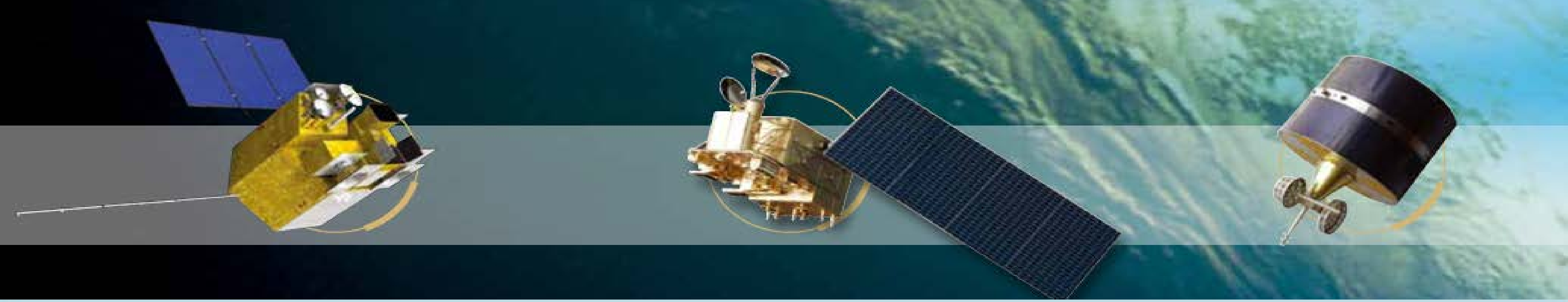

A method to distinguish the hail and rainstorm cloud using Microwave Sounder data

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National Satellite Meteorological Center,
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The Sixth Asia/Oceania Meteorological Satellite Users' Conference
Tokyo, Japan, 9-13 November 2015

Outlines

- Background
- Data and model
- Sensitivity simulation of the microwave radiation characteristics
- The method to detect convective cloud
- The method to distinguish the hail and rainstorm cloud
- Summary

Background

- Hail and rainstorm are two kinds of important disasters caused by severe convective storms, and effective monitoring and warning of them is the key point to weather forecasting.
- Due to the similar feature of the hail and rainstorm cloud, the typical observation using visible and infrared channels is difficult to distinguish them . The microwave sounders carried on NOAA and FY-3 can penetrate high level cloud and get inner characteristics of convection .
- The observation results of these channels are sensitive to ice particles concentration and altitude variation, so it is suitable and beneficial using these data to detect the difference between the hail and rainstorm.

Model and Data Used

- NOAA-16/17/18 AMSU-B data
- FY-3B/C MWHS data
- SA band Radar data
- Lightning data (SAFIR)

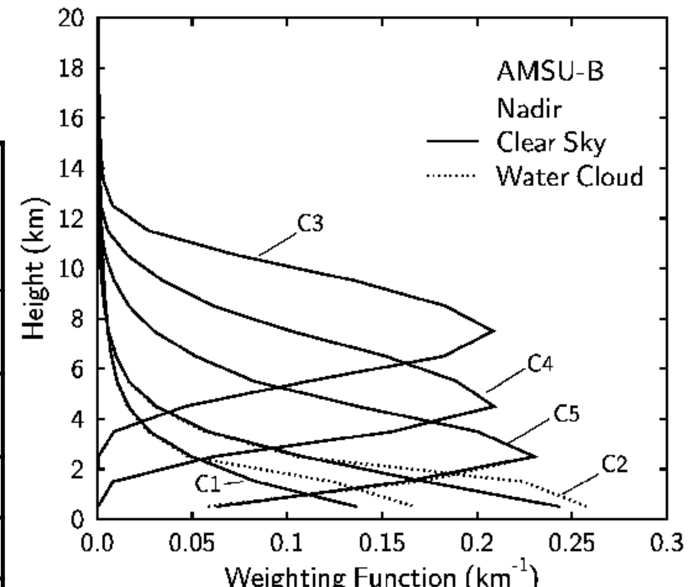
- **VDISORT(Vector Discrete Ordinate Radiative Transfer)**
- **MM5 model**
- **Cloud Resolving Model (cumulus cloud)**

NOAA: AMSU-B

- AMSU-B is a five-channels microwave sounder onboard NOAA-15/16/17/18 with two channels centered nominally at 89 and 150 GHz, and the other three channels centered around the 183.31 GHz water vapor line . The purpose is to measure radiation from a number of different layers of the atmosphere in order to obtain global humidity profiles.
- Absorption, radiation and scattering effects due to water vapor and liquid water particles, Weighting function varies according to the different channel.
- Spatial resolution:16km

AMSU-B Instrument Characteristics

Channel Number	Center Frequency (GHz)	Main absorption gas	purpose	Height of weighting function	Equivalent Noise (K)	polarization
1	89.0	H_2O	surface properties、precipitation	surface		V
2	150.0	H_2O	surface properties、precipitation	surface	0.68	V
3	183.3±1	H_2O	Water vapor	400hPa	0.57	
4	183.3±3	H_2O	Water vapor	600 hPa	0.35	
5	183.3±7	H_2O	Water vapor	850hPa	0.30	V

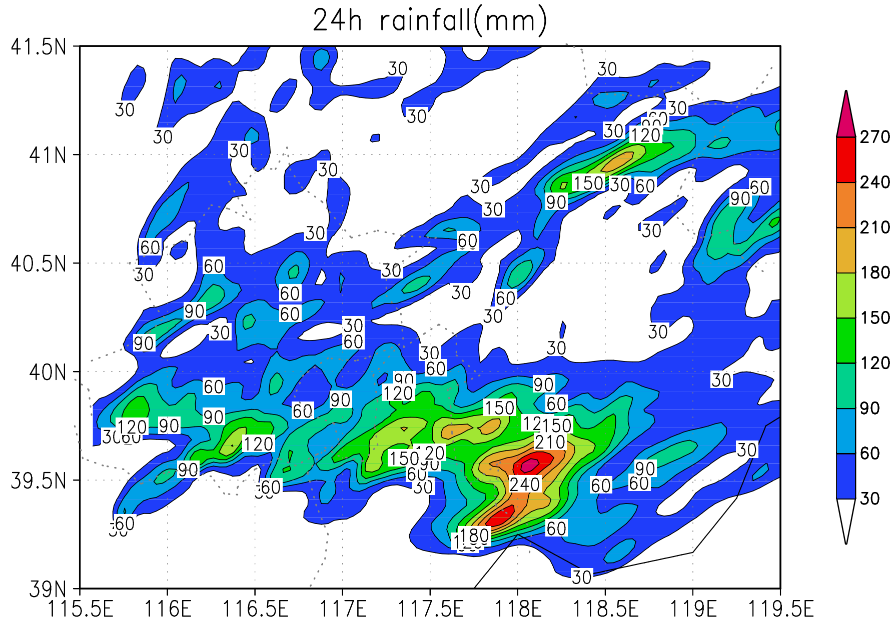


Clear-sky and water cloud weighting functions for the AMSU-B channels

The peak heights of channel 3,4,5 is 8,5,3 km respectively

Sensitivity simulation of the microwave radiation characteristics

- Sensitivity to hydrometeor water contents
- Sensitivity to the size of ice particles
- Simulation to altitude response of ice particles



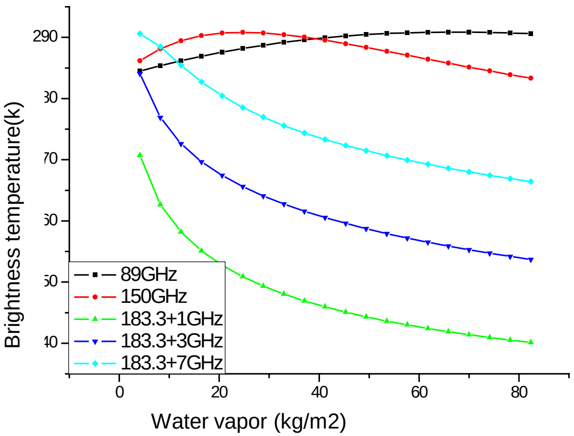
case of a heavy rainstorm around Huaihe river

