CLIK Training: June 7-9, 2017 (Bangkok, Thailand)
June 14-16, 2017 (Naypyitaw, Myanmar)

Lecture 4-1

Downscaling of seasonal prediction

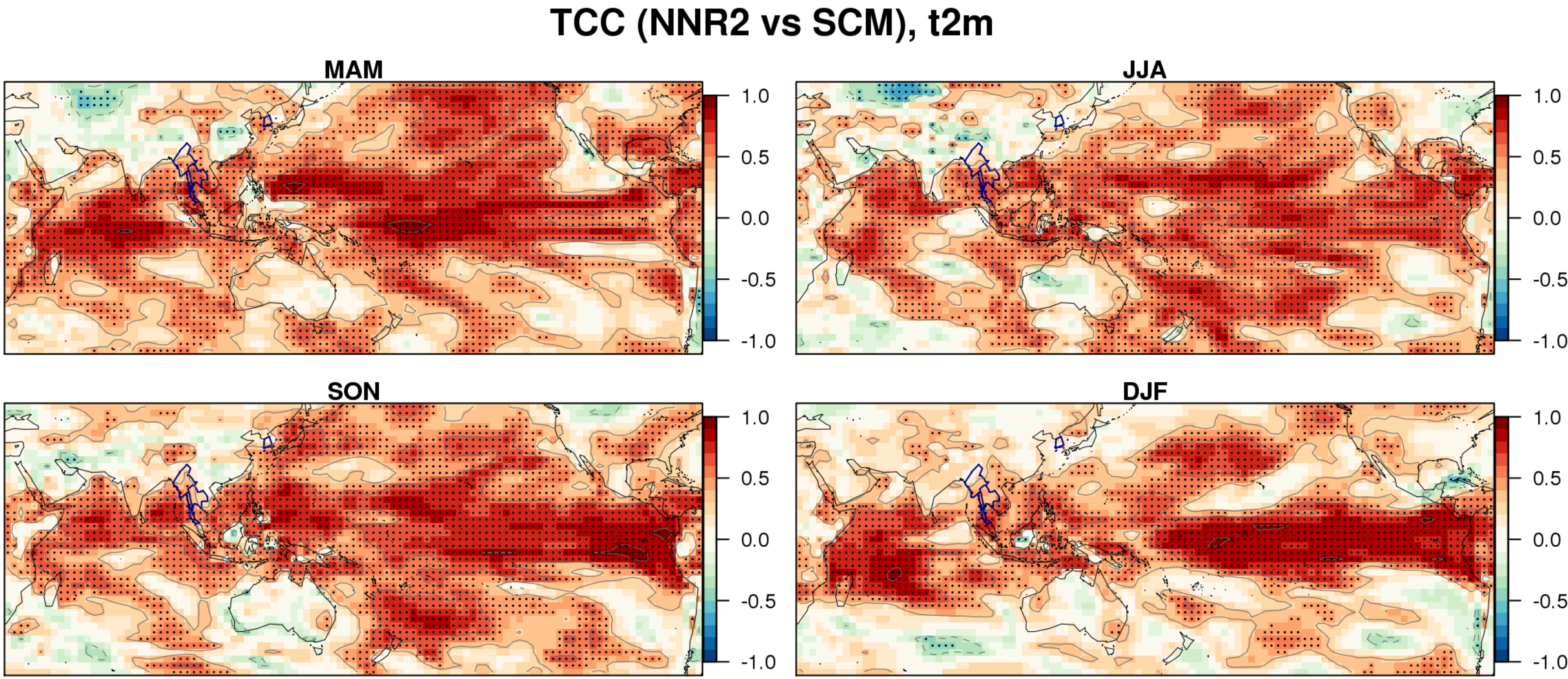
Yun-Young Lee

APCC APEC CLIMATE CENTER

Why downscaling is required?

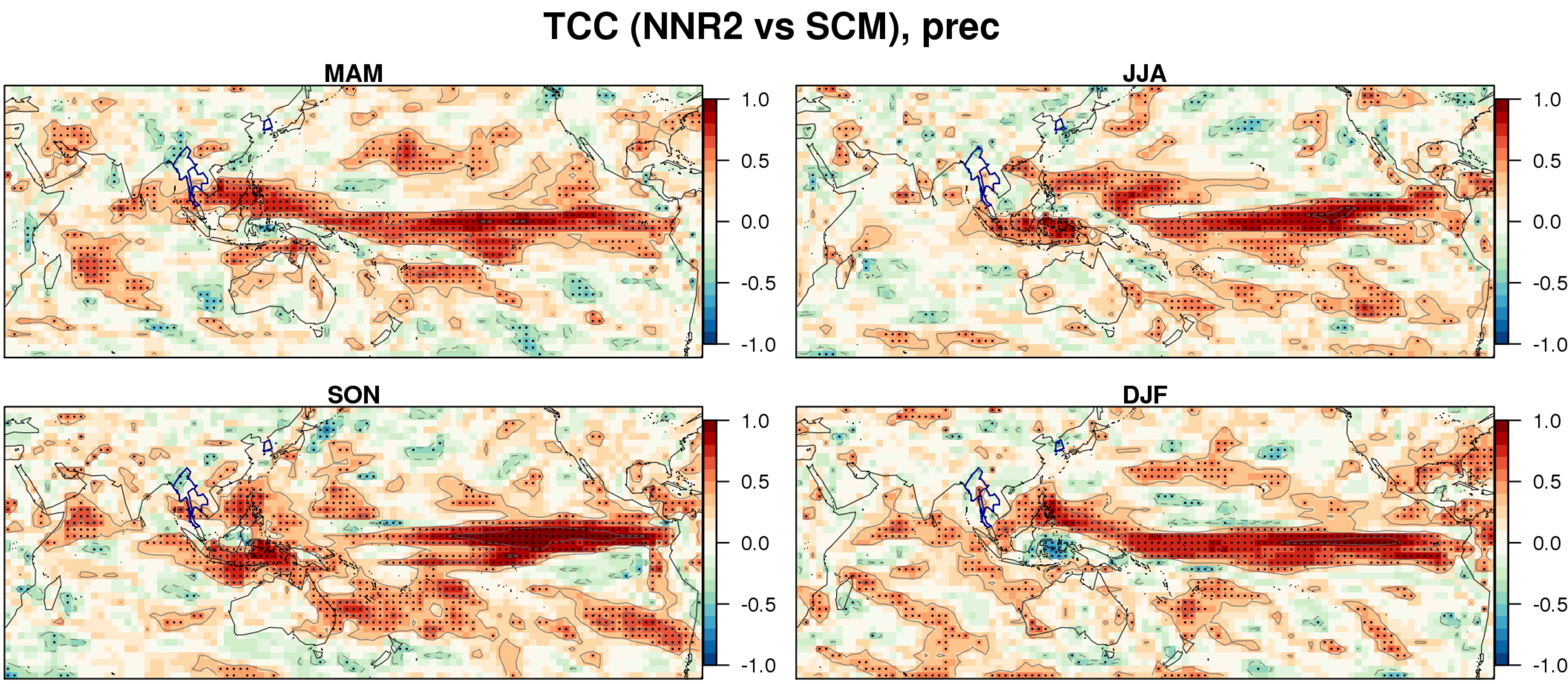
1. Low skill of dynamical seasonal forecast…

- near surface temperature…



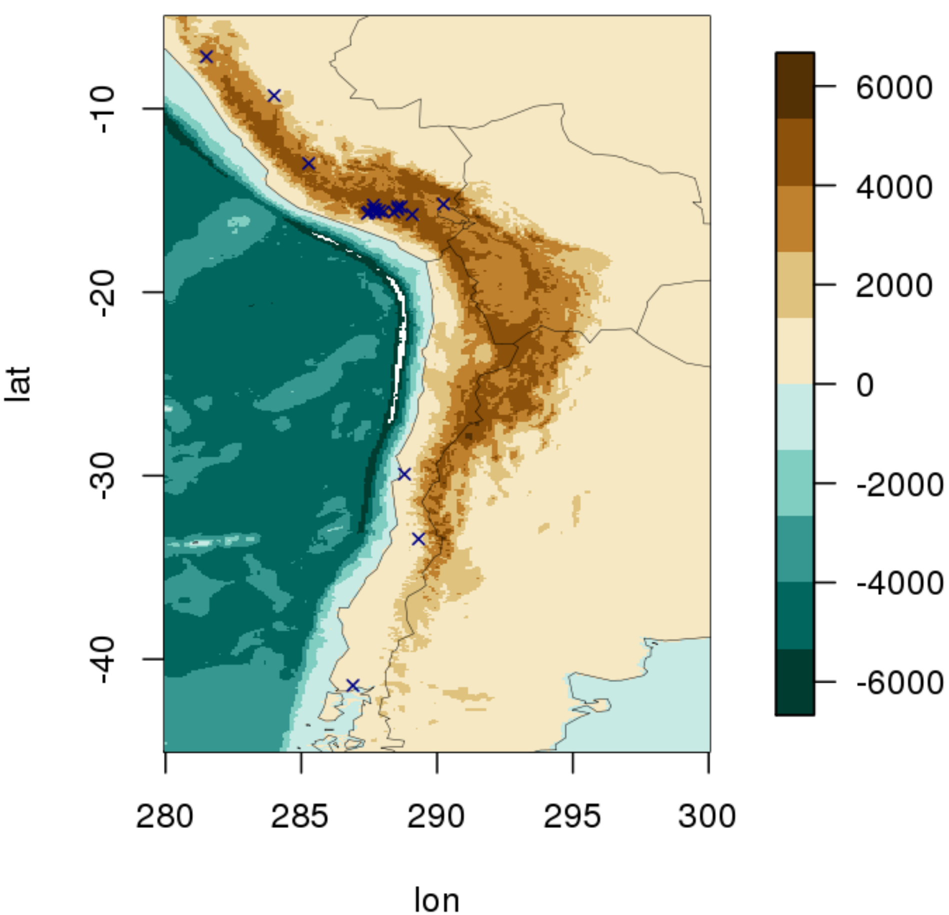
1. Low skill of dynamical seasonal forecast…

- ***Rainfall ?***
- *tropical Pacific only?*
- *Southeast Asia?*



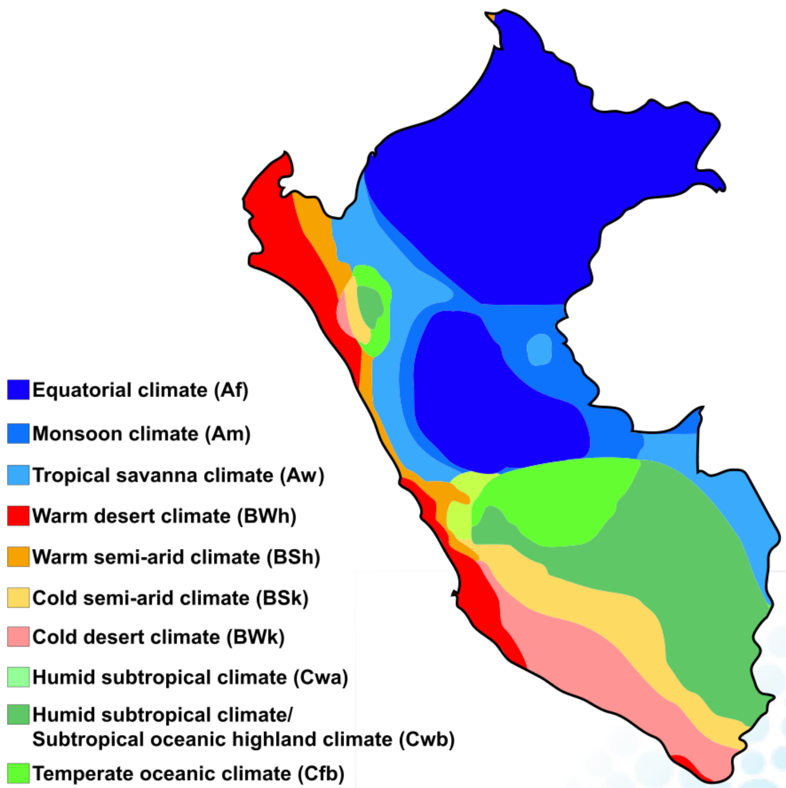
2. Climate Locality

20 stations (Peru + Chile)



- Complicate climate of Peru

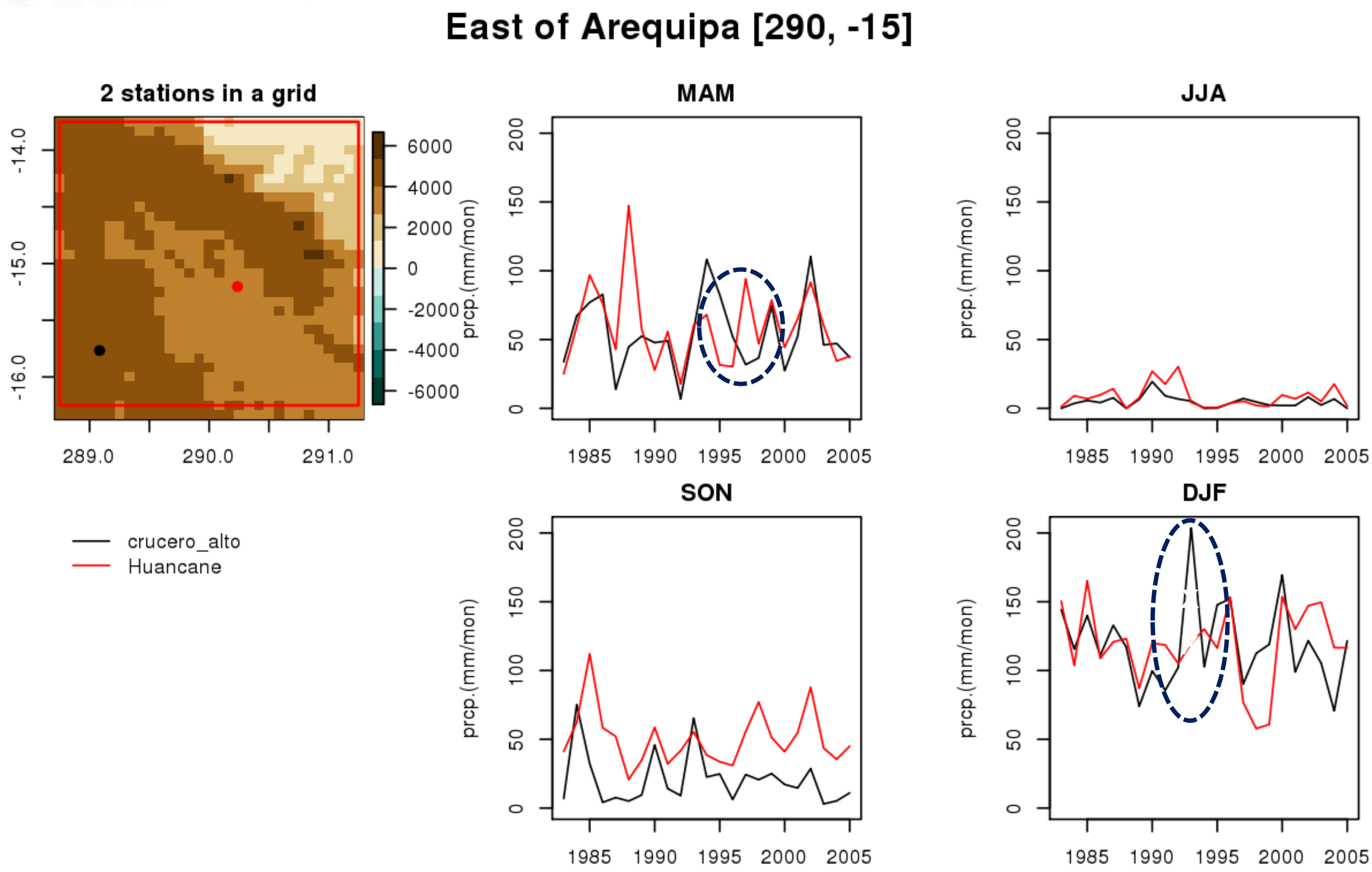
Peru map of Köppen climate classification



✓Can 2.5 by 2.5 grid pixel simulate ***steep terrain*** effect therefore ***locality of station climate*** ? Not really.

