

# Overview of APCC Operational Multi-Model Ensemble Seasonal Prediction System

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**Climate Prediction Team**  
**APEC Climate Center**

# 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 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>



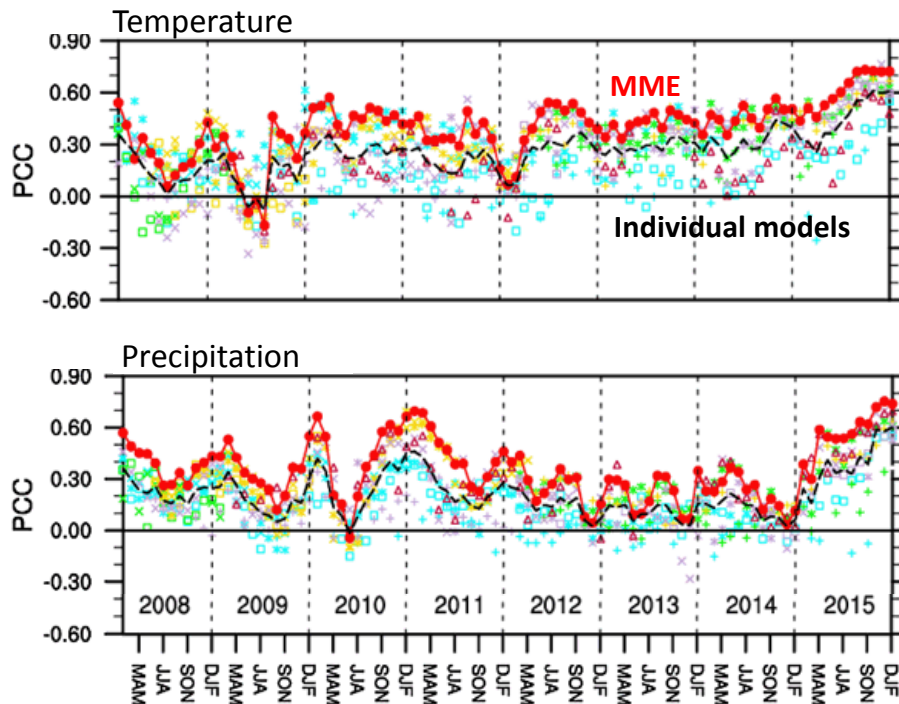
Climate Information

Information Service System

# 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



International Research Institute  
for Climate and Society



# Institutes: MME Seasonal Forecasts



Country	Institutes	Participating Models
USA	NMME (North American Multi-Model Ensemble)	7 models in 5 operational centers from USA and Canada (NCEP, NASA, NCAR, GFDL, MSC)
USA	IRI (International Research Institute for Climate and Society)	Same as NMME
Europe	EUROSIP (European Seasonal to Interannual Prediction)	4 models from USA and Europe (ECMWF, UKMO, Meteo France, NCEP)
Europe	C3S (Copernicus Climate Change Service)	3 models from Europe (ECMWF, UKMO, Meteo France)
Korea	WMO LC-LRF (WMO Lead-Center for Long-Range Forecast)	13 models from designated GPCs (BCC, CPTEC, ECMWF, UKMO, BOM, MSC, HMC, DWD, SAWS, KMA, JMA, Meteo France, NCEP)

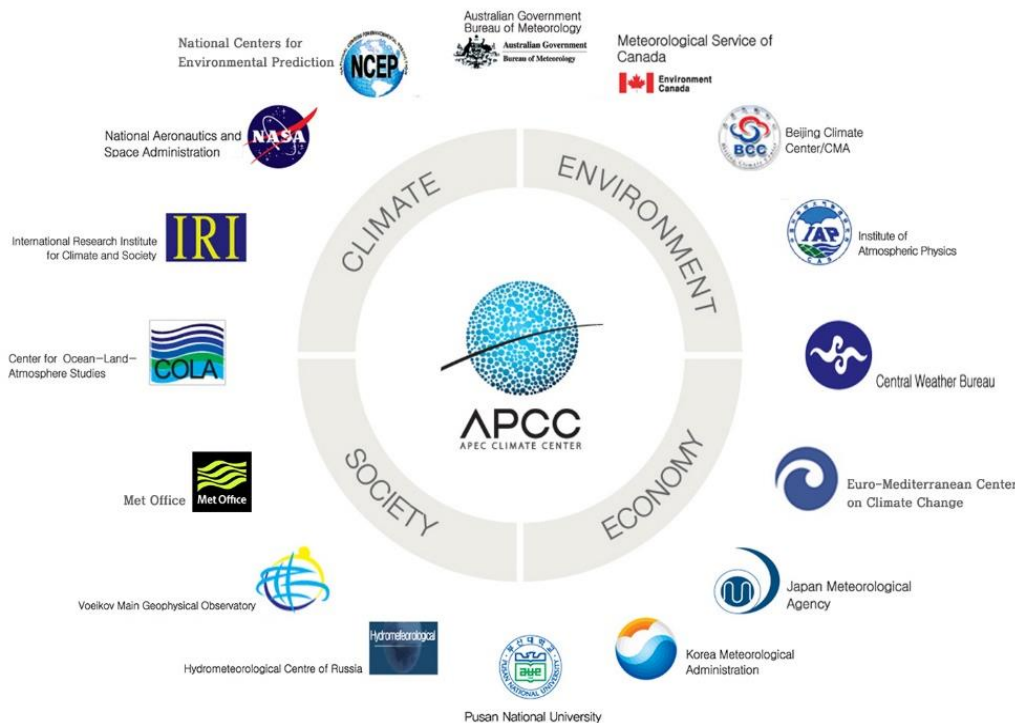
# APCC MME Seasonal Forecast



- Based on ensembles of dynamical seasonal climate prediction from 14 leading operational and research centers in 10 different countries

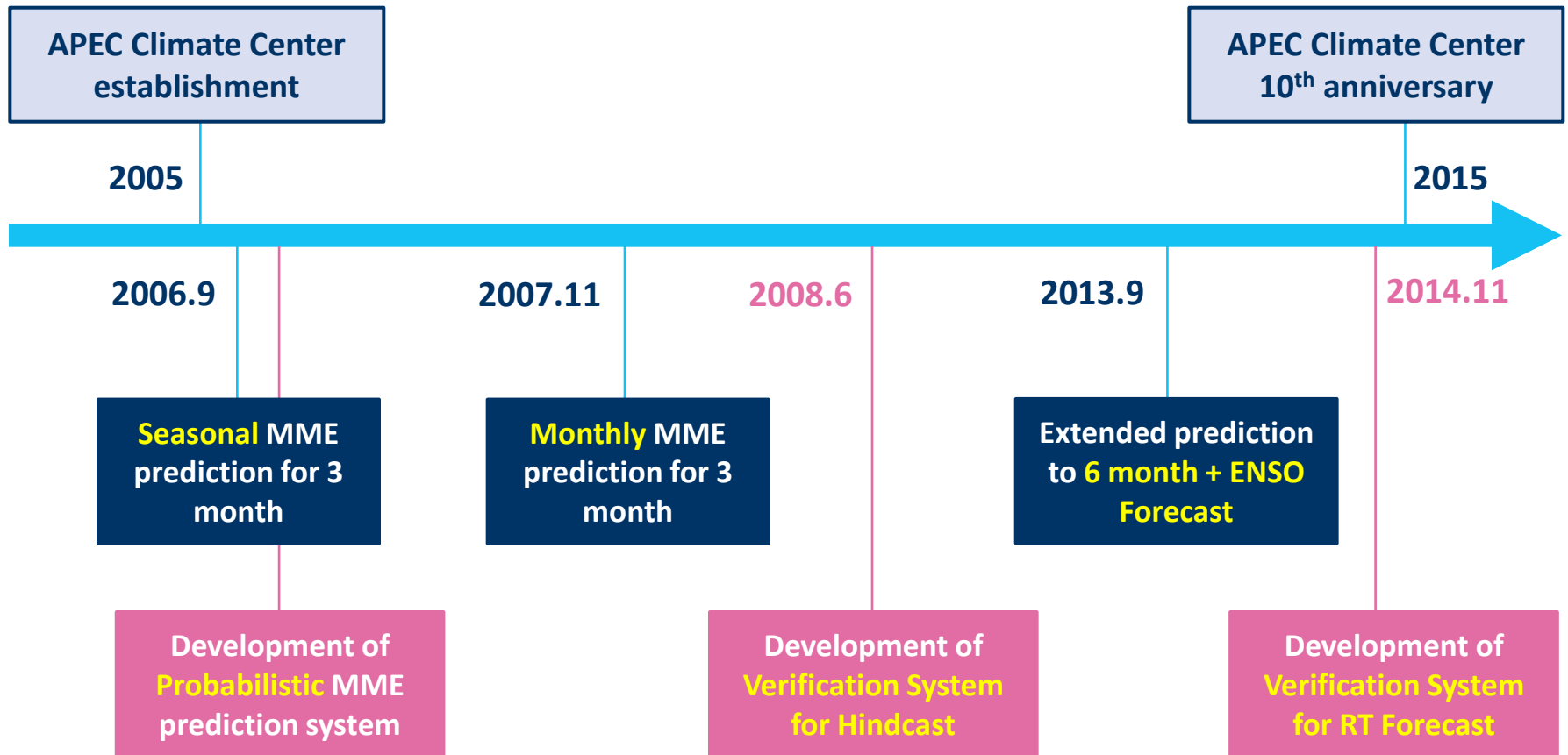
(as of Sep. 2018)

## Multi-institutional Cooperation



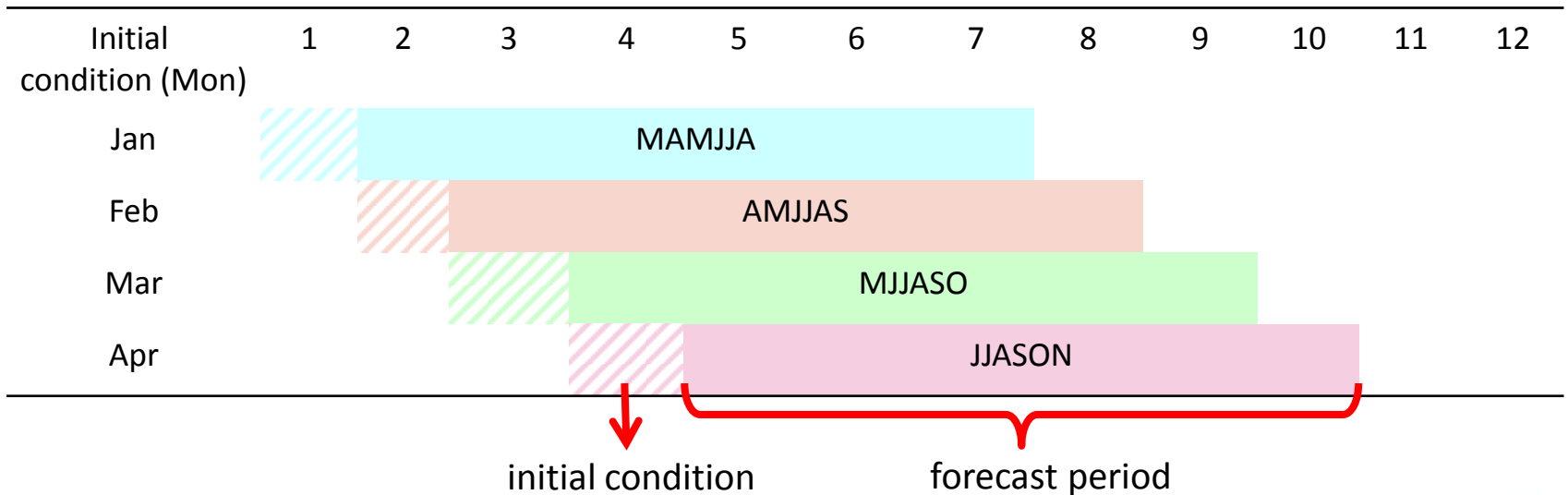
Economy	Organization/Institute
Australia	Bureau of Meteorology (BoM)
Canada	Meteorological Service of Canada (MSC)
China	Beijing Climate Center (BCC)
Chinese Taipei	Central Weather Bureau of Chinese Taipei (CWB)
Italy	Euro-Mediterranean Center on Climate Change (CMCC)
Japan	Japan Meteorological Agency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

