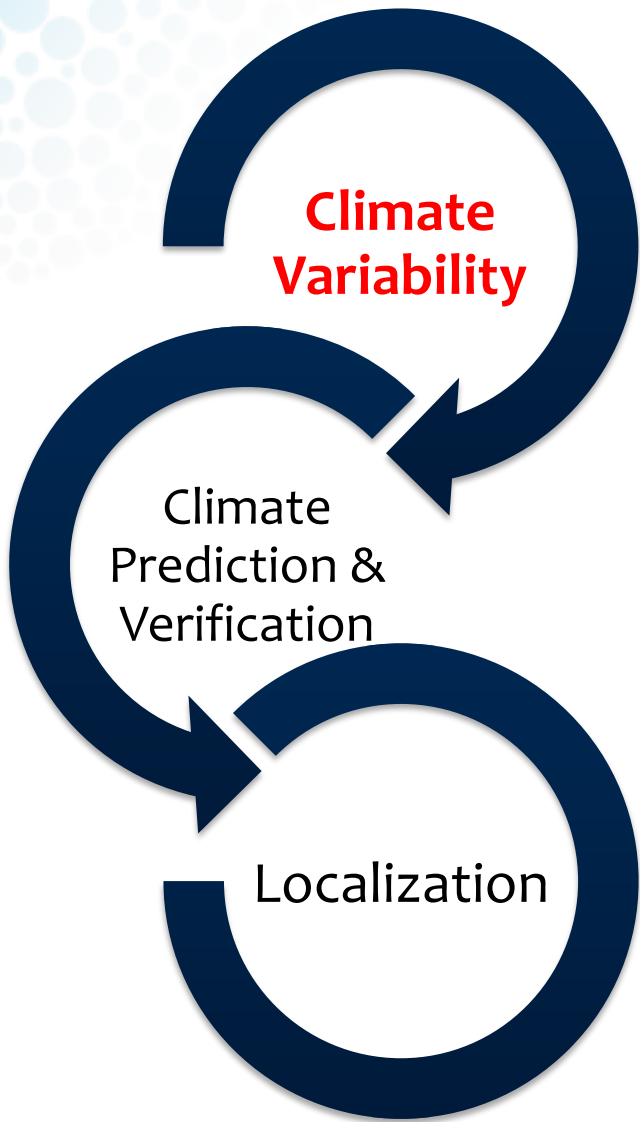


MME Seasonal Prediction & its Localization using CLIK



&



**Generating
Seasonal Outlook**

Climate Variability

Yun-Young Lee



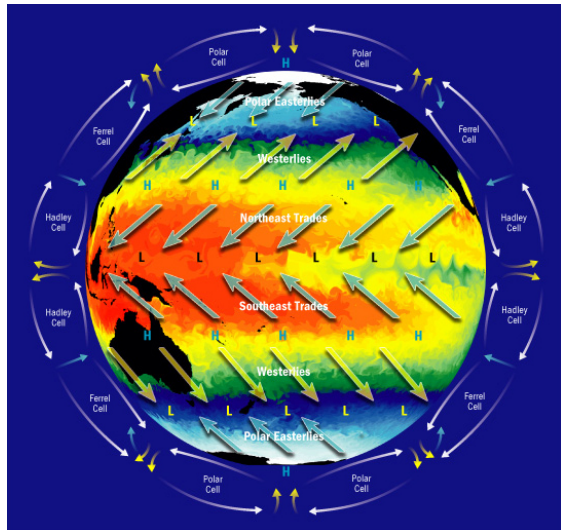


CLIMATE?



**Weather is what we get,
Climate is what we expect!**

Climate = Expectation





CLIMATE VARIABILITY?

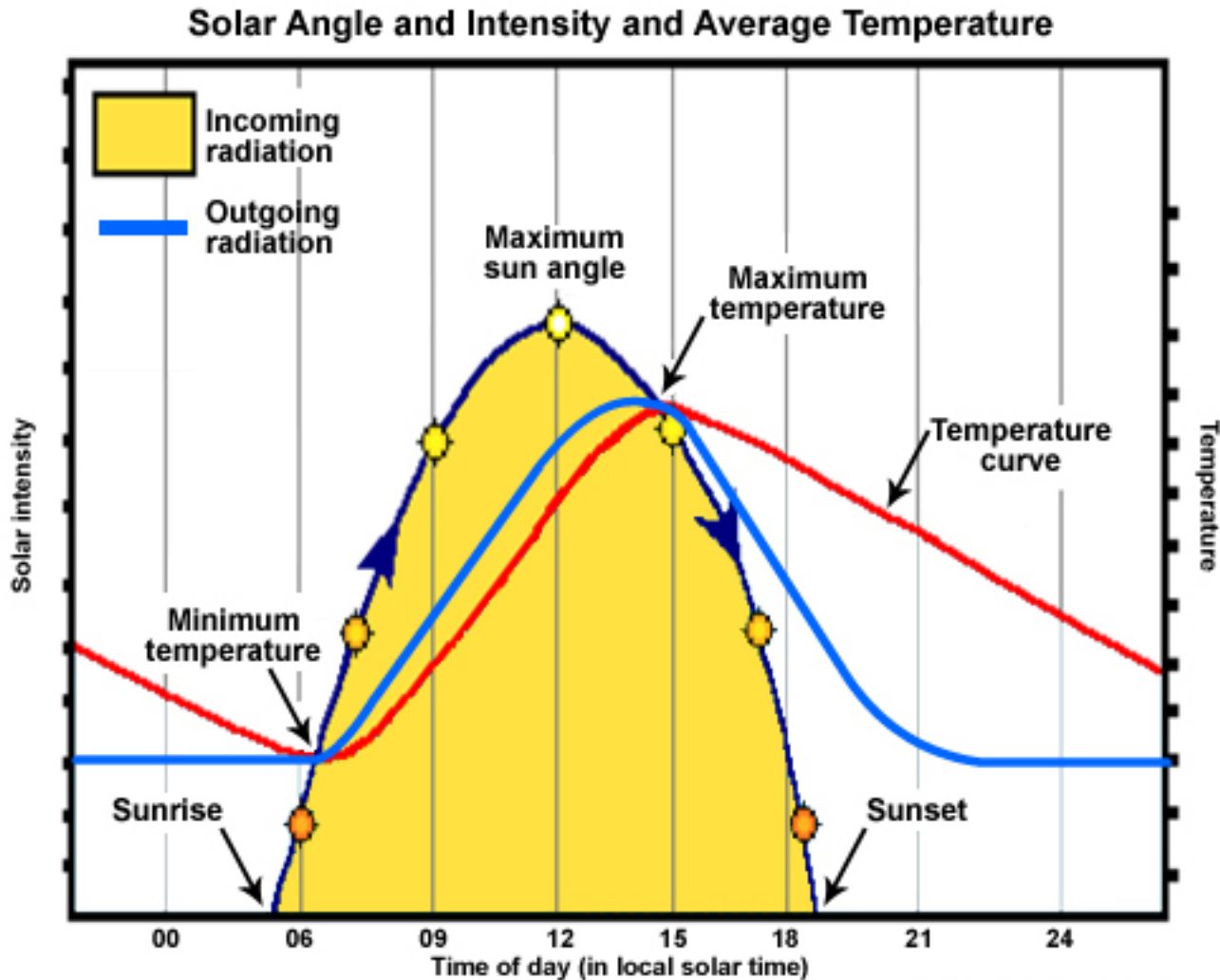


Climate Variability

Climate variability = (variability of expectation)
= *spatiotemporal fluctuations (oscillations) of mean atmospheric condition associated with dynamical atmospheric/oceanic systems*

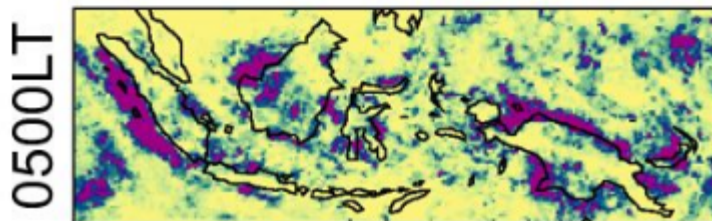
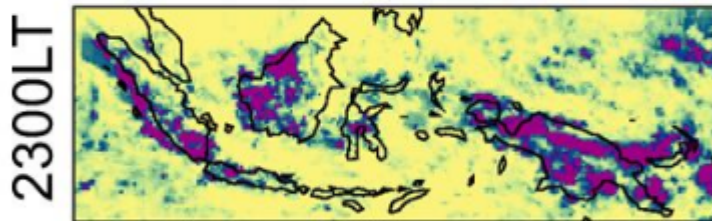
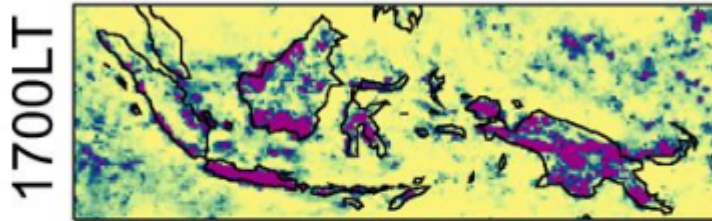
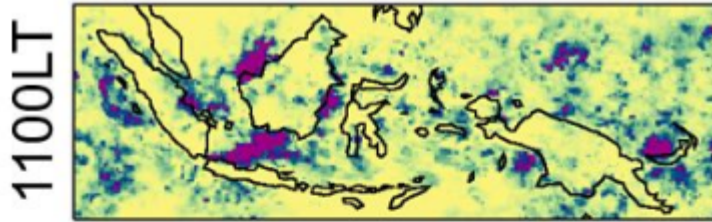
What are they?

Diurnal cycle



- ✓ Humidity
- ✓ Cloudiness
- ✓ Wind

Diurnal cycle

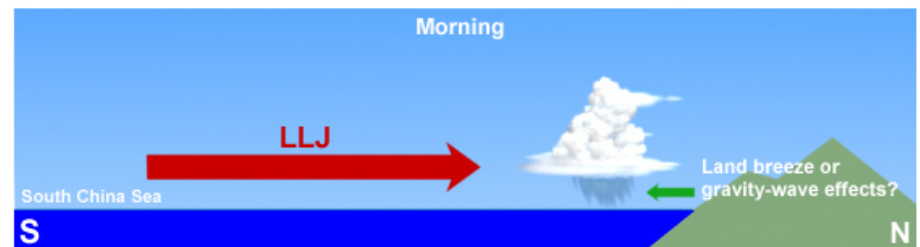
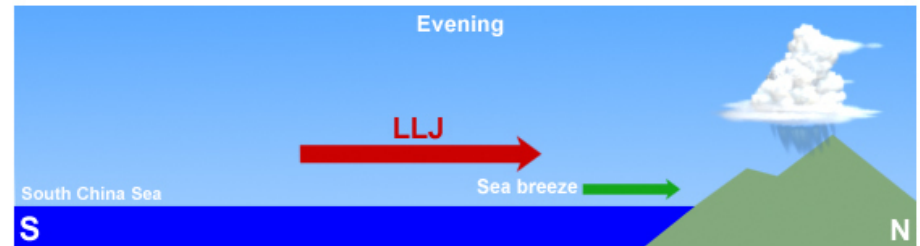


From Jane Strachan

Land-sea breeze

Mountain-Valley circulation

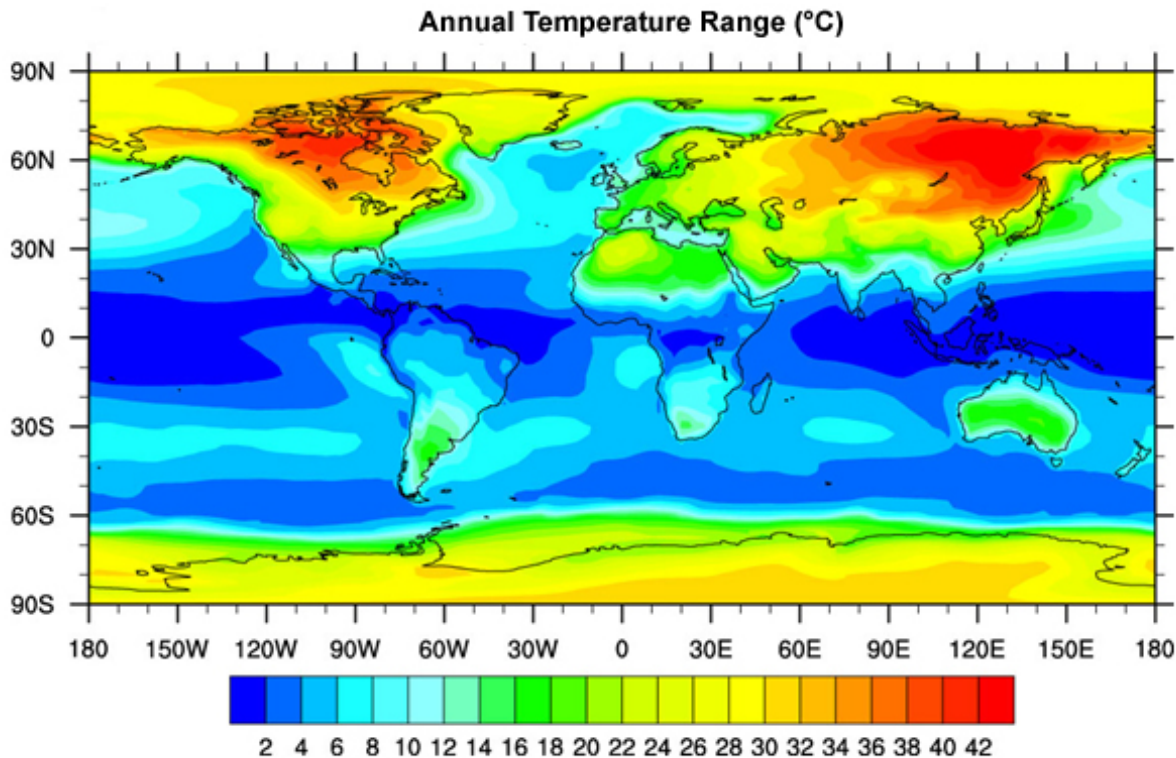
Diurnal Land-Sea Breeze Interaction with Diurnally Varying Low-Level Jet



From R. Johnson

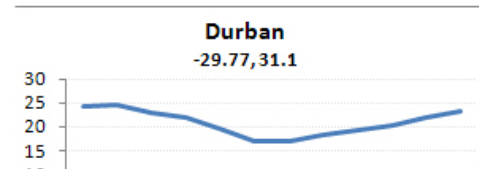
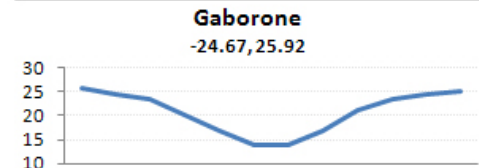
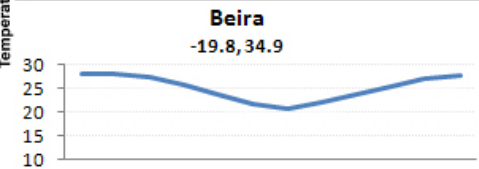
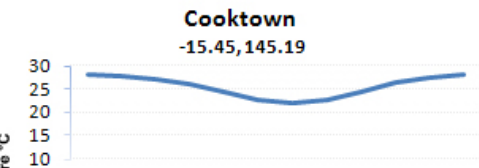
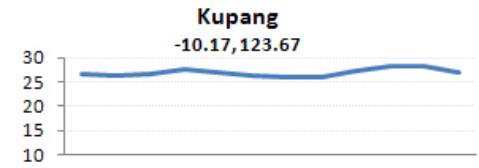
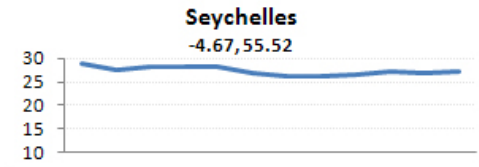
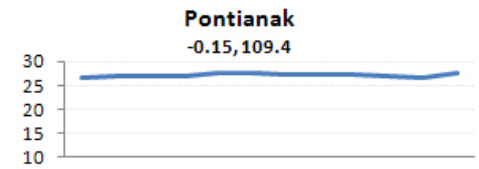
Seasonal cycle

- ✓ Latitude
- ✓ Continentality
- ✓ Clouds and Precipitation
- ✓ Albedo



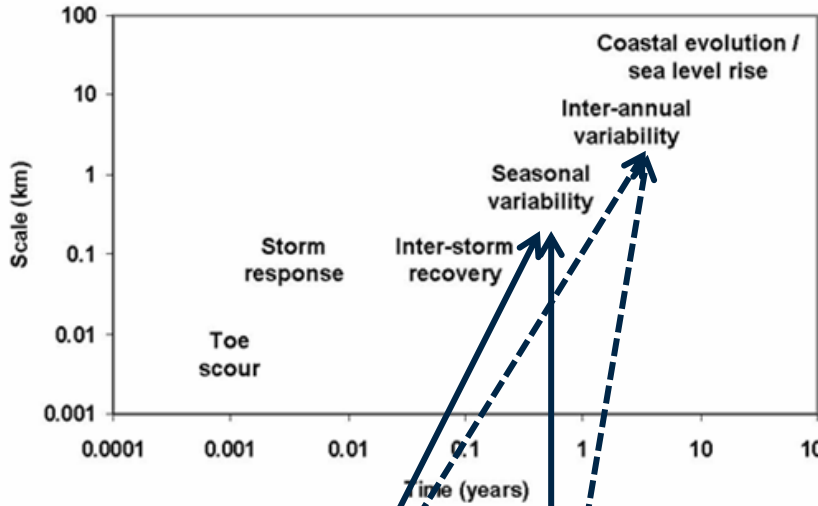
UCAR / The COMET Program

Monthly Mean Temperature (°C)



J F M A M J J A S O N D

Climate Variability

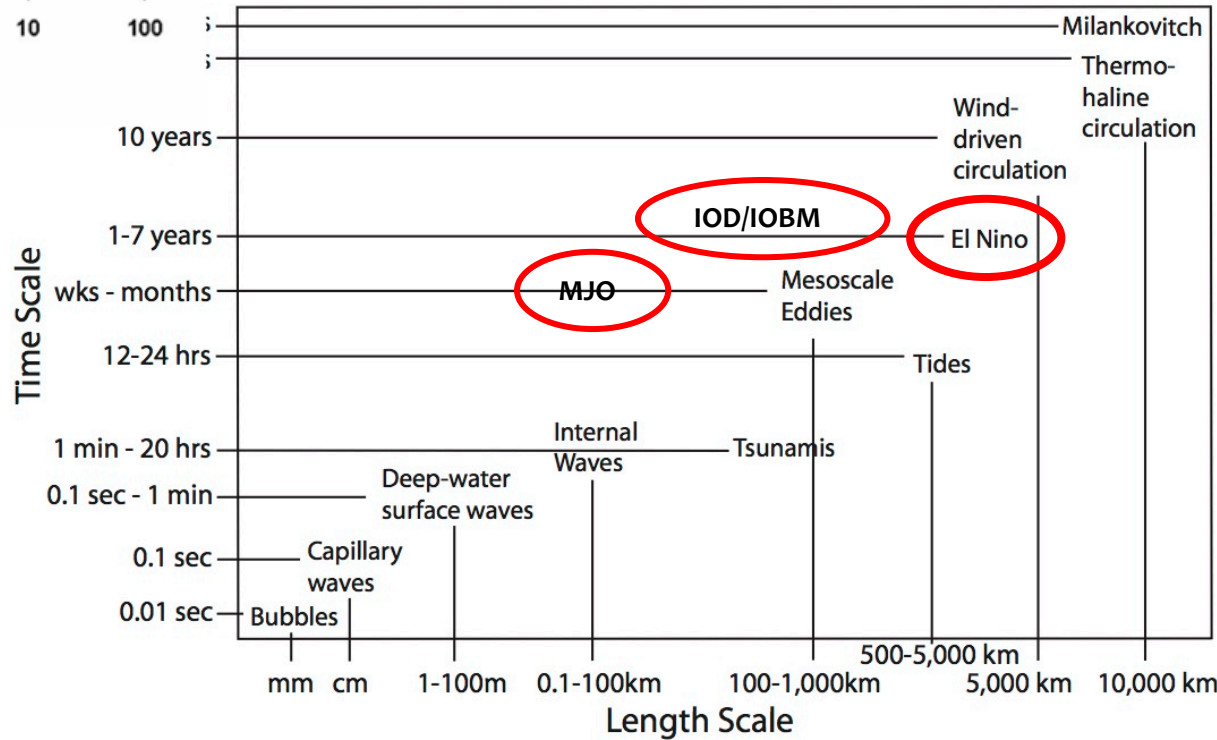


MONSOON (circled in red)

ITCZ (circled in red)

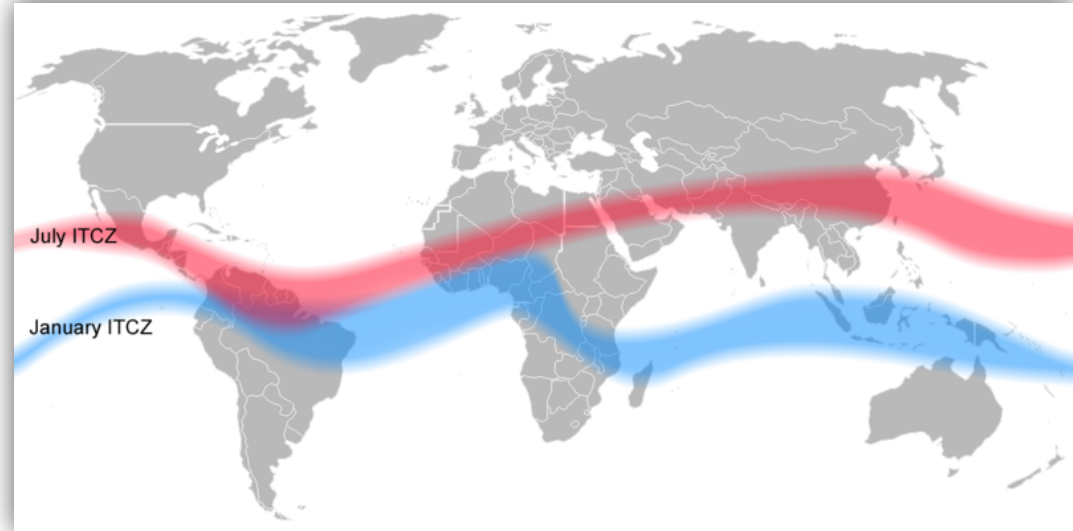
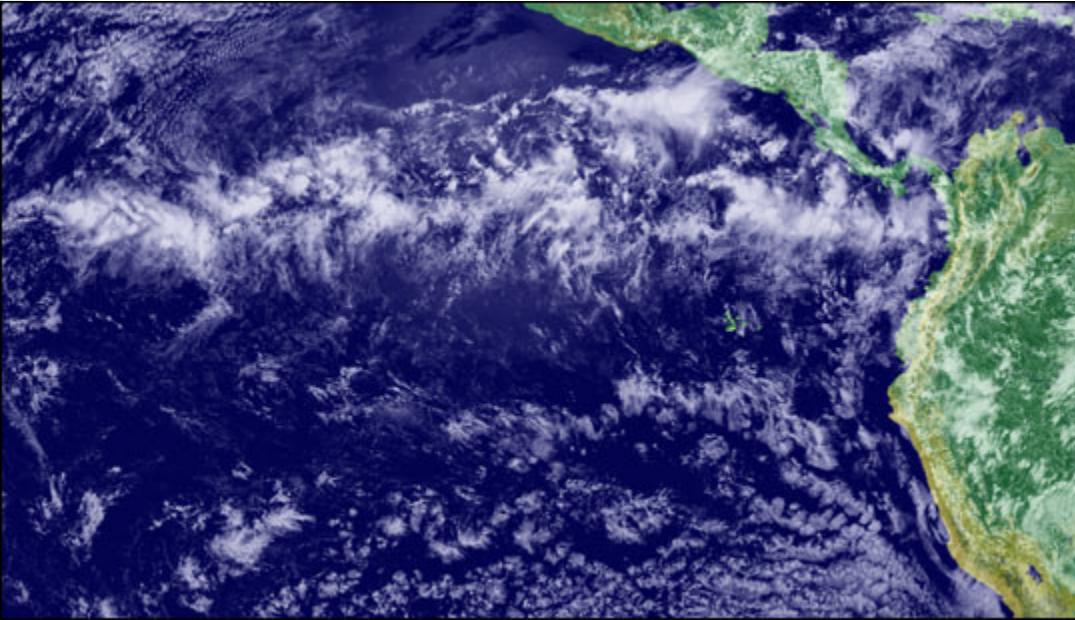
Energy Source: Solar radiation

Very obvious diurnal and seasonal cycle due to earth rotation & resolution (relative to the Sun)



