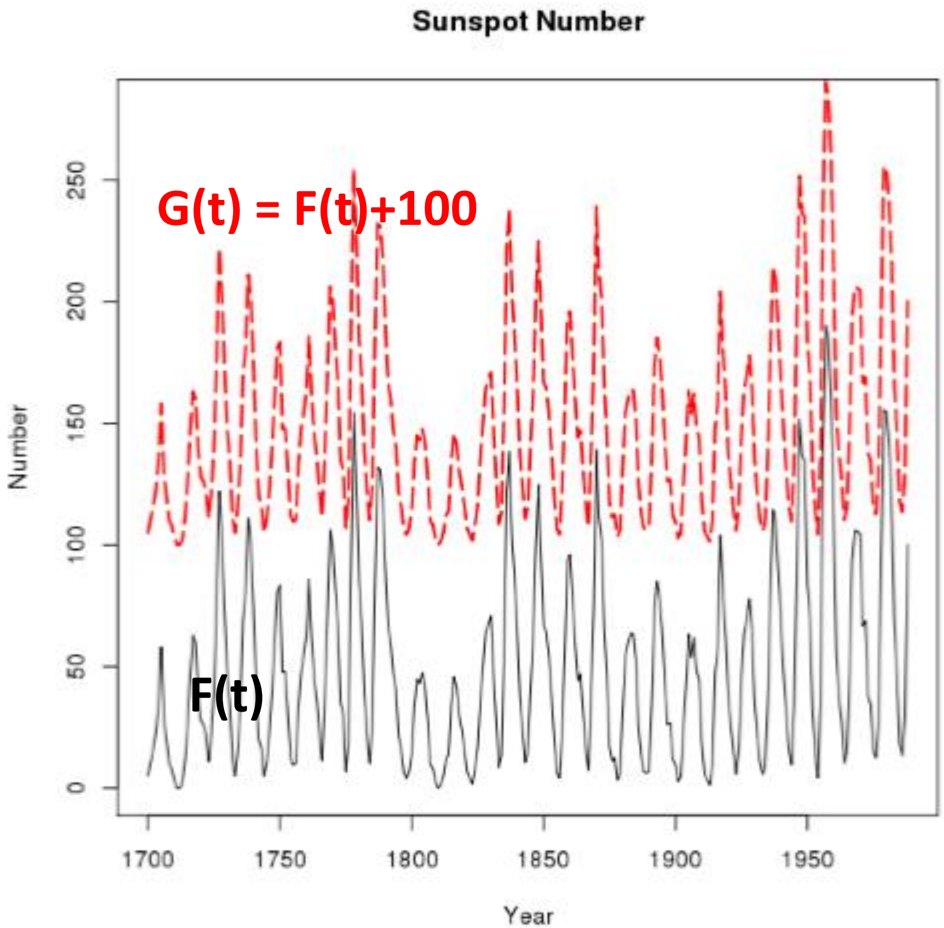
Verification for Probabilistic MME method

Reliability Diagram	Relative Operating Characteristics Curve	Heidke Skill Score	Ranked Probability Skill Score

How good are they?

Verification for Deterministic MME method

Anomaly Correlation Coefficient	Root Mean Square Error



Correlation coefficient?
RMSE?

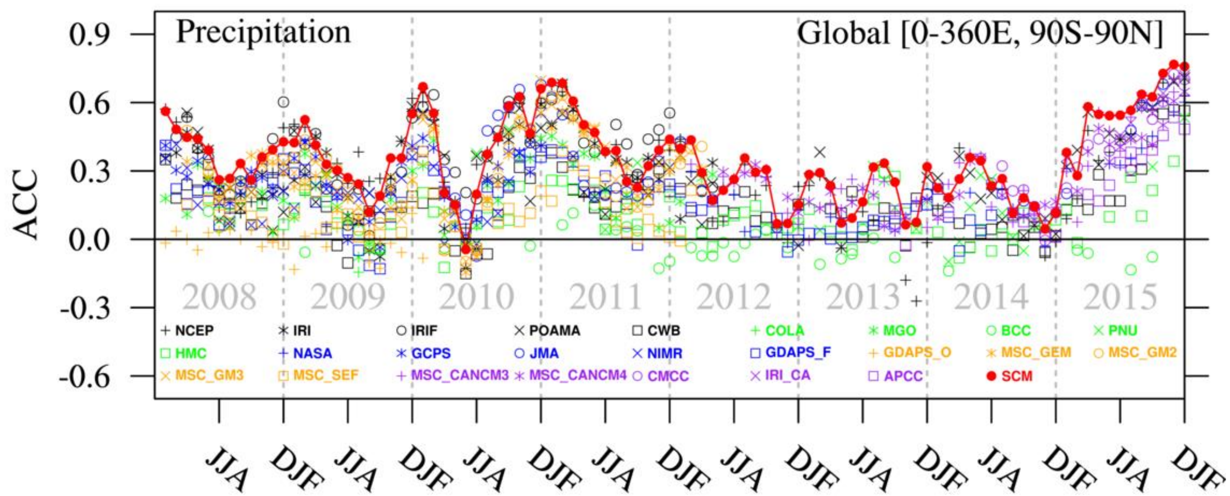
How good are they?

Verification for Probabilistic MME method

Reliability Diagram	Relative Operating Characteristics Curve	Heidke Skill Score	Ranked Probability Skill Score

How good are they?

- APCC operational forecast



	APCC	WMOLC	ECMWF	NCEP	UKMO	JMA
AN	0.569457	0.541897	0.535531	0.52996	0.528975	0.531497
NN	0.520962	0.521424	0.537661	0.519823	0.524022	0.514656
BN	0.567702	0.533777	0.516511	0.535767	0.516994	0.534244

Realtime rainfall forcast for last 4 years (12-15)
ROC score : Perfect = 1, Meaningless(no skill) =0.5,

How good are they?

Clim Dyn
DOI 10.1007/s00382-017-3576-2

CrossMark

Skill of real-time operational forecasts with the APCC multi-model ensemble prediction system during the period 2008–2015

Young-Mi Min[1] · Vladimir N. Kryjov[1] · Sang Myeong Oh[1] · Hyun-Ju Lee[1]

- 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

ADSS APCC Data Service System

LOGIN | REGISTER | CONTACT US

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?

DataSet	Areal Coverage	Grid Size	Time Step	Access	Source	Requirements
APCC-MME(6-MON)	Global	2.5×2.5(degree)	Monthly	About FTP OpeNDAP	APCC	Login
APCC-MME(3-MON)	Global	2.5×2.5(degree)	Monthly	About FTP OpeNDAP	APCC	Login
INDIVIDUAL-MODEL(6-MON)	Global	2.5×2.5(degree)	Monthly	About FTP OpeNDAP	APCC	Login
INDIVIDUAL-MODEL(3-MON)	Global	2.5×2.5(degree)	Monthly	About FTP OpeNDAP	APCC	Login
CORDEX-SEA25	Regional	25km	Daily	About FTP OpeNDAP	APCC	
CORDEX-SEA50	Regional	50km	Daily	About FTP OpeNDAP	APCC	
Clipped CMIP5	National level (22 Countries)	Depending on GCMs	Daily	About FTP OpeNDAP	ESGF	
IRI_DATA_LIBRARY	Global	2.5×2.5(degree)	Various	About Link	IRI	
NCEP	Global	2.5×2.5(degree)	Daily	About FTP OpeNDAP	NOAA	
NCEP-SFC	Global	2.5×2.5(degree)	Daily	About FTP OpeNDAP	NOAA	
NOAA-OLR	Global	2.5×2.5(degree)	Daily	About FTP OpeNDAP	NOAA	
TMI	Global	2.5×2.5(degree)	Daily	About FTP OpeNDAP	REMSS	
QUICKSCAT	Global	0.25×0.25(degree)	Daily	About FTP OpeNDAP	REMSS	
GPCP	Global	1.0×1.0(degree)	Daily	About FTP OpeNDAP	NASA	
GHCN	Global	5.0×5.0(degree)	Monthly	About FTP OpeNDAP	NOAA	
UD	Global	0.5×0.5(degree)	Monthly	About FTP OpeNDAP	University of Delaware	

Seasonal forecast data

Climate change scenario data

Observed data

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

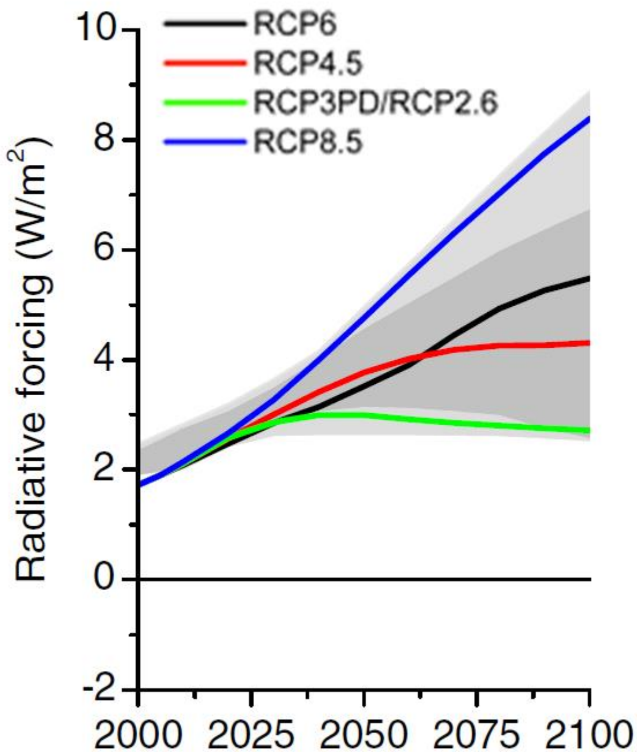
Provide simulations for assessment in the Assessment Report (AR)5 of IPCC (Intergovernmental Panel on Climate Change)

What else does APCC provide?

Climate change scenario data

Coupled Model Intercomparison Project (CMIP) Phase 5

Representative Concentration Pathways (RCPs) scenarios



Source: IPCC

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

Total radiative forcing

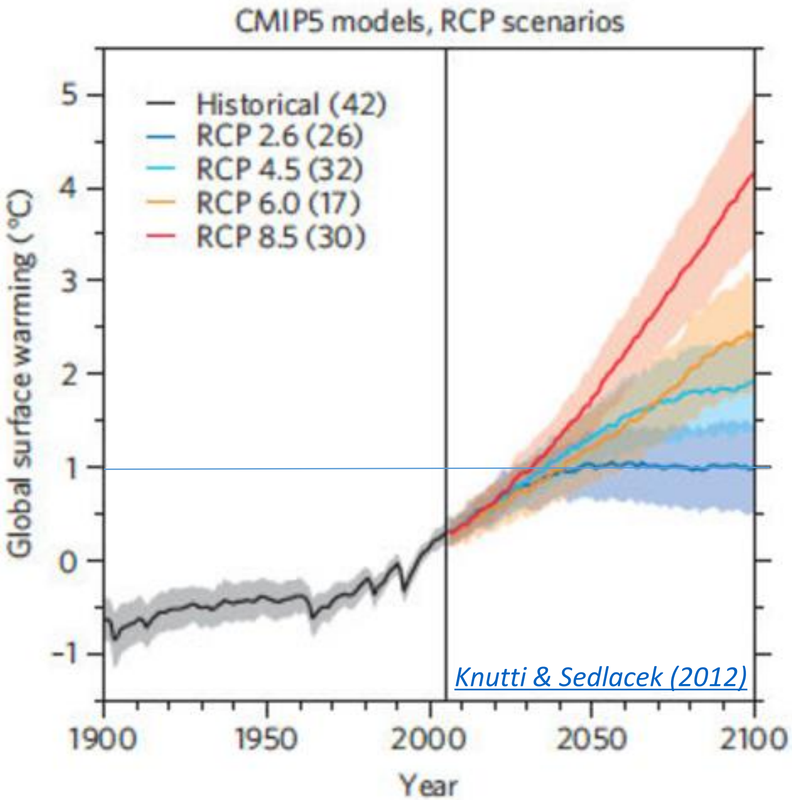
cumulative measure of human emissions of GHGs from all sources expressed in Watts per square meter

What else does APCC provide?

Climate change scenario data

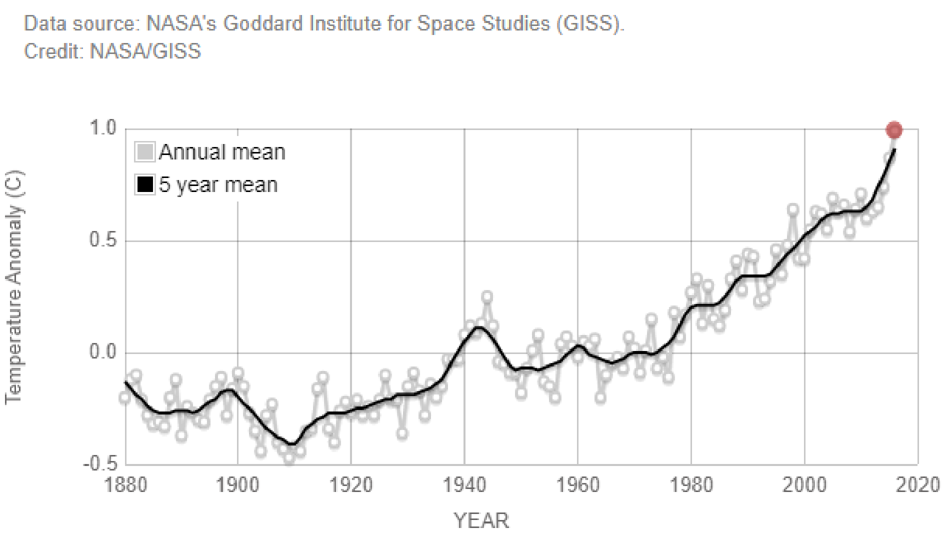
Coupled Model Intercomparison Project (CMIP) Phase 5

Representative Concentration Pathways (RCPs) scenarios



relativeto1986–2005

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



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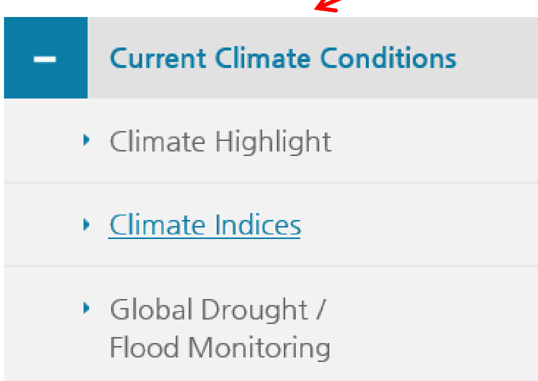
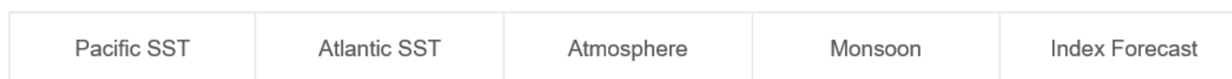
Clipped CMIP5	National level (22 Countries)	Depending on GCMs	Daily	About FTP OpeNDAP	ESGF	

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

Scenarios	Countries	Variables
Historical	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	Precipitation, max/min temperature, wind speed, relative humidity, solar radiation
RCP4.5		
RCP8.5		

What else?





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

Assume you want to predict X = Xsignal + Xnoise

Signal >> Noise : more predictable

Signal << Noise : less predictable

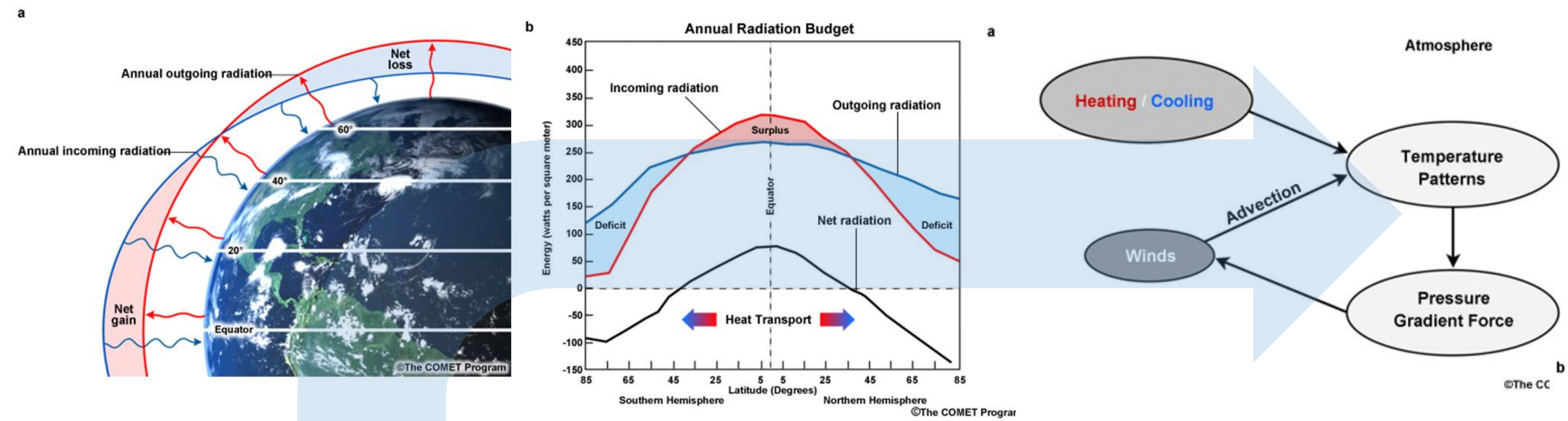
Can you answer all the questions?

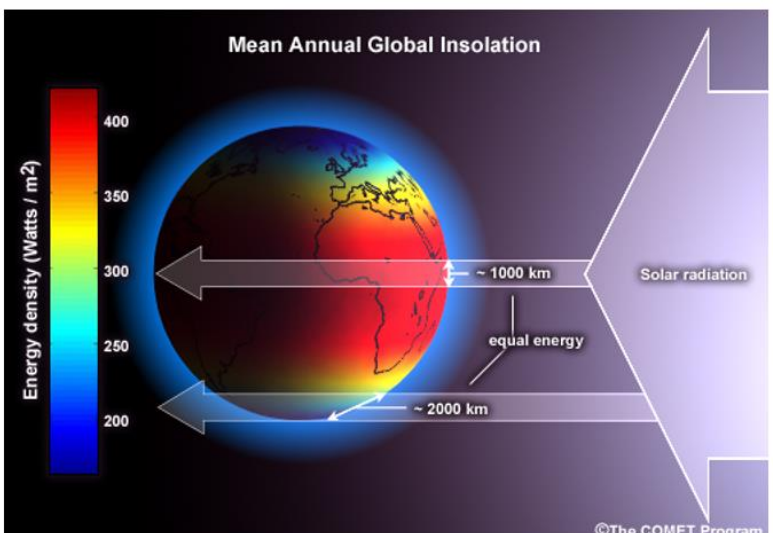
I. Can you distinguish between weather and climate?
II. What does APEC Climate Center do?
III. How do we predict?
IV. How does APCC predict?
V. How good are they?
VI. What else does APCC provide?

Climate variability

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

What drives atmospheric circulation?

