Latest status of HIRAS onboard FY-3D/3E and FY-4B/GIIRS

Chengli Qi, Chunqiang Wu, Lu Lee, Zhuoya Ni, Xiuqing Hu, Lei Yang

National Satellite Meteorological Center, China Meteorological Administration(CMA)

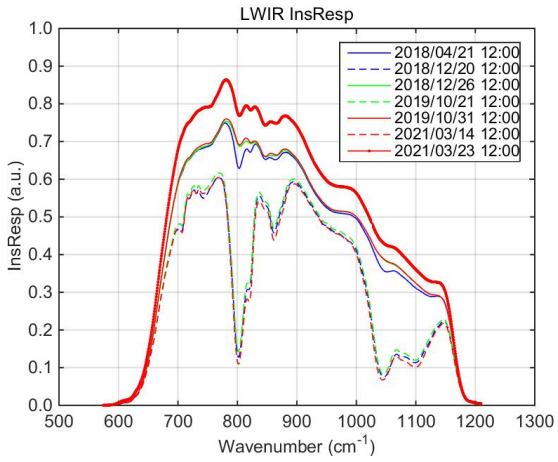
Outline

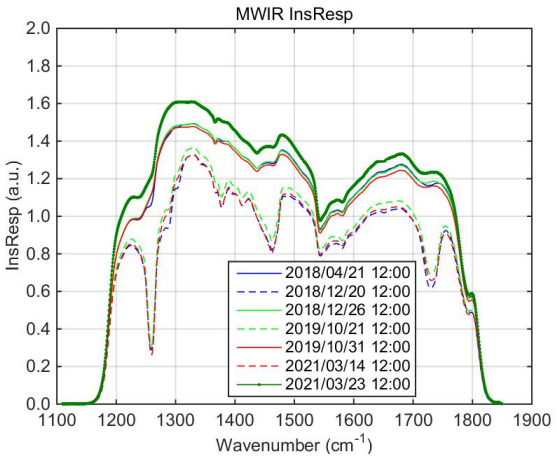
1. FY-3D/HIRAS current status
2. FY-3E/HIRAS introduction and pre-lauch performance
3. FY-4 GIIRS instrument introduction
4. FY-4B/GIIRS pre-launch performance
5. Conclusion

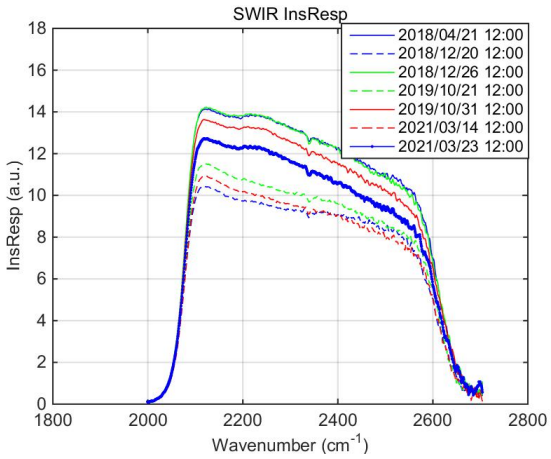
1. FY-3D HIRAS current status

Heating operation on Mar 15, 2021

ISRF compared with best signal status

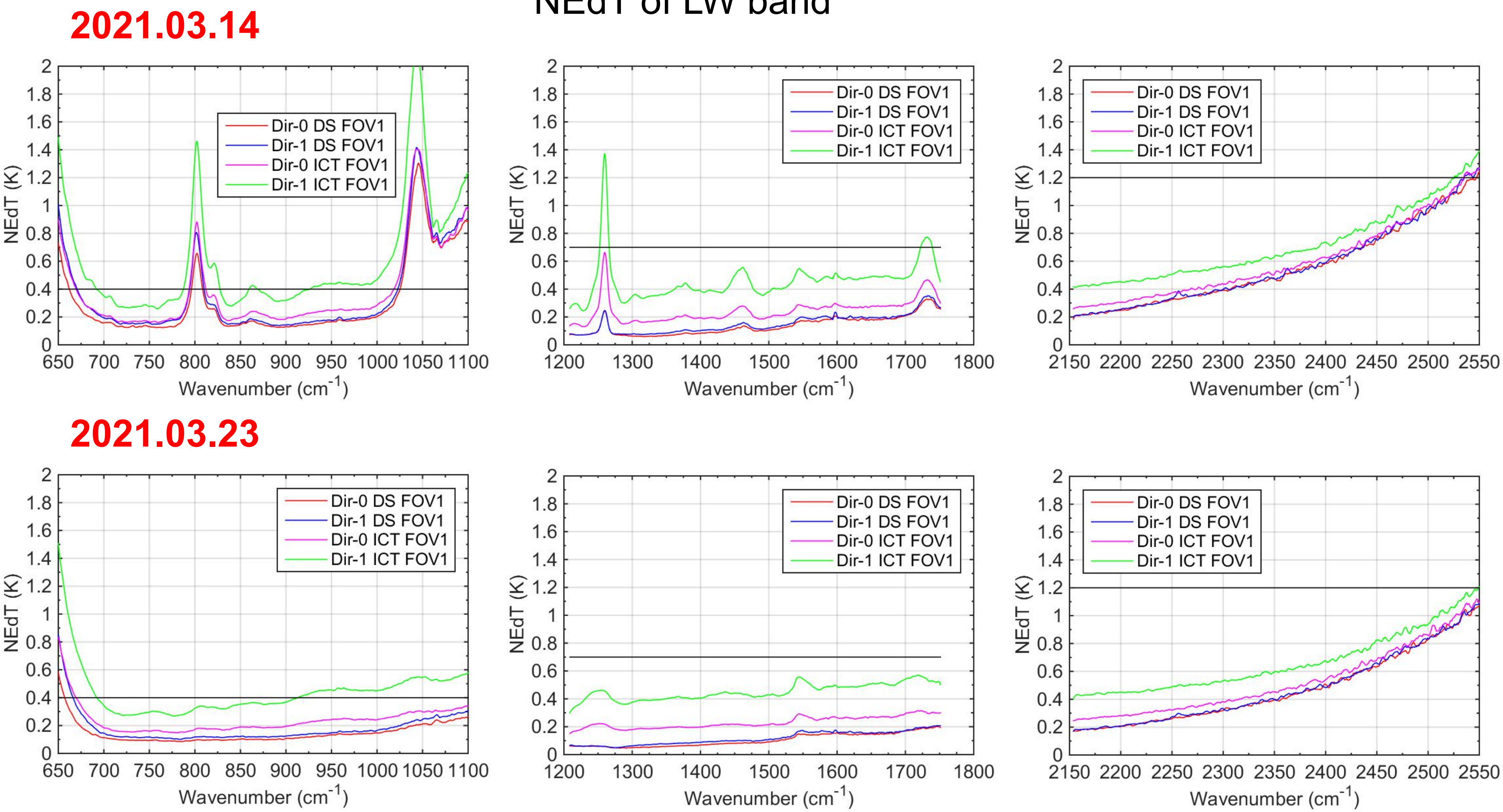






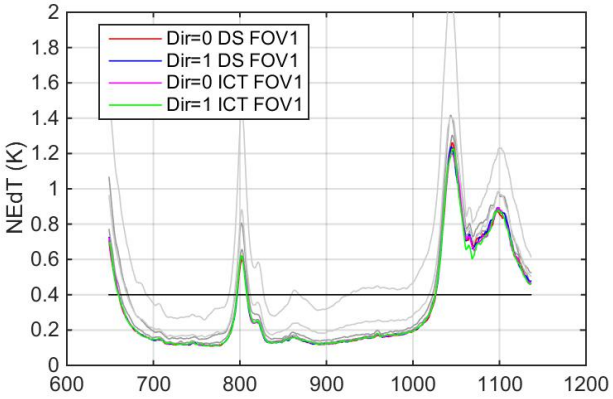
- LW and MW bands signal are nearly recovered.
- SW band is slight weaker in signal

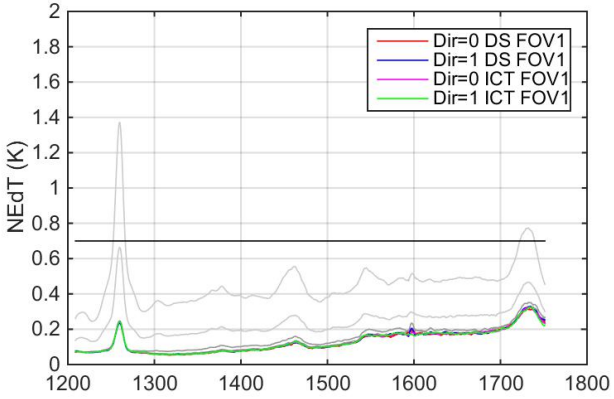
NEdT of LW band

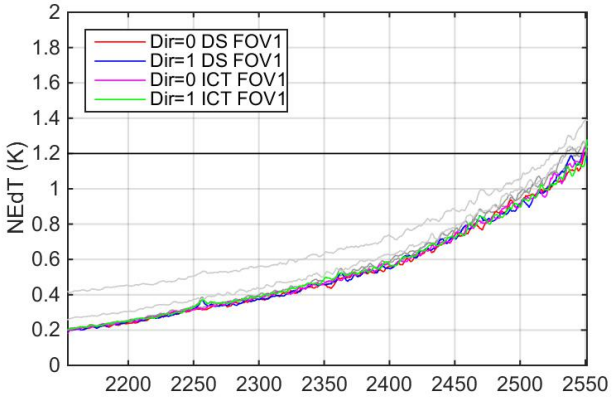


NEdT on contaminated band has recovered after heating, while more correlated noise in ICT spectra uplifts the noise baseline, especially on ICT dir-1 data. The correlated noise is caused by the accumulated alignment errors in HIRAS interferometer.