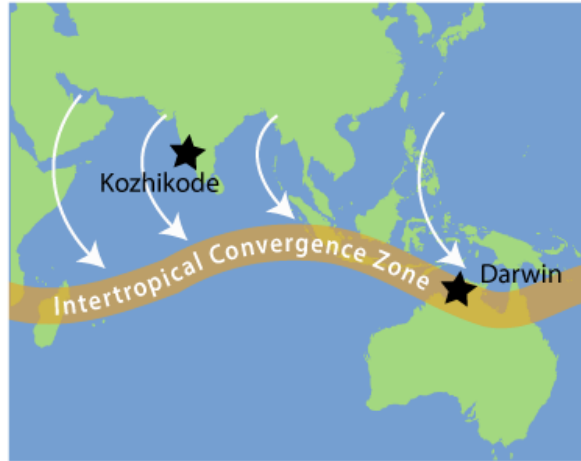
Inter Tropical Convergence Zone (ITCZ)

<https://earthobservatory.nasa.gov/IOTD/view.php?id=703>

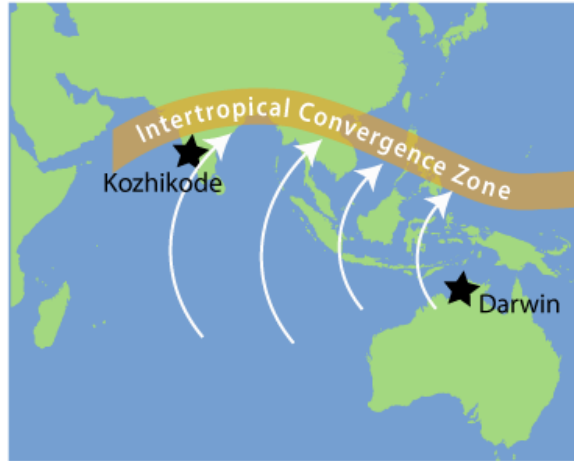


Inter Tropical Convergence Zone (ITCZ)

DECEMBER and JANUARY

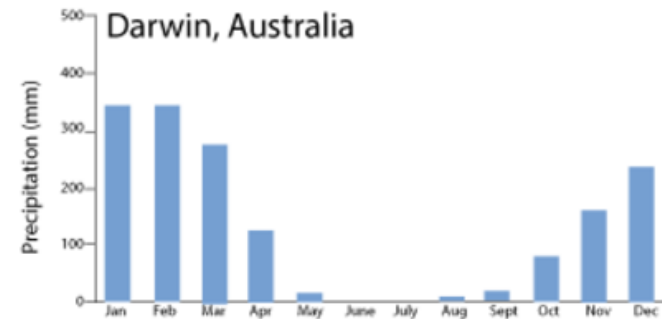
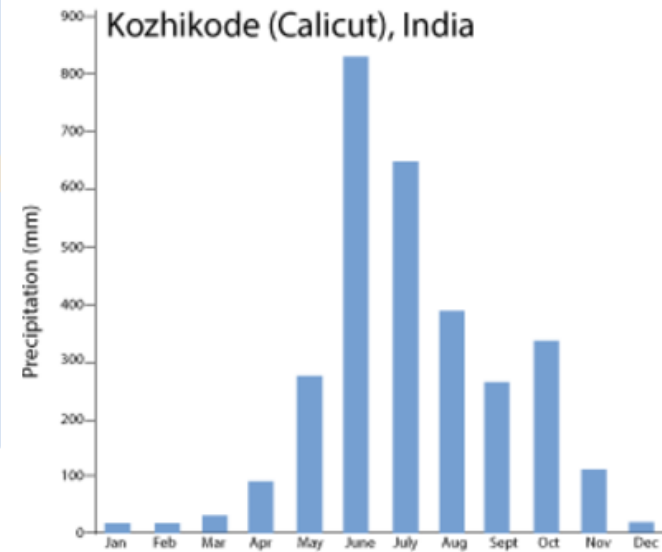


JUNE and JULY

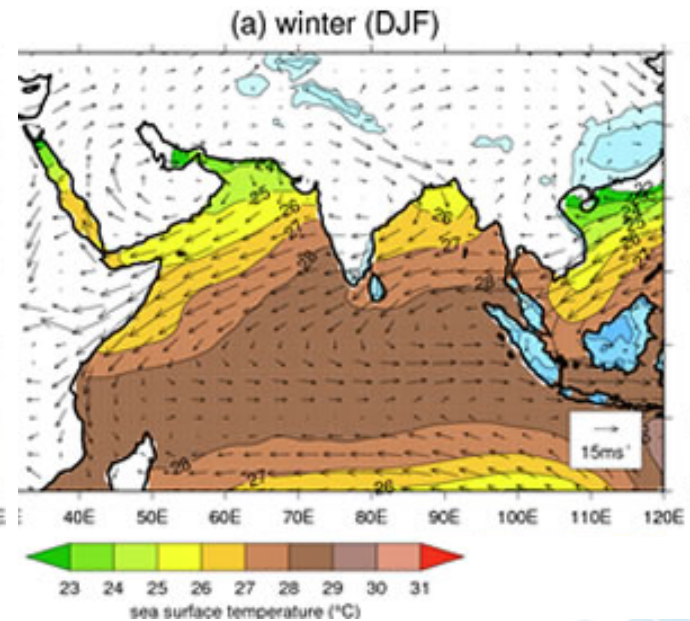
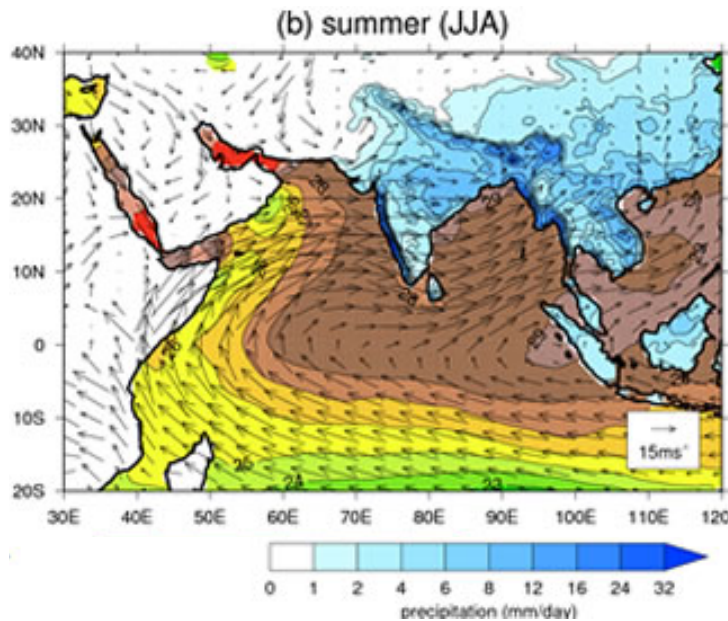
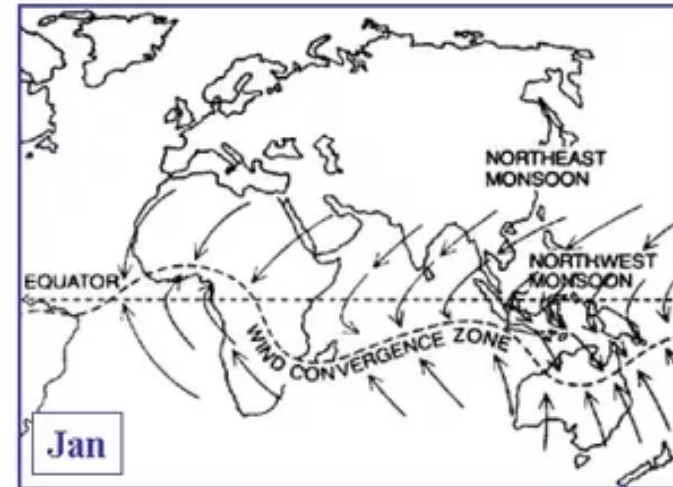


As the Intertropical Convergence Zone (ITCZ) changes location through the year, the winds, rains, and the location of wet monsoon weather changes, too. In this example from Asia and Australia, the ITCZ moves from the Southern Hemisphere (left map) to the Northern Hemisphere (right map). (Images: UCAR)

As the ITCZ swings north during the summer months, it brings monsoon rains to Kozhikode, India. As the ITCZ drops south during summer in the Southern Hemisphere, it brings monsoon rains to Darwin, Australia. (Images: UCAR)



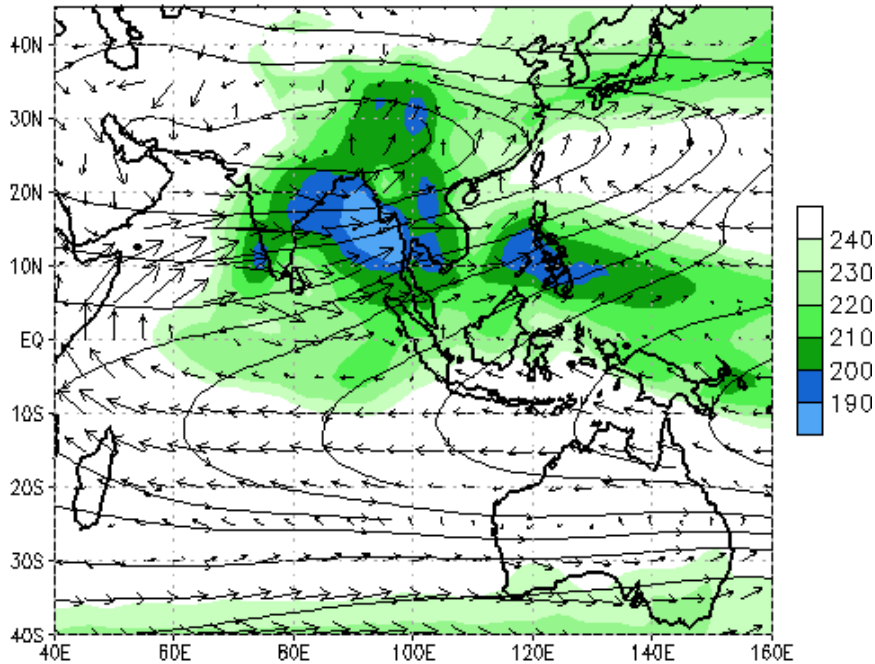
Monsoon



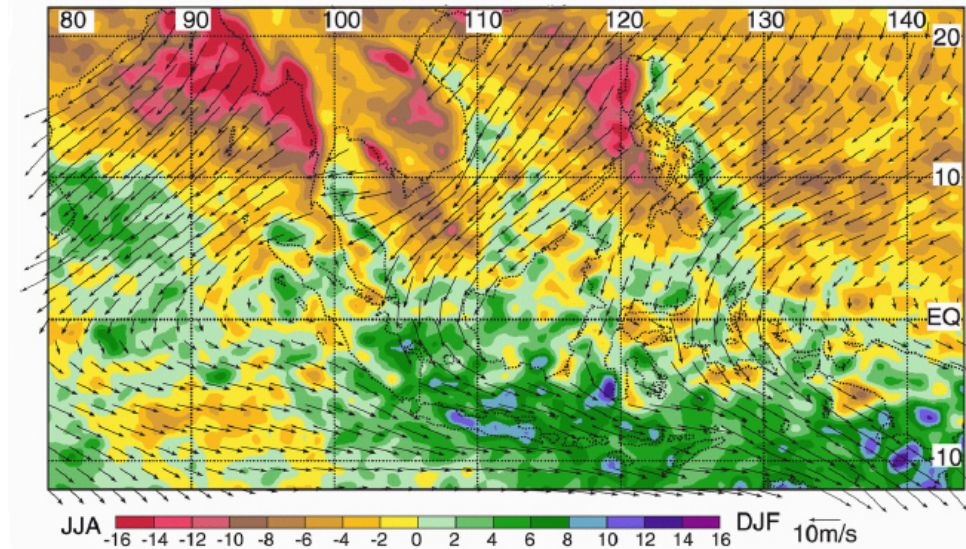
Monsoon

OLR, 200-hPa Streamlines and 850-hPa Wind Clim (1979-1995)

02JUL

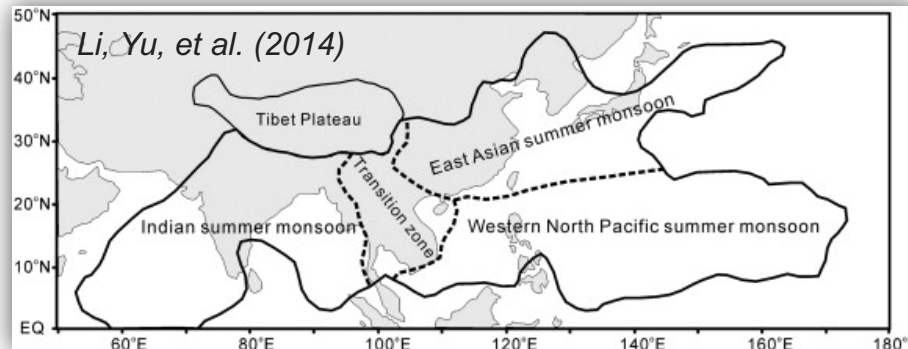


DJF-minus-JJA TRMM PR(mm day⁻¹) and Quikscat winds



Chang et al. 2005

Data Sources: OLR - NESDIS/ORA, Winds - NCEP CDAS/ Reanalysis



Seasons in Sri Lanka

Monsoons

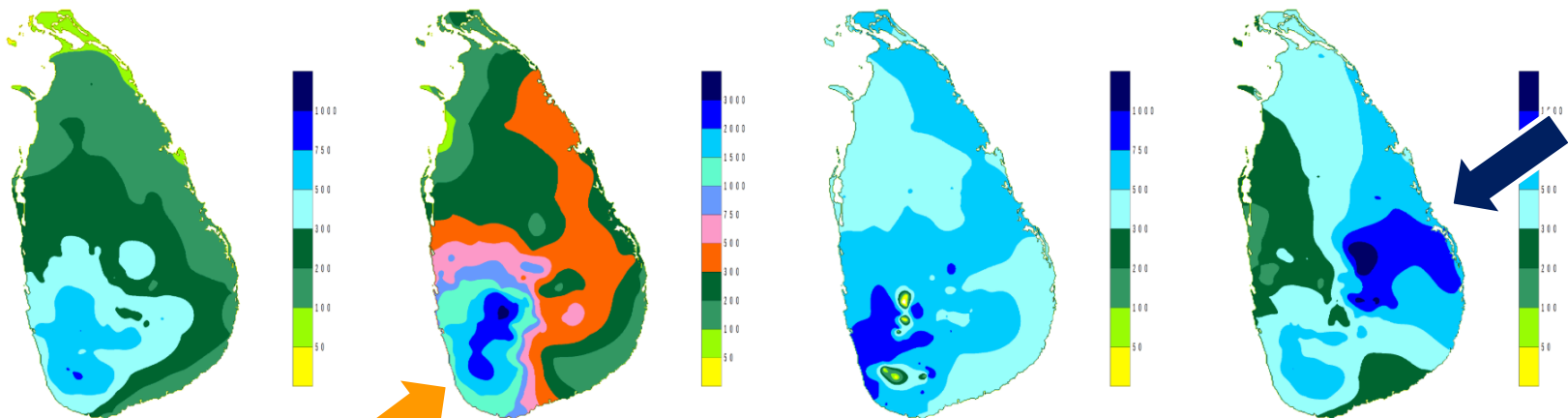
Due to its location in the equatorial and tropical zones, [Sri Lanka](#) has been influenced by the monsoons which consist of four very distinctive seasons.

First Inter-monsoon Season (March – April) – Thunderstorm type rainfall with warm and uncomfortable conditions

Southwest-Monsoon Season (May – September) – The warm season is eased away by the windy weather during this particular monsoon season. Rains can be expected during any time of the day

Second Inter-monsoon Season (October – November) – Rains occur with thunder storms while the influence of the weather system like depression and cyclones in the Bay of Bengal is considered to be common. The whole island experiences wide spread rain with strong winds

Northeast-Monsoon Season (December – February) – Cold and dry windy weather can be expected during this season while cloud free and days filled with sunshine can be expected. Rain can be expected in several parts of the island as well.



First Inter-monsoon Season

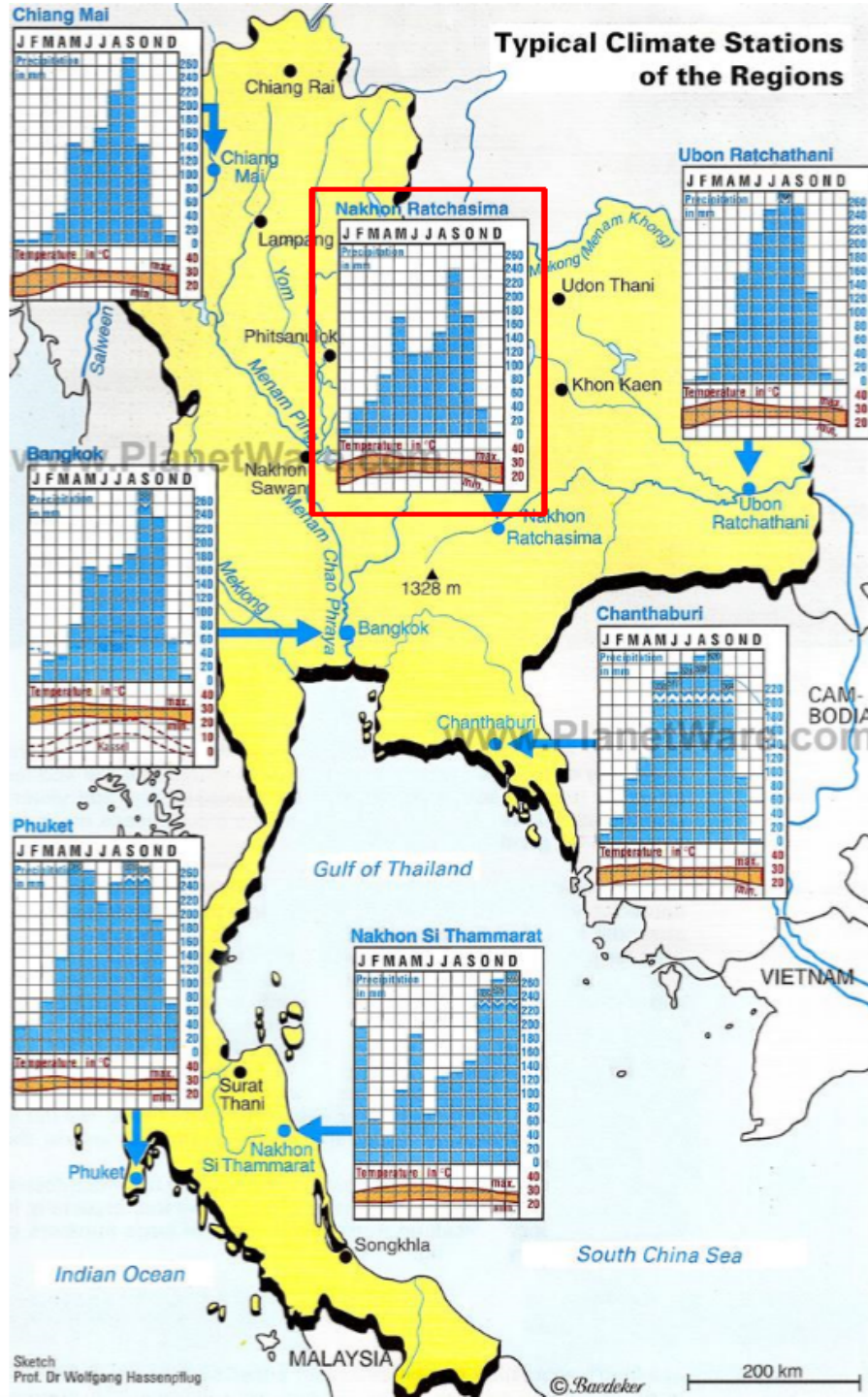
Southwest-monsoon Season

Second Inter-monsoon Season

Northeast-monsoon Season

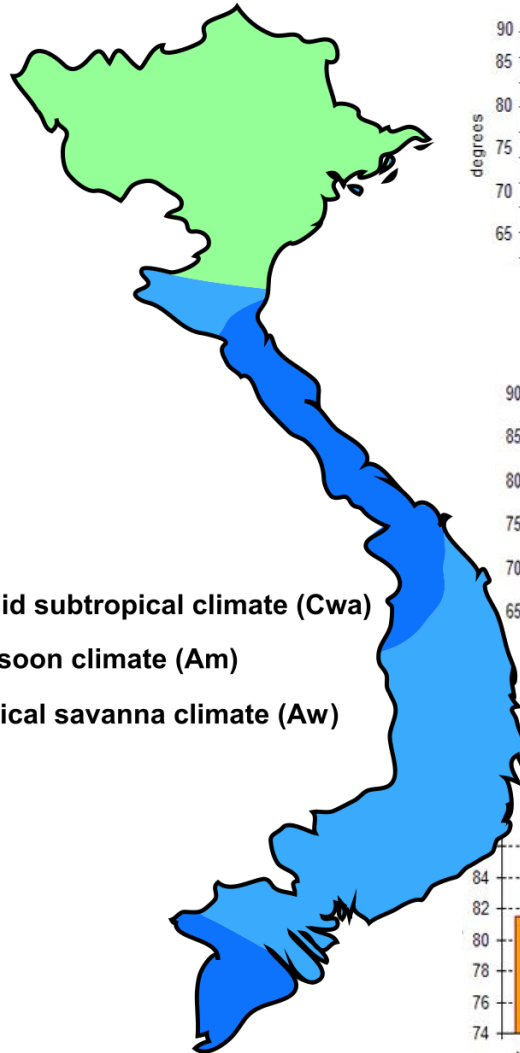
Regional difference (Thailand)

Peninsula area vs Northern Inland



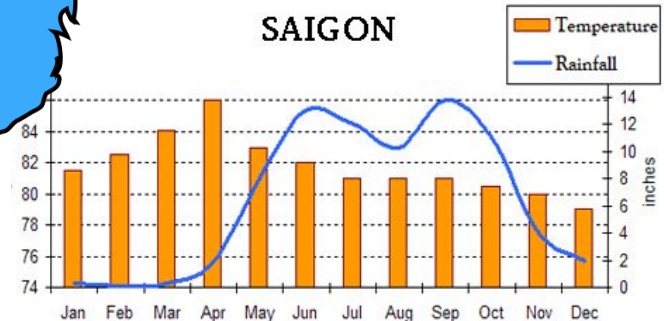
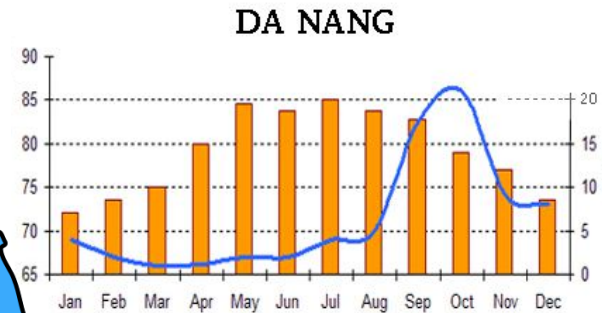
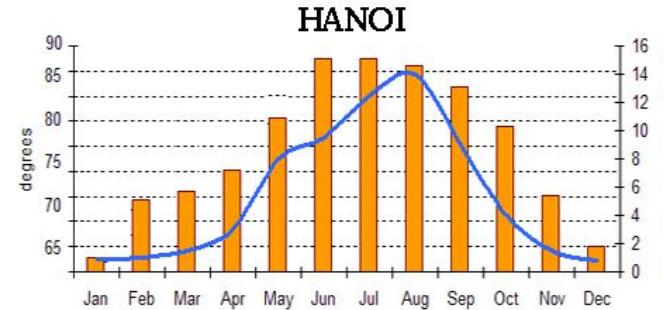
Regional difference (Vietnam)

Vietnam map of Köppen climate classificator



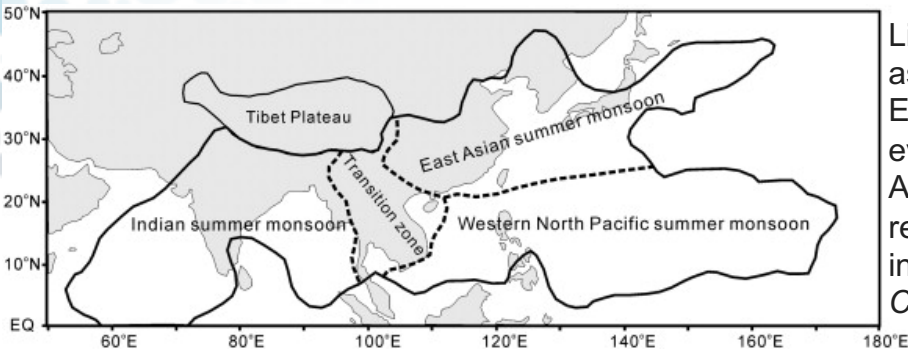
**North
& Central
& South**

- Humid subtropical climate (Cwa)
- Monsoon climate (Am)
- Tropical savanna climate (Aw)

