Overview of APCC Operational Multi-Model Ensemble Seasonal Prediction System

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Overview of the APEC Climate Center

Asia-Pacific Economic Cooperation (APEC) Climate Center (APCC) is a leading climate information service provider in the Asia-Pacific region. We provide seasonal climate forecasts and other climate information products and services, conduct research and development activities, and organize capacity building initiatives for scientists from developing economies.

APEC Climate Center
12 Centum 7-ro, Haeundae-gu, Busan, Rep. Korea

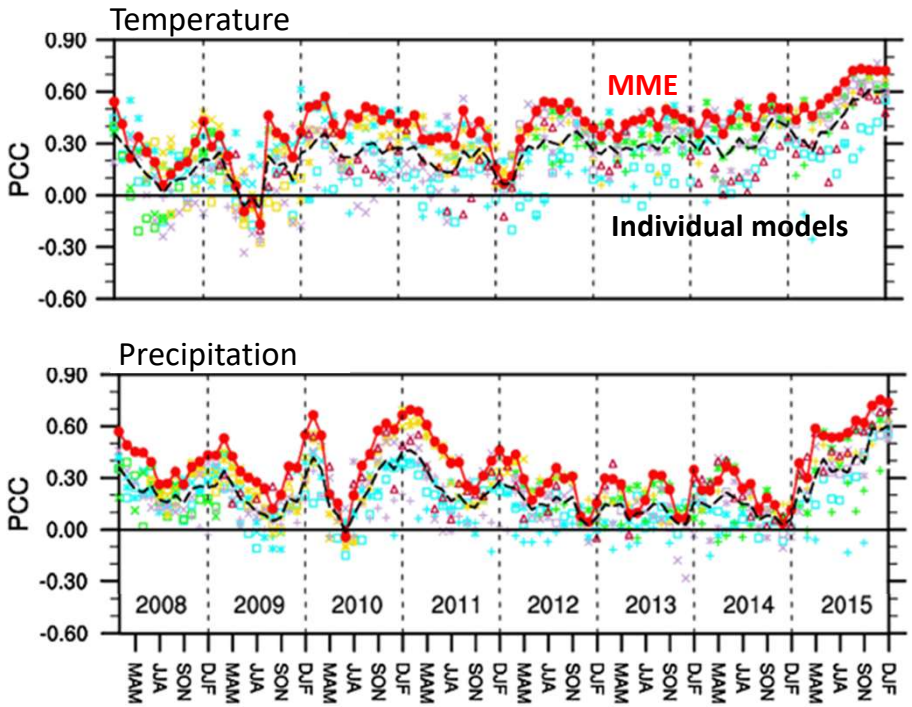
Climate Prediction & Information Service

✓ ***http://www.apcc21.org***

APCC Seasonal Forecasts

- **Producing skillful real-time climate predictions and developing a value-added reliable climate prediction system based on a Multi-Model Ensemble (MME) technique.**

Anomaly Pattern Correlation



Min et al. (2017), Climate Dynamics

Operational Institute/Organization

NMME The North American Multi-Model Ensemble

International Research Institute for Climate and Society

ECMWF

Government of Canada / Gouvernement du Canada

WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble

APEC CLIMATE CENTER

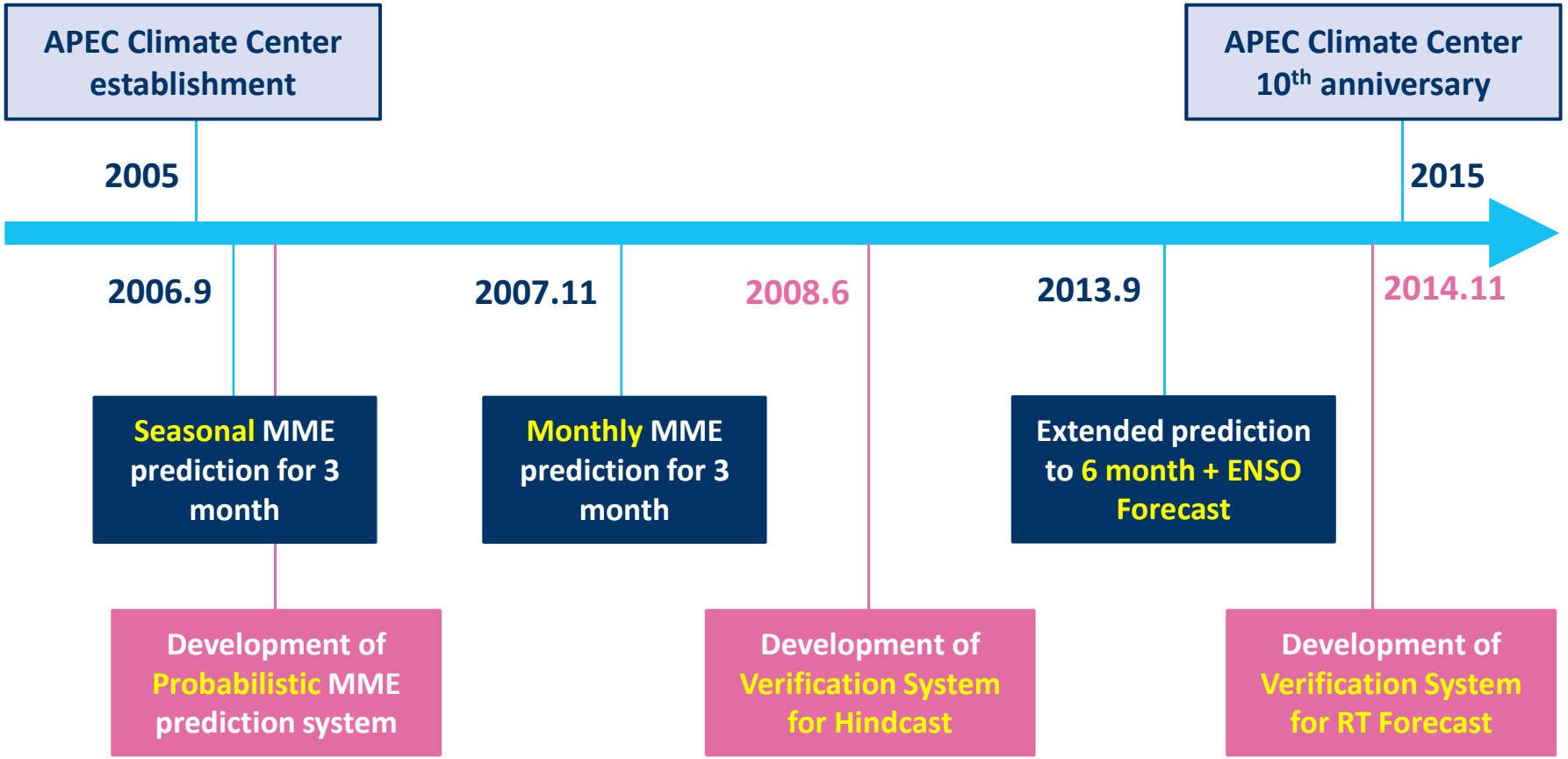
APCC MME Seasonal Forecast

- **Based on a set of ensembles of dynamical seasonal climate prediction from 17 leading operational and research centers**

Multi-institutional Cooperation

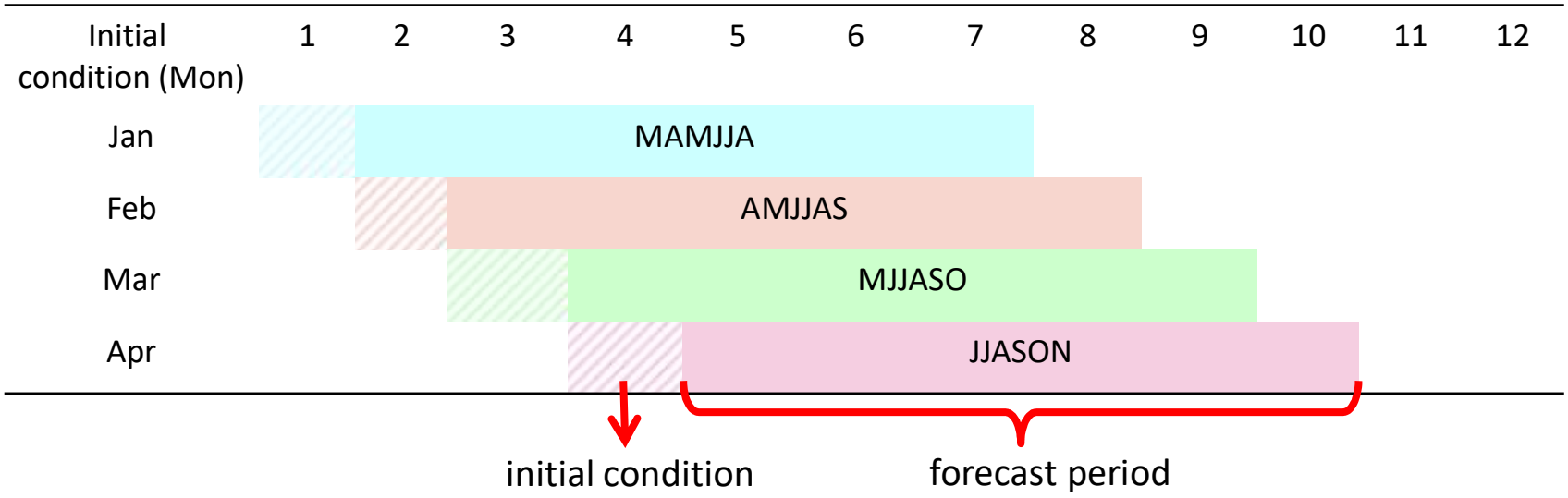
Economy	Organization/Institute
Australia	Bureau of Meteorology (BoM)
Canada	Meteorological Service of Canada (MSC)
China	Beijing Climate Center (BCC) Institute of Atmospheric Physics of China (IAP)
Chinese Taipei	Central Weather Bureau of Chinese Taipei (CWB)
Italy	Euro-Mediterranean Center on Climate Change (CMCC)
Japan	Japan Meteorological Agency (JMA)
Korea	Korea Meteorological Administration (KMA) Pusan National University (PNU)
Russia	Hydrometeorological Centre of Russia (HMC) Main Geophysical Observatory of Russia (MGO)
UK	Met Office
USA	Center for Ocean-Land-Atmosphere Studies (COLA) International Research Institute for Climate and Society (IRI) National Aeronautics and Space Administration (NASA) National Center for Environmental Prediction (NCEP) / National Ocean and Atmospheric Administration (NOAA)

