



CMA Progress in Hyper-spectral Sounding

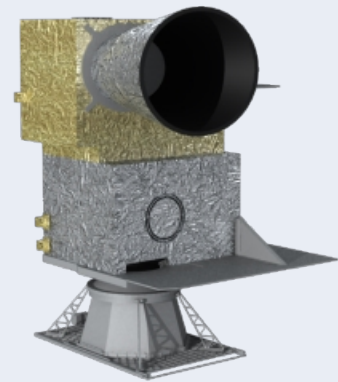
Presented to CGMS-48 Plenary, Session: HSIR observations,
Agenda item 4.2

Contributed by GIIRS & HIRAS teams from CMA
Presented by Qiang Guo & Chengli Qi

Current hyperspectral infrared sounding capabilities: GIIRS on GEO Orbit

Main Specifications of GIIRS

	Range	Resolution	Channels	
Spectral Parameters (Normal mode)	LWIR: 700-1130 cm^{-1}	0.625 $^{-1}$	689	1650
	S/MIR: 1650-2250 cm^{-1}	0.625 $^{-1}$	961	
	VIS : 0.55- 0.75 μm			
Spatial Resolution	LWIR/MWIR :	16 Km SSP		
	VIS :	2 Km SSP		
Operational Mode	China area	5000 \times 5000 Km^2		
	Mesoscale area	1000 \times 1000 Km^2		
Temporal Resolution	China area	<1 hr		
	Mesoscale area	<1/2 hr		
Sensitivity ($\text{mW}\cdot\text{m}^{-2}\cdot\text{sr}\cdot\text{cm}^{-2}$)	LWIR: 0.5-1.1	S/MIR: 0.1-0.14		
	VIS: S/N>200($\rho=100\%$)			
Calibration accuracy	1.5 K			
Calibration accuracy	10 ppm			
Quantization Bits	13 bits			



Current hyperspectral infrared sounding capabilities: GIIRS on GEO Orbit

Milestones of GIIRS L1 Data

(Operation, Distribution and Application)

- ❑ 2016.12~2017.10: Commissioning and Preliminary Validation
- ❑ 2017.11~2018.04: User Readiness (i.e. observation mode optimization, training)
- ❑ 2018.05~2018.11: Experimental Application (i.e. NWP and retrieval)
- ❑ 2018.12: Operational Application in GRAPES (direct radiation assimilation)
- ❑ 2019.01: V1 Data Distribution to International Users;
- ❑ 2019.08: V2 Data in Operation
- ❑ 2019.10: V2+ available (spectral coding error corrected)
- ❑ 2019.11: V3 Data in Operation (diurnal BT biases variation corrected)

Current hyperspectral infrared sounding capabilities: GIIRS on GEO Orbit

Key Improvements of GIIRS L1 Data in V2~V3

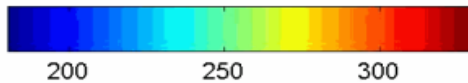
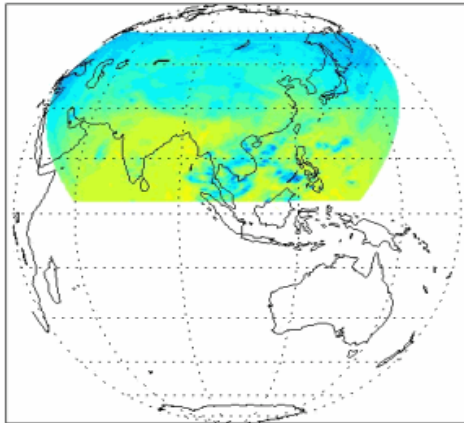
- ✓ **Abnormal Observations (bad graduals) Correction**
- ✓ **Spectral Optimization**
 - ◆ Off-axis effects correction (for 32×4 detector array)
 - ◆ Accurate spectral shift correction
- ✓ **Radiometric Optimization**
 - ◆ ZPD-aligning improvement
 - ◆ New calibration model for diurnal-varying on GEO platform
- ✓ **Processing Efficiency Optimization**
 - ◆ Fast DFT for GIIRS utilization (increased by 8~10 times)
- ✓ **Optional Apodization upon L1 Data**
 - 0813~0828: *Humming Apodization*
 - 0829~ : *Unapodization*

Current hyperspectral infrared sounding capabilities: GIIRS on GEO Orbit

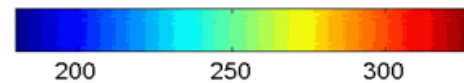
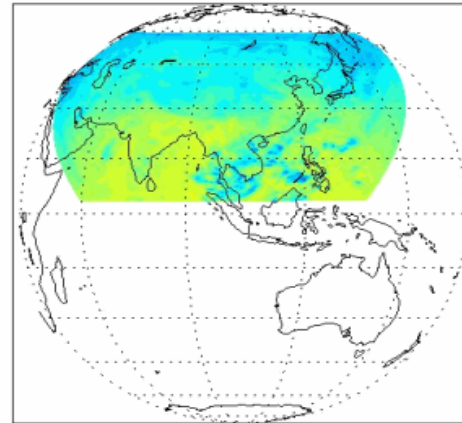
Bad granules occurred in V1 has been overcome completely: 11/350≈3%

20190509000000-20190509013000:1050.000(cm^{-1})

V2/V3

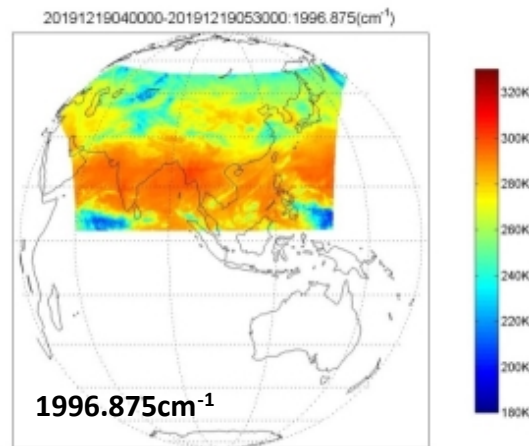
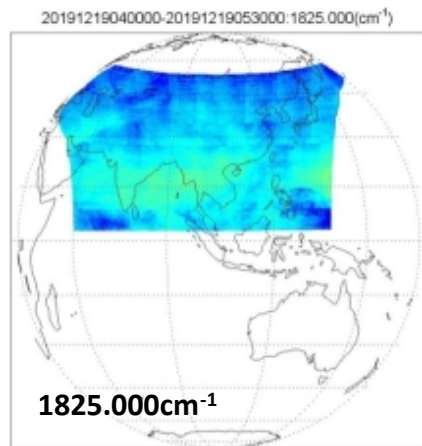
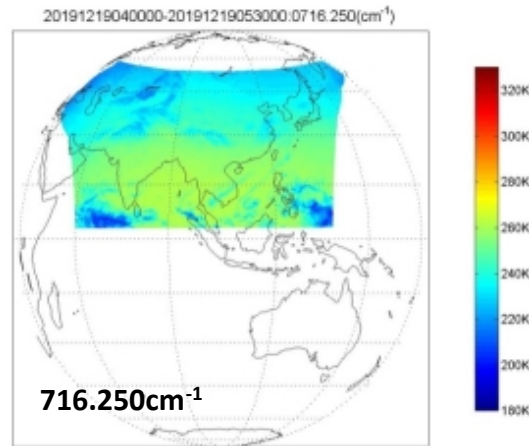
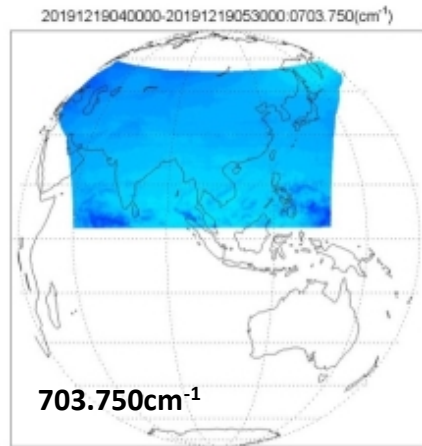


