Applications of GIIRS in weather nowcasting and forecasting

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Eumetrain Event week on MTG
08 - 12 December 2025

Content

- Fengyun sounding product
- Applications of GIIRS in NWP
- Applications of Fengyun sounding products in nowcasting
- GIIRS for atmospheric composition
- Summary

Fengyun satellite sounding products

Polar orbiting satellites （FY-3D/3E)

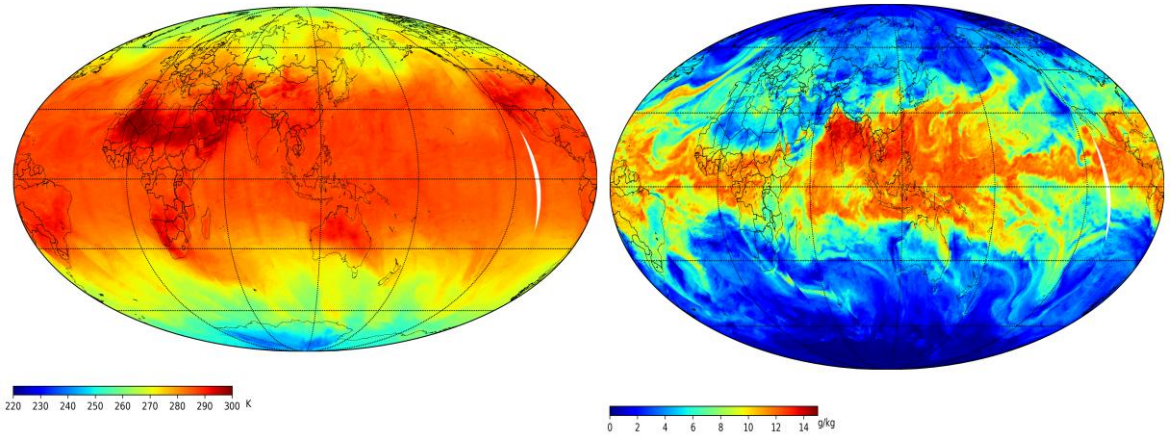
MWTS, MWHS、 HIRAS combined VASS product (MW+IR)

- ✓ Global 3D atmospheric temperature and moisture
- ✓ All-sky
- ✓ Twice per day for every satellite

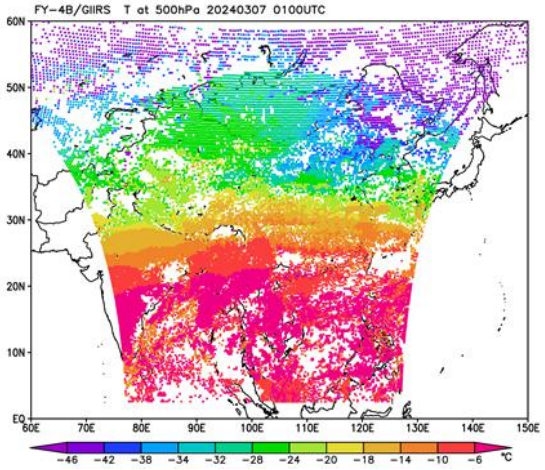
Geostationary satellites (FY-4A/4B)

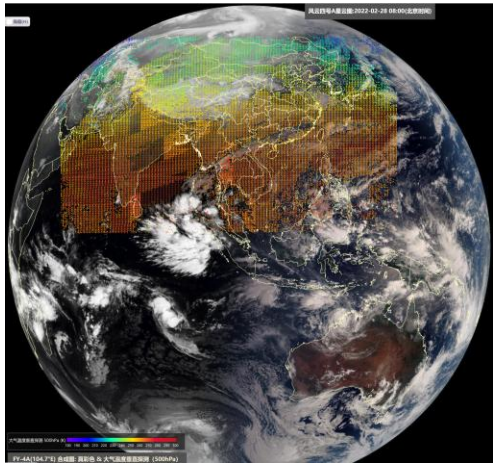
(GIIRS) (IR only)

- ✓ Regional 3D atmospheric temperature and moisture
- ✓ Clear sky and partly cloudy sky
- ✓ Every 2 hours for China and adjacent regions



VASS temperature (K) and moisture (g/kg) at 850 hPa on 12 Sept 2021

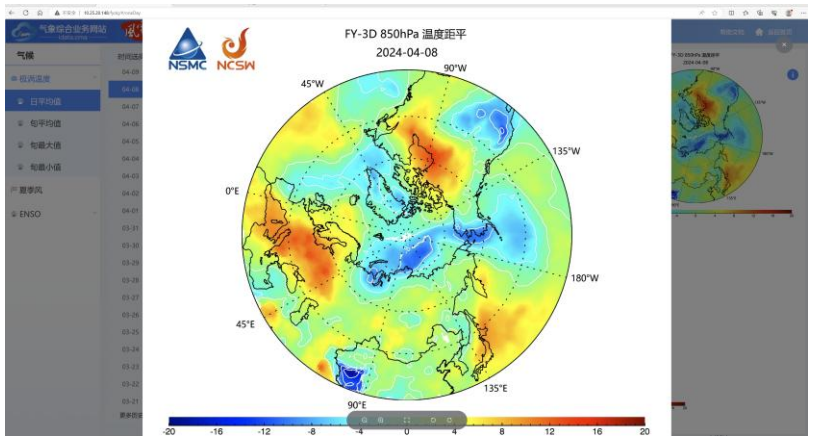


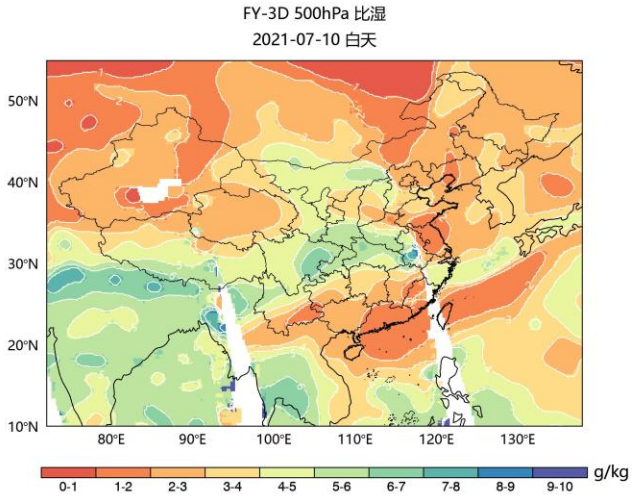


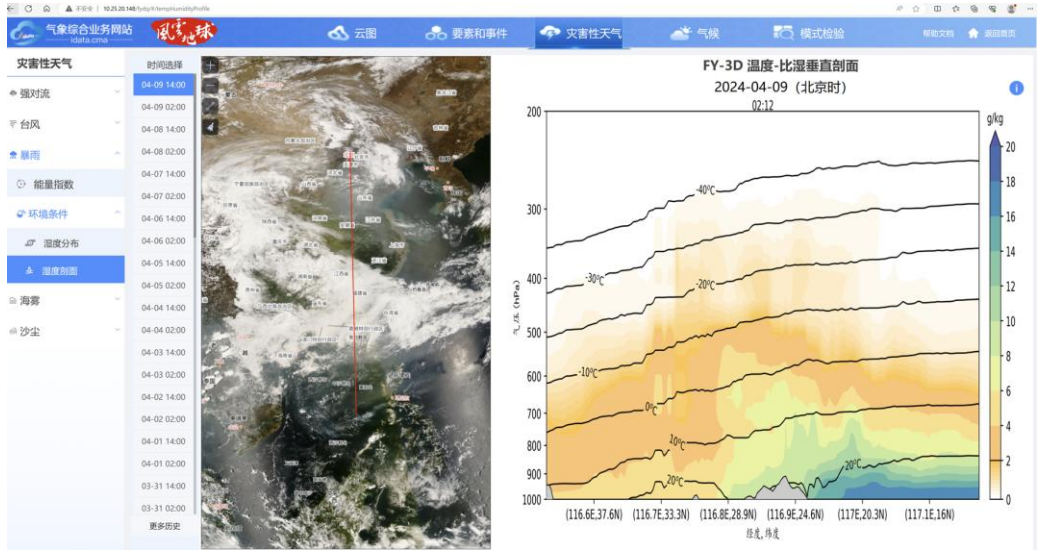
FY-4B/GIIRS temperature (C°) 500 hPa on 07 March 2024

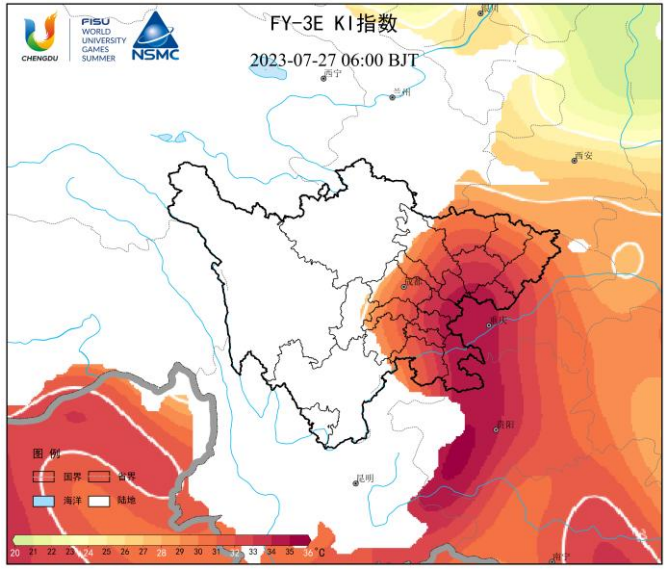
Fengyun sounding products

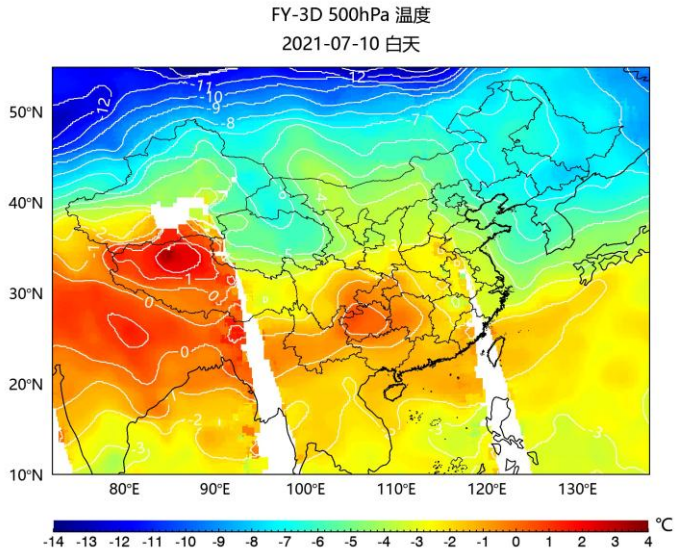
VASS products in real-time application platform – Fengyun Earth (a Fengyun Near-real time application system)



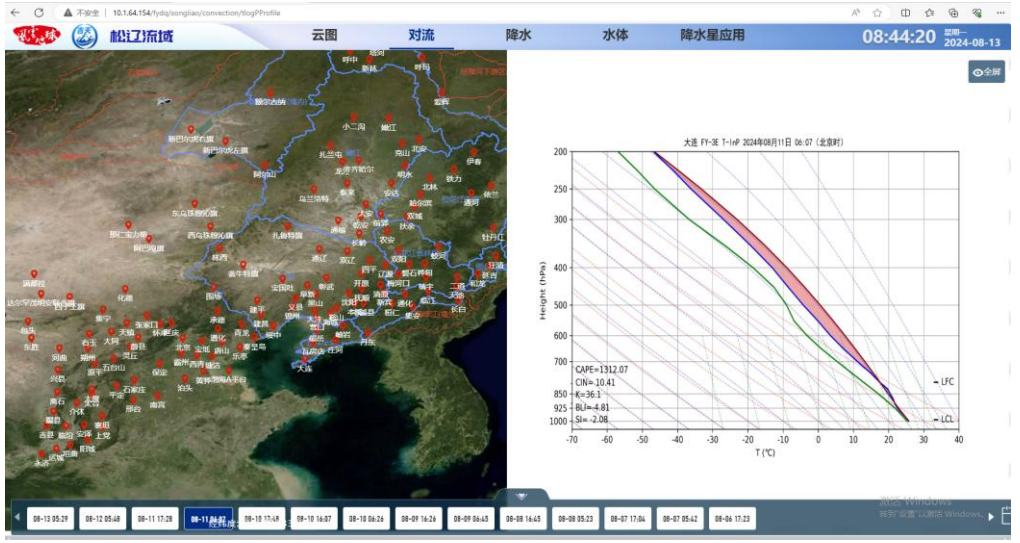






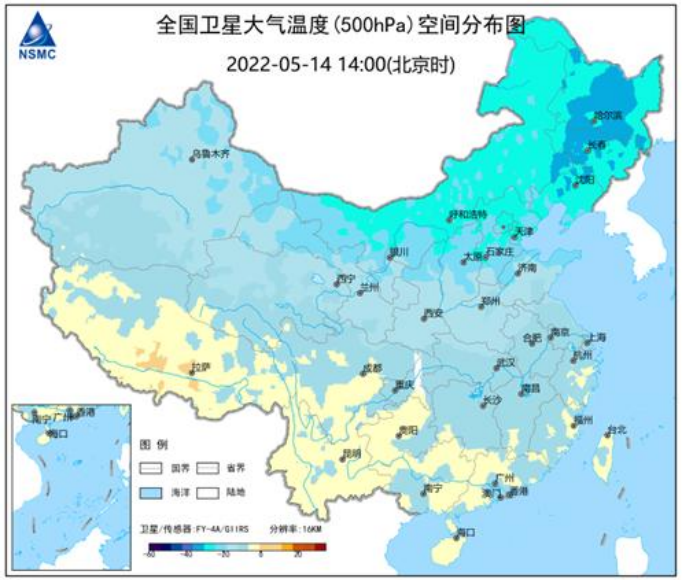


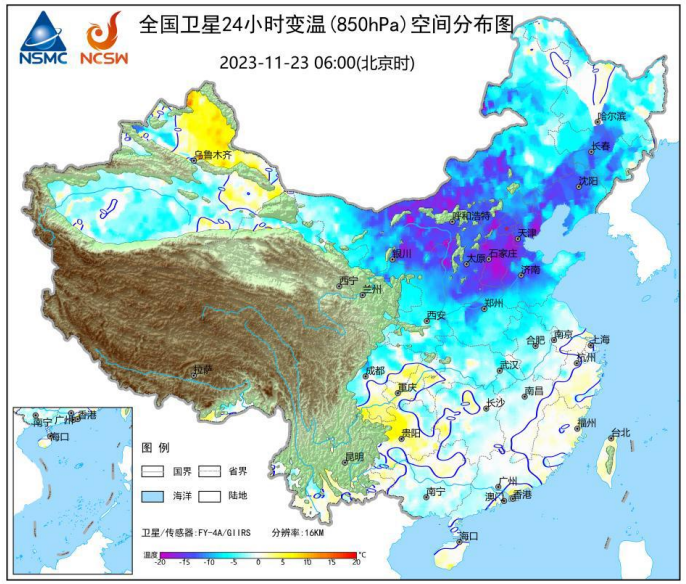
T-lnp

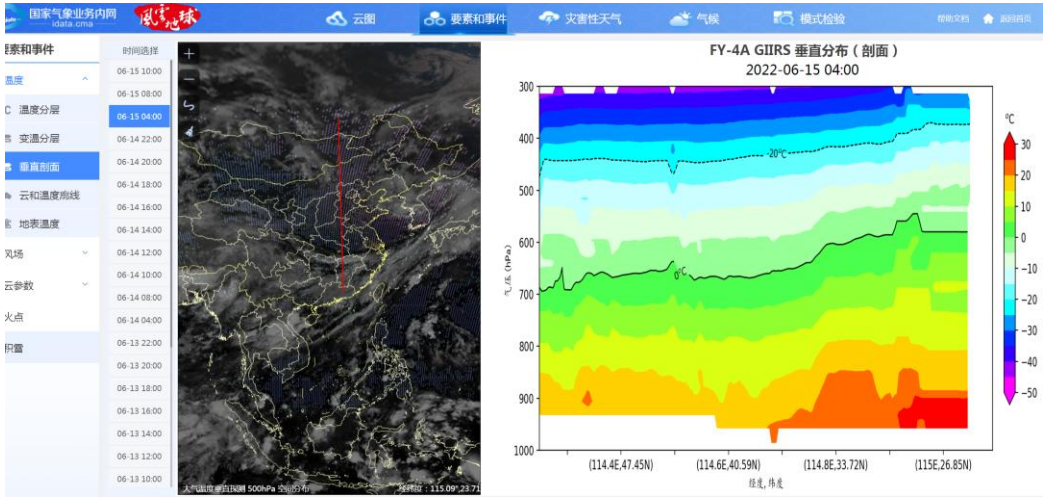


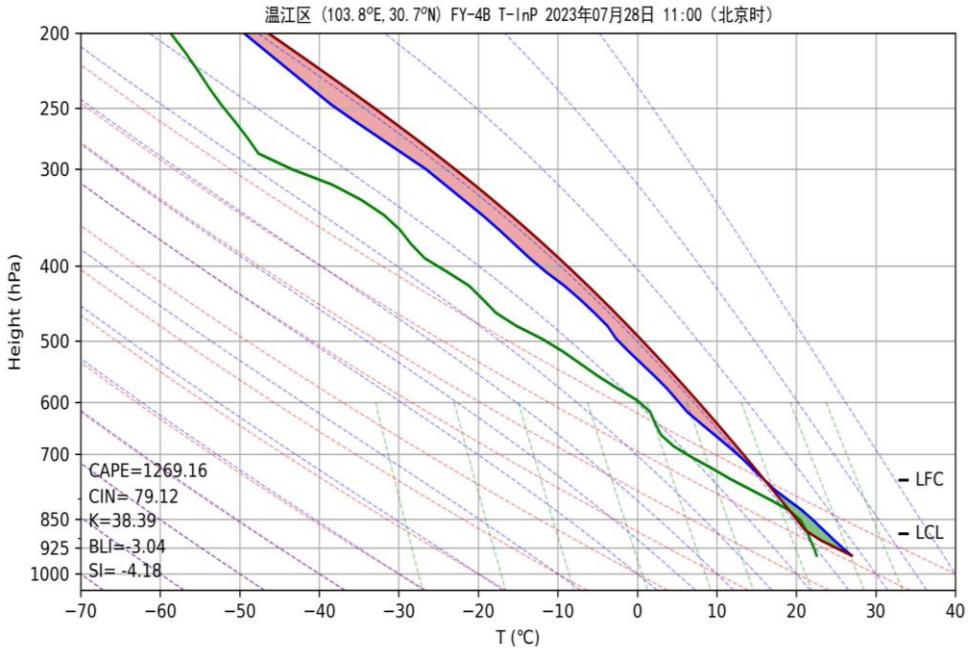
Fengyun sounding products

GIIRS products in real-time application platform – Fengyun Earth (a Fengyun near-real time application system)

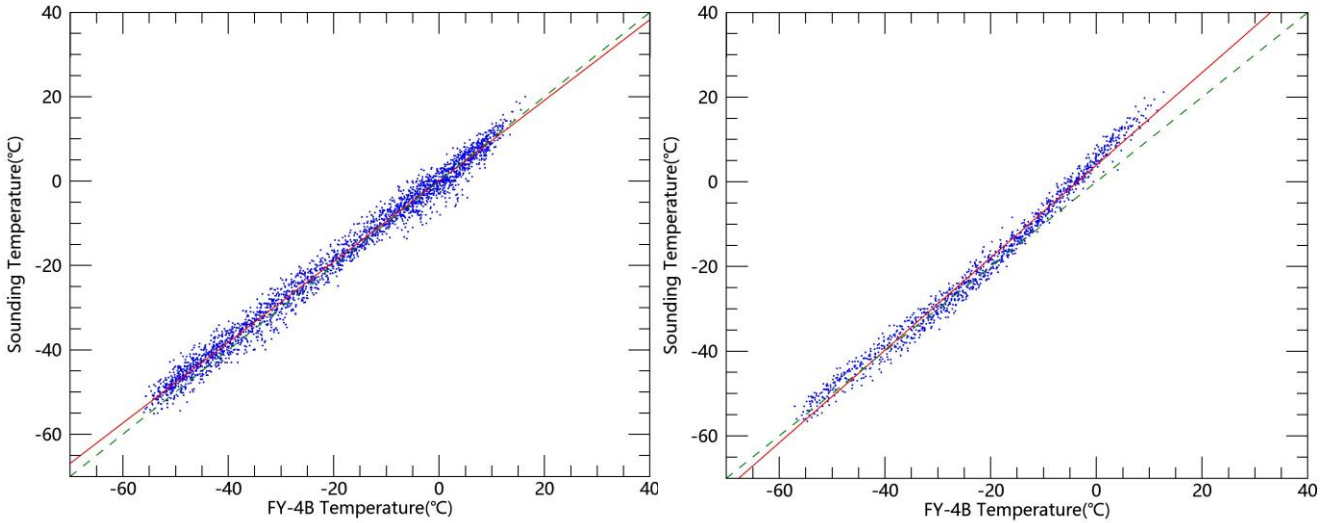




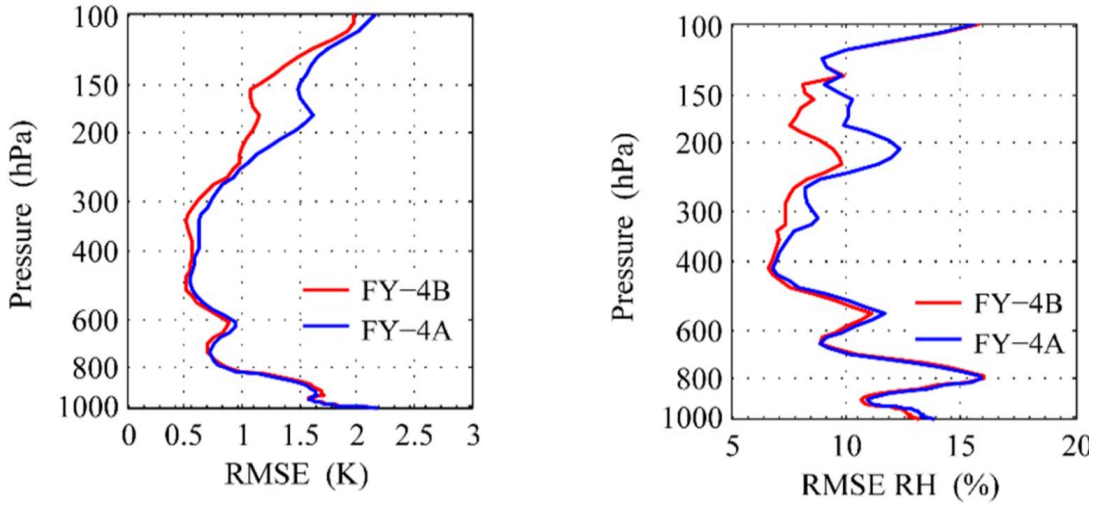


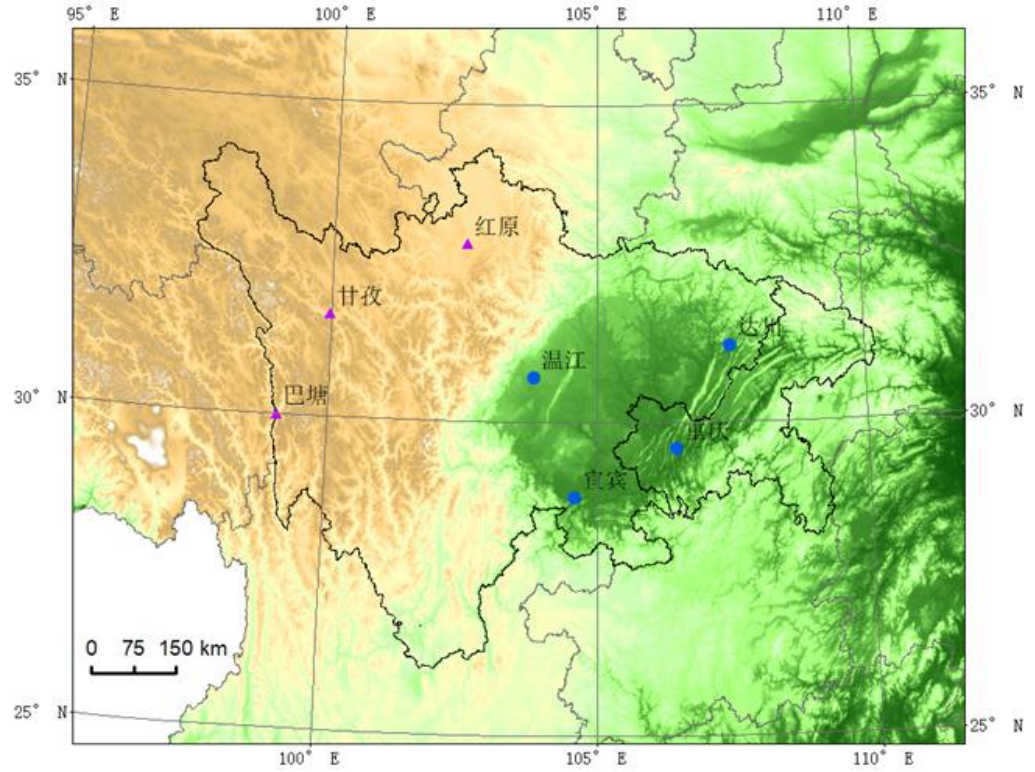


Sounding products in “Fengyun Earth”



Scatterplot of FY-4B and RAOB (Left：Sichuan Basin；right：West Sichuan Terrian) 2023.1.16 - 2023.3.10





Wang, Sufeng, Feng Lu, and Yutao Feng. "An Investigation of the Fengyun-4A/B GIIRS Performance on Temperature and Humidity Retrievals." Atmosphere 13, no. 11 (2022): 1830.