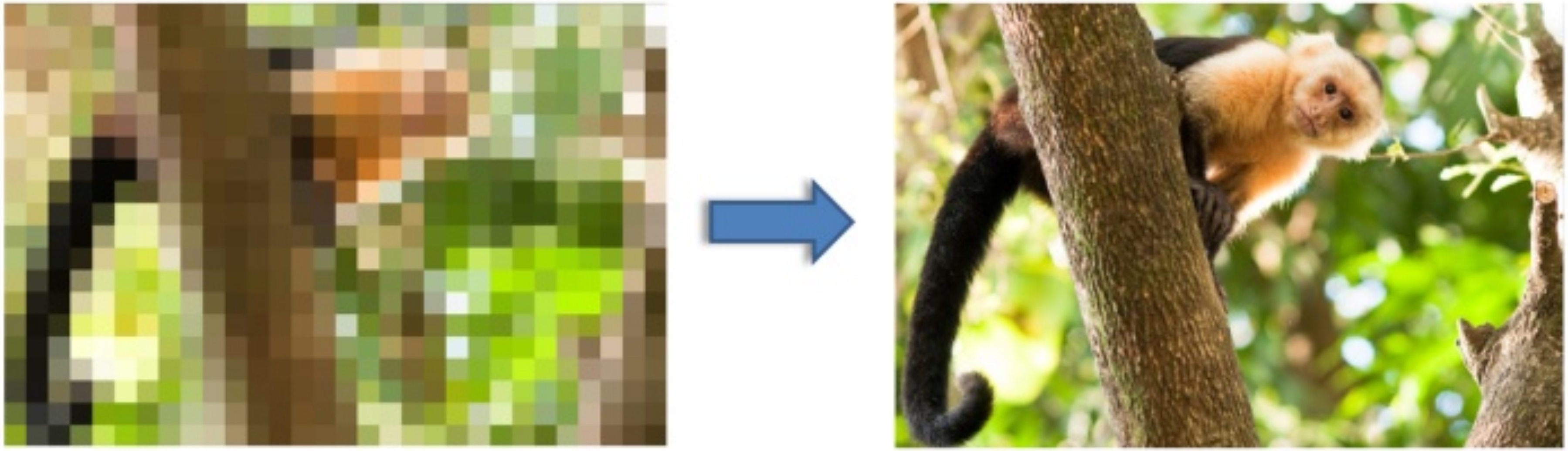
2. Climate Locality

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

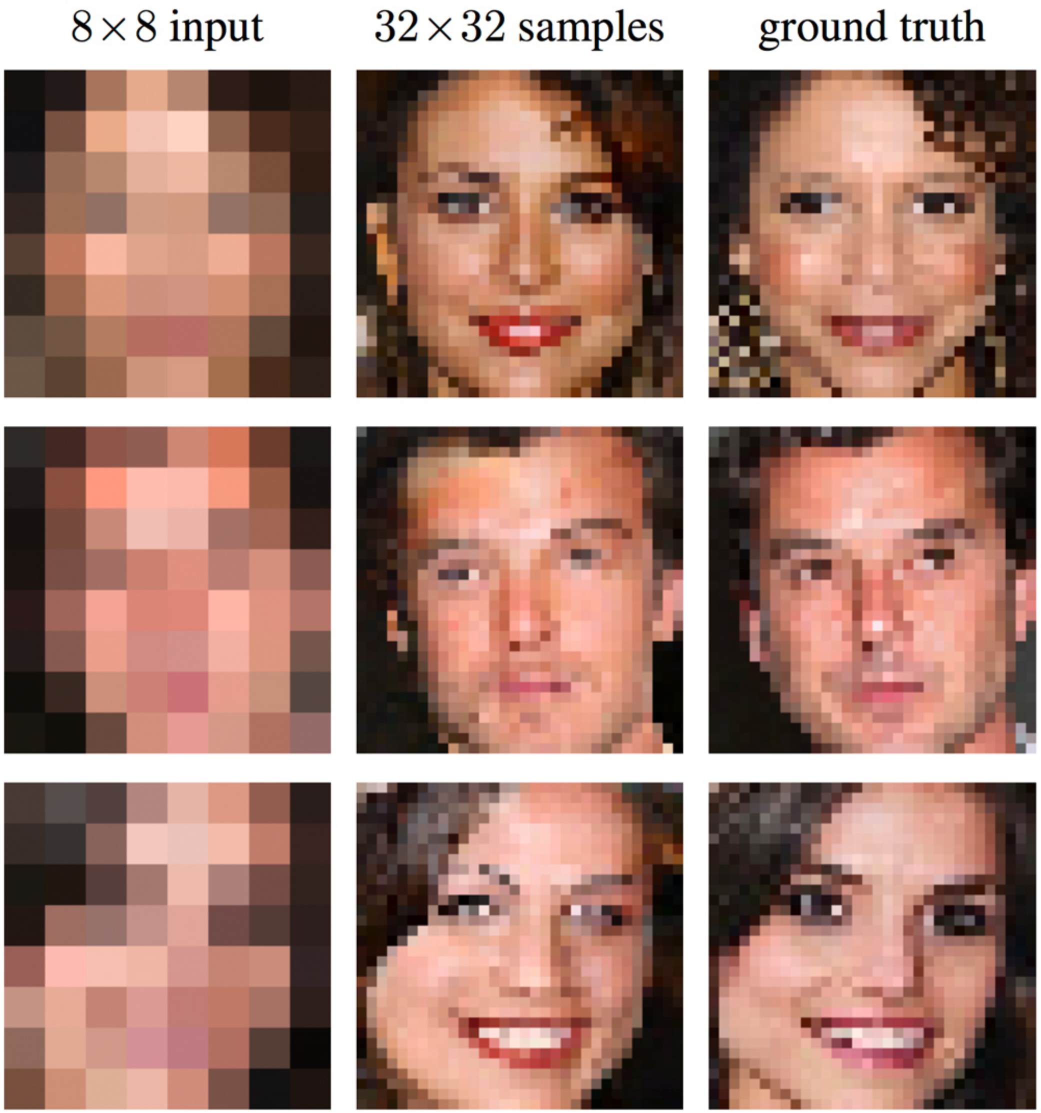


What is downscaling?

Who are you?

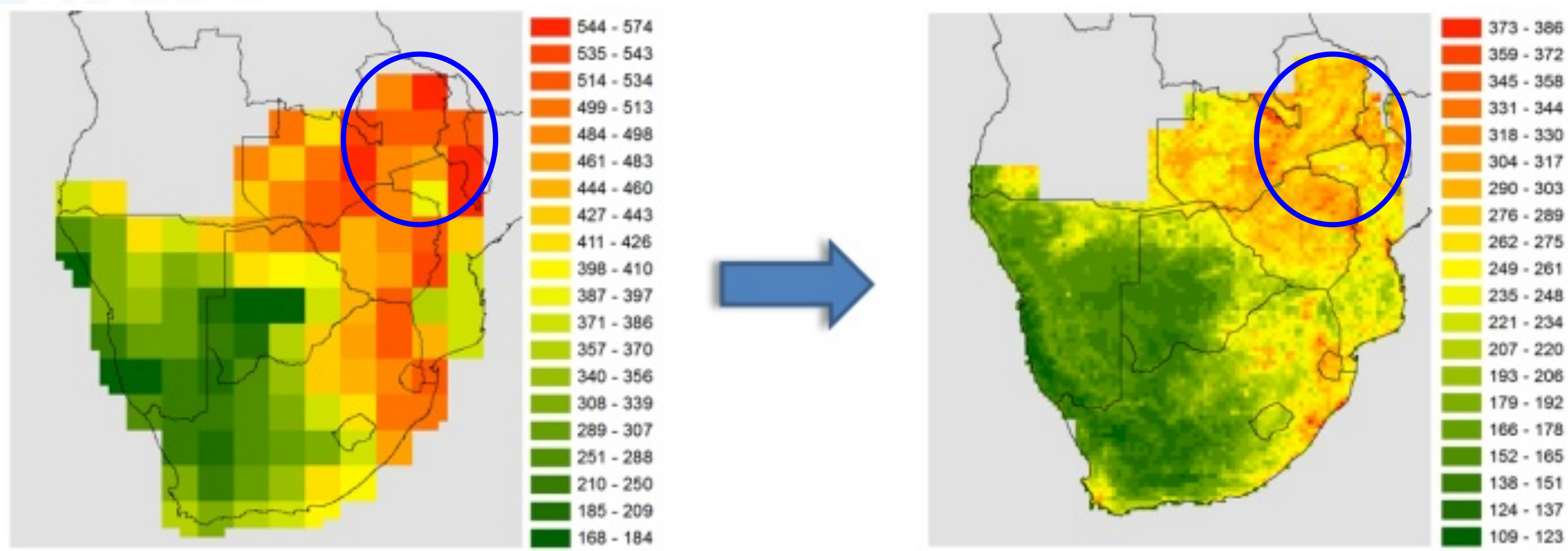


Google uses AI to sharpen low-res images



https://www.engadget.com/2017/02/07/google-ai-image-enhancement/

Downscaling/tailoring



In seasonal prediction,

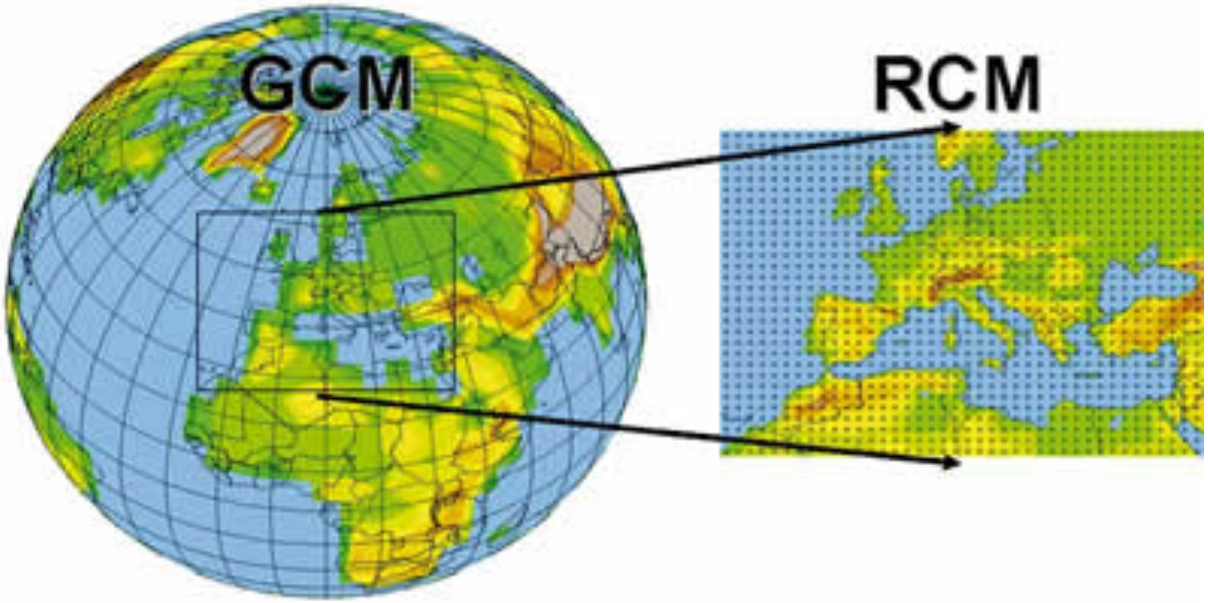
how to draw the **information of a particular "point"** from **COARSE grid model data ?**

We need extra information to downscale!

How to overcome?

- Resolve the (dynamical/physical) process determining sub-grid scale point value
- Find a ***relationship between the point and large scale pattern***

What is dynamical downscaling?



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

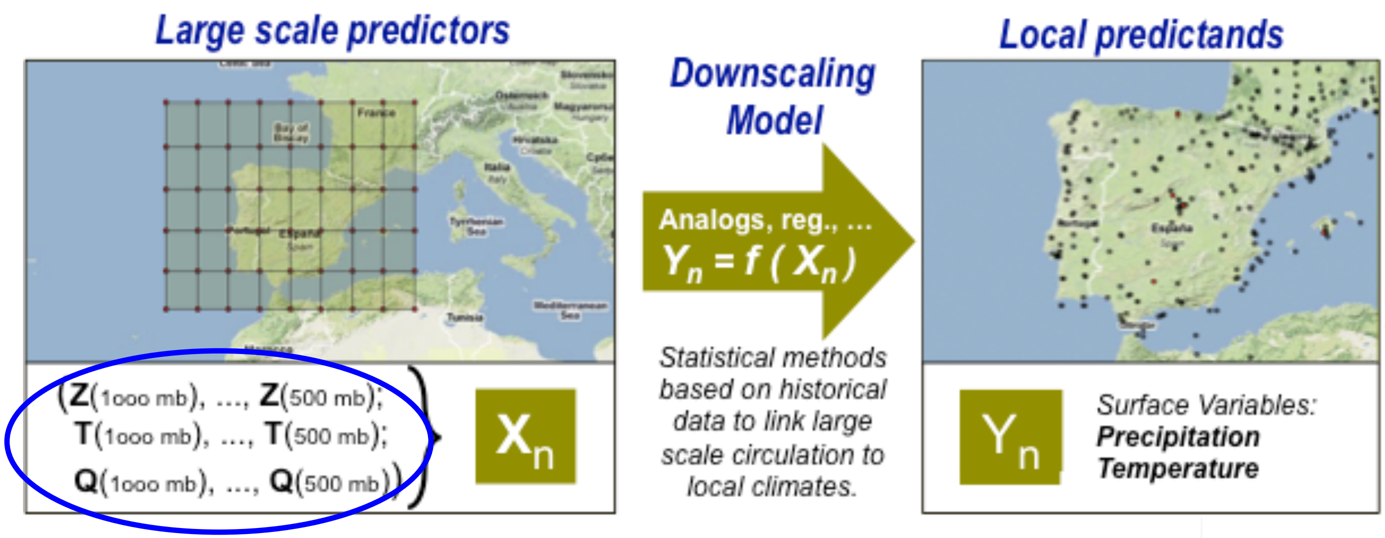
- BC from GCM, IC → solving dynamic equations!