V1



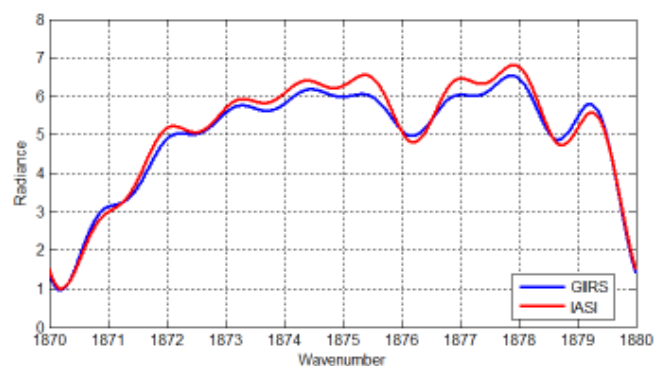
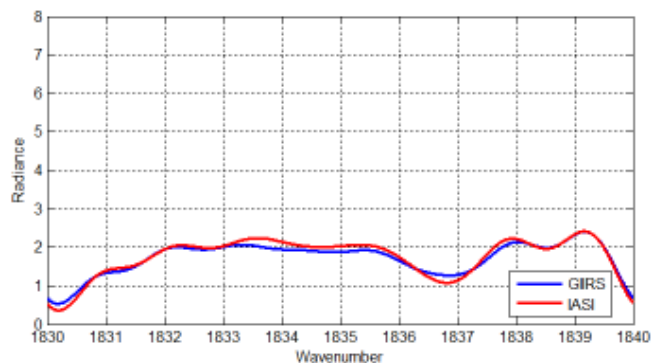
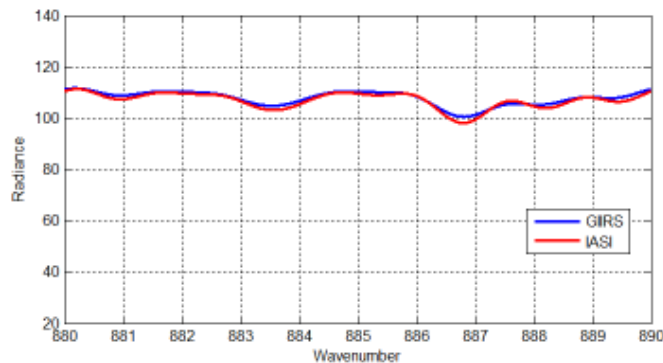
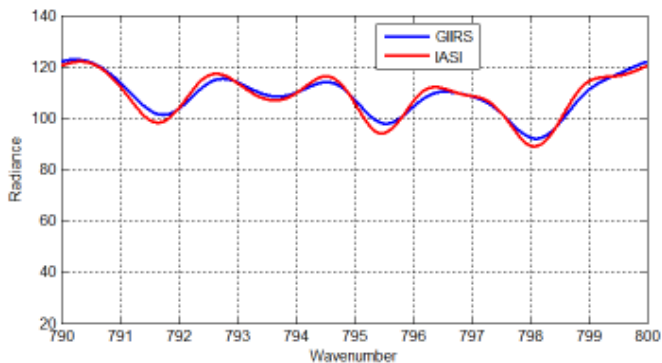
Current hyperspectral infrared sounding capabilities: GIIRS on GEO Orbit

Typical Earth scene spectra from GIIRS/V3 at UTC0400-0530 December 19, 2019



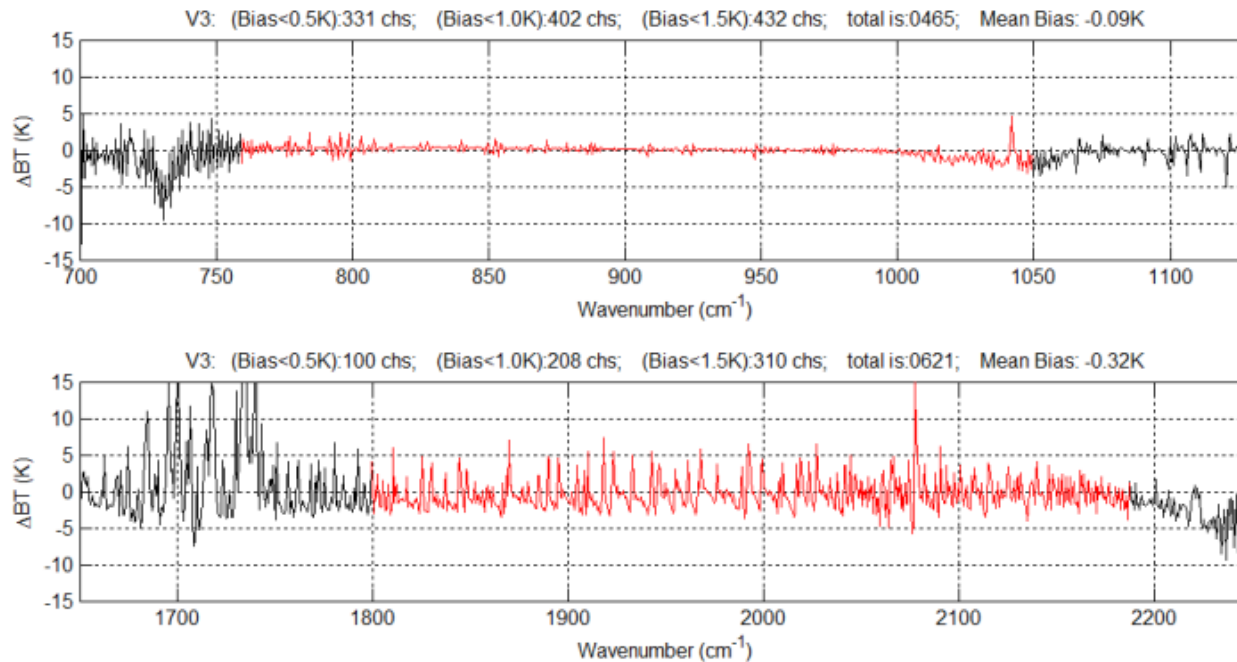
Current hyperspectral infrared sounding capabilities: GIIRS on GEO Orbit

