南京大學
NANJING UNIVERSITY

TPE-GHP/GEWEX Joint Workshop

Regional Climate Modeling over Tibetan Plateau

Jianping Tang, Pinhong Hui, Linyun Yang, and Shuyu Wang

wsy@nju.edu.cn
Nanjing University
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Tibetan Plateau

- Complex landscape: mountainous ranges, alpine lakes, glaciers…
- Complex processes: terrain related convection, thermo-dynamics, land-atmosphere interactions
- Climate systems: monsoons, westerly
- Human Activities: mining, manufacturing, etc.
- Changing regional climate: effect on regional natural resources, effect on the downstream climate, etc.

Where the Data Come From

- Observations
- Global and Regional Reanalyses
- Model Simulations

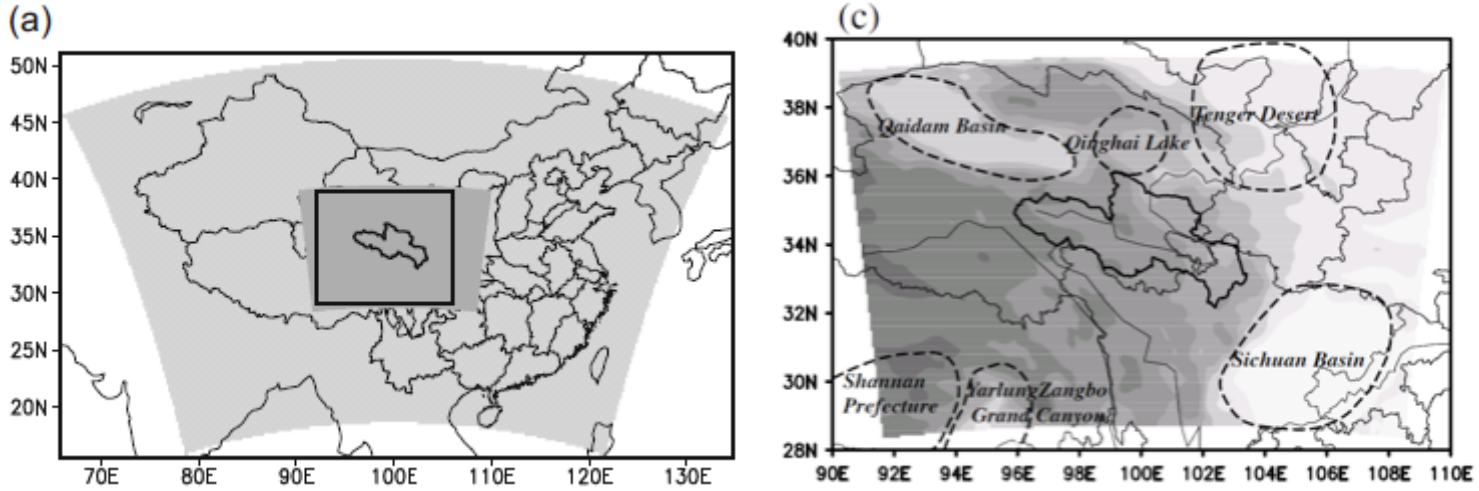
Regional Climate Models

- Models can properly address the thermo-dynamics and physical processes …

Motivation

- Can higher resolution improve the model performance over Tibetan Plateau?
- Influence of RCM's model physics on regional climate
- Can ensemble help to reduce the uncertainty of climate change on the Plateau?

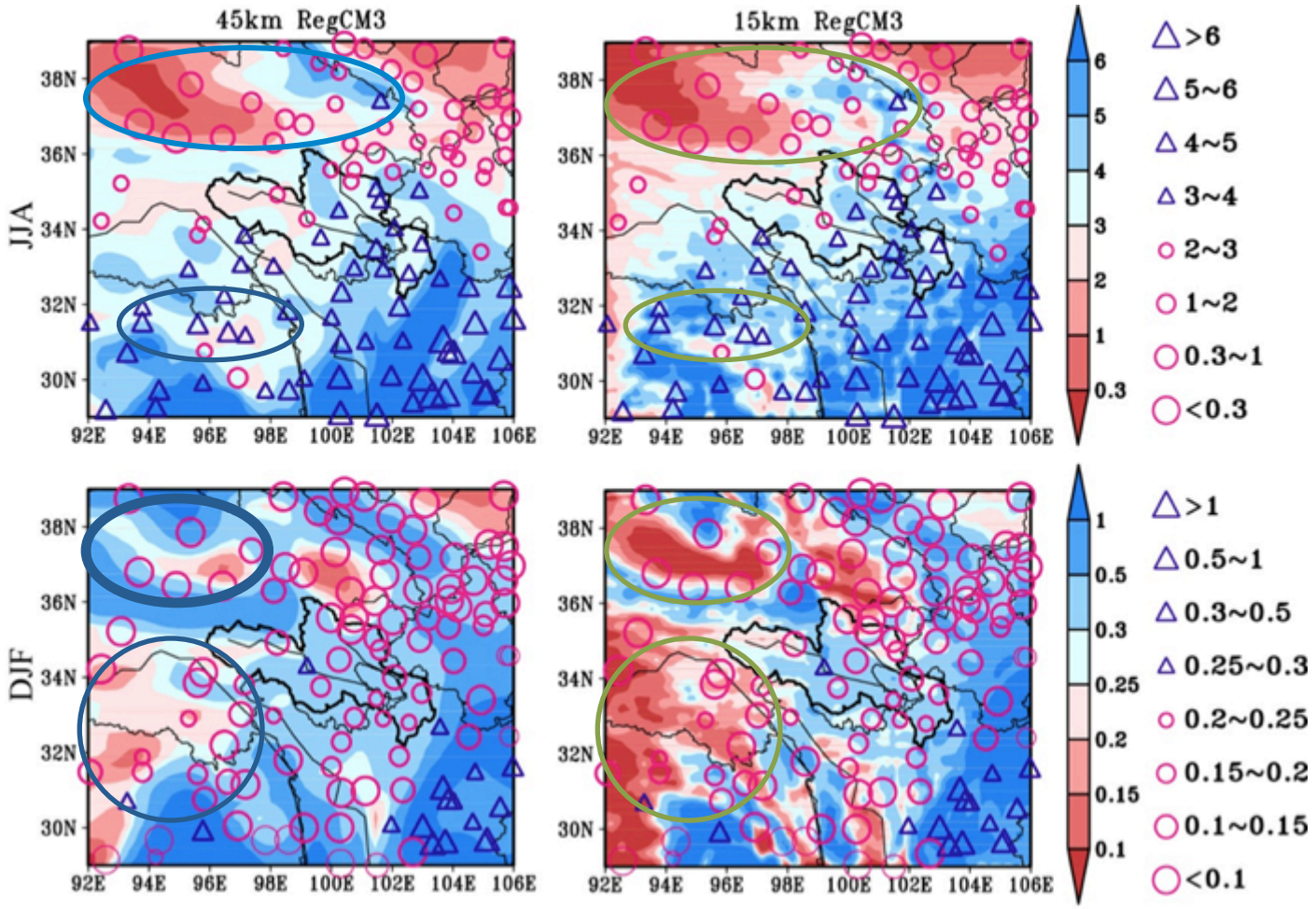
Impact of resolution on regional climate modeling in the source region of Yellow River using ReGCM3



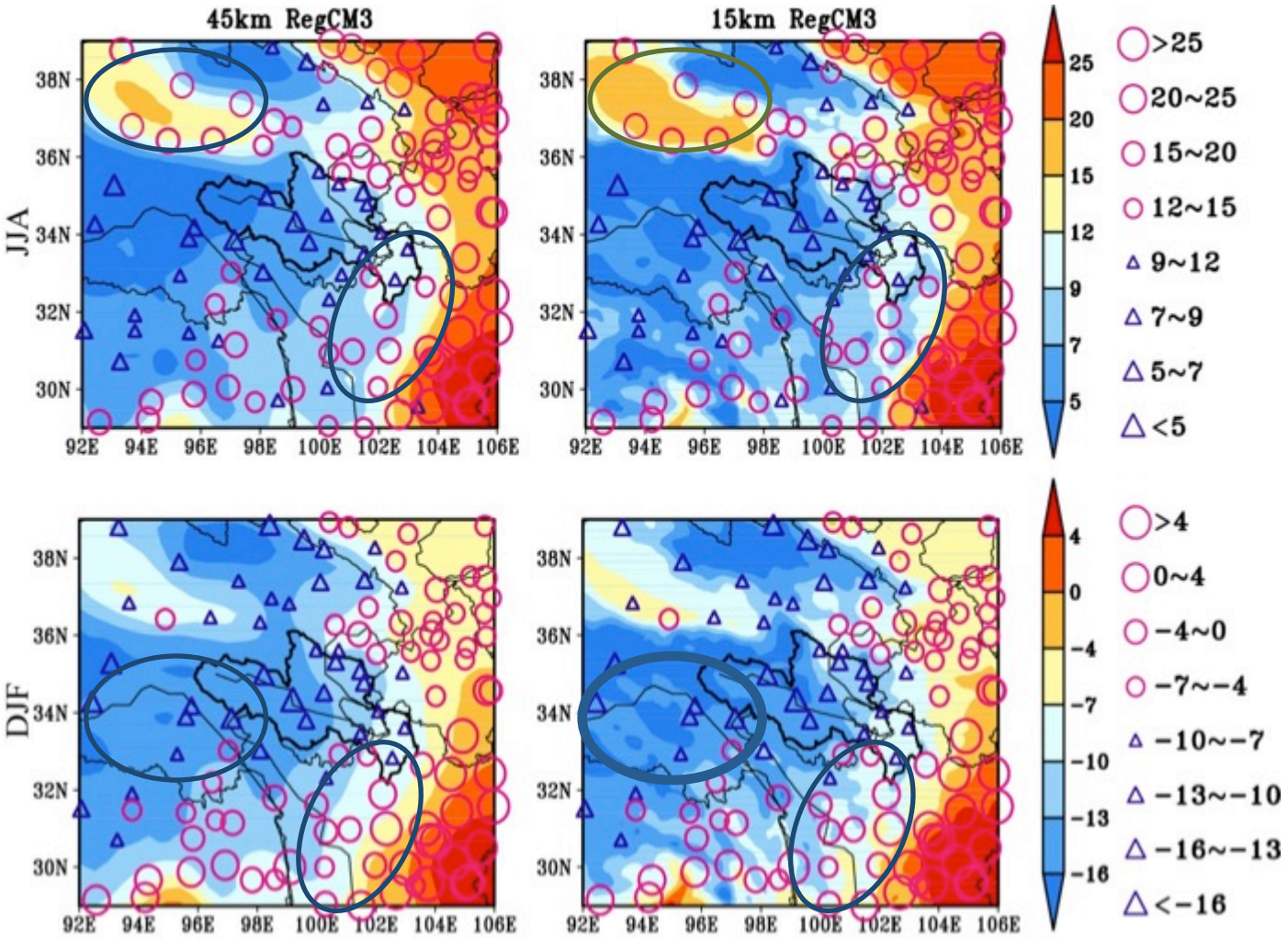
Simulation period	1990-2009
IC/BC	ERA-Interim
Resolution	15km nested within 45km
Land surface	BATS
Radiation	CCM3
Microphysics	SUBEX
PBL	Holtslag
Cumulus Convection	Grell

- Daily surface observations from the China Meteorological Administration (CMA)
  - Precipitation
  - surface air temperature
  - daily maximum and minimum surface air temperature
- Consists of 756 meteorological stations, covering the whole country and provides the best data available for China
- 116 stations included in our analysis domain
- Interpolated the model results onto the station locations and evaluated the quality of the simulations

