中国气象局人工影响天气中心

CMA Weather Modification Centre (WMC)

Weather Modification Research in China

Xiaofeng LOU, Yue CHEN

Bangkok, Thailand, 2018/8/6

ASEAN : A COMMUNITY OF OPPORTUNITIES

WMO

Outlines

1. **Numerical model seeding simulation**
2. **Field observation experiments**

1. Bulk water cloud models

Model	year	variables
1-D mix-phased dual-parameterized convective cloud model	1987	qv,qc,qr,qi,qg,qh,ni,nr ,ng,nh,Fc
3-D nested convective cloud model	1993	qv,qc,qr,qi,qg,qh,ni,nr ,ng,nh,Fc
Convective cloud seeding model	2001	qv,qc,qr,qi,qg,qh,nr,ni ,ng,nh,Fc,Naer Naim
Convective cloud seeding model	2002	qv,qc,qr,qi,qs,qg,qh,nr ,ni,ns,ng,nh,Fc,Naer Naim
3-D cloud series model	2003	qv,qc,qr,qi,qs,qg,Nr,N i,Ns,Ng,Fc

Bin cloud models

- 1988 1-D, Qv ,101bin, 0.03μm-1μm, salt particle bins, 1μm-3250μm,cloud and rain particles
- 1998 1-D,Qv , Q c, Q r, Q i, Ni, N r(bin) , 100 μm - 6 mm,37 bin
- 2001 3-D,Qv , Q c, Q i, N i , Qr , Qs, Qh(bin) , 100 μm-7 cm,21bin

Seeding models

- Hygroscopic seeding model:

  Aerosol and water drop bin model:

  0.01um -1cm, 256 bins

  Nacl seeding model:Qn, Nn

- AgI seeding model:

  c

  stratiform model

  hail cloud model

coupled to WRF，GRAPES，ARPS

WRF based AgI seeding model

- A WRF based AgI seeding model has been developed :Sbc + Sic + Sbr + Sir + Sdv

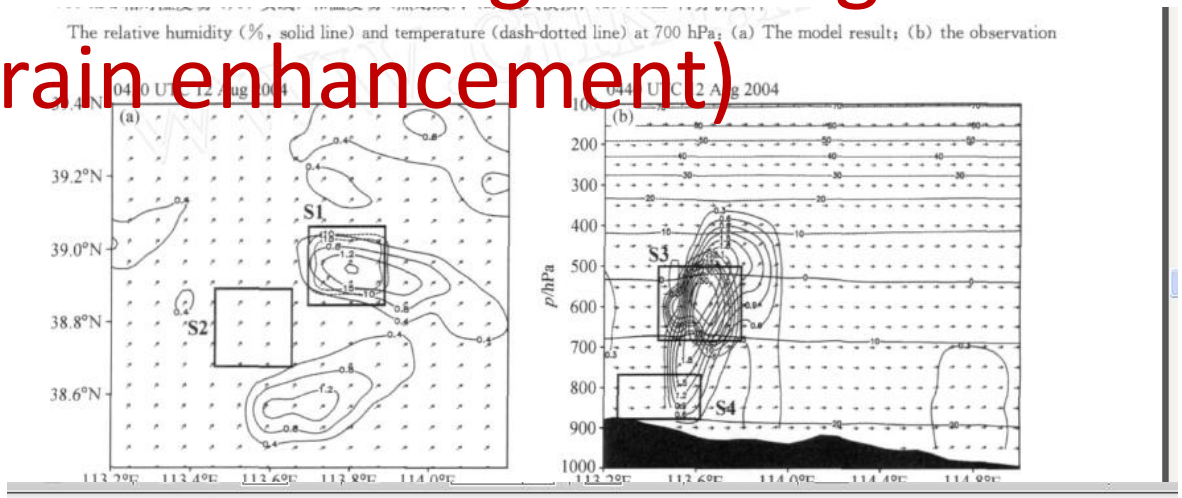
3-D AgI convective cloud model

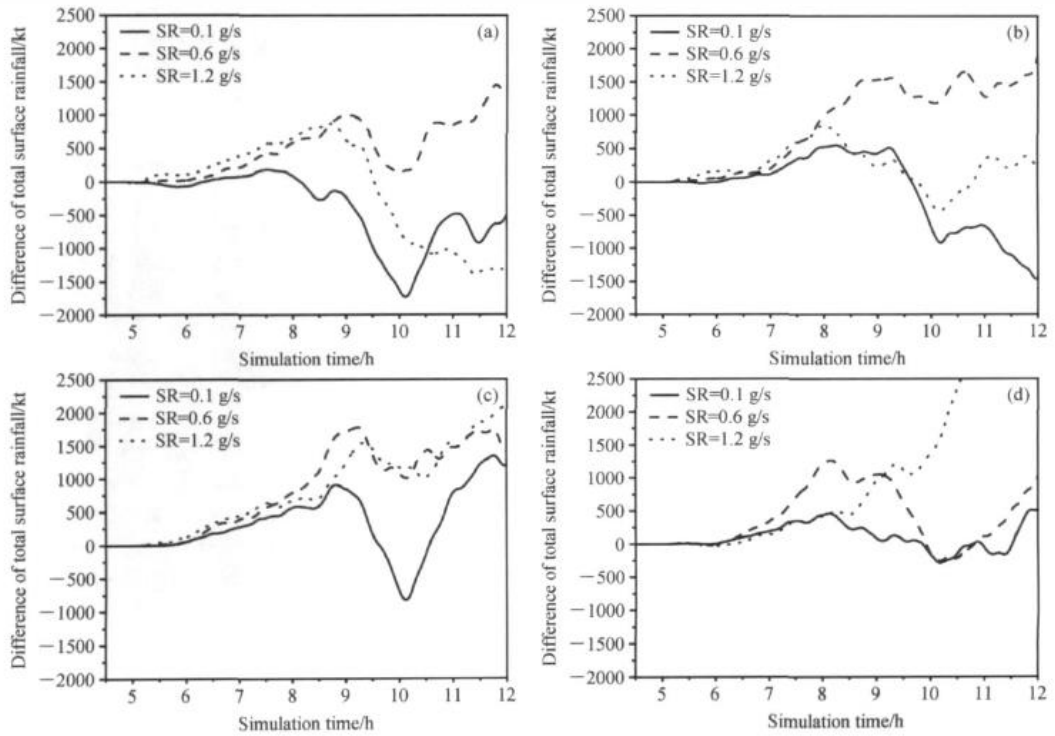
- 4 nucleation modes: Fdep , Fcdf , Fctf ,Fimf, function of T and S（Sw,Si）(DeMott, 1995)

ARPS and GRAPES based AgI seeding model

- Hail, frozen rain drop, AgI， qia, nia

WRF-based AgI seeding simulation (rain enhancement)

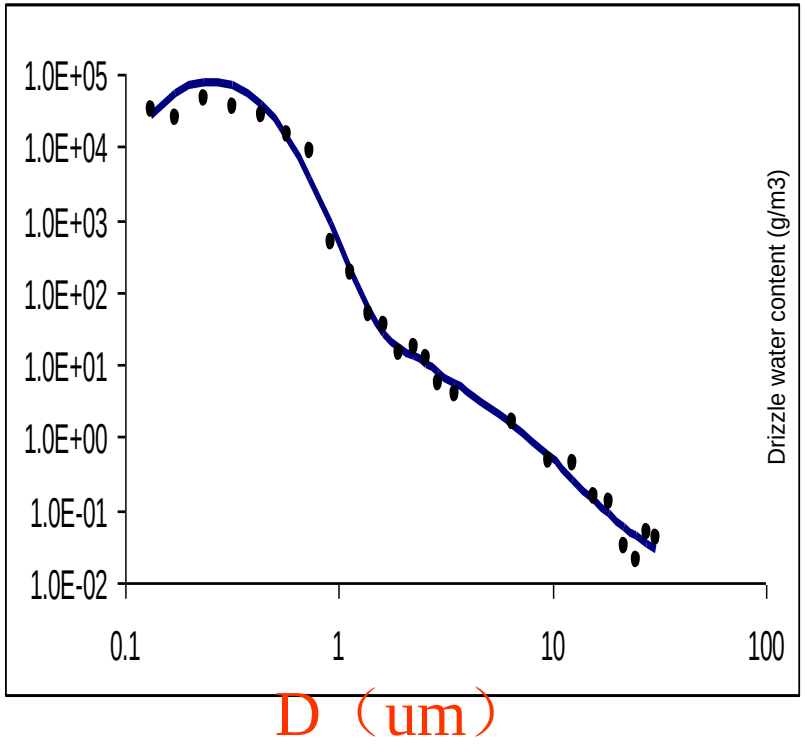




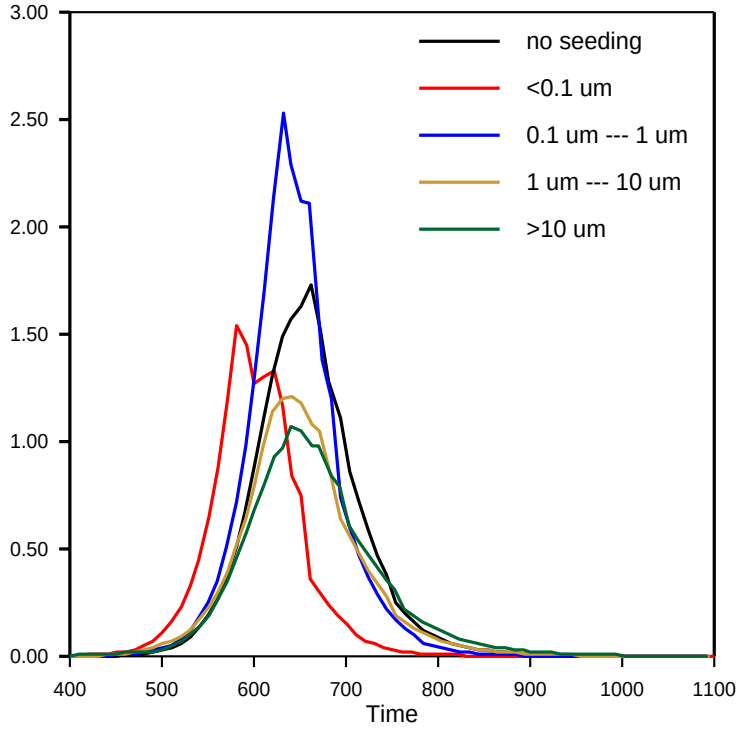
Seeding locations

Seeding effects

Hygroscopic seeding with bin model (Rain enhancement)



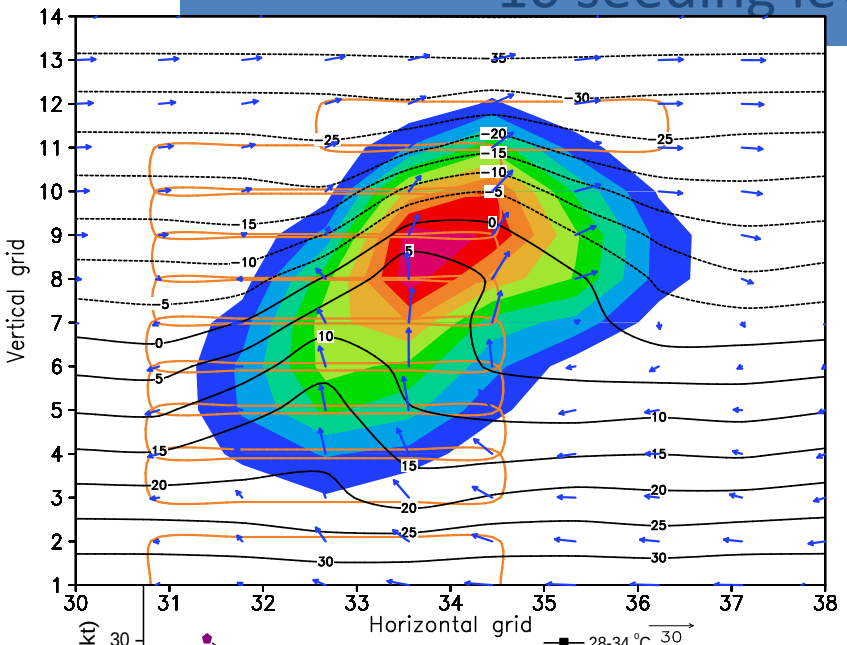
Seeding spectra

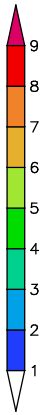


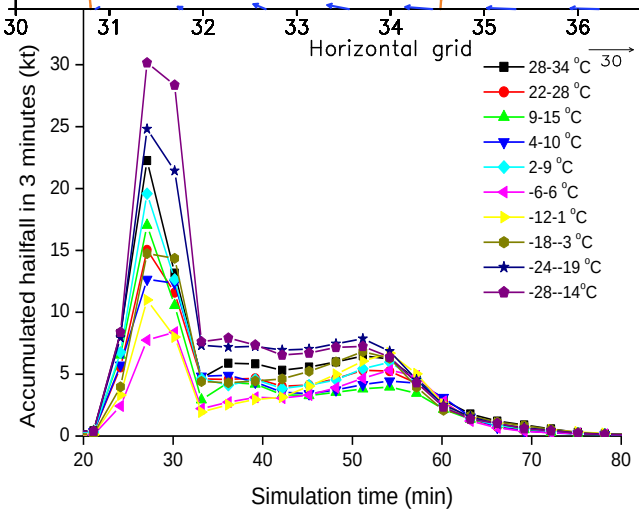
Simulated rainfall of four seeding particle ranges

