A numerical study on the winter monsoon and cold surge over East Asia

Yihui Ding, Qiaoping Li

National Climate Center, CMA, Beijing, China

E-mail: Dingyh@cma.gov.cn

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Introduction

❖ The winter monsoon in East Asia is one of the most significant systems of winter circulation over the northern hemisphere. It plays an important role in the winter climate over China and the surrounding areas.

❖The Winter Monsoon experiments in the 1970s and later studies revealed certain observational facts of winter monsoon and cold surge, especially the interaction between mid- and lower-latitude atmosphere when cold surge occurs.

❖The statistical and numerical studies have shown that ENSO events have significant effects on both winter rainfall over China and the intensity of winter monsoon. It can also increase winter rainfall over South China in El Niño year, but decrease rainfall in La Niña year.

❖Compared with the East Asian summer monsoon, relatively little work on winter monsoon and rainfall has been carried out, especially for numerical study.

About the Regional Climate Model (RegCM_NCC)

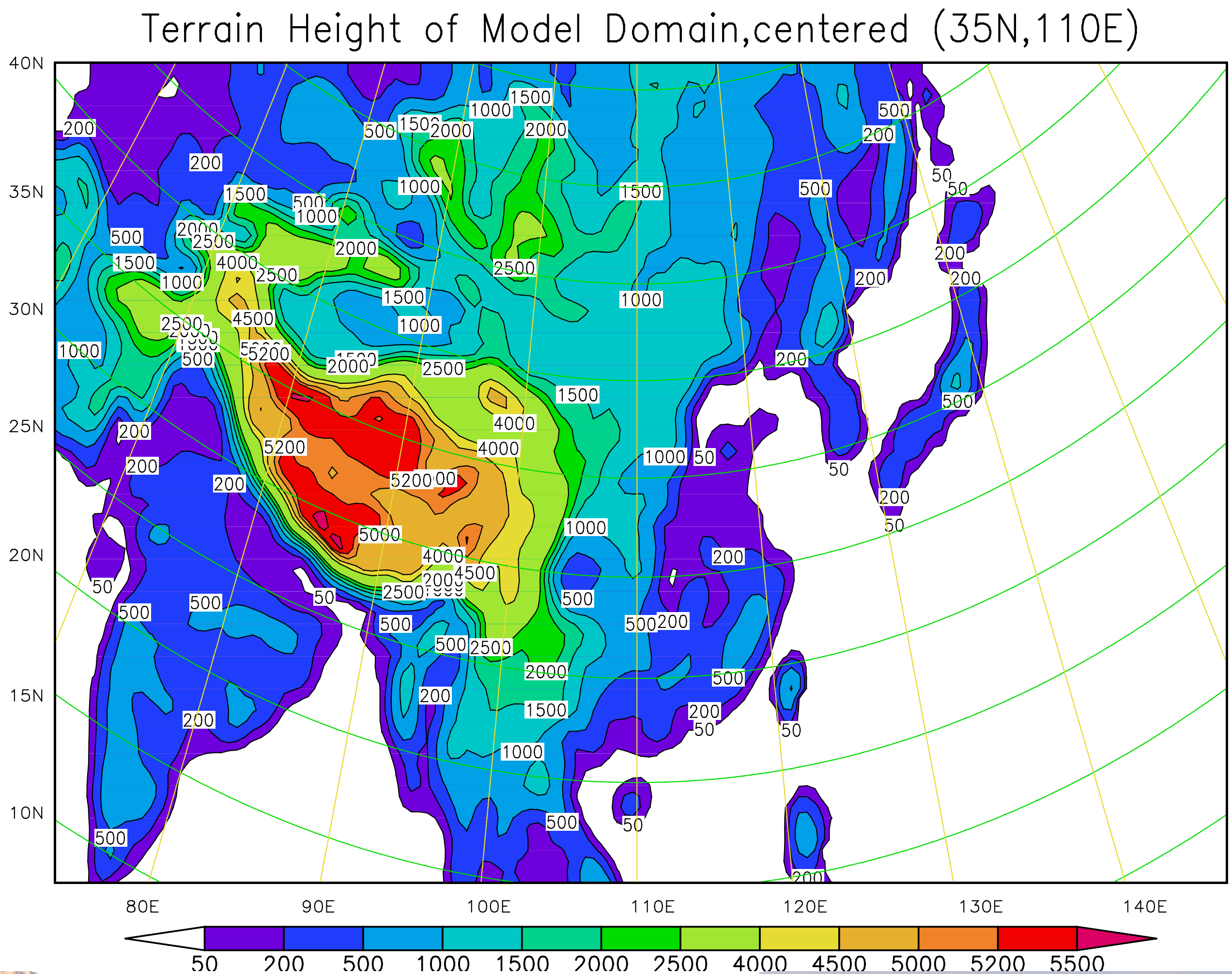
❖**RegCM_NCC** is developed based on RegCM2/NCAR (Ding et al.,1998), by modifying the various physical process parameterization schemes. The improved physical process mainly including the land-surface process, the cumulus convective and radiation transfer process, the planetary boundary layer, and so on.

❖A ten-yr(1991-2001) integration for summer(JJA) was made to produce the model climatology and hindcasts. The real-time experimental predictions for summer in 2001-2006 by using the nested RegCM_NCC were made in March each year. The model has also been widely used in some case study, such as flood events in 1991 and 1998.

Model description

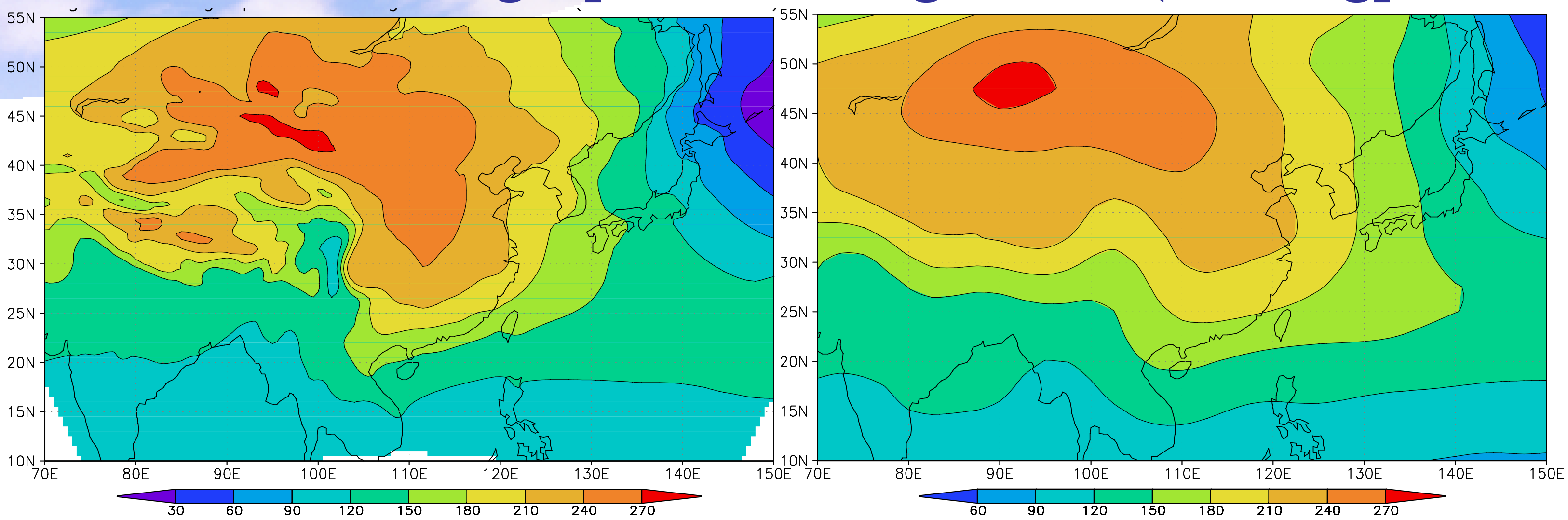
Model Configuration	RegCM-NCC
Horizontal grids	60 km (99 X 151)
Vertical layers (top)	16 sigma layers (50 hPa)
Cumulus convection	Betts-Miller(Betts A K,1986)
Moisture scheme	implicit
PBL	Holtslag(Holtslag,1990)
Radiation	CCM3(Kiehl,1996)
Land surface	NCC/ LPM2(Shi,2000)
Boundary condition	Exponential laxation
Initial, boundary condition	NCEP/NCAR Reanalysis II 12^h
Sea Surface Temperature	NOAA OI.v2 7^d
Integration period	1991-2001(just for winter)