History of the APCC MME Operations

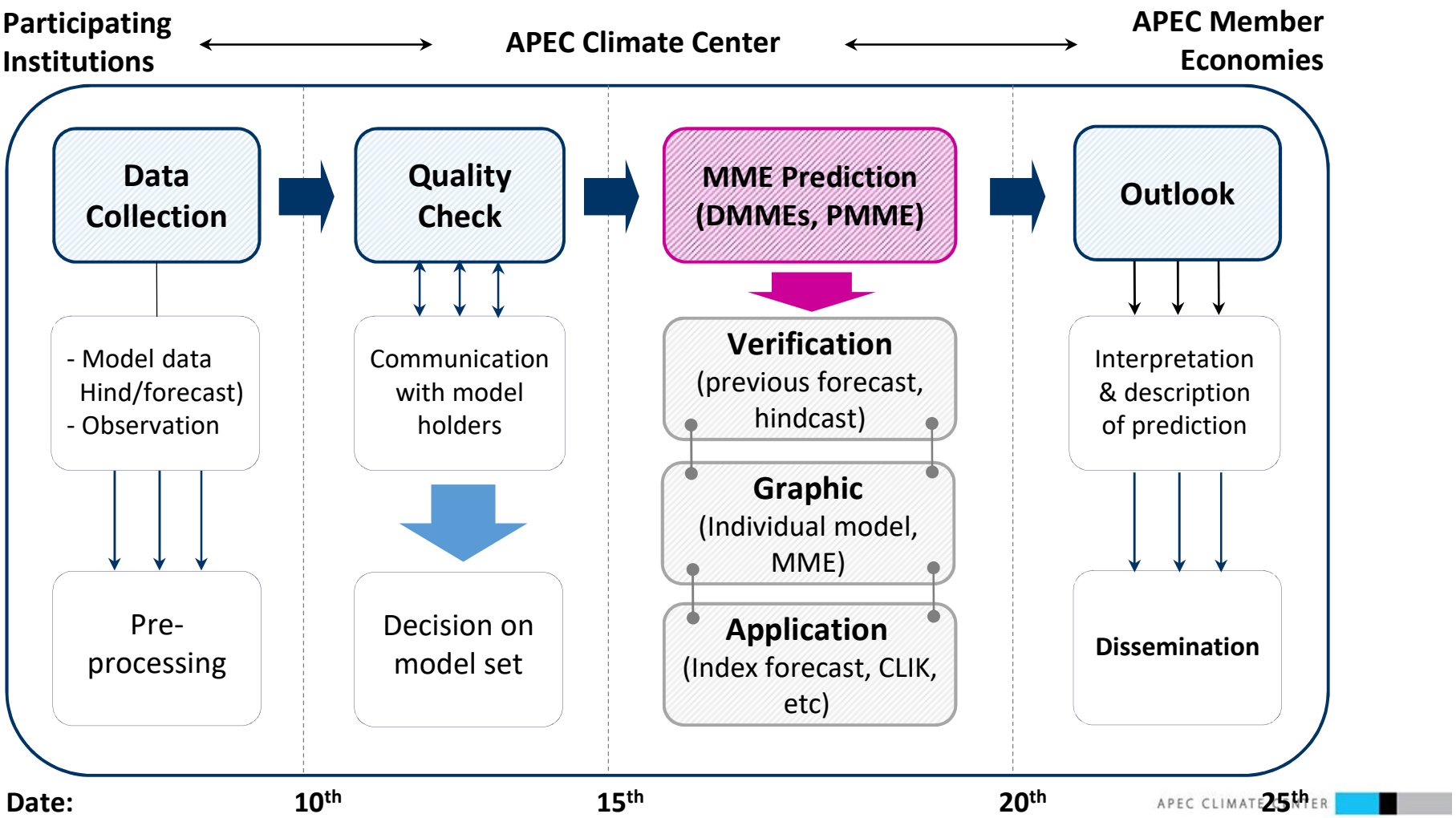


APCC Seasonal MME Forecast

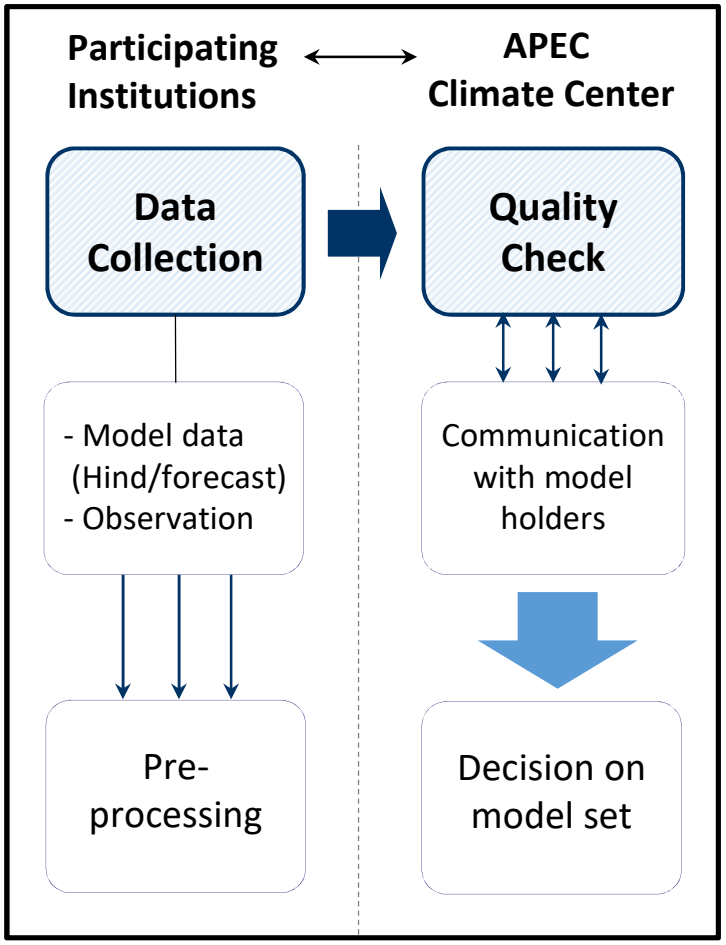
- APCC has been providing monthly MME forecasts for the next 6-month, with 1-month lead time, around 25th of every month.
- Precipitation, temperature at 2m and 850hPa levels, geopotential height of 500hPa surface and sea-level pressure at both global and regional scales



Operation Schedule



Procedure of Operations: Data Request



- Schedule: 1st ~ 15th every month
- Data requirement:

(1) Hindcast and forecast data
- Period: 1979~present (more than 6 months)
- SMIP-2/HFP or CMIP-type experiments in hindcast

(2) Data Provision/Submission
- Type: monthly mean data for individual ensemble members
- Format: 2.5°x2.5° degree interval over global domain
- Grid or NetCDF formats are encouraged.

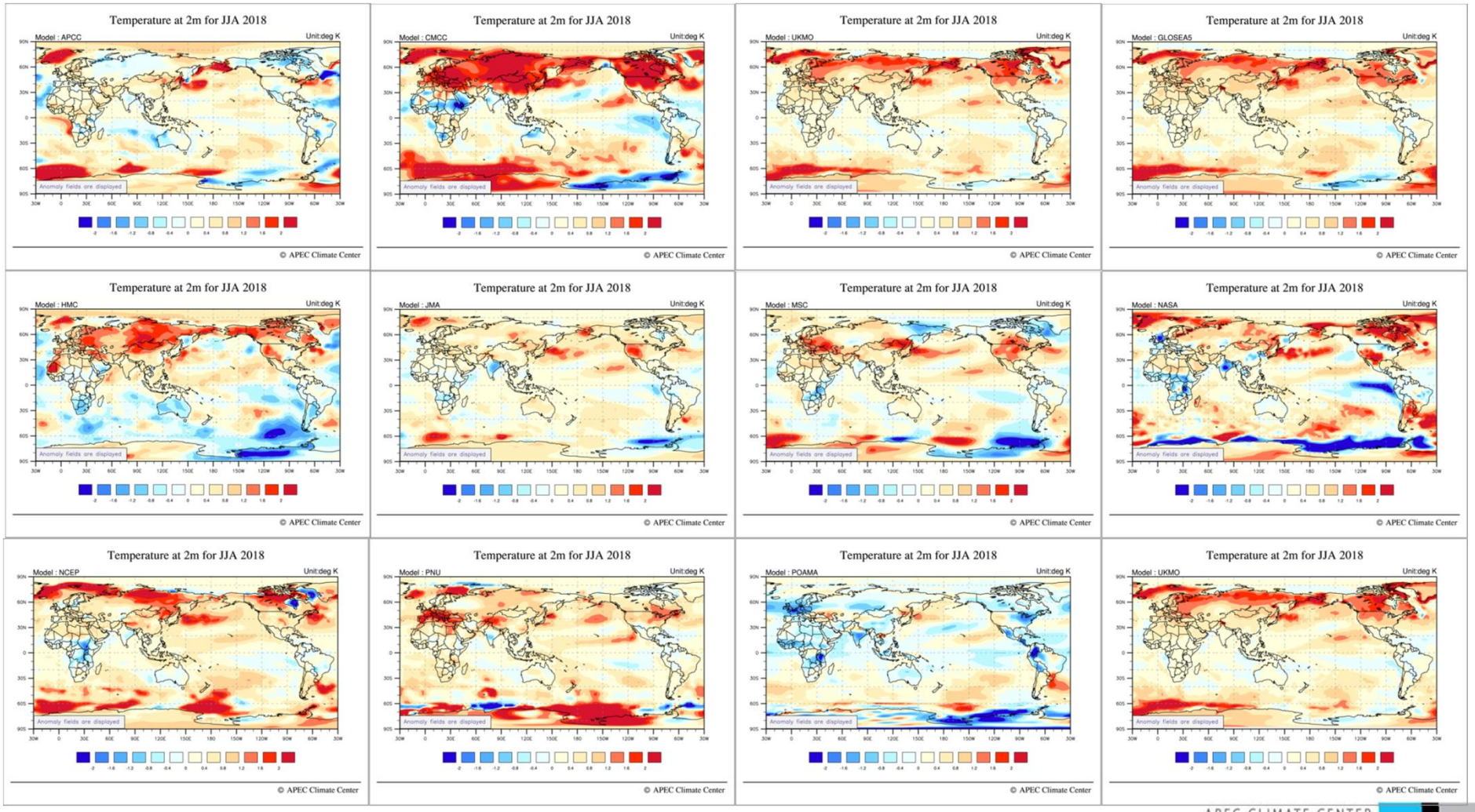
(3) Variables
- At least 11 variables are strongly recommended. (T2m, SST, Prec, SLP, T850, Z200, Z500, u/v850, u/v200)

APCC Participating Models

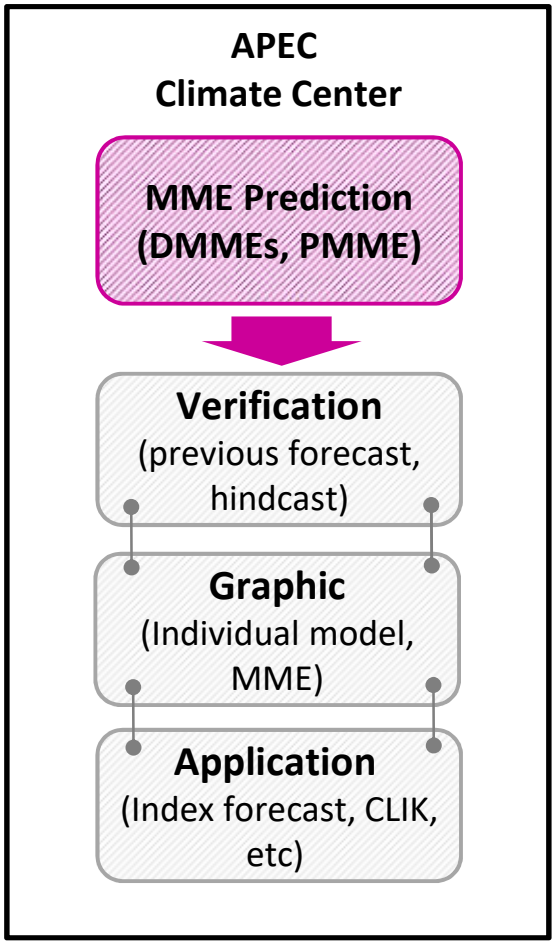
Institute	Model Name	SST Specification (H/F)	Ens. (H/F)	Forecast Period	Hindcast Period
APCC	SCoPS	Predicted/Predicted	10/10	6-month	1982-2013
CMCC	CMCC-SPSv2	Predicted/Predicted	9/9	11-month	1981-**2005**
CWB	CWB	Predicted/Predicted	30/30	6-month	1982-2017
JMA	JMA/MRI-CPS2	Predicted/Predicted	10/51	3(6)-month	1979-2014
MSC	CanCM	Predicted/Predicted	20/20	11-month	1981-2010
NASA	GMAO	Predicted/Predicted	10/11	8-month	1981-2010
NCEP	CFSv2	Predicted/Predicted	20/20	6(9)-month	1982-2010
PNU	PNU CGCM v1.0	Predicted/Predicted	5/5	6-month	1980-2015
BOM	POAMA-M24	Predicted/Predicted	33/33	6-month	**1983**-2011
Met Office	UKMO	Predicted/Predicted	12/42	5-month	1993-2015
BCC	BCC	Predicted/Predicted	24/24	6-month	1991-2015
KMA	GLOSEA5	Predicted/Predicted	12/42	6-month	1991-2010
HMC	HMC	Persistent/Persistent	10/20	4-month	1985-2010
MGO	MGOAM2	Observed/Persistent	6/10	3-month	1979-2004

** Grey: participating models in MME; yellow: not available for their Hindcast period or experiment type*

Individual Model Forecast: 2018JJA, TEMP



Procedure of Operations: MME production



- Schedule: 15th ~ 20th every month
- **Deterministic forecast (DMME)**
  - SCM: Simple Composite Method
  - MRG: Multiple Regression Method
  - SPM: Stepwise-pattern Projection Method
  - SSE: Synthetic multi-model Super Ensemble method
- **Probabilistic forecast (PMME)**
  - Tercile-based categorical probabilities
- **Verification**: in terms of skill score recommended by WMO Standard Verification System for Long-Range Forecast (SVS-LRF)
- Application: CLIK, statistical downscaling

APCC Deterministic MME Methods

- **SCM:** simple averaged MME with equal weight (simple composite method)

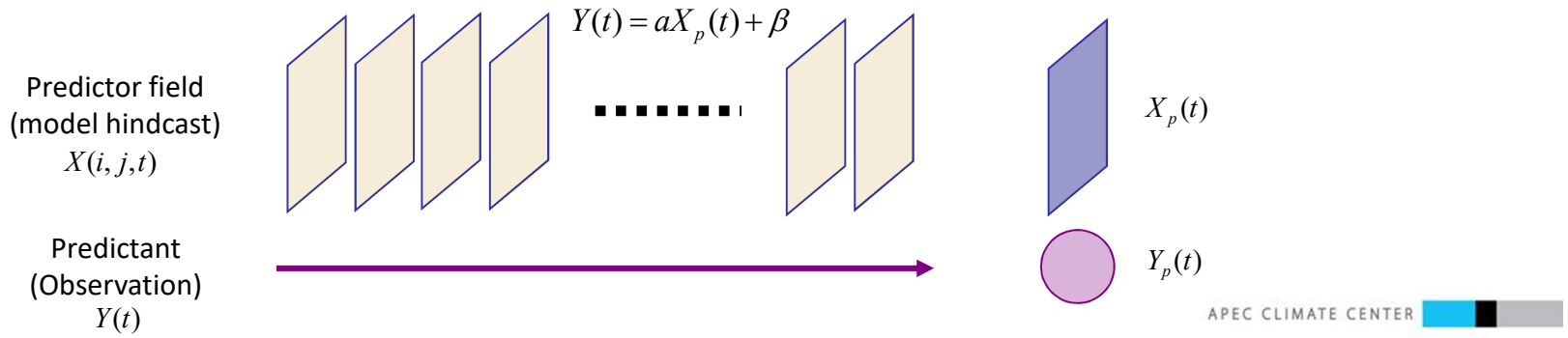
$$P = \frac{1}{M}\sum_{i=1}^{M} F_i$$

M: number of forecast models
F_i: forecast of i^{th} model

- **SPM:** calibrated MME estimated as a composite of individual model forecasts corrected based on a **step-wise pattern projection method** (Kug et al. 2008)

$$P = \frac{1}{M}\sum_{i=1}^{M} \hat{F}_i$$

$\hat{F}_i$: corrected forecast of i^{th} model

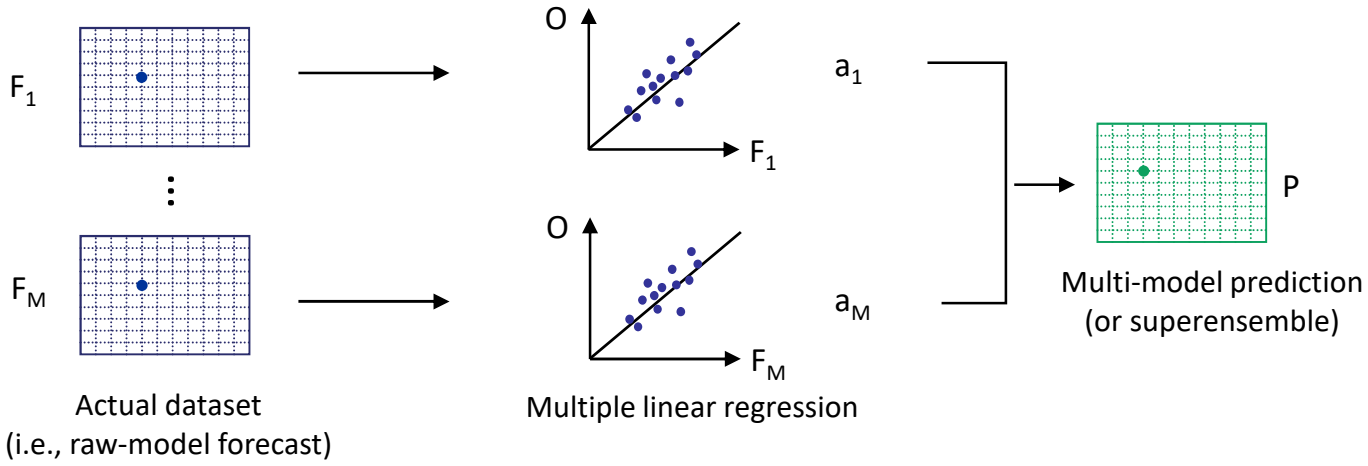


APCC Deterministic MME Methods

- **MRG: empirically weighted MME** with **multiple-linear regression coefficients** (Yun et al. 2003)

$$P = \sum_{i=1}^{M} a_i F_i$$

M: number of forecast models
F_i: forecast of i^{th} model
a_i: regression coefficients during the training period

