

Evaluation of the forecast skill of multi-model ensembles

TAKAHASHI Kiyotoshi

Tokyo Climate Center/Japan Meteorological Agency

Background of this investigation

WMO RA II Operating Plan

5. To evaluate the forecast skill of objective seasonal forecasts, based on multi-model ensembles from dynamical climate models at sub-regional scale and users' need for the forecasts and capability of NHMSs and/or RCFs to operationalize it (2021-2023)
6. Adoption of objective seasonal predictions into RCOF processes on a trial basis (2024)

Some JMA members of RAII WG-S ET-CS have been replaced in April 2023.

ET and Leader	IP/DP/PP in RA II OP	Core member	Associate member
Expert Team on Climate Services (ET-CS) Leader: KYODA Masayuki (Vice Chair of WG-S) → SATO Hirotaka	RA II-17-S-IP-7: Promote Climate Services implementation	ZHANG Peiqun (RCC-Beijing) WAKAMATSU Shunya (RCC-Tokyo) → TAKAHASHI Kiyotoshi (RCC-Tokyo) O.P. Sreejith (RCC-Pune) Iman Babaian (IRIMO) Mr Du Duc Tien (VNMHA)	Yashar Falamarzi (IRIMO) Mr S. M. Quamrul Hassan (BMD) Ms Maryam Al. Khulaifi (QMD) YAMAMOTO Kosuke (JMA) → HORITA Ryosuke (JMA) YAMADA Ken (JMA) Hangameh Shiavand (IRIMO) Rajib Chattopadhyay (IMD)

Historical background leading to Objective Seasonal Forecast in RAI Operating Plan

SASCOF-8 introduced Objective Seasonal Forecasting into consensus outlook in 2016

WMO International Workshop on Global Review of RCOFs in September 2017

recommended that RCCs “access digital forecast and hindcast data from the WMO LC-LRFMME and produce an objectively consolidated forecast product combining information of various GPCs-LRF to be used as a first estimate for RCOF discussions”

Decision 9 (EC-72) in October 2020

OPERATIONALIZATION OF OBJECTIVE SEASONAL FORECASTS AND TAILORED PRODUCTS ON SUB-REGIONAL SCALES

Guidance on Operational Practices for Objective Seasonal Forecasting issued in 2020

RA II OPERATING PLAN (RA II-17-S-IP-7) RELATED ACTIVITIES AND TIMELINE (2021-4)

5. Evaluation for operationalization (2021-2023)
6. Adoption of objective seasonal predictions into RCOF processes on a trial basis (2024)

Activity in one year to date

(Mr. Wakamatsu's work)

- Purpose: Evaluation of forecast skill based on MME over RAI
- Used data

C3S (Copernicus Climate Change Service) hindcast:

- Initial month: May for summer season (JJA) 2-month lead
- monthly mean 2mT, total Precipitation (1993-2016)
- Used 8 models
CMCC 35 (SPSv3.5) , DWD 21 (GCFS2.1), ECC3 3 (GEM5-NEMO), ECMWF 5 (SEAS5) ,
JMA 3 (CPS3), Météo France 8 (System 8), NCEP 2 (CFSv2), UK Met 600 (GloSea6)

Observation:

- CRU TS v4.03 1x1 gridded surface Temp and precipitation

LC-LRFMME data weren't used due to data availability, but currently the problem was resolved.

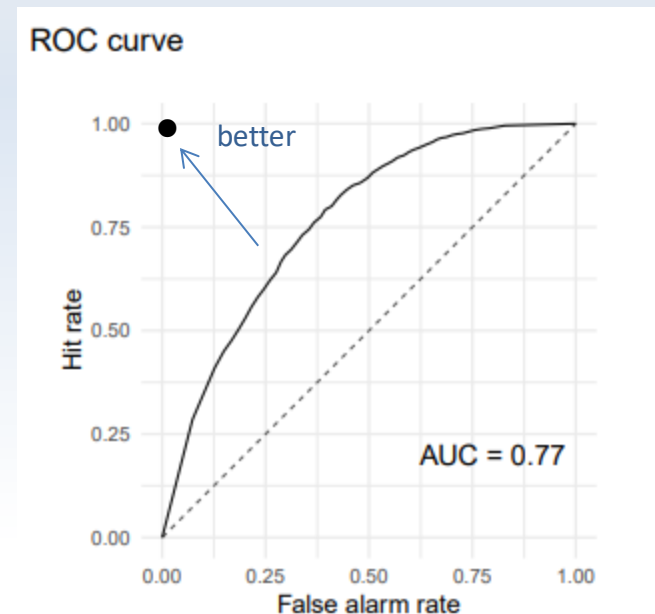
- Climate Prediction Tool (CPT) is used to carry out evaluation. Performance of model products is evaluated with two metrics,
 - Pearson correlation coefficient
 - ROC area (three tercile)

Two metrics for evaluation

- Pearson correlation coefficient
 - linear correlation between two sets of data
 - assess deterministic skill
- Area Under the ROC Curve (AUC)

The Area Under the ROC Curve (AUC) is a positively oriented measure of predictive ability.

- Assess probabilistic skill
- $AUC = 1/2$ for a useless predictor
- $AUC = 1$ for a perfect predictor



Flow of work



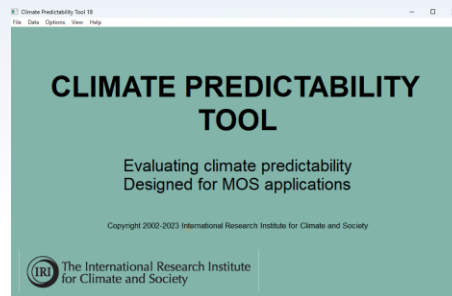
Observation (netCDF)
Hindcast (Grib1)



