FY-3E/WindRAD instrument status and calibration accuracy evaluation

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NSMC, CMA

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PART 01

WindRAD introduction
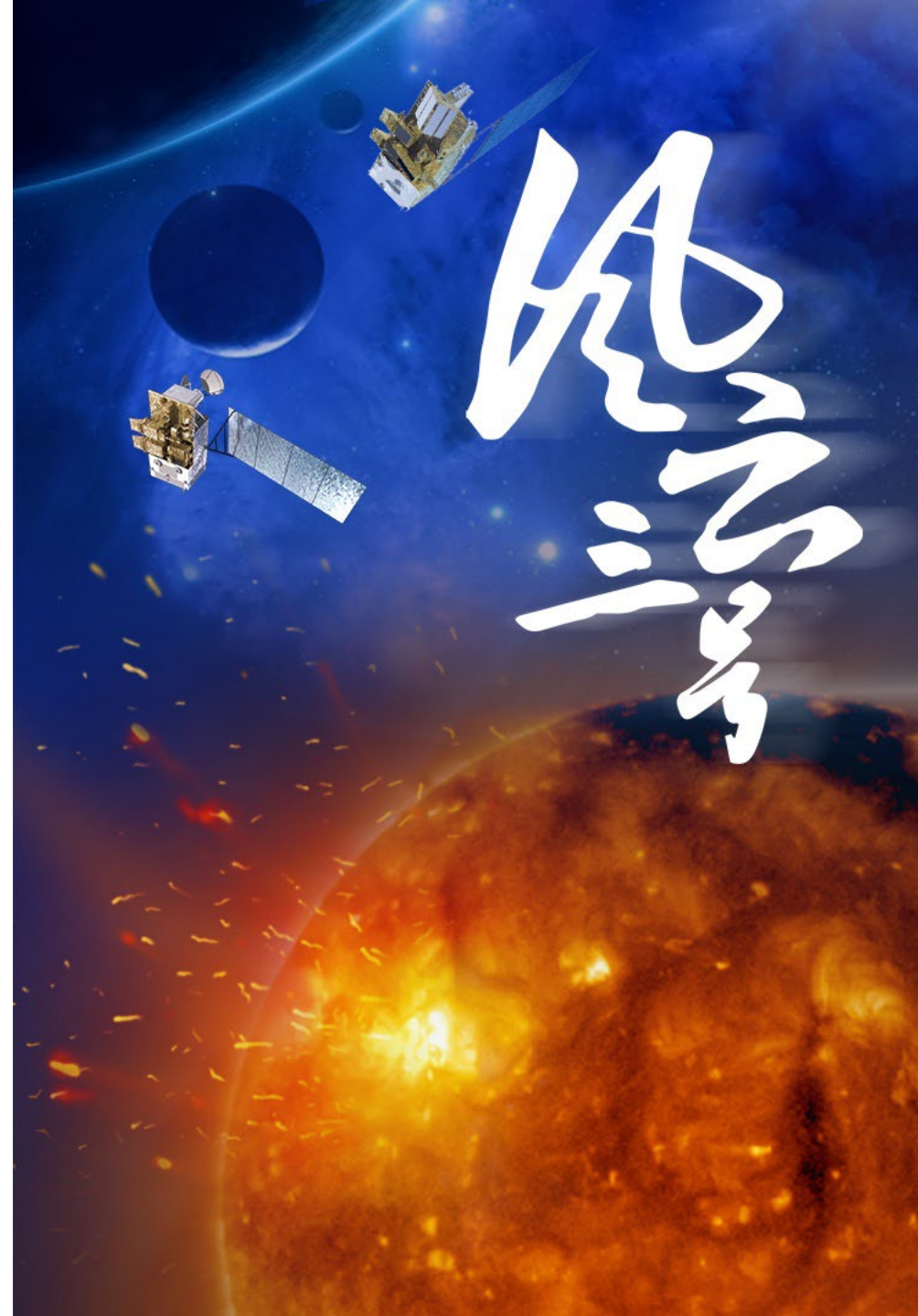
1. WindRAD introduction

WindRAD

FY-3E satellite

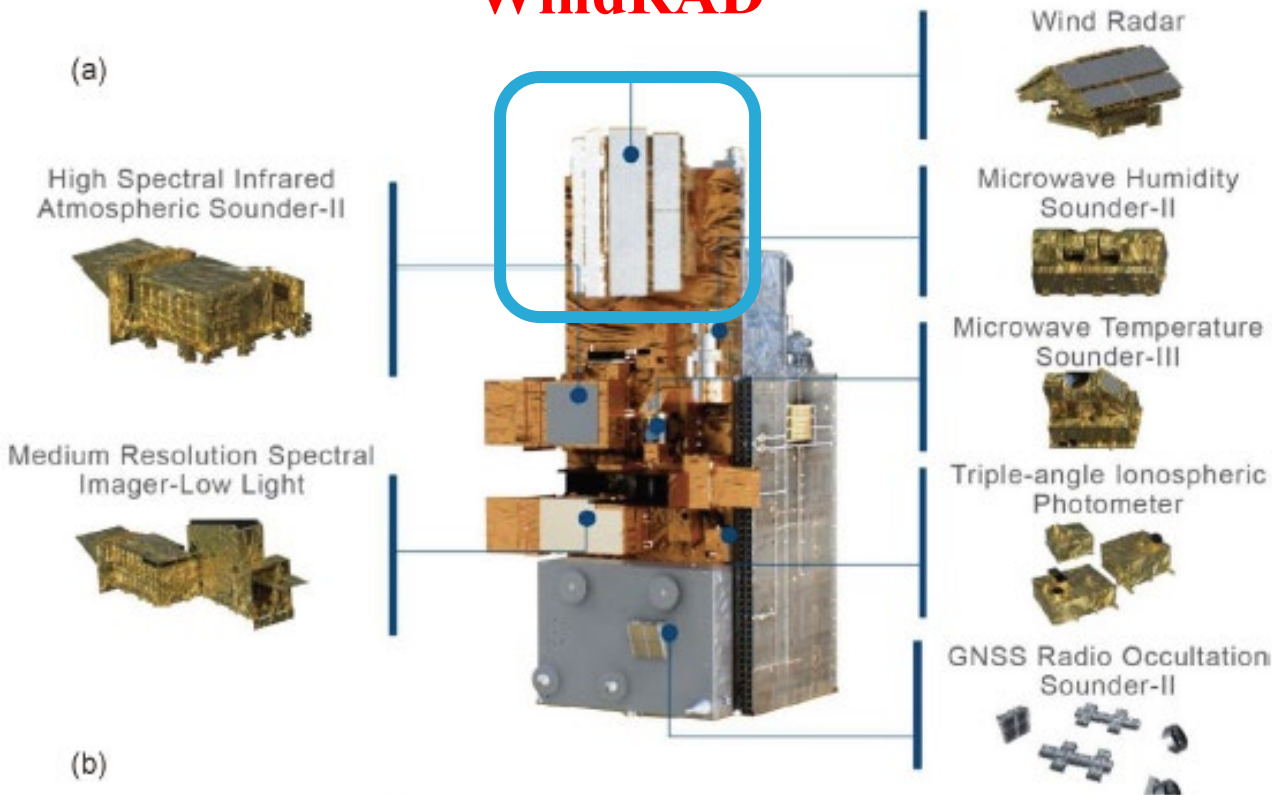➢ **Wind Radar (WindRAD) for Chinese FY-3E satellite**

◆The first active remote sensing instrument of Fengyun series satellite of China.

◆dual-frequency: C & Ku band, both with VV & HH polarizations microwave scatterometer

◆advanced rotating fan-beam

◆Detecting global sea surface wind vector, including wind speed and wind direction.

Main performance specifications

Spectrum specifications

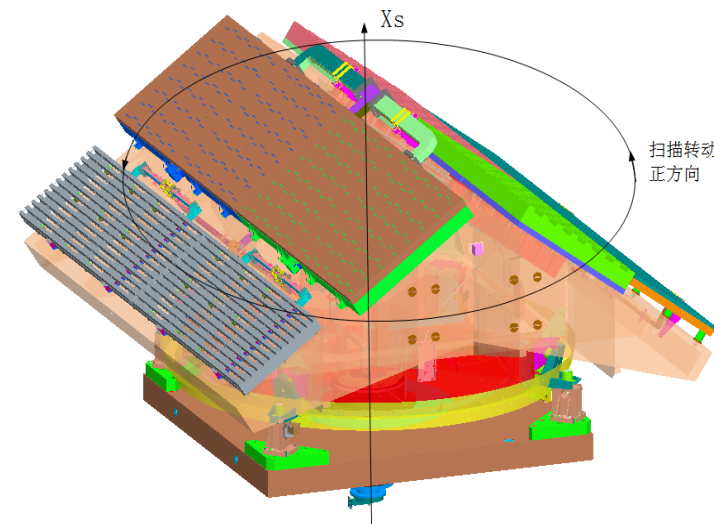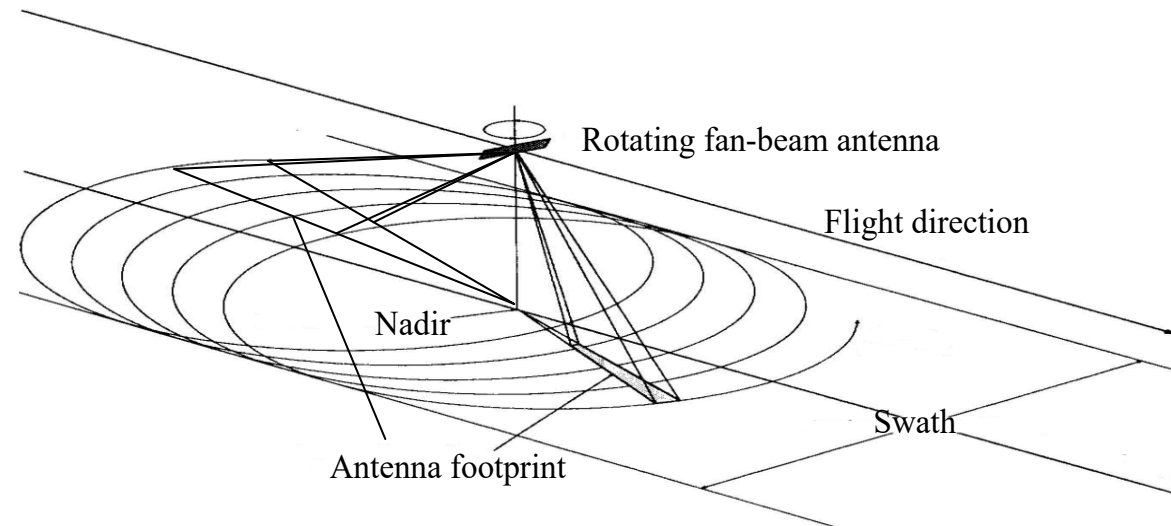| parameter	metric	
Frequency	5.4 GHz （C band)	13.256 GHz （Ku band)
Polarization	VV、HH	VV、HH

Observing geometric specifications

parameter	metric	
	C band	Ku band
（azimuth×range） Spatial resolution	25 ×0.5km	10 ×0.5km
Swath	> 1200km	
Scanning mode	360° conical scanning	

Radiometric specifications

parameter	metric	
	C band	Ku band
Minimum detectable wind speed	3 m/s(-26.2dB)	3 m/s(-30.8dB)
Radiometric resolution	0.5dB （wind speed≥5 m/s) 1.0dB （wind speed＝3 m/s)	
Radiometric accuracy	≤ 0.6dB	