- **1 month computing time for 1 month prediction ?**

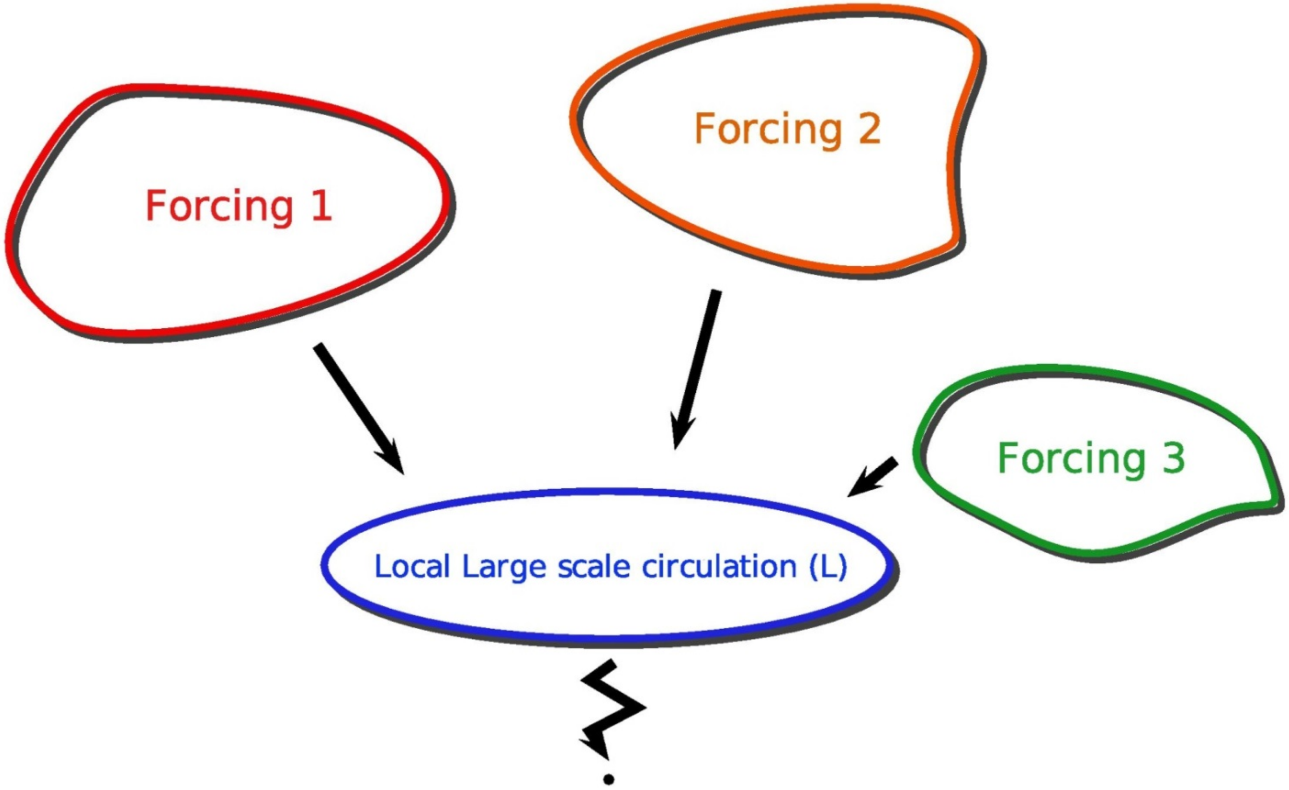
Empirical-statistical downscaling

- Based on empirical relationship between **precipitation/temperature** at particular stations and in-situ/remote large scale **Atmospheric/Oceanic condition**

→ **Developing simple downscaling model (regression)**



Local large scale circulation



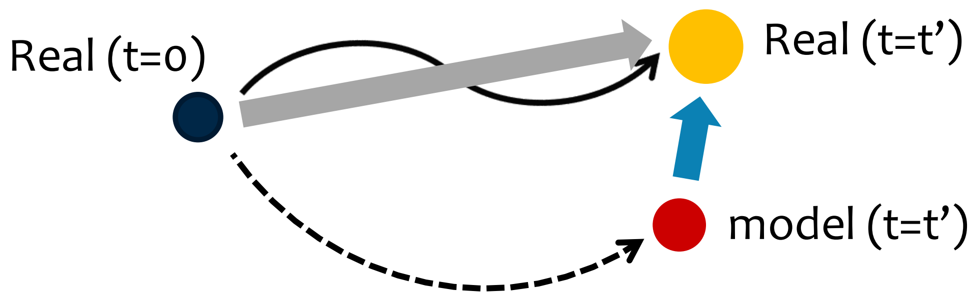
Local weather statistics (Korean summer rainfall)

Approach

- **Statistical downscaling forecast based on *past forecast***

$y(s,t)$: observation
$x(s,t)$: forecast

$$y'(t) = f(x(t), \alpha), \alpha = g(x(1:t-1), y(1:t-1))$$



- **The most common way : Regression**

$$\sum_j b_j y_j = \sum_i a_i x_i + \epsilon$$

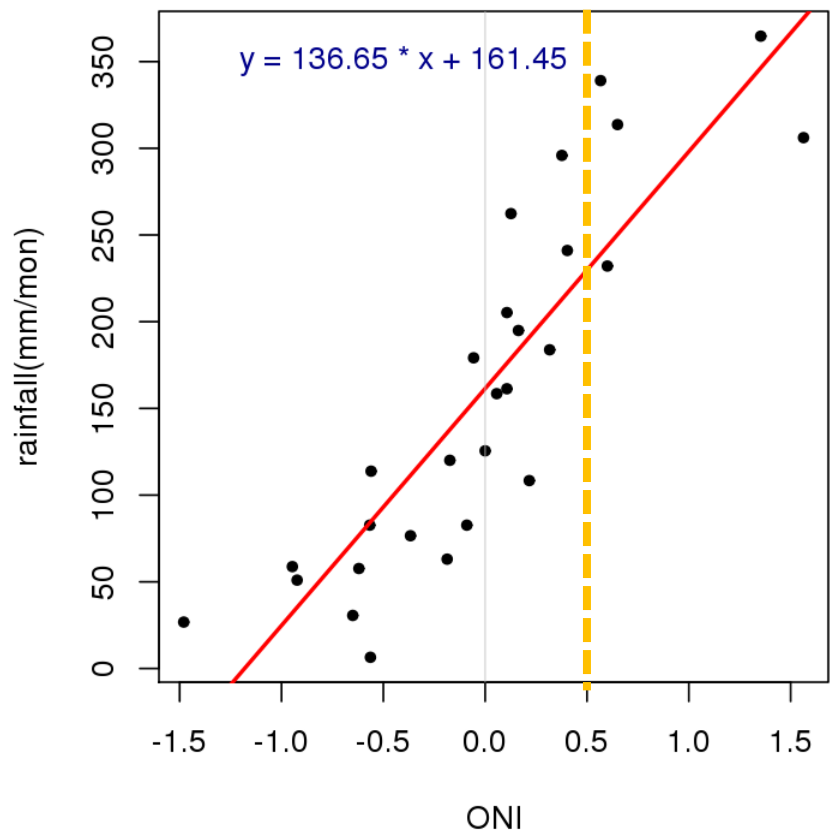
If i & j = 1 : Linear regression
i > 1, j = 1 : Multiple regression
i & j > 1 : CCA, SVD, etc

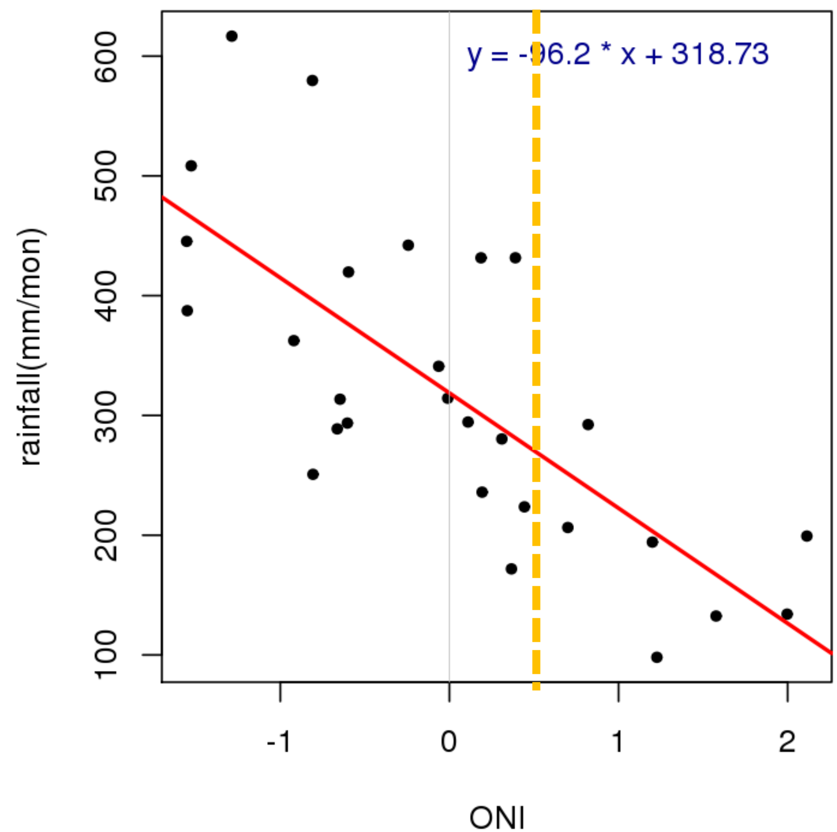
Regression concept!

Scatter plot & least square fitting!

Y= a*x+b

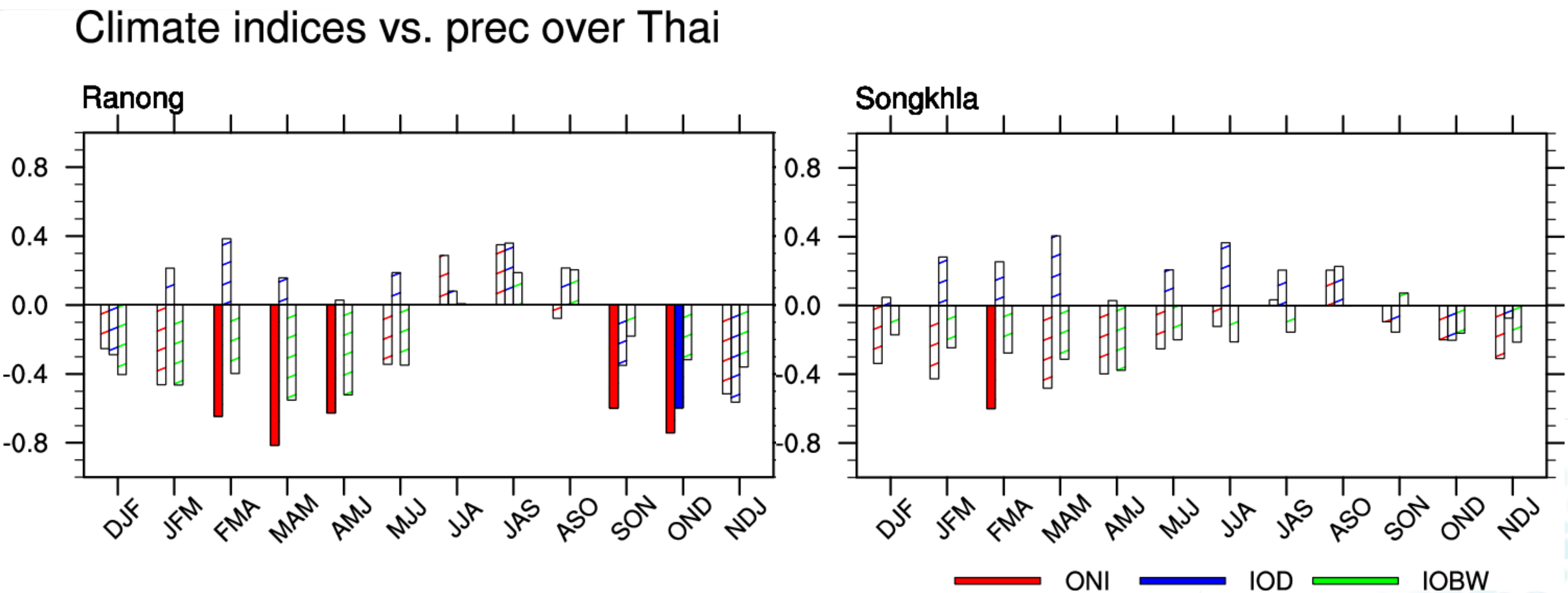
x: predictor (ONI)
y: predictand (rainfall)





e.g. simply utilizing Climate Indices

- TCC for 1987-2000



Pros and Cons

Advantages	Disadvantages
Statistical Downscaling is relatively easy to produce.	There are assumptions of stationarity between the large and small scale dynamics when using statistical downscaling.
Impact-relevant variables not simulated by climate models can be downscaled using statistical downscaling.	Small scale dynamics and climate feedback are not reflected when statistical downscaling is used.

http://www.glisaclimate.org

How downscaling is formulated in CLIK?

:Based on **large scale pattern** associated with local temperature/rainfall

CLIK downscaling

A way to localize existing coarse climate information

CLIK downscaling is mainly based on station to Large Scale Meteorological Field (LSMF) relationship. (Y = a*X + b) By utilizing the simulated LSMF (X, predictor), CLIK estimates seasonal mean precipitation/temperature (Y, predictand) at specific station.

Dynamical fcst.

Simulated LSMF from Individual models

- Hypothesis: The station to LSMF relationship is well replicated in individual models

Statistical dwnsc.