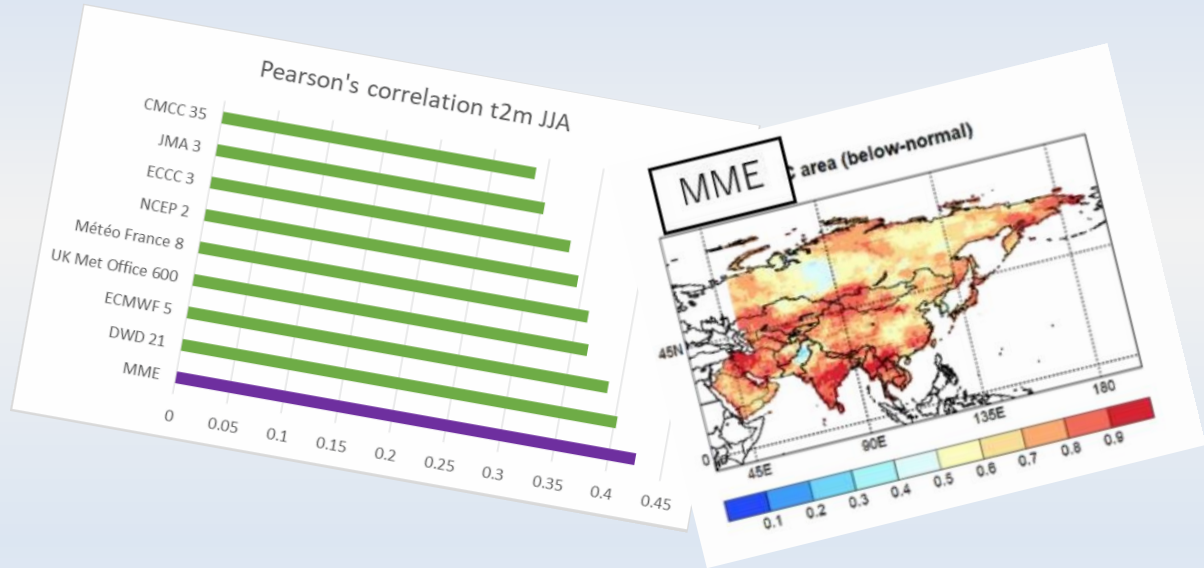
Convert to CPT format
Division into 7 parts