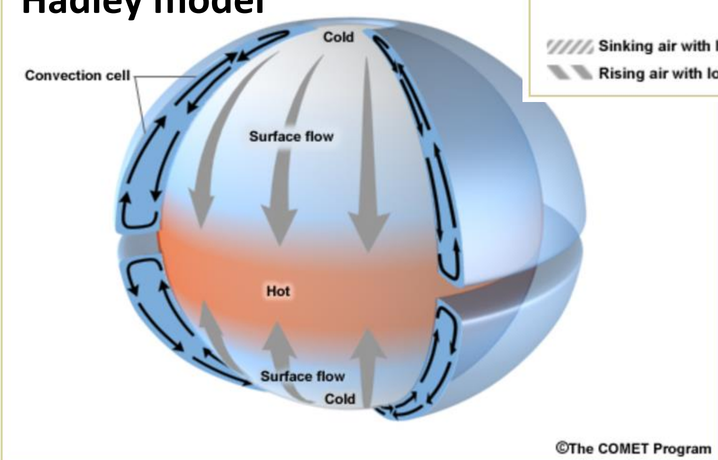




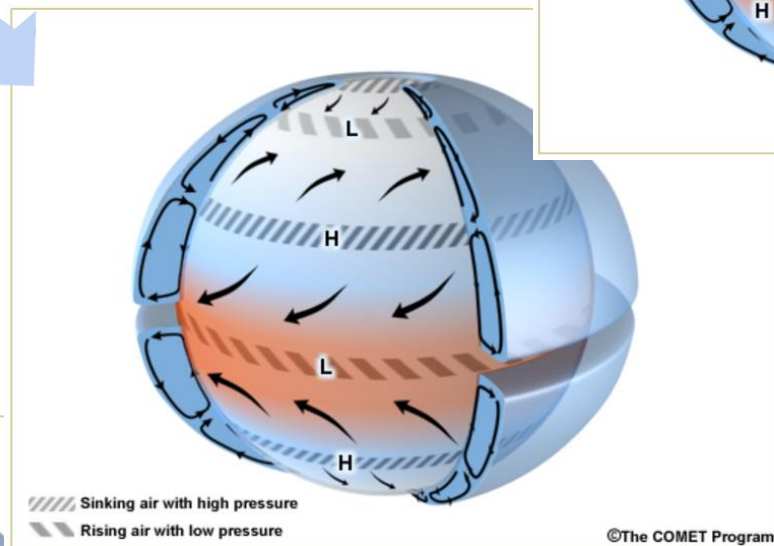
Towards energy balance!
To compensate for the surplus and deficit of radiation in different regions of the globe, atmospheric and oceanic transport processes distribute the energy equally around the earth. This transport is accomplished by atmospheric winds and ocean currents.

General circulation

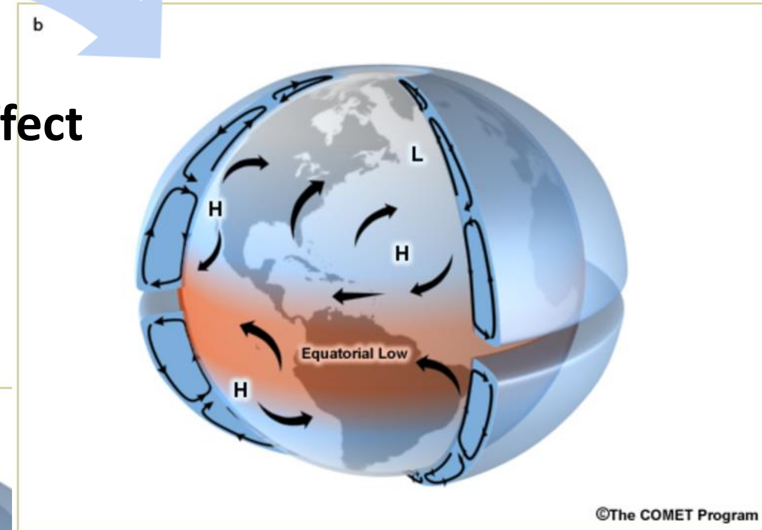
Hadley model



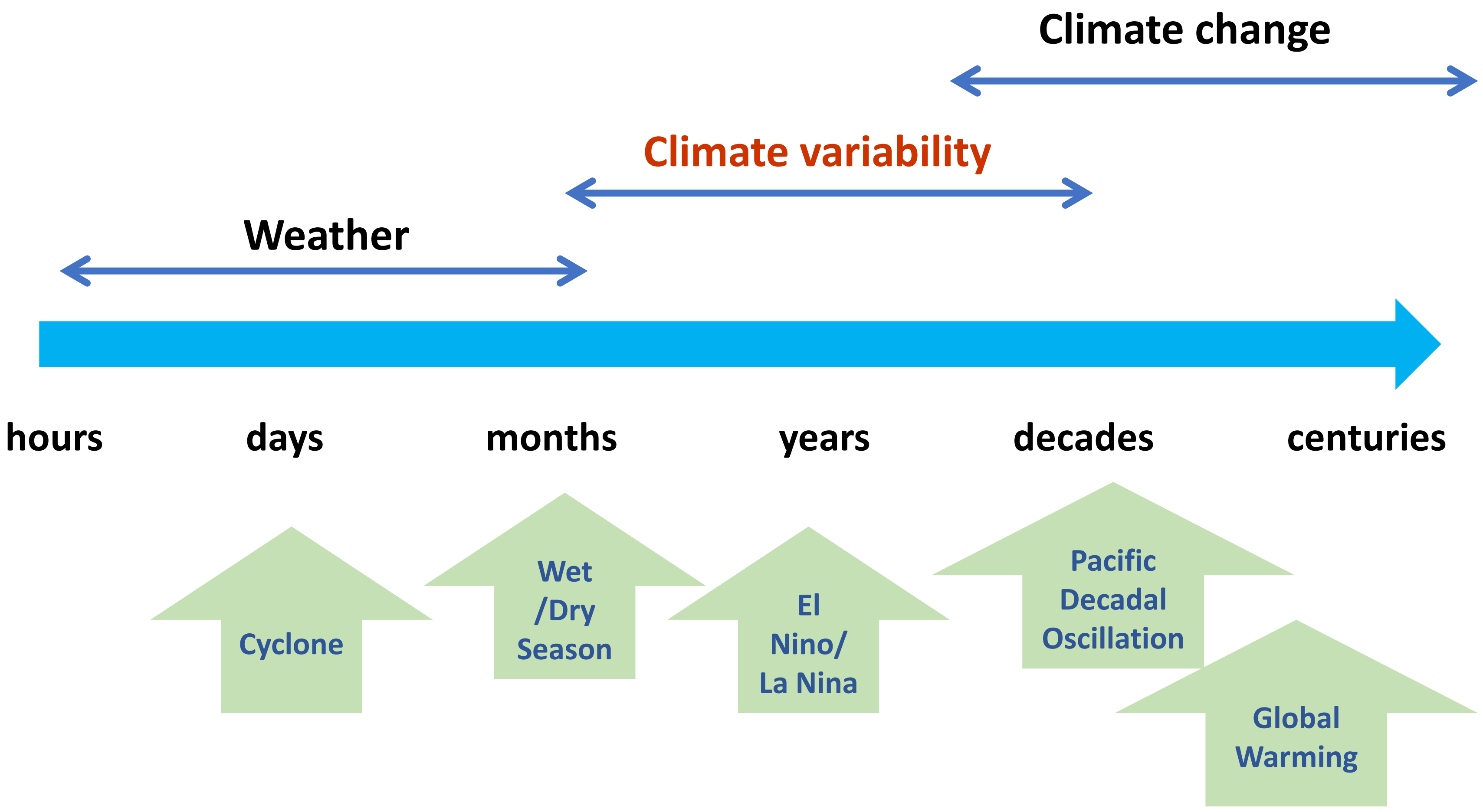
Coriolis effect



Topography effect



Climate variability



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.

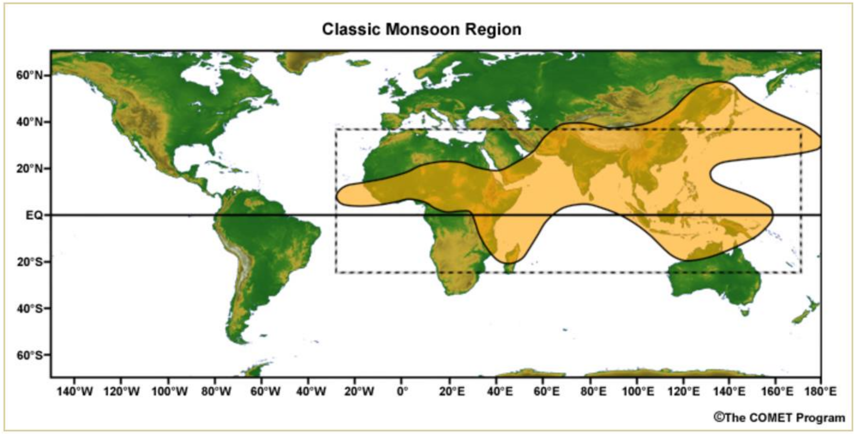
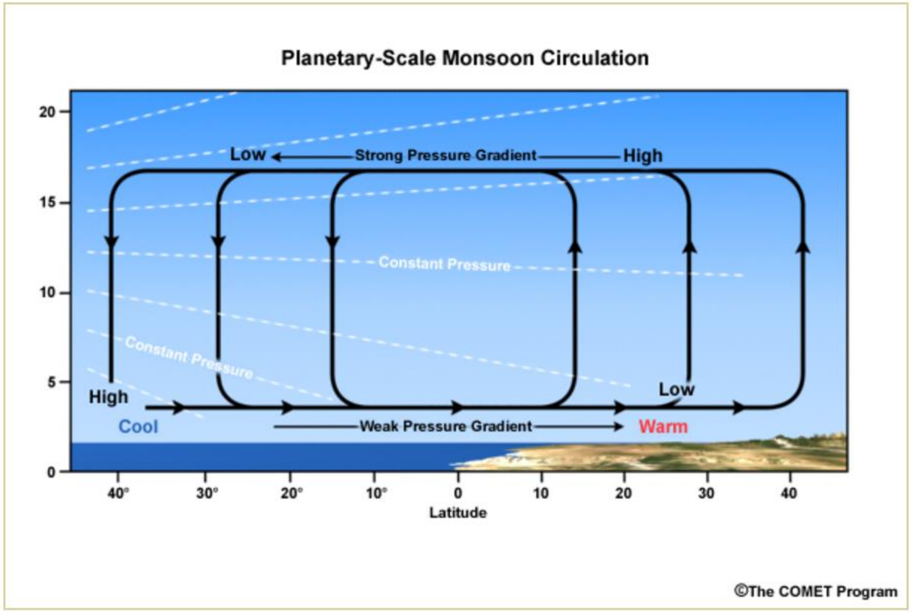
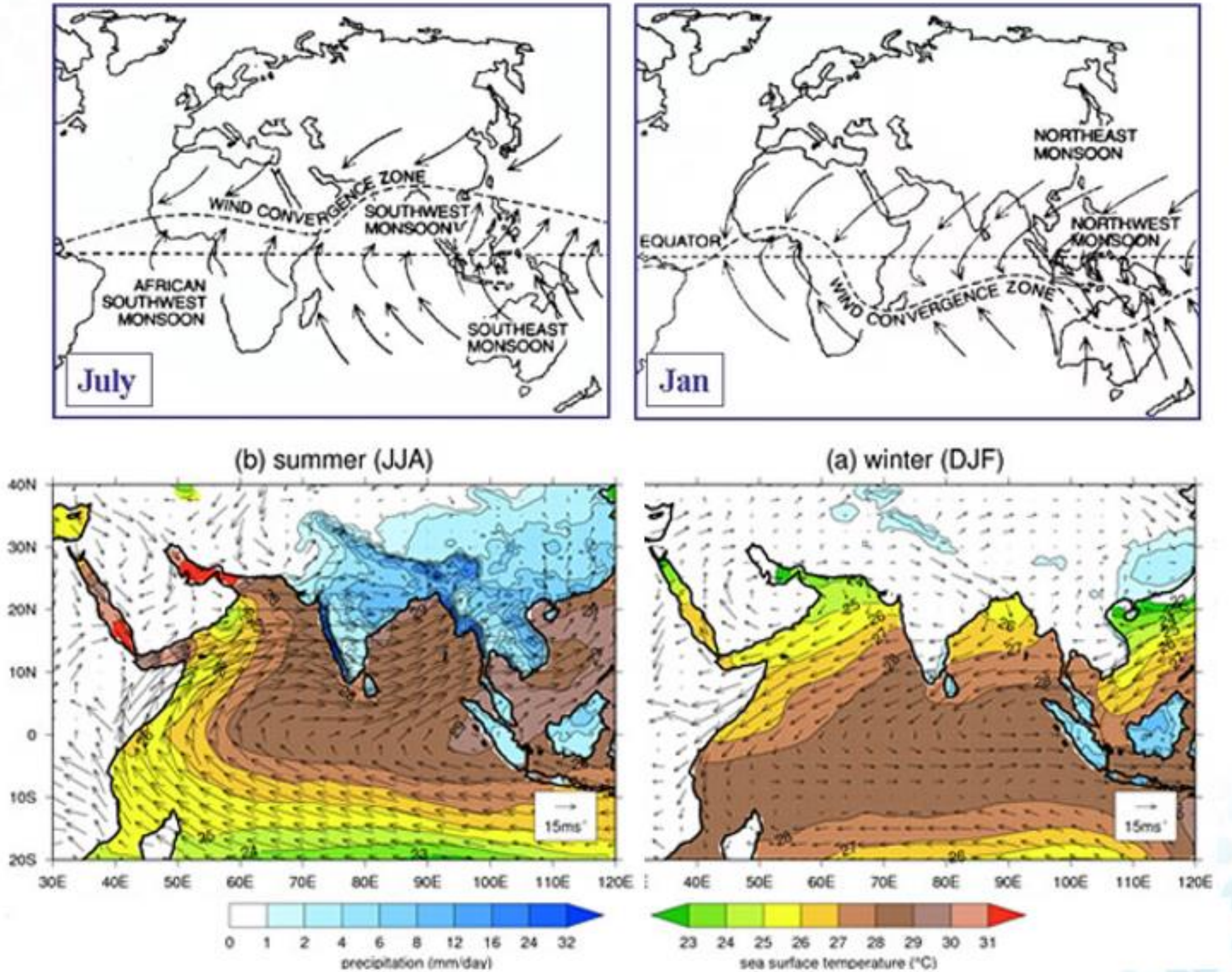


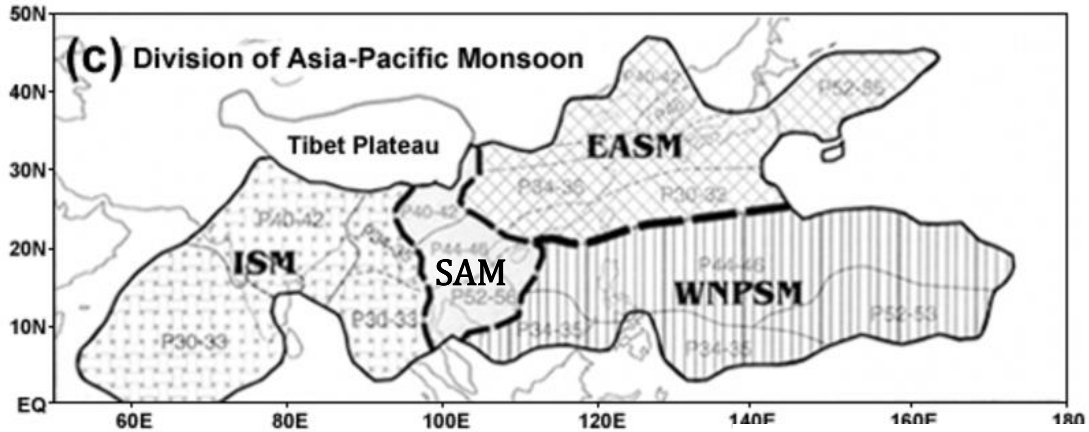
Fig. 3.29. The monsoon regions as defined by Ramage (1971).



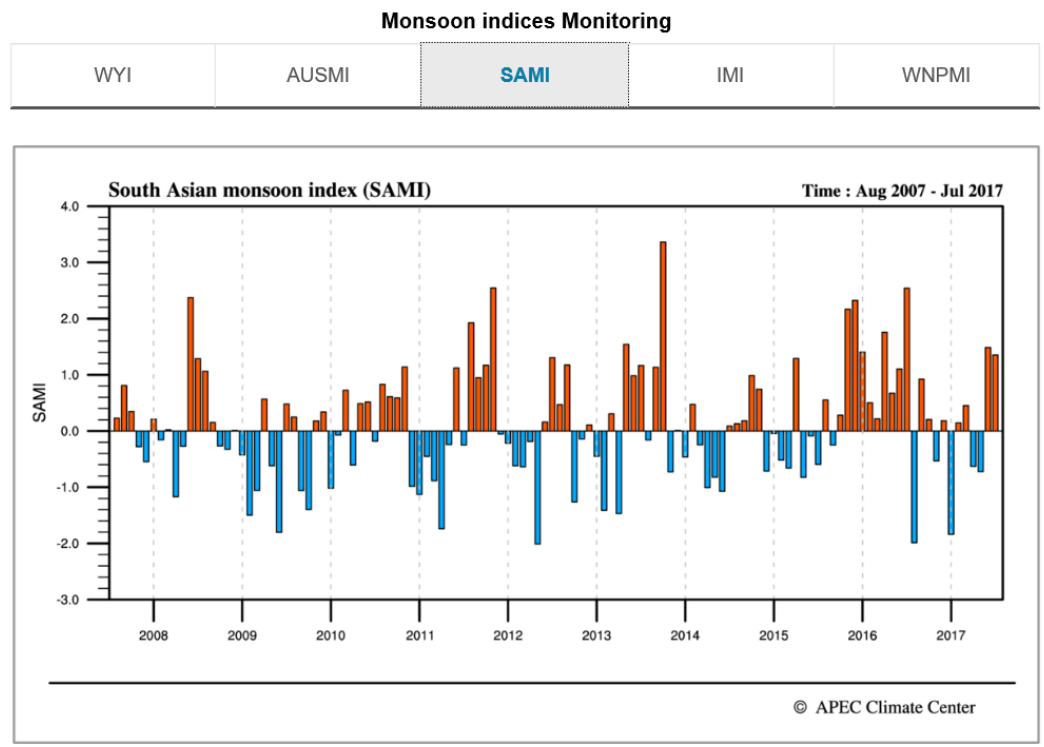
Monsoon


WIND CONVERGENCE ZONE
SOUTHWEST MONSOON
AFRICAN SOUTHWEST MONSOON
SOUTHEAST MONSOON
July
NORTHEAST MONSOON
NORTHWEST MONSOON
EQUATOR
WIND CONVERGENCE ZONE
Jan
(b) summer (JJA)
(a) winter (DJF)
40N
30N
20N
10N
0
10S
20S
30E 40E 50E 60E 70E 80E 90E 100E 110E 120E
15ms
0 1 2 4 6 8 12 16 24 32
precipitation (mm/day)
23 24 25 26 27 28 29 30 31
sea surface temperature (°C)

