Application of Satellite Remote Sensing in Severe Convective Weather and Heavy Rainfall

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outline

- FY Satellite images and derived products used in weather analysis
- The application in heavy rainfall events and server convective system.

FY2 Satellite images and derived products used in weather analysis

- (1)FY2 Satellite images and derived products used in weather analysis
- (2)Boundaries in water vapor imagery
- (3)Divergence and convergence at upper troposphere shown in AMV and WV imagery

FY2 Satellite images and derived products used in weather analysis

1）FY-2 cloud image（IR1、IR3、VIS）

2）FY-2 AMV (Atmospheric Motion Vector)

3）FY-2 TBB and OLR

4）FY-2 PRE(Precipitation Estimation)

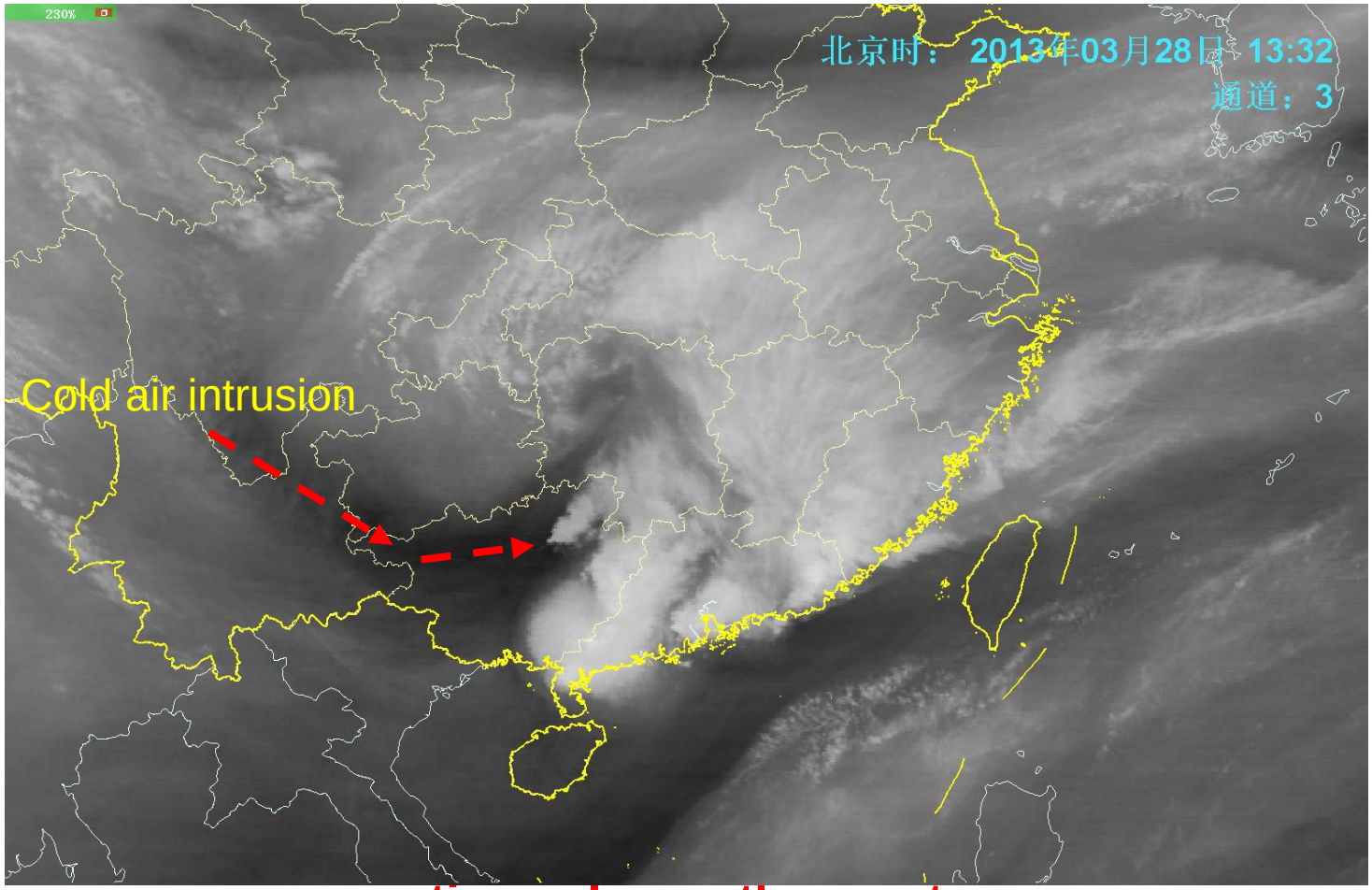
5）FY-2 CLC(Cloud Classification)

1）FY-2 cloud image（IR1、IR3、VIS）

Bands and Wavelength Range of FY-2 satellite

Band	Wavelength Range (μm)	Band Explanation	Spatial Resolution (m) at nadir
IR1	10.3—11.3	far infrared	5000
IR2	11.5—12.5	far infrared	5000
IR3	**6.3—7.6**	**water vapor**	**5000**
IR4	3.5—4.0	middle infrared	5000
VIS	0.50—0.75	Visible/ Reflective	1250

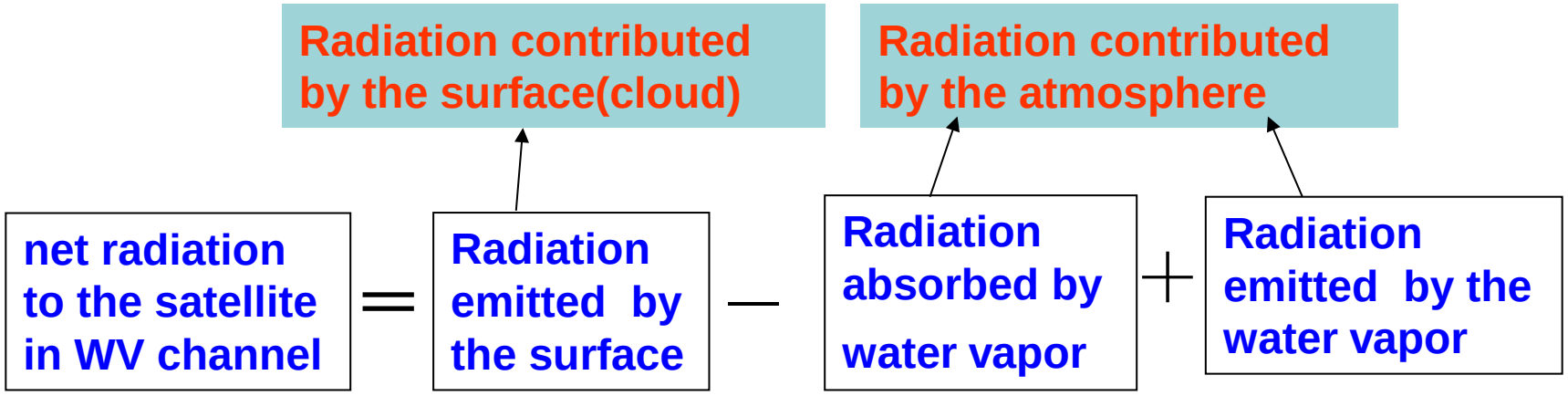
Band	Wavelength Range (μm)	Band Explanation	Spatial Resolution (m) at nadir
IR3	6.3—7.6	water vapor	5000



synoptic-scale weather system,
the upper-troposphere atmosphere circulation. Dark area can show dynamic process in the atmosphere.

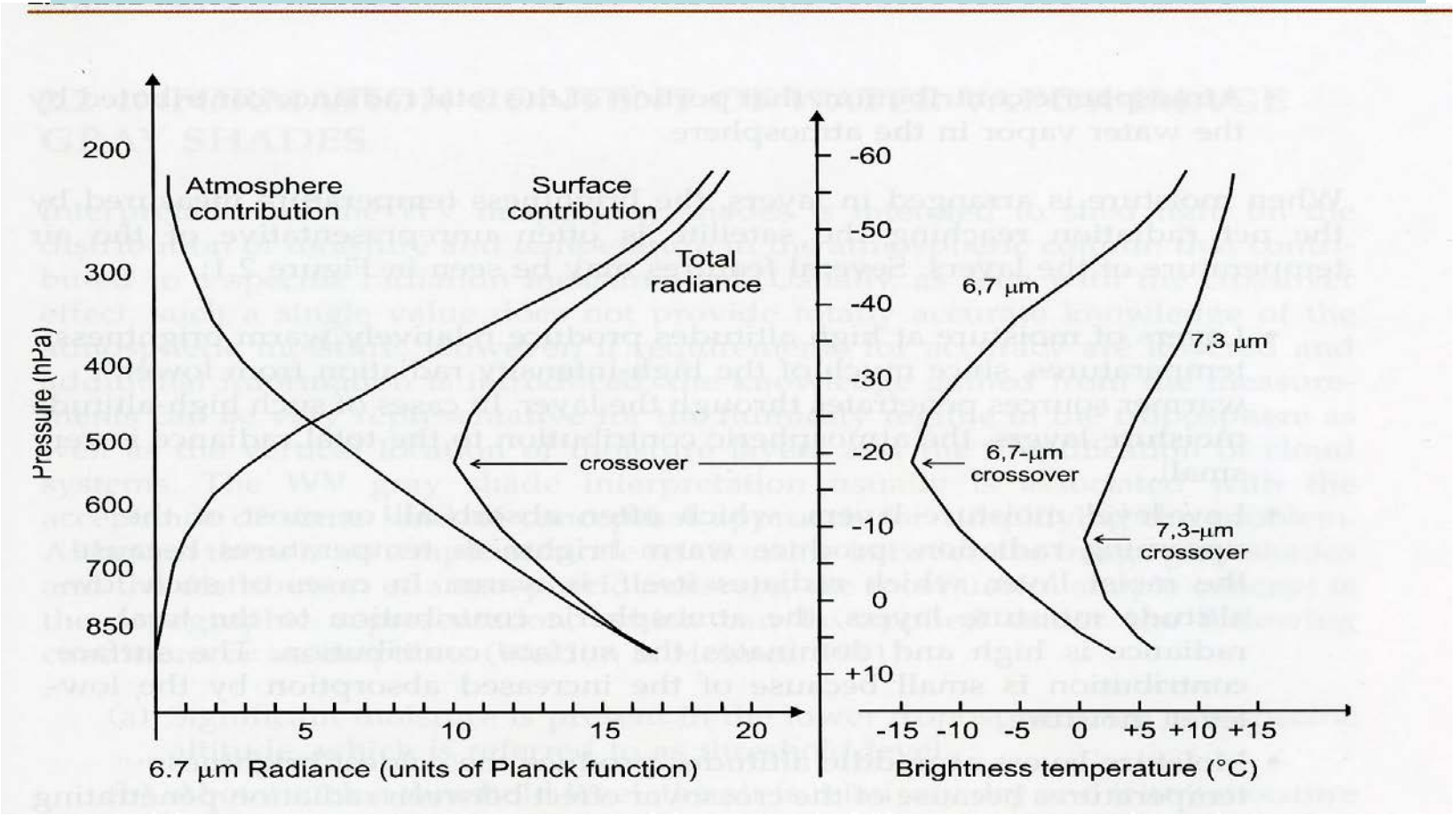
The channels in the water vapor absorption bands, are sensitive to the profiles of both the temperature and the humidity

- **Total radiation to the satellite：which is used to calculate the Brightness temperature**
- **Radiation contribute by the surface(cloud): it is related to the surface(cloud) temperature**
- **Radiation contribute by the atmosphere: the water vapor in the atmosphere can absorb a part the radiation coming from the surface at 6.3-7.6 micrometer**



crossover effect

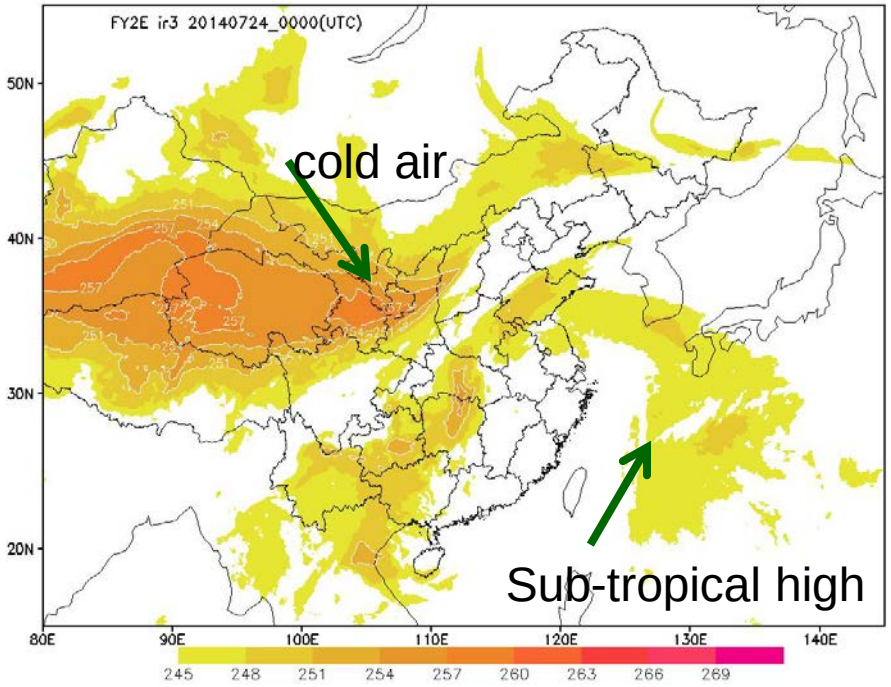
That is when water vapor exist at mid level, the total radiation to satellite in WV channel is the smallest.

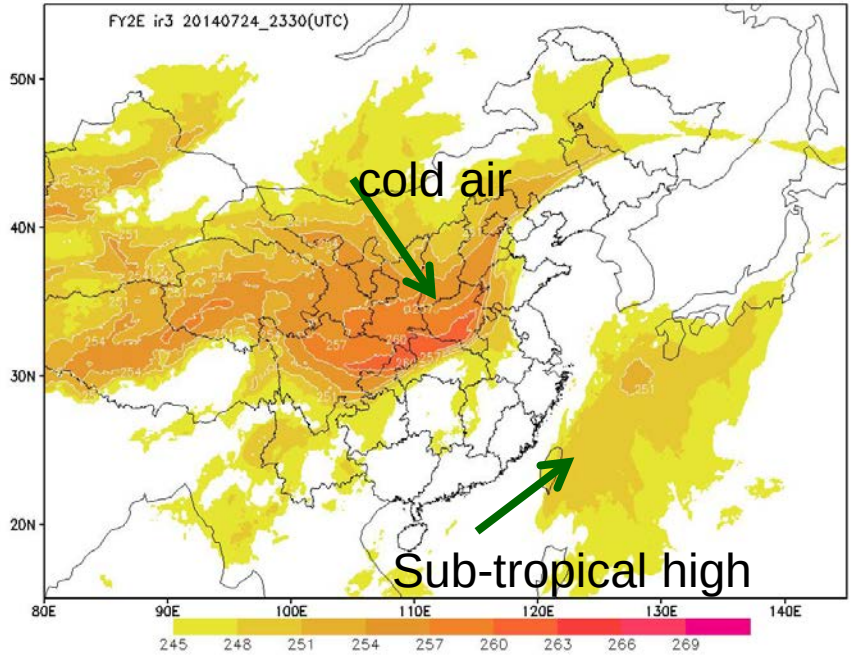


- In WV channel, the most information comes from the mid level of the troposphere.
- It can not detect the 80% water vapor at low levels which is very important to the rainfall. But the WV images are still very useful in weather analysis.

- Firstly, the ascending / descending at mid troposphere can induce the obvious change of the specific humidity. That is, the change of gray level in WV images shows there is ascending or descending at mid troposphere which is important to weather analysis.
- Secondly , one kind of small scale moving dark area in WV images shows the dry and cold air activities in north China which is also important to the heavy rainfall. It also can show the location and strength variation of north-western Pacific subtropical high and so on.
- On WV images, there are many kinds of **boundaries** which are related to different weather.

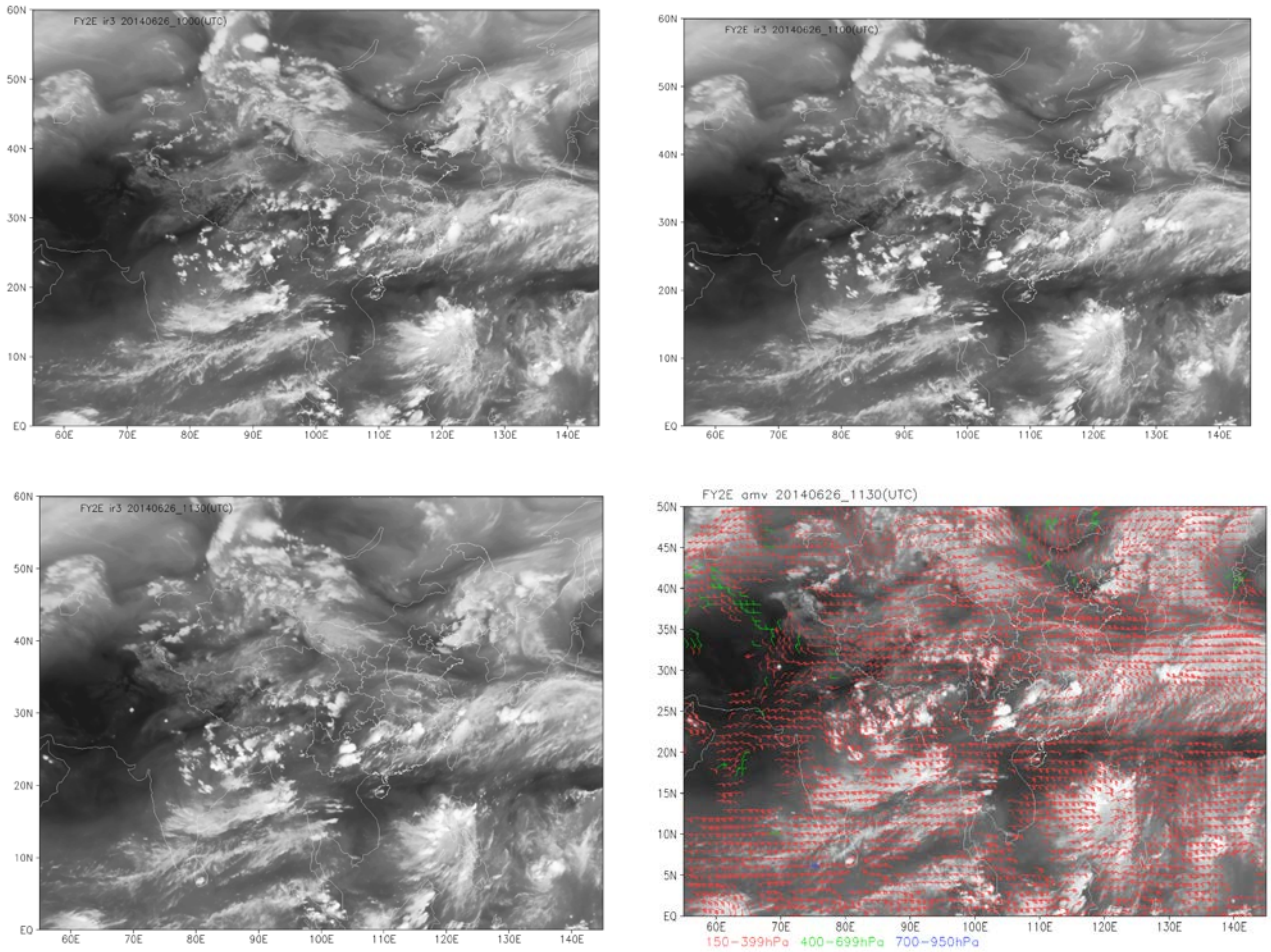
IR3 image dark area





Cold air and sub-tropical high are all important to heavy rainfall, tropical cyclone and other weather system in summer.

2) AMVs derived by IR3 channel images

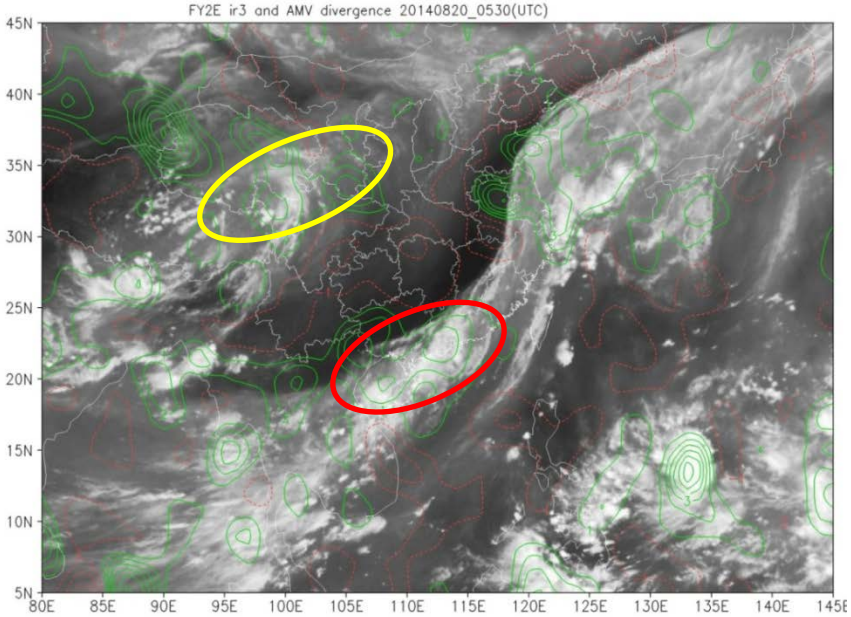


The atmosphere movement vector (AMV) is derived by three consecutive times images. According to the movement of clouds the wind direction and wind speed at different layers of can be calculated.

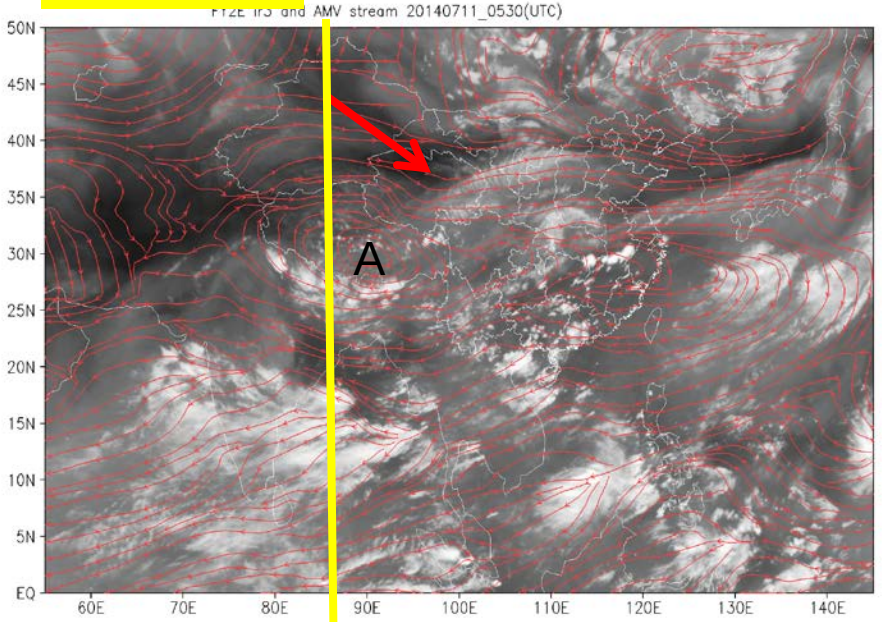
	FY-2E	FY-2G
AMVs	03:00 (UTC)	05:30 (UTC)
	09:00 (UTC)	11:30 (UTC)
	15:00 (UTC)	17:30 (UTC)
	21:00 (UTC)	23:30 (UTC)

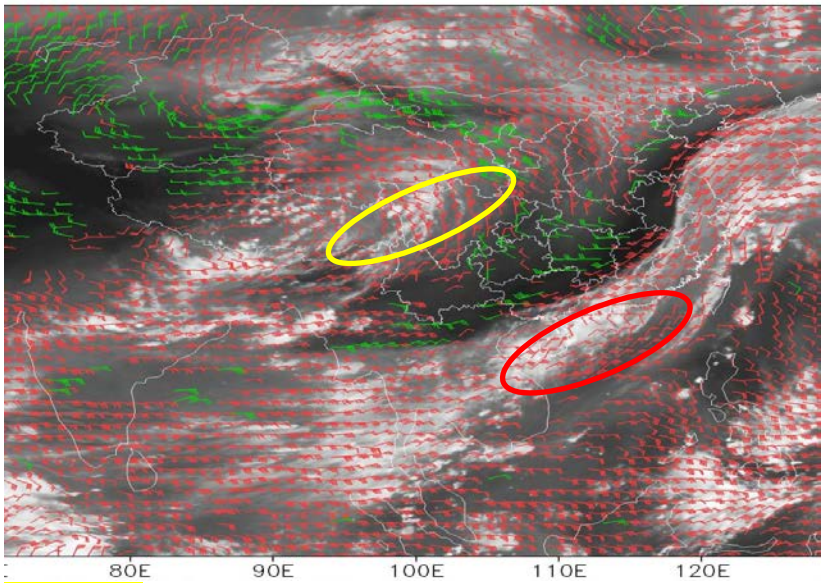
Eight AMV products in one day

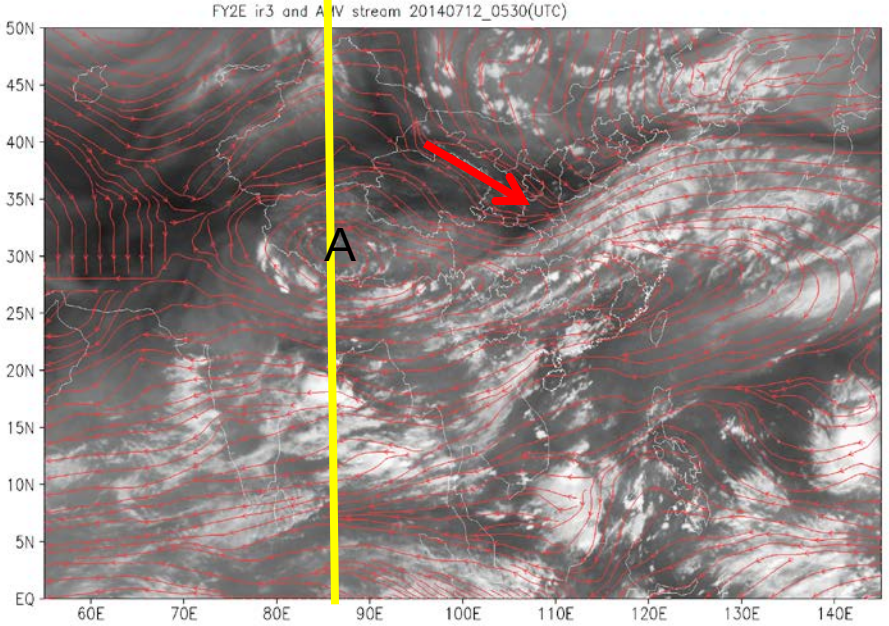
divergence



streamline







wind

The upper –layer div and streamline are also caculated

FY Satellite images and derived products used in weather analysis

- (1)FY Satellite images and derived products used in weather analysis
- (2)Boundaries in water vapor imagery
- (3)Divergence and convergence at upper troposphere shown in AMV and WV imagery

(2)Boundaries in water vapor imagery

1) what are the boundaries?

2) Main boundaries in weather analysis.

1) what are the boundaries?

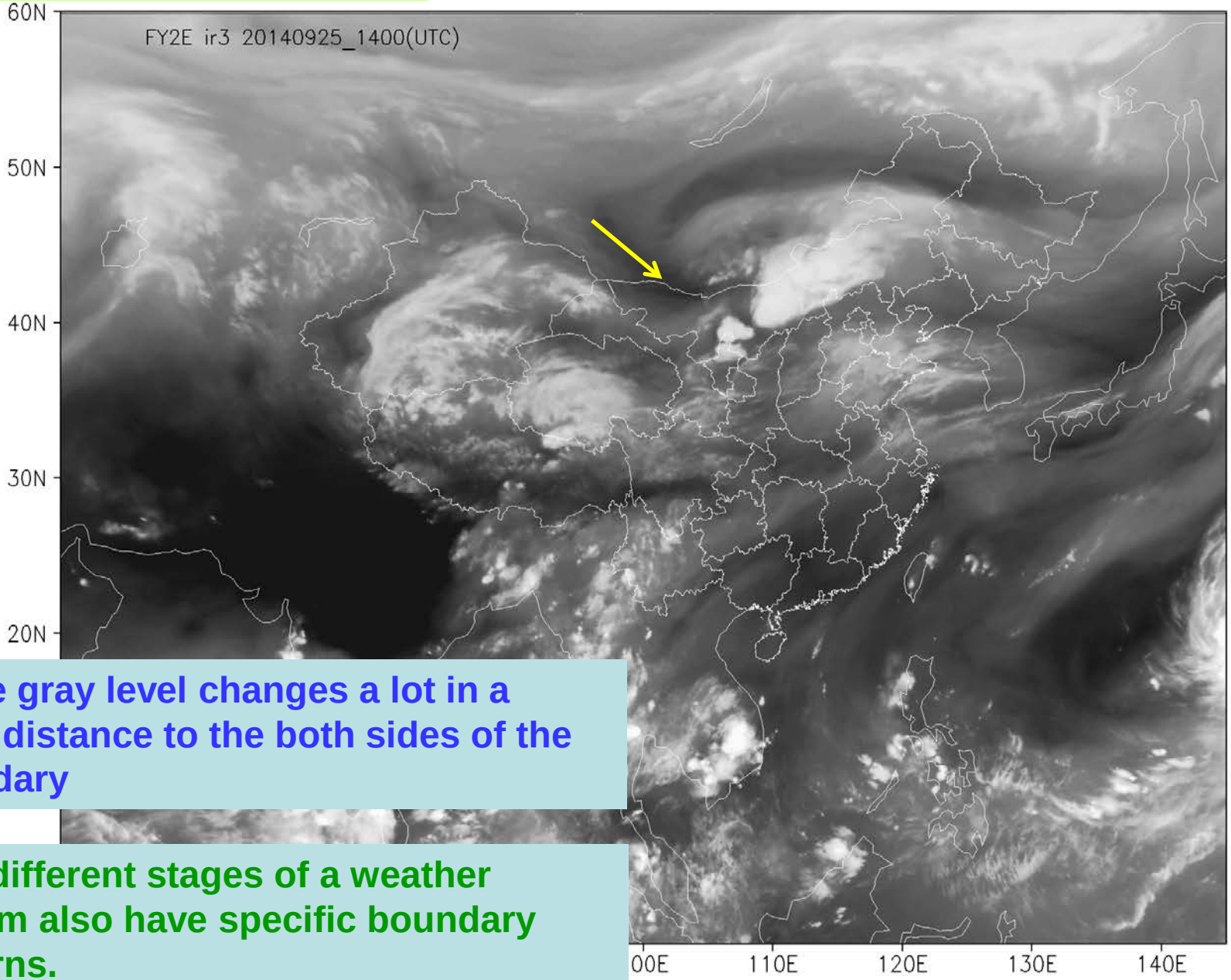


image gray level changes a lot in a short distance to the both sides of the boundary

The different stages of a weather system also have specific boundary patterns.

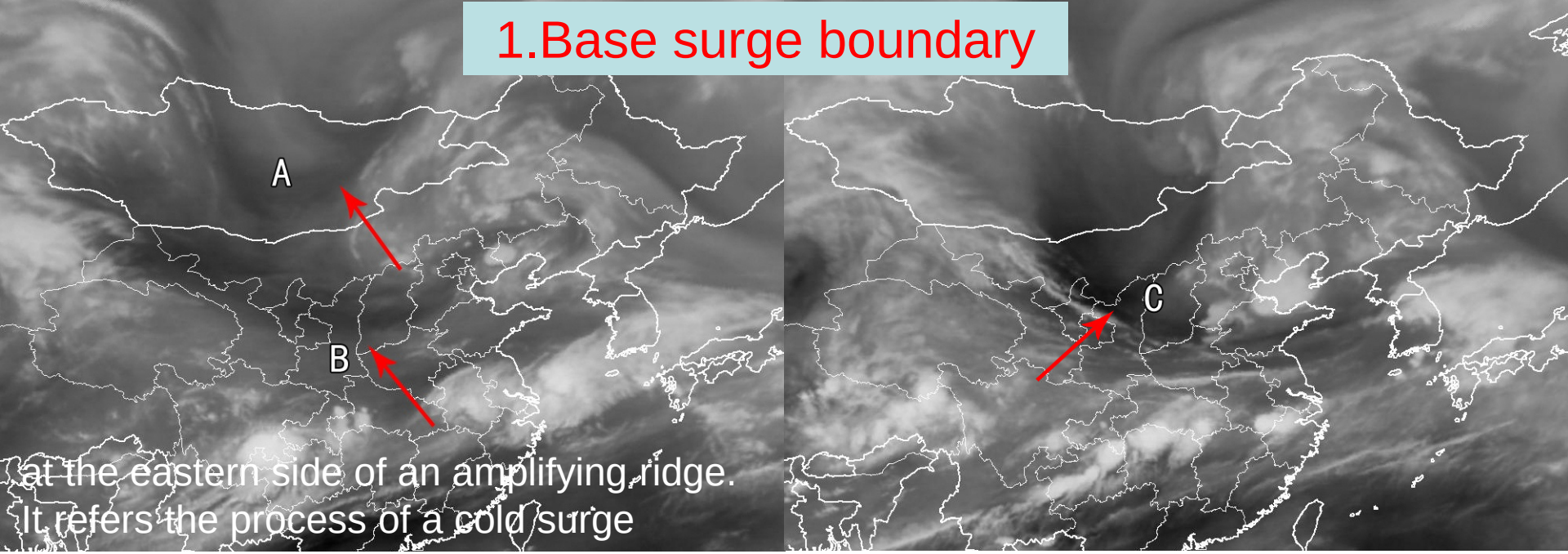
Boundaries in water vapor imagery

- The profile of the boundary indicates weather systems which cause the appearance of image pattern. Thus, **when we watch and analyze a cloud imagery, we pay attention to profile patterns of boundaries firstly.**
- Boundary means that along the boundary line, image gray level changes a lot in a short distance to the both sides of the boundary. **The gray level changes to the both sides of the boundary may be caused by the differences of wet or vertical motion status.**
- Weather systems have specific boundary patterns. **The different stages of a weather system also have specific boundary patterns.** This is why we should pay attention to profile patterns of imagery.