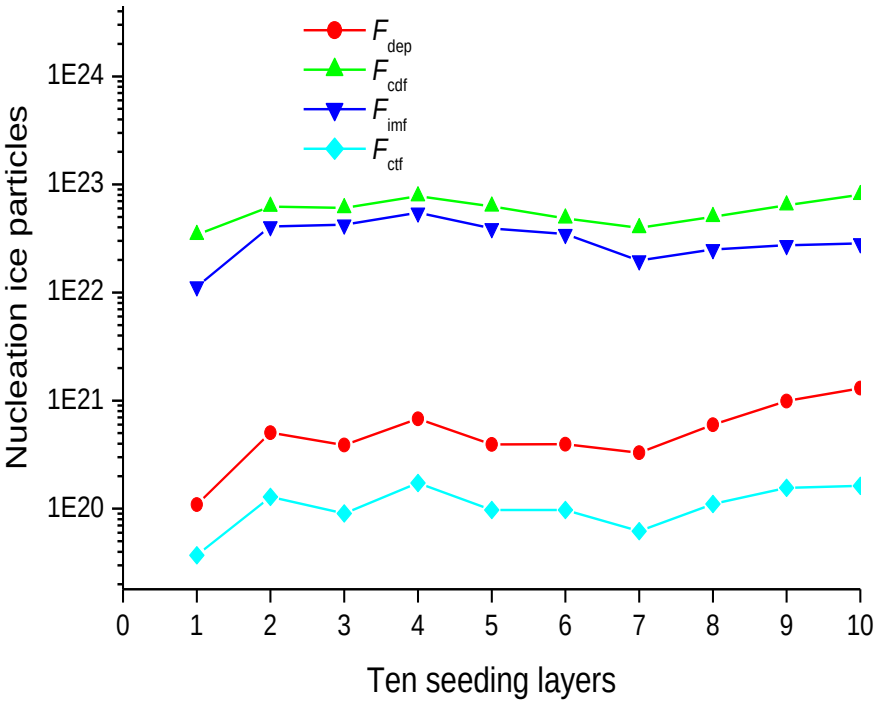
Hail suppression
AgI seeding with 3-D convective model

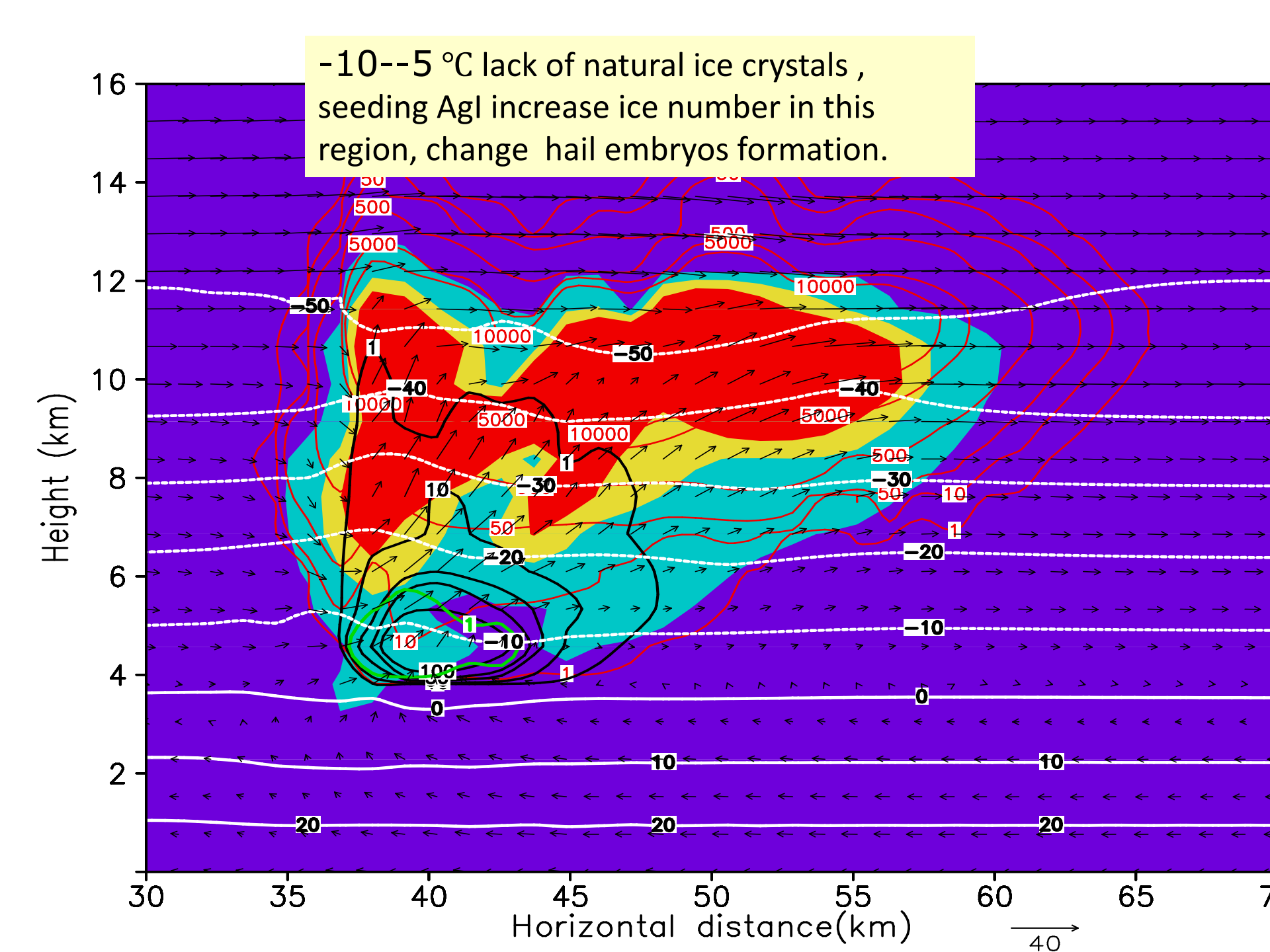
10 seeding levels



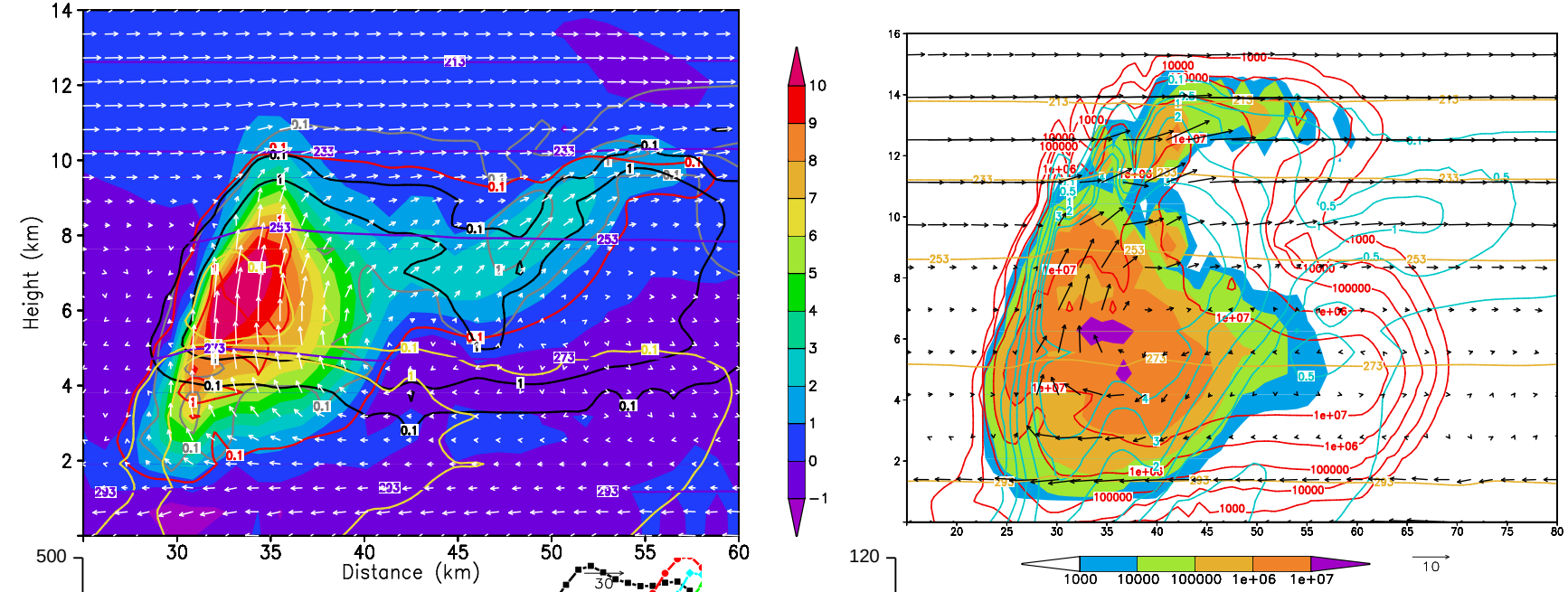


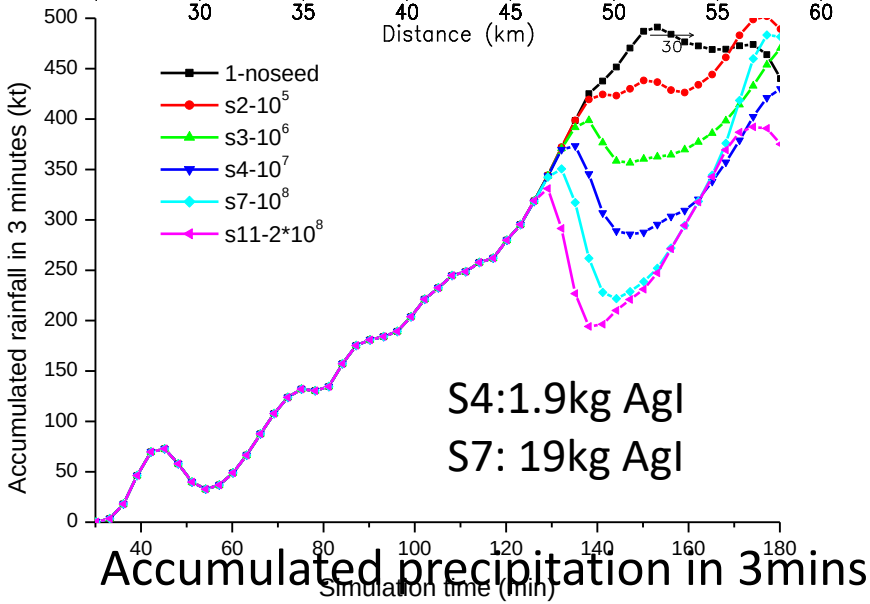




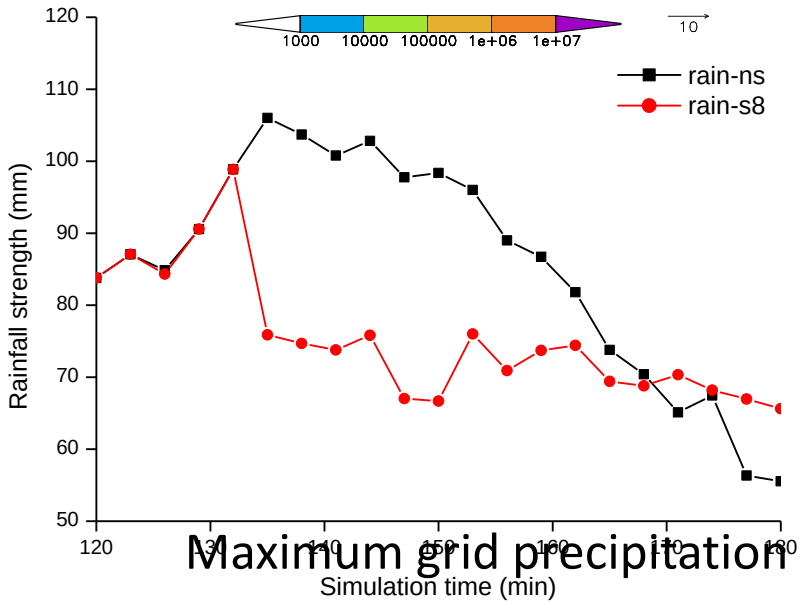

-10--5 ℃ lack of natural ice crystals , seeding AgI increase ice number in this region, change hail embryos formation.
Height (km)
Horizontal distance(km)
40

