

风云卫星新应用研究

覃丹宇

国家卫星气象中心

qindy@cma.gov.cn

National Satellite Meteorological Center (NSMC), CMA

风云卫星用户大会, 成都
2018年11月11-13日

内容提纲

一、风云卫星发展提升了对地观测能力

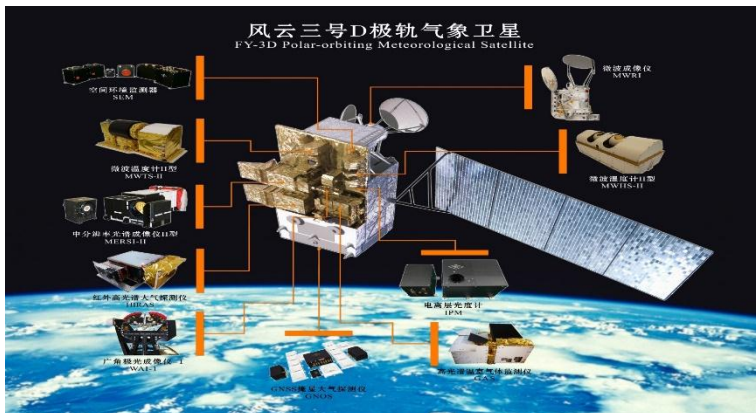
二、风云卫星带来的研究机遇

三、应用研究挑战

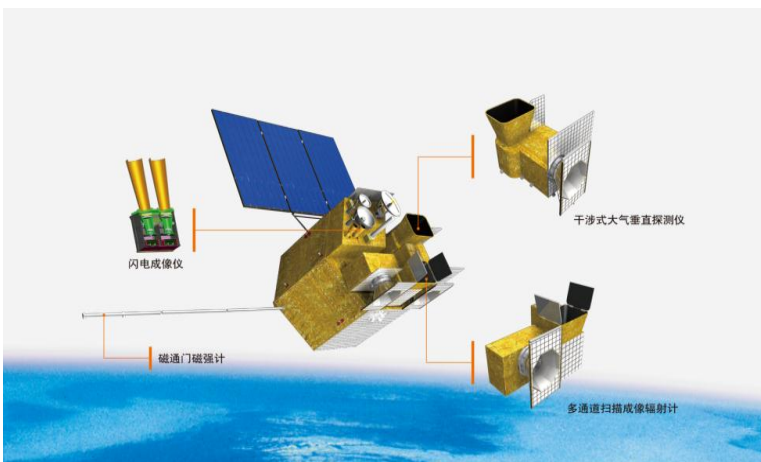
四、人工智能新应用研究

已发射17颗气象卫星

极轨气象卫星



静止气象卫星



1988. 09. 07	风云一号A星	试验	39天
1990. 09. 03	风云一号B星	试验	158天
1999. 05. 10	风云一号C星	业务	6.5年
2002. 05. 15	风云一号D星	业务	10年
2008. 05. 17	风云三号A星	试验业务	在轨工作
2010. 11. 05	风云三号B星	试验业务	在轨工作
2013. 09. 23	风云三号C星	业务	在轨工作
2017. 11. 15	风云三号D星	业务	在轨测试

1997. 06. 10	风云二号A星	试验	约6个月
2000. 06. 25	风云二号B星	试验	约8个月
2004. 10. 19	风云二号C星	业务	8.5年
2006. 12. 08	风云二号D星	业务	在轨备份
2008. 12. 23	风云二号E星	业务	在轨工作
2012. 01. 13	风云二号F星	业务	在轨工作
2014. 12. 31	风云二号G星	业务	在轨工作
2016. 12. 11	风云四号A星	试验	业务运行
2018. 06. 05	风云二号H星	业务	在轨测试



1969. 1. 29

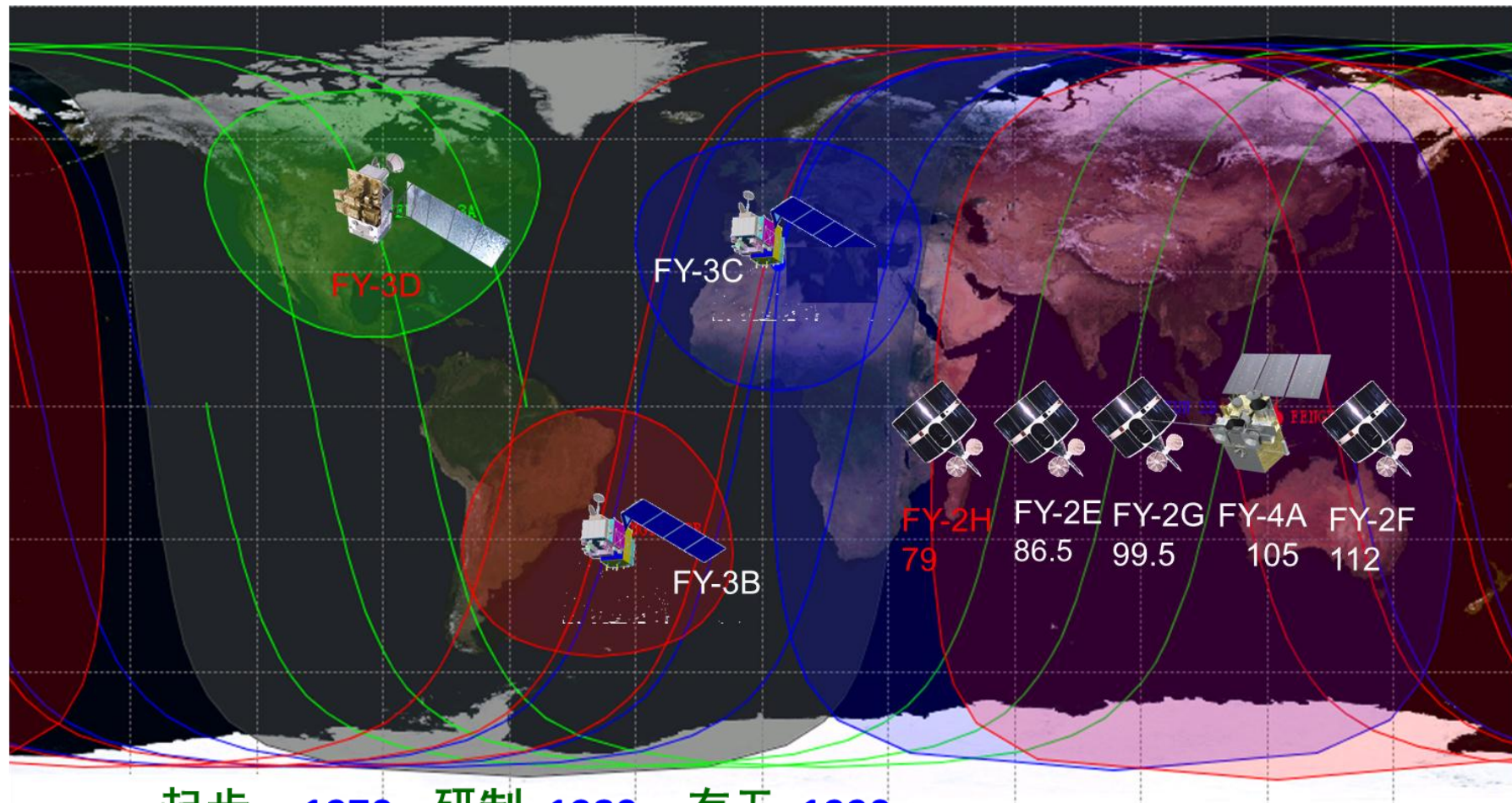
IOT

IOT

当前在轨卫星

风云业务卫星：8颗在轨，其中6颗业务运行，2颗在轨测试

科学实验卫星：碳卫星（Tansat）



起步 1970 研制 1980 有无 1990
业务化 2000 定量化 2010

中国风云卫星：
两个系列，同步发展；
天地一体，业务应用！

目前，中国是世界气象组织对地观测卫星业务监测网的重要成员，为卫星全球观测作出了关键性的贡献。

风云卫星主要仪器载荷

Satellite		No. of Instruments	Name in Abbrev.
FY-1	FY-1 A/B	2	5-channel VIRR
	FY-1 C/D	2	10-channel VIRR
FY-2	FY-2 A/B	1	3-channel VISSR
	FY-2 C/D/E	1	5-channel VISSR
FY-3	FY-3 A/B/C	10	10-channel VIRR
			MERSI
			IRAS
			MWTS
			MWHS
			MWRI
			SBUS
			TOU
			ERM
			SIM

Optical Imager

Atmospheric Sounder

Microwave Imager

Atmospheric Composition

Radiation Budget

FY-2静止气象卫星系列的主要载荷是可见光红外扫描辐射计，FY-3极轨气象卫星系列的载荷包括可见光红外扫描辐射计、红外分光计、中分辨率光谱成像仪、微波探测仪、微波成像仪、紫外臭氧垂直探测仪、紫外臭氧总量探测仪、太阳辐射监测仪、地球辐射监测仪、空间环境监测仪，应用领域覆盖大气、陆表、空间环境监测等。

The FY-3A/B/C/D/E Instrument Suites for NWP

Infrared Atmospheric
Sounder (IRAS) 20 channels
(~HIRS/3)
HIRAS(1370channels)

**Microwave
Temperature
Sounder (MWTS)
4 channel (~MSU)
13 channels
17 channels**

Microwave
Humidity
Sounder (MWSH)
5 channel (~MHS)
15channels with
channels at
118 GHz



WindRAD
C ,Ku
HH, VV

Microwave
Radiation Imager
10 channels
(~AMSR-E)

GNSS
Radio-Occultation
Sounder (GNOS)
(~GPS)

风云静止气象卫星

■任务结束

FY-2C

■业务运行

FY-2D: Full Disk (全圆盘扫描)

FY-2E: Full Disk

FY-2G: Full Disk

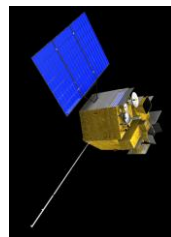
FY-2F: Regional (区域扫描)

FY-2H: Full Disk (79° E一带一路)

■业务运行(实验)

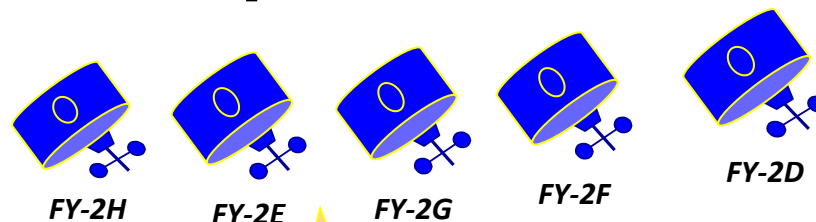
FY-4A

FY-4A Research



Full Disk Scan

Operation



Back-up

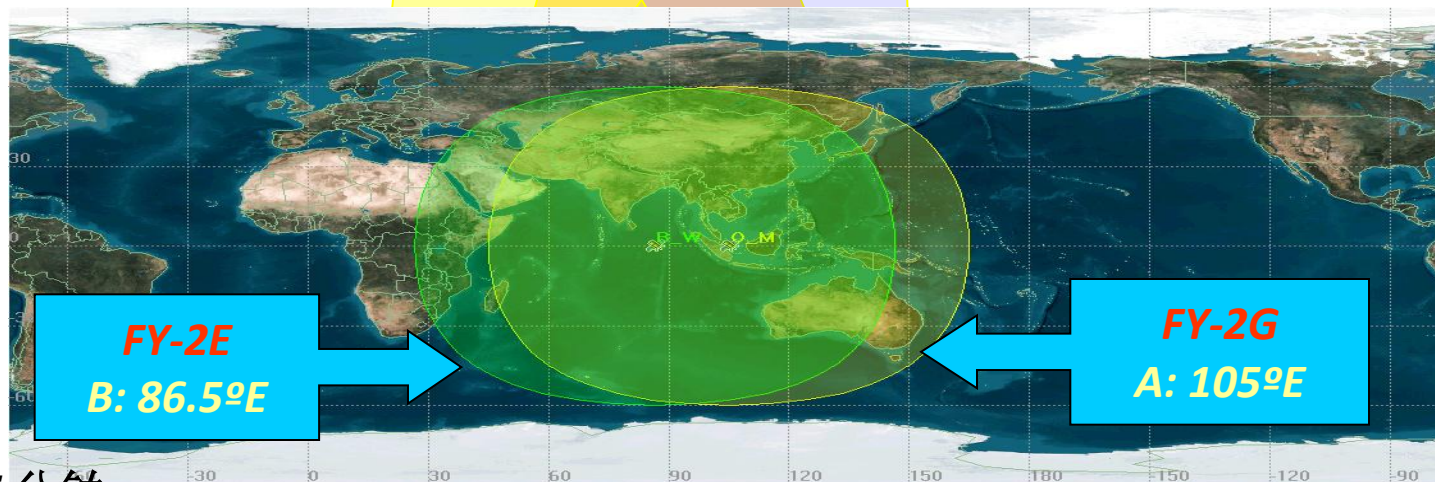
FY-2D

Rapid Regional Scan

(全圆盘扫描)

(区域扫描)

(79° E一带一路)



FY-2E
B: 86.5°E

FY-2G
A: 105°E

持续提高卫星观测时间分辨率

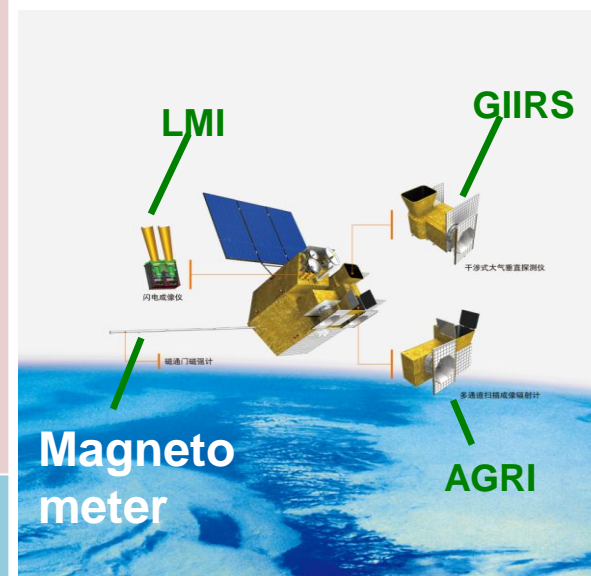
60分钟 → 30分钟 → 15分钟 → 5分钟

FY-2E and FY-2G的位置和覆盖区域

探测能力		FY-4A (中国)	GOES-R (美国)	Himawari-8/9 (日本)
成像观测	空间分辨率	可见光/近红外:0.5-1Km 红外: 2-4Km	可见光/近红外:0.5-1Km 红外: 2Km	可见光/近红外:0.5-1Km 红外: 2Km
	时间分辨率	15分钟 (后续10)	5分钟	10分钟
	波段数量	14 (后续16)	16	16
	探测精度	0.2K (实测优于0.1K)	0.1K	0.1K
大气垂直探测	光谱范围	长波: 8.85-14.29μm 中波: 4.44-6.06μm	无	无
	通道数量	1650		
	光谱分辨率	0.625cm-1		
	空间分辨率	16Km		
闪电探测	中心波长	777.4nm	777.4nm	无
	时间分辨率	2ms	2ms	
空间探测	探测目标	粒子/磁场/X射线	粒子/磁场/对日成像	无

Instruments:

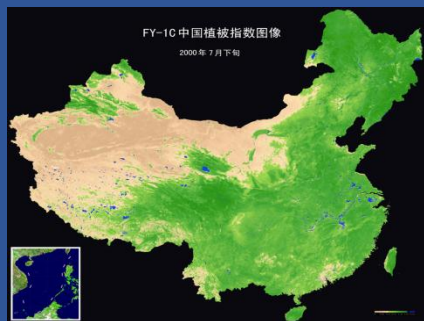
- GIIRS: Geo. Interferometric Infrared Sounder**
- AGRI: Advanced Geosynchronous Radiation Imager**
- LMI: Lightning Mapping Imager**
- SEP: Space Environment Package**



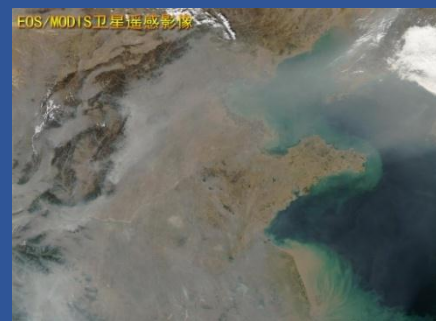
风云卫星观测参数比较

观测要素	中国	欧洲	美国
温湿度廓线	✓	✓	✓
云特性	✓	✓	✓
云廓线	✓	✓	✓
气溶胶	✓	✓	✓
气溶胶廓线	✓	✓	—
降水	✓	—	✓
地球辐射	✓	✓	✓
太阳辐射	✓	—	—
大气化学成分	✓	✓	✓
风速	✓ 计划中	✓	✓
风向	✓ i计划中	—	✓
大气密度（掩星）	✓	✓	(商业化, 小卫星)
冰盖高度	—	—	✓
海面风	✓	✓	—
地表	✓	✓	✓
地球偏振信号	✓ 计划中	✓	✓

形成了门类齐全，覆盖生态环境、天气气候、空间天气等较完整的风云卫星遥感应用体系



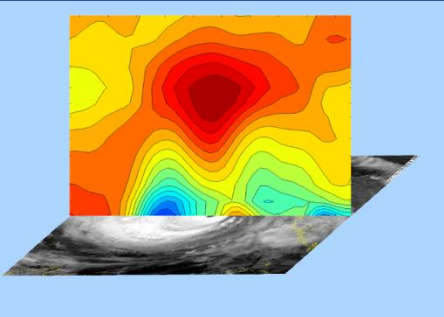
农业



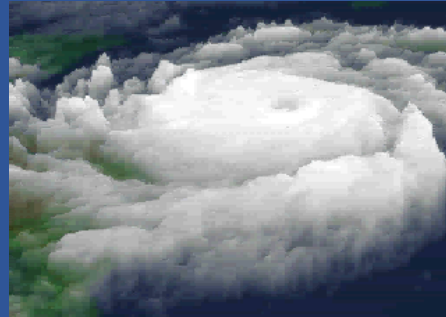
环境



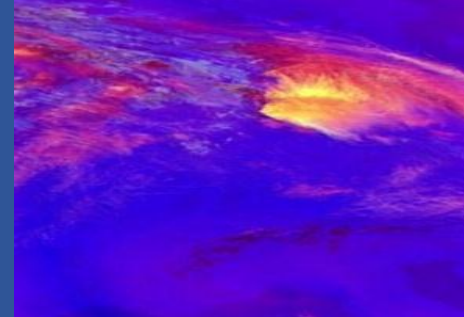
人工影响天气



数值预报



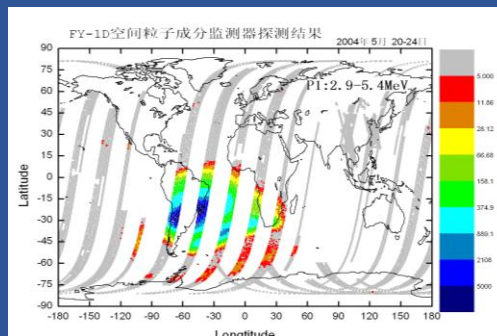
天气



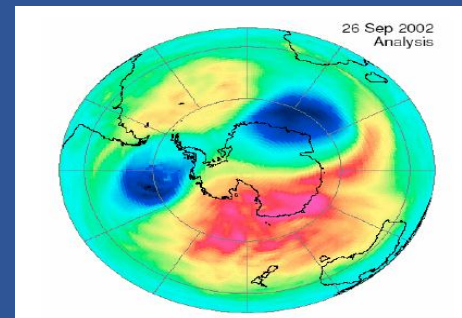
雷电



海洋



空间天气



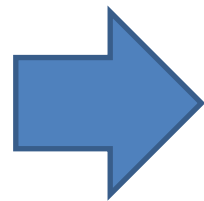
气候与气候变化



生态

风云卫星发展带来的研究机遇

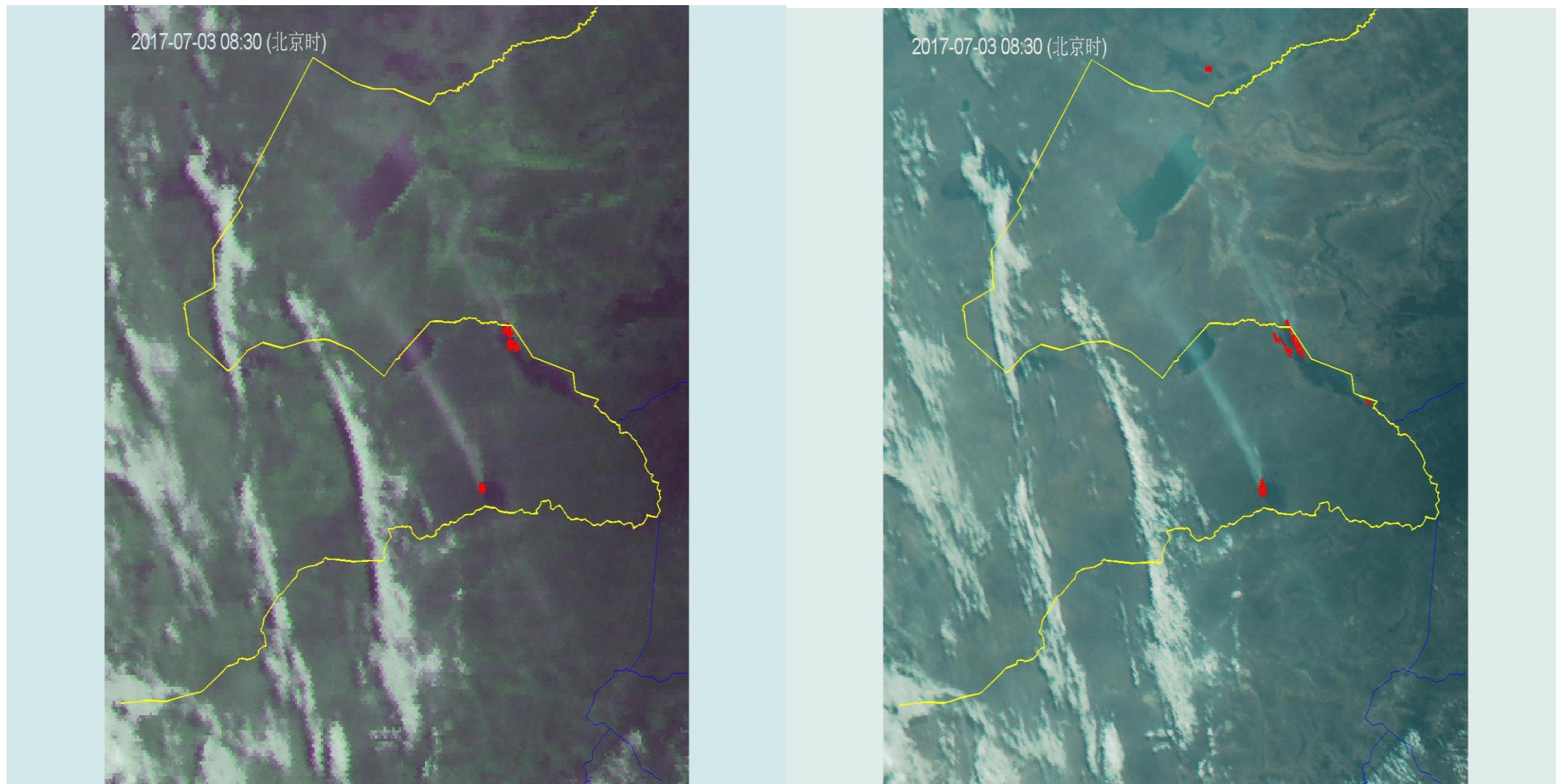
- 卫星越来越多
- 载荷也越来越多
- 光谱通道越来越多
- 光谱分辨率越来越高
- 时空分辨率越来越高



