中 国 气 象 局
China Meteorological Administration

国家卫星气象中心
National Satellite Meteorological Centre

FY-4A/GIIRS Temperature Validation in Winter and Application in Cold Wave Monitoring

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contents

1 Research Significance

Cold waves are among the main disastrous weather events in winter, It brings strong wind, cooling, snowstorms, and freezing rain, which can cause serious losses to the national economy, life, and property。

FY-4A/GIIRS application potential： FY-4A/GIIRS infrared sounding data have been used in numerical weather prediction, and have been proved to be a kind of satellite remote sensing data that has a positive effect. It can provide high spatial and temporal resolution three-dimensional atmospheric temperature making up for the shortage of conventional meteorological sounding data (the interval between terrestrial meteorological sounding stations is about 200km, and the detection is twice a day)

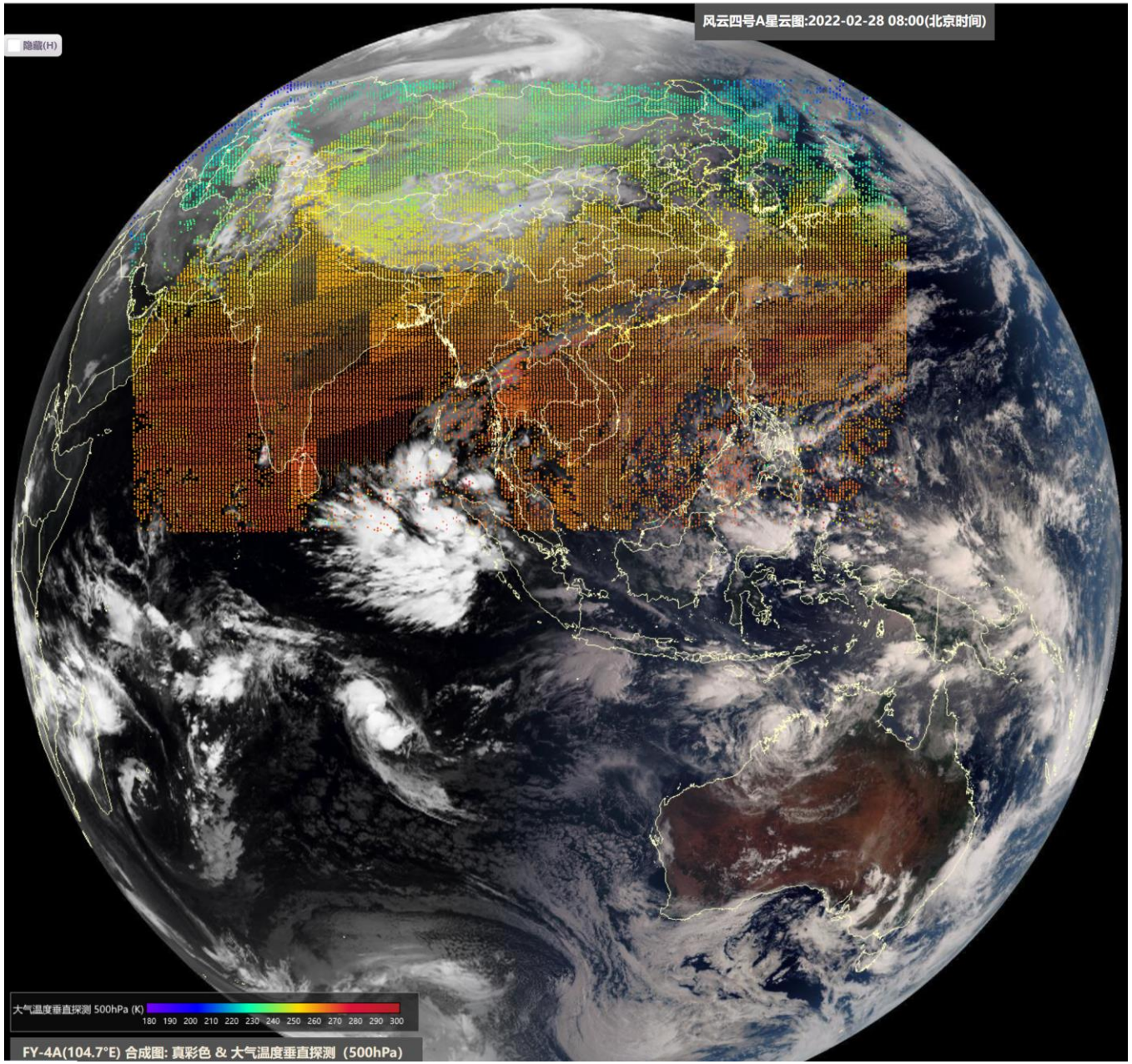
Research goals： FY-4A/GIIRS temperature accuracy and application in winter. Improve the application ability of FY-4A in cold wave monitoring.

2 Data and methods

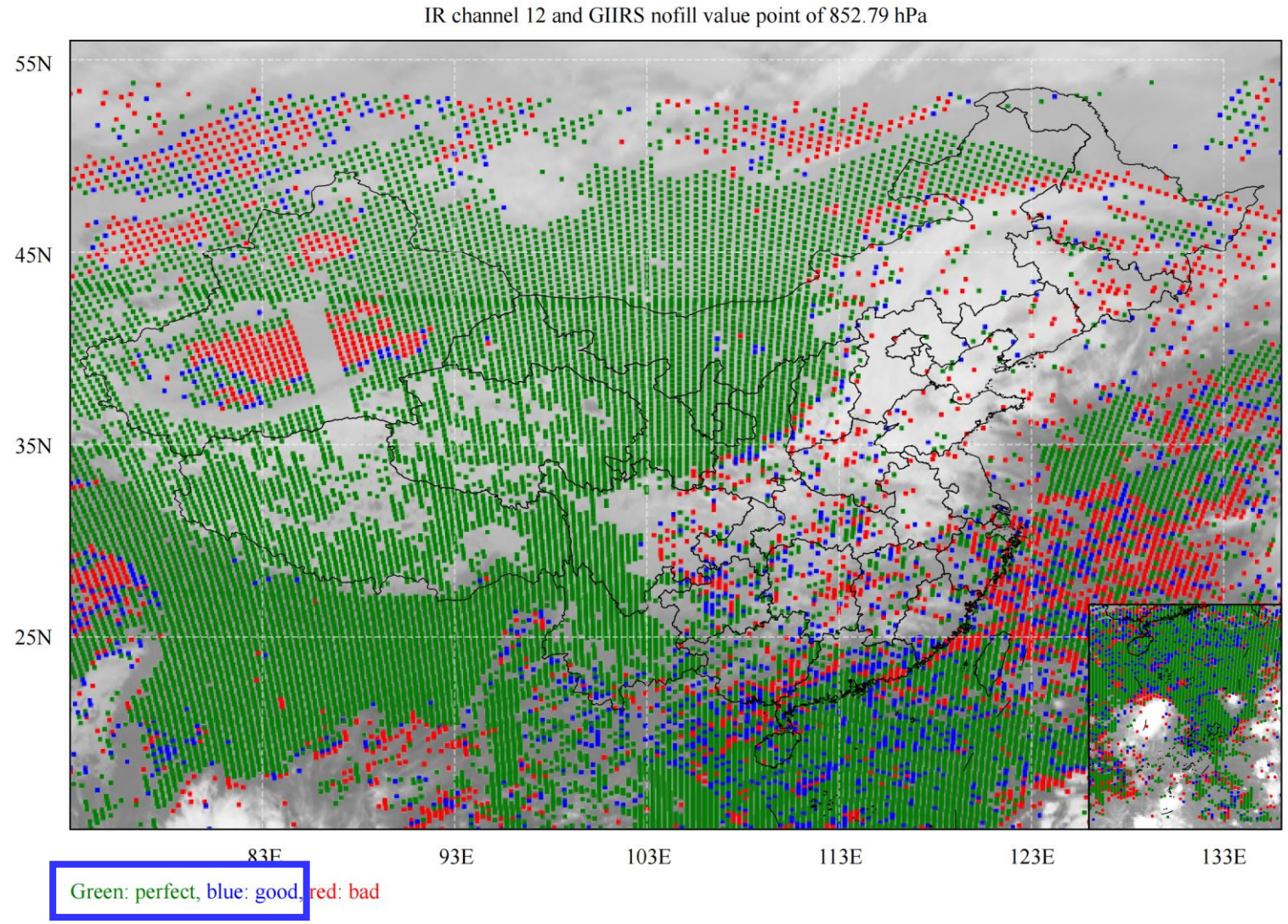
FY-4A/GIIRS temperature

- **The observation times:00, 02, 04, 06, 08, 10, 12, 14, 20, and 22 (UTC) o'clock, for a total number of 10 times a day.**
- **The spatial resolution : 16 km**
- **The pressure layers：** 101
- Scanning Area :（15ºN-55ºN； 70ºE-140ºE）

Data used in this study:
January to March, October to December in 2020
January to March, October to November in 2021



2 Data and methods



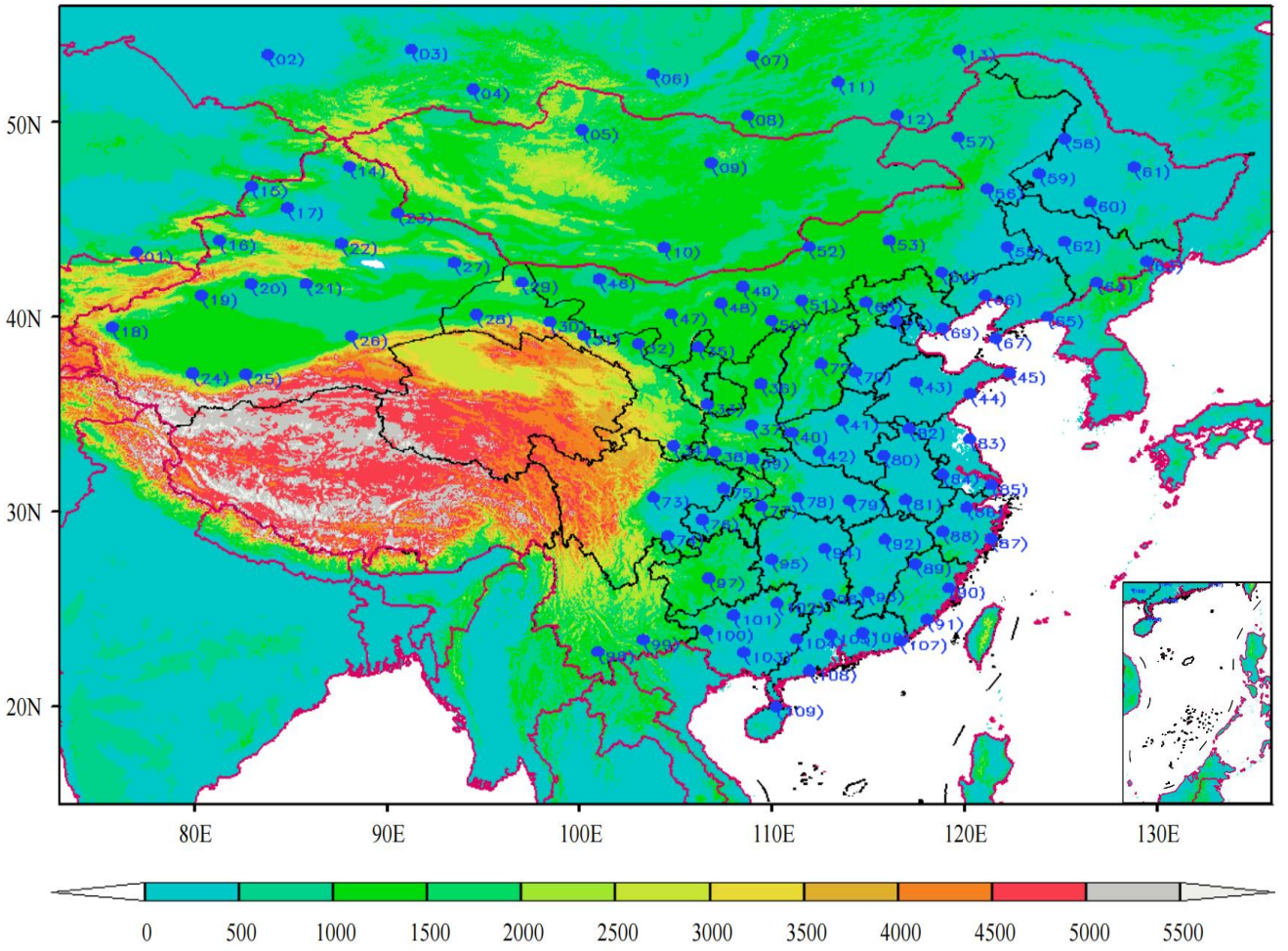
FY-4A /GIIRS temperature quality flag（850hPa,Green：00_perfect；Blue：01_good；Red：02_bad）and FY-4A/AGRI infrared channel cloud image

2 Data and methods

Meteorological sounding station temperature

The true values in the validation

Including 13 international meteorological radiosonde stations (9 in Russia, 3 in Mongolia and 1 in Kazakhstan) and 96 Chinese meteorological radiosonde stations, for a total of 109. Most of the selected stations have low altitude and can effectively detect the temperature at 850 hPa.

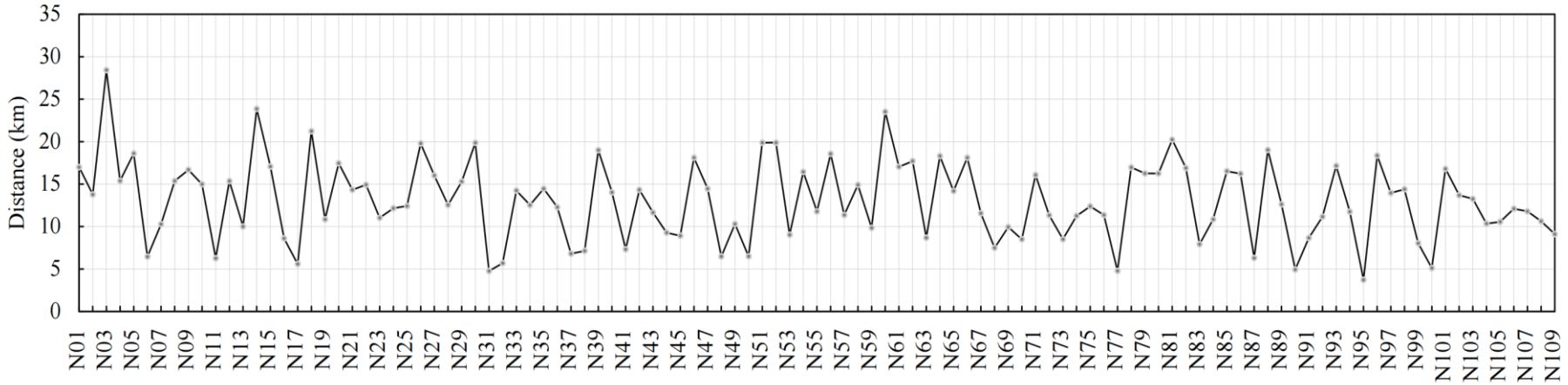


Location (blue dot), number (blue number), and terrain height of meteorological sounding stations selected for data validation.

2 Data and methods

Sounding station and FY-4A/GIIRS data matching method

Horizontal space matching method： we take the selected meteorological sounding station location as the center and search for the nearest FY-4A/GIIRS sounding point within 50 km for horizontal spatial matching.



The average matching distance between the 109 meteorological sounding stations and FY-4A/GIIRS temperature sounding points of the validation samples.

except for the matching distances of N03 N14 and N60 are more than 20 km,the matching distances of the other 105 stations are close to or less than 16 km.

