Quantitative Applications of Geostationary Weather Satellite Data for Nowcasting – Recent Progress and Challenges

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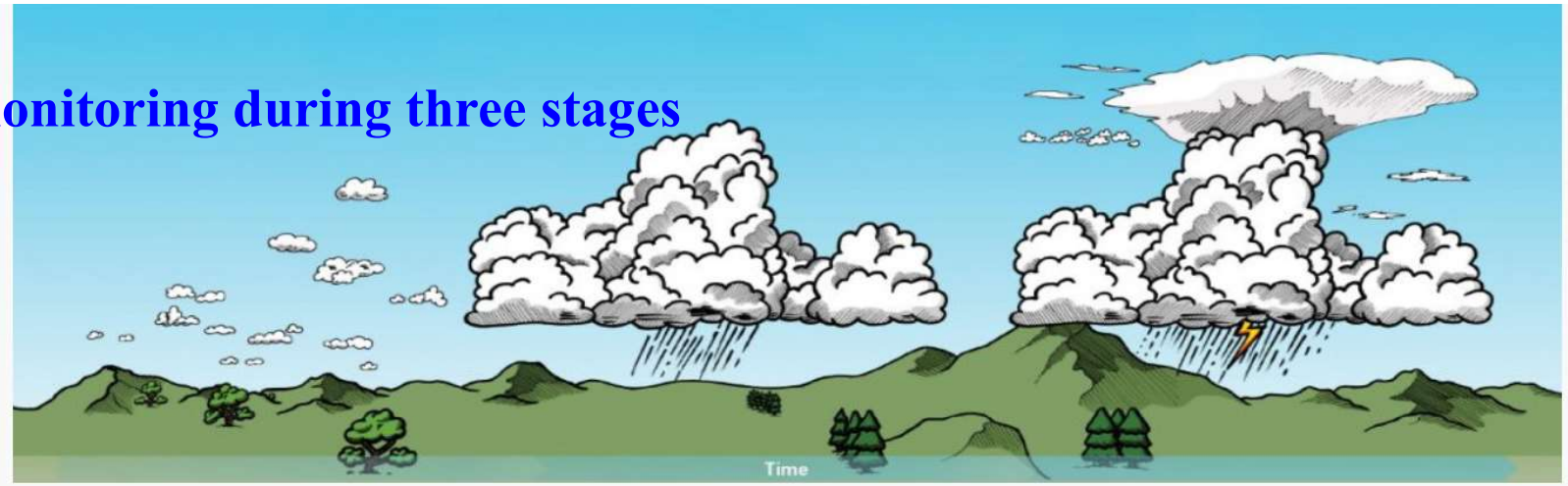
Acknowledgement: CIMSS/SSEC and NSMC colleagues

Outline

- **Monitoring of storm process ;**
- Warning in pre-convection environment ;
- Numerical modeling and predicting ;
- Challenges and future perspectives.

Satellite monitoring during three stages



Refers to the 4-D thermodynamic and wind field present before the convective initiation occurs.

1. Pre-Convective Environment

Useful non-sat data:
NWP data, Radiosonde and aircraft measurements
Useful sat products:
Atmospheric instability
Wind fields
Temperature and moisture profiles

Refers to the process where an existing cumulus cloud begins rapid vertical growth.

2. Convective Initiation

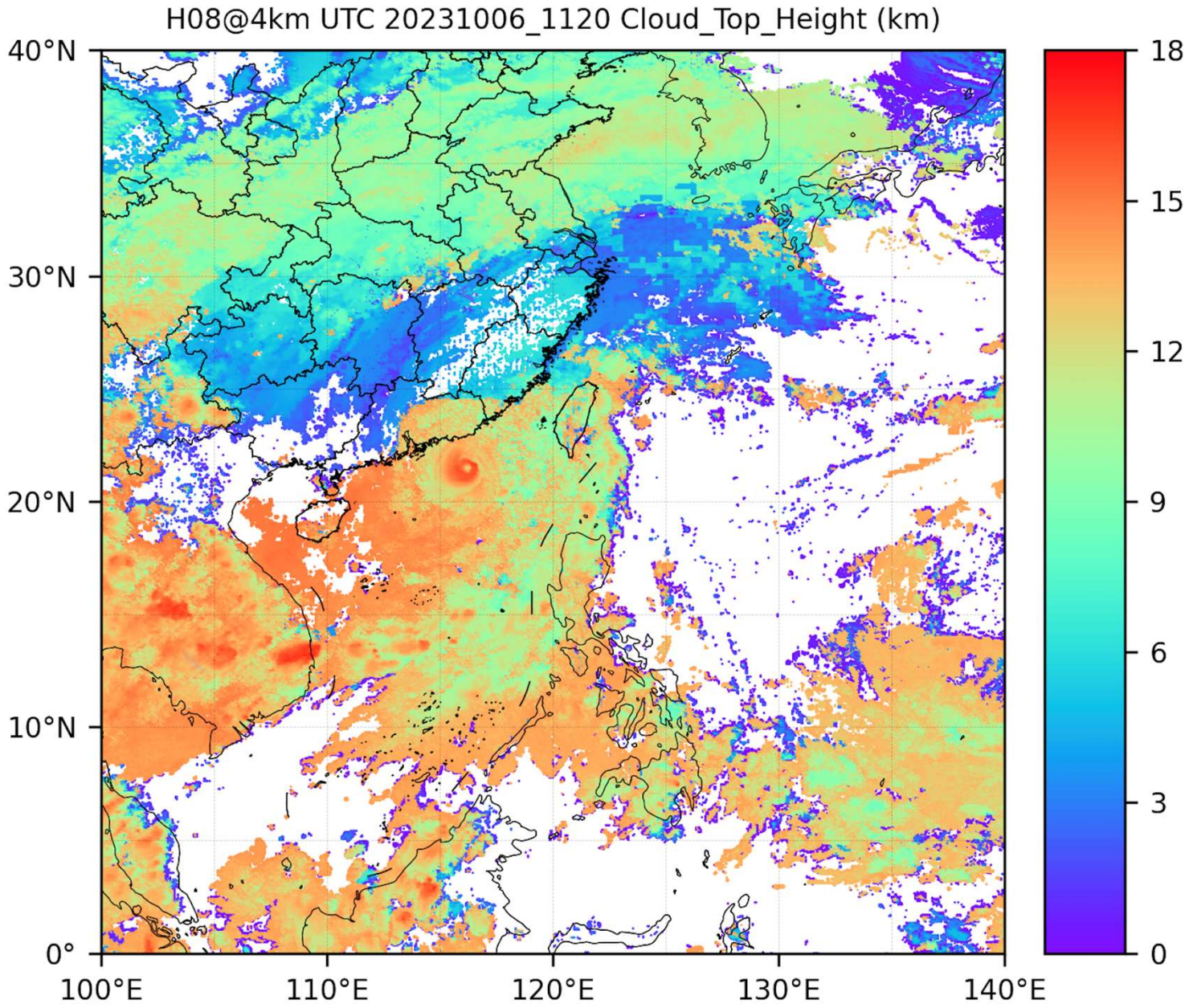
Radar, lightning data
Useful sat products
Cloud Type
Cloud Top Temperature and Height
Cloud Microphysics
Convection Initiation

Refers to the presence of convective clouds with tops at or above their local equilibrium level.

