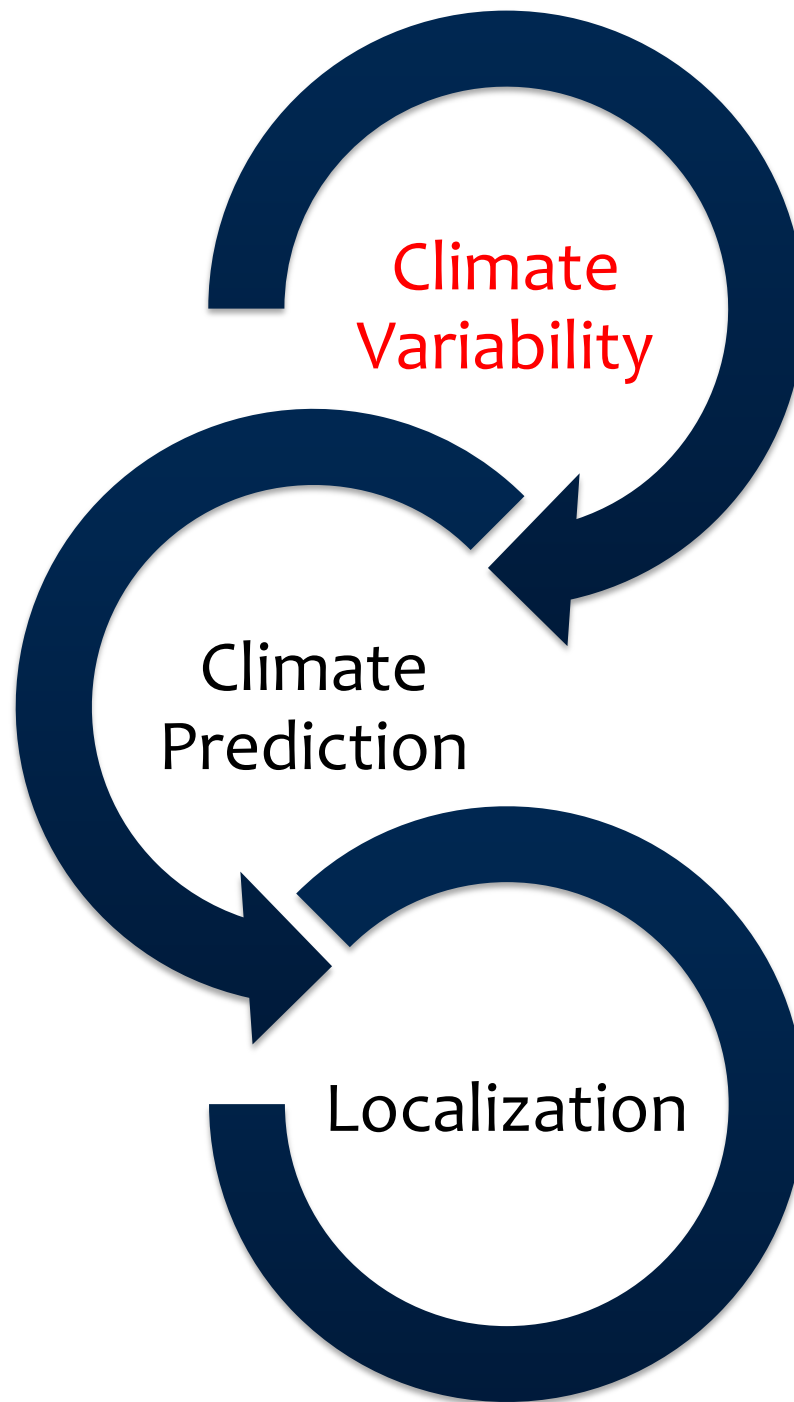


Introduction to Climate Variability & Prediction

Yun-Young Lee

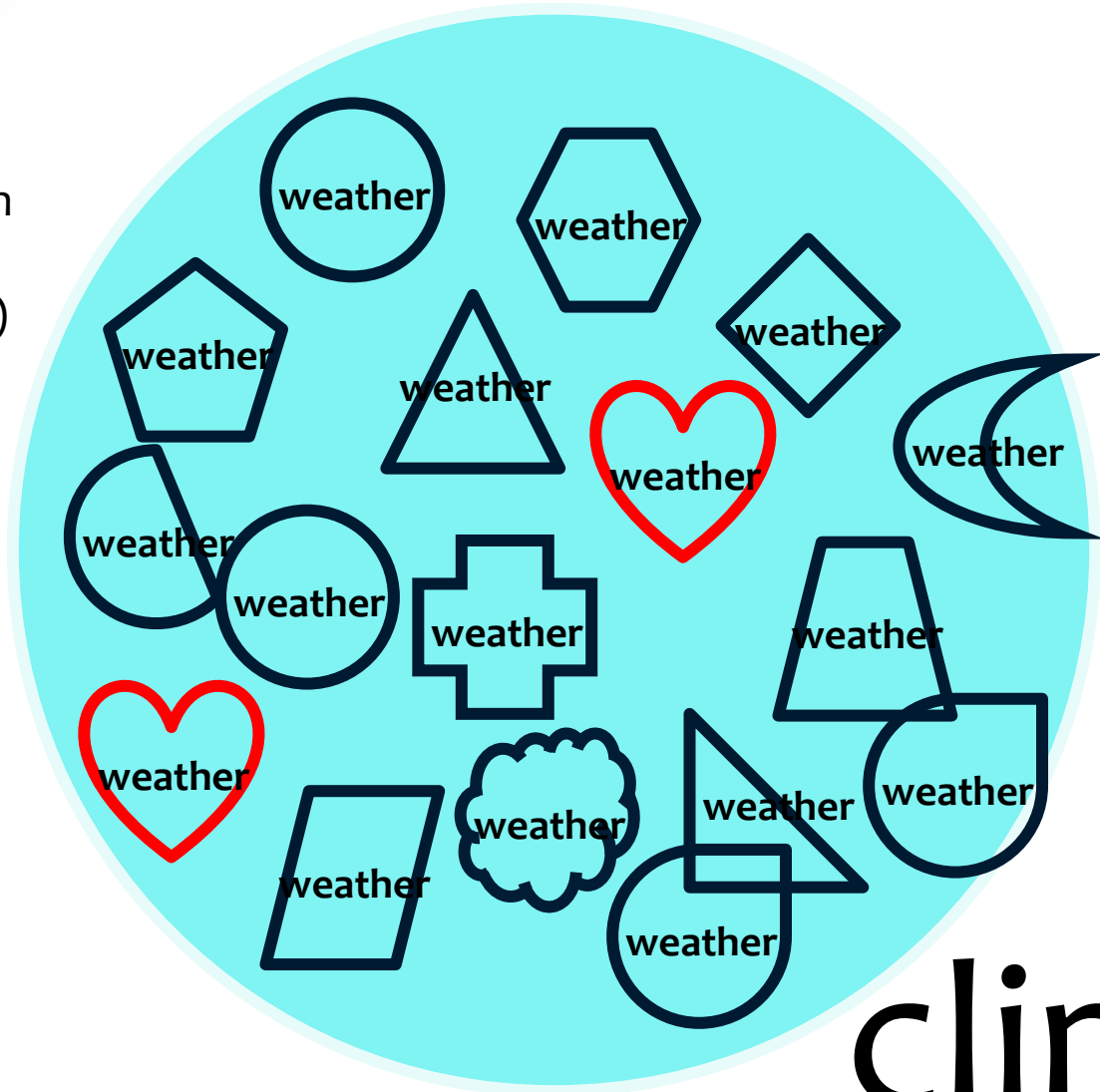




CLIMATE?

Weather summary = Climate

Expectation=
mean condition
of atmosphere
(temp. & Prcp.)

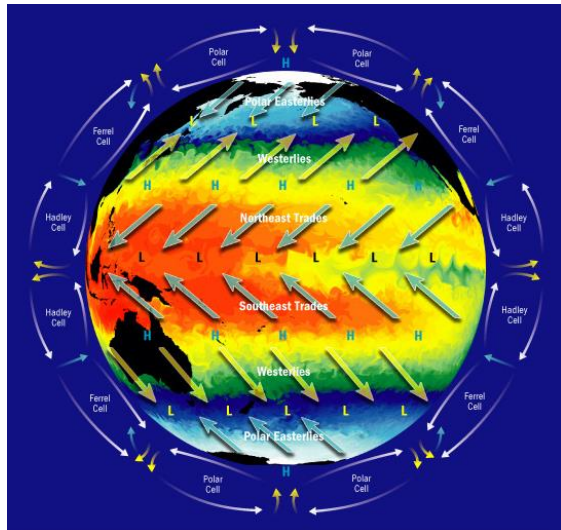


climate



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

Climate = Expectation



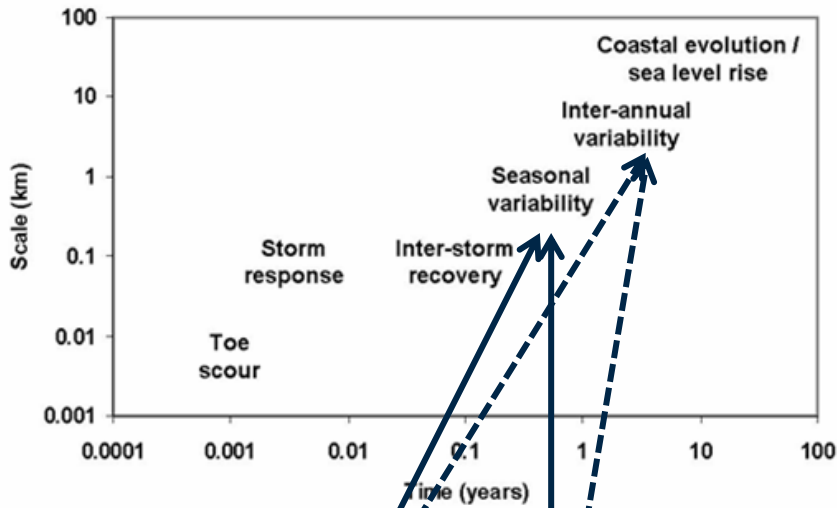
CLIMATE VARIABILITY?

Climate Variability

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

What are they?

Climate Variability

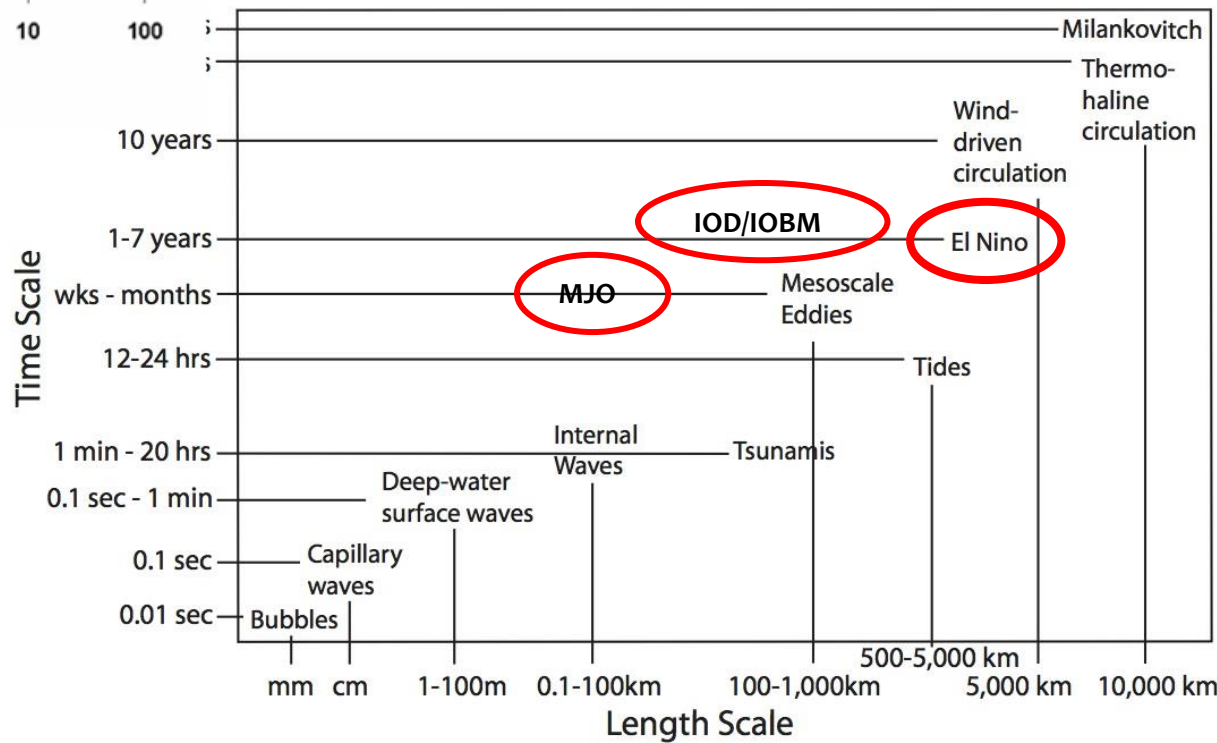


MONSOON (circled in red)

ITCZ (circled in red)

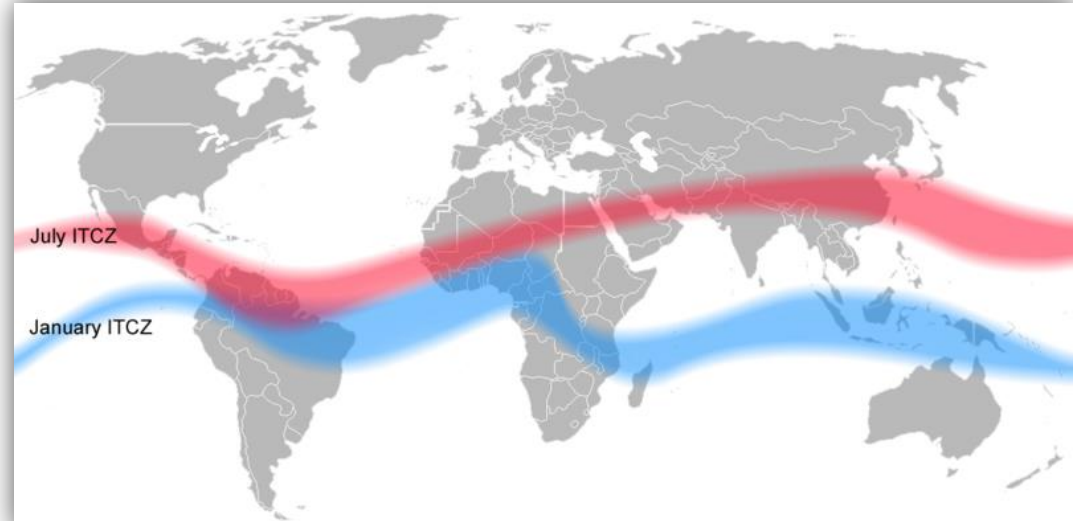
Energy Source: Solar radiation

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



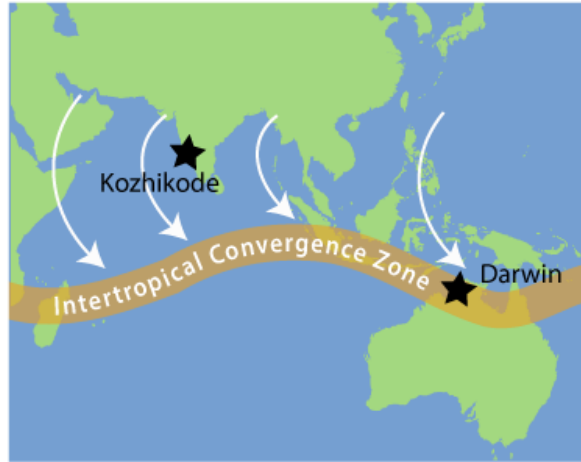
Inter Tropical Convergence Zone (ITCZ)

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

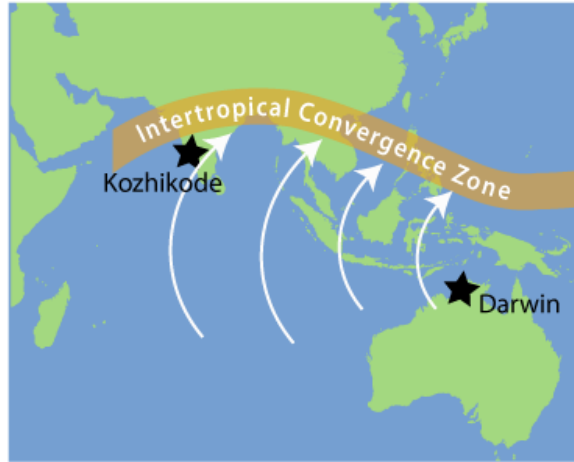


Inter Tropical Convergence Zone (ITCZ)

DECEMBER and JANUARY

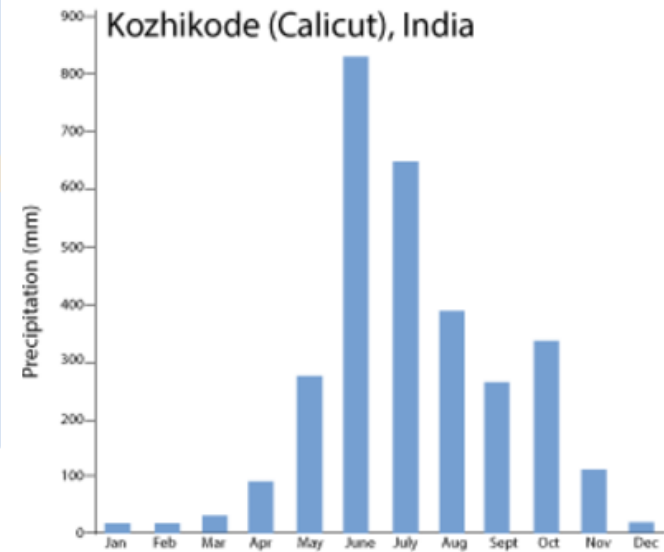


JUNE and JULY

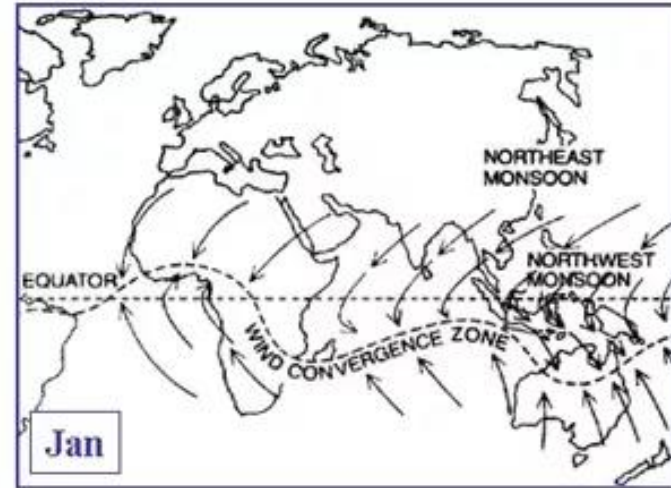


As the Intertropical Convergence Zone (ITCZ) changes location through the year, the winds, rains, and the location of wet monsoon weather changes, too. In this example from Asia and Australia, the ITCZ moves from the Southern Hemisphere (left map) to the Northern Hemisphere (right map). (Images: UCAR)

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)

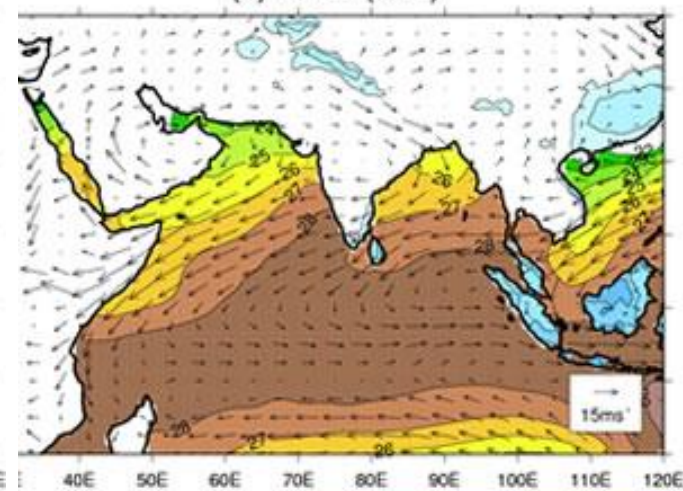
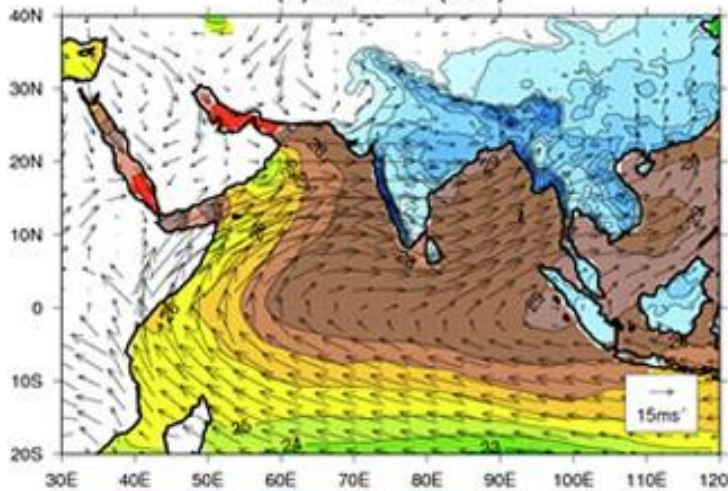


Monsoon



(b) summer (JJA)

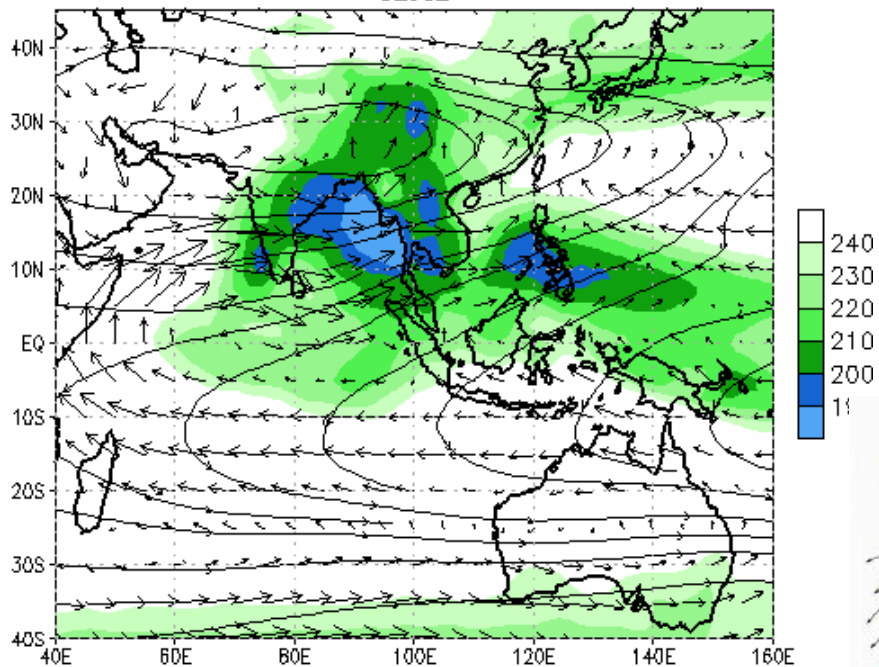
(a) winter (DJF)