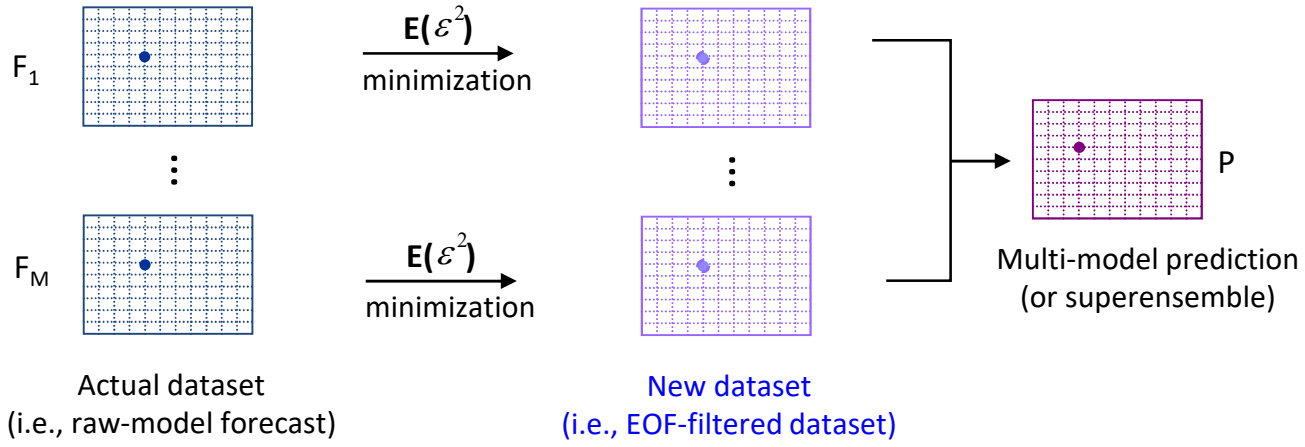


APCC Deterministic MME Methods

- **SSE: empirically weighted MME** with **EOF-filtering of the actual dataset** by finding a consistent spatial pattern between the observed and individual model forecast (Yun et al. 2005)

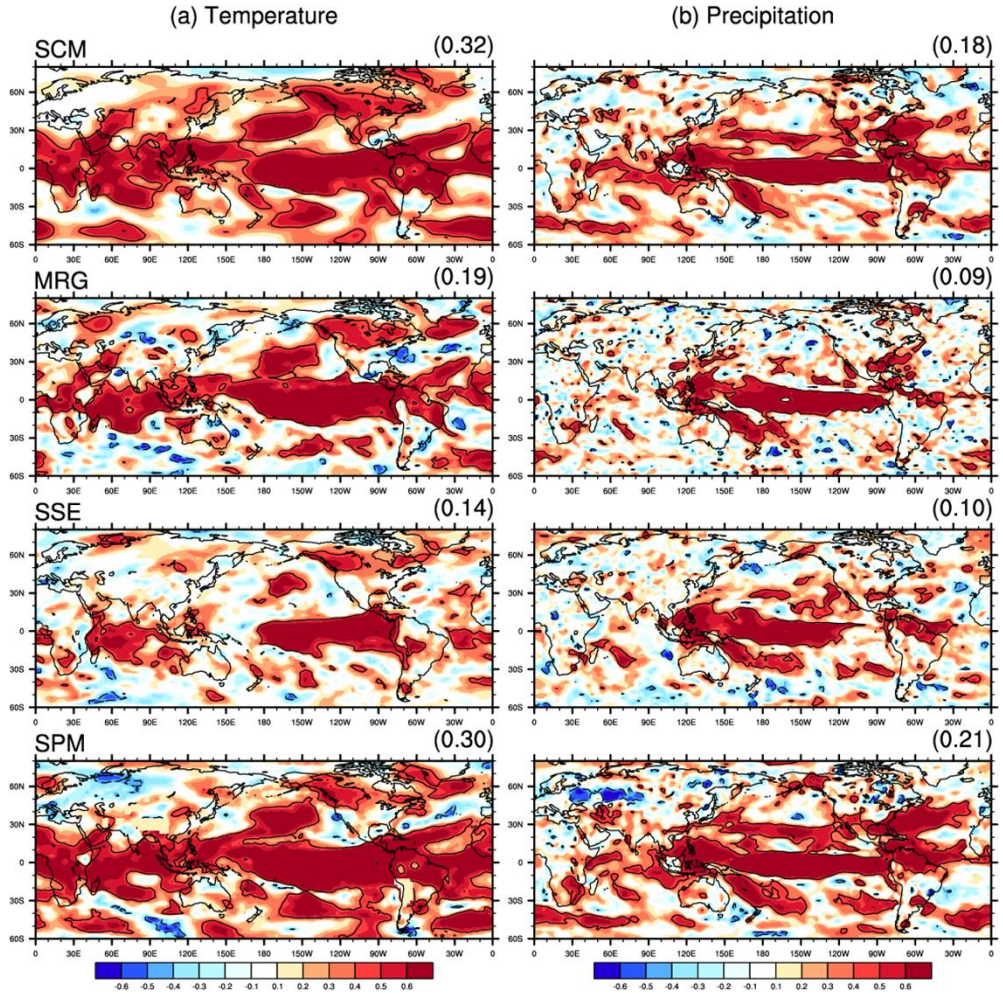
$$P = \sum_{i=1}^{M} a_i \hat{F}_i$$

M: number of forecast models
$\hat{F}_i$: corrected forecast of i^{th} model
a_i: regression coefficients during the training period



Skill Comparisons: DMMEs (Hindcast)

Temporal Correlation



SCM

MRG

SSE

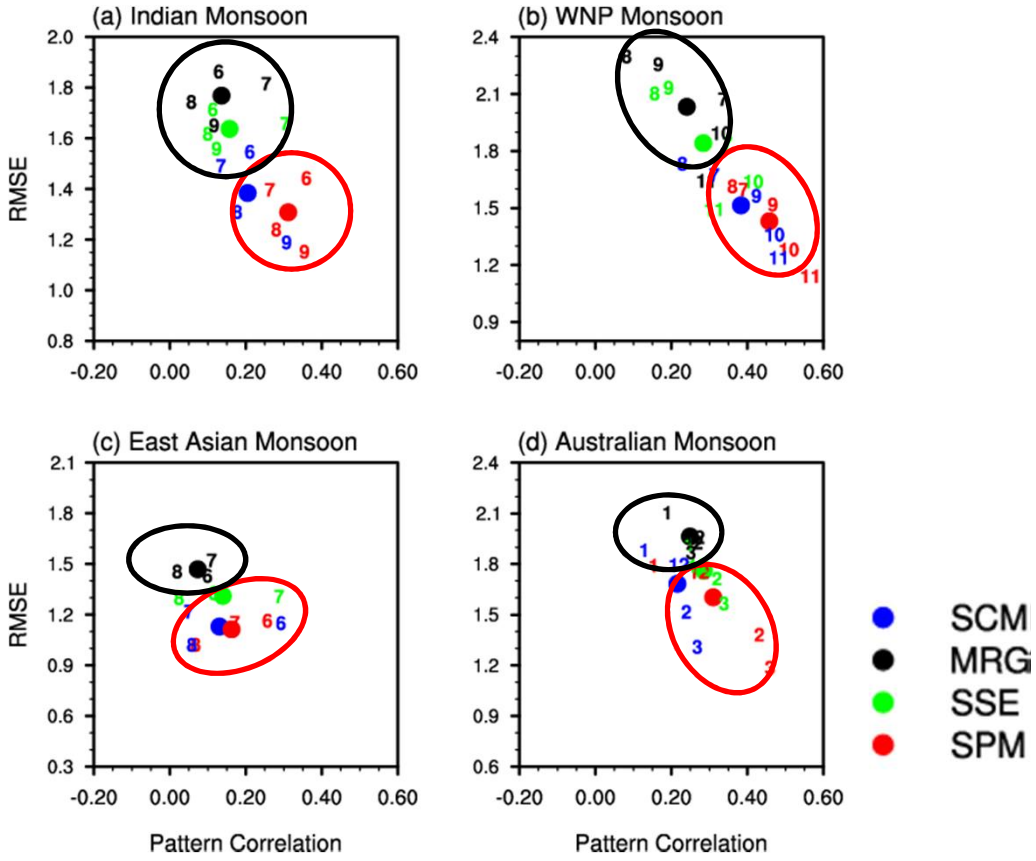
SPM

- ✓ SCM and SPM methods generally outperform the empirically weighted MME methods (MRG and SSE) over most of the globe for the hindcast period.

Min et al. (2014), JGR

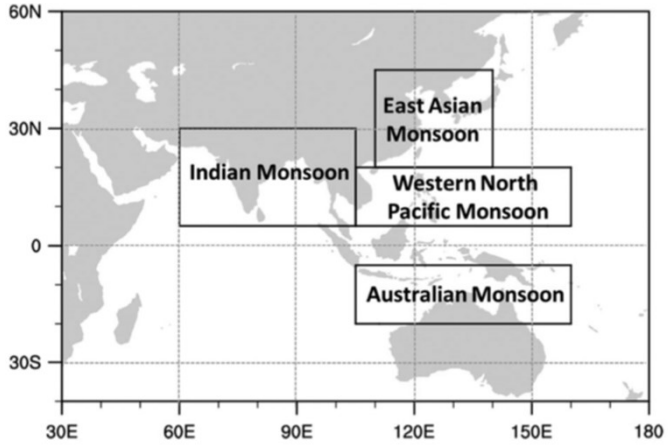
Skill Comparisons: DMMEs (Hindcast)

PCC-RMSE Diagram: Precipitation

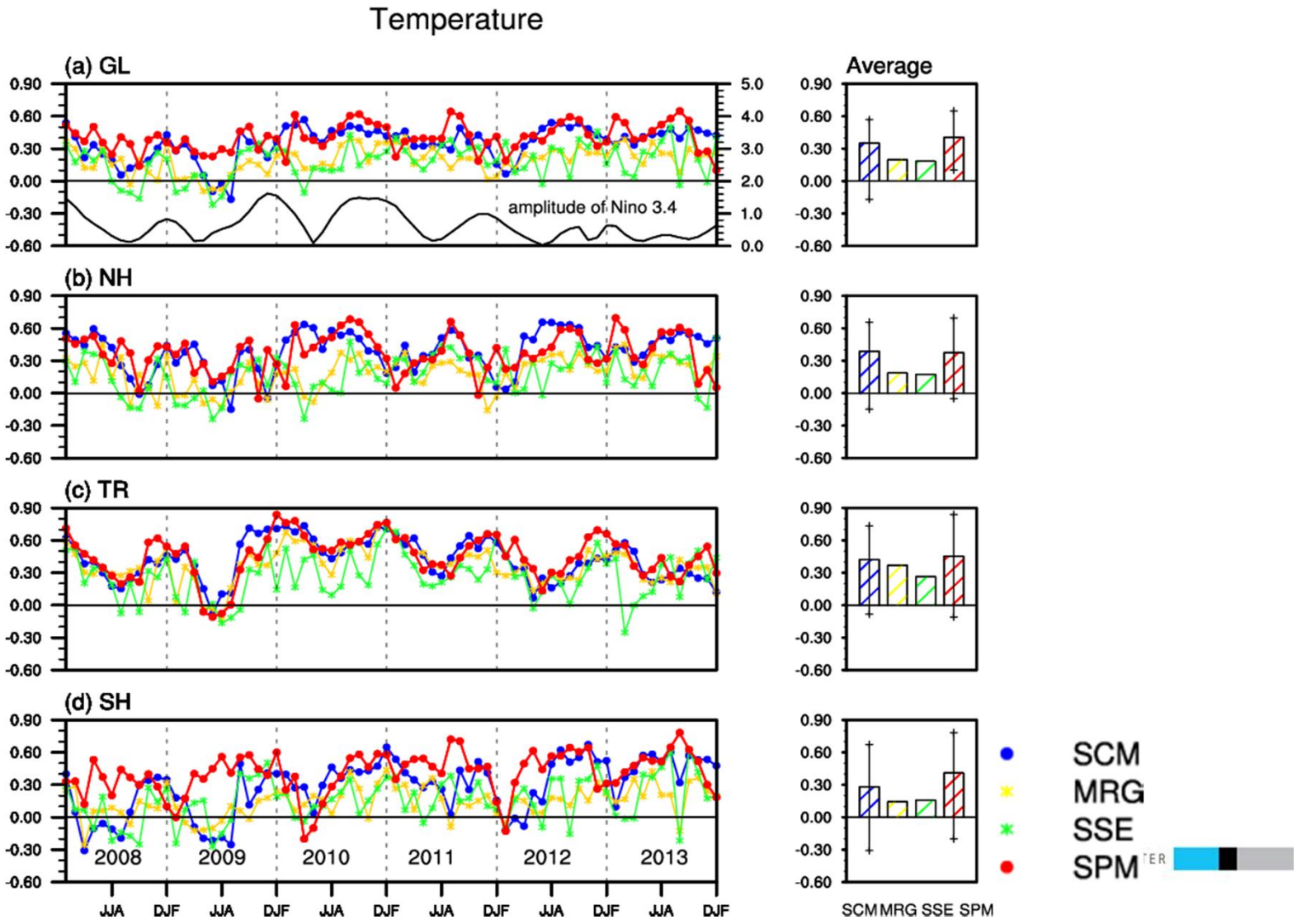


Min et al. (2014), JGR

- ✓ The performance of multi-model predictions by the weighted MME methods are consistently lower than that by simple and calibrated MME methods.



