RMIP
Regional climate Model Inter-comparison Project for Asia

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START Regional Center for Temperature East Asia

NEW CHALLENGE OF GLOBAL CHANGE RESEARCH

- Regional scale estimates of the timing and magnitude of climate change
- Regional analyses of the environmental and socio-economic consequences of climate change
- Integrated assessments of the implications for society and environment of climate change

REGIONAL CLIMATE MODEL INTER-COMPARISON PROJECT FOR ASIA

A joint effort of 10 research groups of 5 countries(Australia, China, S.Korea,Japan and USA) with also the involvement of India, N.Korea, Italy, Mongolia and Russia under the joint support of APN, START and MOST and CAS of CHINA

PARTICIPATING GROUPS

1. START Regional Center for Temperate East Asia, Institute of Atmospheric Physics, CAS, **China**
2. Iowa State University, **U.S.A.**
3. Central Research Institute of Electric Power Industry (CRIEPI), **Japan**
4. Department of Atmospheric Sciences, Yonsei University, **South Korea**
5. Department of Atmospheric Sciences, Seoul National University (SNU), **South Korea**
6. Division of Atmospheric Research, Commonwealth Scientific and Industrial Research Organization (CSIRO), **Australia**
7. Meteorological Research Institute/JMA, Atmospheric Environment and Applied Meteorology Research Department, **Japan**
8. Department of Atmospheric Sciences, Nanjing University, **China**
9. Department of Atmospheric Sciences, Colorado State University, **U.S.A.**
10. Atmospheric Environment Division, National Institute for Environmental Studies, **Japan**

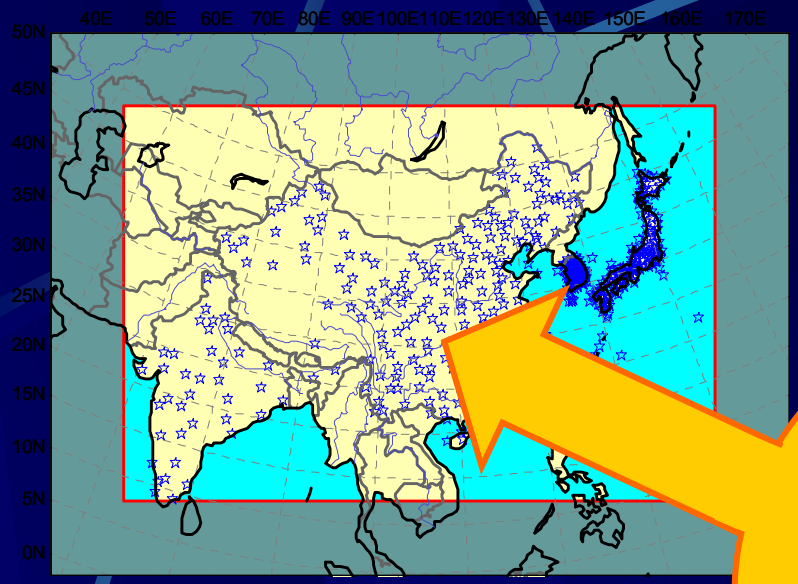
OBJECTIVES OF RMIP

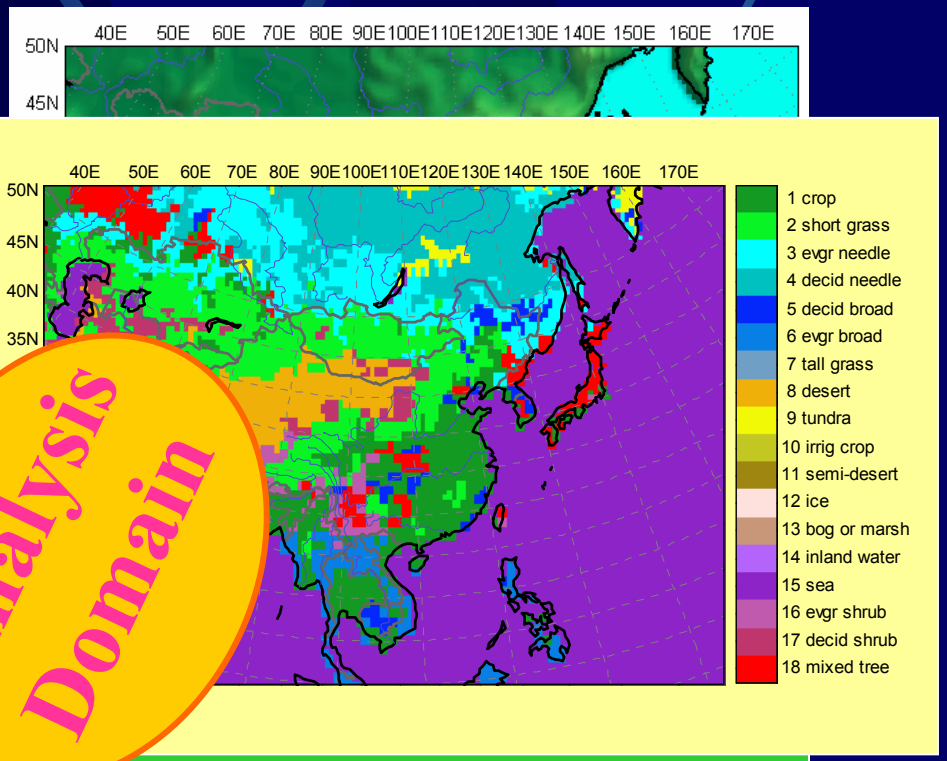
- To further improve the RCMs for application in Asia;
- To develop an ensemble of the results from a group of RCMs;
- To provide higher confident scenarios of regional climate change in Asia .

TASKS OF RMIP

- Phase I, 18 months run, annual cycle and extreme
- Phase II, 10 years run, statistical behaviors
- Phase III, nesting with GCM, projection of climate change in 21 Century,

Simulation Design

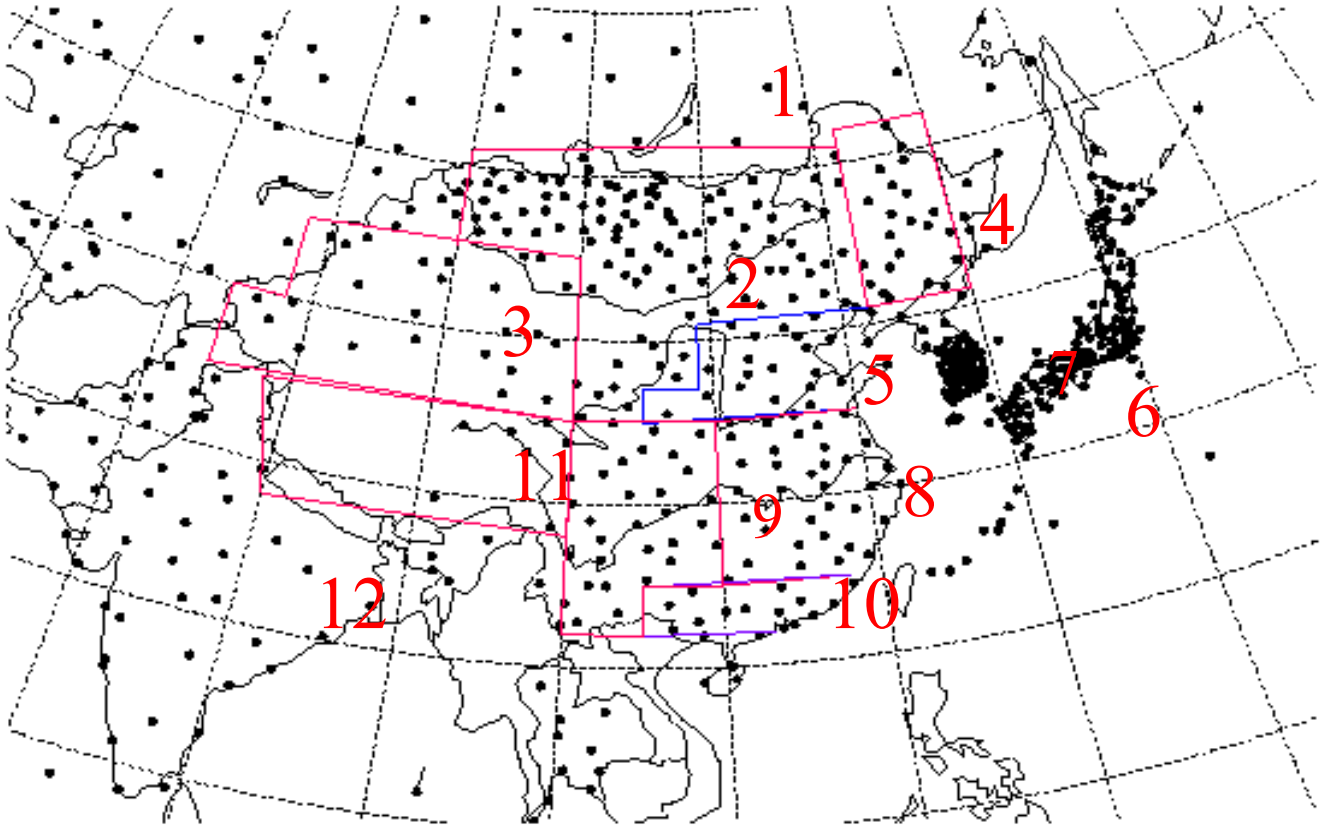




Analysis Domain

- Integration and Analy
  - The Center of Domain:
  - Integration Domain: 151(WE)×111(SN)
  - Horizontal Resolution: 60KM
- Duration of RMIP Phase I: 1997. 3—1998.8
  Duration of RMIP Phase I I: 1988.7—1998.11
- Driving Fields: NCEP Reanalyses

Distribution of observation stations and classification of sub-regions



1:Siberia 2:Eastern arid/semi-arid regions 3:western arid/semi-arid regions
4:Northeast China 5:North China 6:Japan islands 7:Korea peninsula 8:Center China
9:Southwest China 10:South China 11:Tibetan platform 12:Indian sub-continent

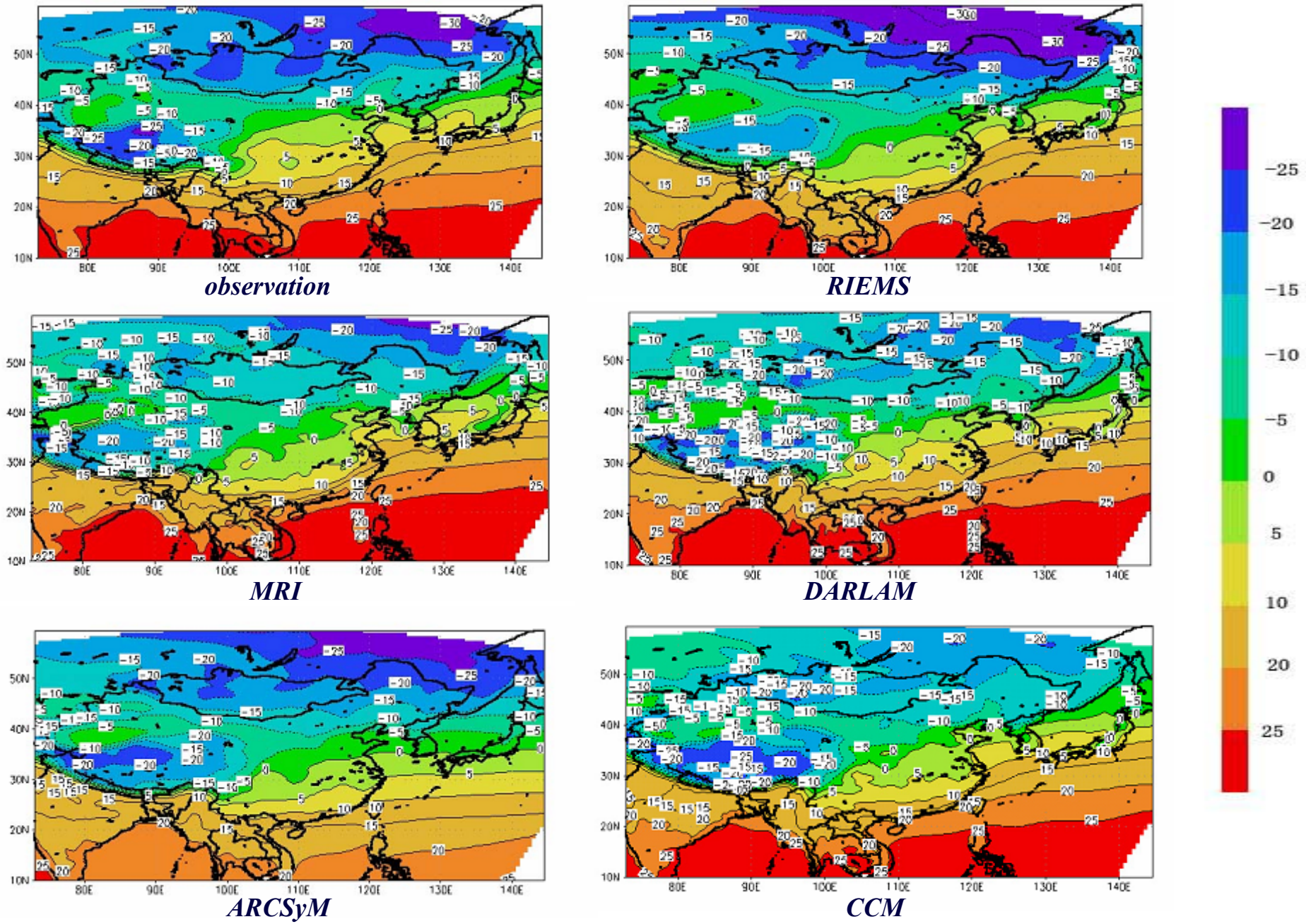
Participating Groups in RMIP Phase I

Model	Group leader	Country
RIEMS	C. Fu	China
Regcm3	H. Kato	Japan
DARLAM	J. MeGregor	Australia
NIES/CCSR	S. Emori	Japan
ARCSyM	W. Wu	U.S.A
NJU RCM	B. Su	China
JMA-BAIM	Y. Sato	Japan
MM5/LSM	W. Gutowski	U.S.A
MM5/LSM, Regcm2	D. Lee	Korea
Regcm	J. Kim	Korea

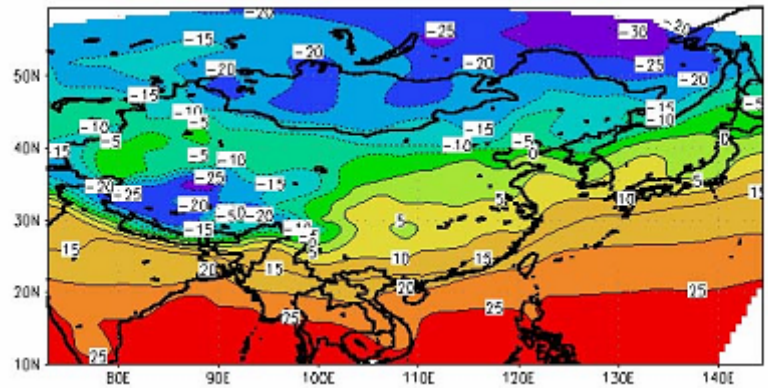
PRODUCTS OF PHASE I

- Surface climate, including T_{mean}, T_{max}, T_{min}, R_{total} and SLP;
- Mean and Correlation fields between model and observation;
- Seasonal variation of area means for sub-regions;
- Evolution of rain belts;
- Bias in different regions and seasons
- Upper air stream fields and moisture transfer
- Surface fluxes
- Extreme events

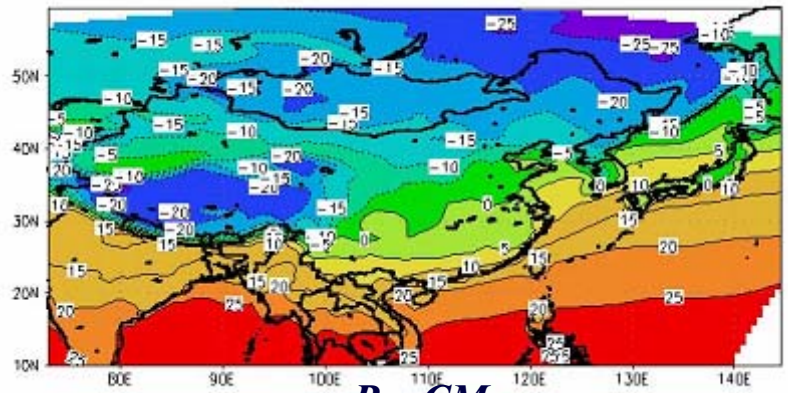
1997 winter mean surface temperature(^{o}C)



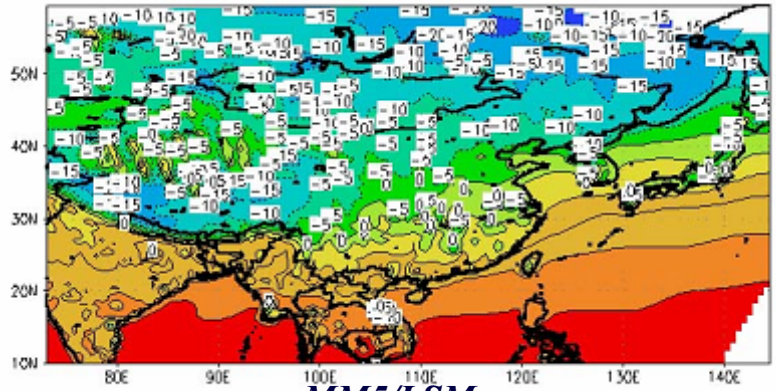
1997 winter mean surface temperature(^{o}C)