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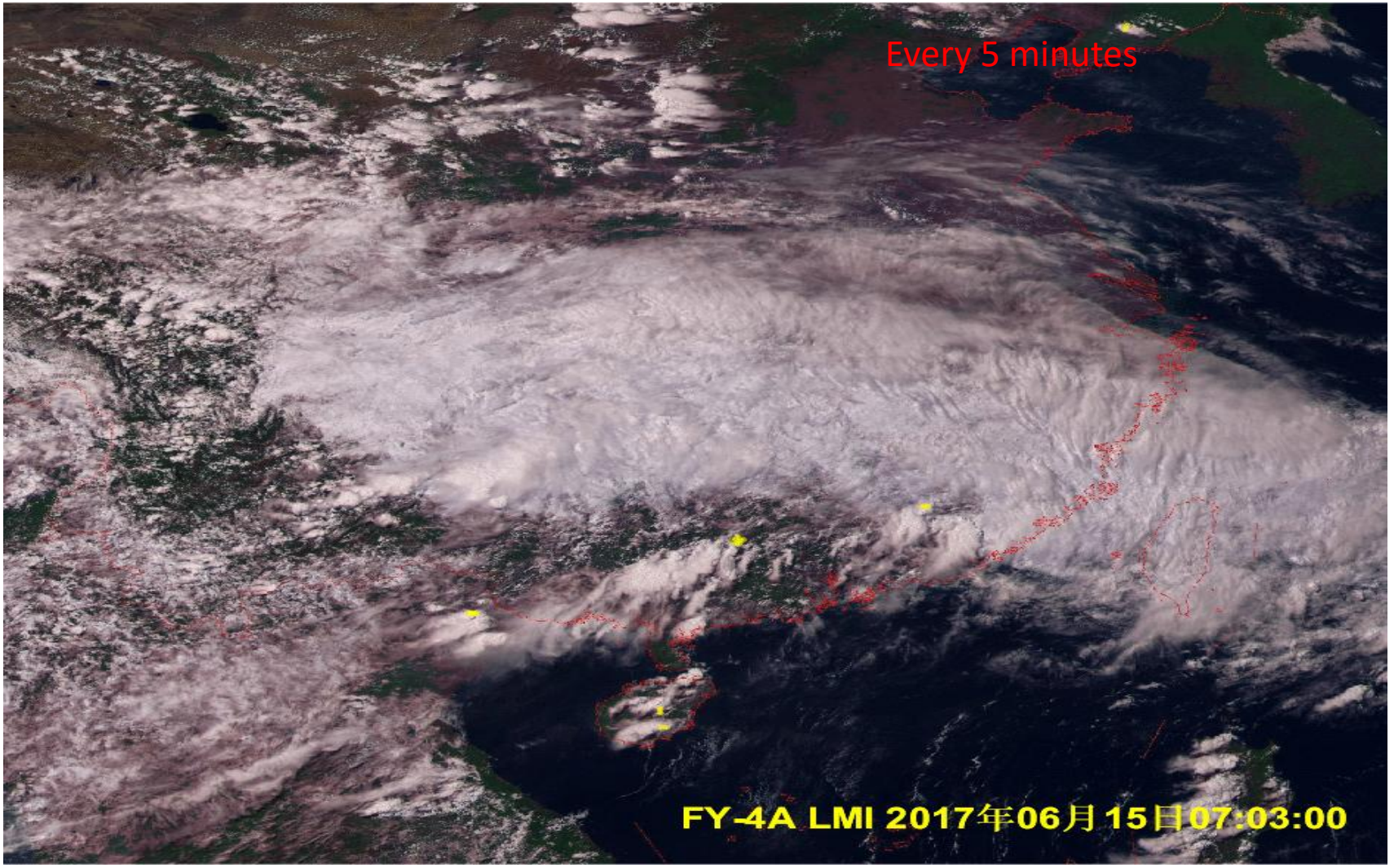
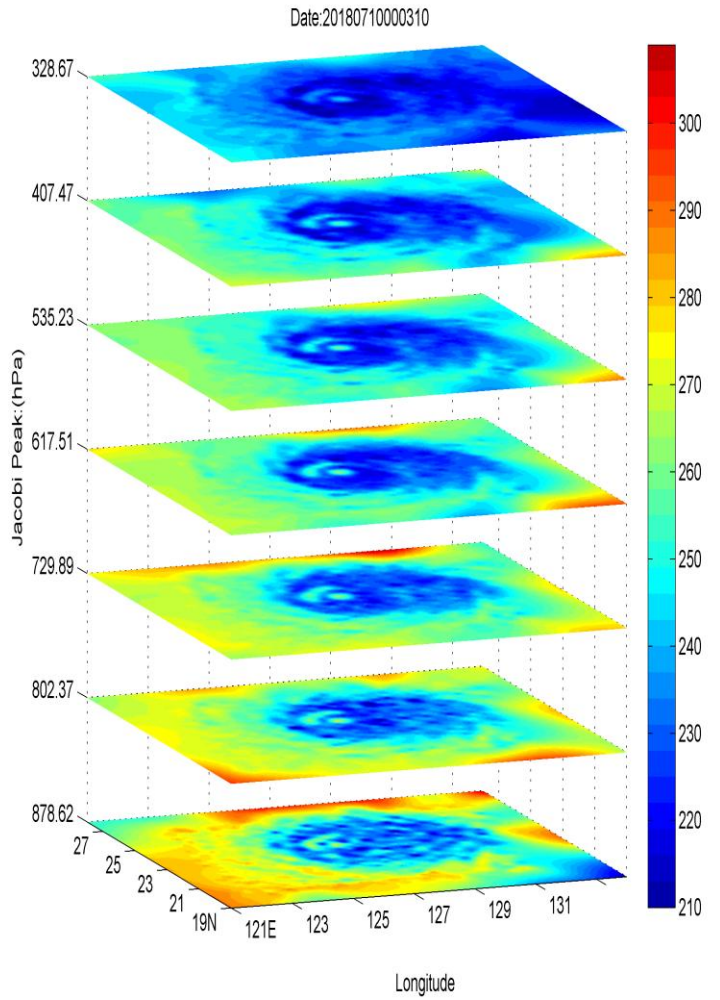
FY-4A： AGRI (Imager) + LMI (Lightening) + GIIRS (Sounding)

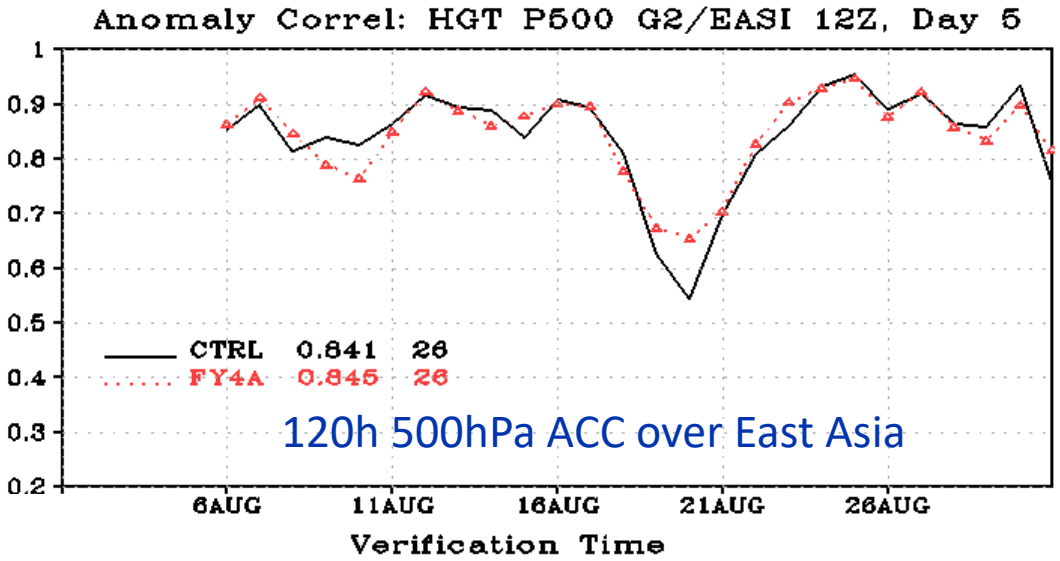




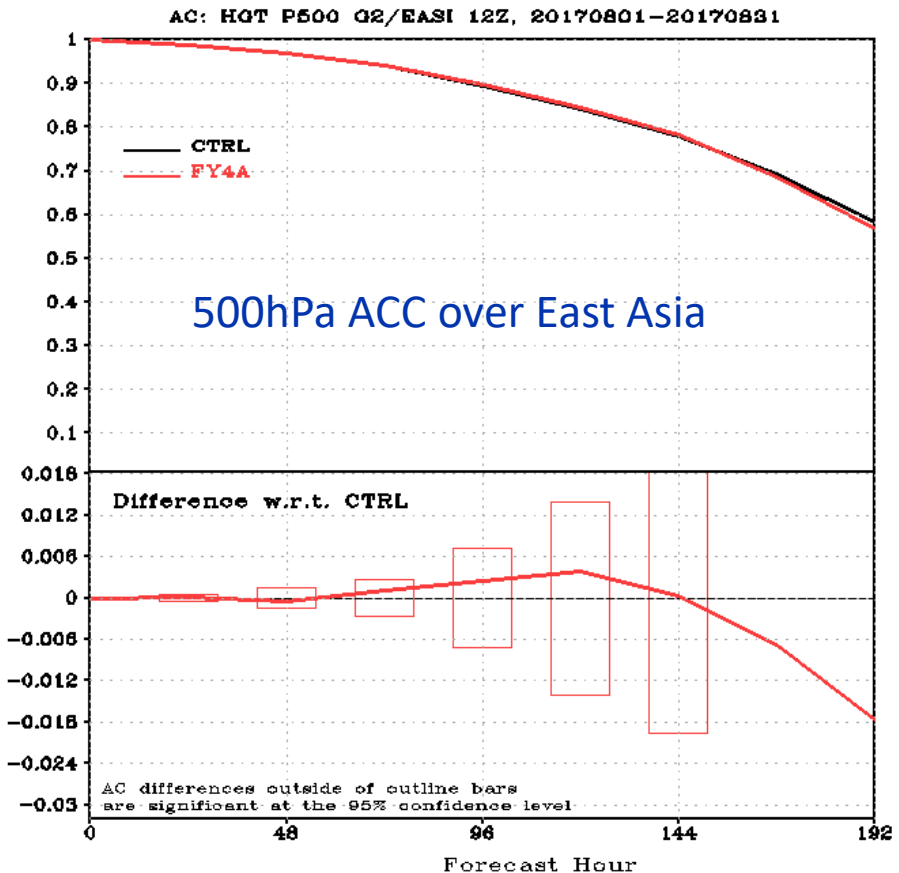
Typhoon”Maria” Every 15 minutes
(1650 Channels)

Impact of FY-4A GIIRS on Forecast over East Asia (August 2017)

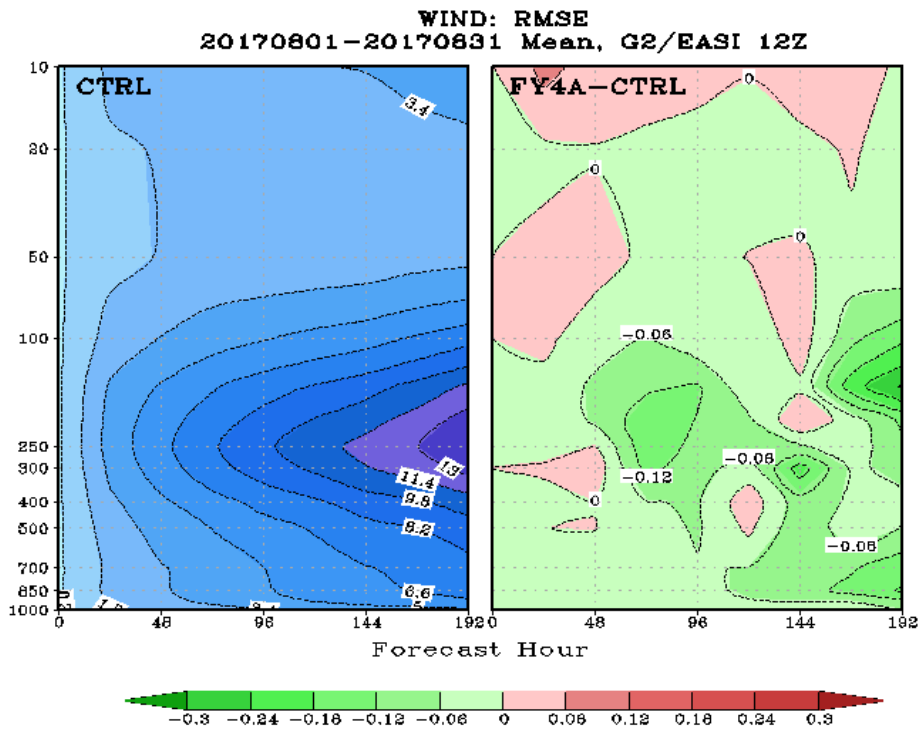
GRAPES gloal 4D-Var
CTRL ： OPER
GIIRS ： OPER + GIIRS



120h 500hPa ACC over East Asia



500hPa ACC over East Asia



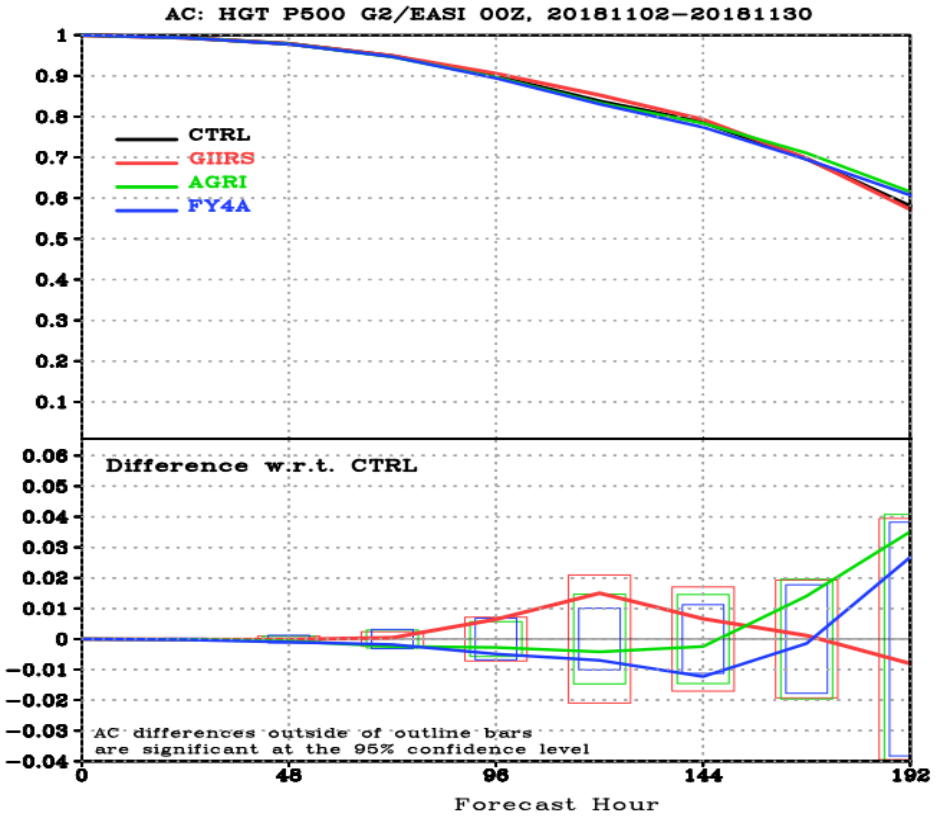
Impact on wind RMSE(green mean reduction)

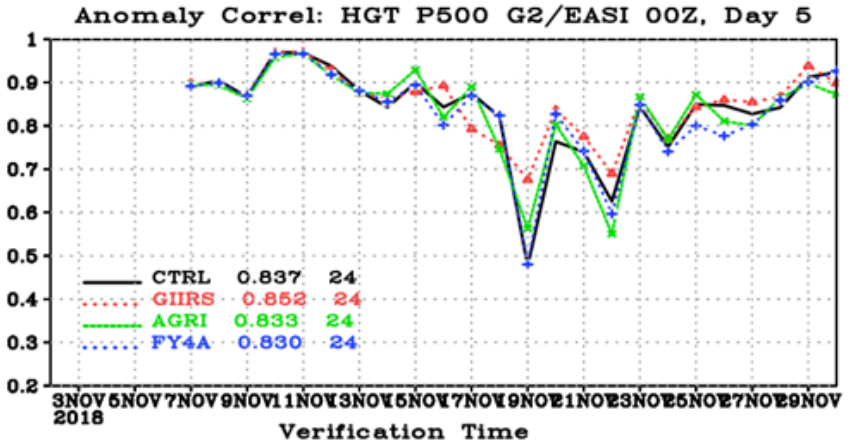
Impact of FY-4A GIIRS over East Asia （November 2018）

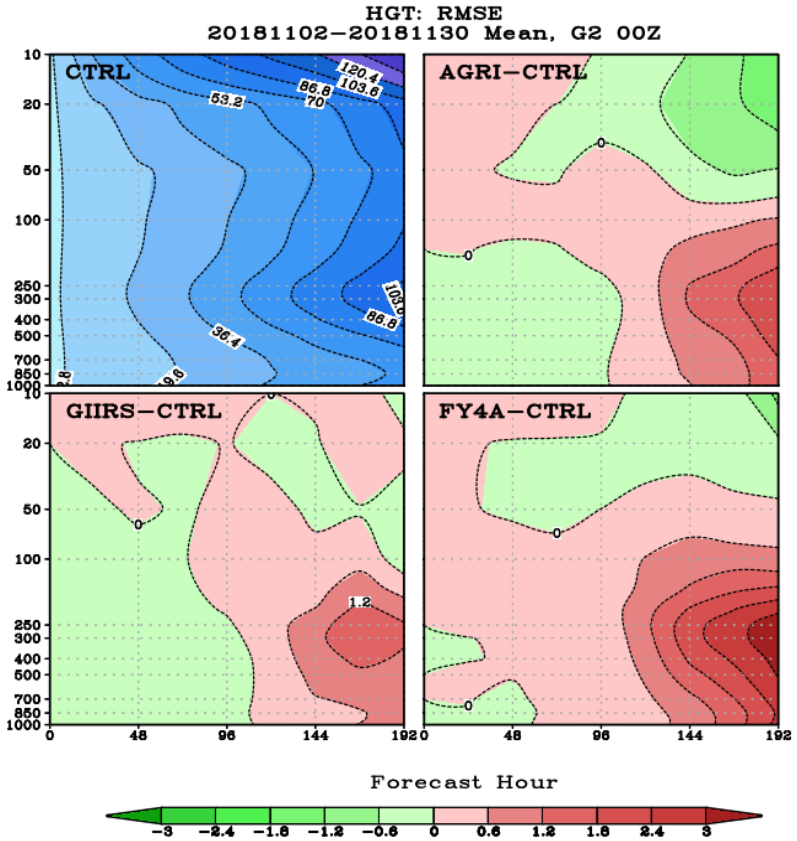
Neutral to positive impact overall,

Positive impact for high impact weather

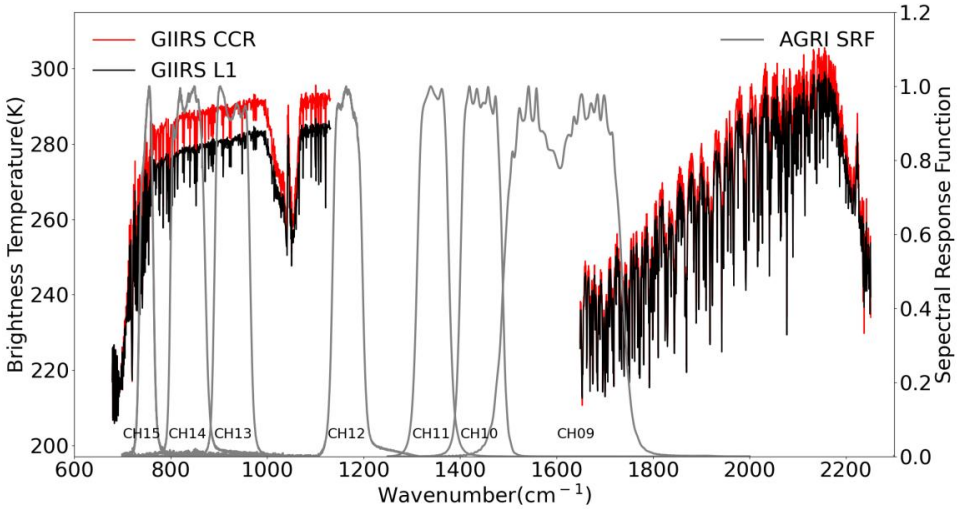
Operational Assimilation of GIIRS in GRAPES 4D-Var since Dec. 25th 2018

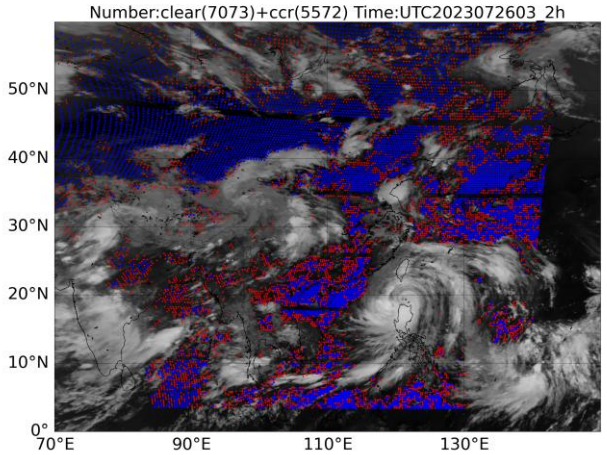






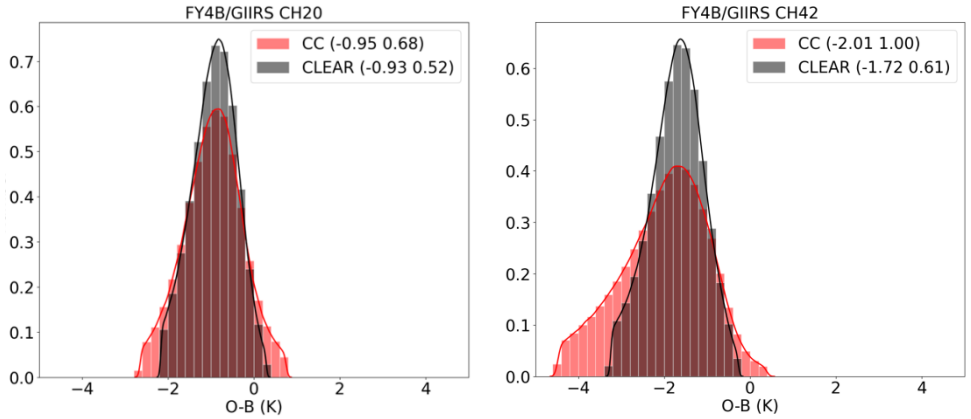
Assimilation of FY-4B GIIRS CCRs in CMA-GFS



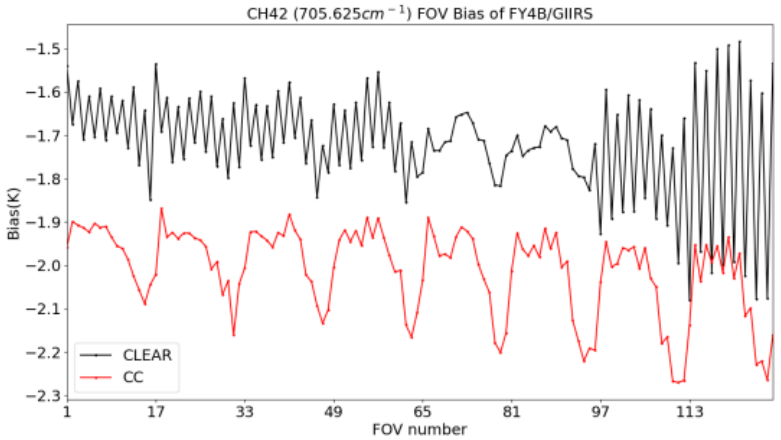


CCRs can increase the number of available assimilation observation data by more than 75% in a month.