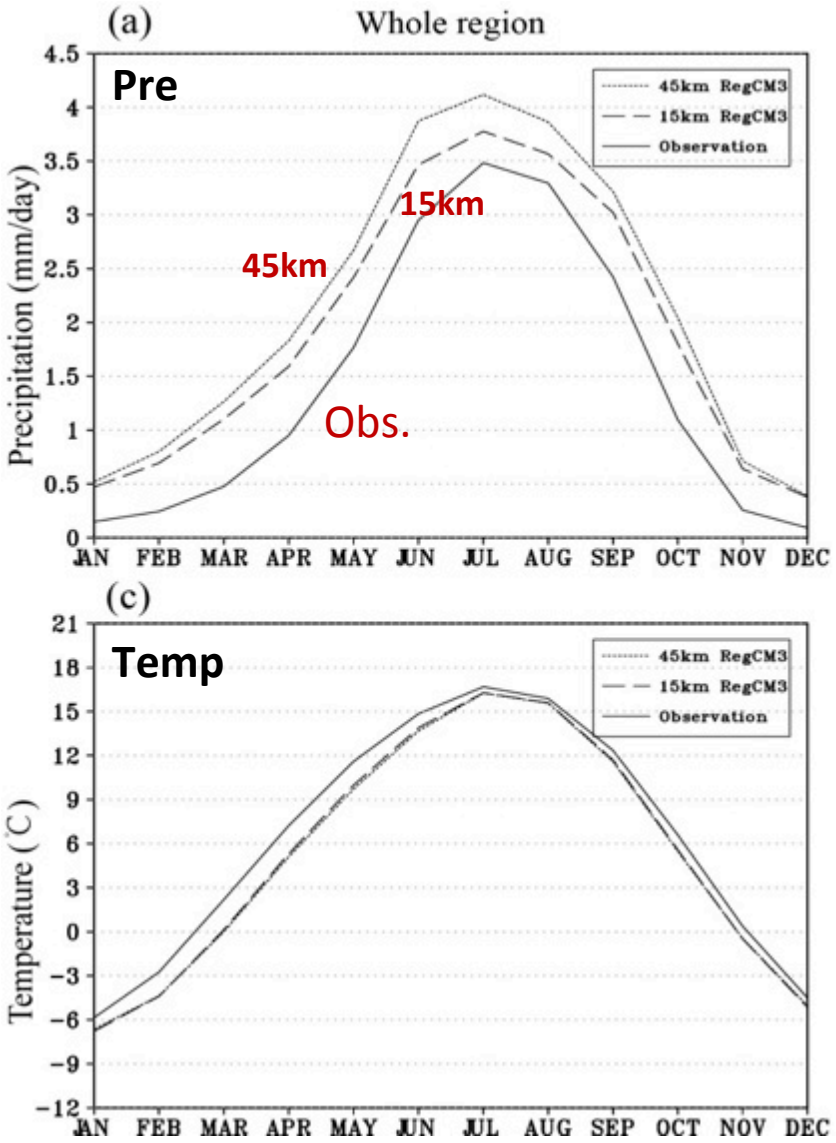
20-year (1990-2009) averaged precipitation with 45 and 15km resolutions (mm/day)



20-year(1990-2009) averaged temperature with 45 and 15km resolutions (℃)



Annual cycles of surface climate

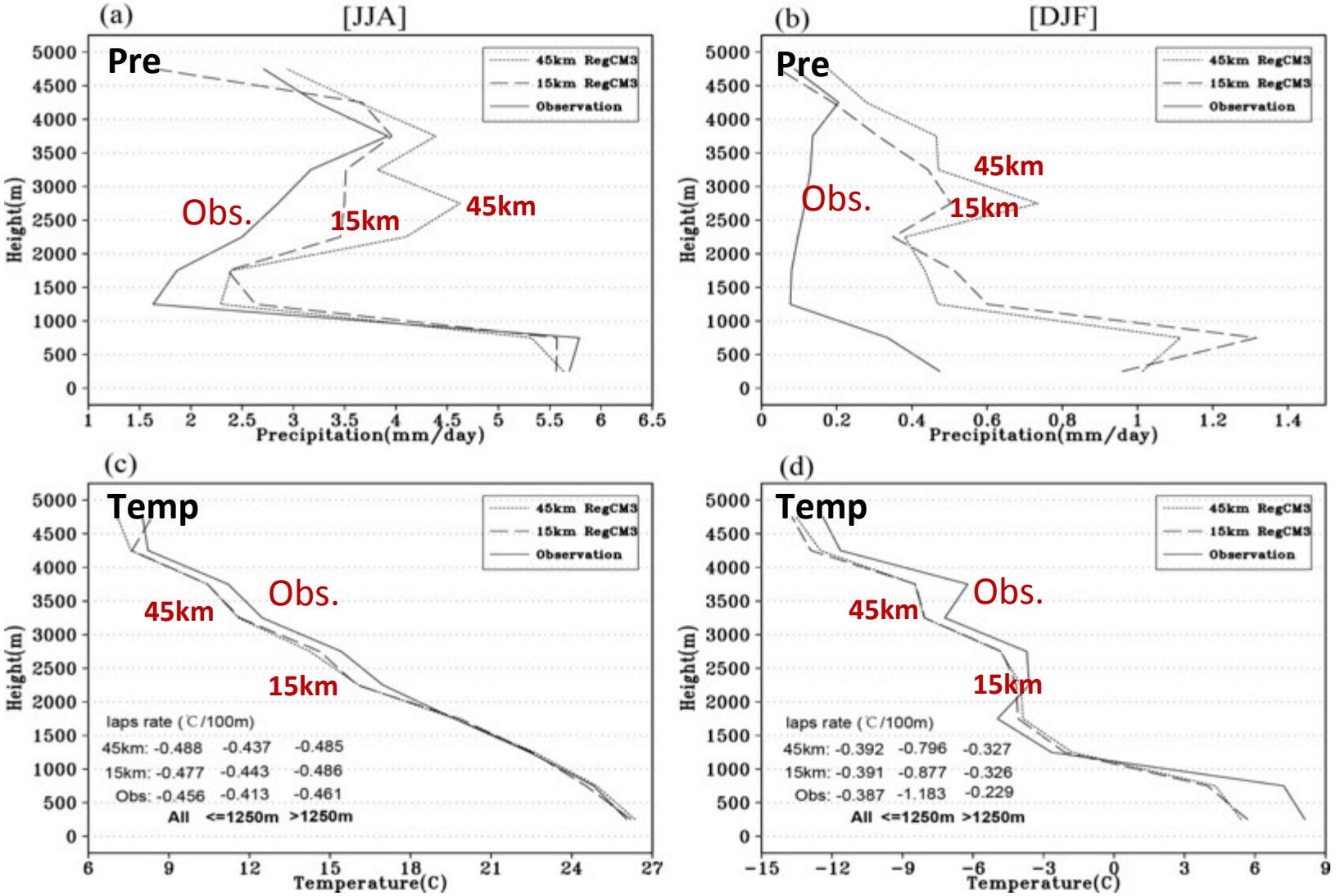


Regional mean statistical indexes for simulated surface climate

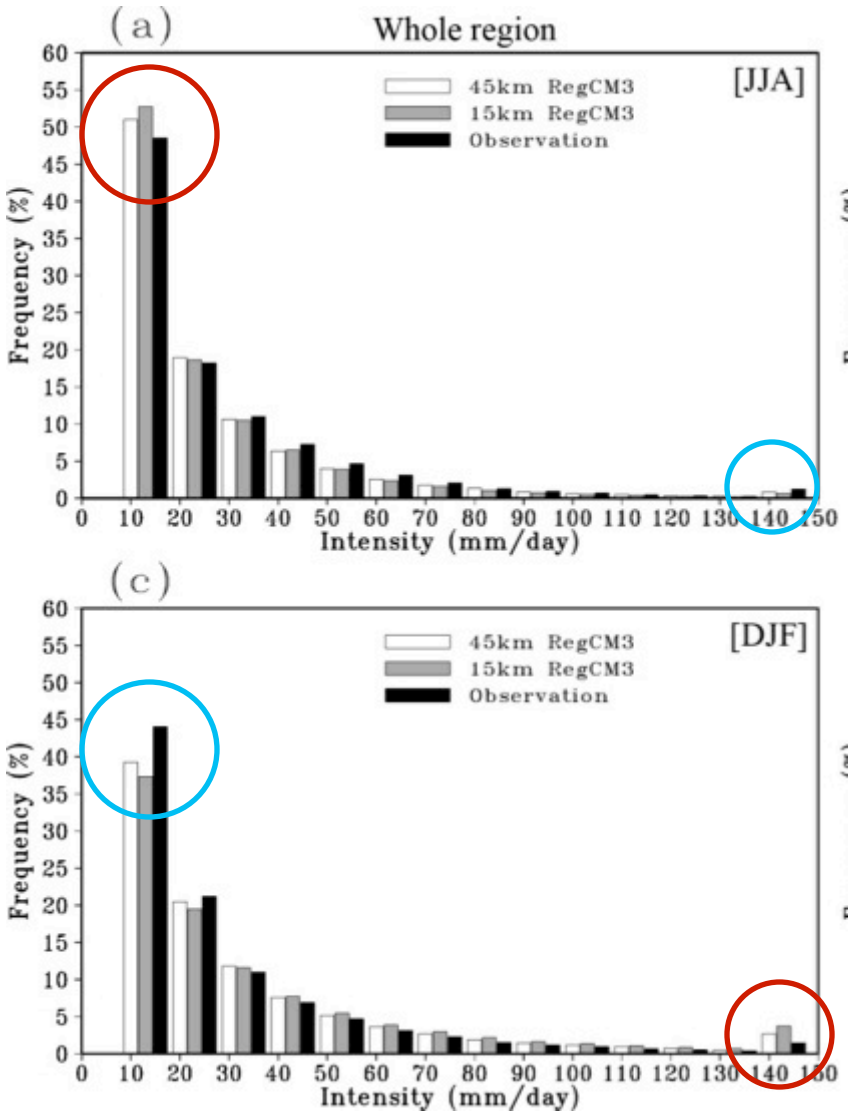
Statistics for Seasonal Pre		Analysis Region			
		MAM	JJA	SON	DJF
BIAS(%)	45km	82.58	22.74	60.44	269.65
	15km	61.83	11.81	46.31	235.99
Spatial R	45km	0.76	0.71	0.74	0.52
	15km	0.75	0.82	0.73	0.57
RMSE(mm/d)	45km	0.89	0.78	0.77	0.41
	15km	0.68	0.49	0.60	0.36

Statistics for Seasonal Temp		Analysis Region			
		MAM	JJA	SON	DJF
BIAS(%)	45km	-1.83	-0.44	-0.67	-0.83
	15km	-1.63	-0.36	-0.60	-0.92
Spatial R	45km	0.98	0.98	0.98	0.94
	15km	0.99	0.99	0.99	0.95
RMSE(C)	45km	1.86	0.53	0.73	0.99
	15km	1.66	0.46	0.68	1.06

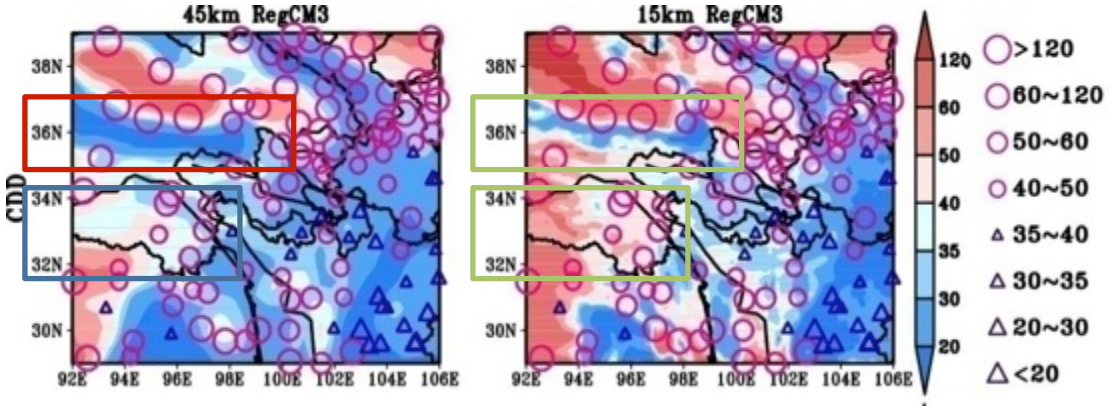
Vertical structure of seasonal regional climate variables