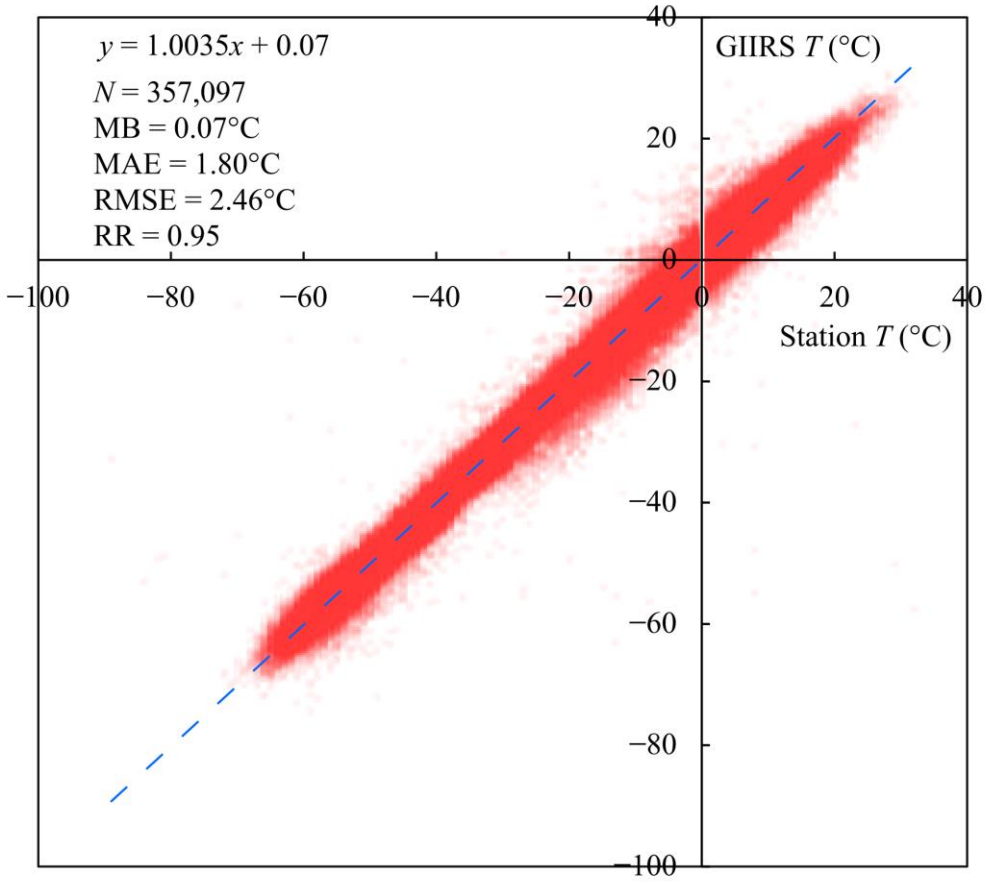
Temporal matching method： The FY-4A/GIIRS temperature at 00:00 and 12:00 is matched with that of the meteorological sounding station temperature at 00:00 and 12:00.

Spatial matching method of vertical layer.

meteorological sounding station	FY-4A/GIIRS
100	103
150	151
200	200
250	247
300	300
400	407
500	497
700	707
850	853
925	932

3 FY-4A/GIIRS temperature accuracy verification

Average accuracy



Scatter distribution of FY-4A/GIIRS temperature and meteorological sounding station temperature.

Mean Bias： MB=0.07℃

Mean Absolute Error：**MAE=1.80 ℃**

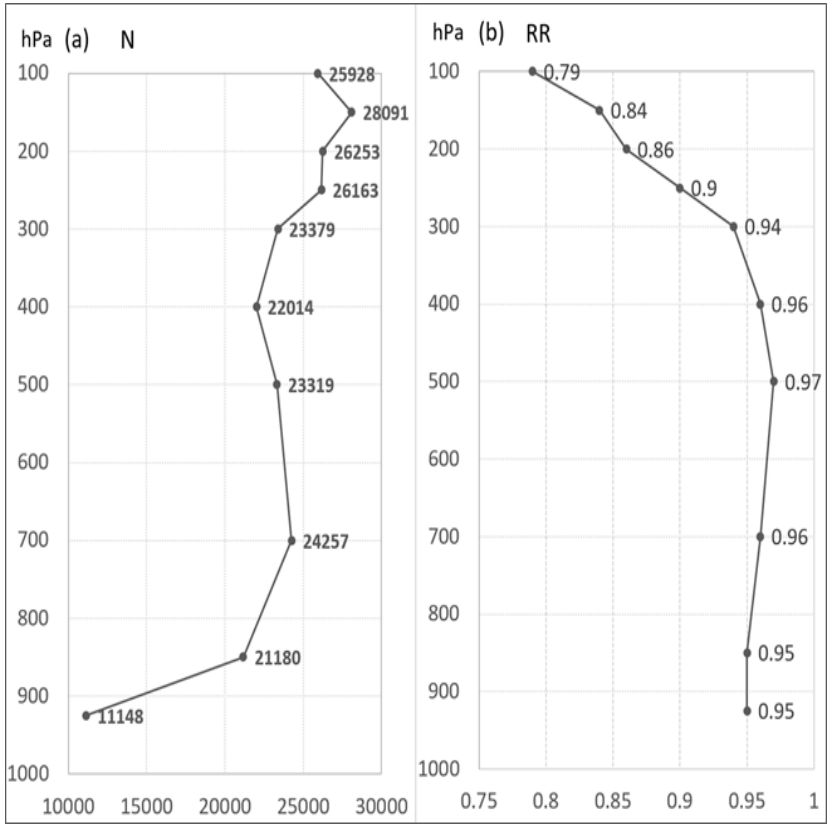
Root Mean Square Error ： RMSE=2.46 ℃

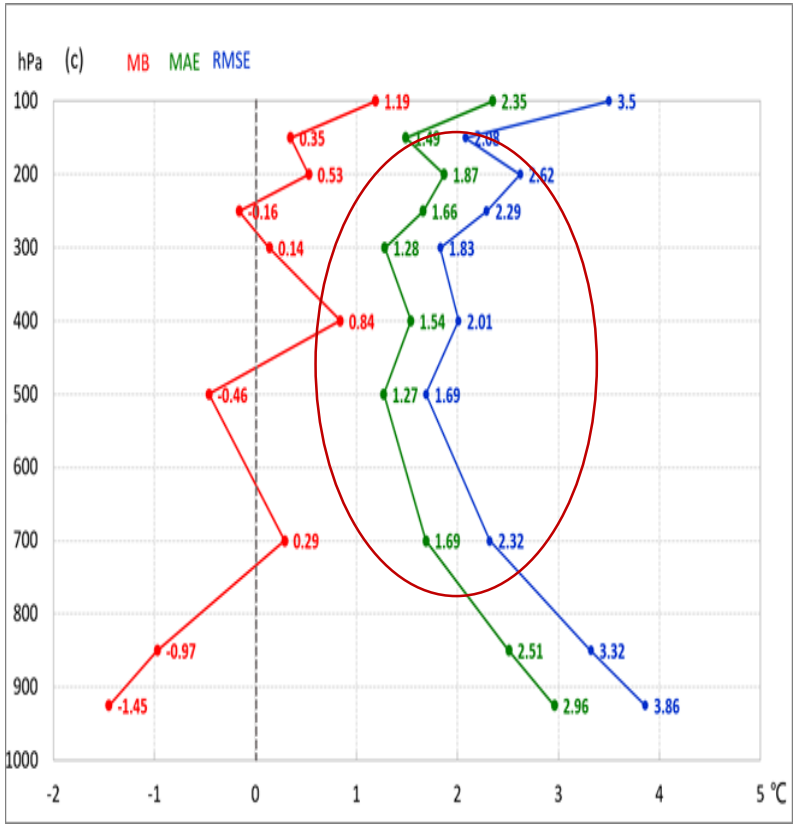
Correlation Coefficient ： RR=0.95

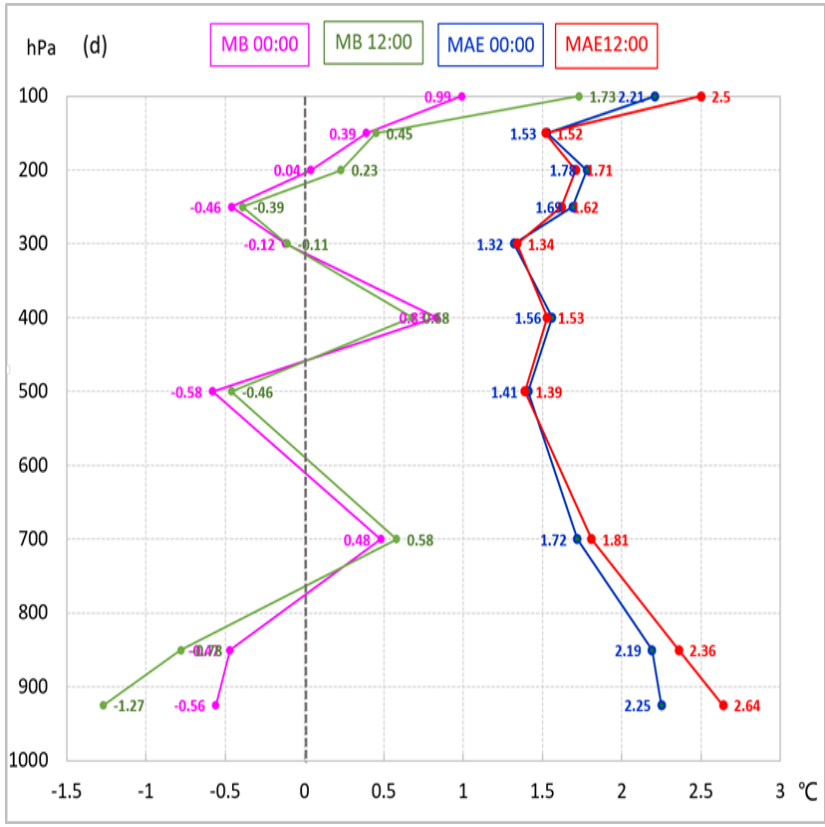
From −50 to −20 ℃ (at middle troposphere), the scatter distribution is closer to the linear regression line, and the *FY-4A*/GIIRS temperature accuracy is higher and more stable.

In the period studied in this paper, through time and space matching methods for 109 sounding stations at 10 vertical levels for two kinds of datasets, the number of matching samples is 357097.

3 FY-4A/GIIRS temperature accuracy verification







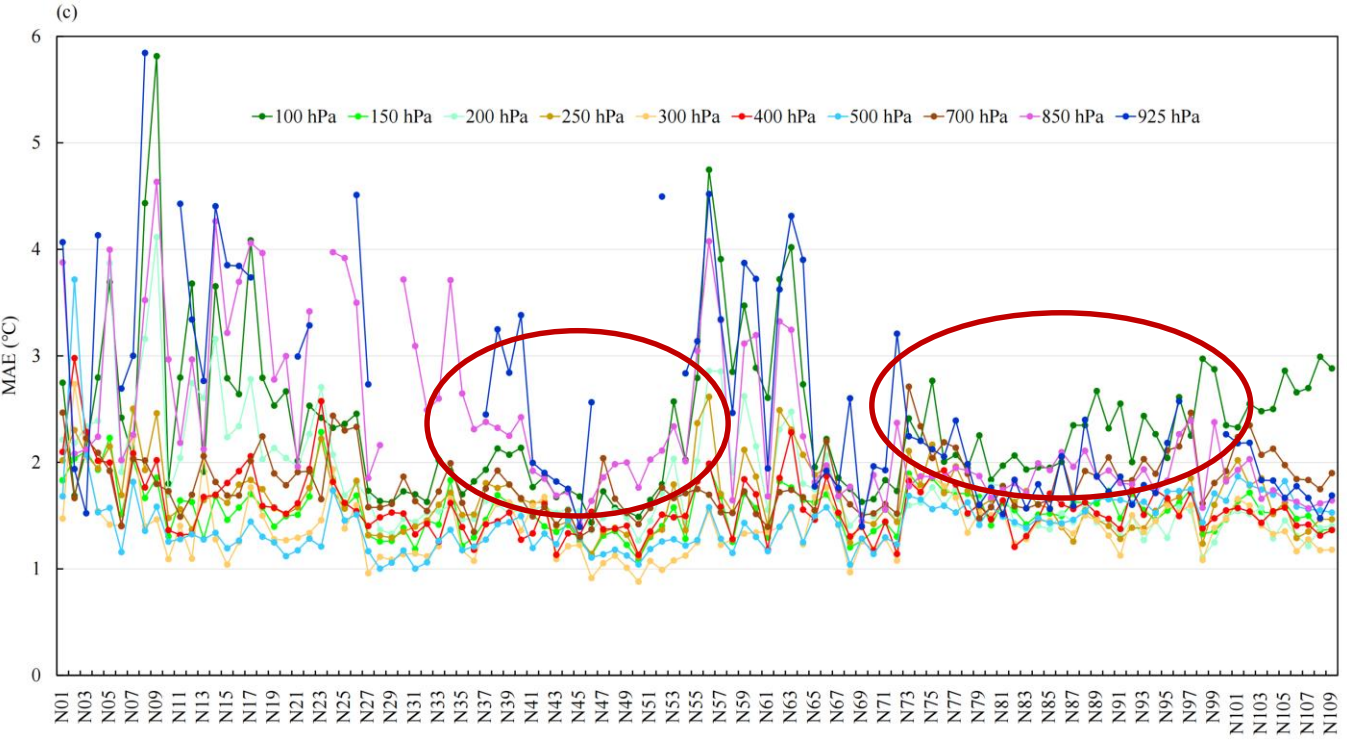
The number of matching samples is the most at 150 hpa (43692) and the least at 925 hPa (21575), and below 850 hPa, the number significantly decreases. The vertical distribution characteristics of the number of matching samples are related to the influence of clouds.

The distributions of mean absolute error MAE and root-mean-square error RMSE are relatively larger in the upper and lower troposphere, and relatively smaller in the middle troposphere.

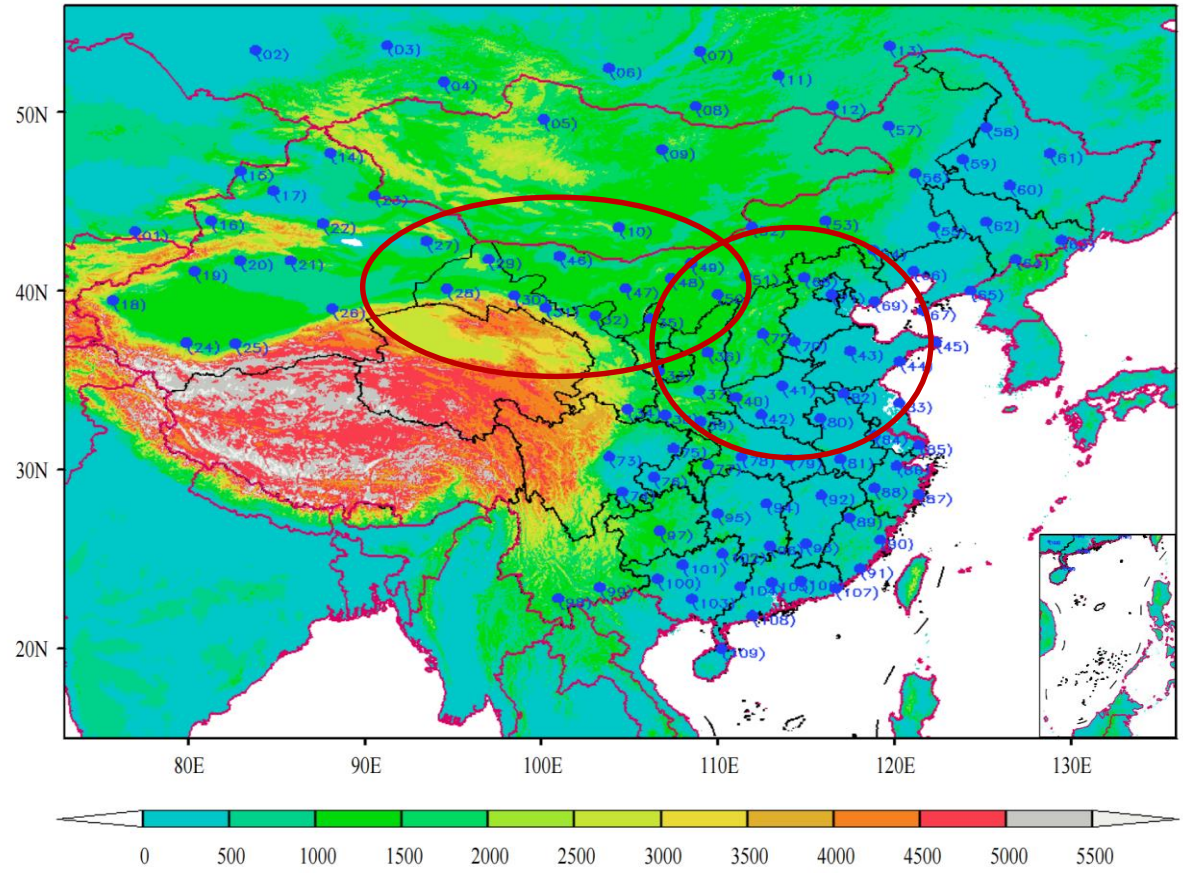
The diurnal variation characteristics of error: the accuracy below 700hPa and above 150hPa at 00:00 is higher than that at 12:00.

