The 24th International TOVS Study Conference (ITSC-XXIV)

Performance Status of GIIRS onboard FY-4B: after 1.5 years in orbit

Lu Lee, Chengli Qi, Weichu Yu, Qiankun Zhang

National Satellite Meteorological Center (NSMC), CMA

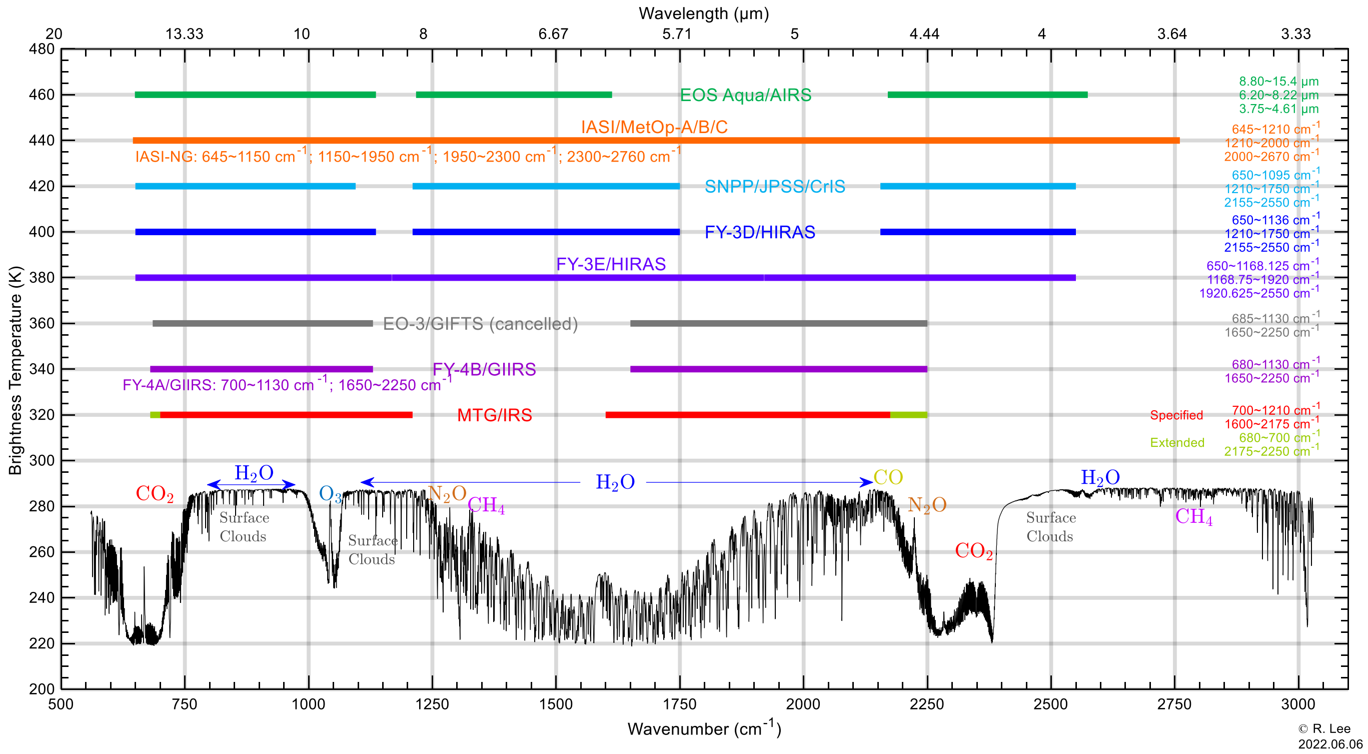
Disclaimer: The presentation contents of FY-4B/GIIRS expressed herein are solely the opinions of the authors and do not necessarily reflect those of NSMC/CMA or the Chinese Government.

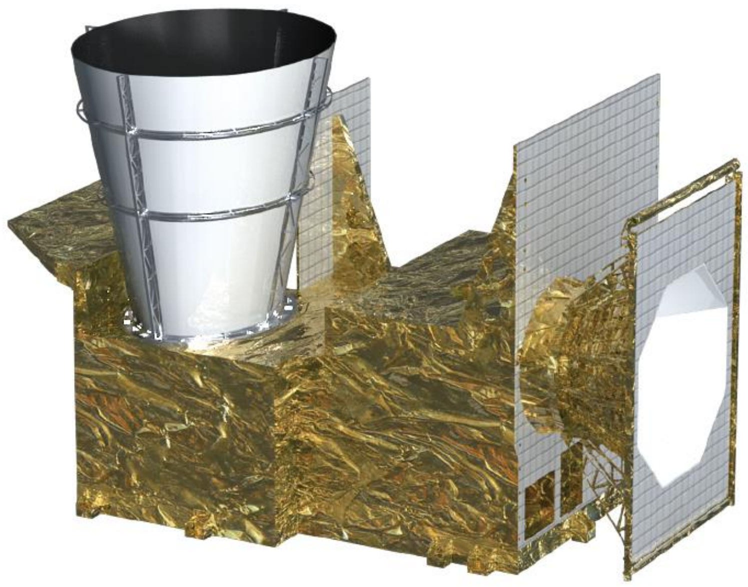
Mar. 16-22, 2023, Tromsø, Norway

Chapter 1

FY-4B/GIIRS Instrument Overview

1.1 FY-4B/GIIRS measurements

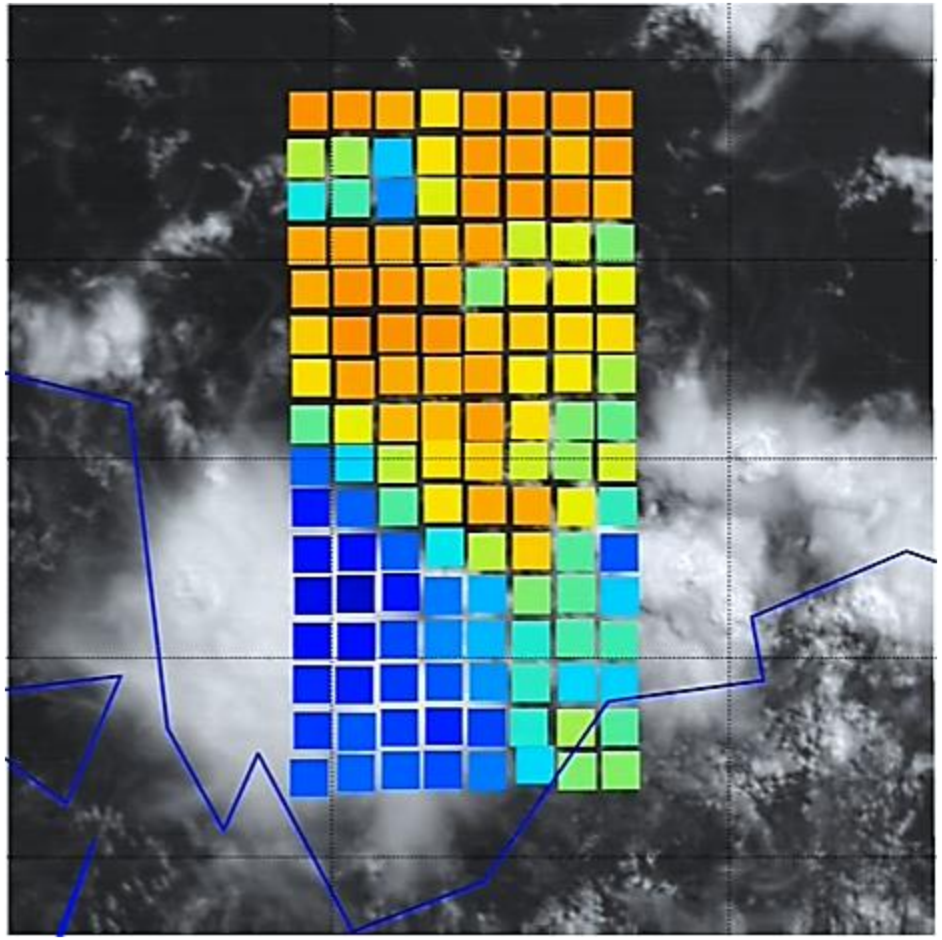




➢ FY-4B/GIIRS was launched on June 3, 2021, which is the second hyperspectral IR sounder of China on the GEO satellite and is used for operational NWP.

➢ GIIRS measures the upwelling IR radiance in 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}. 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 numerical weather prediction (NWP) models, and also supply extensive information about trace gases, surface and cloud properties for climate research.

