Meso-scale Analysis and Forecast of “7.21” Extreme Heavy Rain Event in Beijing

Cui Chunguang, Peng JX,

Wang XF, Li HL, Wang YH

Institute of Heavy Rain,CMA,Wuhan

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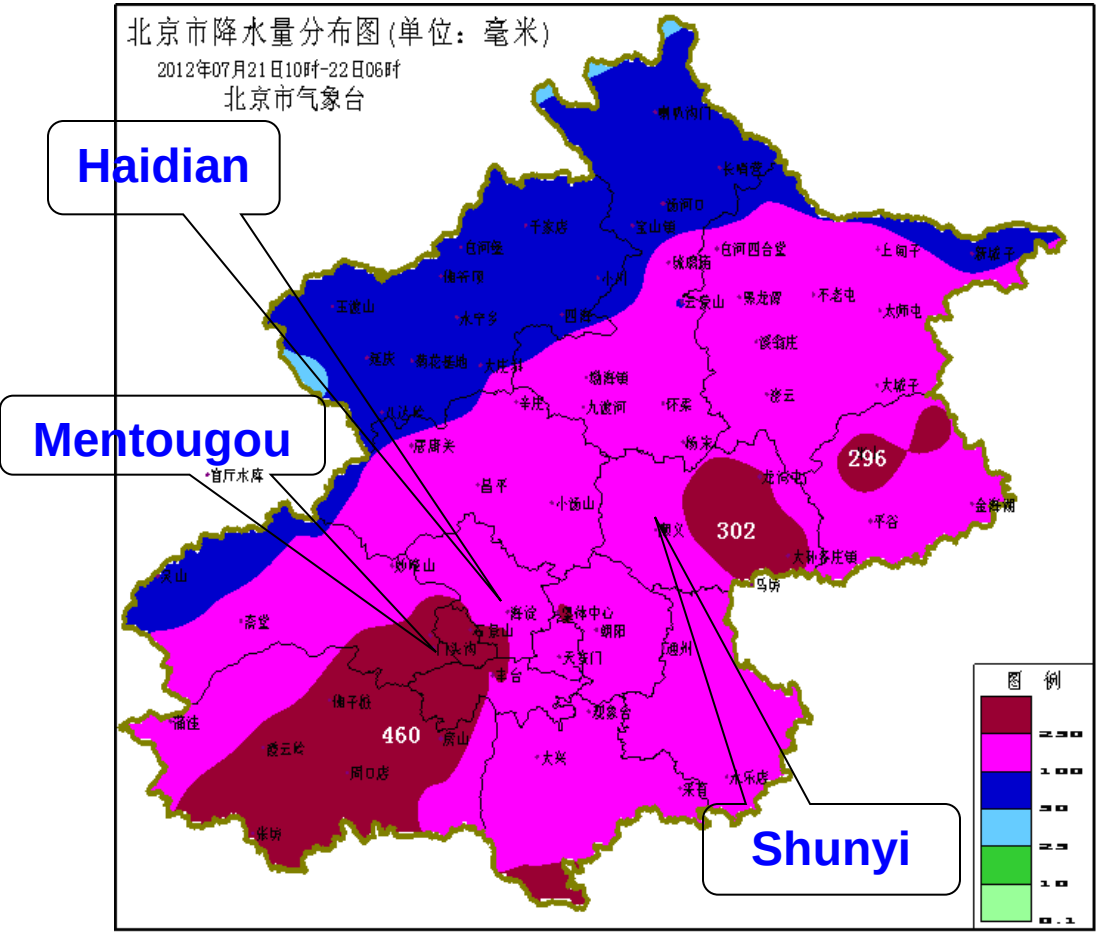
outline

- Precipitation Characteristics
- Circulation pattern and meso-scale systems
- LAPS analysis
- Model results comparison
- Results and the existing problems

Precipitation characteristics of the extreme heavy rain event

20-h accumulated precipitation (mm)
from 10:00 LST 21 July to 06:00 LST 22 July 2012



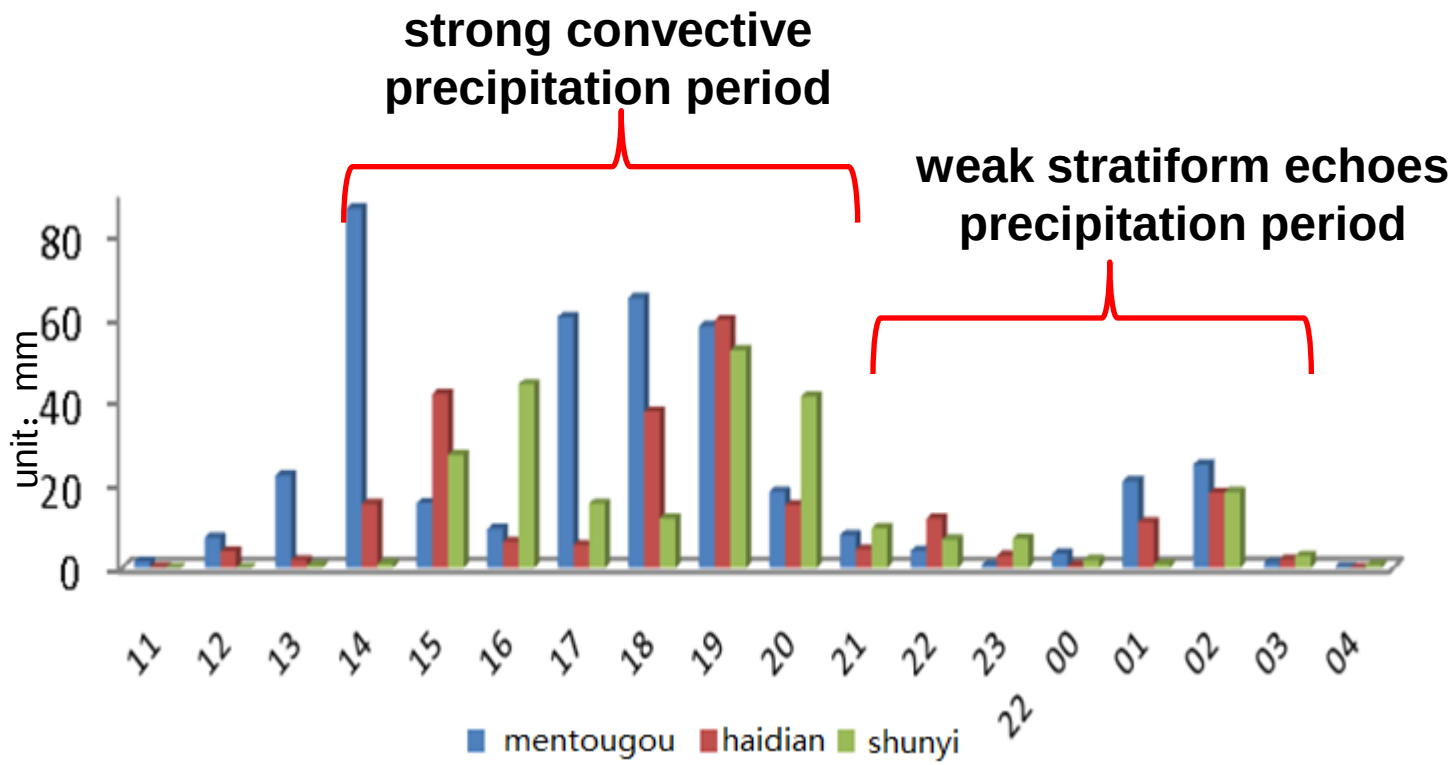
The rain belt is in an southwest-northeast direction.

- **Averaged precipitation in whole Beijing city：170 mm**
- **Averaged precipitation in urban area of Beijing city：215 mm**
- **The maximum 20-h accumulative precipitation：460.0 mm**
- **The maximum 1 h precipitation：100.3 mm**

Strong precipitation & long-lasting
------extreme heavy rain event

Precipitation characteristics of the extreme heavy rain event

hourly precipitation of three automatic stations during 11:00 LST,21st to 04:00 LST,22st,July 2012



strong precipitation period is concentrated

In urban area of Beijing, the strong precipitation period is 14-20 LST,21st. After 20:00 LST it is weak stratiform precipitation.