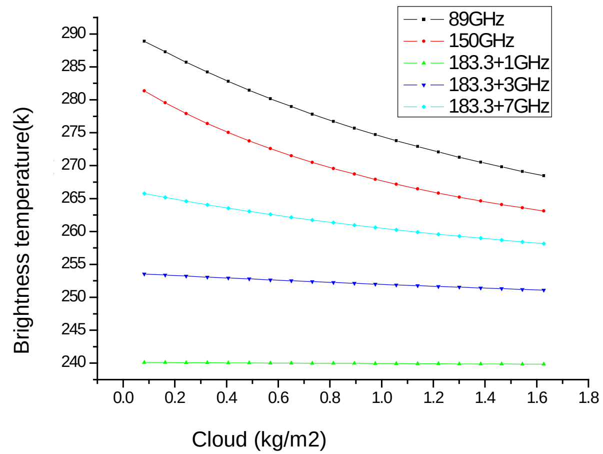
MM5(vertical profile of water content) →VDISORT model

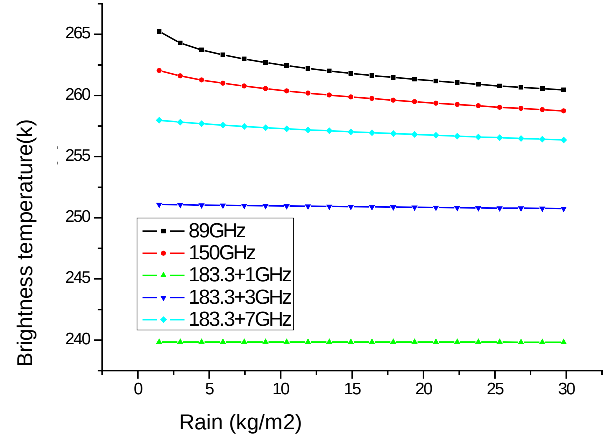
Resolution: 3km

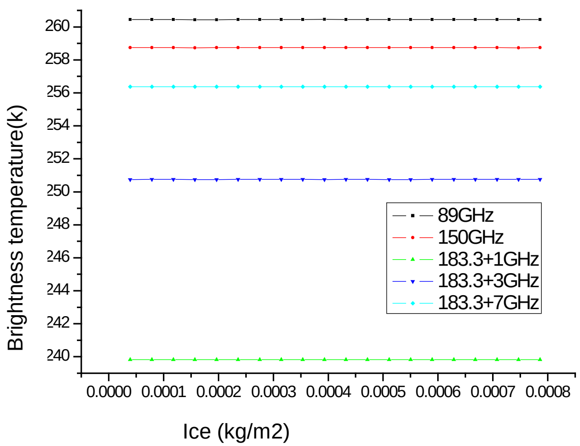
The model used 20 vertical levels with the top of model at 100hPa.(an interval of 50hPa)

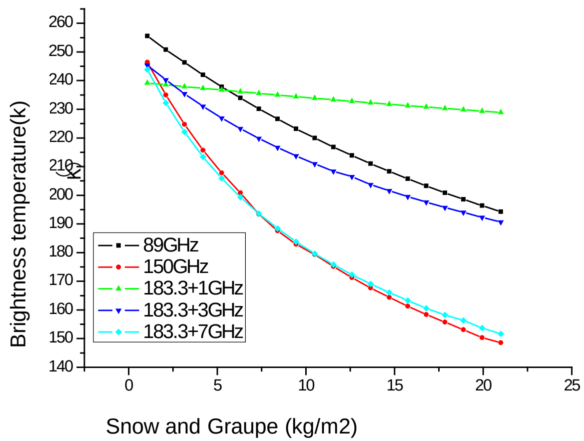
Sensitivity to hydrometeor water contents







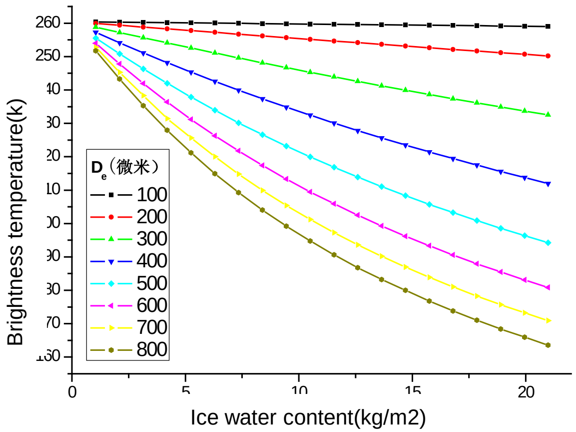




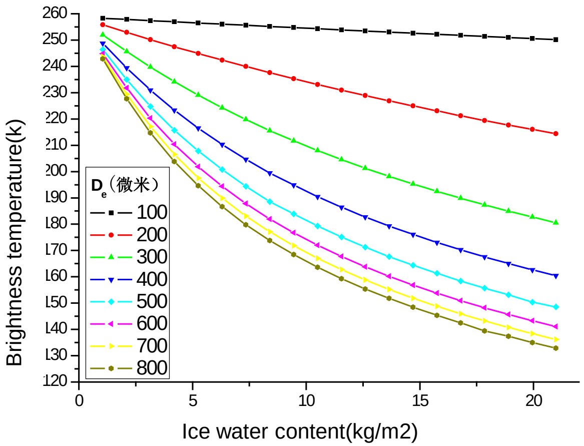
- The brightness temperature of water vapor channels shows depression with the water vapor increasing, these mainly result from water vapor absorption.
- The brightness temperature depression influence from the cloud ,rain and ice is not obviously.
- Snow and graupe: Scattering

The brightness temperature going down with the content increasing, the three water vapor channels around 183 GHz show more obvious difference with each other.

Sensitivity to the size of ice particles



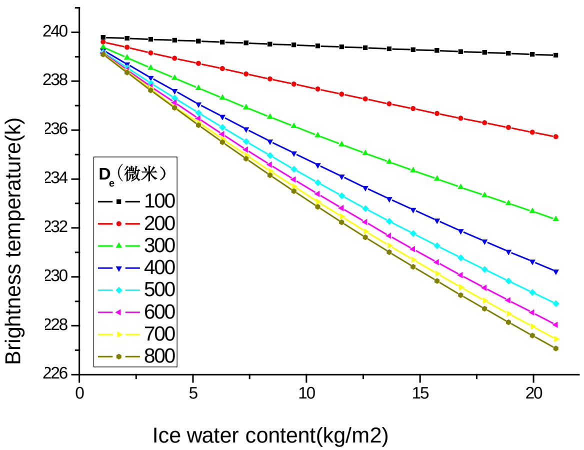
Channel1(89GHz)



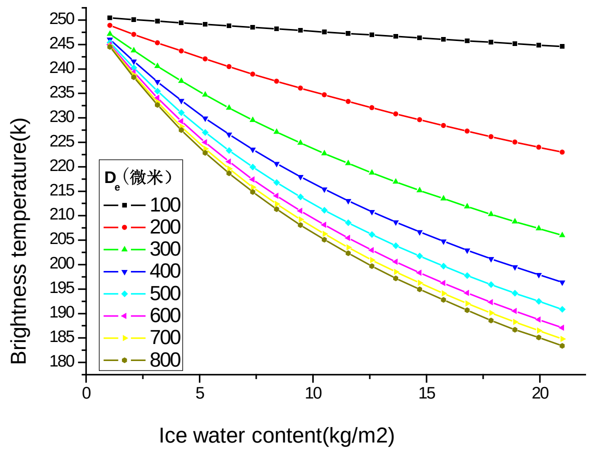
Channel2(150GHz)

For the highest level observation channel, the brightness temperature monotonous decreasing.

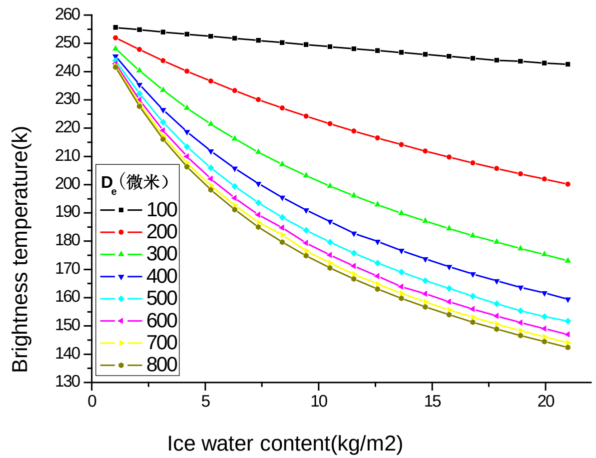
But for the middle and low level channels, with the particles size raising, the depression tendency slowly, due to the particle amount adding, the microwave penetrability reducing, the weighting response level changing to higher.



