



Calibration and Quality Monitoring for Microwave Temperature Sounder (MWTs) onboard FengYun-3 satellite

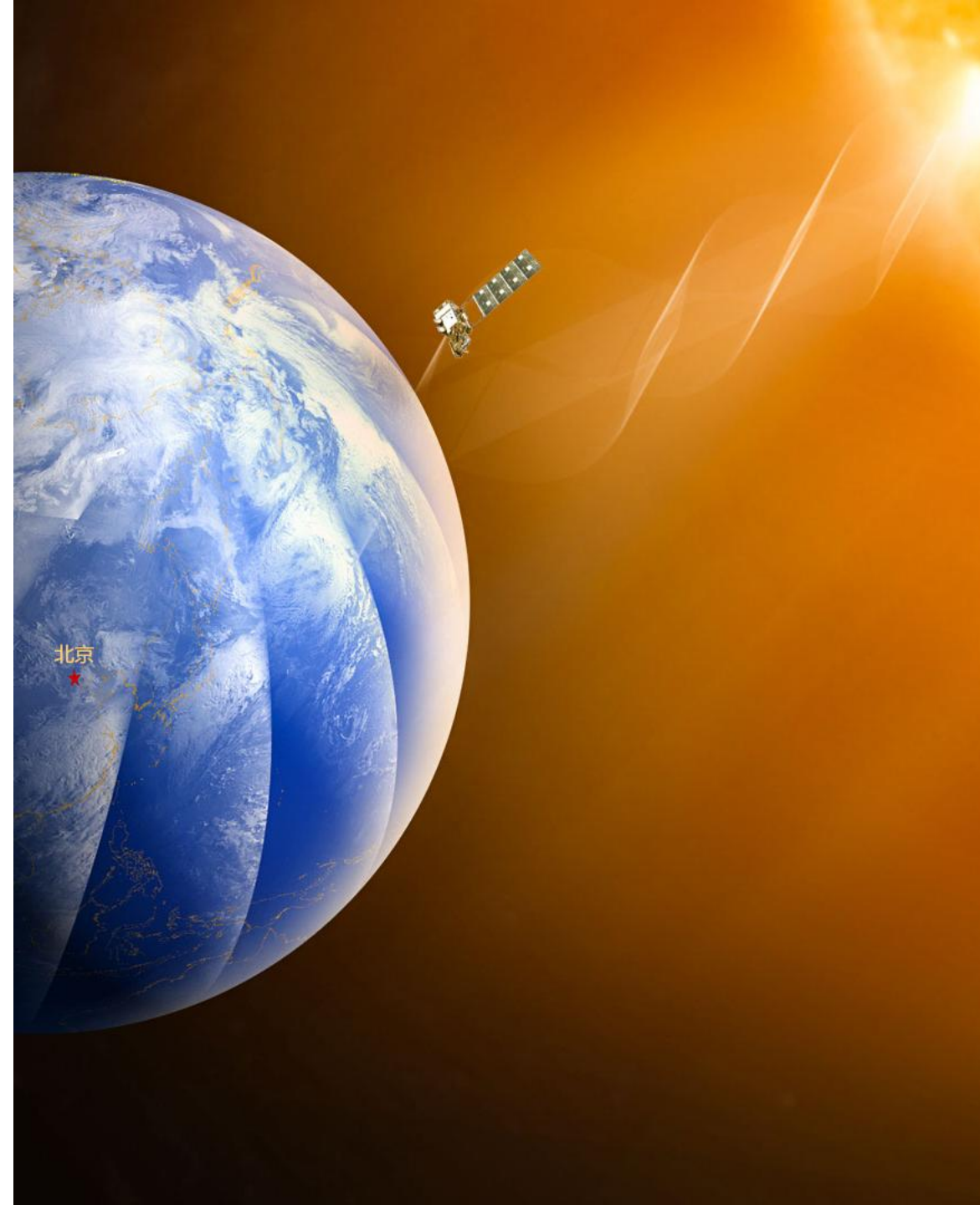
Hu Juyang

**Hu Xiuqing, Xu Na, Shang Jian, Wu Shengli, Gu Songyan,
Guo Yang, An Dawei**

**National Satellite Meteorological Center (National Center for Space
Weather), China Meteorological Administration**

2025.10.29

- ◆ 01 **Instrument Review**
- ◆ 02 Calibration technology
- ◆ 03 Quality Monitoring
- ◆ 04 Data Application
- ◆ 05 Summary and Future work





1. Instrument Review

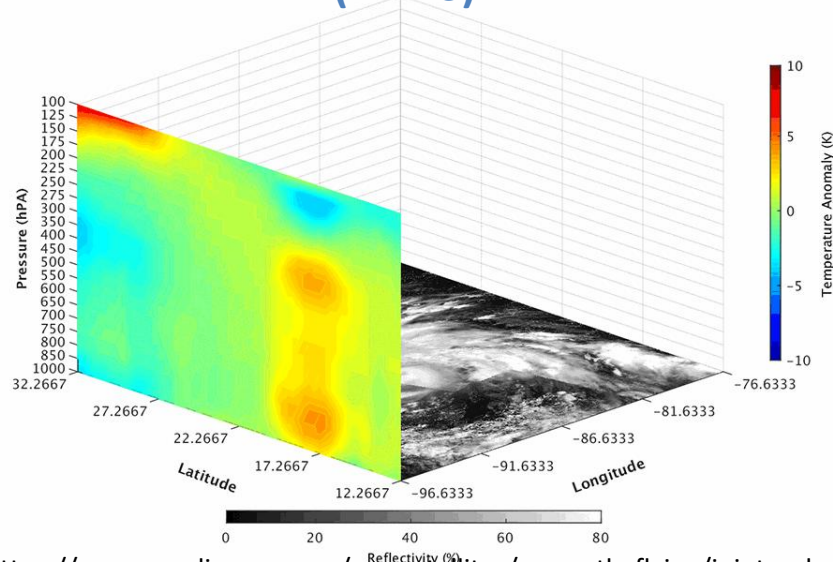
Microwave temperature sounders

- Microwave Radiometer: receive electromagnetic radiation in the 50-60 GHz microwave oxygen absorption spectrum
- Detect the nearly all-sky three-dimensional atmospheric temperature field.

3D Thermodynamic Structure of Typhoons

HELENE 25 September 2024

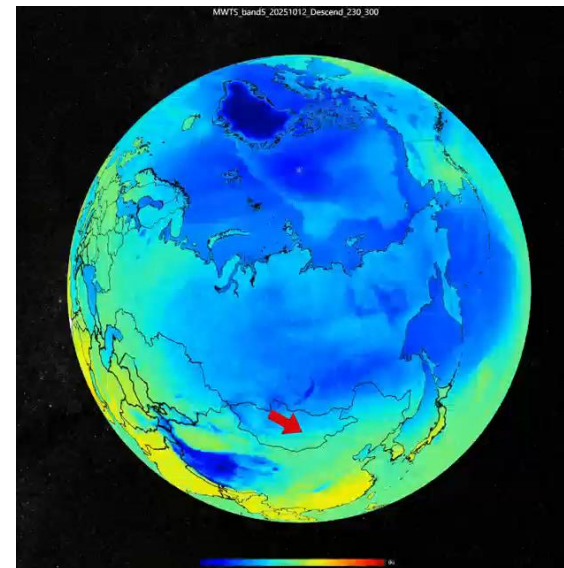
(ATMS)



<https://www.nesdis.noaa.gov/our-satellites/currently-flying/joint-polar-satellite-system/advanced-technology-microwave-sounder-atms>

Cold Wave Processes in the Northern Hemisphere

(FY-3H MWTS-III)



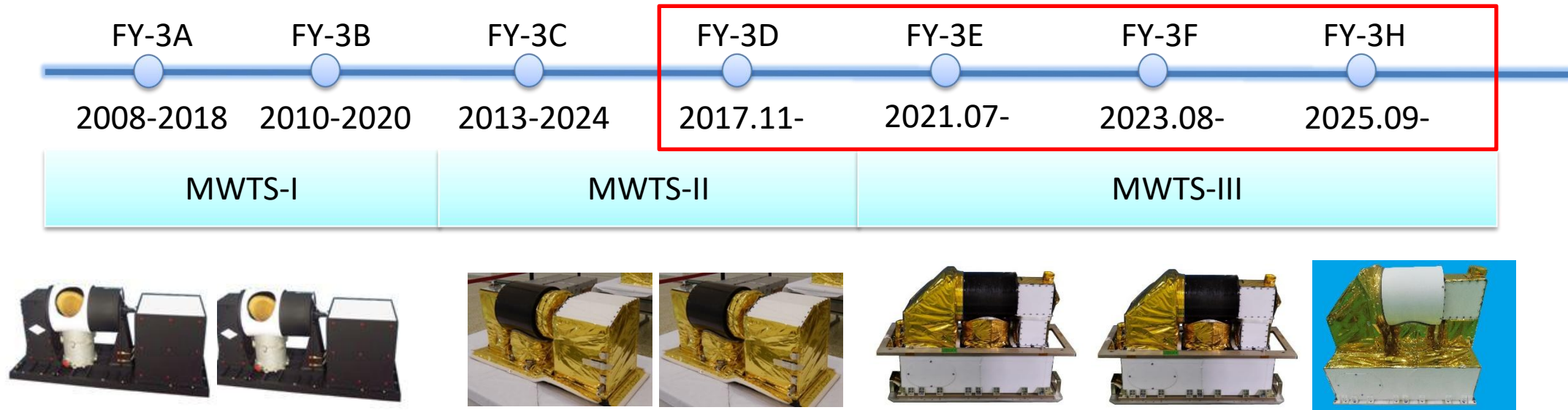


1. Instrument Review

MWTS: Microwave temperature sounders onboard FengYun -3

- MWTS was first carried on the FY-3A satellite launched in 2008.
- The newly launched FY-3H is equipped with the third-generation MWTS (MWTS-III).
- Seven instruments have been launched, with four currently operating in orbit.

in orbit





1. Instrument Review

Comparison of the core specifications across the three generations of MWTS

- a significant increase in the number of channels, along with comprehensive optimization of key performance metrics such as the scan period and integration time.
- These improvements have led to substantial gains in both detection efficiency and accuracy.