# History of the APCC MME Operations

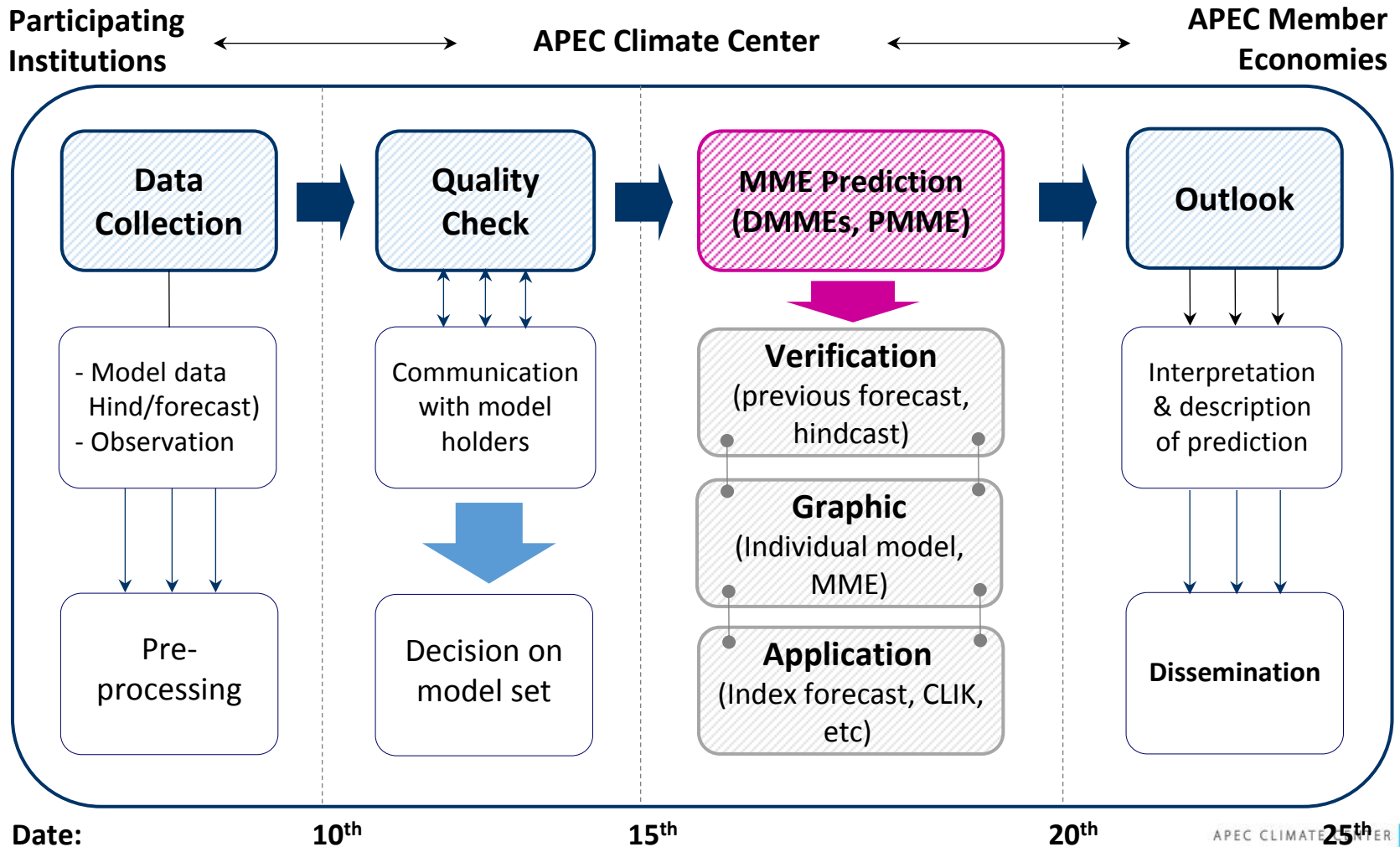


# APCC Seasonal MME Forecast

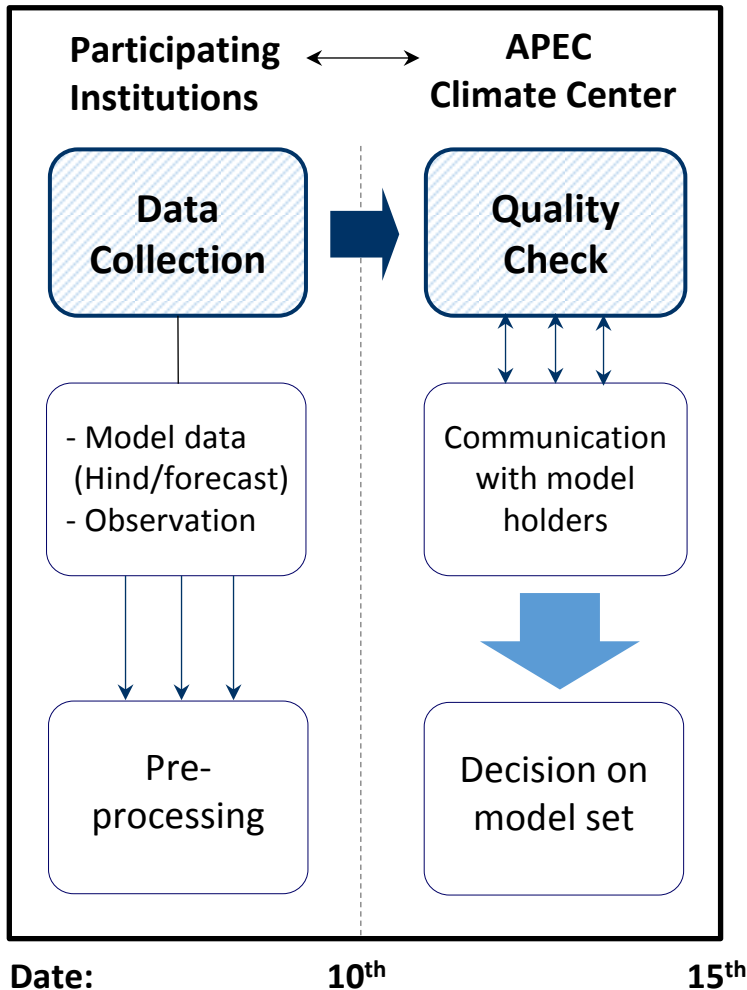
- APCC has been providing monthly MME forecasts for the next 6-month, with 1-month lead time, around 25<sup>th</sup> of every month.
- Precipitation, temperature at 2m and 850hPa levels, geopotential height of 500hPa surface, sea-surface temperature, wind fields at 850hPa and sea-level pressure at both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



# Operation Schedule



# Procedure of Operations: (1) Data Request



- **Schedule:** 1<sup>st</sup> ~ 15<sup>th</sup> 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)

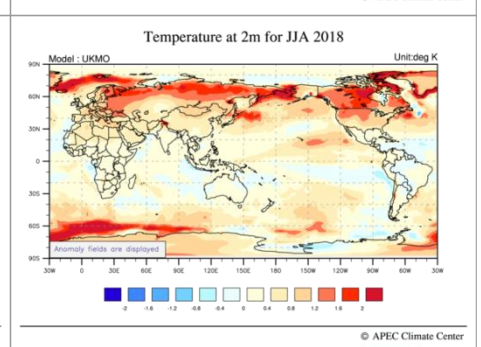
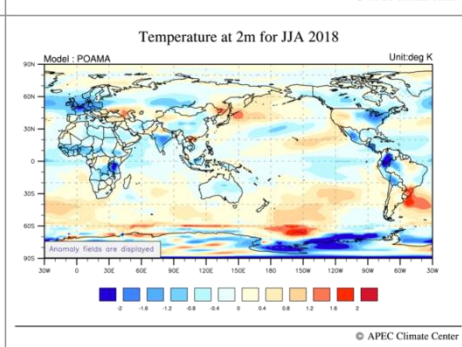
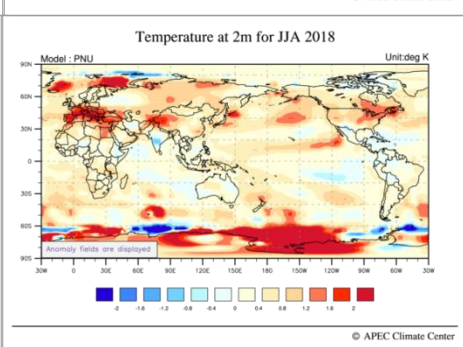
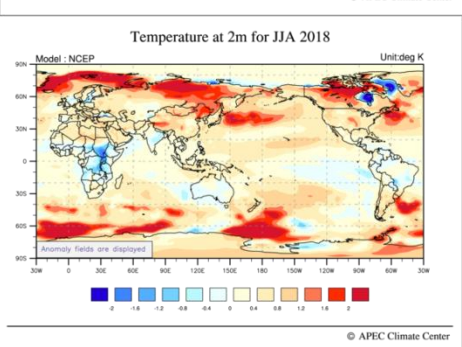
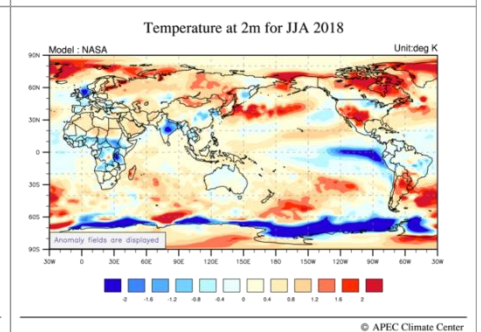
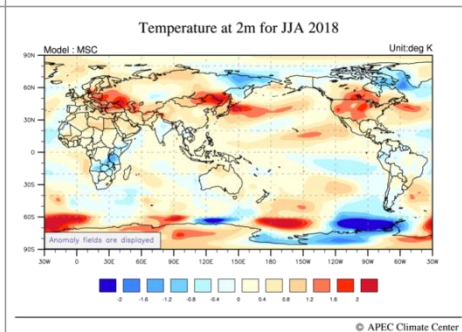
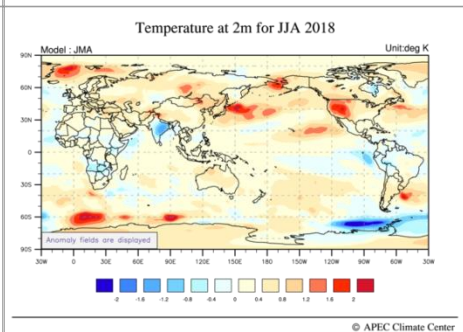
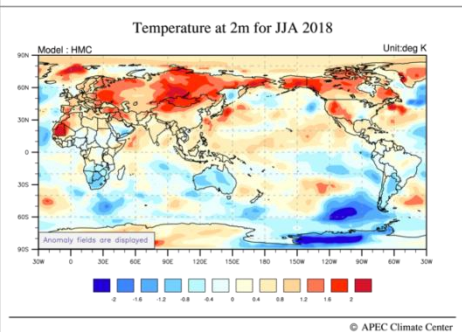
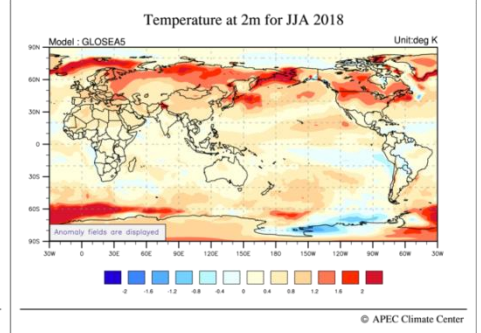
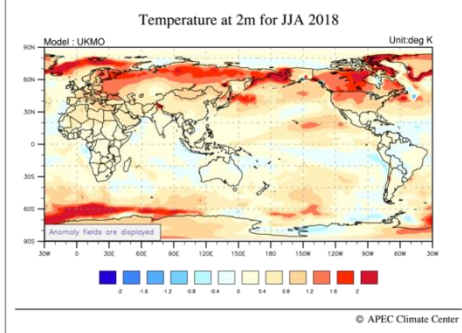
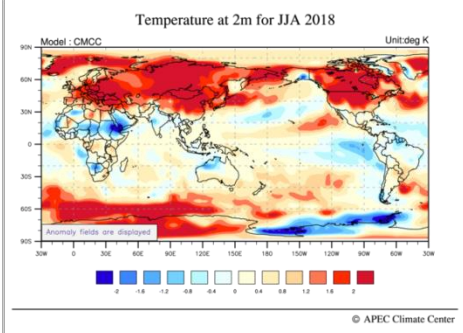
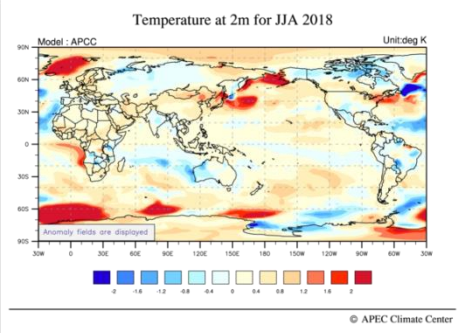
# APCC Participating Models