Channel3(183.3±1GHz)

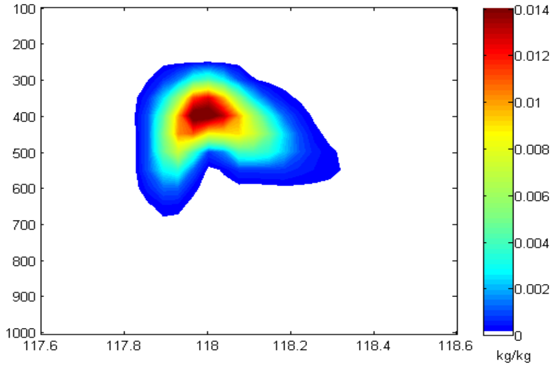


Channel4(183.3±3GHz)

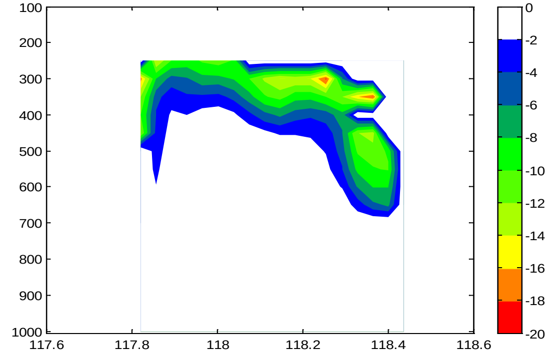


Channel5(183.3±7GHz)

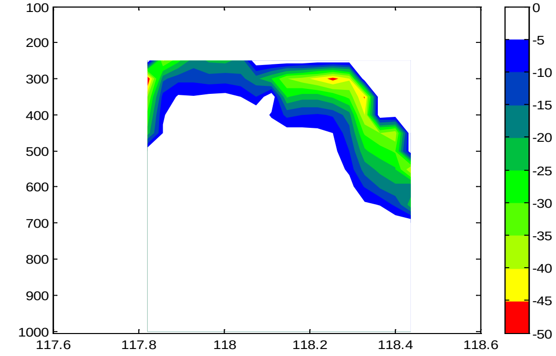
Simulation to altitude response of ice particles



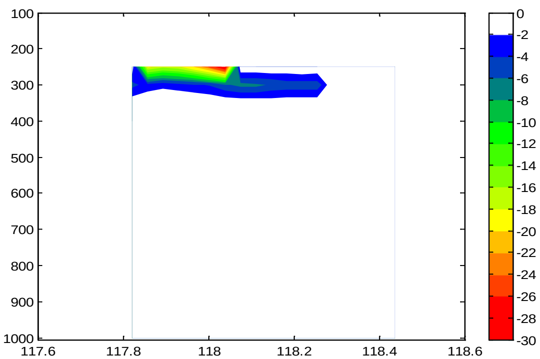
The distribution of ice particles



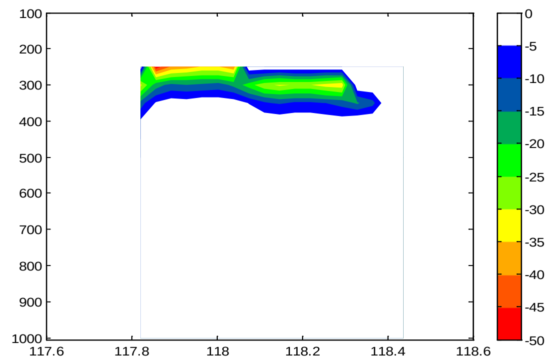
Channel1(89GHz)



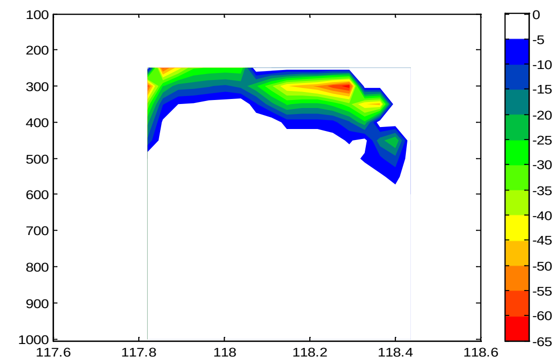
Channel2(150GHz)



Channel3(183.3±1GHz)



Channel4(183.3±3GHz)



Channel5(183.3±7GHz)

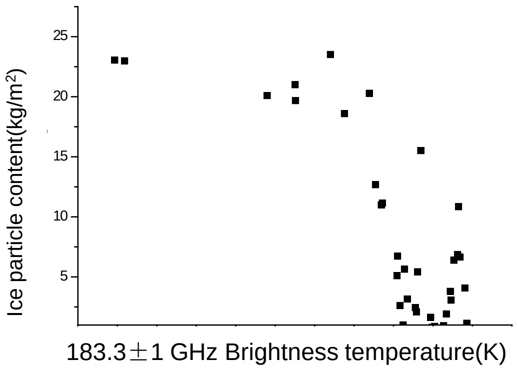
$$J = \frac{\Delta T_B(\nu)}{\Delta w}$$

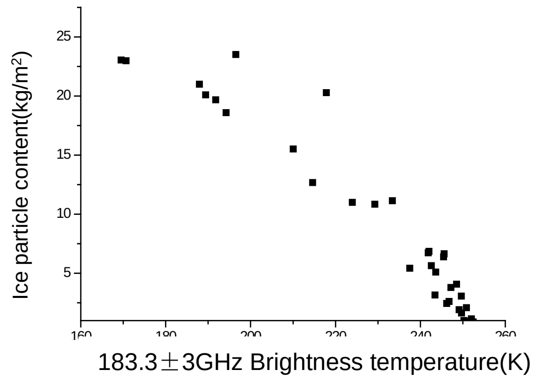
The detectable altitude show evident difference at convective core and around the core, More strong convective area, more shallow detecting level.

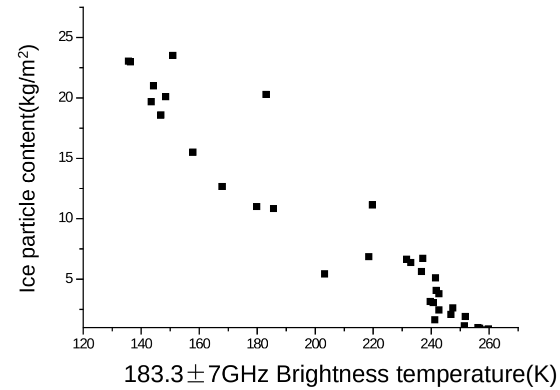
This difference performance at channel5(183.3±7GHz) is the most prominent. And at the convective core, all channels show almost the same altitude response.

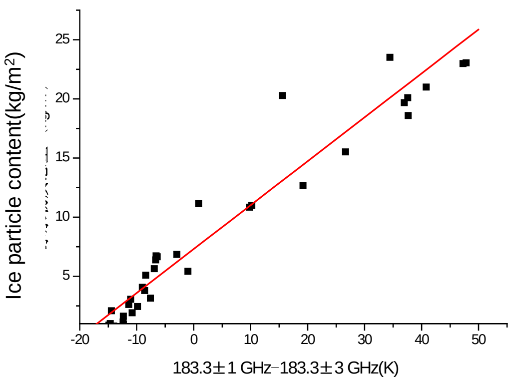
The method to detect convective cloud

Correlation between simulated brightness temperatures and ice particle contents

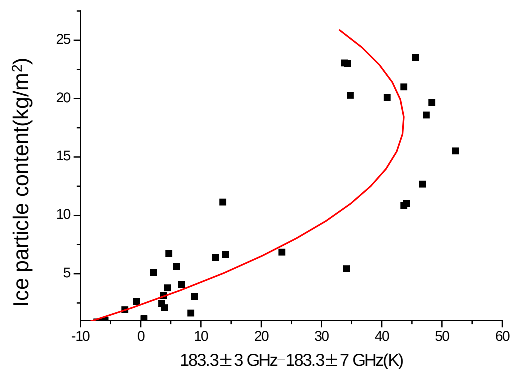




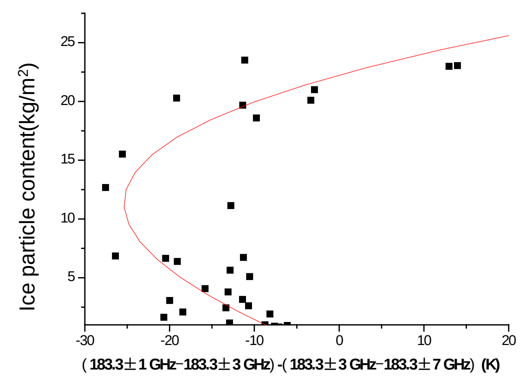




ΔT_{34}(183.3±1-183.3±3)



ΔT_{45}(183.3±3-183.3±7)

