Introduction of FY-4B instruments and post-launch calibration results

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- Brief introduction of FY-4B
- FY-4B/AGRI On-board Performance Status
- FY-4B/ GIIRS On-board Performance Status
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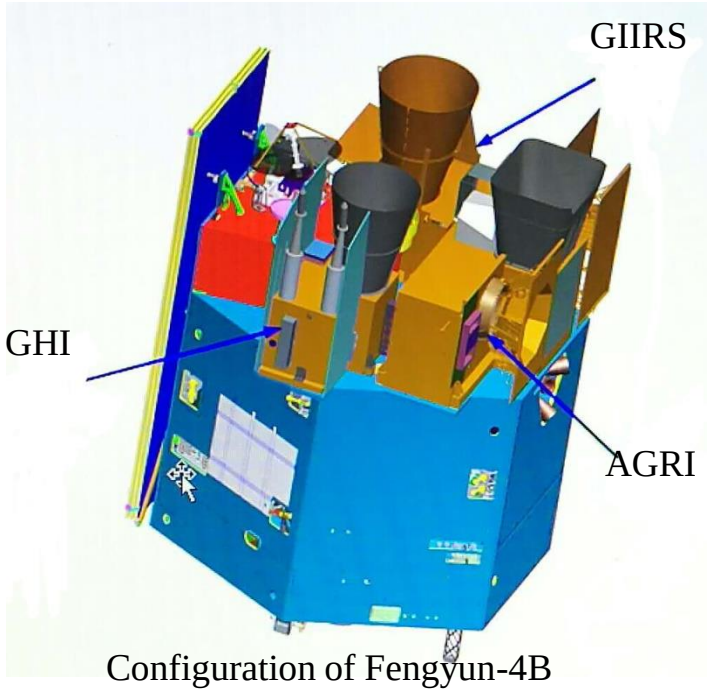
1 Brief introduction of FY-4B

FY-4B satellite was launched successfully on June 3, 2021.

It was designed to be the first operational satellite of the FY-4 series, and was successfully located at 123.5°E on June 10, 2021, and relocated to 133°E on April 11, 2022, for operational service.

The primary payloads onboard FY-4B are Advanced Geostationary Radiation Imager (AGRI), Geostationary Interferometric Infrared Sounder (GIIRS), and Geosynchronous High-speed Imager (GHI) and Space Environment Monitoring Instrument Package (SEP).

The main observation capabilities are similar to those of FY-4A, with some significant performance improvements.



Configuration of Fengyun-4B

Primary payloads on the FY-4B

	Instruments
1	Advanced Geostationary RadiationImager (AGRI)
2	Geostationary Interferometric Infrared Sounder (GIIRS)
3	Geosynchronous High-speed Imager (GHI)
4	Space Environment Monitoring Instrument Package (SEP)

2 FY-4B/AGRI On-board Performance Status

Comparison between FY-4B/AGRI and FY-4B/AGRI

Characteristics of FY4A/AGRI

Type	Channel /Band	Range(μm)	Spatial resolution(km))	Sensitivity/SNR		Primary purpose
Visible & Near-Infrared	1	0.45～0.49	1	S/N≥90 (ρ=100%)		Aerosol
	2	0.55～0.75	0.5～1	S/N≥150 (ρ=100%) @0.5Km	S/N≥3 (ρ=1%) @1Km	Fog, cloud
	3	0.75～0.90	1	S/N≥200 (ρ=100%)	S/N≥3 (ρ=1%)	Vegetation
Short-wave Infrared	4	1.36～1.39	2	S/N≥150 (ρ=100%)	S/N≥3 (ρ=1%)	Cirrus
	5	1.58～1.64	2	S/N≥200 (ρ=100%)	S/N≥3 (ρ=1%)	Cloud, snow
	6	2.1～2.35	2～4	S/N≥200 (ρ=100%)	S/N≥3 (ρ=1%)	Cirrus, aerosol
Mid-wave Infrared	7	3.5～4.0(high)	2	NEΔT≤0.7K (300K)		Fire
	8	3.5～4.0(low)	4	NEΔT≤0.2K (300K)	NEΔT≤2K (240K)	Land surface
Water vapor	9	5.8～6.7	4	NEΔT≤0.2K (300K)	NEΔT≤0.9K (240K)	High level water vapor
	10	6.9～7.3	4	NEΔT≤0.25K (300K)	NEΔT≤0.9K (240K)	Middle level water vapor
Long-wave Infrared	11	8.0～9.0	4	NEΔT≤0.2K (300K)	NEΔT≤0.4K (240K)	Water vapor, cloud
	12	10.3～11.3	4	NEΔT≤0.2K (300K)	NEΔT≤0.4K (240K)	Surface temperature
	13	11.5～12.5	4	NEΔT≤0.2K (300K)	NEΔT≤0.4K (240K)	Surface temperature
	14	13.2～13.8	4	NEΔT≤0.5K (300K)	NEΔT≤0.9K (240K)	Cloud thickness

Characteristics of FY4B/AGRI

Channel/ Band	Center wave length (μm)	Range(μm)	Spatial resolution(km)	Sensitivity/SNR		Primary purpose
1	0.47	0.45~0.49	1	S/N≥90(ρ=100%)		Aerosol
2	0.65	0.55~0.75	0.5	S/N≥150(ρ=100%)@0.5km	S/N≥3(ρ=1%) @1km	Fog, cloud
3	0.825	0.75~0.90	1	S/N≥200(ρ=100%)	S/N≥3(ρ=1%)	Vegetation
4	1.379	1.371~1.386	2	S/N≥120(ρ=100%)	S/N≥2(ρ=1%)	Cirrus
5	1.61	1.58~1.64	2	S/N≥200(ρ=100%)	S/N≥3(ρ=1%)	Cloud, snow
6	2.225	2.10~2.35	2	S/N≥200(ρ=100%)	S/N≥2(ρ=1%)	Cirrus, aerosol
7	3.75	3.50~4.00(high)	2	≤0.7K(315K)		Fire
8	3.75	3.50~4.00(low)	4	0.2K(300K)	2K(240K)	Land surface
9	6.25	5.80~6.70	4	0.2K(300K)	0.9K(240K)	High level water vapor
10	6.95	6.75~7.15	4	0.25K(300K)	0.9K(240K)	Mid level water vapor
11	7.42	7.24~7.60	4	0.25K(300K)	0.9K(240K)	Low level water vapor
12	8.55	8.3~8.8	4	0.2K(300K)	0.4K(240K)	Cloud
13	10.80	10.30~11.30	4	0.2K(300K)	0.4K(240K)	Surface temperature
14	12.00	11.50~12.50	4	0.2K(300K)	0.4K(240K)	Surface temperature
15	13.3	13.00~13.60	4	0.5K(300K)	0.9K(240K)	Cloud thickness

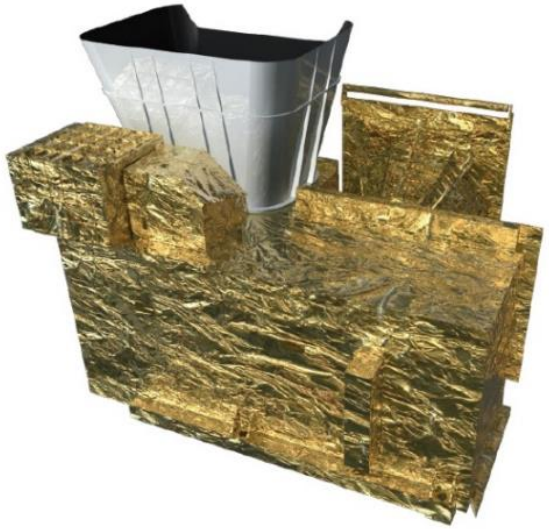
Green color denotes the new added channel; Blue color denotes the band range and the spatial resolution which was optimized

The introduction of FY-4B/AGRI

Compared with FY-4A, 1 new water vapor channel is added, 4 channel band settings are optimized, and the resolution of short wave and medium wave channel is improved to 2km;

