Tentative Training Programme

Understanding of cloud nature and weather modification for water resources management in ASEAN

Hua Hin, Thailand, July 2019 **Lecture at 16:00-17:30 24 July**

中國科学院
CHINESE ACADEMY OF SCIEN

Aircraft measurement on clouds and precipitation processes

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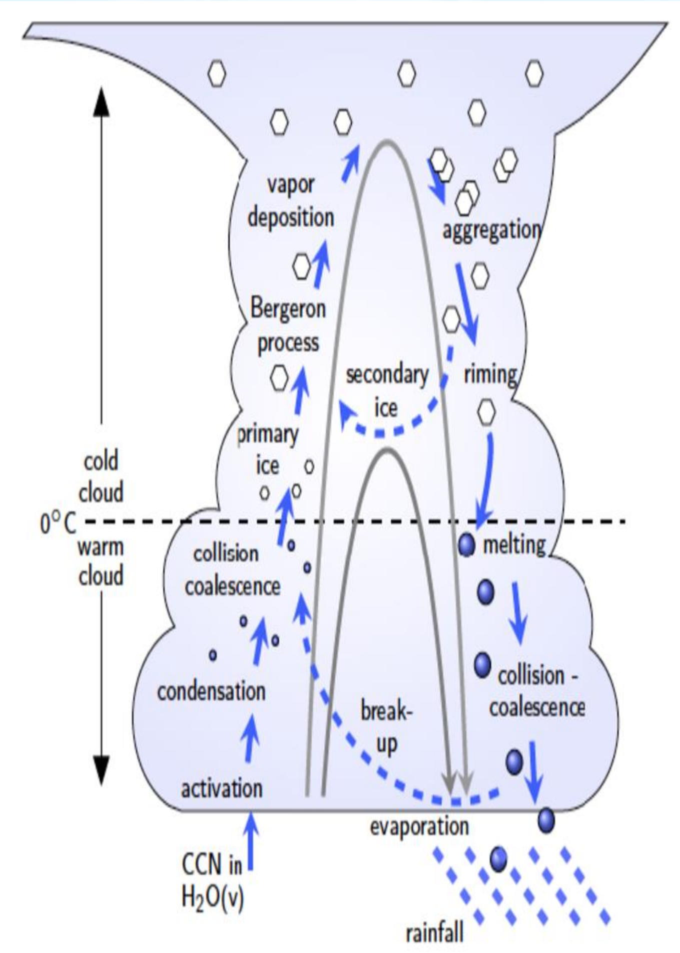
Outline

- Goal and purpose
- Airborne probes and specifications
- Cases and results of aircraft measurement
- Future focus

Goal and purpose

- **Cloud microphysics is critical to clouds and precipitation formation, and cloud seeding;**
- **Accurate description of cloud physics is particularly important in modeling and forecasting in both weather and climate, and climate change;**
- **Yet, many uncertainties still exist since lacking of direct observational validations;**
- **Aircraft measurement is the only direct way to understand the natural clouds and precipitation processes.**

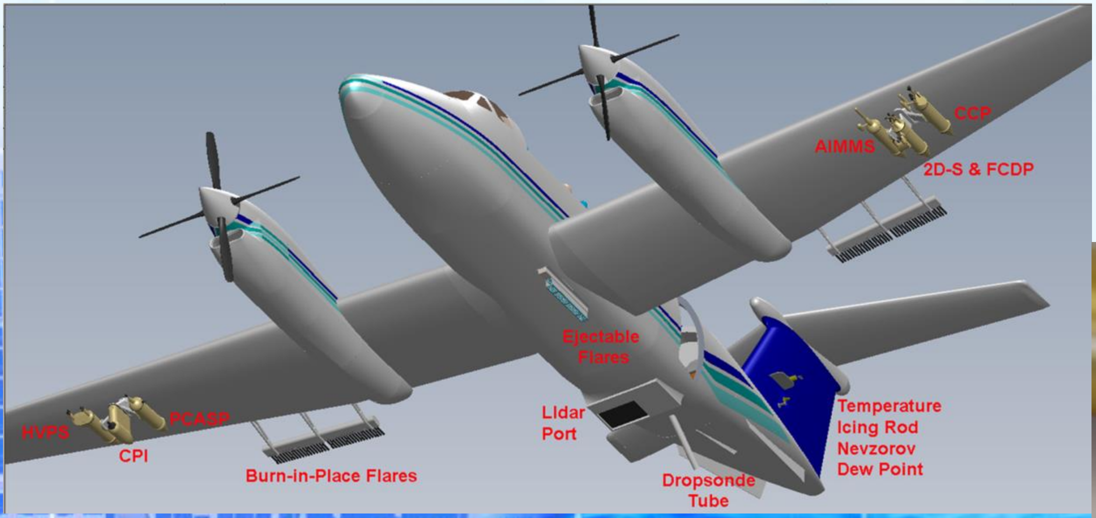


Aircraft measurment for cloud seeding process

- To obtail appropriate seeding condition, such as the content of supercooled water, concentration of ice cristal, and partcle size distribution etc.
- Also, we can verify the seeding effectiveness by measuring clouds seeded with that unseeded.

Airborne probes and specifications

Instrument	Variable	Size range	Resolution	Aircraft
PCASP-100X	Aerosol particles	15 bins, 0.1–3 μm	Changes in particle size	3625
SPP-200	Aerosol particles	30 bins, 0.1–3 μm	Changes in particle size	3830
CCN Counter	CCN concentration	0.75–10 μm	Changes in particle size	3525, 3817, 3830
CAS	Aerosol and cloud particles	30 bins, 0.6–50 μm	Changes in particle size	3830
CDP	Cloud particles	30 bins, 2–50 μm	Changes in particle size	3817
FSSP-ER	Cloud particles	15 bins, 2–47 μm	3 μm	3625
OAP-2D-GA2	Cloud and precipitation particles	62 bins, 25–1550 μm	25 μm	3625
CIP	Cloud and precipitation particles	62 bins, 25–1550 μm	25 μm	3817, 3830
OAP-2D-GB2	Precipitation particles	62 bins,100–6200 μm	100 μm	3625
PIP	Precipitation particles	62 bins,100–6200 μm	100 μm	3817, 3830
King-LWC	Liquid water content (LWC)	0–5 g/m^3	—	3625
Hotwire-LWC	Liquid water content	0–5 g/m^3		3817, 3830
AIMMS-20	Meteorological parameters	—	—	3817, 3830



Aircraft-based research platform in China

机型	最大飞行高度	航程	载重
MA60	7620 m	2450km	5500Kg

King Air 350ER

speed 441km/h

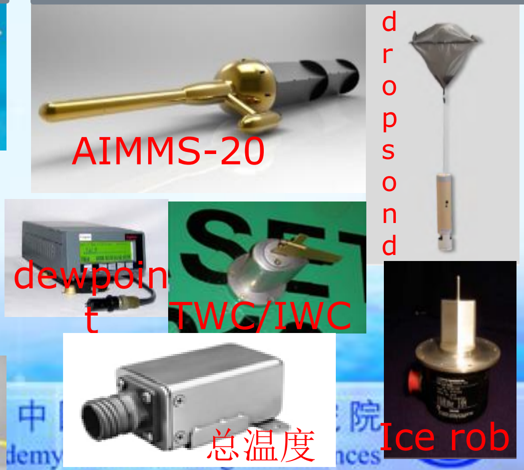
Max speed 561km/h

max time 6h height 10600m

Cloud physics Probe

Aerosol and radiation

Meteorological probe



Aerosol-cloud(fog) experiment

Cases and results of aircraft measurement

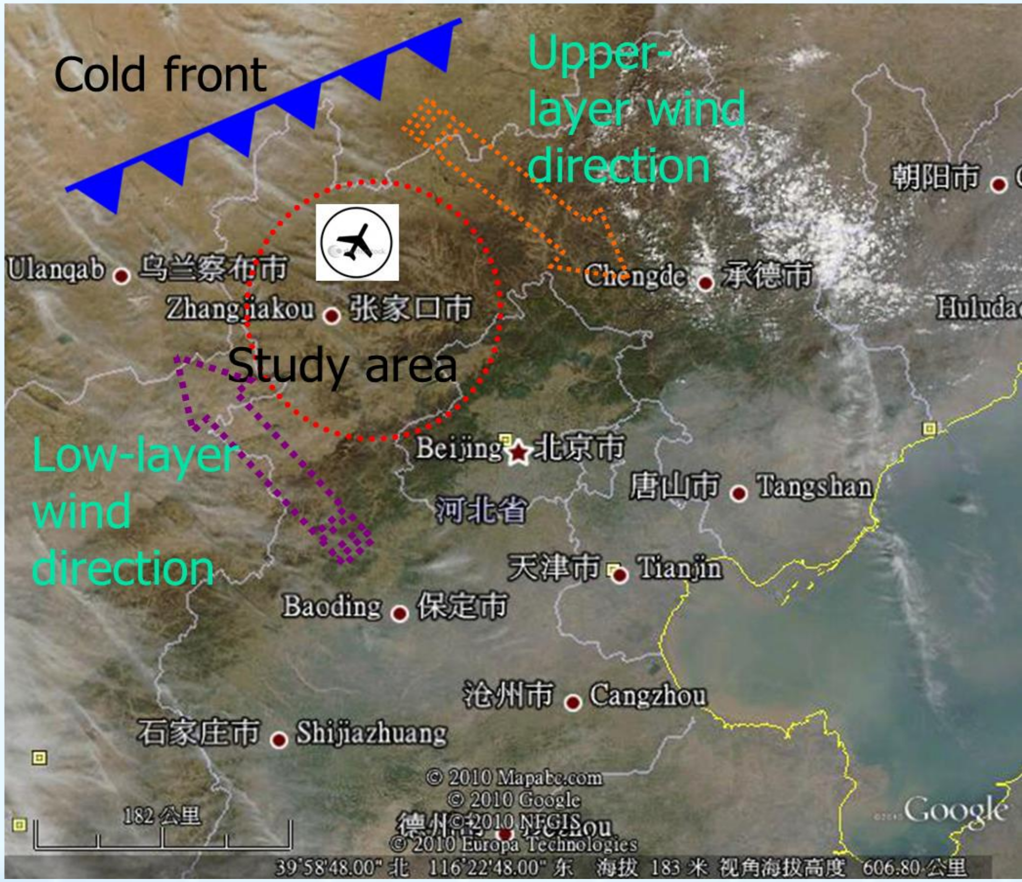
a. Multiple aircraft measurement on cloud microphsycis

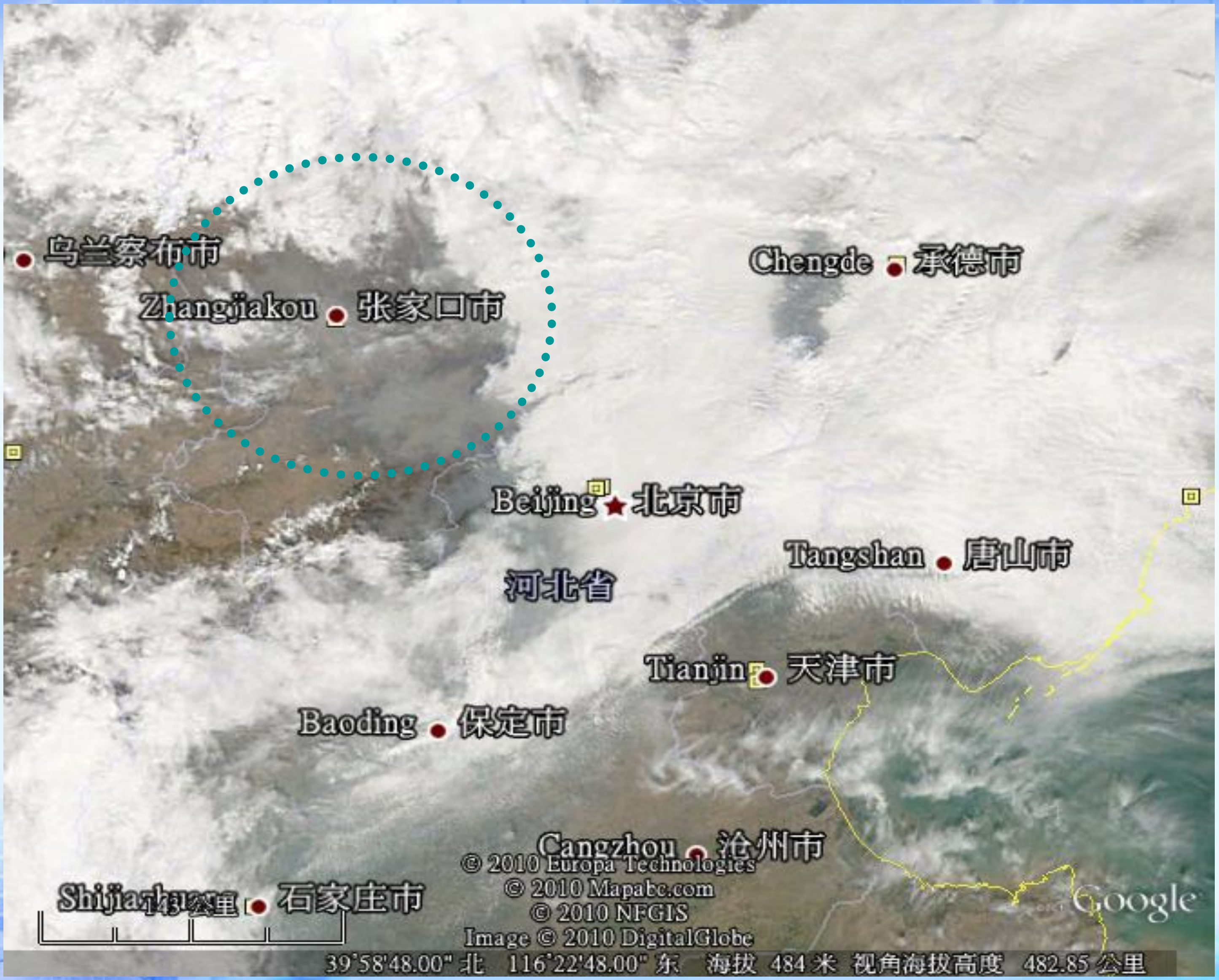
b. Aircraft measurement on melting level of clouds

c. Aircraft measurement on high mountain clouds

Cases and results of aircraft measurement

- Beijing Cloud Experiment (BCE)
- Period: 2007-2012
- Three aircraft with radar system etc.

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Zhangjiakou 张家口市
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Baoding 保定市
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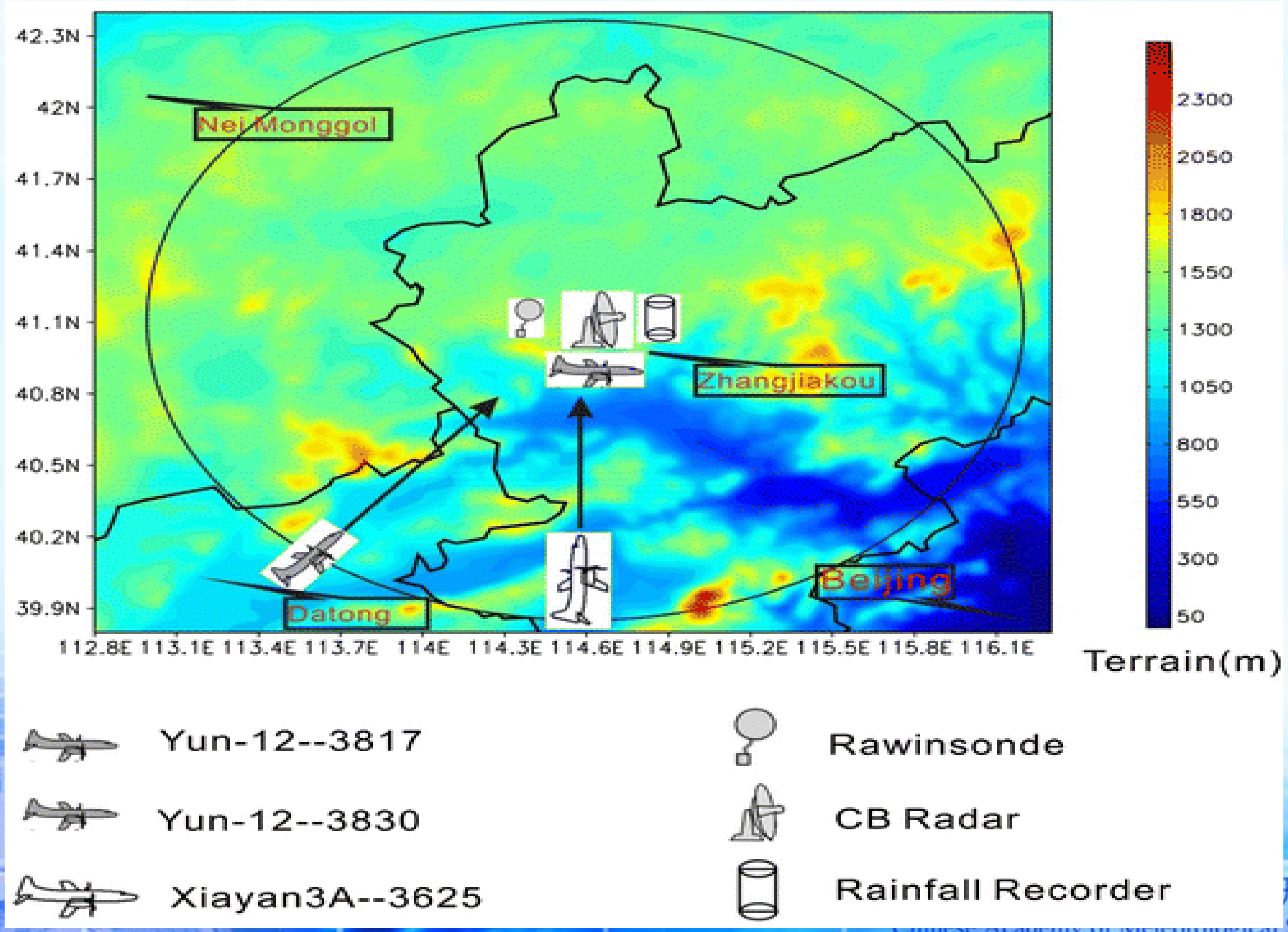
39°58'48.00" 北 116°22'48.00" 东 海拔 484 米 视角海拔高度 482.85 公里

a. Three aircraft measurement on clouds Schematic of the observational region and facilities (the colors indicate the altitudes of terrain)



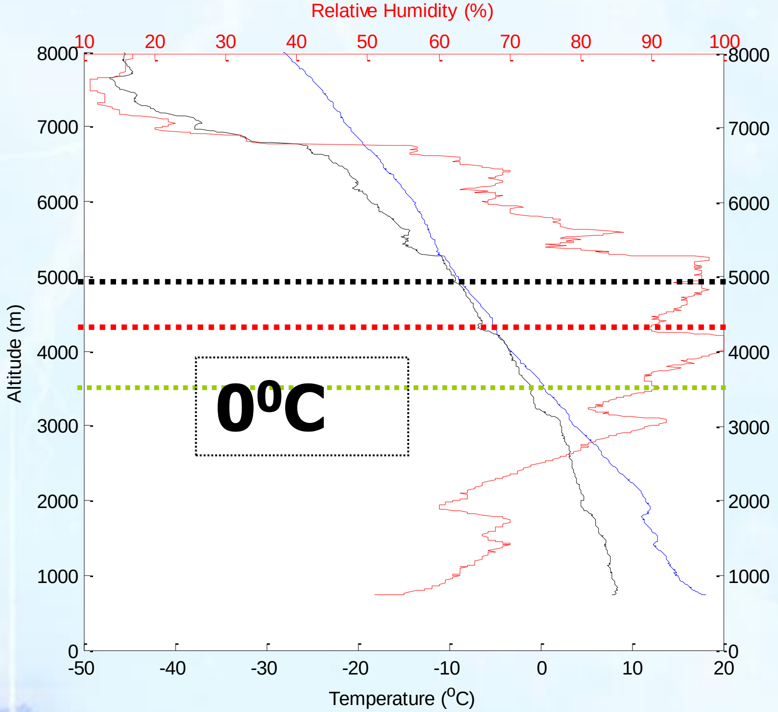
Instrument package for three aircrafts (cloud microphysics and aerosol)