Heavy rain reduction
AgI seeding with 3-D convective model

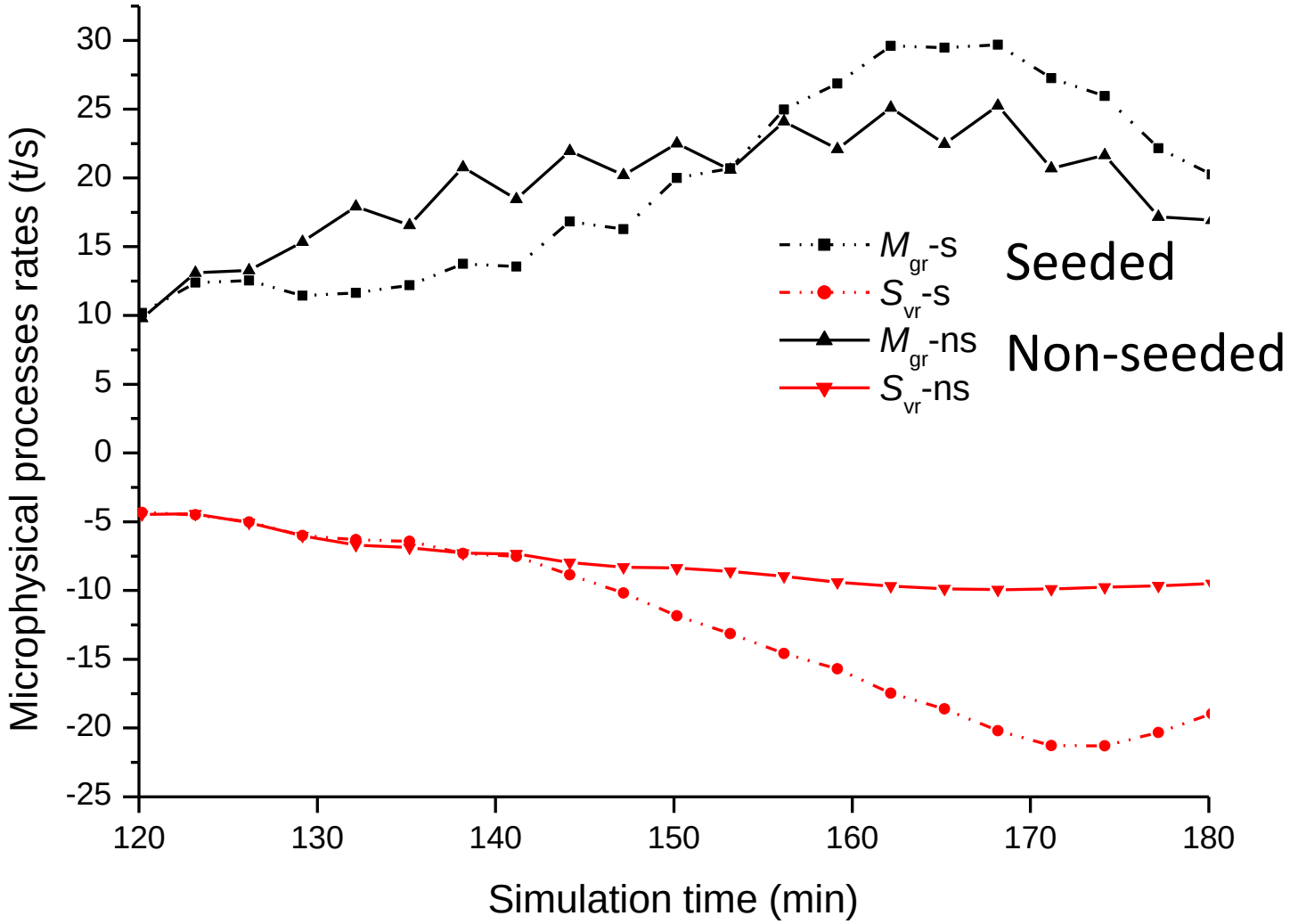




Accumulated precipitation in 3mins



Maximum grid precipitation

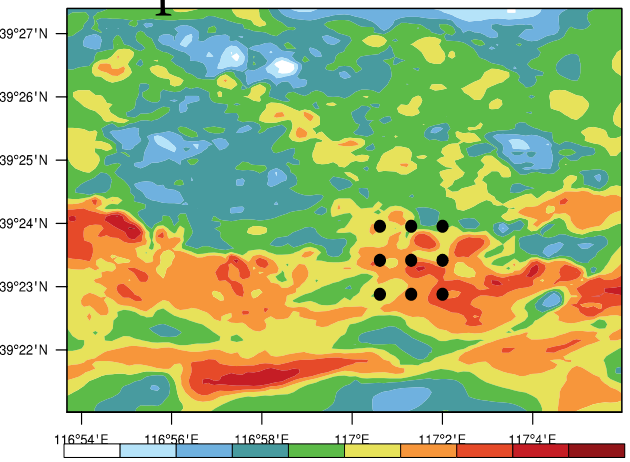


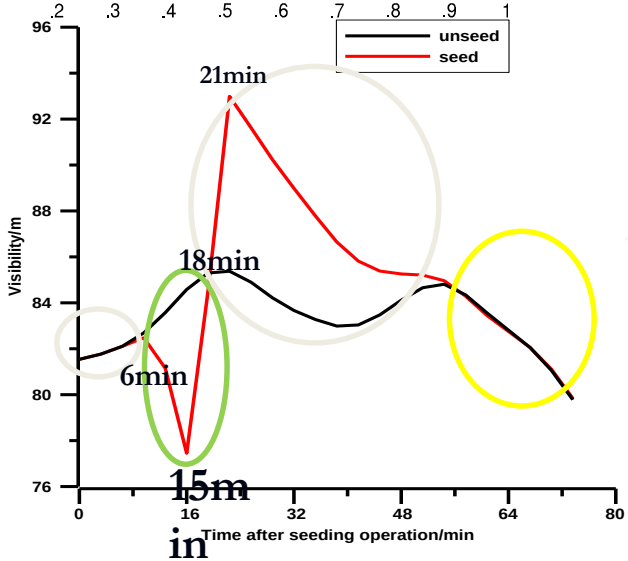
120^{th}-150^{th} :Melting of graupel to rain

150^{th}-180^{th} :Evapration of raindrops

fog dissipiation

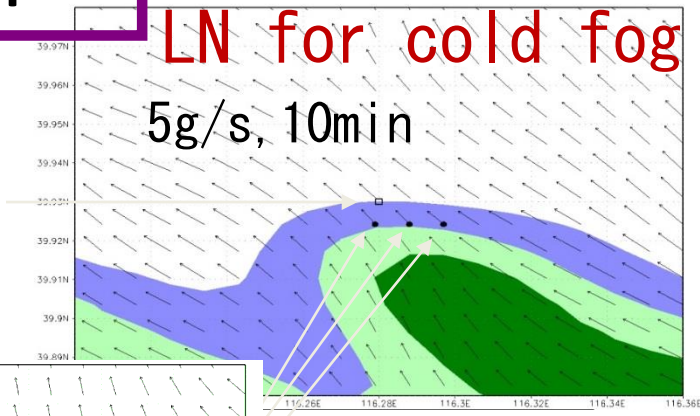
Salt powder for warm fog

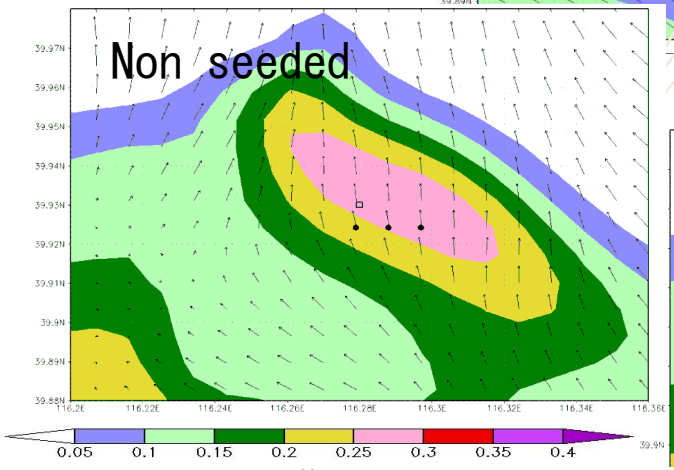




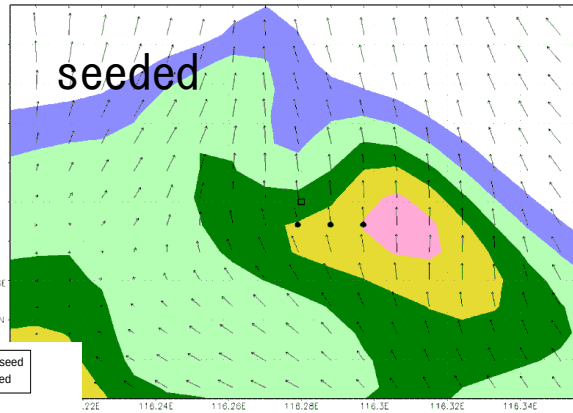
LN for cold fog

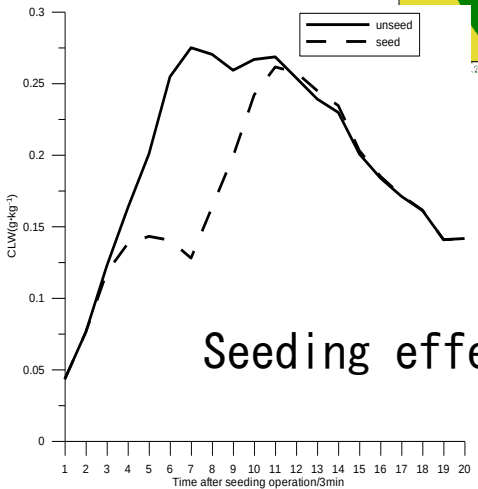
5g/s, 10min





After seedng 24min





9 sites with salt powder at fog top of 0.02 g·m^{-2}·s^{-1}, 5min, total 6 g·m^{-2}.

Seeding effect lasts 25 min

Operational runing

- ✓ MM5, GRAPES model operational running since 2007
- ✓ WRF model operational running since 2016

Explicit cloud schemes: CAMS

MM5(V3) （2002）

显式方案	预报量
Warm rain	qv,qc,qr
Simple ice	qv,qc (qi),qr(qs)
Mix phase	qv,qc,qr,qi,qs,
gsfc	qv,qc,qr,qi,qs,qg
reisner2	qv,qc,qr ,qi,qs,qg,ni
schultz	qv,qc ,qr, qi,qs,qg,
CAMS	qv,qc,qr,qi,qs,qg; nr,ni,ns,ng,fc

GRAPES（2007）

显式方案	预报量
kessler	qv,qc,qr
ncepcloud3	qv,qc (qi),qr(qs)
lin	qv,qc,qr,qi,qs,qg
ncepcloud5	qv,qc,qr,qi,qs
etamp	qv,qc,qr (qi,qs)
etampnew	qv,qc (qr, qi,qs)
simice	qv,qc,qr (qi)
wsm3	qv,qc,qr (qi,qs)
wsm5	qv,qc,qr ,qi,qs
wsm6	qv,qc,qr ,qi,qs ,qg
thompson	qv,qc,qr,qi,qs,qg,ni
CAMS	qv,qc,qr,qi,qs,qg; nr,ni,ns,ng,fc

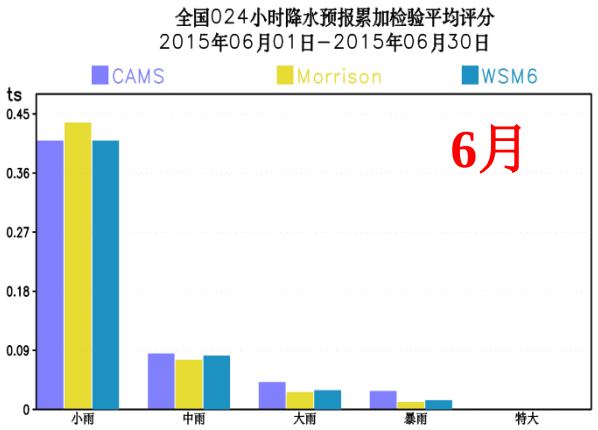
WRF(V3.2)

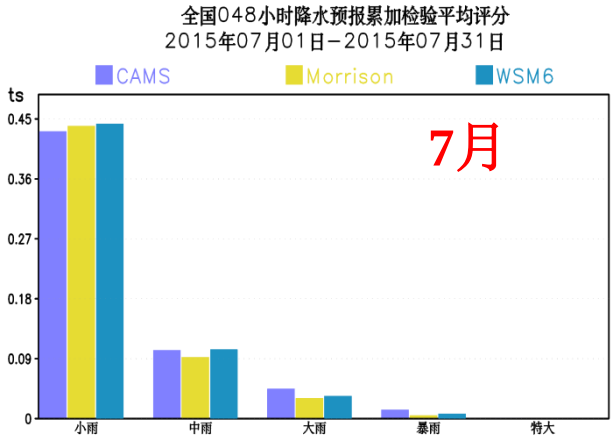
显式方案	预报量
kessler	qv,qc,qr
Sbu_ylin	qv,qc,qr ,qi,qs
lin	qv,qc,qr,qi,qs,qg
gsfcgce	qv,qc,qr,qi,qs,qg
etampold	qv,qc,qr ,qs
Etamp_hwrf	qv,qc,qr ,qi,qs
etampnew	qv,qc ,qr, qi,qs
wsm3	qv,qc,qr (qi,qs)
wsm5	qv,qc,qr ,qi,qs
wsm6	qv,qc,qr ,qi,qs ,qg
thompson	qv,qc,qr,qi,qs,qg,ni,nr
wdm5	qv,qc,qr ,qi,qs ;nn,nc,nr
wdm6	qv,qc,qr ,qi,qs ,qg;nn,nc,nr
Morr_two_moment	qv,qc,qr ,qi,qs ,qg;nr,ni,ns,ng
milbrandt2mom	qv,qc,qr ,qi,qs ,qg,qh;nc,nr,ni,ns,ng,nh
CAMS	qv,qc,qr,qi,qs,qg; nr,ni,ns,ng,fc
CAMS_seed	qv,qc,qr,qi,qs,qg; nr,ni,ns,ng,fc,Naer,Naim