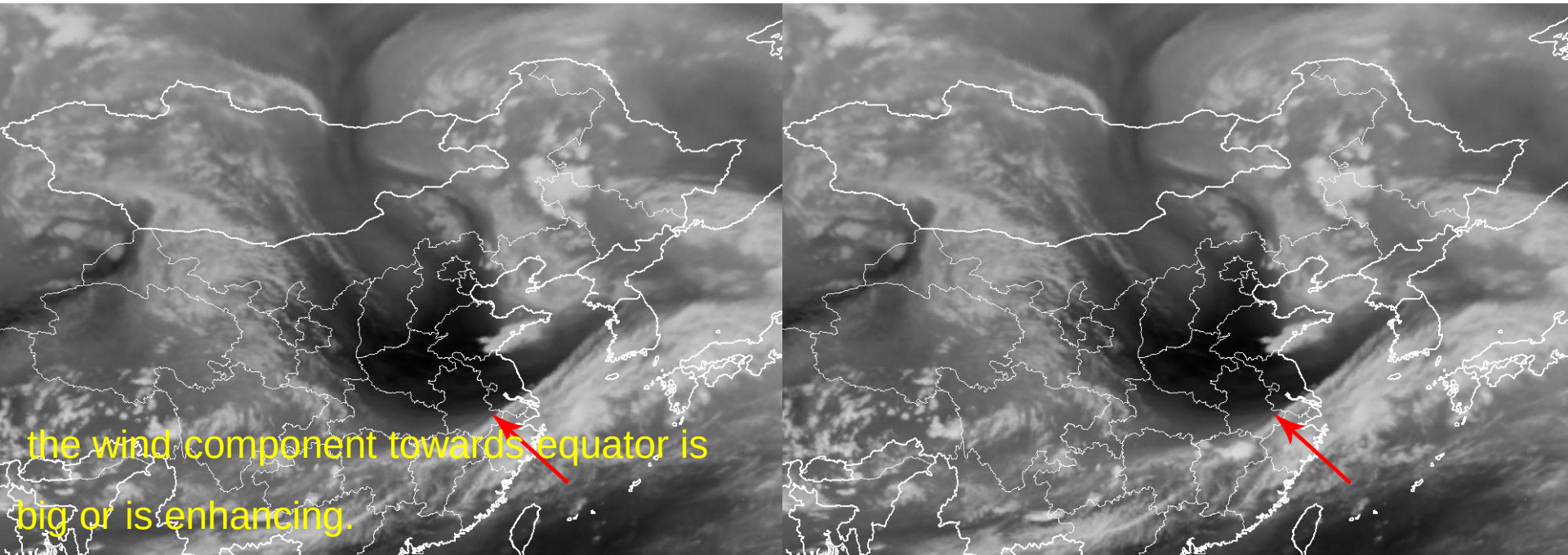
Boundaries associated with troughs, ridges or blocking systems

Boundaries associate with	Boundary name
Ridges	1.Base surge boundary
Troughs	2.Parallel jet stream boundary
	3.Dry surge boundary
	4.Baroclinic leaf boundary
Blocking systems	5.Head boundary in synoptic scale
	6.Inner boundary

1.Base surge boundary



Base surge boundary， July 9-10，2007 ， FY-2C

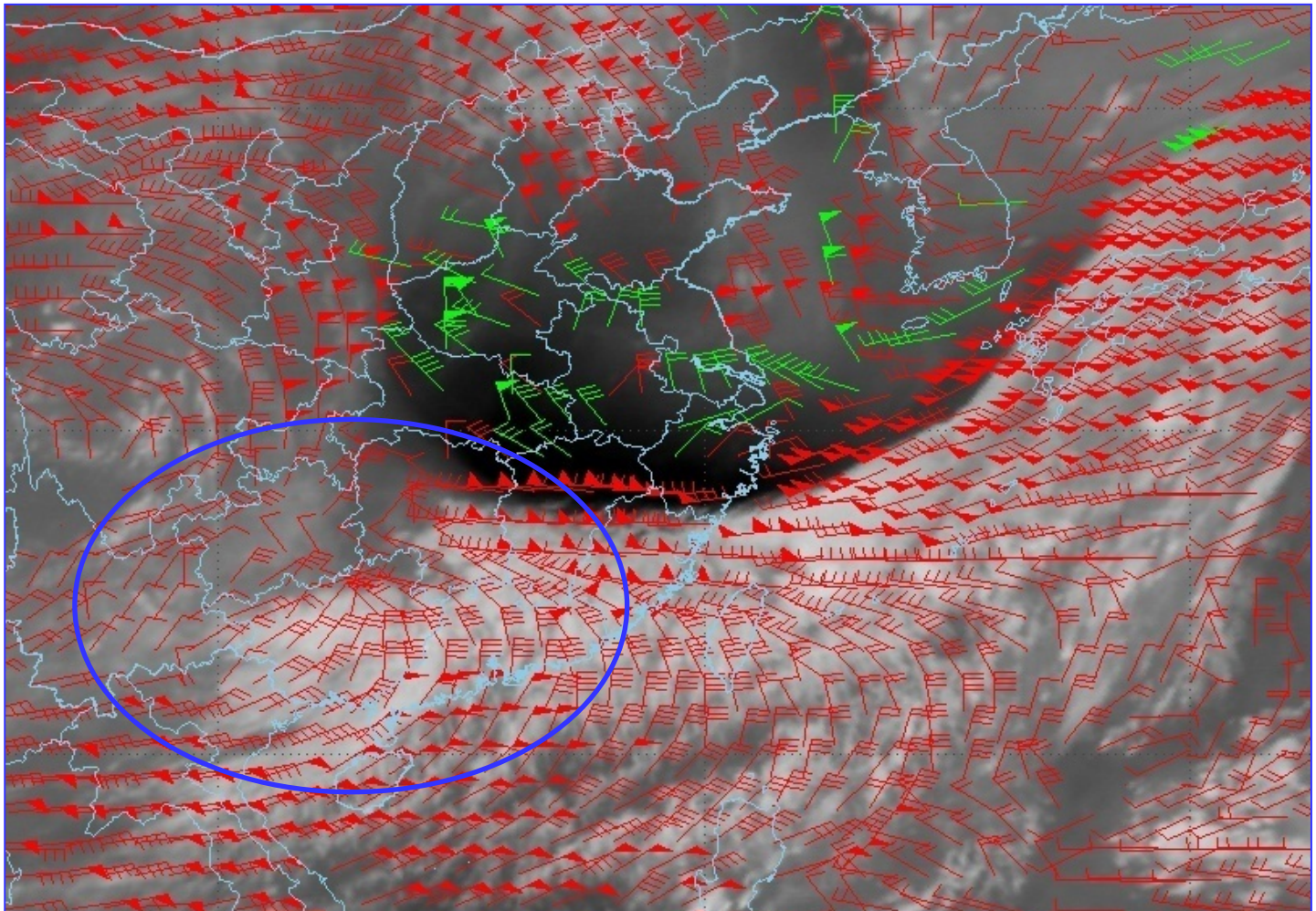


1.Base surge boundary

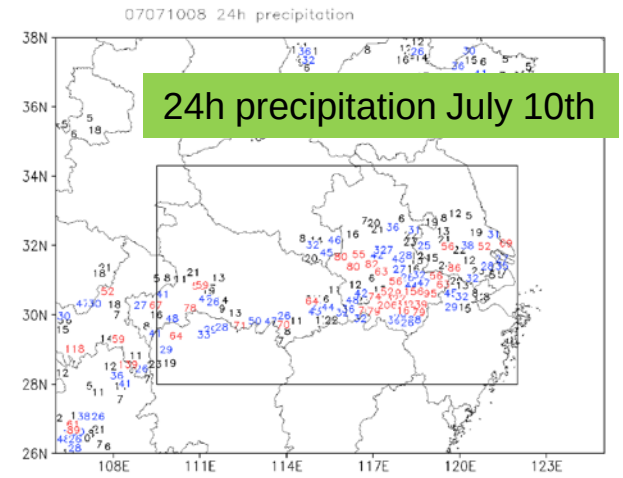
- Base surge boundary is located at the eastern side of an amplifying ridge. It refers the process of a cold surge.
- By watching successive water vapor images, such boundary is recognizable. The appearance of base surge boundary reflects that the wind component towards equator is big or is enhancing.

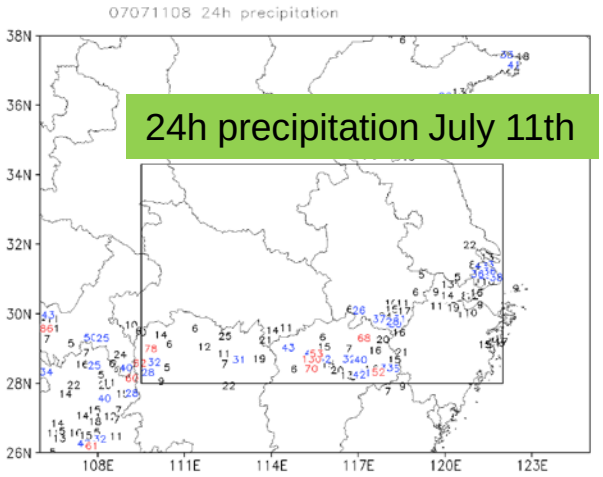
Weather near the bottom part of base surge boundary

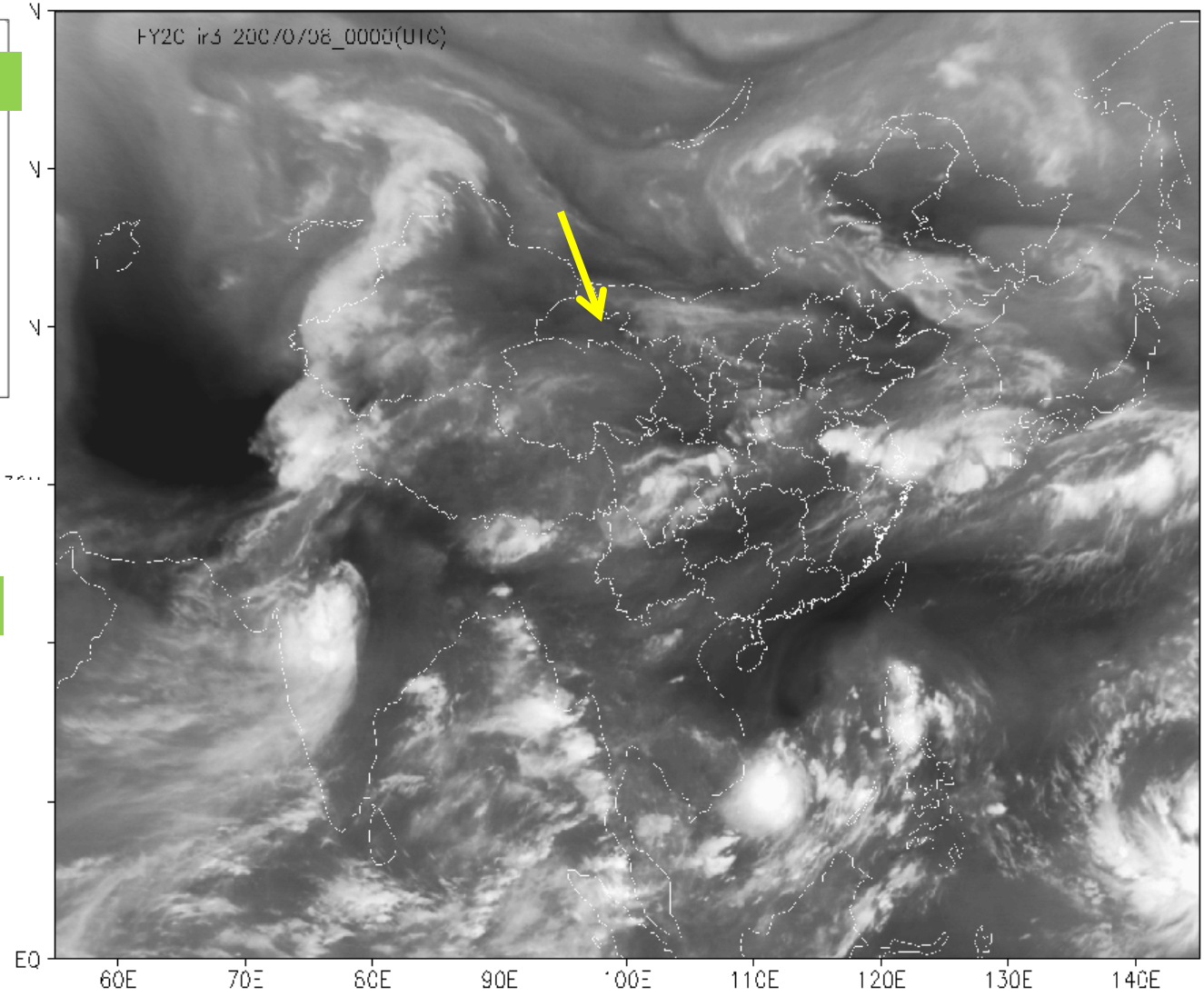
- If there is a major anti-cyclonic ridge to the south of the base surge boundary , severe weather is often observed. Example shown is July 3, 2009.



Animation shows base surge process, July 8-11,2007

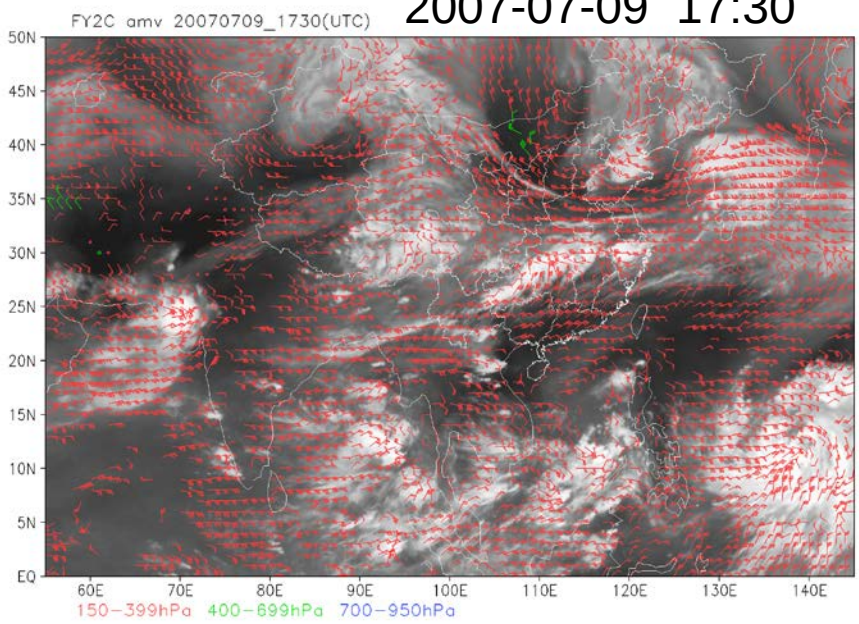




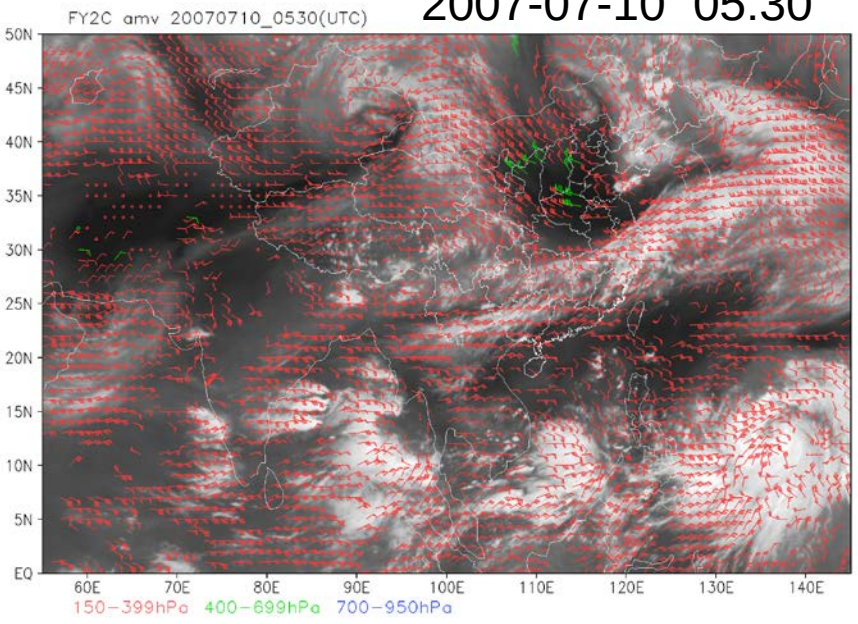


In front of a ridge，strong north wind, heavy precipitation in frond of the moving direction. The rainfall can not last for a long time because of the rapid movement of the system

2007-07-09 17:30

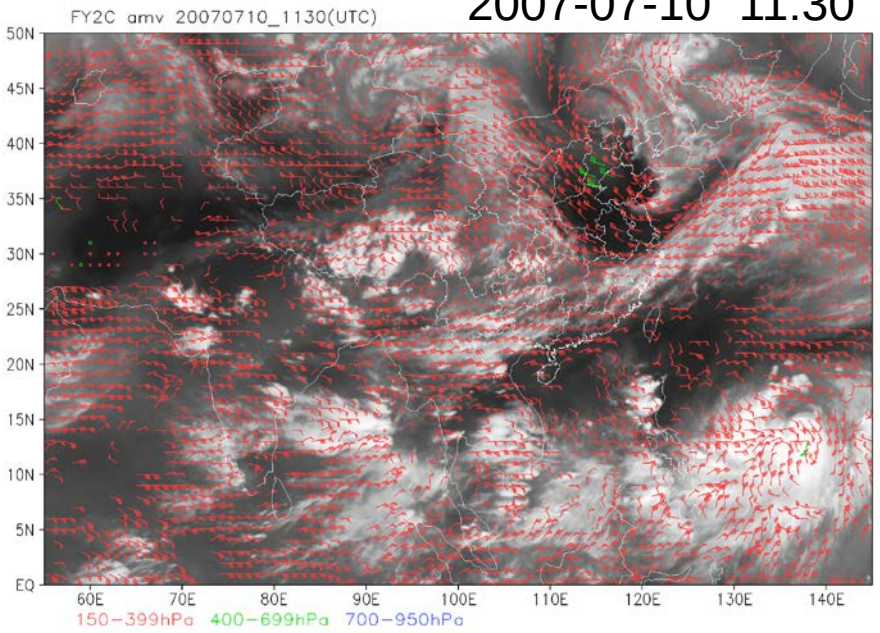


2007-07-10 05:30



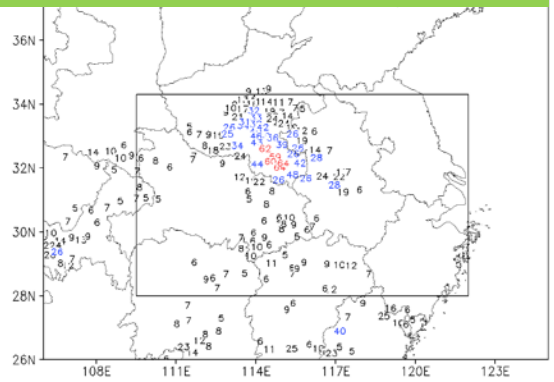
Base surge process shown with water vapor images and derived AMV.

2007-07-10 11:30



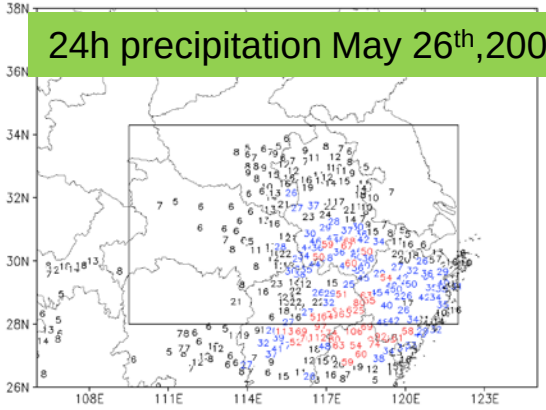
The base surge boundary towards the south-west direction.
The heavy rainfall takes place in frond of the moving direction.

24h precipitation May 25th,2009



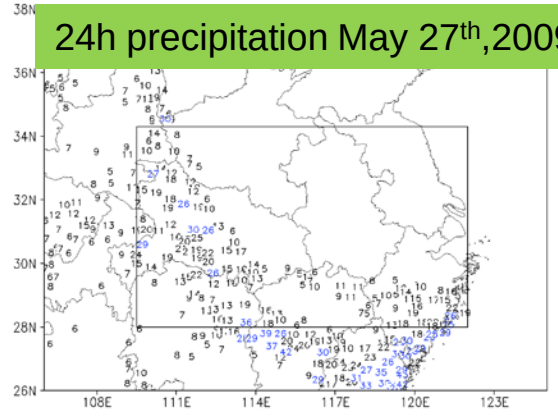
09052608 24h precipitation

24h precipitation May 26th,2009

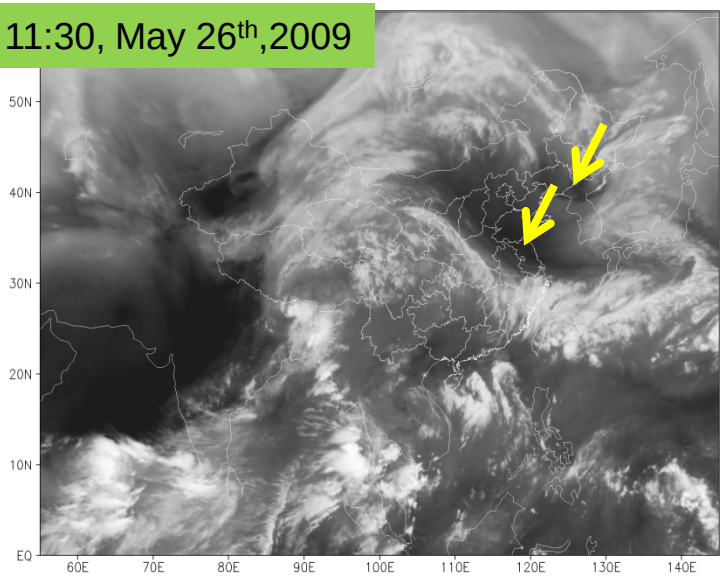


09052708 24h precipitation

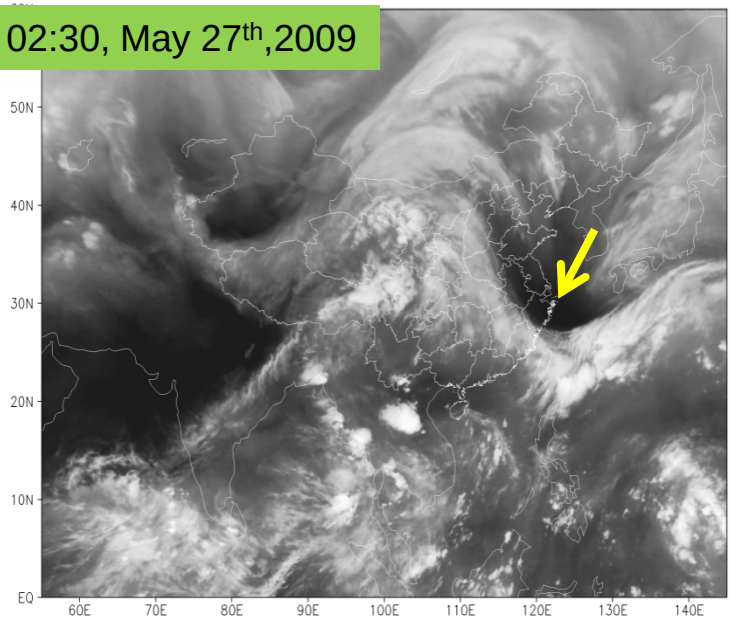
24h precipitation May 27th,2009



WV 11:30, May 26th,2009



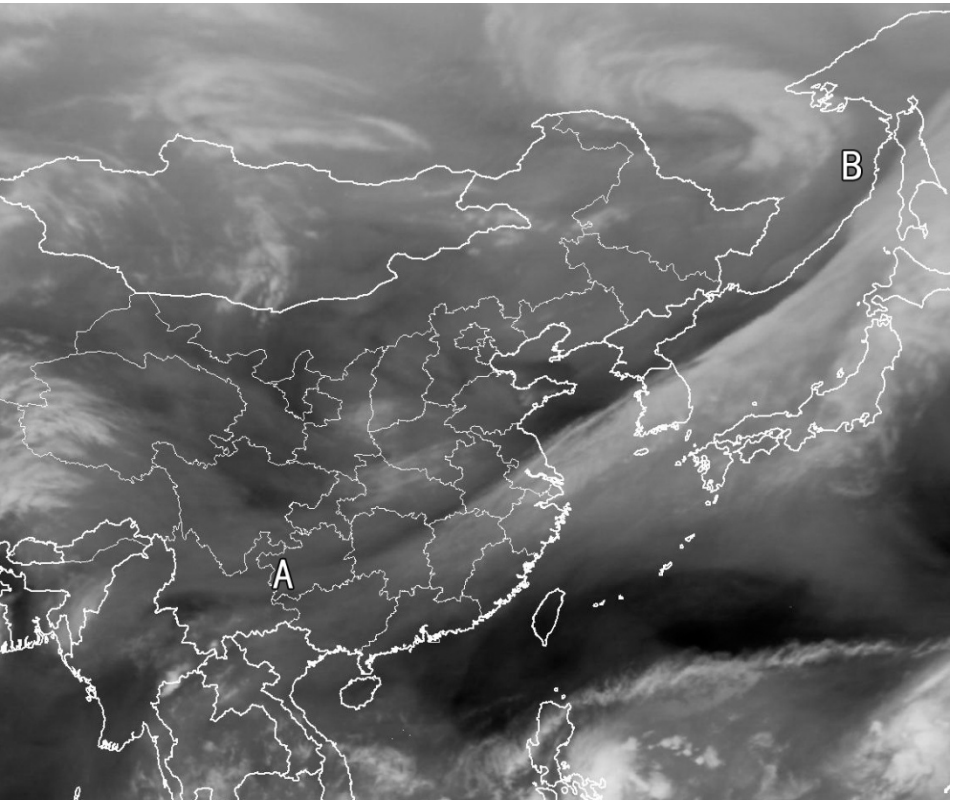
WV 02:30, May 27th,2009

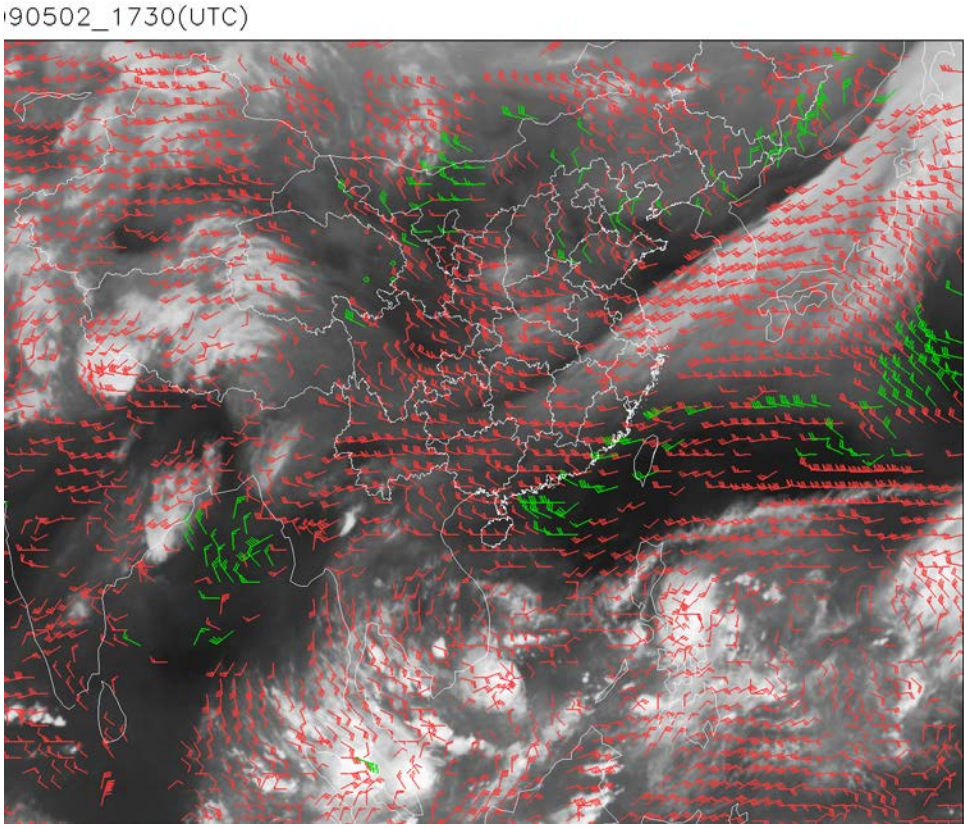


2.Parallel jet stream boundary

Parallel jet stream boundary shown in WV images
1730UTC， May 2， 2009， FY-2C

AB is a parallel jet stream boundary, lasting thousands of kilometers. Notice that in water vapor imagery, the dark slot is quite narrow. Narrow dark slot means that the wind is parallel to the boundary.





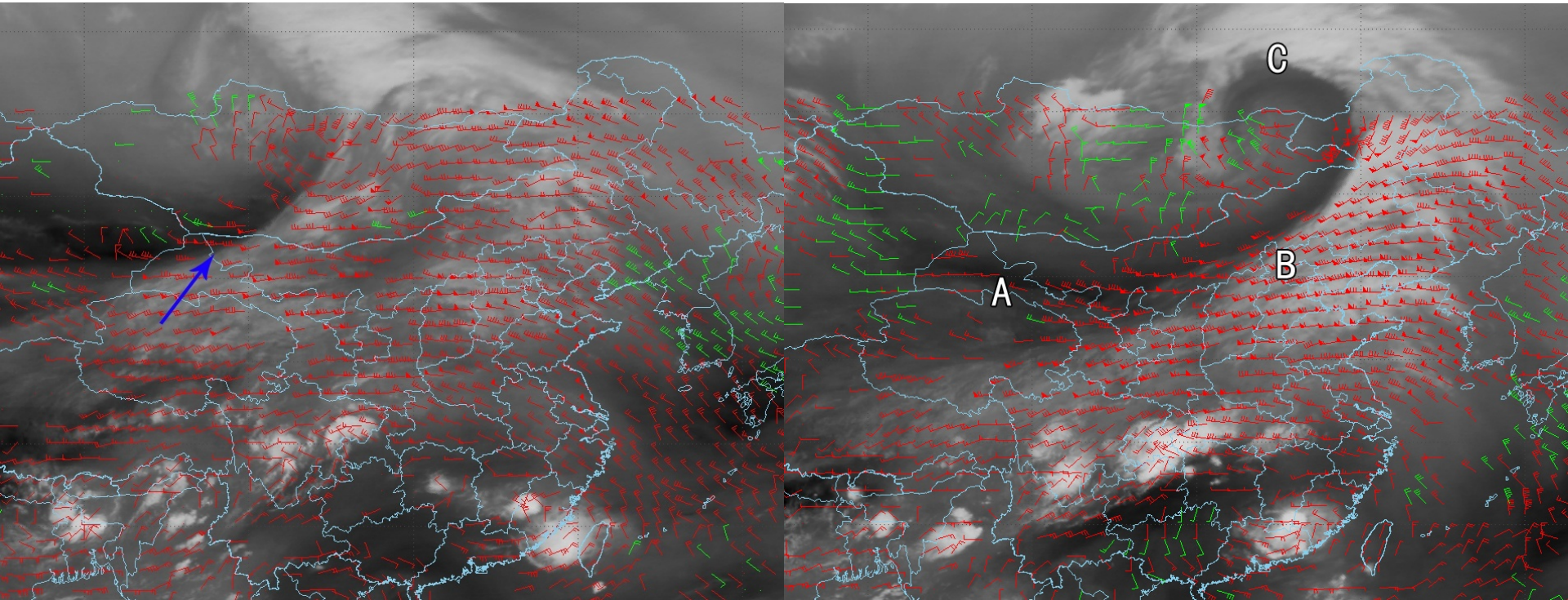
2.Parallel jet stream boundary

- Boundary parallel to a straight jet stream with no major curvature may appear in front of a trough. Such boundary may appear in a straight circulation environment. It is the remaining of the previous weather system. The weather is not active in the vicinity.
- Curvature of boundary should be paid attention. It is a major character of a cloud system. A developing cloud system may appear wave type pattern. If there is no major curvature, the system is not under development.

3.Dry surge boundary

Dry surge boundary shown with water vapor images and wind field， Sept. 18-19， 2009

ABC is a large scale boundary. Segment AB is dry surge boundary；Segment BC is parallel jet boundary.



3.Dry surge boundary

- One other type boundary **in front of the trough is dry surge boundary.** The dry surge boundary is hollow to the dry side of the boundary. To the dry side of the boundary, the dry region is wide, rather than a narrow dry slot as the parallel jet boundary.
- **The difference between the parallel jet boundary and the dry surge boundary is the curvature and the width of the dark region.** The dry surge boundary have a hollow curvature and a wider dark region; while the parallel jet boundary have a straight boundary and a narrow dark slot. Those differences are due to the difference of crossing angle between the jet and the boundary.