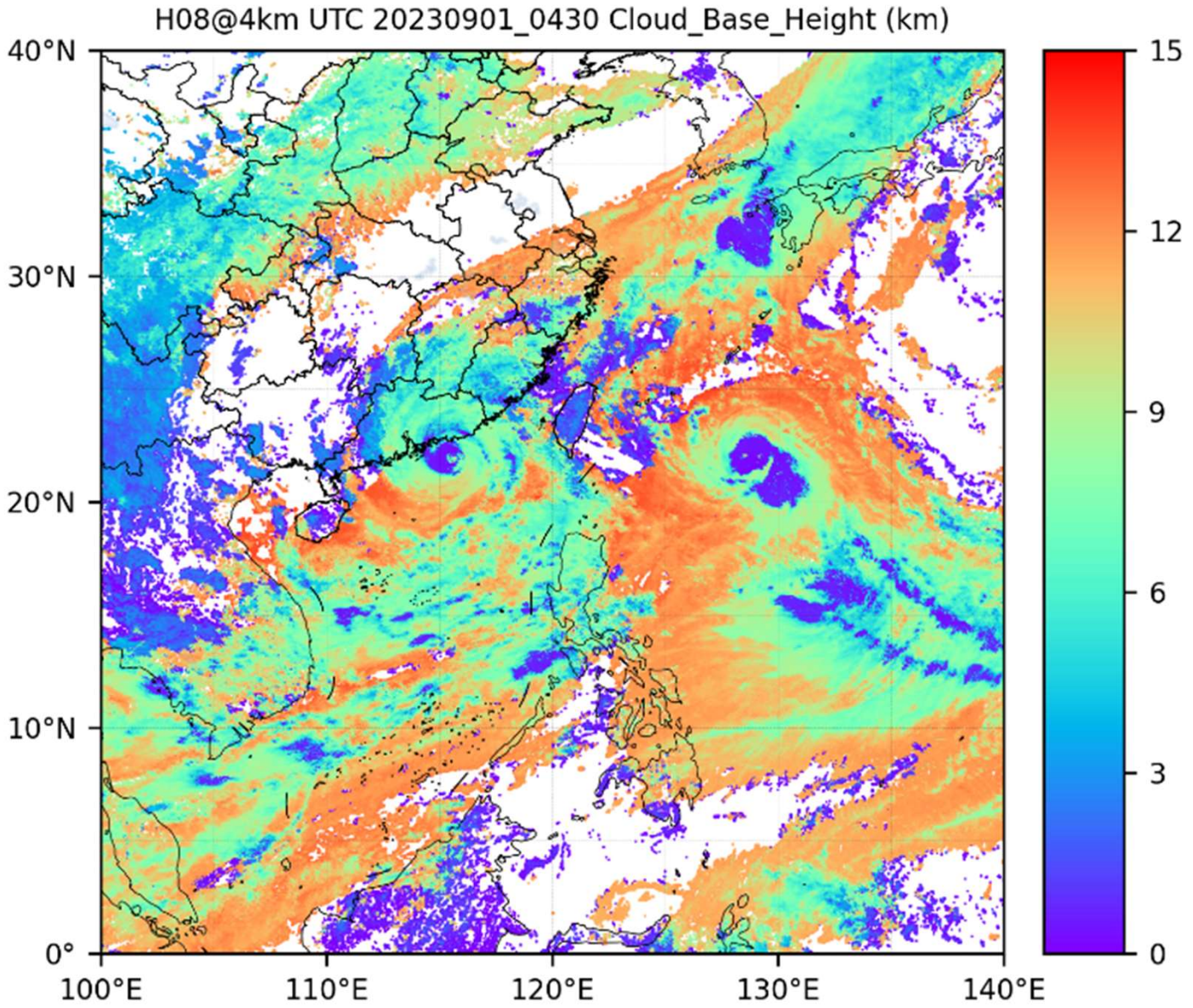
3. Mature Convective Storm

Radar, lightning data
RDT Product – storm tracking
Precipitating Clouds
CRR Product – precipitation
NEFODINA
Overshooting Top Detection
MSG Sandwich Product (HRV+IR10.8 enhanced)
Lightning Density

Cloud-top height for Typhoon (06 October 2023).

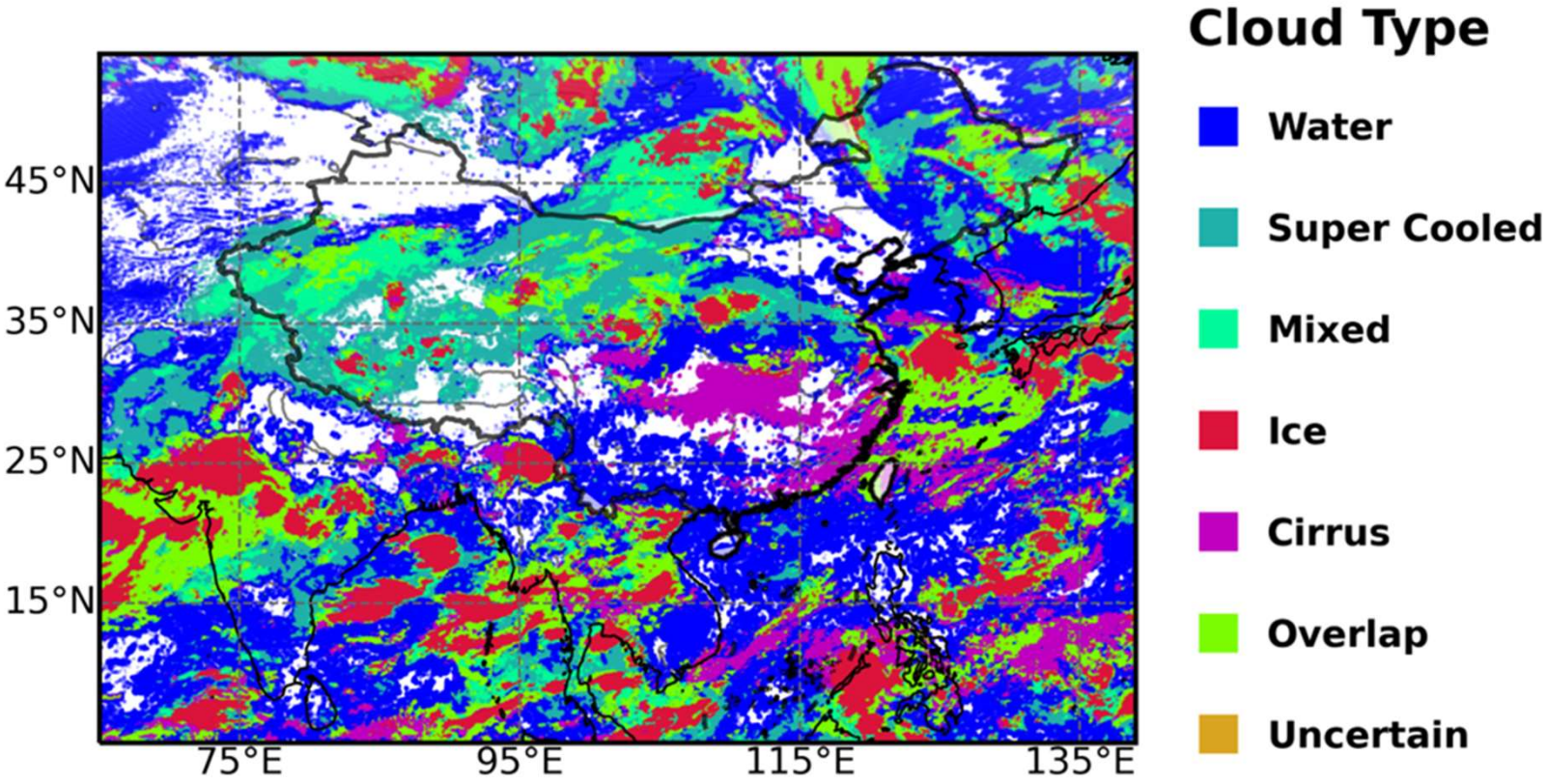


Cloud-base height for Typhoon (01 October 2023).