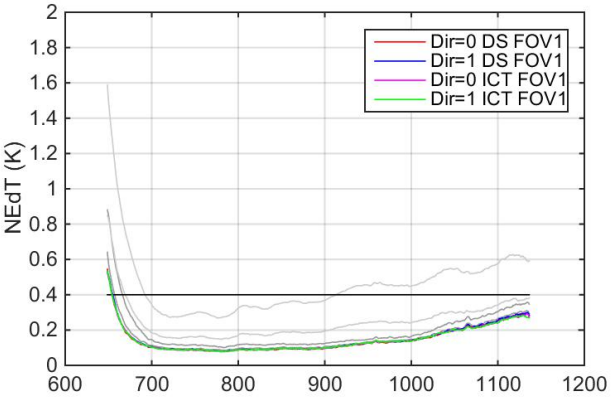
2021.03.14

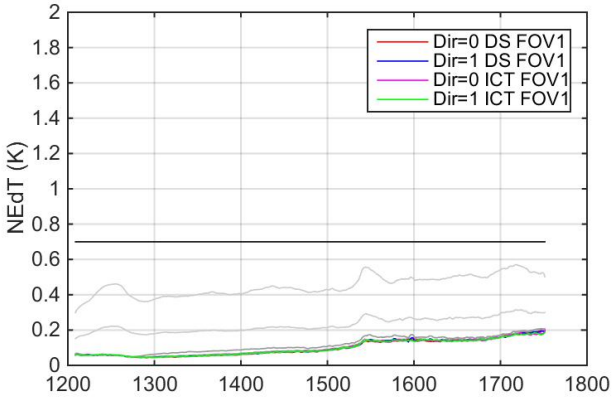


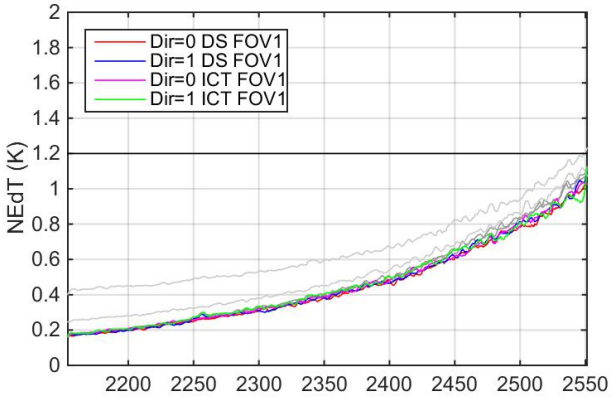




2021.03.23





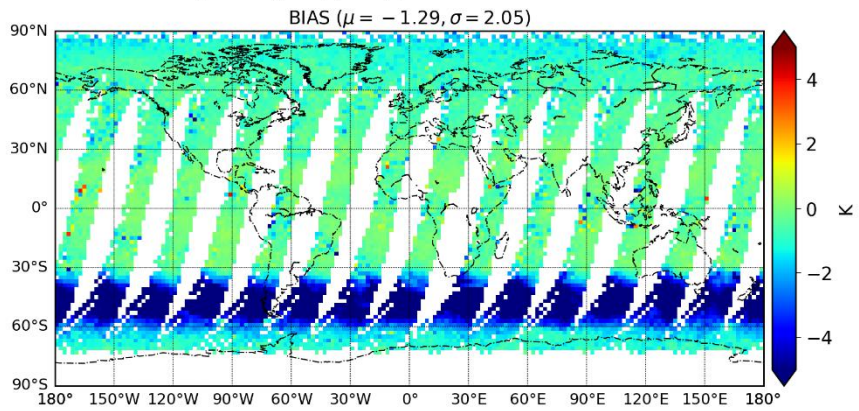


- Remove the correlated noise by PCA technique, the NEdT calculated by random noise seems to be as well as HIRAS early days.
- For consideration of instrument safety and stability, no on-orbit fine alignment correction operation was taken.

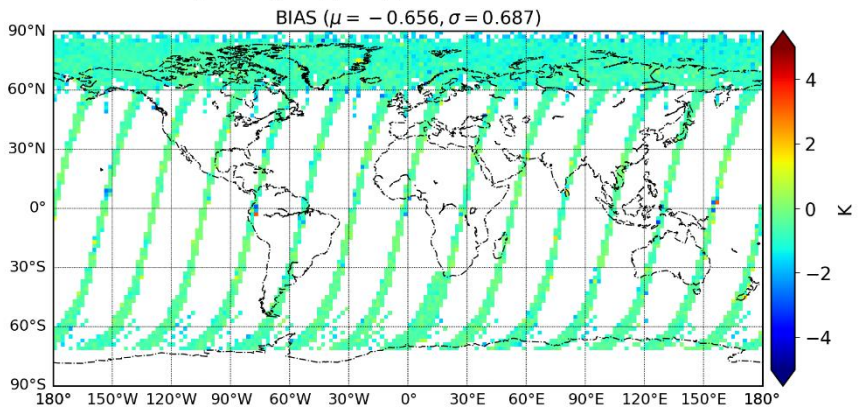
Cold space view angle adjustment

FY-3D/HIRAS(FOV-3) & SNPP/CrIS BT bias via SNOx technique @ 1500 cm^{-1}

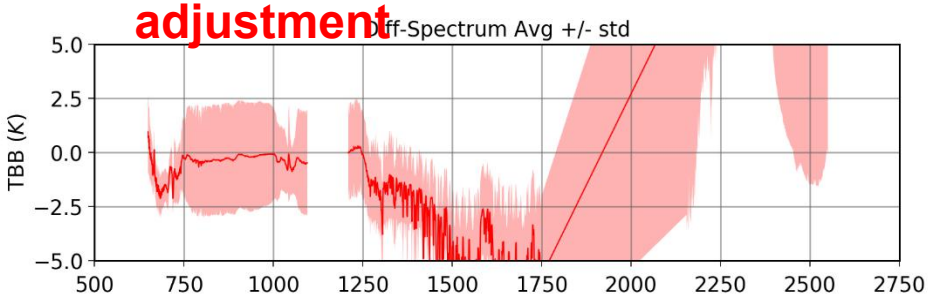
2019.12.07



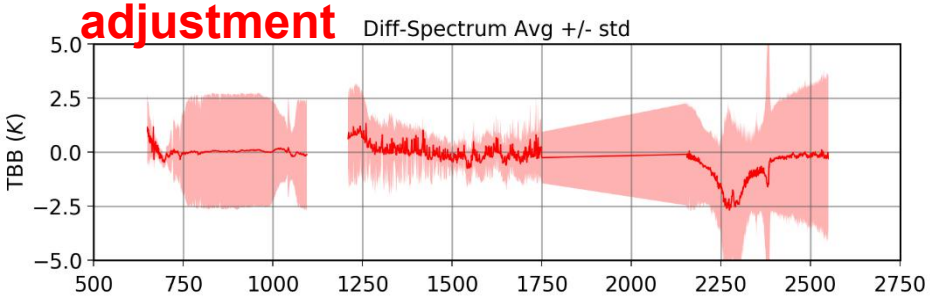
2019.12.14



Before DS view angle adjustment



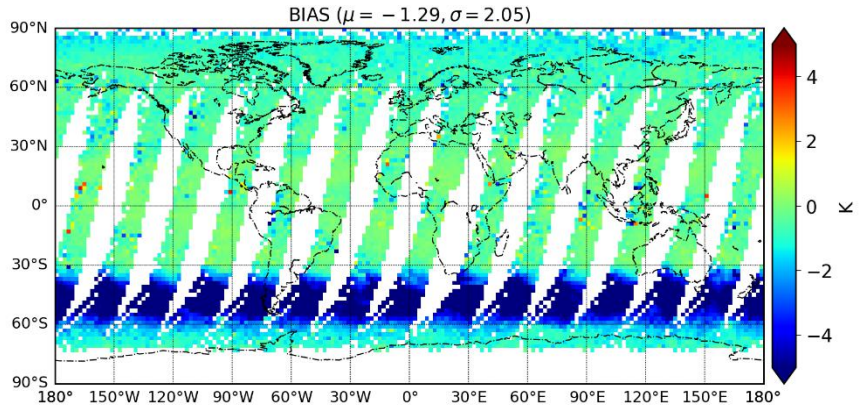
After DS view angle adjustment



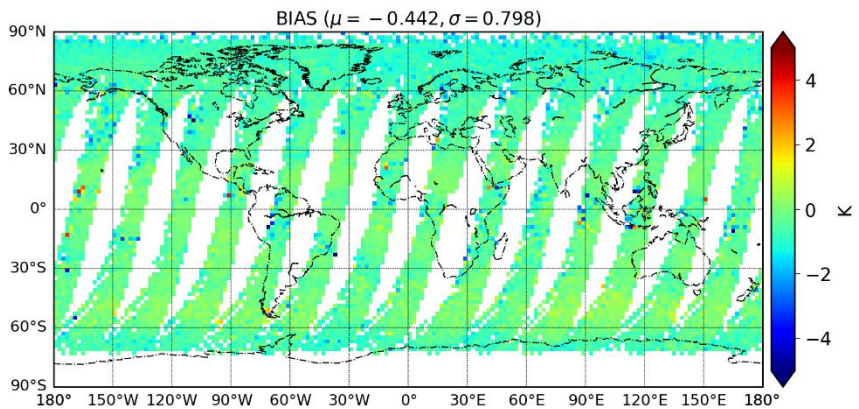
In winter and spring seasons, HIRAS FOV-3 DS calibration view is frequently contaminated by the solar stray light, when the satellite files towards the descending orbit terminal. This problem can make a great calibration bias in the region of 30˚S~60˚S, and thus on 2019-12-13, the sensor DS view angle had adjusted from -71˚ to -87 ˚for stray lights evasion.

