

风云三号D星微波类仪器介绍

微波成像仪（MWRI） 武胜利

微波温度计（MWTS） 安大伟

微波湿度计（MWHS） 郭杨

全球导航卫星掩星探测仪（GNOS） 杨光林

国家卫星气象中心

2019/3/1

主要内容

- 风云三号D星微波成像仪MWRI
 - 微波成像仪简介
 - 在轨性能评价
 - L1数据格式介绍及使用指南
 - 数据读取
 - 产品示例
- 风云三号D星微波温度计MWTS
- 风云三号D星微波湿度计MWHS
- 风云三号D星全球导航卫星掩星探测仪GNOS



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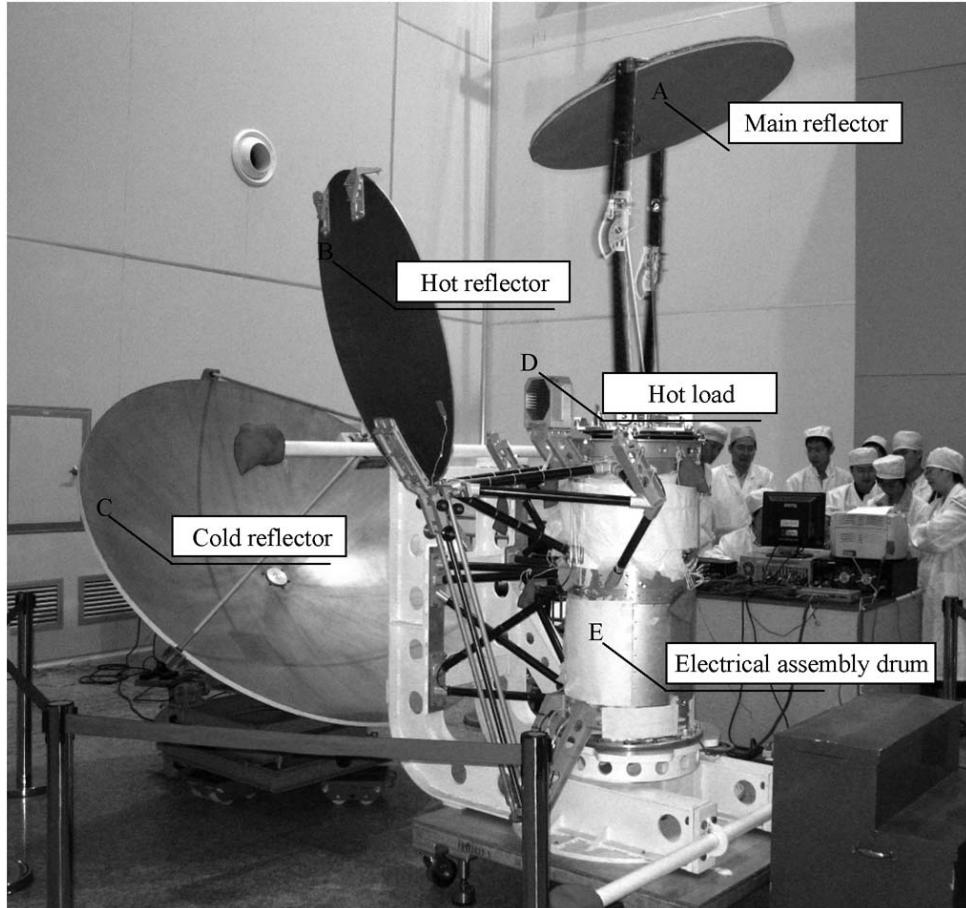
微波成像仪简介



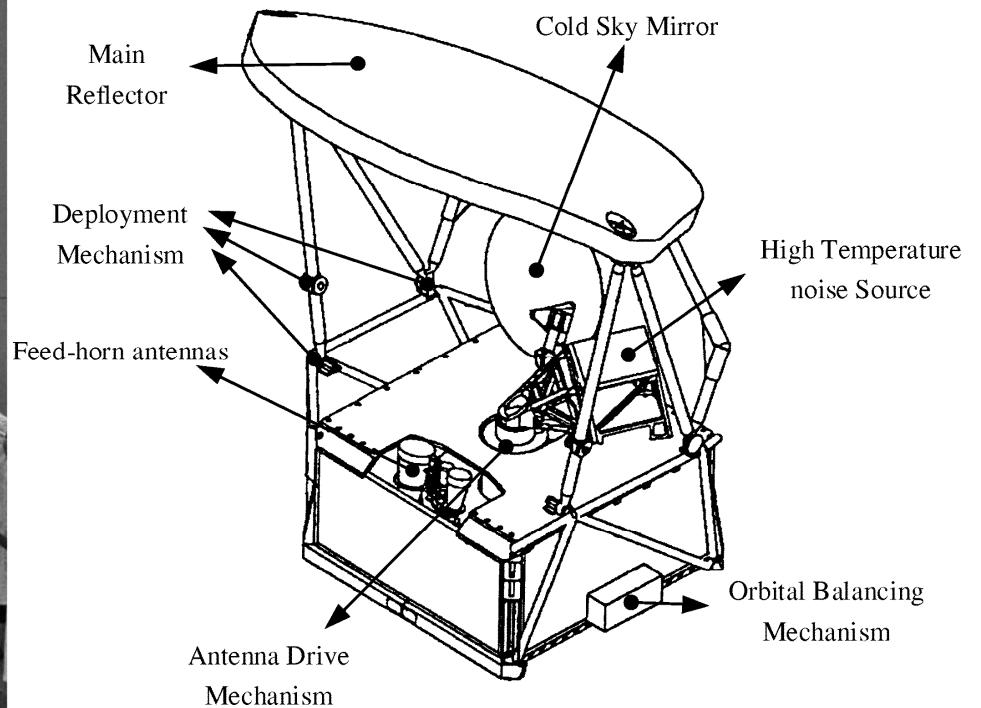
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FY-3/MWRI



AMSR-E

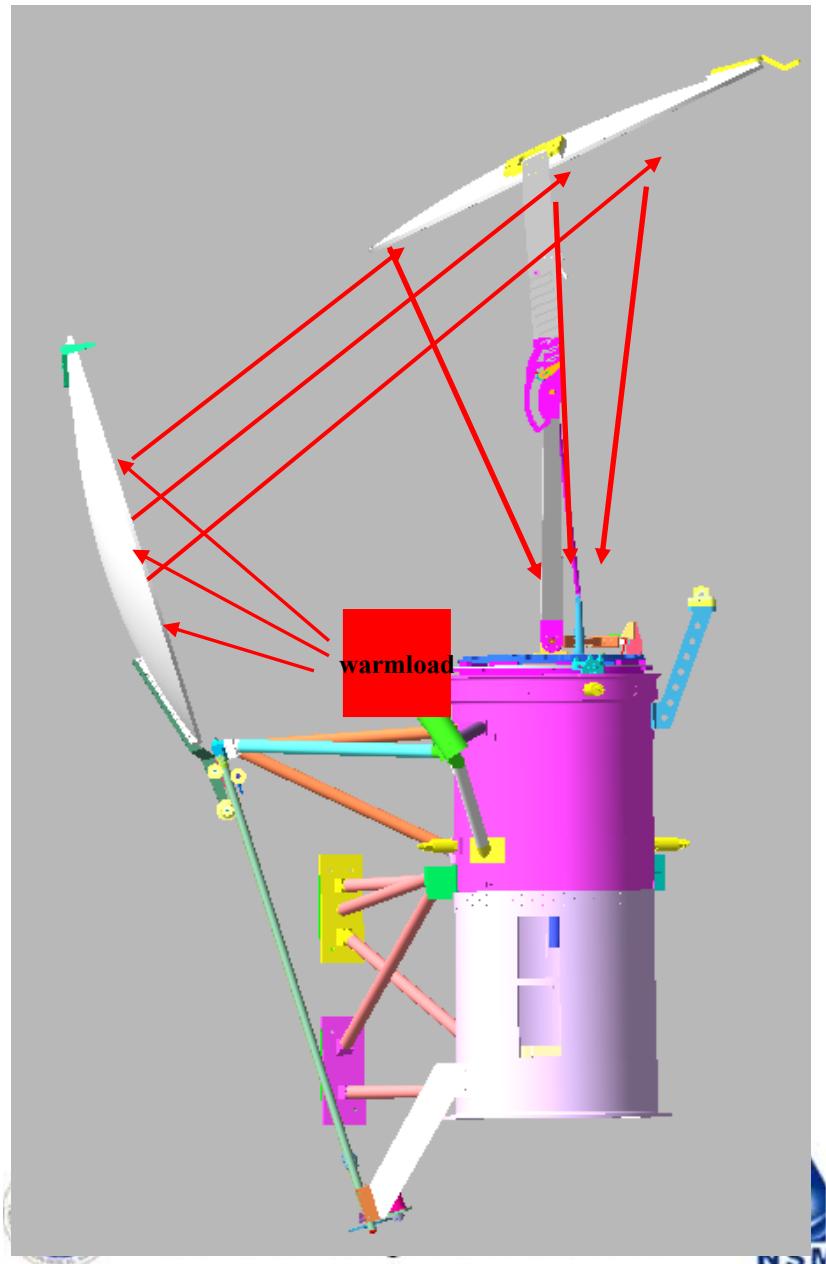


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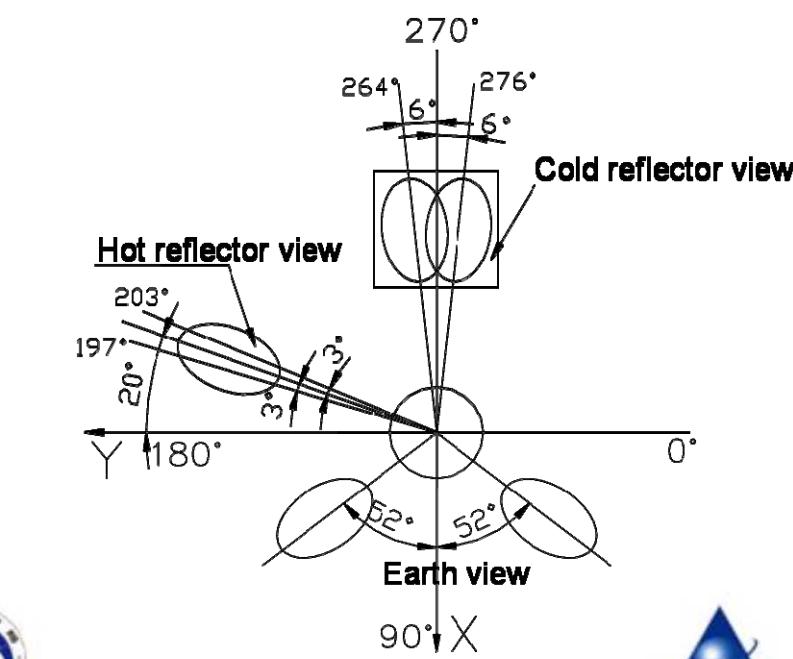
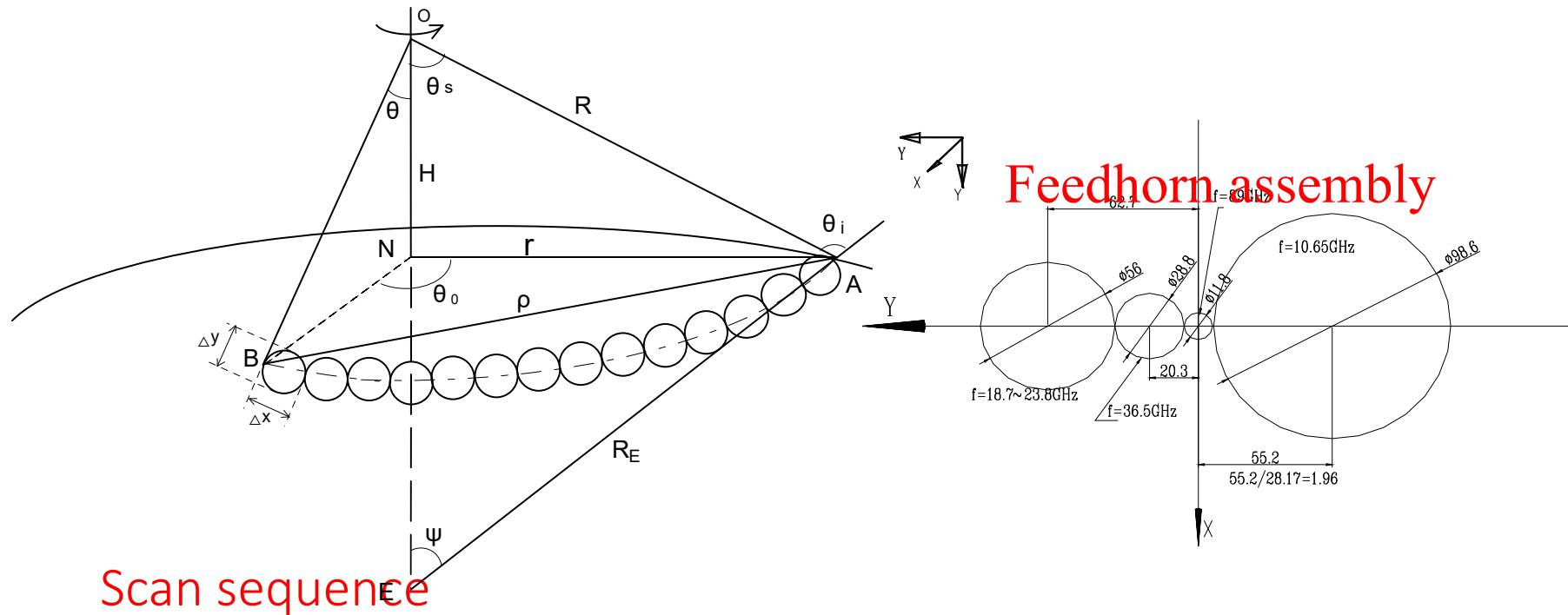


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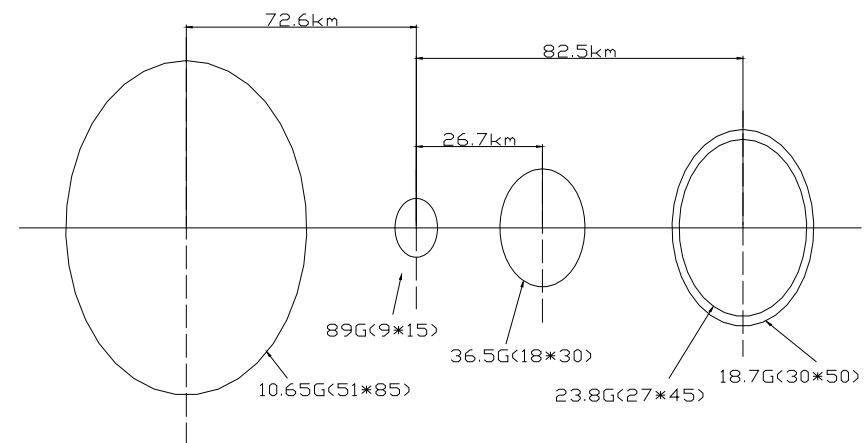
微波成像仪参数



频率(GHz)	10.65	18.7	23.8	36.5	89
极化	V.H	V.H	V.H	V.H	V.H
带宽*(MHz)	180	200	400	900	2×2300
灵敏度(k)	0.5	0.5	0.5	0.5	0.8
定标精度(k)	2.0	2.0	2.0	2.0	2.0
动态范围(k)	3~340				
采样点数	266(1.8s)				
黑体温度均匀性	0.3K				
接收机非线性	非线性偏差小于1K				
量化等级	12比特				
主波束效率	≥90%				
地面分辨率* ≤(km×km)	51×85	30×50	27×45	18×30	9×15
通道间配准	波束指向误差<0.07°				
扫描方式	圆锥扫描				
幅宽(Km)	≥1400				
天线视角(°)	45±1 (稳定性 0.1)				
扫描周期(s)	1.8±0.1*				
扫描周期误差(ms)	≤0.36ms* (相邻扫描线)				
	≤1ms (连续 30 分钟内)				
极化隔离度	≥20dB				