探测能力越来越强，
获取信息越来越丰富

(1) 生态环境遥感：火情监测

风云四号火点监测

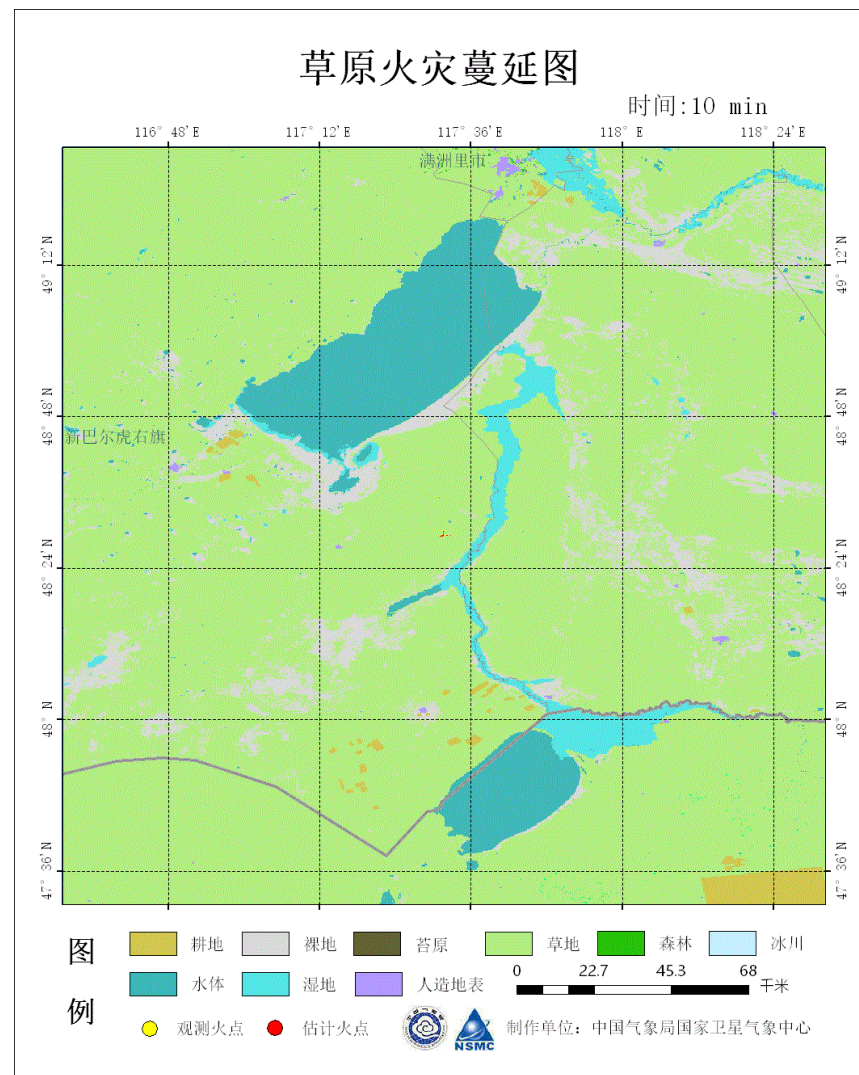
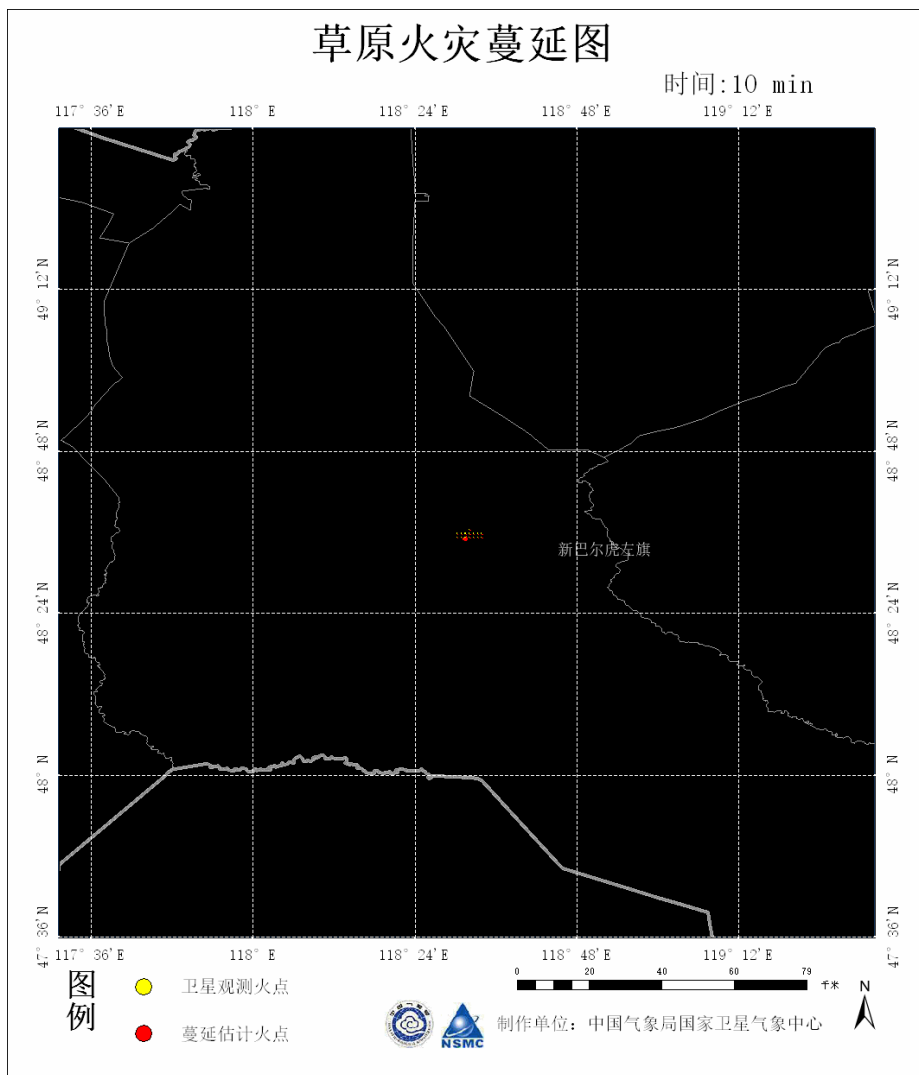


FY4A, 分辨率: 0.02°

H8, 分辨率: 0.01°

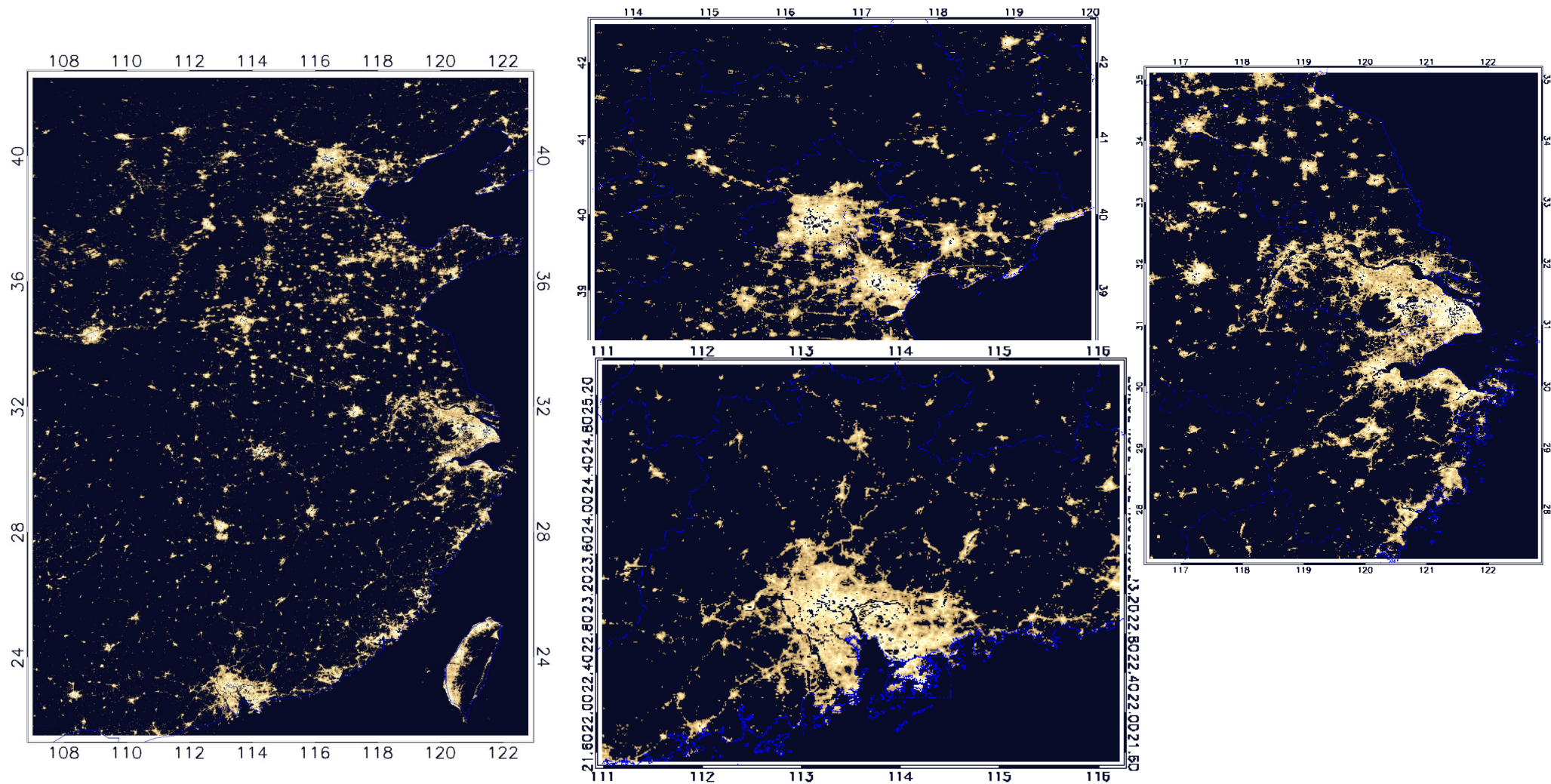
2017年7月3日
观测时间间隔: 30分钟

高频次卫星监测火情与气象预报和林火蔓延模型结合，可预测火情蔓延



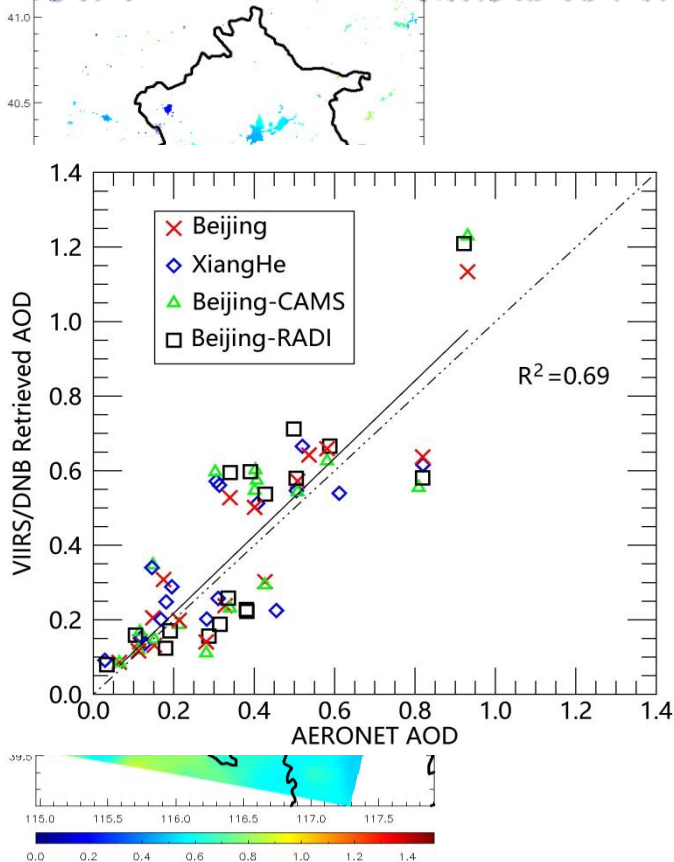
(2) FY-3微光应用

微光图像城市灯光多时相融合技术



微光资料定量应用—气溶胶，夜间积雪

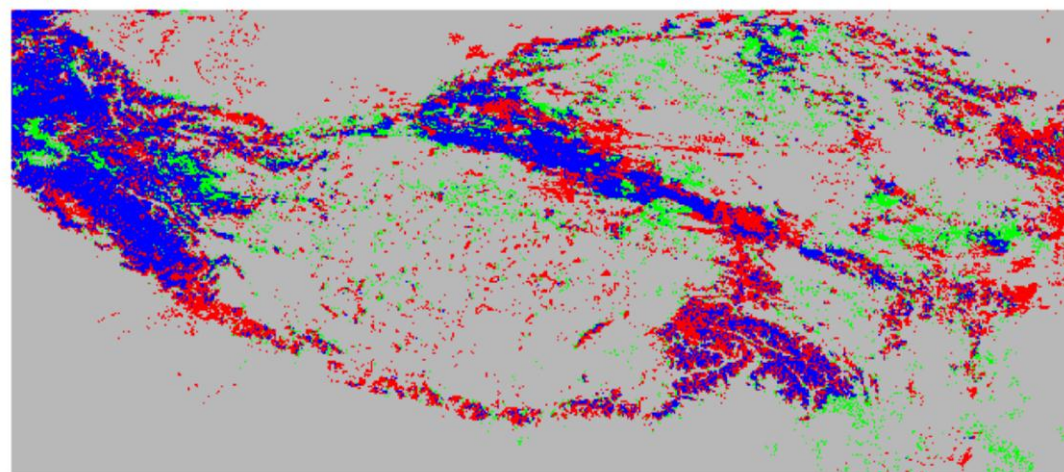
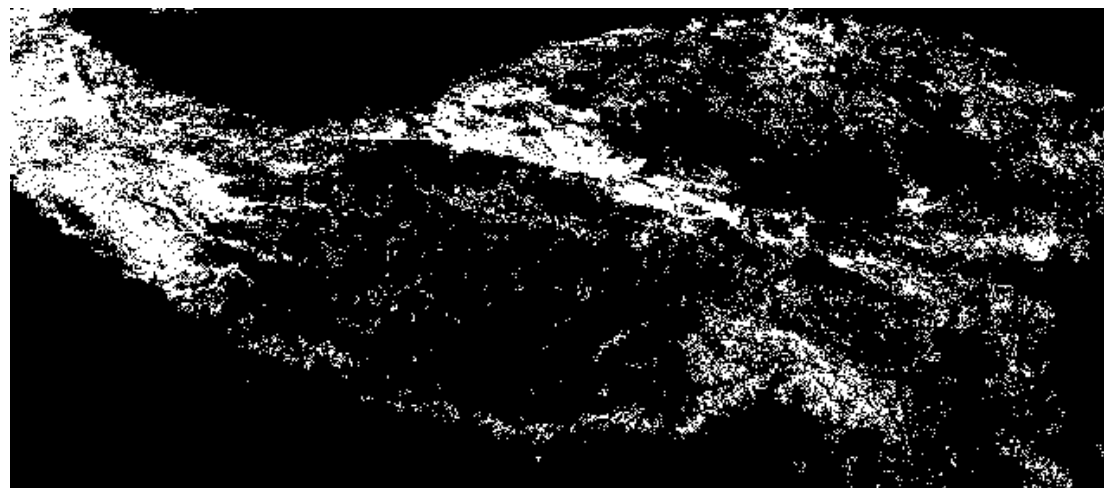
夜间VIIRS/DNB气溶胶反演结果



3月22-24日MODIS AOD产品(平均后)

夜间气溶胶反演

夜间积雪遥感

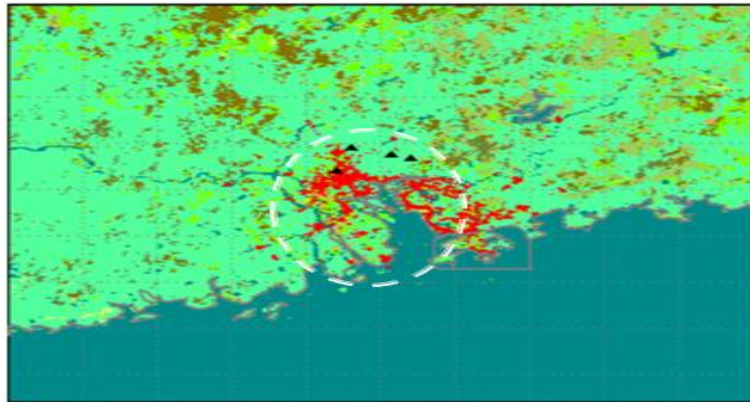


■ 一致有雪 ■ 一致无雪 ■ MODIS有雪/DNB无雪 ■ MODIS无雪/DNB有雪

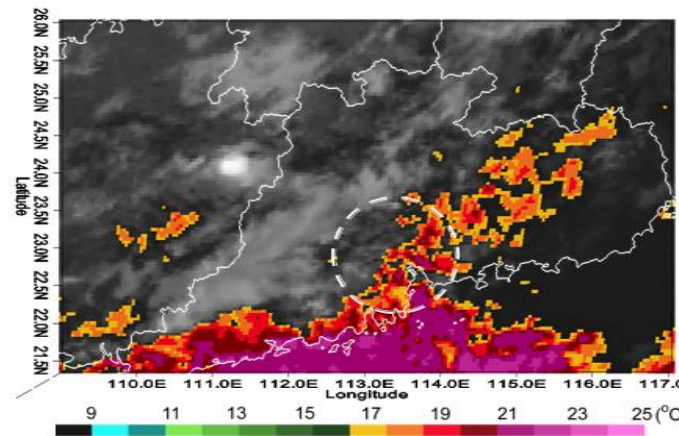
(3) FY4A 3.75 μm 通道资料在“5.7”暴雨过程分析中的释用

- FY4A 3.75 μm 通道上可以监测到广州地区的强降水发生前有明显的城市热岛效应
- 可见光和红外通道上可以监测到广州地区由城市非均匀下垫面动力强迫产生的对流辐合线

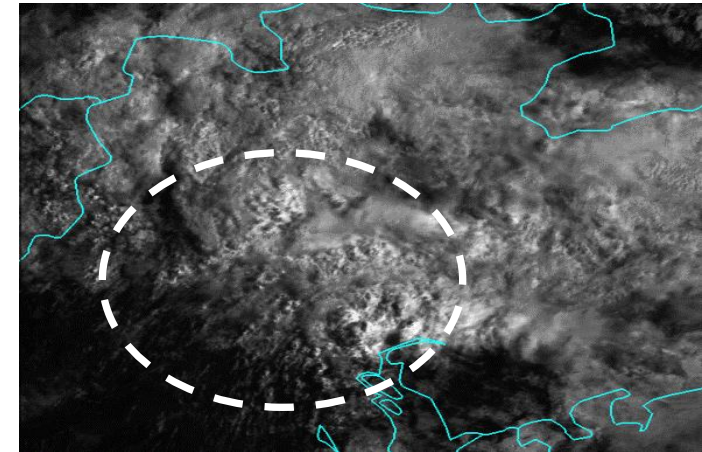
下垫面类型



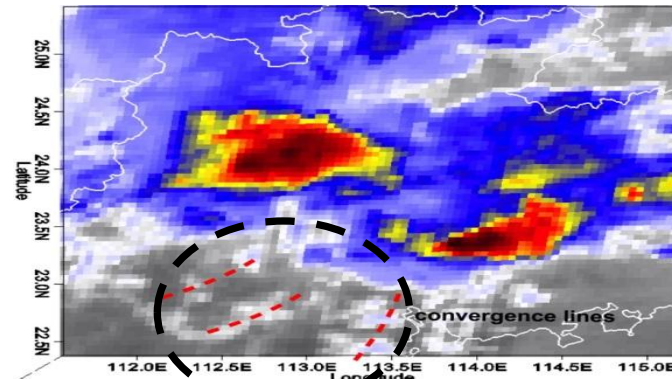
FY-4 2017-05-06 16:15 UTC (05-07 00:15 LST)



FY-4A visible channel (500 m) 5/7 08:00-14:00 LST



FY-4A IR channel (10.8 μm) (4 km)
5/7 06:00 LST



Radar 5/7 09:00 LST



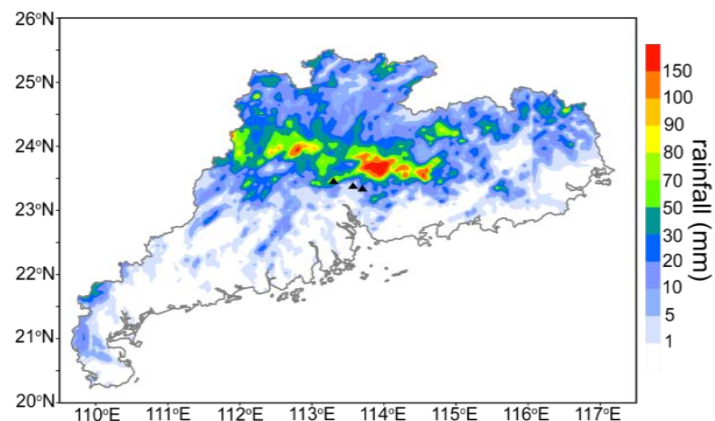
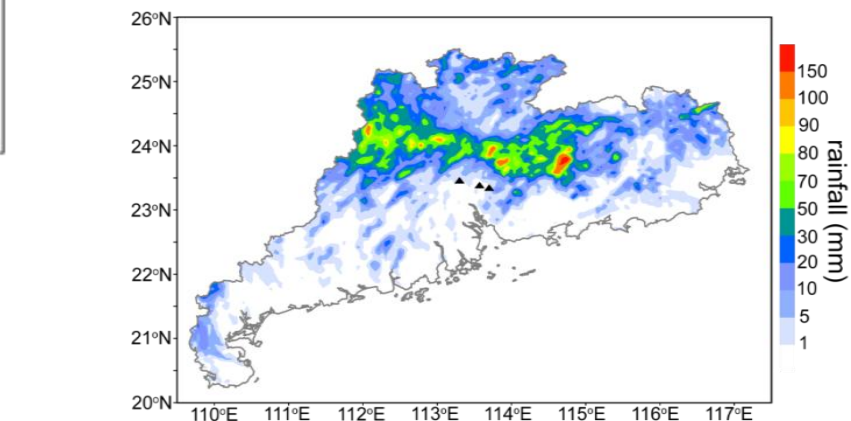
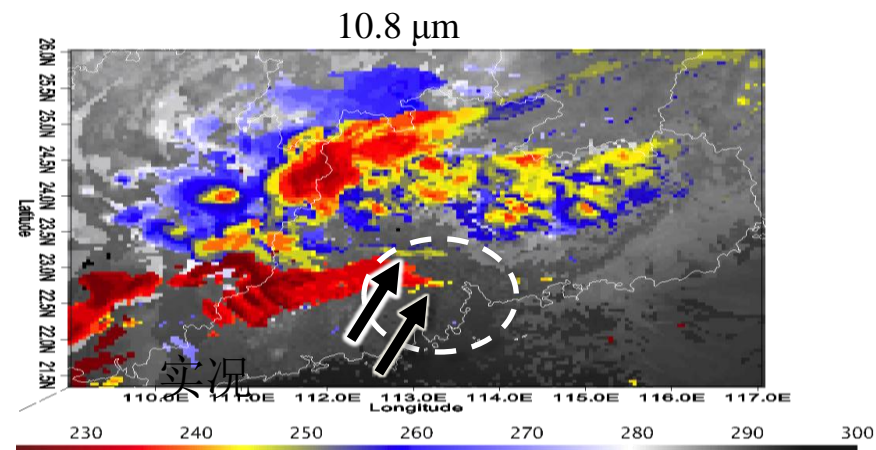
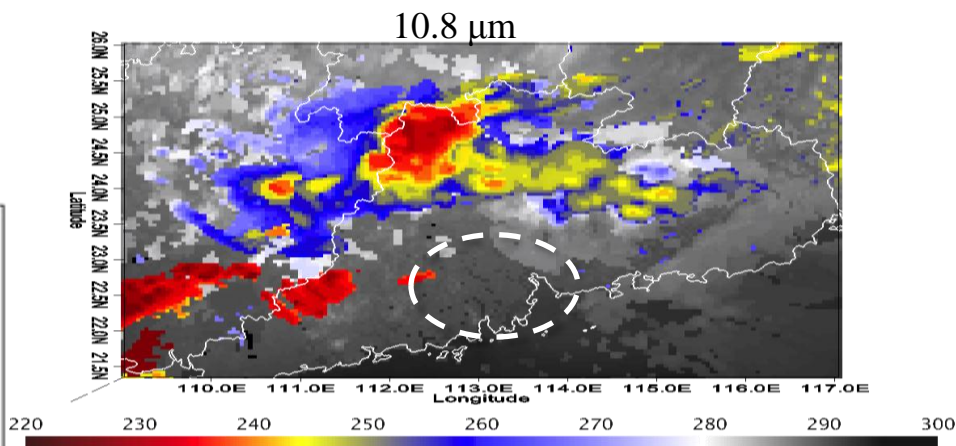
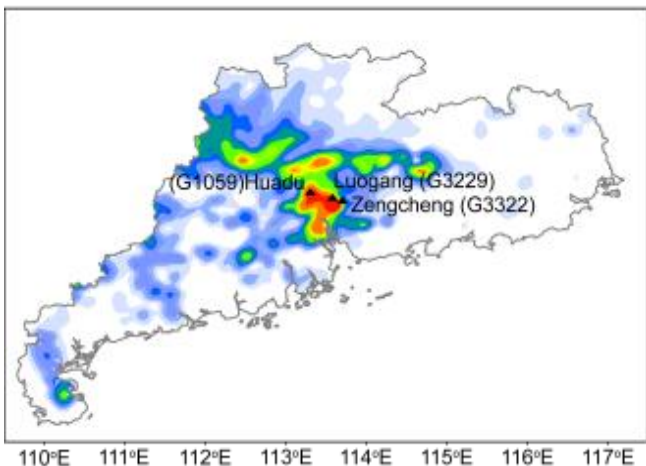
观测敏感性试验

城市下垫面引起的热力和动力强迫作用对“5.7”暴雨过程具有重要作用：城市边界层引起的非均匀性会引起局地大气不稳定性增强，在城市中心及其下风区形成辐合，深湿对流增强，降水增幅。