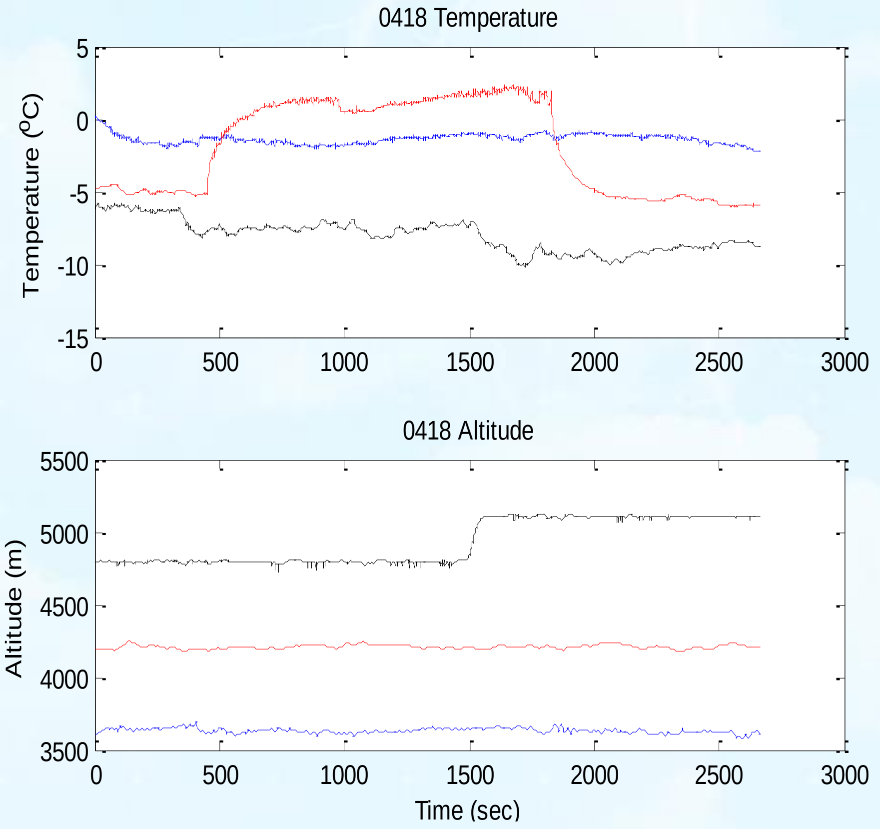
Probes	parameter	range	resolution
FSSP-ER	Cloud particle	2～47μm	3μm
PCASP-100X	aerosol	0.1～3μm	0.02μm-0.5μm
OAP-2D-GA2	Cloud particles	25～1550μm	25μm
OAP-2D-GB2	Precipitation particles	100～6200μm	100μm
CCN Counter	CCN	0.75～10μm	
King-LWC	Liquid water content	0～3g/m^3	—
CAS	Aerosol and cloud particles	0.6～50μm	
CIP	Cloud image particles	25～1550μm	25μm
PIP	precipitation	100～6200μm	100μm
SPP-200	aerosol	0.1～3μm	
CDP	Cloud particles	2～50μm	
AIMMS-20	Atmospheric state	—	—

Aircraft type and flights in 2009

	Cheyenne III-A	Y-12	Y-12	Cloud type
April 18	16:14-19:00	17:05-18:55	16:50-19:04	Sc
Aril 30	17:45-20:41	17:30-19:24	18:08-20:12	Cb、Ci
May 1	08:27-11:31	08:31-11:34	08:46-11:30	As

Temperature and altitude derived from three aircrafts
Aircraft one: blue (low), flying around 3600m(melting level)
Aircraft two: red (middle), flying around 4200m
Aircraft three: black (high), flying around 4700-5000m

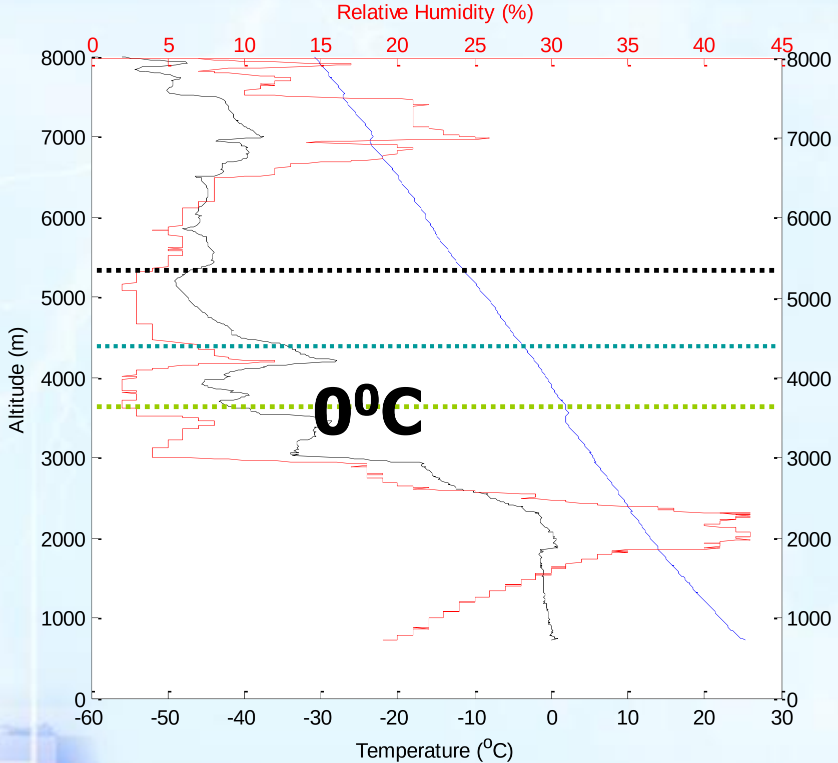


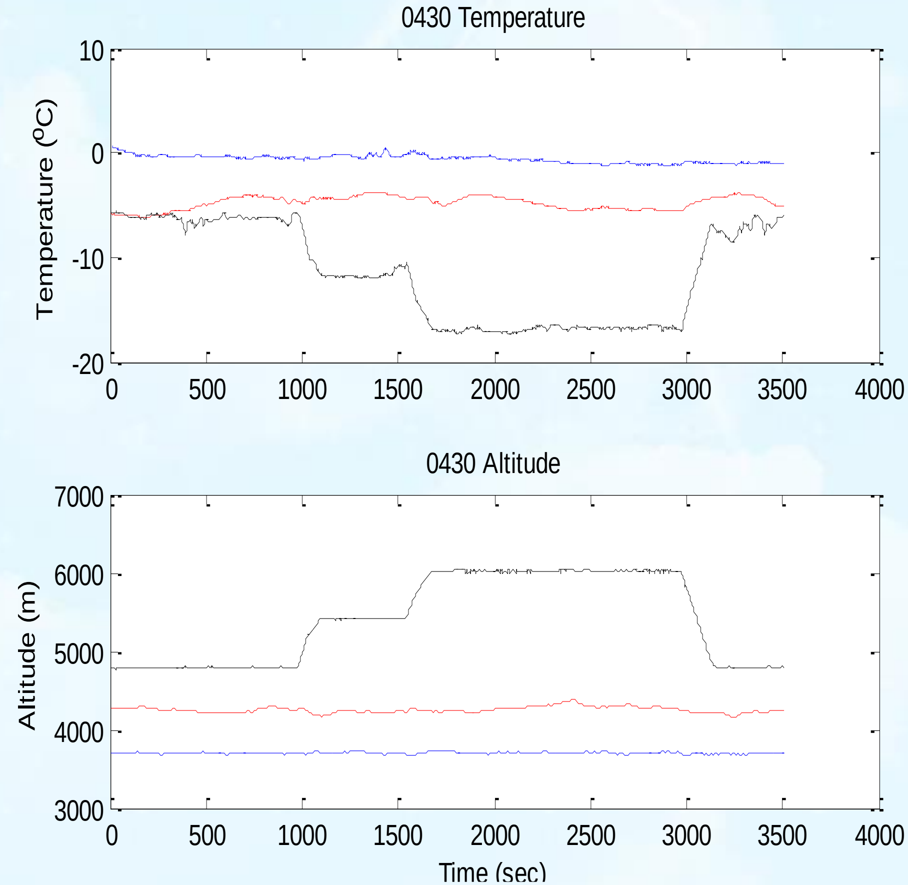


Sounding at 17:00 BST on April 18 at observation site (Zhang Jiakou)

（1）0^{0} C height: 3594m，weak inversion layer:1800-2000m
（2）data time:17:20-18:12 (52 min)

Temperature and altitude derived from three aircrafts
Aircraft one: blue (low), flying around 3800m(melting level)
Aircraft two: red (middle), flying around 4200m
Aircraft three: black (top), flying around 4700-6000m

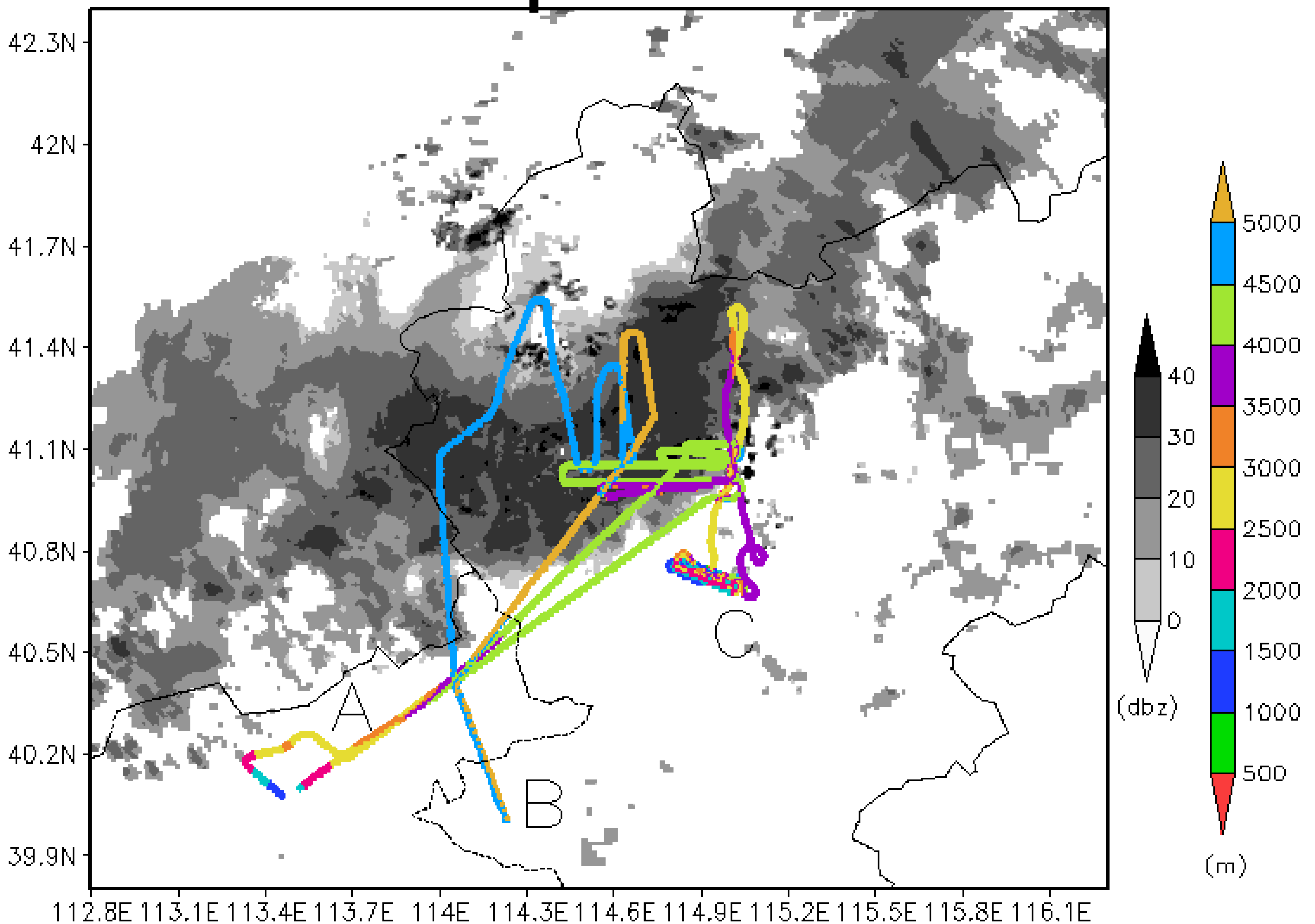


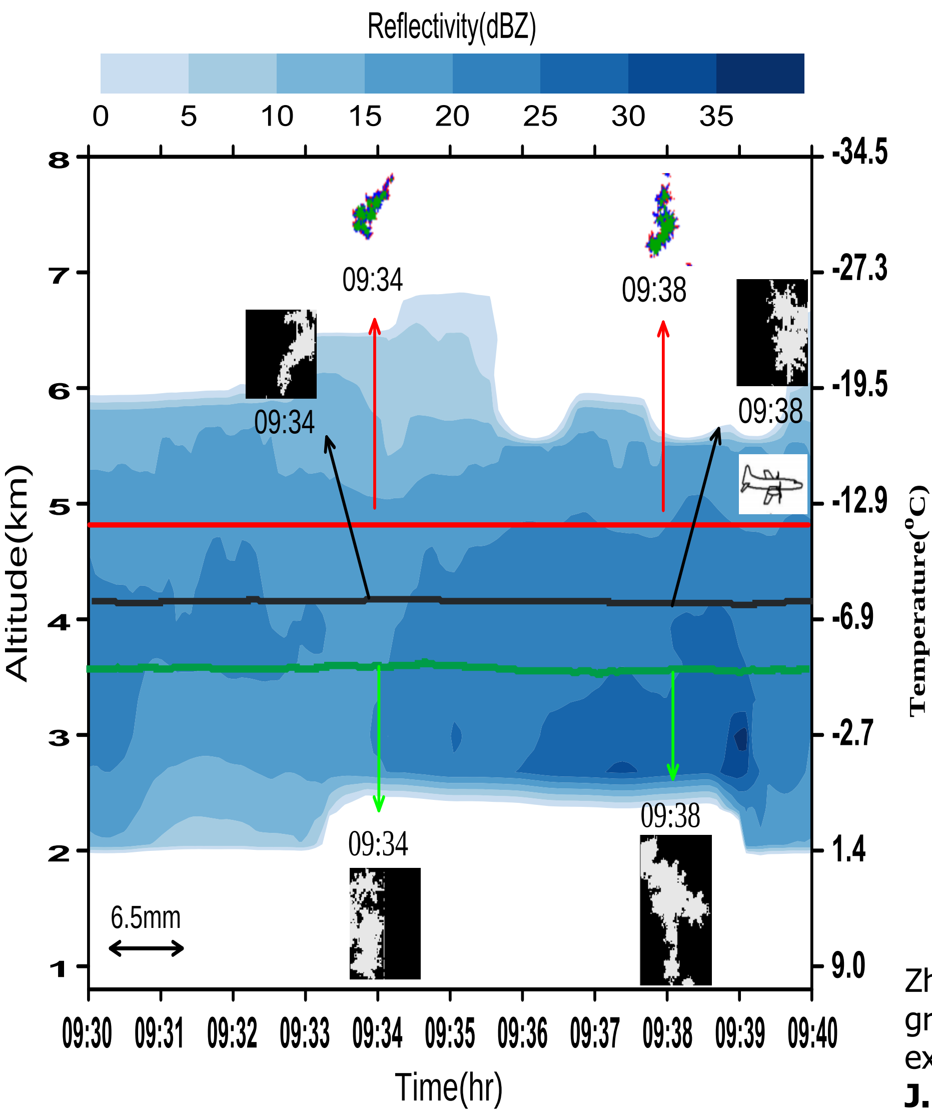


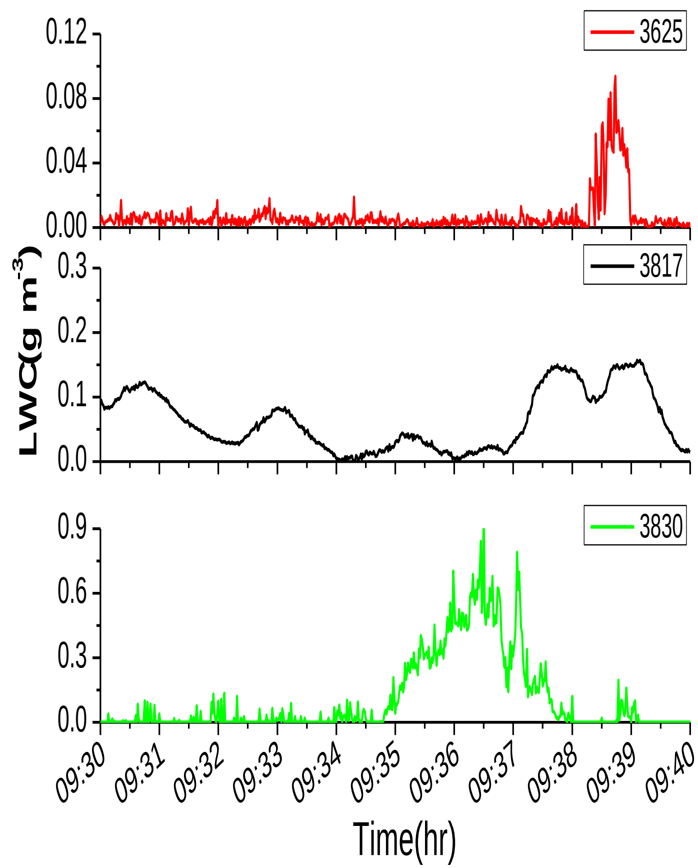
Sounding at 16:00 BST on April 30 at observation site (Zhang Jiakou)

a. 0^0C height:3864m， dry layers are obvious, RH is below10% for most fli
b. Data time:18:32-19:30

Cloud Field Campaign with multiple aircraft







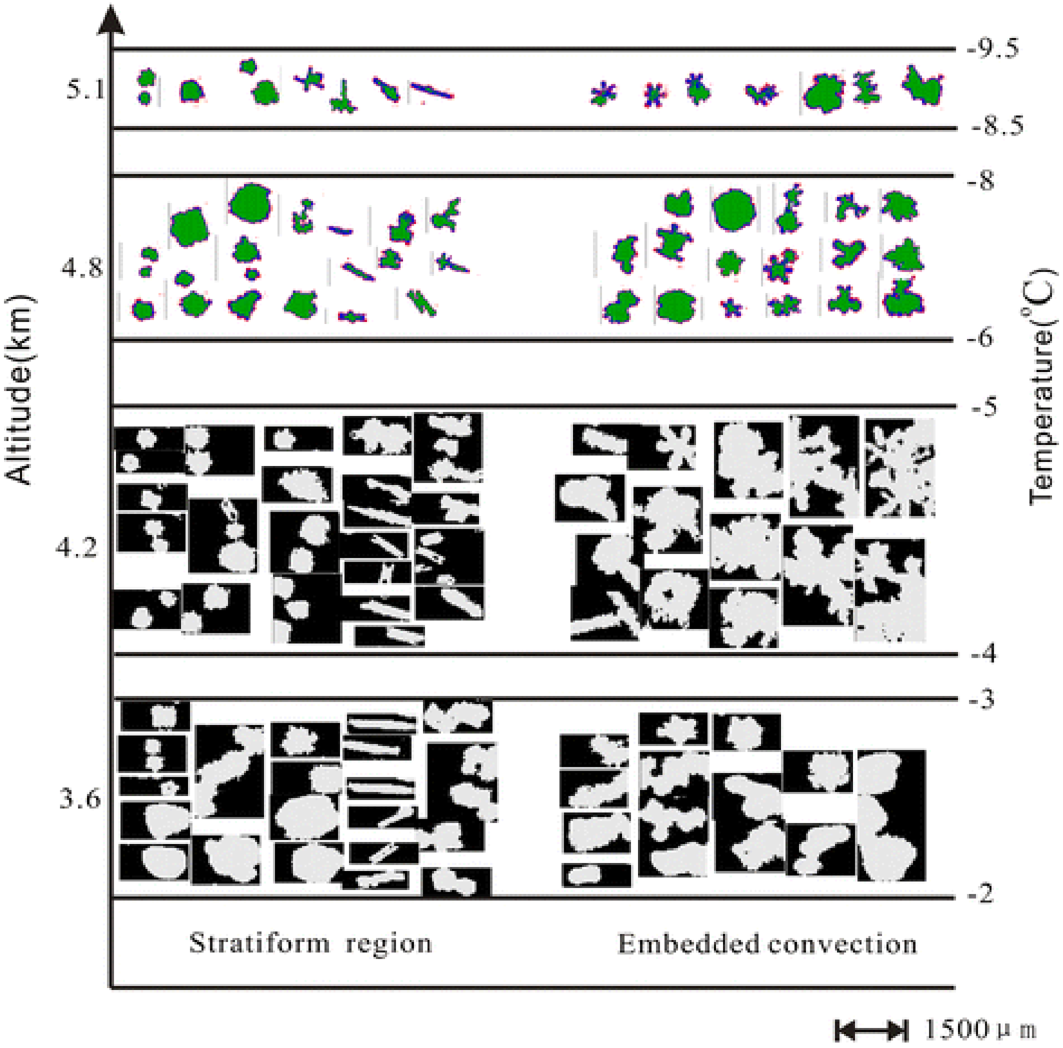
Zhu, S., X.Guo, G. Lu and L. Guo,2015: Ice crystal habits and growth processes in stratiform clouds with embedded convection examined through aircraft observations in Northern China, **J. Atmos. Sci.,** 72, 2011–2032

