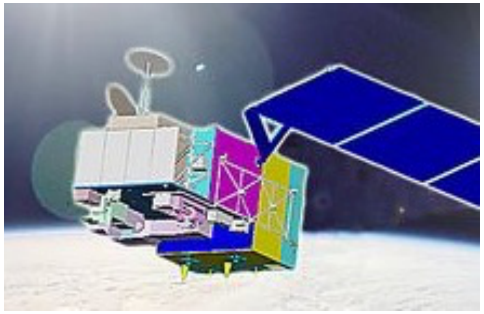
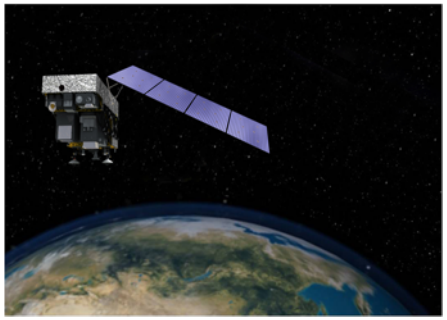
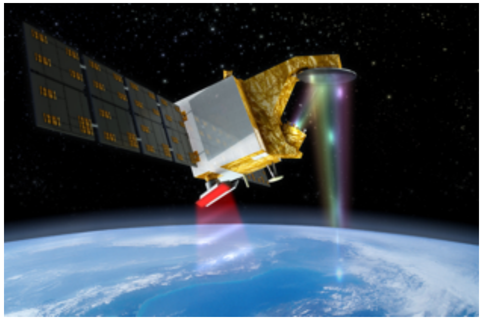
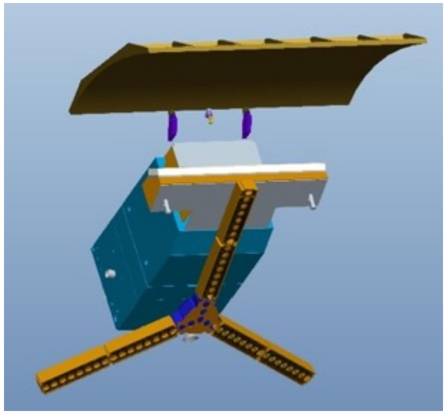
NSSC Update of EO Missions and CAL/VAL





Xiaolong DONG
National Space Science Center
Chinese Academy of Sciences
(NSSC,CAS)



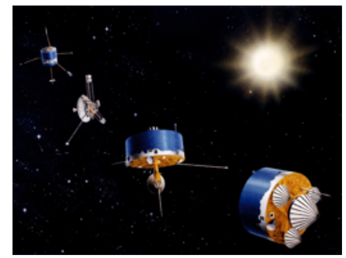


CEOS WGCV-47
Virtual meeting
July 14-17, 2020

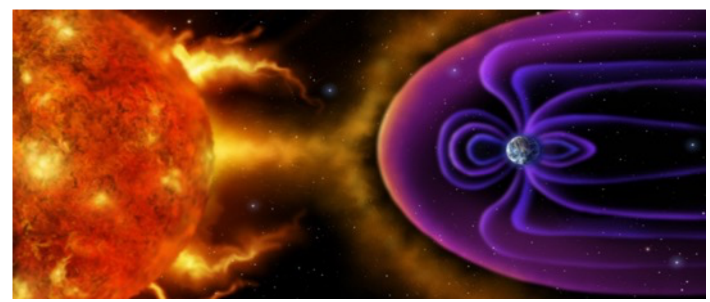
National Space Science Center, CAS

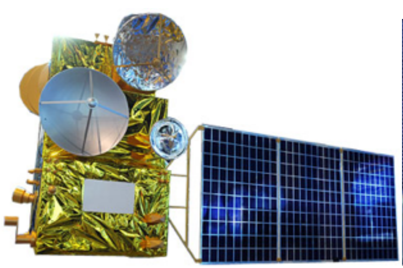
An institution for Science, Technology, and Engineering

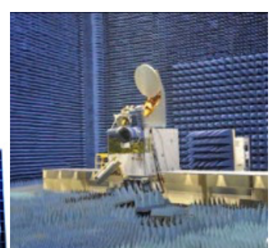
Planning, Development, Implementation and Operation of Space Science Programs

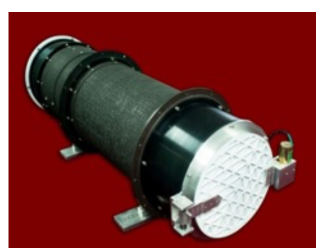


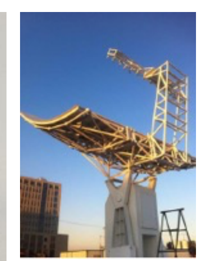
Research and Development of Space Science and Frontier Technologies

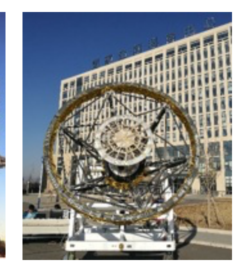












Remote Sensing Activities at NSSC

Oceanic Remote Sensing

- **Radar altimetry** for ocean surface topography
- **Radar scatterometry** for ocean surface vector wind and current
- **Microwave radiometry** for ocean surface temperature, salinity, wind and pressure
- **GNSS-R** for ocean surface wind and waves

Atmospheric Remote Sensing

- **Microwave radiometry** for atmospheric humidity/temperature profiling
- **Microwave/Millimeter wave radar** for cloud, precipitation and atmospheric wind
- **GNSS-Occultation** for atmospheric sounding
- **UV-Visible sounding** of ozone and aerosols

NSSC contributions to EO Satellite Missions: in Operation and Development

- HY-2 (Ocean Dynamic Environment Missions)
  - Dual-frequency radar altimeter (DFRA)
  - Atmospheric Correction MW Radiometer (ACMR)
  - Radar scatterometer (SCAT)
  - HY-2A (2011.8.16-) HY-2B (2018.10.25-) in operation; HY-2C to be launched in 2020
- CFOSAT (China-France Oceanographic Satellite)
  - Radar scatterometer (SCAT)
  - In operation, launched on Oct 29, 2018)
- COSM (Chinese Ocean Salinity Mission)
  - MICAP (Microwave Imager Combined Active Passive)
  - In preparation, to be kicked-off in 2020
- FY-3 (LEO meteorological Satellite)
  - Microwave Humidity/Temprature Sounder (MWHTS)
  - GNSS Occultation/Reflectrometry Sounder (GNOS)
  - Ozone total amount imager (TOA)
  - Atmospheric pollutant and aerosol imager (UV and visible spectrometer)
  - FY-3B, 3C, 3D in operation, FY-3E to be launched in 2020/2021
- GF-5 (Atmospheric Hyperspectral Satellite)
  - AAS (Absorbing Aerosol Sensor)
  - New payload for GF-5B, to be launched in 2020

Update of CAL/VAL Activities at NSSC

Oceanic Remote Sensing

- CFOSAT Radar Scatterometer Calibration
- HY-2B Radar Altimeter Calibration

Atmospheric Remote Sensing

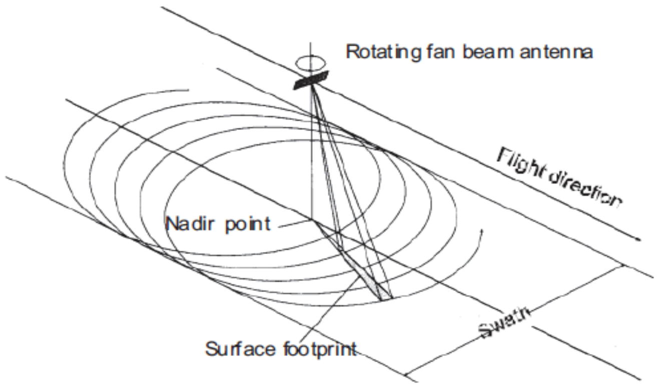
- FY-3D Microwave Humidity Temperature Sounder
- FY-3C/D GNSS Occultation Sounder
- FY-3C Total Ozone Unit
- FY-3E HRTOU (High-Resolution Total of Ozone Unit)

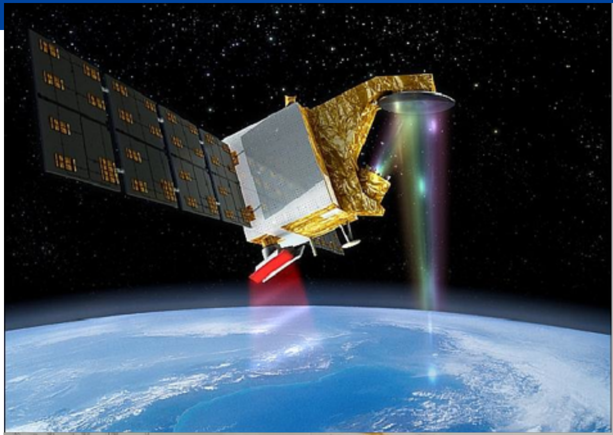
Recalibration/Processing

- Microwave radiometer data

CFOSAT Scatterometer

- **CFOSAT (Chinese-French Oceanic SATellite) is a China-France jointly developed oceanography satellite**
- **CFOSAT has two radar payload**
  - SCAT: a Ku-band rotating fan-beam radar scattermeter (SCAT) for ocean surface wind vector measurement;
  - SWIM: a Ku-band real aperture radar for measurement of directional ocean surface wave spectrum
- **Launched on October 29, 2019**

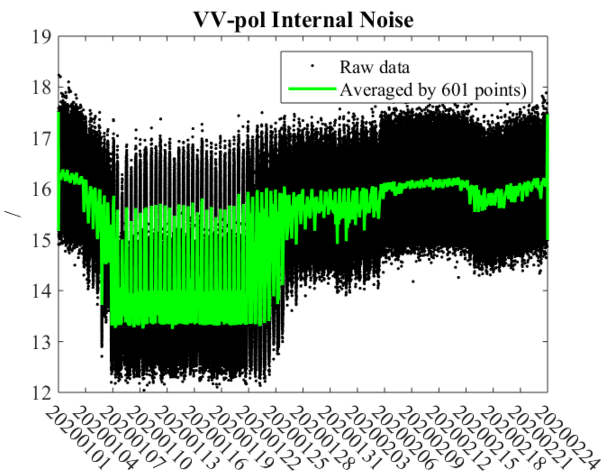


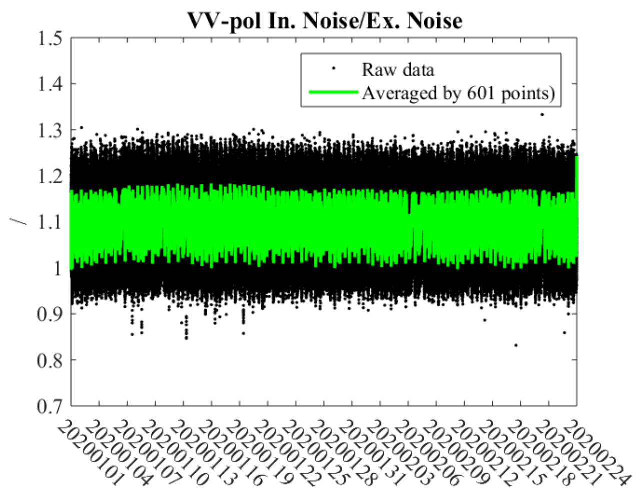


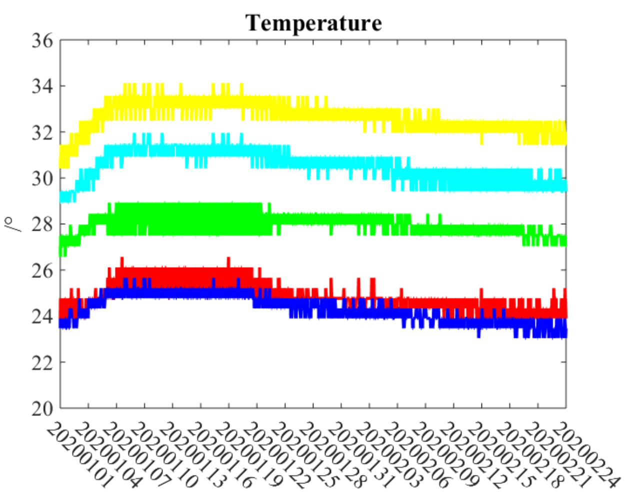
Update CFOSAT SCAT Calibration

- There was a system switch in on December 30, 2019, due to anomaly of TWTA;
- Calibration for the data of CFOSAT SCAT T/R subsystem after switch
  - Noise Calibration Factor Correction
  - NWP Ocean Calibration
- Ground Station Calibration Campaign