Item	MWTS-I	MWTS-II	MWTS-III
Viewing Angle	$\pm 48.3^\circ$	$\pm 49.5^\circ$	$\pm 53.35^\circ$
Samples per scan	15	90	98
Step Angle	6.9°	2.2°	1.1°
Nadir Resolution	50~75 km	33 km	33 km
Scan Period	16s	5245 ms	5236 ms
Integration Time	0.78s	16 ms	16 ms
Channels	4	13	17

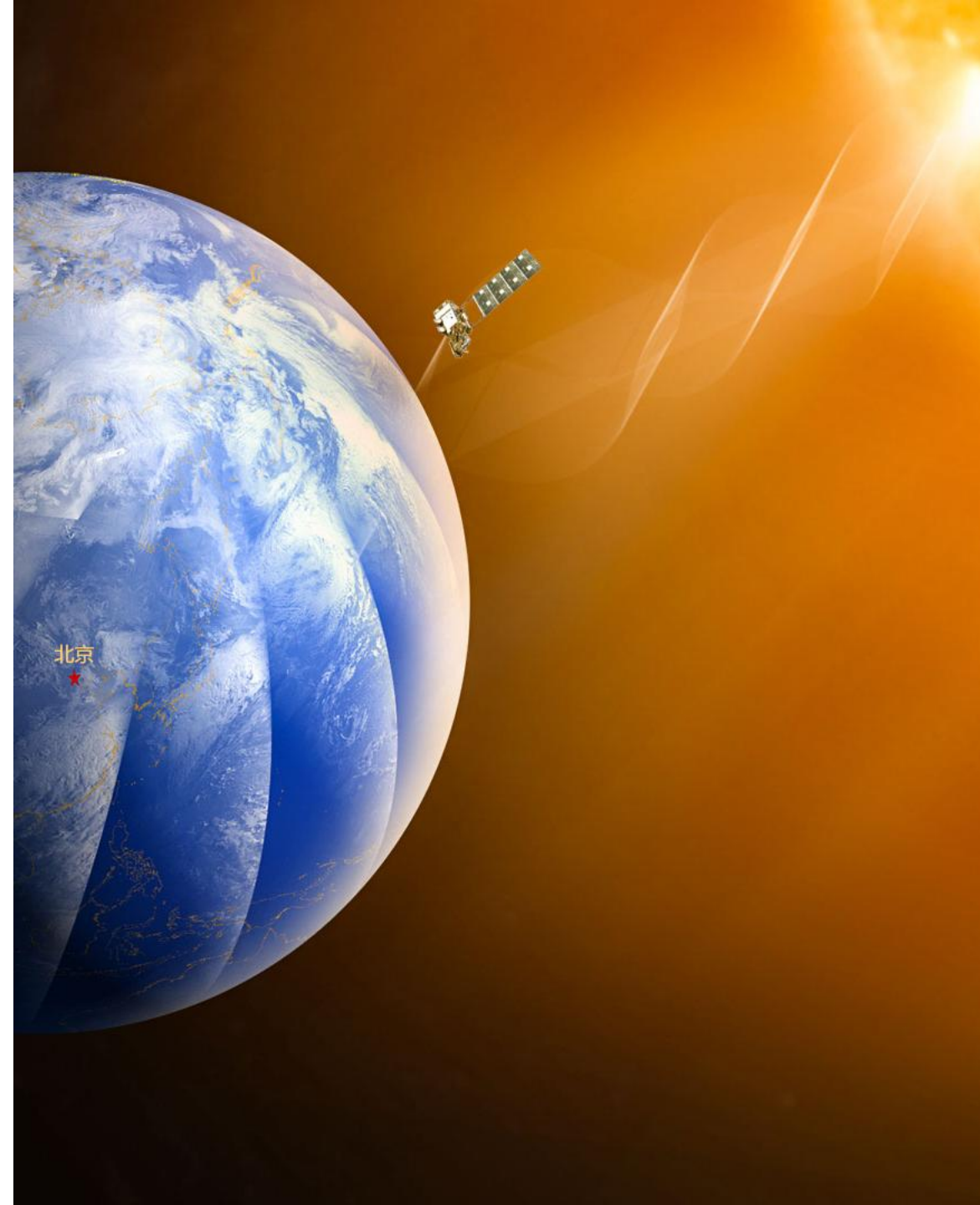
CH	Center frequency (GHz)	Band width (MHz)	NEDT (K)	FY-3D NEDT	ATMS	AMSU-A	Metop-SG-A1 MWS
1	23.8	270	0.3		1	1	1
2	31.4	180	0.35		2	2	2
3	50.3	180	0.35	1.2	3	3	3
4	51.76	400	0.3	0.75	4		
5	52.8	400	0.3	0.75	5	4	4
6	53.246±0.08	140	0.35				5
7	53.596±0.115	170	0.3	0.75	6	5	6
8	53.948±0.081	142	0.35				7
9	54.40	400	0.3	0.75	7	6	8
10	54.94	400	0.3	0.75	8	7	9
11	55.50	330	0.3	0.75	9	8	10
12	57.290344(fo)	330	0.6	0.75	10	9	11
13	fo±0.217	78	0.7	1.2	11	10	12
14	fo±0.3222±0.048	36	0.8	1.2	12	11	13
15	fo±0.3222±0.022	16	1.0	1.7	13	12	14
16	fo±0.3222±0.010	8	1.2	2.4	14	13	15
17	fo±0.3222±0.0045	3	2.1	3.6	15	14	16

Green: MWTS-I channels. Red: The channel addition from MWTS-II to MWTS-III.

- 01 Instrument Review
- 02 **Calibration technology**
- 03 Quality Monitoring
- 04 Data Application
- 05 Summary and Future work

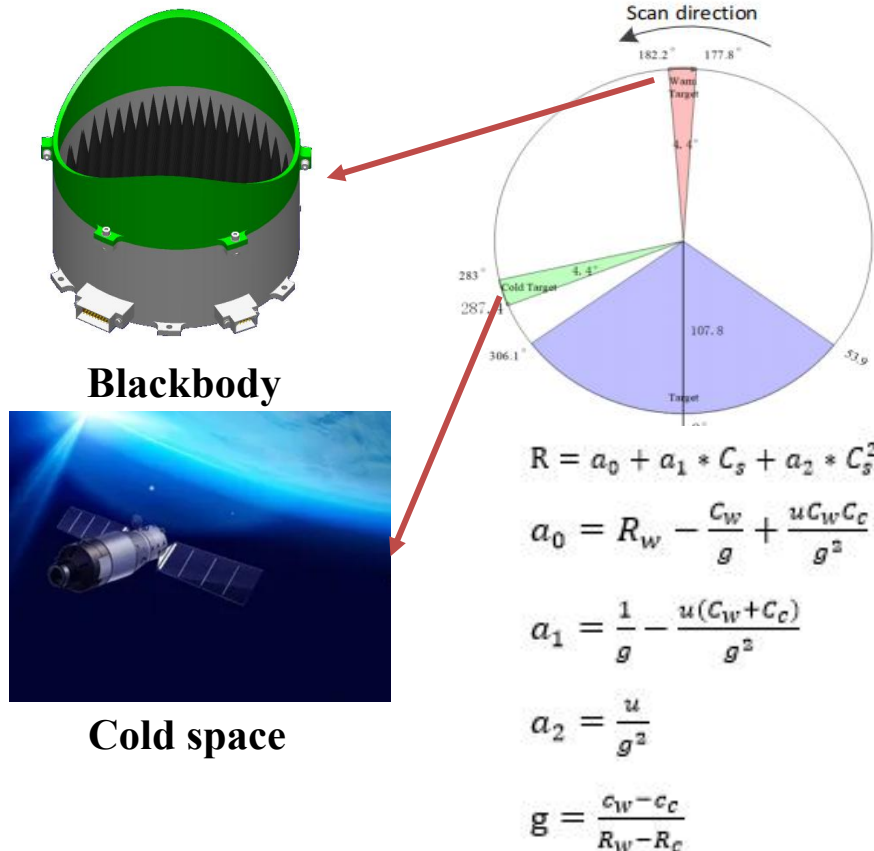
Calibration is the process of converting the output voltage value into a radiance value.

An effective calibration must incorporate the instrument's response characteristics into the conversion process.



In-orbit Calibration method

Periodic Two-Point Calibration



calibration processing

- ① Telemetry and Remote Sensing Data Quality Inspection
- ② Lunar Radiation Contamination Detection and Correction
- ③ Hot/cold calibration target view count data smooth
- ④ Hot/cold calibration target temperature calculation
- ⑤ Unlinear coefficients calculation
- ⑥ Two-point calibration coefficients calculation
- ⑦ Antenna brightness temperature calculation
- ⑧ Scene brightness temperature calculation (antenna correction)

Special processing

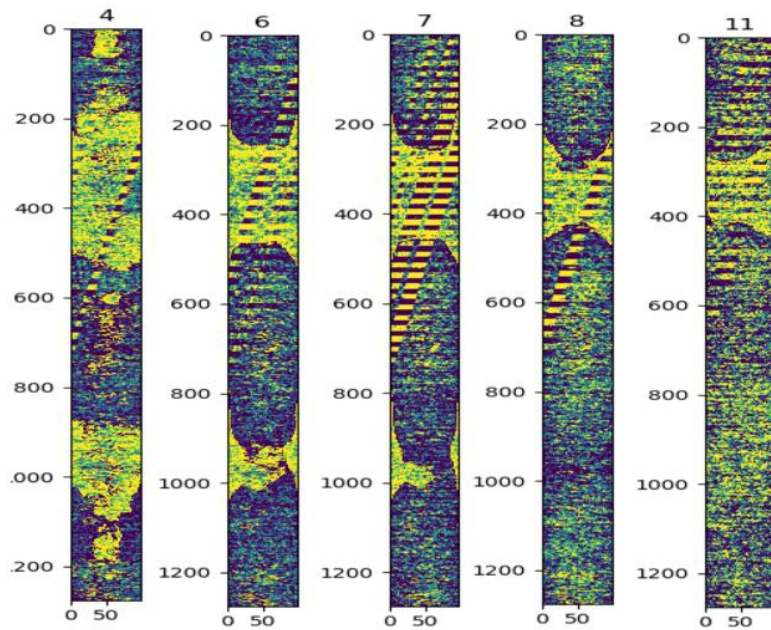
- Radar Interference Mitigation (FY-3E)
- Out-of-band Radiance correction (FY-3E) and Channel Crosstalk correction (FY-3F)

2. Calibration technology

Radar Interference Mitigation (FY-3E MWTS-III)

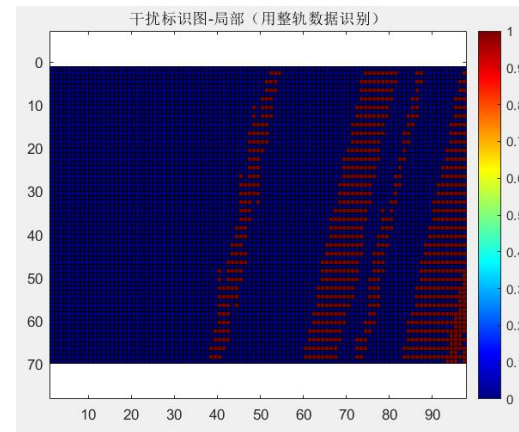
- Oblique stripes with a BT approximately 2-3 K higher than the others were identified in FY-3E MWTS-III channels 4, 6-8, and 11.
- The source of this interference: the radiation from the WindRAD instrument, which shares the same satellite platform.
- The effectiveness of this destriping algorithm is dependent on the number of available scan lines.

