RCMs' Dynamic Downscaling Ability and a few Major Factors that Affect this Ability

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Questions: The most important issue is whether, and if so, under what conditions the dynamic downscaling method (DDM) is really capable of improving/adding more climate information at different scales compared to the GCM or reanalysis that imposes LBC to the RCMs.

Hypothesis: *RCMs have limited downscaling ability under certain conditions, highly associated to the RCM setting, its dynamic approach, and physical parameterizations, mainly land surface processes and PBL, convective and radiation schemes.*

We uses regional/global Reanalyses and high resolution observational data for evaluation.

Warner et al. (1997), Giorgi and Mearns (1999), & Denis et al. (2003) indicate the following issues affecting downscaling ability:

1. Numerical nesting: mathematical formulation and strategy
2. Spatial resolution difference between the driving data and the nested model
3. Spin-up
4. Update frequency of the lateral boundary conditions (LBCs)
5. Domain size and boundary locations
6. Horizontal and vertical interpolations errors
7. Physical parameterizations consistencies
8. Quality of the driving data
9. Climate drift or systematic errors

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Some major factors contributing to the dynamic downscaling ability

I. Domain Size and LBC location tests

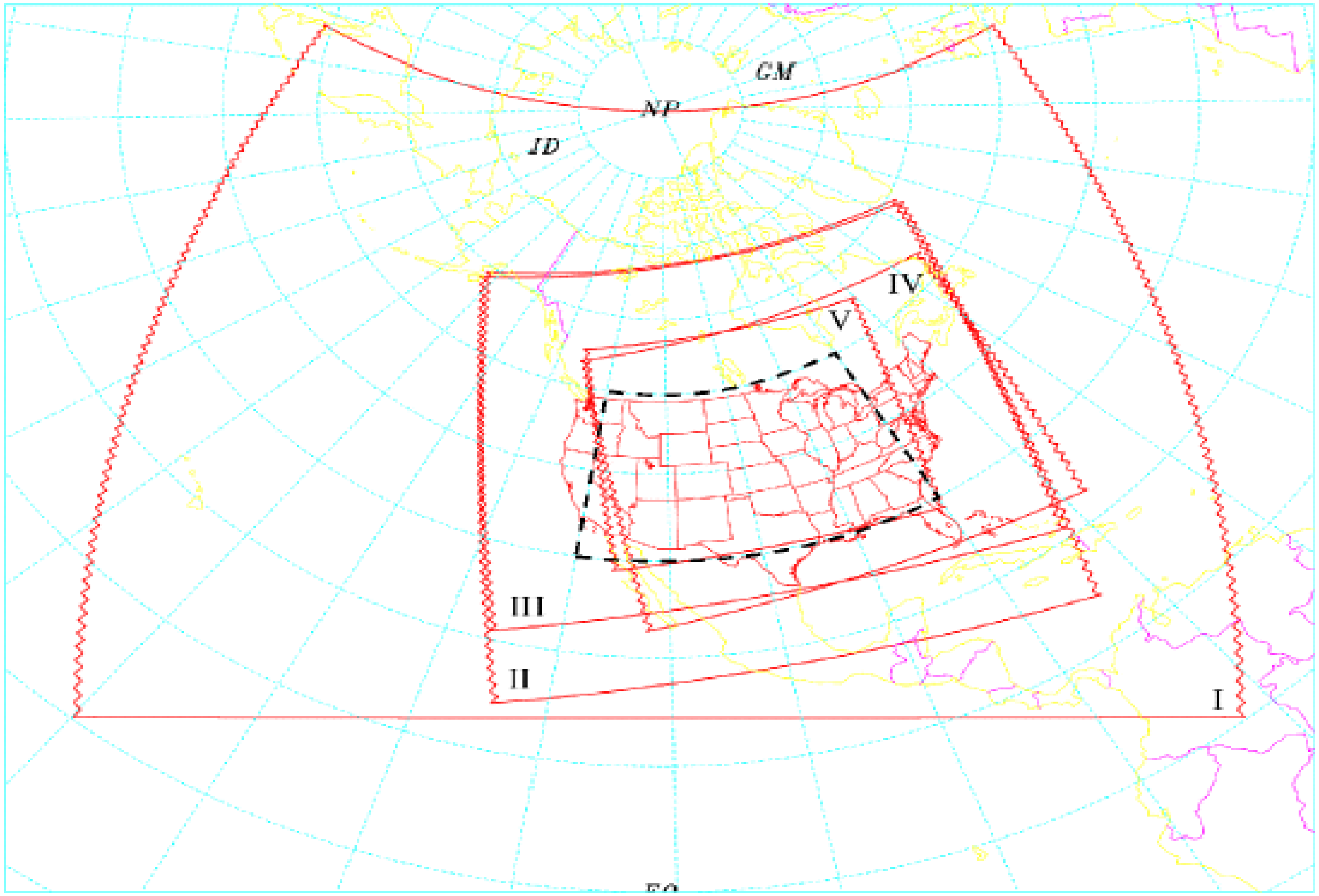
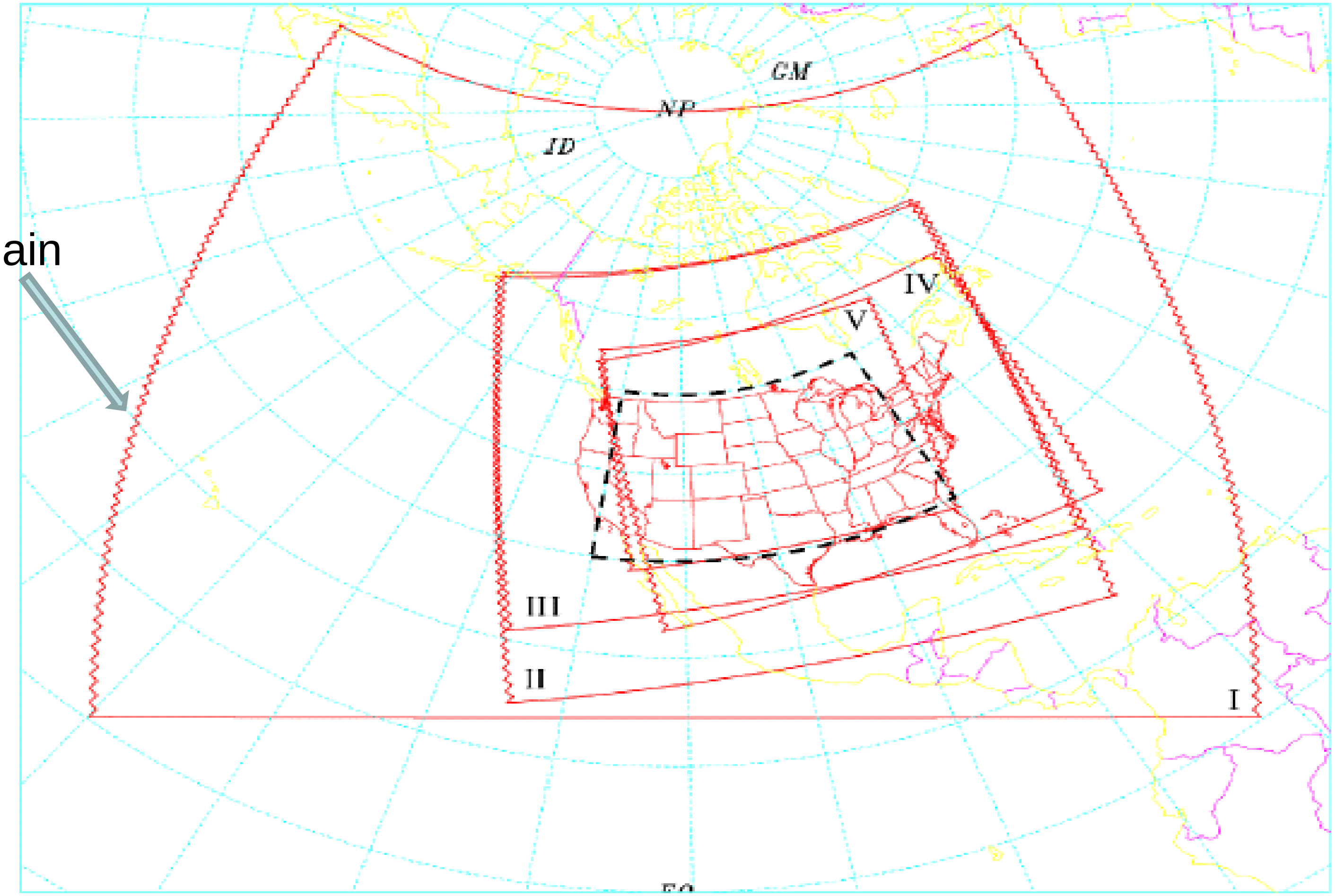


Fig. 3

Fig. 3. Eta domains for model sensitivity experiments: (I) Large Domain, (II) South Domain, (III) Medium Domain, (IV) Small Domain, (V) Land Domain. See text for domain definition. Dash lines indicate the Test Area.