1.2 FY-4B/GIIRS instrument



An IR BT image (900 cm^{-1}) superimposed on the visible image of the Cenderawasih Bay, Indonesia

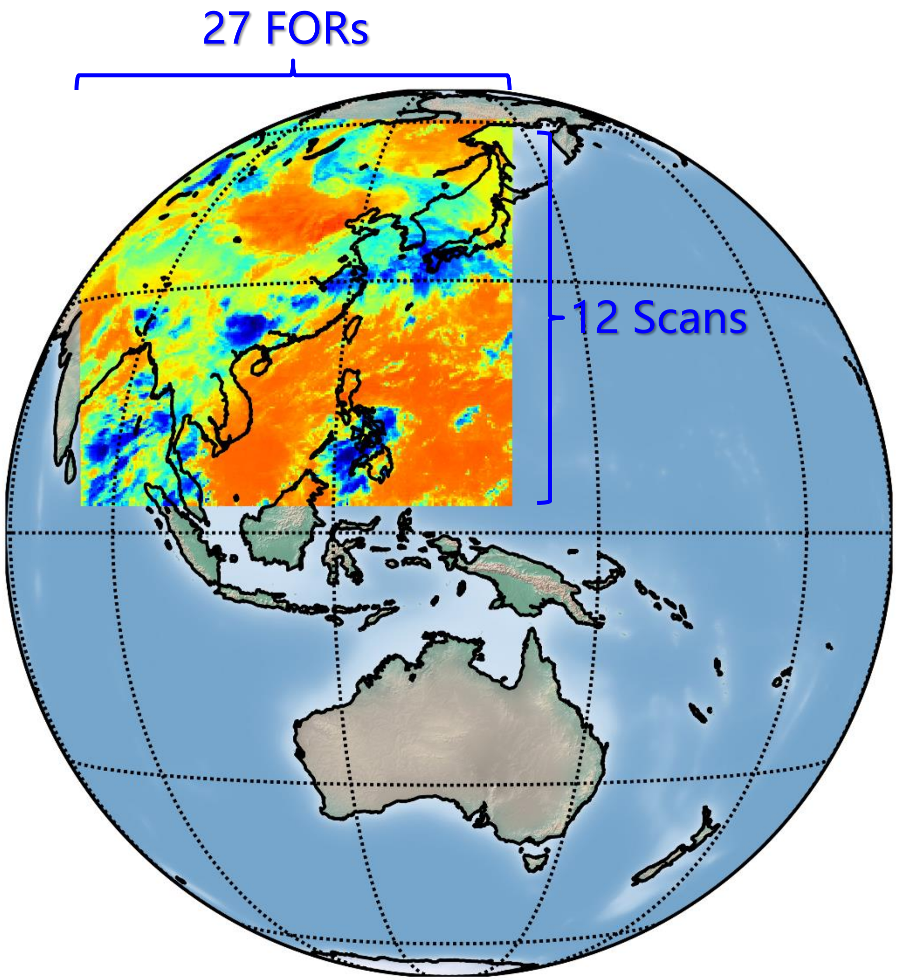
1	17	33	49	65	81	97	113
2	18	34	50	66	82	98	114
3	19	35	51	67	83	99	115
4	20	36	52	68	84	100	116
5	21	37	53	69	85	101	117
6	22	38	54	70	86	102	118
7	23	39	55	71	87	103	119
8	24	40	56	72	88	104	120
9	25	41	57	73	89	105	121
10	26	42	58	74	90	106	122
11	27	43	59	75	91	107	123
12	28	44	60	76	92	108	124
13	29	45	61	77	93	109	125
14	30	46	62	78	94	110	126
15	31	47	63	79	95	111	127
16	32	48	64	80	96	112	128

A sparse layout of IR detector

- GIIRS instrument contains a infrared sounder and a visible light Integrated Imager.
- The IR detector has 16×8 pixels, the imager detector has 512×512 pixels.
- The IR sounder is a FTS based on Michelson interferometer, and used for IR radiance measurement.
- The visible imager co-shares the scan mirror and the telescope optics, and supports the instrument for day-time navigation and cloud detection.

NSMC

1.3 FY-4B/GIIRS operational scan pattern

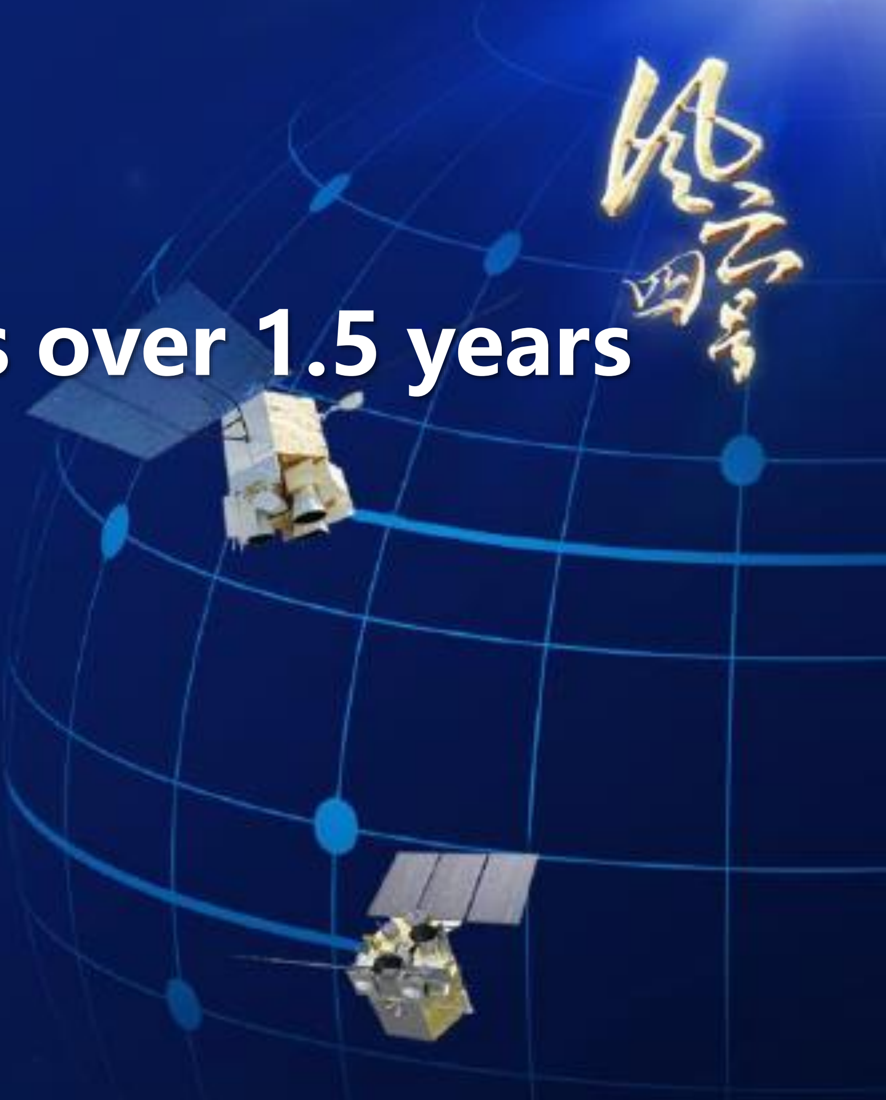


FY-4B/GIIRS observation pattern

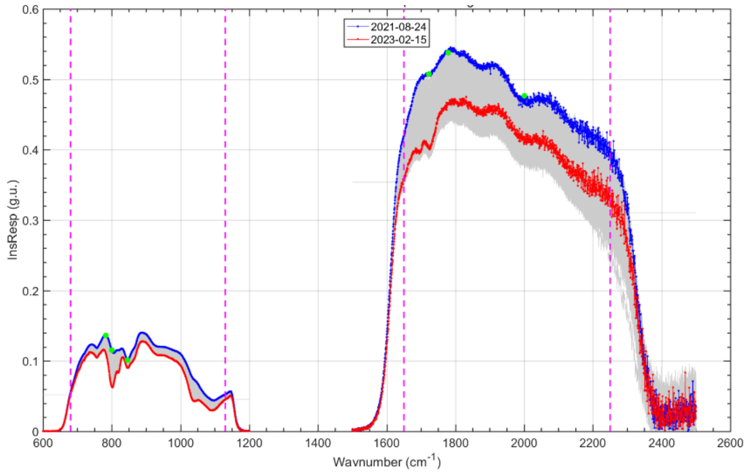
- GIIRS scans the Earth in a “step-stare” mode: the sounder observes the Earth covered by one field of regard (dwell), collecting 16×8 interferograms in 10.4s, and then jumps to the next adjacent dwell.
- Since March 26, 2022, FY-4B is positioned at 133°E, and the GIIRS observation area (53°E~148°E, 2.2°N~66°N) requires 27 FORs×12 Scans for coverage, with one coverage taking about 1.5 hours.
- The FY-4B/GIIRS L0~L1 data processing algorithm was delivered on June 29, 2022, and the L1 radiance products were operationally disseminated at the same time.