Monsoon



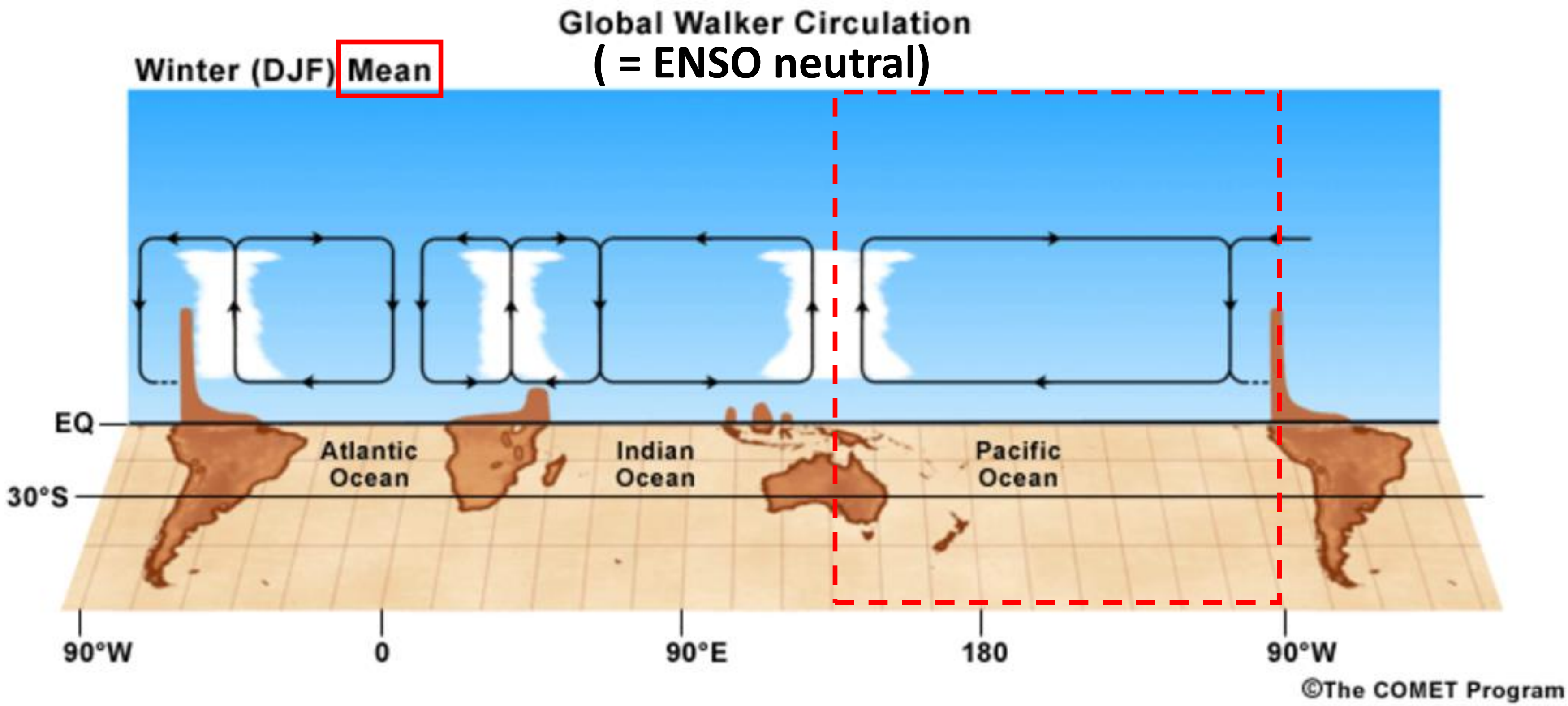
(c) Division of Asia-Pacific Monsoon
Tibet Plateau
EASM
ISM
SAM
WNPSM
50N
40N
30N
20N
10N
EQ
60E
80E
100E
120E
140E
160E
180



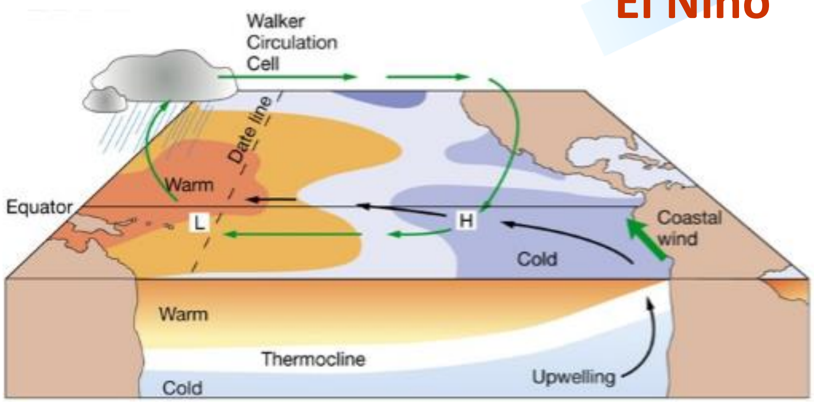
Monsoon indices Monitoring
WYI
AUSMI
SAMI
IMI
WNPMI
South Asian monsoon index (SAMI)
Time : Aug 2007 - Jul 2017
SAMI
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
© APEC Climate Center

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

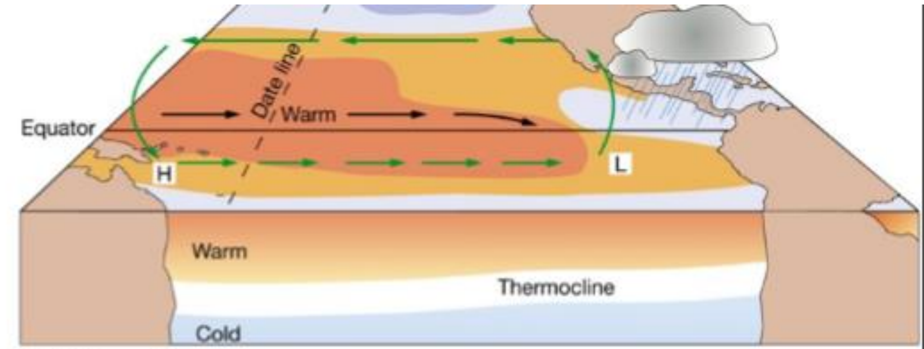


ENSO



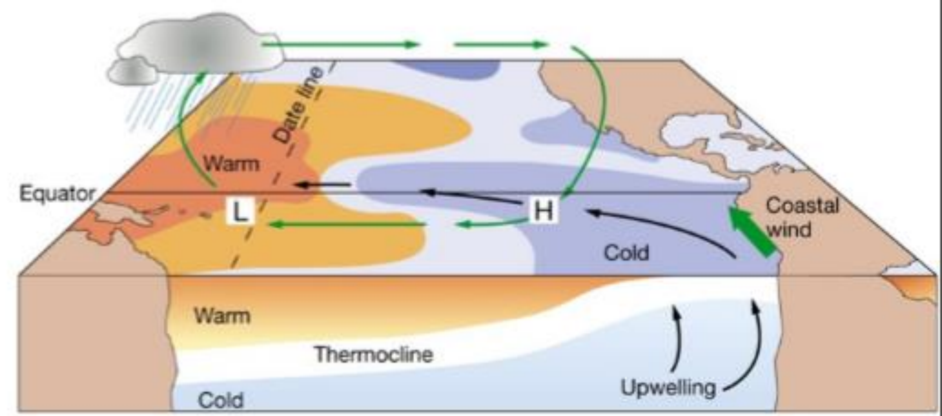
(a) Normal conditions

El Nino



(b) El Niño conditions

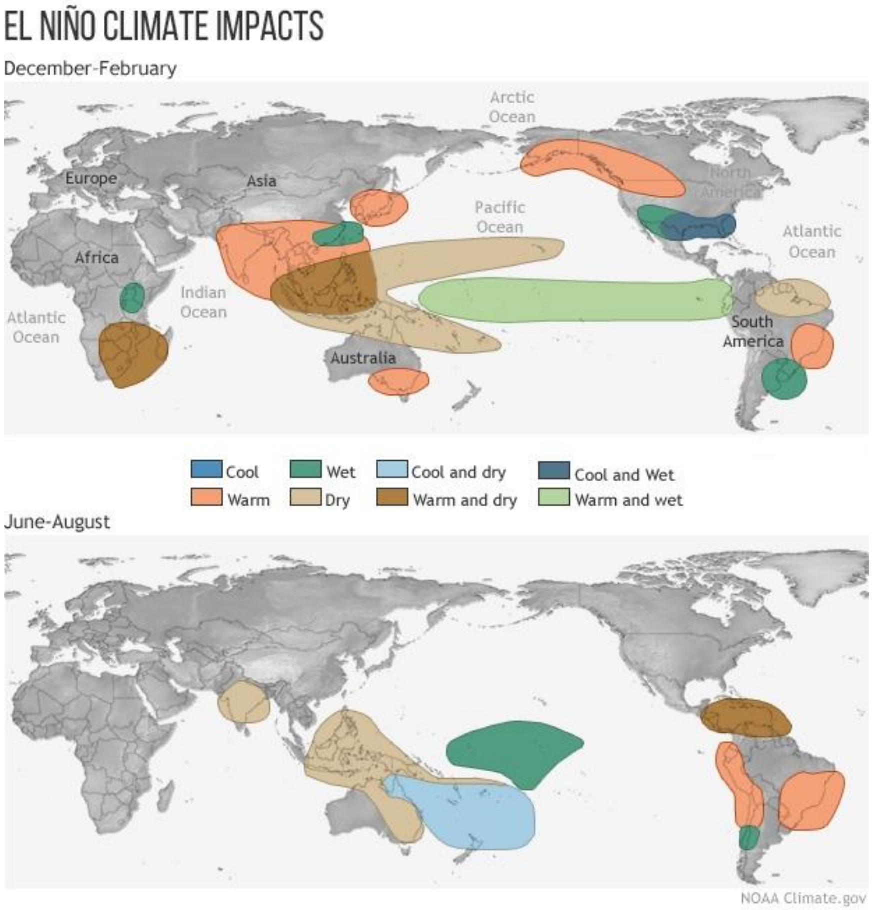
La Nina

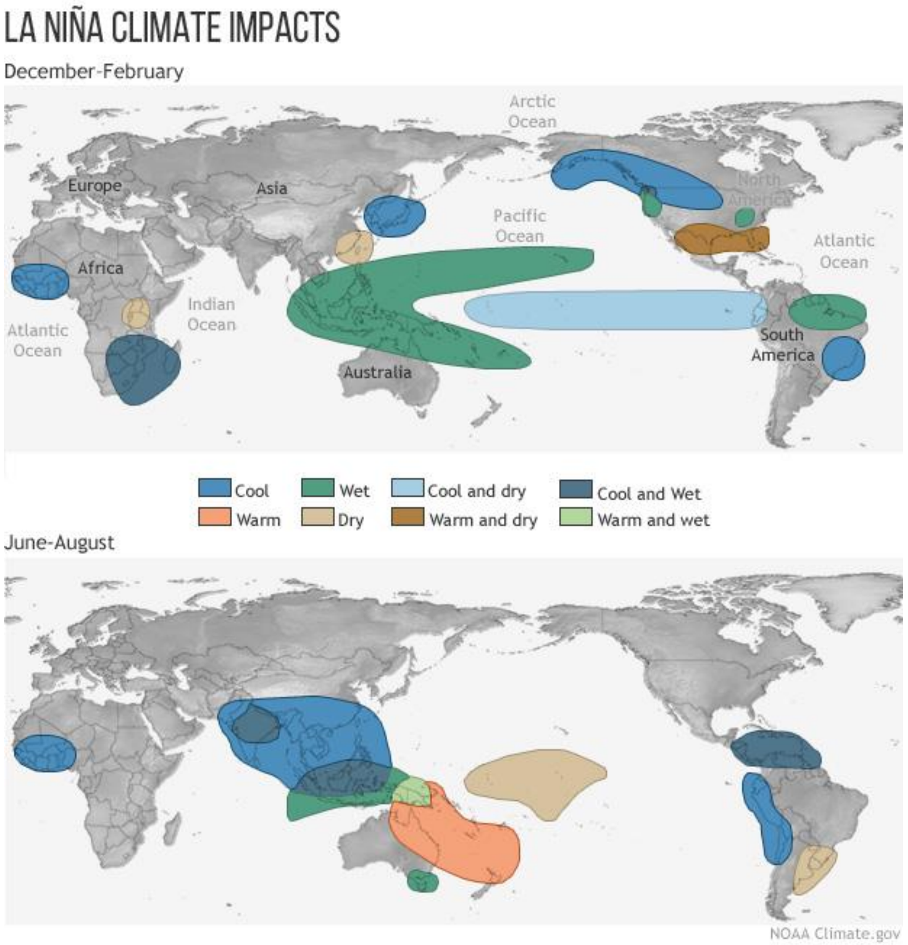


(c) La Niña conditions

ENSO

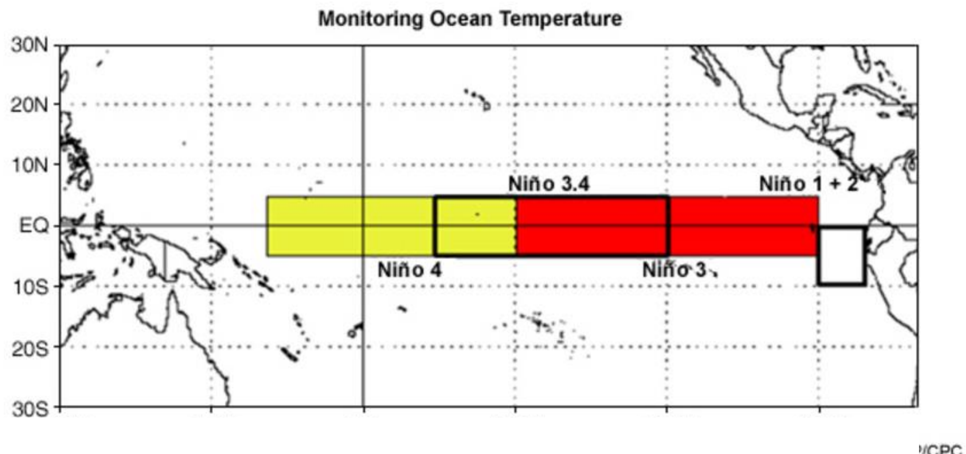
- Why do we care ENSO?





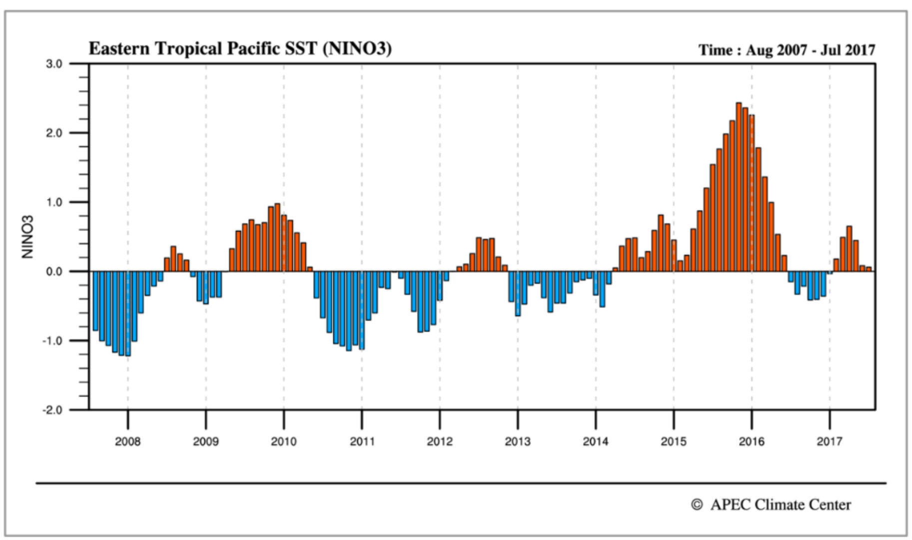
ENSO

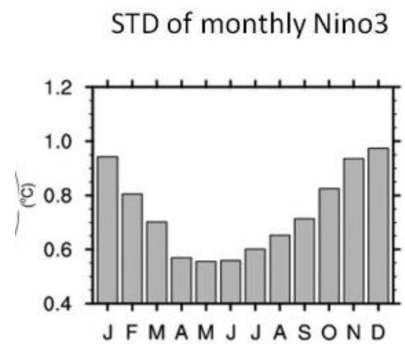
- ENSO monitoring

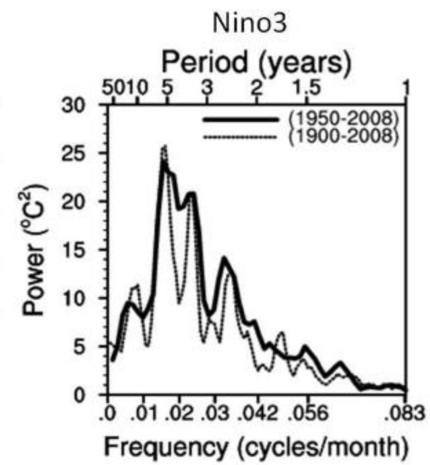


Pacific SST indices Monitoring

NINO1+2	NINO3	NINO3.4	NINO4	ONI	TNI	PACWARM	EOFPAC	EMI



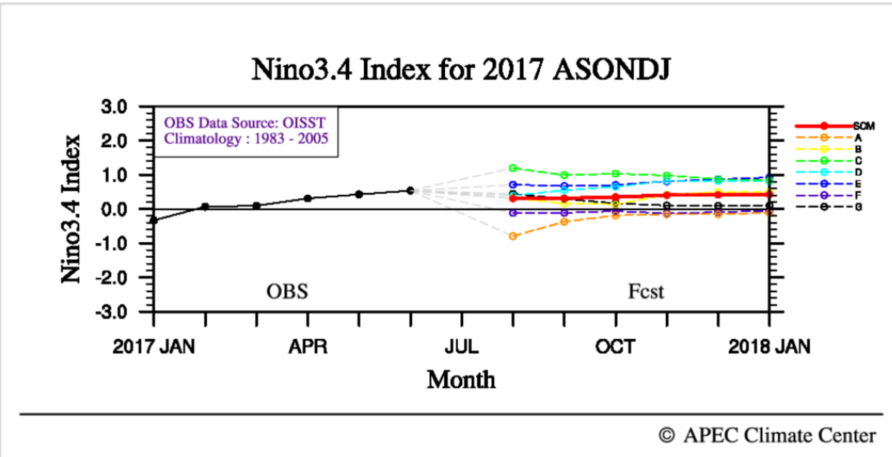




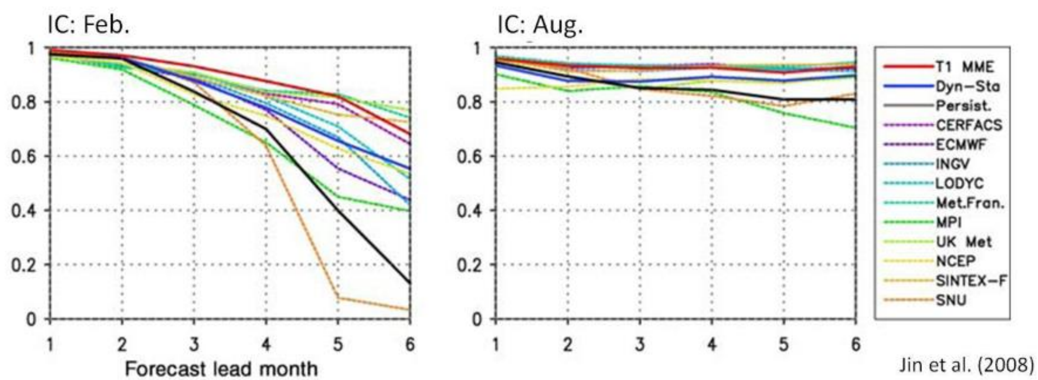
- Strongest in the boreal winter
- 3-7 years of period

