Assimilation of Total Precipitable Water in a 4D-Var System: A Case Study

Zhang Lei

Lanzhou University,Lanzhou,Gansu,China

Ma Gang, Fang Zongyi

National Satellite Meteorological Center,Beijing,China

outline

- Theory
- Experiment design
- Results and discussion

4D-Var

$$J(x(t_0)) = \frac{1}{2}(x(t_0) - x_b)^T B^{-1}(x(t_0) - x_b) +$$

$$\frac{1}{2}\int_0^\tau (y(t_n) - H(x(t_n)))^T O^{-1}(t_n)(y(t_n) - H(x(t_n)))dt$$

The objective of 4D-Var is to find an optimal model state that minimizes in a least-square sense the distance between a selected output quantity of the model and its observed equivalent, given a background constraint

For precipitation assimilation,the functional can be written as:

$$J(x(t_0)) = \frac{1}{2}(x(t_0) - x_b)^T B^{-1}(x(t_0) - x_b)$$

$$+ \frac{1}{2}\sum_{n=0}^{N}(pw(t_n) - pwobs(t_n))^T O^{-1}(t_n)(pw(t_n) - pwobs(t_n))$$

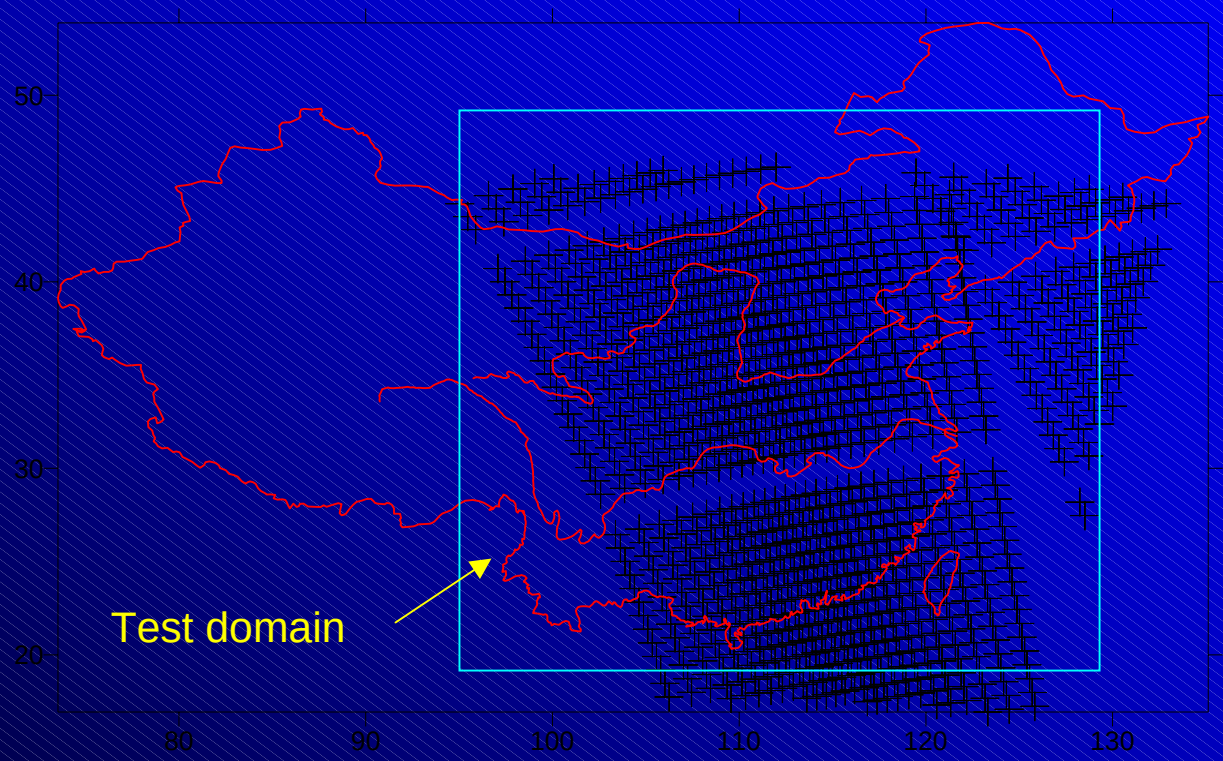
Experiment setup

- MM5 4D-Var system
- Test domain center:112.5°E, 31.5°N
- Horizontal grid:61×61, vertical level:23, Horizontal resolution :54km
- Integrate time: 20020722 00UTC—20020725 00 UTC
- Background field: NMC T 213 00, 06, 12, 18GM T 4 global forecast, horizontal resolution:0.5625°×0.5625°
- Satellite data: ATOVS retrieved total column water vapour