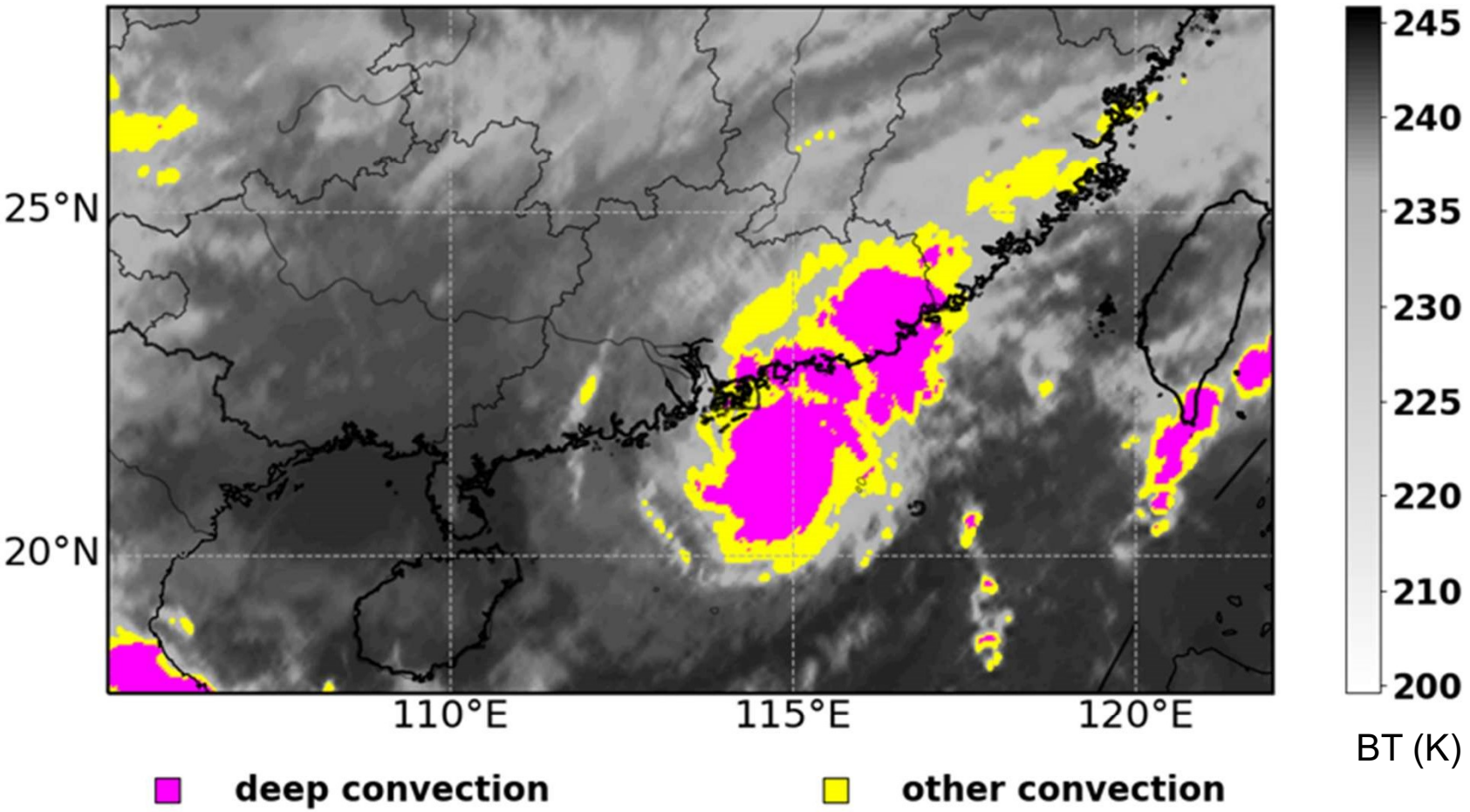


Lin, H., Li, Z., Li, J., Zhang, F., Min, M. and Menzel, W.P., 2022: Estimate of daytime single-layer cloud base height from advanced baseline imager measurements. Remote Sensing of Environment, 274, p.112970.

Cloud type product from advanced GEO imager observations



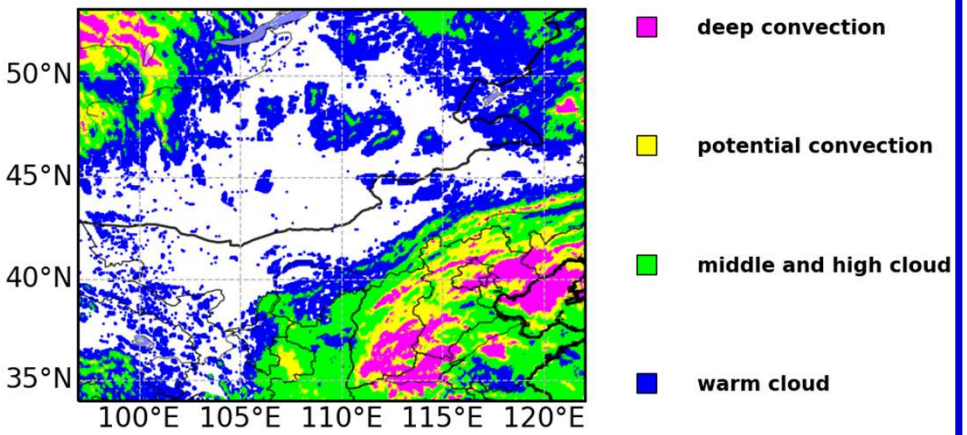
Operational cloud type product from Fengyun-4B AGRI



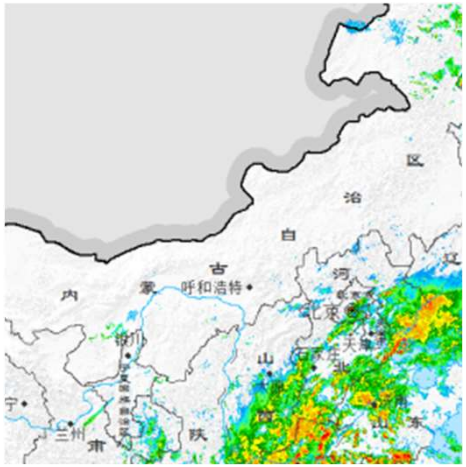
Automatic and quick extraction of deep convection from GEO imager all IR bands

Comparison between AGRI and radar observations for deep convection (12：30 Beijing local time 29 July 2023)

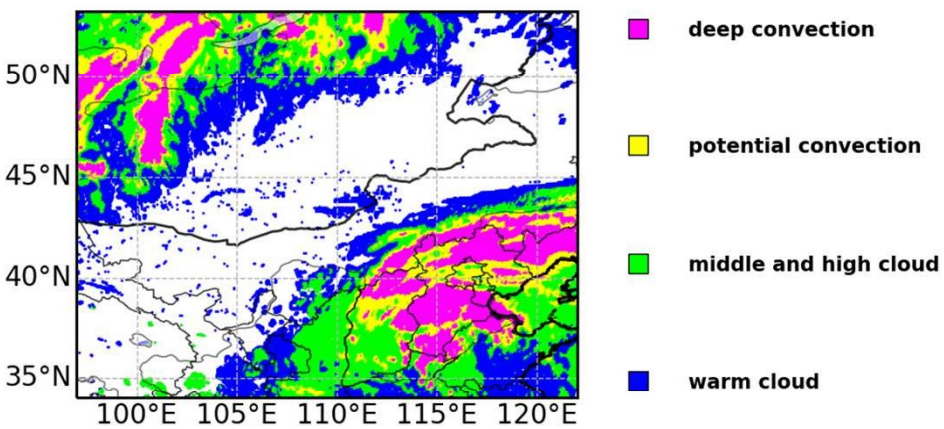
Convection from AGRI



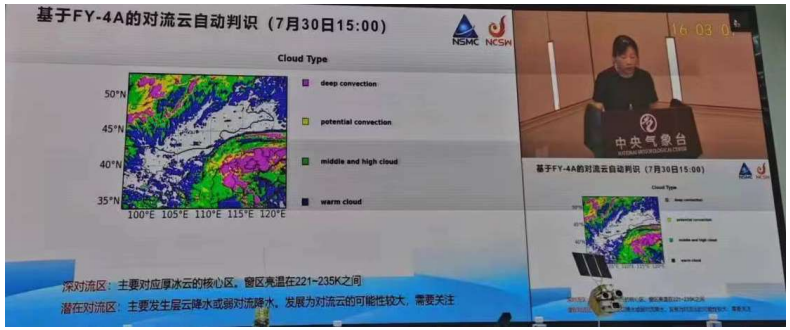
Radar observations



Hourly convection evolution from AGRI (00-24 Beijing local time 30 July 2023)