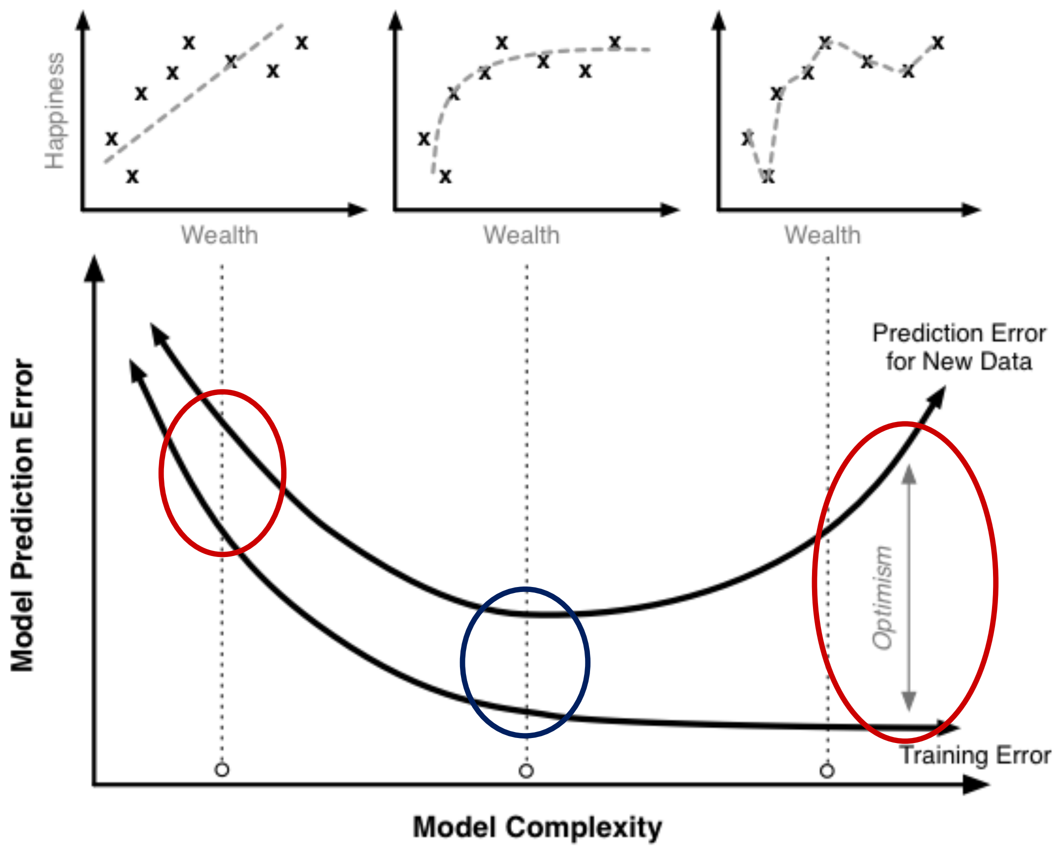
Station to LSMF regression relationship

- Predictor: LSMF
- Predictand: Prec. at specific station

A kind of hybrid system for point-wise seasonal forecast

Weakness : overfitting

- **Consider potential predictability**



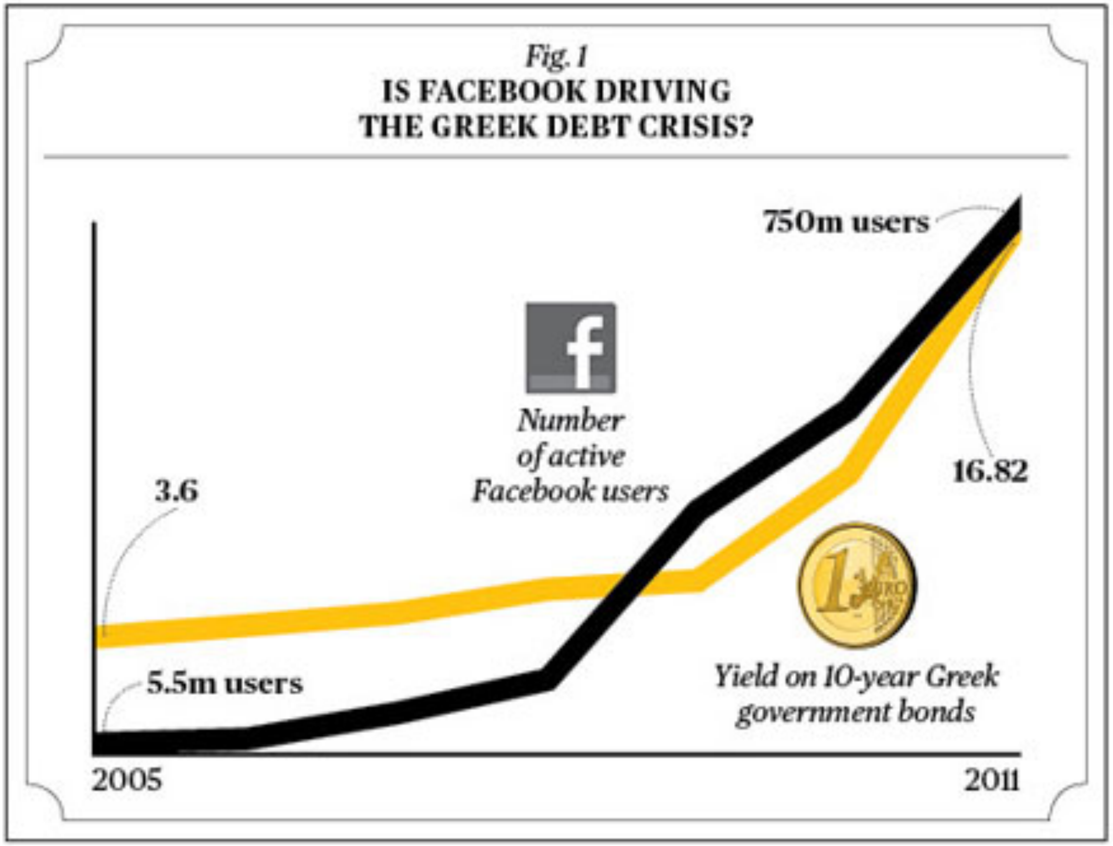
from Scott Fortmann-Roe 2012

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?



From *business week*

If yes, why?

If not, why?

Predict global average temperature with Carbon dioxide concentration

Is it appropriate?

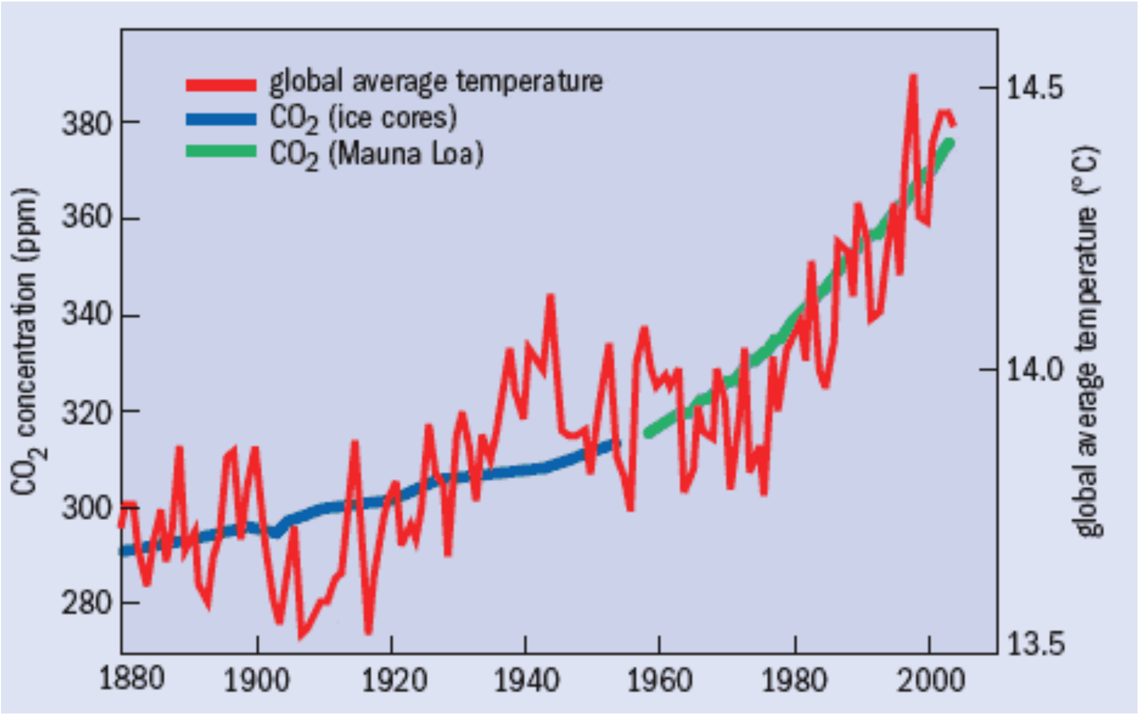


Image Source: images.iop.org

If yes, why?

If not, why?

The most important things...

1. Physical understanding of,

- What weather event/system consists of your seasonal climate (LOCAL, predictand)
- What external (slow varying factor) controls the weather system (GLOBAL, predictor)

➔ Finding ***predictors*** (large scale meteorological patterns (circulations) associated with local prcp/temp of your station)

2. whether GCM (MME) is able to reproduce those patterns/relationship?

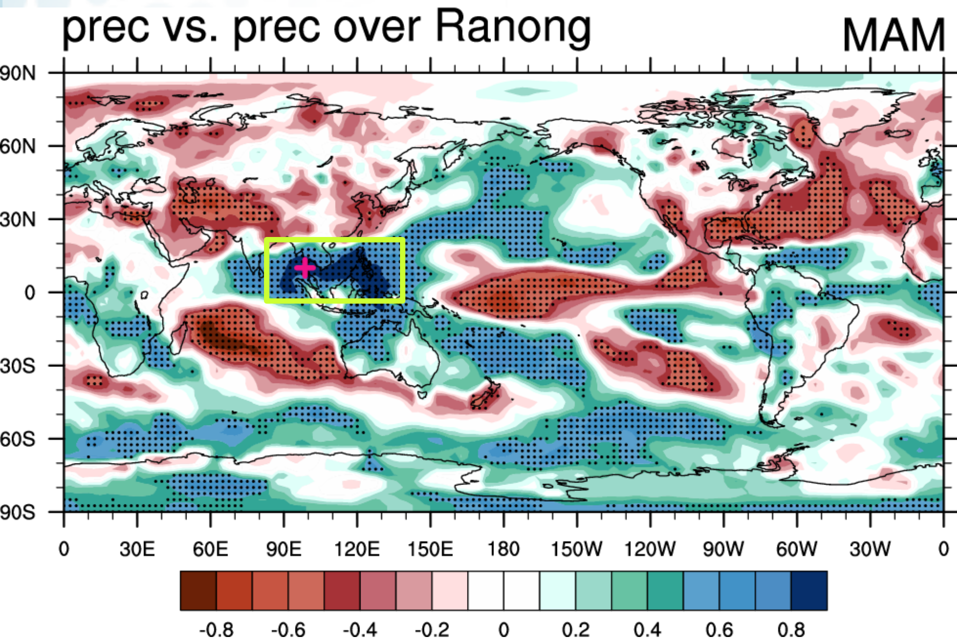
➔ ***Applicability*** of downscaling

Example of Domain Selection

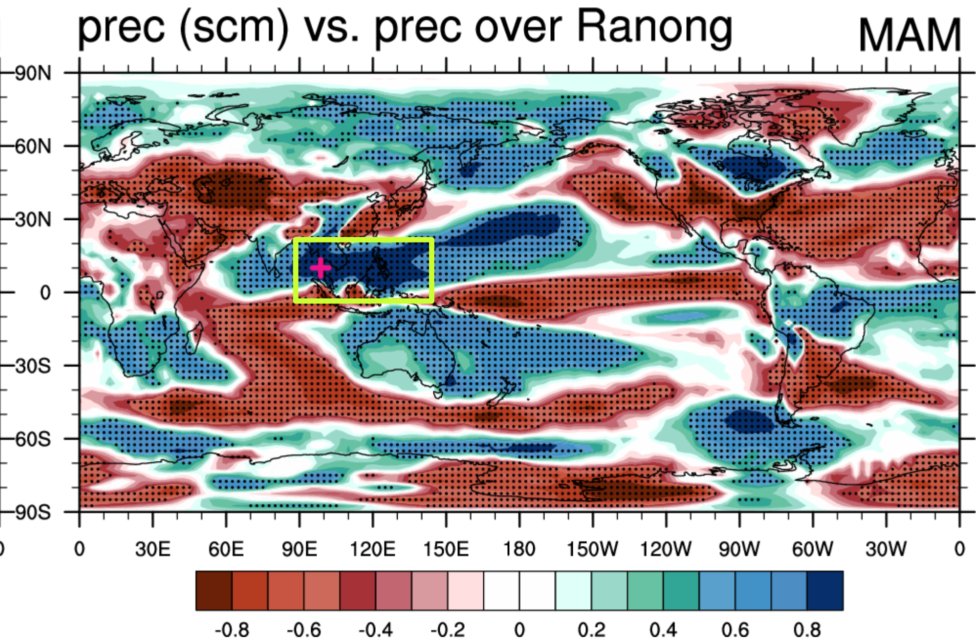
:should be based on **large scale pattern** associated with local temperature/rainfall

Station to LSMP relationship

OBS (Reanalysis)



Model (SCM)



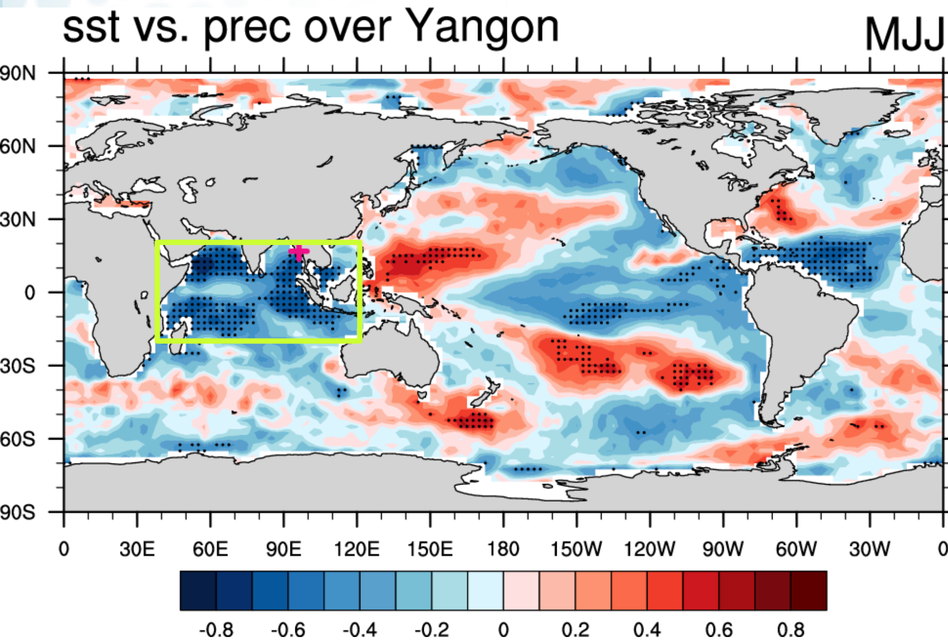
Large-scale rainfall system over Maritime Continent:

LR↑ → Ranong rain ↑

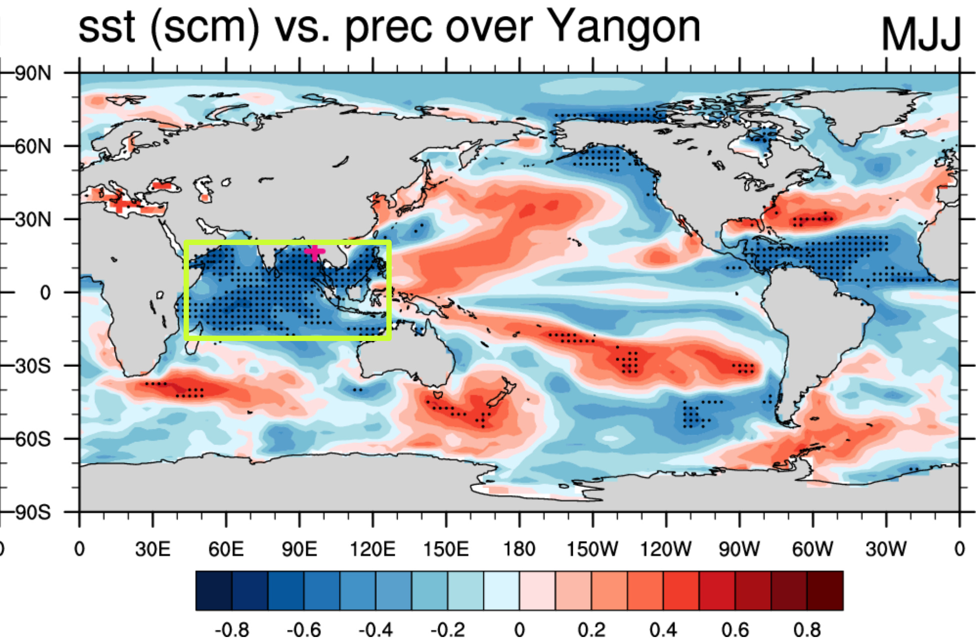
LR↓ → Ranong rain ↓

Station to LSMP relationship

OBS (Reanalysis)



Model (SCM)



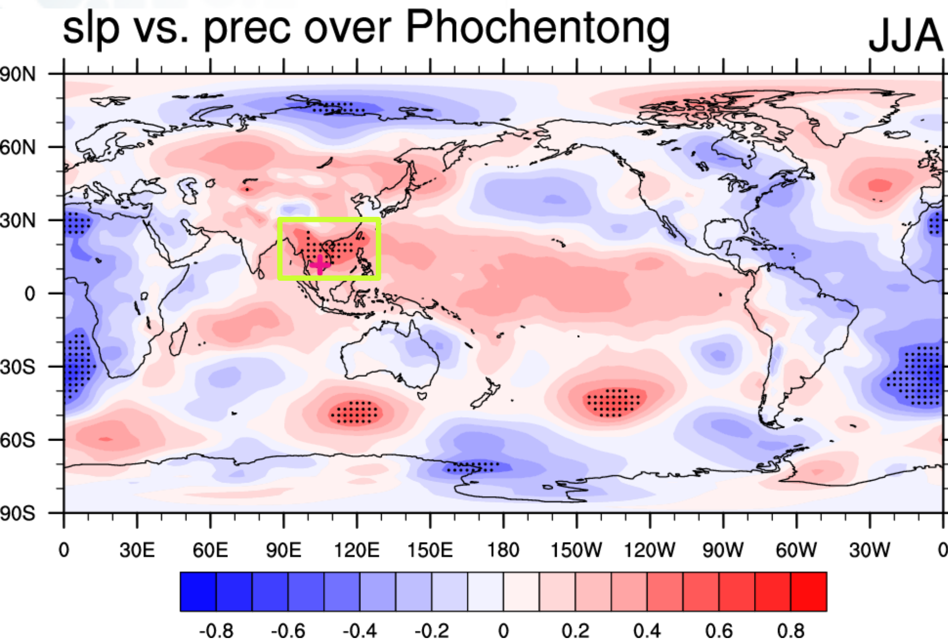
Indian Ocean Basin-wide Cooling:

SST↓ → Yangon rain ↑

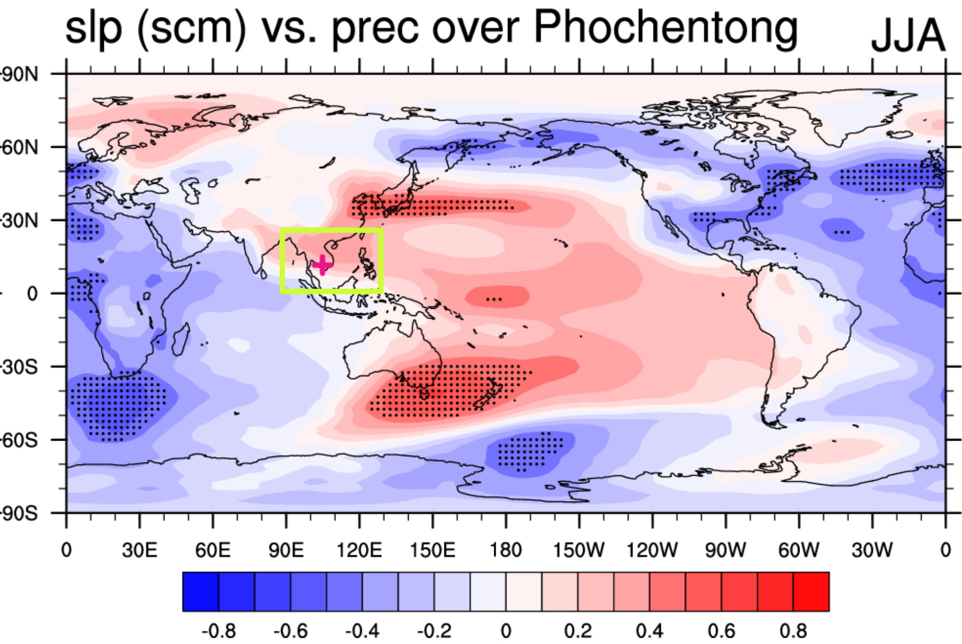
SST↑ → Yangon rain ↓

Station to LSMP relationship

OBS (Reanalysis)



Model (SCM)



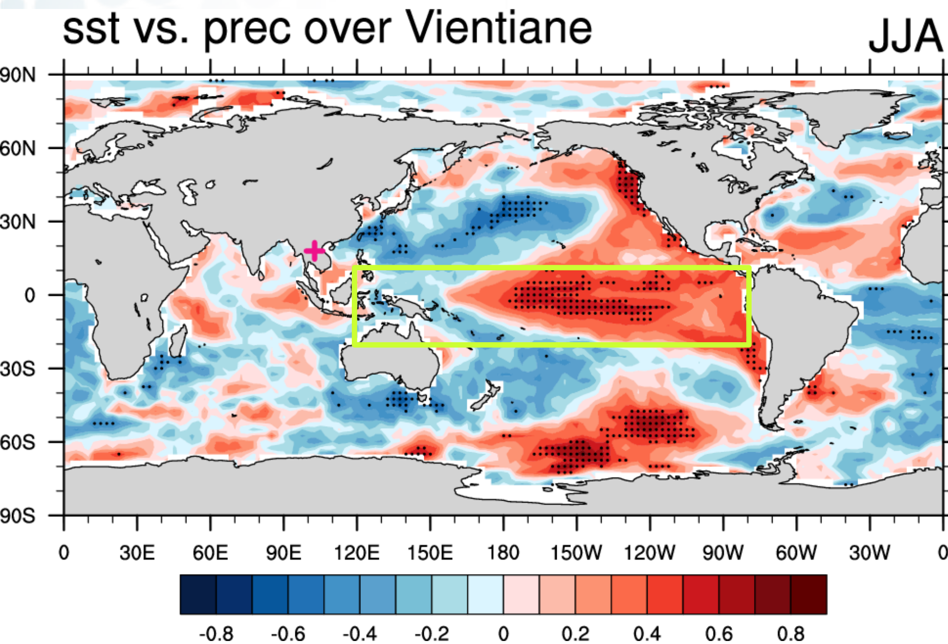
Low pressure system:

Pressure↓ → Phochentong rain ↑

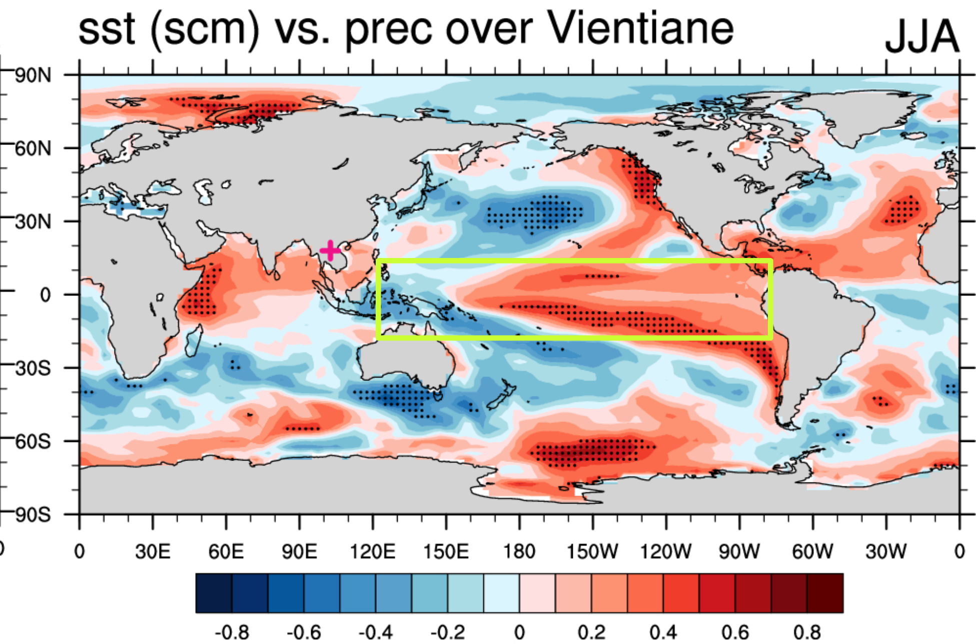
Pressure↑ → Phochentong rain ↓

Station to LSMP relationship

OBS (Reanalysis)



Model (SCM)



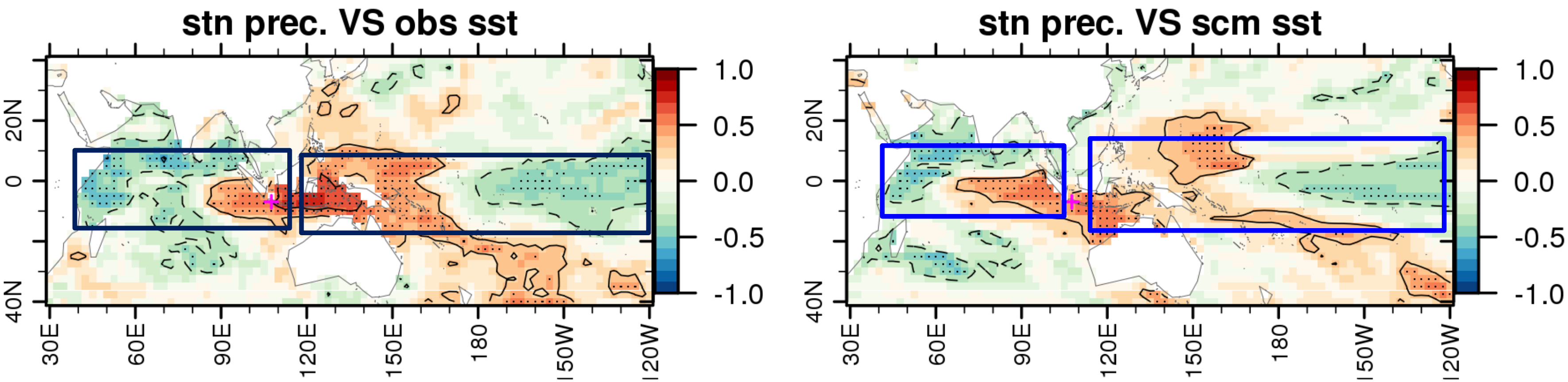
ENSO system:

El Nino → Vientiane rain ↑

La Nina → Vientiane rain ↓

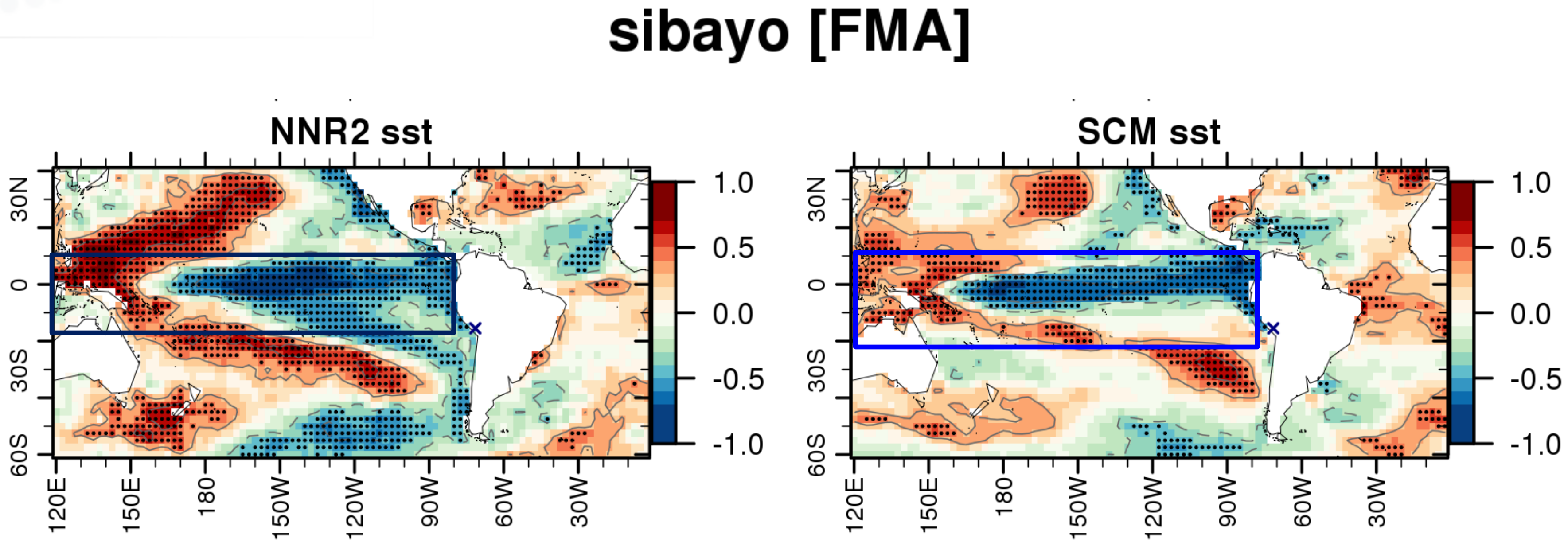
Maritime Continent: Indonesia

SON [Jakarta]