Cloud-cleared radiances (CCRs) are derived using "optimal cloud-clearing" method (Li et al. 2005)



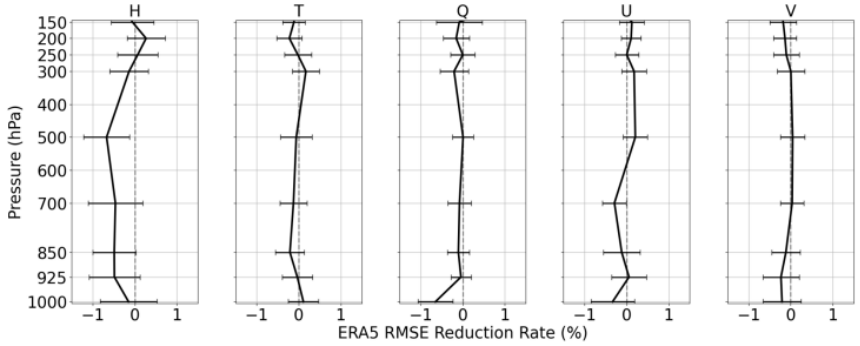
The lower peaking GIIRS channels show larger bias differences between the clear sky and the CCRs.

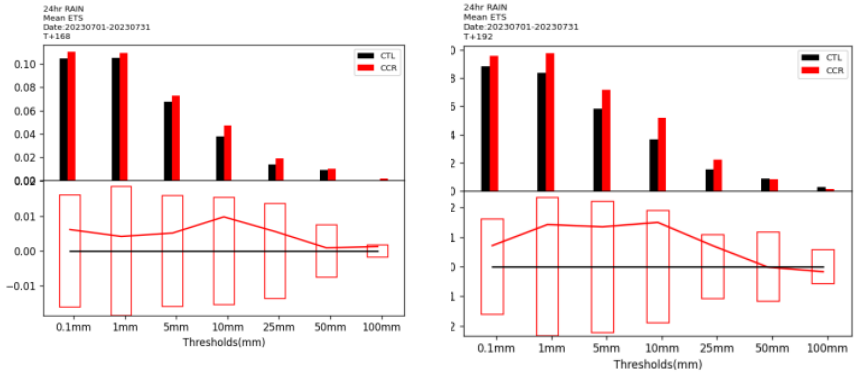


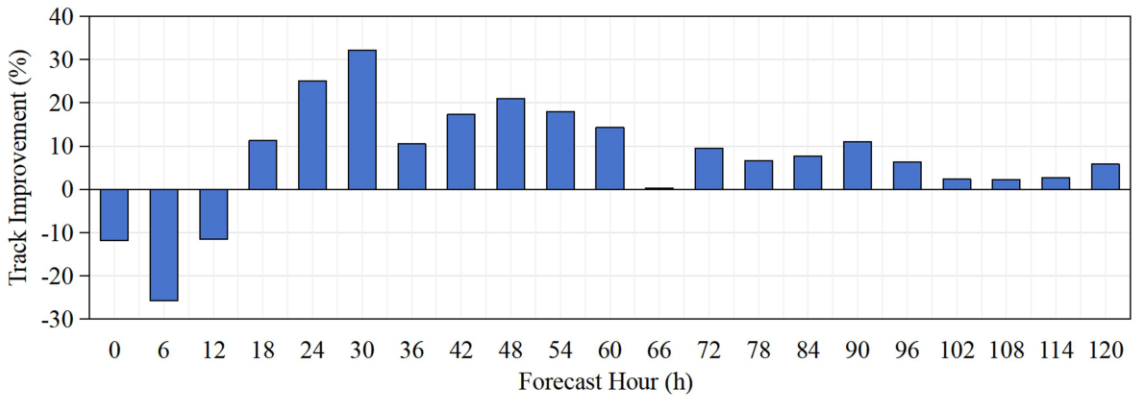
CCRs show smaller FOV-dependent bias fluctuations, which may be because the CC algorithm brings some smoothing effect.

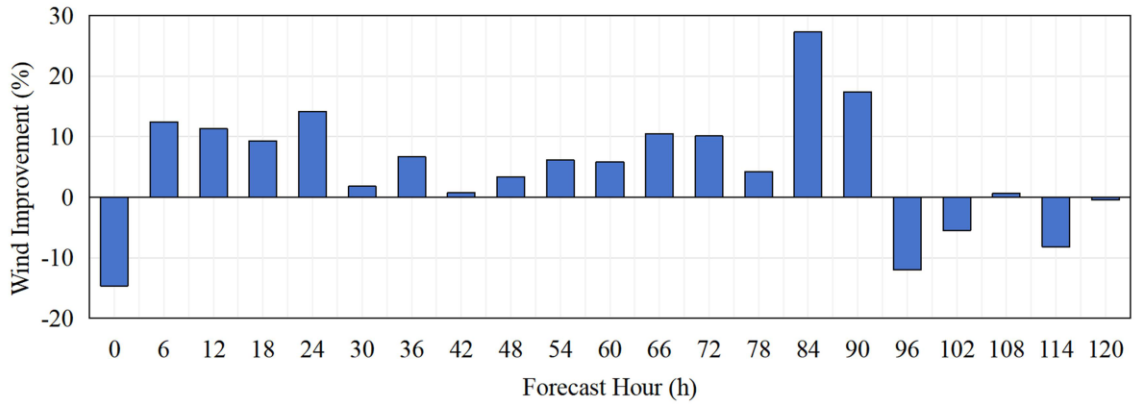
Assimilation of FY-4B GIIRS CCRs in CMA-GFS

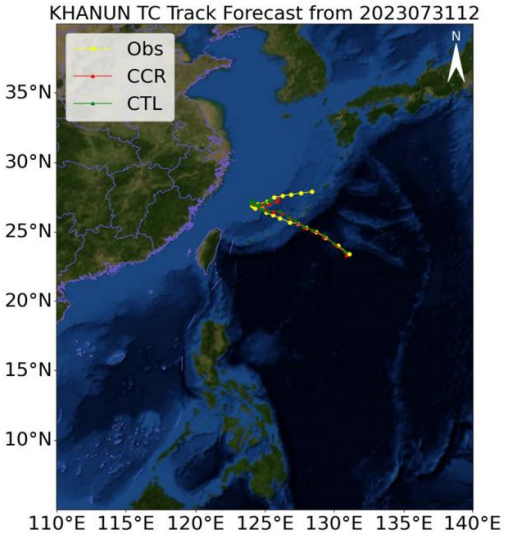
- The assimilation of GIIRS cloud-cleared radiances (CCRs) has a positive impact on the model analysis and forecast fields, especially for typhoon events.
- The results of 1 month cycle assimilation experiment show the potential operational application of FY-4B GIIRS CCRs in NWP.

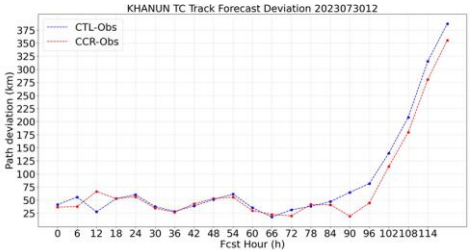








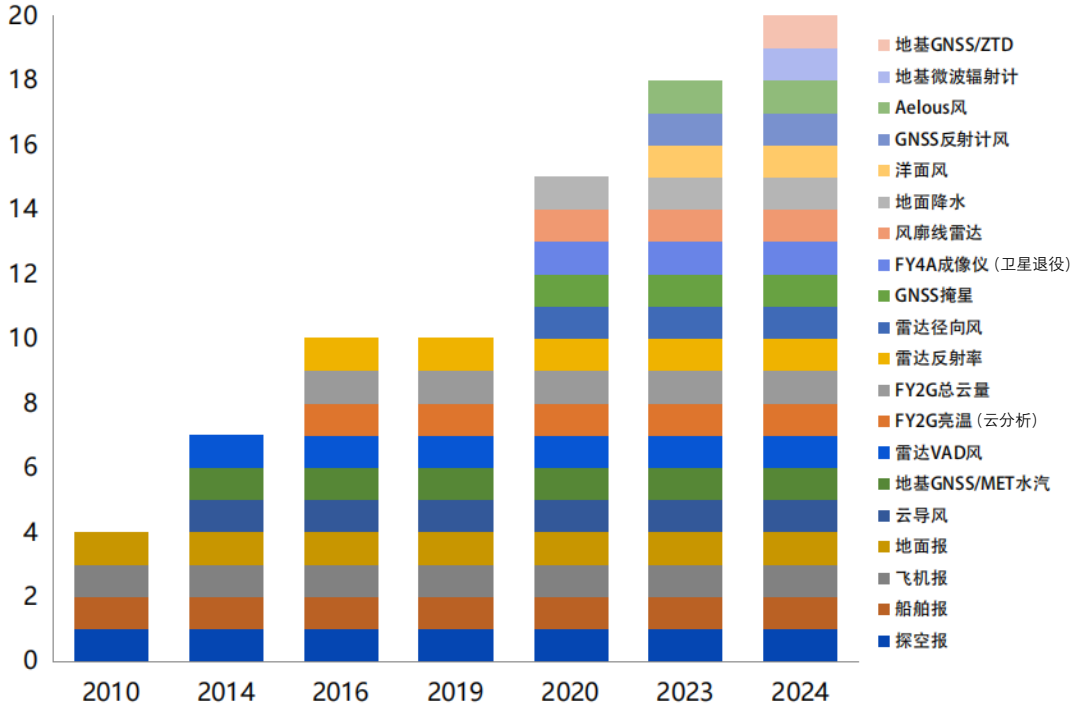




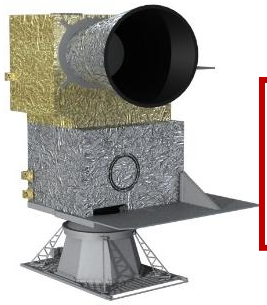
Yin, R., Han, W., Zhao, Z., Gong, X., Kong, S., Zhang, F., & Li, J. (2025). The preliminary assimilation and impacts of FY-4B Geostationary Interferometric Infrared Sounder (GIIRS) cloud-cleared radiances. Journal of Geophysical Research: Atmospheres, 130, e2025JD043520. https://doi.org/10.1029/20251D043520

Assimilation of FY-4B GIIRS in CMA-MESO V6.0

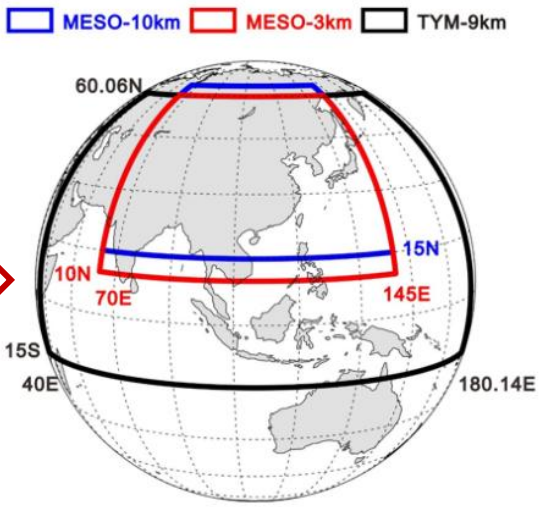
Types of observation data applied in CMA-MESO



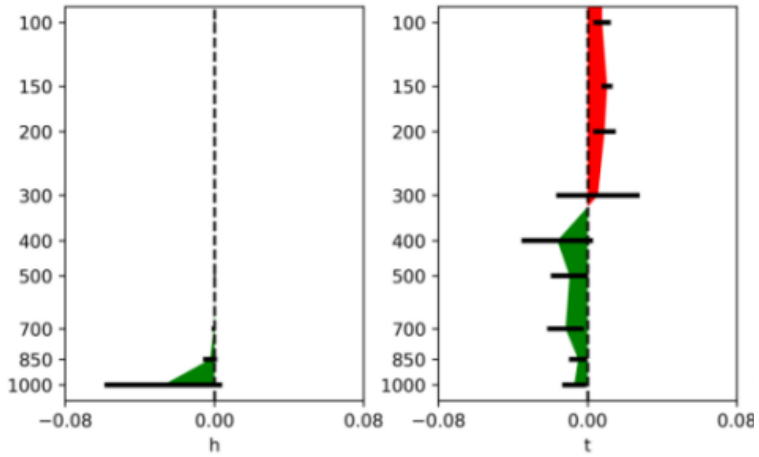
The operational CMA-MESO model does not directly assimilate satellite radiance data at present.



Assimilate GIIRS radiance observations into CMA-MESO

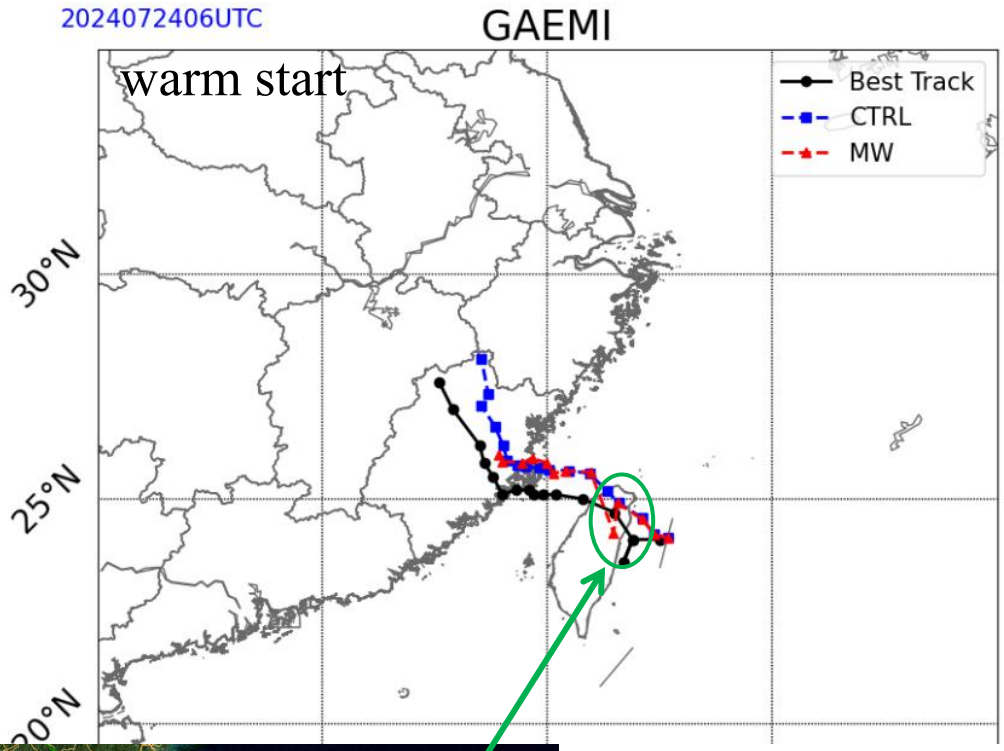


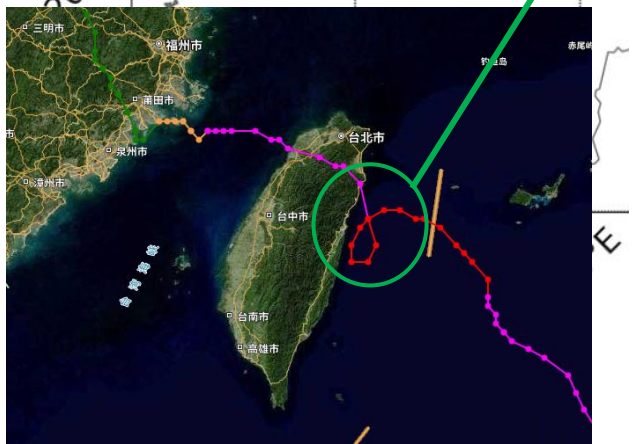
Technology: observation operator, quality control, channel selection, assimilation application



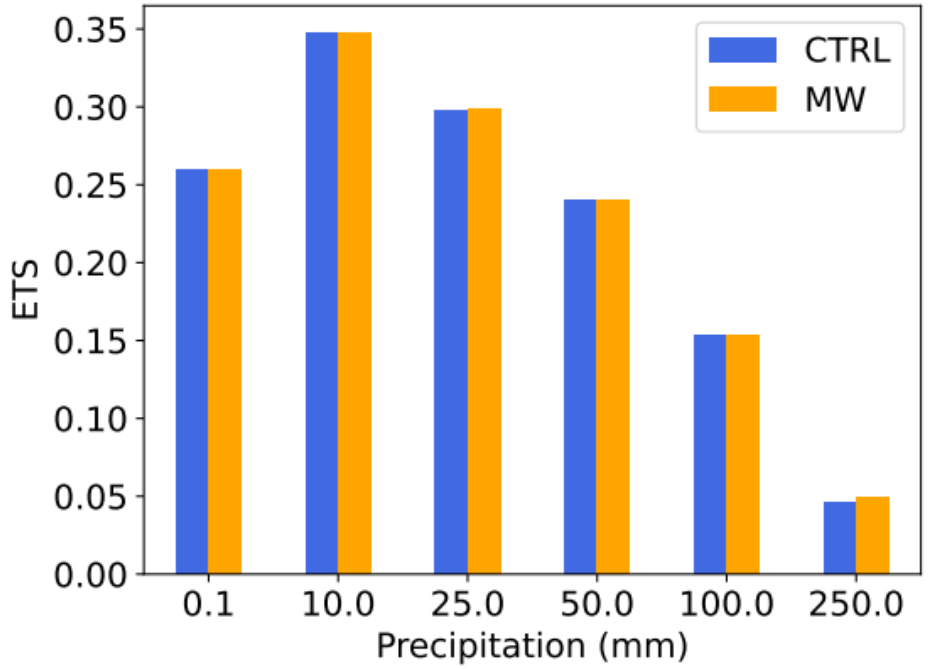
Some improvements in the analysis field

Assimilation of FY-4B GIIRS in CMA-MESO V6.0



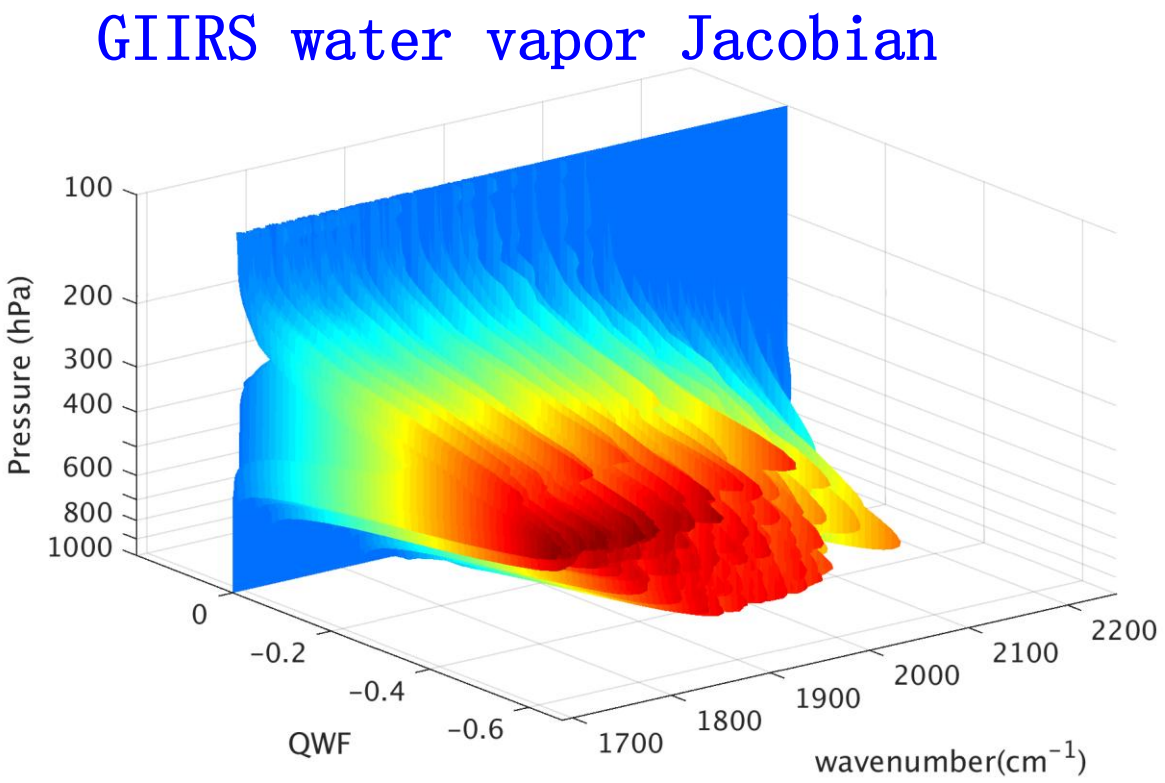


After assimilating GIIRS in CMA-MESO 3 km, the trend of typhoon rotation were predicted, which is closer to the Best track.