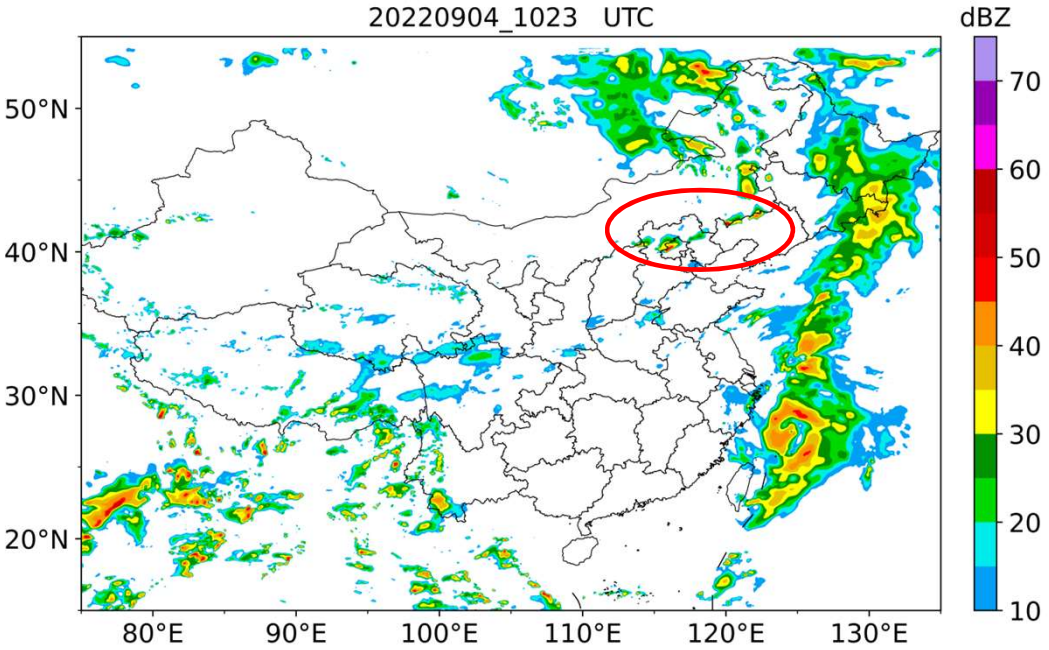


Utilized for decision making

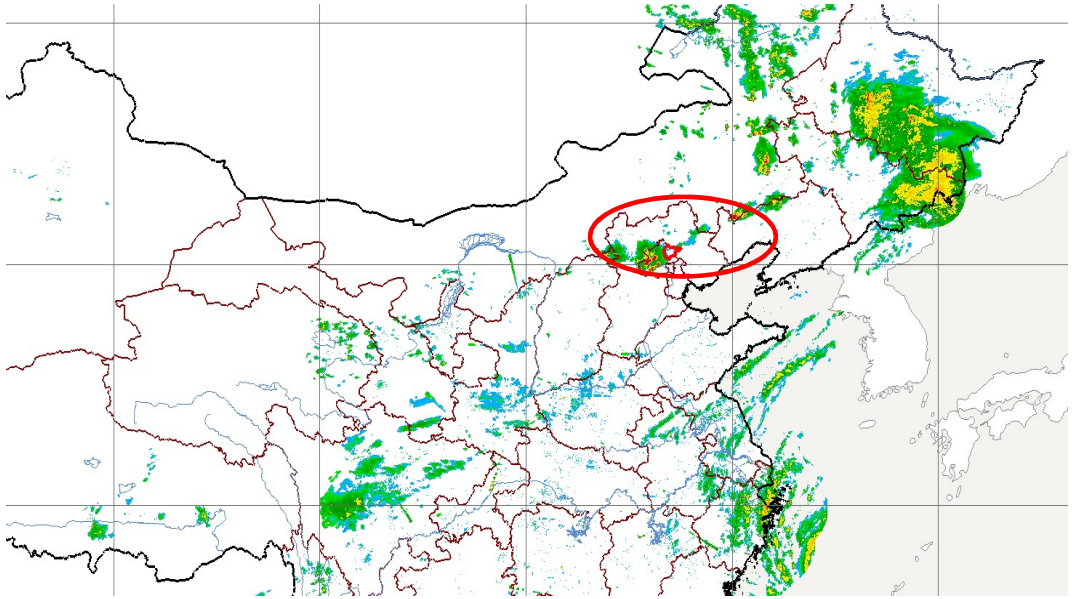


Radar simulation from AGRI observations

Validation：Hailstorm on 04 September 2022 in North China (Beijing)



AGRI-based radar retrievals



Radar observations

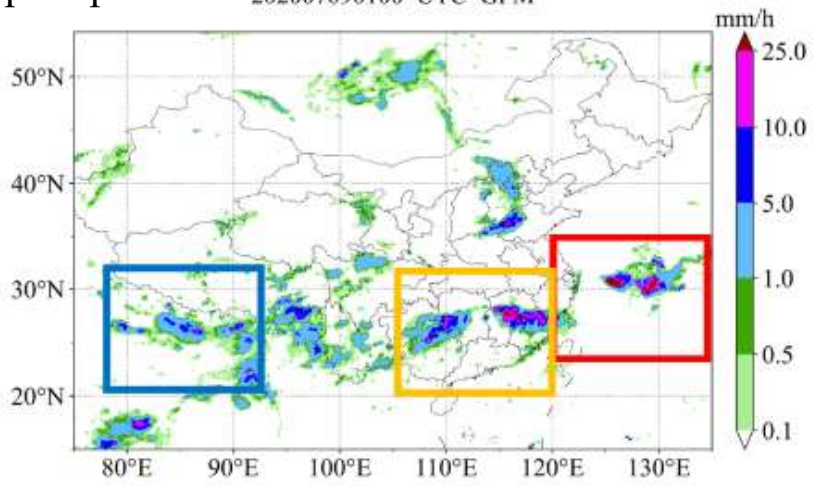
Radar retrieval product has been used operational at National Meteorological Center (NMC/CMA).

Yang, Ling, Qian Zhao, Yunheng Xue, Fenglin Sun, Jun Li, Xiaoqiong Zhen, and Tujin Lu, 2022: Radar Composite Reflectivity Reconstruction Based on FY-4A Using Deep Learning. Sensors, 23, no. 1, 81.

