Downscaling of seasonal prediction

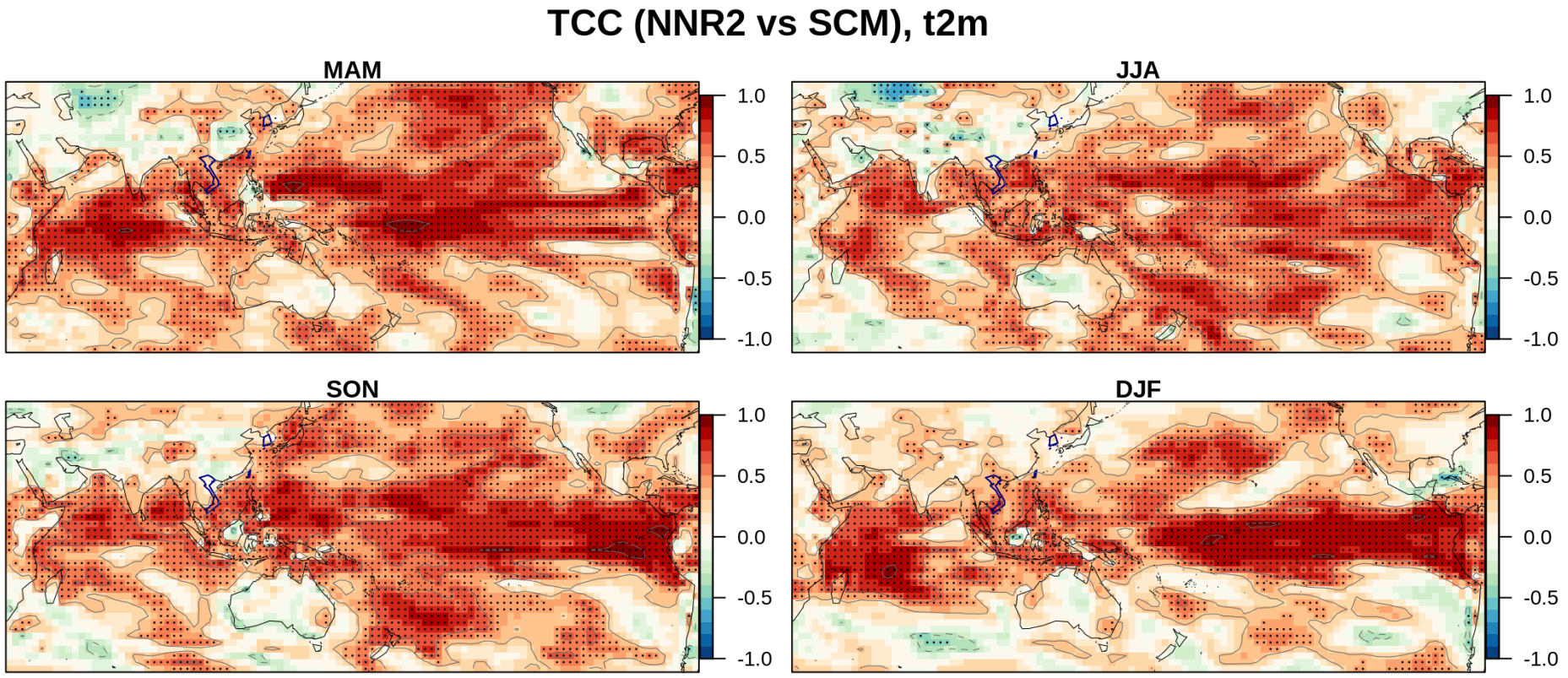
Yun-Young Lee

APCC APEC CLIMATE CENTER

Why downscaling is required?

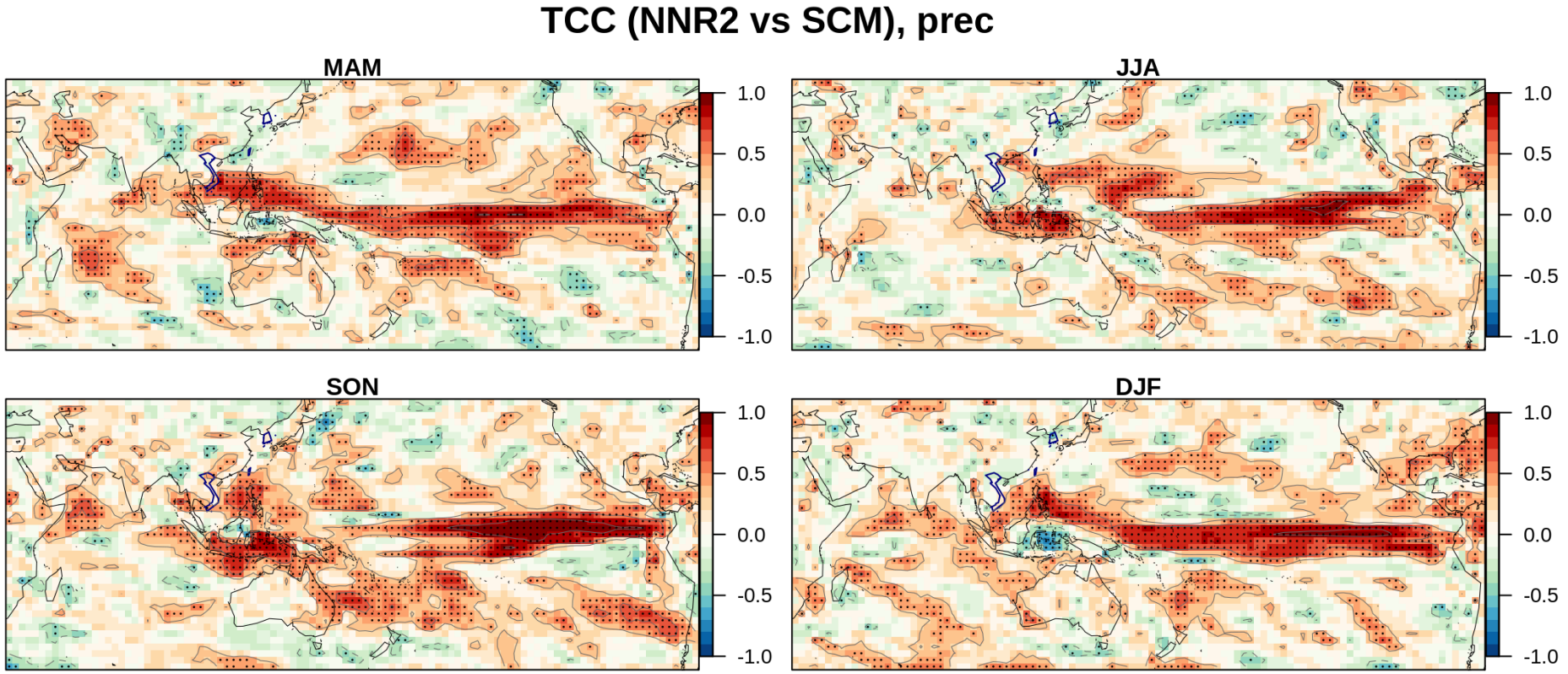
1. Low skill of dynamical seasonal forecast…

- near surface temperature…

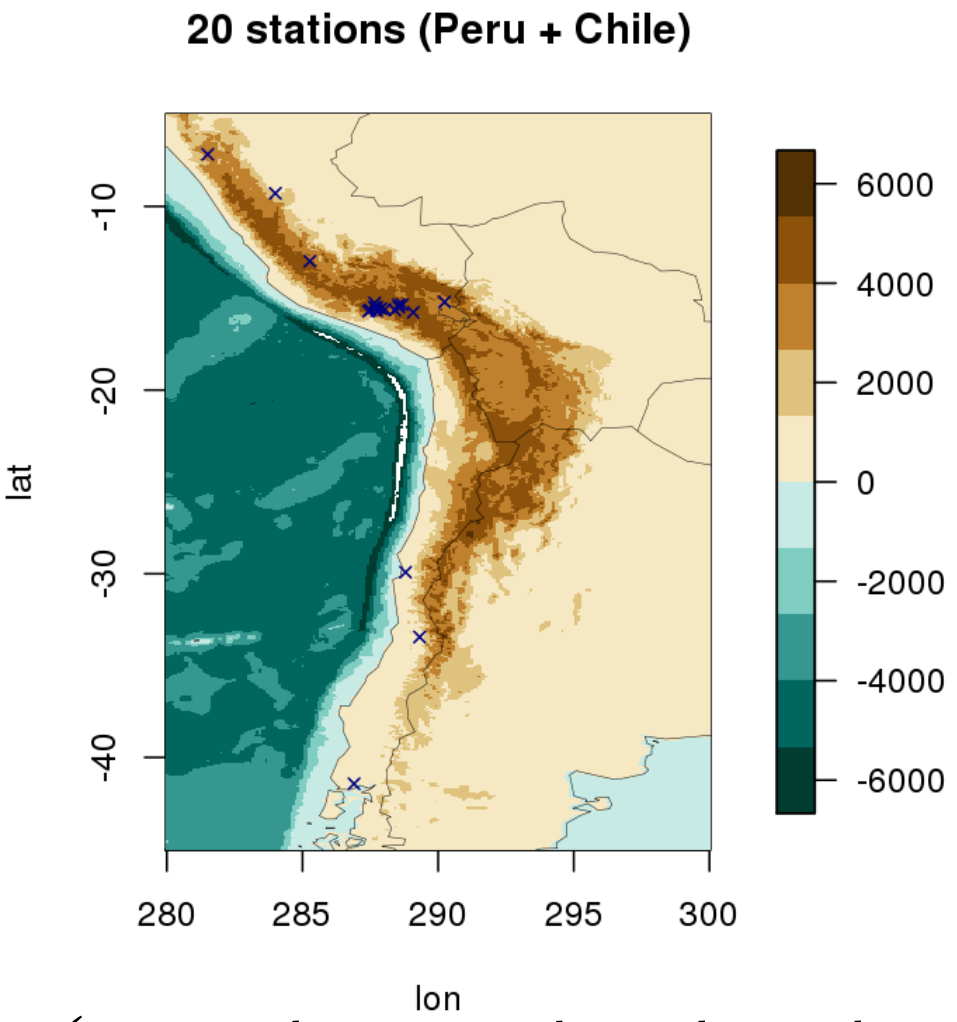


1. Low skill of dynamical seasonal forecast…

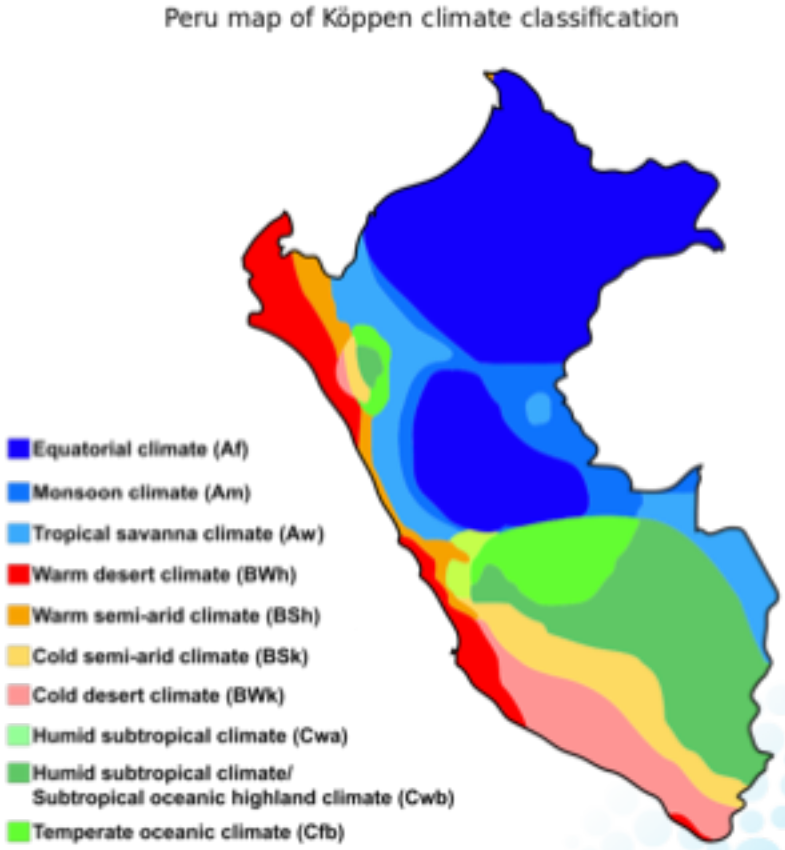
- ***Rainfall ?***
- *tropical Pacific only?*
- *Southeast Asia?*