Evaluation by CPT



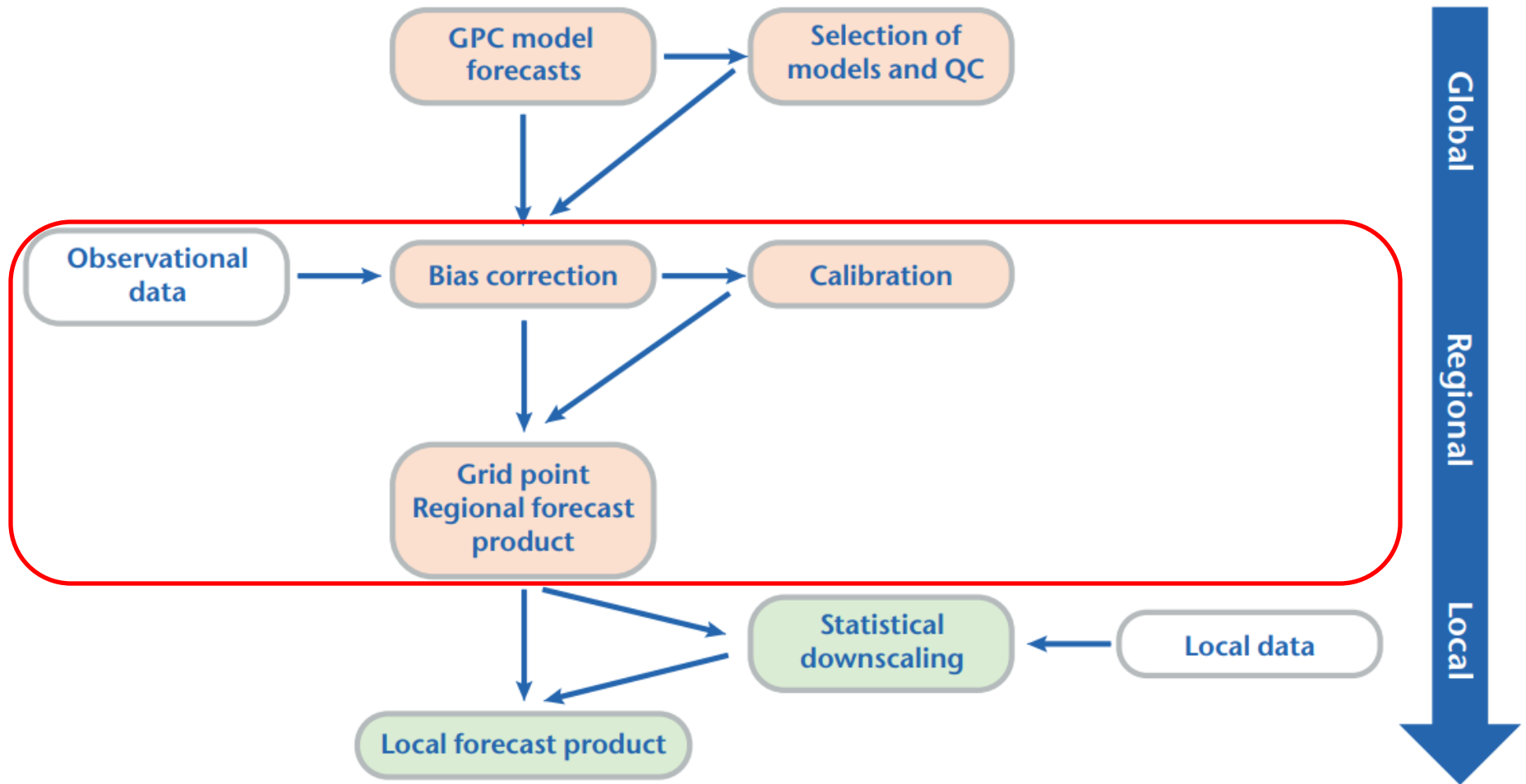
Reconstruction of data
Spatial average



Outline of CPT

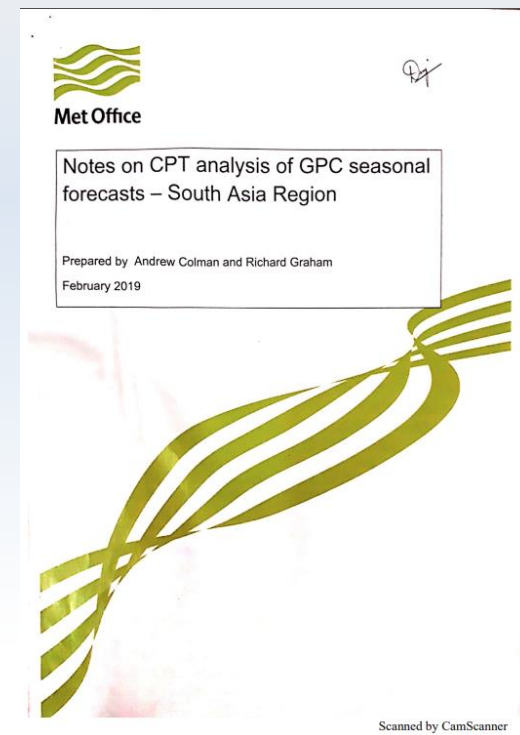
- The Climate Predictability Tool (CPT) is a software package developed by the International Research Institute for Climate and Society (IRI) for
 - constructing a seasonal climate (statistical) forecast model,
 - performing model validation,
 - producing forecasts given updated data.
- Its design has been tailored for
 - producing seasonal climate forecasts using model output statistic (MOS) corrections to climate predictions from general circulation model (GCM),
 - producing forecasts using fields of sea-surface temperatures or similar predictors.
- CPT can be used in more general settings to perform
 - canonical correlation analysis (CCA),
 - principal components regression (PCR),
 - multiple linear regression (MLR)on any data, and for any application.

Role of CPT



OSF in SASCOF (based on information by Dr.Sreejith)

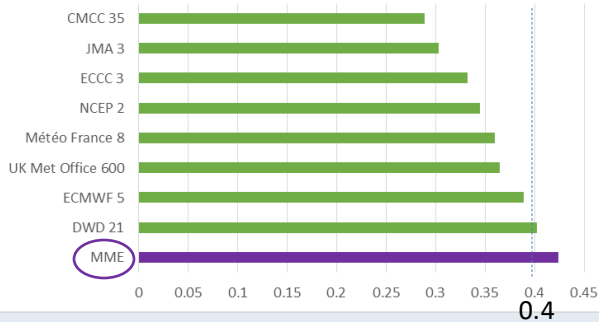
- 2010: SASCOF started with providing rainfall forecast.
- 2016: started using climate model output and generate the initial map (simple MME) and then subjectively correct it using CPT and other methods.
- 2021: improved the method further based on the objective seasonal forecast guideline.
- Recent years initial forecast generated by weighted MME is match well with calibrated CPT result using local observation data.



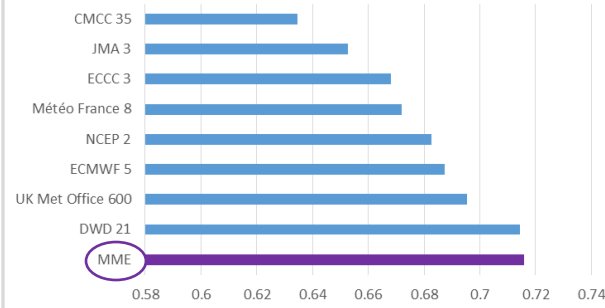
Results (Pearson's correlation) over the entire RAI1