ENSO

- ENSO prediction



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

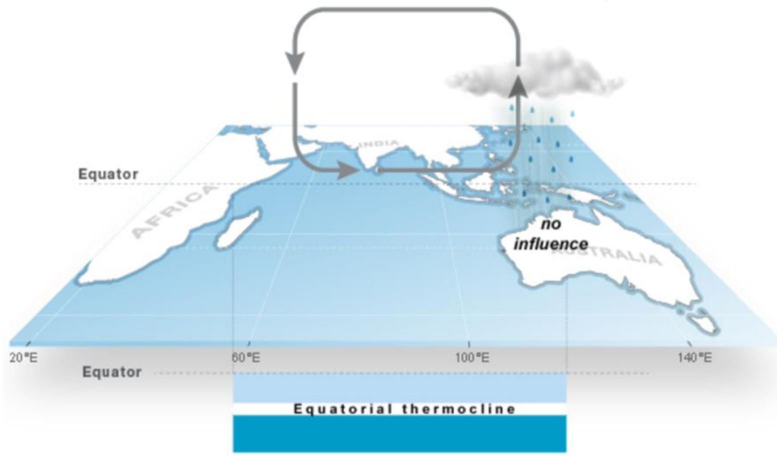


- ENSO can be predicted even 6 months ahead
- ENSO forecast is difficut from Feb-Apr, called the

“spring predictability barrier”

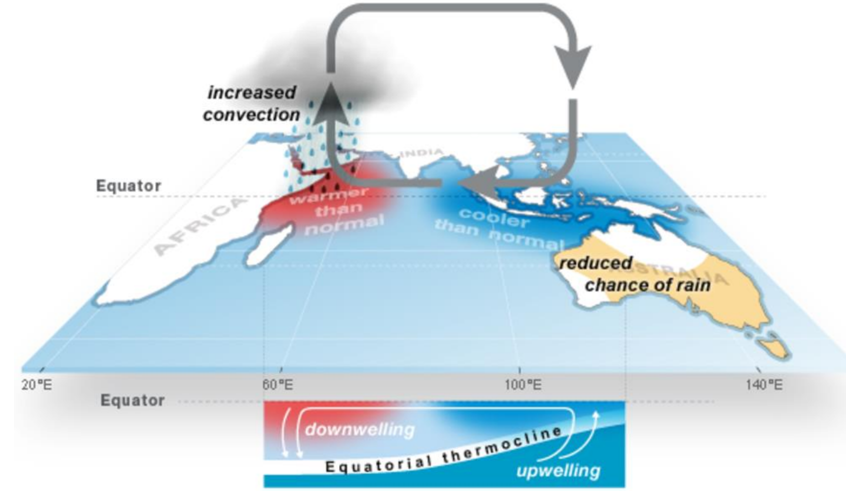
IOD

- Indian Ocean Dipole



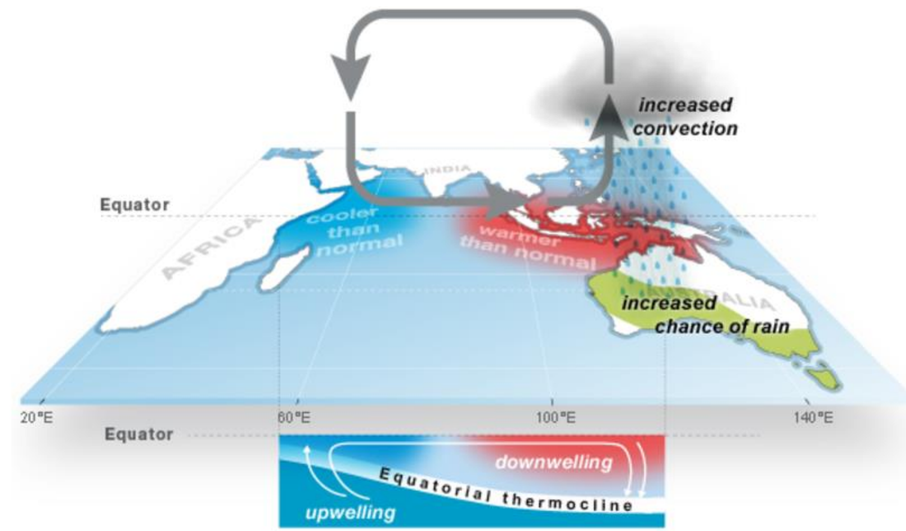
Indian Ocean Dipole (IOD): **Neutral phase**

Positve



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

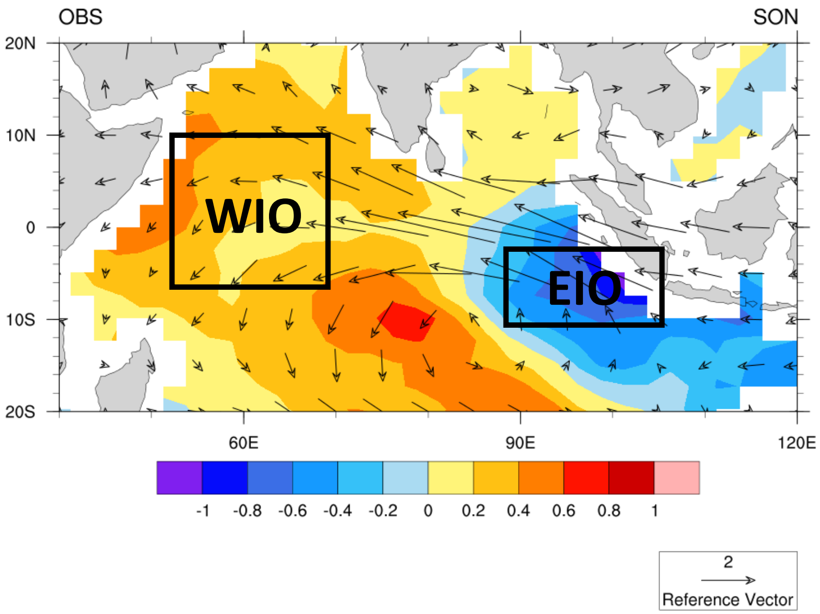
Negative



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

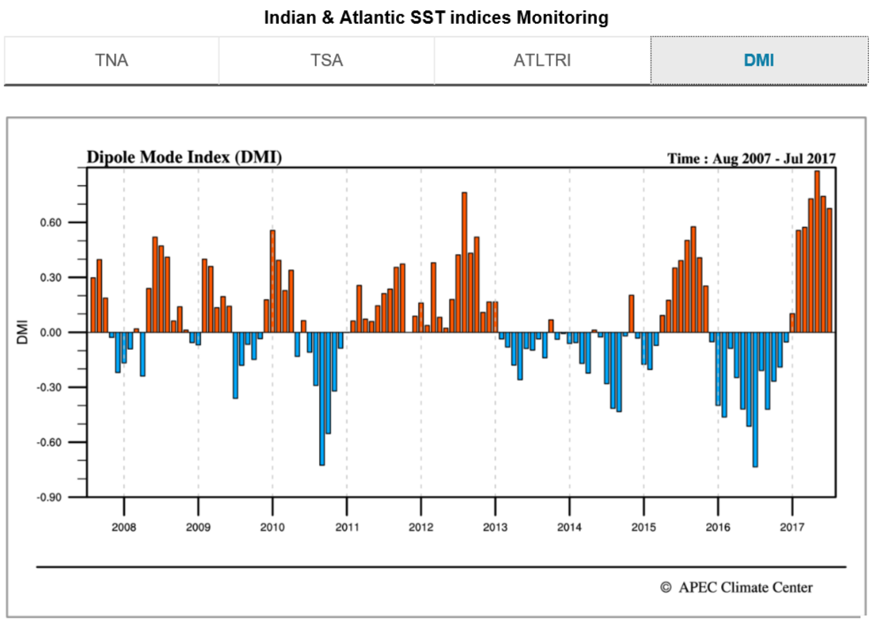
IOD

- 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 Nino (La Nina) with positive (negative) IOD
- Dipole Mode Index = SST_{WIO}-SST_{EIO}



IOD

- Dipole Mode Index = SST_{WIO}-SST_{EIO}



Monitoring

Forecast

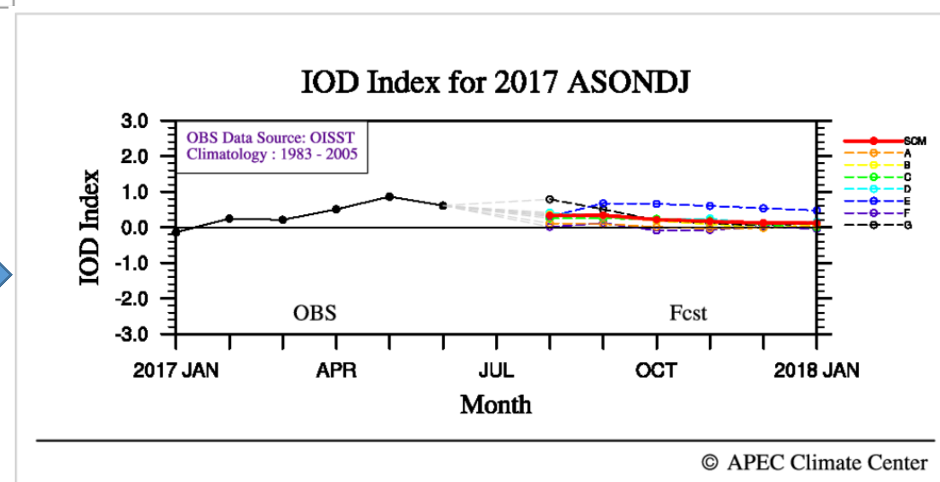
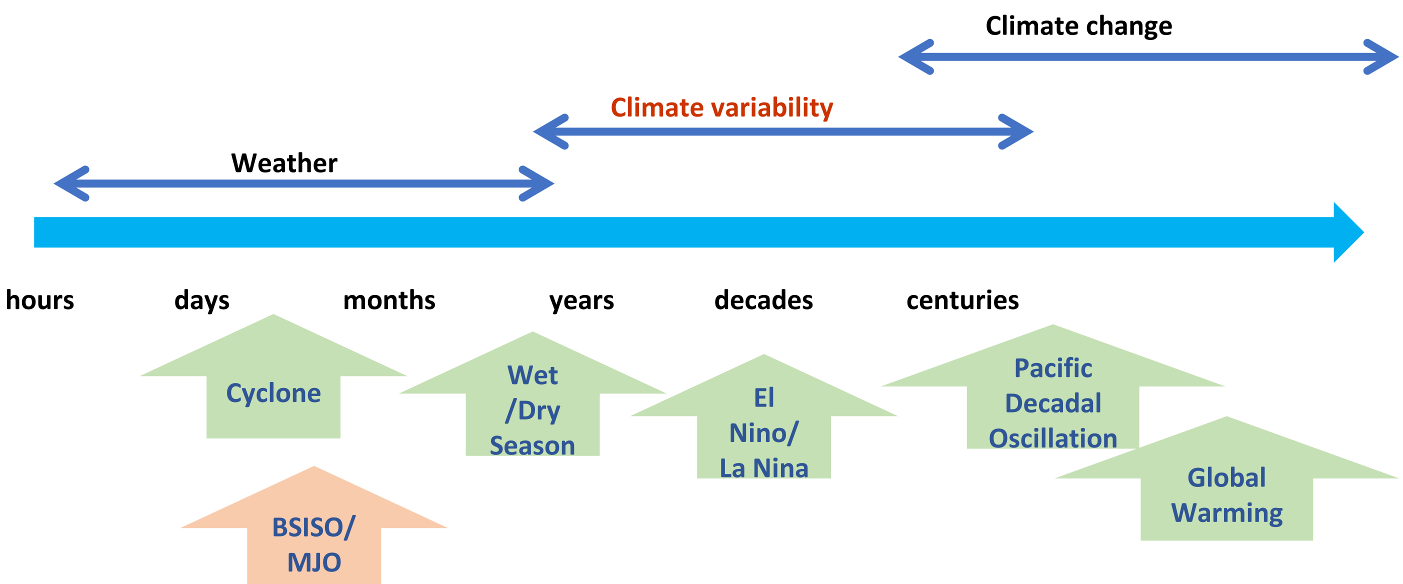


Fig. 2. Predicted Indian Ocean Dipole mode index (IODMI) from individual models (A, B, C, D, E, F and G) and the SCM.

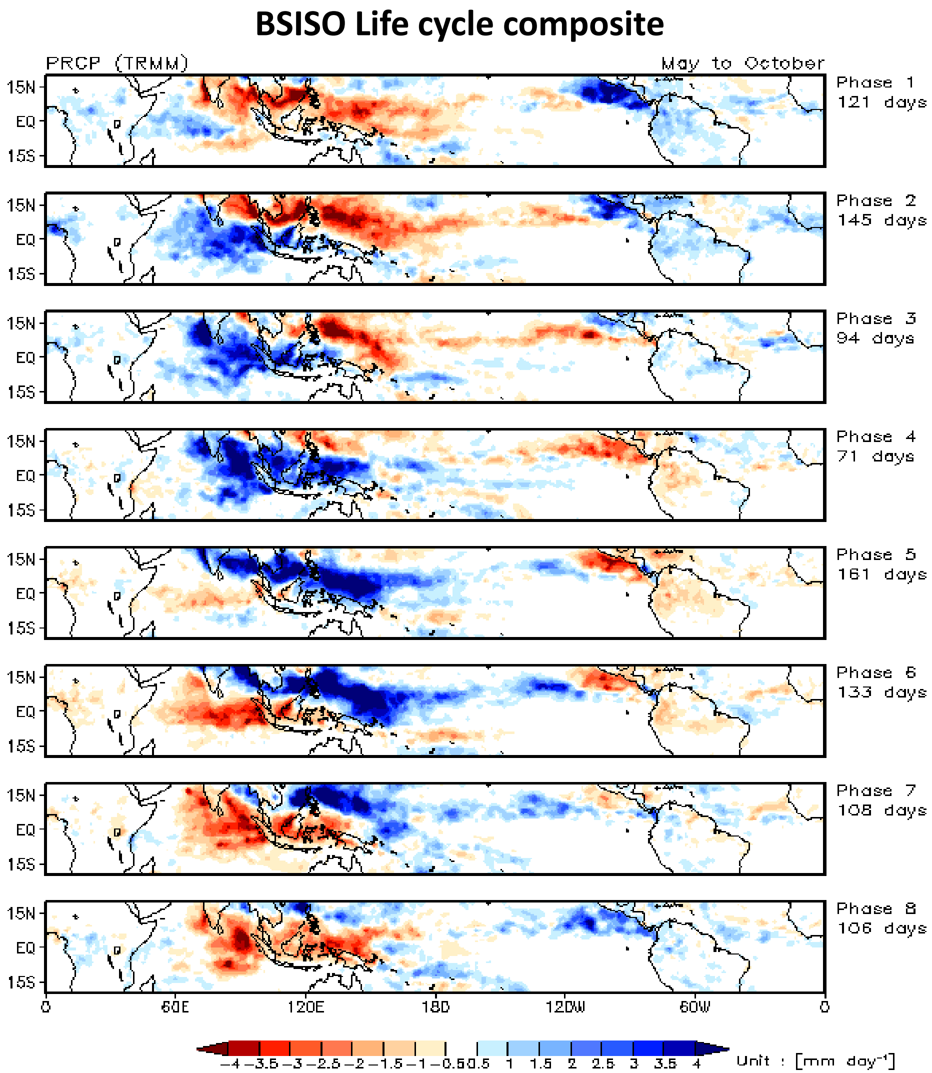
Last but not least

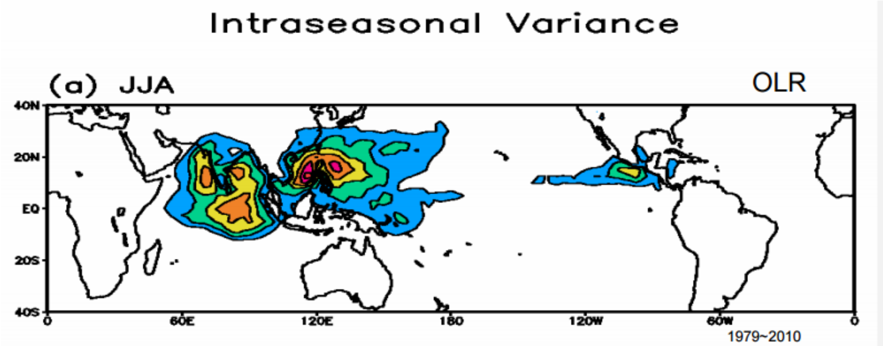
- Don’t forget our BSISO forecast!

- Boreal Summer **Intraseasonal** Oscillation (2 weeks upto a season = *subseasonal*)

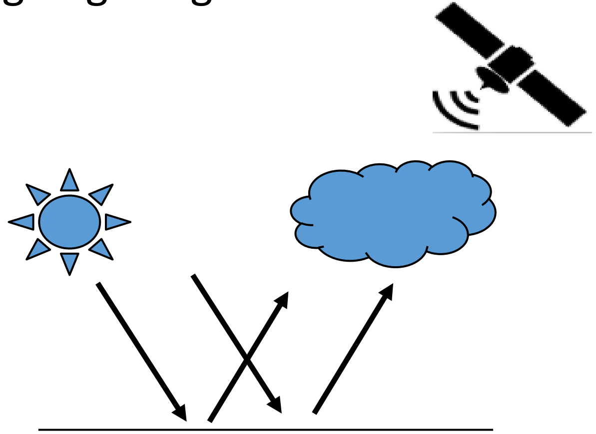


BSISO

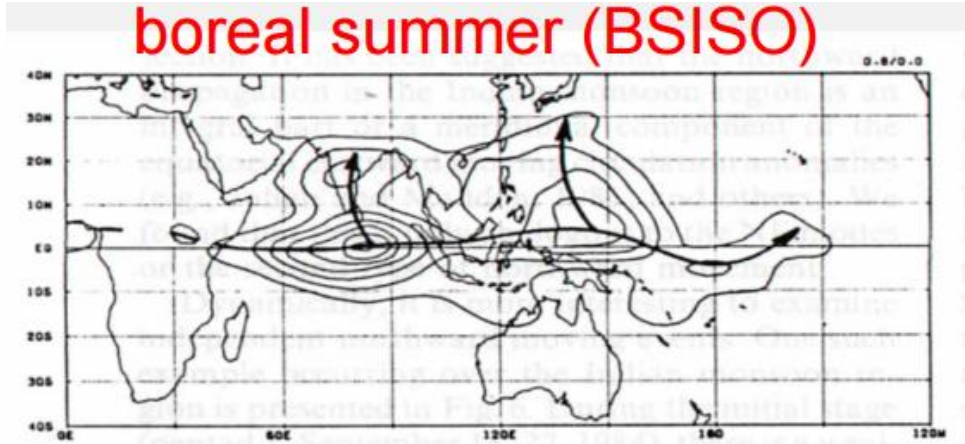




- ❖ Intraseasonal: 2 weeks upto a season (20-90 days)
- ❖ OLR: Outgoing Longwave radiation