2. Climate Locality



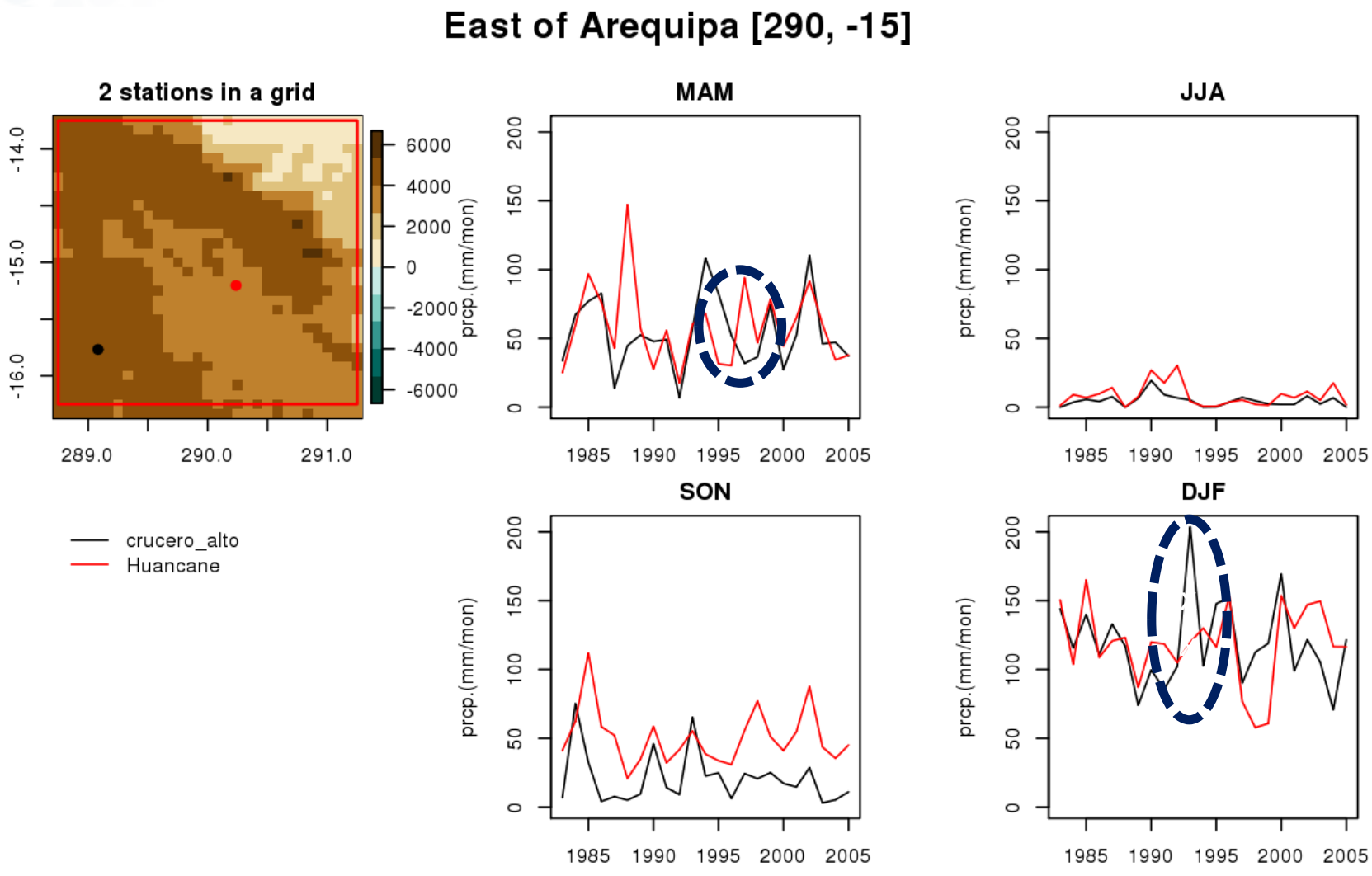
- Complicate climate of Peru



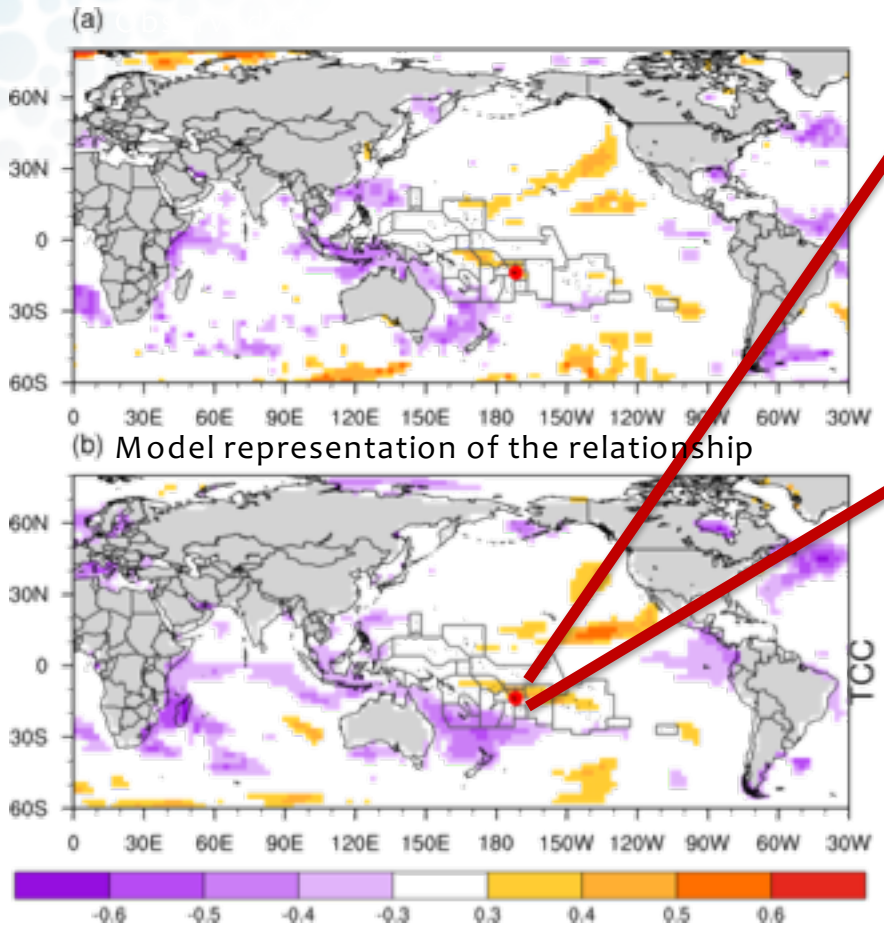
✓Can 2.5 by 2.5 grid pixel simulate ***steep terrain*** effect therefore ***locality of station climate*** ? Not really.

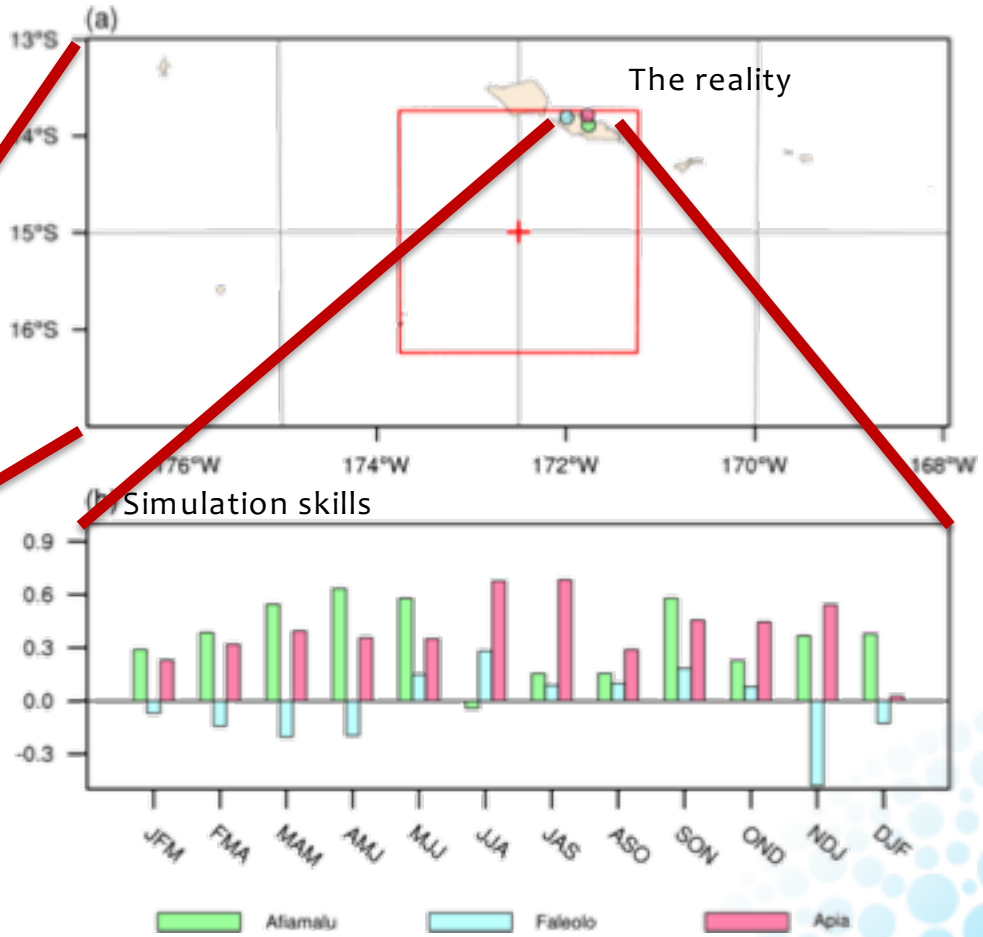
2. Climate Locality

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



Island Climate



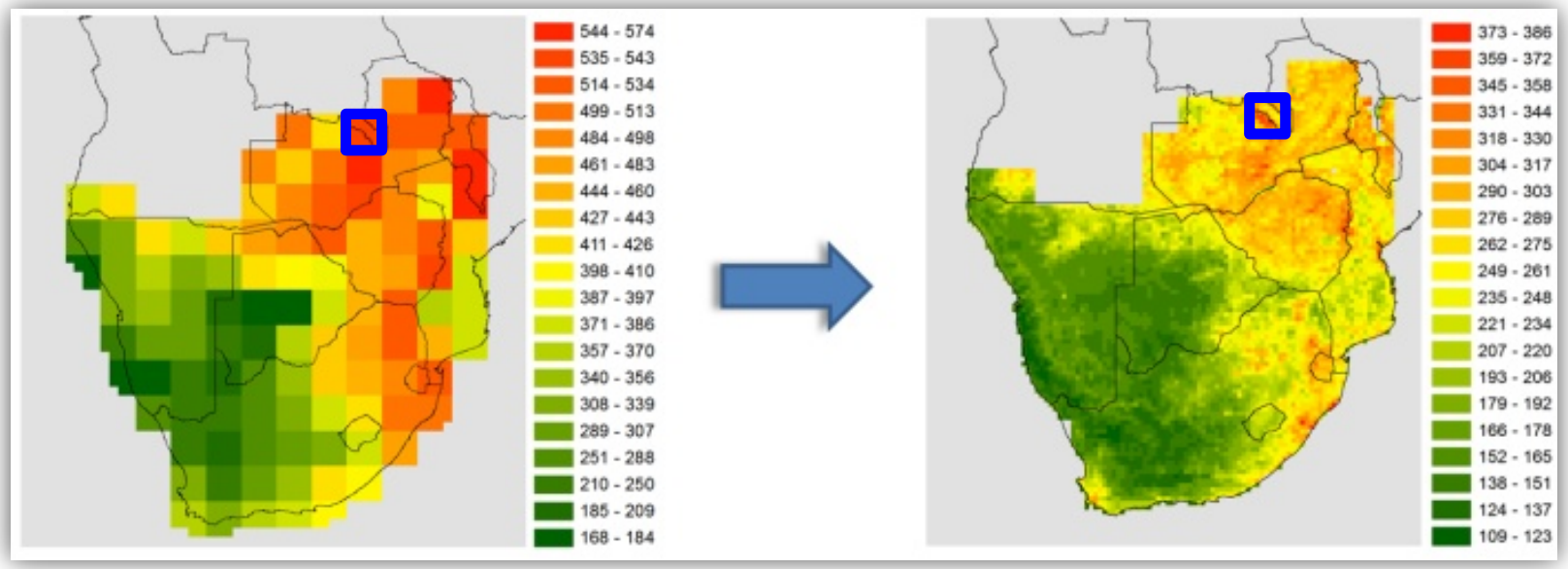


✓Can 2.5 by 2.5 grided model tell the difference of ***local climates between adjacent stations***? Not really.

What is downscaling?

Who are you?

Look inside!


544 - 574
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221 - 234
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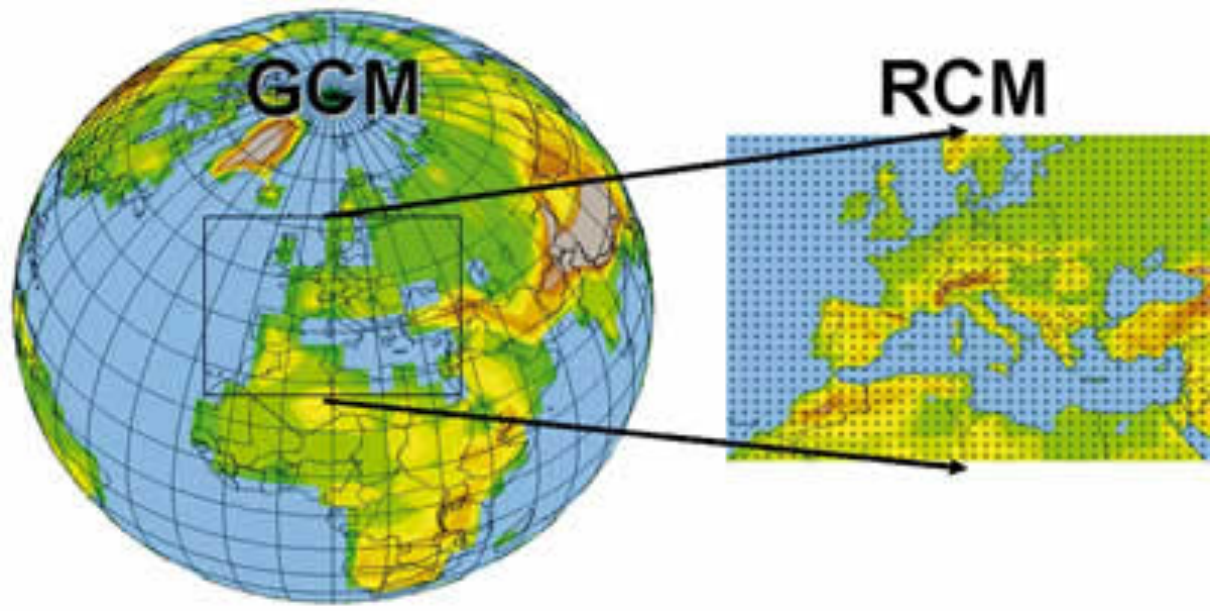
193 - 206
179 - 192
166 - 178
152 - 165
138 - 151
124 - 137
109 - 123

What is downscaling?

POST-PROCESSING!

=optimization/localization/customization of climate information

What is dynamical downscaling?



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

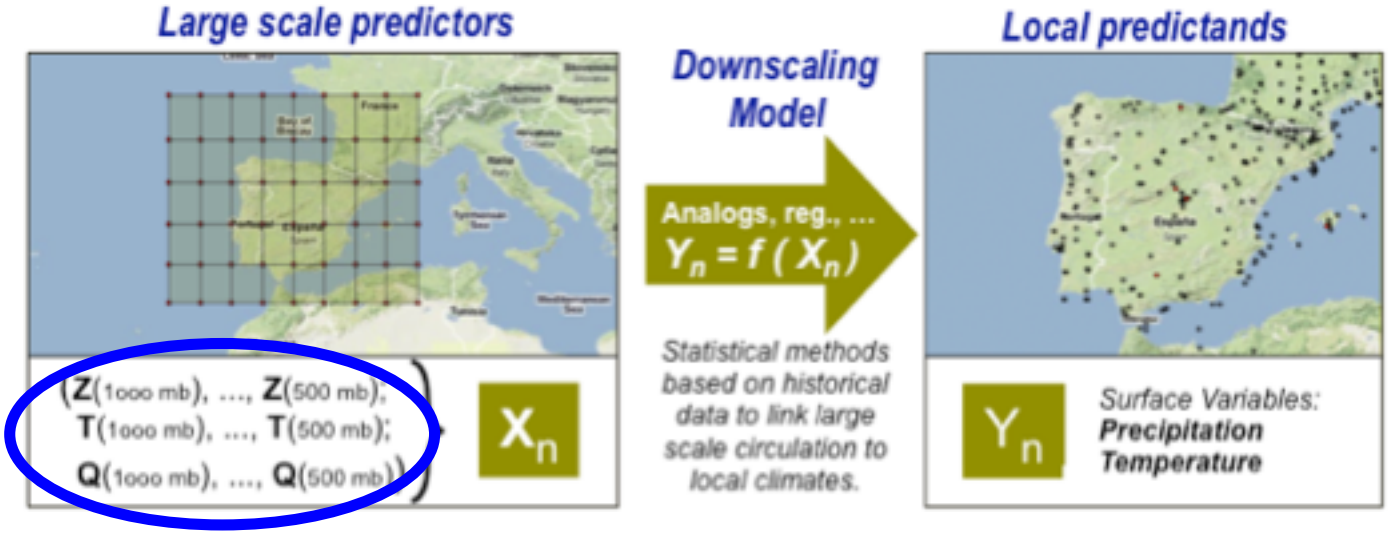
- BC from GCM, IC → solving dynamic equations!