Monsoon

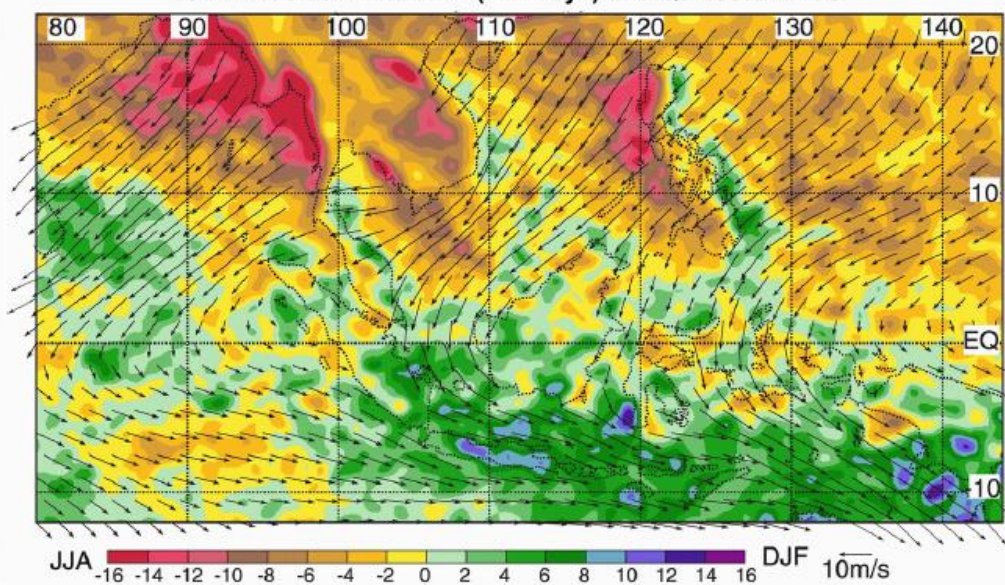
OLR, 200-hPa Streamlines and 850-hPa Wind Clim (1979-1995)

02JUL



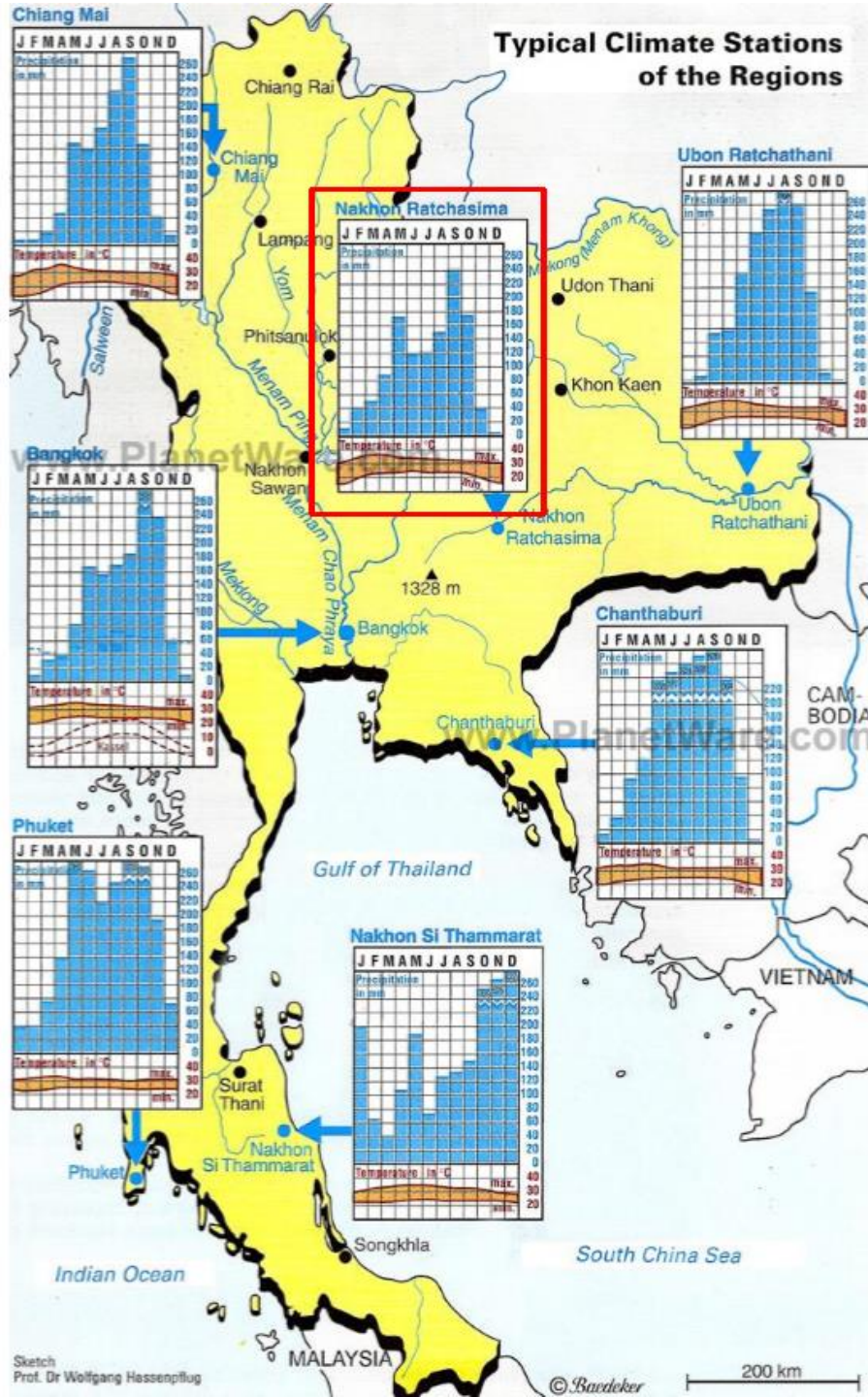
Data Sources: OLR - NESDIS/ORR, Winds - NCEP CDAS/ Reanalysis

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

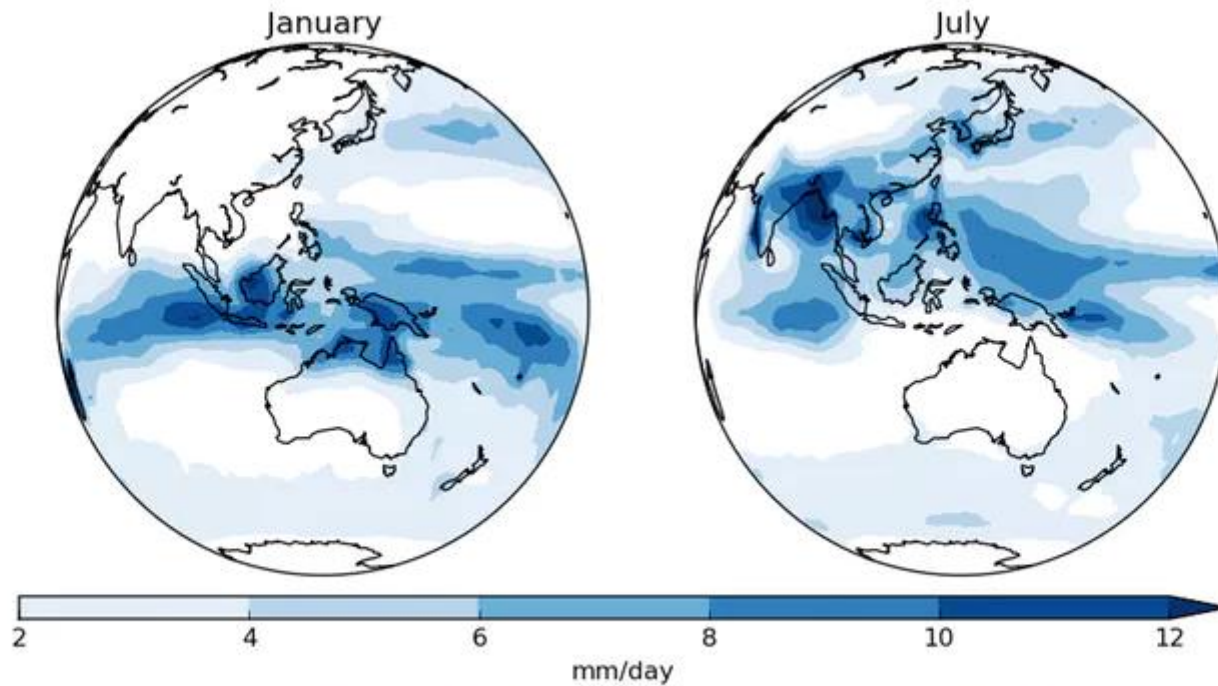


Regional difference

Coastal area **vs** Inland



Australian Monsoon

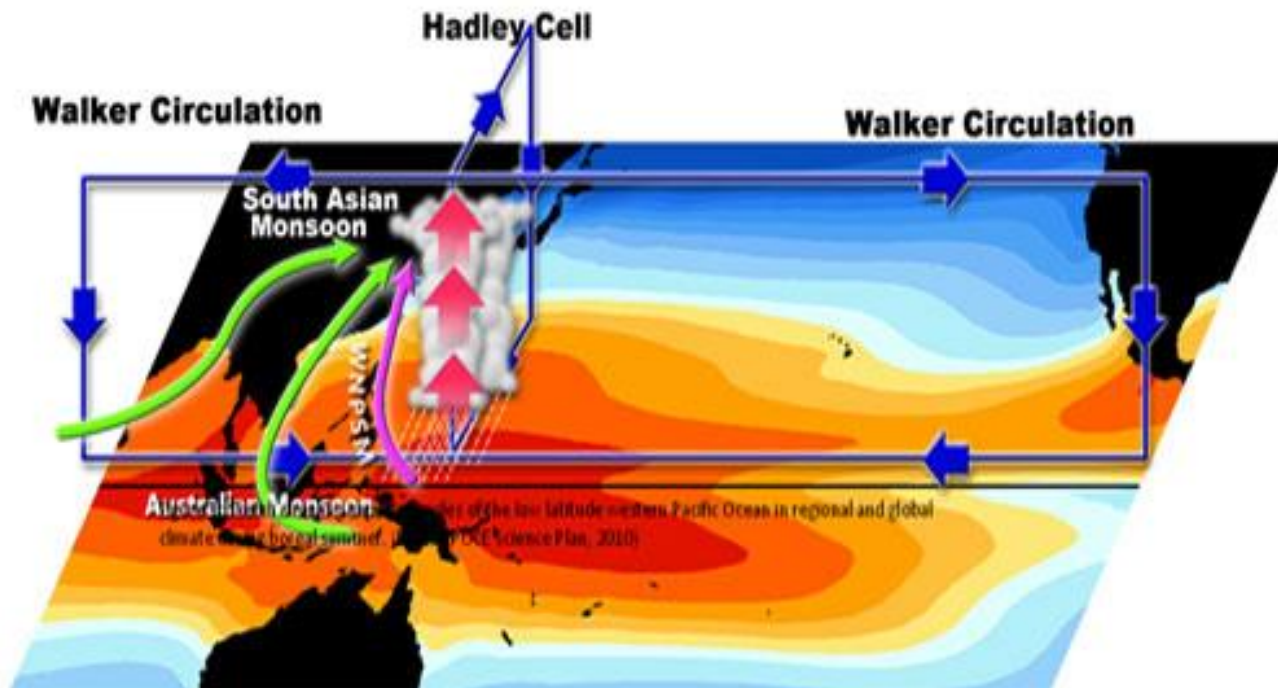


Global rainfall daily averages (1979-2008) for the months of January (left) and July (right). The monsoon trough is positioned over northern Australia in the southern summer, and moves northward during the southern winter. NOAA/OAR/ESRL PSD (<http://www.esrl.noaa.gov/psd/>)

Western Pacific Warm Pool (WPWP)

- Climate Engine : remember “mean” feature

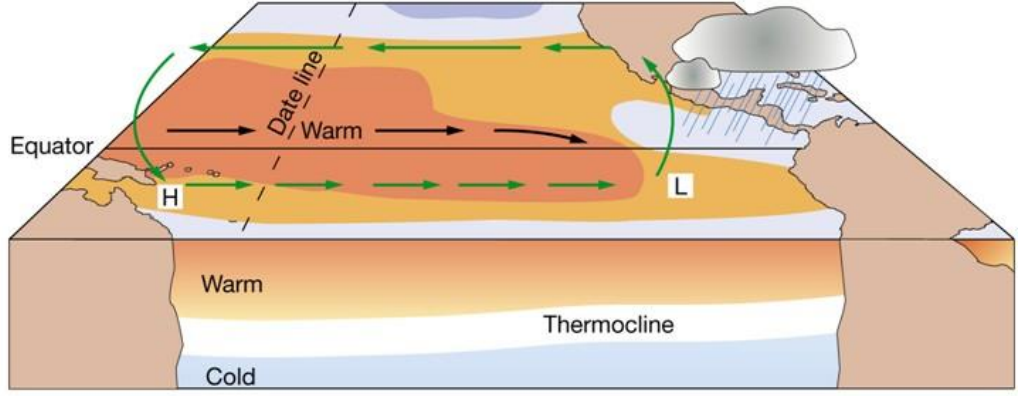
SST > 28.5° C



<http://npoce.qdio.ac.cn/background>

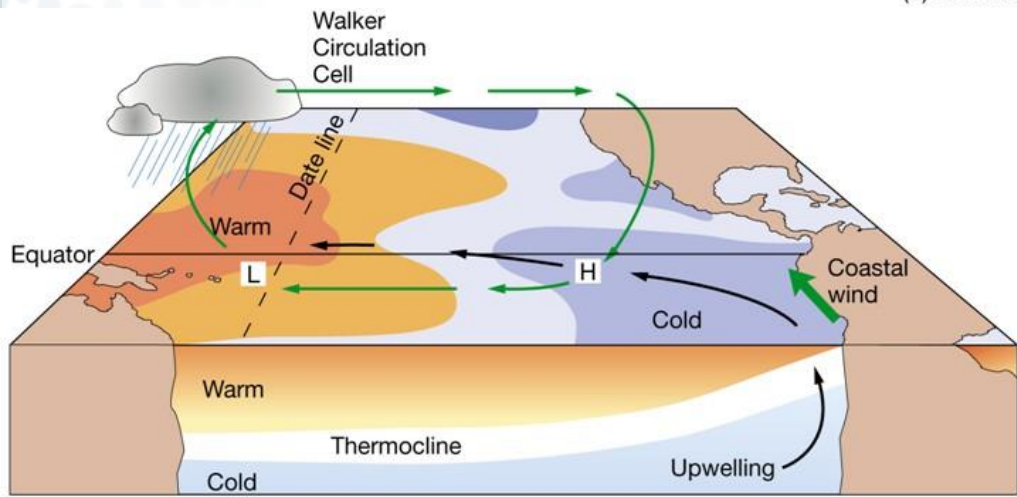
ENSO

- A Big Ocean Swing



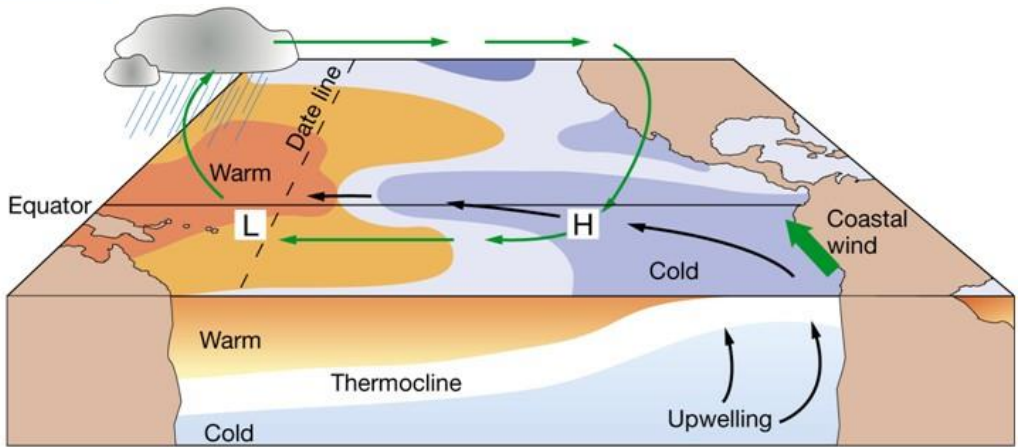
(b) El Niño conditions

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(a) Normal conditions

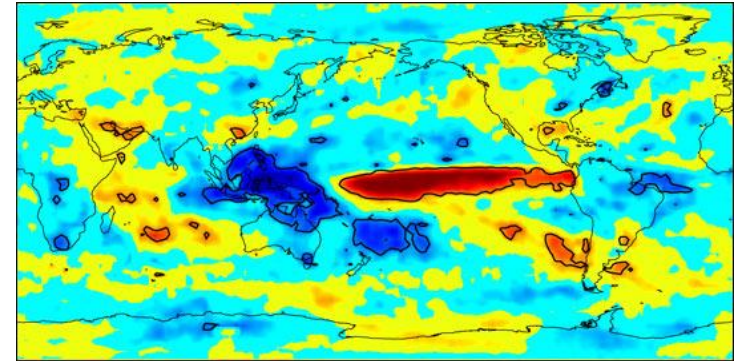
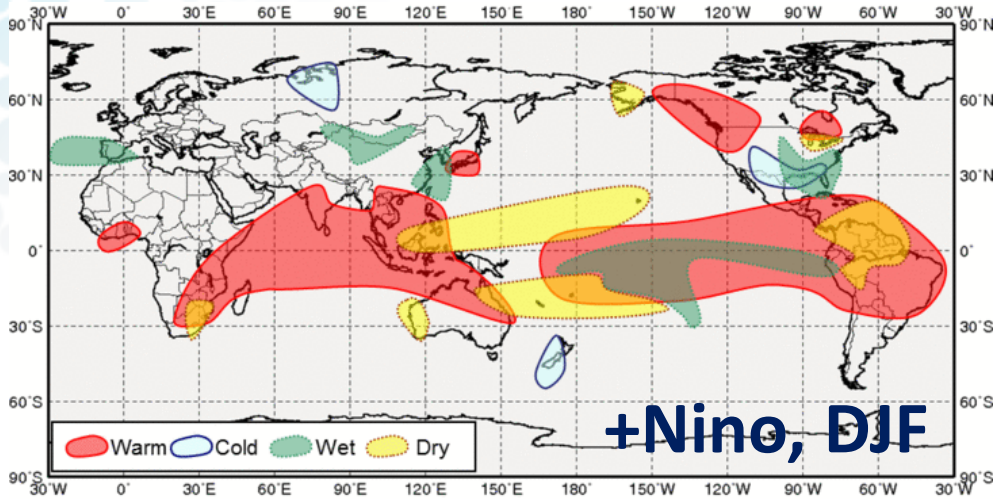
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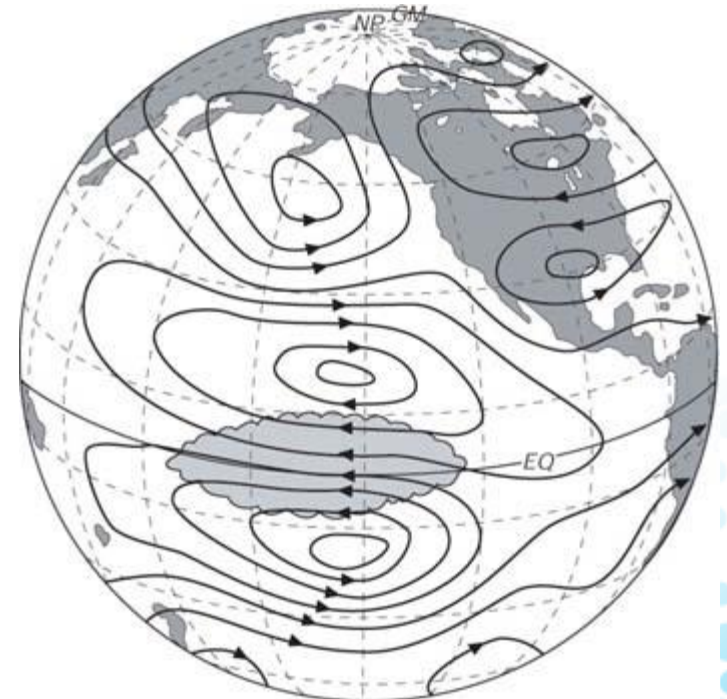
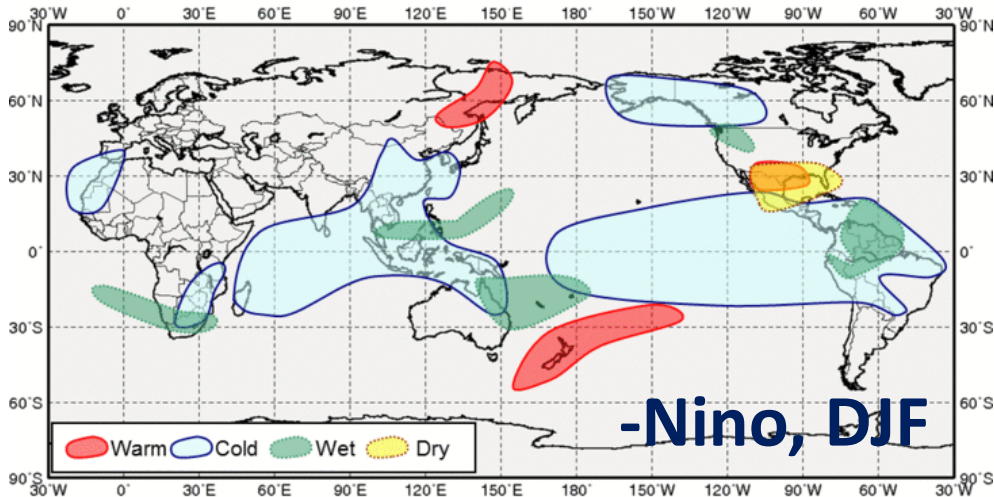
(c) La Niña conditions