Model domain and terrain height

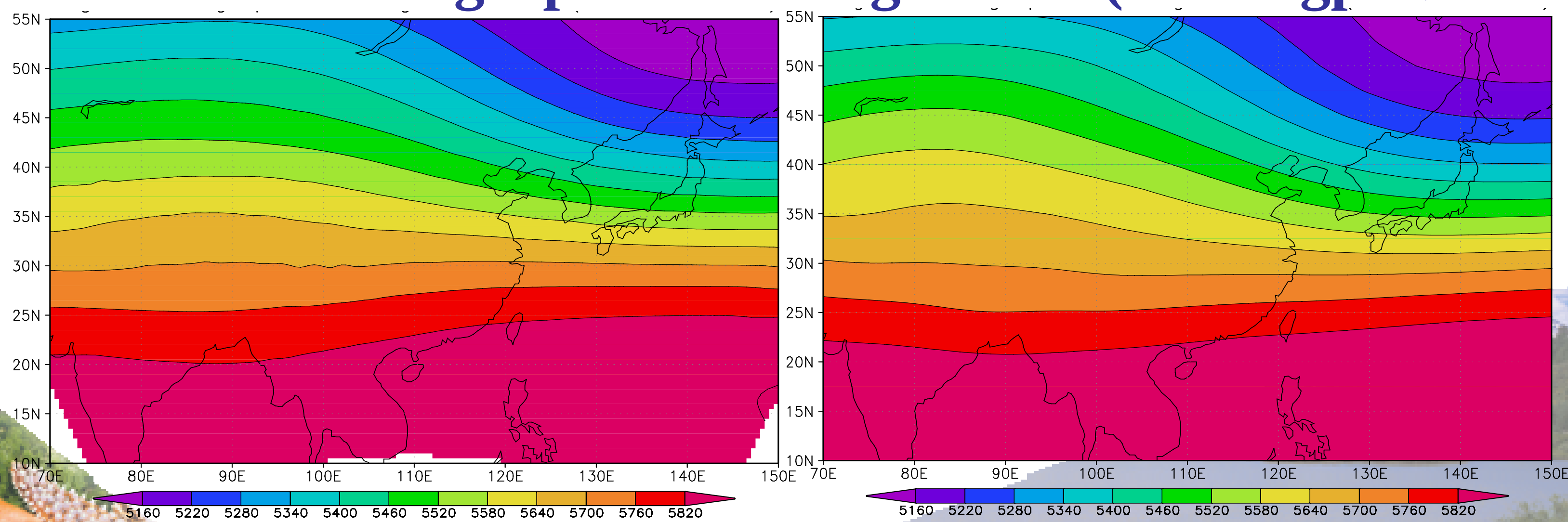


Simulations for 10 years winter

1000 hPa mean geopotential height field (Units: gpm）

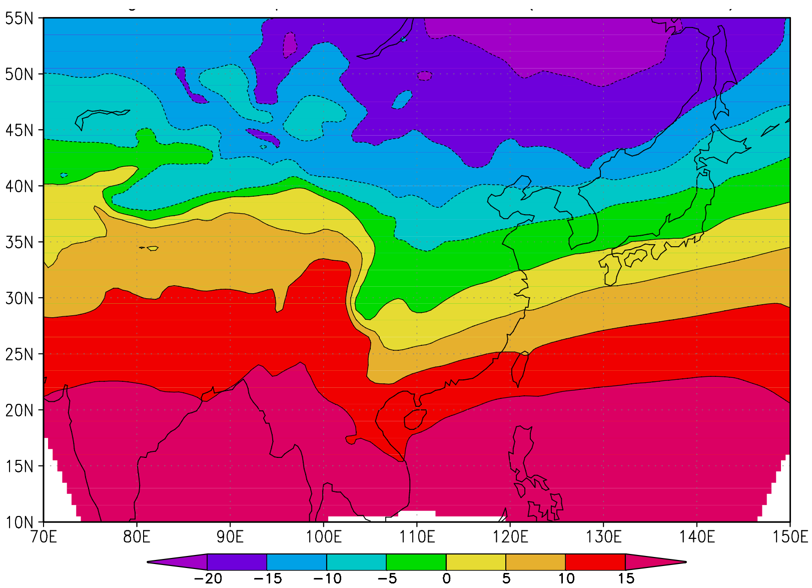


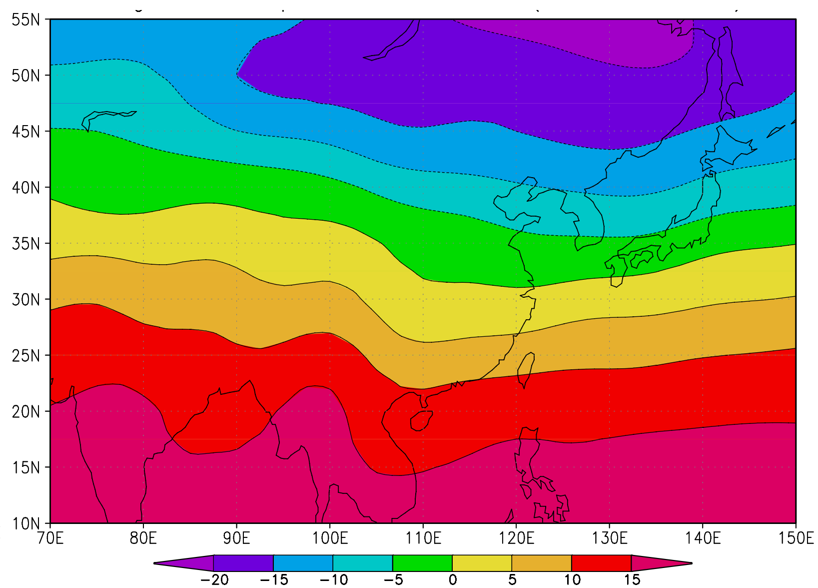
500 hPa mean geopotential height field (Units: gpm）



Simulation (left) reanalysis (right)

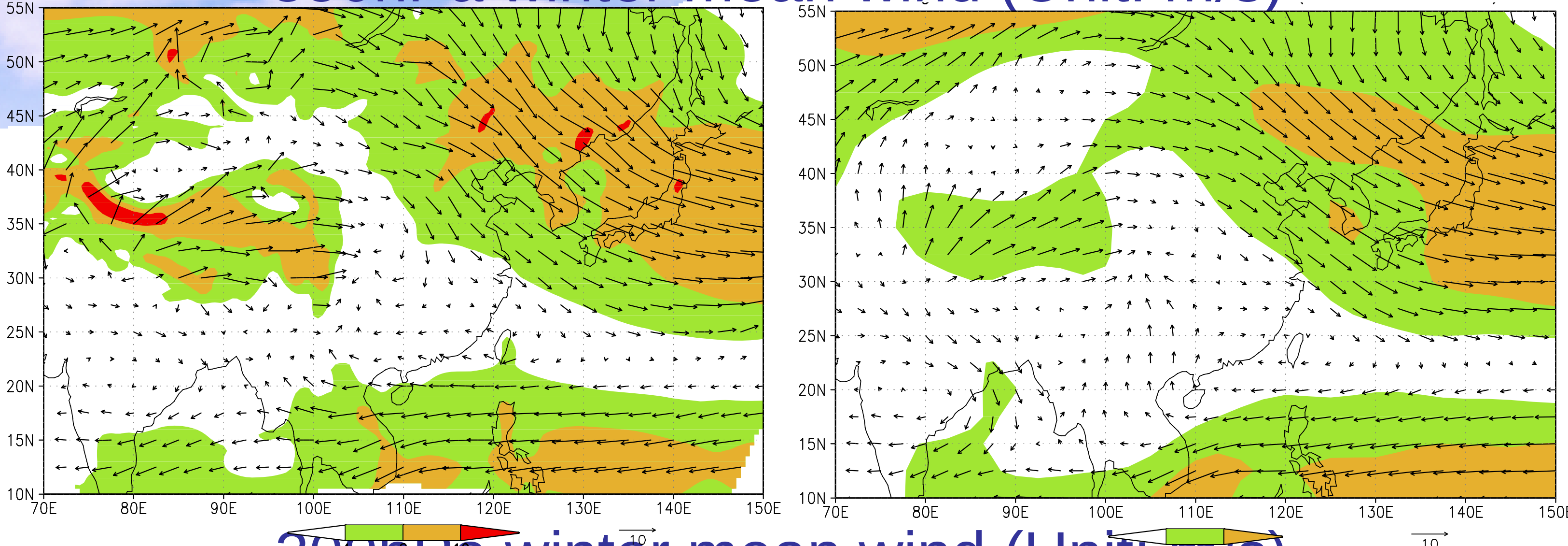
850 hPa mean air temperature (Units: ºC）



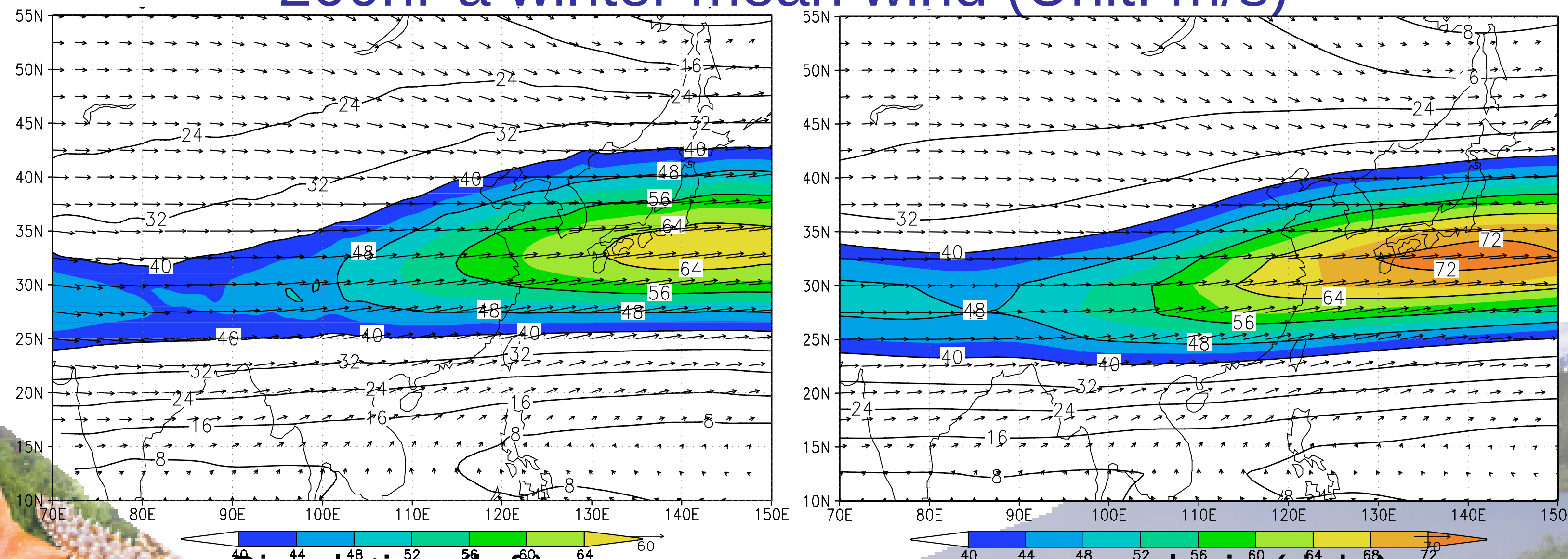


Simulation (left) reanalysis (right)

850hPa winter mean wind (Unit: m/s)



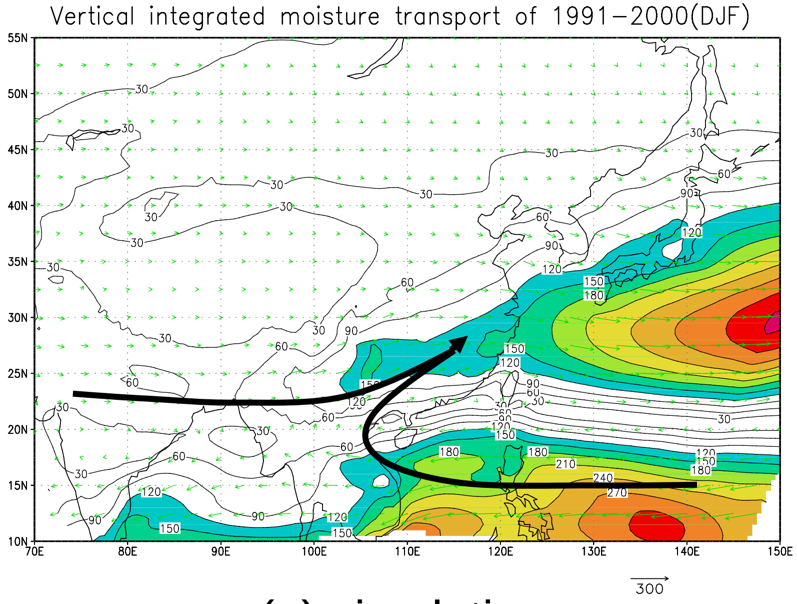
200hPa winter mean wind (Unit: m/s)