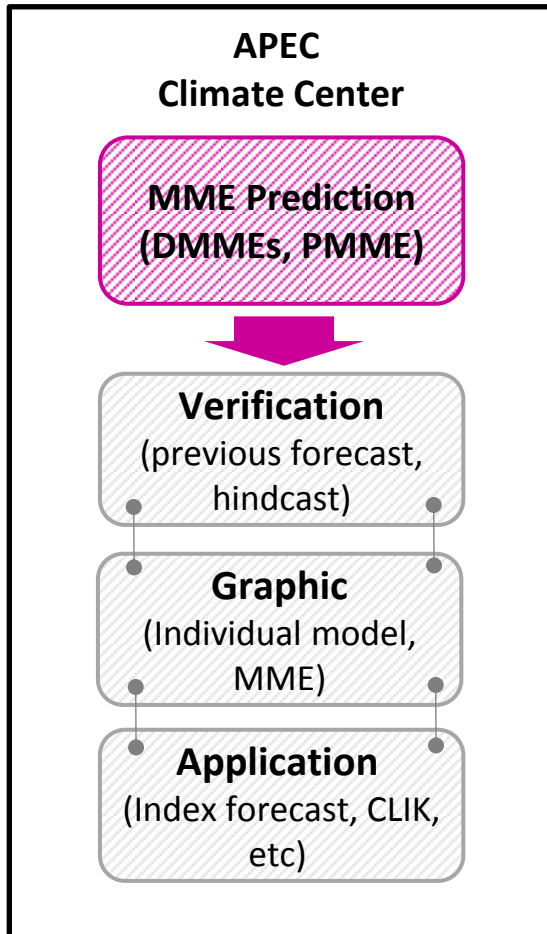
Institute	Model Name	SST Specification (H/F)	Ens. (H/F)	Forecast Period	Hindcast Period	Resolution
APCC	SCoPS	Predicted/Predicted	10/10	6-month	1982-2013	T159, L31
<b>CMCC</b>	CMCC-SPSv2	Predicted/Predicted	9/9	11-month	1981- <b>2005</b>	T63, L19
CWB	CWB	Predicted/Predicted	30/30	6-month	1982-2017	T119, L40
JMA	JMA/MRI-CPS2	Predicted/Predicted	10/51	3(6)-month	1979-2014	T159, L60
MSC	CanCM	Predicted/Predicted	20/20	11-month	1981-2010	T63, L35
NASA	GMAO	Predicted/Predicted	10/11	8-month	1981-2010	288x181, L72
NCEP	CFSv2	Predicted/Predicted	20/20	6(9)-month	1982-2010	T126, L64
PNU	PNU CGCM v1.0	Predicted/Predicted	5/5	6-month	1980-2015	T42, L18
BOM	POAMA-M24	Predicted/Predicted	33/33	6-month	<b>1983</b> -2011	T47, L17
<b>Met Office</b>	UKMO	Predicted/Predicted	12/42	5-month	1993-2015	1.875x1.25, L85
BCC	BCC	Predicted/Predicted	24/24	6-month	1991-2015	T106, L26
KMA	GLOSEA5	Predicted/Predicted	12/42	6-month	1991-2010	0.83°x0.56°, 85L
HMC	HMC	Persistent/Persistent	10/20	4-month	1985-2010	1.125x1.40625, L28
MGO	MGOAM2	Observed/Persistent	6/10	3-month	1979-2004	T42, L14

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

# Individual Model Forecast: 2018JJA, Temp.



# Procedure of Operations: (2) MME production



- Schedule: 15<sup>th</sup> ~ 20<sup>th</sup> 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**)

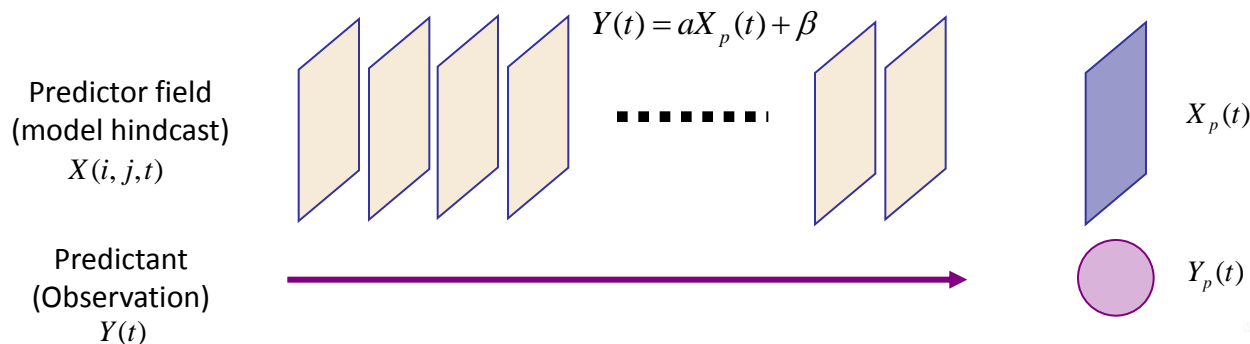
$$P = \frac{1}{M} \sum_{i=1}^M F_i$$

M: number of forecast models  
F<sub>i</sub>: forecast of i<sup>th</sup> 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<sup>th</sup> model



# APCC Deterministic MME Methods

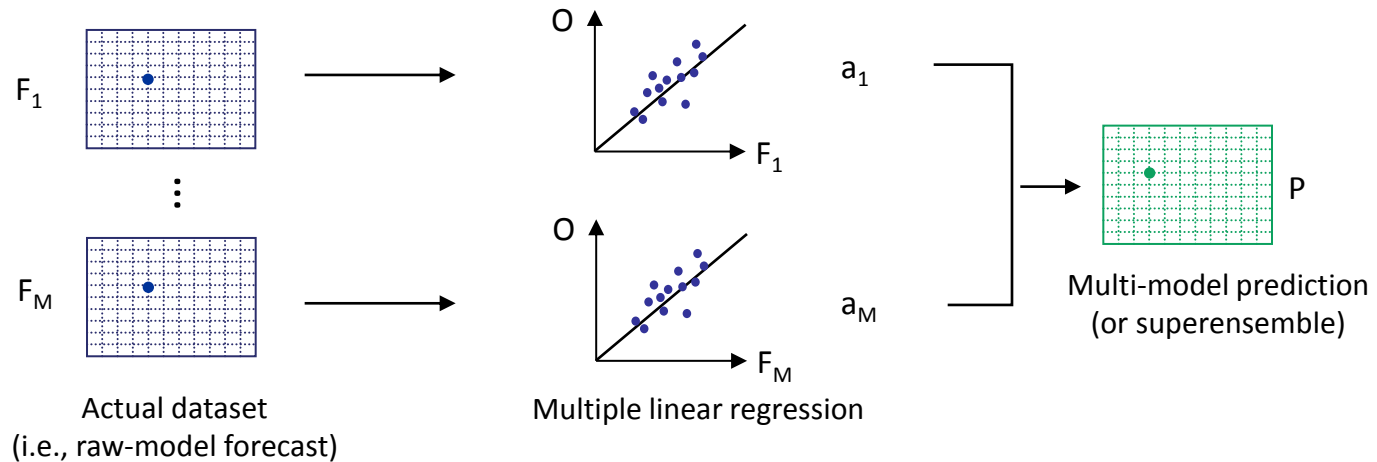
- **MRG**: empirically weighted MME with **Multiple-linear ReGression** coefficients (Yun et al. 2003)