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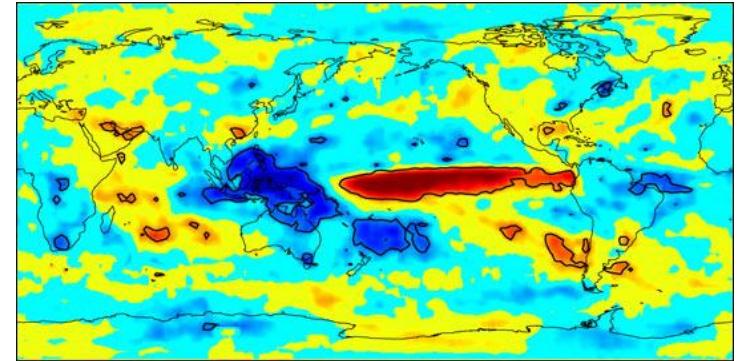
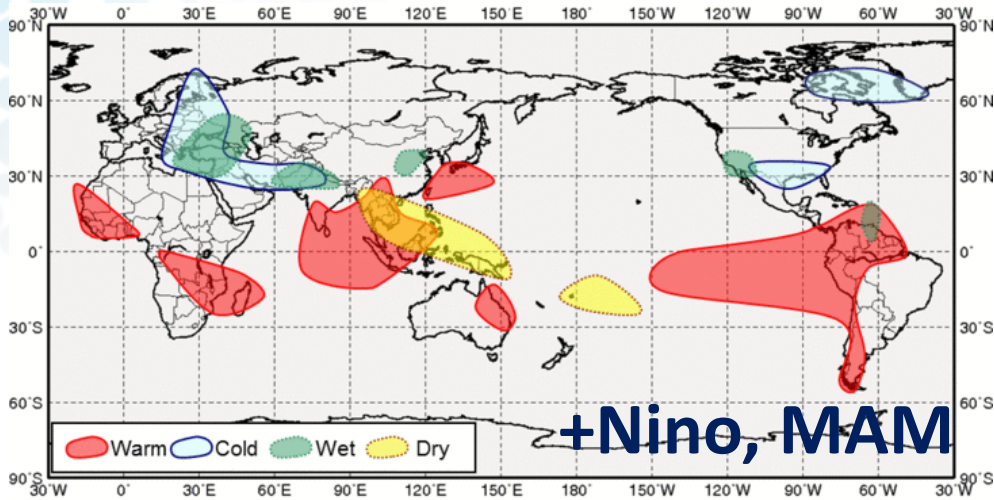
ENSO impact



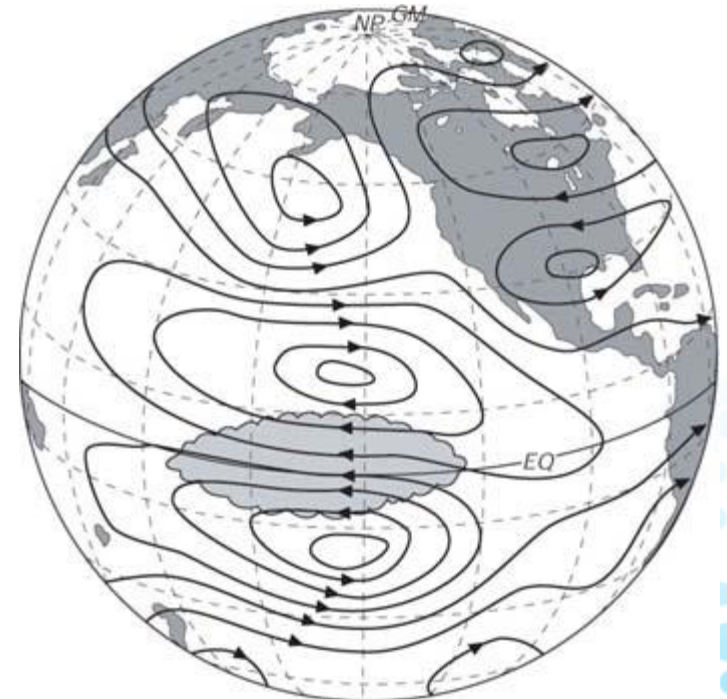
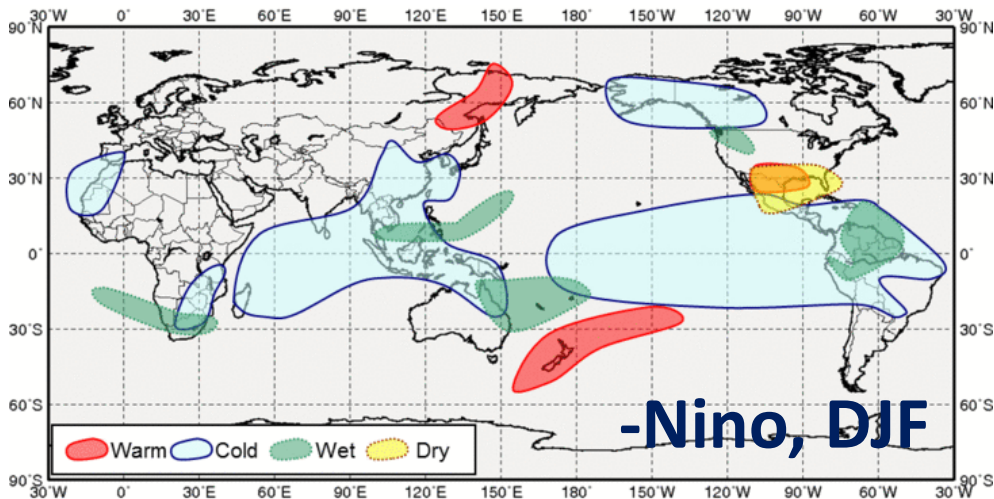
Precipitation (peak El Niño)
lower than normal normal higher than normal



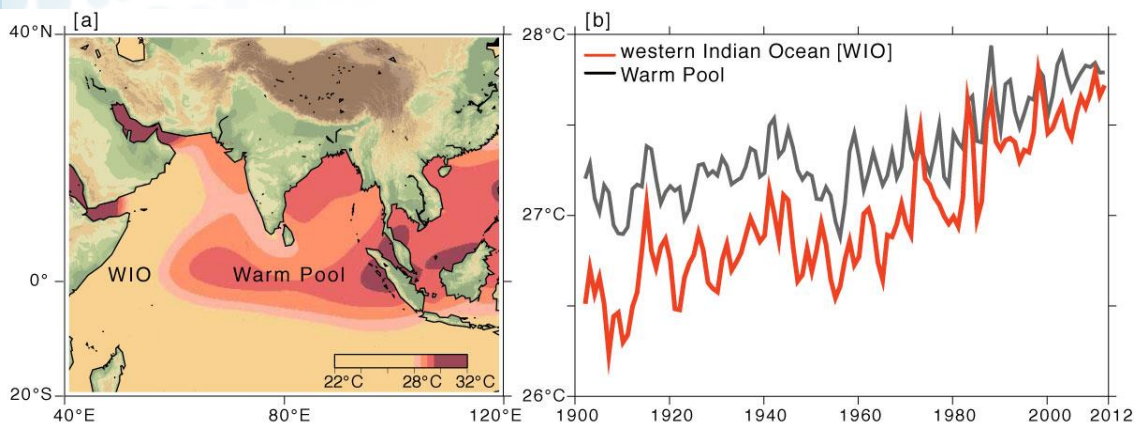
ENSO impact



Precipitation (peak El Niño)
lower than normal normal higher than normal

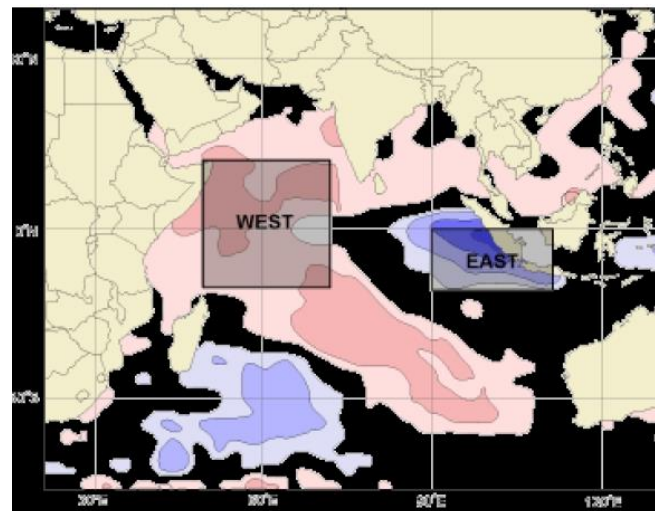


Don't forget Indian Ocean



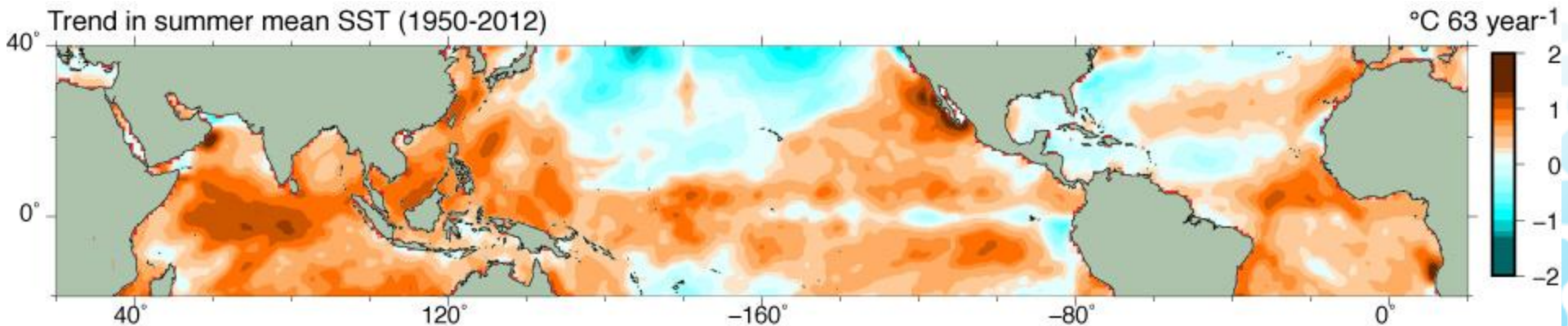
Source: <http://www.climate.rocksea.org/research/indian-ocean-warming/>

Indian Ocean Dipole

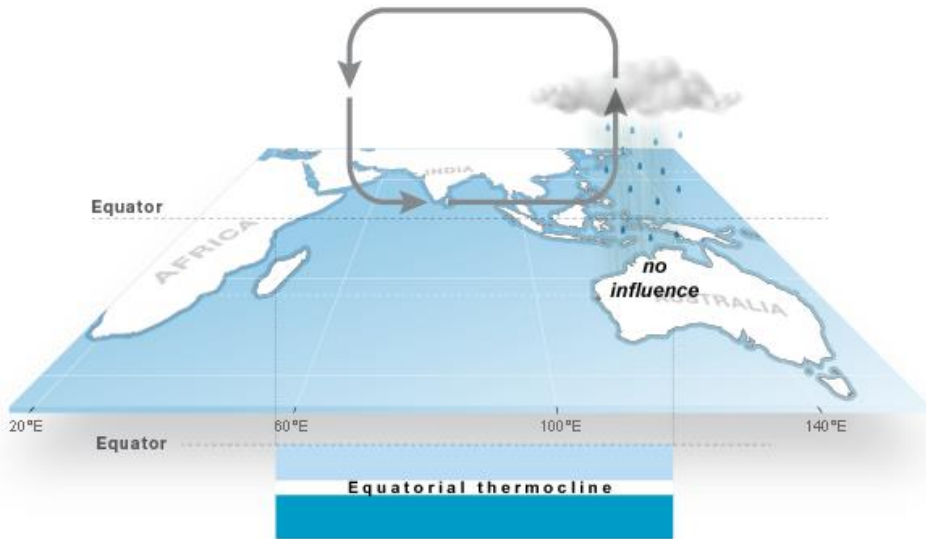


<http://devconsultancygroup.blogspot.kr/2010/08/la-nina-disasters-much-worst-probably.html>

Indian Ocean Basin Mode

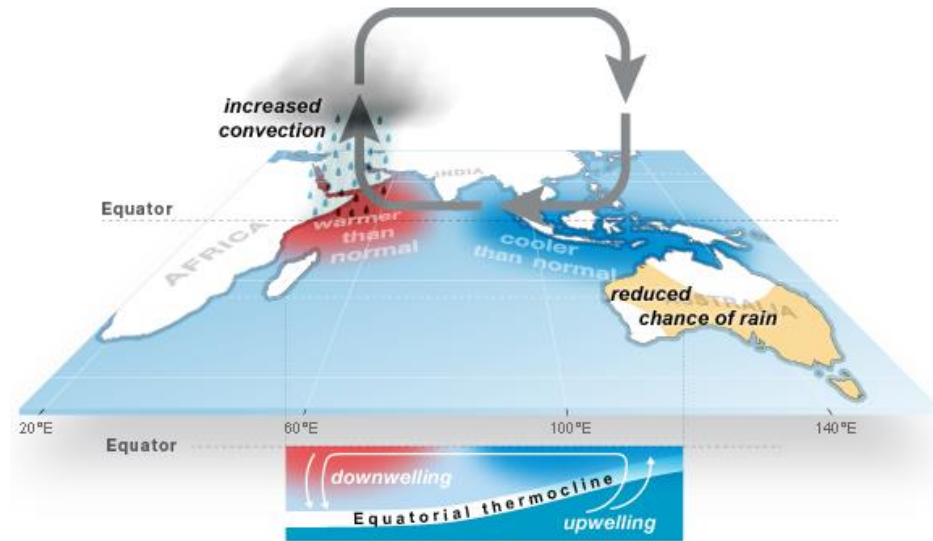


Indian Ocean Dipole (IOD)



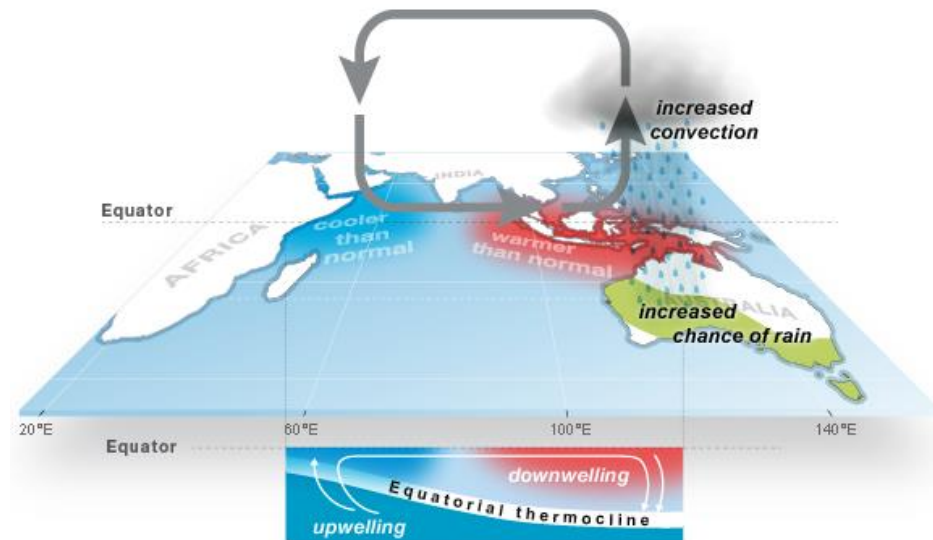
Indian Ocean Dipole (IOD): **Neutral phase**

© Commonwealth of Australia 2013.



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

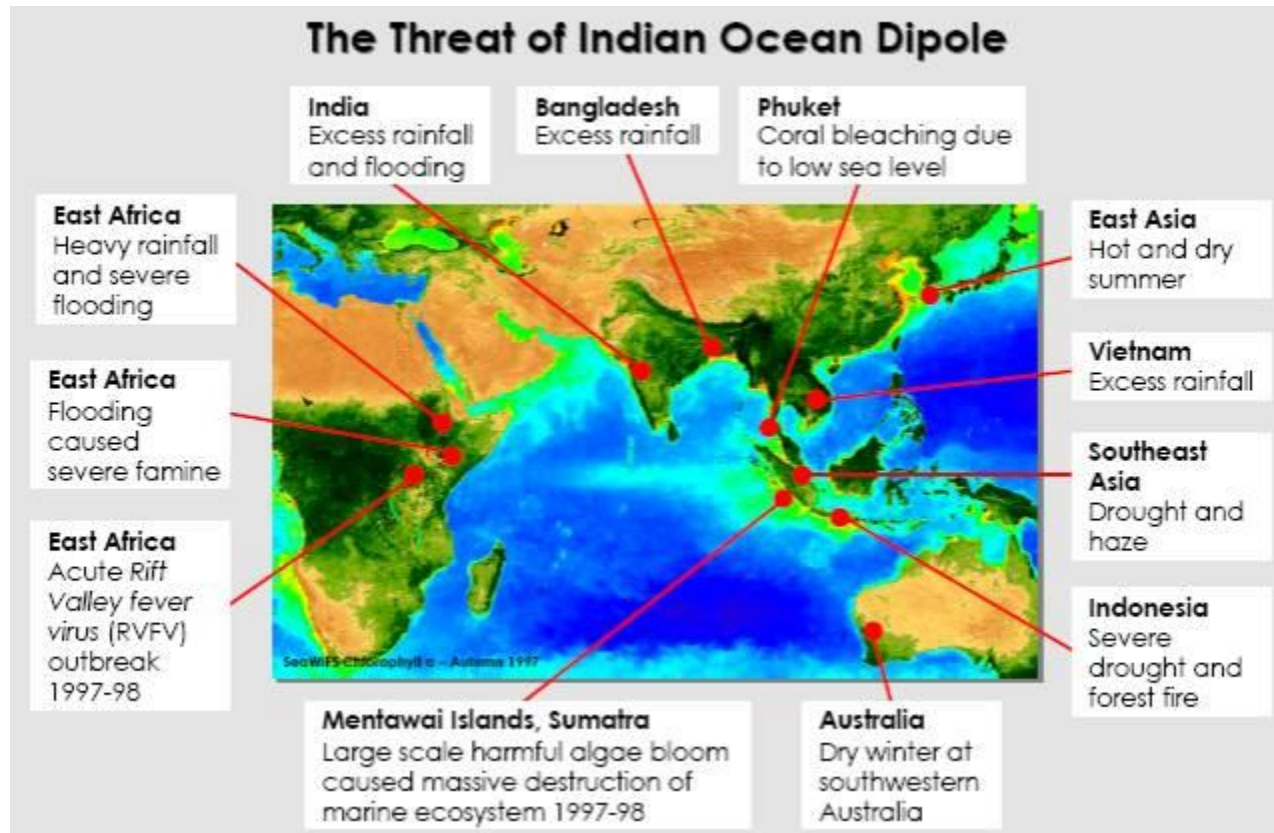
© Commonwealth of Australia 2013.



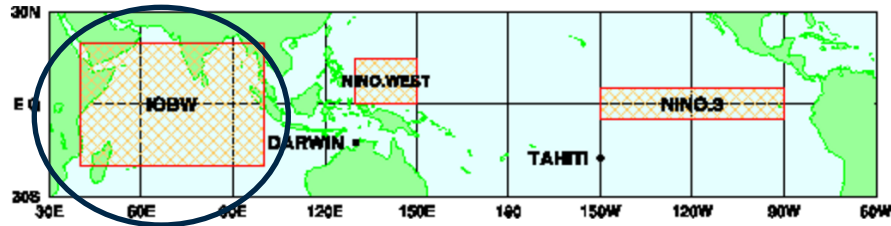
Indian Ocean Dipole (IOD): **Negative phase**

© Commonwealth of Australia 2013.

Indian Ocean Dipole (IOD)

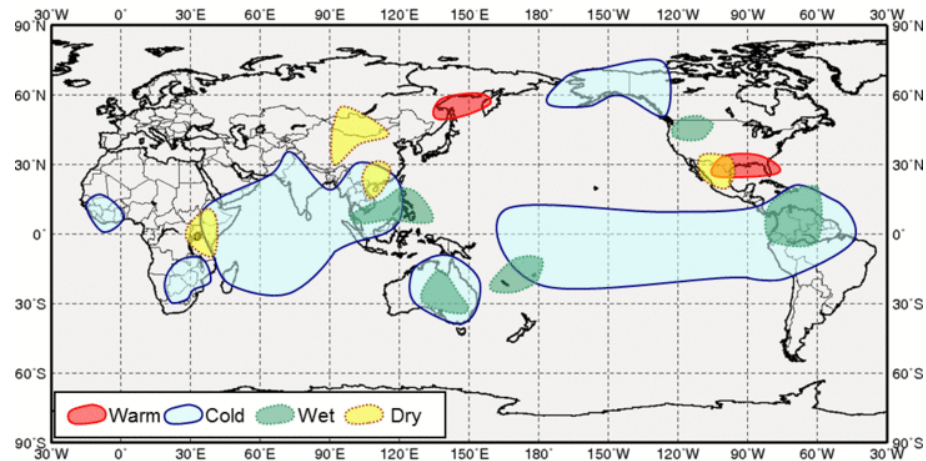


Indian Ocean Basin-wide Mode (IOBM)

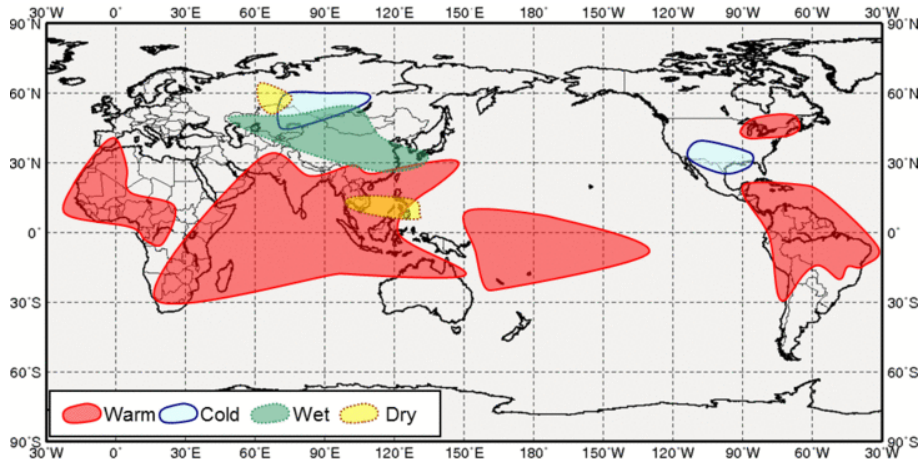


Source: TCC, JMA

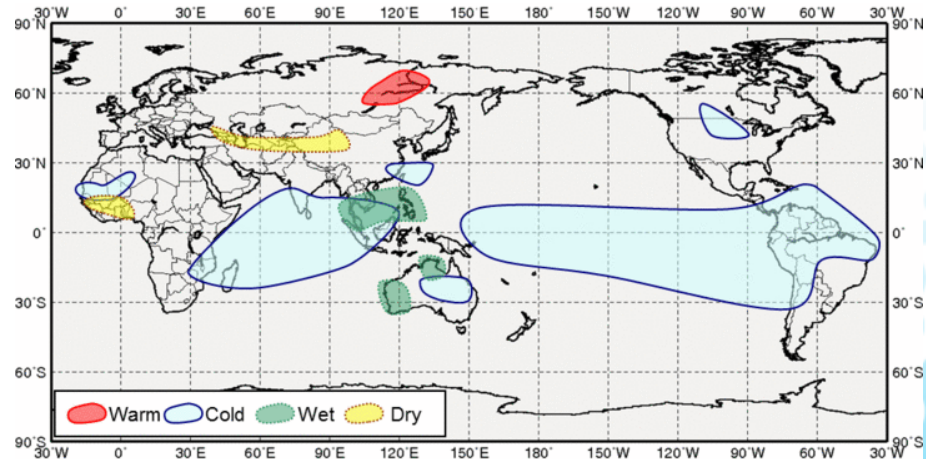
Negative IOBW, DJF



Positive IOBW, MAM

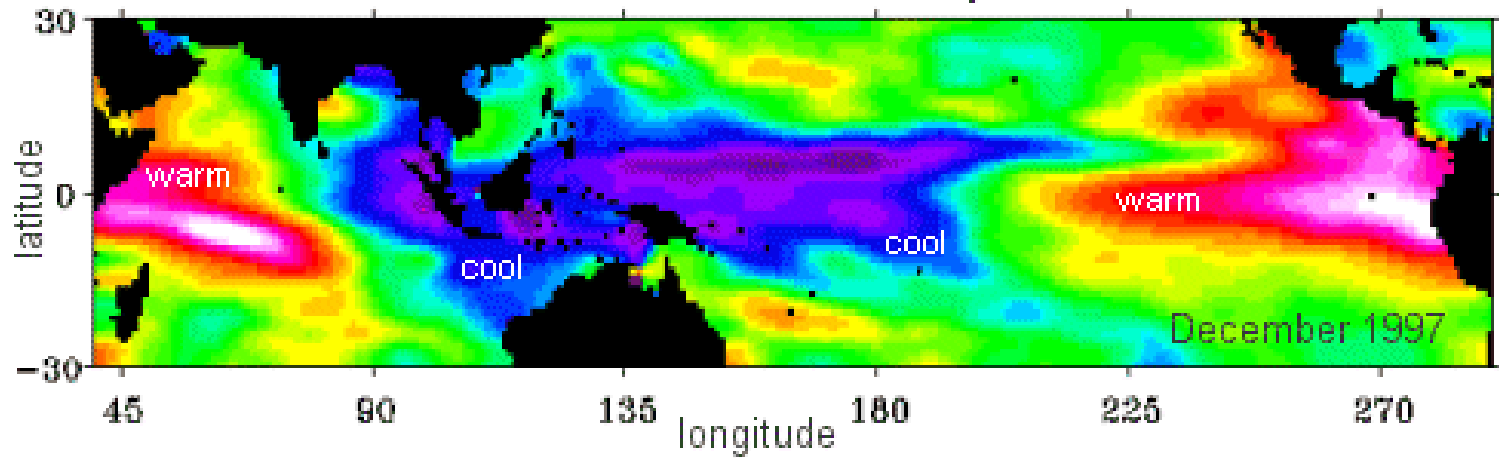


Negative IOBW, MAM



ENSO + IOD

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

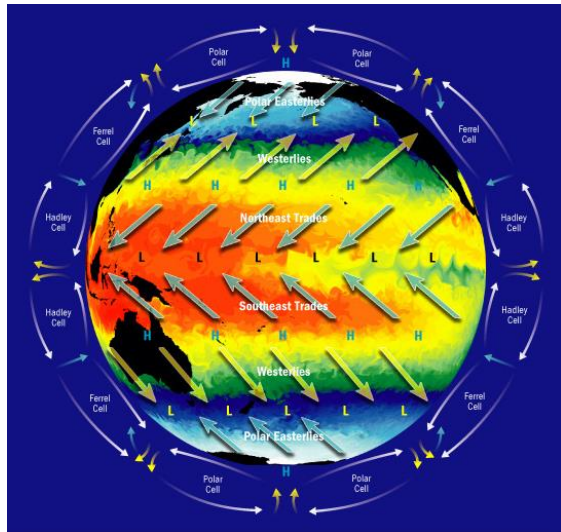


Climate
Variability

Climate
Prediction

Localization

Climate = Expectation



Climate = **Expectation**
Change = *Should be changed!*



Climate = **Expectation**
Prediction *of*
Expectation

How uncertain!