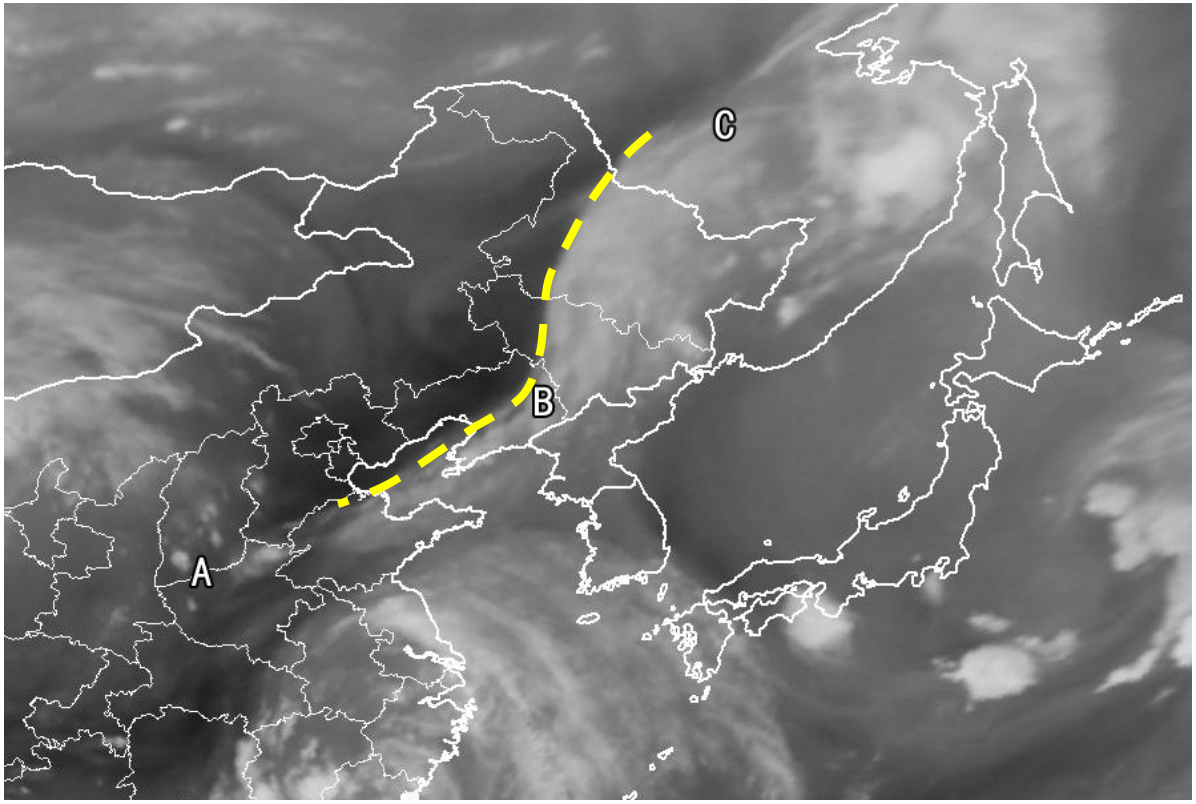
Differences between base surge boundary and dry surge boundary

Dry surge boundary and base surge boundary are both associated with a wide dry dark region

- Dry surge boundary: moving eastward, weak rainfall, **the amplitude of the ridge to its west is small.**
- Base surge boundary: moving southward or south-westward, strong rainfall, **the amplitude of the ridge to its west is big.**

4.Baroclinic leaf boundary

Baroclinic leaf boundary shown with water vapor image，1400UTC，July 29，2008



It is related to a developing system.

The baroclinic leaf boundary has a wave shape **curvature** like a letter S with both positive and negative curvatures.

4.Baroclinic leaf boundary

- This kind of type boundary in front of the trough is the most significant of the three.
- It is related to a developing system.
- The baroclinic leaf boundary has a wave shape curvature like a letter S with both positive and negative curvatures.

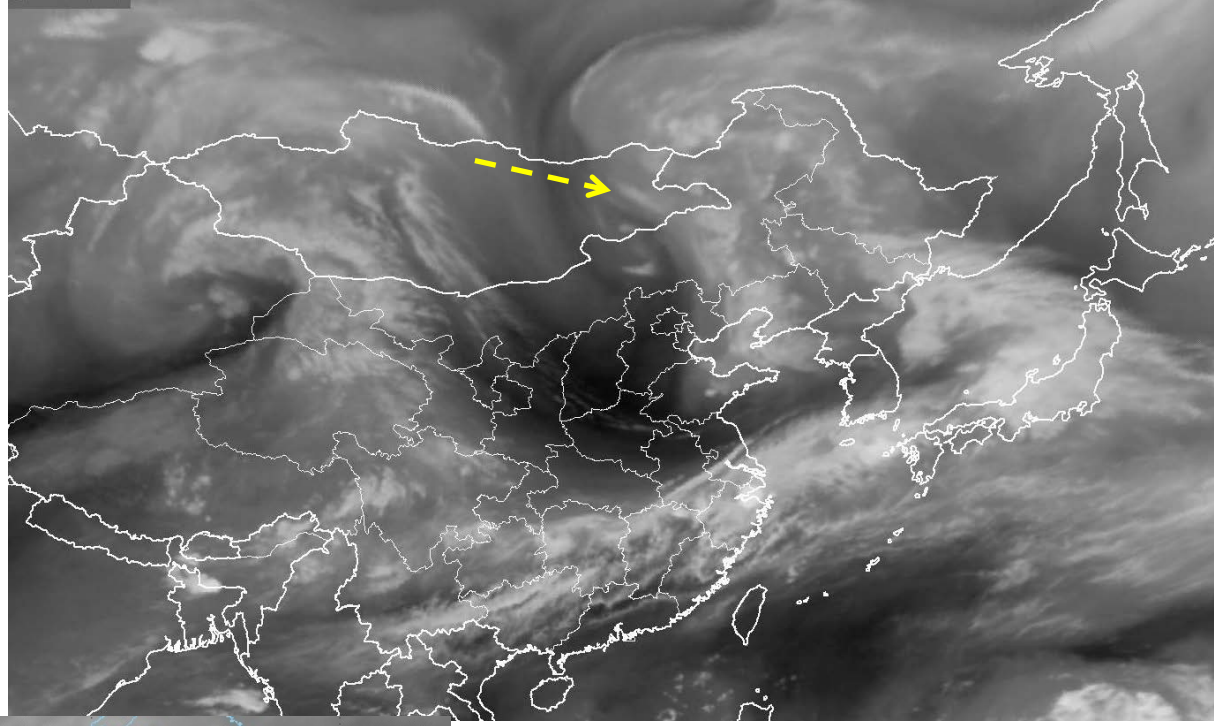
Boundaries associated with blocking

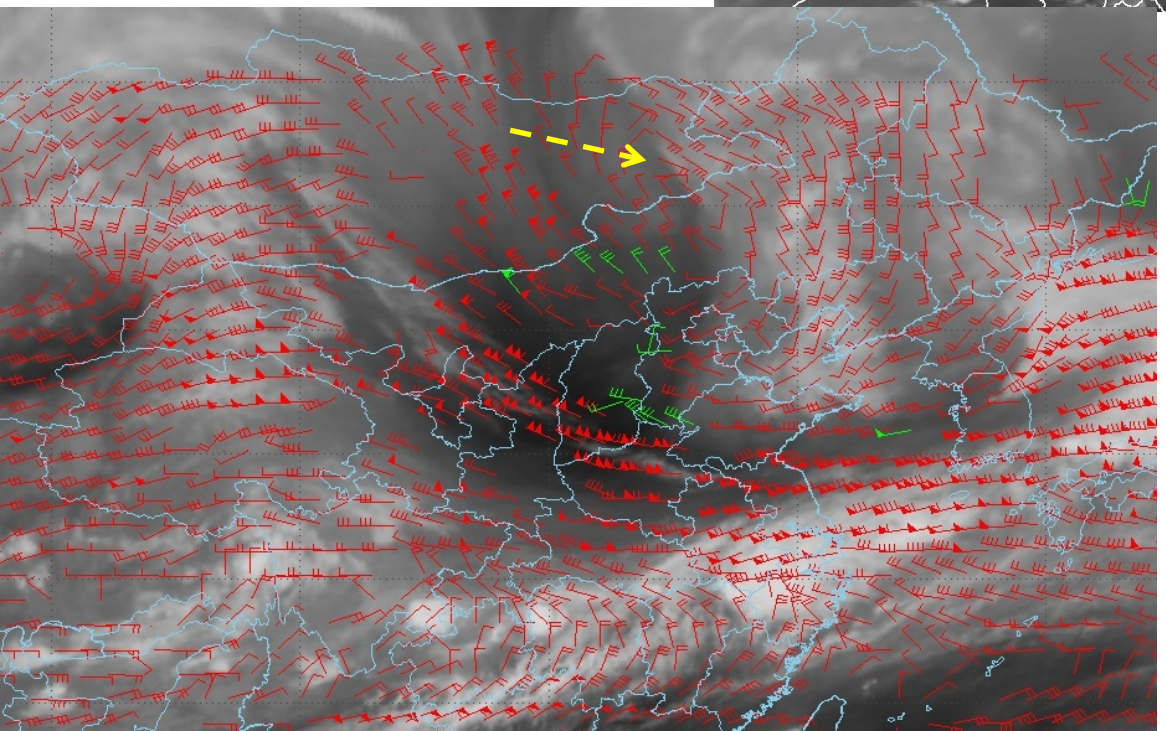
Blocking systems	5.Head boundary in synoptic scale
	6.Inner boundary

- The two boundaries are both accompanied with a high level easterly.
- Head boundary is associated with a cyclone.
- Inner boundary is associated with an anti-cyclone. To the south side of the anti-cyclone, a cyclone format to the equatorial side.

5.Head boundary in synoptic scale, July 10, 2007

This case is related with blocking situation. The head part of the cyclone supply a wet region with easterly. To the west side, there is a dry environmental current。The boundary is distinct.





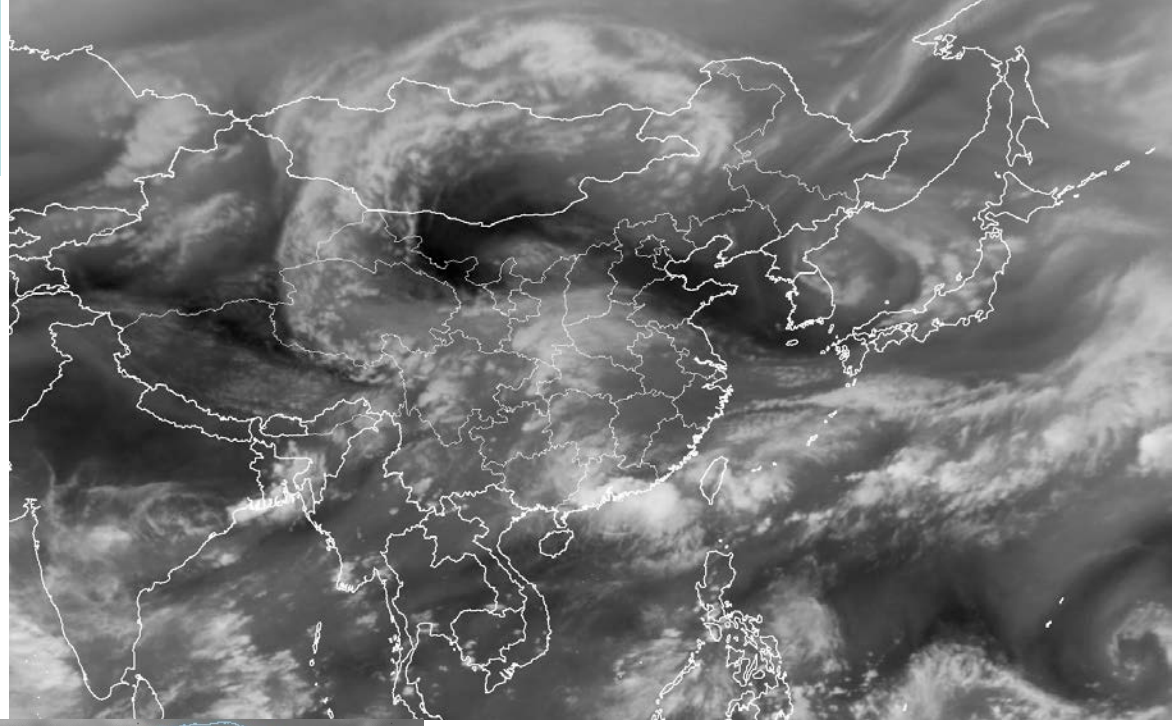
To the east side of the wet body, the boundary is not distinct. The gray scale changes gradually.

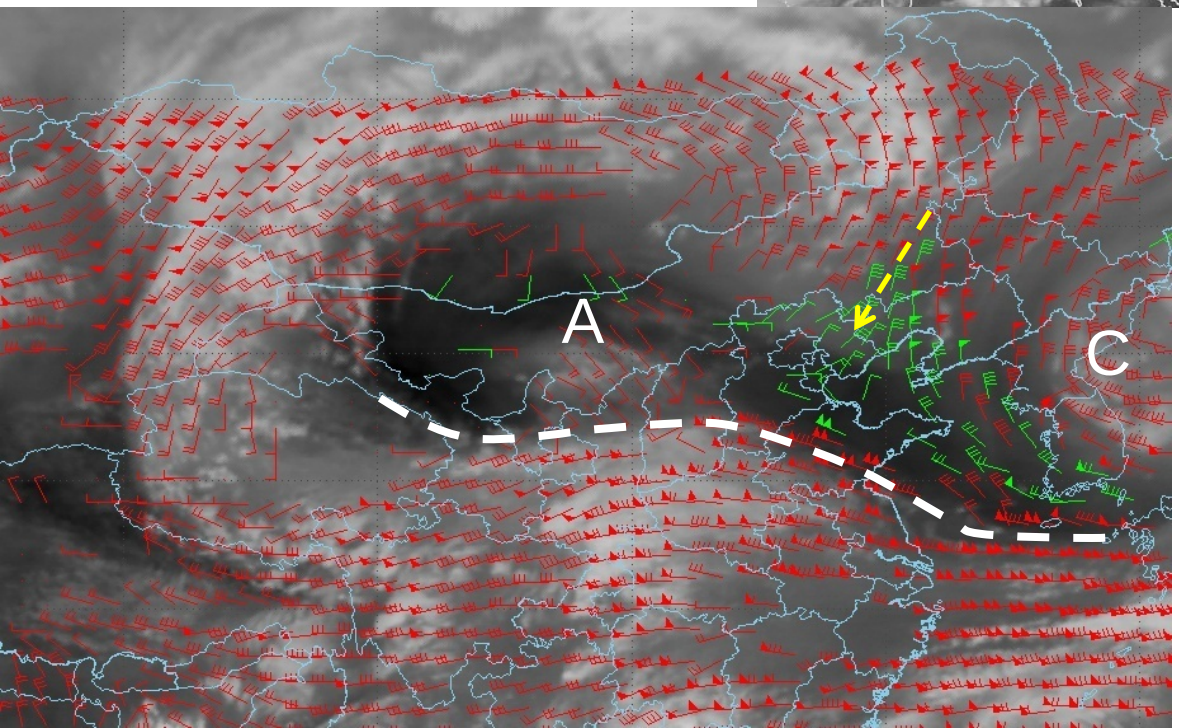
6.Inner boundary

Inner boundary is associated with an anti-cyclone. To the south side of the anti-cyclone, a cyclone format to the equatorial side.

Inner boundary, June, 8 2007

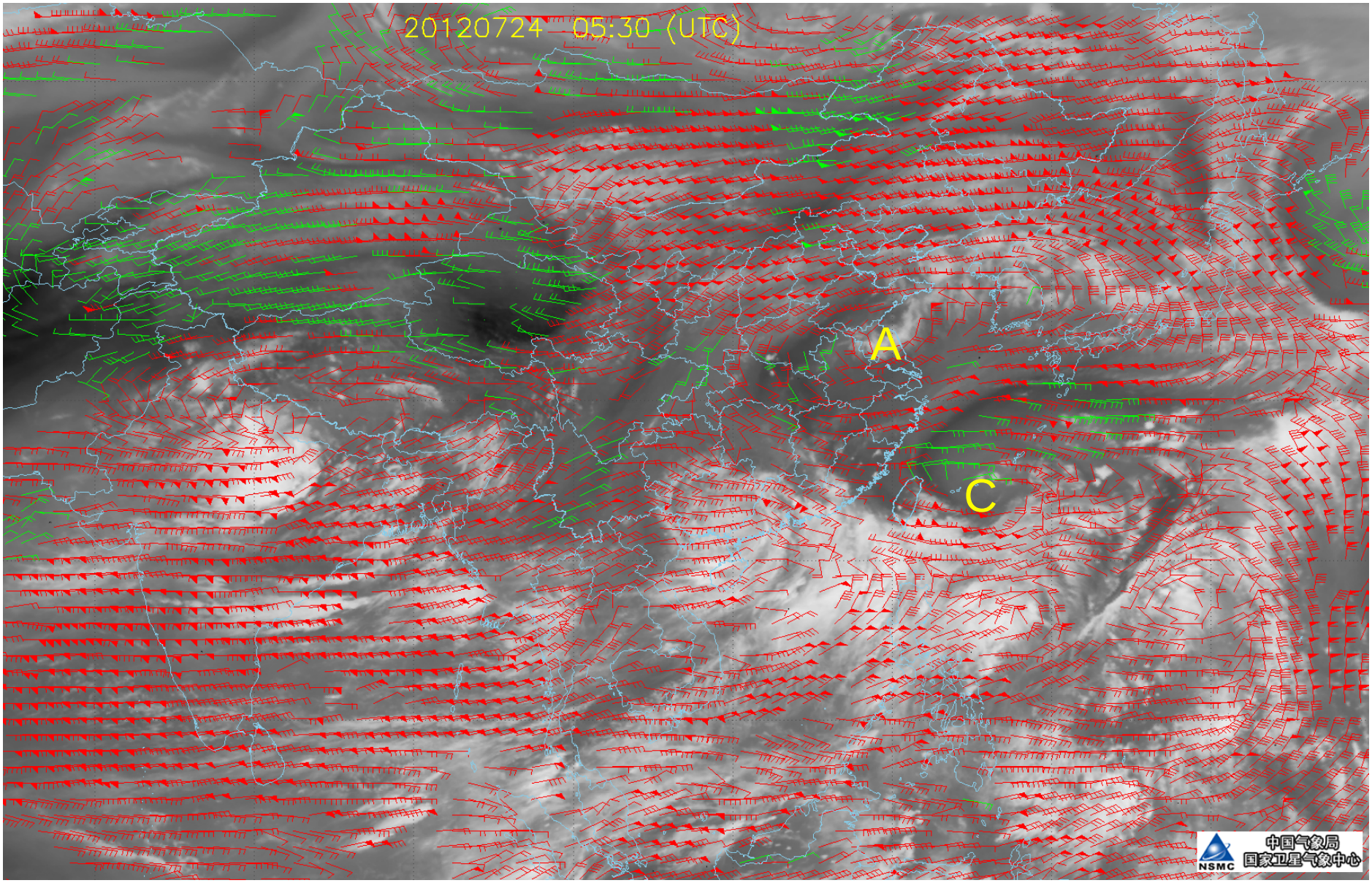
There is an anti-cyclone. To the south of the anti-cyclone, there is a easterly with subsidence. This dry easterly meet the relative wet environmental current. An inner boundary forms.



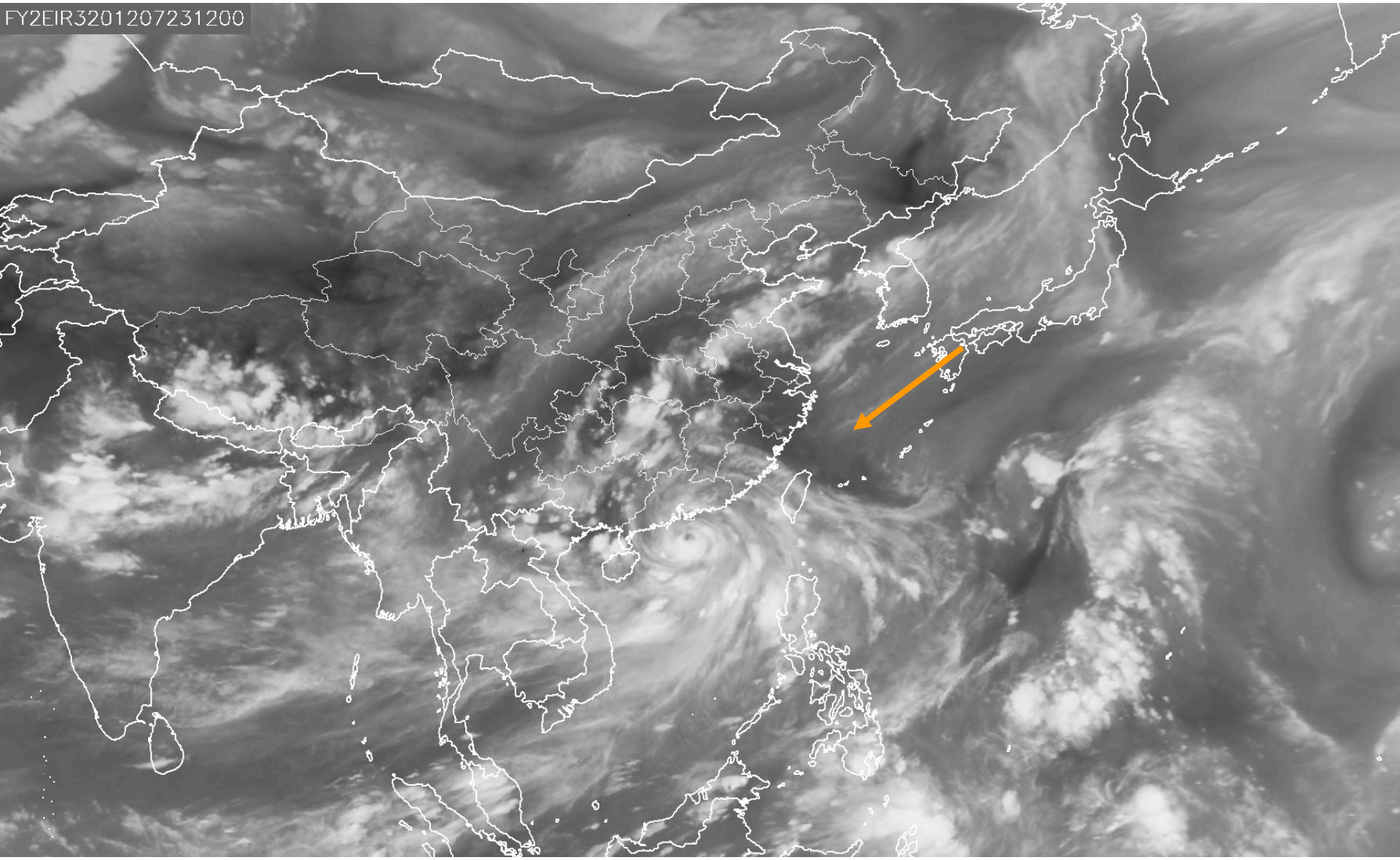


In wind field, a complex of anti-cyclone / cyclone is clearly seen.

FY-2E AMV July 24th 05:30,2012

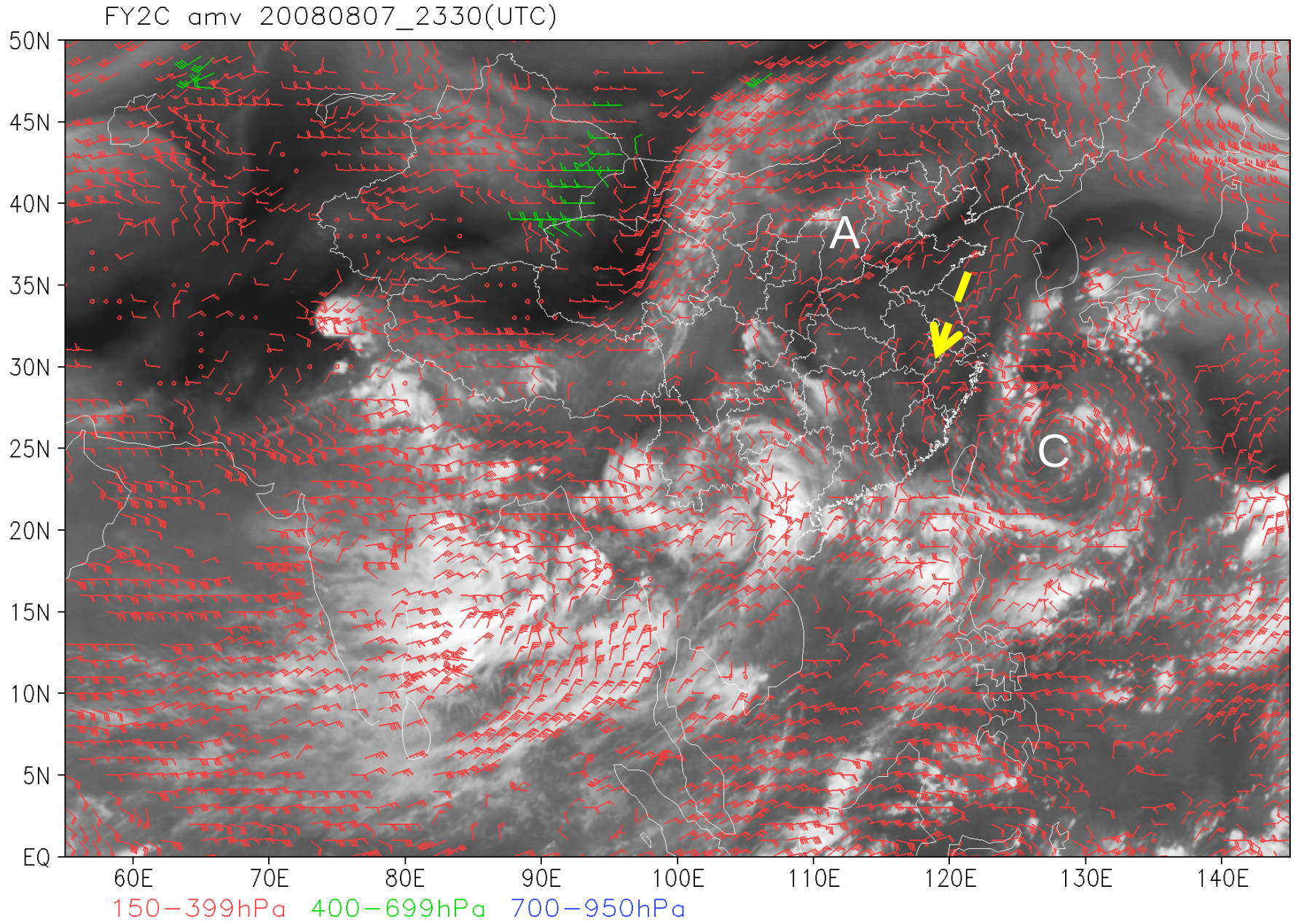


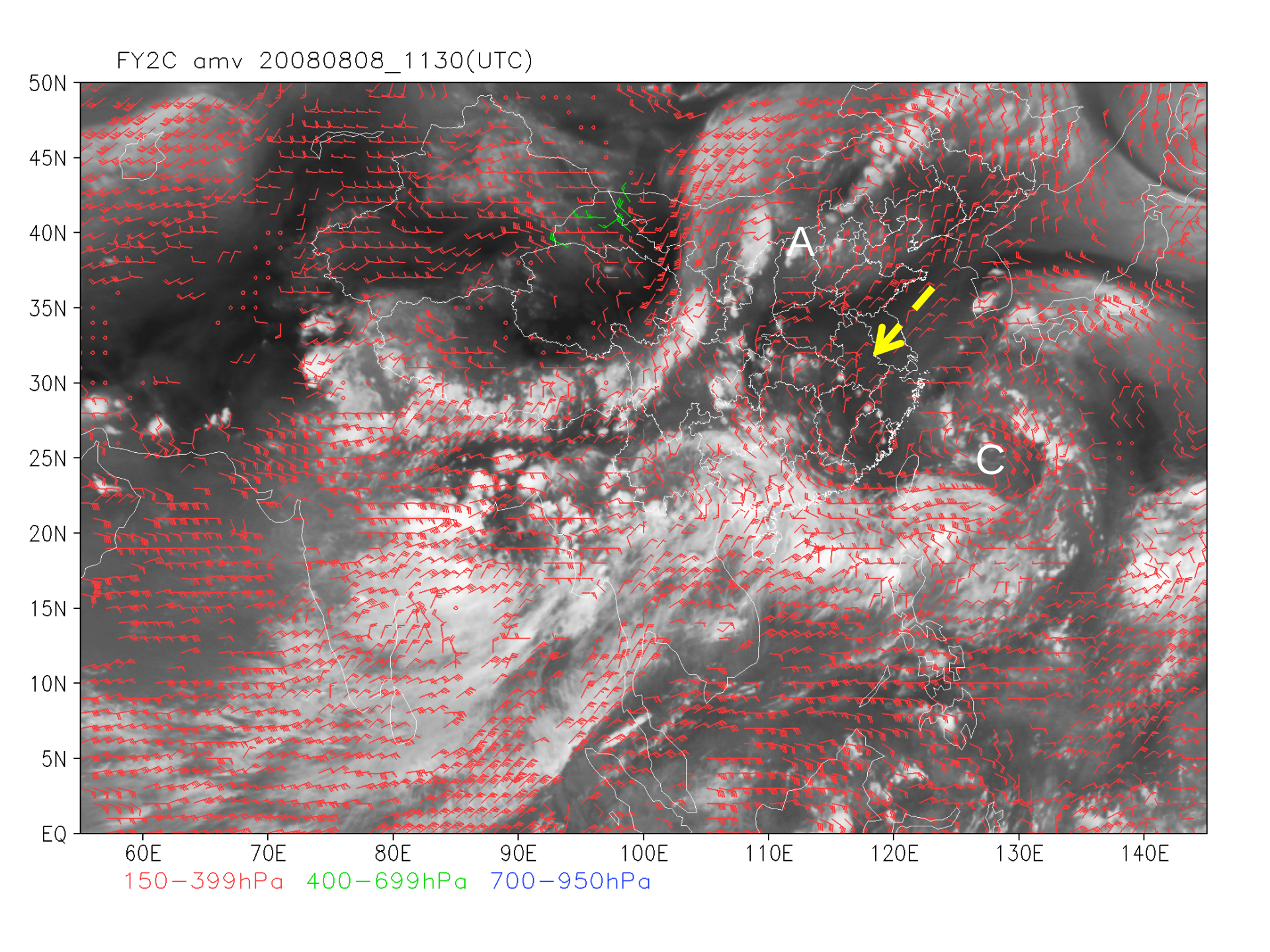
FY-2E ir3 From July 23th 12:00 to 24th 05:30,2012

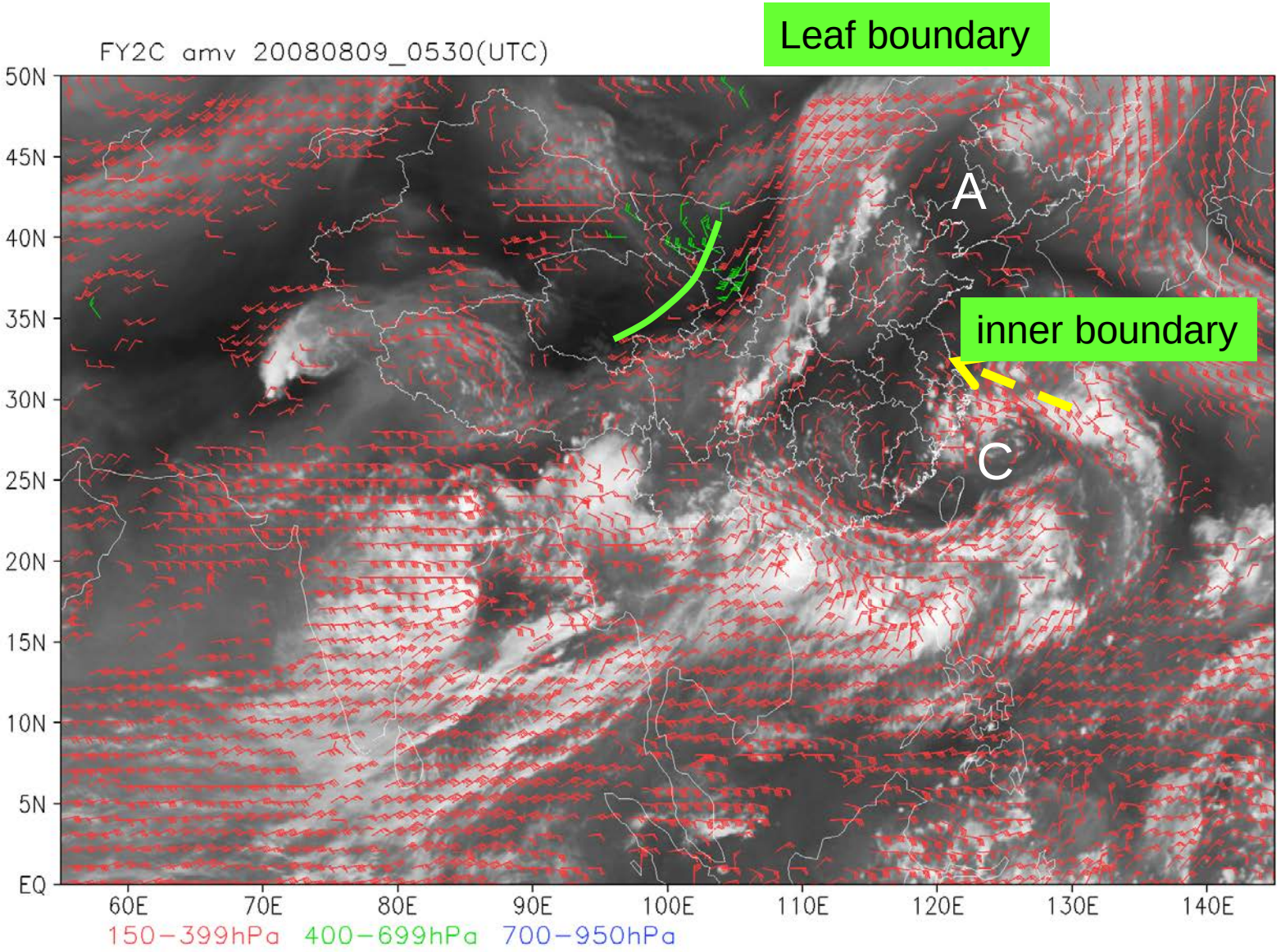


Aug 8-9, 2008 for the weather at the opening of Olympic game and the next day

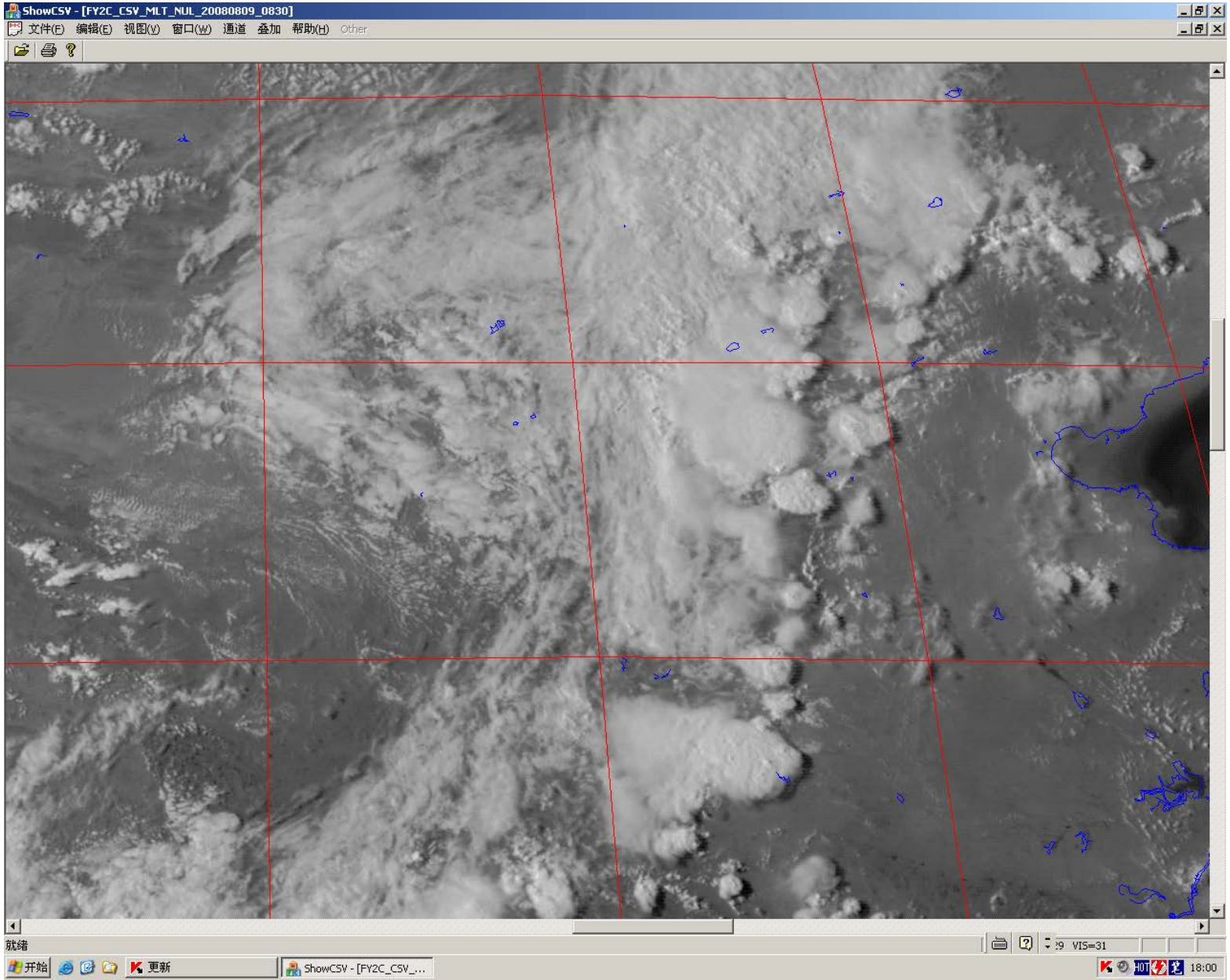
- The system which influences the opening of Olympic game on August 8, 2008 was very weak. It is not an leaf type pattern.
- For the next day, August 9, 2008， A well developed leaf type system influence Beijing.