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

M: number of forecast models

$F_i$ : forecast of  $i^{\text{th}}$  model

$a_i$ : regression coefficients during the training period



# APCC Deterministic MME Methods

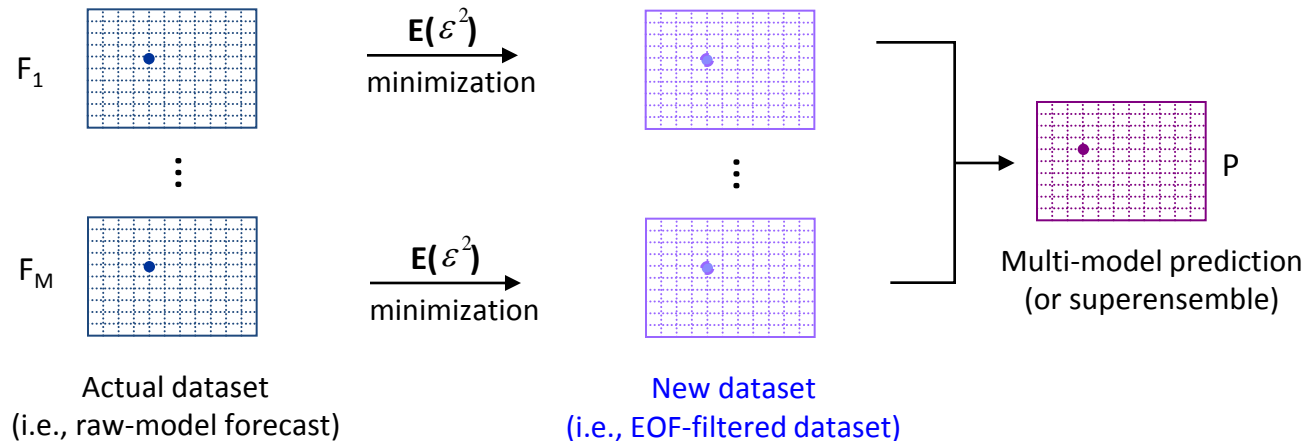
- **SSE**: empirically weighted MME with EOF-filtering of the actual dataset by finding a consistent spatial pattern between the observed and individual model forecast (**Synthetic Super-Ensemble method** ; Yun et al. 2005)

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

M: number of forecast models

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

$a_i$ : regression coefficients during the training period



# Skill Comparisons: DMMEs (Hindcast)

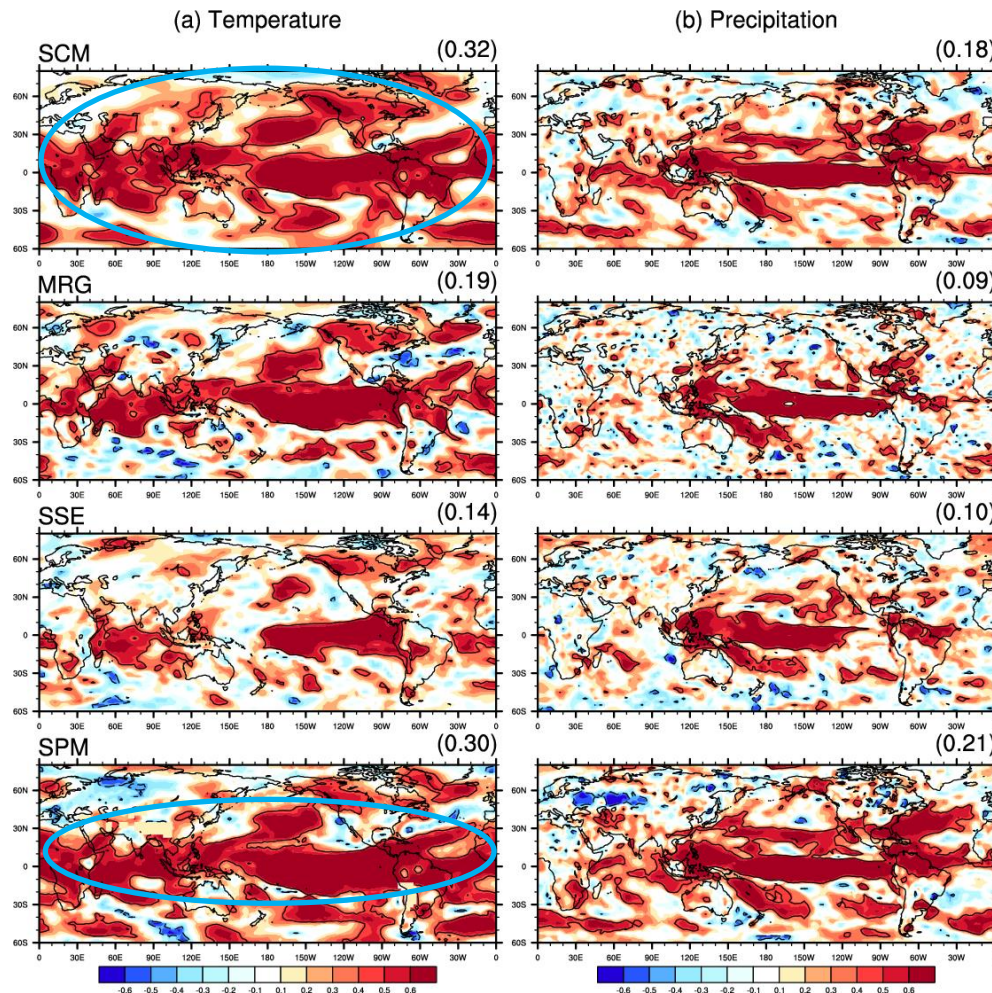
## Temporal Correlation (1983-2005)

SCM

MRG

SSE

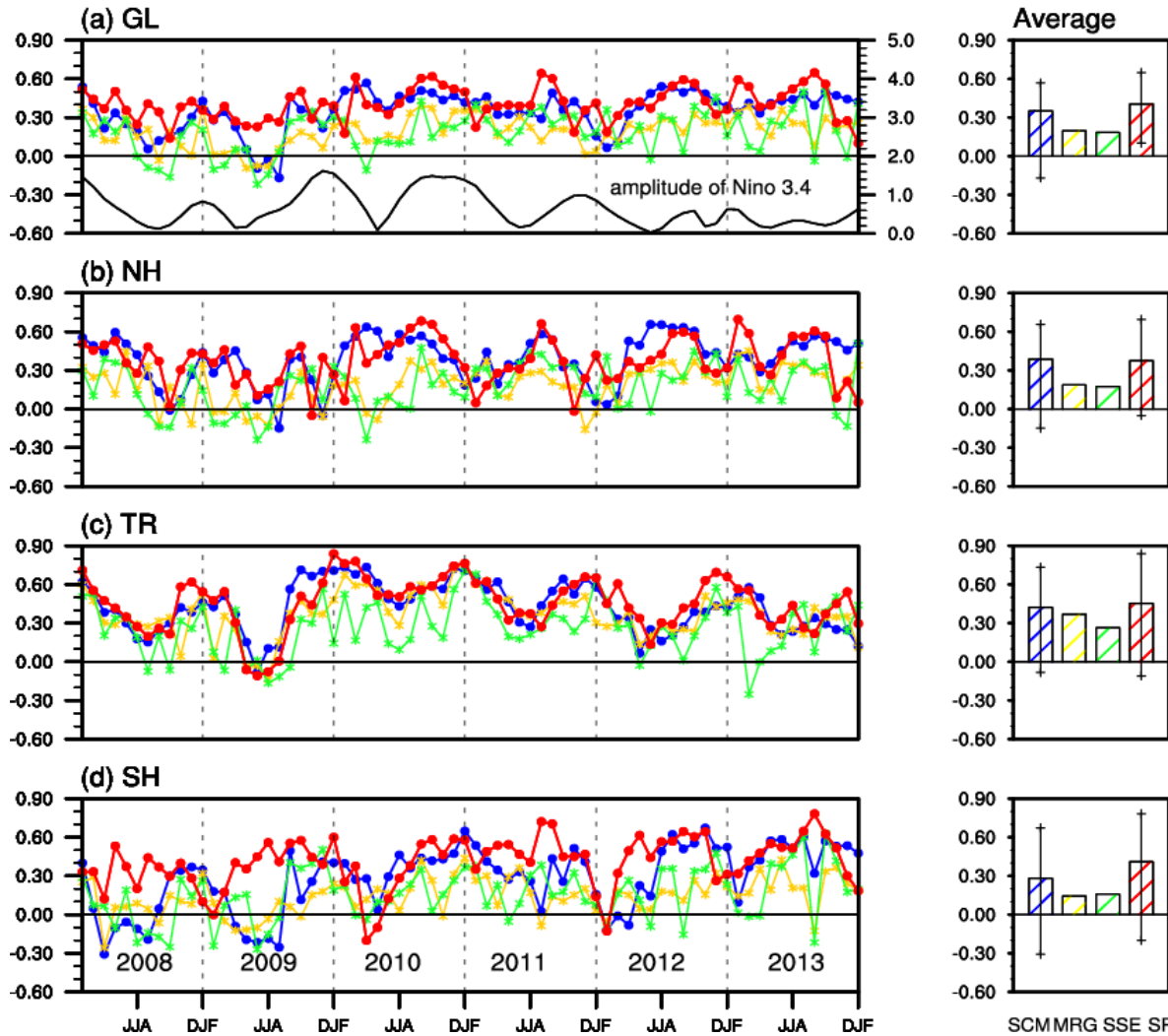
SPM



- ✓ The performance of multi-model predictions by two weighted MME methods (MRG, SSE) are consistently lower than that by simple and calibrated MME methods (SCM, SPM).
- ✓ The averaged TCCs over the globe of SCM and SPM for both variables are comparable.

# Skill Comparisons: DMMEs (RT-Forecast)

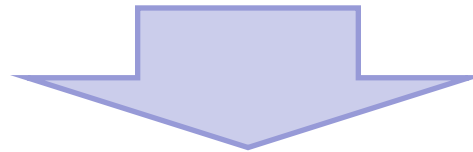
## Anomaly Pattern Correlation



Min et al. (2014)  
JGR

# Skill Comparisons: Results

- (i) SCM and SPM methods generally outperform the empirically weighted MME methods (MRG and SSE) in both hindcast and real-time forecast.
- (ii) SPM has positive effect in reducing errors and improving the multi-model prediction in some regions and seasons.