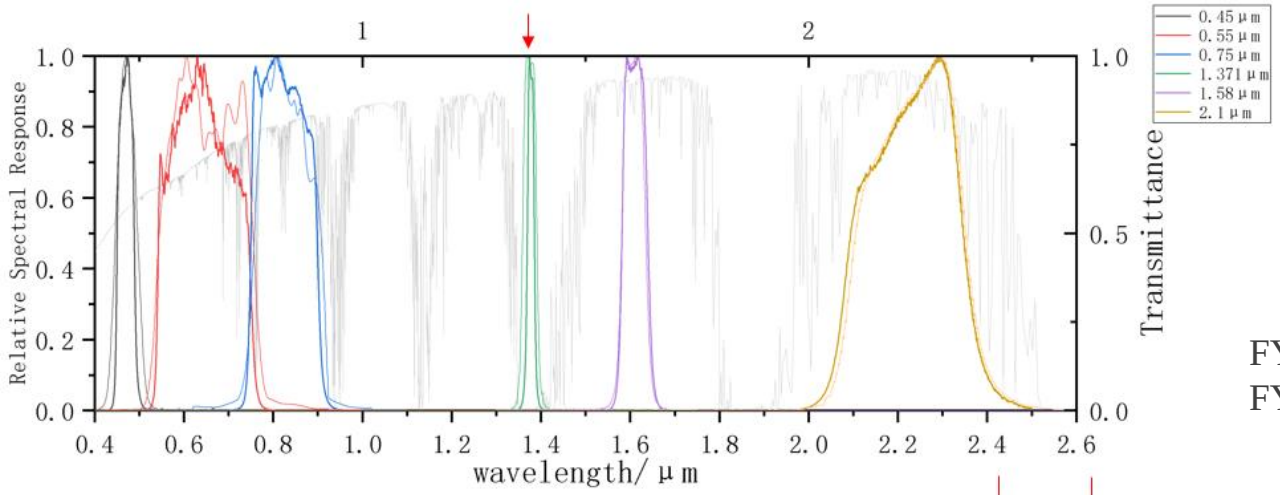
- The dynamic range of the instrument is set reasonably;
- All 15 channel sensitivities meet the requirements.
- The SNR of the reflection channel and the sensitivity of the long-wave IR channel are doubled compared to the FY-4A.

The scanning mode of FY-4B/AGRI is to acquire full disk images every 15 minutes at equal time intervals.

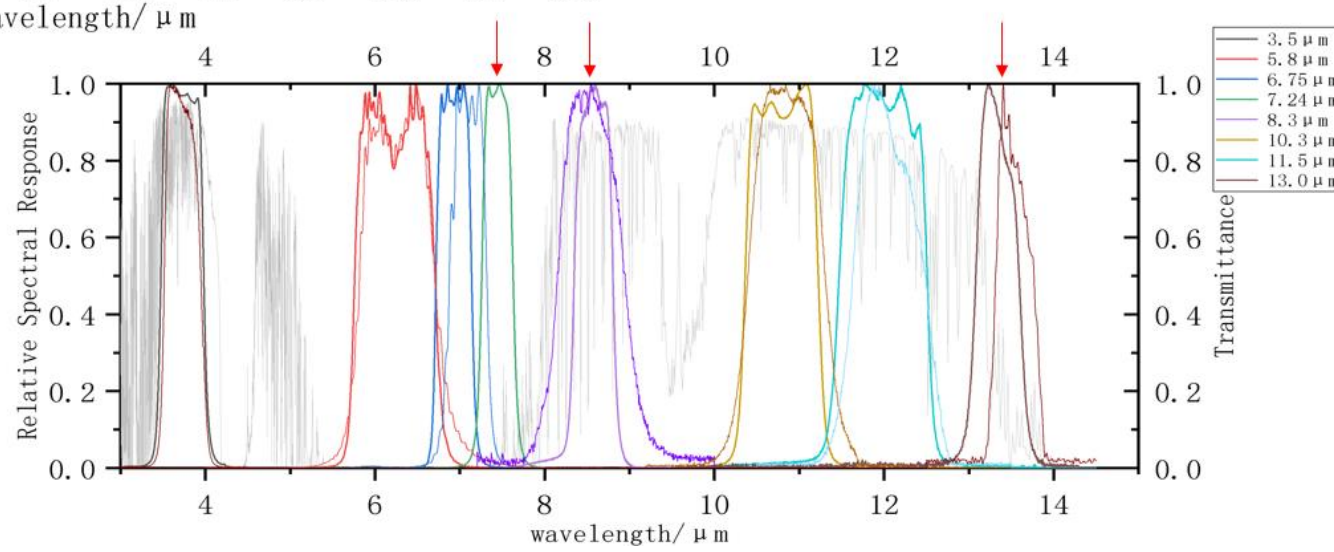


AGRI of FY-4B

The Spectral Response Function Curve of FY-4A/B AGRI



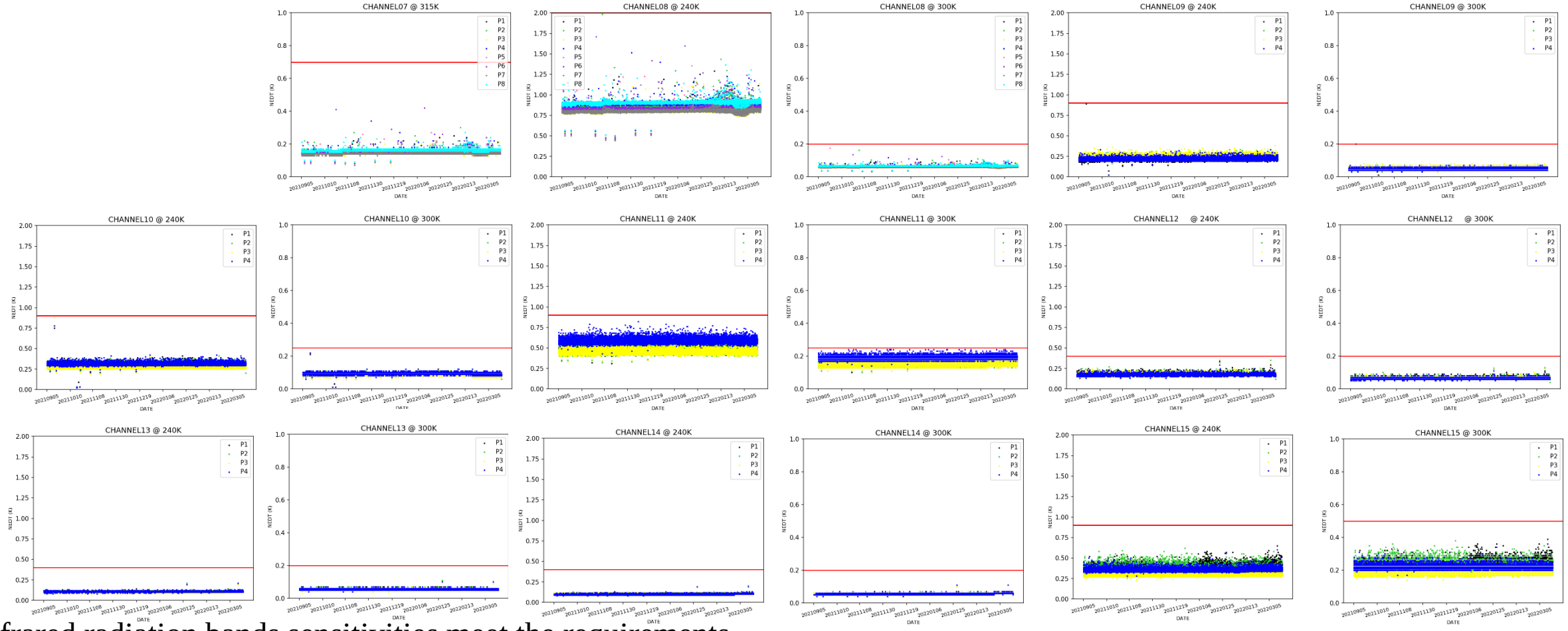
FY-4A/AGRI Thin line
FY-4B/AGRI **Thick line**



Compared with FY-4A/AGRI, some spectrums have been optimized and adjusted in FY-4B/AGRI .