Spectra comparison between GIIRS/V3 and IASI for some paired SNO observations during November 8-14, 2019



Current hyperspectral infrared sounding capabilities: GIIRS on GEO Orbit

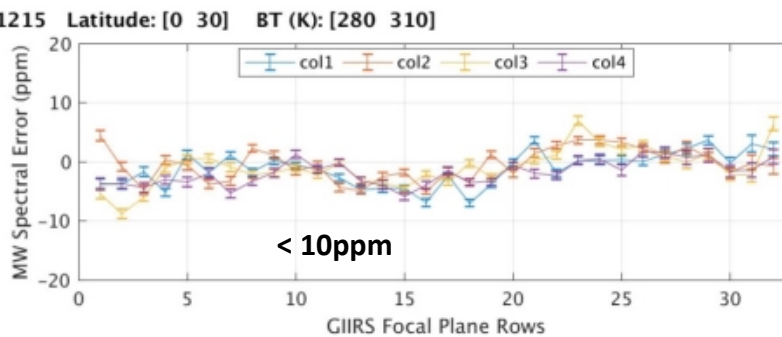
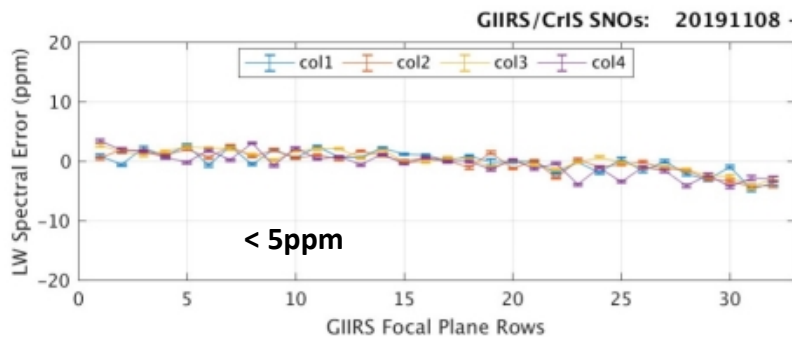
Radiometric biases GIIRS/V3 evaluated by intercalibrating with IASI using fully-overlapped SNO observations during November 8-14, 2019



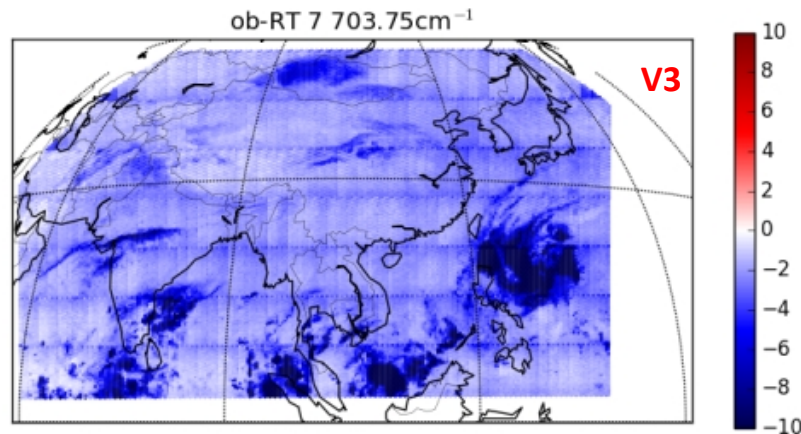
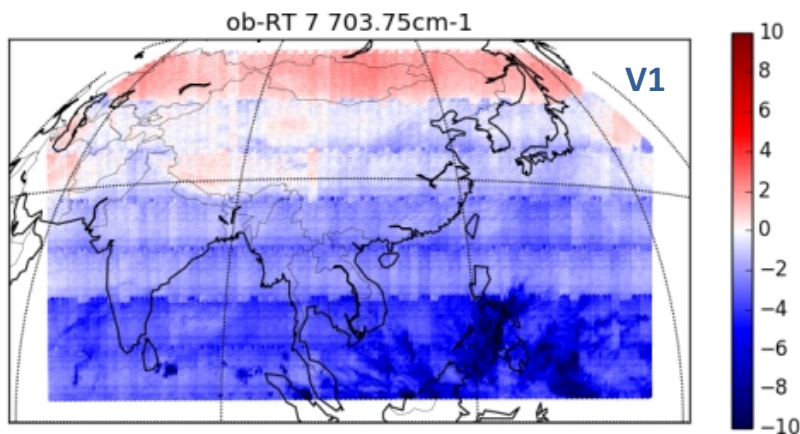
Band	Radiometric Calibration for Uncontaminated Region (LW:465chs; MW:621chs)												Spectral Calibration		
	ch	chLW	chMW	chSNO	chSNO	chSNO	chSNO	chSNO	chSNO	chSNO	chSNO	chSNO	chSNO	Mean BT Bias	Mean (ppm)
LW	331	71	30	0.1K	2ppm	8ppm	331	71	30	0.1K	2ppm	8ppm	-0.1K	2ppm	8ppm
MW	100	108	102	-0.3K	8ppm	7ppm	100	108	102	-0.3K	8ppm	7ppm	-0.3K	8ppm	7ppm

Current hyperspectral infrared sounding capabilities: GIIRS on GEO Orbit

SSEC/UW Assessments of V3 Spectral Shifts



ECMWF Assessments of V3 Radiance (O-B): channel7 (~100hPa)

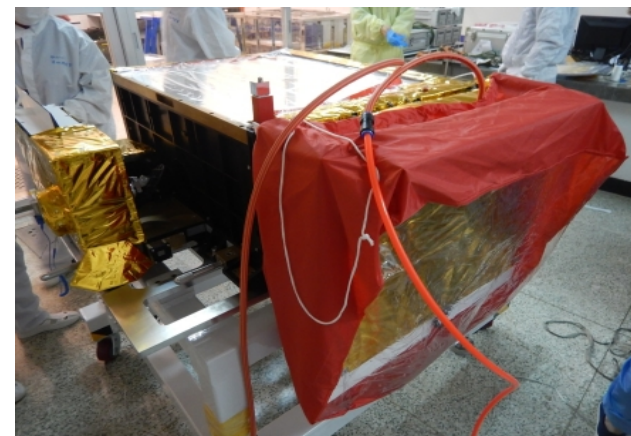


Less than **1K** for most channels in LW band

Current hyperspectral infrared sounding capabilities: HIRAS on LEO Orbit

Main Specifications of FY-3D/HIRAS

Parameters	Specification
Scan Period	10s
View Angle	1.1 \oplus
Pixels per scan line	116 (4 FOVs \times 29 FORs)
Maximum scan angle	\oplus 50.4 \oplus
Radiometric calibration accuracy	< 1 K
Spectral calibration accuracy	< 10 ppm
Direction pointing bias	< \pm 0.25 $^\circ$