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

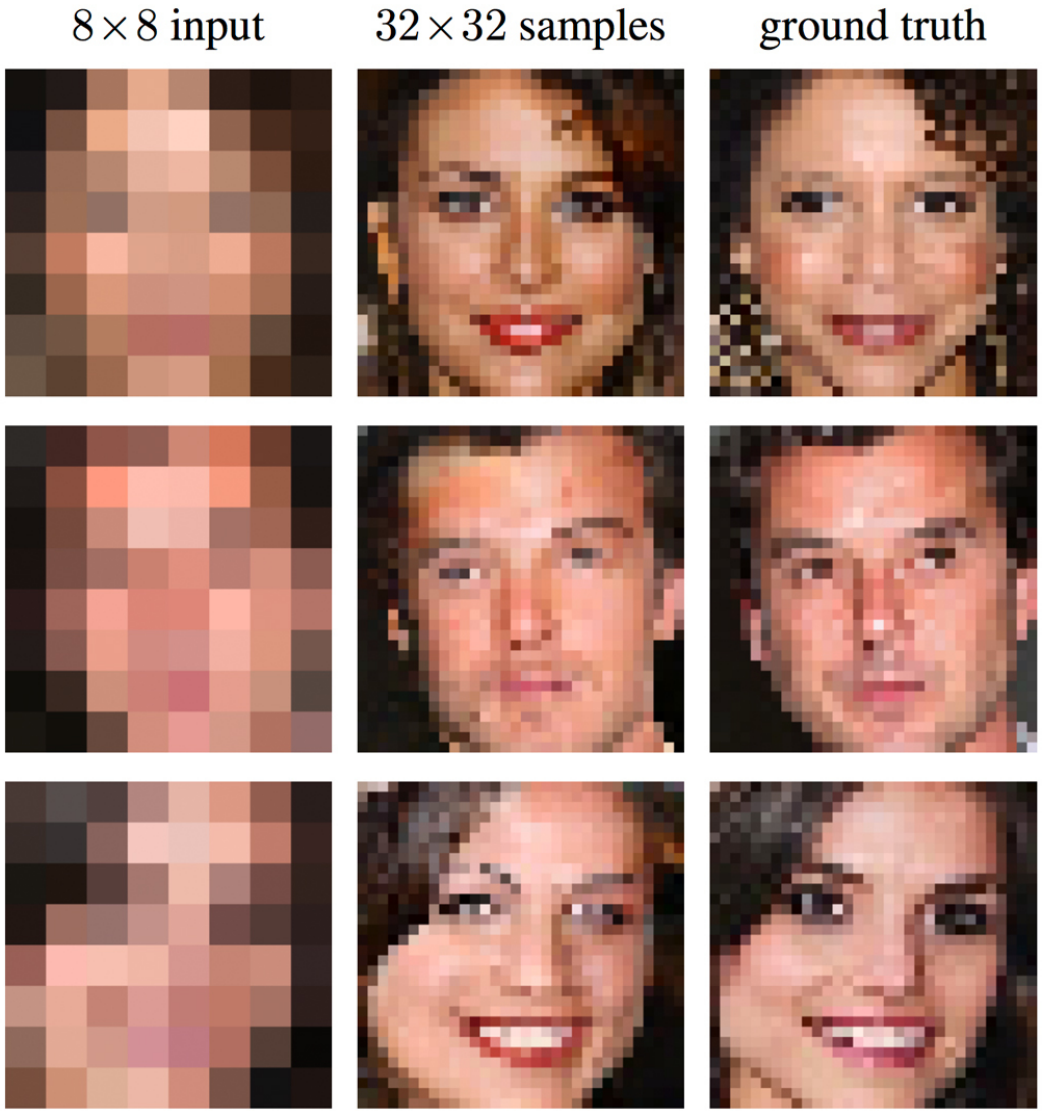
Empirical-statistical downscaling

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

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



Google uses AI to sharpen low-res images



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

CLIK Downscaling

✓***In changing climate …***

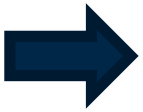
: increase of climate related disasters

✓***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)



http://clik.apcc21.org/

✓***What we have!***

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

✓***What we know!***

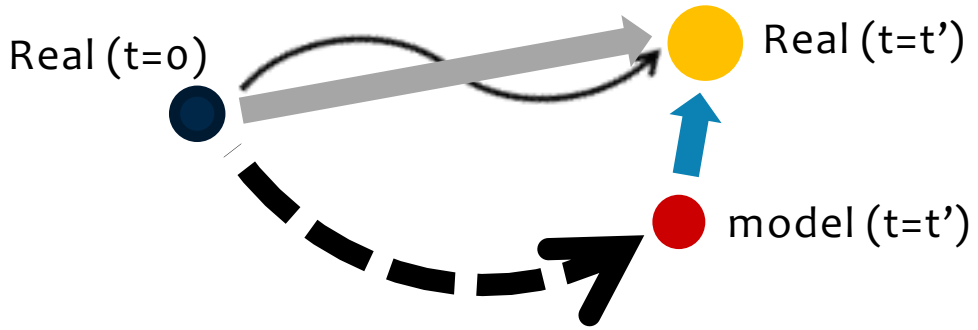
: past relationship (site – large scale field)

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**

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

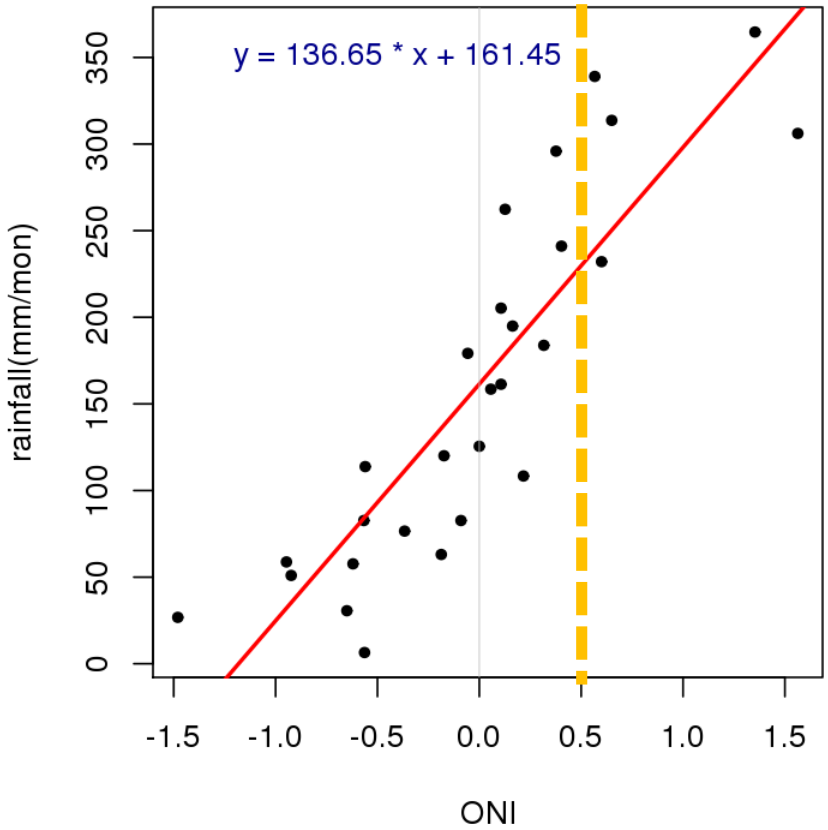
If i & j = 1 : Linear regression
i > 1, j = 1 : Multiple regression
i & j > 1 : CCA, SVD, etc

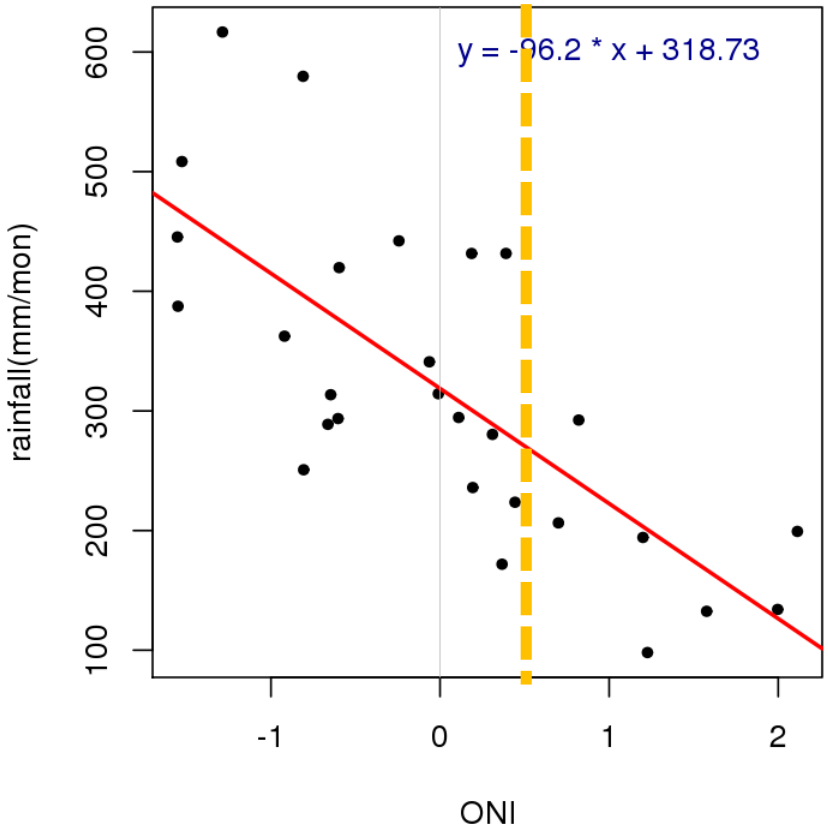
Regression concept!

Scatter plot & least square fitting!

$Y = a*x+b$

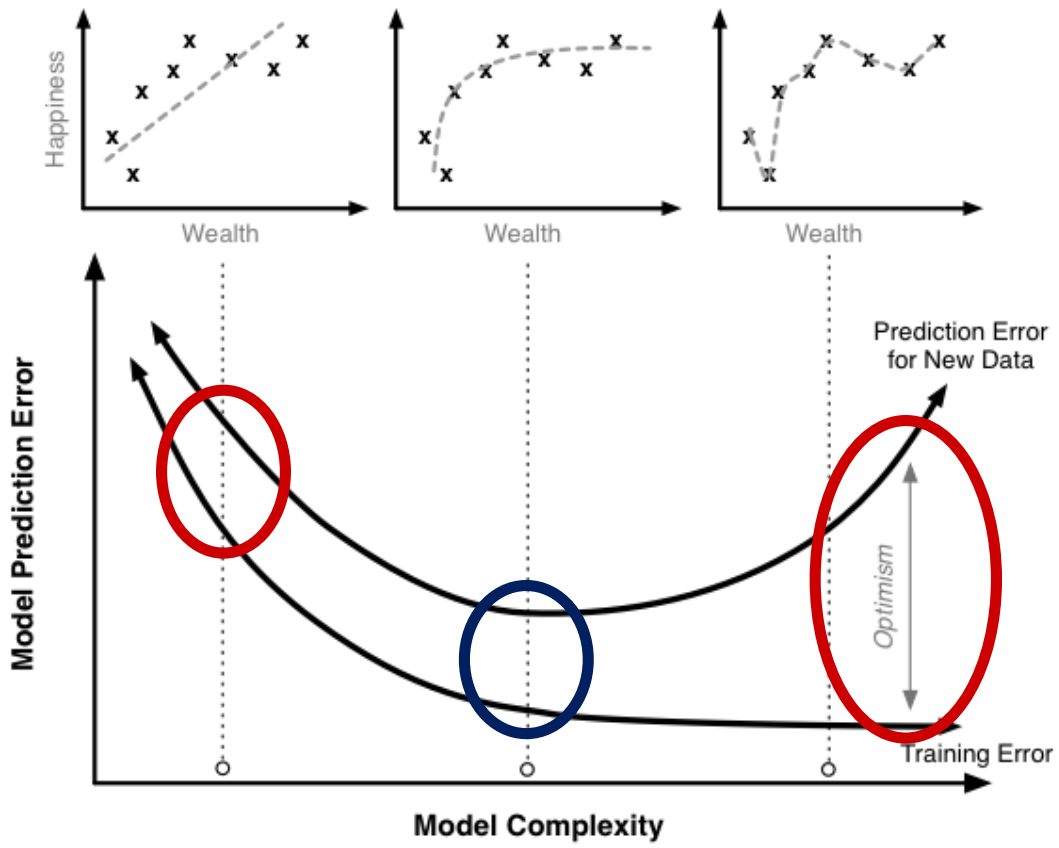
x: predictor (ONI)
y: predictand (rainfall)





Weakness : overfitting

- **Consider potential predictability**



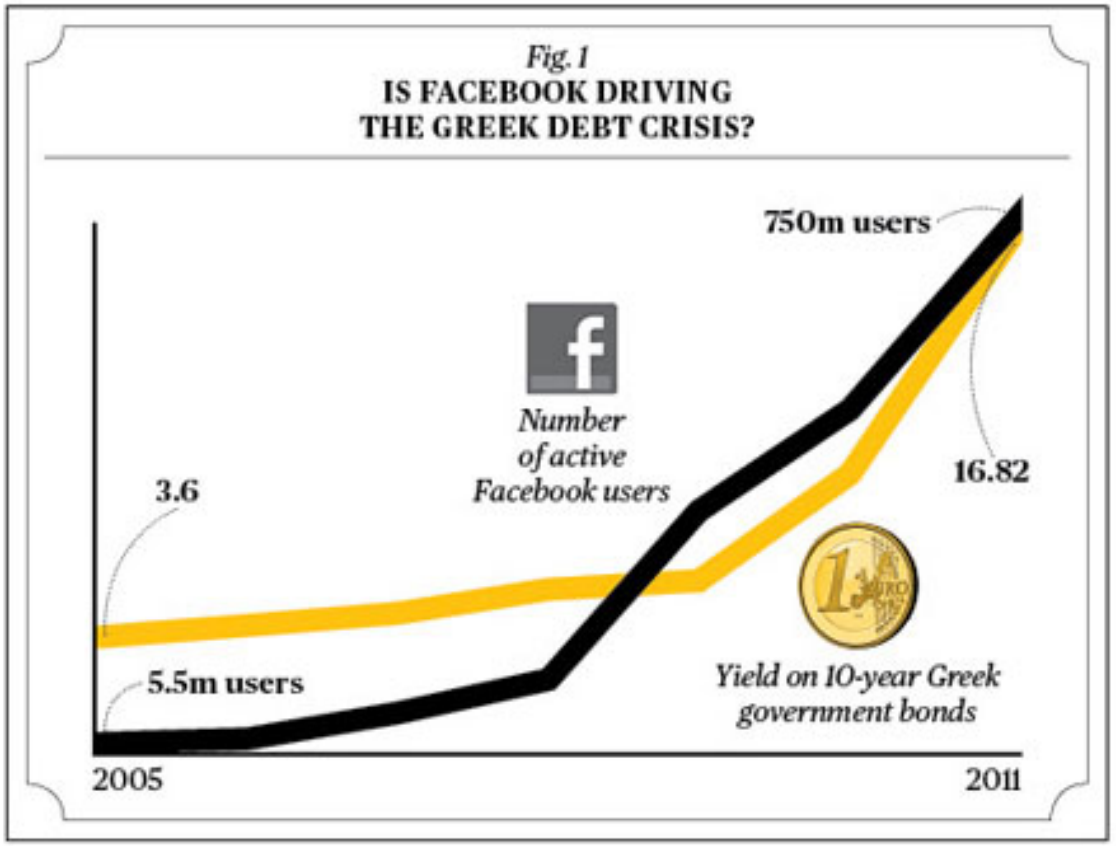
from Scott Fortmann-Roe 2012

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?