Skill Comparisons: DMMEs (RT-forecasts)



Min et al. (2014) JGR

Skill Comparisons: Results

(i) The simple averaged MME (SCM) and calibrated (or corrected) MME (SPM) methods show consistently better performance than two weighted MMEs (MRG and SSE) in both hindcast and forecast.

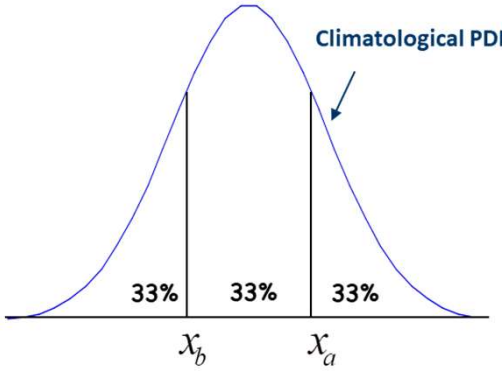
(ii) SPM has positive effect in reducing errors and improving the multi-model prediction in a large proportion of cases.

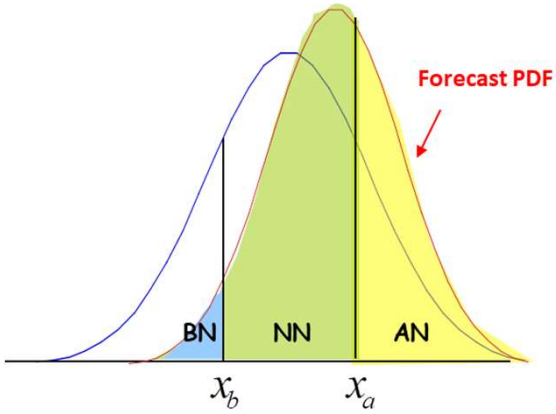
"Considering many issues from an operational point of view"

- The use of **SCM method** is the practical way of utilizing the multi-model approach **in an operational environment**.

APCC MME Method: Probabilistic

- **Probabilistic MME Method (PMME)**
  - Forecast probability is estimated based on a parametric **Gaussian fitting** method for each model and then combined with model weights being **proportional to the square root of ensemble size** (Min et al. 2009)



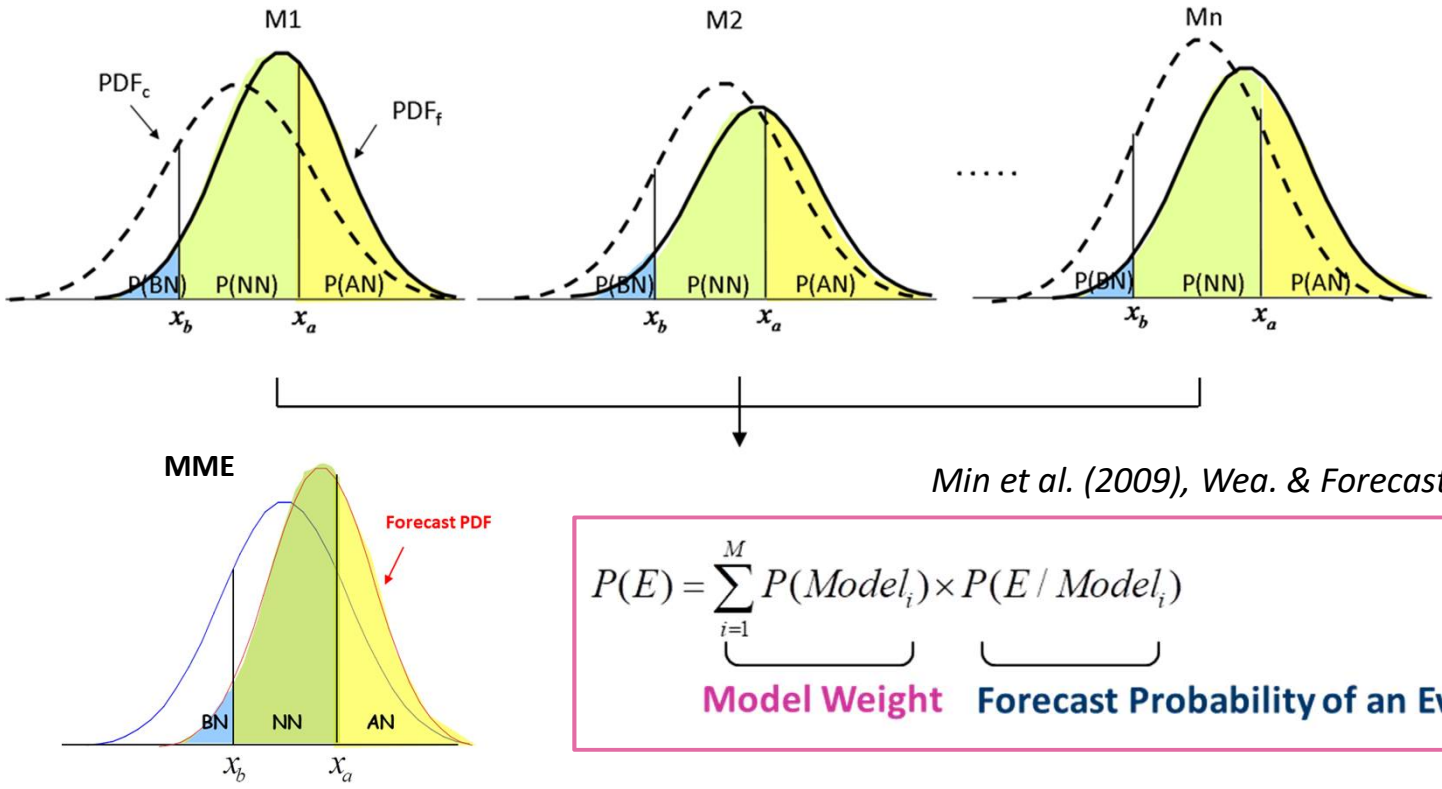


- For the middle/upper tercile boundary:
: mean plus 0.43 times the standard deviation

- For the lower/middle tercile boundary:
: mean minus 0.43 times the standard deviation

- **AN** : **probability of above-normal**
- **NN** : **probability of near-normal**
- **BN** : **probability of below-normal**

APCC MME Method: Probabilistic



Min et al. (2009), Wea. & Forecasting

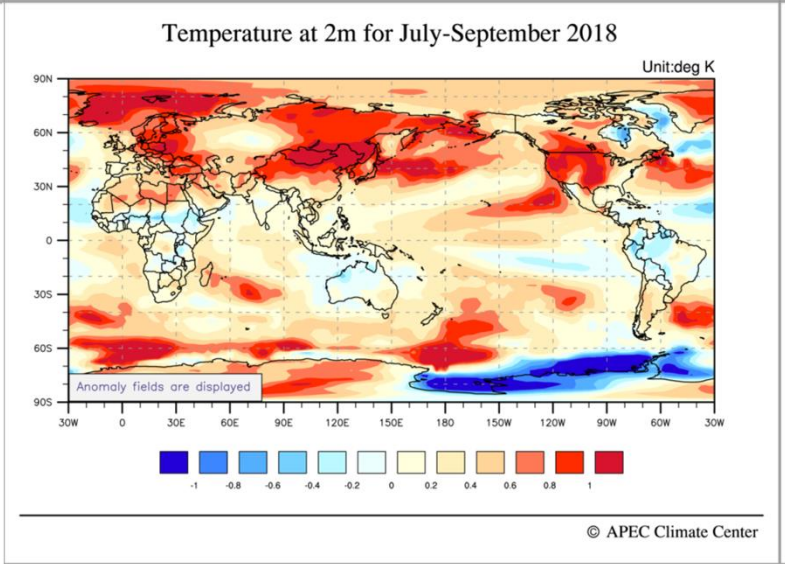
$$P(E) = \sum_{i=1}^{M} P(Model_i) \times P(E / Model_i)$$

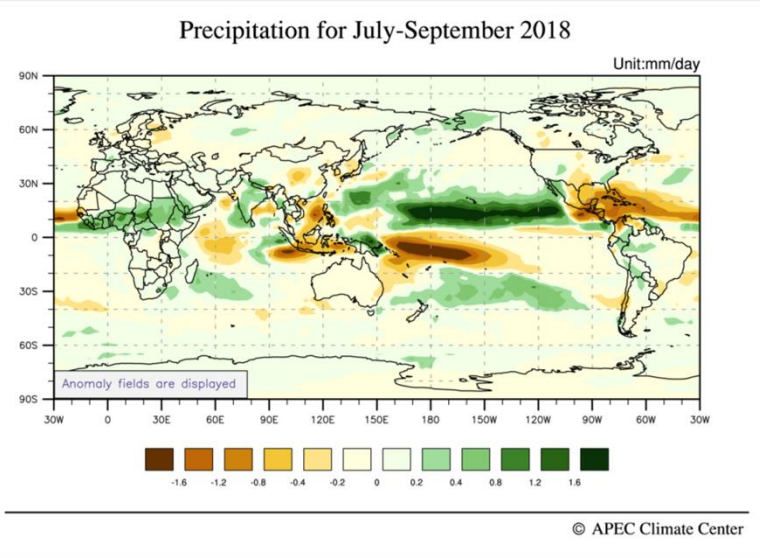
Model Weight **Forecast Probability of an Event**

- The APCC operational PMME prediction system has also been implemented at **WMO Lead Center**, as a basic operational prediction tool.

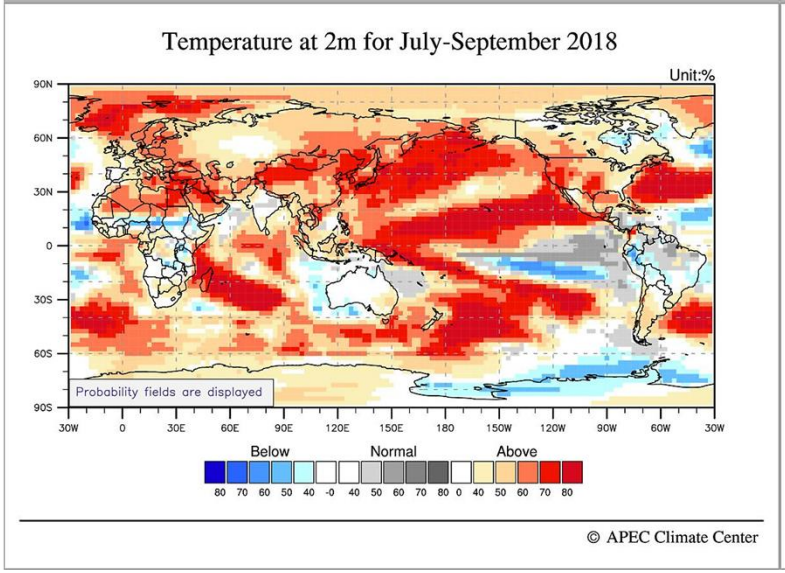
MME Forecast: 2018JJA

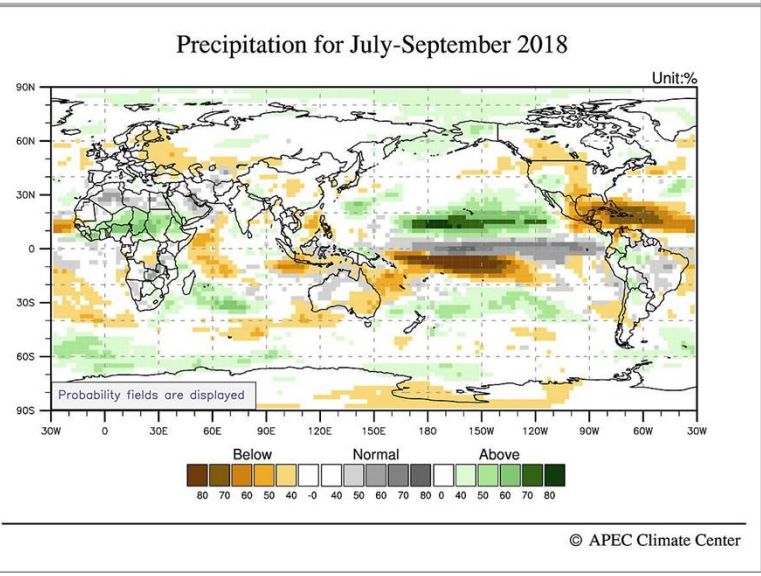
DMME





PMME





Verification Information

- The APCC verification system is based on recommendations from WMO SVS-LRF in terms of verification metrics and regions.
- Metrics used to measure prediction skill: deterministic (ACC, RMSE, TCC, MSSS), probabilistic (ROC, HSS, RPSS, BSS, RD)