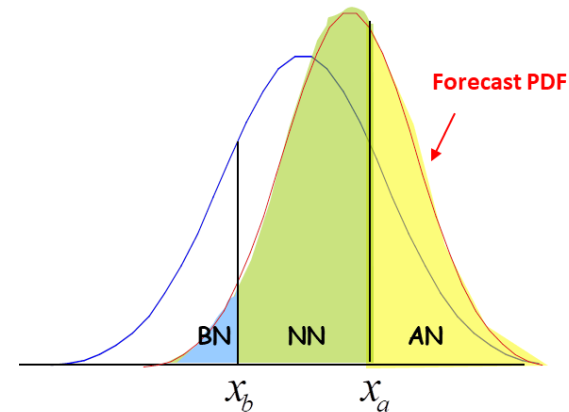
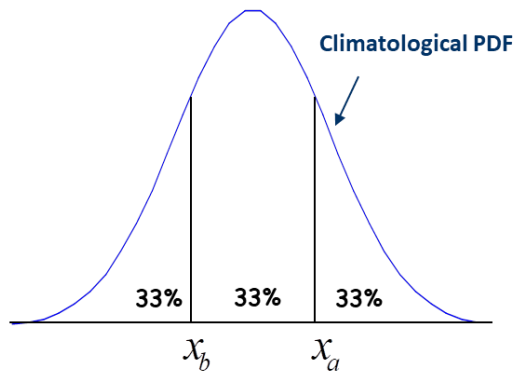


*“Considering many issues from an operational point of view”*

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

# APCC MME Method: Probabilistic

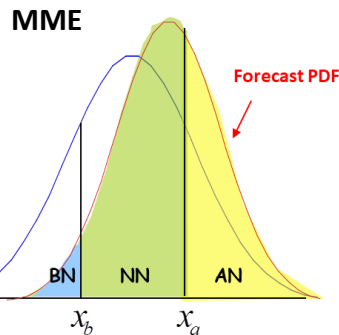
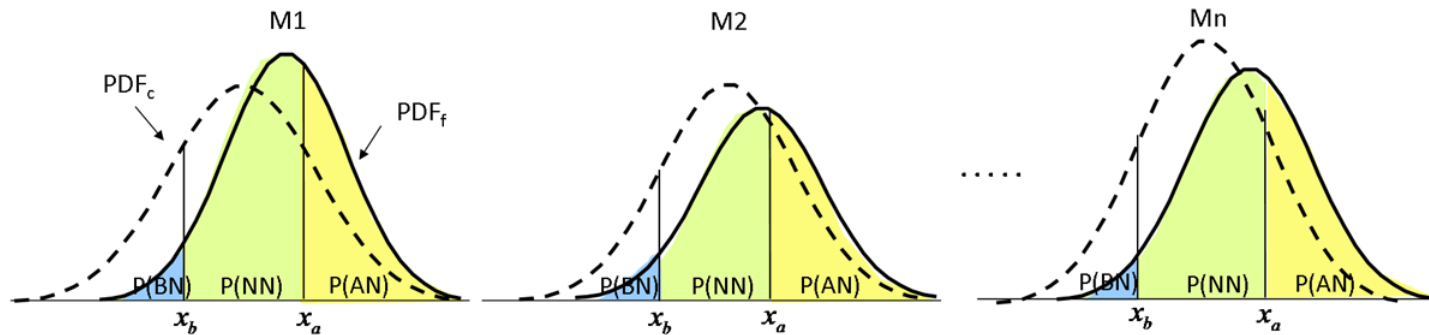
- **Probabilistic MME Method (PMME): Tercile-based categorical forecast**
  - Three-categorical forecast probability is estimated based on a **parametric Gaussian fitting** method for each model and then combined with model weights being **proportional to the square root of ensemble size** (Min et al.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

$$P(E) = \sum_{i=1}^M \underbrace{P(\text{Model}_i)}_{\text{Model Weight}} \times \underbrace{P(E / \text{Model}_i)}_{\text{Forecast Probability of an Event}}$$

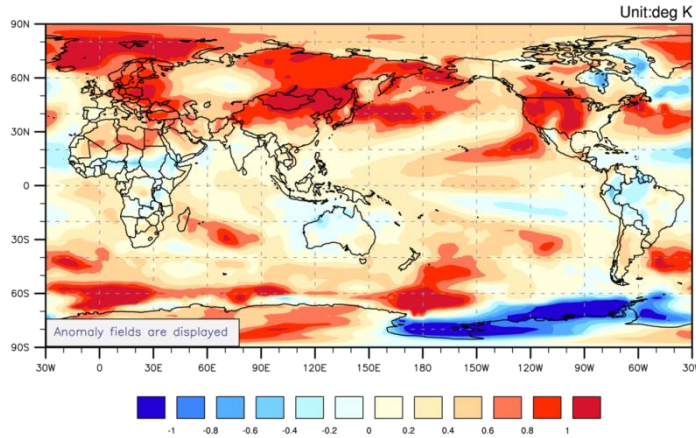
- The APCC operational PMME prediction system has also been implemented at **WMO Lead Center**, as a basic operational prediction tool.

# APCC Official MME Products: 2018JJA



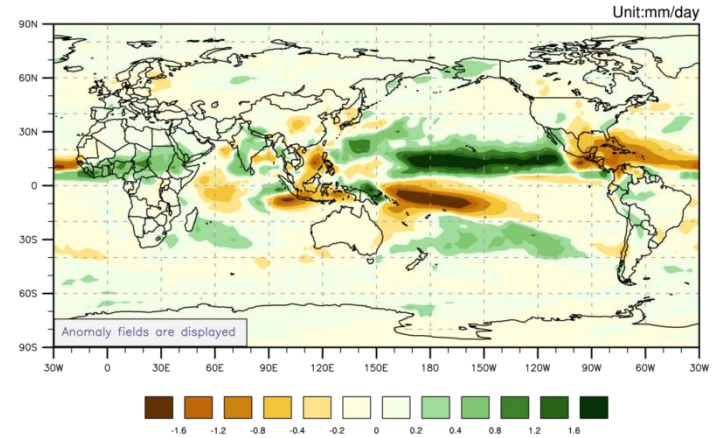
## DMME

Temperature at 2m for July-September 2018



© APEC Climate Center

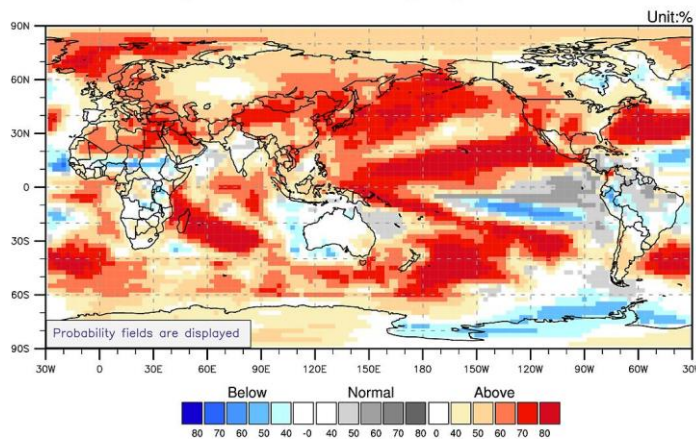
Precipitation for July-September 2018



© APEC Climate Center

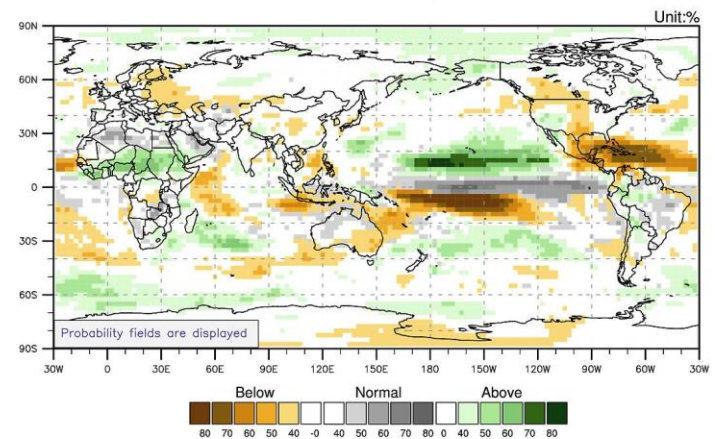
## PMME

Temperature at 2m for July-September 2018



© APEC Climate Center

Precipitation for July-September 2018



© APEC Climate Center

# 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)

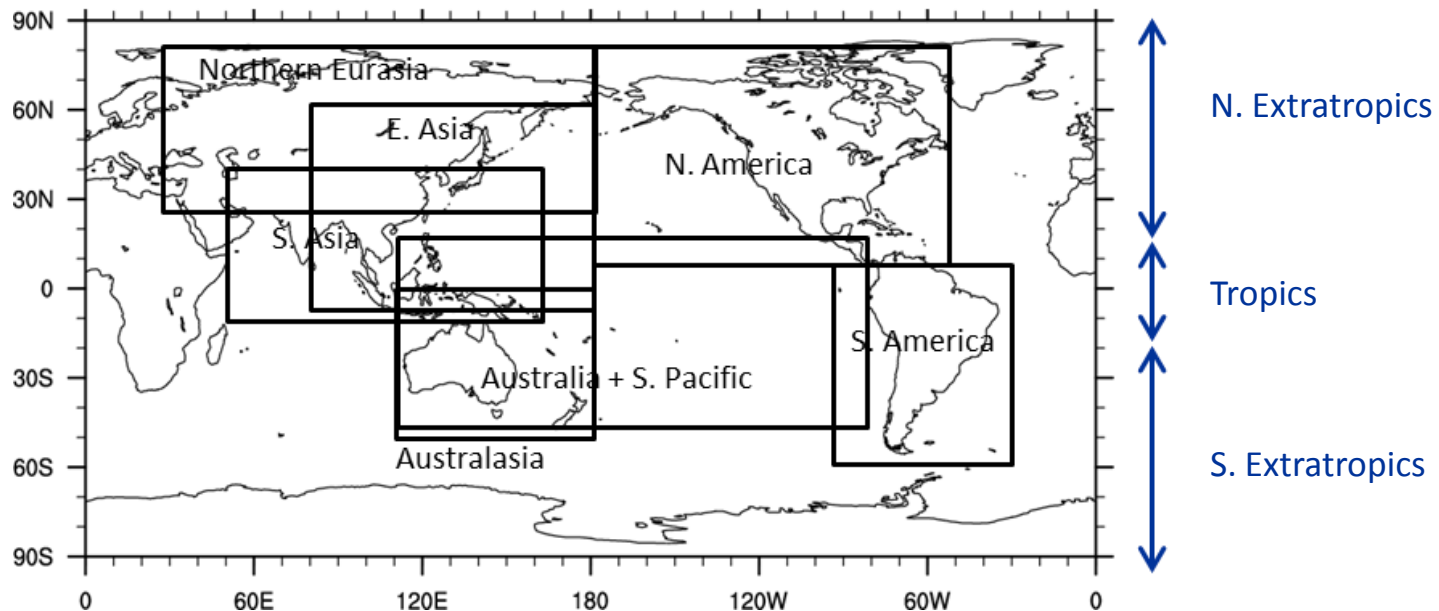
Parameters	Region	Deterministic forecast	Probabilistic forecast
<i>Diagrams and scores to be produced for regions</i>			
Basic variable (T850, T2m, PREC, Z500, SST)	GL, TR, NE, SE	MSSS	ROC curve
		ACC	ROC score
		RMSE	Reliability diagram
	EA, SA, NAm, SAm, AUS, AUS+SP, NEu, ME	ACC	HSS
		RMSE	RPSS
			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
<i>Grid-point data for mapping</i>			
Basic variable	Grid-point verification on a 2.5° x 2.5° grid	MSSS	ROC score
		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
  - NOAA OISST