3 FY-4A/GIIRS temperature accuracy verification

Horizontal distribution characteristics of temperature accuracy



The mean absolute error MAE of FY-4A/GIIRS temperature in 10 vertical layers of 109 sounding stations



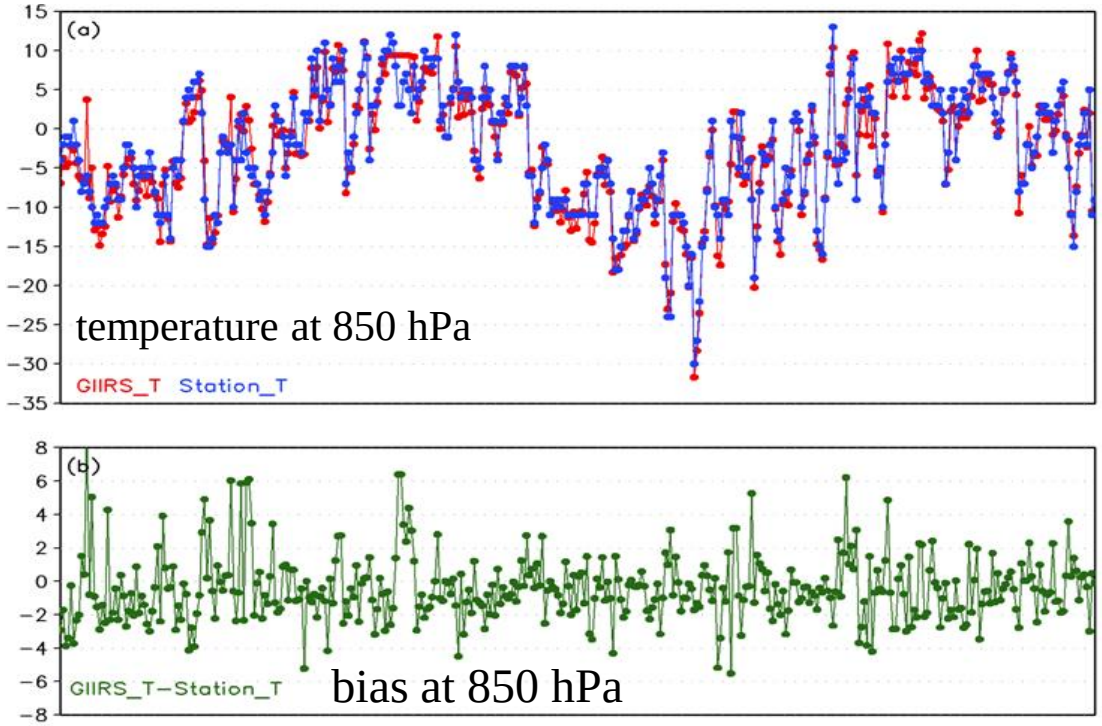
The FY-4A/GIIRS temperatures in the regions where N42–N53 and N65–N109 stations are located (in Inner Mongolia, North China, the east of Northwest China, and South China) have high accuracy at most vertical levels.

Temperature accuracy at Beijing and Zhangjiakou meteorological sounding stations

FY-4A/GIIRS temperature accuracy at Beijing meteorological sounding station (station no. 54511, N71)

54511	RR	MB	MAE	RMSE	N
100hPa	0.62	0.54	1.83	3.65	460
150hPa	0.61	-0.18	1.44	3.34	466
200hPa	0.74	-0.19	1.59	3.53	476
250hPa	0.76	0.13	1.56	3.50	440
300hPa	0.80	0.04	1.26	3.13	414
400hPa	0.89	0.92	1.44	2.55	397
500hPa	0.93	-0.54	1.30	2.16	411
700hPa	0.95	0.80	1.61	2.24	427
850hPa	0.97	-0.43	1.56	2.07	396
925hPa	0.96	-1.06	1.93	2.36	363
平均值		0.02	1.55	2.95	

FY-4A/GIIRS temperature accuracy verification at Beijing meteorological sounding station (station no. 54511, N71)



误差大于3℃的样本数约占总样本数（共369）的11.6%

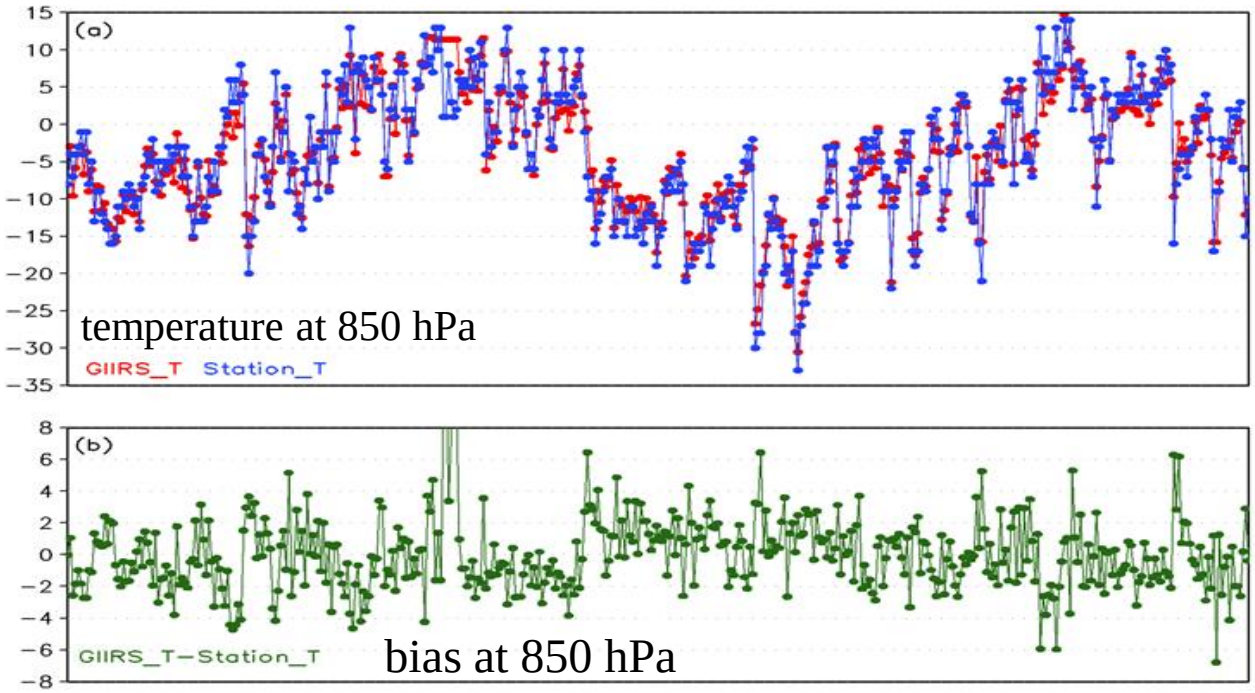
The total number of samples with absolute error greater than 4°C (bias greater than 4°C and less than −4°C) is 20, the number of samples with absolute error of 3–4°C is 26, **and the number of samples with absolute error greater than 3°C accounts for about 11.6% of the total number of samples** (369).

Temperature accuracy at Beijing and Zhangjiakou meteorological sounding stations

FY-4A/GIIRS temperature accuracy at **Zhangjiakou** meteorological sounding station (station no. 54401, N68) in Hebei Province

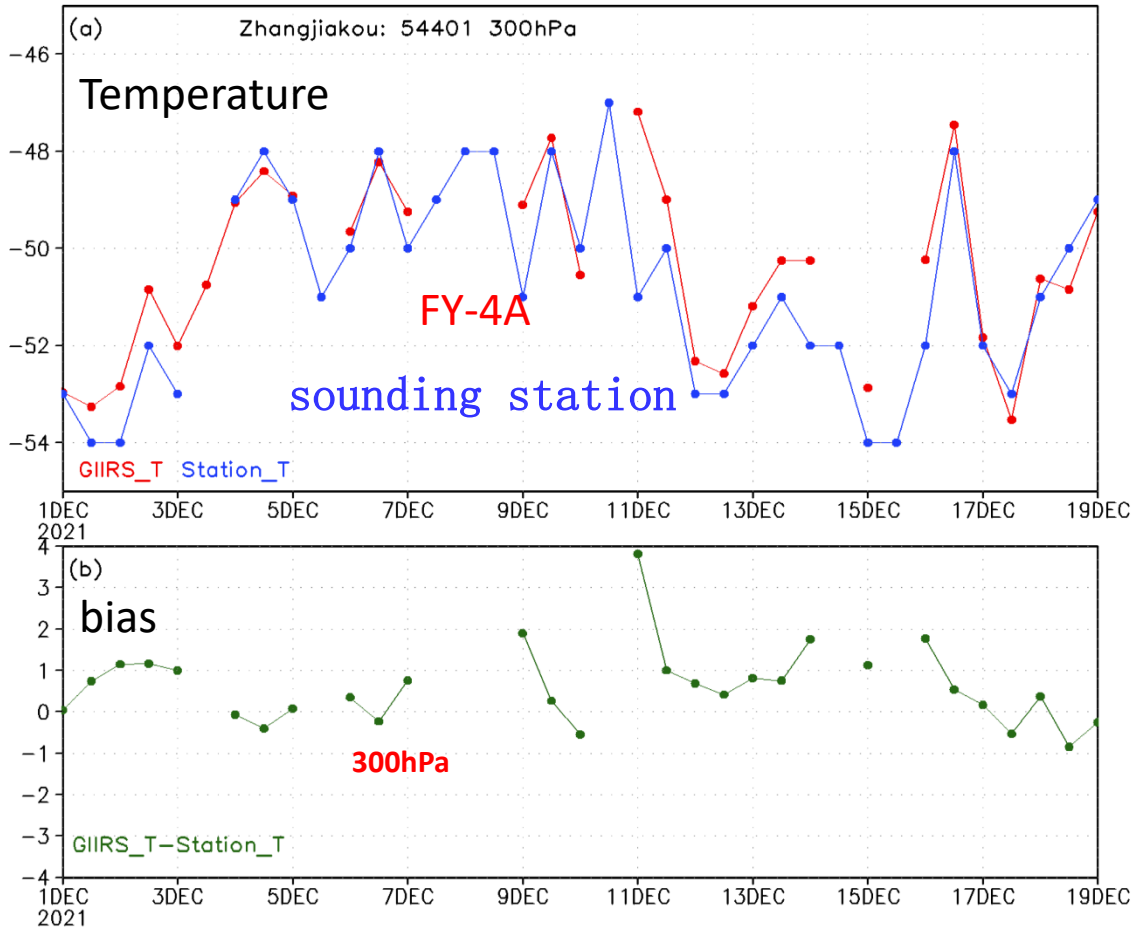
54401	RR	MB	MAE	RMSE	N
100hPa	0.79	-0.14	1.75	2.22	484
150hPa	0.85	0.22	1.20	1.56	493
200hPa	0.89	0.14	1.40	1.86	499
250hPa	0.93	-0.10	1.25	1.60	487
300hPa	0.95	0.13	0.97	1.29	442
400hPa	0.97	1.11	1.30	1.59	437
500hPa	0.97	-0.38	1.04	1.38	448
700hPa	0.96	0.90	1.61	2.19	473
850hPa	0.97	0.01	1.77	2.33	444
925hPa	0.92	0.08	2.60	3.28	363
平均值		0.19	1.47	1.97	

FY-4A/GIIRS temperature accuracy verification at **Zhangjiakou** meteorological sounding station (station no. 54401, N68)



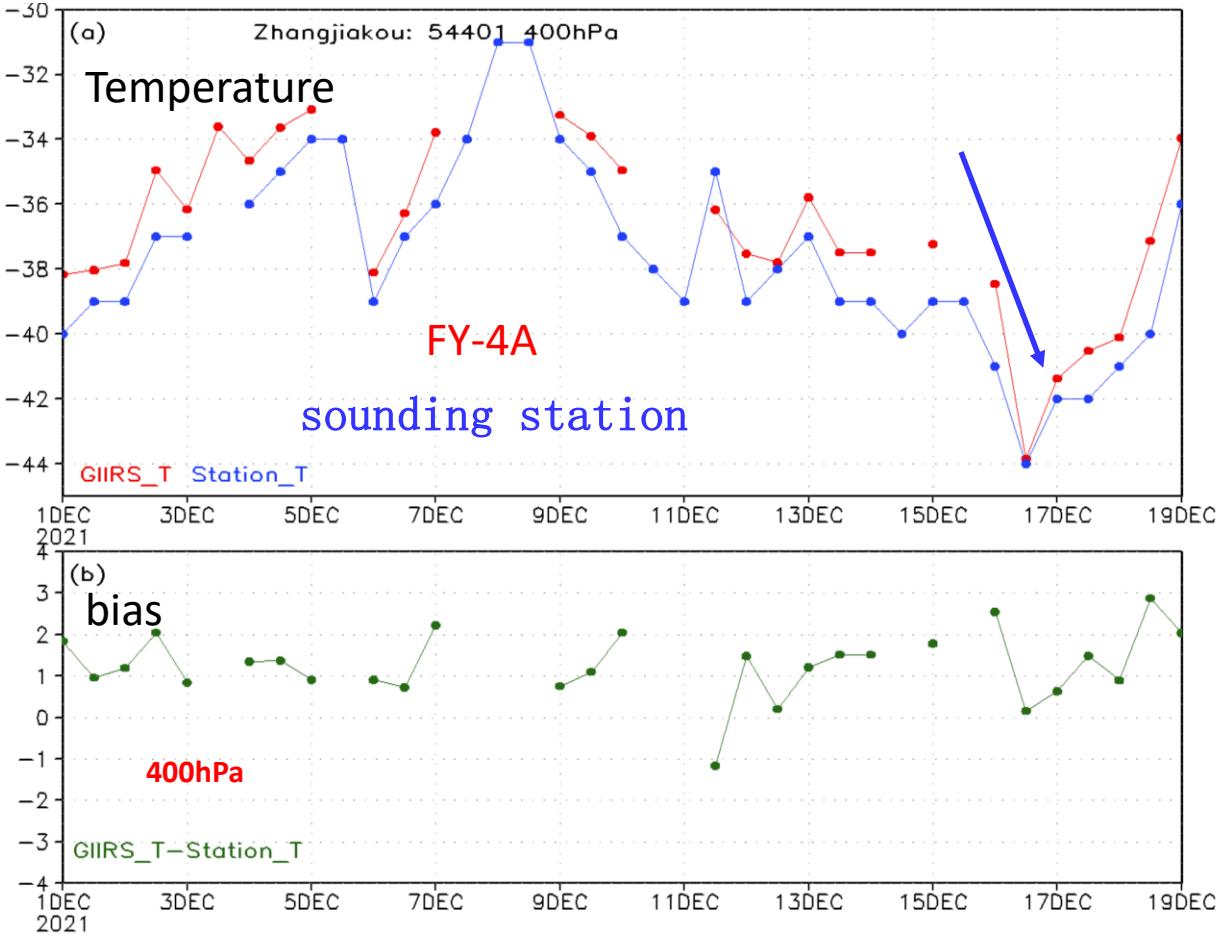
The number of samples with absolute error greater than 3°C accounts for about 13.3% of the total number of samples (444). The proportion of samples with error greater than 3°C is slightly higher than that of the Beijing meteorological sounding station.