Band	Spectral Range (cm $^{-1}$)	Spectral Resolution(cm $^{-1}$)		MPD(cm)		Ch No	
		FR	DR	FR	DR	FR	DR
LW	650~1135	0.625	0.625	0.8	0.8	781	781
MW	1210~1750	0.625	1.25	0.8	0.4	869	433
SW	2155~2550	0.625	2.5	0.8	0.2	637	159

- ◇ DR : Designed Resolution, international direct received data processing
- ◇ FR: Full Resolution , operational version

Current hyperspectral infrared sounding capabilities: HIRAS on LEO Orbit

FY-3D/HIRAS status updates in 2019

(instrument status and software version)

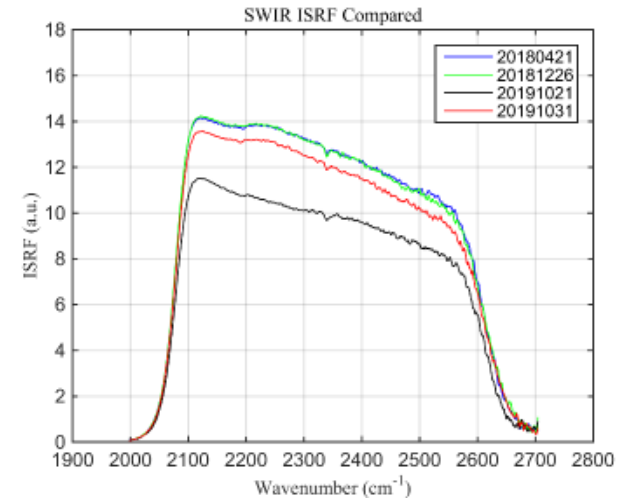
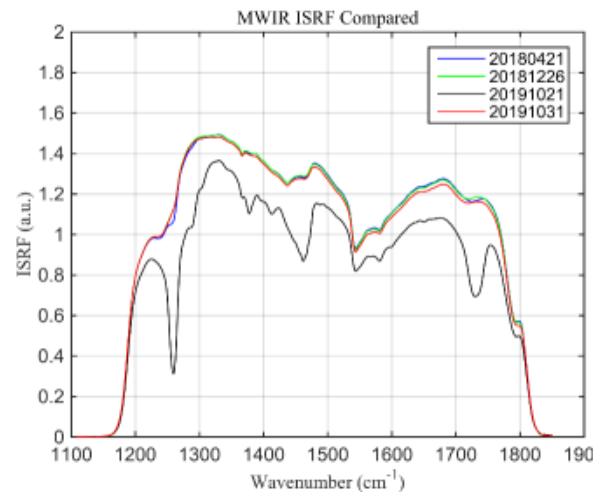
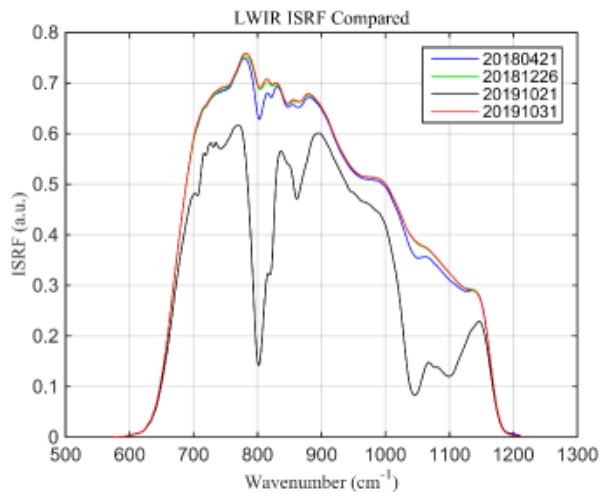
- ❑ Instrument heating and decontamination
 - 2018.12 1st
 - 2019.10 2nd
- ❑ Cold space view angle adjustment
 - Deep space pointing angle was changed from -71 ° to -87 °
- ❑ No software updates.

Current hyperspectral infrared sounding capabilities: HIRAS on LEO Orbit

Instrument heating and decontamination

ISRF compared with best signal status

Heating operation on Oct 21, 2019



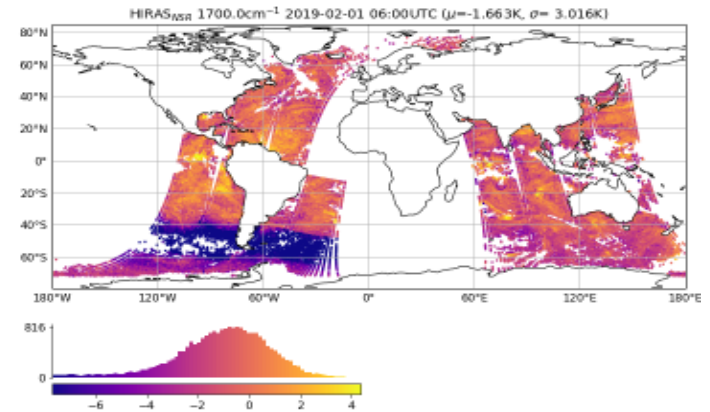
- LW and MW bands signal are nearly recovered.
- SW band is slight weaker in signal