Rotating fan-beam antenna

Flight direction
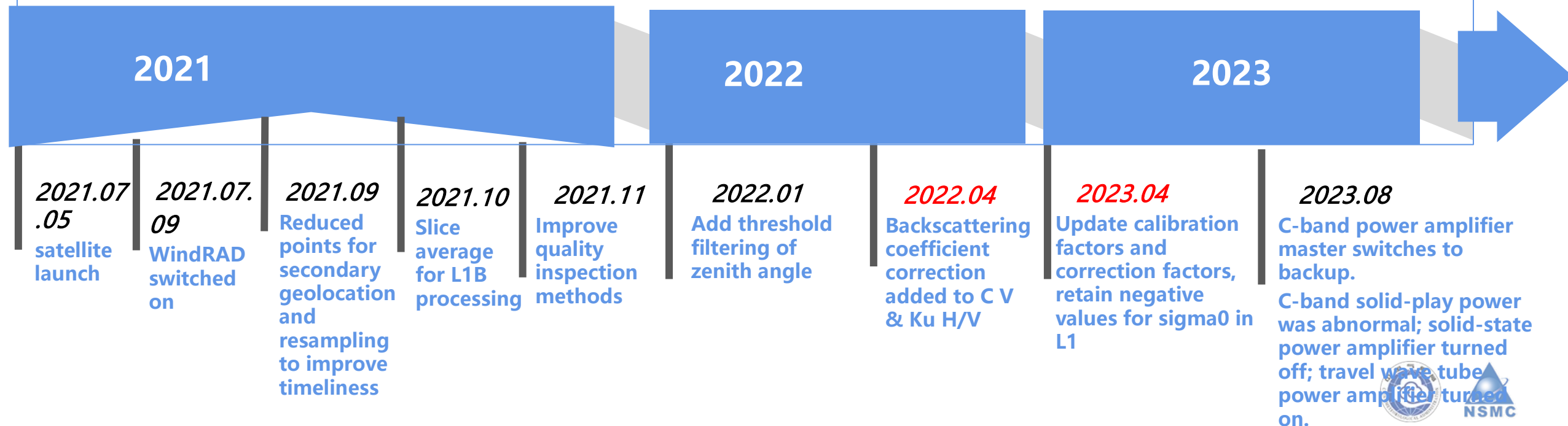
Nadir

Swath

Antenna footprint

Xs

扫描转动
正方向

PART 02
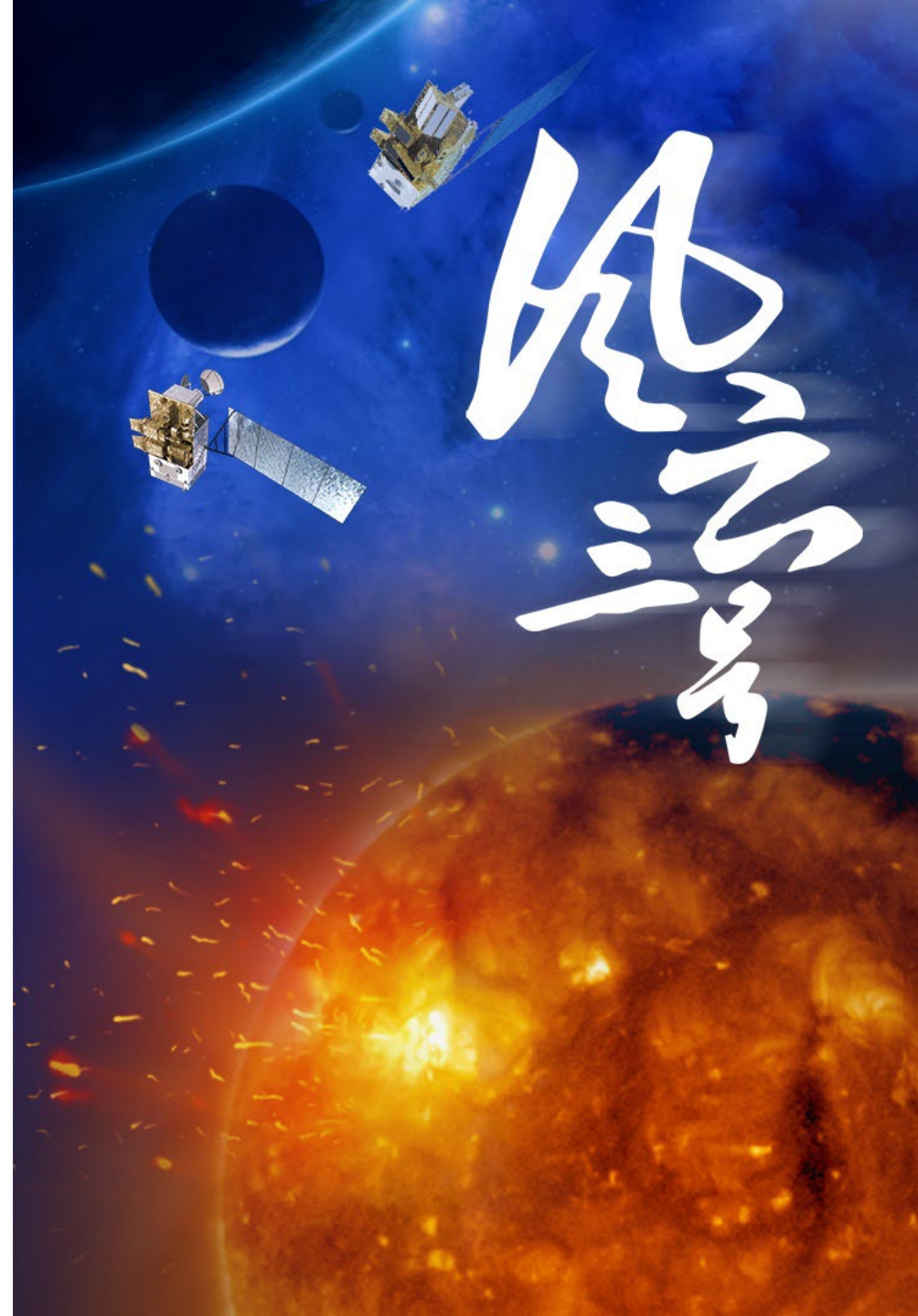
Instrument status

FY-3E/WindRAD (Wind Radar)

WindRAD has been turned on and conducted the global observation since July 9th, 2021.

Its status is quite stable. Except for several operations for solving the turbulence influence of high-energy particle events and other mode testing.

Major operational updates of WindRAD L1 processing have been carried out from 2021 to 2023.

2021	2022	2023

2021.07.05
satellite launch

2021.07.09
WindRAD switched on

2021.09
Reduced points for secondary geolocation and resampling to improve timeliness

2021.10
Slice average for L1B processing

2021.11
Improve quality inspection methods

2022.01
Add threshold filtering of zenith angle

2022.04
Backscattering coefficient correction added to C V & Ku H/V

2023.04
Update calibration factors and correction factors, retain negative values for sigma0 in L1

2023.08
C-band power amplifier master switches to backup.
C-band solid-play power was abnormal; solid-state power amplifier turned off; travel wave tube power amplifier turned on.

2. Instrument status

Key telemetry parameters (green: Ku, blue: C)
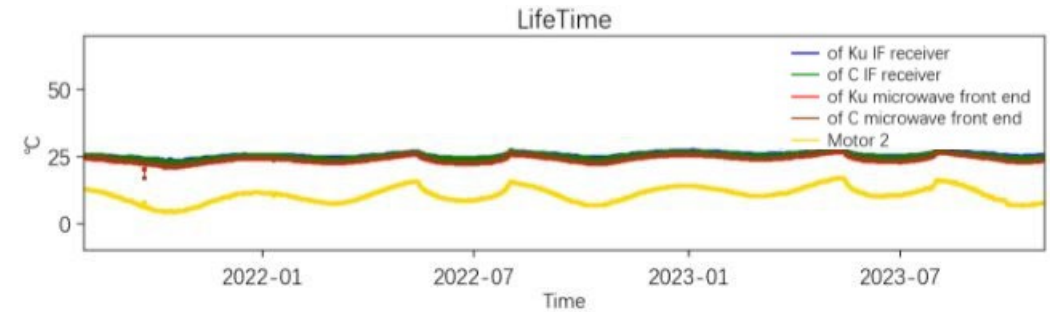
- Actual rotation speed
- Temperature of key components
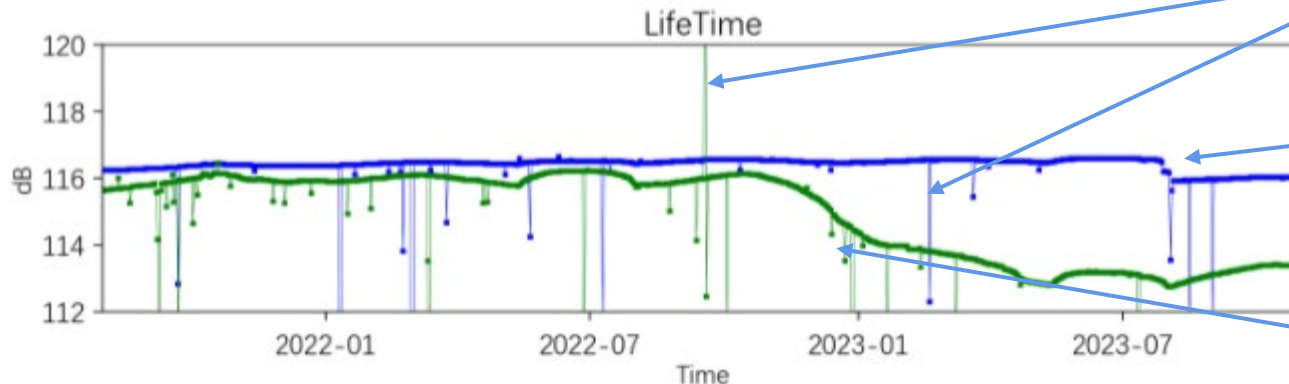- Internal calibration value