FY-3D/HIRAS(FOV-3) & SNPP/CrIS BT bias via SNOx technique @ 1500 cm^{-1}

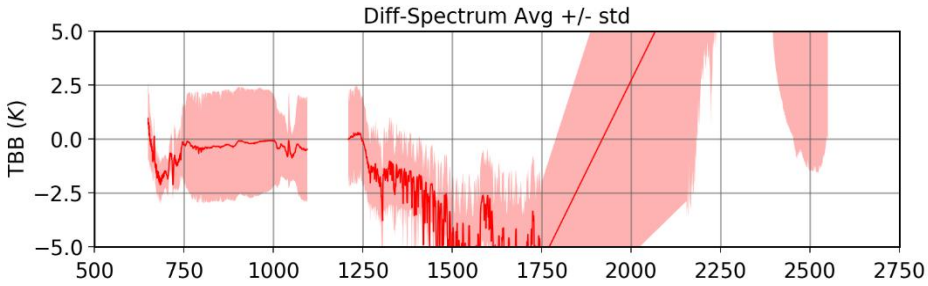
2019.12.07

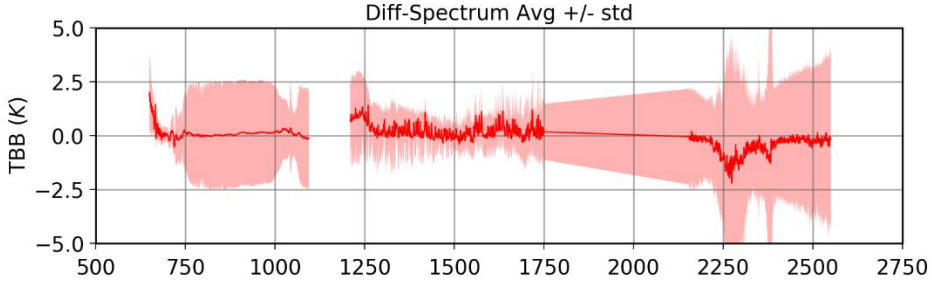


Before Correction



After Correction

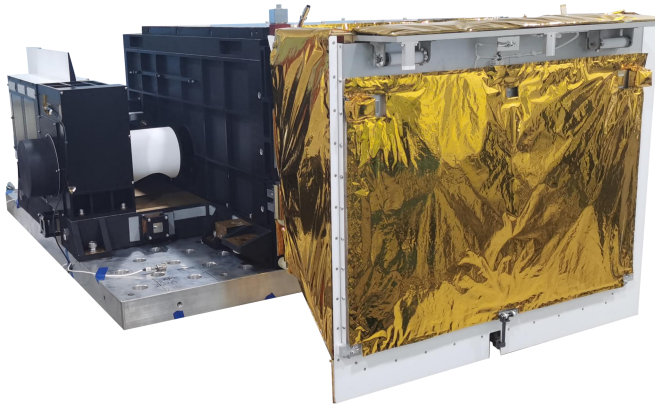




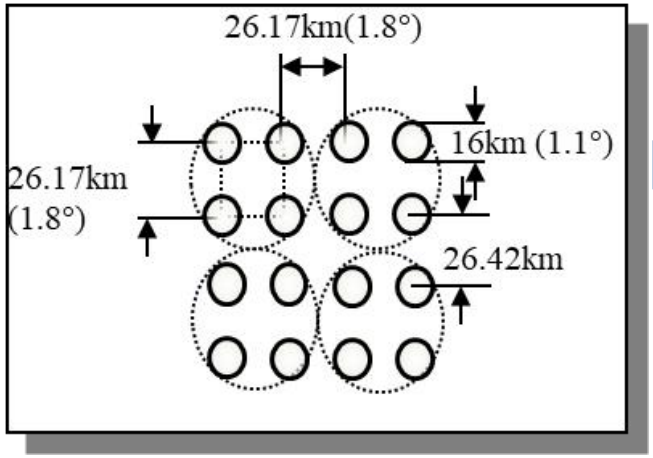
As for the historic data before DS view angle adjustment, we have develped a method to correct the contaminated DS spectra for earth radiance re-calibration. The paper is in preparing by Lee et al.

2. FY-3E/HIRAS-II：Specification

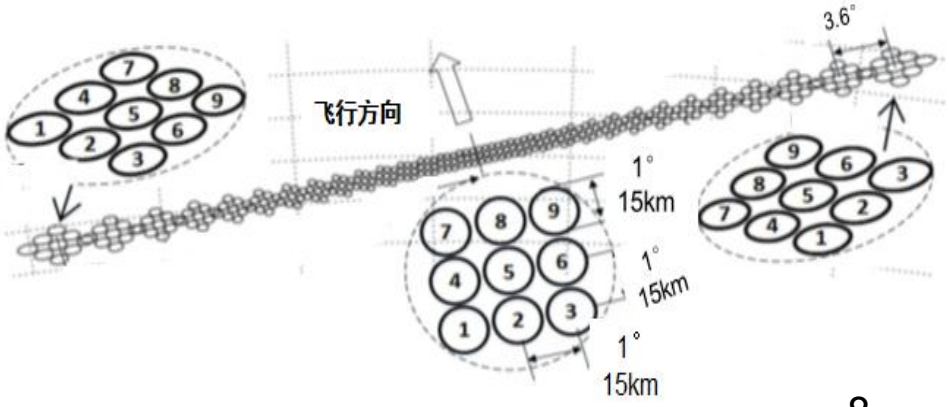
Parameters	Specification(FY-3D)	Specification(FY-3E/F/H)
Scan angle	50.4 Deg	50.4 Deg
Pixels per scan line	29*4	28*9
view angle	1.1 Deg	1 Deg
Nadiv spatial resolutinon	16 Km	14 Km
Scan period	10 s	8 s
Detectors arrangement	2 × 2	3 × 3
Pointing precision	0.1 Deg	0.06 Deg
Pointing stability	/	0.45 Mrad



FY-3D

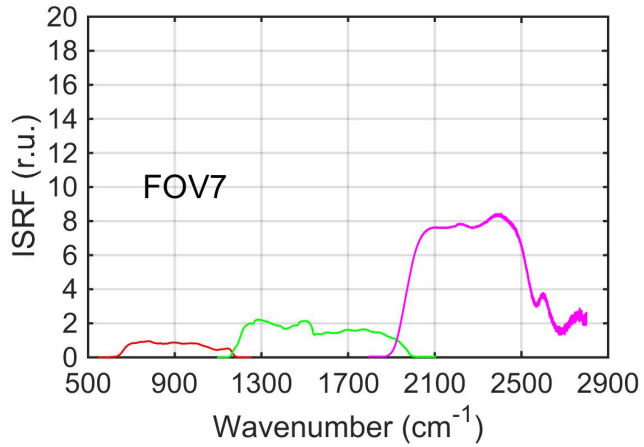


FY-3E



HIRAS performance requirement improment

Band	Spectral range(cm^{-1}) (FY-3D/E/F/H)	Spectral relolution(cm^{-1}) (FY-3D/E/F/H)	(NEΔT@280K)			Ch number
			FY-3D	FY-3E/F/H		
LW	650 ~ 1135 (15.38μm ~ 8.8 μm)	0.625(DR) 0.625(FR)	0.4K	650 ~ 667 cm^{-1}	0.8K	781(DR) 781(FR)
				667 ~ 689 cm^{-1}	0.4K	
				689 ~ 1000 cm^{-1}	0.2K	
				1000 ~ 1136 cm^{-1}	0.4K	
MW	1210 ~ 1750 (8.26μm ~ 5.71 μm)	1.25(DR) 0.625(FR)	0.7K	1210 ~ 1538 cm^{-1}	0.2K	433(DR) 869(FR)
				1538 ~ 1750 cm^{-1}	0.3K	
SW	2155 ~ 2550 (4.64μm ~ 3.92 μm)	2.5(DR) 0.625(FR)	1.2K	2155 ~ 2300 cm^{-1}	0.3	159(DR) 637(FR)
				2300 ~ 2550 cm^{-1}	0.5	

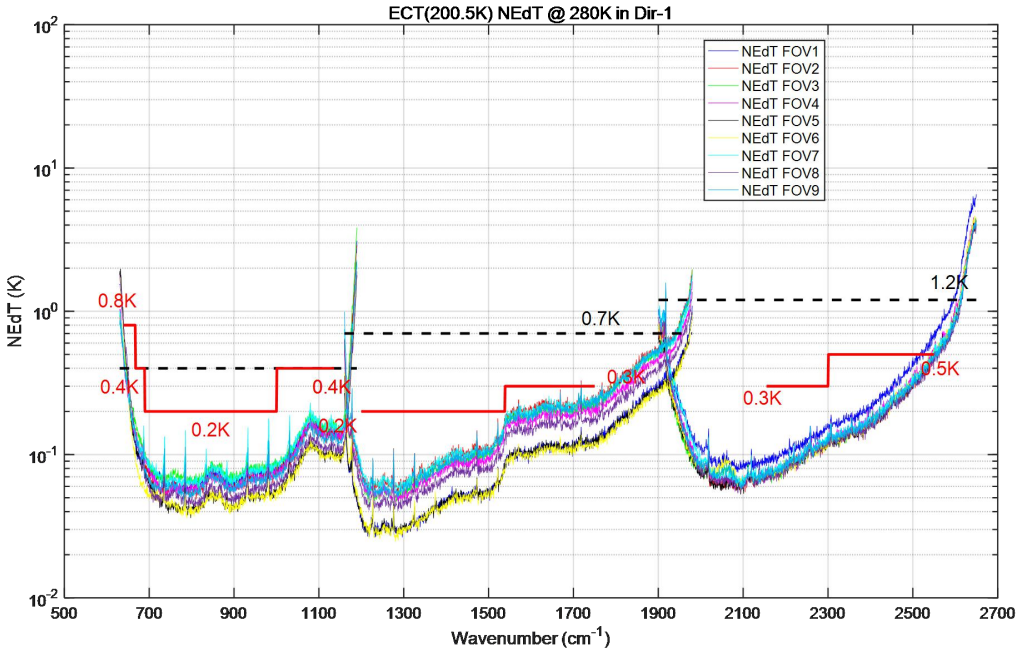


- Greater improvement of FY-3E/HIRAS-II sensitivity requirments , MW and SW are increased by more than 1 times;
- FY-3E/HIRAS will provide the whole continuous spectrum of 650~2550 cm-1.