Chapter 2

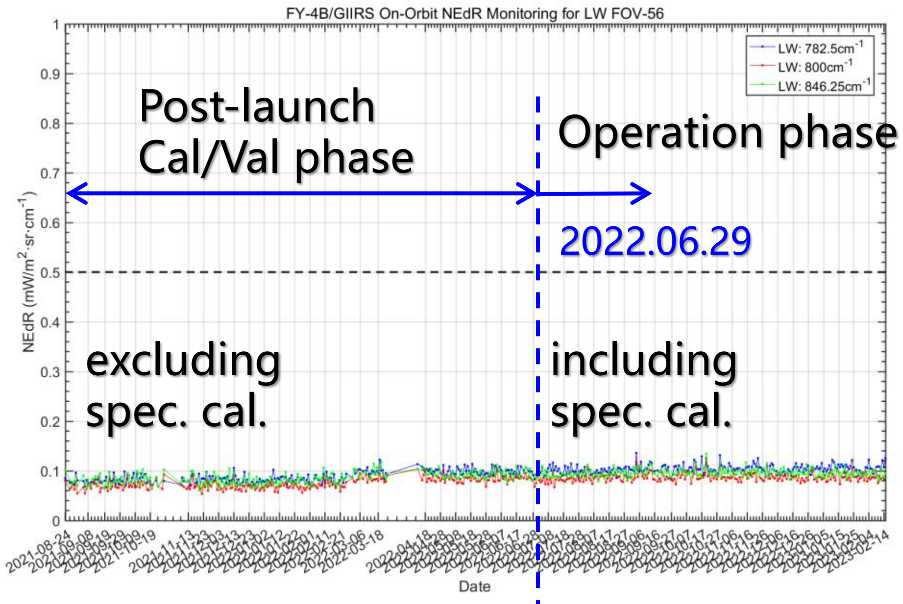
FY-4B/GIIRS Performance Status over 1.5 years

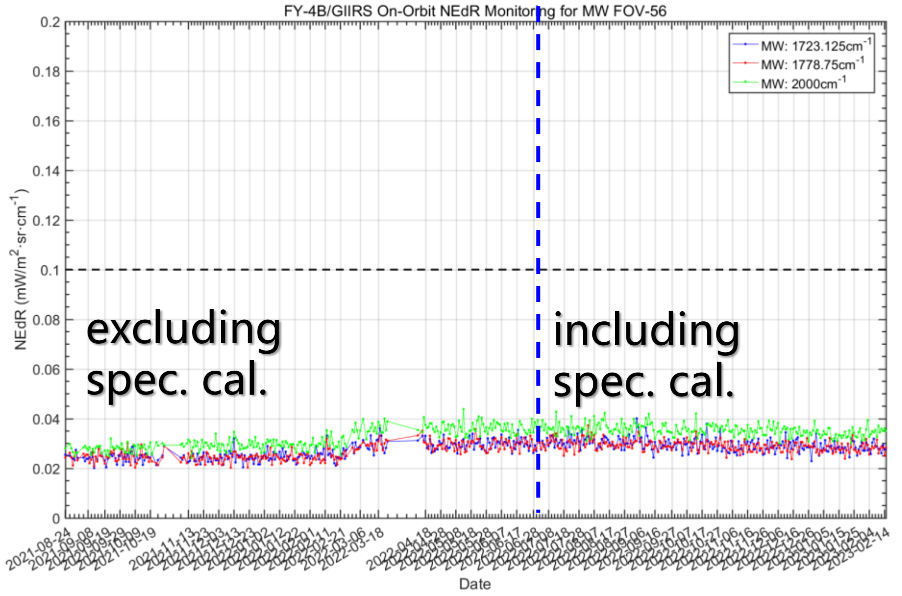


2.1 GIIRS noise performance



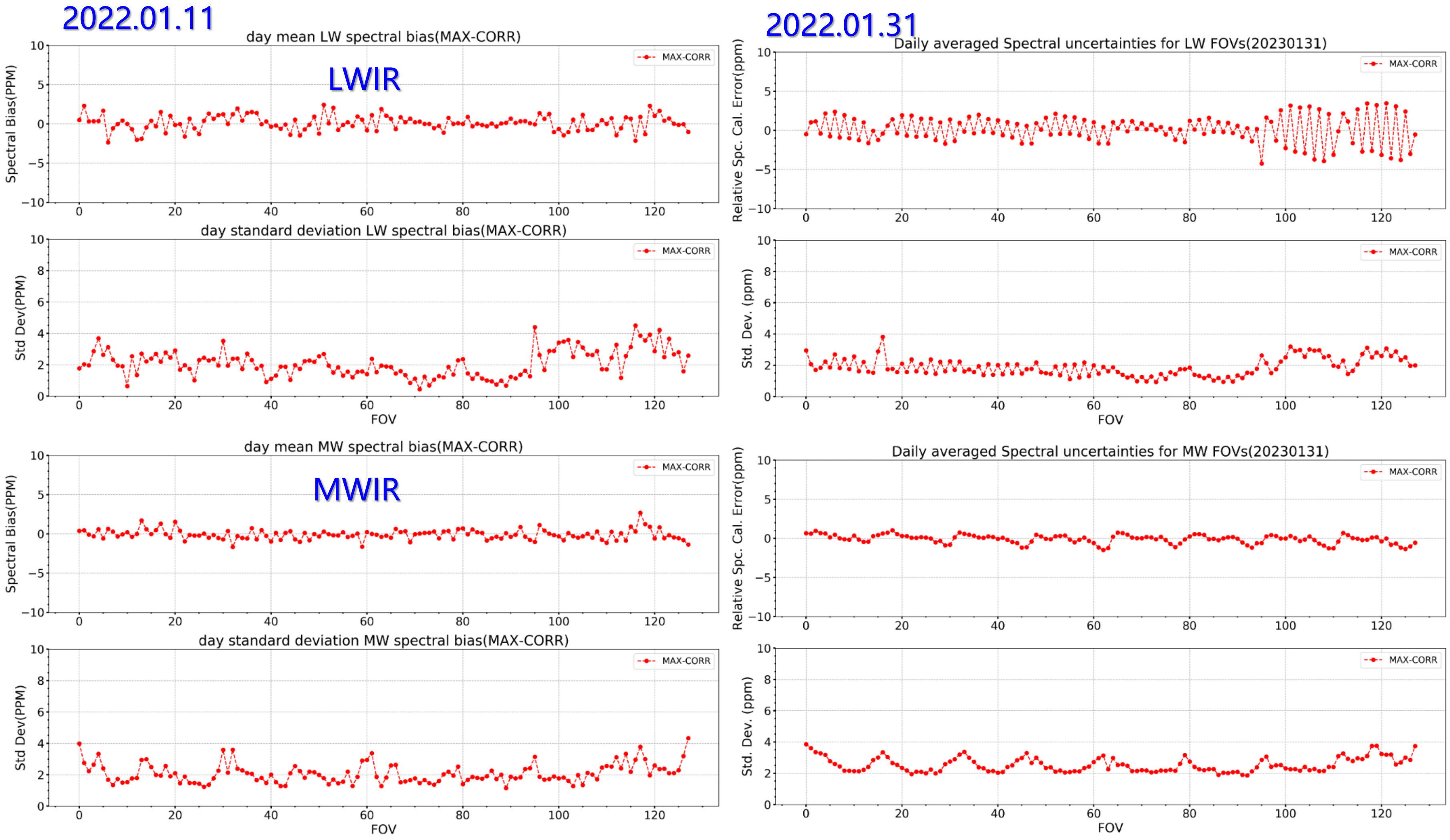
FY-4B GIIRS InsResp Monitoring





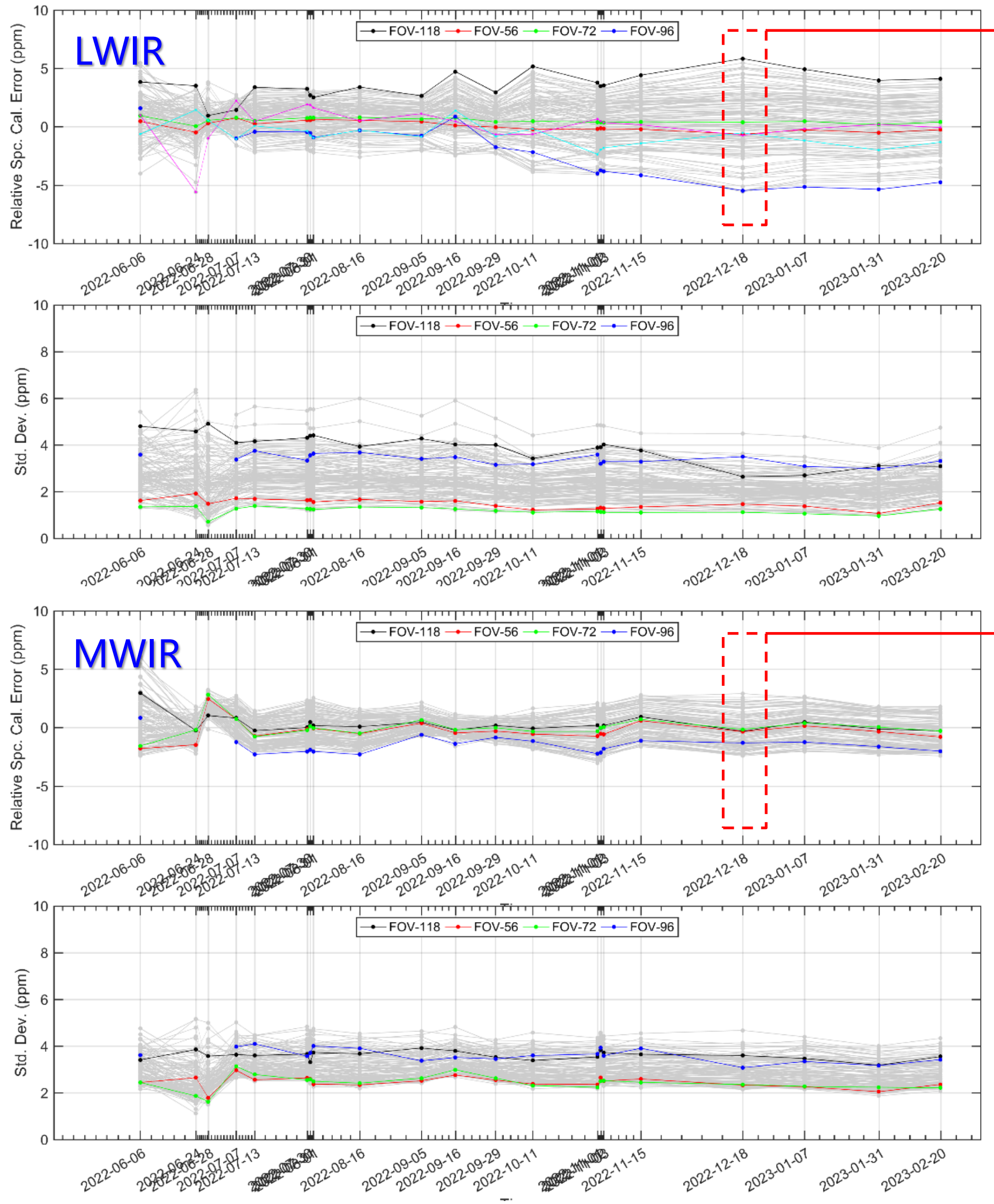
- FY-4B/GIIRS meets the noise specification (of 0.5 r.u., 0.1 r.u.) in both LWIR and MWIR band.
- Although the responsivity has the spectral contamination like that in FY-3D/HIRAS and FY-4A/GIIRS, the sensitivity is still under the specification line, and the NEdR trends are stable for more than 1.5 years after launch.