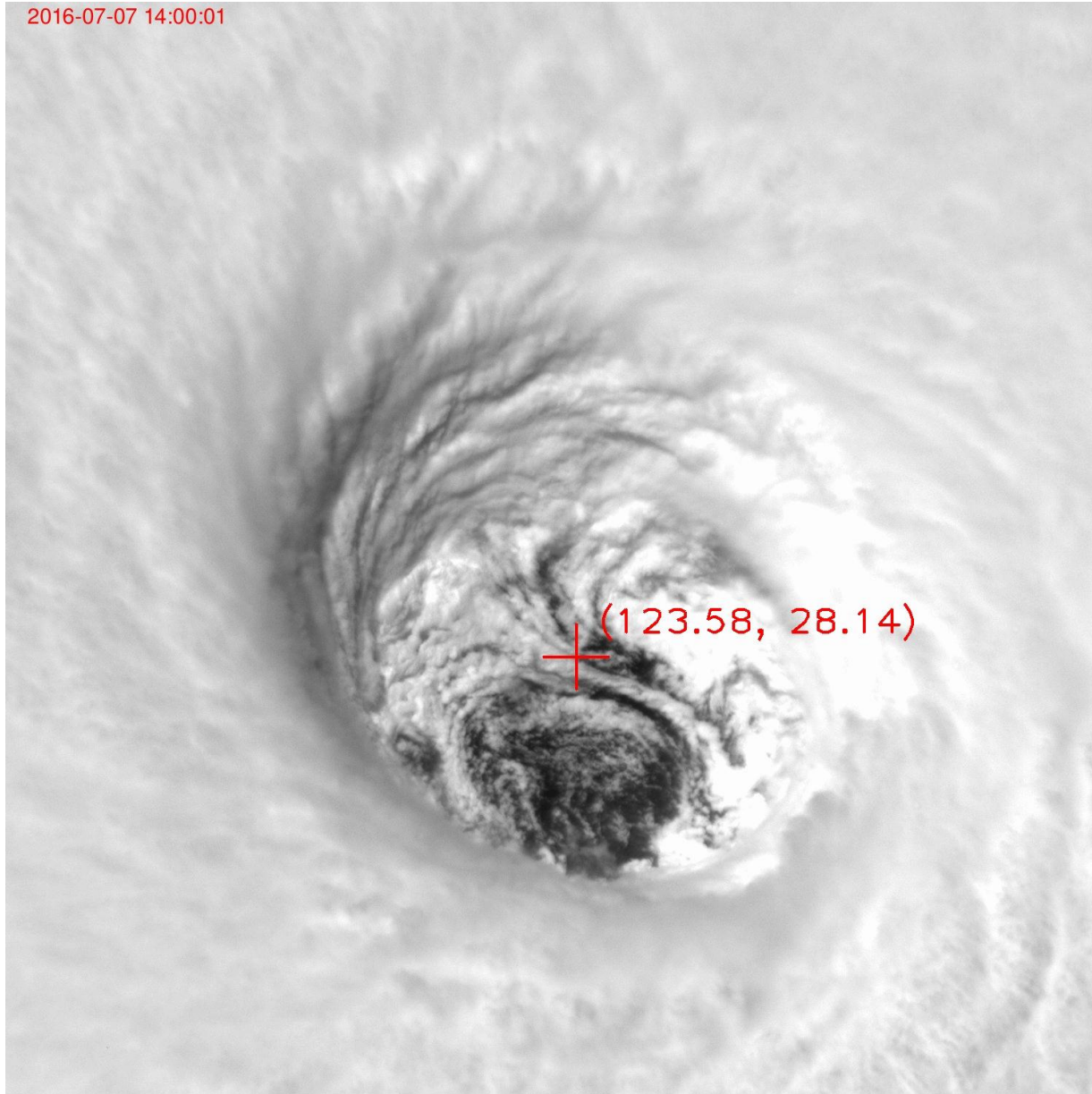
没有城市下垫面影响下的的模拟降水和FY4A云图

城市下垫面影响下的模拟降水和FY4A云图

实况



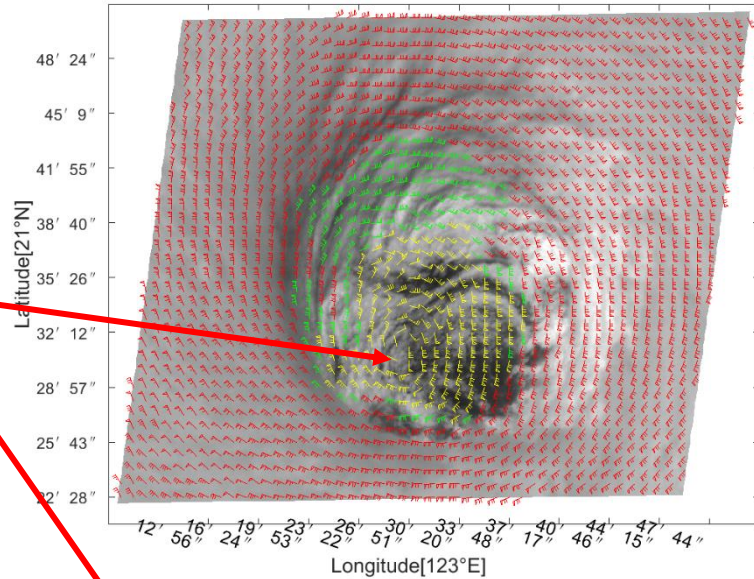
(4) 高精度台风定位



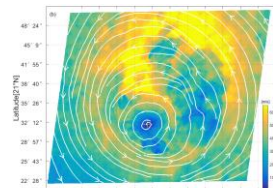
台风尼伯特 (Nepartak) 中心定位, GF-4/PMI (光流法)

Typhoon Nepartak Centric Position Track

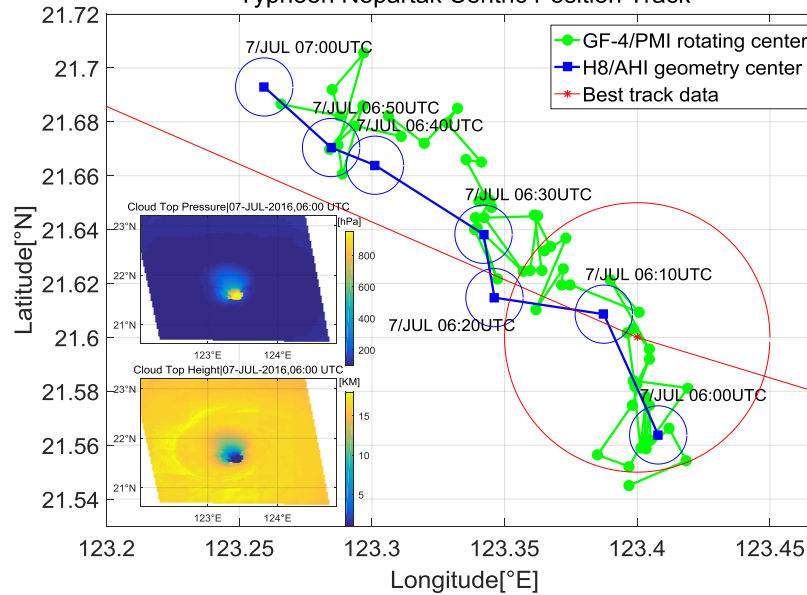
台风中心



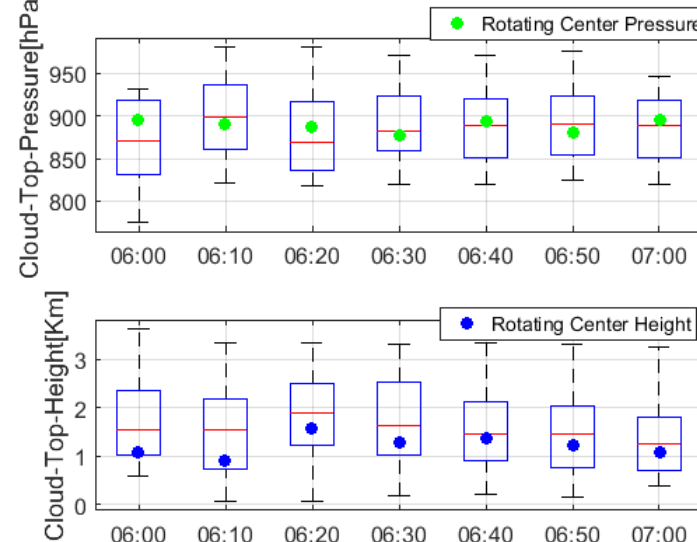
(a) Cloud-tracking motion velocity distribution of the centric eye, red: 0~400Pha, green: 400~700Pha, yellow: 700~1100Pha



(c) Cloud-tracking motion velocity distribution of the centric eye, white solid lines represent the streamlines



(b) Typhoon Nepartak rotating center tracks derived from GF-4/PMI (based on the optical flow method)



(d) uncertainty analysis and re-calculated cloud top heights and pressures of the Typhoon Nepartak eye area from H8/AHI: difference mean value 6.5hpa, std 7.3hPha

Simulation of different H8/AHI scanning modes with different spatiotemporal levels by GF-4 data

Enhance temporal resolution

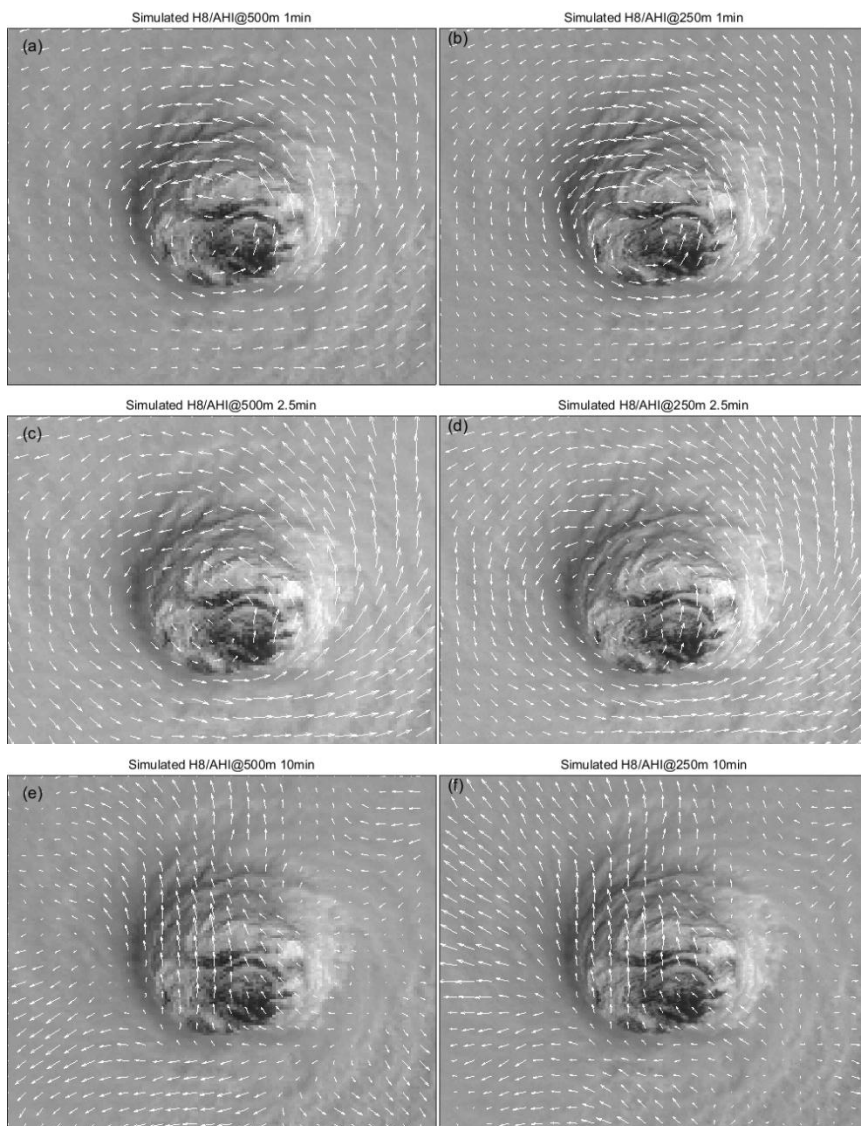


Fig.1 Scenario simulation for AHI by GF-4 data using OF method at different spatiotemporal levels with (a) 500m and 1min, (b) 250m and 1min, (c) 500m and 2.5min, (d) 250m and 2.5min, (e) 500m and 10min, (f) 250m and 10 min.

Enhance spatial resolution

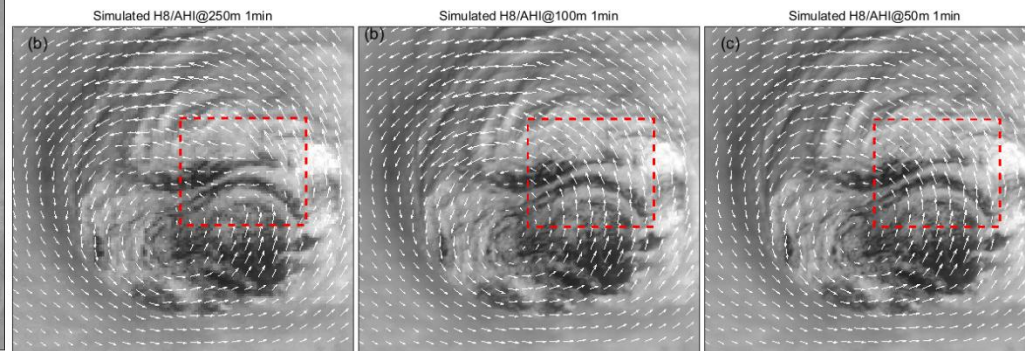


Fig.2 Scenario simulation for AHI by GF-4 data using OF method at different spatiotemporal levels with (a) 250m and 1min, (b) 100m and 1min, (c) 50m and 1min; The red rectangle areas show the difference of OFs with different spatial scales.

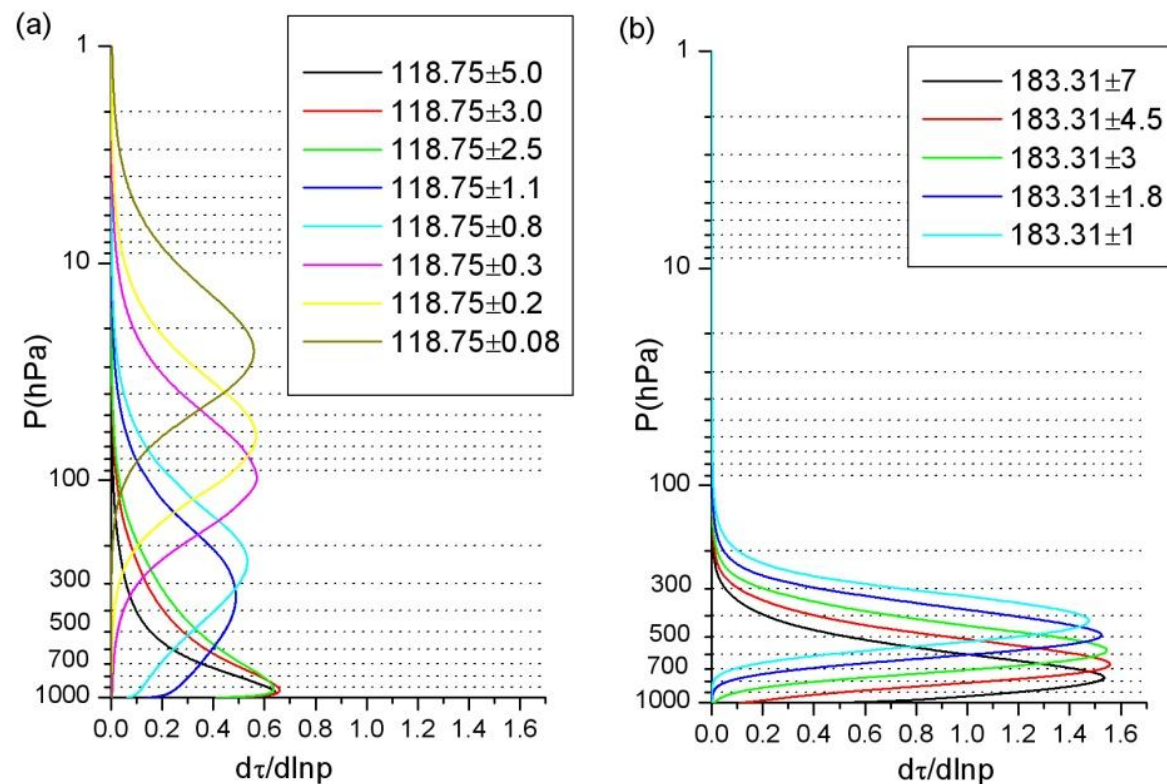
From this experiment, the final conclusion is that the imager observation mode with an interval time greater than **1-min** is not conducive to the seek the super typhoon rotation center. **The results for 50m and 100m show a good OFs pattern.** In contrast, the simulated AHI data at 250m resolution have locally distorted OFs pattern in the red rectangle areas. This is most likely due to the blurred image texture after reducing the resolution of image and the good features for track are lost.

(5) FY-3 118GHz应用

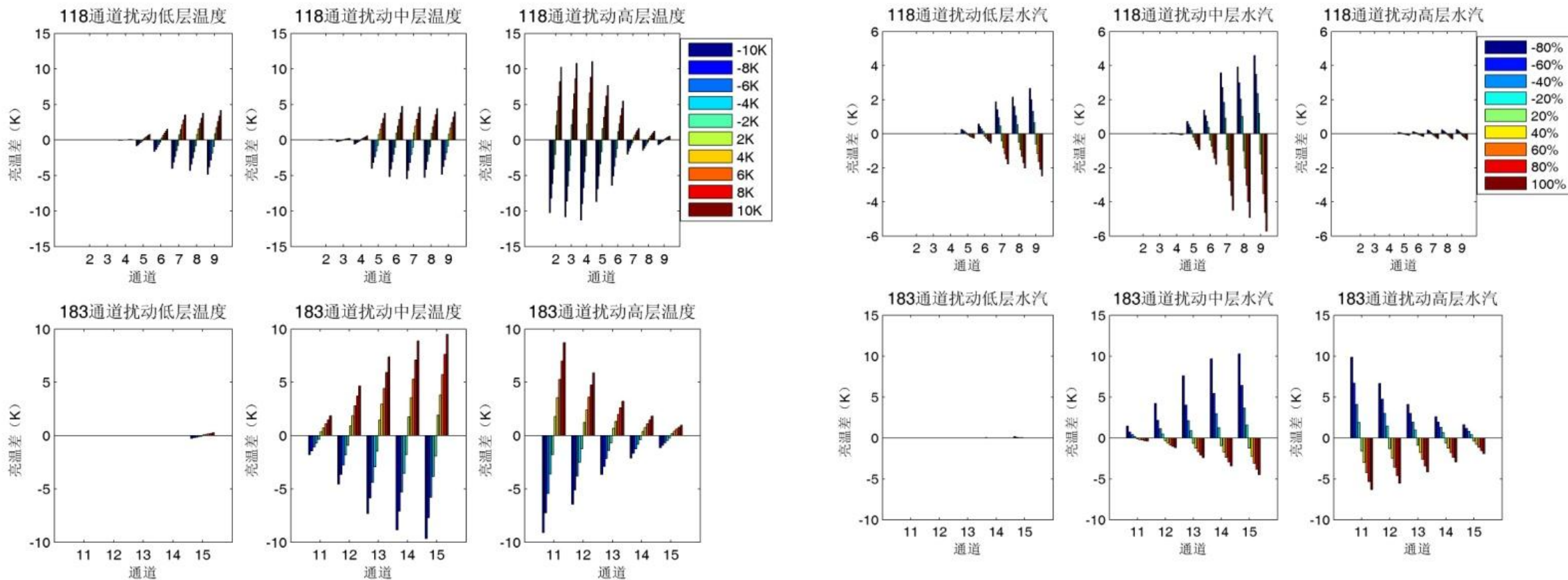
FY3C/D MWHS II 通道设置

通道序号	中心频率 (GHz)	极化	带宽 (MHz)	主要应用目的
1	89.0	V	1500	背景微波辐射探测、降水检测。
2	118.75±0.08	H	20	大气温度和降水参数垂直结构探测。
3	118.75±0.2	H	100	
4	118.75±0.3	H	165	
5	118.75±0.8	H	200	
6	118.75±1.1	H	200	
7	118.75±2.5	H	200	
8	118.75±3.0	H	1000	
9	118.75±5.0	H	2000	
10	150.0	V	1500	
11	183.31±1	H	500	大气湿度垂直结构探测。
12	183.31±1.8	H	700	
13	183.31±3	H	1000	
14	183.31±4.5	H	2000	
15	183.31±7	H	2000	

MWHS II weight function



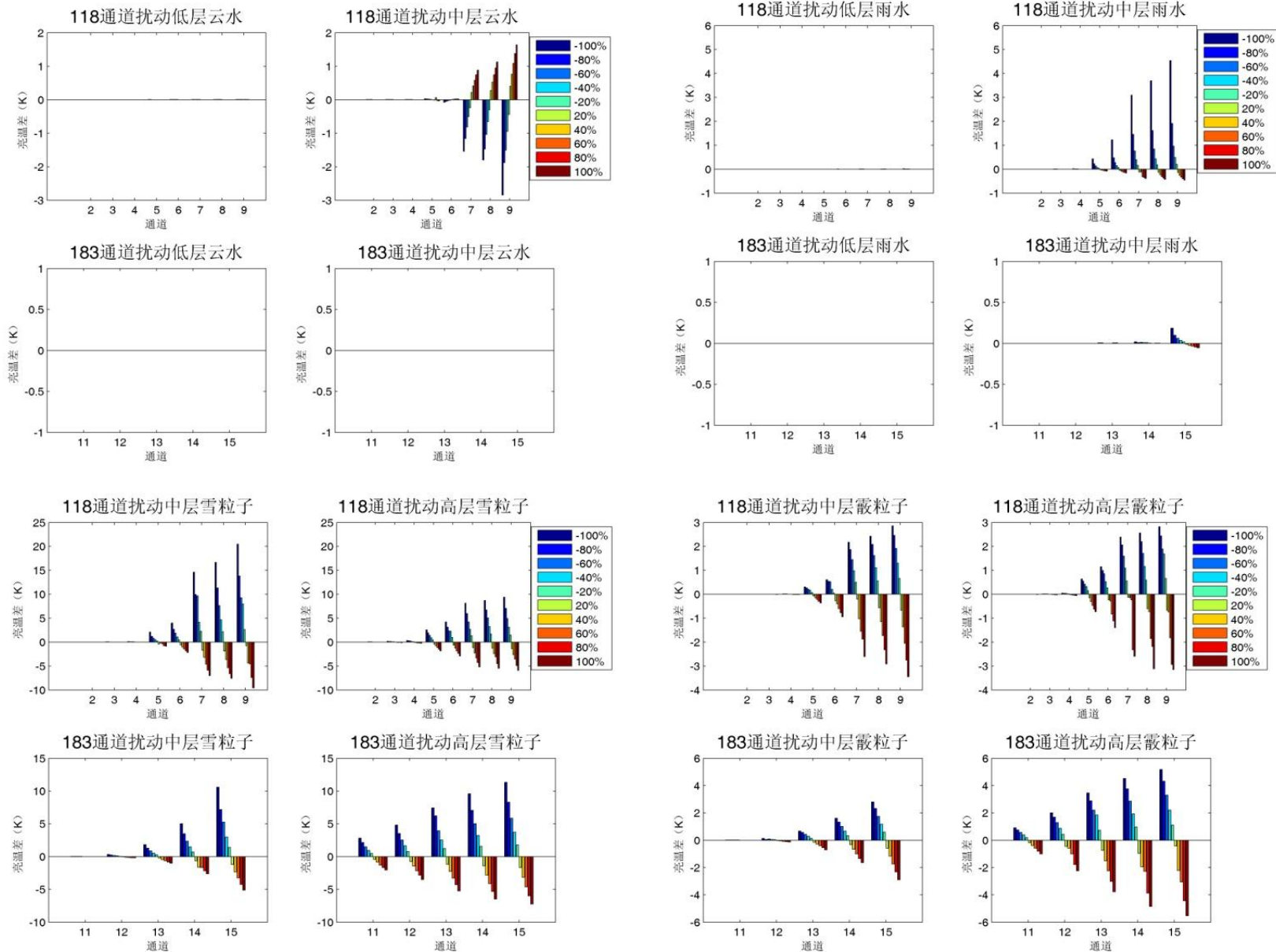
MWHTS通道特性分析-温度和水汽敏感性分析



118GHz通道作为首次使用的大气探测通道，能够很好地反映大气中各层温度的变化，尤其是对对流层中上层大气系统的温度变化更为敏感。

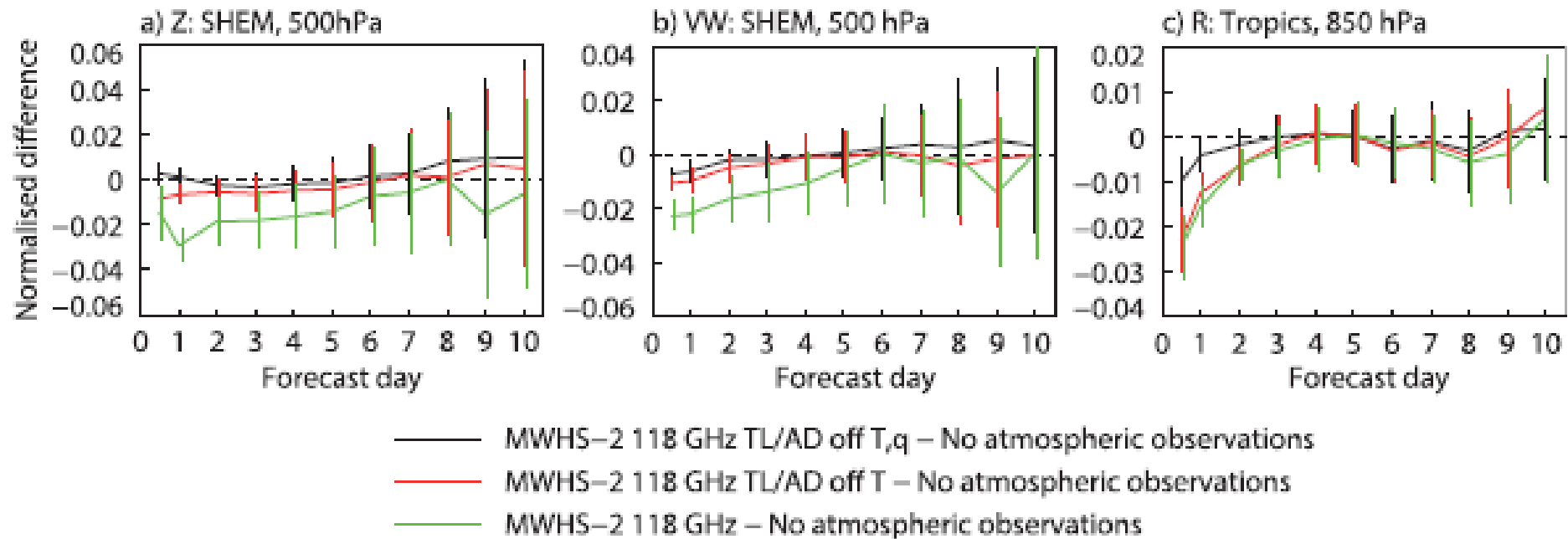
183GHz通道对中、高层大气湿度结构的探测具有优势；低层大气水汽的变化对118GHz的温度探测结果会有影响，这说明水汽的存在对氧气通道产生了“污染”，即大气温度廓线反演的精度也会受到大气湿度状态的影响，但在高层118GHz受大气湿度廓线的响应就很小，这也进一步说明了118GHz在高层的高精度温度探测能力。