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

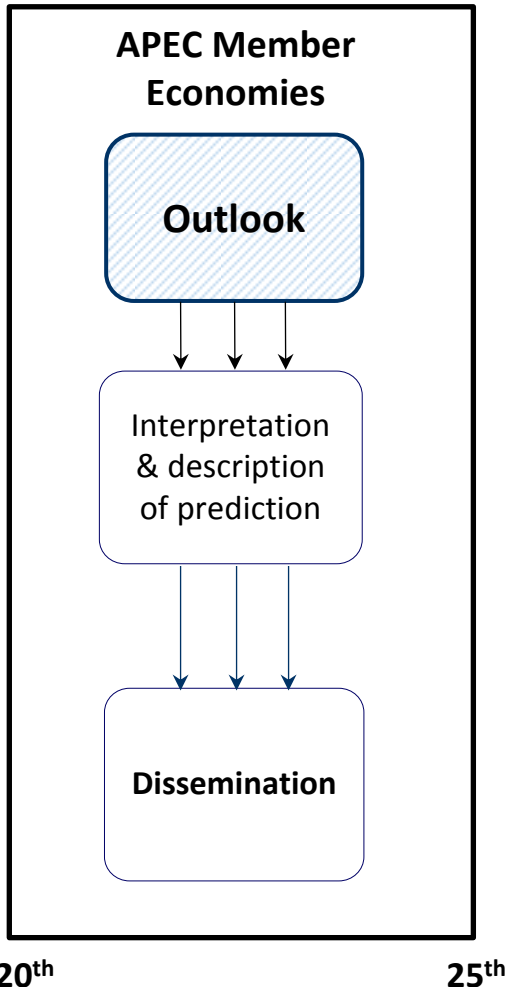
# Verification Information

- 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: (3) Dissemination

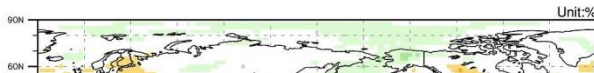


- Schedule: 20<sup>th</sup> ~ 25<sup>th</sup> every month
- **Outlook**
  - Interpretation and description of Global & PICs prediction
  - Release official outlook 5 days prior to the forecast period
- **All information can be available on the APCC web-site.** (<http://www.apcc21.org>)
- Anyone can access APCC monthly global MME 6-month forecast around 25<sup>th</sup> of every month.
- Climate monitoring and hindcast/forecast verification

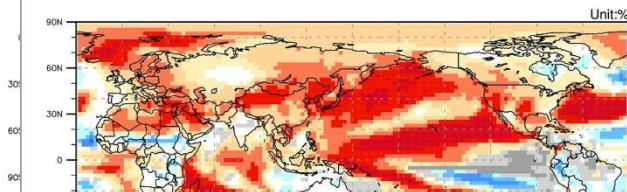
# APCC Official Seasonal Outlook: Globe



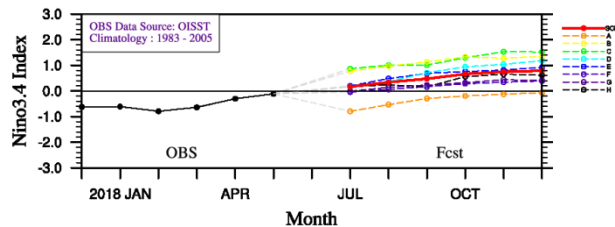
Precipitation for July-September 2018



Temperature at 2m for July-September 2018



Nino3.4 Index for 2018 JASOND



© APEC Climate Center

- ✓ Description of current climate conditions and interpretation of global and regional prediction
- ✓ Release official APCC outlook around 25<sup>th</sup> 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 ....

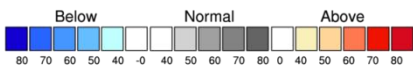
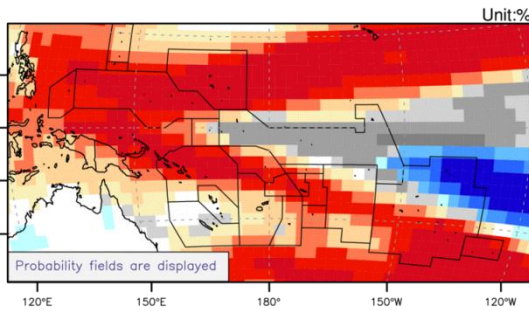
#### Temperature and Precipitation Outlook:

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. ...

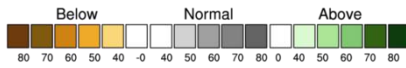
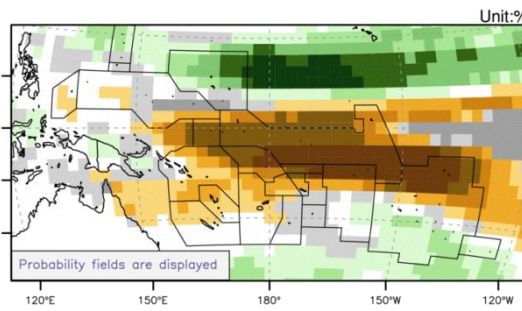
# Seasonal Outlook: Pacific Islands Counties (PICs)



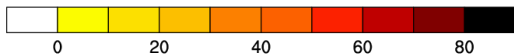
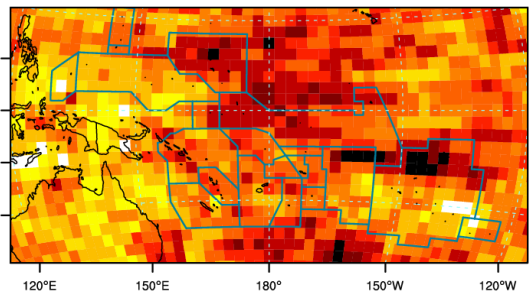
Temperature at 2m for June-August 2018



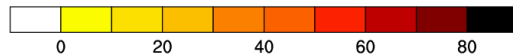
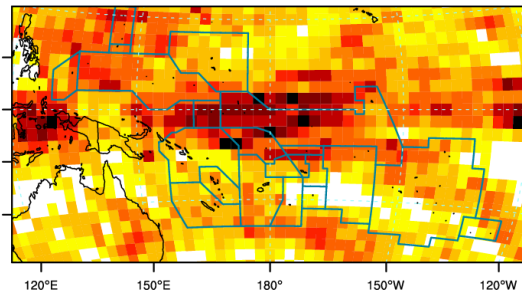
Precipitation for June-August 2018



Heidke Skill Score : T2M, JJA (1983-2005)



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



**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

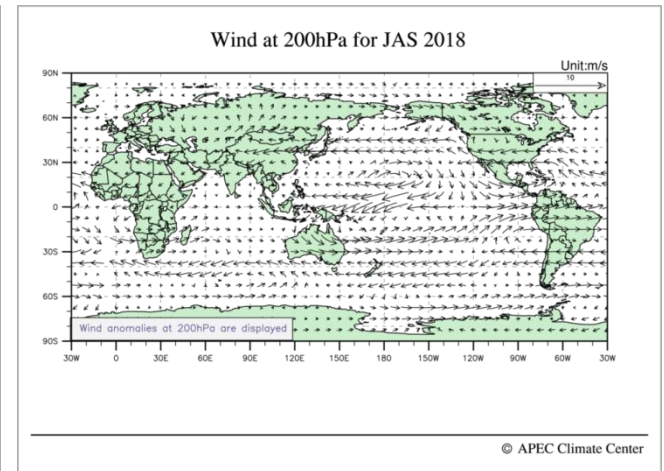
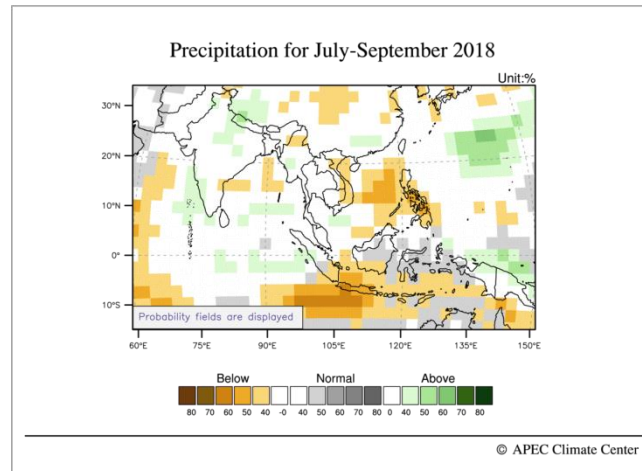
Information Service System

## 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

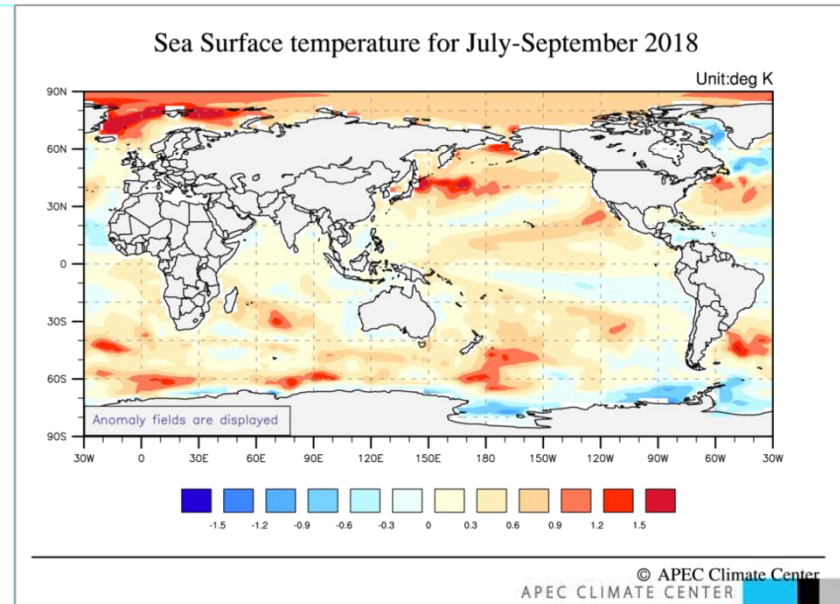
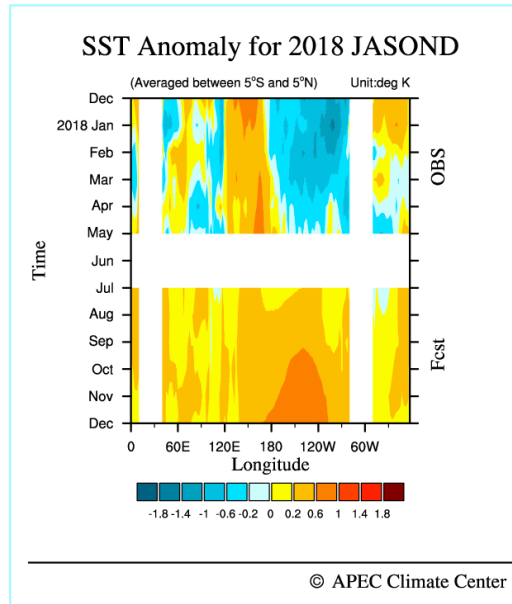