Cloud microphysical properties observed by aircraft

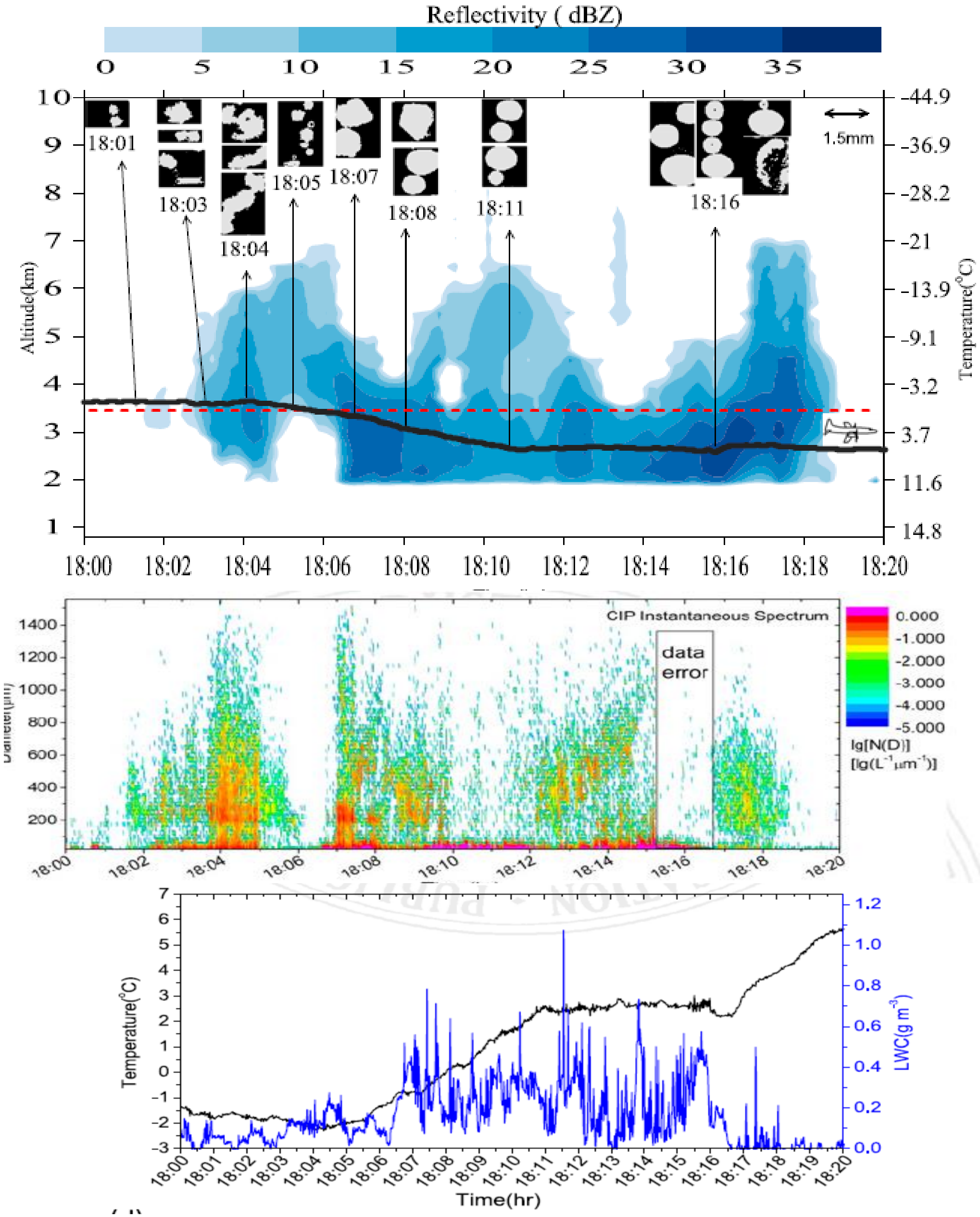
Ice Crystal Habits and Growth Processes:

- **Typical habits: Plate-like, needle column, capped column, dendrite, and irregular.**
- **Typical growth: riming, aggregation.**

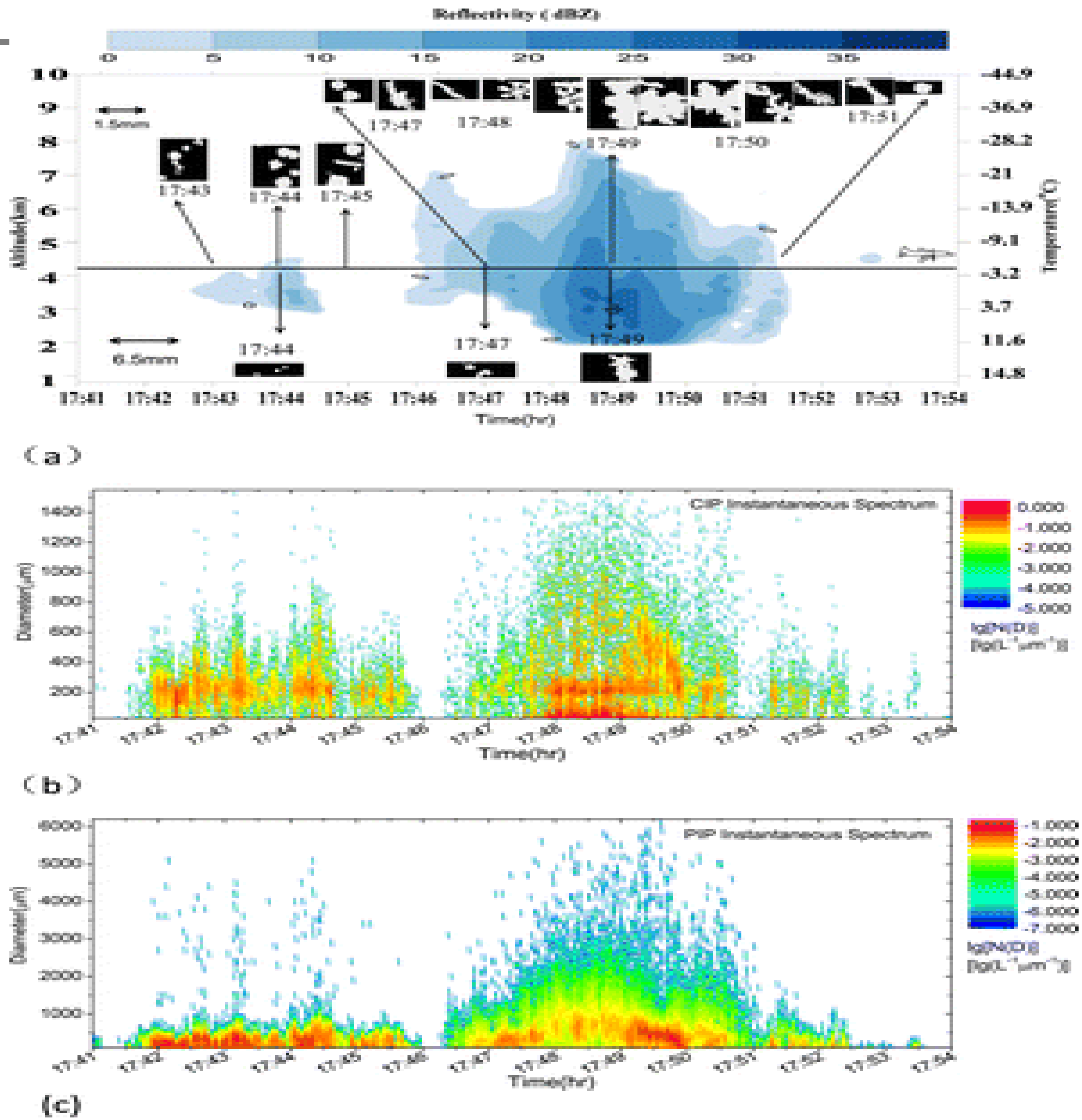
Zhu, S., X.Guo, G. Lu and L. Guo,2015: Ice crystal habits and growth processes in stratiform clouds with embedded convection examined through aircraft observations in Northern China, **J. Atmos. Sci.,** 72, 2011–2032



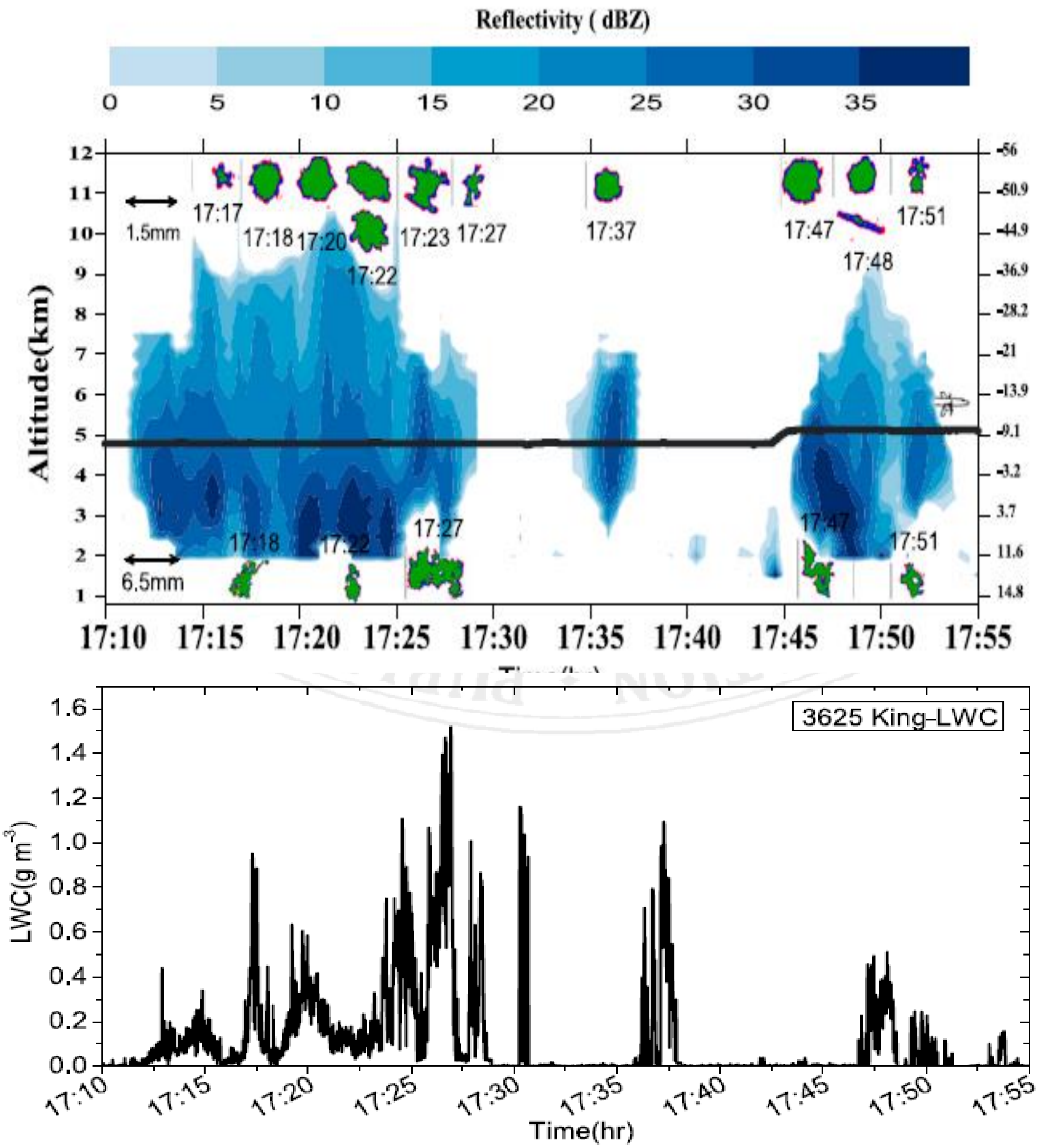
The cloud penetration dat recorded by aircraft 3830 on 18 Apr 2009:
(a)cross section of radar reflectivity for flight path and ice crystal habits recorded through CIP, where black solid line represents flight track, red dashed line represents the 0° C layer;
(b) CIP instantaneous spectrum; and
(c)PIP instantaneous spectrum,
(d) temperature (black) and LWC (blue).



The penetration data recorded by aircraft 3817 on 18 Apr 2009: (a)cross section of radar reflectivity for flight path, ice crystal images recorded through CIP (panel top)and PIP (panel bottom), and *T* (black line); (b)CIP instantaneous spectrum; and (c) PIP

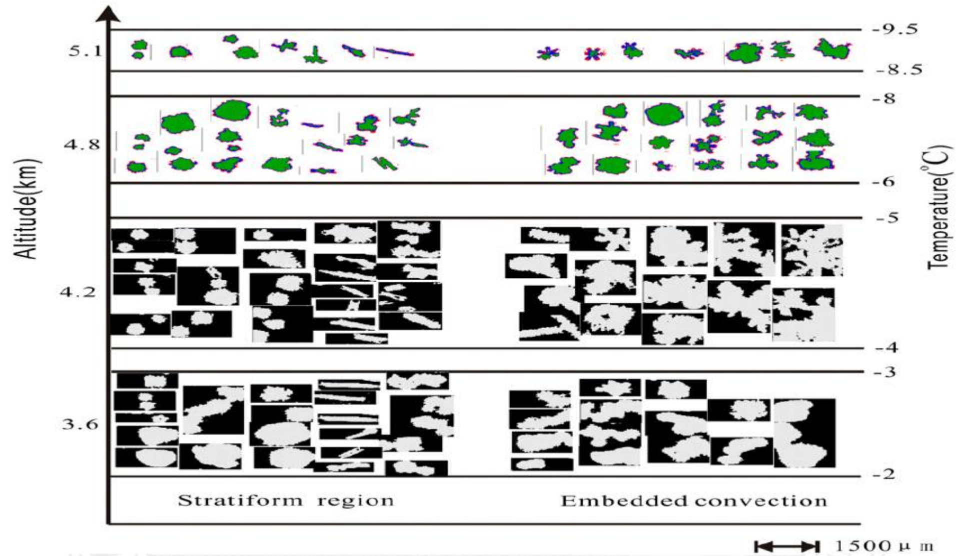


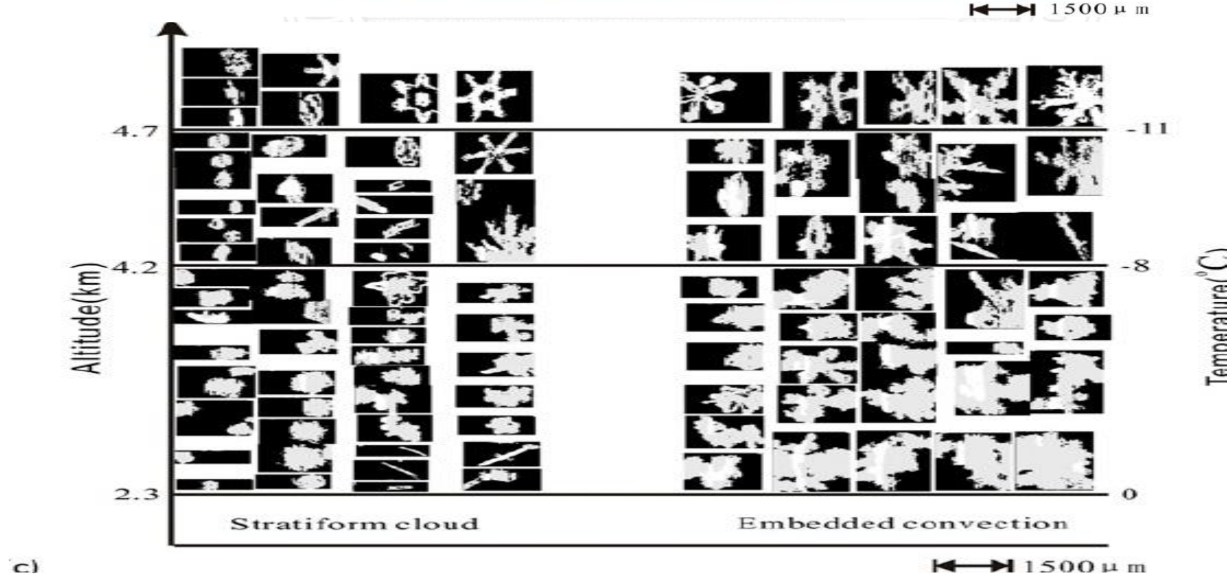
The penetration data recorded by aircraft 3625 on 18 Apr 2009: cross-section of radar reflectivity for flight path, ice crystal images recorded with 2DC and LWC.



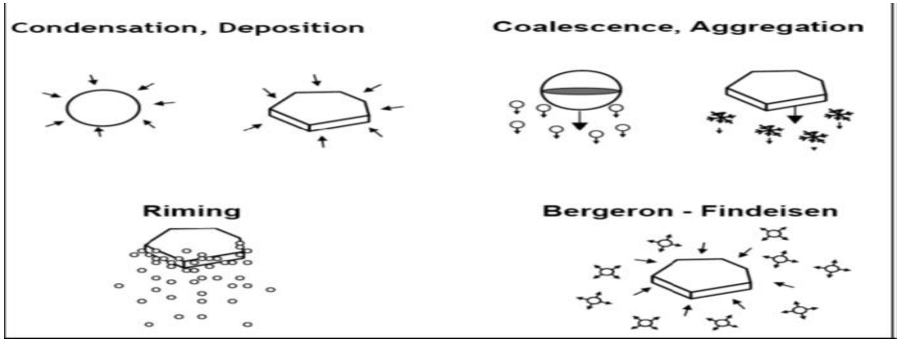
Comparison of two cases

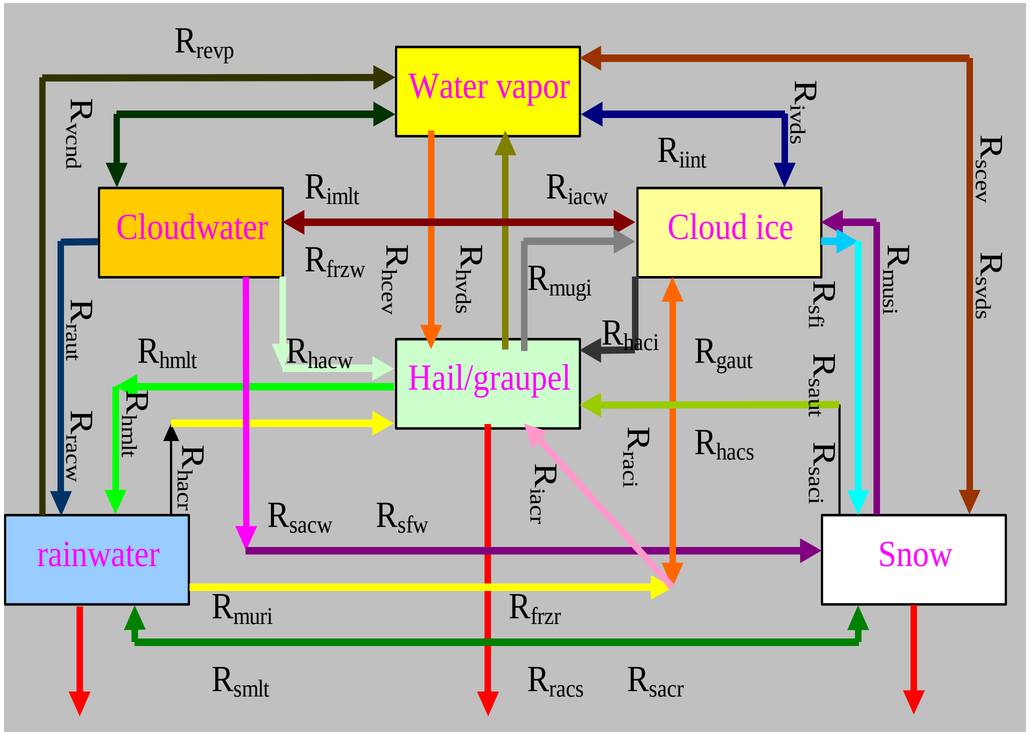
Typical ice crystal images recorded by the three aircraft on April 18 and 1 May 2009