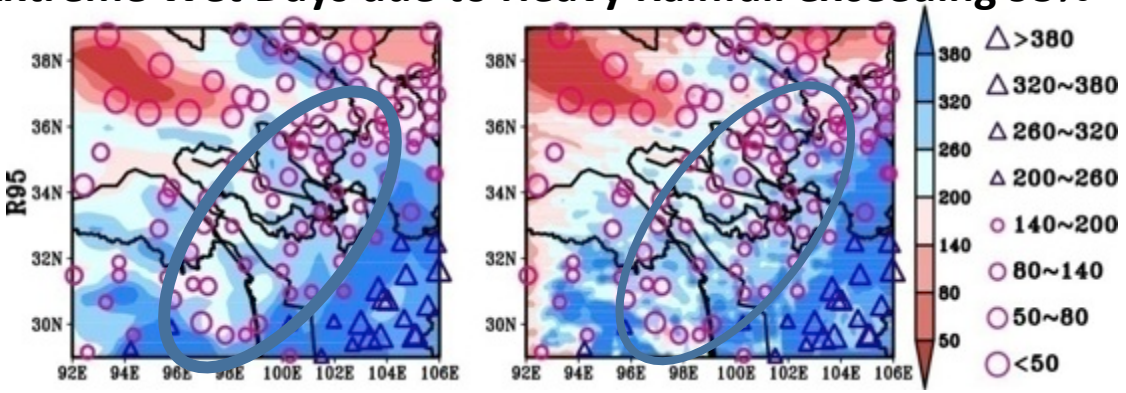
PDFs of daily precipitation



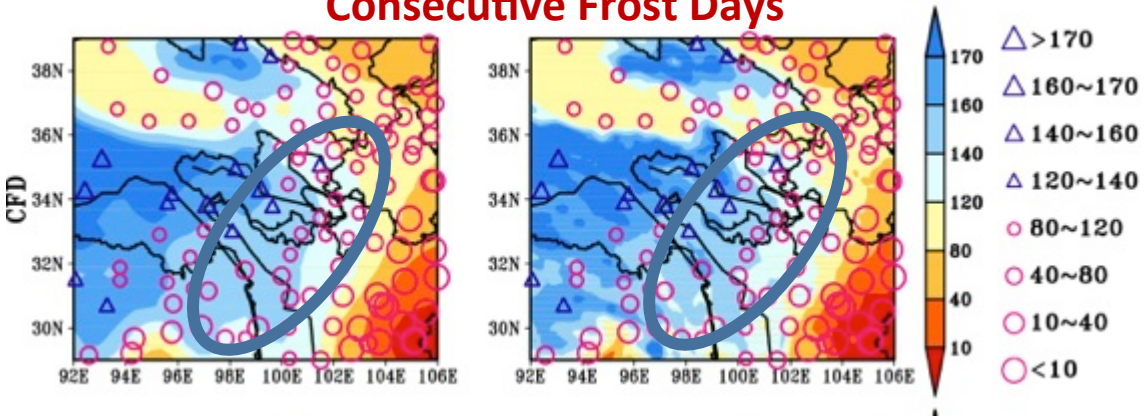
Consecutive Dry Days with rainfall < 1mm/d



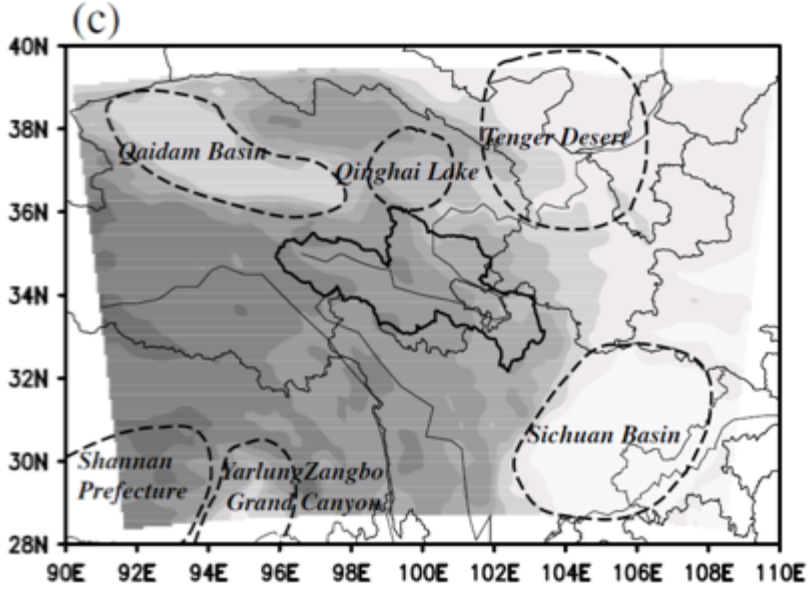
Extreme Wet Days due to Heavy Rainfall exceeding 95%

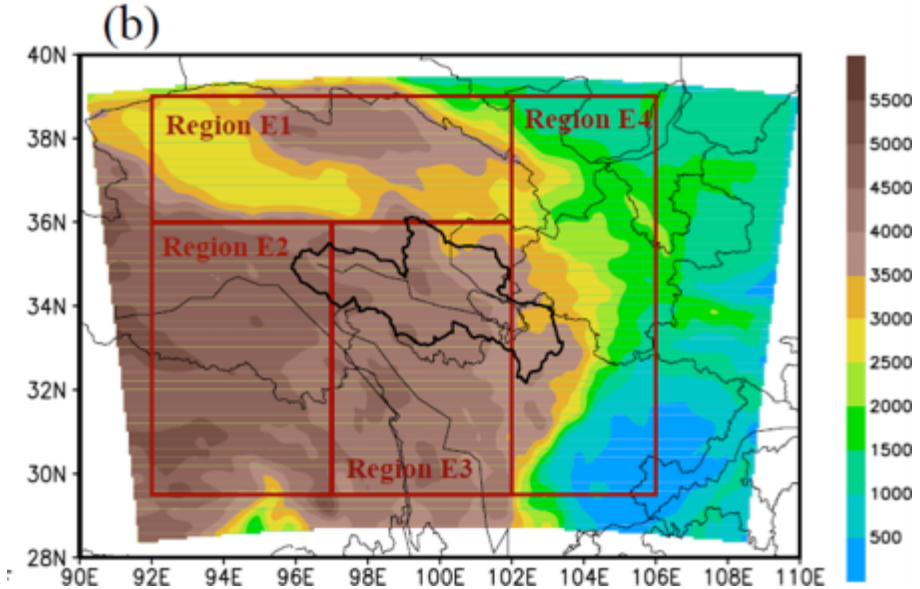


Consecutive Frost Days



High Resolution Regional Climate Change Projection around the Source Region of Yellow River



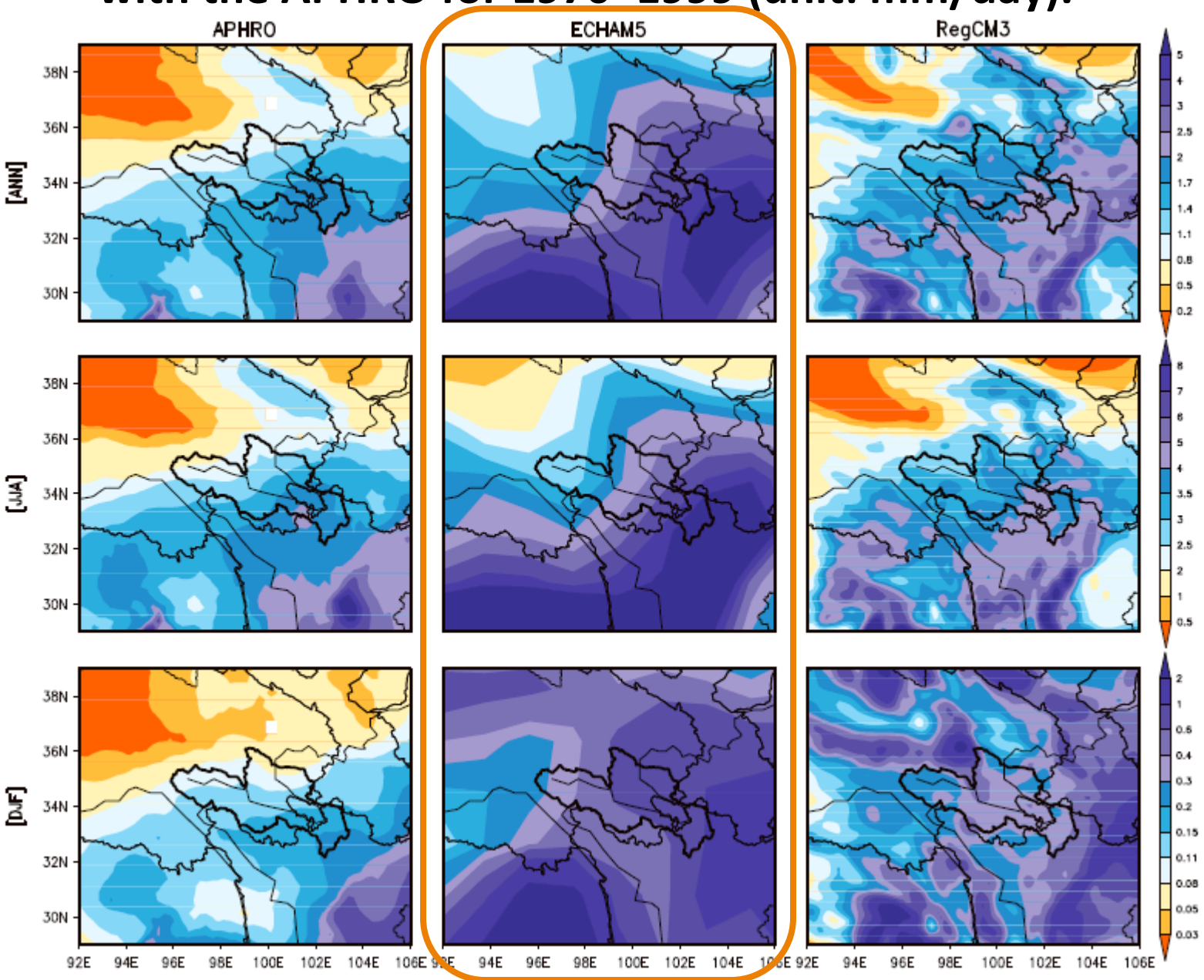


Simulation periods	1979-1999/ 2010-2098
Resolution	15km
IC/BC	ECHAM5
Scenario	A1B
Land surface	BATS
Radiation	CCM3
Microphysics	SUBEX
PBL	Holtslag
Cumulus Convection	Grell