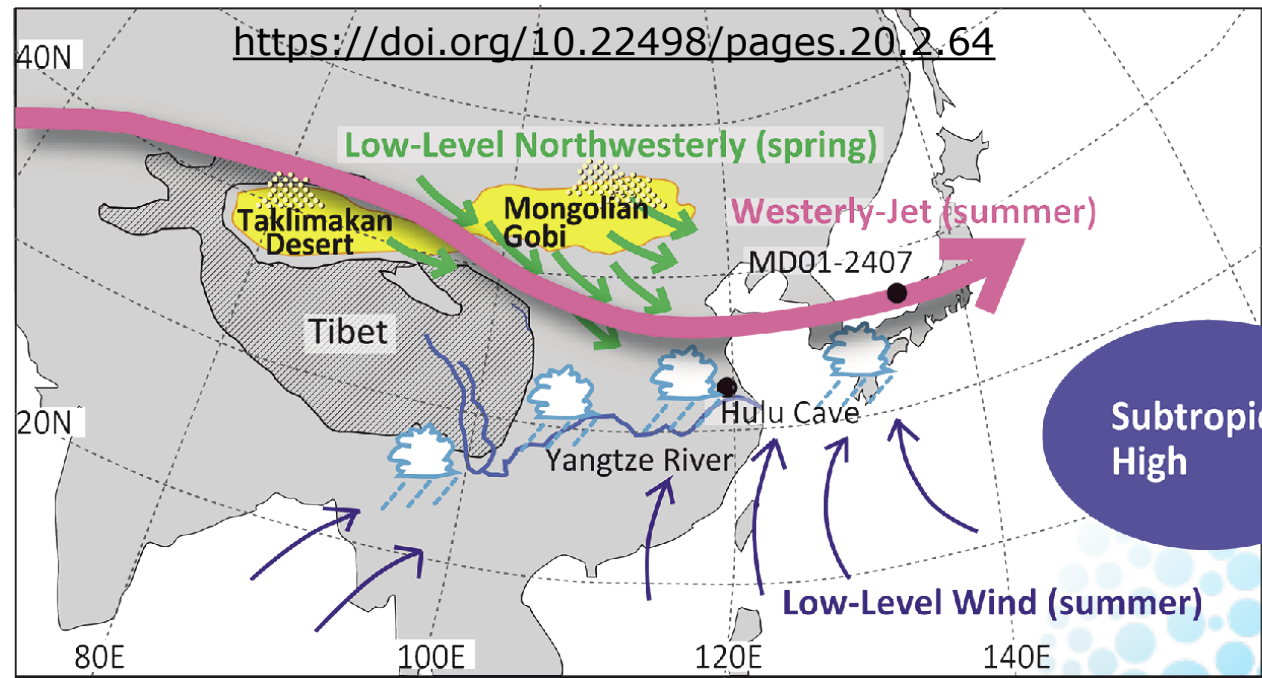


<https://www.fareastour.asia/when-is-the-best-time-to-visit-Vietnam/>

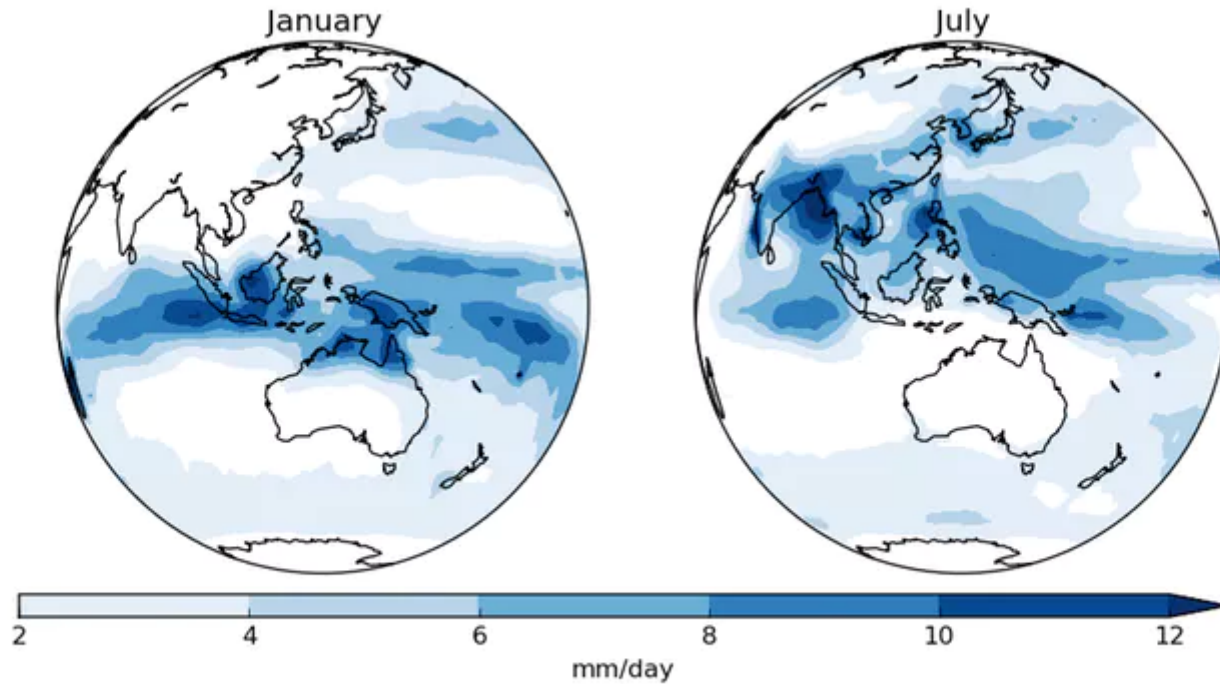
East Asia Summer Monsoon



Li, Yu, et al. "Synchronous or asynchronous Holocene Indian and East Asian summer monsoon evolution: A synthesis on Holocene Asian summer monsoon simulations, records and modern monsoon indices." *Global and Planetary Change* 116 (2014): 30-40.



Australian Monsoon

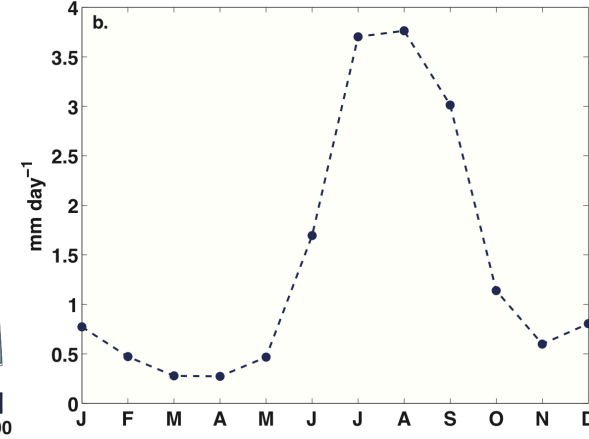
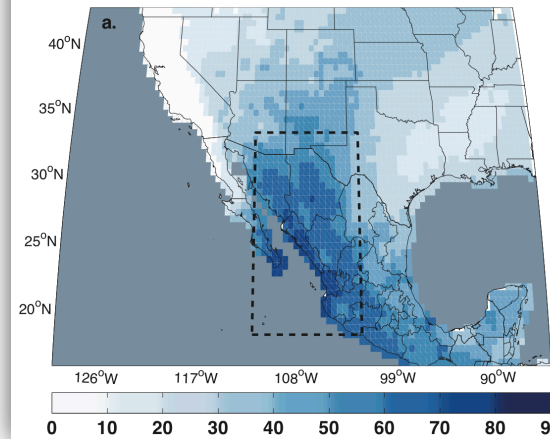


Global rainfall daily averages (1979-2008) for the months of January (left) and July (right). The monsoon trough is positioned over northern Australia in the southern summer, and moves northward during the southern winter. NOAA/OAR/ESRL PSD (<http://www.esrl.noaa.gov/psd/>)

North America Monsoon



The North American Monsoon (GPCC, 1980-1999)
JAS Precipitation, % of Annual
Monthly Climatology



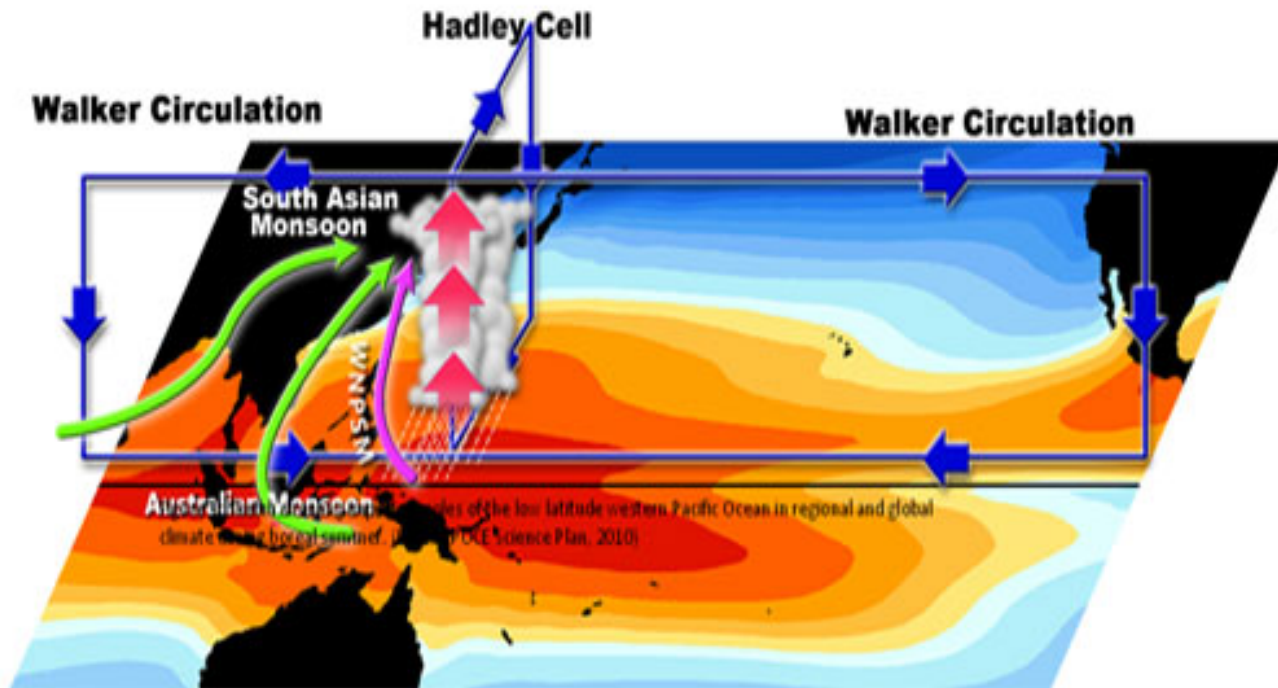
<http://ocp.ldeo.columbia.edu/res/div/ocp/glodech/10Monsoon.html>

<https://climate-woodlands.extension.org/the-north-american-monsoon-system/>

Western Pacific Warm Pool (WPWP)

- Climate Engine : remember “mean” feature

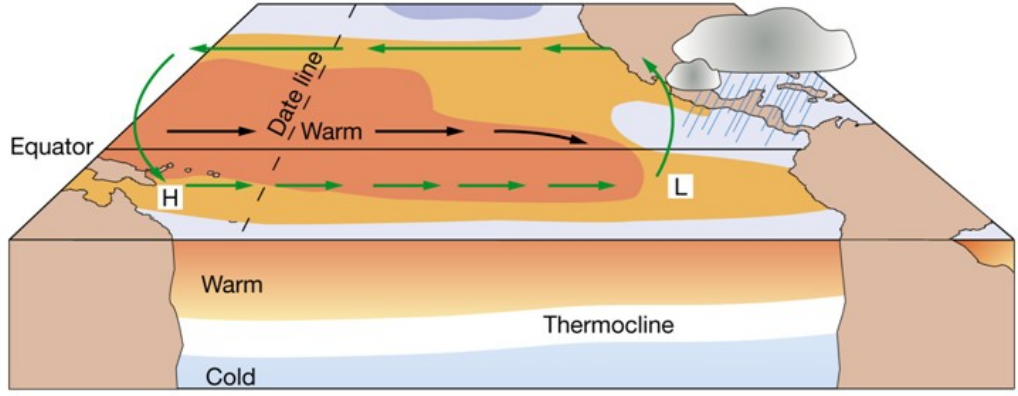
SST > 28.5° C



<http://npoc.e.qdio.ac.cn/background>

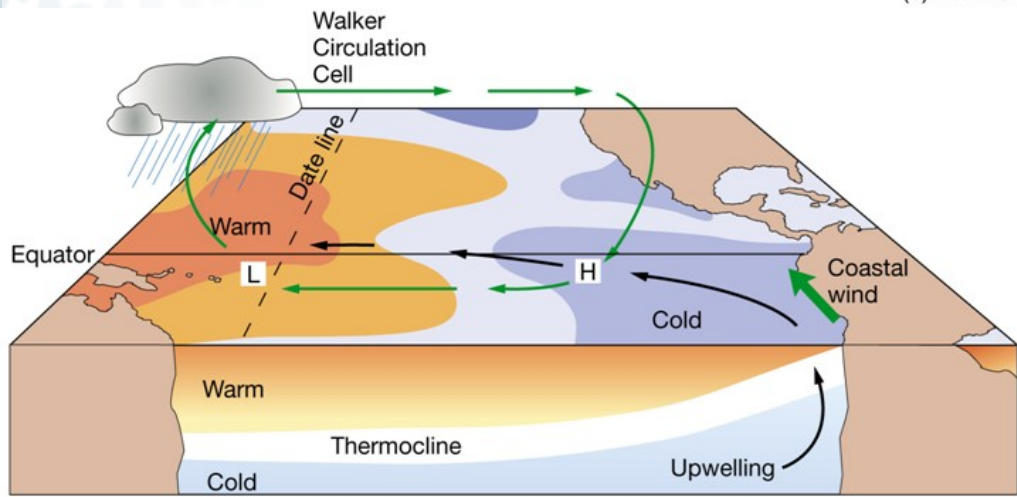
ENSO

- A Big Ocean Swing



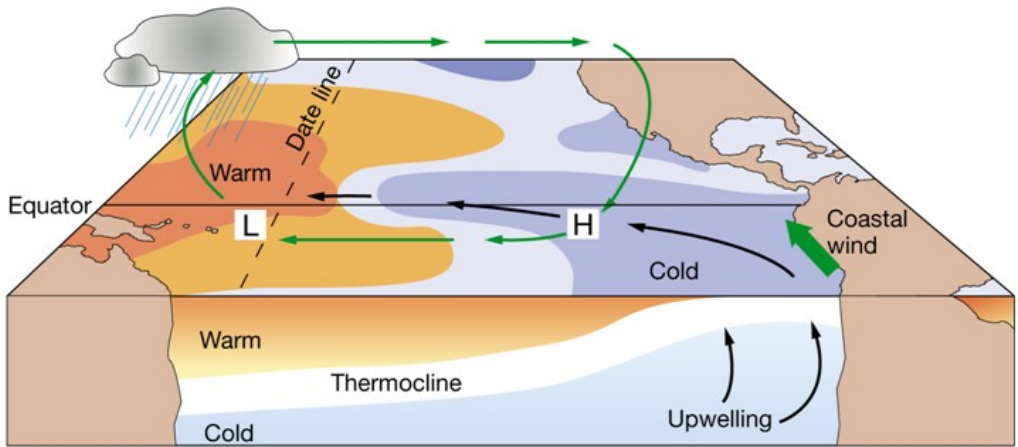
(b) El Niño conditions

Copyright © 2005 Pearson Prentice Hall, Inc.



(a) Normal conditions

Copyright © 2005 Pearson Prentice Hall, Inc.

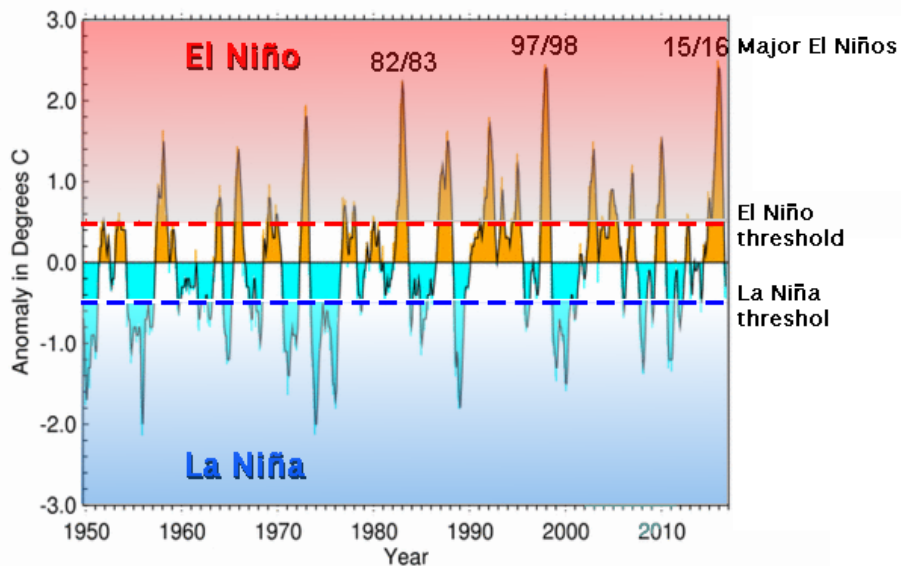


(c) La Niña conditions

Copyright © 2005 Pearson Prentice Hall, Inc.

ENSO, why it oscillates?

SST Anomaly in Nino 3.4 Region (5N-5S,120-170W)

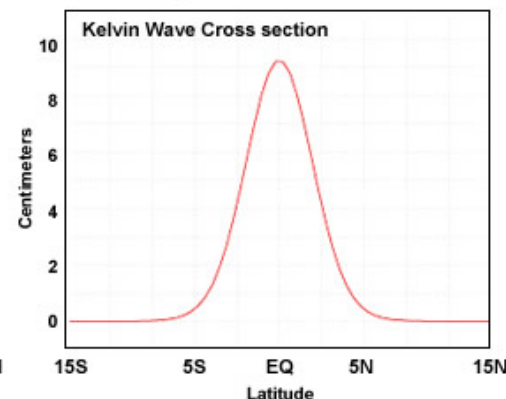
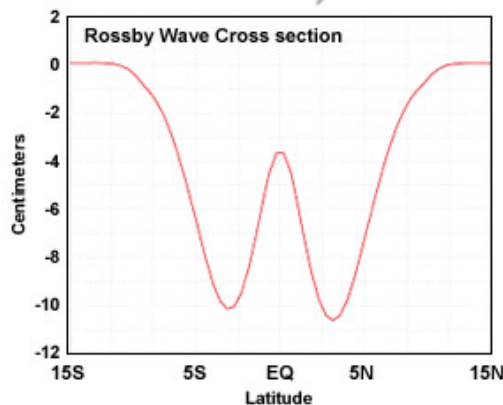
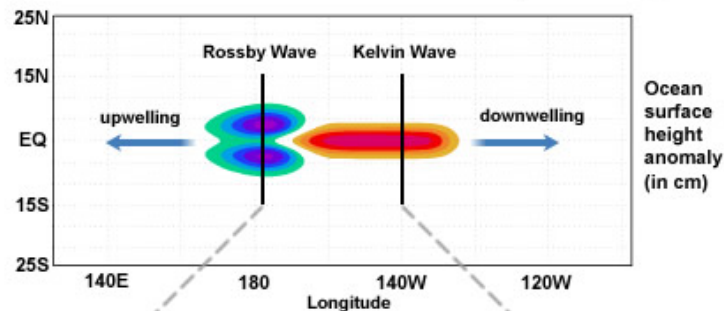


National Centers for Environmental Information / NESDIS / NOAA

The period/cycle of 2 - 7 years

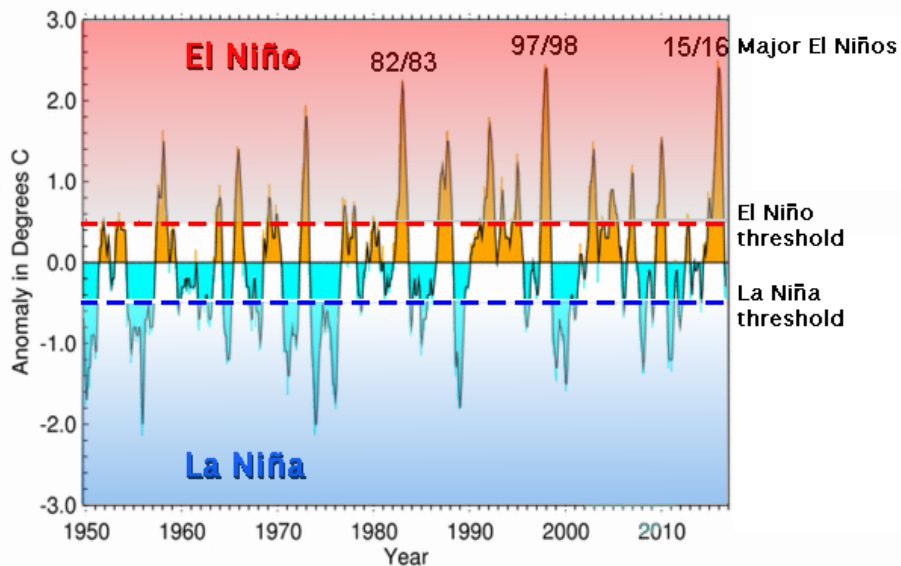
Delayed Oscillator

Simple Model of Wind Induced Perturbation of the Tropical Pacific Ocean



ENSO, why it oscillates?

SST Anomaly in Nino 3.4 Region (5N-5S,120-170W)

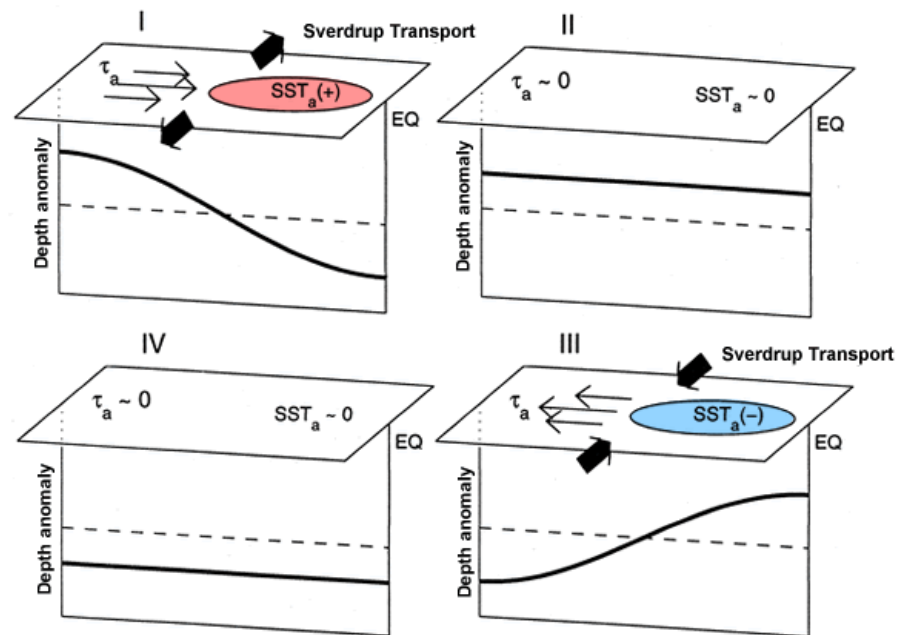


National Centers for Environmental Information / NESDIS / NOAA

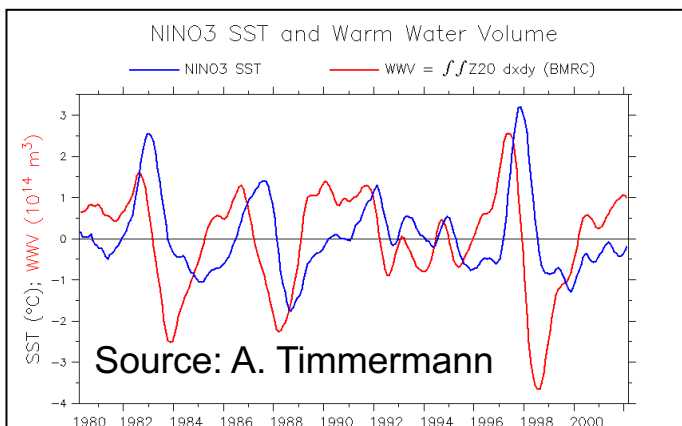
The period/cycle of 2 - 7 years

Recharge-discharge Oscillator

Schematic of the Recharge/Discharge Theory of ENSO



Meinen and McPhaden 2002



2015-16 wetter monsoon in Sri Lanka

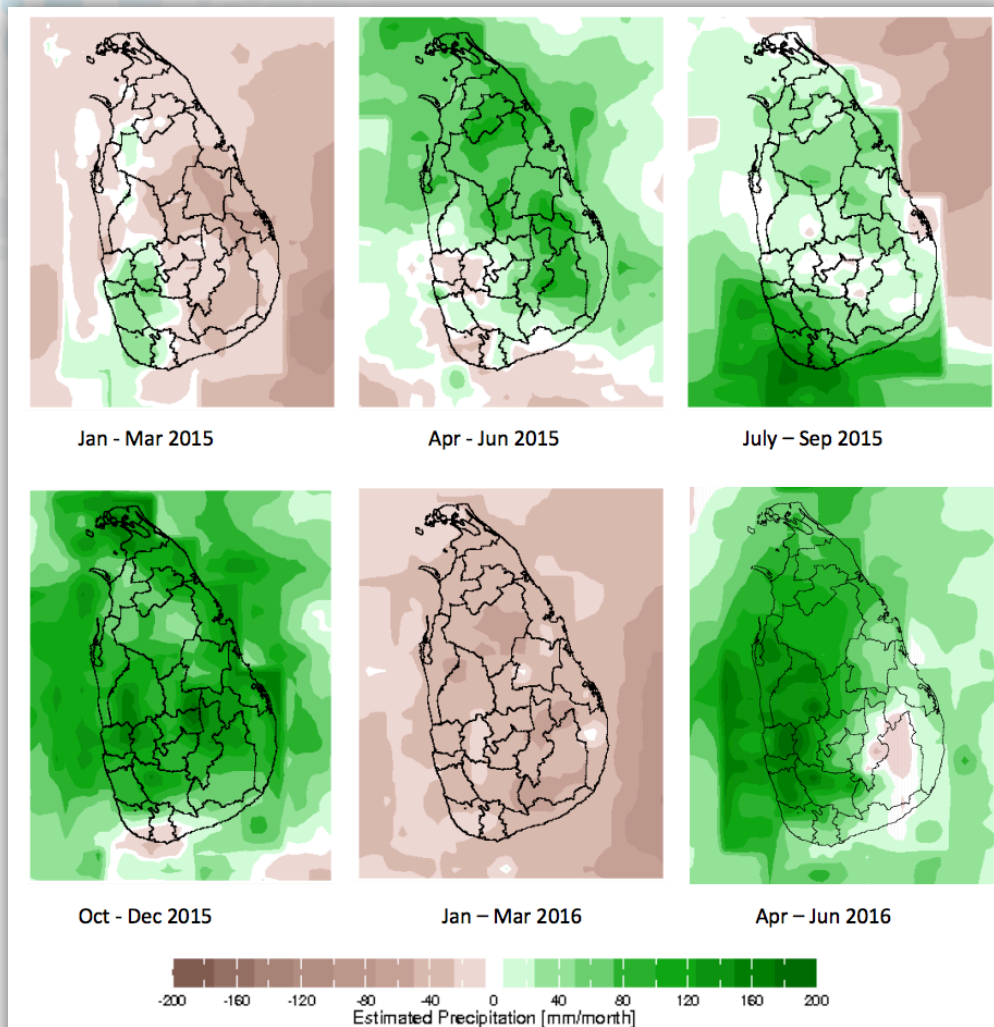


Figure 3: Quarterly seasonal precipitation anomalies for Sri Lanka for 2015 to Mid-2016. Top Row - Rainfall departures from historical averages (anomalies) for January-March (late Maha), April-June (early Yala), July-September (late Yala) for 2015. Bottom Row - October-December 2015 (early Maha), and January-March (late Maha), April-June (early Yala) for 2016. The historical average rainfall was calculated for January 2001-2016. (Image source: FECT).