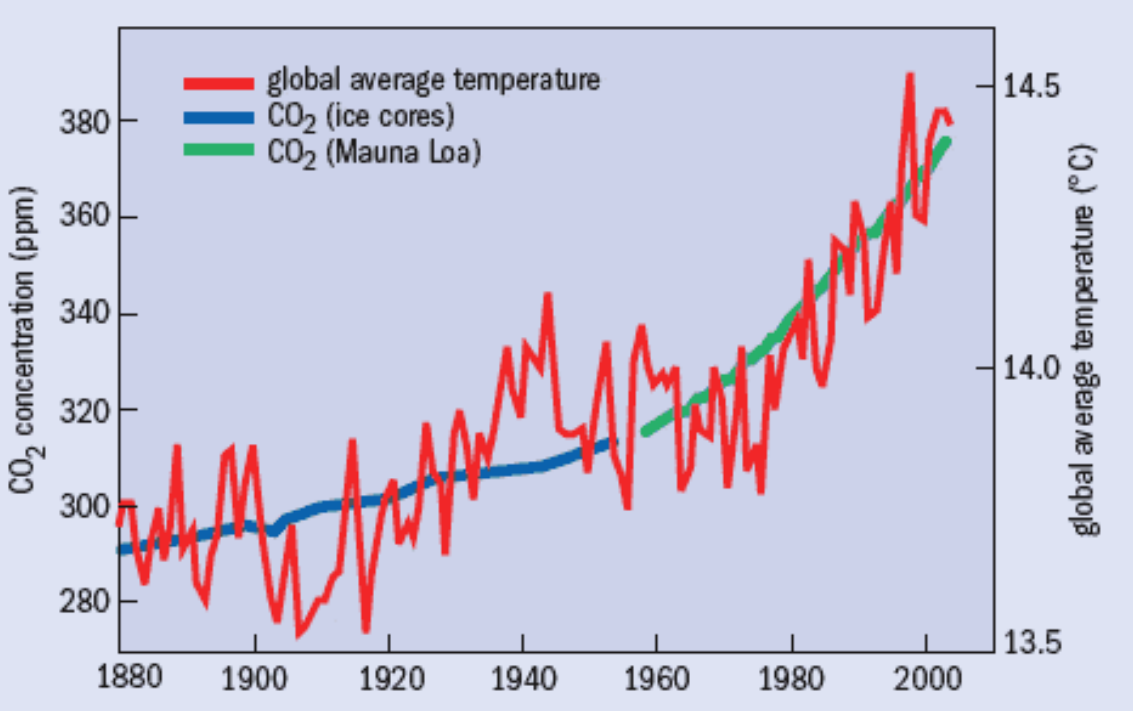


Image Source: images.iop.org

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 prec/temp of your station)

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

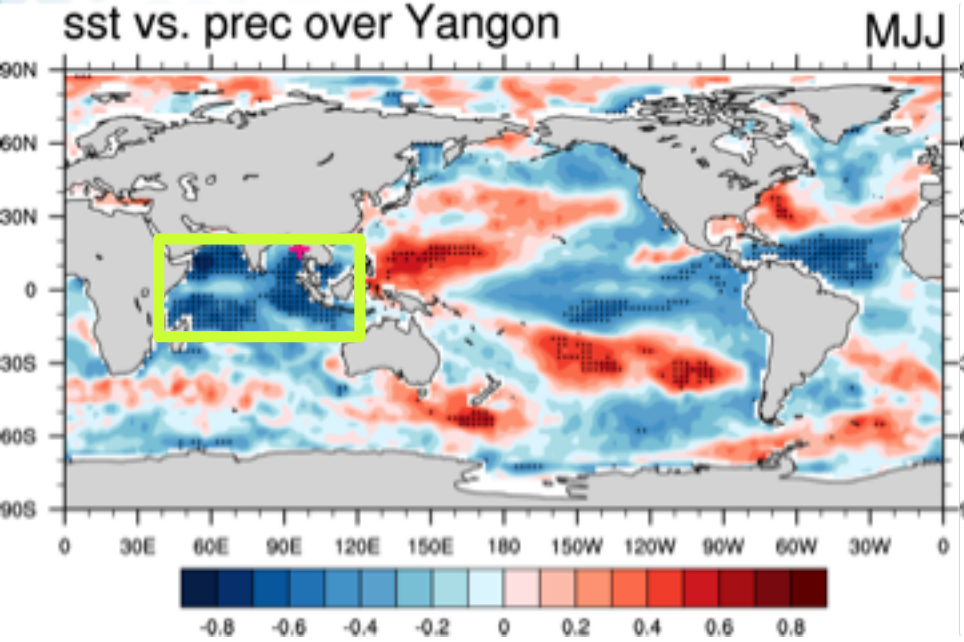
➔ ***Applicability*** of downscaling

Example of Domain Selection

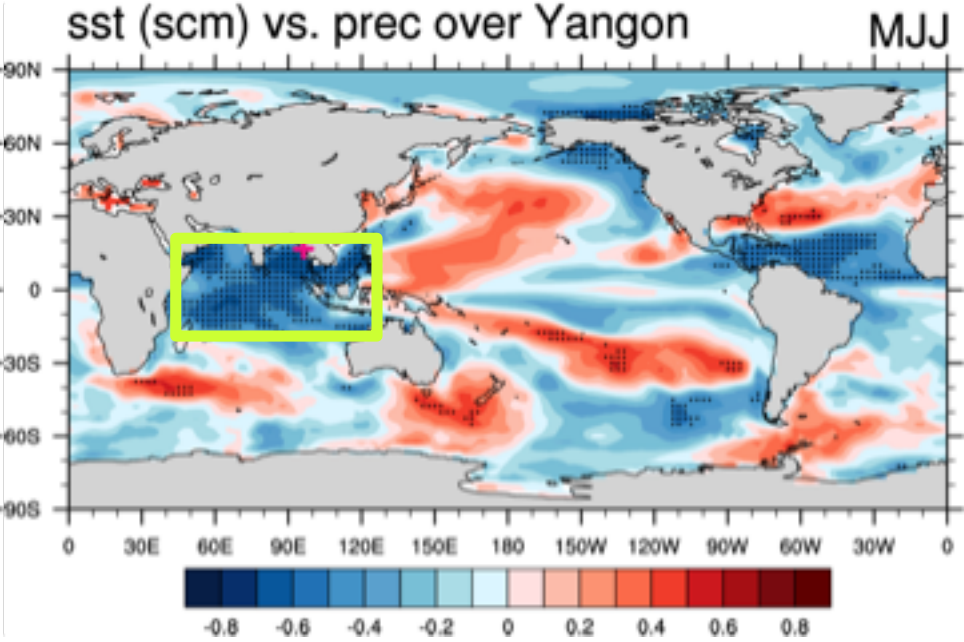
:should be based on **large scale pattern** associated with local temperature/rainfall

Station to LSMP relationship

OBS (Reanalysis)



Model (SCM)



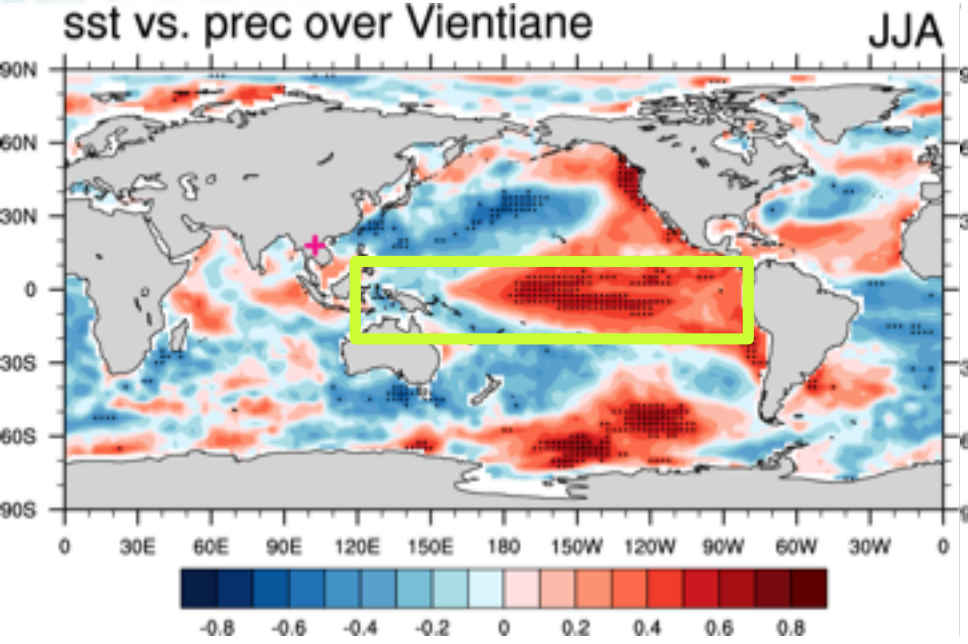
Indian Ocean Basin-wide Cooling:

SST↓ → Yangon rain ↑

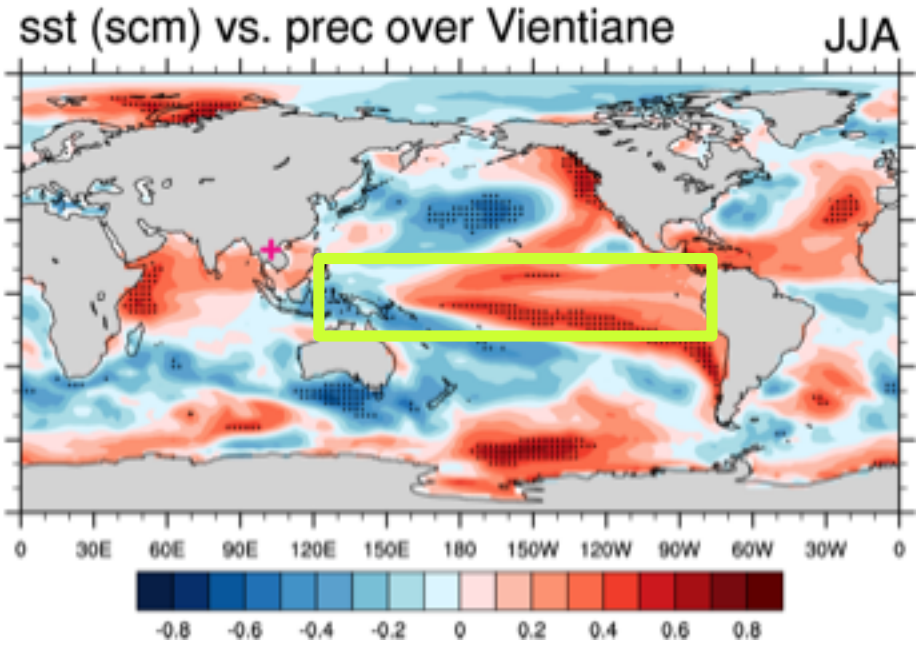
SST↑ → Yangon rain ↓

Station to LSMP relationship

OBS (Reanalysis)



Model (SCM)



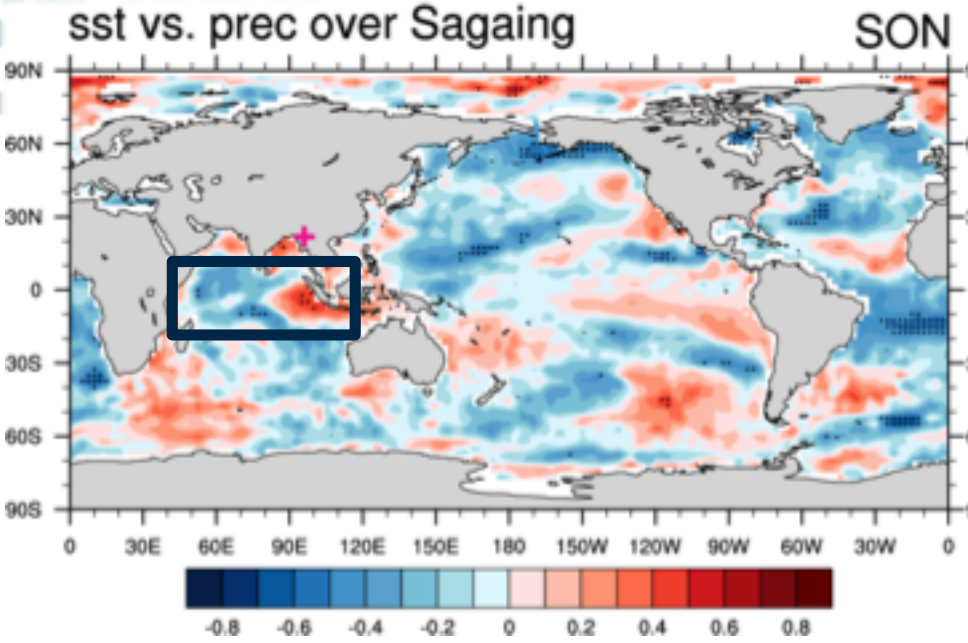
ENSO system:

El Nino → Vientiane rain ↑

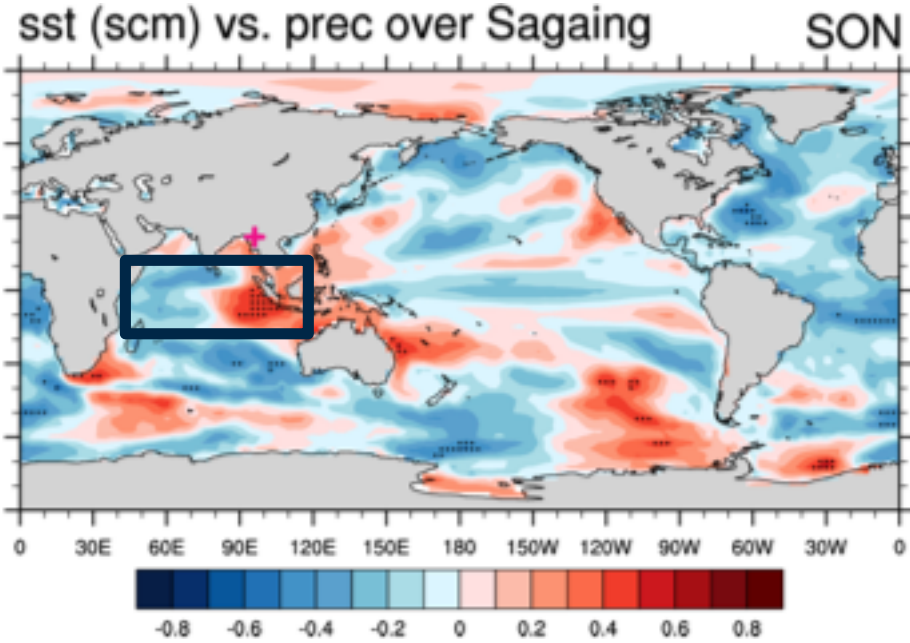
La Nina → Vientiane rain ↓

Station to LSMP relationship

OBS (Reanalysis)



Model (SCM)



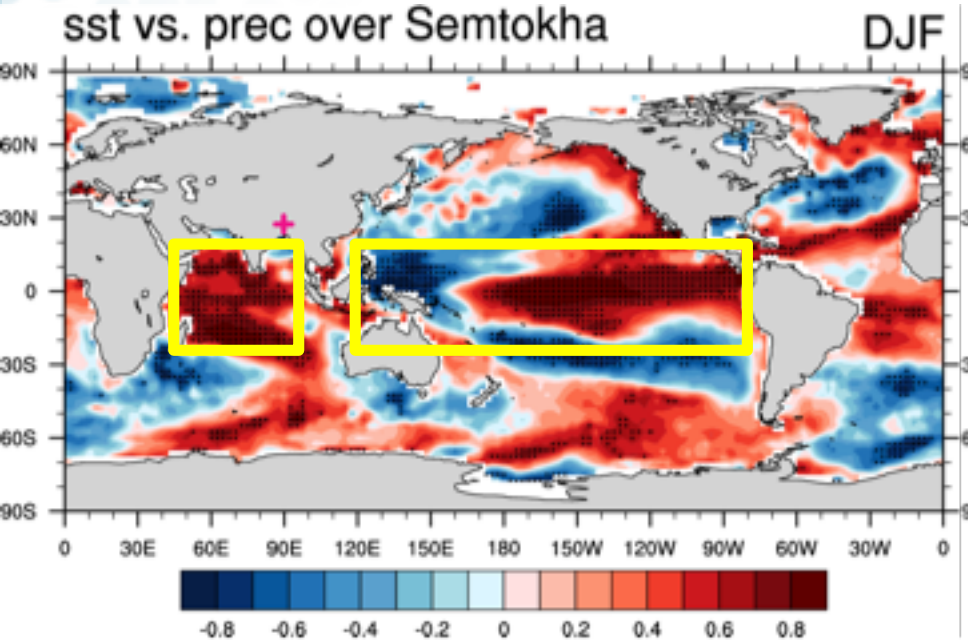
Indian Ocean Dipole:

Neg. IOD → Sagaing rain ↑

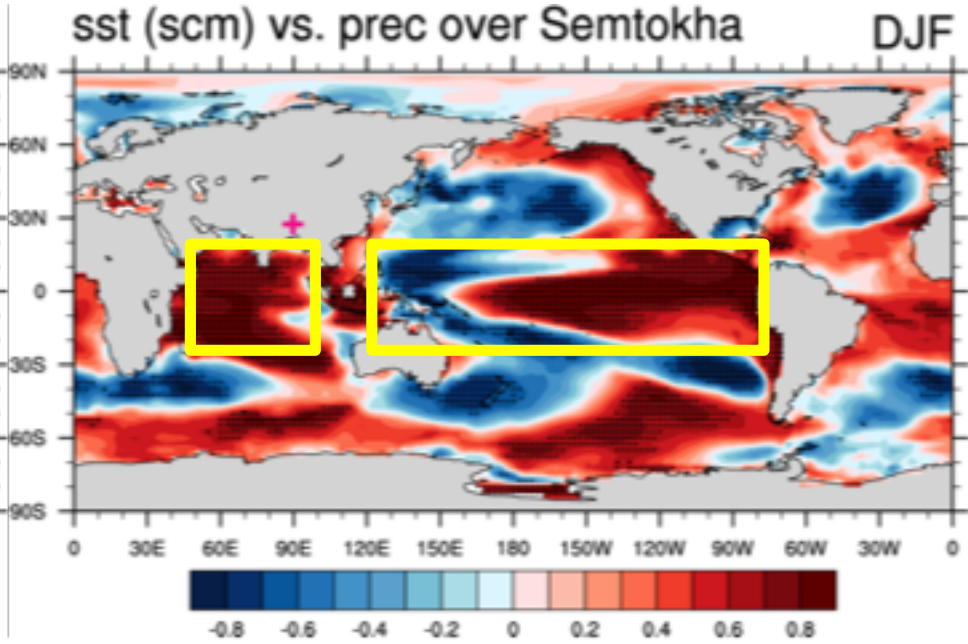
Pos. IOD → Sagaing rain ↓

Station to LSMP relationship

OBS (Reanalysis)



Model (SCM)

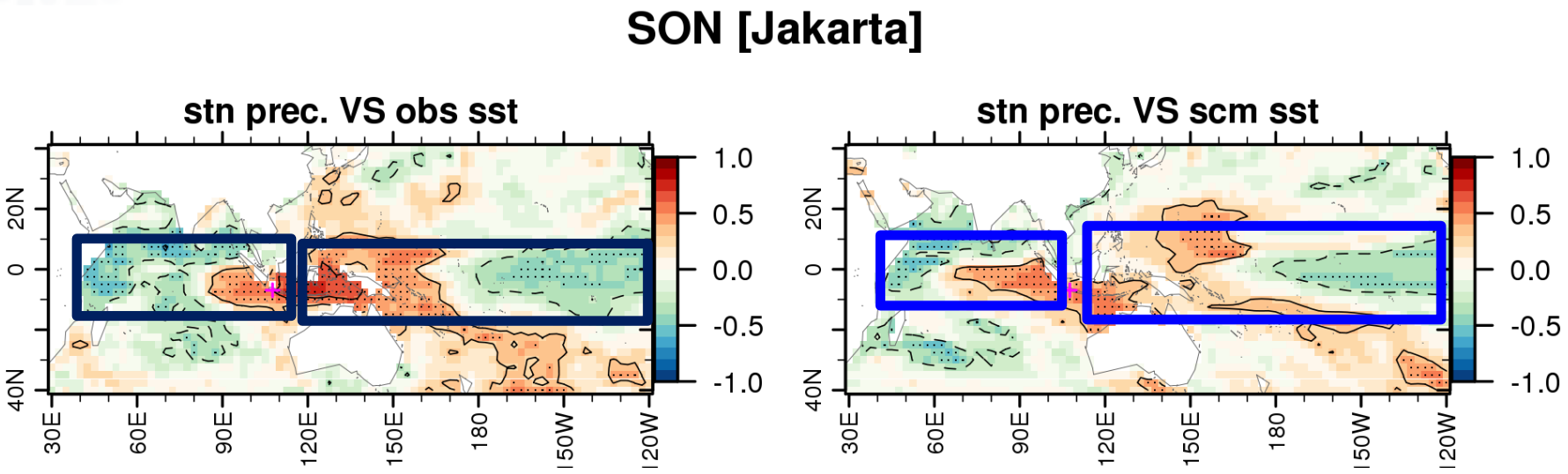


IOBM + ENSO:

IO warming & El Nino → Semtokha rain ↑

IO cooling & La Nina → Semtokha rain ↓

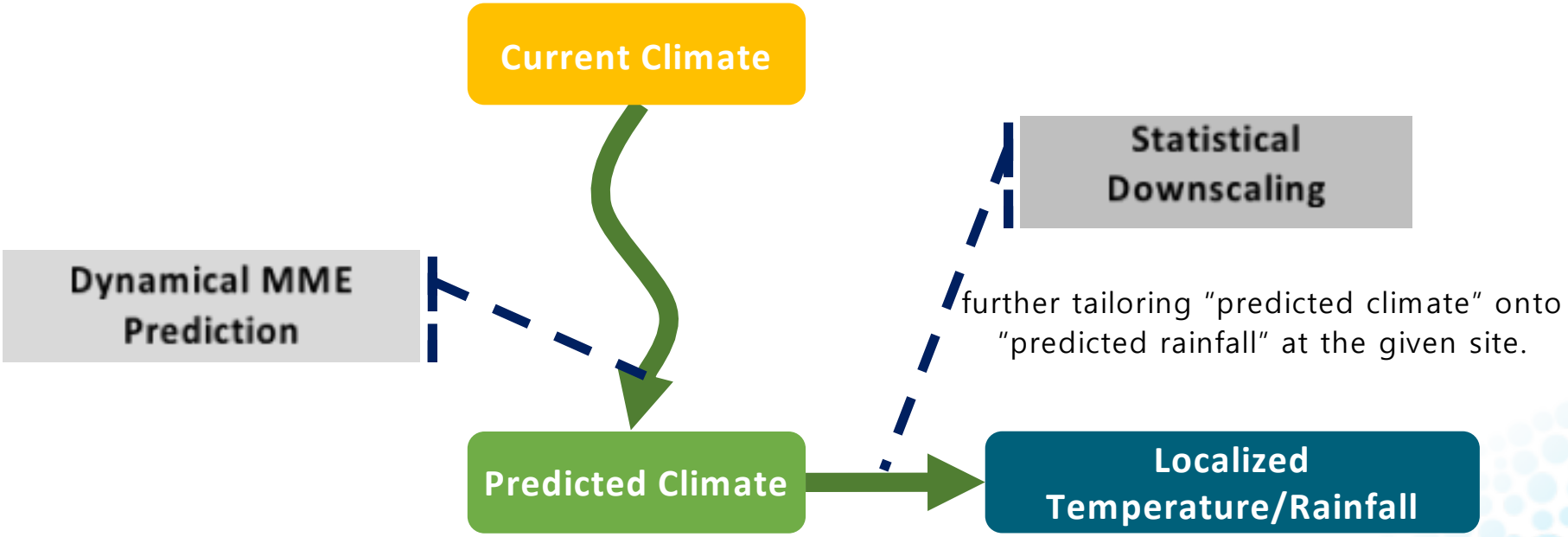
Maritime Continent: Indonesia



La Nina (and negative IOD) signature

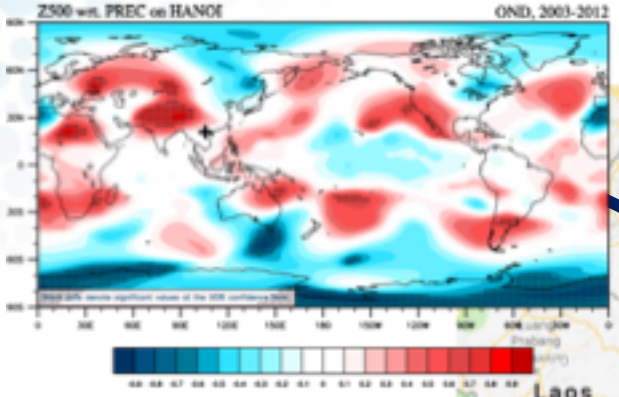
Downscaling/tailoring of dynamical MME

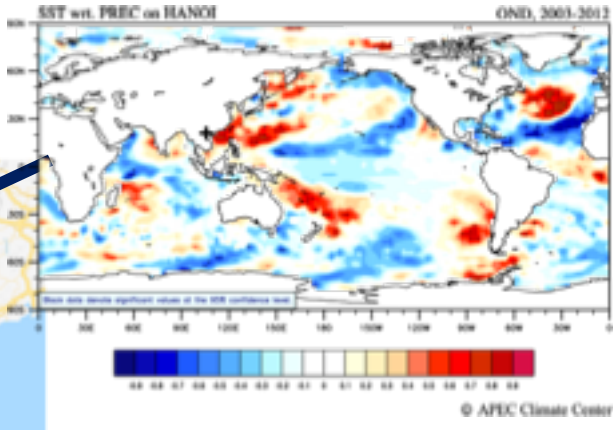
Clik
Climate Information Toolkit



1) Physical/dynamical process
2) Model biases *vs* Observed dynamics

OND, PREC


Z500 wrt. PREC on HANOI
OND, 2003-2012


SST wrt. PREC on HANOI
OND, 2003-2012
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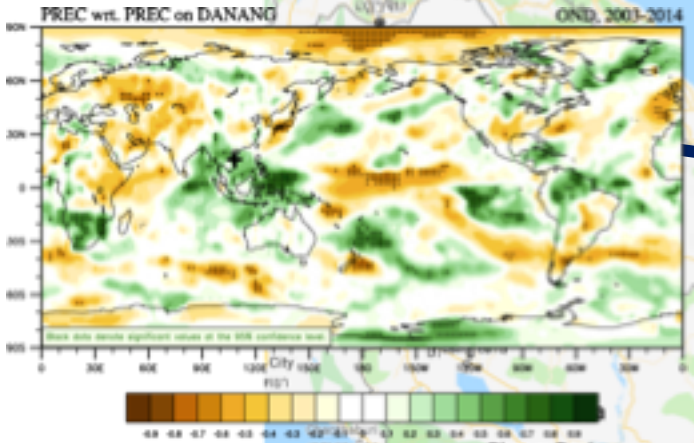
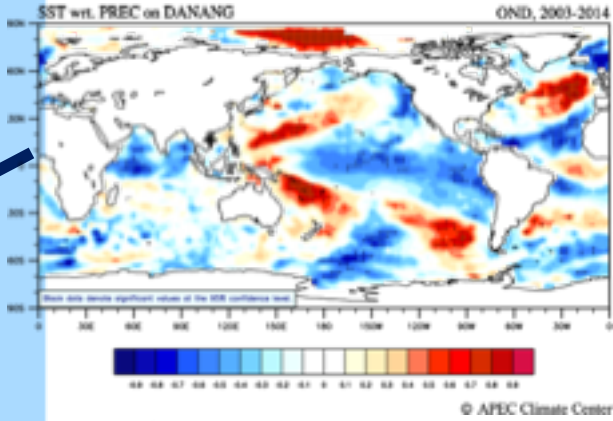

PREC wrt. PREC on DANANG
OND, 2003-2014


SST wrt. PREC on DANANG
OND, 2003-2014
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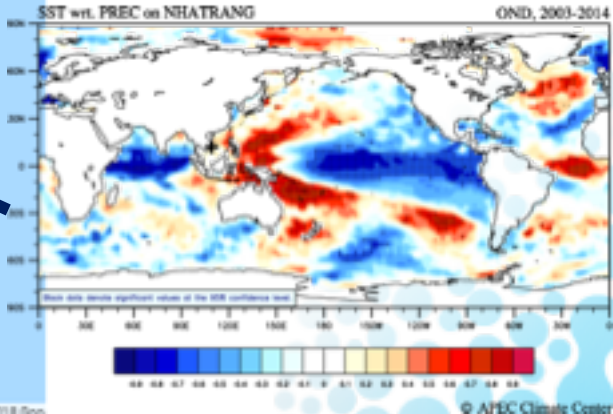
SST wrt. PREC on NHATRANG
OND, 2003-2014
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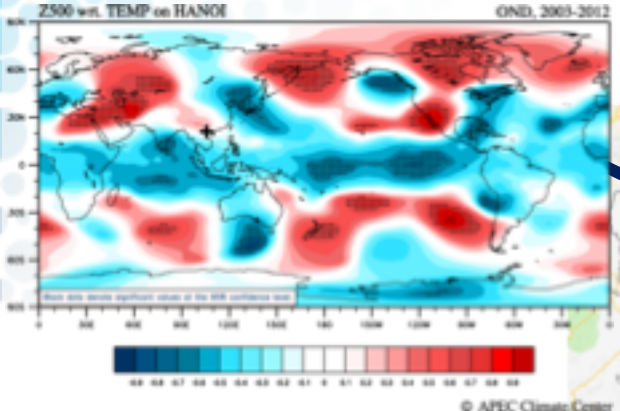
Nanning
Hanoi
Hai Phong
Laos
Vientiane
HAINAN
Vietnam
Phnom Penh
Ho Chi Minh City
Nha Trang
Dalat
Vung Tau
Can Tho
Gulf of Thailand
Google

OND, TEMP


Z500 wrt. TEMP on HANOI
OND, 2003-2012
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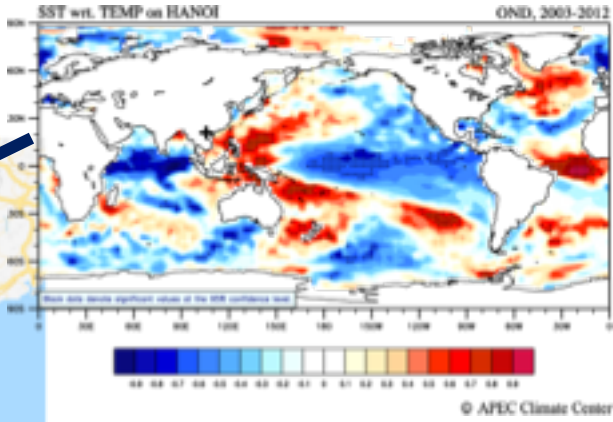
SST wrt. TEMP on HANOI
OND, 2003-2012
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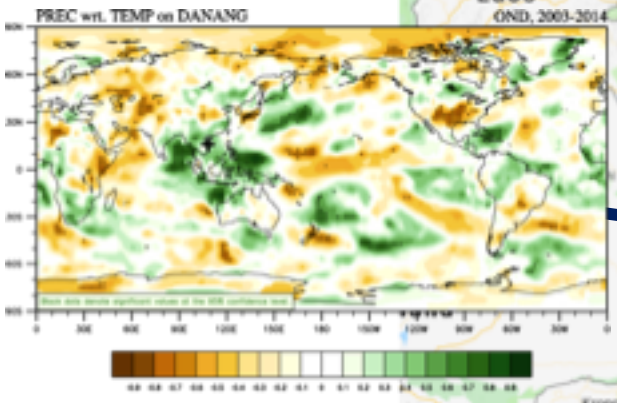
PREC wrt. TEMP on DANANG
OND, 2003-2014
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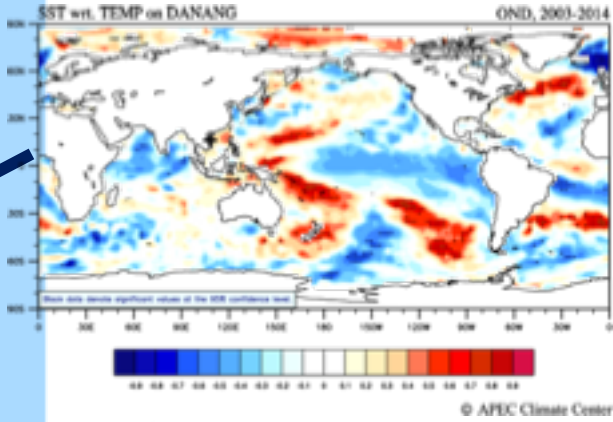
SST wrt. TEMP on DANANG
OND, 2003-2014
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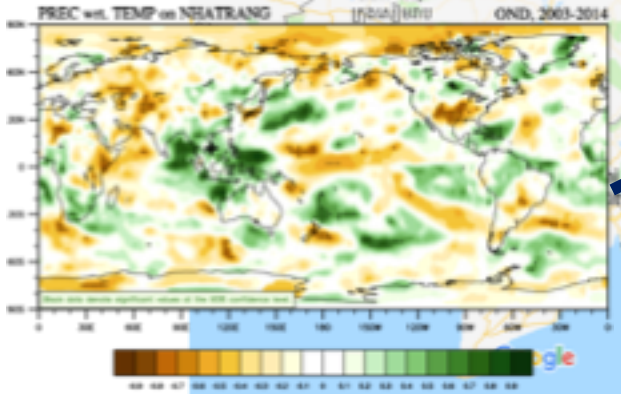
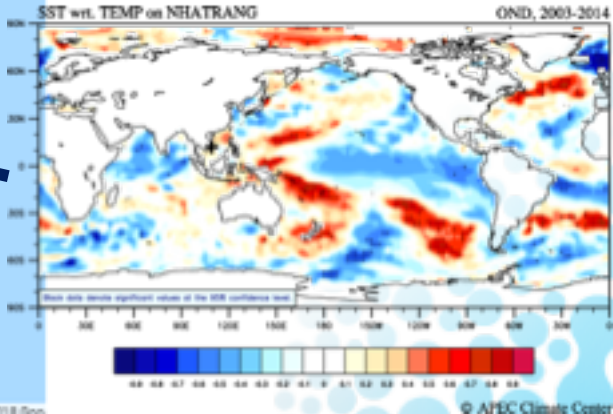