BSISO

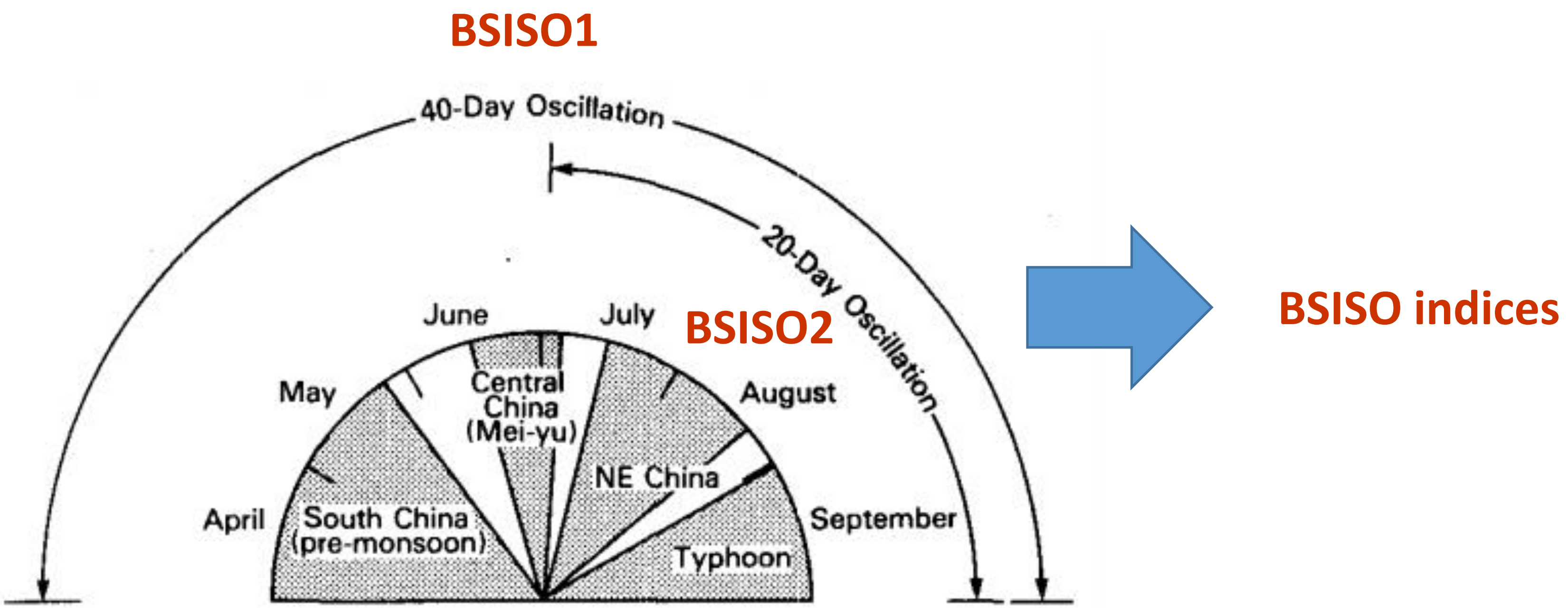


Wang and Rui 1990

- 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**

BSISO

- Two modes of BSISO

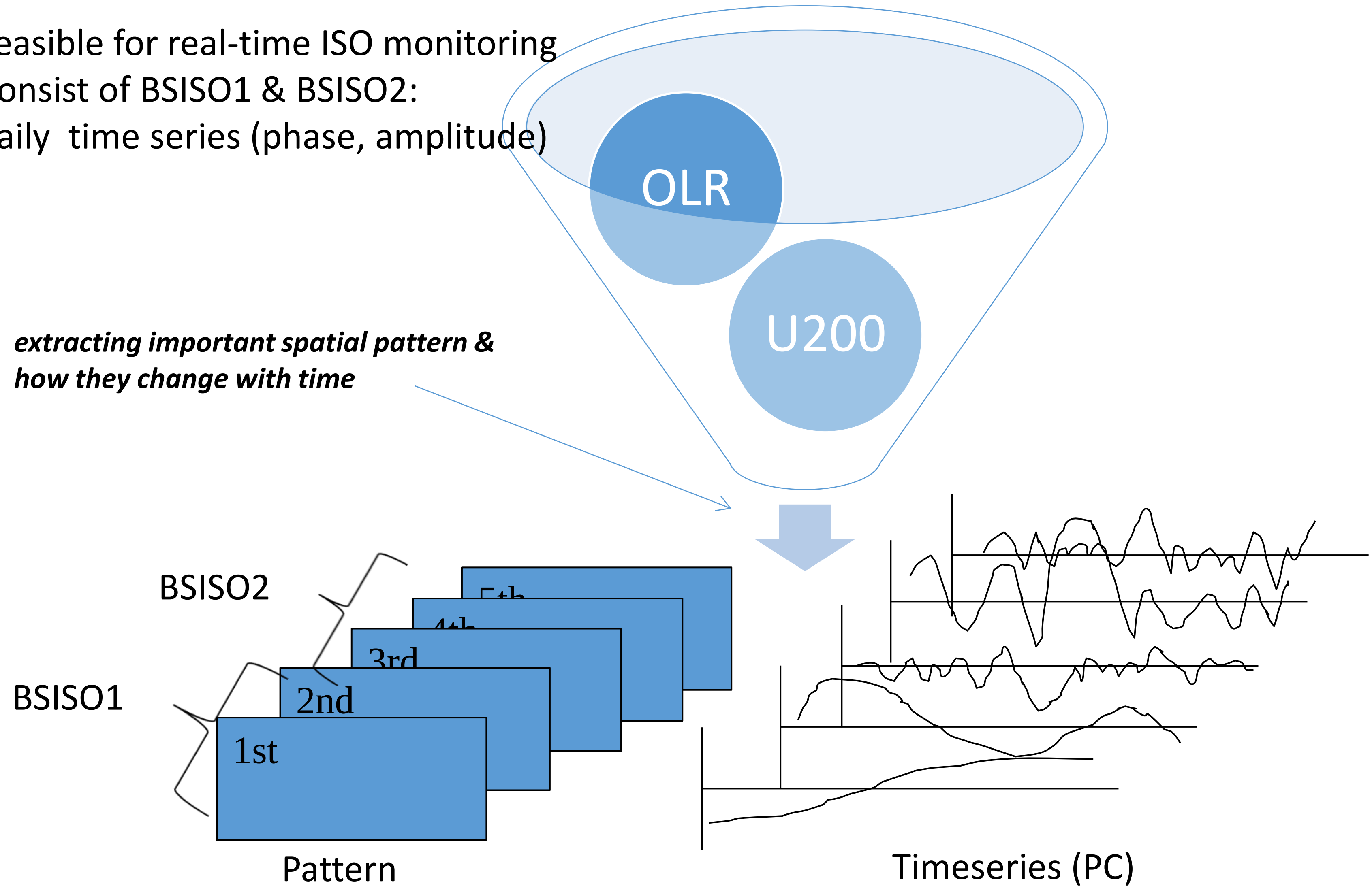


Lau et al (1988) found that the 40-day & 20-day Oscillations are related to rainfall fluctuations over East Asia.

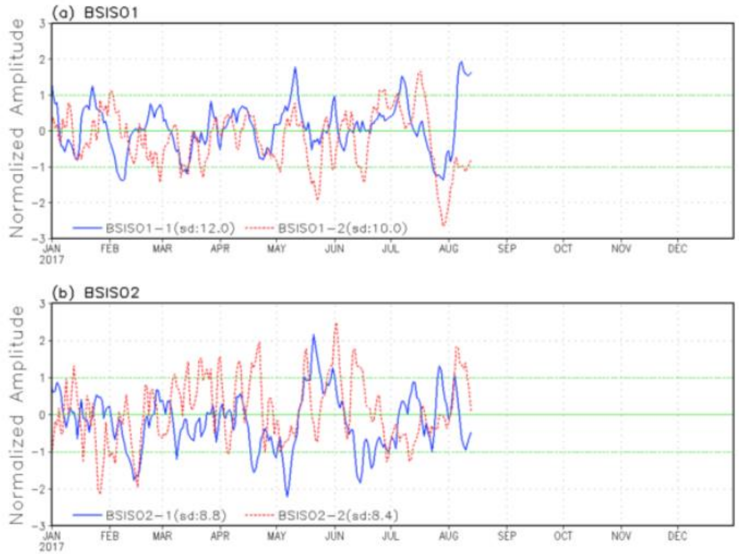
BSISO

- BSISO indices: Multivariate EOF (A statistcal tool)

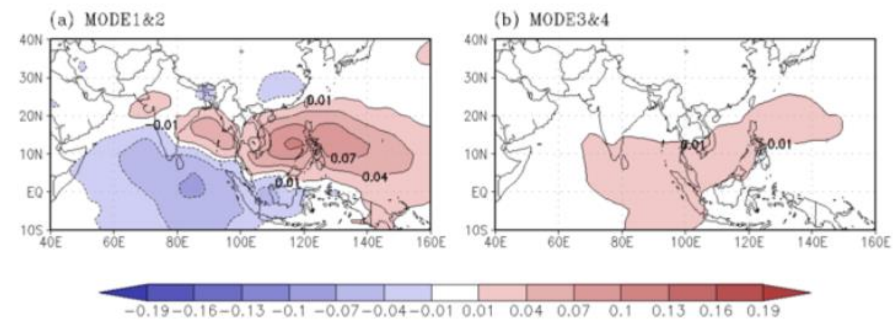
Feasible for real-time ISO monitoring
Consist of BSISO1 & BSISO2:
daily time series (phase, amplitude)



BSISO

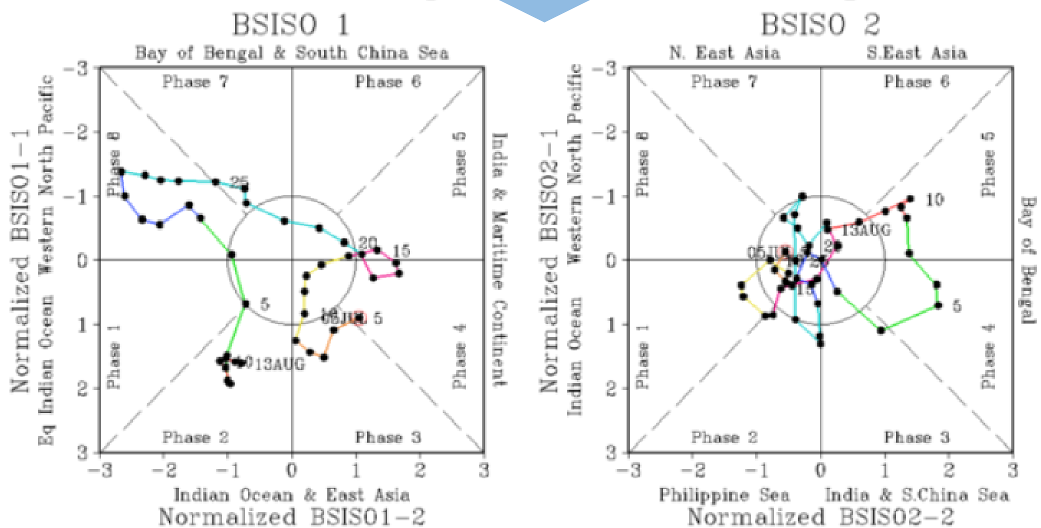


Reconstructed OLR anomaly
based on the BSISO indices (13Aug2017)



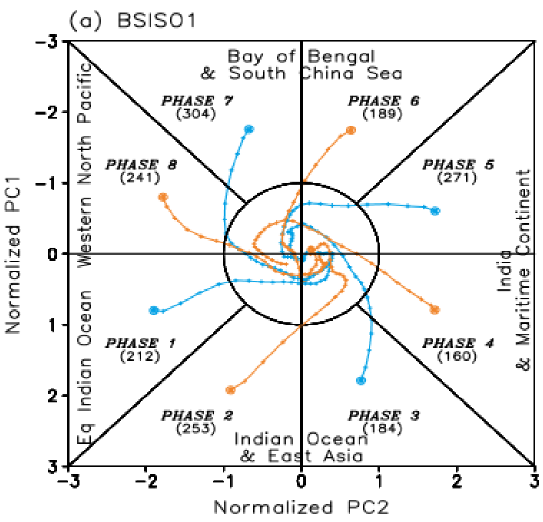
Monitoring

BSISO Monitoring for 05Jul2017~13Aug2017

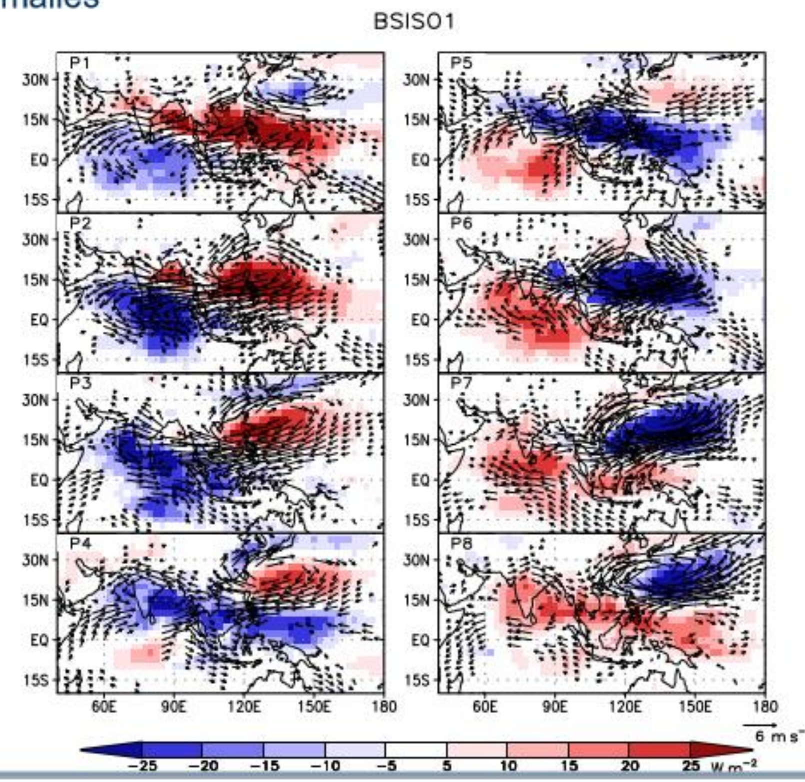


BSISO1

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



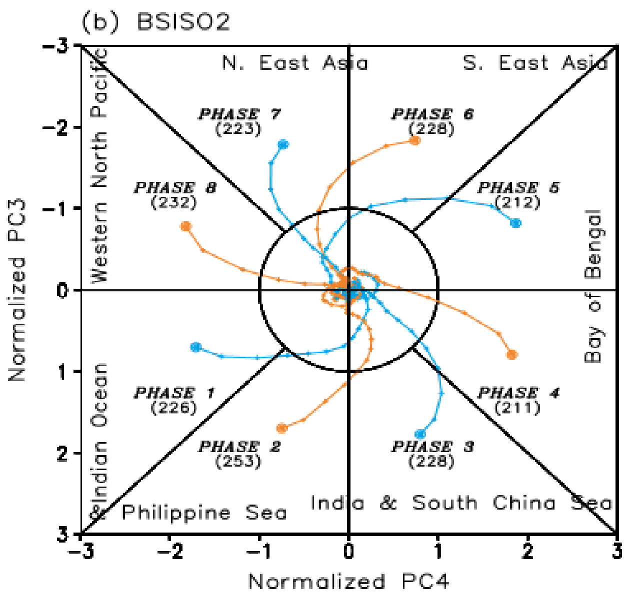
Life cycle composite of OLR (shading) and 850-hPa wind anomalies



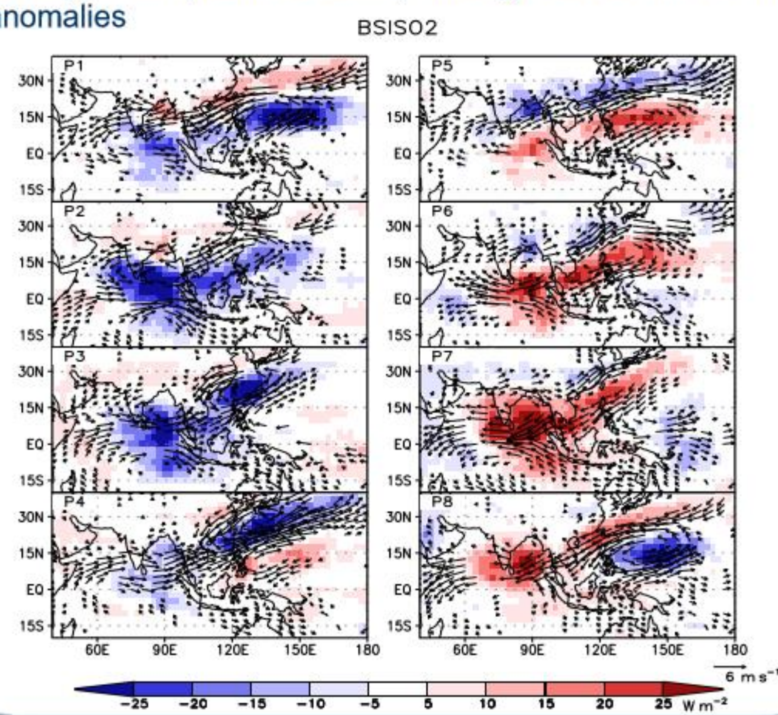
Lee et al (2013)

BSISO2

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

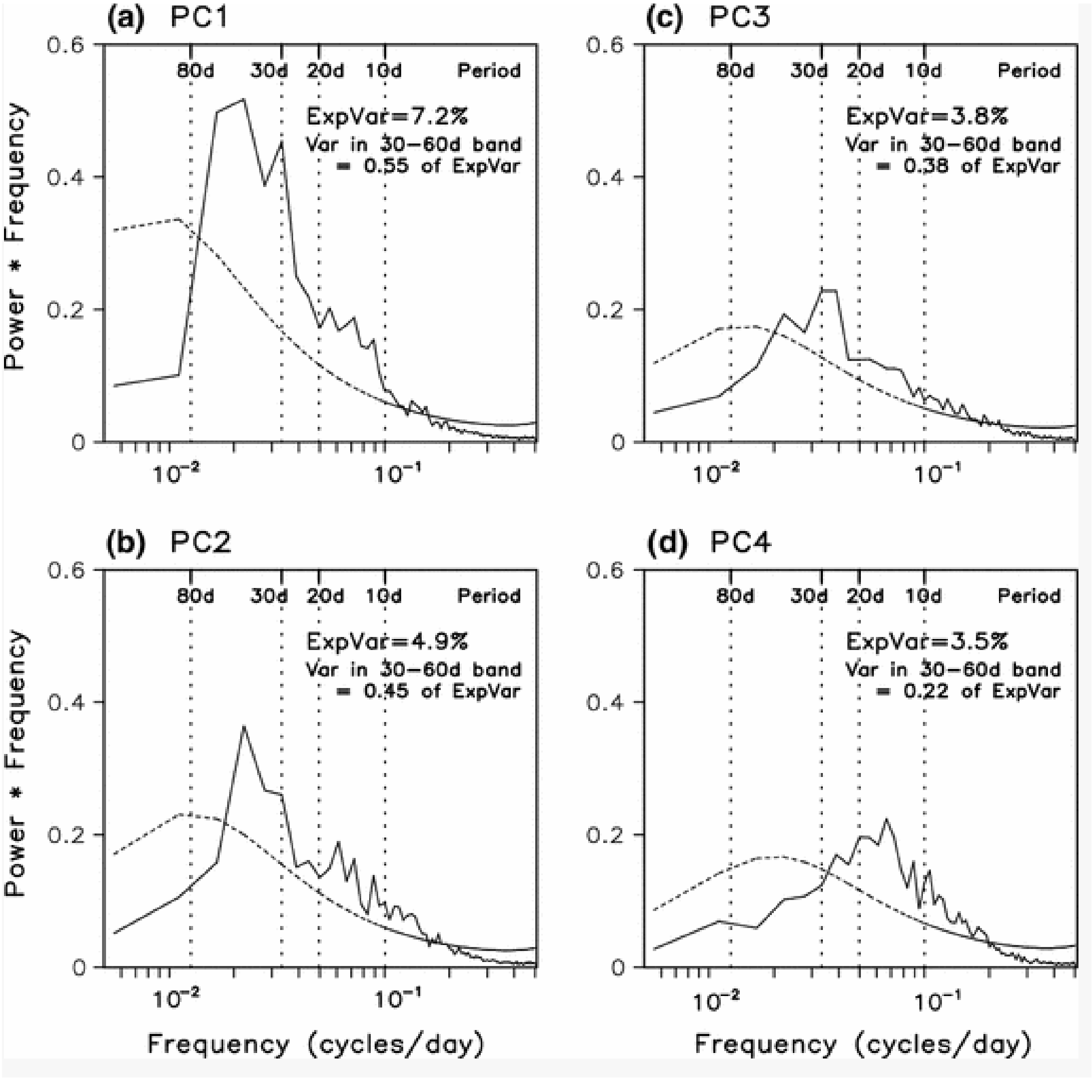


Life cycle composite of OLR (shading) and 850-hPa wind anomalies



Lee et al (2013)