Example application case: Yangtze River heavy precipitation event

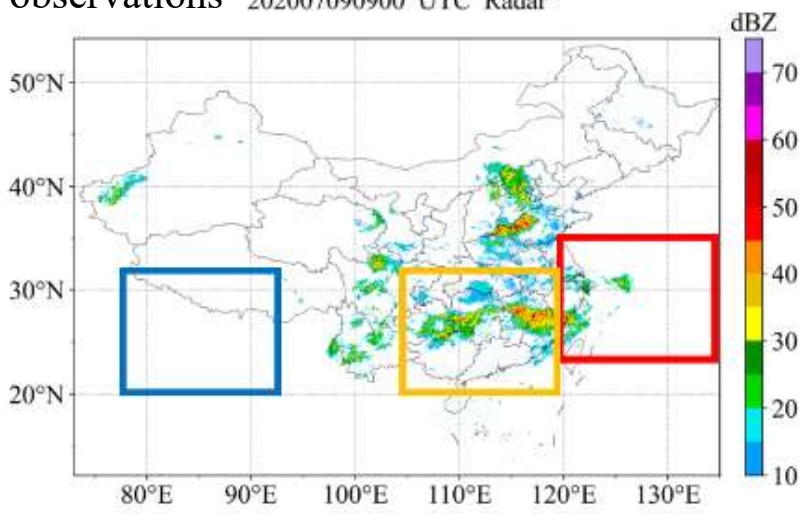
09 July 2020

GPM precipitation 202007090100 UTC GPM

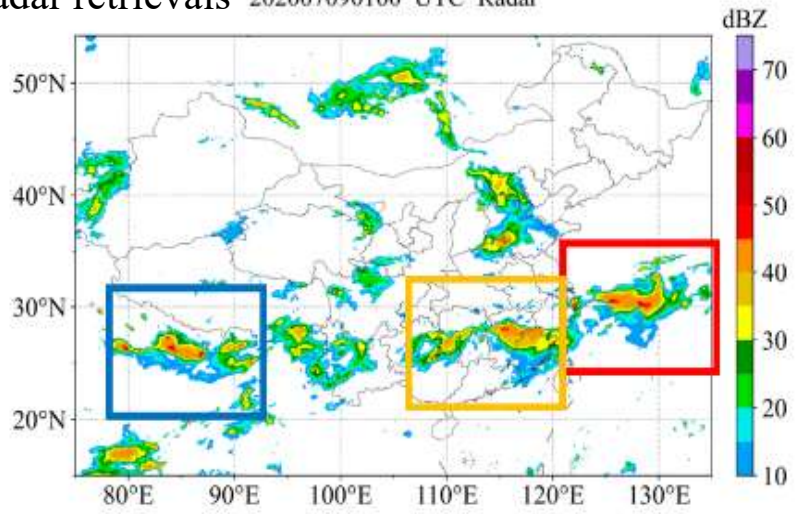


(1) The radar retrievals accurately simulate the two active storms along Yangtze River, with good agreement on intensity between radar retrievals and observations.
(2) The radar retrievals also reveal the distributions of convective storms in South of TP and over ocean where no radar observations are available.

Radar observations 202007090900 UTC Radar



Radar retrievals 202007090100 UTC Radar



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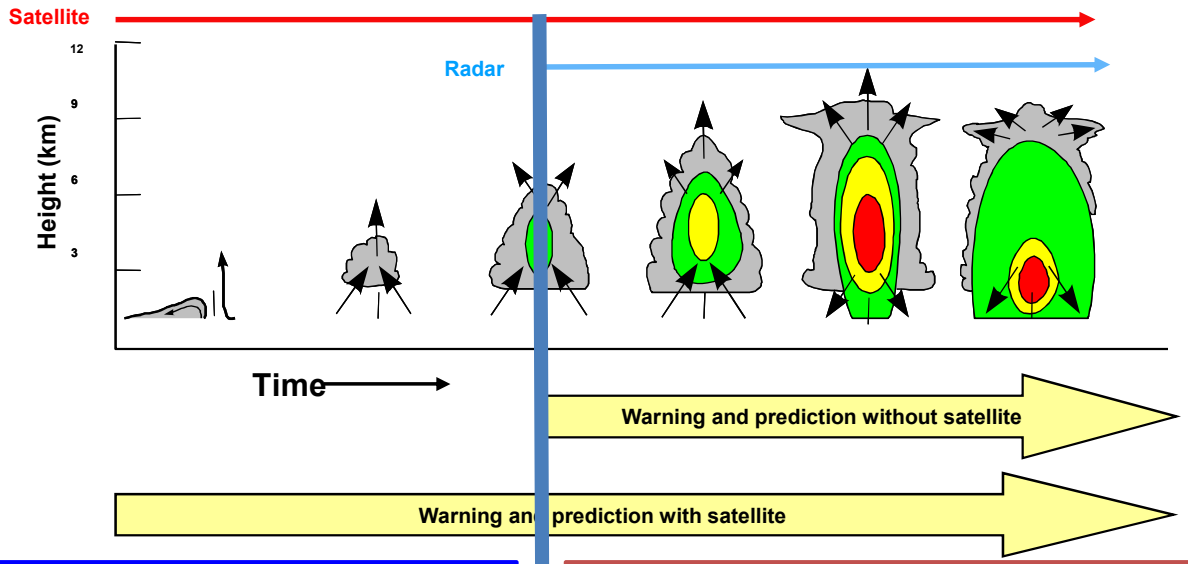
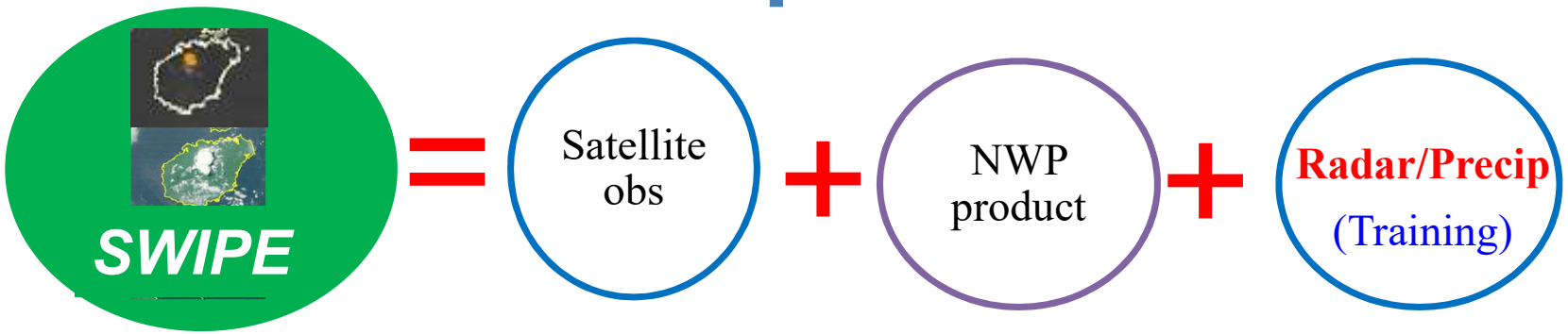
SWIPE: Storm Warning in Pre-convection Environment



Q1: How to predict storm occurrence, location and intensity 0 – 2 hours ahead of radar observations (CI)?

Q2: When convection is initiated, how to predict its development and evolution (e.g., 0 – 6 forecast after CI)?



Hail storm (Beijing) on 04 September 2022

「冰雹预警」北京市气象台2022年9月4日18时55分发布冰雹黄色预警信号

播报文章

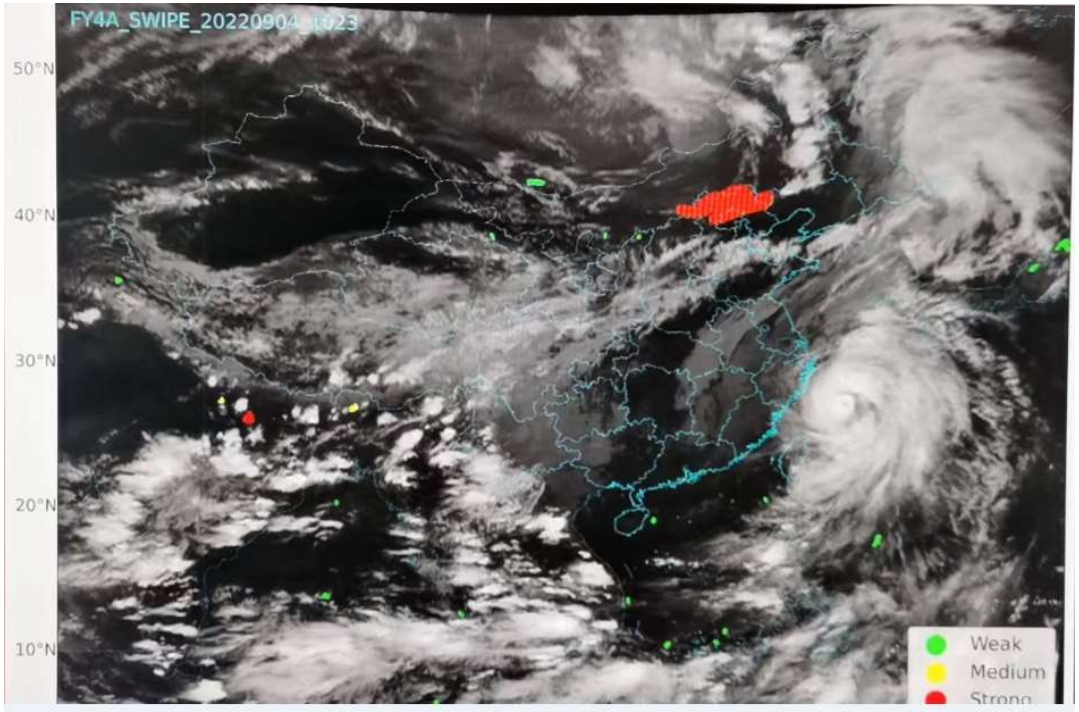
北京预警发布
2022-09-04 19:09 | 国家预警信息发布中心下属账号 关注