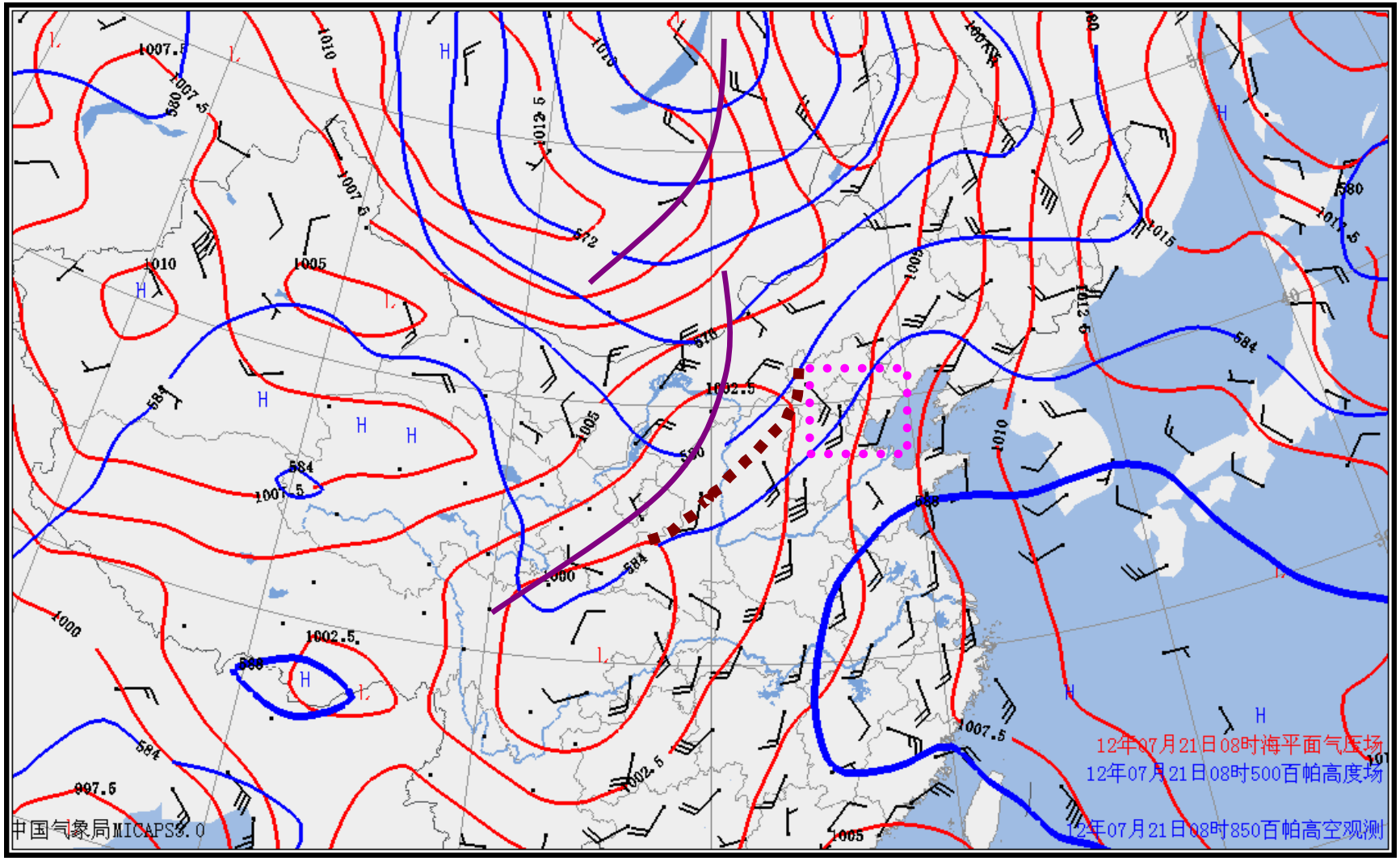
disastrous hazards

destroyed bridge

Severe waterlogging in main urban area of Beijing city

Save by assault boat

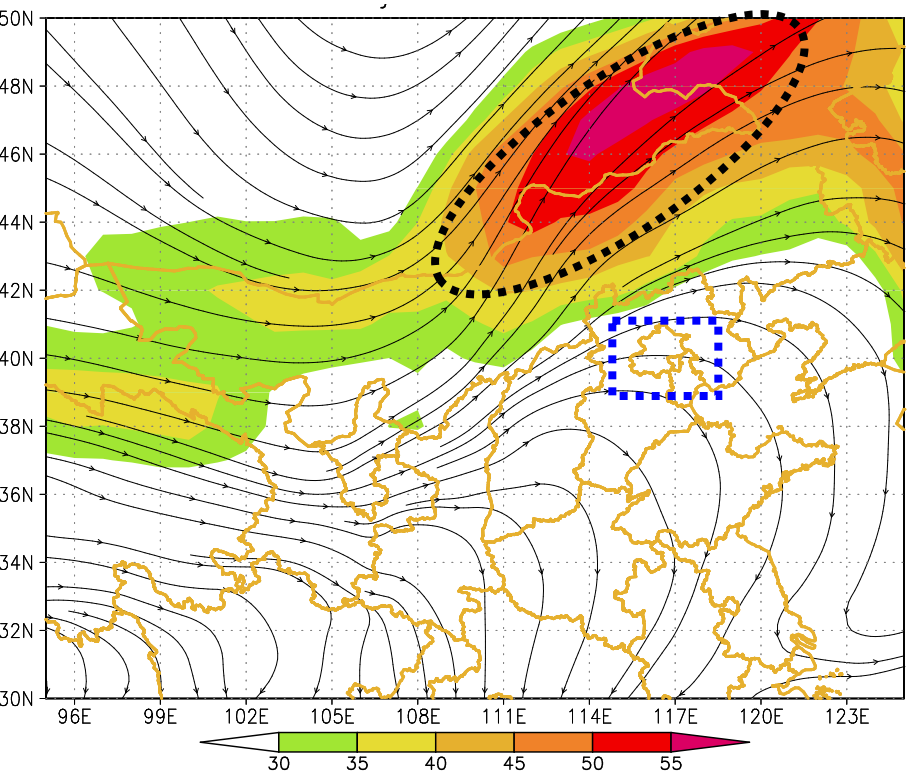
Environmental characteristics --------synoptic situation



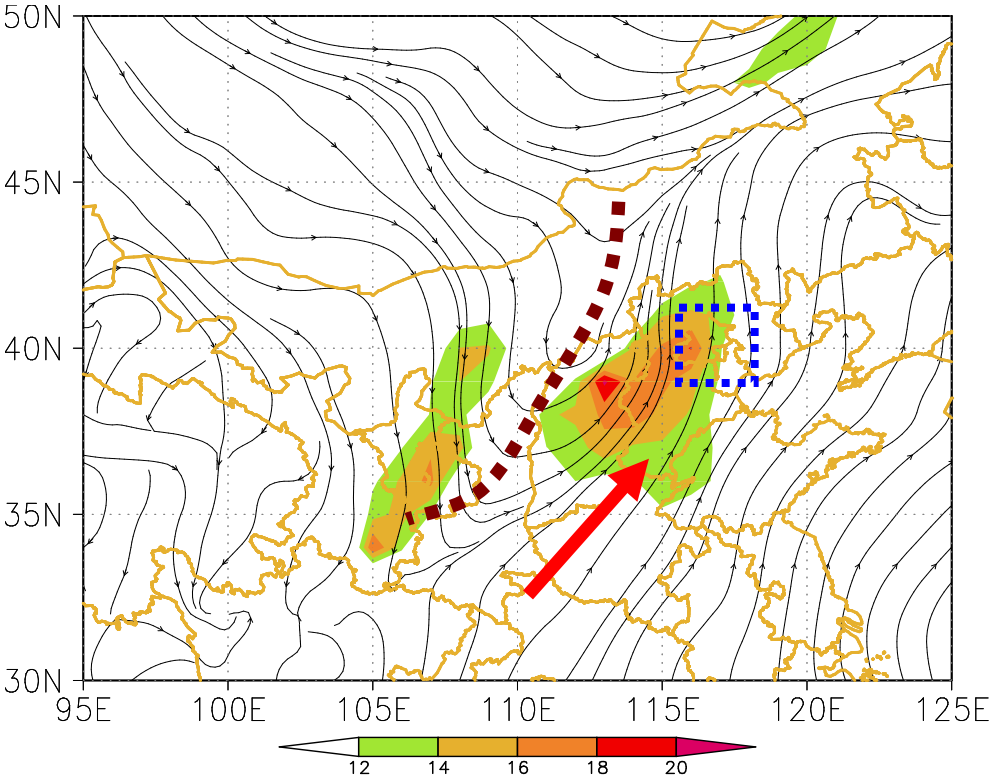
Beijing is affected by the joint influence of upper-layer thick deep cold trough and middle-lower shear, and is located in the front of surface cold front.

environmental characteristics --------upper- and low-level jet

14:00 LST 200hPa flow field and jet

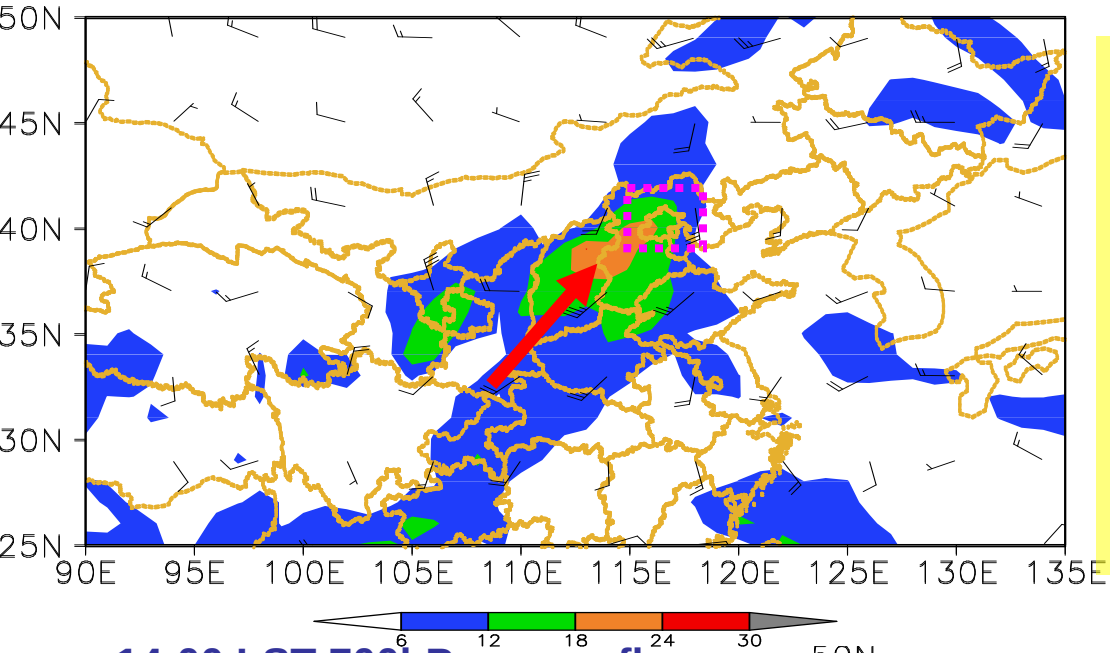


14:00 LST 700hPa flow field and jet



Heavy rain area is located on the right side of the upper-level jet exit and the front of low-level jet. The allocation of strong upper-level divergence and low-level convergence is beneficial to the development and maintenance of the synoptic scale vertical ascending motion in heavy rain area.

environmental characteristics --------water-vapor condition

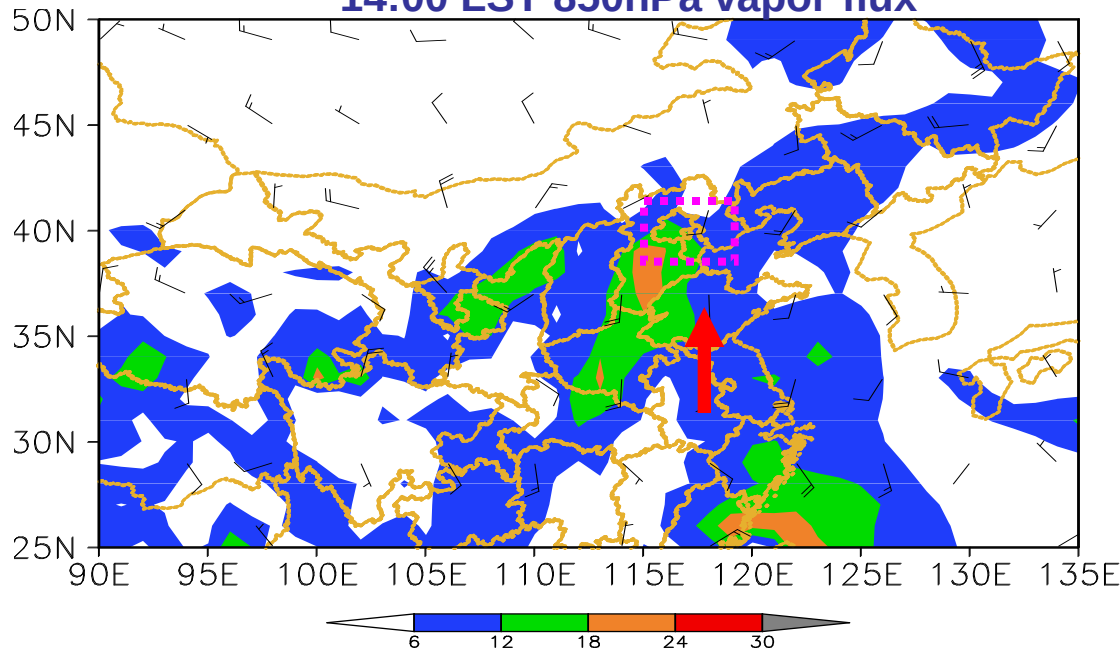


14:00 LST 700hPa vapor flux
(shaded,≥6 g·cm^{-1}·s^{-1}·hPa^{-1})

Water-vapor source:

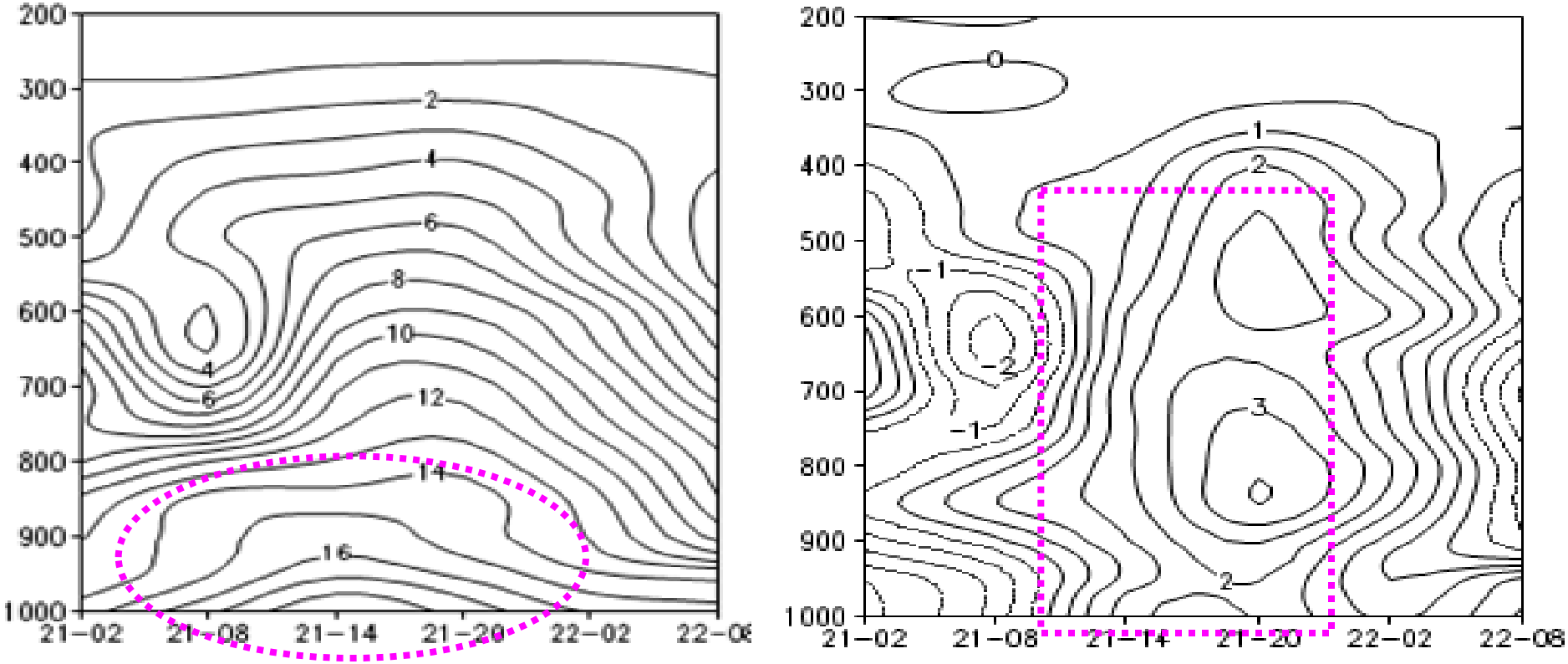
1. **southwest warm moist stream carried by 700hPa low-level jet is from Indian Ocean.**
2. **Southerly stream in the periphery of subtropical high at 850hPa is from southeast coast of China.**

14:00 LST 850hPa vapor flux



The southwest and south side of heavy rain area in middle-lower troposphere is the maximum value area of vapor flux.