2 FY-4B/AGRI On-board Performance Status

The noise performance of FY-4B/AGRI



Infrared radiation bands sensitivities meet the requirements.

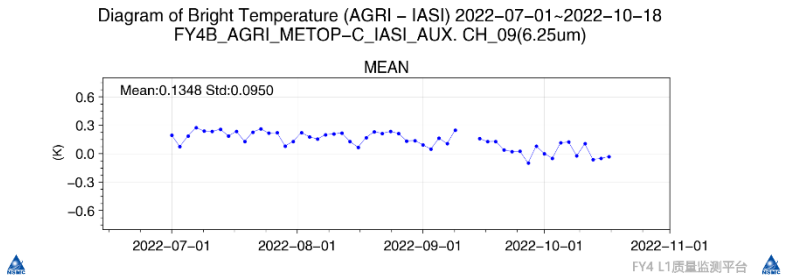
The sensitivity of the long-wave channel are doubled compared to the FY-4A.

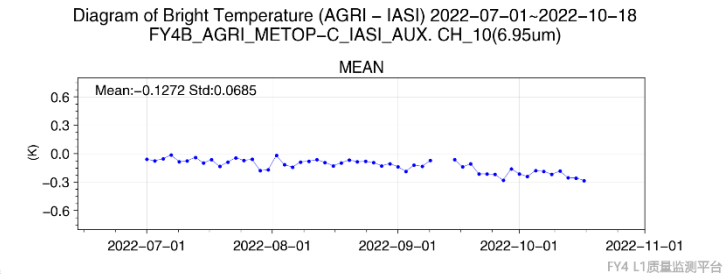
IR Calibration accuracy of FY-4B/AGRI

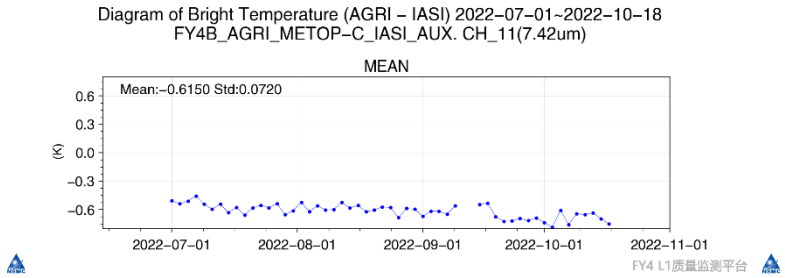
The mean brightness temperature bias of FY4B/AGRI IR bands with respect to Metop-C/IASI

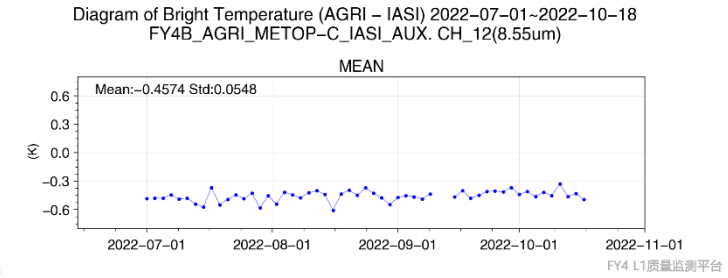
Band	Mean BIAS（K）
09	0.13
10	-0.13
11	-0.62
12	-0.46
13	-0.44
14	-0.28
15	-0.63

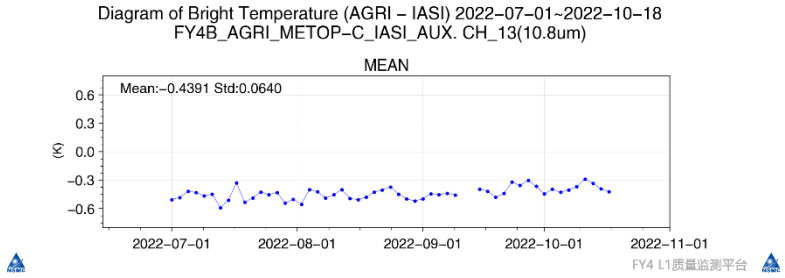
The mean brightness temperature bias of FY-4B/AGRI is better than 0.7K with respect to Metop-C/IASI

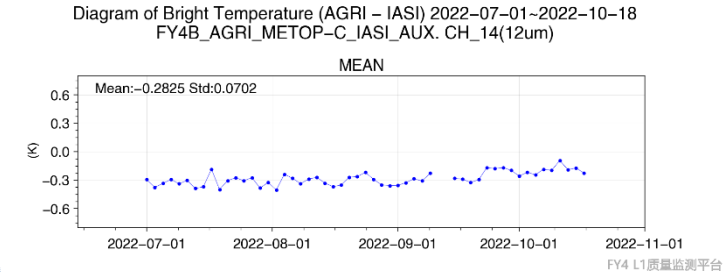


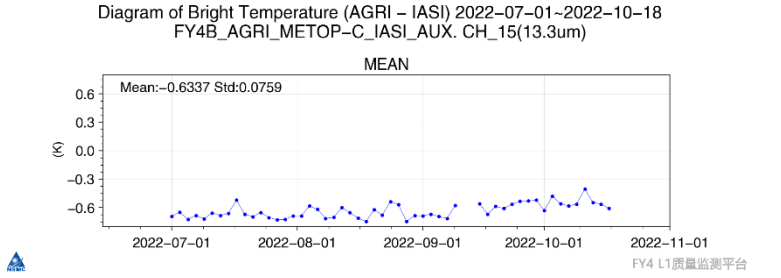








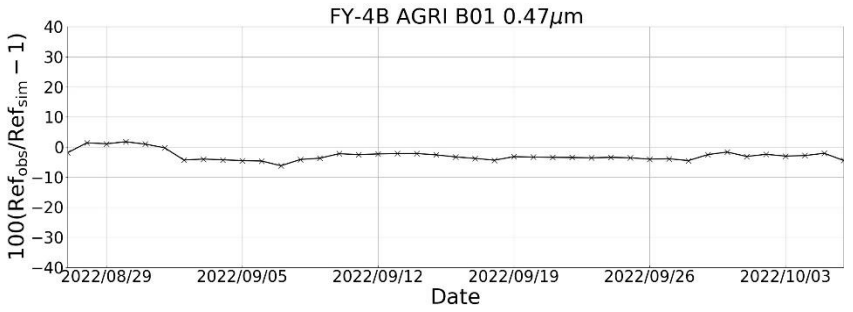


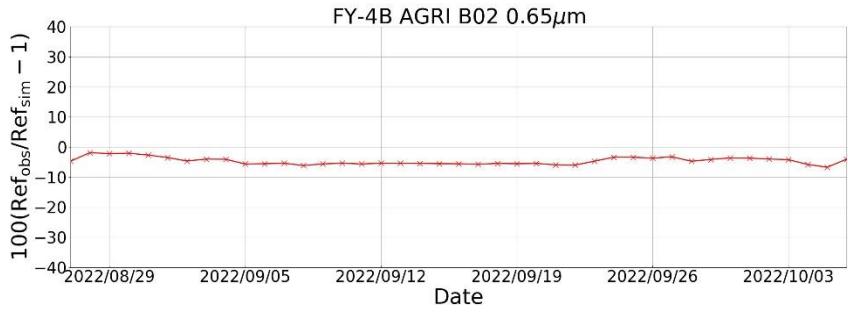


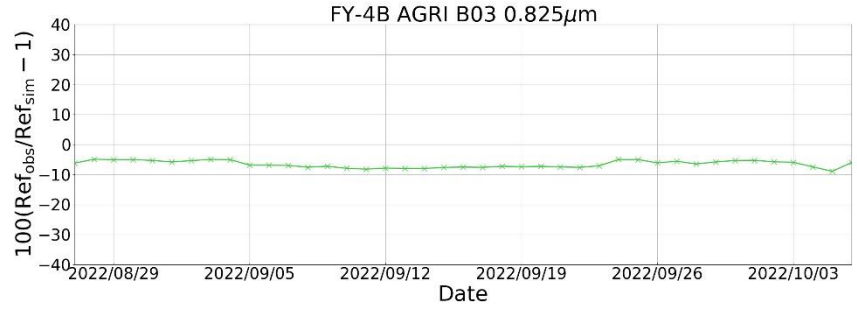
VIS/NIR Calibration accuracy of FY-4B/AGRI