Interference Phenomenon



DN values after image enhancement

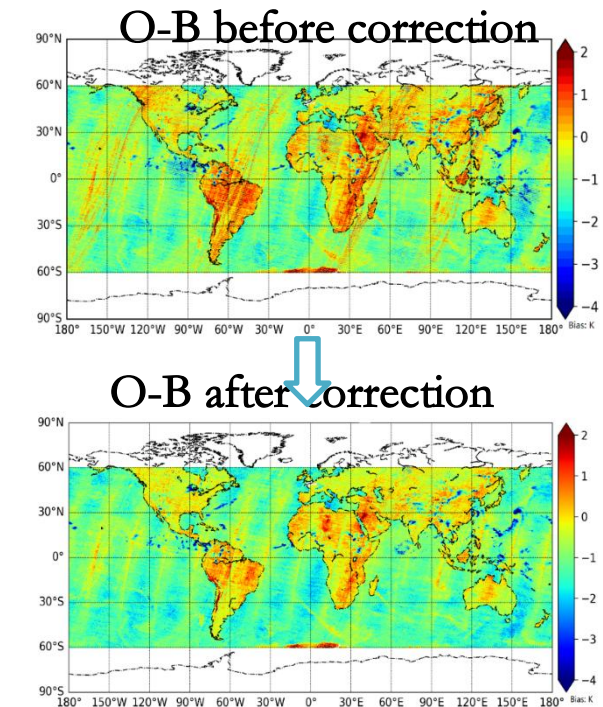
Interference identification



DN value correction

$$DN_i = (DN_{i-1} + DN_{i+1}) / 2$$

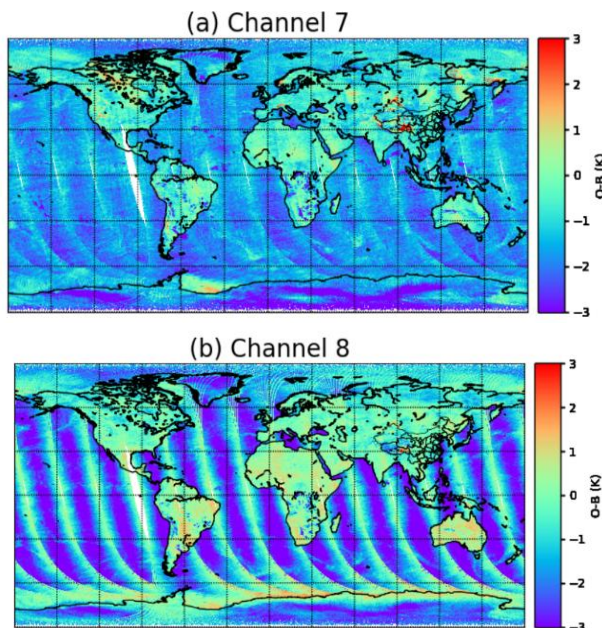
Mitigation performance



Out-of-band Radiance correction (FY-3E MWTS-III)

- Out-of-band radiance response causes a land-sea contrast in the sounding channels, which should not be present.
- A physically-based correction expression was developed, with its coefficients derived through a variational approach.
- The bias of channel 7 and 8 has been improved significantly. The land-sea contrast bias has been mitigated.
- The operational calibration program has been updated on December 8, 2022.

Before correction



Correction Expression Construction

$$BT_k = (1 - a_k) * BT_{in} + a_k * BT_{out} \quad k=7 \text{ or } 8$$

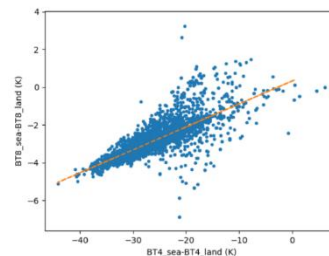
$$BT_{k_sea} = (1 - a_k) * BT_{in} + a_k * BT_{out_sea}$$

$$BT_{k_land} = (1 - a_k) * BT_{in} + a_k * BT_{out_land}$$

$$a_k = \frac{BT_{k_sea} - BT_{k_land}}{BT_{out_sea} - BT_{out_land}}$$

$$BT_{out_k} = x * BT_m \quad m=3 \text{ or } 4$$

Correction Coefficients Variational Calculation

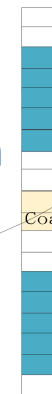


$$a_k = \frac{BT_{k_sea} - BT_{k_land}}{x * (BT_{m_sea} - BT_{m_land})}$$

$$b_k = x * a_k$$

$$b_k = \frac{BT_{k_sea} - BT_{k_land}}{BT_{m_sea} - BT_{m_land}}$$

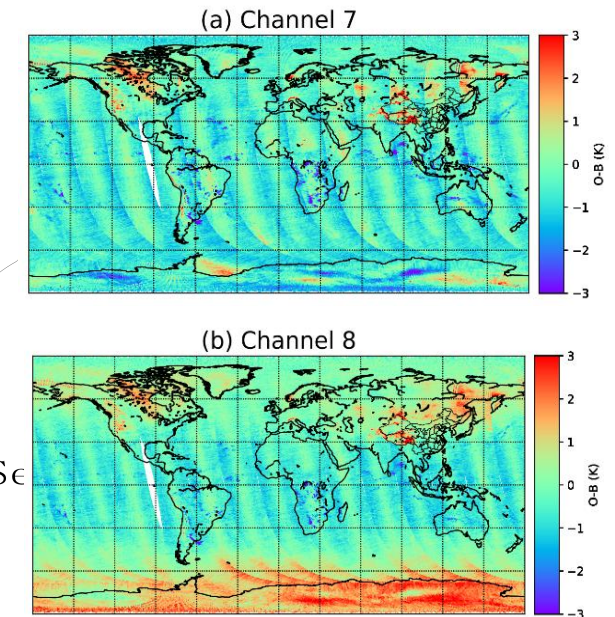
Land



Coastline

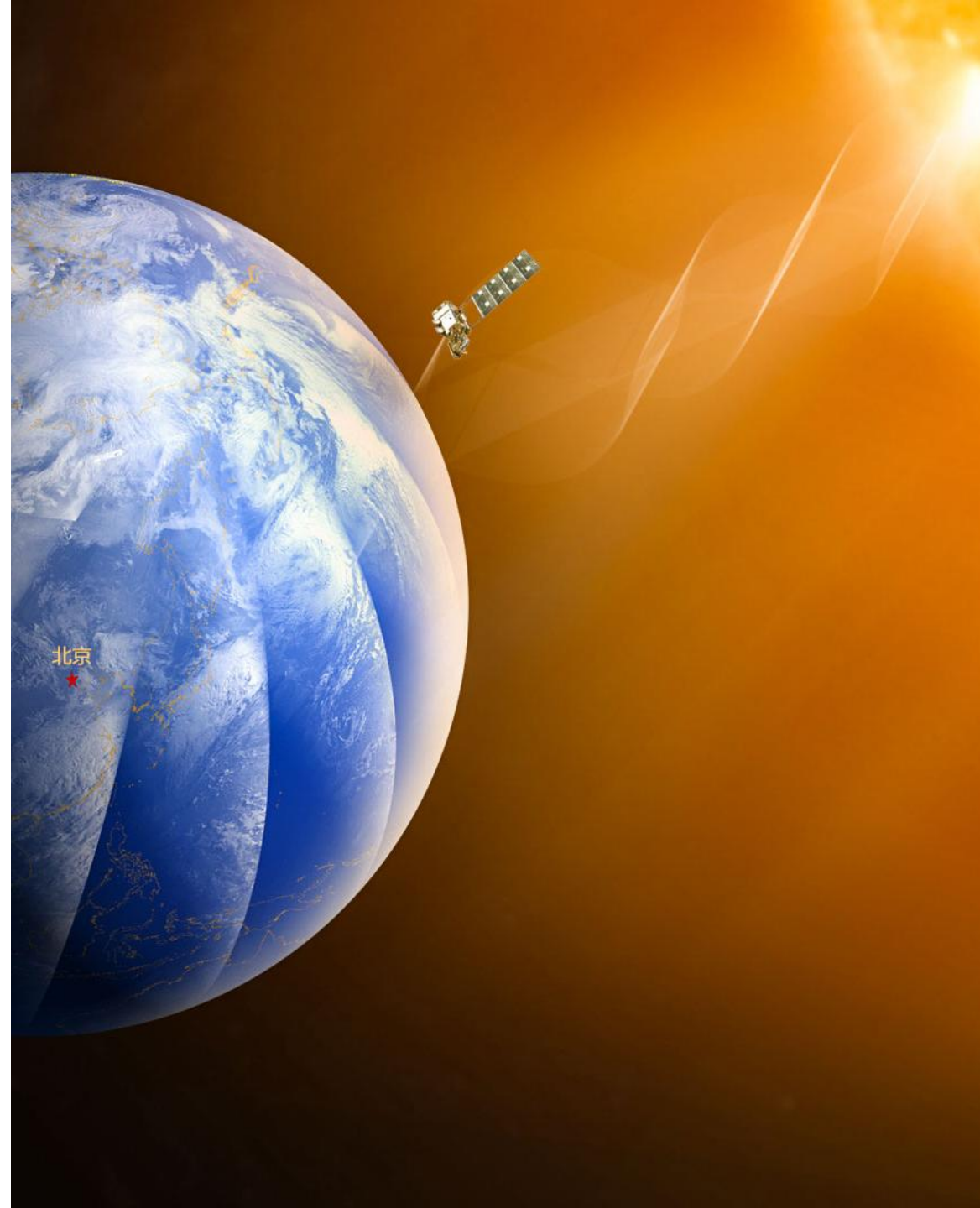
Sea

After correction



- 01 Instrument Review
- 02 Calibration technology
- 03 **Quality Monitoring**
- 04 Data Application
- 05 Summary and Future work

Good calibration is key to quality data, and maintaining it demands ongoing data monitoring.