HIRAS performance requirement improment

band	Spectral range(cm^{-1})	Radiometric Calibration accuracy（K） min requirement /Expectations		Spectral Calibration accuracy（ppm） min requirement /Expectations	
		FY-3D	FY-3E/F/H	FY-3D	FY-3E/F/H
LW	650 ~ 667 cm^{-1}	1K/0.7K	1K/0.8K	10 ppm	7 ppm /5 ppm
	667 ~ 689 cm^{-1}		0.5K/0.4K	10 ppm	7 ppm /5 ppm
	689 ~ 1000 cm^{-1}		0.4K/0.3K	10 ppm	7 ppm /5 ppm
	1000 ~ 1136 cm^{-1}		0.5K/0.4K	10 ppm	7 ppm /5 ppm
MW	1210 ~ 1538 cm^{-1}	1K/0.7K	0.4K/0.3K	10 ppm	7 ppm /5 ppm
	1538 ~ 1750 cm^{-1}		0.5K/0.4K	10 ppm	7 ppm /5 ppm
SW	2155 ~ 2300 cm^{-1}	1K/0.7K	0.5K/0.4K	10 ppm	7 ppm /5 ppm
	2300 ~ 2550 cm^{-1}		0.6K/0.5K	10 ppm	7 ppm /5 ppm

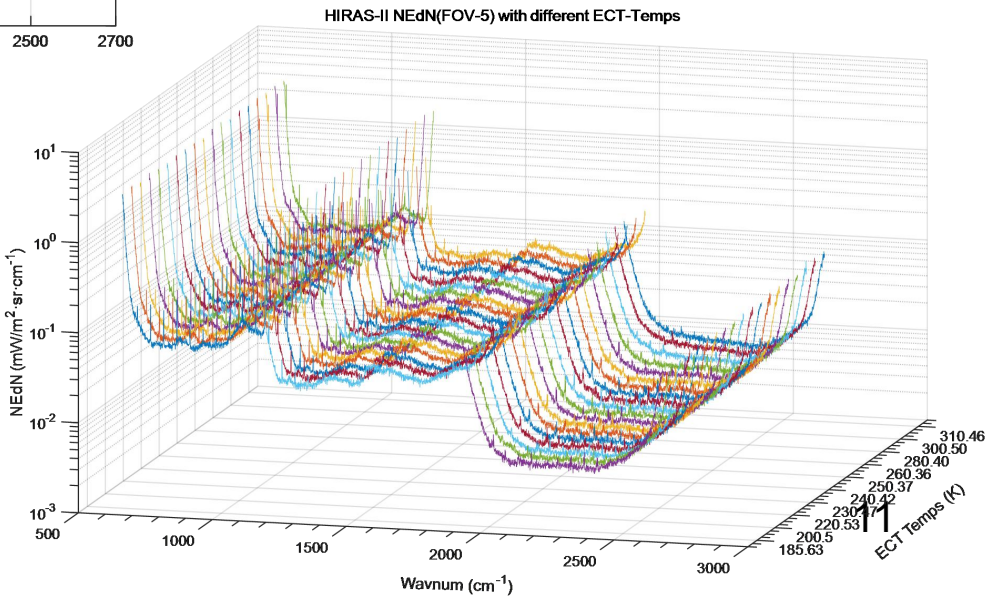
2. FY-3E/HIRAS pre-lauch performance



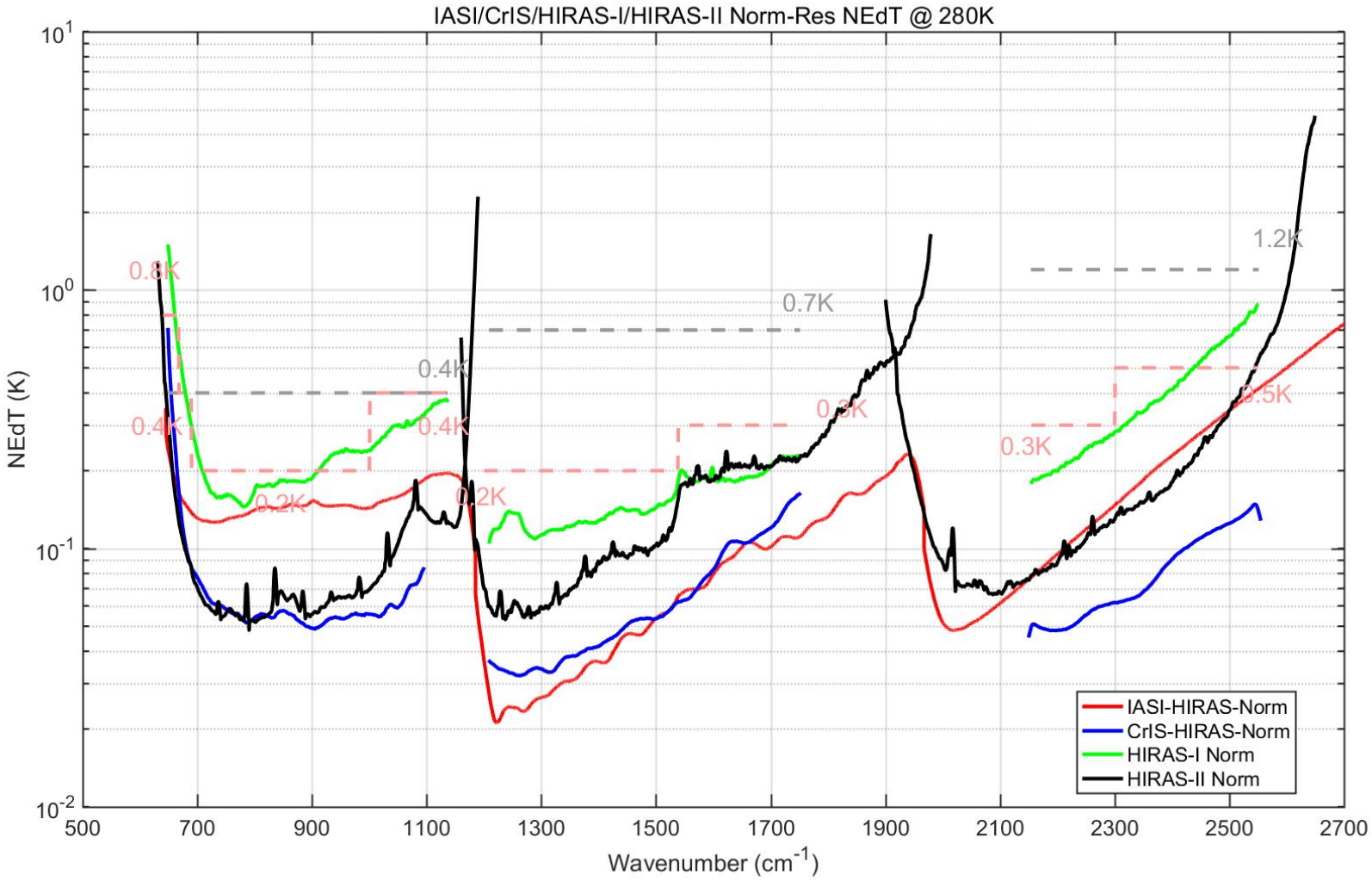
FY-3E Plann to lauch in July, 2021.

- NEdTs of all channels for 3 bands get great improvement from 3D HIRAS and meet specification.

- NEdTs for different ECT temperature.
- NEdTs are stable and without obvious dependency on object temperature.

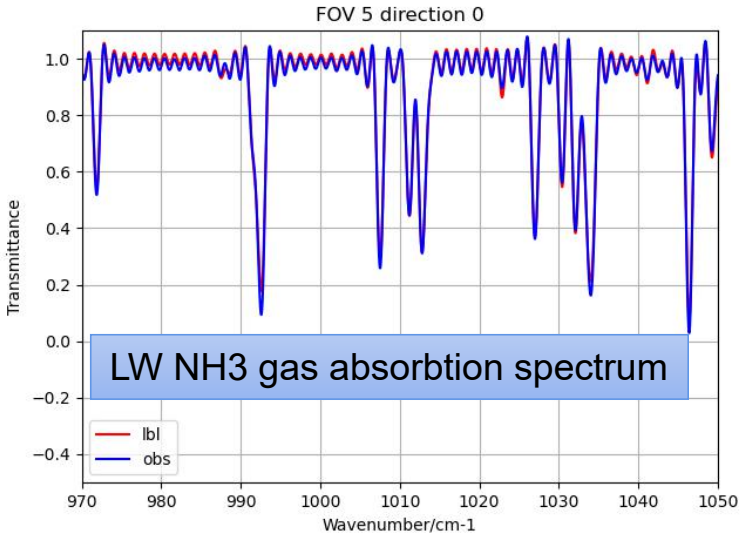


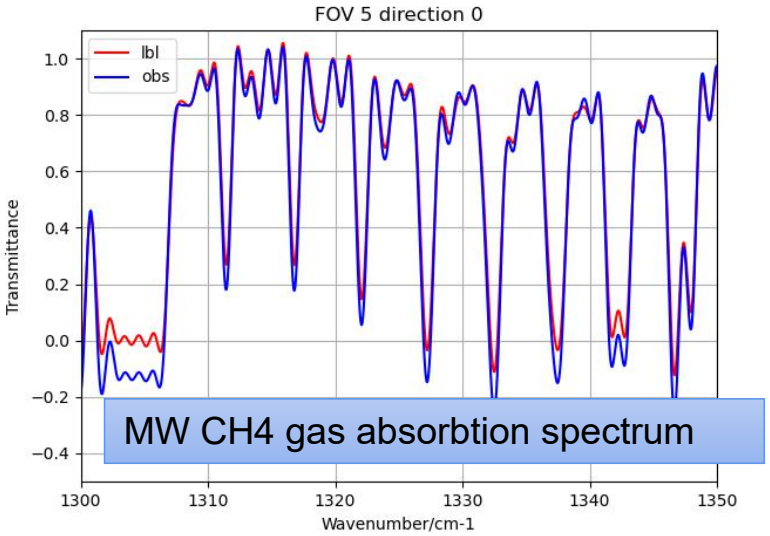
FY-3D to 3E, sensitivity of HIRAS are significantly improved