Actual rotation speed

Stable
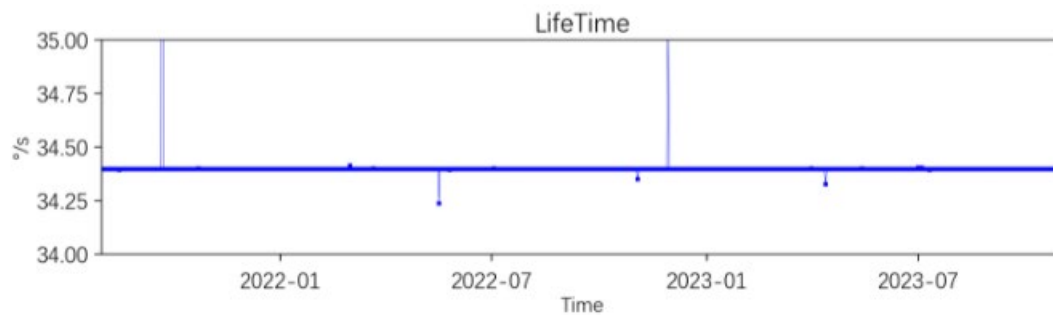
Temperature

Internal calibration value
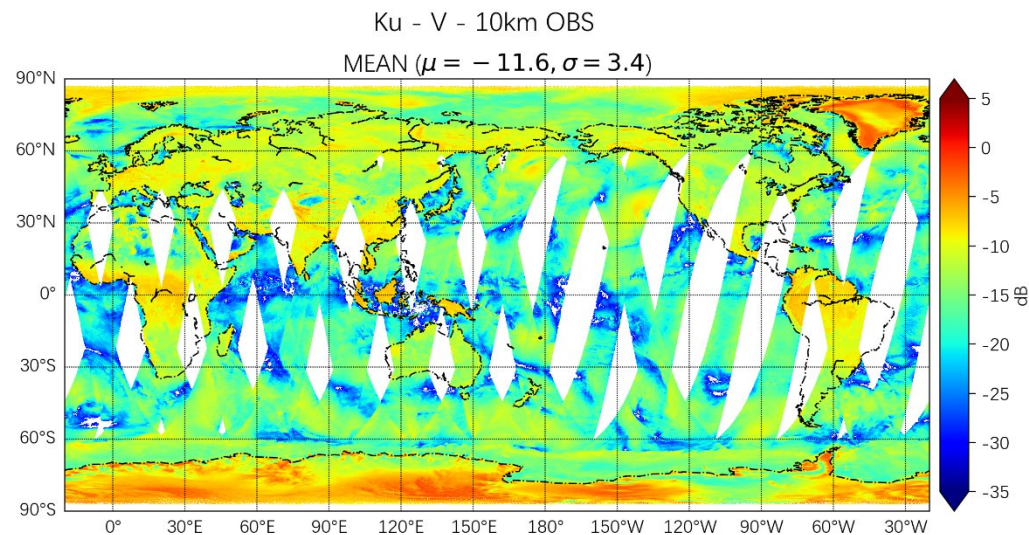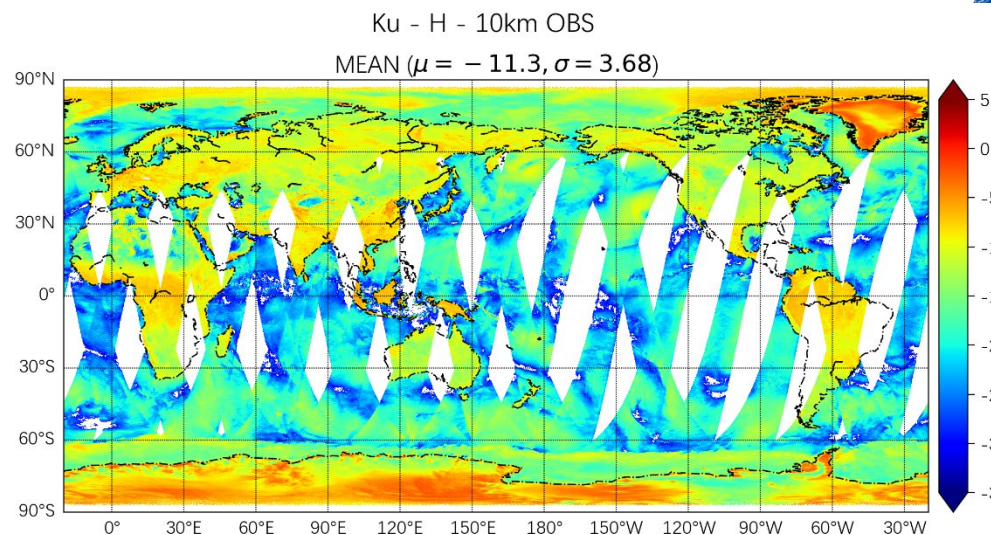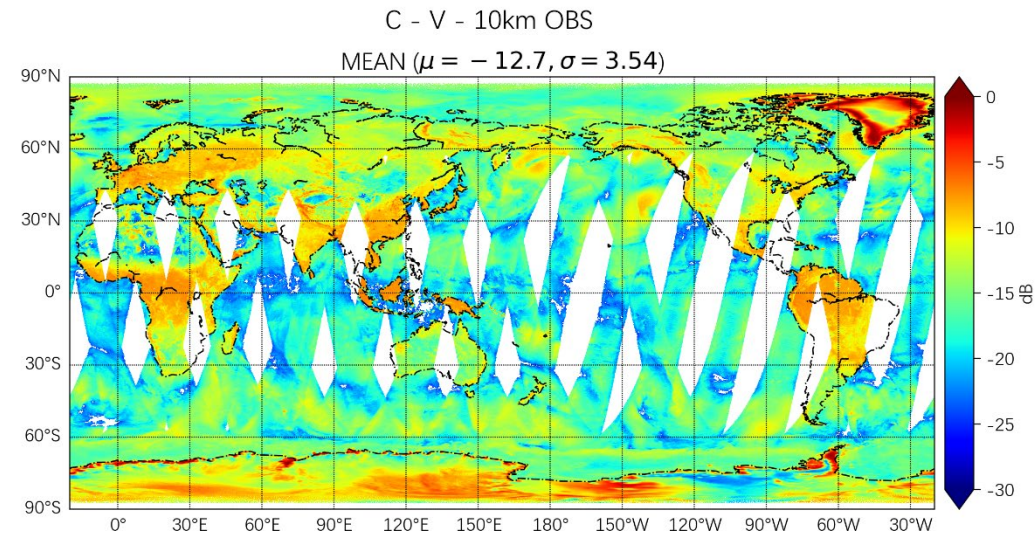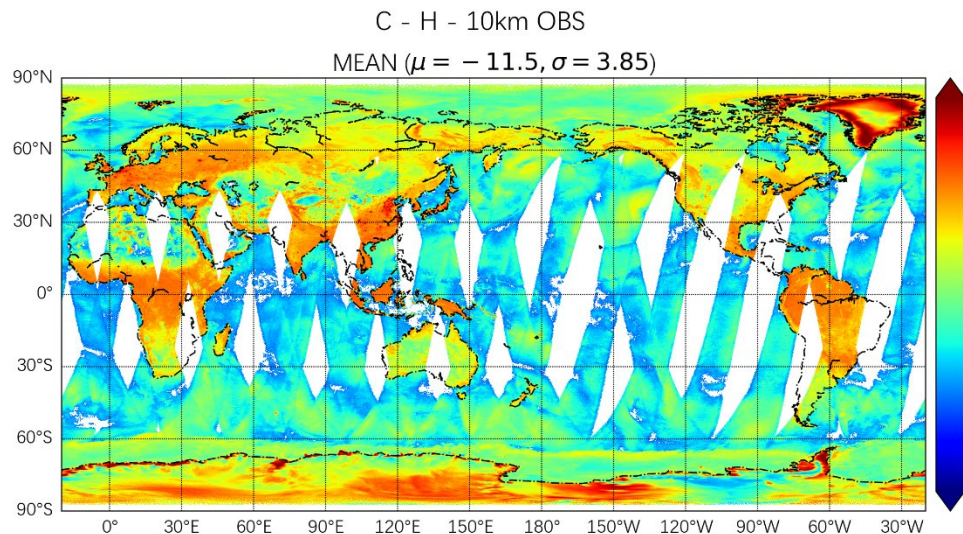

Caused by high-energy particle events

The power amplifier master switches to backup

The channel gain changes slowly; also changes with temperature

Global land/sea surface backscattering L1 products of FY-3E/WindRAD (20231114)

C - H - 10km OBS
MEAN ($\mu = -11.5, \sigma = 3.85$)

C - V - 10km OBS
MEAN ($\mu = -12.7, \sigma = 3.54$)

Ku - H - 10km OBS
MEAN ($\mu = -11.3, \sigma = 3.68$)

Ku - V - 10km OBS
MEAN ($\mu = -11.6, \sigma = 3.4$)

PART 03

L1 Data Validation

3. L1 Data Validation
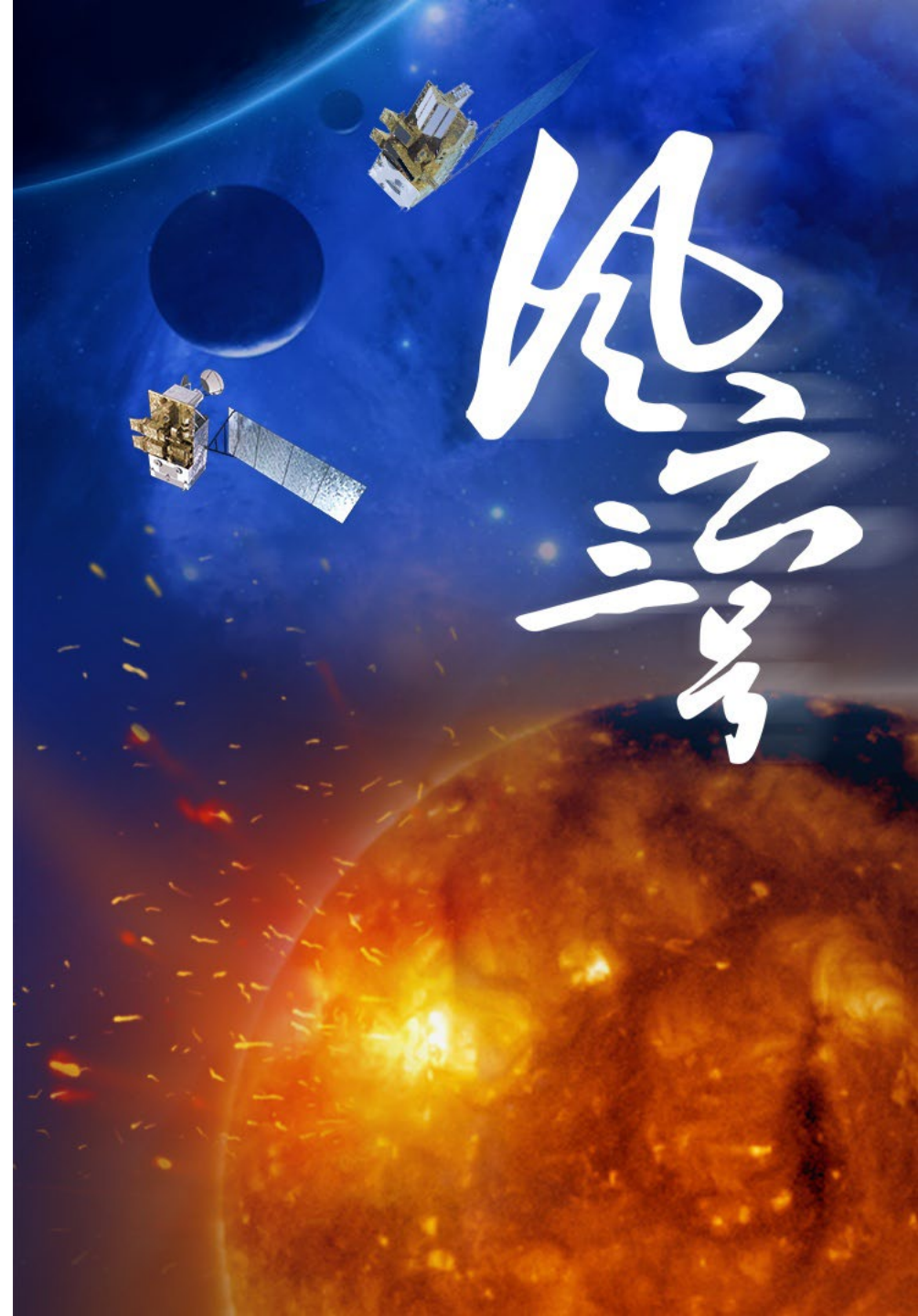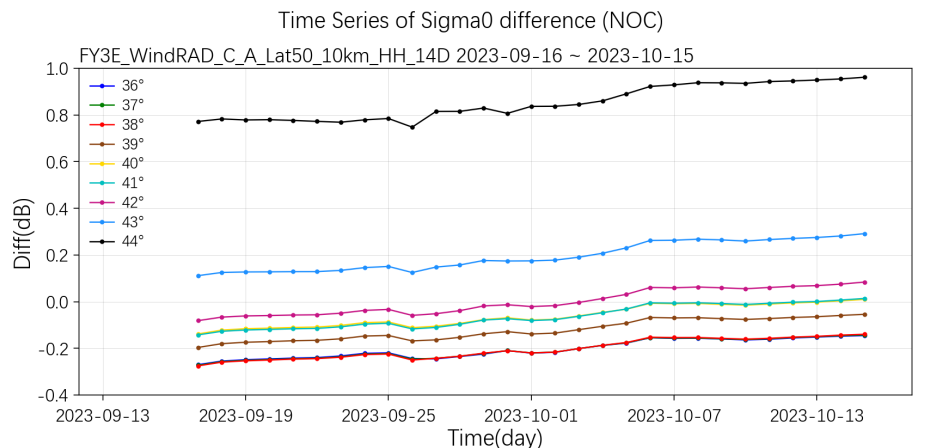
WindRAD L1 Validation

Focus on L1 product validation

- **L1 product validation:** the long term observation data from natural distributed targets and the data of similar instruments are used to evaluate L1 results.