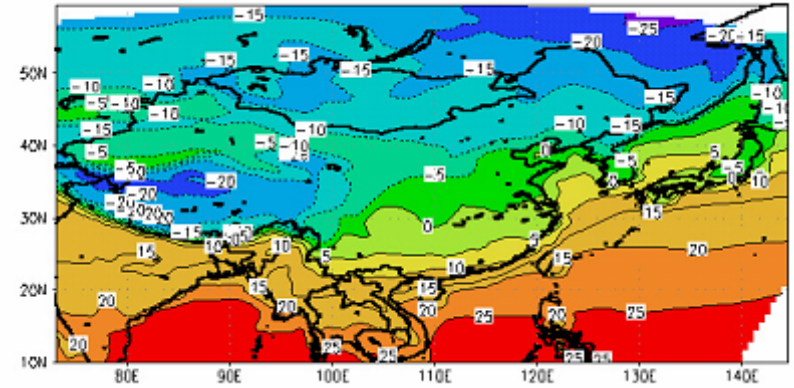
Observation



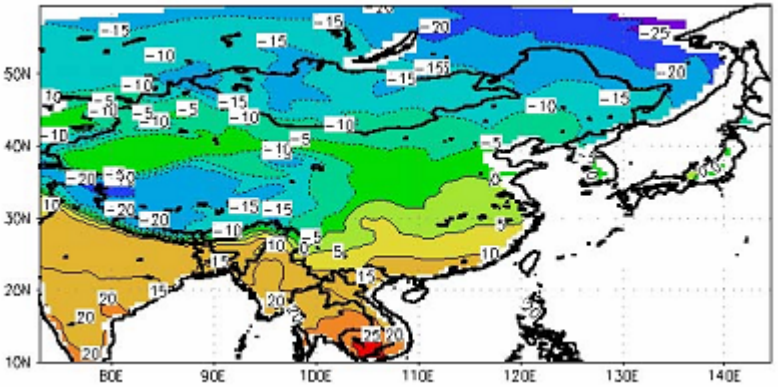
RegCM



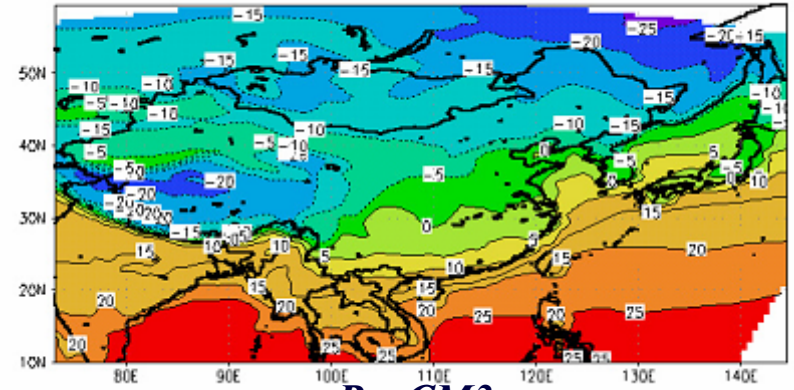
MM5/LSM



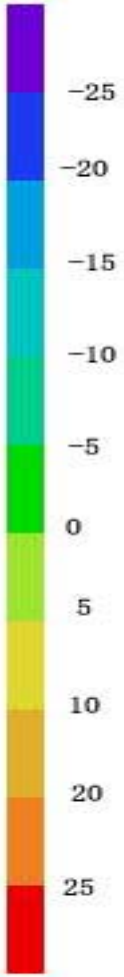
RegCM2



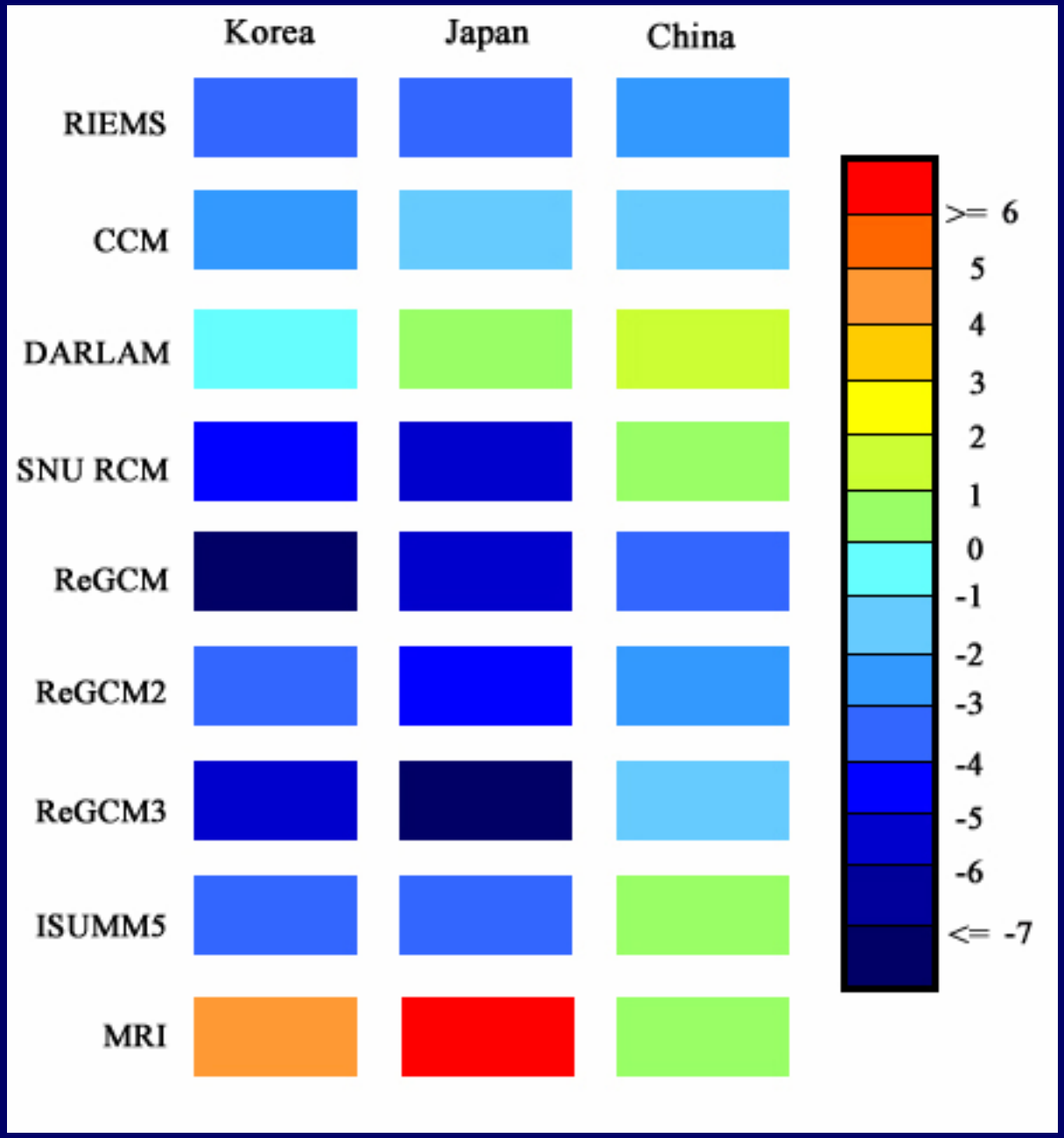
ISU MM5



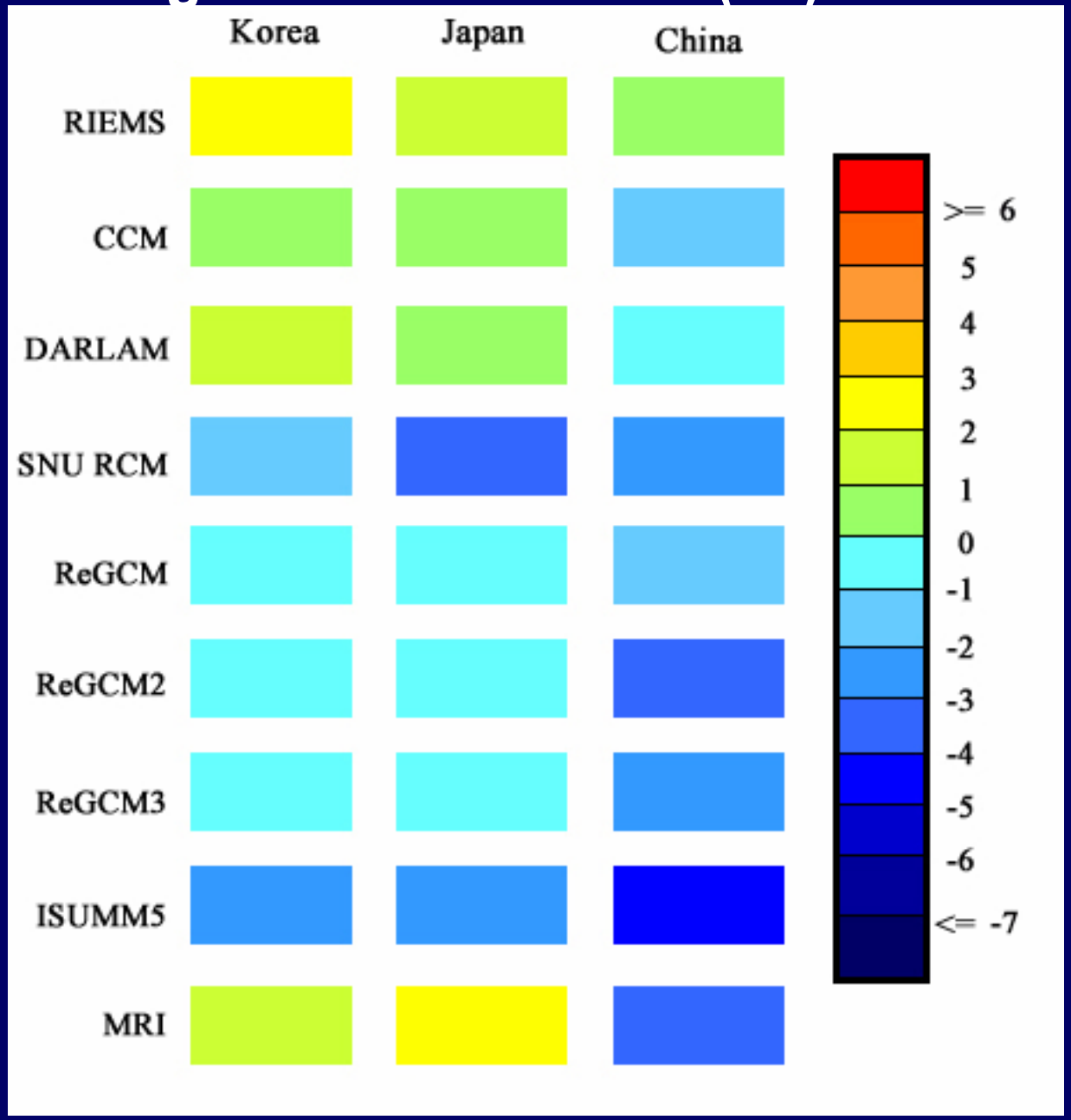
RegCM3



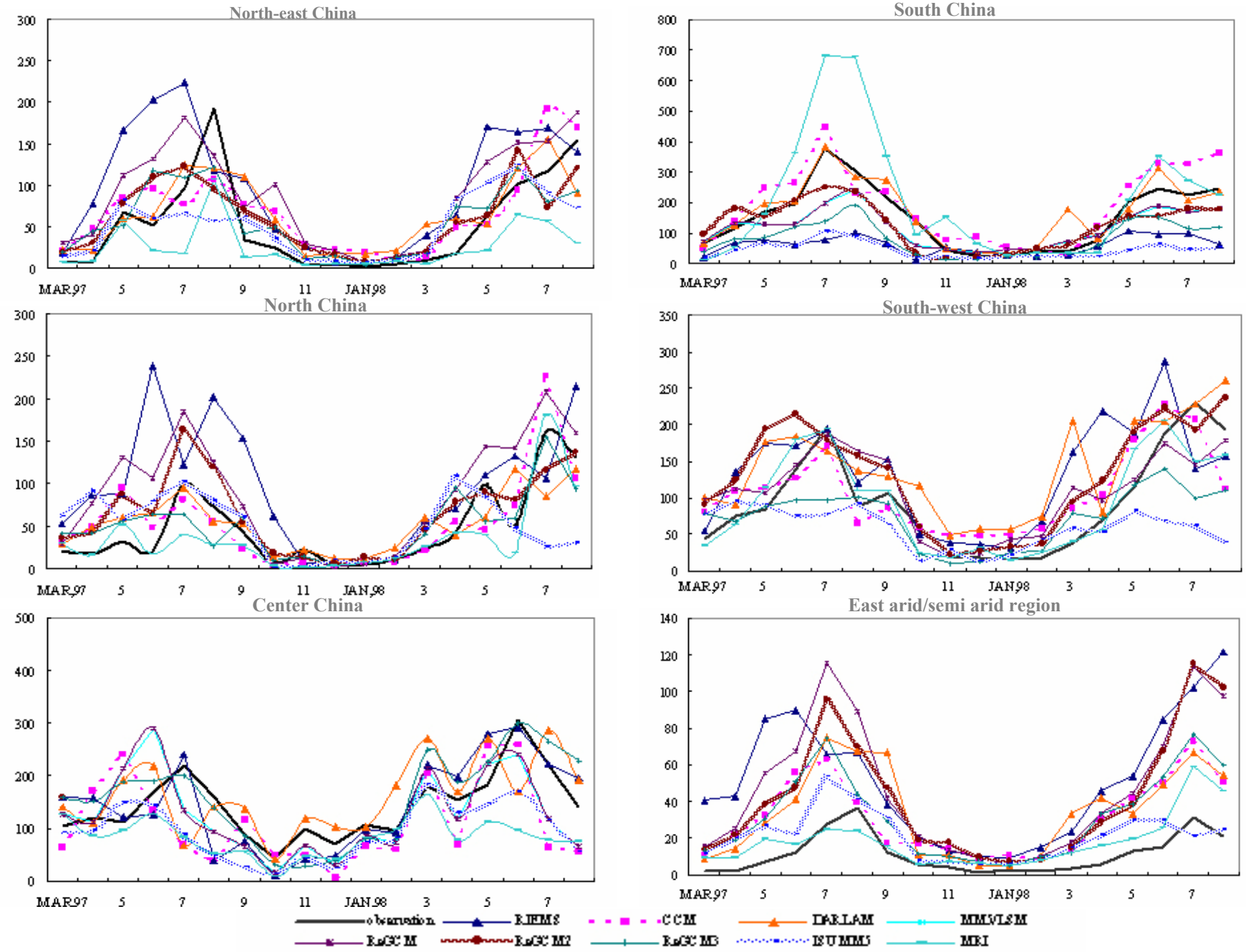
Seasonal averaged surface T bias (° C) in winter 1997



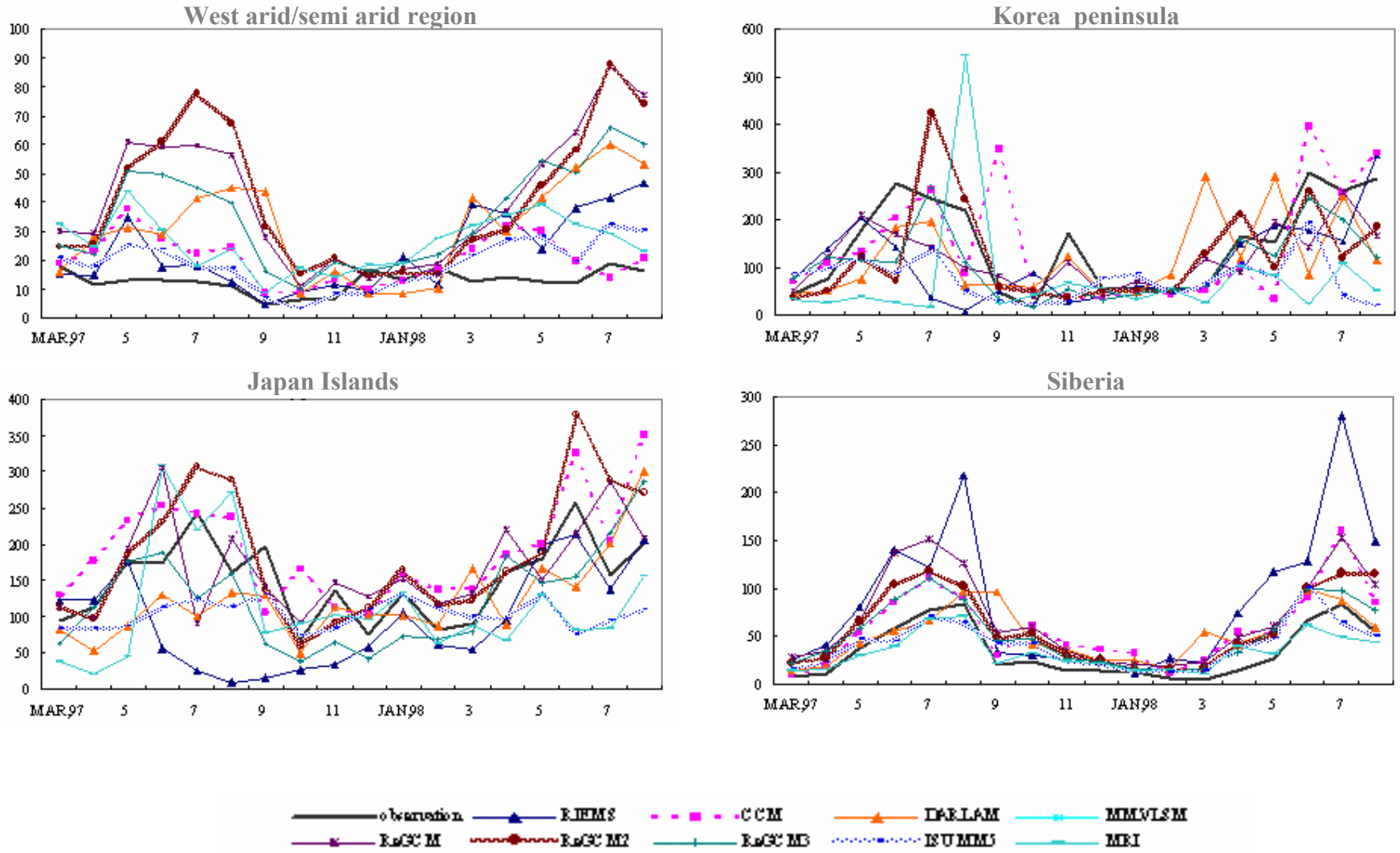
Seasonal averaged surface T bias (°C) in summer 1998