3. Quality Monitoring

FengYun Satellite Instrument Status and L1 Data Quality Monitoring System

- Monitoring whether the instrument is operating normally in orbit, geolocation accuracy, and calibration accuracy.

Quality monitoring for MWTS-III



Telemetry Parameters

- Instrument temperatures
- Blackbody temperatures
- Scan angles
- Blackbody Count Number
- Coldspace Count Number
- Scan period
-



Instrument Status Parameters

- Calibration coefficients
- NEDT



Geolocation Accuracy

- Along track
- Cross track



Calibration Accuracy

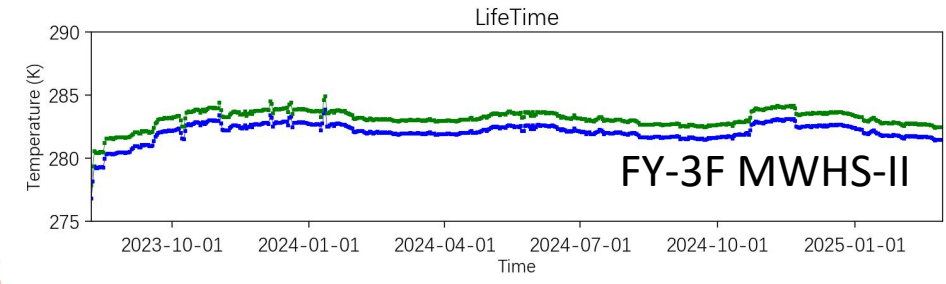
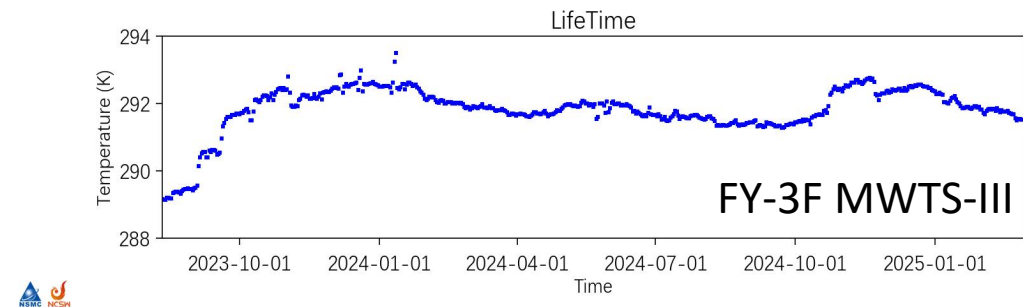
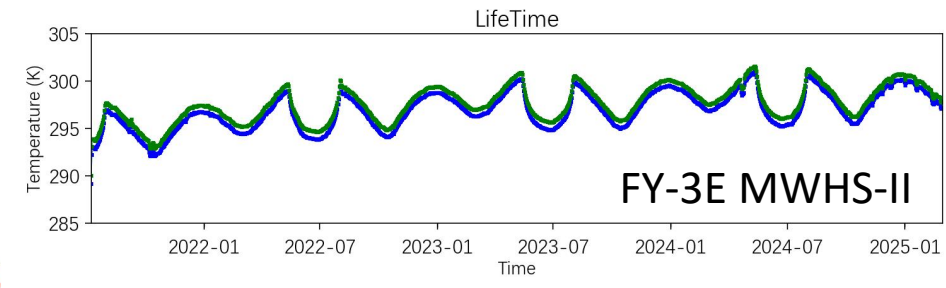
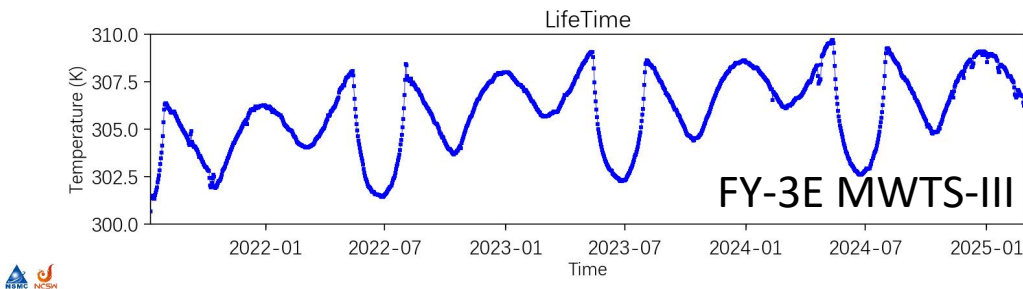
- Accuracy
- Stability



3. Quality Monitoring

Instrument Thermal Status

- The instrument temperature of the FY-3F (morning orbit) instruments are lower and more stable than those of FY-3E (early morning orbit) instrument.
- The temperature trends of MWTS and MWHS (Microwave Humidity Sounder) are similar.

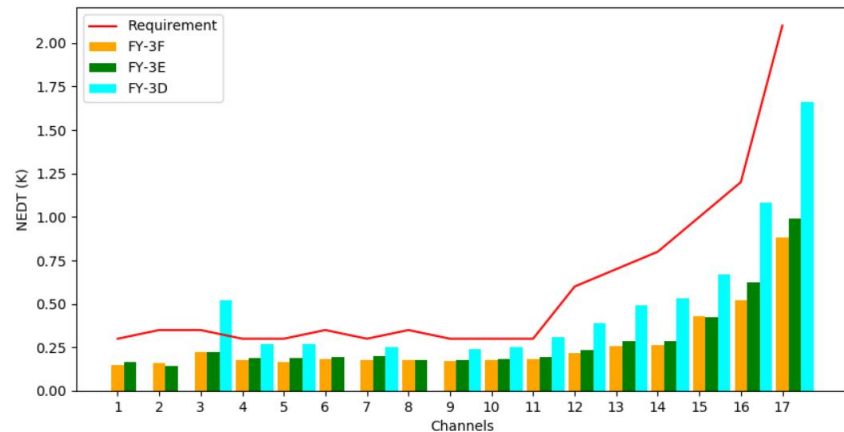




3. Quality Monitoring

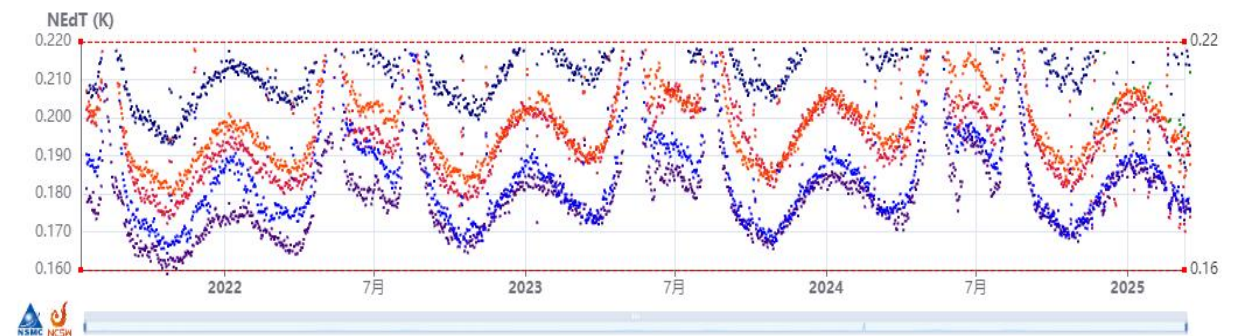
Instrument Noise Status

- NEDT (Noise Equivalent Differential Temperature) is a little better for FY-3F MWTS than FY-3E.
- NEDT varies with instrument temperature.



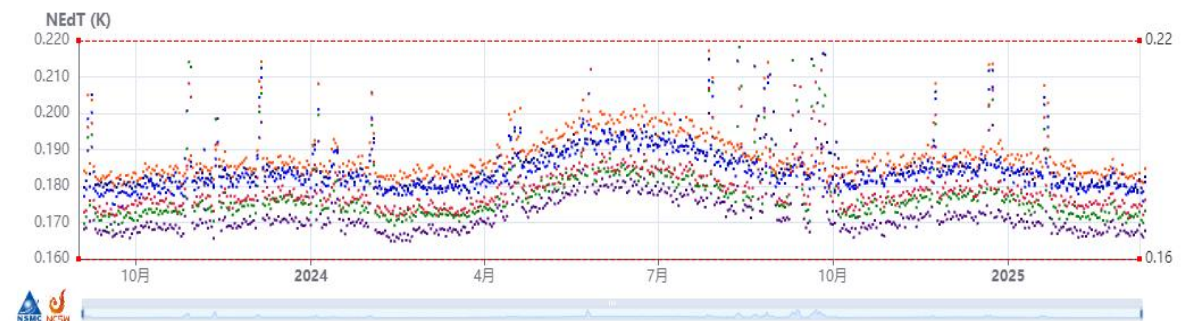
FY-3E MWTS (Ch 6-11)

FY3E_MWTS-III 其他参数-NEdT-NEdT
NEDT 2021-07-10-2025-03-11



FY-3F MWTS (Ch6-11)