·Environmental characteristics------local water-vapor condition

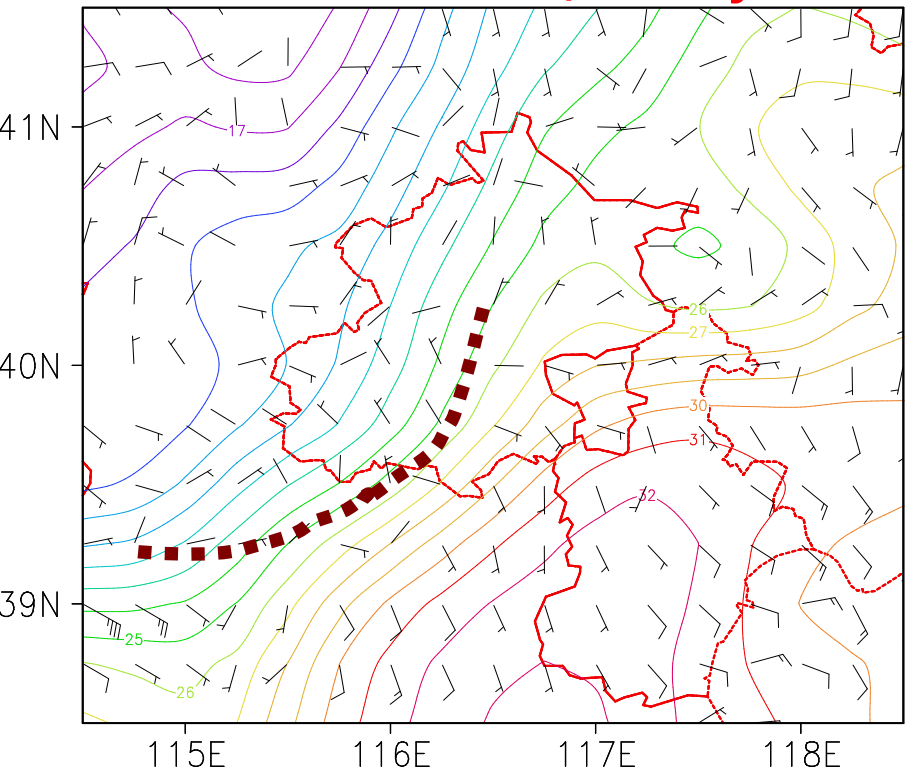


Time-height profile of specific humidity (a) and perturbation specific humidity (b) of Beijing station during 11:00 LST,21st to 04:00 LST,22nd,July,2012 (unit: g·kg^{-1})

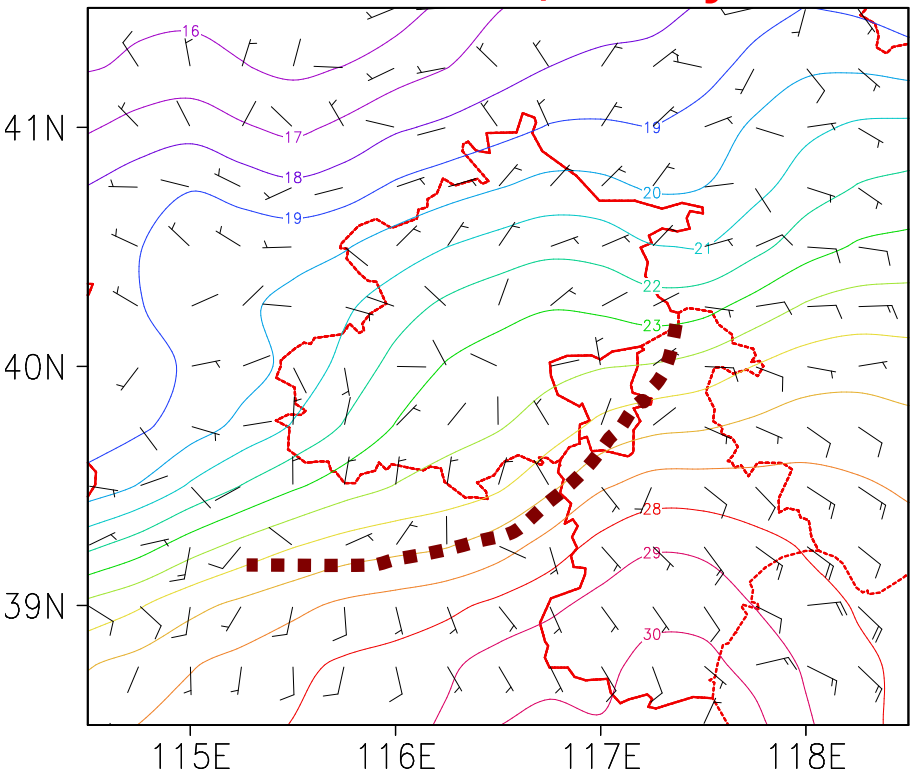
Humidification in lower troposphere in Beijing area during 11:00 LST,21st to 04:00 LST,22nd is very distinctly.

Environmental characteristics------ surface convergence line

14:00 LST,21 July



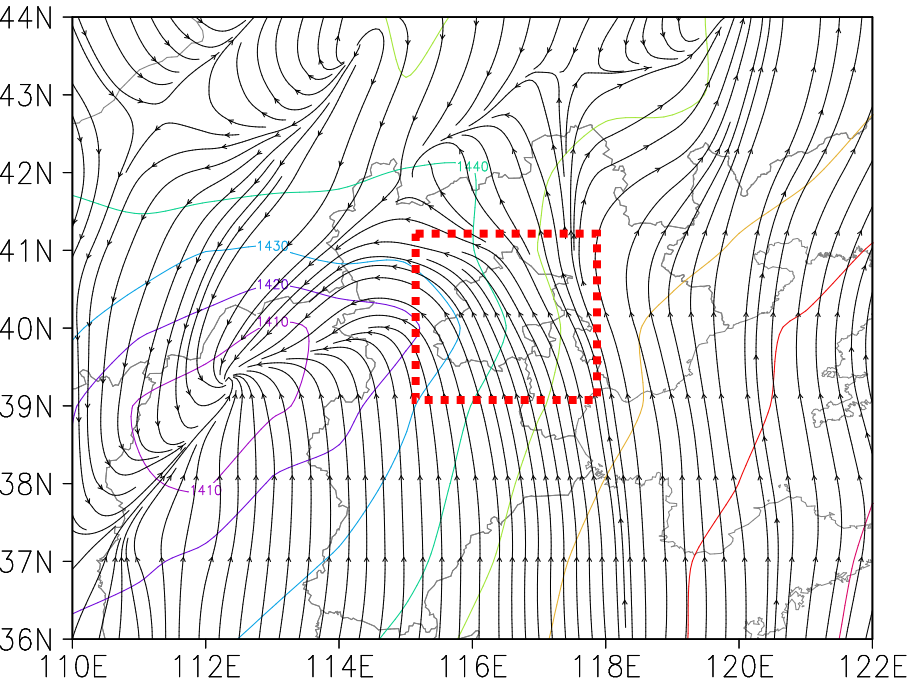
21:00 LST,21 July



surface wind field (half bar is 2 m/s,) and temperature field (solid line,ºC)

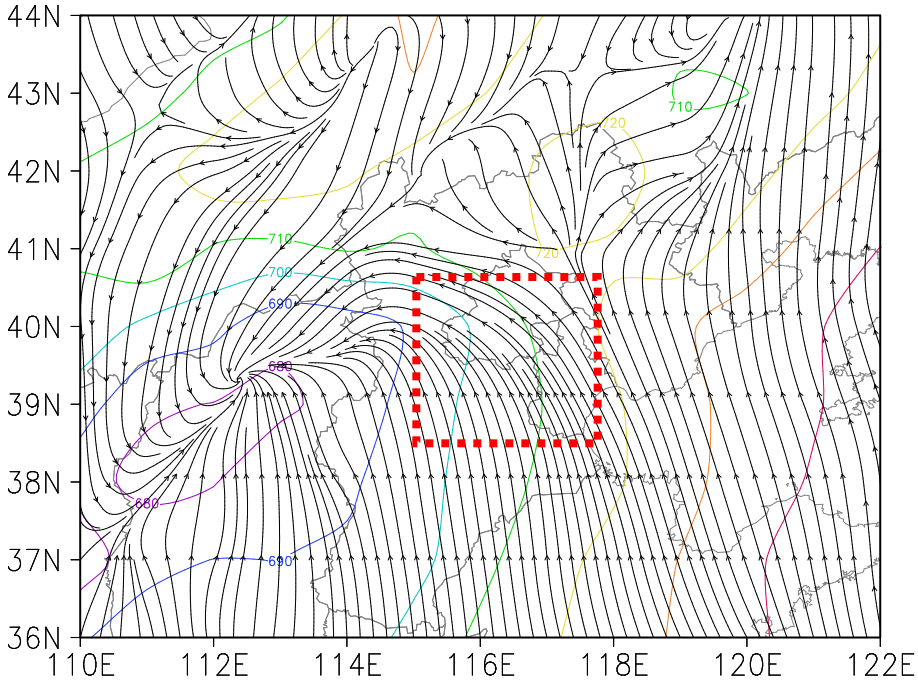
Surface convergence line in wind field keeps staying in Middle Hebei to Southeast Beijing during 12-20h and moves southeastward after 20h.

Environmental characteristics -------- strong rainfall period



850hPa height and wind field at 14:00 LST, 21st

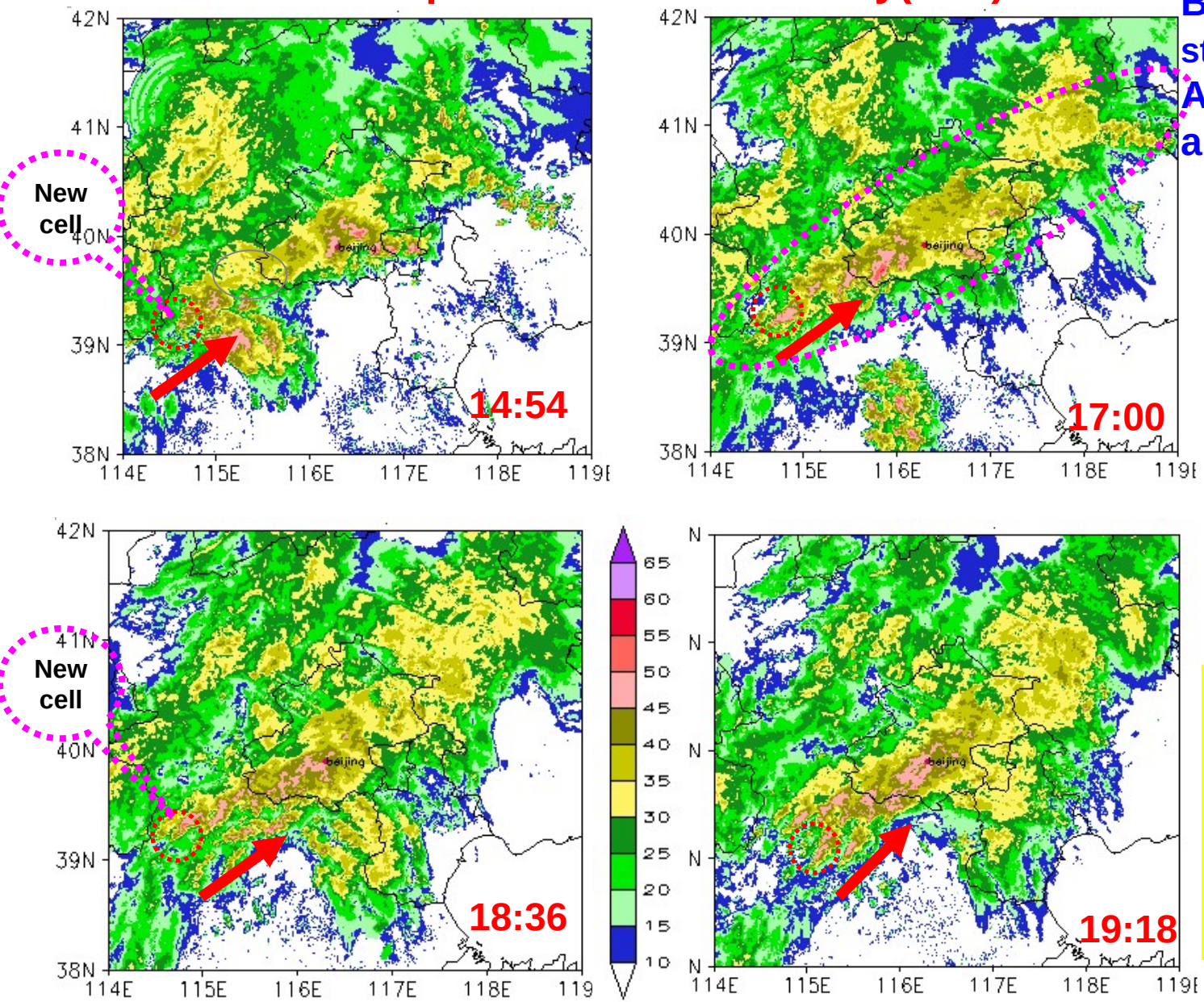
925hPa height and wind field at 14:00 LST, 21st