Temperature accuracy evaluation in cold wave weather process

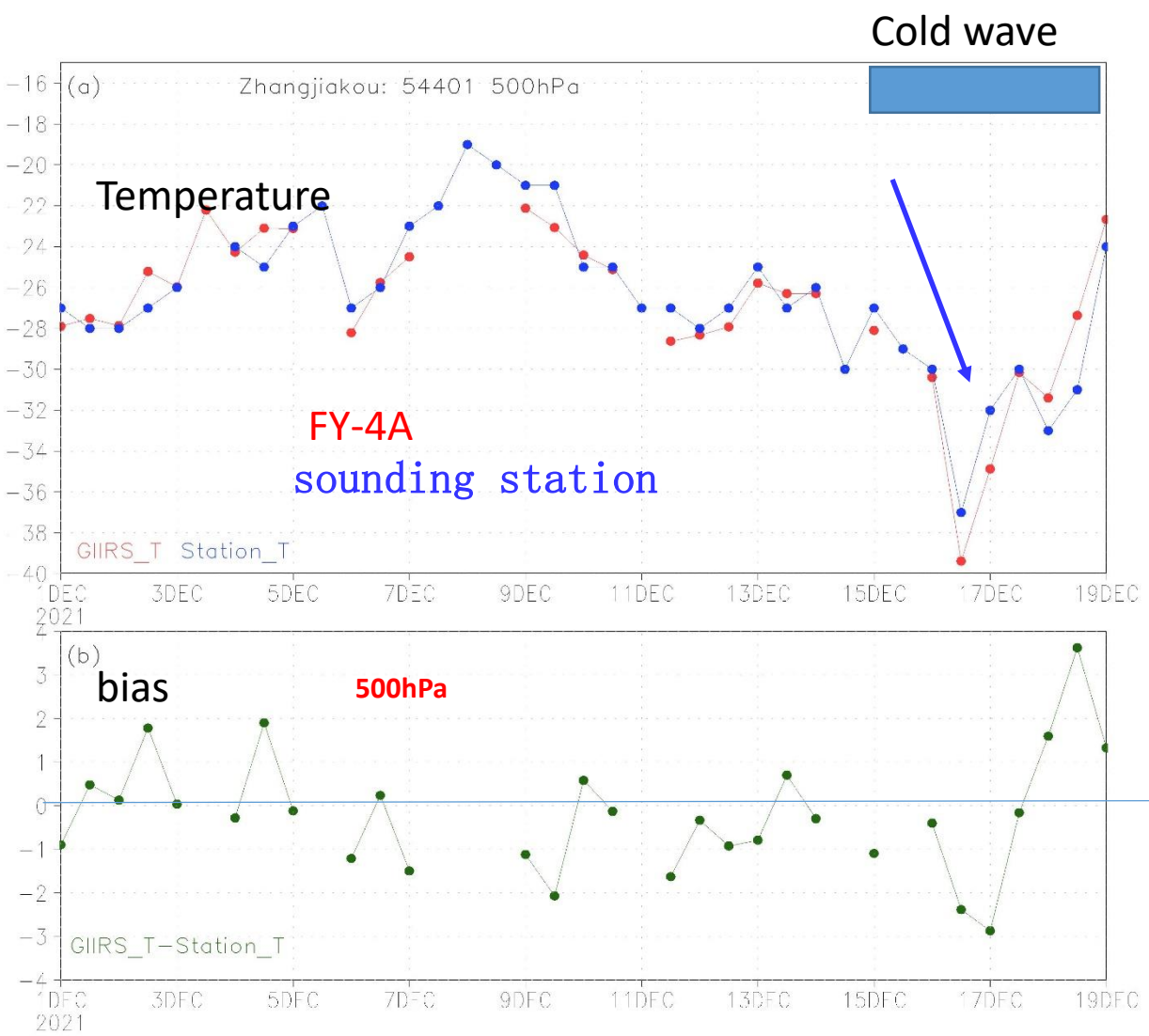


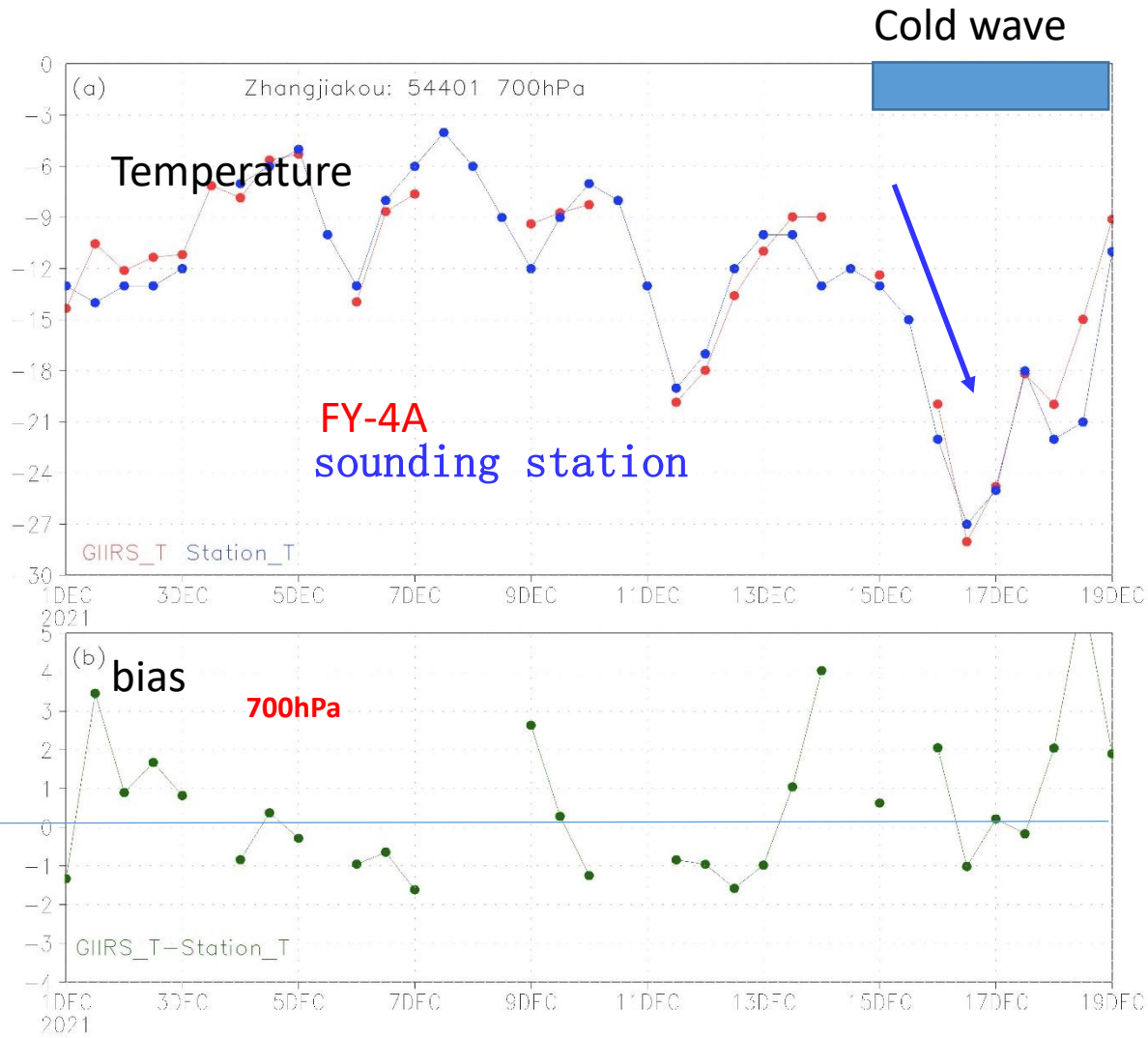
FY-4A/GIIRS Temperature accuracy evaluation on December 1 to 19 in2021

(cold wave on December 15 to 17 in 2021, Zhangjiakou meteorological sounding station (station no. 54401, N68)

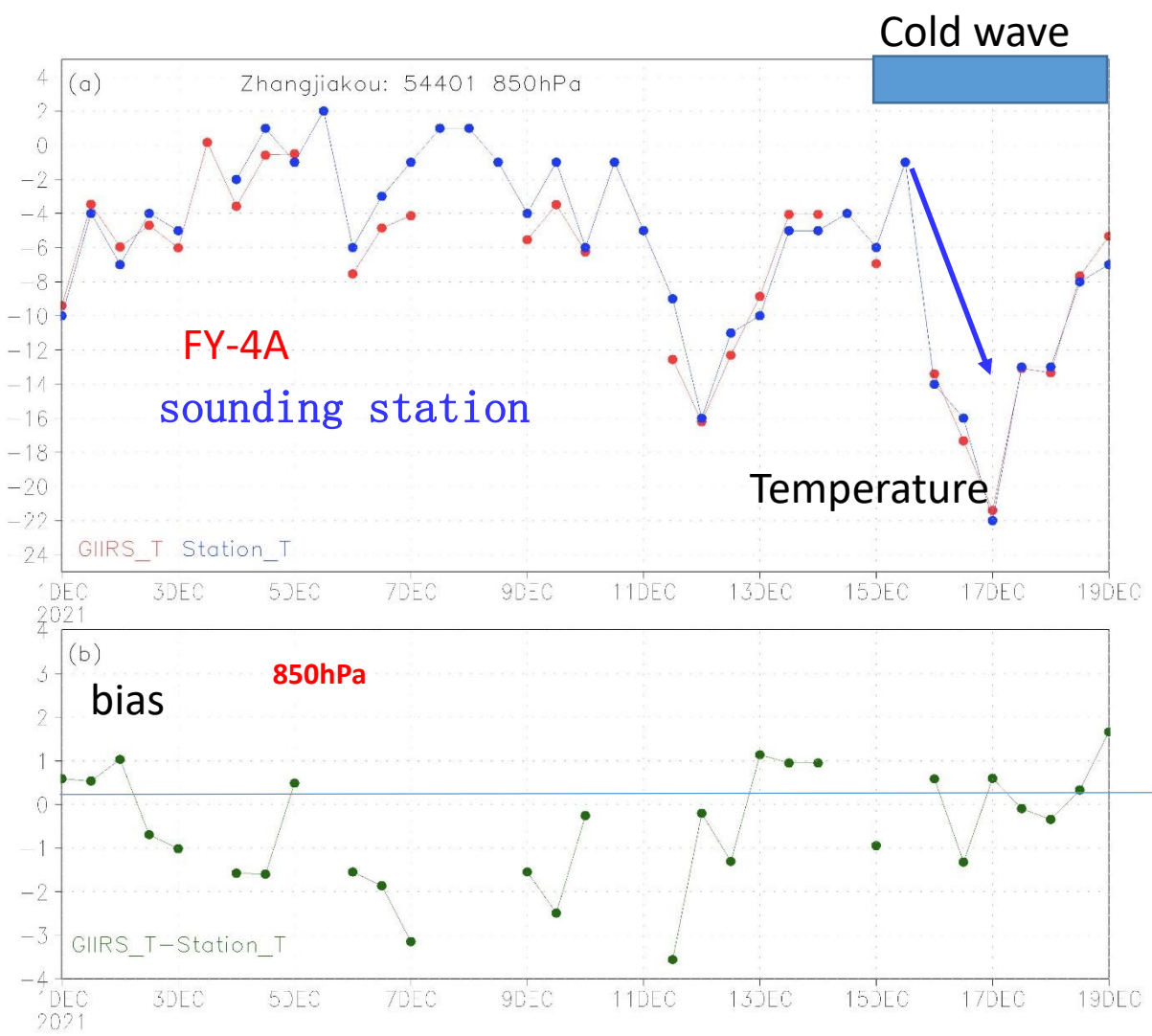


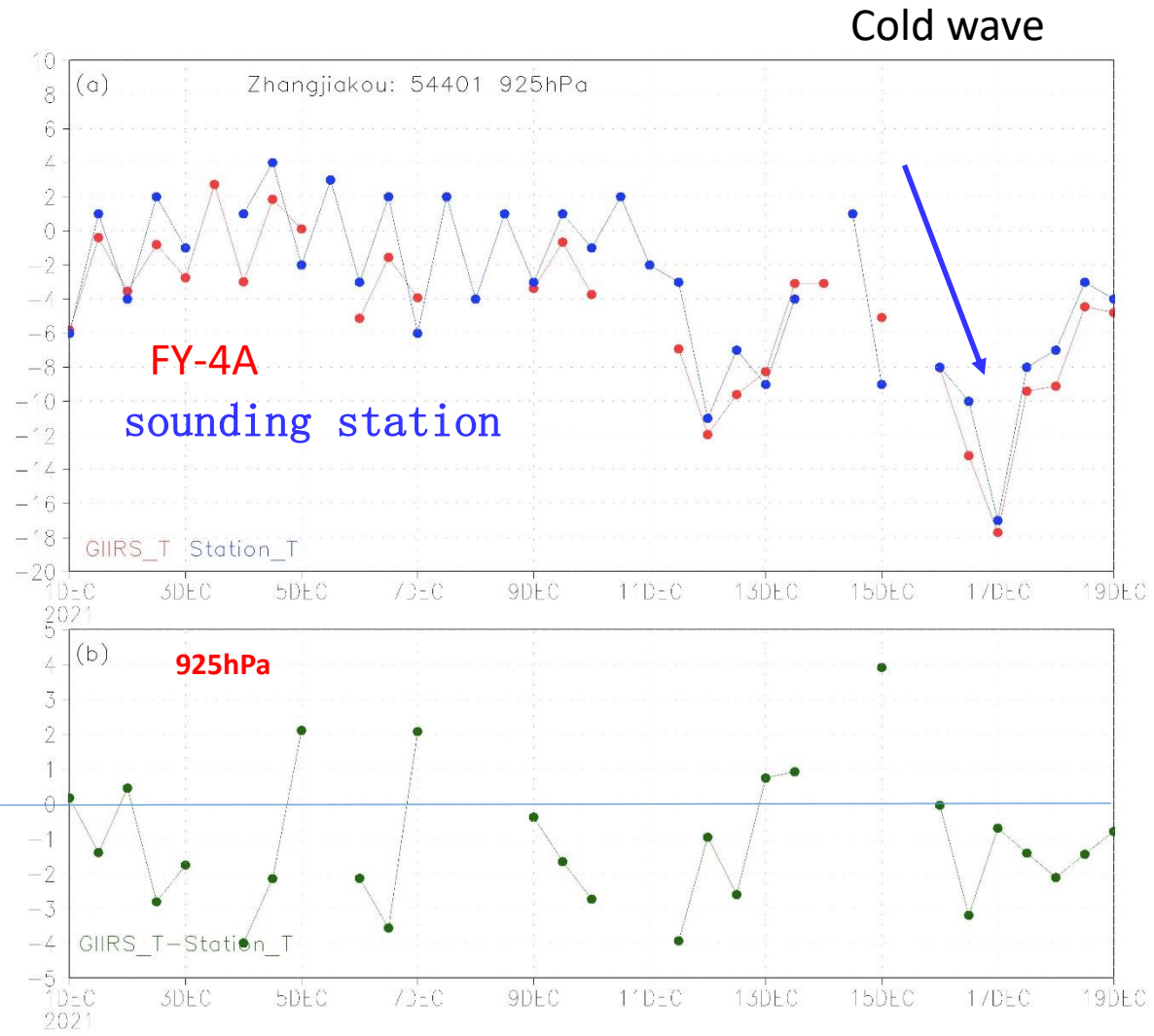
Hourly comparison of sounding (blue) and FY-4A GIIRS temperatures (red) at 08:00 and 20:00 on December 1-19, 2021 (Zhangjiakou 54401)