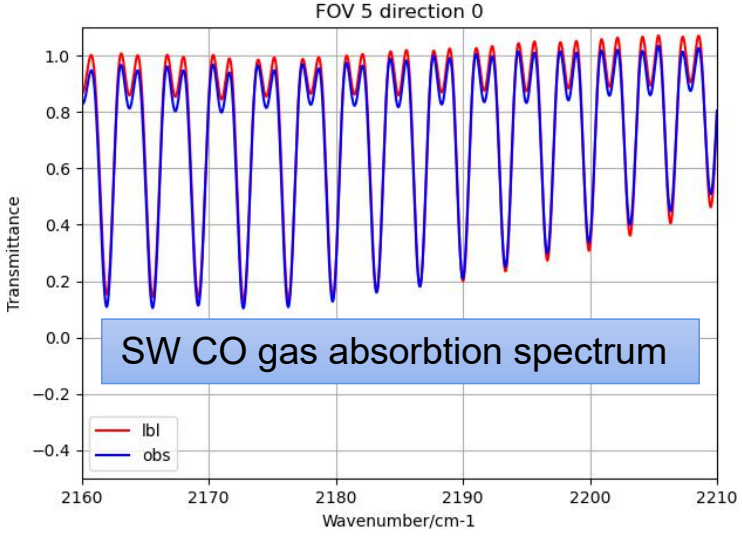


- Sensitivity of HIRAS in LW and SW are comparable to CrIS and IASI respectively.

HIRAS-II Spectral calibration







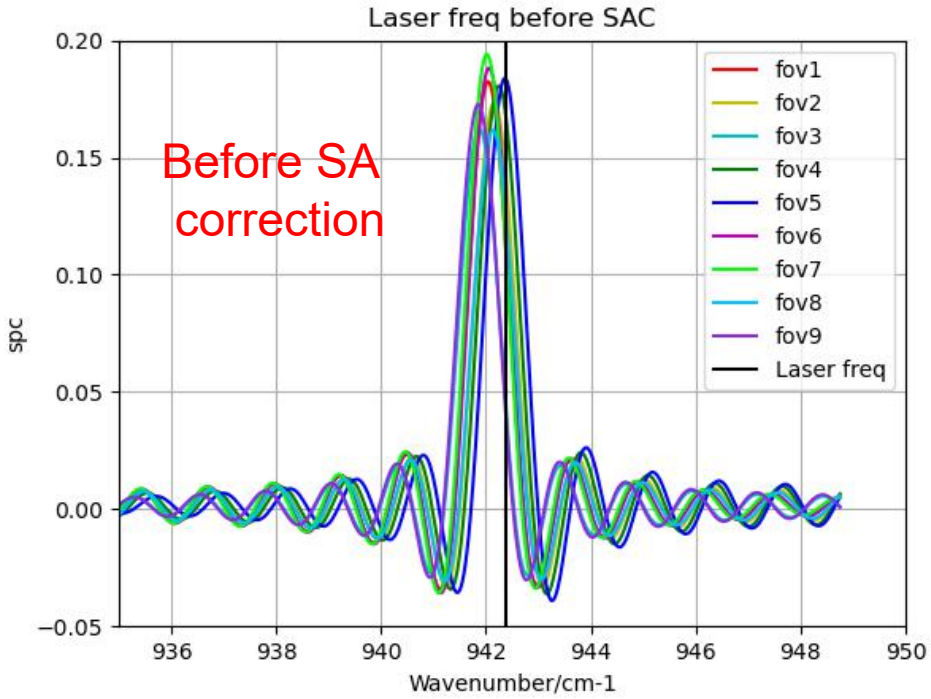
- LBL calculated transmittances are consistant with measurement transmittance.
- Generate the spectral correction parameters that will be used in orbit based on pre-launch gas pool test data.

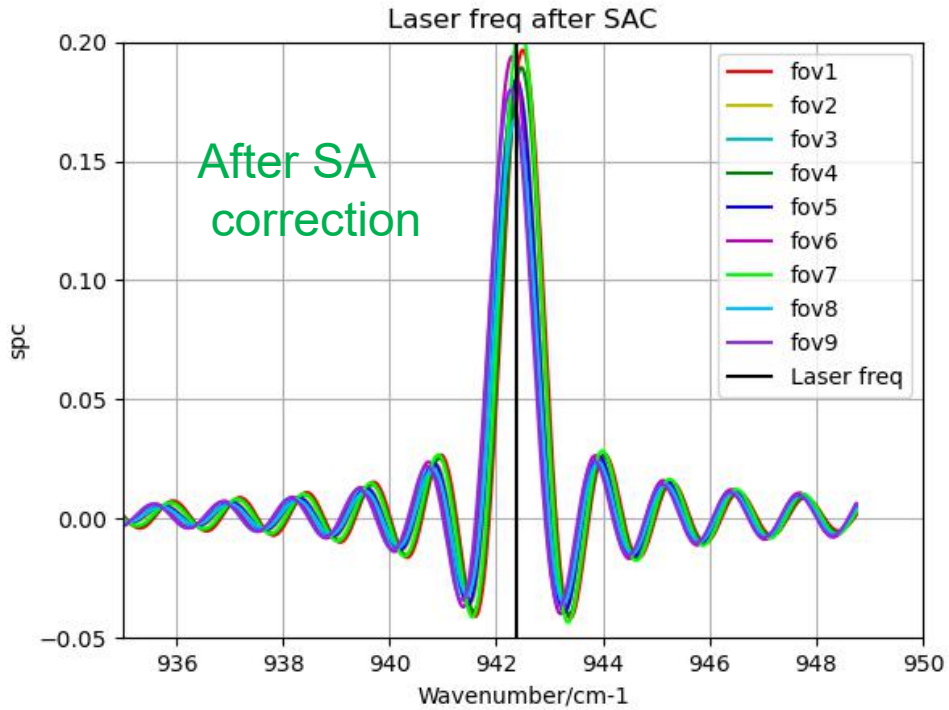
Spectral bias evaluation based on LBL simulation and gas pool observation with pre-launch raw off-axis parameters

Detector		FOV1 (ppm)	FOV2 (ppm)	FOV3 (ppm)	FOV4 (ppm)	FOV5 (ppm)	FOV6 (ppm)	FOV7 (ppm)	FOV8 (ppm)	FOV9 (ppm)
LW	Before SA correction	355.54	230.00	534.97	148.24	25.02	339.15	382.90	268.43	567.64
	After SA correction	-124.39	-28.19	56.16	-95.84	4.54	90.45	-73.10	30.73	123.76
MW	Before SA correction	339.90	219.71	533.97	149.75	32.68	352.04	405.96	291.37	603.91
	After SA correction	-131.93	-23.62	56.49	-95.72	11.38	99.90	-69.73	39.00	125.61
SW	Before SA correction	361.27	214.72	520.31	158.54	23.86	319.62	406.55	261.85	568.68
	After SA correction	-129.04	-20.80	76.24	-108.51	5.86	90.32	-75.24	26.82	119.16

- Spectral frequency bias before SA correction are 25 ~ 567 ppm in LW, 32 ~ 603 ppm in MW and 23 ~ 568 ppm in SW bands.
- After SA correction, spectral frequency bias largely decreased, but still with large shift and need adjustment for the off-axis parameters .

Spectral bias evaluation based on laser observation and pre-launch raw off-axis parameters--LW band