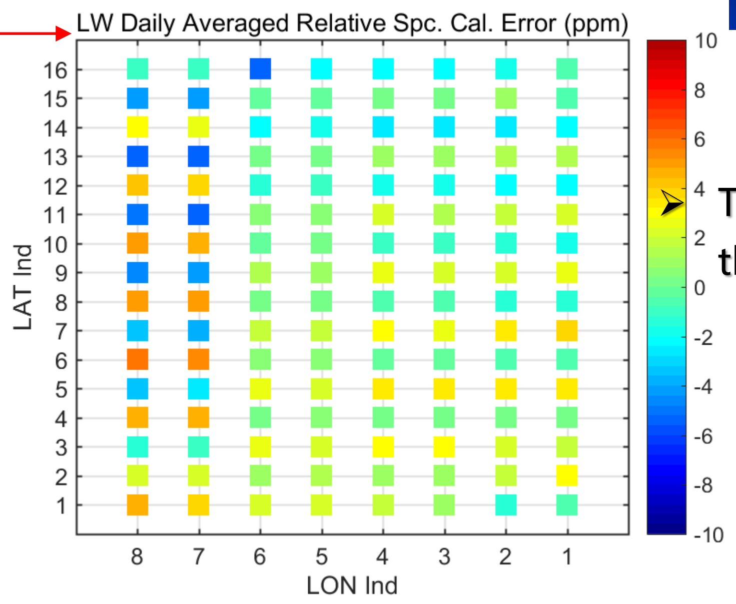
2.2 GIIRS spectral calibration accuracy

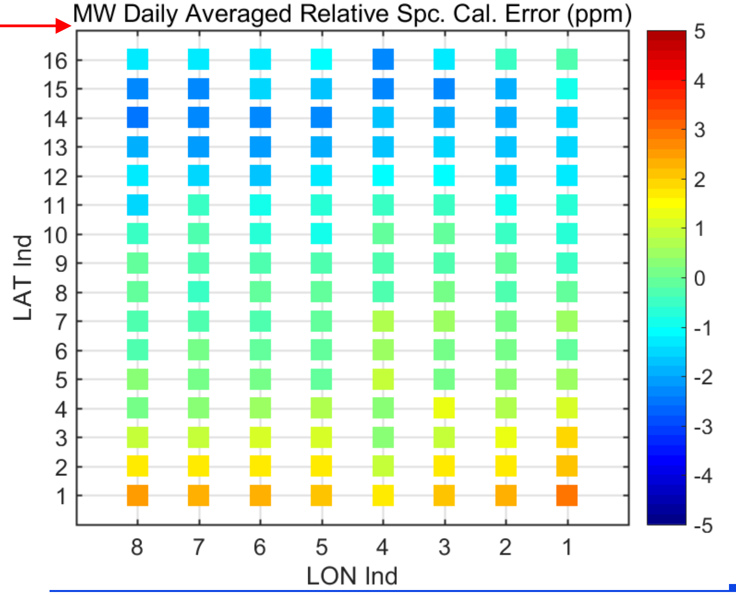


- GIIRS spectral accuracy is assessed using the LBLRTM simulated spectrum.
- The relative offsets are less than 7 ppm (std. < 5ppm) in average for all pixels in both bands.
- The offsets oscillation among LWIR odd-even pixels is generated from the clutter signal in the electronic circuit, and also be affected by the seasonal fluctuations of internal temperature field.

2.2 GIIRS spectral calibration accuracy

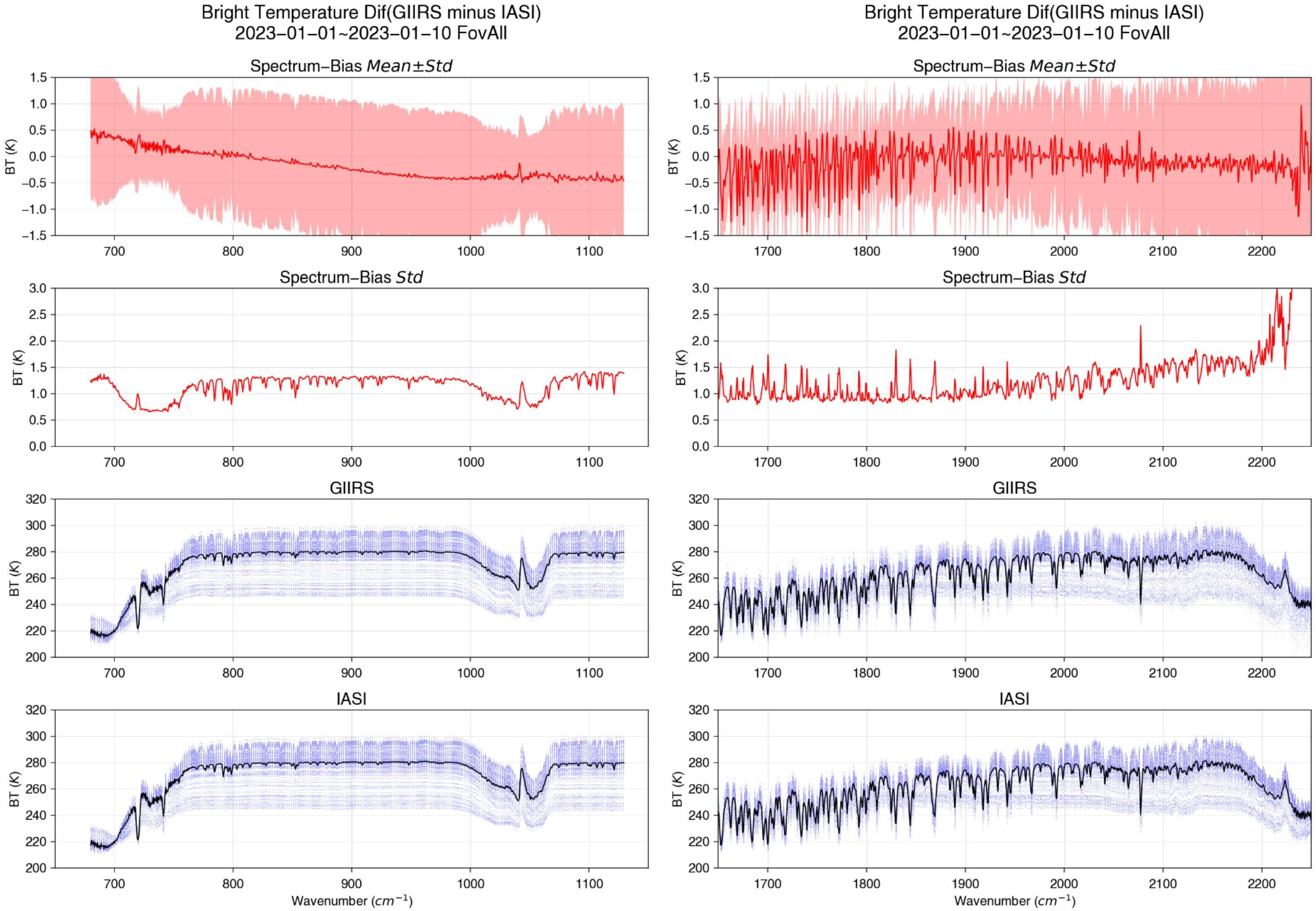






➢ The oscillation and seasonal fluctuation of the spectral offsets are under monitoring.