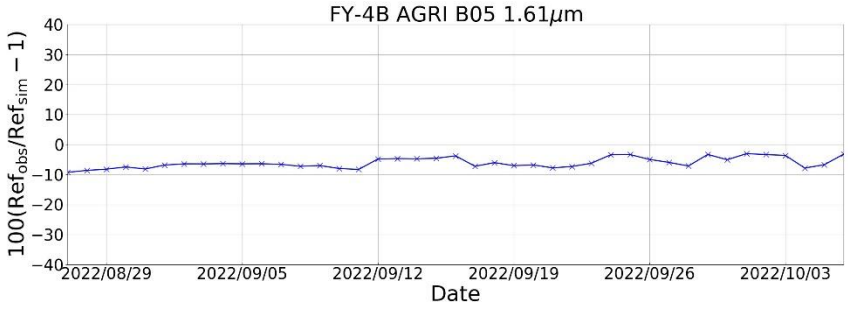
The calibration accuracy of FY4B/AGRI reflective solar bands(RSB) with reference to the simulated radiation from multiple sites

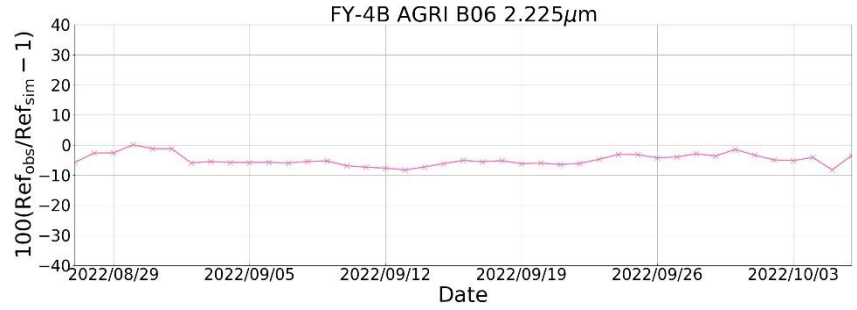
Band	Average relative deviation	STD
01	-3.23%	1.27%
02	-4.84%	0.99%
03	-6.69%*	1.10%
05	-5.85%	1.60%
06	-5.11%	1.77%









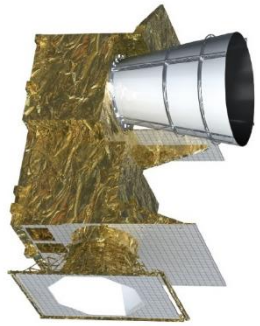


It shows that the most RSBs' calibration accuracy is near 5%.

Percentage difference of FY-4B AGRI RSBs using on-orbit solar diffuser (SD) calibration parameters with reference to the simulated radiation from multiple sites.

3 FY-4B/GIIRS On-board Performance Status

- FY-4B/GIIRS is the second infrared GEO-sounder of China. Unlike the scientific demonstration of FY-4A/GIIRS, this sounder is expected to be used for numerical weather prediction (NWP) operational models.
- GIIRS measures the hyperspectral atmospheric upwelling infrared radiance in the two spectral bands: the long-wave IR (LWIR) band from 680 to 1130 cm^{-1}, and the mid-wave IR (MWIR) band from 1650 to 2250 cm^{-1}. With low instrument noise, high spectral resolution and thousands of spectral channels, the radiance spectra provide a critical high vertical resolution information to retrieve the atmosphere's structure of temperature and water vapor in retrieval algorithms and NWP models, and also supply extensive information about trace gases, surface and cloud properties for climate research.
- GIIRS acquires the spectral soundings by measuring a number of interferograms. The interferograms are measured simultaneously over a so-called dwell using a two-dimensional detector array for each band. **The 16×8 pixels of the detector with sparse arrangement give 128 interferograms per band and per dwell**. A pixel spans 120 μm and the field of view (FOV) is 336 μrad. Thus, **the spatial sampling on the Earth surface is 12 km at Nadir, and one dwell covers an area of 384×192 km**. The observed region as seen from the geostationary orbit will be covered by a succession of dwells with measuring the upwelling radiation at the top of atmosphere at a moderate high spectral resolution of 0.625 cm^{-1}, defined by the sampling length of the interferogram.

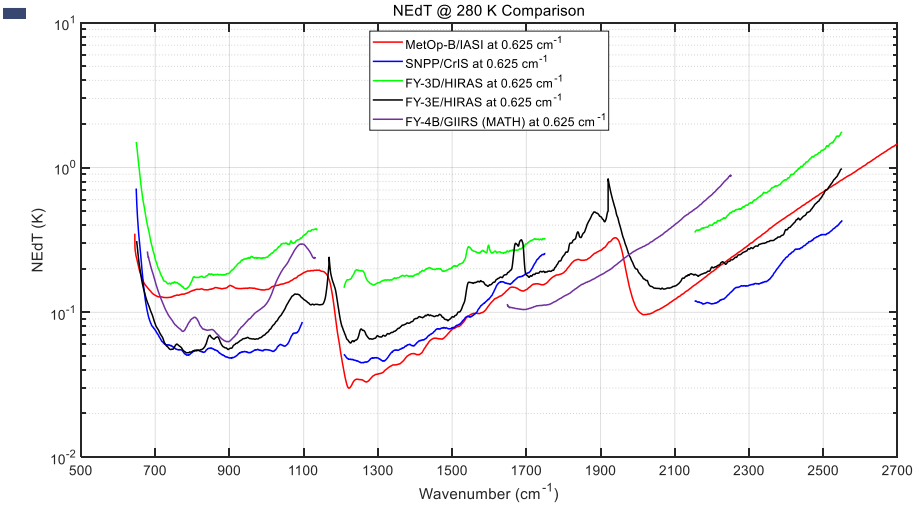


FY-4B/GIIRS model

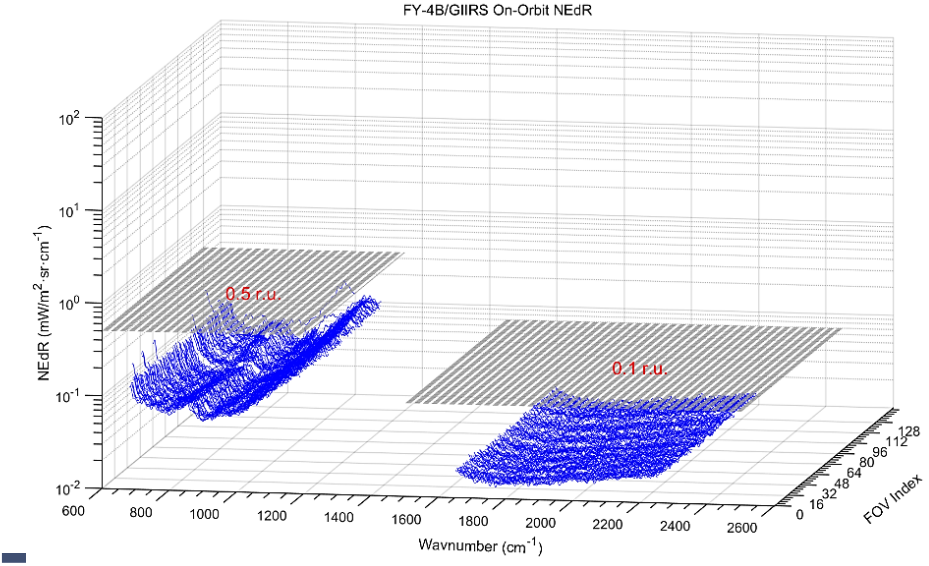
FY4B/GIIRS measuring requirements

Item	Band	
	LWIR	MWIR
Nominal Spectral range (cm^{-1})	680-1130	1650-2250
MPD(cm)	0.8	0.8
Spectral Resolution(cm^{-1})	0.625	0.625
Number of Channels	721	961
NEΔR [$mW/(m^{-2}\cdot sr\cdot cm^{-1})$]	<0.5	<0.1
Spatial Resolution(s.s.p) (km)	12x12	12x12
Frequency Uncertainty (ppm)	7	7
Radiometric Calibration Accuracy (k)	0.7	0.7