Periods of BSISO1 & BSISO2

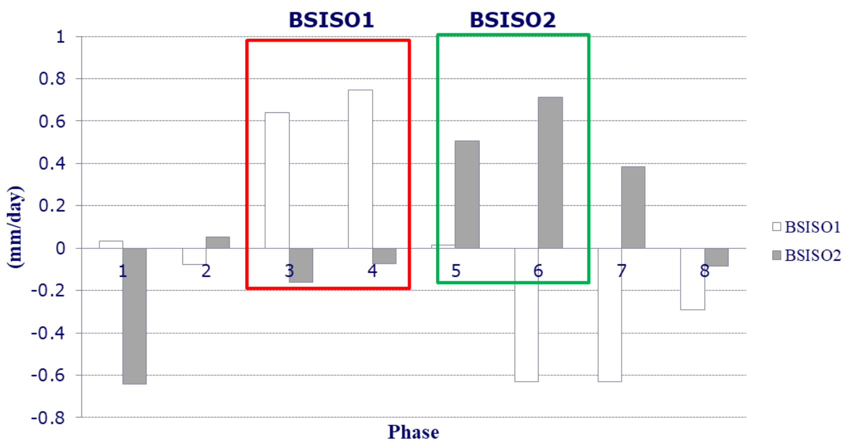


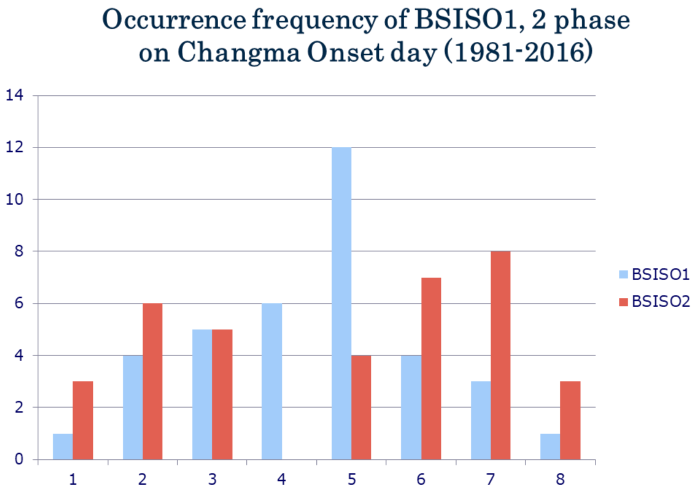
Lee et al (2013)

BSISO

Changma onset in Korea

Changma: long rainy period of over Korea within EASM
The rainfall during Changma asccounts for 30% of annual precipitation in Korea

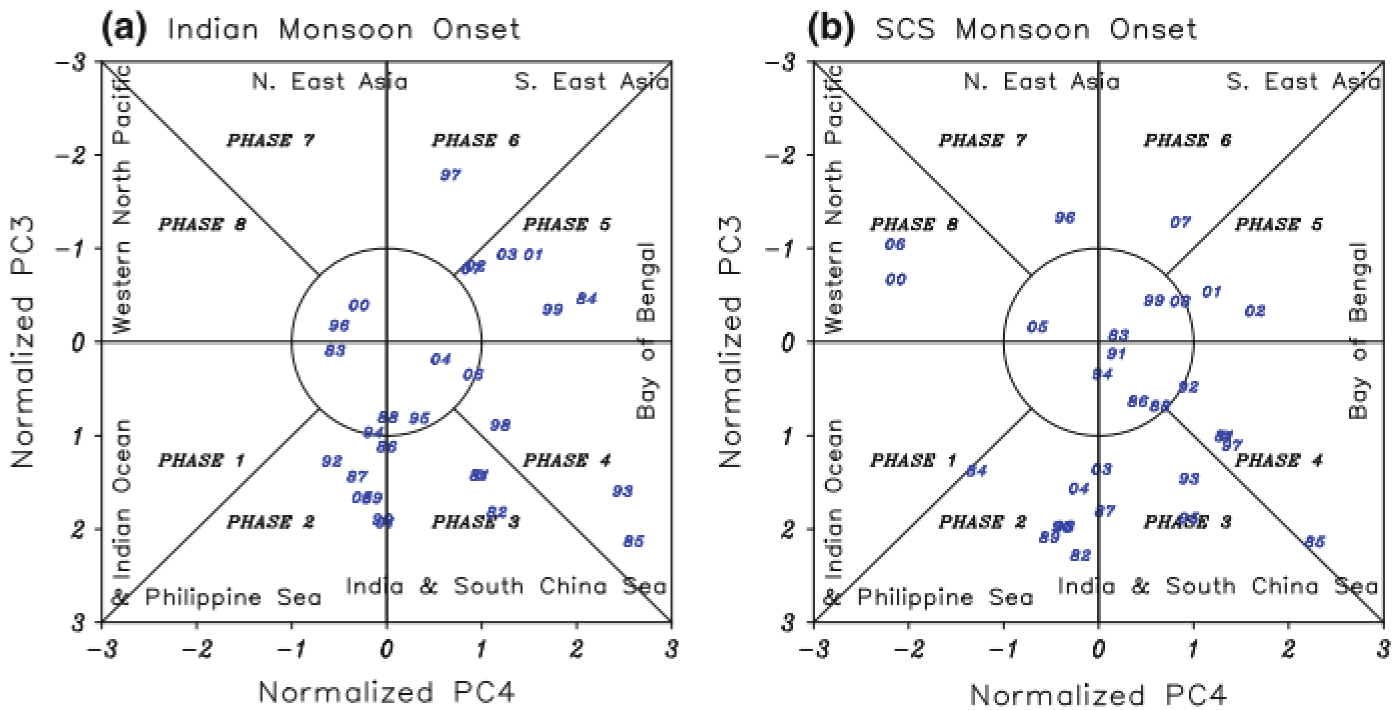




BSISO

Monsoon Onset over the ASM region

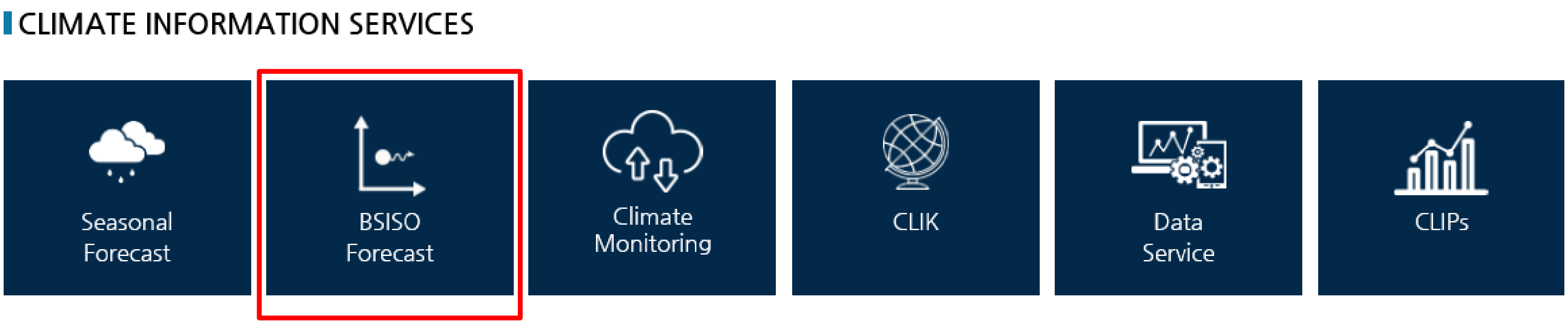
Lee et al (2013)



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

BSISO forecast



Forecast

Monitoring

Methodology

- 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**

Institute	Model	Ensemble Size	Forecast Period	Update frequency	Resolution
NCEP	Climate Forecast System	4	40 days	Once a day	T126 L64
	Global Forecast System	1	16 days	Once a day	T574, T190 L64
Australia	POAMA 2.4 multi-week model	33	40 days	Twice per week	T47 L17
ECMWF	ECMWF Ensemble Prediction System	51	32 days	Twice per week	T639, T319 L62
Taiwan CWB	*CWB EPS T119*	*1*	*40 days*	*Every 5 days*	T119 L30

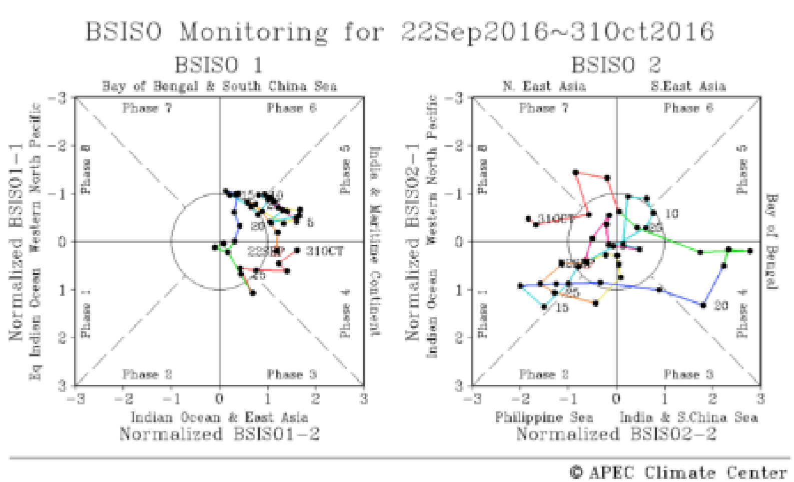
BSISO forecast

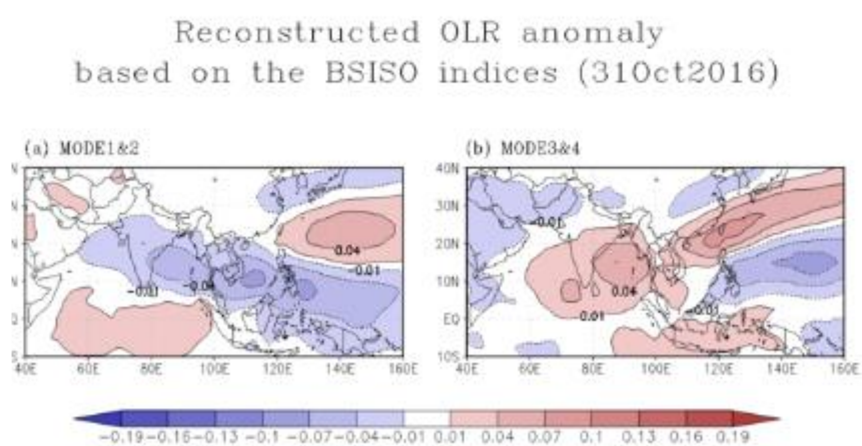
- **Monitoring**

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

- **Monitoring**

Monitoring

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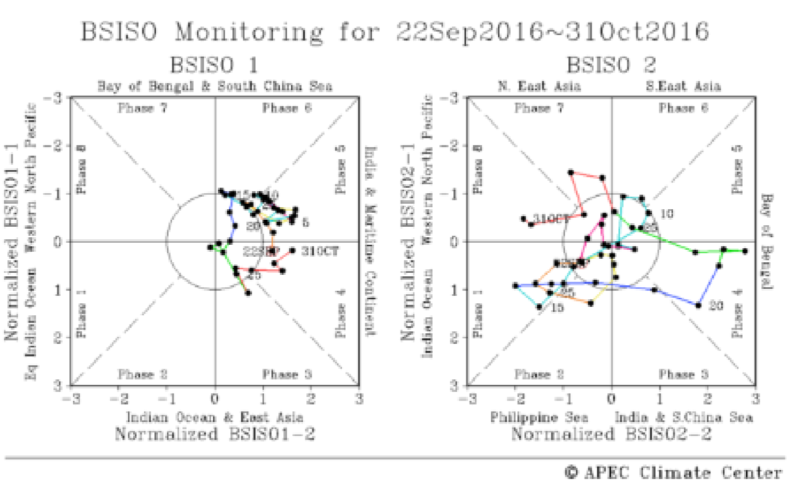
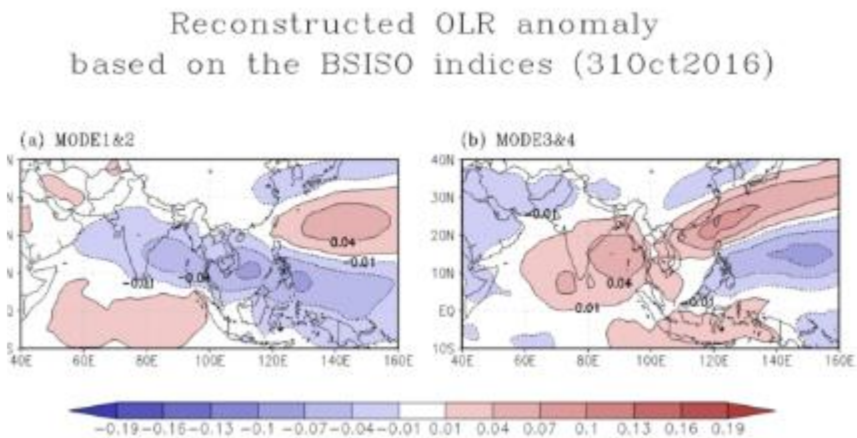




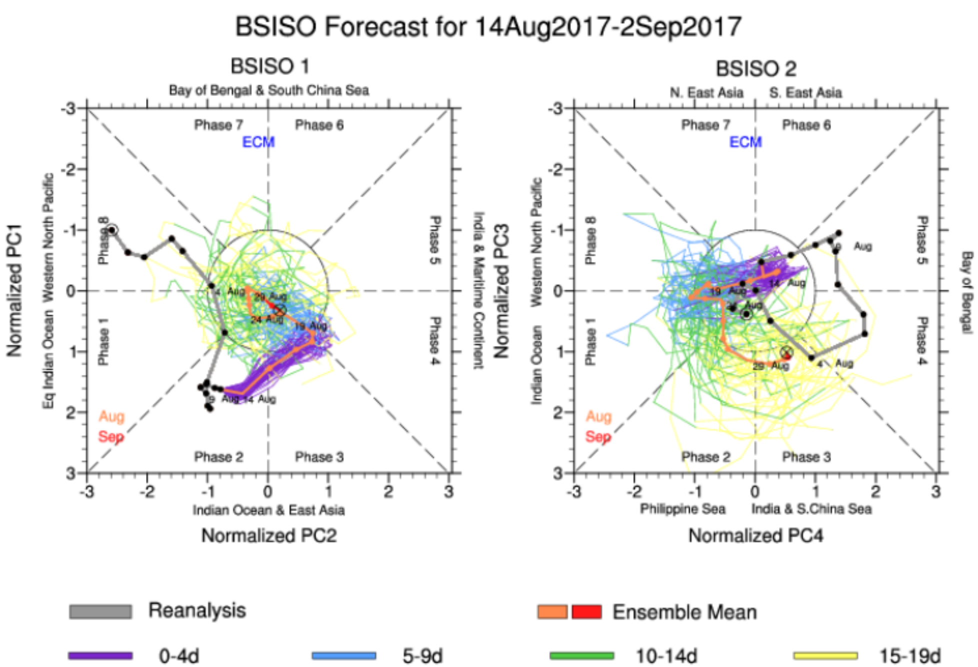
BSISO forecast

- **Forecast**

Phase Diagram	Spatial OLR Anomalies	Heavy Rainfall Probability	Verification	Participation

Phase Plots of BSISO Index Forecasts

BOM	CFS	GFS	ECM	CWB

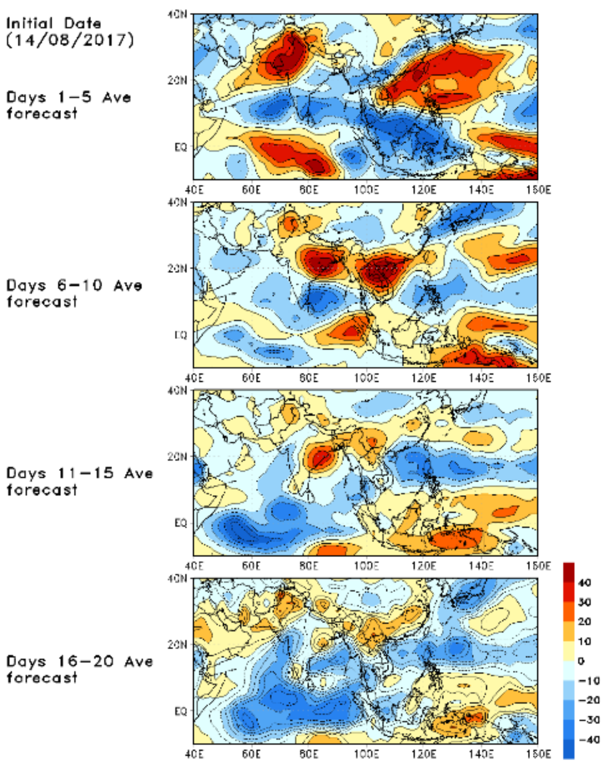


BSISO forecast

- **Forecast**

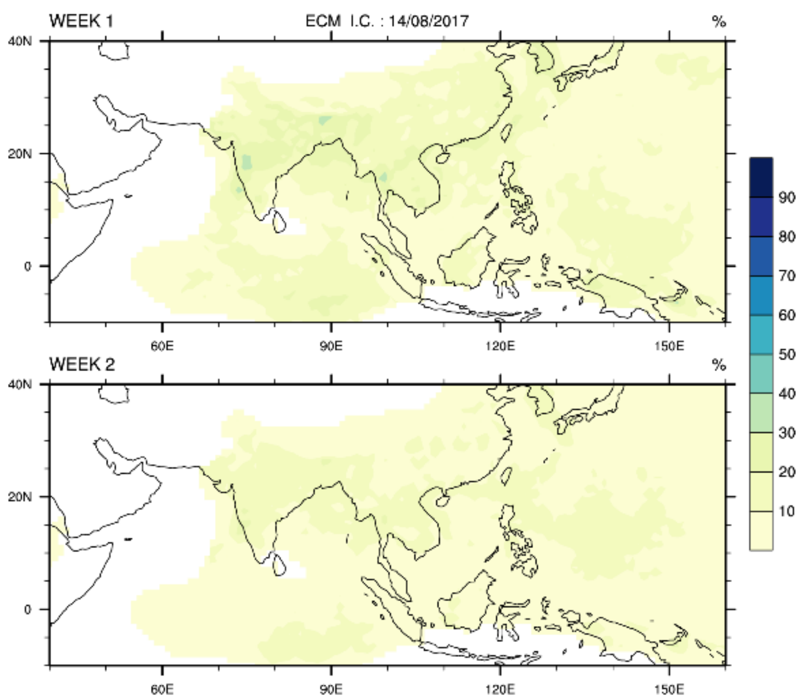
Phase Diagram	Spatial OLR Anomalies	Heavy Rainfall Probability	Verification	Participation

BOM	CFS	GFS	ECM	CWB



BOM	CFS	GFS	ECM	CWB

Probability of heavy rainfall determined by predicted BSISO

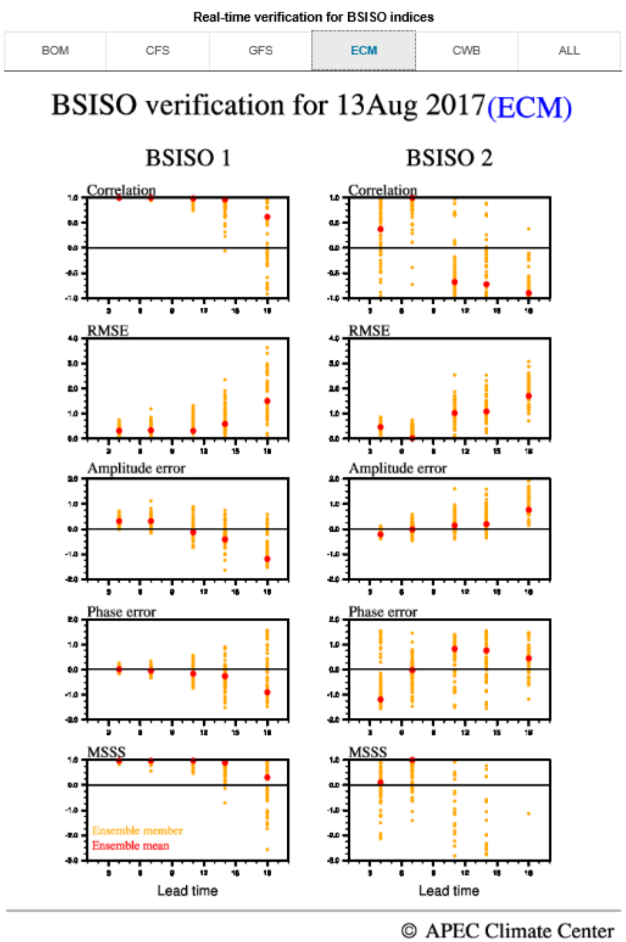


Probability of occurrence for heavy rainfall event as defined by daily rainfall exceeding the 90th percentiles value (22.6 mm/day) for Aug. during 1981-2010.