Prediction

: a rigorous (often quantitative,) statement forecasting **what** will happen **under specific conditions**

(in meteorology)

- What : atmospheric state
(weather)

- Conditions:

*current state, physical rules,
external forcing factors*

**Atmosphere is
dynamical system!**

$$\frac{d\vec{X}}{dt} = F(\vec{X}, a)$$

$$\vec{X}(t_0 + \tau) = \vec{X}(t_0) + \int_0^\tau F(\vec{X}(t), a(t)) dt$$

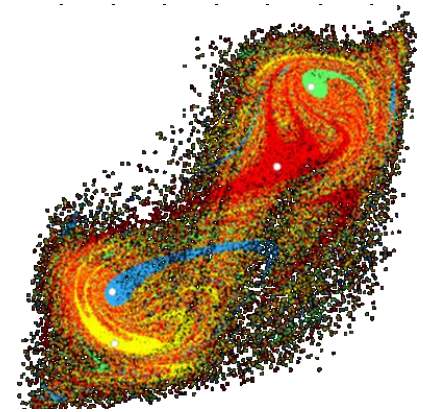
Determinism

Perfect prediction is possible when we have knowledge of all necessary "conditions"

$$\frac{d\vec{X}}{dt} = F(\vec{X}, a)$$

Chaos

Small difference in the initial state cause huge difference later even in the deterministic nonlinear system.



Our knowledge is never perfect!

→ *perfect forecast is impossible...*

Predictability

Depends on **what to predict**

Lead time(τ)

- ✓ *Temperature of this room tomorrow*
- ✓ *Temperature of this room in 30days later*
- ✓ *Temperature of this room in 30years later*

Location

- ✓ *Temperature of Seoul (Korea)*
- ✓ *Temperature of Jakarta (Indonesia)*
- ✓ *Temperature of Villa Las Estrellas (Antarctica)*

Predictability

- ✓ *Temperature*
- ✓ *rainfall*
- ✓ *wind speed*

Physical variables

- ✓ *Mean Temperature during a day*
- ✓ *Mean Temperature during a month*
- ✓ *Mean Temperature during a century*

Time-scale of predictand

Why Predictability is varying with location/variables

Characteristics of variability is different!

- In Tropics : weather = **local** convection (time scale ~ **few hours**)
- In Extratropics : weather = **synoptic** system (time scale ~ **few days**)
- (daily) **Rainfall** is more chaotic (highly nonlinear) than **temperature/pressure**

Signal & Noise

Two scales

- **Fast and small** scale processes : **noise**
 - Weather by tropical cyclone etc.
- **Slow and large** processes : **signal**
 - Climate by **ENSO**, ITCZ, monsoon, **MJO** and so forth

- What is the **Signal**? (How we can “see”?)
 - Tendency of weather that has to be physically caused by **slow varying processes**

Potential predictability

Matter of

Signal

&

Noise

$$X = X_s + X_n$$

Measured by relative magnitude
(variance) of signal and noise

Signal >> Noise : more predictable

Signal << Noise : less predictable

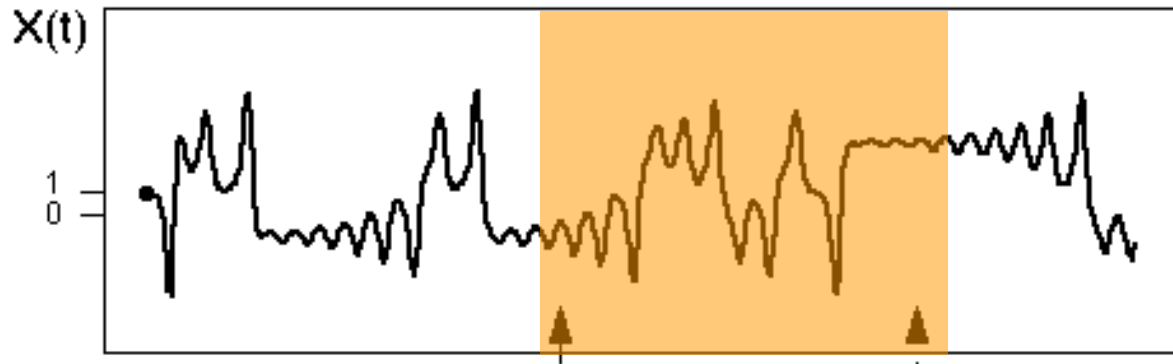
How long
(time domain)?

Time mean of
weather

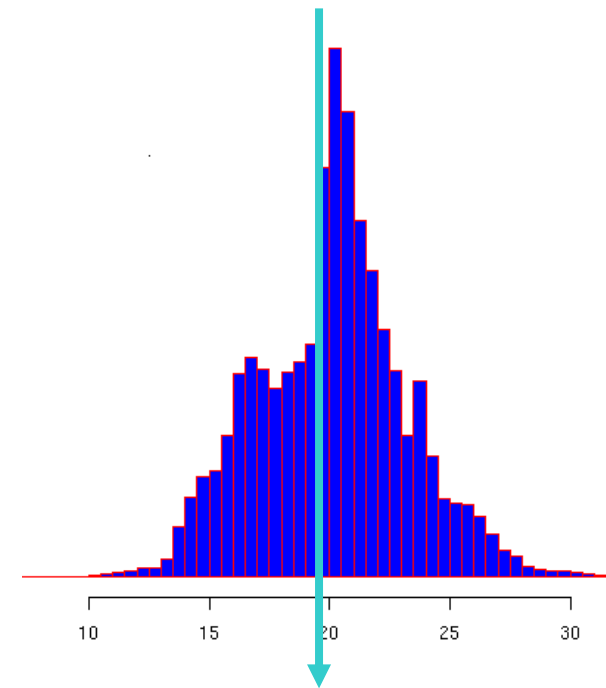
Subseasonal
climate

prediction

Weather statistics



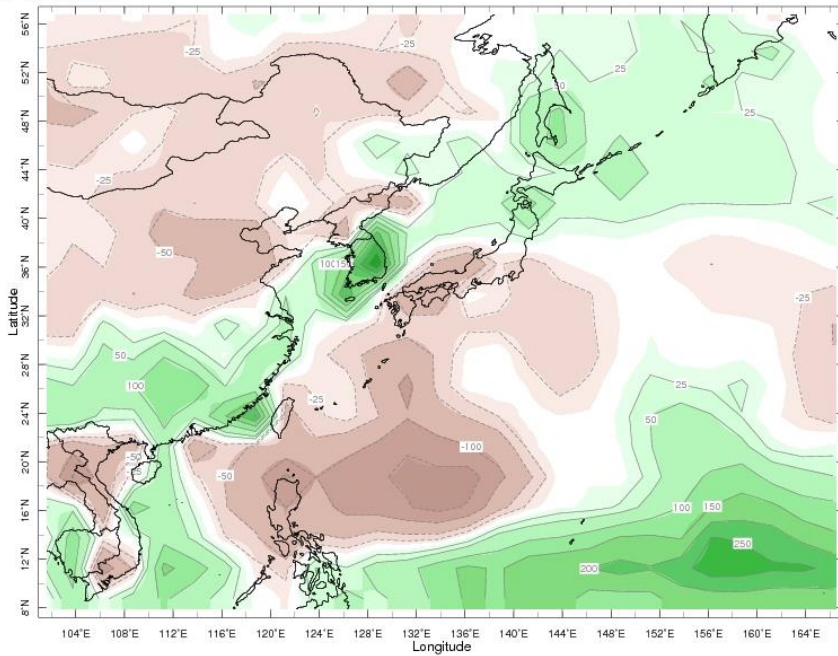
Primary seasonal weather statistics :
seasonal **mean**



Seasonal
mean

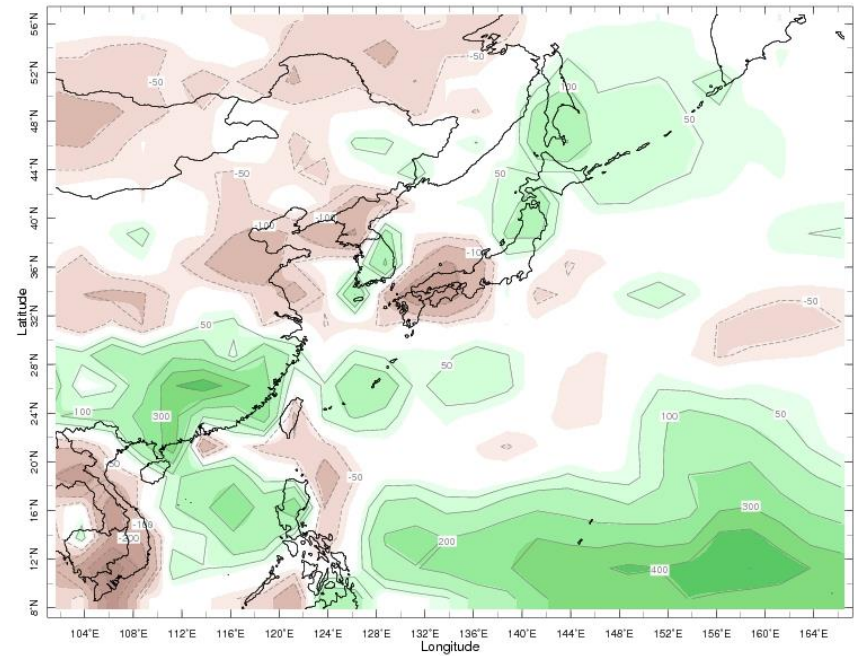
2002 summer (JJA) rainfall

Monthly mean prec. (Aug)



Aug 2002

Summer mean prec.



Jun-Aug 2002

Typhoon "RUSA" passed at 8/31 (1000mm a day)

Methods

- **Statistical (Empirical)**

- Use observed relationship of climate system to predict future
- Linear

- **Dynamical**

- Based on “physical law” of climate system and expect to mimic “the memory”
- Nonlinear

Pros/Cons

Statistical/Empirical

- Simple and cheap
- Based on (observation) data
- Data is real thing but do we have enough?
- Unprecedented events predictable ????

Dynamical

- Complex and expensive
- Based on Law
- Is our understanding accurate?

Statistical forecasting

(0) Climatology

- Baseline of seasonal forecasting
- “Nothing particular, Sir.”

$$x(t + 1) = \bar{x}$$

- ✓ Rainfall amount will be similar to 30 year average.
- ✓ I don't know? (33%:33%:33%) or Near Normal?

(1) Persistence

- Assume that future will be same as it is now.

$$x'(t + 1) = x'(t)$$

- ✓ Often Close to people's expectation.
- ✓ Effective when the autocorrelation is large (e.g. ENSO forecast)

(2) Regression

- The most popular method and many variations

$$x'(t + 1) = ay(t) + b$$

x : predictand (e.g. rainfall at a station)

y : predictor (e.g. NINO3.4 SST)

Regression based forecast

Question #1 : Predictor selection

- How to define **predictor (y)**?
- By definition, predictor should cause some changes in variation of predictand.

Question #2 : appropriate Function

- How to define **a** and **b**?
- *Your choice*: linear, nonlinear, single, multi...complex ones are not necessarily better.

$$x'(t + 1) = ay(t) + b$$

Predictand : my mood in the morning
Predictor? Relationship?

$$x'(t + 1) = ay(t) + b$$

$$x'(t + 1) = a_1y_1(t) + a_2y_2(t)b$$

$$x_1'(t + 1) + x_2'(t + 1) = a_1y_1(t) + a_2y_2(t)b$$

One to One : often not very satisfactory

One to Multi : easy to overfit (lie)

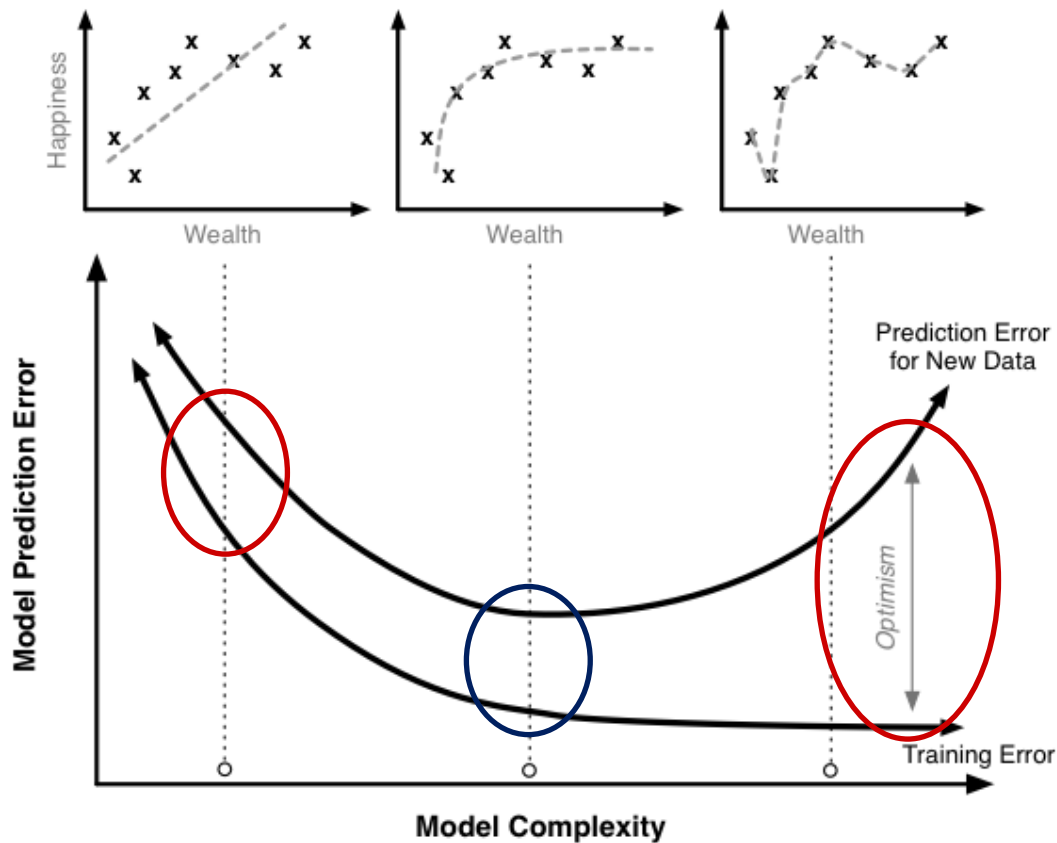
Multi to Multi : looks nice but often produce nothing practical

- ✓ If they gives similar result, **the simpler is the better!**

- ✓ Should be based on **Physical relationship** between predictors and predictands
- ✓ Predictor cannot be tiny signal in the seasonal forecast
- ✓ Keep “doubt” on the possibility of selection by chance
- ✓ Selected predictor should be validated with separate data

Weakness : **overfitting**

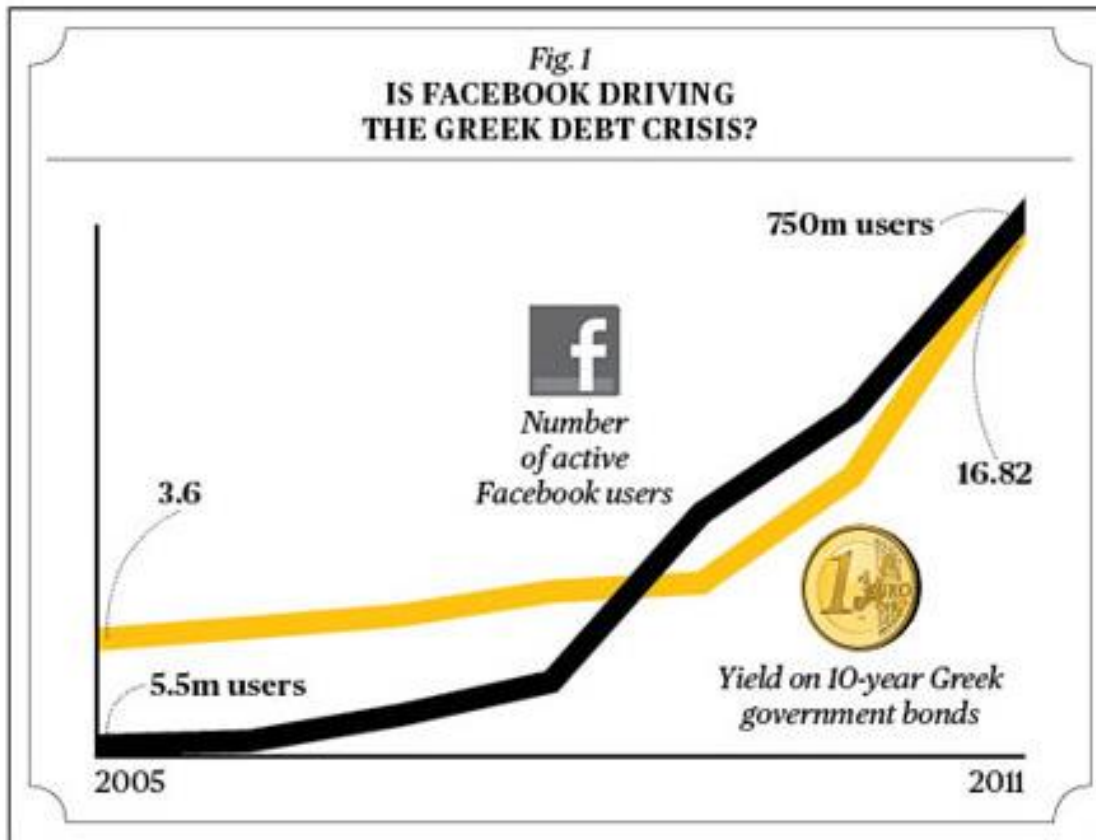
■ Consider potential predictability



If model output is fitted to the unpredictable noise : Overfitting.
What if we remove “noise” in the observation?

Predict yield of Greek bonds with number of Facebook users

Is it appropriate?



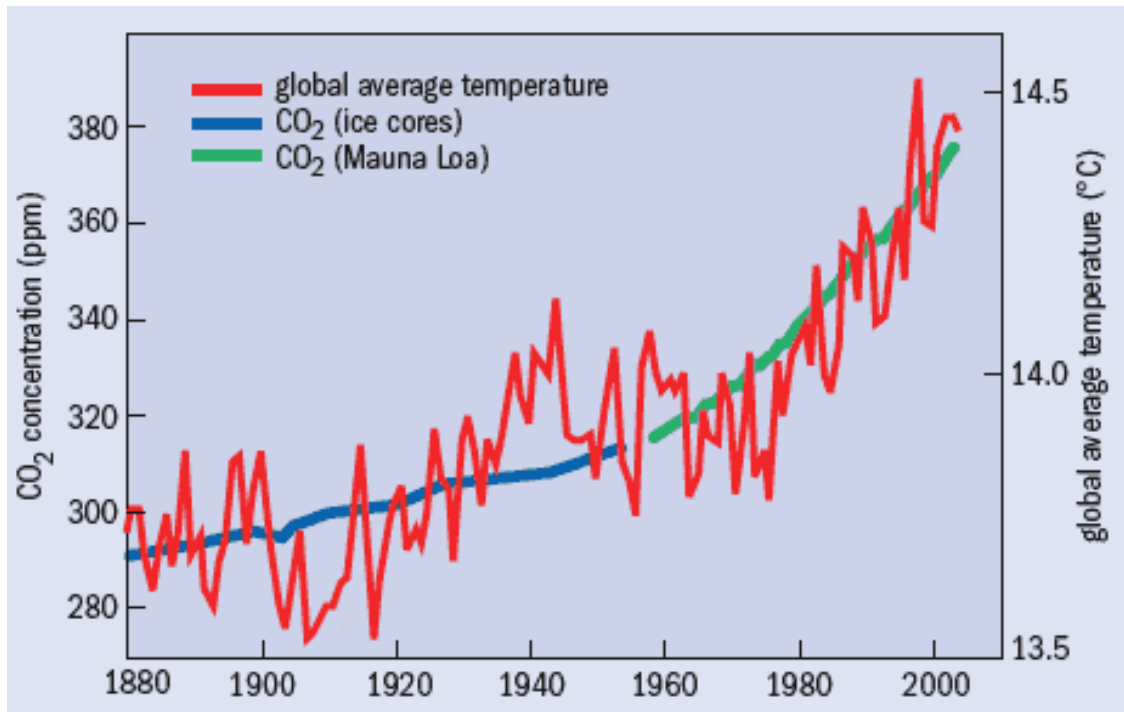
If yes, why?