**Antenna Pattern
Ground footprint**



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Nation
NSMC

Vacuum test system

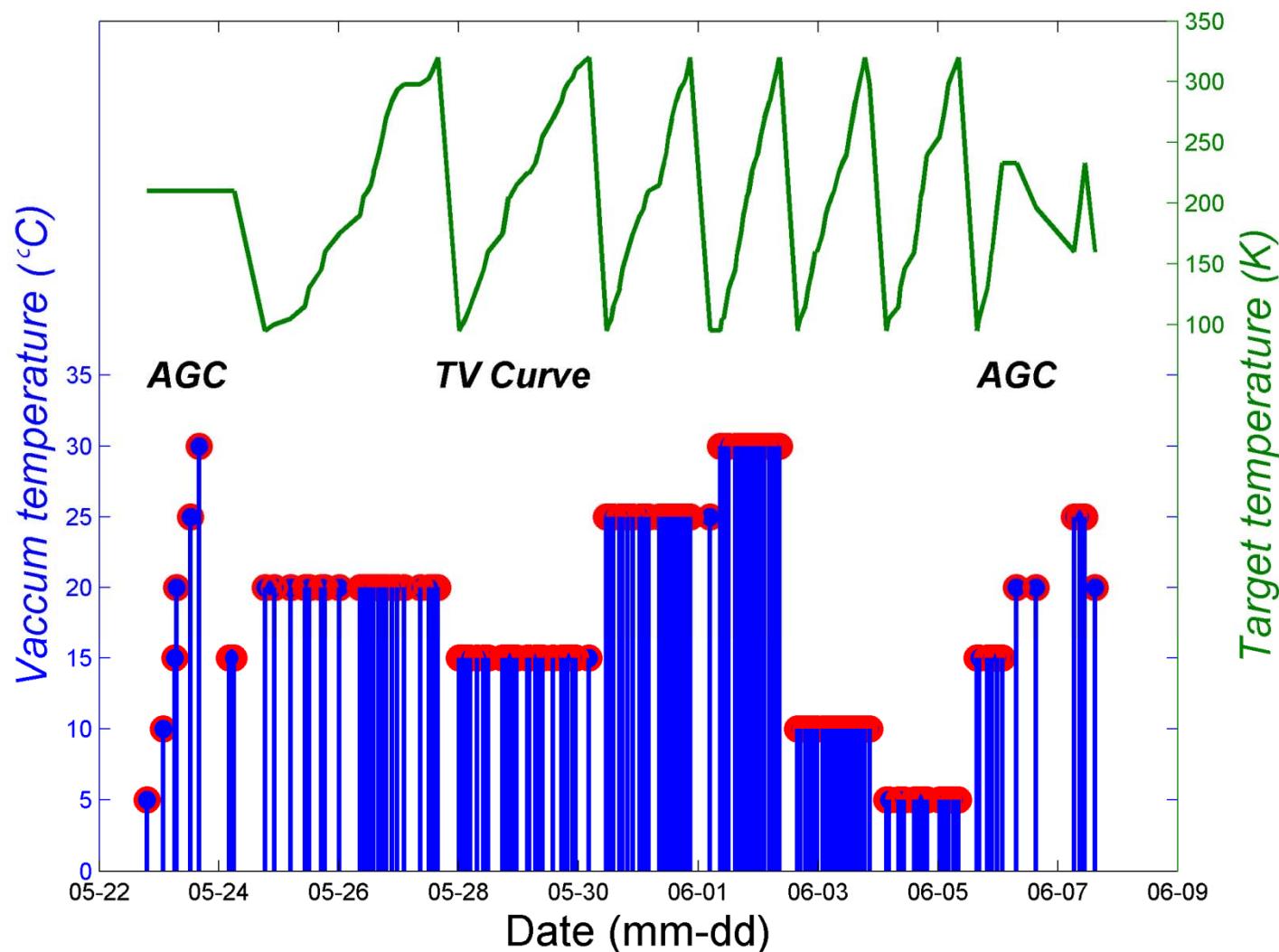


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Process of Vacuum test



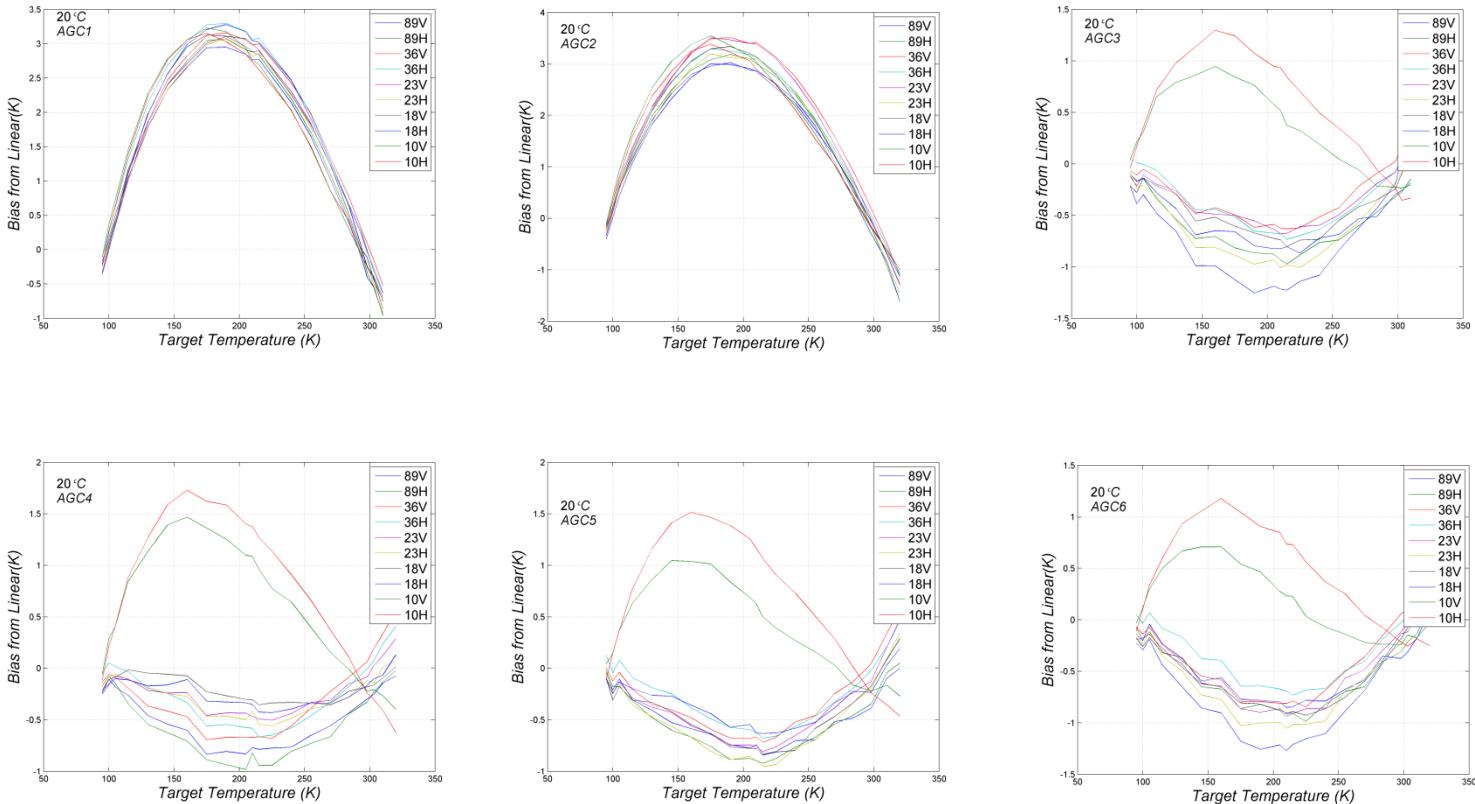
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Result

(1) T-V Curve (20°C)



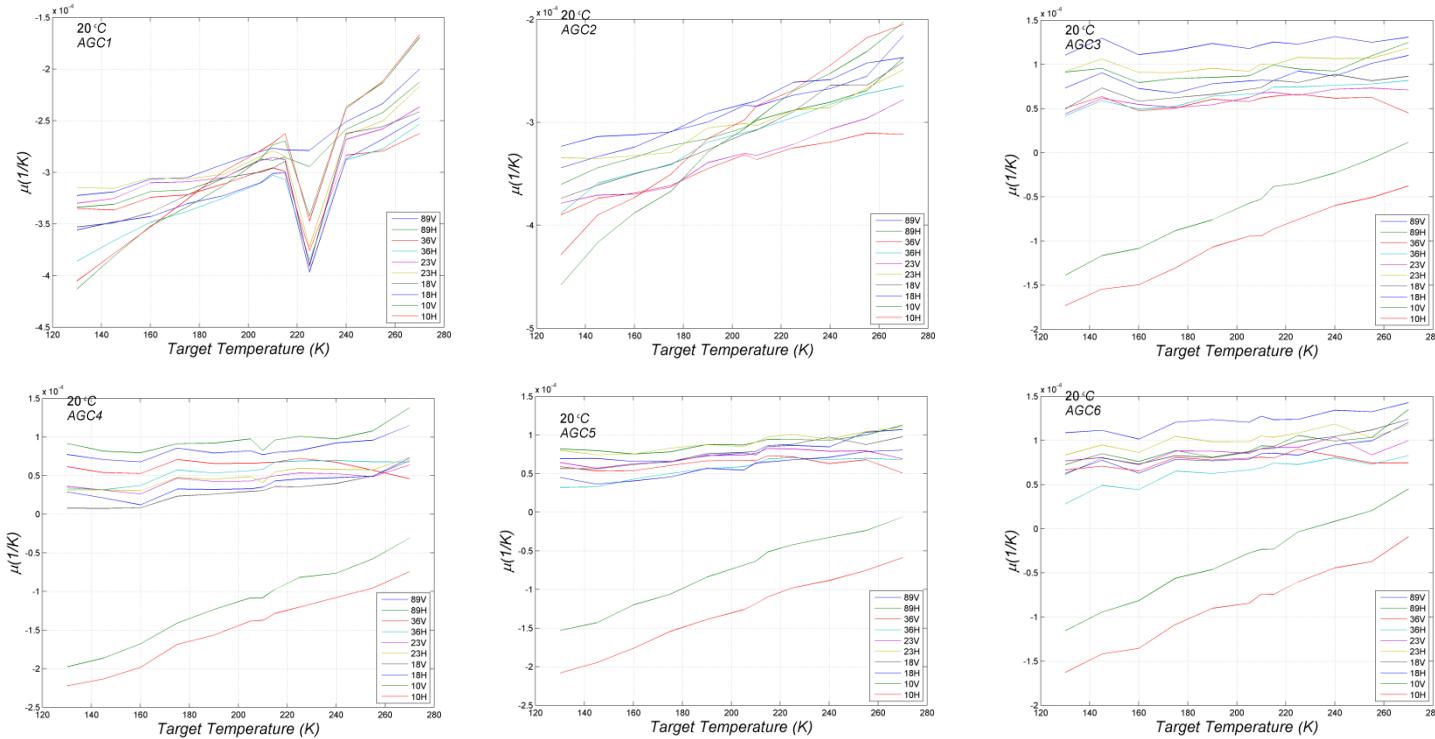
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Result

(2) Non-linearity coefficient (20°C)



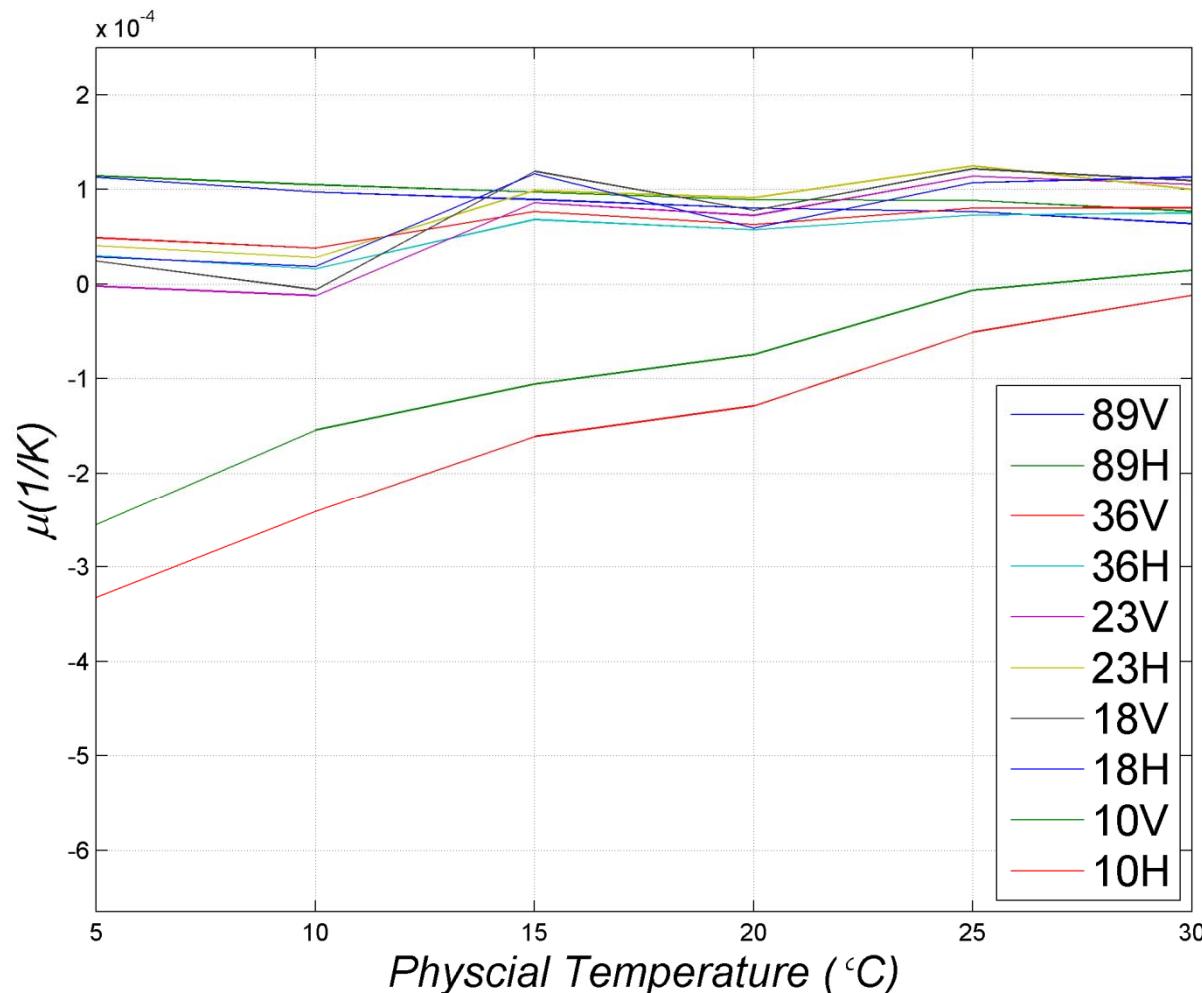
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Result

(3) Non-linearity coefficient VS Receiver Temperature



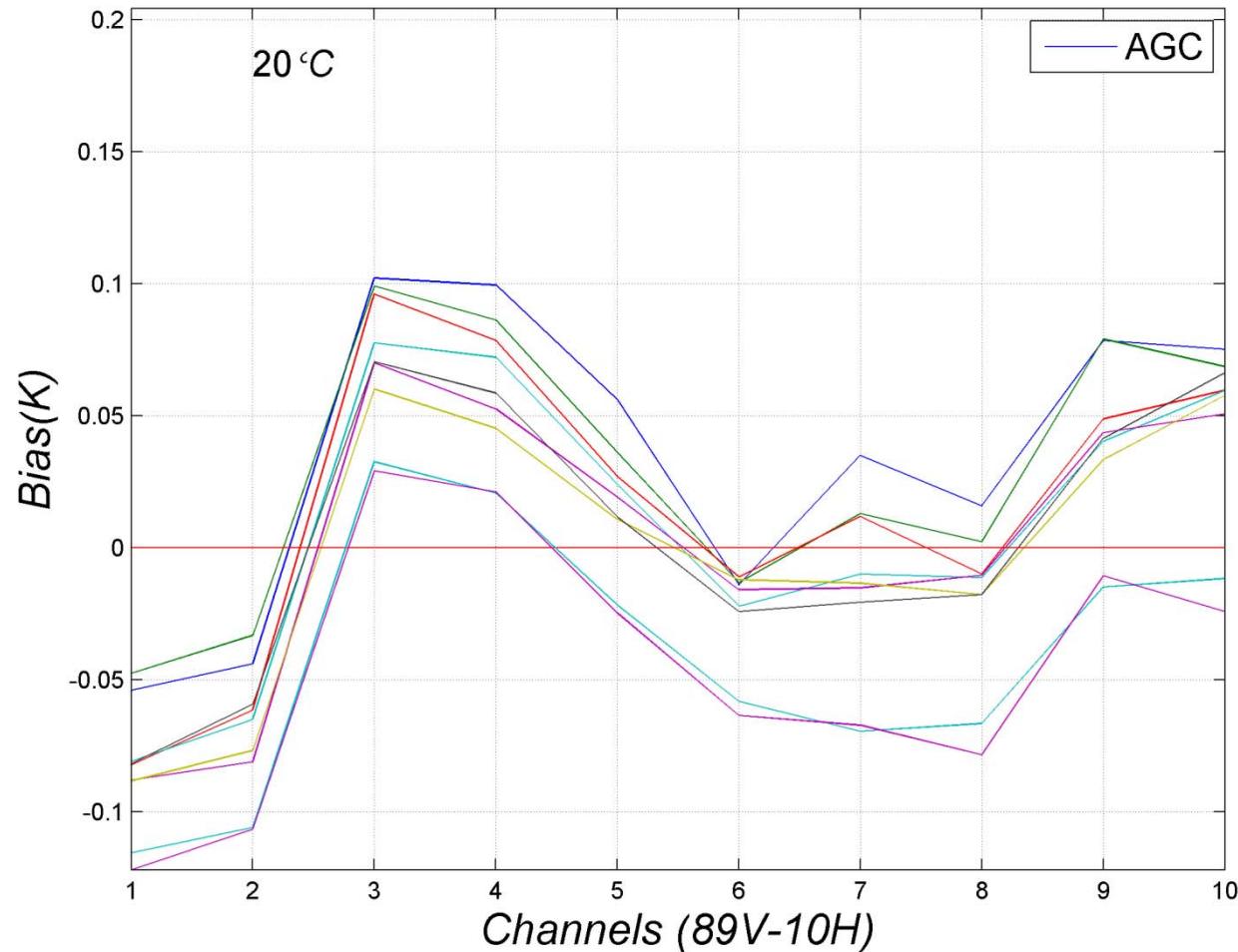
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Result

(4) Residual error after non-linearity correction (20°C)



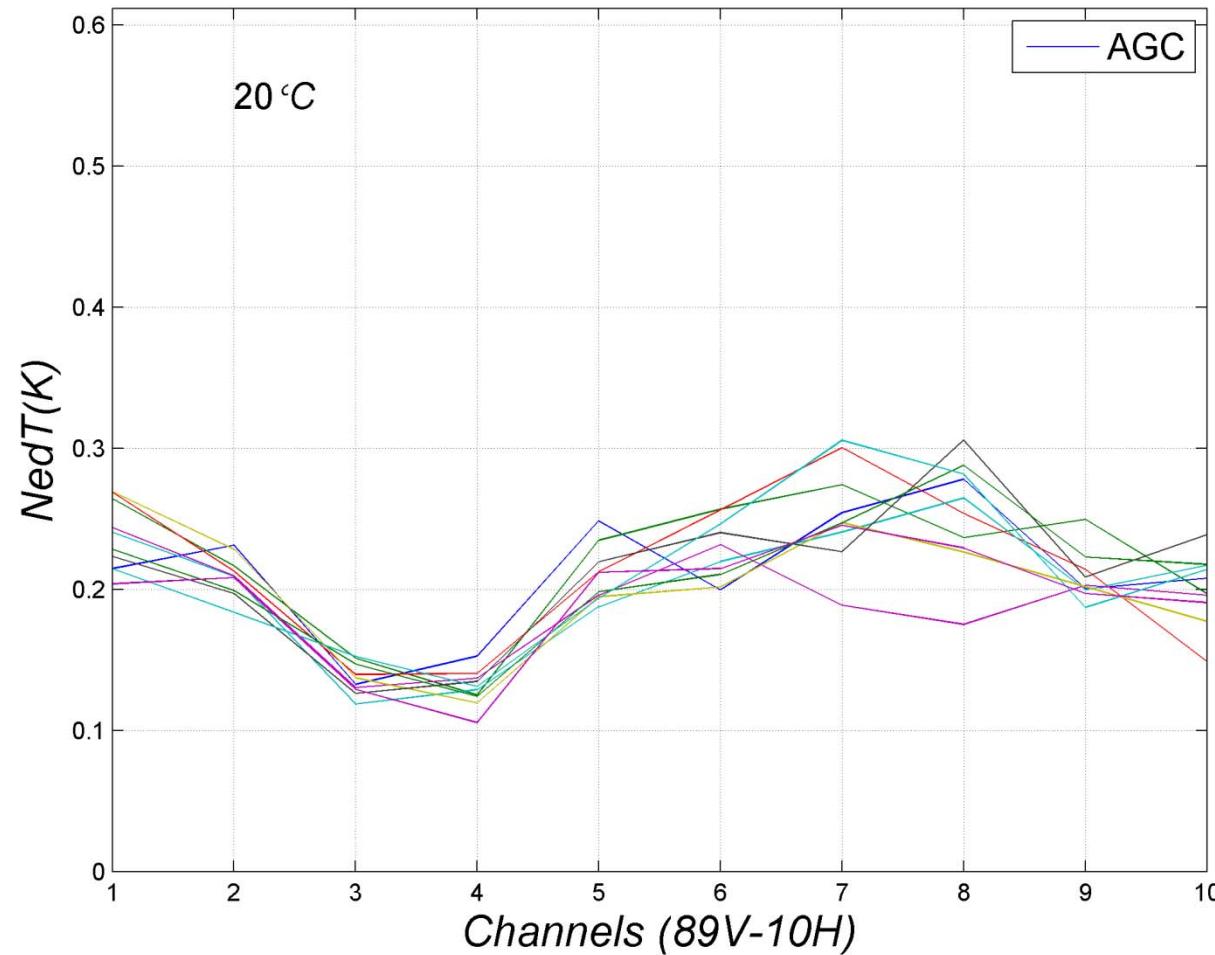
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Result

(5) NeDT (20°C)