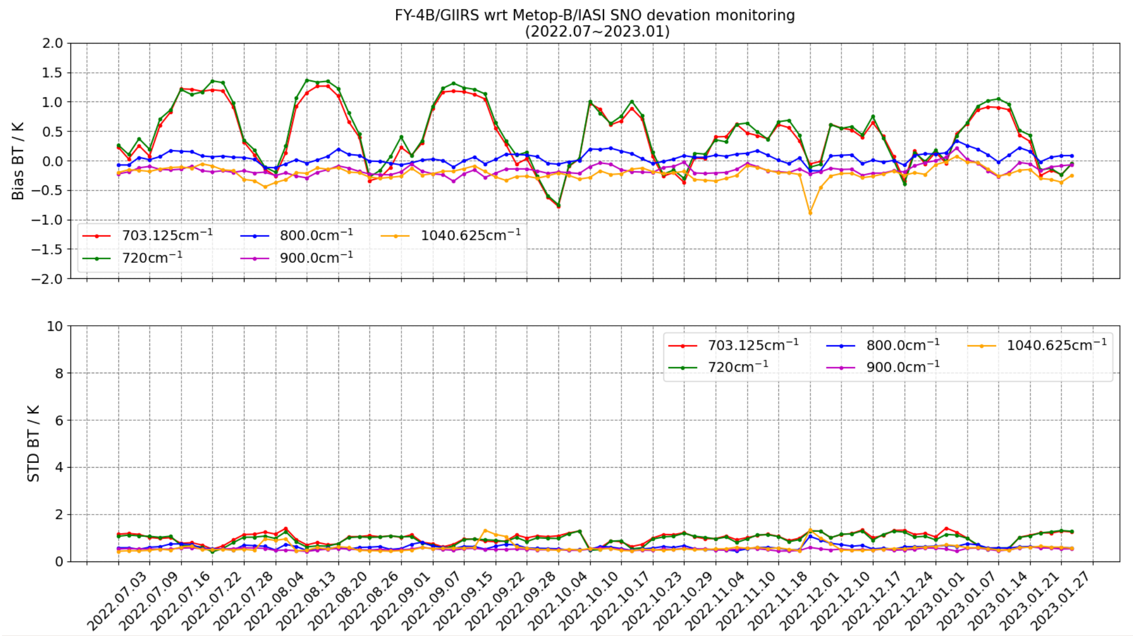
2.3 GIIRS radiometric calibration accuracy

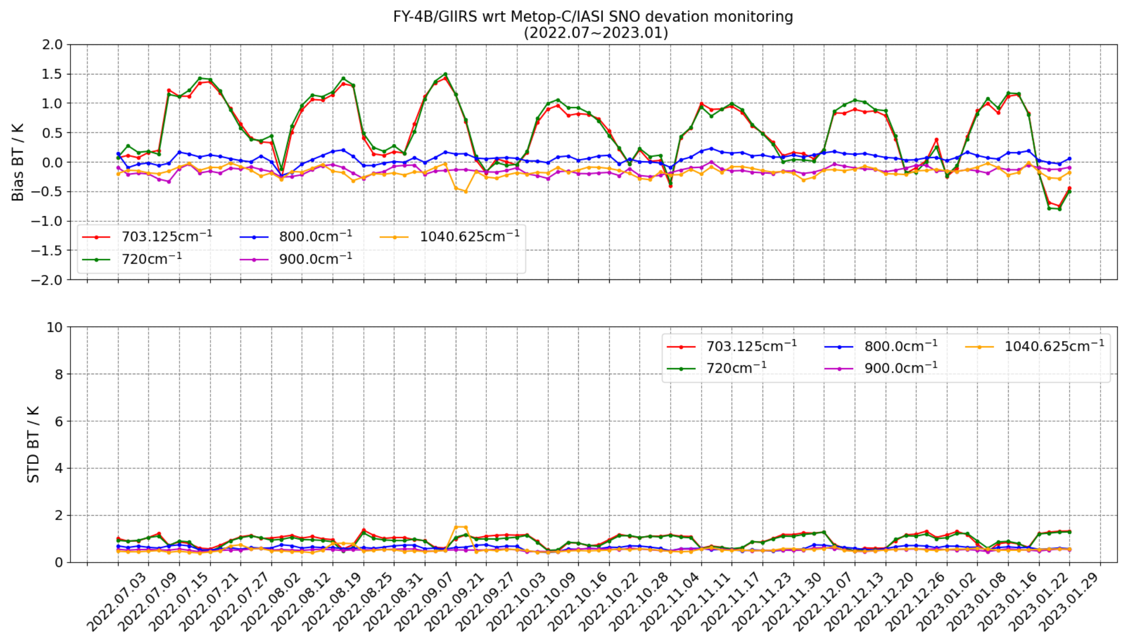


- GIIRS radiometric accuracy is mainly assessed by the inter-comparisons with MetOp-B/C IASI.
- The average calibration bias is less that 1K except in some spectral channels, which are affected by noise.
- The radiometric calibration is related to instrument status (such as internal temperature、detector non-linearity), and is still in the phase of improvement.

SNO Criteria:
Time difference: <=300 s
Pixel distance: <=12 km
Zenith angle difference: abs[cos(zen1)/cos(zen2)-1]<=0.01
Scene homogeneity: StdDev(AGRI_B13)/Mean(AGRI_B13)<1%

2.3 GIIRS radiometric calibration accuracy

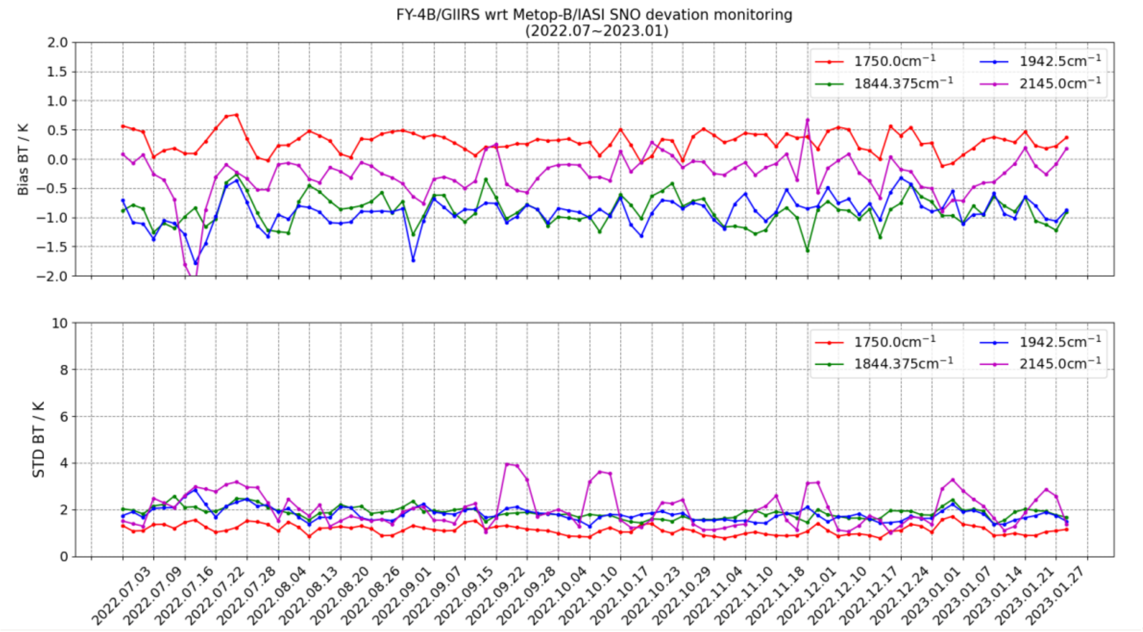


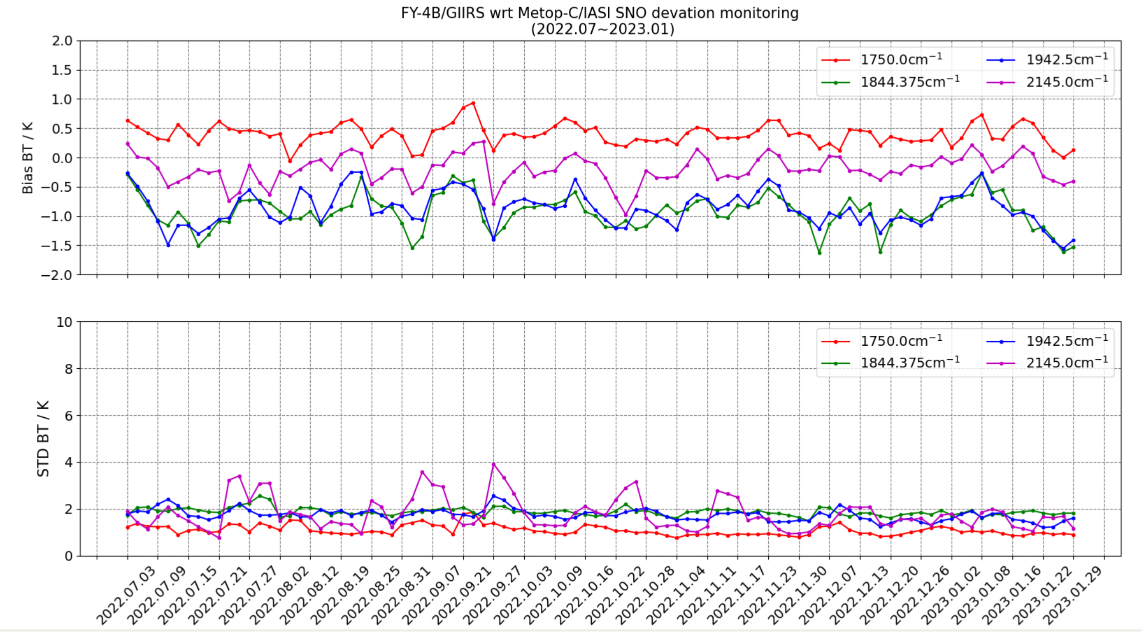


For GIIRS and IASI (B & C) inter-comparison, the LWIR BT difference results from GIIRS/IASI-B and GIIRS/IASI-C are consistent.