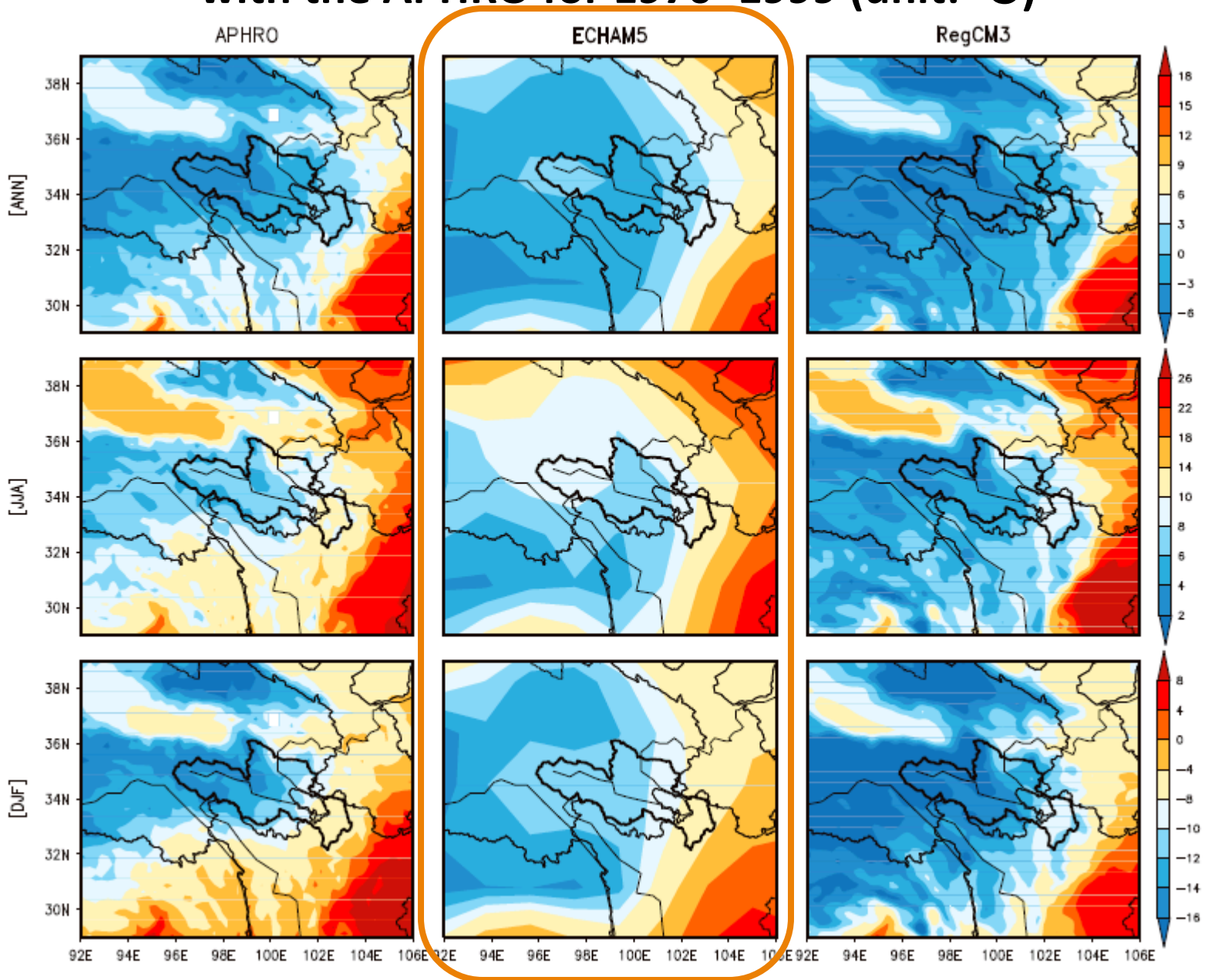
Observation for current climate validation

- APHORODITE at 0.25x0.25

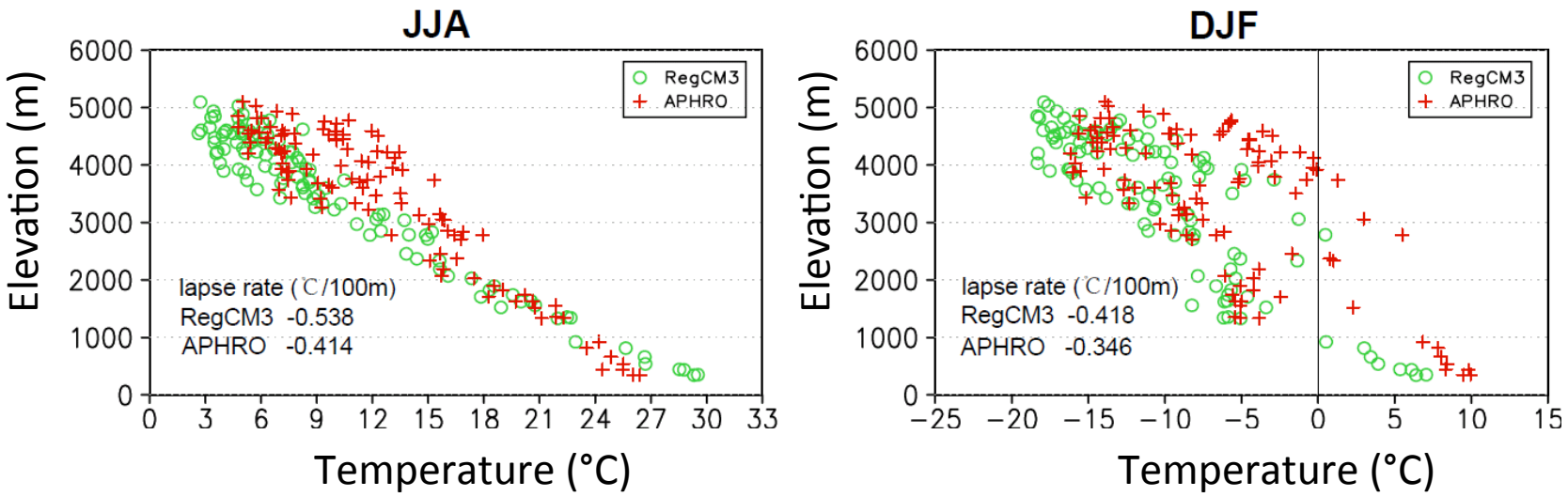
Precipitation climatology from ECHAM5 and RegCM3 compared with the APHRO for 1970–1999 (unit: mm/day).



Temperature climatology from ECHAM5 and RegCM3 compared with the APHRO for 1970–1999 (unit: ℃)

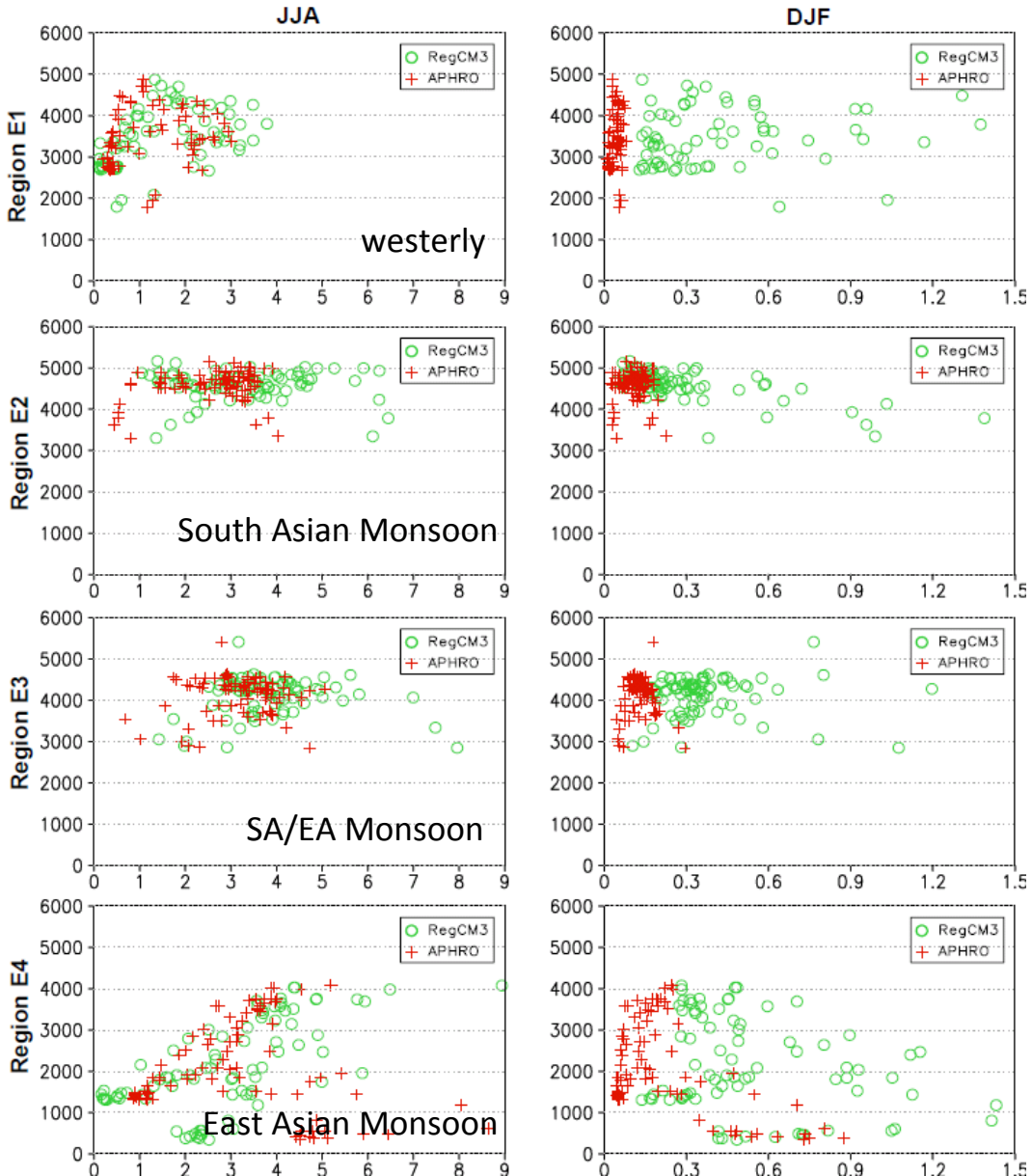


Scattering diagrams of surface air temperature against elevation

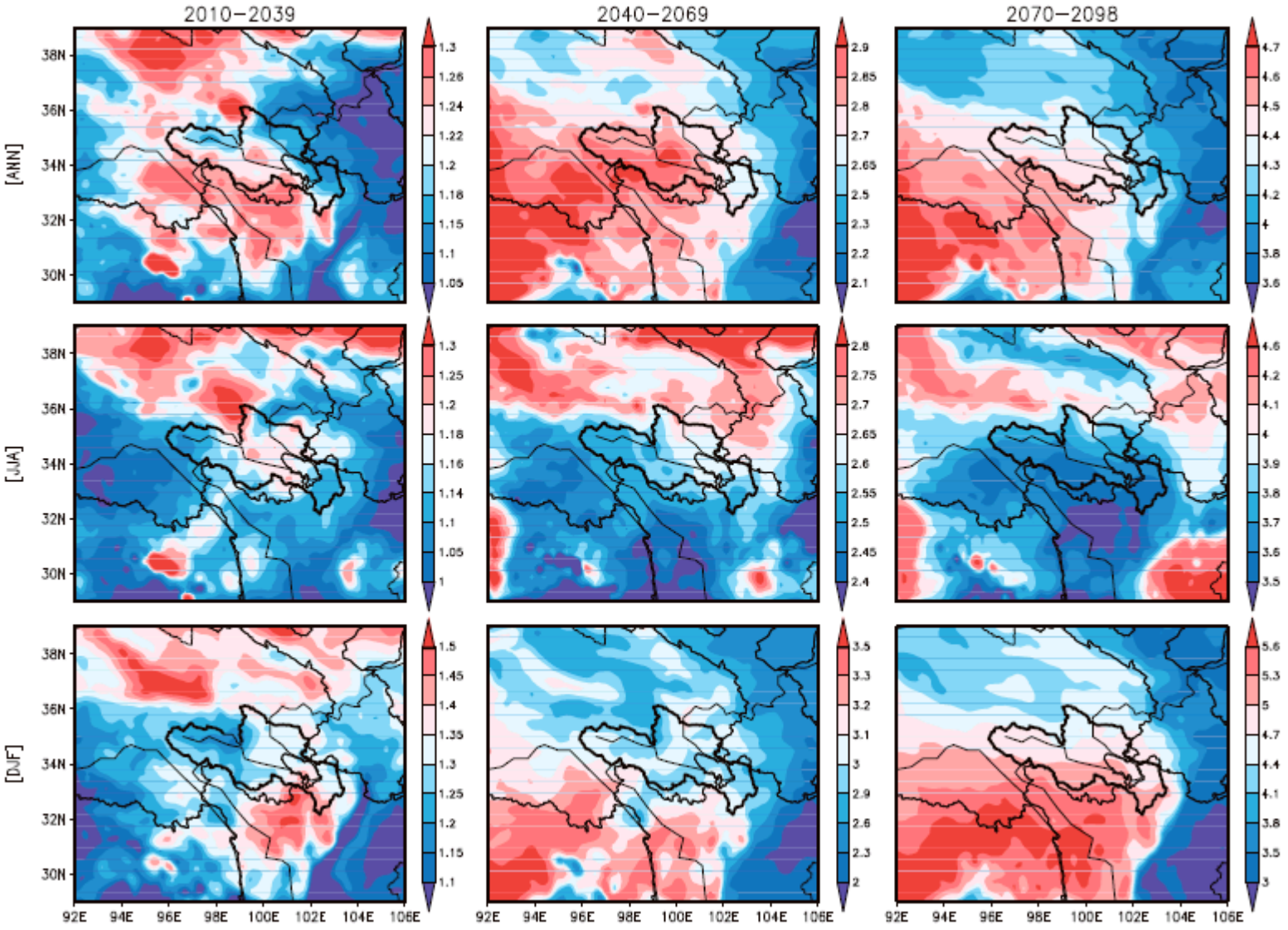


- At the same altitude, the climate model is colder.
- Higher above the sea level, the larger the model's cold bias.