There is no meso-small scale system features in Middle-lower troposphere of NCEP analysis field when strong rainfall begins.

MCS evolution characteristics

composite radar reflectivity(dBz)



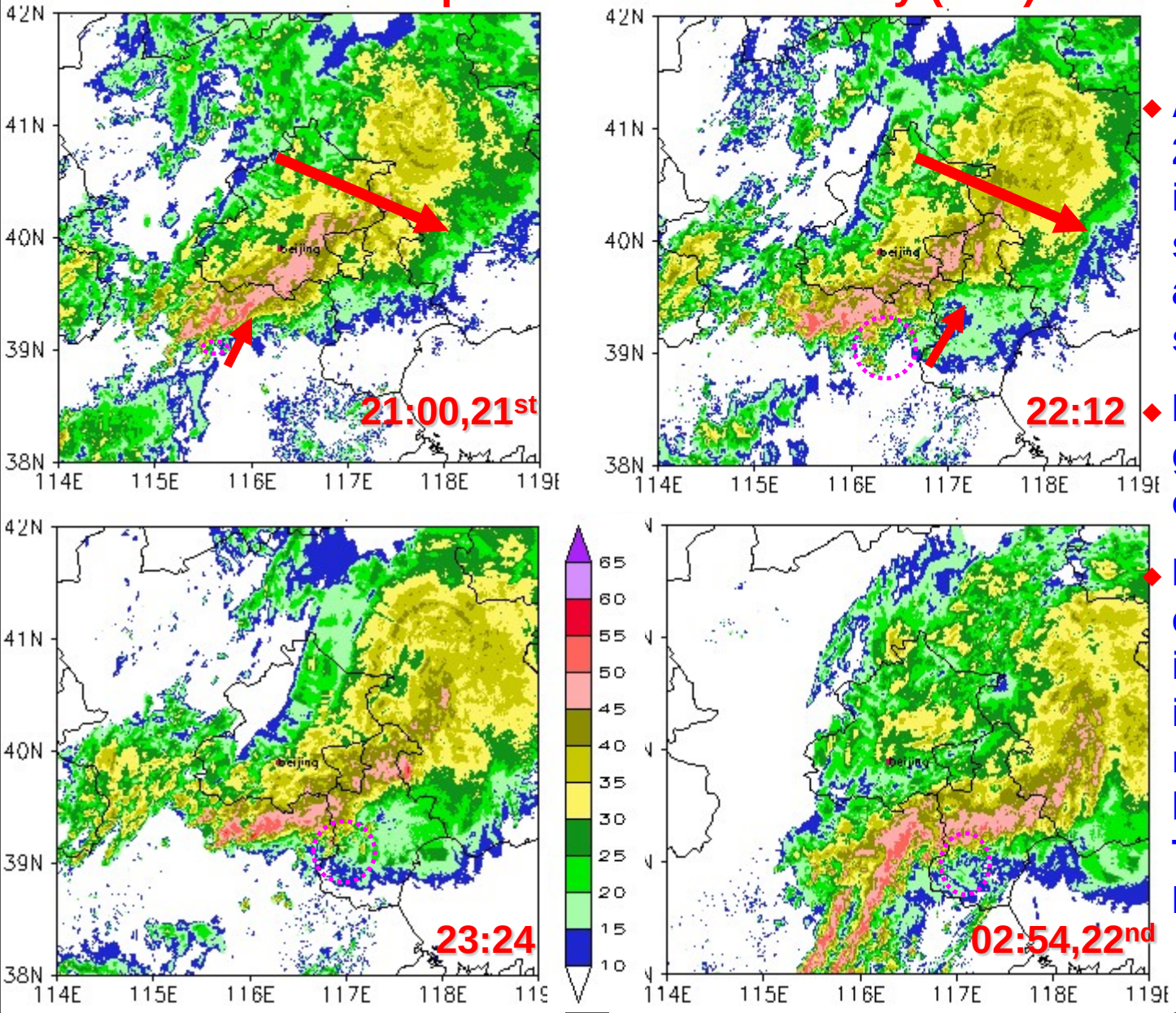
BB(backbuilding/qusi-stationary) MCS: About 500km-long and 80km wide

New cells keep generating repeatedly in the upstream of the system, and then move into the anterior system in a line-parallel direction.

A BB MCS keeps staying at Beijing area for 10h and leads to the extreme heavy rain event.

MCS evolution characteristics

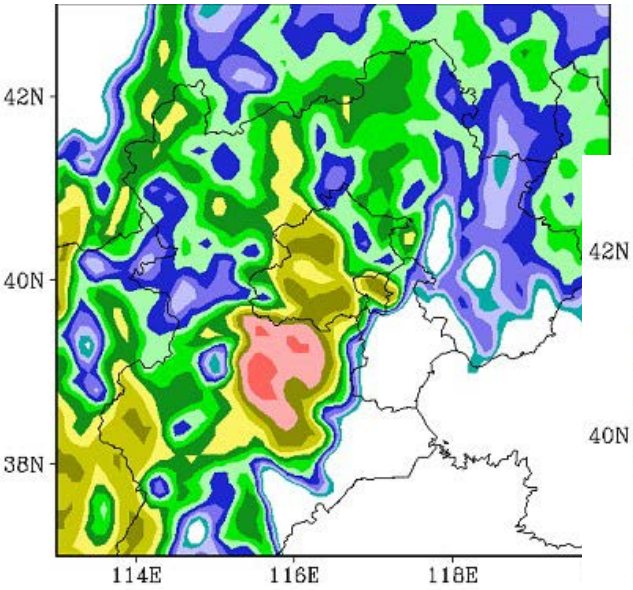
composite radar reflectivity (dBz)



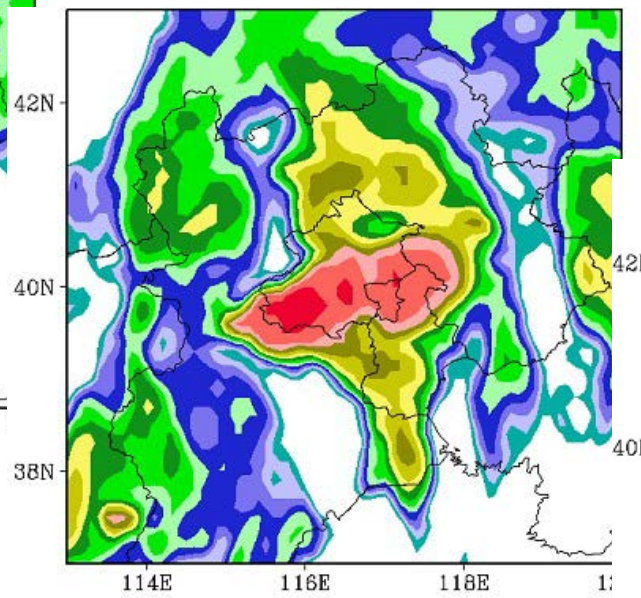
- After 20h LST in 21st,BB MCS turns into TS (trailing stratiform) MCS, and moves southeastwards.
- New cells is generating in front of the system.
- Besides leading to extreme heavy rain in Beijing, it also induces large-scale moderate rainfall in later period in Tianjin city and Hebei province.