Xue et al., 2007, *J. Climate*

Large domain



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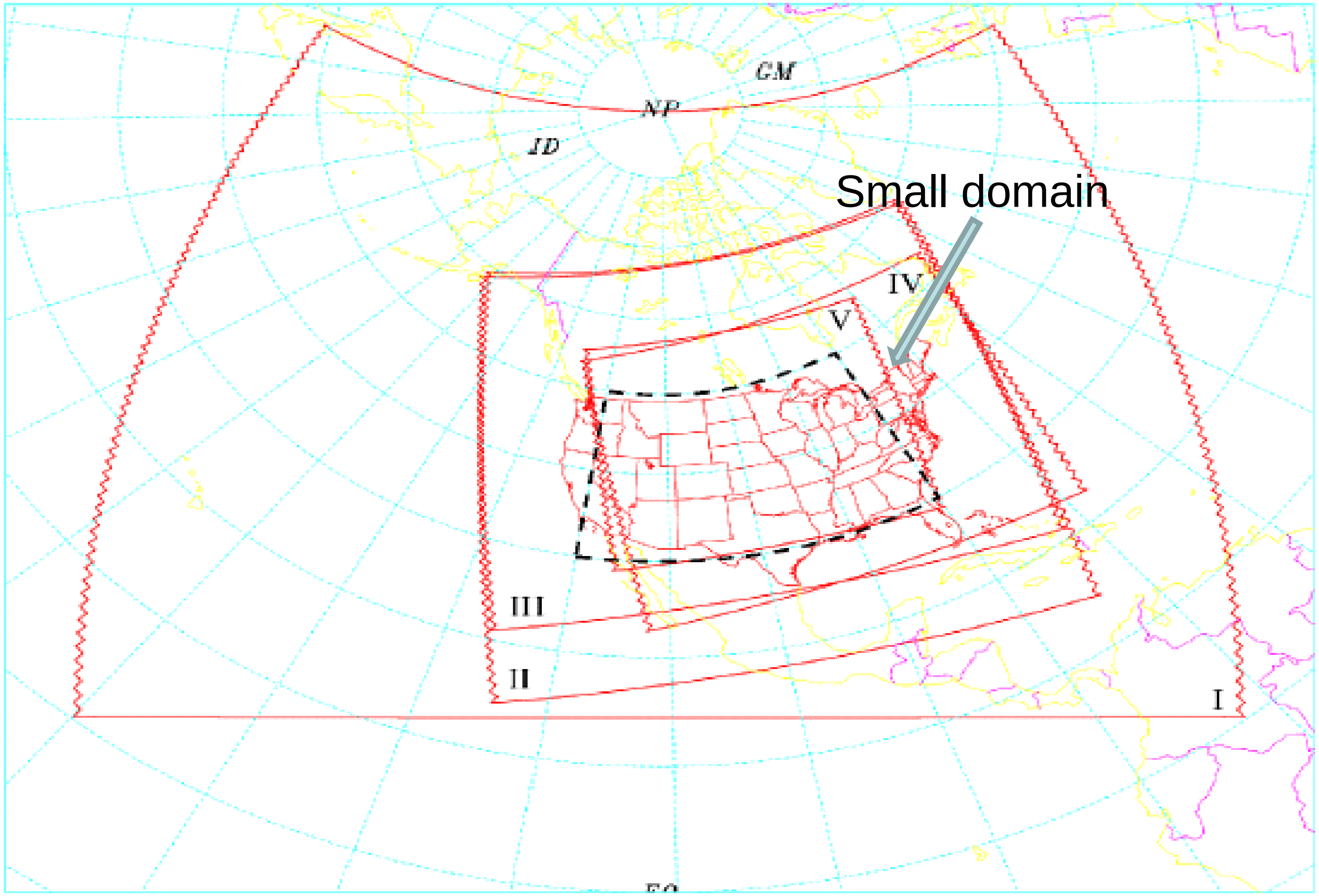

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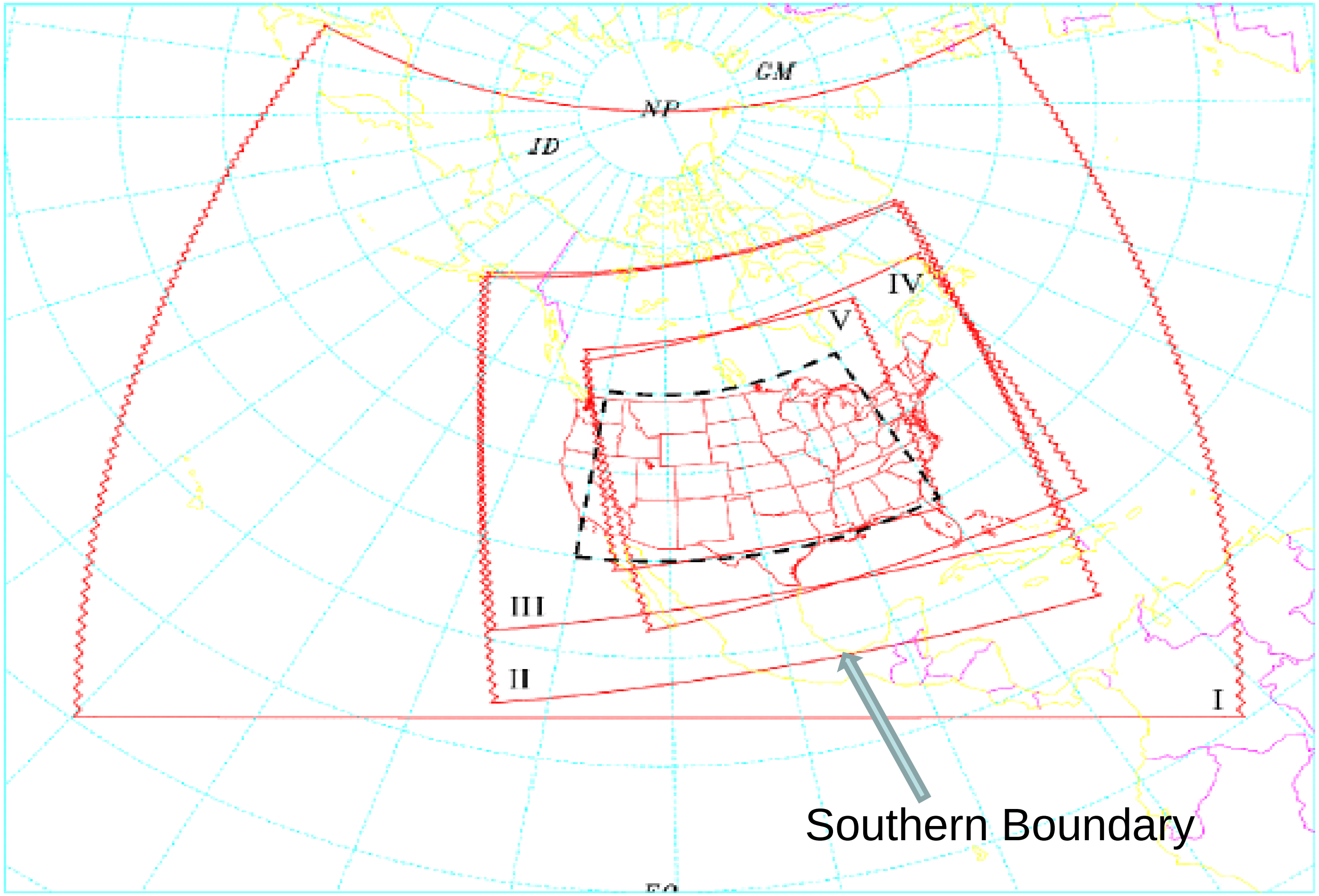

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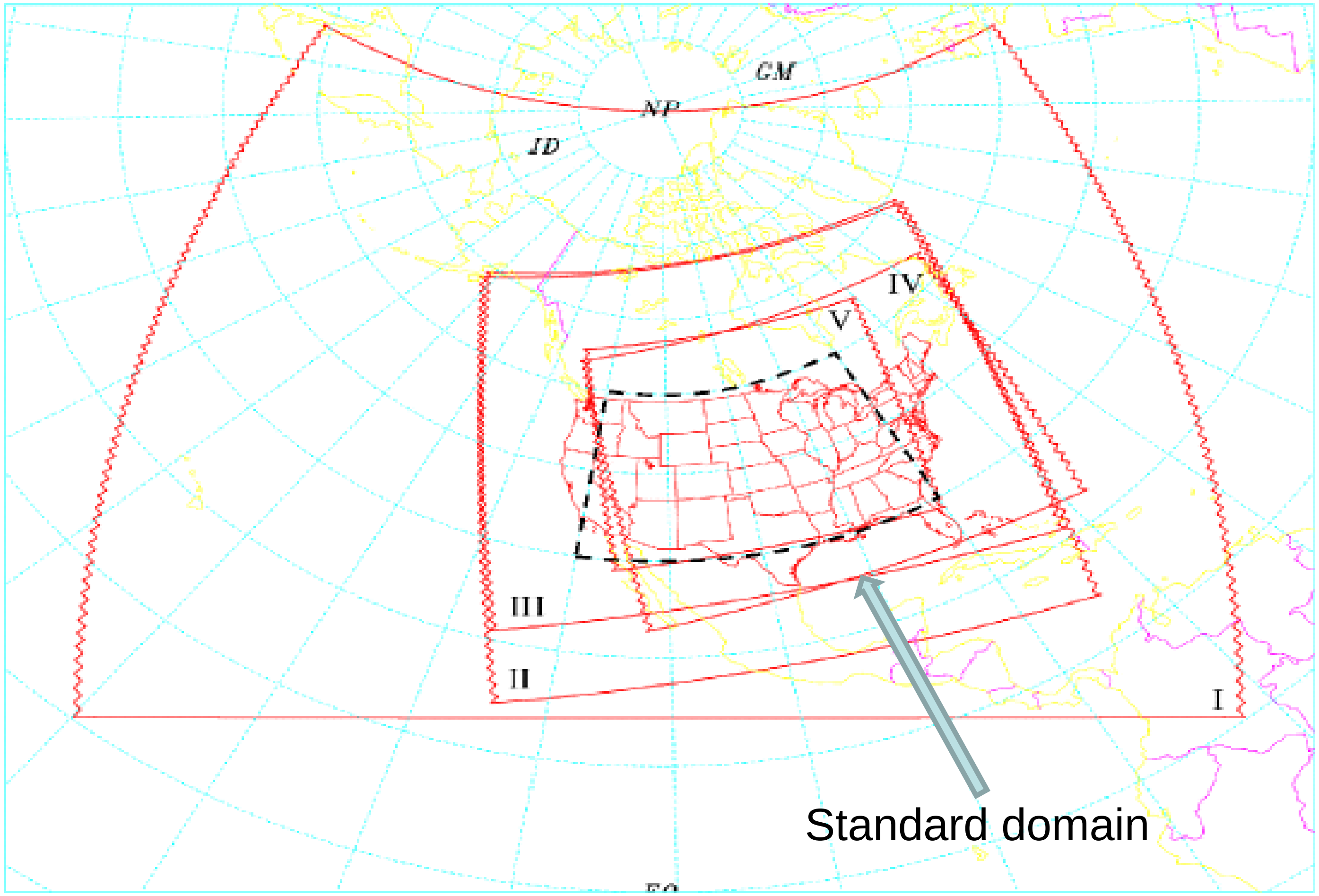