2m temperature for JJA

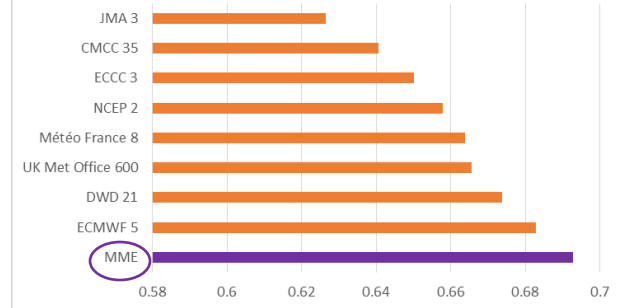
Pearson's correlation t2m for JJA



ROC area (below-normal) t2m for JJA

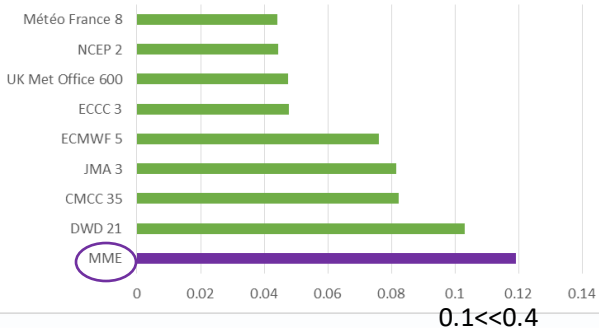


ROC area (above-normal) t2m for JJA

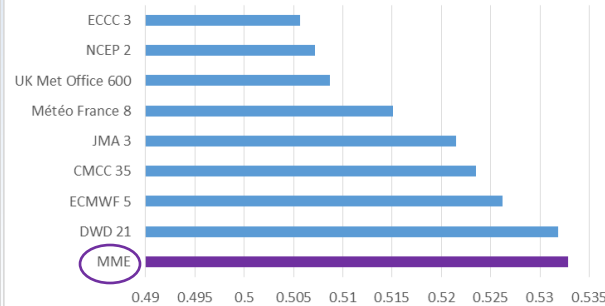


precipitation for JJA

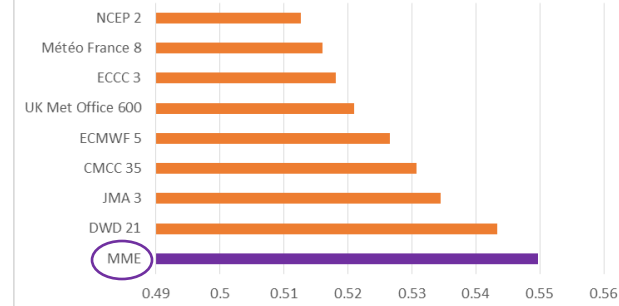
Pearson's correlation prec for JJA



ROC area (below-normal) prec for JJA



ROC area (above-normal) prec for JJA

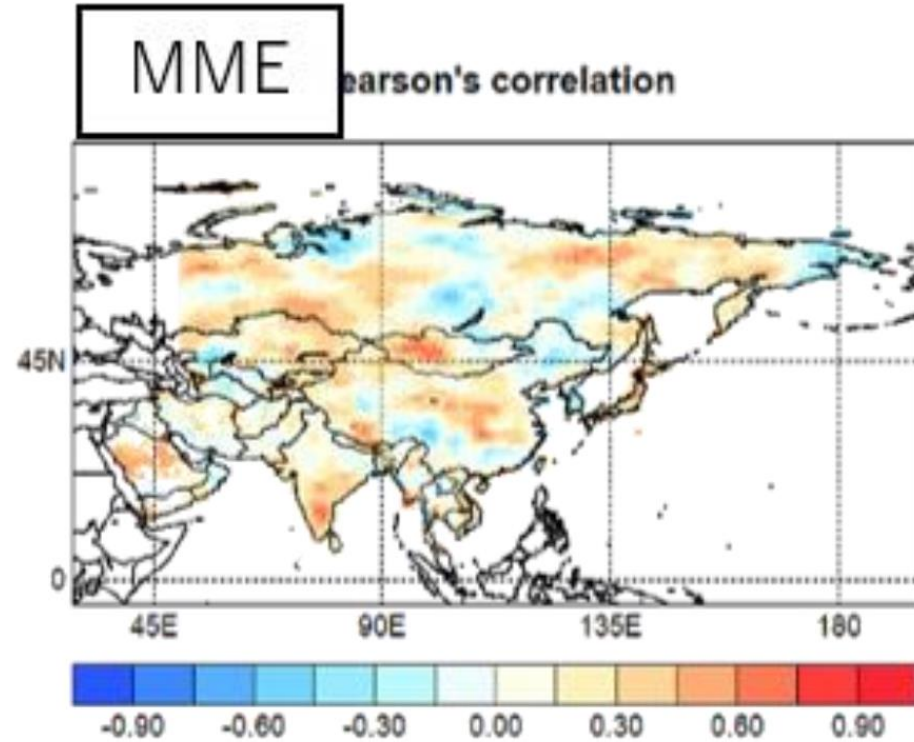
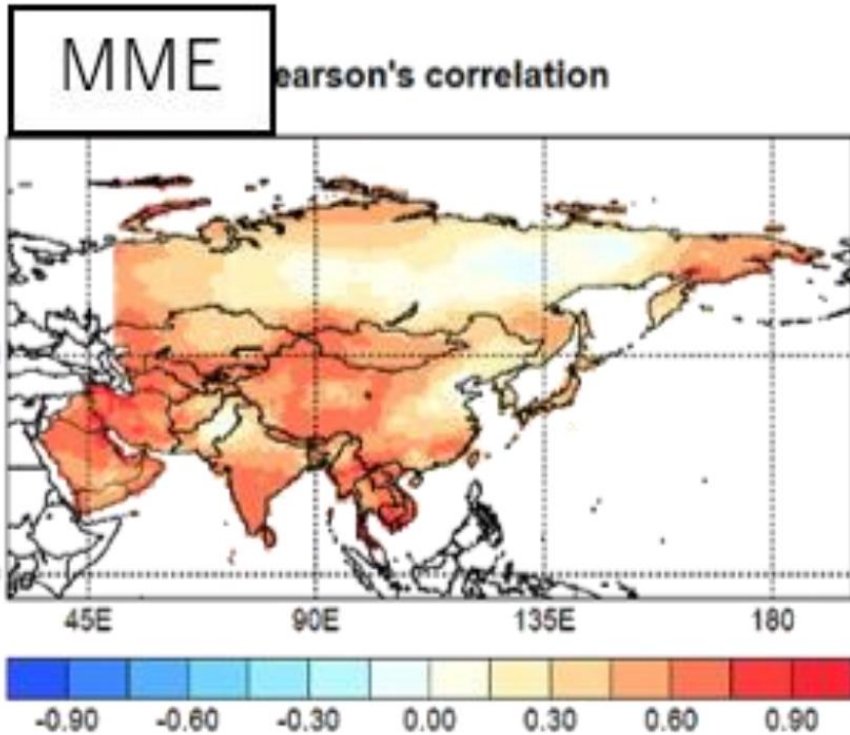