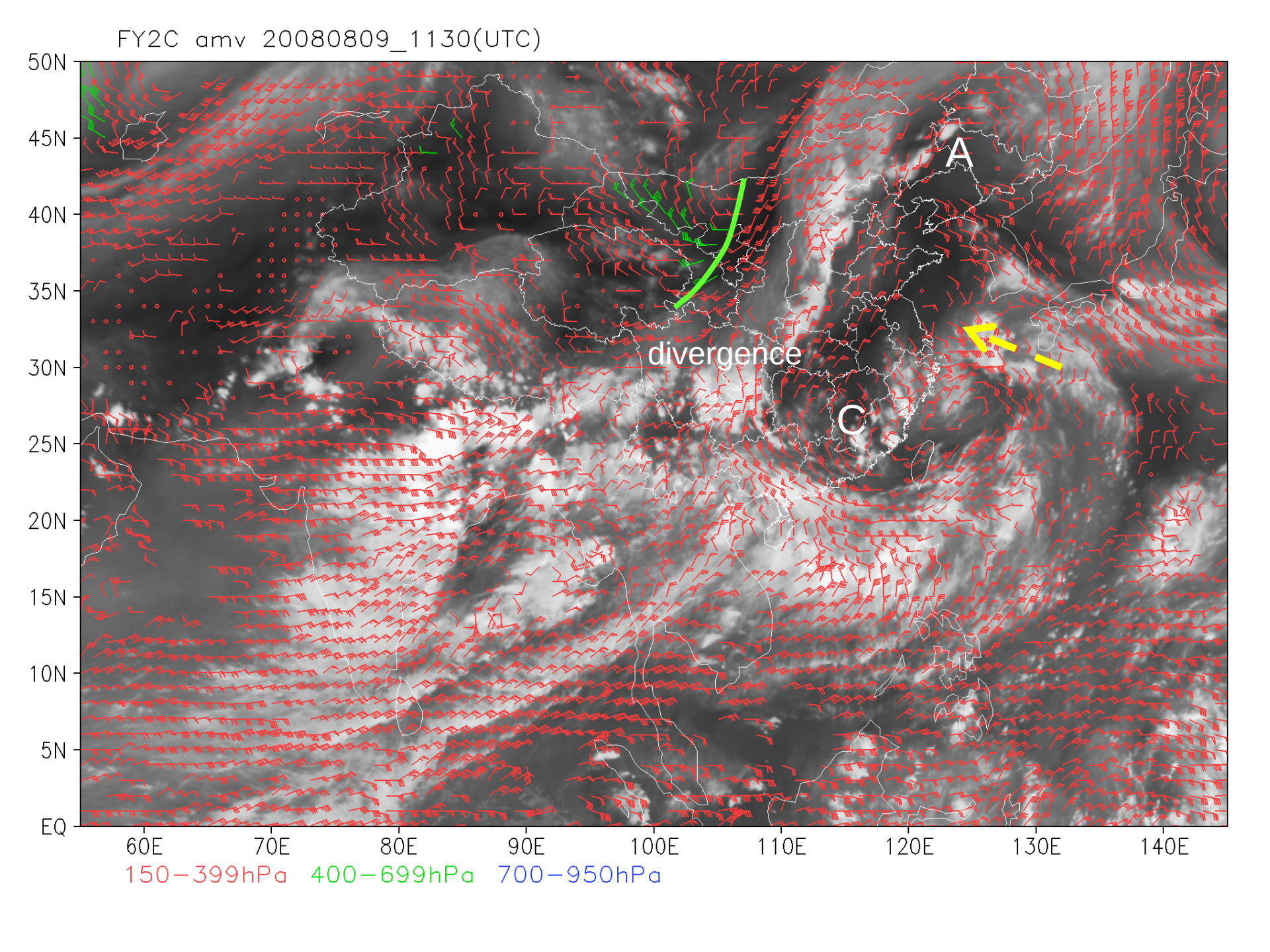

FY2C amv 20080807_2330(UTC)
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
60E
70E
80E
90E
100E
110E
120E
130E
140E
A
C
150-399hPa
400-699hPa
700-950hPa


FY2C amv 20080808_1130(UTC)
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
60E
70E
80E
90E
100E
110E
120E
130E
140E
A
C
150-399hPa
400-699hPa
700-950hPa

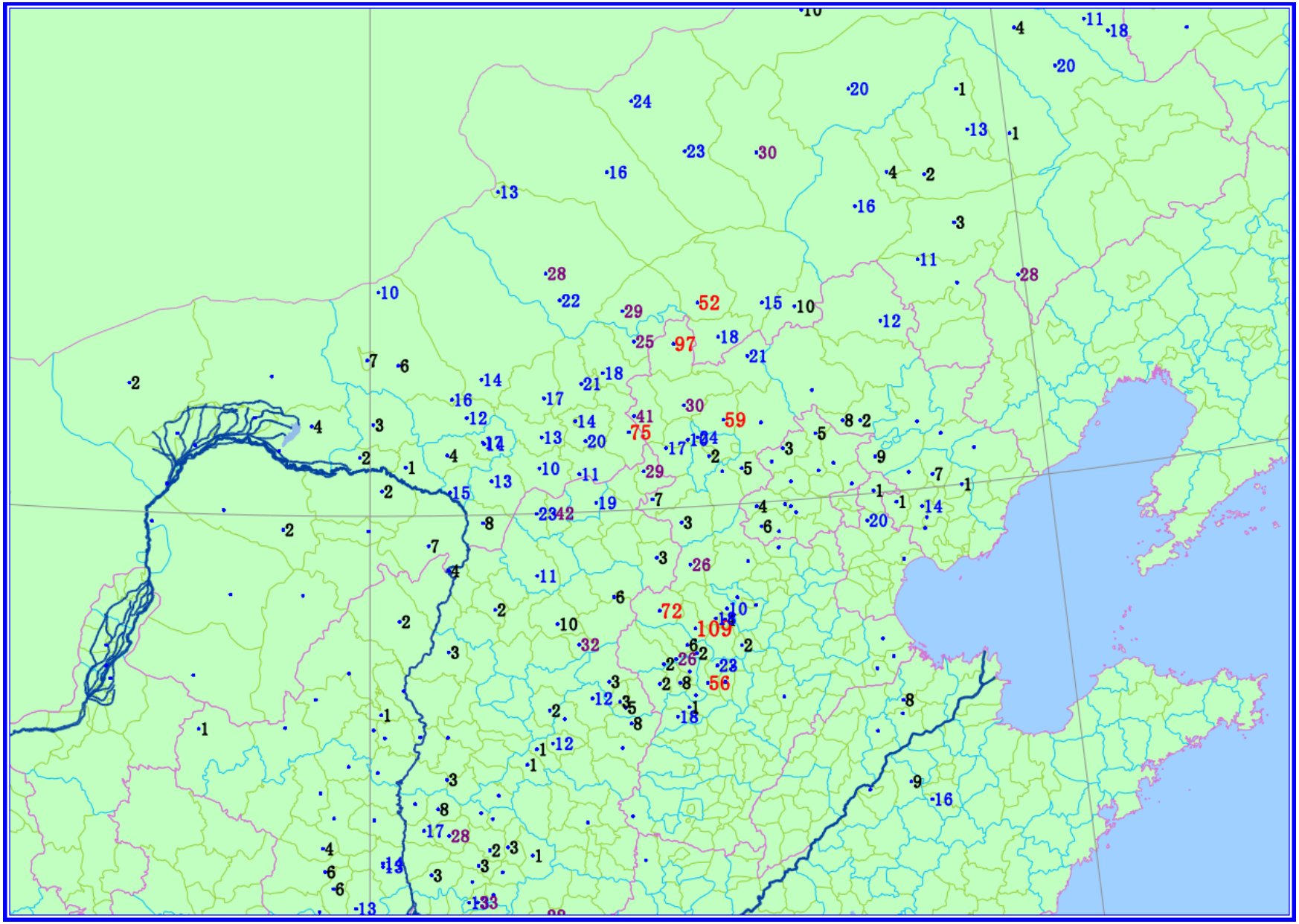

Leaf boundary
FY2C amv 20080809_0530(UTC)
A
inner boundary
C
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
60E
70E
80E
90E
100E
110E
120E
130E
140E
150-399hPa
400-699hPa
700-950hPa

VIS, 0830z, Aug. 9, 2008

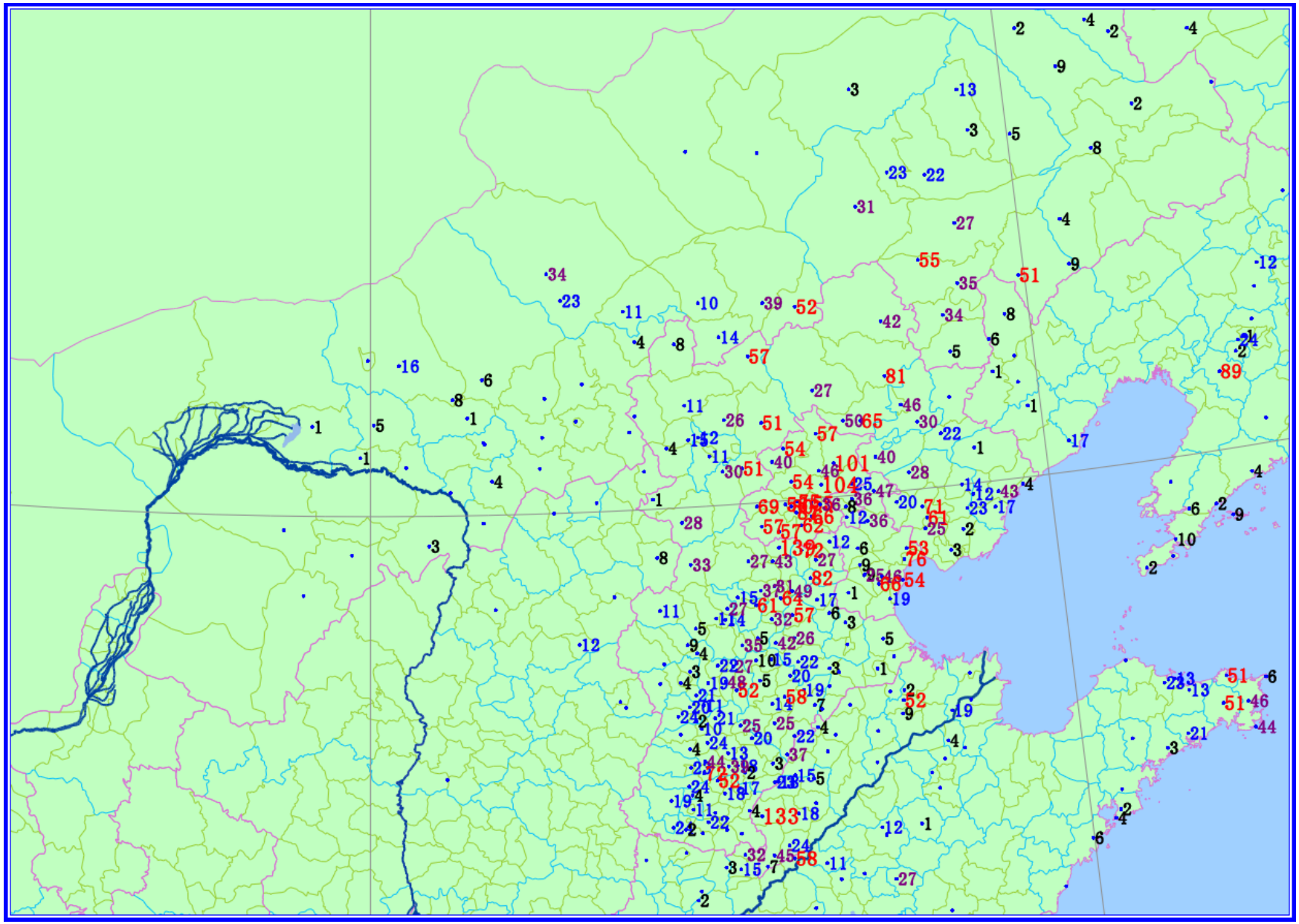



FY2C amv 20080809_1130(UTC)
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
60E
70E
80E
90E
100E
110E
120E
130E
140E
A
divergence
C
150−399hPa
400−699hPa
700−950hPa

24 hour rainfall for 00z, Aug. 9-10, 2008

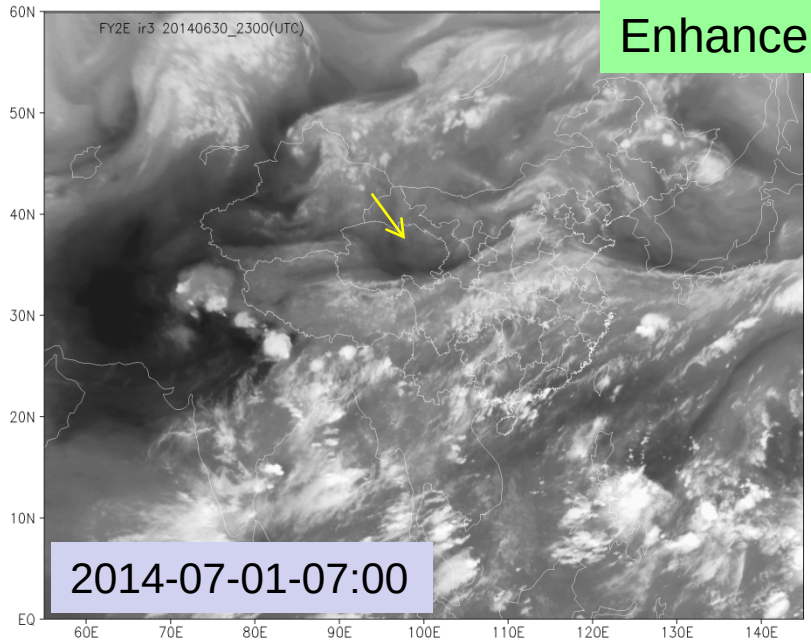


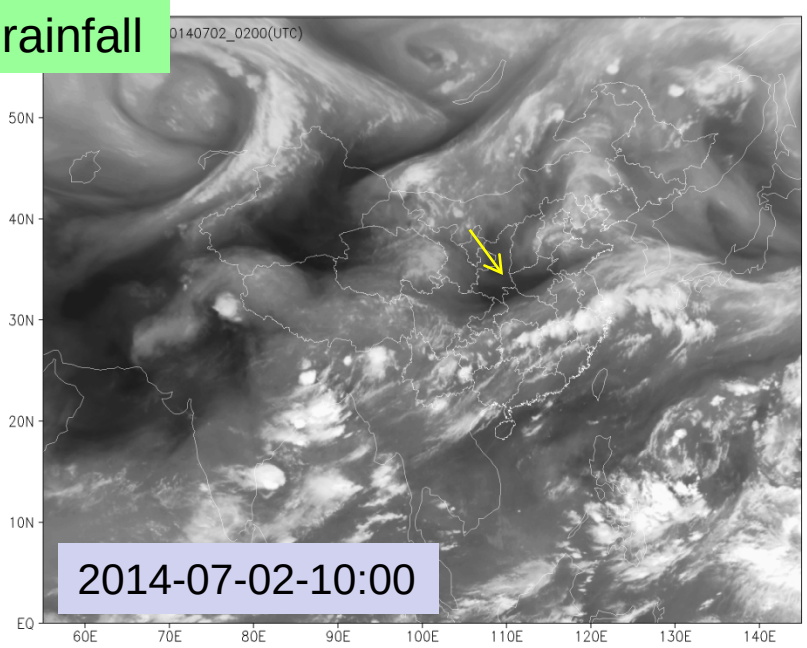
24 hour rainfall for 00z, Aug. 10-11, 2008

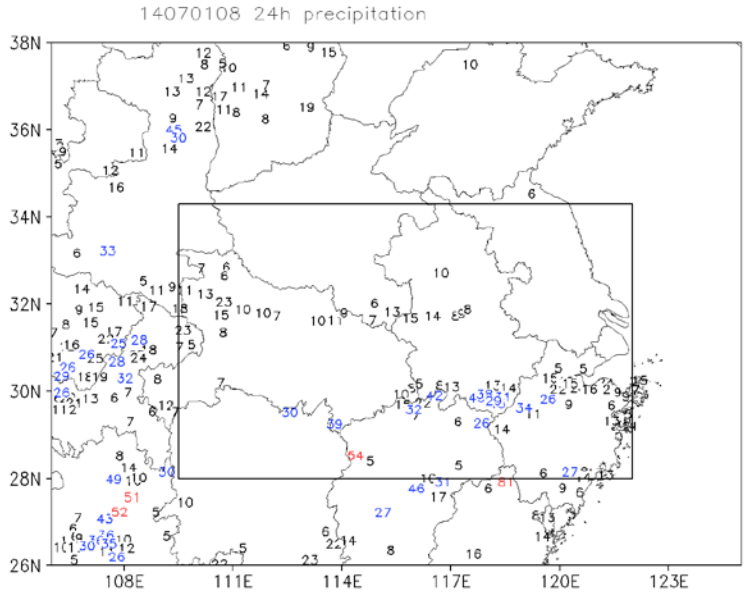


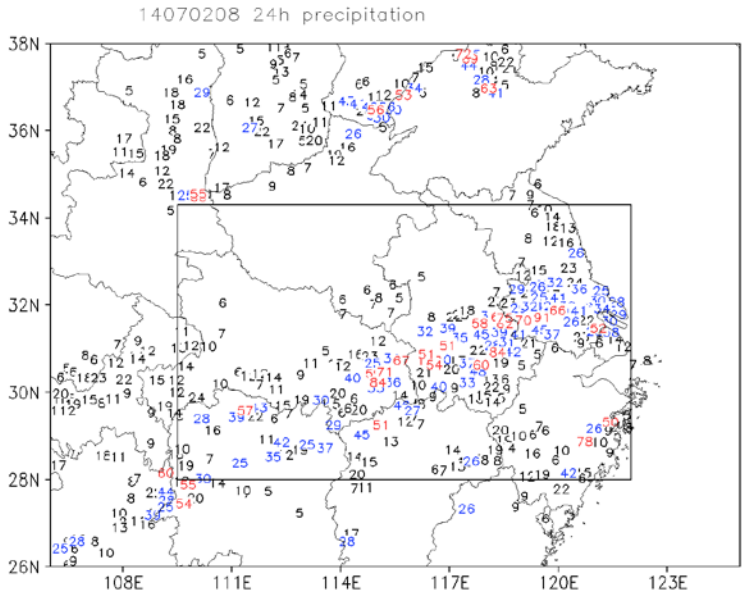
Small scale dark area in front of a ridge or in the back of a trough

Enhance the rainfall









FY Satellite images and derived products used in weather analysis

- (1)FY Satellite images and derived products used in weather analysis
- (2)Boundaries in water vapor imagery
- (3)Divergence and convergence at upper troposphere shown in AMV and WV imagery

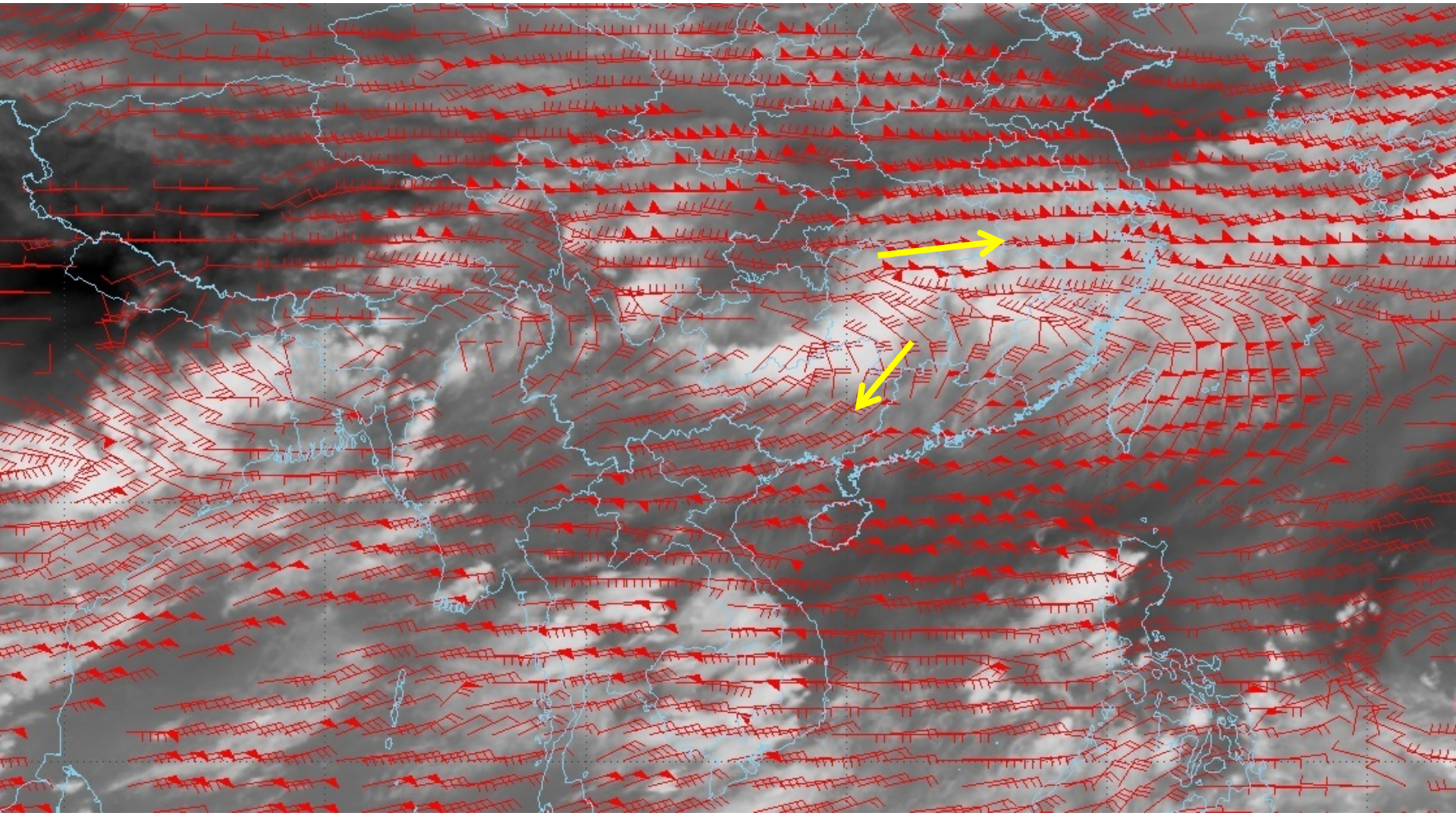
Divergence and convergence at upper troposphere shown in AMV and WV imagery

Dispersed flow field	Dispersed trough
	Dispersed ridge
	Dispersed asymptote
Confluent flow fields	confluent trough
	confluent ridge
	confluent asymptote
Without obvious divergence or convergence	Inactive anti-cyclone
	Inactive cyclone

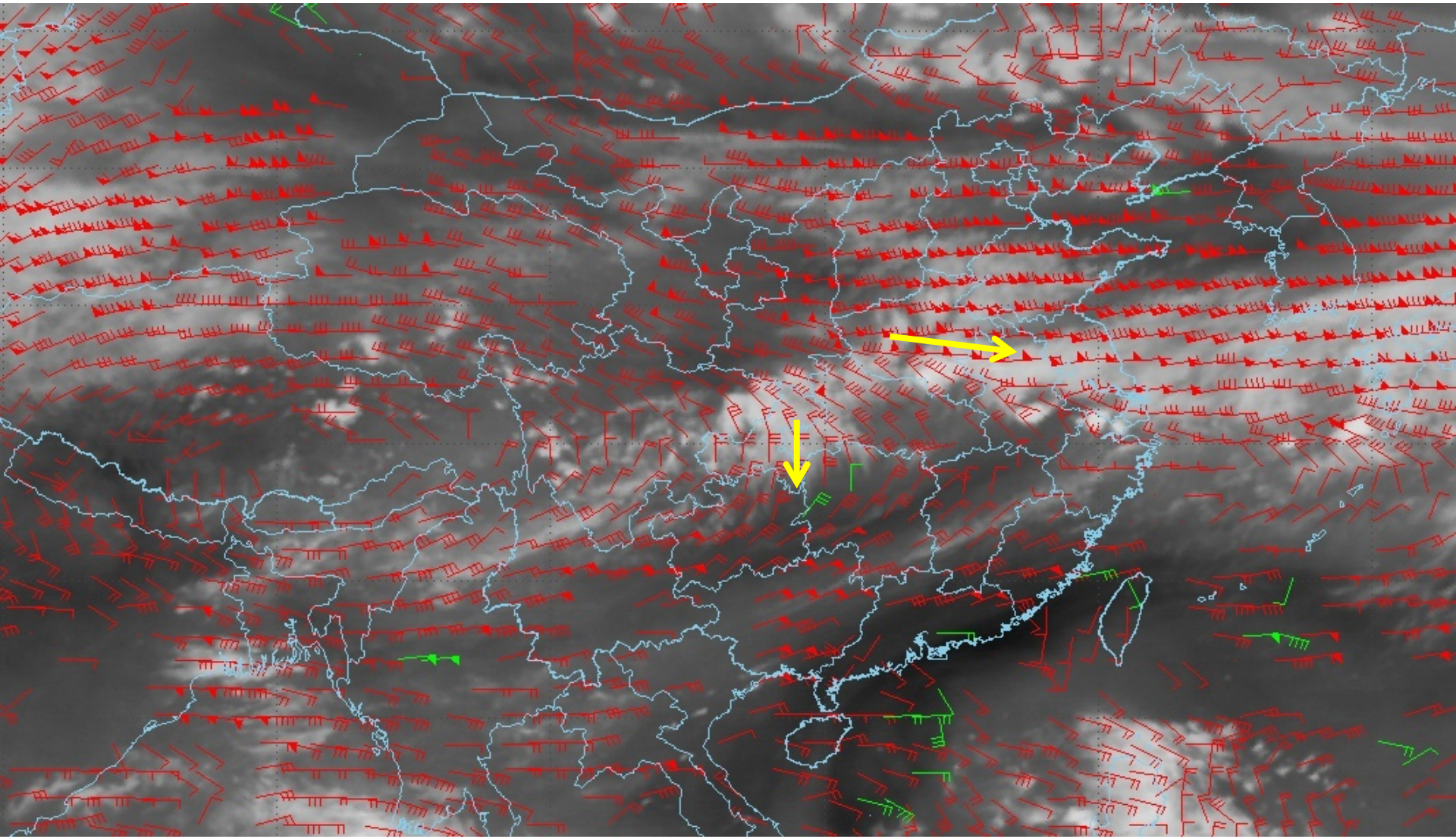
Dispersed flow field associated with the South Asian High

- Dispersed flow field in upper level in wet region is a significant indication to large area precipitation or convections.