  ➢ ocean calibration, SNO, rainforest

  ✓ **Geophysical Model Functions (NSCAT-4 and CMOD7) are used for ocean calibration.**

  ✓ **The calibration accuracy is also evaluated by cross calibration method based on reference instruments, including Metop ASCAT, CFOSAT SCAT and HY-2 SCAT.**

  ✓ **The variation of sigma0 in rainforest region with incidence angle is analyzed.**

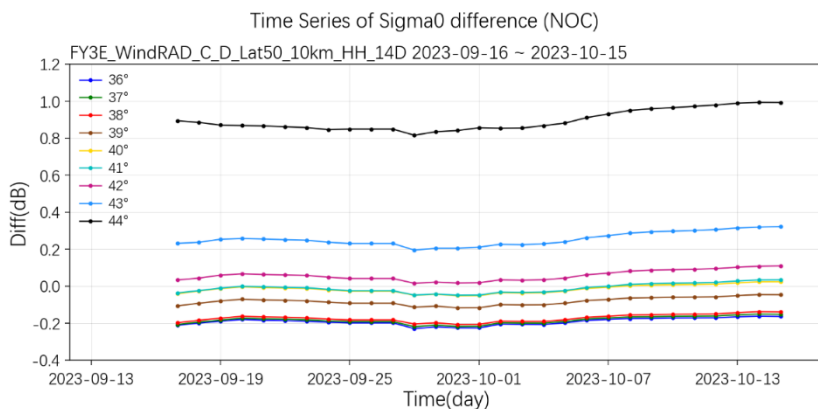 -----The ocean calibration and SNO results are then presented in detail.

➢NOC (NWP Ocean Calibration)
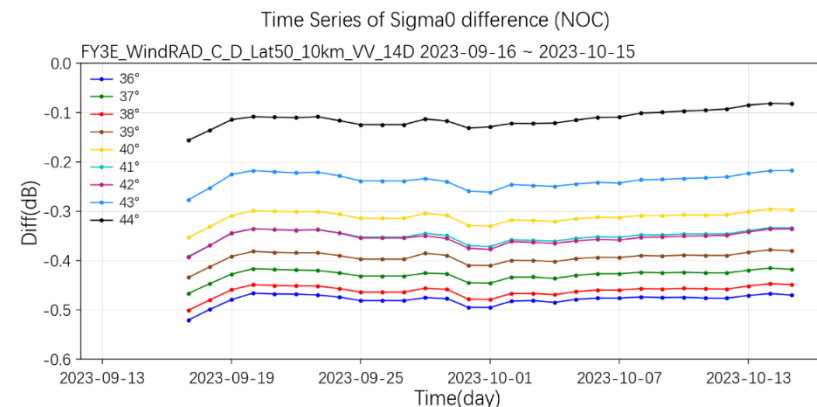
➢Time series diagram of sigma0 difference (NOC) for C-band（September 16th to October 15th）.
➢Bias is stable, and the bias of different incident angles is different.
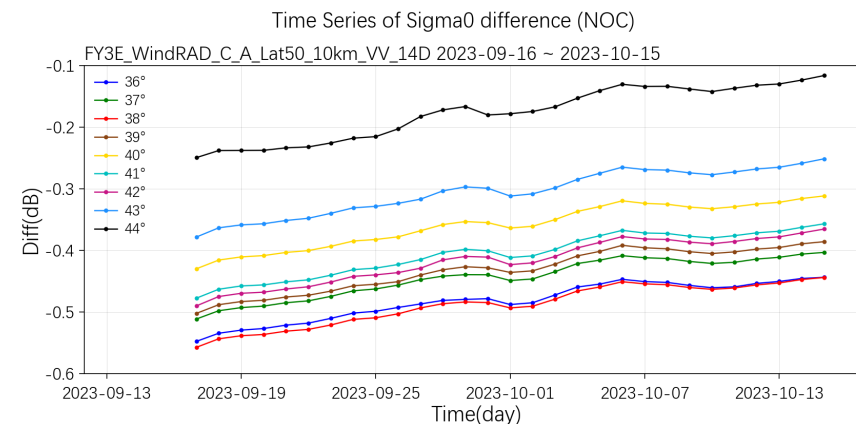
vertical axis: the difference between observed sigma0 and simulated sigma0.

C H Ascending(10km grid)

C V Ascending(10km grid)

C H Descending(10km grid)

C V Descending (10km grid)

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3. L1 Data Validation
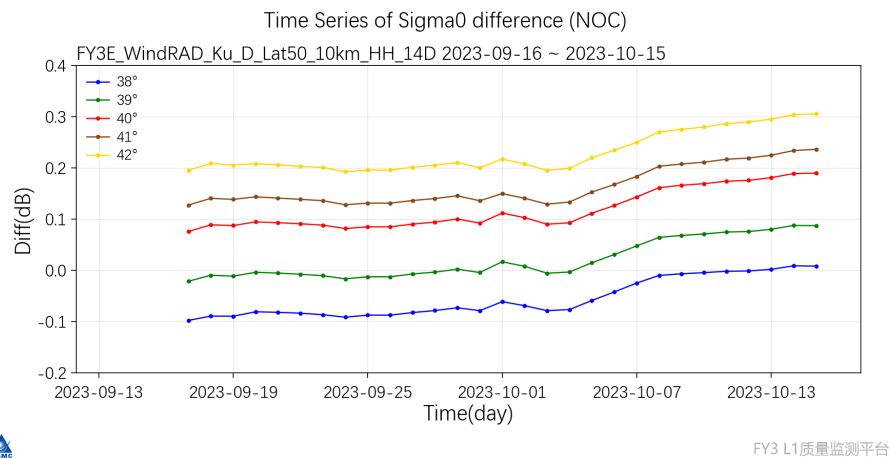
> ## NOC (NWP Ocean Calibration)

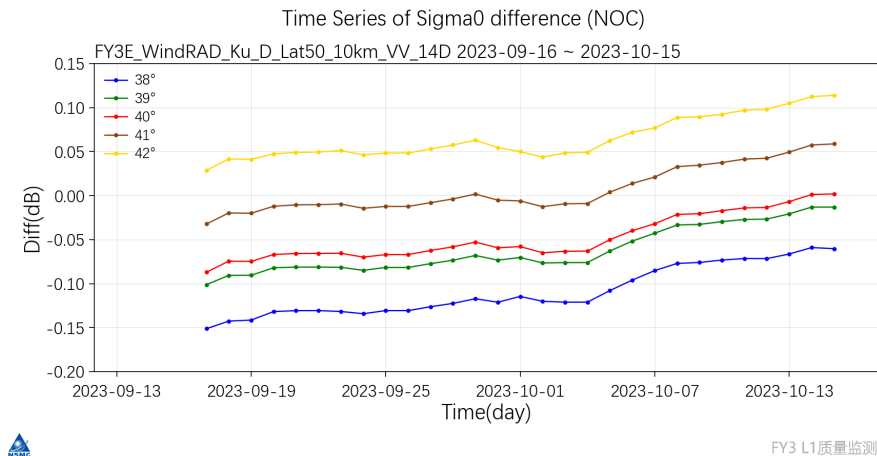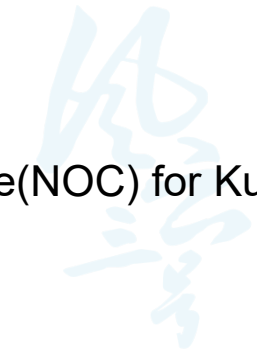> Time series diagram of Sigma0 difference(NOC) for Ku-band（September 16th to October 15th）.
> The sigma0 bias of Ku band is smaller.
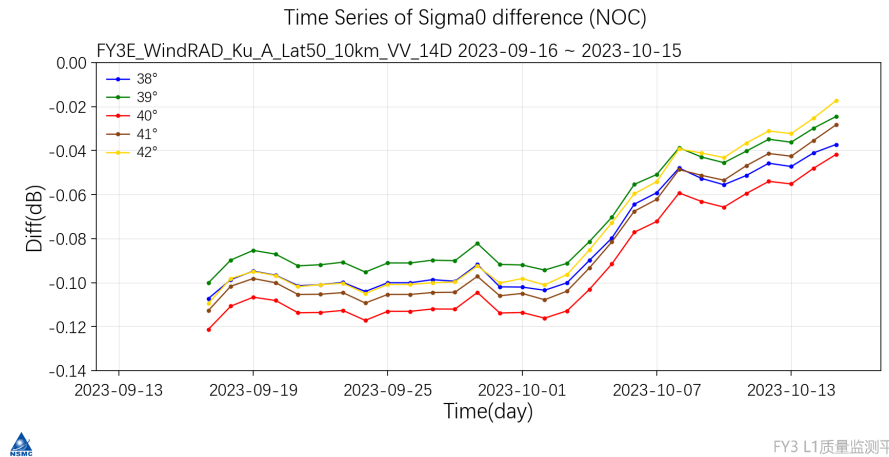
Ku H Ascending(10km grid)

Ku V Ascending(10km grid)

Ku H Descending(10km grid)

Ku V Descending (10km grid)

NOC (NWP Ocean Calibration)

➤Incidence angle distribution of sigma0 difference for C band data from 20230916 to 20231015.
➤The variation of the calibration bias with the incidence angle can be seen more clearly.

C H Ascending(10km grid)
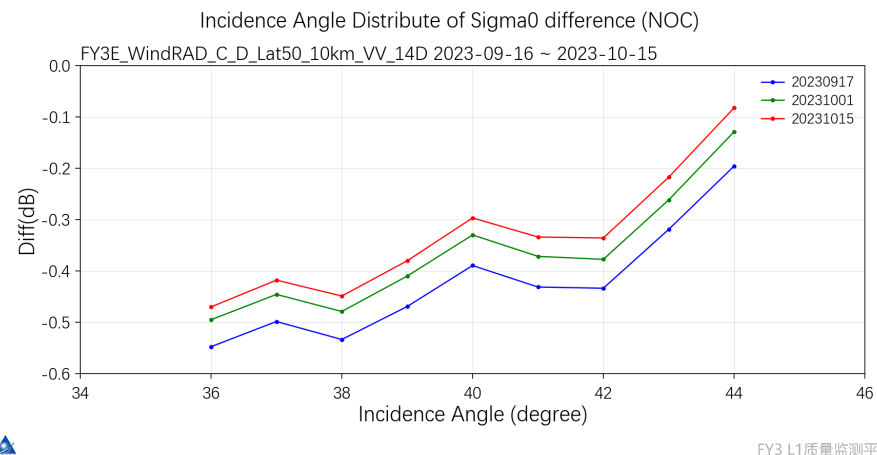
C V Ascending(10km grid)

C H Descending(10km grid)

C V Descending (10km grid)

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NOC (NWP Ocean Calibration)

➢Incidence angle distribution of sigma0 difference for Ku band data from 20230916 to 20231015.
➢Angle correction can be carried out in the retrieval.