MWHTS通道特性分析-水凝物敏感性分析



液态粒子的存在只对118GHz的远翼通道亮温产生了明显影响，通道9的亮温随中层雨水含量的增加下降了约4.5K，即**只有118GHz通道能够反映出云雨大气中层云水和雨水含量的变化。**

冰态水凝物的散射作用会对FY-3C微波湿温探测仪主探测通道的亮温产生影响，**尤其是中层雪粒子的增加可使通道9亮温下降10K，这为空中雪晶的探测带来希望。**



预报场和同化MWHS 11的118GHz通道后分析场的差值标准差
 a) 南半球500hPa位势高度 b) 南半球500hPa风矢量 c) 热带地区850hPa相对湿度
 负值表示和只同化地面资料相比，同化118GHz的改进

只同化118GHz观测资料时，对温度、湿度、云和降水信息的预报准确性有正效果

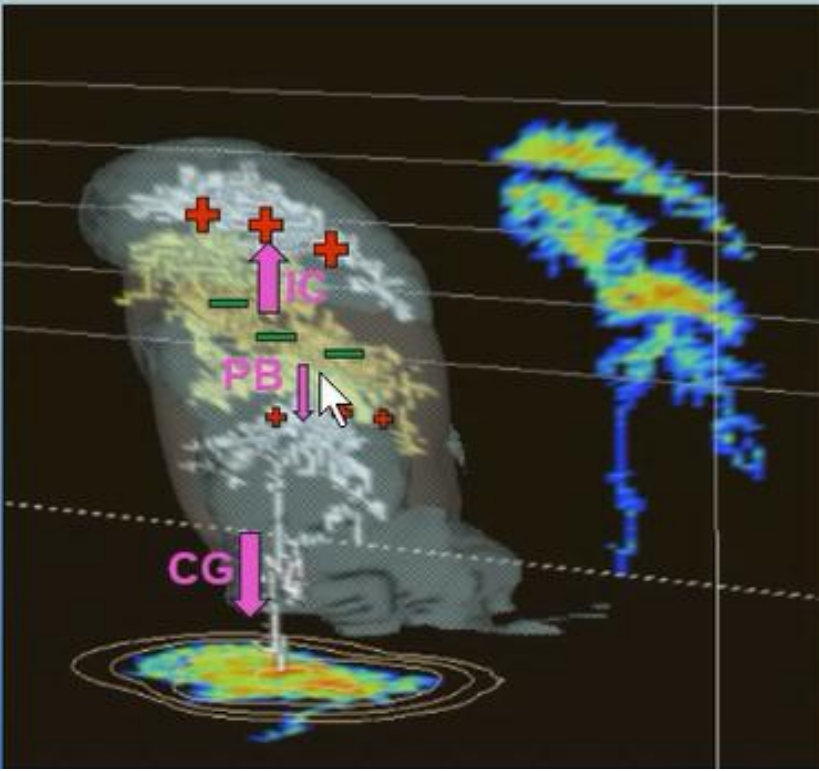
在全观测资料同化系统中，同时同化118GHz观测资料时，对1-10天预报准确度有微弱贡献，但对短期预报和观测的一致性有正效果——对南半球850hPa云导风有0.2%的改进；对SSMIS成像通道的一致性改进0.2%-0.3%；南半球云和降水场的改进在0.5%。这些改进表明118GHz对降水反演有优势。

(6) FY-4闪电同化应用

闪电资料同化 (LDA)基本思路:

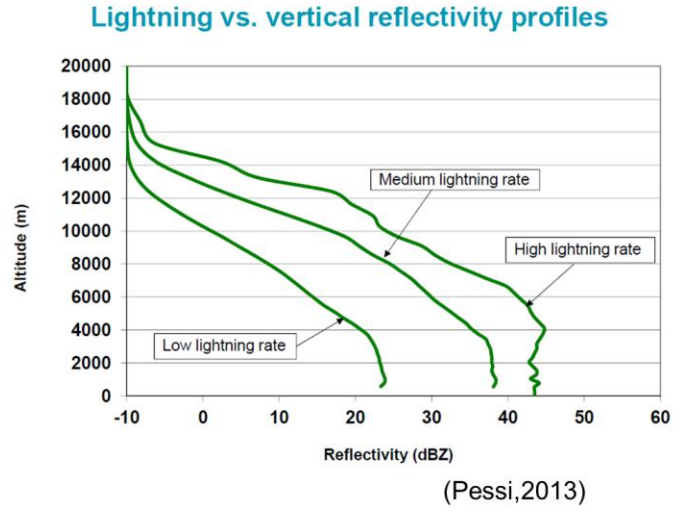
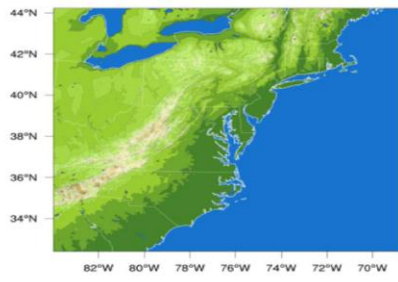
- ✓ 同化系统: LAPS(Local Analysis Prediction System)
- ✓ 闪电events与3-D雷达反射率场关系→用于模式三维云分析, 影响云水凝物分布→预报系统
- ✓ 预报系统: WRF-ARW, LAPS为预报模式提供初始场

建立闪电events与3-D雷达反射率场关系→用于模式三维云分析, 影响云水凝物分布→预报系统



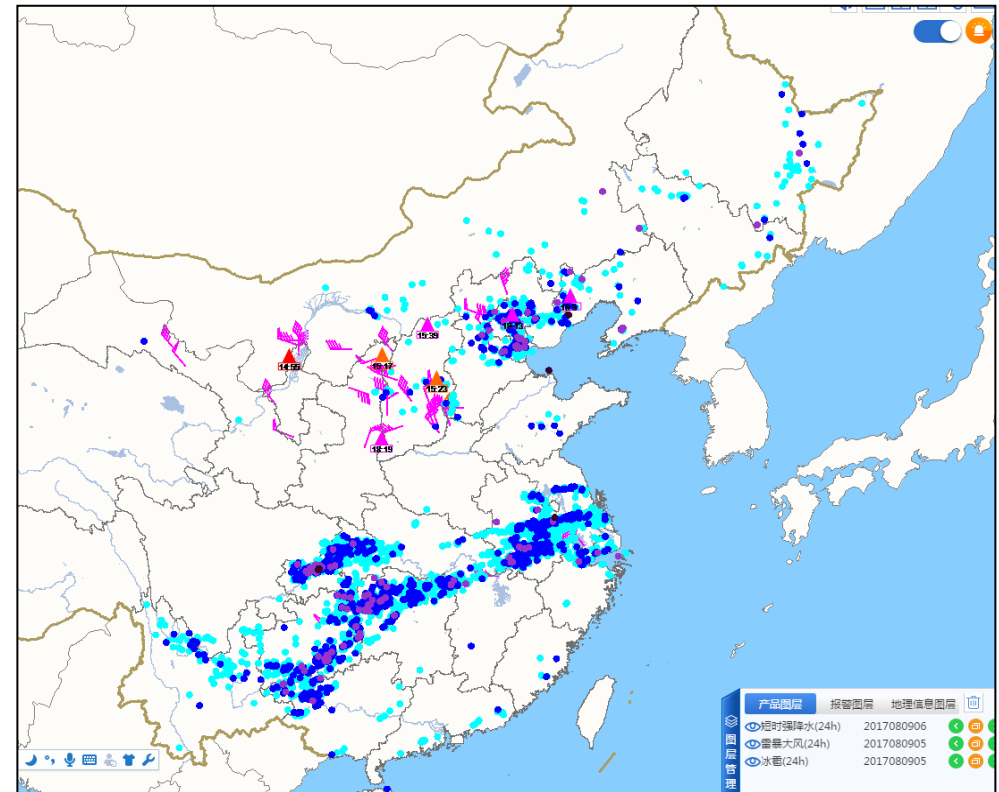
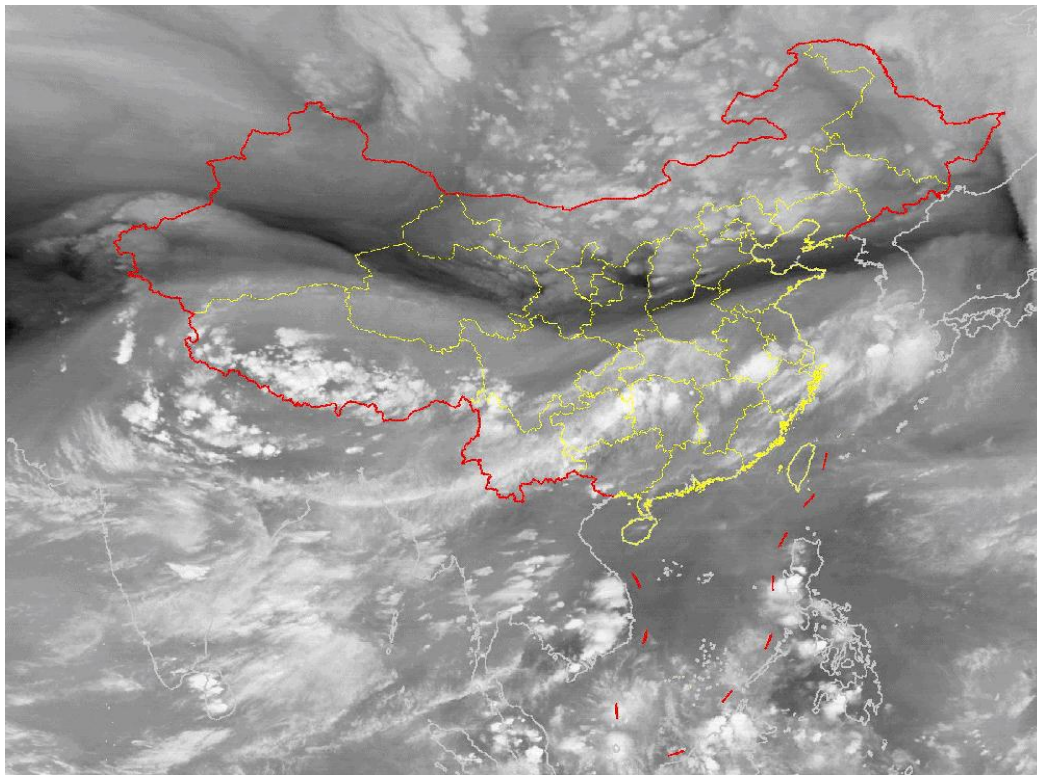
闪电-雷达反射率关系

- 采用了美国科罗拉多建立的闪电-雷达反射率关系数据库
- 包含美国东北部5个月共计226000个闪电数据样本



2017年8月8日暴雨过程

风云四号卫星水汽监测动画8月8日20:00—9日07:00



试验方案

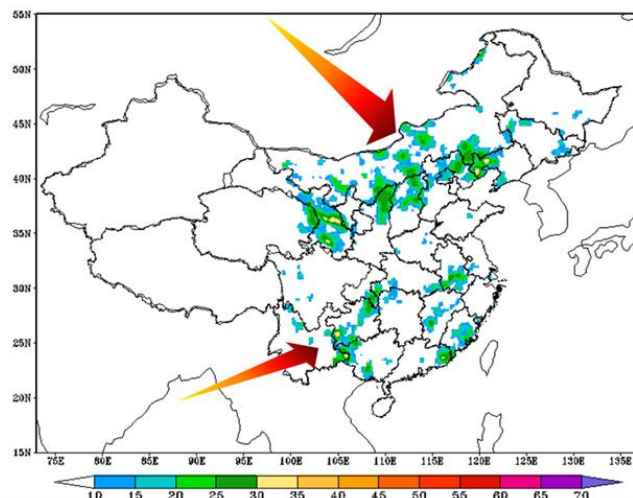
LAPS分析：

- ◆ 使用GFS背景场，
- ◆ 5km分辨率
- ◆ 同化FY-4闪电资料，10分钟时间窗

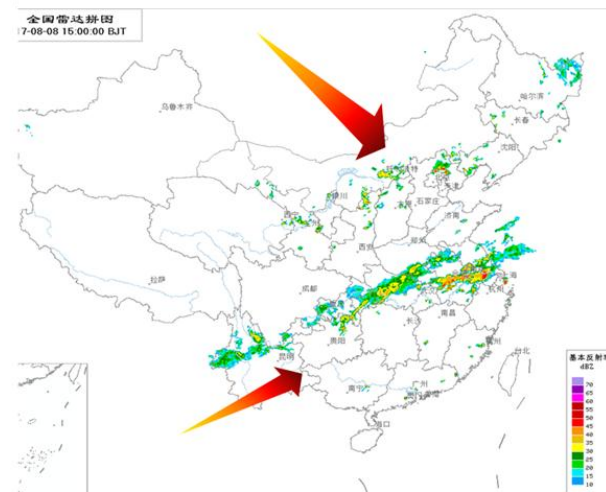
WRF预报：

- ◆ WRF3.4.1
- ◆ 5km空间分辨率，垂直19层
- ◆ 24小时预报
- ◆ 3组预报试验：
 - 1) 控制试验（Control Run）；
 - 2) 不同化FY-4闪电资料试验（NoLig）
 - 3) 同化FY-4闪电资料试验（Lig）

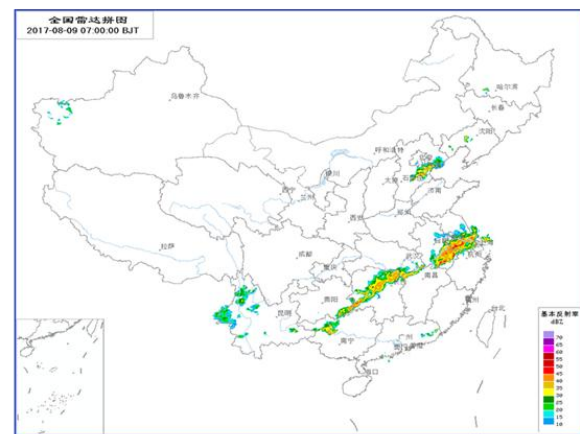
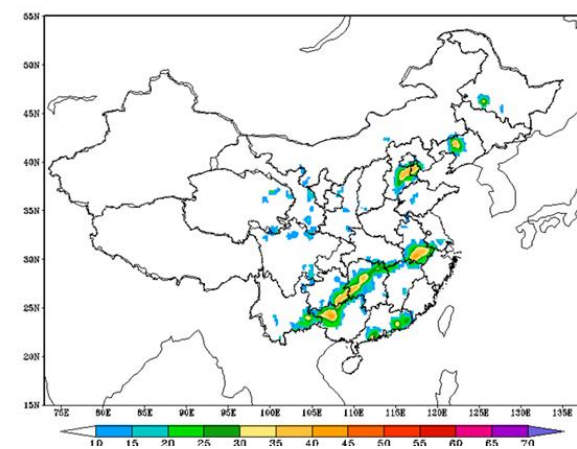
闪电转换的虚拟雷达反射率



雷达拼图



2017年8月8日23时（世界时）



水凝物分布

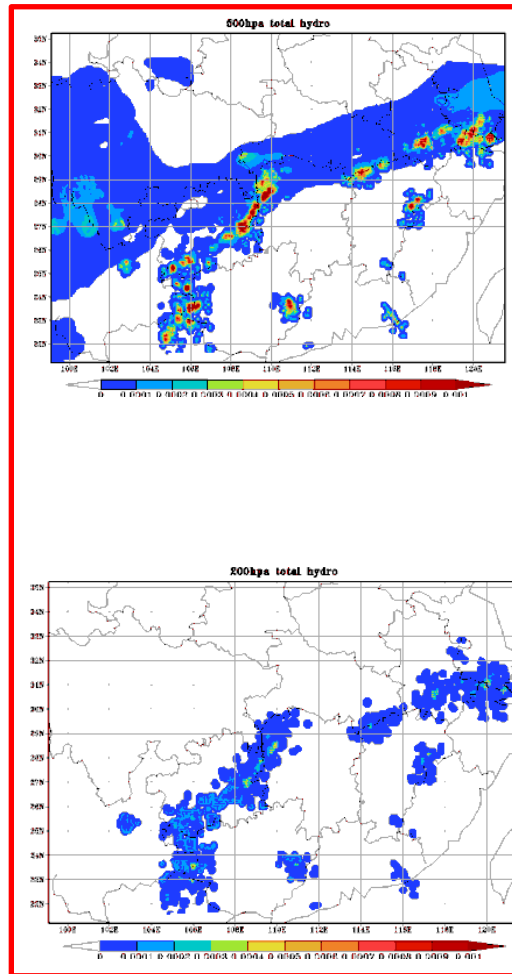
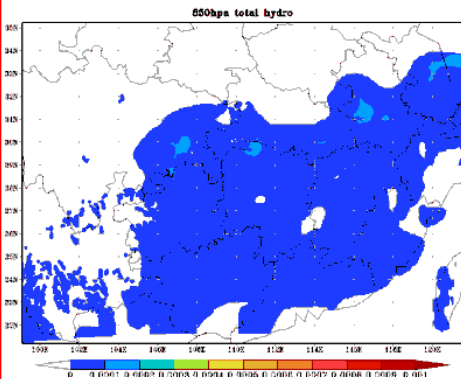
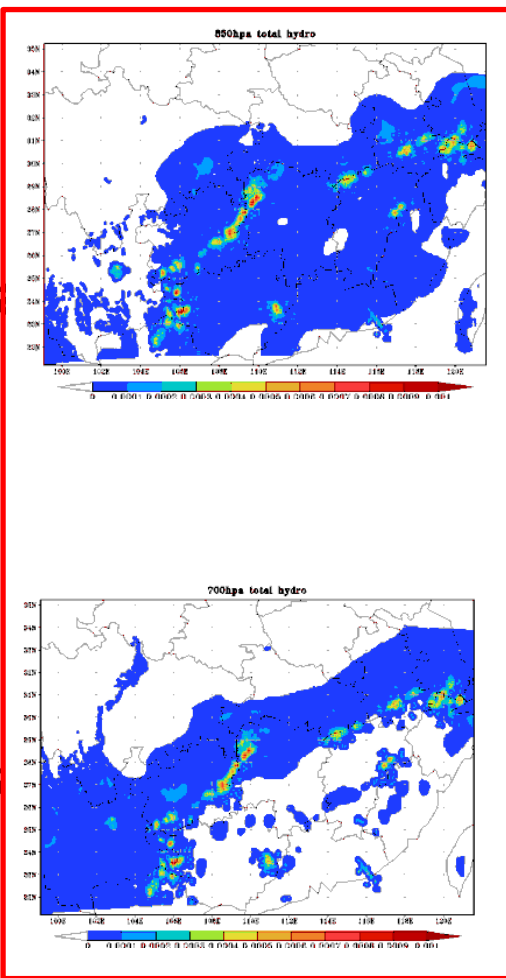
同化闪电后

同化闪电前

同化闪电后

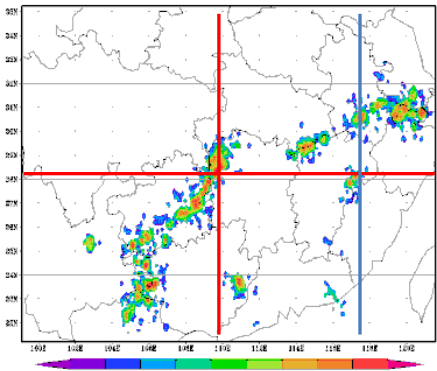
同化闪电前

850hpa



500hpa

200hpa

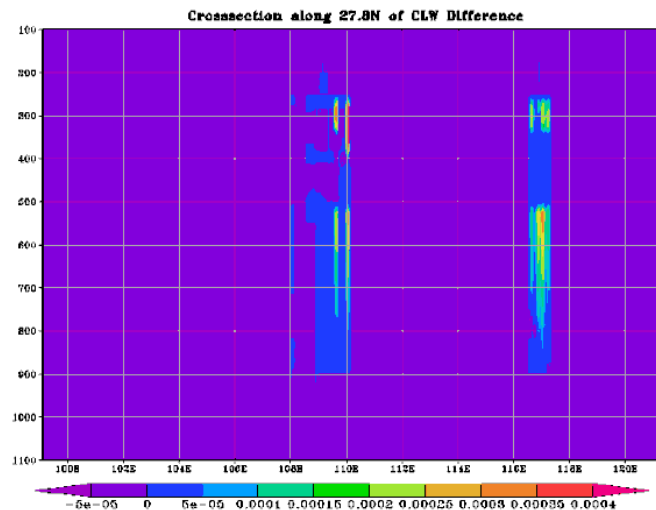
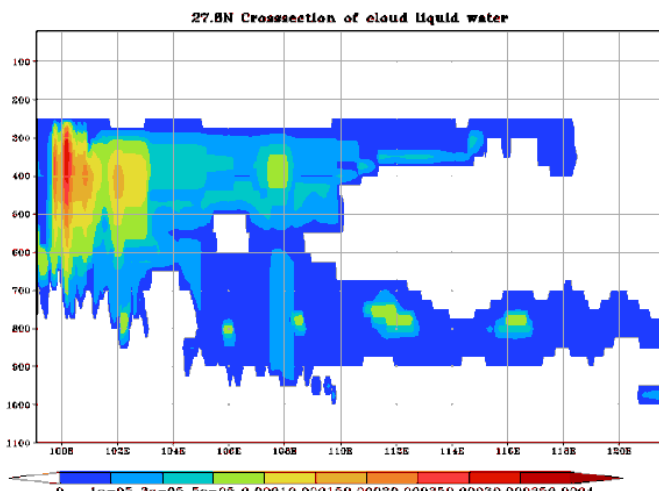
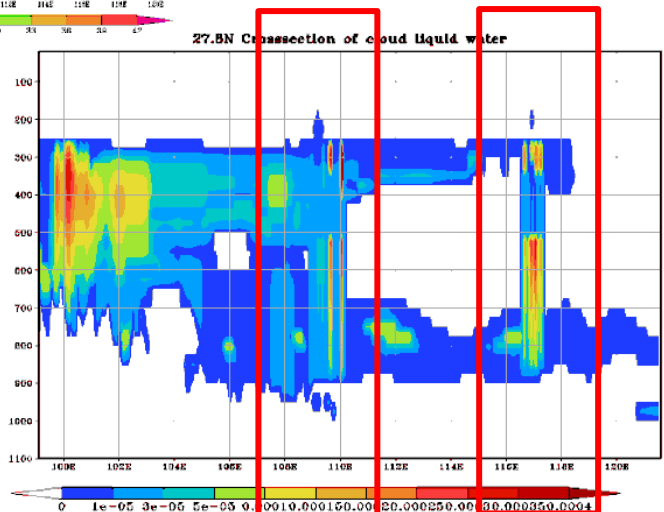