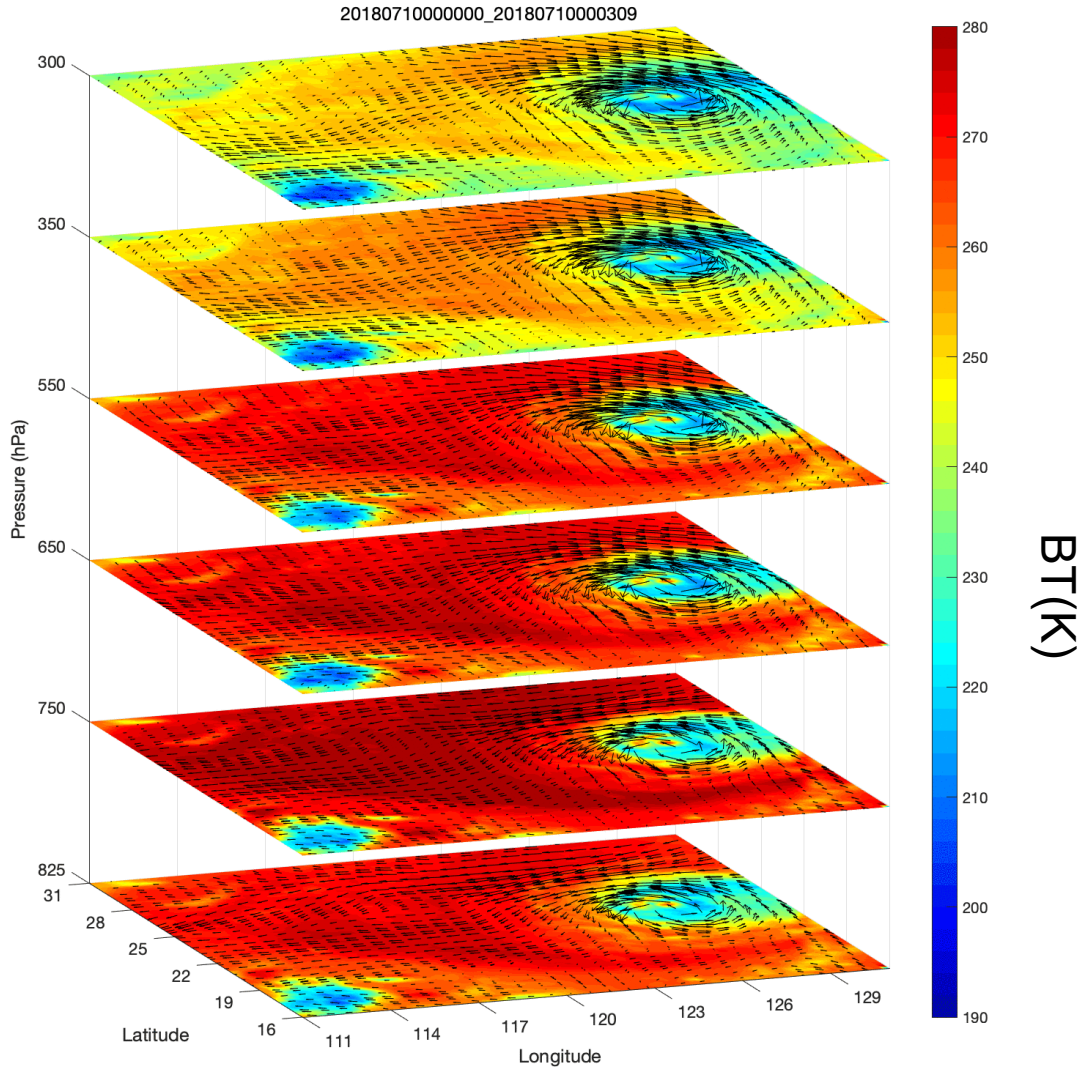
The ETS of 24-hr cumulative precipitation forecast (14-day experiment) shows that the main impact is neutral, and there is an improvement trend for precipitation forecasts above 250 mm.

Using high temporal resolution data from geostationary hyperspectral infrared sounders (GIIRS), such as data at 15 - 30 minute intervals, three-dimensional wind fields in clear skies and parts of cloud regions can be obtained. (1000 – 250 hPa)



Ma, Z., Li, J.*, Han, W., Li, Z., Zeng, Q., Menzel, W.P., Schmit, T.J., Di, D., Liu, C.-Y., 2021. **Four-Dimensional Wind Fields** From **Geostationary Hyperspectral Infrared Sounder** Radiance Measurements With **High Temporal Resolution**. *Geophysical Research Letters* 48, e2021GL093794. https://doi.org/10.1029/2021GL093794

00-10 UTC 10 July 2018, every 15 minutes



Images: Selected GIIRS WV channels peaking at different atmospheric layers (see right for QWF).
Vectors: Winds at selected levels overlaying on BT.

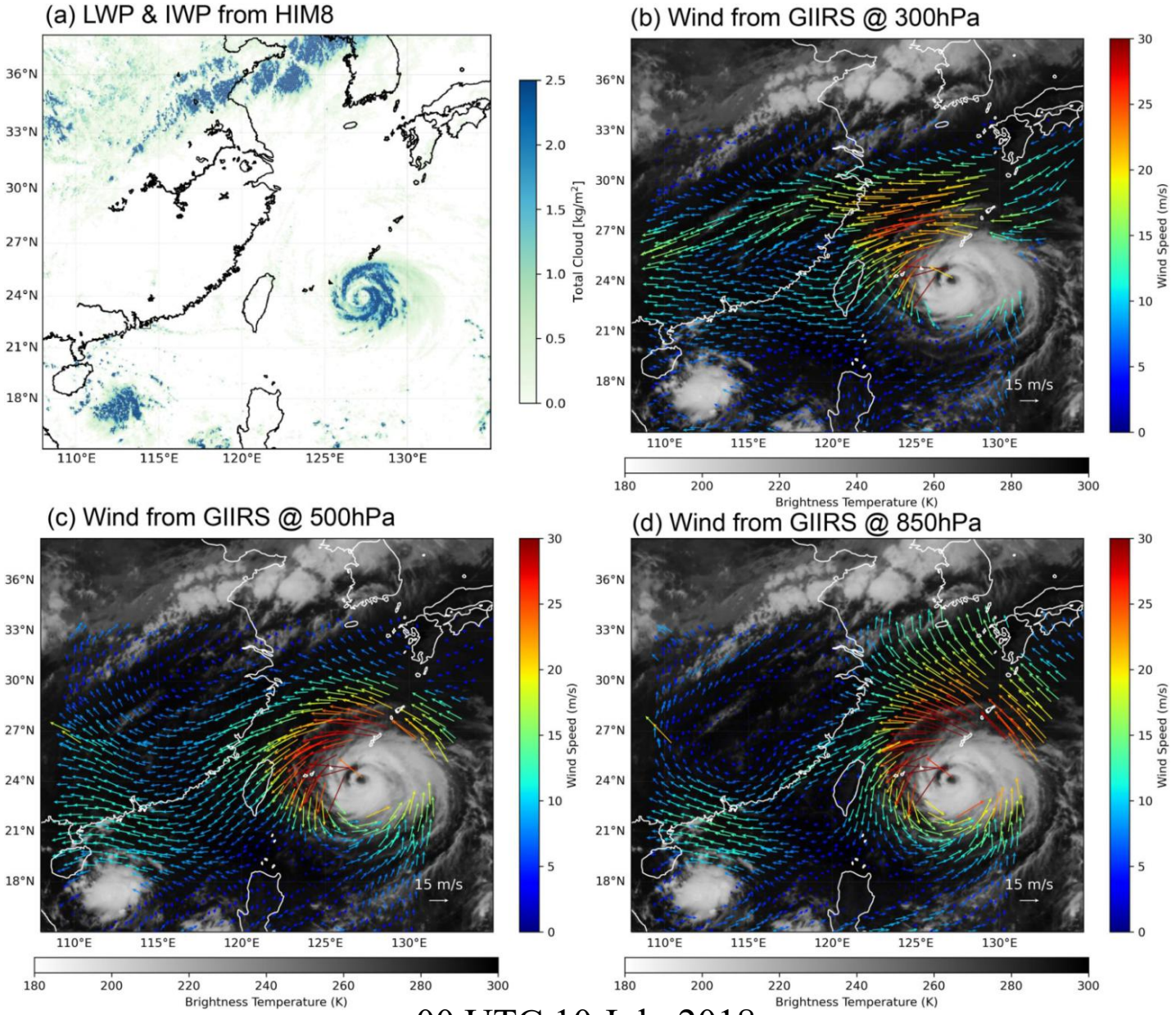
Q1: Compared to the satellite data already used, what is the added values of 3D winds from GIIRS for NWP?

Control Experiment:
Conventional and satellite data already used, including geostationary satellite imager data.

Impact Experiment:
Control experiment + GIIRS 3D wind field

Model: WRF

Assimilation System: WRFDA



00 UTC 10 July 2018

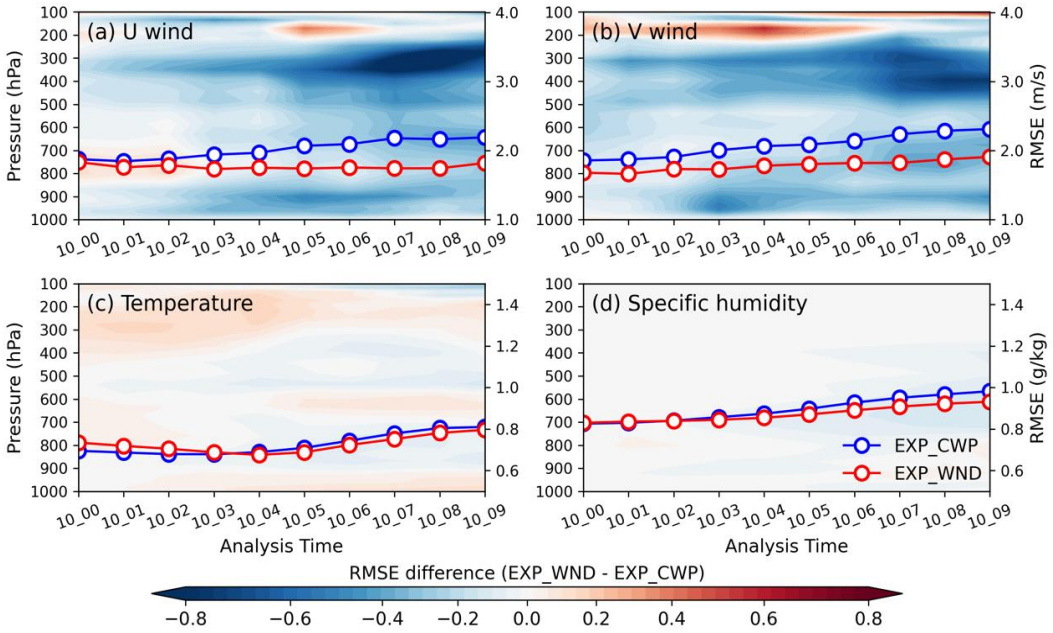
16

The added values of three-dimensional wind field assimilation on typhoon analysis field and forecast results

Impact on analysis from 3D wind assimilation

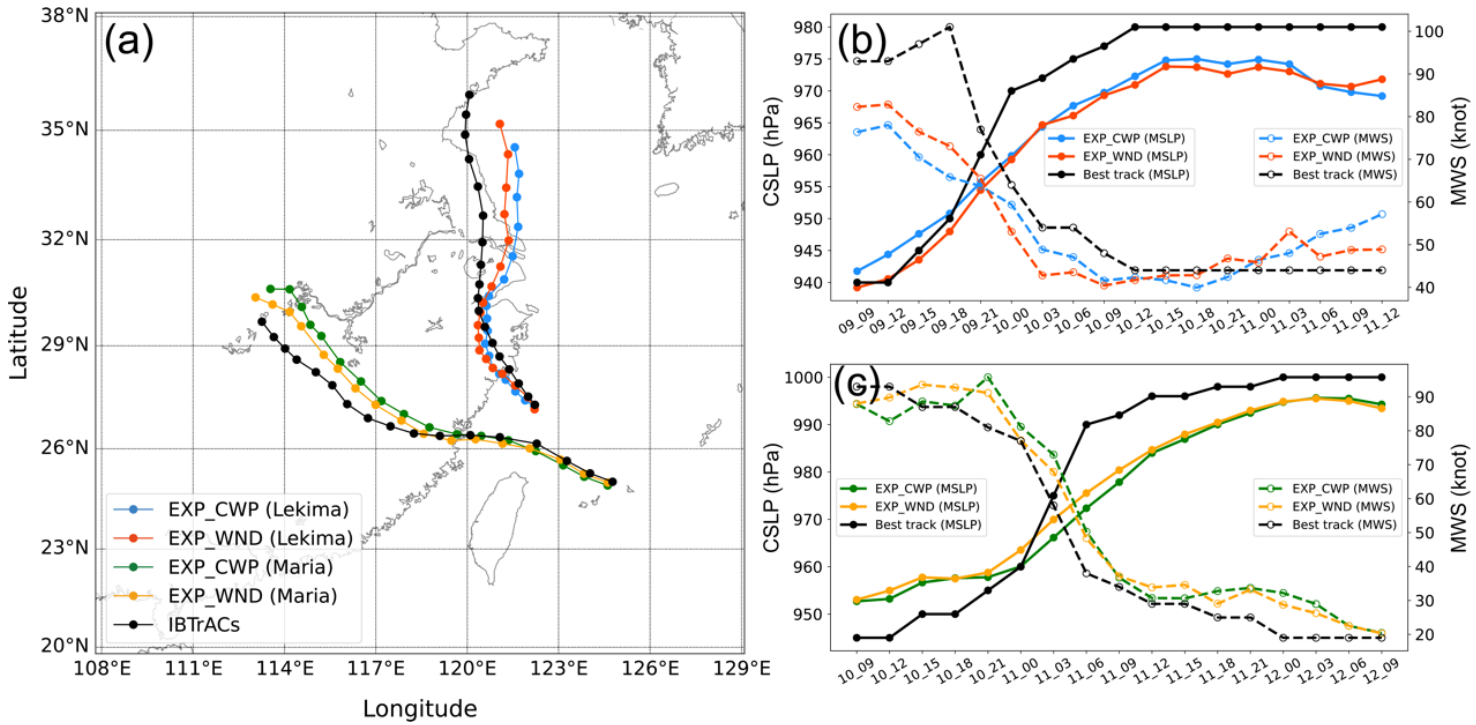
Experiments	Data assimilated
Control Exp	GTS + AHI LWP & IWP
Impact Exp	GTS + AHI LWP & IWP + GIIRS Wind

RMSE difference between EXP_WND and EXP_CWP



The 3D wind (EXP_WND) assimilation improves the model's analysis of winds, temperature, and humidity fields.

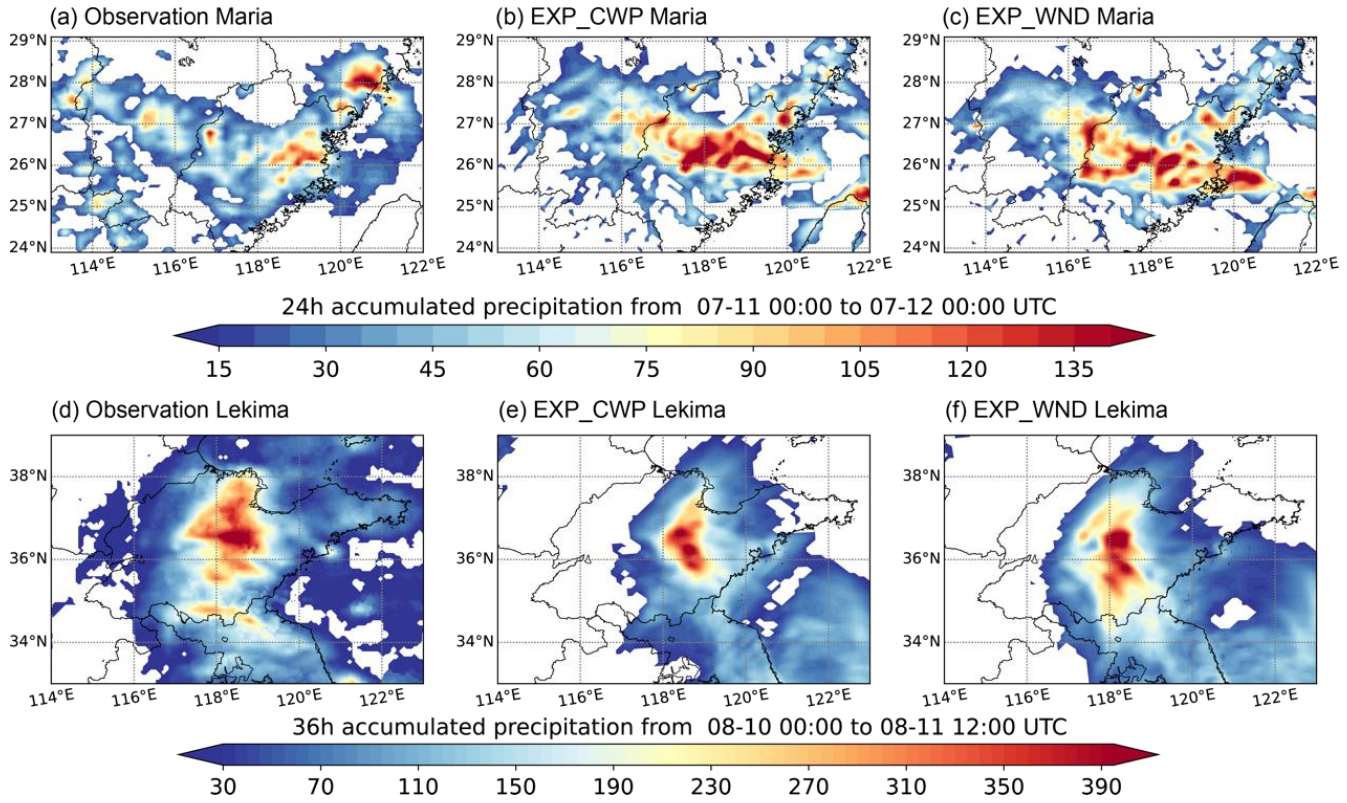
Track and intensity： Maria (2018) and Lekima (2019)



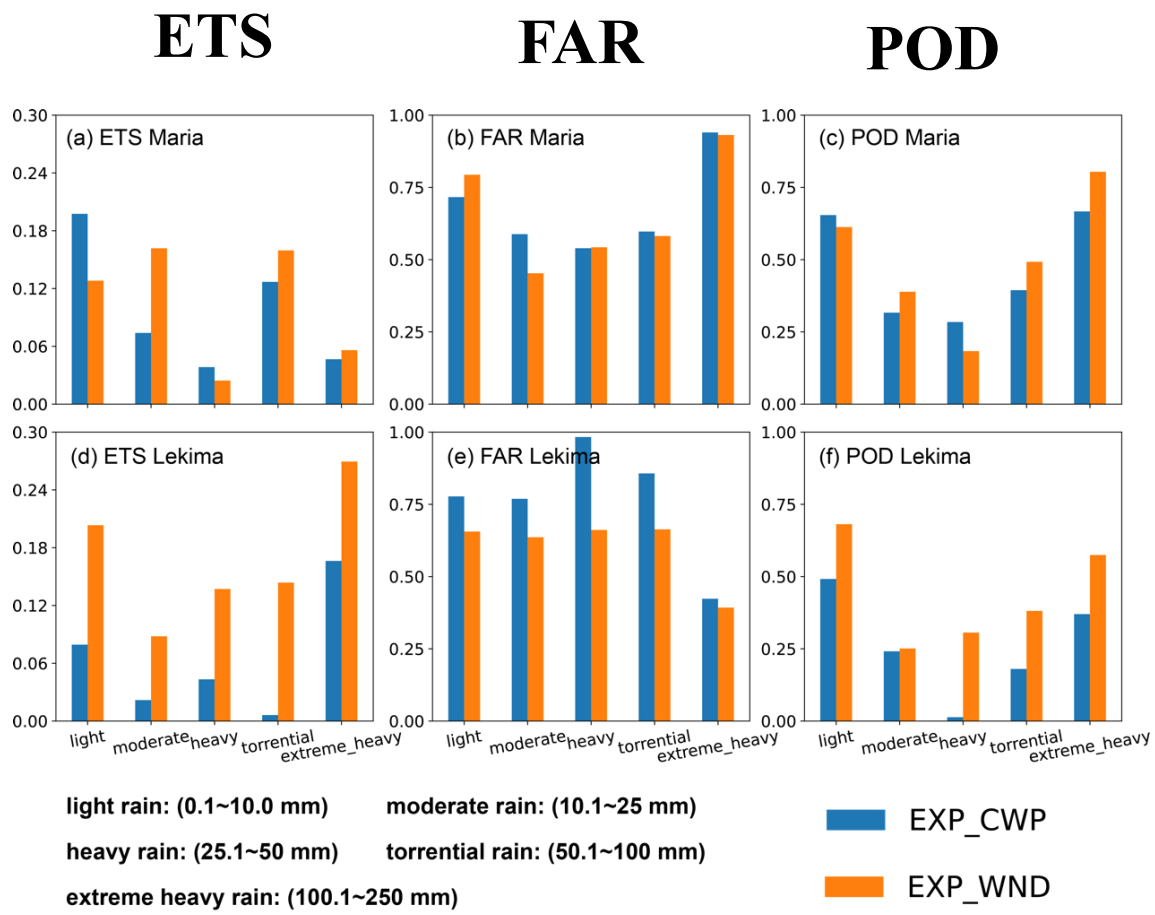
The 3D wind (EXP-WND) improves track and intensity forecasts

Meng, Deming, Zhe-Min Tan*, Jun Li, Zheng Ma, and Yaodeng Chen, 2024: Added value of three-dimensional horizontal winds from Geostationary Interferometric Infrared Sounder for typhoon forecast in a regional NWP Model. Journal of Geophysical Research: Atmospheres, Vol. 129, No. 6, e2024JD040736. https://doi.org/10.1029/2024JD040736

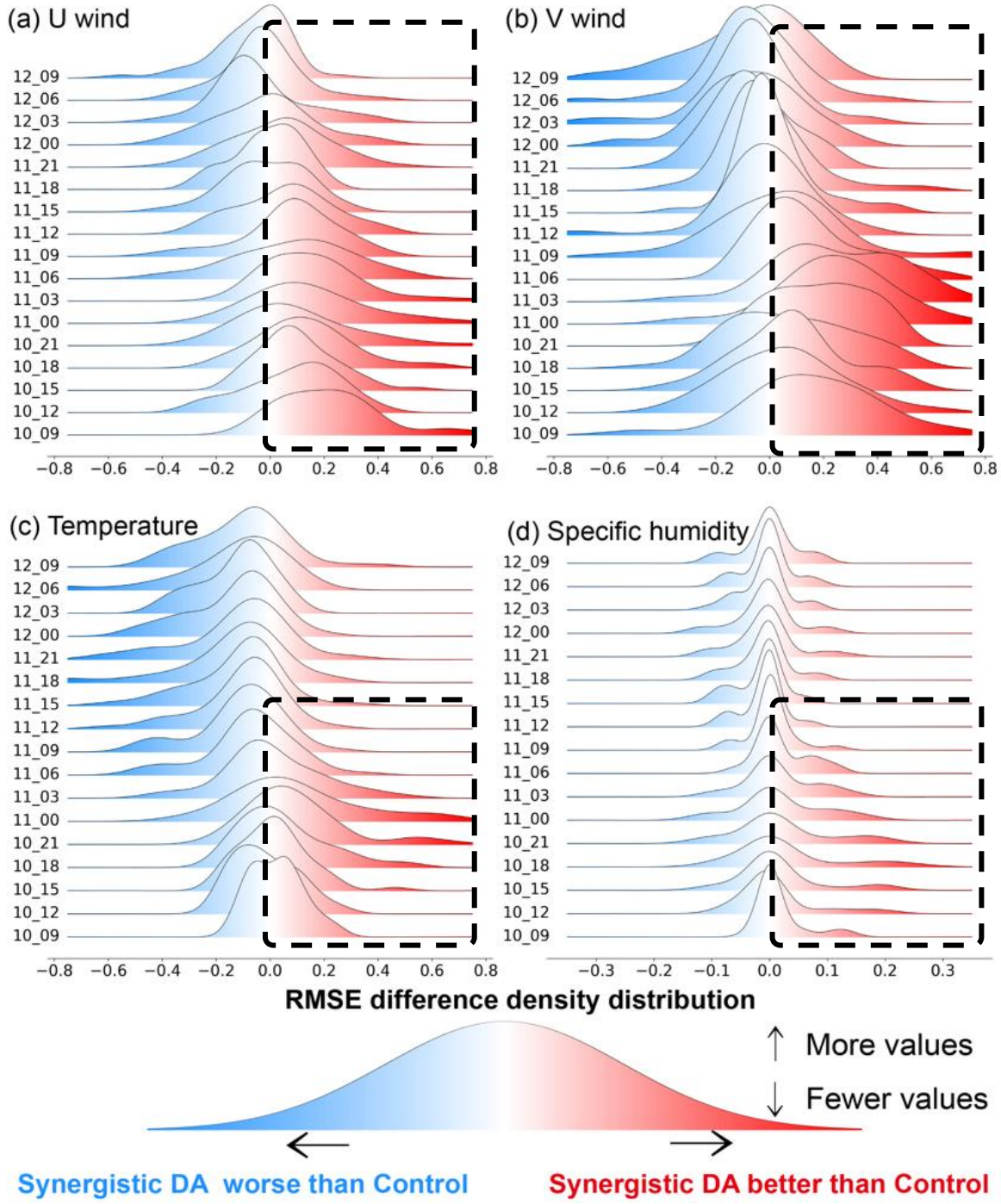
Impact of 3D wind assimilation on precipitation forecasts



After GIIRS 3D wind assimilation, the rainfall forecasts for Maria and Lekima improved.