3 FY-4B/GIIRS On-board Performance Status

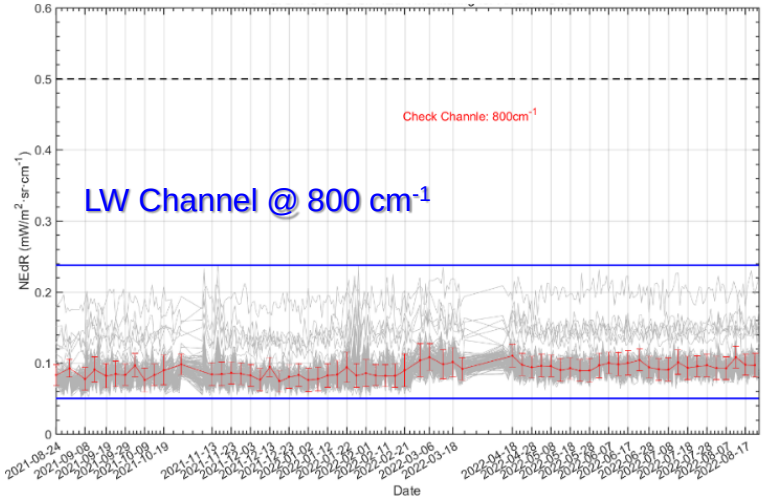


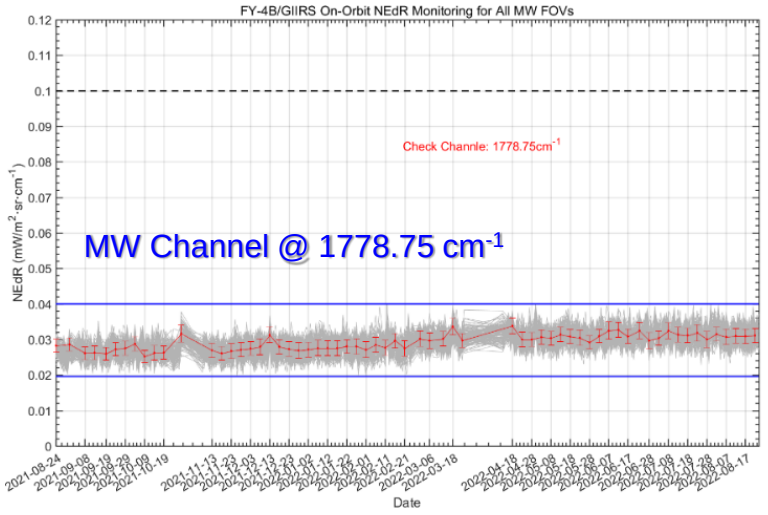
FY-4B/GIIRS on-orbit NEdT@280K is compared with international similar sounders



FY-4B/GIIRS noise performance (NEdR) for all 128 FOVs

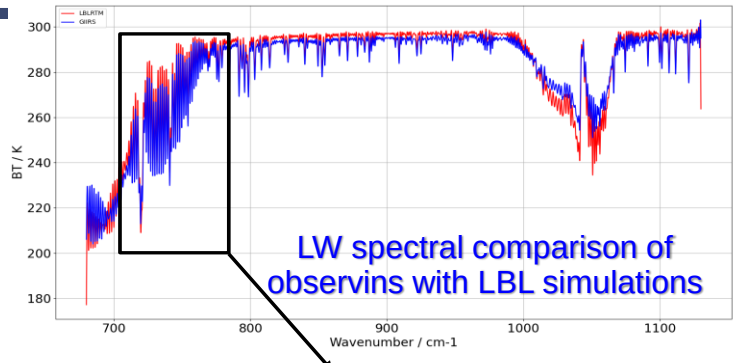
FY-4B/GIIRS on-orbit NEdRs monitoring for 128 FOVs in typical channels (2021.08.24~2022.08.24)



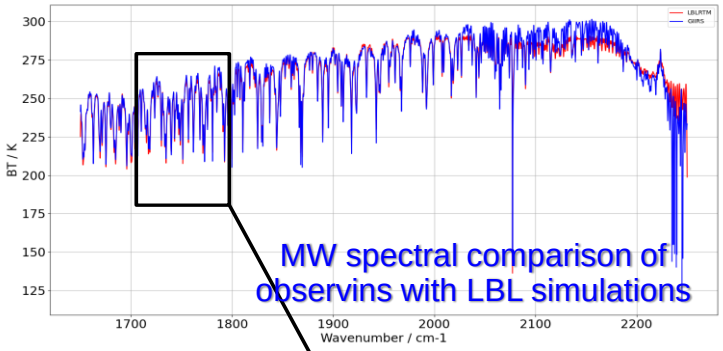


- FY-4B/GIIRS has a good noise performance with the radiance noise levels (NEdR) being better than 0.5 and 0.1 in mW/(m^2·sr·cm^{-1}) for both the LWIR band and the MWIR bands, respectively.
- **GIIRS in-flight NEdRs are stable in 2022**.

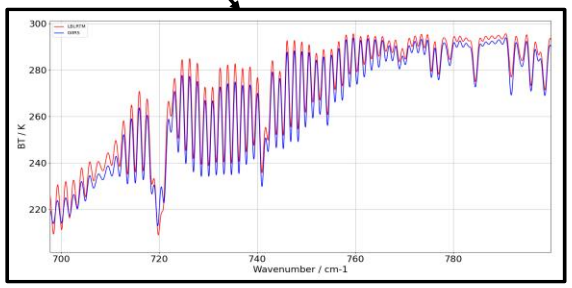
3 FY-4B/GIIRS On-board Performance Status