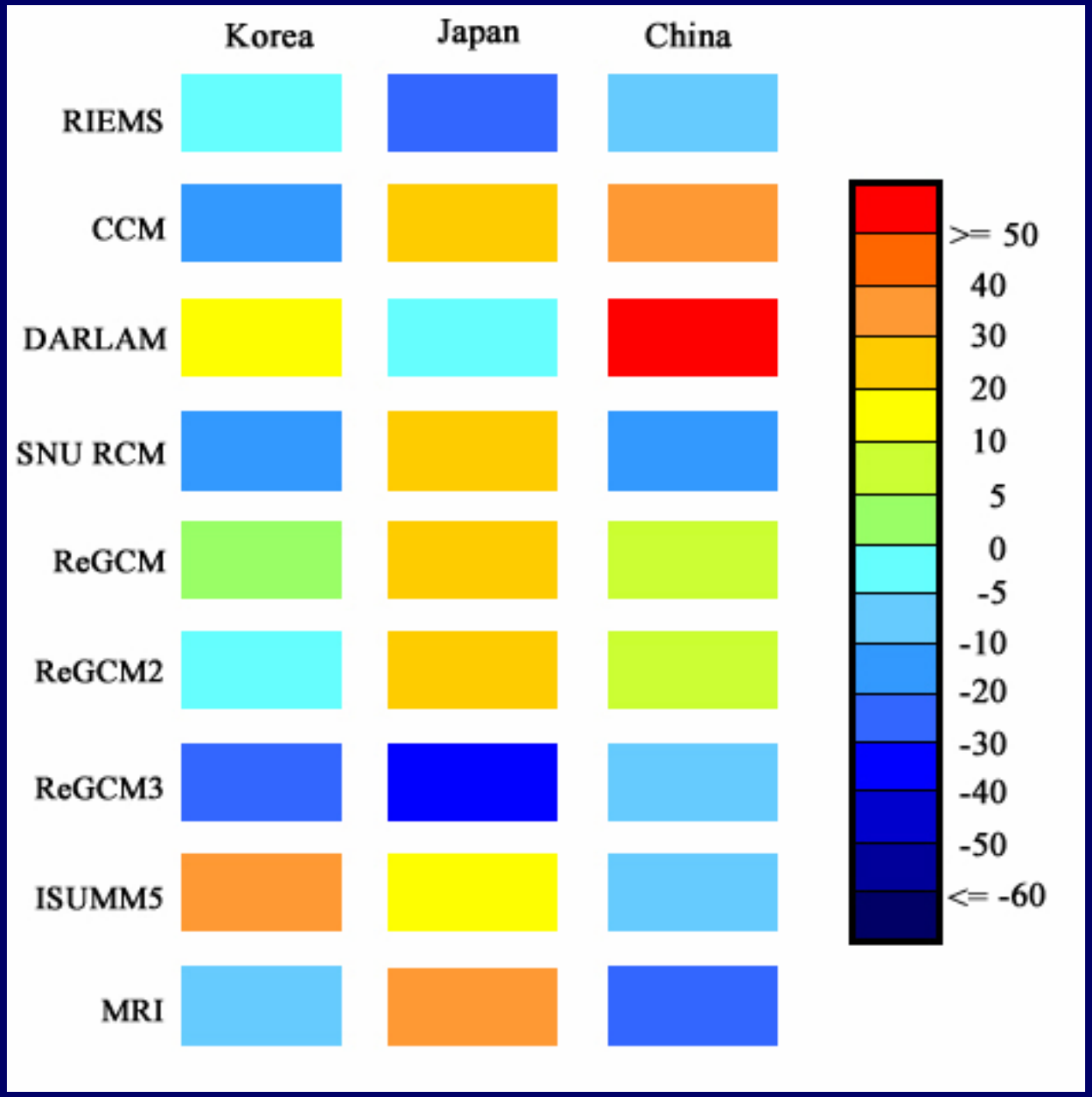
Seasonal cycle of monthly total precipitation(mm) over different regions(o)



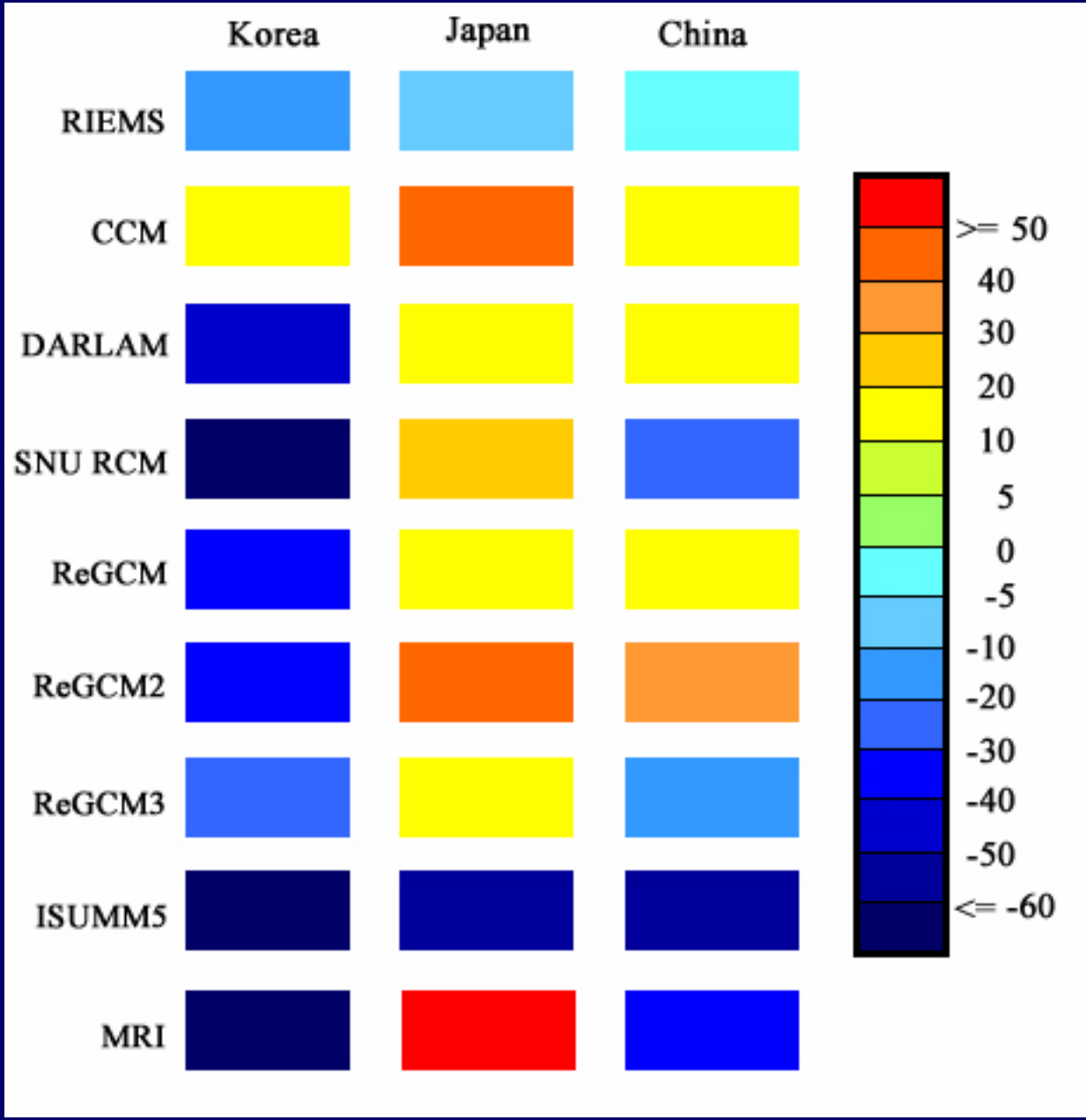
Seasonal cycle of monthly-total precipitation(mm) over different regions(o)



Seasonal total precipitation bias(%) in winter 1997



Seasonal total precipitation bias (%)in summer 1998

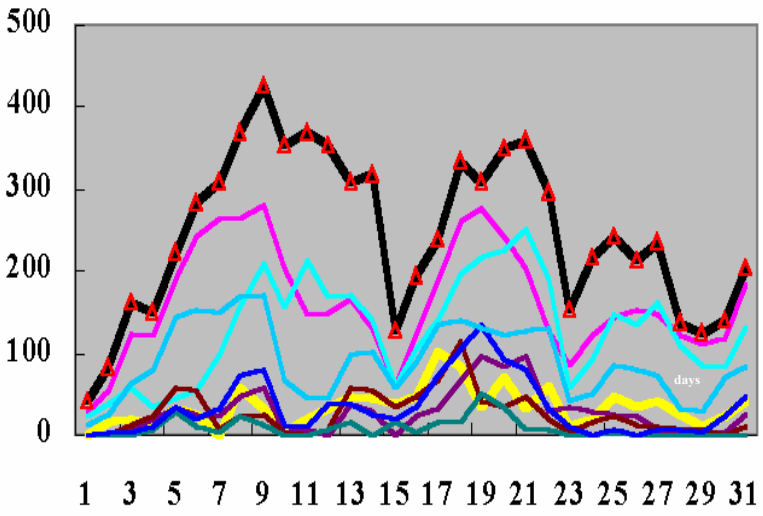


EXTREME EVENTS

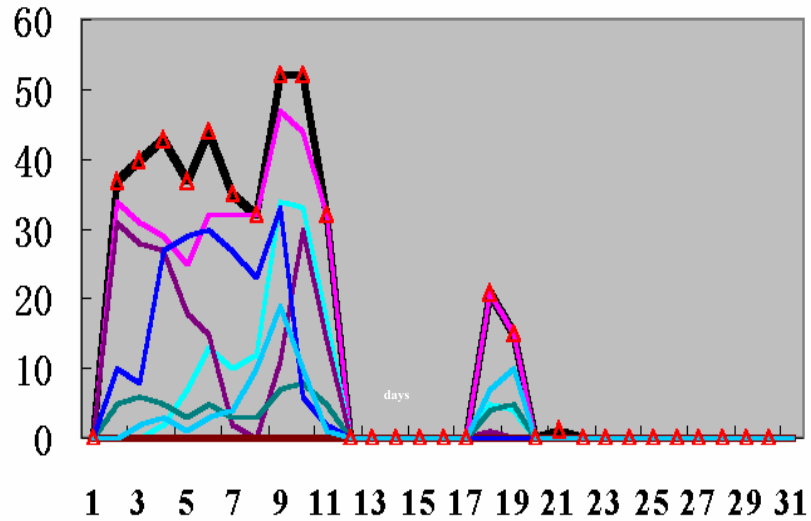
- Hot summer in 1997
- Heavy rain fall in June, 1998

Simulation of the extreme hot summer of 1997

Daily grid number with T_{max} above 35°C in the north of 35 N, July,1997

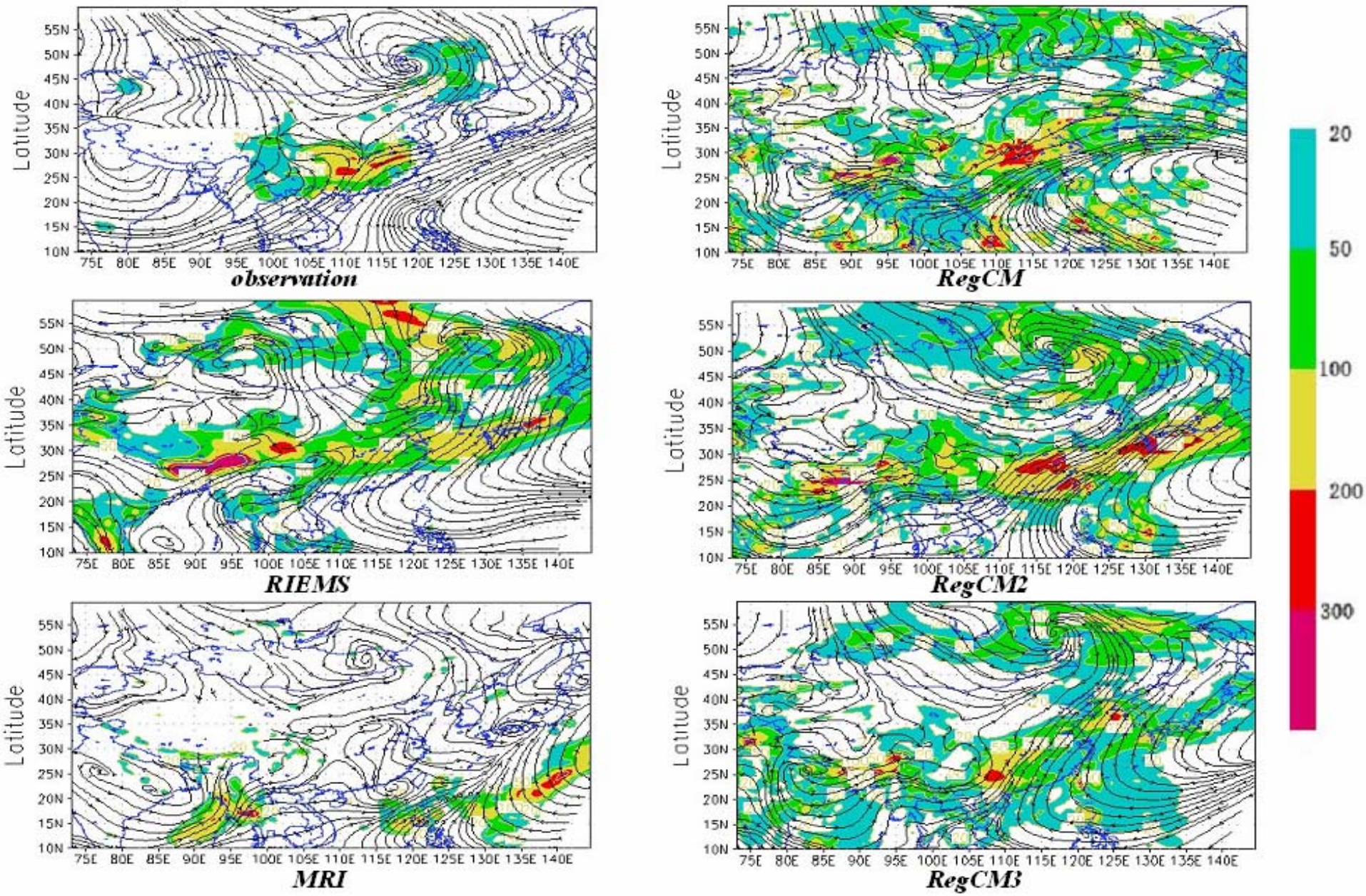


Daily grid number with T_{max} above 38°C in the south of 35 N, July,1997

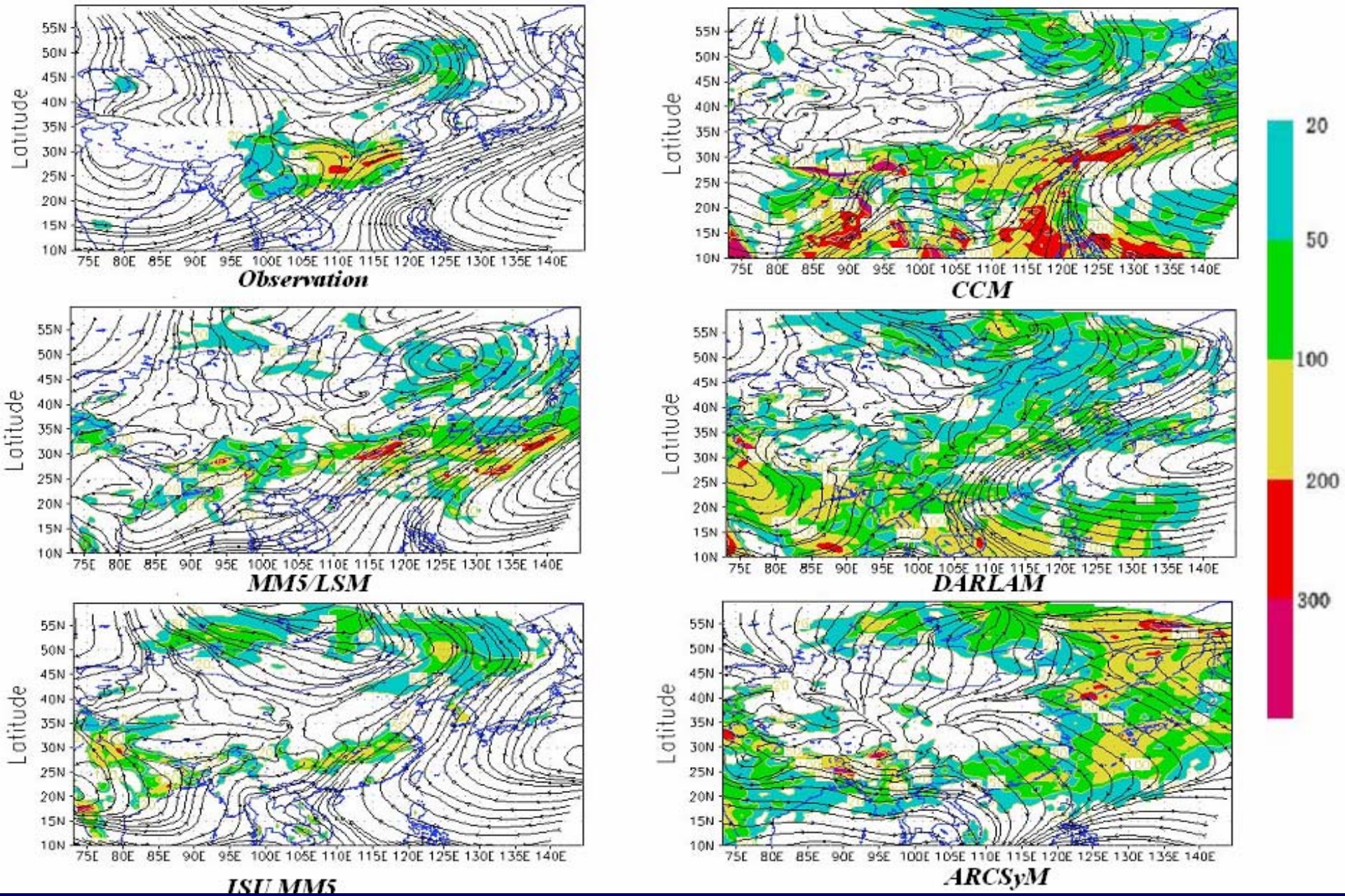


OBSERVATION
RIEMS
Regcm3
DARLAM
N/C RAMS
ARCSyM
NJU RCM
MM5/LSM
RegCM

850hpa streamlines and total precipitation in June 11-20 1998



850hpa streamlines and total precipitation in June 11-20 1998



AIMS OF RMIP PHASE II

- More systematic evaluation of RCM's performance in Asia through 10 years consequent runs of participating models;
- To provide more solid knowledge for further improvement of RCM applied for Asia;
- To provide the confidence level for using RCM's simulated results