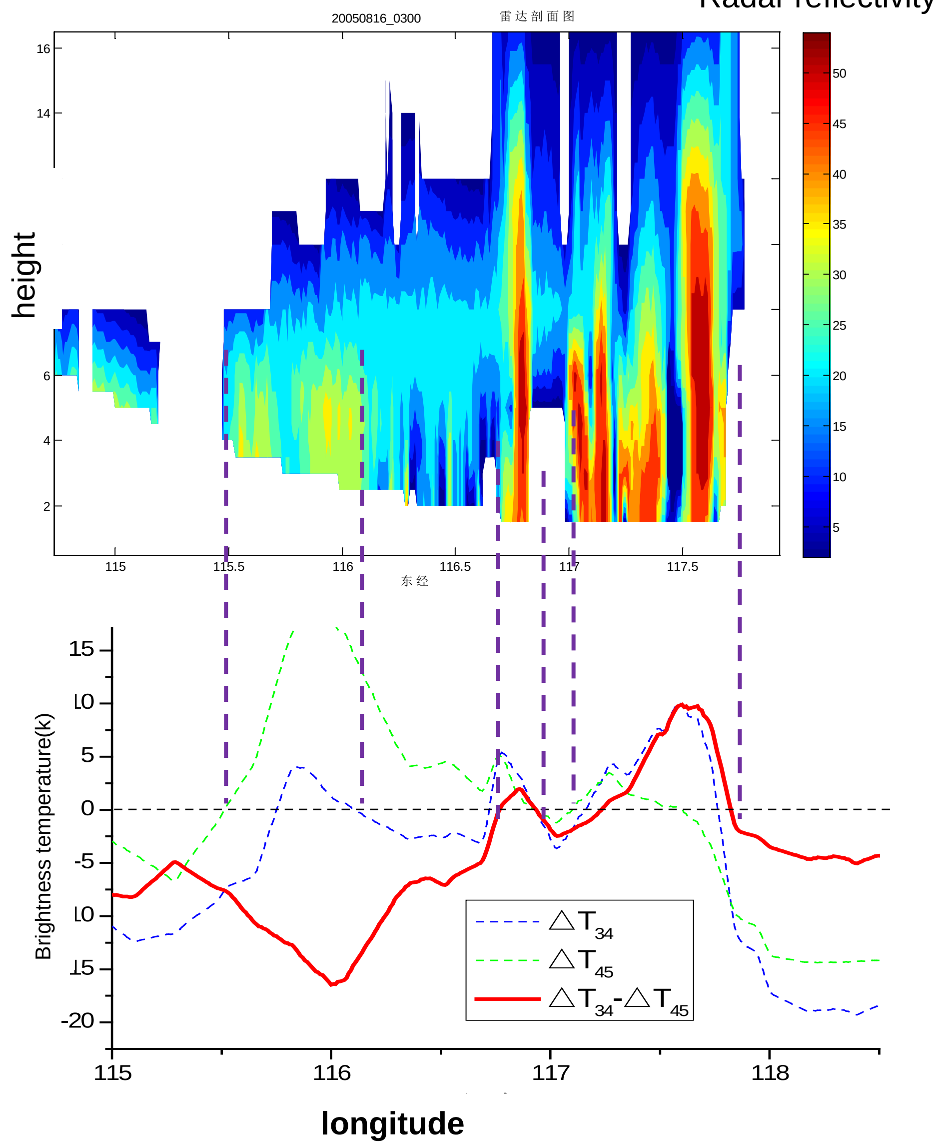


ΔT_{34}-ΔT_{45}

With the particle contents raising, the difference between channel 3 and channel 4 is linear raising, and the difference between channel 4 and channel 5 reverses when the particle contents reach more than 15kg/m2, and the same reversal tendency shows while we use the difference of all the three water vapor channels.

Analyses of convective cloud by AMSU-B observation

Radar reflectivity



Case of August 16 ,2005

The method of convective cloud detection using AMSU-B data

Convective cloud：

$$\Delta T_{34} = (T_{183.3\pm1} - T_{183.3\pm3}) > 0 \quad (1)$$

$$\Delta T_{45} = (T_{183.3\pm3} - T_{183.3\pm7}) > 0 \quad (2)$$

Severe convective cloud（meet the criteria of convective cloud）：

$$\Delta T_{34} - \Delta T_{45} = (T_{183.3\pm1} - T_{183.3\pm3}) - (T_{183.3\pm3} - T_{183.3\pm7}) > 0 \quad (3)$$

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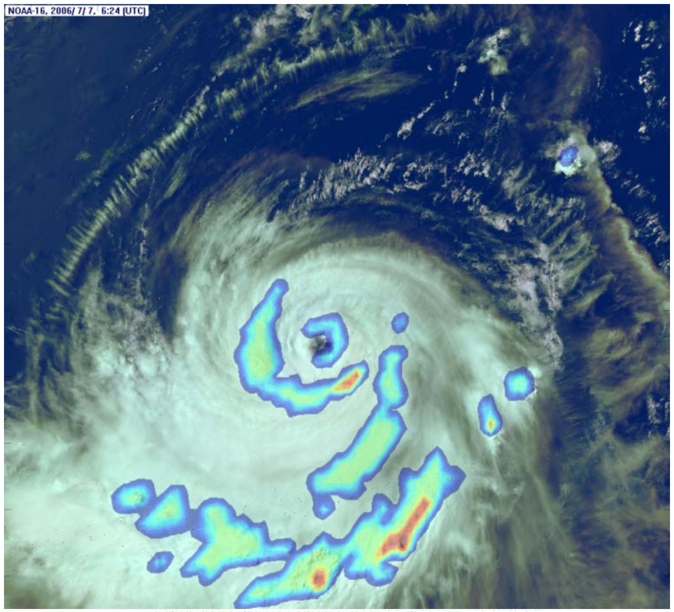
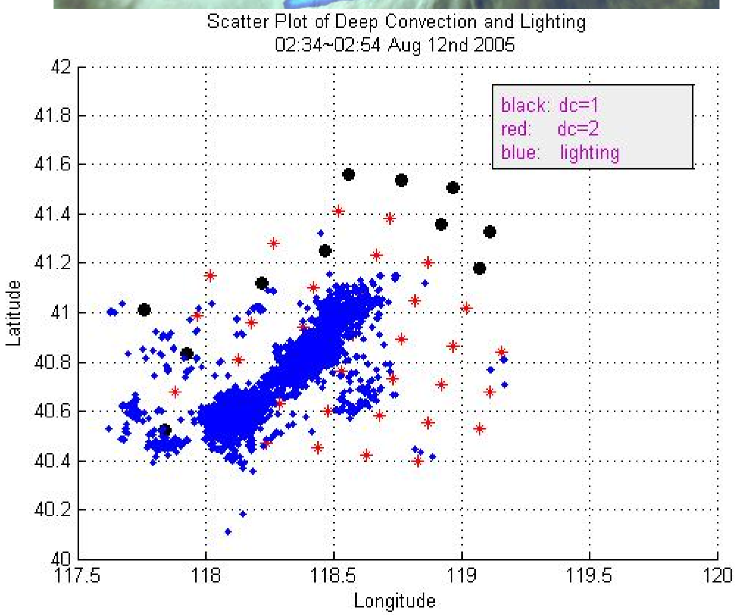
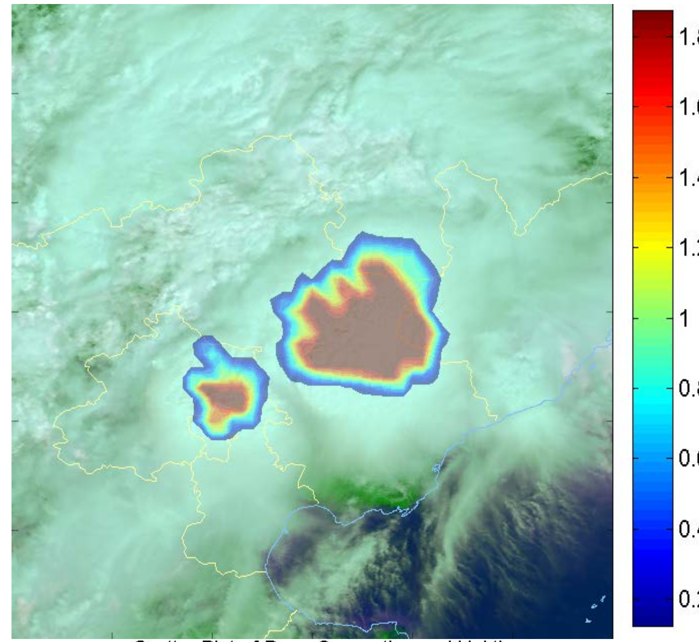
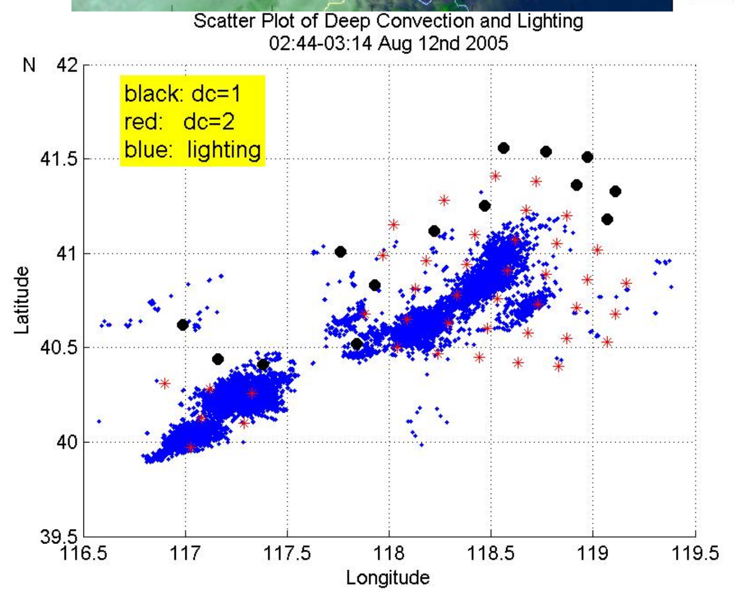
Results and validations