Signal stability monitoring

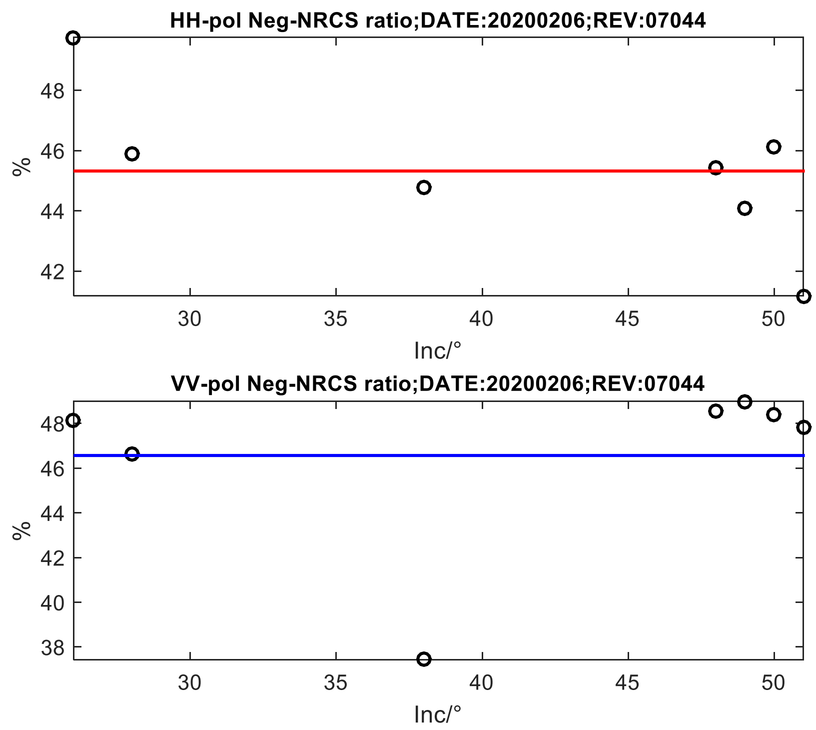






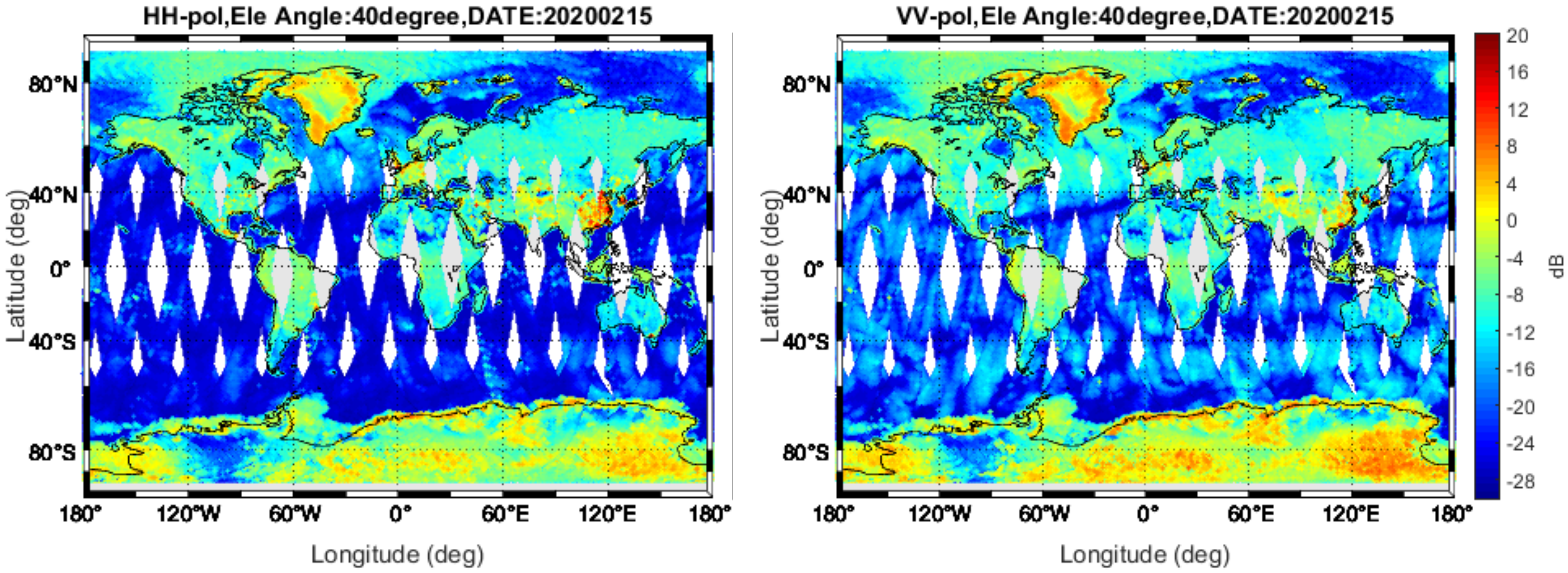
- At the initial stage of the switch to backup system, the received signal fluctuates obviously
- The temperature of the instrument also fluctuates at the initial stage of the switch to backup system
- The ratio of internal noise to external noise is not affected by signal fluctuation(ocean area), which means that SCAT works normally and the noise calibration can be carried out correctly

Noise Calibration Factor Correction



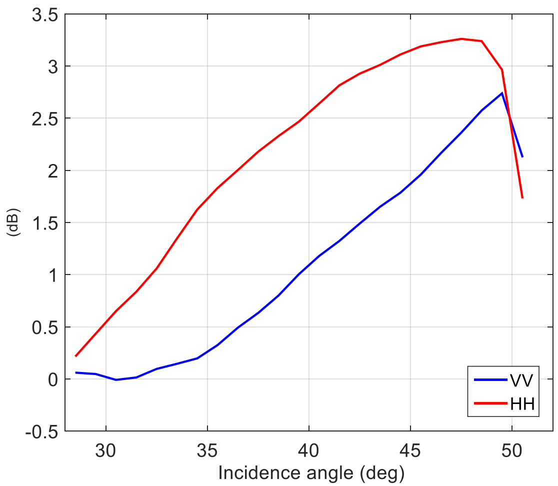
- **The noise should be exactly subtracted form the echo signals, usually the noise calibration factor should be corrected by real data**
- **The proportion of negative NRCS below 1m/s wind used for verification; theoretically, close to 50% should be reasonable(left figure).**

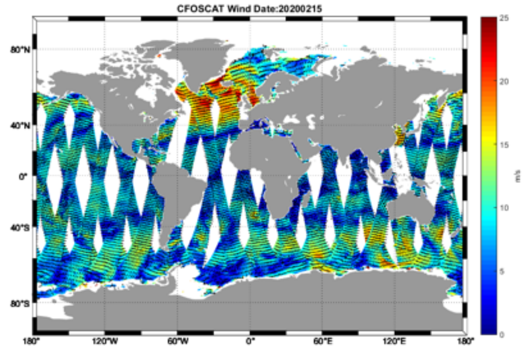
CFOSAT SCAT NRCS of One Day



NWP ocean calibration

- **The L1B processor is updated**
  - **The internal calibration is implemented for different scanning azimuth bins**
  - **The X-factor LUTs is updated**
  - **The input data testing and processing quality control is improved**
- **The NWP ocean calibration coefficients are be derived based on the new data and new noise calibration factor correction**
  - **Calibration is implemented on the Level 2A data**
  - **Corresponding to L1B processing, the scanning azimuth bins are considered respectively**



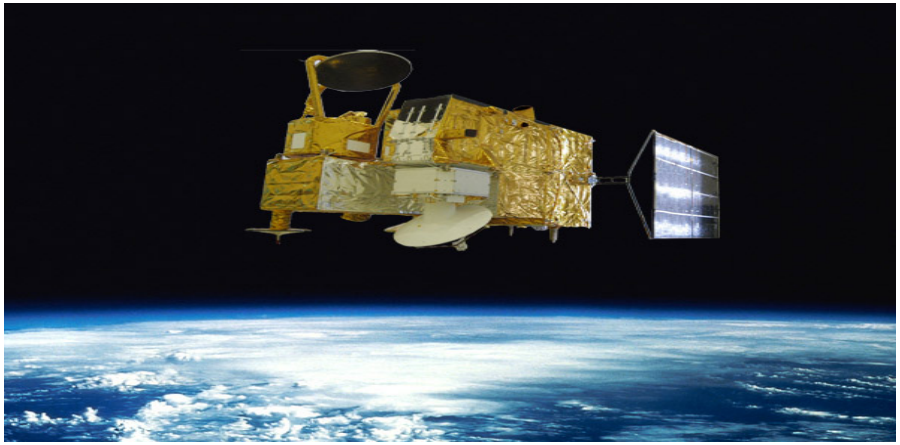


Ground Station Calibration Campaign

- **Experimental Time**
  - In June ~ July 2020, 35days
  - 6:00~8:30; 16:30~19:00
- **Experimental Site**
  - Xinbalhu banner, Inner Mongolia
  - Yiminhe Town, Inner Mongolia
  - Hailaer District, Inner Mongolia
- **1 transponder, 2 receiver, linearly deployed with 100km distance**
- **In-orbit antenna pattern test and absolute calibration**
- **The calibration experiment is on going in Inner Mongolia, China**

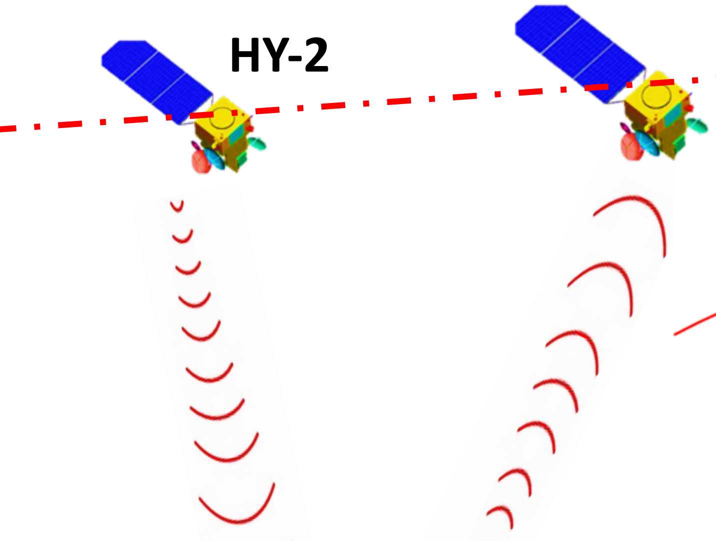
HY-2B Radar Altimeter

- HY-2 is oceanic dynamic environment measurement mission
- HY-2A and 2B, were launched on August 16th, 2011 and October 25th, 2018 respectively.
- The main payloads of HY-2 include:
    - Dual frequency radar altimeter
    - atmospheric correction microwave radiometer
    - Radar scatterometer
    - Microwave radiometer (Imager)