June 19, 2010 Severe rainfall to the south of Yantz river



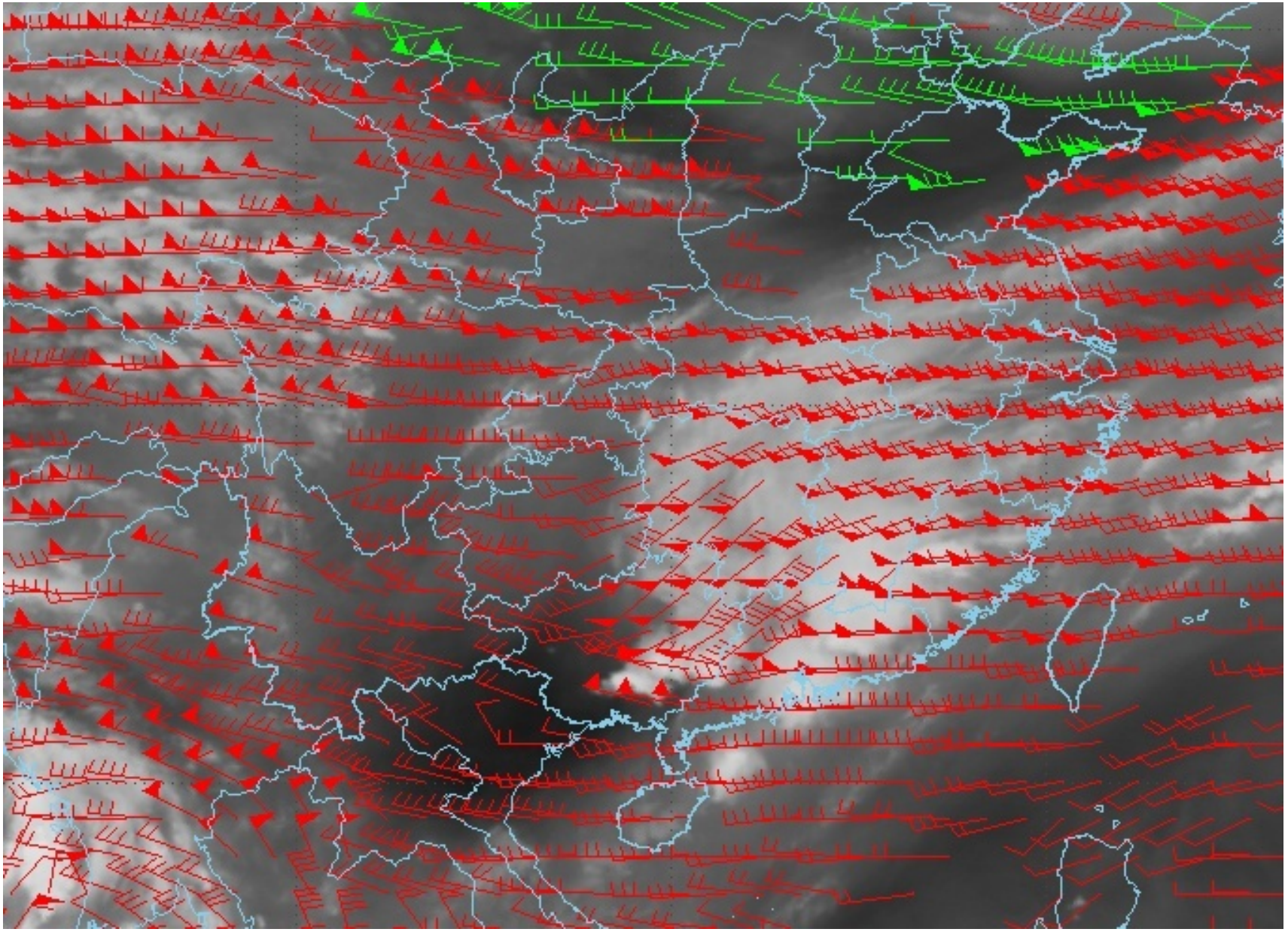
June 30 – July 9, 2007 severe rainfall in Hui He river basin



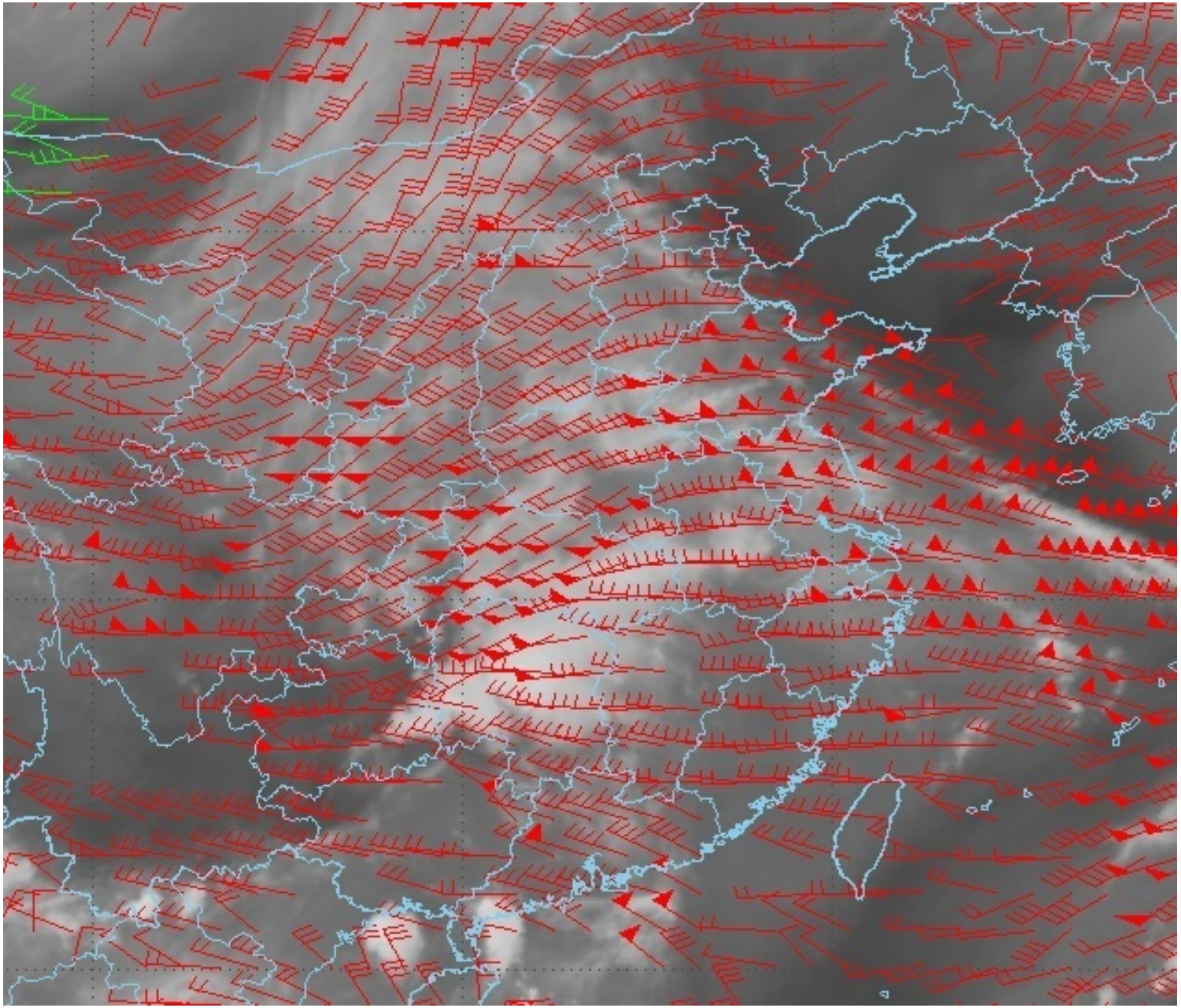
Disperse flow field in front of a trough

Disperse flow field in front of the trough is also the character for cyclogenesis and regional precipitation.

May 19, 2010 Guang Xi severe rainfall



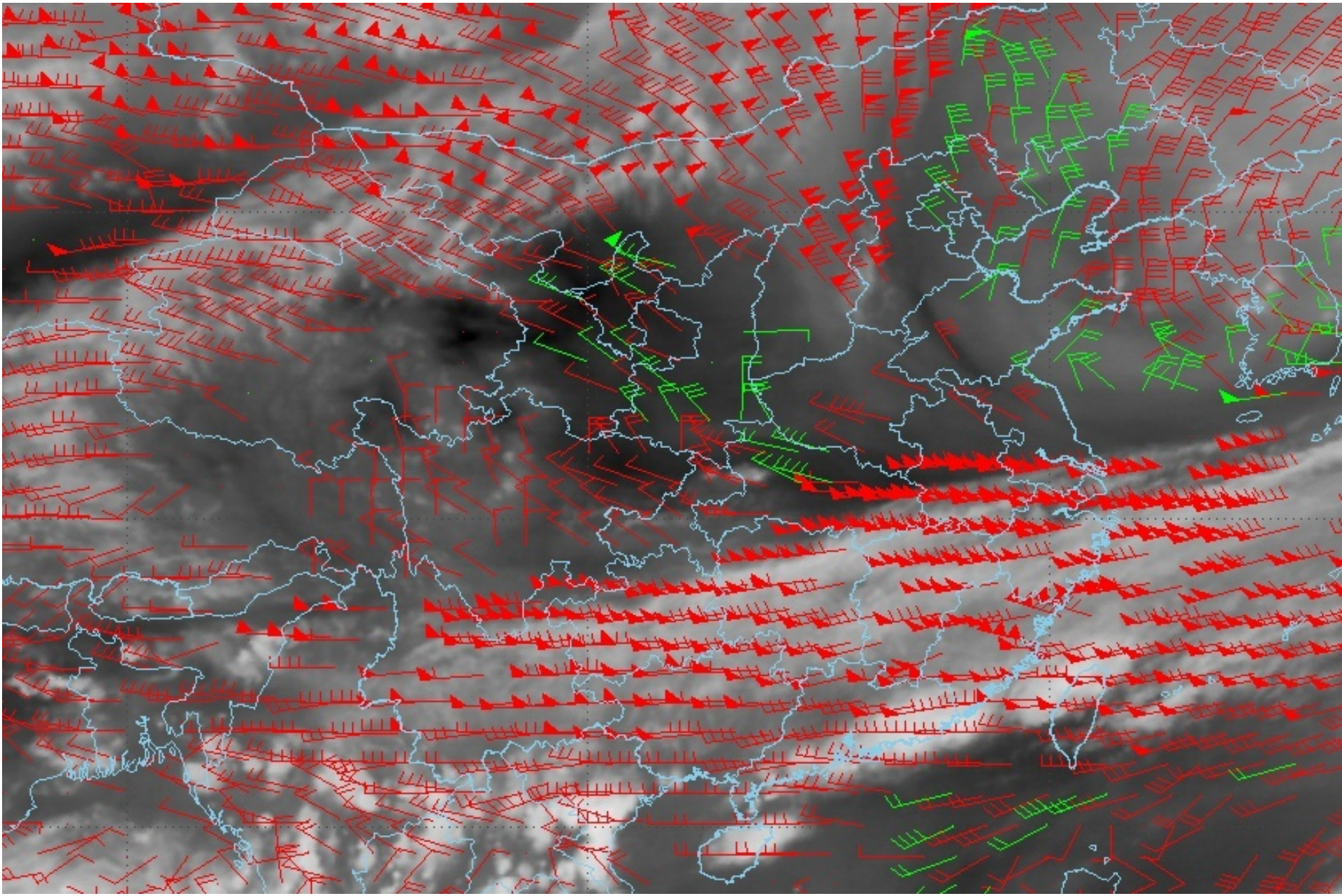
June 7, 2010 severe rainfall in northern China



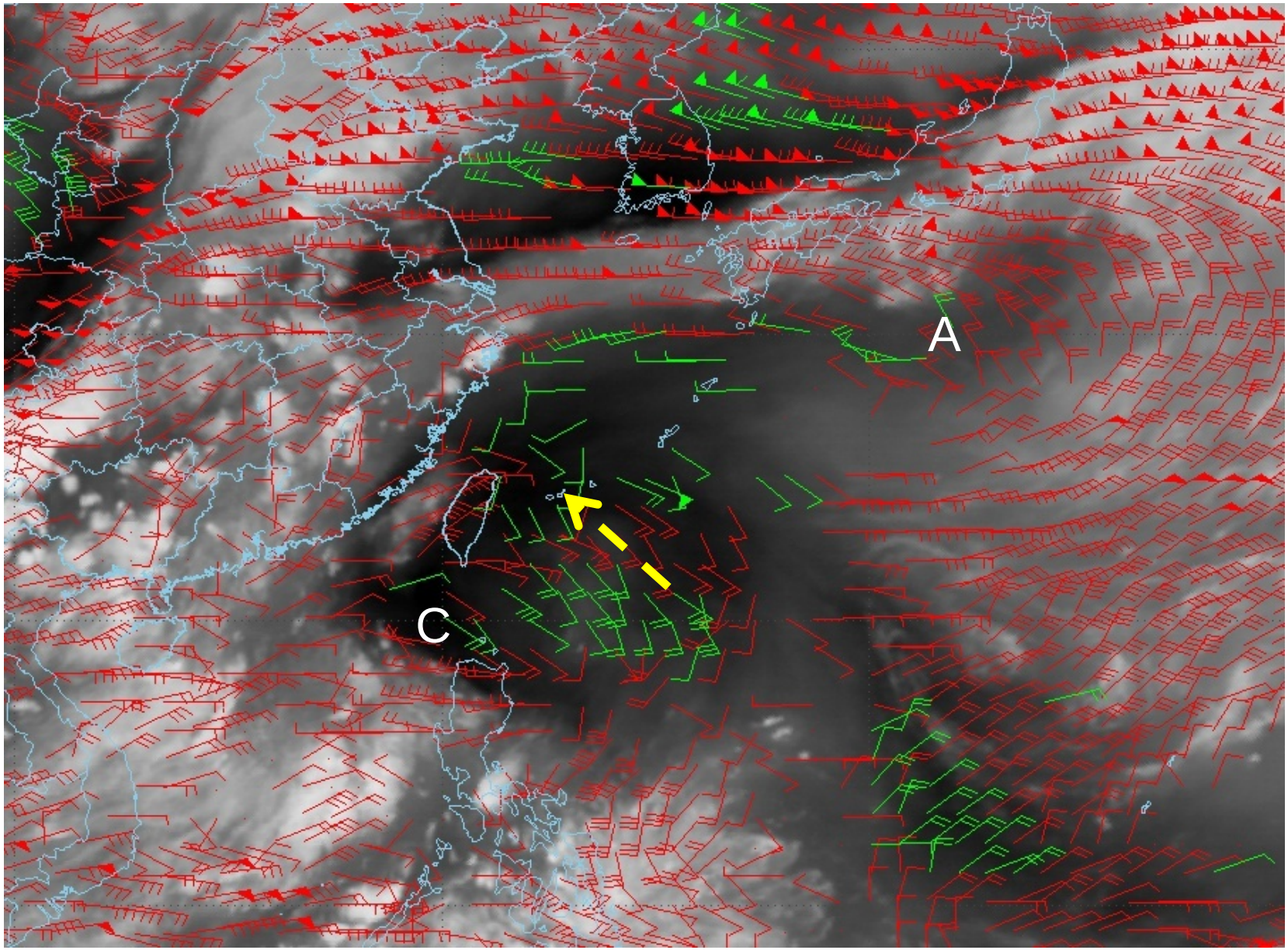
Confluent flow field inside of a dark region

Good weather

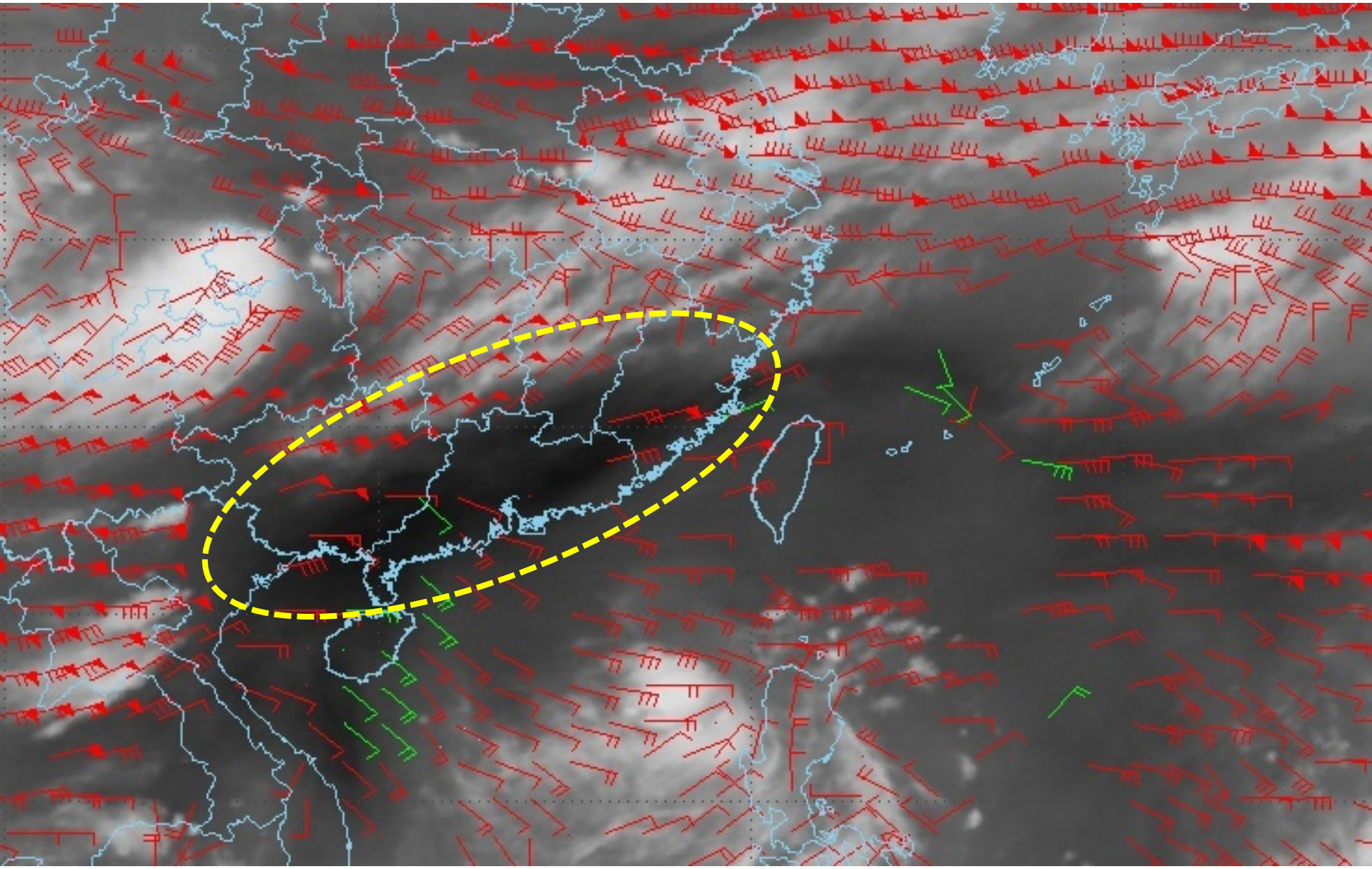
Confluent in front of the trough



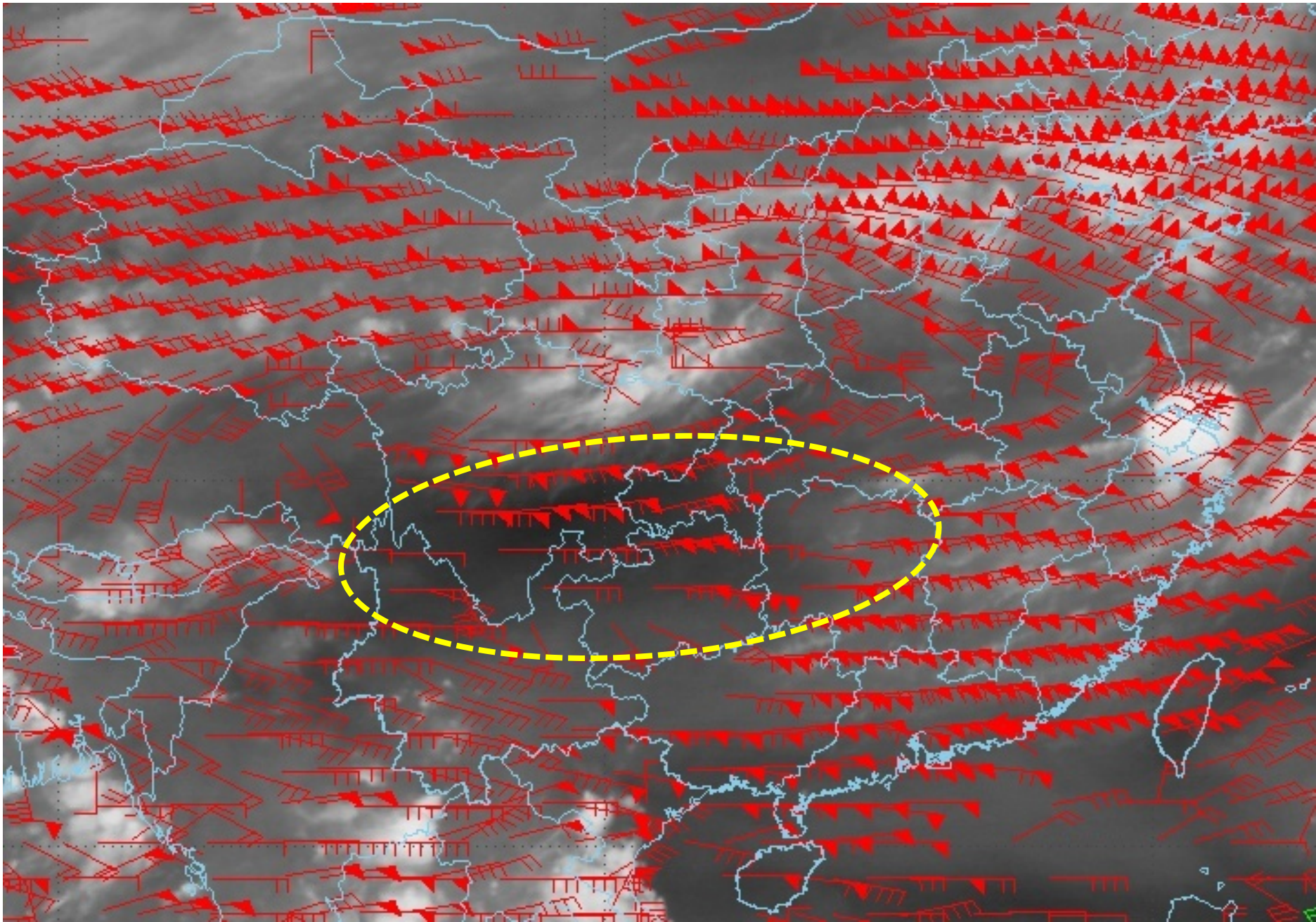
Confluence inside of the inner boundary



Confluent asymptote inside the easterlies.



Confluent asymptote inside the unitary flow field, drought in Chong Qing



Summary----1

- The importance of WV images in server weather analysis.
- Introduction to satellite derived products (AMV) application in server weather analysis.
- This PPT also shows characteristics of 6 major boundaries: Head boundary, inner boundary, dry surge boundary, base surge boundary, parallel jet boundary, Baroclinic leaf boundary.
- We also emphasized the importance of disperse and confluence above an cloud system to the significant weather.

outline

- FY Satellite images and derived products used in weather analysis
- The application in heavy rainfall events and server convective system.

The application examples of WV images in heavy rainfall events and server convective system.

The importance of WV image

The indication of dark area on IR3 image to heavy rainfall

Example 1: heavy rainfall in south China (Meiyu frontal system in early July, 2007)

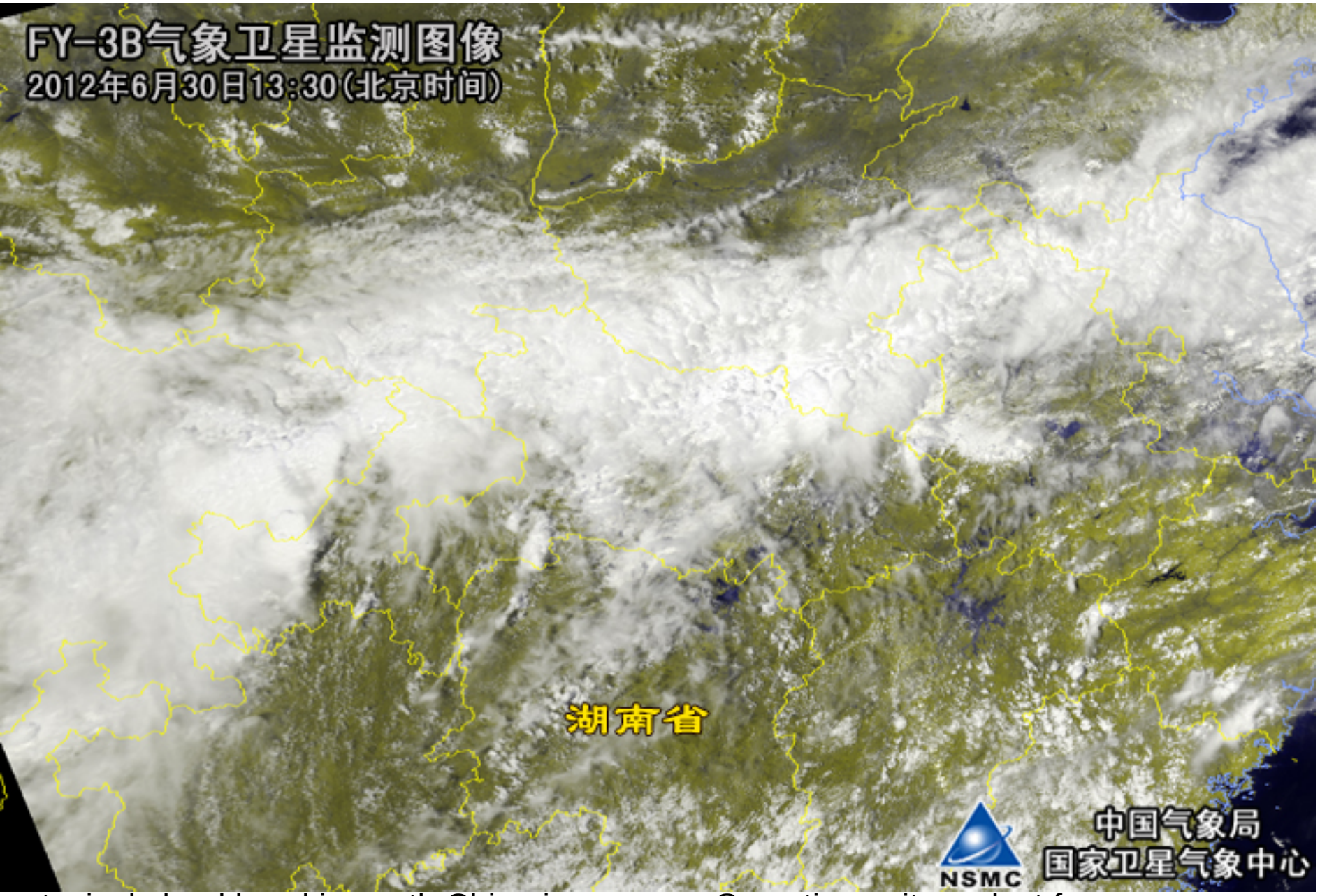
Example 2: heavy rainfall in north China (frontal system in late July, 2012)

the importance of IR3 image

The indication of dark area on IR3 image to heavy rainfall

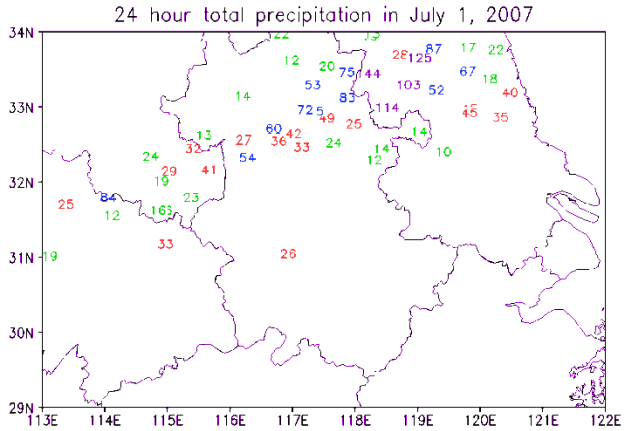
Example 1: heavy rainfall in south China (Meiyu frontal system in early July, 2007)

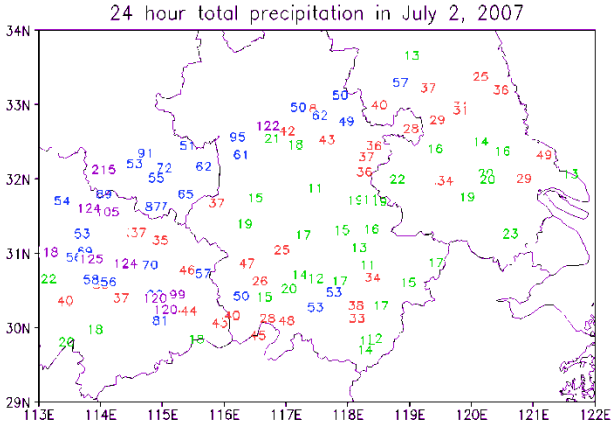
Example 2: heavy rainfall in north China (frontal system in late July, 2012)

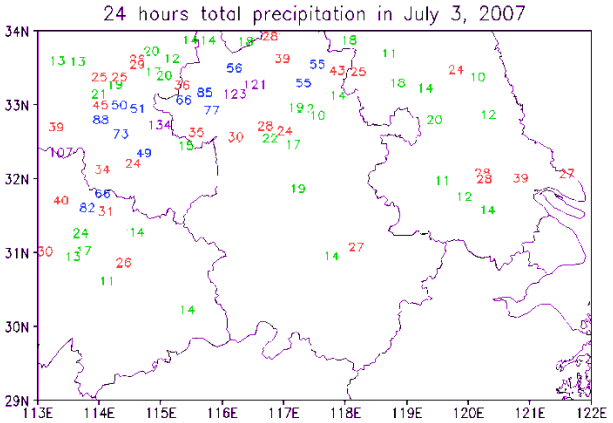


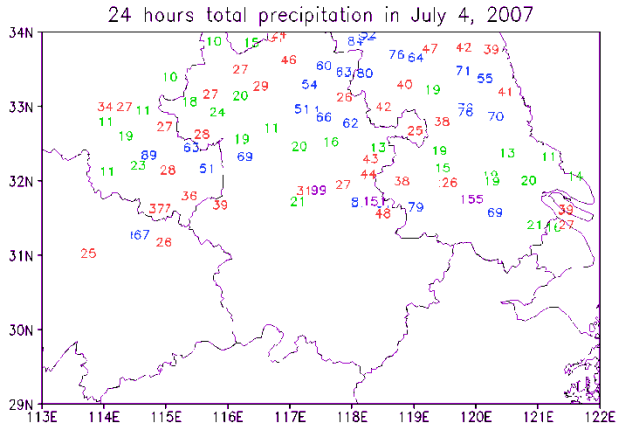
a typical cloud band in south China in summer, Sometimes, it can last for several days and cause heavy rainfall.