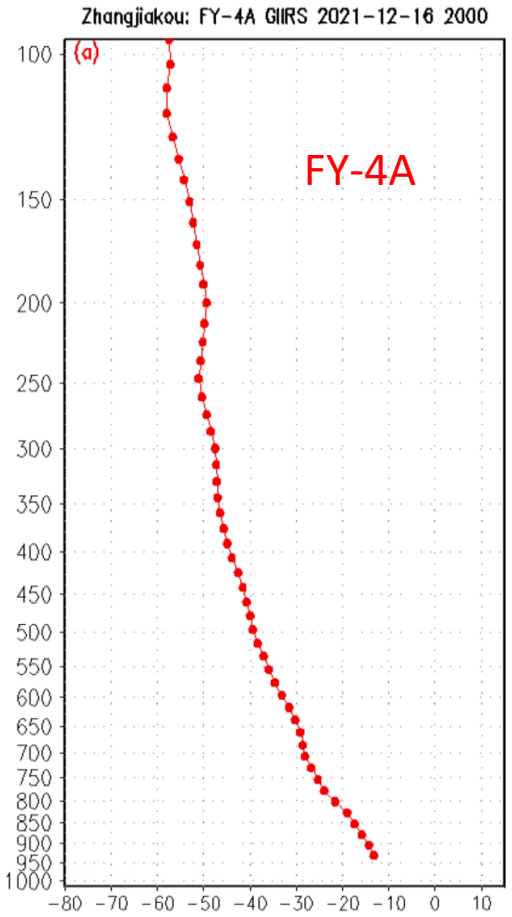


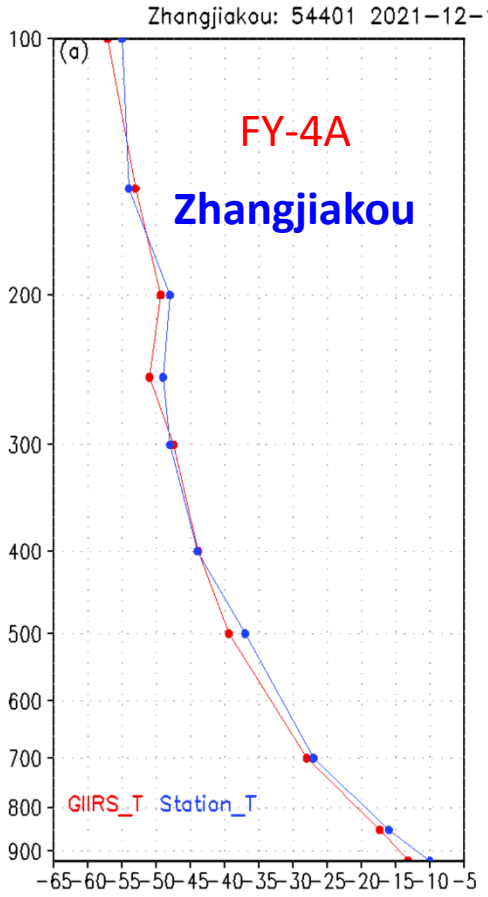
Hourly comparison of sounding (blue) and FY-4A GIIRS temperatures (red) at 08:00 and 20:00 on December 1-19, 2021 (Zhangjiakou 54401)

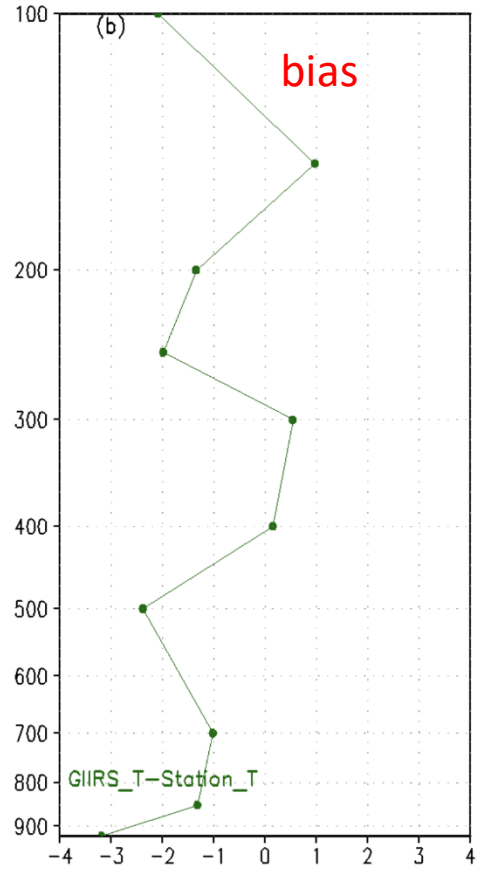




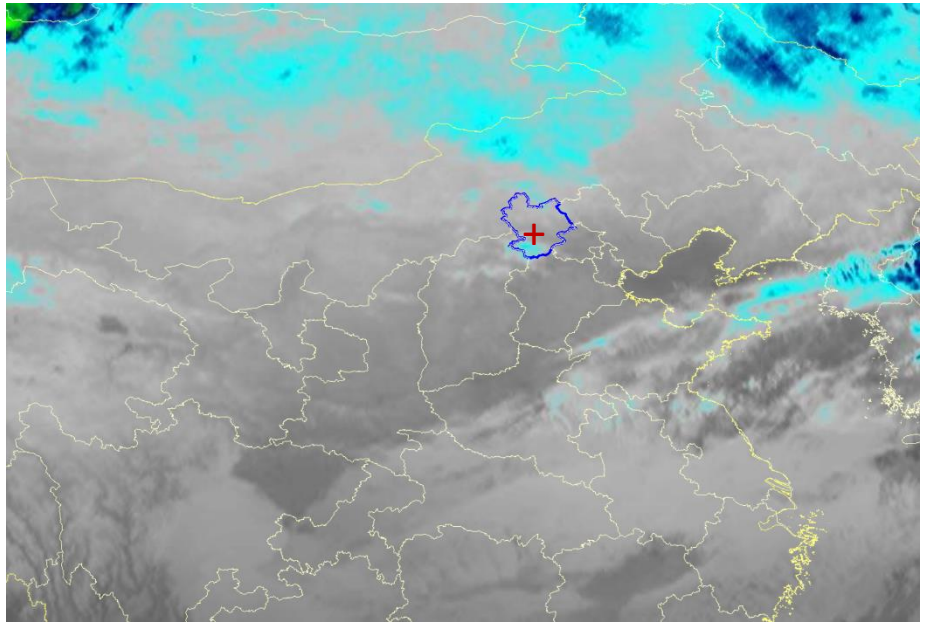
Temperature comparison between sounding and FY-4A at 12:00(UTC) on December 16, 2021.





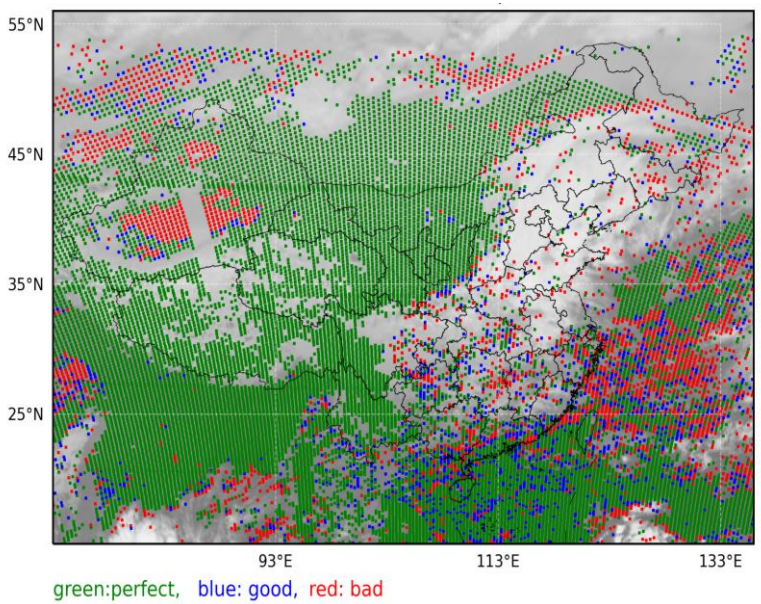


FY-4A IR cloud image at 12:00 on December 16, 2021

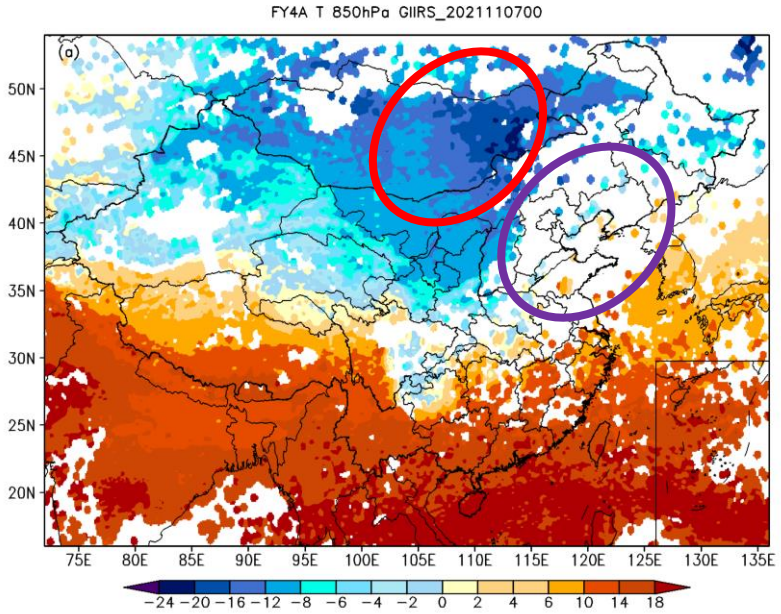


The temperature bias is negative below 500hPa, and -2.3 ℃ at 500hPa, -1.0 ℃ at 700hPa, -1.3 ℃ at 850hPa. The temperature bias at 400hPa is the minimum, and at 300hPa is about 0.5 ℃ .

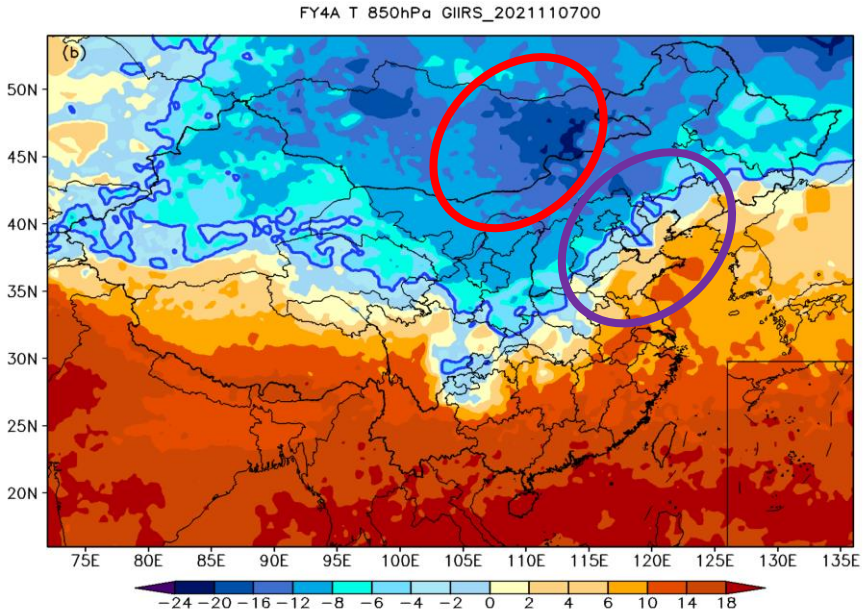
4 FY-4A/GIIRS temperature data reconstruction effect evaluation



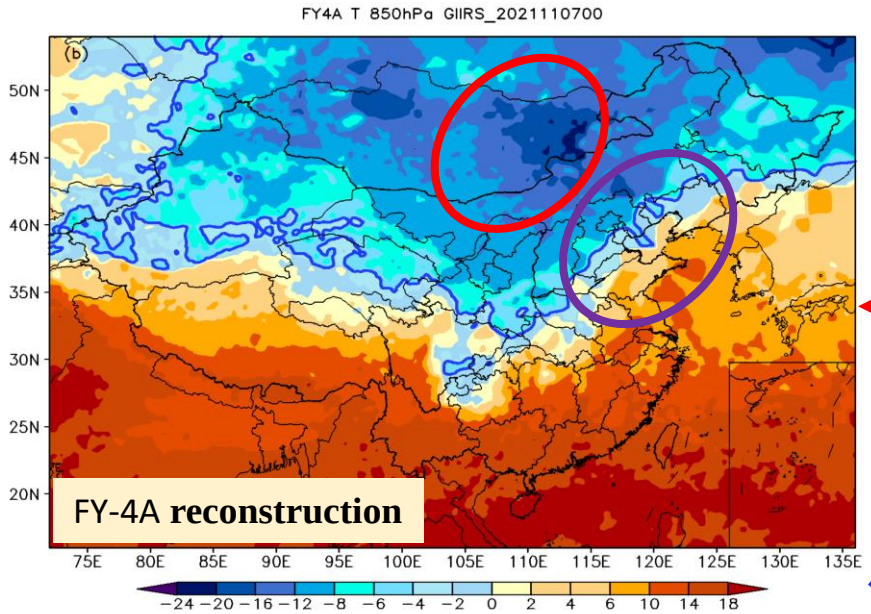
- In view of the requirements for the continuity of the weather process in meteorological services, as well as the requirements for the accuracy of image production, it is necessary to reconstruct the data with FY4A/GIIRS temperature in the cloud area or the area lacking measurement, so as to form a continuous and uniform temperature field in space.
- Based on the analysis of commonly used interpolation algorithms, this paper optimizes Cressman interpolation algorithm by adopting the method of step by step difference analysis, and realizes the improvement of calculation speed and high-precision difference iteration.