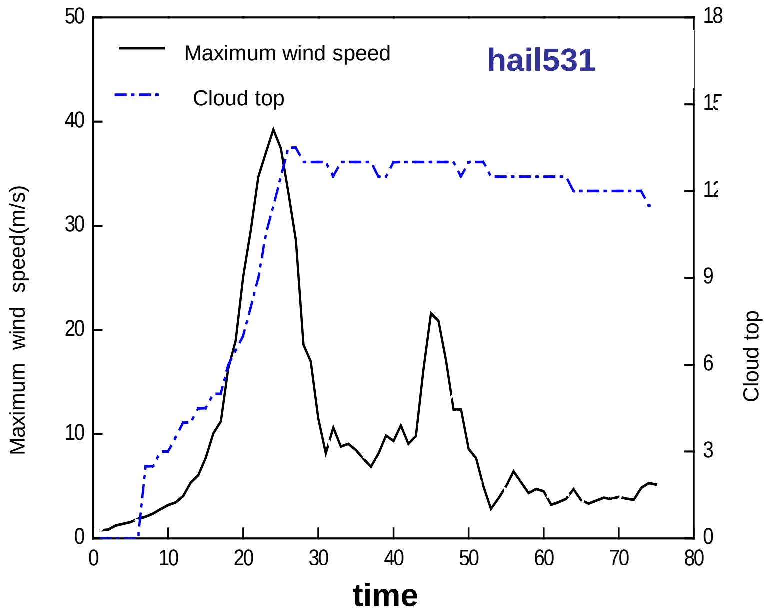


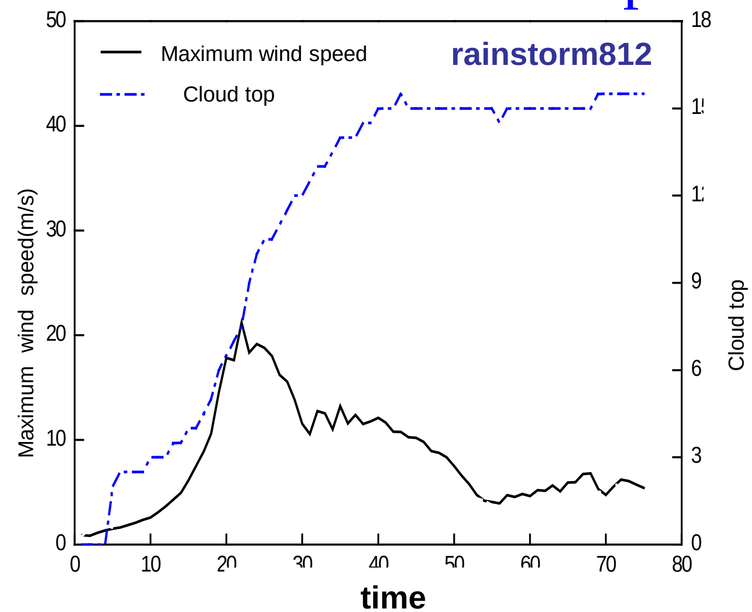




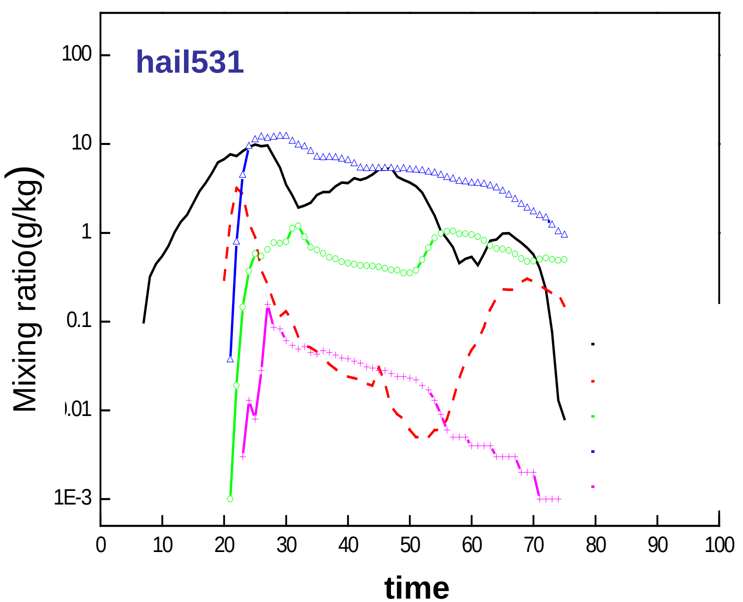
The method to distinguish the hail and rainstorm cloud

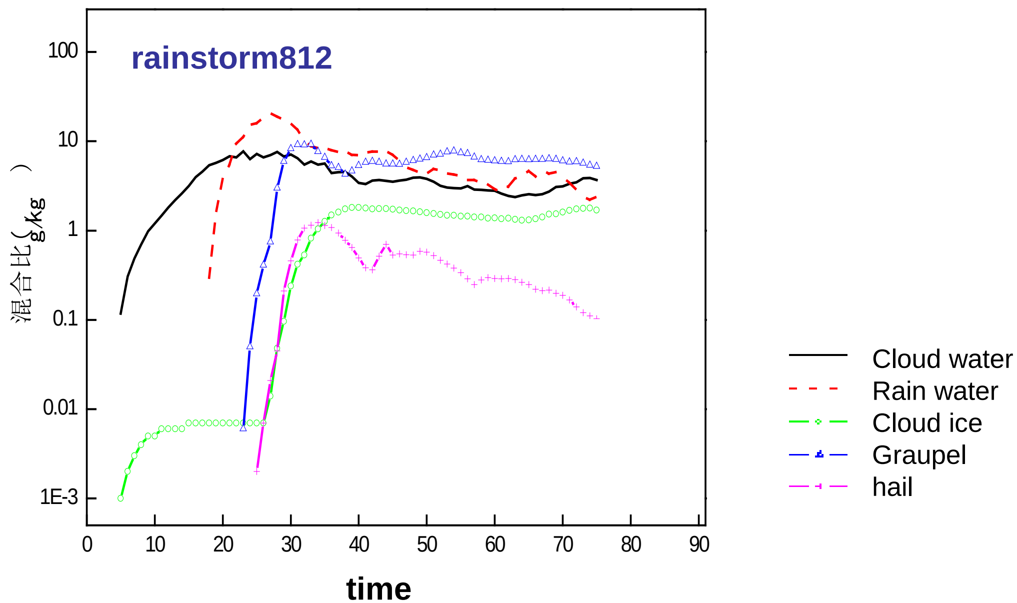
Simulations of the hail and rainstorm cloud-Temporal change





The wind speed and mixing ratio have rapid and severe variation in hail cloud, and these parameters change relatively flat in the rainstorm cloud.