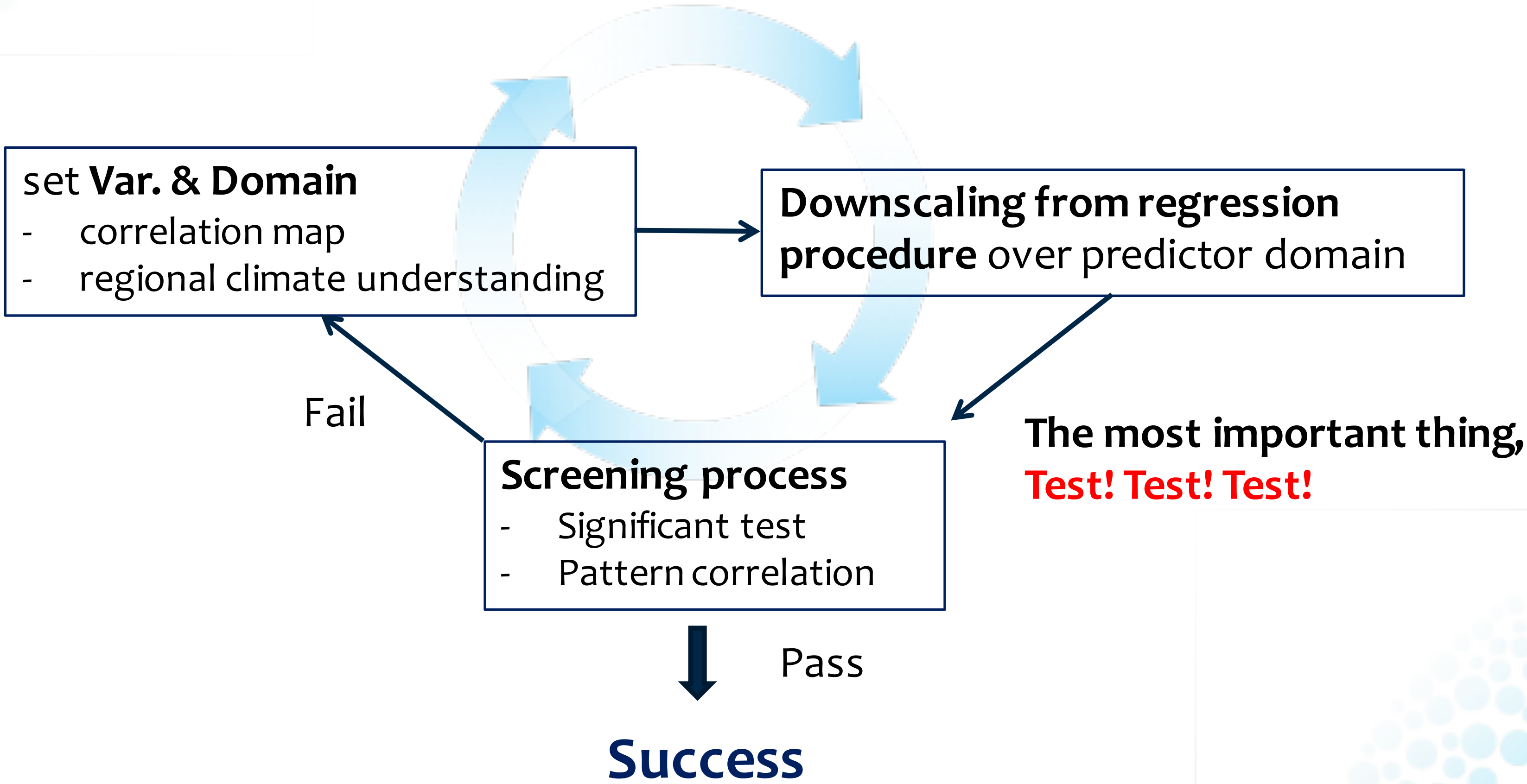
La Nina (and negative IOD) signature

West South America: Sibayo



La Nina signature

CLIK downscaling procedure



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Lecture 4-2

Evaluation of seasonal prediction

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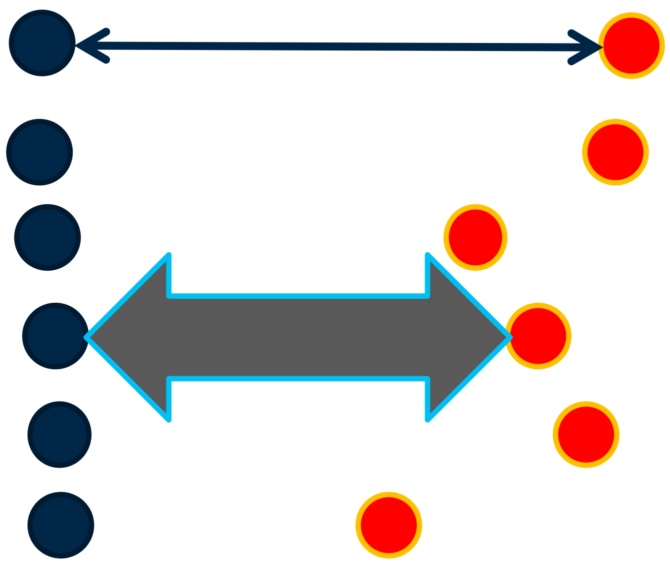
How GOOD?

- Evaluation of forecast : verification

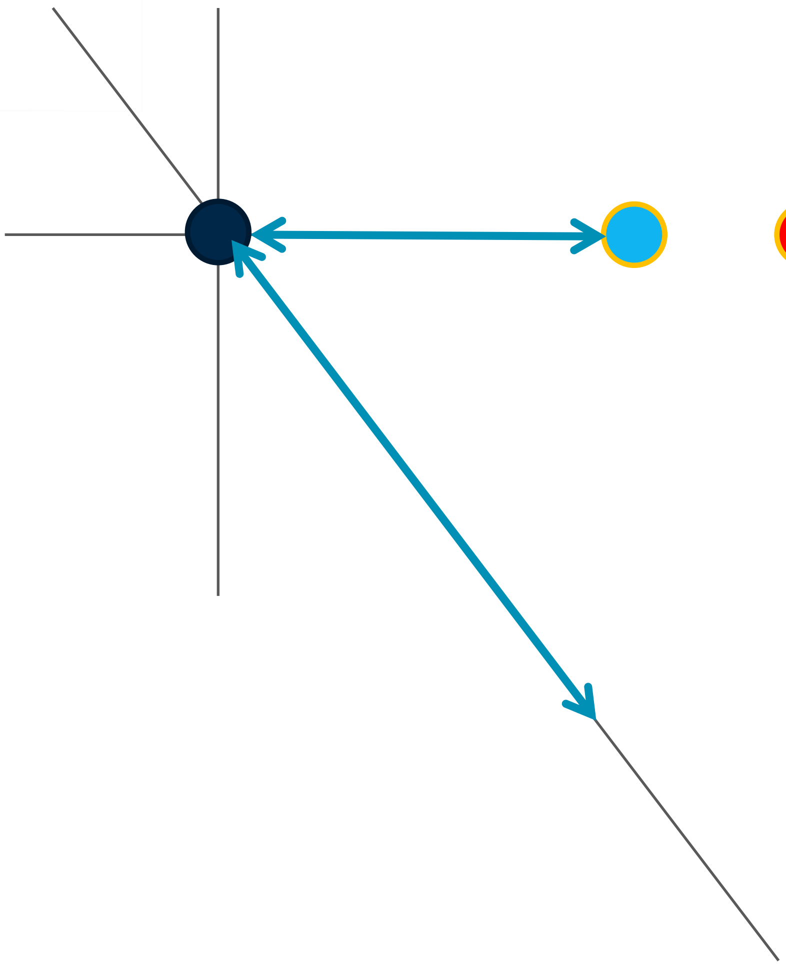
Verification

- Evaluation : measure of **closeness**



Verification

- Evaluation : depends on **Dimension/Viewpoint**



Deterministic forecast

- Various measures
  - MSE (Mean Square Error), RMSE (Root MSE)

$$MSE = \frac{1}{N}\sum_i (F_i - O_i)^2$$

skill score = $\frac{SCORE_{forecast} - SCORE_{reference}}{SCORE_{perfect\ forecst} - SCORE_{reference}}$

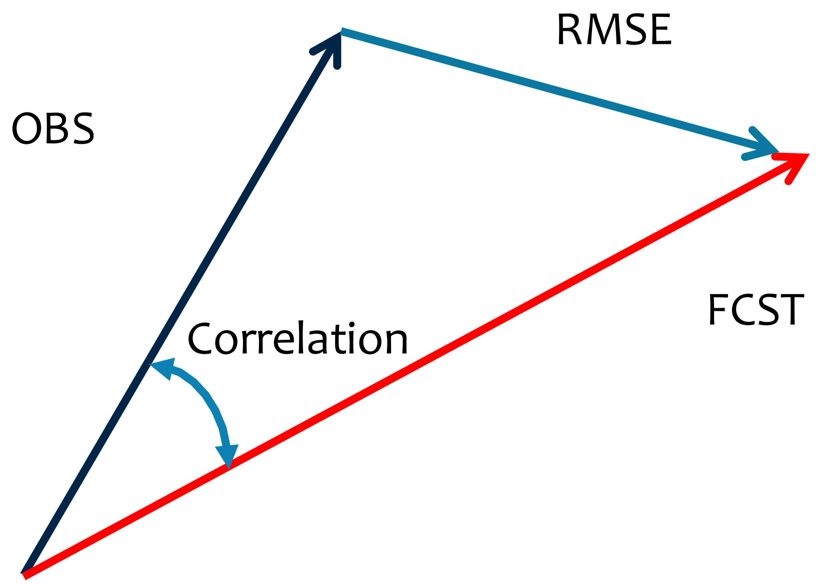
,Which is designed to give an answer for the question "What is the relative improvement of the forecast over some reference forecast?

  - MSSS (Mean Square Skill Score)
    - Conventional form of "skill score"
    - $1 - \frac{MSE}{MSE_c}$, MSE : error/penalty, MSE_c : error of climatology forecast
  - ACC(Anomaly correlation, Pattern), TCC (Temporal correlation)

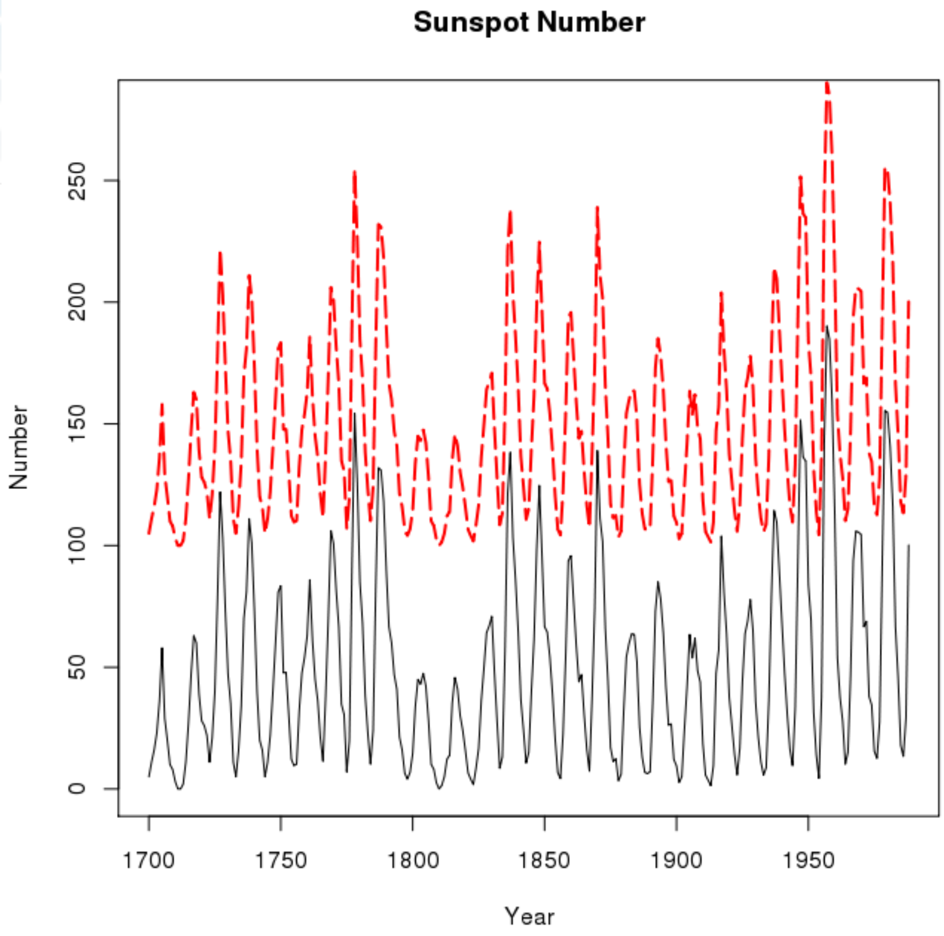
$$ACC = \frac{\sum_{i=1}^{N} w_i(f_i - \bar{f})(o_i - \bar{o})}{\sqrt{\sum_{i=1}^{N} w_i(f_i - \bar{f})^2 \sum_{i=1}^{N} w_i(o_i - \bar{o})^2}}$$

Verification

- Evaluation : depends on **Dimension/Viewpoint**



Examples



F(t)

G(t) = F(t) + 100

RMSE?
But, Correlation?

Probabilistic forecast

- Brier score (BS)
  - **MSE of prob. forecast**

$BS = \frac{1}{N}\sum_i (F_i \quad - O_i)^2$

F=probability(forecast),

O=1/0 (actual outcome of instance)

Eg. Binary events such as **"rain" or "no rain"**

Range: 0 to 1, Perfect score = 0

Intuitively, High value = High Score?

skill score = $\frac{SCORE_{forecast} - SCORE_{reference}}{SCORE_{perfect\ forecst} - SCORE_{reference}}$

,Which is designed to give an answer for the question "What is the relative improvement of the forecast over some reference forecast?