FY3F_MWTS-III 其他参数-NEdT
NEDT 2023-09-01-2025-03-11



3. Quality Monitoring

Calibration Accuracy

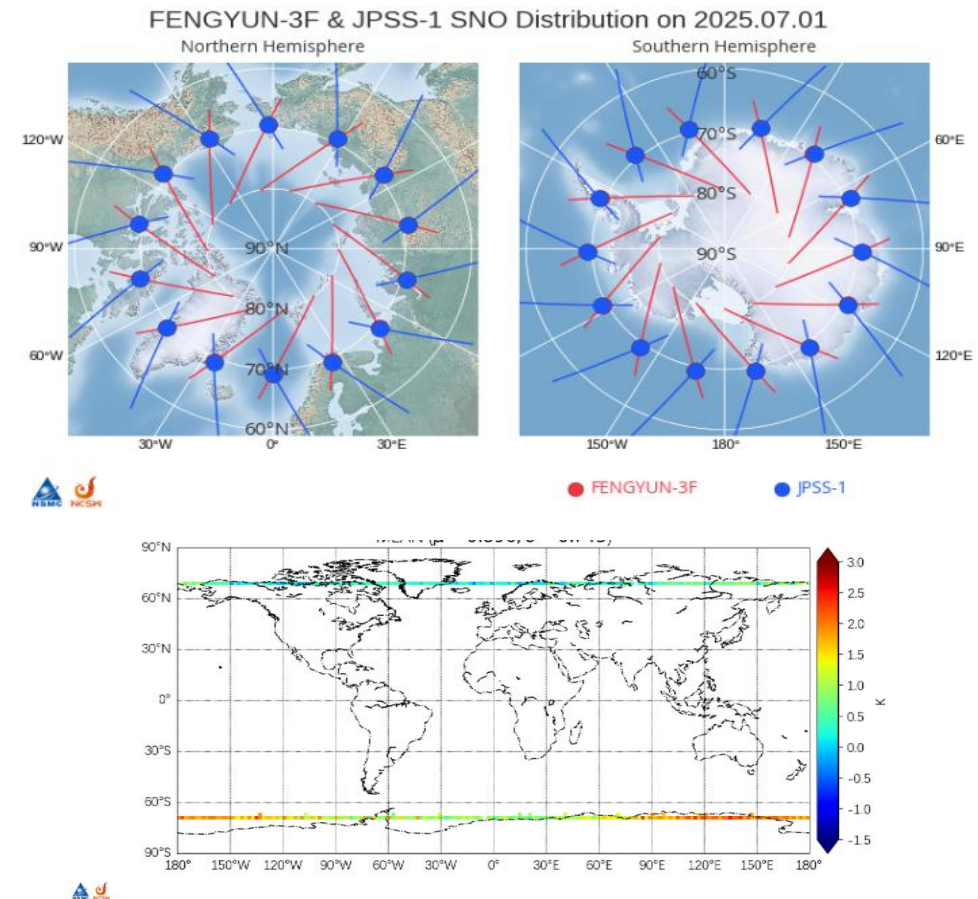
➤ SNO method

- compared with other microwave temperature sounding data
- Simultaneous Nadir Overpass (SNO) observations

MWTS vs Reference data:

- Observe time difference < 20min
- Distance < 15km
- Difference of satellite zenith angles < 5°
- Two nadir pixels for Ch 1-5

SNO pixels are all located in high-latitude regions



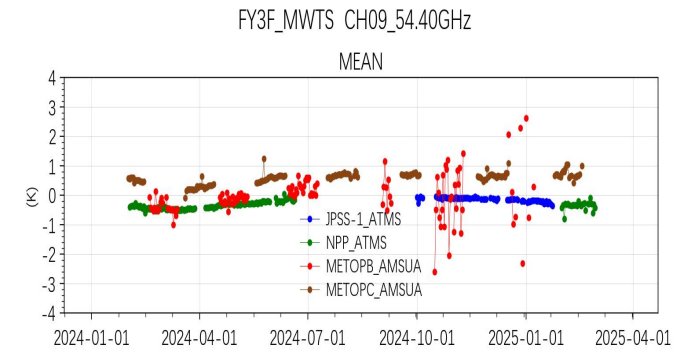
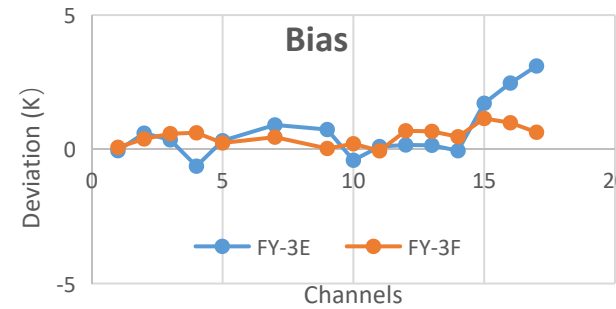
3. Quality Monitoring

Calibration Accuracy

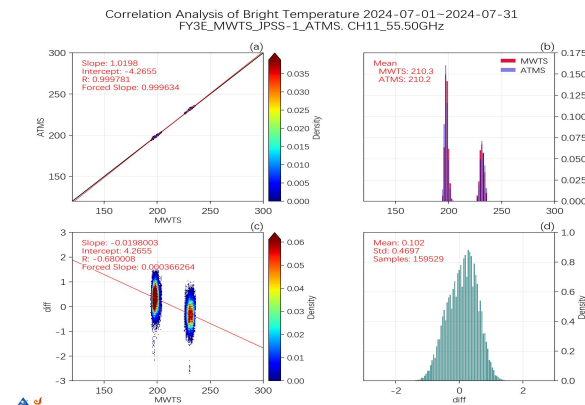
➤ SNO method result

- Because of the very different Spectral Response Function (SRF), **SRF adjustment** is needed in inter-satellite comparison for MWTS.
- Compared with JPSS-1 ATMS, the BT differences of most channels are **lower than 1K**.
- The BT difference shows seasonal fluctuations, related to **seasonal changes** in instrument temperature.

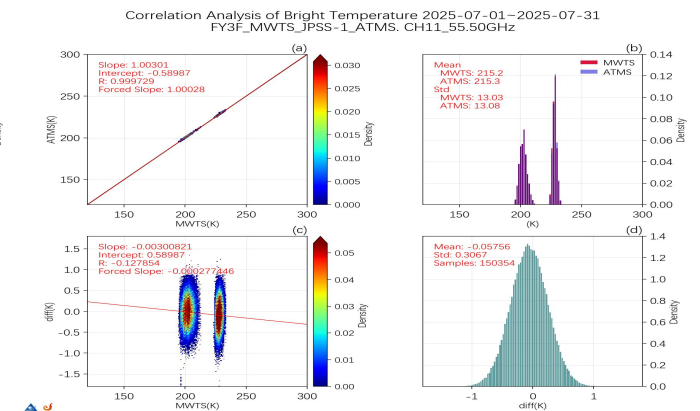
The SRF difference has been adjusted when using ATMS, but not in using AMSU-A.



FY-3E Ch11

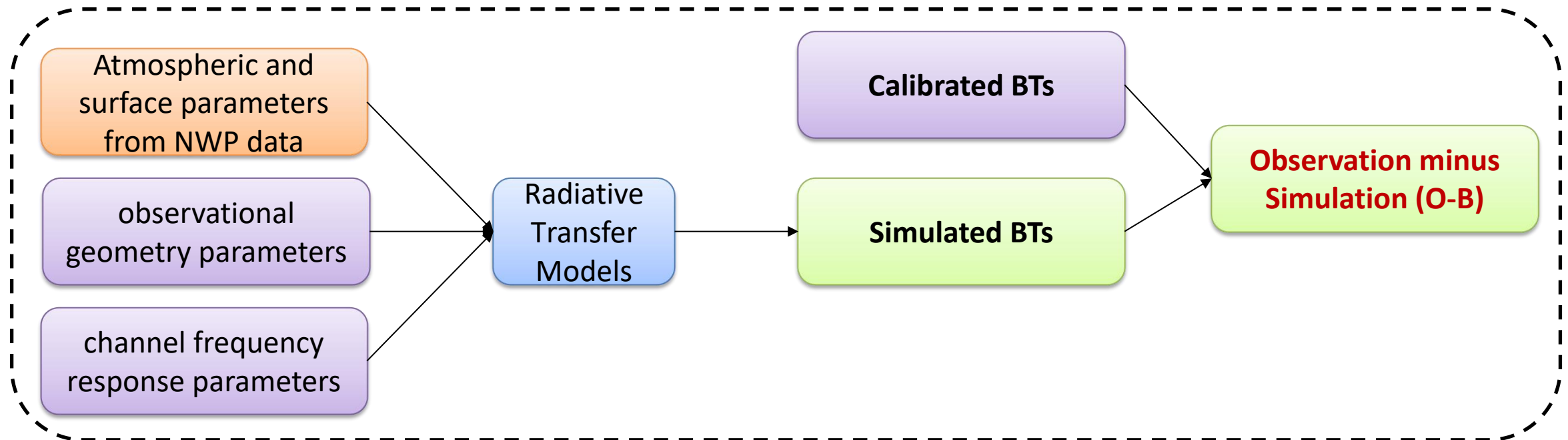


FY-3F Ch11



Calibration Stability

➤ O-B method (ERA5+RTTOV)