同化闪电后

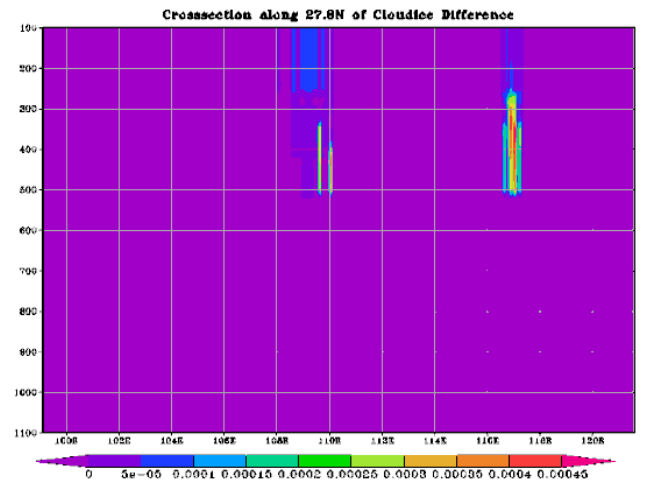
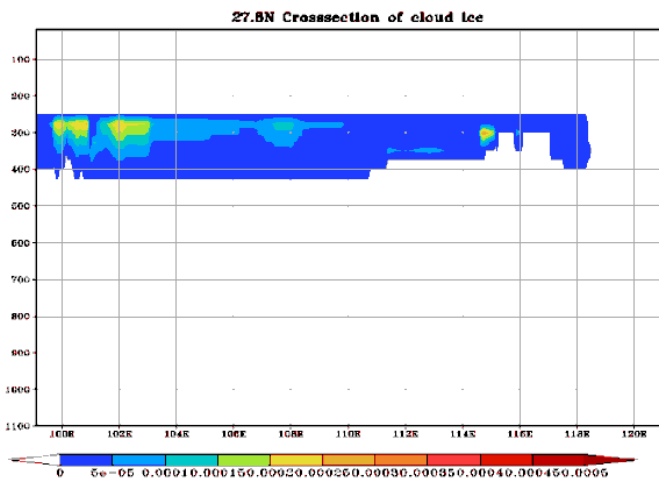
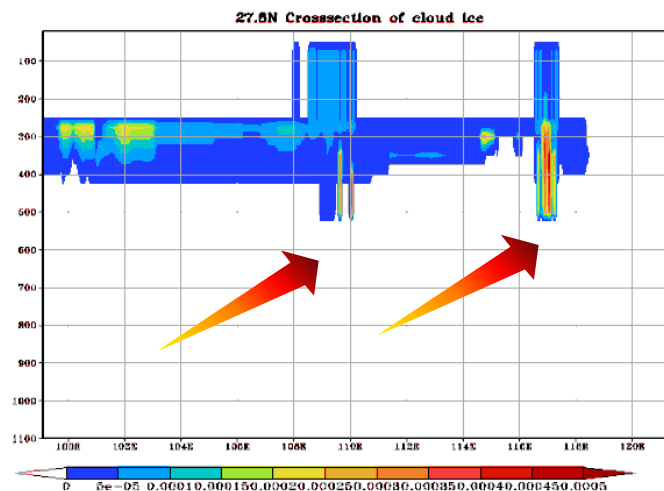
同化闪电前