As expected,

2015:

late southwest-monsoon ☐

Second inter-monsoon (OND) ☐

2015-16:

Late northeast-monsoon (JFM) ⬇️

2016:

Early southwest-monsoon ☐

2015-16 Drought in Southeast Asia

10,302 views | May 25, 2016, 01:39am

Why Vietnam Is Running Dry, Worst Drought In Nearly 100 Years



Tim Daiss Contributor
Oil markets analyst, journalist and author based in Southeast Asia

TWEET THIS

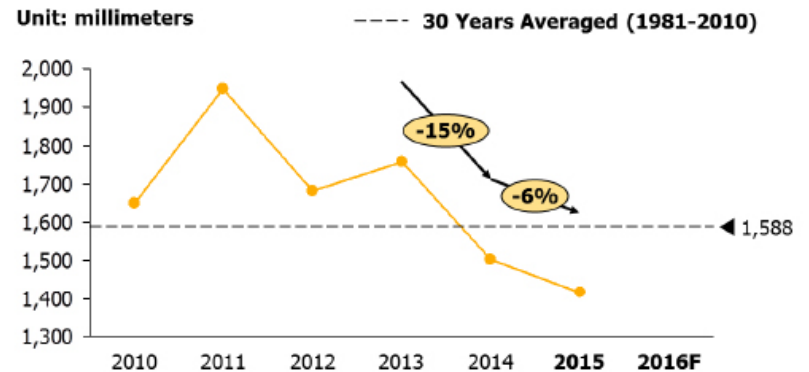
Vietnam's Mekong Delta is suffering from its worst drought in nearly a century, and the effects have been devastating.

this year's drought could also lead to a serious reduction in exports of major goods produced in the region, including rice, seafood, and coffee.



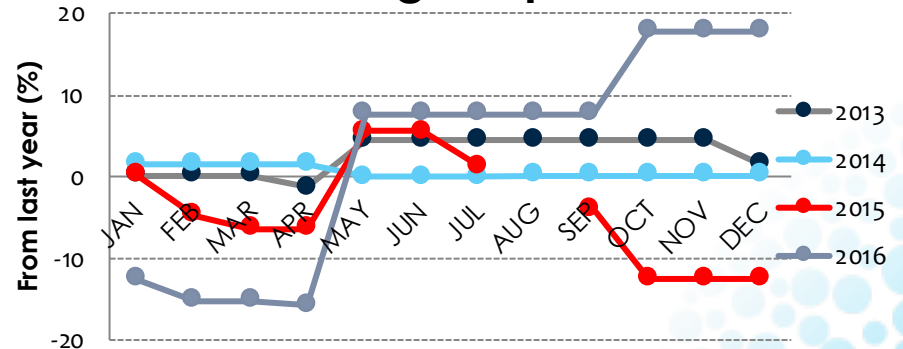
<https://www.forbes.com/sites/timdaiss/2016/05/25/why-vietnam-is-running-dry-worst-drought-in-nearly-100-years/#35d4df0874b3>

Figure 1: Cumulated rainfall in Thailand between 2010 and 2015



Source: EIC analysis based on data from Water Watch and Monitoring System, Royal Irrigation Department.

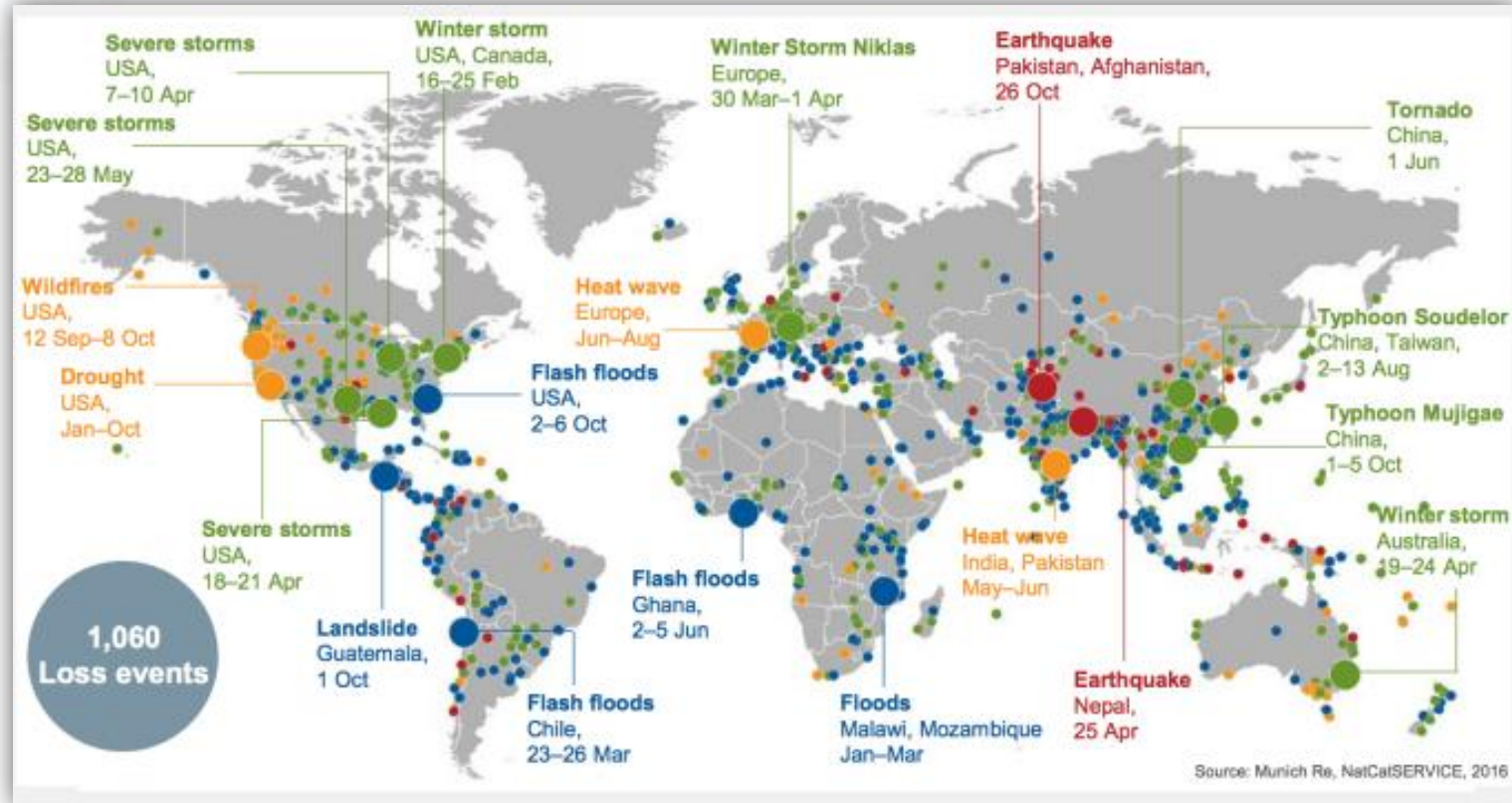
Rice: Change in production



Source: USDA World Agricultural Production

What happen in Chile during 15-16 prolonged El Nino?

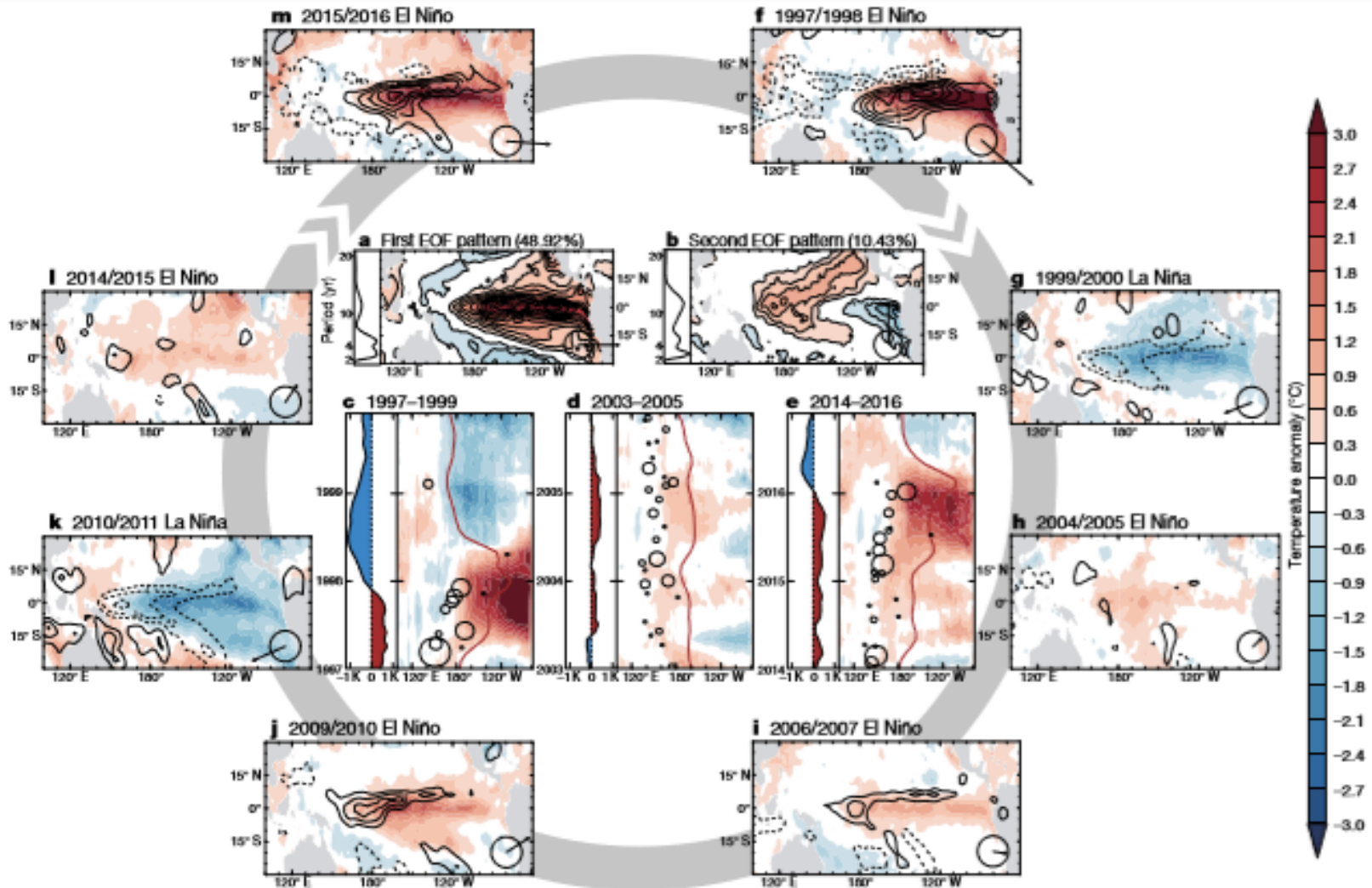
Munich-Re: El Niño curbs losses from natural catastrophes in 2015



- Heavy rainfall during march!

ENSO Complexity

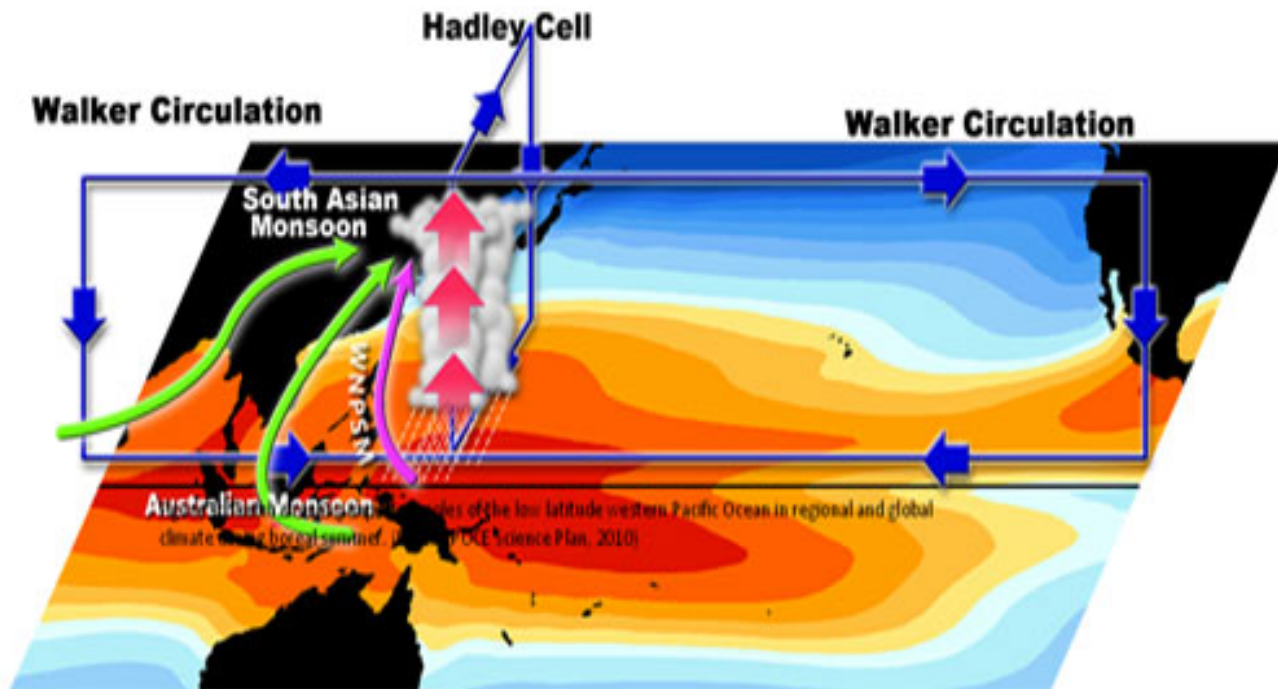
In Time & Space - Any distinct regional impacts of different type of ENSO?



Timmermann, A., An, S. I., Kug, J. S., Jin, F. F., Cai, W., Capotondi, A., ... & Stein, K. (2018). El Niño–Southern Oscillation complexity. *Nature*, 559(7715), 535.

Western Pacific Warm Pool (WPWP)

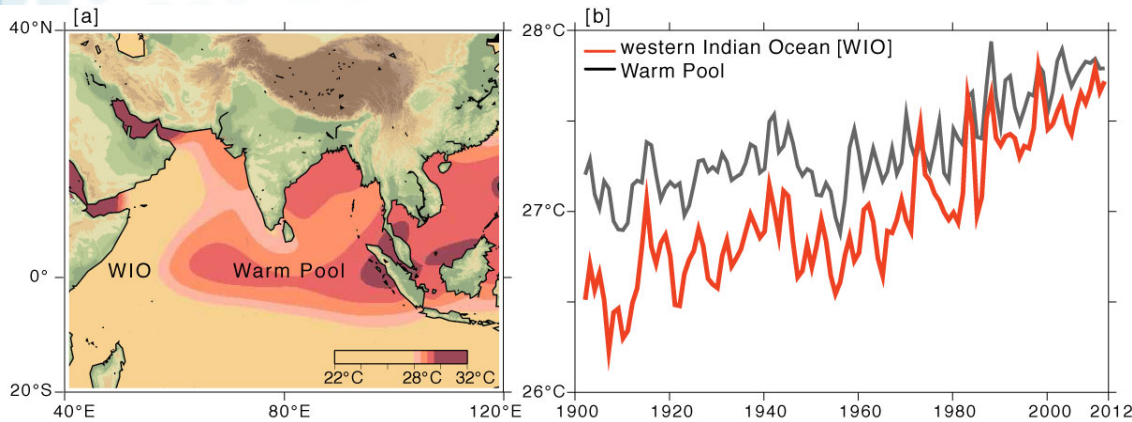
- Climate Engine : remember “mean” feature



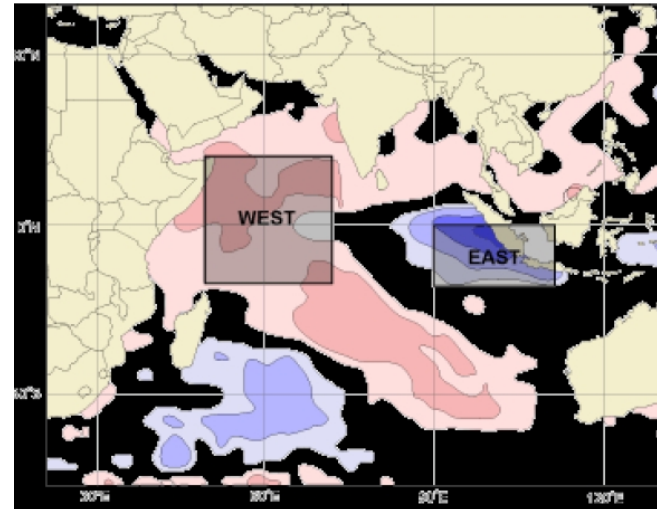
<http://npoc.e.qdio.ac.cn/background>

Don't forget Indian Ocean

Indian Ocean Dipole



Source: <http://www.climate.rocksea.org/research/indian-ocean-warming/>

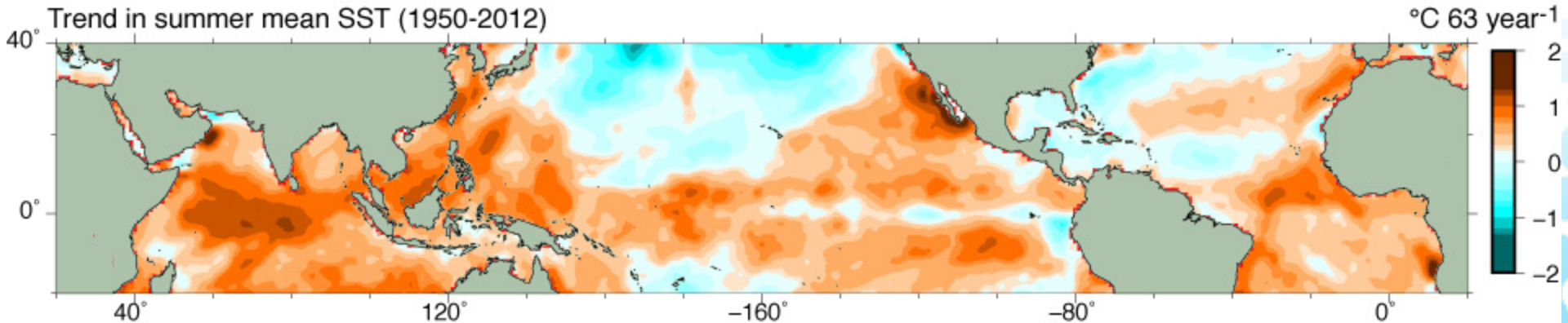


<http://devconsultancygroup.blogspot.kr/2010/08/la-nina-disasters-much-worst-probably.html>

Indian Ocean Basin Mode

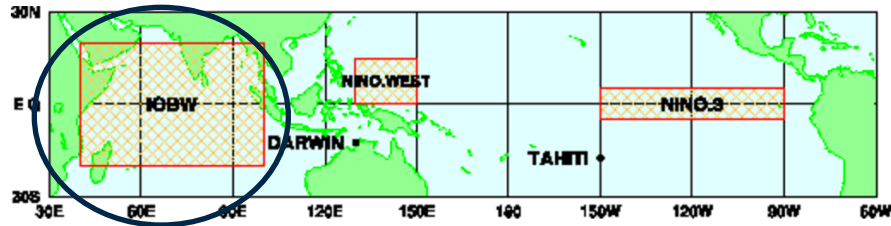
Long-term drying of Sahel?