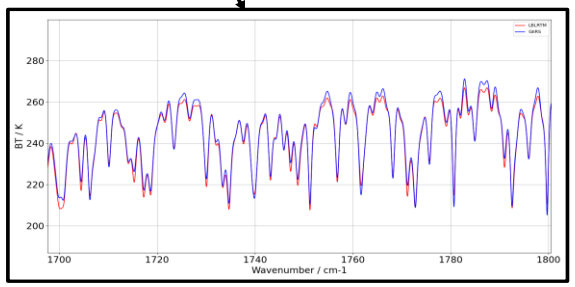


LW spectral comparison of observins with LBL simulations

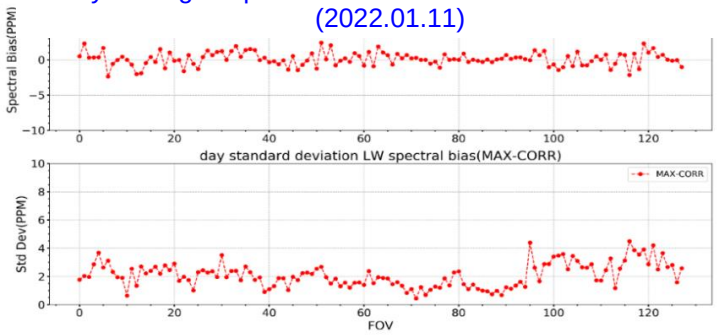


MW spectral comparison of observins with LBL simulations

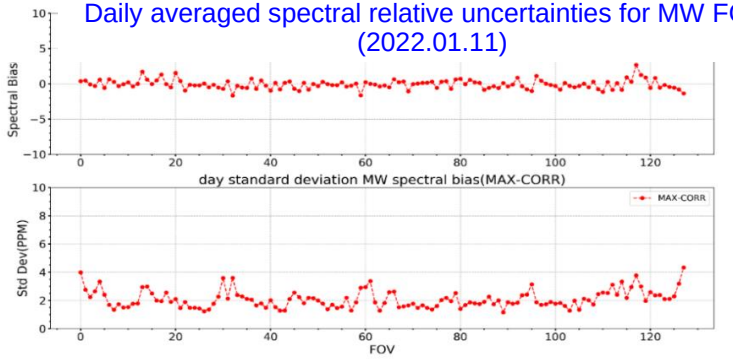


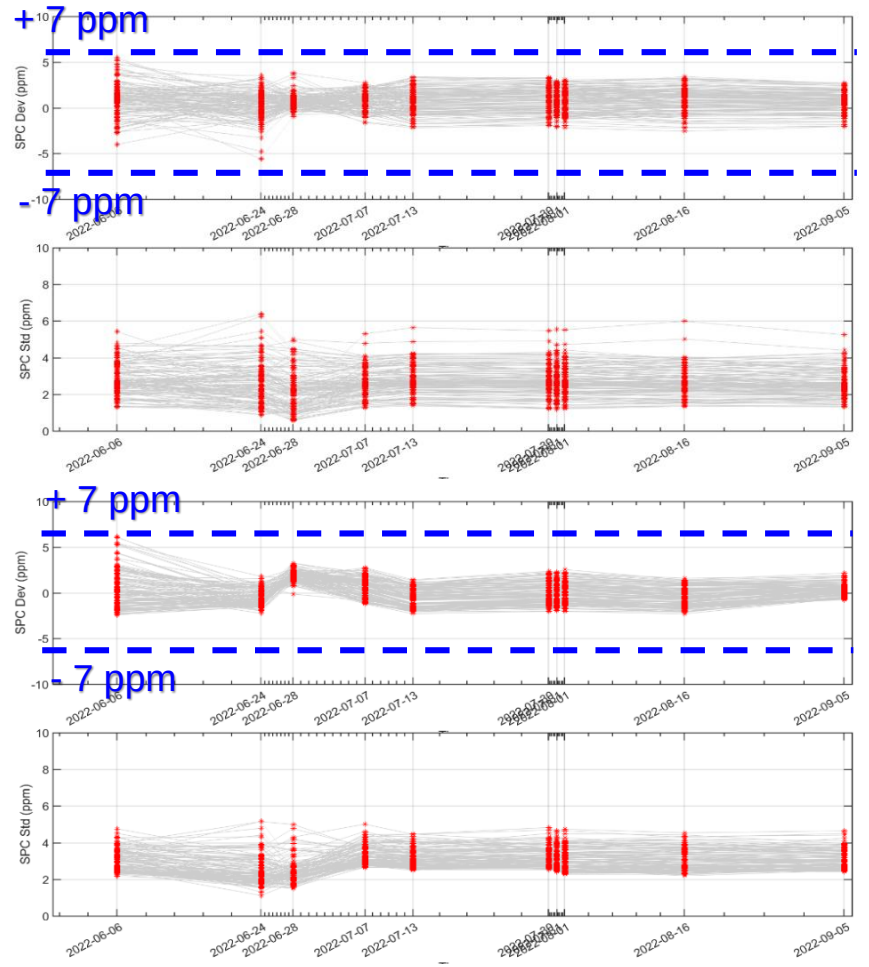


Daily averaged spectral relative uncertainties for LW FOVs (2022.01.11)



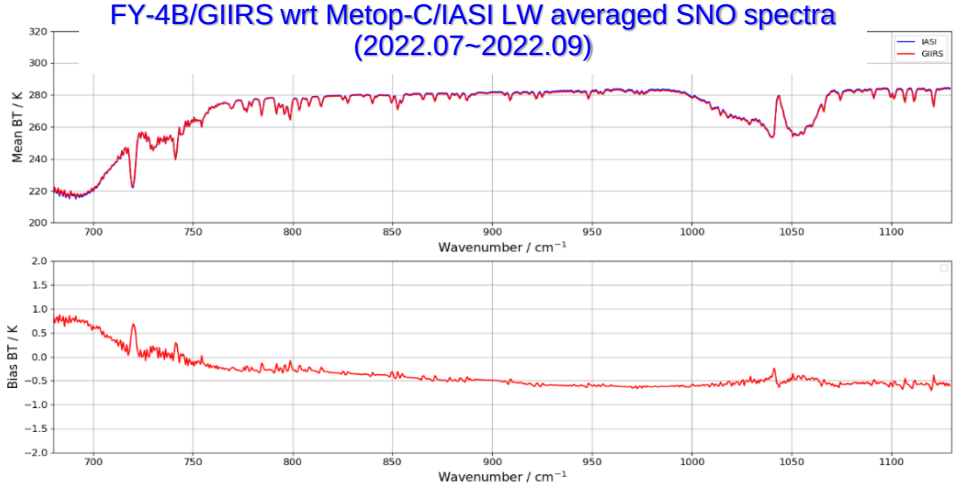
Daily averaged spectral relative uncertainties for MW FOVs (2022.01.11)