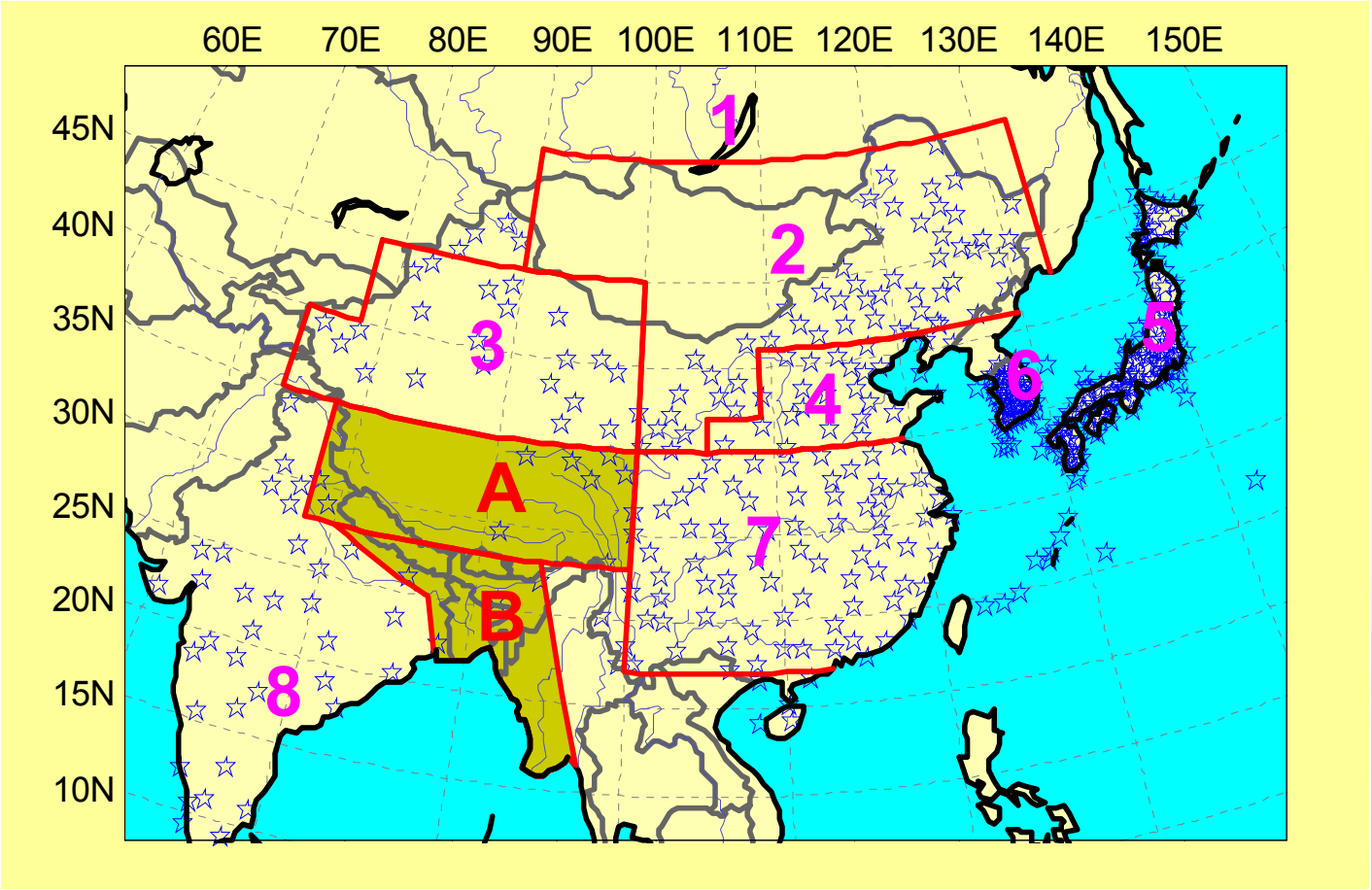
TASKS OF RMIP PHASE II

- 10 years run of participating models;
- Preliminary analysis of each individual model and inter-comparison;
- Test of simulating of climate in 21st century by RCM nested with GCM;

Data for Model Validation

❖**Station Data:**

China(193),Japan(155),Korea(68),India(40)



Model Information

Model	RIEMS Congbin Fu China	RegCM3 Hisashi Kato Japan	NJU MM5 Bingkai Su China	SNU RCM D. Lee Korea	MRI (JSM_BAIM) Yasuo Sato Japan	CSIRO CCAM J. McGregor Australia
Vertical levels	σ -17 levels	σ -14 levels	σ -16 levels	σ -23 levels	σ -23 levels	σ - 18 levels
Dynamics	hydrostatic	hydrostatic	non-hydrostatic	non-hydrostatic	hydrostatic	ccam
LBC	ER	ER	ER	ER	ER+ Spectral coupling	Far-field nudging
Convective scheme	Kuo-Anthes	Kuo-Anthes	Grell	Grell	Moist convective adjustment	Arakawa-Gordon
Land surface	BATS	LSM	LSM	LSM	BAIM	Kowalczyk
PBL scheme	Holtslag	Holtslag	MRF	MRF	Yamada Level 2 Louis scheme	Louis-Holtslag
LW radiation scheme	CCM3	CCM3	CCM2	CCM2	Sugi	GFDL
SW radiation scheme	CCM3+ aerosol	CCM3	CCM2	CCM2	Lacis& Hansen	GFDL

*LR : linear relaxation *ER: exponential relaxation

MAIN PRODUCTS OF RMIP PHASE II
Preliminary Inter-comparison

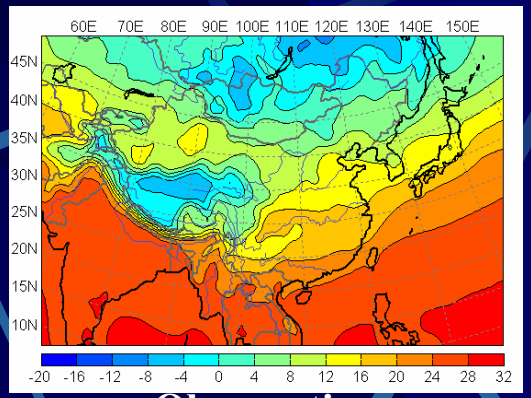
- Mean fields
- Bias and correlation between simulations and observation
- Variability (Standard deviation) analysis
- EOF analysis of temperature and precipitation
- Sub-regional and entire continental statistical analysis
- The evolution of main rain belts

- 10 years mean

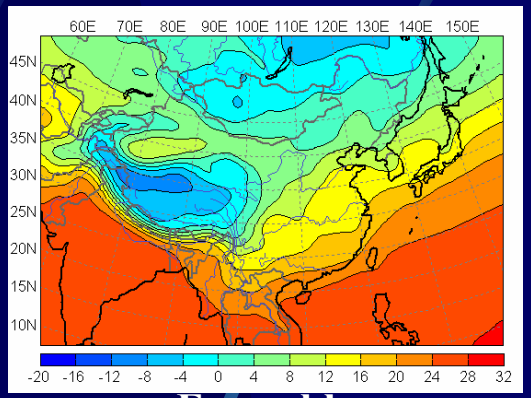
Temperature

- All models can reproduce the spatial patterns of summer/winter/yearly mean temperatures;
- The spatial patterns of extreme temperature ranges are reasonably simulated;
- Correlations between simulated and observed temperature are significant;
- Model simulated yearly mean temperatures are 2~5℃ cooler than the observation in Middle-West China;

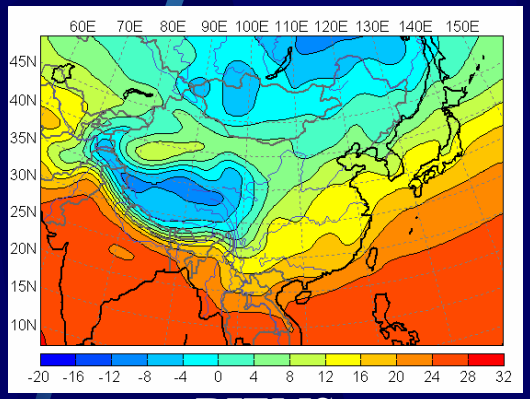
10–years Averaged annual T_{surf}(℃)



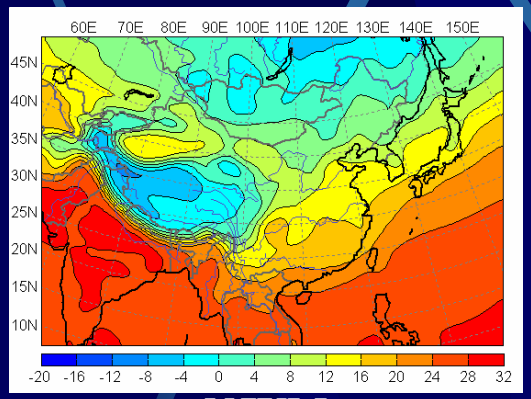
Observation



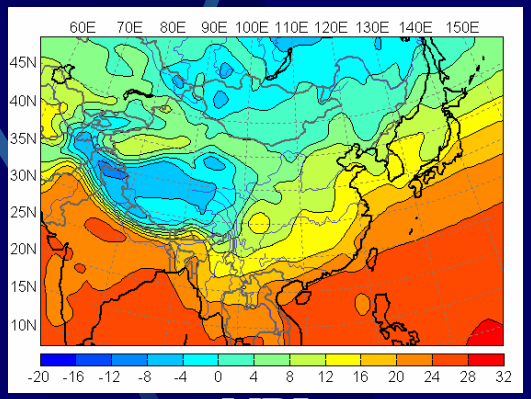
Ensemble



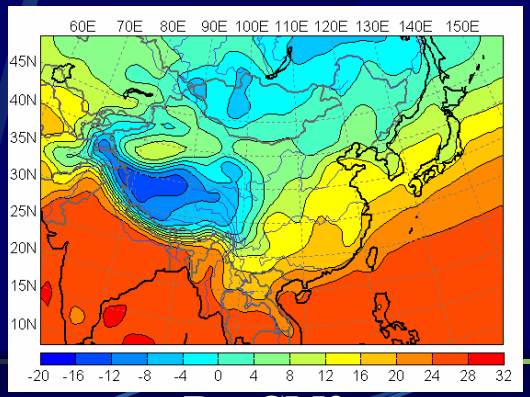
RIEMS



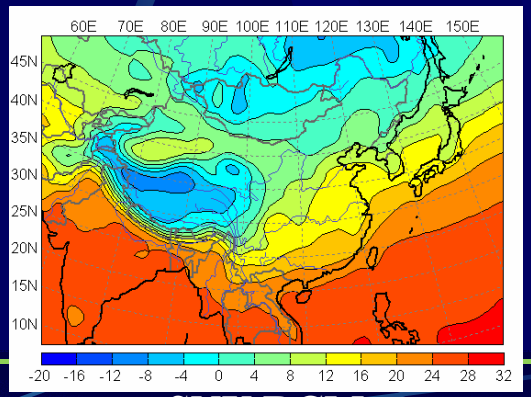
NJUM



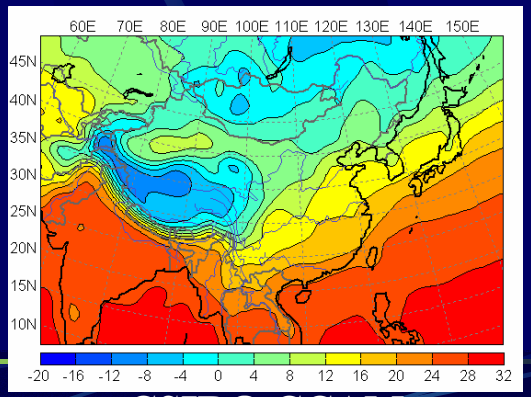
MRI



RegCM3

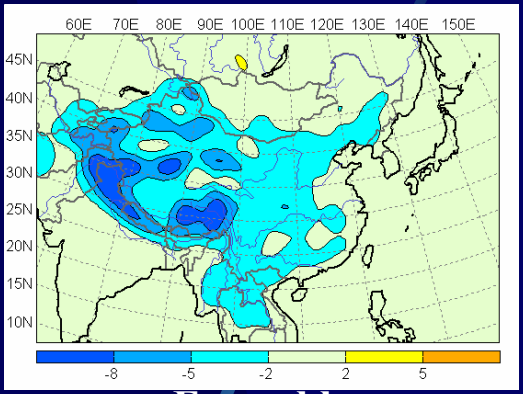


SNU RCM



CSIRO CCAM

Bias of Simulated annual T to Observation (℃)



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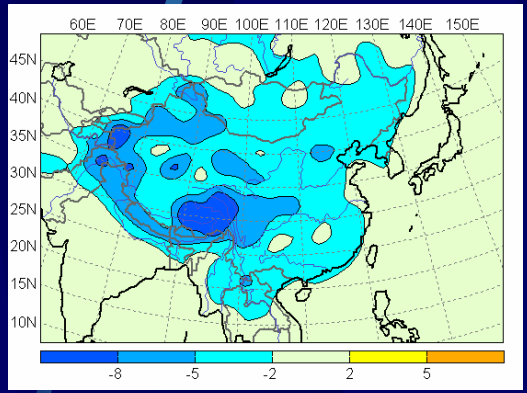
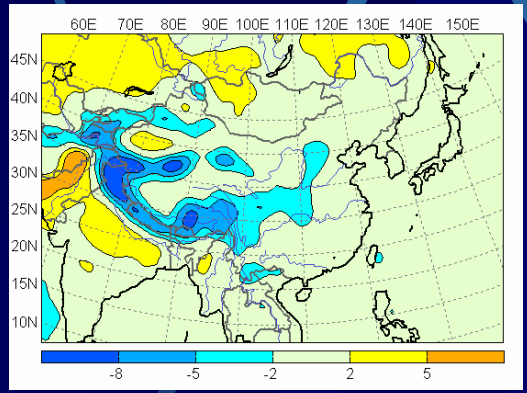
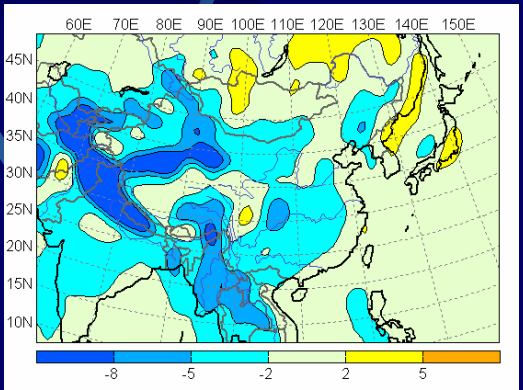


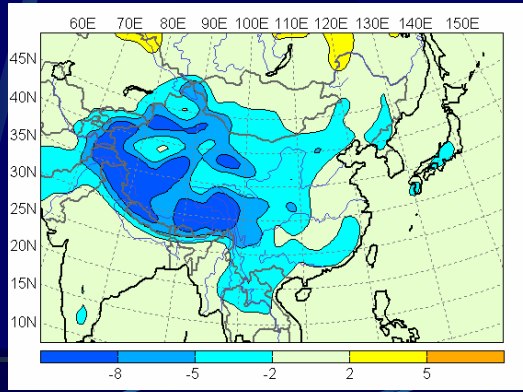
RIEMS



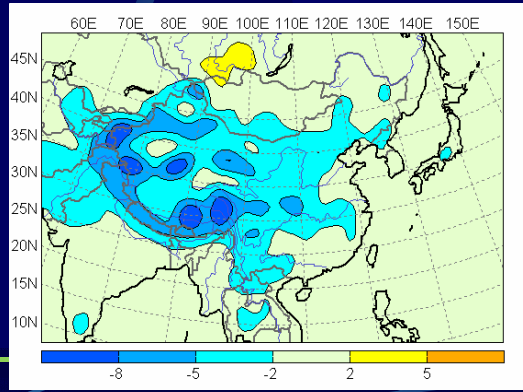
NJUM



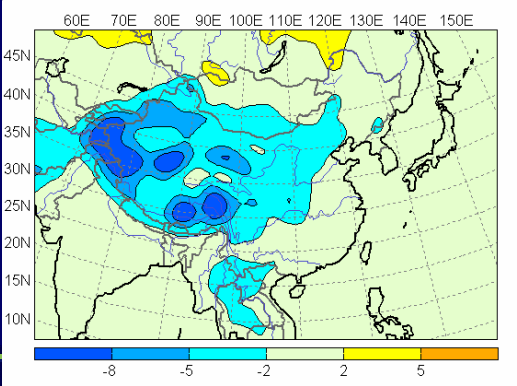
MRI



RegCM3



SNU RCM

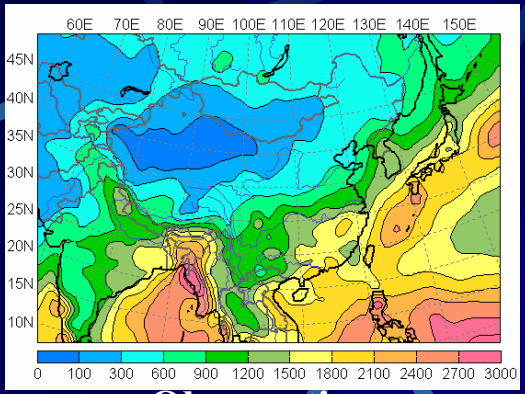


CSIRO CCAM

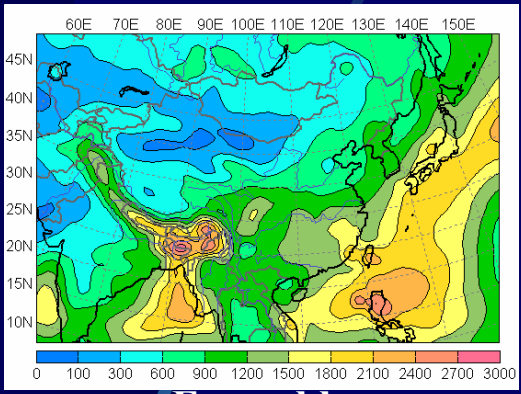
Precipitation

- Most models have the reasonable reproduction of the spatial pattern of multi-years averaged summer/winter/annual total precipitations.
- Correlations between simulated and observed precipitation are significant over most areas.
- Locations of the main rain belts are in less agreement with observation and most models tend to overproduce precipitation by 200% at maximum in West China and underestimate precipitation over southern domain by 50%.