The results showed that the FAR value decreased and the ETS score increased, especially in the case of heavy rain.



Ridgeline plots of RMSE differential distribution (controlled experiment with reduced impact) show (a) U-wind speed (m/s), (b) V-wind speed (m/s), (c) temperature (K), and (d) specific humidity (g/kg).

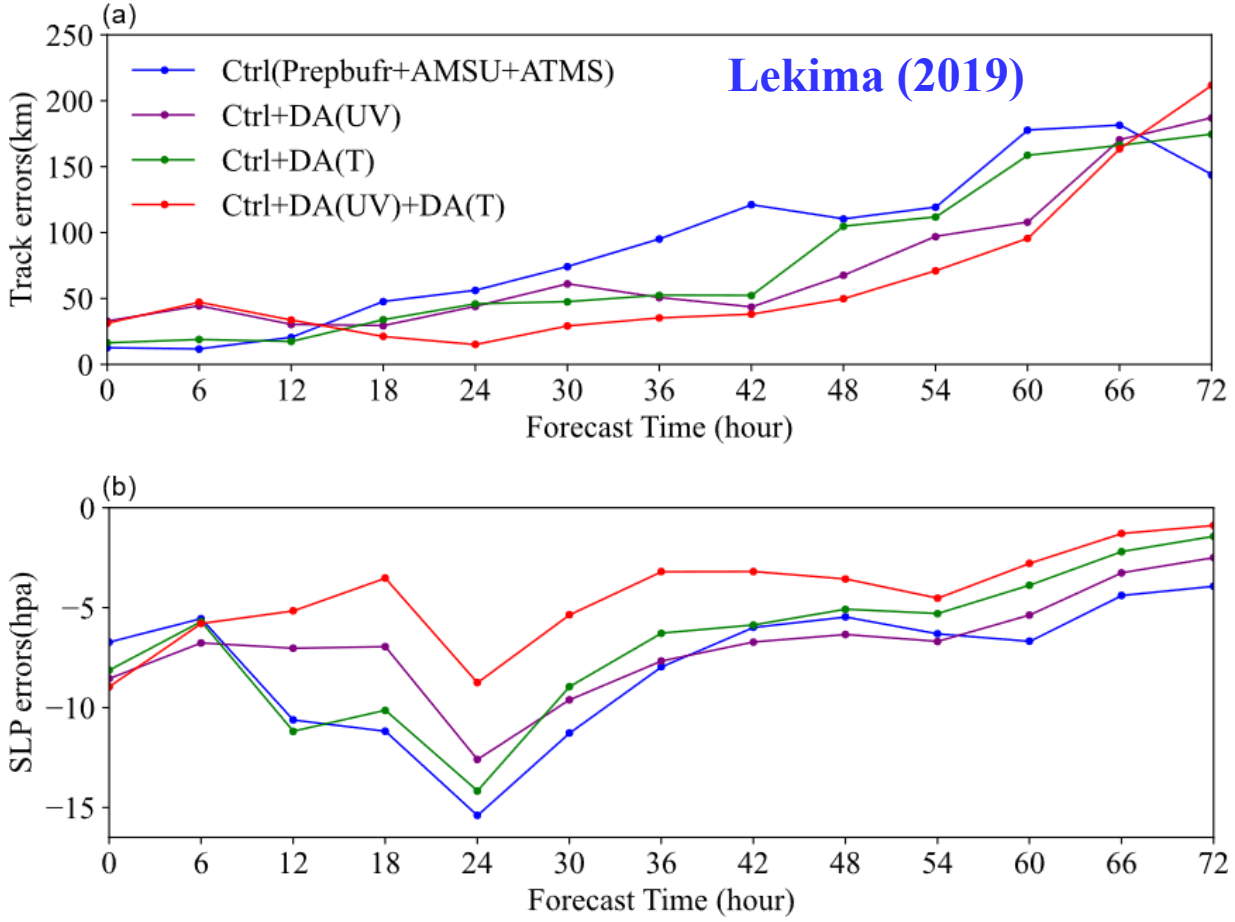
The positive offset between the curves clearly demonstrates the significant advantage of the 3D wind field data assimilation experiment in forecasting U and V winds. Although the improvements in temperature and specific humidity are not as significant as those in the dynamic field, there are still noticeable improvements in the early forecast stages.

Li, J.*, Santek, D., Li, Z., Lim, A., Di, D., Min, M., Velden, C. and Menzel, W.P., 2025. Tracking Atmospheric Motions for Obtaining Wind Estimates Using Satellite Observations—From 2D to 3D. Bulletin of the American Meteorological Society, 106(2), pp.E344-E363.

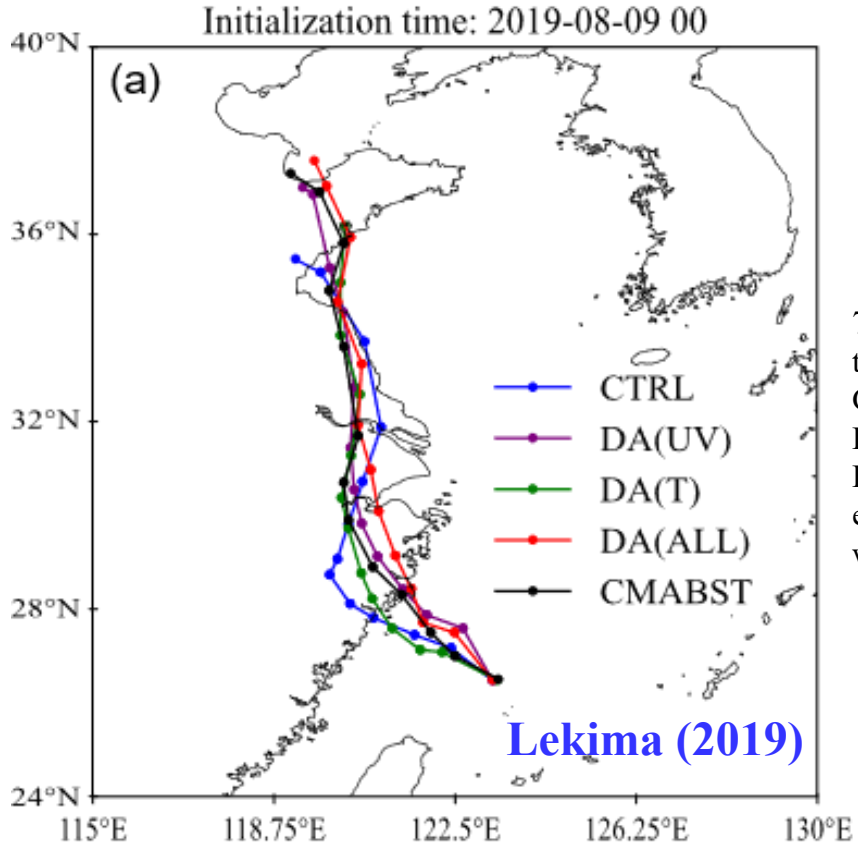
Q2: GIIRS provides thermal and dynamic information. When 3D wind field data is used in conjunction with thermal information, what additional value does it bring to TC forecasting?

(1) Both thermal and dynamic information from GIIRS have a positive impact on TC forecasts, and the combination of the two can produce the best effect, reducing the 48-hour intensity forecast error by up to 50%;

(2) Regional NWP (WRF/WRFDA) assimilation studies show that dynamic information has a greater impact than thermal information.



Statistical analysis of 72-hour (a) track forecast errors and (b) minimum sea level pressure (SLP) forecast bias for multi-initial times in the assimilation experiments compared with the best track.

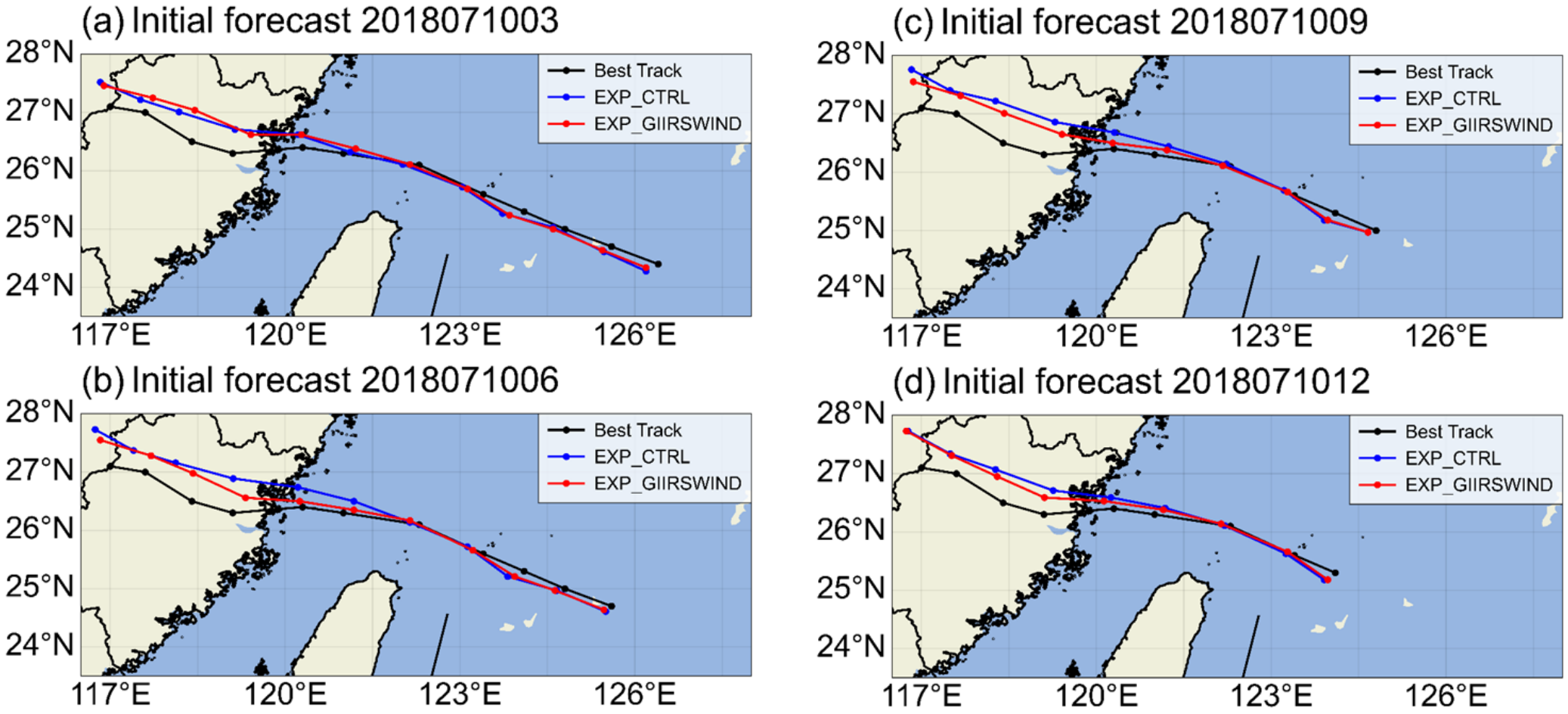


72-hour typhoon track forecasts of CTRL, DA(UV), DA(T), and DA(ALL) experiments along with the best track.

Liu, Y.A., Zhang, Z., Li, J.*, Li, Z., Min, M., Di, D. and Bai, W., 2025. Impacts of thermodynamic and dynamic information from geostationary hyperspectral infrared sounder on tropical cyclone forecasts. *Journal of Geophysical Research: Atmospheres*, 130(5), p.e2024JD042194.

Q3: What is the potential value of 3D wind fields in operational NWP?

In CMA regional operational NWP model CMA-MESO, assimilating the GIIRS 3D winds has a positive impact on typhoon forecasting.



(1) The added value of 3D winds in the CMA operational regional model (CMA-MESO) was verified;

(2) It was revealed that the dynamic field has a greater impact on typhoon numerical forecasting than the thermal field in the regional NWP.

Wang, H., Han, W., Li, J., Chen, H. and Yin, R., 2025. Impact of assimilation of FY-4A GIIRS three-dimensional horizontal wind observations on typhoon forecasts. Advances in Atmospheric Sciences, 42(3), pp.467-485.

Content

- Fengyun sounding product
- Applications of GIIRS in NWP
- Applications of Fengyun sounding products in nowcasting
- GIIRS for atmospheric composition
- Summary

(1) Cold wave and associated rain and snowstorm monitoring

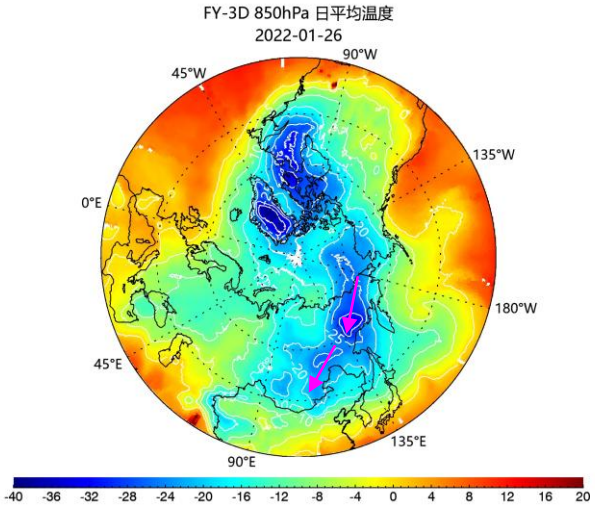
Cold Wave

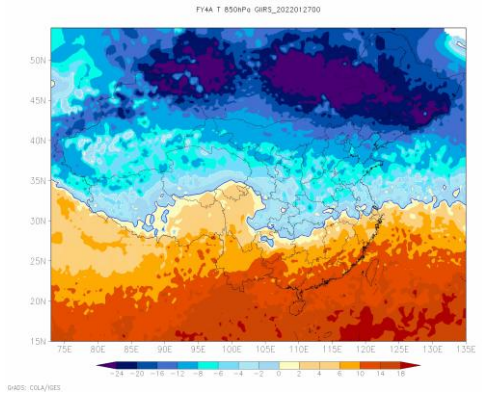
Monitoring of cold air activities in polar regions during the mid-term period

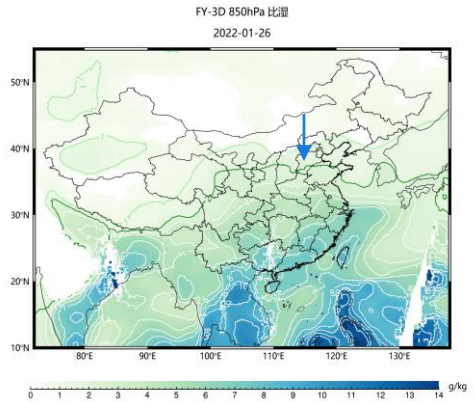
Monitoring cold wave using soundings

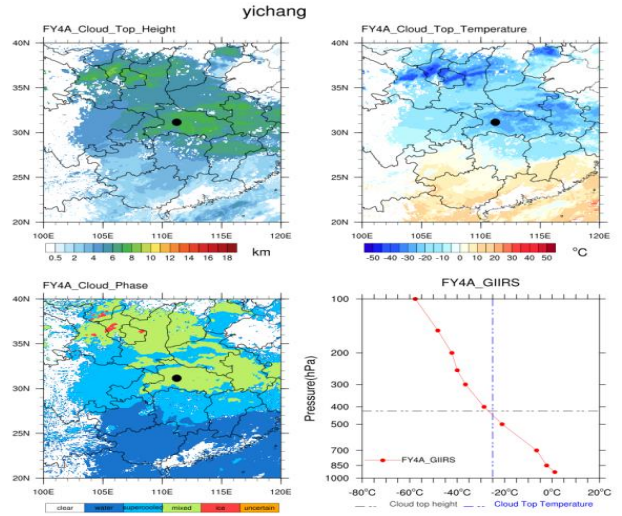
Monitoring of cold air activities

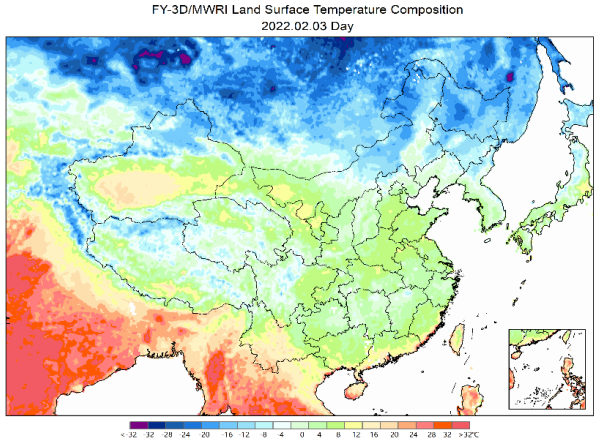
Rain and snow phase analysis using cloud and temperature parameters

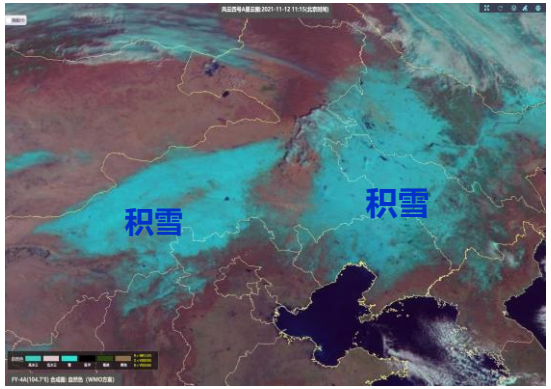


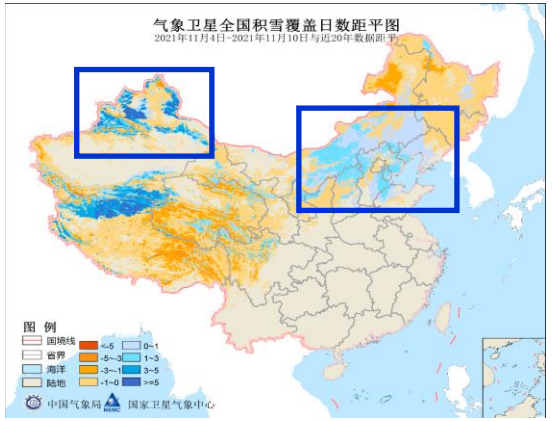












Monitoring and analysis of surface parameters affected by cold waves

Application of FY-4/GIIRS Temperature in Monitoring East Asian Cold Wave from November 26th to December 1st, 2022

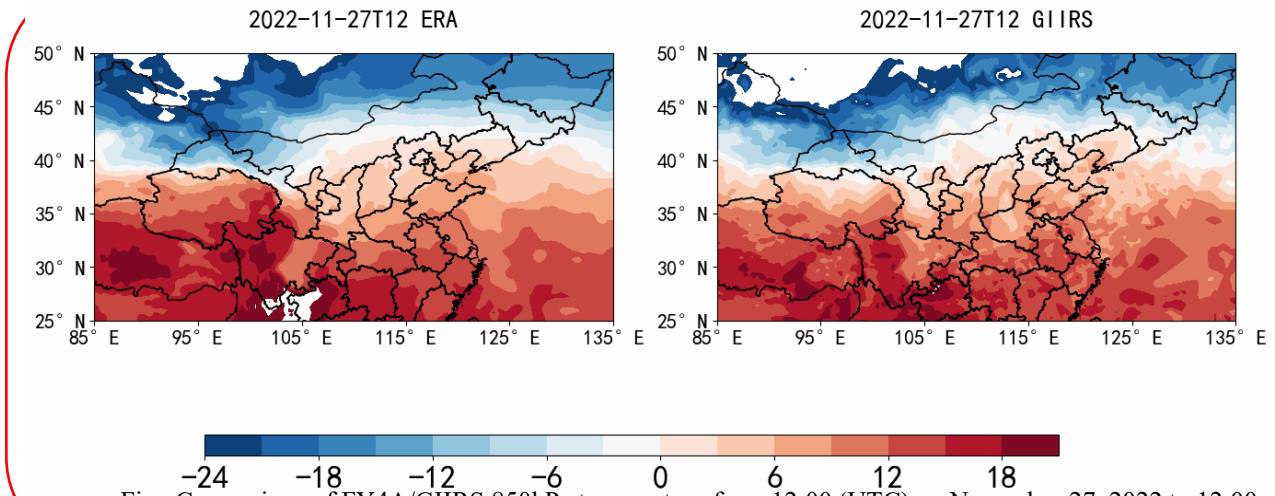


Fig Comparison of FY4A/GIIRS 850hPa temperature from 12:00 (UTC) on November 27, 2022 to 12:00 (UTC) on December 1, 2022

FY4A/GIIRS temperature monitoring reveals that the movement characteristics of cold air in the lower troposphere are consistent with the temperature characteristics of ERA5