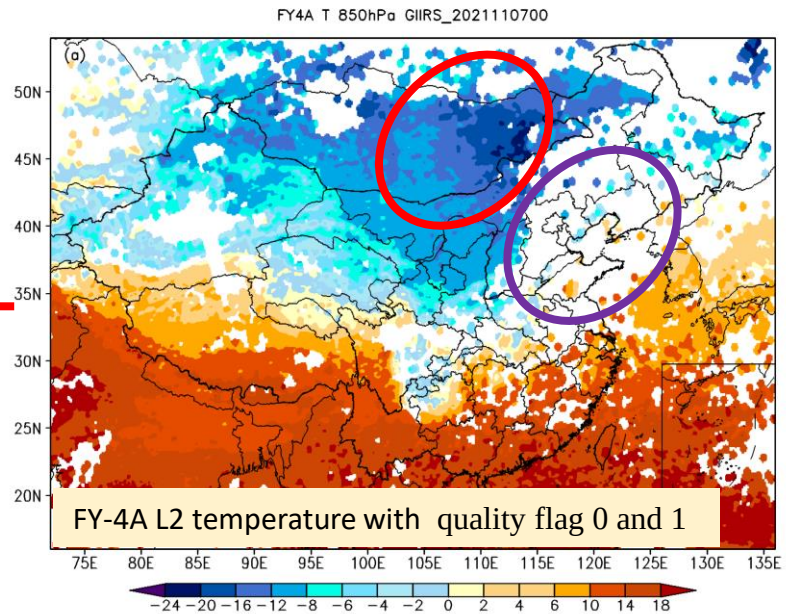


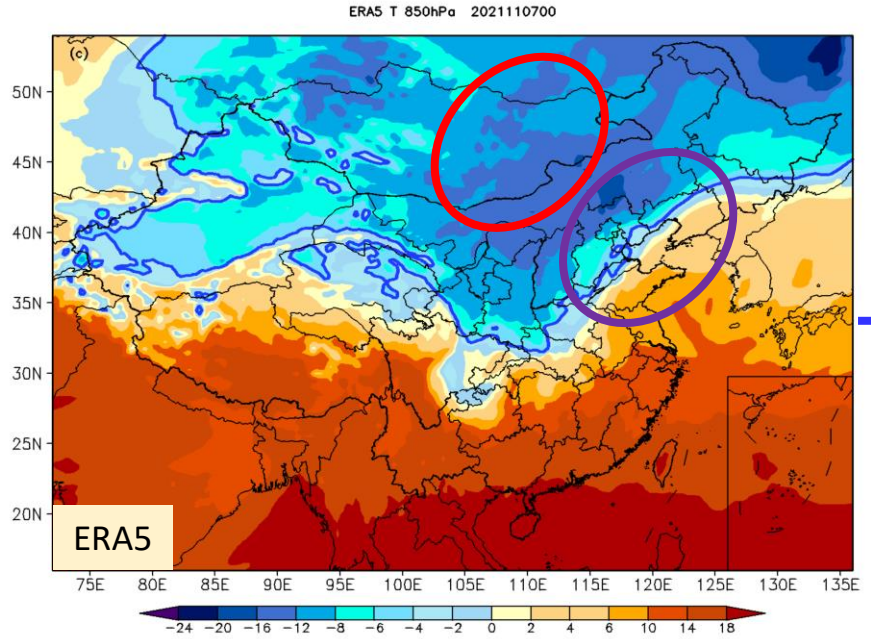
reconstruction

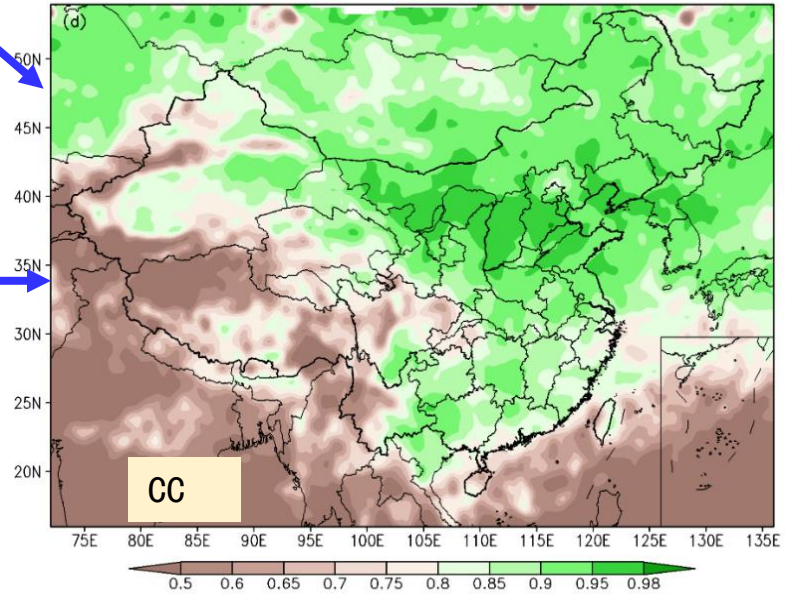


4 FY-4A/GIIRS temperature data reconstruction effect evaluation







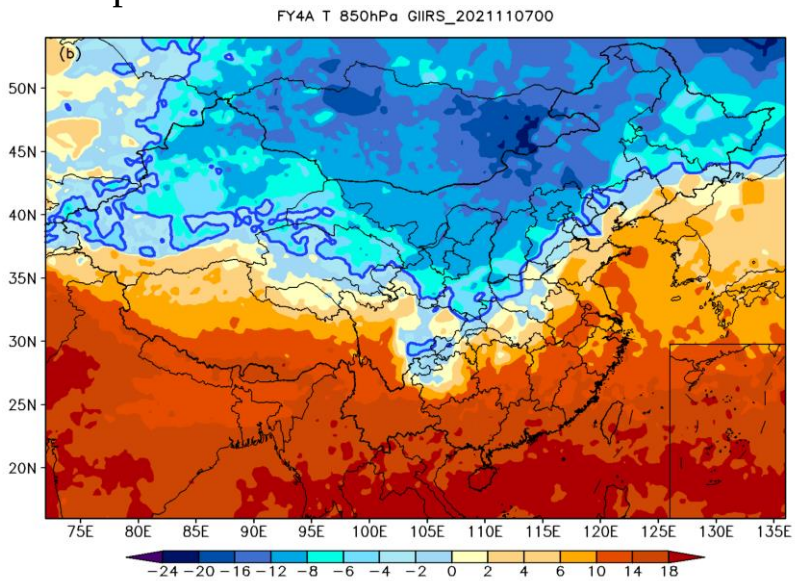


Except for the Tibetan Plateau, the correlation coefficient in most regions of China is greater than 0.8, and the correlation coefficient in Mongolia, the east of Northwest China, and North China is greater than 0.9 in the key areas of cold air activity. It shows that the reconstructed temperature has efficient performance in cold wave monitoring.

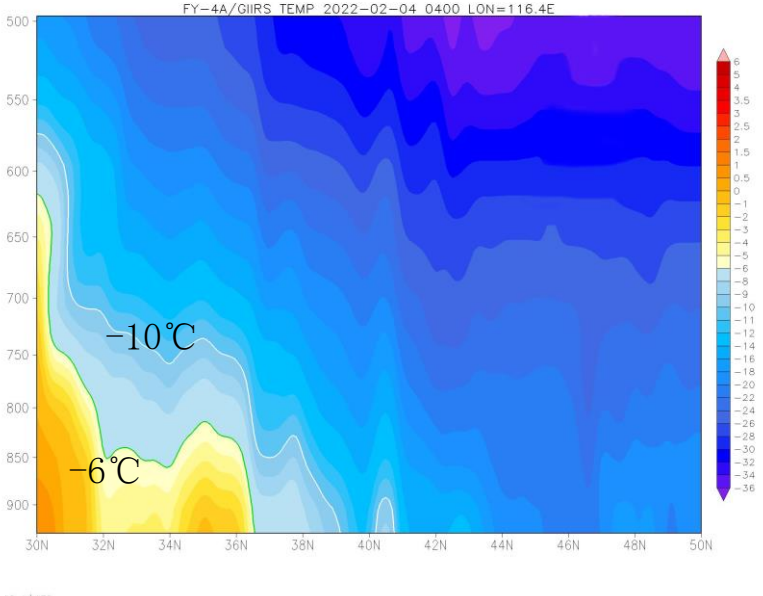
Regional distribution of Correlation Coefficient between FY-4A 850hPa **reconstruction temperature** and ERA5 temperature from November 1 to 30, 2021.

FY-4A/GIIRS Cold Wave Monitoring Products（based on the reconstructed data)

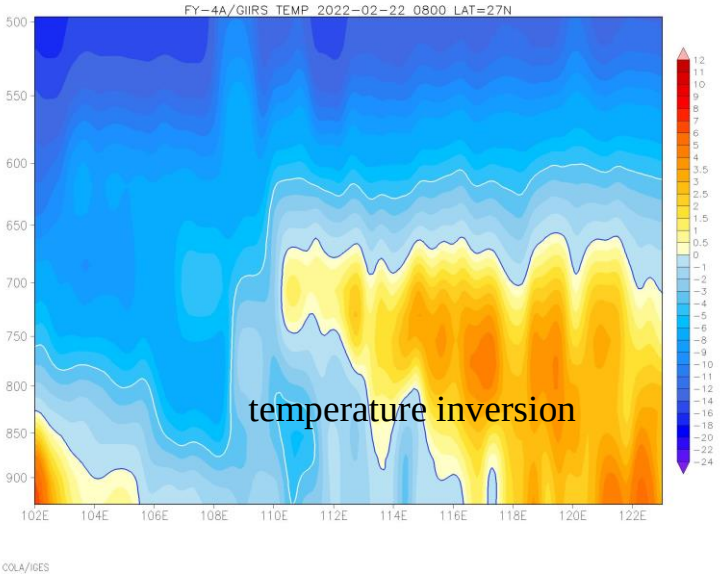
Temperature at 850hPa



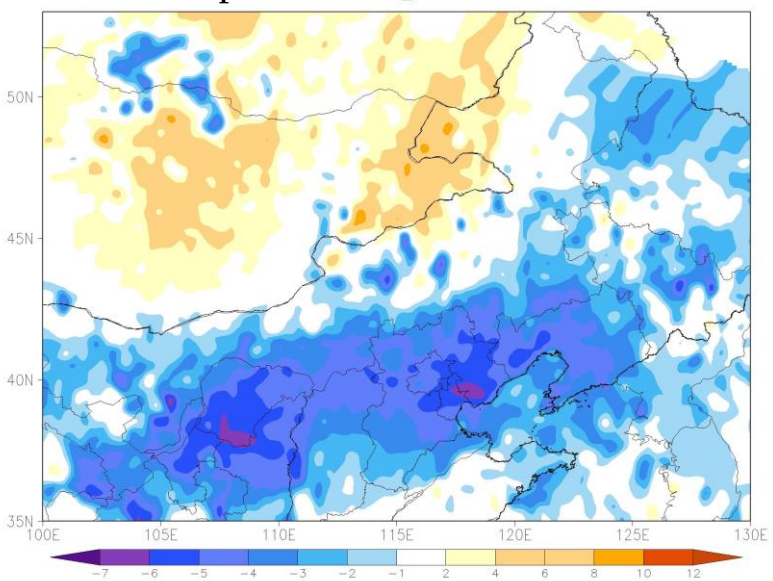
Vertical distribution of temperature



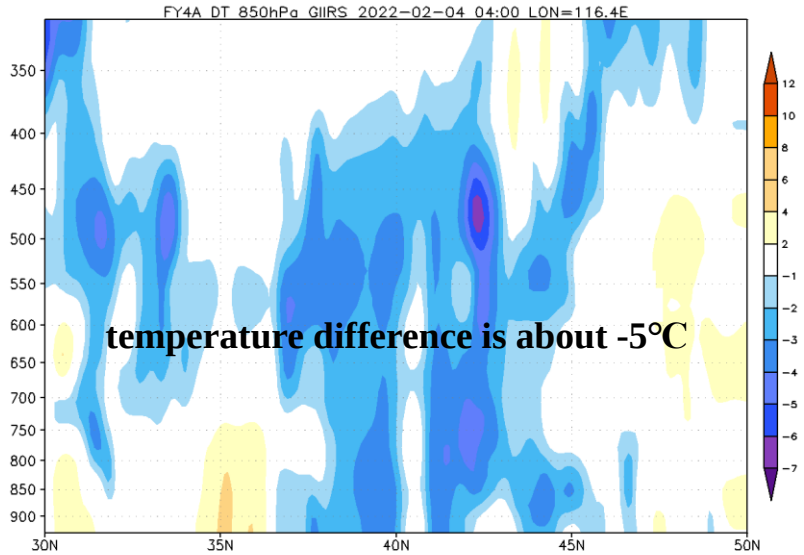
Vertical distribution of temperature

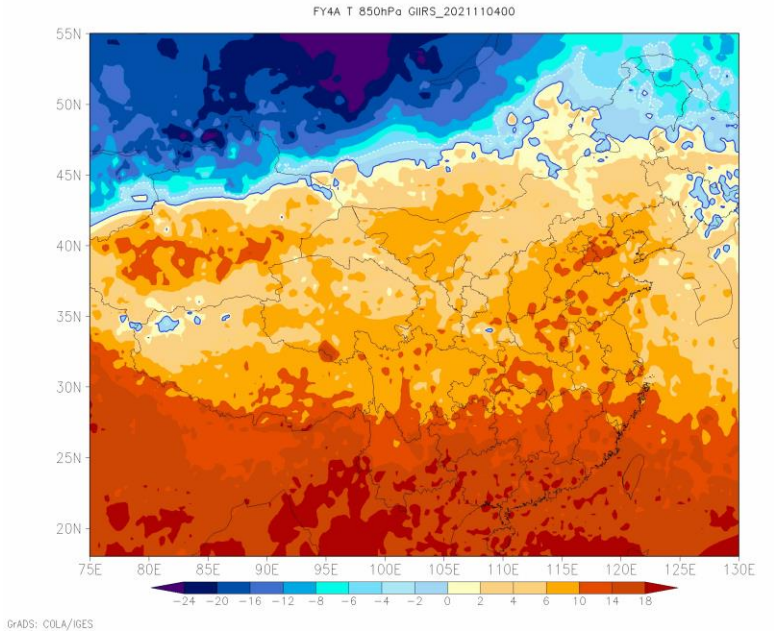


24-hour temperature difference at 850hPa



vertical distribution of 24-hour temperature difference

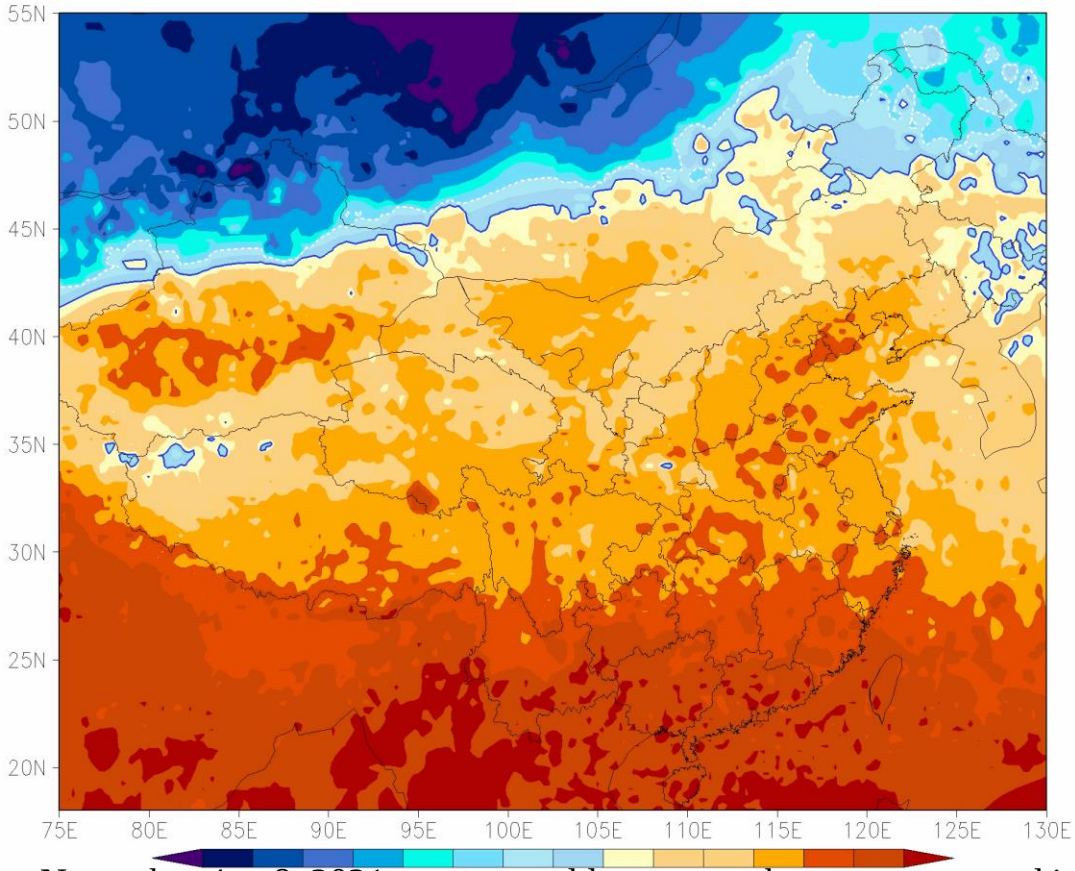




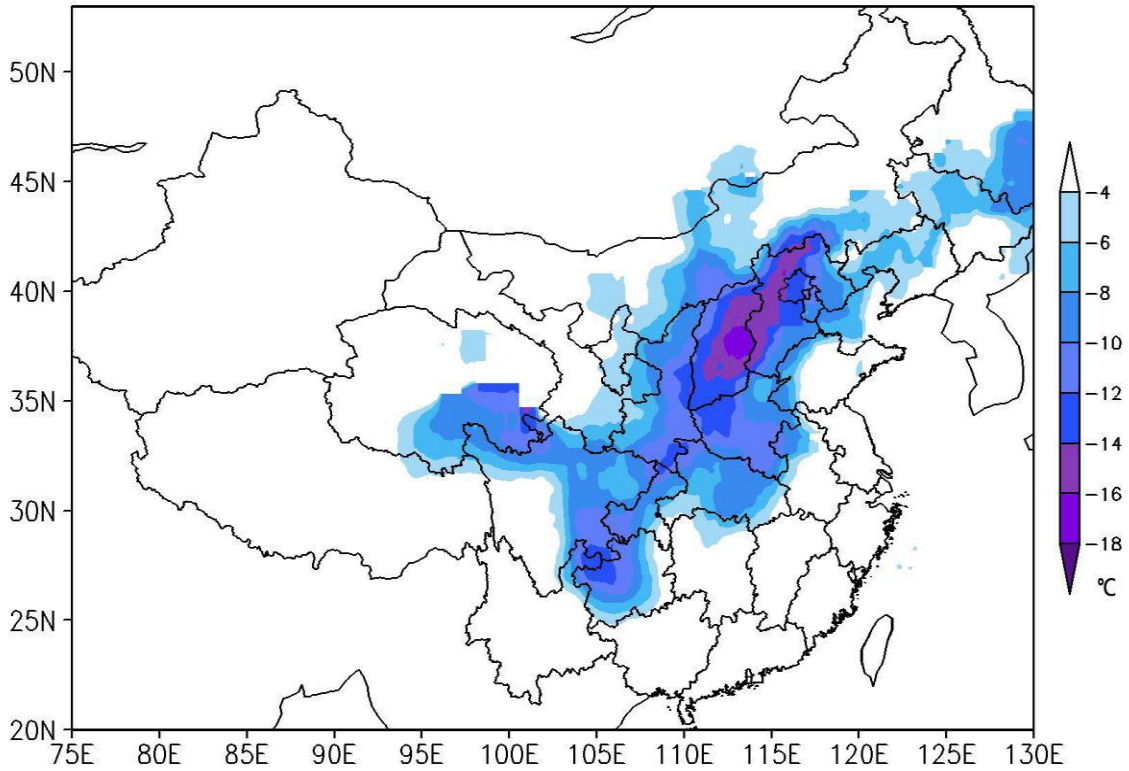
5. FY-4A/GIIRS temperature application in cold wave weather monitoring in 2021