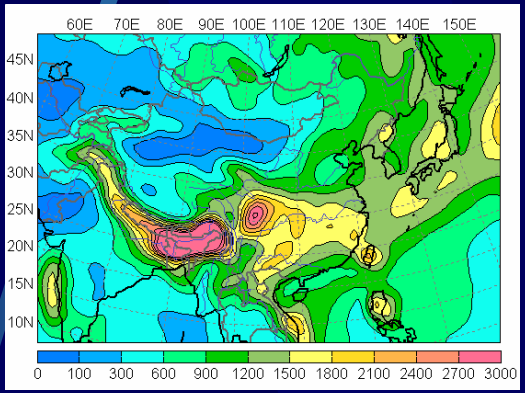
10–years Averaged Annual Total Precipitation (mm)



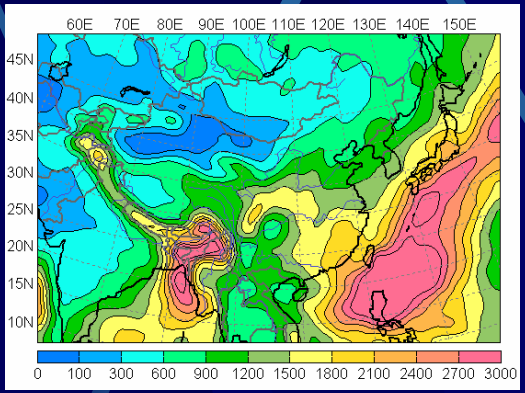
Observation



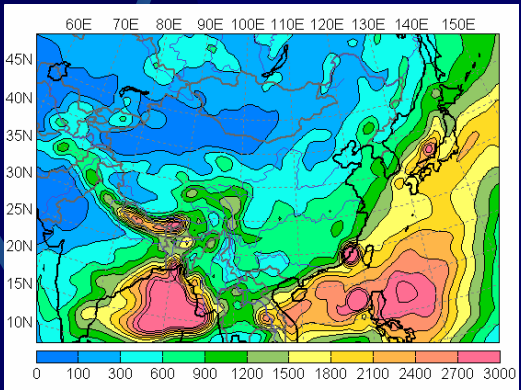
Ensemble



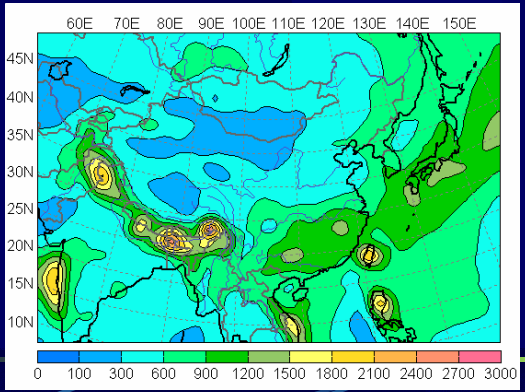
RIEMS



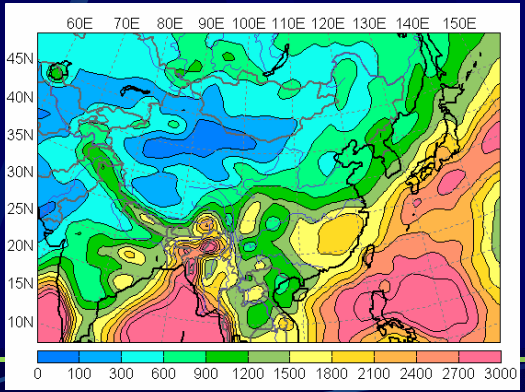
NJUM



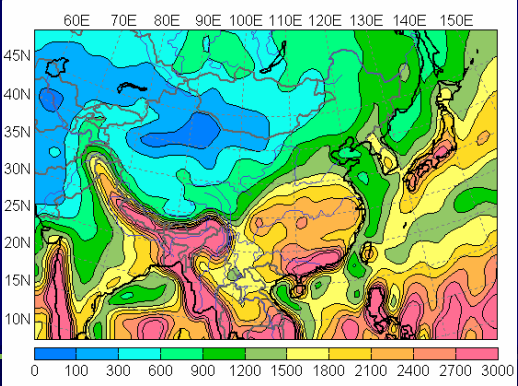
MRI



RegCM3

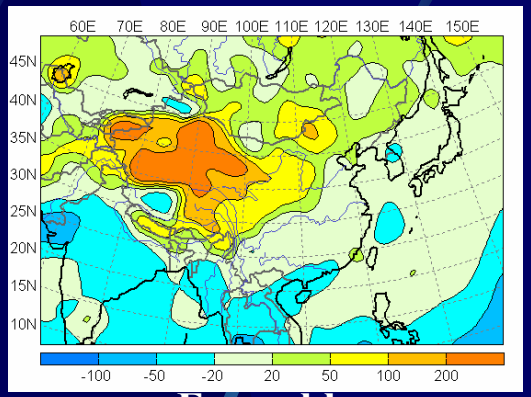


SNU RCM

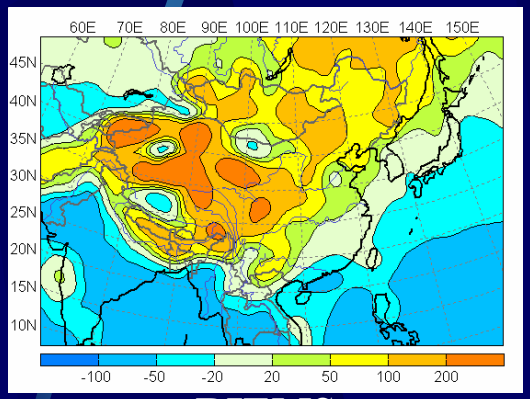


CSIRO CCAM

Bias of Simulated Annual Total Precipitation to Observation (%)



Ensemble



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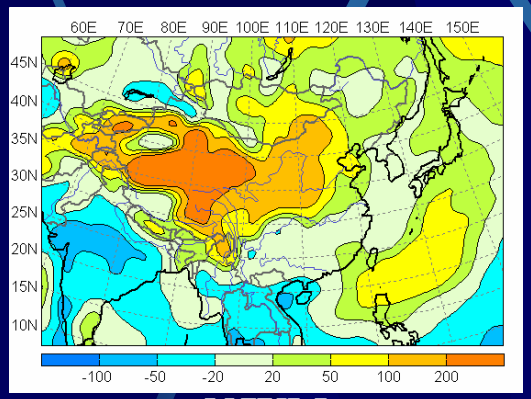

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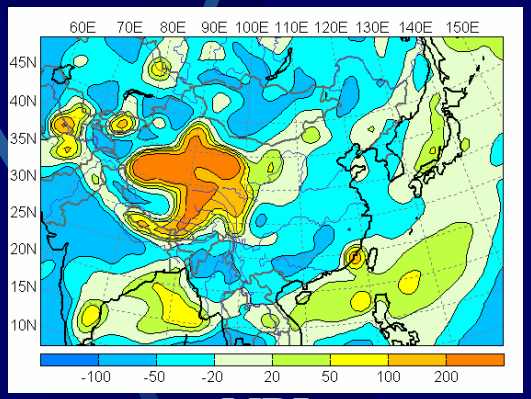

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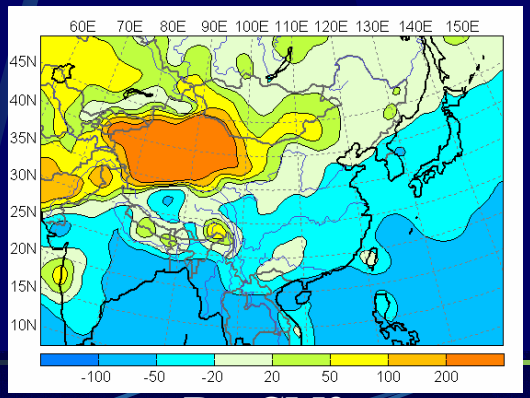
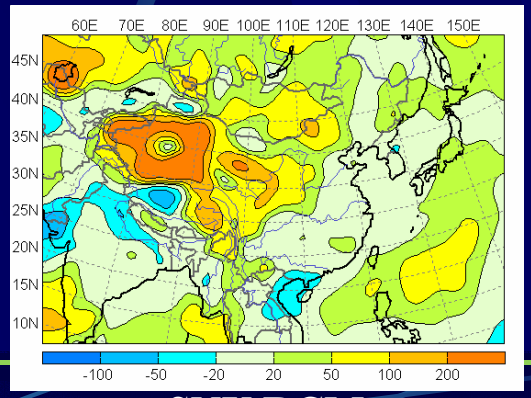
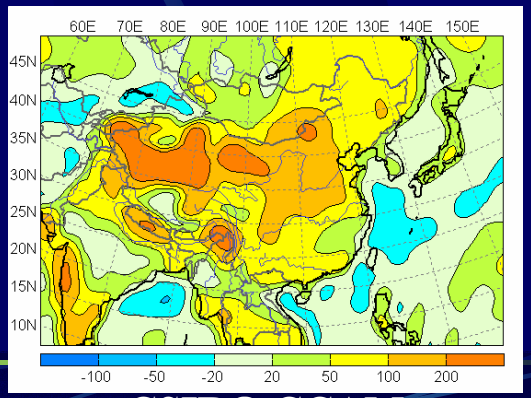


RegCM3



SNU RCM



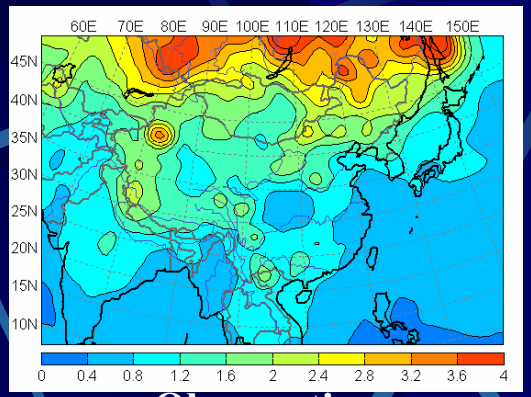
CSIRO CCAM

Standard Deviation

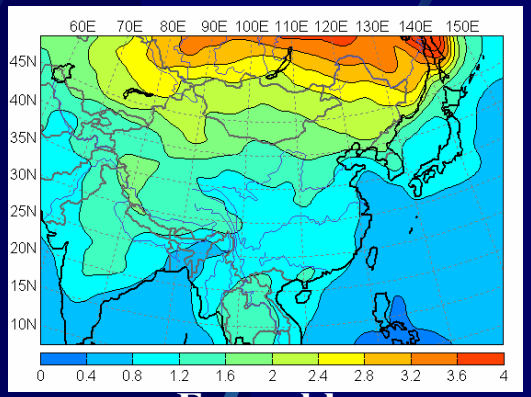
- Surface Air Temperature
- Total Precipitation

Standard Deviation of January T_{surf}

$$std = \sqrt{\frac{1}{10}\sum_{i=1}^{10}\left(V_i - \frac{1}{10}\sum_{i=1}^{10}V_i\right)^2}$$



Observation



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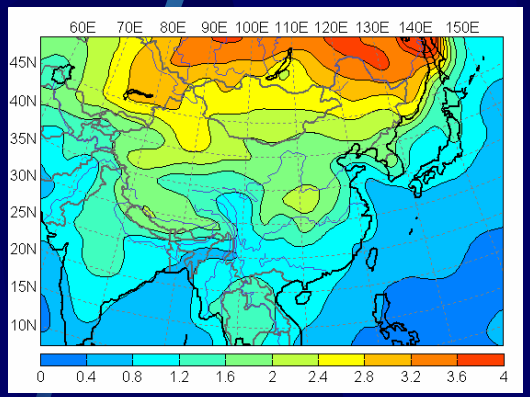

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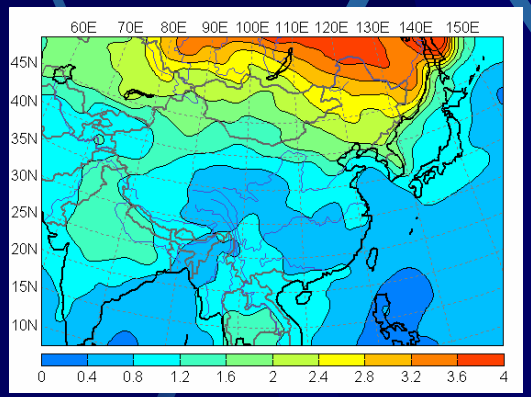

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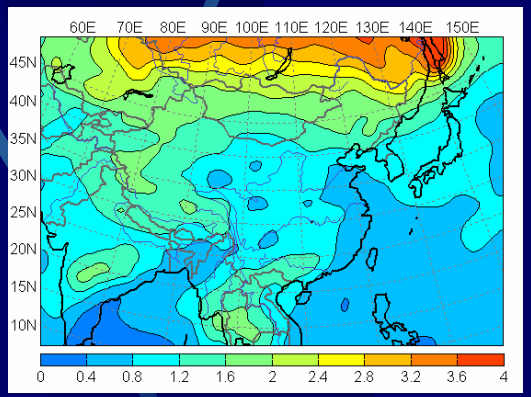

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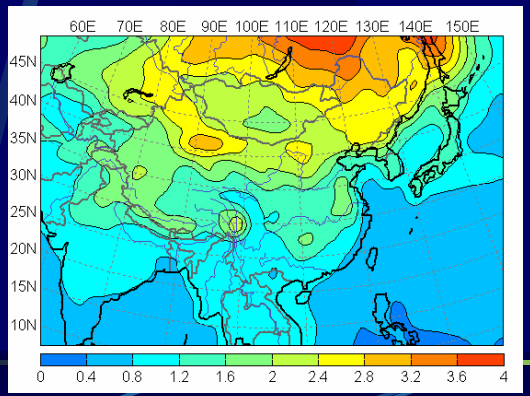

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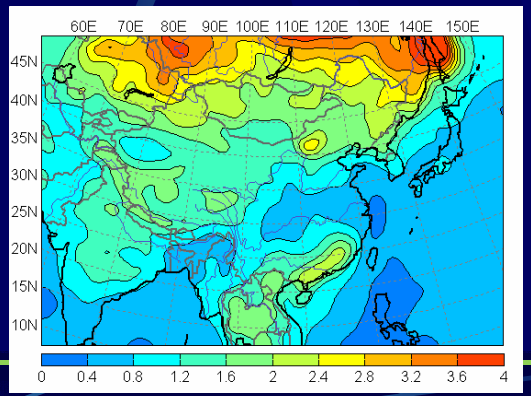

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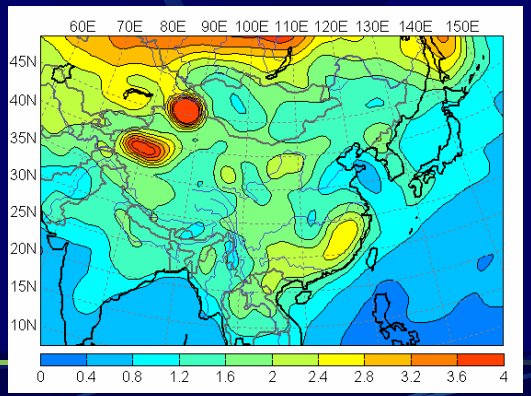
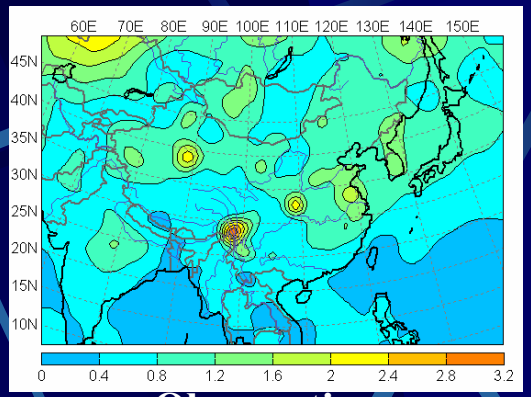
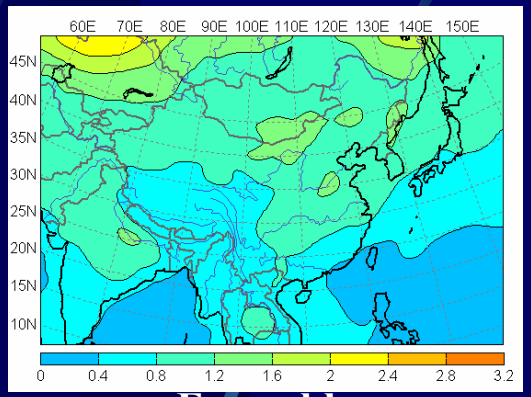


CSIRO CCAM

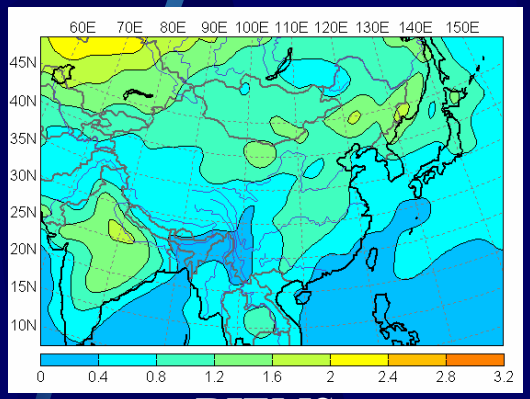
Standard Deviation of July T_{surf}



Observation



Ensemble



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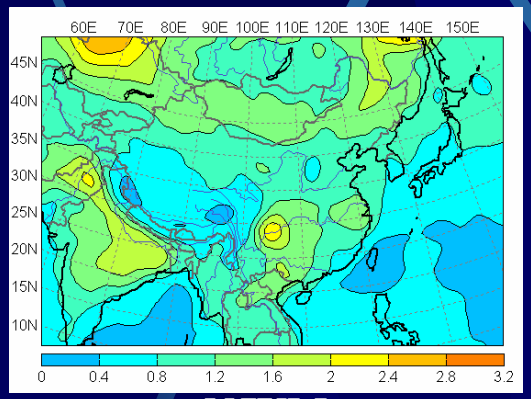

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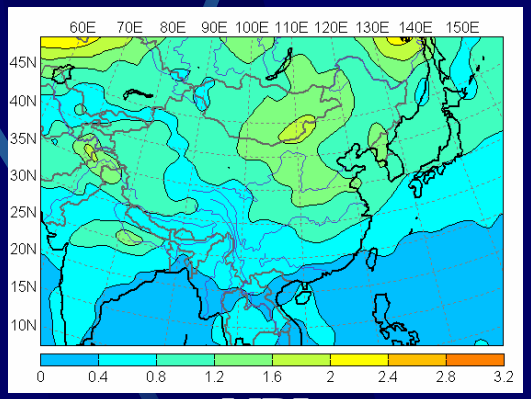

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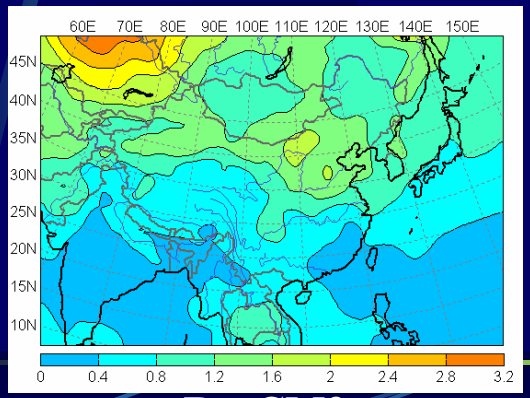

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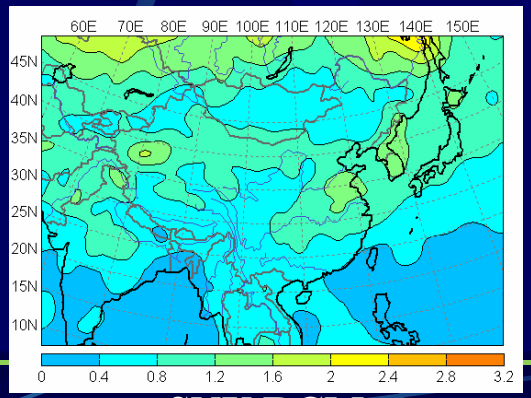
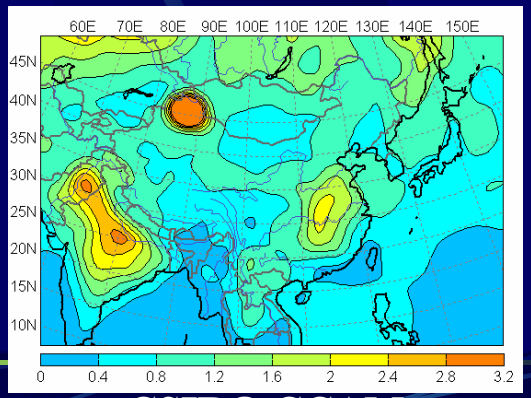