Trend in summer mean SST (1950-2012)

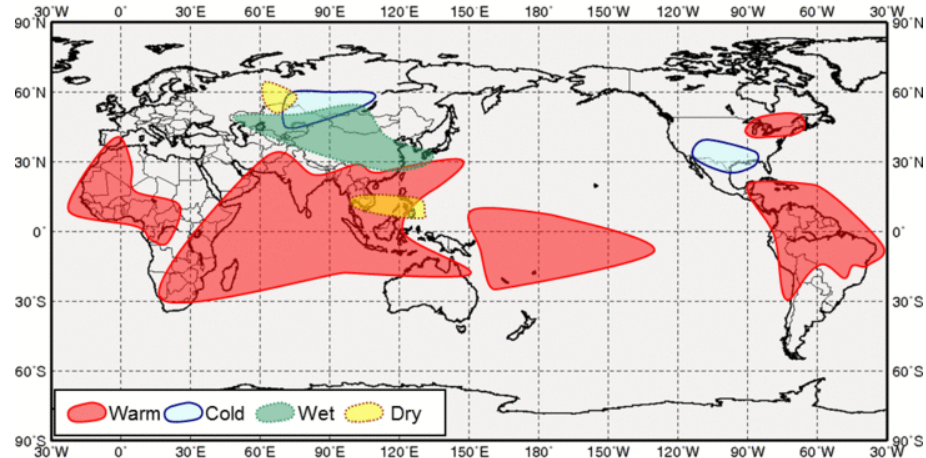


Indian Ocean Basin-wide Mode (IOBM)

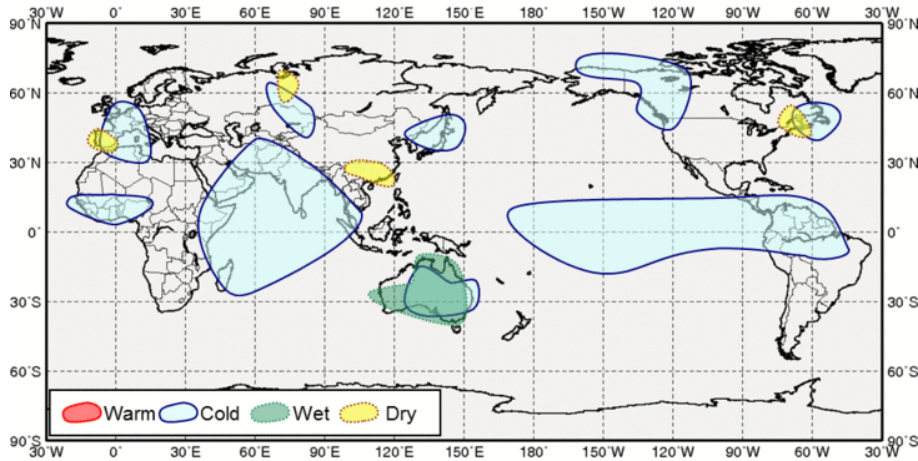
Positive IOBW, MAM



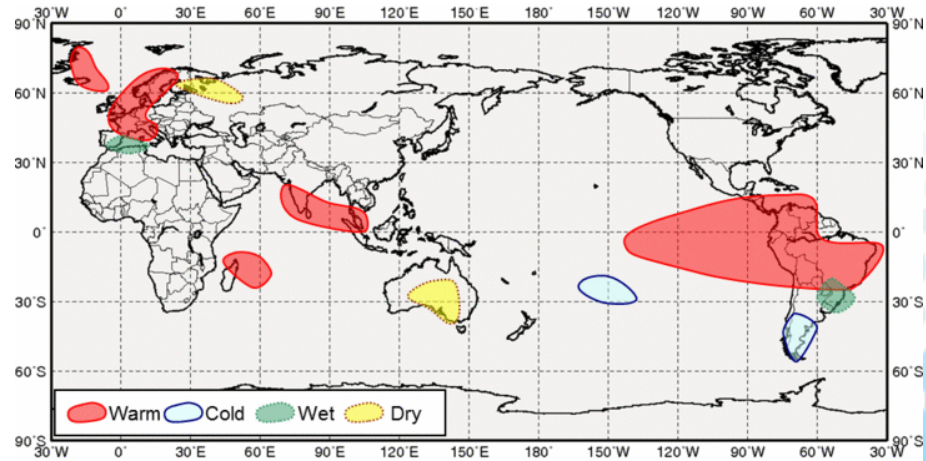
Source: TCC, JMA



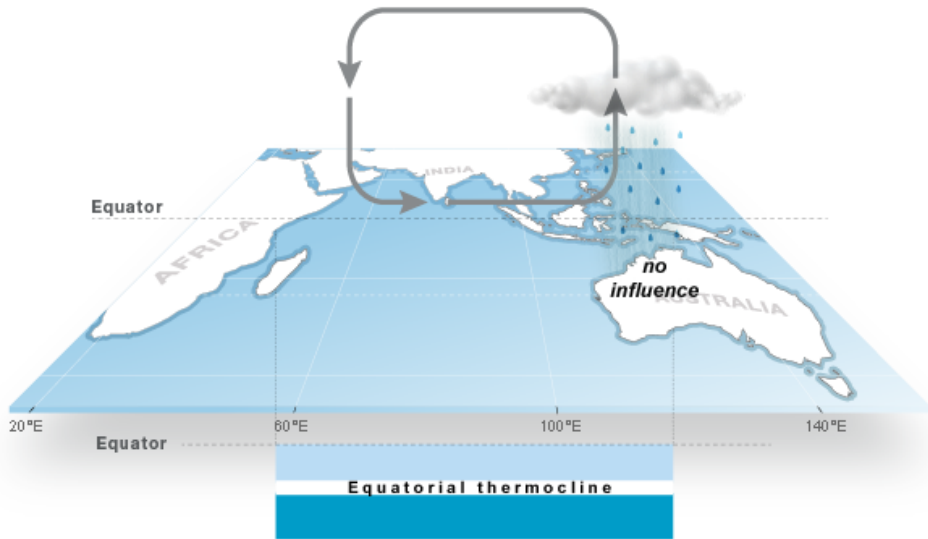
Negative IOBW, SON



Positive IOBW, SON

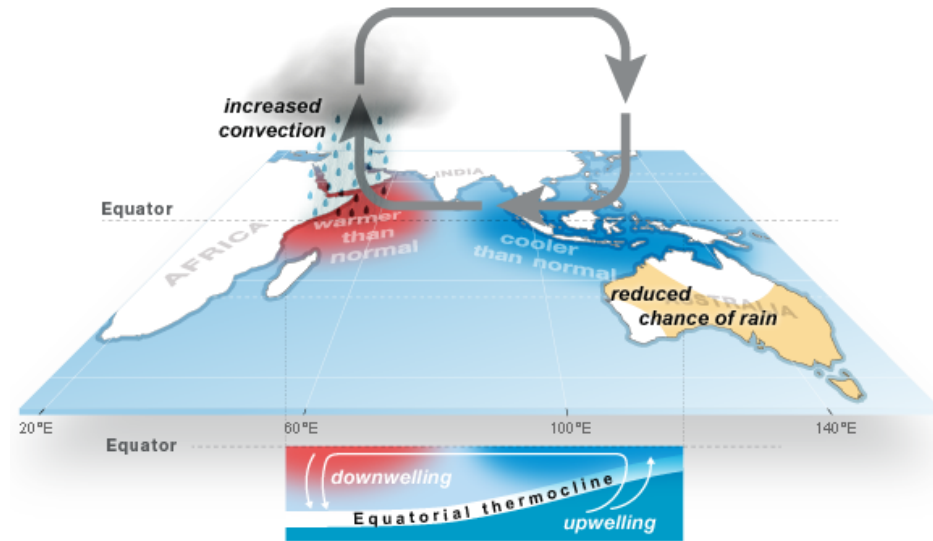


Indian Ocean Dipole (IOD)



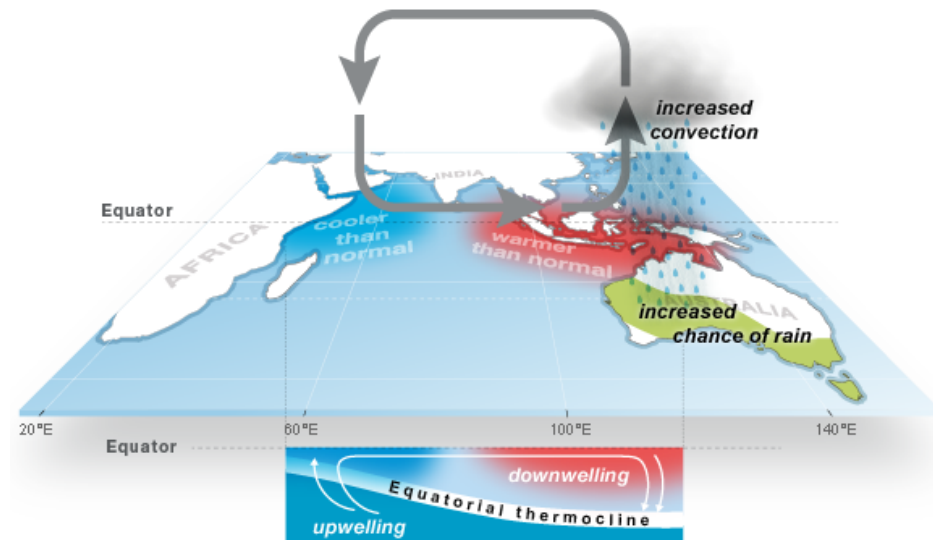
Indian Ocean Dipole (IOD): **Neutral phase**

© Commonwealth of Australia 2013.



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

© Commonwealth of Australia 2013.

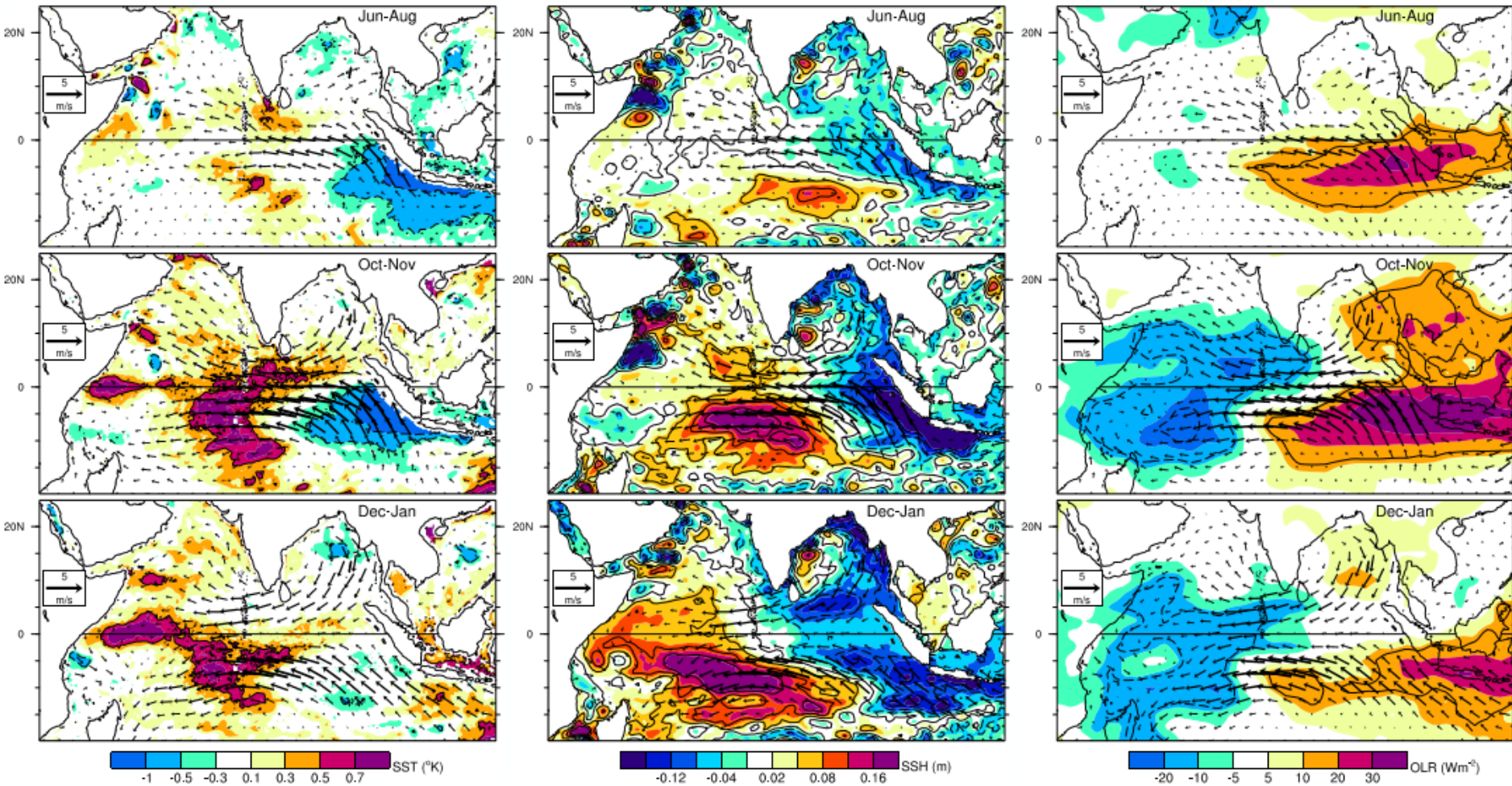


Indian Ocean Dipole (IOD): **Negative phase**

© Commonwealth of Australia 2013.

Evolution of Positive IOD

By Saji N Hameed

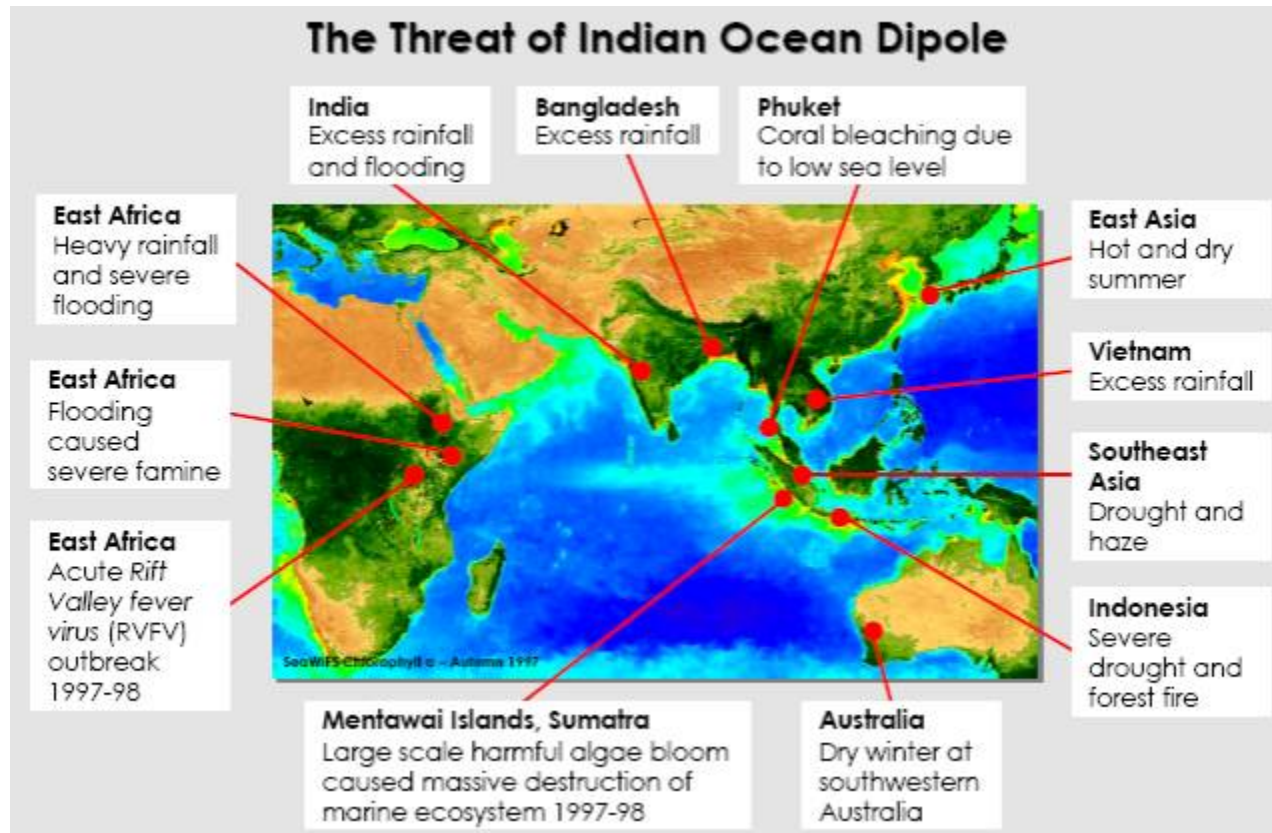


(a) SST

(b) SSH

(c) OLR

Indian Ocean Dipole (IOD)

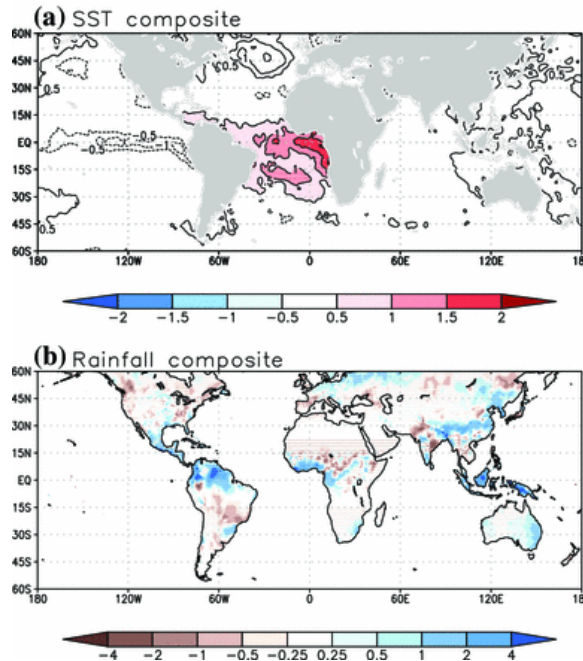
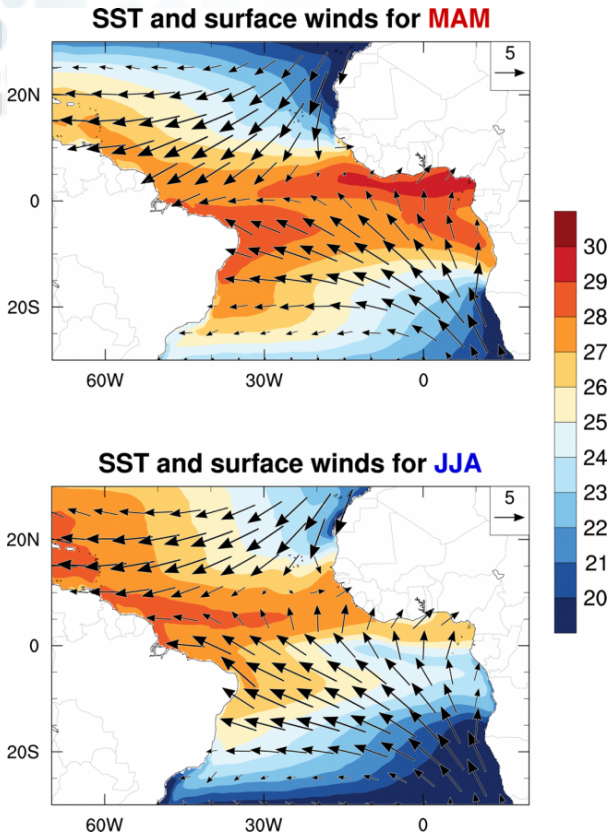


How about Atlantic Ocean?

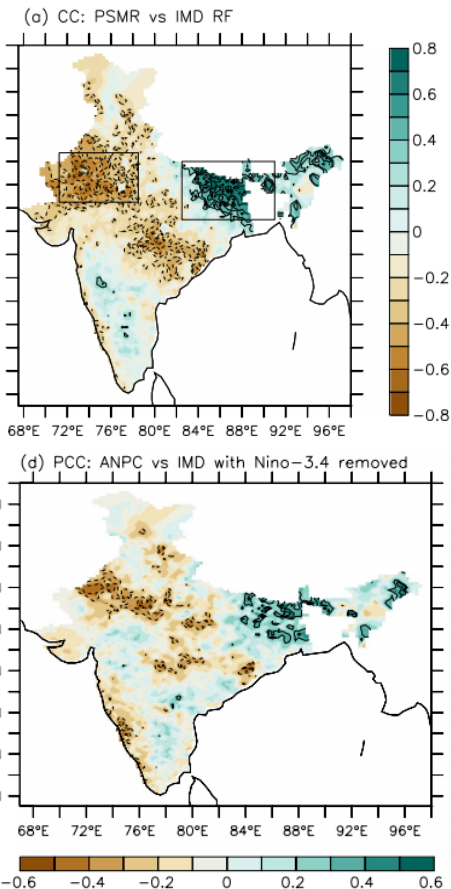
Atlantic Nino

(Atlantic equatorial mode)
STA, NTA ...

Africa, northern Latin America



Modulation of Indian summer monsoon



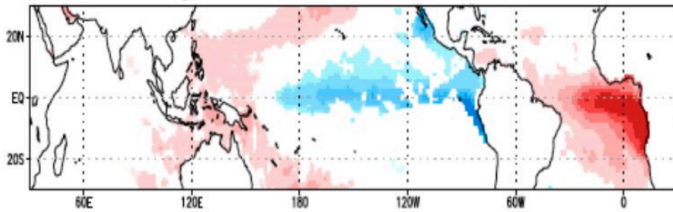
Mohino, E. & Losada, T. *Clim Dyn* (2015) 45: 225. <https://doi.org/10.1007/s00382-015-2471->

Yadav, R. K. et al. (2018)

http://www.jamstec.go.jp/aplinfo/client/mate/?page_id=1566

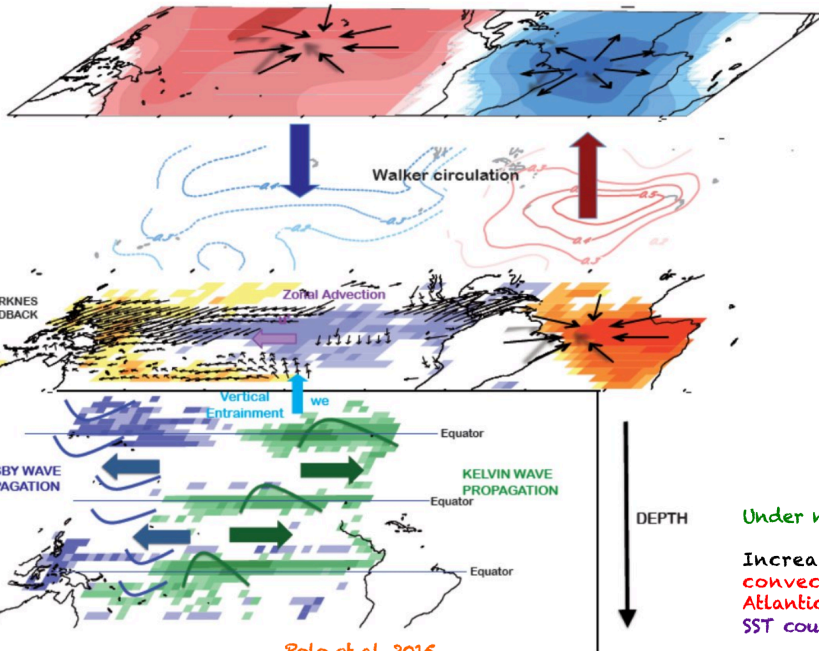
Atlantic-Pacific Niños connection

Atlantic-Pacific Niños connection



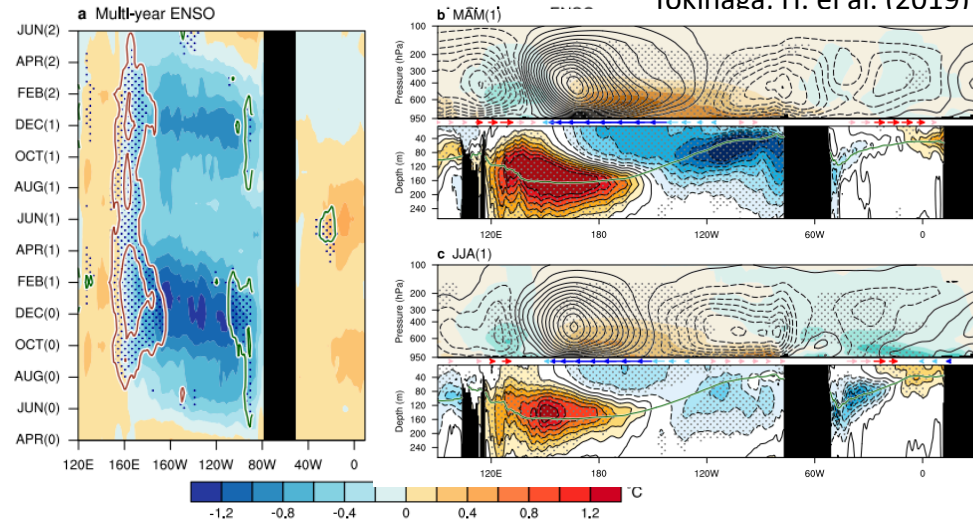
Rodríguez-Fonseca et al. 2009; Keenlyside and Latif 2007; Polo et al 2008; Ding et al. 2012

Through an air-sea coupled mechanism



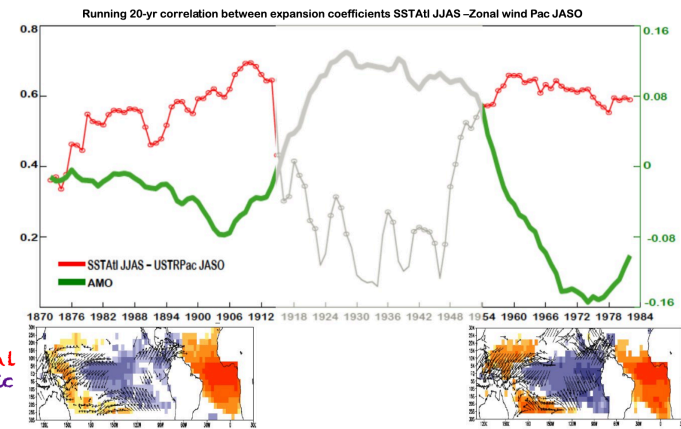
Polo et al. 2015

Multi-year Pacific ENSO



Tokinaga. H. et al. (2019)

At multidecadal time scales coinciding with negative AMO



AMO

Under negative AMO:

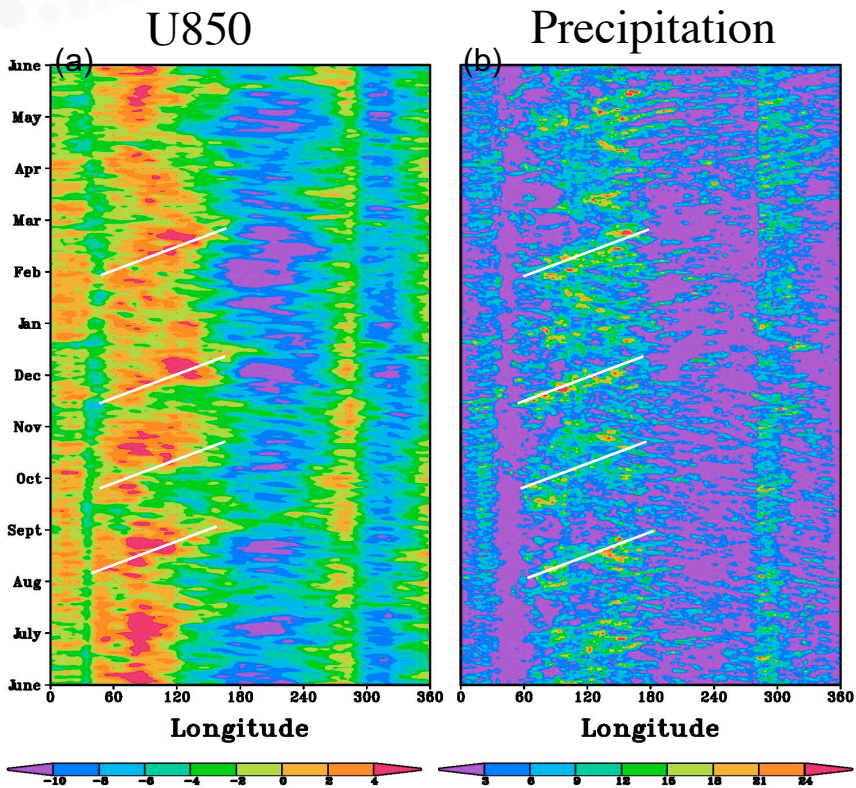
Increased variability in atmospheric convection over western equatorial Atlantic and eastern equatorial Pacific SST could favour the Atl-Pac link

Martín-Rey, Marta & Polo, Irene & Rodríguez-Fonseca, Maria Belen & Losada, Teresa & Lazar, Alban. (2016). On the configurations of the Atlantic Niño phenomena under negative AMO phases.