MME shows better performance than any single model

Map of Pearson's correlation

2m temperature

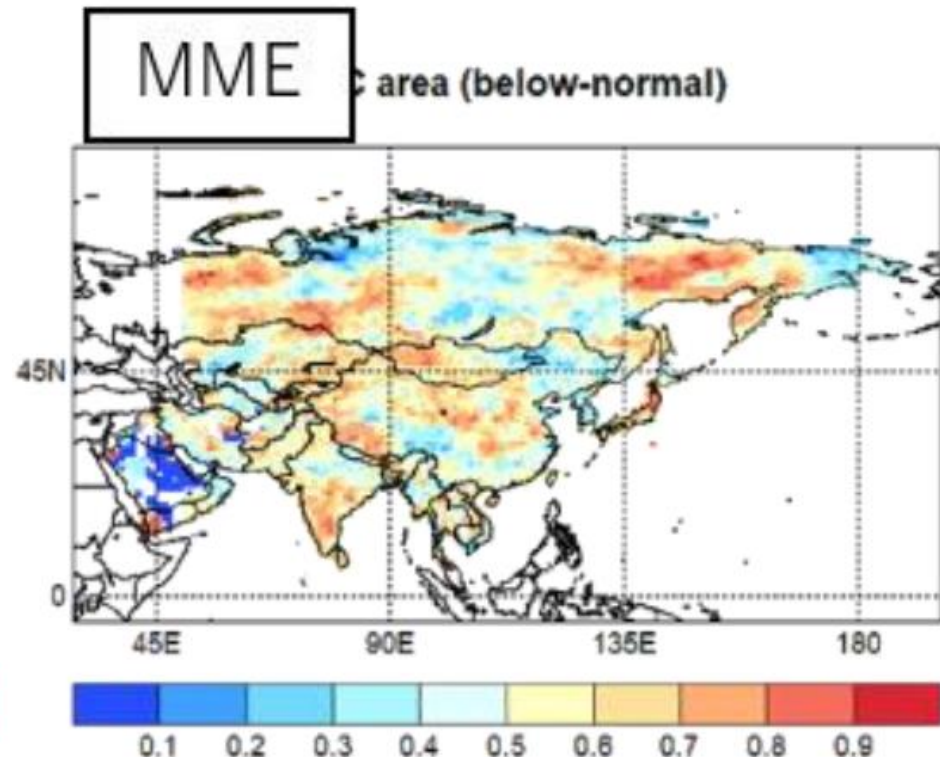
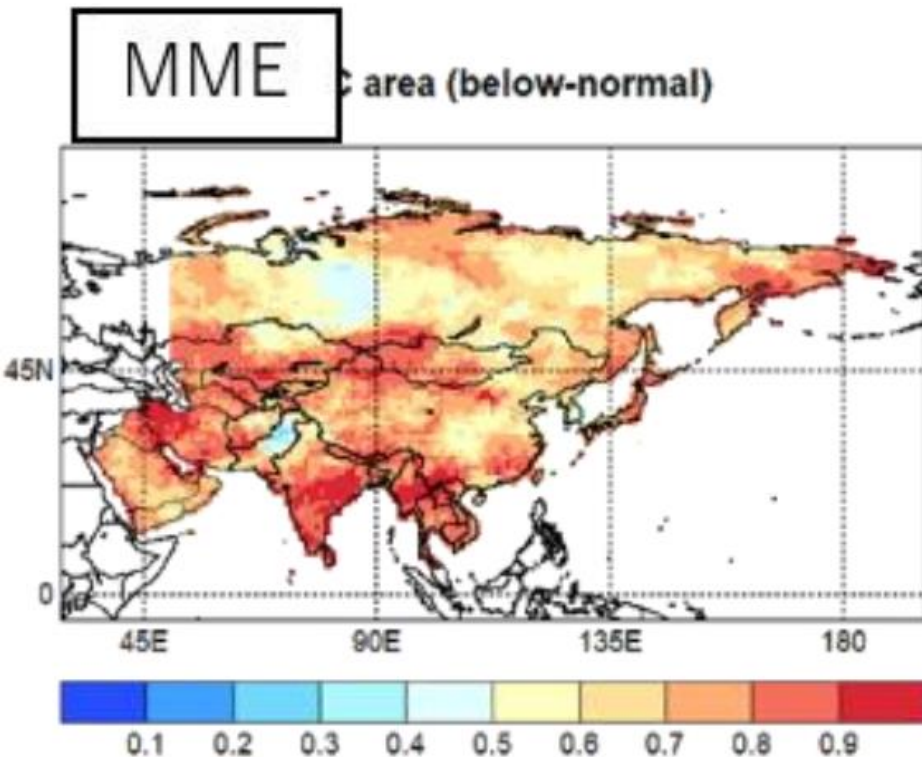
Precipitation



Map of ROC Area(below-normal)

2m temperature

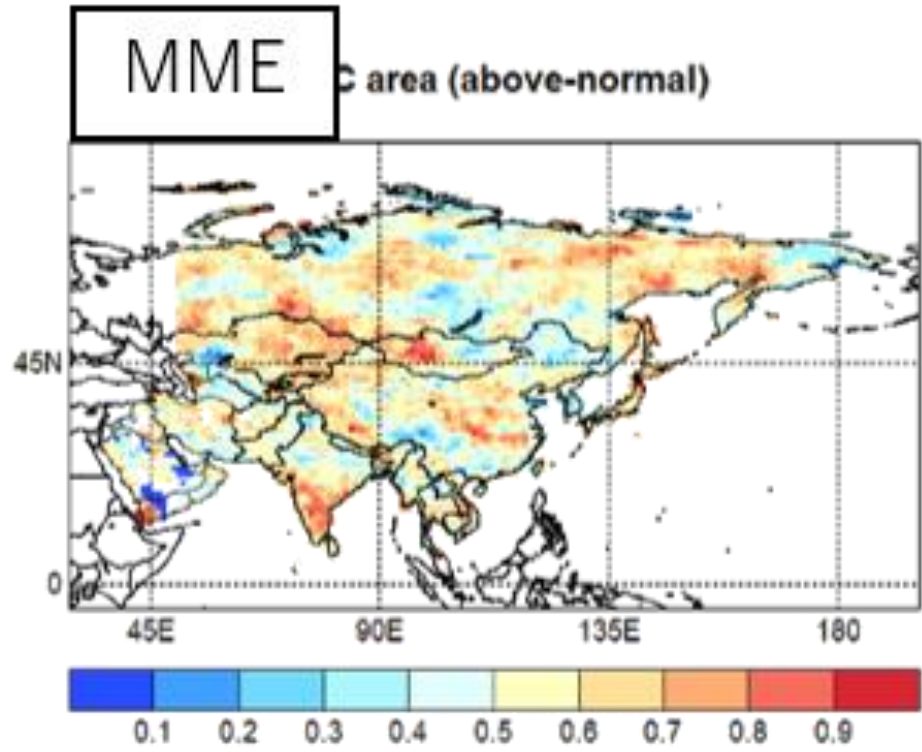
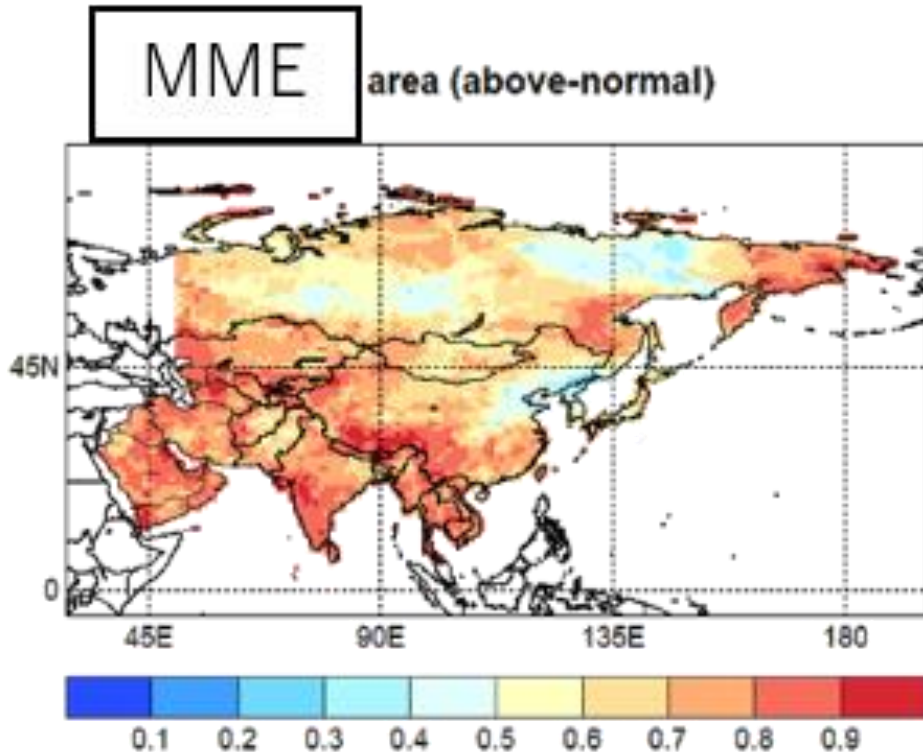
Precipitation





