MCS evolution -----TBB characteristics

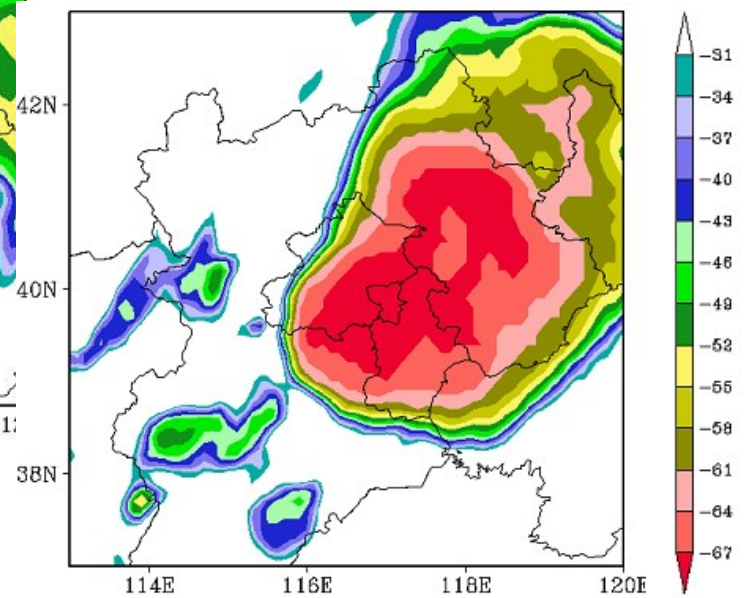
14:00 LST



18:00 LST

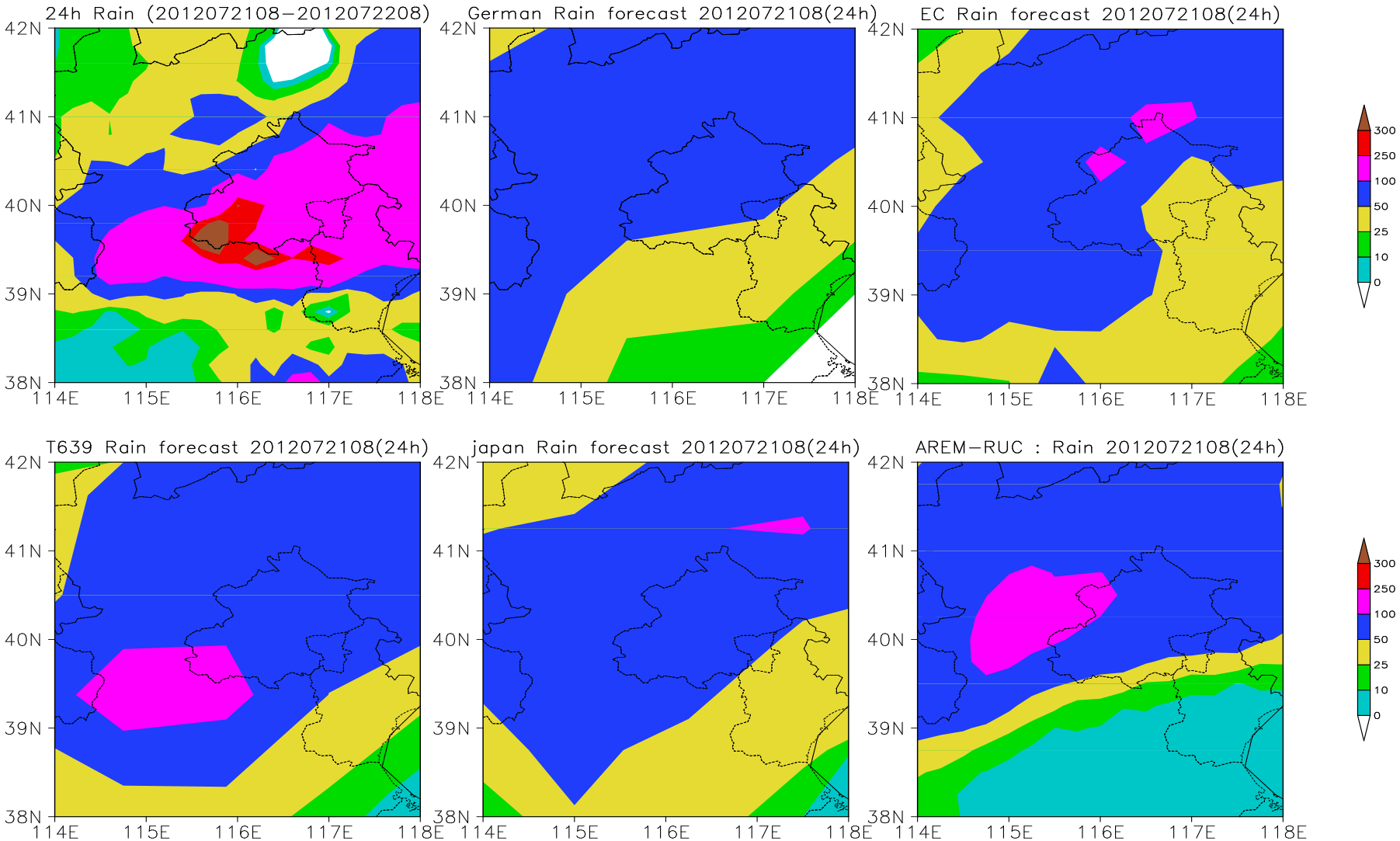


22:00 LST



- **Strong convective cloud cluster during 14-20h in 21st.**
- **After 20h the cloud cluster moves southeastward and continues strengthened and developing.**

model prediction results



For all models, the forecast precipitation intensity is smaller than observation, and the beginning time of strong precipitation is 6-h lag.

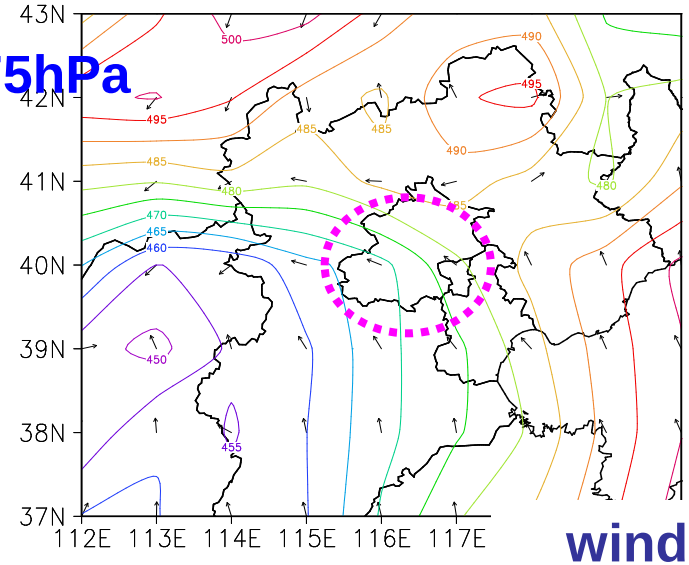
LAPS analysis

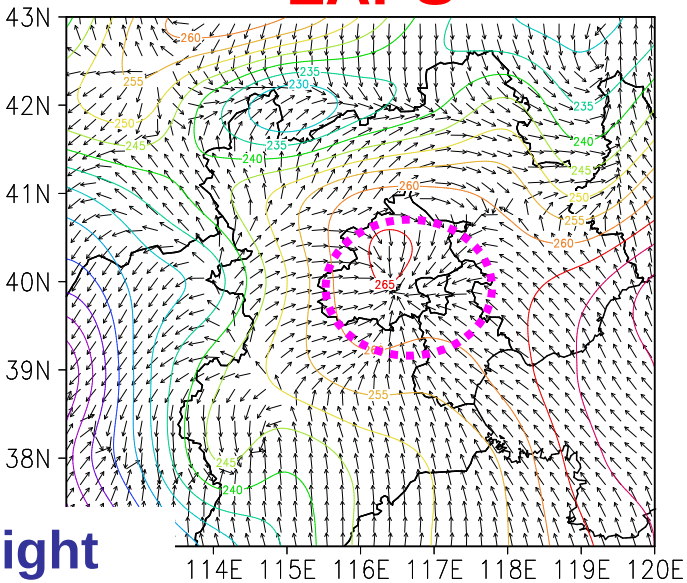
- **Number of vertical levels : 22**
- **Top pressure： 100hPa**
- **Time resolution： 1h**
- **Spatial resolution： 3km**
- **Background field: fnl data**
- **Ingest data:**
  Surface observation,Sounding observation,
  Radar(6 stations) , Satellite(FY3E)

comparison of LAPS and NCEP

NCEP **LAPS**

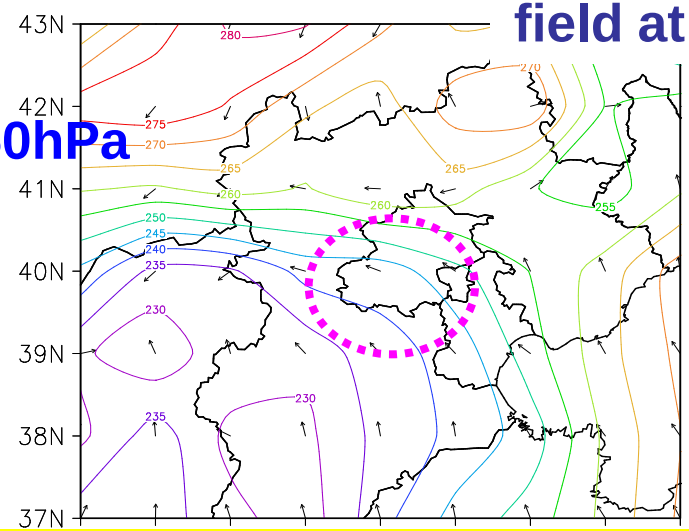
975hPa

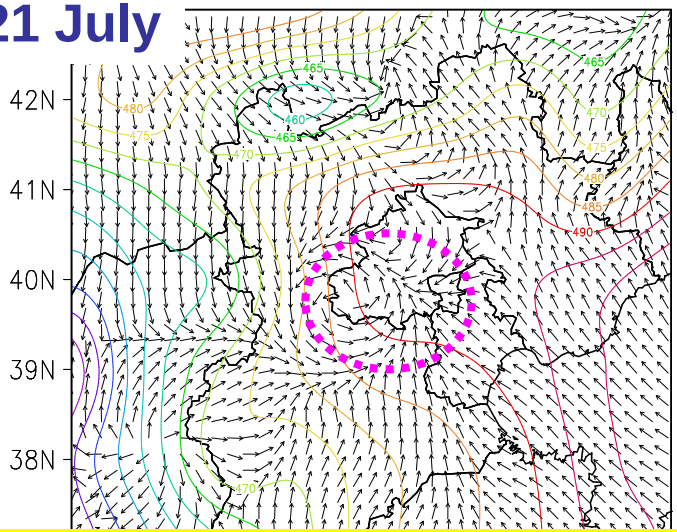




wind field and height field at 14:00 LST 21 July

950hPa





LAPS: obvious wind-convergence and vortex system in lower-troposphere at 14h.
NCEP: it is not obvious.