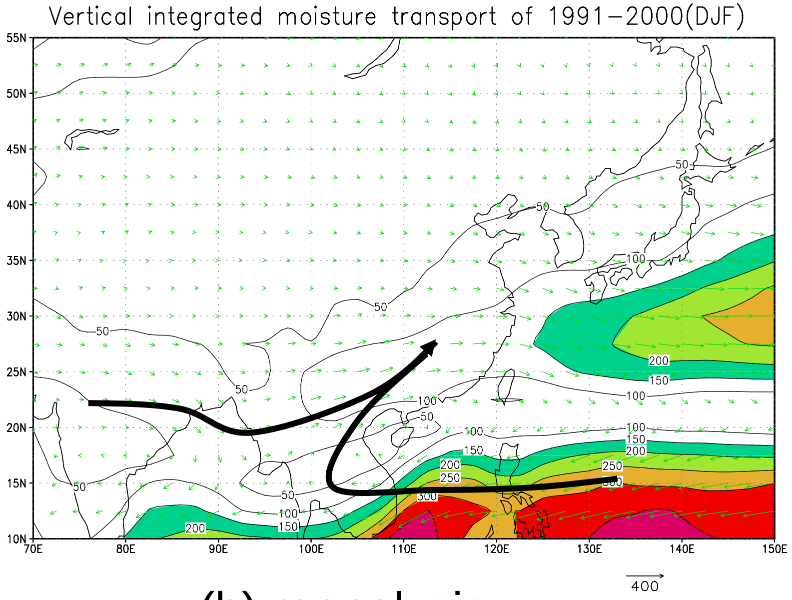
Simulation (left)

reanalysis (right)

Vertically integrated moisture transport field (Units: g/(s·cm))

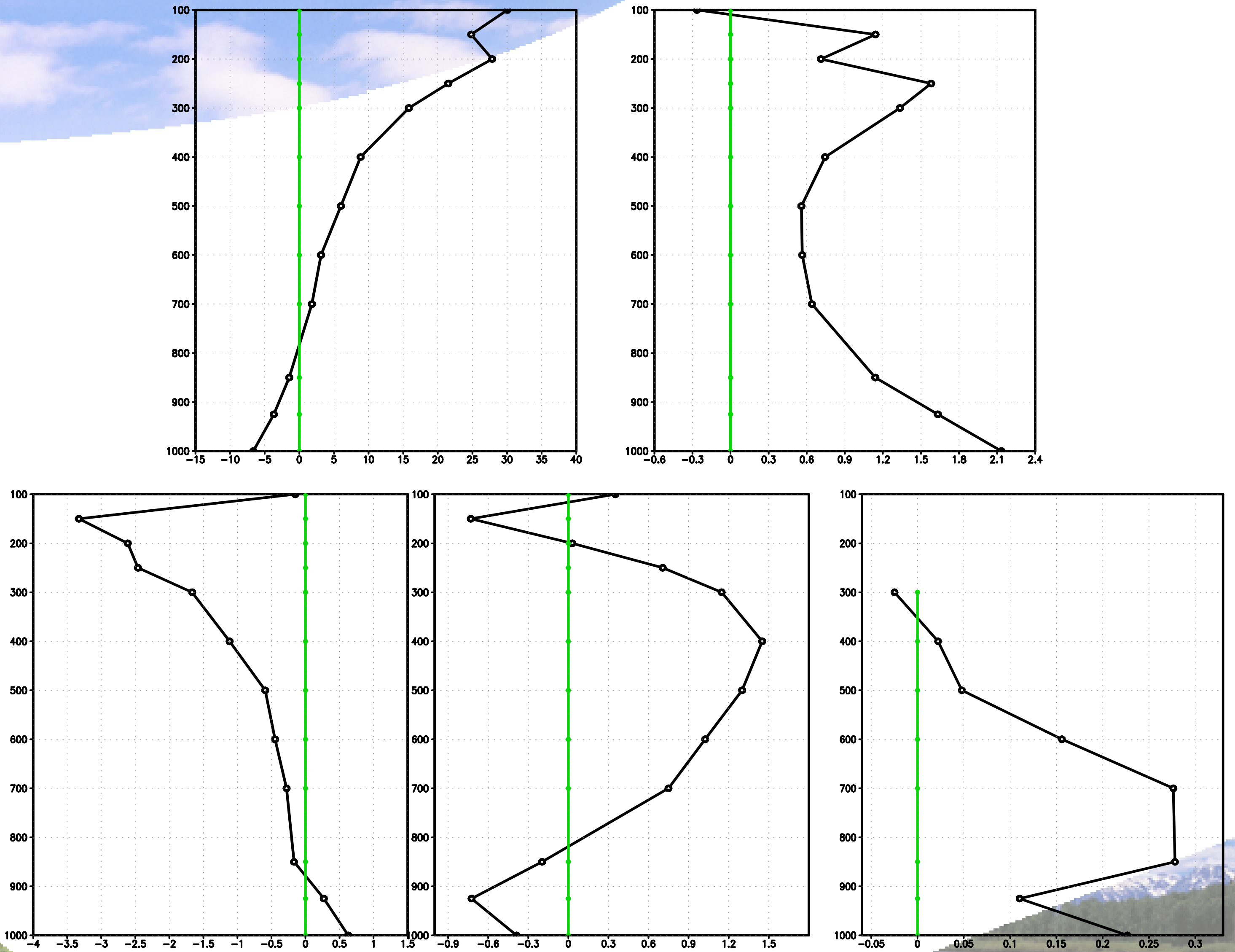


(a) simulation



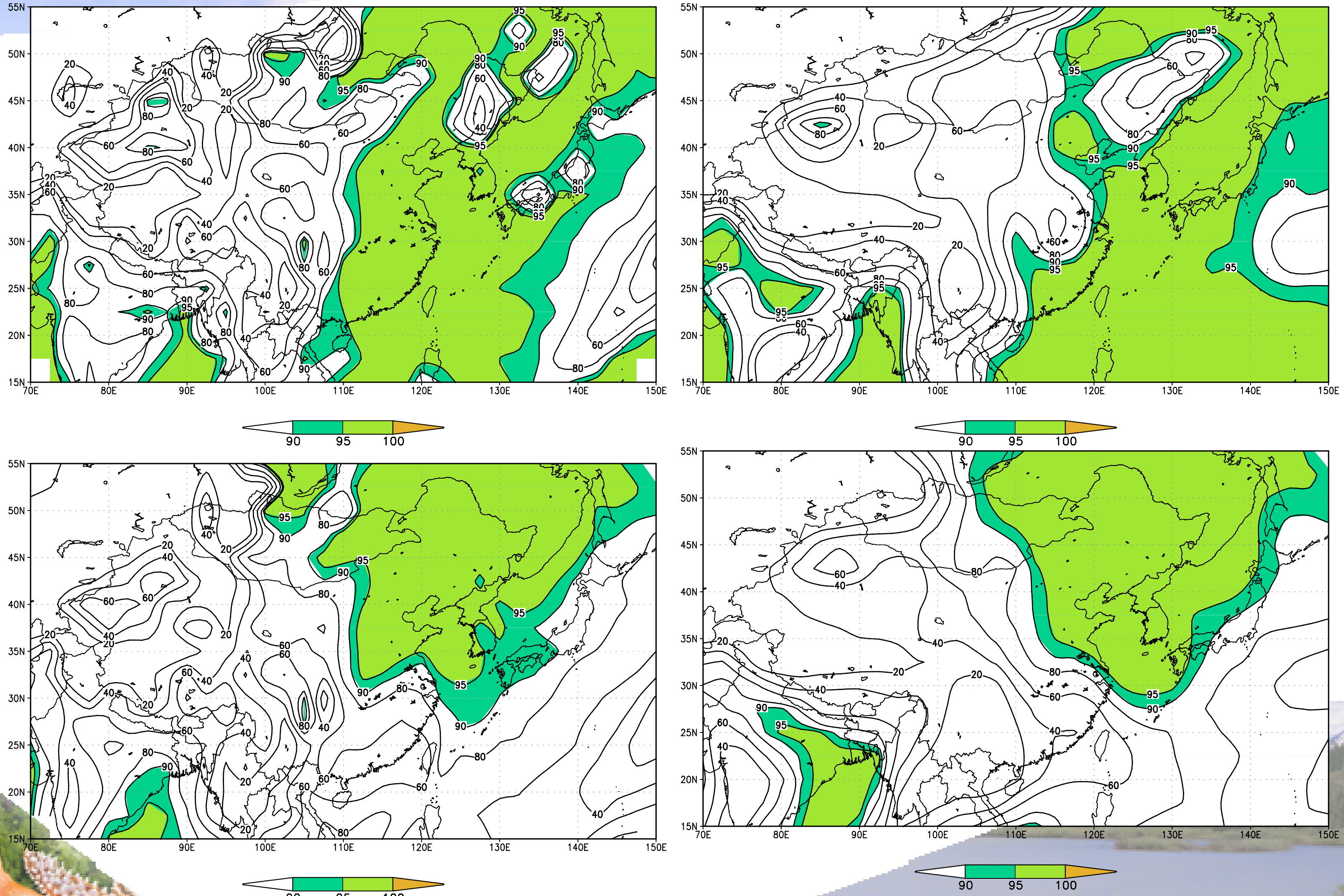
(b) reanalysis

The water vapor over South China mainly comes from the Bay of Bengal along the strong southwesterly flow ahead of the westerly wind trough. Another moisture transport comes from near-equatorial west-Pacific along the turning flow from the easterly trade wind. The two branches of moisture transports converge in South China.



Vertical profiles of the difference between simulations and reanalysis (a) geopotential height (gpm); (b) tmperature (K); (c) zonal wind (m/s); (d) meridional wind (m/s); (e) specific humidity (k/kg)

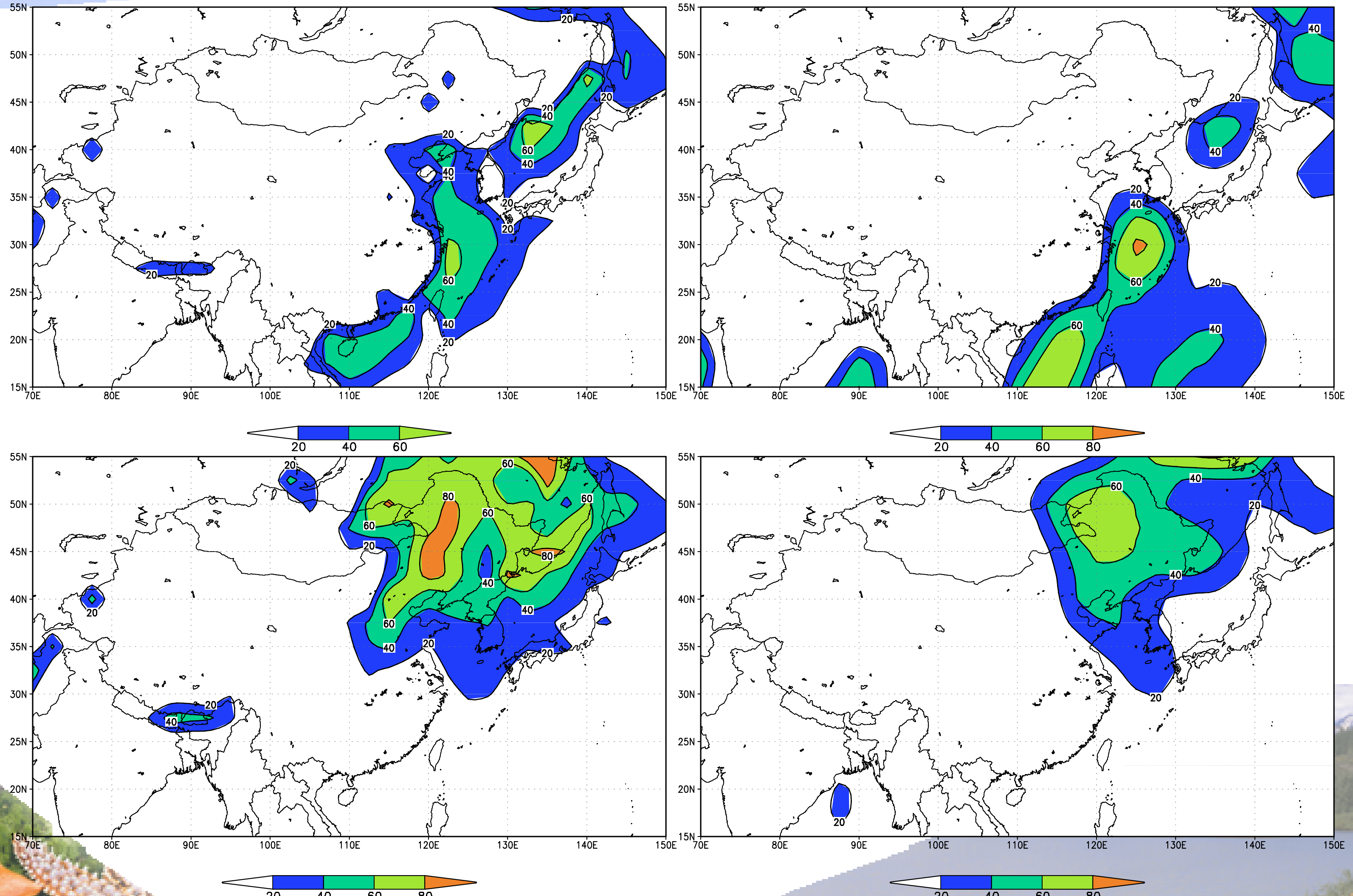
Winter mean distribution of occurrence frequency of northerly wind (v<0) at 1000 hPa and 850 hPa (Units: %)