Case study

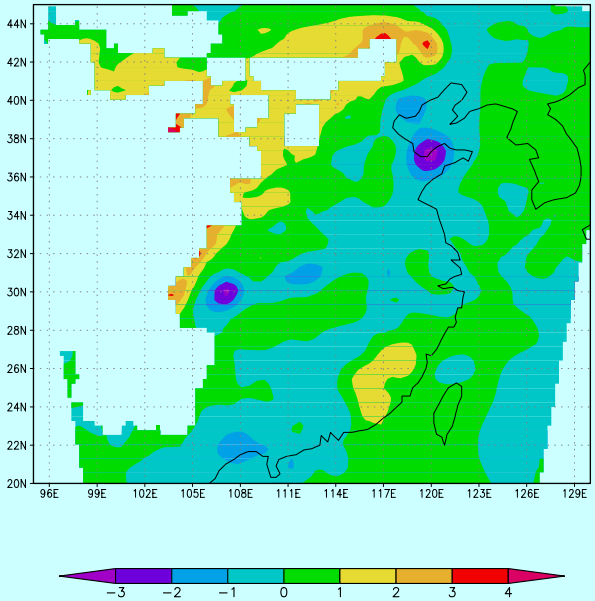
- Period: July 22 – 25, 2002
- Assimilation time-window: 6 hour
00UTC - 06UTC July 22 , 2002
- Integrate time 72 hours
- Control run: without satellite data
- Test run : with satellite data

Satellite data over the test domain

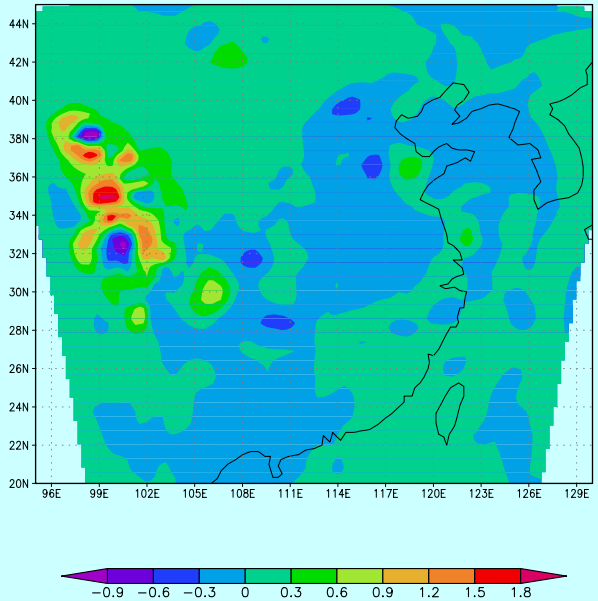


- Comparison between including and excluding satellite data at the initial time
- Effects on precipitation forecast

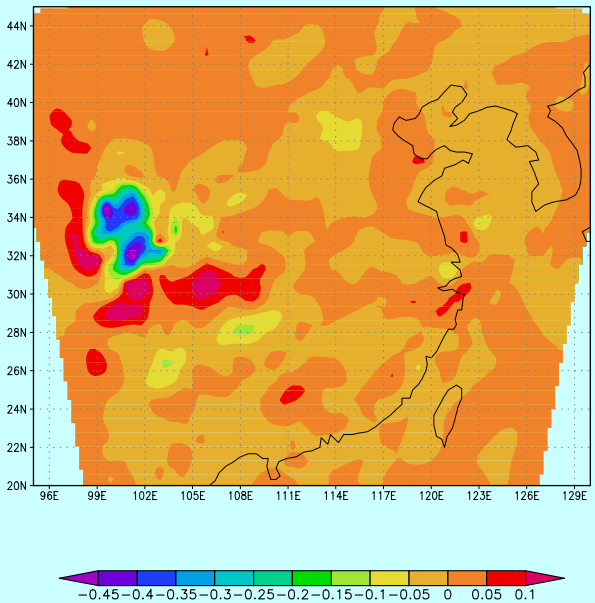
850 hpa



500 hpa



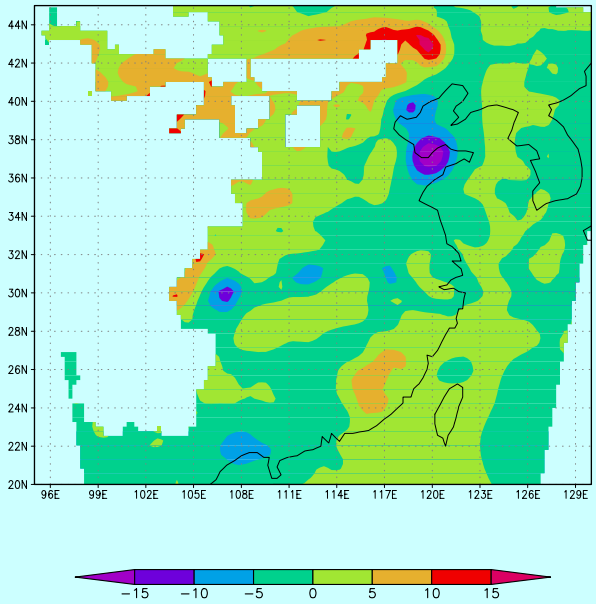
300 hpa



increment of specific humidity at the initial time (test-control)