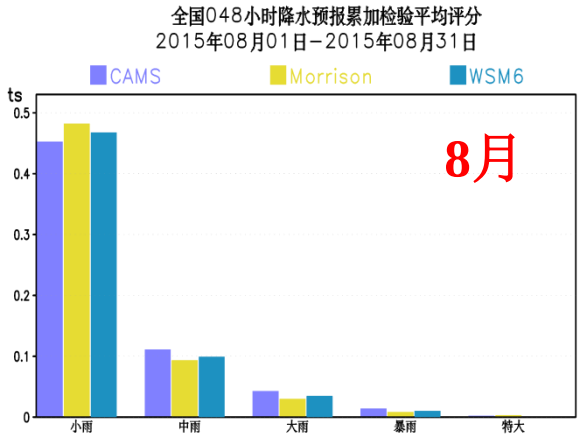
Lou Xiaofeng, et al. Cloud-resolving model for weather modification in China. Chin Sci Bull, 2012. (SCI)

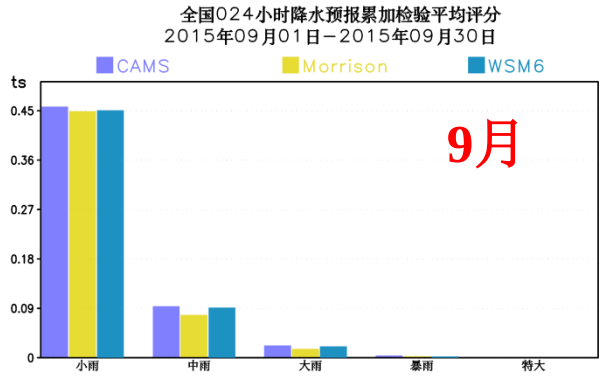
	MM5_CAMS,15 levels	WRF_CAMS, 35 levels
Precipitation	Rain/h (cm)	
	Rain/3h(cm)	Rain/3h(cm)
	Rain/6h (cm)	Rain/6h (cm)
	Rain/day (cm)	Rain/day (cm)
Macro and micro physical fields	Lwc (mm)	Lwc (g/m^2)
	Super cooled lwc (mm)	Supercooled lwc (g/m^2)
		CTT (K)
		CTH (m)
	500,700,850hPa , Q+w+T	500,700,850hPa ,Q+w+T
	Qc (g/kg)	Qc (kg/kg)
	Qr (g/kg)	Qr (kg/kg)
	Qi (g/kg)	Qi (kg/kg)
	Qs (g/kg)	Qs (kg/kg)
	Qg (g/kg)	Qg (kg/kg)
	Ni (#/ m^3)	Ni (#/ m^3)
	Nr (#/ m^3)	Nr (#/ m^3)
	Ns (#/ m^3)	Ns (#/ m^3)
	Ng (#/ m^3)	Ng (#/ m^3)

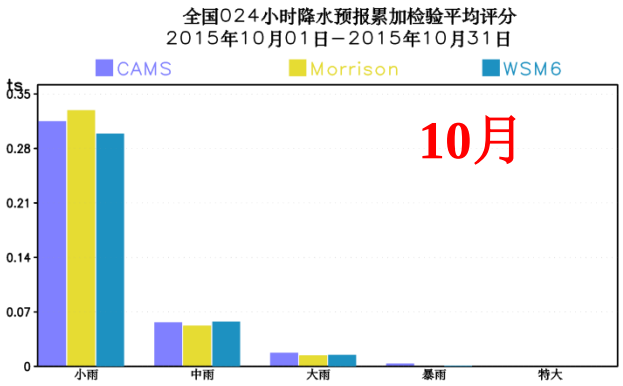
Three explicit schemes: CAMS, Morrison, WSM6
Precipitation forecast comparison(2015,6-11)

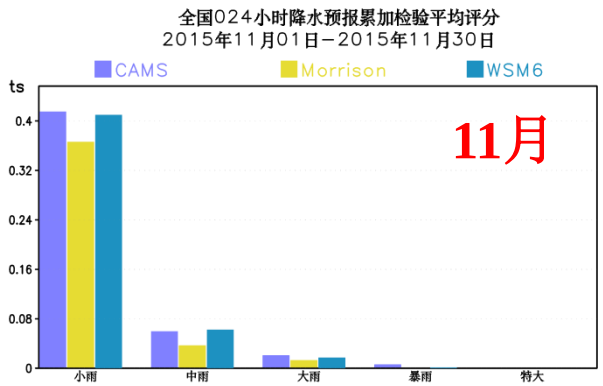












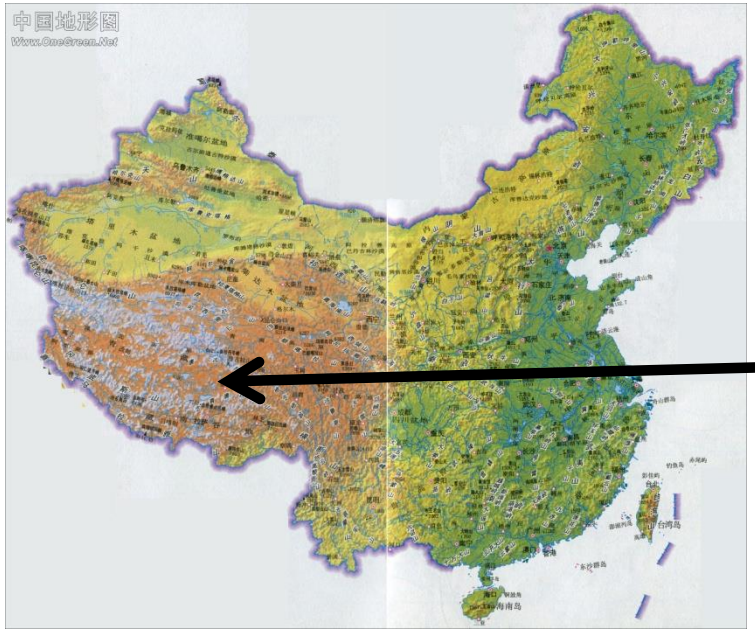
>10, moderate rain, heavy rain ,CAMS good.

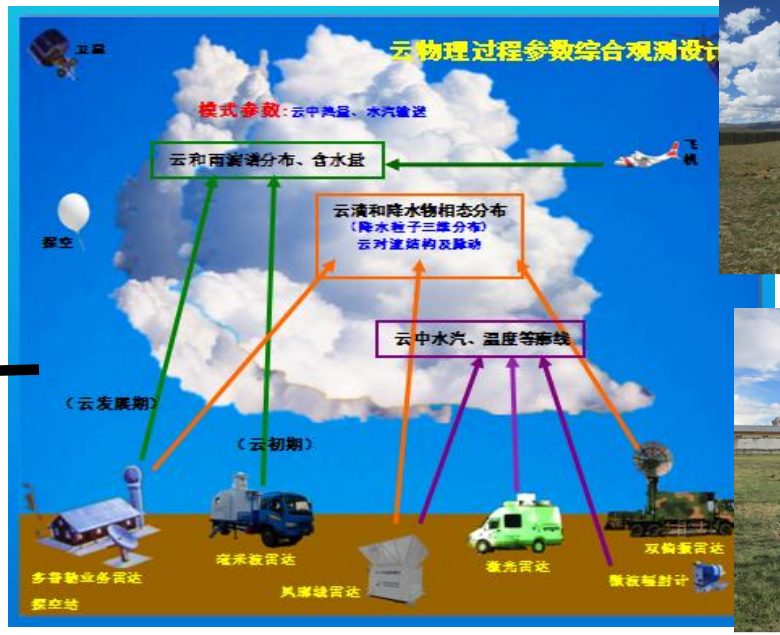
<10mm, light rain, CAMS need to be improved

2. Field observation experiments

Field observation of Clouds and precipitation in Tibet Plateau

- Vertical structures of clouds and precipitation : radar （Ka, Ku, C）, Microwave radiometer, disdrometer;
- Three-dimensional structure observation of plateau convective system: precipitation strength, phase, rain drop, dual-doppler to 3-d wind.
- Microphysical Characteristics of clouds and precipitation: King Air and airborne equipments, 200km×200k





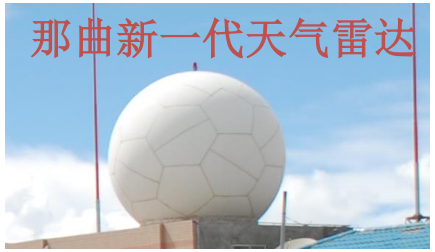
Ground observation equipments

水汽、云和气溶胶探测Laser Radar

C-band Continuous wave radar

多普勒测风激光雷达 Lidar

Microwave rain radar



Microwave radiometer

Cloud and precipitation vertical observation

Precipitation phase and W

大气环境和雨滴谱观测系统

King Air 350ER and probes

飞机搭载设备

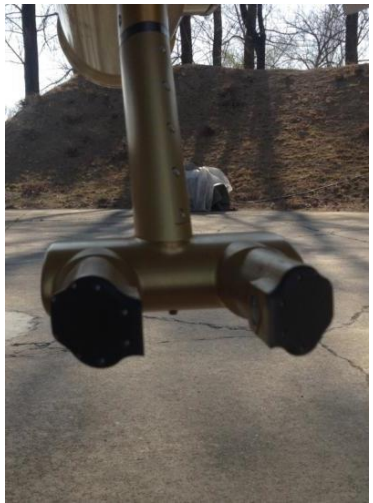
HVPS：precipitation particles,150μm-19200μm