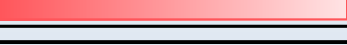
Map of ROC Area(above-normal)

2m temperature




























Precipitation



Results of 2m Temperature

2m Temperature	SASCOF		
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)
CMCC 35	 0.48	 0.76	 0.77
DWD 21	 0.43	 0.75	 0.73
ECCC 3	 0.43	 0.71	 0.73
ECMWF 5	 0.47	 0.75	 0.77
JMA 3	 0.42	 0.72	 0.72
Météo France 8	 0.43	 0.75	 0.72
NCEP 2	 0.34	 0.69	 0.67
UK Met Office 600	 0.45	 0.77	 0.74
MME	 0.51	 0.78	 0.78

SASCOF

2m Temperature	EASCOF		
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)
CMCC 35	 0.31	 0.68	 0.64
DWD 21	 0.43	 0.72	 0.66
ECCC 3	 0.39	 0.69	 0.65
ECMWF 5	 0.47	 0.74	 0.68
JMA 3	 0.40	 0.69	 0.65
Météo France 8	 0.45	 0.72	 0.66
NCEP 2	 0.37	 0.68	 0.66
UK Met Office 600	 0.44	 0.72	 0.67
MME	 0.49	 0.74	 0.69

EASCOF

Results of Precipitation

Precipitation	SASCOF					
		Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)		
CMCC 35		0.10		0.54		0.55
DWD 21		0.09		0.53		0.53
ECCC 3		0.09		0.53		0.56
ECMWF 5		0.15		0.56		0.56
JMA 3		0.10		0.54		0.53
Météo France 8		0.06		0.54		0.53
NCEP 2		0.14		0.57		0.56
UK Met Office 600		0.13		0.54		0.54
MME		0.15		0.56		0.56

SASCOF

Precipitation	EASCOF					
		Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)		
CMCC 35		0.11		0.55		0.54
DWD 21		0.11		0.54		0.55
ECCC 3		0.03		0.50		0.50
ECMWF 5		0.05		0.54		0.52
JMA 3		0.07		0.53		0.52
Météo France 8		0.11		0.55		0.55
NCEP 2		0.02		0.50		0.51
UK Met Office 600		0.07		0.53		0.53
MME		0.13		0.55		0.55

EASCOF

Summary

As a result of preliminary evaluation of MME performance for June-July-August, followings are confirmed.

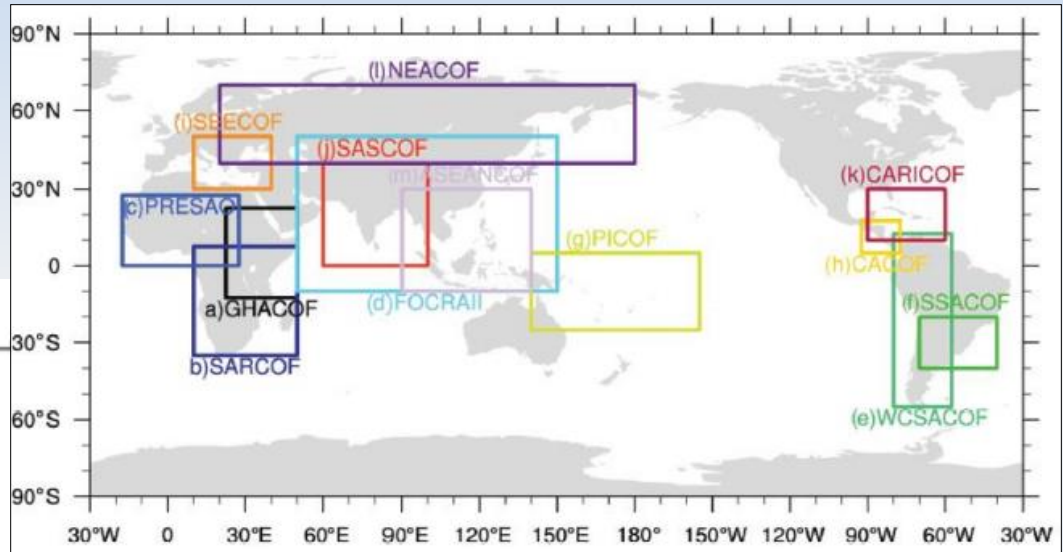
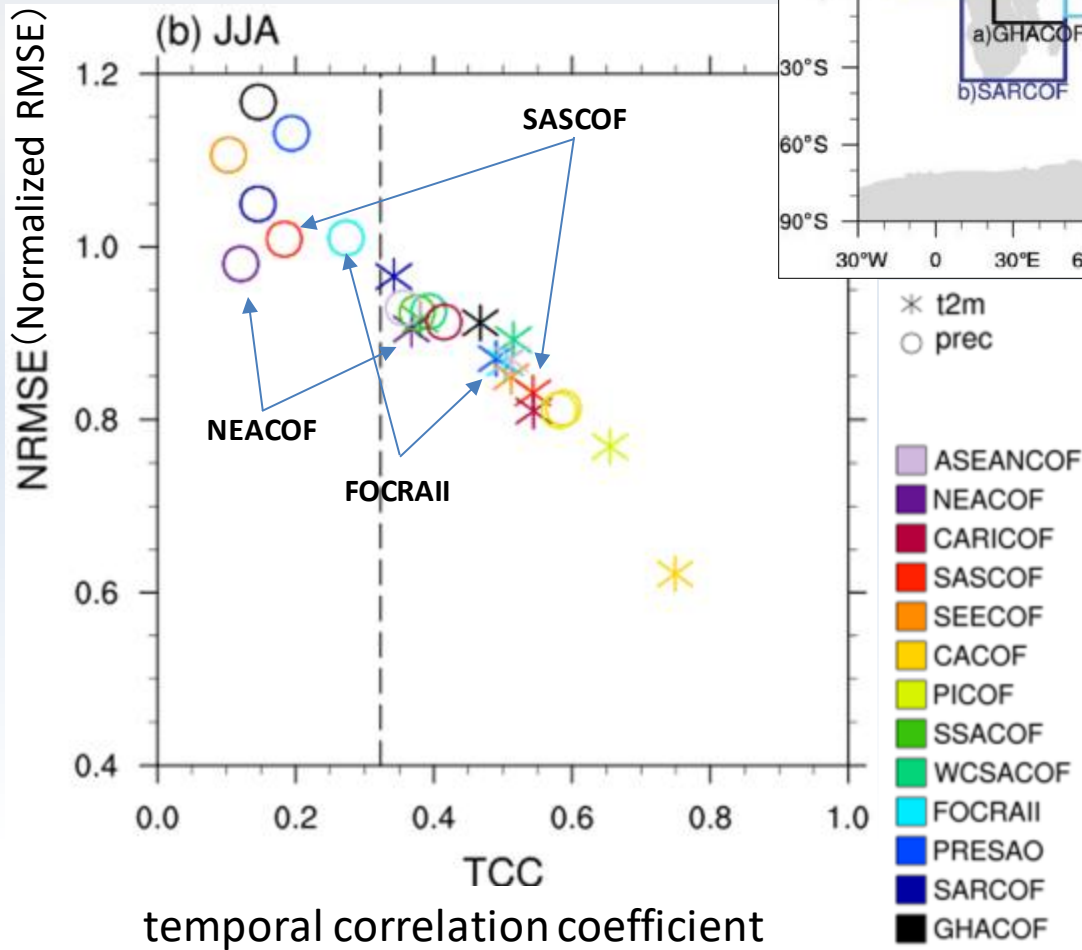
- Over the entire RAll, for surface temperature, MME showed good performance in predictability, while none of the models, including MME, had any skill for precipitation.
- In all cases, MME shows the best performance.
- Generally the prediction scores in the high-latitude are lower than in the low-latitude.