unit g/kg

850 hpa



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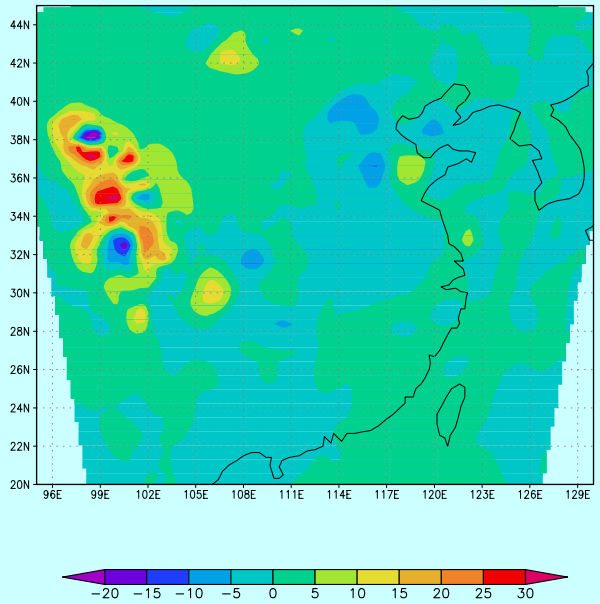

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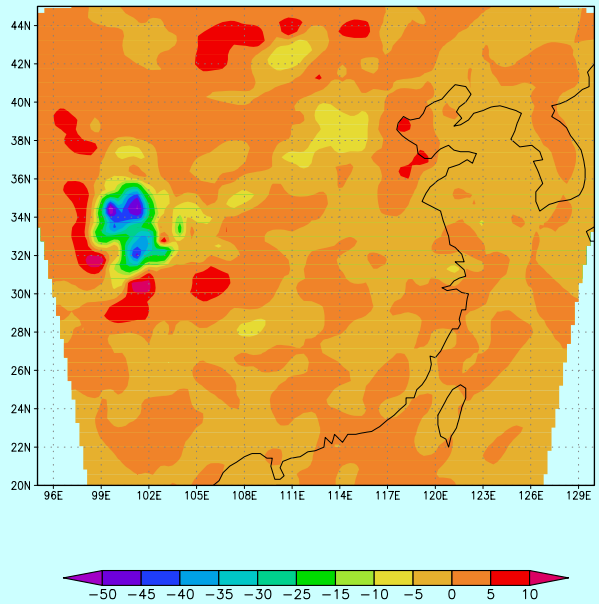
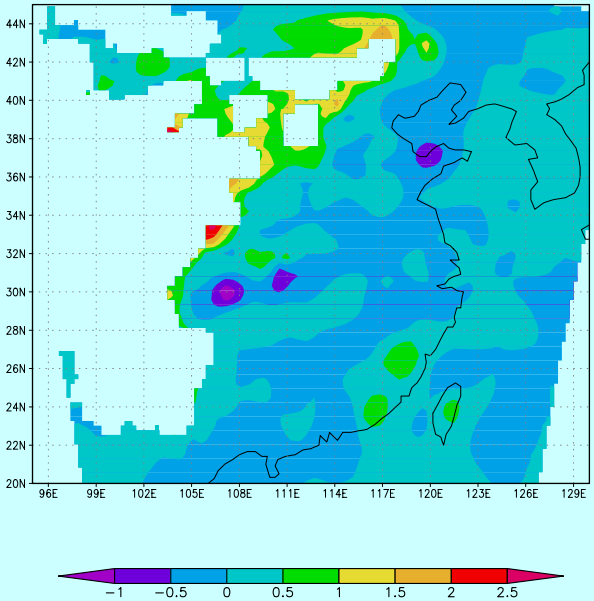


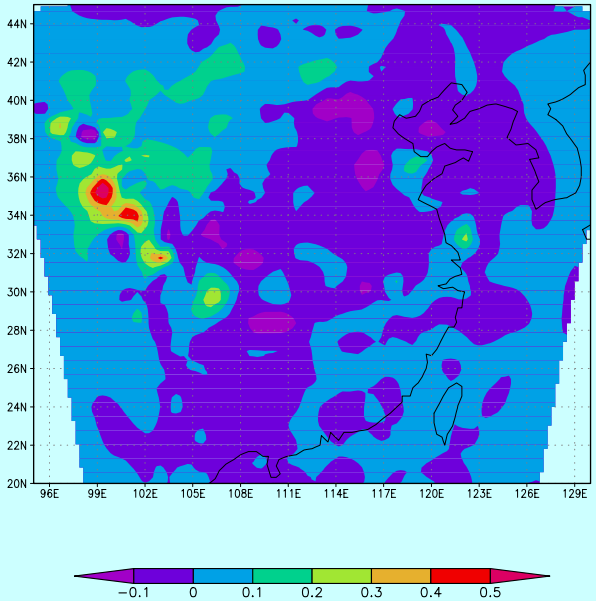
Increment of relative humidity(test-control)