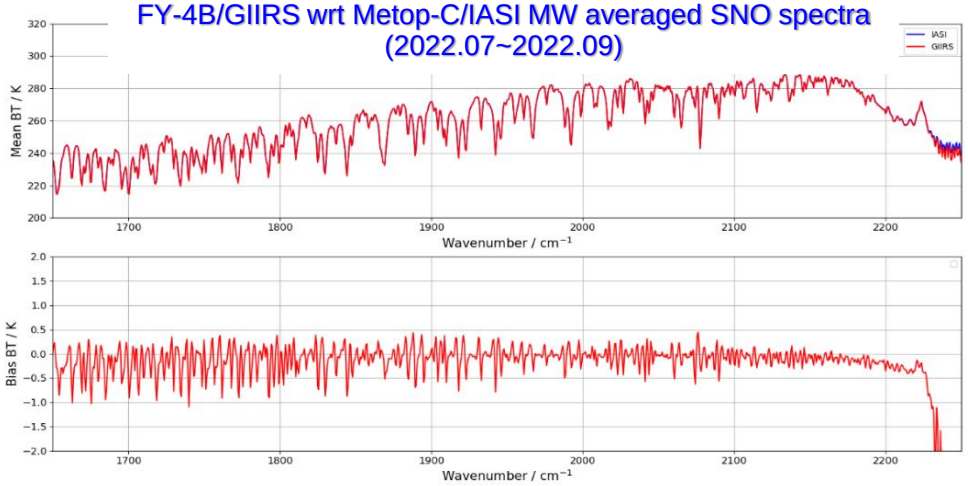


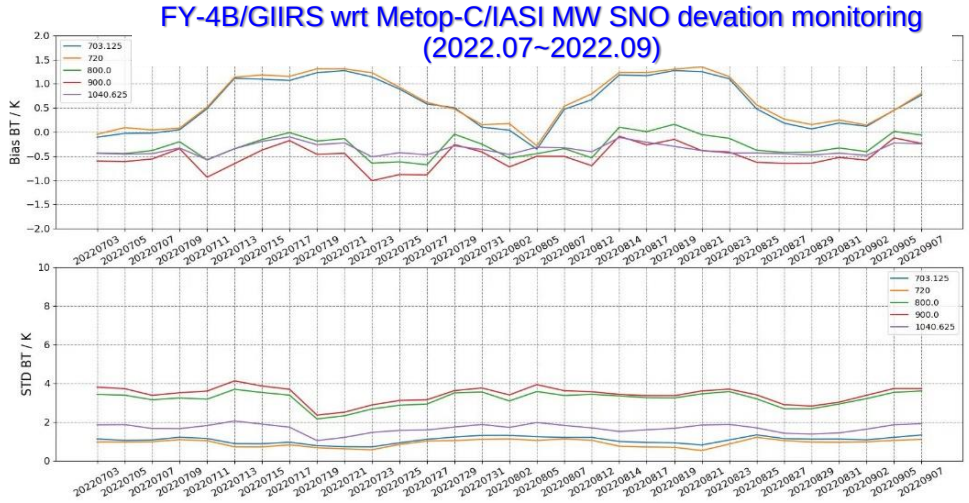


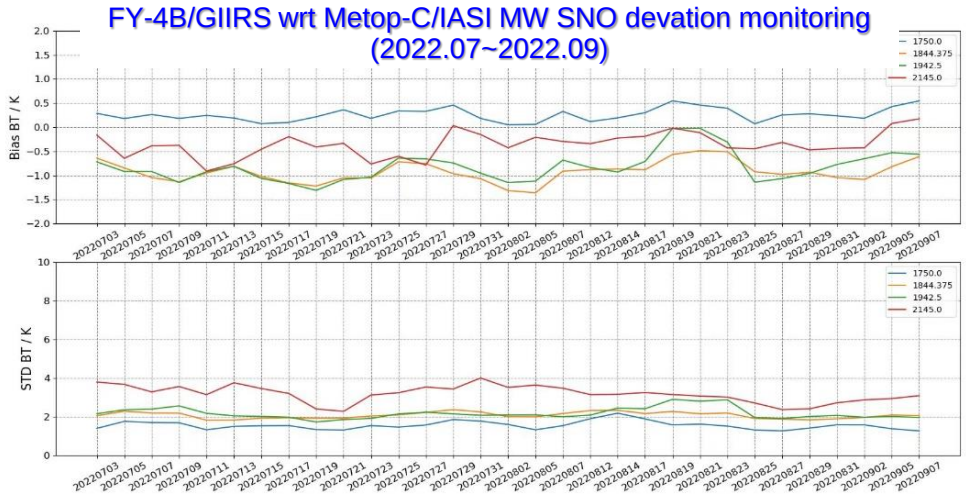
FY-4B/GIIRS spectral calibration uncertainties are assessed using the LBLRTM simulated spectra. The uncertainties in both LWIR and MWIR bands are better than 7 ppm **.** NSMC has released the L1 data since June 2022, and the spectral uncertainties of GIIRS are stable in the first four months (from Jun. to Sept. 2022).

3 FY-4B/GIIRS On-board Performance Status









- The radiometric calibration of FY-4B/GIIRS is mainly assessed using the SNO observations with IASI onboard MetOp-B & C satellites.
- The average calibration bias is better than 1K except in some spectral channels, which are affected by noise.
- The radiometric performance is related to instrument status, and is still in the phase of improvement.

The introduction of FY-4B/GHI

Geosynchronous High-speed Imager (GHI) is an experimental multi-spectral flexible imaging radiometer on Fengyun-4B satellite.

- ✓ Nominal scenario: 1 min continuous images of 2000km ×1800km;
- ✓ Ground resolution: 0.25km~0.5km(VNIR), 2km(LWIR);
- ✓ True color images of 0.5km from geostationary orbit;
- ✓ Full color band of 0.25km to perform star observations to determine the absolute LOS.

Fig. 11 GHI of FY-4B.

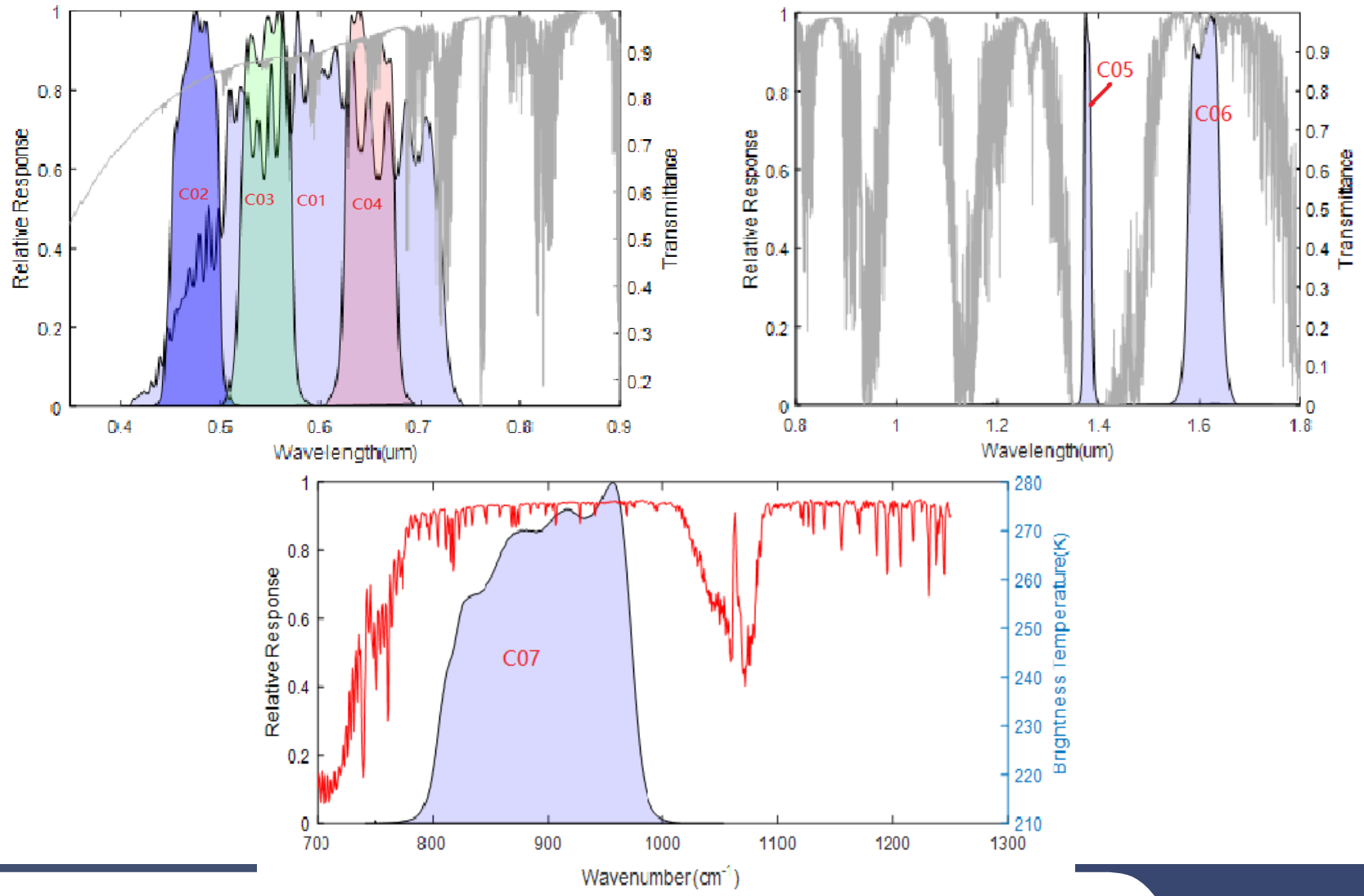
Characteristics of GHI

Channel/Band		Range(μm)	IFOV(μrad)	IFOV at s.s.p.(km)	Focal Plane Array	Primary purpose
VNIR	1	0.45~0.75	7	0.25	2048×1	**Full color, Daytime vegetation, stars**
	2	0.445~0.495	14	0.5	1024×1	**"blue" for true color, Daytime aerosol**
	3	0.52~0.57	14	0.5	1024×2	**"green" for true color, Daytime aerosol**
	4	0.62~0.67	14	0.5	1024×1	**"red" for true color, Daytime aerosol**
	5	1.371~1.386	14	0.5	1024×1	**Daytime thin cirrus**
	6	1.58~1.64	14	0.5	1024×1	**Daytime cloud/snow, water/ice cloud**
LWIR	**7**	**10.3~12.5**	**56**	**2**	**256×4**	**Nighttime imaging**