For further investigation, the followings are examined towards thorough evaluation of OSF performance.

- To extend this evaluation to winter season
- To further evaluate over each RCOF cover region

Supplement

Previous research (Kim et al., 2021)

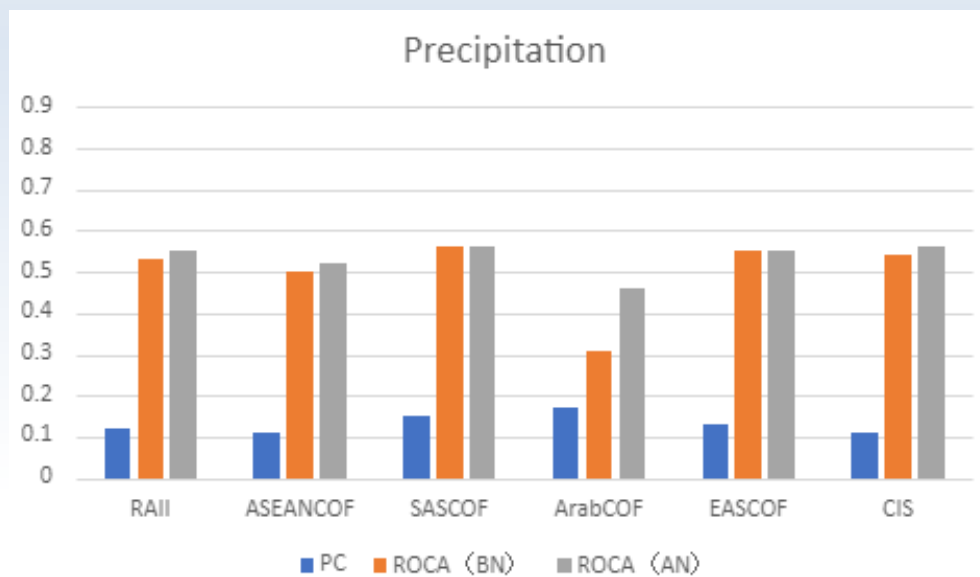
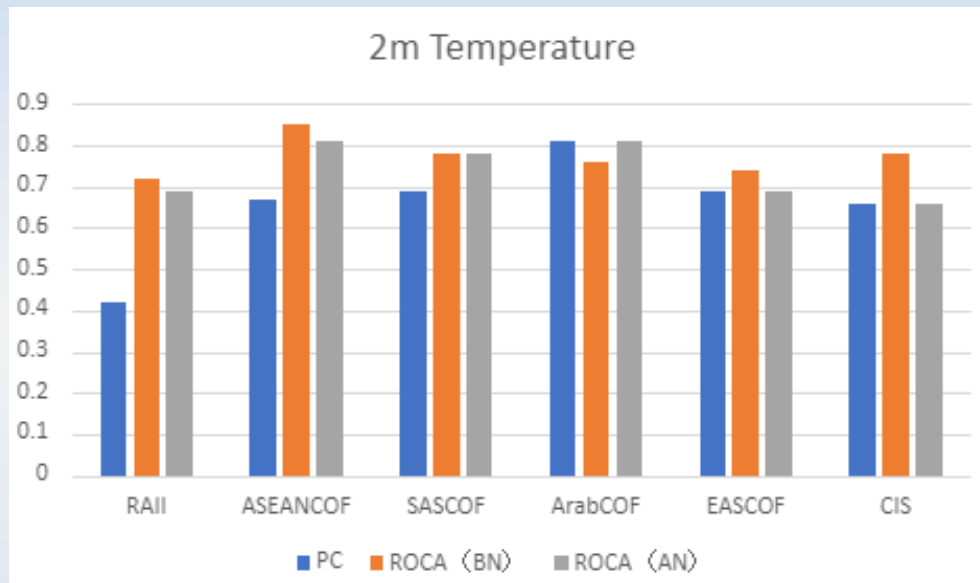


Kim, Gayoung & Ahn, Joong Bae & Kryjov, Vladimir & Lee, Woo-Seop & Kim, Dong-Joon & Kumar, Arun. (2020).