If not, why?

From *business week*

Predict global average temperature with Carbon dioxide concentration

Is it appropriate?



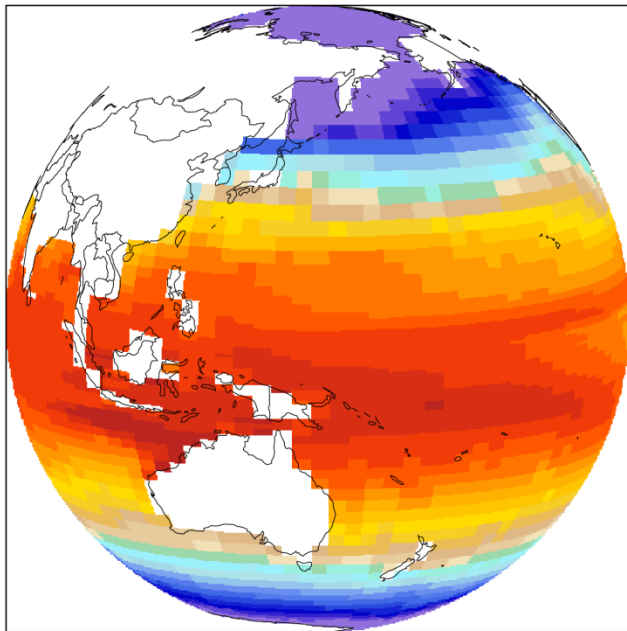
If yes, why?

If not, why?

Image Source: images.iop.org

Dynamical forecast

- Use GCM : Global Climate Model
 - It used to be called “General Circulation Model”



Dynamical forecast

- Governing Equations → Written as computer program code (NWP)

$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla) \mathbf{u} = \nabla \Phi - 2\Omega \times \mathbf{u} - \frac{1}{\rho} \nabla p + \mathcal{F}$$

$$\frac{\partial \rho}{\partial t} + \bar{\nabla} \cdot (\rho \bar{\mathbf{u}}) = 0 \quad \Leftrightarrow \quad \frac{D\rho}{Dt} = -\rho \nabla \cdot \mathbf{u}$$

$$\frac{\partial \theta}{\partial t} + \bar{\mathbf{u}} \cdot \bar{\nabla} \theta = l$$



```
//Behradek functions:
//
//   DTstage(T+9.11)^-2.05
//
MinTime=pow(T[j]+9.11, -2.05);//Minimum time to advance to stage (in days)
for(k=0;k<numLifeStage;k++)
{
  MaxRate[k]=MinTime*DTstage[k];
  MaxRate[k]=MaxRate[k]*ToSecs;//Convert to seconds
  MaxRate[k]=1.0/MaxRate[k];//Convert to rate.
}

//Parameters for Ivlev functions controlling food dependence
//
//   R=a*(1-exp(-b*(food-c)))--development rate (days^-1)
//
// But, idea is that temp sets max growth rate, and food tells us how close
// we get to the max. In this sense, a=1 (Campbell figured an absolute
// rate, we're essentially normalizing his rates by rate at 40c.
//
//b=[ones(1,6)*params.bnaup,ones(1,6)*params.btop];

for(k=0;k<6;k++)
  Rfood[k]=[1.-exp(-[F[j]-c]*params.bnaup)];
for(k=6;k<12;k++)
  Rfood[k]=[1.-exp(-[F[j]-c]*params.btop)];

//Multiply Rfood by MaxRate to get the actual rate.
for(k=0;k<12;k++)
  R[k]=MaxRate[k]*Rfood[k];

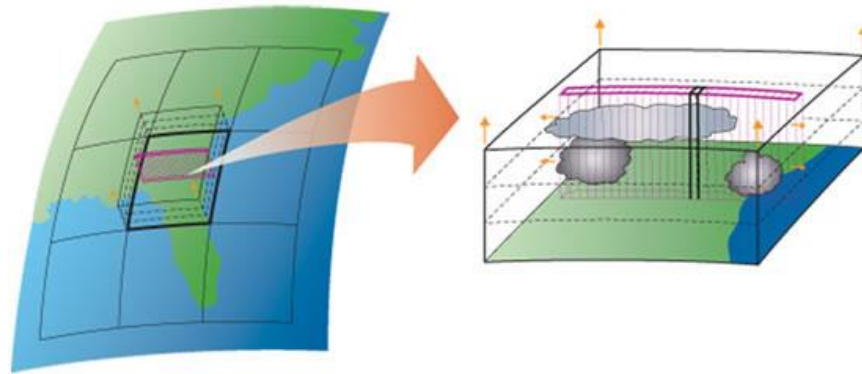
R[12]=0.;//adults don't molt

//M(k)=mortality rate for stage k at node j
//
gammaT=gamma0*(1.-gamma0)+pow(T[j]/Tc,z);
//gammaT=0.1; //Override temp dependent mortality
```

Numerical modeling

■ Issue

- Digitization (physical variable is continuous, but computer needs digitization”)
 - ✓ Resolution, subgrid-scale parameterization



- Unknown processes, tunable parameters
- Initialization (for forecasting)

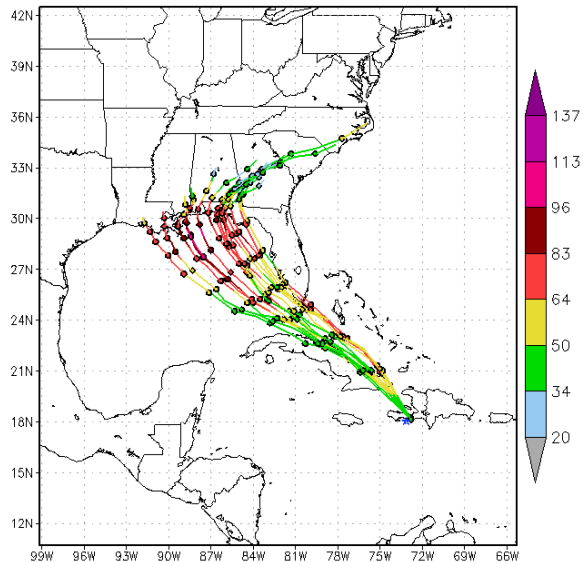
NO perfect GCM

NOT the same with NATURE

Ensemble Forecasting

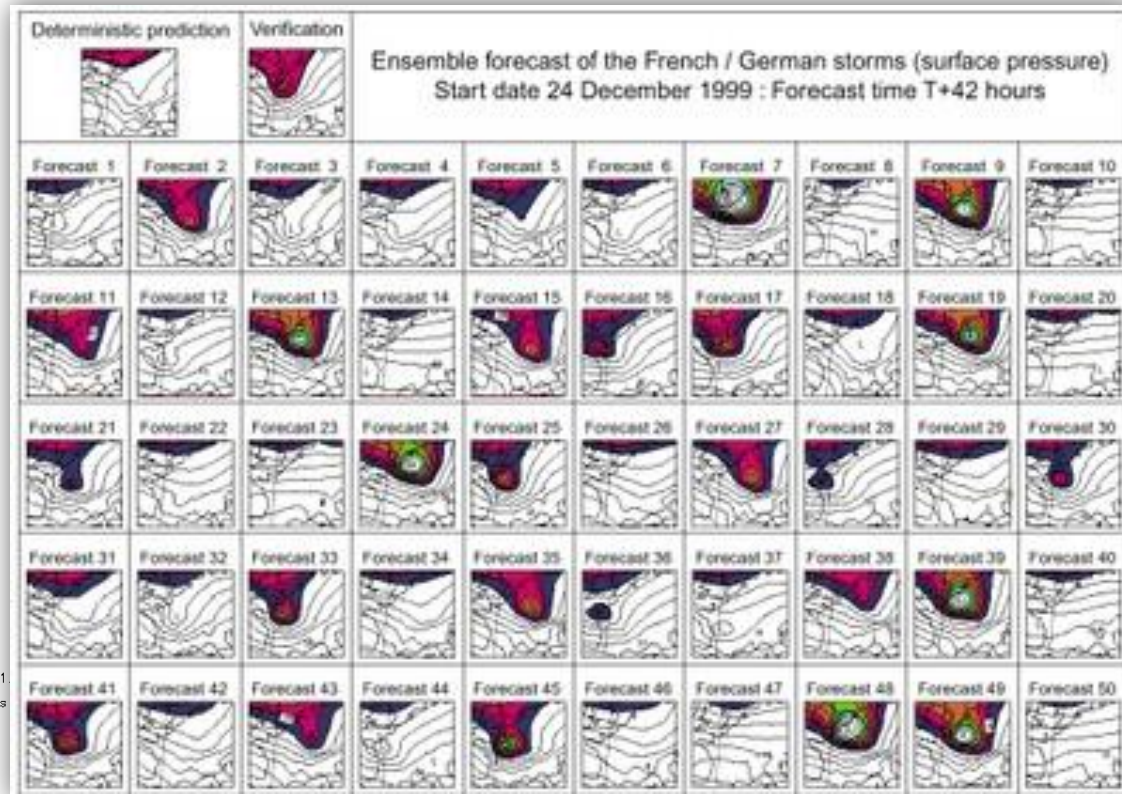
- Run many times
 - Starts from slightly different initial conditions

6-hourly Track and Intensity (kt) for ISAAC09L
GFDL ensemble forecast for the 126 hrs from 06Z25AUG2012



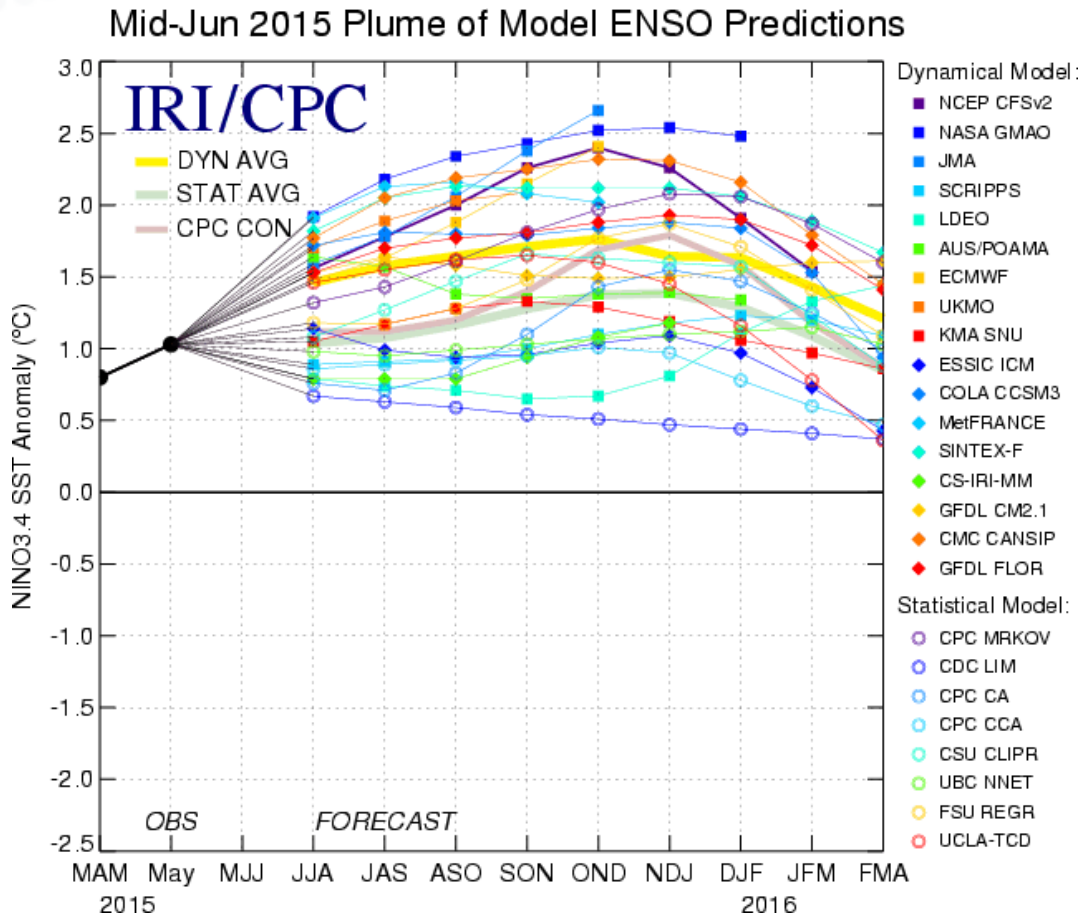
missing members (out of 16) at t=0: 0
indicates ISAAC09L observed center at initial time

Track forecast positions are marked every 1
GFDL Hurricane Dynamics



Multi Model Ensemble Forecasting

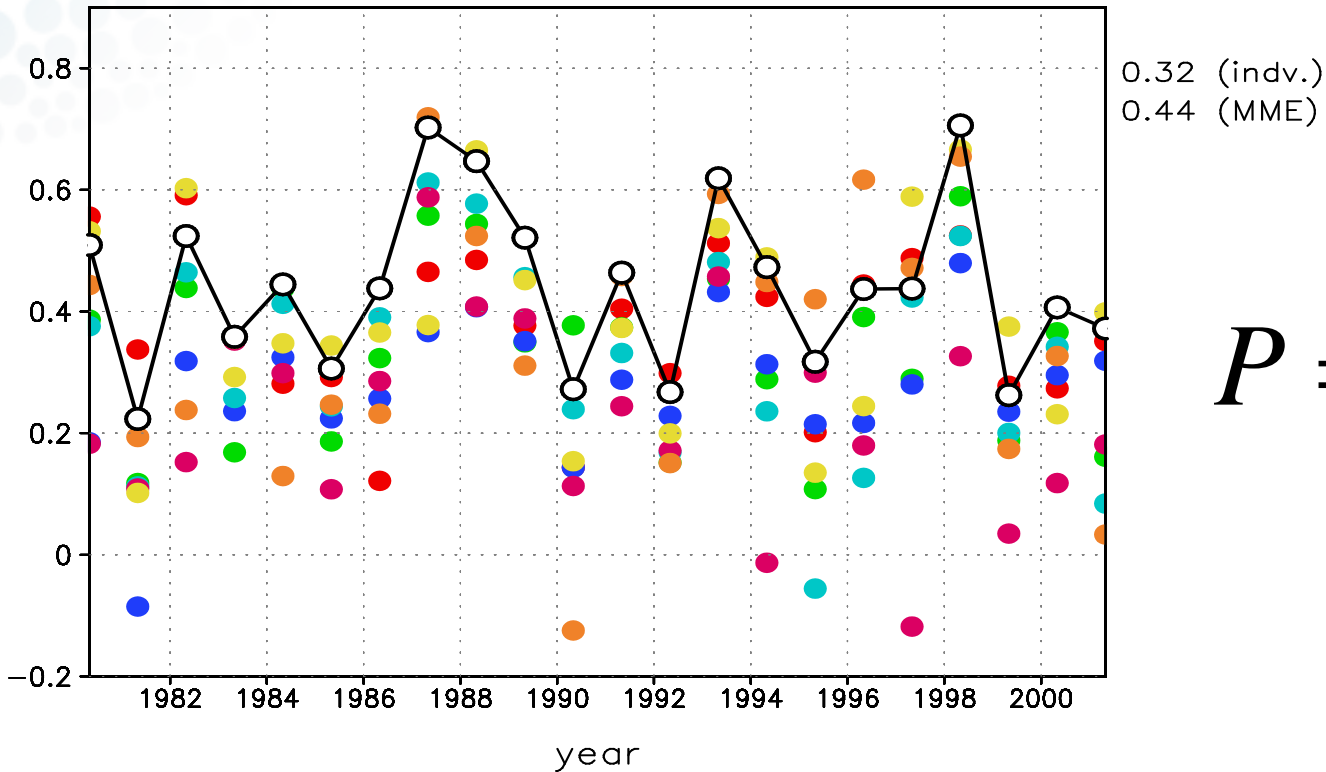
- Run with many models



Which one??

Use all!

Pattern correlation : summer monsoon precip.



$$P = \sum_i a_i F_i$$

A way to **reduce prediction uncertainties** generated when any single model is selected (to avoid extremely wrong forecast), in the end, to **improve overall prediction skill** (global sense)

APCC MME Climate Prediction Information

Seasonal outlook (global & Pacific)

Climate Outlook for May- October 2017

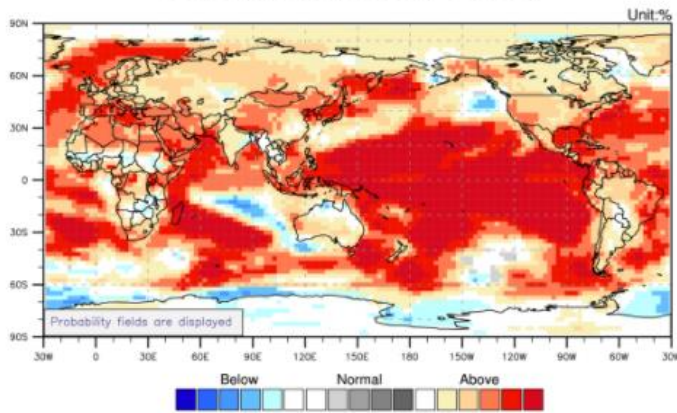
BUSAN, 25 April 2017 – Synthesis of the latest model forecasts for May to October 2017 (MJJASO) at the APEC Climate Center (APCC), located in Busan, Korea, indicates persistent positive temperature anomaly across the tropical Pacific with the positive El Niño-Southern Oscillation (ENSO) phase. The forecast for the whole period shows a warm tendency over the most part of Eurasia and North and South America. Above normal temperature is highly probable over the tropical Pacific, eastern subtropical South Pacific, the western and southern Indian Ocean, and the Barents Sea. For the same period, below and near normal rainfalls are probable over the Great Australian Bight and the central Pacific, respectively. The forecast for MJJ 2017 suggests a negative temperature anomaly over the northeastern Pacific and the central Indian Ocean. Below normal rainfalls are highly probable for the central Indian Ocean. The forecast for ASO 2017 shows dry conditions over the maritime continent and the Caribbean Sea.

Temperature and Precipitation Outlook:

1. Forecast for May- July 2017

Strongly enhanced probability for above normal temperature is predicted for the tropical and subtropical Pacific and Atlantic, the Barents Sea, the Norwegian Sea, the Bering Sea, the Sea of Okhotsk, the Arabian Sea, the Bay of Bengal, the western and southern Indian Ocean including Madagascar, the Mediterranean Sea, the Gulf of Mexico, and the Caribbean Sea. Enhanced probability for above normal temperature is predicted for the eastern Indian Ocean, the maritime continent, Mongolia, the western and northeastern China, the Middle East, and northern Africa. A warm tendency is expected for the Arctic, Greenland, most of Eurasia, and North and South America. Enhanced probability for below normal temperature is predicted for the northeastern North Pacific and the central Indian Ocean. Enhanced probability for above normal precipitation is predicted for the southern Philippine Sea, central Africa, and southern South America. Strongly enhanced probability for below normal precipitation is predicted for the central Indian Ocean and the Great Australian Bight. Enhanced probability for below normal precipitation is predicted for the eastern Indian Ocean, Australia, the northern Philippine Sea, and the central off-equatorial North Pacific. Precipitation in the central and eastern equatorial Pacific, the Middle East, and the northern and southern Africa is predicted to be near normal.

Temperature at 2m for May-July 2017



ENSO & IOD prediction

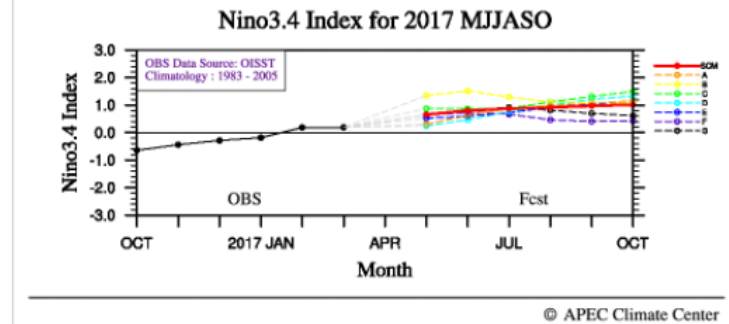
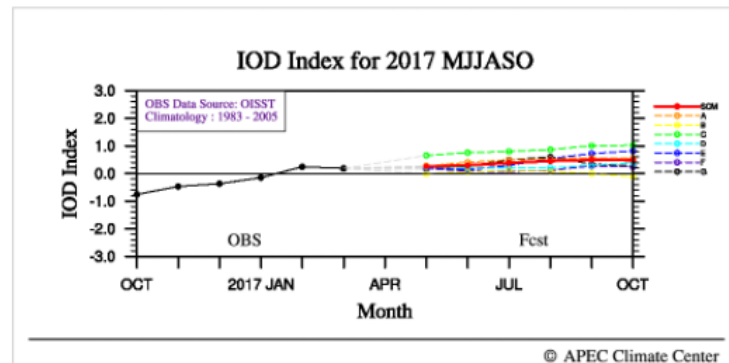
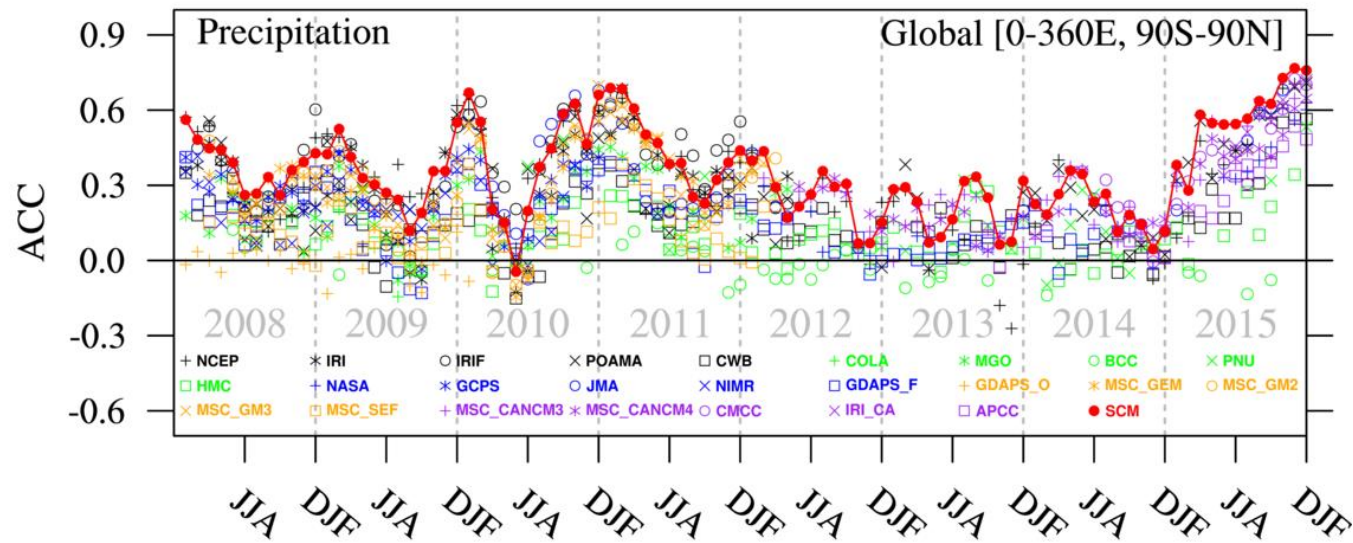


Fig. 1. Predicted Niño 3.4 Index from individual models (A, B, C, D, E, F and G) and the simple composite Multi-Model Ensemble (MME) method (SCM).