Current hyperspectral infrared sounding capabilities: HIRAS on LEO Orbit

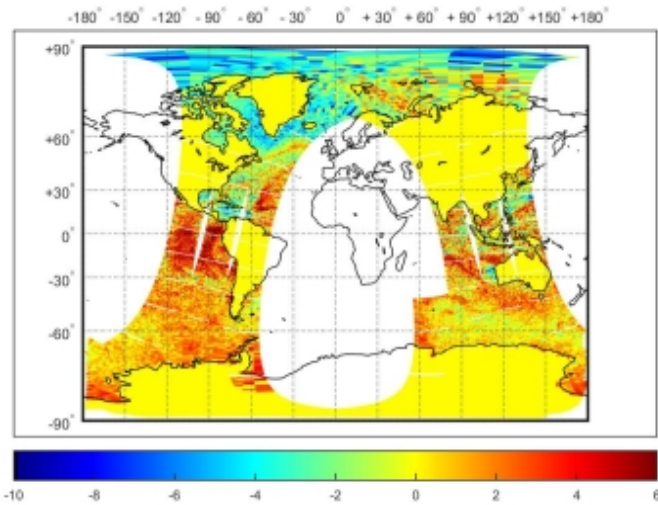
Cold space view angle adjustment

Assessment from Met Office

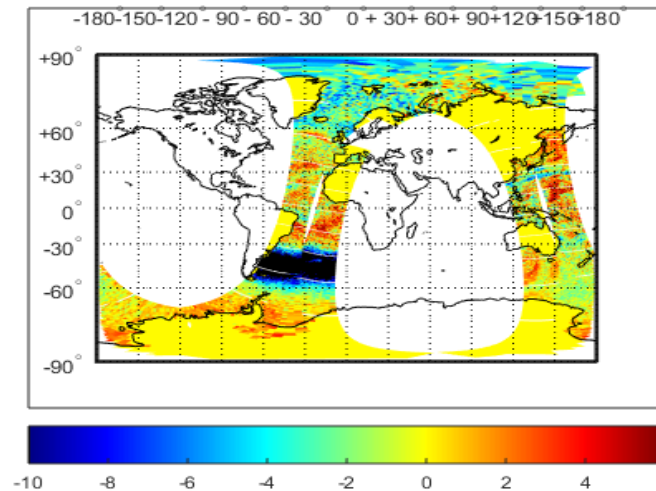
abnormal negative deviations of Detector 3 in the middle wave band in some areas. (Carminati, F, Xiao, X, Lu, Q, et al. Assessment of the Hyperspectral Infrared Atmospheric Sounder (HIRAS), *Remote Sens*, 2019, 11, 2950, doi: 10.3390/rs11242950)



After adjustment



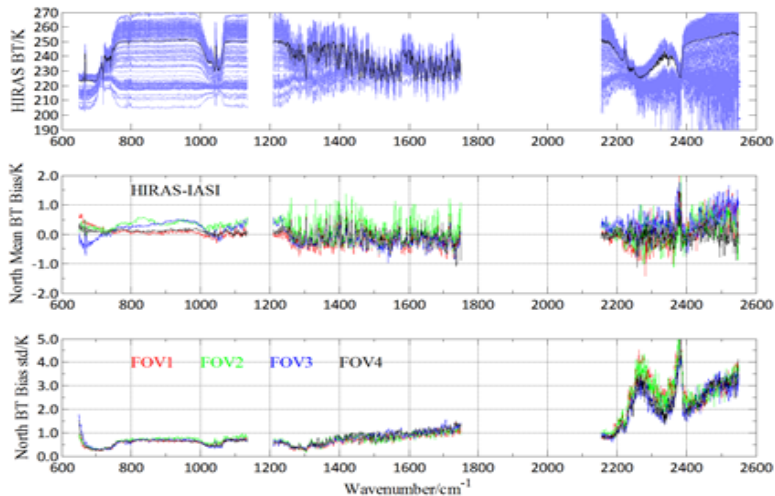
Before adjustment



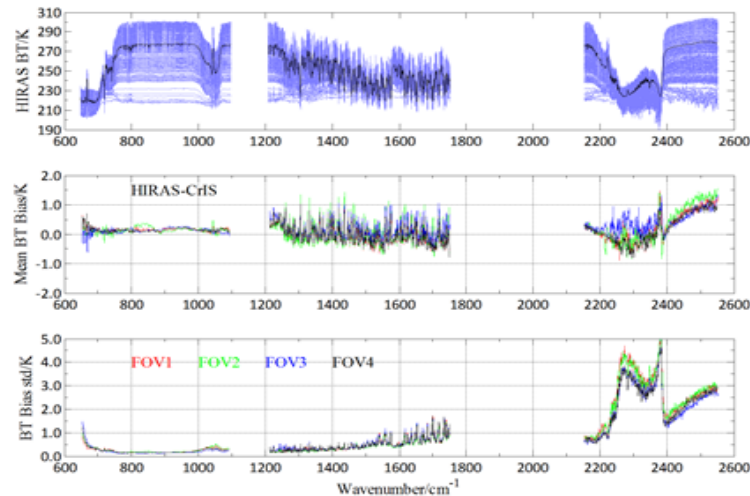
Abnormal deviation result from solar contamination. after the cold space view angle adjustment, the O-B bias abnormal is basically eliminated.

Current hyperspectral infrared sounding capabilities: HIRAS on LEO Orbit

HIRAS vs NPP/CrIS



HIRAS VS Metop/IASI



SNO BT comparison with NPP/CrIS and Metop/IASI

general less than 0.3, 0.7 and 1.0 K in the LWIR, MWIR and SWIR bands, respectively.

Spectral bias	mean (ppm)				Std(ppm)			
	FOV1	FOV2	FOV3	FOV4	FOV1	FOV2	FOV3	FOV4
LW	-1.63	-1.21	0.04	1.92	1.62	1.51	1.51	1.74
MW	-2.75	-1.49	-1.54	-2.18	2.67	2.65	2.35	2.59
SW	-0.13	1.16	1.74	2.49	3.27	3.61	2.57	2.25

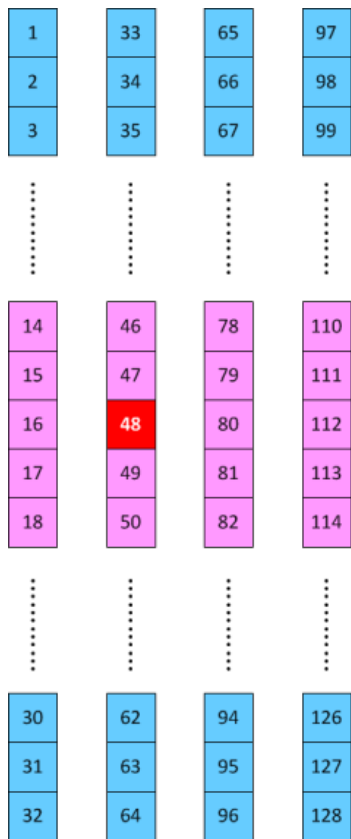
Mean and standard deviation(std) of the spectral bias relative to the line-by-line simulated spectra are within 5 ppm.