Assessment of MME methods for seasonal prediction using WMO LC-LRFMME hindcast dataset.

International Journal of Climatology

Results of among sub-regions with MME



Results for the entire RAI

2m Temperature	RAI		
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)
CMCC 35	0.29	0.63	0.64
DWD 21	0.40	0.71	0.67
ECCC 3	0.33	0.67	0.65
ECMWF 5	0.39	0.69	0.68
JMA 3	0.30	0.65	0.63
Météo France 8	0.36	0.67	0.66
NCEP 2	0.34	0.68	0.66
UK Met Office 600	0.36	0.70	0.67
MME	0.42	0.72	0.69

2m
temperature

Precipitation	RAI		
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)
CMCC 35	0.08	0.52	0.53
DWD 21	0.10	0.53	0.54
ECCC 3	0.05	0.51	0.52
ECMWF 5	0.08	0.53	0.53
JMA 3	0.08	0.52	0.53
Météo France 8	0.04	0.52	0.52
NCEP 2	0.04	0.51	0.51
UK Met Office 600	0.05	0.51	0.52
MME	0.12	0.53	0.55

Precipitation

Results

Precipitation

Precipitation	RAII		
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)
CMCC 35	0.08	0.52	0.53
DWD 21	0.10	0.53	0.54
ECCC 3	0.05	0.51	0.52
ECMWF 5	0.08	0.53	0.53
JMA 3	0.08	0.52	0.53
Météo France 8	0.04	0.52	0.52
NCEP 2	0.04	0.51	0.51
UK Met Office 600	0.05	0.51	0.52
MME	0.12	0.53	0.55

Precipitation	RA II in CIS countries		
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)
CMCC 35	0.06	0.52	0.52
DWD 21	0.11	0.54	0.55
ECCC 3	0.06	0.52	0.53
ECMWF 5	0.08	0.53	0.53
JMA 3	0.08	0.53	0.55
Météo France 8	0.02	0.51	0.52
NCEP 2	0.03	0.51	0.50
UK Met Office 600	0.03	0.51	0.52
MME	0.11	0.54	0.56

Precipitation	RA II in ArabCOF		
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)
CMCC 35	0.18	0.31	0.48
DWD 21	0.06	0.32	0.42
ECCC 3	0.00	0.29	0.41
ECMWF 5	0.01	0.30	0.44
JMA 3	0.13	0.31	0.46
Météo France 8	0.07	0.45	0.30
NCEP 2	0.07	0.30	0.49
UK Met Office 600	0.00	0.31	0.45
MME	0.17	0.31	0.46

Precipitation	EASCOF		
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)
CMCC 35	0.11	0.55	0.54
DWD 21	0.11	0.54	0.55
ECCC 3	0.03	0.50	0.50
ECMWF 5	0.05	0.54	0.52
JMA 3	0.07	0.53	0.52
Météo France 8	0.11	0.55	0.55
NCEP 2	0.02	0.50	0.51
UK Met Office 600	0.07	0.53	0.53
MME	0.13	0.55	0.55

Precipitation	RA II in ASEANCOF		
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)
CMCC 35	0.10	0.54	0.56
DWD 21	0.17	0.56	0.57
ECCC 3	0.01	0.50	0.52
ECMWF 5	0.10	0.52	0.55
JMA 3	0.02	0.51	0.52
Météo France 8	0.08	0.52	0.54
NCEP 2	0.08	0.56	0.53
UK Met Office 600	0.11	0.50	0.52
MME	0.13	0.54	0.55

Precipitation	SASCOF		
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)
CMCC 35	0.10	0.54	0.55
DWD 21	0.09	0.53	0.53
ECCC 3	0.09	0.53	0.56
ECMWF 5	0.15	0.56	0.56
JMA 3	0.10	0.54	0.53
Météo France 8	0.06	0.54	0.53
NCEP 2	0.14	0.57	0.56
UK Met Office 600	0.13	0.54	0.54
MME	0.15	0.56	0.56

Results

2m temperature

2m Temperature	RAII			
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)	
CMCC 35		0.29		0.63
DWD 21		0.40		0.71
ECCC 3		0.33		0.67
ECMWF 5		0.39		0.69
JMA 3		0.30		0.65
Météo France 8		0.36		0.67
NCEP 2		0.34		0.68
UK Met Office 600		0.36		0.70
MME		0.42		0.72
2m Temperature	RA II in CIS countries			
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)	
CMCC 35		0.21		0.58
DWD 21		0.34		0.69
ECCC 3		0.23		0.62
ECMWF 5		0.29		0.63
JMA 3		0.22		0.62
Météo France 8		0.28		0.63
NCEP 2		0.30		0.67
UK Met Office 600		0.27		0.65
MME		0.34		0.68
2m Temperature	RA II in ArabCOF			
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)	
CMCC 35		0.39		0.64
DWD 21		0.63		0.78
ECCC 3		0.66		0.82
ECMWF 5		0.61		0.78
JMA 3		0.38		0.60
Météo France 8		0.43		0.66
NCEP 2		0.49		0.68
UK Met Office 600		0.61		0.80
MME		0.62		0.76
2m Temperature	RA II in ASEANCOF			
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)	
CMCC 35		0.63		0.83
DWD 21		0.63		0.81
ECCC 3		0.69		0.83
ECMWF 5		0.65		0.84
JMA 3		0.55		0.74
Météo France 8		0.59		0.79
NCEP 2		0.51		0.80
UK Met Office 600		0.70		0.85
MME		0.67		0.85
2m Temperature	EASCOF			
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)	
CMCC 35		0.31		0.68
DWD 21		0.43		0.72
ECCC 3		0.39		0.69
ECMWF 5		0.47		0.74
JMA 3		0.40		0.69
Météo France 8		0.45		0.72
NCEP 2		0.37		0.68
UK Met Office 600		0.44		0.72
MME		0.49		0.74
2m Temperature	SASCOF			
	Pearson's correlation	ROC area (below-normal)	ROC area (above-normal)	
CMCC 35		0.48		0.76
DWD 21		0.43		0.75
ECCC 3		0.43		0.71
ECMWF 5		0.47		0.75
JMA 3		0.42		0.72
Météo France 8		0.43		0.75
NCEP 2		0.34		0.69
UK Met Office 600		0.45		0.77
MME		0.51		0.78