Simulation (left)

reanalysis (right)

Winter mean distribution of occurrence frequency of northerly wind speed greater than 5m/s at 1000 hPa and 850 hPa (Units: %)



Simulation (left)

reanalysis (right)

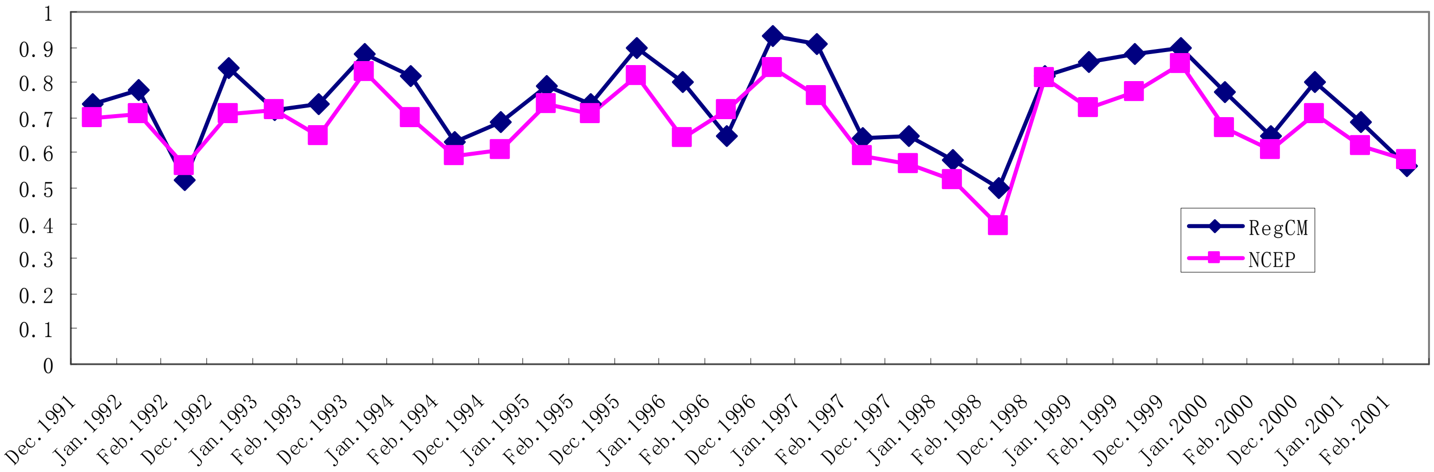
Table 1 Winter mean monsoon index

	A_n				I_n			
	Dec	Jan	Feb	mean	Dec	Jan	Feb	mean
simulation	0.82	0.77	0.65	0.75	5.77	5.55	5.56	5.63
reanalysis	0.75	0.68	0.62	0.68	5.32	5.19	5.30	5.27

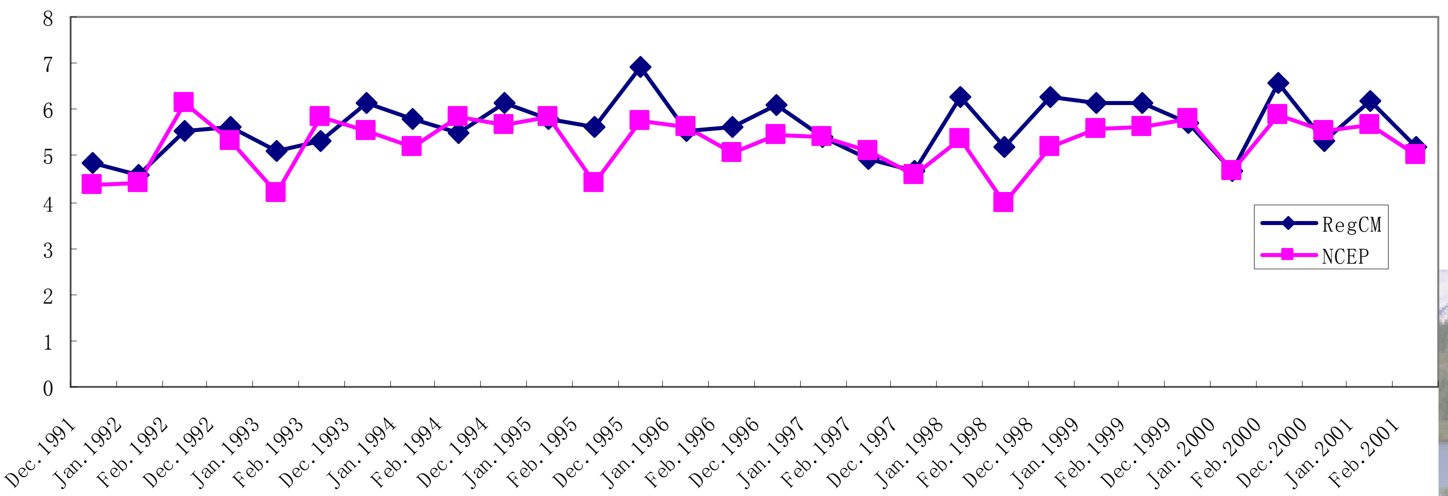
(based on the method described by Qiao et al., 2002)

In the range of 20~40ºN and 100~140ºE, Northerly wind area index（AN）and intensity index（IN）：AN=nN/N，IN=∑UN/nN
where nN is the grid points of northerly wind in the region at 850hPa, respectively. UN represent wind speed of the northerly wind, and N denotes the whole grid points in the region.

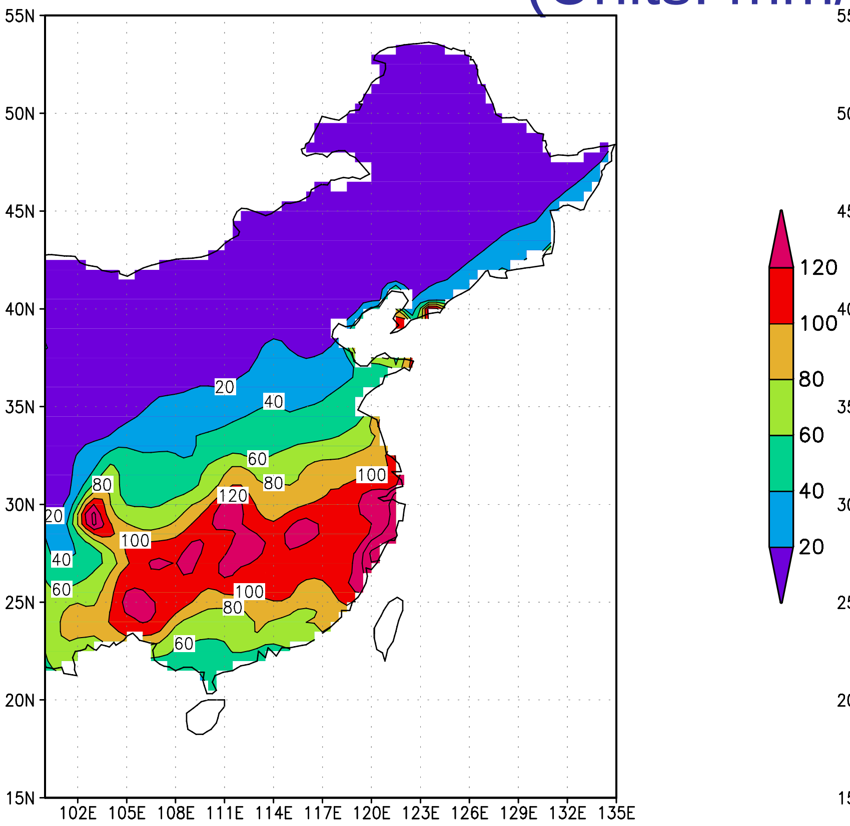
Area Index of the Northerly wind



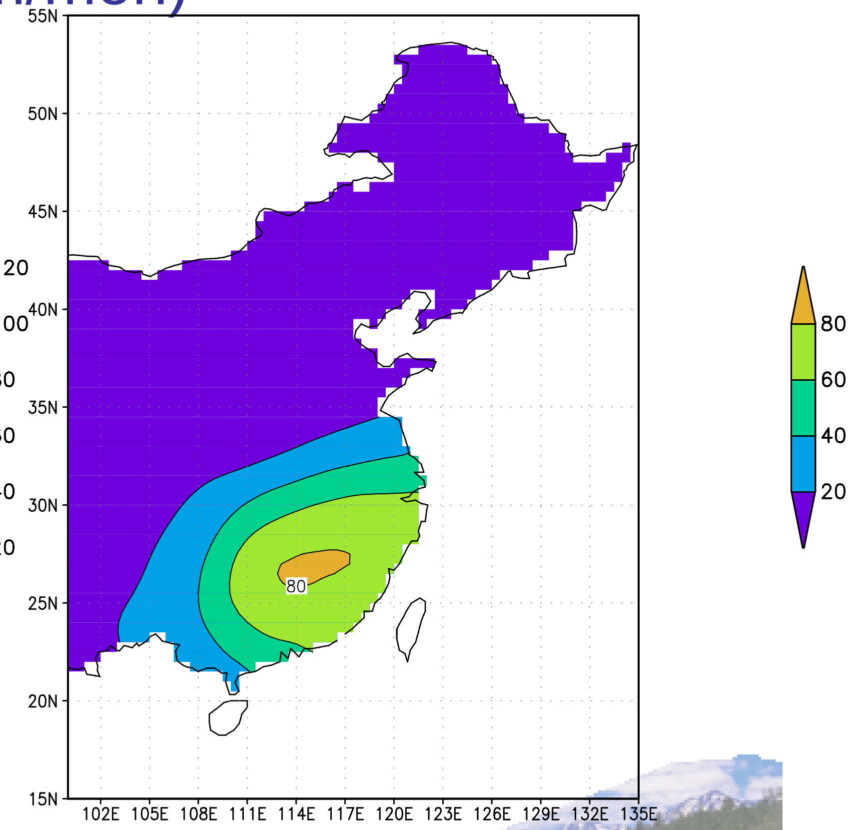
Intensity Index of the Northerly wind



Winter mean precipitation over Eastern China (Units: mm/mon)