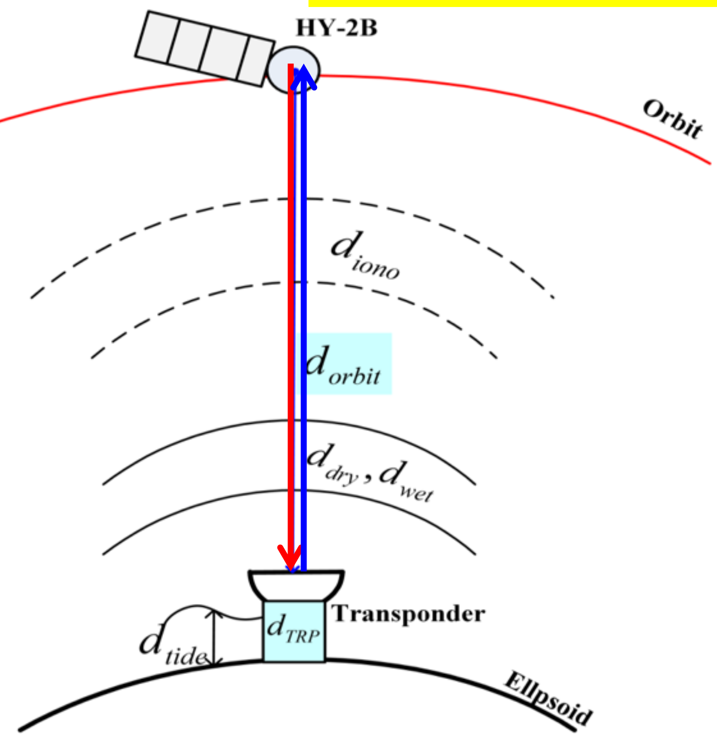


Orbit

- SSH Calibration: internal delay
- Clock Drift Correction



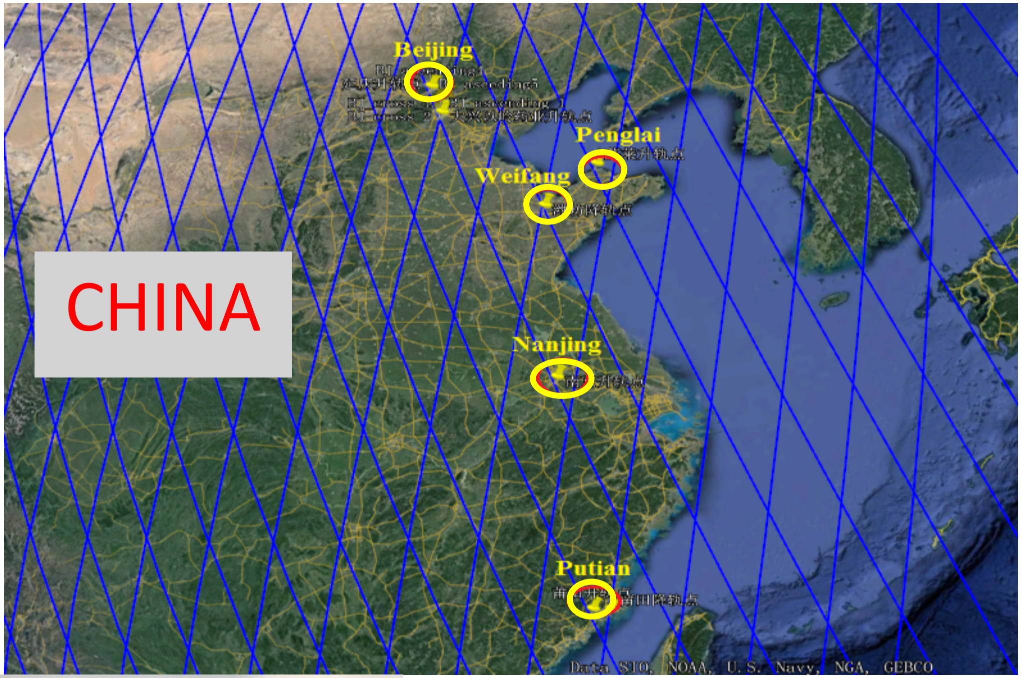
HY-2B Transponder



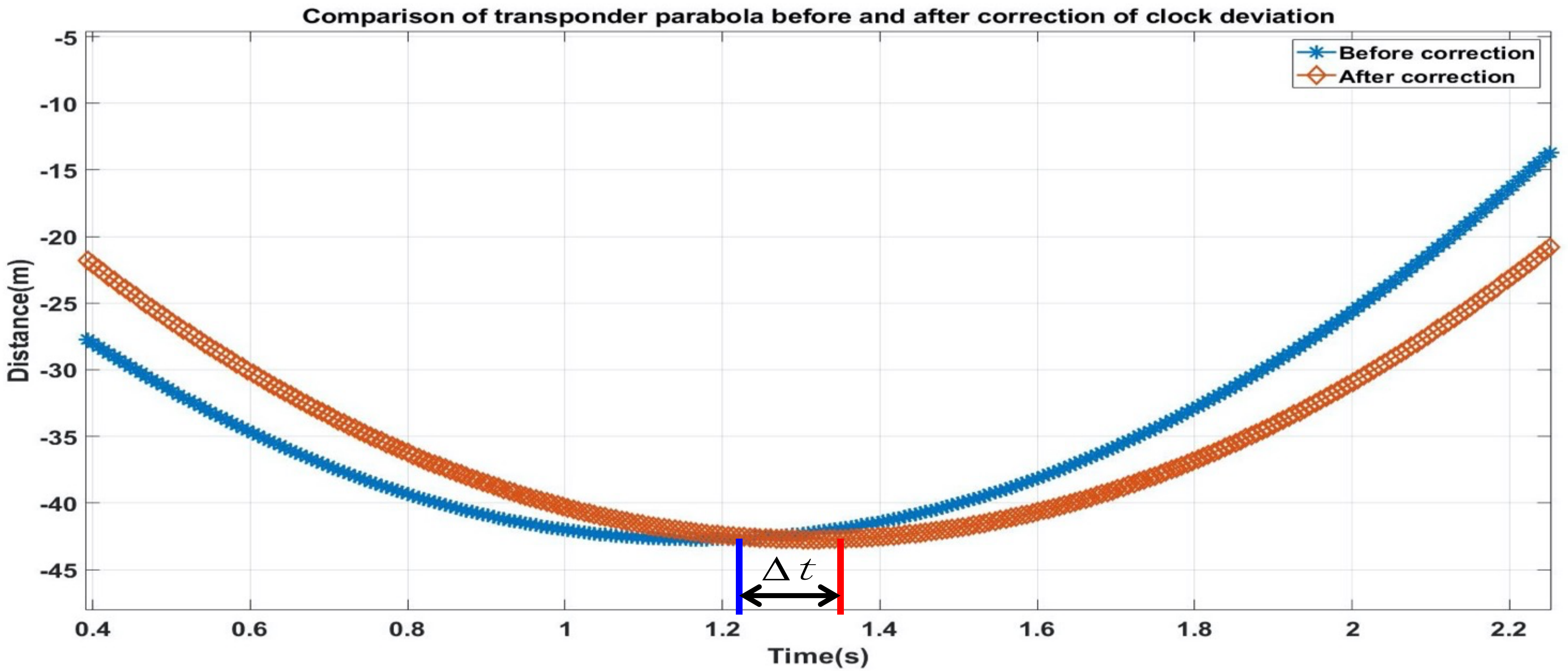
$$d_{sys} = \boxed{d_{alt}} + \boxed{d_{USO}}$$
$$= (d_{range} - d_{wet} - d_{dry} - d_{iono} - d_{tide} - \boxed{d_{TRP}}) - d_{orbit}$$

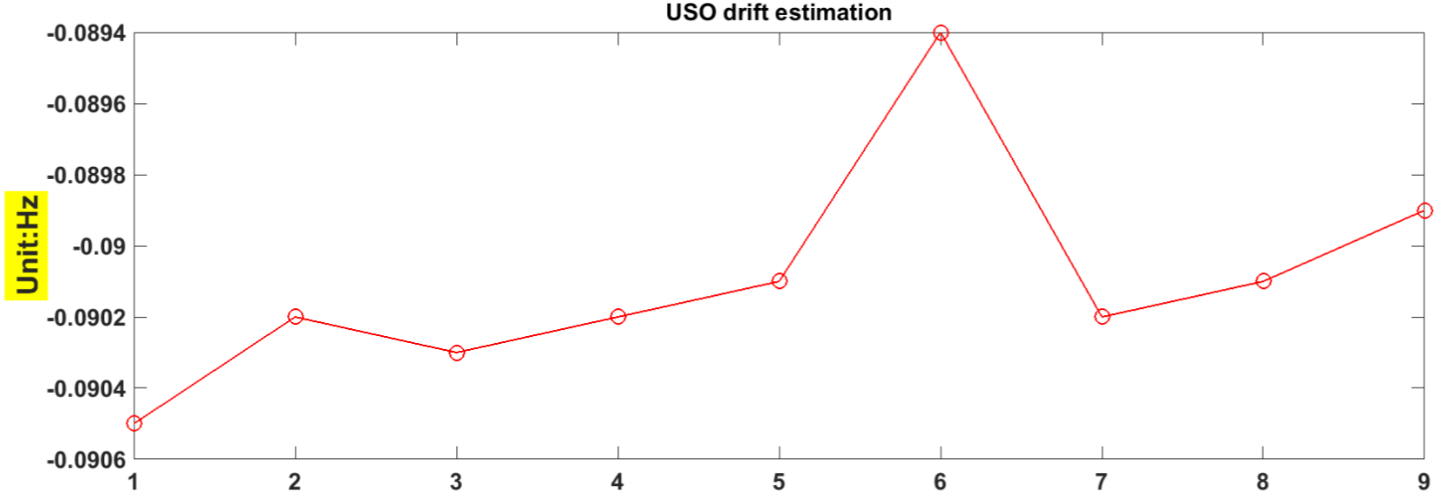
$$\boldsymbol{d_{TRP}} = \mathbf{18.81} + \textit{Preset signal delay}$$