Martín-Rey et al. 2014

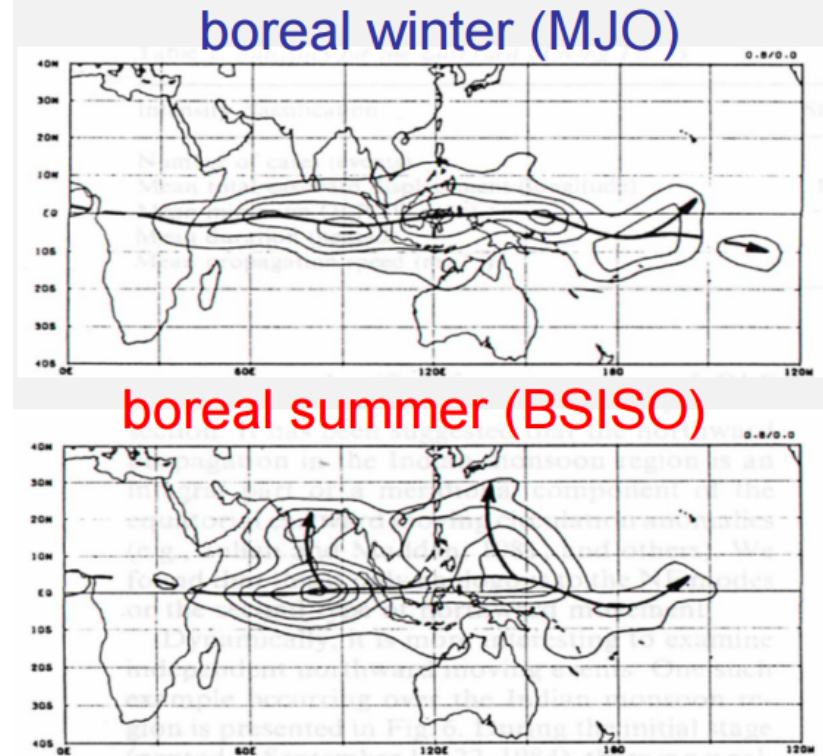
Intra-Seasonal Oscillation (ISO)

Intraseasonal : 20-90



By Ji-Hyun Oh

Northward & Eastward propagation

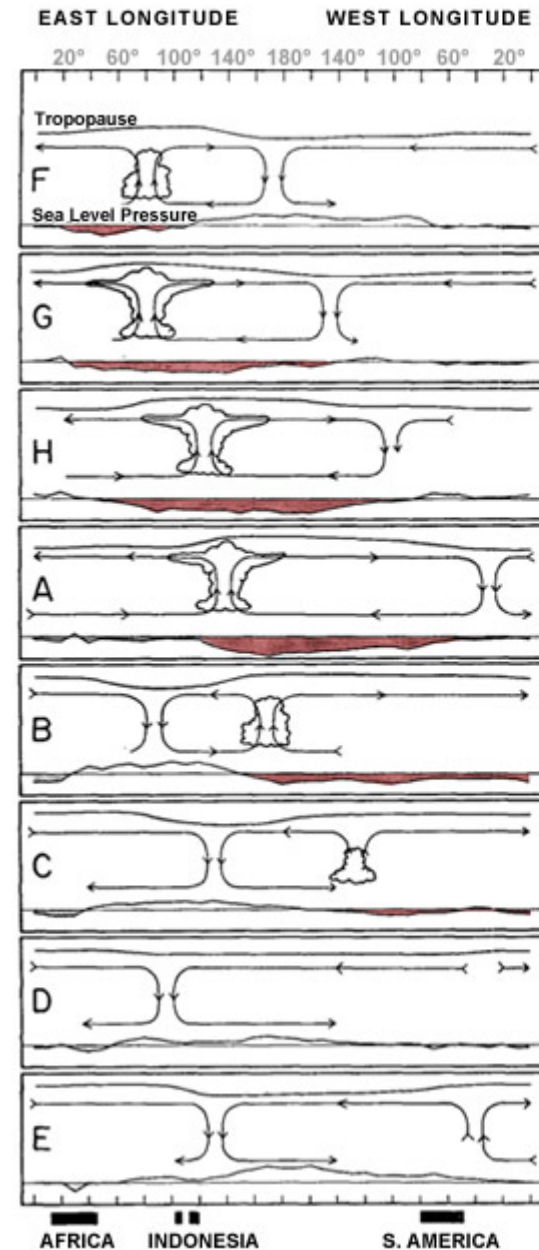


Wang and Rui 1990

Madden Julian Oscillation

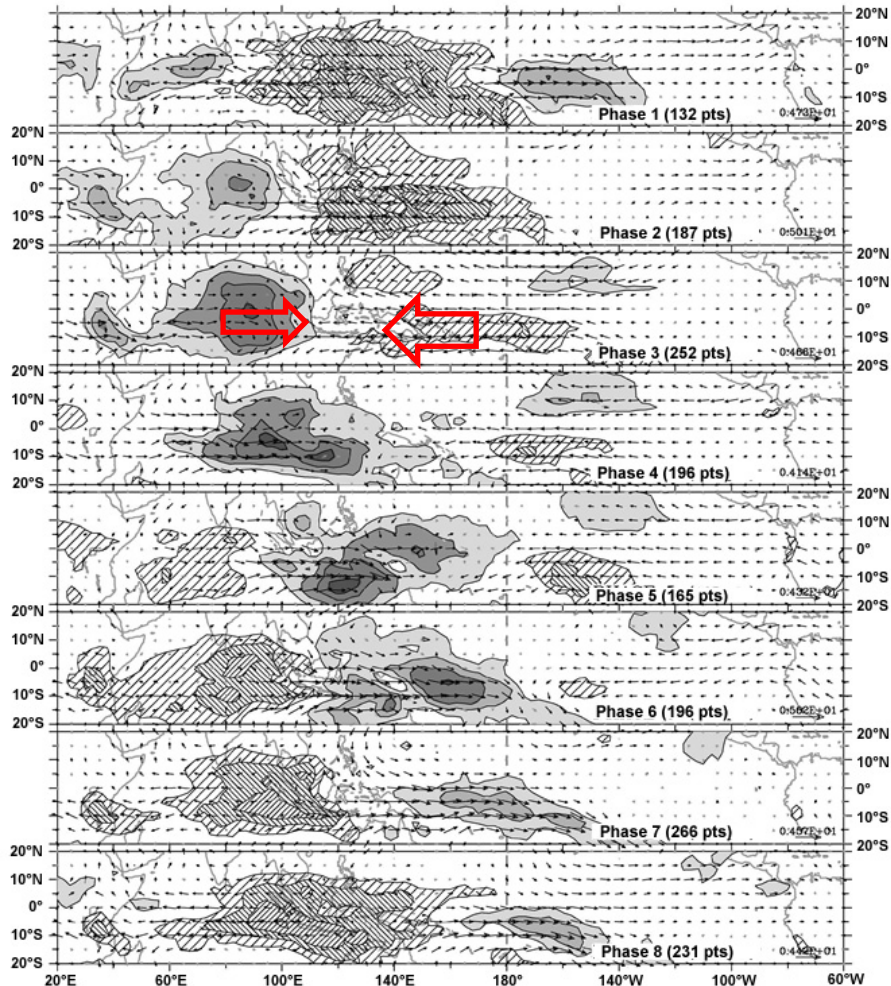
Intraseasonal Oscillation (ISO)
during **boreal winter**

Intraseasonal: 20-90



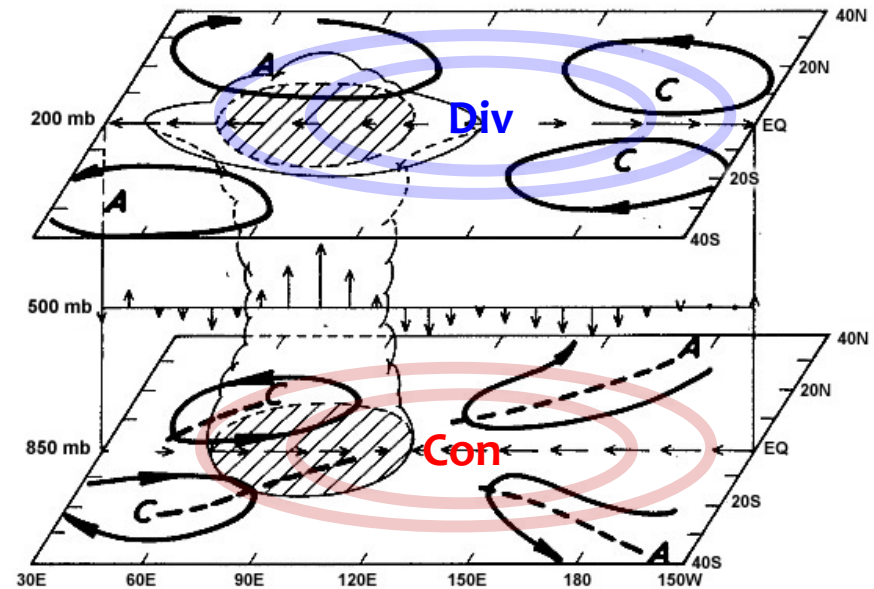
MJO (Madden Julian Oscillation)

Boreal Winter (DJF) Composite OLR and 850 hPa Vector Wind Anomalies



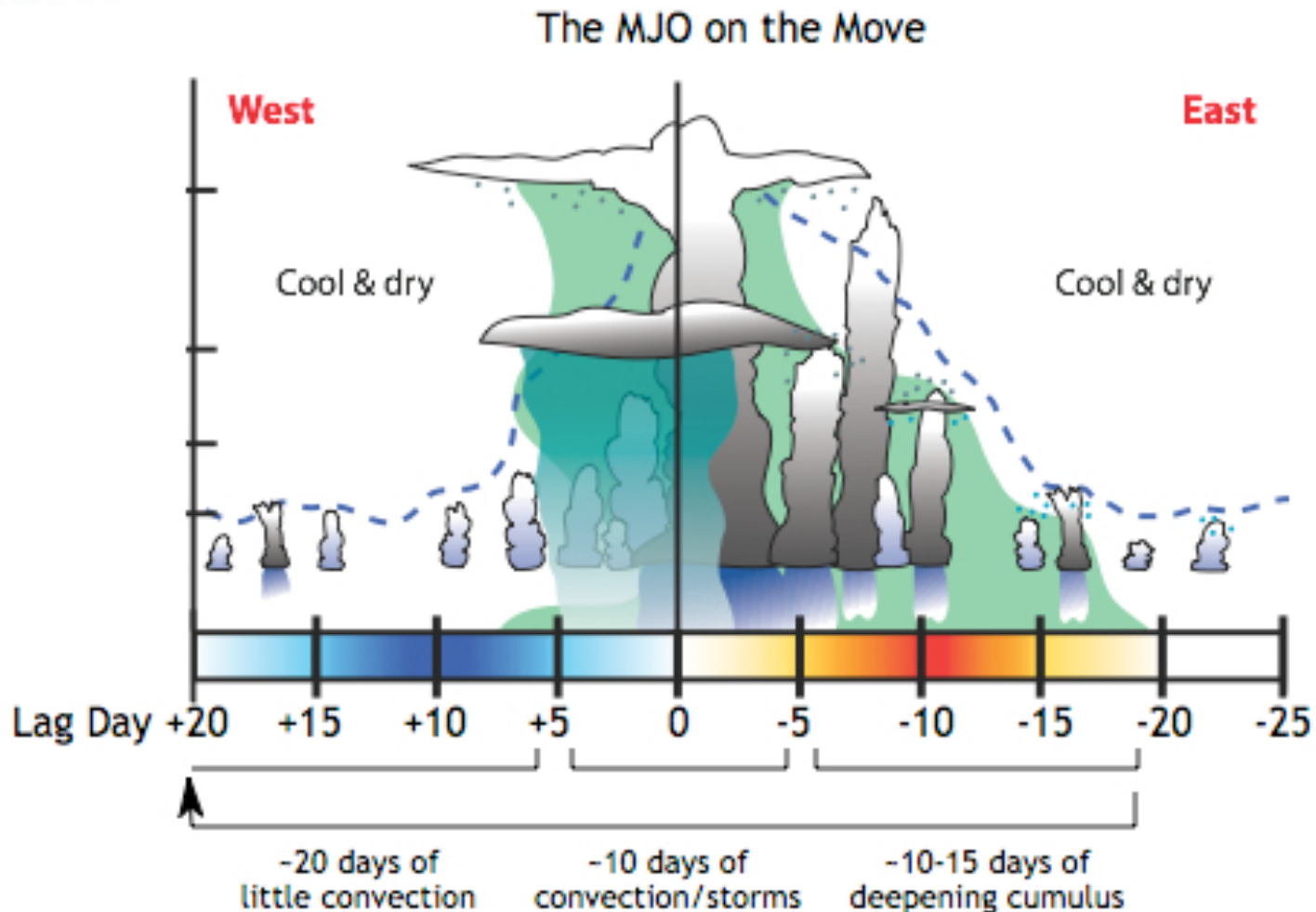
Wheeler and Hendon 2004

Schematic Depiction of the Large-scale Wind Structure of the MJO



Rui and Wang 1990

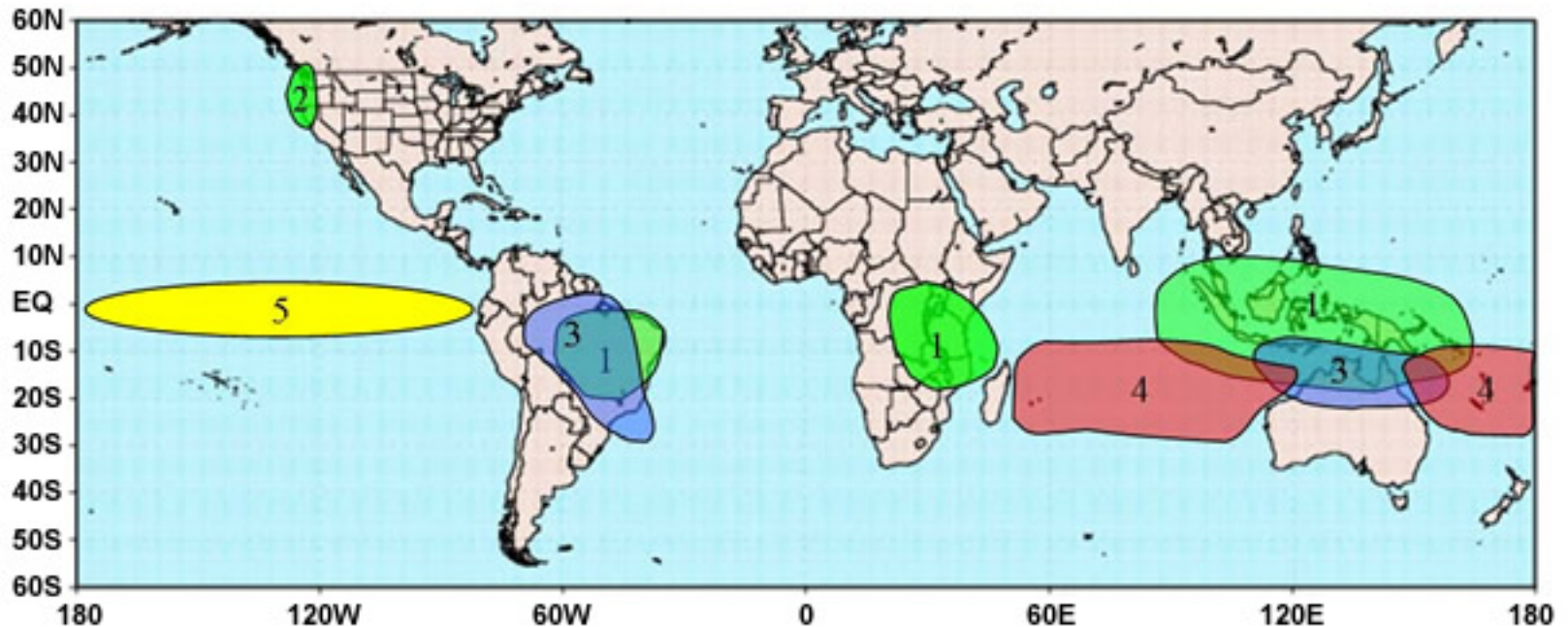
MJO (Madden Julian Oscillation)



A schematic of the MJO from cmmmap.org

MJO impacts

MJO Impacts during Boreal Winter



- 1 - Alternating wet/dry conditions
- 2 - Tropical moisture plume to higher latitudes
- 3 - Modulation of monsoon systems
- 4 - Modulation of tropical cyclone activity
- 5 - Modulation of ENSO through oceanic Kelvin waves

BSISO (Boreal Summer ISO)

Intraseasonal Oscillation ISO
during **boreal summer**

BSISO1

BSISO2

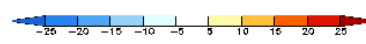
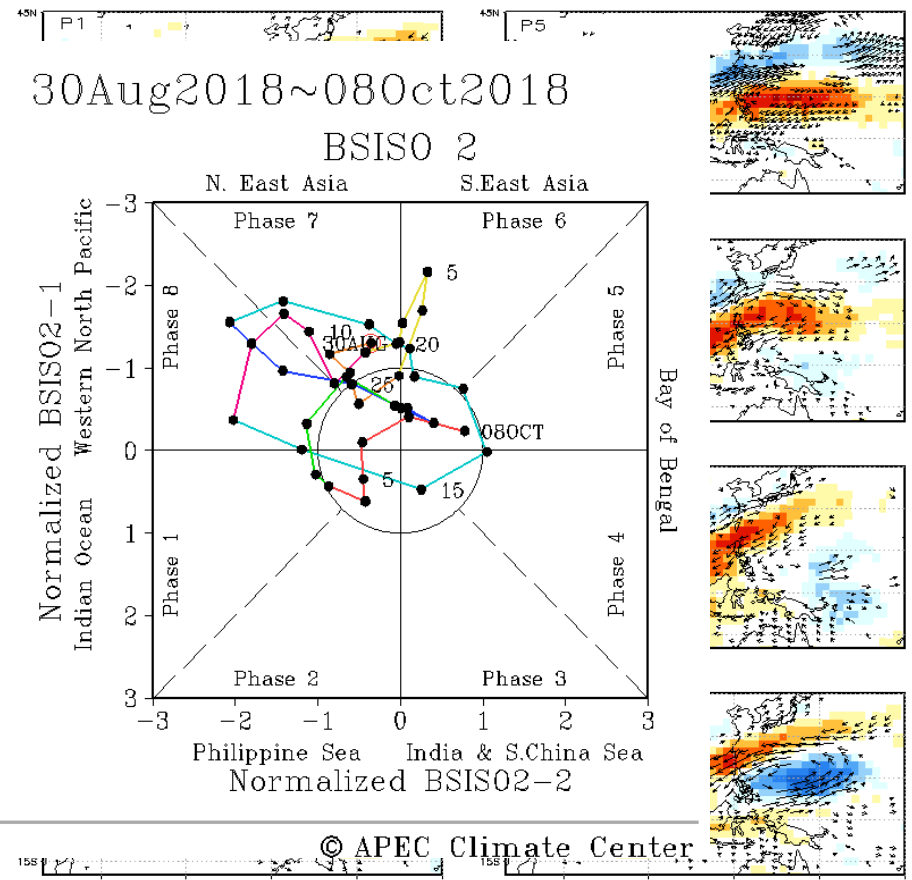
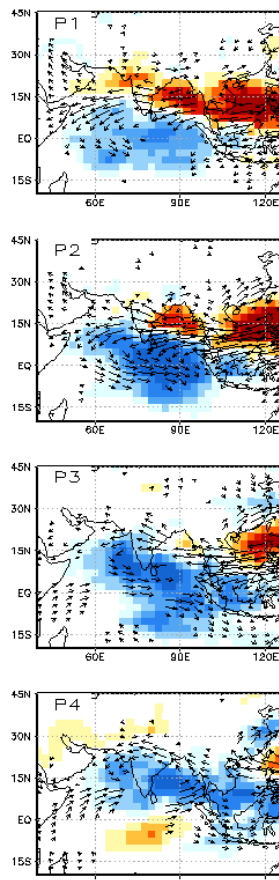
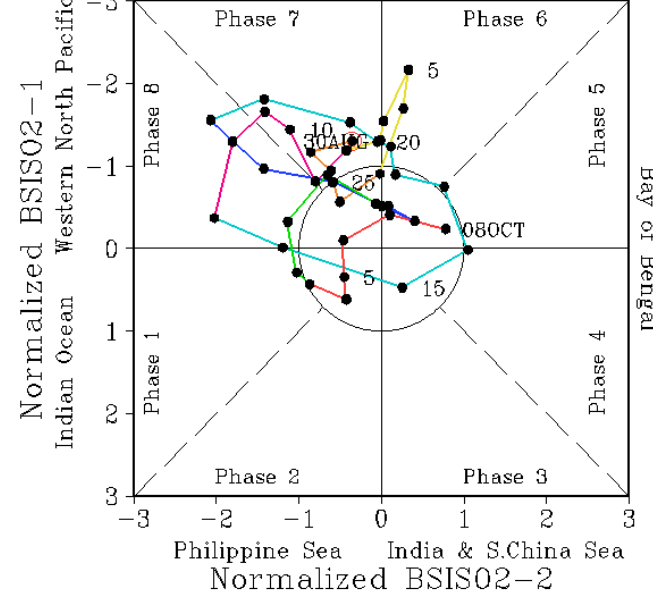
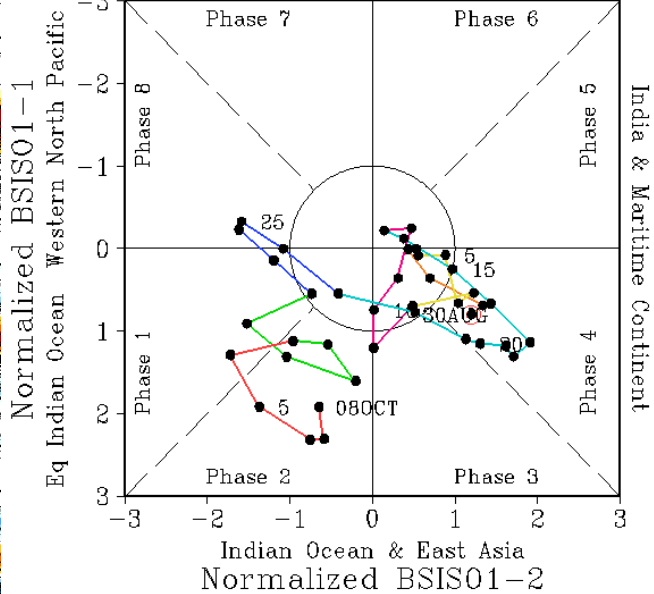
BSISO Monitoring for 30Aug2018~08Oct2018

BSISO 1

BSISO 2

Bay of Bengal & South China Sea

N. East Asia S.East Asia



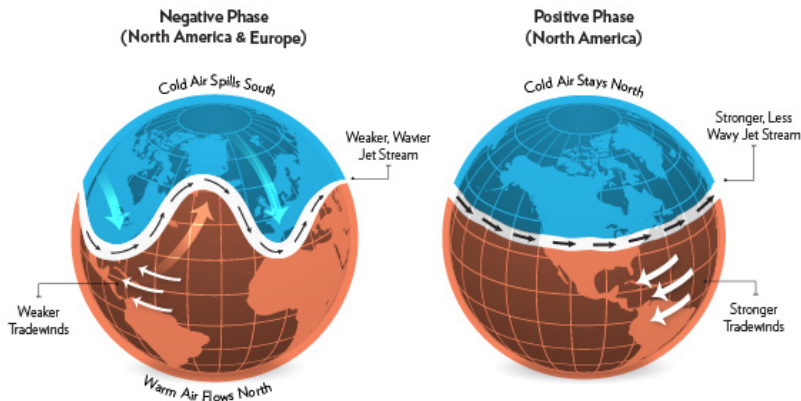
© APEC Climate Center

Source: APCC

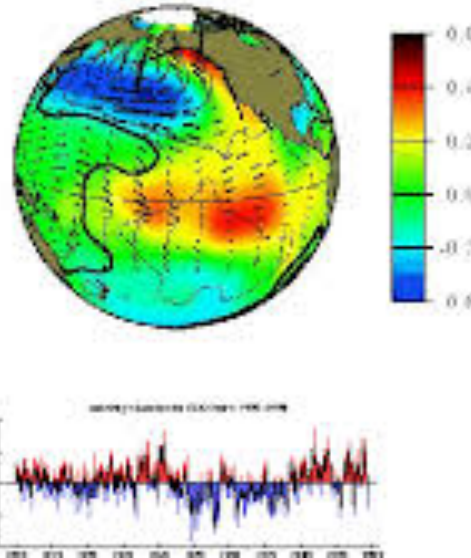
2 weeks to multi-decadal climate variability