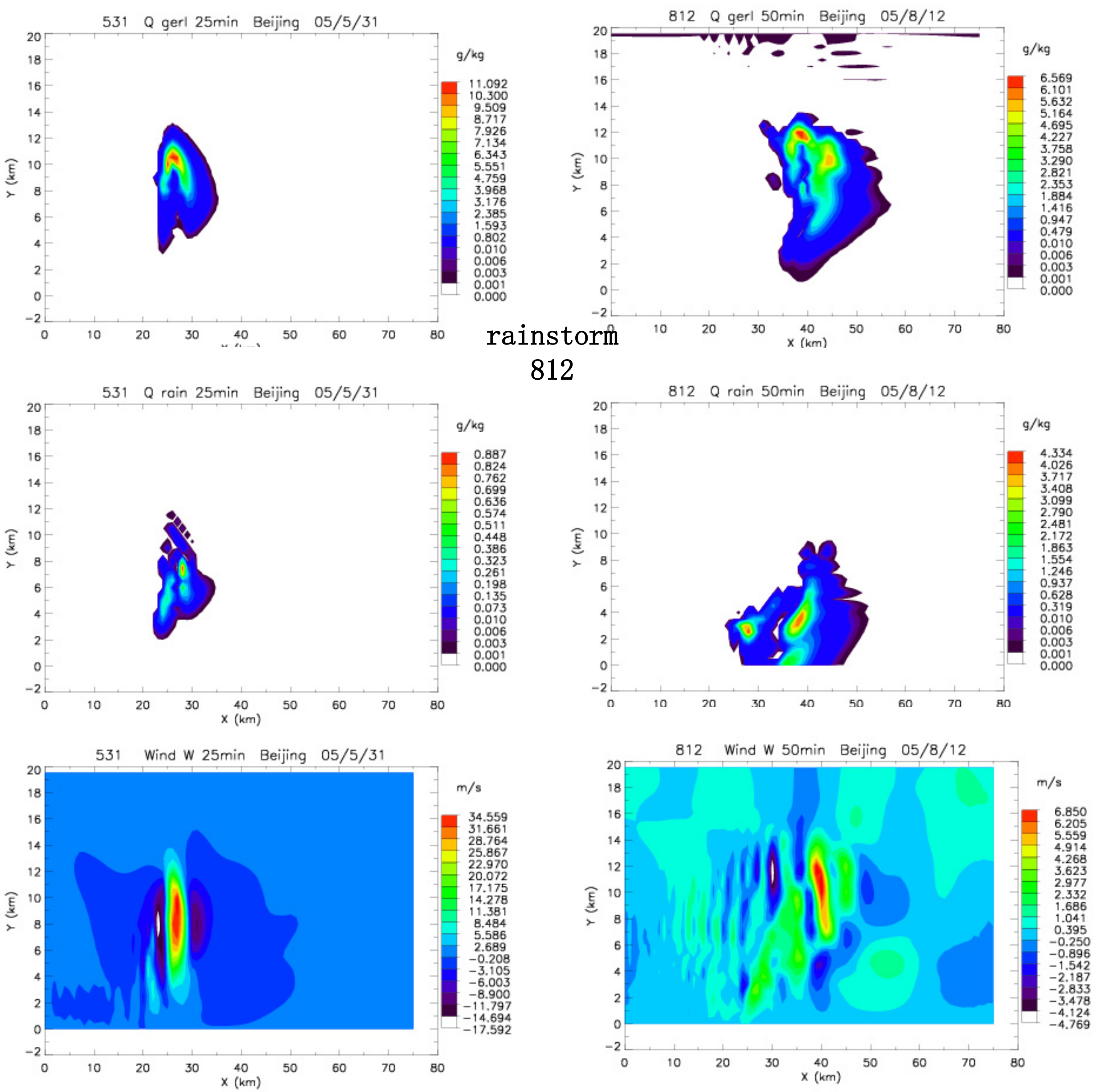
Simulations of the hail and rainstorm cloud-Space distribution

Hail

531

rainstorm

812



The ice particles distribution concentrate at the hail core and higher altitude, as the dispersion distribution at rainstorm.

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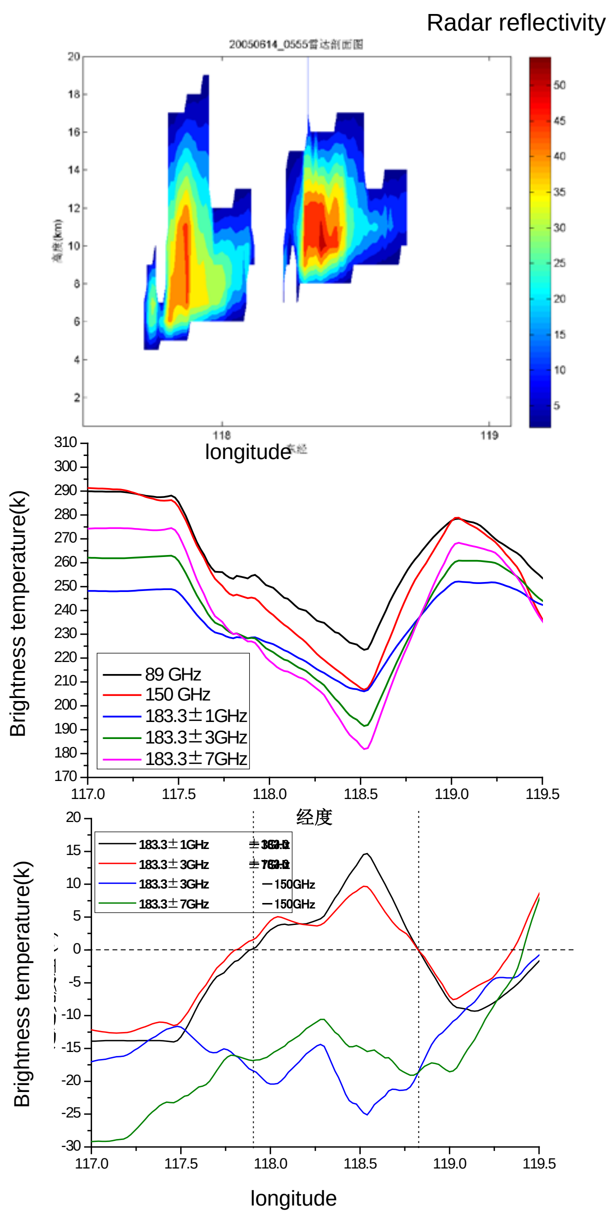
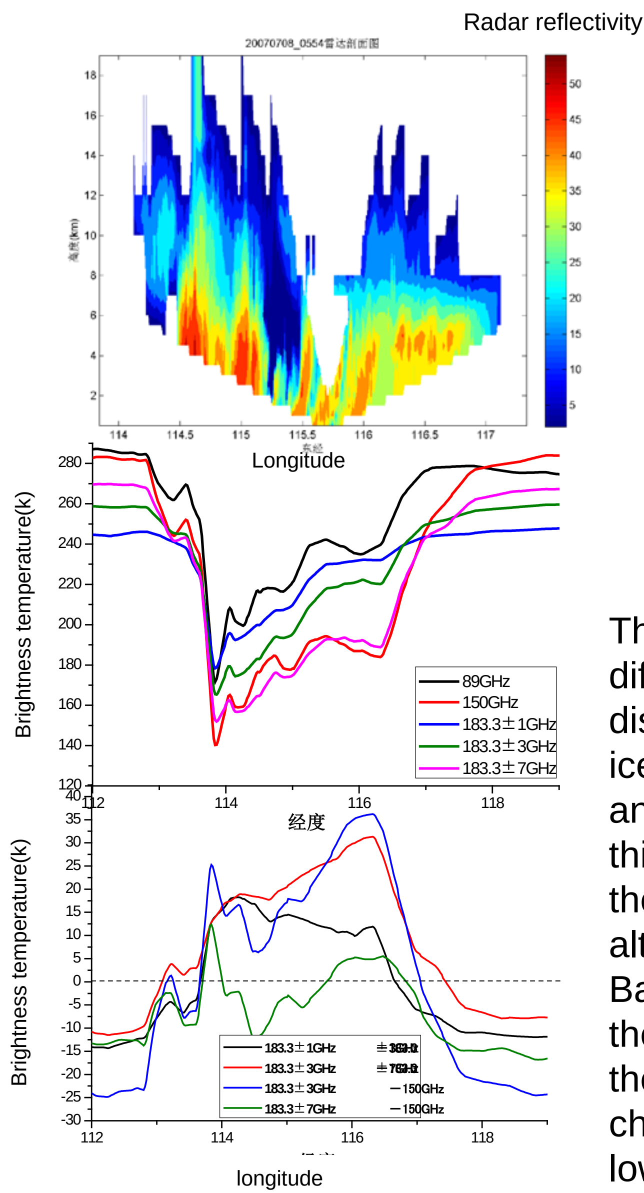
Hail and rainstorm cloud: observation