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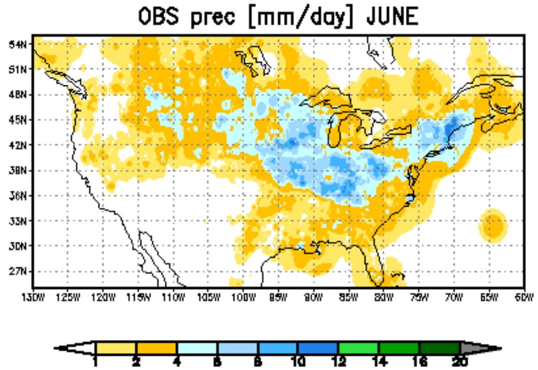
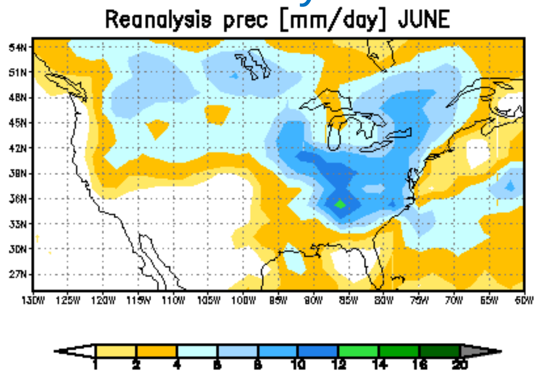
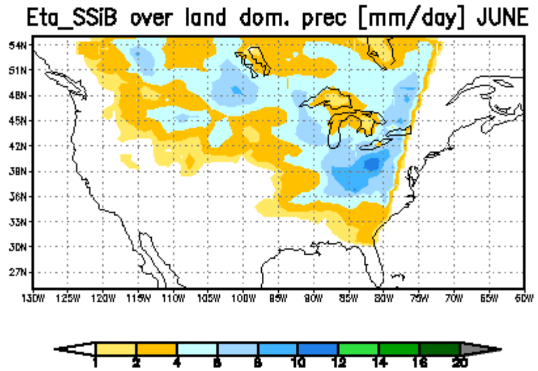
Observation



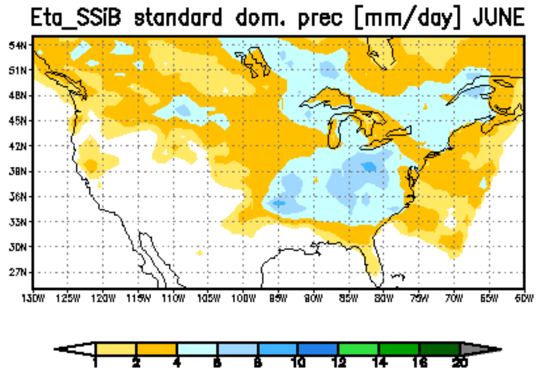
Reanalysis



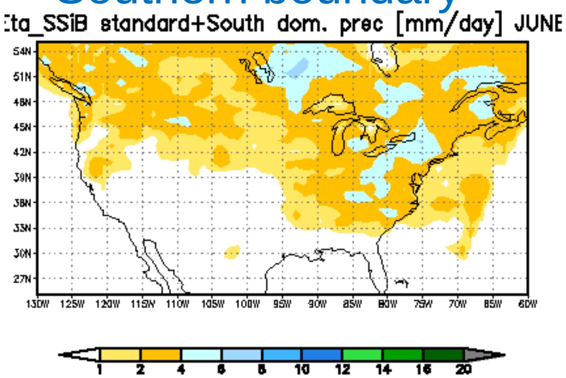
Land domain



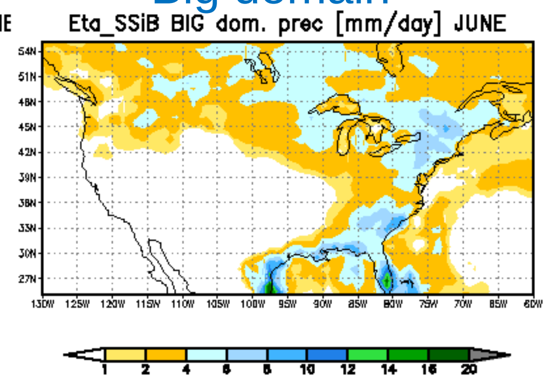
Standard domain



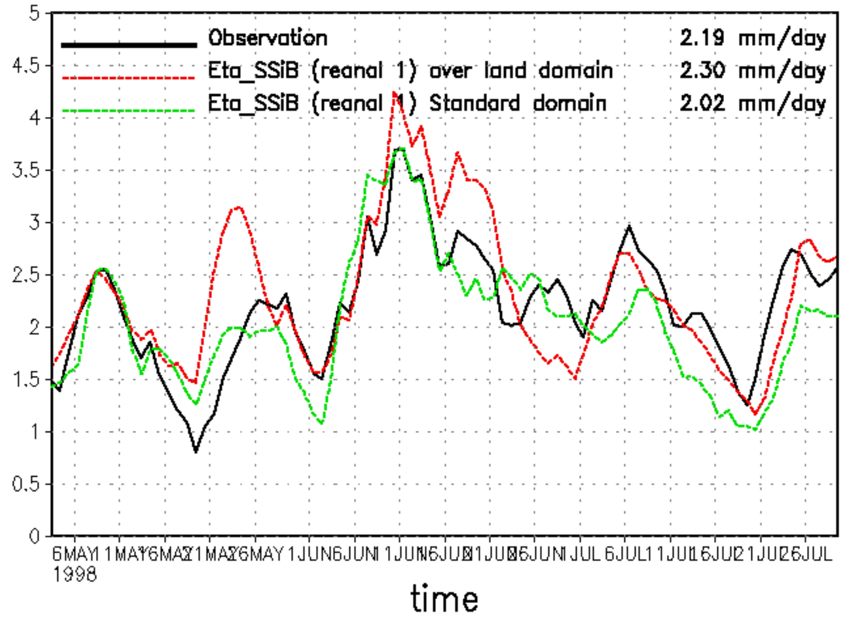
Southern boundary

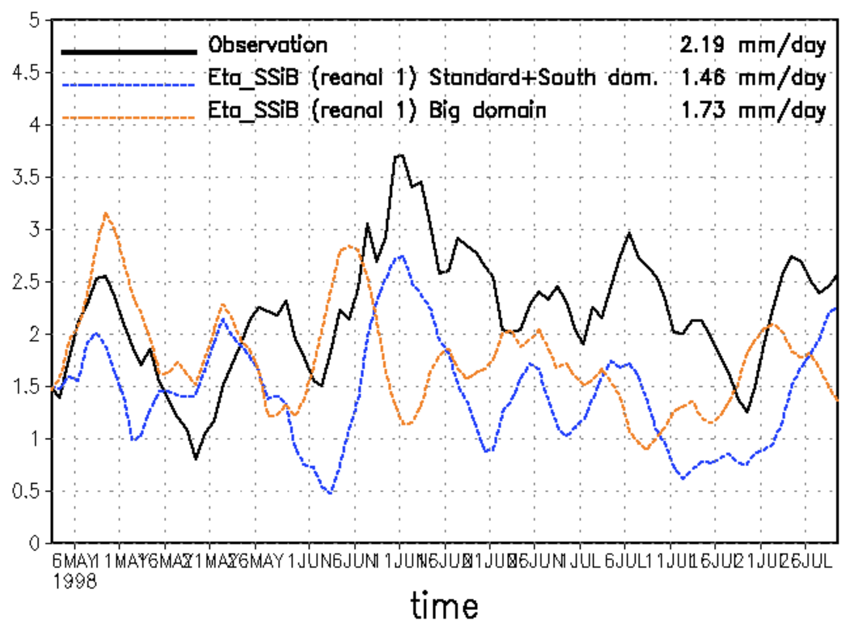


Big domain



MJJ 1998 precip (−120W/−80W,30N/50N)





June 98 200hPa Zonal wind (m/s)

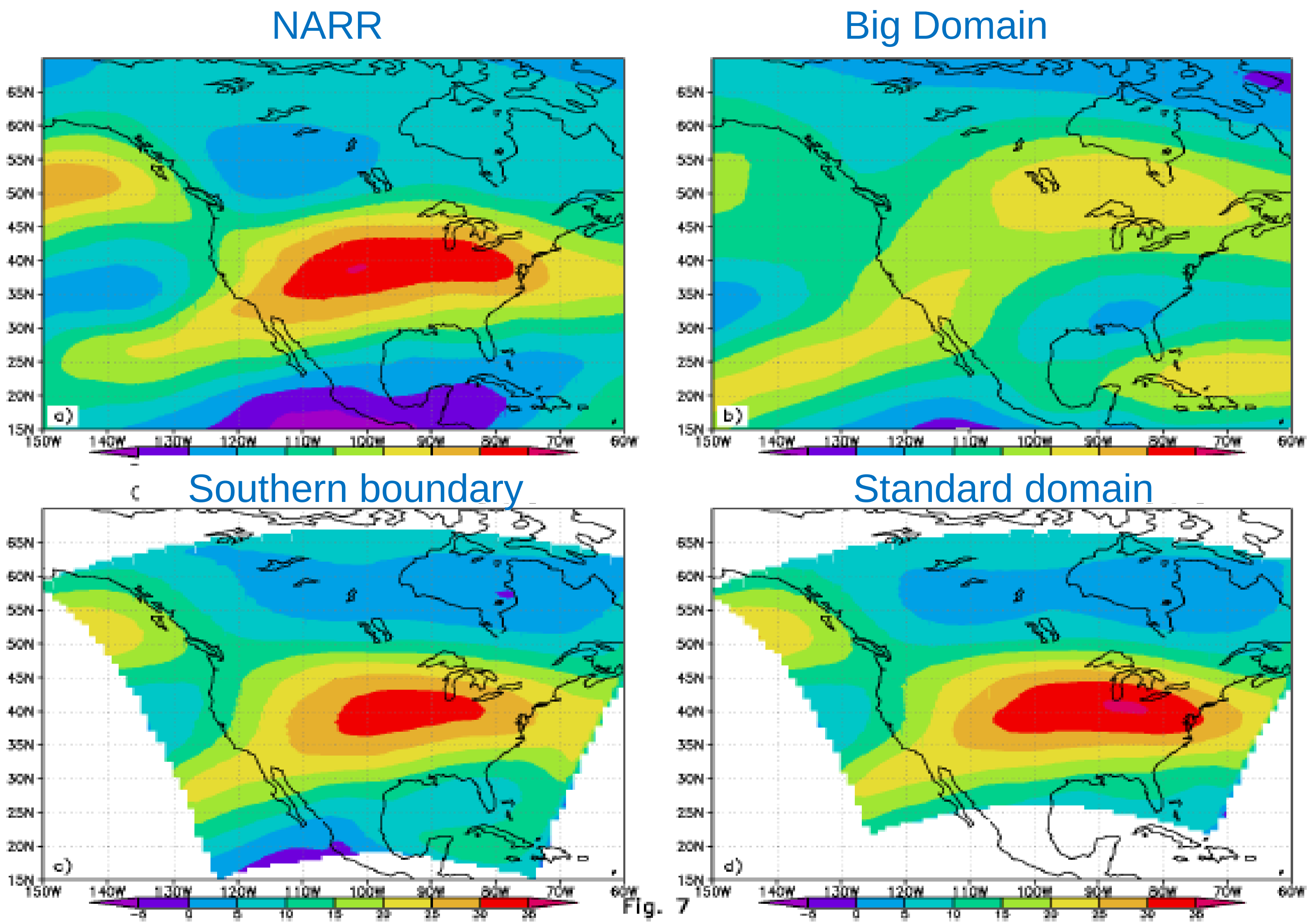


Fig. 7. June 200 hPa wind (m s^{-1}): (a). NARR; (b): Case 1); (c) Case 2; (d): Case 3.