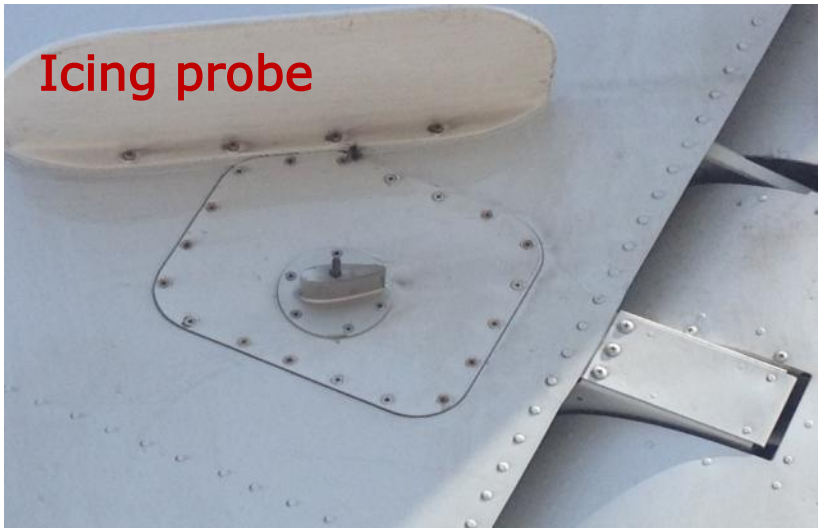
Nevzorov LWC/TWC Sensor

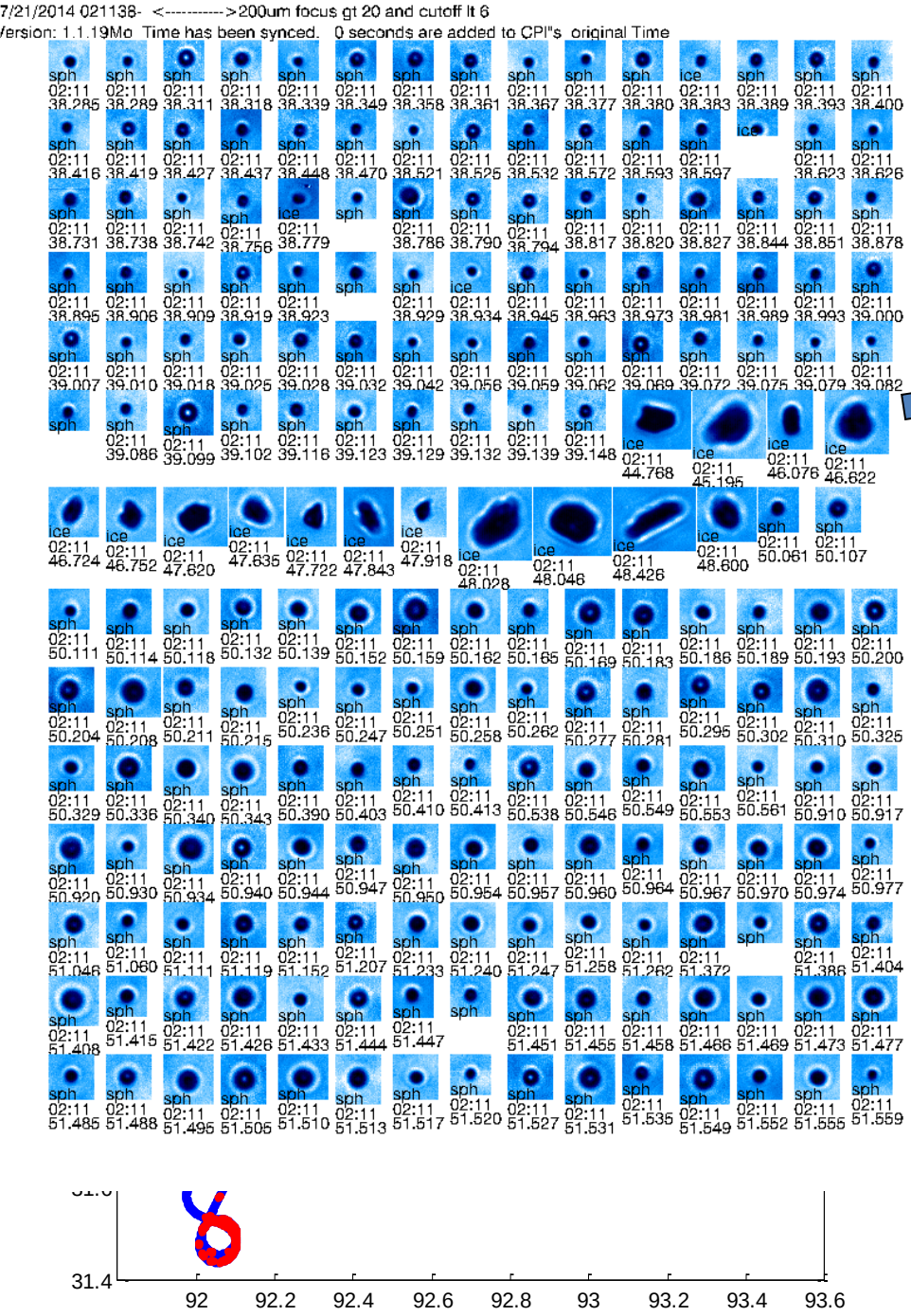
3V-CPI:25-1550μm

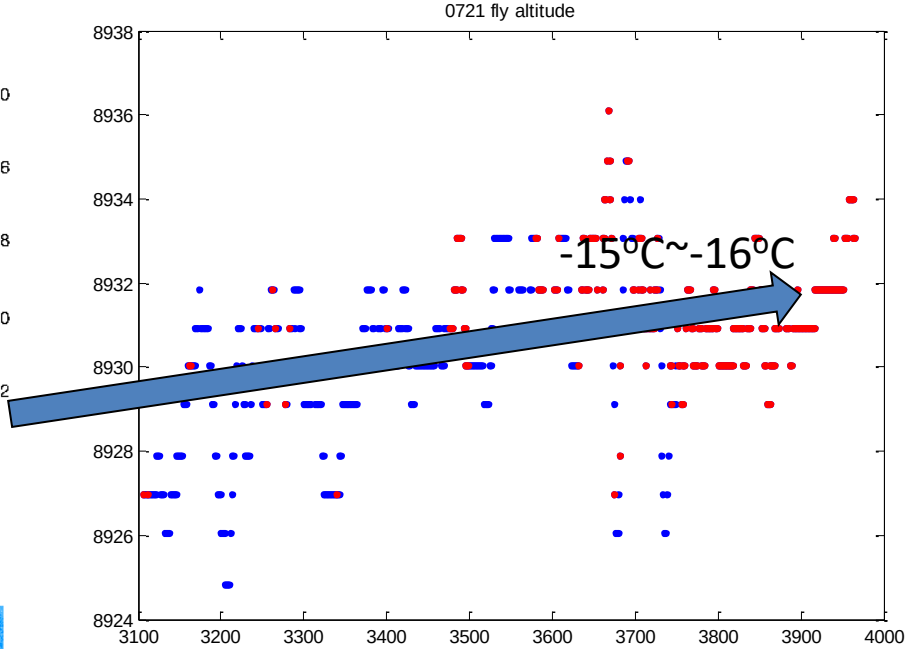
AIMMS-20：T, RH, P, W

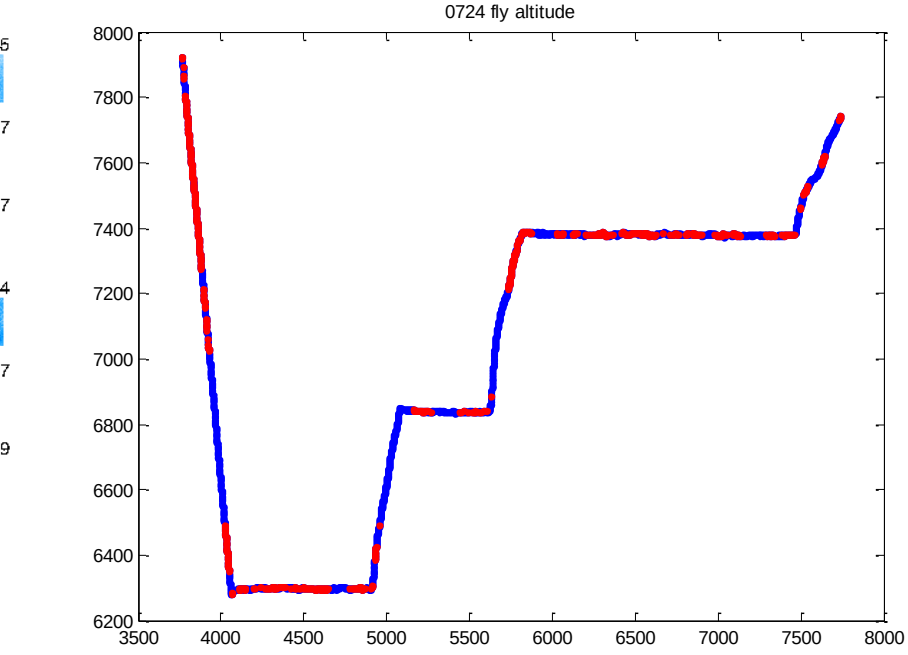
FCDP：2μm-50μm





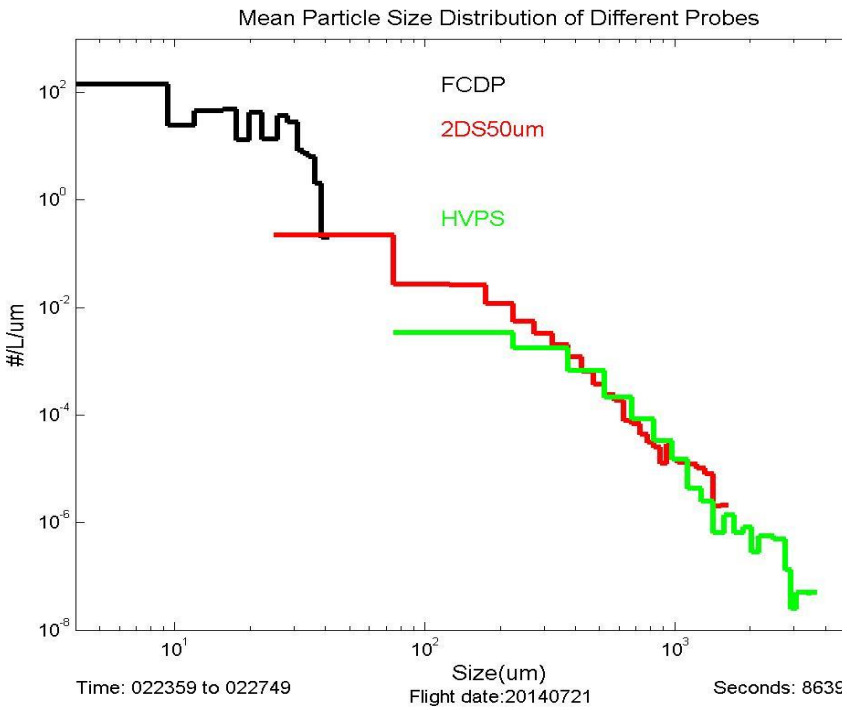

7/21/2014 021138- <----------->200um focus gt 20 and cutoff lt 6
Version: 1.1.19Mo Time has been synced. 0 seconds are added to CPI"s original Time


0721 fly altitude
-15°C~-16°C
8938
8936
8934
8932
8930
8928
8926
8924
3100
3200
3300
3400
3500
3600
3700
3800
3900
4000

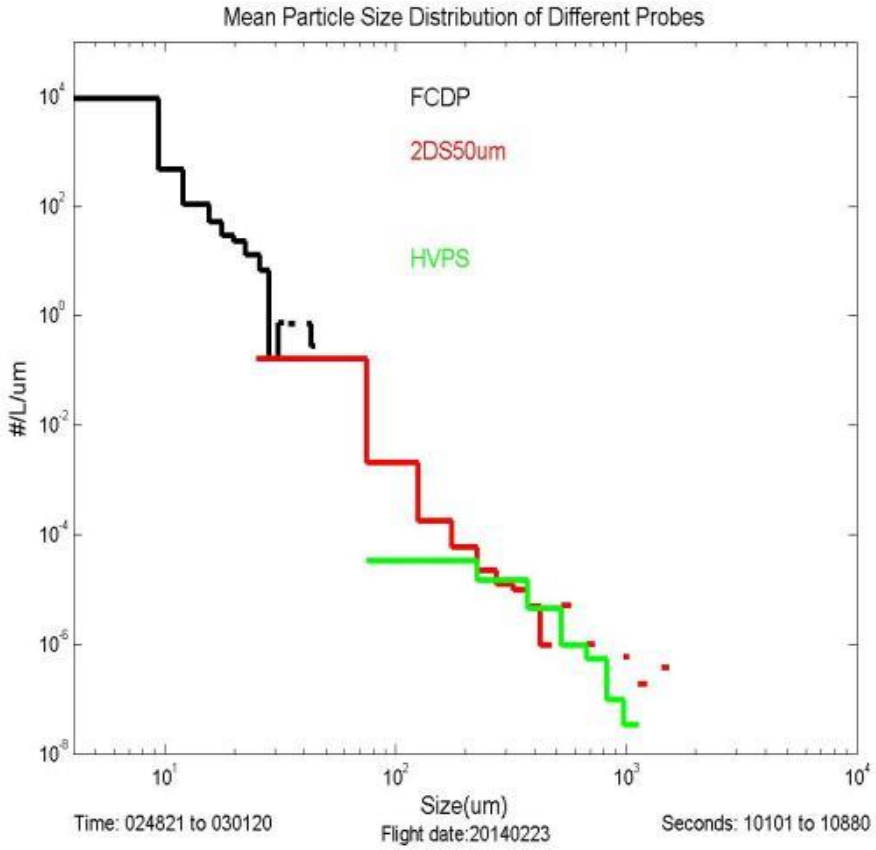

0724 fly altitude
8000
7800
7600
7400
7200
7000
6800
6600
6400
6200
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000

31.4
92
92.2
92.4
92.6
92.8
93
93.2
93.4
93.6

Tibet plateau



Beijing



Tibet plateau: less small particles, wide spectra distribution

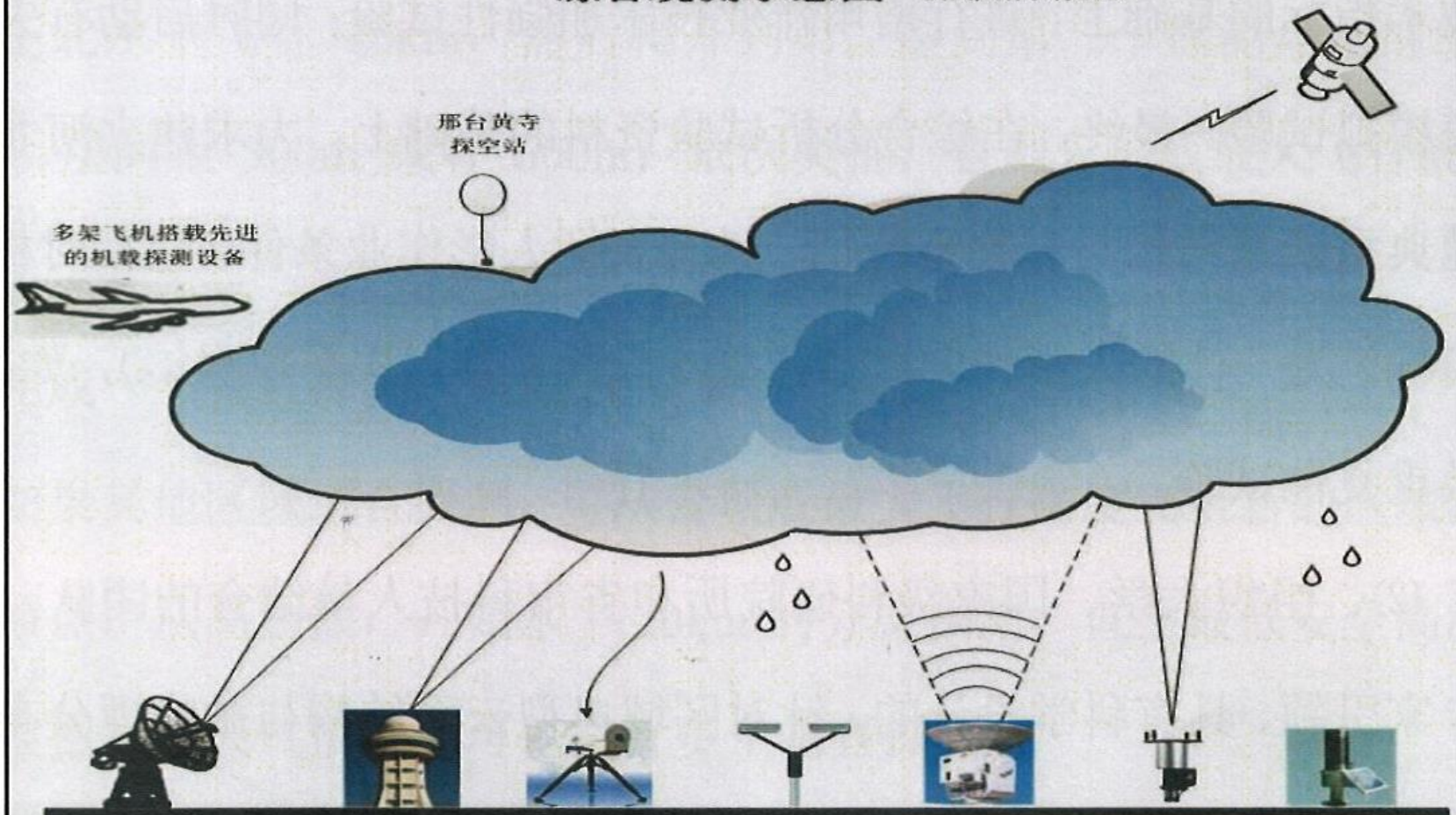
Beijing: more small particles.