- Brier **Skill Score (BSS)**

BSS = 1 $- \frac{\boldsymbol{BS}}{\boldsymbol{BS_c}}$

BS : error/penalty,

BS_c: BS of climatology forecast

Range: -infinity to 1

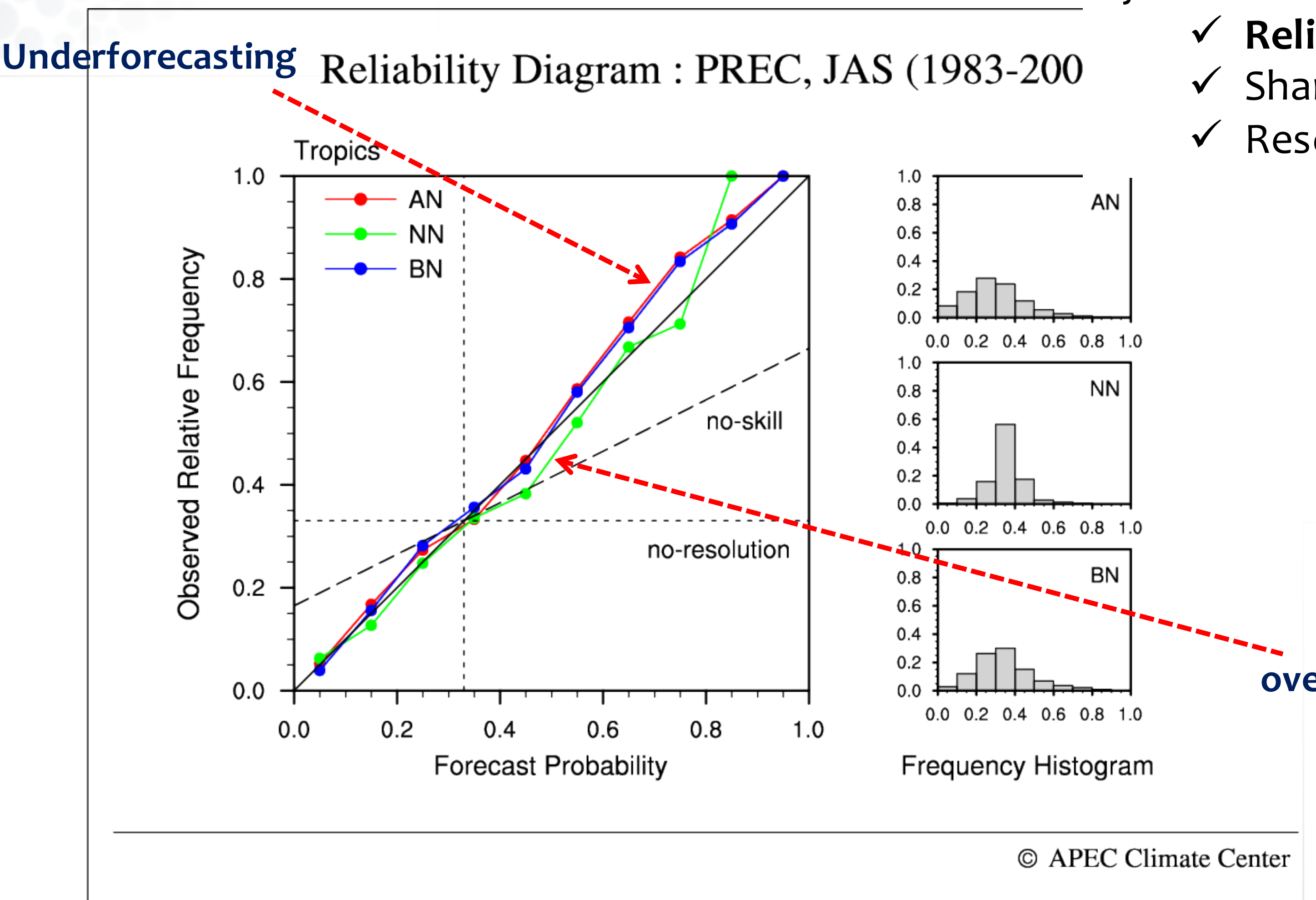
Perfect score = 1

Probabilistic forecast (Categorical)

- Reliability curve

Accurate probability forecast system

- ✓ **Reliability**
- ✓ Sharpness
- ✓ Resolution



Probabilistic forecast (Categorical)

F \ O	"rain" Yes	"no rain" No
Yes	Hit (H)	False Alarm (F)
No	Miss (M)	Correct Rejection (C)

Correct forecast

- *HR (Hit rate) = H/(H+M)*

  0 to 1, perfect score = 1

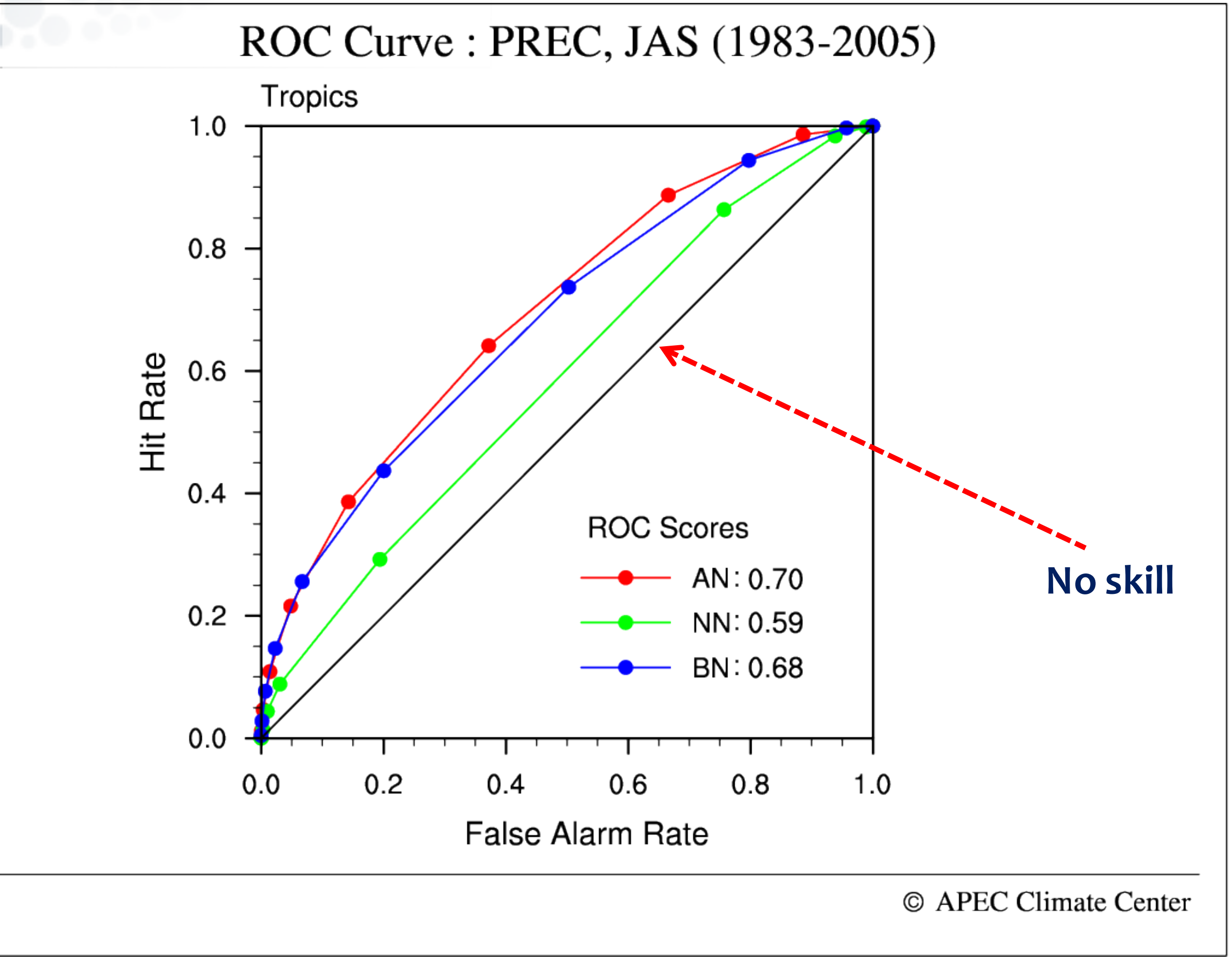
- *FAR (False Alarm rate) = F/(F+C)*

  0 to 1, perfect score = 0

Good forecast : HR↑, FAR ↓

Probabilistic forecast (Categorical)

- ROC (Relative Operating Characteristics)

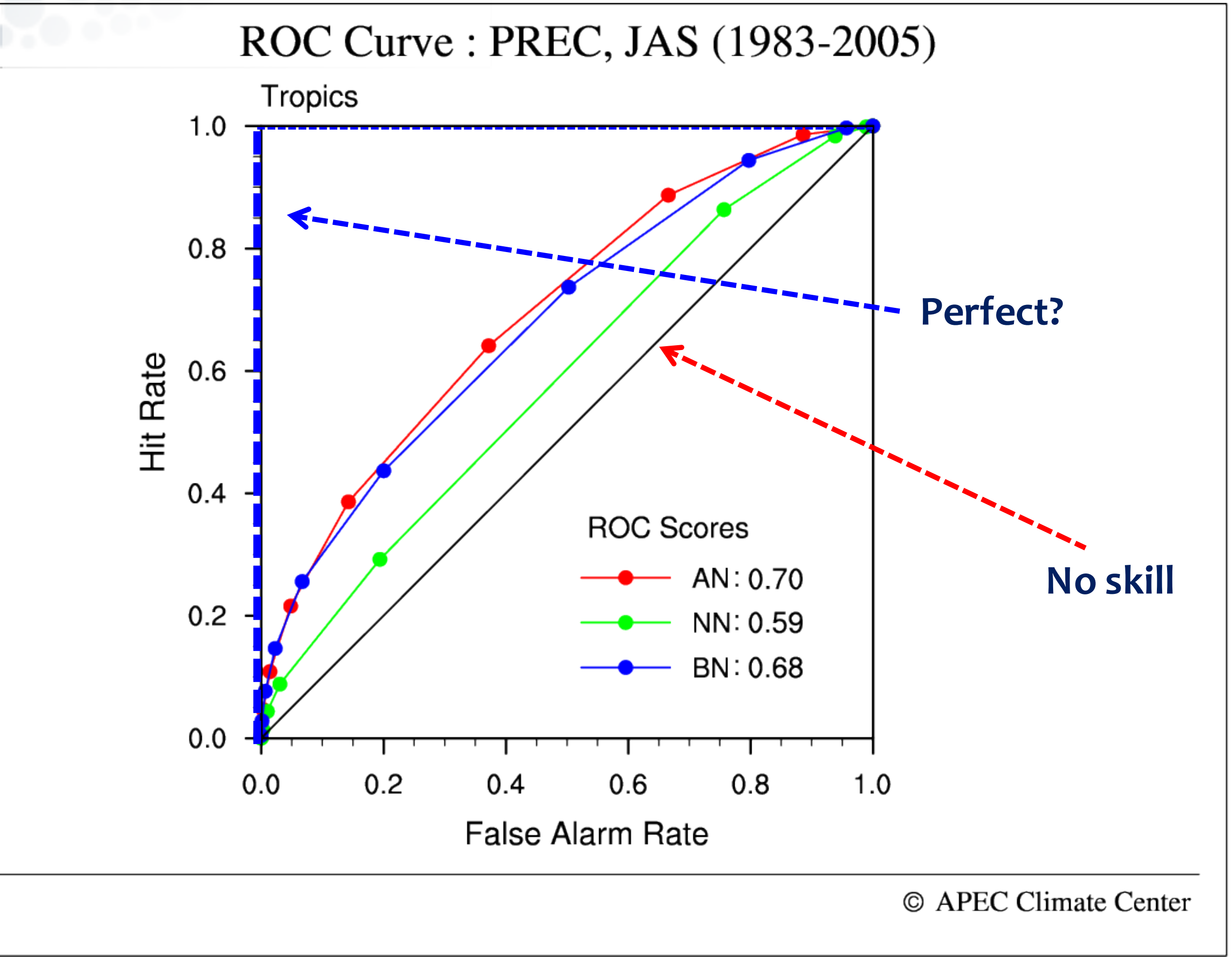


ROC score
=Area of ROC curve

Range: 0 to 1
perfect: ROC score = 1
no skill: ROC score = 0.5
(no added value)

Probabilistic forecast (Categorical)

- ROC (Relative Operating Characteristics)



ROC score
=Area of ROC curve

Range: 0 to 1
perfect: ROC score = 1
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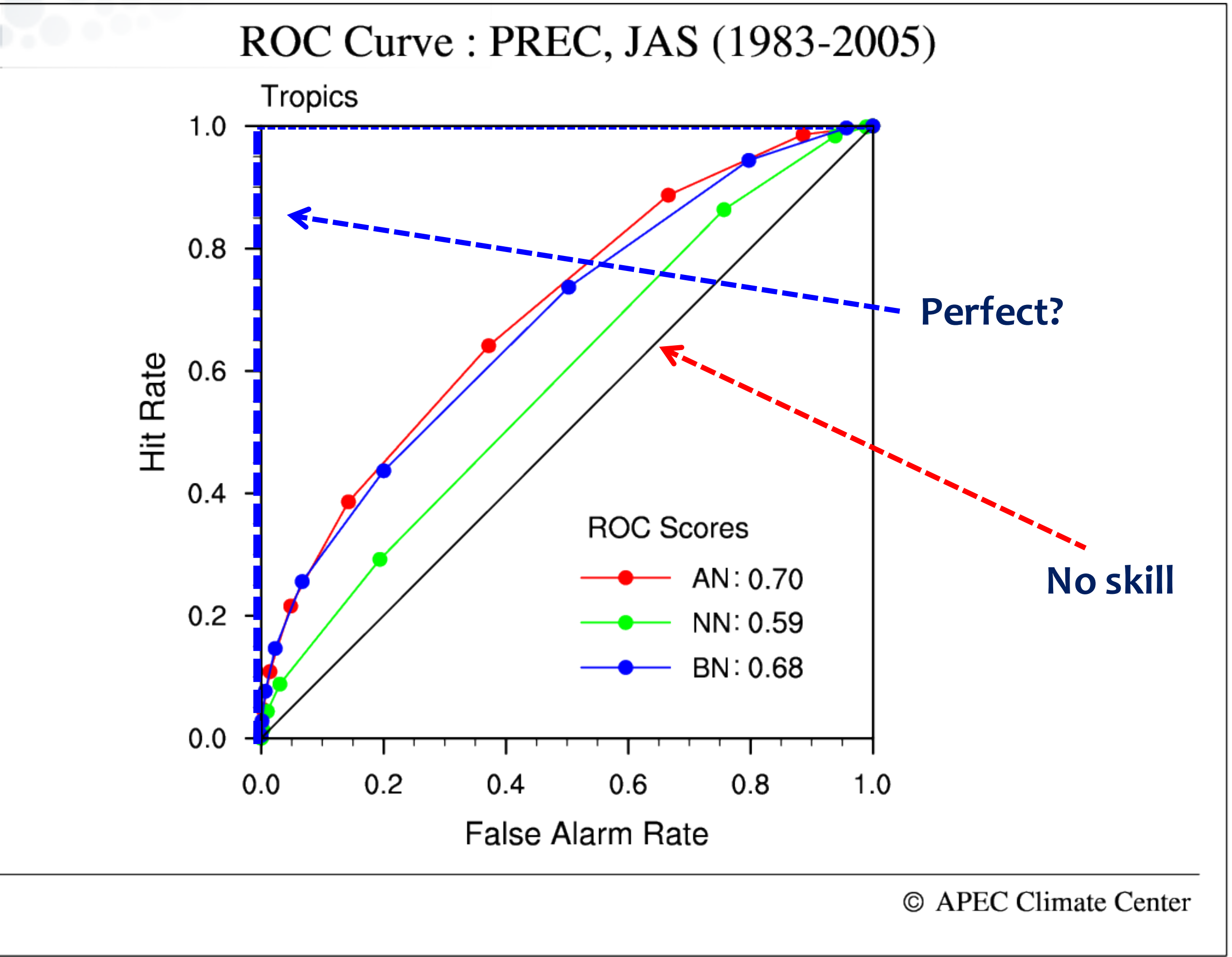
Probabilistic forecast (Categorical)

- ROC (Relative Operating Characteristics)



- ✓ Biased forecast with high ROC score
- ✓ A measure of ***potential usefulness***

ROC score
=Area of ROC curve

Range: 0 to 1
perfect: ROC score = 1
no skill: ROC score = 0.5
(no added value)

Probabilistic forecast (Categorical)

- HSS (Heidke **Skill Score**)

*Giving the answer for the question **"What was the accuracy of the forecast in predicting the correct category, relative to that of random chance?"***

F \ O	**Yes**	**No**
Yes	Hit (H)	False Alarm (F)
No	Miss (M)	Correct Rejection (C)

$$\text{HSS} = \frac{SCORE_{forecast} - SCORE_{by\ chance}}{SCORE_{perfect\ forecst} - SCORE_{by\ chance}}$$

$$= \frac{\left\{\frac{(H+C)}{n} - \frac{[(H+F)(H+M)+(F+C)(M+C)]}{n^2}\right\}}{\left\{1 - \frac{[(H+F)(H+M)+(F+C)(M+C)]}{n^2}\right\}}$$

Range: - infinity to 1, 0=no skill, 1=perfect skill

Forecast economic value

$$V = \frac{E_{cli} - E_{fore}}{E_{cli} - E_{per}}$$

V=1 : perfect forecast

V=0 : climatological forecast

E_{fore} : Expected expense of forecast

E_{per} : Expected expense of perfect forecast

E_{cli} : Expected expense of climatological forecast

		Observation (real event)	
		Yes	No
Forecast (action)	Yes	Hit (h) Cost (C)	False alarm (f) Cost (C)
	No	Miss (m) Loss (L)	Correct rejection (c) 0

$$E_{fore} = (h + f)C + mL$$

- When the forecast is perfect, f = m = 0. and h=ō. Then, $E_{per} = hC = \bar{o}C$

- When the forecast is climatology. The only one kind of action will be kept.