Parameters	Region	Deterministic forecast	Probabilistic forecast
Diagrams and scores to be produced for regions			
Basic variable	GL, TR, NE, SE	MSSS	ROC curve
(T850, T2m, PREC,		ACC	ROC score
Z500, SST)		RMSE	Reliability diagram
	EA, SA, NAm, SAm, AUS,	ACC	HSS
	AUS+SP, NEu,ME	RMSE	RPSS
			BSS
Nino Index	Nino1+2/3/3.4/4	TCC	N/A
ENSO-Modoki index	EMI	TCC	N/A
IOD index	IOD	TCC	N/A
Grid-point data for mapping			
Basic variable	Grid-point verification on	MSSS	ROC score
	a 2.5° x 2.5° grid	Difference map	HSS
		Ensemble spread map	RPSS
			BSS

✓ **Lead time**:
- Monthly mean
- Seasonal mean

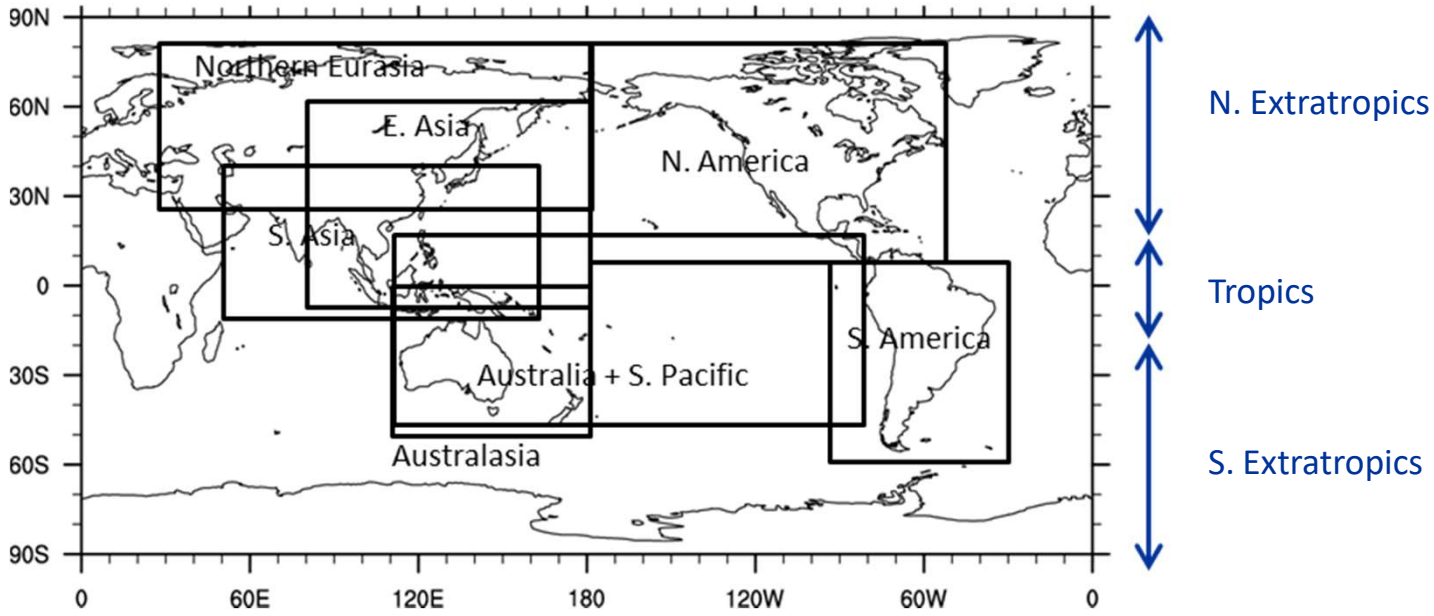
✓ **Variable**:
- Basic variables
- SST indices

✓ **Observation**
- NCEP II Reanalysis
- CAMS-OPI

** CAMS-OPI: Climate Anomaly Monitoring System and Outgoing longwave radiation Prediction Index*

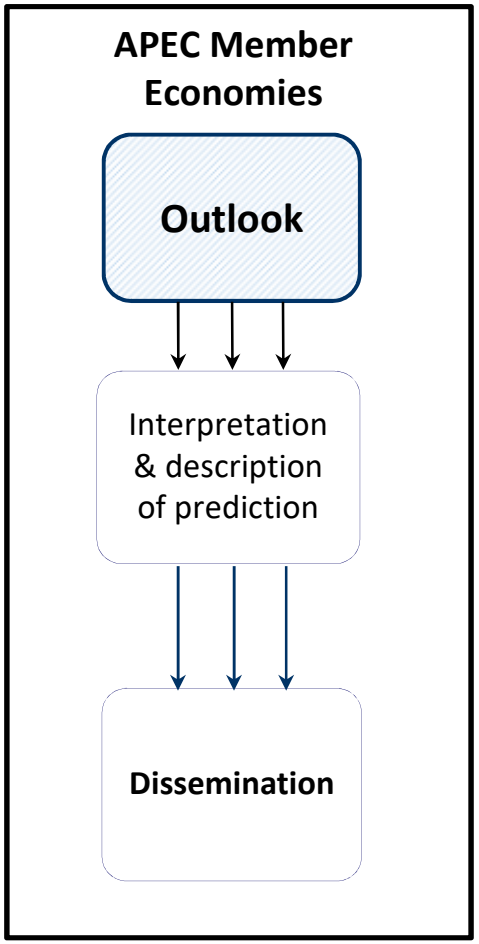
Verification Information

- Recommendations from WMO SVS-LRF and CORDEX.
- Large-scale statistics: Globe, Tropics, N. Extratropics, S. Extratropics
- Sub-region statistics: E. Asia, S. Asia, N. America, S. America, Australasia, Australia + S. Pacific, Northern Eurasia, Middle East.



** CORDEX: Coordinated Regional Climate Downscaling Experiment*

Procedure of Operations: Dissemination



- Schedule: 20th ~ 25th every month

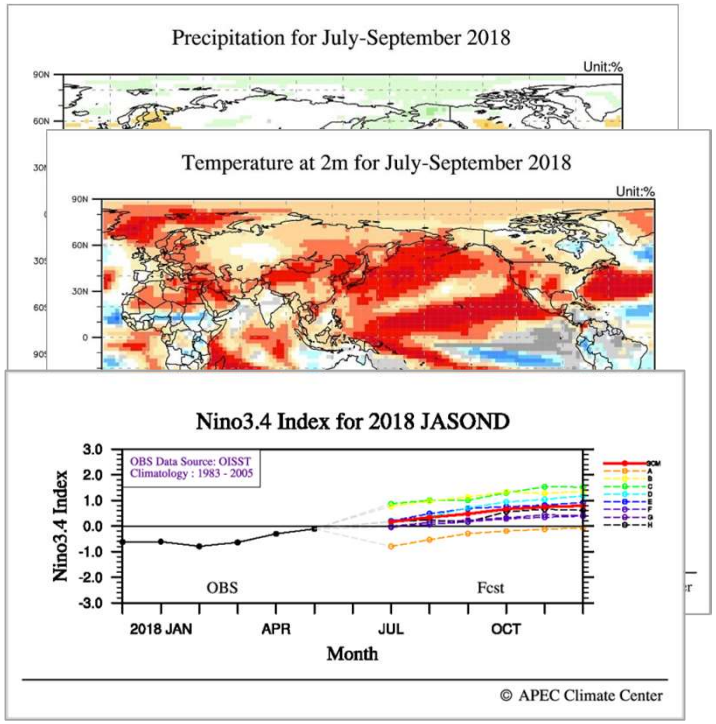
- **Outlook**
- Interpretation and description of Global & PICs prediction
- Release official outlook 5 days prior to the forecast period

- **All information can be available on the APCC web-site.** (http://www.apcc21.org)

- Anyone can access APCC monthly global MME 3-month forecast through our web-site around 25th of every month.

- Climate monitoring and hindcast/forecast verification

APCC Official Seasonal Outlook: Globe



- ✓ **Interpretation and description of global and regional prediction**
- ✓ **Release official APCC outlook around 25th of every month**

The APEC CLIMATE CENTER
Climate Outlook for June – November 2018

BUSAN, 25 May 2018 – The synthesis of the latest model forecasts for June to November 2018 (JJASON) from the APEC Climate Center (APCC), located in Busan, South Korea, indicates a neutral El Niño-Southern Oscillation (ENSO) phase. The forecasts show positive temperature anomalies to prevail over the Northern Hemisphere, with highly probable above normal temperatures over Eurasia and the subtropical Pacific and Atlantic for the whole forecast period. The forecasts for JJA 2018 suggest below normal rainfall over the central off-equatorial South Pacific and above normal rainfall over the central off-equatorial North Pacific, whereas the forecasts for SON 2018 show below and near normal rainfall over the central off-equatorial South Pacific and central equatorial Pacific, respectively.

Current Climate Conditions

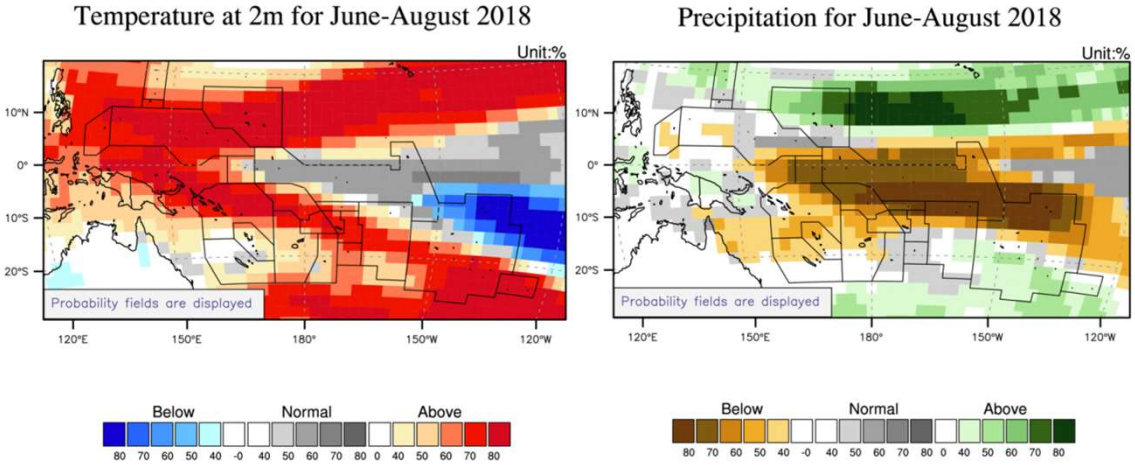
In March through the middle of May, the ENSO phase remained slightly negative. Positive seasonal mean temperature anomalies were observed over the Arctic and Antarctic, Bering Sea, South Atlantic, Australia, New Zealand, the Pacific except for the central and eastern equatorial parts, the Middle East, Europe, Africa, western USA, Mexico, and South America. Negative seasonal temperature anomalies prevailed over most parts of Canada, northern USA, western Siberia, North Atlantic …

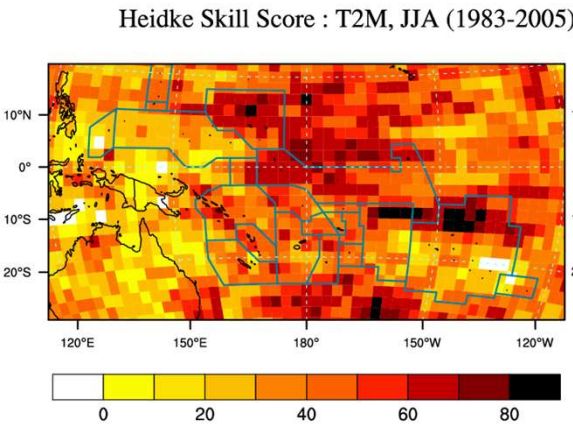
Forecast

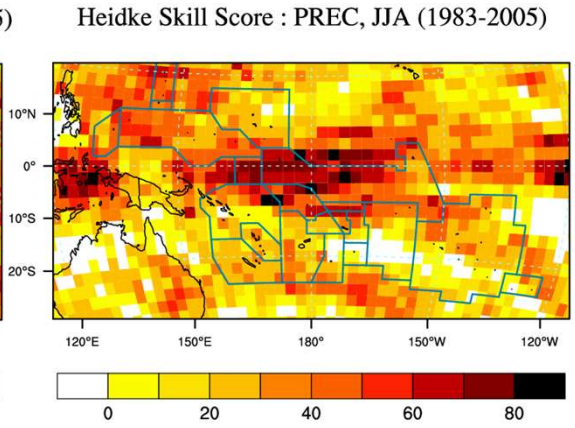
Sea Surface Temperature and ENSO Outlook:
A tongue of slightly negative Sea Surface Temperature (SST) anomalies in the central and eastern equatorial Pacific is predicted through the first half of the forecast period. Weak positive SST anomalies are expected to surround this cold tongue. However, the negative anomalies are too small for ENSO conditions to be La Niña, which means a neutral ENSO condition is expected for the whole forecast period ….

Temperature and Precipitation Outlook:
Strongly enhanced probability for above normal temperatures is predicted for the Barents, Norwegian, Greenland, and Bering Seas, northern North Pacific, subtropical Pacific and Atlantic, and southern Indian Ocean. Enhanced probability for above normal temperatures is expected for Eurasia (excluding the Indochina peninsula, the southern half of India, and western Russia), Greenland, the Arctic and Antarctic, maritime continent, Canada, USA, Alaska, and North Africa. …

Seasonal Outlook: Pacific Islands Counties (PICs)







The APEC CLIMATE CENTER

Climate Outlook for Pacific Islands

for June – November 2018

BUSAN, 25 May 2018 – The synthesis of the latest model forecasts for June to November 2018 (JJASON) from the APEC Climate Center (APCC), located in Busan, South Korea, indicates a neutral El Niño-Southern Oscillation (ENSO) phase. Above normal temperatures are expected to prevail over all of Melanesia and the whole of Micronesia and Polynesia, except in the equator for the first half of the forecast period ….

Forecast

Sea Surface Temperature and ENSO Outlook:

A tongue of slightly negative Sea Surface Temperature (SST) anomalies in the central and eastern equatorial Pacific is predicted through the first half of the forecast period. Weak positive SST anomalies are expected to surround this cold tongue. However, the negative anomalies are too small for ENSO conditions to be La Niña, which means a neutral ENSO condition is expected for the whole forecast period ….