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### ✓ ENSO

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

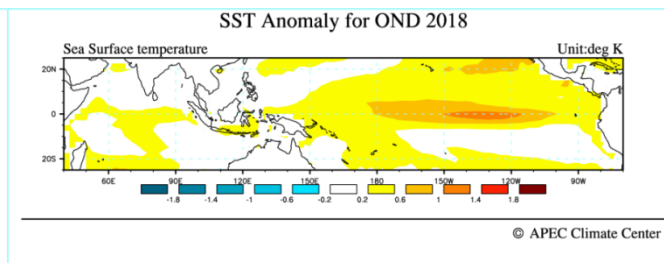
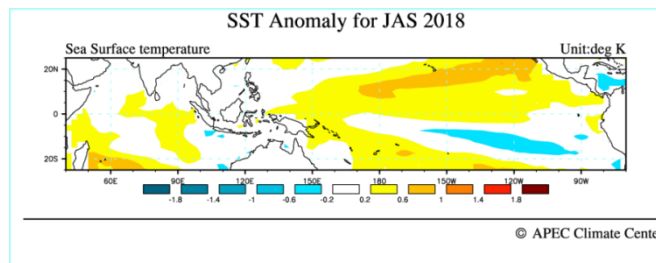
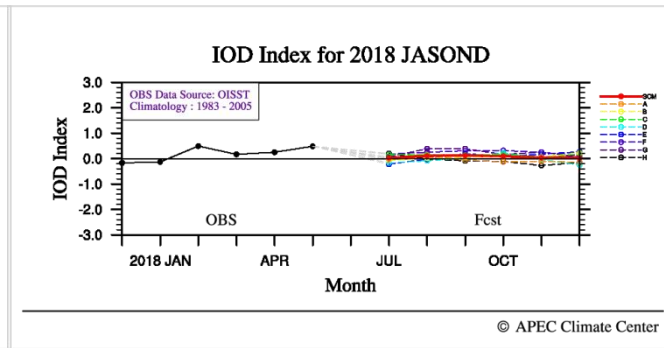
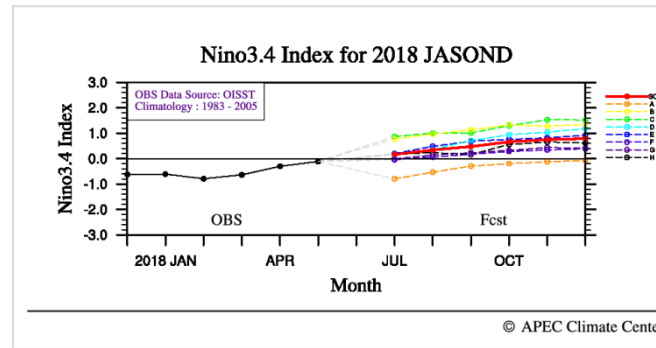


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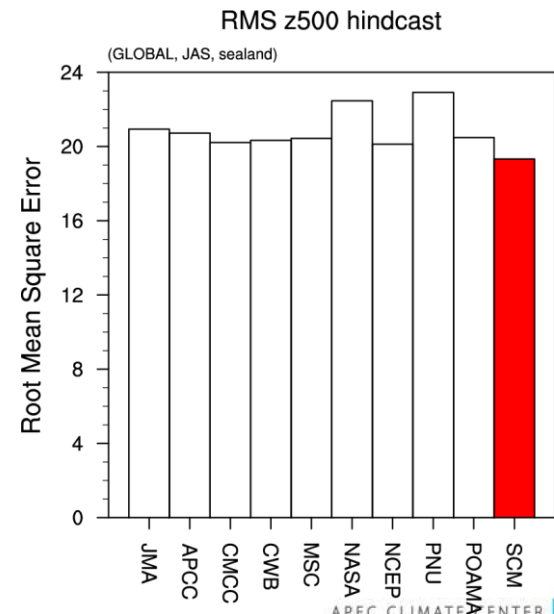
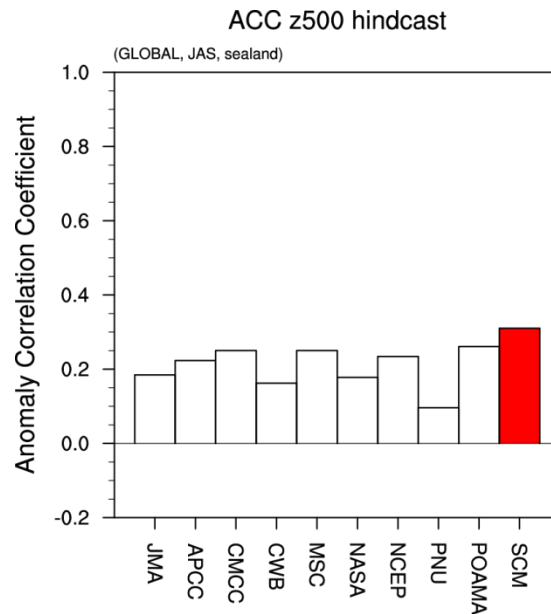


## Climate Information Service

-	Seasonal Forecast
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▸	ENSO
▸	Verification
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## ✓ Verification

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

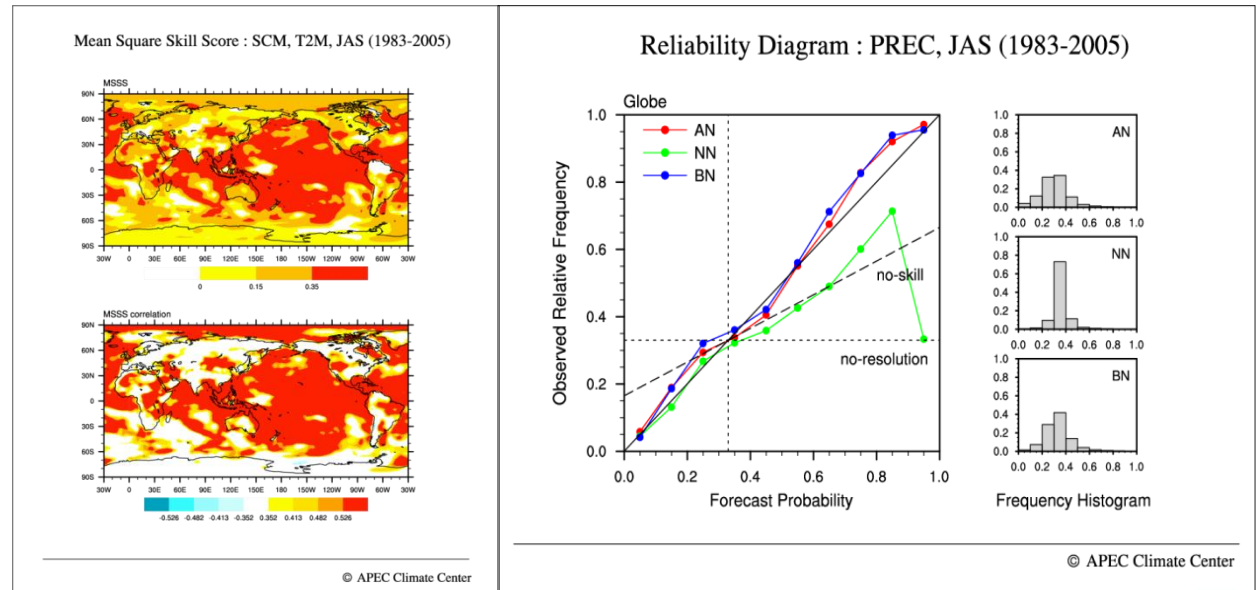


## Climate Information Service

- Seasonal Forecast
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# Recent Improvement and future plans

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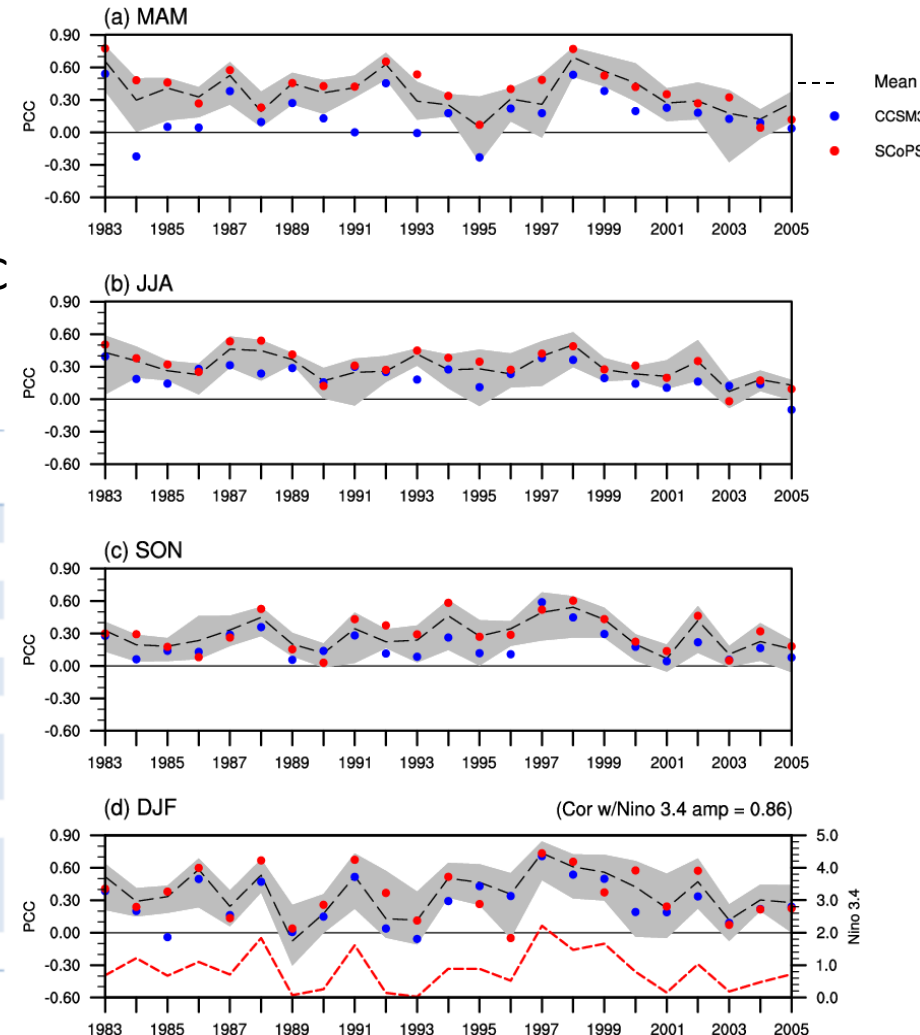
# Recent Improvements

## ○ 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	

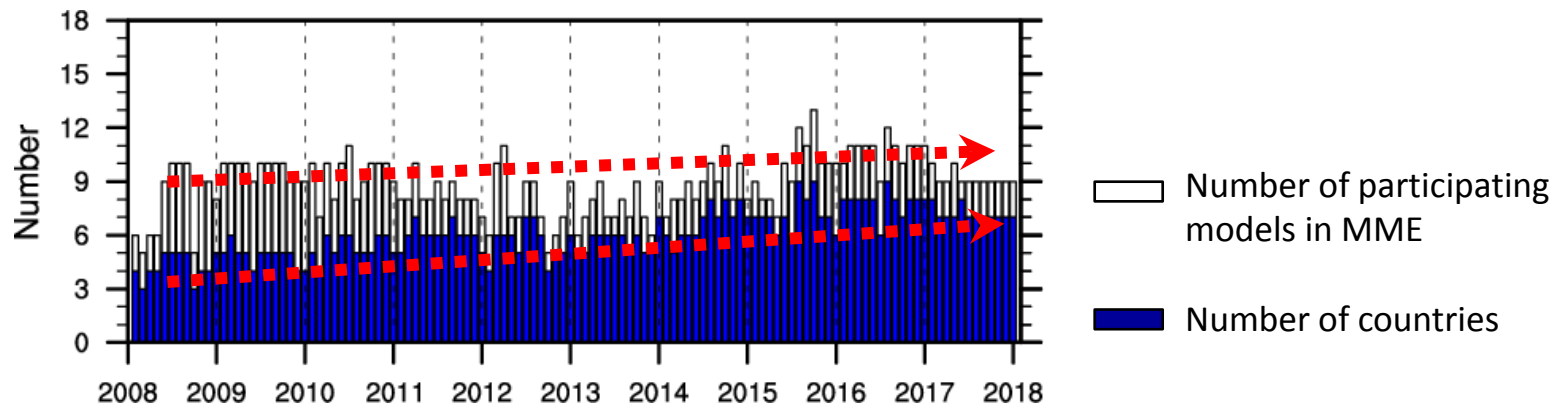
## Interannual Variation: GL, PREC



# Recent Improvements

## ○ Diversification of participating models

- APCC have made an effort to encourage the model 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