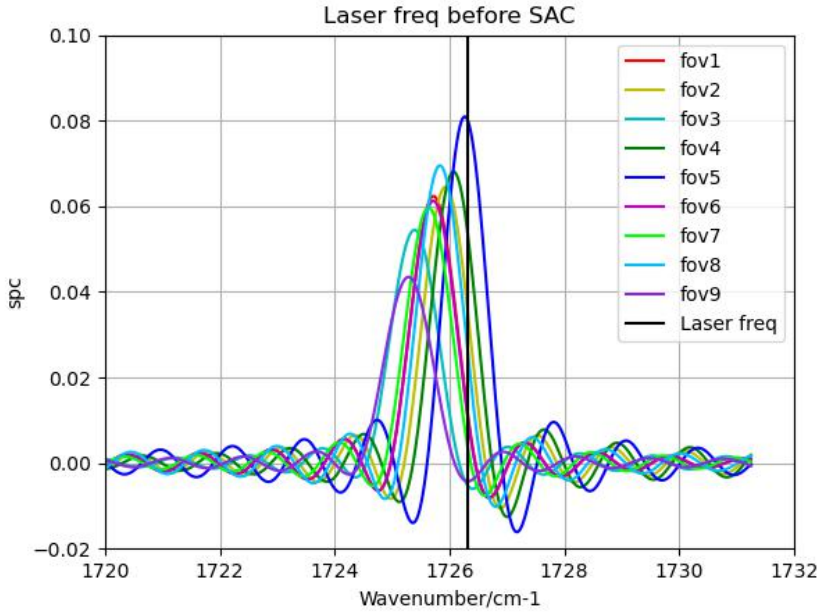


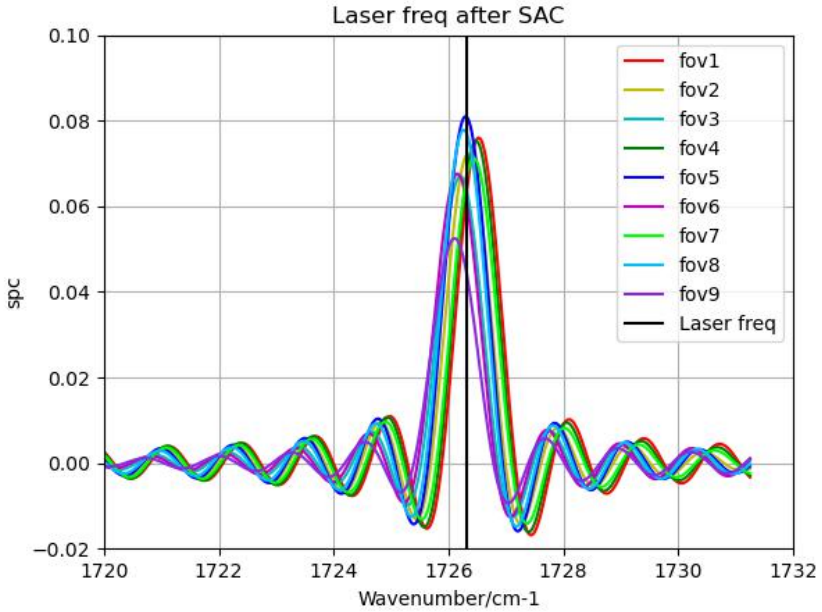


Detector		FOV1 (ppm)	FOV2 (ppm)	FOV3 (ppm)	FOV4 (ppm)	FOV5 (ppm)	FOV6 (ppm)	FOV7 (ppm)	FOV8 (ppm)	FOV9 (ppm)
LW	Before SA correction	361.52	236.84	540.92	146.17	22.14	342.73	386.45	22.75	559.70
	After SA correction	-122.93	-25.13	63.59	-95.73	2.71	89.49	-74.36	18.92	116.37

- Spectral frequency bias are 22 ~ 559 ppm before SA correction and 2.7 ~ 122 ppm after SA correction in LW band.

Spectral bias evaluation based on laser observation and pre-launch raw off-axis parameters--MW band





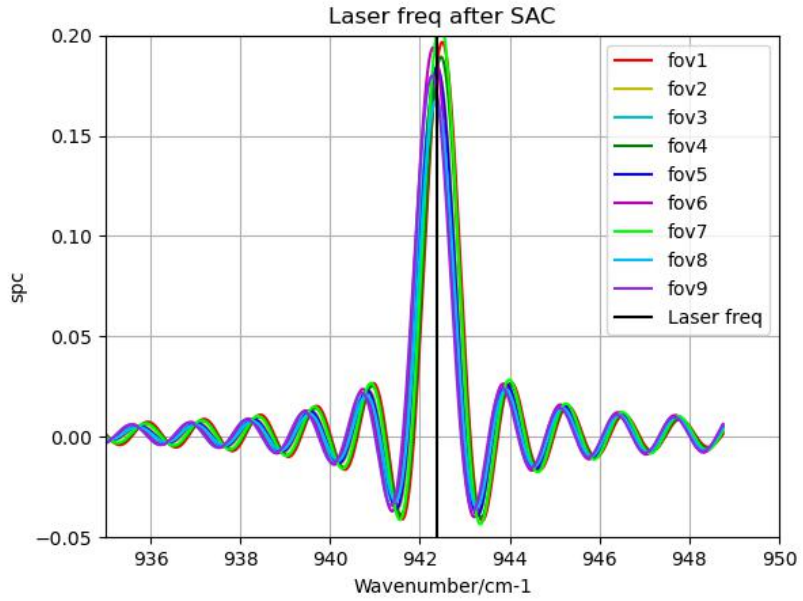
Detector		FOV1 (ppm)	FOV2 (ppm)	FOV3 (ppm)	FOV4 (ppm)	FOV5 (ppm)	FOV6 (ppm)	FOV7 (ppm)	FOV8 (ppm)	FOV9 (ppm)
MW	Before SA correction	349.93	228.66	541.91	147.52	34.56	352.23	399.61	285.23	601.84
	After SA correction	-116.75	-10.51	70.27	89.18	15.64	98.73	-67.96	34.73	126.84

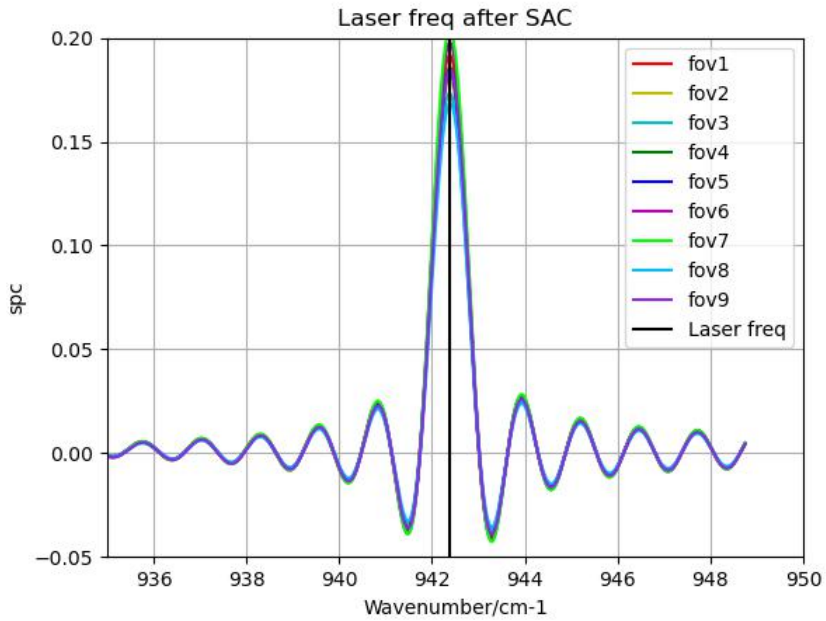
- Spectral frequency bias are 34 ~ 601 ppm before SA correction and 15 ~ 126 ppm after SA correction in LW band.

Spectral shift bias evaluation after off-axis parameters adjustment for 3 bands

Detector		FOV1 (ppm)	FOV2 (ppm)	FOV3 (ppm)	FOV4 (ppm)	FOV5 (ppm)	FOV6 (ppm)	FOV7 (ppm)	FOV8 (ppm)	FOV9 (ppm)
LW	gas pool observation	0.43	3.01	1.70	0.98	1.58	0.72	0.44	0.79	0.89
	laser observation	-2.7	1.8	2.03	2.47	4.73	1.88	3.41	6.8	4.3
MW	gas pool observation	1.16	1.03	5.54	2.13	0.73	1.19	2.36	2.20	2.10
	laser observation	-1.32	-1.68	-6.10	-5.74	-2.56	-2.56	-6.95	-4.22	-6.26
SW	gas pool observation	1.75	1.18	4.8	1.3	1.14	2.99	-6.24	0.64	-5.07
	/	/	/	/	/	/	/	/	/	/

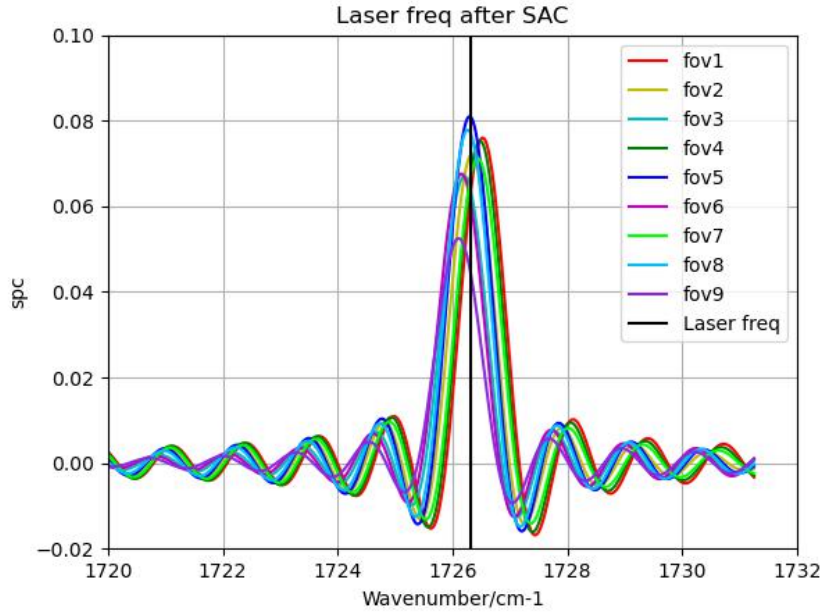
- Adjust off-axis parameters and verify spectral bias using gas pool and laser observation.
- Spectral frequency bias are within 7 ppm after off-axis parameters adjustment in LW, MW and SW bands.