Temperature and Precipitation Outlook:

Strongly enhanced probability for above normal temperatures is predicted for Micronesia and Polynesia, except in the equatorial belts, and northern Melanesia. Strongly enhanced probability for below normal temperatures is expected for the off-equatorial southern Polynesia. Enhanced probability for near normal temperatures is predicted for equatorial Micronesia and Polynesia. Strongly enhanced probability for above normal precipitation is expected for eastern off-equatorial Micronesia ...

Climate Prediction & Information Service

✓ ***http://www.apcc21.org***

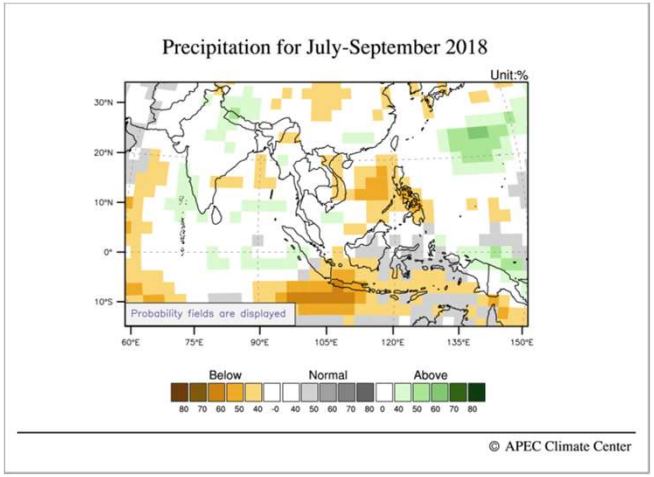
Climate Information (http://www.apcc21.org)

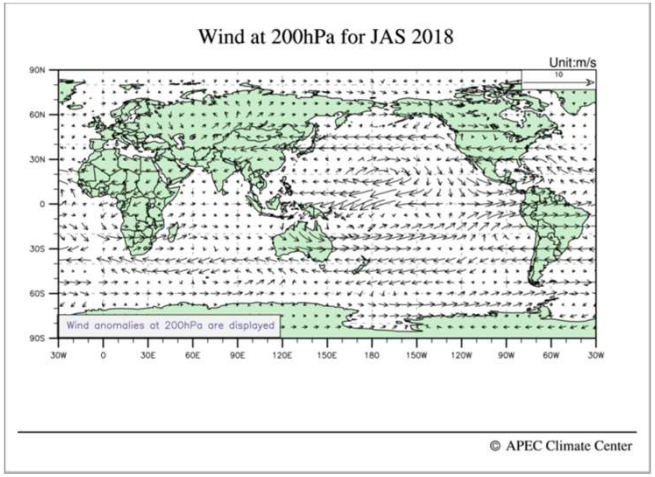
Climate Information Service

- **Seasonal Forecast**
  - Outlook
  - ENSO
  - Verification
    - Forecast
    - Hindcast
- **BSISO Forecasts**
- **Applied Forecast**
- **Current Climate Conditions**
- **CLIK**
- **CLIPs**
- **ADSS**
- **OpenWPS**

✓ Seasonal Forecast

- MME and individual model forecasts on a monthly basis
- 6-month forecasts with a 1-month lead time
- Deterministic & probabilistic
- T2m, T850, Prec, Z500, SLP, U/V wind
- Both global and regional scales





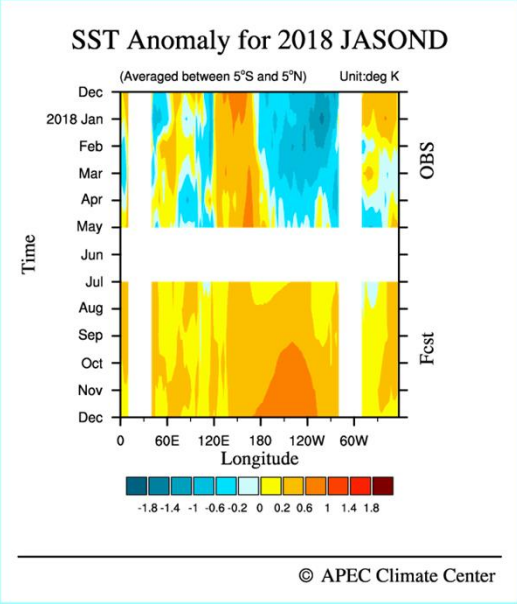
Climate Information (http://www.apcc21.org)

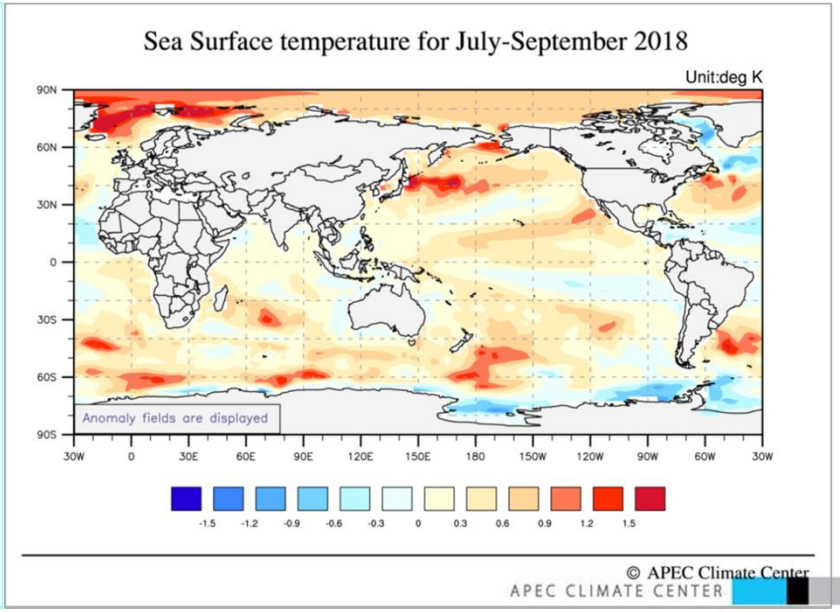
Climate Information Service

- **Seasonal Forecast**
  - Outlook
  - ENSO
  - Verification
    - Forecast
    - Hindcast
- **BSISO Forecasts**
- **Applied Forecast**
- **Current Climate Conditions**
- **CLIK**
- **CLIPs**
- **ADSS**
- **OpenWPS**

✓ ENSO

- MME and individual model predictions
- SST, ENSO & IOD indicies (Nino 1+2/3/3.4/4, EIOD)
- Spatial distribution, time-longitude cross section, time series





Climate Information (http://www.apcc21.org)

Climate Information Service

- **Seasonal Forecast**
  - Outlook
  - ENSO
  - Verification
    - Forecast
    - Hindcast
- **BSISO Forecasts**
- **Applied Forecast**
- **Current Climate Conditions**
- **CLIK**
- **CLIPs**
- **ADSS**
- **OpenWPS**

✓ ENSO

- MME and individual model predictions
- SST, ENSO & IOD indicies (Nino 1+2/3/3.4/4, EIOD)
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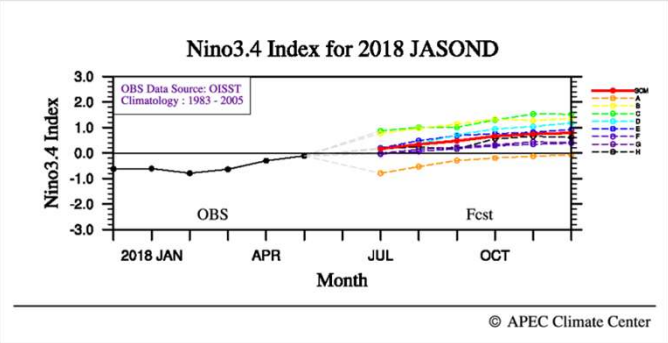

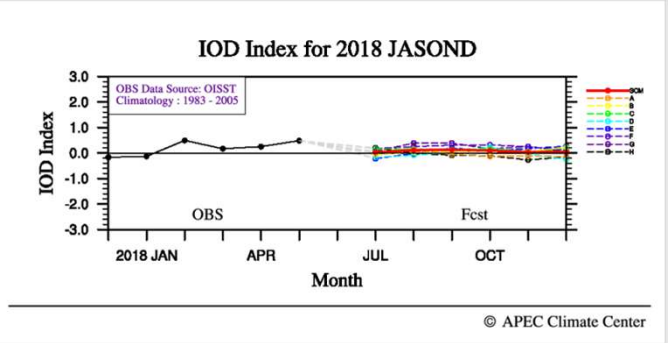

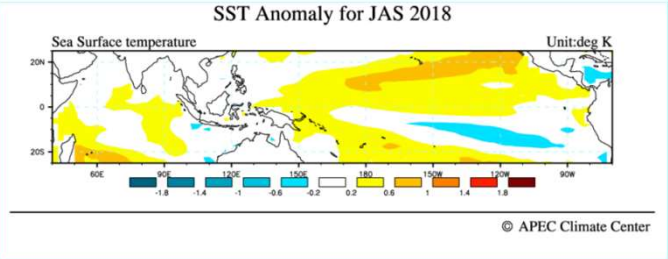

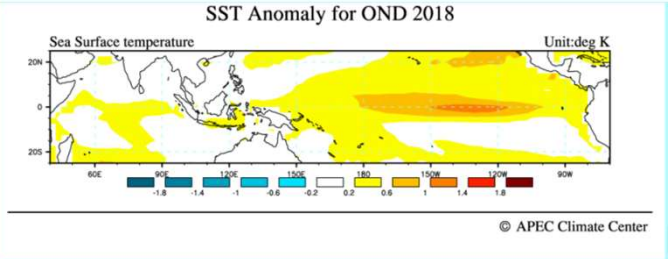

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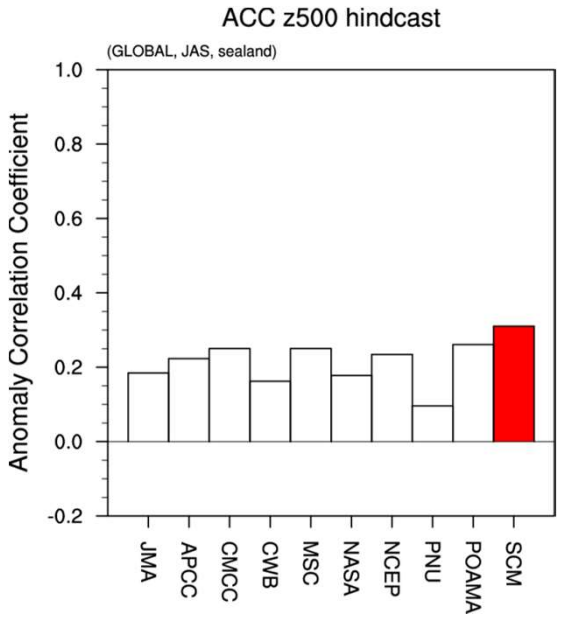
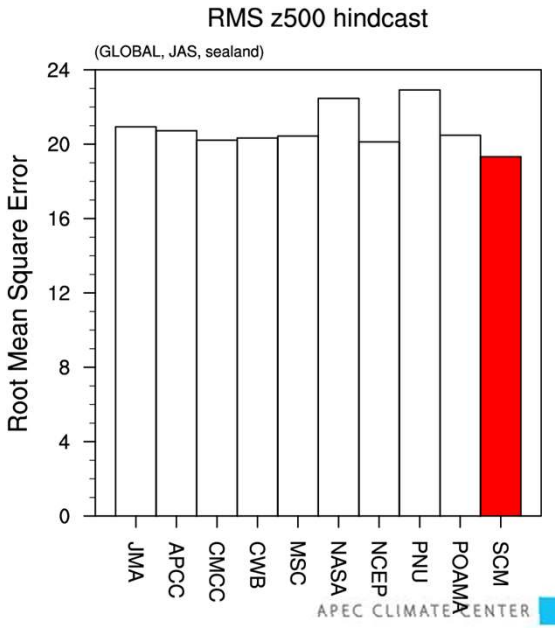
- Verification information for Hindcast and Real-time forecast
- Deterministic: ACC, RMSE, MSSS
- Probabilistic: Reliability diagram, ROC curve, HSS, RPSS, BSS