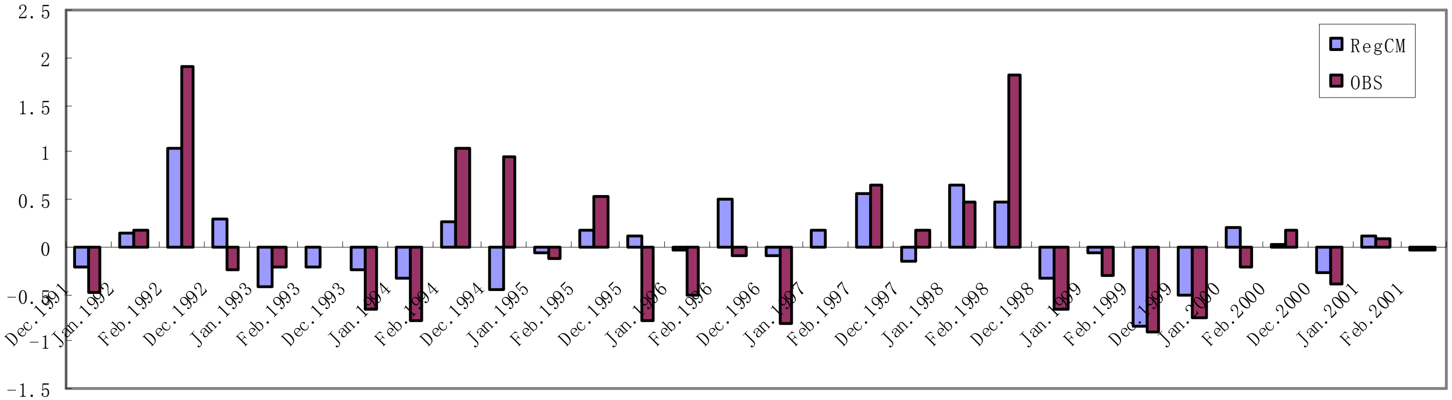


(a) simulation



(b) observation

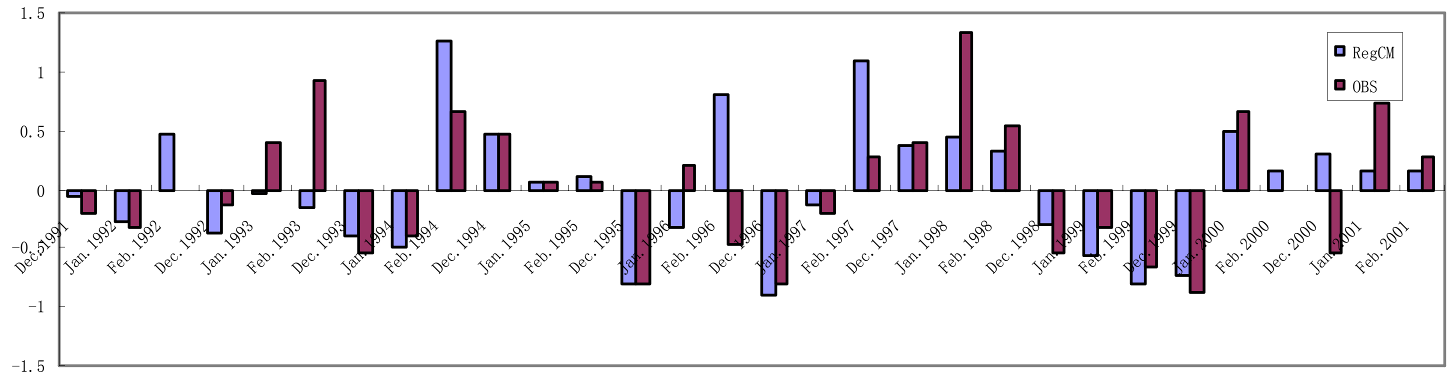
Percentage departure from the mean rainfall for the simulation (blue) and observation (red) (Unit: %)



R=0.6606

23/30

Mid-lower Yangtze River Basins

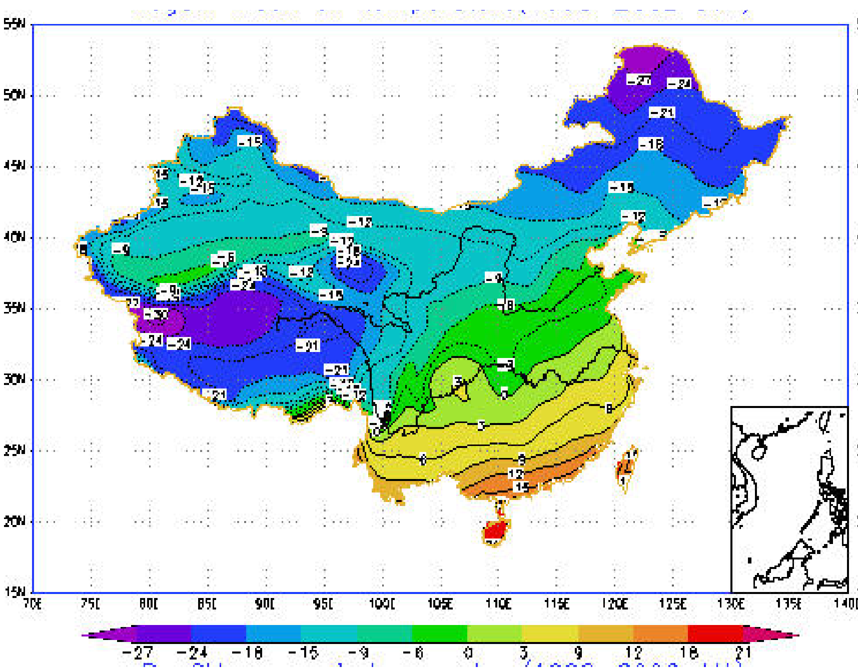


R=0.6184

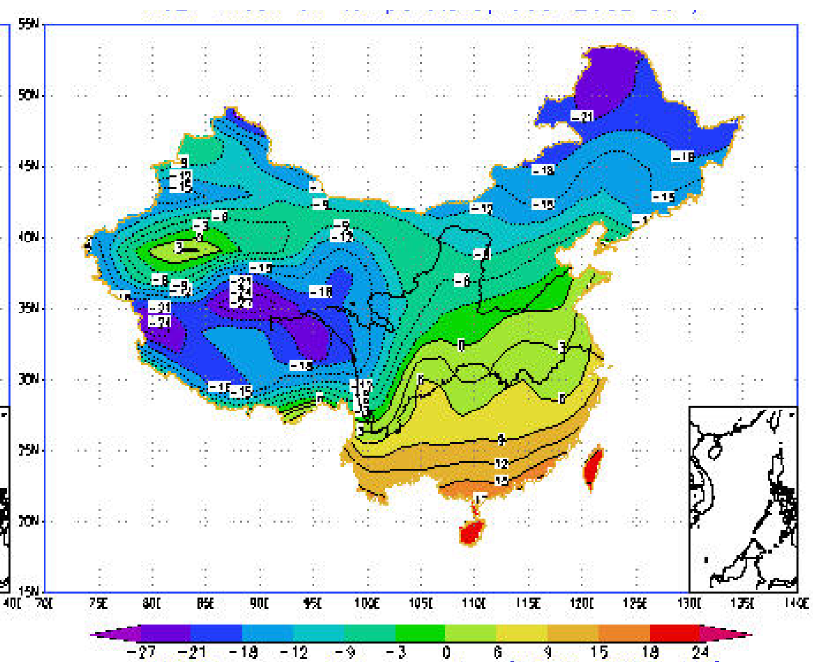
22/30

South China

Winter mean surface air temperature (Units: ºC)