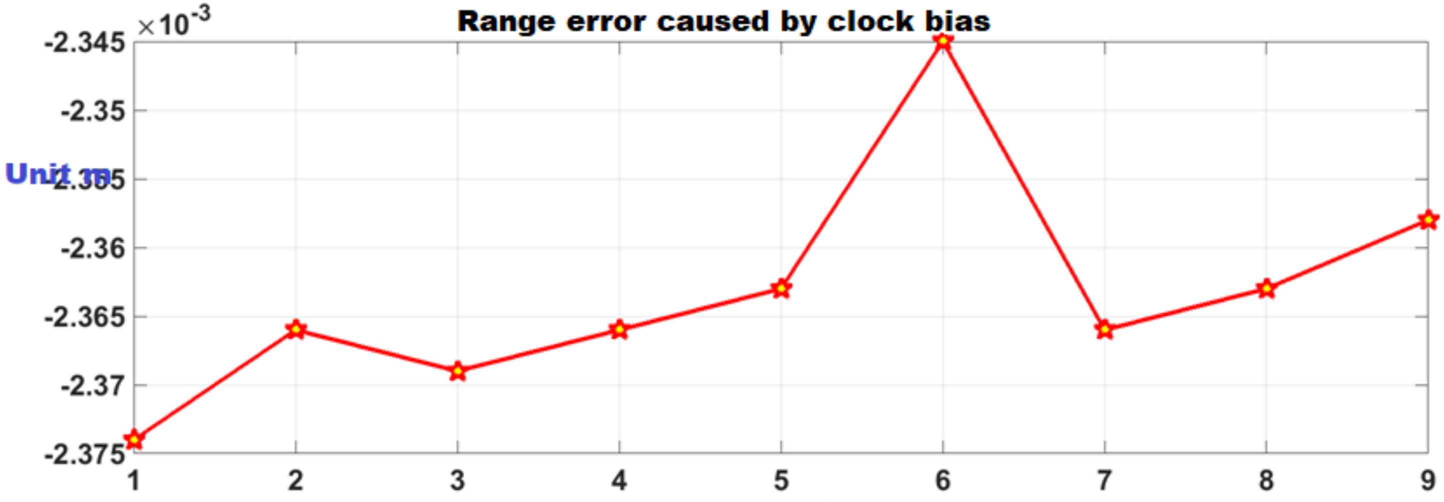
Calibration sites of HY-2B altimeter



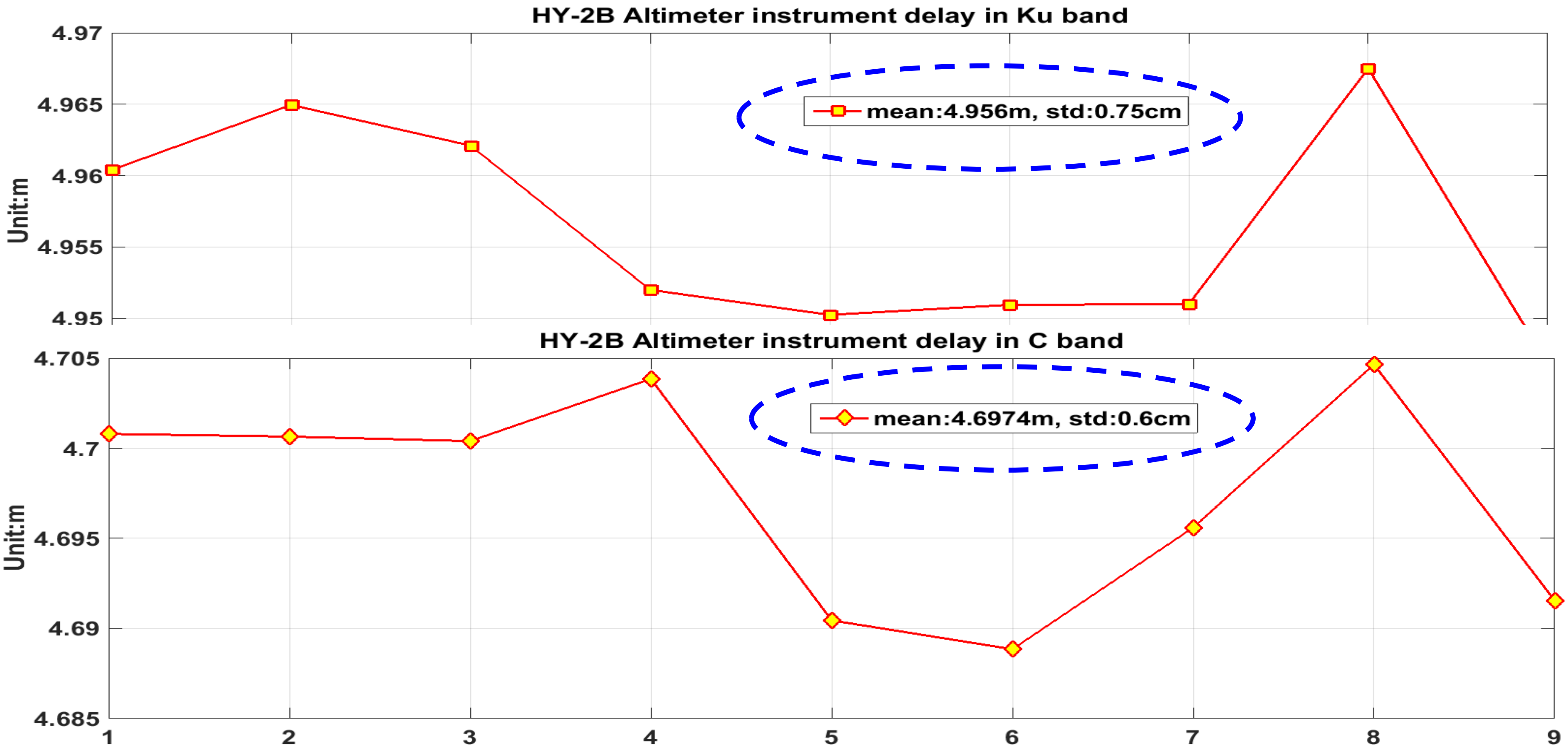
USO drift estimation

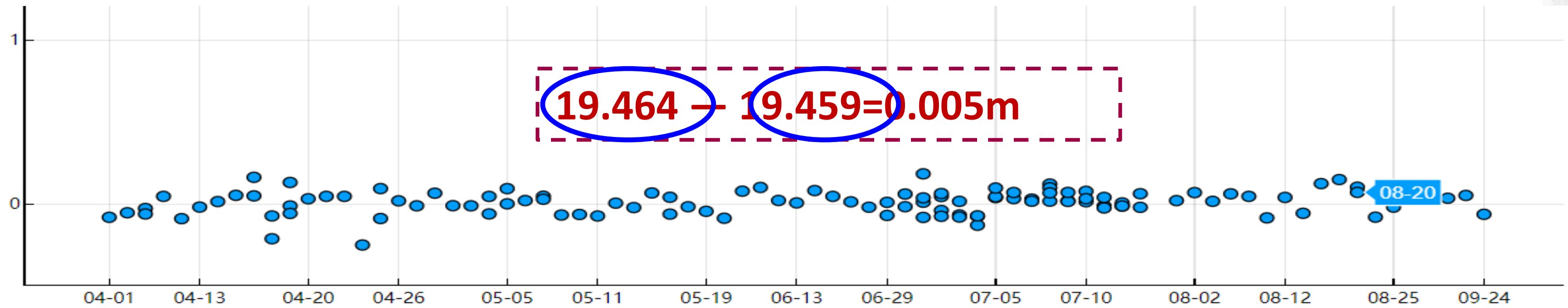



USO drift estimation
Unit:Hz
-0.0894
-0.0896
-0.0898
-0.09
-0.0902
-0.0904
-0.0906
1
2
3
4
5
6
7
8
9

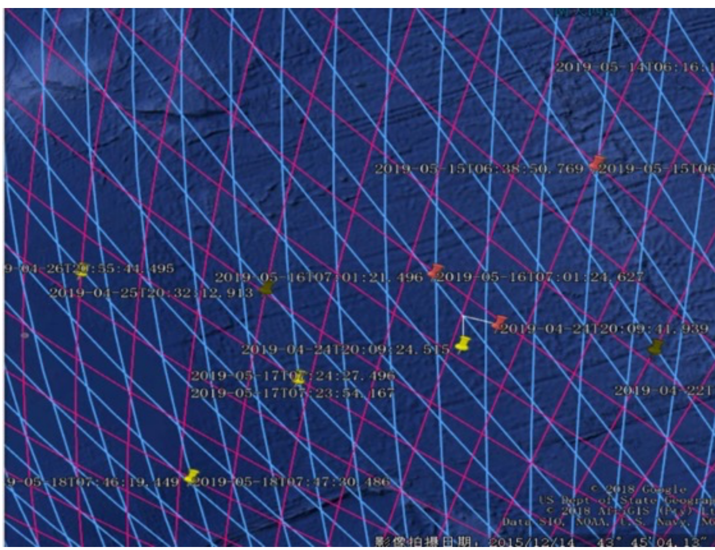

Range error caused by clock bias
×10-3
Unit m
-2.345
-2.35
-2.355
-2.36
-2.365
-2.37
-2.375
1
2
3
4
5
6
7
8
9

HY-2B Altimeter instrument delay





Corrected SSH difference between HY-2B and Jason3 on cross track points from April to September



GF-5B/AAS (Absorbing Aerosol Sensor

Index	Characteristics
Science Objects	absorbing aerosol
Spectral range/nm	340-550nm
Spectral resolution/nm	～2nm
Field of View	±57°
Spatial resolution	4km×4km（at nadir）
SNR	＞1000（10.89μW/cm^2 .sr.nm）
Wavelength calibration accuracy	0.1nm
Dynamic range	10^4
Stray light	10^{-4}
Working mode	Nadir radiance measurement Radiometric Calibration

The AAS is a UV/VIS spectrograph that combines high spatial resolution and lower spectral resolution together with daily global coverage

GF-5B will be launched in 2020.

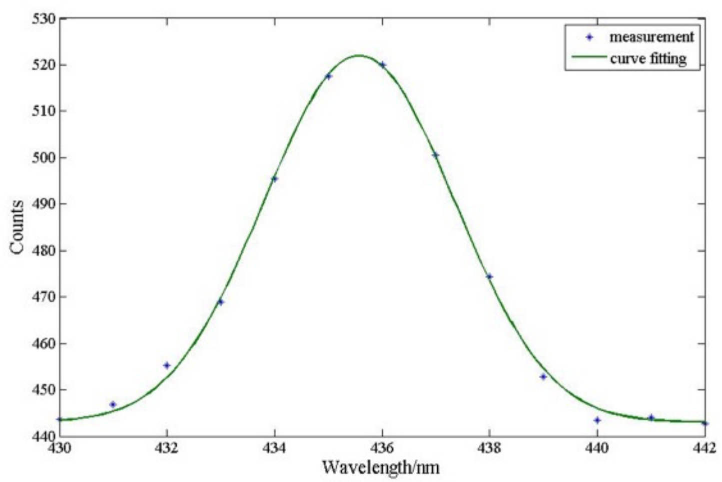
Prelaunch calibration of GF-5B/AAS

- **Wavelength Calibration Accuracy using 4 wavelengths of Hg light : <0.1 nm**

1. calibration equation derived from 3 wavelengths of Hg spectral lamp (365.0158 nm, 435.8335 nm and 546.0750)
2. calculating the fourth wavelength of Hg lamp (404.6565) using the calibration equation
3. comparison between actual wavelength and the calculated one

Number	Field location	Actual wavelength（nm）	Calculated wavelength(nm)	Deviation
1	-1	404.6565	404.6902	0.0337
2	-0.6	404.6565	404.6629	0.0064
3	-0.2	404.6565	404.6188	-0.0377
4	0	404.6565	404.6109	-0.0459
5	0.2	404.6565	404.6364	-0.0201
6	0.6	404.6565	404.605	-0.0515
7	1	404.6565	404.6565	-0.0203

Wavelength calibration results

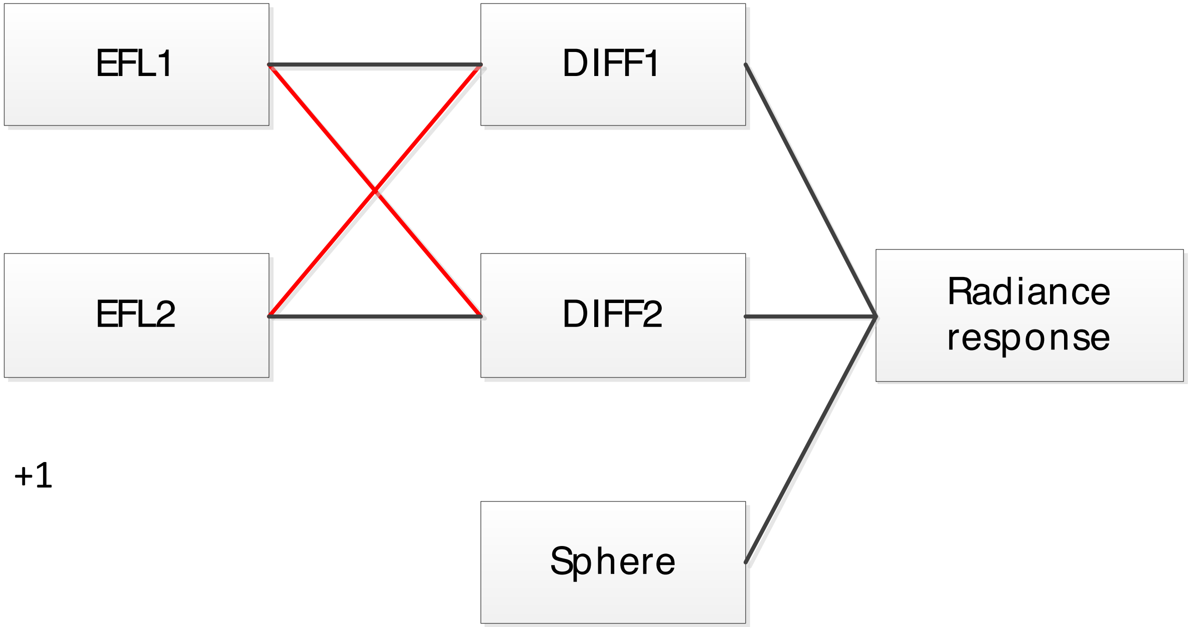


Wavelength curve fitting

Prelaunch calibration of GF-5B/AAS

- Radiance Calibration
- Irradiance Calibration
- BRDF

-1 0 +1

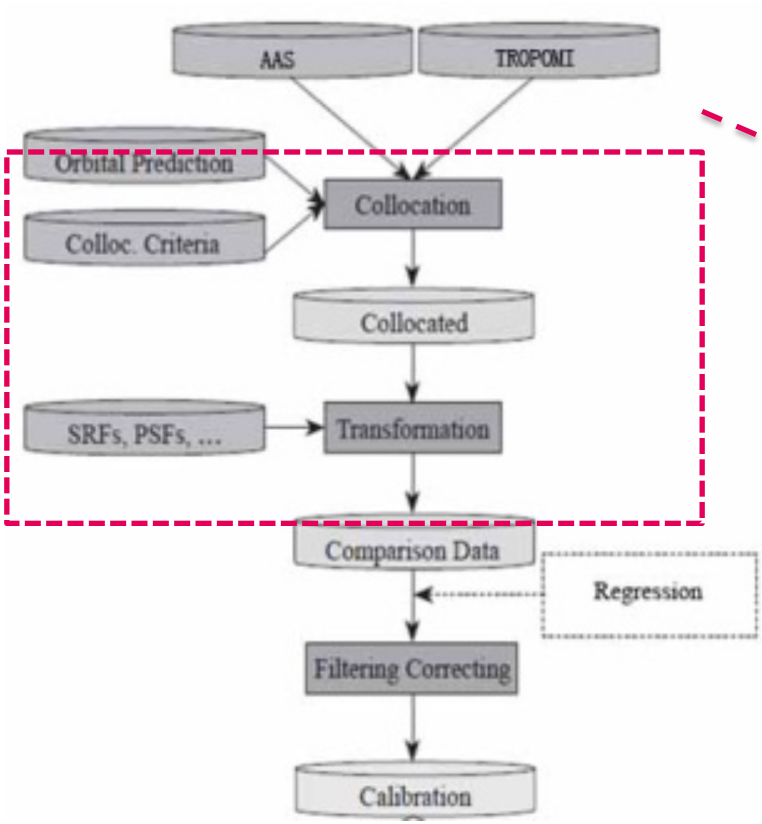


Radiation calibration

Multiple redundent ,independent calibration testing

Calibration of of GF-5B/AAS

➤ **Inter-calibration of radiance between AAS and TROPOMI**



(1) Orbit Forecast (SGP): < 5 min — Satellite

⬇

(2) Temporally Concurrent: <5 min — Pixel observation time

⬇

(3) Location Matching: <25 km — Pixel center

⬇

(4) Geometrically Aligned — Viewing geometry

⬇

(5) Spatial Collocated (Uniformity estimation)