Taihang ShandongLu cloud and Precipitation Aircraft Observation experiment)

(2017-2019,10million (Yuan), more than 75 expert: Hebei Province, WMC, University, CAS

太行山东麓人工增雨防雹作业技术试验示范项目
综合观测示意图

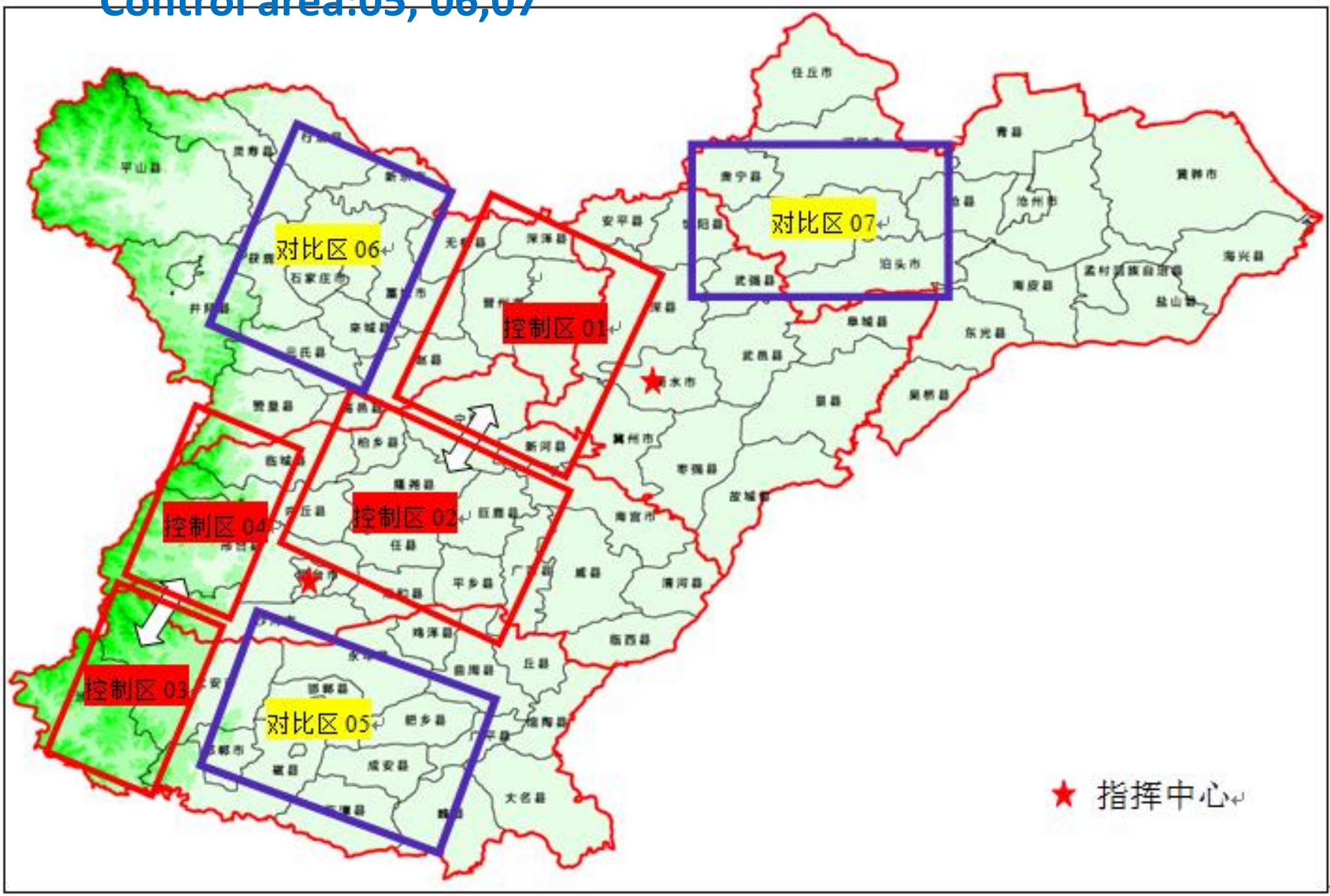
段英, 胡向峰, 2017



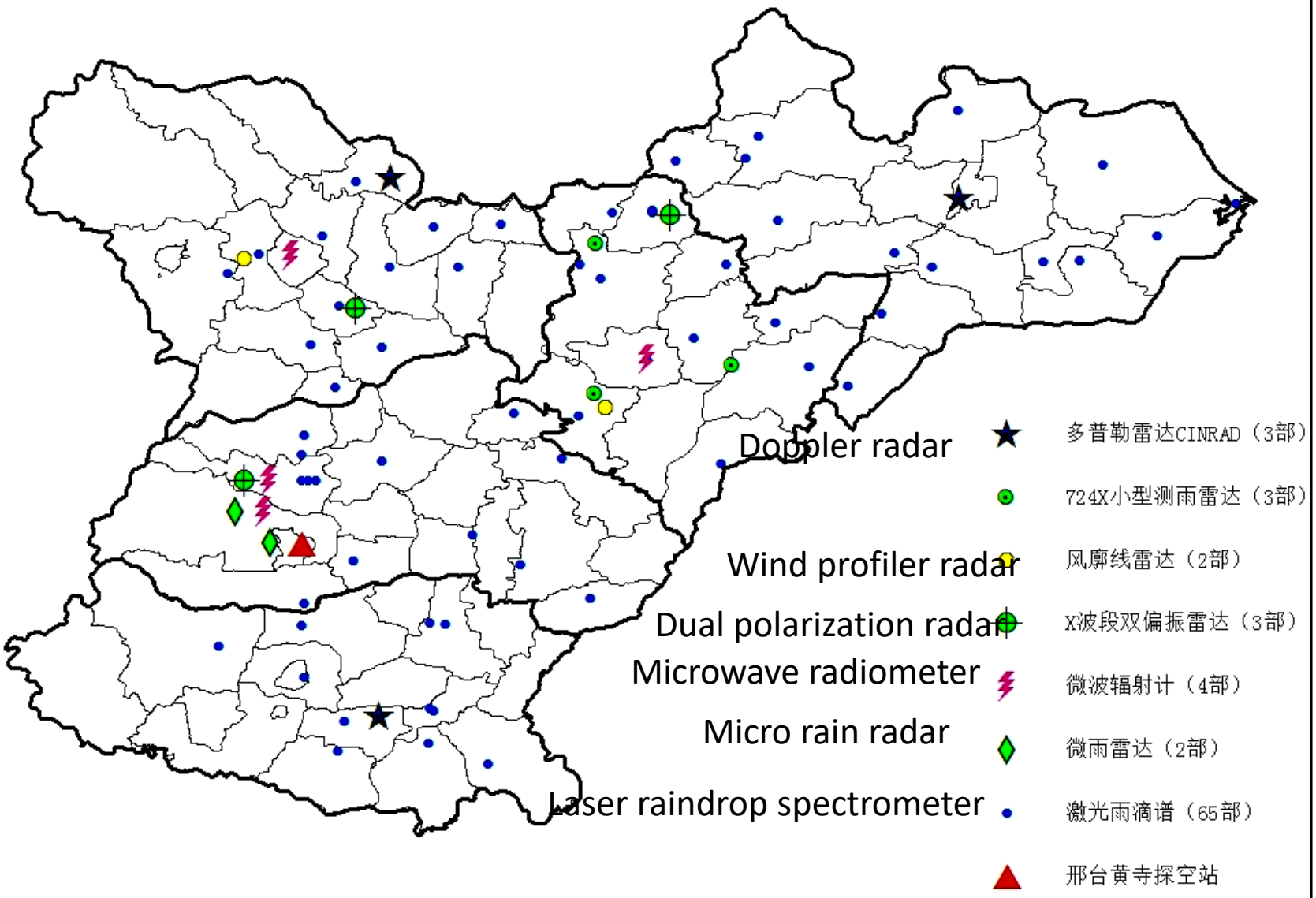
X波段双偏振雷达 3部，石家庄、邢台内丘、衡水饶阳； 724X小型测雨雷达 3部，衡水； MRR2微型雨雷达 2部，邢台市、黄寺	多普勒雷达SA 2部，石家庄、沧州	微波辐射计 4部，石家庄鹿泉、邢台内丘、邢台黄寺、衡水	OTT Parsivel 激光雨滴谱 65部，石家庄、邢台、邯郸、衡水、沧州	L波段风廓线雷达，2部，石家庄鹿泉，衡水冀州	UAT-2超声风速温度仪 1部，衡水冀州	自动站 75个国家站，1239个区域站