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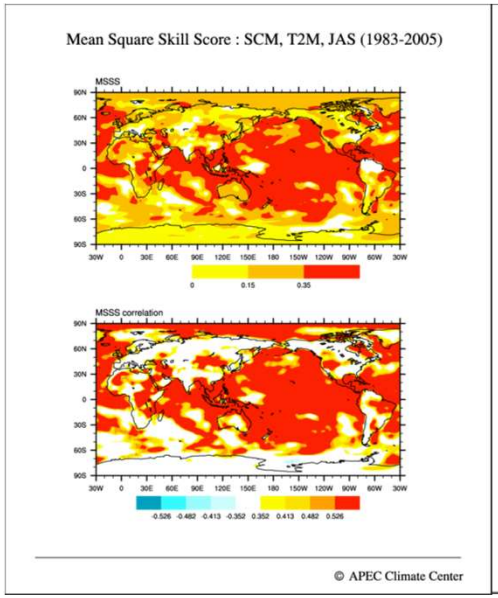
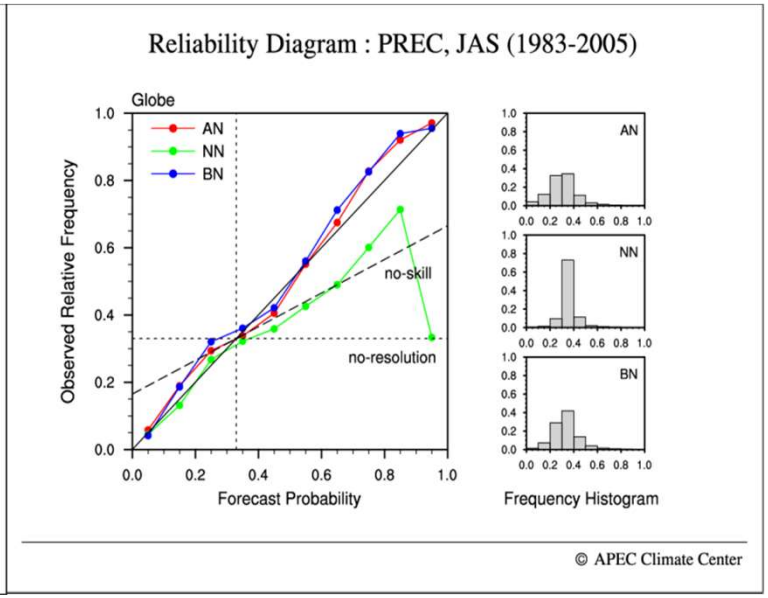
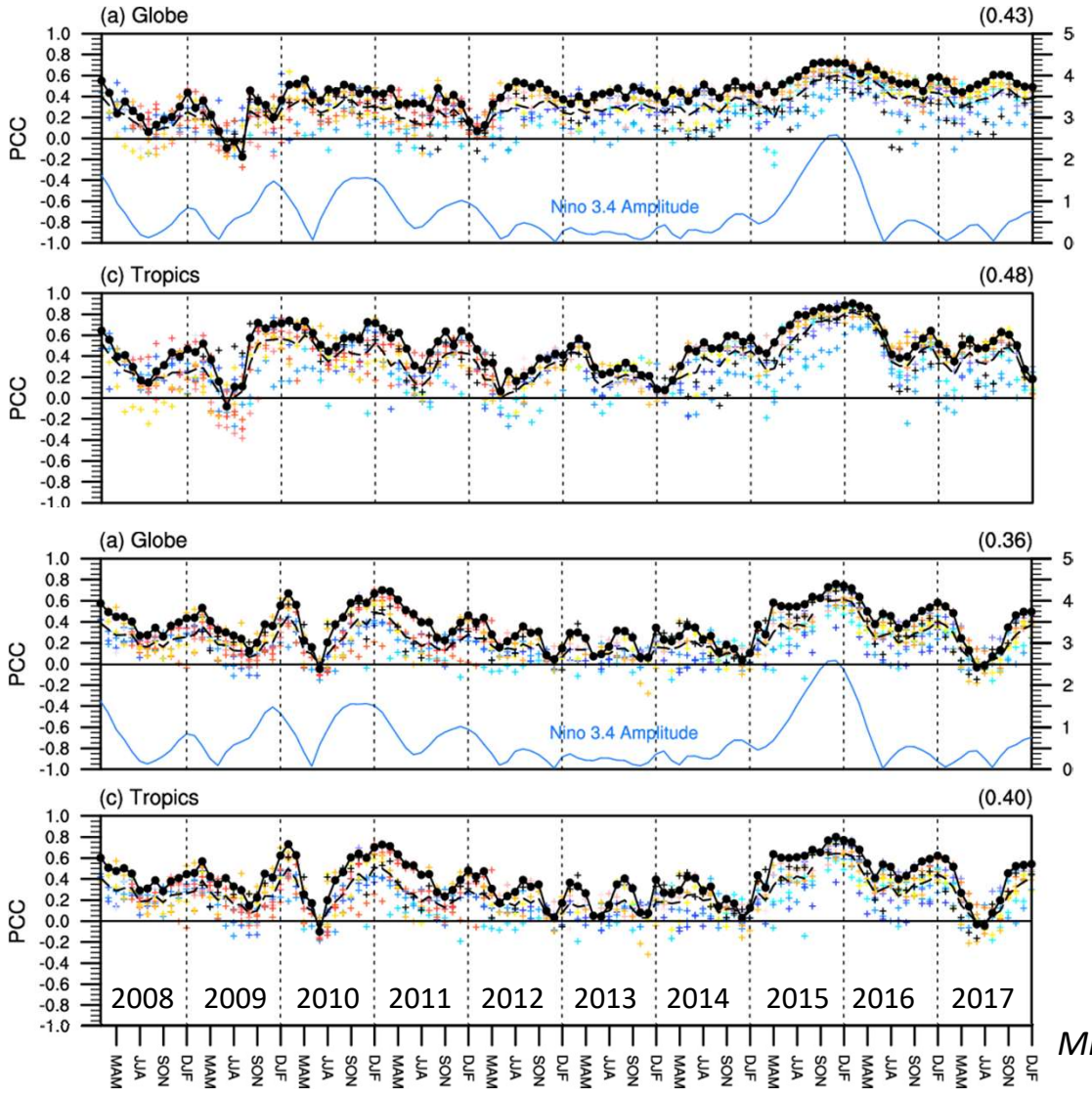




Performance of the APCC MME prediction system

Anomaly Pattern Corr.: RT-Forecast

T850



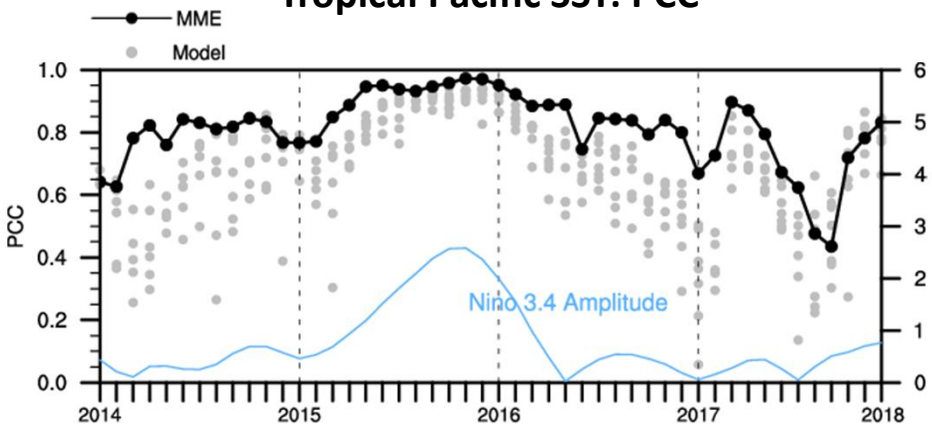
PREC

- ✓ The MME's skill is not always the highest for a given particular forecast in different regions and seasons, however its performance is generally higher than that of any single model.
- ✓ The skill of the APCC forecasts strongly depends on seasons and regions that it is higher for the tropics and boreal winter.
- ✓ The APCC MME forecasts show a reasonably good level of the prediction skill.

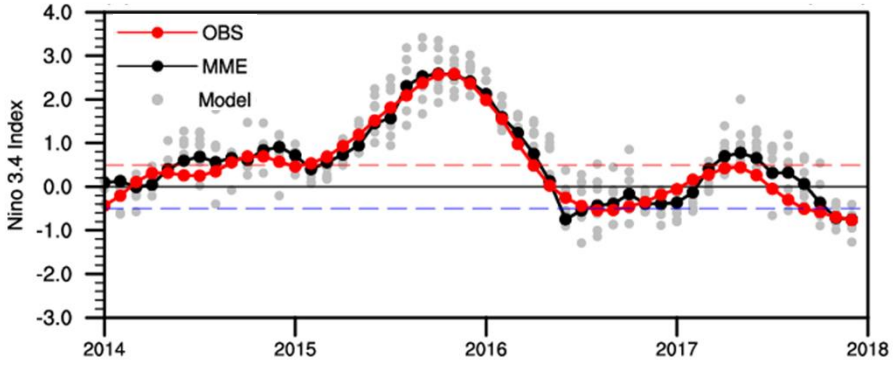
Min et al. (2017), CD

SST and ENSO Predictions

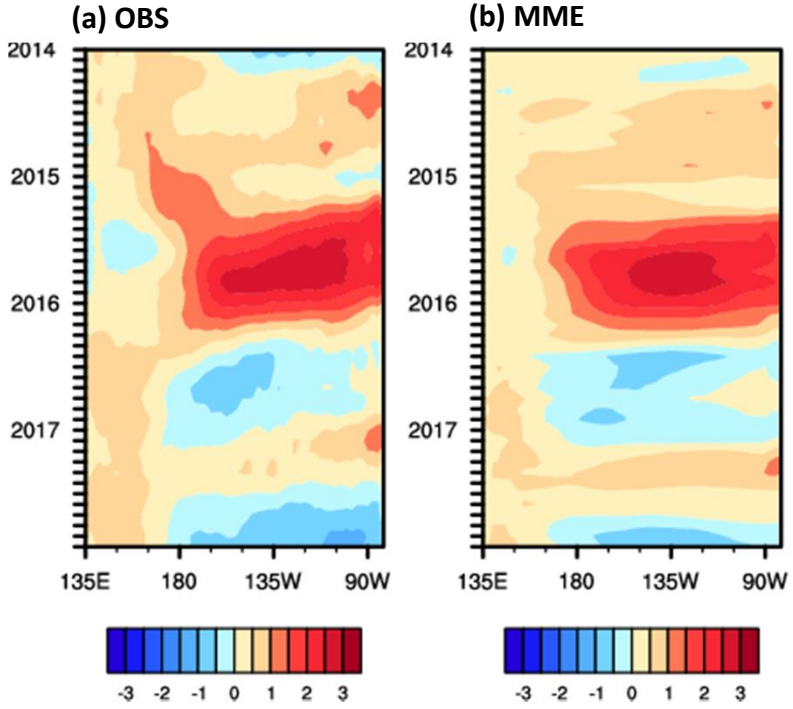
Tropical Pacific SST: PCC



Time Series of Nino 3.4 Index



Evolution of Equatorial Pacific SST



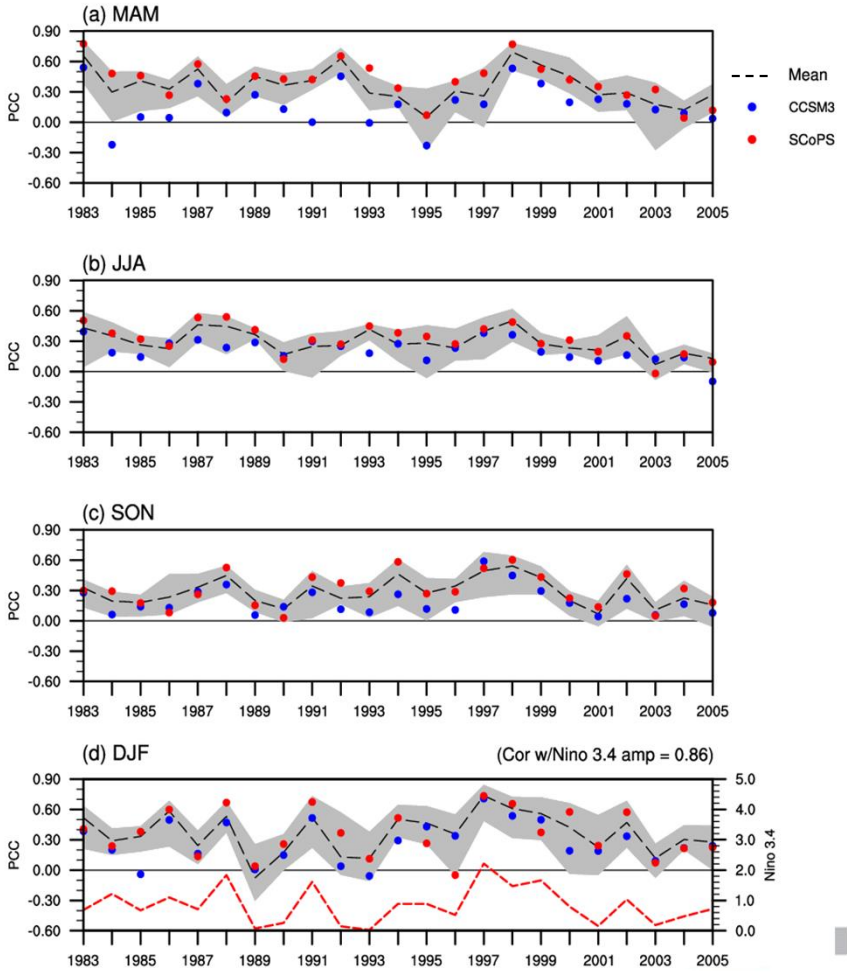
Recent Improvements

❍ Development of in-house model

- Upgrading APCC in-house forecast system CCSM3 → SCoPS
- SCoPS model has participated in the APCC MME prediction since Nov. 2017.

		SCoPS	CCSM3
Model Description	Atmos.	ECHAM v5.3	CAM3
	Ocean	POP v2.0.1	POP v1.4.3
	Sea ice	CICE v4.1	CSIM4
Resolution	Atmos.	T159 // 31 levels	T85 // 26 levels
	Ocean	1° X 0.5 // 40 levels	
Initial condition	Atmos.	3D nudging from CFSR	–
	Ocean	EAKF from CFSR SST and profile data (WOD)	3D nudging from GODAS
Hindcast period		1982~2013	1983~2013
Ensemble configuration		Time lagged with perturbation on Gaussian noise	Time lagged
Ensemble		10	

Interanuual Variation: GL, PREC

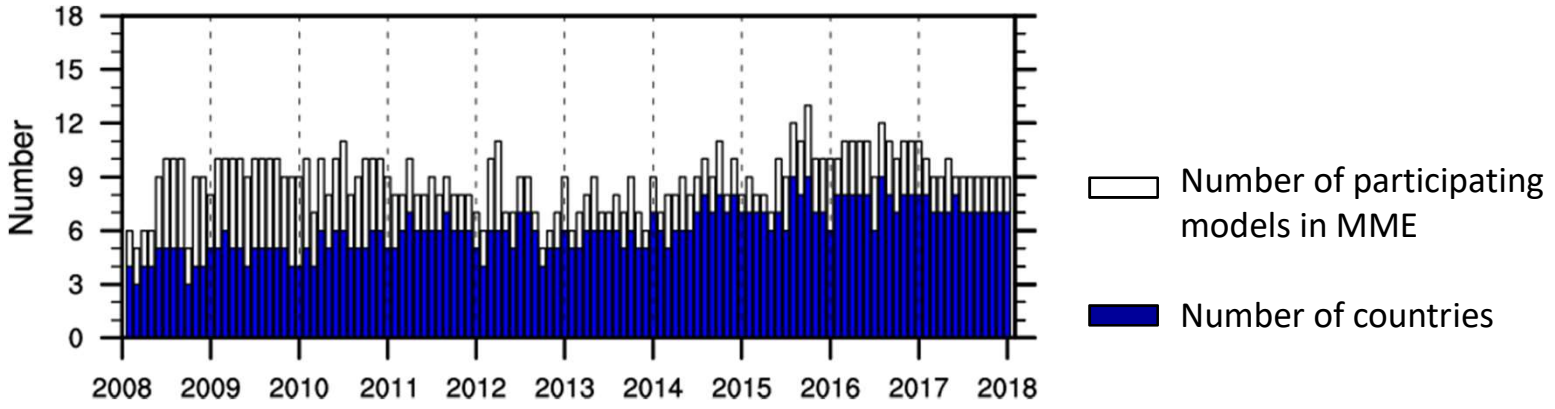


Recent Improvements

❍ Diversification of participating models

- APCC have made an effort to encourage the groups providing seasonal forecast to participate in the APCC MME prediction.