In CO_2 temperature channels (700~800 cm^{-1}), a monthly cycle (actually results from diurnal cycle) of BT difference is revealed from the 8 month monitoring.

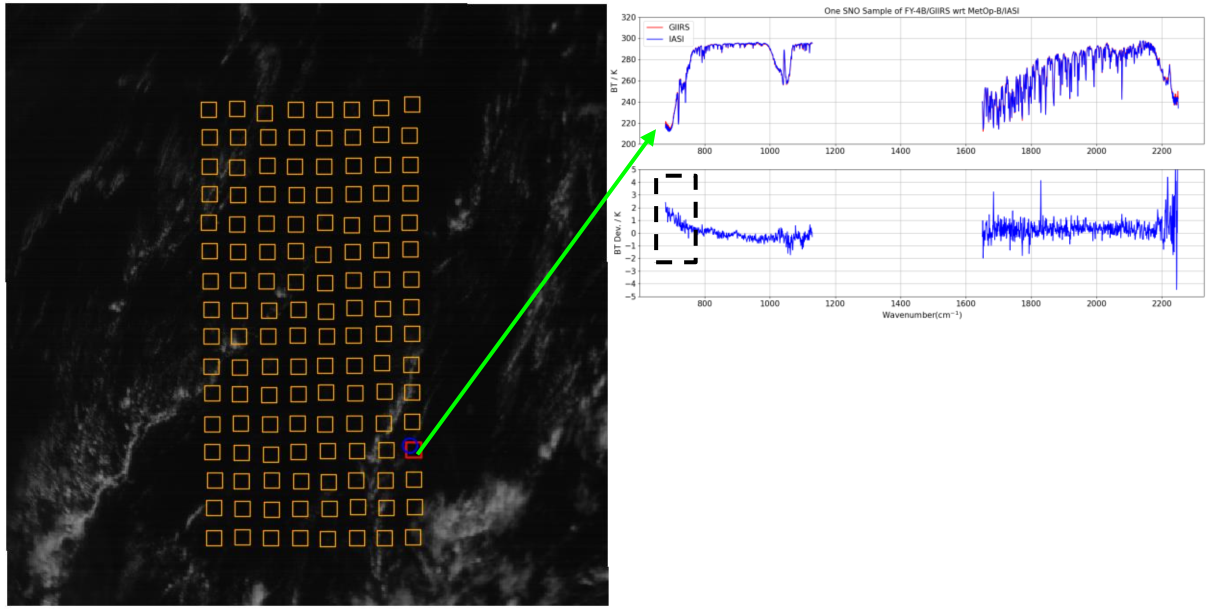
2.3 GIIRS radiometric calibration accuracy



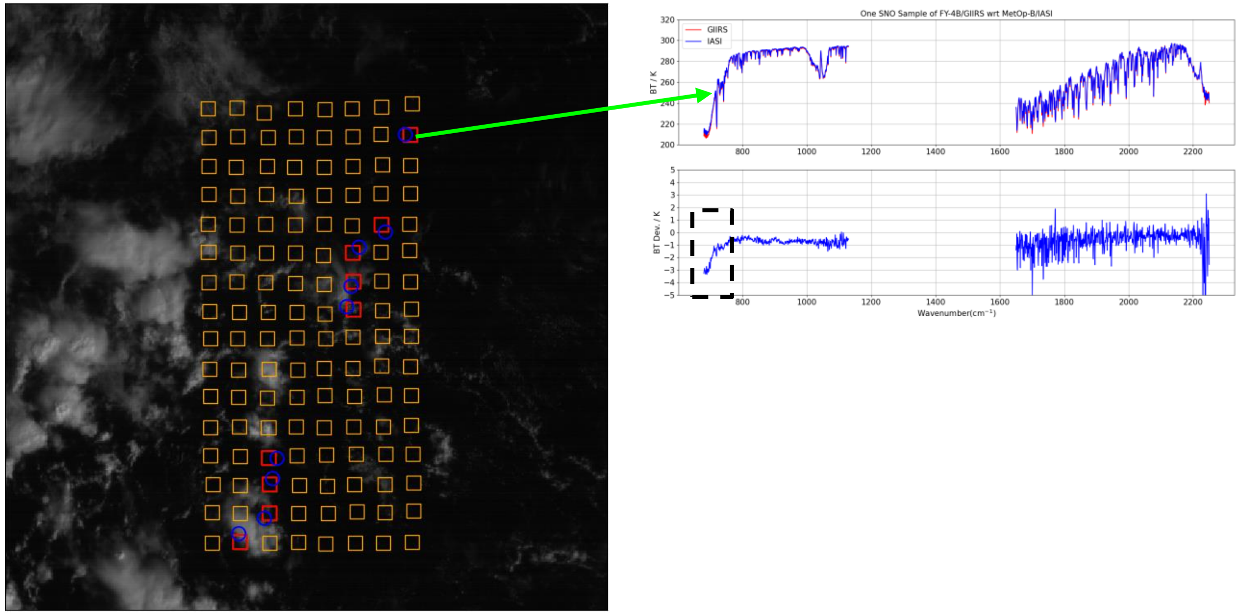


For GIIRS and IASI (B & C) inter-comparison, the MWIR BT difference results from GIIRS/IASI-B and GIIRS/IASI-C are consistent. No monthly cycle was observed in the MWIR channels.

2.3 GIIRS radiometric calibration accuracy



FOR-03 at 04:09:37 UTC on Jan.10, 2023



FOR-27 at 00:09:37 UTC on Jan.25, 2023

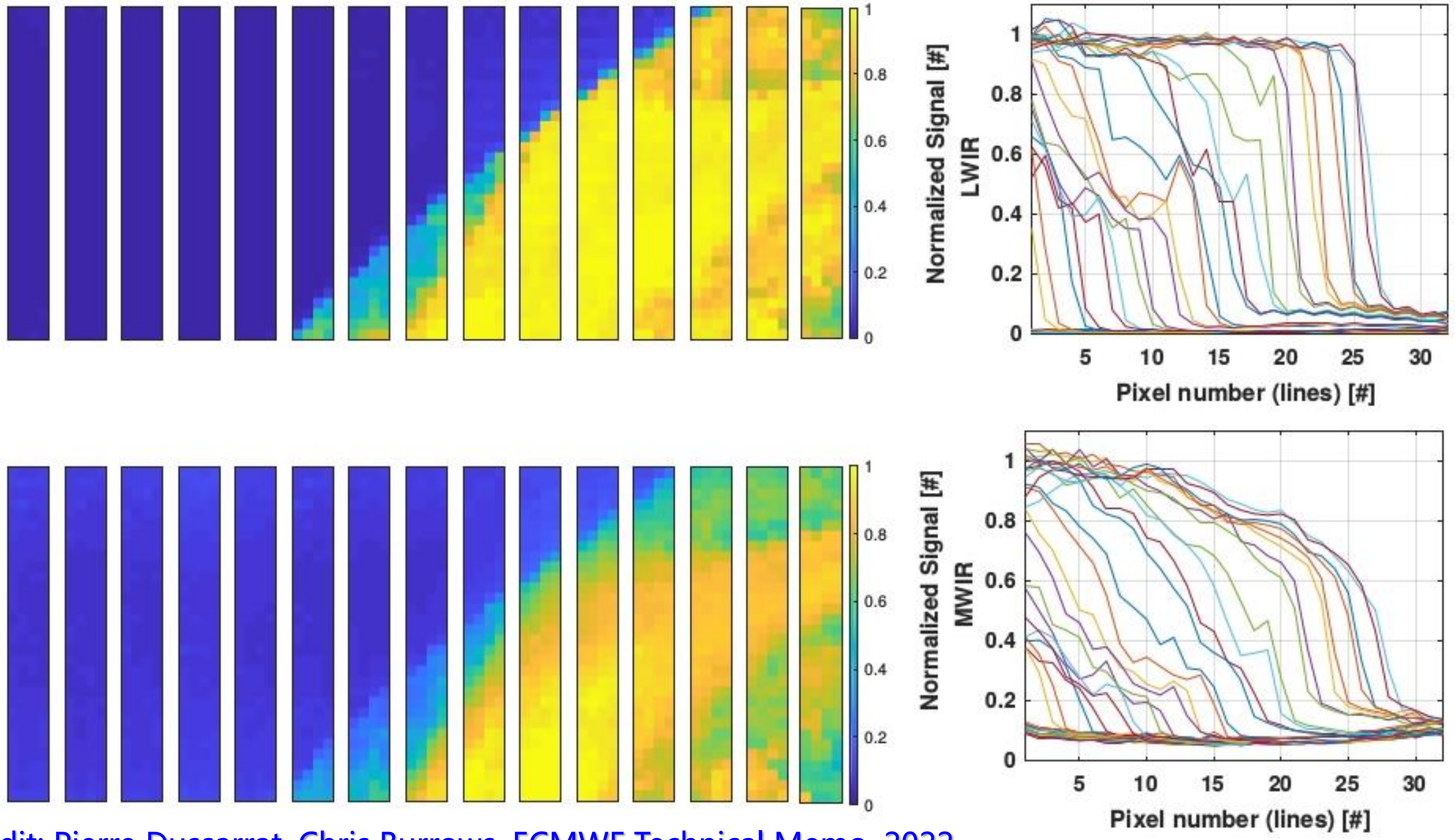
- At noon time, GIIRS seems warmer than IASI in LWIR CO_2 region.
- At morning time, GIIRS seems colder than IASI in LWIR CO_2 region.