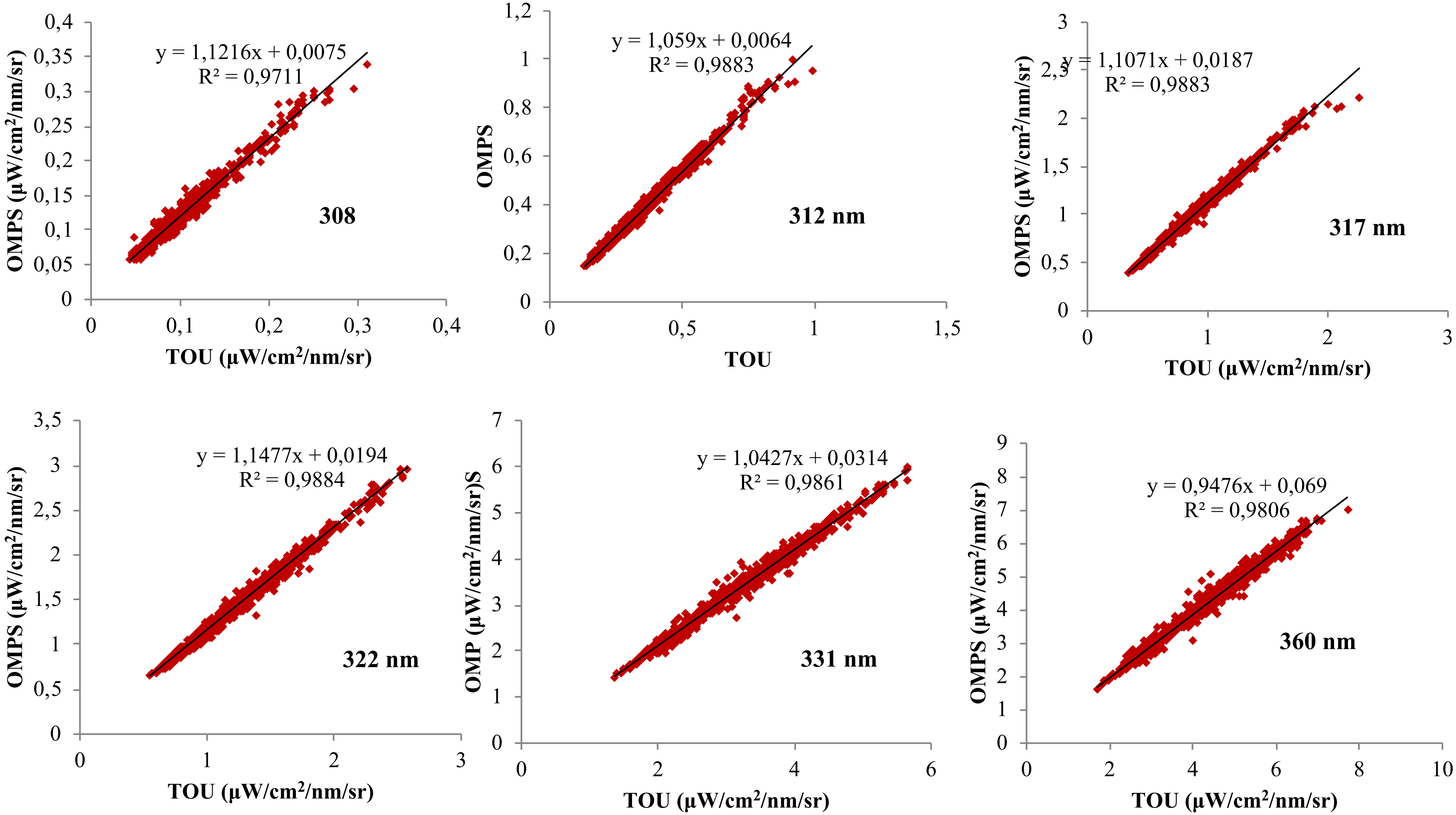
⬇

(6) Spectral Consistent — Convolution

The Methodology is similar to that of FY-3/TOU , Inter-calibration and Validation will completed by comparing between AAS and TropOMI/OMPS/UVNS

Calibration of of GF-5B/AAS

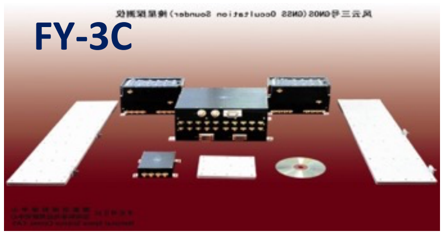
➢ **A case of inter-calibration of L1b radiance between FY-3A/TOU and NPP OMPS**

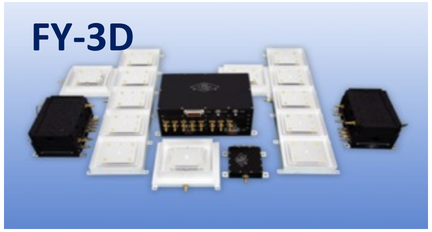


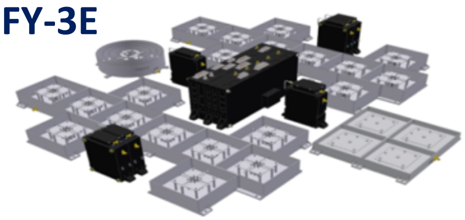
FY3/GNOS & GNOS II

GNOS
(GNss Occultation Sounder)

GNOS II
(GNss Occultation Sounder II)







FY-3F/R/G

. . .

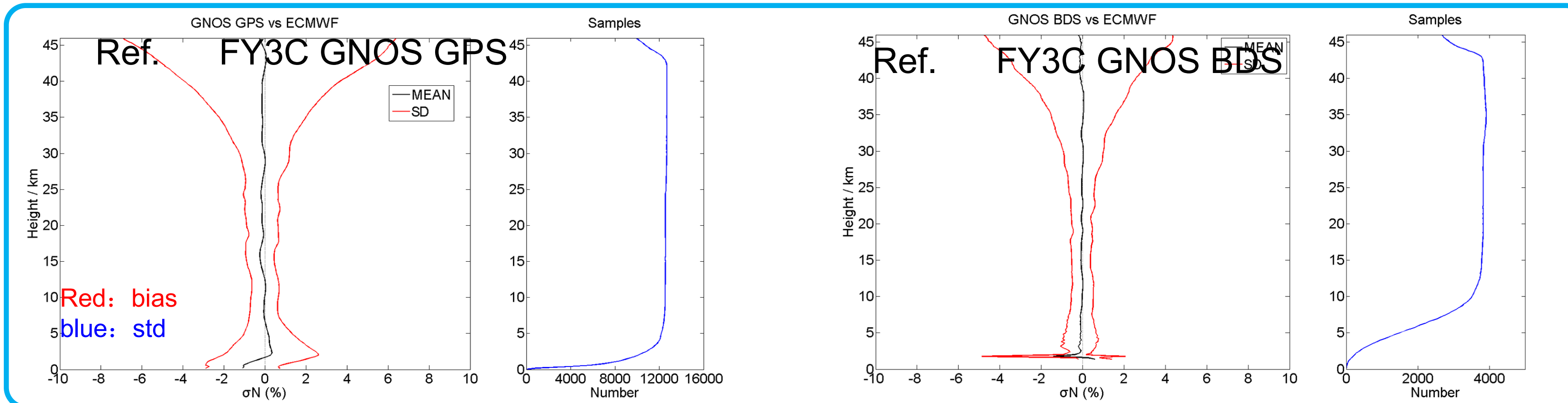
FY-3C GNOS has been launched on Sep. 23rd, 2013, which can receive both GPS and BDS signals.

FY-3D GNOS has been launched on Nov. 11st 2017, it is testing in-orbit.

FY-3E GNOS II plan to be launched in 2021, and its will integrate the GNSS RO and GNSS-R techniques in one payload.

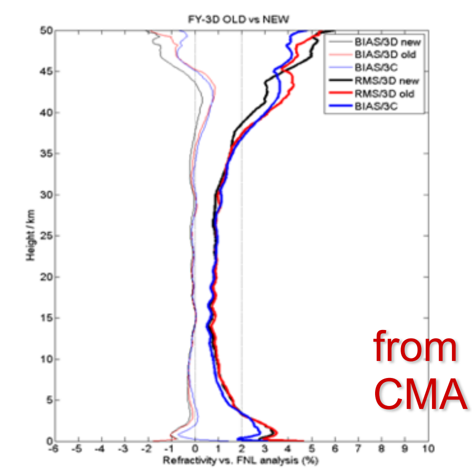
The following FY-3 satellites will carry GNOS II as a key payload...

FY3-C/D GNOS in-orbit validation (Atmospheric occultation products)



within 200km，±1 h(time)

5-25km	Ref.（%）	
	Bias	std
GNOS-GPS vs ECMWF	-0.09	0.75
GNOS-BDS vs ECMWF	-0.04	0.53
COSMIC vs ECMWF	-0.12	0.71

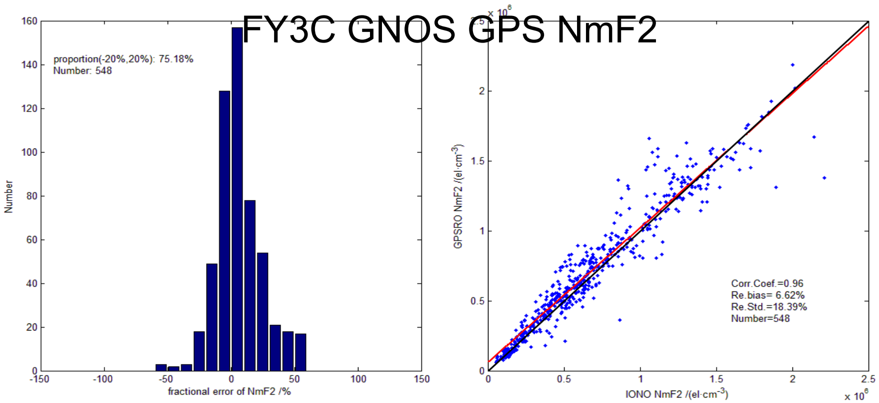


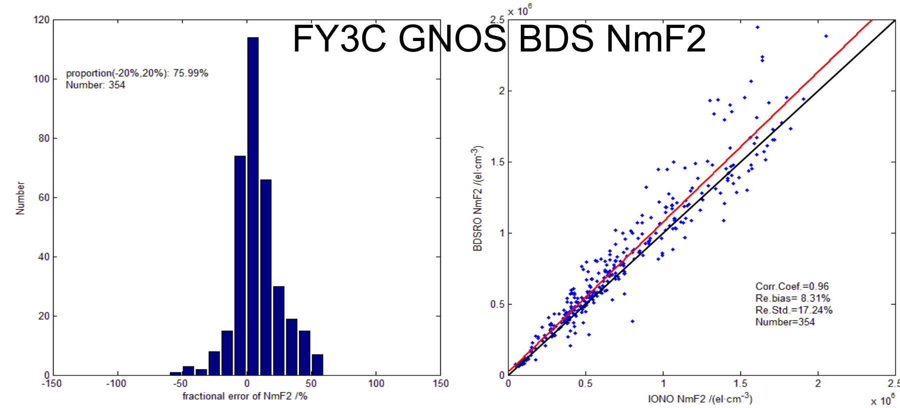
from CMA

FY3D results of in-orbit testing are consistent with those of FY3C

Liao Mi,et al. Preliminary validation of the refractivity from the new radio occultation sounder GNOS/FY-3C. Atmos. Meas. Tech, 9,781-792,2016

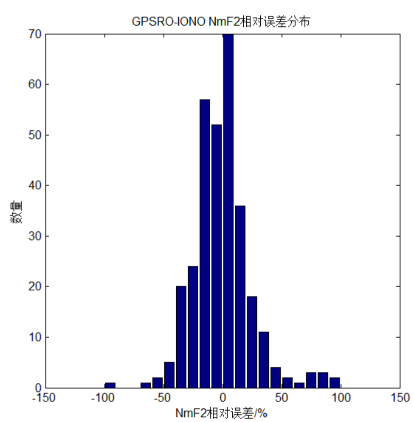
FY3-C/D GNOS in-orbit validation (Ionosphere occultation products)