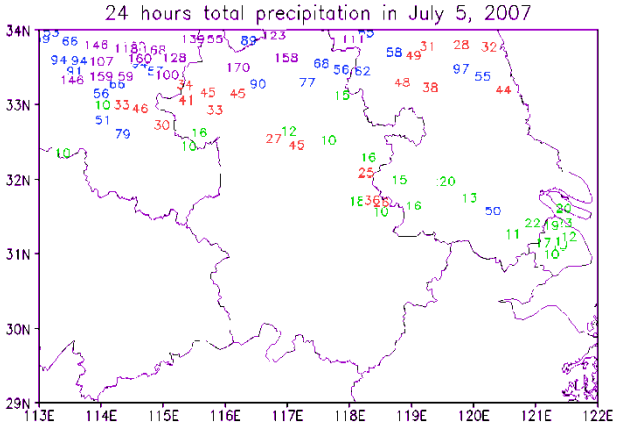
24 hours total precipitation in July 2007

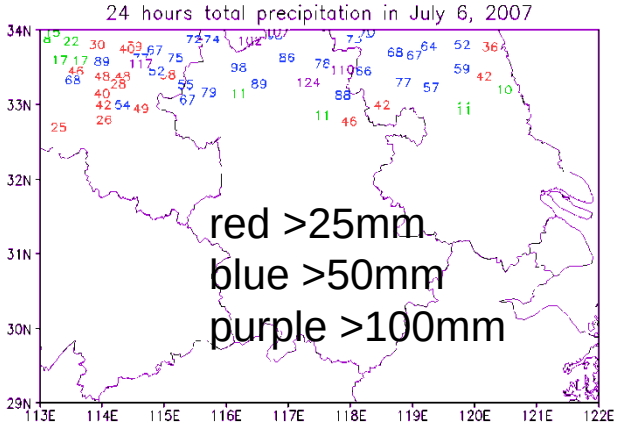


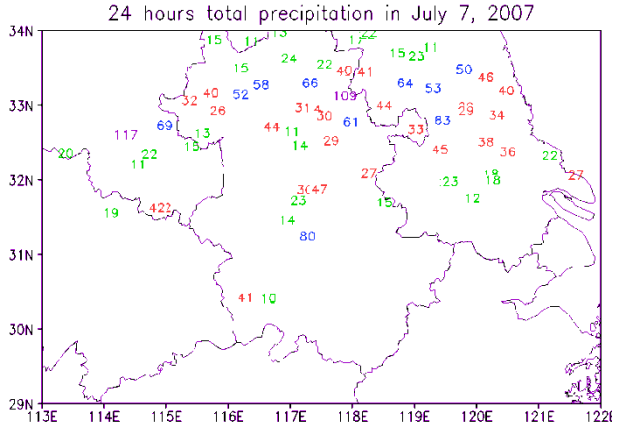


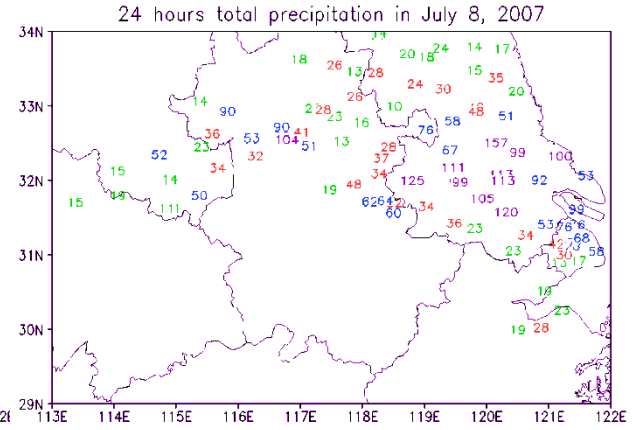


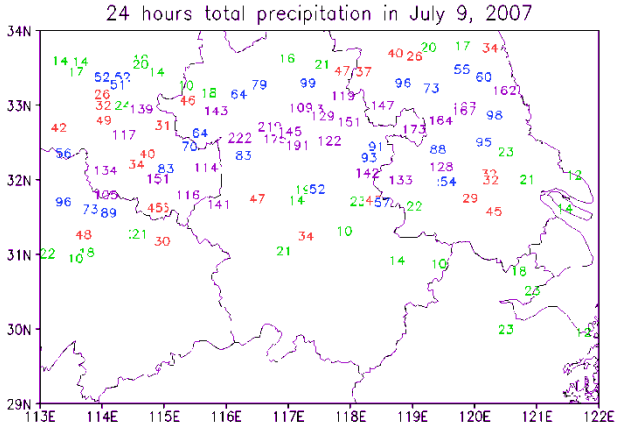




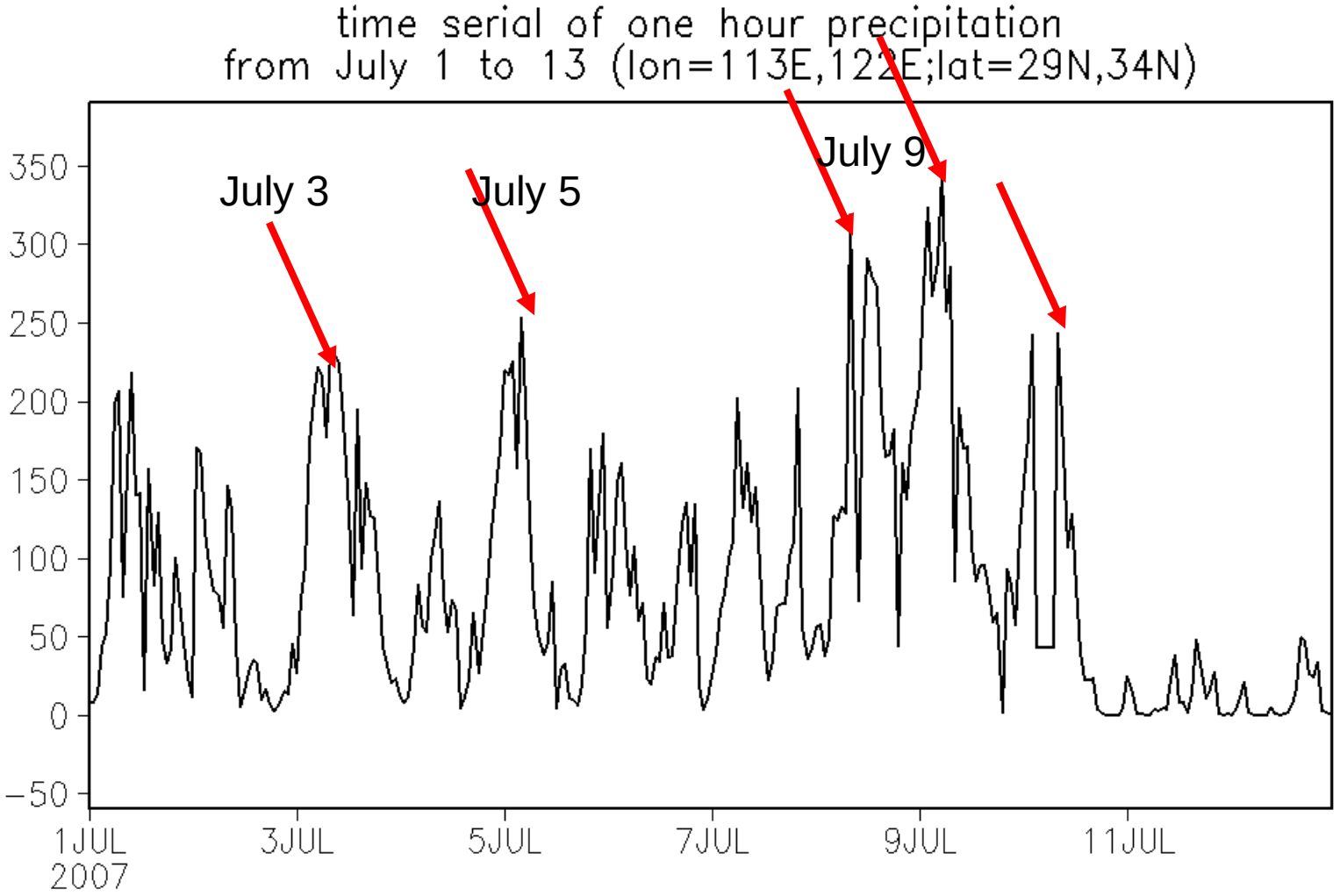


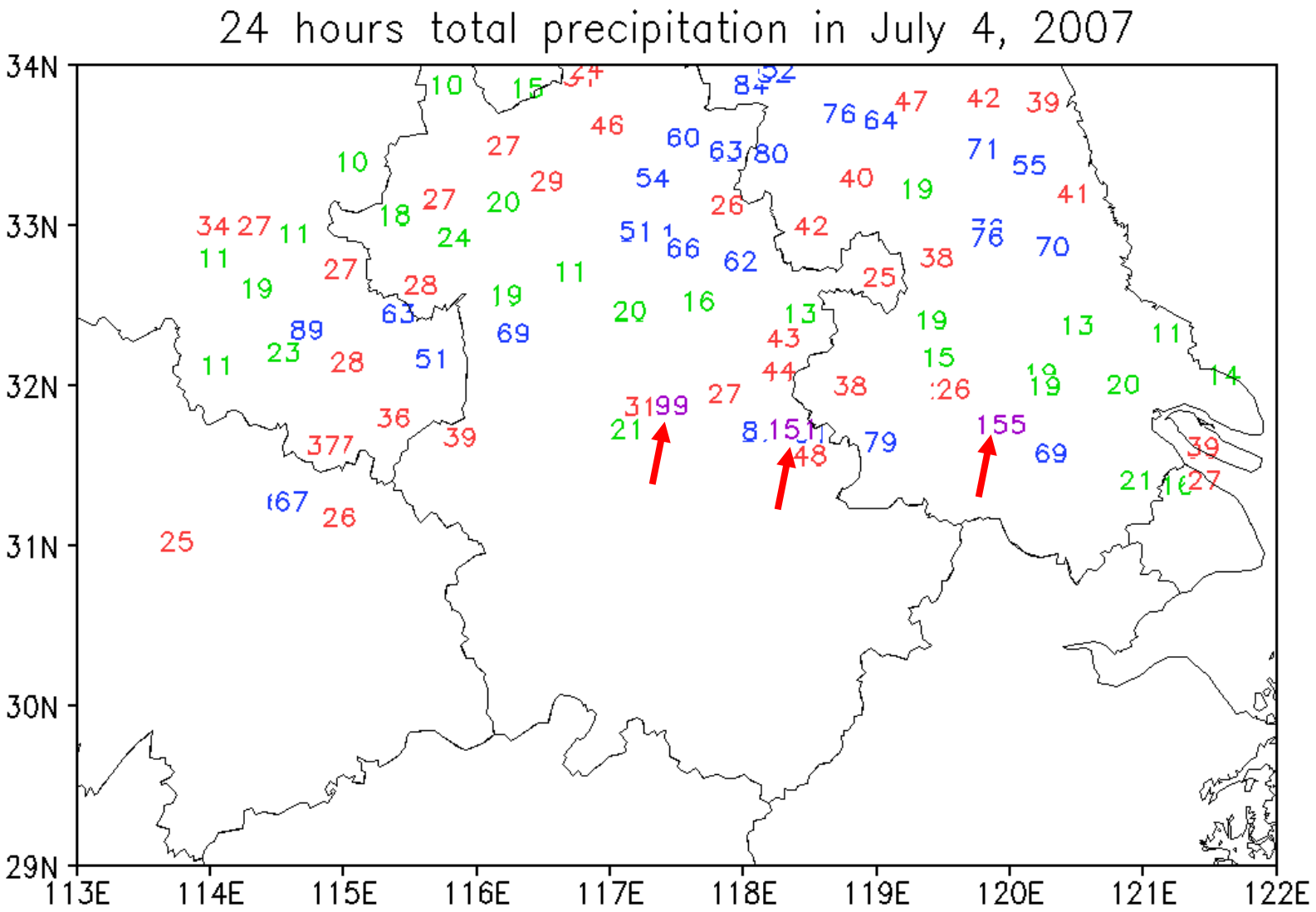






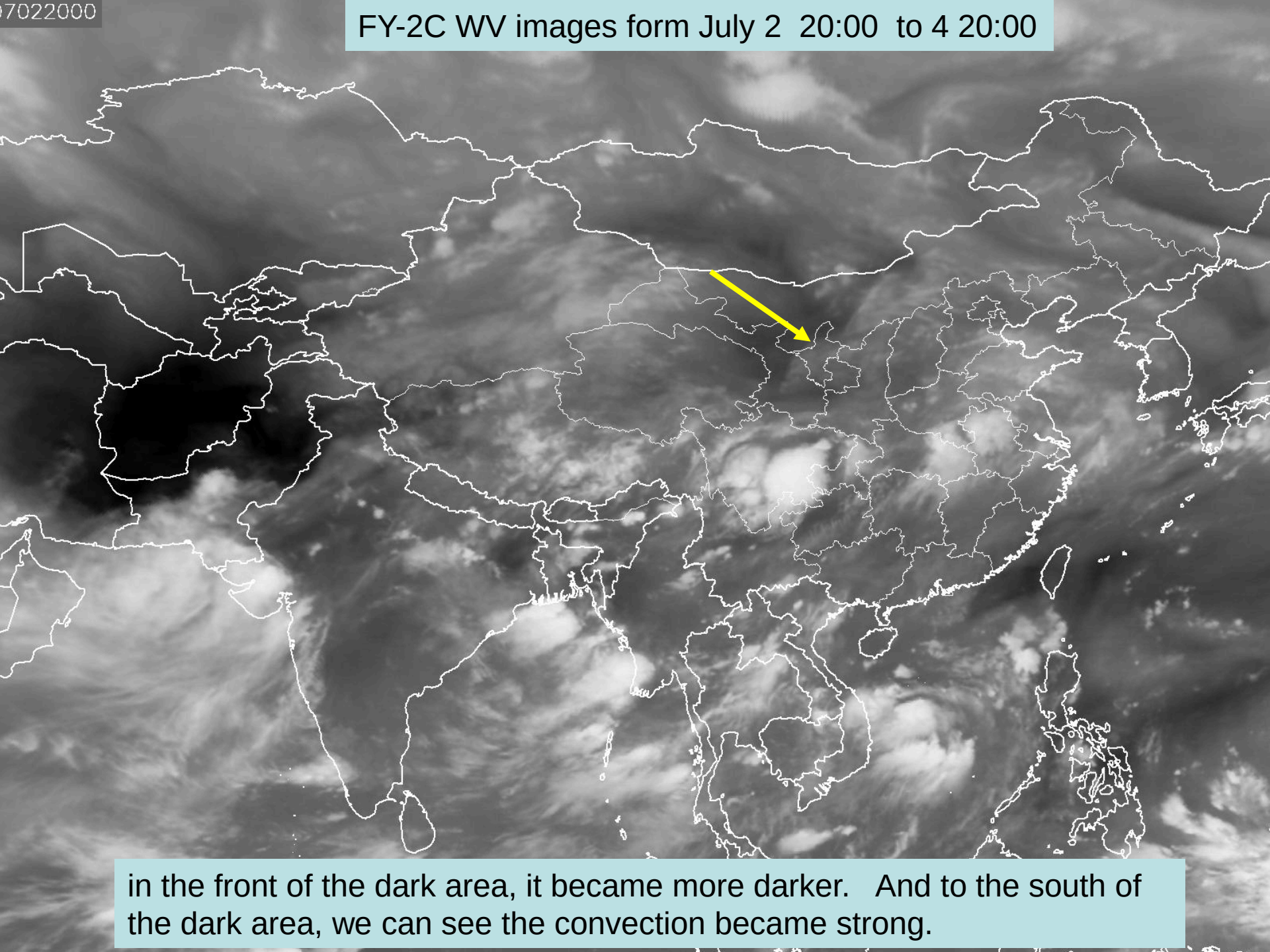
during the continuous rainfall there were several extremely strong periods

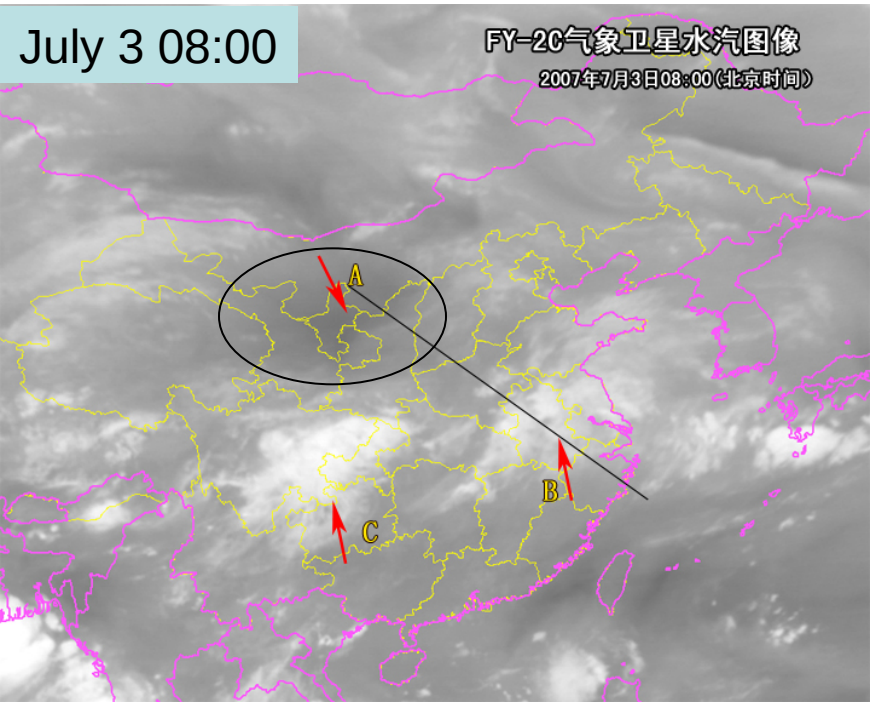


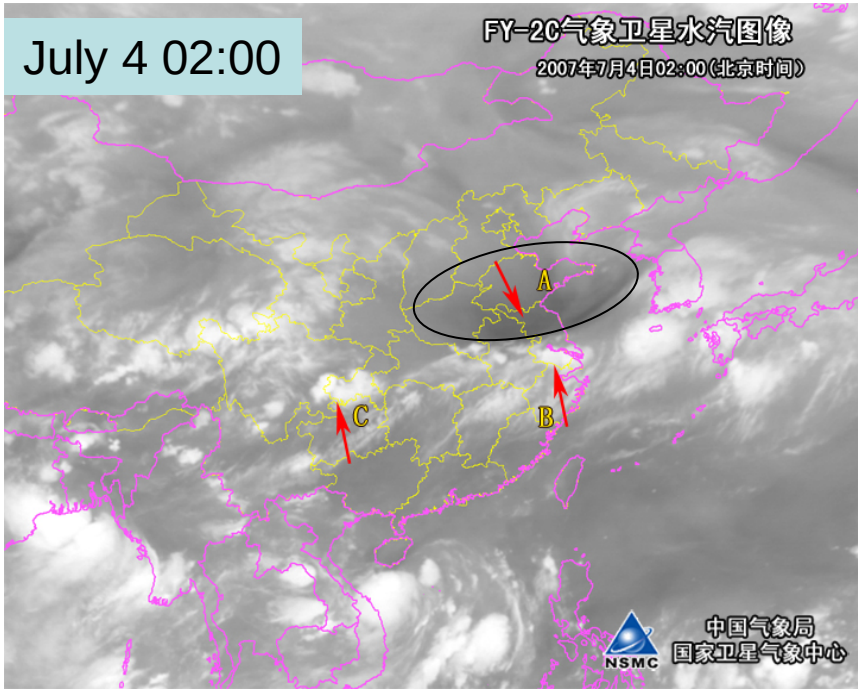


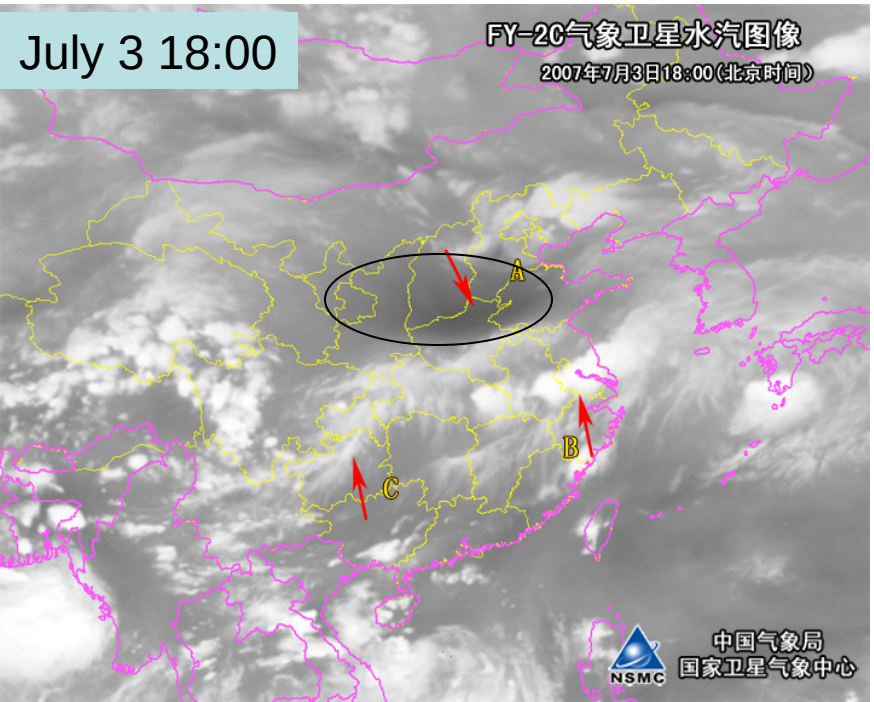
at many observation stations the rainfall is greater than 50mm/day

The largest one is 155 mm/day

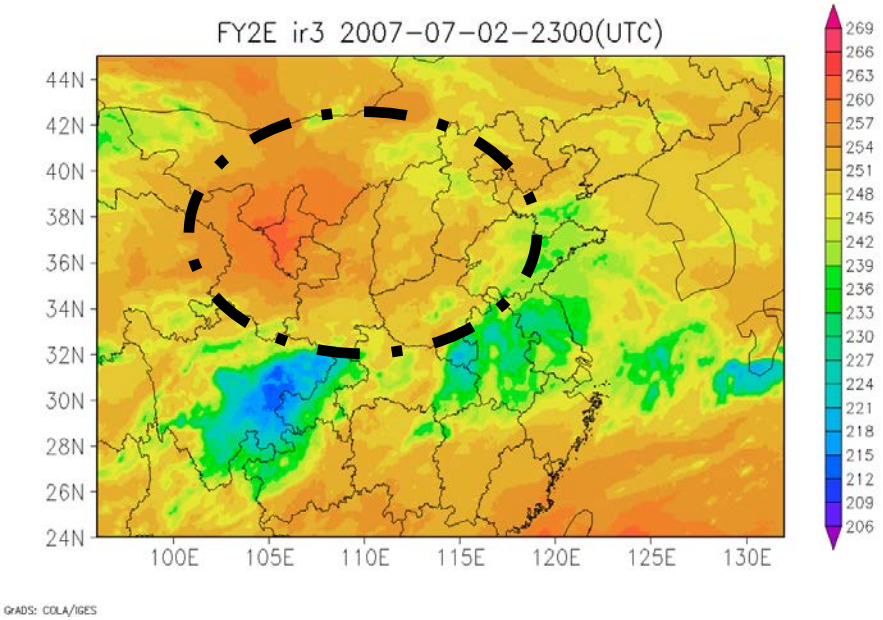

7022000
FY-2C WV images form July 2 20:00 to 4 20:00
in the front of the dark area, it became more darker. And to the south of the dark area, we can see the convection became strong.







Why the dark area in WV image can effect on the precipitation?


FY2E ir3 2007-07-02-2300(UTC)
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36N
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32N
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100E
105E
110E
115E
120E
125E
130E
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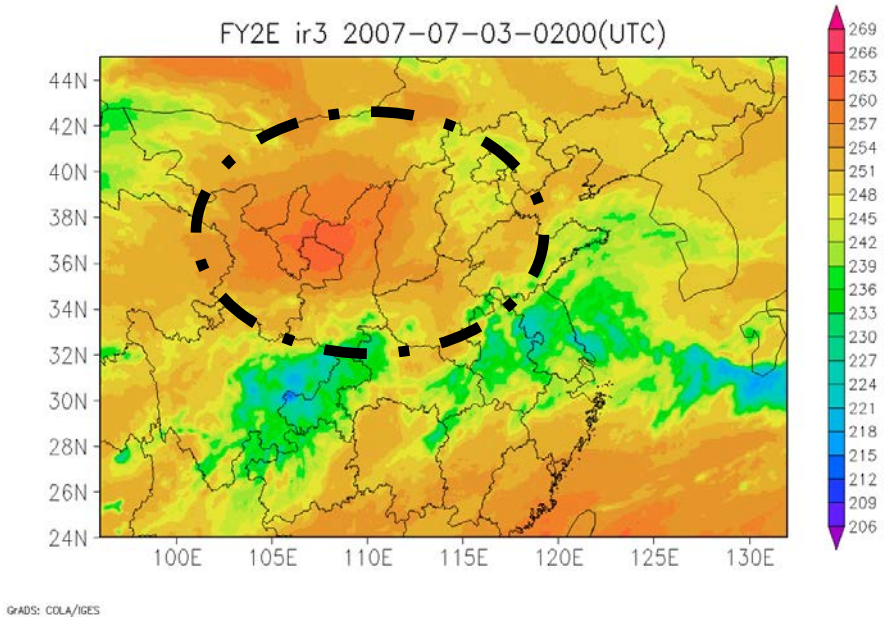
GrADS: COLA/IGES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120E
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130E
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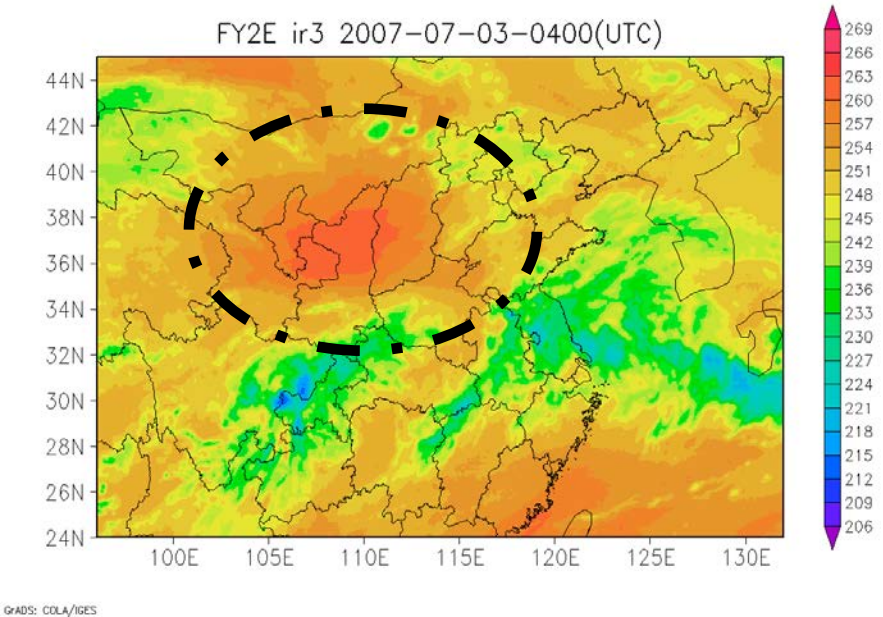
GrADS: COLA/IGES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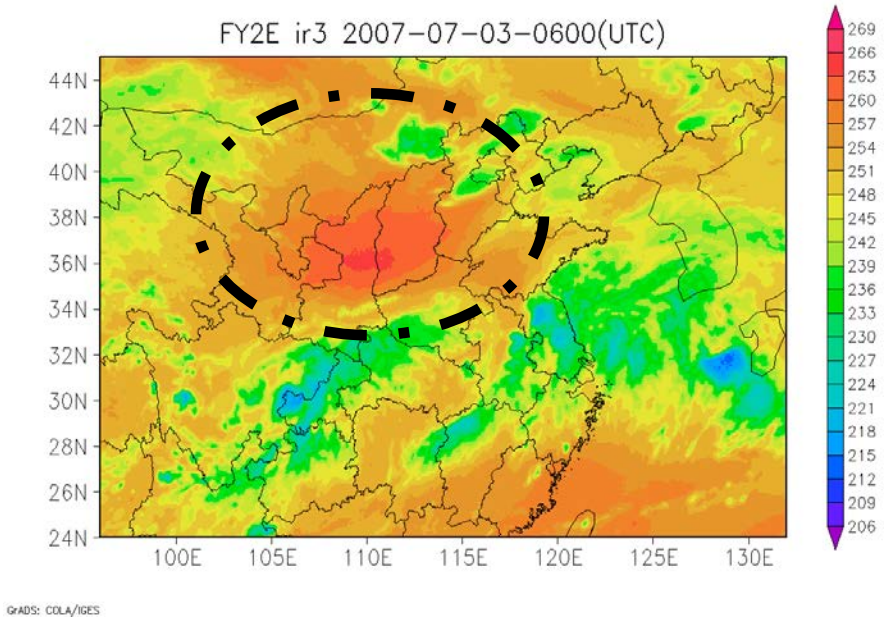
GrADS: COLA/IGES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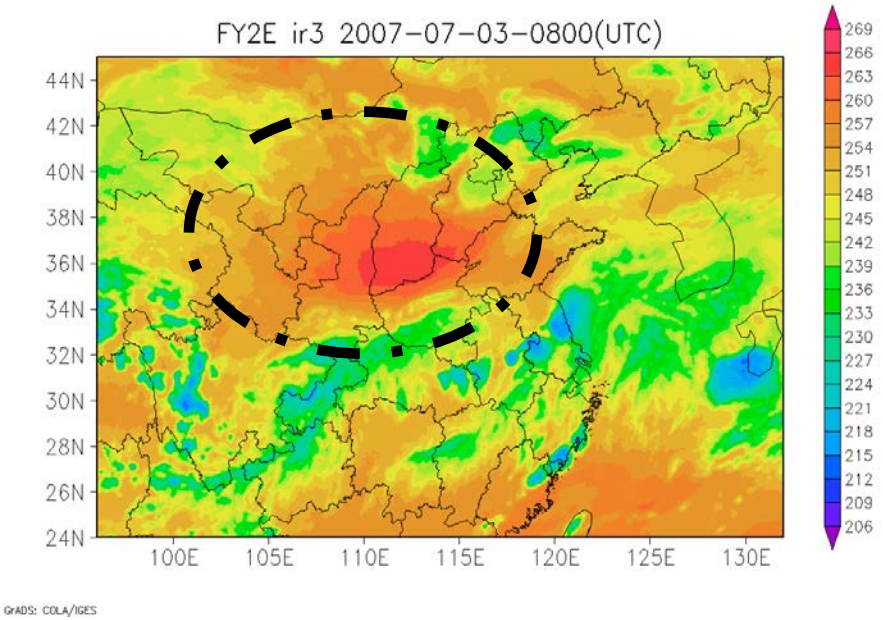
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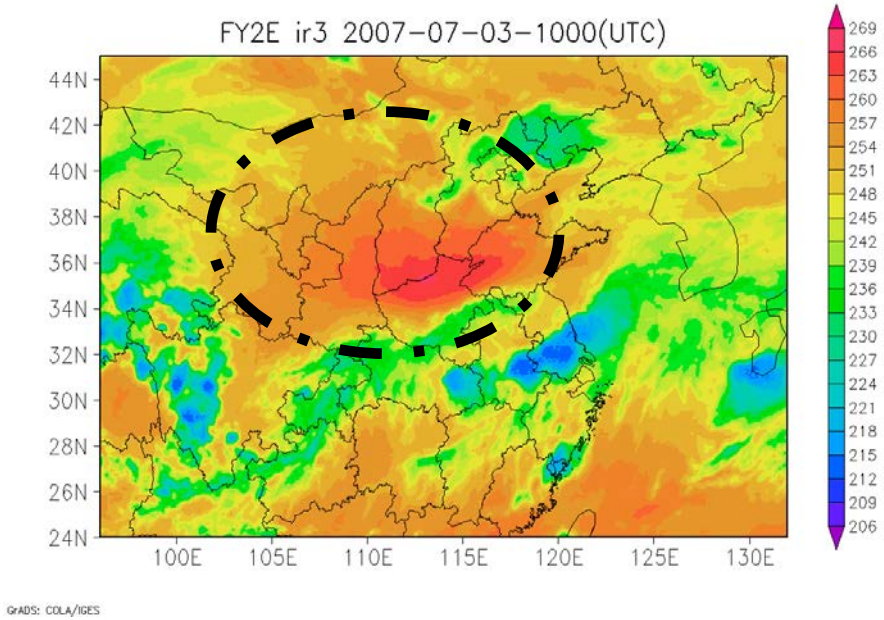
GrADS: COLA/IGES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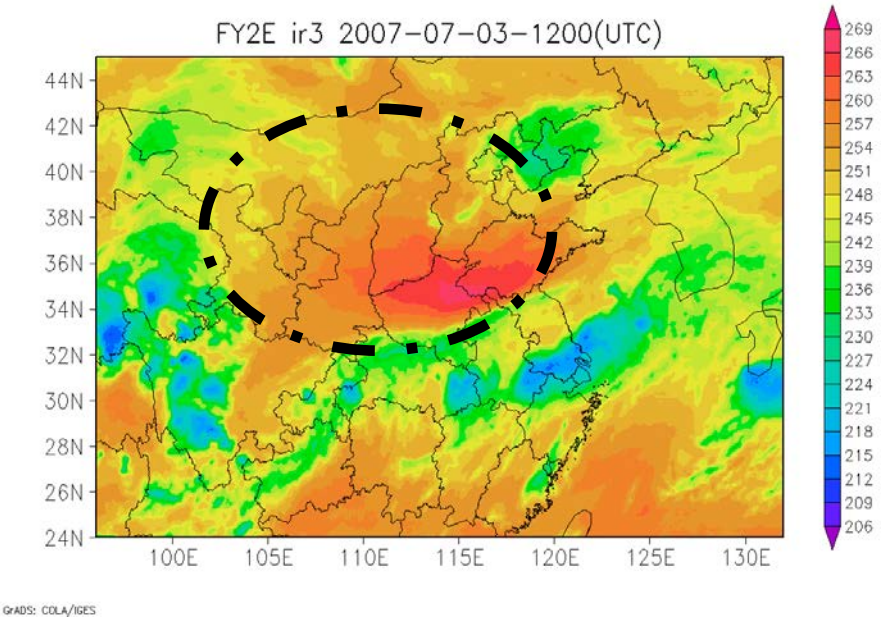
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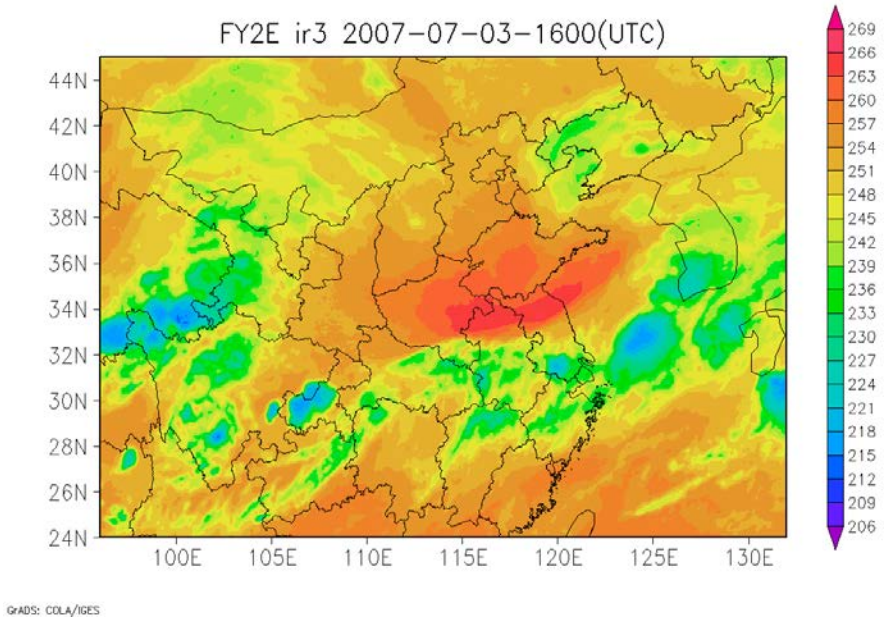
GrADS: COLA/IGES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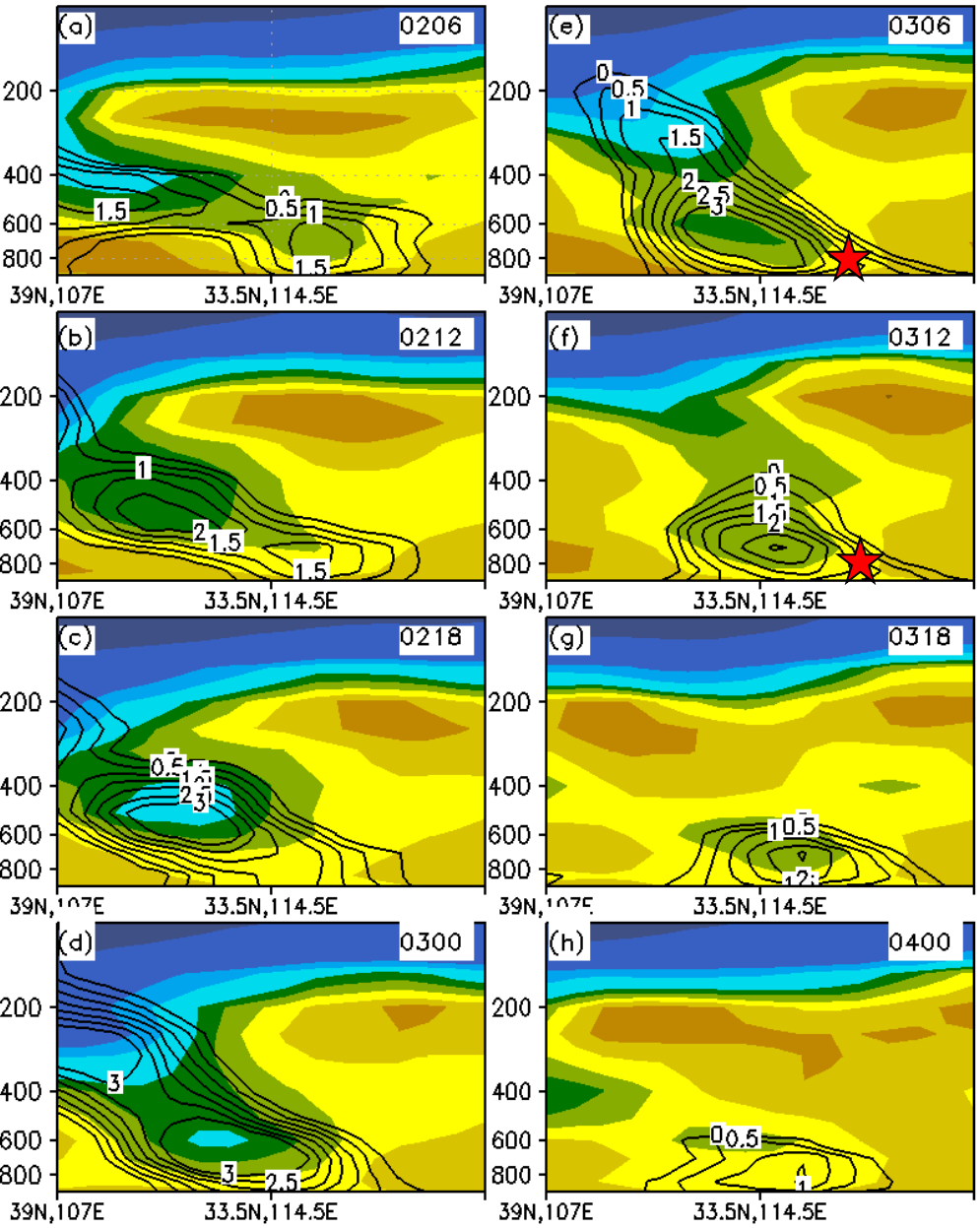
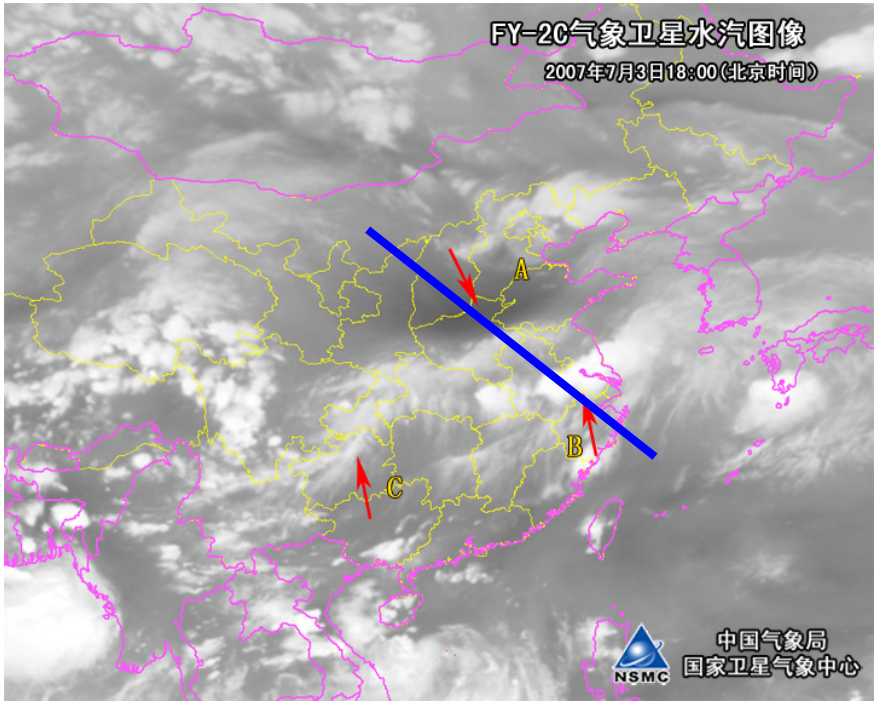
GrADS: COLA/IGES