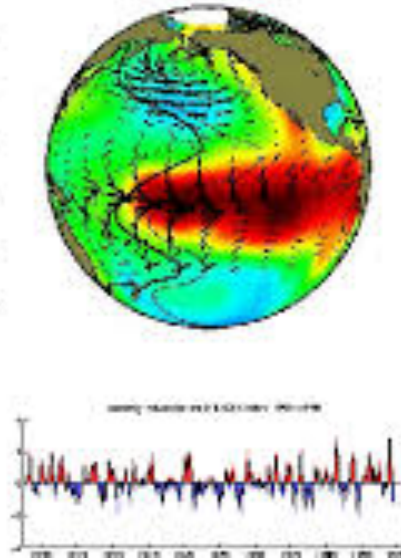
Arctic Oscillation (AO)



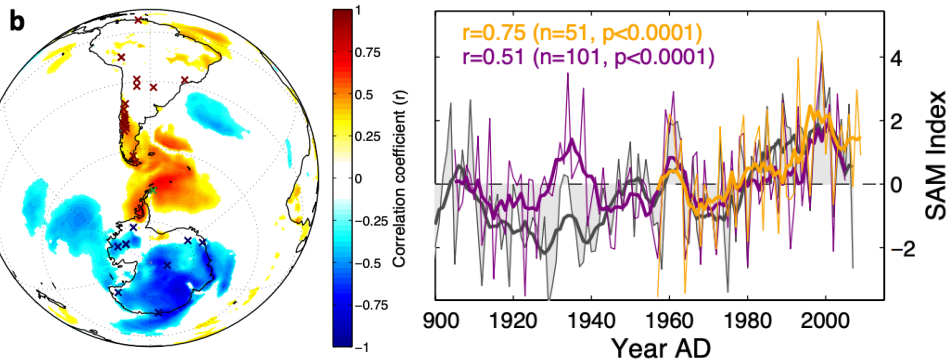
Pacific Decadal Oscillation



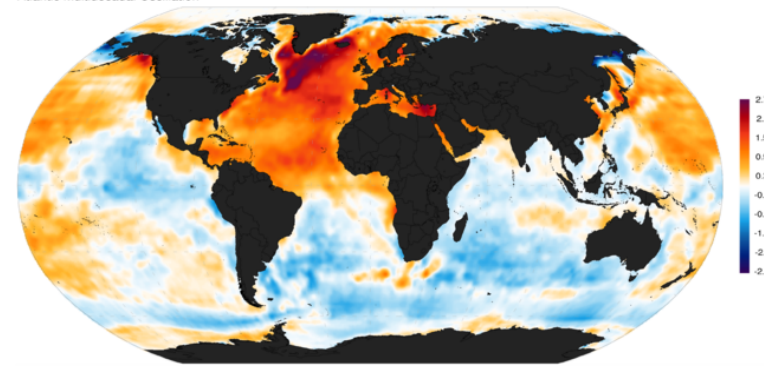
El Niño/Southern Oscillation



Abram, Nerilie J., et al. "Evolution of the Southern Annular Mode during the past millennium." *Nature Climate Change* 4.7 (2014): 564.



Atlantic Multidecadal Oscillation

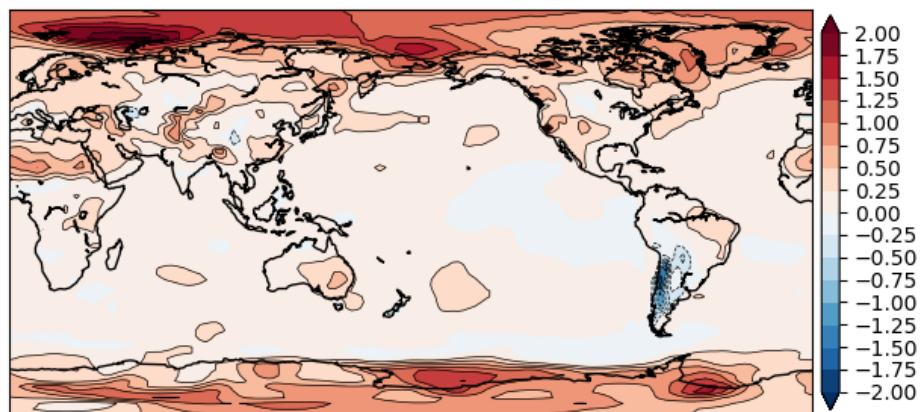


Global warming?

Climate variability can change?

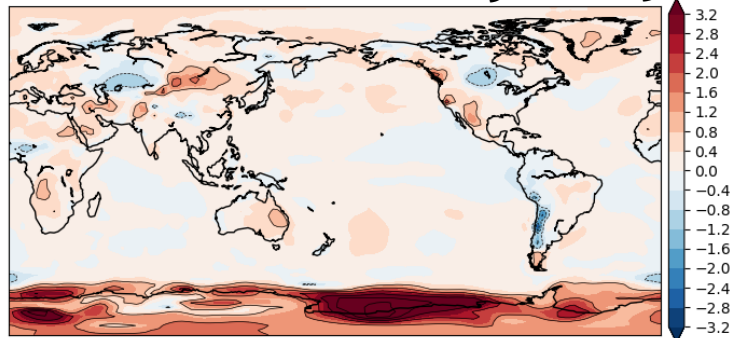
OBS

1981-2010



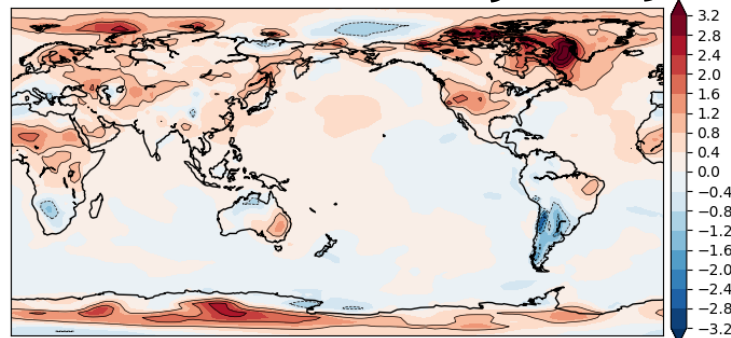
JJA:OBS

1981-2005

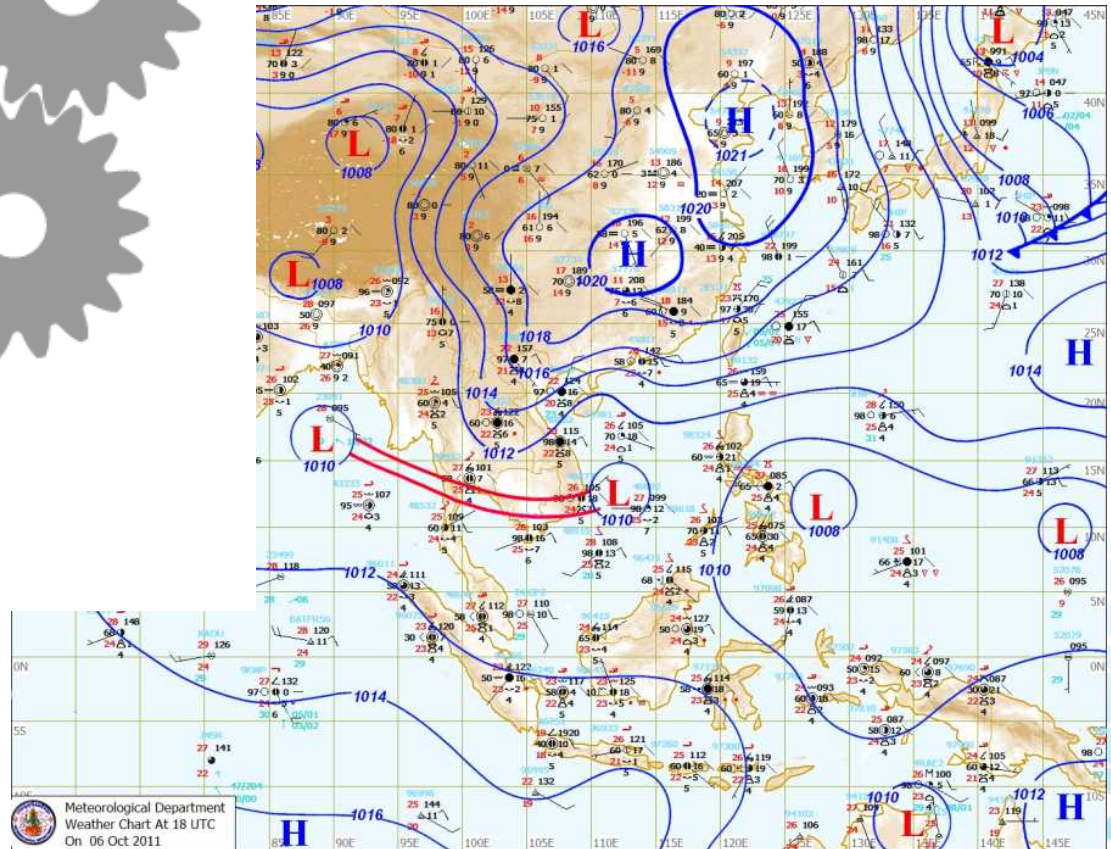
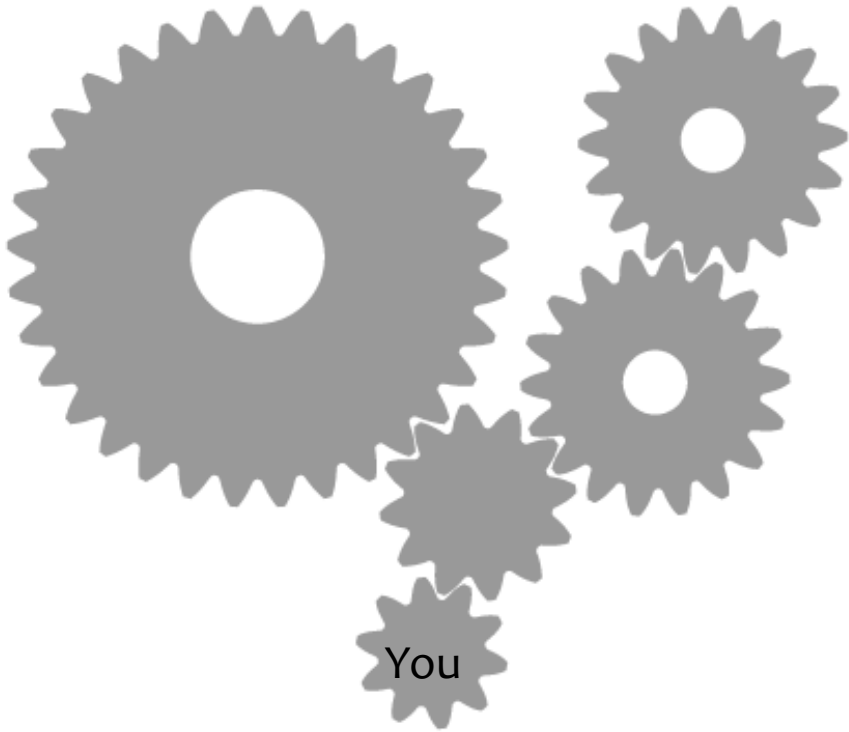


DJF:OBS

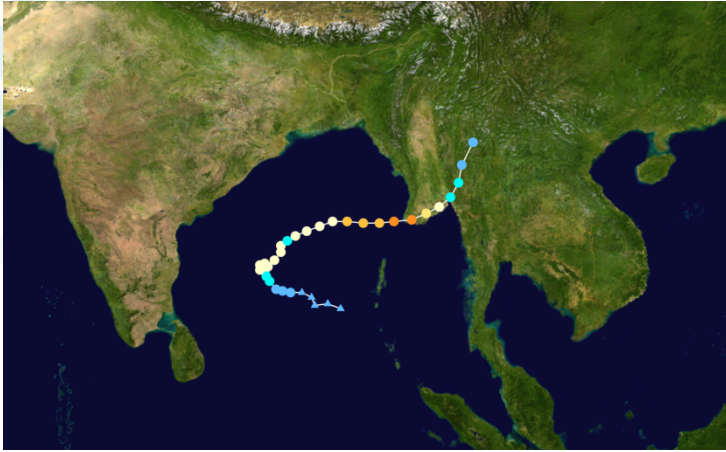
1981-2005



How they change weather?



Extreme rainfall (flood)

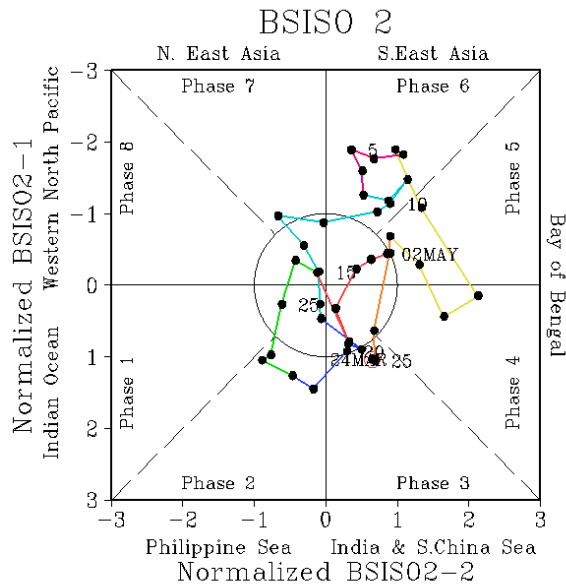


- Tragic Myanmar flood associated with Cyclone Nargis (early May 2008)!

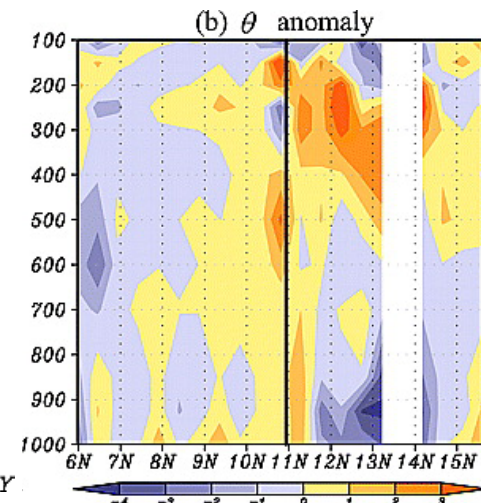
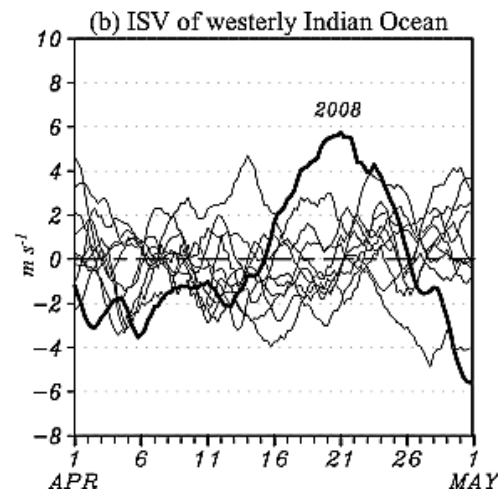
https://en.wikipedia.org/wiki/Cyclone_Nargis

- ✓ Northward movement of **MJO convection**

Kikuchi, K., B. Wang, and H. Fudeyasu (2009), Genesis of tropical cyclone Nargis revealed by multiple satellite observations, *Geophys. Res. Lett.*, 36, L06811, doi:[10.1029/2009GL037296](https://doi.org/10.1029/2009GL037296).



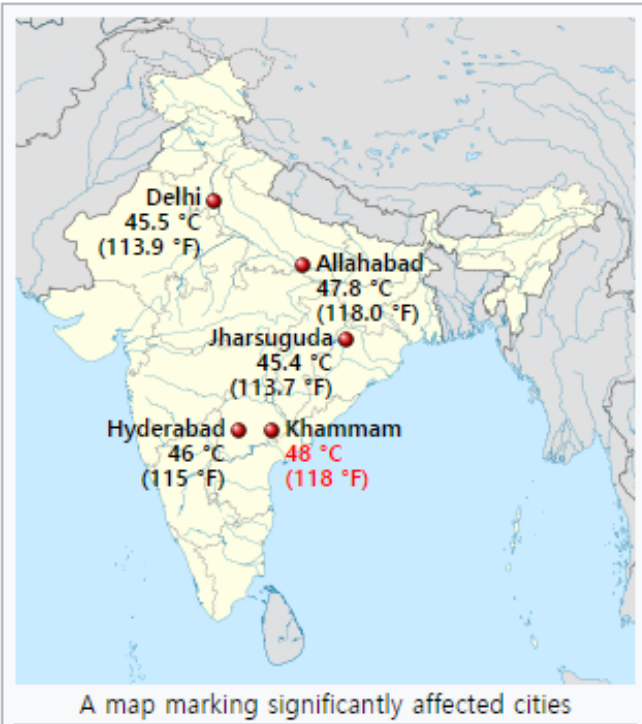
Source: APCC BSISO monitoring



Heat waves

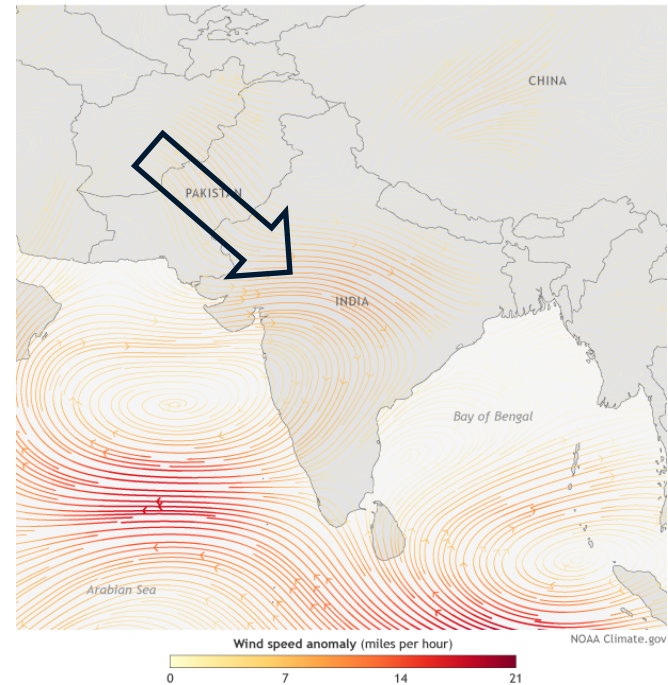
- 2015 India heat wave

2015 Indian heatwave



-“Heat Bomb” : unusual northwesterlies → sparse showers and their sudden end during pre-monsoon season (before June)

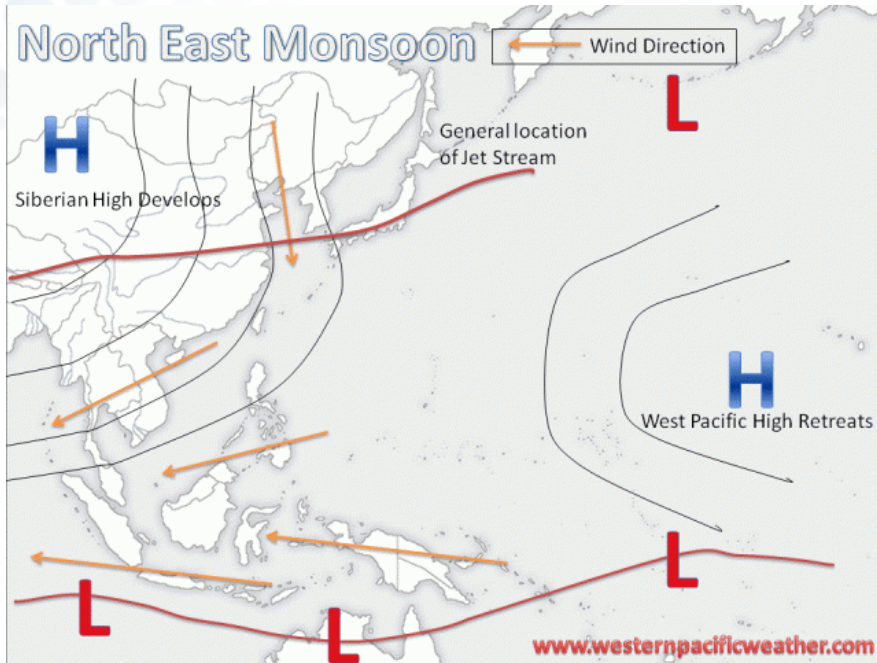
Wind anomaly (May 20–30, 2015)



- El Nino effect?