差值

云水含量

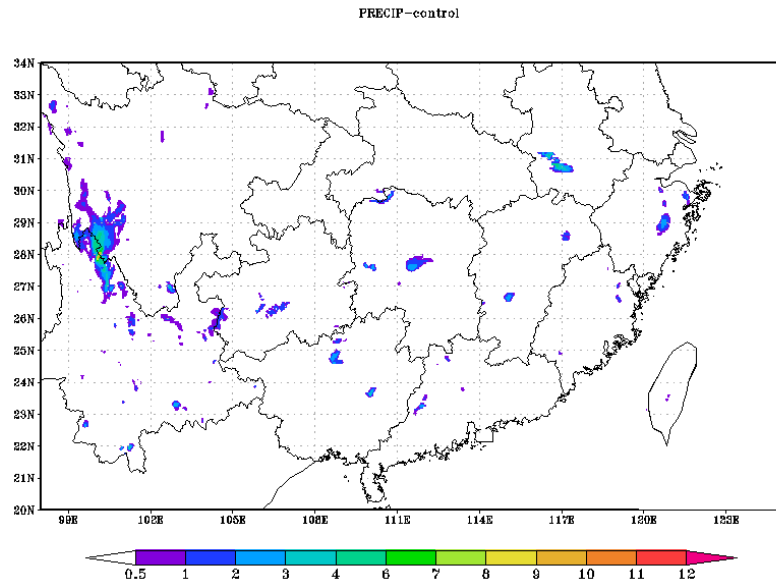


云冰含量

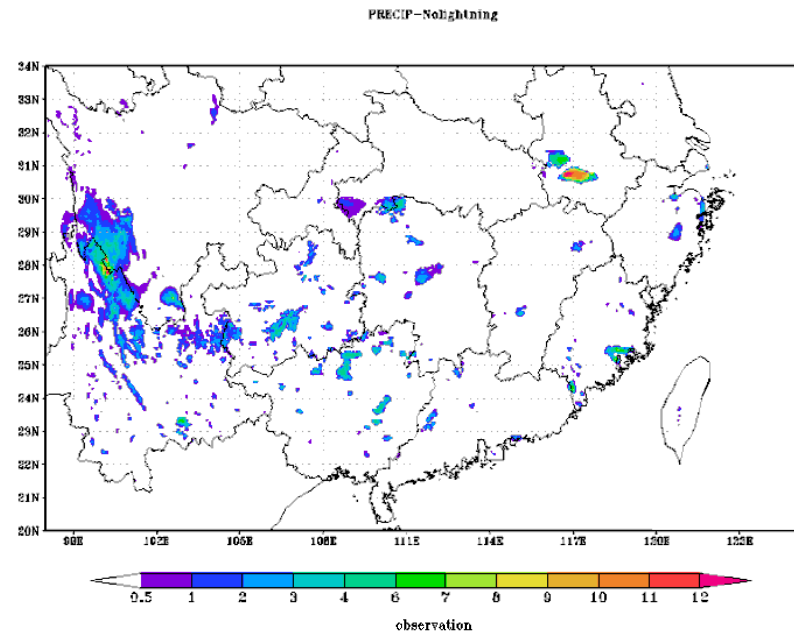


降水预报效果评估 1h

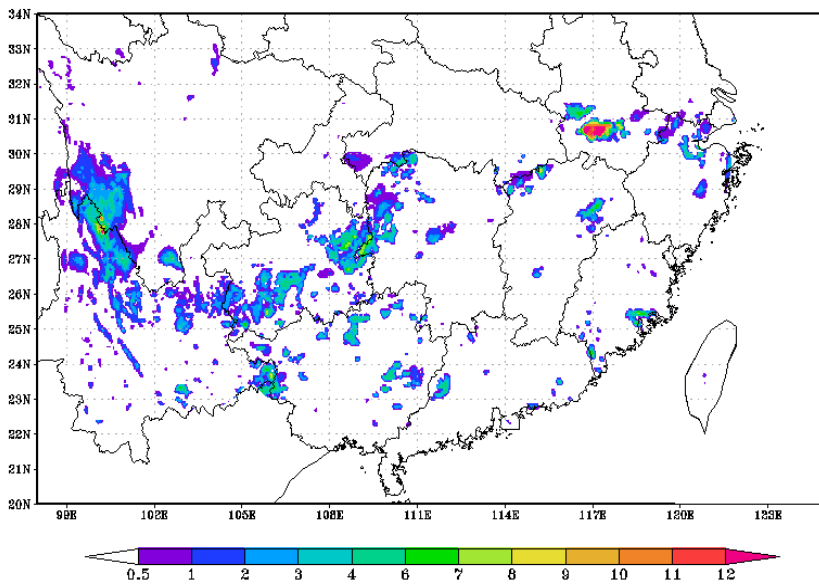
Control Run



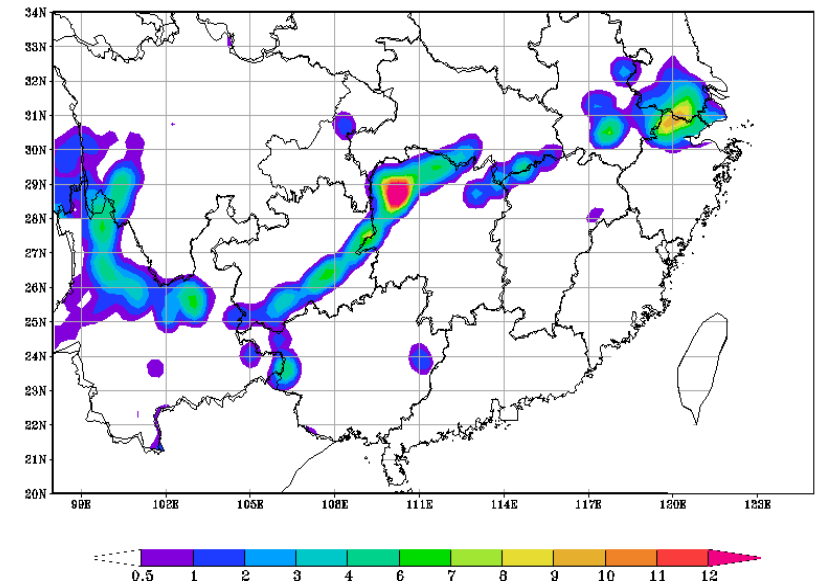
No lightning



FY4 lightning



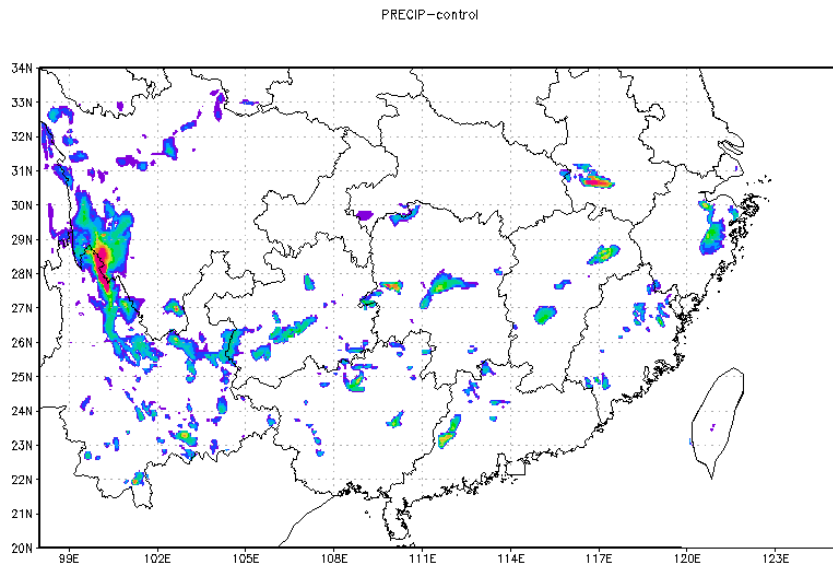
Observation



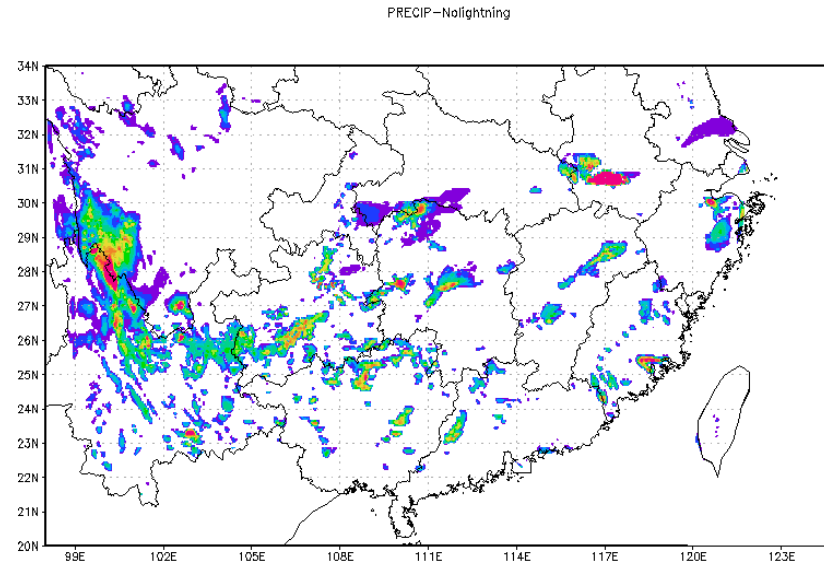
降水预报效果评估

2h

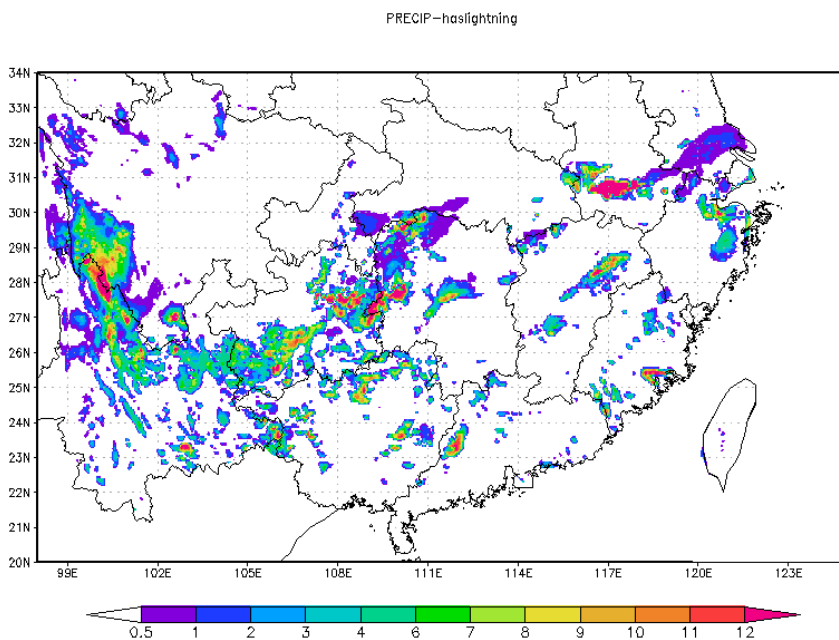
Control Run



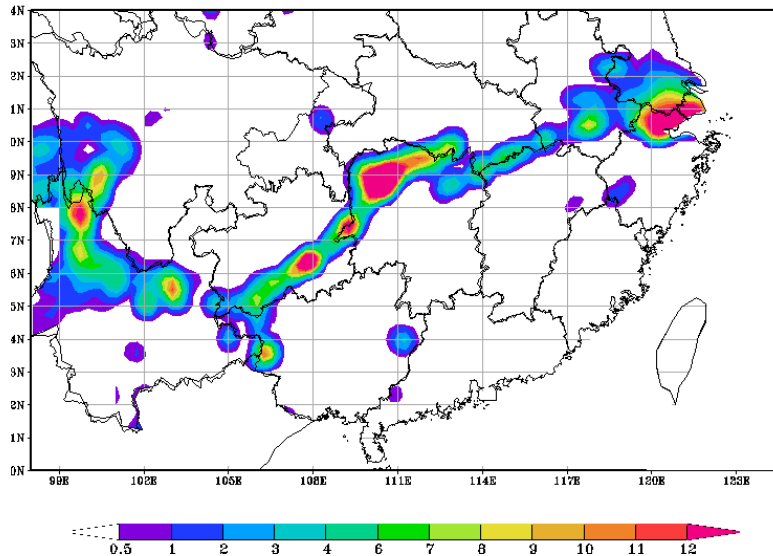
No lightning



FY4 lightning



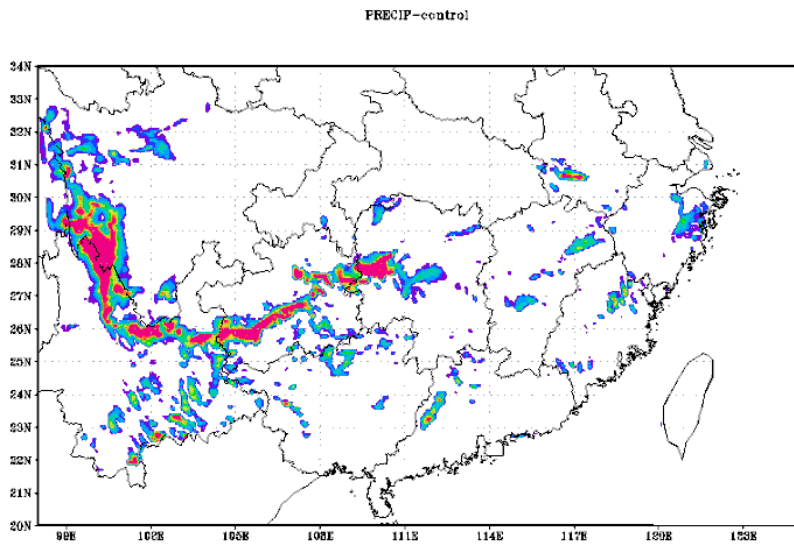
observation



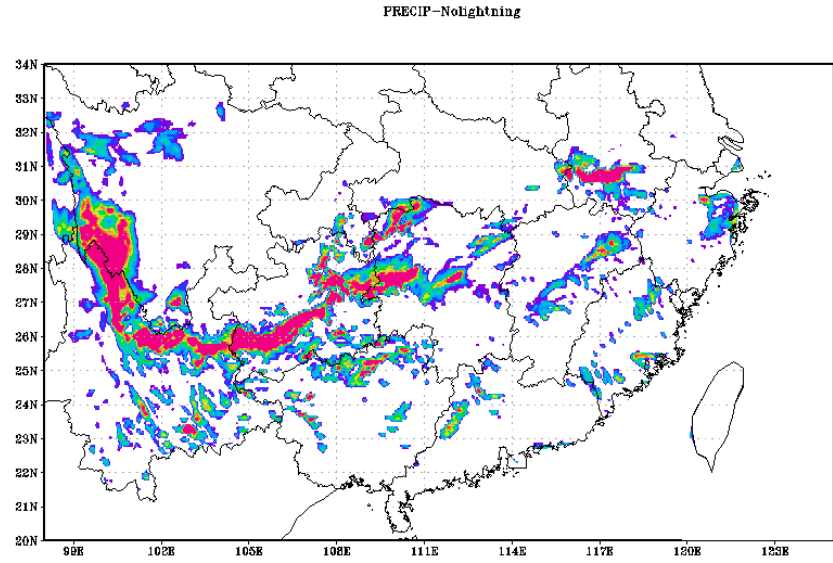
Observation

降水预报效果评估 6h

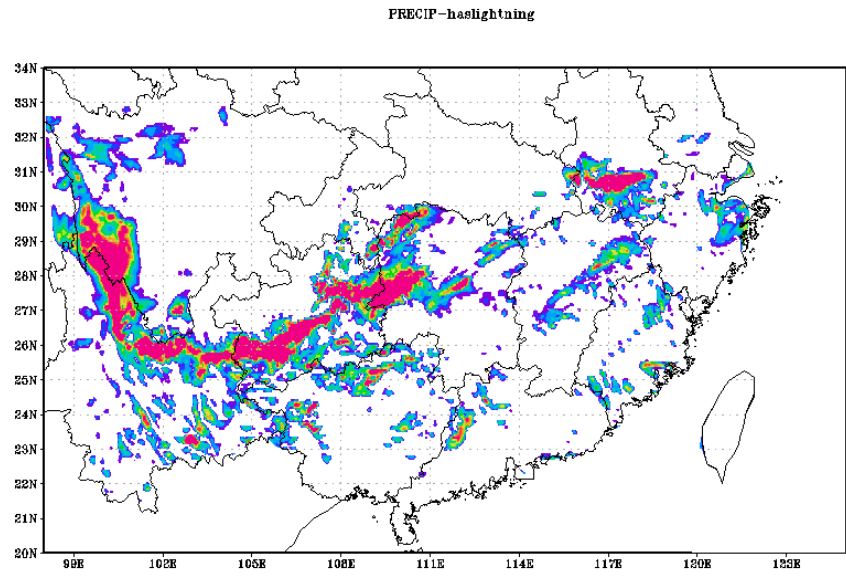
Control Run



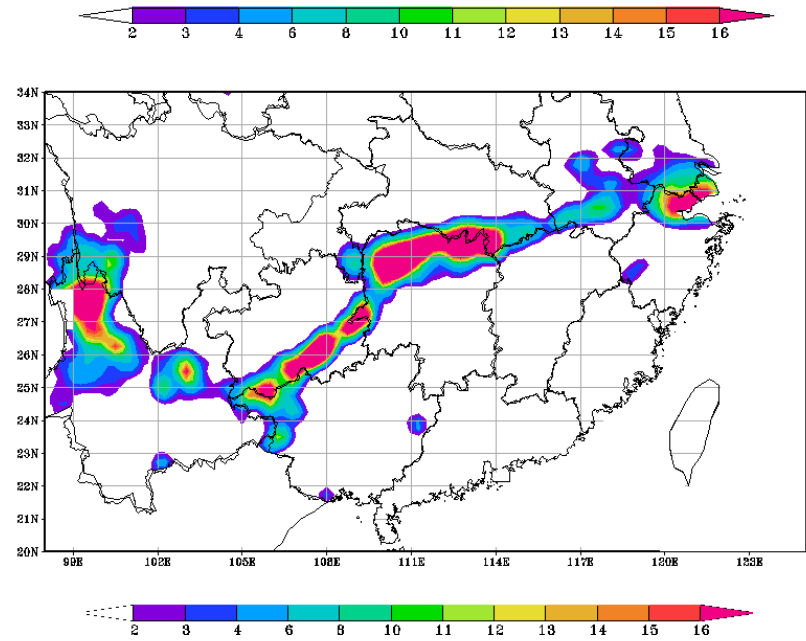
No lightning



FY4 lightning

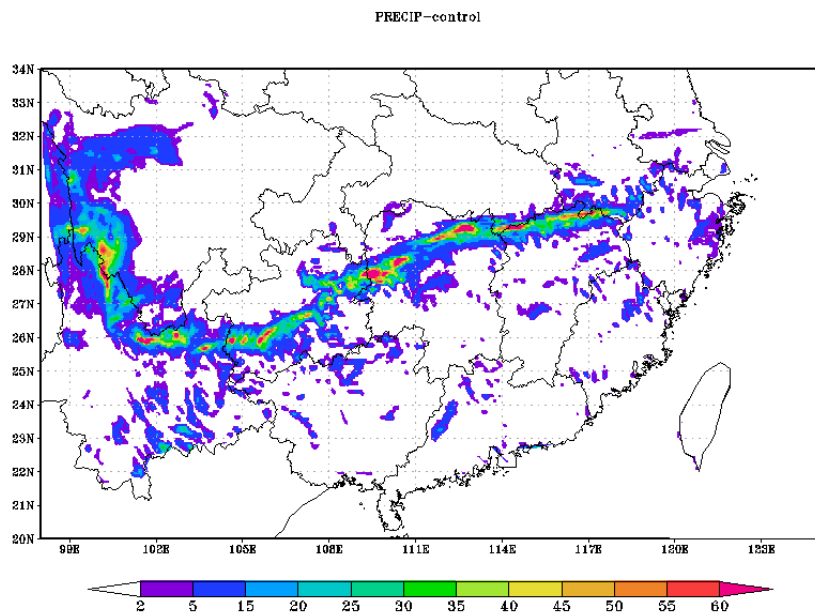


Observation

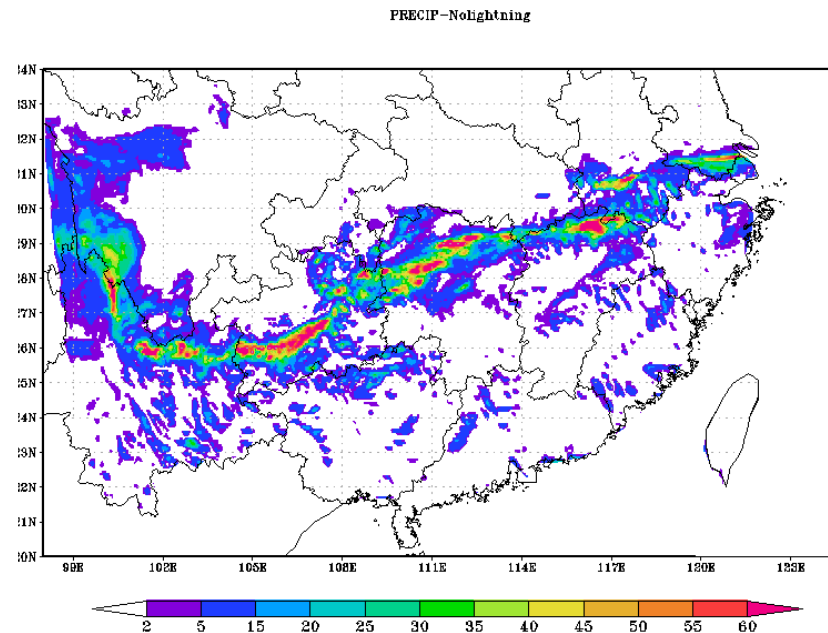


降水预报效果评估 12h

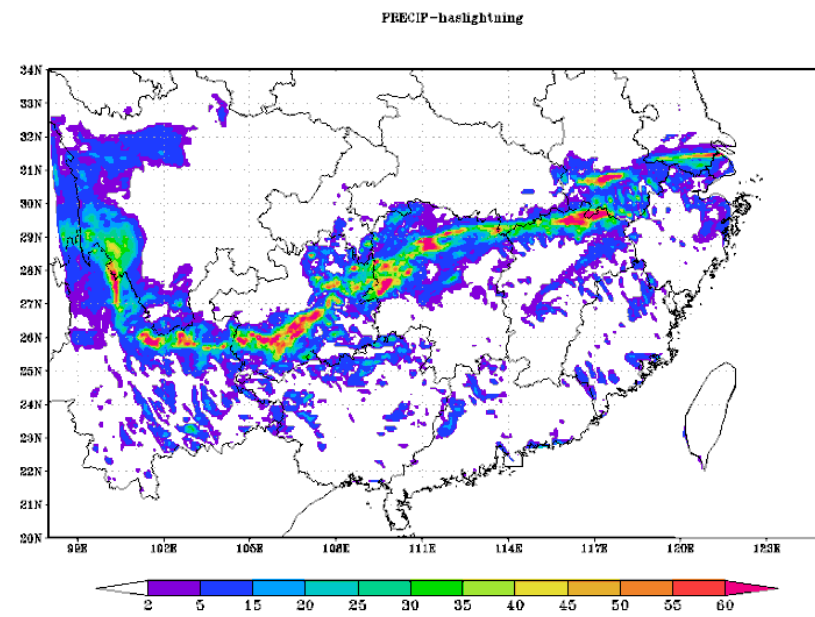
Control Run



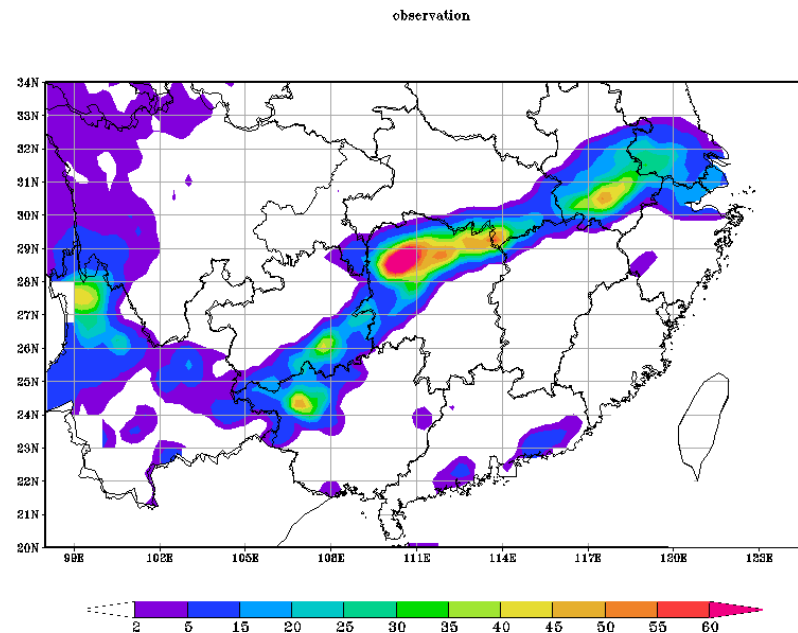
No lightning



FY4 lightning

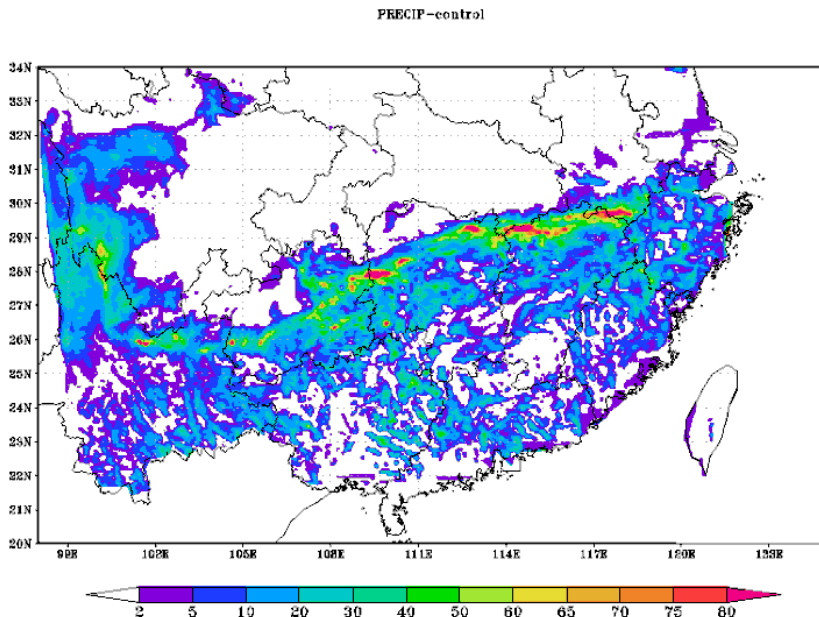


Observation

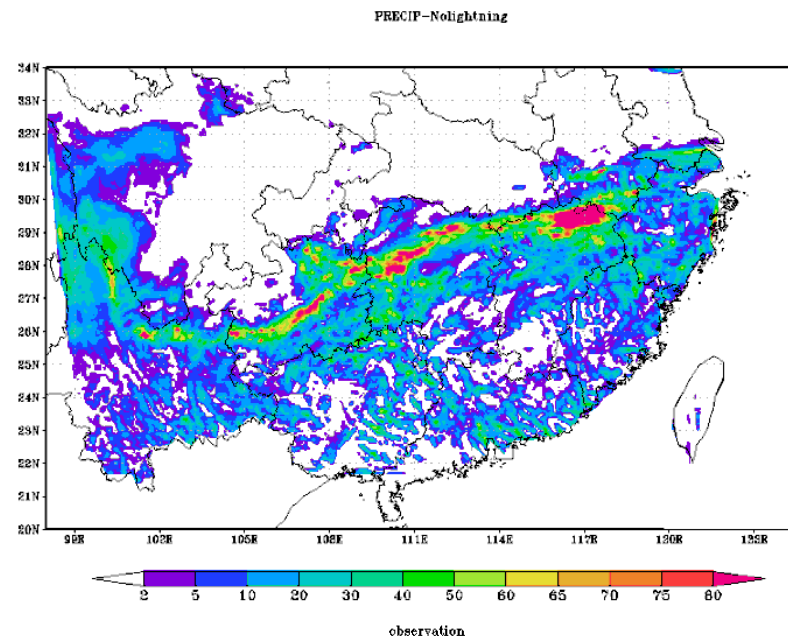


降水预报效果评估 24h

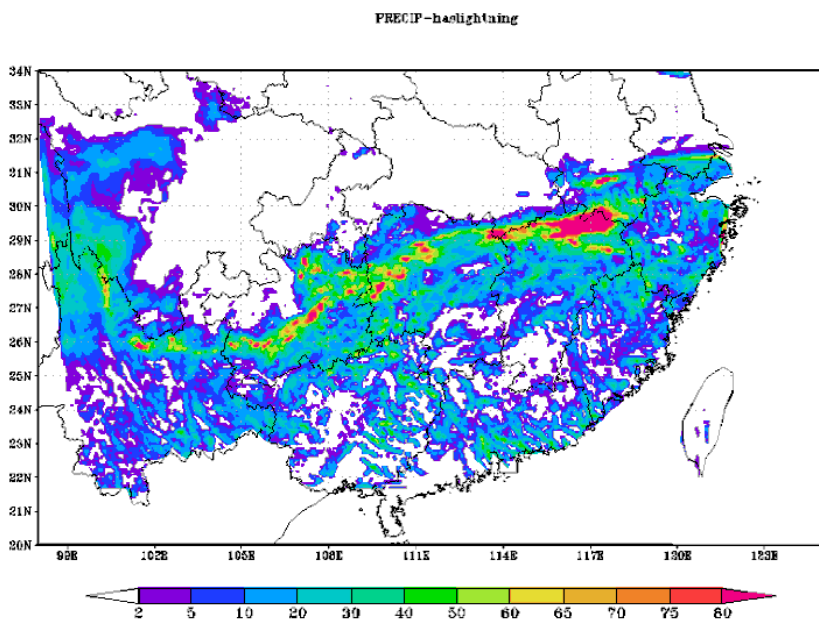
Control Run



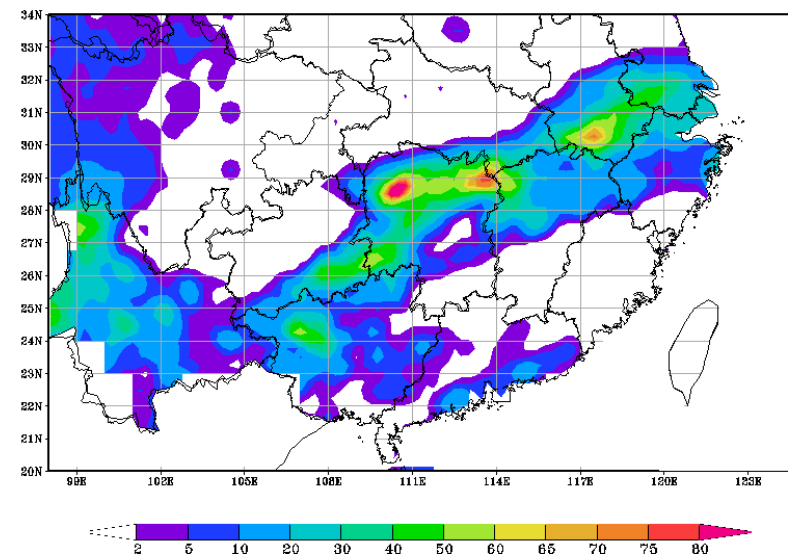
No lightning



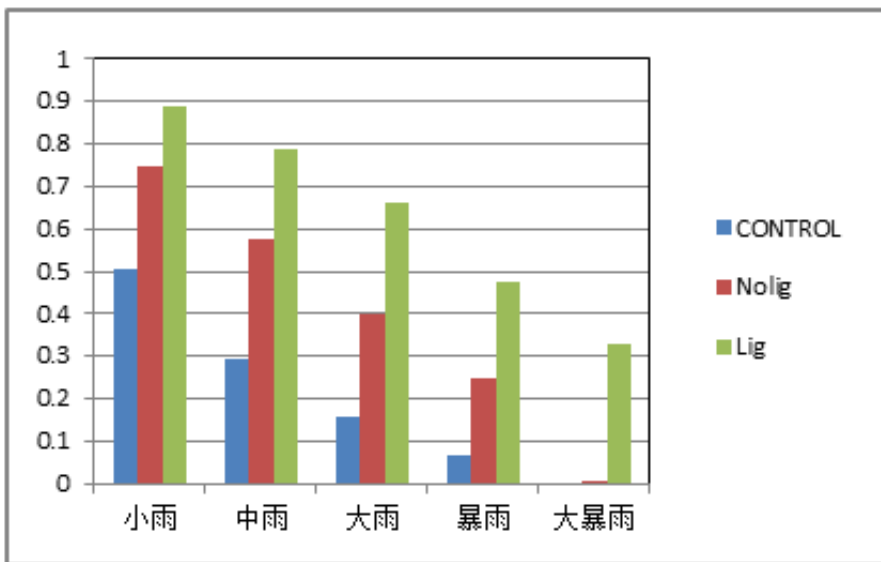
FY4 lightning



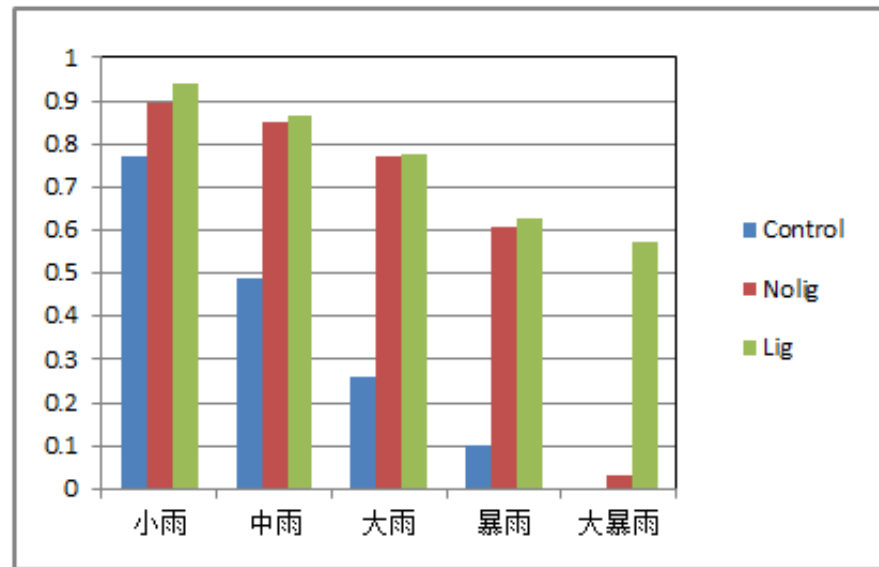
Observation



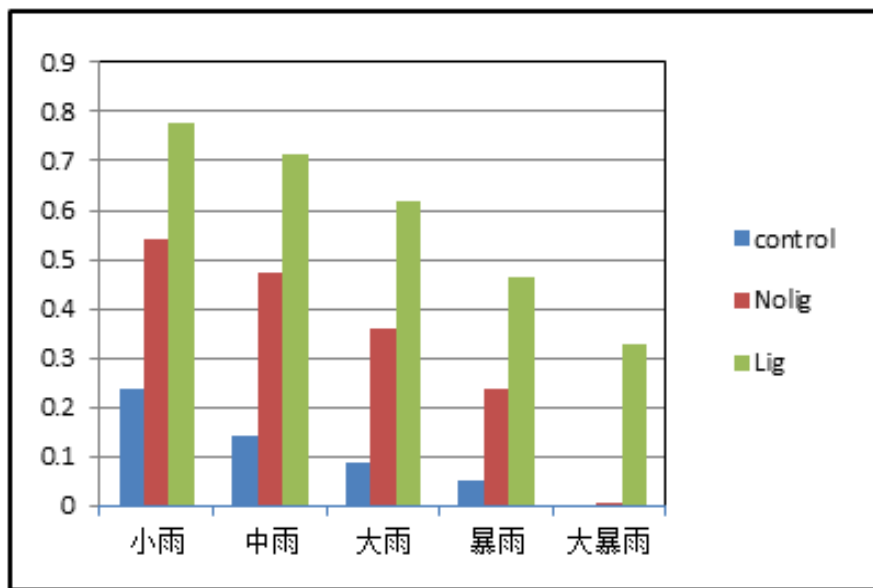
TS



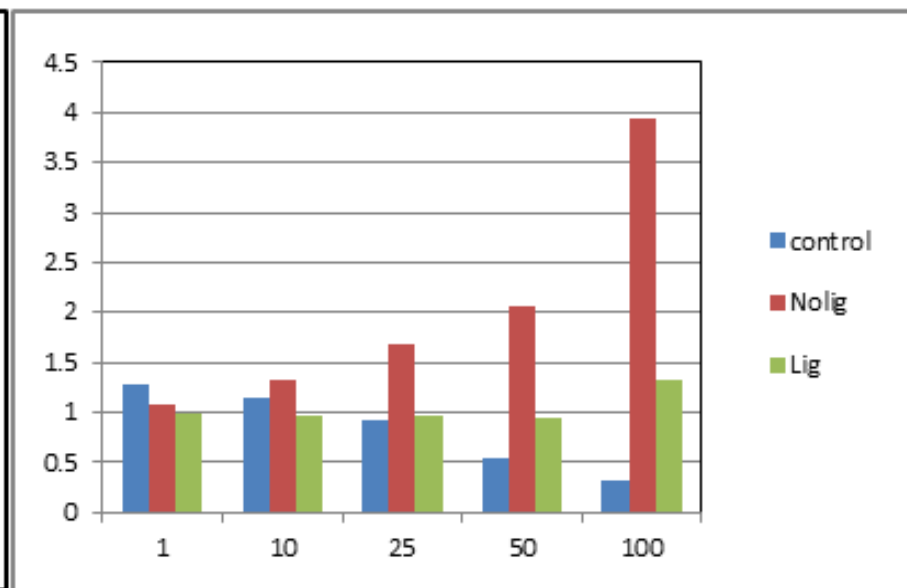
POD



ETS



BIAS

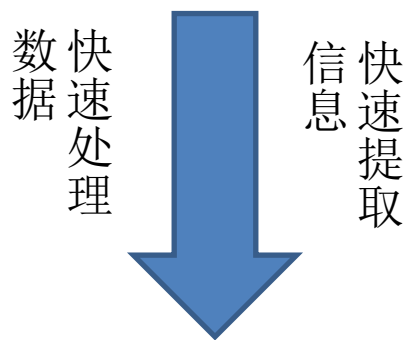


同化闪电资料后降水预报TS, ETS评分略高于同化前
 预报准确率高于同化前, BIAS小于同化前

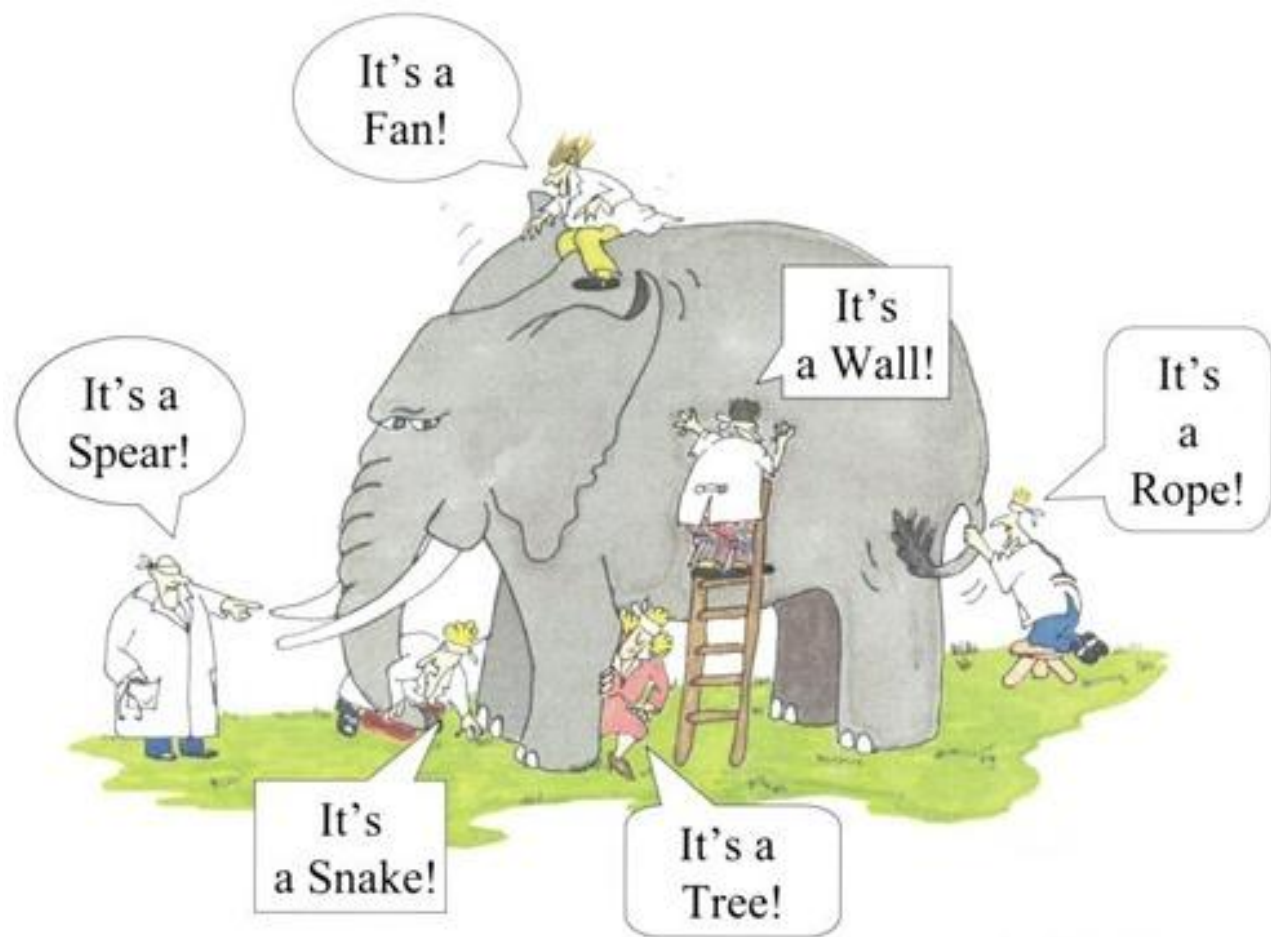
总结: 同化FY4LMI闪电仪观测后, 对模式云及水凝物初始
 场有改进作用, 从而对局地强降水预报有所改进;

应用挑战

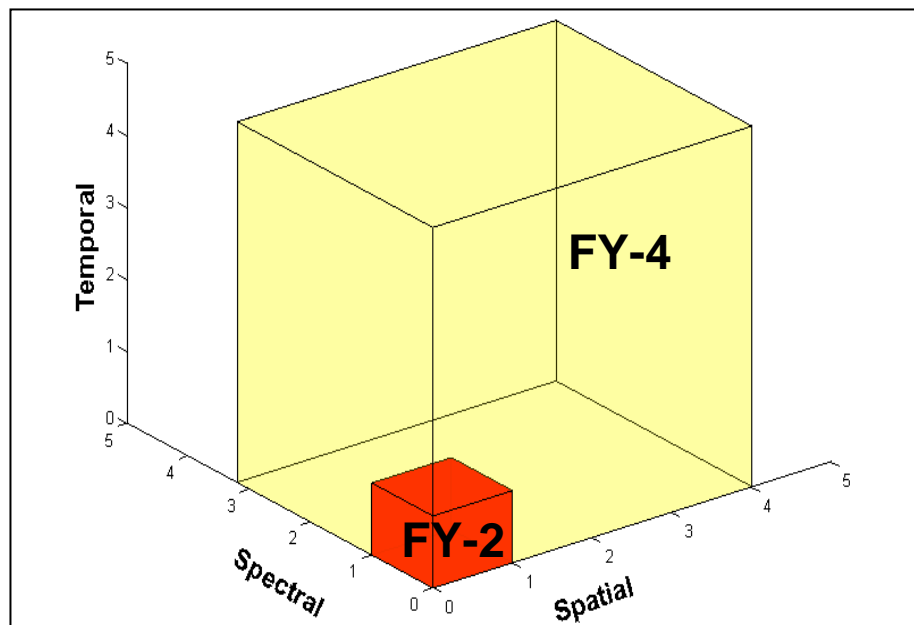
- 数据量大
- 信息丰富



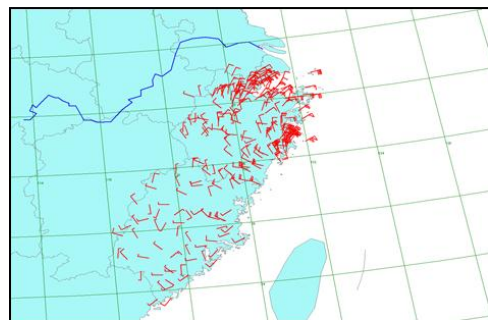
(决策) 应用



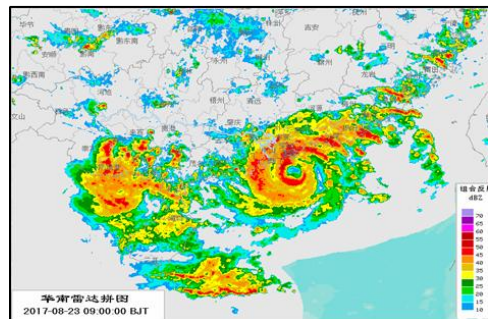
卫星大数据时代的到来



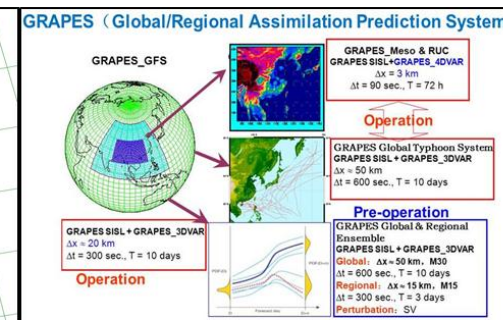
In situ (surface AWS)



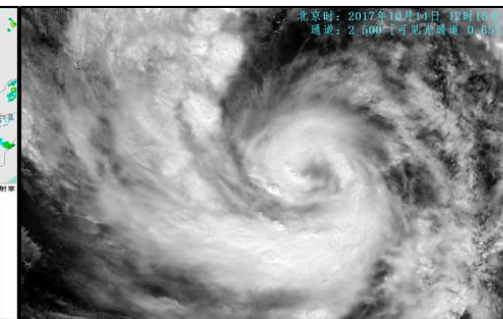
Radar



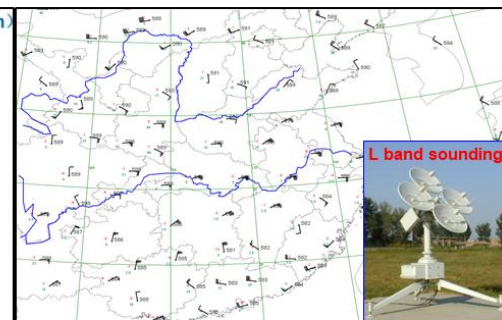
NWP (GRAPES_GFS)



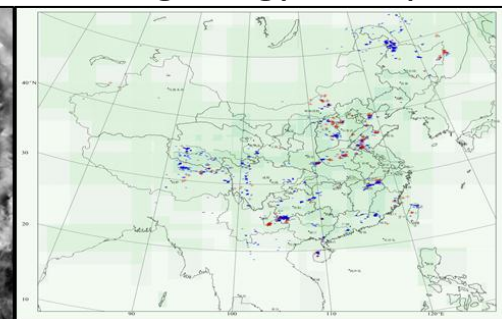
FY Satellites



In situ (sounding)



Lightning(surface)