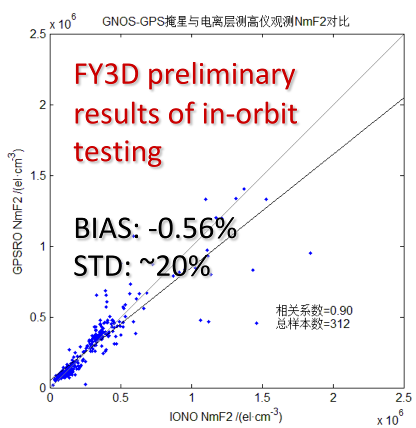


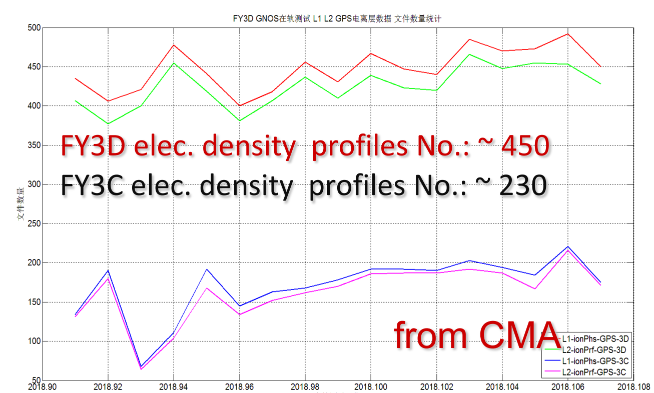


Elec. Density peak	Bias	Std	correlation	Sample No.
NmF2(GPS)	6.62%	18.39%	0.96	548
NmF2(BDS)	8.31%	17.24%	0.96	354

Yang G L, Sun Y Q, Bai W H, et al. Validation results of NmF2 and hmF2 derived from ionospheric density profiles of GNOS on FY-3C satellite[J]. Science China Technological Sciences, 2018:1-12.





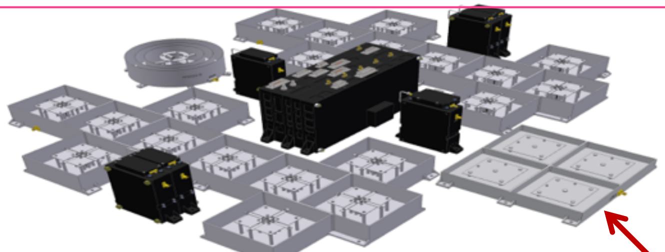


Overview of FY3-E GNOS II' s GNSS-R function

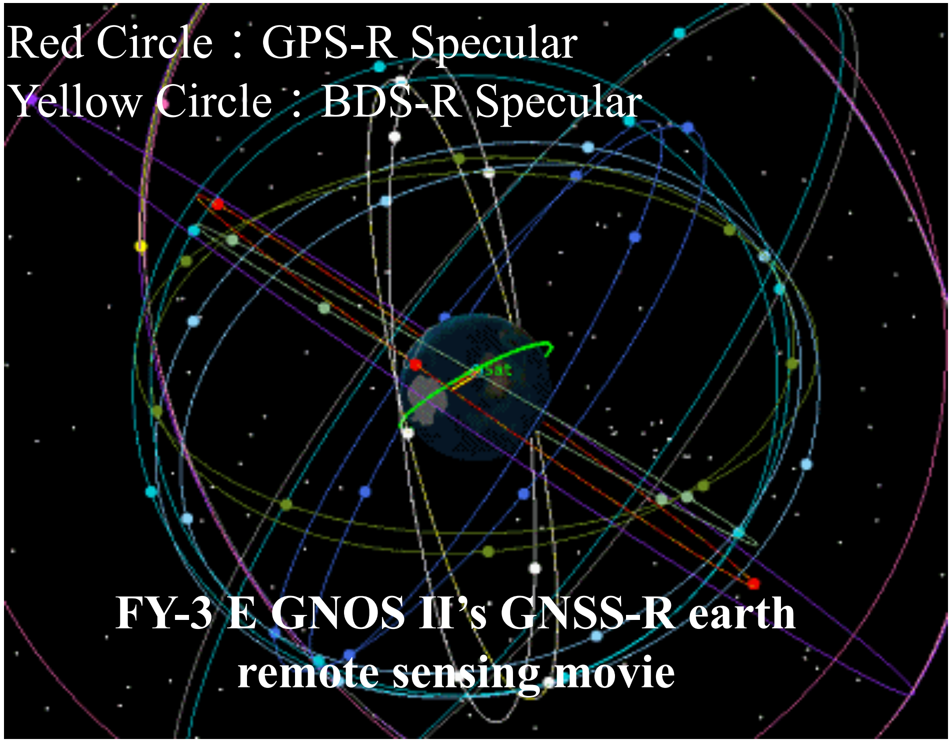
FY3-E GNOS Ⅱ, developed by NSSC, **is a kind of new GNSS remote sensing receiver, possessing both GNSS occultation and GNSS reflection functions**. It will be launched in the end of year 2020 as scheduled. The satellite orbit altitude is 833km, and the incline angle is 98.8°。

Primary GNSS-R product:
Sea surface wind speed (2m/s or 10%)

Main characters:
✓Provide both BDS-R and GPS-R products
✓Cooperate with a microwave scatterometer fitted on the same satellite



FY3-E GNOS Ⅱ and its GNSS-R antenna



FY-3 E GNOS II's GNSS-R earth remote sensing movie

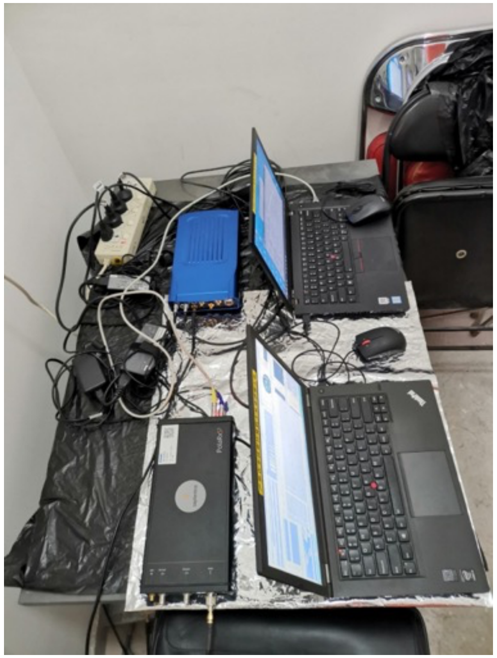
FY3-E GNOS II’ s GNSS-R Prelaunch calibration

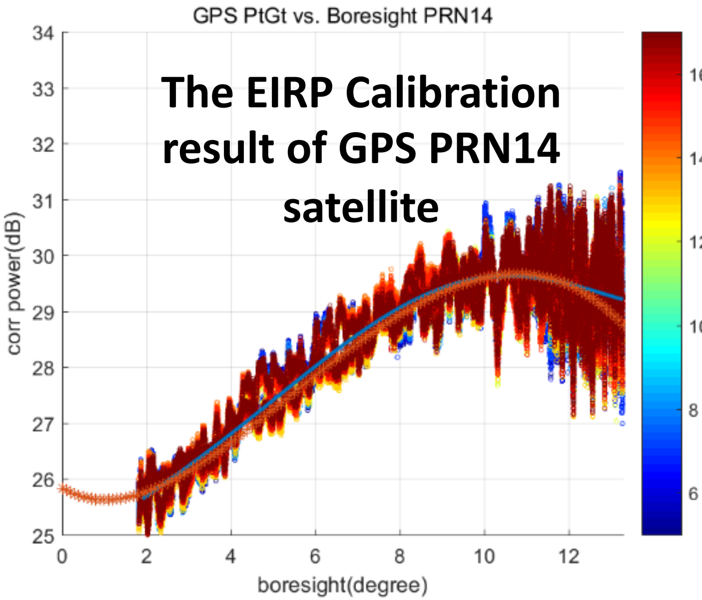
GNSS satellite calibration

All BDS and GPS satellites’ EIRP was calibrated utilizing a special GNSS Receivers on the ground.

$$EIRP = P_t G_t$$

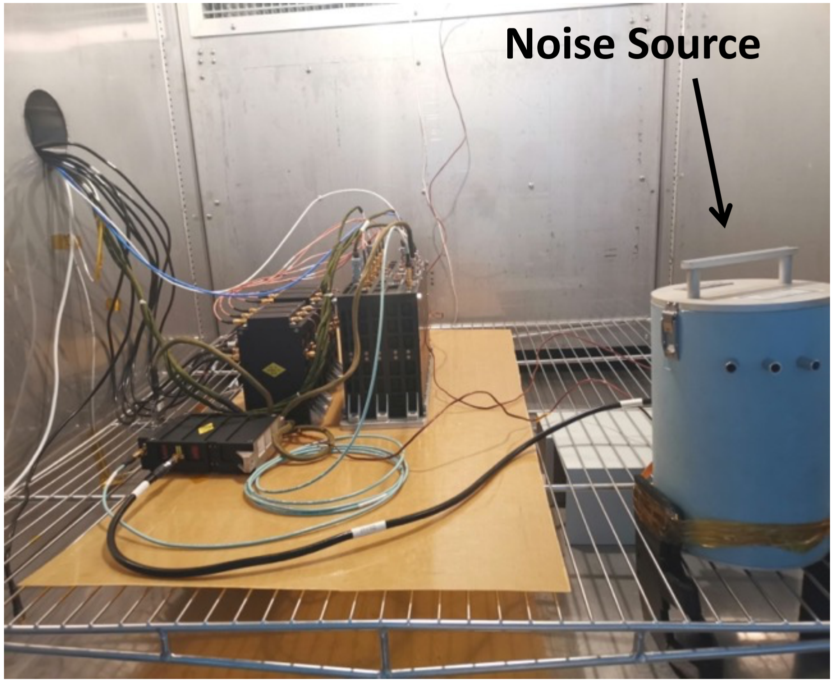
P_t and G_t is the GNSS signals’ radiation power and the radiation antenna’s Gain，most of which is unknown and some of which are changed from time to time.



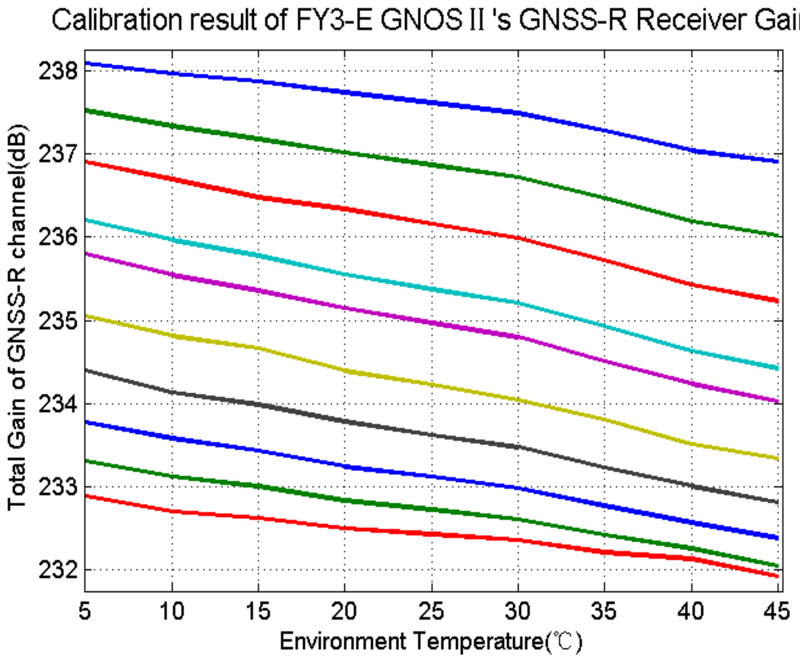


FY3-E GNOS II’ s GNSS-R Prelaunch calibration

GNOS II Receiver calibration



High and Low temperature Noise Source calibration for GNOS II



Calibration result of GNSS-R channel gain

(different line in the figure corresponding to different receiver work state)