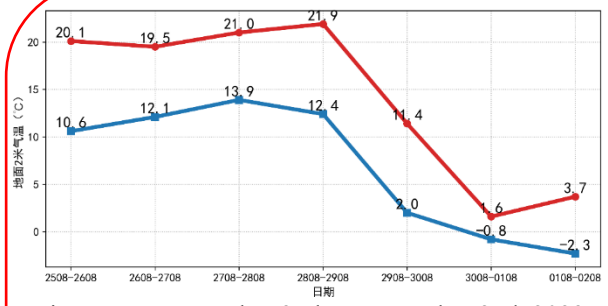
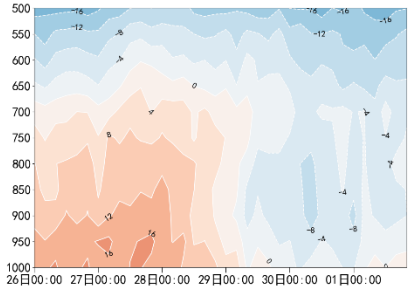
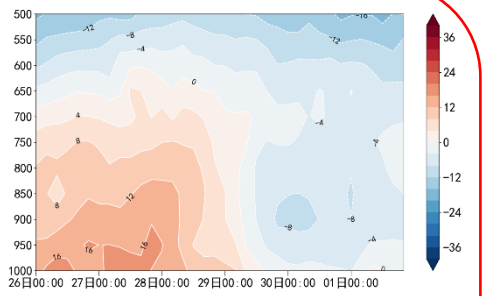


Fig From November 25th to December 2nd, 2022, the highest (red) and lowest (blue) 2M ground temperatures of Hefei Station ((117.3E, 31.8N)



Changes of FY-4A/GIIRS with altitude over Hefei Station ((117.3E, 31.8N)

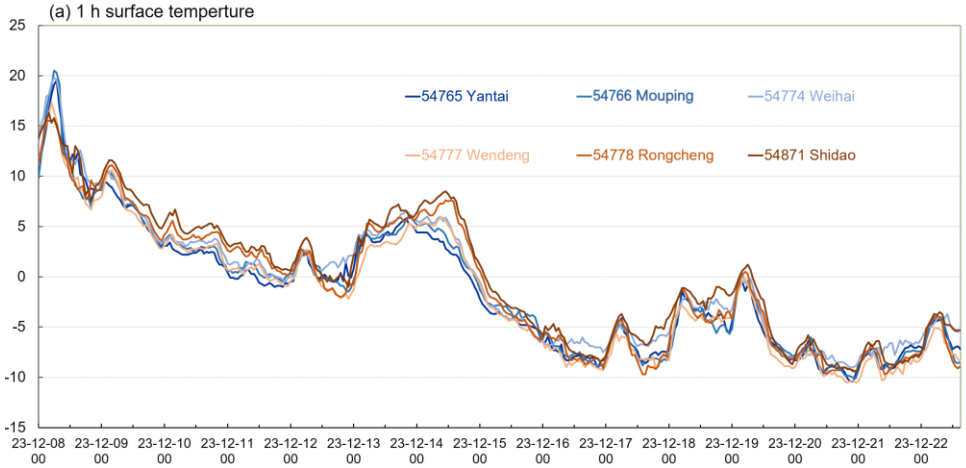


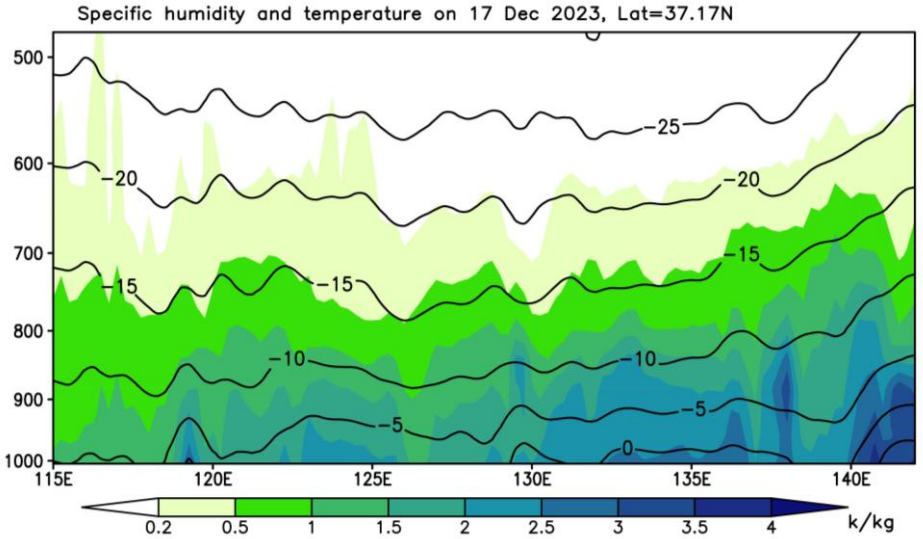
Changes of ERA5 with altitude over Hefei Station ((117.3E, 31.8N)

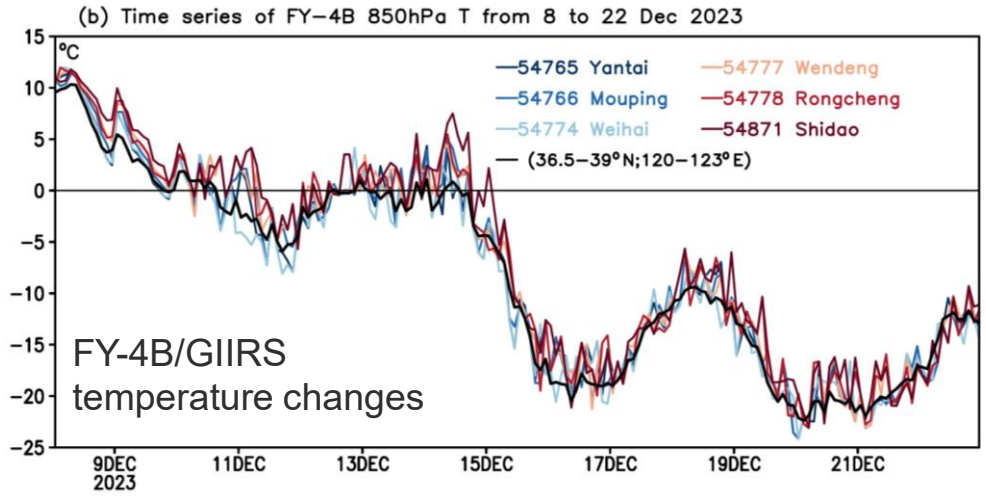
Using FY-4A/GIIRS temperature data and ERA5 temperature data, we analyzed the temporal variation characteristics of the cold air over Hefei station, which are basically consistent with the evolution characteristics of the actual surface temperature. However, the cold air temperature analyzed from the FY-4A/GIIRS temperature data at the same height level is generally lower than that from the ERA5 temperature data analysis

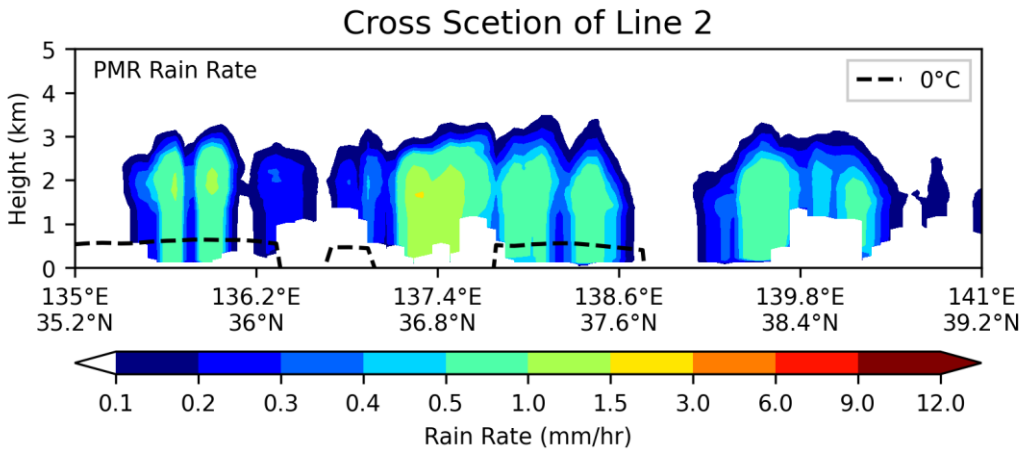
Applications of soundings in snowstorm monitoring

In December 2023, China's strong cold wave set new records for low temperature and snow accumulation in many places (the polar vortex activity caused cold current snowfall in Shandong, and the snow depth reached 74 cm on the 22nd at Zhongwendun, significantly breaking the provincial record)



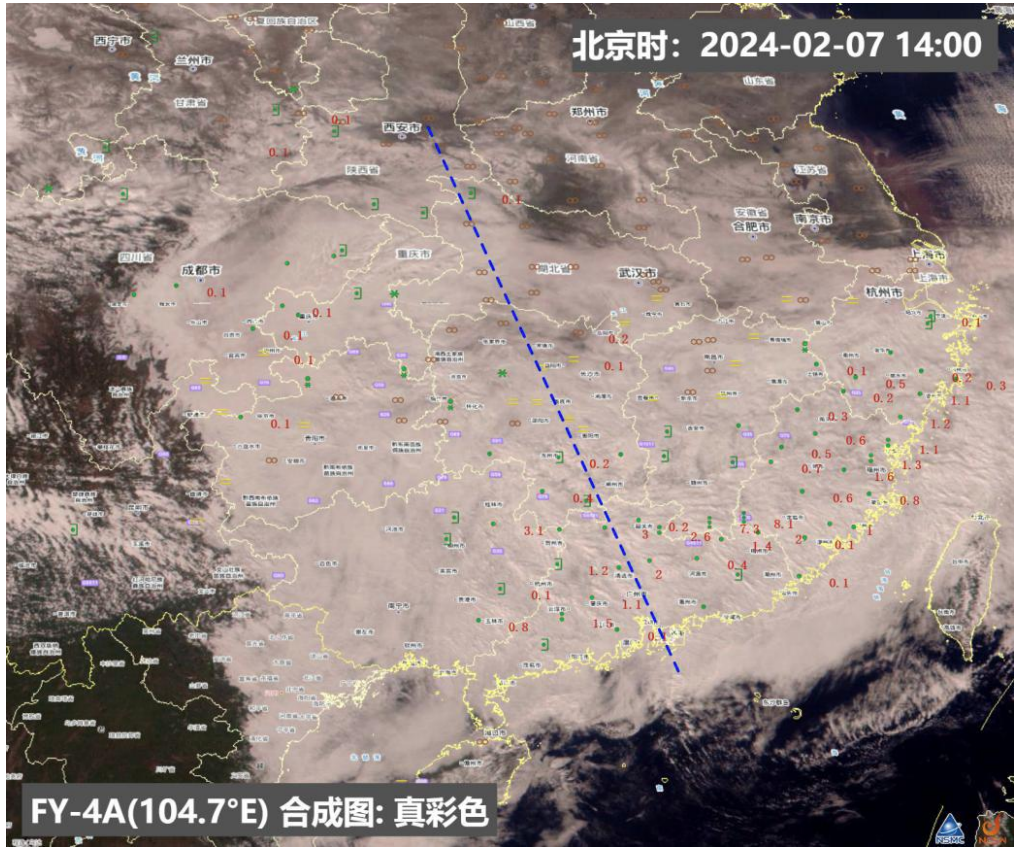


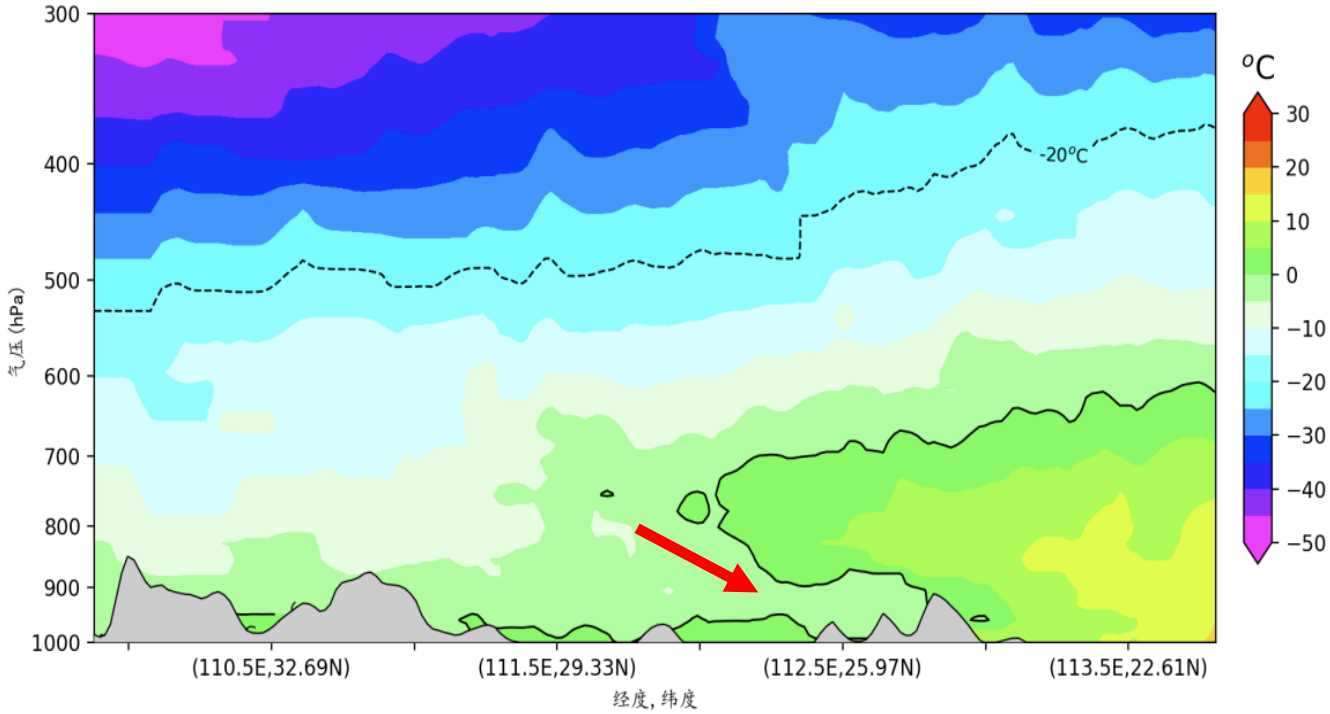




(2) Applications of soundings in Frozen rain monitoring

Frozen rain: Meteorological satellite monitors rain, snow and freezing weather in central and eastern China: On February 7, 2024, under the combined influence of cold and warm air, rain, snow and freezing weather continued in central and eastern my country.





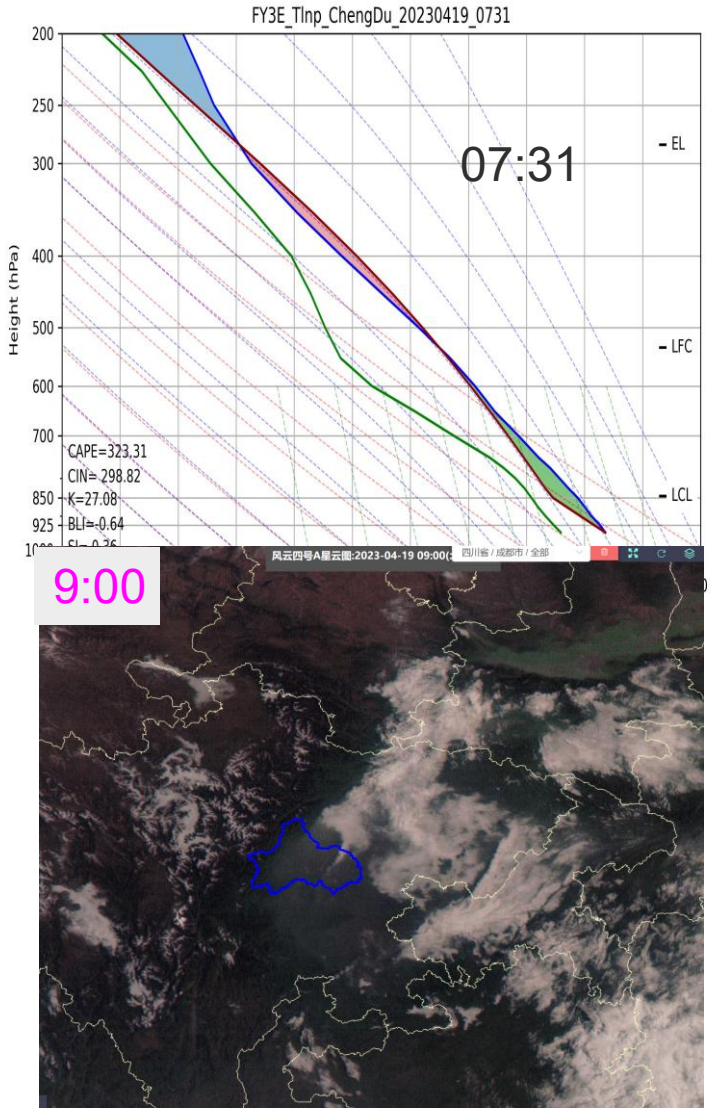
Temperature inversion: FY-4A GIIRS vertical temperature profile (profile location along the blue dashed line on the left) (10:00 on February 7, 2024)

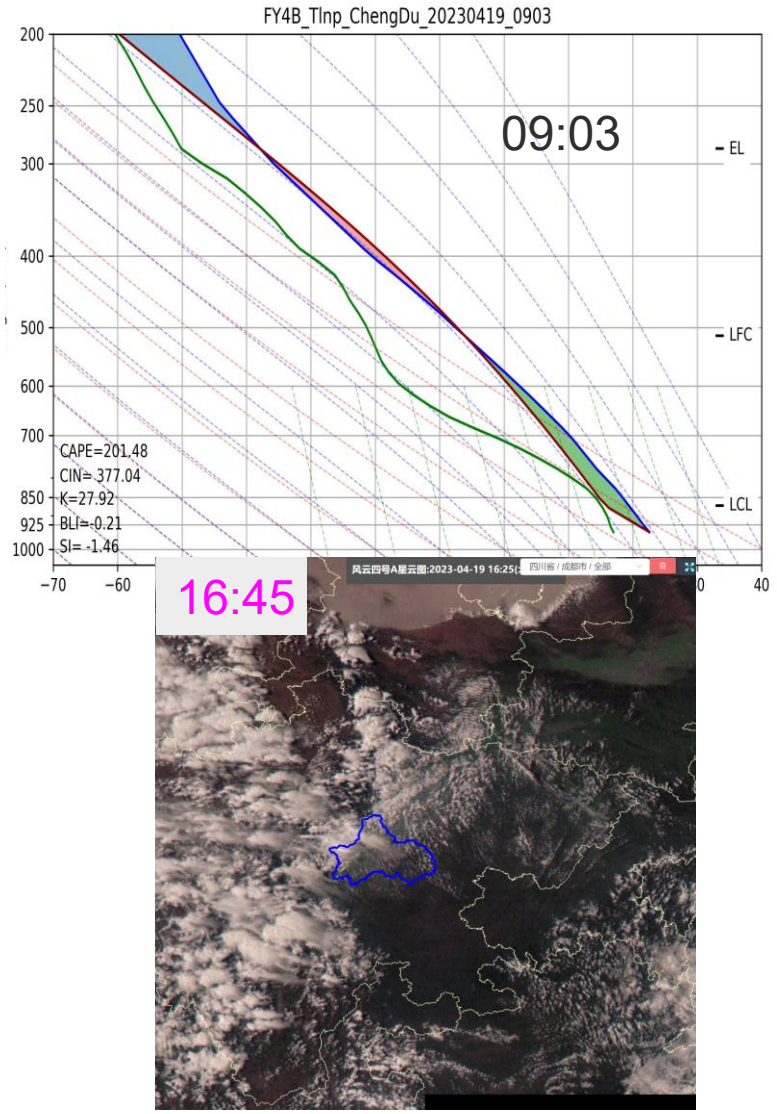
The inversion layer and the vertical distribution of temperature are indicative of freezing rain

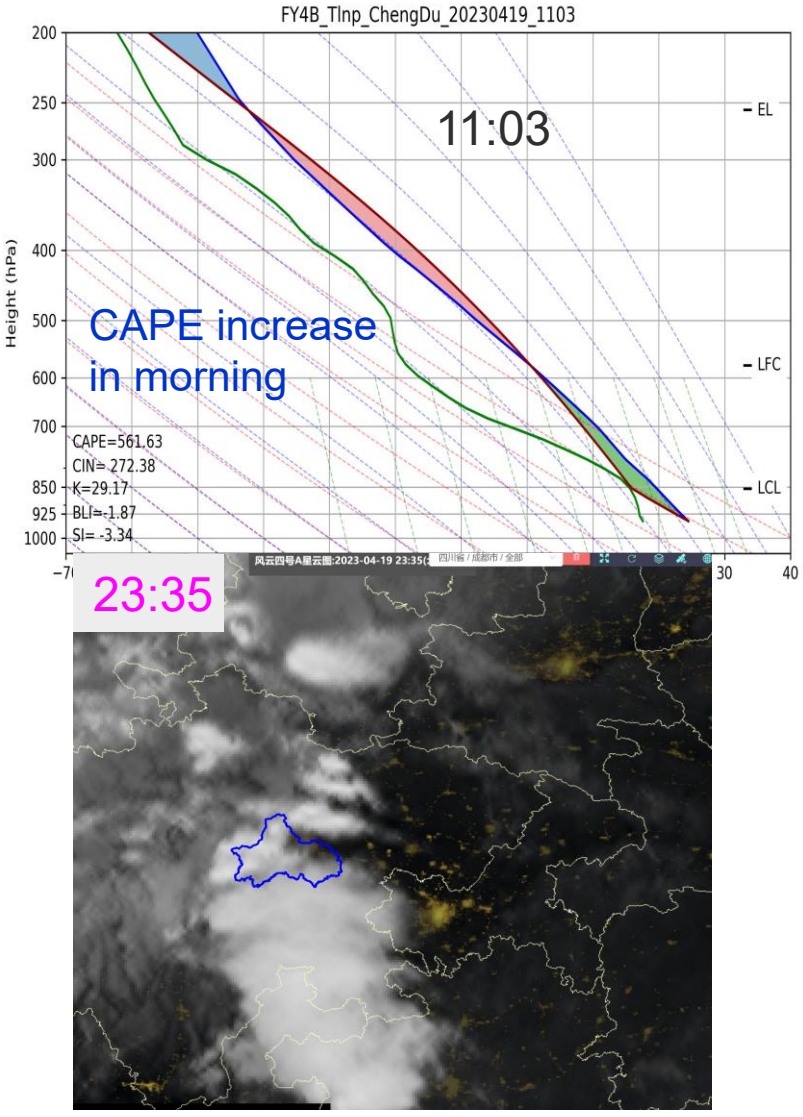
(3) Applications of soundings in convection monitoring

Convective storm: During the morning session, the unstable energy in the clear sky atmosphere monitored by FY-4/GIIRS increased, which is beneficial for the development of convection in the afternoon and at night

Environmental characteristics of heavy rain and severe convective weather FY-3D FY-3E FY-4B joint application April 19, 2023