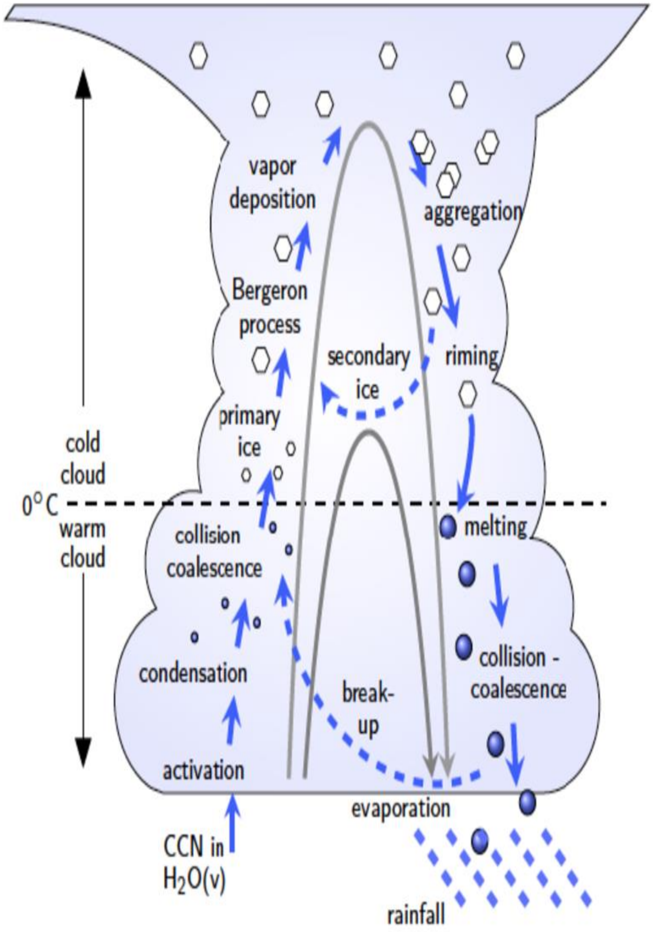




Application of aircraft measurement in verification of cloud physics in model

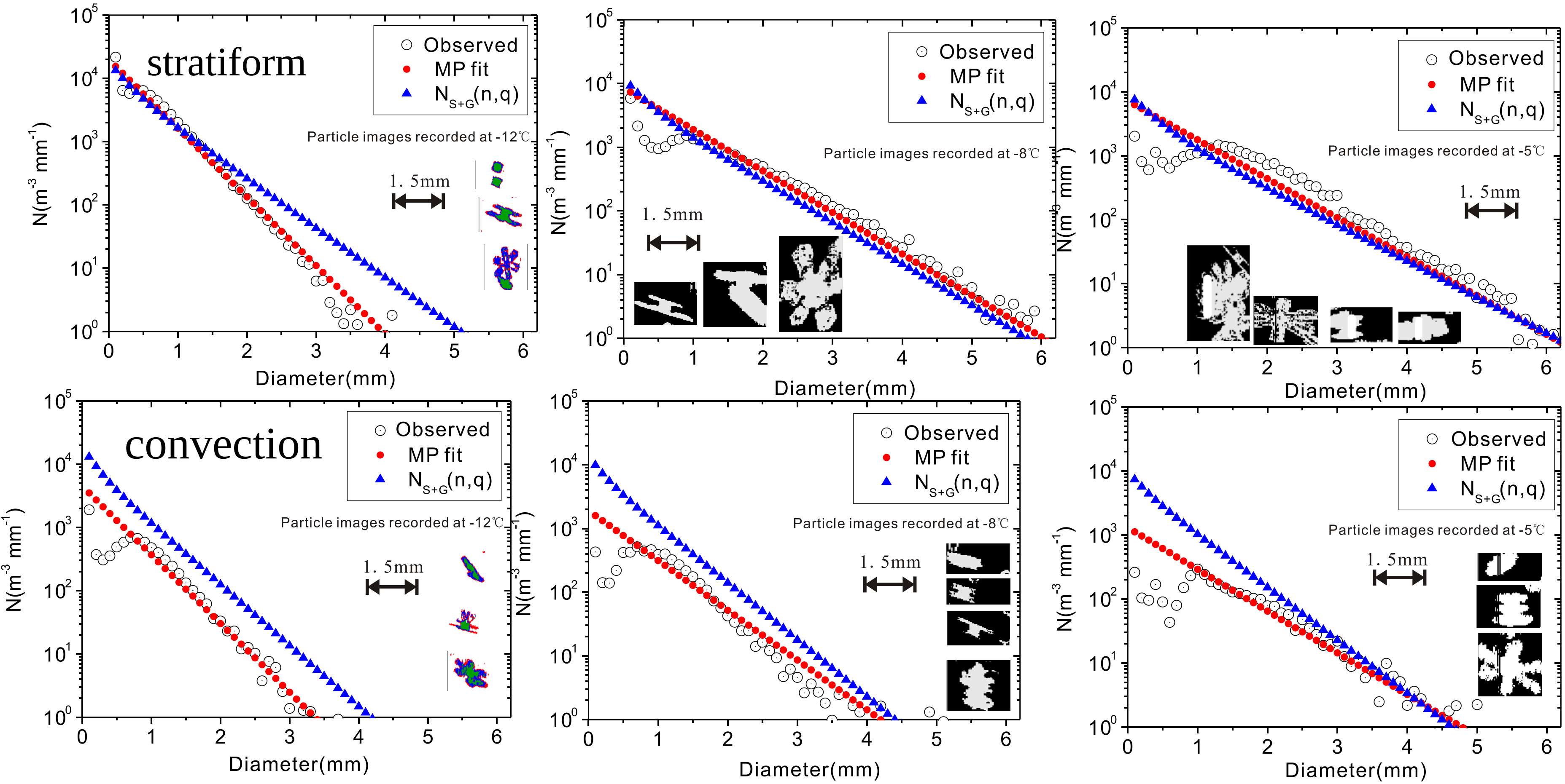






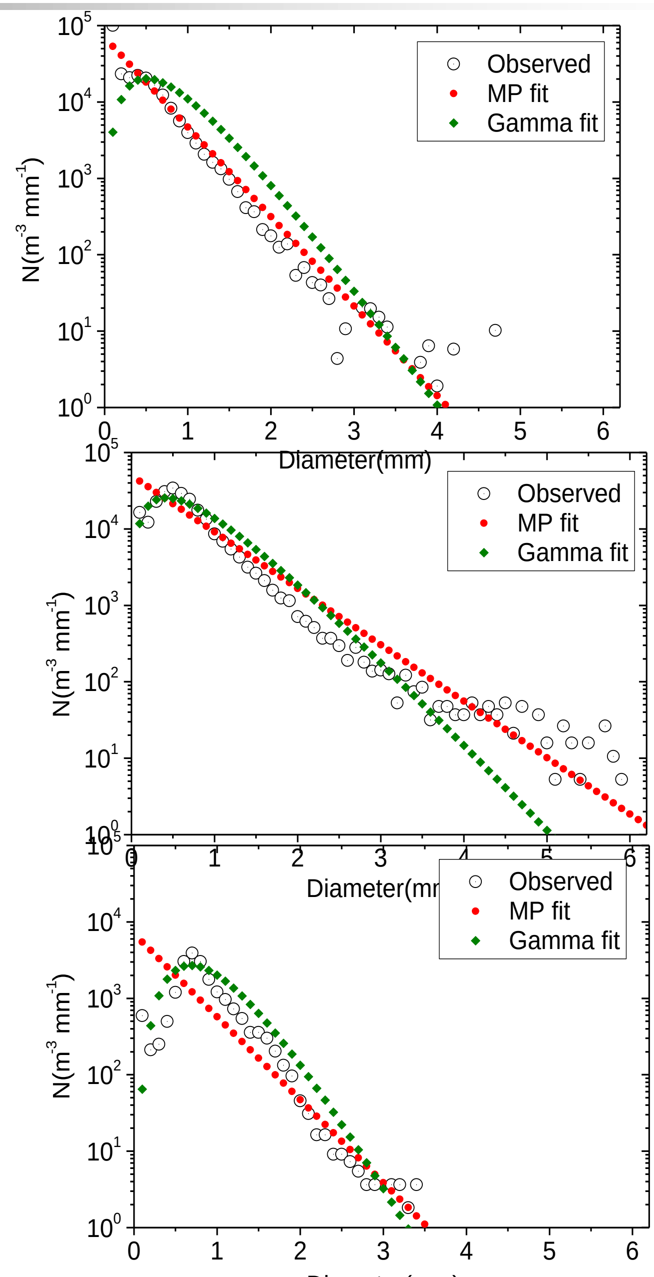
Validation of Cloud microphysical processes in cloud-resolving model

The larger differences existed between modeled and observed size distributions, in particular for small-size particles.

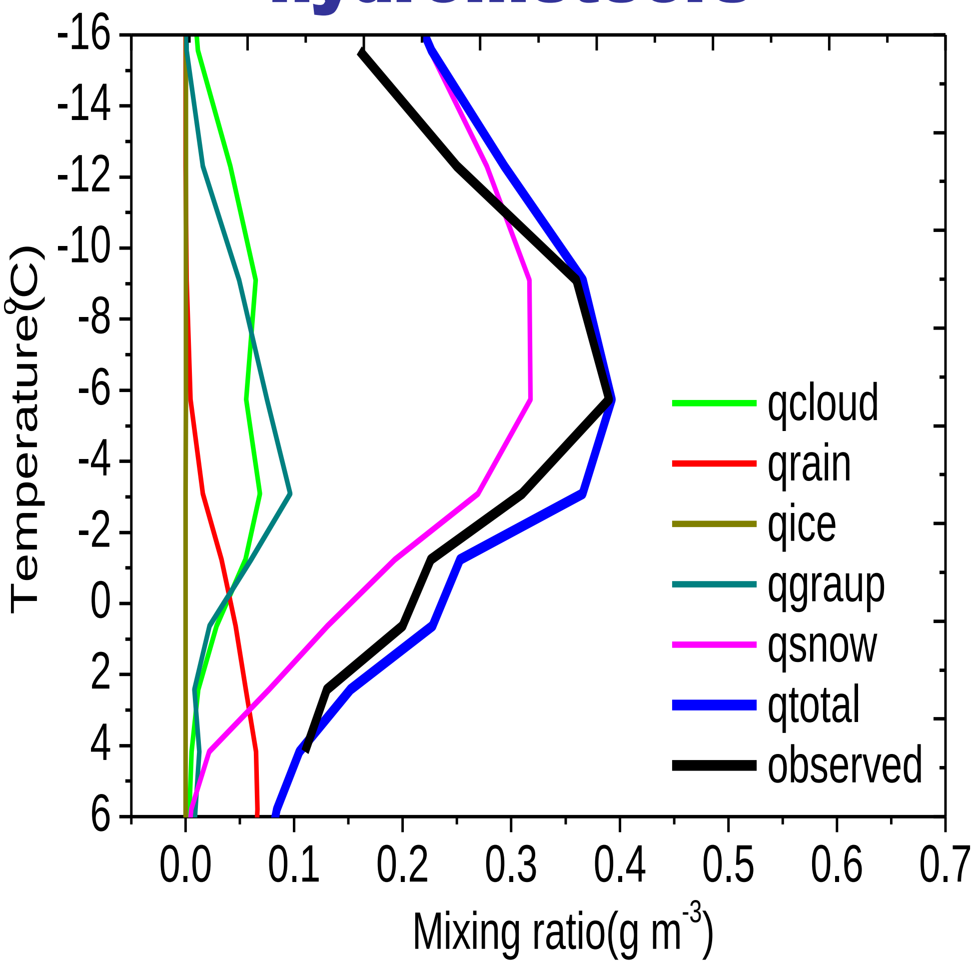


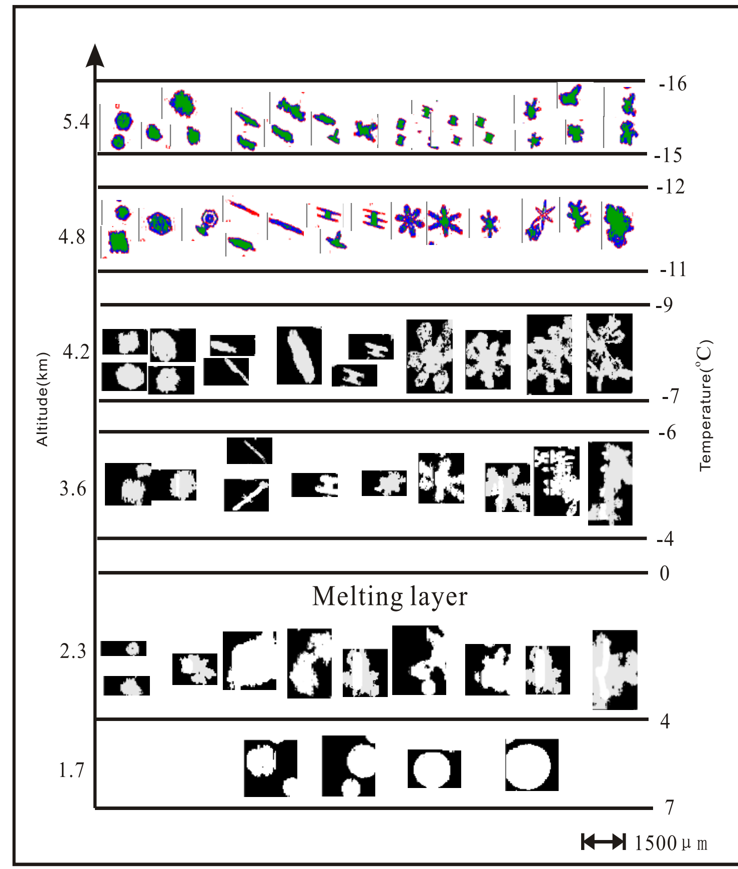
The aircraft observation indicated that the Gamma distribution can be more applicable for some complex cloud system such as stratiform clouds with embedded convections.

Relatively, the M-P distribution fits more homogeneous and stable clouds such as stratus.

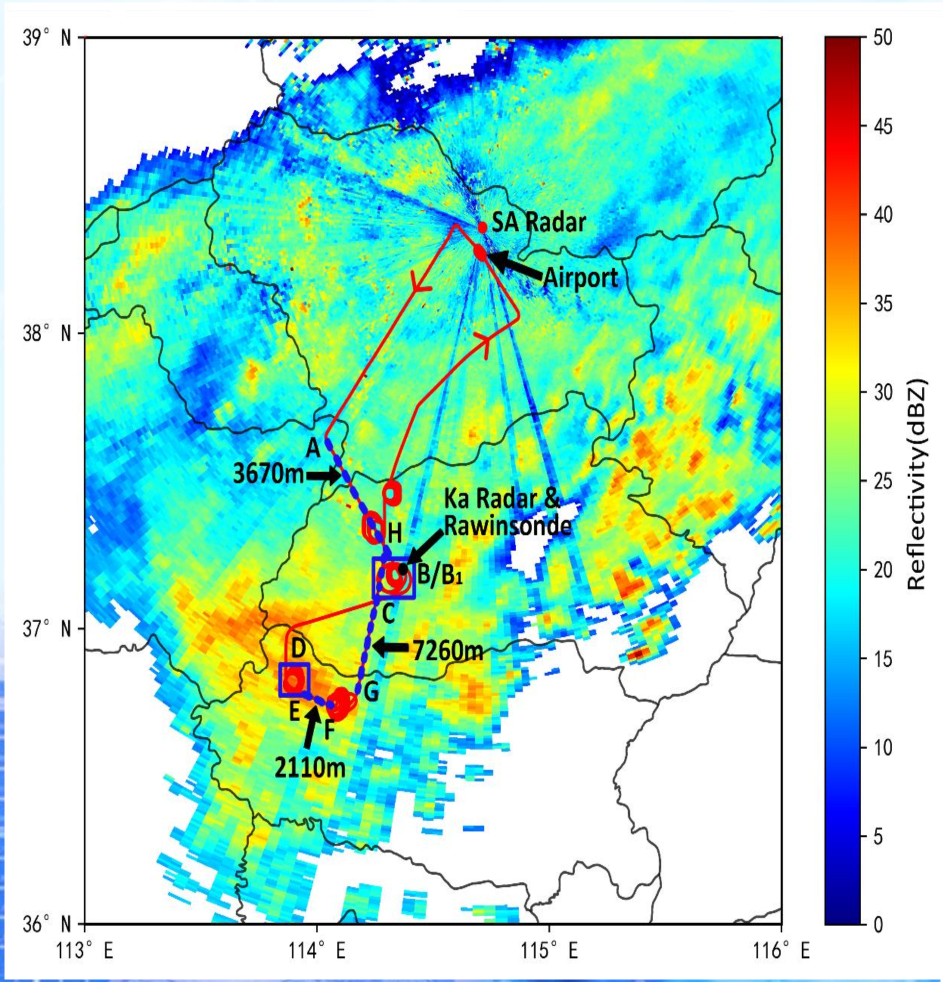


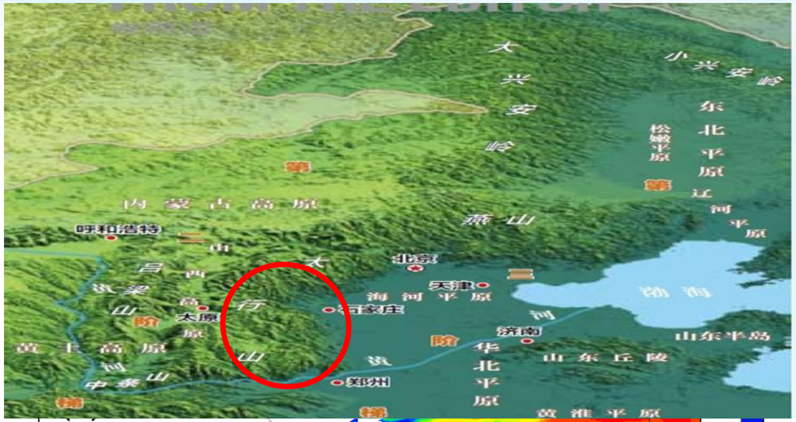
Validation for vertical profiles of hydrometeors