FY3-E GNOS II’ s GNSS-R air-borne experiment

Time: 18- 25 october,2018

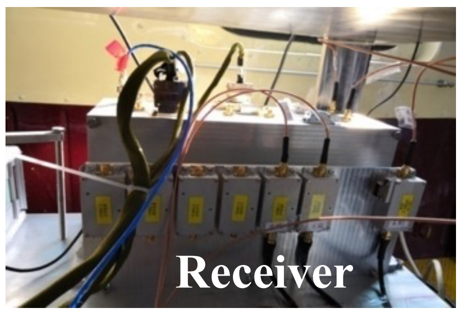
Place: Bohai Sea, China

Flight altitude: 3000 m

Flight times: 4

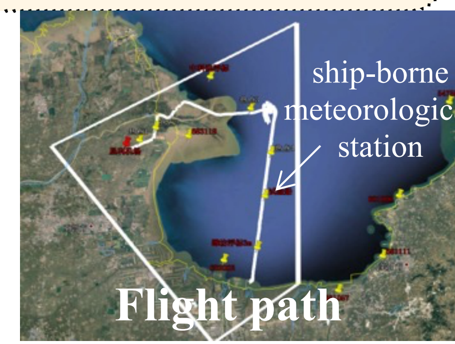
Flight Number	Time	Sea surface wind speed ranges (m/s)
1	Am,18,Oct,2018	5.6～9.3
2	Am,18,Oct,2018	1.9～5.8
3	Am,25,Oct,2018	6.4～9.9
4	Pm,25,Oct,2018	7.1～9.8

Y-5

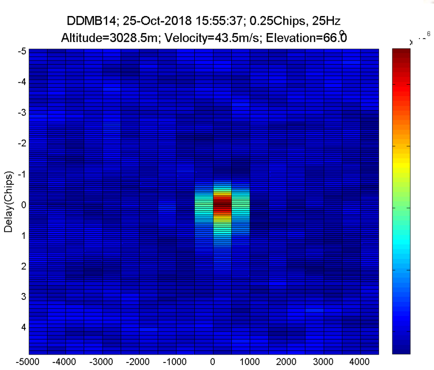


Receiver

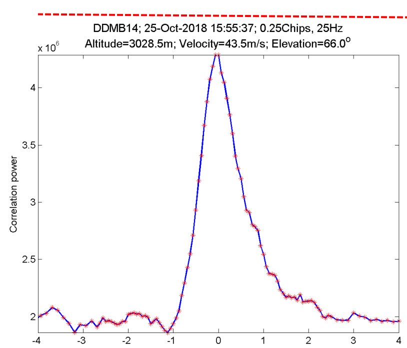
GNSS-R antenna



Flight path

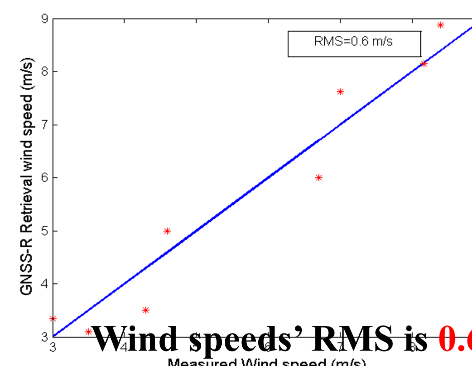


BDS-R DDM



BDS-R DM

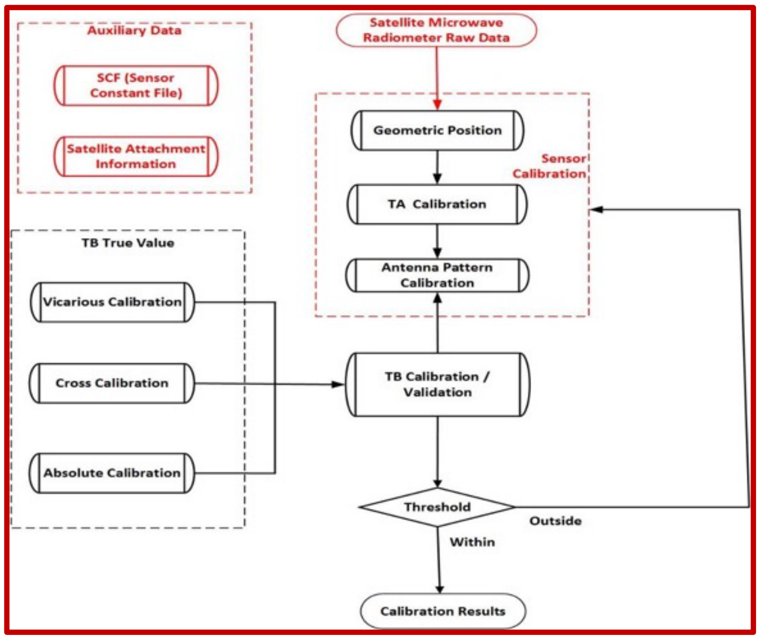
ship-borne meteorological station



Wind speeds’ RMS is 0.6 m/s (2m/s ～10m/s)

Microwave Radiometer Calibration update

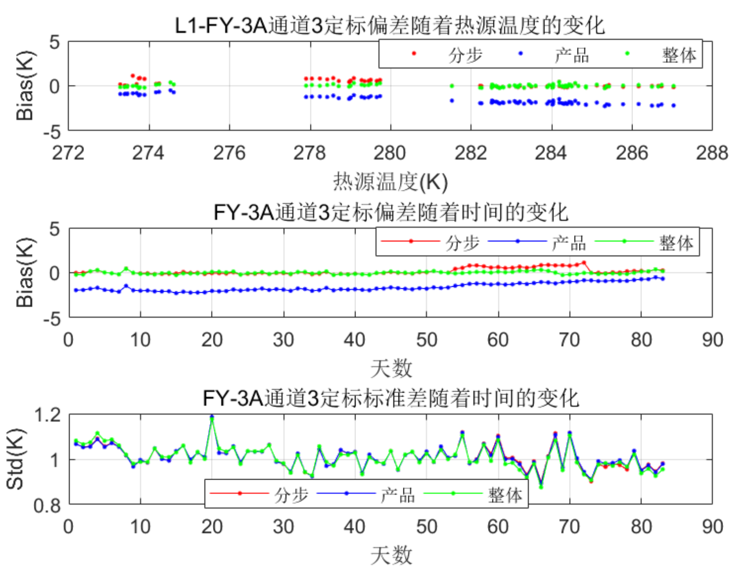
ISO standard study on Cal/Val of space-borne microwave radiometer

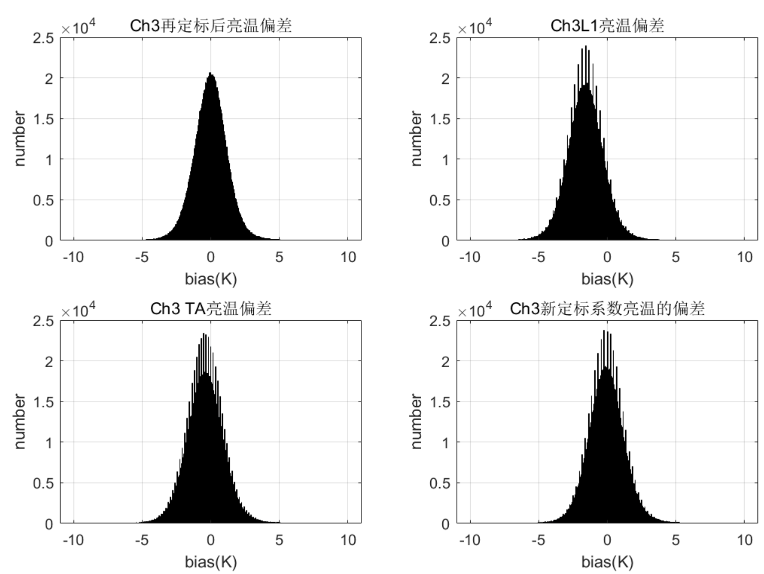


Date	Stage	Activity
2019-03-05	10.00	Proposal for new project registered
2019-03-06	10.20	New project ballot initiated
2019-07-08	10.99	New project approved
2019-07-08	20.20	CD study/ballot initiated
2019-10-31	20.20	WD1 submitted
2020-04-15	20.20	WD2 submitted
2021-06	40.00	DTS to be submitted
2021-12	50.00	FDTS to be submitted
2022-07-04 ~ 2023-01-05	60.60	International Standard published limit date

Historical data re-calibration of series MWHS on FY-3 satellites

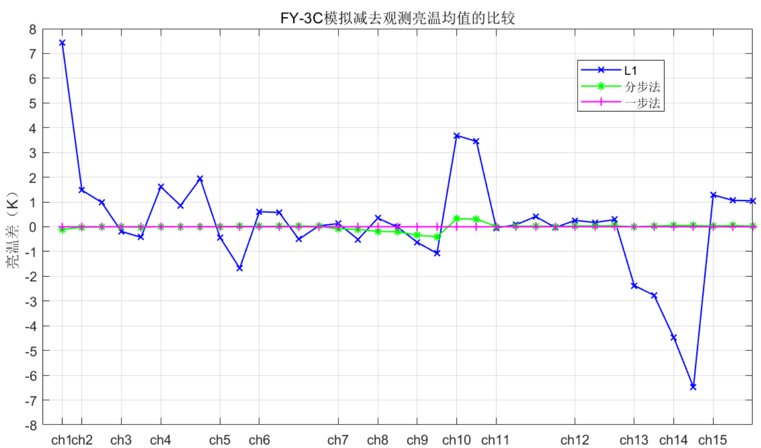
- ✓Using different methods for calibrate the inconsistency with time
- ✓FY-3A:2008.7-2014.3

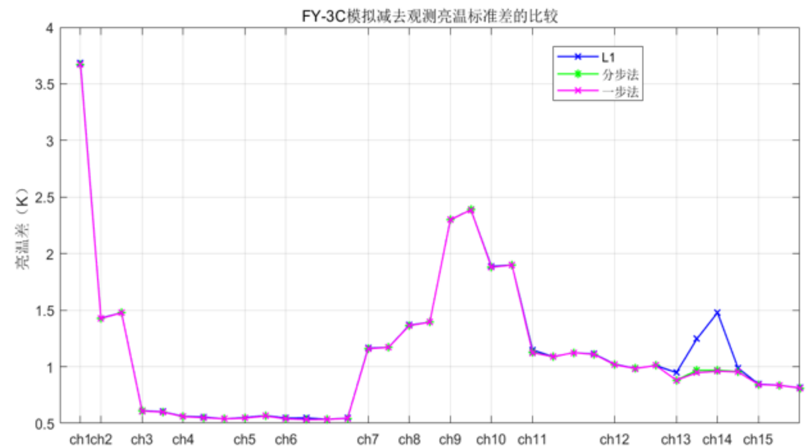


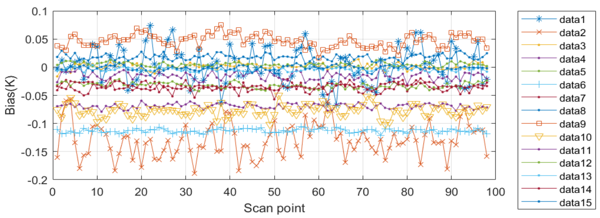


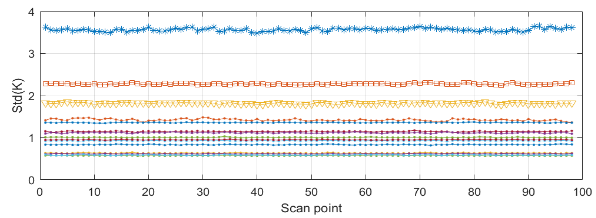
Historical data re-calibration of series MWHS on FY-3 satellites