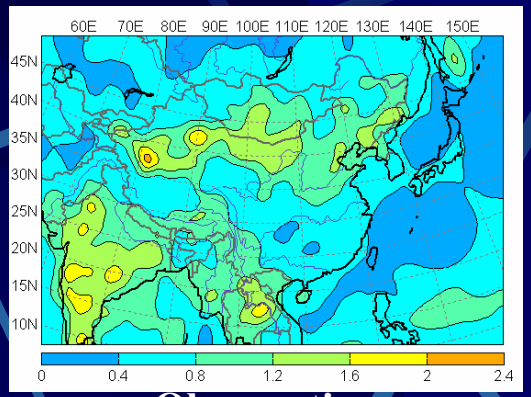
SNU RCM



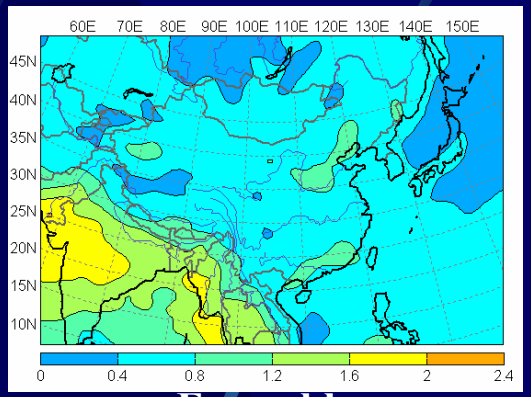
CSIRO CCAM

Standard Deviation of January Total Precipitation

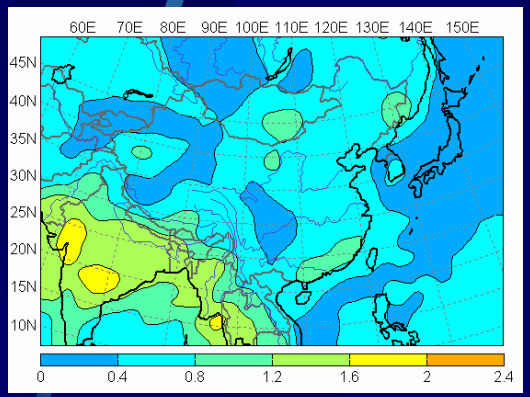
$$P_{std} = \sqrt{\frac{1}{10}\sum_{i=1}^{10}\left(V_i - \overline{V}\right)^2} \Big/ \overline{V}$$



Observation



Ensemble



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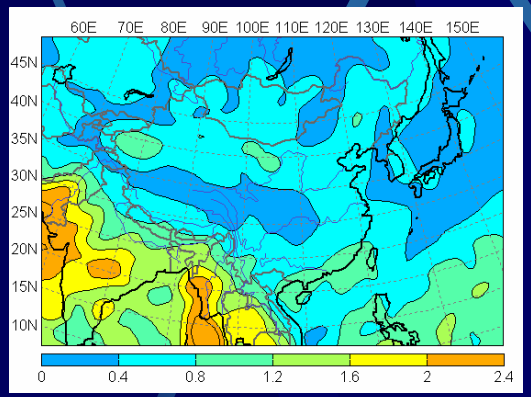

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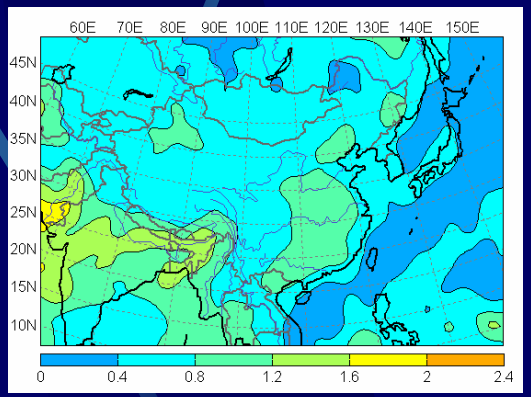
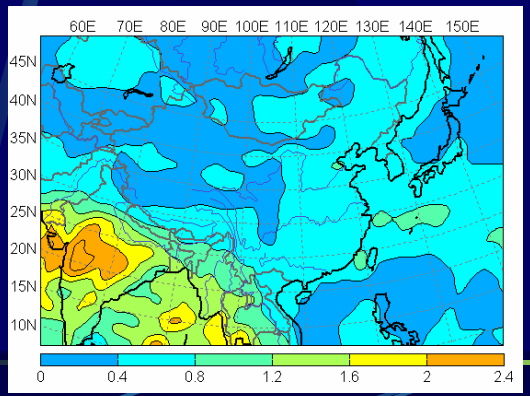
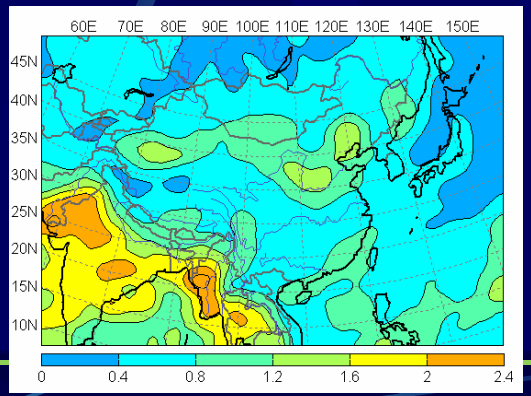


MRI



RegCM3



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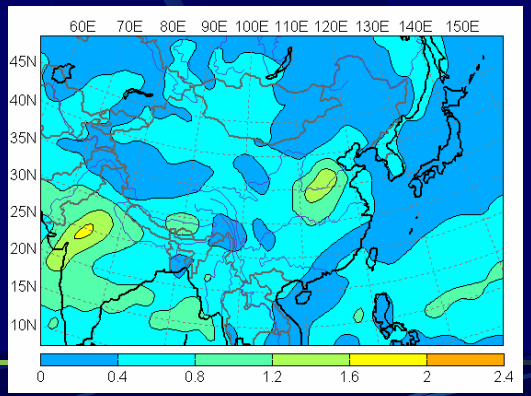
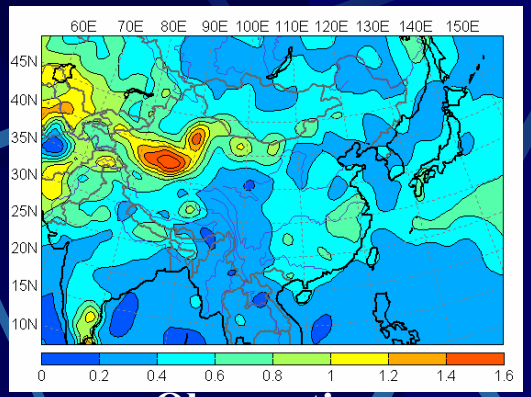
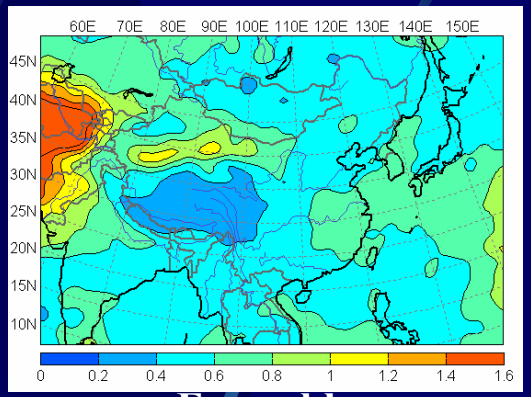


CSIRO CCAM

Standard Deviation of July Total Precipitation



Observation



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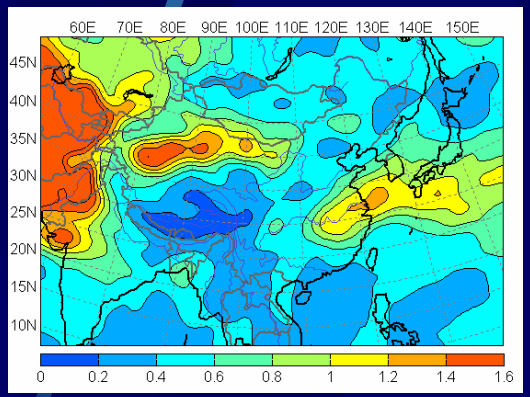

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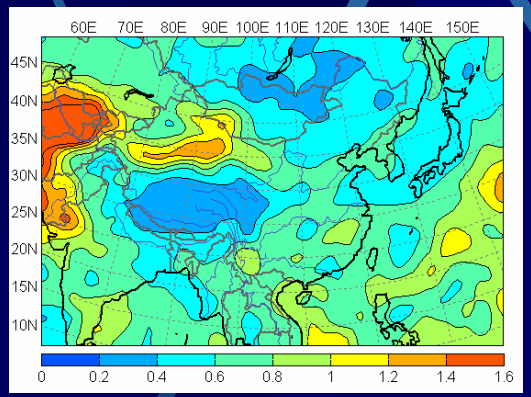

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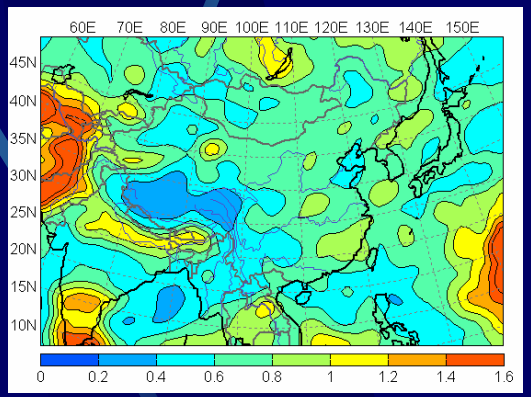
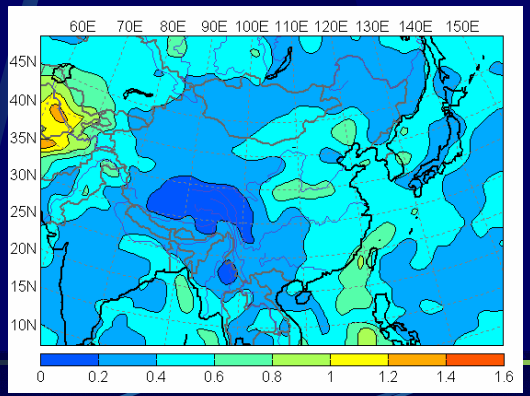
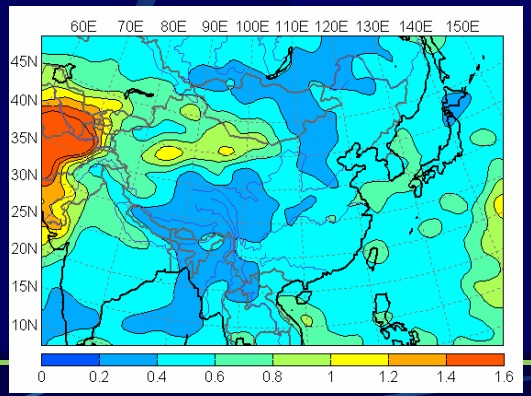


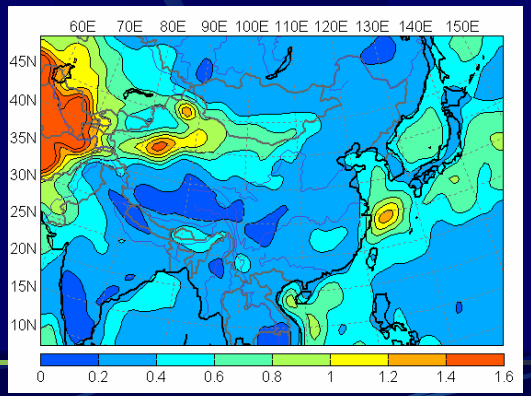
MRI



RegCM3



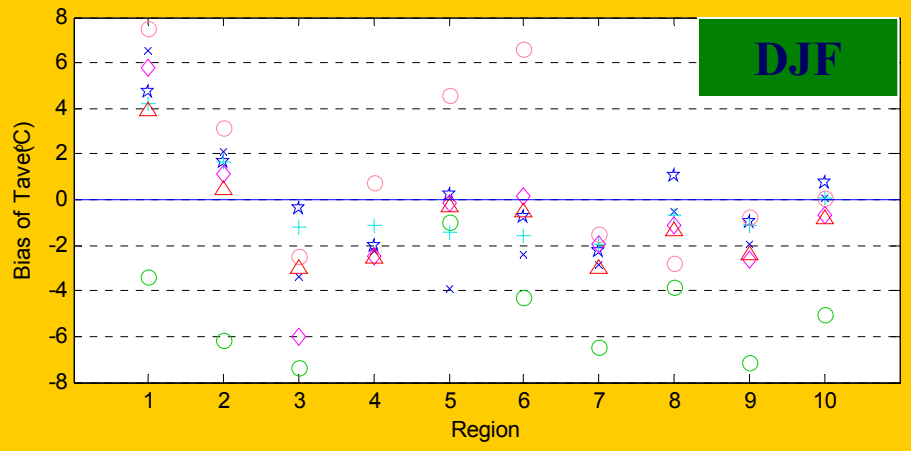
SNU RCM

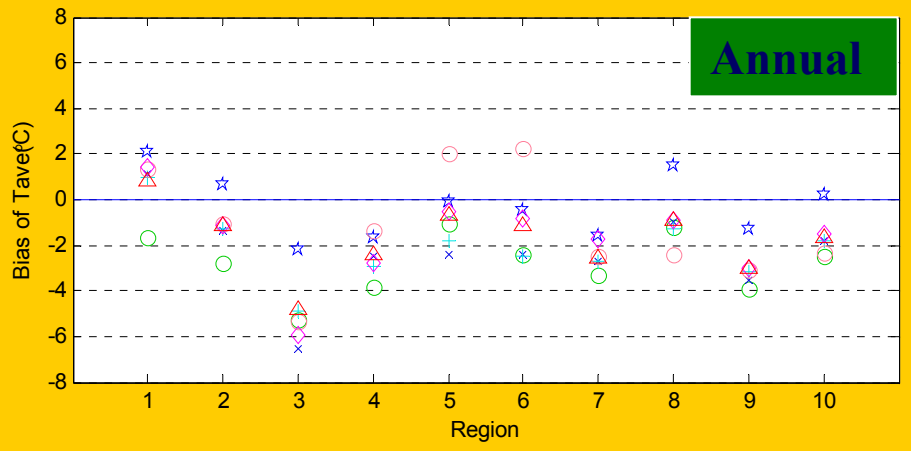


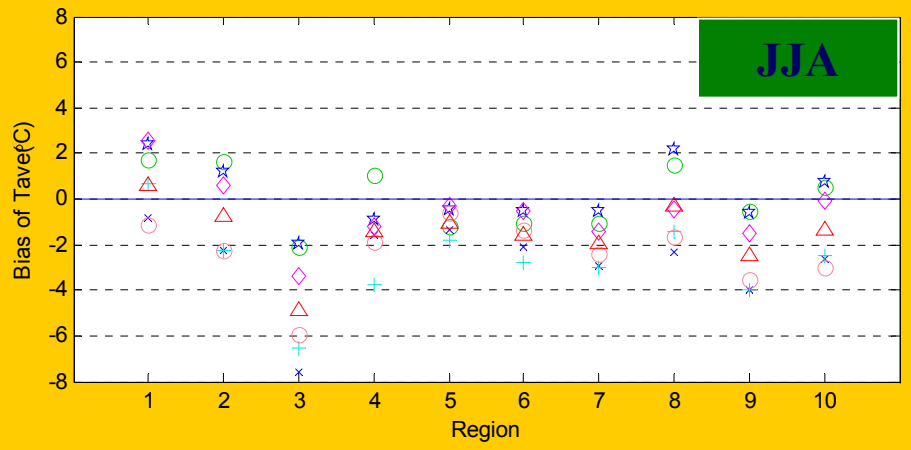
CSIRO CCAM

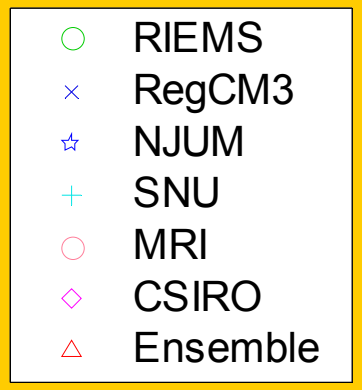
Sub-regional statistical analysis

Temperature Bias

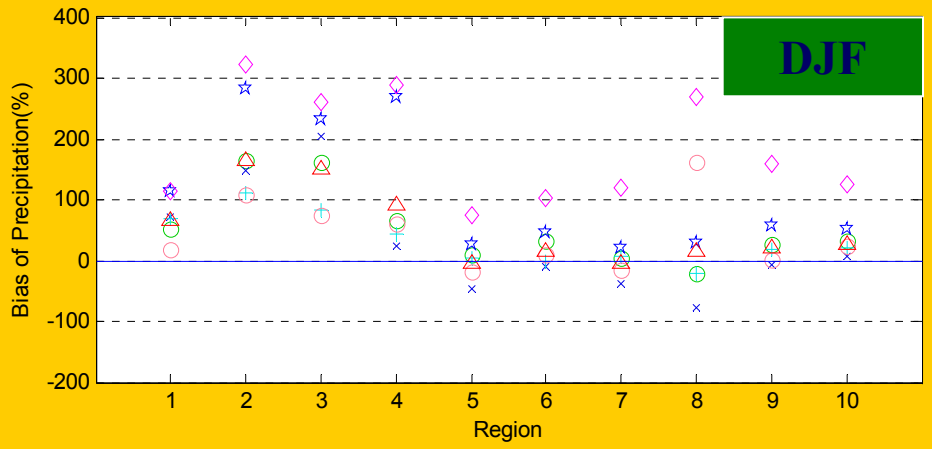


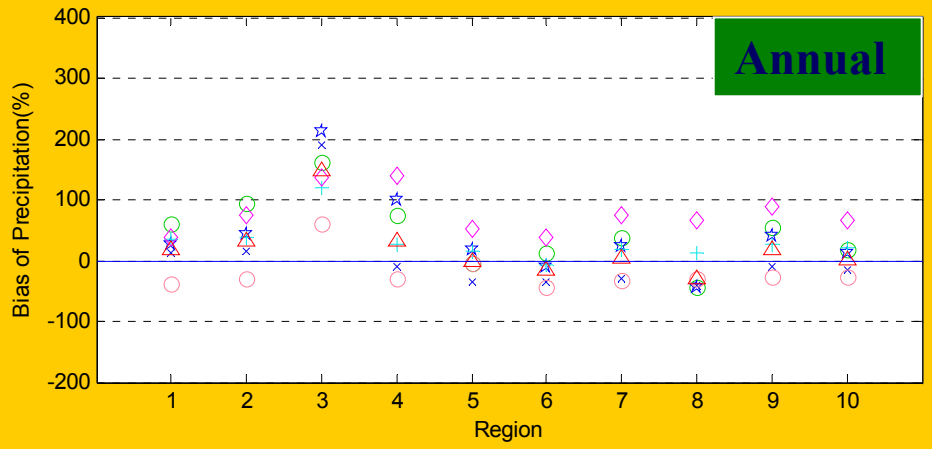


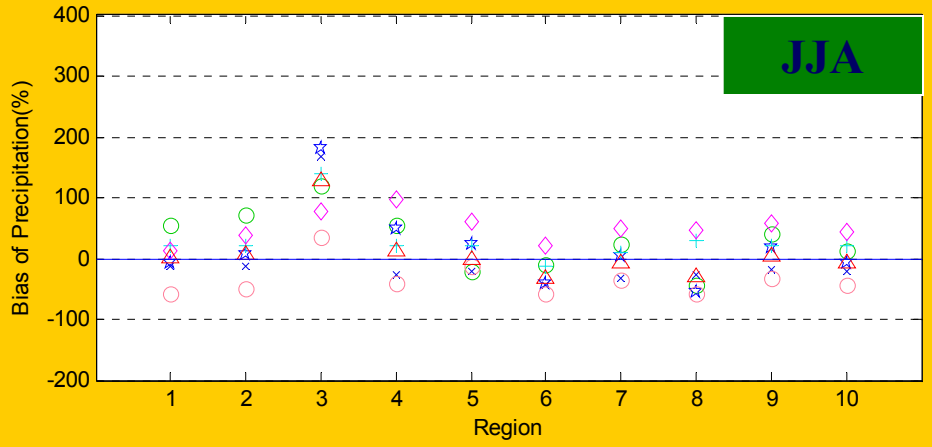


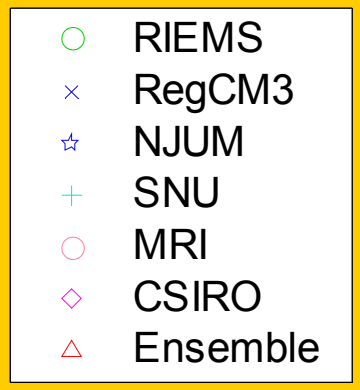


Precipitation Bias(%)