June 98 wind stream lines and moisture transport

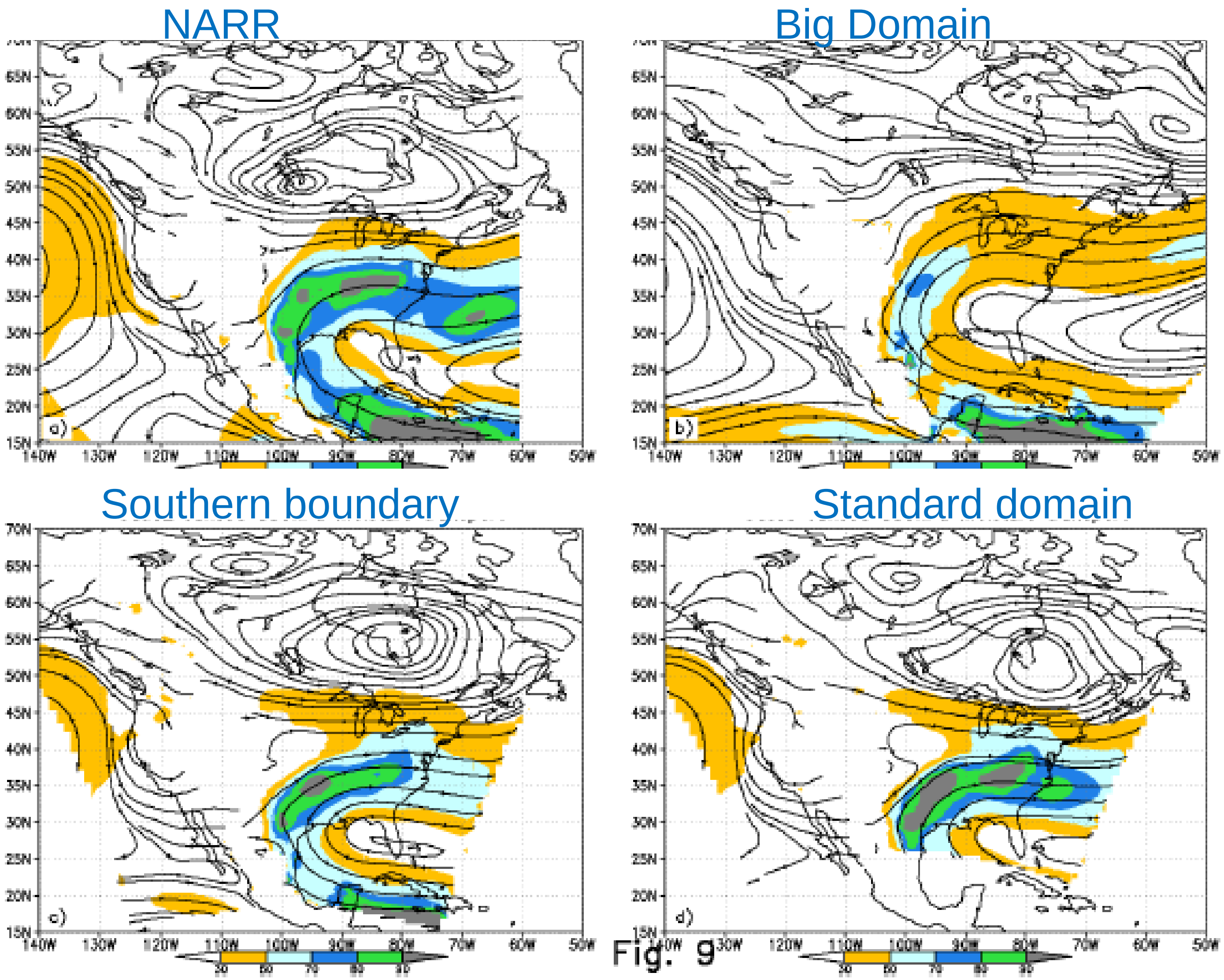
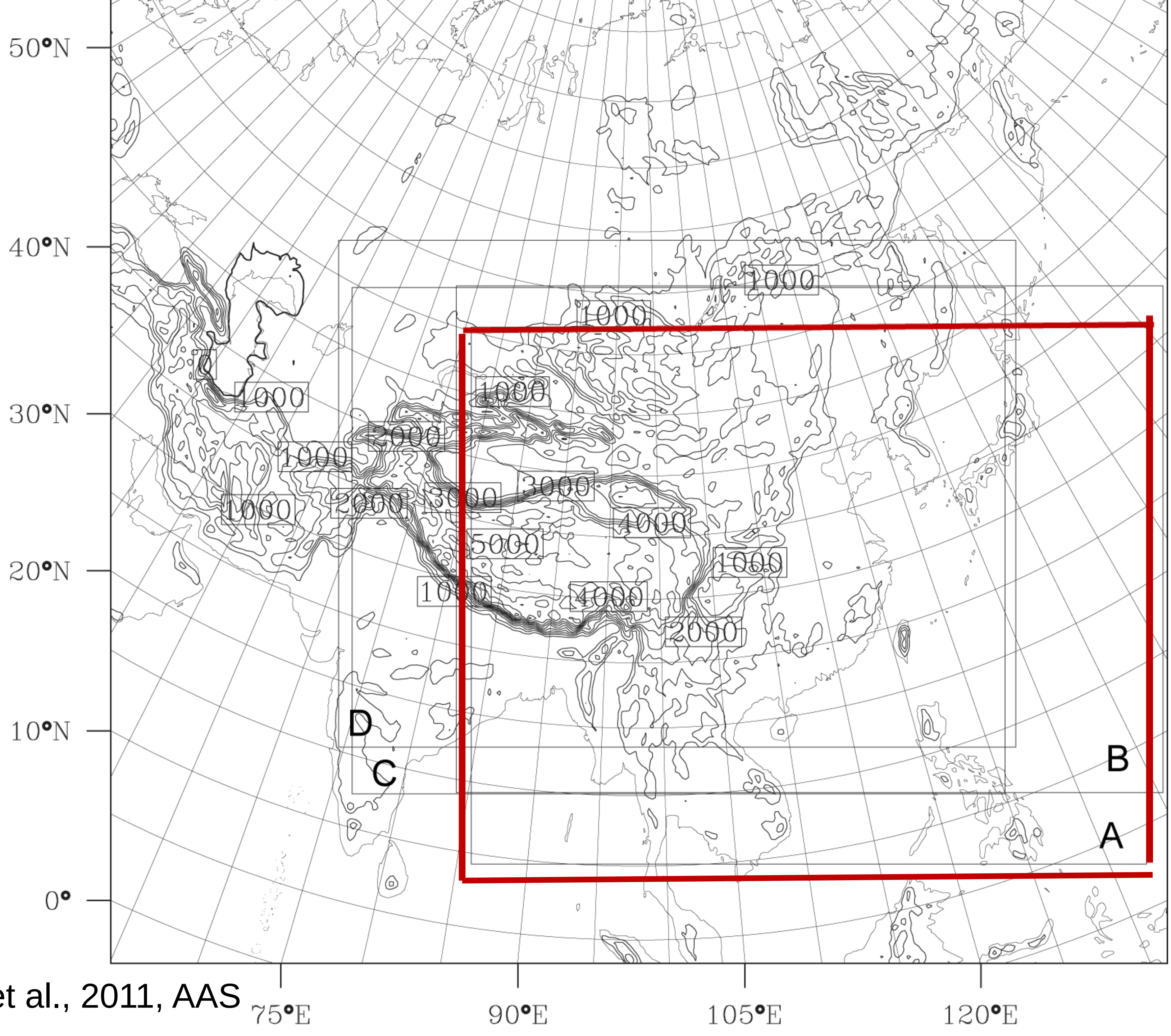
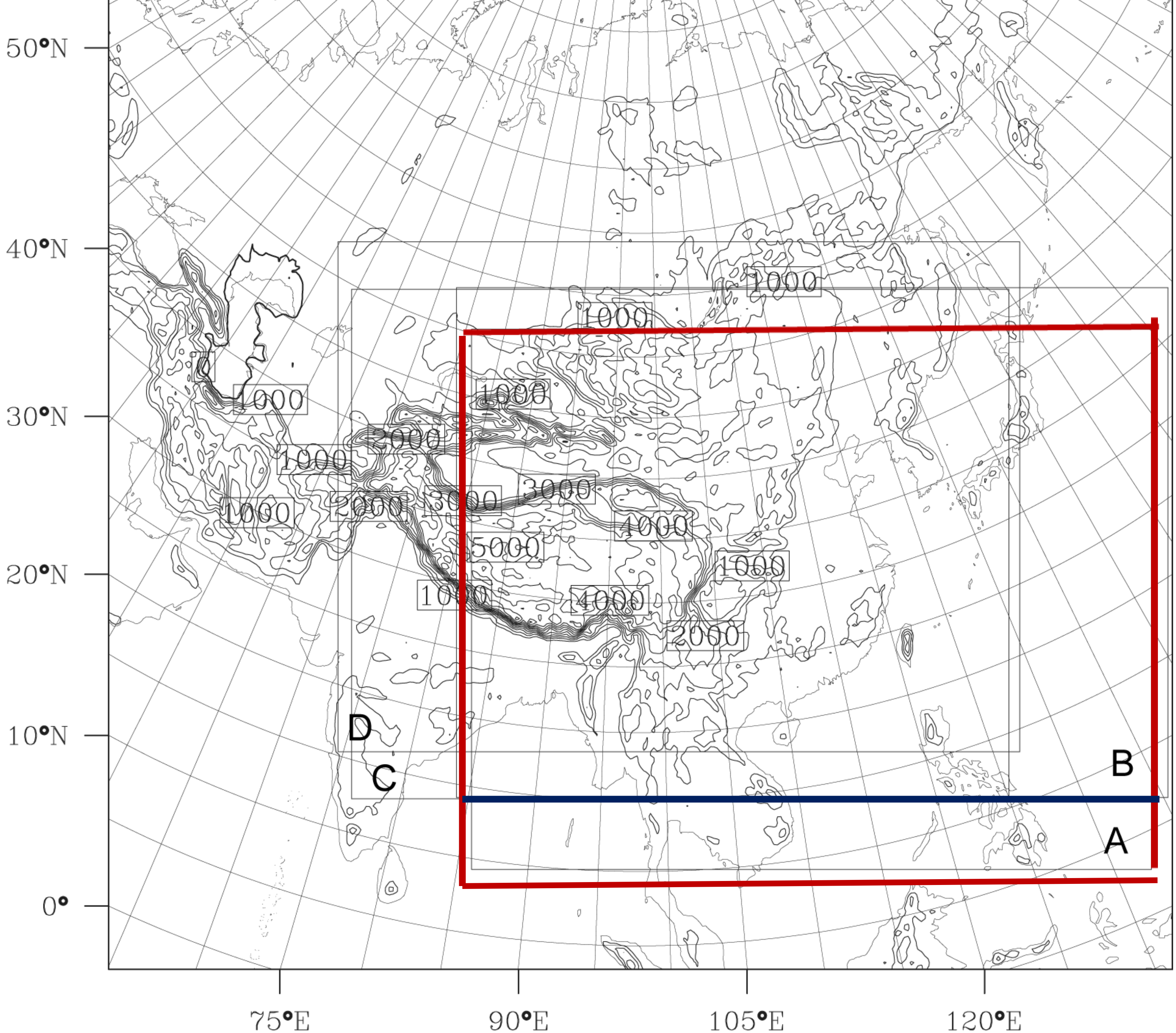
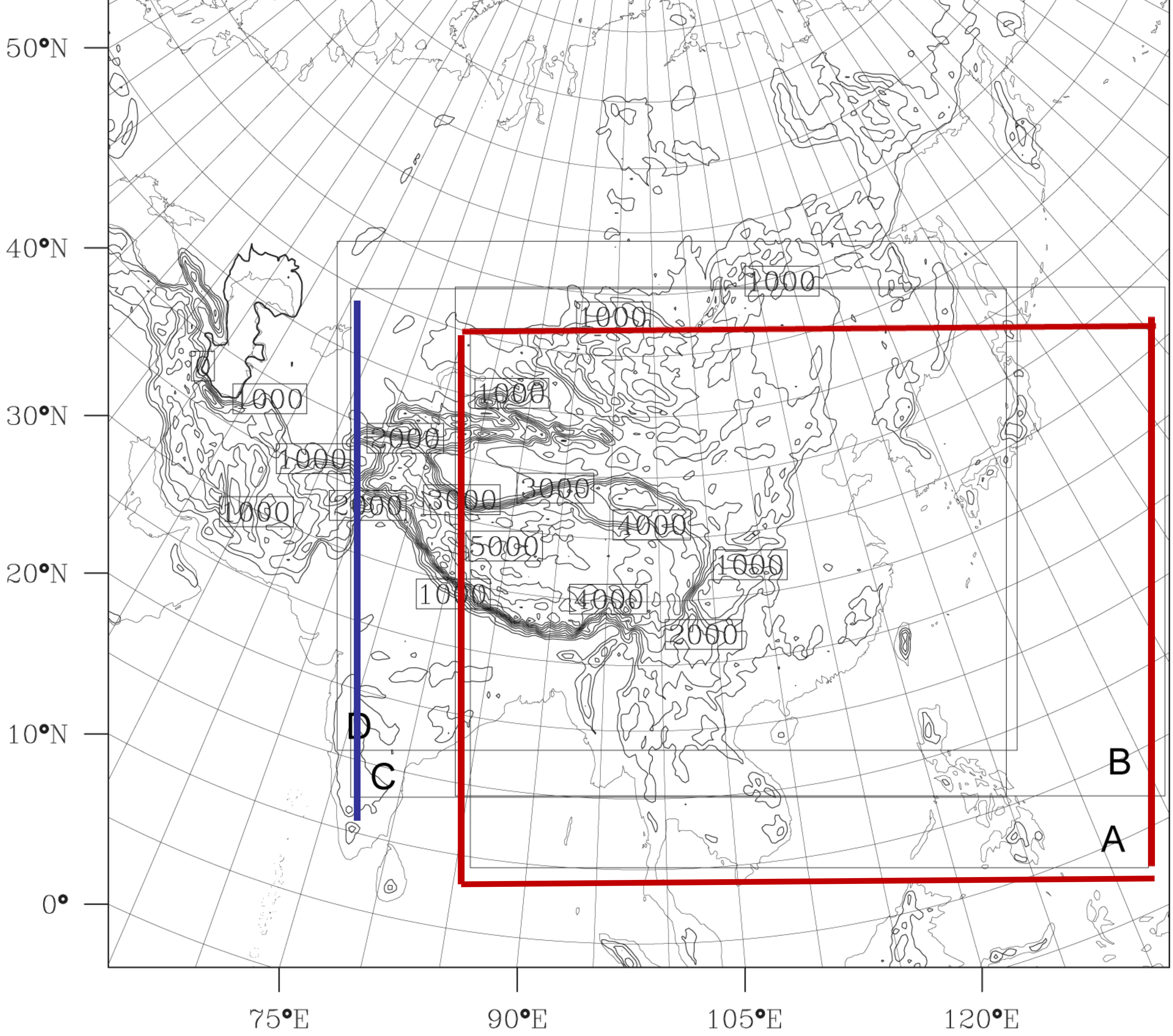