- Lee's understanding: Thermal ambiance of geo-sounder & GIIRS calibration path.

2.4 Possible stray light

LWIR

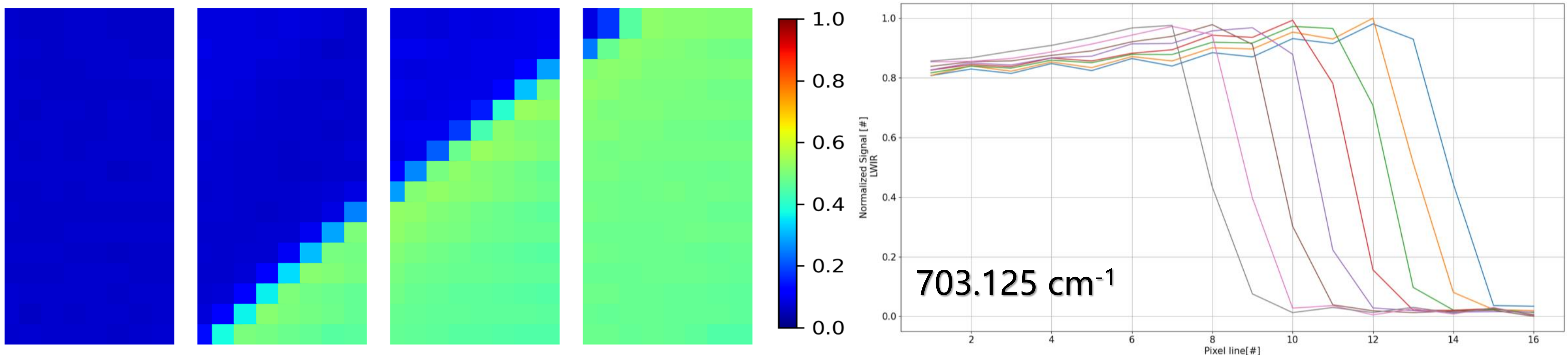
MWIR

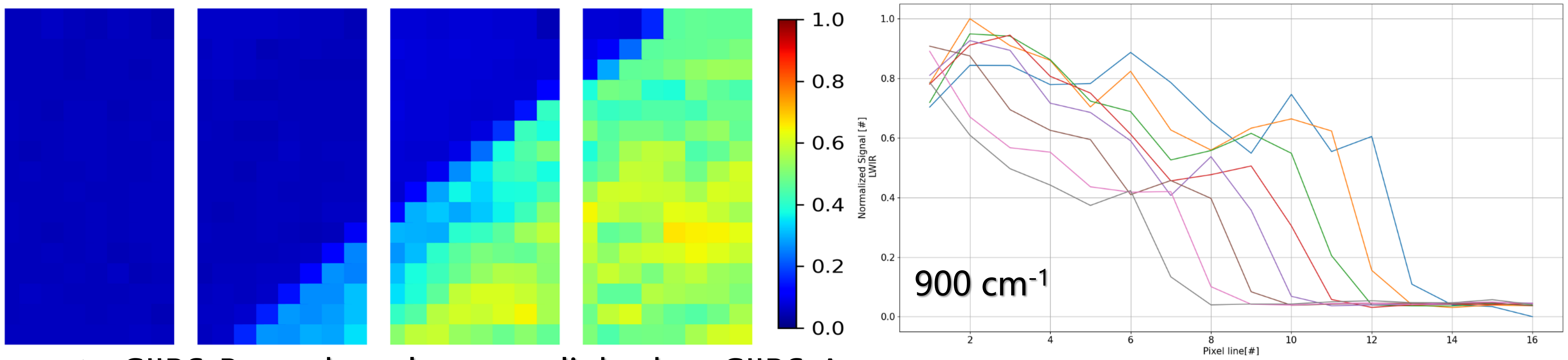


Credit: Pierre Dussarrat, Chris Burrows, ECMWF Technical Memo, 2022

FY-4A/GIIRS footprint with smooth earth-space boundary

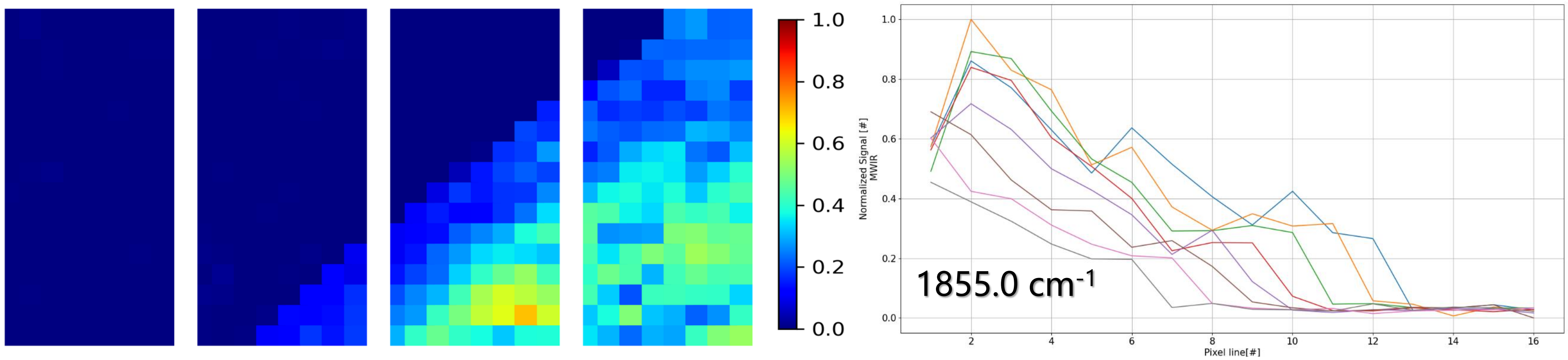
2.4 Possible stray light

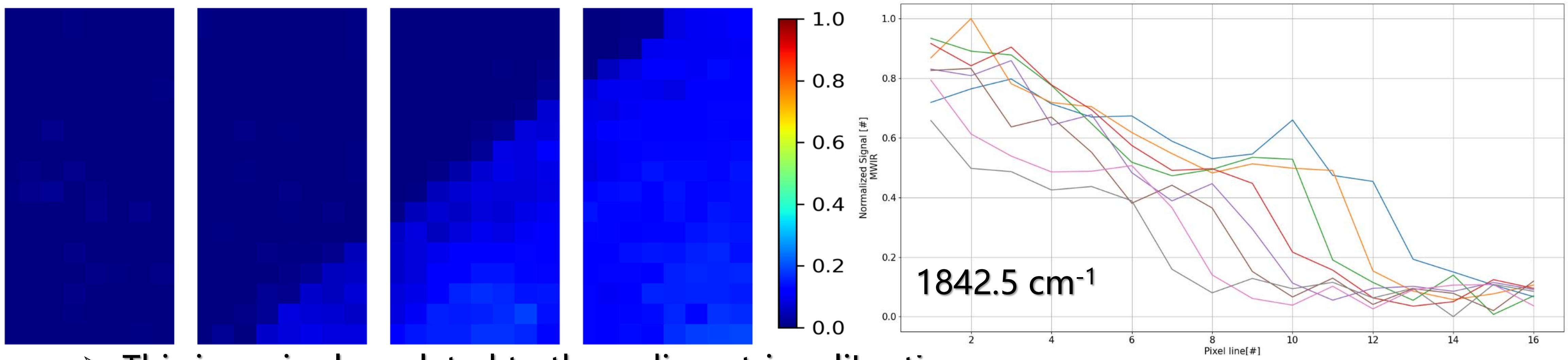




- GIIRS-B may have less stray light than GIIRS-A

2.4 Possible stray light

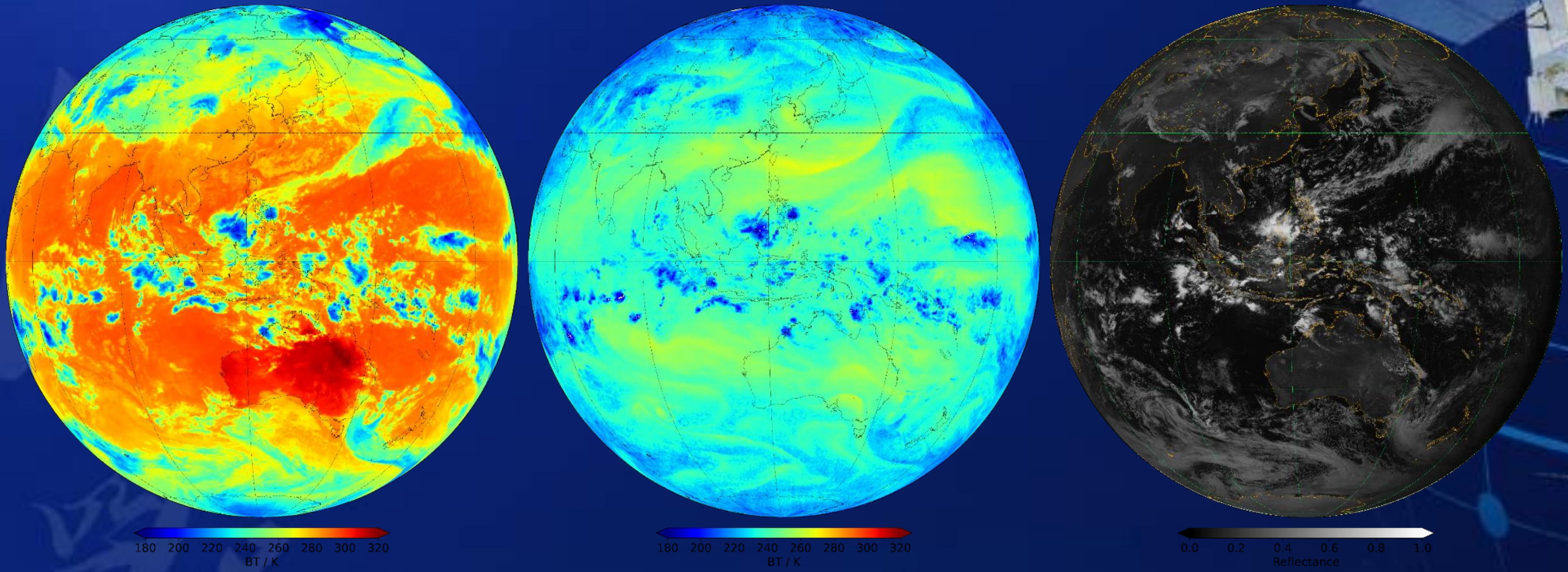




- ➢ This issue is also related to the radiometric calibration

Chapter 3

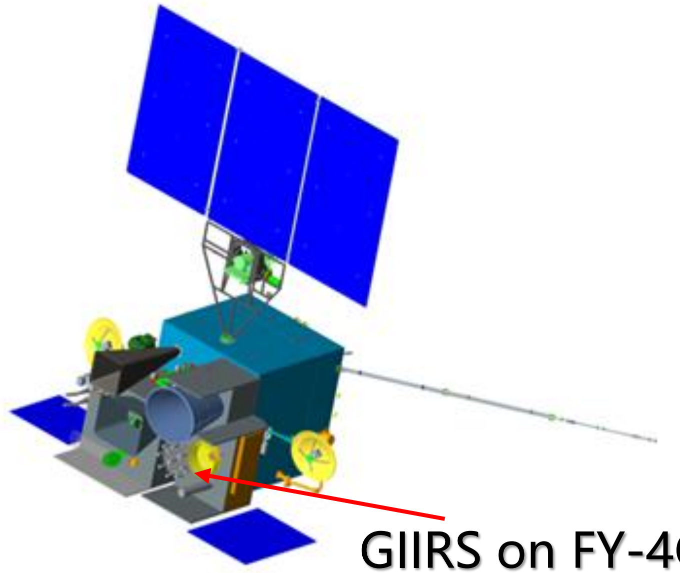
FY-4C/GIIRS and future



Full Earth disk observed by FY-4B/GIIRS in 2022/03/09.

3.1 FY-4C/GIIRS v.s. FY-4B/GIIRS

Item	**FY-4B**	**FY-4C**
Spectral Range	LWIR: 680~1130 cm^{-1} MWIR: 1650~2250 cm^{-1}	LWIR: 650~1130 cm^{-1} MWIR: 1650~2250 cm^{-1}
Spectral Sampling	0.625 cm^{-1}	0.625 cm^{-1}
Sensitivity	LWIR: less than 0.5 r. u. MWIR: less than 0.1 r. u.	LWIR: less than 0.5 r. u. MWIR: less than 0.1 r. u.