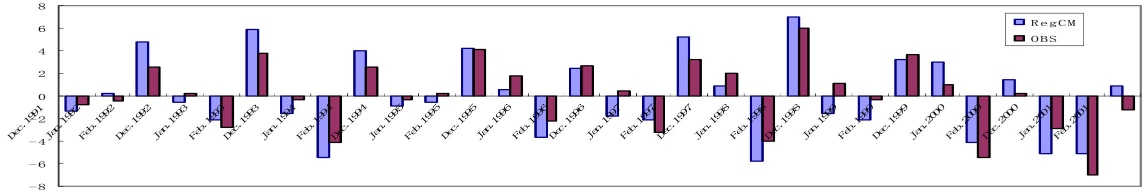


(a) simulation



(b) observation

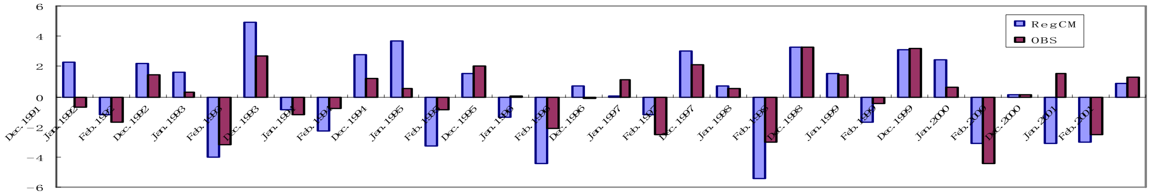
Northeast China



R=0.7107

24/30

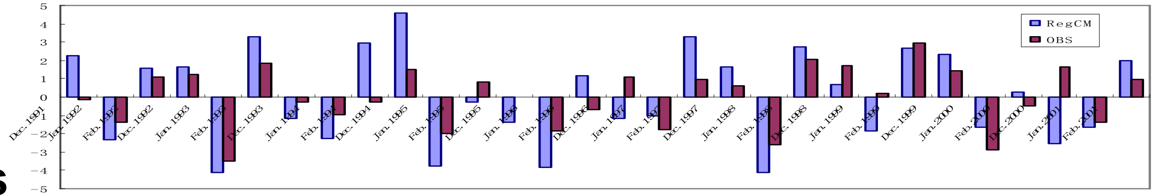
North China



R=0.7780

26/30

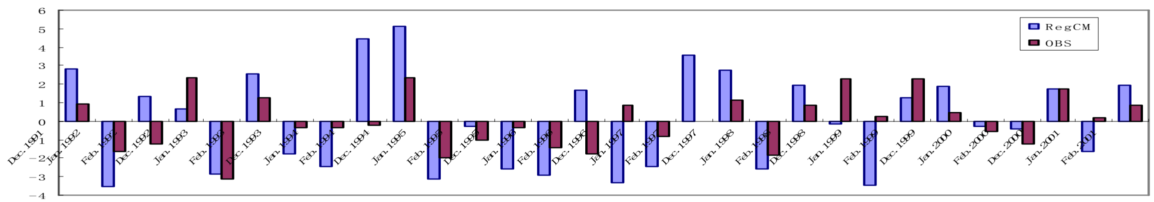
Mid-lower Yangtze River Basins



R=0.7309

21/30

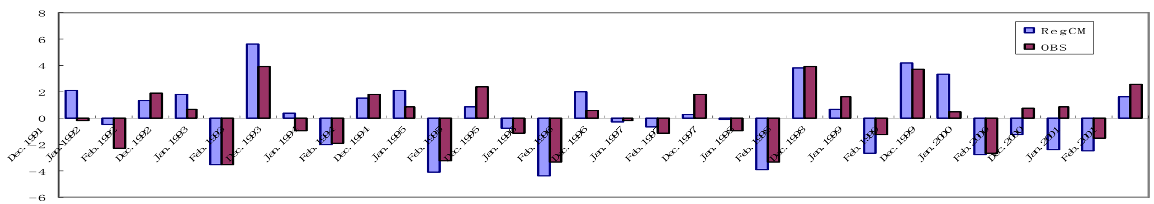
South China



R=0.5298

22/30

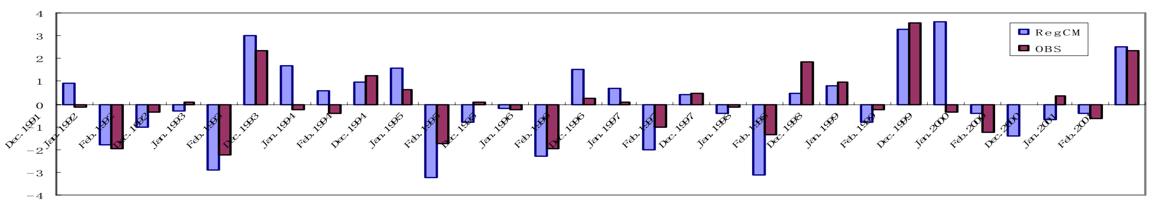
Northwest China



R=0.8502

26/30

Southwest China

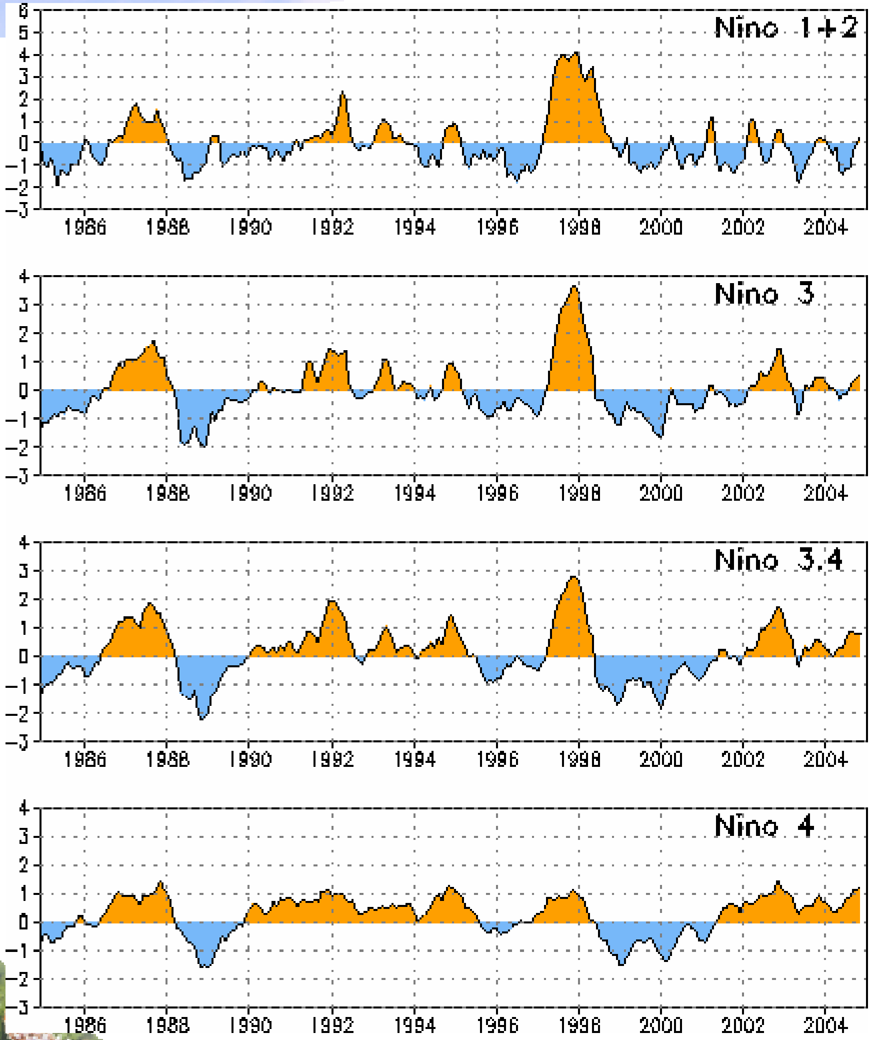


R=0.7743

22/30

Air temperature departure for the simulation (blue) and observation (red) (Unit: °C)

The effects of ENSO events



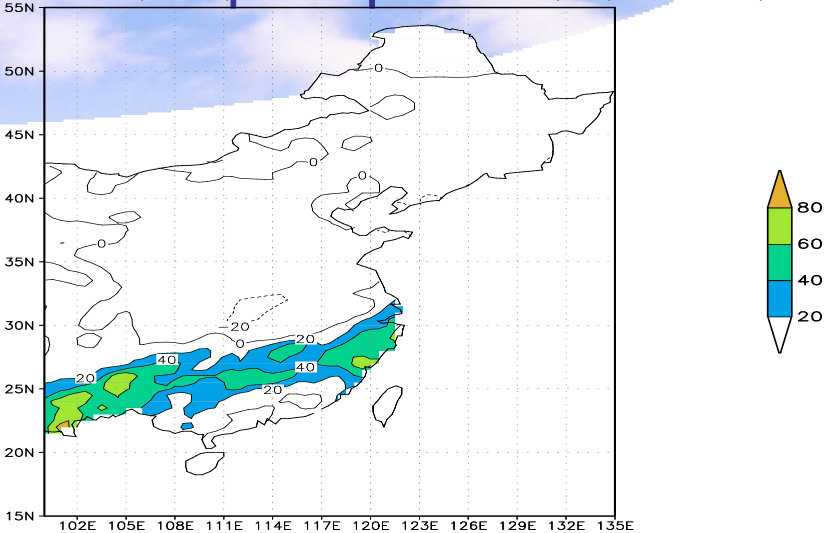
Major **El Niño** episodes:

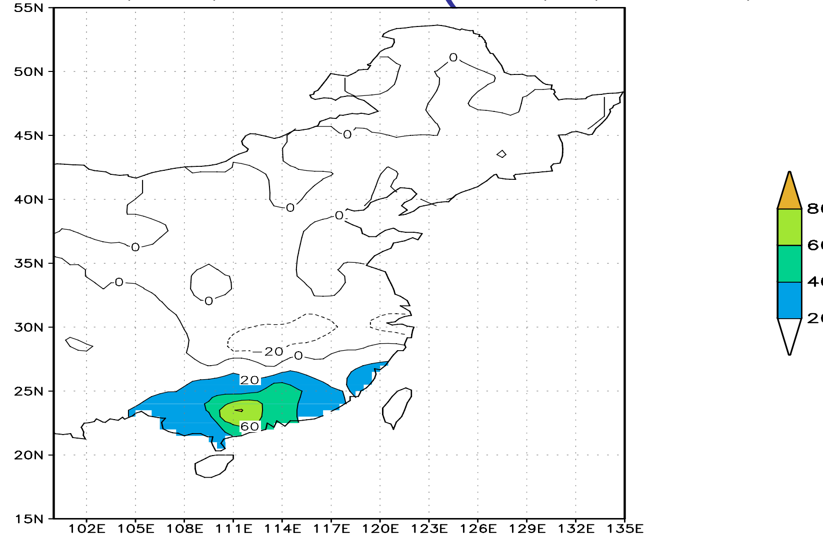
1991/92, 1994/95,1997/98

Majer **La Niña** episodes:

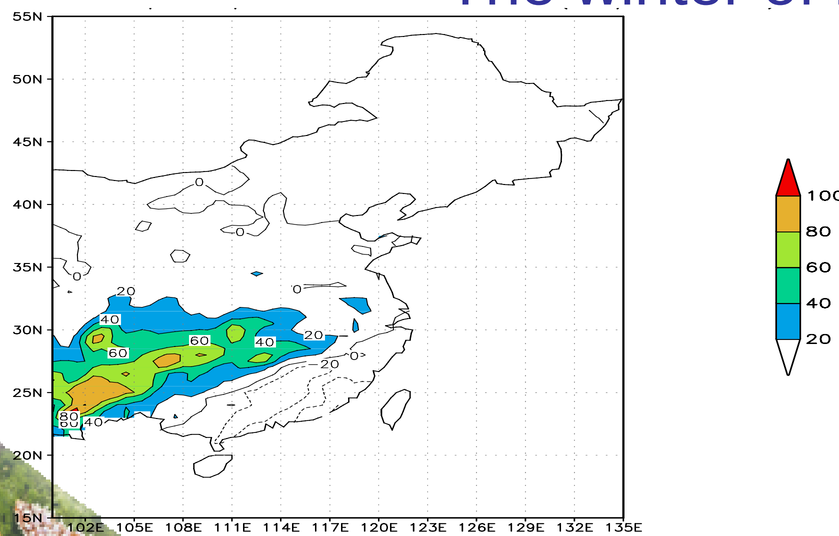
1998/99,1999/2000

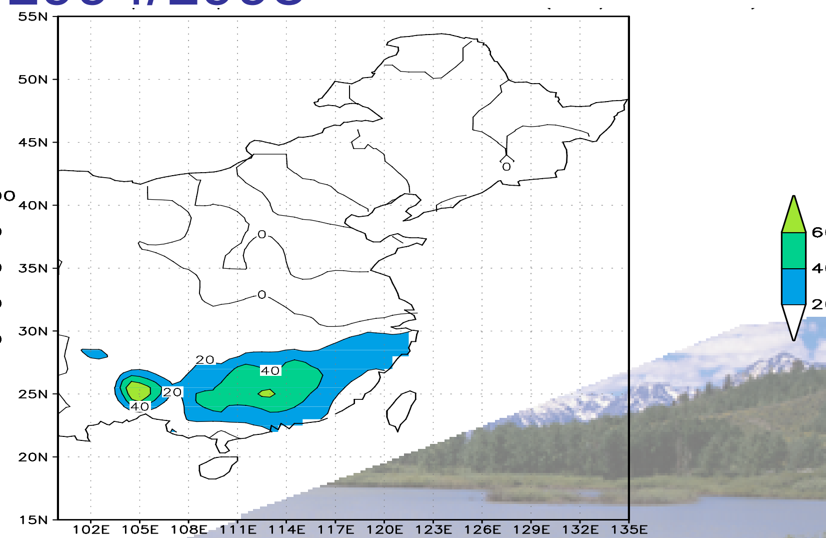
Anomalous precipitation the winter of 1991/1992(Units: mm/mon)