unit %

850 hpa



500 hpa



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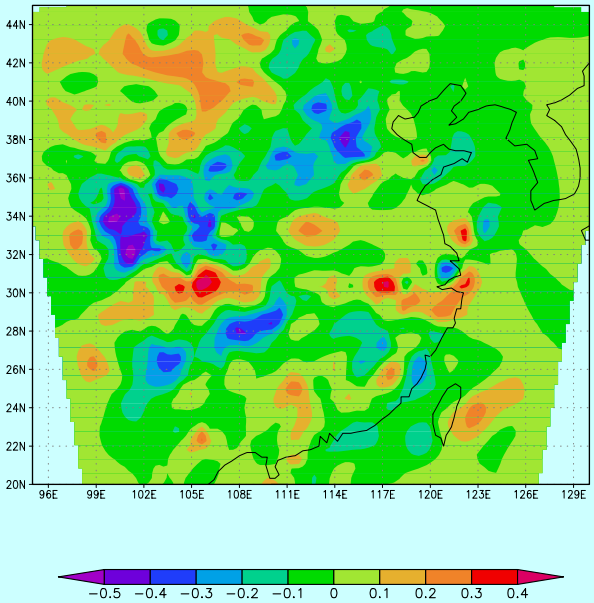
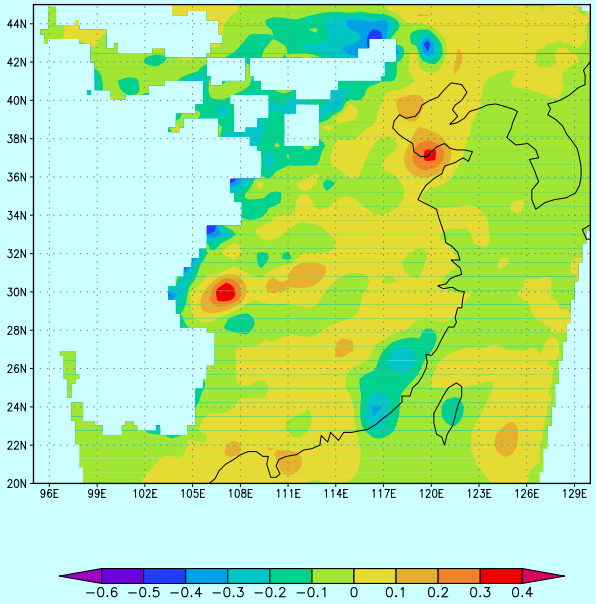


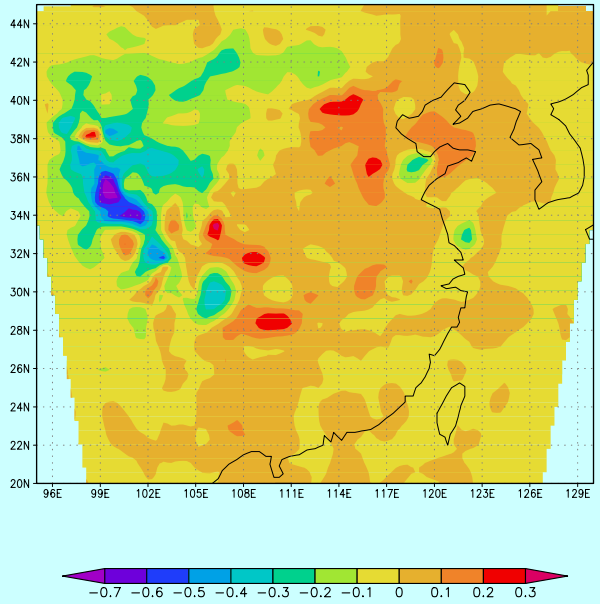
Increment of temperature (test-control)