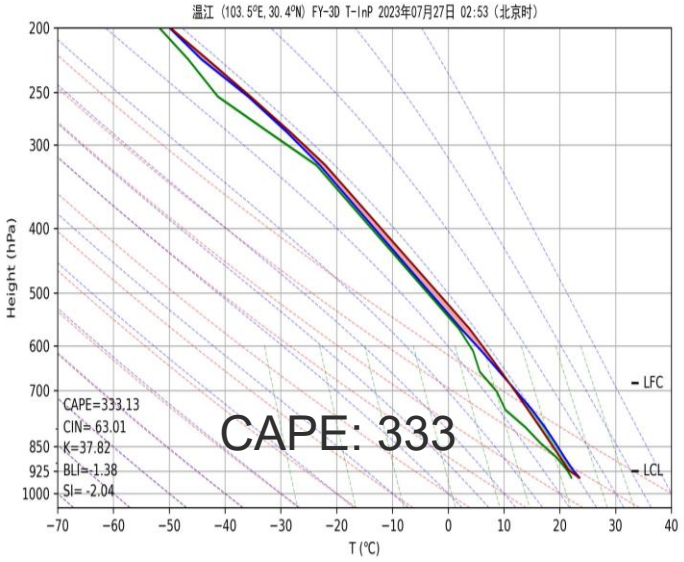




(4) Applications of soundings in event service

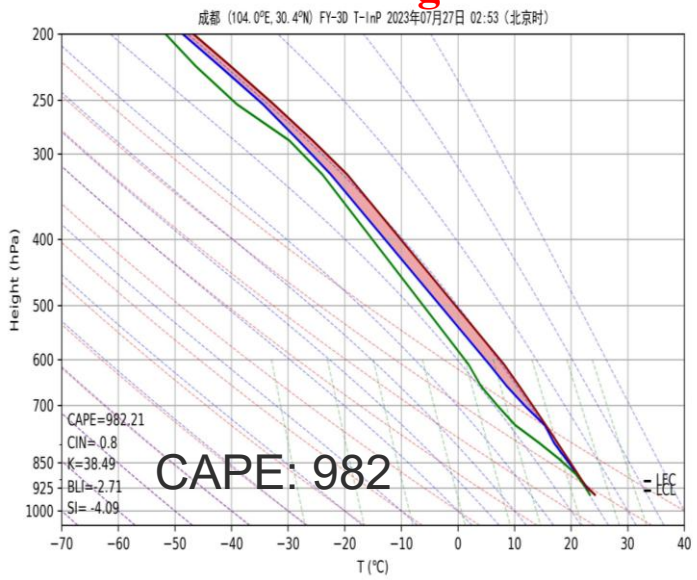
Satellite sounding T-lnP at 03:00 on 27th

Wenjiang

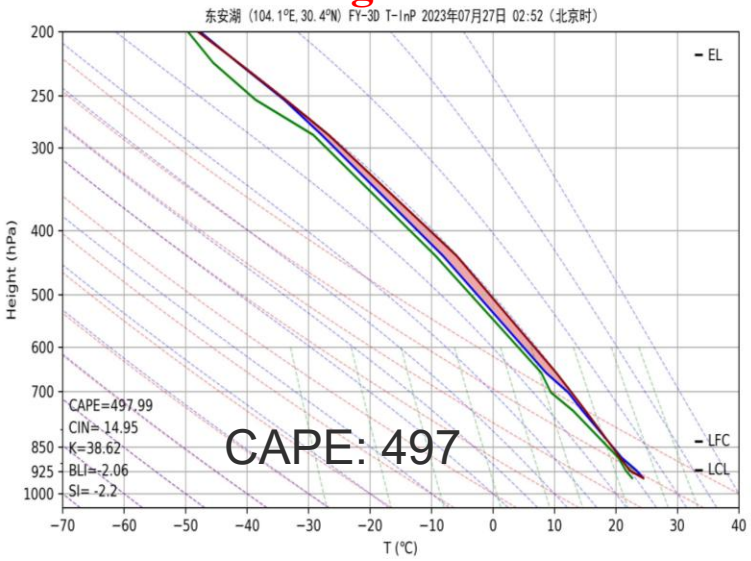


West of service area

Chengdu



Dongan Lake

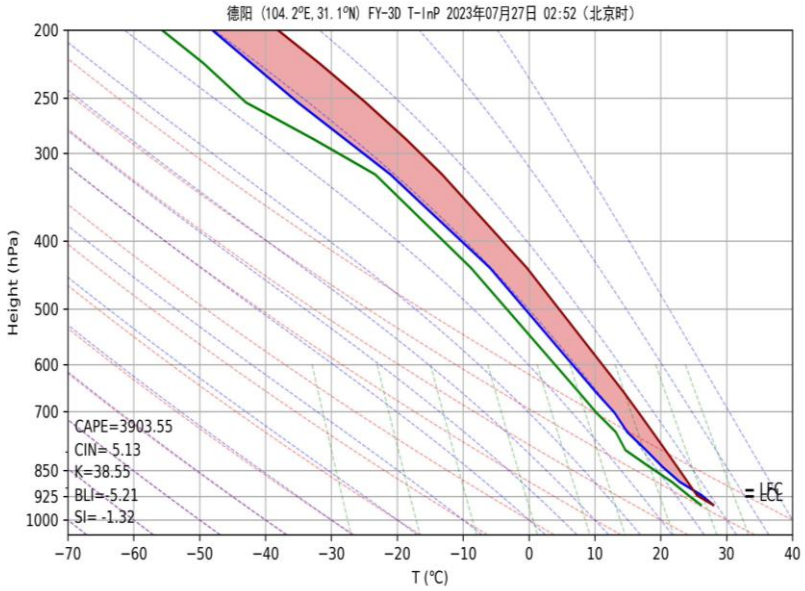


On the 27th, the atmospheric energy CAPE on the north side of the service area is large, which is conducive to heavy rainfall

Meteorological service for World University Games Summer

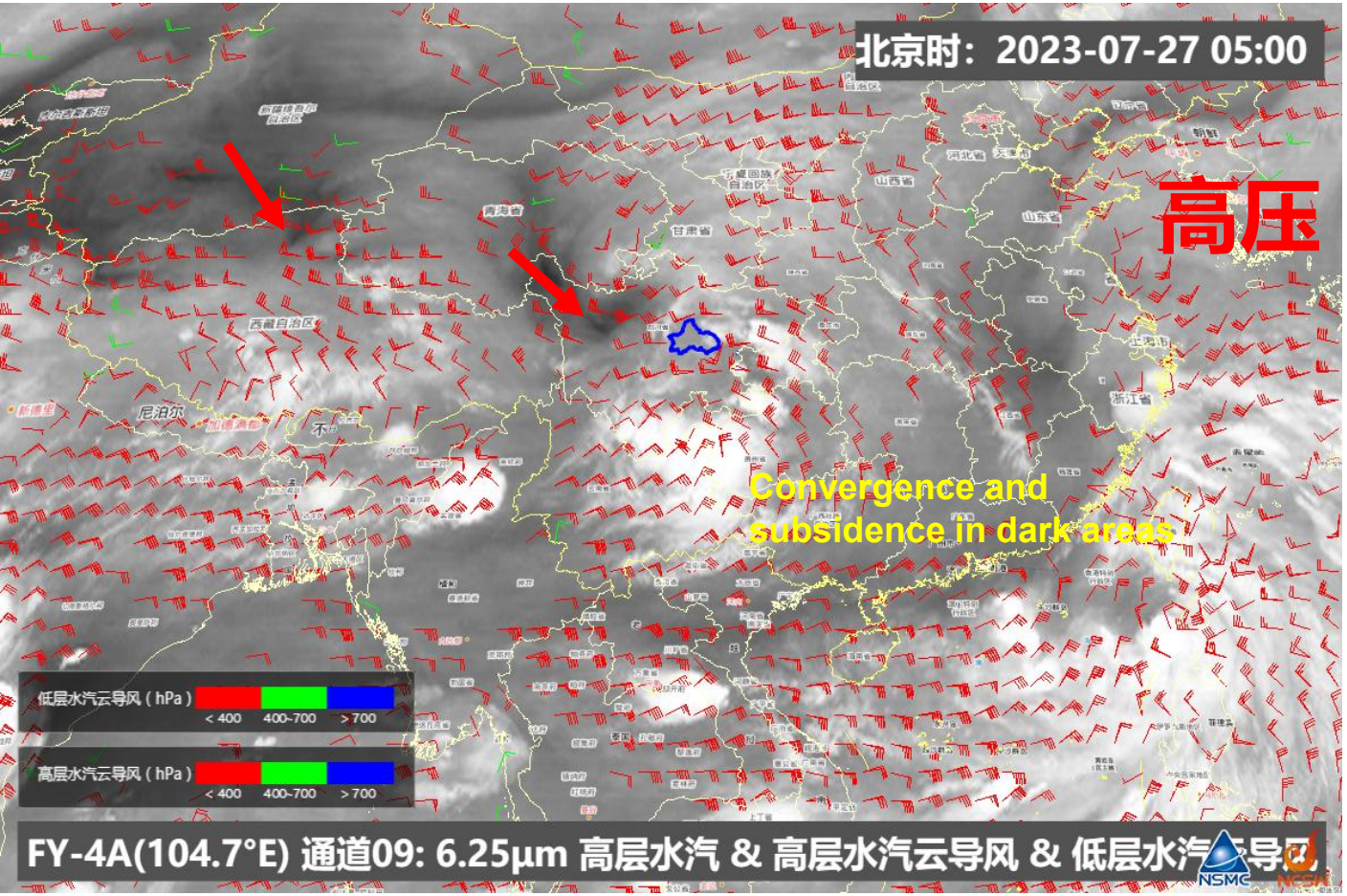
Temperature and humidity characteristics on the 27th

Deyang

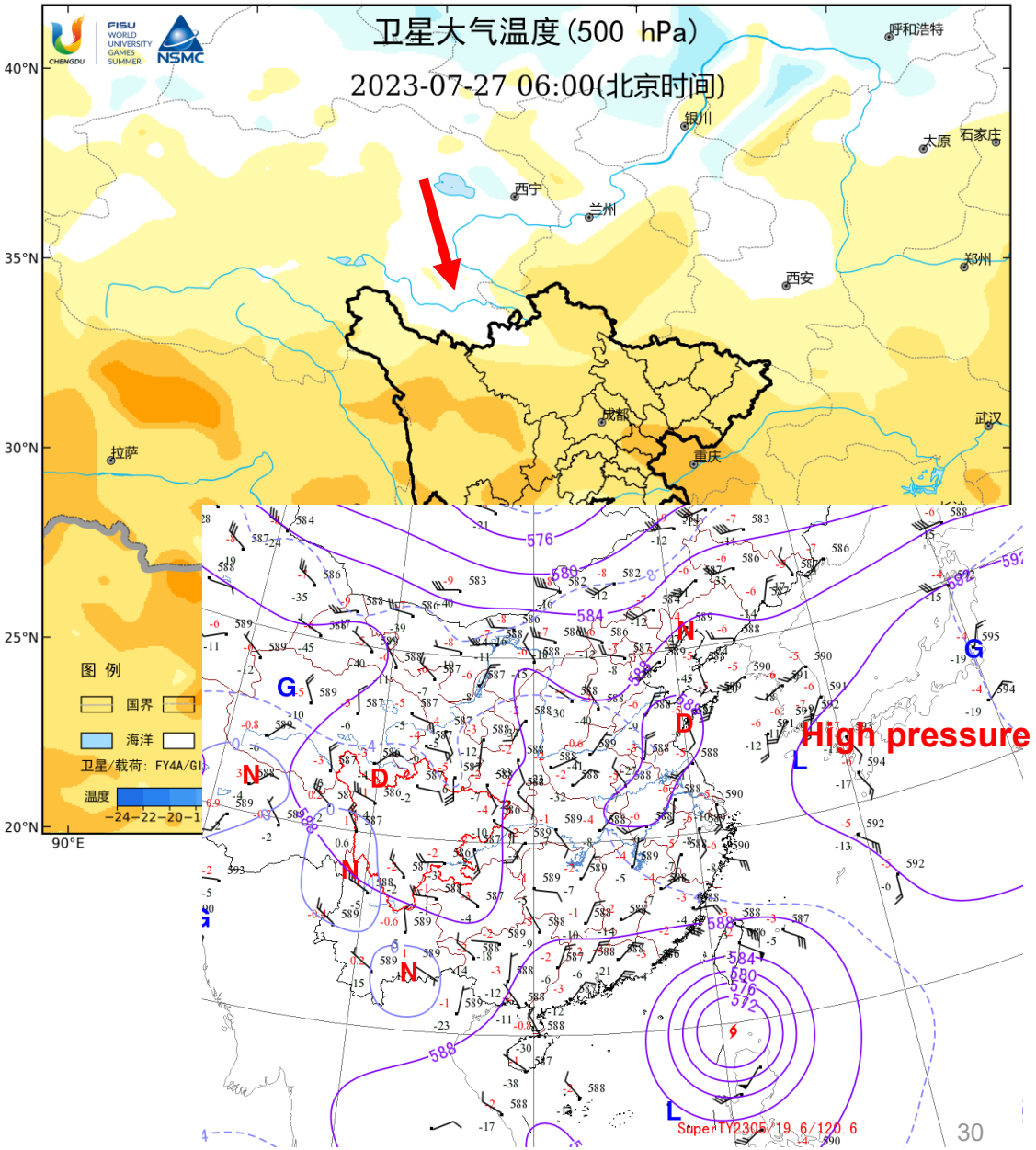


North of service area

Applications of soundings in event service



GIIRS 500 hPa Temperature

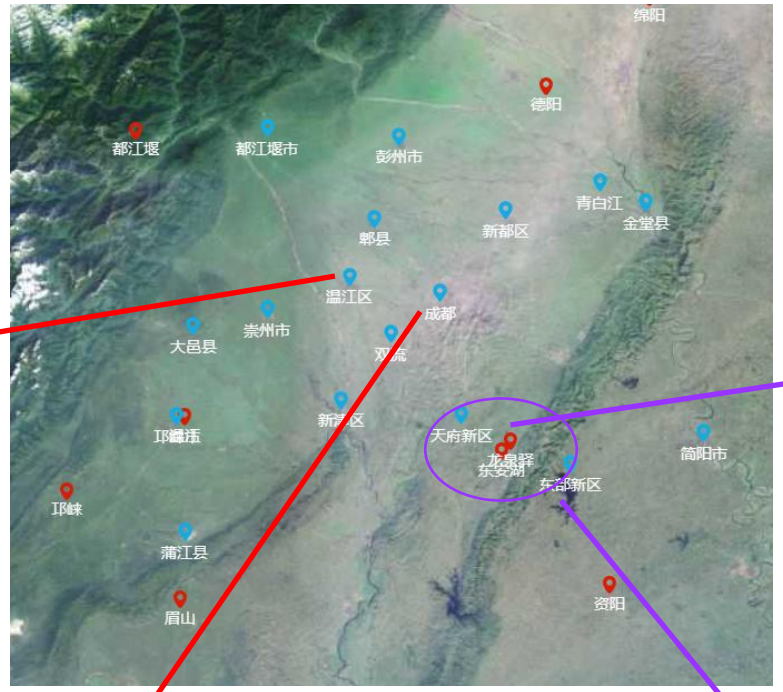


Evolution of Weather Systems

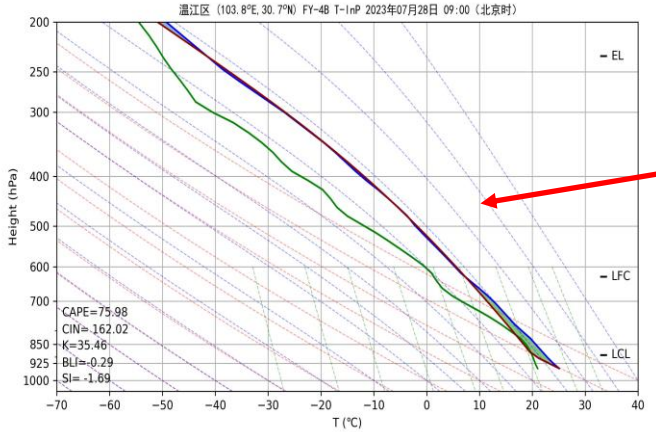
On the 27th, a plateau vortex moved eastward on the northwest side of Chengdu, and the FY-4/GIIRS 500 hPa temperatures showed cold air activity.

Applications of soundings in event service

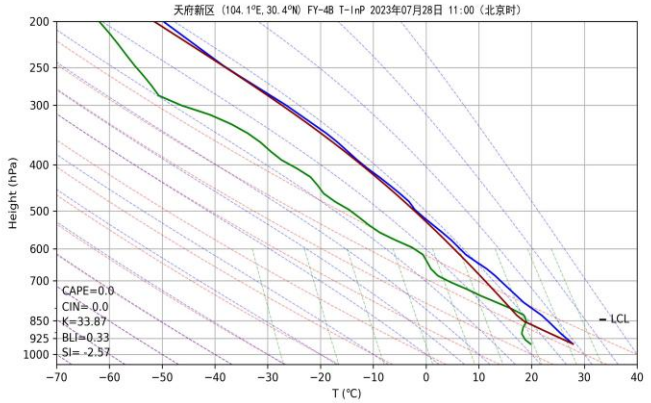
FY-4B GIIRS T-lnP on 28th



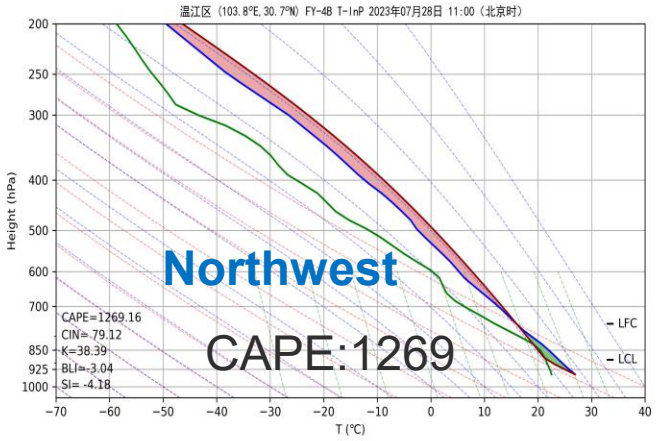
Wenjiang 09 BJT



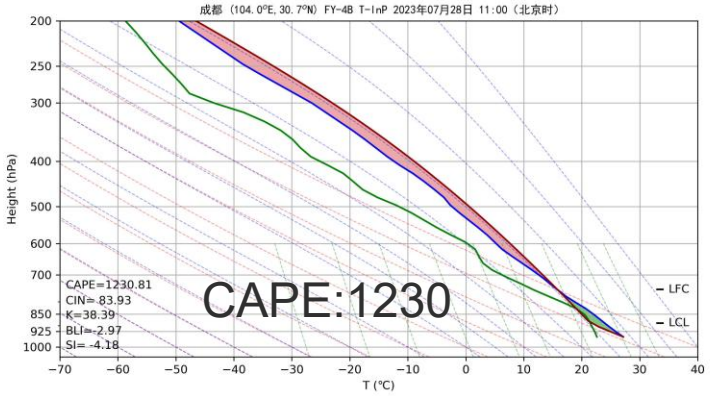
Tianfu District 11 BJT (no rain)



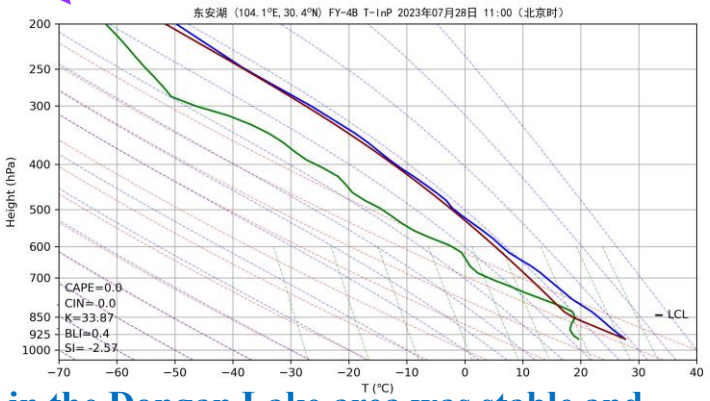
Wenjiang 11 BJT



Chengdu 11 BJT

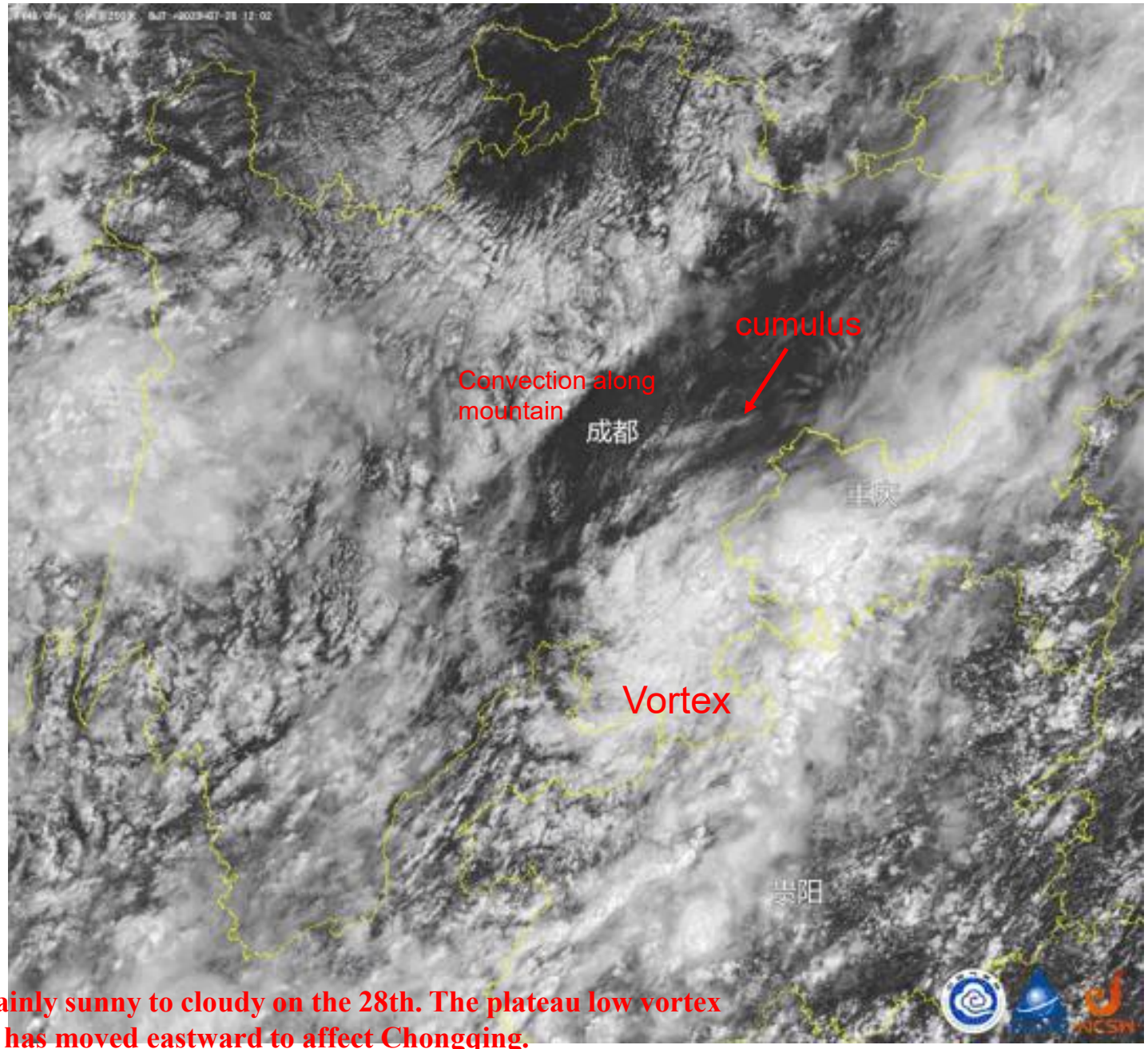


Dongan Lake 11 BJT (No rain)



On the morning of the 28th, FY-4B/GIIRS T-lnP observations showed that the atmospheric structure in the Dongan Lake area was stable and favorable for clear weather

FY-4B VIS (July 28, opening ceremony)



The service area will be mainly sunny to cloudy on the 28th. The plateau low vortex precipitation cloud system has moved eastward to affect Chongqing.