- BCC: improved BCC v2.0 to 1-tier prediction system from 2-tier for 2016
- CWB: improved their resolution from T42 → T119 for 2018
- **BOM**: will be replaced the prediction system from POAMA (250km) to ACCESS-S (60km)

### Topography

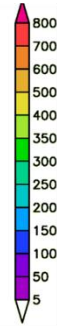
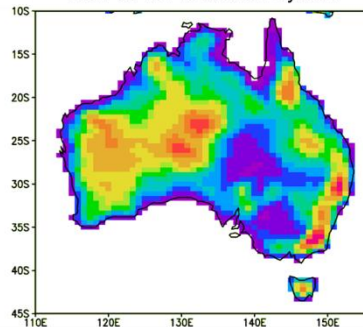
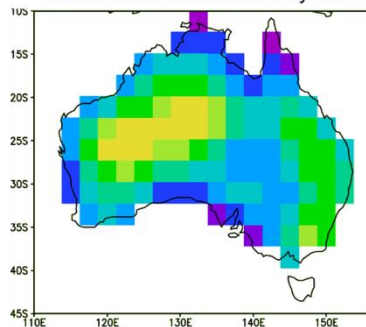
Grid resolution increase from 250 km to 60 km  
Able to resolve Dividing Range, Tasmania, coastal zone

#### POAMA-2

#### ACCESS-S

Current 250 km resolution system

New 60 km resolution system



### Mean Rainfall (mm/day) for August

Higher resolution greatly improves the depiction of mean rainfall

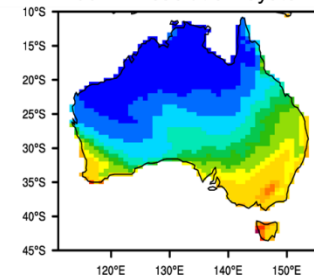
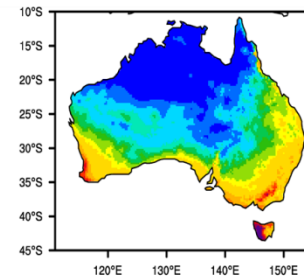
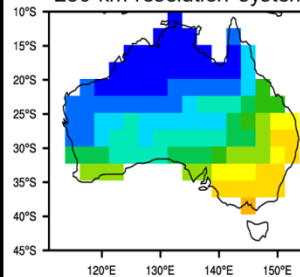
#### POAMA-2

#### Observations

#### ACCESS-S

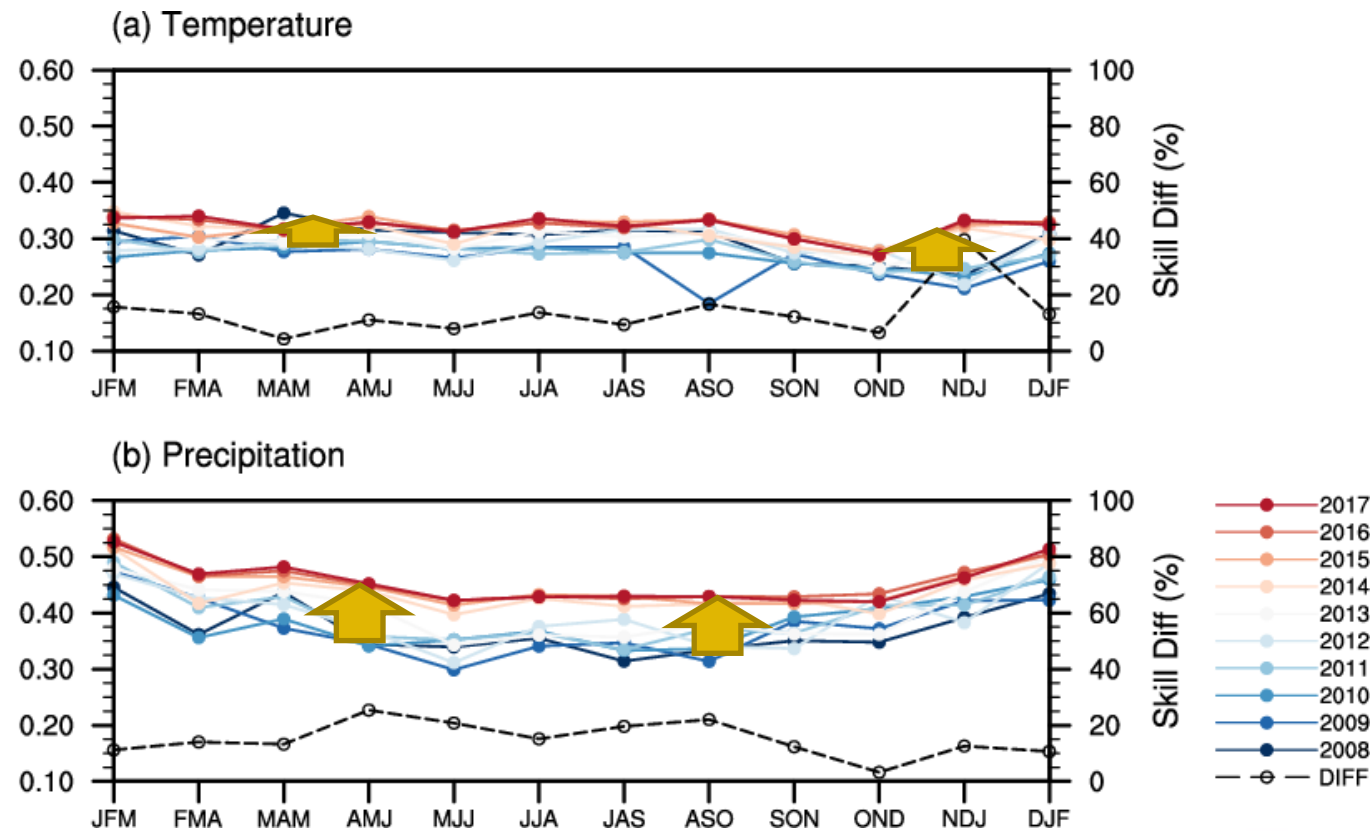
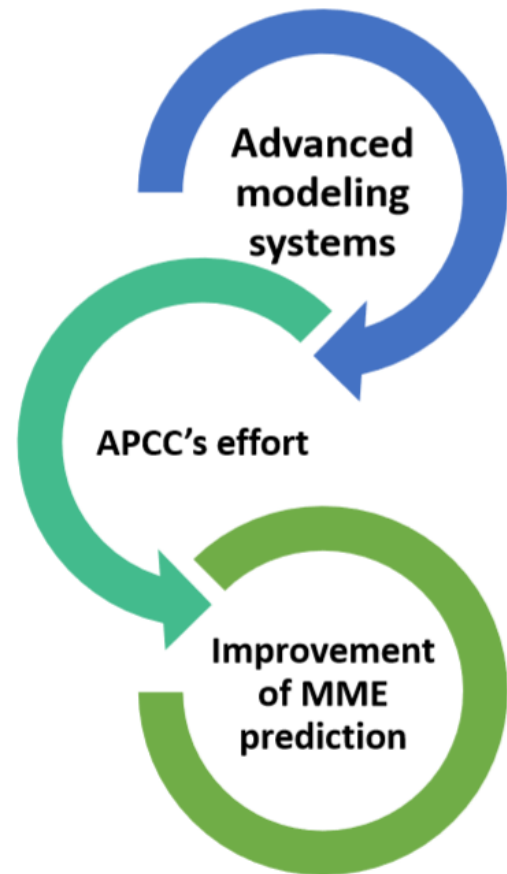
250 km resolution system

60 km resolution system



# Improvement of the APCC MME Prediction

## Hindcast Skill of APCC MME



# Future Plans



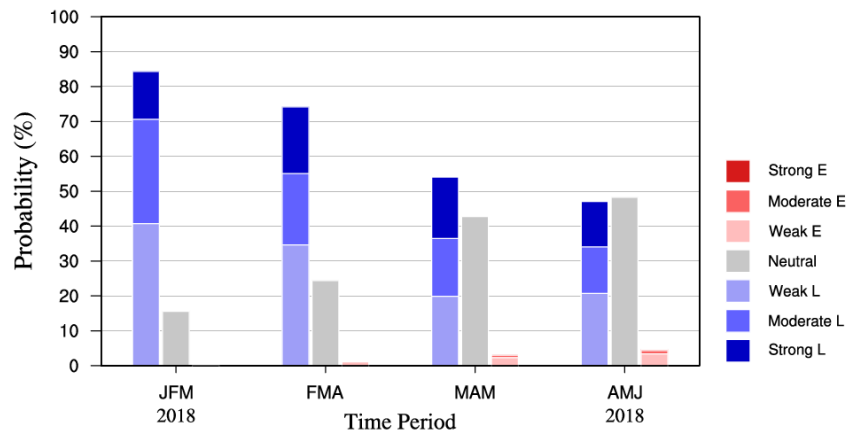
Spatial Resolution Test

Hindcast Period Sensitivity Test

Diverse Contents: ENSO intensity

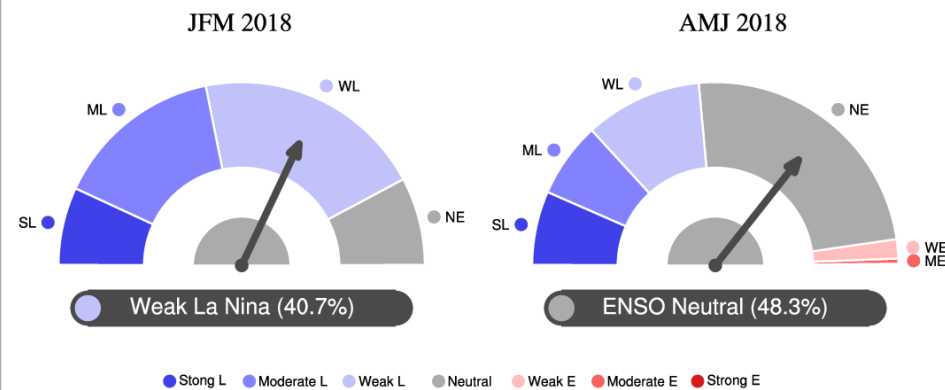
Improvement of In-House Model

Probabilistic ENSO Forecast for 2018 JFMAMJ



\* ENSO Intensity based on 3M Mean Nino3.4 SST Anomaly (Category Boundries: +/-1.5, 1.0, 0.5°C)

Probabilistic ENSO Forecast



\* ENSO Intensity based on 3M Mean Nino3.4 SST Anomaly (Category Boundries: +/-1.5, 1.0, 0.5°C)

# 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-month 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 25<sup>th</sup> of each month.



**THANK YOU**

**(<http://www.apcc21.org>)**