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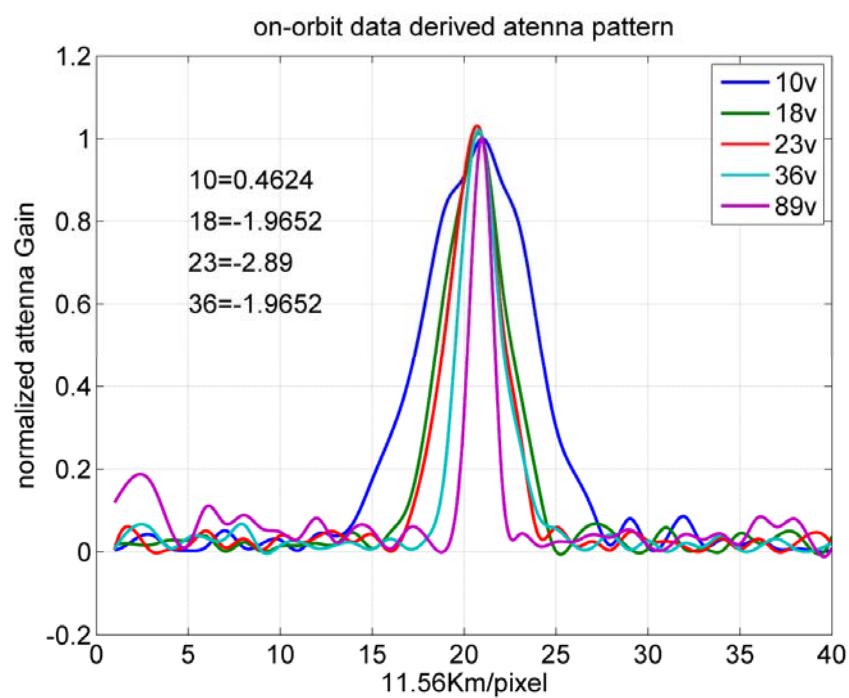
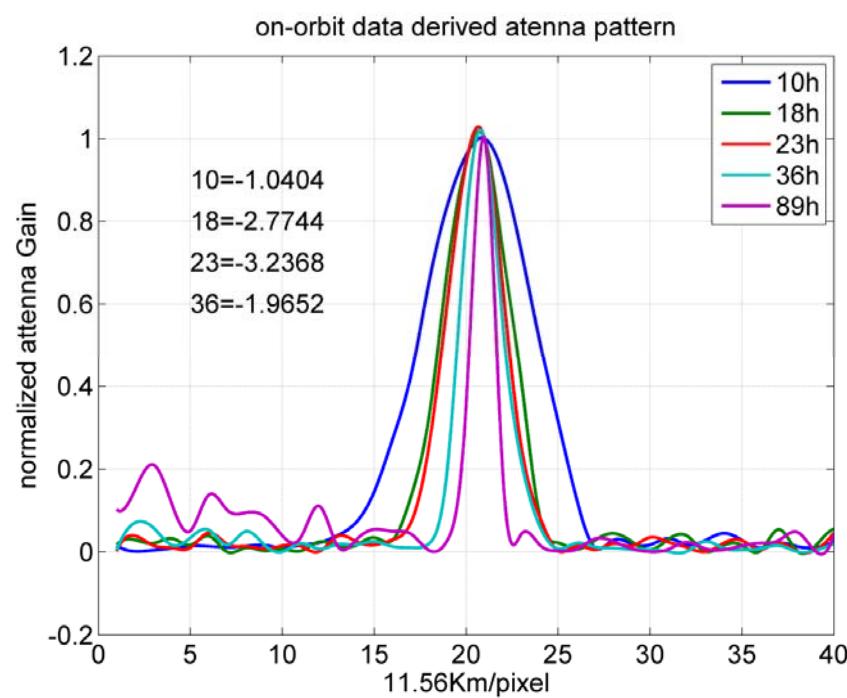
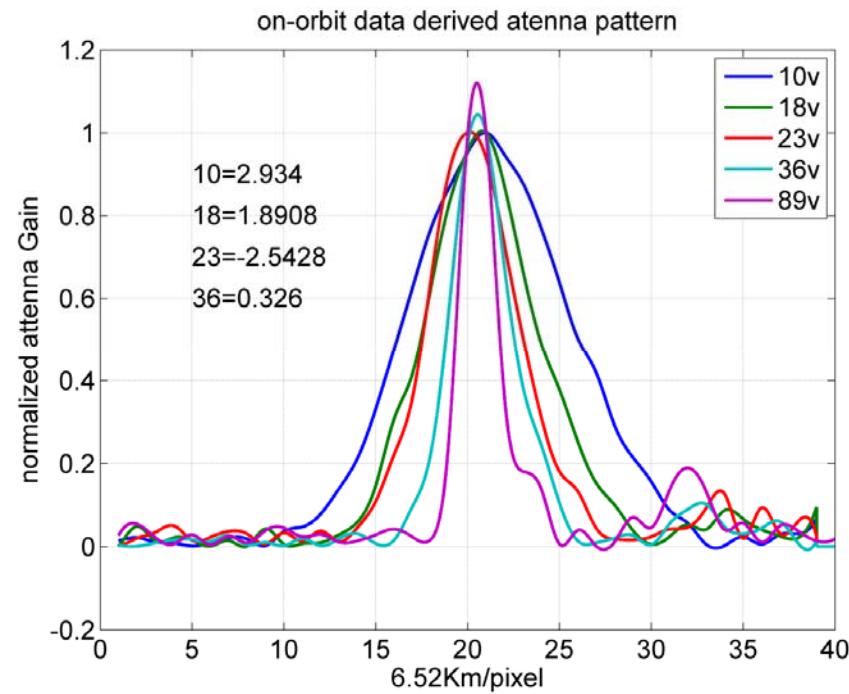
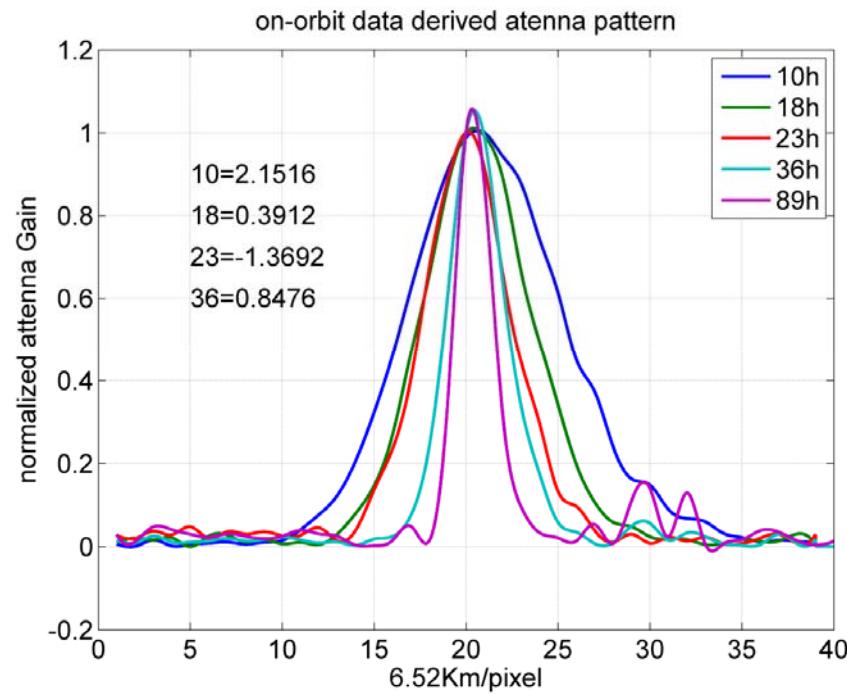
微波成像仪在轨 性能评价



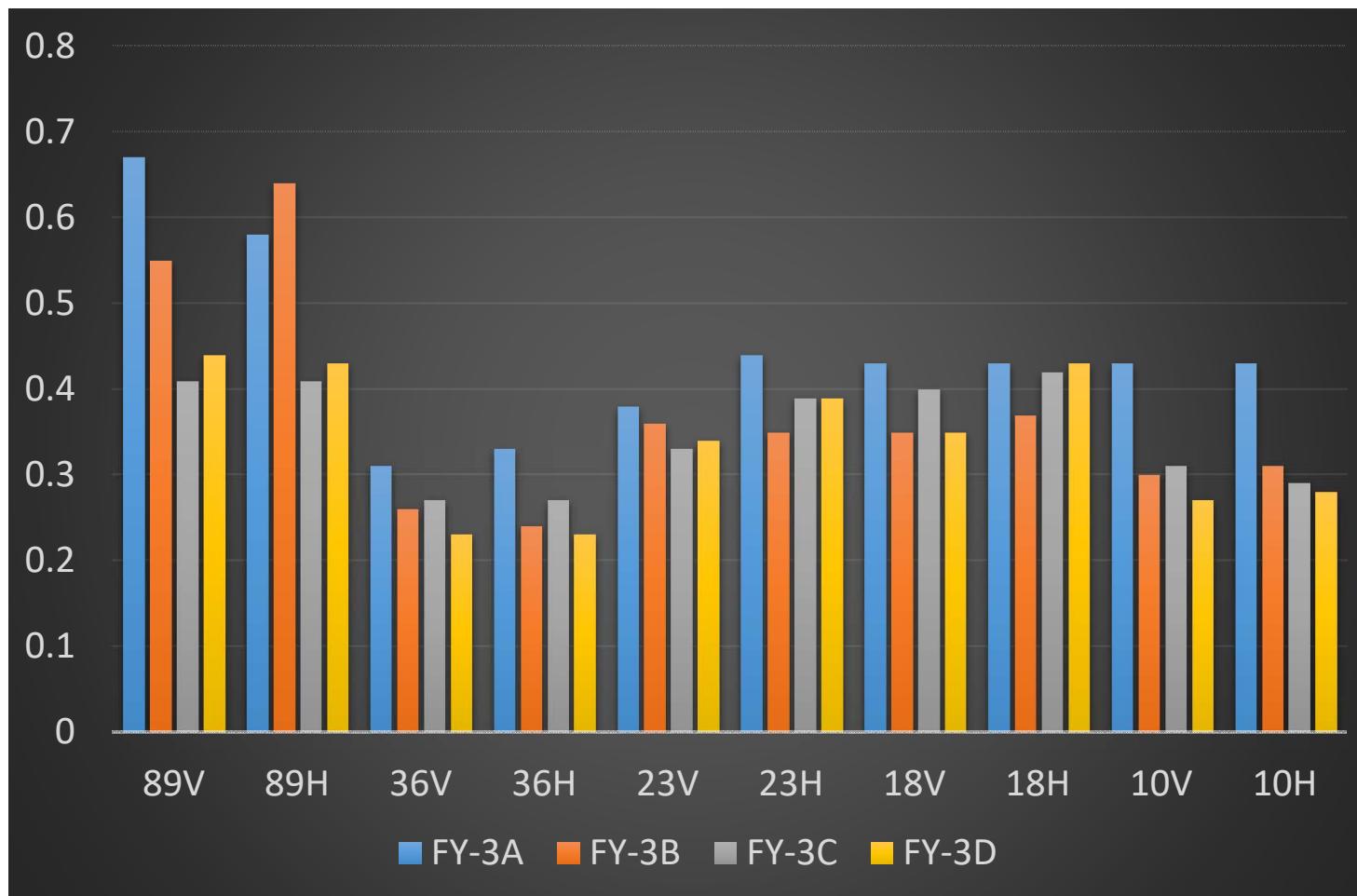
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NeDT of FY-3A/B/C/D MWRI



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Xcal of FY3D/MWRI and GPM/GMI (hot end)

	Bias(K)	Std (K)	Corr.
10V	-1.58	1.01	0.951
10H	-1.27	1.40	0.961
18V	0.39	0.95	0.993
18H	1.15	1.14	0.996
23V	-1.34	0.82	0.998
36V	-2.85	0.73	0.992
36H	-2.93	0.91	0.998
89V	-1.49	0.82	0.997
89H	-1.42	0.96	0.999



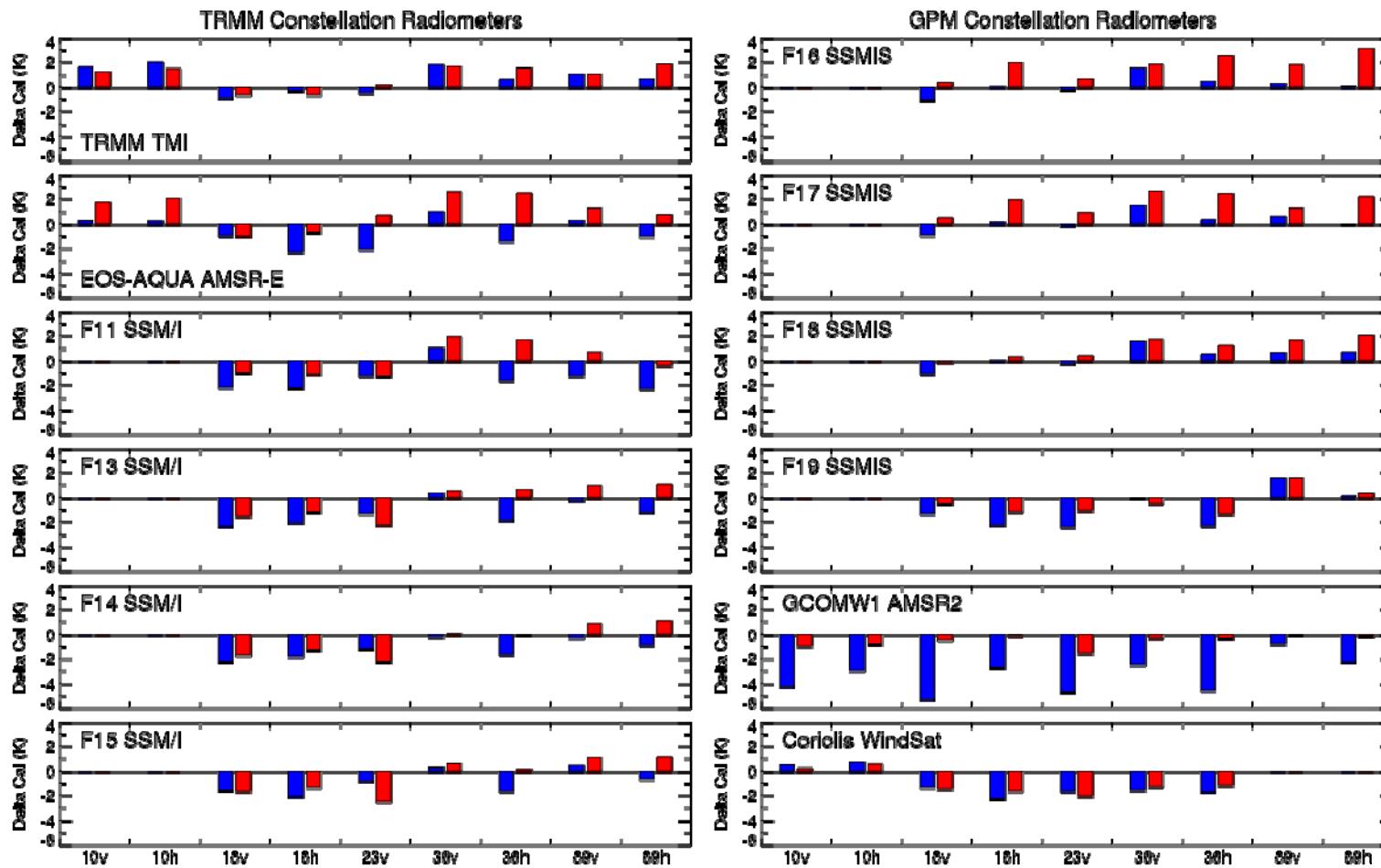
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圆锥扫描微波辐射计定标精度 (与GMI交叉比对)

Wesley Berg (CSU), Rachael Kroodsma, Faisal Alquaeid, Steve Bilanow, Ruiyao Chen, Joyce Chou, Saswati Datta, David Draper, Hamideh Ebrahimi, Spencer Farrar, Yimin Ji, Linwood Jones, Darren McKague, Erich Stocker, Tom Wilheit et al.



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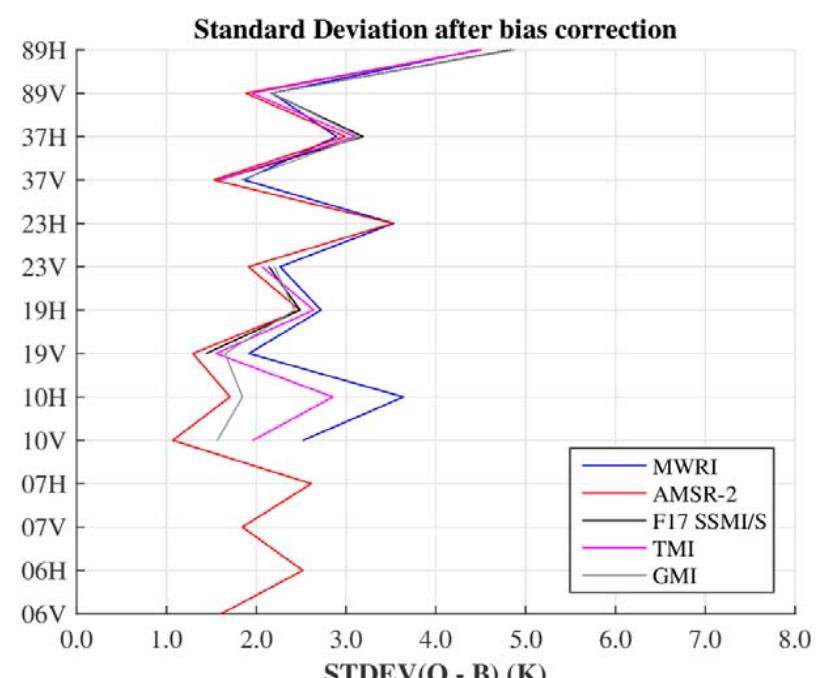
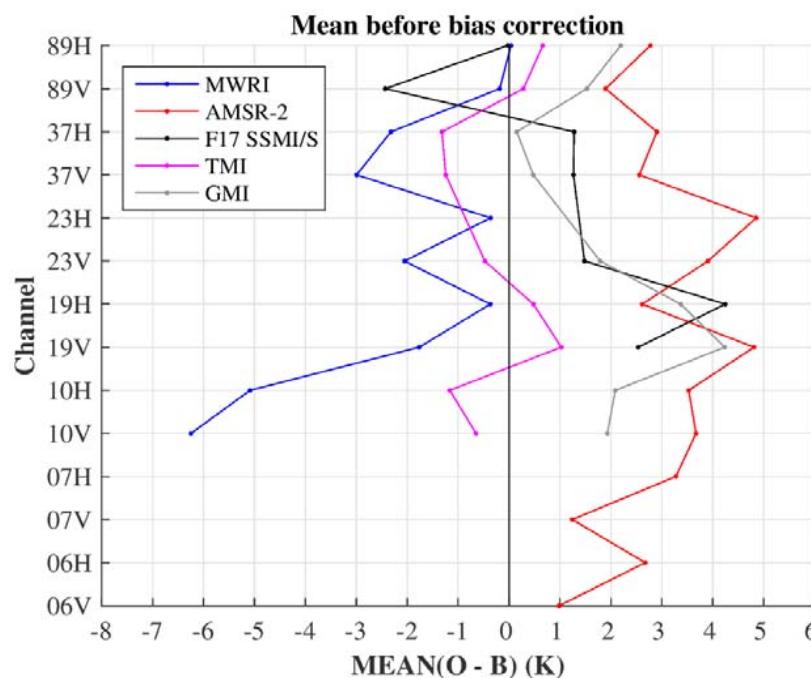


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Different on-orbit passive microwave radiometer performance

Observation minus ECMWF Background Statistics for **June 2014**

Data: 1 month, after cloud screening, ocean +/- 60 latitude



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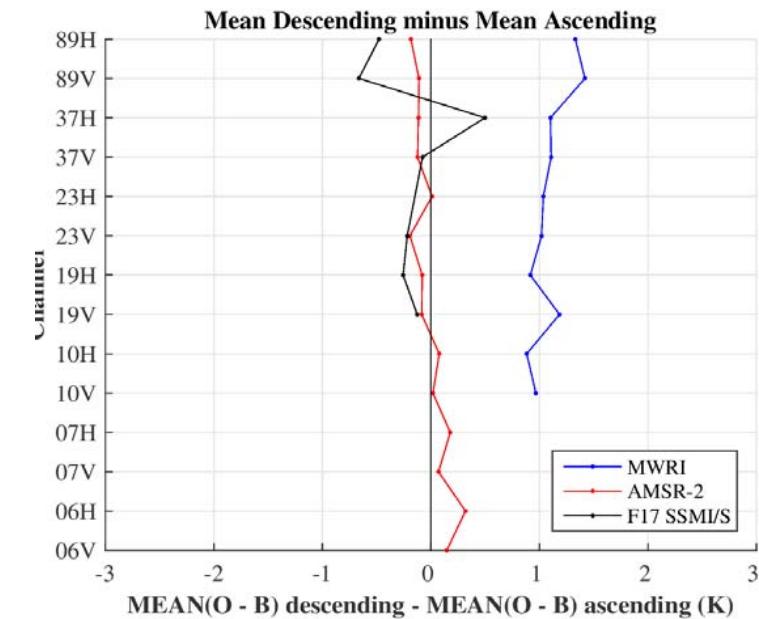
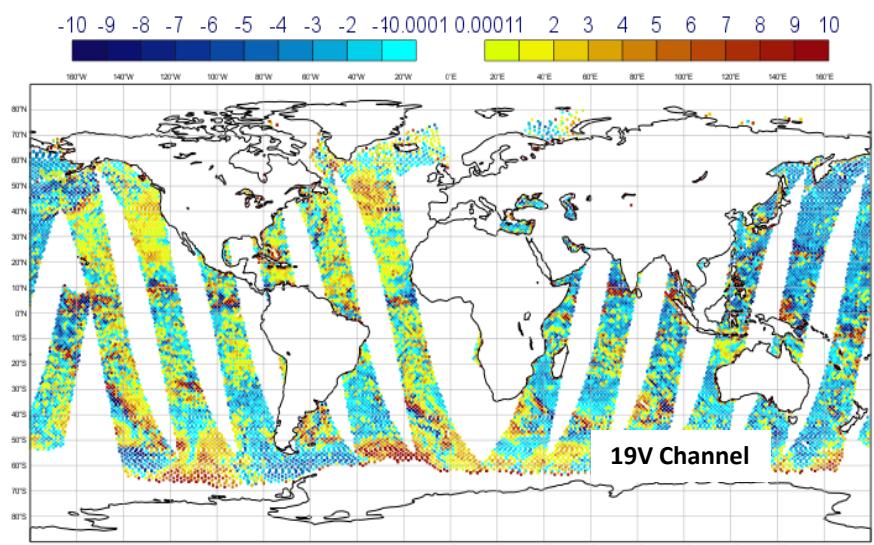
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FY-3C telecon, 16 June 2016