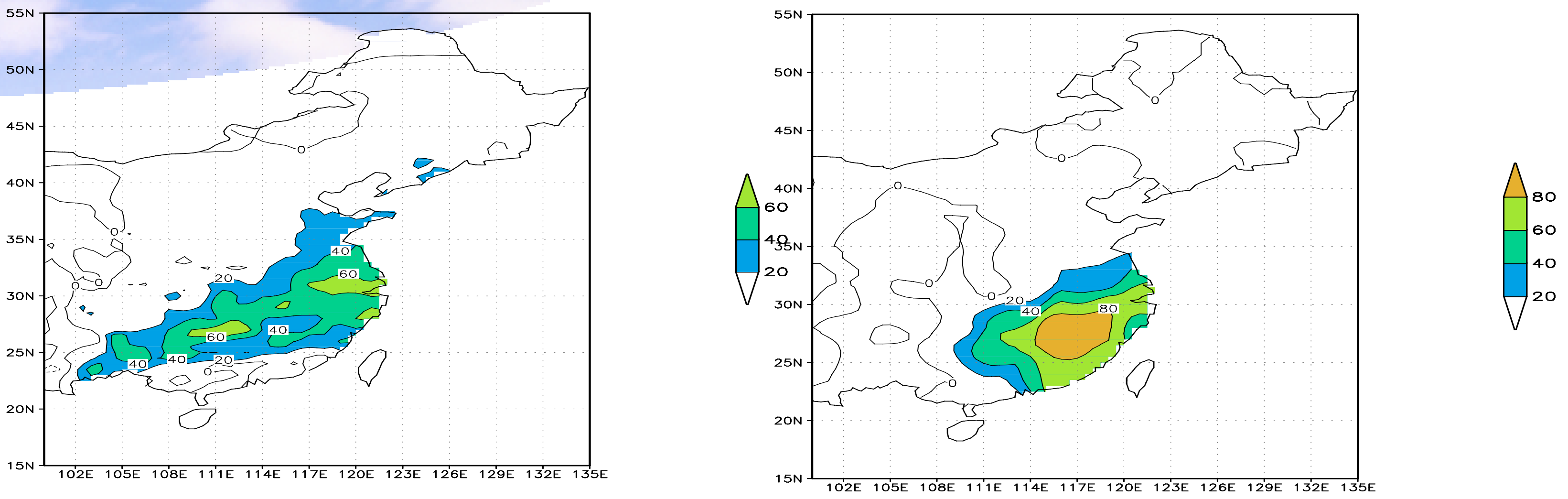
The winter of 1994/1995



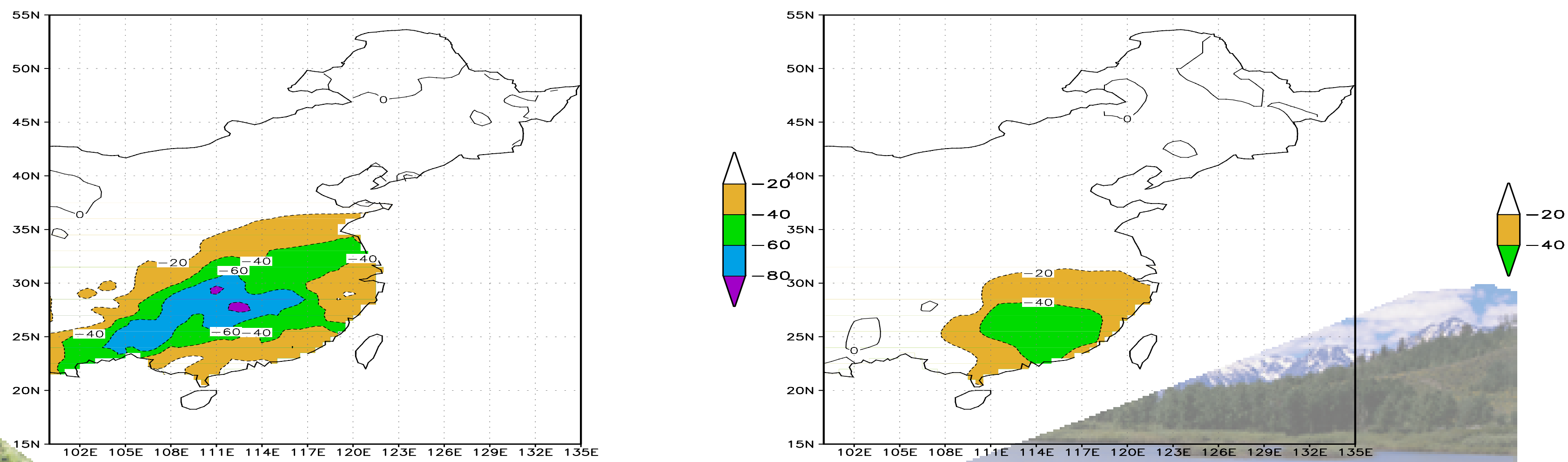


simulation (left) observation (right)

The winter of 1997/1998



The winter of 1998/1999

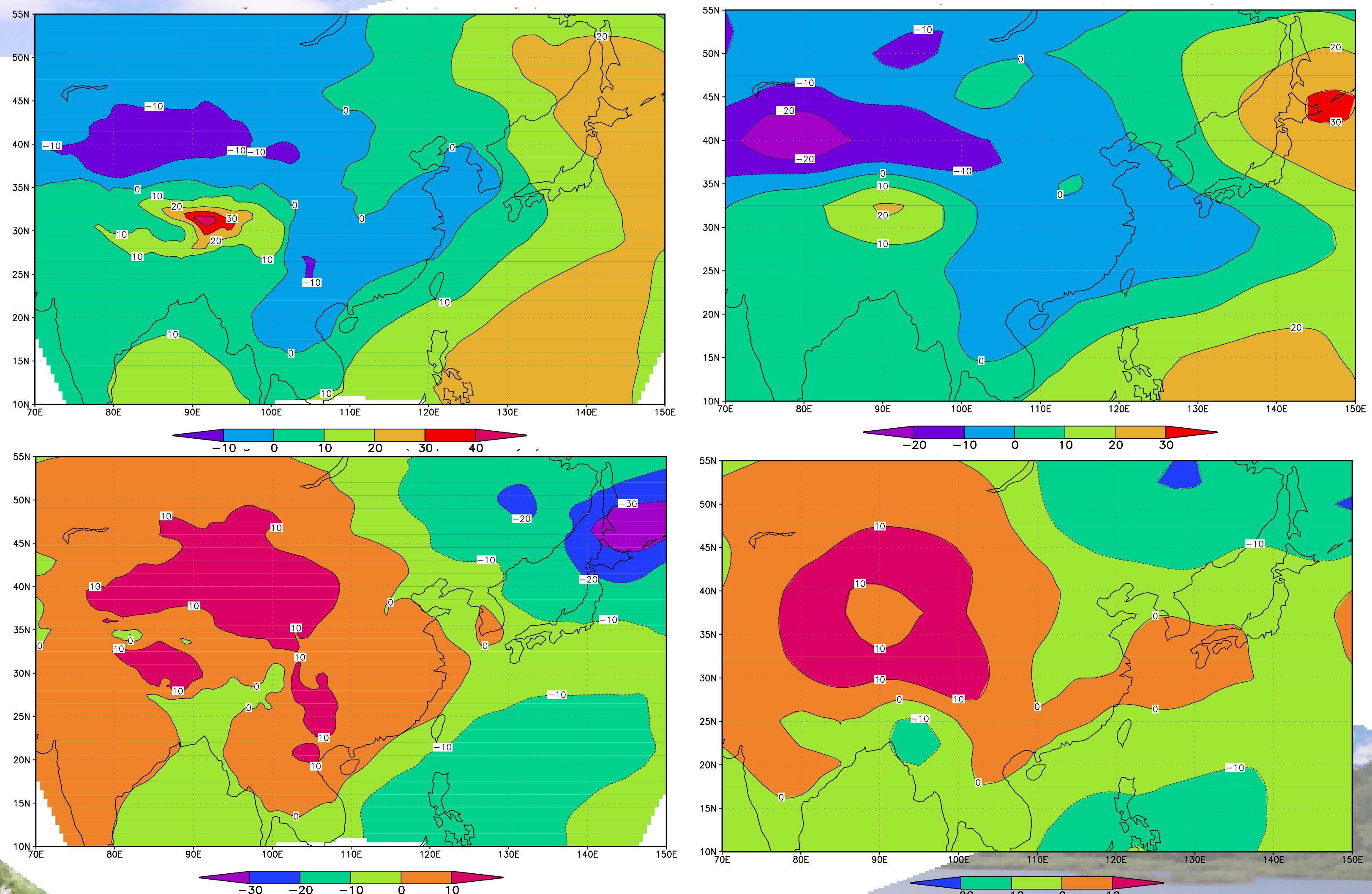


simulation (left) observation (right)

Anomalous height field at 1000hPa (Units: gpm)