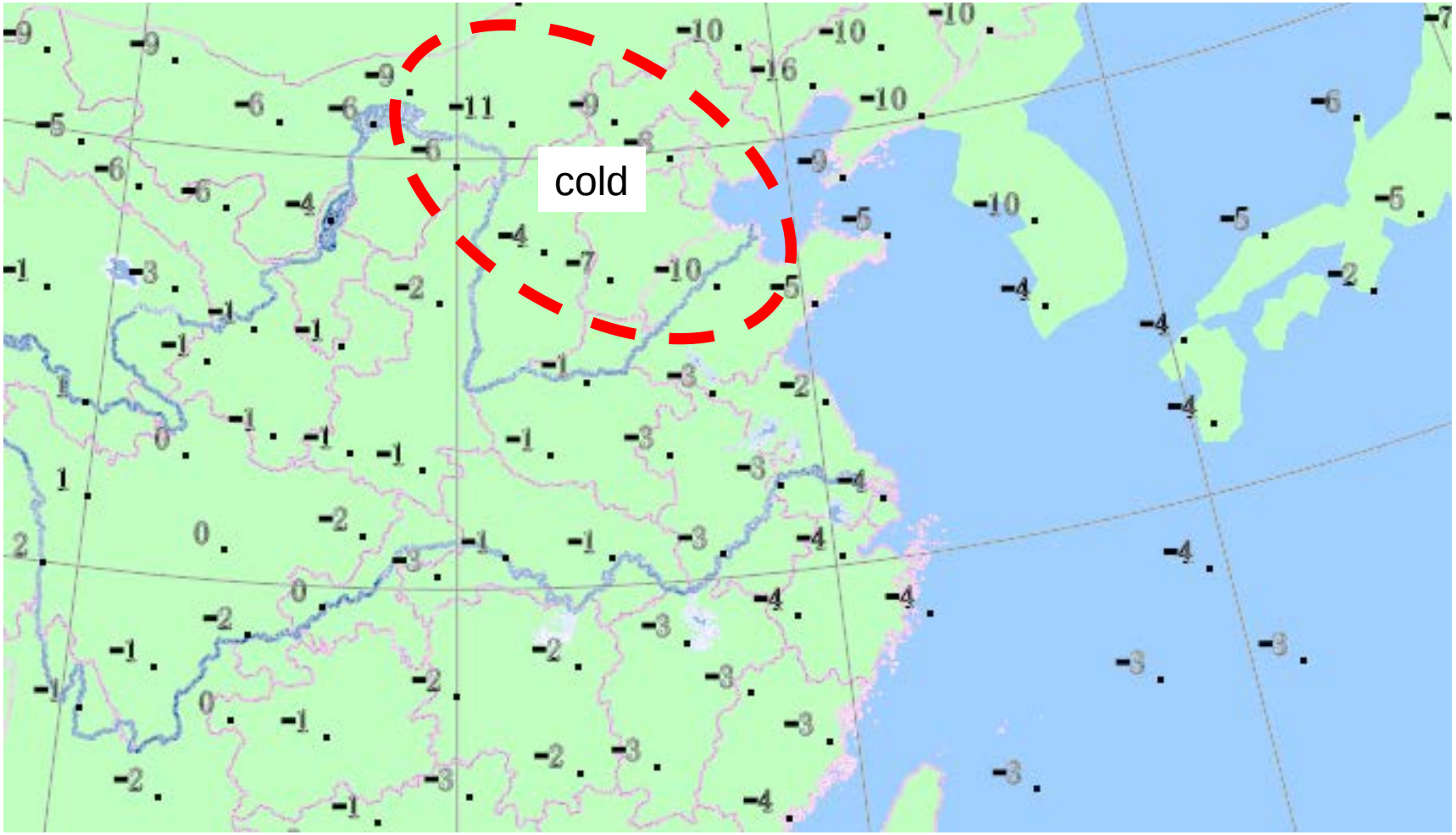
the shaded is PV, the blue color is strong PV, the contour line is positive vertical vorticity.

during the dark area moving south-eastward, the high PV and strong positive vorticity also extend from upper to lower levels.

(28N 122E)



the PV and positive vorticity stretching to Huaihe Rive region caused the heavy rainfall



Weather map at 1200 GMT on 3th July 2007
500hPa temperature

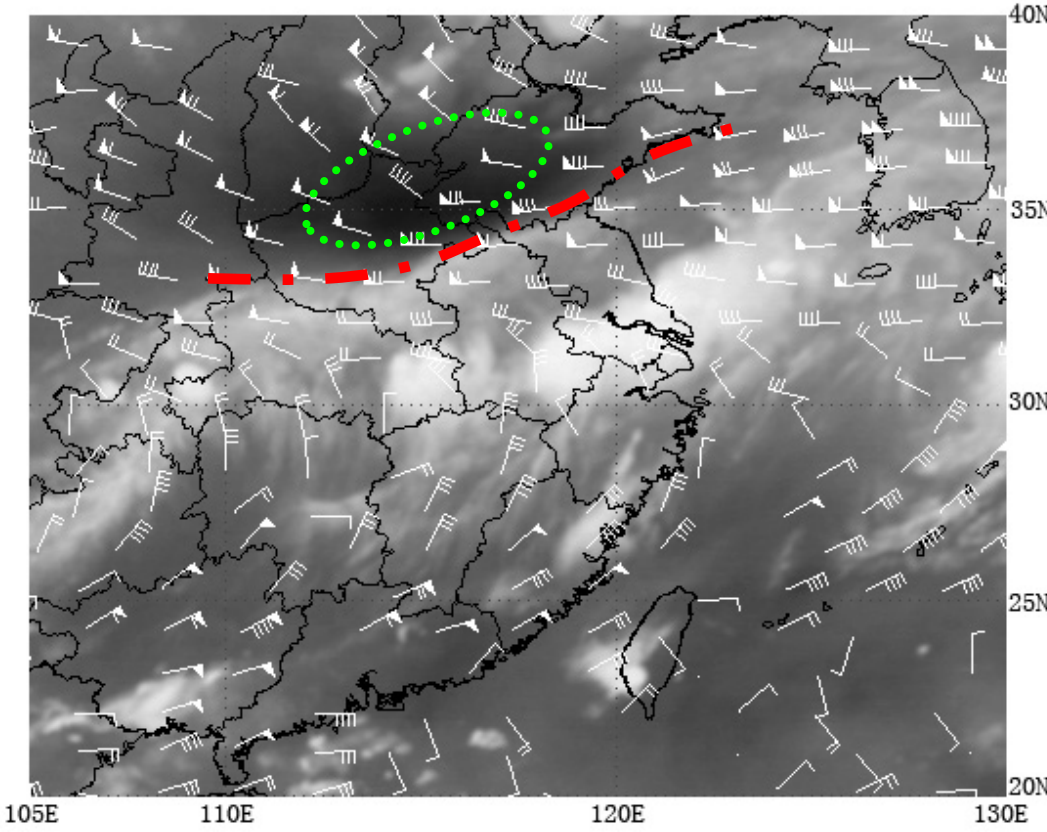
dry

2g/kg

Specific humidity

Weather map at 1200 GMT on 3th July 2007 500hPa

Water vapor (WV) image and the high level (above 400hPa) winds from FY2C at 1130 GMT 3th July 2007



The main body of the dry intrusion with zero specific humidity on the 500 hPa map is just at the center of the black area in WV image

- The small scale dark area in WV images in north China usually is the dry and cold air in the mid or high troposphere.
- The dark area has the strong PV and positive vorticity, it extant downward when it moving south-eastward.
- The approaching of dark area to the north can intensify the precipitation.

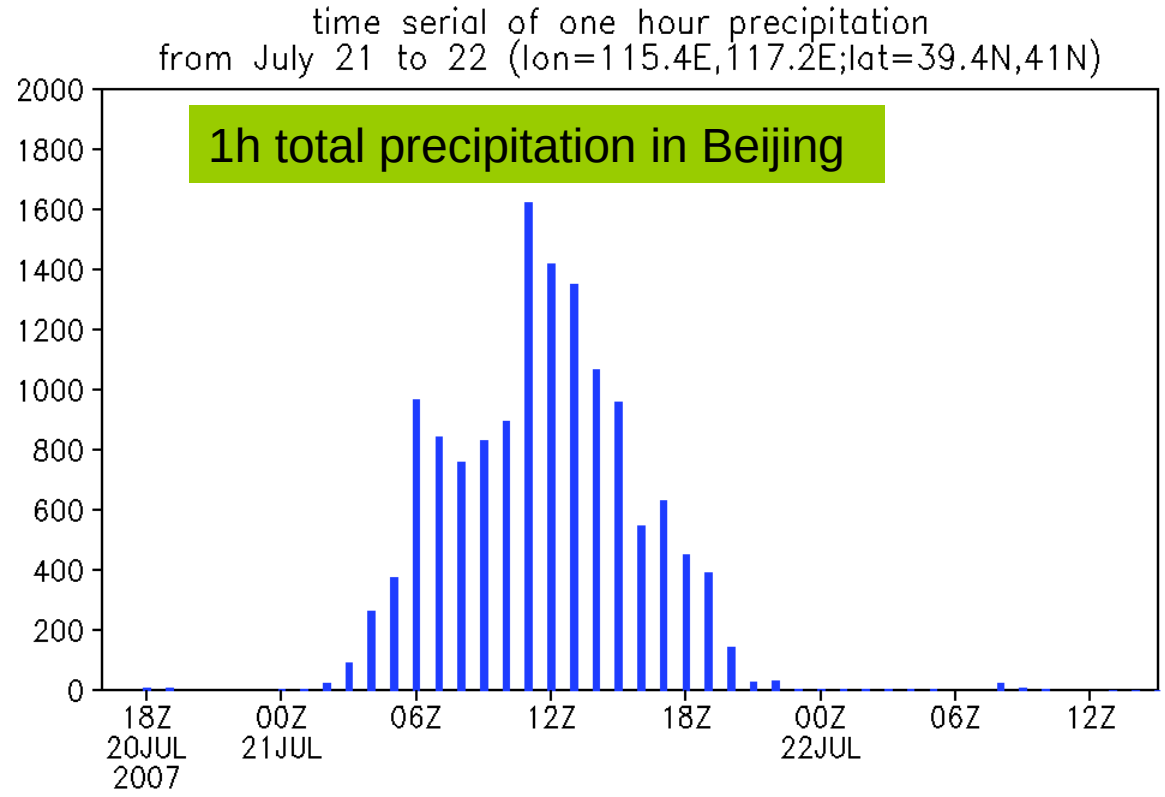
the importance of WV image

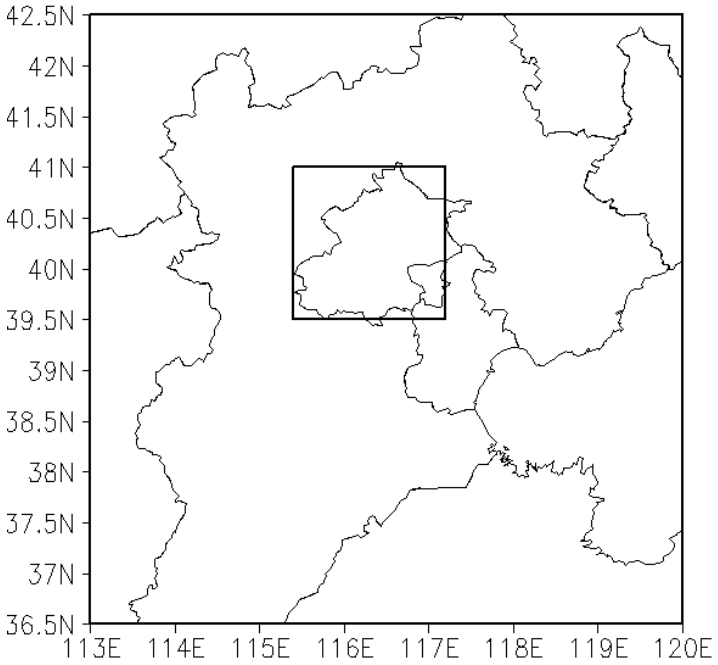
The indication of dark area on IR3 image to heavy rainfall

Example 1: heavy rainfall in south China (Meiyu frontal system in early July, 2007)

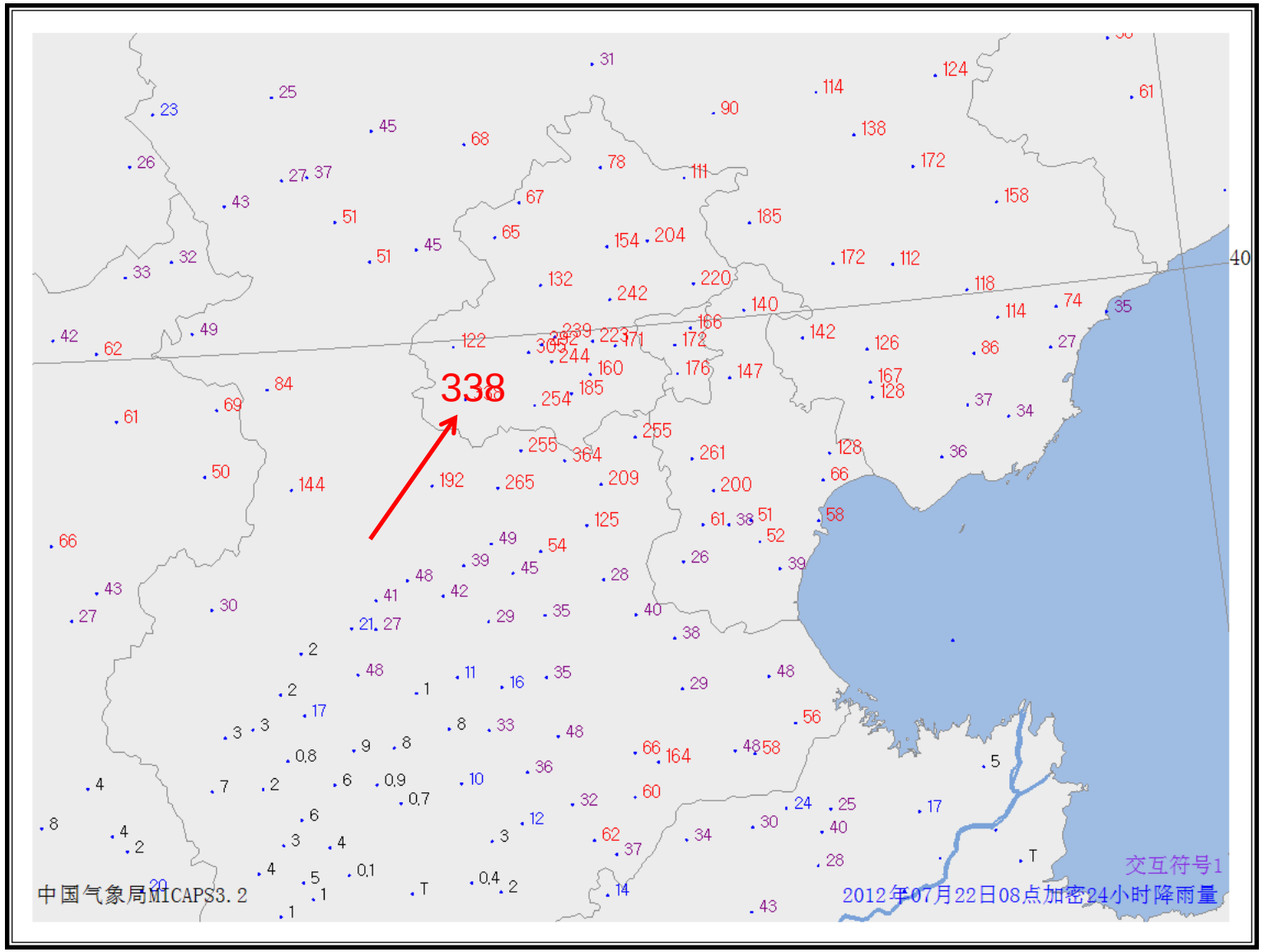
Example 2: heavy rainfall in north China (frontal system in late July, 2012)

Rainfall in North China, July 21st , 2012
Heavy precipitation in Beijing



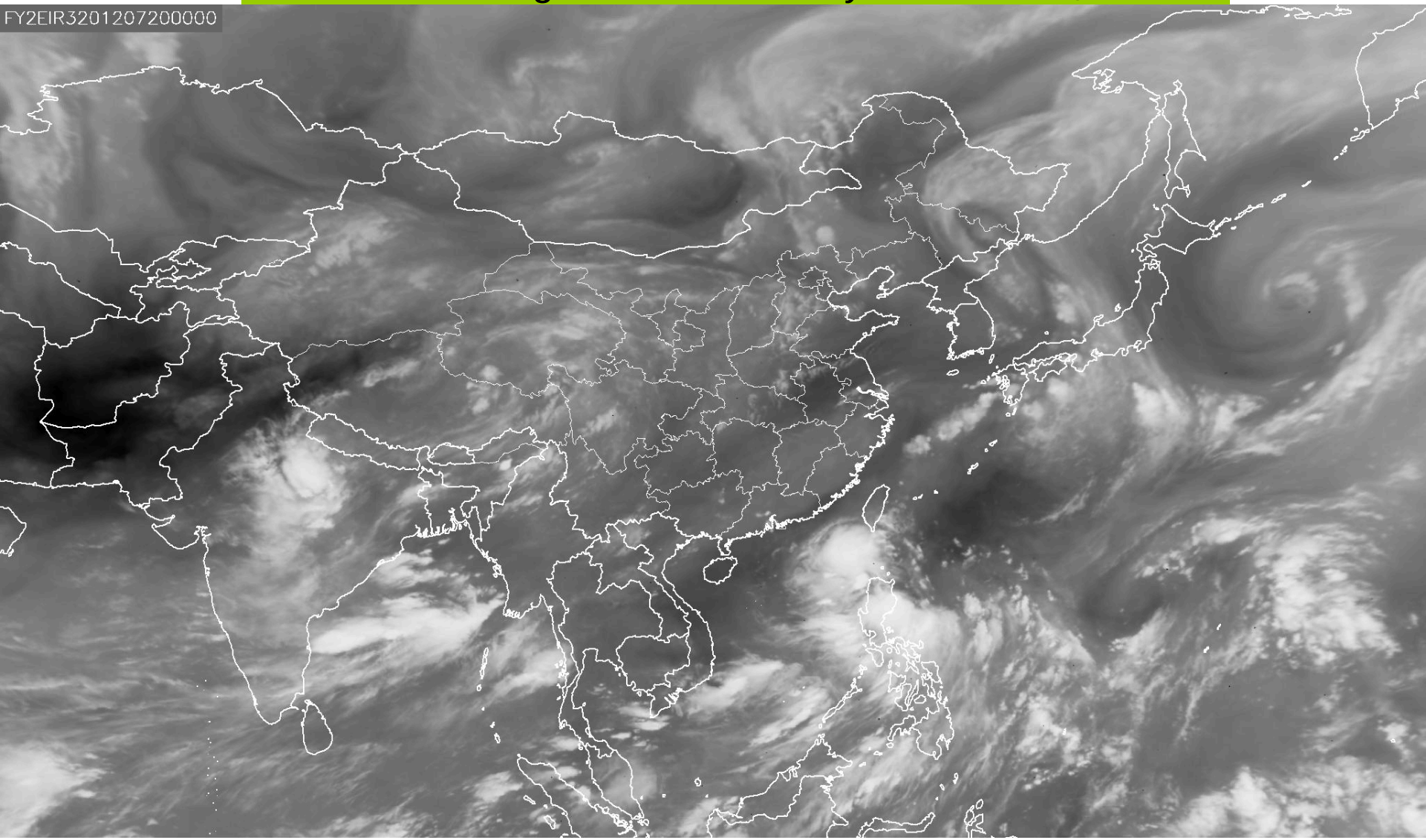


24h precipitation July 21-22,2012

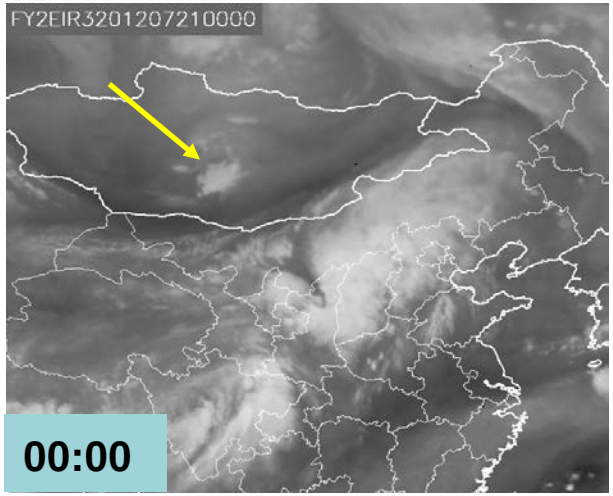


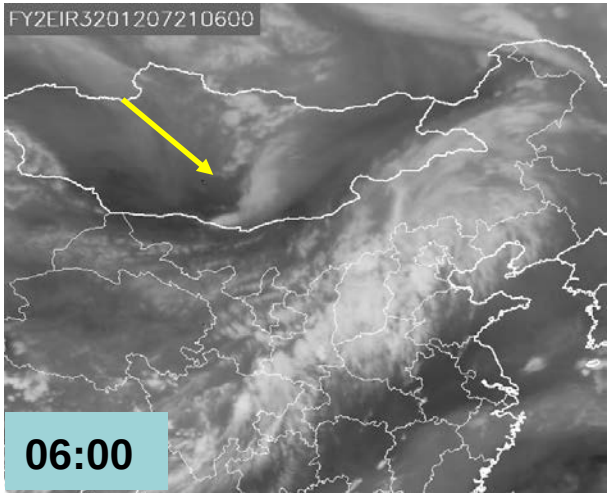
Beijing Severe Rainfall, July 21, 2012

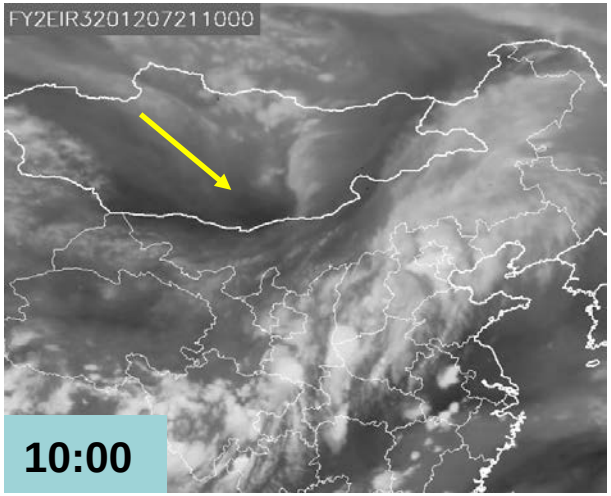
FY-2 IR3 image movie form July 20th to 22th,2012