Problem1:

Ascending/Descending Biases:

e.g. channel 3 (19V) O - B



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FY-3C telecon, 16 June 2016

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Warm Calibration system of FY-3/MWRI

$$T_A = T_{EA} \frac{\Omega_A}{\Omega_p} + T_{ET} \frac{\Omega_T}{\Omega_p} + T_{EC} \frac{\Omega_{MC}}{\Omega_p} + \varepsilon T_H \frac{\Omega_M}{\Omega_p}$$

$$\eta_A = 1 - \frac{\Omega_A}{\Omega_p}$$

is the efficiency of main reflector;

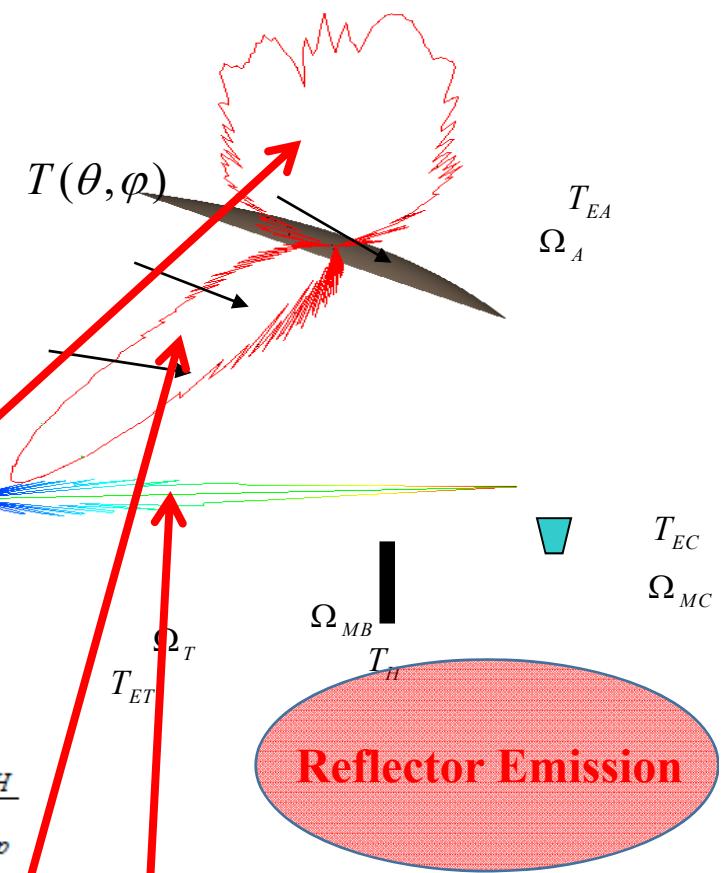
$$\eta_T = 1 - \frac{\Omega_T}{\Omega_p - \Omega_A}$$

is the efficiency of hot-reflector

$$\eta_H = 1 - \frac{\Omega_C}{\Omega_p - \Omega_A - \Omega_T} = \frac{\Omega_H}{\Omega_C + \Omega_H}$$

is the efficiency of warm-load

$$\begin{aligned}
 T_A &= T_{EA} \cdot \frac{\Omega_A}{\Omega_p} + T_{ET} \cdot \frac{\Omega_T}{\Omega_p} + T_{EC} \cdot \frac{\Omega_C}{\Omega_p} + \varepsilon T_H \cdot \frac{\Omega_H}{\Omega_p} \\
 &= T_{EA}(1 - \eta_A) - \eta_A \{ T_{ET}(1 - \eta_T) + \eta_T [1 - \varepsilon] [T_{EC}(1 - \eta_H) + T_H * \eta_H] \} + \varepsilon * T_R
 \end{aligned}$$



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Warm Target correction : Error Source 1 and 2

- Brightness temperature of earth-surface in the direction of the warm reflector back lobe;

Error Source 1

Error Source 2

$$T_{EA}(1 - \eta_A) - \eta_A \{ T_{ET} (1 - \eta_T) + \eta_T (1 - \varepsilon) [T_{EC}(1 - \eta_H) + T_H * \eta_H] + \varepsilon * T_R \}$$



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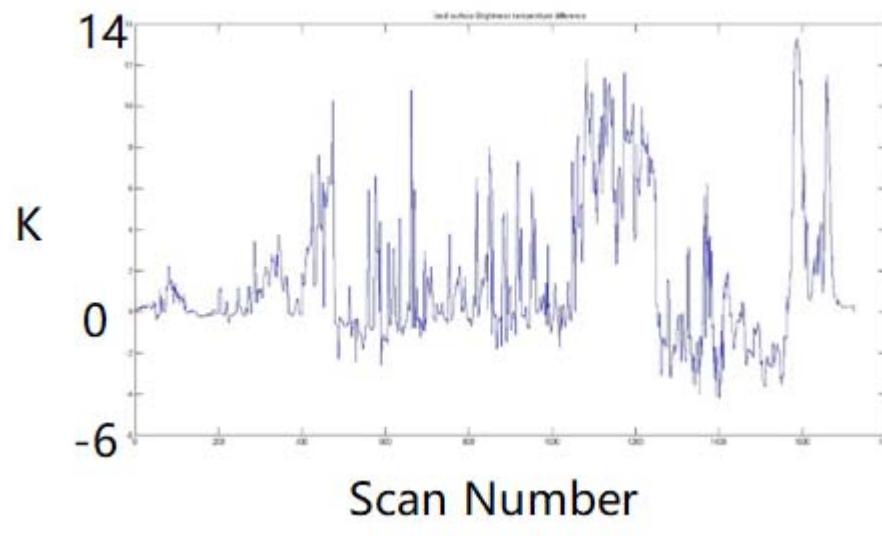
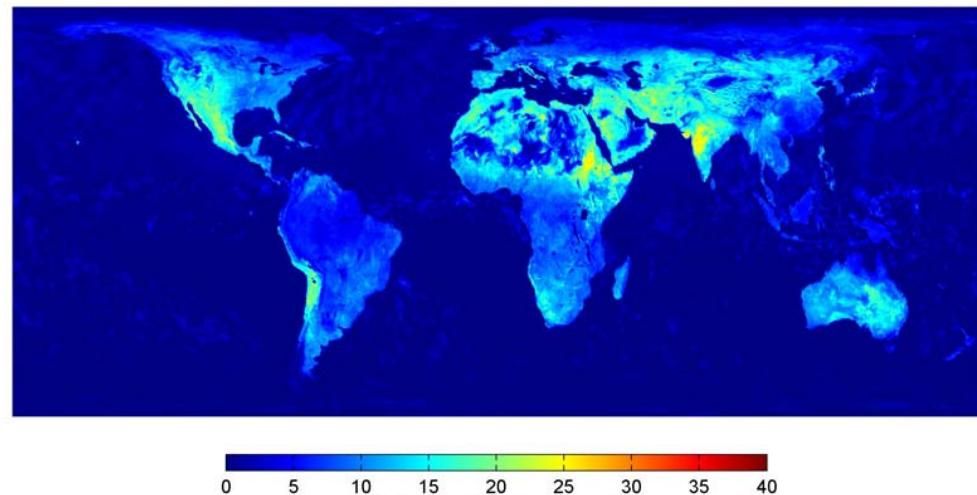
Warm Target correction : Error Source 1

Difference of Min/Max BT

operational: using a climate brightness Temperature dataset (from AMSR-E Jan-Dec/2006, monthly average);

Improve: Consider the local time of the warm reflector back lobe direction

Difference of BT result before and after correction



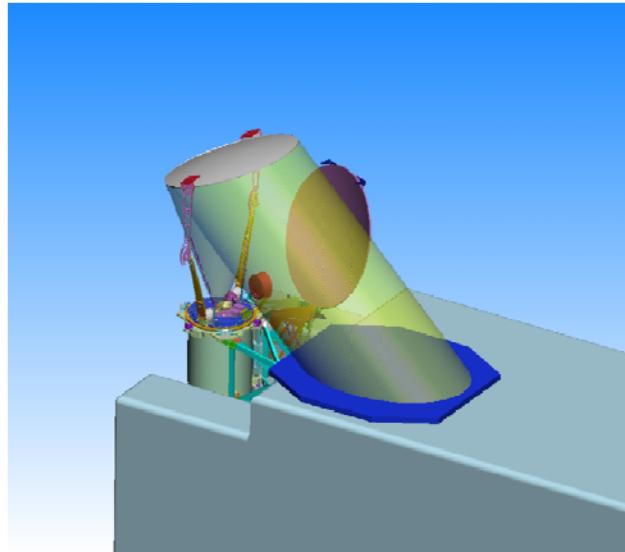
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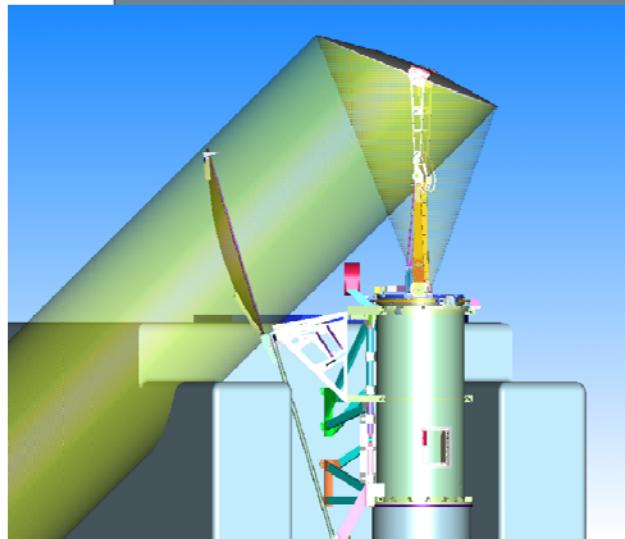
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Warm Target correction : Error Source 2

cold



Warm



$1 - \eta_T$ is not the **real** factor of warm reflector back lobe, the true value should be **smaller**.

We can't use the ground measured η_T to get the back lobe factor directly.



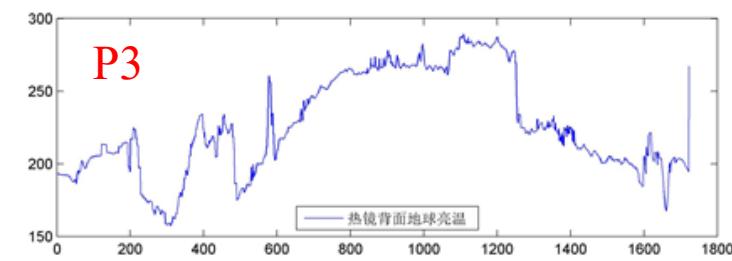
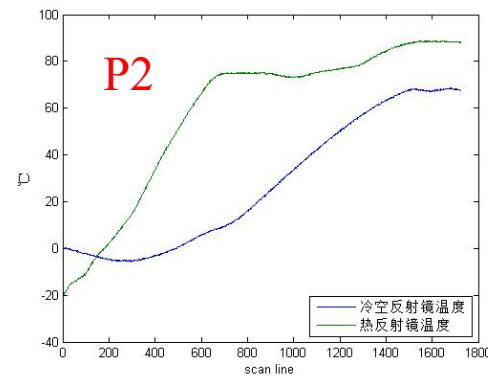
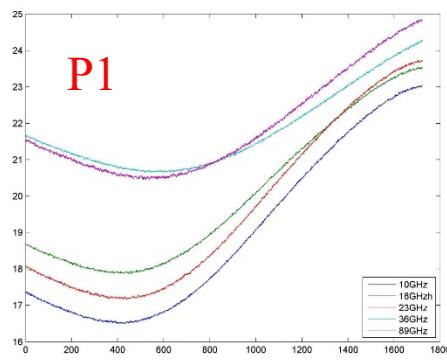
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Warm Target correction : Error Source 2

- The parameters that affect scale factors(Gain)
 - Temperature of Receiver (**Parameter 1**);
 - Warm/cold reflectors emission(**Parameter 2**);
 - Back lobe of warm reflector(**Parameter 3**).
- Sudden change Only appear on back lobe of warm reflector.



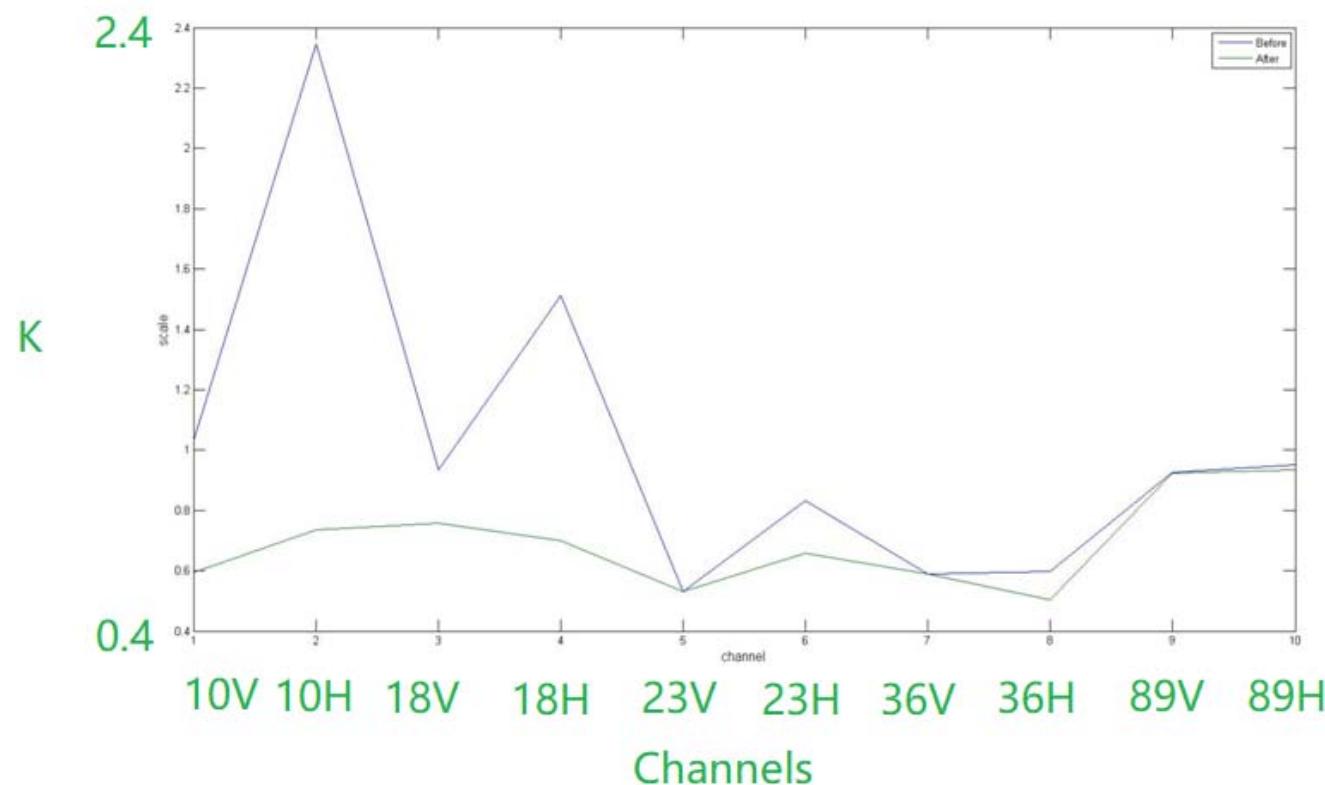
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Warm Target correction : Error Source 2

NeDT(total orbit data)



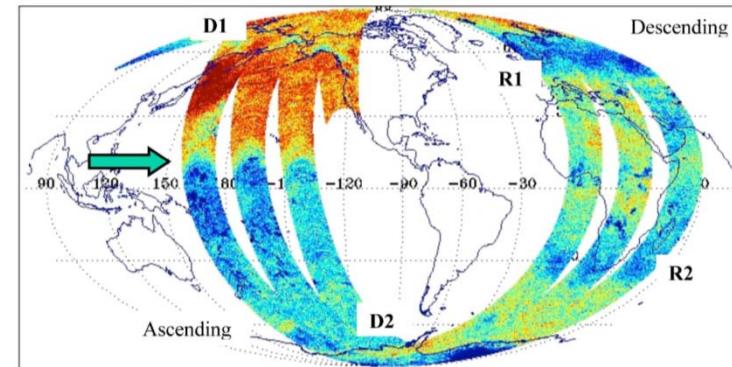
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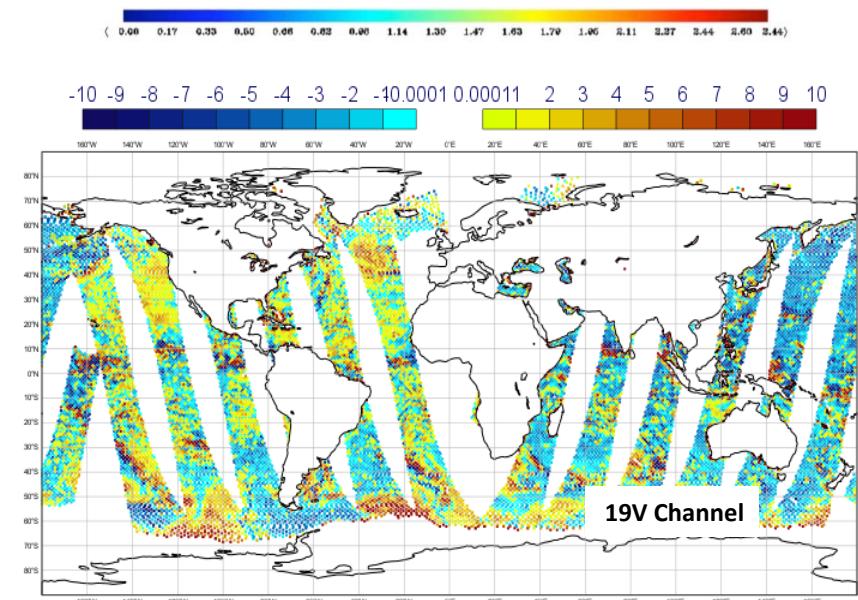
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Reflector Correction

SSMIS



MWRI



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Warm/cold reflector emission

$$T_{BE}^1 = G(T_{BH}^1 - T_{BC}^1) + T_{BC}^1 + T_{nlin} \quad \text{“Real” BT}$$

$$T_{BE}^2 = G(T_{BH}^2 - T_{BC}^2) + T_{BC}^2 + T_{nlin} \quad \text{MWRI BT}$$

$$\begin{aligned} & T_{BE}^{1,D} - T_{BE}^{1,A} - (T_{BE}^{2,D} - T_{BE}^{2,A}) \\ &= \underline{\varepsilon_H (G^D (T_{HM}^D - T_{HS}^D) - G^A (T_{HM}^A - T_{HS}^A))} \\ &+ \underline{\varepsilon_C ((1-G^D)(T_{CM}^D - 2.7) - (1-G^A)(T_{CM}^A - 2.7))} \end{aligned}$$

~~nonlinear~~
~~Back lobe~~

Ascending/Descending Bias =**warm reflector emission**+**cold reflector emission**



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Warm/cold reflector emission

$$\begin{aligned} & (T_{BE}^{1,L} - T_{BE}^{1,A}) - (T_{BE}^{2,D} - T_{BE}^{2,A}) \\ &= \underline{\varepsilon_H (G^D (T_{HM}^D - T_{HS}^D) - G^A (T_{HM}^A - T_{HS}^A))} \\ &\quad + \underline{\varepsilon_C ((1 - G^D)(T_{CM}^D - 2.7) - (1 - G^A)(T_{CM}^A - 2.7))} \end{aligned}$$

$$Y = \varepsilon_H X_1 + \varepsilon_C X_2 + b$$



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Coast Buffer and Scatter filter