BSISO forecast

- **Forecast**

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



- **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

Postive: 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)**

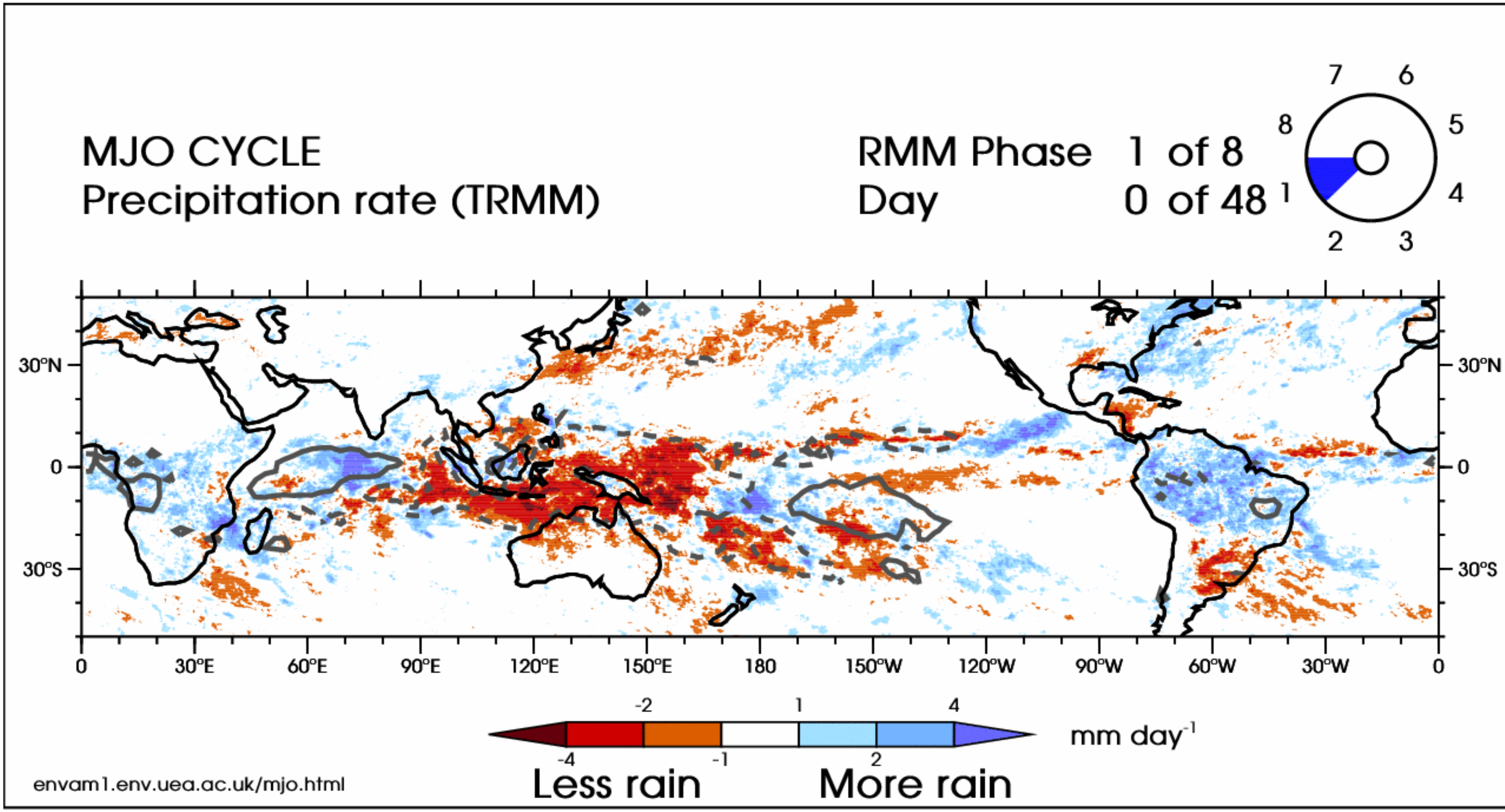
Perfect score: 1

Relative level of skill of forecast compared to a climatological forecast that predict no BSISO signal

Kim (2014) APCC Research report

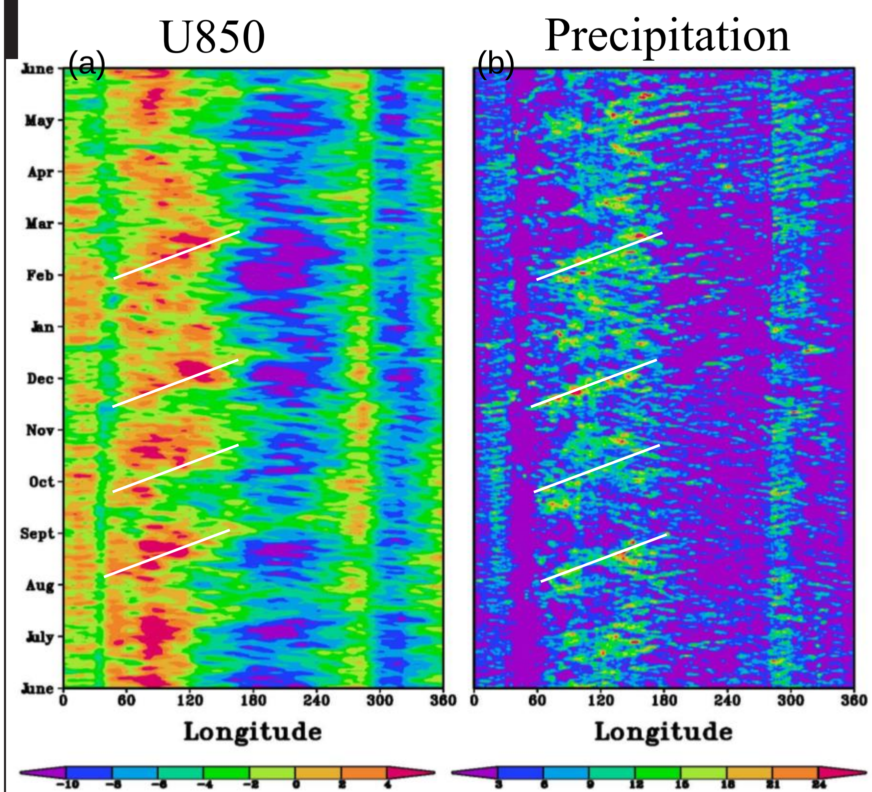
Boreal winter ISO: MJO

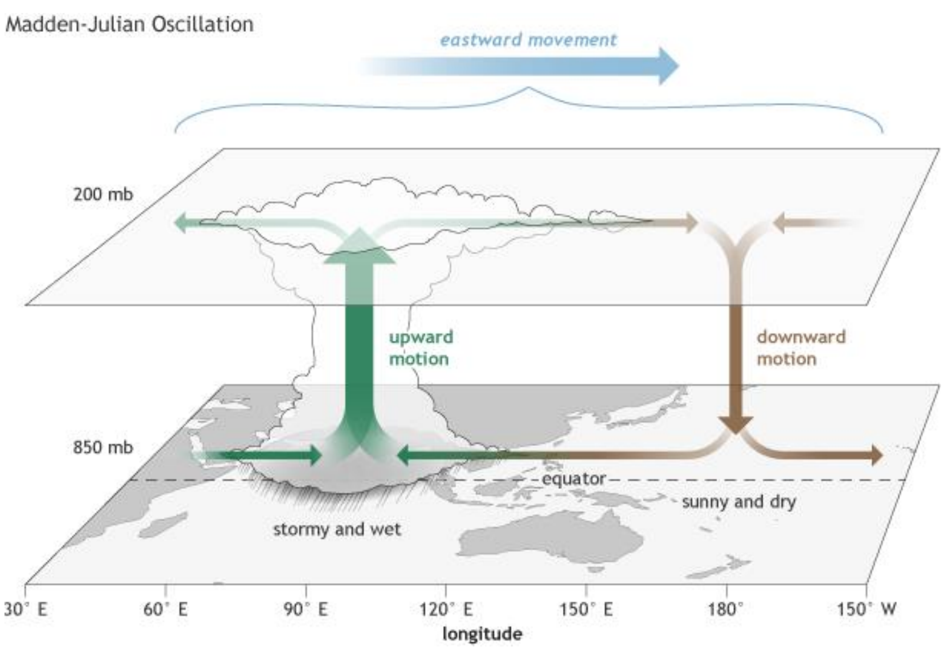
- Madden-Julian Oscillation: Eastward propagation of rainfall
- Discovered by Roland Madden and Paul Julian in early 1970’s



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

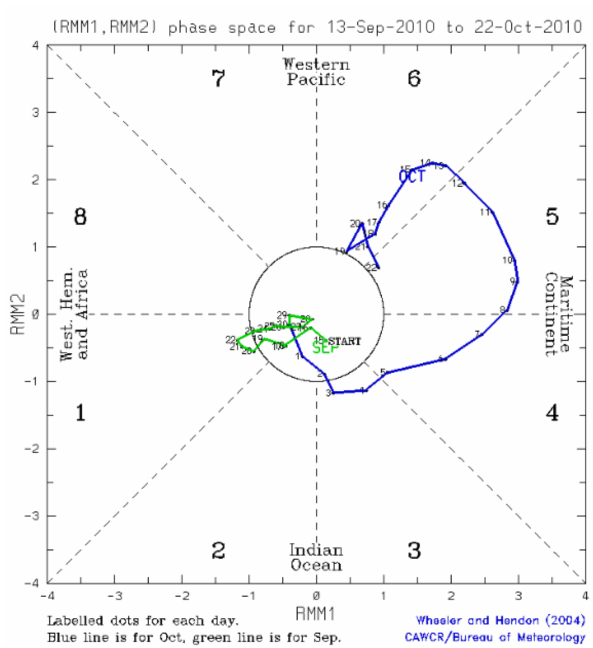


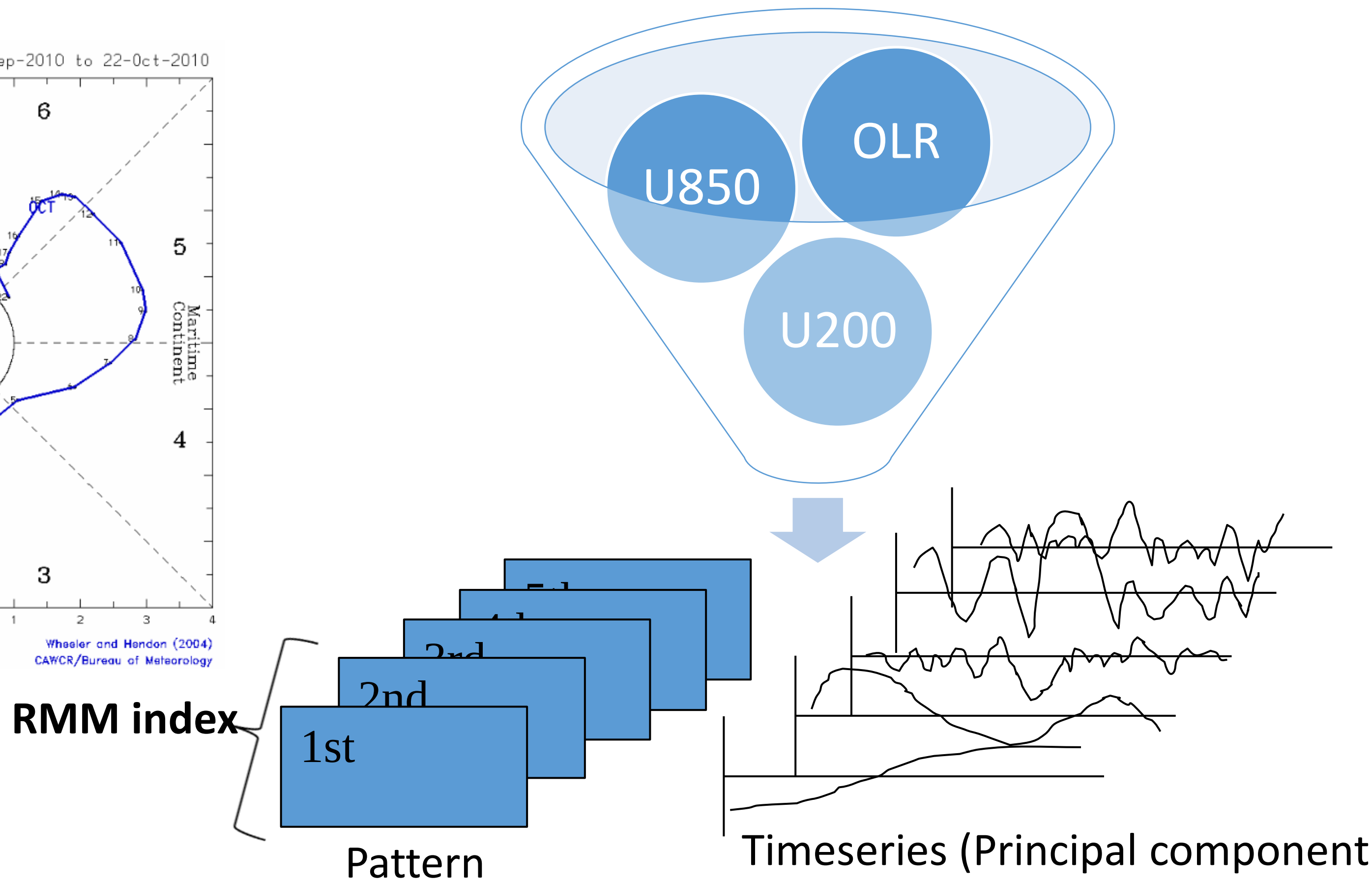


Climate.gov

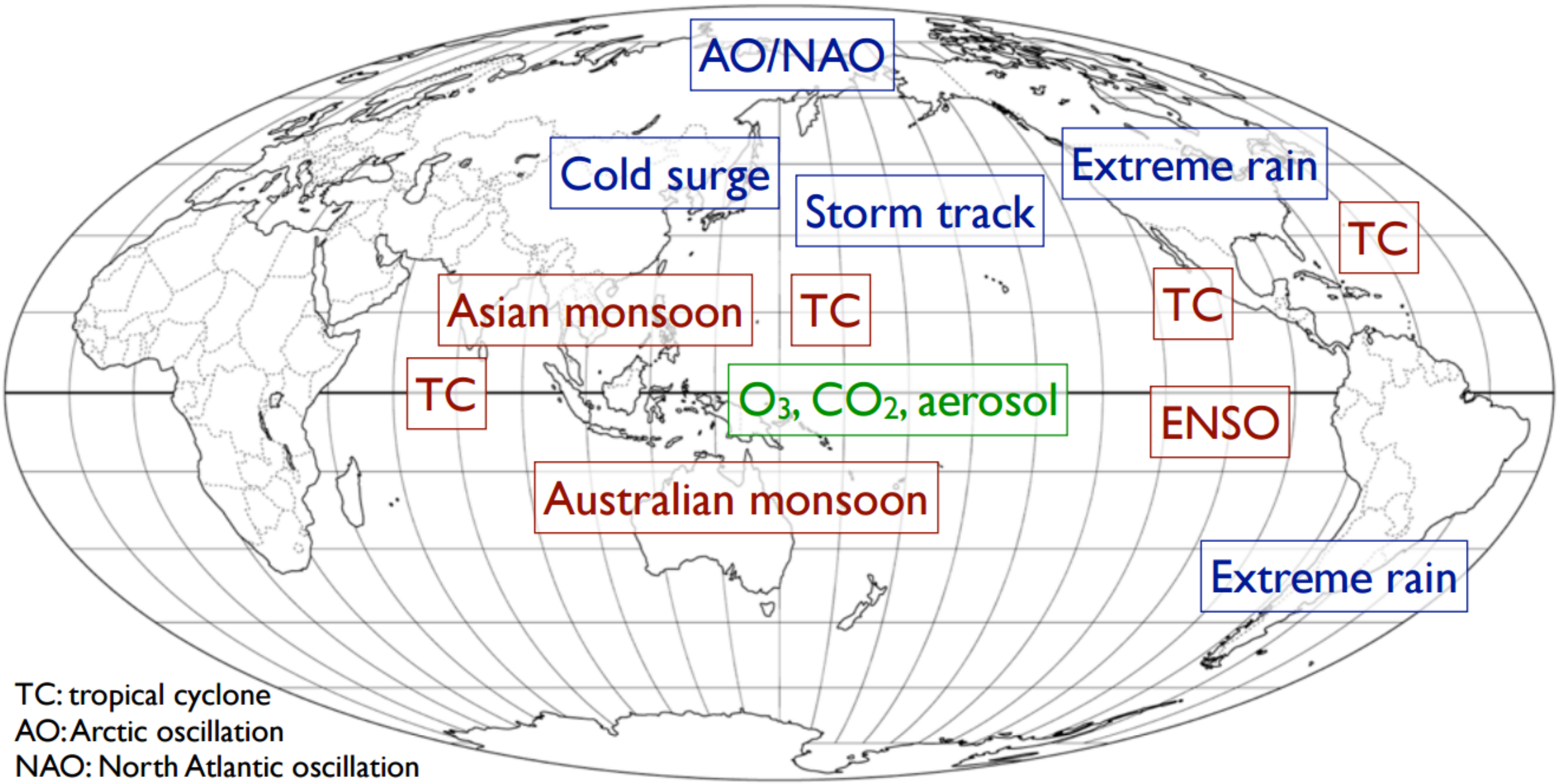
MJO index

- 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?)