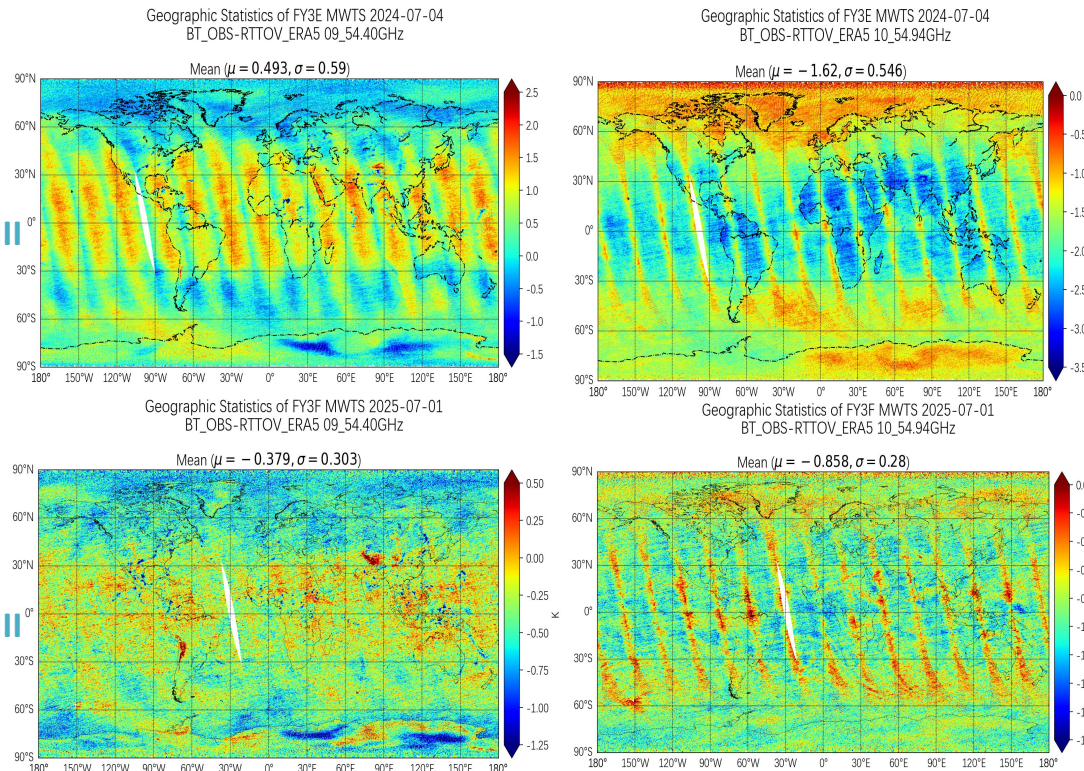




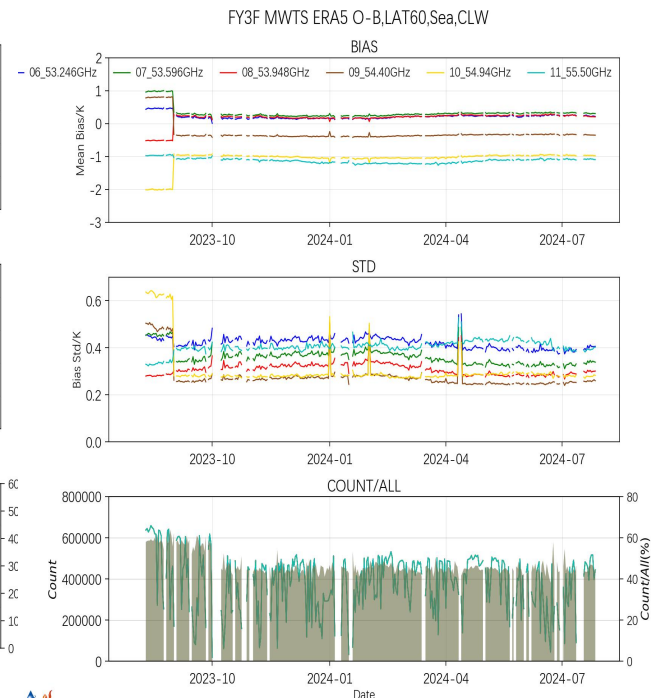
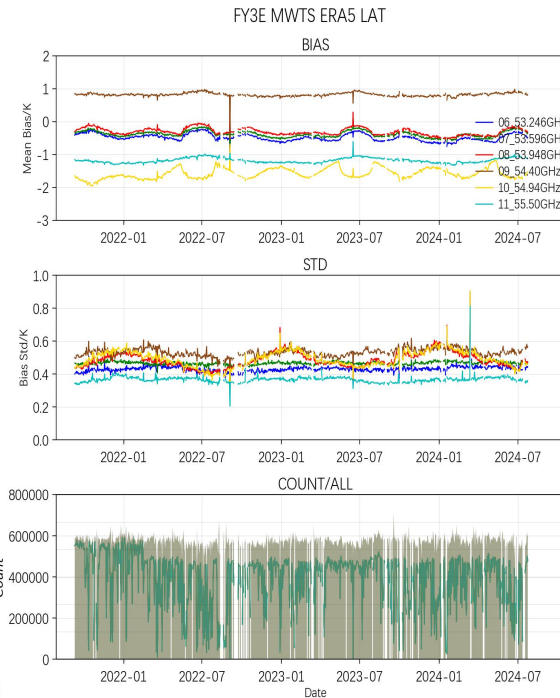
3. Quality Monitoring

- Due to improvements in instrument manufacturing, the calibration of FY-3F MWTS-III is significantly better than that of FY-3E in terms of cross-track stability and the differences between sea and land pixels.
- Due to a more stable orbital thermal environment, the FY-3F MWTS-III also exhibits better calibration temporal stability.

FY-3E
MWTS-III



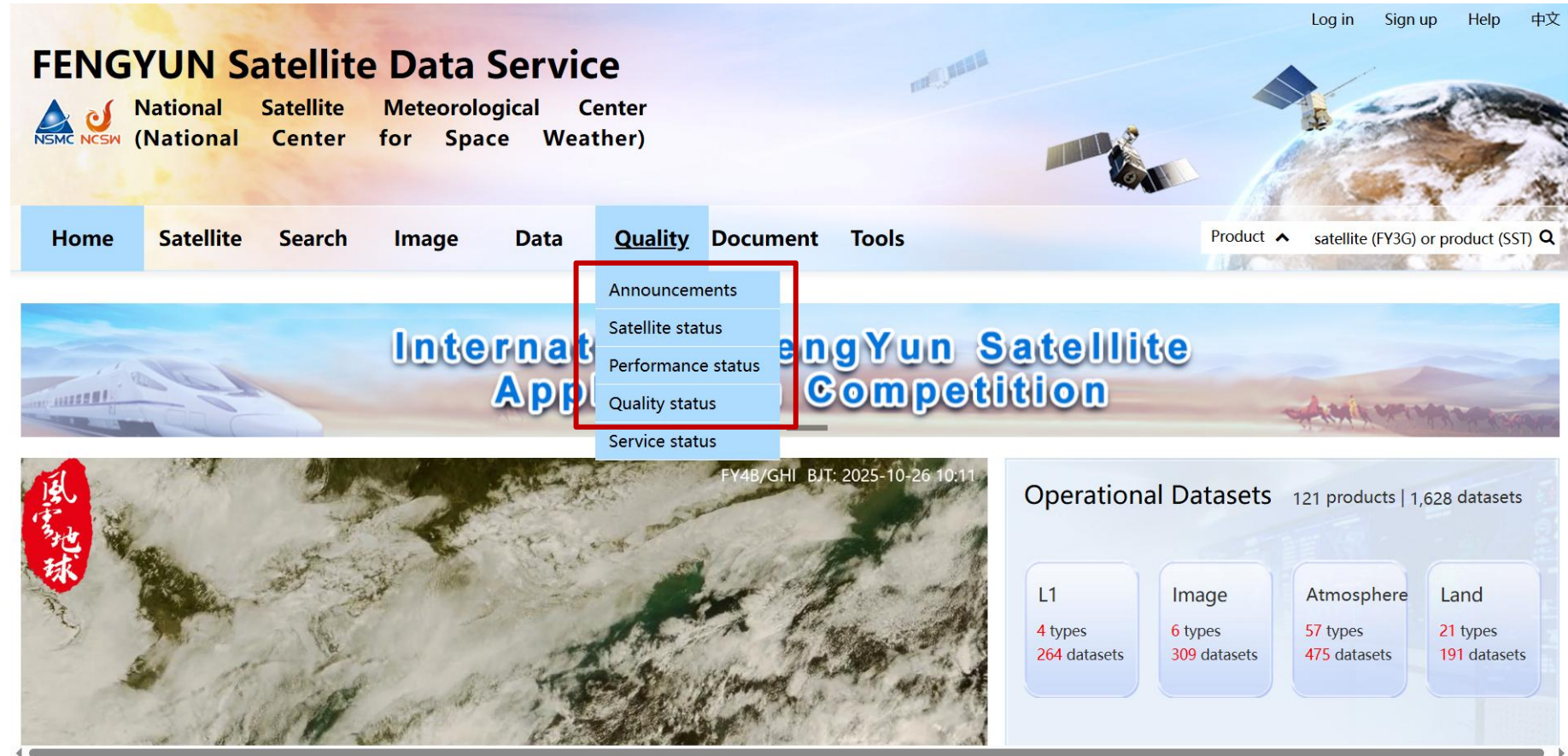
FY-3F
MWTS-III





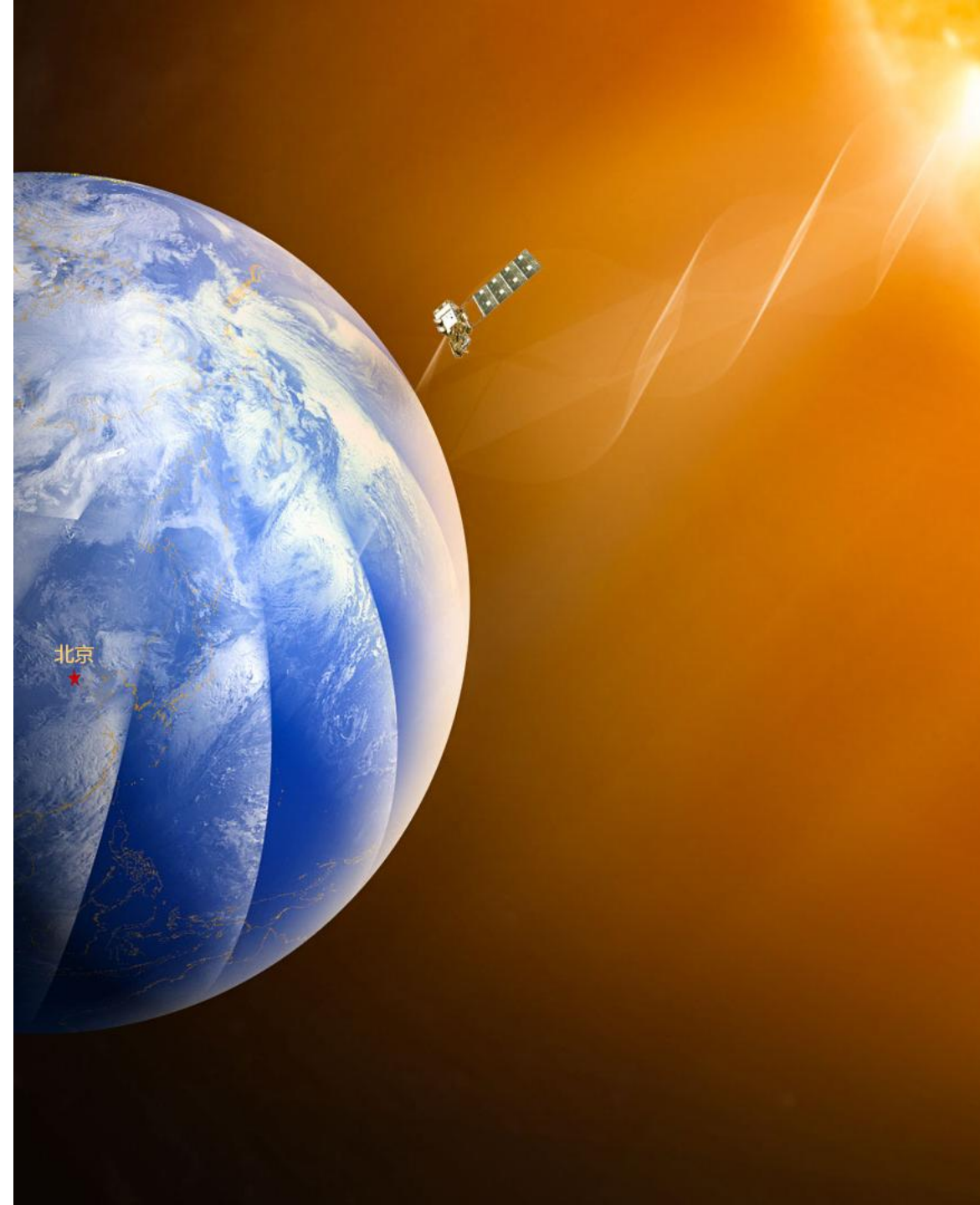
3. Quality Monitoring

Quality information publishing website



<https://satellite.nsmc.org.cn/DataPortal/en/home/index.html>

- 01 Instrument Review
- 02 Calibration technology
- 03 Quality Monitoring
- 04 **Data Application**
- 05 Summary and Future work