unit K

850 hpa



500 hpa



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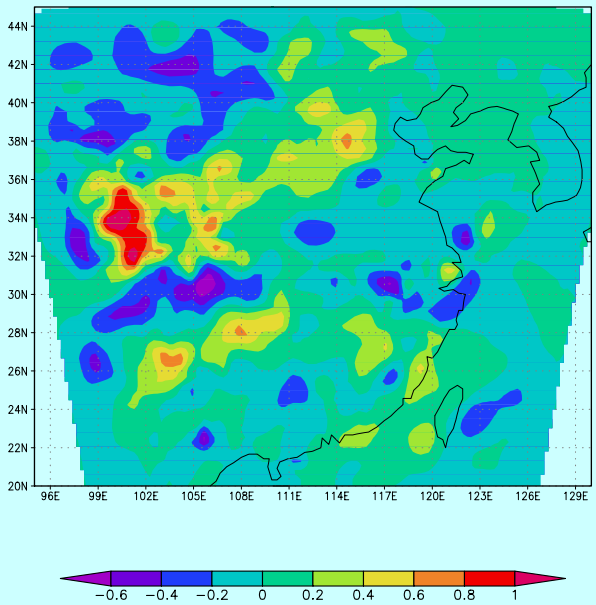
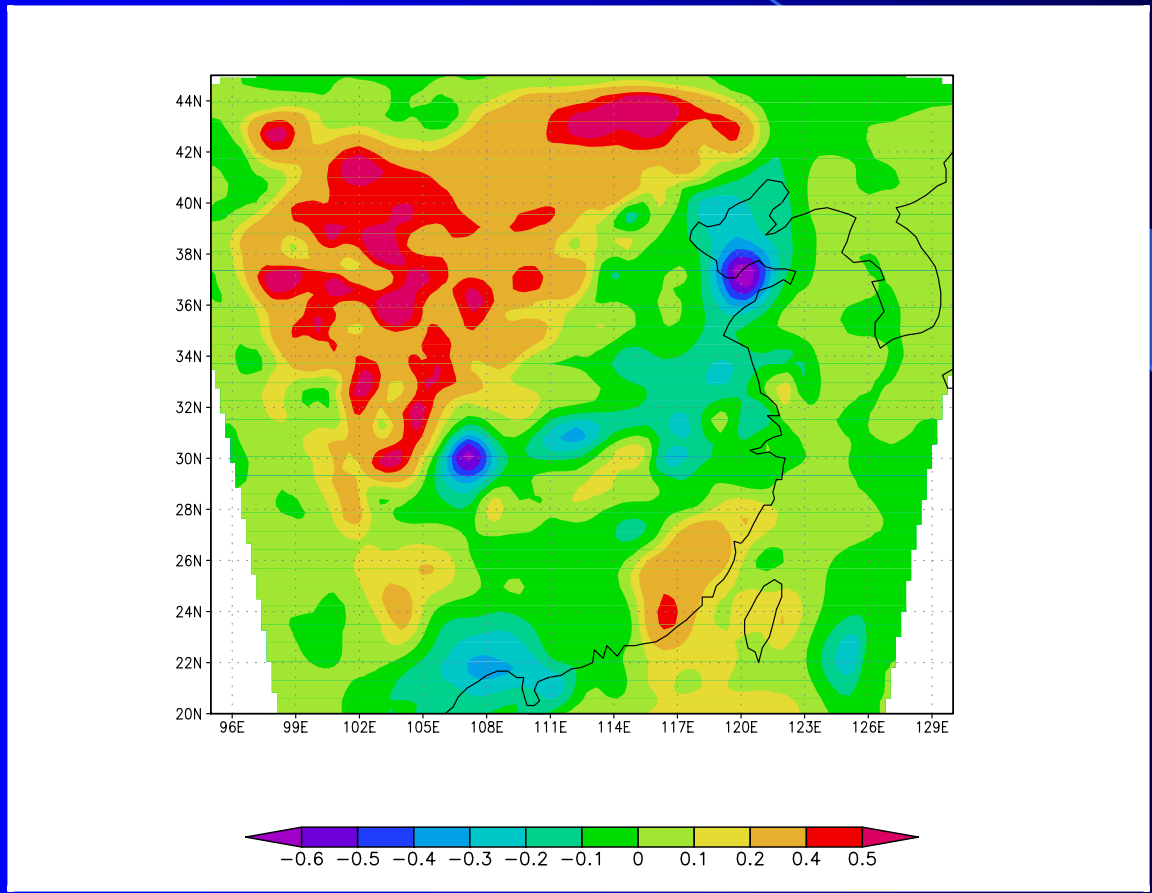


Increment of geopotential Height(test-control)

unit m

Increment of total precipitable water at the initial time



unit cm test-control

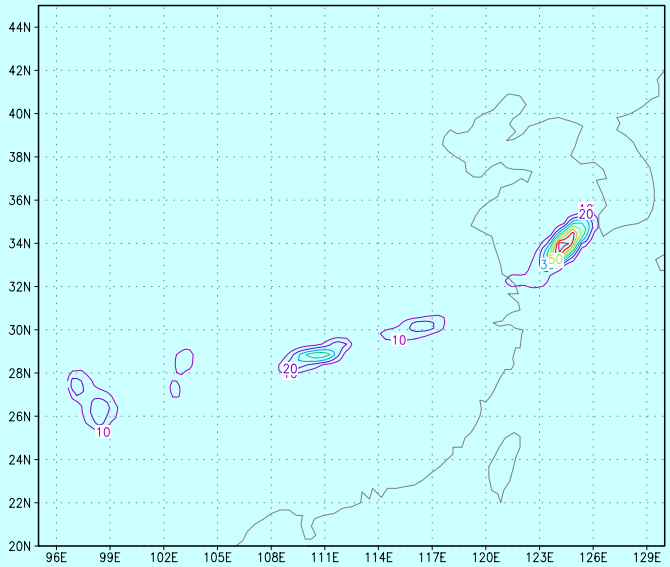
- Comparison between including and excluding satellite data at the initial time
- Effects on precipitation forecast

Effects on precipitation forecast

- Effects on 6-hour precipitation forecast
- Effects on 24-hour precipitation forecast