风云卫星数据的光谱、空间和时间维度都大大增加。

如何高效的从海量的卫星数据里面寻找和挖掘有效信息是一个全新的挑战和机遇。

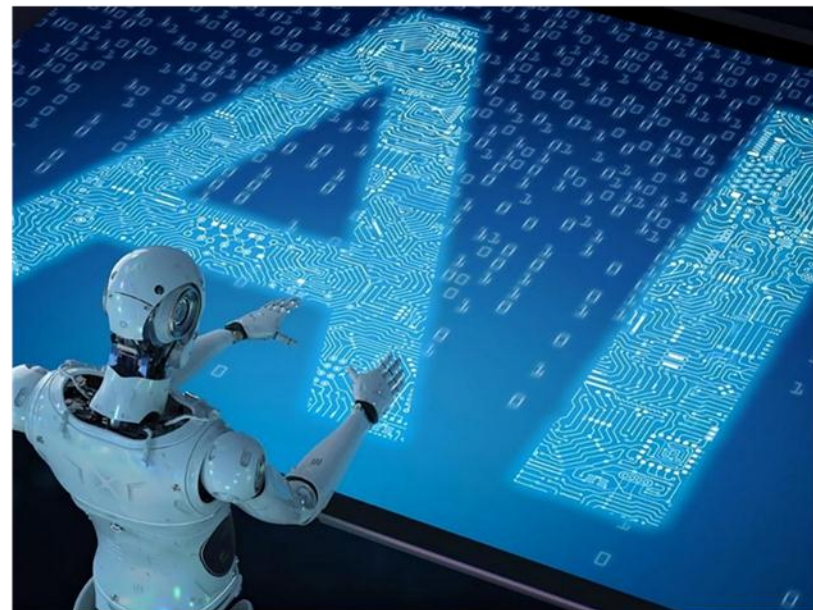
需要充分探索机器学习在卫星大数据中的应用潜力，挖掘海量卫星数据中蕴藏的有效信息。

新应用研究

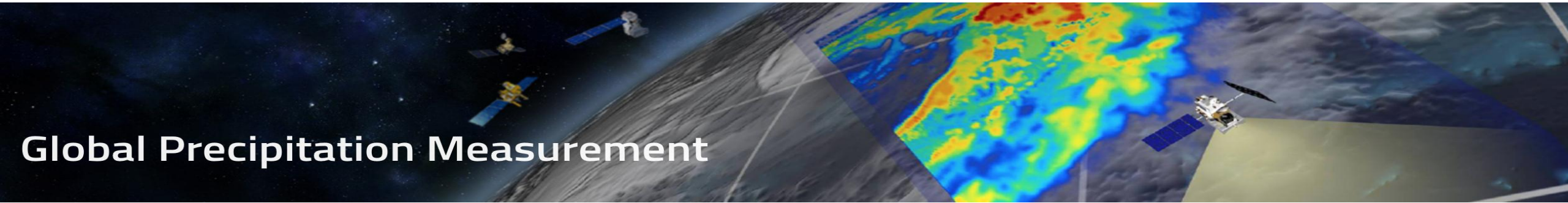


人工智能是新一轮科技革命和产业变革的重要驱动力量，加快发展新一代人工智能是事关我国能否抓住新一轮科技革命和产业变革机遇的战略问题。要深刻认识加快发展新一代人工智能的重大意义，加强领导，做好规划，明确任务，夯实基础，促进其同经济社会发展深度融合，推动我国新一代人工智能健康发展。

——2018年10月31日中共中央政治局第九次集体学习会

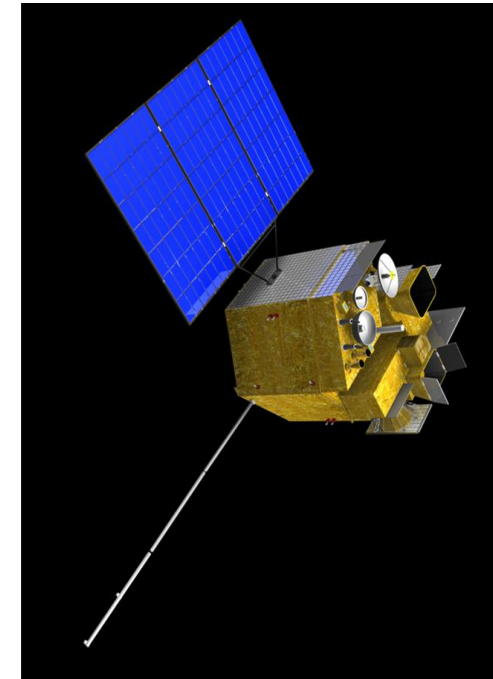


(1) Machine Learning for predicting **QPE** and **Convective Storm** of GEO satellite



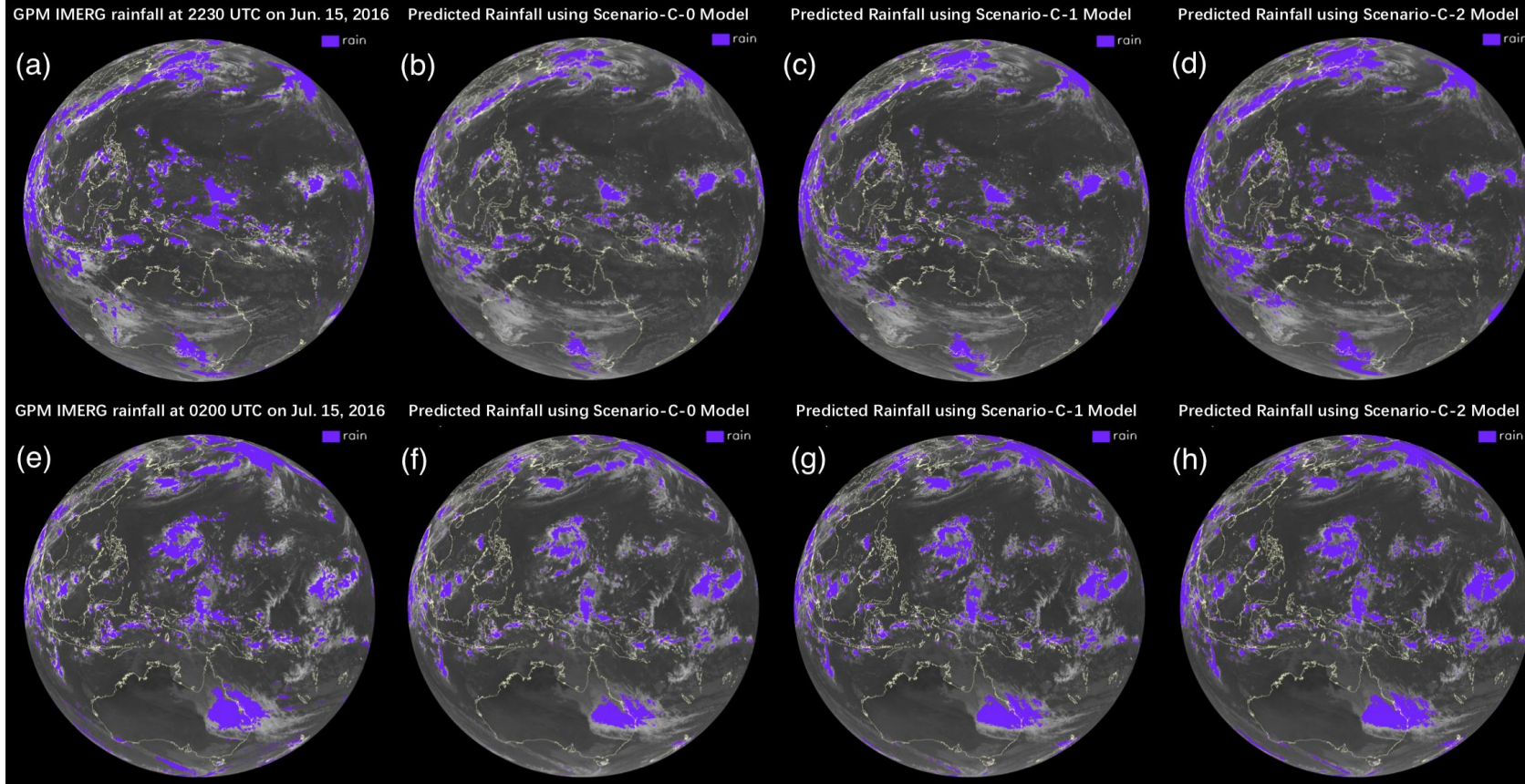
Data

- NASA GPM IMERG $0.1^\circ \times 0.1^\circ$ grid data in a half hour resolution (Truth or benchmark for training)
- FY-4A/AGRI or Himawari-8/AHI **FullDisk** infrared band measurements (TBB) for training the model
- Numerical Weather Prediction (NWP) data (GFS $0.5^\circ \times 0.5^\circ$ /Grapes $0.25^\circ \times 0.25^\circ$)
- Surface ancillary data (i.e., elevation, surface type)



FY-4

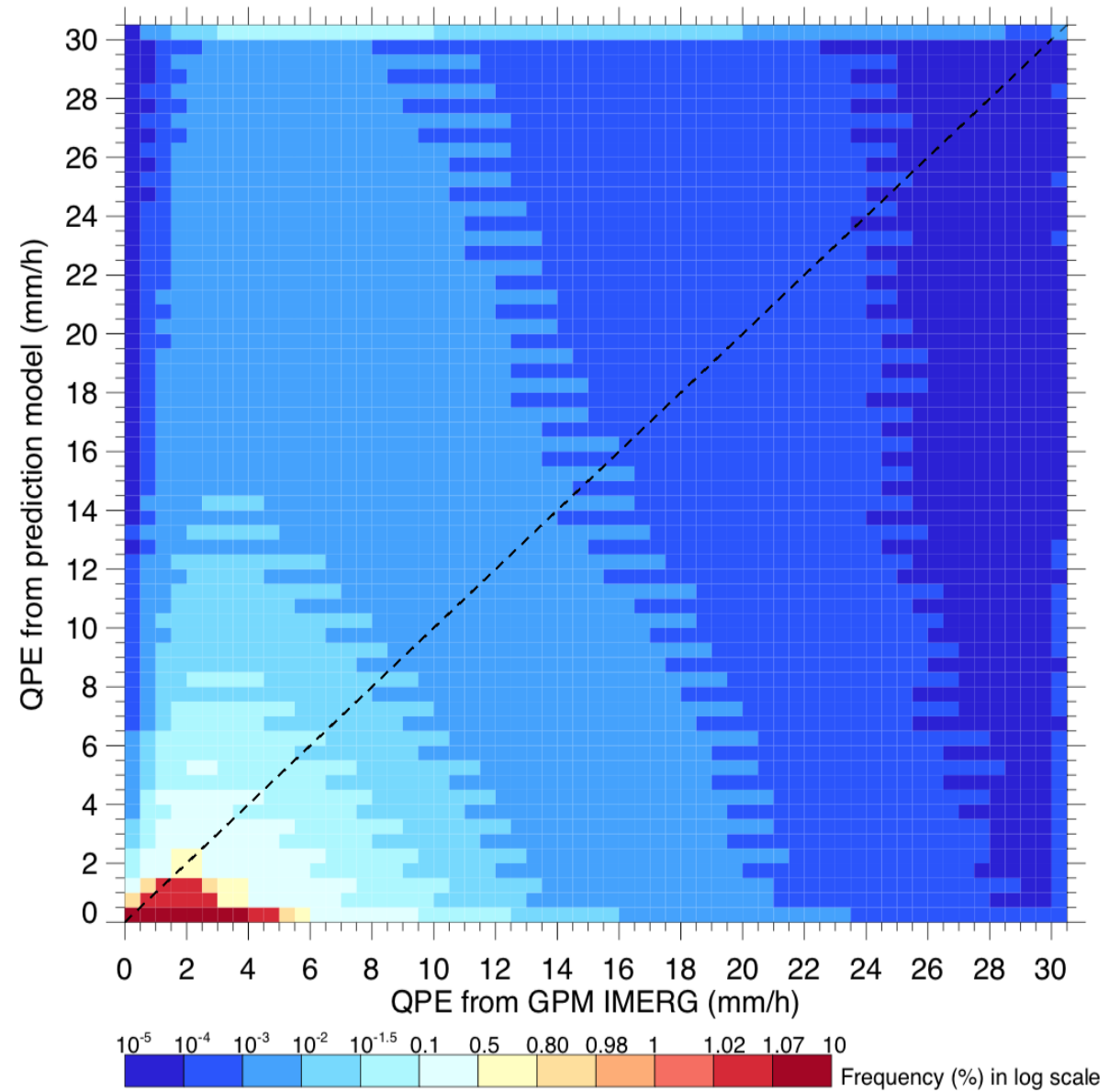
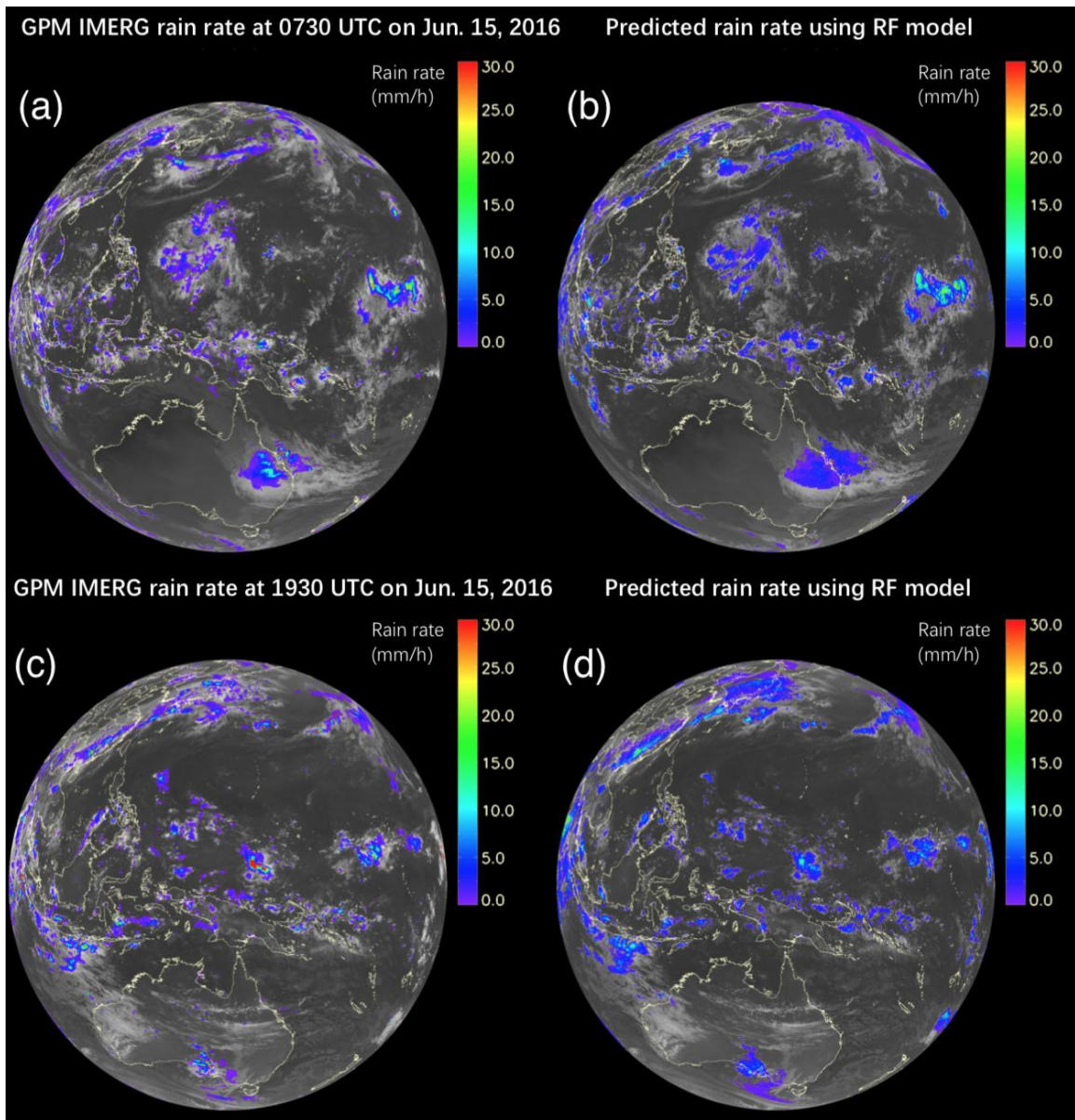
QPE retrieval of GEO satellite



Model Name	POD	FAR	CSI	HSS	HR
Scenario-C-0	0.48	0.27	0.41	0.53	0.88
Scenario-C-1	0.58	0.33	0.45	0.54	0.87
Scenario-C-2	0.68	0.41	0.46	0.54	0.86

Statistics on the performance metrics of precipitation classification using three independent RF classification models based on the scenarios used to train samples: Scenario-C-0/1/2 ($n_estimators=300$, $max_depth=20$, and $max_features=7$).

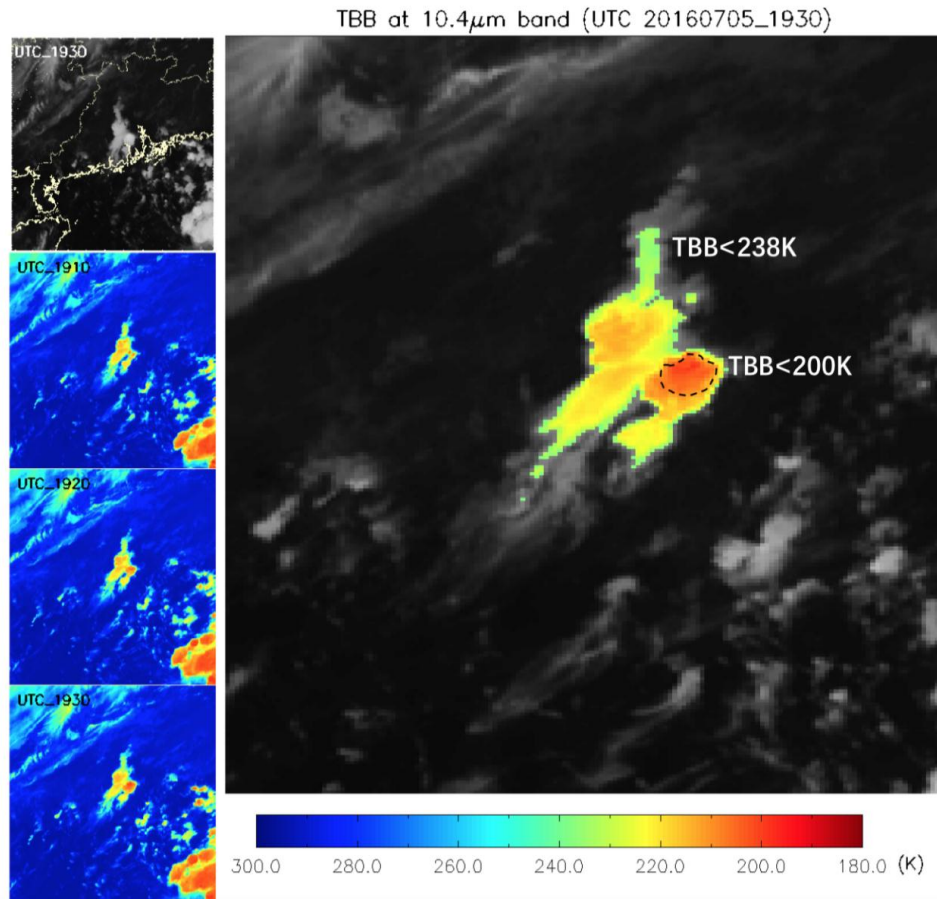
Comparisons of non-precipitation/precipitation (a, b, c, d at 2230 UTC on June 15, 2016, and e, f, g, h at 0200 UTC on July 15, 2016) between the GPM IMERG QPE products (first column) and the predictions using three different RF classification models based on the samples of Scenario-C-0 (second column), Scenario-C-1 (third column), and Scenario-C-2 (fourth column). Purple area represents the presence of rainfall.



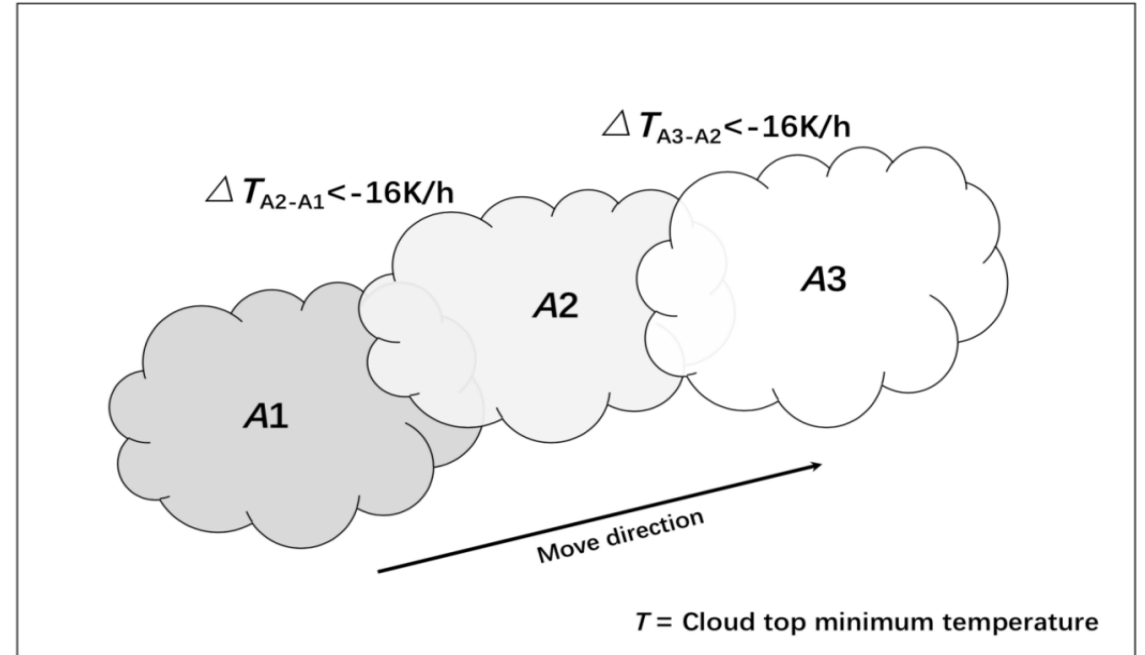
Comparisons of QPE (a, b at 0730 UTC on July 15, 2016, and c, d at 1930 UTC on June 15, 2016) between the GPM IMERG product (left panel) and the prediction (right panel) using the RF classification and regression models.

The final MAE and RMSE of all the predicted QPE are respectively **0.51** and **2.0 mm/h**

(2) Convective Storm tracking and identification of GEO satellite

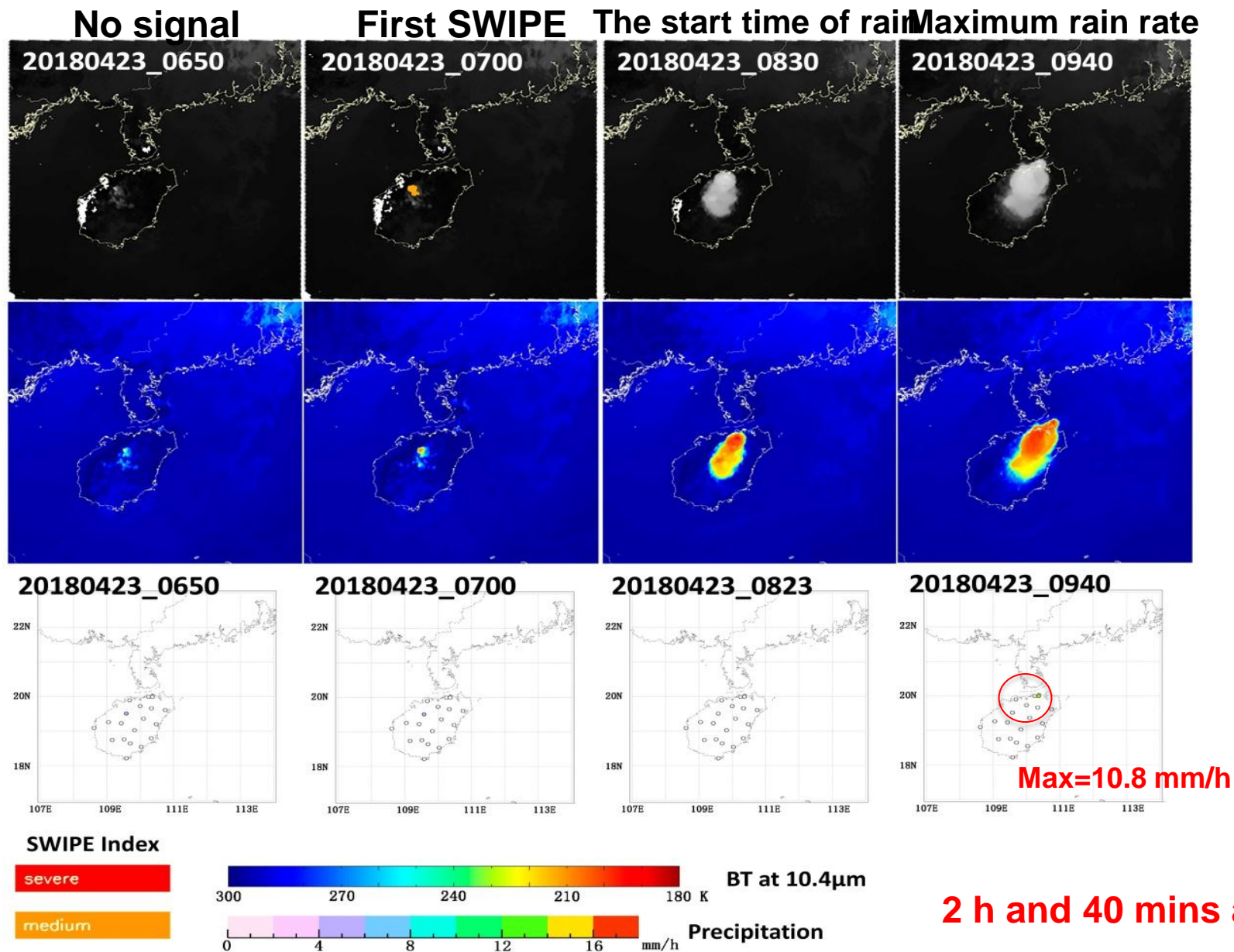


A real case of tracked convective storm system at 19:30 UTC on 05 July 2016 in Guangdong province of China based on H08/AHI observations. The first small sub-figure at the upper-left corner is the grayscale TBB picture at 10.4 μ m band with coast line (yellow solid line). The 2-4 small colorful sub-figures at the left panel respectively represent the variation of BTs at 10.4 μ m from 19:10 to 19:30 UTC. The colorful layer in the big sub-figure (right panel) represents the pixels of H08/AHI with BT < 238 K at 19:30 UTC on 05 July 2016.