Ku H Ascending(10km grid)

Ku V Ascending(10km grid)
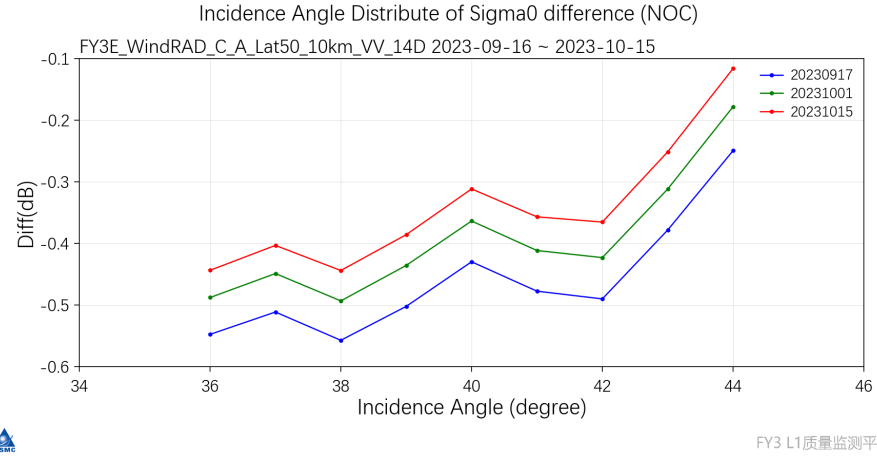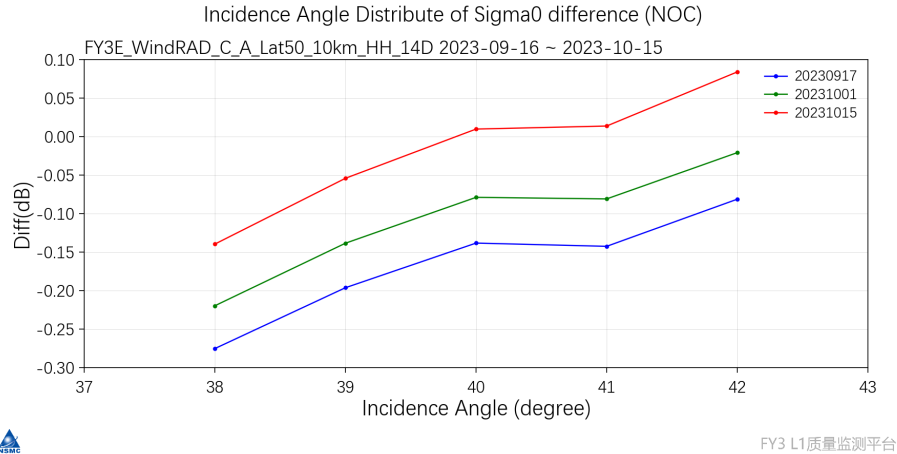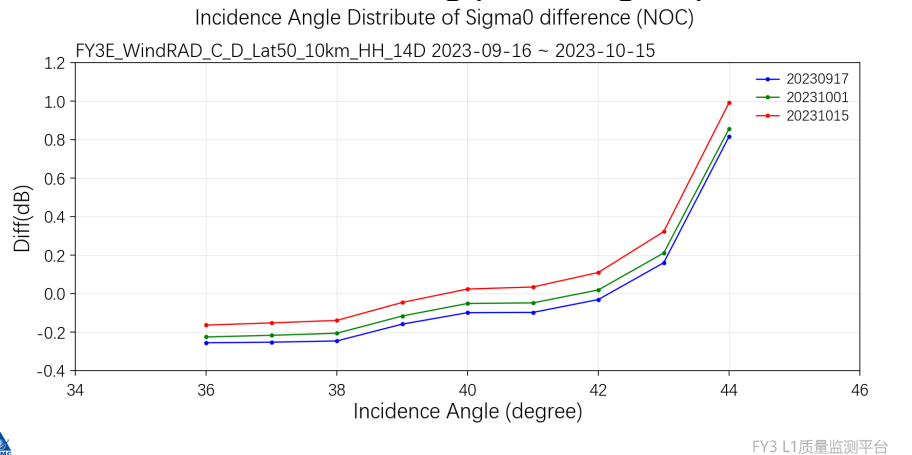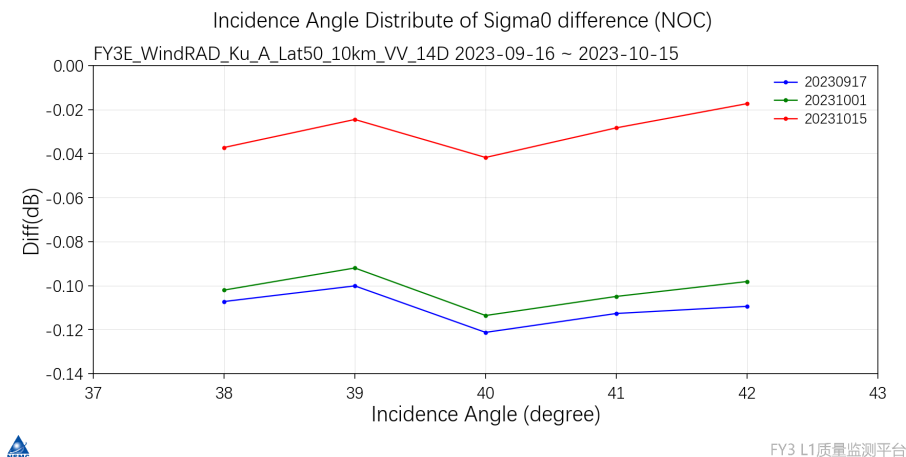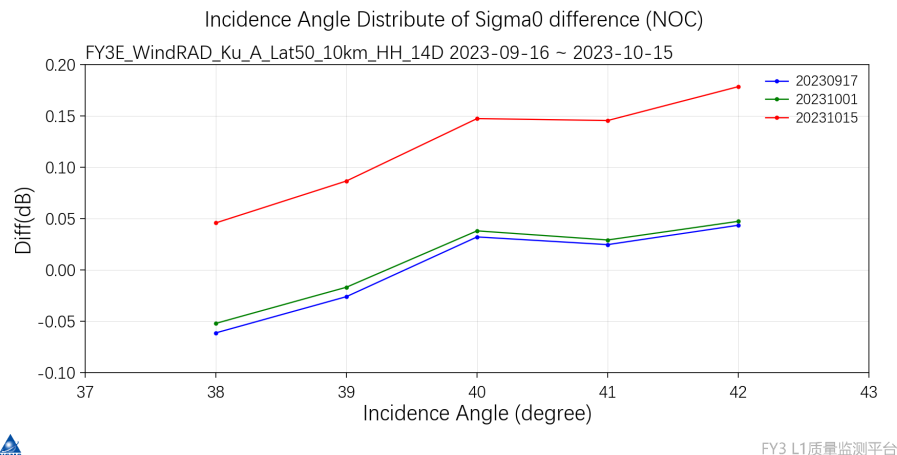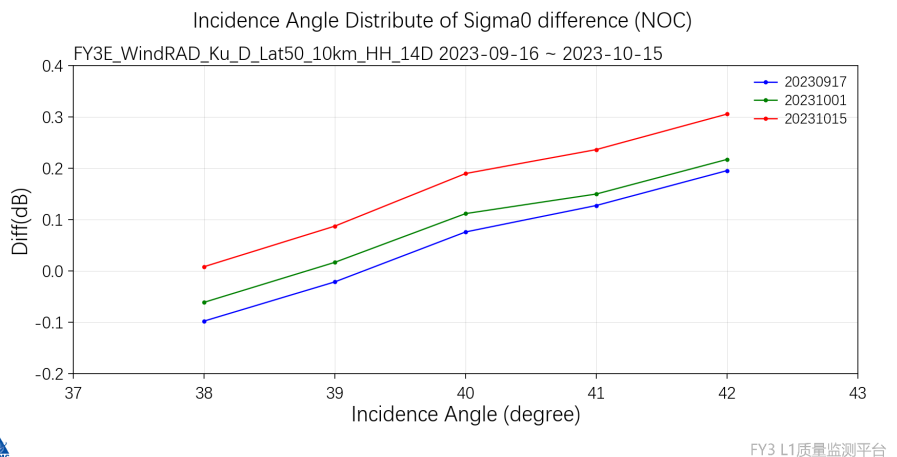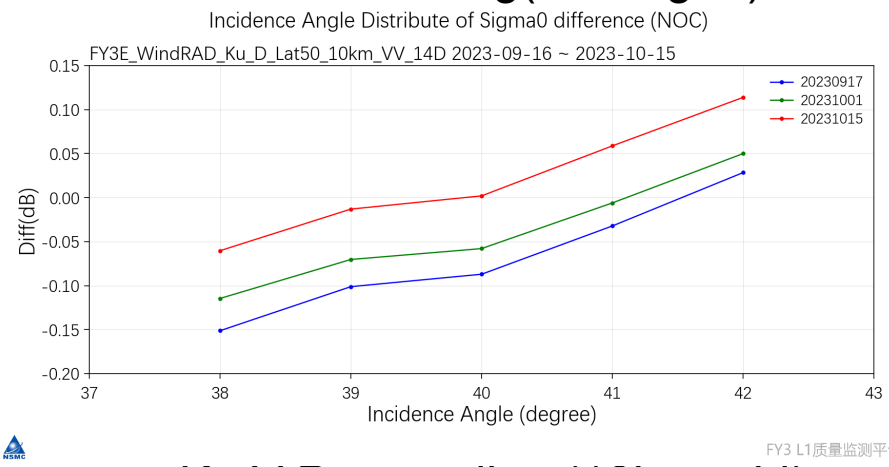

Ku H Descending(10km grid)

Ku V Descending (10km grid)

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3. L1 Data Validation

➢ NOC (NWP Ocean Calibration)

The results of calibration accuracy based on NWP ocean calibration:

Band	Mean bias（dB）			Std of bias（dB）		
	Ascend	Descend	All	Ascend	Descend	All
C-H-10km	1.13	0.56	0.78	1.66	1.24	1.45
C-H-20km	0.92	0.47	0.64	1.35	1.05	1.20
C-V-10km	0.16	0.08	0.11	1.09	0.75	0.89
C-V-20km	0.00	0.01	0.01	0.73	0.53	0.61
Ku-H-10km	0.47	0.57	0.52	0.82	0.93	0.88
Ku-H-20km	0.42	0.52	0.47	0.74	0.86	0.80
Ku-V-10km	0.12	0.21	0.16	0.37	0.47	0.43
Ku-V-20km	0.09	0.19	0.14	0.34	0.44	0.40

➢ The calibration accuracy is less than 1 dB. Smaller bias in C VV and larger bias in C HH.

（The forward model of C H band is jointly developed with NUIST, and the coefficient of GMF will be further updated.）

➢ Further improvements will be made after the update of GMF.

3. L1 Data Validation

➤ SNO for WindRAD L1 validation

◆ In addition to NOC, the calibration accuracy is evaluated by cross calibration method based on reference instruments, including Metop ASCAT, CFOSAT SCAT and HY-2 SCAT.

The two data sets are matched by adjusting

- Time threshold
- Space threshold
- Incidence angle threshold
- Azimuth angle threshold
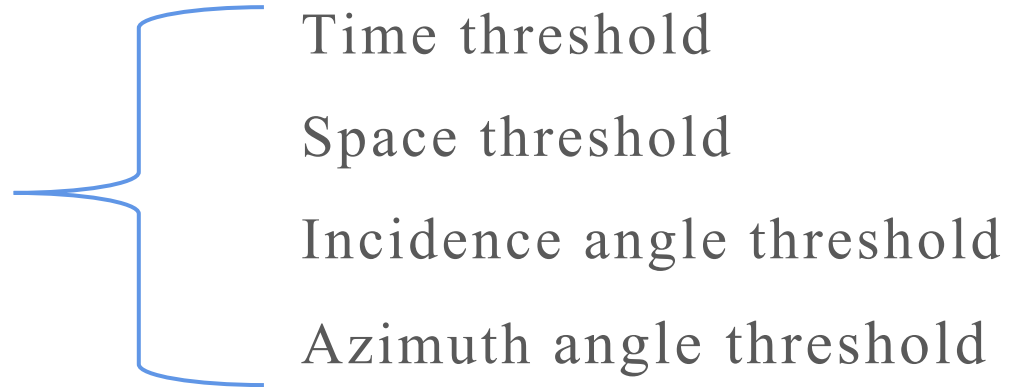
Metop ASCAT	CFOSAT SCAT	HY-2 SCAT
• C band, VV	• Ku band, HH & VV	• Ku band, HH & VV

3. L1 Data Validation

The following is SNO results of :

> FY-3E WindRAD vs. CFOSAT SCAT Ku HH data
(20221101-20221129)

Ku HH

WindRAD vs. CFOSAT SCAT	HH 10km	VV 10km
Matching points	96182	88784
Correlation coefficient	0.93	0.94
Mean / dB	1.23	0.21
Std / dB	1.94	0.56