PREC wrt. TEMP on NHATRANG
OND, 2003-2014


SST wrt. TEMP on NHATRANG
OND, 2003-2014
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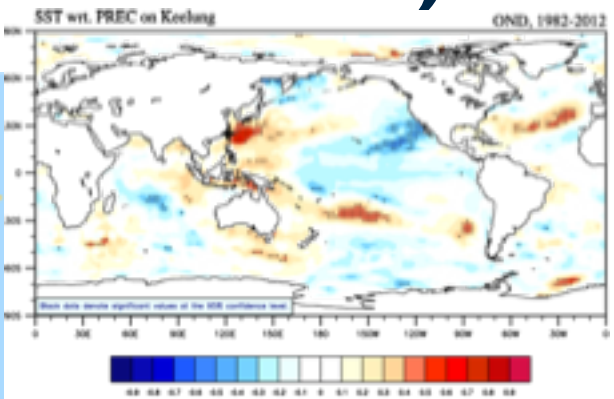
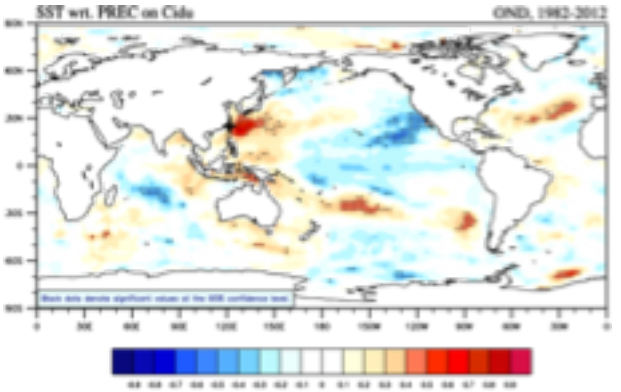
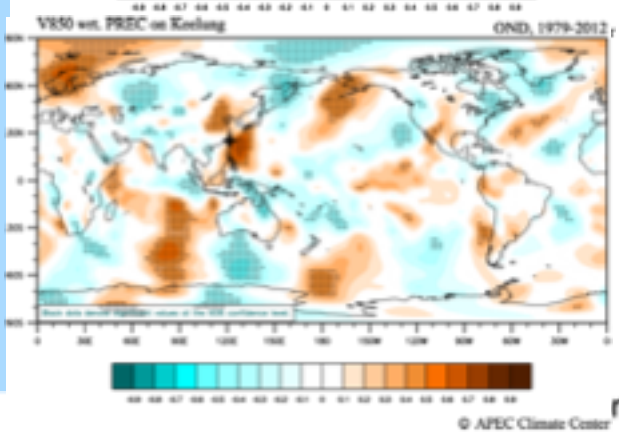
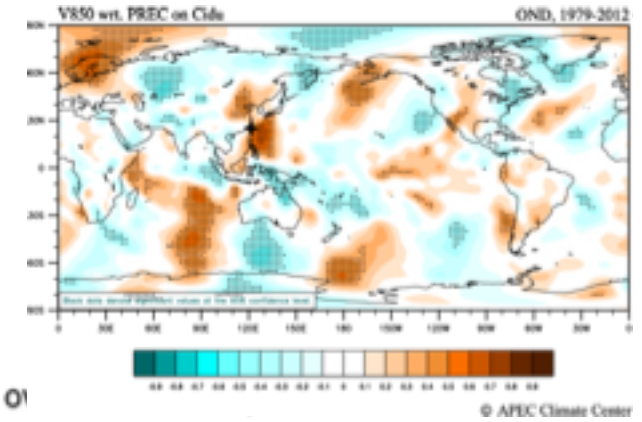
TAIWAN, OND


Taipei
台北
Hsinchu City
新竹市
Taichung City
Hualien
County
花蓮縣
Taiwan
臺灣
Taiwan
Tainan City
Kaohsiung
City


SST wrt. PREC on Keelung
OND, 1982-2012


SST wrt. PREC on Cidu
OND, 1982-2012


V850 wrt. PREC on Keelung
OND, 1979-2012
© APEC Climate Center


V850 wrt. PREC on Cidu
OND, 1979-2012
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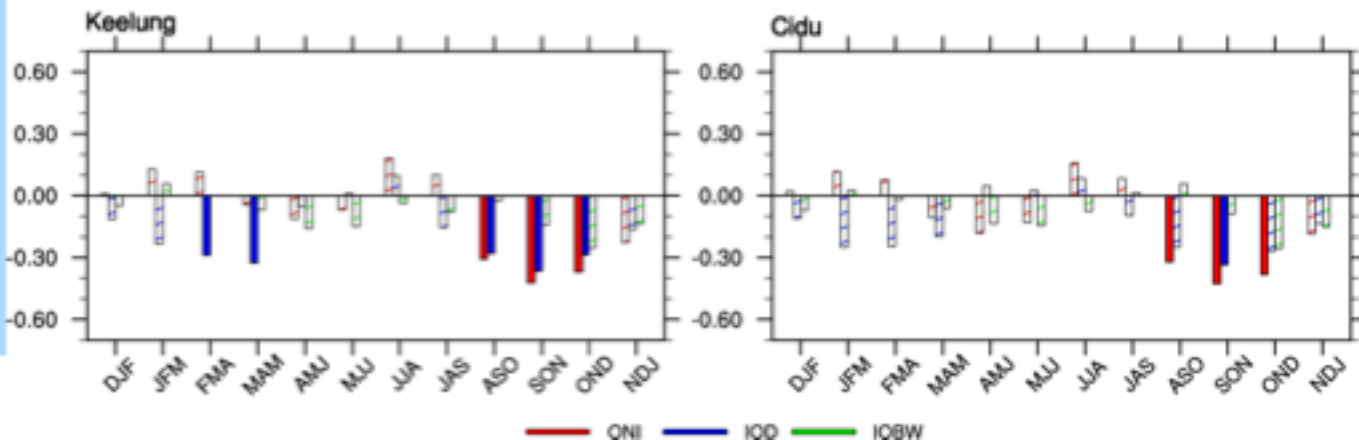
Keelung
Cidu
0.60
0.30
0.00
-0.30
-0.60
DJF
JFM
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AMJ
MJJ
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JAS
ASO
SON
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NDJ
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IOD
IOBW

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 prec/temp of your station)

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

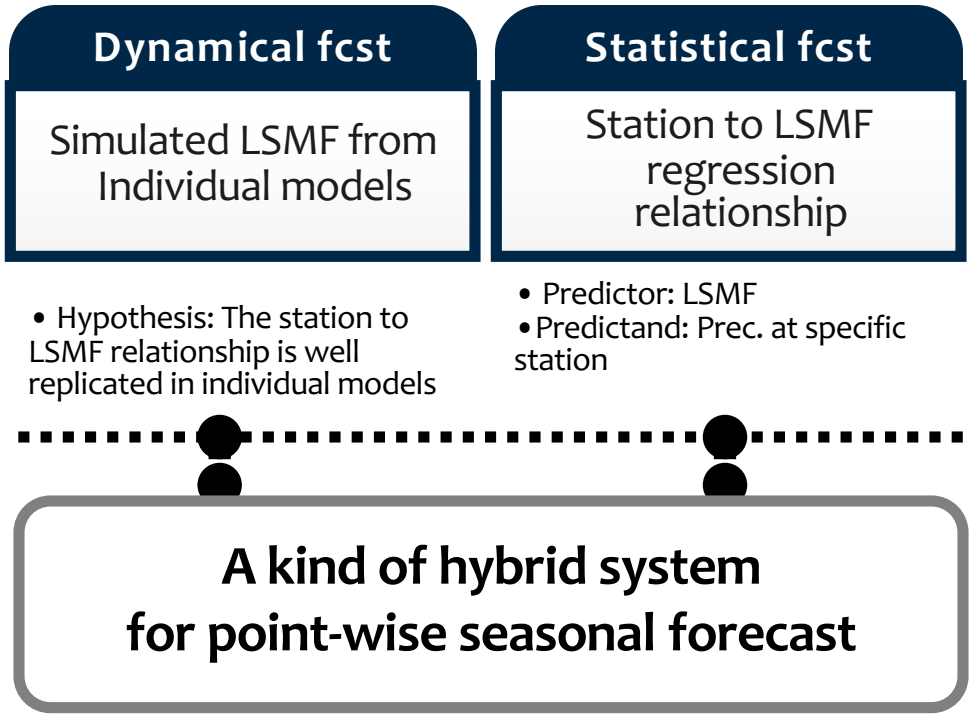
➔ ***Applicability*** of downscaling

Availability of Downscaled information?

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.



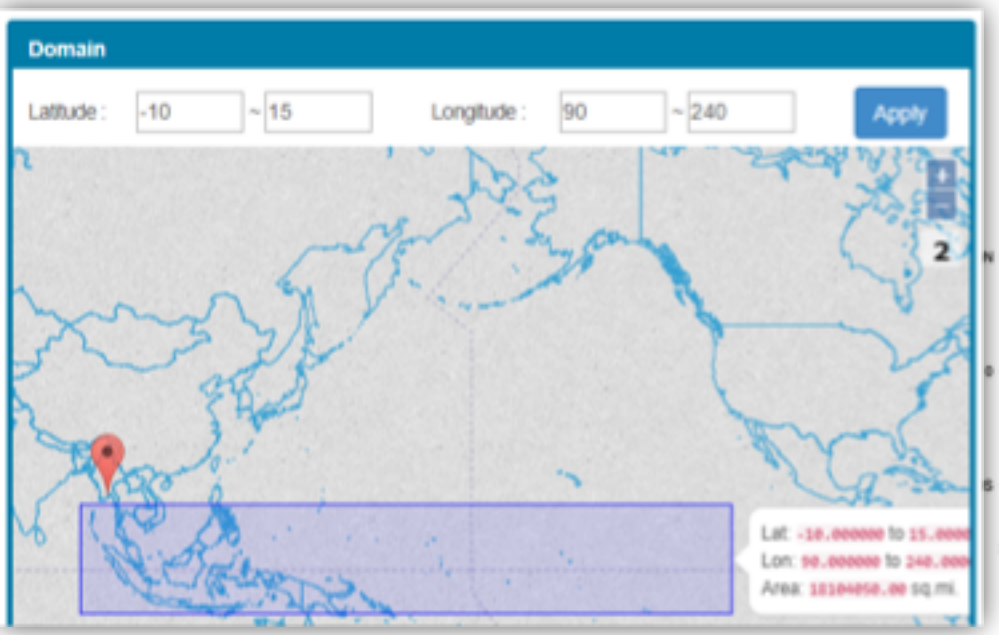
CLIK downscaling

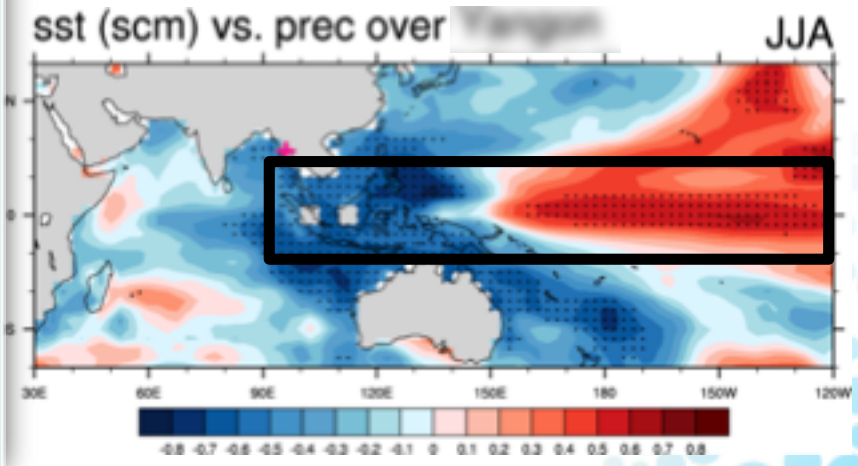
A way to localize existing coarse climate information

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.