Fig. 9. June 850 hPa wind stream lines and moisture transport (g g^{-1} m s^{-1}): (a) NARR; (b) Case 1; (c) Case 2; (d) Case 3.



Gao et al., 2011, AAS


50°N
40°N
30°N
20°N
10°N
0°
75°E
90°E
105°E
120°E
1000
2000
3000
4000
5000
A
B
C
D


50°N
40°N
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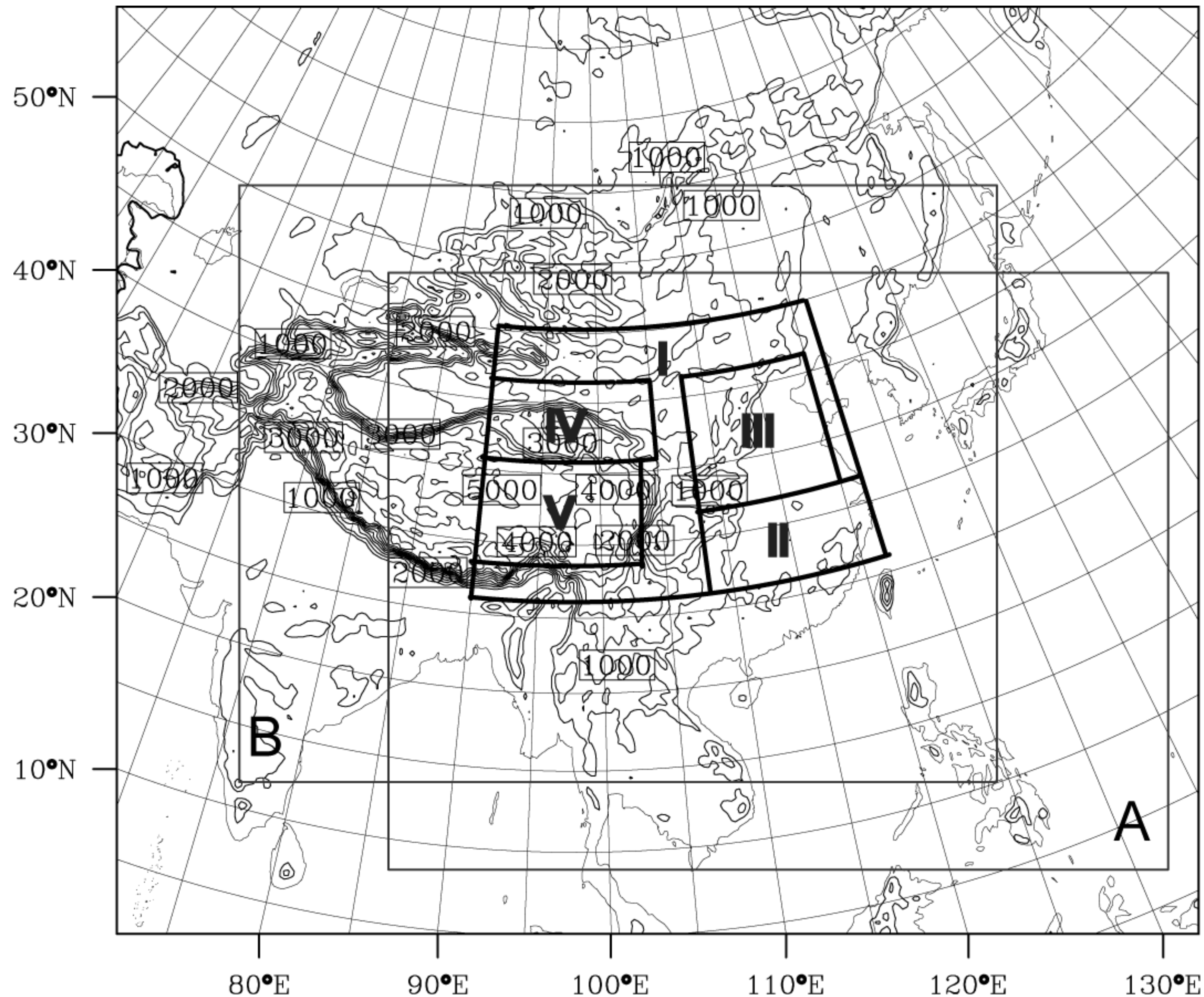