Coast Buffer



Scatter Filter

$37V - 37H > 50 \text{ K}$
 $37V > 19V$
 $19H < 185 \text{ K}$
 $37H < 210 \text{ K}$
 $89V - 19V > 10 \text{ K}$
 $89H - 19H > 30 \text{ K}$
 $89V > 23V$
 $89V > 37V$
 $89H - 37H > 10 \text{ K}$

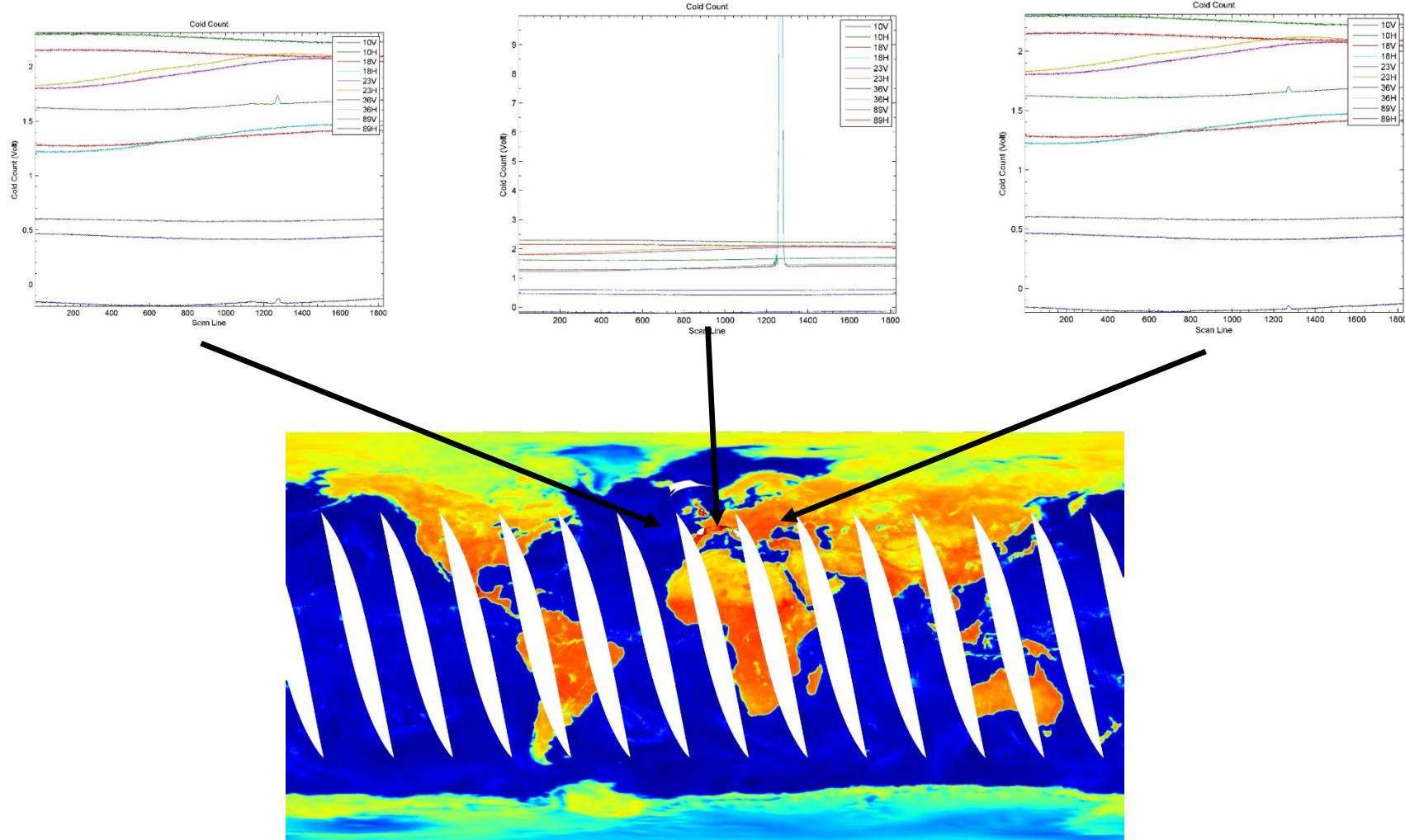


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Cold Targent filter

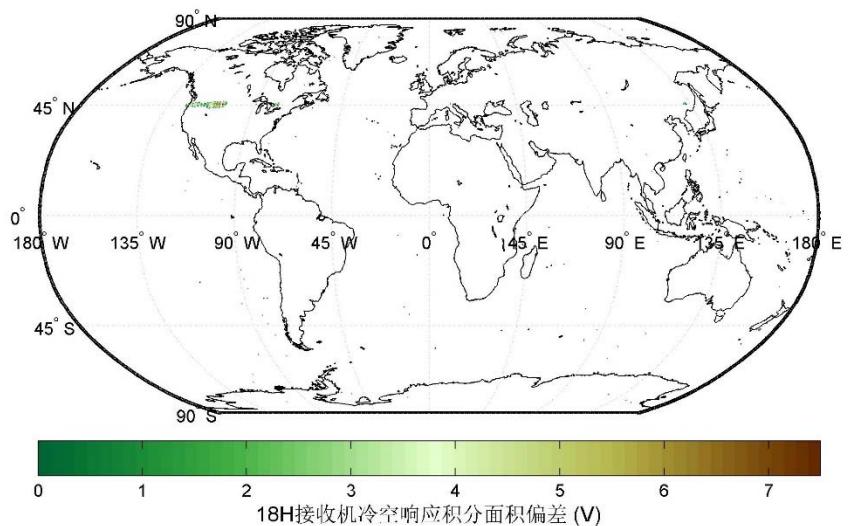
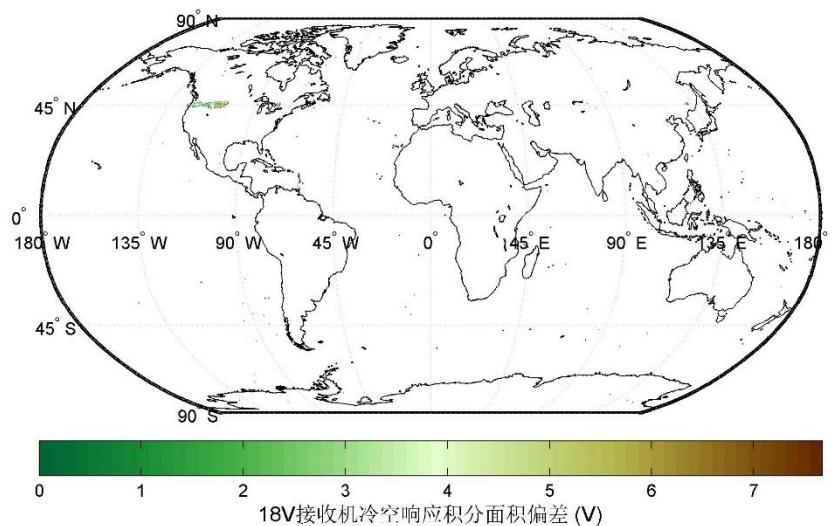
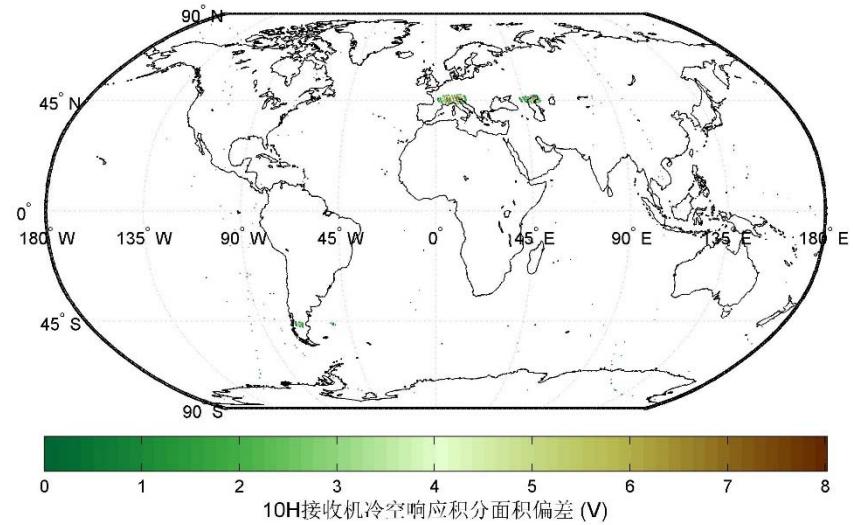
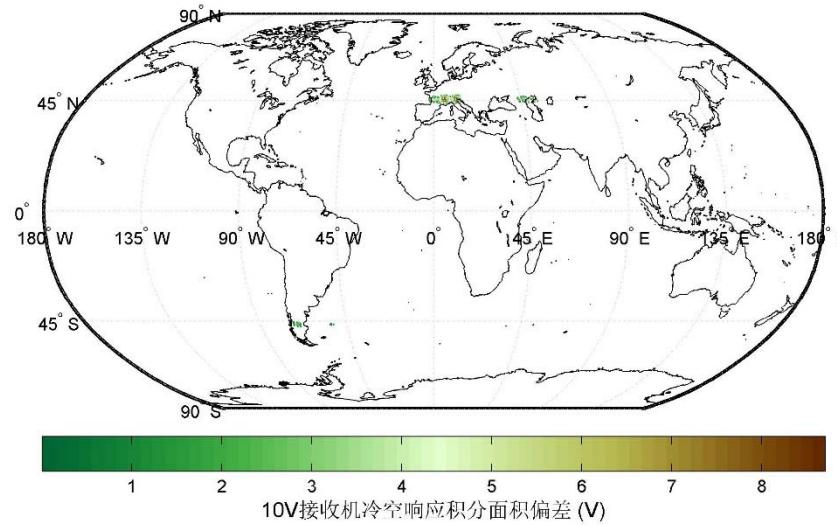


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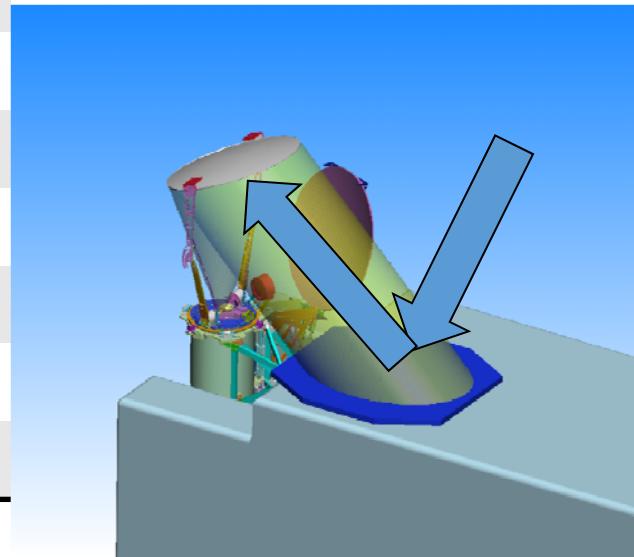
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Cold Tangent Irregular Points Ground Position (10V/10H/18V/18H)



EU:10.65GHz/US:18.7GHz

Satellite	Location	Frequency
TelStar18	138E	12.5
TelStar12	15W	11.5
TelStar11	37.5W	11.7
Hotbird	13E	11.6
TelStar14R	63W	12.2
AnikF1R	107.3W	12.2
AnikF2	111.1W	12.2
AnikF3	118.7W	11.7
DirecTV10	103W	19.1
DirecTV11	99W	18.5
SpaceWayF1	102.8W	18.3-19.8

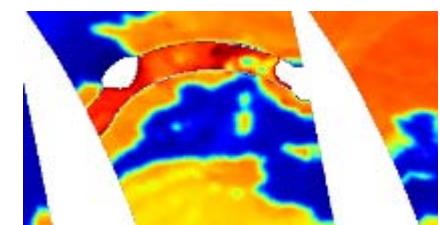
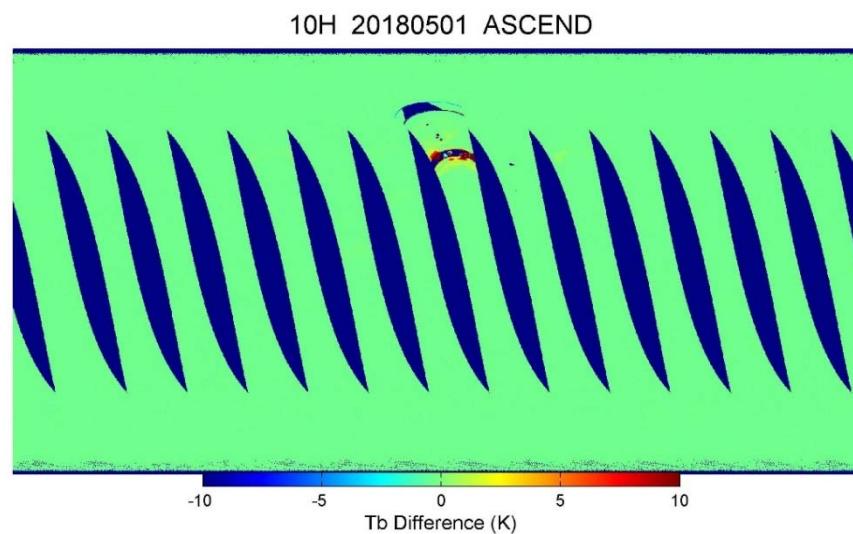
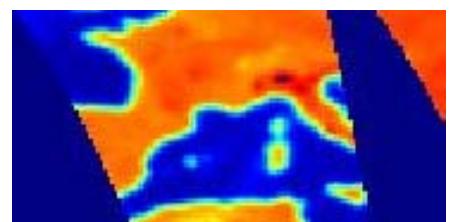
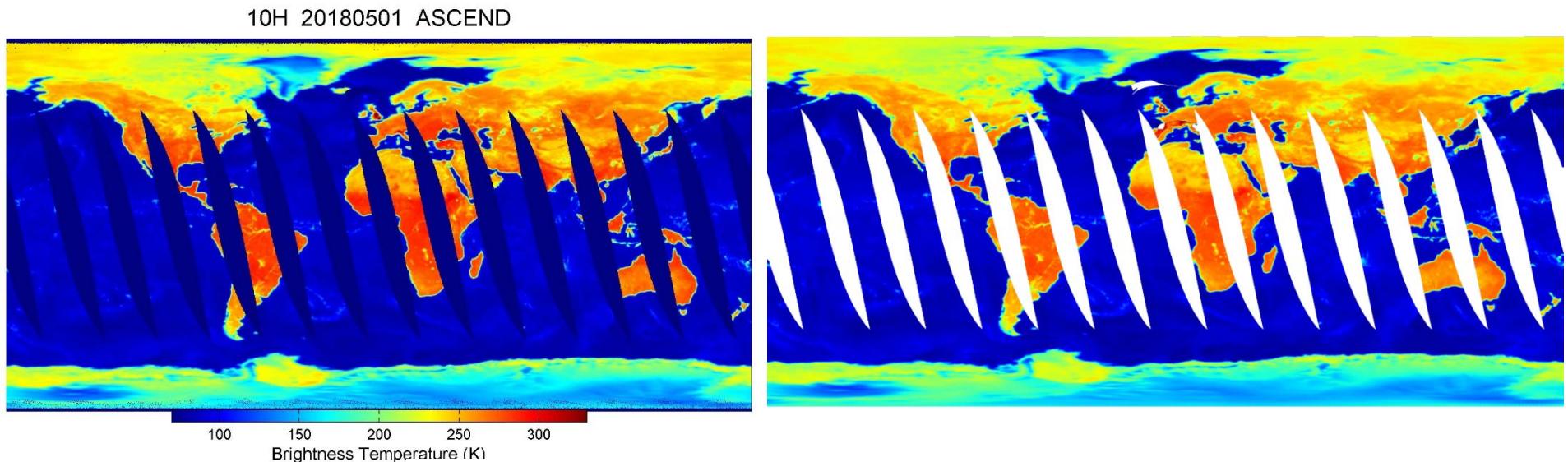


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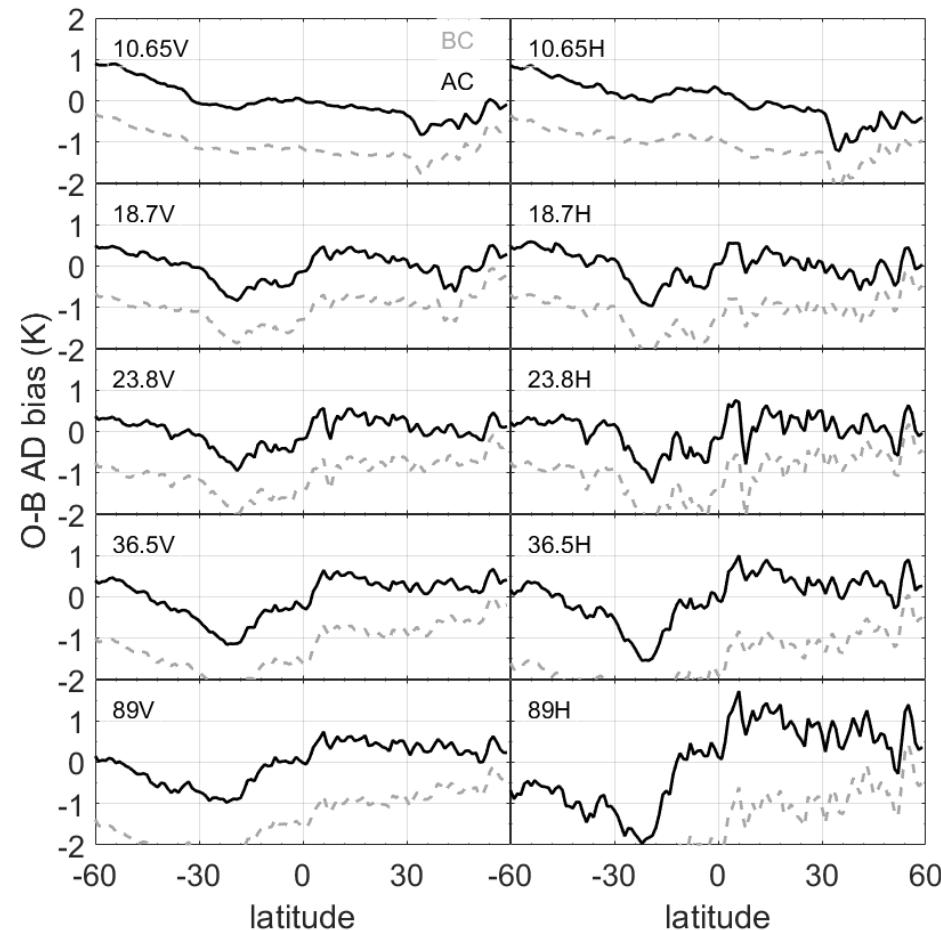
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Before and after filter