Empirical relationship: LSMP (OBS) ~ local station rainfall

LSMP (MME) → Local station rainfall

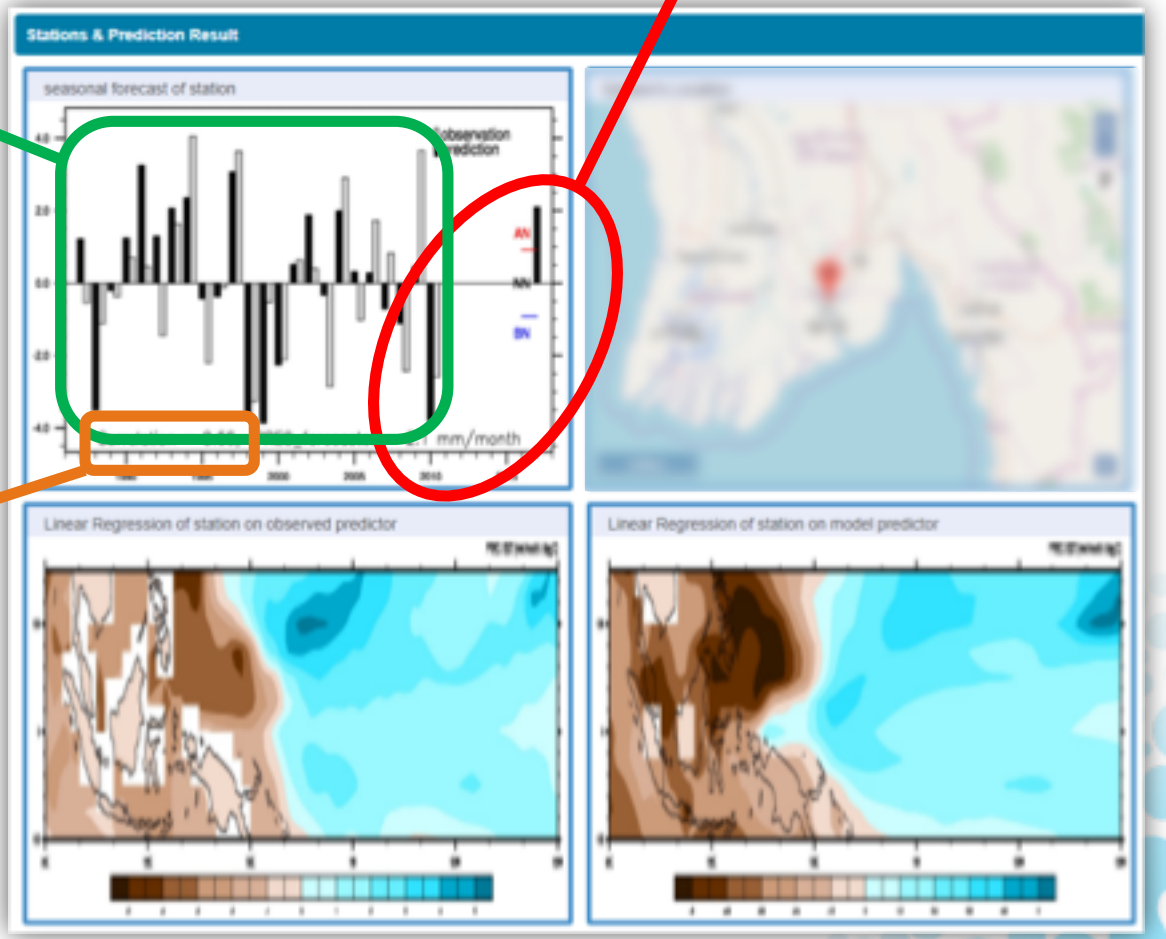




Downscaled forecast at a given site

Deterministic forecast with **tercile range** for target year/season

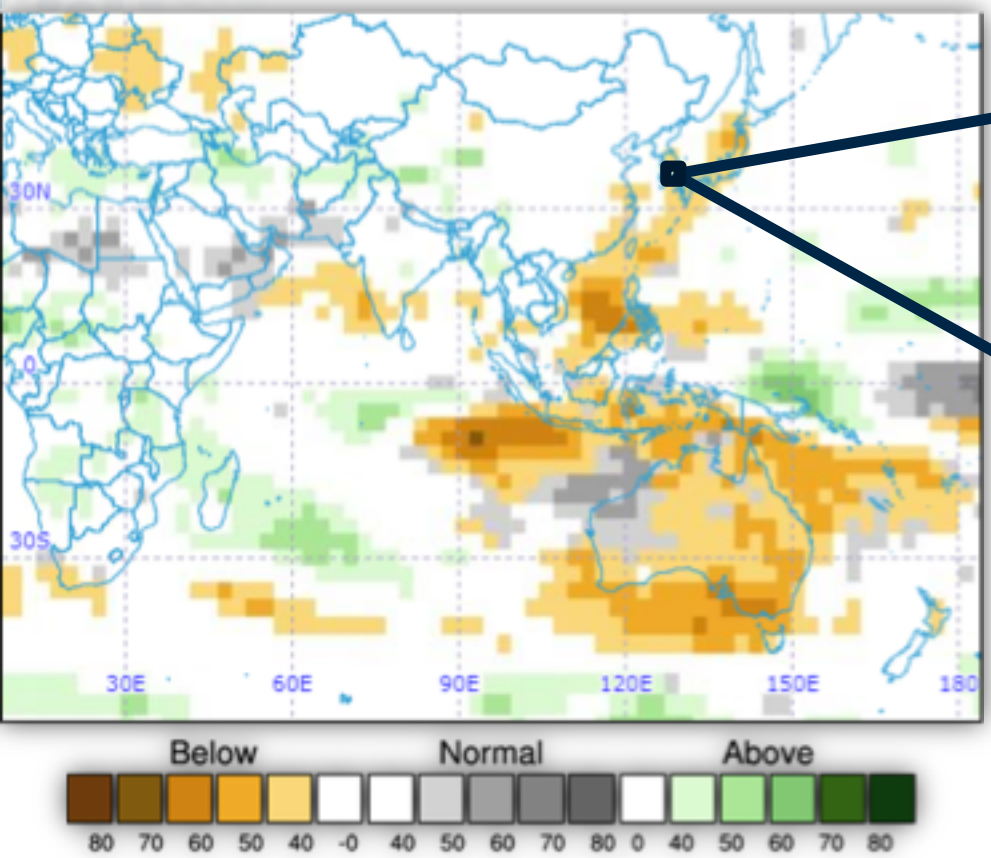
Historical time series: obs & downscaled from MME

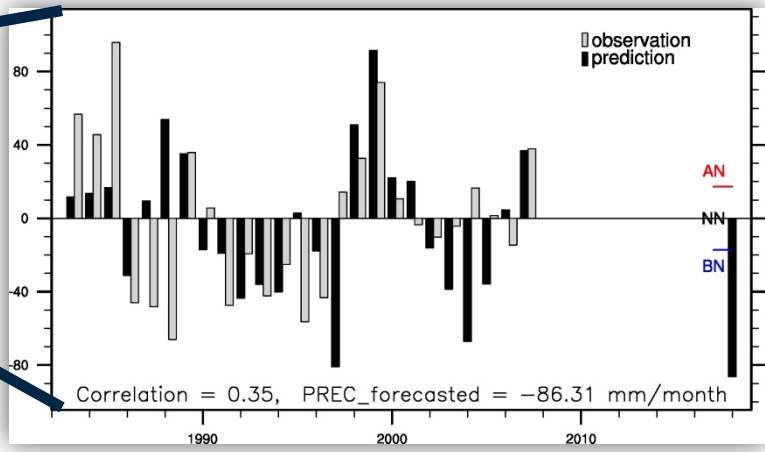


Temporal Correlation Coefficient **(TCC) skill**

2018 SON Rainfall forecast (Busan, KOREA)

PMME (dynamical, grid) & Downscaled (pointwise)

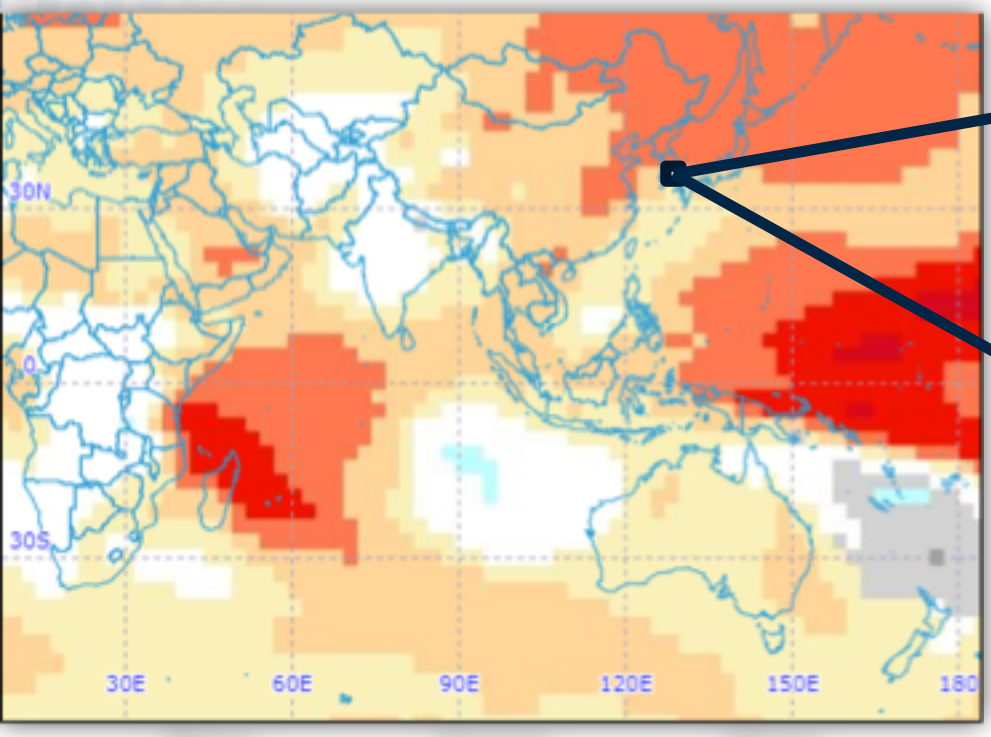


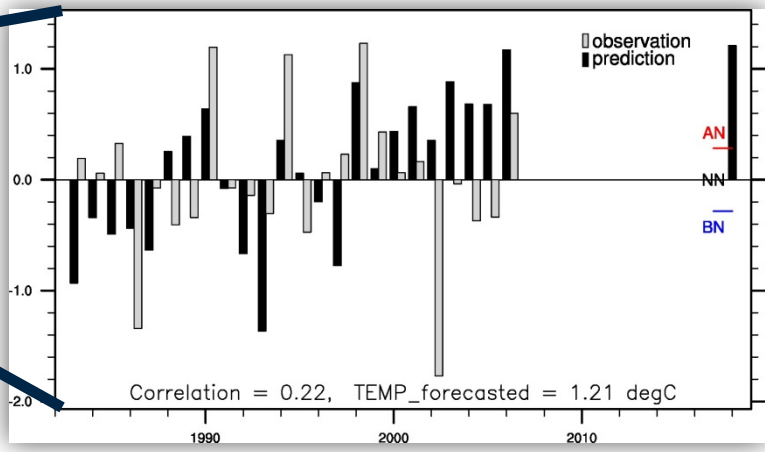


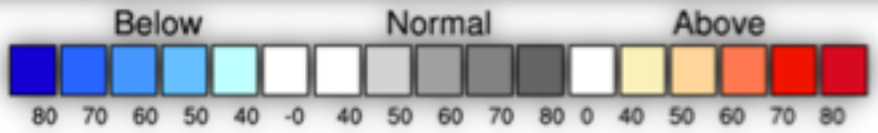
Lead Month: 3, Year: 2018, Season: 9, Methods: GAUS
Model: APCC,CMCC,CWB,MSC,NASA,NCEP,PNU,POAMA
created by CLIK(2018-8-22)

2018 SON Temp. forecast (Busan, KOREA)

PMME (dynamical, grid) & Downscaled (pointwise)



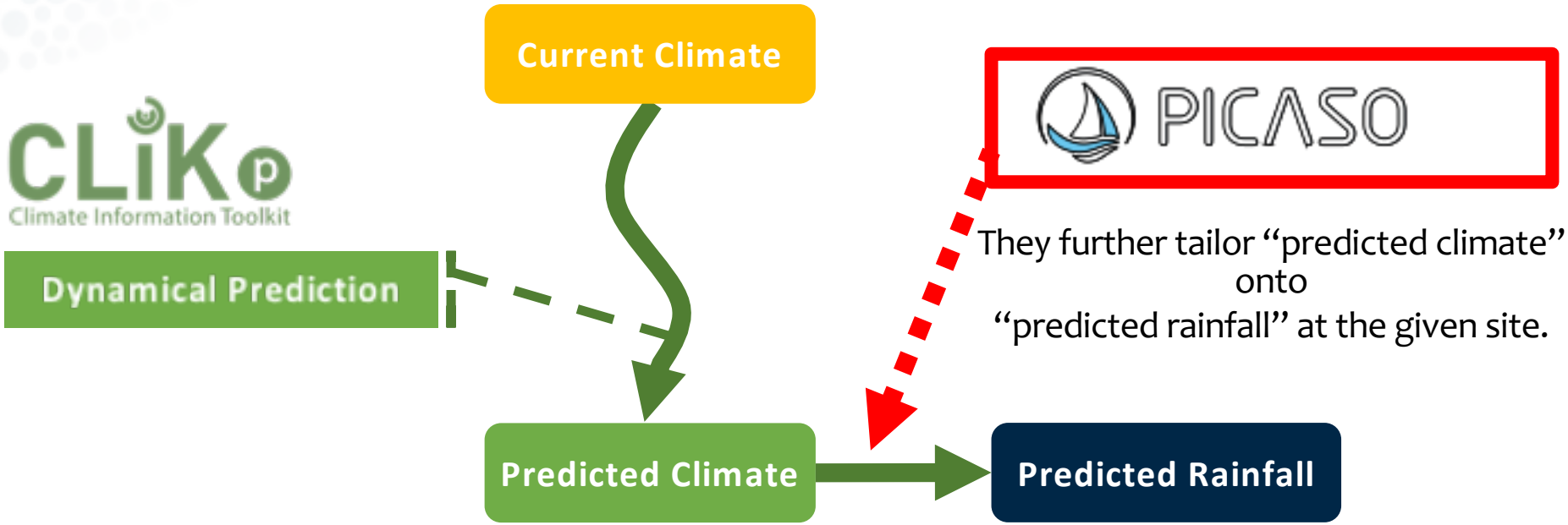




Lead Month: 3, Year: 2018, Season: 9, Methods: GAUS
Model: APCC,CMCC,CWB,MSC,NASA,NCEP,PNU,POAMA
created by CLIK(2018-8-22)


PICASO
Pacific Island Countries Advanced Seasonal Outlook

Downscaling/tailoring of dynamical MME



1) Physical/dynamical process
2) Model biases *vs* Observed dynamics

ROK-PI CliPS: Overview

Republic **O**f **K**orea-**P**acific **I**slands **Cli**mate **P**rediction **S**ervices

- Objective:

  "*To strengthen the adaptive capacity of vulnerable communities to climate risks at the seasonal timescale.*"

- Working Pillars:

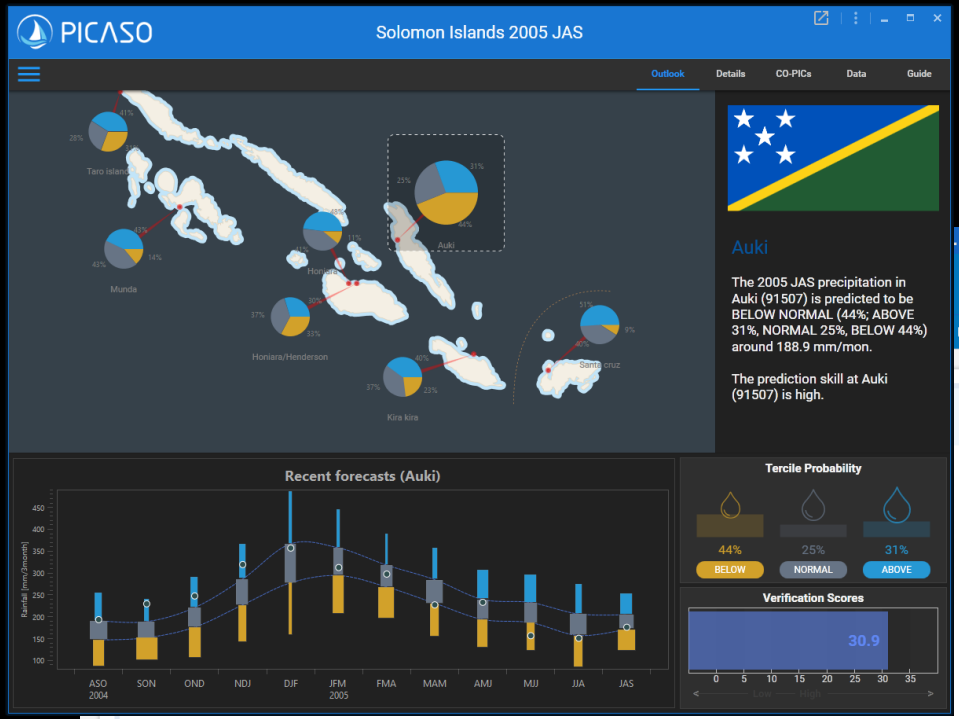
  One Dynamical Seasonal Forecasting System
  → CLiKP Climate Information Toolkit

  Two Downscaled Prediction System
  → PICASO

  Three Development of the Application Guideline
  → Forecast Guidance I & II

  Four Training of the Climate Information Application
  → Training & Young Scientist Support Program

Intuitive climate outlook



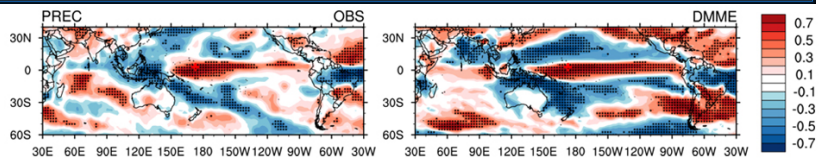


Figure 2.Temporal correlation coefficients (TCCs) between local precipitation of Butaritari(91601) and precipitation at each grid during the April – June(AMJ) for (left) observation and (right) DMME. The black dots indicate grid points for which TCC is significant at the 95% confidence level.