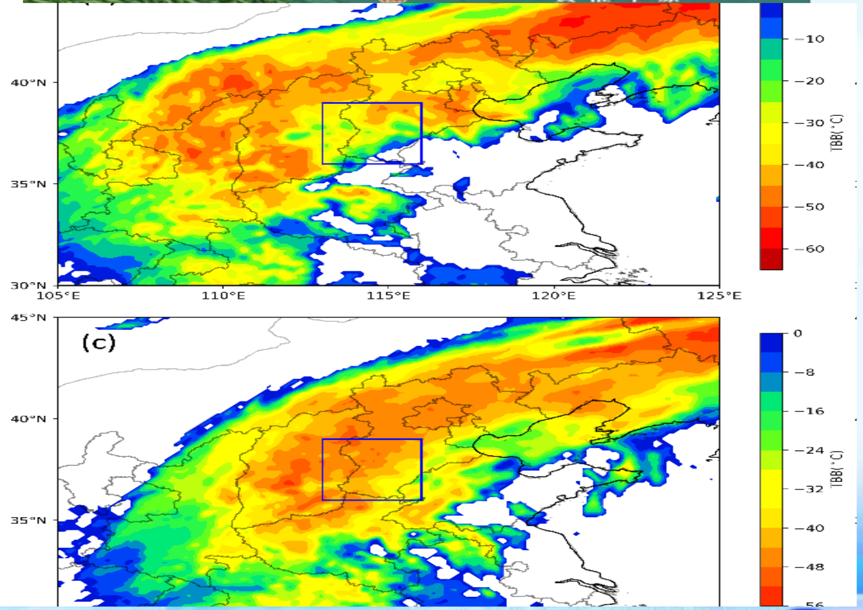




b.Aircraft measurement on melting level of clouds

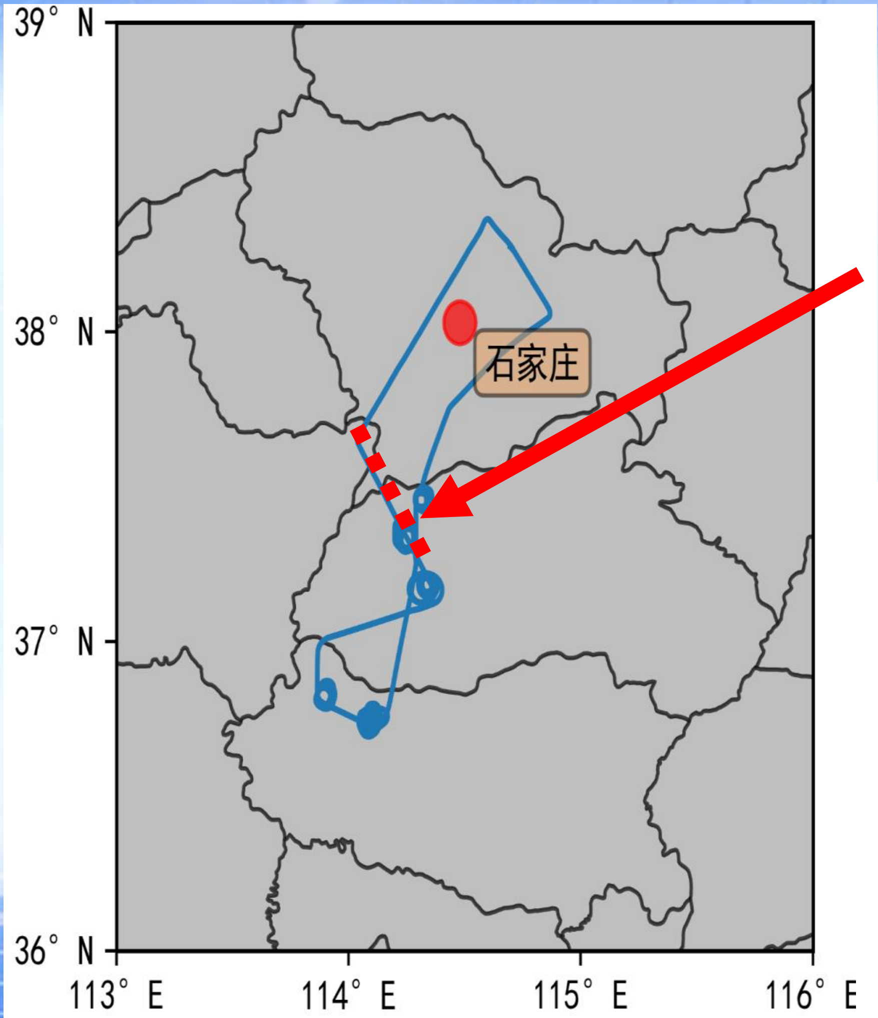




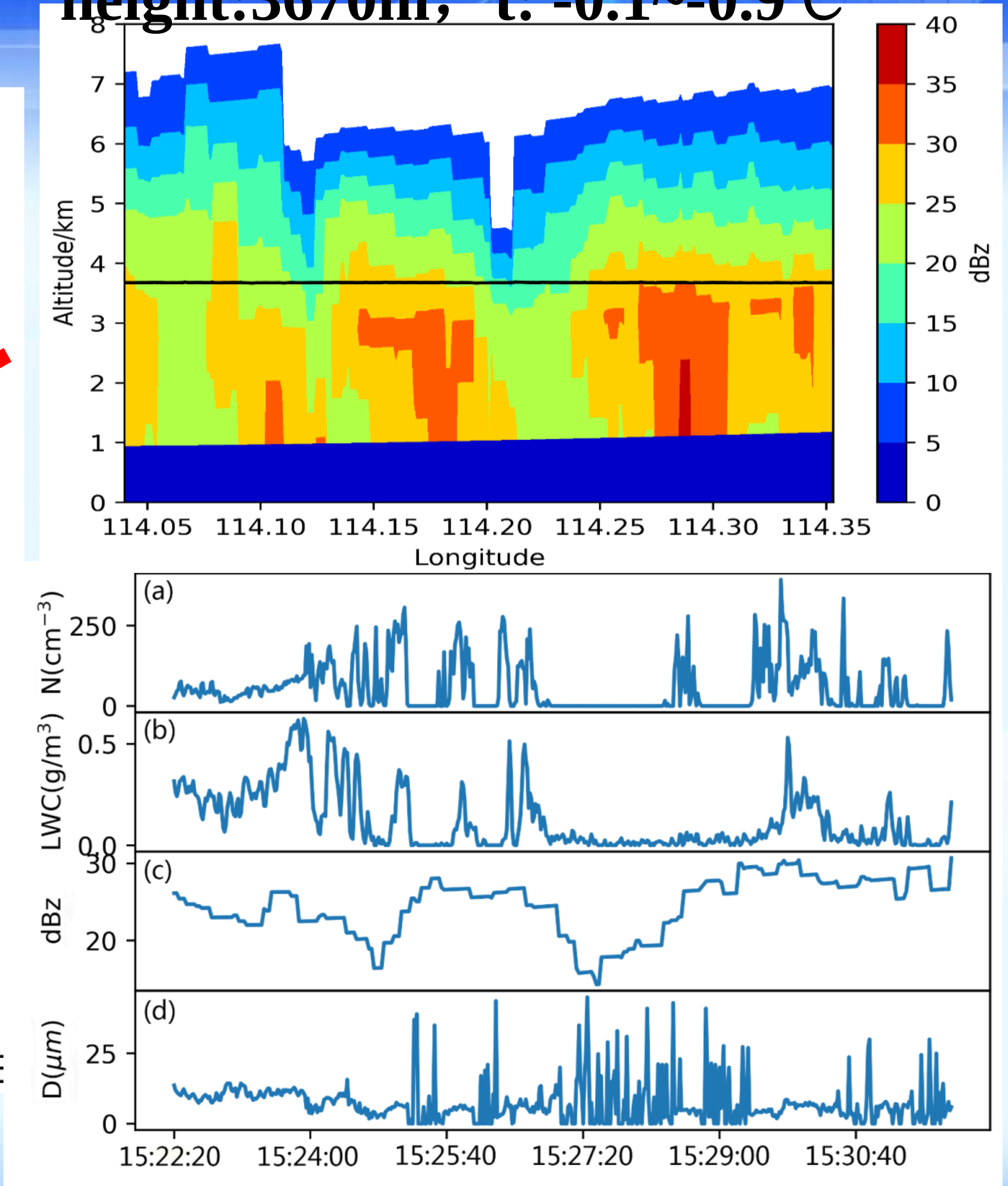


King-AIR 350ER and probes

3670m（15:22—15:31）



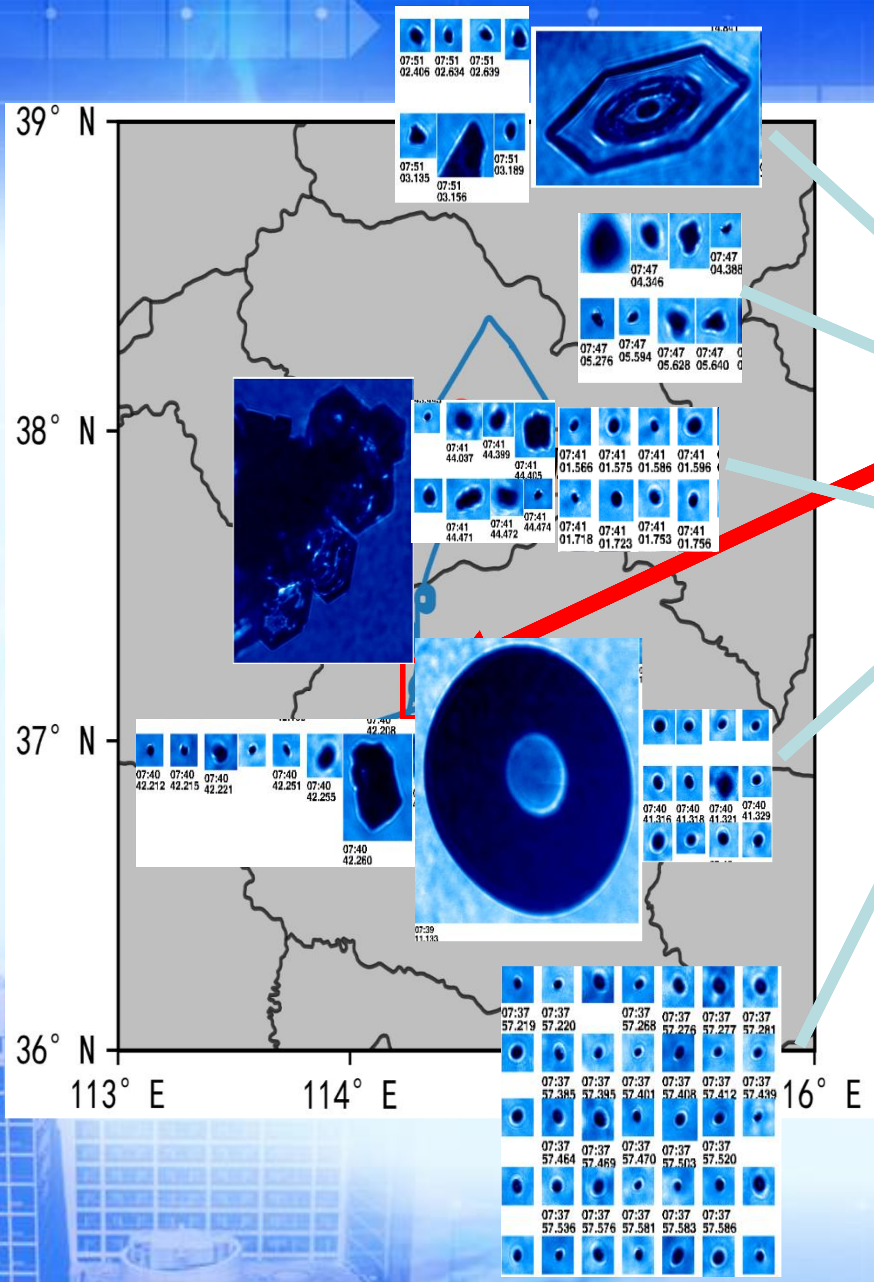
height:3670m，t: -0.1~-0.9℃

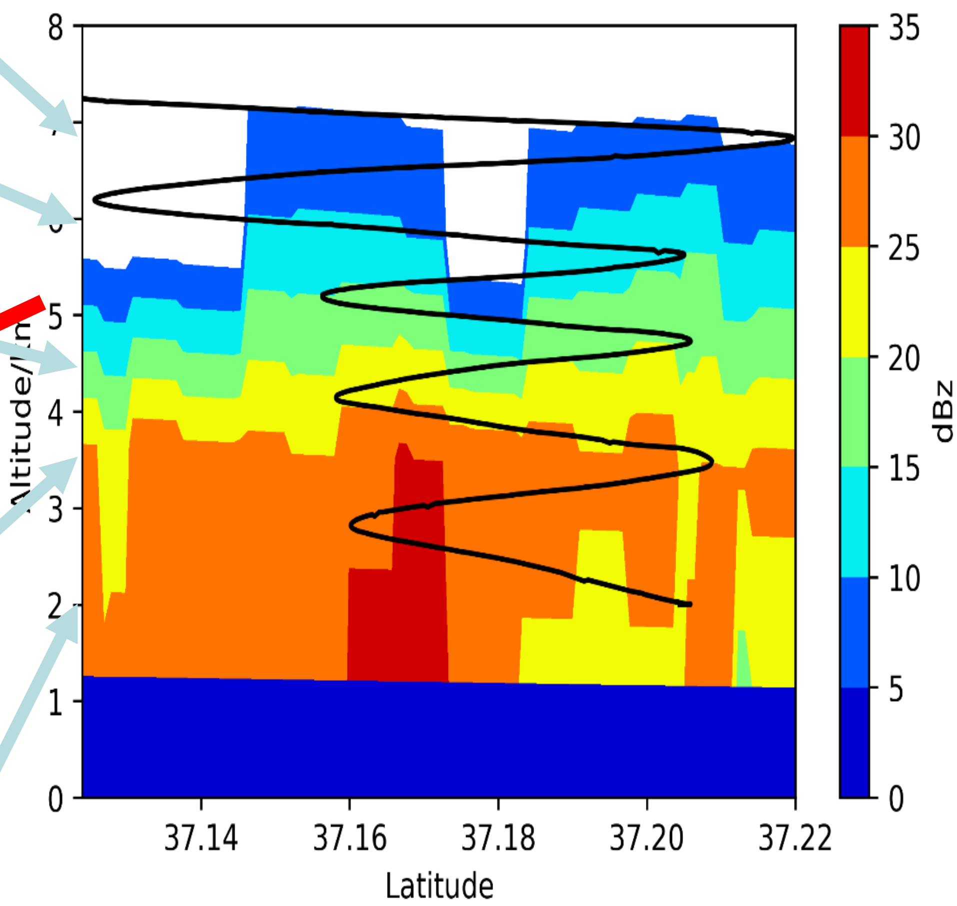


blue line:Aircraft flight track

a. CDP-N，b. Hotwire-LWC
c. Ref.，d. CDP-Dmean

A-area（15:37—15:52）



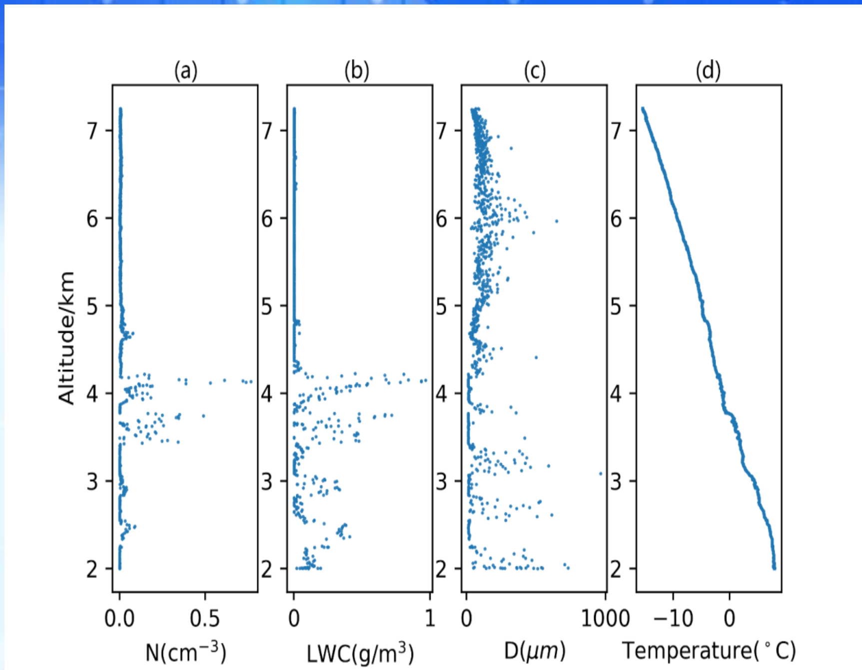


height: 2000~7250m，

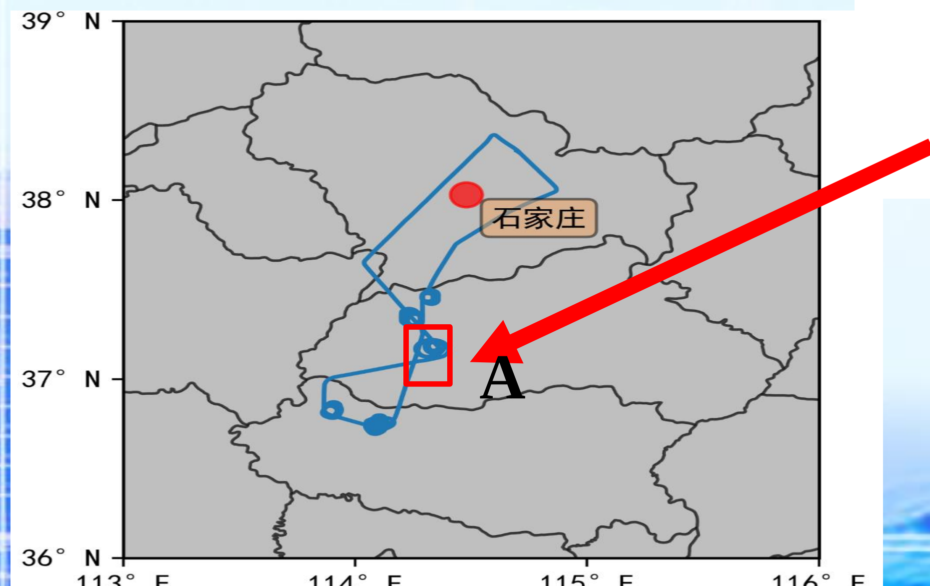
temprature: 8.0~-15.4℃，

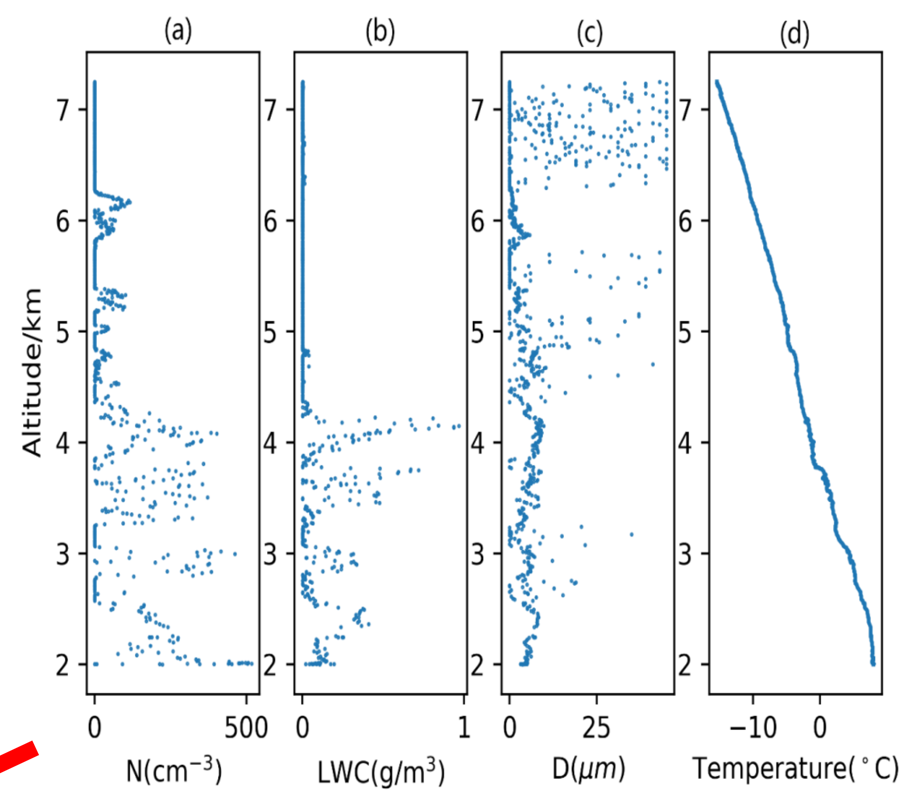
0℃level:3760m

A-area（15:37—15:52）



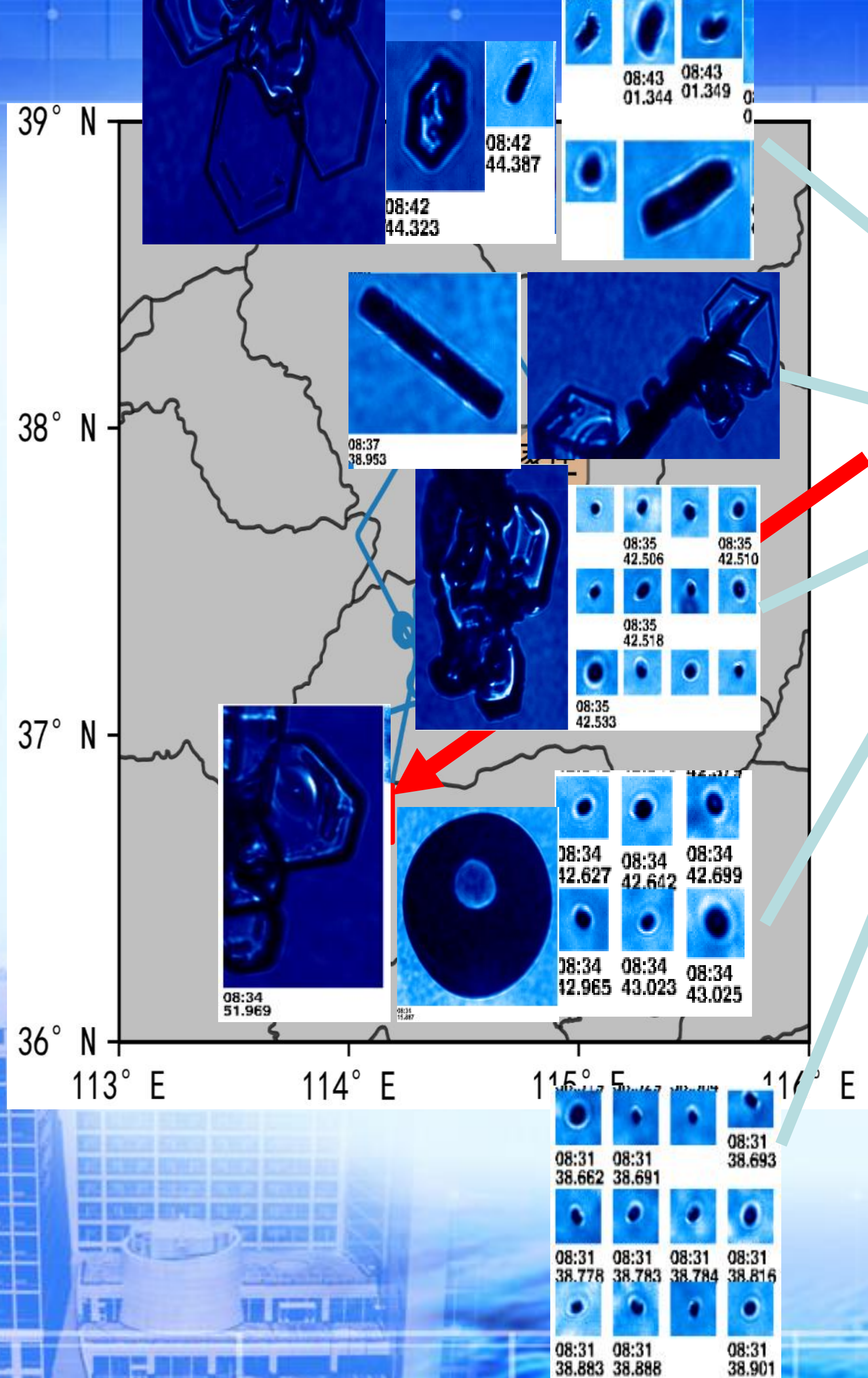
a.CIP-N，b. hotwire-LWC
c. CIP-Dmean， d. Temp.