Effects on 6-hour precipitation forecast from t+00 to t+06

a



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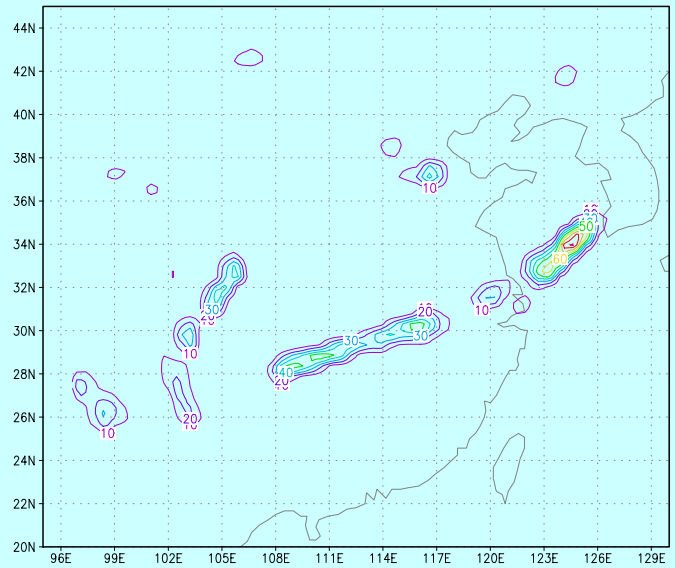
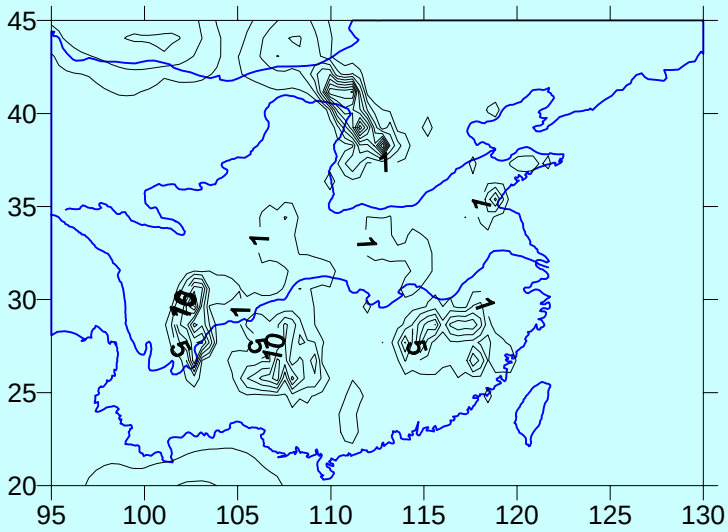


c



a.6-hour precipitation forecast without satellite data

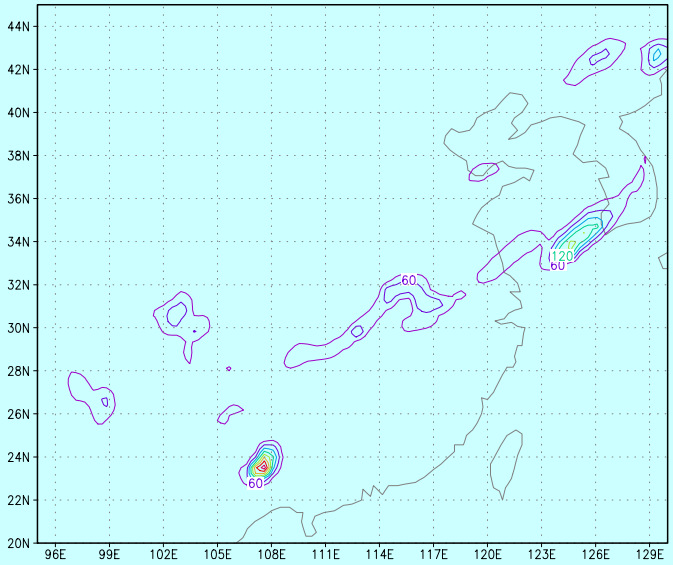
b.6-hour precipitation forecast with satellite data

c.observed 6-hour precipitation

unit mm

Effects on 24-hour precipitation forecast: from t+00 to t+24

a



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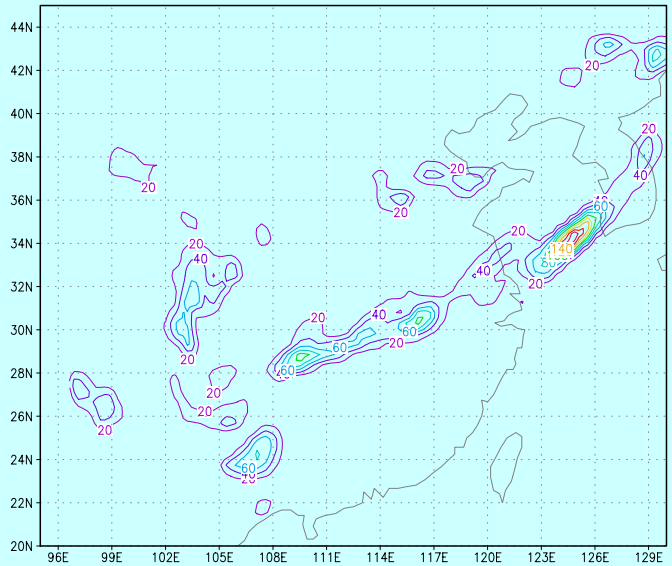
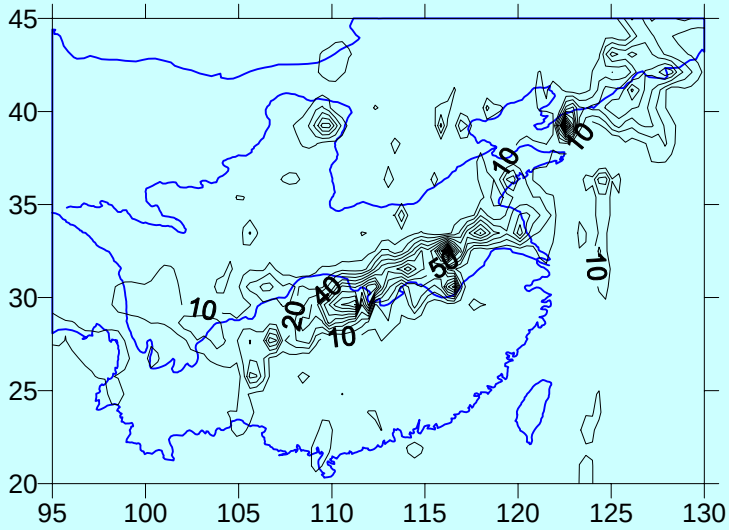