50°N
40°N
30°N
20°N
10°N
80°E
90°E
100°E
110°E
120°E
130°E
A
B
I
II
III
IV
V
1000
2000
3000
4000
5000

Table. Bias and Correlations (SC) for June between observation and reanalysis and simulated precipitations over different sub-regions

	South China		Northwest China		Tibetan Plateau	
	SC	Bias	SC	Bias	SC	Bias
NCEP R1	0.58	-29.9	0.54	-1.88	0.65	120.6
Standard domain	0.27	-8.82	0.74	28.3	0.74	106.5
Domain shift to north	-0.29	-145.1	0.25	37.3	-0.11	125.2
Domain shift to west	0.6	96.1	0.75	34.8	0.76	100.9

Unit: mm/month

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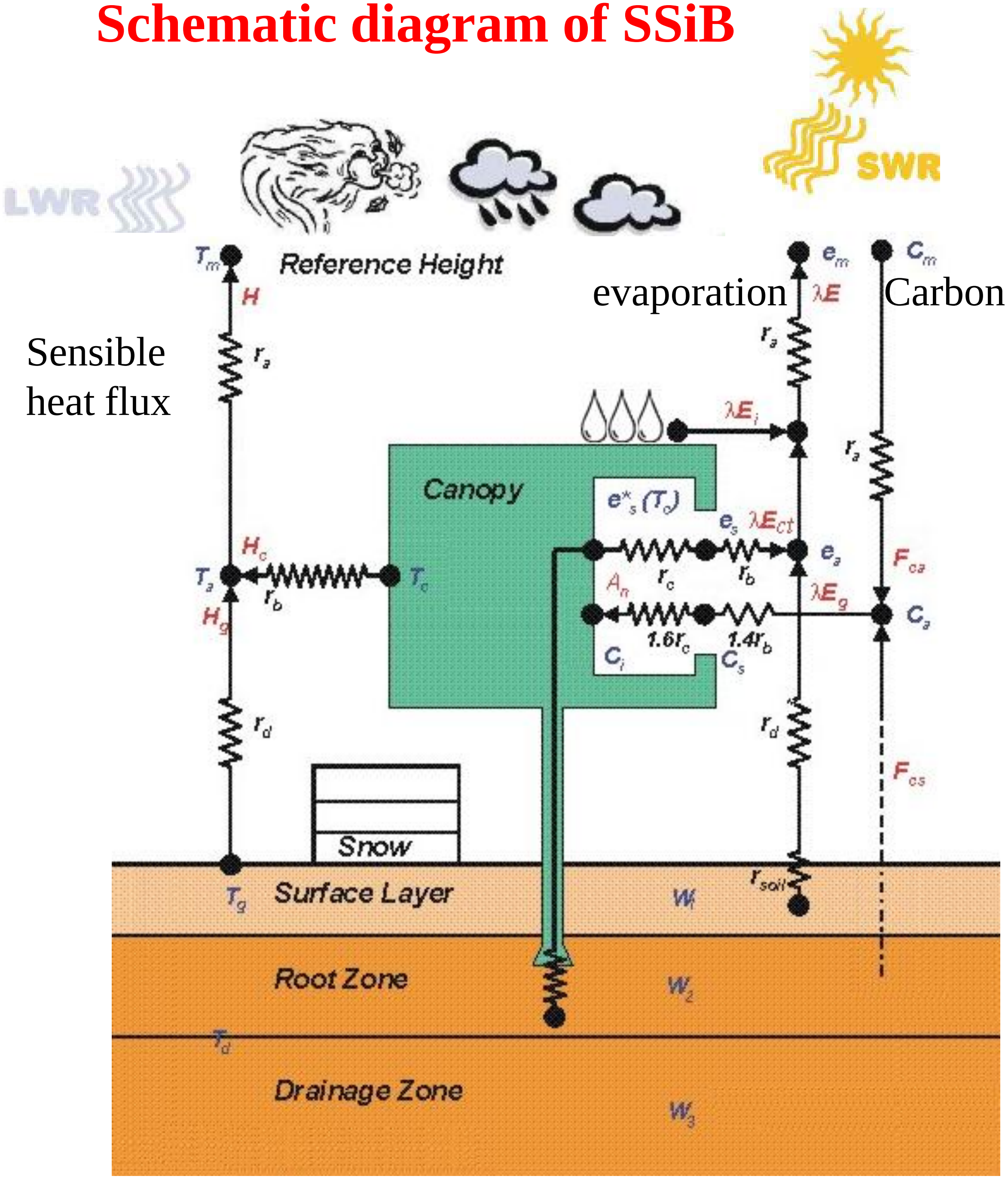
II. Land surface processes Parameterizations

- 1. Vegetation parameterizations
- 2. Snow scheme effects
- 3. Land surface and PBL coupling
- 4. Initial surface conditions

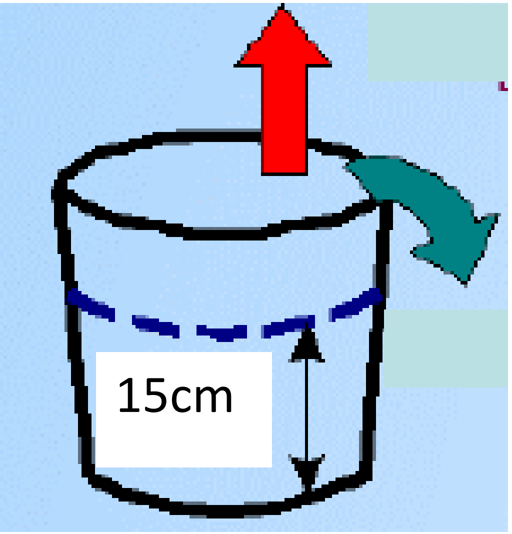
II. Land surface processes parameterizations

1. Vegetation parameterizations

Schematic diagram of SSiB



Bucket Model



July 1993 Average Daily Precipitation

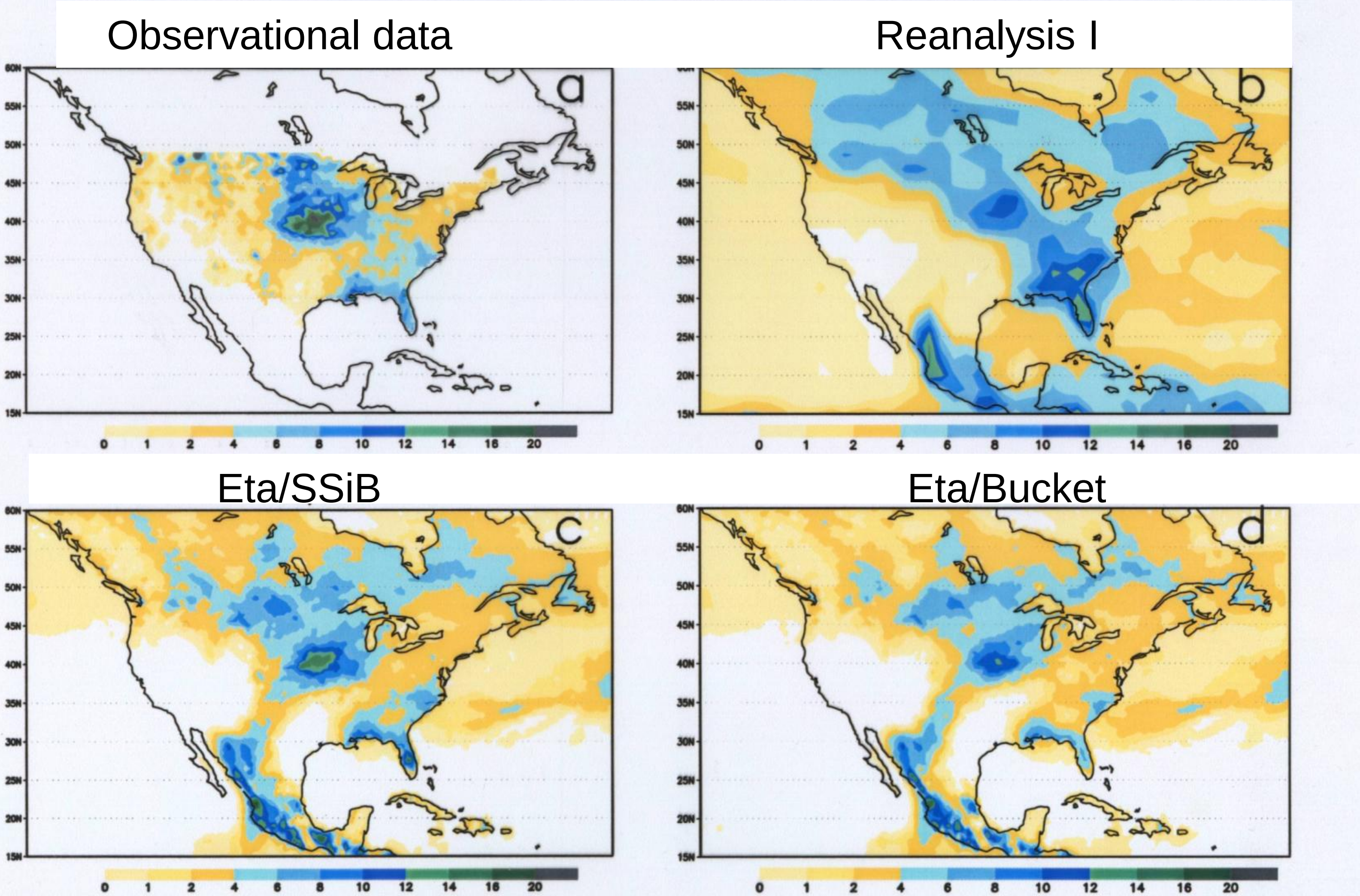
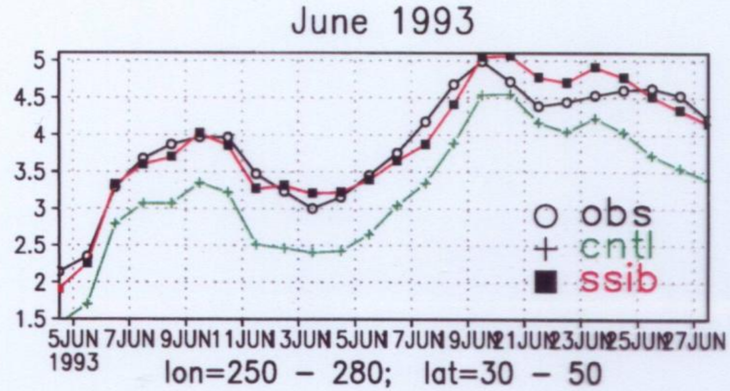