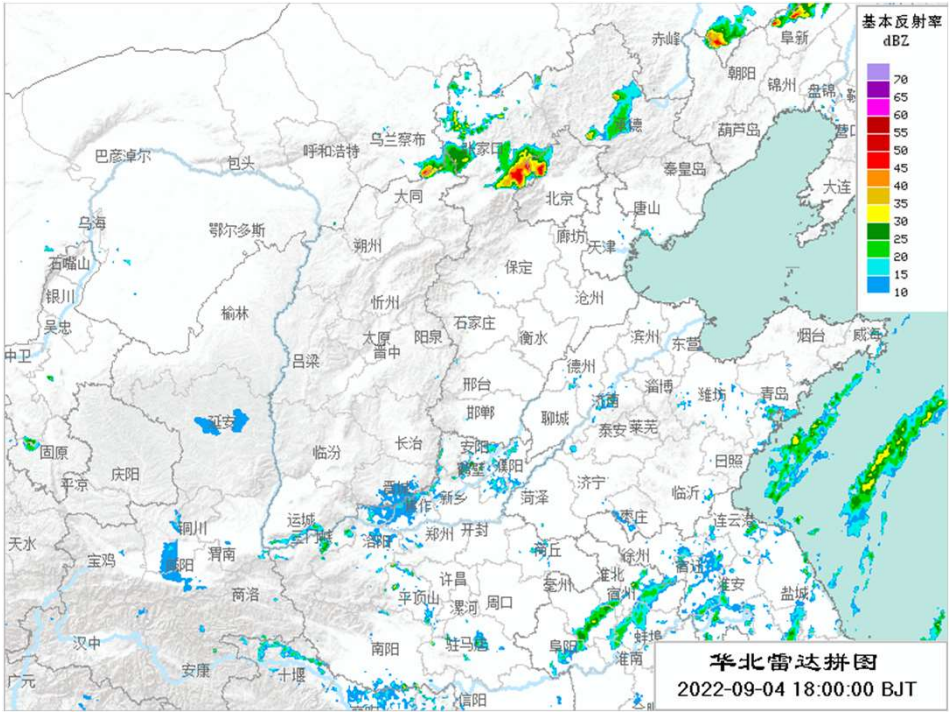
市气象台2022年9月4日18时55分发布冰雹黄色预警信号：

预计当前至21时，本市平原地区将出现冰雹，请注意防范。

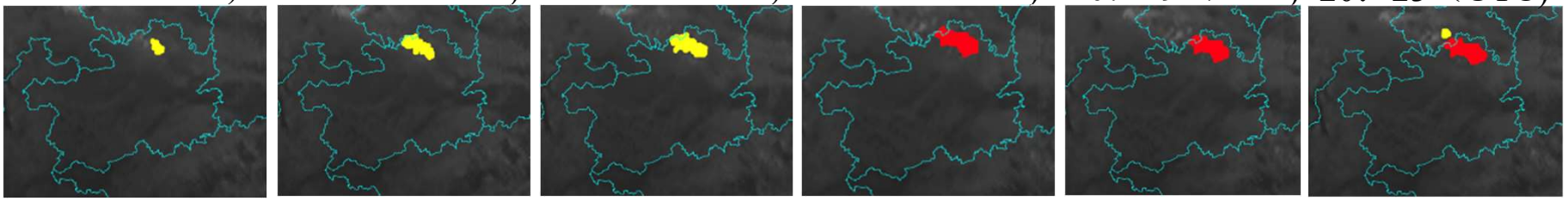
（信息来源：国家预警发布中心）

SWIPE2.0 issues warning at 18：34 BJT , the Beijing Weather Service issued warning at 18:55 BJT.