4 FY-4B/GHI On-board Performance Status

Fengyun-4B GHI SRFs & Atmospheric Brightness Temperature Spectrum

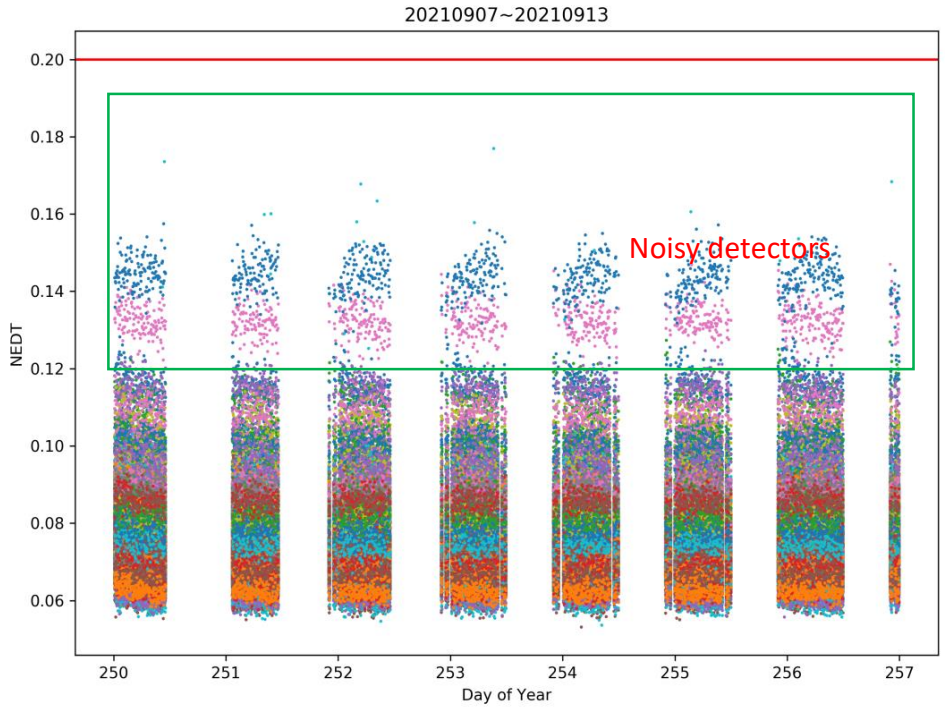
Relative Spectral Response



Detector quality

Calculated SNR and NEdT from prelaunch and on-orbit measurements

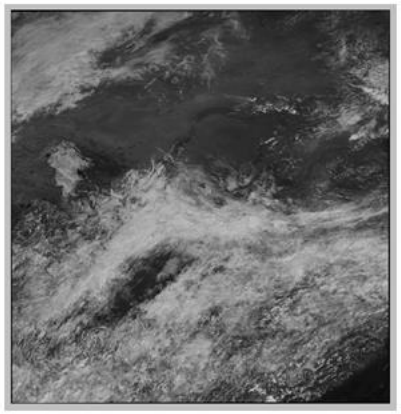
Channel/Band	Requirements	Prelaunch results@100%	On-orbit results@ρ0	Prelaunch results@ρ0
1	300@100%	776.073	160.0835@0.1541	163.9545@0.1590
2	200@100%	533.6230	121.557@0.1264	80.9868@0.1279
3	300@100%	501.656	119.6506@0.104	122.9714@0.1126
4	300@100%	461.213	191.0075@0.2231	203.925@0.2288
5	150@60%	191.651	/	/
6	300@100%	413.923	205.647@0.3377	258@0.3311
7	0.2K@300K	<0.182K	<0.18K	



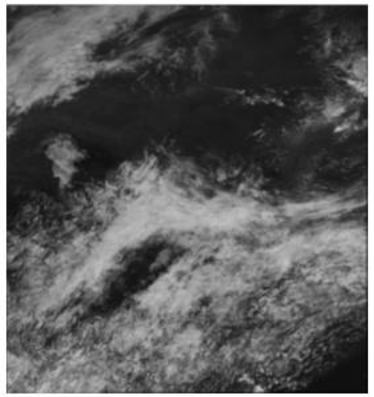
Channel 7's NEdT for Sep, 7 to 13, 2021

4 FY-4B/GHI On-board Performance Status

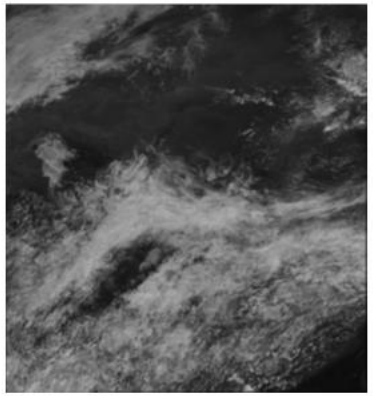
Initial Imagery



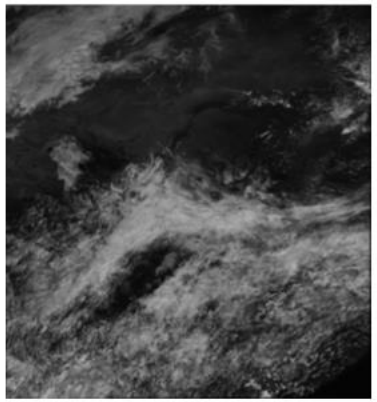
Band1



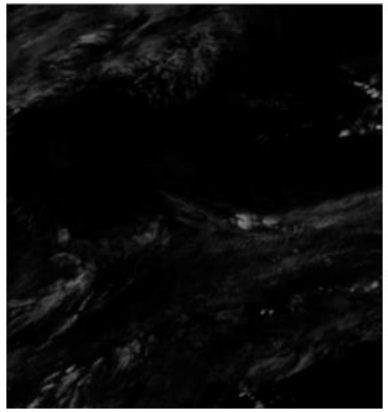
Band2



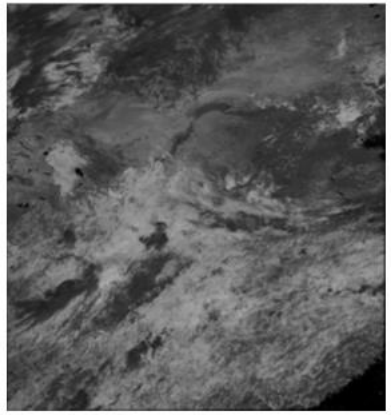
Band3



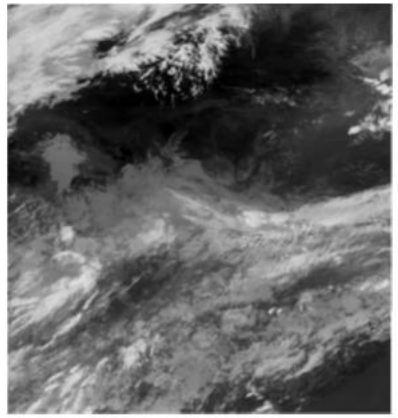
Band4



Band5



Band6



Band7

5.Summary

FY-4B/AGRI

- The SNR of the reflection channel and the sensitivity of the IR channel have met the specification.
- The radiometric calibration bias has met the specification of 0.7K in IR bands, while 5% in VIS/NIR bands.

FY-4B/GIIRS

- The noise performance characterized by NEdR meet the specifications of LW NEdR<0.5 and MW NEdR<0.1 $mW/(m^2 \cdot sr \cdot cm^{-1})$.
- The spectral calibration uncertainties in both LWIR and MWIR bands are be than 7 ppm.
- The radiometric calibration averaged biases are about 1K for both LW and MW bands.

FY-4B/GHI

- The results from the post-launch test show that the GHI IR images mean brightness temperature (Tb) bias with respect to Metop-B/IASI is better than 0.7K.

Validations and investigations are still ongoing to improve L1 data quality of all the three instruments.

Reference

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- Lu Li, Zhuoya Ni, Chengli Qi, Lei Yang, Changpei Han. Pre-Launch Radiometric Calibration of Geostationary Interferometric Infrared Sounder on FengYun-4B Satellite. Acta Optica Sinica, 2022, 42(6): 0630001(in chinese).
- Zhao, Cheng Zeng, Lu Lee, and Chengli Qi. Diurnal carbon monoxide observed from a geostationary infrared hyperspectral sounder: First result from GIIRS onboard FY-4B. Atmos. Meas. Tech., Discuss., 2022.
- Chapter5.1 AGRI instrument test，FY-4B space segment post-launch test report ,2021.12 NSMC
- Chapter5.8 AGRI calibration and validation，FY-4B ground segment post-launch test report ,2022.06 NSMC
- Chapter5.1 GIIRS instrument test，FY-4B space segment post-launch test report ,2021.12 NSMC
- Chapter5.2 GIIRS calibration and validation，FY-4B ground segment post-launch test report ,2022.06 NSMC
- Chapter5.1 GHI instrument test，FY-4B space segment post-launch test report ,2021.12 NSMC
- Chapter5.1 GHI calibration and validation，FY-4B ground segment post-launch test report ,2022.06 NSMC

Thank you for your attention!

If you have any questions, please contact us at the email address below.

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