Cold surge

- Outbreak of Siberian cold air



The Extreme Cold Anomaly over Southeast Asia in February 2008: Roles of ISO and ENSO*

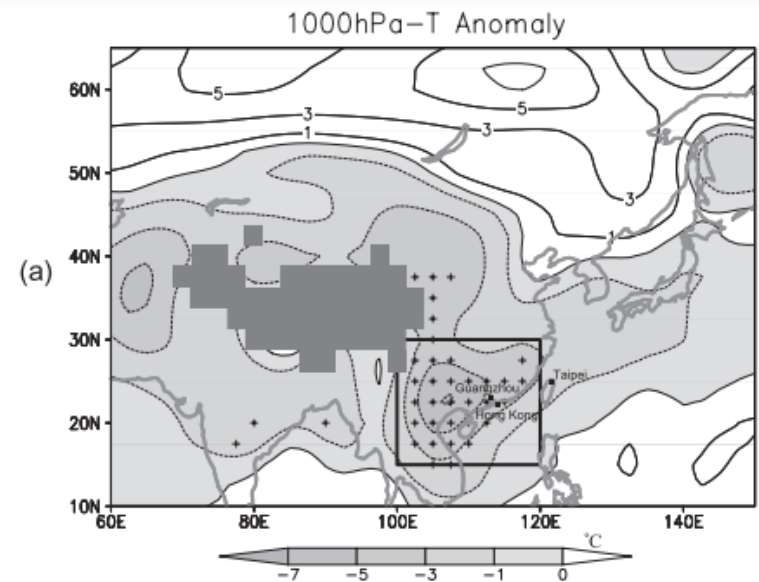
CHI-CHERNG HONG

Department of Science, Taipei Municipal University of Education, Taipei, Taiwan

TIM LI

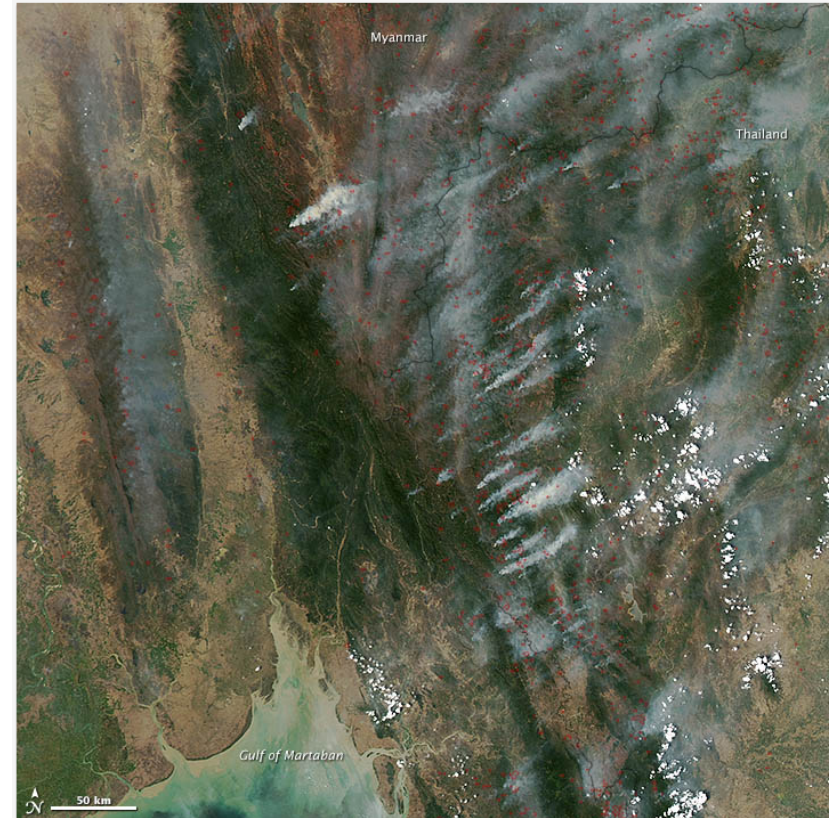
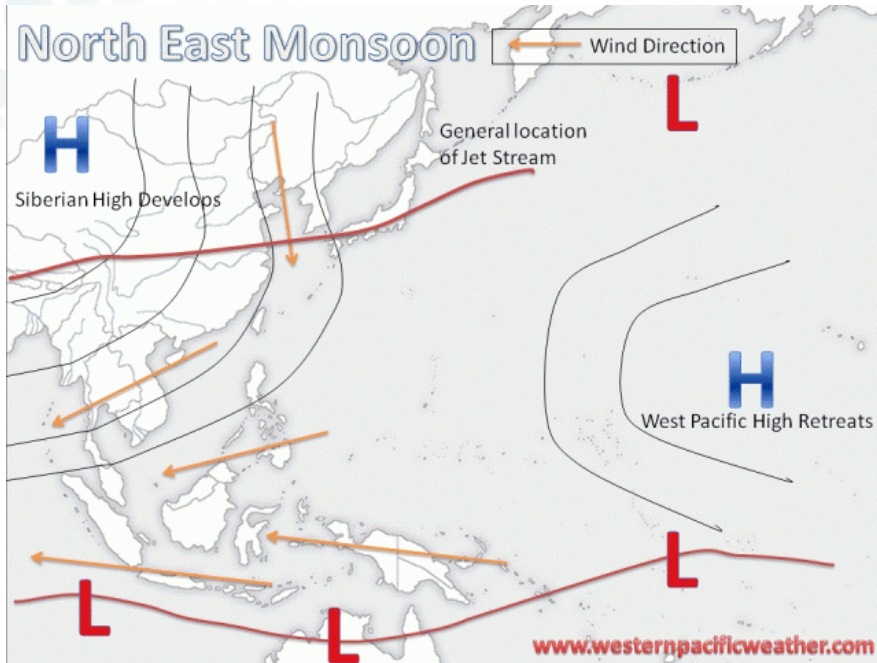
*International Pacific Research Center/School of Ocean and Earth Science and Technology,
University of Hawaii at Manoa, Honolulu, Hawaii*

(Manuscript received 30 September 2008, in final form 12 January 2009)



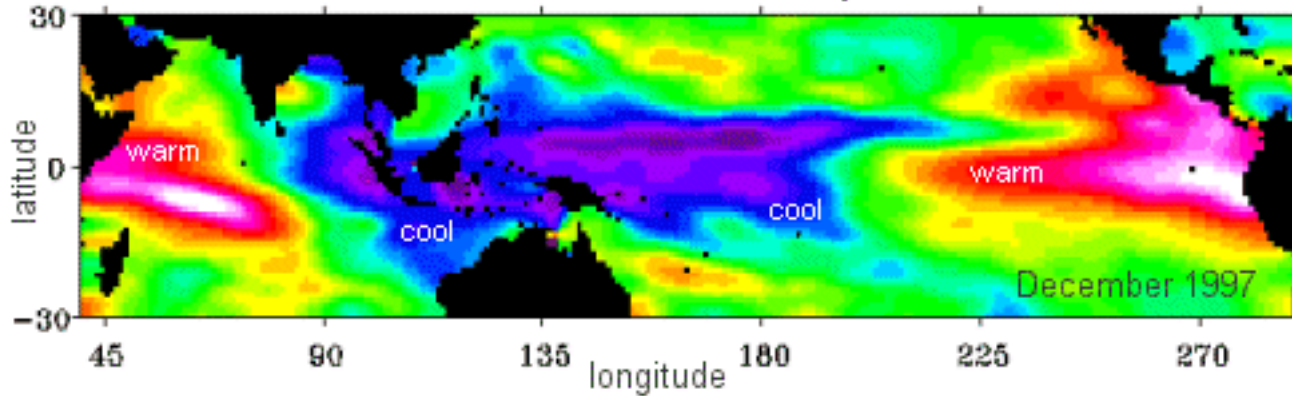
Dry spell (wildfire)

- Outbreak of Siberian dry air + dry monsoon (Nov-Mar)

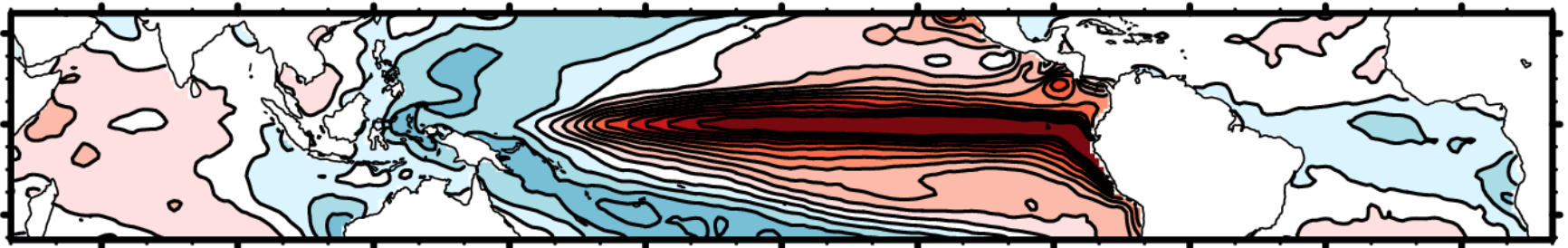


ENSO + IOD + (Atl. ENSO)?

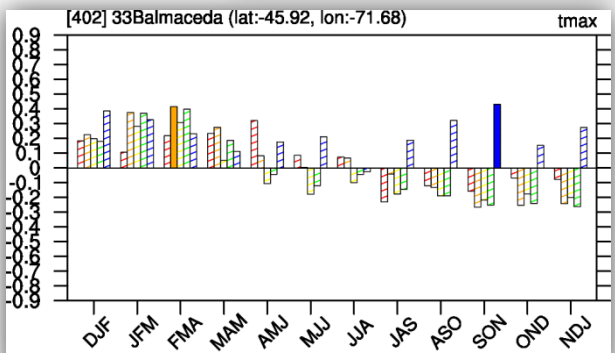
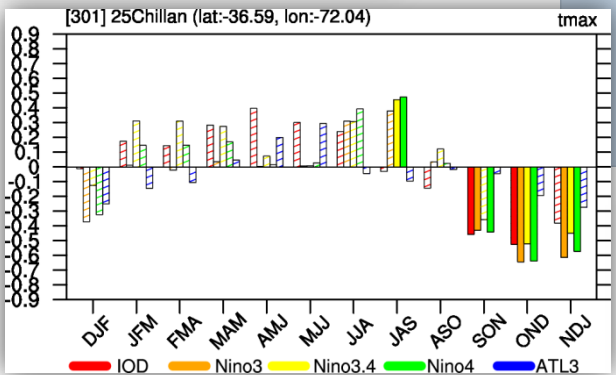
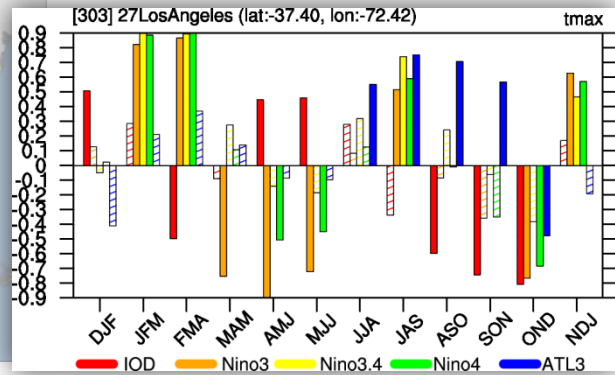
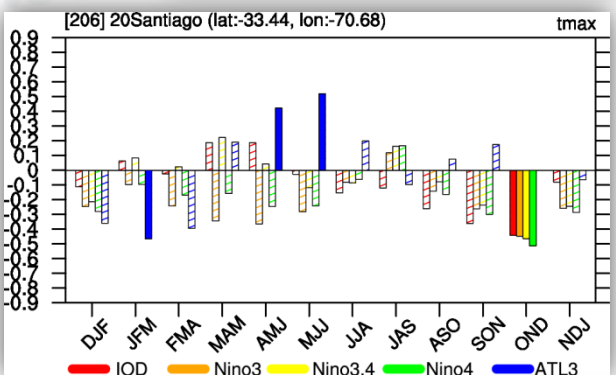
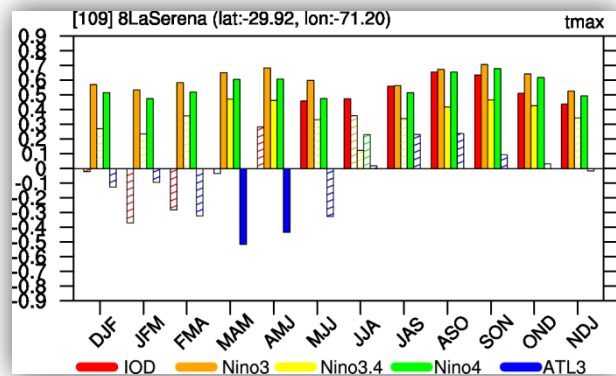
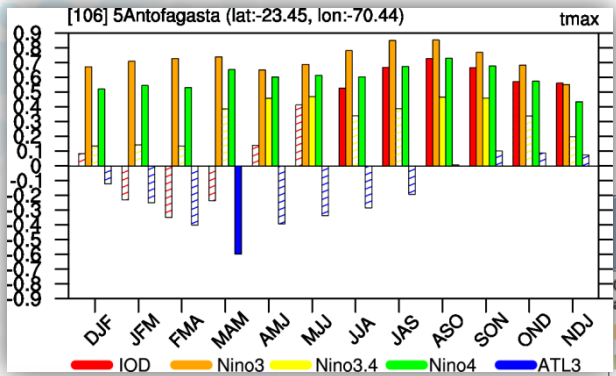
El Niño and the Indian Ocean Dipole -- Dec. 1997



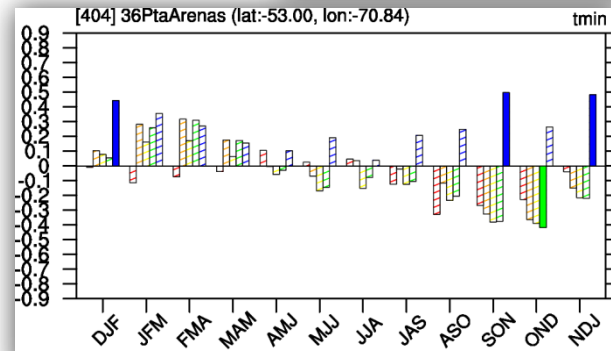
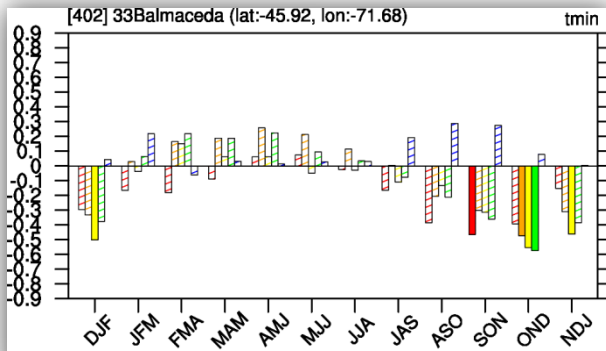
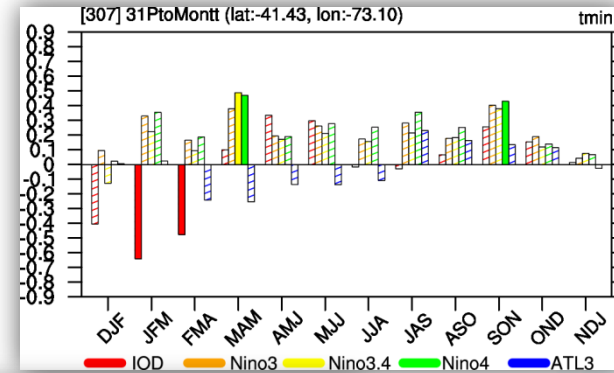
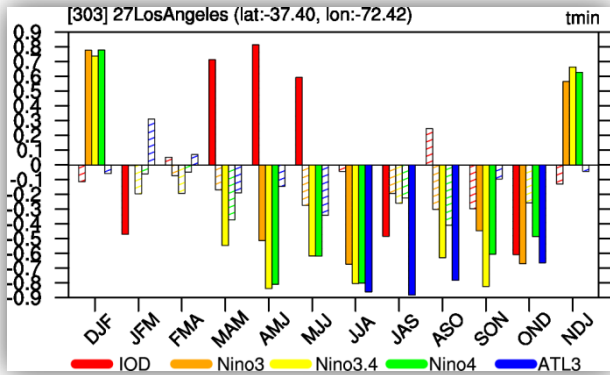
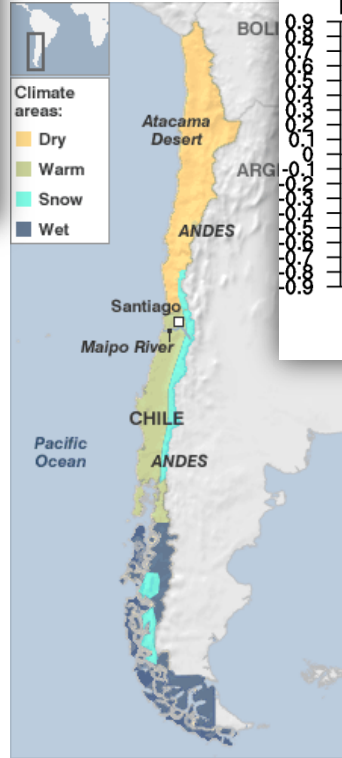
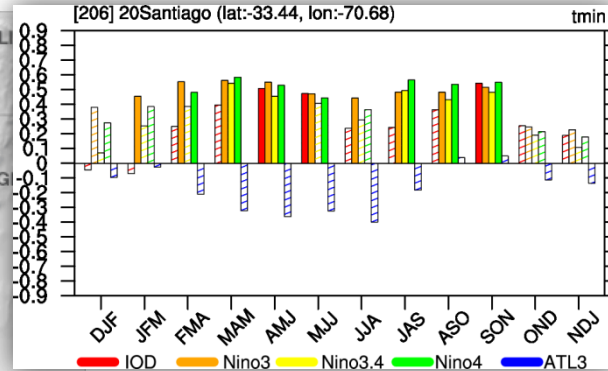
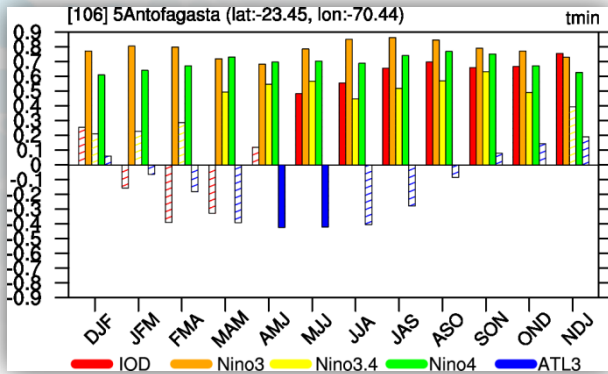
OISST-M1: 31.9%



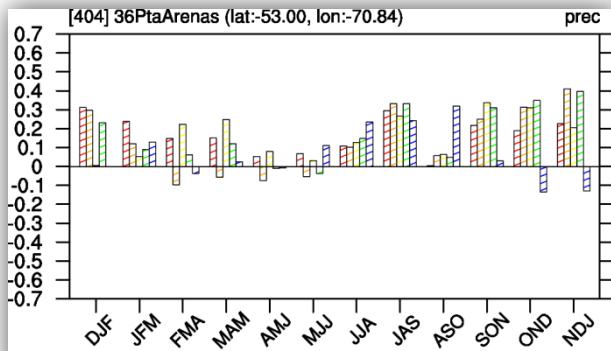
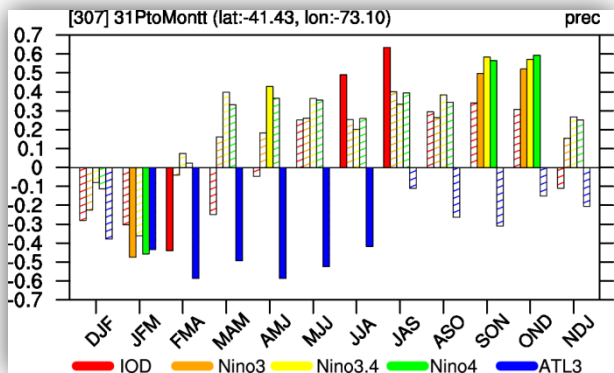
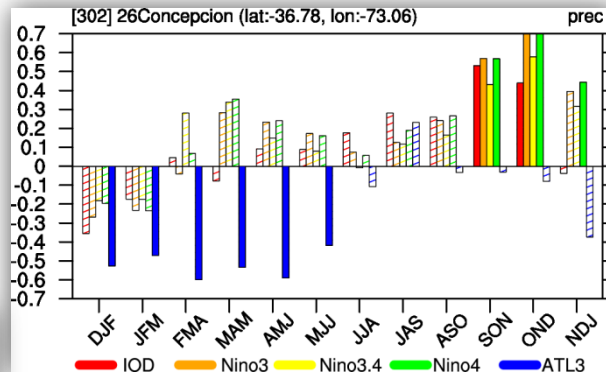
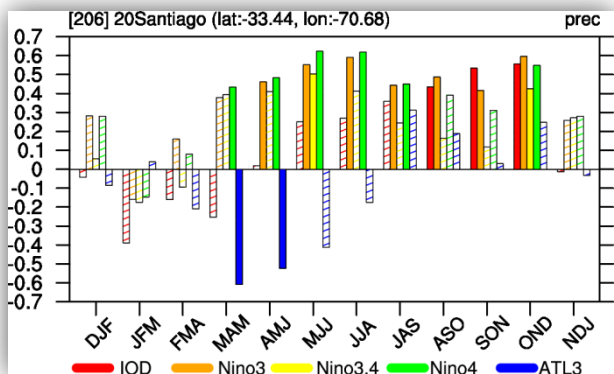
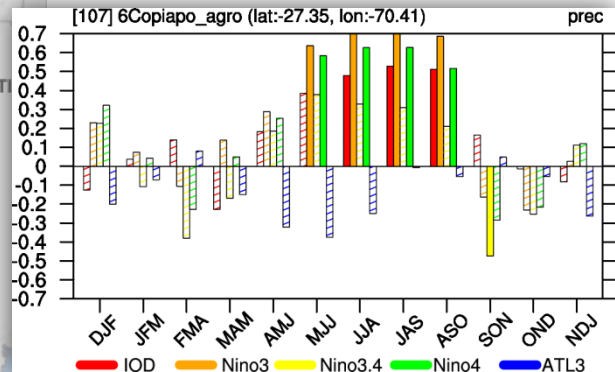
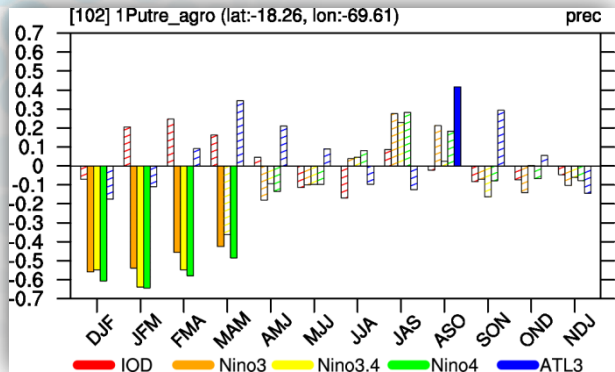
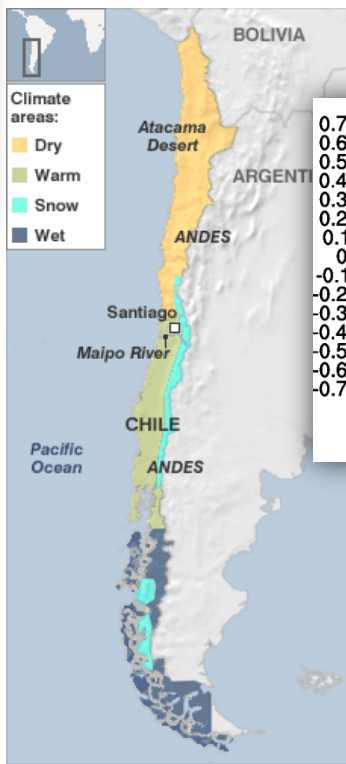
Tx



Tn



RR





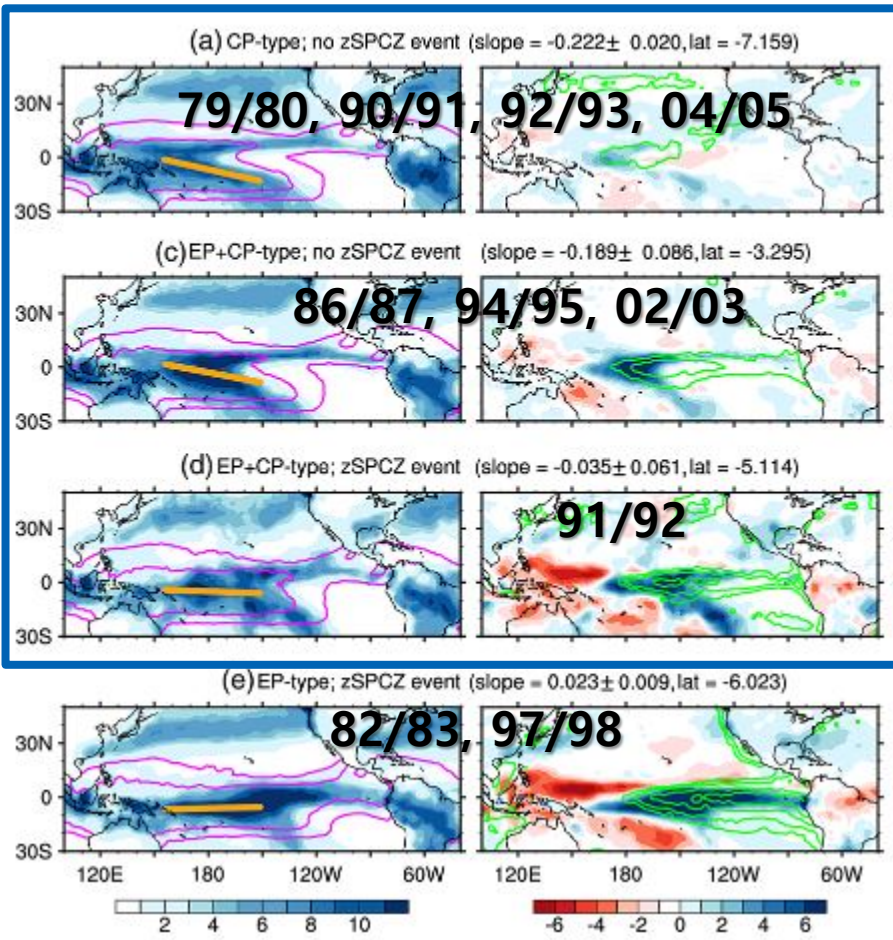
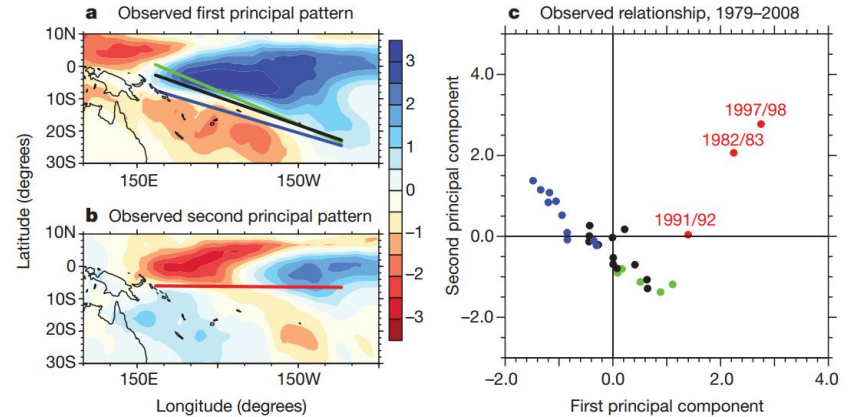
Thank you

Extreme Swing of SPCZ

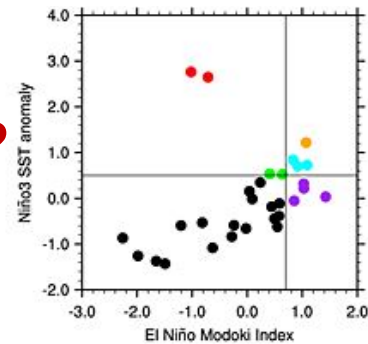
Cai et al (2012) & Borlace et al (2014)

-Strong (Super) EP type El Nino (82/83, 97/98) → **zonal SPCZ**

-EP/CP (91/92) El Nino → **Zonal SPCZ**



How about 2018/19?



ONI (nino34, DJF mean)