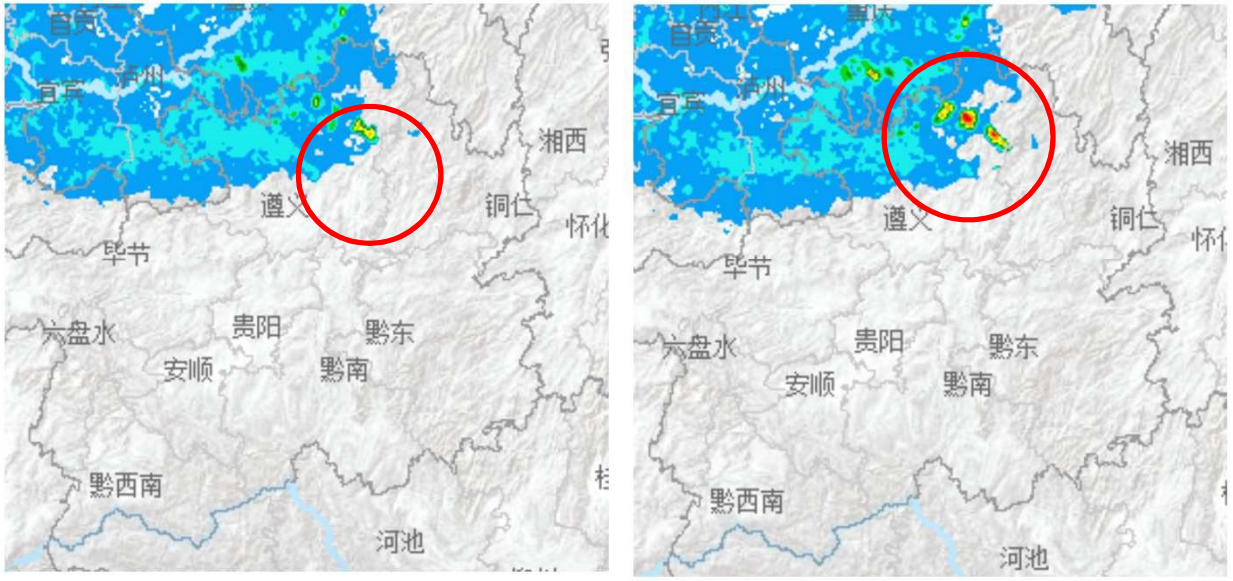




19：34（UTC） 19：45（UTC） 20：00（UTC） 20：15（UTC） 20：19（UTC） 20：23（UTC）



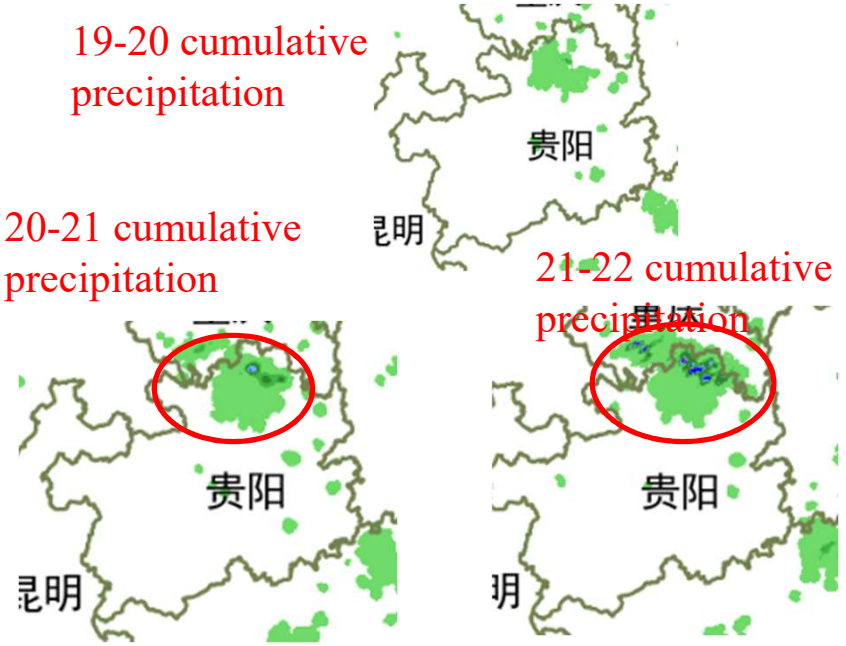
19：48（UTC） 20：00（UTC）



19-20 cumulative precipitation

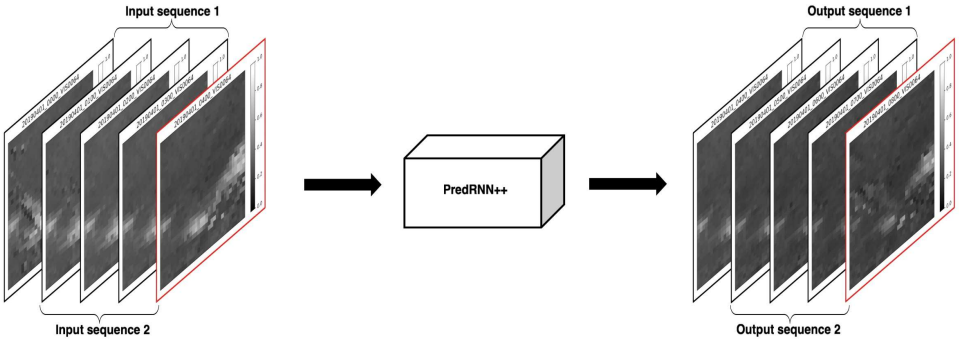
20-21 cumulative precipitation

21-22 cumulative precipitation



SWIPE V2.0 issued a moderate intensity convective warning for a cloud located in northern Guizhou at 19:34 (UTC), which was upgraded to a severe convective warning at 20:15 (UTC). The precipitation generated by this cloud cluster further increased, with cumulative precipitation exceeding 15 mm at 20-21 and 21-22 hours. On the radar echo, at 19:48 (UTC), an echo exceeding 35dBz appeared for the first time, and at 20:00 (UTC), an echo exceeding 45dBz appeared.

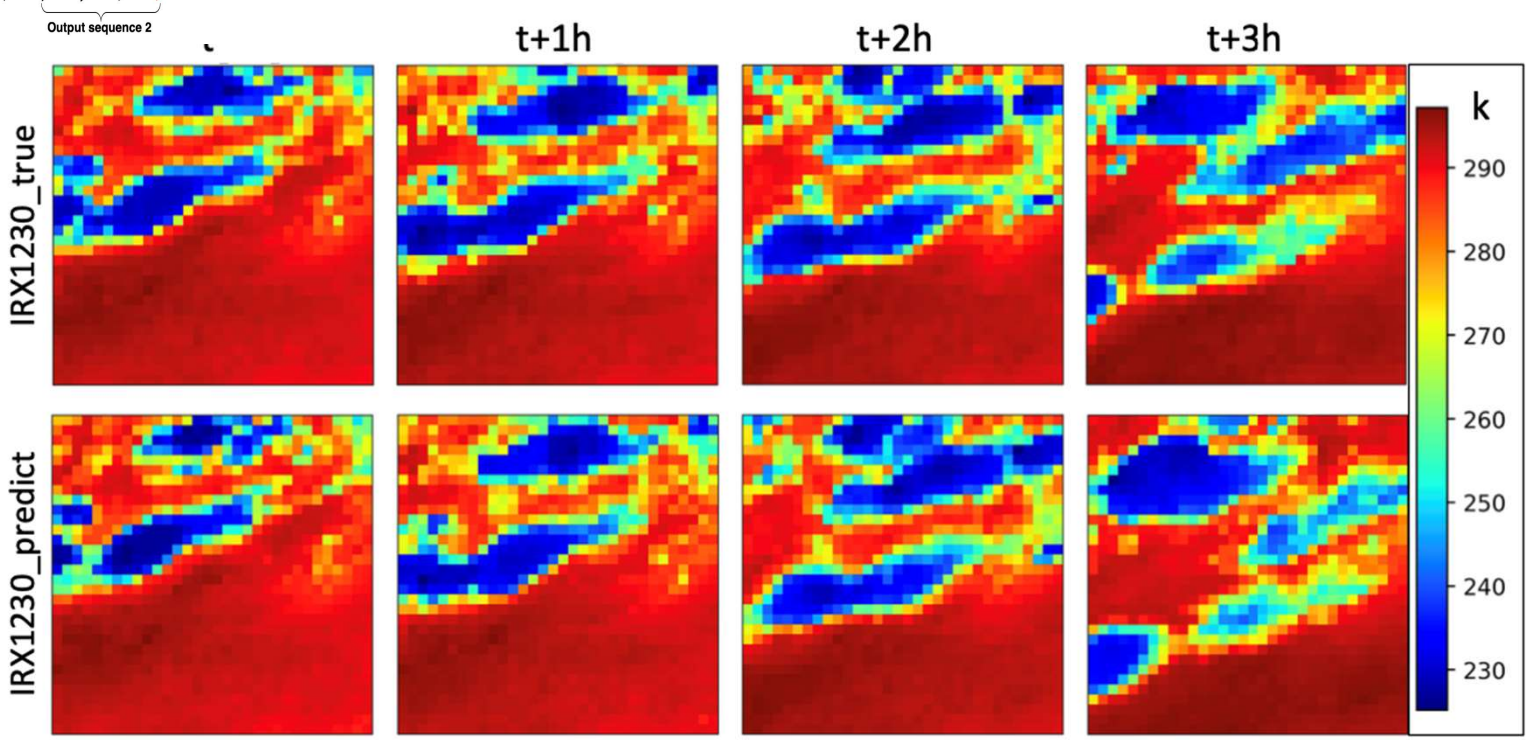
0 – 4 hours rapid prediction of GEO IR brightnesss temperature (BT) images with AI



True (obs): upper panels
Predicted: lower panels

Shortwave bands: 0.64um, 0.86um, 1.6um ;
Infrared bands : 3.90um, 7.00um, 11.20um, 12.30um ;

7 spectral bands are used as input for prediction



Prediction verification

Pan Xia, Lu Zhang, Min Min, Jun Li, Yun Wang, Yu Yu, Shengjie Jia, 2023. Accurate nowcasting on cloud cover at solar photovoltaic plants using geostationary satellite images [J]. Nature Communications (under review).