Planned/future hyperspectral infrared sounding capabilities: GIIRS on FY-4B/C

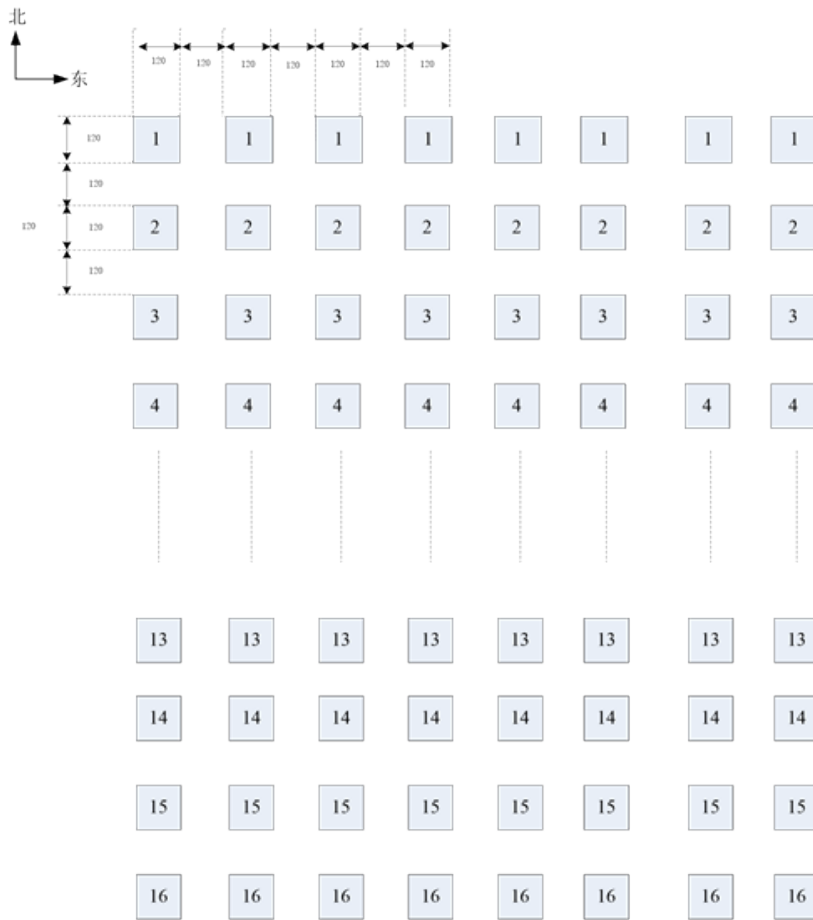
Performance	FY-4A	FY-4B	FY-4C
Band	LW: 700-1130cm ⁻¹ MW: 1650-2250cm ⁻¹	LW: 680 -1130cm ⁻¹ MW: 1650-2250cm ⁻¹	LW: 650 -1130cm ⁻¹ MW: 1650-2250cm ⁻¹
Spectral Resolution	LW: 0.8cm ⁻¹ MW: 1.6cm ⁻¹	LW: 0.8 cm ⁻¹ MW: 0.8 cm ⁻¹	LW: 0.625 cm ⁻¹ MW: 0.625 cm ⁻¹
Temporal Resolution	67min(5000*5000Km ²)	45min(5000*5000Km ²)	45min(5000*5000Km ²)
Spatial Resolution	16Km	12 Km	4-8 Km
NEDR (mW/m ² .sr.cm ⁻¹)	LW: 0.5 MW: 0.1	LW: 0.5 MW: 0.1	LW: 0.3 MW: 0.06
Calibration	Radiometric: 1.5K Spectral: 10ppm	Radiometric: 0.7 K Spectral: 10ppm	Radiometric: 0.5 K Spectral: 5 ppm

- Spectral region of LW band extends from 700cm⁻¹ to 680⁻¹ and 650cm⁻¹ gradually, the main purpose of which is to enhance the capabilities of temperature sounding as well as spectral calibration with the CO₂ absorption bands;
- Spatial resolution is also improved from 16km to 12km, and 4-8km in FY-4B/C respectively, to increase the utilization efficiency of GIIRS observations, particularly for the FOV contaminated by cloud targets.

Planned/future hyperspectral infrared sounding capabilities: GIIRS on FY-4B/C



FY-4A: 32x4@16km



FY-4B: 16x8@12km

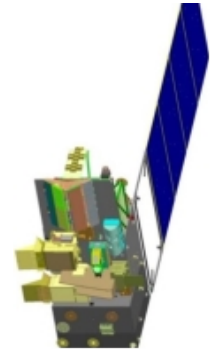
Planned/future hyperspectral infrared sounding capabilities: HIRAS on FY-3E/F/G

Band	Spectral Range (cm ⁻¹)	Spectral Resolution (cm ⁻¹)	Sensitivity (NEΔT@280K)		Num of Channels	
			FY-3D	FY-3E		
LWIR	650~1136 (15.38μm~8.8 μm)	0.625(DR) 0.625(FR)	0.15~0.4K	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	
MWIR1	1210~1750 (8.26μm~5.71 μm)	1.25(DR) 0.625(FR)	0.1~0.7K	1210~1538 cm ⁻¹	0.2K	433(DR) 869(FR)
				1538~1750 cm ⁻¹	0.3K	
MWIR2	2155~2550 (4.64μm~3.92 μm)	2.5(DR) 0.625(FR)	0.3~1.2K	2155~2300 cm ⁻¹	0.3	159(DR) 637(FR)
				2300~2550 cm ⁻¹	0.5	

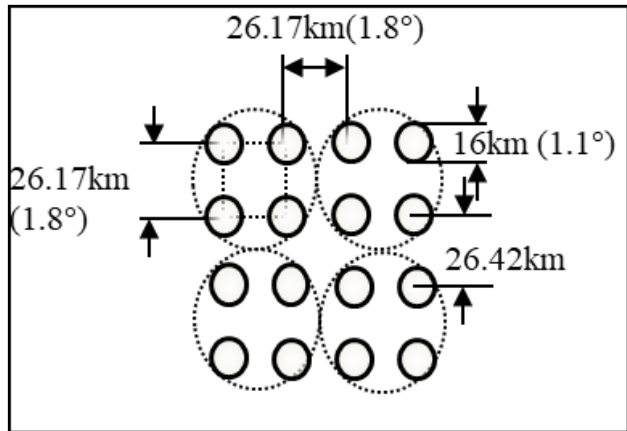
- The second HIRAS will fly on the FY-3E satellite in an early-morning orbit with a local time of around 6:00 A.M;
- the number of detectors from the current 4 to 9 per band.
- Plan to provide a full coverage of the spectral range from 650 to 2550 cm⁻¹ without any spectral gaps

Planned/future hyperspectral infrared sounding capabilities: HIRAS on FY-3E/F/G

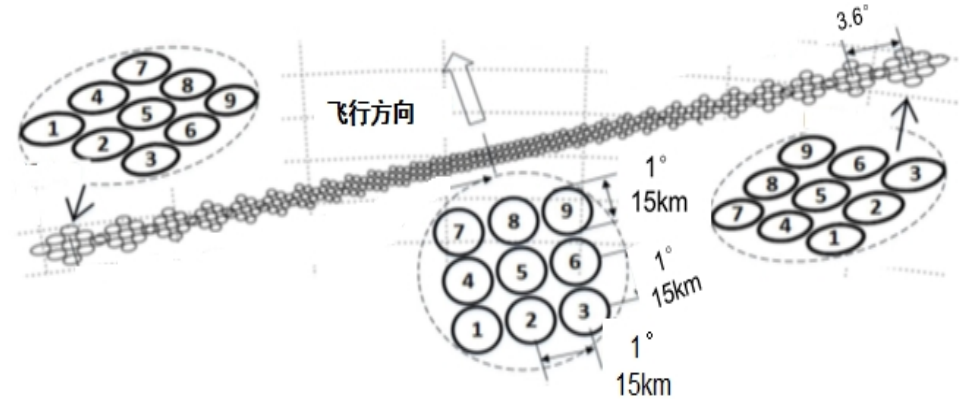
HIRAS Improvement from FY-3D to FY-3E Early Morning orbit