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 wellrelated to warm equatorial Pacific state (e.g., El Niño), and it can be best recognized by the predicted (MME) remoteprecipitationover the Western Pacific. Therefore, remotepre-cipitationis selected as the internal predictor in PICASO.

TRAINING SCORES

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%

TRAINING HISTORY (PREDICTION/OBSERVATION)

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

VALIDATION SCORES

Name	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	N
HSS	0.14	0.2	0.14	0.57	0.5	0.03	0	0.32	0.14	0.28	0.09	0
LEPS	33%	35%	27%	31%	35%	22%	35%	20%	22%	38%	38%	2

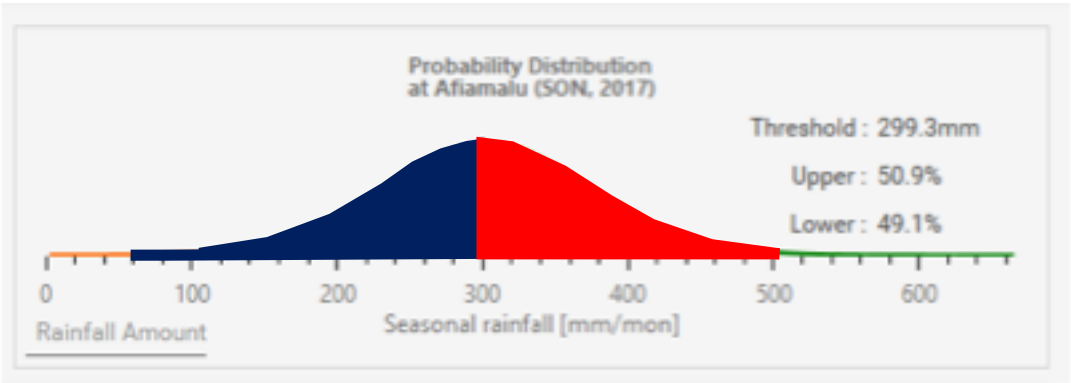
VALIDATION HISTORY (PREDICTION/OBSERVATION)

Name	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	N
2016	0-/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	0
2014	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	+
2012	+-/-	0+/-0	0-/0	0+-/+	0+-/0	-/-	0+/-0	0-/0	0+-/+	0+-/0	0+-/+	0
2011	+-/-	0-/0	+-/-	+-/-	0+-/0	+-/-	0/0	-/-	+-/-	-/-	+-/-	-
2010	0+-/0	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
2008	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	0-/+	+
2006	0+/-	0/-	-/-	-/-	0/0	0+/-	0/-	0+/-	0/-	+/+	0+/-	+

PICASO > Details > 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**

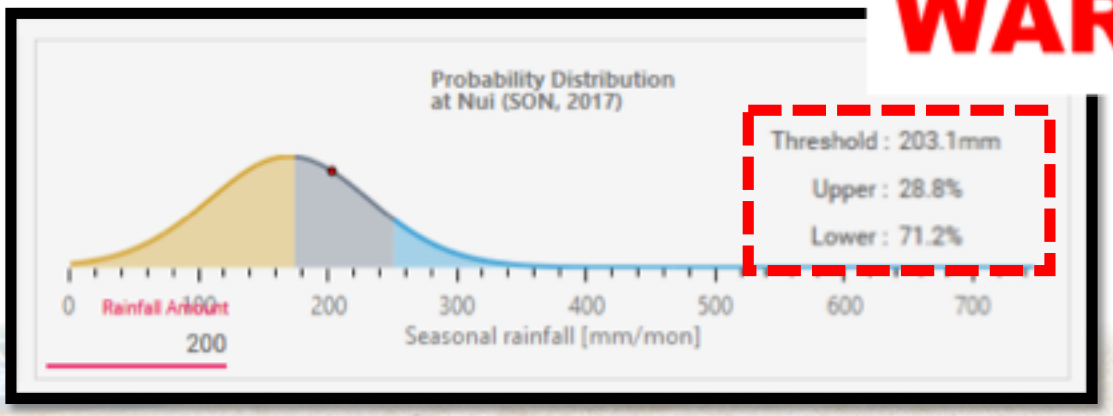
Water resources management — Disaster Risk Reduction — Agricultural planning

Tuvalu

Current Water Resources

- **Primary - Rain water (rain harvest and banked at individual household)**
- Supplementary - RO desalination plant source from either the groundwater or direct from the sea.
- Secondary - ground water (only for secondary usage - lavatory cleaning, bathing) mainly during the dry spells.

Average annual rainfall: 3000mm ~ 4000mm (in the southern islands)



WARNING!

Samoa

Watershed Management Plans

Zoning regime

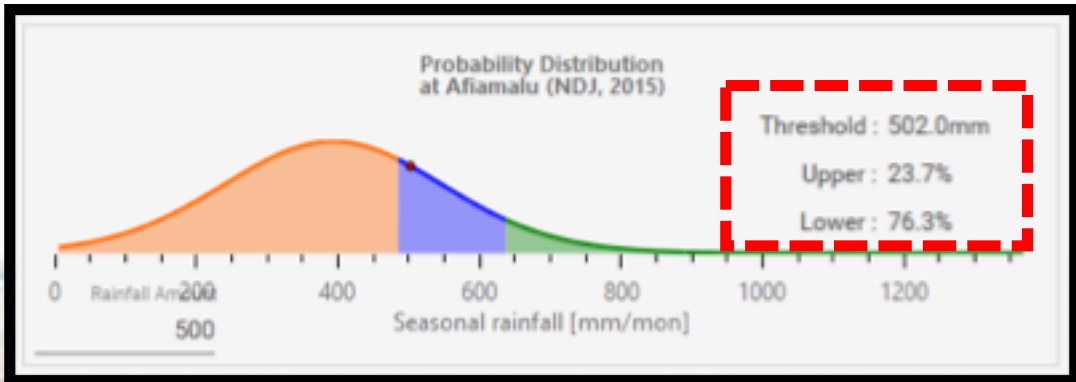
Zone 3: Exclusion Zone (above 600m altitude)
Zone 2: Restricted Zone (300m-600m above mean sea level)
Zone 1: Development Zone (0-300m above mean sea level)

- ✓ Zone 1 is the lower watershed area where population/development is concentrated and where the needs for watershed ecological services are greatest.
- ✓ Development planning is essential in implementing **flood hazard plans** and also in ensuring that activities have controlled impacts on the receiving coastal waters and soil resources.

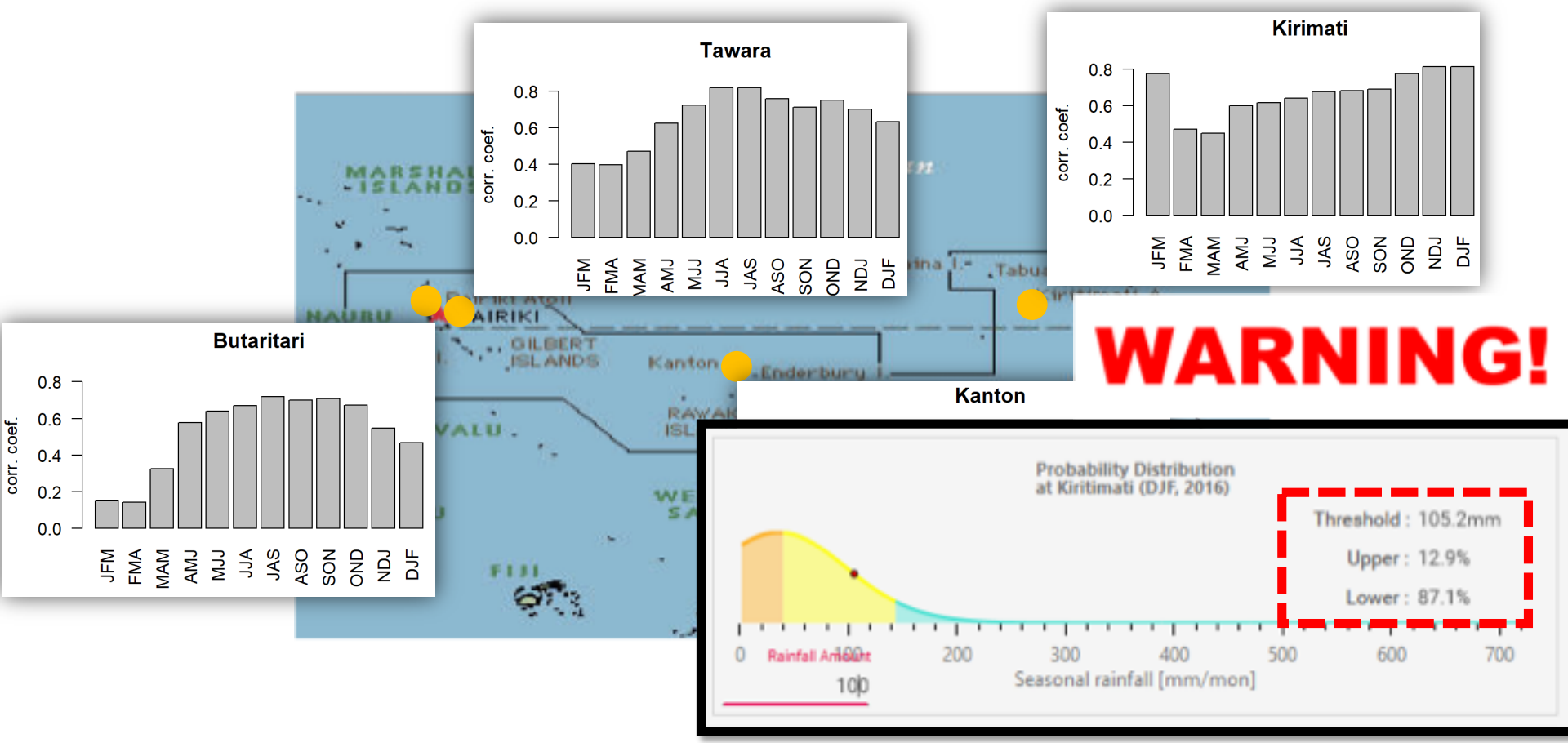
NO WORRIES!

Abundant water resources

- The Average rainfall is over 3,000mm/year (2,500 mm in the north-west parts of the main islands to 6,000 mm in the highlands of Savaii)
- 75 percent of the precipitation occurring during November-January.



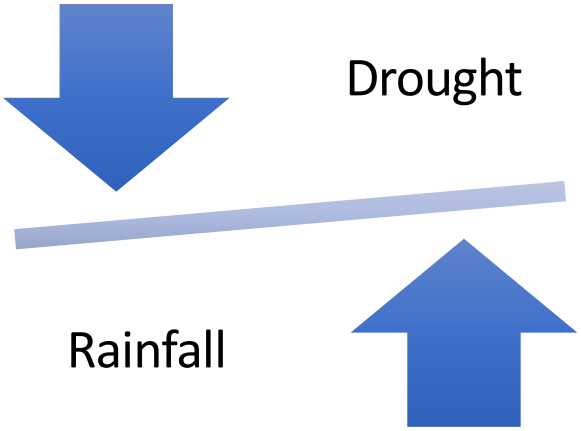
Kiribati



- A vast area of territory covering most equatorial Pacific
- Regionally/seasonally varying - ENSO dependent rainfall
- La Nina coming → Drought expected
  → Advise **the Drought Committee** on the status of the Water reserve

Tonga

Recharge to groundwater



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


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

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

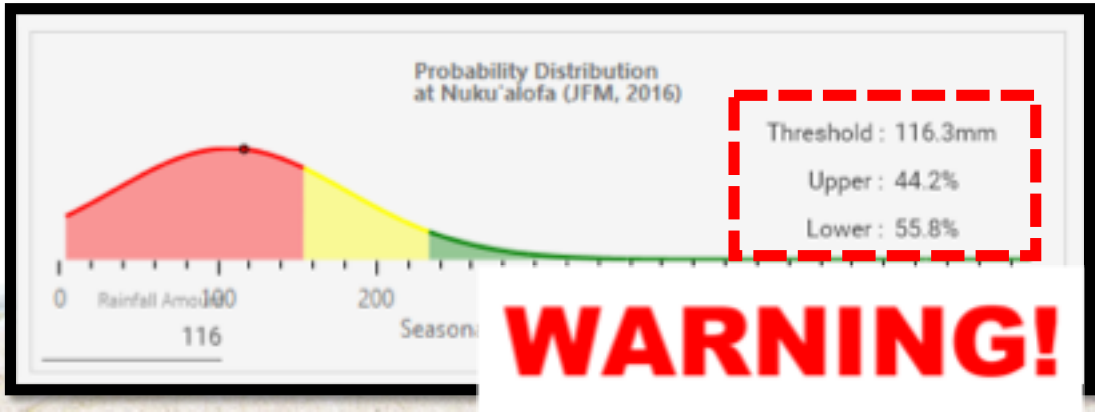
This is seen as an initiative that could encourage more growers to go back to the plantations they abandoned during the past years due to falling prices in overseas markets.

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

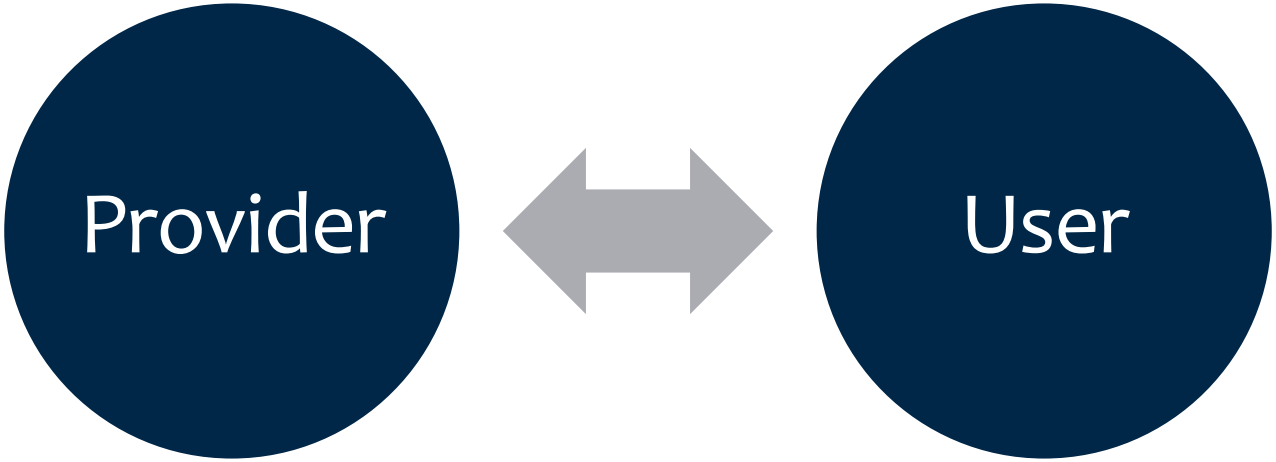
Watering
For good growth, squash and pumpkins require at least one inch of water per week. (One inch of water per thousand square feet is 620 gallons). If water is needed, irrigate thoroughly early in the morning until the soil is moistened eight to twelve inches deep. If rainfall is deficient, it may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



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

Fill the gap



Accuracy
Resolution
Contents

Climate Prediction Service Enhancement