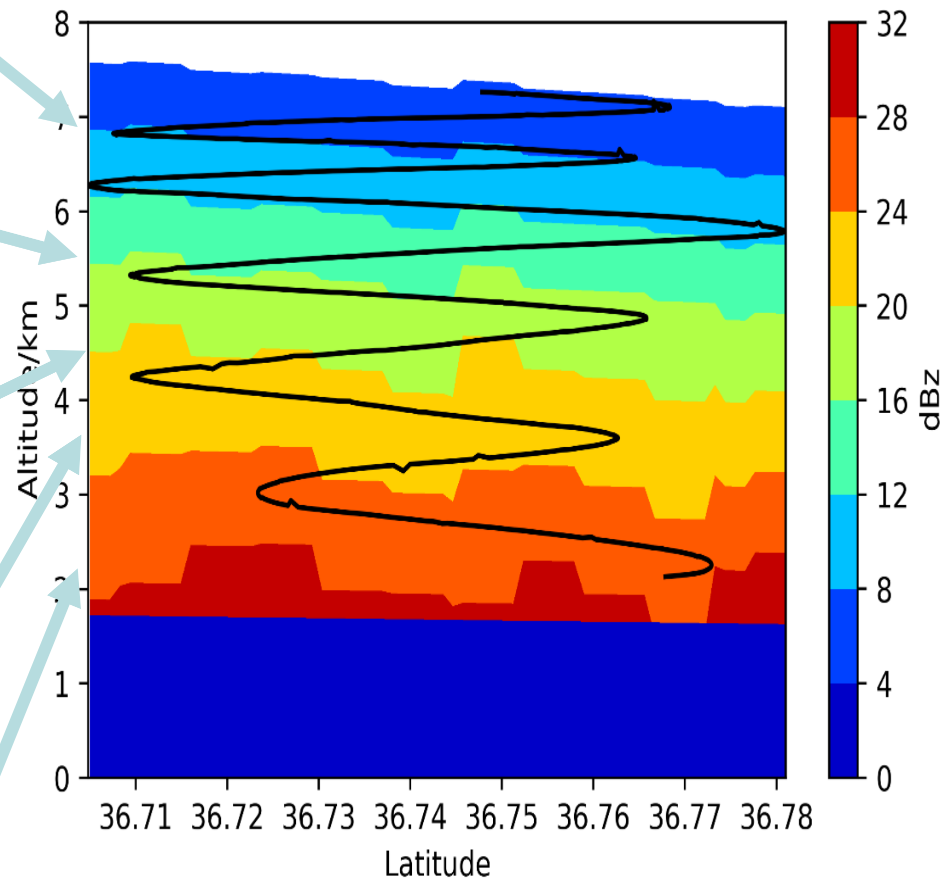




a.CDP-N，b. hotwire-LWC
c. CDP-Dmean， d. Temp.

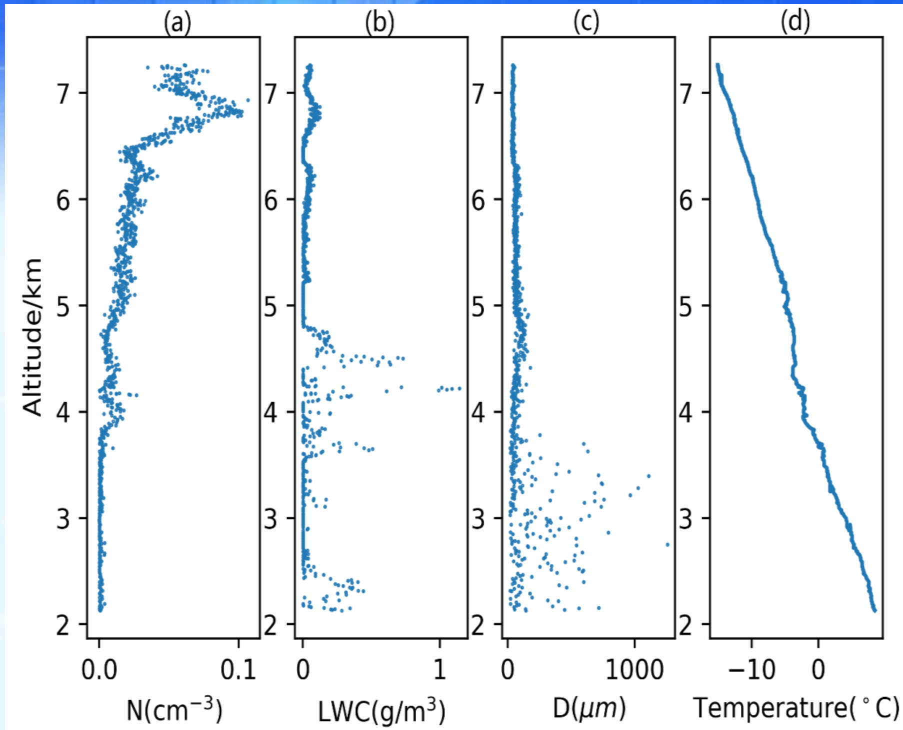
B-area（16:31—16:47）



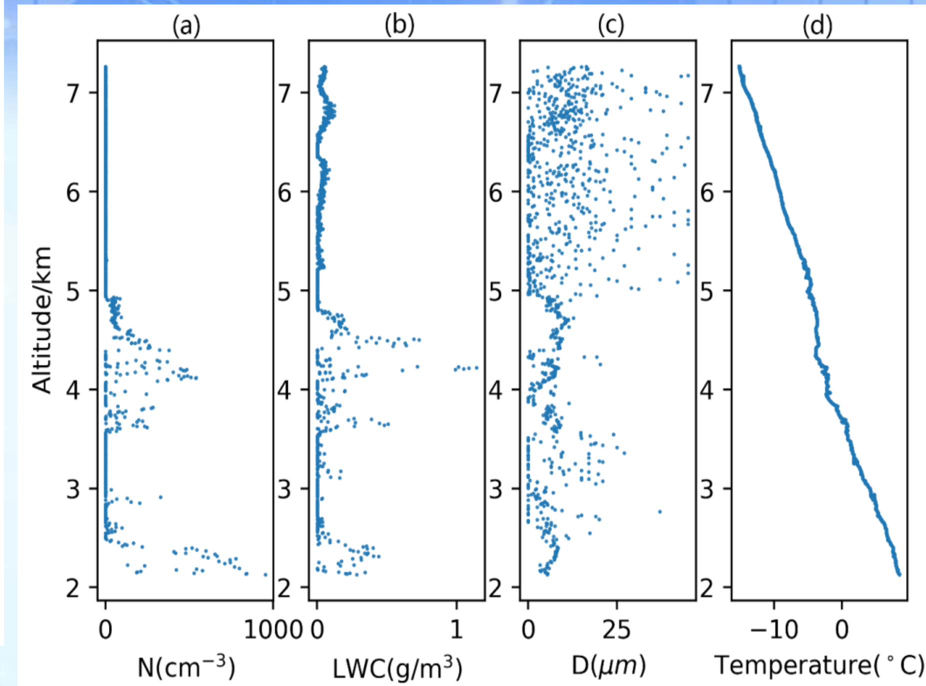


height:2120~7260m，
temperature: 8.6~-15.1℃，
0℃ level: 3700m

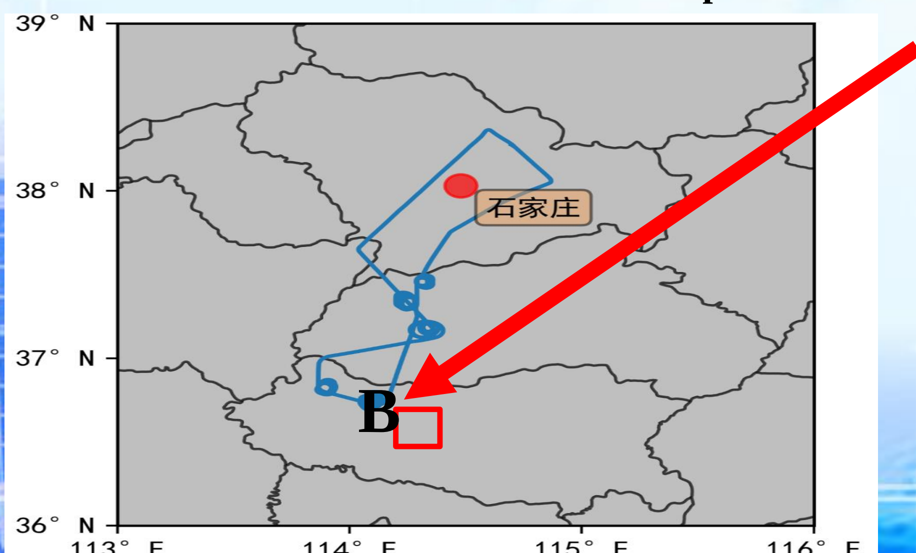
B-area（16:31—16:47）



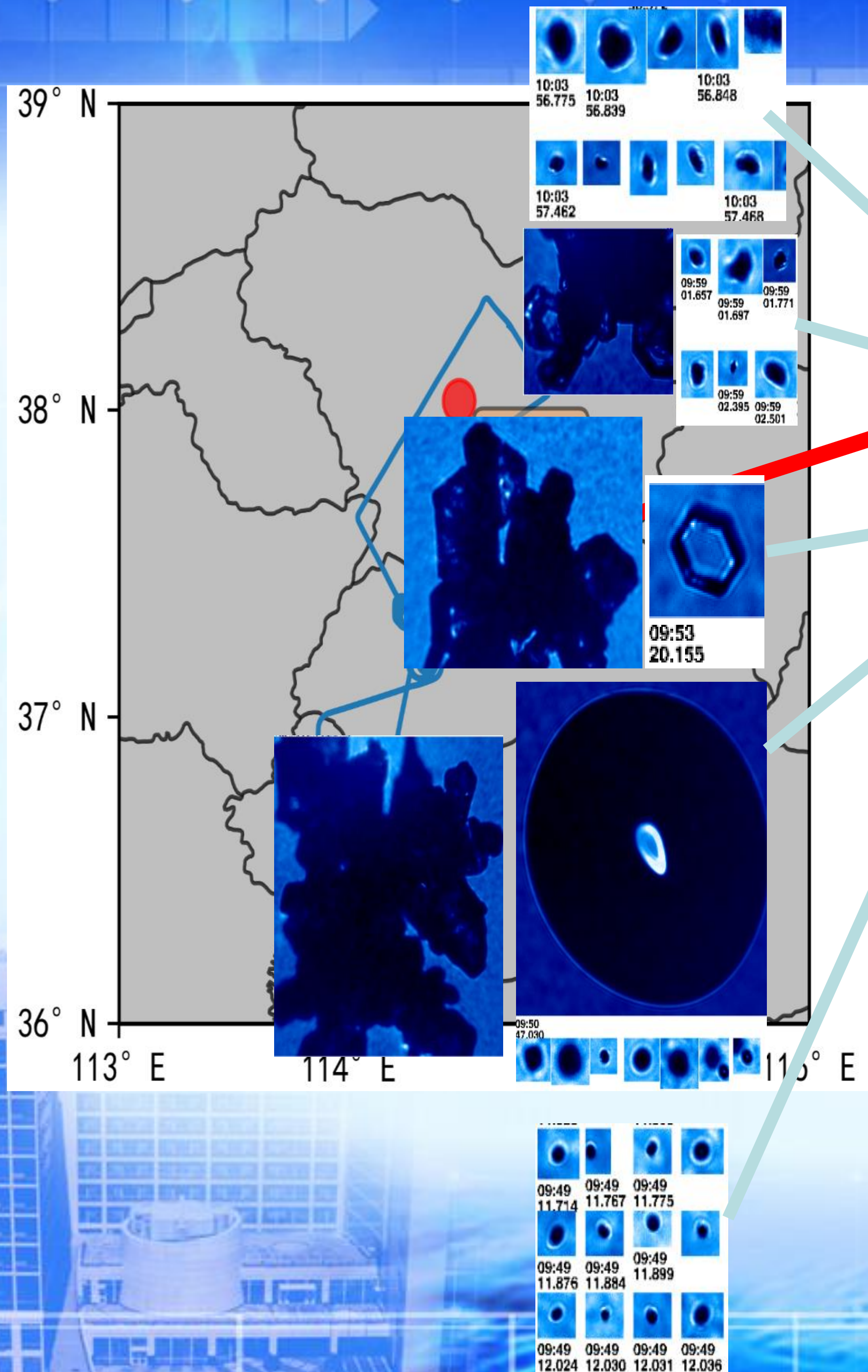
a.CIP，b. hotwire
c. CIP-mean diameter，d. temp.

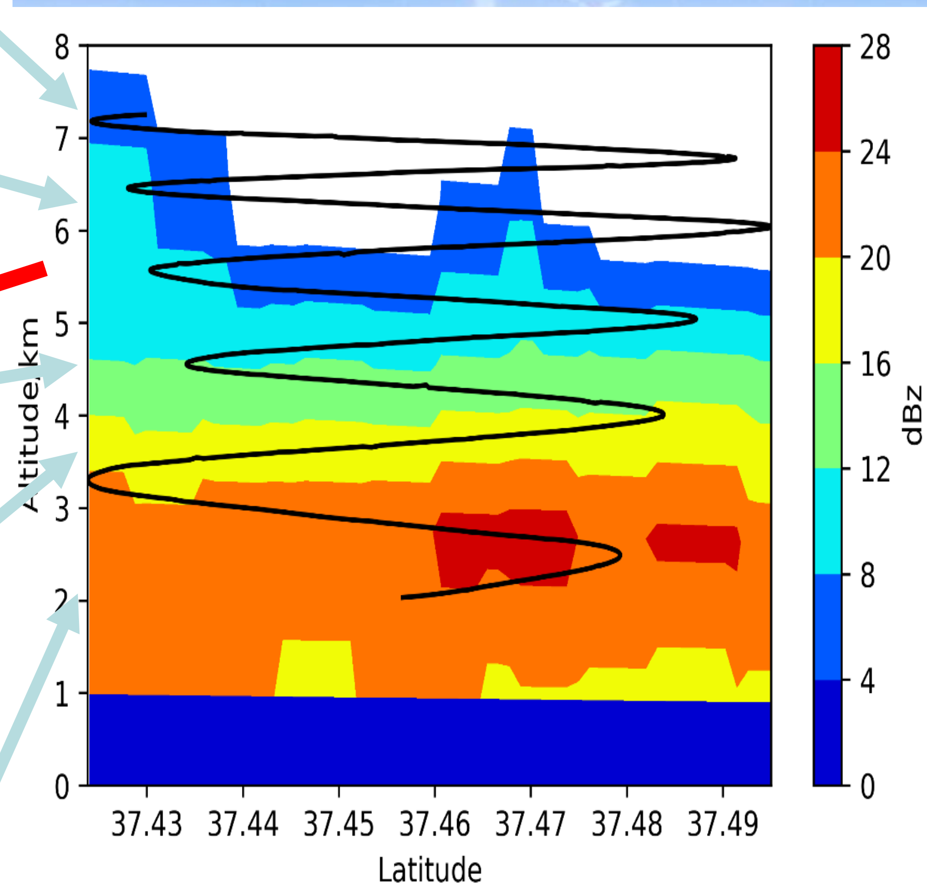


a.CDP，b. hotwire
c. CDP mean diameter，d. temperature



C-area（17:49—18:04）



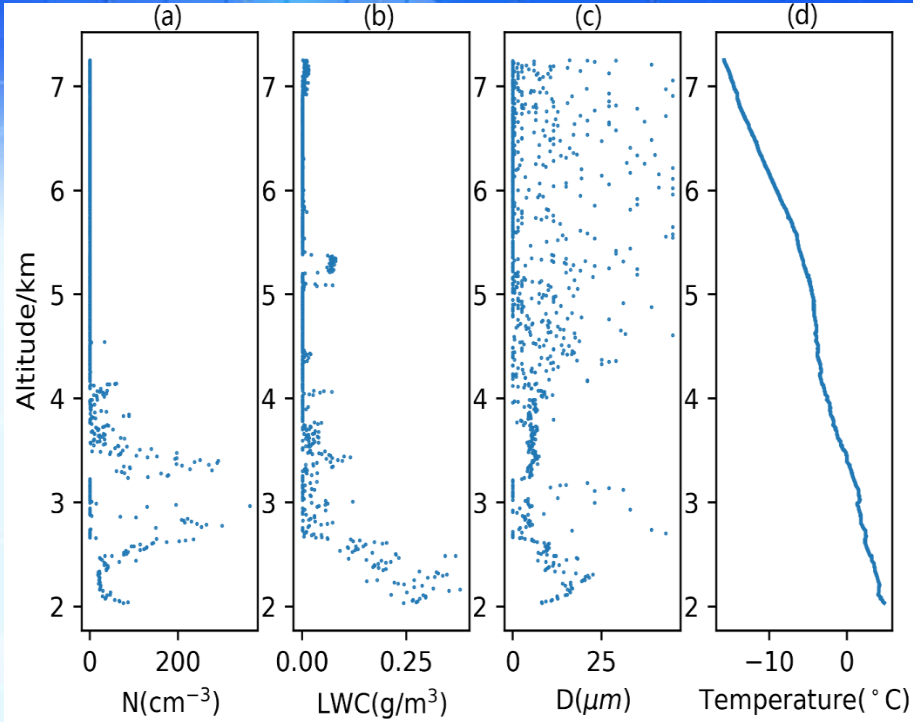


height: 2020~7250m，

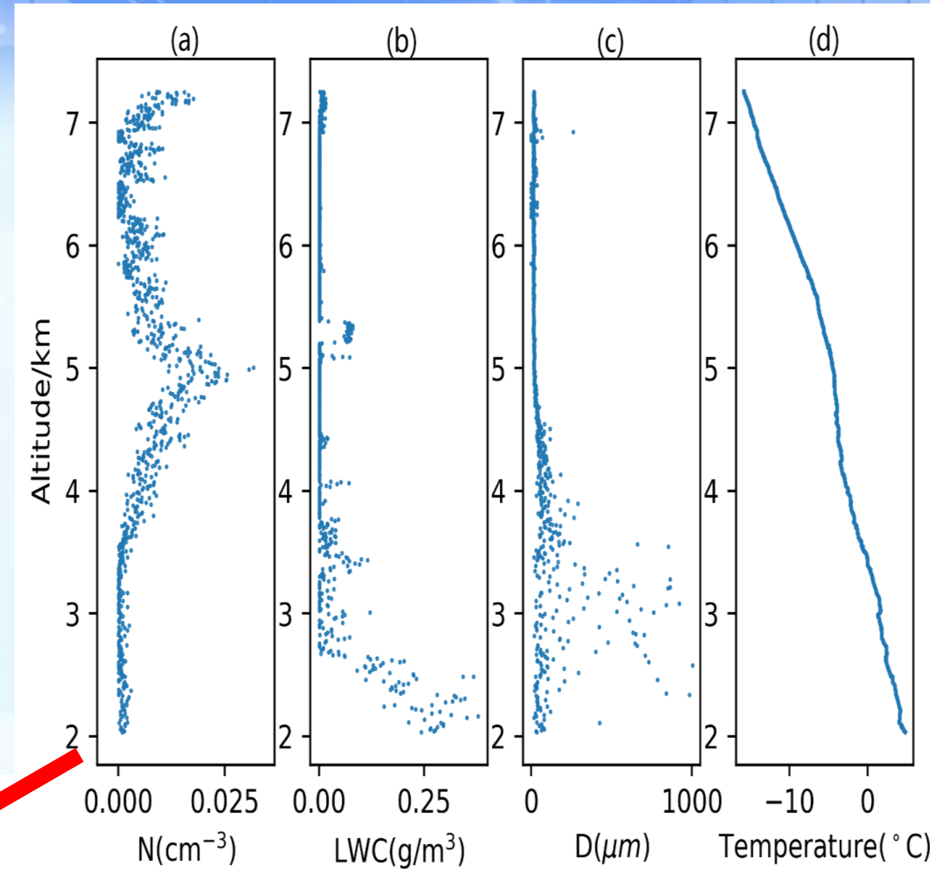
Temp. 4.9~-15.8℃，

0℃： 3400m

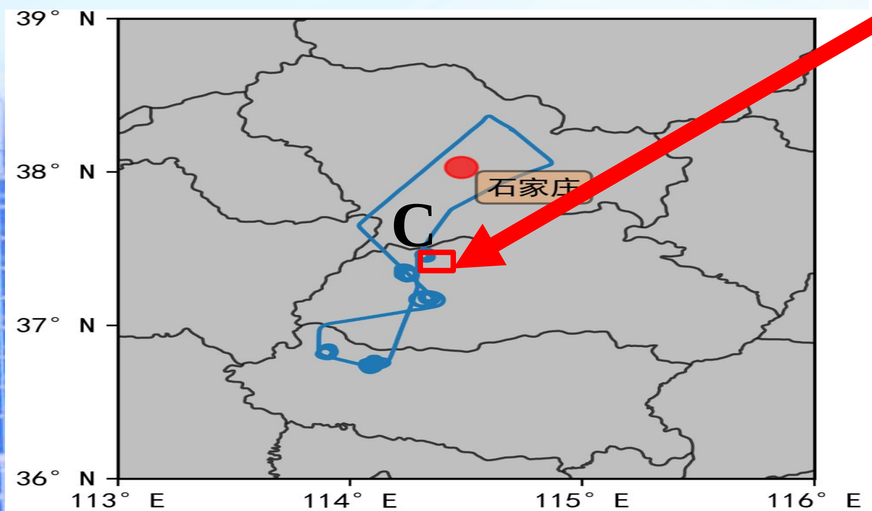
C-area（17:49—18:04）



a.CDP，b.Hotwire-LWC
c. CDP mean D，d. temp.



a.CIP，b.hotwire
c. CIP mean D，d. Temp.