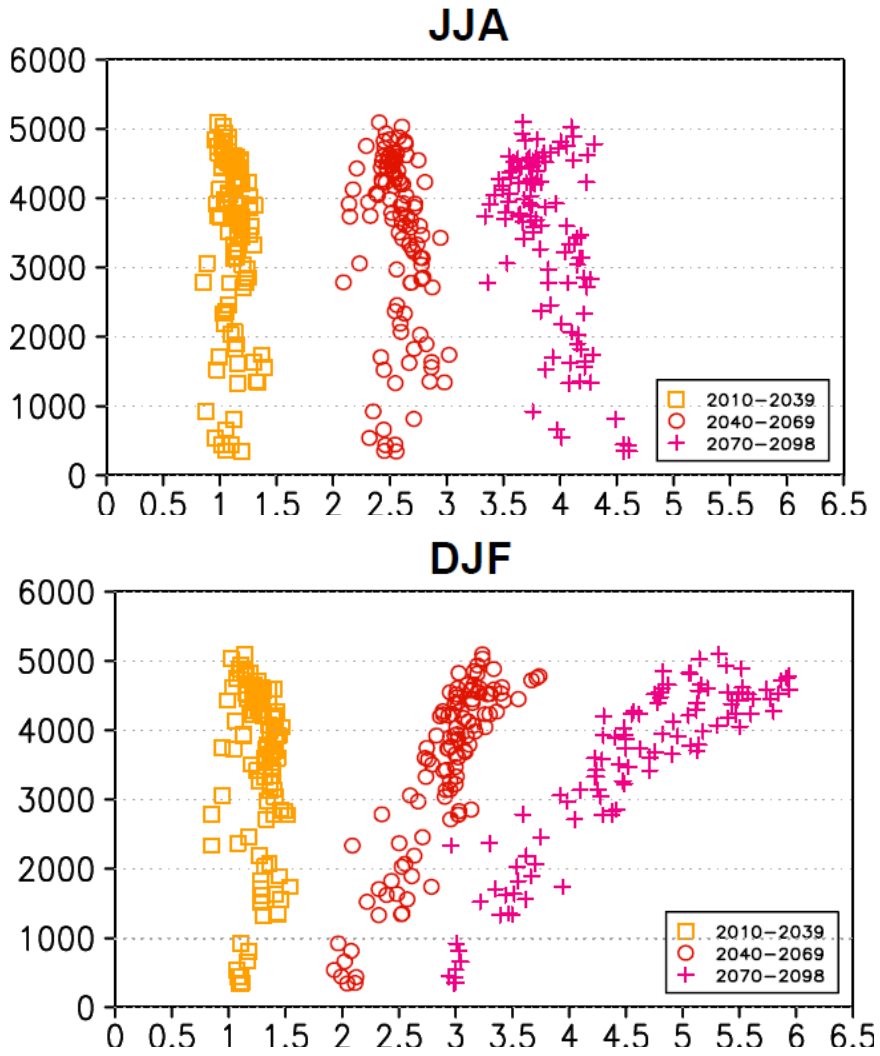
Scattering diagrams of precipitation versus elevation in the different precipitation sub-regions



Projected temperature changes relative to the control period (1970–1999) (unit: ℃)

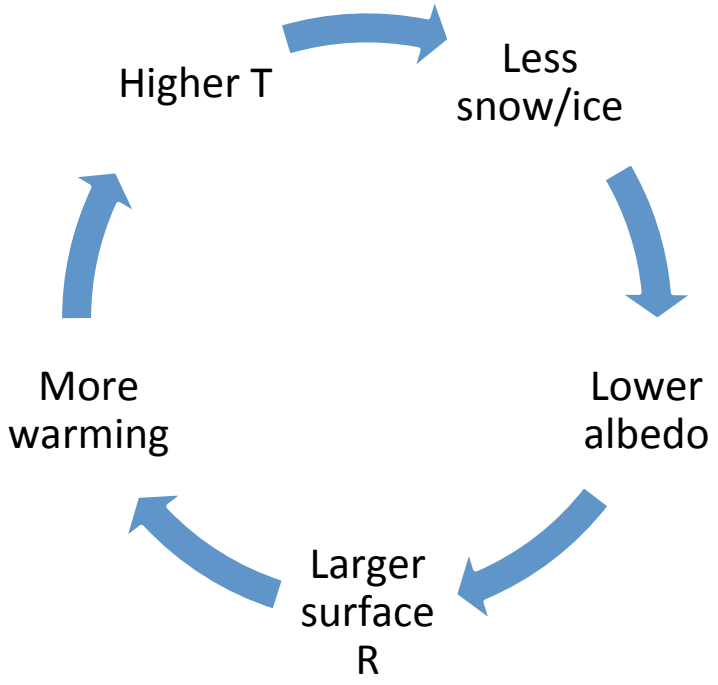


Relationship between seasonal temperature change and elevation

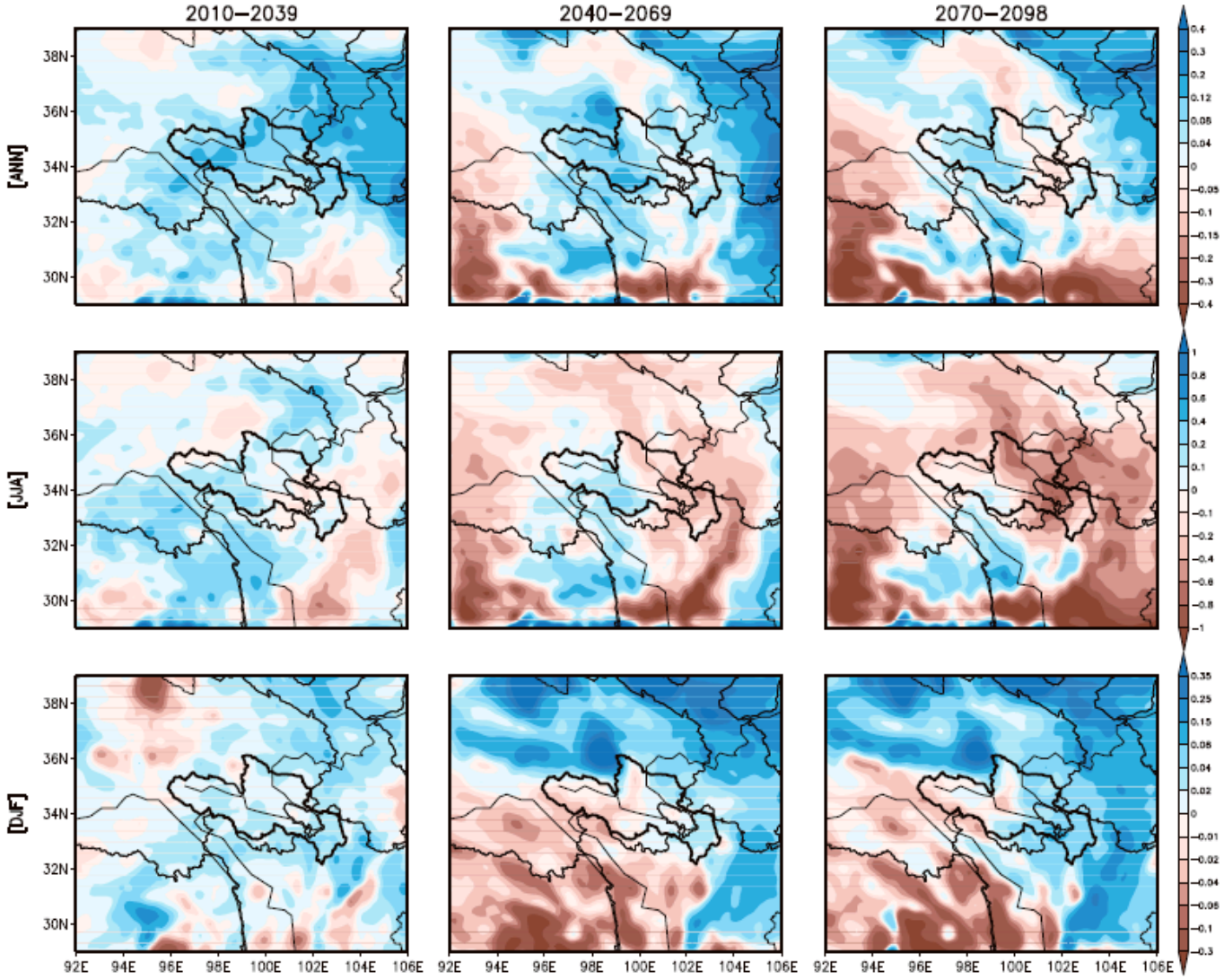


No altitude dependence of JJA warming;

But for DJF, with the evolution of projection time, higher altitude regions experience stronger warming.