FY-3D

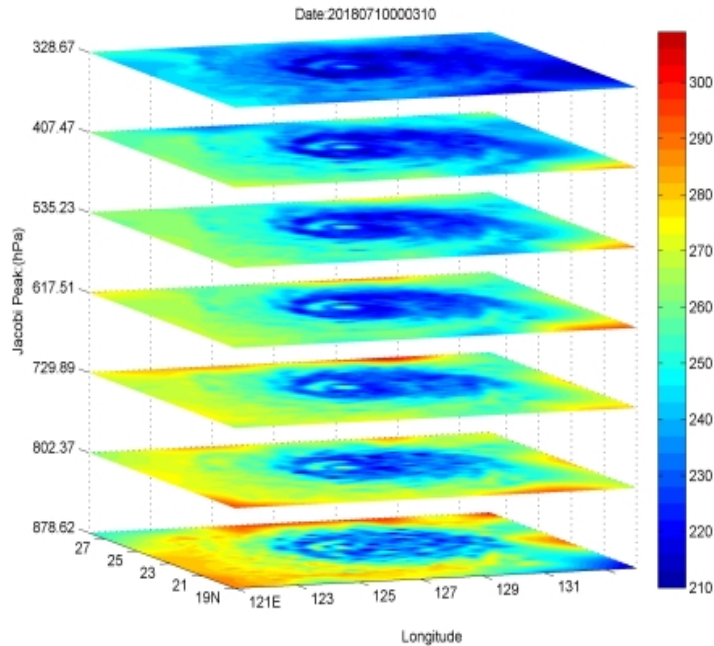


FY-3E



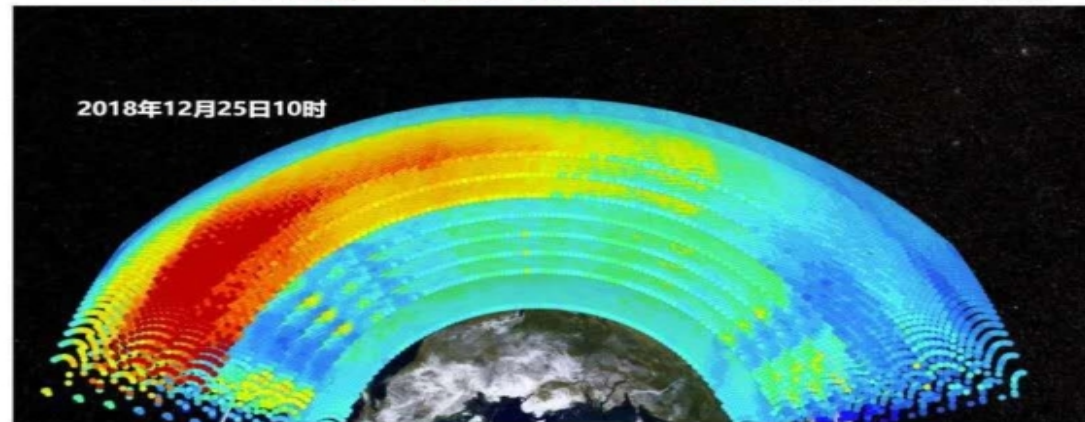
Hyperspectral infrared sounding application areas (NWP and beyond)

GIIRS L1 radiance has been operationally assimilating in GRAPES model since Dec. 2018



Brightness Temperature Animation of FY-4A/GIIRS within MW Spectral Region

风云四号卫星高光谱探测仪GIIRS，已于2018年12月25日正式在GRAPES全球4D-Var中业务化，GIIRS监测到北极区平流层的爆发性增温和对流层寒潮

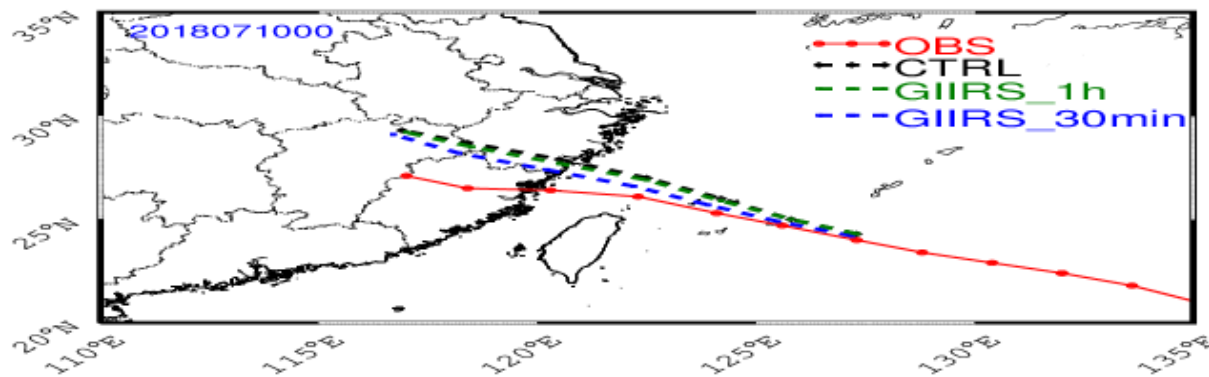
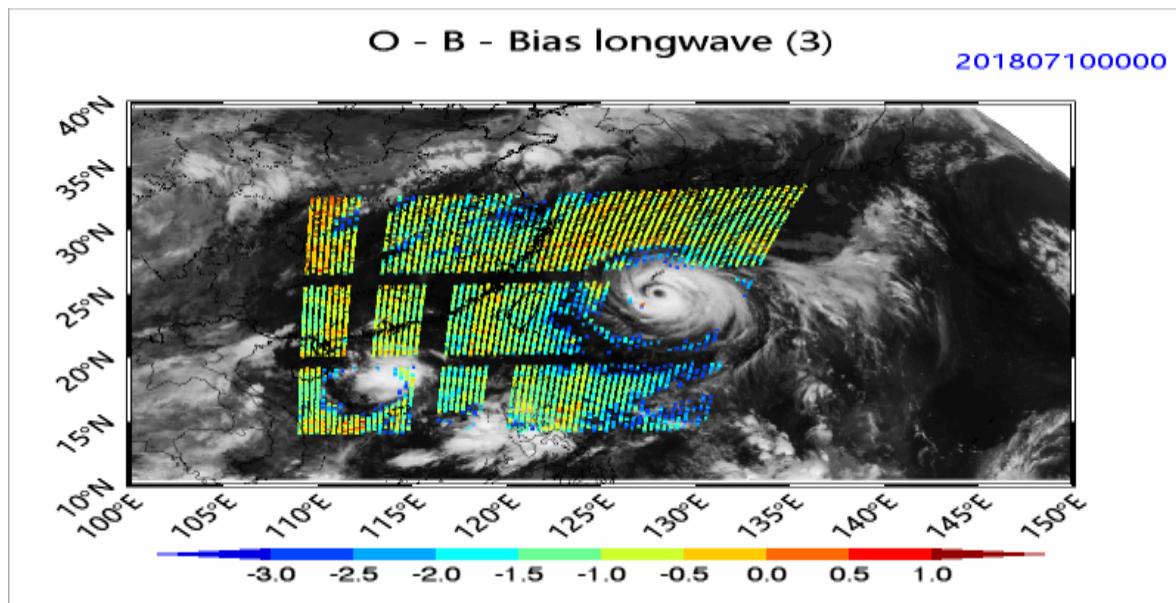