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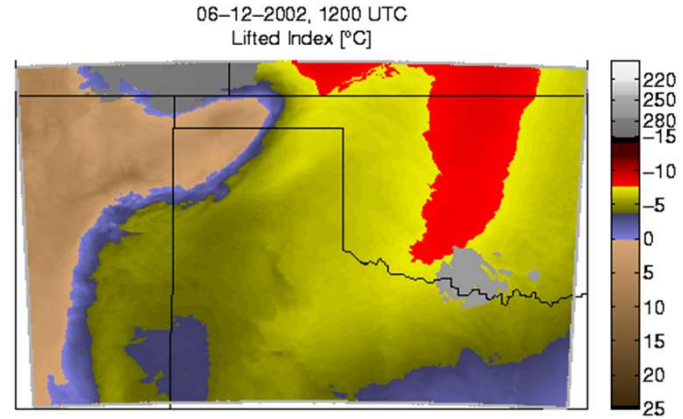
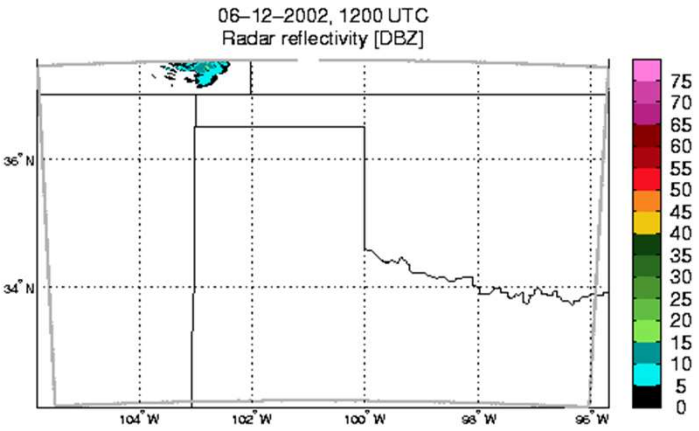
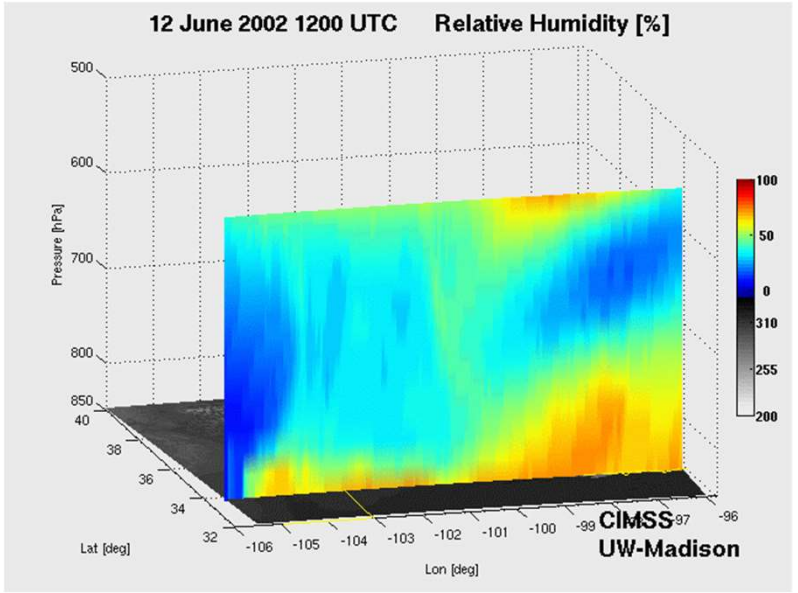
Lifted Index (LI) and radar simulation from high resolution (600 m) WRF



Red = extreme instability



Simulated Radar



UW/CIMSS

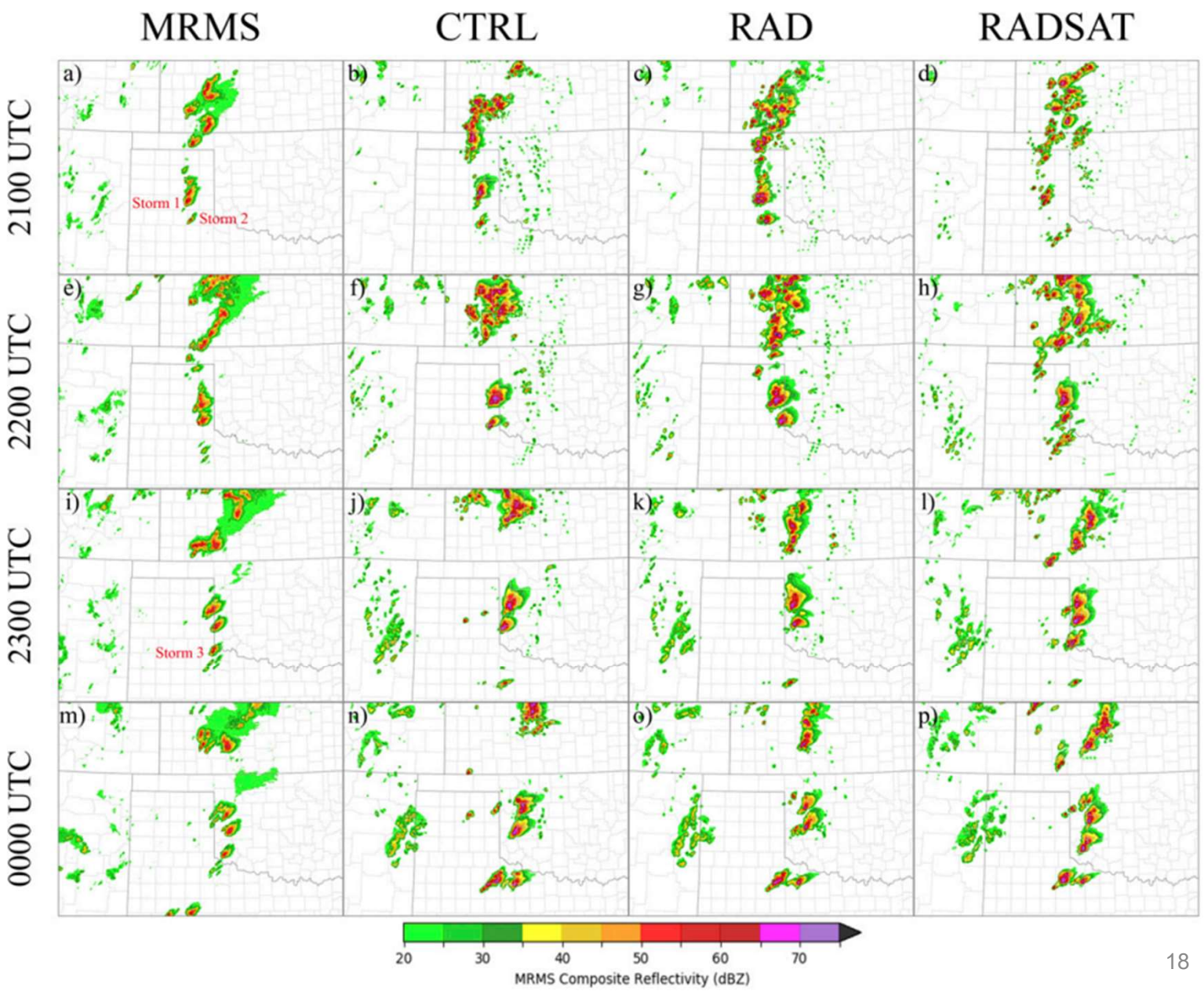
Li, J., Jinlong. Li, J. Otkin, T. J. Schmit, and C. Liu, 2011: Warning information in a preconvection environment from the geostationary advanced infrared sounding system - A simulation study using IHOP case, Journal of Applied Meteorology and Climatology, 50, 776 - 783.

Pan, S., J. Gao, T. A. Jones, Y. Wang, X. Wang, and Jun Li, 2021: The Impact of Assimilating Satellite-derived Layered Precipitable Water, Cloud Water Path and Radar Data on Short-Range Thunderstorm Forecasts. Monthly Weather Review, doi: https://doi.org/10.1175/MWR-D-20-0040.1.

Positive impact from radar+satellite

is better than

that from radar in storm scale NWP



Challenges and future perspectives

- Challenges
  - Data Assimilation in Storm Scale Models:
  - Large Data Process for Near Real-time Applications;
  - Satellite products relate to surface observations;
  - Sounding Applications.
- Future perspectives
  - Handling Complex Weather Interactions:
  - Combining Multi-Spectral and Hyperspectral Imaging:
  - Combining Active and Passive Remote Sensing Techniques:
  - Using Artificial Intelligence (AI) and Machine Learning (ML):
  - Combining Storm Scale NWP, Statistical Models, and Surface observations for Nowcasting Applications.