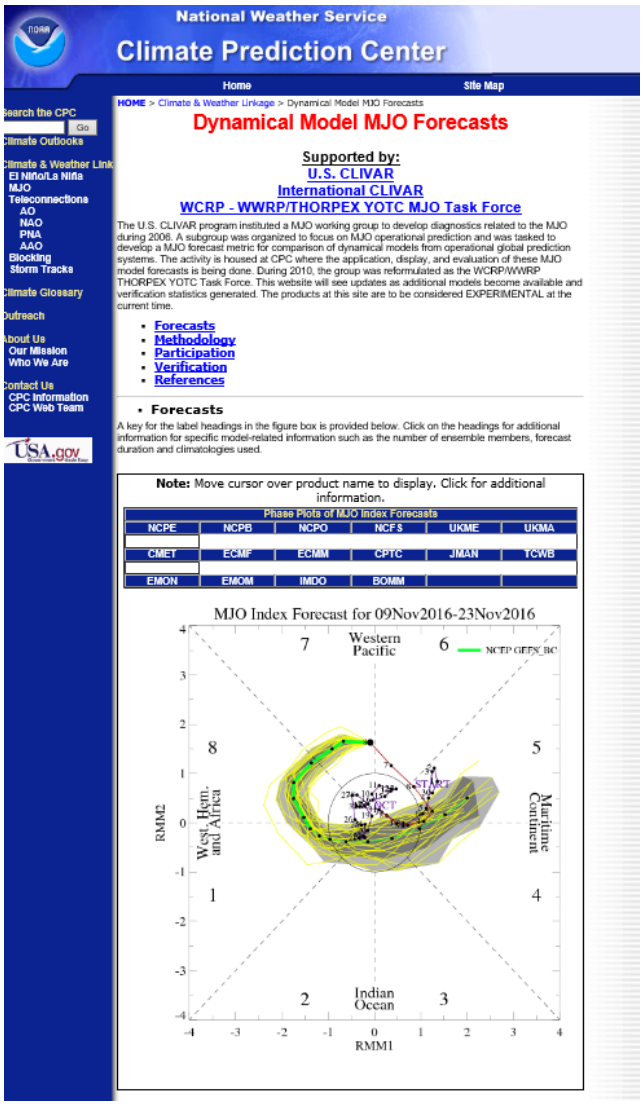




MJO impact


AO/NAO
Cold surge
Storm track
Extreme rain
TC
Asian monsoon
TC
TC
TC
O3, CO2, aerosol
ENSO
Australian monsoon
Extreme rain
TC: tropical cyclone
AO: Arctic oscillation
NAO: North Atlantic oscillation

MJO forecast



MJO operational prediction:

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/CLIVAR/clivar_wh.shtml

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

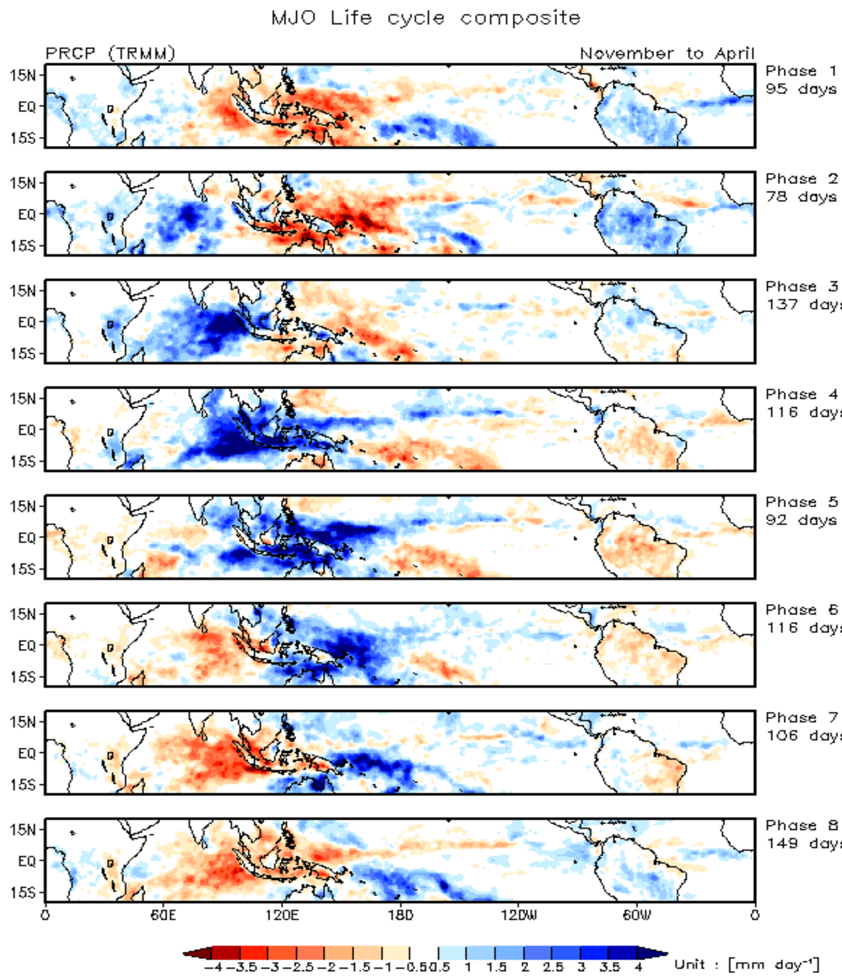
TCWB: Taiwan Central Weather Bureau - Operational Prediction System

IMDO: India Meteorology Department - Operational Global Forecast System

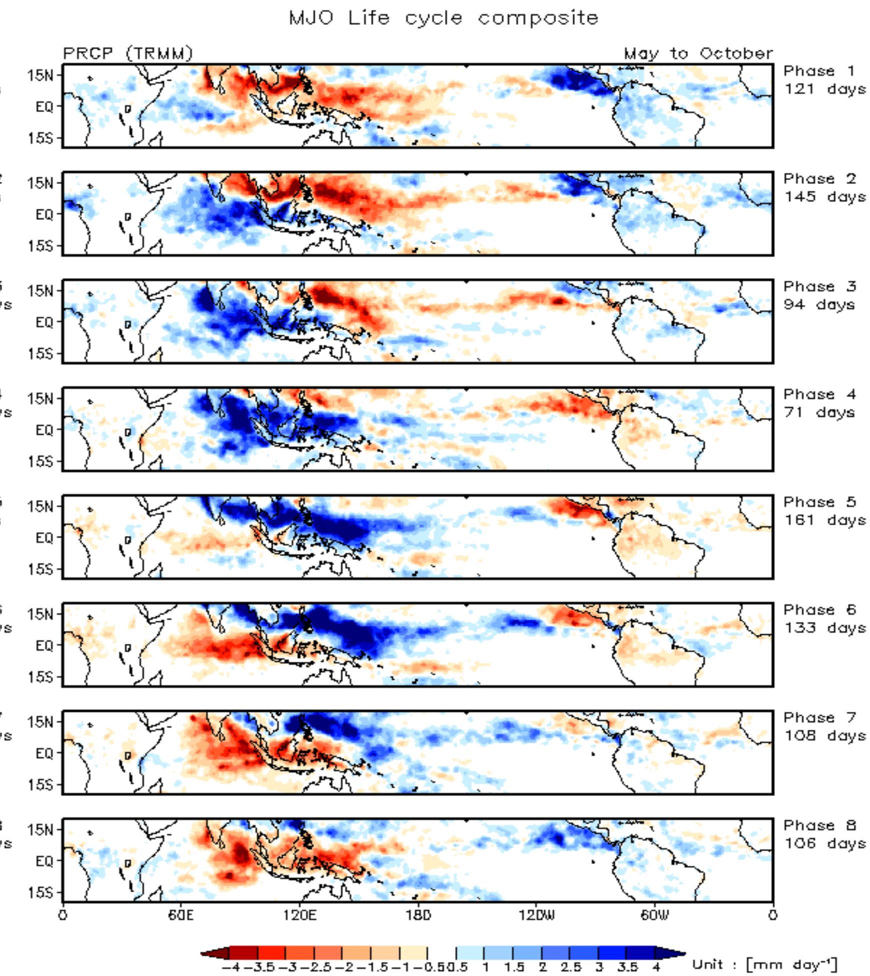
EMON: European Centre for Medium Range Weather Forecasts - Seasonal Prediction Ensemble Forecast System
EMOM: European Centre for Medium Range Weather Forecasts - Seasonal Prediction Ensemble Forecast System (anomalies based on lead dependent model climatology, weekly - Thursday only)

Seasonality of ISO

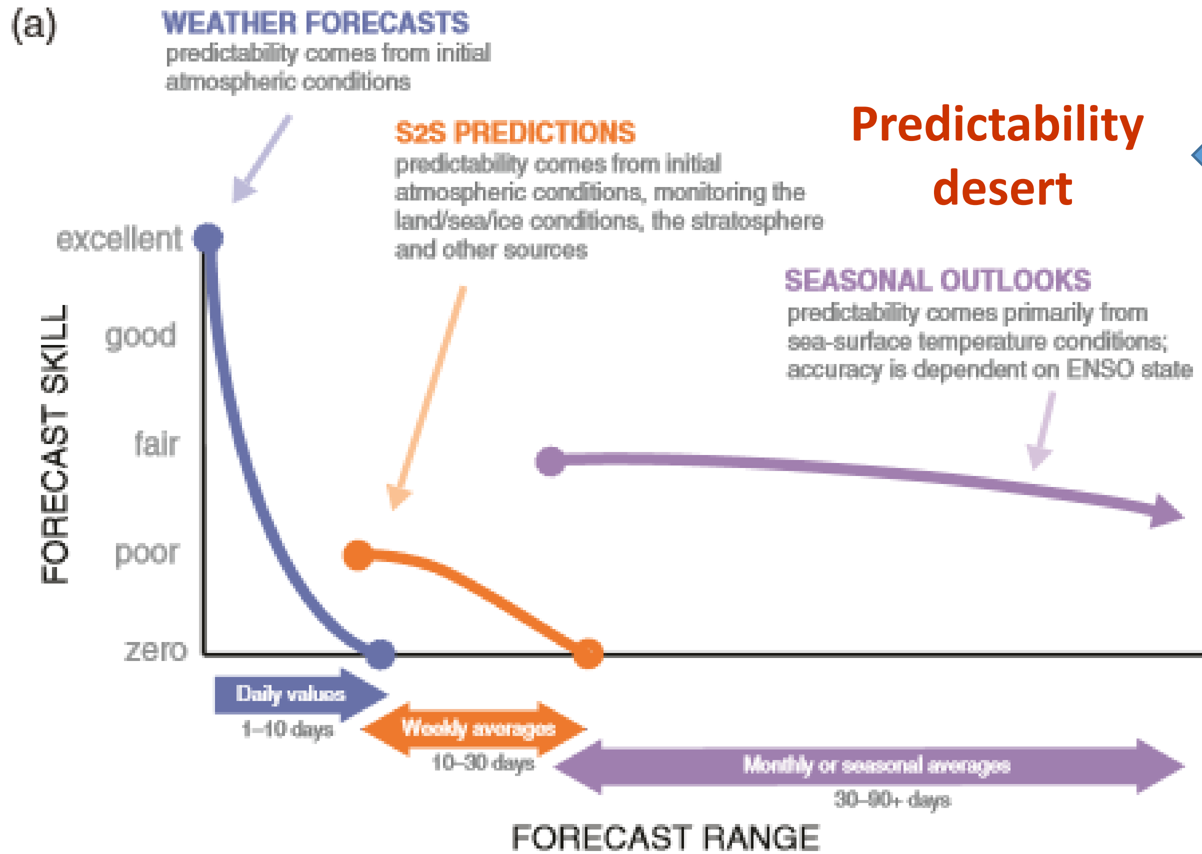
MJO



BSISO



S2S: Subseasonal to seasonal

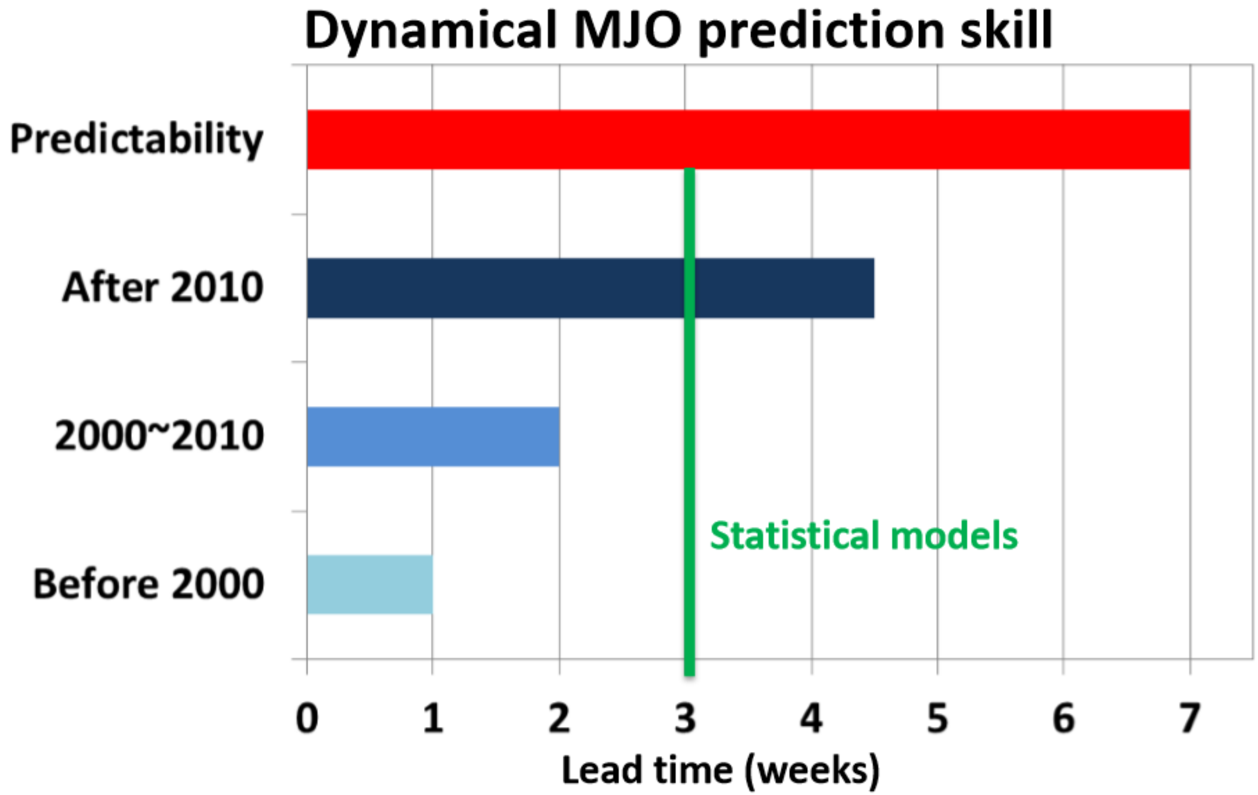


Predictability desert ⟷ **Window of opportunity**

White et al.,2017

S2S: Subseasonal to seasonal

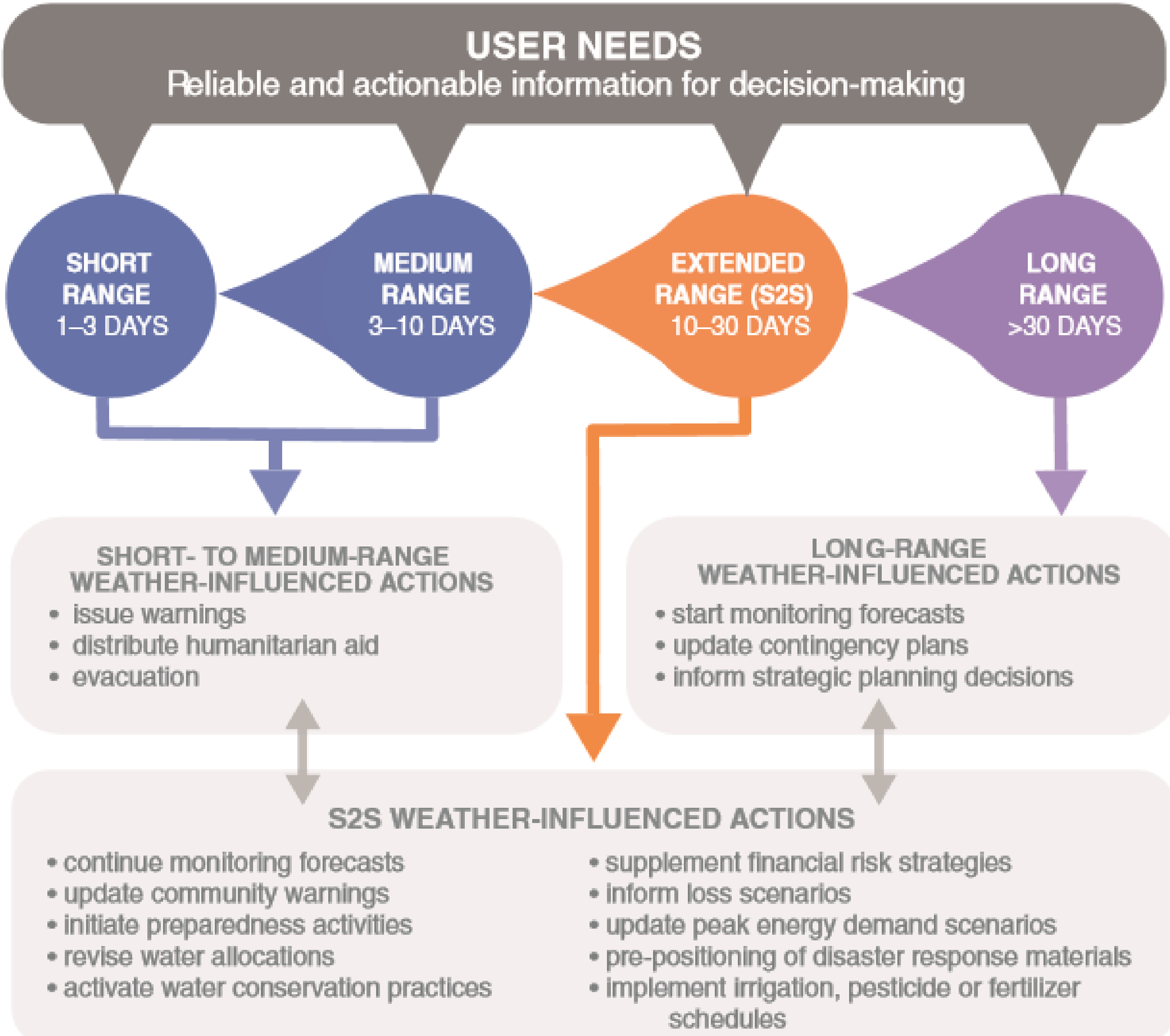
- We are progressing!



(Chen and Alpert 1990, Jones et al. 2000, Hendon et al. 2000, Waliser et al. 2003, Seo et al. 2005, 2009, Pegion and Kirtman 2008, Lin et al. 2008, Vitart and Molteni 2010, Weaver et al. 2011, Arribas et al. 2011, Fu et al. 2011, 2013, Rashid et. al.,2011, Kang et al. 2013, Ham et al. 2013, Kim et. al. 2014, Neena et al. 2014, Vitart 2014, Wang et al. 2014)

Courtesy of Hyemi Kim (SUNY/stony brook)

Decision making process based on S2S information



White et al.,2017


THANK YOU
APEC 기후센터
APEC Climate Center