c



a.24-hour precipitation forecast without satellite data

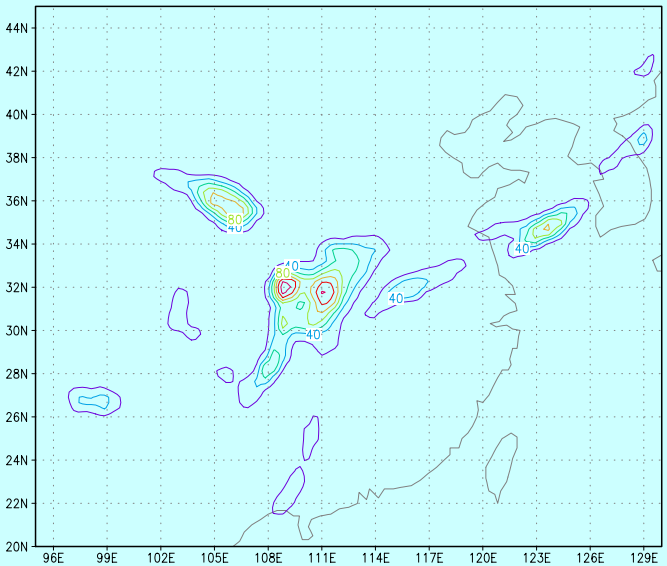
b.24-hour precipitation forecast with satellite data

c.observed 24-hour precipitation

unit mm

Effects on 24-hour precipitation forecast: from t+24 to t+48

a



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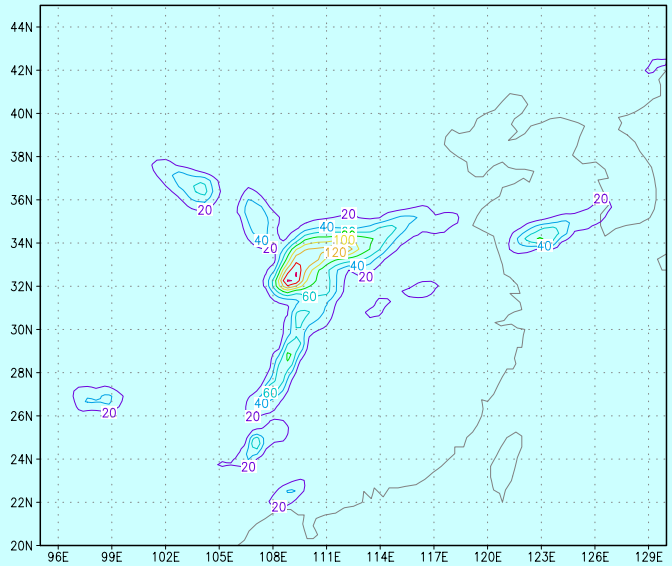

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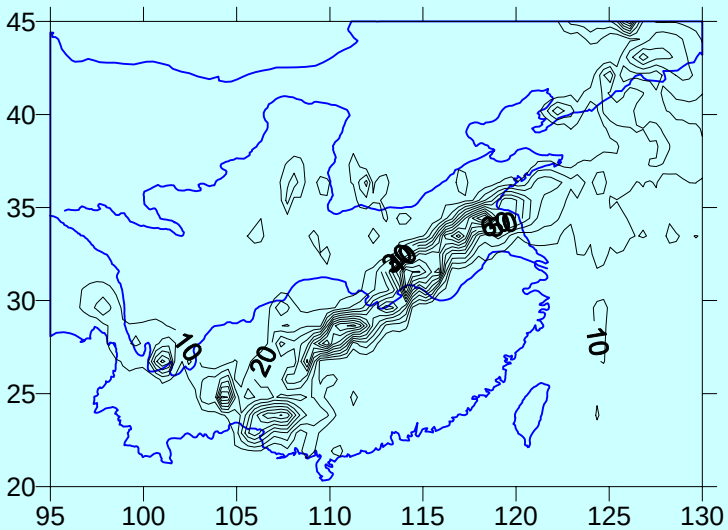