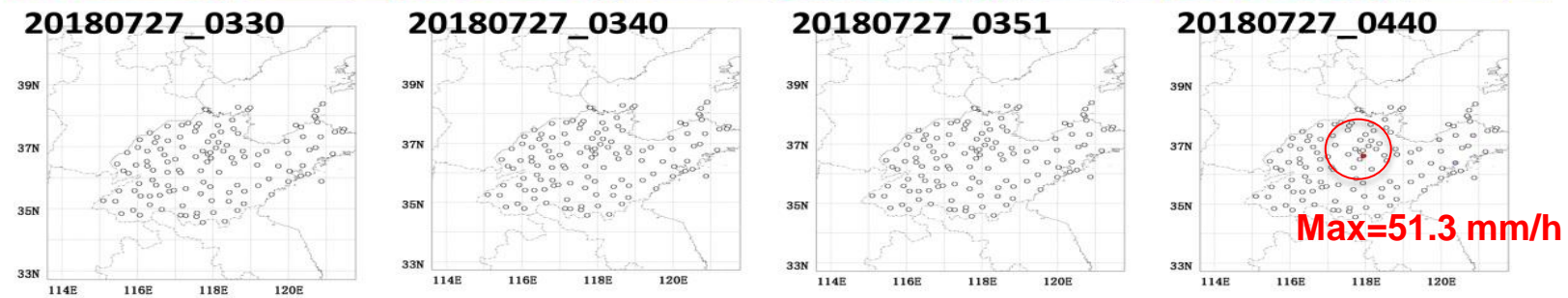
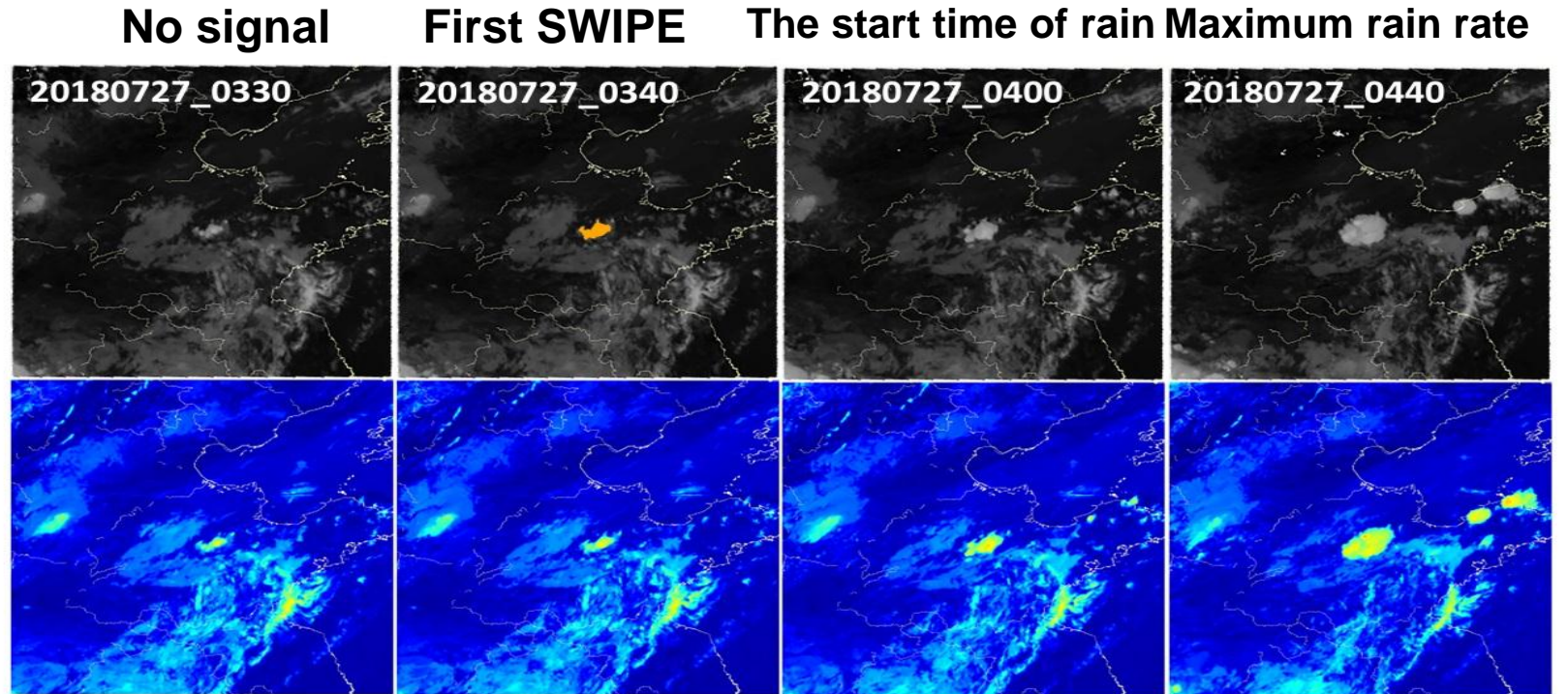


Schematic diagram of the convective-tracking method using three continuous imageries within a 10-minute observation interval. ΔT represents the cloud top cooling rate. A1, A2, and A3 represent tracked convective cloud cluster areas.

CASE-1: SWIPE 07:00 UTC on 23 April 2018 in Hainan province of China



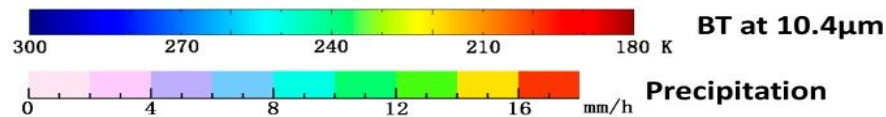
CASE-2: SWIPE at 03:40 UTC (Beijing time 11:40) on 27 July 2018 in Shandong province of China



SWIPE Index

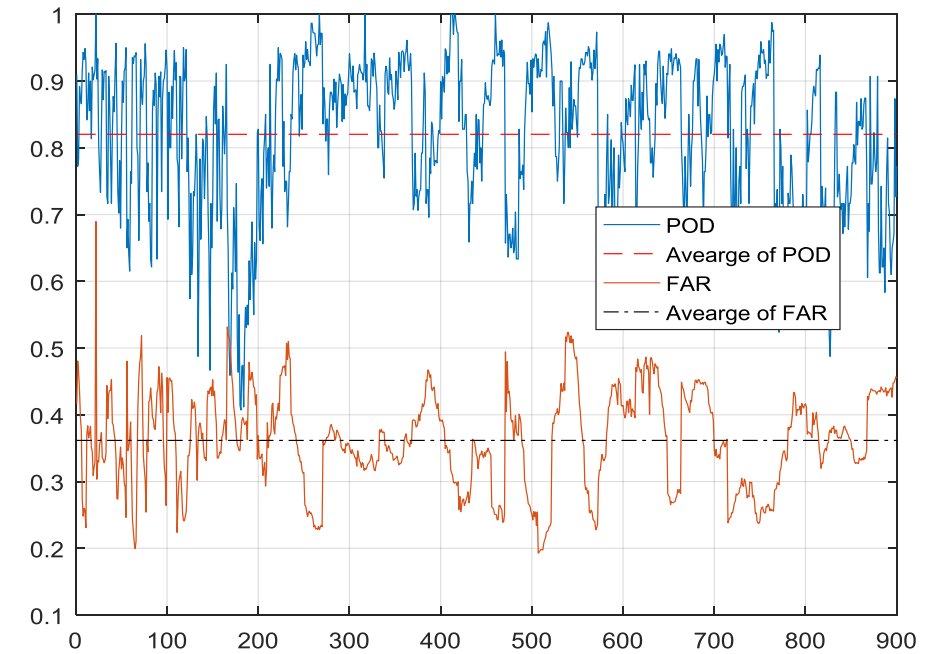
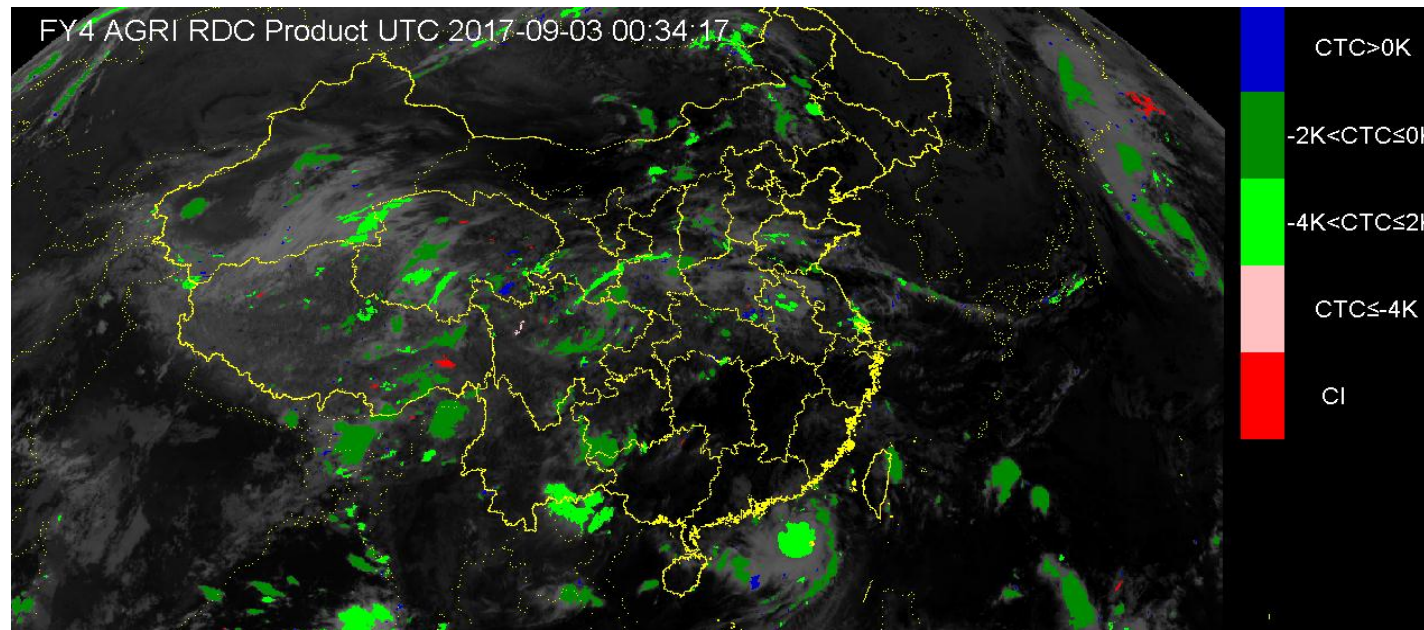
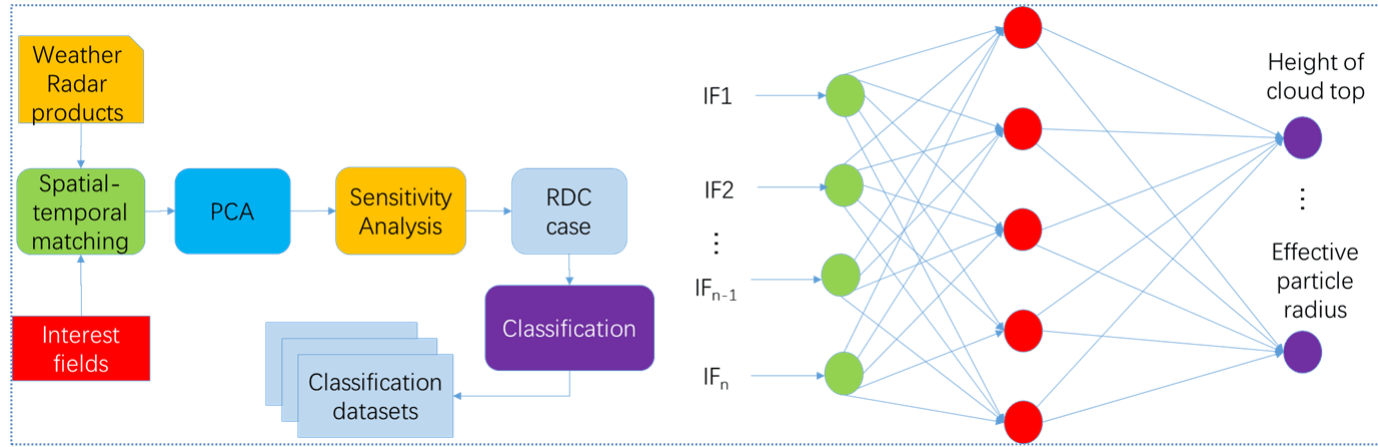
severe

medium



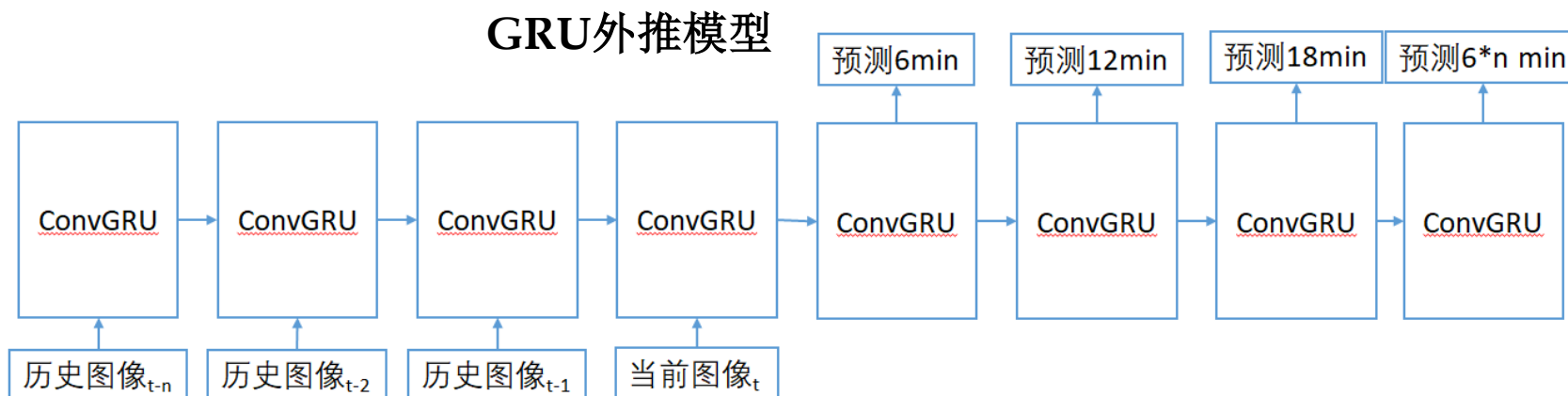
1 h ahead

(3) Rapid Developing Convective Clusters Monitoring System



(4) 降雨系统一小时临近预报系统

- 基于深度序列学习模型，即门控循环单元神经网络（Gated Recurrent Unit，简称GRU）建立了卫星+雷达回波外推模型



GRU模型是序列预测中常用的模型之一，通过特殊的网络结构设置，对输入序列，其能选择性的记忆重要的信息，并对未来的序列做出预测。在该模型中，输入是一个序列，输出也是一个序列。

2018年3月19日 测试结果 (21: 00~22: 00)

2018-03-19

22:00

更新

最新

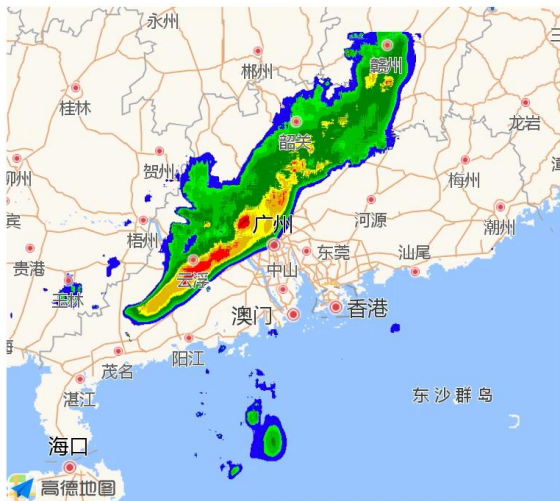


上一个

暂停

下一个

GAN模型1: 2018-03-19 21:06



GRU修时: 2018-03-19 21:06



光流法: 2018-03-19 21:06



GAN模型2: 2018-03-19 21:06



未来1H实况: 2018-03-19 21:06



雷达实况: 2018-03-19 21:06



2018年5月7日 测试结果 (19: 00~20: 00)

2018-05-07

20:00

更新

最新

上一个

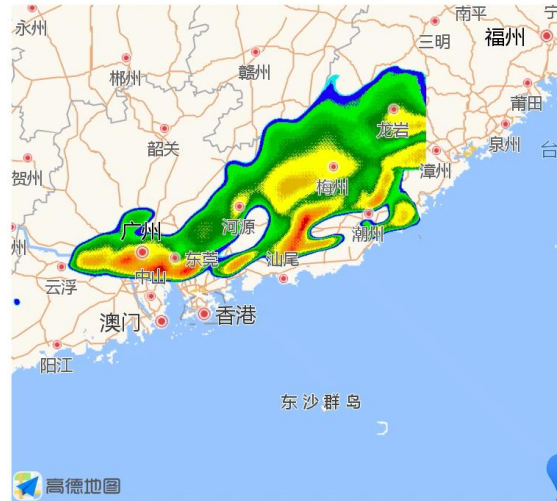
暂停

下一个

GAN模型1: 2018-05-07 19:12



GRU修时: 2018-05-07 19:12



光流法: 2018-05-07 19:12



GAN模型2: 2018-05-07 19:12



未来1H实况: 2018-05-07 19:12



雷达实况: 2018-05-07 19:12



2018年9月16日 测试结果 (13: 00~14: 00)

2018-09-16

14:00

更新

最新

上一个

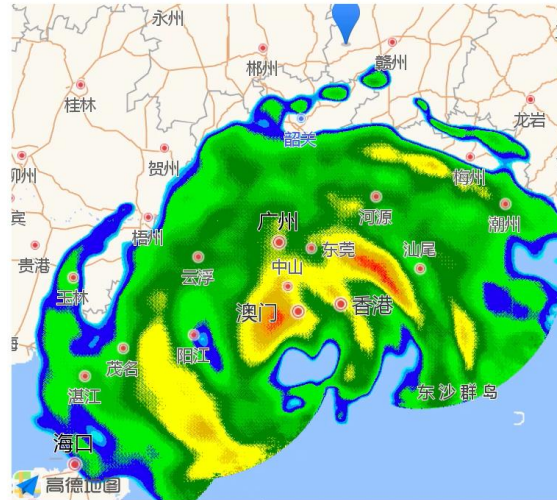
暂停

下一个

GAN模型1: 2018-09-16 13:12



GRU修时: 2018-09-16 13:12



光流法: 2018-09-16 13:12



GAN模型2: 2018-09-16 13:12



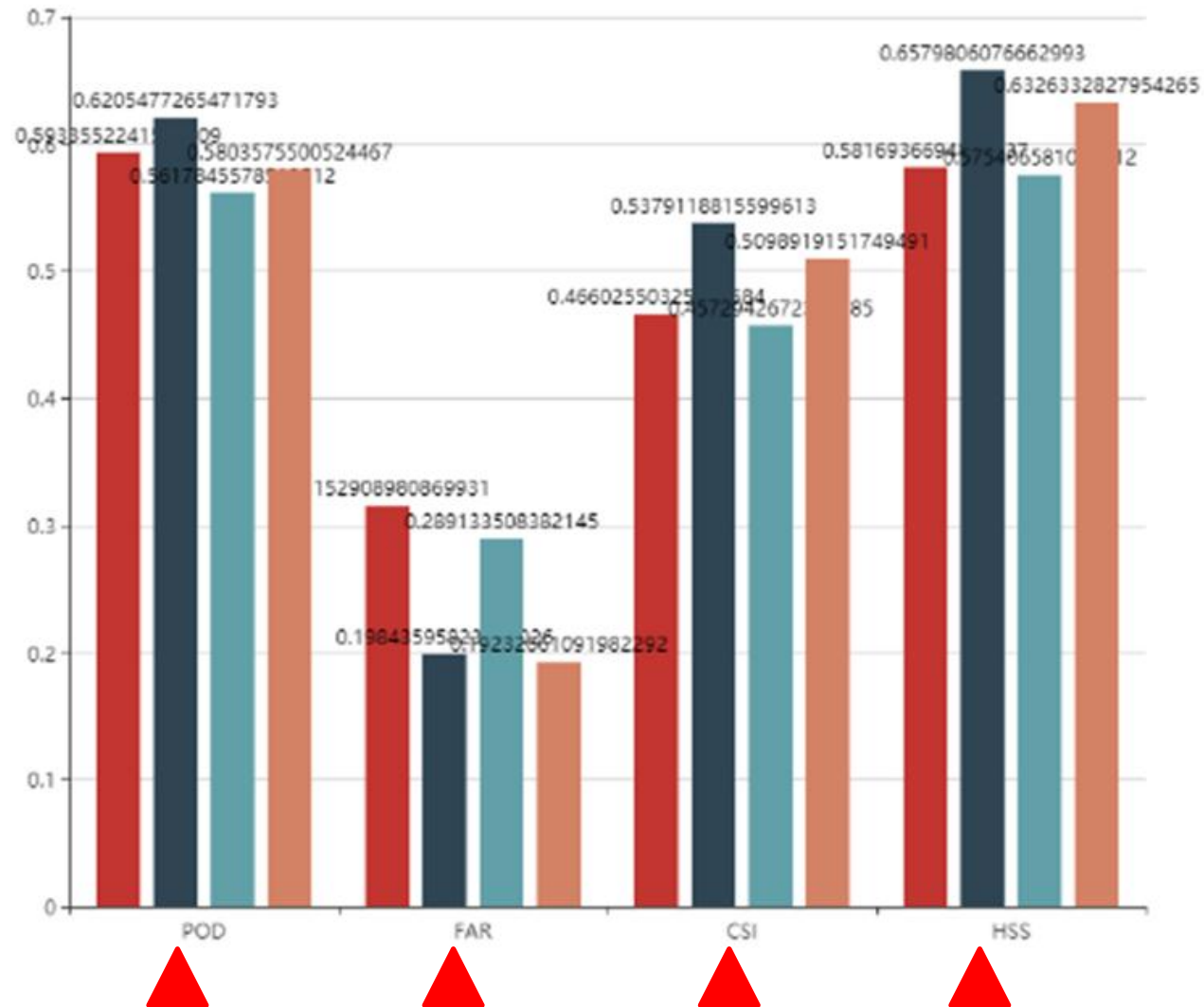
未来1H实况: 2018-09-16 13:12



雷达实况: 2018-09-16 13:12

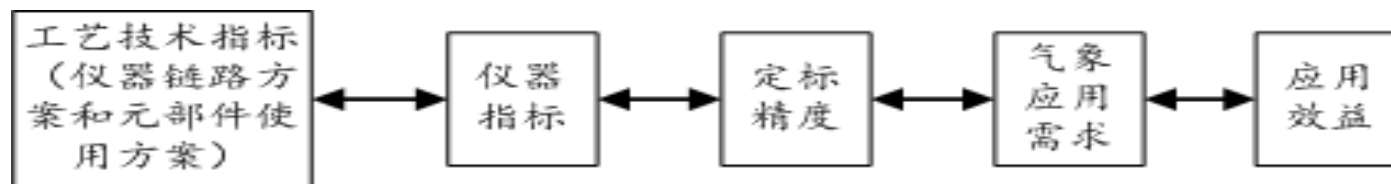


- 使用深度学习技术初步实现了短临预报的业务化应用，相比于现行的光流法预报方式，位置和强度更精准，效果有10%左右的提升（基于FAR, POD, CSI和HSS等常用指标评价）



结论

1. 风云卫星探测能力越来越强，数据越来越丰富，可应用的范围越来越广；
2. 风云卫星数据质量的稳步提高也大大提升了定量同化应用水平；
3. 在大数据和人工智能时代，未来的定量应用水平可望取得新的突破，应用模式也将会发生巨大改变。





谢谢！