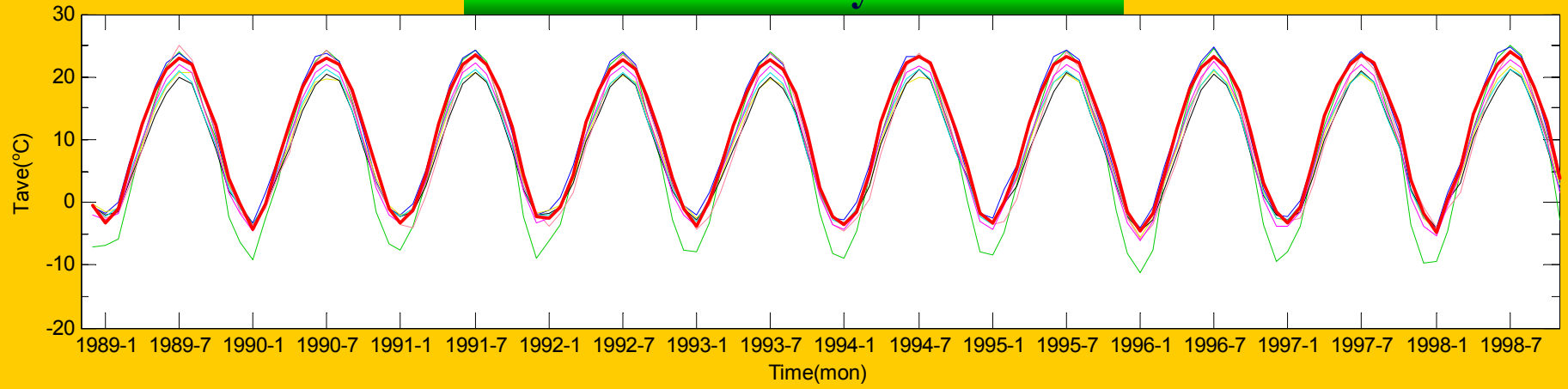




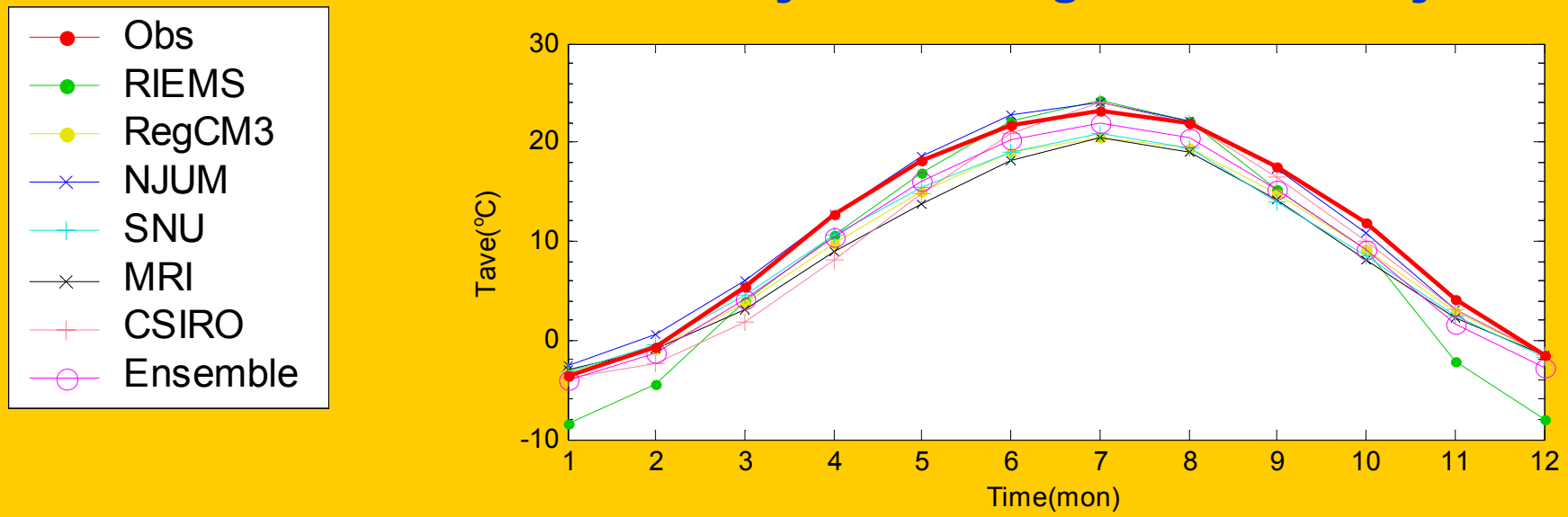


Temporal Variation of Regional Averaged T_{surf} for Entire Continent

Annual Cycle

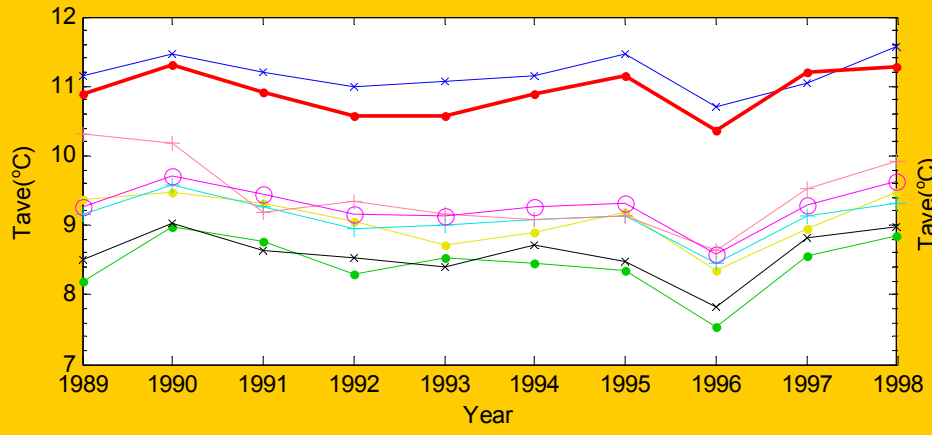


10-years averaged seasonal Cycle

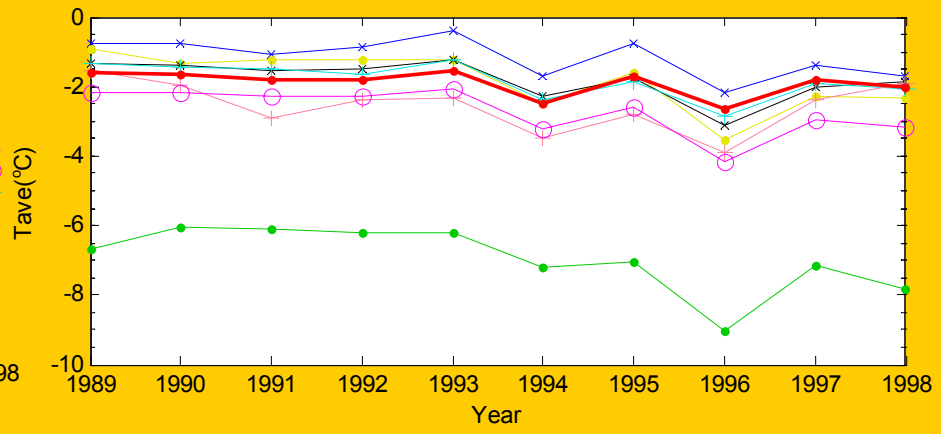


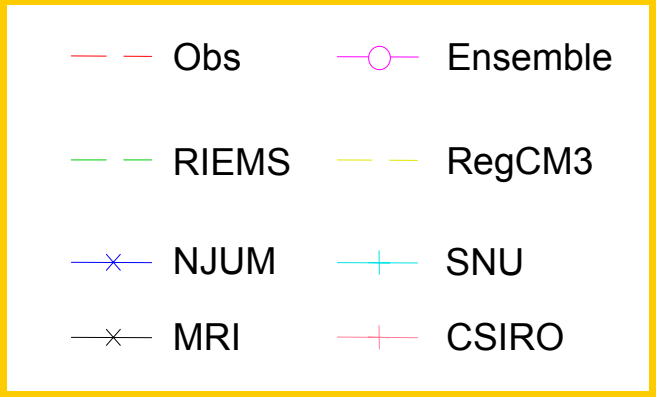
Inter-annual variation of surface temperature

Annual mean .



DJF





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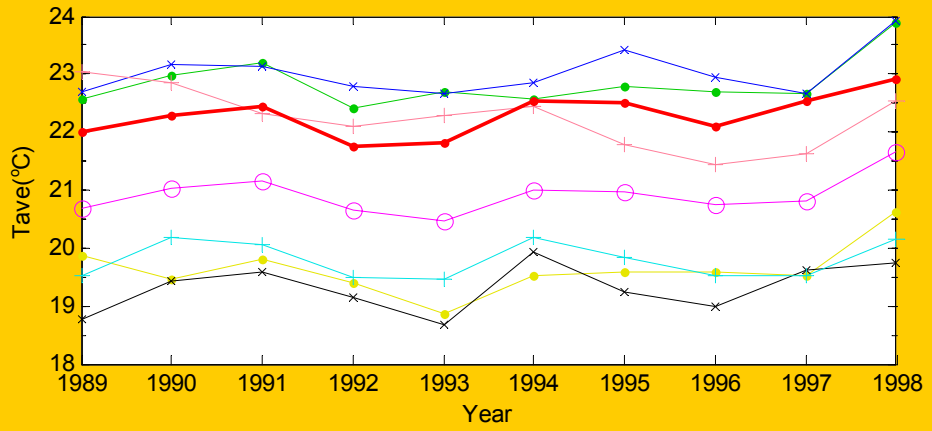
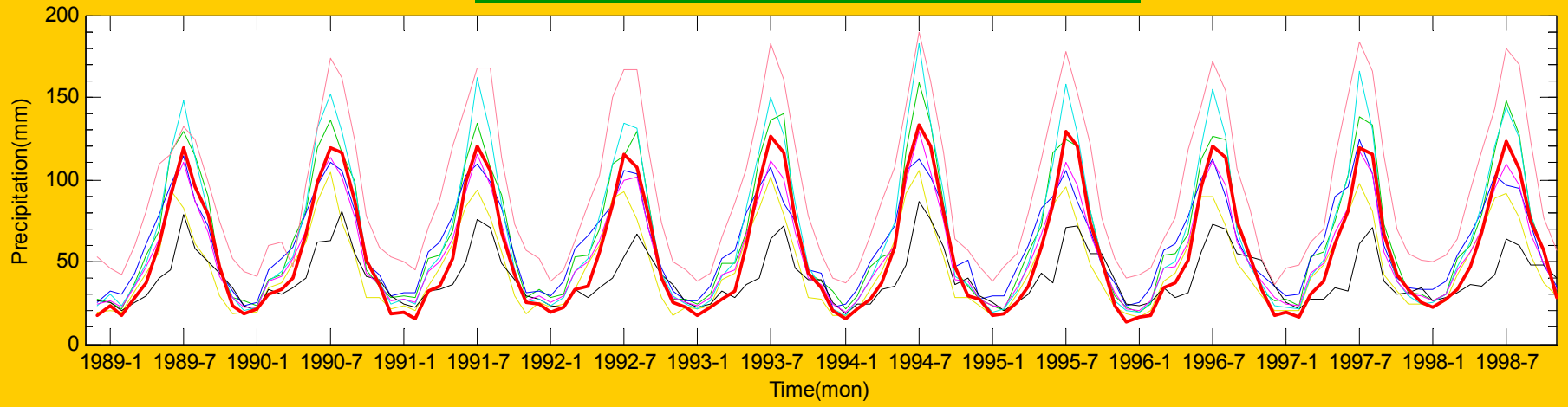
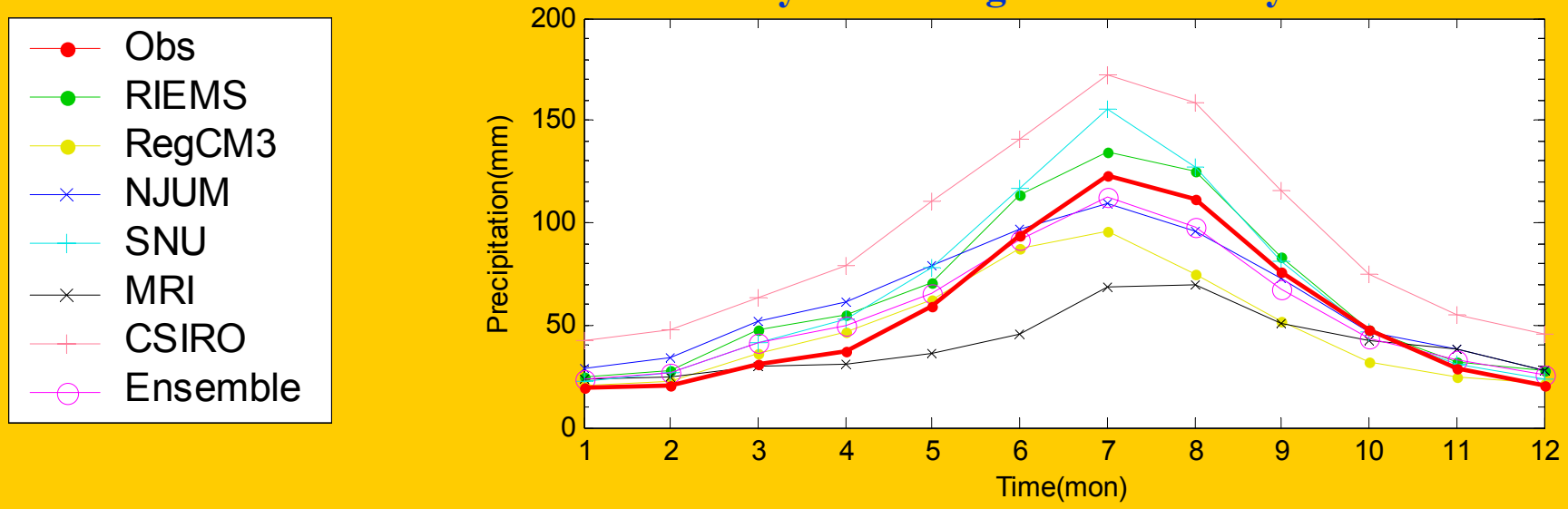


Temporal Variation of Regional Averaged Precipitation over Entire Continent

Annual Cycle

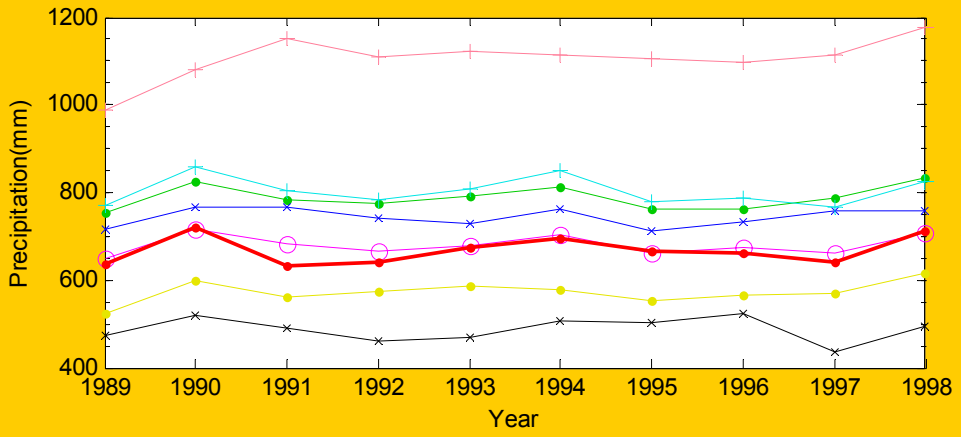


10- year Averaged Seasonal Cycle



Inter-annual variation of total precipitation

Annual total .