a.24-hour precipitation forecast without satellite data

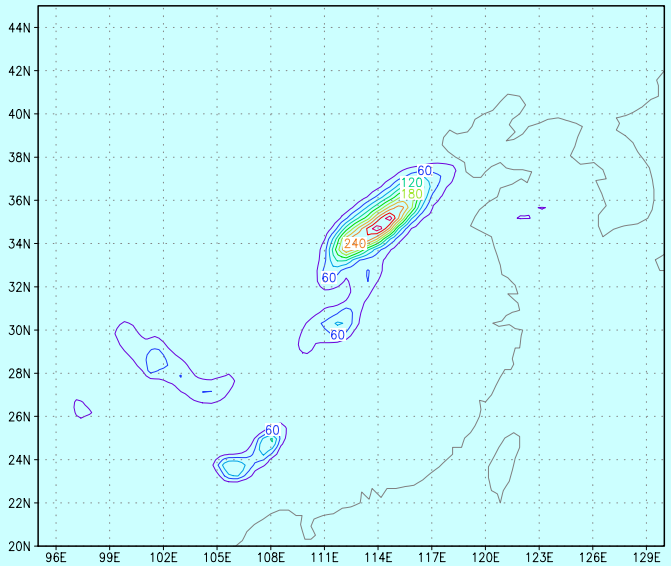
b.24-hour precipitation forecast with satellite data

c.observed 24-hour precipitation

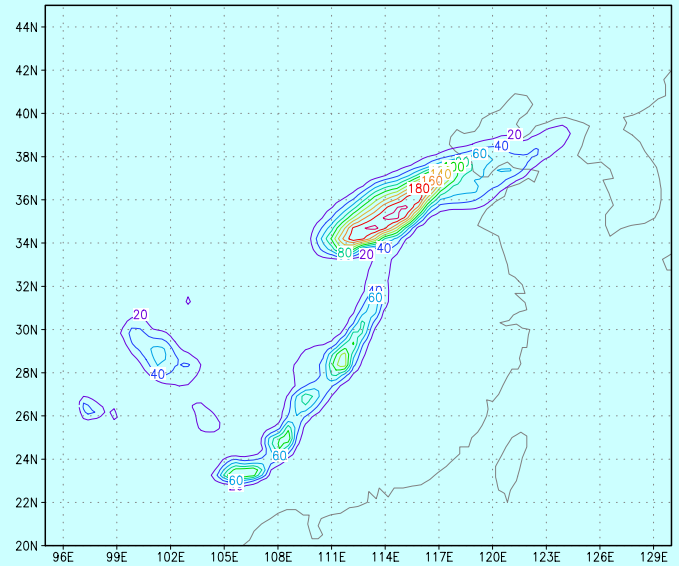
unit mm

Effects on 24-hour precipitation forecast: from t+48 to t+72

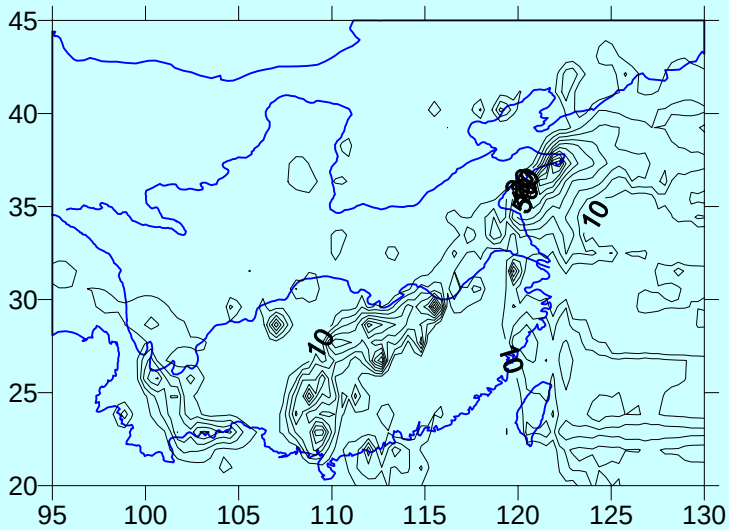
a



b



c



a.24-hour precipitation forecast without satellite data

b.24-hour precipitation forecast with satellite data

c.observed 24-hour precipitation

unit mm

conclusion

- the initial humidity field was improved by assimilating the satellite retrieved total column water vapour, especially over the rainfall areas

- the initial temperature field and the geopotential height field were also improved after assimilating the satellite data

conclusion

- 6-hour precipitation forecast has been improved during the assimilation time-window after introducing satellite data into the modeling system
- 24-hour precipitation forecast also has been improved after assimilating satellite data into the modeling system more precipitation information can be obtained

Thank you !

International TOVS Study Conference, 14th, ITSC-14, Beijing, China, 25-31 May 2005.
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,
Cooperative Institute for Meteorological Satellite Studies, 2005.