NSMC



Hail 614



rainstorm708

Criteria to distinguish the hail and rainstorm:

Hail cloud:

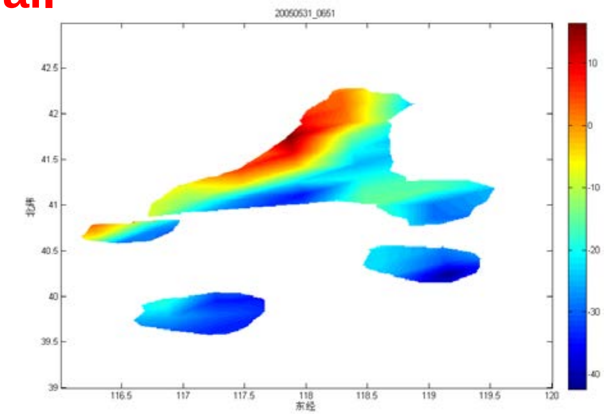
when the area meet the criteria

$$T_{183.3\pm3} - T_{150} < 0$$

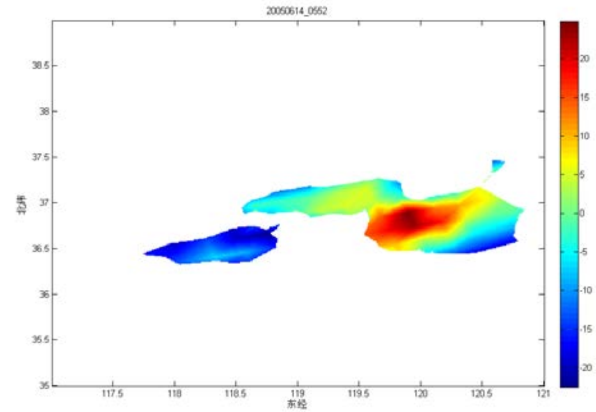
more than 70%.

The mainly reason is the difference of the ice particles distribution. In the hail cloud, the ice particles are concentrated and located at higher altitude, this form the scatter bam, and all the AMSU-B channels response altitude at approximate level. Base on the mie scattering theory, the higher frequency channel has the higher scattering ratio. So the channel 4 brightness temperature lower than channel 2.

(1) Hail

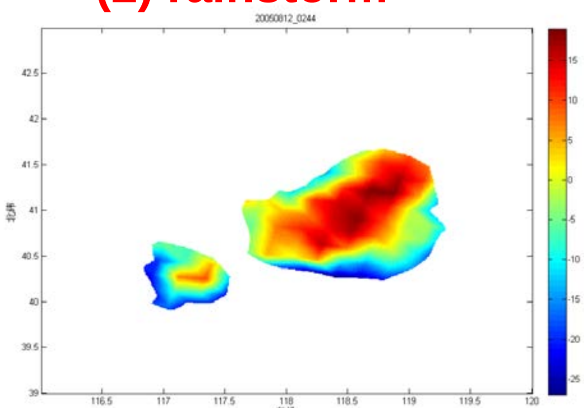


May 31, 2005,Beijing

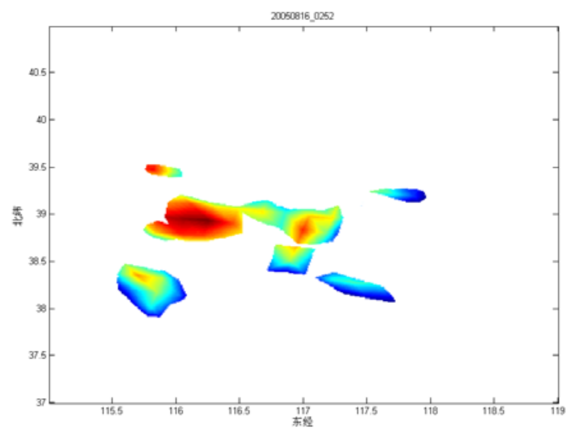


June 14,2005,Shandong

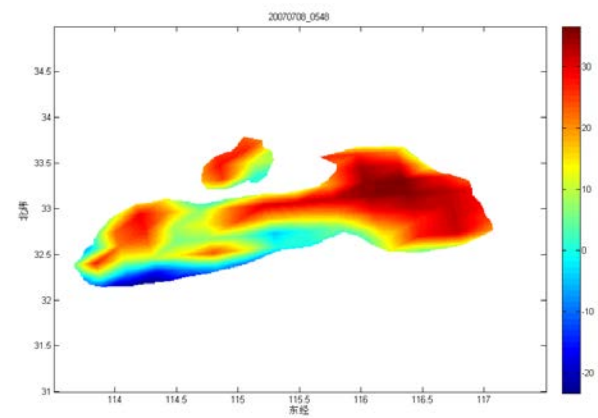
(2) rainstorm



August 12, 2005,in North China



August 16, 2005,in North China



July 8,2007,in Huaihe river basin

Same method using FY-3 B/C MWHS

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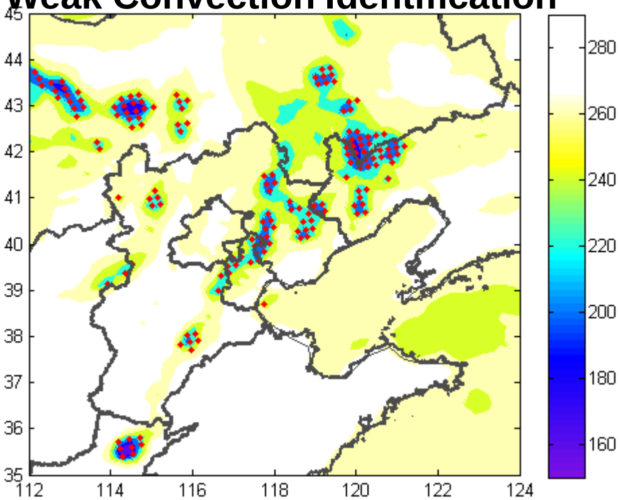
NSMC

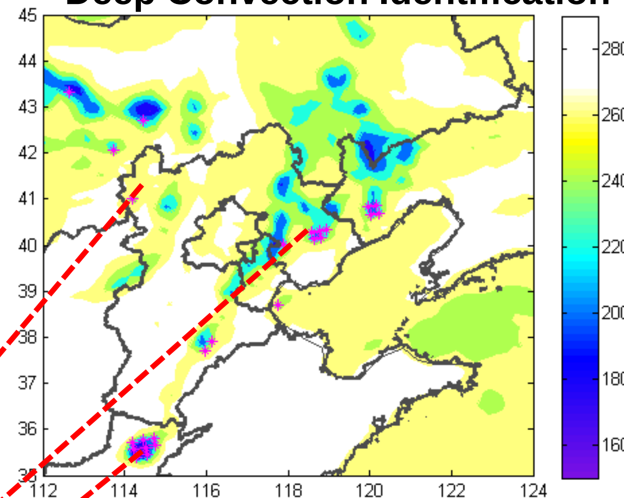
A Convection Case June 10th, 2015 Hua Bei Area, China

04:51 (UTC)