Spacial Distribution of (Sigma_bias) 2022-11-01~2022-11-29
FY3E_WRAD_K_CFO_SCAT HH_10km global

spatial distribution diagram

Correlation Analysis of FY3E_WRAD_K_CFO_SCAT. HH_10km
global 2022-11-01~2022-11-29
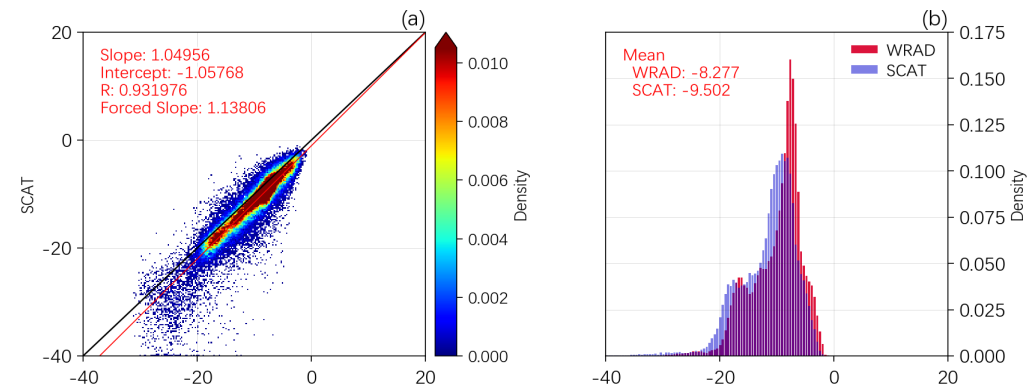
correlation analysis diagram

Diagram of (Sigma_bias) 2022-11-01~2022-11-29
FY3E_WRAD_K_CFO_SCAT. HH_10km global
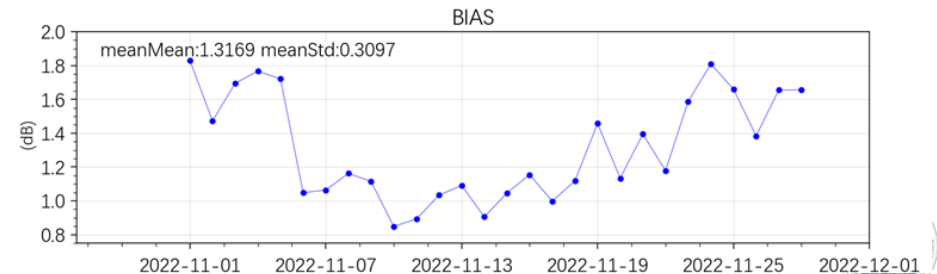
time series diagram

> Matching points are distributed in two latitude regions of north and south poles.
> The correlation coefficient is 0.93, mean bias is 1.23, and standard deviation is 1.94.
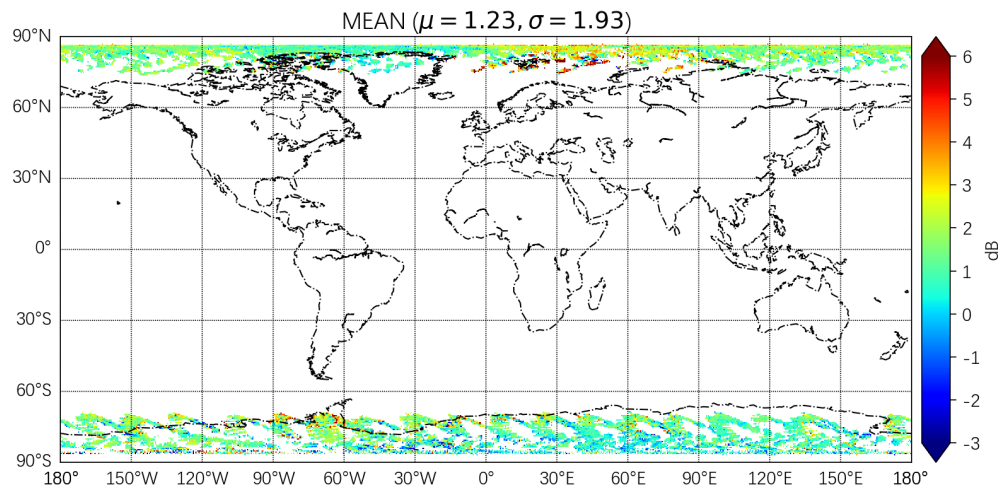
3. L1 Data Validation

The following is SNO results of :

➤FY-3E WindRAD vs. CFOSAT SCAT Ku VV data
(20221101-20221129)

Ku VV

WindRAD vs. CFOSAT SCAT	HH 10km	VV 10km
Matching points	96182	88784
Correlation coefficient	0.93	0.94
Mean / dB	1.23	0.21
Std / dB	1.94	0.56

Spacial Distribution of (Sigma_bias) 2022-11-01~2022-11-29
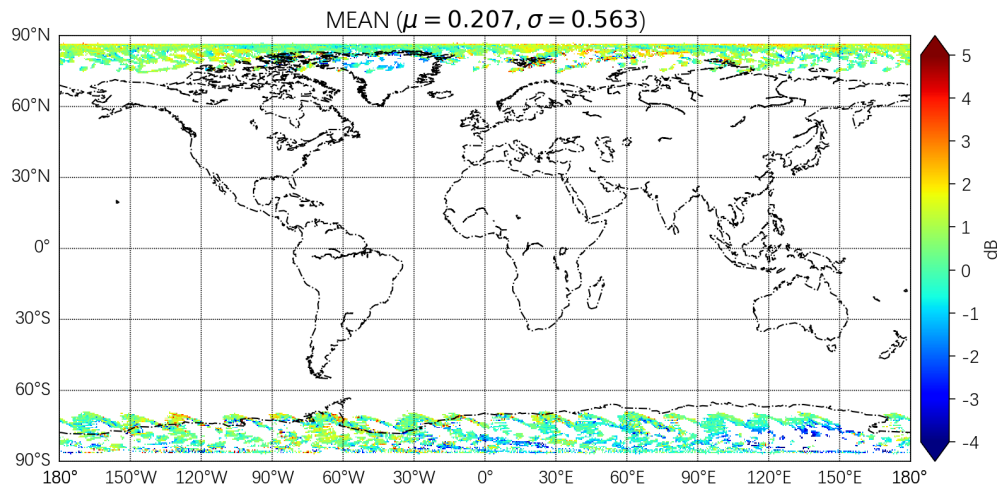FY3E_WRAD_K_CFO_SCAT VV_10km global

MEAN ($\mu = 0.207, \sigma = 0.563$)

FY3 L1质量监测平台

Correlation Analysis of FY3E_WRAD_K_CFO_SCAT. VV_10km
global 2022-11-01~2022-11-29

Slope: 1.00564
Intercept: -0.413209
R: 0.935025
Forced Slope: 1.04053

Mean
WRAD: -8.765
SCAT: -8.972

Diagram of (Sigma_bias) 2022-11-01~2022-11-29
FY3E_WRAD_K_CFO_SCAT. VV_10km global

BIAS

meanMean:0.2445 meanStd:0.4646

➤The correlation coefficient is 0.94, mean bias is 0.21, and standard deviation is 0.56.

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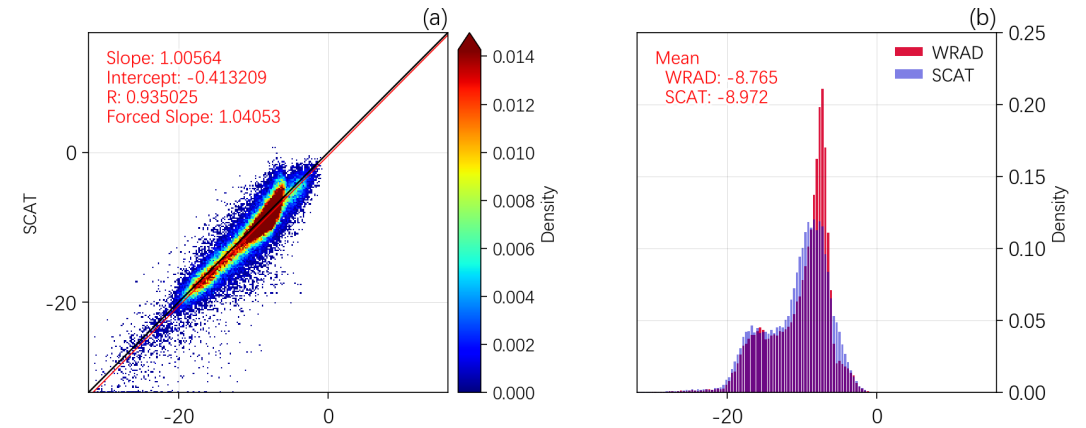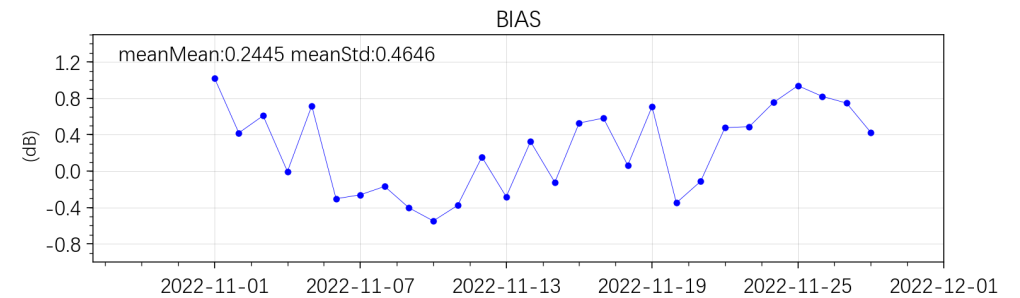
3. L1 Data Validation

The following is SNO results of :

➢FY-3E WindRAD vs. HY-2B SCAT Ku HH data
(WindRAD 20231001-1031)

Ku HH
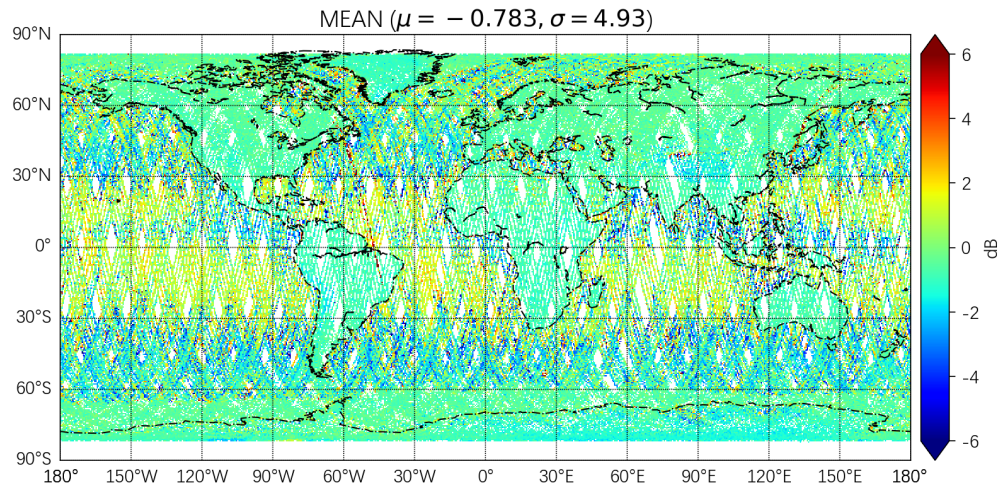
WindRAD vs. HY-2B SCAT	HH WVC
Matching points	583390
Correlation coefficient	0.95
Mean / dB	-0.78
Std / dB	2.47

Spacial Distribution of (Sigma_bias) 2023-10-01~2023-10-31
FY3E_WRAD_K_HY2B_SCA_WVC HH global

MEAN ($\mu = -0.783, \sigma = 4.93$)

Correlation Analysis of FY3E_WRAD_K_HY2B_SCA_WVC. HH
global 2023-10-01~2023-10-31

Slope: 0.975155
Intercept: 0.0372767
R: 0.953793
Forced Slope: 0.973292

Mean
WRAD: -12.17
HY2B: -11.39

Diagram of (Sigma_bias) 2023-10-01~2023-10-31
FY3E_WRAD_K_HY2B_SCA_WVC. HH global

BIAS

meanMean:-0.7712 meanStd:0.1247

➢Matching points are distributed globally.
➢The correlation coefficient is 0.95, mean bias is minus 0.78, and standard deviation is 2.47.