What APCC has achieved!

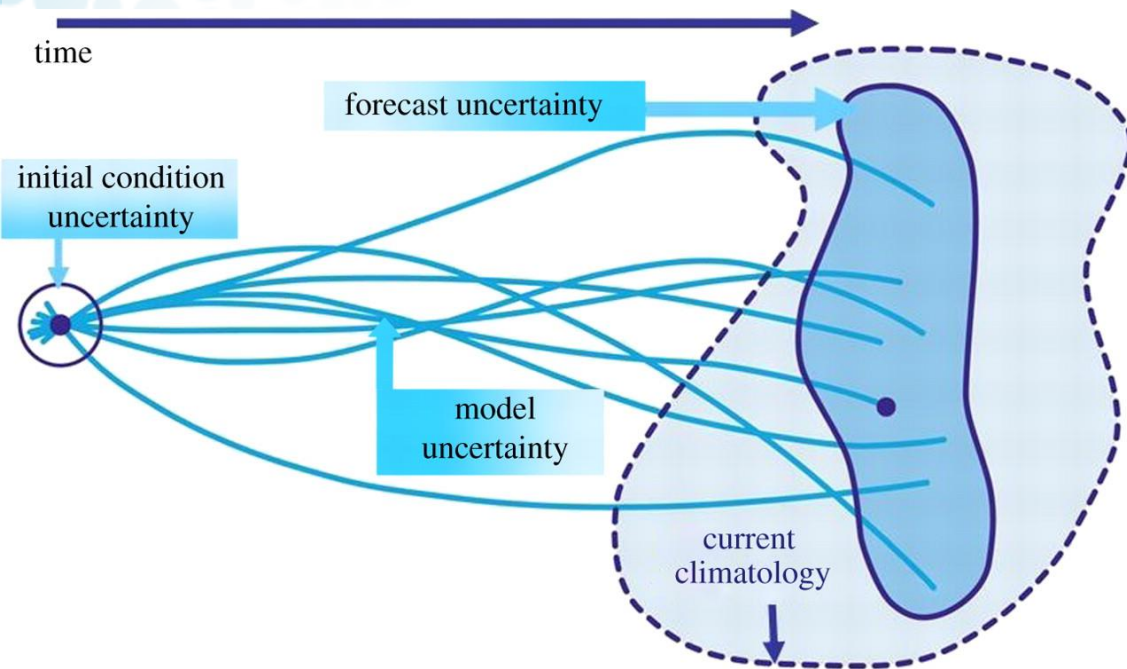


Realtime **rainfall** forecast for last 4 years (12-15)

	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

ROC score : Perfect = 1, Meaningless(no skill) = 0.5

Uncertainty in climate prediction



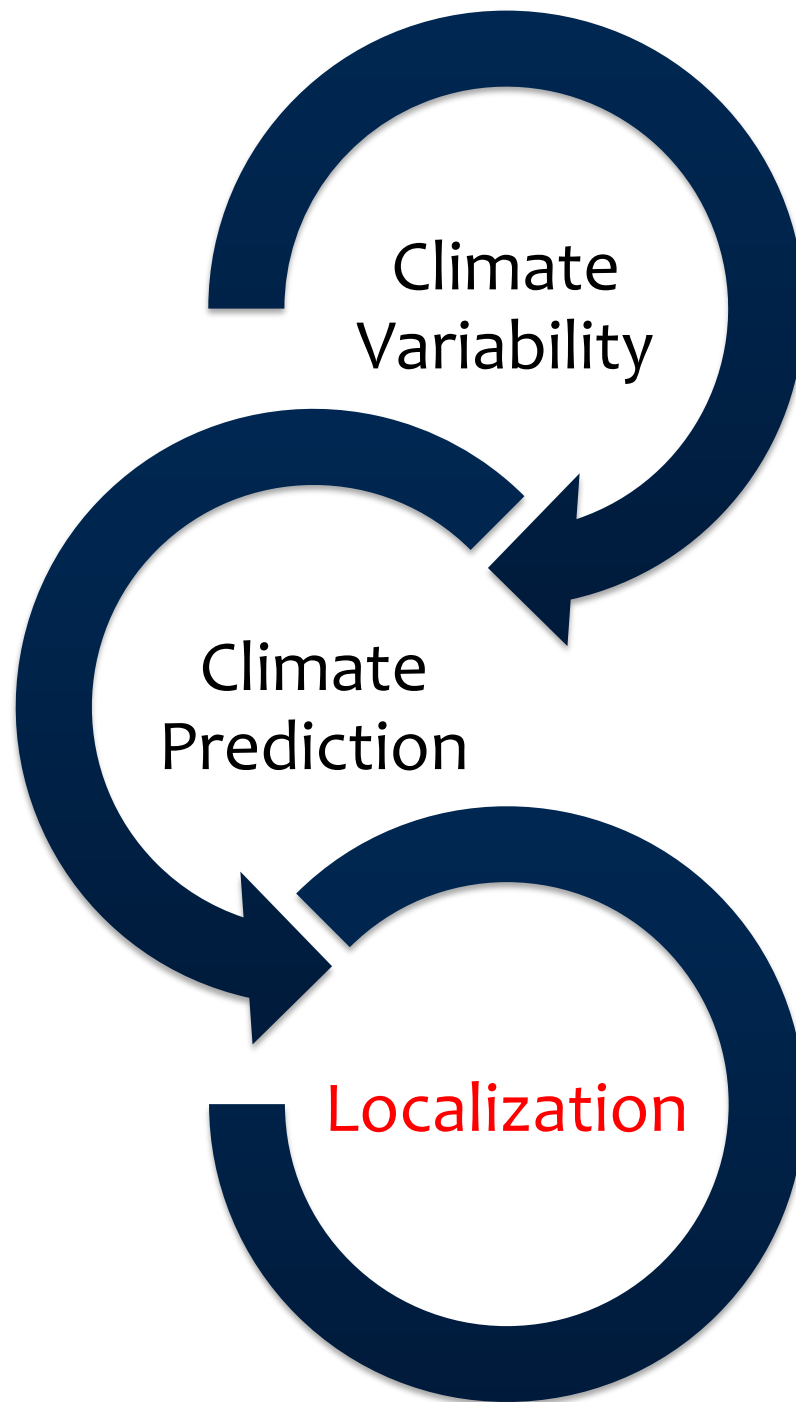
A long way to go...



Slingo, Julia, and Tim Palmer. "Uncertainty in weather and climate prediction." *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* 369.1956 (2011): 4751-4767.

**Even with MME, still many region in the world, prediction skill is very low...
Any room for further improvement?**

Further actions required/requested!



Climate/weather related disasters

5. Jan. 13 — Flooding in the capital



Flood

Indonesia landslide: 20 dead and dozens still missing

14 December 2014 | Asia

Landslide



Strong wind



Rescuers, including local residents, are still hoping to find survivors

2015 Drought in Thailand

<http://monsoon.yale.edu/thailand-drought-leaves-lasting-effects-even-as-rainy-season-begins/>

TIME | World

SEARCH SIGN IN SUBS



THAILAND

Thailand is Suffering From The Worst Drought in Decades

Helen Regan
Jul 16, 2015



Thailand is experiencing the worst drought in decades, with seven out of 67 provinces affected and water rationing taking place in almost a third of the country.

Thailand's Irrigation Department said that the amount of usable water in dams across the country, except in the West, have **dwindled** to below 10 percent and in the capital Bangkok tap water production

<http://time.com/3960462/thailand-drought/>



Water reserves run low in Thailand's Lamtakong Dam.



Dario Pignatelli | Bloomberg | Getty Images

Farmer Pramote Kongburi inspects his dried rice field in Praek Siracha, Chainat province, Thailand, on July 3, 2015.

2015 Drought in Thailand :during prolonged El Nino

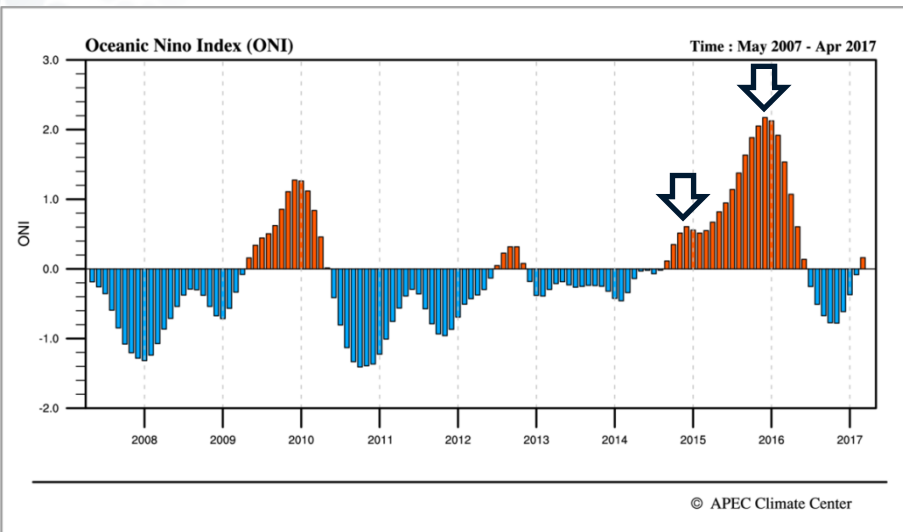
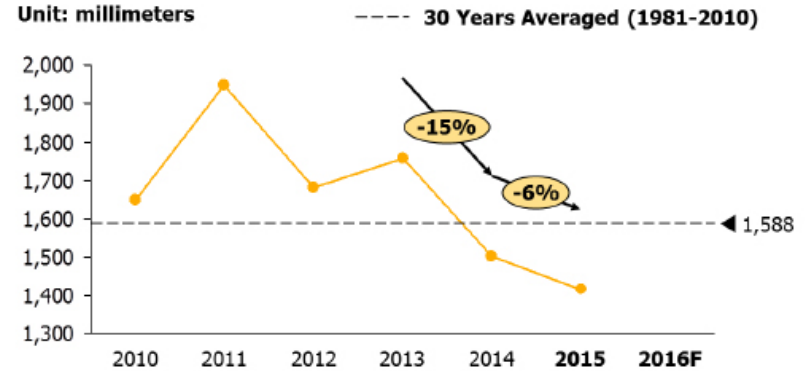
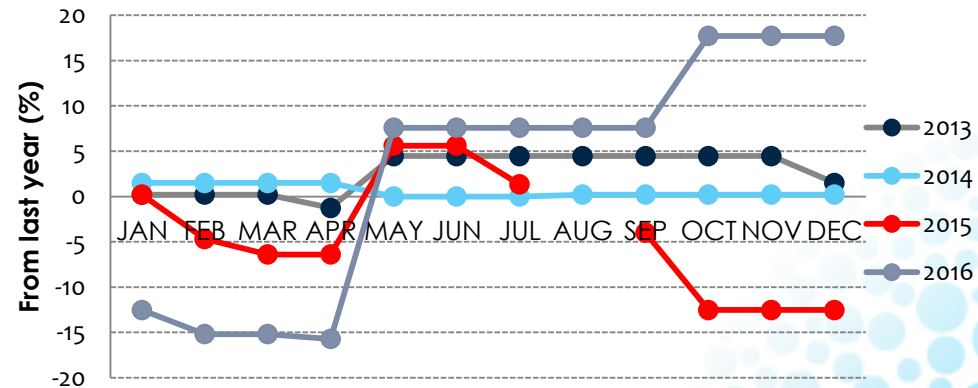


Figure 1: Cumulated rainfall in Thailand between 2010 and 2015



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

Rice: Change in production



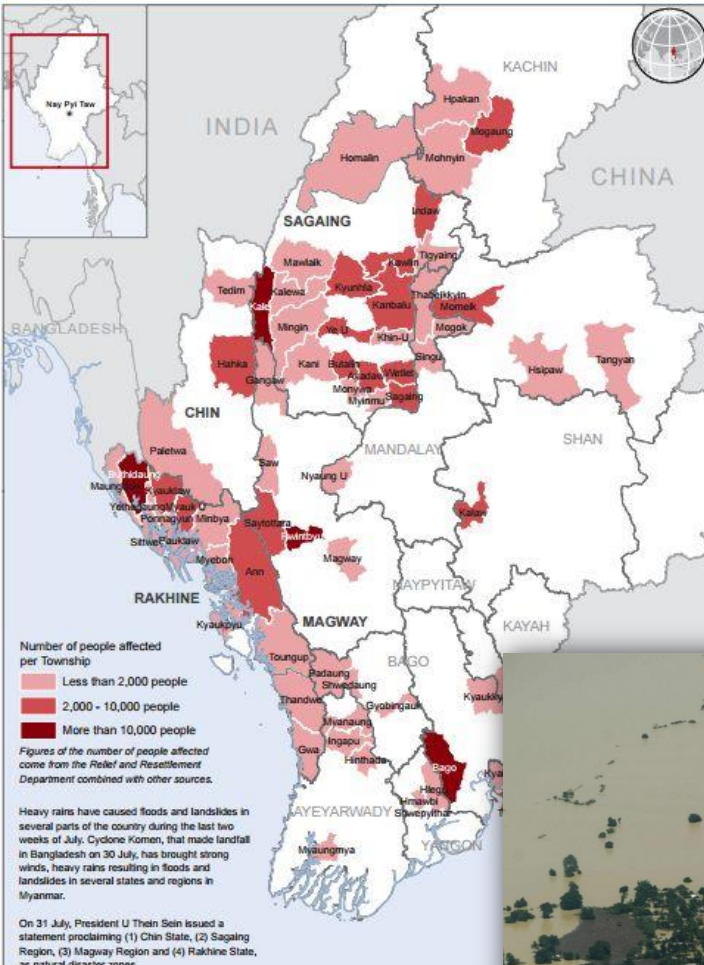
Source: USDA World Agricultural Production

2015 Myanmar Flood

:the worst for decades

MYANMAR: Flood Affected Areas (3 Aug 2015)

OCHA



Beginning on 16 July 2015, **unusually heavy monsoon** rain fell on Myanmar, causing rivers and creeks to overflow with rainwater and flooding low-lying areas around waterways. In addition to the higher-than-average rainfall, ... **deforestation caused by logging** ~ **Cyclone Komen**, which struck in late July, also made the situation worse.

https://en.wikipedia.org/wiki/2015_Myanmar_floods



2016 Drought in Southeast Asia

Cambodia faces severe and prolonged drought

POSTED ON: March 23, 2016 | CAMBODIA - CURRENT AFFAIRS - FEATURED | By: Daniel Besant

Experts say that this year's drought will be worse than in 2015, with soaring temperatures and a delayed monsoon season likely

Cambodia is officially in a drought, and the conditions could last longer and be more severe than last year, when monsoon rains did not fall until July.



On the banks of the Mekong River in Cambodia's Kandal Province. Photo: EPA/Mak Remissa

"Based on our monitoring, drought has been detected in Cambodia," said the Mekong River Commission (MRC) Secretariat. "The current drought in Cambodia since March 2016 could be at least as severe as last year, and is likely to be getting worse in coming months."

Last year, according to the MRC, the monsoon season was delayed until July. A similar delay is expected this year, with rains due in May, until as late as August.

Schools face water shortages and government says entire nation is affected as rainy season is forecast to be delayed by months



7 photos: Children are among hardest hit by El Nino-related drought in Cambodia

Indonesia wildfire

:97/98, 2013, 2015 dry season

The Asian Forest Fires of 1997-1998

From October through November 1997, fires in Indonesia and the resulting haze made front-page news around the world. The fires spread from the north, Sri Lanka to the west to the east, and from Southeast Asian "tiger" economies to the west. The fires burned millions of miles of rainforest, plantations, and agricultural land in Sumatra, Sulawesi, Irian Jaya, and Kalimantan in Indonesia, Malaysia, and the Philippines. Though official government figures estimate that 750,000 ha (1,875,000 acres) of forest were destroyed, environmental groups like WAHLI (the Indonesian Environmental Action Group) estimate that 1,714,000 ha (4,240,000 acres) went up in smoke. The 1997-1998 haze alone in 1998 range from 445,000 to 1,112,500 ha (1,112,500 to 2,775,000 acres). Regardless of the extent of the fires, the resulting haze caused health problems and economic damage.

<https://rainforests.mongabay.com/>



https://www.google.co.kr/search?q=indonesia+wildfire+1997&source=lnms&tbn=isch&sa=X&ved=0ahUKEwigoOGUhqrcAhUJFogKHTaIBeEQ_AUICigB&biw=1745&bih=861#imgdii=DA3nBYrF9rmWdM:&imgsrc=ELAMGJFKU97fPM:

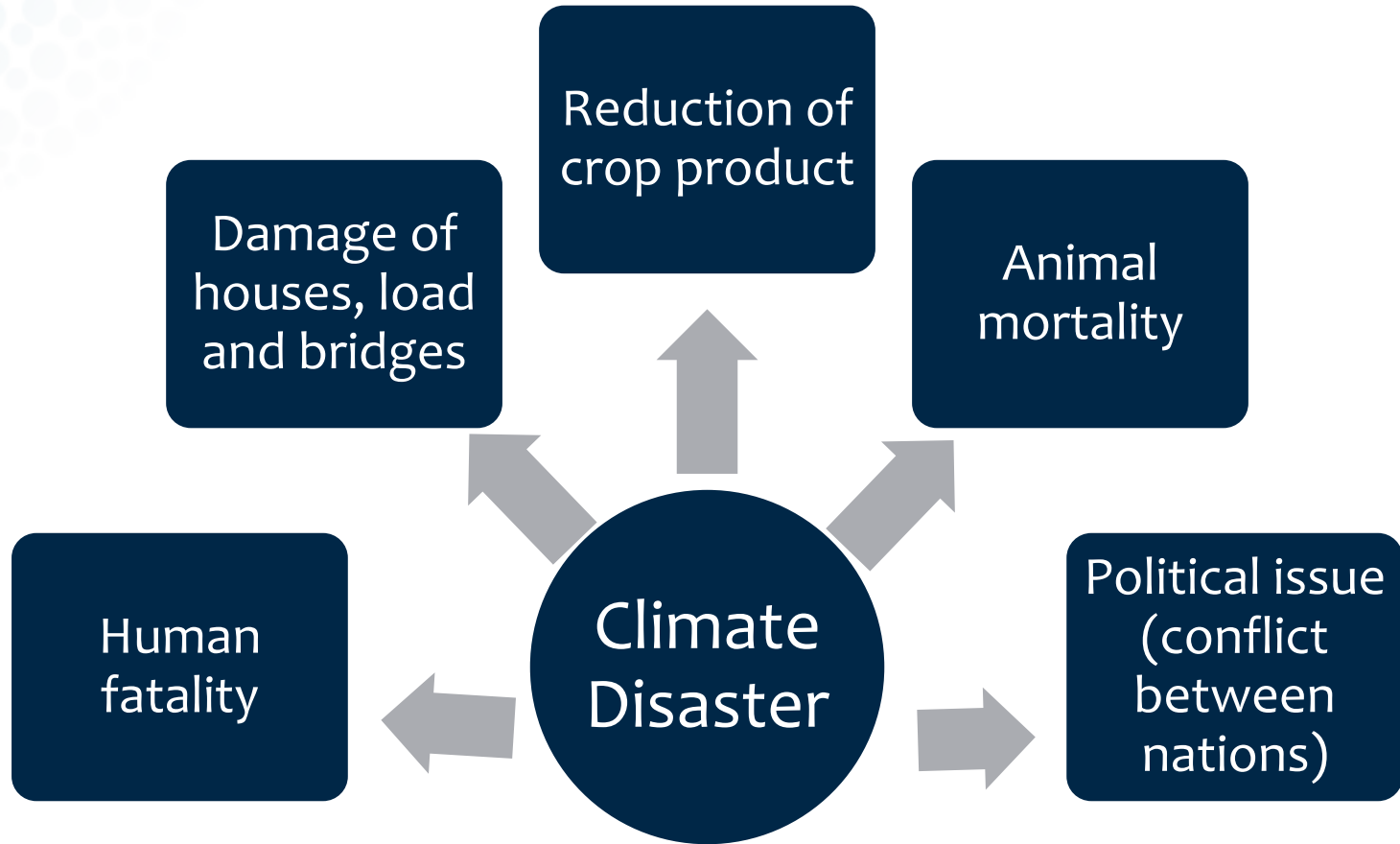


https://en.wikipedia.org/wiki/1997_Indonesian_forest_fires



https://www.google.co.kr/search?q=indonesia+wildfire+1997&source=lnms&tbn=isch&sa=X&ved=0ahUKEwigoOGUhqrcAhUJFogKHTaIBeEQ_AUICigB&biw=1745&bih=861#imgsrc=2OnzANCTqgpQcM:

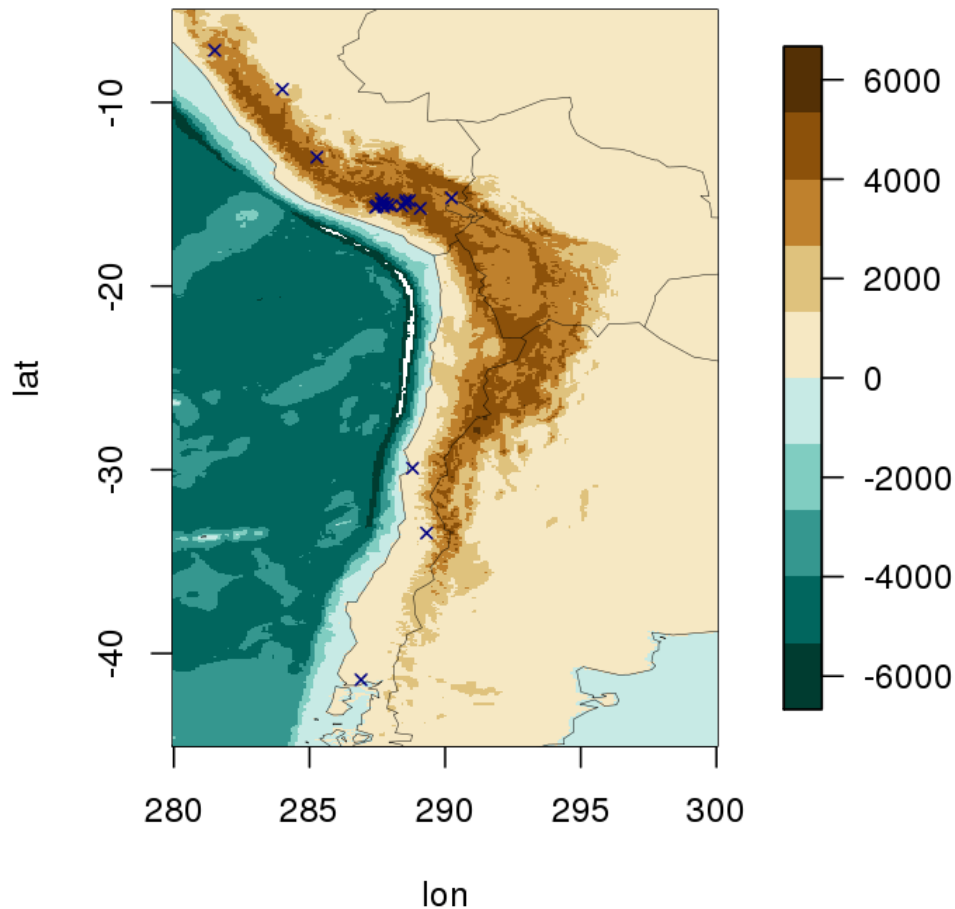
Importance of “Accurate” prediction



ACCURATE climate prediction optimized to your region (city) will make early warning possible and reduce economic and human losses.