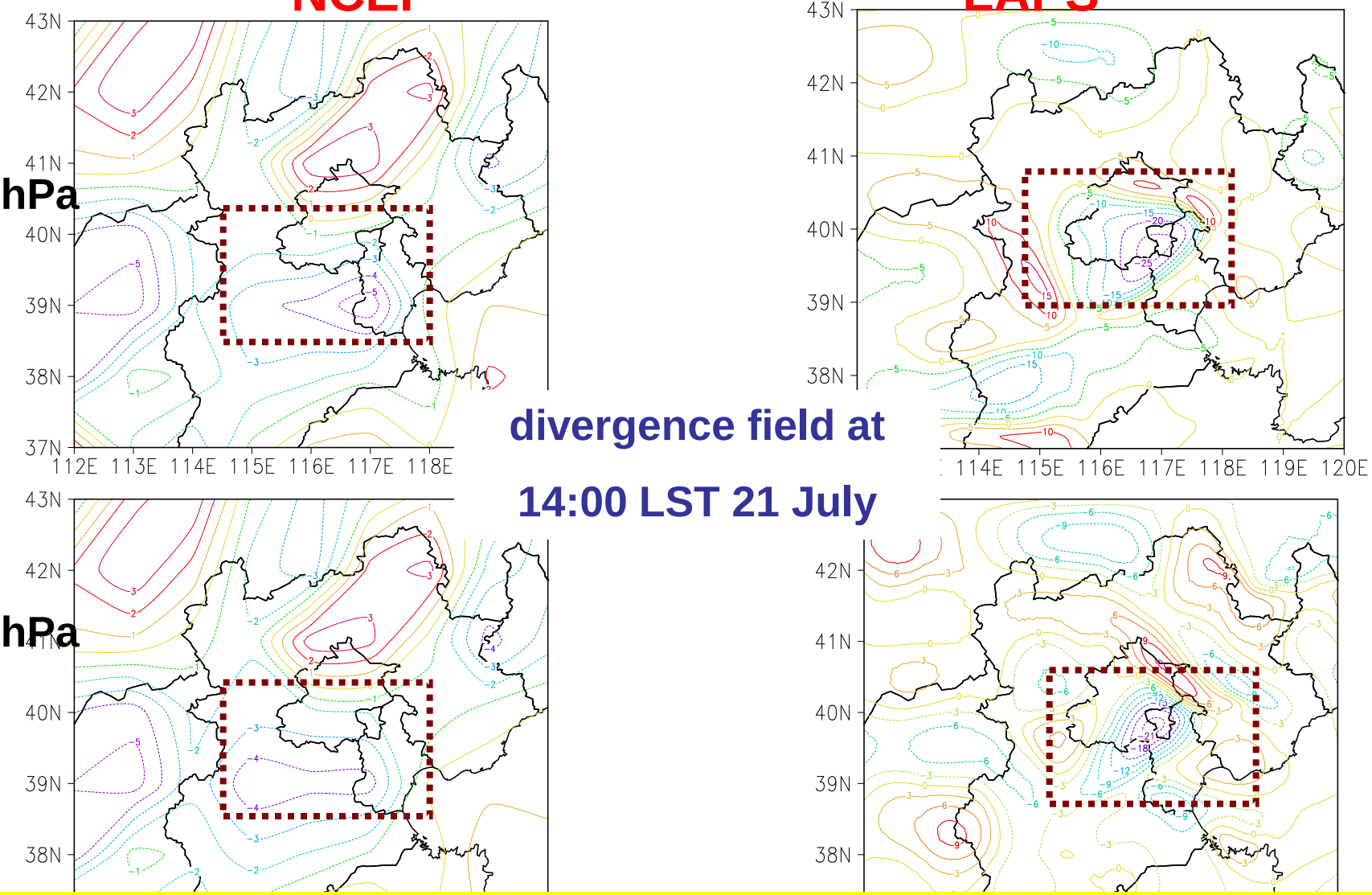
comparison of LAPS and NCEP

NCEP

LAPS

975hPa

950hPa

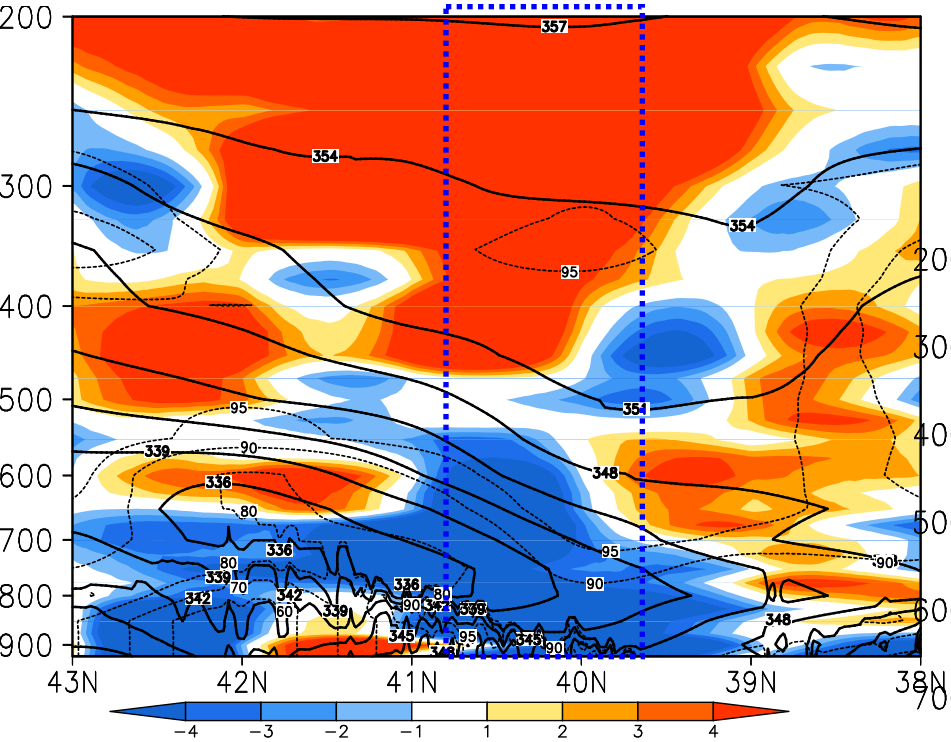


divergence field at

14:00 LST 21 July

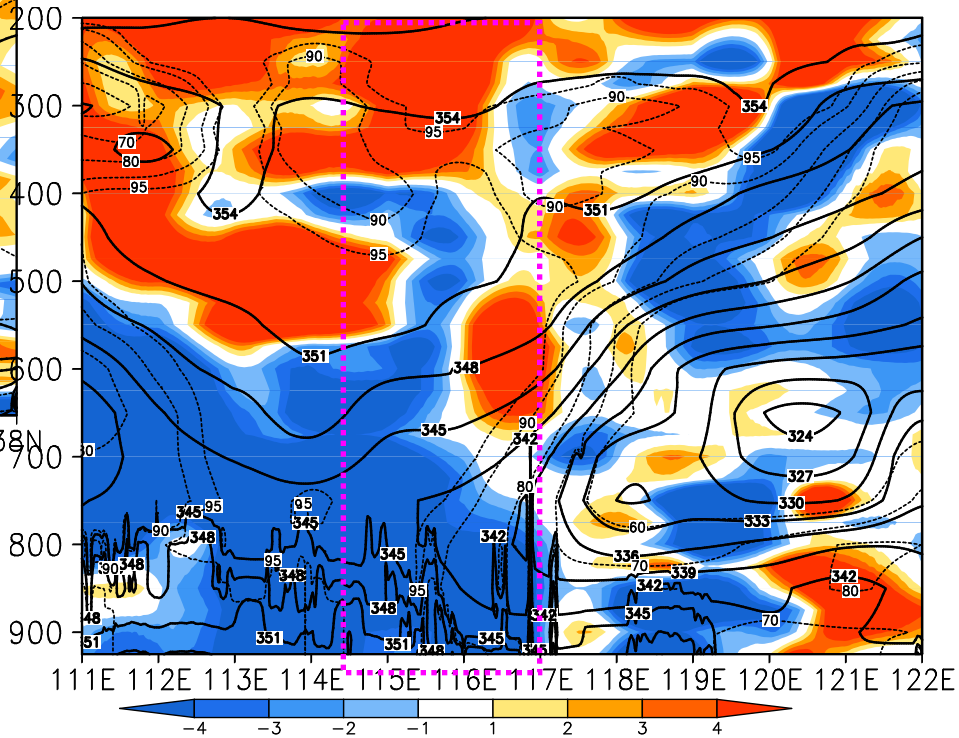
At 14h, there is stronger convergence in lower troposphere of LAPS analysis field than that of NCEP.

LAPS Analysis



along 116ºE

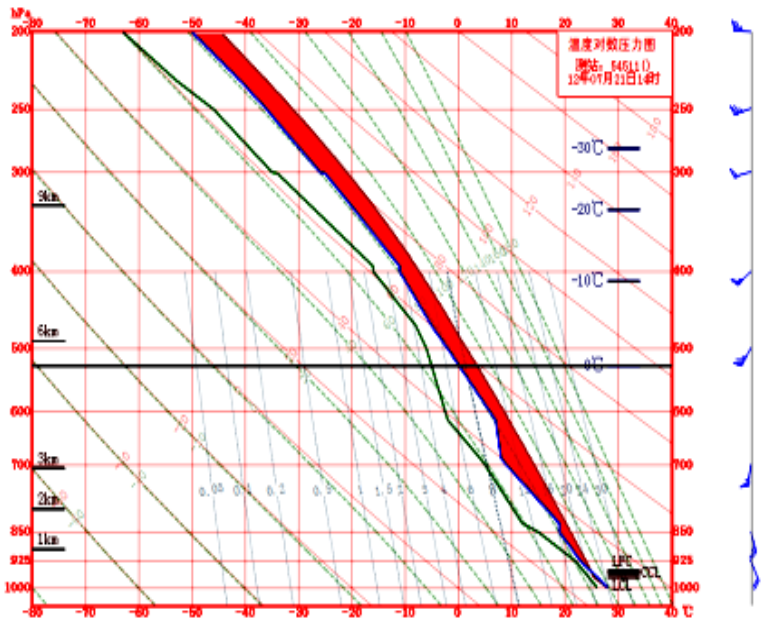
Profile of divergence (1×10^{-5} s^{-1})、relative humidity(%)、equivalent potential temperature (K) at 18h,21st



along 39.8ºN

- **The allocation of lower level strong convergence and upper level strong divergence over heavy rain area;**
- **In lower-layer high temperature and high humidity airflow extends to heavy rain area.**

comparison of LAPS and NCEP



stability analysis

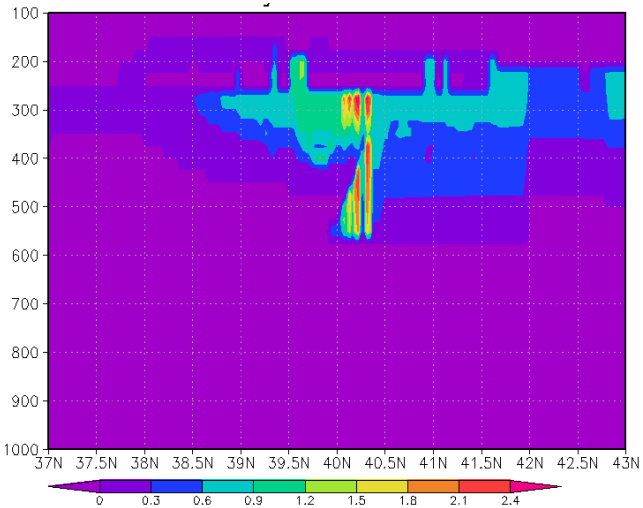
Before heavy rain occurrence, large unstable energy is accumulated over Beijing area.

Every parameter is favorable to strong rainfall development.

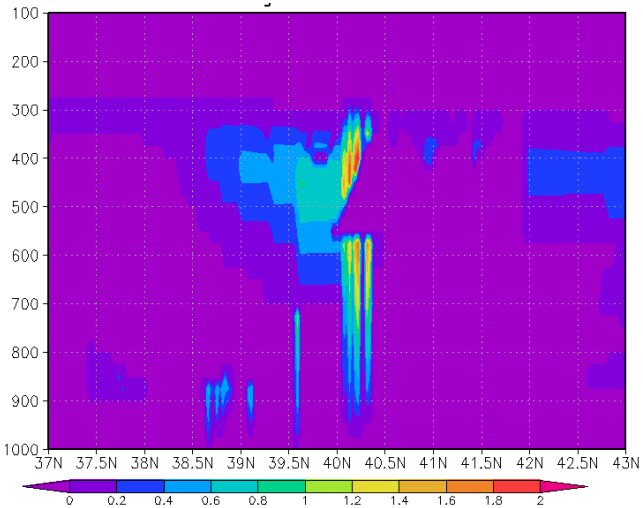
physics parameter	Observed data	laps	ncep
CAPE/(J·kg^{-1})	2089	2000	2748
K Index/° C	32	29	29
SI Index/℃	3.0	2.56	2.60

vertical distribution of cloud-ice and cloud-water during strong precipitation period