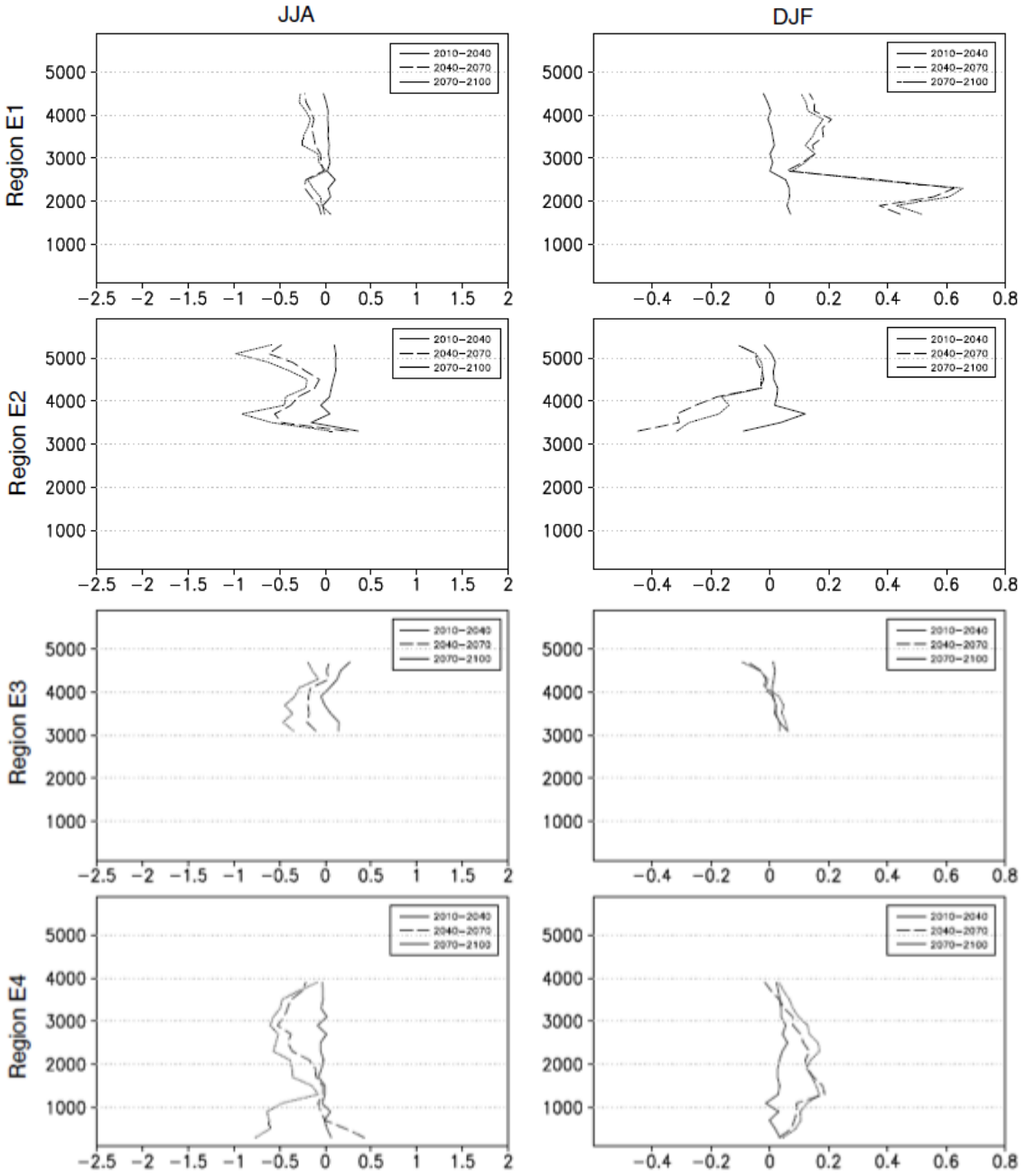


Projected precipitation changes relative to the control period (1970–1999) (mm/day)

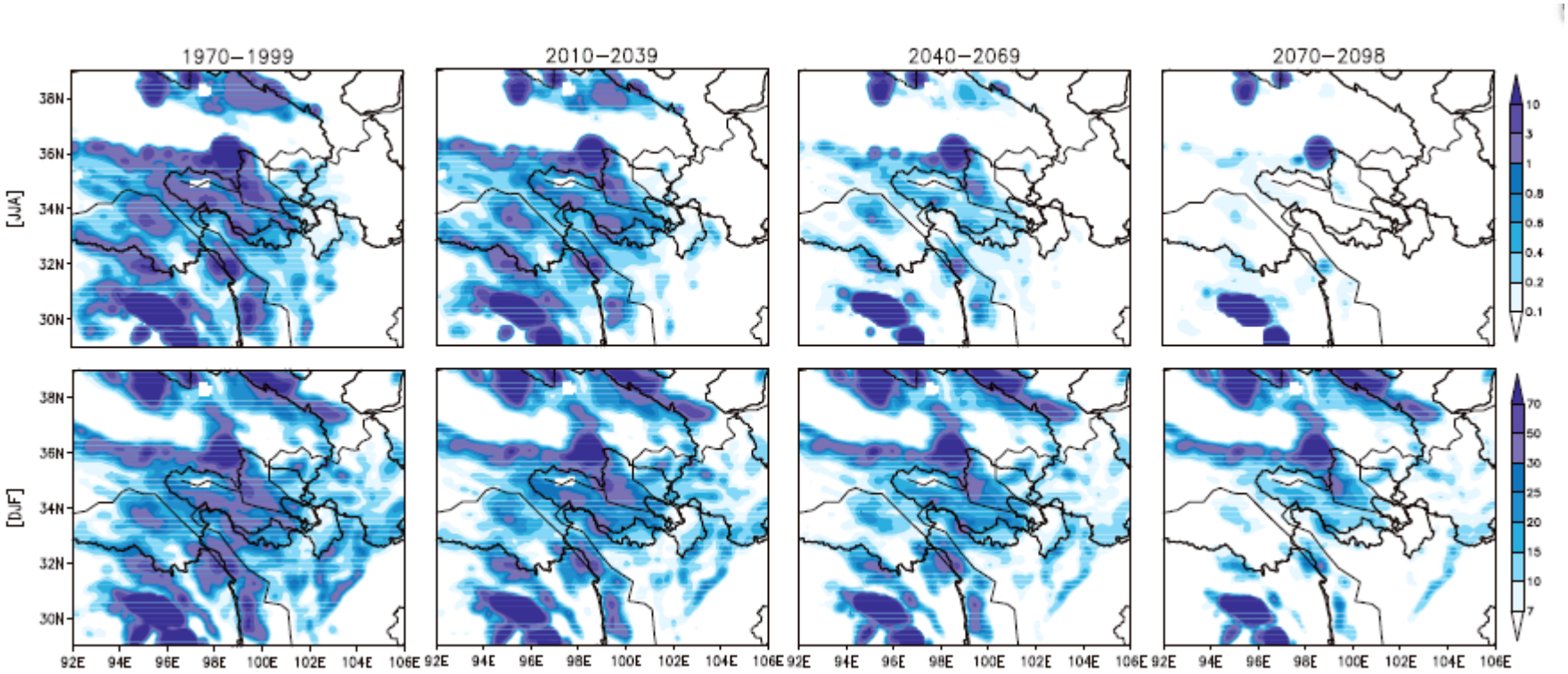


Relationship between seasonal precipitation change and elevation

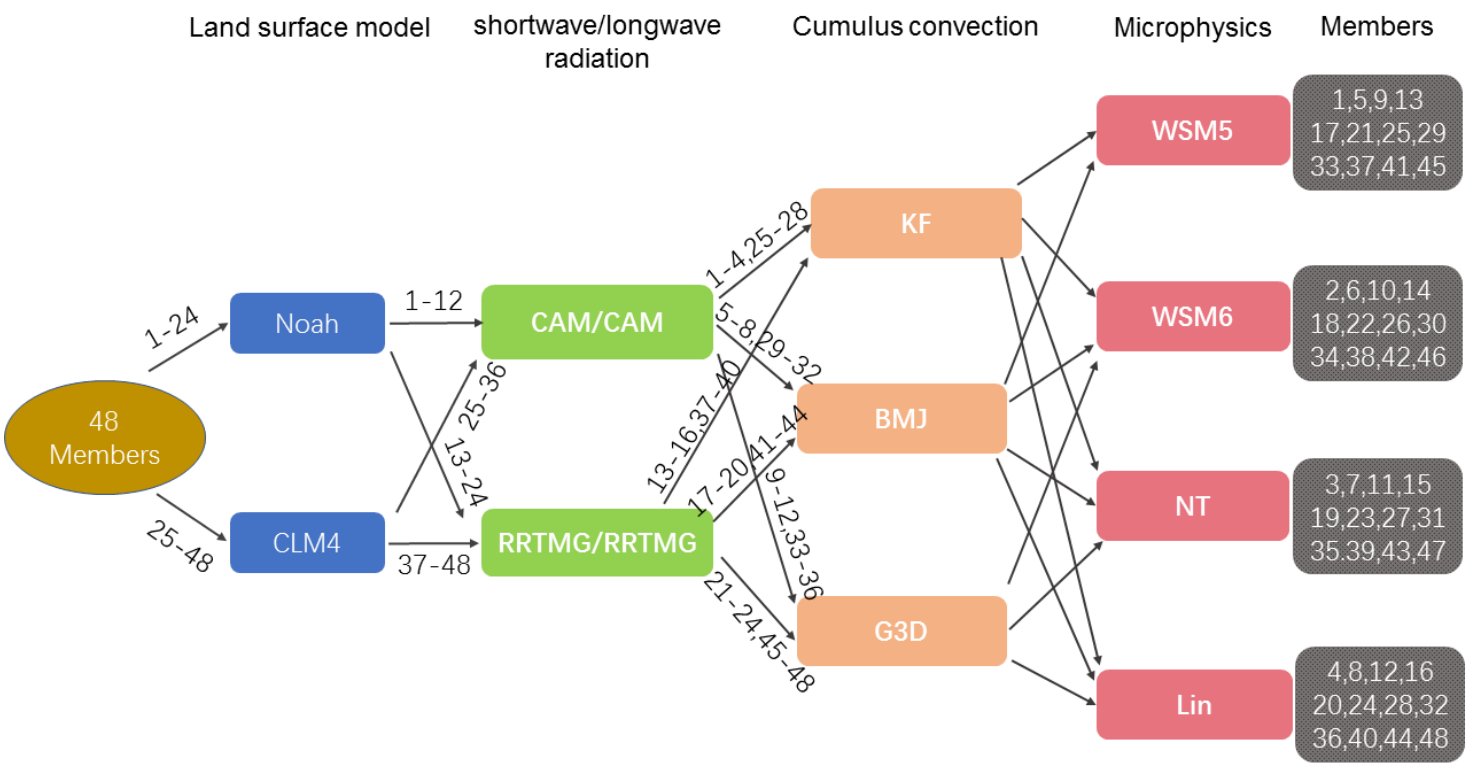
- Not like temperature, changes of precipitation can depend on geo-positions, climate regimes, altitudes, seasons, and projecting times in the future



Snow water equivalent for the current period (1970–1999) and each 30 year future period in the 21st century (2010–2098) (unit: mm)