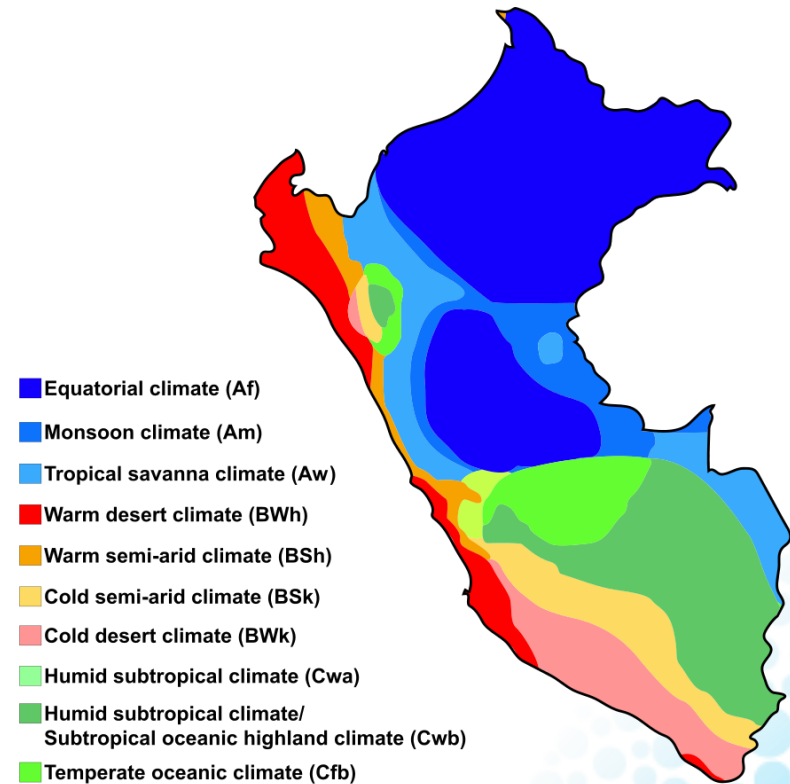
Climate Locality

20 stations (Peru + Chile)



- Complicate climate of Peru

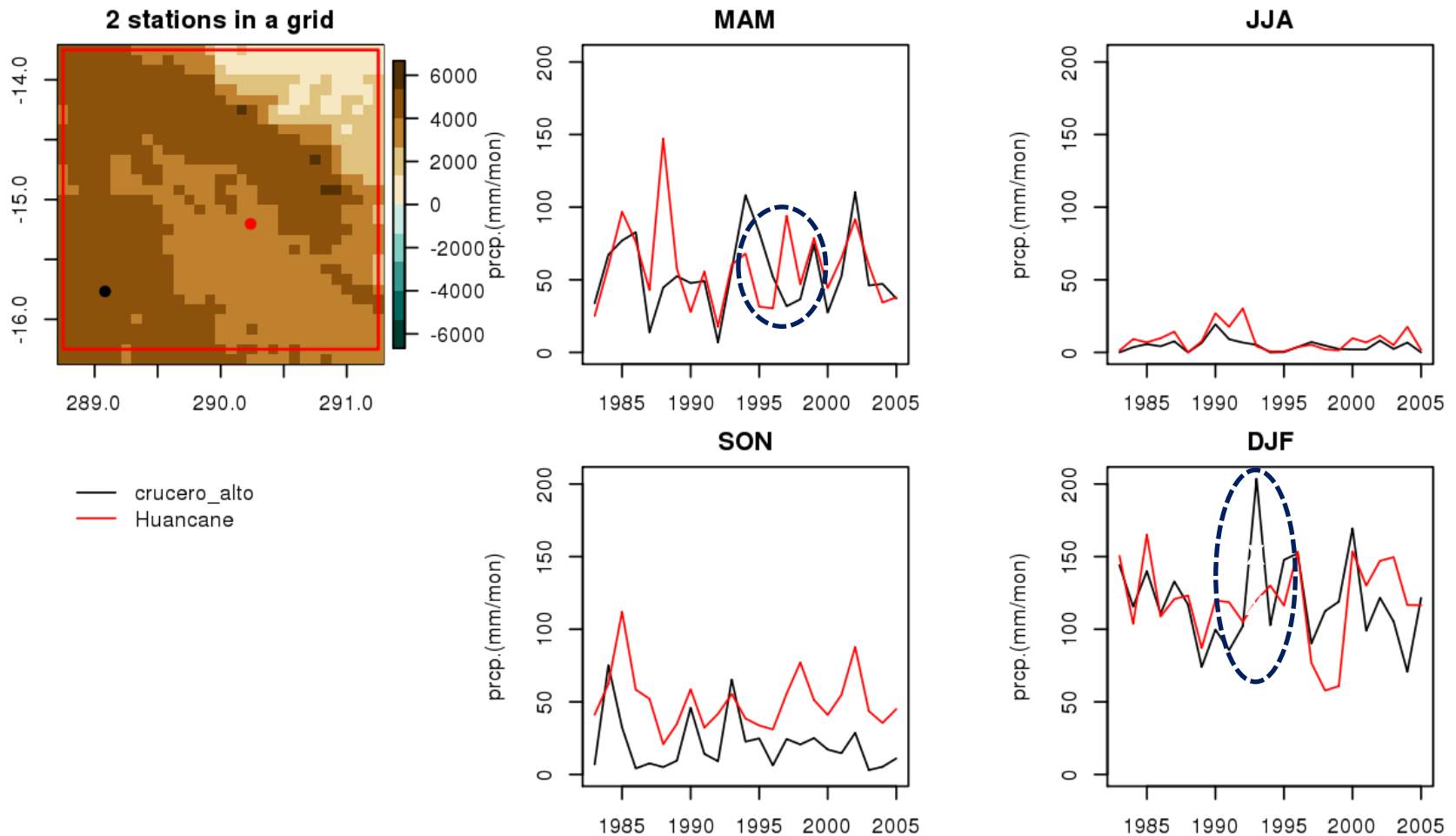
Peru map of Köppen climate classification



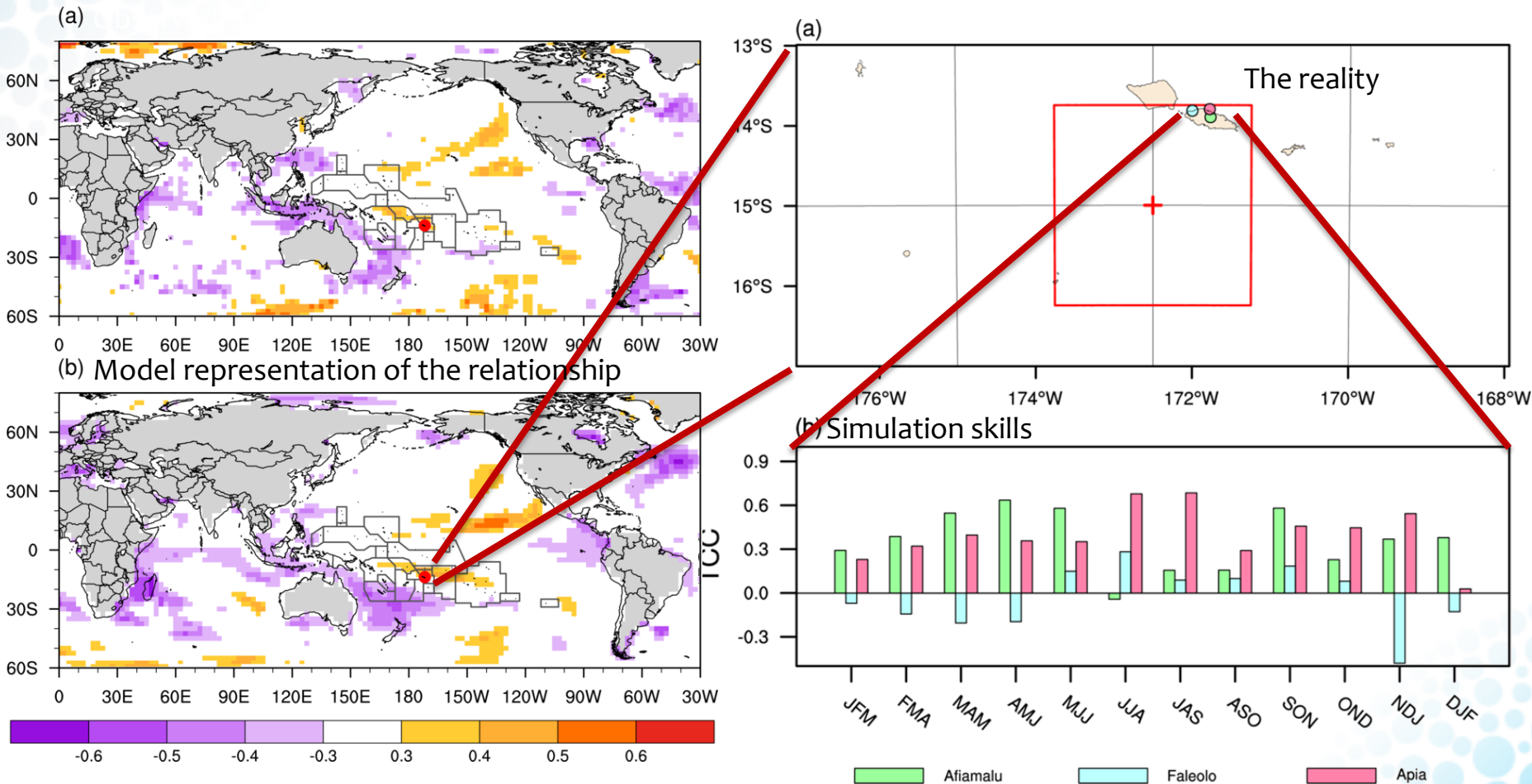
Mountain Climate

How different is the climate between 2 adjacent stations **in the east of Arequipa?**
But, they are in one grid! OMG!!!

East of Arequipa [290, -15]

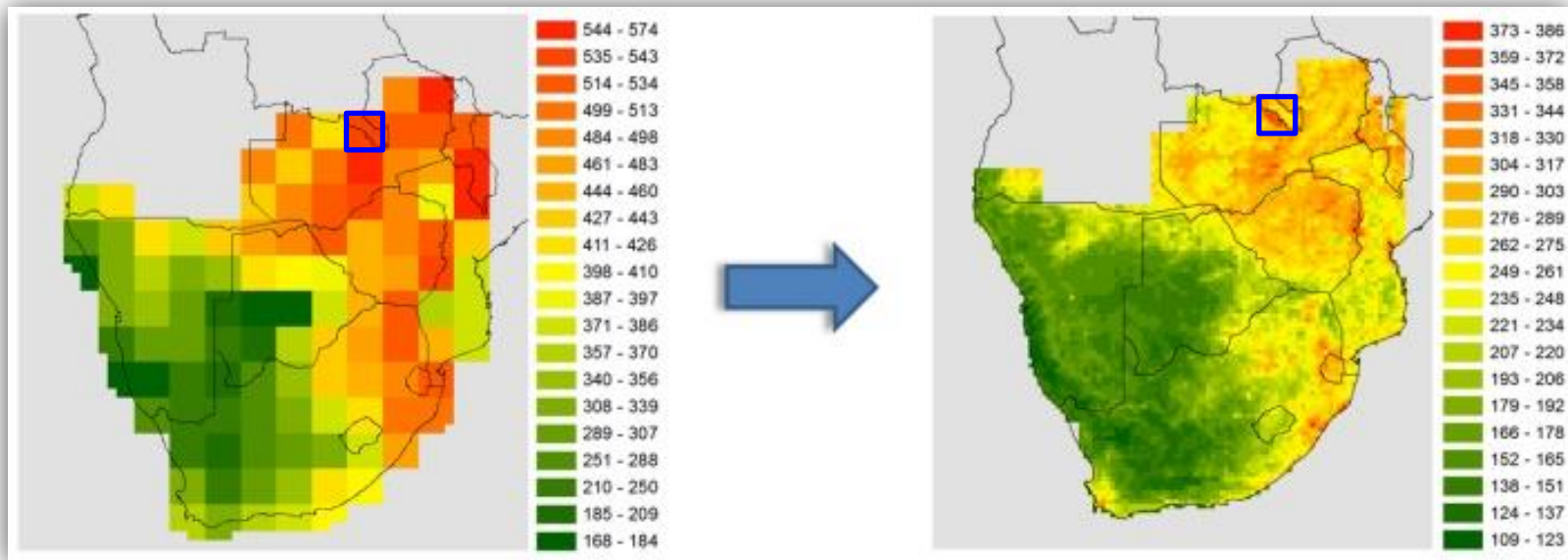


Island Climate



✓ Can 2.5 by 2.5 grided model correctly simulate *mountain/island climate* therefore tell *local climates between adjacent stations*? Not really.

Look inside!

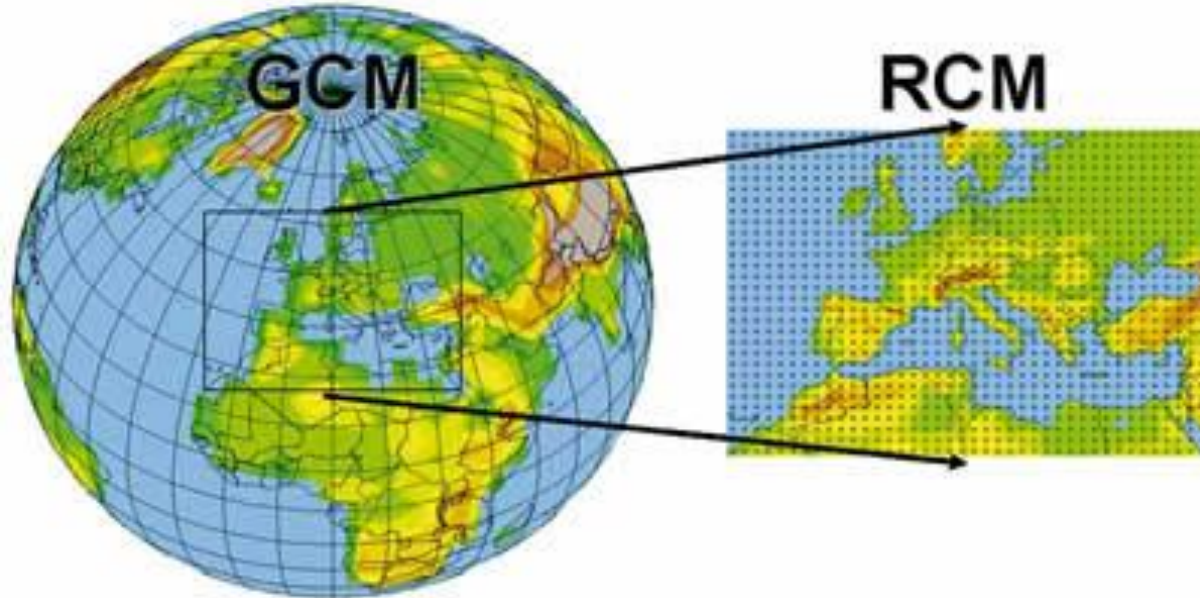




POST-PROCESSING /DOWNSCALING!

**=OPTIMIZATION/LOCALIZATION/CUSTOMIZ
ATION OF CLIMATE INFORMATION**

Dynamical downscaling



- Simply, it is running a regional climate model (**RCM**).

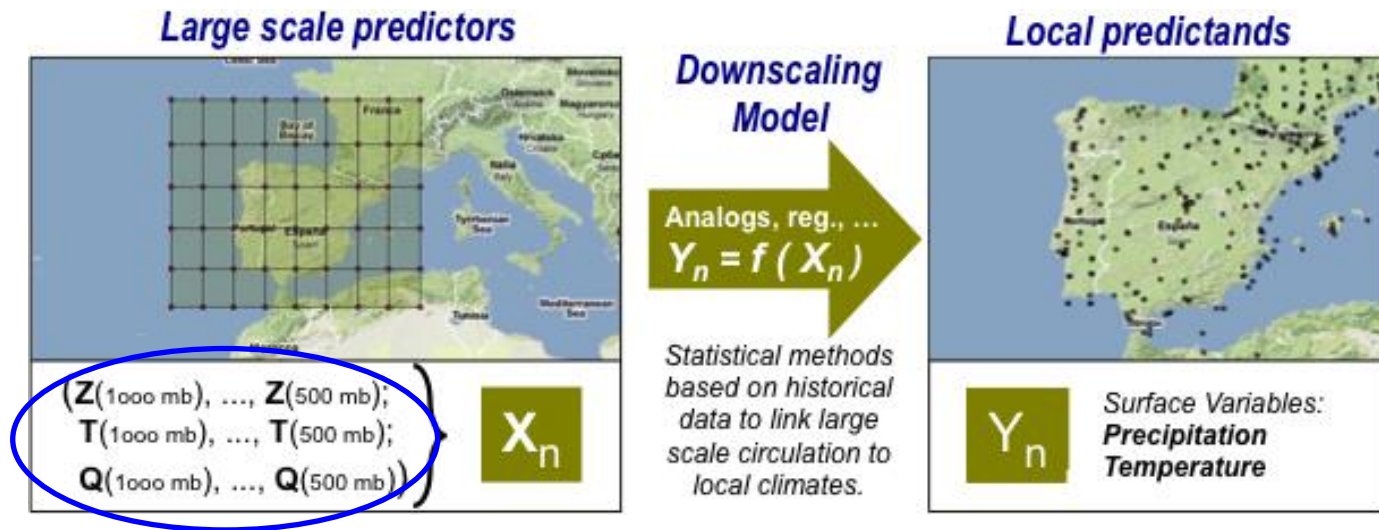
- BC from GCM, IC \rightarrow solving dynamic equations!

- 1 month computing time for 1 month prediction ?



Empirical-statistical downscaling

- Based on empirical relationship between **precipitation/temperature** at particular stations and **in-situ/remote large scale Atmospheric/Oceanic condition**
- Developing simple downscaling model (regression)



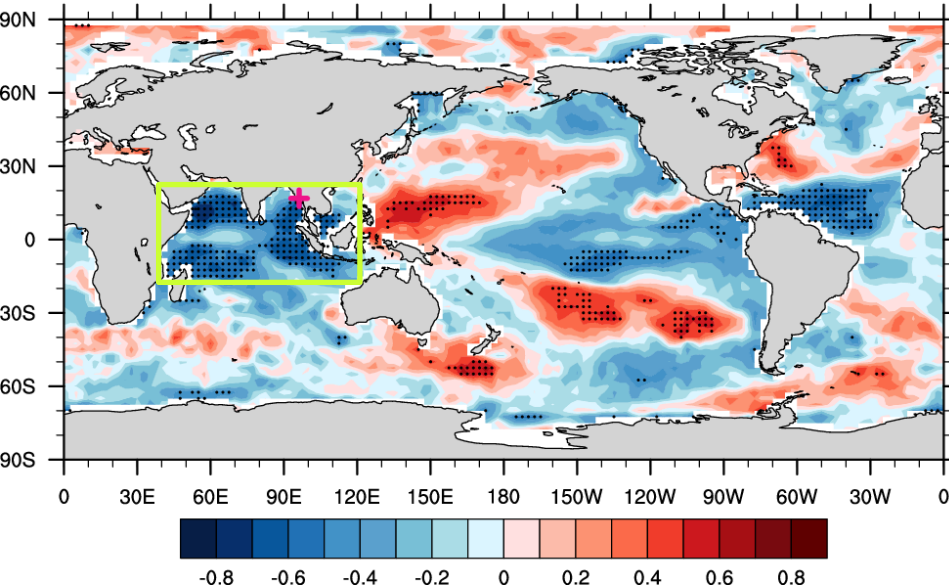
Station to LSMP relationship

Western Southeast Asia

OBS (Reanalysis)

sst vs. prec over Yangon

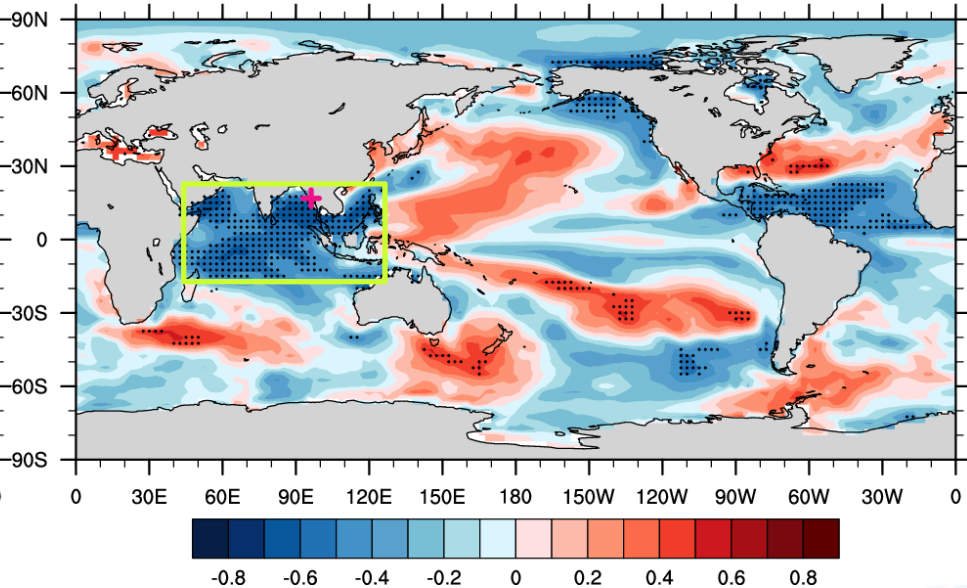
MJJ



Model (SCM)

sst (scm) vs. prec over Yangon

MJJ



Indian Ocean Basin-wide Cooling:

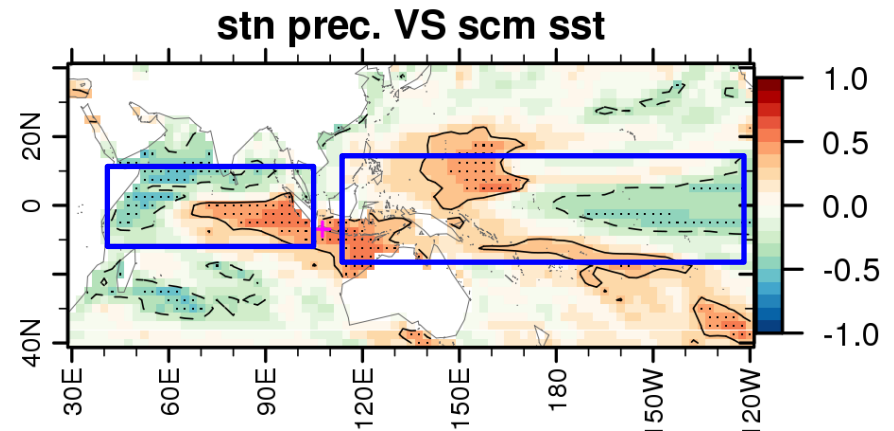
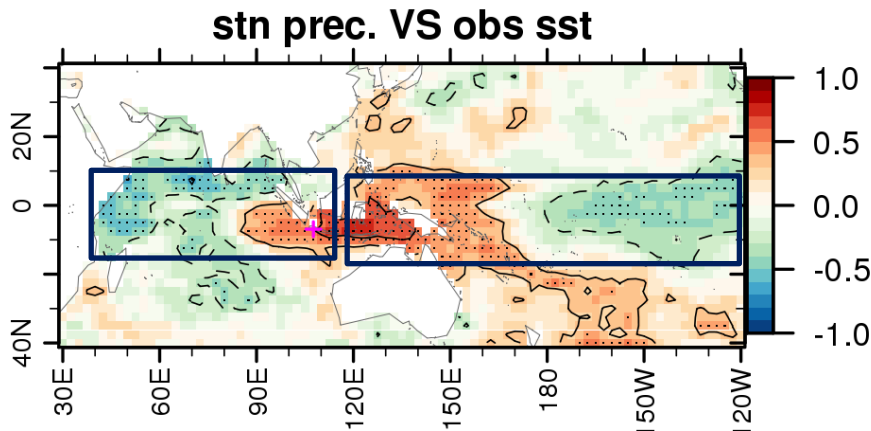
SST ↓ → Yangon rain ↑

SST ↑ → Yangon rain ↓

Station to LSMP relationship

Maritime Continent: Indonesia

SON [Jakarta]



La Niña (and negative IOD) signature

Indian Ocean Dipole:

Cold West Warm East → Jakarta rain ↑

Warm West Cold East → Jakarta rain ↓

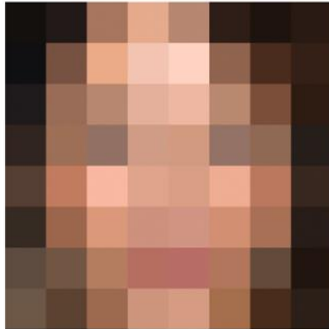
Pacific ENSO:

La Niña → Jakarta rain ↑

El Niño → Jakarta rain ↓

Google uses AI to sharpen low-res images

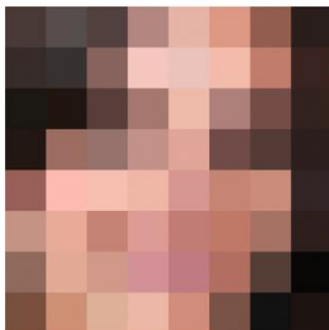
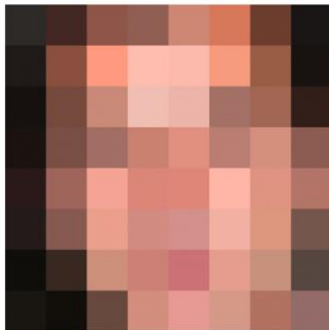
8×8 input



32×32 samples



ground truth



APCC Downscaling Tools

✓ *In changing climate ...*

: increase of climate related disasters

✓ *The gaps...*

: low dynamical prediction skill, coarse model resolution but climate locality, limited human and material resources

✓ *The needs...*

: prediction of next season climate in local community (e.g. small islands)

✓ *What we have!*

: Prcp/temp station data (past) & coarse GCM data (past & future)

✓ *What we know!*

: past relationship (site – large scale field)



<http://clik.apcc21.org/>

&



<http://clikp.sprep.org/>

PICASO

Pacific Island Countries Advanced Seasonal Outlook

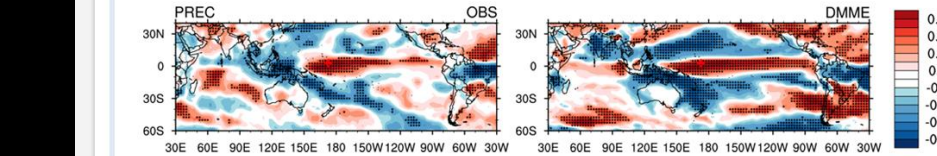
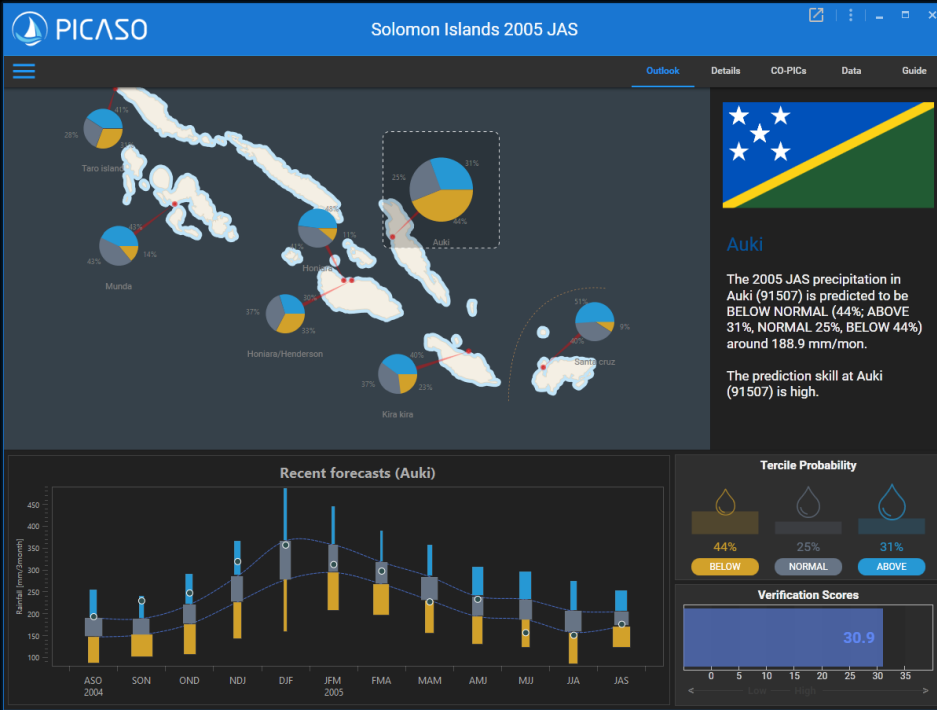


Figure 2. Temporal correlation coefficients (TCCs) between local precipitation of Butaritari(91601) and precipitation at each grid during the April - June (AMJ) for (left) observation and (right) DMME. The black dots indicate grid points for which TCC is significant at the 95% confidence level.

The large-scale oceanic and atmospheric signals associated with the local precipitation at Butaritari(91601) during April - June (AMJ) season are displayed in Figure 1 and 2. The dynamical seasonal prediction system (APCC-MME based PICASO) represents that the AMJ precipitation of Butaritari(91601) is well related to warm equatorial Pacific state (e.g., El Niño), and it can be best recognized by the predicted (MME) remote precipitation over the Western Pacific. Therefore, remote precipitation is selected as the internal predictor in PICASO.

Name	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ	TOTAL
HSS	0.14	0.2	0.14	0.57	0.5	0.03	0	0.32	0.14	0.28	0.09	0.11	0.21
LEPS	33%	35%	27%	31%	35%	22%	35%	20%	22%	38%	38%	23%	0%

Name	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2005	0/0	0/-	+/0	0/+	-/+	+/+	0/+	+/-	0/+	+/-	0/+	+/-
2004	0/+	0/+	0/0	0/0	0/0	0/+	0/+	0/+	0/+	0/0	0/+	+/-
2003	0/0	+/-	0/0	0/+	0/+	0/+	0/+	0/+	0/+	0/+	0/+	0/+
2002	0/0	0/+	0/0	0/0	0/+	0/+	0/0	0/+	0/0	0/0	0/+	0/+
2001	+/-	0/+	0/0	0/+	0/+	0/-	0/+	0/0	0/+	0/+	0/+	0/+
2000	+/-	0/0	+/-	+/-	0/+	+/-	0/0	0/-	0/-	0/-	0/+	0/+
1999	0/+	0/+	+/-	+/-	0/+	0/+	+/-	+/-	0/+	0/+	0/0	0/+
1998	0/0	0/0	0/+	0/0	0/0	0/0	0/+	0/+	0/0	0/0	0/0	0/+
1997	0/+	0/0	0/0	0/+	0/+	0/+	0/0	0/+	0/0	0/+	0/+	0/+
1996	0/+	0/+	0/+	0/0	0/+	0/+	0/+	0/0	0/+	0/+	0/+	0/+
1995	0/+	0/0	0/0	0/0	0/0	0/+	0/0	0/+	0/0	0/+	0/+	0/+
1994	0/0	+/-	+/-	0/0	0/0	0/+	+/-	0/0	0/+	0/0	0/0	0/+

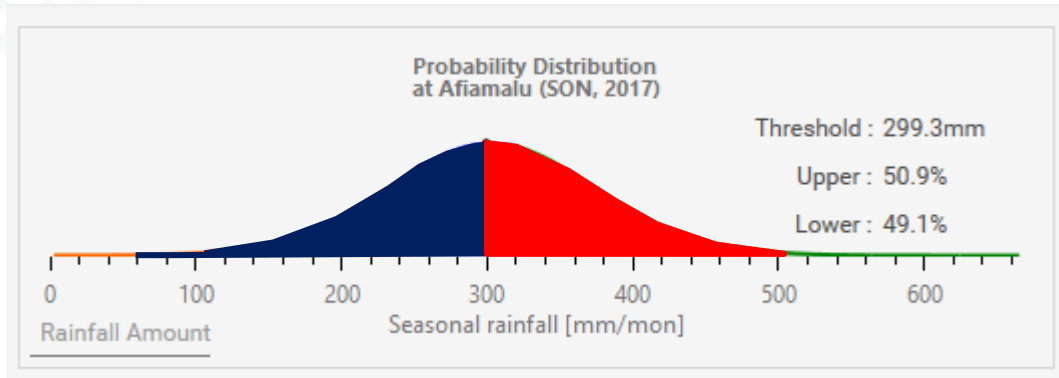
Name	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
HSS	0.14	0.2	0.14	0.57	0.5	0.03	0	0.32	0.14	0.28	0.09	0.11
LEPS	33%	35%	27%	31%	35%	22%	35%	20%	22%	38%	38%	23%

Name	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2016	0/0	0/-	+/0	0/+	-/+	+/+	0/+	+/-	0/+	+/-	0/+	+/-
2015	0/+	0/+	0/0	0/0	0/0	0/+	0/+	0/+	0/+	0/+	0/0	0/0
2014	0/0	+/-	0/0	0/+	0/+	0/+	0/+	0/+	0/+	0/+	0/+	0/+
2013	0/0	0/0	0/0	0/0	0/+	0/0	0/0	0/+	0/0	0/0	0/+	0/+
2012	+/-	0/+	0/0	0/+	0/+	0/0	0/0	0/+	0/0	0/+	0/+	0/+
2011	+/-	0/0	+/-	+/-	0/+	0/+	0/0	0/0	0/0	0/0	0/+	0/+
2010	0/+	0/+	+/-	+/-	0/0	0/+	0/+	0/+	0/+	0/+	0/0	0/0
2009	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
2008	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
2007	0/+	0/+	0/+	0/0	0/+	0/+	0/+	0/0	0/+	0/+	0/+	0/+
2006	0/+	0/0	0/0	0/0	0/0	0/+	0/0	0/+	0/0	0/0	0/0	0/+

PICASO > Probability Distribution

Interactive Probability Scale

Probability below/above specific criteria



**Chance of rainfall more than
299.3mm/mon during SON, 2017
= 50.9%**

**Chance of rainfall less than
299.3mm/mon during SON, 2017
= 49.1%**

- **Applicable to other sectors**

Water
resources
management

Disaster Risk
Reduction

Agricultural
planning

Nauru

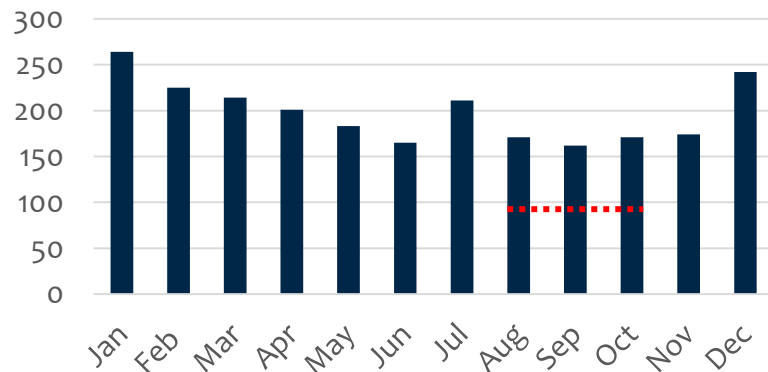
For the past decades, water security has been an issue!

- ✓ **Rainwater**: the principal source of water with more than 90% of the population
- ✓ No surface water
- ✓ Groundwater: brackish polluted

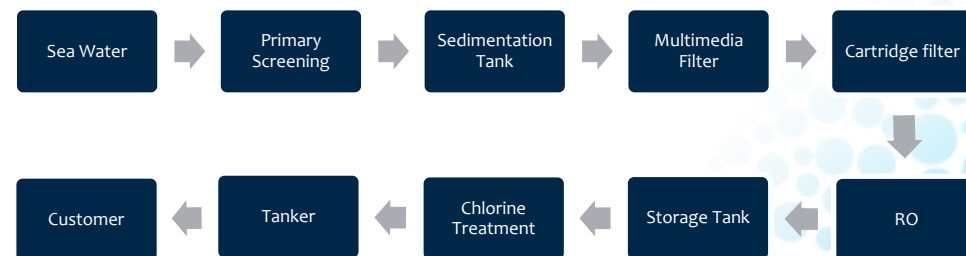
- ✓ **Drought periods are relatively frequent in Nauru.**



Rainfall Curve (mm)

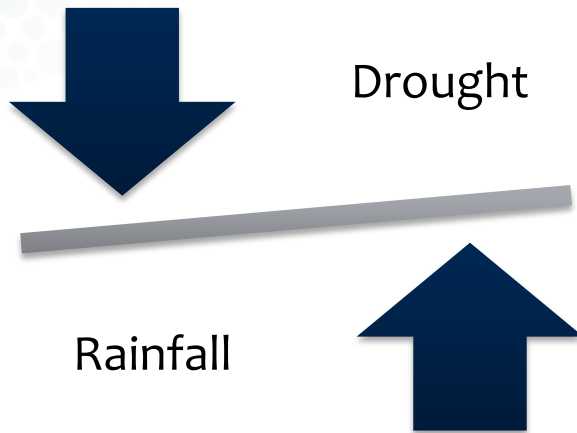


NUC Water Services Flow Chart



Tonga

Recharge to groundwater



Annual Rainfall: 1,770 mm
Potential Evaporation: 1,550 mm

Tonga Water Board (TWB)
: **water supply services** for domestic, stock, horticultural, industrial, commercial, recreational, environmental and other beneficial uses

TONGA'S FIRST COMMERCIAL CONSIGNMENT OF SQUASH PUMPKIN IS ON ITS WAY TO CHINA



(Radio & TV Tonga, Nuku'alofa, 28/11/2016)

The Chinese Government has approved the export of Tonga's squash pumpkin into its market.

This is seen as an initiative that could encourage more growers to go back to the plantations they abandoned during the past years due to falling prices in overseas markets.

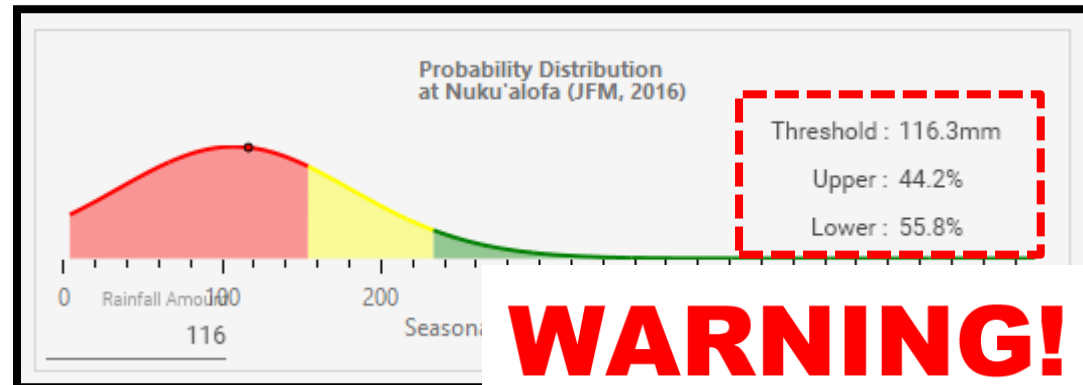
The CEO of Agriculture – Dr. Viliami Manu told Radio Tonga news, this is a result of an evaluation visit of a team from China's Quarantine Department to oversee the quality of squash pumpkin in Tonga.

<http://www.tonga-broadcasting.net/?p=3959>

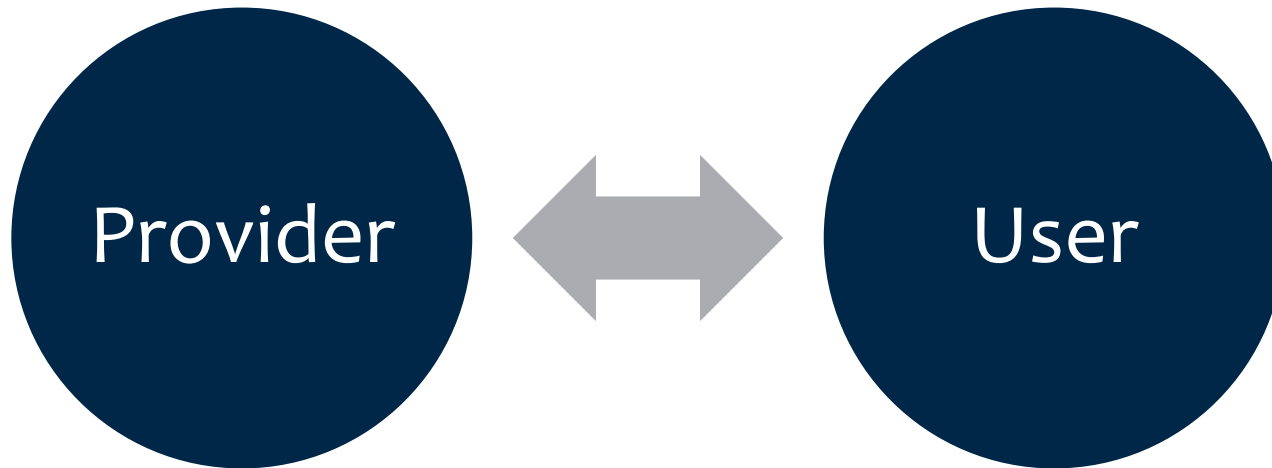
Watering

For good growth, squash and pumpkins require at least one inch of water per week. (One inch of water per thousand square feet is 620 gallons). If water is needed, irrigate thoroughly early in the morning until the soil is moistened eight to twelve inches deep. If rainfall is deficient, it may be necessary to water once a week, perhaps two times per week in sandy soils.

https://ag.umass.edu/sites/ag.umass.edu/files/fact-sheets/pdf/pumpkins_and_squash.pdf

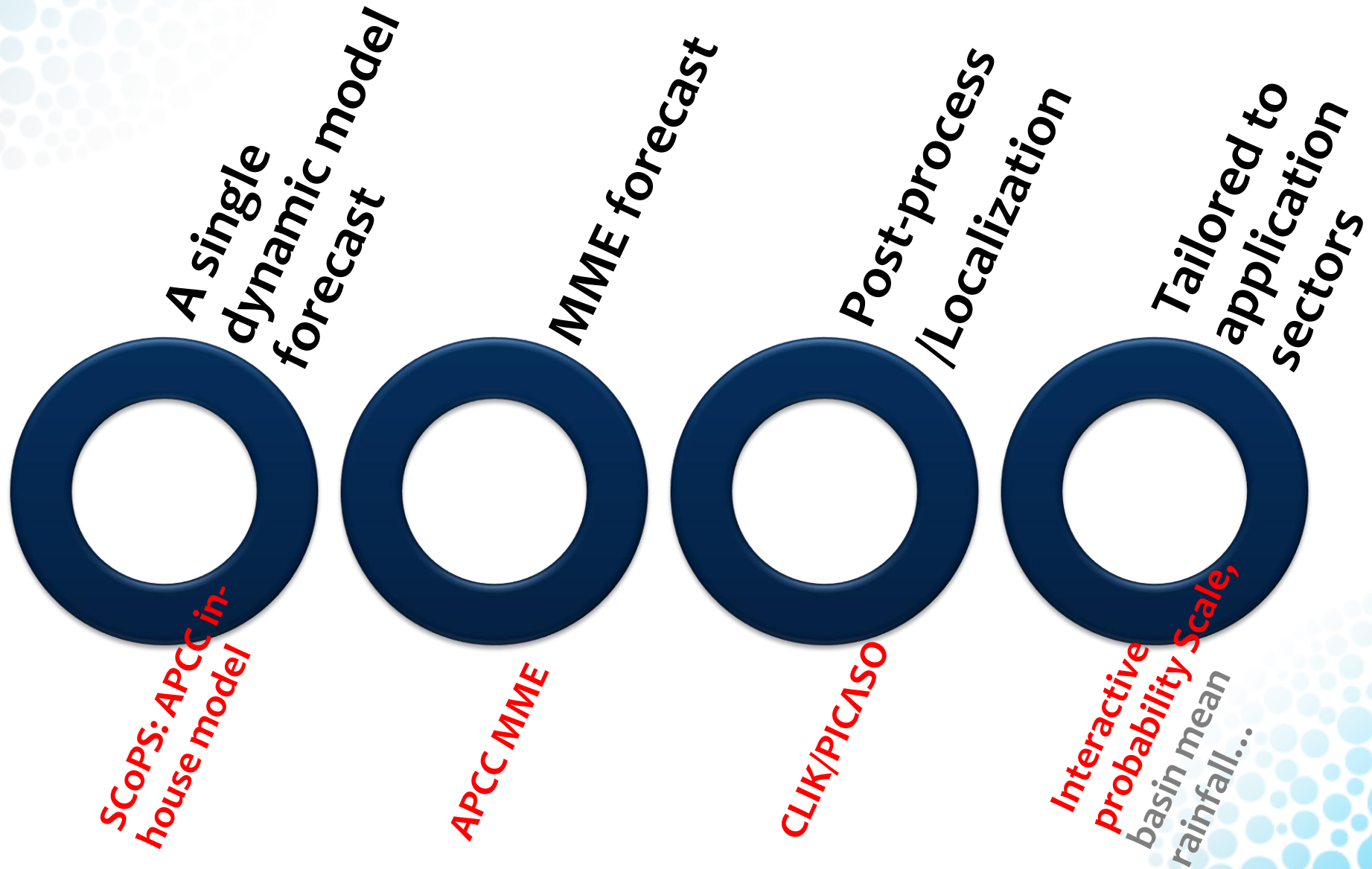


Fill the gap



Accuracy
Resolution
Contents

Climate Prediction Service Enhancement





Thank you