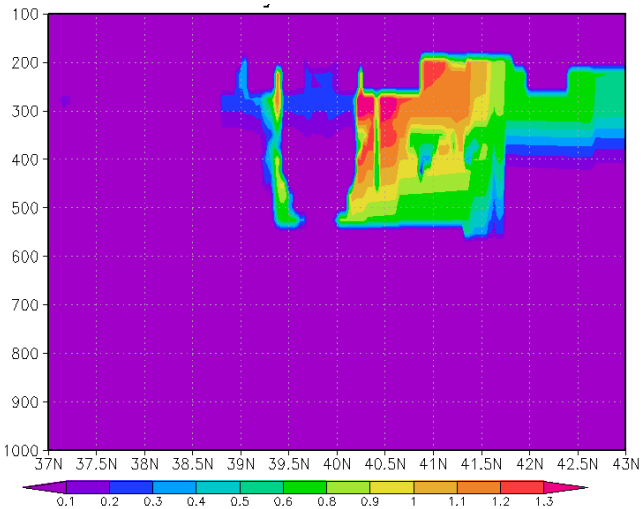
Ice along116E 14Z21JUL2012



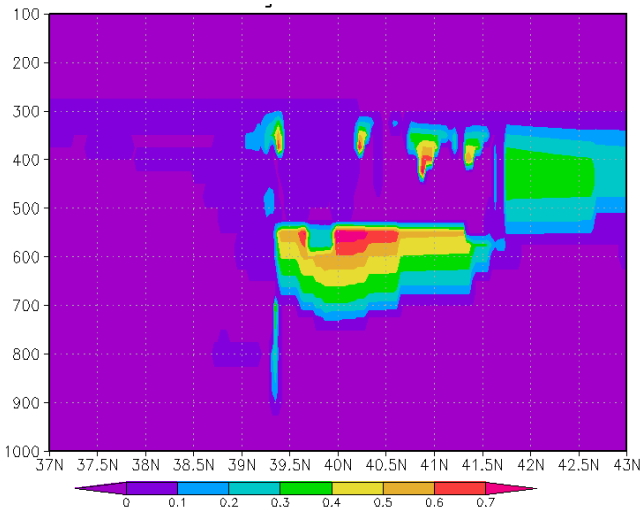
lwc along116E 14Z21JUL2012



Ice along117E 19Z21JUL2012

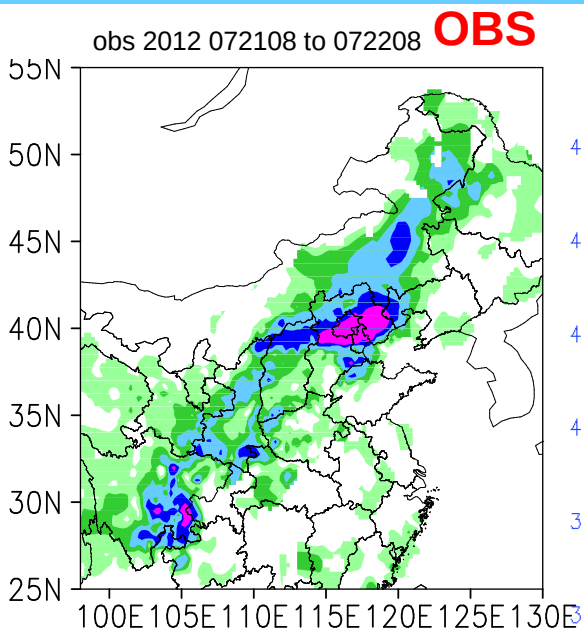


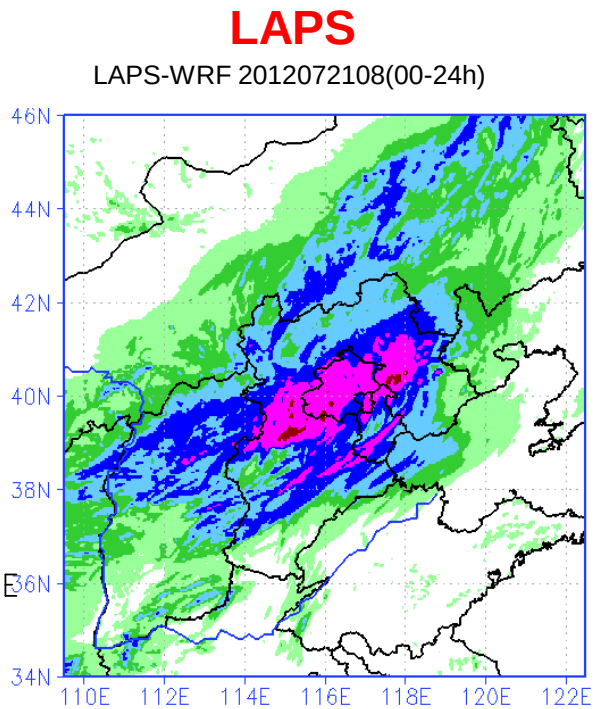
lwc along117E 19Z21JUL2012

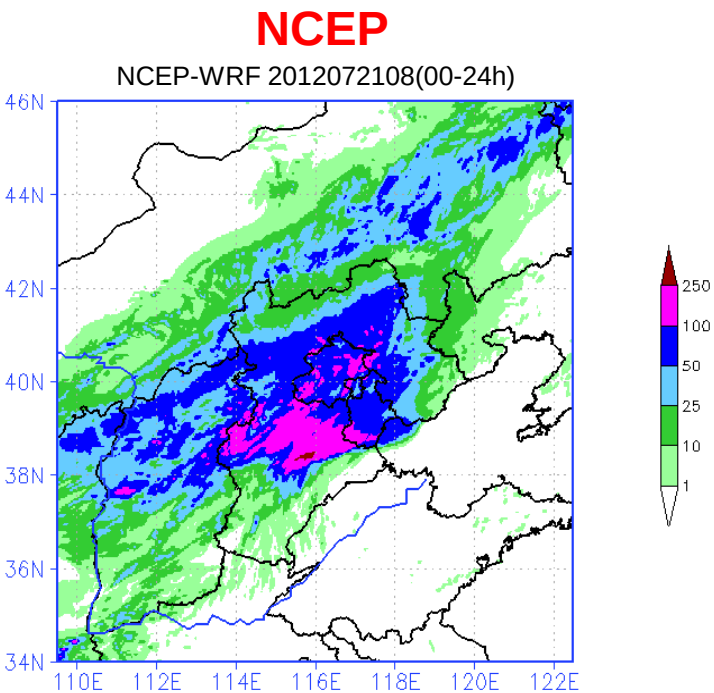


Water substance is rich.
It is richer at 14h than at 19h.

WRF (V3.0.1, WSM3) results between using LAPS and NCEP as initial field







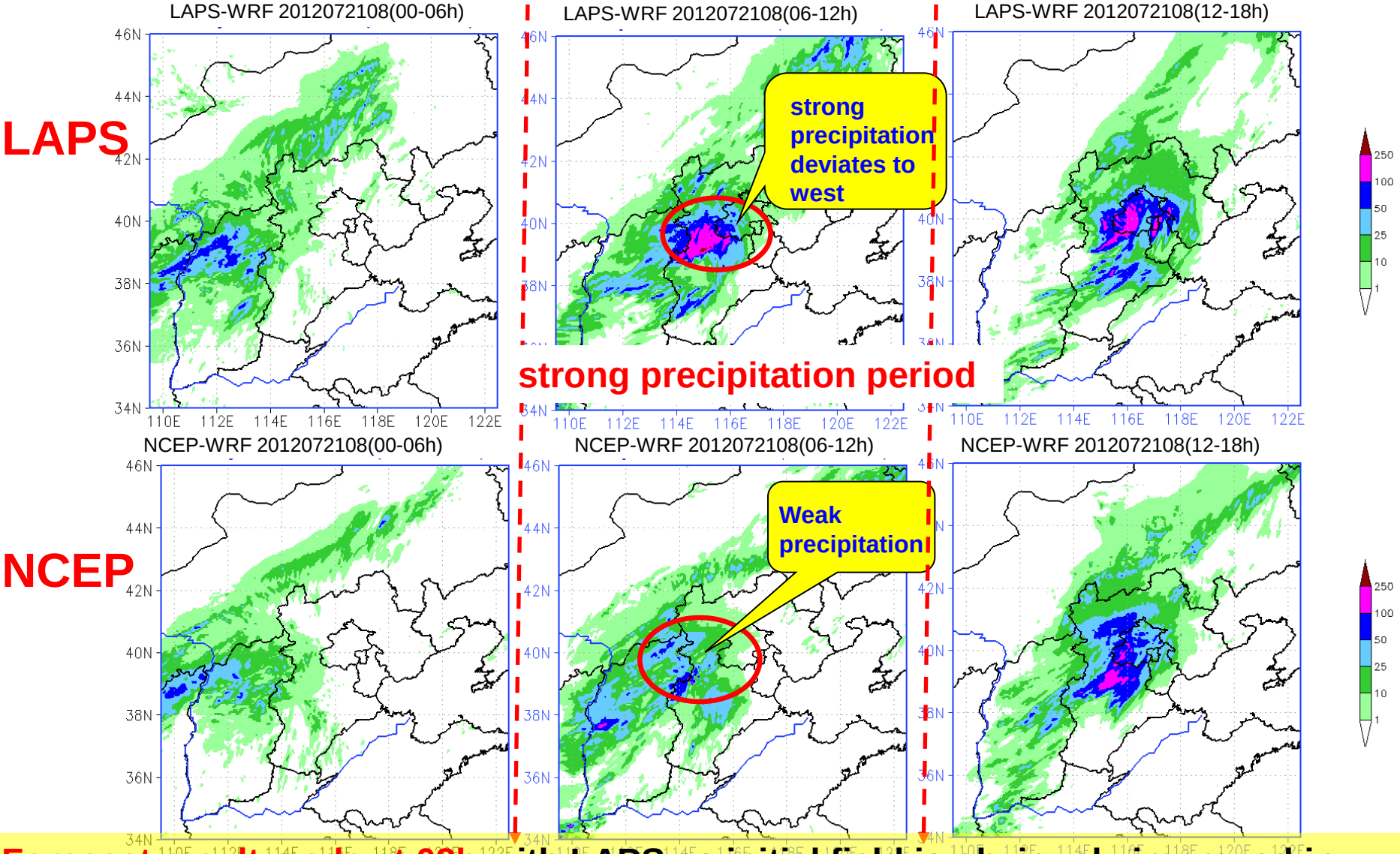
24h predicted precipitation intensity and falling area can be improved by using LAPS as the initial field of WRF model.

Simulated rain belt is close to the observation.

The predicted area of strong precipitation deviates to south and precipitation intensity is weaker than observation.

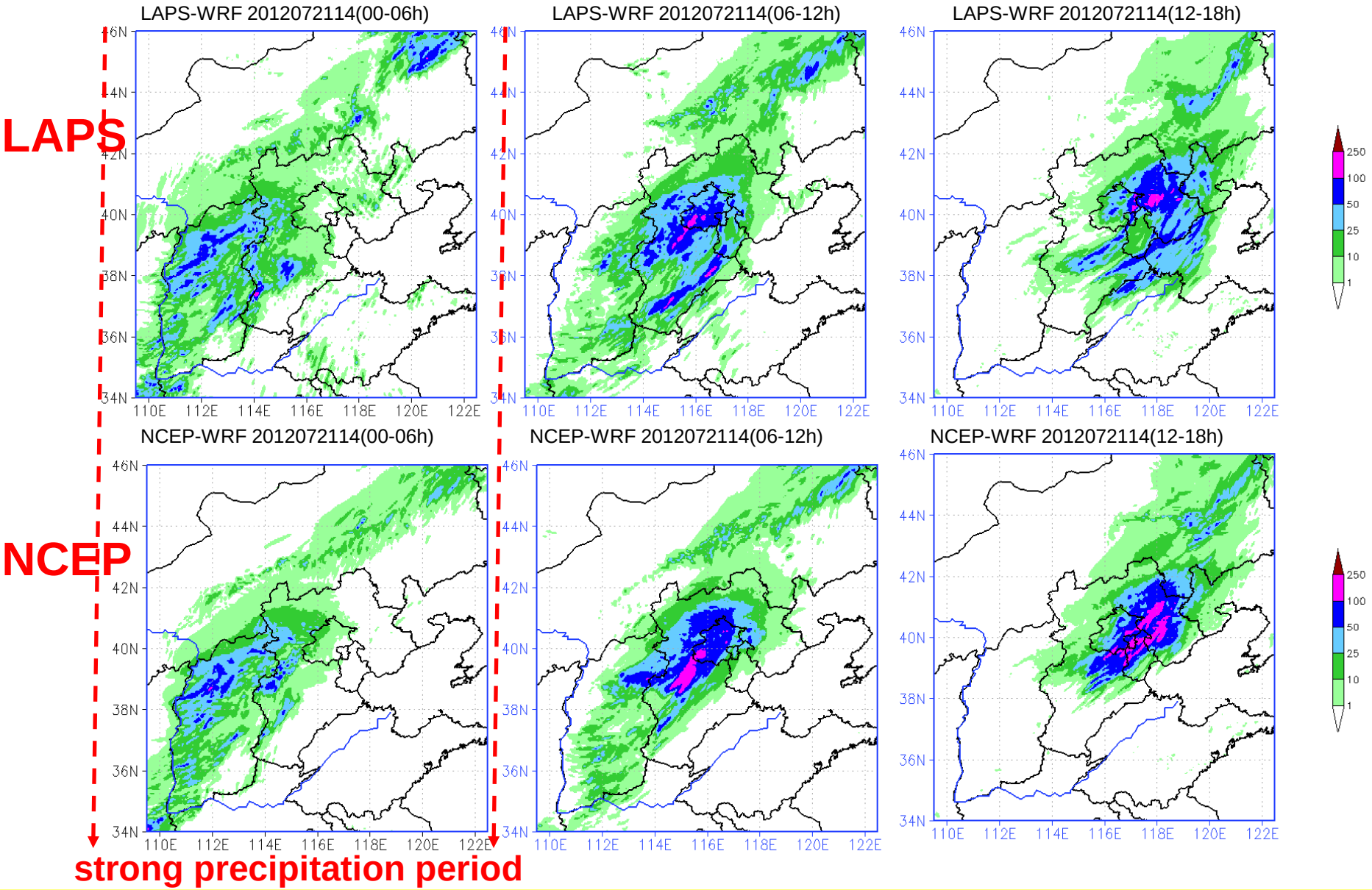
Forecast made at 08h is obviously improved in strong precipitation beginning time and intensity, while the predicted rainfall location deviates a little to west.

WRF results between using LAPS and NCEP as initial field



Forecast result made at 08h with LAPS as initial field is obviously improved in strong precipitation occurring time and intensity, while the predicted rainfall location deviates a little to west.

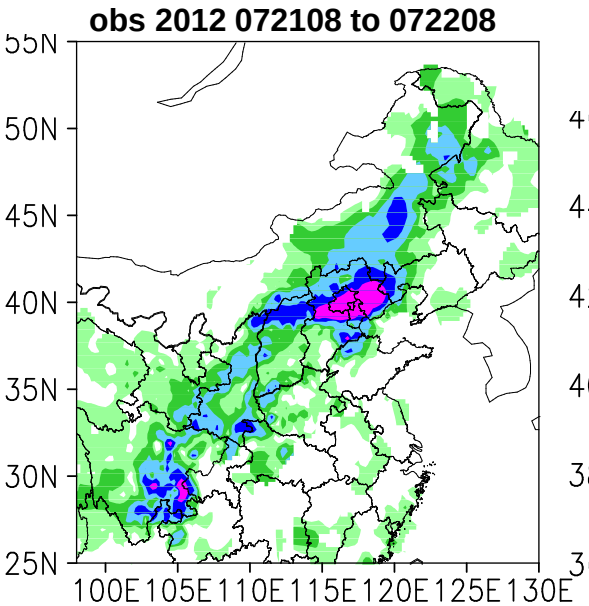
WRF results between using LAPS and NCEP as initial field



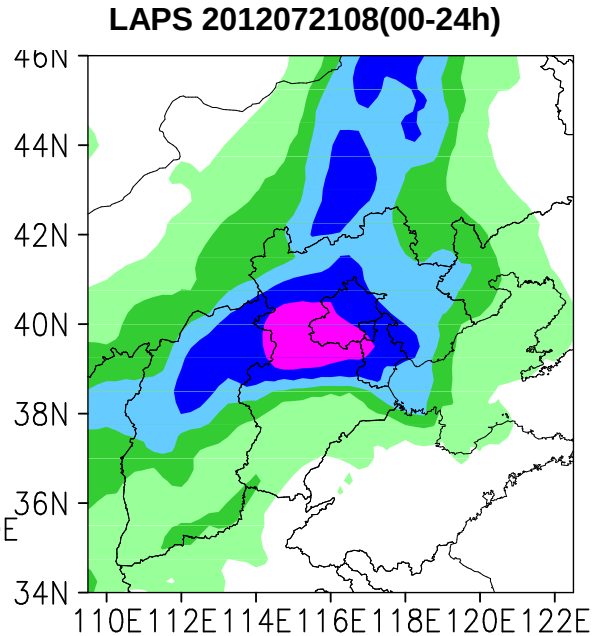
Forecast result made at 14h is not improved in strong precipitation occurrence.