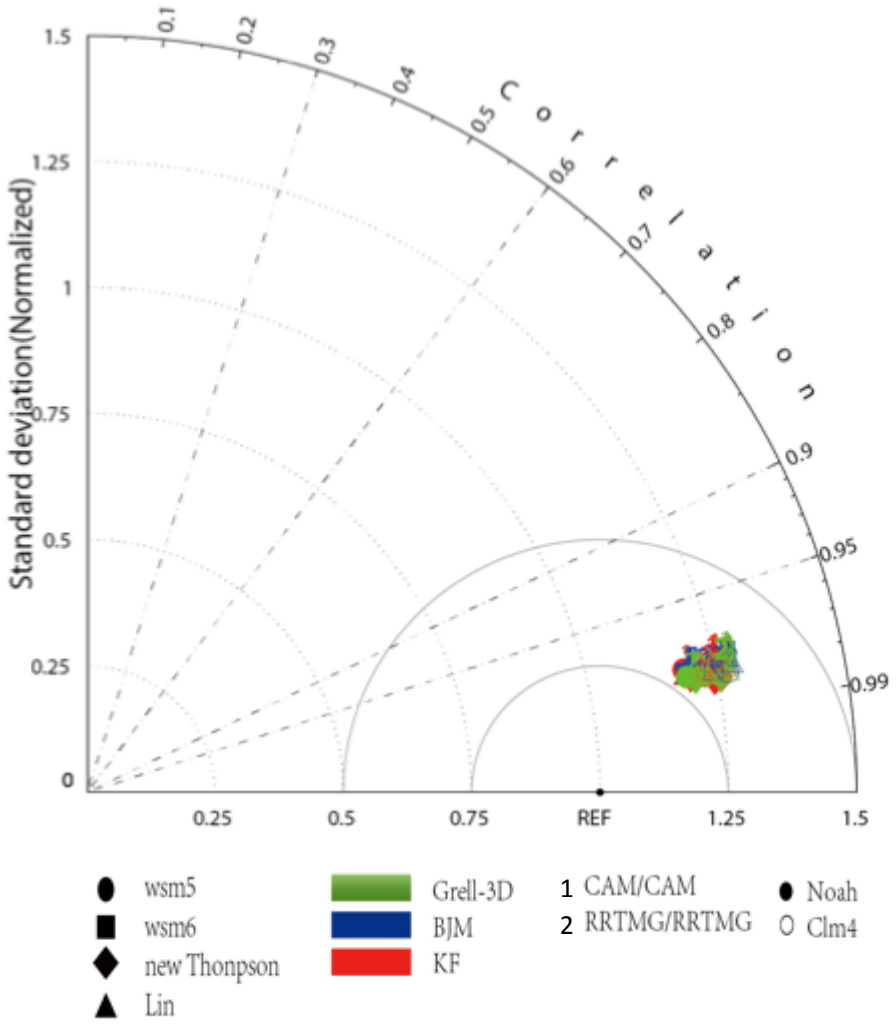


Effect of Model physics on regional climate modeling

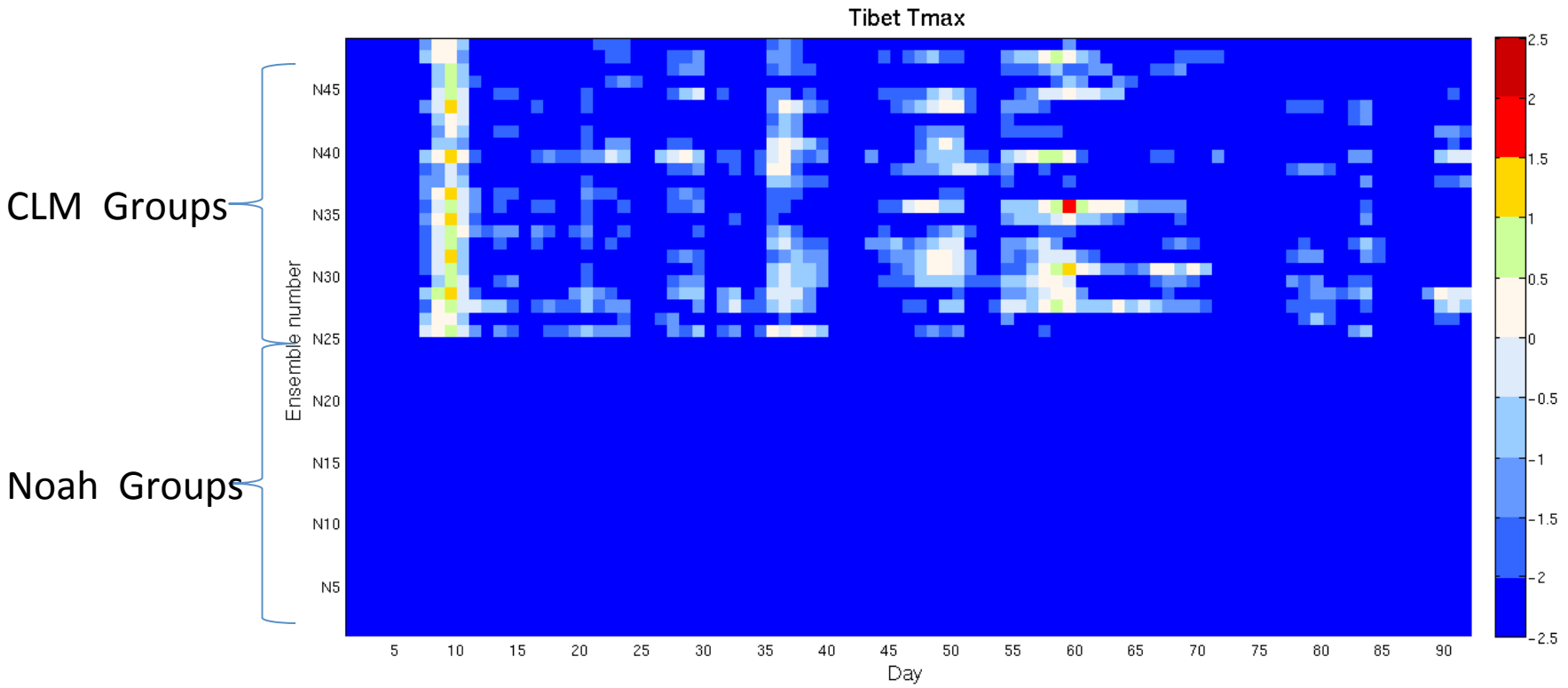


- **WRF model**
- **CORDEX EA-II domain at 25km**
- **ERA-Interim as large scale forcing**
- **June 1-September 1, 2013**

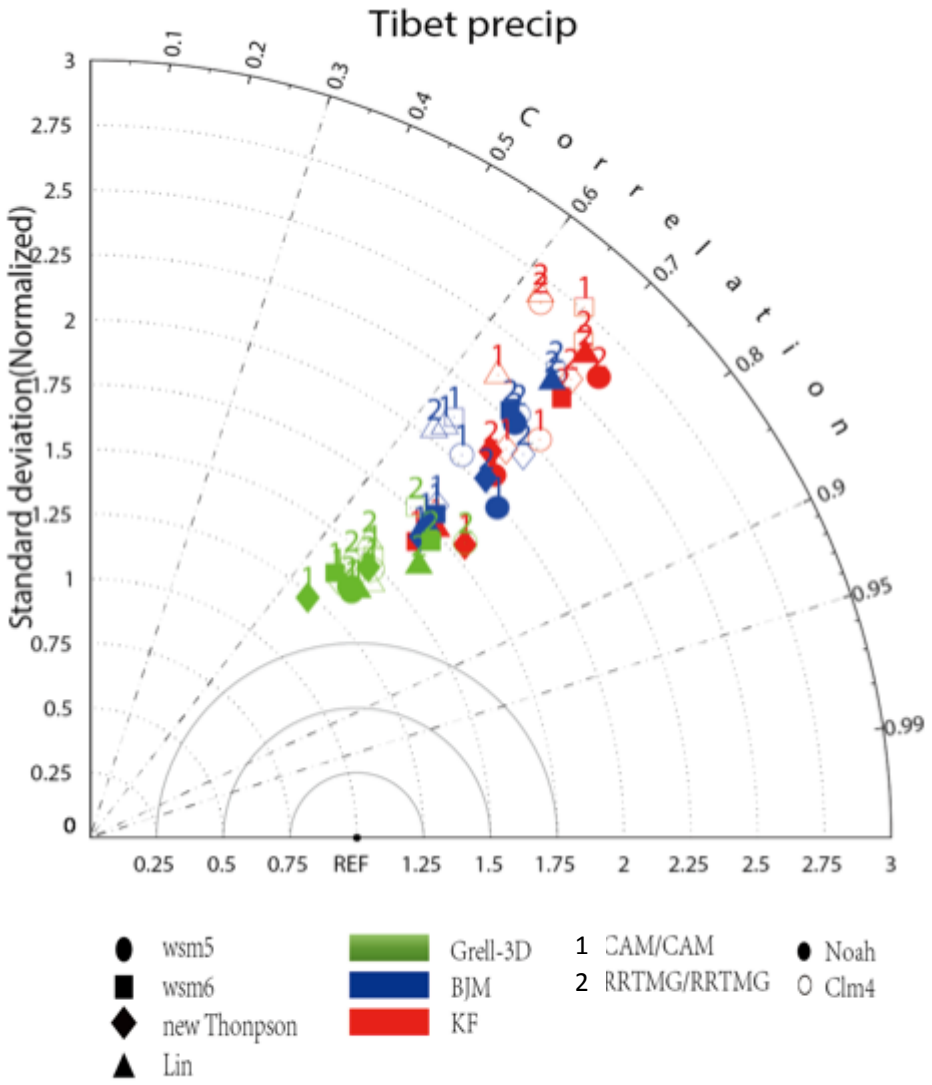
JJA Maximum Temperature over Tibetan Plateau



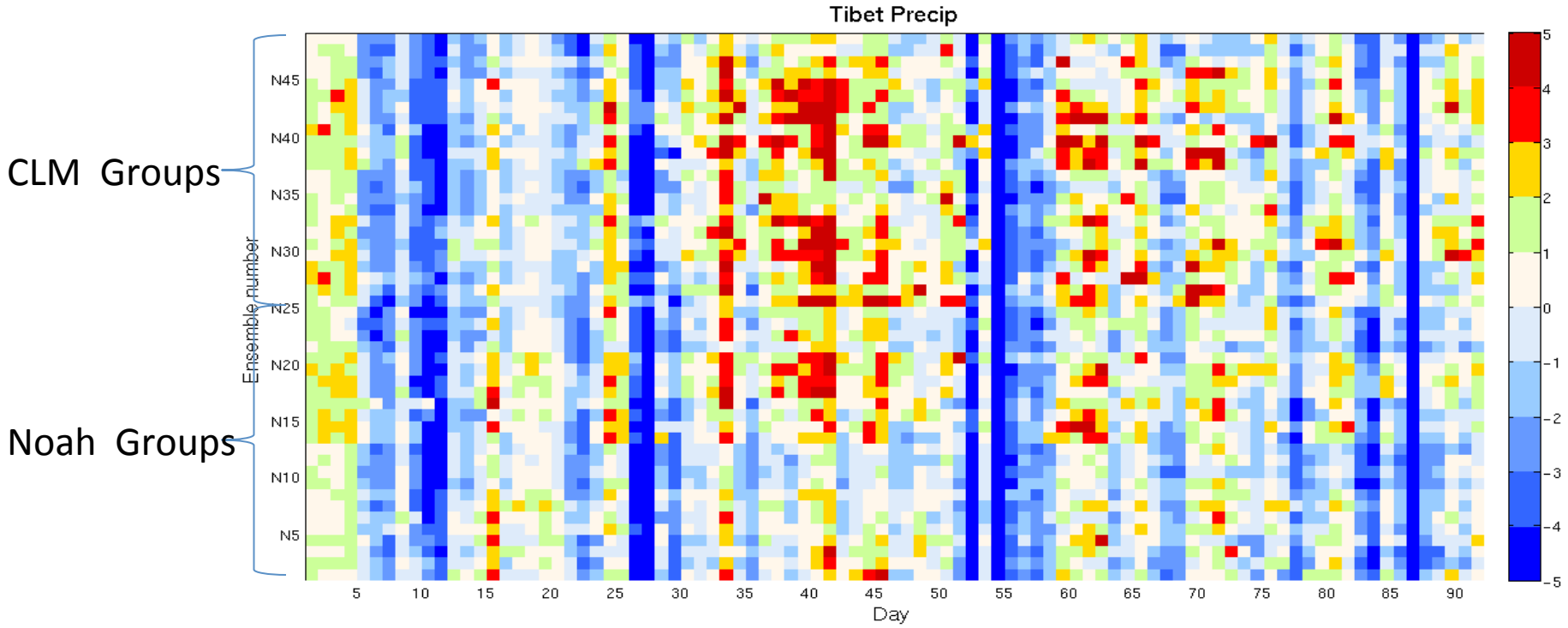
Tmax Biases against the observation over Tibetan Plateau