风云四号卫星高光谱探测仪GIIRS高时间分辨率三维温度探测信息的同化改进了寒潮预报

Stratospheric Sudden Warming in Arctic region Monitored by GIIRS in Dec.25, 2018

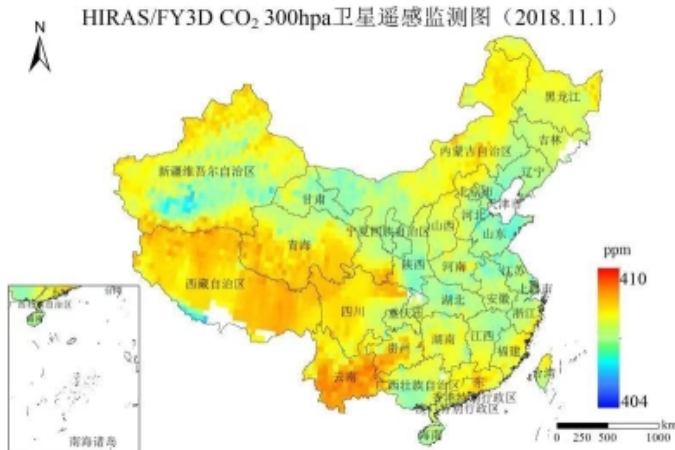
Hyperspectral infrared sounding application areas (NWP and beyond)

GIIRS NWP Application in GRAPES



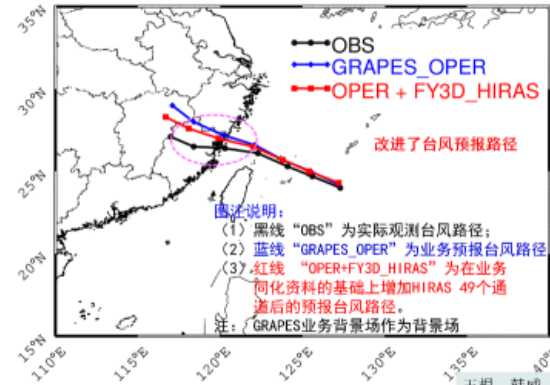
Hyperspectral infrared sounding application areas (NWP and beyond)

CO₂ retrieval

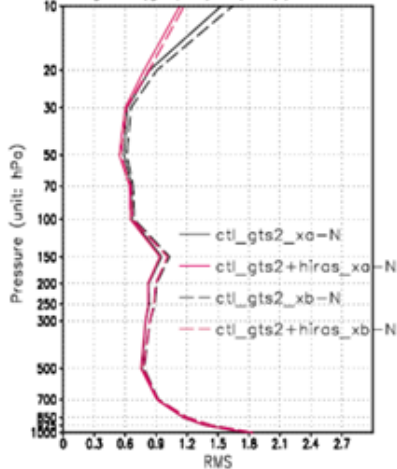


Typhoon prediction application

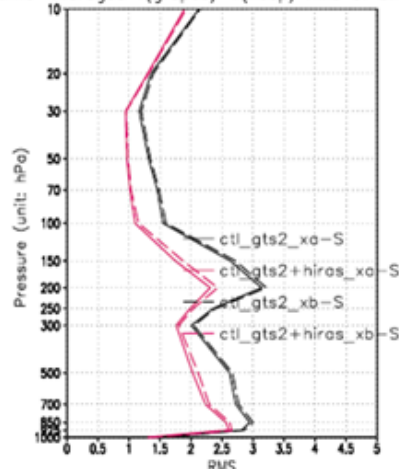
FY3D/HIRAS长波温度通道亮温在GRAPES-4DVar应用
2018071000UTC MARIA 以台风“玛莉亚”为例



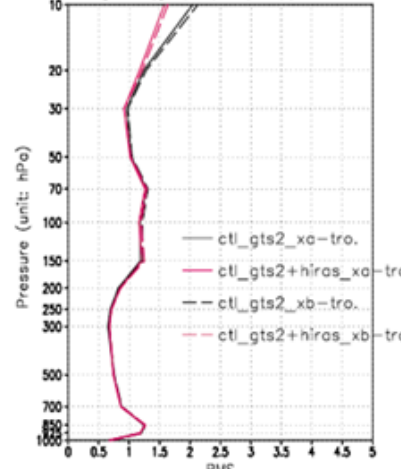
time-averaged T(grapes)-T(ncp) RMS of N.Hemis



time-averaged T(grapes)-T(ncp) RMS of S.Hemis



time-averaged T(grapes)-T(ncp) RMS of Tropics



CMA NWP center :
After assimilated HIRAS observation, It can control the error growth significantly and has a positive contribution to the global analysis quality

To be considered by CGMS/recommendations:

- FY-4A/GIIRS L1 radiance is generally accepted by NWP and T/H profile retrieval applications, where the spectral shifts (less than 5ppm for LW band and less than 10ppm for MW band) and radiometric accuracy (less than 1K for most channels) behave reasonable well;
- Furthermore, the main enhancement of FY-4B/C specifications are generally for the continuous increasing for NWP and retrieval uses;
- Quick scanning observations for the local convection monitoring are under developed with the more experimental & exploring cases.
- HIRAS completed the 2nd decontamination in Dec, 2019, where MW and SW bands FOV3 solar contamination was eliminated by adjustment of cold space viewing angle from -71° to -87° ;
- Calibration accuracy are general less than 0.3, 0.7 and 1.0 K in the LWIR, MWIR and SWIR bands, respectively. Mean and standard deviation(std) of the spectral bias relative to the line-by-line simulated spectra are within 5 ppm;
- HIRAS data has been in operational retrievals of atmospheric T and WV profiles and OLR products, been in test applications of NWP, atmospheric composition retrieval, and global stratospheric gravity wave research.