3. L1 Data Validation

The following is SNO results of :

➤FY-3E WindRAD vs. HY-2C SCAT Ku HH data
(WindRAD 20231001-1031)

WindRAD vs. HY-2C SCAT	HH WVC
Matching points	171797
Correlation coefficient	0.94
Mean / dB	-0.39
Std / dB	2.45

Ku HH

Spacial Distribution of (Sigma_bias) 2023-10-01~2023-10-31
FY3E_WRAD_K_HY2C_SCA_WVC HH global
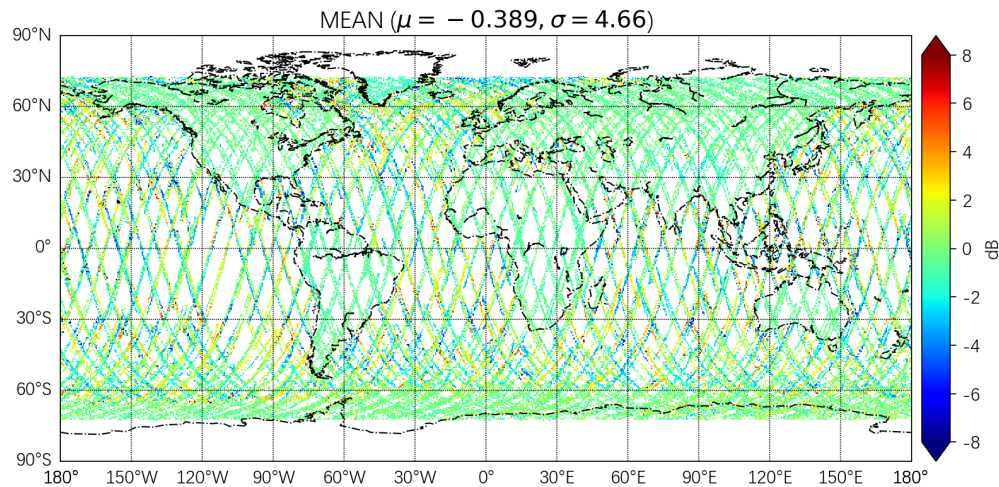

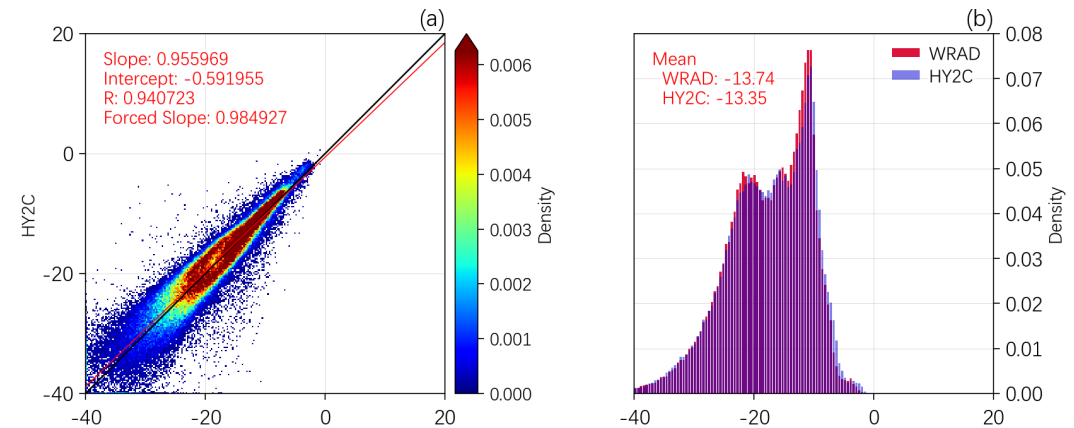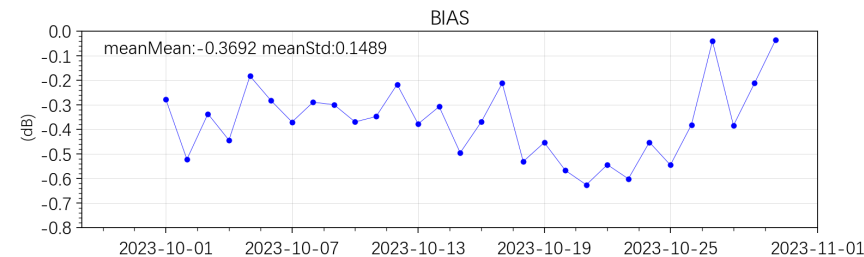Correlation Analysis of FY3E_WRAD_K_HY2C_SCA_WVC. HH
global 2023-10-01~2023-10-31

Diagram of (Sigma_bias) 2023-10-01~2023-10-31
FY3E_WRAD_K_HY2C_SCA_WVC. HH global

➤Matching points mainly in the low and mid-latitude.
➤The correlation coefficient of SNO is 0.94, mean bias is minus 0.39, and standard deviation is 2.45.
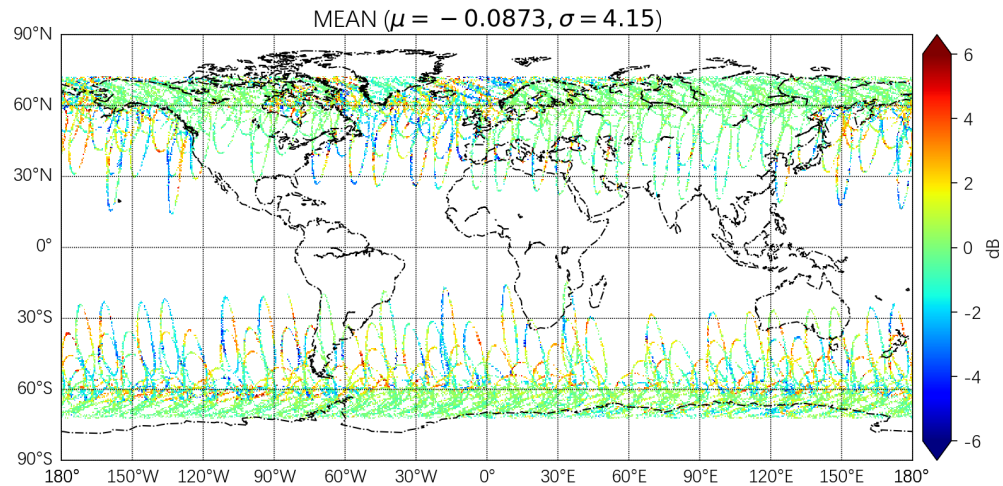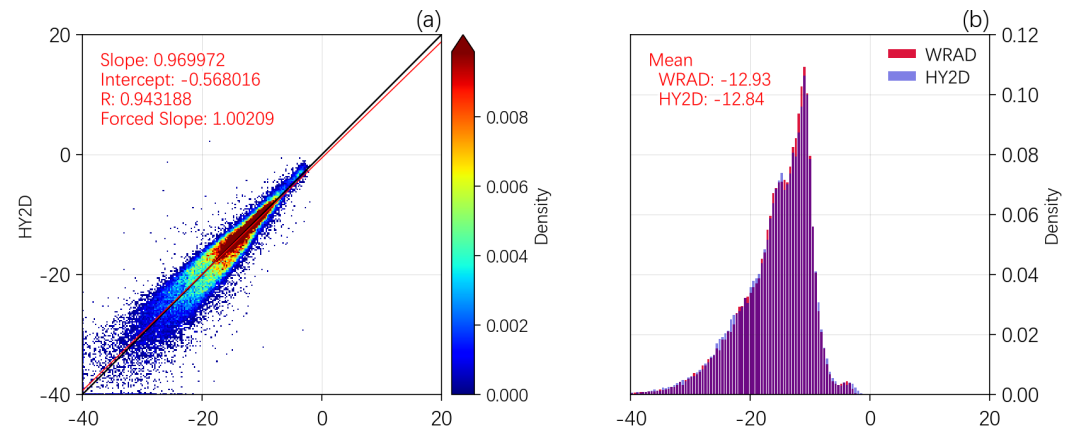
3. L1 Data Validation

The following is SNO results of :

➢FY-3E WindRAD vs. HY-2D SCAT Ku HH data
(WindRAD 20231001-1031)

Ku HH

WindRAD vs. HY-2D SCAT	HH WVC
Matching points	85361
Correlation coefficient	0.94
Mean / dB	-0.09
Std / dB	1.95

Spacial Distribution of (Sigma_bias) 2023-10-01~2023-10-31
FY3E_WRAD_K_HY2D_SCA_WVC HH global

MEAN ($\mu = -0.0873, \sigma = 4.15$)

FY3 L1质量监测平台

Correlation Analysis of FY3E_WRAD_K_HY2D_SCA_WVC. HH
global 2023-10-01~2023-10-31

Slope: 0.969972
Intercept: -0.568016
R: 0.943188
Forced Slope: 1.00209

Mean
WRAD: -12.93
HY2D: -12.84

Diagram of (Sigma_bias) 2023-10-01~2023-10-31
FY3E_WRAD_K_HY2D_SCA_WVC. HH global

BIAS

meanMean:-0.0654 meanStd:0.1512

FY3 L1质量监测平台

➢Matching points mainly in the mid-latitude.
➢The correlation coefficient is 0.94, mean bias is minus 0.09, and standard deviation is 1.95.
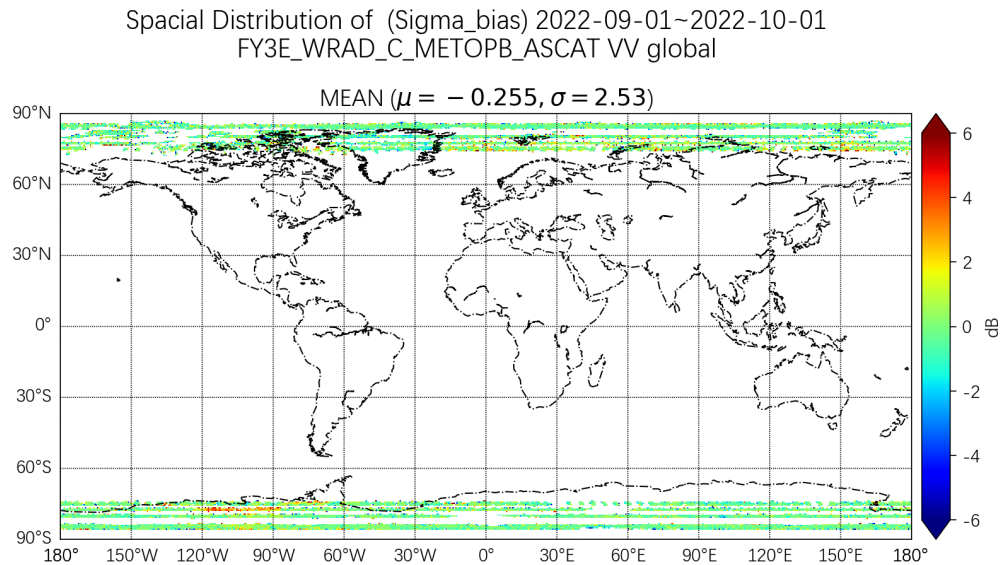
3. L1 Data Validation

The following is SNO results of :

➤FY-3E WindRAD vs. Metop-B ASCAT C VV data (WindRAD data, 20220901-20221001(No recent matches))

C VV

WindRAD vs. Metop-B ASCAT	VV WVC
Matching points	449119
Correlation coefficient	0.77
Mean / dB	-0.25
Std / dB	2.53

Spacial Distribution of (Sigma_bias) 2022-09-01~2022-10-01
FY3E_WRAD_C_METOPB_ASCAT VV global

MEAN ($\mu = -0.255, \sigma = 2.53$)

Correlation Analysis of FY3E_WRAD_C_METOPB_ASCAT. VV global 2022-09-01~2022-10-01

(a)
Slope: 0.641051
Intercept: -4.03864
R: 0.769342
Forced Slope: 0.893727

(b)
Mean
WRAD: -10.78
ASCAT: -10.53

Diagram of (Sigma_bias) 2022-09-01~2022-10-01
FY3E_WRAD_C_METOPB_ASCAT. VV global

BIAS
meanMean:-0.2517 meanStd:0.0821
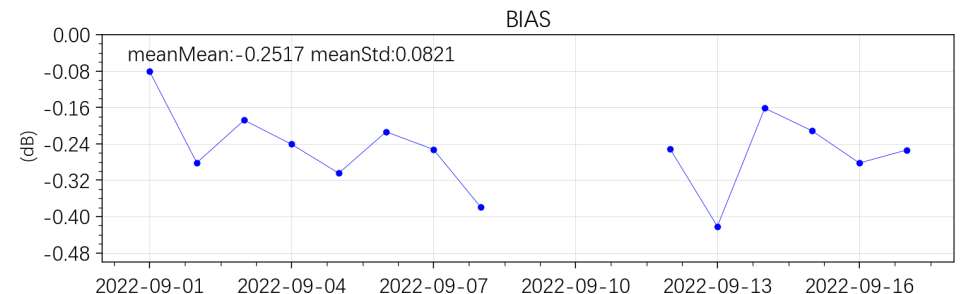
➤Matching points mainly in the North and South poles.
➤The correlation coefficient is 0.77, mean bias is minus 0.25, and standard deviation is 2.53.