MWTS-III data has been widely used in the following two fields:

Numerical Weather Prediction Model Assimilation

Geophysical Parameter Inversion

Cloud Liquid Water Content

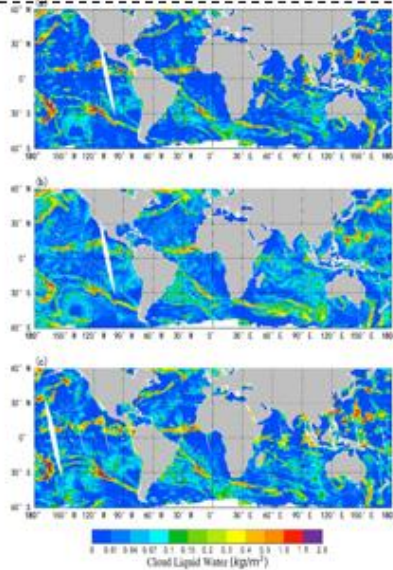


Figure 12. CLW retrieved from MWTS-III and ATMS over global oceans on 1 August 2021. (a,c) The cloud liquid water path retrieved from MWTS-III and ATMS using the physical algorithm; (b) CLW from ERA5 reanalysis at the time of MWTS-III.

(Dong C et al. ,2022)

Precipitable Water Vapor

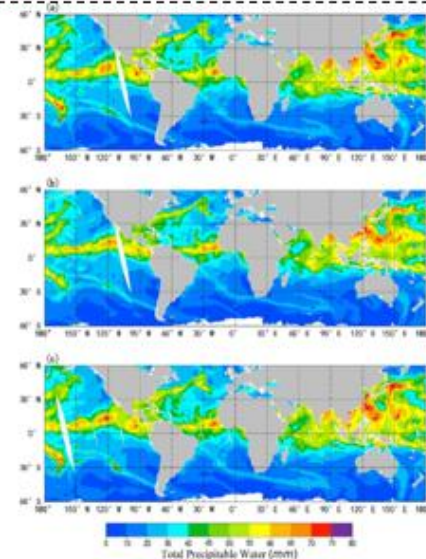
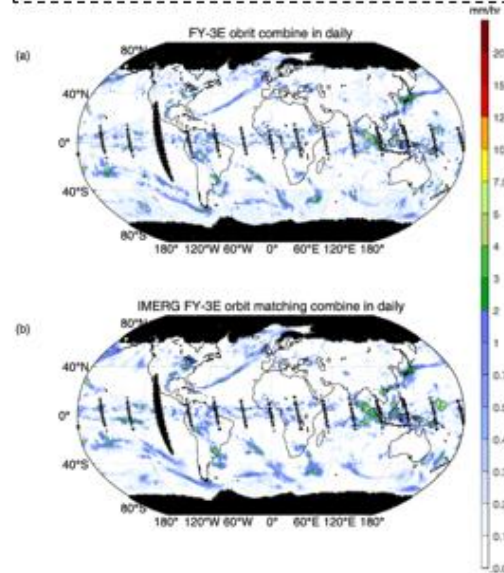


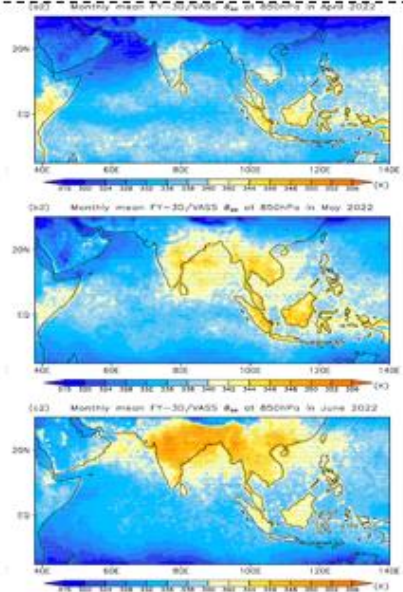
Figure 13. TPW retrieved from MWTS-III and ATMS over global oceans on 1 August 2021. (a,c) The cloud liquid water path retrieved from MWTS-III and ATMS using the physical algorithm; (b) TPW from ERA5 reanalysis at the time of MWTS-III.

Rainfall Rate, Snowfall Rate



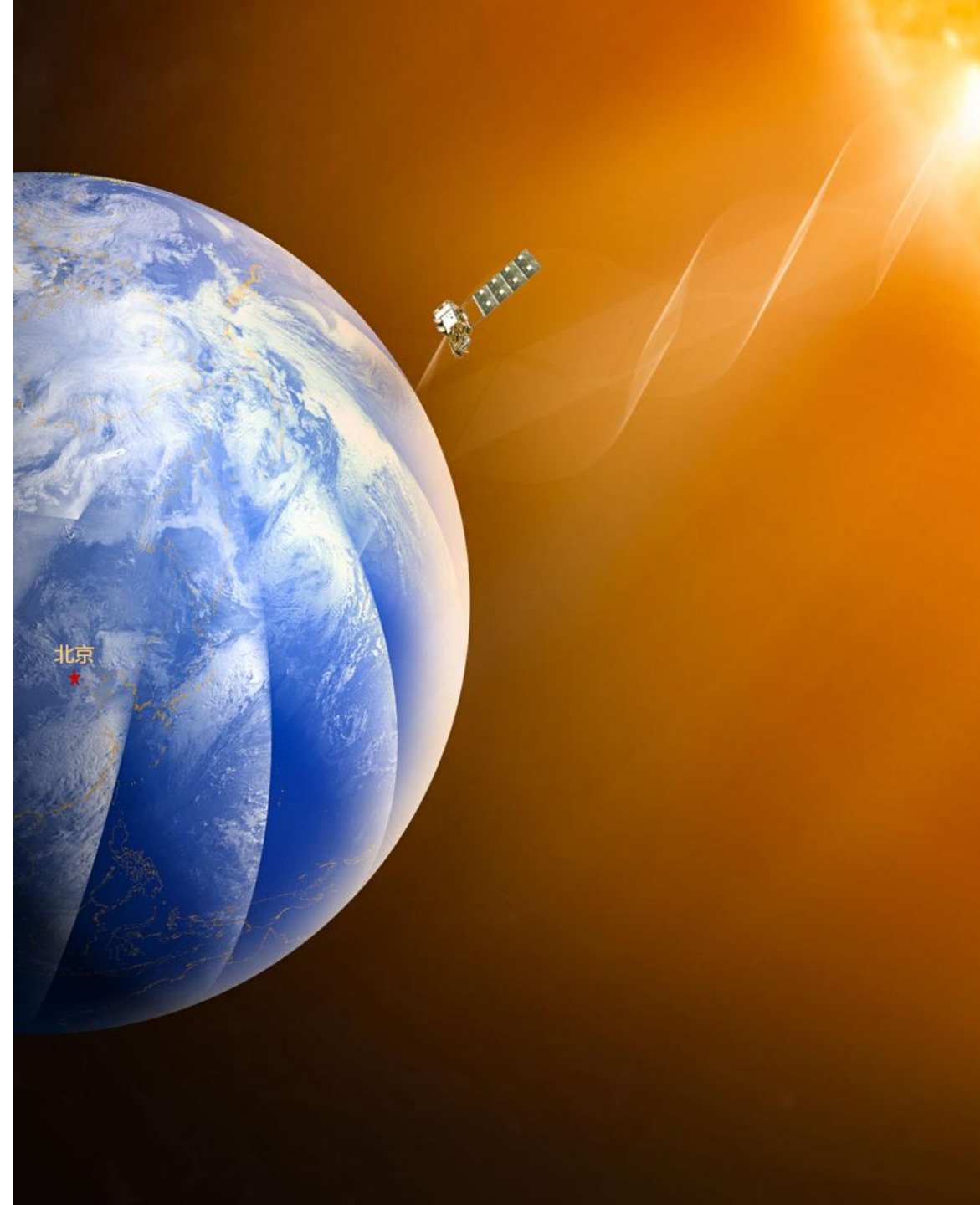
(Zhao, R. et al., 2024)

Equivalent Potential Temperature



(Ren, S. et al., 2023)

- 01 Instrument Review
- 02 Calibration technology
- 03 Quality Monitoring
- 04 Data Application
- 05 **Summary and Future work**





5. Summary and Future work

Summary

- The adaptive calibration algorithm specifically for MWTS can effectively address its unique instrumental characteristics.
- The accuracy and stability of MWTS are evaluated using a combined approach of Simultaneous Nadir Overpass (SNO) and Observation-minus-Background (O-B) analysis.
- Operating in an early-morning orbit, the FY-3E MWTS-III is well-positioned for collaborative observation with similar payloads on other satellites. This enables a coordinated observation network, achieving more comprehensive global coverage.
- The instrument quality of the FY-3F MWTS-III is significantly superior to that of FY-3E.

Future work

- Developing the FY-3H MWTS-III Calibration Algorithm
- Enhancing FY-3E/3F MWTS-III Calibration Accuracy and Stability
- Establishing a Multi-Satellite Consistent Calibration Algorithm



Welcome Suggestions!

