MME Seasonal Prediction & its Localization using CLIK
Climate Variability
Climate Prediction & Verification
Localization
Generating Seasonal Outlook
Downscaling of seasonal prediction

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Why downscaling is required?
1. Low skill of dynamical seasonal forecast...

- near surface temperature...
1. Low skill of dynamical seasonal forecast...

- *Rainfall?*
- *Outside tropical Pacific?*
2. Climate Locality

Very small Island Climate

(a) Can 2.5 by 2.5 grided model tell the difference of small island climate and ocean climate? Not really.
Island of Sri Lanka

- Horana in wet zone vs Angamedilla in dry zone
- Almost opposite temporal variation between two stations in a grid

[Graph showing seasonal cycle with grid and station locations]
2. Climate Locality

- Complicate climate of Chile

✓ 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!!!
Northern arid region: **RR Coast & Inland?**

- 2 stations (*Calama & Antofagasta*) in a grid (2.5 degLat by 2.5 degLon)
- Less consistency among stations in a grid

Seasonal cycle

All Chilian stations

Rain shadow with strong solar insolation

ASO

Selected stations
Northern arid region: \textbf{Tmax} (Coast vs Inland)

- 2 stations (Calama & Antofagasta) in a grid (2.5 by 2.5)
- Less consistency among stations in a grid
Central region: **RR Slope & Valley?**

- **4 stations in a grid (2.5 degLat by 2.5 degLon)**
- **Strong temporal consistency among stations in a grid**
South region: RR Slope & Inland?

- 3 stations in a grid (2.5 degLat by 2.5 degLon)
- Aysen: less consistent with other stations in a grid
What is downscaling?
Who are you?
Look inside!
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 \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)
Google uses AI to sharpen low-res images

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

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*

\[
y(s, t) \text{ : observation} \\
x(s, t) \text{ : forecast}
\]

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

- 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!

\[ Y = a \cdot x + b \]
\[ x: \text{predictor (ONI)} \]
\[ y: \text{predictand (rainfall)} \]
Weakness: overfitting

- Consider potential predictability

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

from Scott Fortmann-Roe 2012
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
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

ENSO system:
El Nino $\rightarrow$ Vientiane rain $\uparrow$
La Nina $\rightarrow$ Vientiane rain $\downarrow$
Station to LSMP relationship

Indian Ocean Dipole:
Neg. IOD $\rightarrow$ Sagaing rain $\uparrow$
Pos. IOD $\rightarrow$ Sagaing rain $\downarrow$
Station to LSMP relationship

OBS (Reanalysis)

Model (SCM)

IOBM:

IO warming  →  Dewahuwa rain ↑

IO cooling  →  Dewahuwa rain ↓
Indian Ocean Basin-wide Cooling:
SST ↓ → Yangon rain ↑
SST ↑ → Yangon rain ↓
Station to LSMP relationship

OBS (Reanalysis)
sst vs. prec over Semtokha

Model (SCM)
sst (scm) vs. prec over Semtokha

IOBM + ENSO:
IO warming & El Nino $\rightarrow$ Semtokha rain ↑
IO cooling & La Nina $\rightarrow$ Semtokha rain ↓
IOBM + ENSO:

IO cooling & La Nina $\rightarrow$ Horana rain $\uparrow$

IO warming & La Nina $\rightarrow$ Horana rain $\downarrow$
Maritime Continent: Indonesia

SON [Jakarta]

La Nina (and negative IOD) signature
Station to LSMP relationship

OBS (Reanalysis)  
Model (SCM)

ENSO system:
El Nino → Osorno rain ↑
La Nina → Osorno rain ↓
Station to LSMP relationship

OBS (Reanalysis)

Model (SCM)

ENSO + IOBM:

La Nina + Indian Ocean Basin Warming → Visviri rain ↑

El Nino + Indian Ocean Basin Cooling → Visviri rain ↓
Station to LSMP relationship

ENSO + Indian Ocean Dipole:
El Nino + Pos. IOD $\rightarrow$ Santiago rain $\uparrow$
La Nina + Neg. IOD $\rightarrow$ Santiago rain $\downarrow$
Station to LSMP relationship

ENS0 + Tropical Atlantic Ocean Variability:

La Nina + Atlantic Nino $\rightarrow$ Visviri rain $\uparrow$

El Nino + Atlantic Nina $\rightarrow$ Visviri rain $\downarrow$
Station to LSMP relationship

OBS (Reanalysis)  Model (SCM)