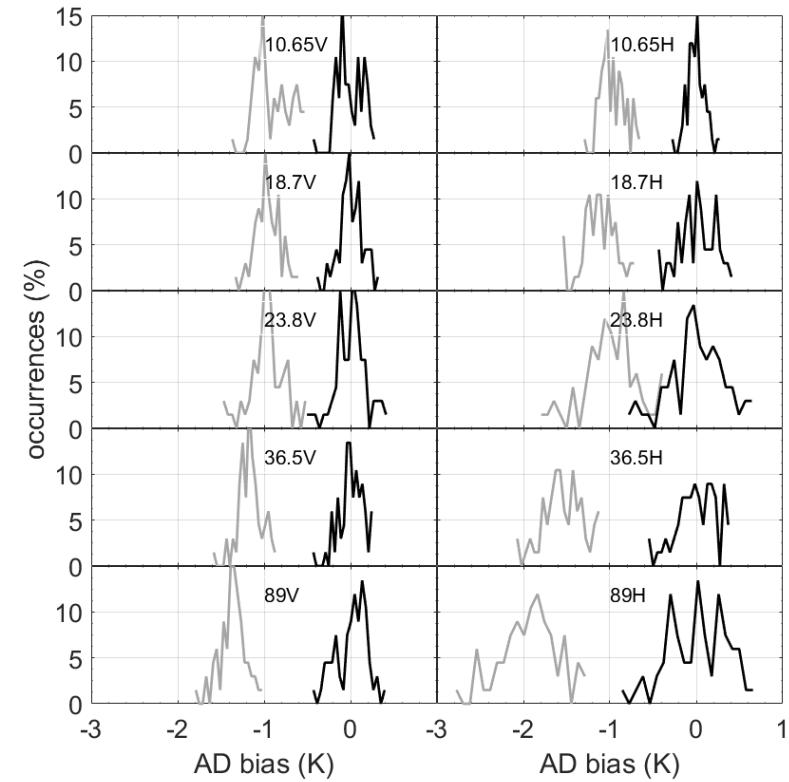


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201801 FY3D A/D Bias VS Lat



201801-03 FY3D A/D Bias



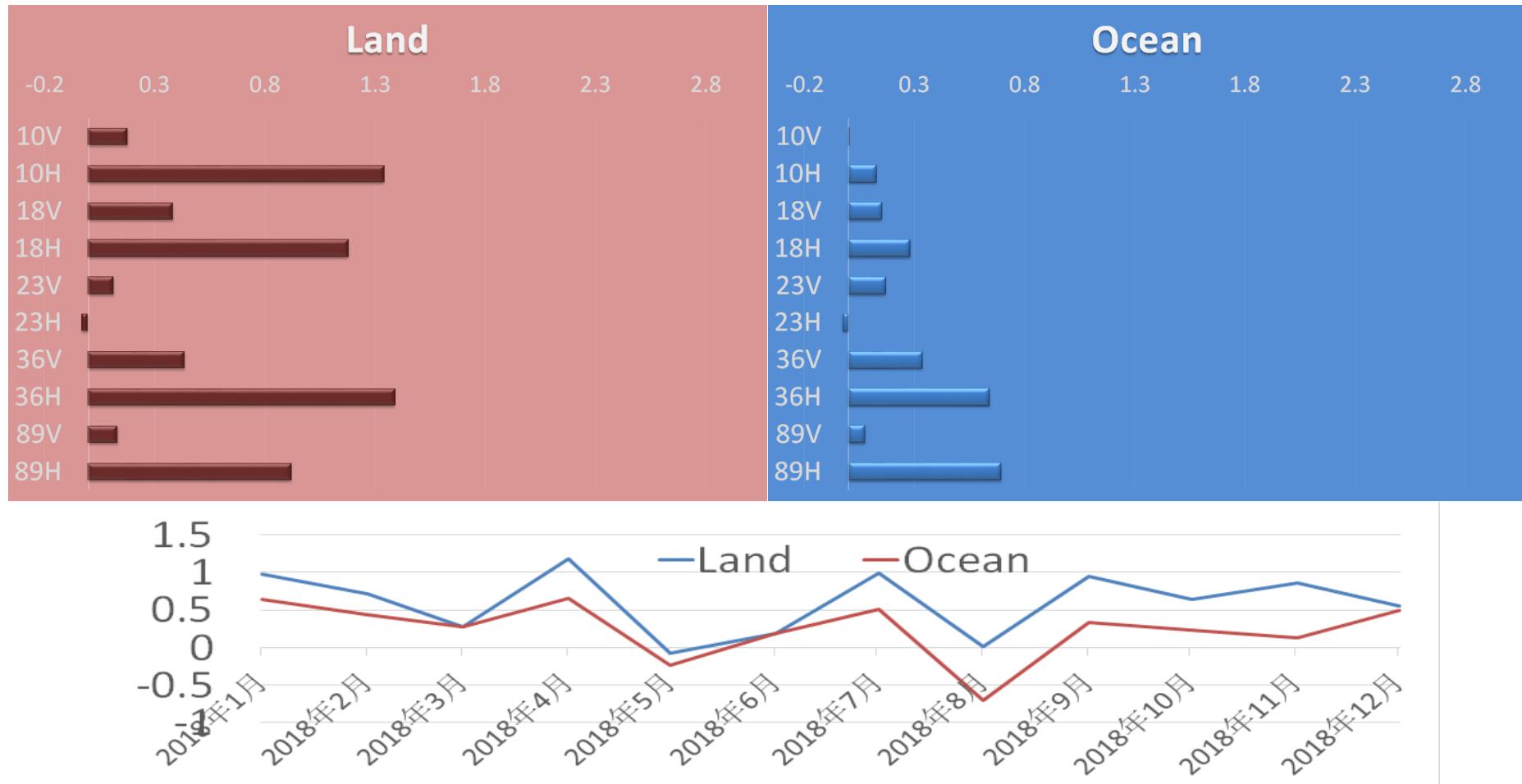
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FY-3D/MWRI A/D Bias Using GMI

20180101-20181231



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FY-3/MWRI launch schedule

- Past:

- 2008:FY-3A(10-89GHz, Dul-p), Shut down;
- 2010:FY-3B(10-89GHz, Dul-p), Operational;
- 2013:FY-3C(10-89GHz, Dul-p), Operational;
- 2017:FY-3D(10-89GHz, Dul-p), Operational;

- Future:

- 2020:FY-3F(**Reflector increased from 1m to 1.8m**);
- 2021:FY-3P(**Precipitation Satellite, Lower orbit, Reflector increased from 1m to 1.6m**);
- 2022:FY-3G(**Reflector increased from 1m to 1.8m**);
- The emissivity of reflector will be much improved for these 3 sensors.



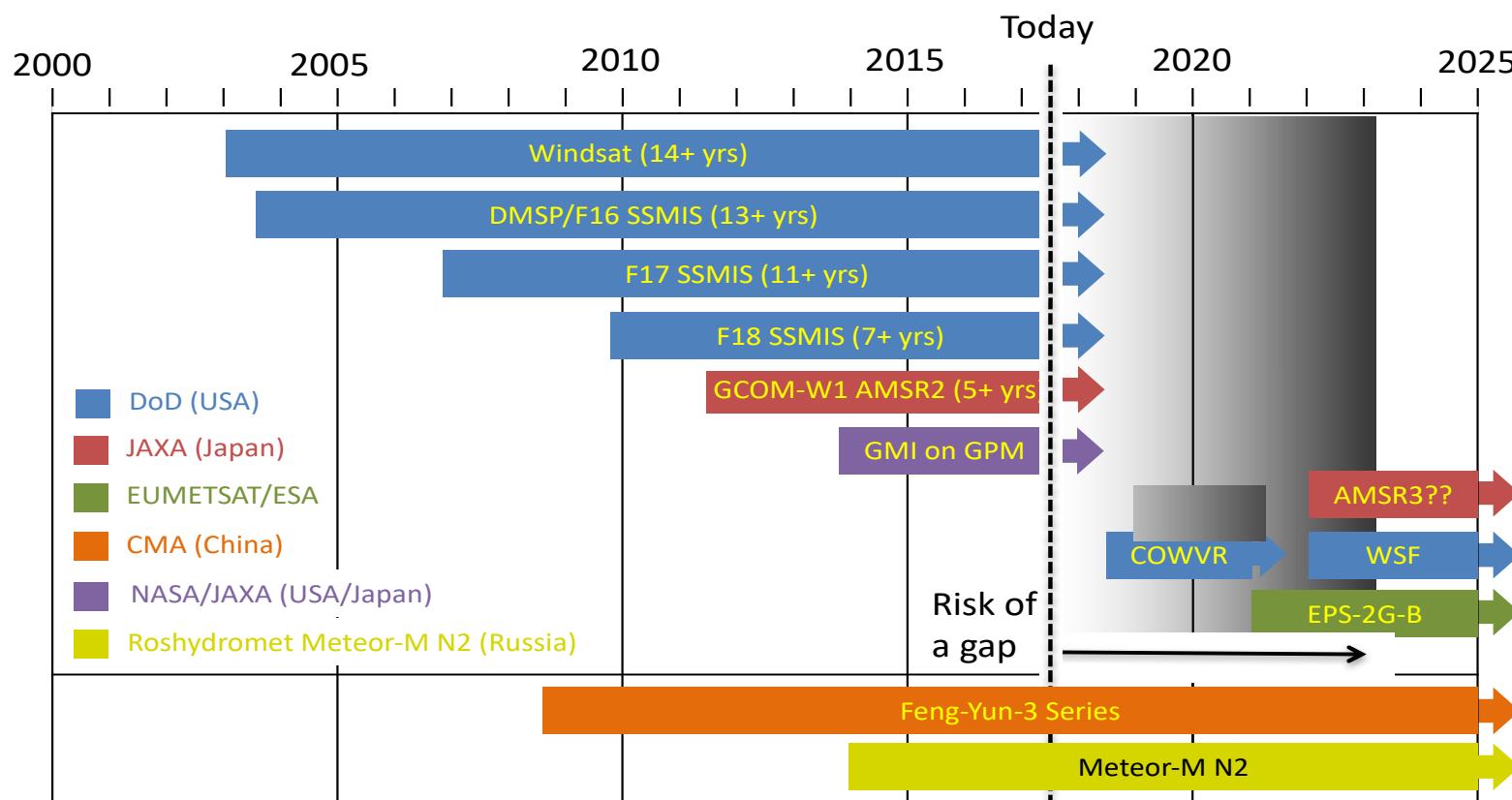
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Passive Microwave Imagers: Current and Planned

Current and future polar orbiting passive microwave coverage



Walt Meier, NSIDC/NASA



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L1数据介绍



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L1数据文件

表 3-1 FY-3D 微波成像仪数据产品文件汇总

序号	产品名称	产品格式	周期	产品描述	关键词
1	FY3D_MWRIA_GBAL_L1_YYYYMMDD_HHMM_010KM_MS.HDF	HDF	54 分钟	升轨亮温轨道数据	A
2	FY3D_MWRID_GBAL_L1_YYYYMMDD_HHMM_010KM_MS.HDF	HDF	54 分钟	降轨亮温轨道数据	D

每日全球28轨
每条轨道38-40MB



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Geolocation Fields	SDS 1	Latitude	纬度	Latitude
	SDS 2	Longitude	Longitude	经度
	SDS 3	Sensor_Zenith	Earth Observation Sensor Zenith Angle	卫星对地观测天顶角
	SDS 4	Sensor_Azimuth	Earth Observation Sensor Azimuth Angle	卫星对地观测方位角
	SDS 5	Solar_Zenith	Earth Observation Solar Zenith Angle	太阳天顶角
	SDS 6	Solar_Azimuth	Earth Observation Solar Azimuth Angle	太阳方位角
Calibration Fields	SDS 7	EARTH_OBSERVE_BT_10_to_89GHz	10-89GHz Earth Observation Brightness Temperature	10-89GHz V 和 H 极化对地观测亮温数据
	SDS 8	LandCover	Land Cover	89GHz 频点分辨率水平的 IGBP 陆表覆盖分类
	SDS 9	LandSeaMask	Land Sea Mask	海陆掩码
	SDS 10	DEM	Digital Elevation Model	地表高程
	SDS 11	Scan_Daycnt	Scan Line Time (day count)	扫描线日计数
	SDS 12	Scan_Mscnt	Scan Line Time (milliseconds count)	扫描线毫秒计数
QA Fields	SDS 13	QA_Scan_Flag	QA Flag for Scanline	扫描线预处理质量标识
	SDS 14	QA_Ch_Flag	QA Flag for Channel Data Integrity	通道数据完整性质量标识



频率测试结果

表 4-1 FY-3D 微波成像仪带宽测试结果

通道	带宽设计值	D 星带宽
10.65V	180±10%	178.8
10.65H	180±10%	180.8
18.7V	200±10%	197.9
18.7H	200±10%	198.8
23.8V	400±10%	388.8
23.8H	400±10%	402
36.5V	900±10%	873
36.5H	900±10%	873
89V	2300±10%	2×2330
89H	2300±10%	2×2344

表 4-1 FY-3D 微波成像仪频率测试结果

频率	本振频率设计值	D 星本振频率
10.65	10.45±0.01	10.4482438
18.7	19.3±0.01	19.297447
23.8	23.1±0.01	23.0979401
36.5	35.05±0.01	35.0512857
89	89±0.02	88.999806



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核心SDS

L1 数据中，亮温数据集为 SDS7 EARTH_OBSERVE_BT_10_to_89GHz，其中存储了每条轨道定标后的各个通道亮温数据，为了节约存储空间，进行了格式转换。

通过下式可计算得到亮温结果，单位为 K。

$$Tb = DN \times 0.01 + 327.68$$

其中：

Tb 为亮度温度，DN 为 SDS7 中所存数值。

亮温数据集大小为 [nscans,npoints,10]，是一个三维数组，其中，nscans 为该条轨道扫描线数，npoints 为每条扫描线的扫描点数，10 对应 10 个通道，顺序为 10V\10H\18V\18H\23V\23H\36V\36H\89V\89H。

- `data = hdf5read(filename, '/Calibration/EARTH_OBSERVE_BT_10_to_89GHz')`



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核心 SDS

SDS1 和 SDS2 分别为纬度和经度数据集，大小均为[nscans,npoints]，其中，nscans 为该条轨道扫描线数,npoints 为每条扫描线的扫描点数。

- data = hdf5read(filename, ‘/Geolocation/Longitude’)
- data = hdf5read(filename, ‘/Geolocation/Latitude’)



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典型产品

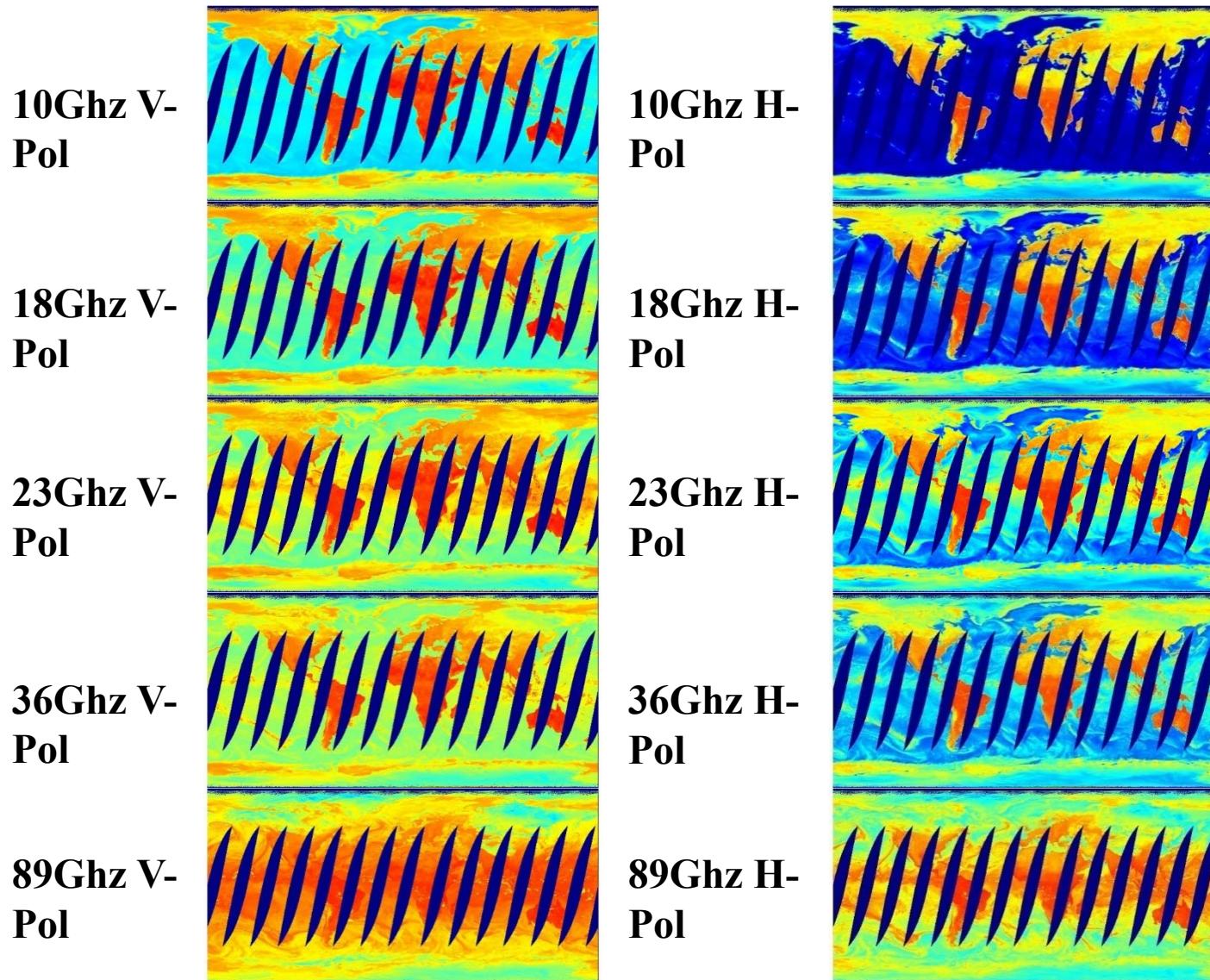


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产品示例



- 左图为微波成像仪2017年11月26日10-89Ghz, V/H极化共计10通道的降轨全球亮温拼图, 表征当地时间凌晨1点30分左右地球表面10-89GHz, V/H极化的辐射亮温分布情况。
- 由于随着频率增加, 地表辐射受大气影响逐渐增大, 因此全球亮温拼图中由上到下的海陆差异逐渐缩小。
- 在10-89GHz频率范围内, 陆表发射率高于海表, 因此全球中低纬度的陆地表现为红色的高亮温特征, 而在海洋区域, 由于强降雨、海浪的影响, 也会出现较大范围明显的高亮温区域。



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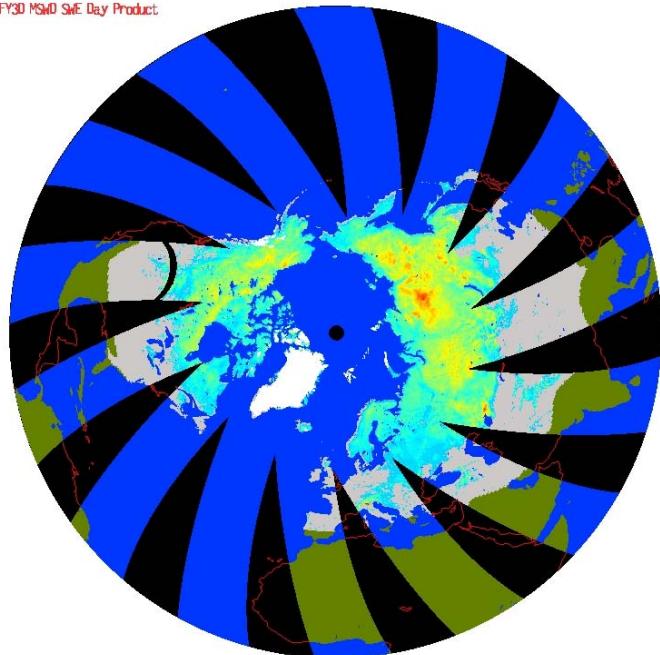