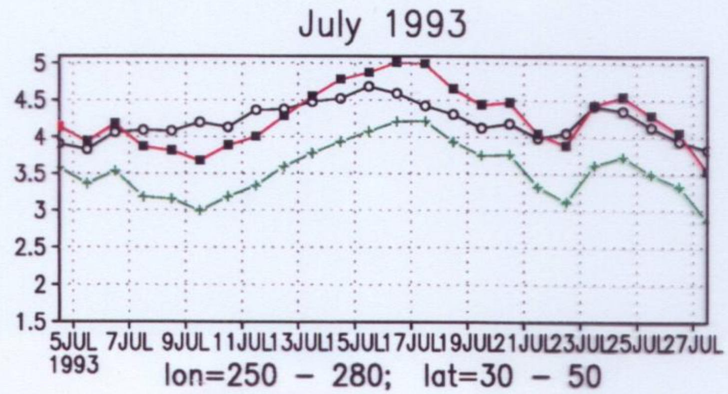
Fig 4a–d

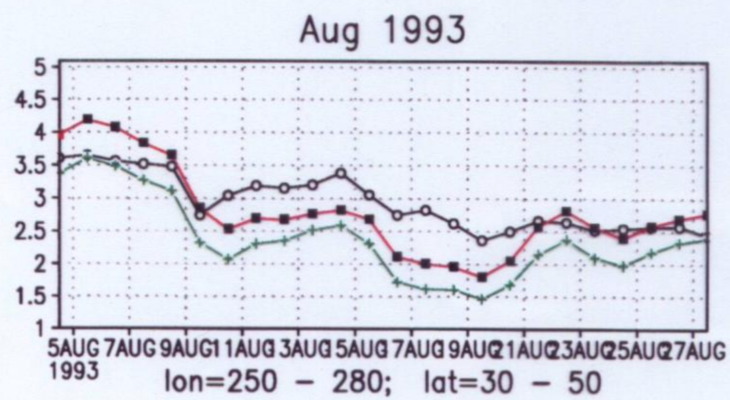
Monthly mean
based on 24 hour simulation

Xue et al., 2001, *Mon. Wea. Rev.*

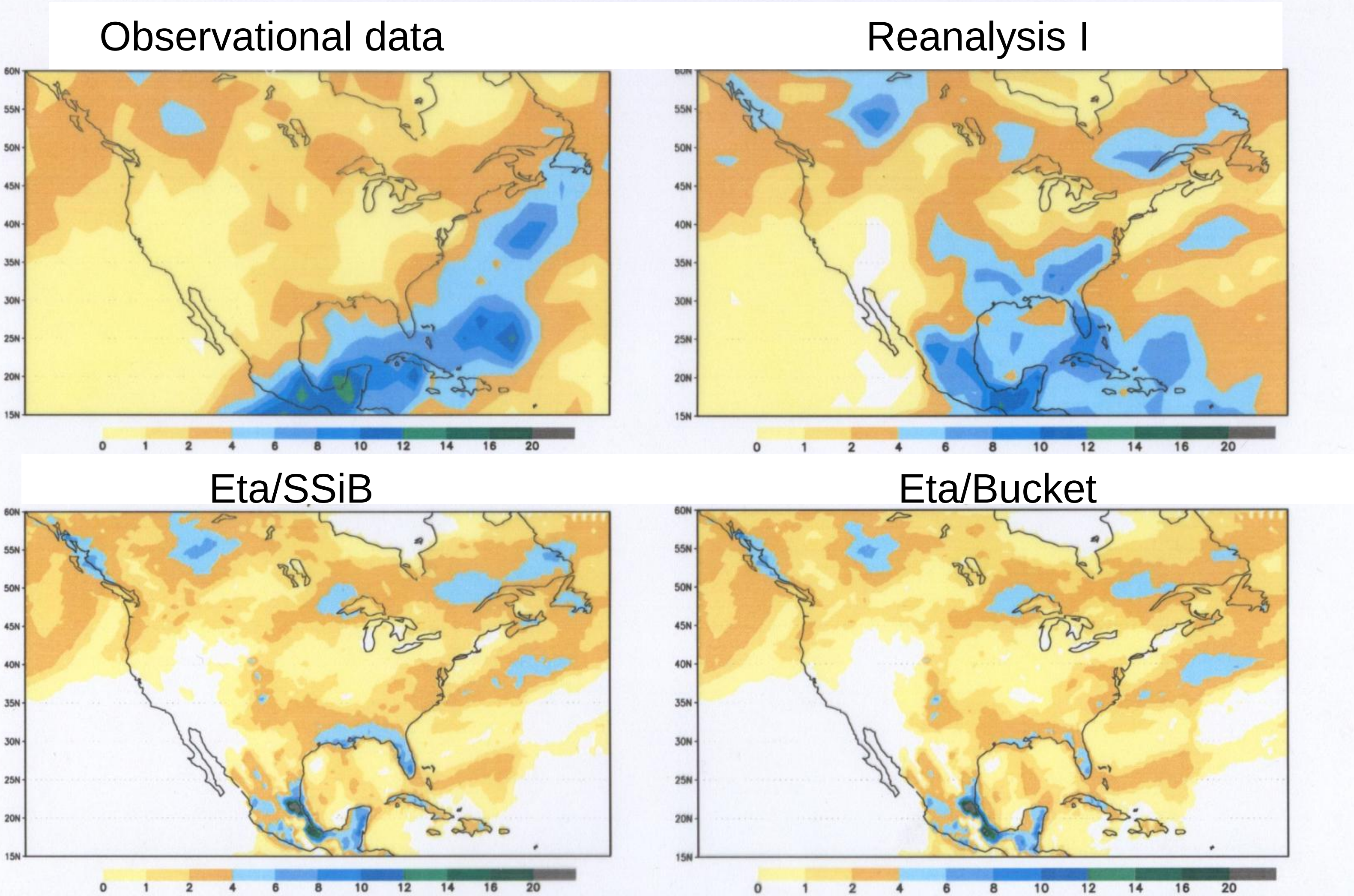
5 day running mean of precip (mm)