Using FY-4A GIIRS temperature products to carry out cold wave service： Cold wave weather process on November 4-8, 2021

850hPa temperature from November 4 to November 11,2021



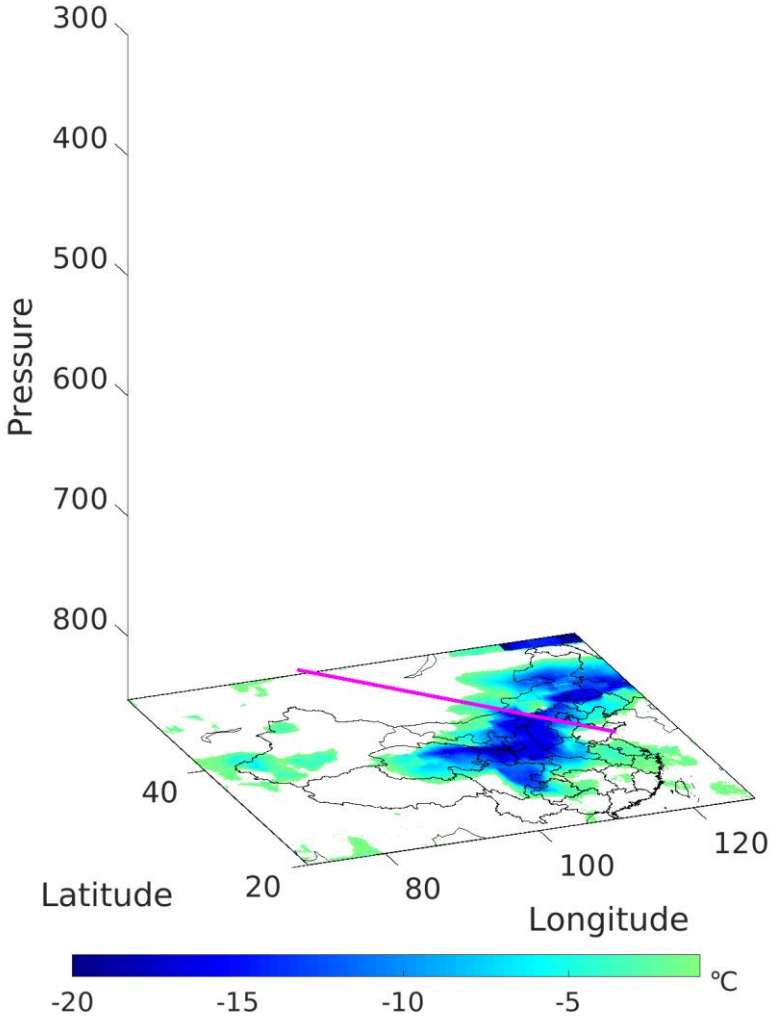
The 24-hour temperature difference at 850 hPa at 00:00 from November 6 to 7, 2021



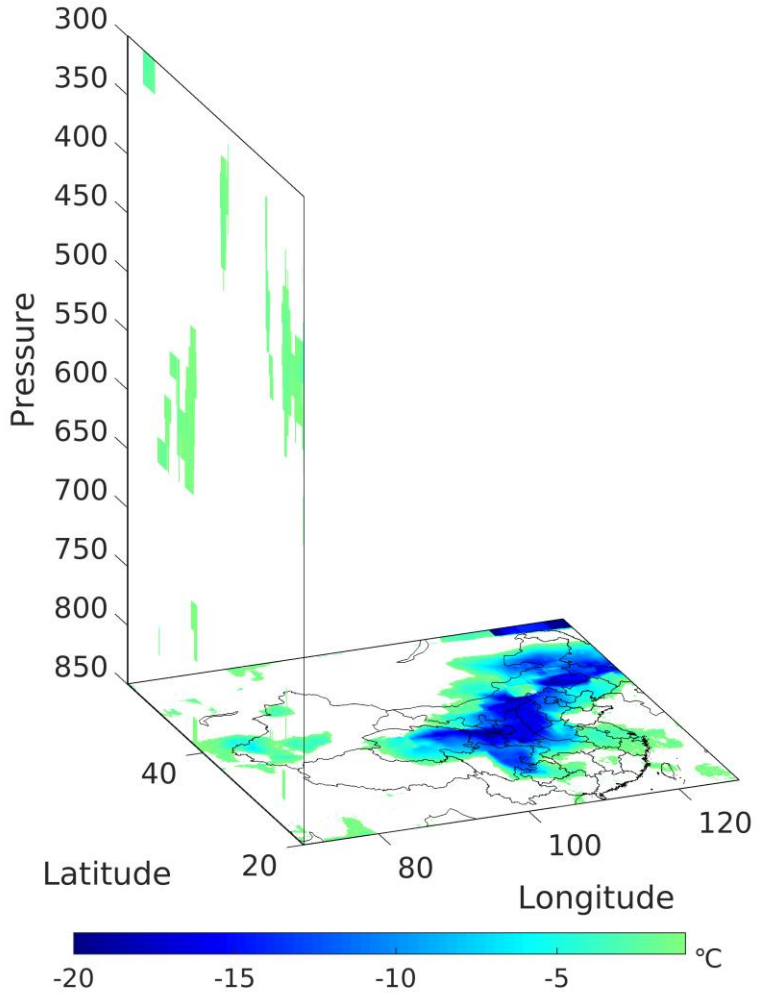
From November 4 to 8, 2021, a strong cold wave weather event occurred in China, with strong cooling and wide influence. The cold air activity caused a sharp drop in temperature. The daily minimum temperature in most areas of China decreased by 10–14 ℃, and even up to 16℃ in some areas.

that the strong cooling center is located in the east of northwest China and North China, and the local temperature exceeds 18 degrees.

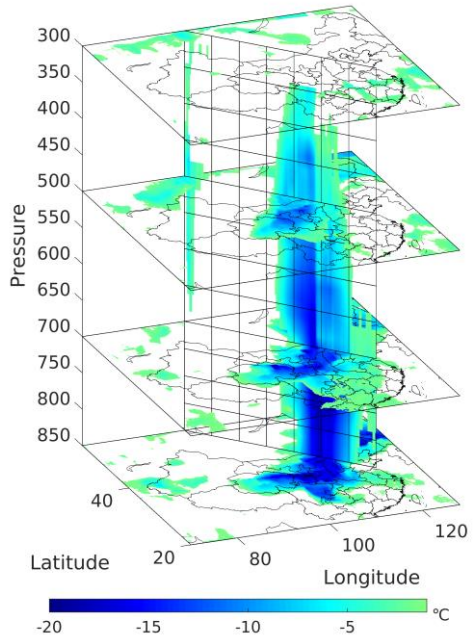
The three-dimensional structure of cold air activity can be seen in the vertical profile of 24-hour temperature difference from 20:00 on November 5 to 20:00 on November 6, 2021

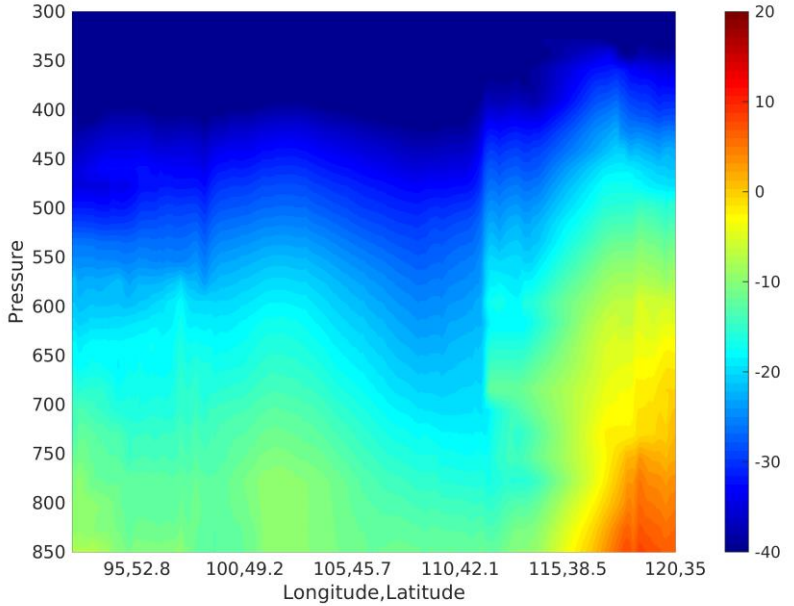


（ Bottom-up animation）

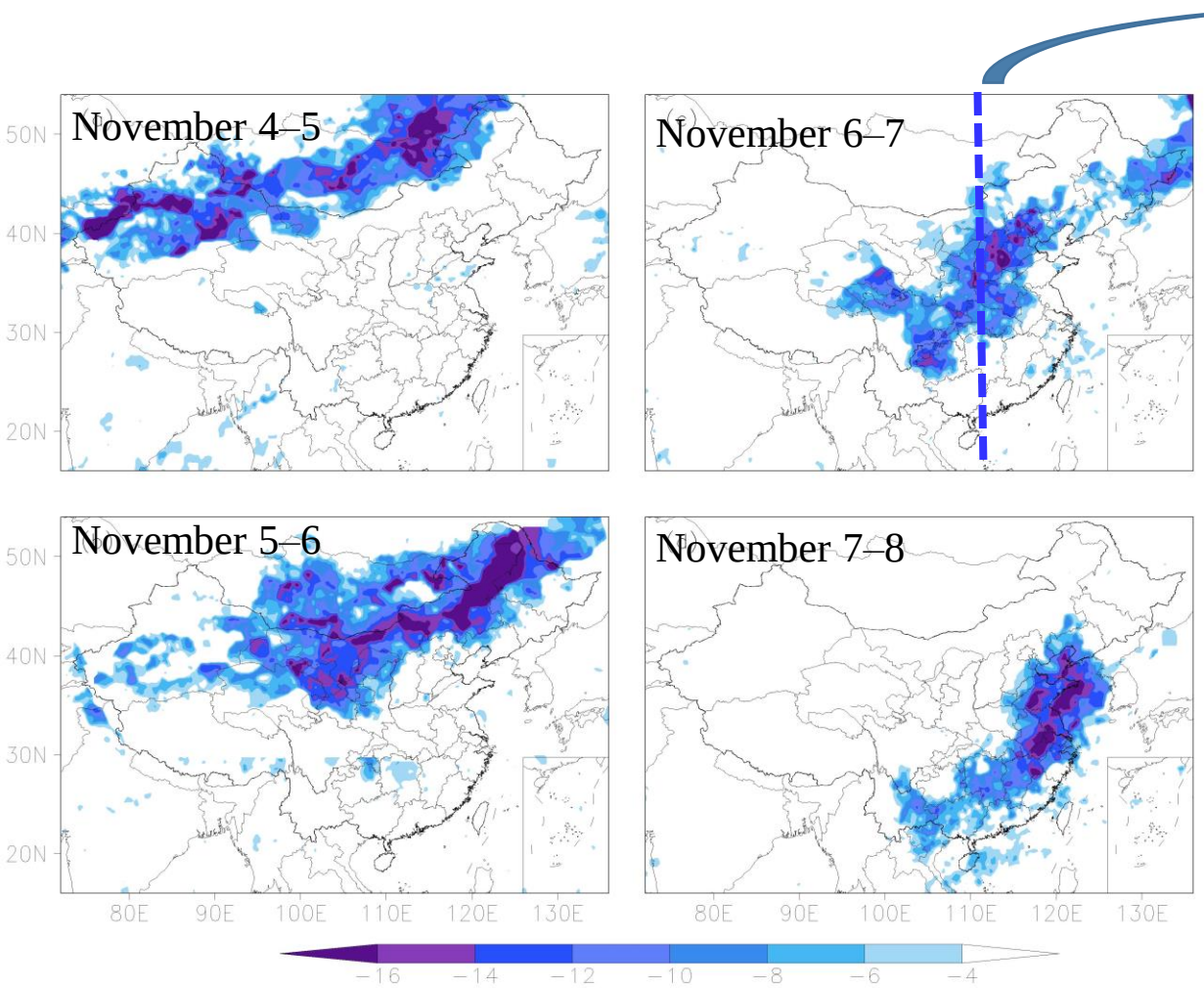


（ West to East Animation）

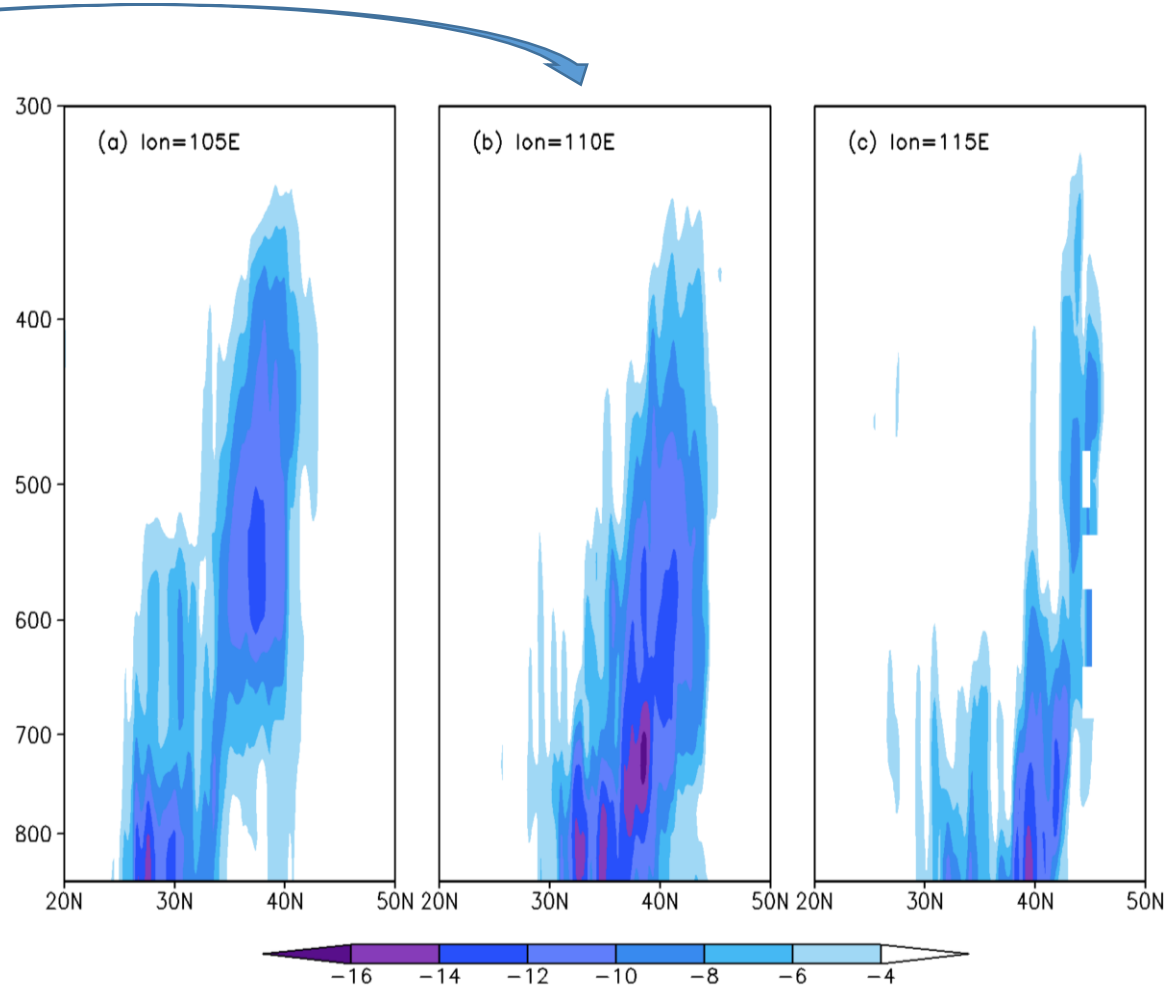




Vertical temperature profile: the cold air advancement



The 24-hour temperature difference at 850 hPa at 00:00 from November 4 to 8, 2021 (a: November 4–5; b: November 5–6; c: November 6–7; d: November 7–8).