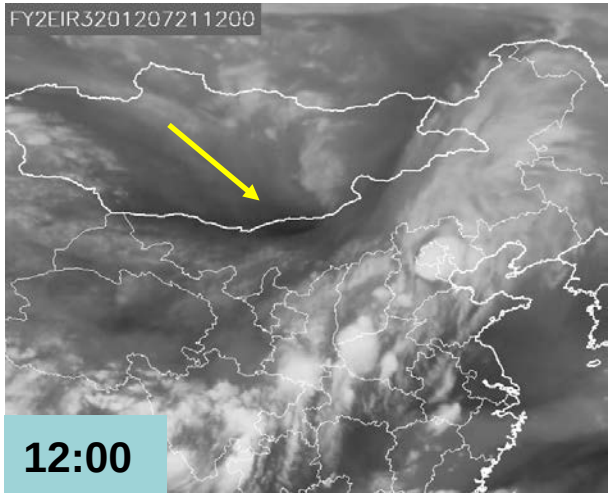


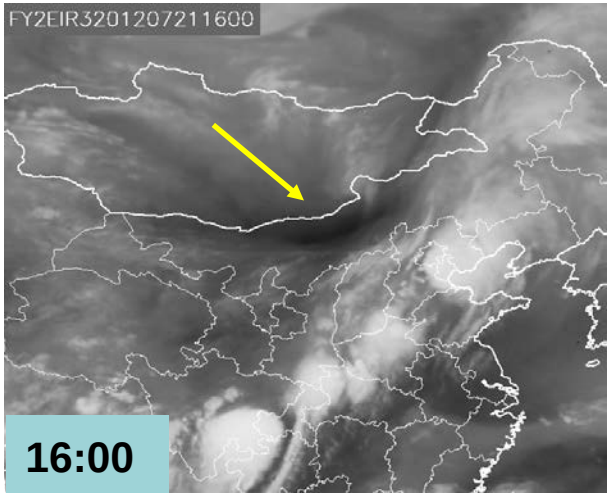
IR3 images

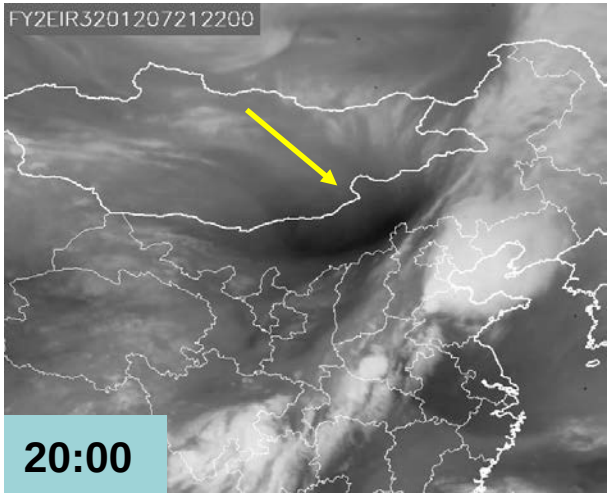

FY2EIR3201207210000
00:00

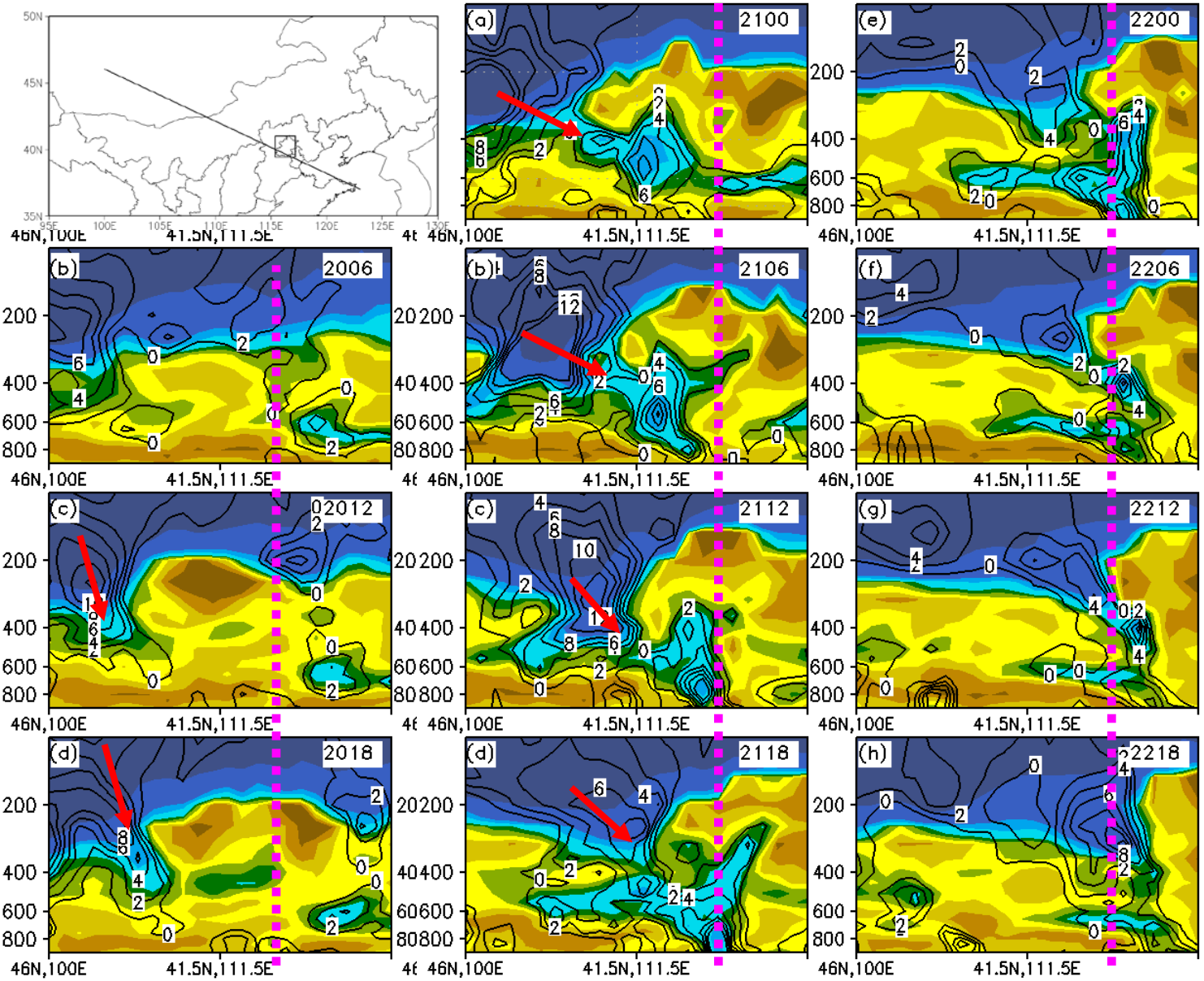

FY2EIR3201207210600
06:00

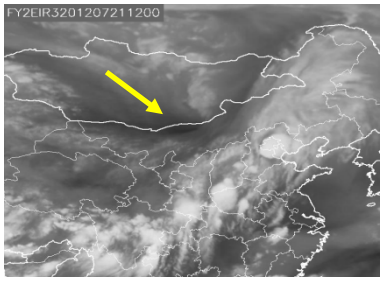

FY2EIR3201207211000
10:00


FY2EIR3201207211200
12:00

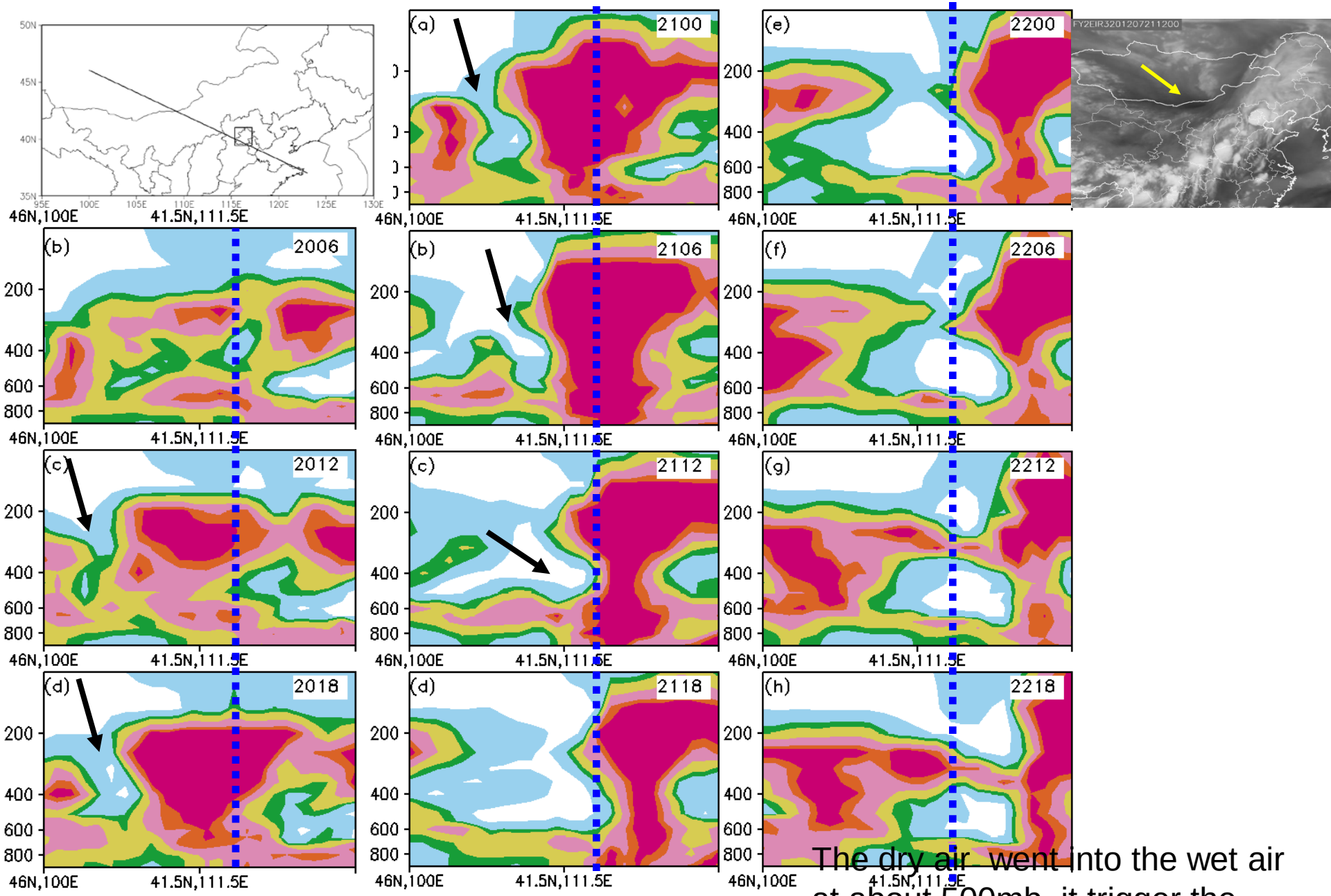

FY2EIR3201207211600
16:00


FY2EIR3201207212200
20:00





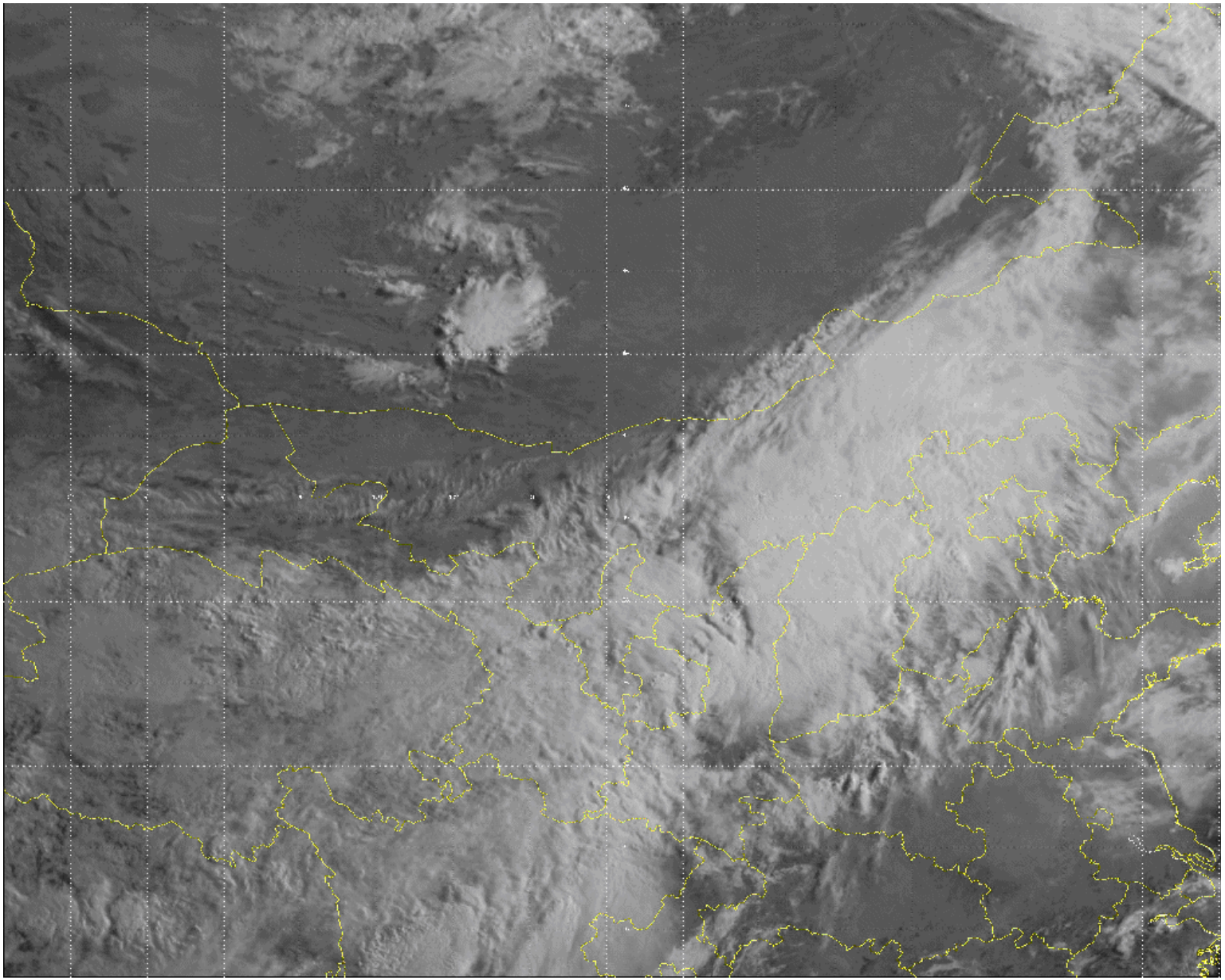
Shaded: Potential vorticity **Contour: Vertical vorticity**



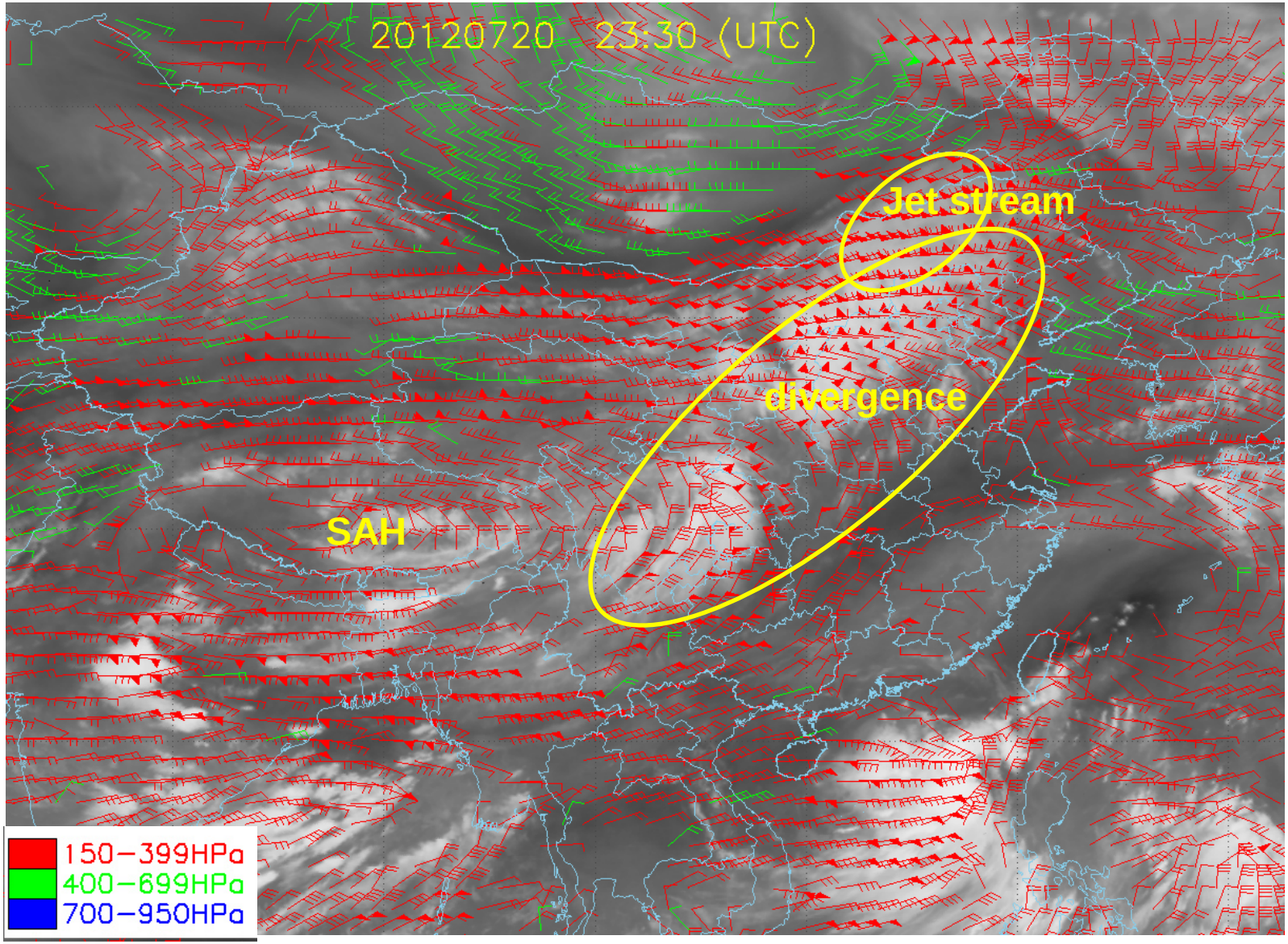
Relative Humidity

The dry air went into the wet air at about 500mb, it trigger the convection

FY-2 VIS image movie form 00:00 to 10:00,
July 21st, 2012 (UTC)

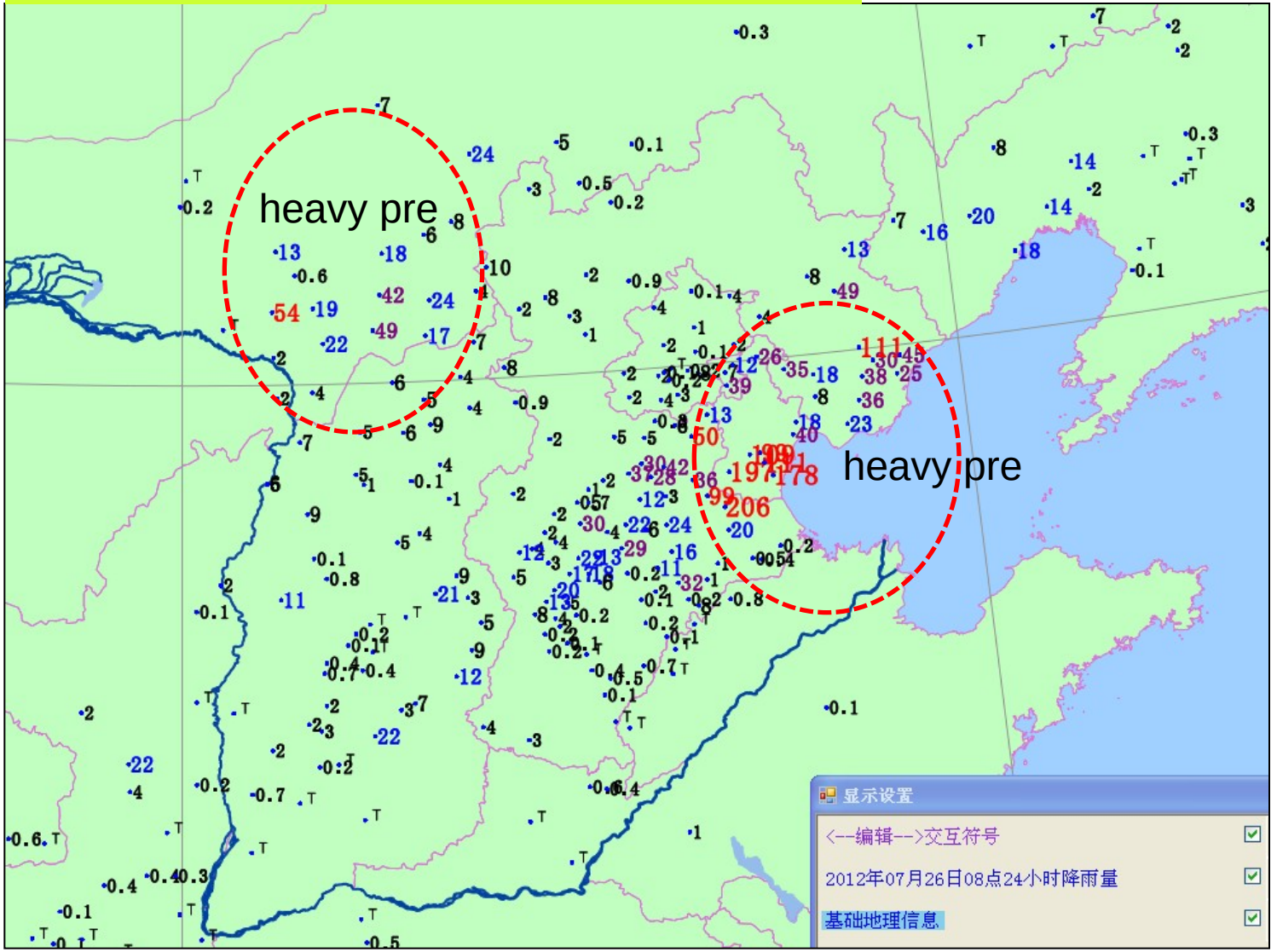


IR3 image and AMVs at 23:30, July 20th

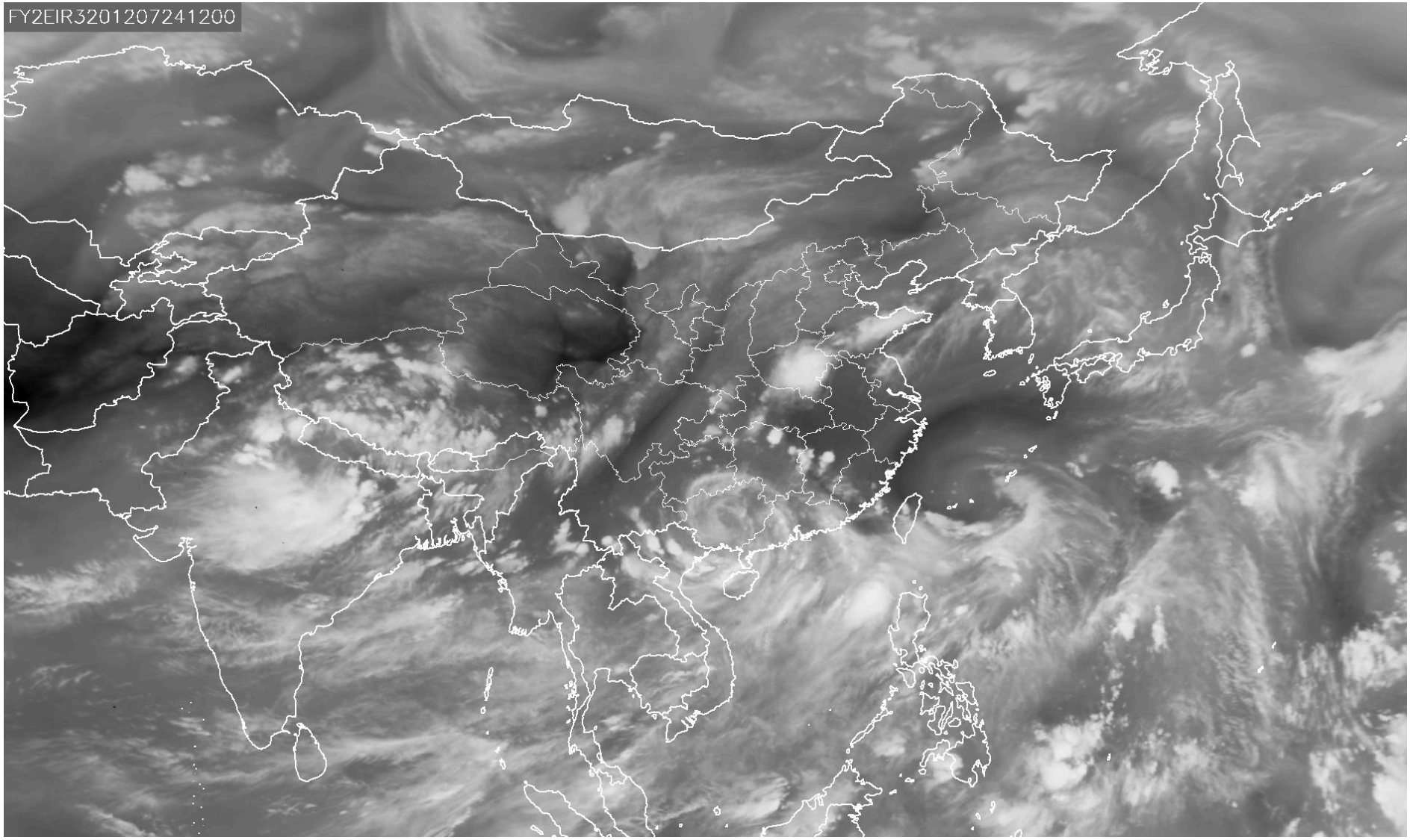


Rainfall in North China, July 25th , 2012
The precipitation is small in Beijing

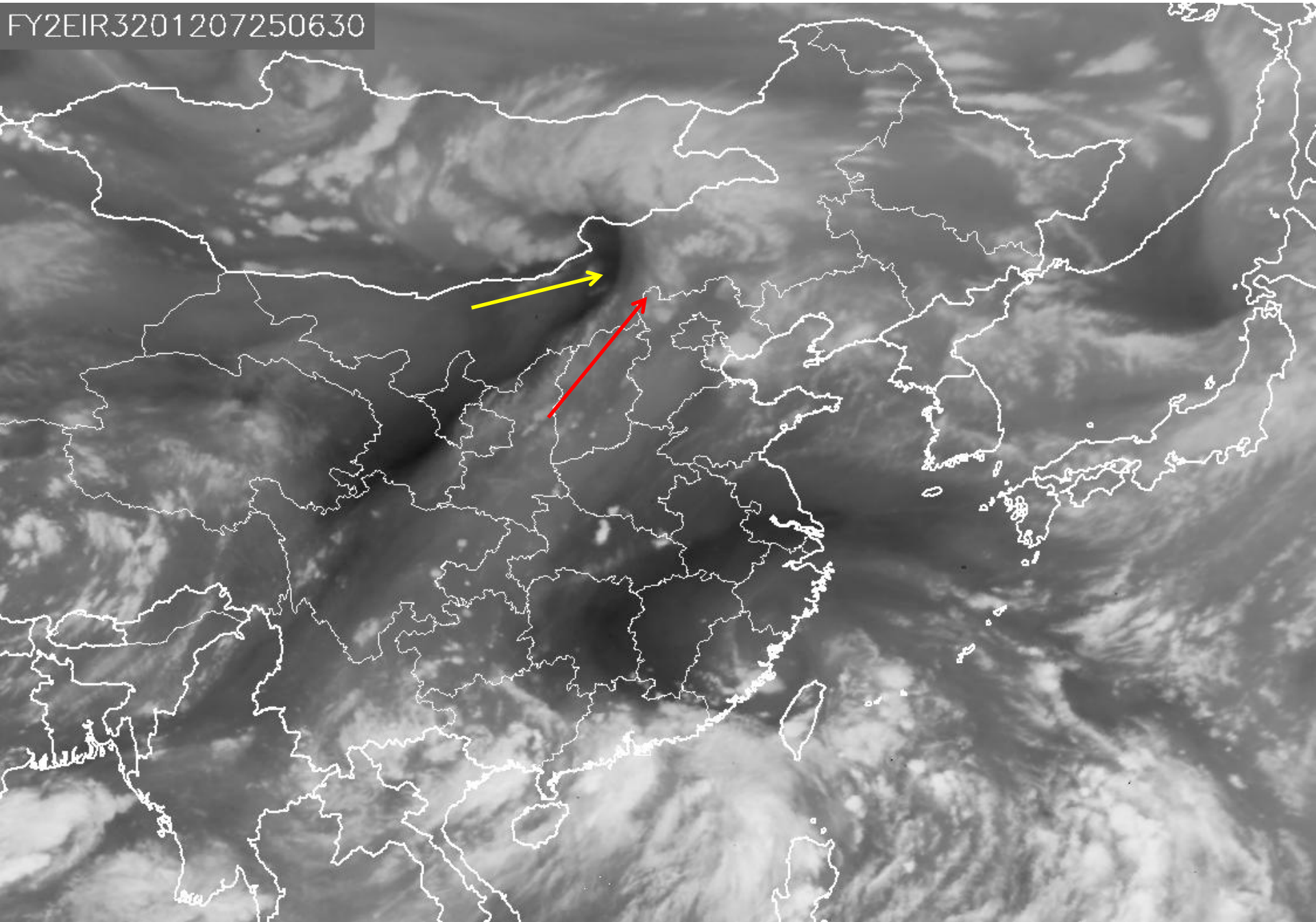
24h precipitation from 25th to 26th July, 2012

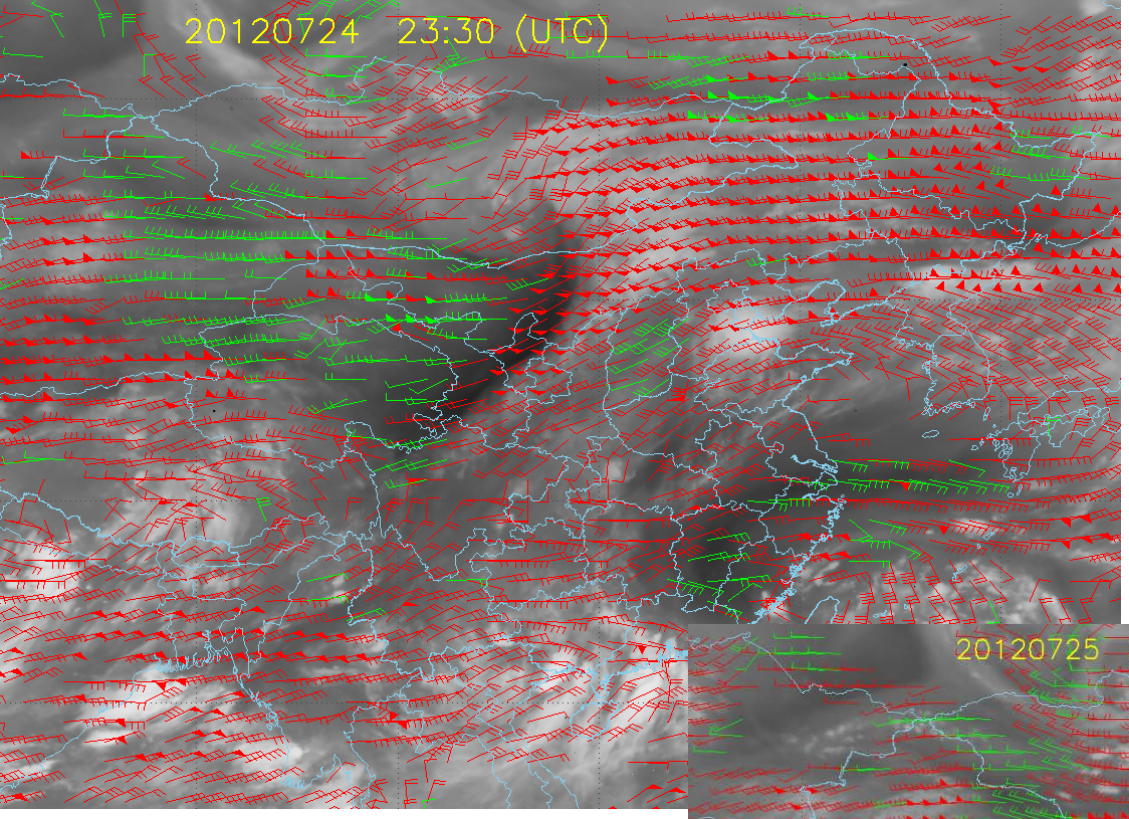


FY-2E IR3 movie
From 24th 12:00 to 25th 05:30 (UTC), July, 2012

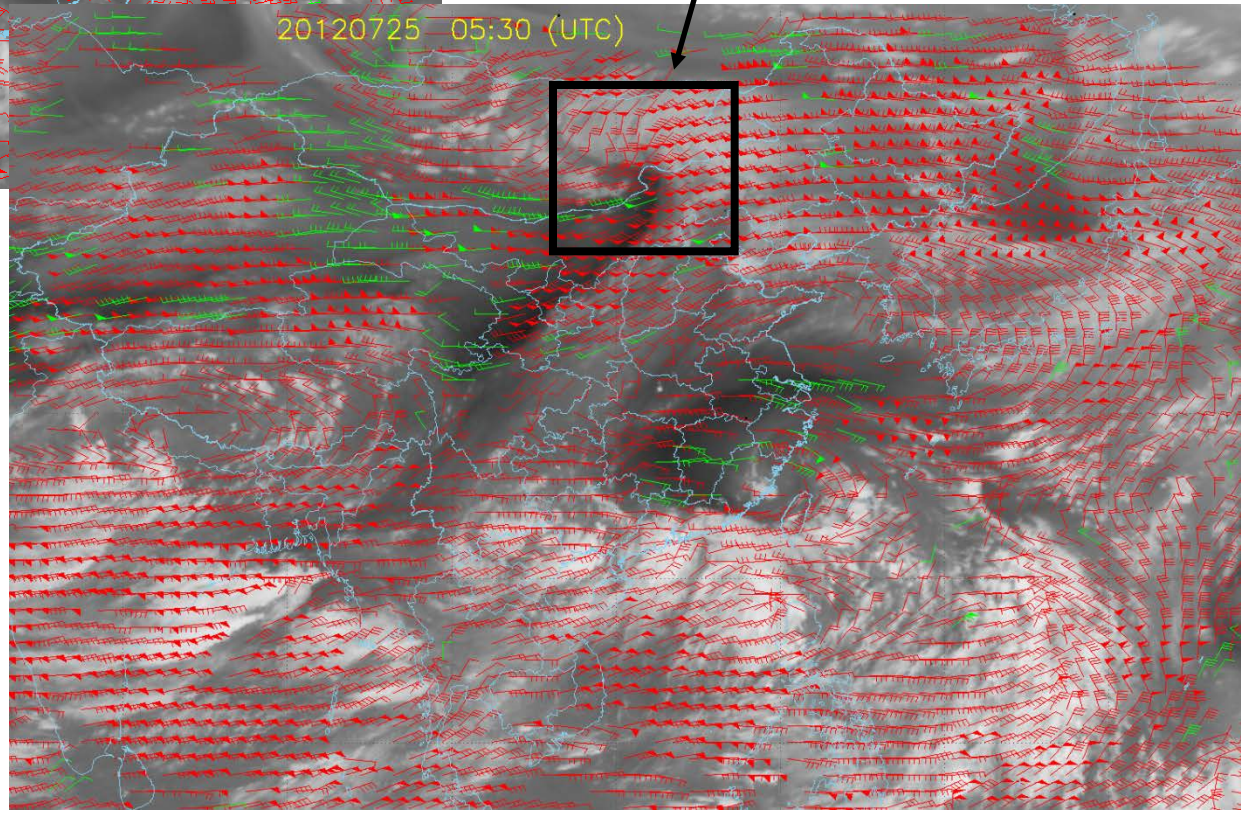


FY-2E IR3 image at 06:30（UTC）,July 25th ,2012

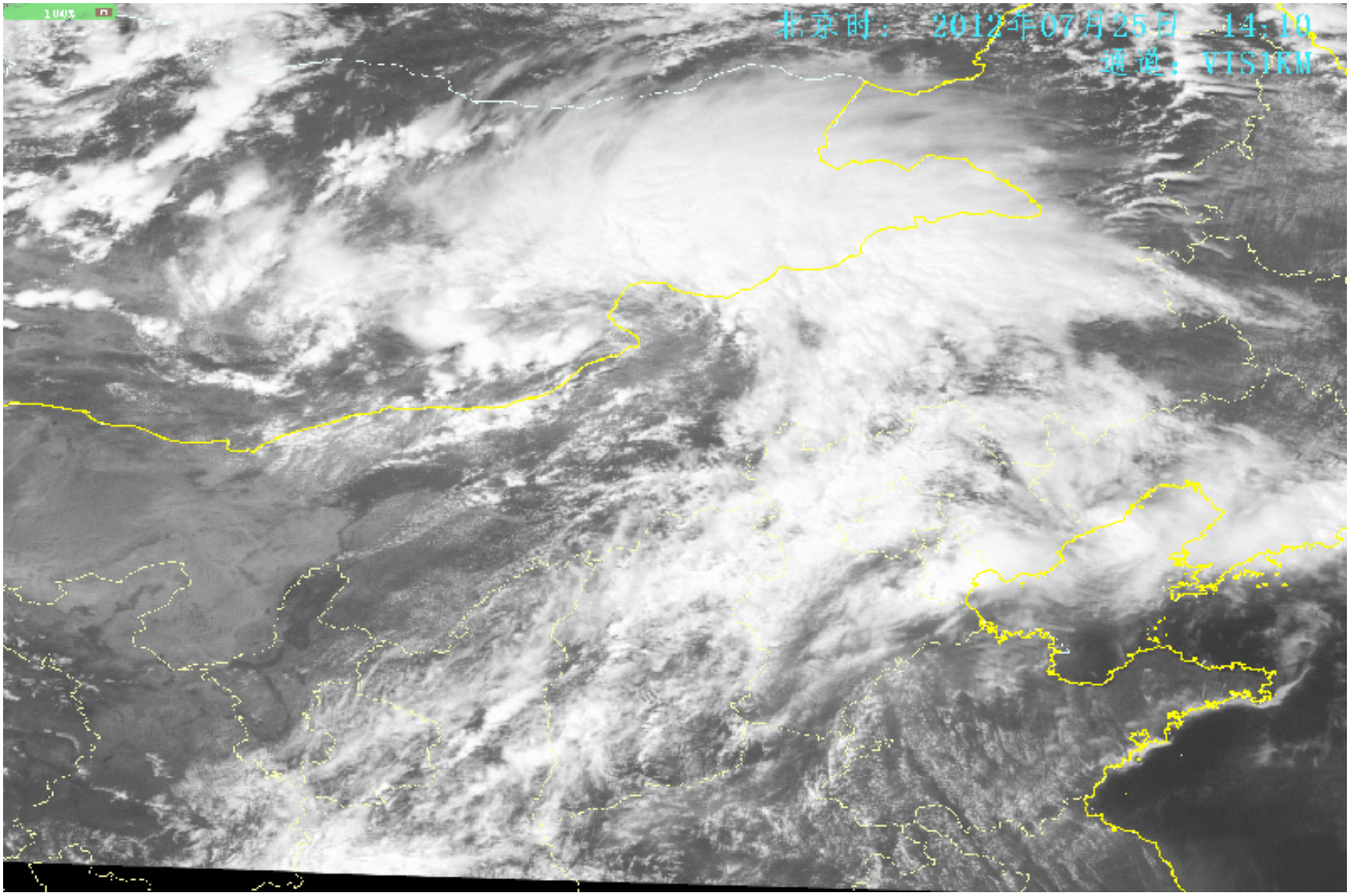




Wind direction and the cloud boundary has intersection angle.



FY-2F satellite VIS movie in regional scan mode
intervals at 6 minutes
July 25th,2012 06:10-07：20 (UTC)



summary

WV image： the upper-troposphere atmosphere circulation, Synoptic-scale weather system, cold air activity, north-western Pacific subtropical high, the upper-troposphere cirrus outflow, et.al.

AMV：the upper-troposphere atmosphere circulation, divergence, et.al.

Thanks