JJA Precipitation over Tibetan Plateau

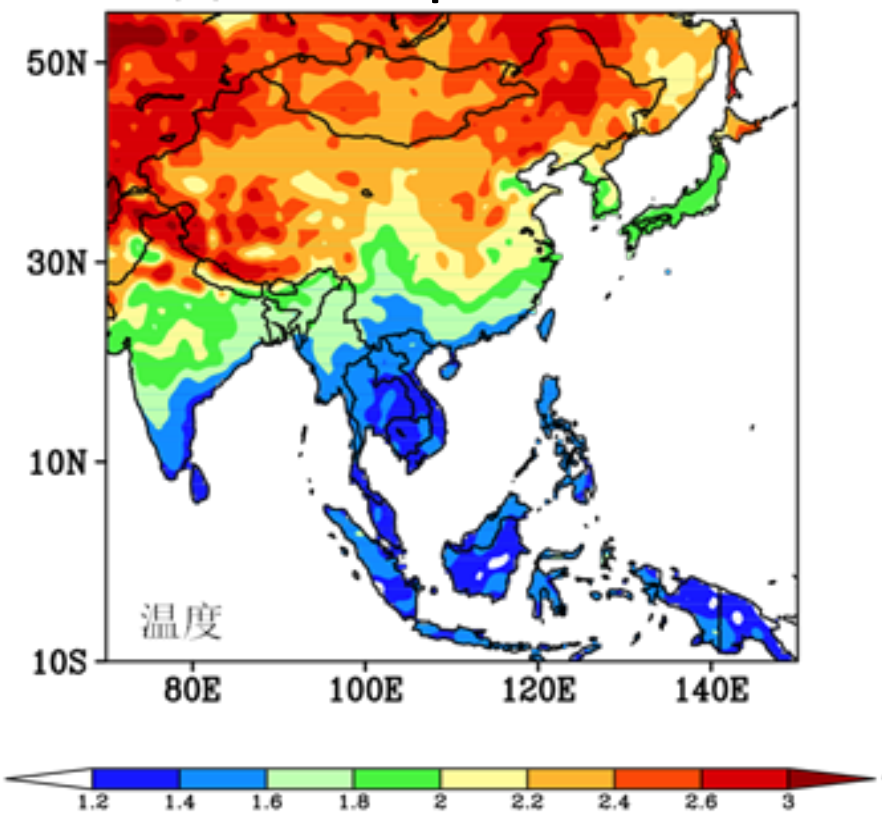


Pre. Biases against the observation over Tibetan Plateau

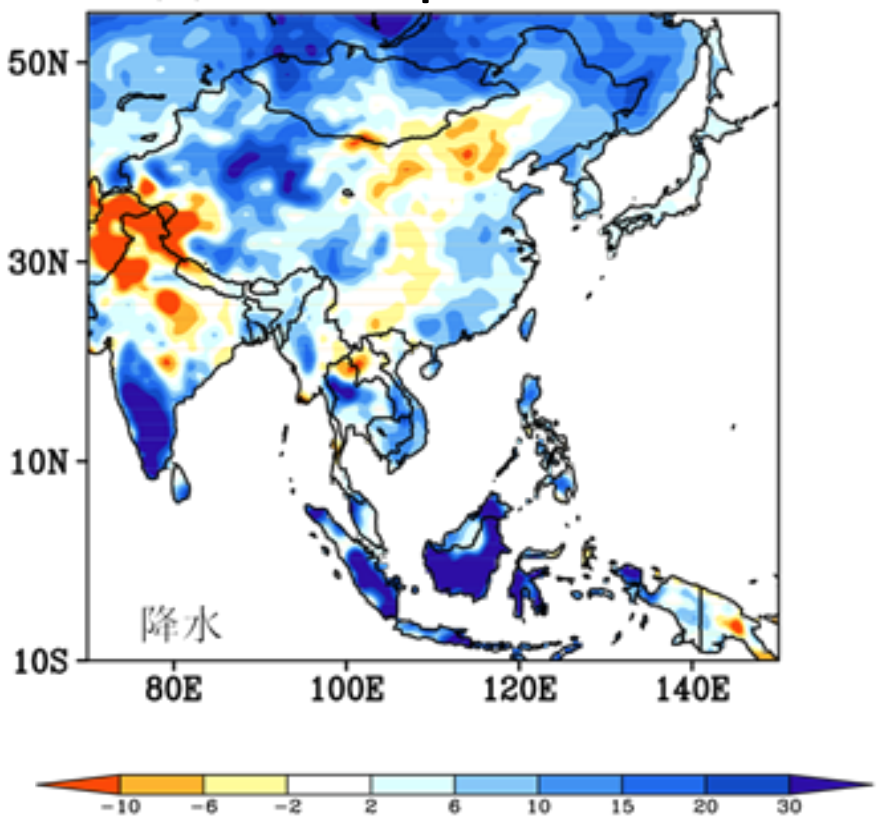


Ensemble Projection of Regional Climate change for 2040-2060 under A1B Scenario

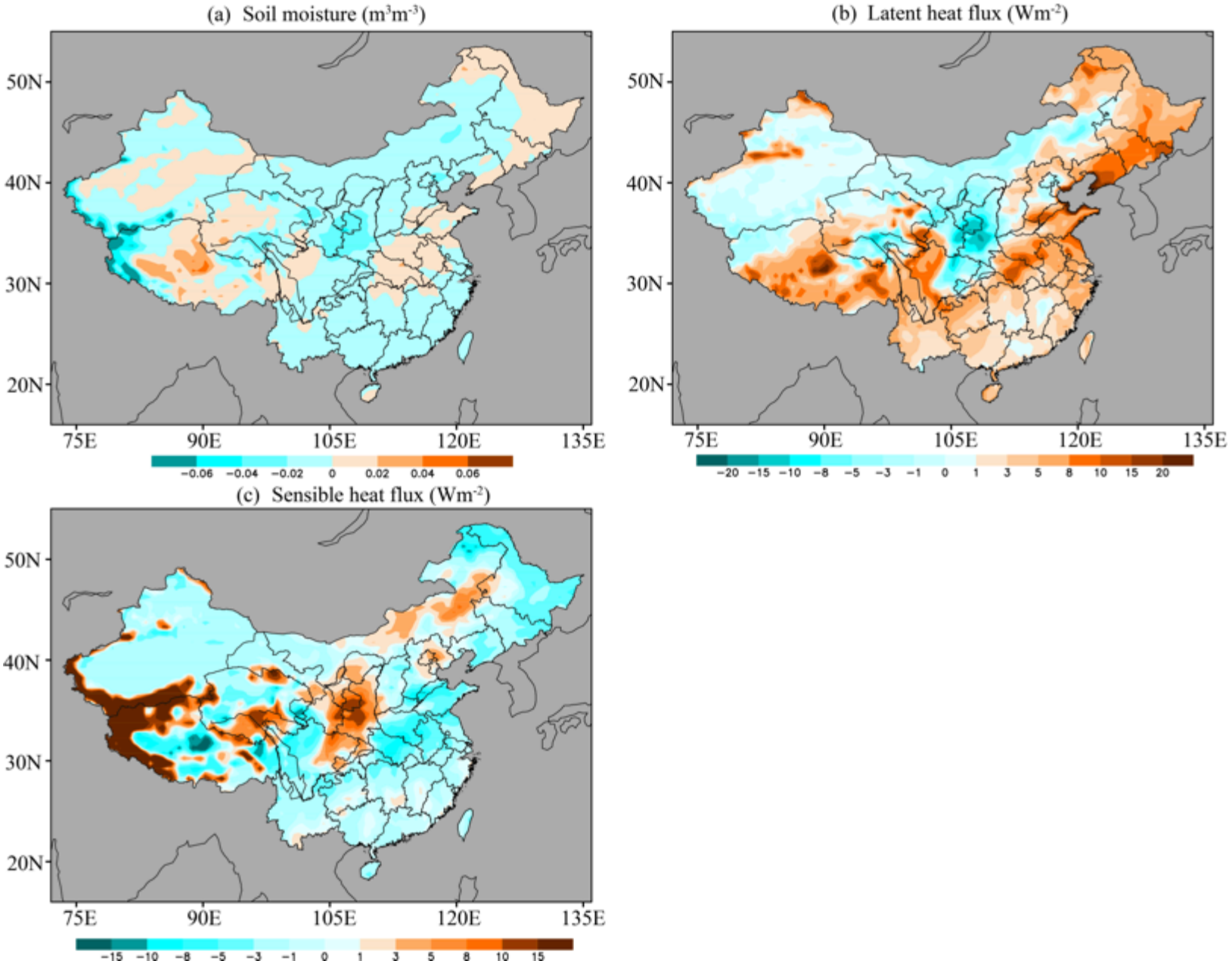
(c)REA **Temperature**



(c)REA **Precipitation**

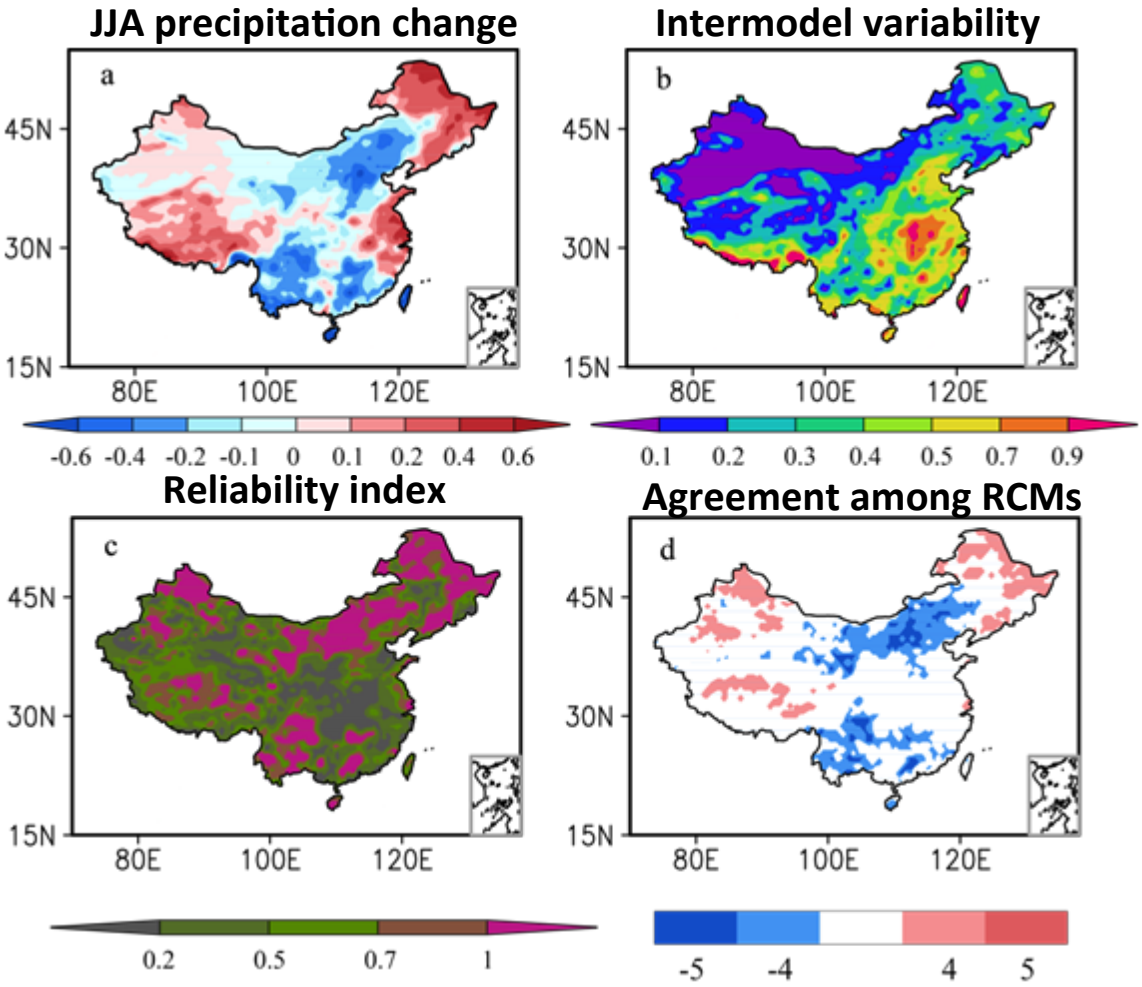


Ensemble Projection of Regional Climate change for 2040-2060 under A1B Scenario



Ensemble Projection of Regional Climate change for 2040-2060 under A1B Scenario

Multi-model Projection of Precipitation Change and Reliability Analysis



Summary

- **High-resolution demonstrates certain advantage in improving the simulation of surface climatology, and is more evident over the relatively homogeneous land surface and climate regime. It can correct the positive bias in the vertical distribution of precipitation, which may be related to its better representation of the local topography.**
- **With increasing projection time, the Tibetan Plateau would experience summer drying, which could greatly affect the region's lifetime of glacier, snow coverage, and glacier-fed lakes.**
- **Warming is more significant at higher elevations. Snow-albedo feedback would be important in the local warming and drying, suggesting the essential role of land surface process in understanding the regional climate change.**
- **Further attention should be paid by modelers on the regional convection triggered by topography over Tibetan Plateau.**