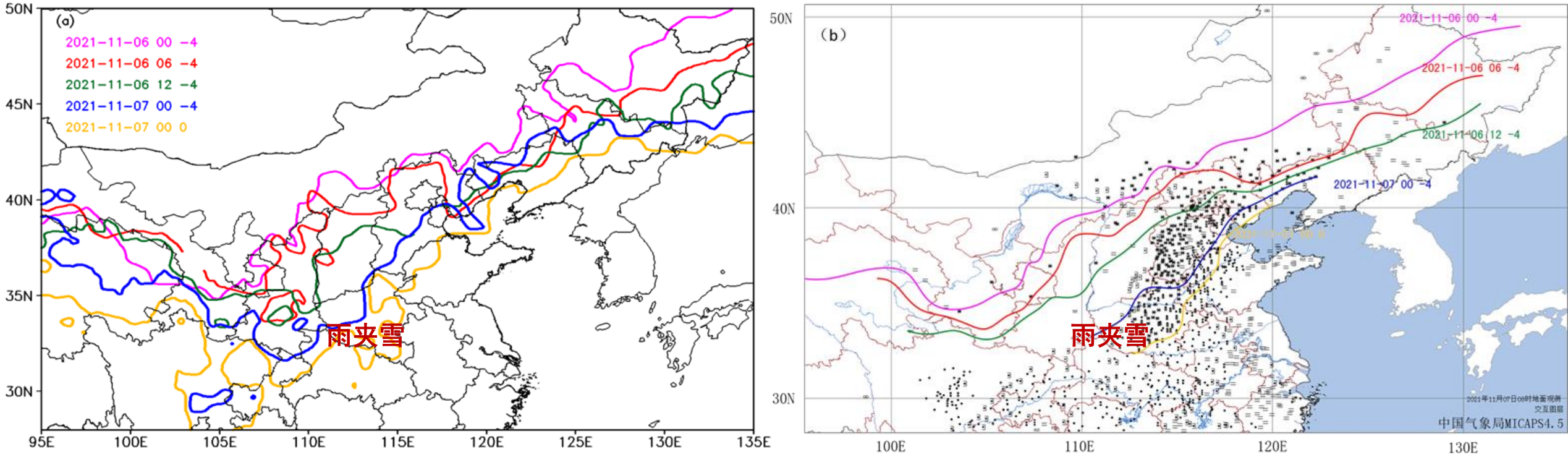


Vertical distribution of 24-hour temperature difference at 850 hPa at 00:00 from November 6 to 7, 2021 (a: 105E; b: 110E; c: 115E).

The results show that the cold wave process has deep cold air mass, the cold air affected the lower troposphere earlier than the middle troposphere, the temperature drop intensity in the lower troposphere is stronger, and the strongest 24-hour temperature difference is more than 16℃ in some areas.

00:00, 06:00, 12:00 and 00:00 on November 6, 2021

rain and snow



（a）**FY-4A/GIIRS −4℃ and 0℃ temperature contour lines at 850 hPa**, (b) ground observation snow line and sleet line, and ground observation weather symbol at 00:00 on November 7 ("*" is snow, "·" is rain and "*·" is sleet).

FY-4A/GIIRS temperature effectively monitored the transformation of rain and snow phases during this cold wave. Generally speaking, at 850 hPa, the −4℃ temperature contour line can be used as the key indicator of the snow line, −4 to 0℃ is for sleet, and above 0℃ is for rain.

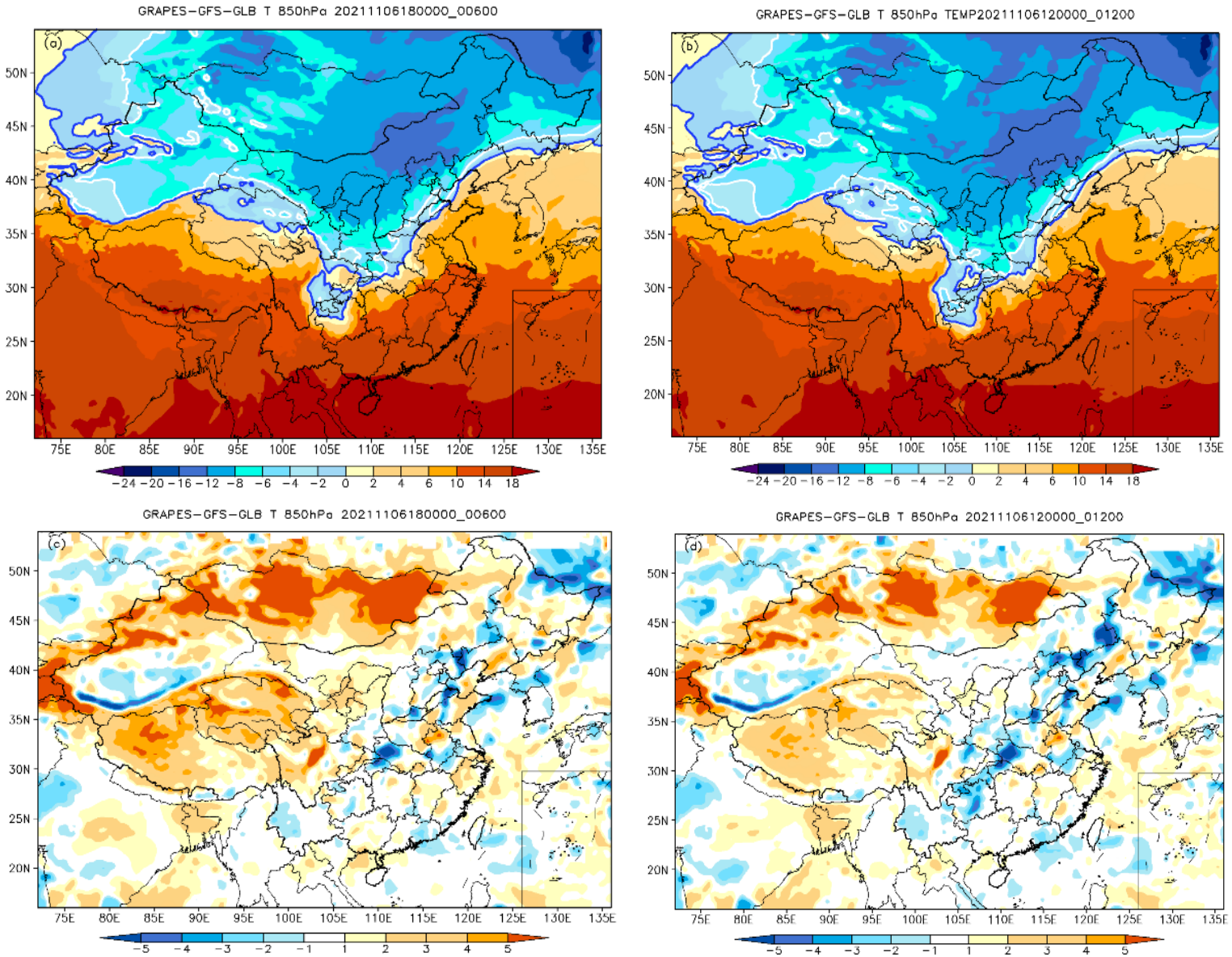
Verification of 6–12 h temperature prediction accuracy of GRAPES-GFS model using FY-4A/GIIRS temperature

Another application of FY-4A/GIIRS temperature in cold wave monitoring is the accuracy verification of model prediction.

the model has a good prediction for cold air advancing, while the predicted temperature deviated near the cold air center. and the range of temperature decrease at the beginning of the cold air advancing is lower.

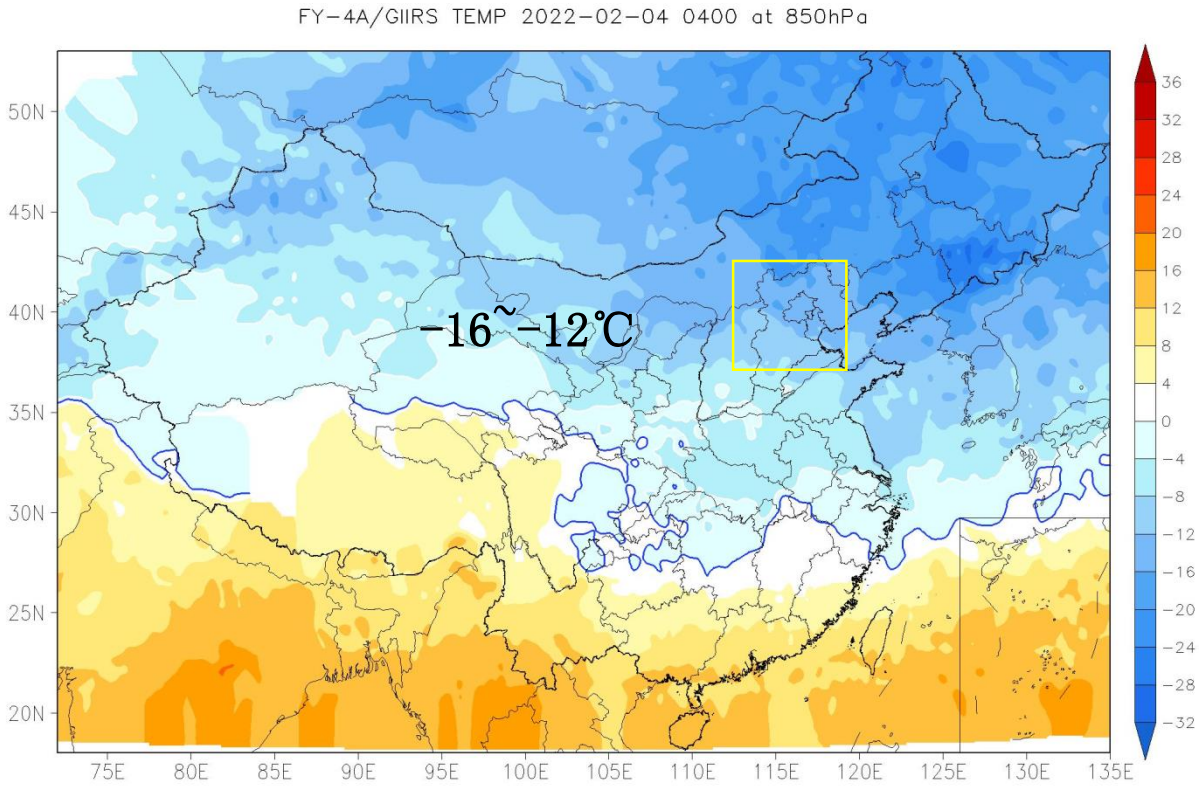
（2021-11-06 1800 006）

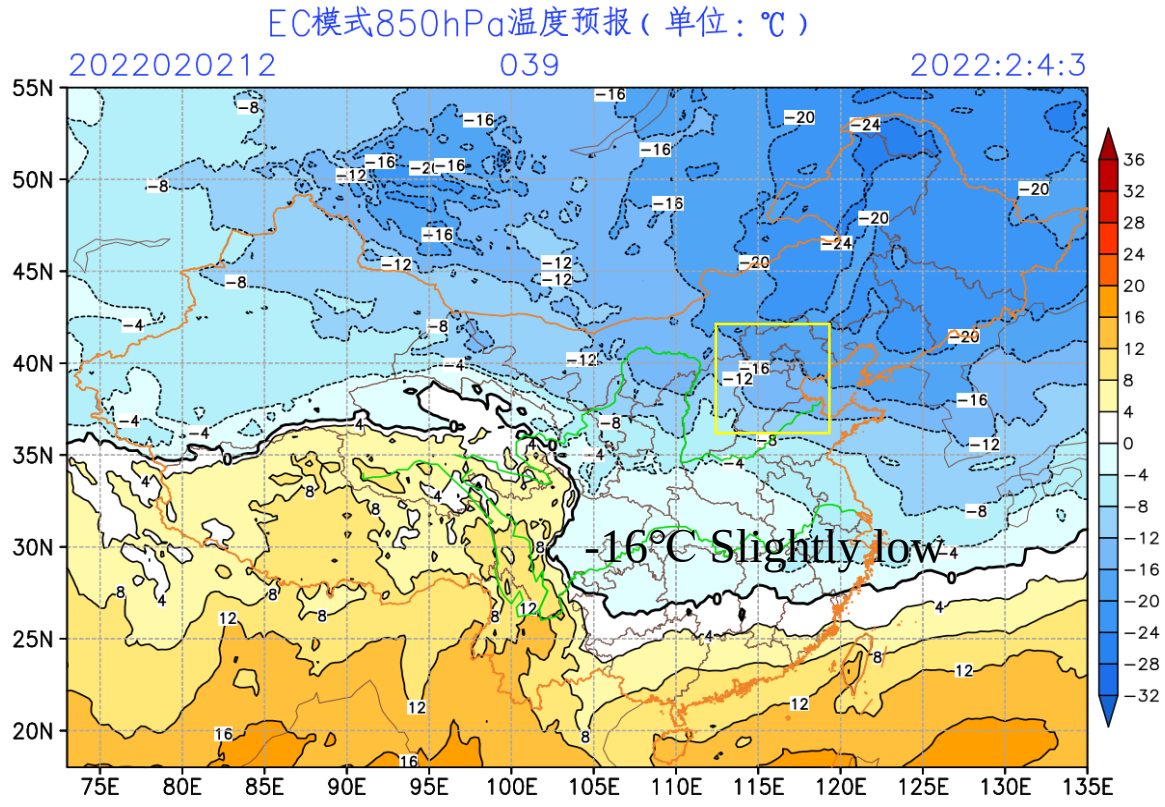
（2021-11-06 1200 012）



GRAPES-GFS - FY-4A/GIIRS

Exampel: validition of FY-4A/GIIRS temperature products on EC model (application in Beijing Winter Olympics)





6. Conclusion and discussion

Method： Using FY-4A/GIIRS temperature, according to the data quality identification, remove the data with low retrieval accuracy affected by clouds, and form the temperature products with high accuracy covering the whole region through data interpolation to carry out operational weather services.

Characteristics： **High precision satellite retrieved temperature data in clear sky and with thin clouds, and three-dimensional data of atmospheric temperature at about 2 hour intervals**，

Applications： **（1）Vertical detection of atmospheric temperature in clear sky or with thin clouds**

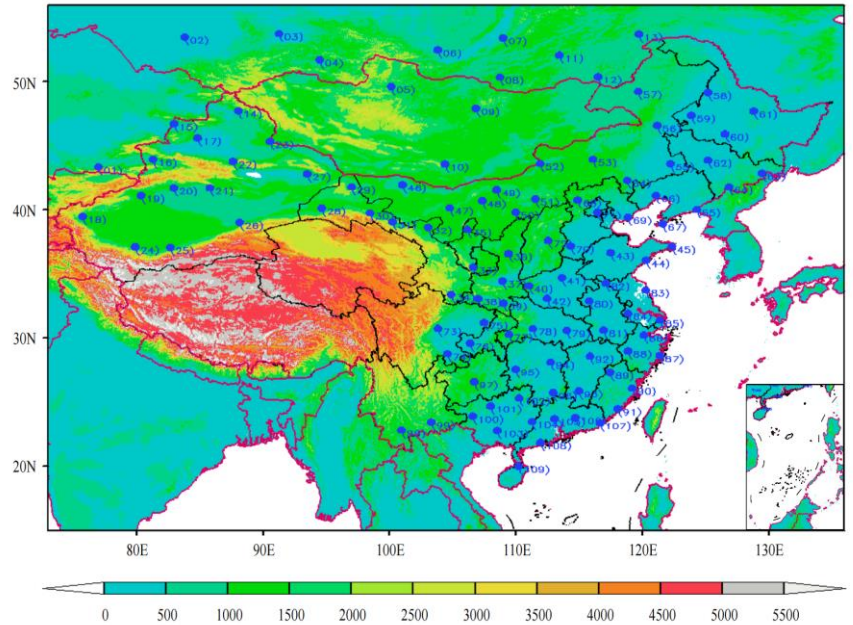
（2）cold wave monitoring in winter

Mean Bias： MB=0.07℃

Mean Absolute Error：**MAE=1.80 ℃**

Root Mean Square Error： RMSE=2.46 ℃

Correlation Coefficient： RR=0.95



Suling REN, Jianying JIANG, Xiang FANG, Hui LIU, Zhiqiang CAO, ***FY-4A*/GIIRS Temperature Validation in Winter and Application to Cold Wave Monitoring**. Journal of Meteorological Research,2022, 36(4): 658-676. doi: 10.1007/s13351-022-2015-4

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THANKS