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雪深/雪水当量产品



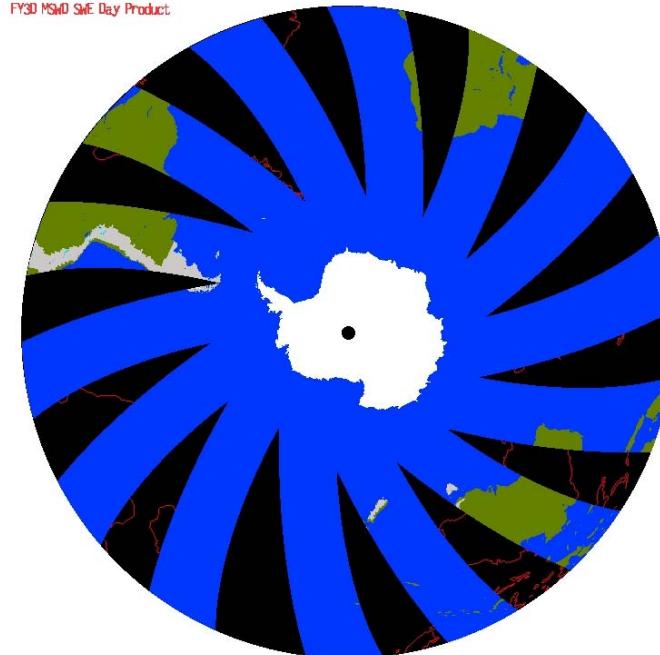
FY3D MSG0 SWE Day Product



- MISSING
- RAIN
- COLD RAIN
- ICE
- Land Snow Impossible
- WATER



FY3D MSG0 SWE Day Product



- MISSING
- RAIN
- COLD RAIN
- ICE
- Land Snow Impossible
- WATER

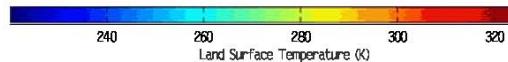
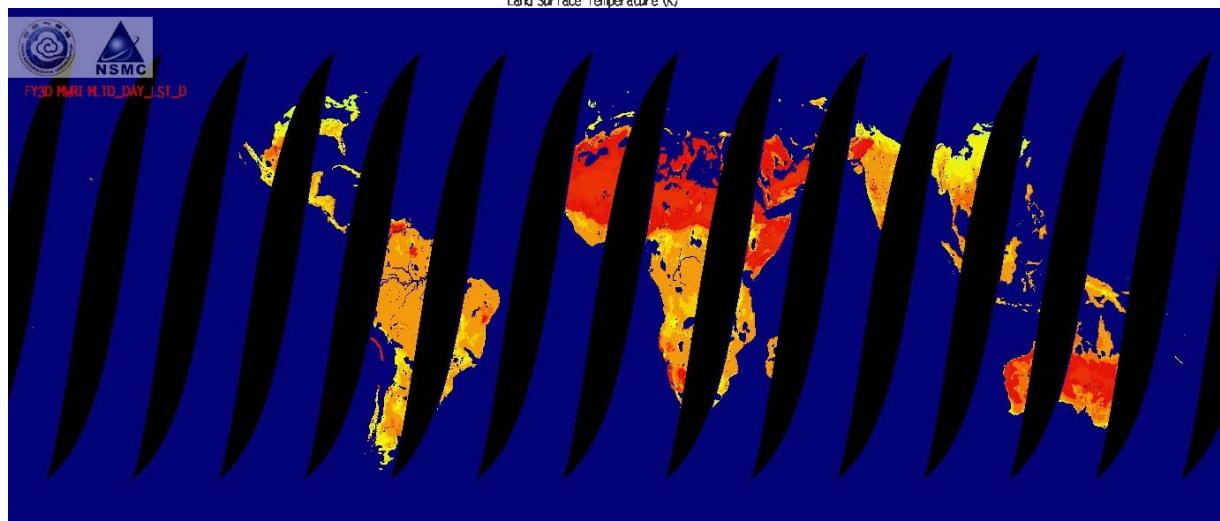


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陆表温度产品

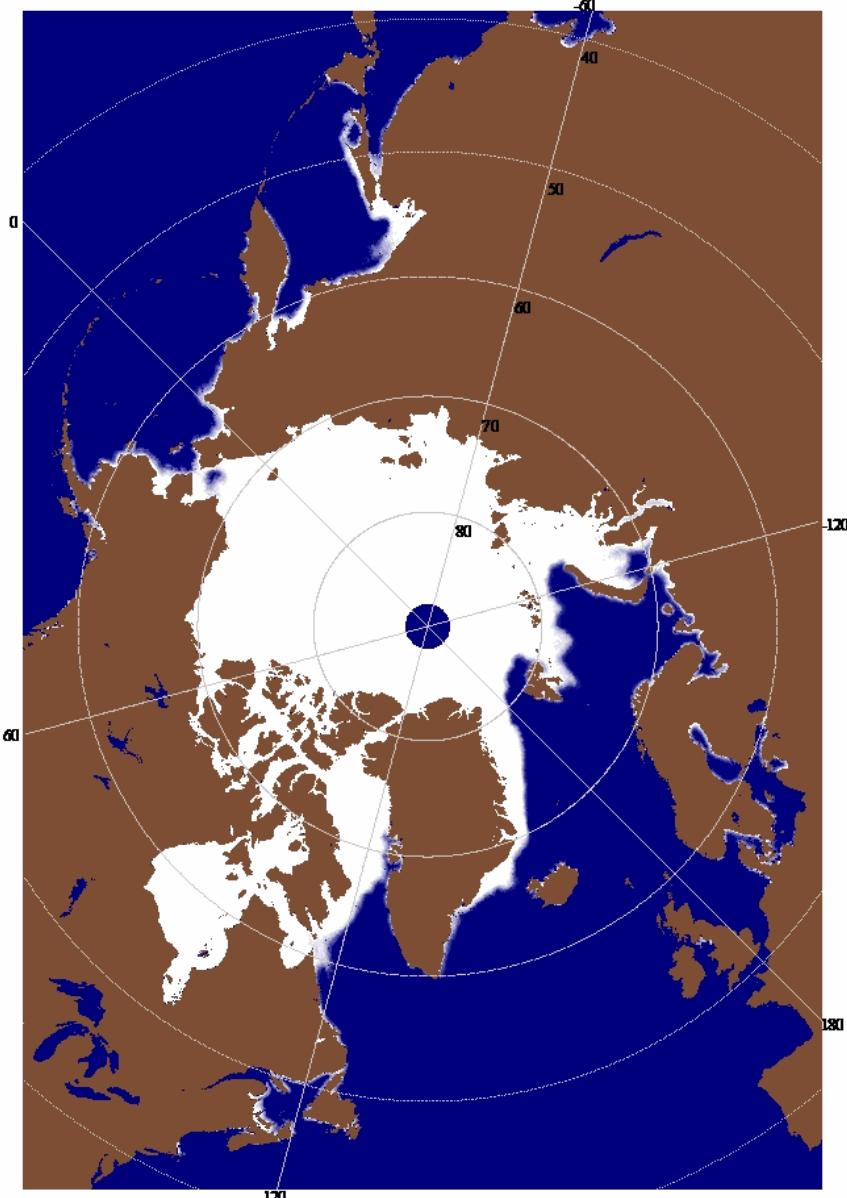


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极区海冰 覆盖度产品

FY-3D MWRI SIC North Daily Product: 2018-01-01



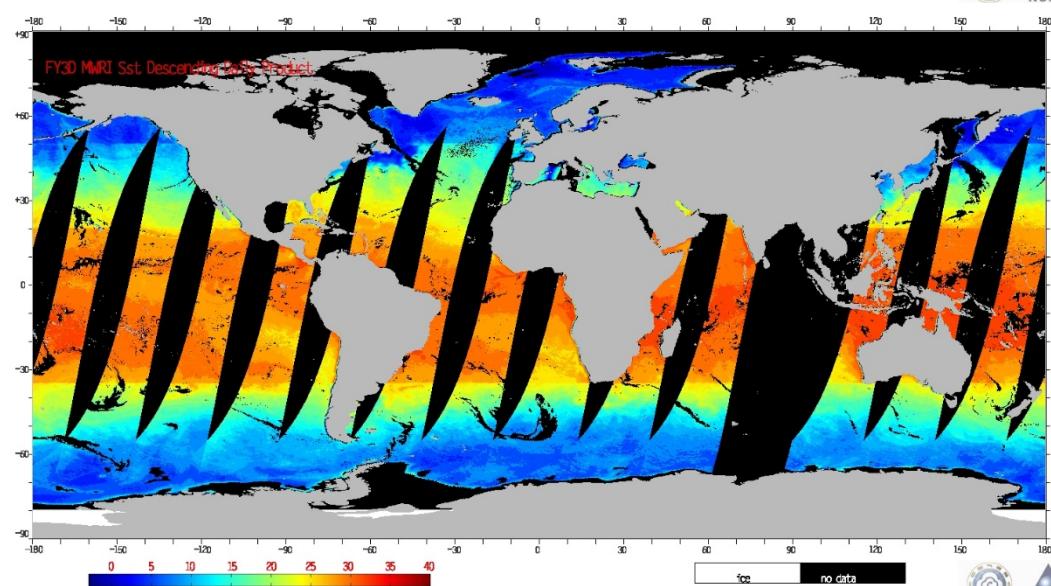
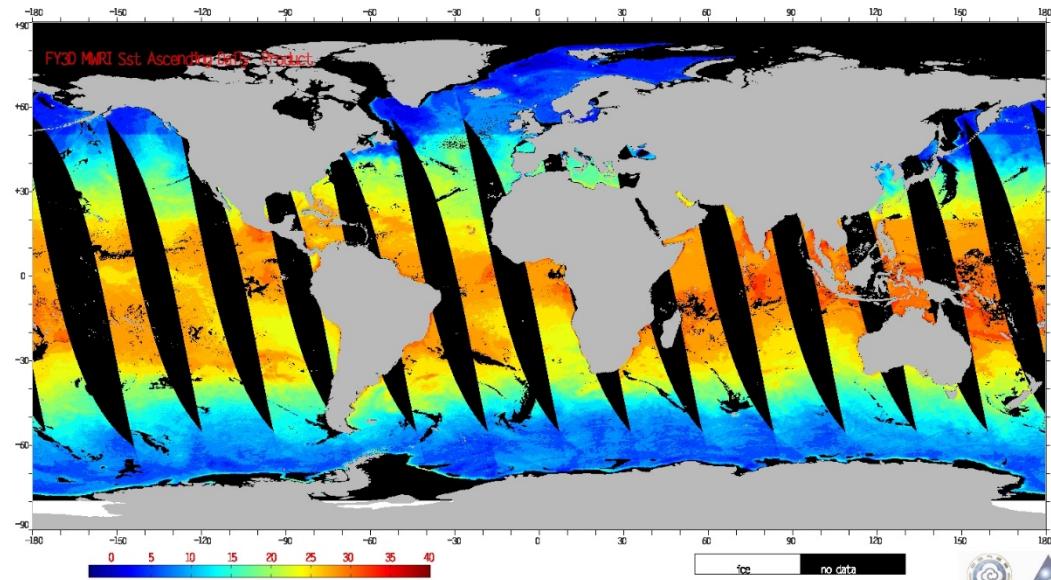
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海表温度产品

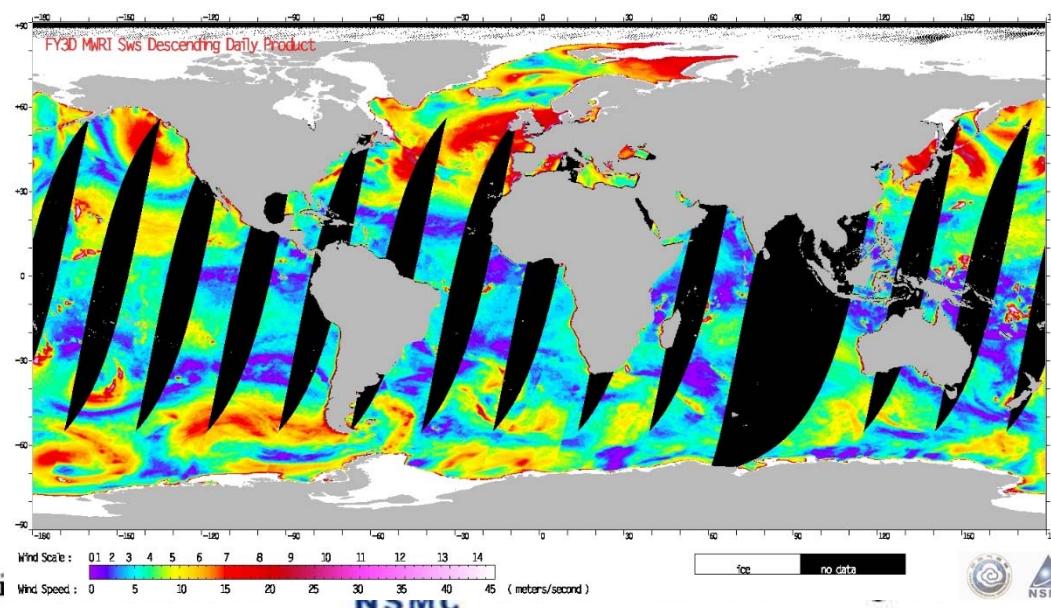
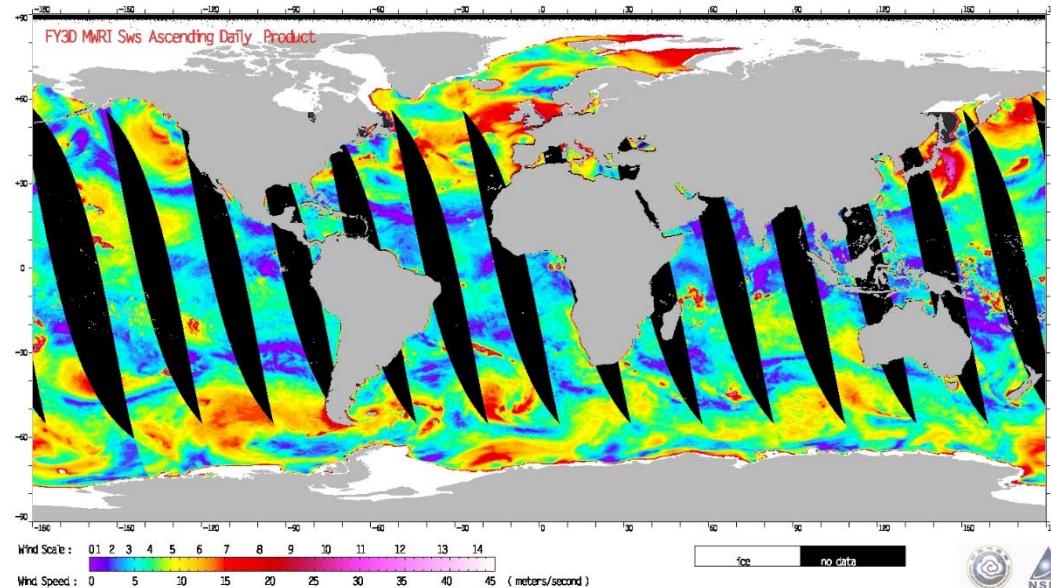


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NSMC

National Satellite Meteorological Center

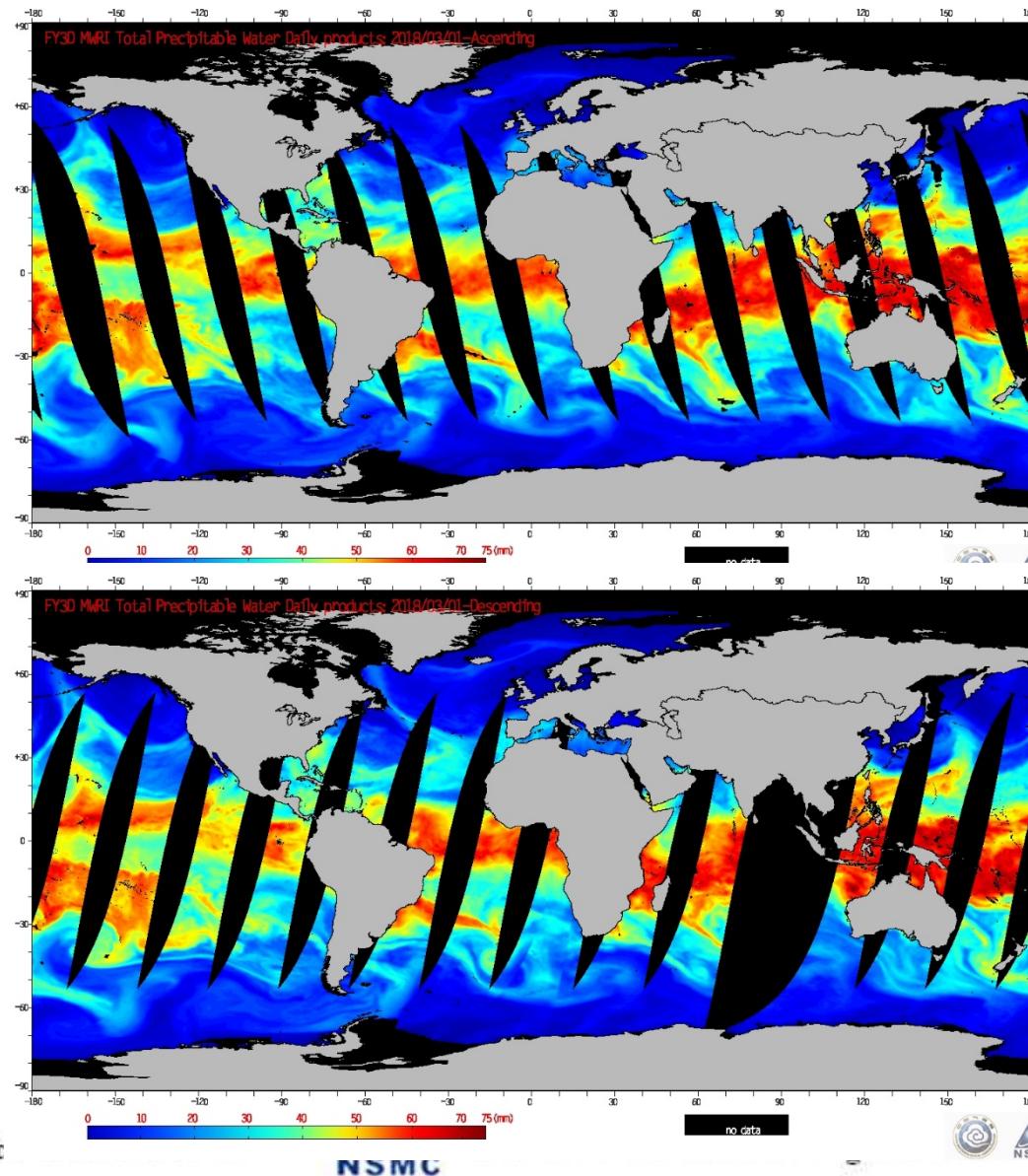
洋面风产品



Chinese Meteorologi

NSMC

大气可降水日产品



Chinese Meteorologic



NSMC

风云三号D星微波温度计



Chinese Meteorological Administration



National Satellite Meteorological Center



CMA

一. 温度计简介

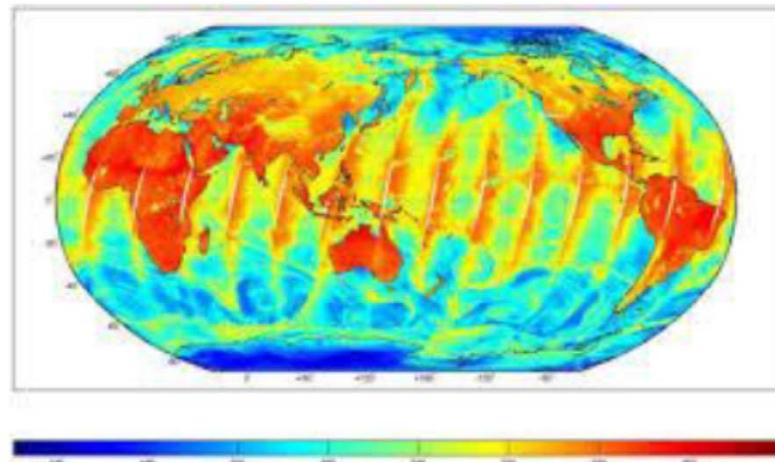


风云三号卫星微波温度计 (MWTS)

- ✓ 01批A/B星配置与MSU相同：大气温度廓线；
A星在轨运行四年半，B星运行三年半；C星运行一年半。
- ✓ 02批C/D星配置相当于ATMS3-15。

通道设置

序号	探测频率 (GHz)	
	01批A/B星	02批C/D星
1	50.3	50.3
2	/	51.76
3	/	52.8
4	53.74	53.596
5	/	54.40
6	54.96	54.94
7	/	55.50
8	57.95	57.290344(fo)
9	/	fo±0.217
10	/	fo±0.3222±0.048
11	/	fo±0.3222±0.022
12	/	fo±0.3222±0.010
13	/	fo±0.3222±0.0045