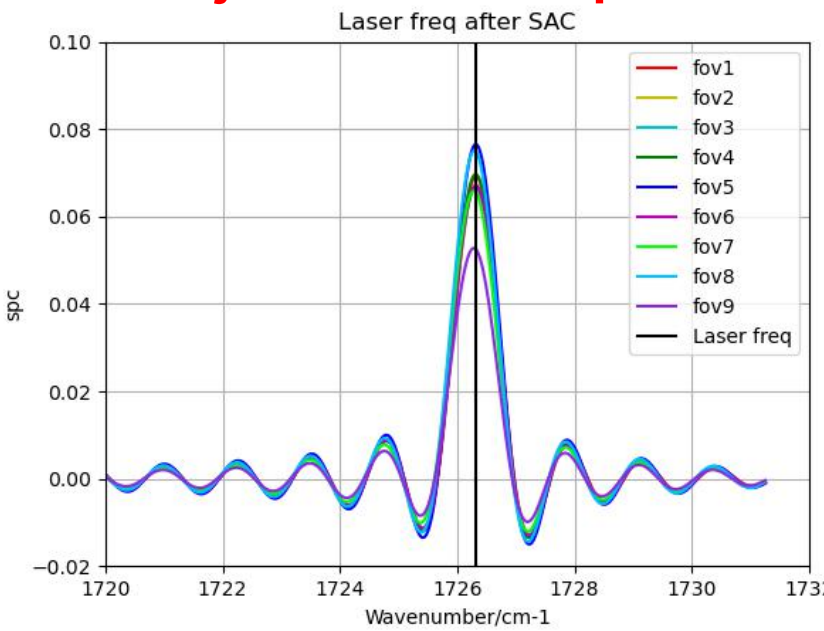




Raw off-axis parameters

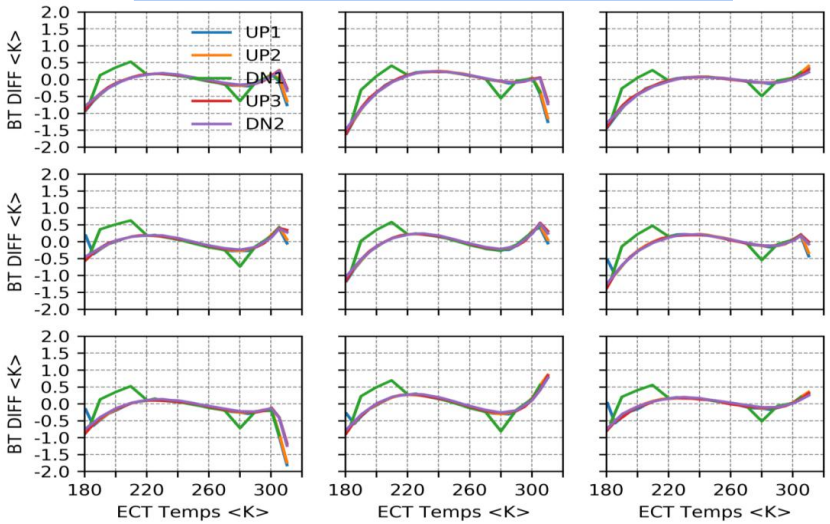
Adjusted off-axis parameters



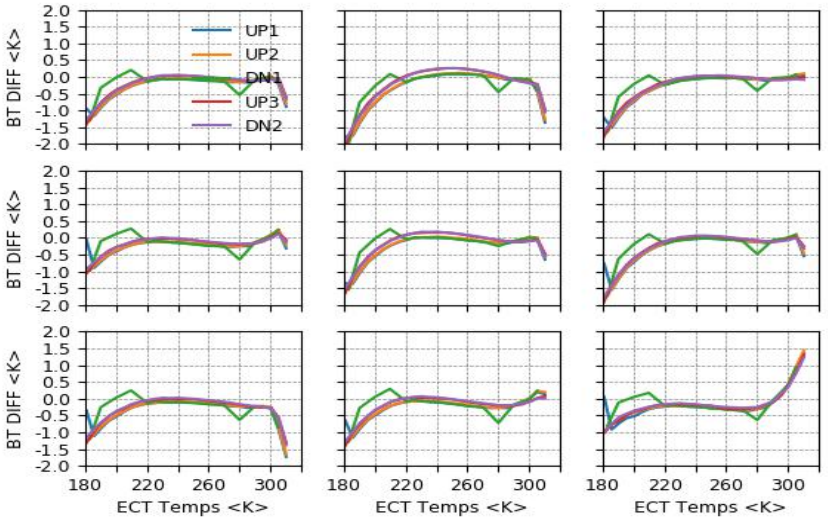


HIRAS-II Radiometric calibration verification

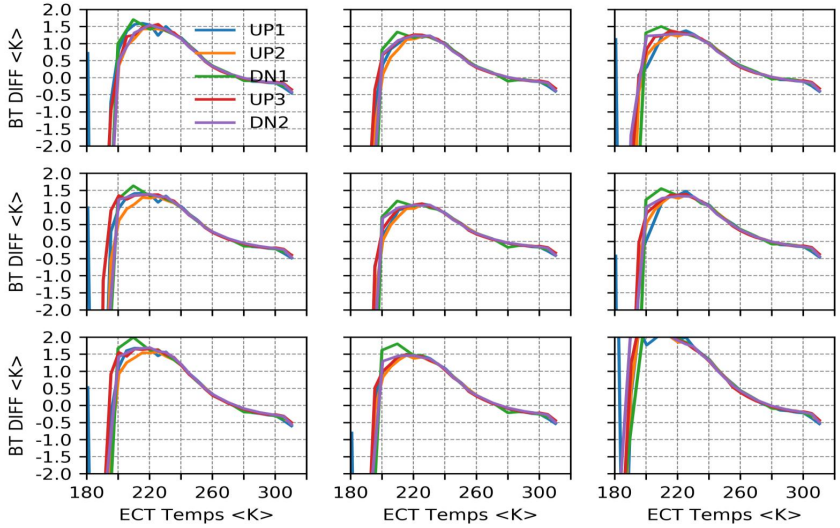
LW channel calibration bias / K



MW channel calibration bias / K



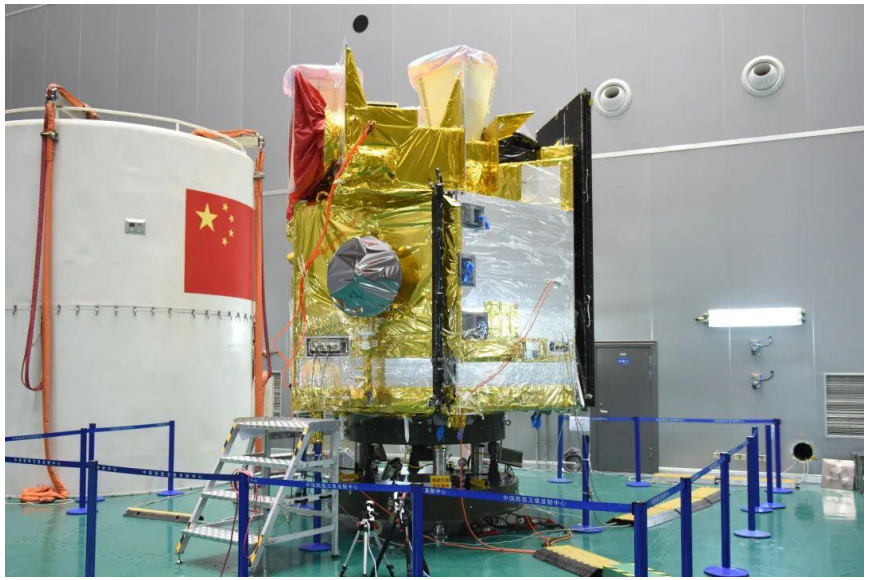
SW channel calibration bias / K



- LW and MW exhibit obvious Non-Linerity characteristics.
- After NL correction, LW and MW channels calibration biases are within 0.5 K.
- SW without NL correction, but displays abnormal large bias structure due to weak singal and large noise for object temperature of less than 260 K.

3.Introduction of FY-4B GIIRS

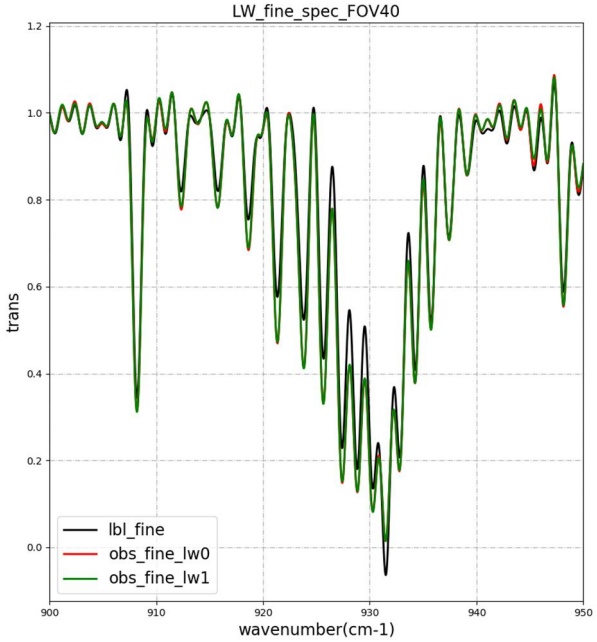
- FY-4B which is the **first operational** geostationary satellite in FY-4 series had been launched successfully on June 3rd, 2021。
- Successfully positioned at 123.5 E longitude on June 10th.
- Instrument specification requirements get much improved, with upgraded design.