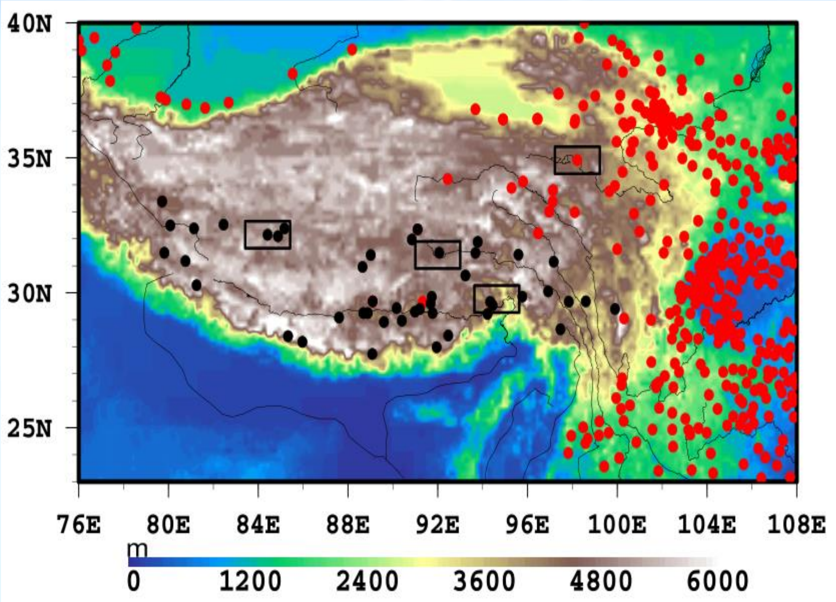


Summary for this case

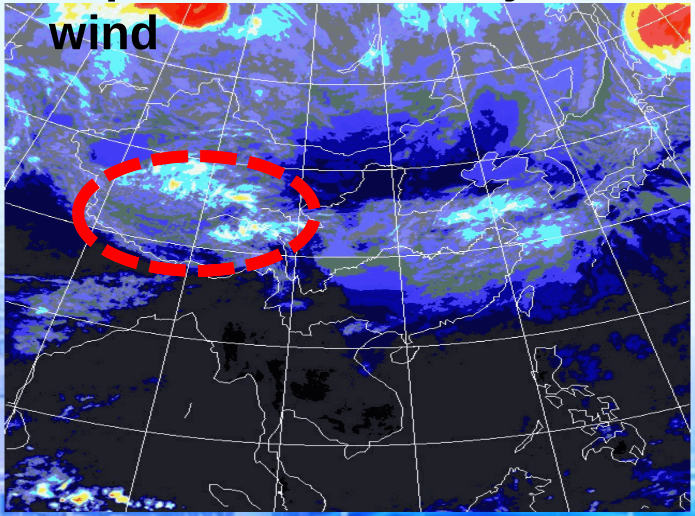
- ✓cloud properties: cloud-top 7km, in which,3km-warm clouds, 4km-cold clouds. Cloud-top temp. -17℃, cloud-base temp.+ 15℃。0℃ level 3.4-3.7km.
- ✓This cloud is ideal for cloud seeding.
- ✓Seeder-feeder is main mechanism for precipitation formation, however, some differences existed in different cloud postions.

c. Aircraftment on high mountain clouds

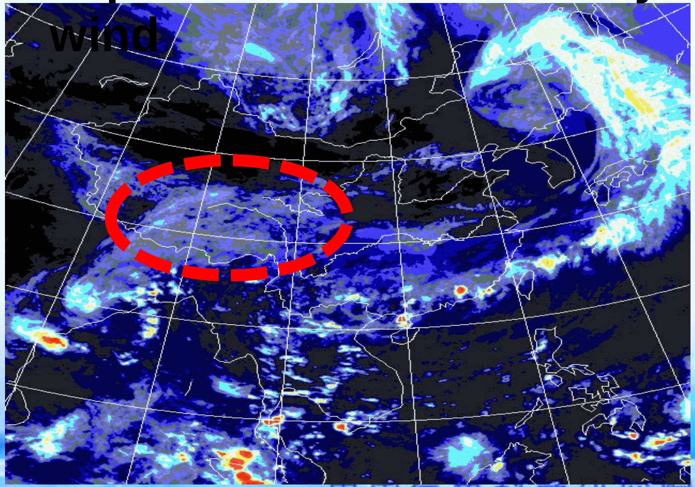
- The Tibetan Plateau is the world's highest and largest Plateau, approximately 1000 X 2500 km, with an average elevation exceeding 4500 m.
- It serves as a "water tower", and plays an important role in hydrological cycle. Its impact on weather system and climate change is of particular scientific interest.



Impact from westerly wind



Impact from southwesterly wind



Field campaign on summer clouds and precipitation over Tibet Plateau

- **From July-August, 2004-2005, intensive field campaigns for clouds and precipitation were conducted in order to reveal the physical process of meteorology and atmosphere over the Tibetan Plateau.**

  The field campaign used state-of-the-art observational instruments such as aircraft, C-band radar and Ka-band cloud radar, as well as raindrop disdrometer, lidar, ceilometer etc.

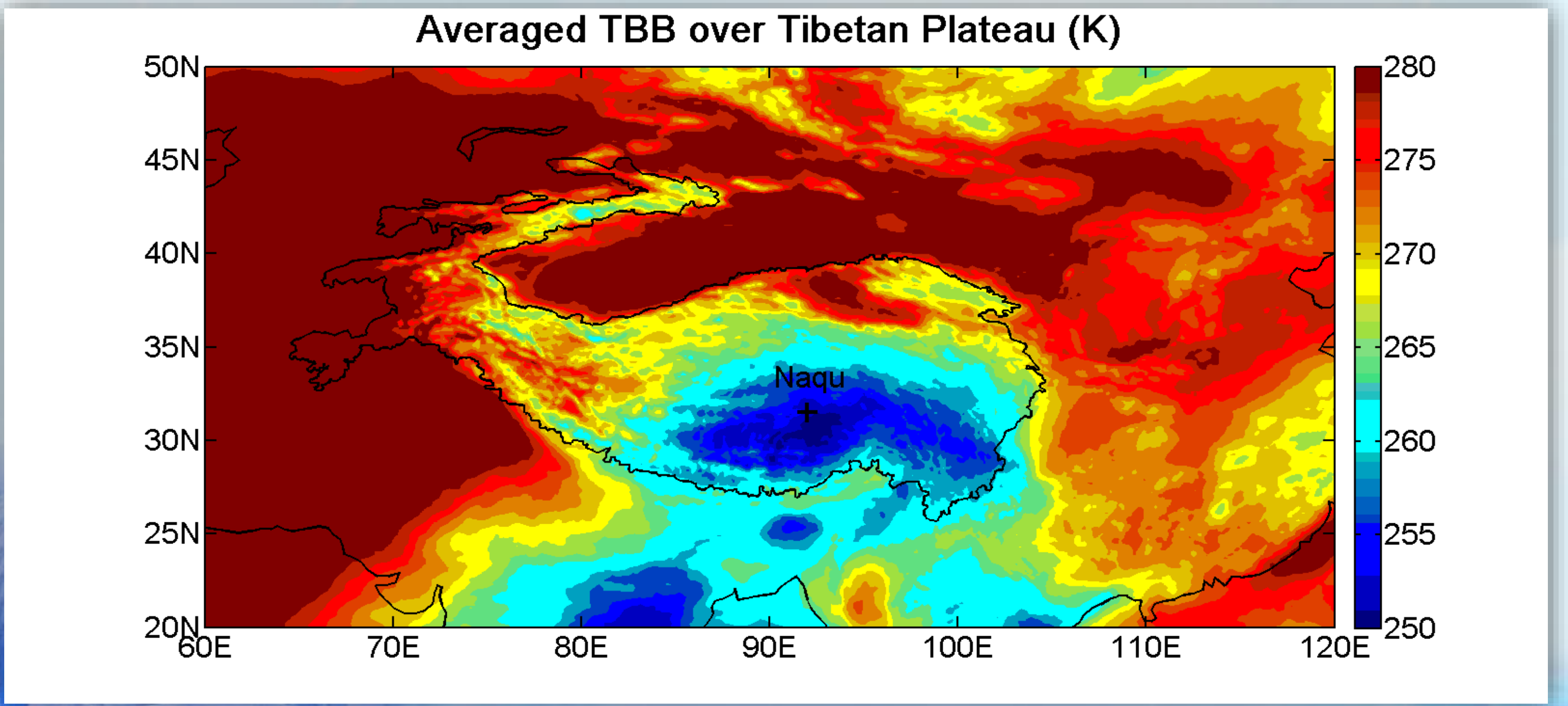
To understand the clouds and precipitation processes and improve the numerical model forecasting over the plateau.

Clouds microphysical structure derived from aircraft measurements

Period: July 1-24,2014
Flight times : 12
Data available times : 6

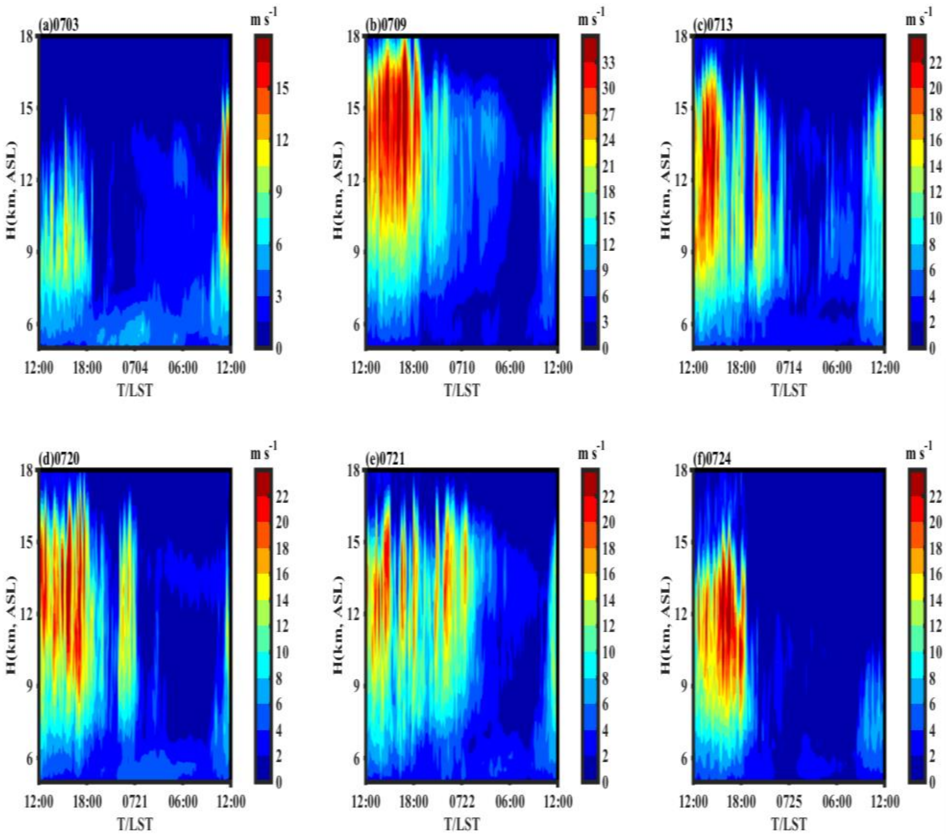
The target clouds aircraft measured include weak convections and stratiform clouds. The flight height ranged from 6000-8500m ASL. The frequent strong turbulence and icing always occurred during the flights.

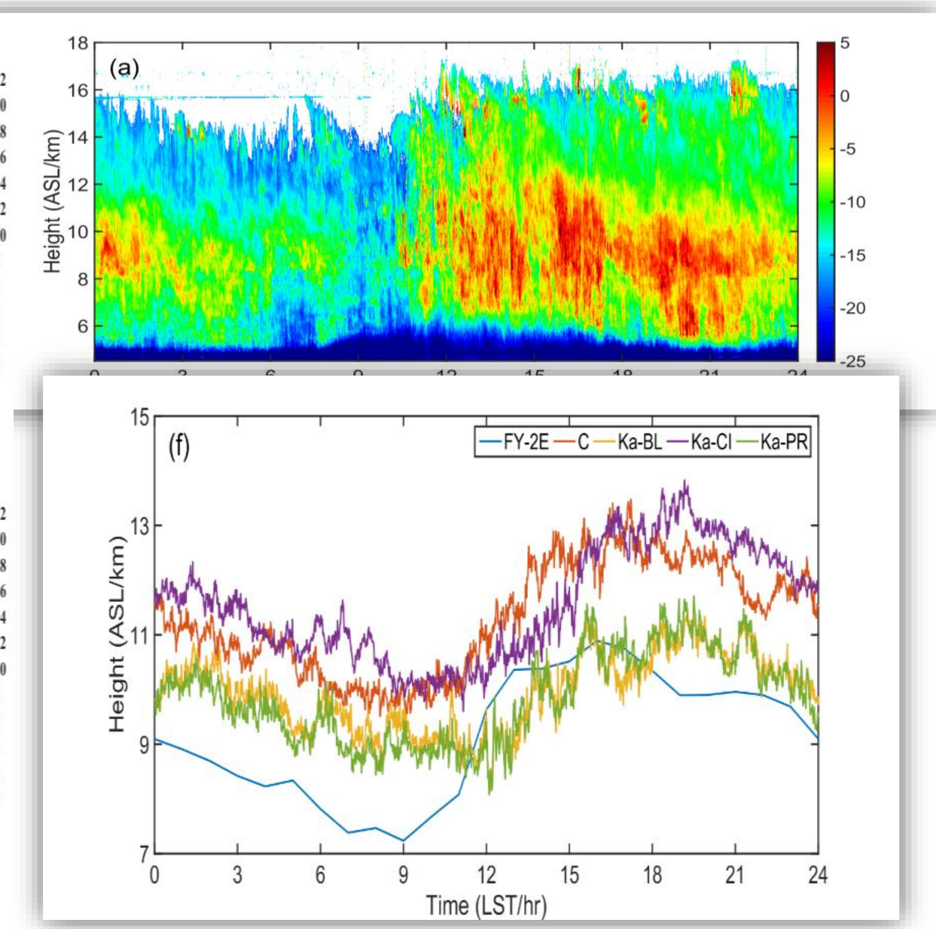
The summer clouds and precipitation over Tibet plateau has a prominent characteristic of daily variation



July-August, 2014

Clouds and precipitation over the Tibetan Plateau

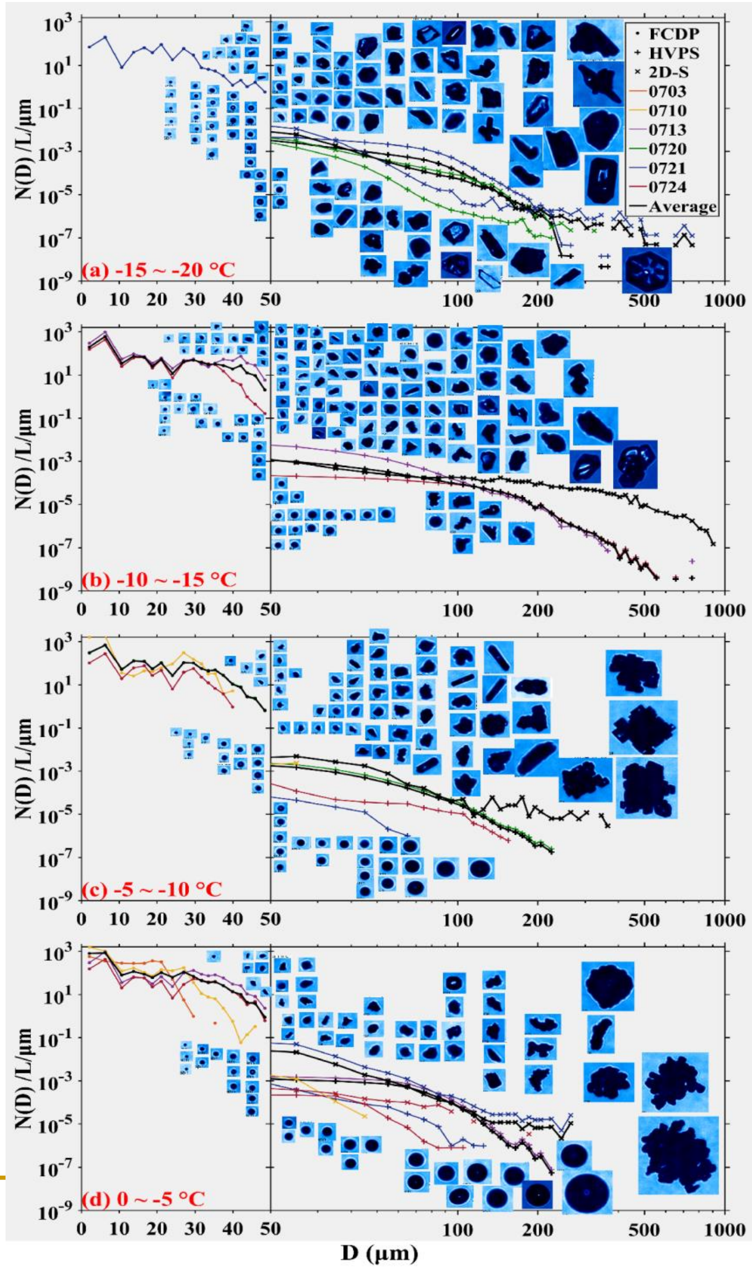


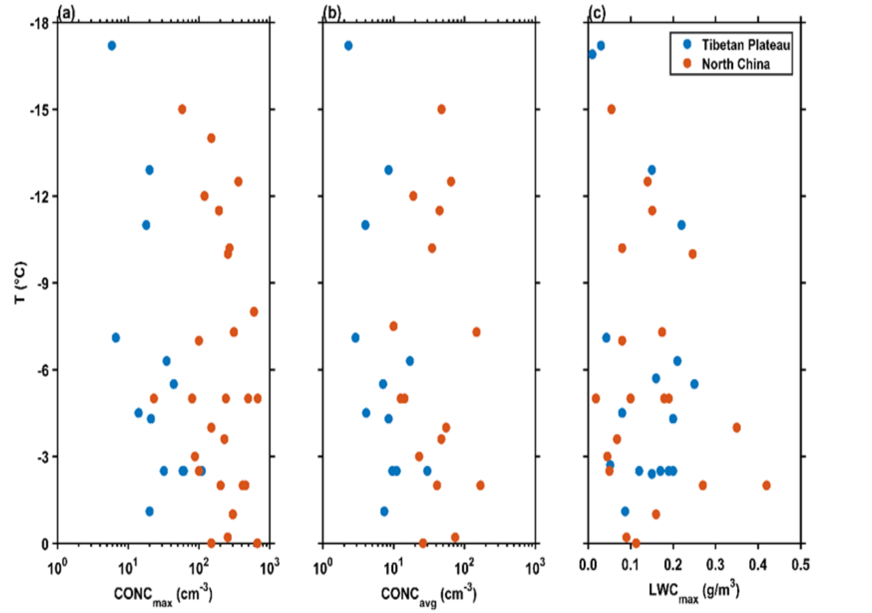


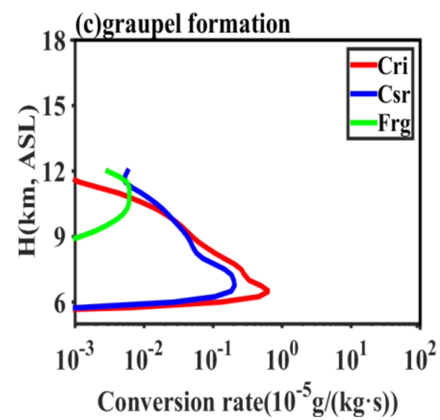
Zhao, P., X. Xu, F. Chen, X. Guo, X. Zheng, L. Liu, Y. Hong, Y. Li, Z. La, H. Peng, L. Zhong, Y. Ma, S. Tang, Y. Liu, H. Liu, Y. Li, Q. Zhang, Z. Hu, J. Sun, S. Zhang, L. Dong, H. Zhang, Y. Zhao, X. Yan, A. Xiao, W. Wan, Y. Liu, J. Chen, G. Liu, Y. Zhaxi, and X. Zhou, 2017: The Third Atmospheric Scientific Experiment for Understanding the Earth-Atmosphere Coupled System over the Tibetan Plateau and Its Effects. ***Bull. Amer. Meteor. Soc***. doi:10.1175/BAMS-D-16-0050.1

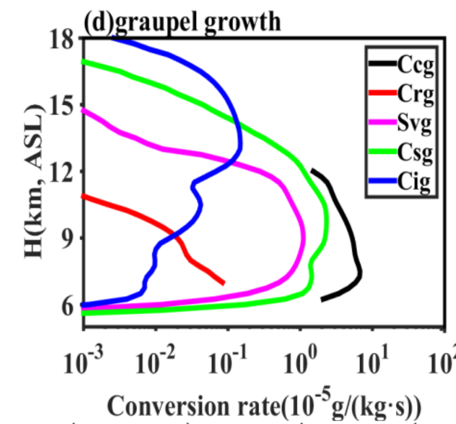
Chang Yi, Xueliang Guo, Jie Tang, Guangxian Lu, 2019: Aircraft measurement campaign on summer cloud microphysical properties over the Tibetan Plateau, **Scientific Reports**, volume 9, Article number: 4912.