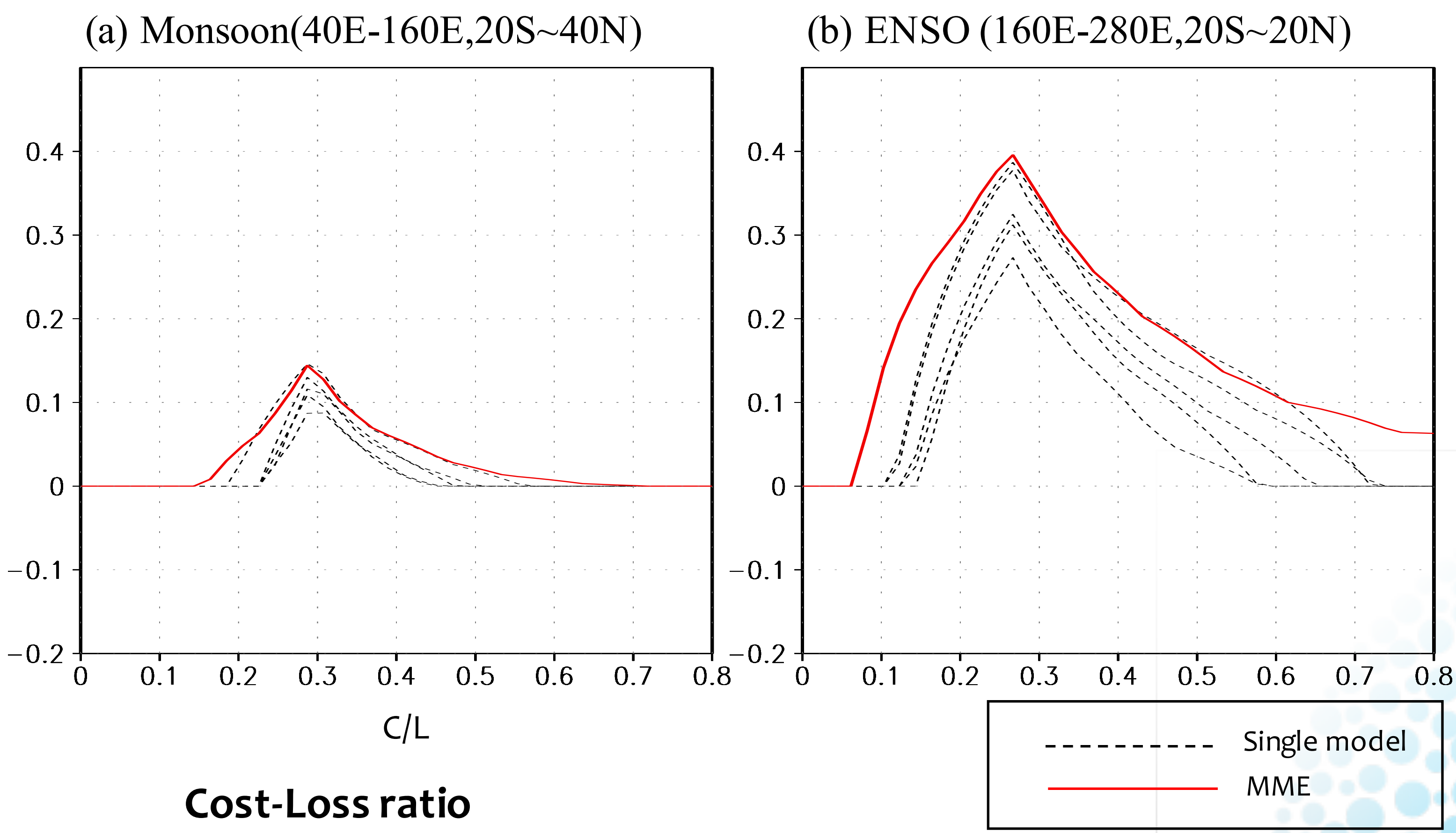
If Yes : E=(h+f)C=C, otherwise E=mL=ōL.

Decision: action of low expense. Thus, $E_{cli} = \min(C, \bar{o}L)$

$$V = \frac{\min(\frac{C}{L}, \bar{o}) - (h + f)\frac{C}{L} - m}{\min(\frac{C}{L}, \bar{o}) - \frac{C}{L}\bar{o}}$$

Value of Probabilistic forecast (Above normal) : GCMs

$$V = \frac{\min(\frac{C}{L}, \bar{o}) - (h+f)\frac{C}{L} - m}{\min(\frac{C}{L}, \bar{o}) - \frac{C}{L}\bar{o}} = \frac{\min(\frac{C}{L}, \bar{o}) - f(1-\bar{o})\frac{C}{L} + h\bar{o}(1-\frac{C}{L}) - \bar{o}}{\min(\frac{C}{L}, \bar{o}) - \frac{C}{L}\bar{o}}$$

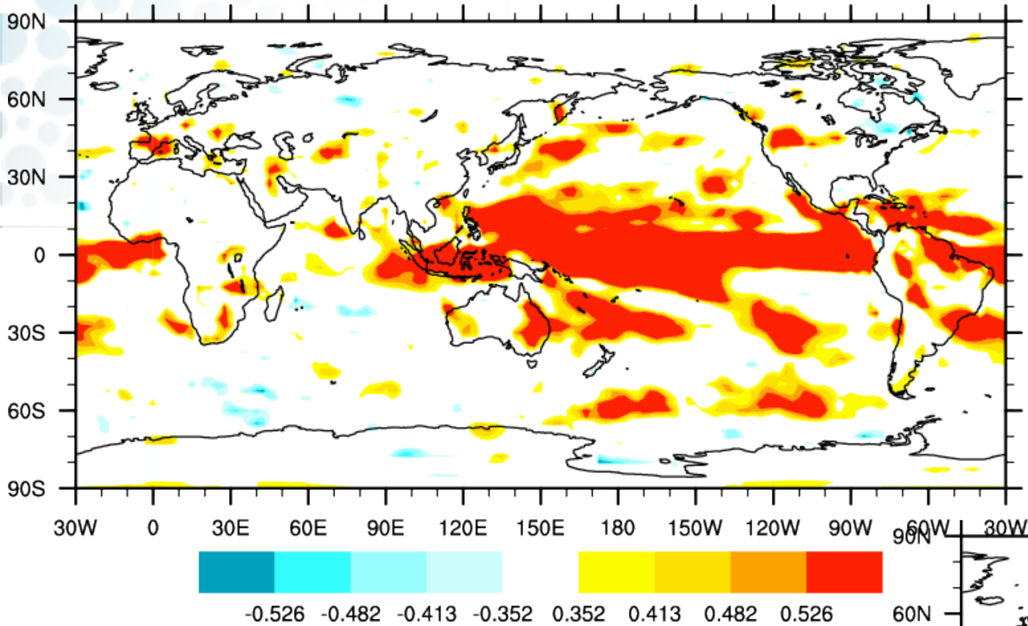


Cost-Loss ratio

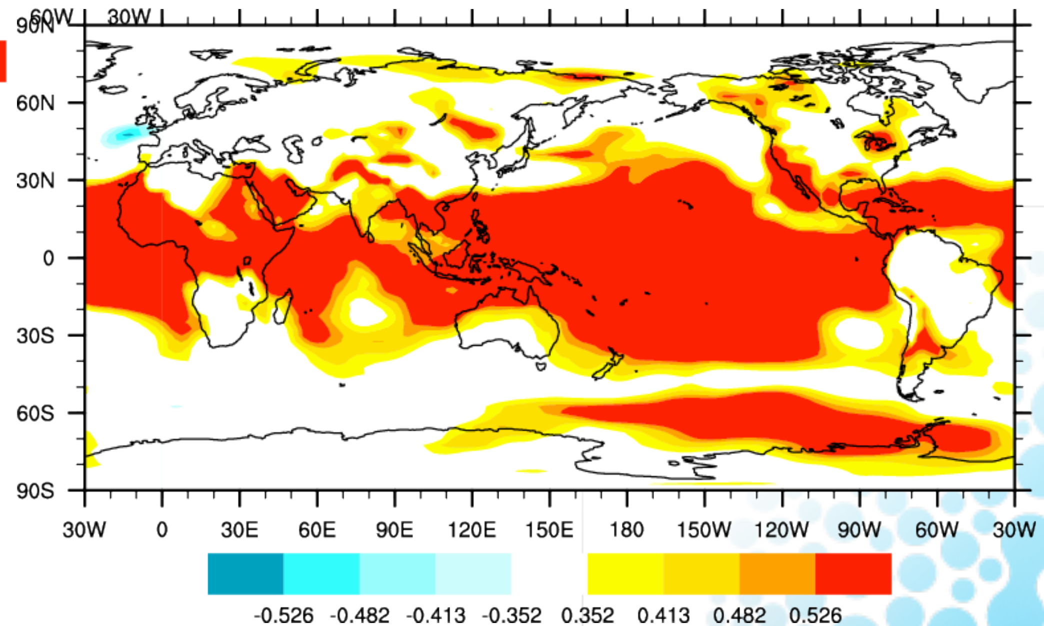
Forecast Verification

- Multi aspect evaluation is necessary.
- A single verification score (e.g. R=0.5, explaining 25% variance) cannot tell everything.
- User oriented verification would be useful.
- If not clear, use popular one.
- Difficulties in "translating" meteorological skill score into Public wording.
- Let's see some results!!!

APCC MME (TCC)

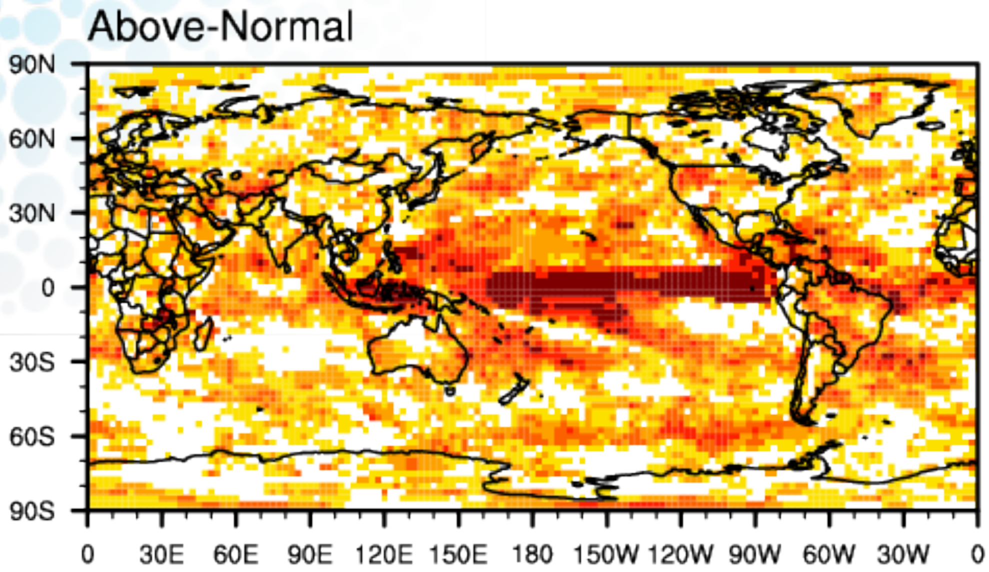


Rainfall (JJA)

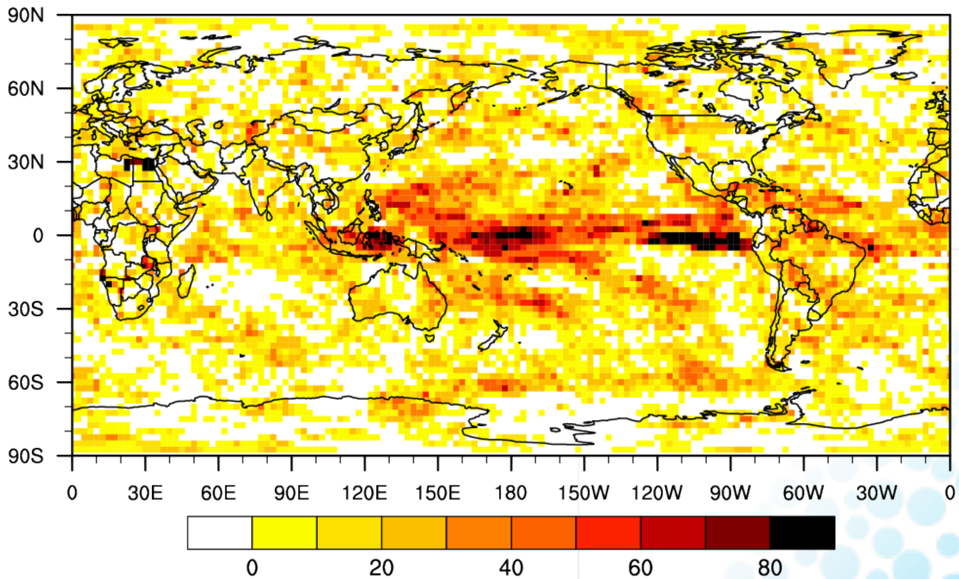


SLP (JJA)

ROC Score : PREC, JJA (1983-2005)



Heidke Skill Score : PREC, JJA (1983-2005)




Thank you