✓FY-3C:2013.11-2016.12

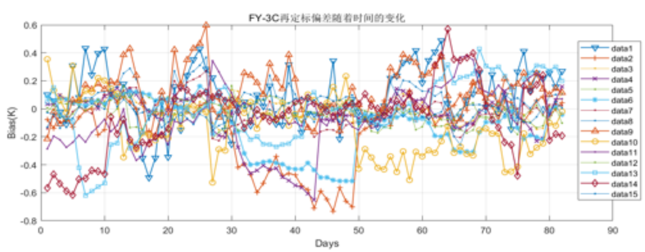


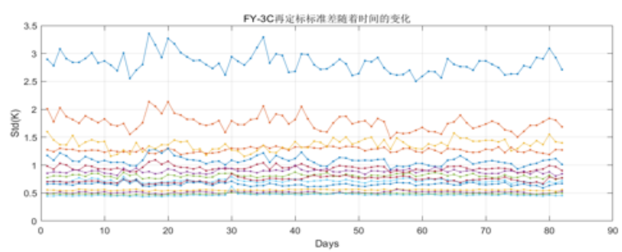




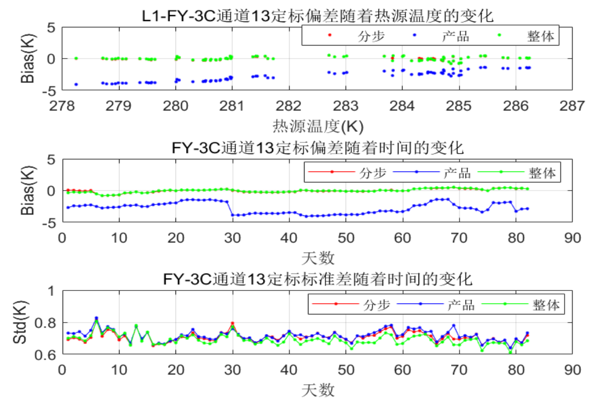


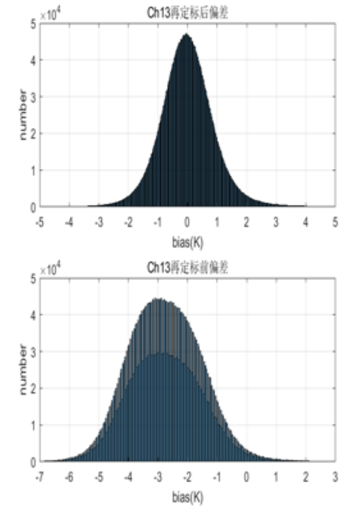
Bias and STD & 98 scan pionts



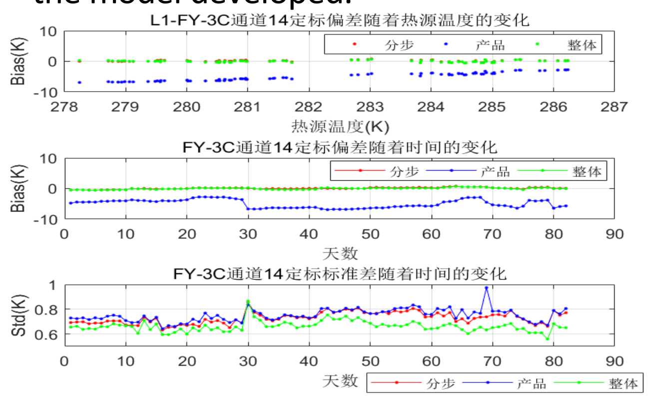


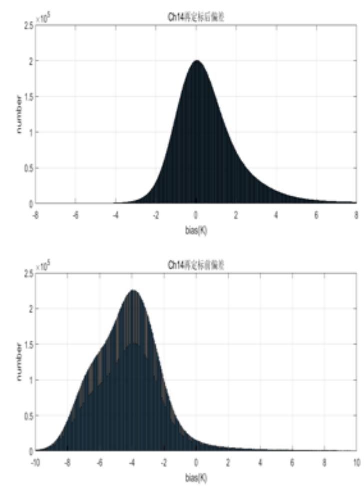
Bias and STD & 82 days from 2013.11 to 2016.12



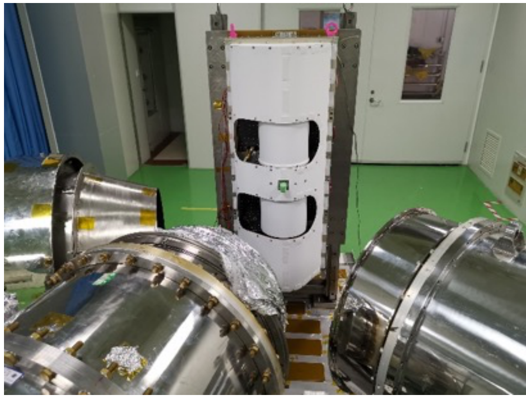


The biases for 13 and 14 channels are vary during those days, which were corrected by the model developed.



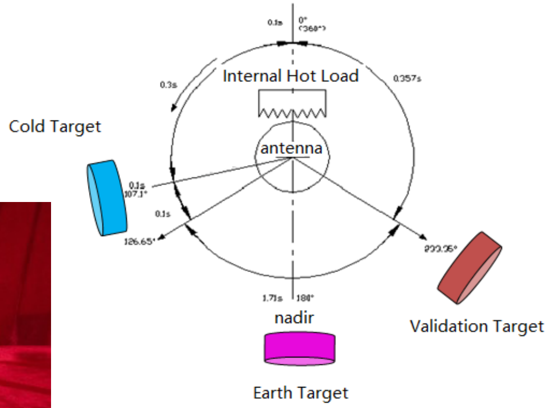


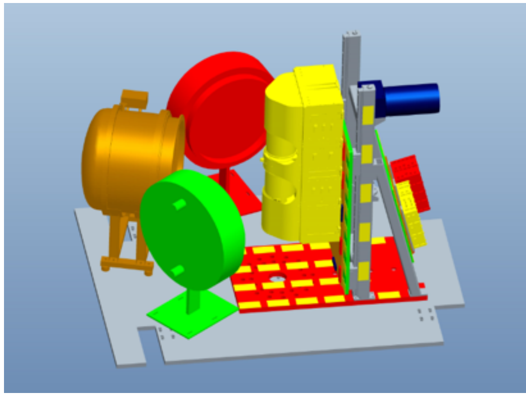
FY-3E MWHTS/MWHS-II prelaunch calibration finished at the end of 2019



- The first tempt for validating the calibration results by an independent target—Validation Target.
- The results from the tests found the discrepancies

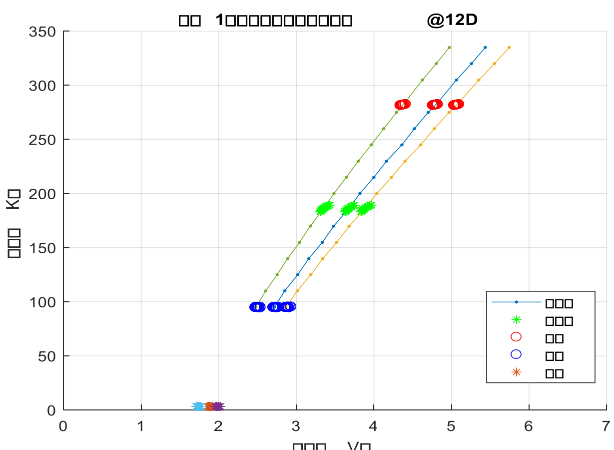
among the three targets and the internal hot load of MWHS-II.



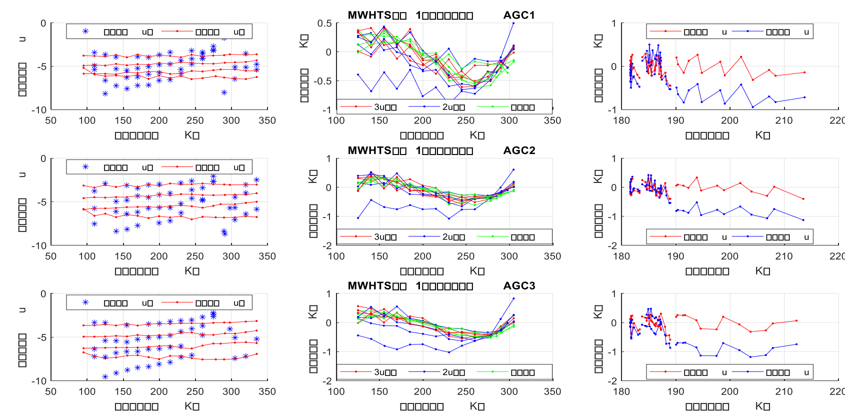


Initial Results from FY-3E prelaunch calibration

- **Nonlinearity coefficients found in prelaunch calibration by the differences between TB of the Earth target to the TB from two-point calibration would result in biases of onboard calibration by cold space and internal hot load.**



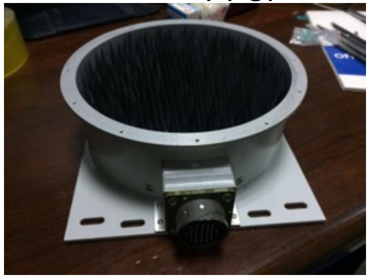
Three lines refer to three calibration cycles with different AGCs. The voltage circles of the cold space were extrapolated by three points of the hot load, validation target and cold target.

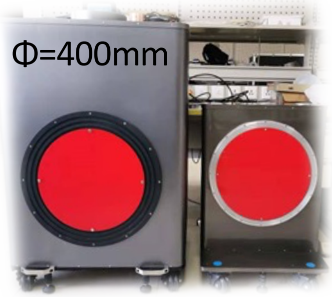


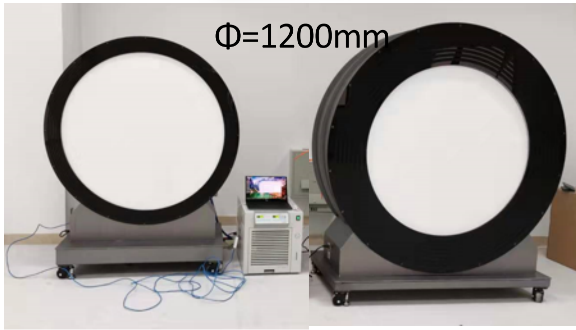
Nonlinearity u are different from 2-point and 3-point, and 2-point u will bring bigger calibration residues when them are used onboard calibration.

MWR Calibration facility development for calibration transfer

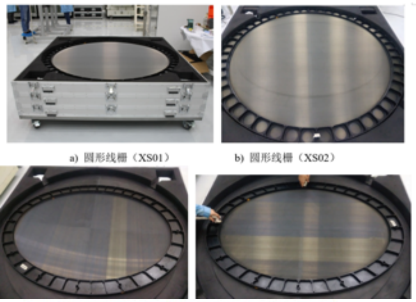
FY-3F



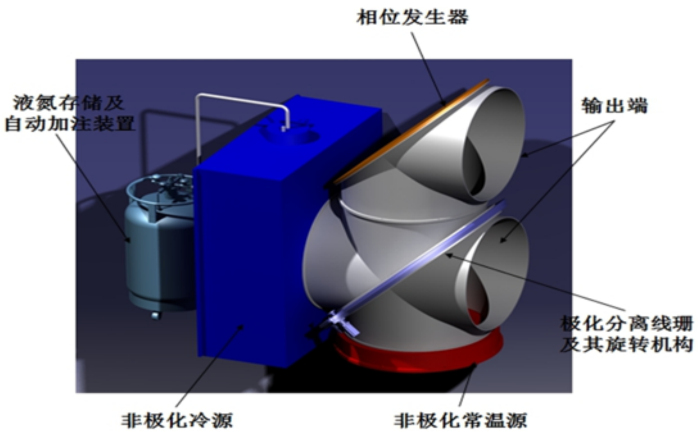




- **Large aperture calibration targets**



C-W band
Transitivity
>0.99



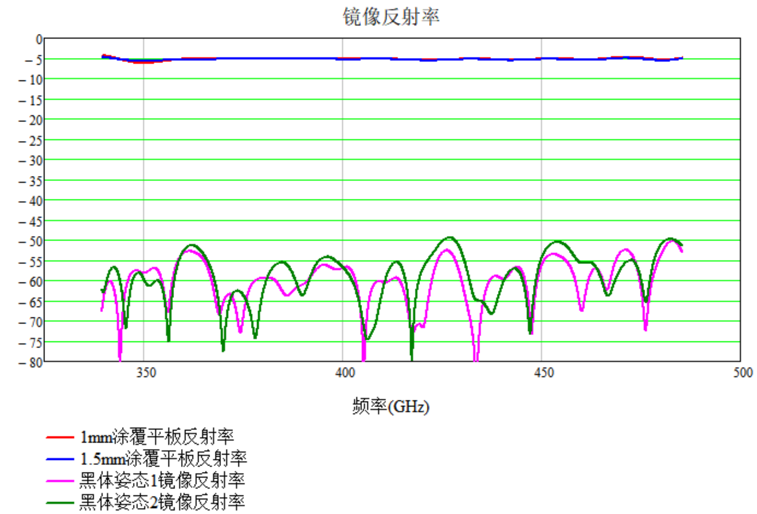
Full-polarimetric microwave target
with aperture of 1000mm

Polarizer grid
With aperture from 50 to 1800 mm

Emissivity measurement system from 50 to 500GHz

发射率测量（散射系数C_g=2）		
频率(GHz)	实测值	测量不确定度$U(k=2)$
10.7	0.9999	0.0020
18.7	0.9999	0.0020
23.8	0.9999	0.0020
37.0	0.9995	0.0020
50.0	0.9996	0.0020
89.0	0.9999	0.0020
150.0	0.9999	0.0020
183.0	0.9998	0.0020

微波辐射黑体反射率10-200GHz频段的测试结果



Emissivity >0.9997 at
75-200GHz for FY-3F MWHS

Reflectivity <-40dB at 300~500GHz