FY3 L1质量监测平台

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3. L1 Data Validation

➤ SNO for WindRAD L1 validation

● According to the SNO results, the distribution characteristics of the sigma0 are generally consistent with those of similar instruments.

● SNO results will continue to be analyzed in the future.

WindRAD vs. CFOSAT SCAT	HH 10km	VV 10km
Matching points	96182	88784
Correlation coefficient	0.93	0.94
Mean / dB	1.23	0.21
Std / dB	1.94	0.56

WindRAD vs. HY-2 SCAT	HY-2B HH WVC	HY-2C HH WVC	HY-2D HH WVC
Matching points	583390	171797	85361
Correlation coefficient	0.95	0.94	0.94
Mean / dB	-0.78	-0.39	-0.09
Std / dB	2.47	2.45	1.95

| WindRAD vs. Metop-B ASCAT	VV WVC
Matching points	449119
Correlation coefficient	0.77
Mean / dB	-0.25
Std / dB	2.53

PART 04

Summary
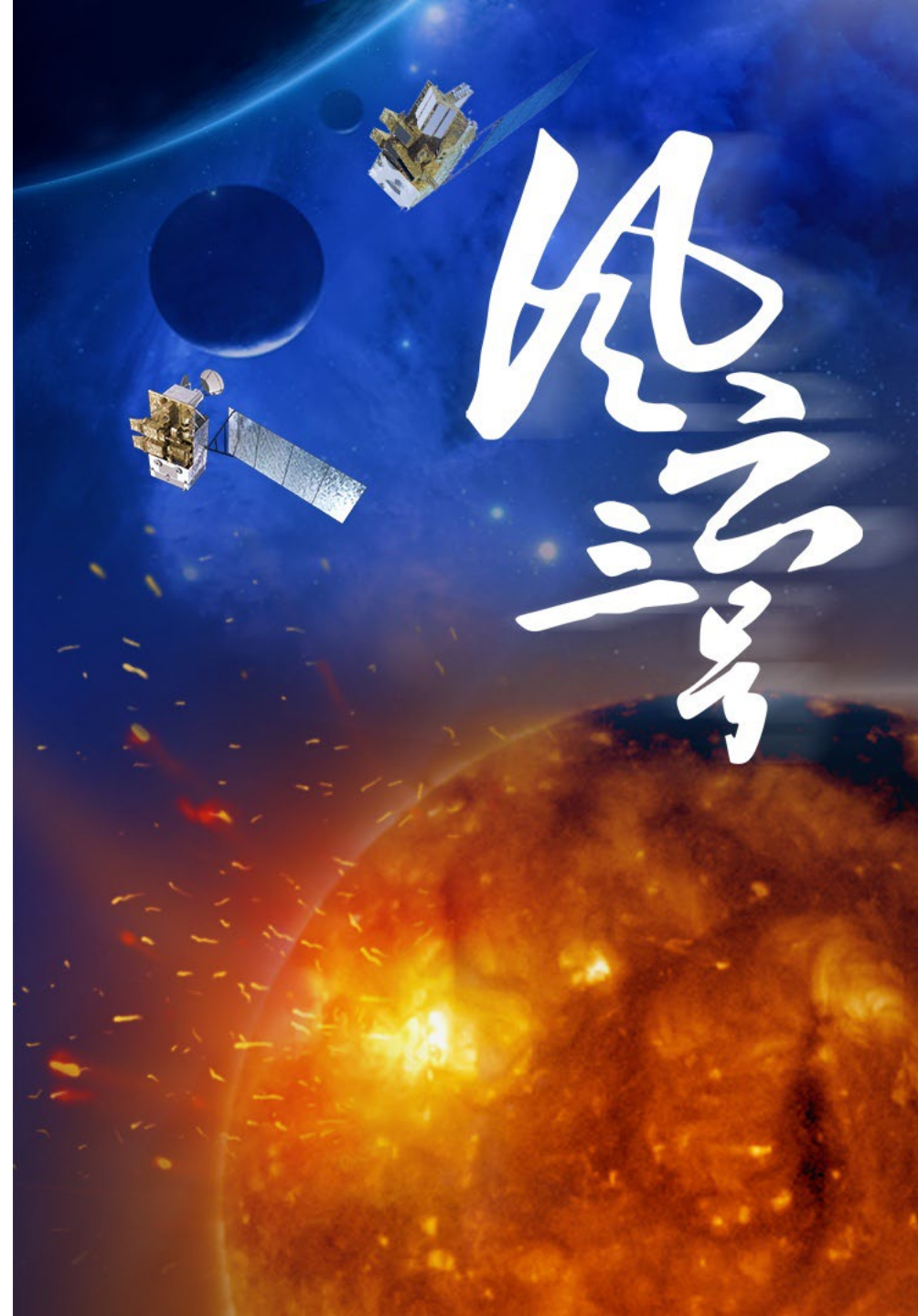
4. Summary

➢The status of WindRAD is quite stable. High-energy particle events happened many times and some observation data were influenced from these events.

➢Several major updates of L1 data processing were carried out, including QA, correcting backscattering coefficient , updating calibration factors and correction factors, and so on.

➢According to the NOC results, the deviation under each incident angle is stable. C band HH data will be reevaluated in the near future.
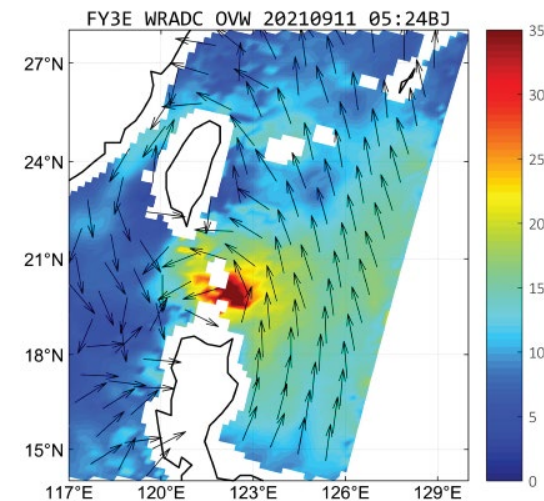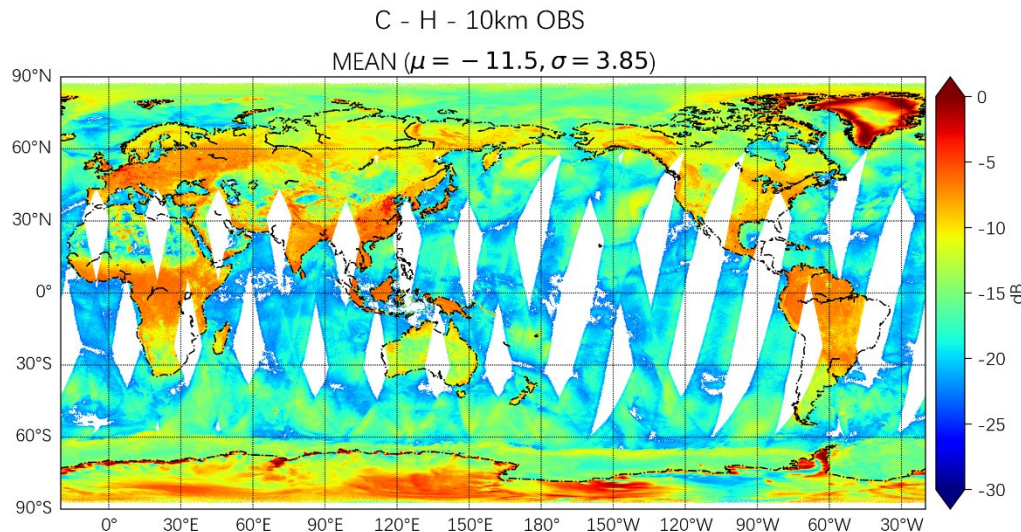
4. Summary

➢According to the SNO results, the distribution characteristics of the sigma0 are generally consistent with those of similar instruments.

➢After 6 months of trial operation, FY-3E ground system has been successfully entered the operational stage in 2022. WindRAD L2 products continue to provide services for typhoon monitoring, and has started assimilation application research in NWP.

➢Further improvements will be made to L1 data processing and new validation results will be provided.
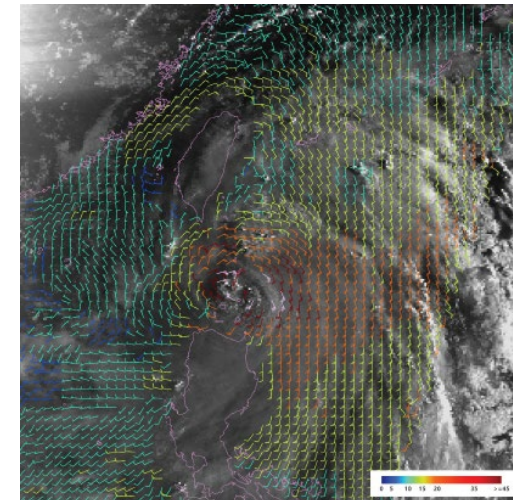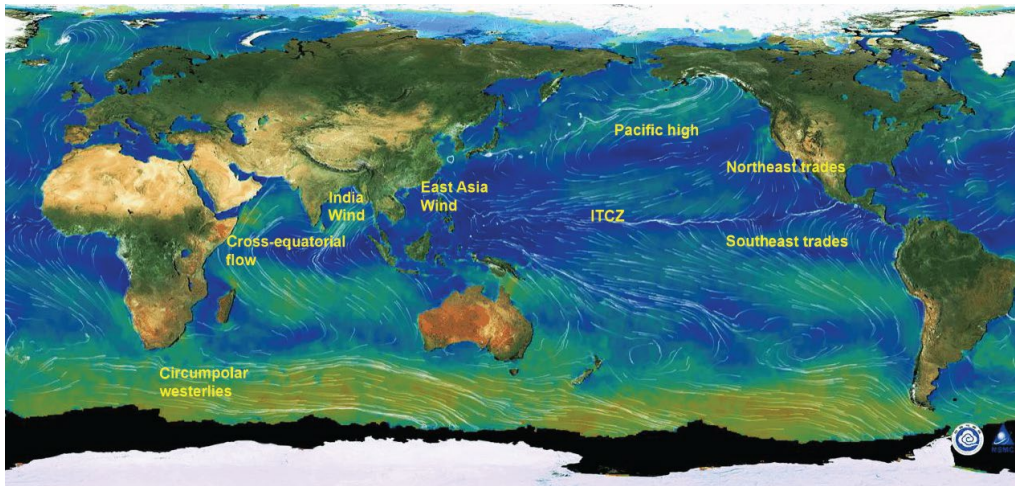
Thank you for your attention

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