1997/1998

1998/1999



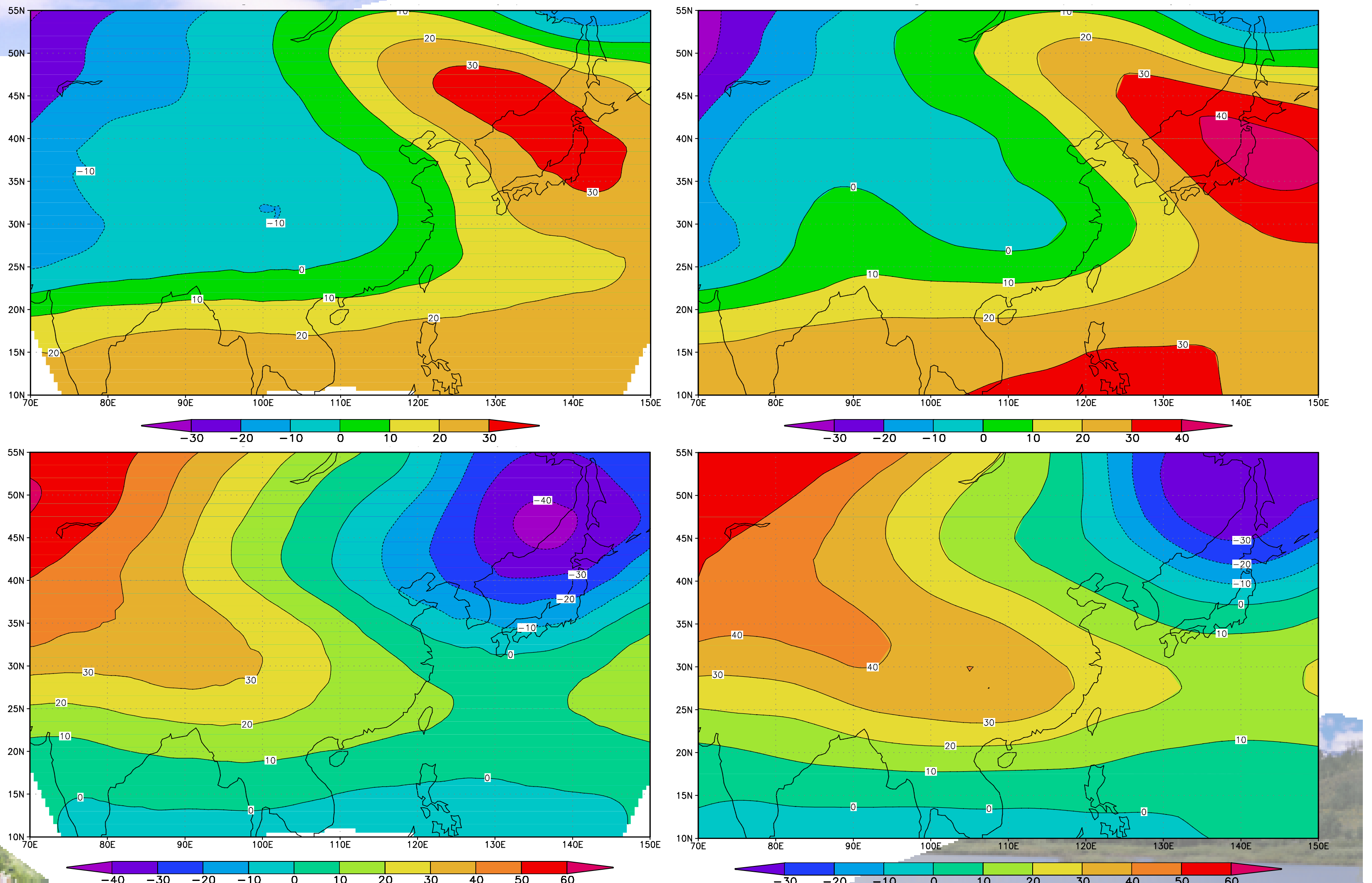
simulation (left)

reanalysis (right)

Anomalous height field at 500hPa (Units: gpm)

1997/1998

1998/1999



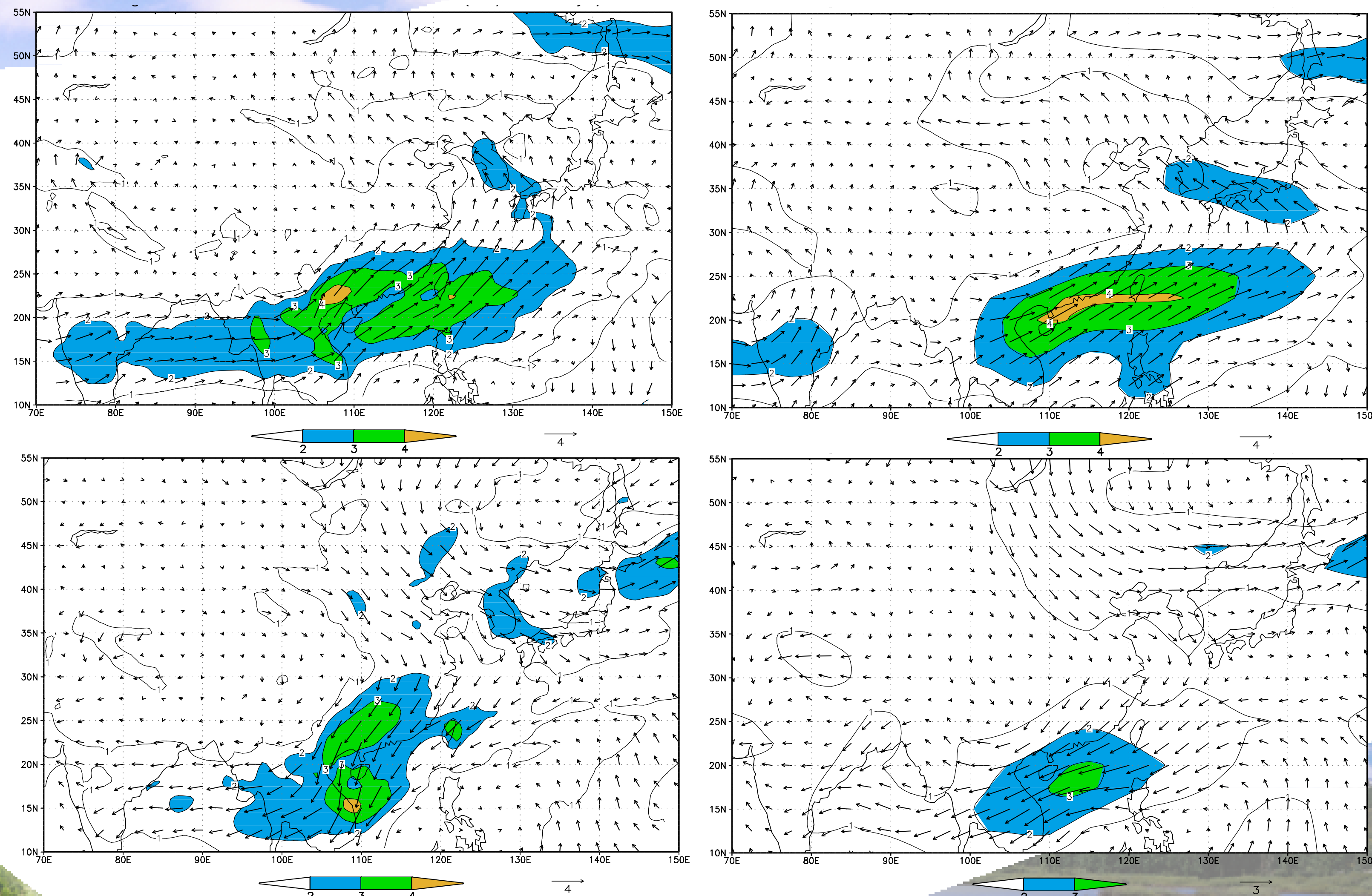
simulation (left)

reanalysis (right)

Anomalous wind field at 850hPa （Units：m/s）

1997/1998

1998/1999



simulation (left)

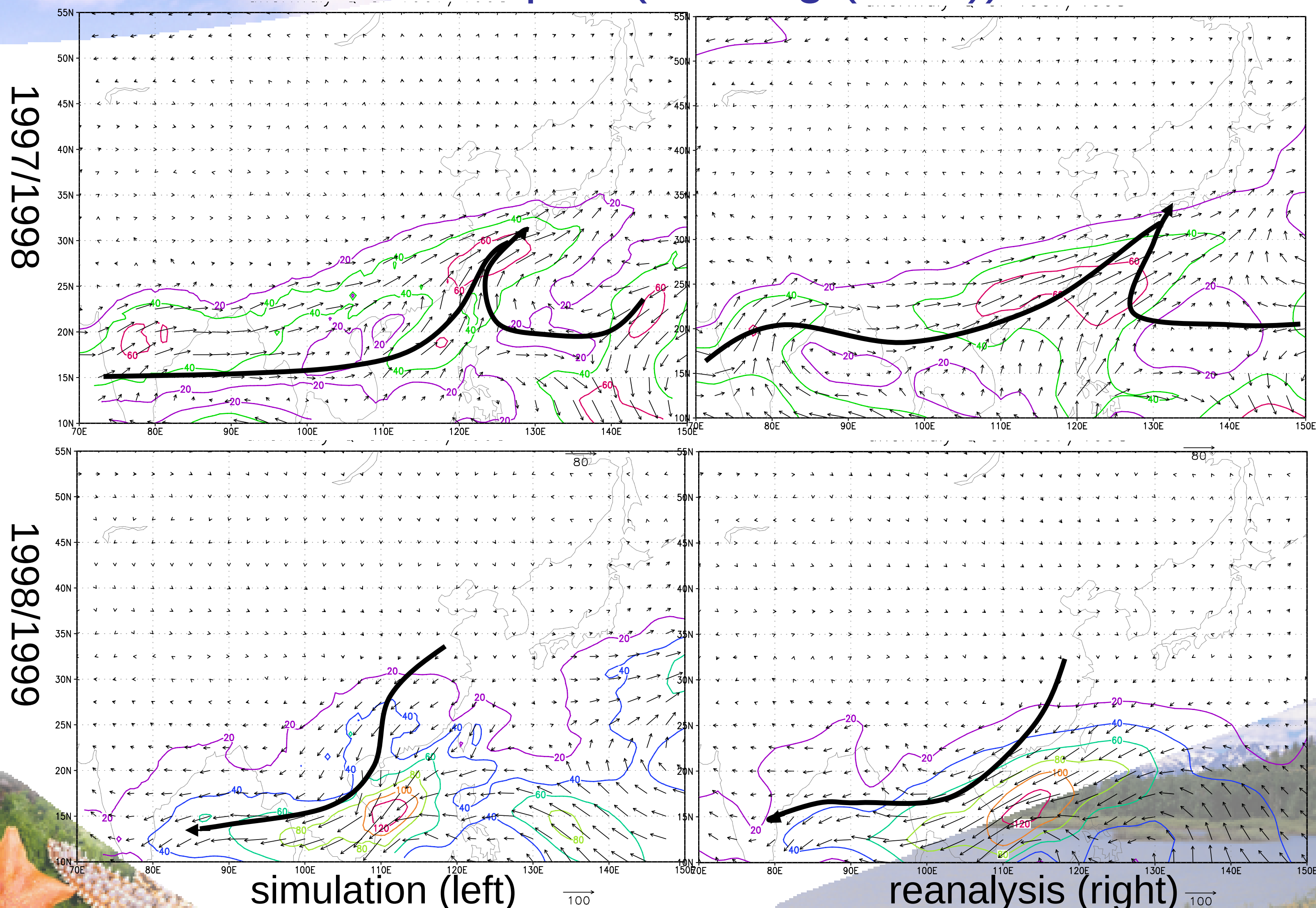
reanalysis (right)

Table 2 Monsoon index in the winter of 1997/1998 and 1998/1999

	A_n				I_n			
	Dec	Jan	Feb	mean	Dec	Jan	Feb	mean
1997/98	0.65/0.57	0.58/0.52	0.50/0.39	0.58/0.49	4.69/4.57	6.28/5.37	5.18/4.0	5.38/4.65
1998/99	0.82/0.81	0.86/0.73	0.88/0.77	0.85/0.77	6.26/5.17	6.14/5.59	6.13/5.64	6.18/5.47

notes: the simulation is on the left of '/' and reanalysis results is on the right of '/'.

Anomalous field of the vertically integrated moisture transport (Units: g/(s·cm))



Conclusions

- The model can reproduce well basic characteristics of the winter monsoon circulations. The simulated occurrence frequency and the regions of the cold surge, as well as the intensity of the winter monsoon are also consistent with the observation.
- The simulated air surface temperature and rainfall distribution are in agreement with the observation, but the rainfall amounts has been overestimated in the model.
- The simulation also indicates the significant differences of circulation patterns and rainfalls in the winters that were affected by cold and warm ENSO events, respectively.

Thanks for your attention!