Spectral accuracy	Less than 7 ppm	Less than 5 ppm
Radiometric accuracy	0.7 K	0.5 K
Detector Matrix	16×8, sparse layour	64×64 or 16×16
Spatial Sampling	12 km @ s.s.p.	8 km @ s.s.p.
Observation Coverage	China and its surroundings @ 133°E	China and its surroundings @ 105°E (undetermined)
Repeat Cycle Duration	1.5 hours	~1 hour
VIS Integrated Imager	1 km @ s.s.p.	0.5 km @ s.s.p.

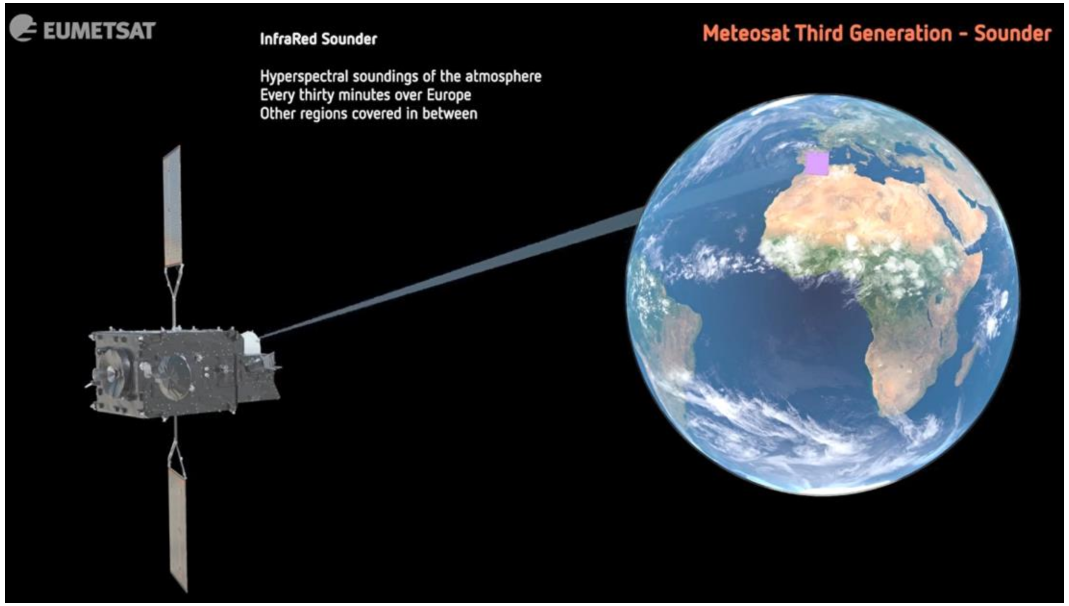


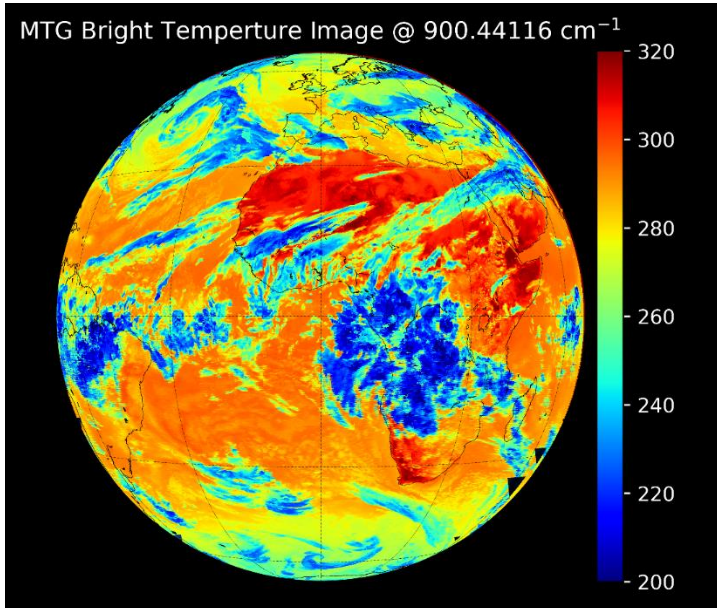
- FY-4C/GIIRS is in the design phase. It is likely to remain a sounder rather than an imaging sounder.

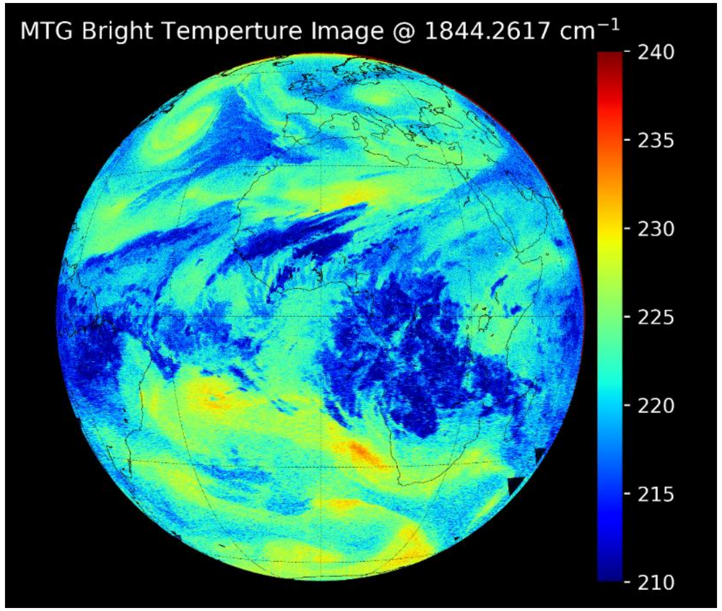
r. u.: radiance unit, mW/[m^2·sr·cm^{-1}]

s.s.p.: sub-satellite point

3.2 Future: From Sounder to Imaging Sounder







MTG/IRS full-disk scanning pattern and the BT images from proxy data

- Severe weather capture and forecast need:
  - Lower noise
  - Higher spatial resolution
  - Higher temporal resolution
  - Higher calibration accuracy

Fin

Thank you for your attention！

Lu Lee

lilu@cma.gov.cn