Non-canonical ENSO system:
CP-type El Nino $\rightarrow$ Puerto Montt rain $\uparrow$
CP-type La Nina $\rightarrow$ Puerto Montt rain $\downarrow$
Station to LSMP relationship

OBS (Reanalysis)  Model (SCM)

Southern Tropical Atlantic Ocean Variability:
Tropical Atlantic Cooling → Valparaiso rain ↑
Tropical Atlantic Warming → Valparaiso rain ↓
Station to LSMP relationship

OBS (Reanalysis)

Model (SCM)

Rossby wave & warm easterly:
Easterly $\rightarrow$ Santiago rain $\uparrow$
Westerly $\rightarrow$ Santiago rain $\downarrow$
Station to LSMP relationship

OBS (Reanalysis)  Model (SCM)

Large scale convective system:
Wet → Isla de Pascua rain ↑
Dry → Isla de Pascua rain ↓
Downscaling/tailoring of dynamical MME

Current Climate

Predicted Climate

Statistical Downscaling

Localized Temperature/Rainfall

1) Physical/dynamical process
2) Model biases vs Observed dynamics
Northern arid region
Central region
South region
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
CLIK downscaling is mainly based on station to Large Scale Meteorological Field (LSMF) relationship. 
\( Y = aX + b \) By utilizing the simulated LSMF (X, predictor), CLIK estimates seasonal mean precipitation/temperature (Y, predictand) at specific station.

**A kind of hybrid system for point-wise seasonal forecast**

- **Dynamical fcst**
  - Simulated LSMF from Individual models
  - Hypothesis: The station to LSMF relationship is well replicated in individual models

- **Statistical fcst**
  - Station to LSMF regression relationship
  - Predictor: LSMF
  - Predictand: Prec. 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. 

\( Y = a \times X + b \)

By utilizing the simulated LSMF \( X \), predictor, CLIK estimates seasonal mean precipitation/temperature \( Y \), predictand) at specific station.

Empirical relationship: LSMP (OBS) \( \rightarrow \) local station rainfall

LSMP (MME) \( \rightarrow \) 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

http://clik.apcc21.org
2018 SON Temp. forecast (Busan, KOREA)

PMME (dynamical, grid) & Downscaled (pointwise)
2019 AMJ Temp. forecast (Busan, KOREA)

PMME (dynamical, grid) & Downscaled (pointwise, SCM)

Busan 2019 AMJ mean temp. 17.87 degC
Normal (median) 17.27 degC + 0.6 degC

Correlation = 0.22, TEMP_forecasted = 0.89 degC
Availability of Downscaled information?
PICASO
Pacific Island Countries Advanced Seasonal Outlook
Downscaling/tailoring of dynamical MME

They further tailor “predicted climate” onto “predicted rainfall” at the given site.

1) Physical/dynamical process
2) Model biases vs Observed dynamics
ROK-PI CliPS: Overview
Republic Of Korea-Pacific Islands Climate Prediction Services

• Objective:
  “To strengthen the adaptive capacity of vulnerable communities to climate risks at the seasonal timescale.”

• Working Pillars:
  One  Dynamical Seasonal Forecasting System ➔ CLiKe
  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

The 2005 JAS precipitation in Auki (91507) is predicted to be BELOW NORMAL (64%), ABOVE NORMAL (33%) and NORMAL (3%).

The prediction skill at Auki (91507) is high.

Figure 2: Temporal correlation coefficients (TCCs) between local precipitation at Butararai (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 Butararai (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 Butararai (91601) is well-related to warm equatorial Pacific state (e.g., El Niño), and it can be best recognized by the predicted (MME) remotedevelopment over the Western Pacific. Therefore, remotedevelopment is selected as the initial predictor in Picaso.
PICASO > Details > Probability Distribution

- Interactive Probability Scale
  
  *Probability below/above specific criteria*

![Probability Distribution at Afiamalu (SON, 2017)](image)

- 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)
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.

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.

NO WORRIES!
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

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

Recharge to groundwater

Drought

Rainfall

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

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

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/factsheets/pdf/pumpkins_and_squash.pdf

WARNING!
Fill the gap

Provider

Accuracy
Resolution
Contents

User
Climate Prediction Service Enhancement

A single dynamic forecast

MME forecast

Post-process / Localization

Tailored to application sectors

SCoPS: APCC in-house model

APCC MME

CLIK/PICASO

Interactive basin mean rainfall...
Thank you.