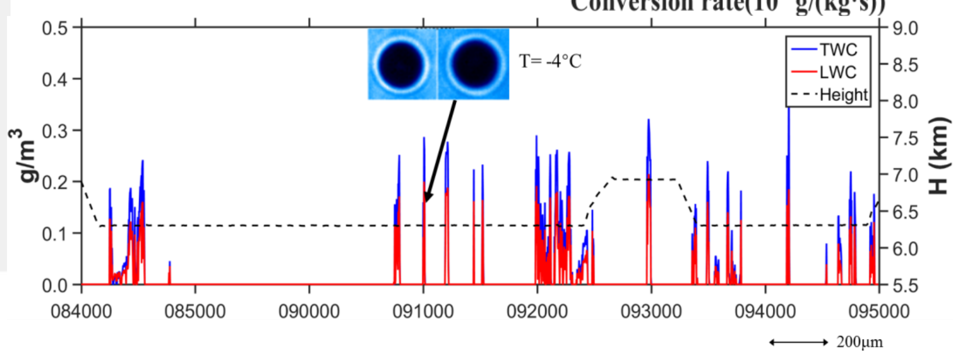
Aircraft measurements over the Tibetan Plateau

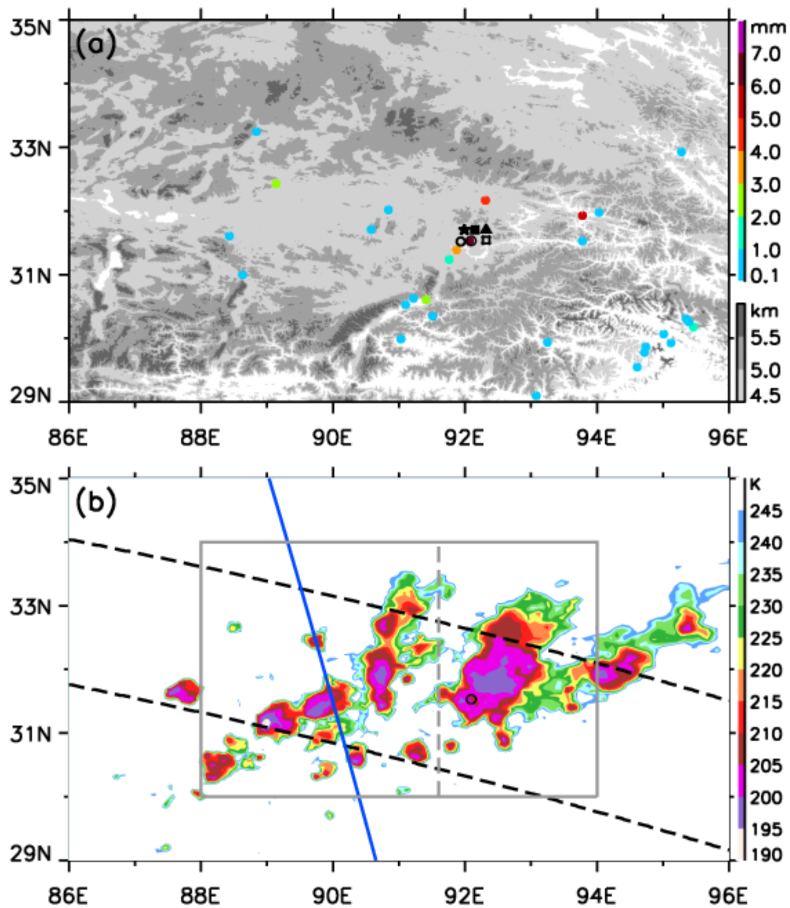


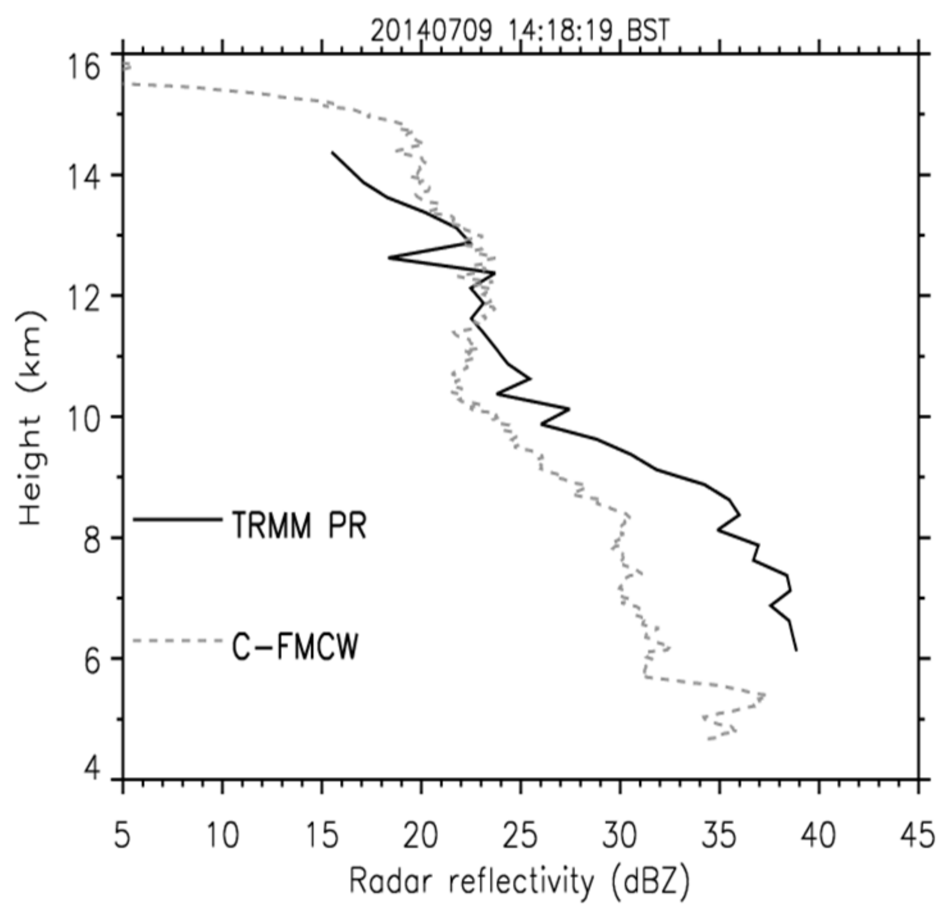









(a)
(b)
35N
33N
31N
29N
86E
88E
90E
92E
94E
96E
mm
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.1
km
5.5
5.0
4.5
K
245
240
235
230
225
220
215
210
205
200
195
190


20140709 14:18:19 BST
Height (km)
Radar reflectivity (dBZ)
TRMM PR
C-FMCW

Relevant publications

1. Zhao, P., X. Xu, F. Chen, X. Guo, et al., 2017: The Third Atmospheric Scientific Experiment for Understanding the Earth-Atmosphere Coupled System over the Tibetan Plateau and Its Effects. *Bull. Amer. Meteor. Soc*. doi:10.1175/BAMS-D-16-0050.1

2. Chang Yi, Xueliang Guo, Jie Tang, Guangxian Lu, 2019: Aircraft measurement campaign on summer cloud microphysical properties over the Tibetan Plateau, Scientific Reports, volume 9, Article number: 4912.

3. Zhu, S., X.Guo, G. Lu and L. Guo,2015: Ice crystal habits and growth processes in stratiform clouds with embedded convection examined through aircraft observations in Northern China. J. Atmos. Sci., 72, 2011–2032.

4. Fu, D., and X. Guo, 2012: A cloud-resolving simulation study on the merging processes and effects of topography and environmental winds. J. Atmos. Sci., 69, 1232–1249.

5. Lu G. X., and Guo, X., 2012: Distribution and origin of aerosol and its transform relationship with CCN derived from the spring multi-aircraft measurements of Beijing Cloud Experiment (BCE). Chin. Sci. Bull. 57: 1□11, doi: 10.1007/s11434-012-5136-9.

6. Fu, D., X. Guo, and C. Liu, 2011: Effects of cloud microphysics on monsoon convective system and its formation environments over the South China Sea: A two-dimensional cloud-resolving modeling study, J. Geophys. Res., 116, D07108,doi:10.1029/2010JD014662.

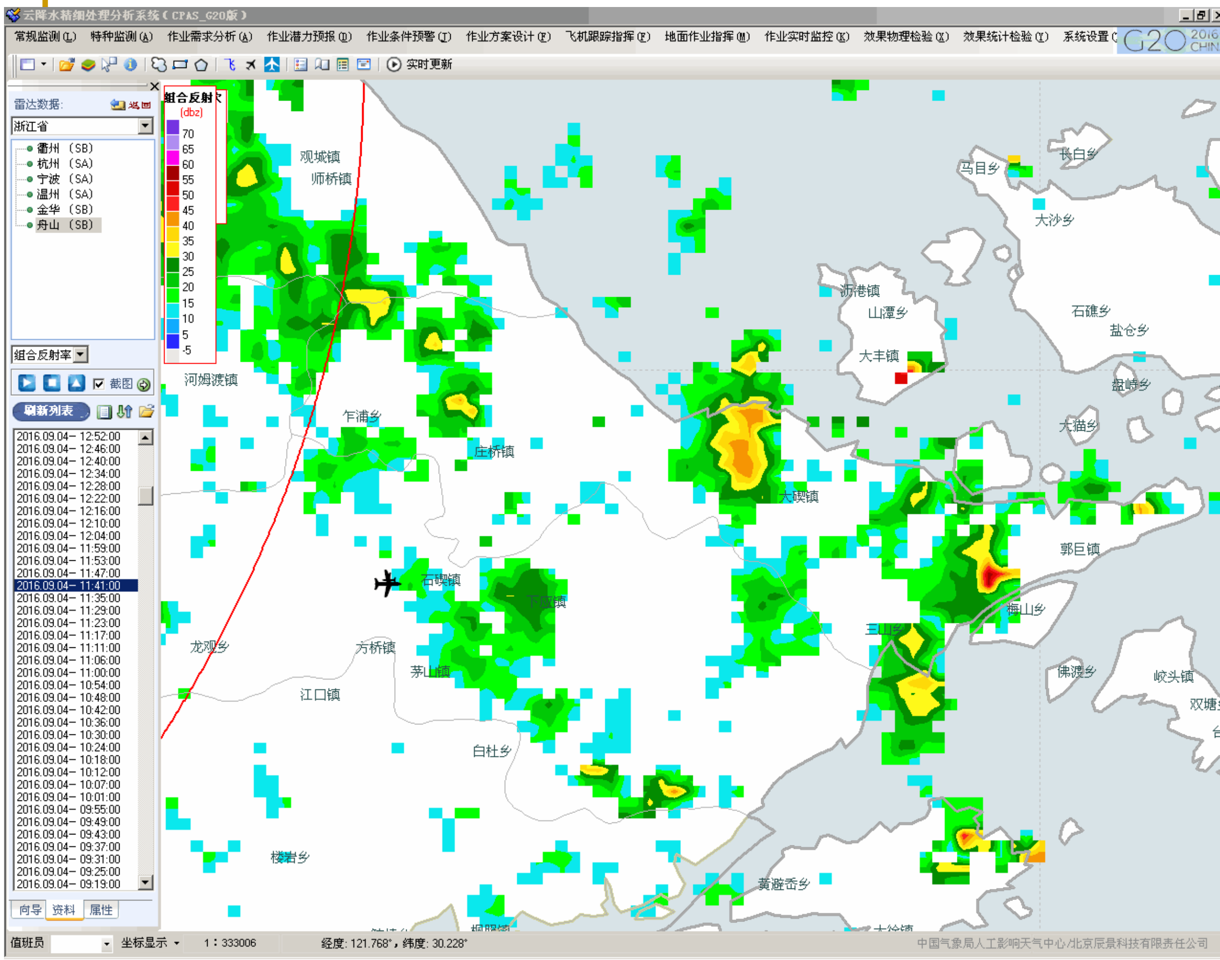
7. Guo Xueliang and Zheng Guoguang, 2009: Advances in weather modification from 1997 to 2007 in China, Adv. Atmos. Sci., 26,240-252.

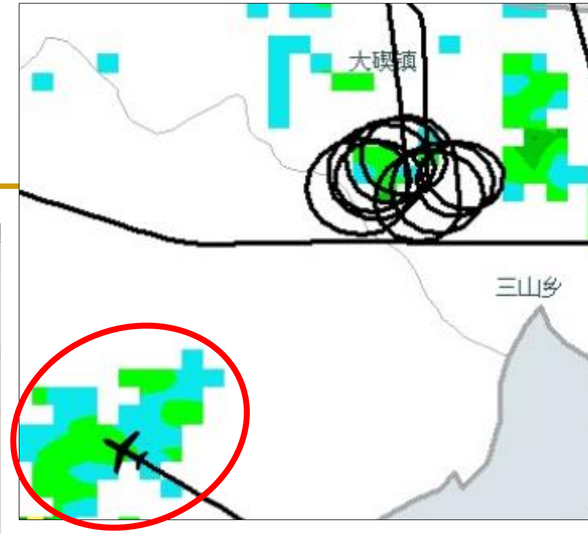
8. Li Xinyu, Guo Xueliang, Zhu Jiang, 2008: Climatic features of cloud water distribution and cycle over China, Adv. Atmos. Sci., 25，437-446

Future focus

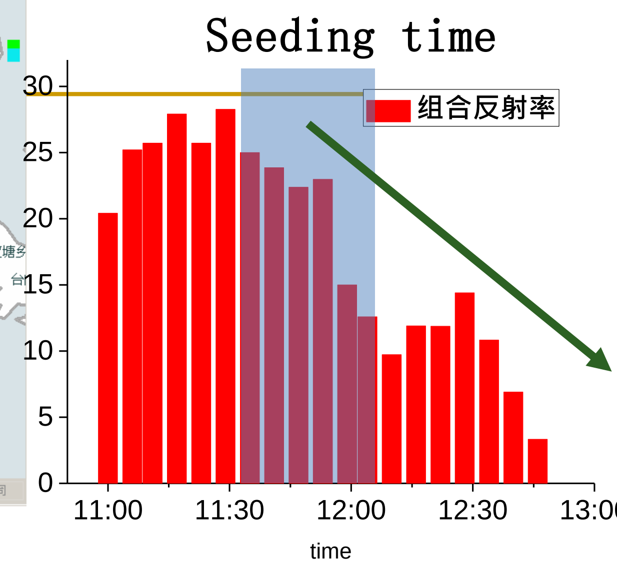
- to understanding physical process in many subjects, such as cloud seeding, weather forecasting and climate change and environmental issues.
- to improve the parameterization of cloud microphysics processes in models.
- to quantify the interactions among aerosols and cloud microphysical processes and precipitation

How to verify the seeding effectiveness by aircraft measurement ?





Return penetration



Are precipitation anomalies associated with aerosol variations over eastern China?

Xiangde Xu[1], Xueliang Guo[1,2], Tianliang Zhao[3], Xingqin An[1], Yang Zhao[1], Jiannong Quan[4], Fei Mao[1], Yang Gao[5], Xinghong Cheng[1], Wenhui Zhu[1], and Yinjun Wang[1]

[1]State Key Laboratory of Severe Weather (LASW), Chinese Academy of Meteorological Sciences, Beijing, 100081, China
[2]Key Laboratory for Cloud Physics, Chinese Academy of Meteorological Sciences, Beijing, 100081, China
[3]Collaborative Innovation Center on Forecast and Evaluation of Meteorological Disasters, Key Laboratory for Aerosol–Cloud–Precipitation of China Meteorological Administration, Nanjing University of Information Science & Technology, Nanjing, 210044, China
[4]Institute of Urban Meteorology, Chinese Meteorological Administration, Beijing, 100089, China
[5]Beijing Weather Modification Office, Beijing, 100089, China

Correspondence to: Tianliang Zhao (tlzhao@nuist.edu.cn) and Xueliang Guo (guoxl@camscma.cn)

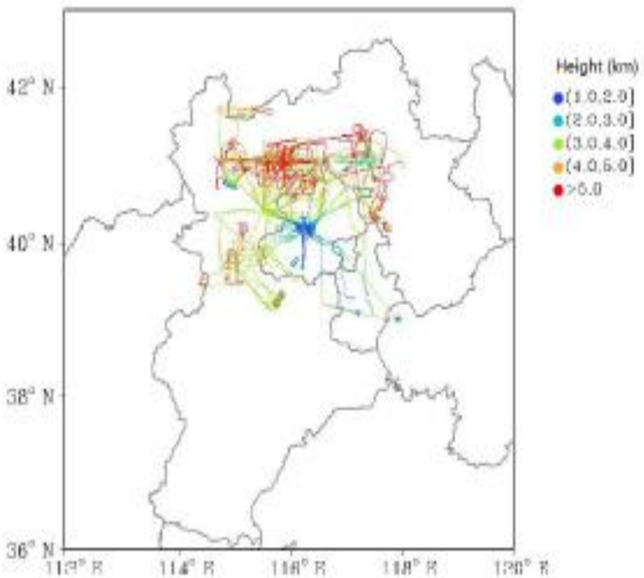
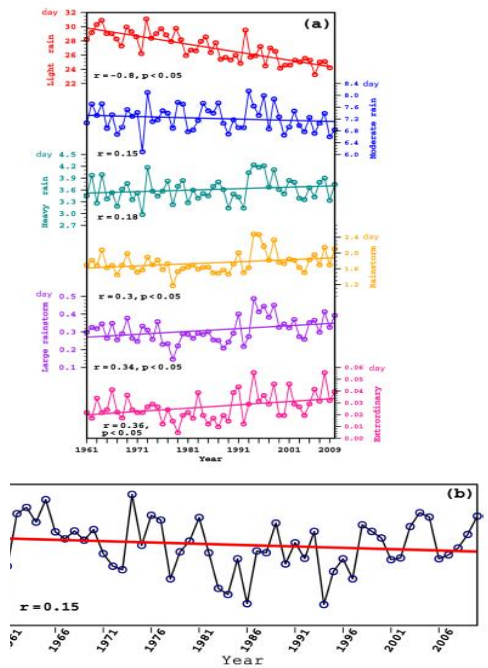


Figure 1. Area and tracks of 40 aircraft flights carried out in Beijing and its surrounding regions during aerosol–cloud experiments from 2008 to 2010 by the Beijing Weather Modification Office, China.



Interannual variations with their anomalies (broken lines)
s (straight lines) in (a) various precipitation intensities in
aerosol concentration area in the EC region and (b) light
: relatively clean area of the Tibetan Plateau.

in the north in summer during 1961–2010, while the correlations between visibility and low-level cloud amount were distributed as positive in the north and negative in the south in EC during 1961–2010 (Fig. 5b), indicating that the effect

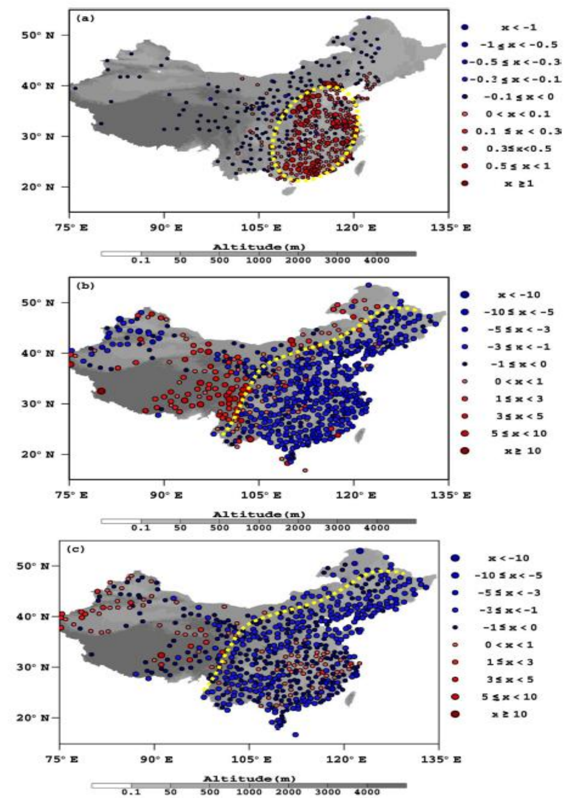


Figure 4. Distribution of interannual change trends (day per 10 years) in (a) haze frequency, (b) visibility and (c) light rain frequency in summer in mainland China in 1961–2010. The yellow dash lines mark the borders of frequent haze areas or the eastern borders of plateaus in China.

Cloud chamber

Thank you for your attention！