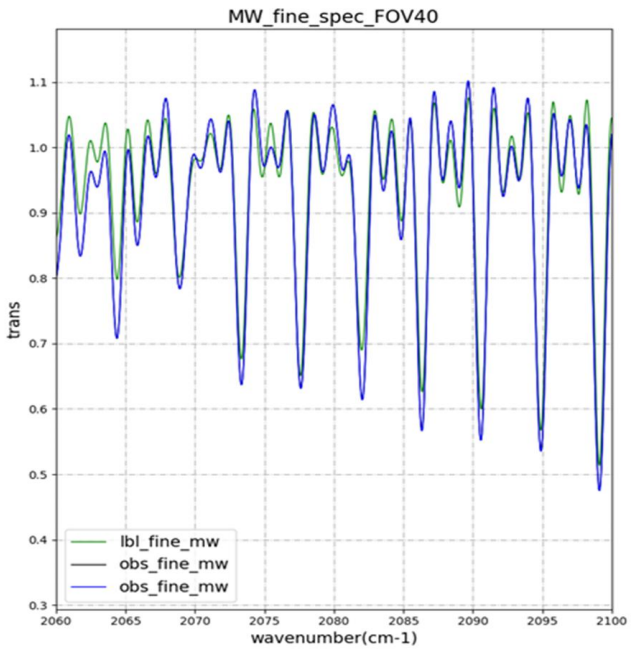


FY-4A/B GIIRS specifications

Sensor		FY-4A	FY-4B
GIIRS	Spectral Range	LWIR：700cm^{-1}-1130cm^{-1} S/MIR：1650cm^{-1}-2250cm^{-1} VIS：0.55-0.75μm	LWIR：680 cm^{-1}-1130 cm^{-1} S/MIR：1650 cm^{-1}-2250 cm^{-1} VIS：0.55-0.75μm
	Spectral Resolution (Normal mode)	LWIR：0.625cm^{-1} S/MIR：0.625cm^{-1}	LWIR：0.625cm^{-1} S/MIR：0.625cm^{-1}
	Operational Mode	1000*1000km^2 5000*5000 km^2	5000*5000 km^2
	Temporal Resolution	China area: <1hr Mesoscale area: <0.5hour	China area: <45min
	Sensitivity (mW/m^{2}sr cm^{-1})/S/N	LWIR：0.5-1.1 S/MIR：0.1-0.14 S/N≥200（ρ=100%）	LWIR：≤0.5 S/MIR：≤0.1 S/N≥200（ρ=100%）
	Calibration accuracy (radiation)	1.5K	0.7K
	Calibration accuracy (spectrum)	10ppm (3σ)	<10ppm (3σ)
	Spatial Resolution	L/S/MIR：16km VIS：2km	L/S/MIR：12km VIS：1km
	Focal FOV array	LW/MW:32*4 VIS:330*256	LW/MW:16*8 VIS:512*512

4.TVAC results- spectrum calibration accuracy

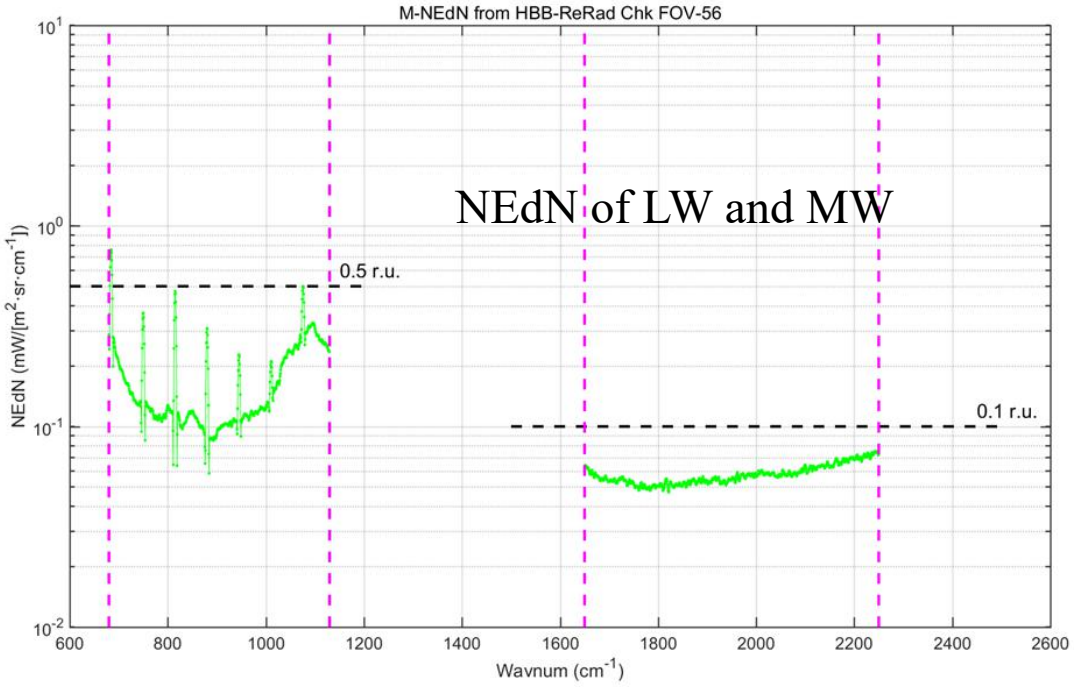




Spectrum calibration accuracy is better than 10 ppm.

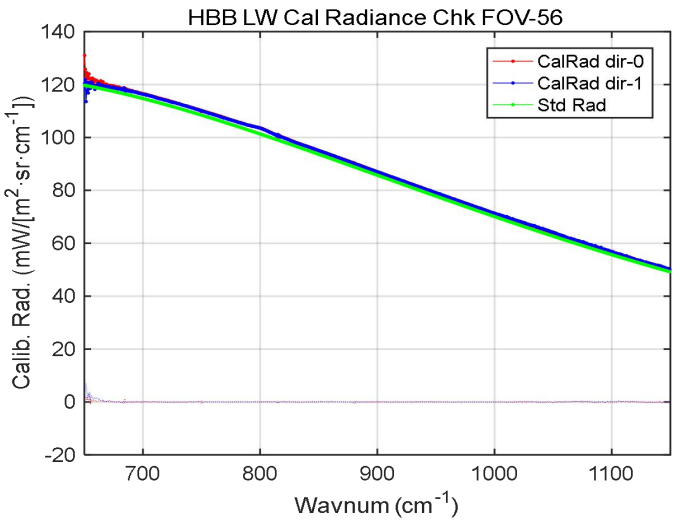
The comparison of fine spectrum between the observation transmittance and LBL transmittance.

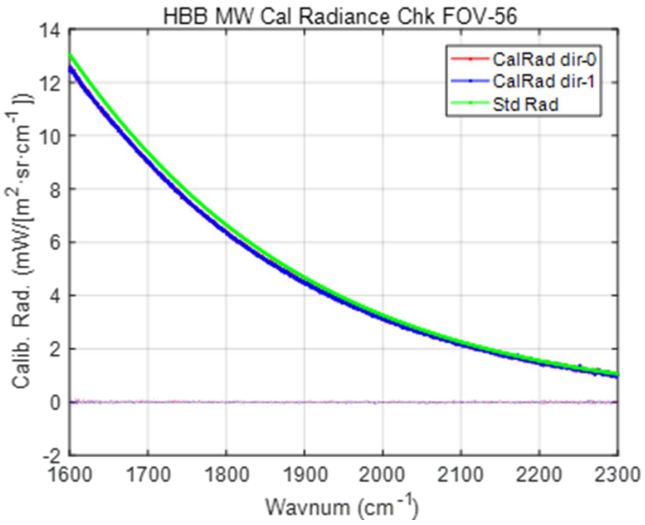
TVAC results- sensitivity



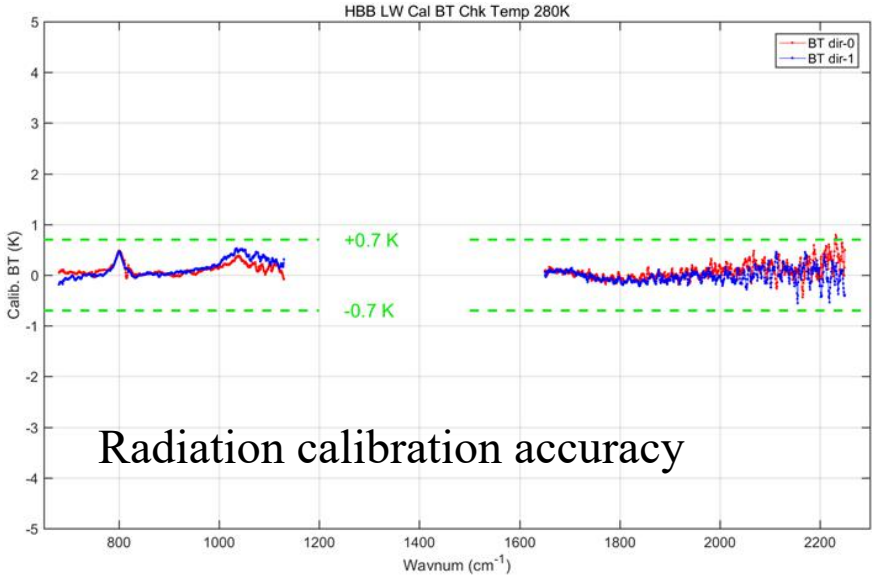
- The sensitivity is improved significantly, such as less than 0.5 mW/m^2 sr m-1 for LWIR, and less than 0.1 mW/m^2 sr m-1 for MWIR.

TVAC results- radiation calibration accuracy





The comparison between the calibration spectrum and theoretical spectrum



Radiation calibration accuracy satisfies the requirement (0.7K).

6. Summary

- ✓ **FY-3D/HIRAS is in stable operational status, completed the 4th decontamination in Mar, 2021.**
- ✓ **Sensitivity of HIRAS-II for 3 bands get great improvement from 3D HIRAS, are comparable to CrIS and IASI in LW and SW respectively.**
- ✓ **Spectral calibration bias are within 7ppm, most detectors are better than 5ppm and meet requirement.**
- ✓ **LW and MW bands still exbihit strong NL characteristics.**
- ✓ **Compared with FY 4A/GIIRS, FY 4B/GIIRS improves the spectral calibration, radiation calibration, sensitivity, and spatial resolution, and TVAC results show the instrument meet the requirements, such as spectral calibration (<10 ppm), radiation calibration (0.7K), sensitivity ($\leq$ 0.5 mW/m^2 sr cm^{-1} for LW, $\leq$ 0.1 mW/m^2 sr cm^{-1} for MW), and expected have better application in NWP, atmospheric trace gas retrieval, etc.**

Thanks for your attention