Hu Juyang
huji@cma.gov.cn



Quality information publishing

- Announcements

<https://www.nsmc.org.cn/nsmc/en/news/index.html>

nsmc.org.cn/nsmc/en/news/index.html

Welcome to NSMC!

中文 | Русский | عربي

National Satellite Meteorological Center
(National Center for Space Weather)

Home | News | Belt & Road | About NSMC | Satellite Program | Operation | Imagery and Product | Data | Support | Application

Home / Operation / Announcements

Operational Information

- Announcements
- Outline of GEO System
- Outline of LEO System
- GEO Image Browse
- LEO Image Browse
- Calibration and Validation
- Data Transmission
- Direct Broadcast
- CMACast

Announcements

5 records ▾

Search

[A Notification on FY-4B's Intensified Observation](#)
2025-10-20

On user requirement for service, FY-4B will have an intensified observation every 1 minutes over Haikou, from 16:00 October 20 to 16:00 October 22, 2025(UTC).

[A Notification on FY 4B's Orbital Control](#)
2025-10-11

The Xi'an Satellite Control Center will exercise an west-east orbital control to FY- 4B from 8:16 to 8:44 October 14, 2025(UTC). During the period, ground receiving stations shall cease to receive the cloud imageries sent by FY- 4B from 8:16 to 8:44(UTC). Under a normal circumstance, the imageries' positioning accuracy will see some bias within 24 hours after the orbital control. Please forgive the inconvenience caused.

[A Notification on FY 4B's Orbital Control](#)
2025-09-26

The Xi'an Satellite Control Center will exercise an west-east orbital control to FY- 4B from 8:16 to 8:44 September 29, 2025(UTC). During the period, ground receiving stations shall cease to receive the cloud imageries sent by FY- 4B from 8:16 to 8:44(UTC). Under a normal circumstance, the imageries' positioning accuracy will see some bias within 24 hours after the orbital control. Please forgive the inconvenience caused.

- Satellite Status

<https://www.nsmc.org.cn/nsmc/en/operation/status.html>

nsmc.org.cn/nsmc/en/operation/status.html

Welcome to NSMC/ 中文

National Satellite Meteorological Center
(National Center for Space Weather)

Home News Belt & Road About NSMC Satellite Program Operation Imagery and Product Data Support Application

Home / Satellite / Operational Status

FengYun Satellite

Instruments

Satellite Status

Operational Status ▾

FY In-Orbit Status

FY GEO Status

FY LEO Status

Satellite Parameter ▲

Operational Orbit

FY In-Orbit Satellite Operational Status

Updated: 2025-10-26 16:12:33 (Local)

Type	Satellite	Status	Position/ECT
Geo	FY-2G	Operational	99.5°E (before 2015-06-01), 105°E (2015-06-01 to 2018-04-09), 99.2°E (after 2018-04-16)
	FY-2H	Operational	79°E
	FY-4A	Operational	104.7°E (before 2024-03-05), 86.5°E (from 2024-05-01 to 2025-01-21), 123.5°E (after 2025-02-18)
	FY-4B	Operational	133°E (before 2024-02-01), 105°E (after 2024-03-05)
Leo	FY-3D	Operational	14:00 asc
	FY-3E	Operational	05:30 desc
	FY-3G	Operational	Inclining orbit
	FY-3F	Operational	10:15 desc
	FY-3H	In-orbit testing	14:00 asc

FY-3F Operational Status

Description

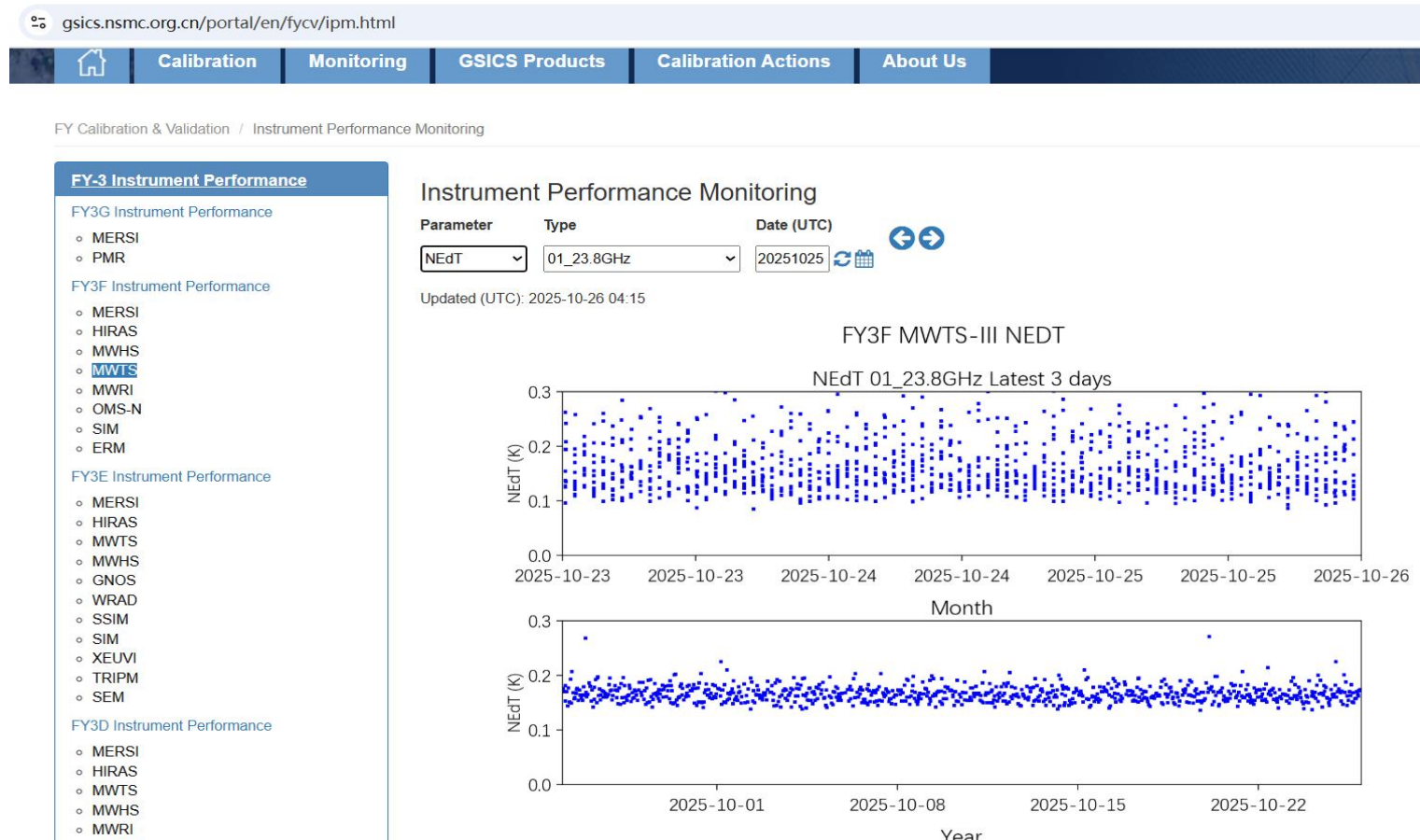
Acronym	FY-3F
Full Name	FengYun 3F
Altitude	836 km
ECT	10:00~10:20 desc
Launch Date	2023-08-03

Instrument Status

Acronym	Full Name	Status	Monitoring
MERSI-III	Medium Resolution Spectral Imager-III	Operational	OBC
HIRAS-II	Hyperspectral Infrared Atmospheric Sounder-II	Operational	OBC
MWTS-II	Micro-Wave Temperature Sounder-II	Operational	OBC
MWHS-II	Micro-Wave Humidity Sounder-II	Operational	OBC
MWRI-II	Micro-Wave Radiation Imager-II	Operational	OBC
GNOS-II	GNSS Radio Occultation Sounder-II	Operational	
OMS-L	Ozone Monitoring Suite -Limb	Operational	
OMS-N	Ozone Monitoring Suite -Nadir	Operational	OBC
ERM-II	Earth Radiation Measurement-II	Operational	OBC
SIM-II	Solar Irradiance Monitor-II	Operational	OBC

- Performance Status

<https://gsics.nsmc.org.cn/portal/en/fycv/ipm.html>





- Quality Status




National Satellite Meteorological Center
(National Center for Space Weather)

[Home](#)
[Satellite](#)
[Search](#)
[Image](#)
[Data](#)
[Quality](#)
[Document](#)
[Tools](#)

Product ▲
satellite (FY3G) or product (SST) Q

[Home](#) / [Data Quality](#) / [L1 Quality Report](#)

Quality Status Announcements

Satellite Status

Performance Status

Quality Status

L1 Quality Status ▼

L1 Quality Report

L2L3 Quality Status ▲

Data Service Status

L1 Quality Report

Show
25
entries

Search:

File Name	Date
FY-3F Payload and L1 Product Quality Monthly Report - 2025/09	2025-10-06
FY-3G Payload and L1 Product Quality Monthly Report - 2025/09	2025-10-05
FY-3E Payload and L1 Product Quality Monthly Report - 2025/09	2025-10-03
FY-3F Payload and L1 Product Quality Monthly Report - 2025/08	2025-09-06
FY-3G Payload and L1 Product Quality Monthly Report - 2025/08	2025-09-05

22



- Other Documents




National Satellite Meteorological Center
(National Center for Space Weather)

Home

Satellite

Search

Image

Data

Quality

Document

Tools

Product

satellite (FY3G) or product (SST)

Q

Home / Data Quality / L1 Quality Report

Quality Status Announcements

Satellite Status

Performance Status

Quality Status

L1 Quality Status

L1 Quality Report

L2L3 Quality Status

Data Service Status

Show 25 entries

File Name

Date

FY-3F Payload and L1 Product Quality Monthly Report - 2025/09

2025-10-06

FY-3G Payload and L1 Product Quality Monthly Report - 2025/09

2025-10-05

FY-3E Payload and L1 Product Quality Monthly Report - 2025/09

2025-10-03

FY-3F Payload and L1 Product Quality Monthly Report - 2025/08

2025-09-06

FY-3G Payload and L1 Product Quality Monthly Report - 2025/08

2025-09-05

FY-3E Payload and L1 Product Quality Monthly Report - 2025/08

2025-09-03