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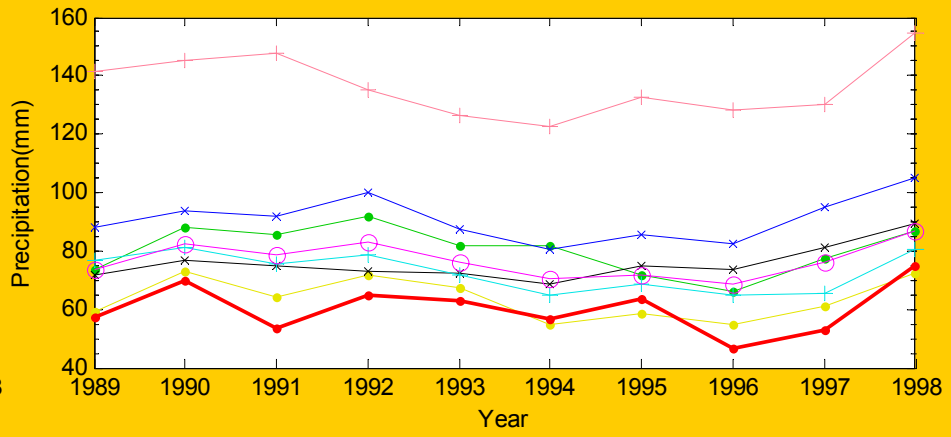

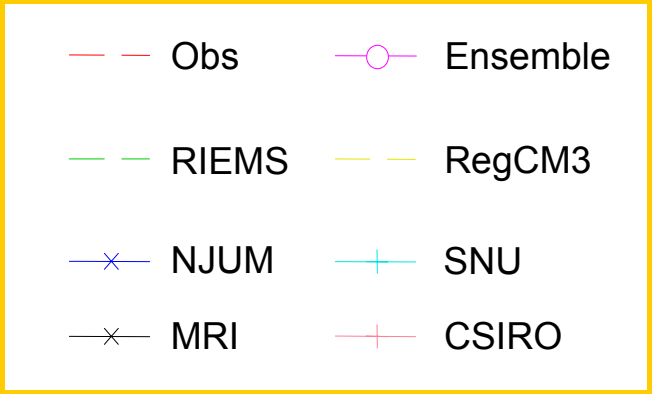

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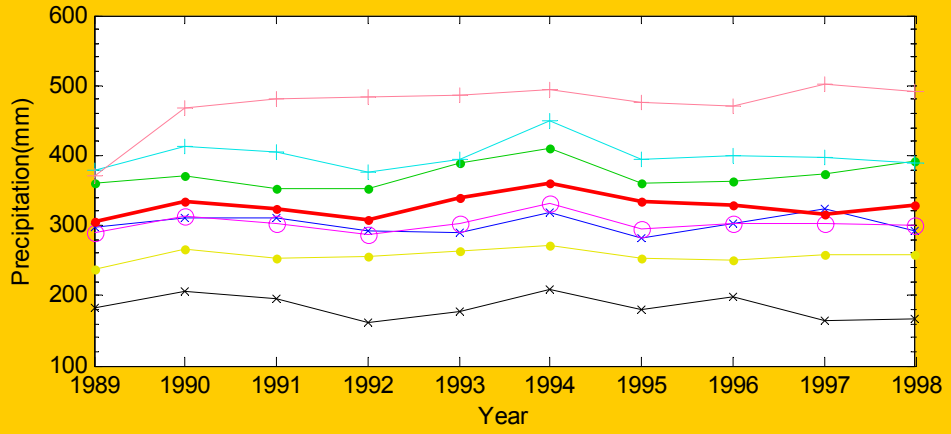
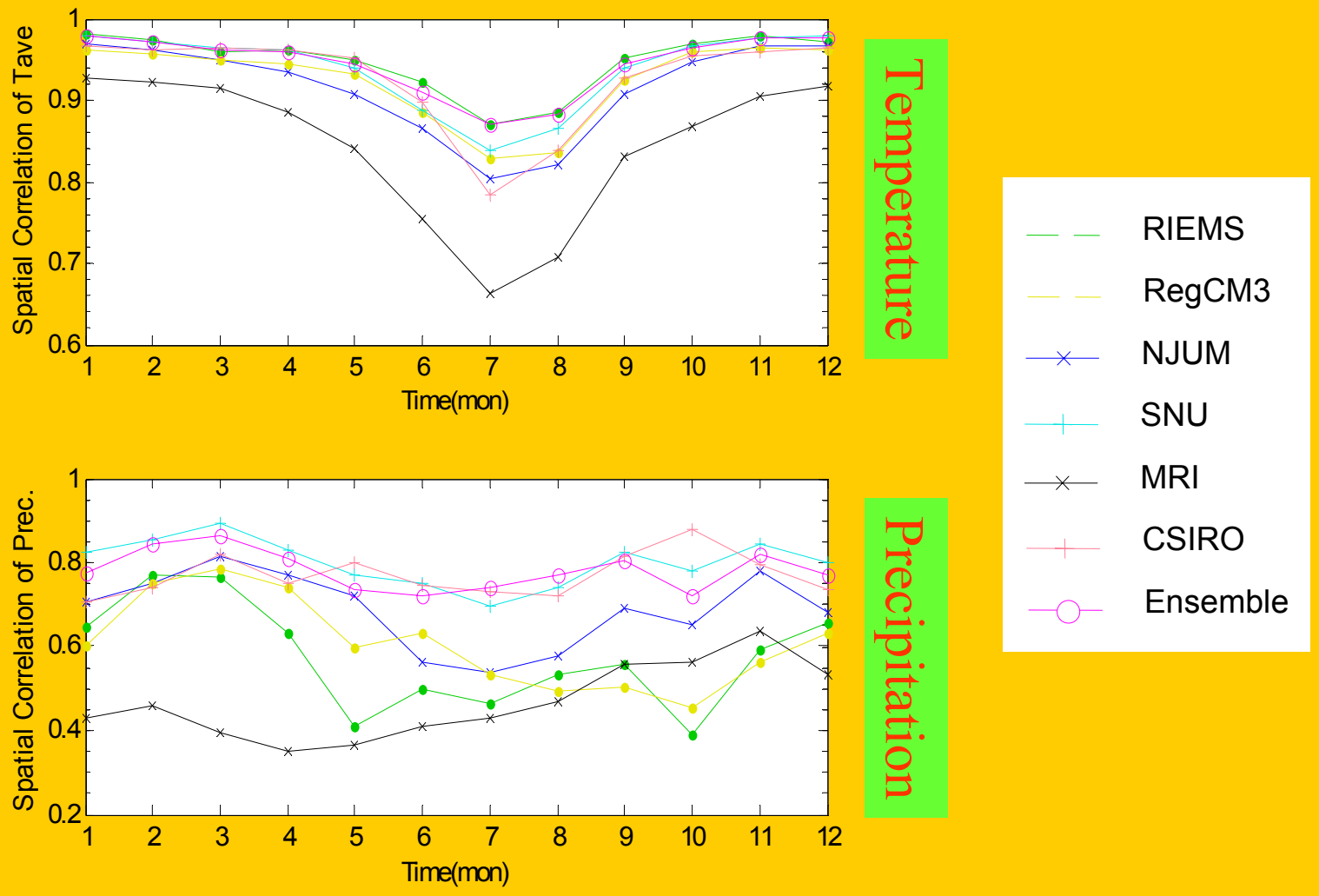
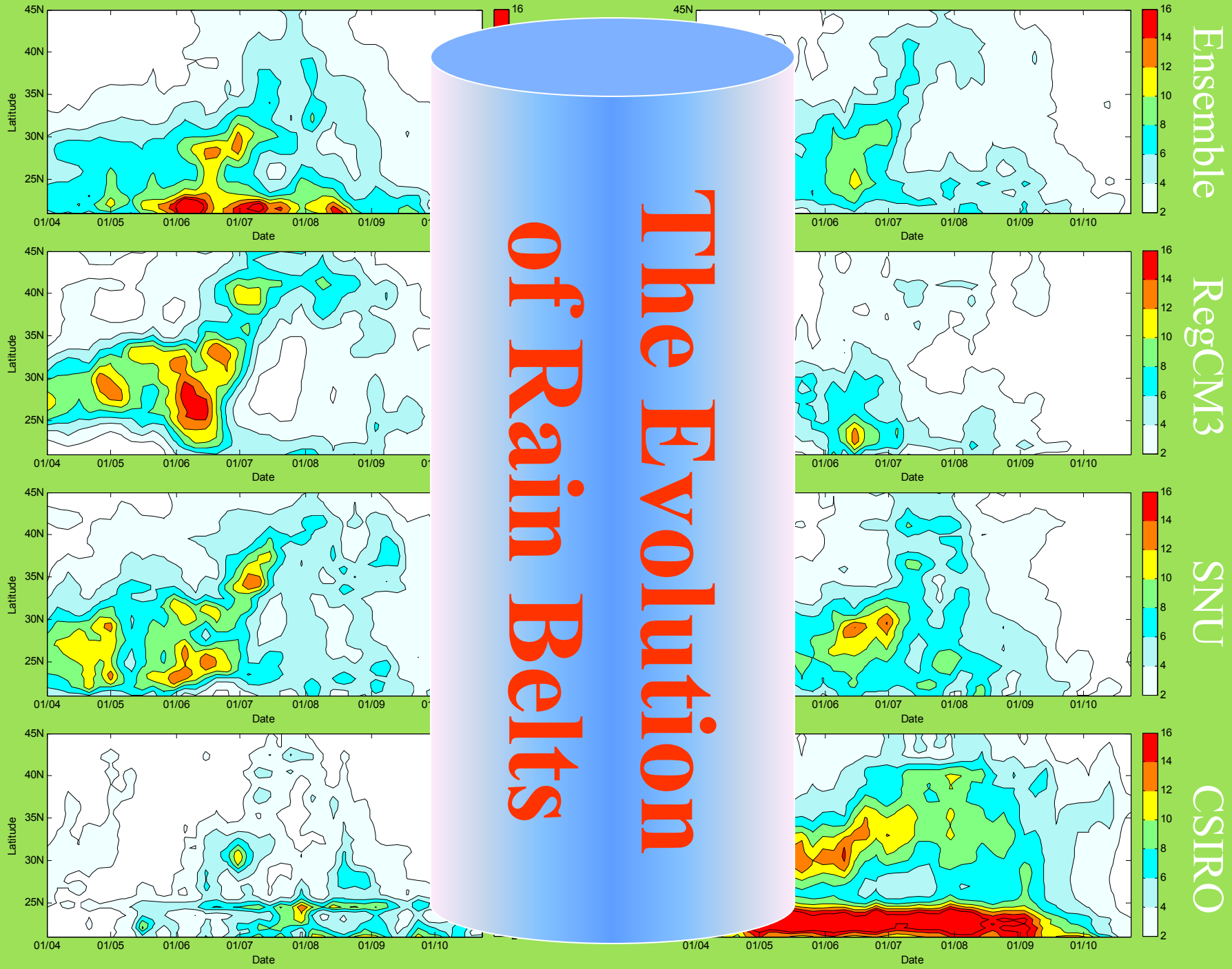


Seasonal Variation of Spatial Correlation Coefficient Between Simulation and Observation



The Evolution of Rain Belts



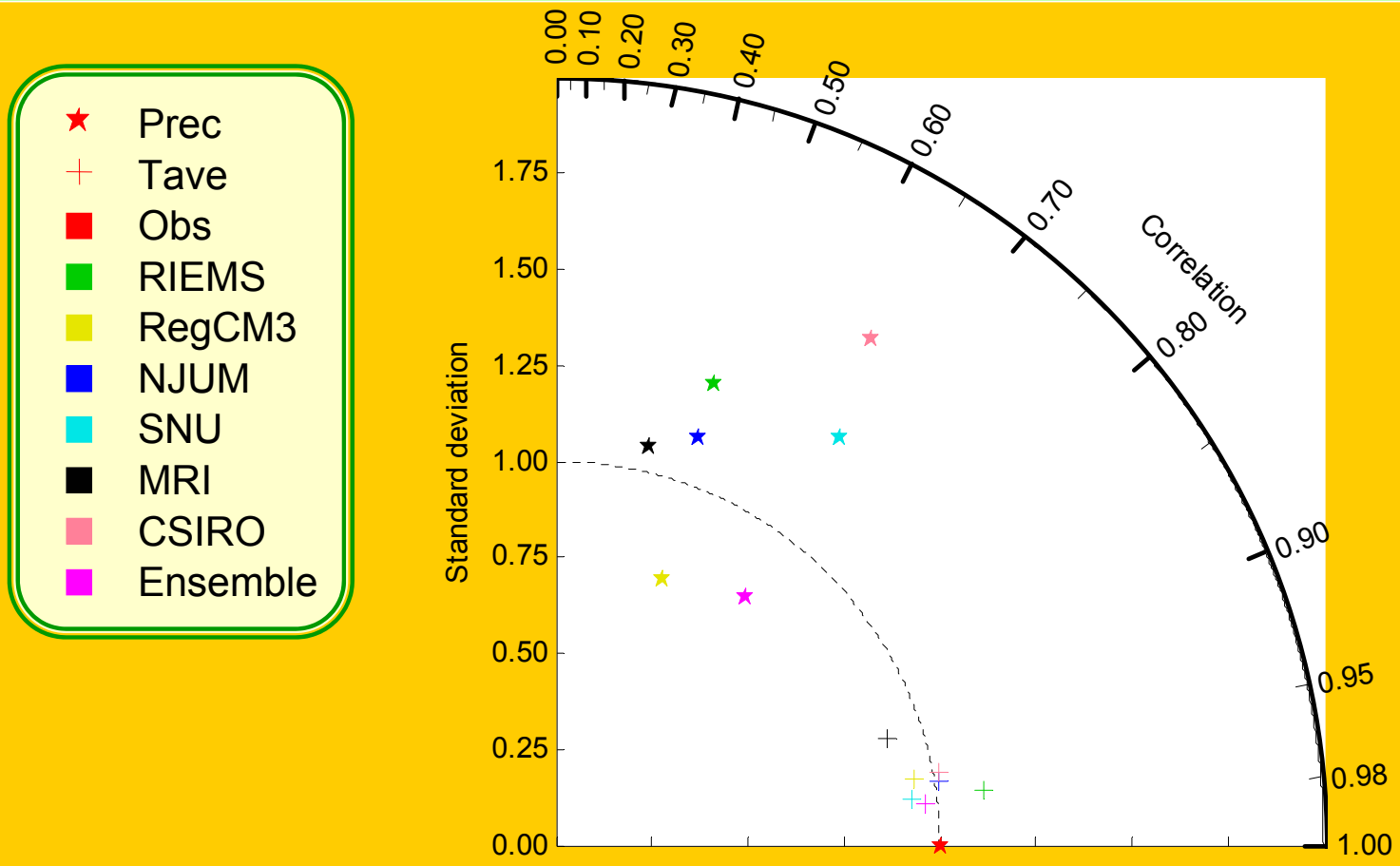
10- year Mean over Continent

Model	Precipitation(mm)						Mean Temperature (℃)					
	Year		Summer		Winter		Year		Summer		Winter	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
OBS	668	36	328	14	60	3.9	10.9	9.4	22.3	0.8	-1.9	1.5
RIEMS	789	38	373	13	80	4.0	8.5	11.6	22.8	1.0	-6.9	2.2
NJUM	744	28	302	9	91	5.0	11.2	9.5	23.0	0.9	-1.2	1.6
RegCM3	573	26	257	10	64	3.4	9.0	8.4	19.6	0.8	-1.8	1.4
MRI	488	16	184	14	76	3.9	8.6	8.2	19.3	1.1	-1.8	1.2
SNU RCM	804	44	400	19	73	4.1	9.1	8.4	19.8	0.9	-1.8	1.4
CSIRO CCAM	1106	45	472	18	136	5.6	9.4	9.7	22.2	1.4	-2.6	1.3
Ensemble	680	30	303	10	77	3.5	9.3	9.2	20.9	0.9	-2.7	1.5

Bias and Correlation Coefficients

Model	Precipitation						Mean Temperature					
	Year		Summer		Winter		Year		Summer		Winter	
	Bias (%)	Corr	Bias (%)	Corr	Bias (%)	Corr	Bias (℃)	Corr	Bias (℃)	Corr	Bias (℃)	Corr
RIEMS	18	0.98	14	0.77	33	0.69	-2.5	0.992	0.6	0.91	-5.0	0.73
NJUM	11	0.94	-8	0.53	51	0.60	0.3	0.996	0.7	0.84	0.7	0.90
RegCM3	-14	0.94	-22	0.31	6	0.80	-1.8	0.997	-2.7	0.85	0.1	0.88
MRI	-27	0.90	-43	0.83	25	0.54	-2.3	0.994	-3.0	0.92	0.1	0.94
SNU RCM	20	0.98	22	0.86	21	0.80	-1.8	0.996	-2.5	0.94	0.1	0.95
CSIRO CCAM	66	0.97	44	0.70	126	0.59	-1.5	0.984	-0.1	0.78	-0.7	0.71
Ensemble	2	0.98	-8	0.87	27	0.79	-1.6	0.997	-1.3	0.96	-0.8	0.91

Correlation Coefficient Between Simulation and Observation and Standard Deviation Normalized by Observation of Monthly Averaged Temperature and Monthly Total Precipitation According to Total Space-Time Series



Preliminary Summary

- All the models can reproduce the spatial patterns of multi-year averaged annual, winter and summer temperature reasonable well;
- The seasonal and inter-annual cycles of temperature are well simulated by all models, but the magnitudes are different from observation by about ±3℃.
- The spatial pattern of seasonal total precipitation are well captured by nearly all the models, with winter results being better, but most models tend to overestimate the precipitation in arid and semi-arid regions of central Asia, especially in winter;
- The seasonal cycles of precipitation are well simulated, but not for the inter-annual variations. .

- **Most models can basically simulate the evolution of main rain belts, but there are bigger differences among different models in against the observations.**

- **The ensemble mean fields of both temperature and precipitation, even in a simple scheme, are in better agreement with the observation than any single model in most cases, but it is not the case for the variability of precipitation.**

Questions

- Cold bias of most models;
- Over estimation of precipitation over semi-arid northwest China;
- Inter-comparison with 18 month-run: Can the longer-term simulation reduce the bias or increase?
- Inter-comparison of RCMs with global variable resolution model: Does RCM make sense in providing useful regional information which are not captured by VGCM?
- Why ensemble approach improve the results of some variables, but not for others?

Deliverable Outcomes

- CD ROMs contain model outputs of 10 years simulation of participating models;
- CD ROMs contain 10 years station data for model validation;
- A website to contain all the information of Phase II data and initial research papers;
- A proceedings of workshop containing scientific papers presented at the workshop or a special issue of a Journal;
- A summary paper of 10 years simulation of surface climate.

Future direction

- Further analysis of 10 years simulation;
- Inter-comparison of RCM with variable resolution GCM;
- Ensemble studies:
  - # a group of RCMs nested with one global analysis or one GCM;
  - # 2-3 GCMs to drive one RCM;
  - # a set of parameterization schemes in one RCM, etc.
- Study of ensemble schemes

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