Target area: 01.02,03,04

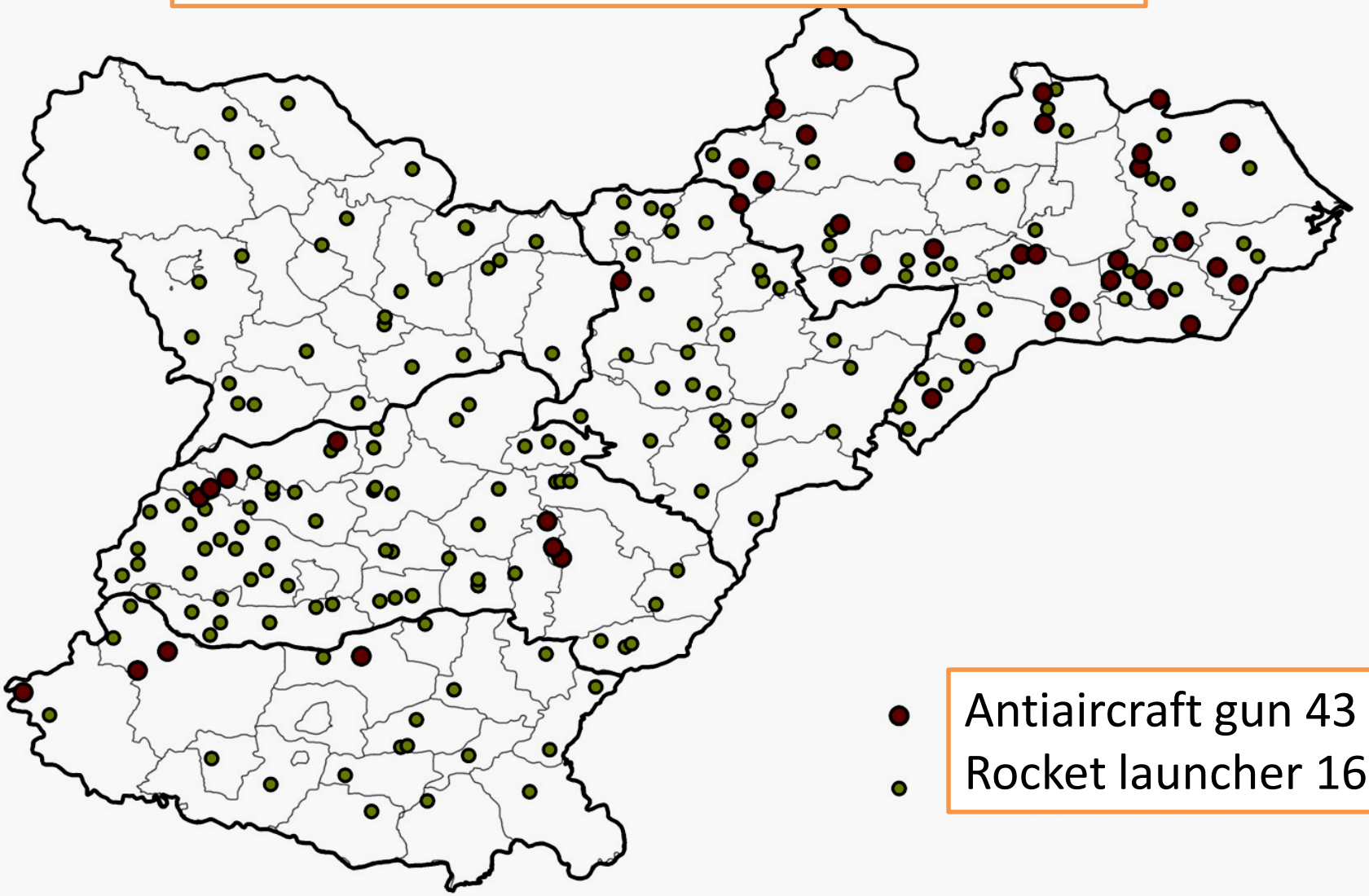
Control area:05, 06,07



Observation equipment network



Seeding sites network



spiral rise

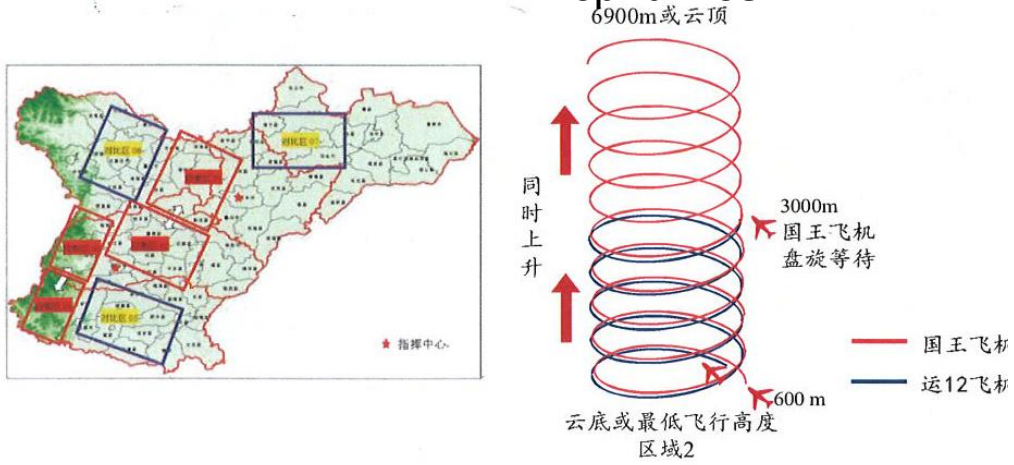


图 16 双机联合探测飞行方案

Horizontal zigzag flying

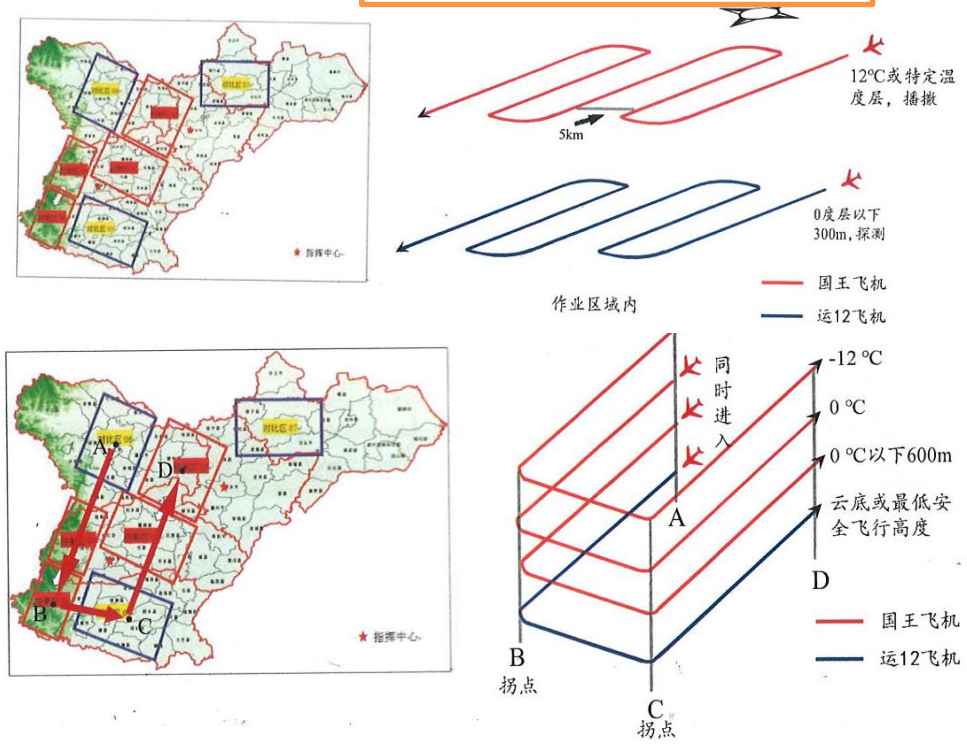


图 12 四架飞机联合探测飞行，三架国王在上面，运 12 飞机在最底层

spiral up, down ,then up

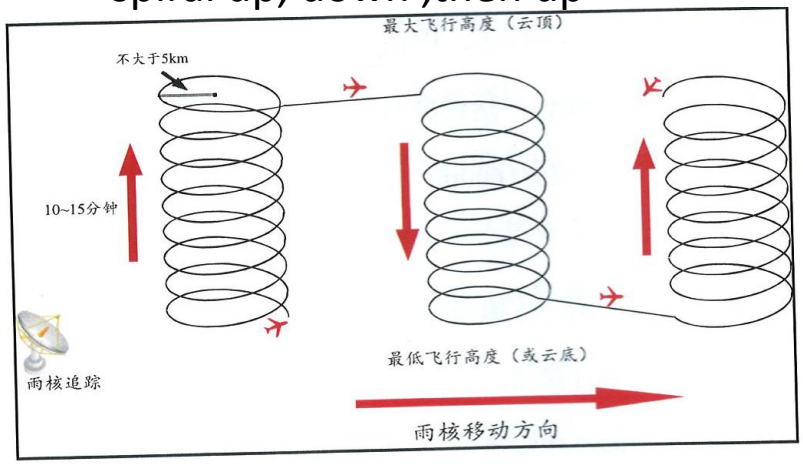
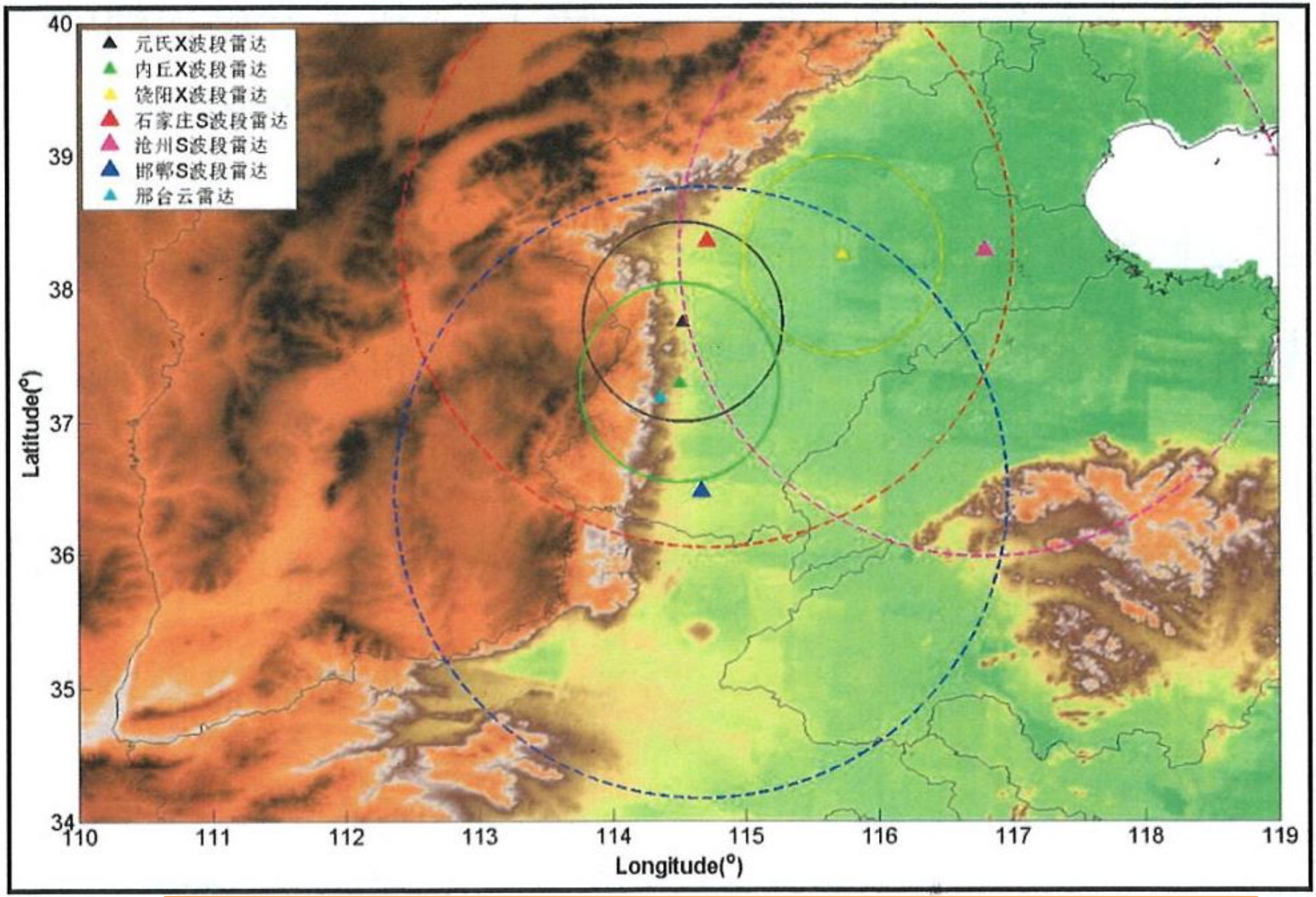


图 10 单机雨核连续探测飞行方案，地面雷达做雨核追踪

Three or four King Air



Radar coverage for hail suppression

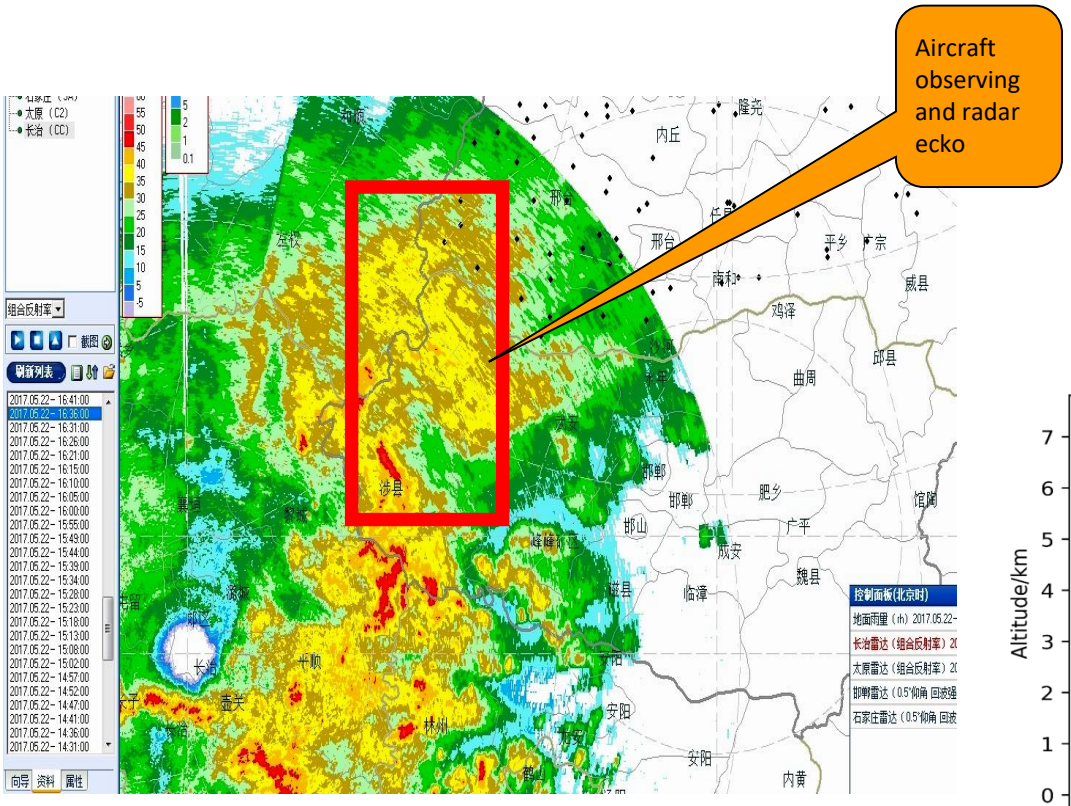
地形云增雨作业试验（5.22）

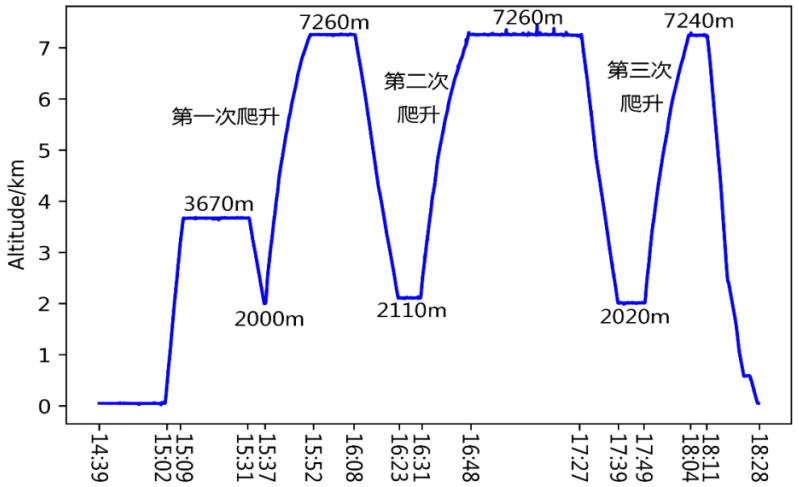
2017-05-22, Weather system: western wind trough