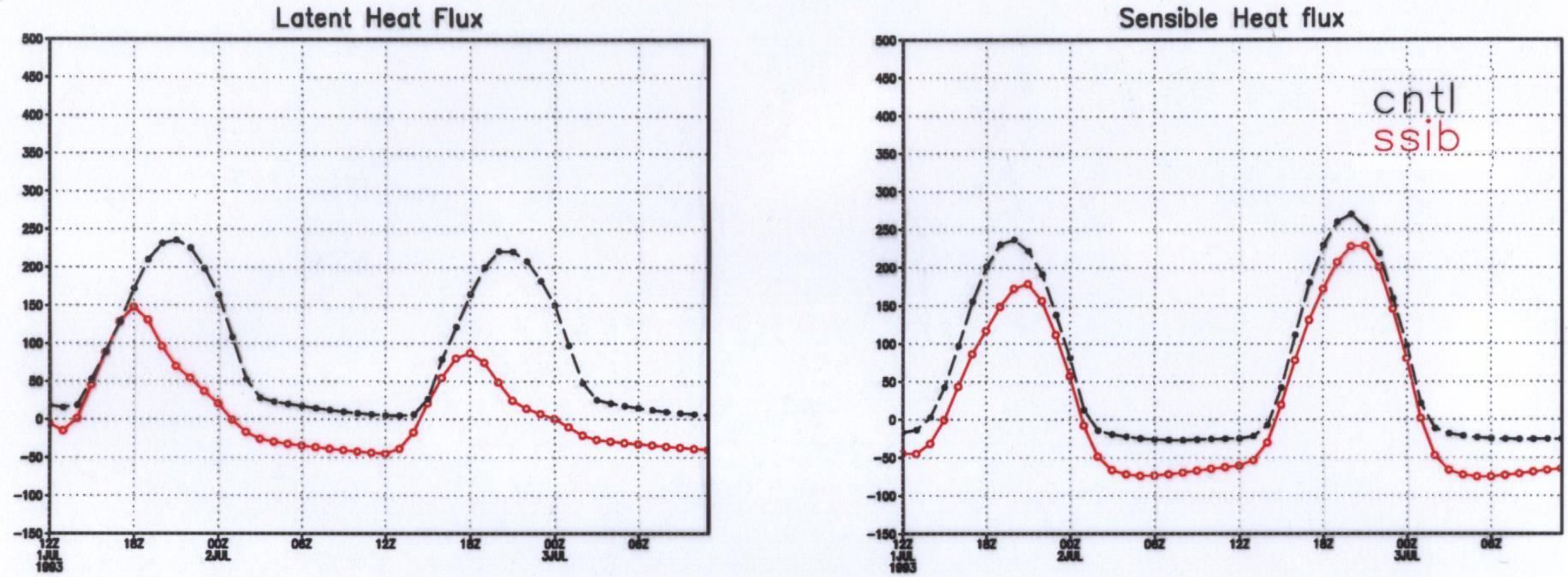


June 1988 ave precipitation

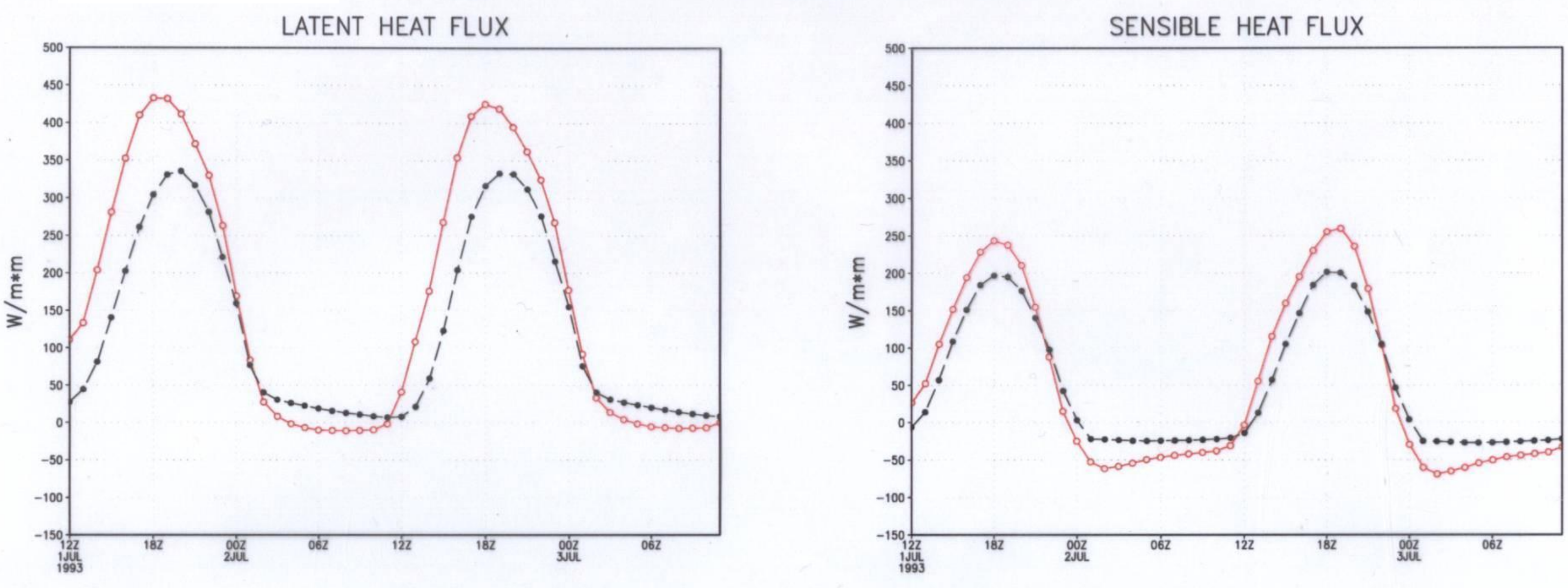


Fig

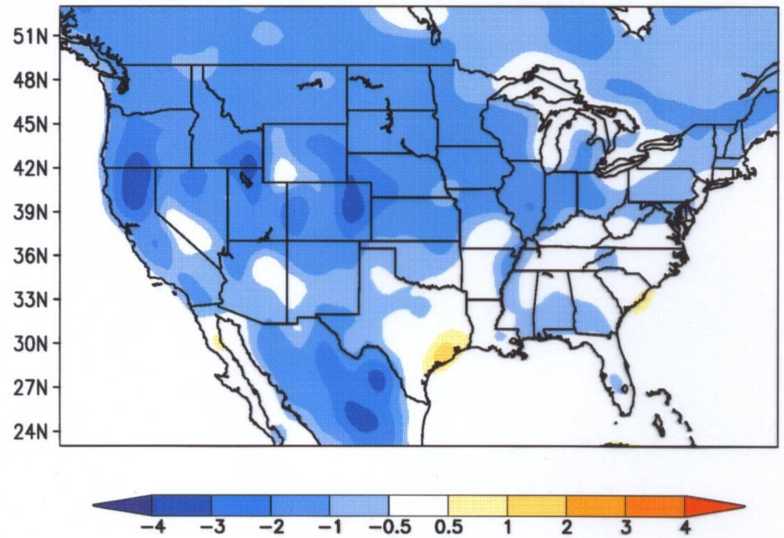
Shrubs and bare ground



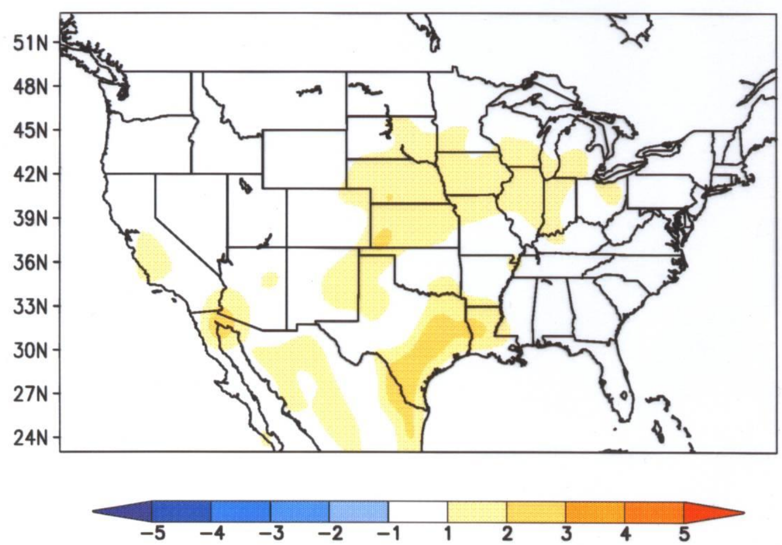
July Mean (Broadleaf–deciduous



Diff of lift index (Eta/ssib−Eta/buc) (18 hr fcst, July, 1991)



Diff of lift index (Eta/ssib−Eta/buc) (06 hr fcst, July, 1991)



II. Land surface processes parameterizations

• 2. Snow scheme effects

SSiB1: One snow layer

SSiB3: Three snow layers

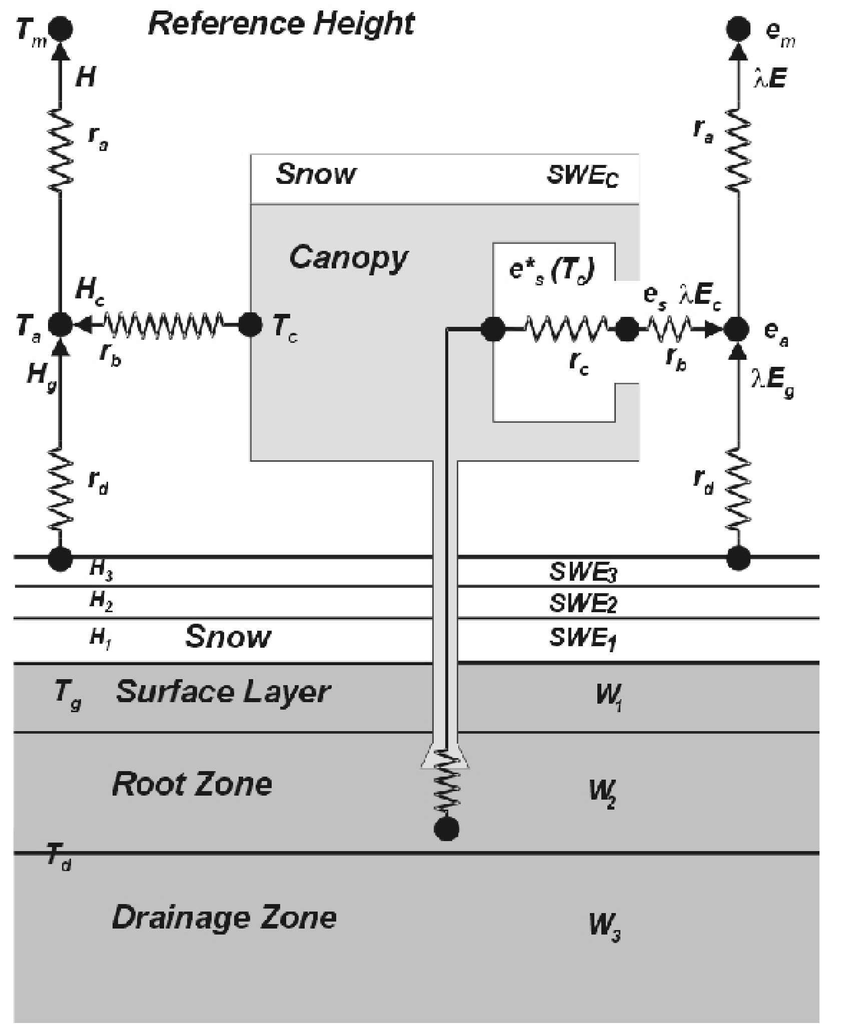


Fig. 1

II. Land surface parameterizations

3. Land surface and PBL coupling

II. Land surface processes

4. Initial surface conditions

- NCEP/NCAR global reanalyses
- ECMWF global reanalysis
- North American regional reanalysis
- GAME Regional reanalysis

Table 2a Precipitation (mm day^{-1}) and correlations between observation and simulation for the 1998 cases over Test Area.

	May	June	July	MJJ	Correlation (%)
Observation	1.80	2.54	2.25	2.19	100
NNGR	3.30	4.13	3.04	3.49	65.3
NARR	1.81	2.54	2.25	2.19	74.3
Case 3 (NNRP)	1.97	2.72	1.75	2.14	55.8
Case 5 (NARR,NNRP initial Soil moisture and temperature)	1.98	3.11	2.78	2.62	62.0
Case 10 (NARR, NARR initial soil moisture and temperature)	2.22	3.04	2.49	2.58	55.3

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Global Reanalysis, R1

Regional Reanalysis but R1for initial

Regional Reanalysis For LBC and initial

Summary

1). Domain size and lateral boundary positions are crucial for the downscaling ability. When the domain size is too big, the model internal variability is very large. The Eta/SSiB model in North American simulation is particularly sensitive to its southern boundary position because of the importance of the moisture transport by the LLJ in summer precipitation. For east Asia, the location of western boundary position along the west of Tibetan Plateau is important.

2. A more realistic representation of vegetation biophysical processes is important to simulate the extreme climate events of 1988 and 1993. The changes in spatial distribution and diurnal cycle of surface latent heat and sensible heat fluxes and atmospheric stability conditions are the primary factors for the proper downscaling of these events.

3. Multi-layer snow models are necessary to produce proper snow melting process and snow spatial distributions during that periods. Both 2 and 3 are crucial for hydrological application.

4. In the initial soil moisture and soil temperature test, with the complex structure of the biophysical model, the direct transfer of soil moisture produced by one biophysical model might not yield the optimal results when they are applied to another biophysical model . However, the difference caused by two initial data sets are not as substantial when compared with those produced by other factors as indicated earlier.

5. Different coupling approaches could produce different atmospheric circulation strength and ground hydrology, and probably is one of the primary sources that produce uncertainty in dynamic downscaling. A consistent approach with a fully consideration of vegetation effect on the surface turbulence is pertinent in the downscaling study.