- Only APEC member economies → European models (CMCC, UKMO)

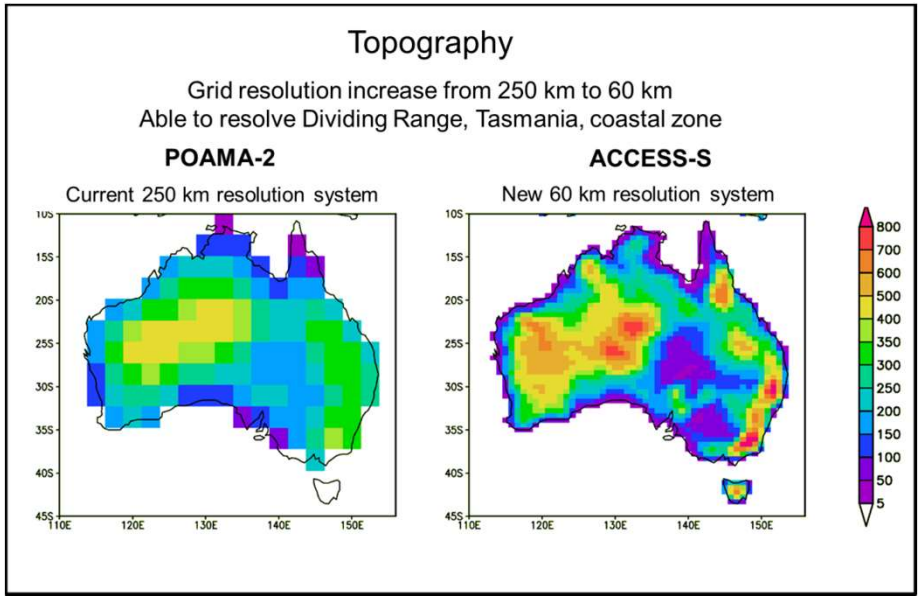


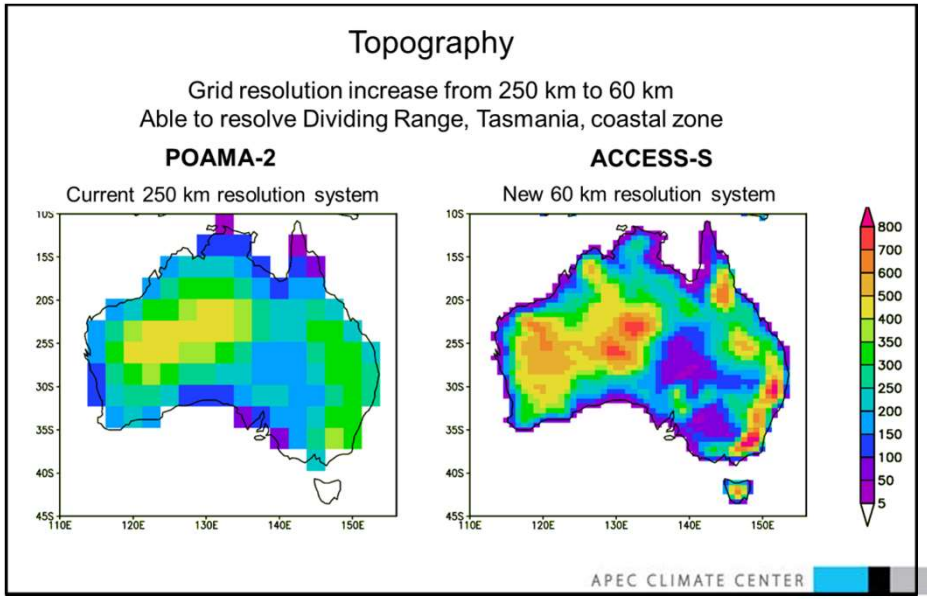
Recent Improvements

❍ Improvement of participating models

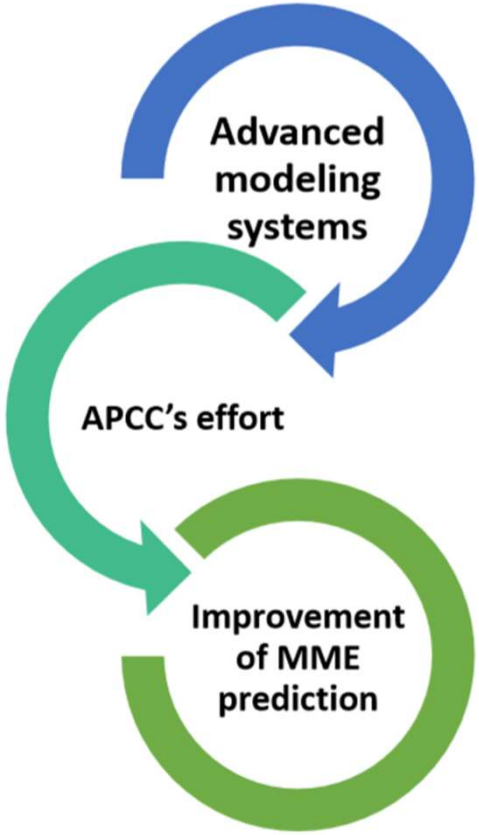
- Improved BCC v2.0 and CWB models to 1-tier prediction system (coupled model) provided from 2-tier prediction system for 2016 and 2018

- Will be replaced BOM prediction system from POAMA to ACCESS-S

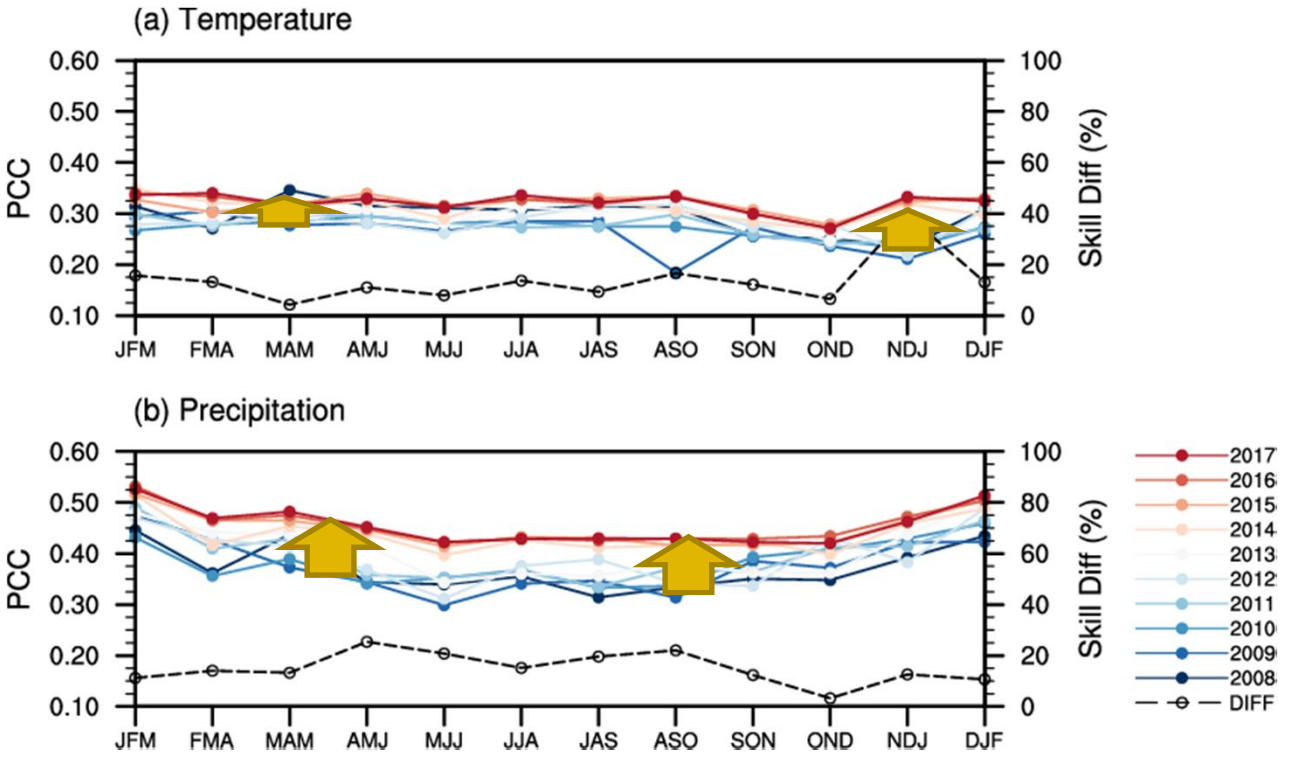




Multi-Institutional Cooperation



Hindcast Skill of APCC MME



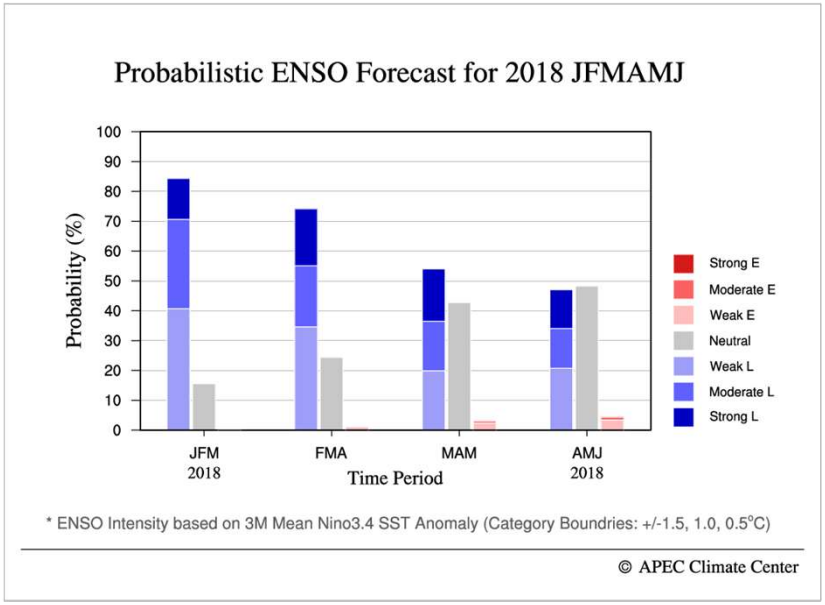
Future Plans

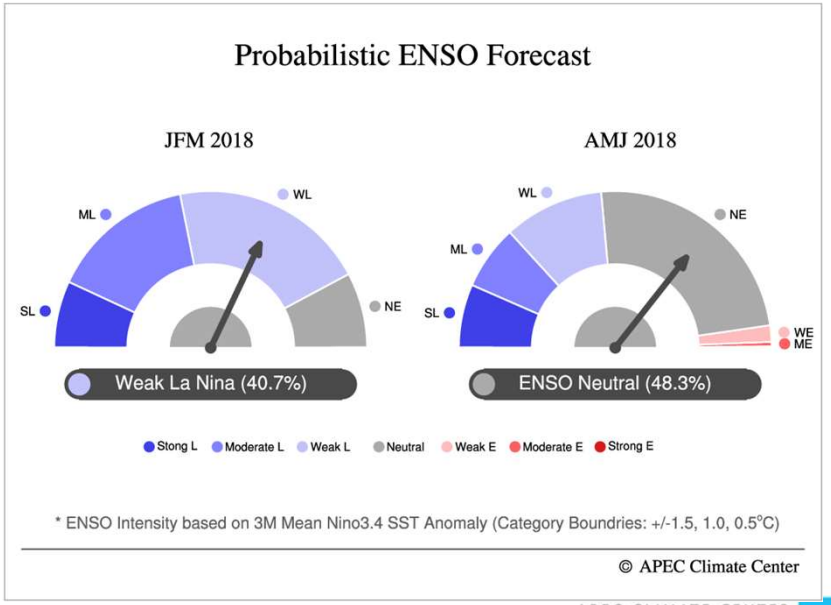
Spatial Resolution Test

Hindcast Period Sensitivity Test

Diverse Contents: ENSO intensity

Improvement of In-House Model





Summary

- APEC Climate Center (APCC) is a leading operational center providing seasonal forecast based on the Multi-Model Ensemble (MME) prediction system in both deterministic and probabilistic forms.

- APCC has operationally implemented different MME methods; SCM, SPM, MRG, and SSE for deterministic forecast and PMME method for probabilistic forecast.

- APCC has been issuing monthly rolling real-time global MME forecasts of temperature and precipitation for the upcoming 6 months, since Nov. 2017. These forecasts contain monthly and 3-month mean values, they are issued monthly with a 1-mont lead.

- We disseminate the climate information (seasonal forecast, monitoring and verification information) through our web-site in the form of graphics and outlook around the 25th of each month.

THANK YOU

(http://www.apcc21.org)