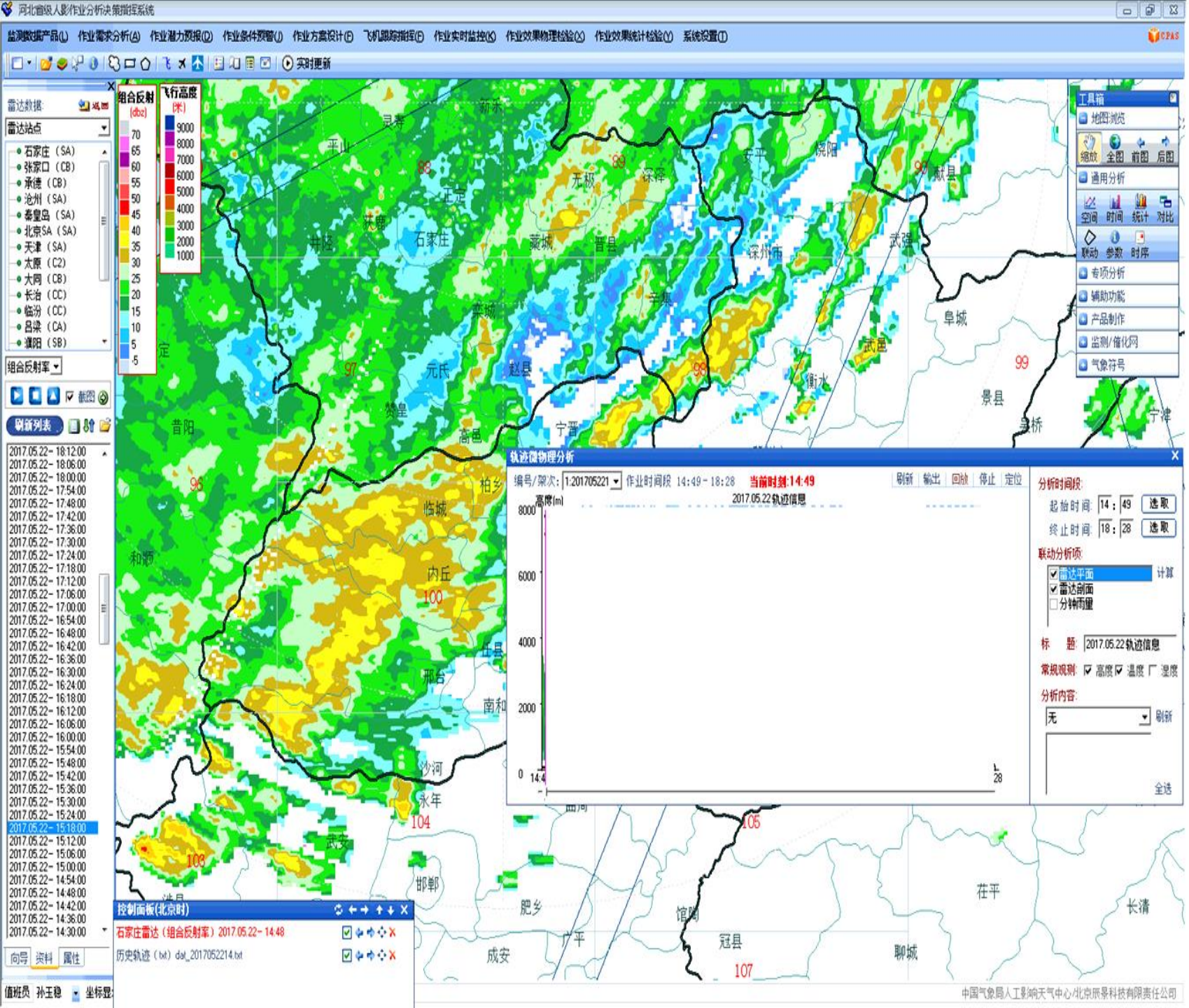
King Air First flight: observing cloud microphysical features, 6:07-08:41

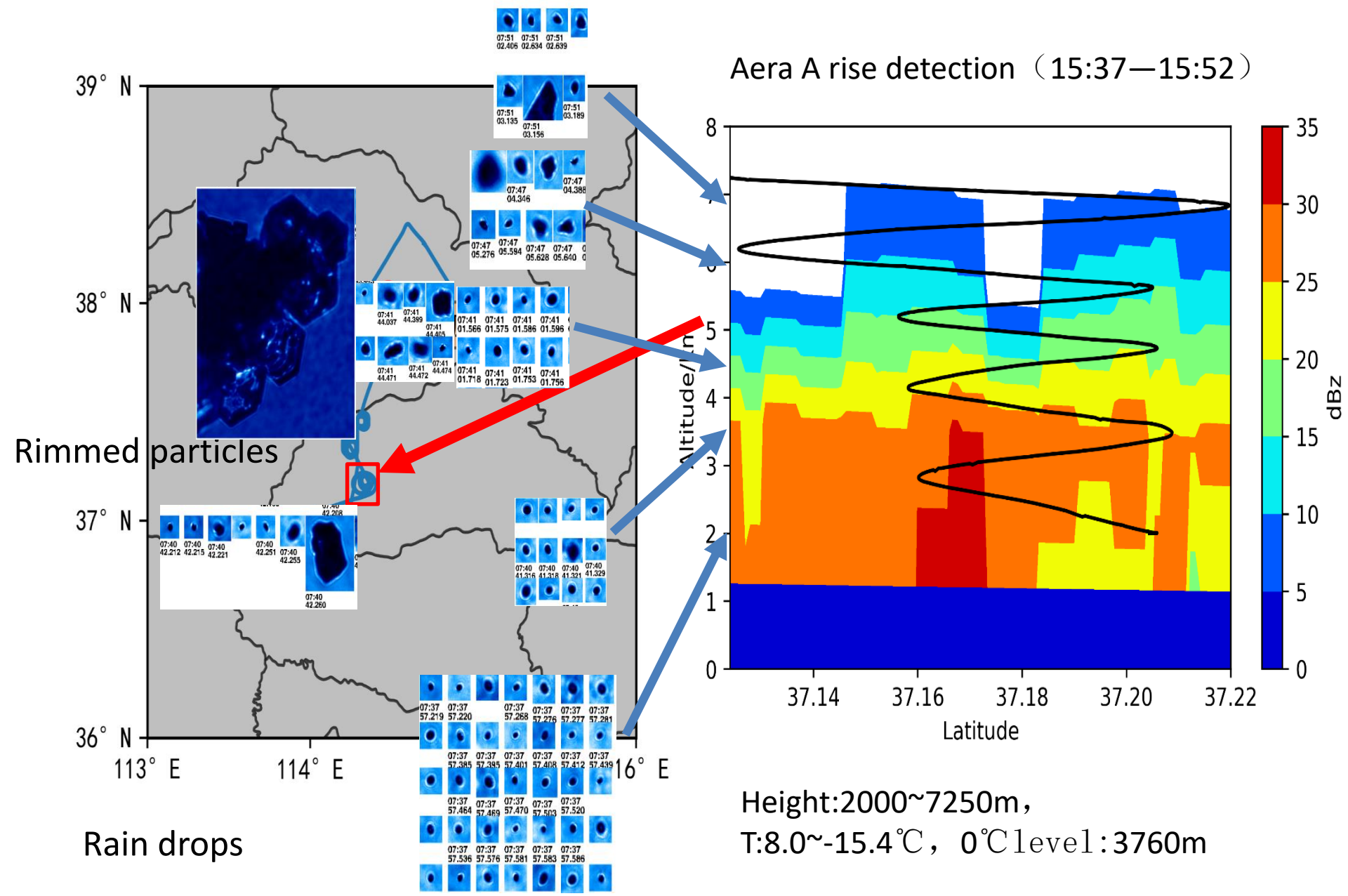
King Air Second flight: comparison obs before and after ground seeding(03,04)15:02-18:00

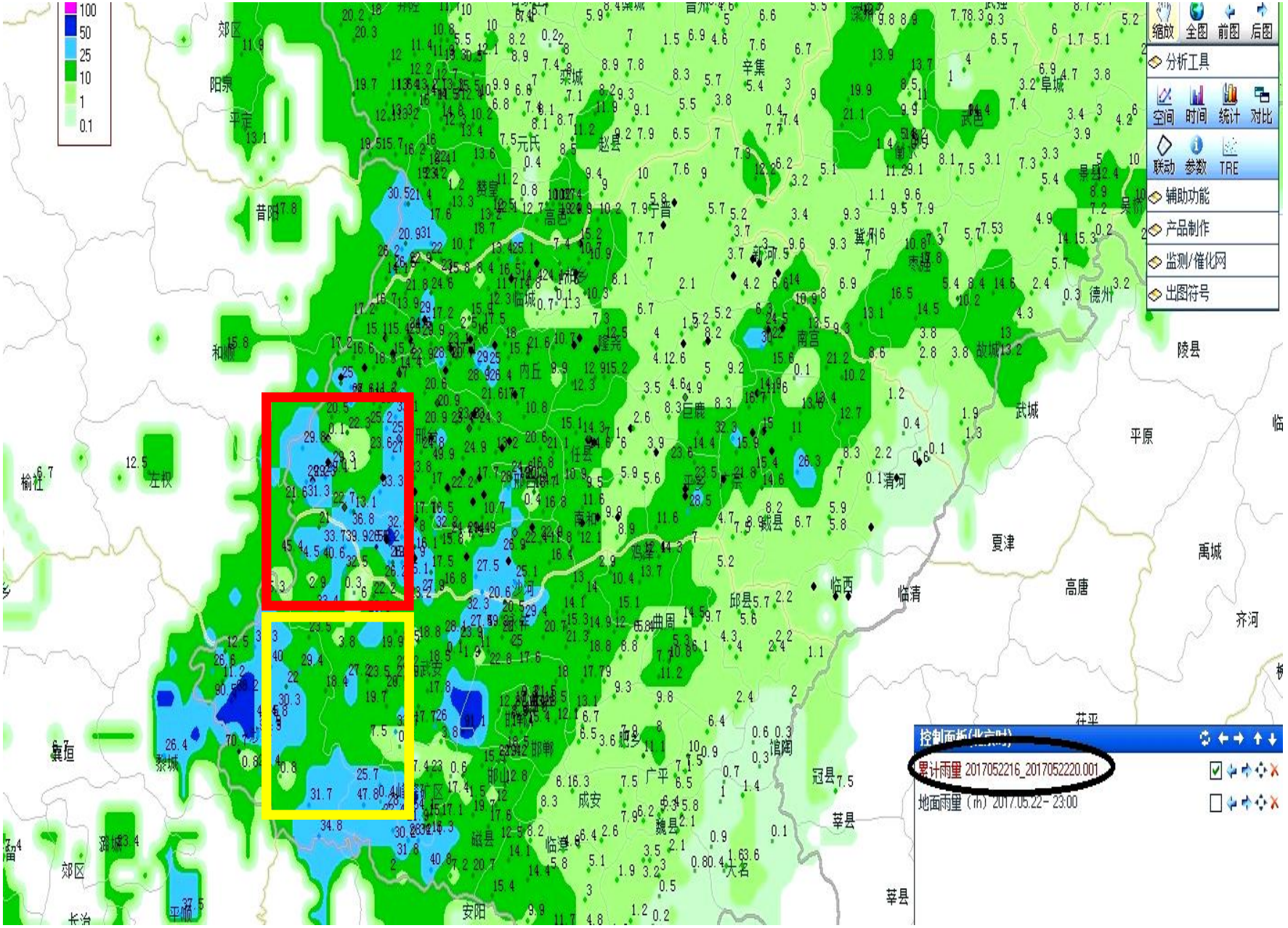
ground seeding :antigun shells 82, rocket shell 167, 17:00, >30dbz,0℃level at 4000m， cloud top 8Km






河北省级人影作业分析决策指挥系统
监测数据产品(L) 作业需求分析(A) 作业潜力预报(D) 作业条件预警(J) 作业方案设计(F) 飞机跟踪指挥(E) 作业实时监控(K) 作业效果物理检验(X) 作业效果统计检验(Y) 系统设置(T)
实时更新
雷达数据
雷达站点
石家庄 (SA)
张家口 (CB)
承德 (CB)
沧州 (SA)
秦皇岛 (SA)
北京SA (SA)
天津 (SA)
太原 (C2)
大同 (CB)
长治 (CC)
临汾 (CC)
吕梁 (CA)
濮阳 (SB)
组合反射率
截图
刷新列表
组合反射 (dbz)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
-5
飞行高度 (米)
9000
8000
7000
6000
5000
4000
3000
2000
1000
工具箱
地图浏览
缩放
全图
前图
后图
通用分析
空间
时间
统计
对比
联动
参数
时序
专项分析
辅助功能
产品制作
监测/催化网
气象符号
轨迹微物理分析
编号/架次: 1:201705221
作业时间段 14:49 - 18:28
当前时刻:14:49
刷新
输出
回放
停止
定位
2017.05.22轨迹信息
高度(m)
8000
6000
4000
2000
0
分析时间段:
起始时间: 14 : 49
终止时间: 18 : 28
选取
联动分析项:
雷达平面
雷达剖面
分钟雨量
计算
标 题: 2017.05.22轨迹信息
常规观测: 高度 温度 湿度
分析内容:
无
刷新
全选
控制面板(北京时)
石家庄雷达（组合反射率）2017.05.22 - 14:48
历史轨迹（txt）dat_2017052214.txt
向导
资料
属性
值班员 孙玉稳
坐标显
中国气象局人工影响天气中心/北京原景科技有限责任公司


Aera A rise detection（15:37—15:52）
Rimmed particles
Rain drops
39° N
38° N
37° N
36° N
113° E
114° E
16° E
Altitude/km
Latitude
37.14
37.16
37.18
37.20
37.22
dBz
35
30
25
20
15
10
5
0
Height:2000~7250m，
T:8.0~-15.4℃，0℃level:3760m


100
50
25
10
1
0.1
缩放
全图
前图
后图
分析工具
空间
时间
统计
对比
联动
参数
TRE
辅助功能
产品制作
监测/催化网
出图符号
累计雨量 2017052216_2017052220.001
地面雨量（mm）2017.05.22－23:00

中国气象局人工影响天气中心
CMA Weather Modification Centre(WMC)