AREM model results comparison between using LAPS and NCEP as initial field

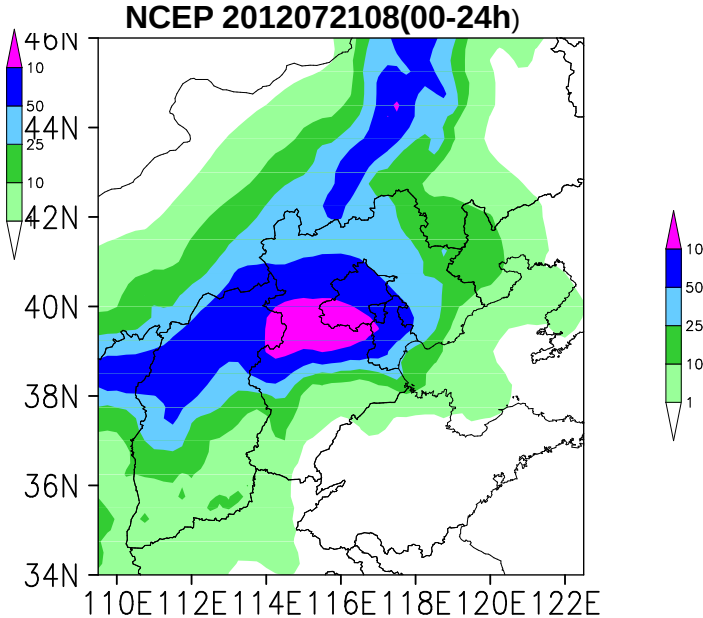
OBS



LAPS



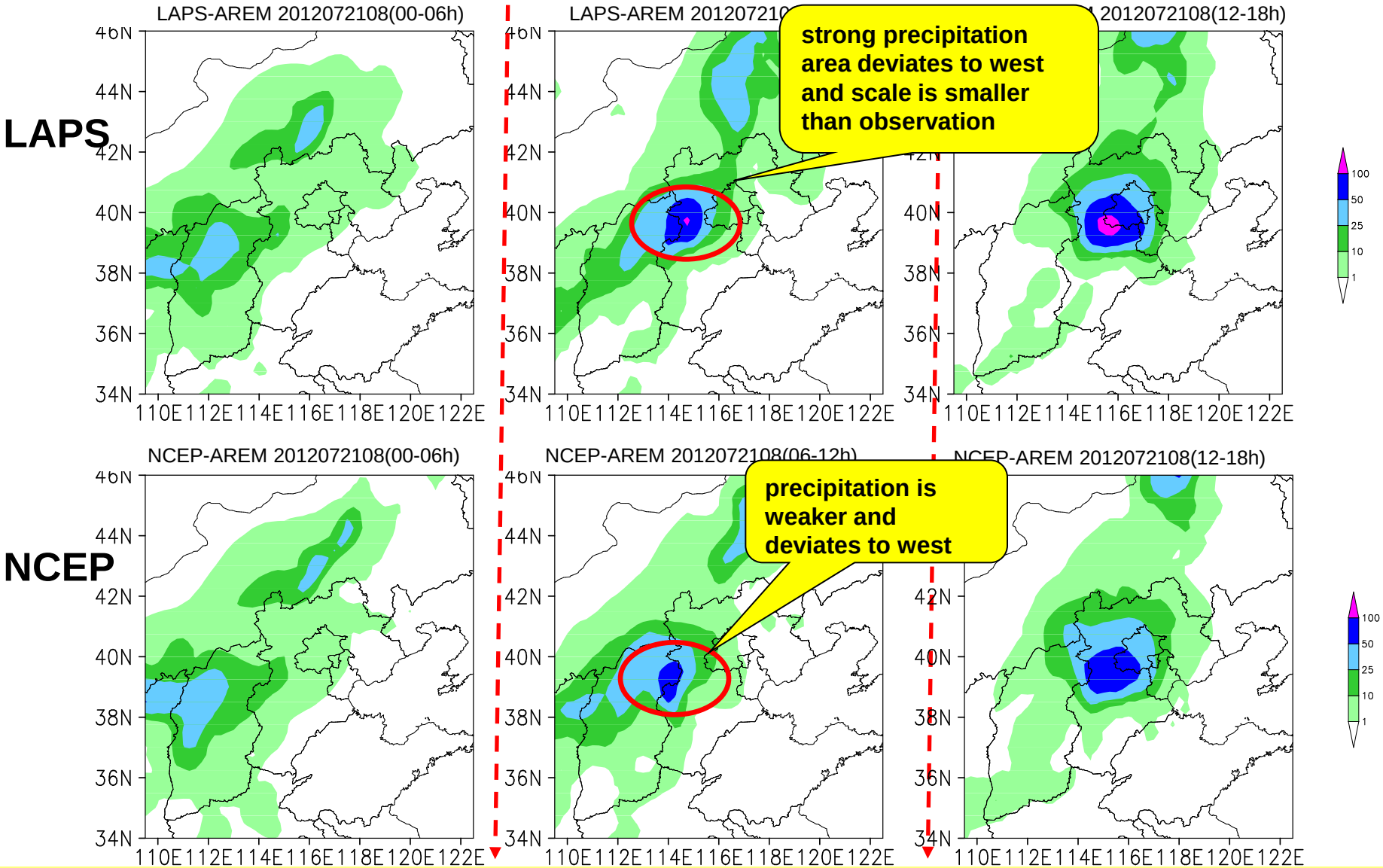
NCEP



strong precipitation area deviates to west

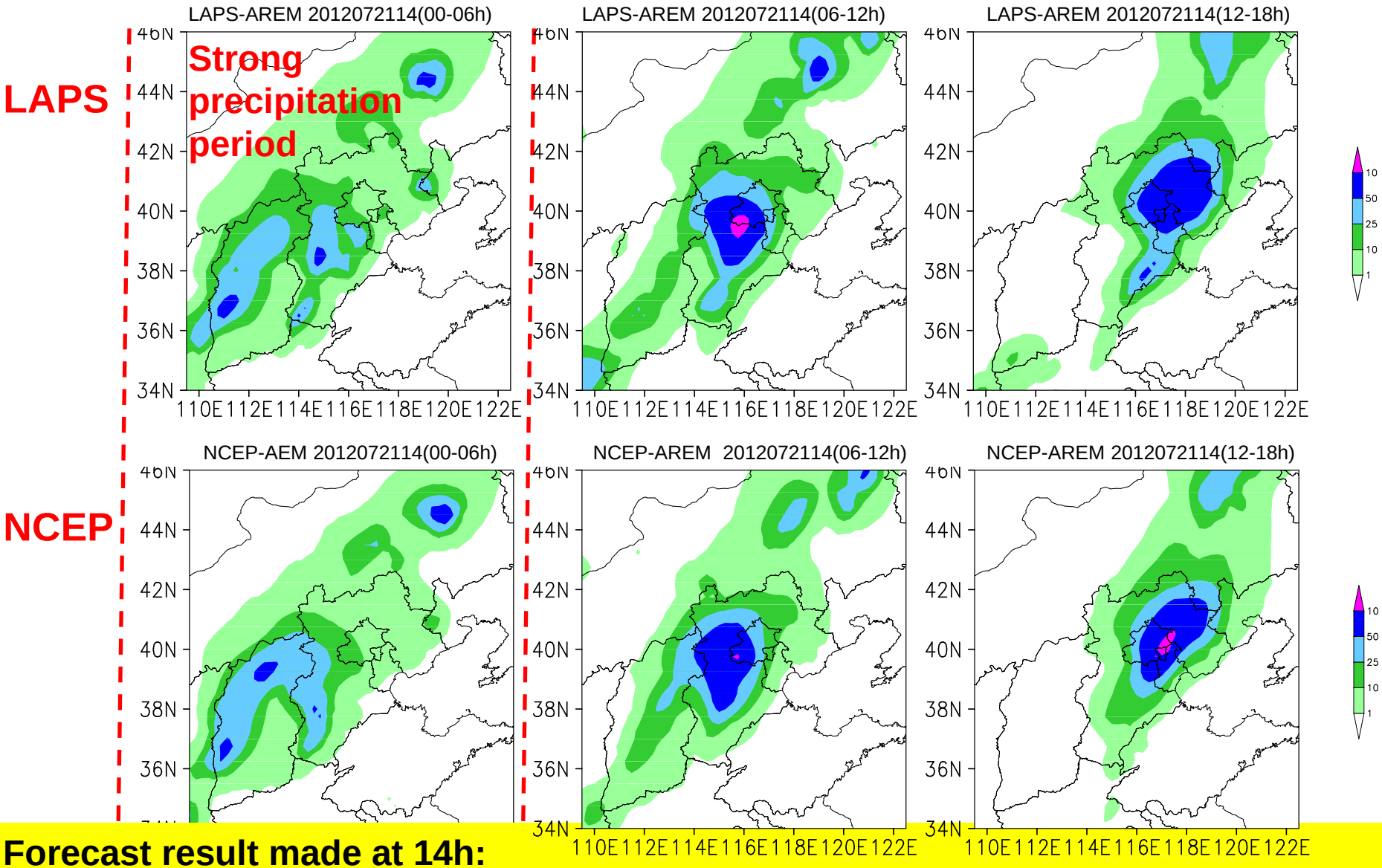
Using either LAPS or NCEP as initial field of AREM, the predicted strong precipitation area deviates to west.

AREM model results comparison between using LAPS and NCEP as initial field



The AREM model made at 08h using LAPS as initial field is a little improved in precipitation beginning time and intensity.

AREM model results comparison between using LAPS and NCEP as initial field



Forecast result made at 14h:

the beginning time of strong precipitation is 06-h lag. No improvement

Existing Problems

- **Models (such as EC, Germany, Japanese,T639, AREM and WRF and so on) all cannot forecast the precipitation beginning time and intensity . The predicted precipitation is weaker and beginning time is more than 6h lag.**
- **With LAPS as initial field, WRF model forecasted precipitation intensity is distinguished improved and the lag time is diminished. But the results is still less than satisfactory.**
- **Two important factors to model forecast:**
  - **Quality of initial field**
  - **Model physics scheme.**

Whether the microphysics scheme , boundary layer and land surface processes can describe exactly the "7.21" extreme heavy rain event in Beijing or not

waits for further study

Result

- The extreme heavy rain event in Beijing is induced by a long-lasting BB MCS. Its development consists two stages:
  1. from 10-20h in 21st, it maintains quasi-static in Beijing;
  2. after 20h,this BB MCS turns into TS MCS and moves southeastwards and influences the areas in Tianjin and Hebei province.
- Upper-level jet divergence and the thick deep convergence system constructed by vortex and shear in middle-lower troposphere and surface inverse trough forms strong ascending motion and keeps its maintenance. The vapor channel from east ocean in the periphery of subtropical high and the vapor of southwest low-level jet provide abundant water vapor condition.
- In LAPS analysis field, there is obvious meso-small scale vortex system and wind-convergence in middle-lower layer at 14:00 LST .While for NCEP, there is no obvious meso-scale system at 14:00 LST.
- According to different models results, the heavy rain event could be simulated (about 50mm), while the precipitation intensity is obviously smaller and the beginning time of strong rainfall is later than real case. The simulated precipitation intensity and beginning time can be significantly improved by using LAPS analysis field as background field.

Thanks for your attention!

中国气象局武汉暴雨研究所
IHR
Institute of Heavy Rain, CMA, Wuhan