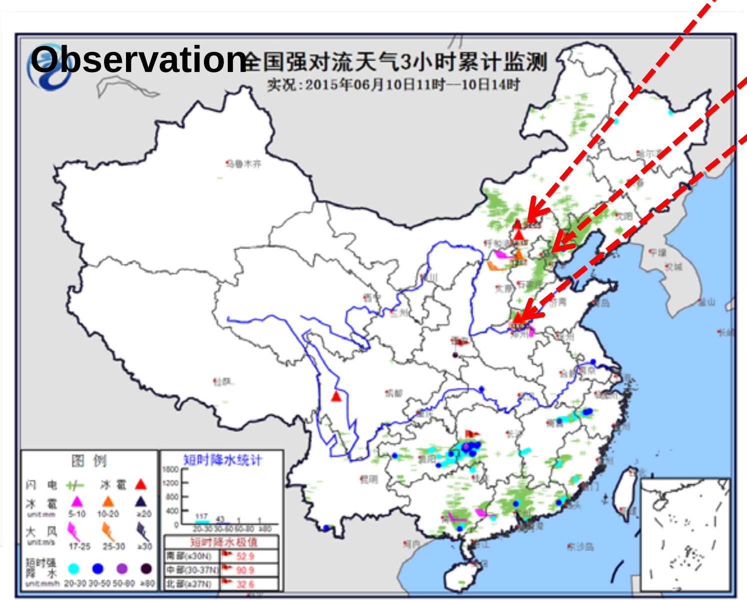
Weak Convection Identification



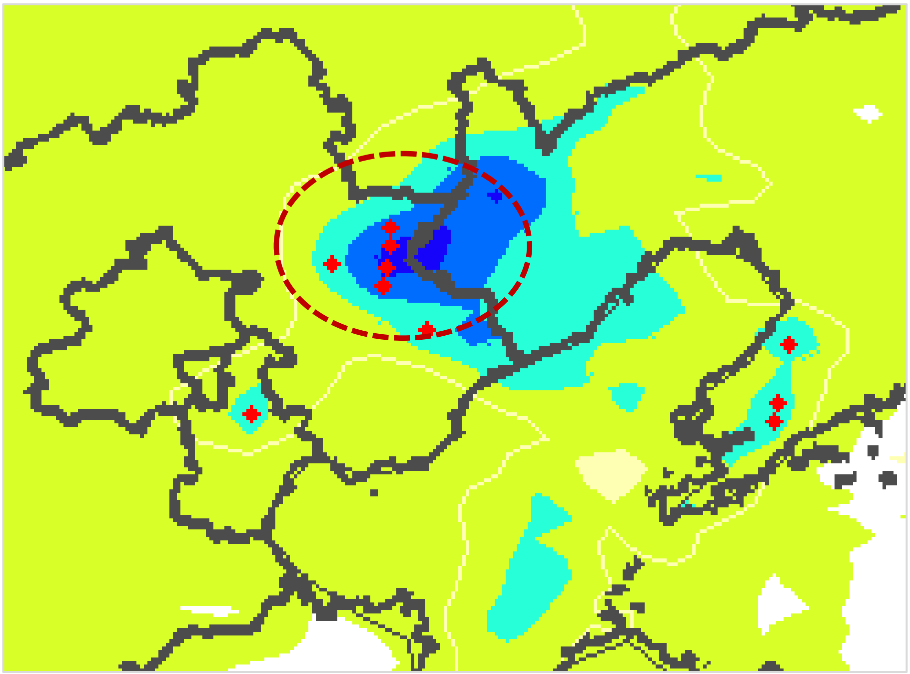
Deep Convection Identification

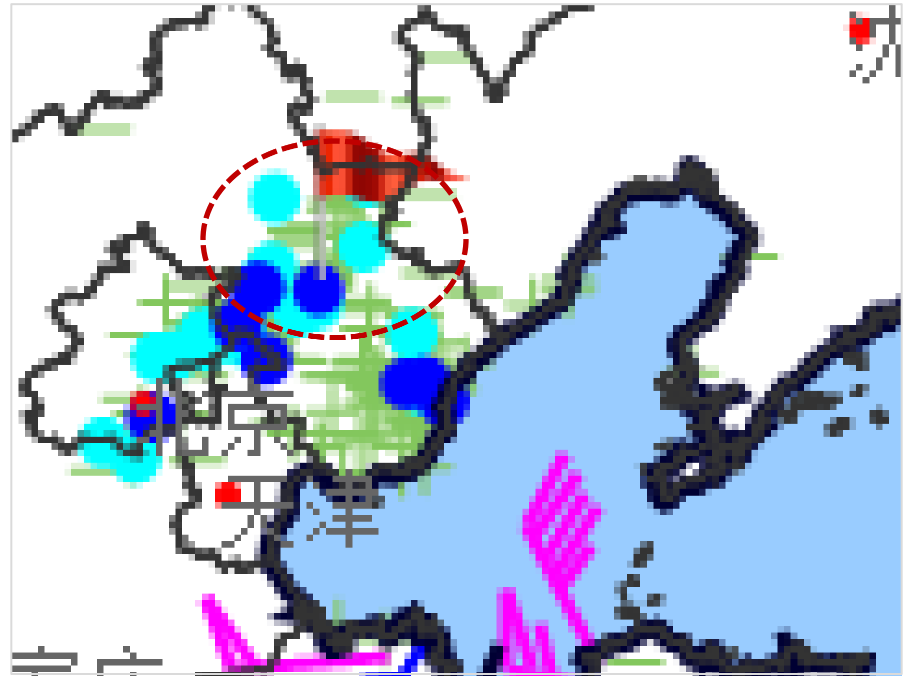


Observation



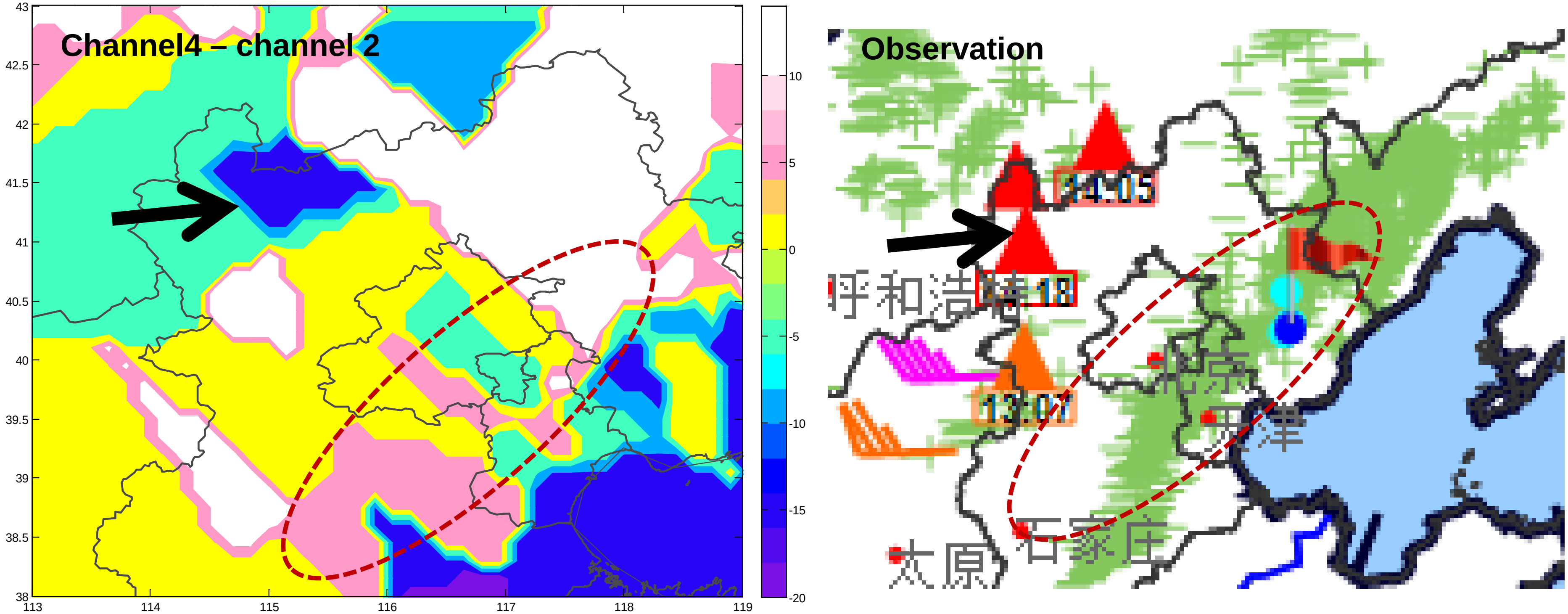
Convection identified results are well fitting with ground observation, three convection centers distribution, one is at northwestern of Beijing, another is at the northwestern of Tianjin, and the third is at southern of Hebei province.





The convection identified results are well fitting with rainstorm center

Distinguish Rainstorm and Hail



- The warm color directed rainstorm happened, the red circle area.
- Cold color directed hail happened, the black arrow area.

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Summary

NSMC

- The observation of AMSU-B channels shows high sensitivity with ice particles concentration. The correlations of the three water vapor channels （183.3±1, 183.3±3, 183.3±7GHz）can be applied for the convection intensity estimation.
- It shows that the concentration of ice particles in hail system is more than that in rainstorm system by simulation and radar observation. Meanwhile， the high concentration of ice particles is mainly distributed in the layers up than 6km. For microwave observation，the reducing rate of brightness temperature for the water vapor channels （183.3±1, 183.3±3, 183.3±7GHz） is higher than that for the window channel （150GHz）in hail system.
- Methods to distinguish hail and rainstorm by the difference of measurements between water vapor channel （183.3±3 GHz ） and window channel （150 GHz） are presented. In the convective region, it can be identified as hail cloud when the area with the difference of brightness temperature between these two channels below zero covers more than 70%.
- And we preliminary develop this method by using FY-3B/C satellites. The results show this microwave identified method suitable for application.

Thanks for your attention!