Content

- Fengyun sounding product
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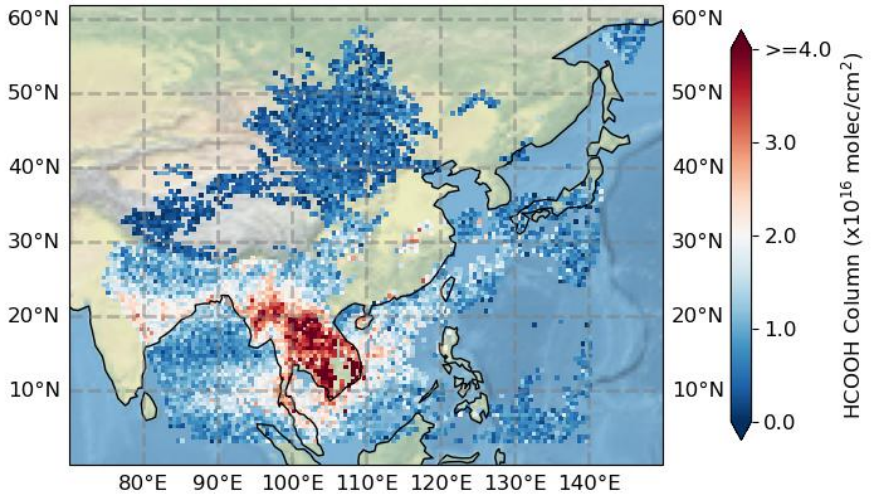
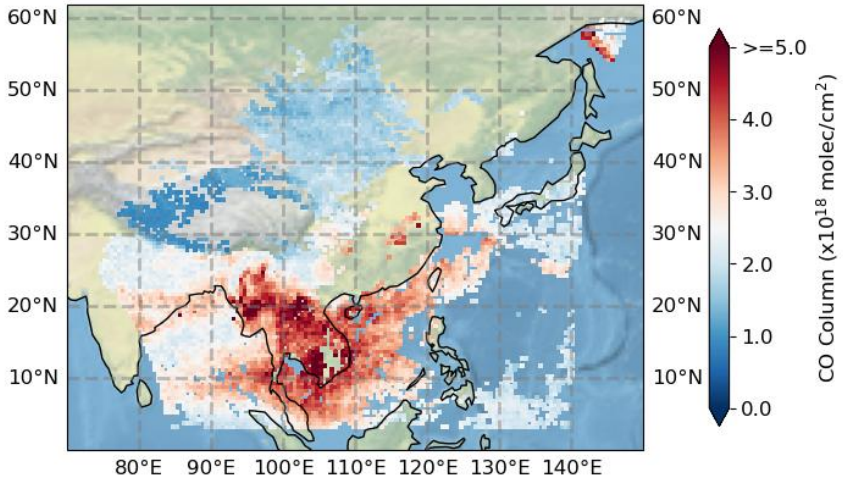
(1) Wildfire CO, NH_3, HCOOH columns from FY-4B/GIIRS

(a) Fire emissions in Southeast Asia

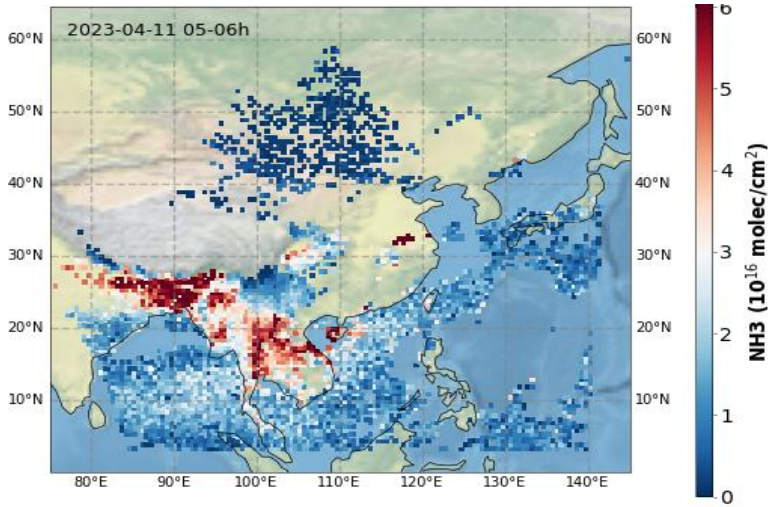
(c) HCOOH column retrievals



(b) CO column retrievals



(d) NH_3 column retrievals



(a) Intense fire emissions in Southeast Asia (Jan to Apr)
#slash-and-burn agriculture;
#loggers use fire to clear roads and lands
#cool and dry weather

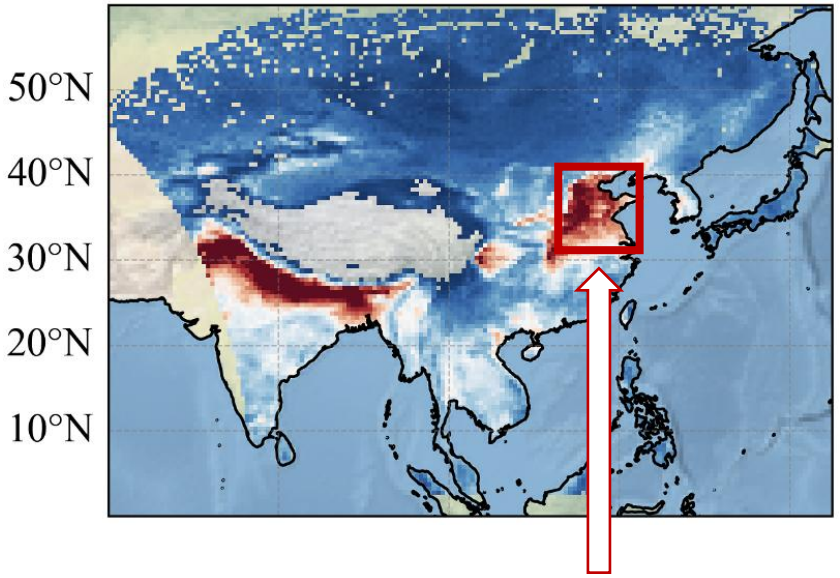
Examples: 11 April 2023, local noontime

(b) CO retrievals from GIIRS tracks the long-range transport (lifetime: weeks to months);

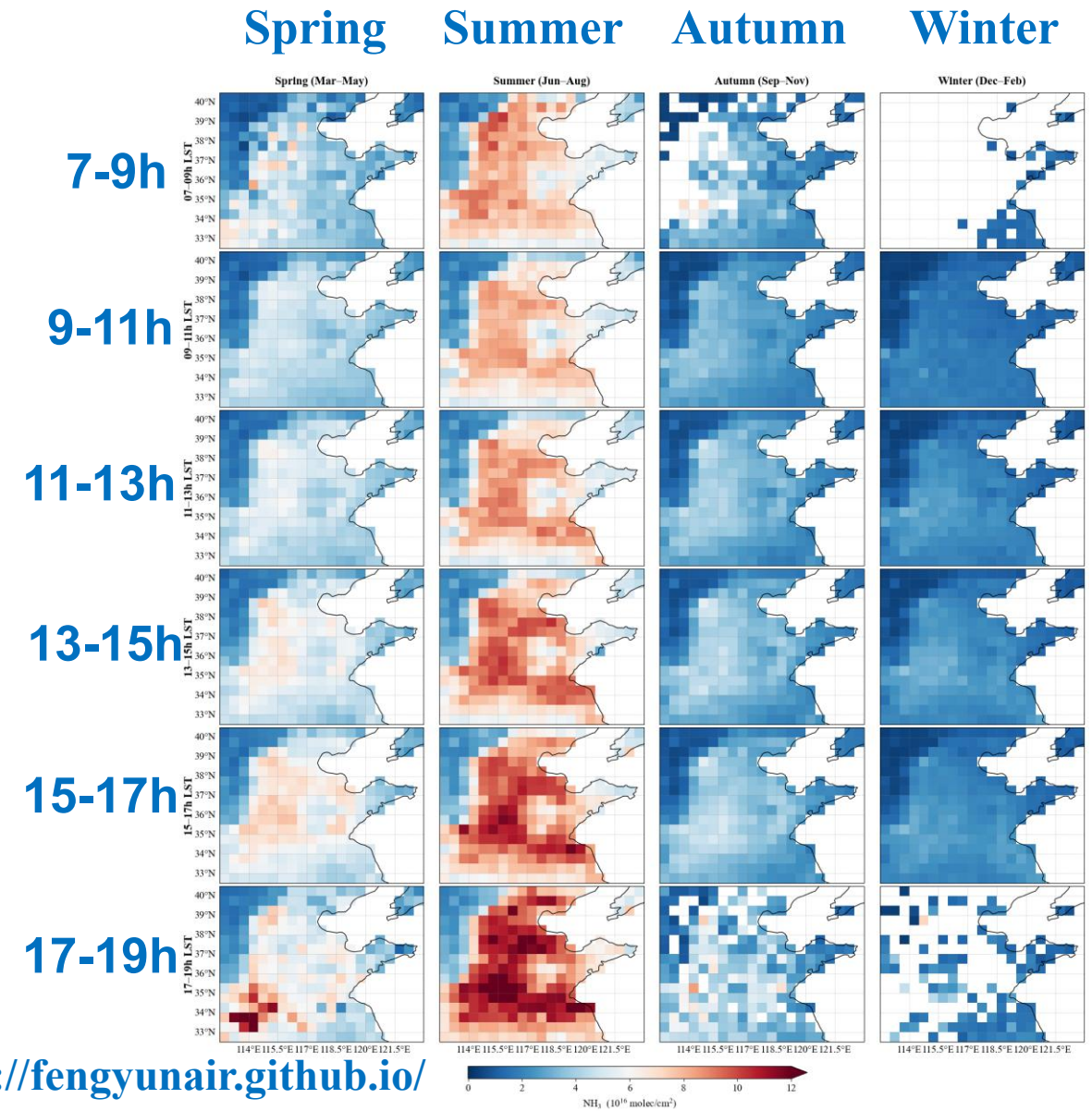
(c) and (d): **HCOOH and NH3** emissions show similar patterns, but with shorter range (shorter lifetime)

(Zeng et al., 2023a,b, AMT; Zeng et al., 2024, JGR-A)

(2) Diurnal NH_3 Columns from GIIRS (North China Plain)



- Much higher NH_3 in the summer;
- The NH_3 columns generally increase from early morning to late afternoon;
- Hotspots may have changed in later afternoon.

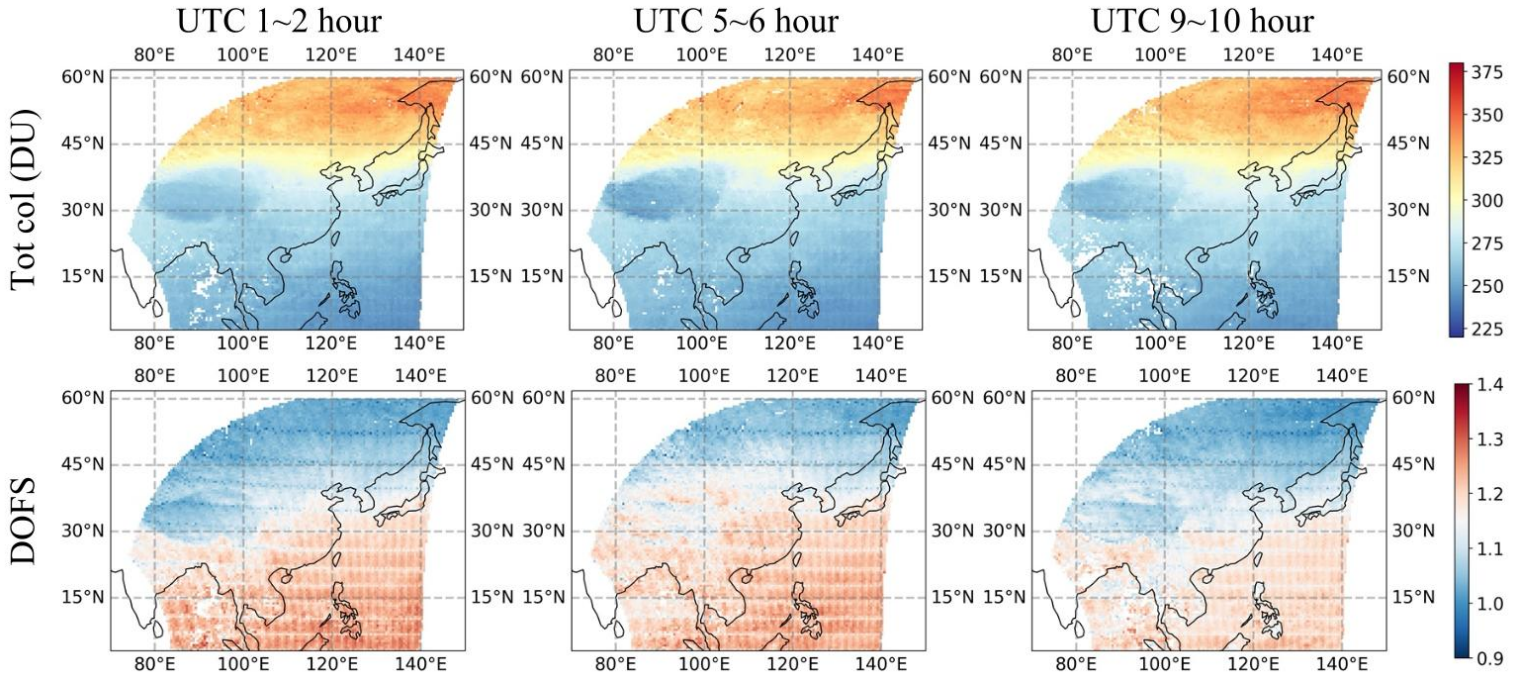


Sheng et al., 2025, ACPD

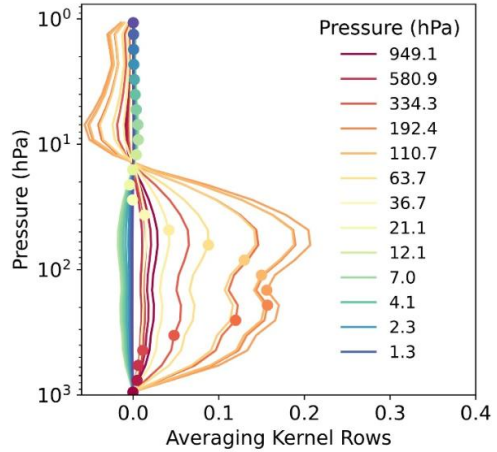
GIIRS NH3 data are publicly available at: https://fengyunair.github.io/

(3) Total ozone column from FY-4B/GIIRS

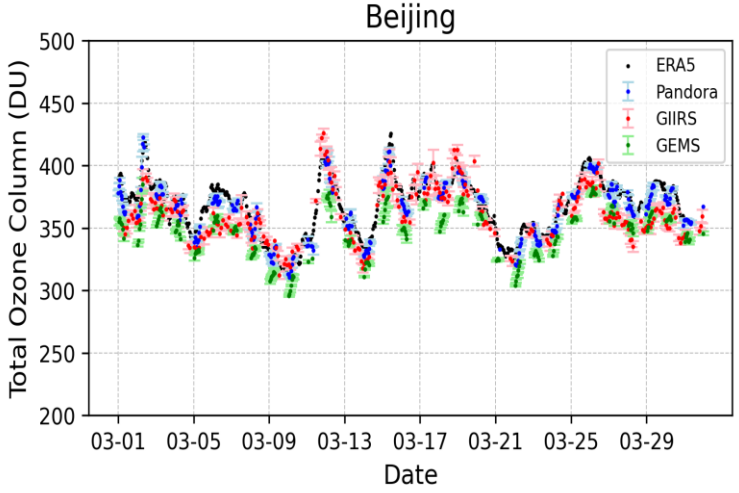
O_3 total column and DOFS



Averaging Kernels



Comparison with ERA5, Pandora, and GEMS



- Examples of monthly averages of Ozone total column for three different hours and the associated DOFS (between 0.9 and 1.4)
- The vertical sensitivity indicated by AK, showing the peak sensitivity in the UTLS region
- Resonable consistency with ERA5, Pandora, and GEMS total column ozone

Liu et al., 2025, JGR-Atmosphere

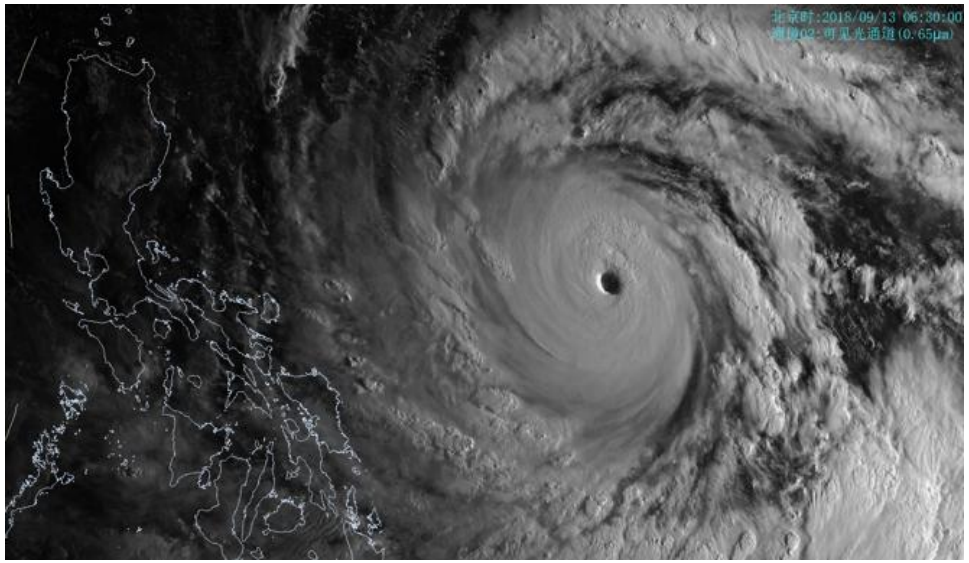
Future GEO plan

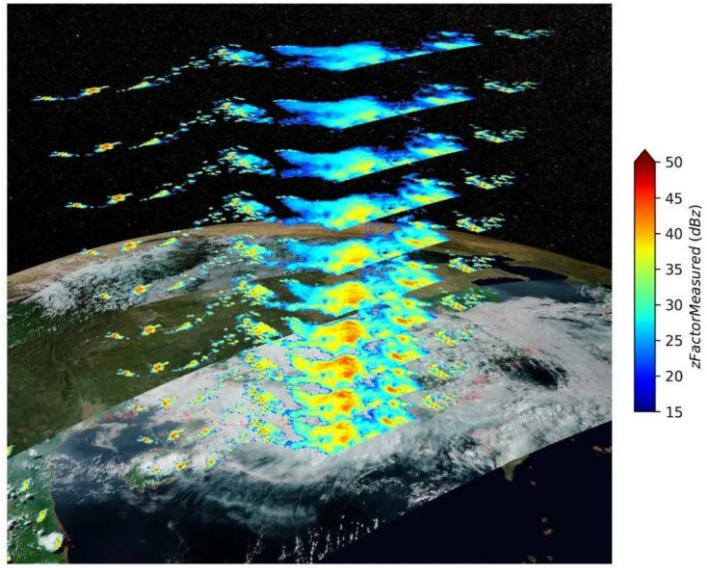
- Fengyun-4C is scheduled to be launched on 27 December 2025
  - AGRI: 18 channels, 0.5 ~ 2 km resolution, 10 minutes for full disk, 1 minute for regional observations
  - GIIRS: 8 km resolution, hourly over great China region
  - LMI: lightning mapper

- 1st GEO microwave satellite, is scheduled in 2026

Main application aspects of FY-4M

- High-frequency data assimilation in NWP model (i.e. CMA-GFS), particularly for cloudy conditions
- Monitoring and Forecasting of Typhoon and Heavy Rainfall, especially focusing on their inner 3D thermodynamic structures
- Application of artificial weather modification in plateau region, where 3D structural characteristics of cloud are in absence

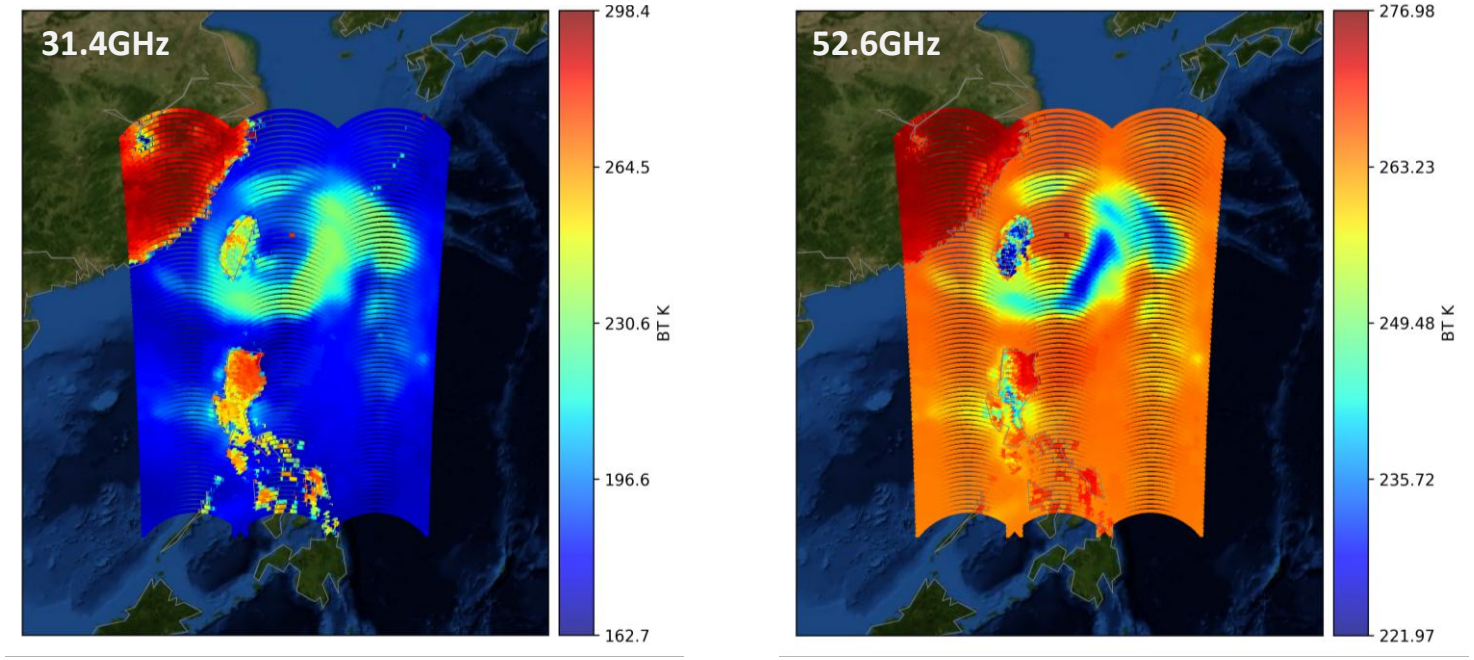




Key processing techniques for FY-4M are ready

- High-accuracy broadband radiometric calibration algorithms are completed, where simultaneous measurements from ground are utilized for inter-calibration
- High-accuracy geolocation and registration algorithms are ready, where some new references in both spaceborne and in-situ are selected for enhancement
- Some preliminary simulation results are generated to support the development of products, i.e. temperature and humidity profiles, precipitation, …….

Regional Simulation



Summary

- GIIRS provides soundings in clear skies and partly cloudy skies, have been operationally assimilated in CMA GFS;
- GIIRS soundings have been used at CMA, mainly in monitoring and predicting cold waves, cold vortex, and convective storms, nowcasting applications are still limited due to coarser spatial resolution which is easy to be affected by clouds;
- GIIRS provides atmospheric composition information with diurnal variations;
- Next FY-4C to be launched in this month will have 8 km resolution for GIIRS and 1 hour temporal resolution for great China region, which is expected to improve nowcasting capability.