CMA



二. 仪器在轨性能评价

通道	FY-3D星MWTS性能指标与测试结果		带宽 (MHz)		主波束效率		波束宽度(3dB) (度)	
	中心频率(GHz)	设计[注1]	测量	设计[注2]	测量	设计	测量	设计[注3]
1	50.3	50.258	180	184.21	>90%	92.31%	2.2	2.375
2	51.76	51.733	400	383.72	>90%	93.81%	2.2	2.325
3	52.8	52.780	400	363.38	>90%	92.98%	2.2	2.275
4	53.596	53.575	400	394.62	>90%	92.98%	2.2	2.225
5	54.40	54.405	400	428.59	>90%	91.87%	2.2	2.200
6	54.94	54.937	400	422.36	>90%	92.44%	2.2	2.175
7	55.50	55.504	330	349.22	>90%	91.93%	2.2	2.250
8	57.290344(fo)	57.290 (fo)	330	297.68	>90%	91.97%	2.2	2.200
9	fo±0.217	fo±0.217	78	76.08	>90%	91.97%	2.2	2.200
10	fo±0.3222±0.048	fo±0.3222±0.048	36	33.73	>90%	91.97%	2.2	2.200
11	fo±0.3222±0.022	fo±0.3222±0.022	16	15.61	>90%	91.97%	2.2	2.200
12	fo±0.3222±0.010	fo±0.3222±0.010	8	8.21	>90%	91.97%	2.2	2.200
13	fo±0.3222±0.0045	fo±0.3222±0.0045	3	2.82	>90%	91.97%	2.2	2.200

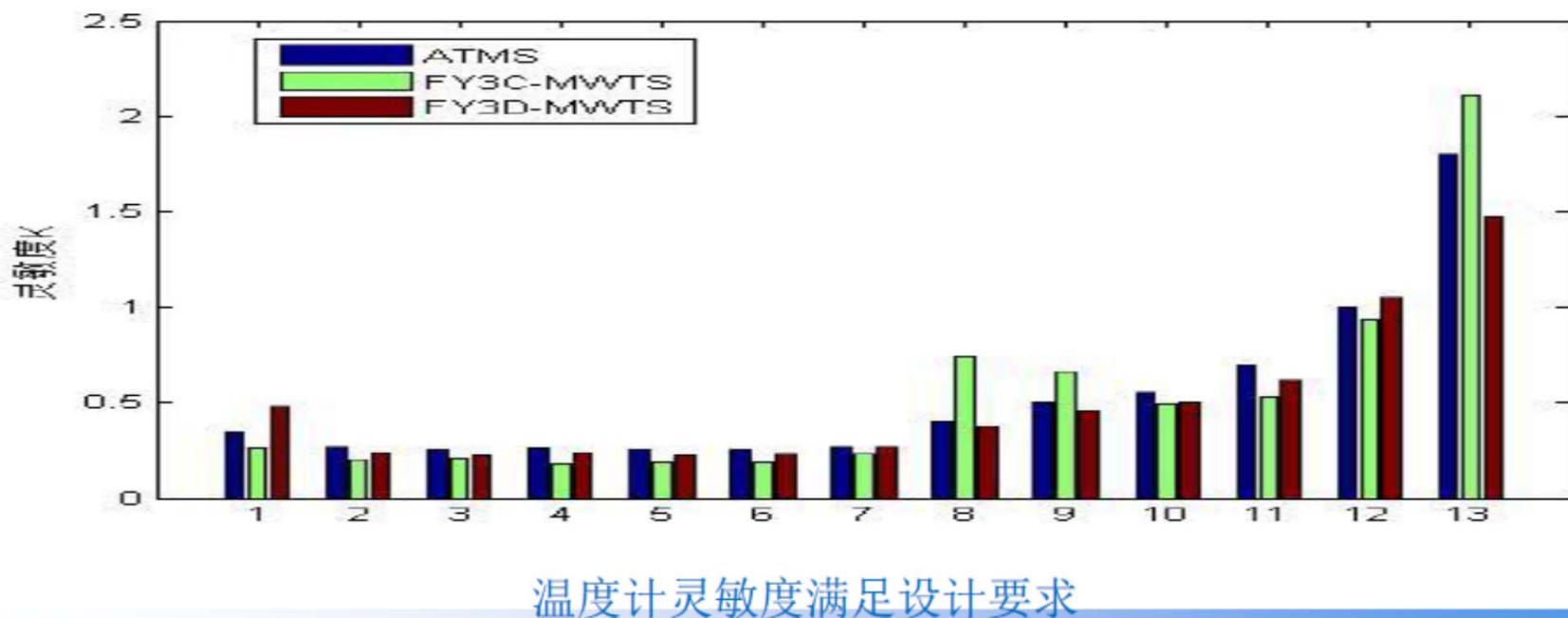


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2.1 灵敏度

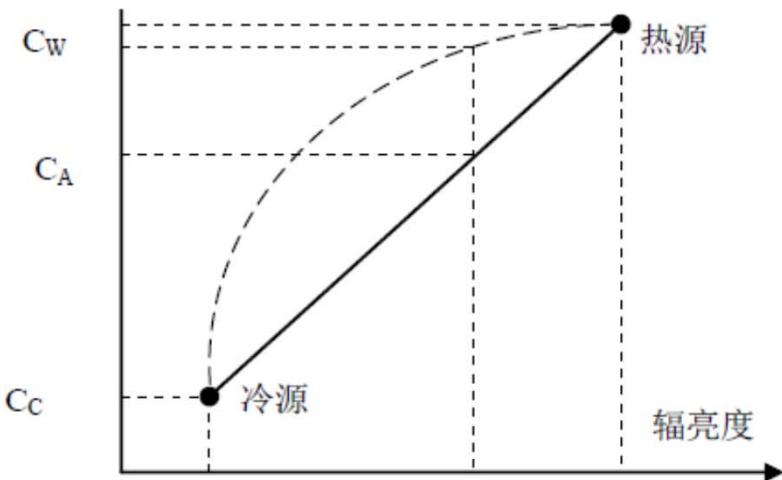


- 在每个工作温度下，在每个变温源的温度点，从900条扫描线中选择连续的200条扫描线的数据进行处理，每20条扫描线计算得到冷定标源的平均温度 T_1 及其输出电压平均值 V_1 ；计算得到热定标源的温度 T_2 及其输出电压平均值 V_2 ；计算冷源和热源输出电压的方差 V_{1rms} ；和 V_{2rms} ，按照式1计算共得到20个 ΔT 值，取其中的第2大值作为本次测量的测温灵敏度。
- $$\Delta T = \frac{T_2 - T_1}{V_2 - V_1} \times \sqrt{(V_{1rms}^2 + V_{2rms}^2)/2} \quad (1)$$
- 图中给出了在轨工作温度下的灵敏度情况的曲线。



2.2 定标精度

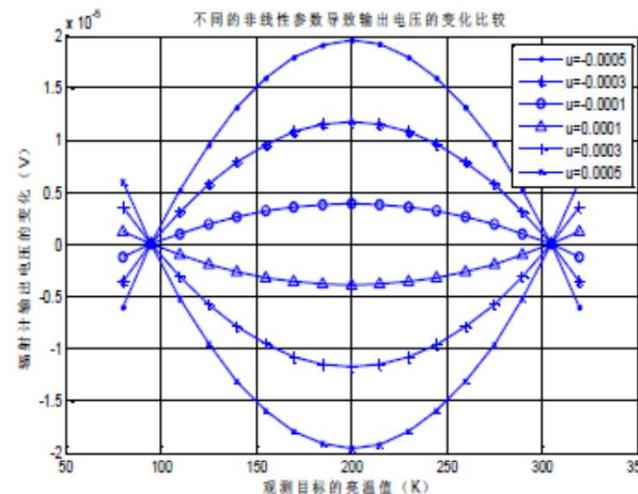
- 微波辐射计定标就是确定微波辐射计对于已知辐射特性的目标的响应特性。
- 定标方程就是描述这个响应特性的函数。通常辐射计的响应特性是线性的，或者是准线性的，因此可以用一次方程或者二次方程描述。



$$R_C = AC_C + B$$

$$A = (R_W - R_C) / (C_W - C_C)$$

$$B = (R_C C_W - R_W C_C) / (C_W - C_C)$$



$$R_A(C) = a_0 + a_1 C_A + a_2 C_A^2$$

$$a_0 = R_H - AC_H + uA^2 C_H C_C$$

$$a_1 = A - uA^2 (C_H + C_C)$$

$$a_2 = uA^2$$



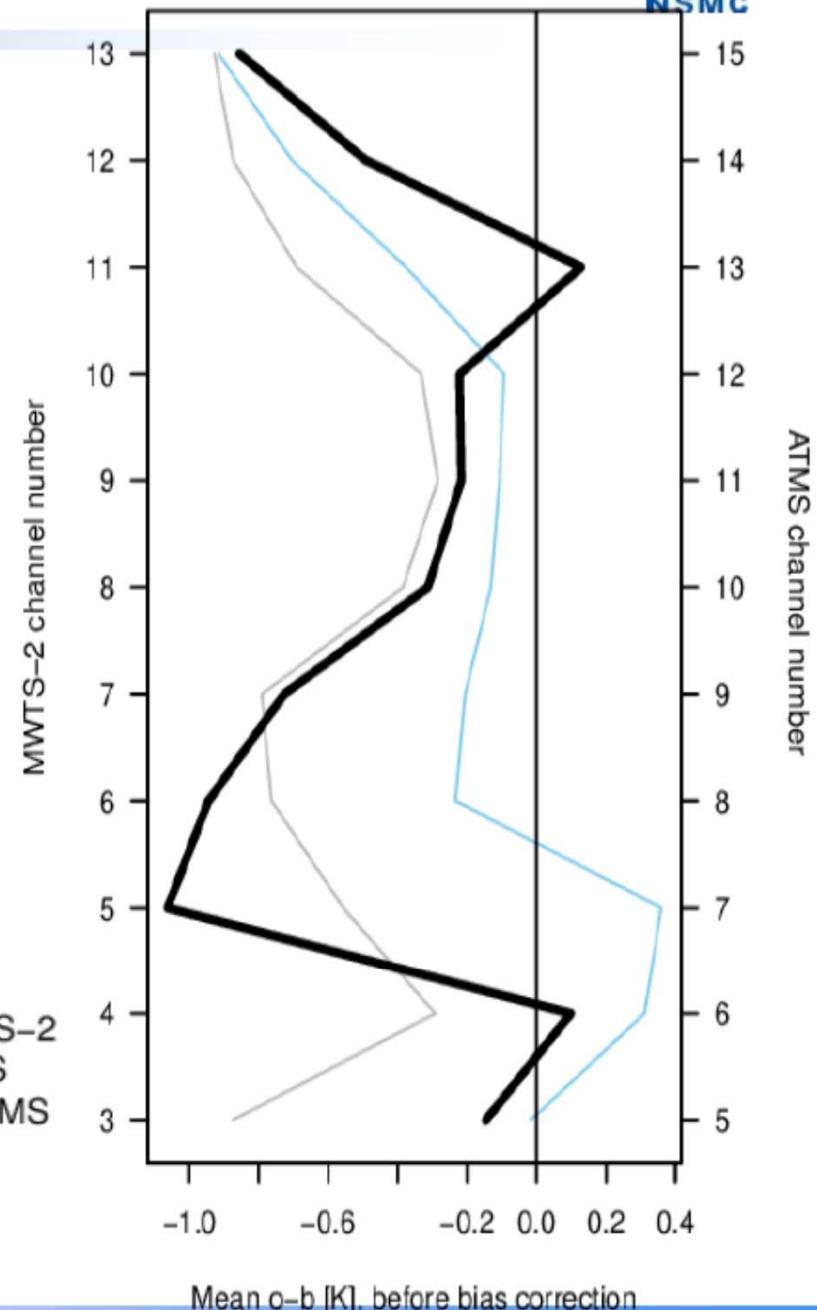
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国际对比



- 国际模式比对偏差结果
- FY3D-MWTS;
- S-NPP ATMS;
- NOAA-20 ATMS

— FY-3D MWTS-2
— S-NPP ATMS
— NOAA-20 ATMS





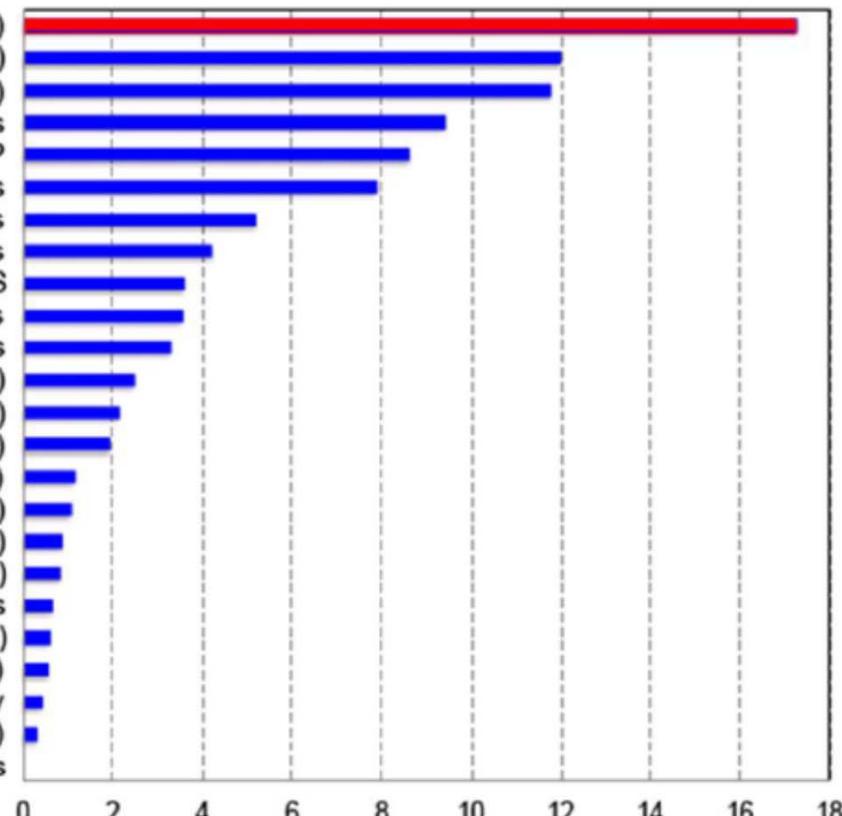
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五. 温度计典型产品及应用情况

Operational ECMWF system September to December 2008. Averaged over all model layers and entire global atmosphere. % contribution of different observations to reduction in forecast error.

AMSU-A: Adv MW Sounder A on Aqua and NOAA POES (T)
IASI: IR Atmos Interferometer on METOP (T,H)
AIRS: Atmos IR Sounder on Aqua (T,H)
AIREP: Aircraft T, H, and winds
GPSRO: RO bending angles from COSMIC, METOP
TEMP: Radiosonde T, H, and winds
QuikSCAT: sfc winds over oceans
SYNOP: Sfc P over land and oceans, H, and winds over oceans
AMSU-B: Adv MW Sounder B on NOAA POES
GOES winds
METEOSAT winds
Ocean buoys (Sfc P, H and winds)
PILOT: Pilot balloons and wind profilers (winds)
HIRS: High-Resol IR Sounder on NOAA POES (T,H)
MSG: METEOSAT 2nd Generation IR rad (T,H)
MHS: MW humidity sounder on NOAA POES and METOP (H)
AMSRE: MW imager radiances (clouds and precip)
SSMI: Special Sensor MW Imager (H and sfc winds)
GMS: Japanese geostationary satellite winds
MODIS: Moderate Resolution Imaging Spectroradiometer (winds)
GOES IR rad (T,H)
MTSATIMG: Japanese geostationary sat vis and IR imagery
METEOSAT IR Rad (T,H)
O3: Ozone from satellites



Note:

- 1) Sounders on Polar Satellites reduce forecast error most
- 2) Results are relevant for other NWP Centers, including NWS/NCEP

Forecast error contribution (%)

Courtesy: Carla Cardinali and Sean Healy, ECMWF

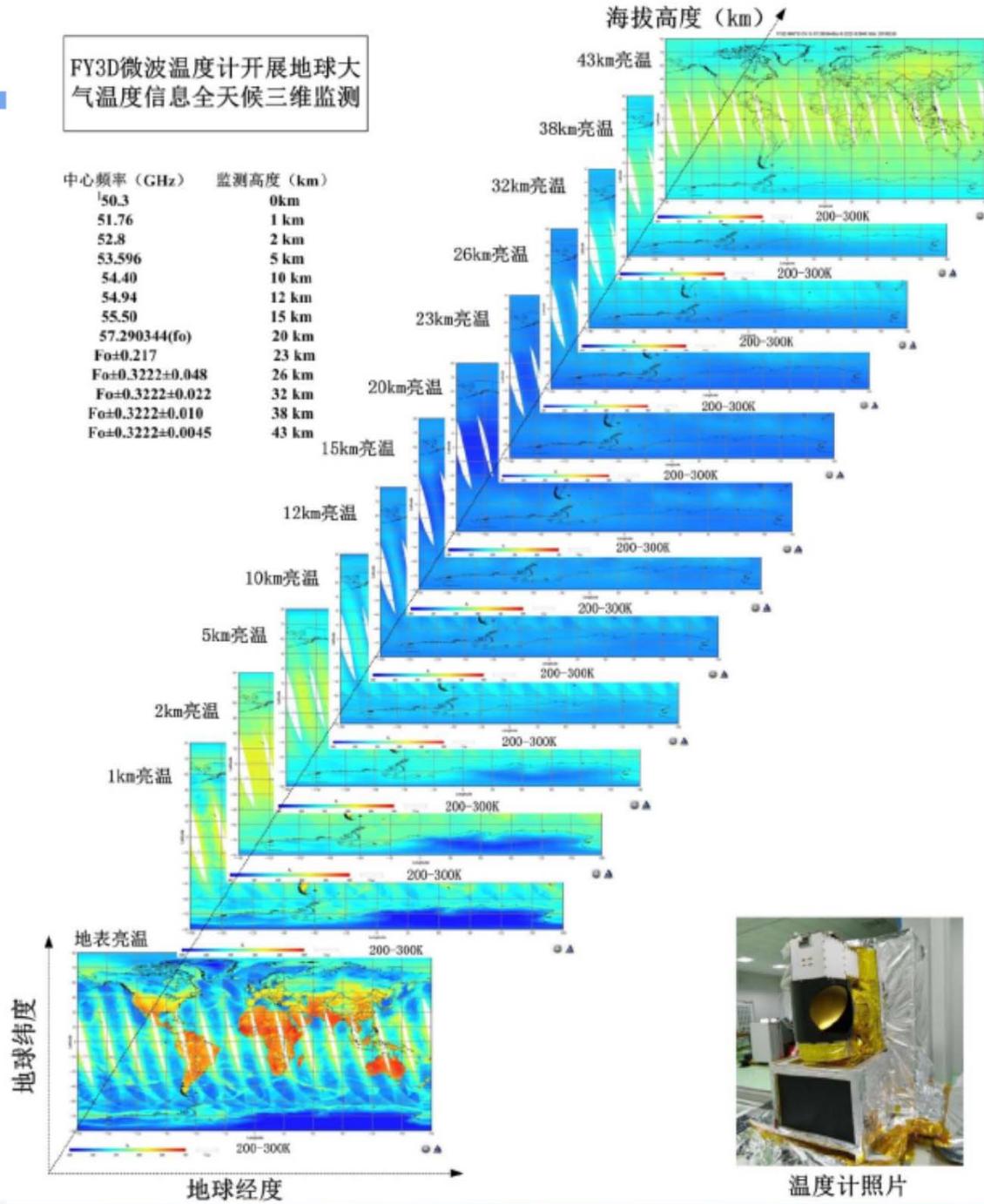


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FY3D微波温度计开展地球大
气温度信息全天候三维监测



中心频率(GHz)	监测高度(km)
50.3	0km
51.76	1 km
52.8	2 km
53.596	5 km
54.40	10 km
54.94	12 km
55.50	15 km
57.290344(fo)	20 km
Fo±0.217	23 km
Fo±0.3222±0.048	26 km
Fo±0.3222±0.022	32 km
Fo±0.3222±0.010	38 km
Fo±0.3222±0.0045	43 km



风云三号D星微波湿度计



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一、FY-3D MWHS II 简介

仪器通道参数设置

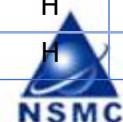
仪器主要参数指标

参数	指 标
对地扫描张角	±53.35°
扫描成像点数	98个点/每条扫描线
在轨定标	周期性两点定标
扫描周期	2667ms
两副天线间配准精度	0.1°（方位、俯仰）
天线指向精度	±0.10°

序号	中心频率 (GHz)	极化	带宽 (MHz)	灵敏度 (K)	定标精度 (K)	3dB波束 宽度
1	89.0	V	1500	1.0	1.3	2.0°
2	118.75±0.08	H	20	3.6	2.0	2.0°
3	118.75±0.2	H	100	2.0	2.0	2.0°
4	118.75±0.3	H	165	1.6	2.0	2.0°
5	118.75±0.8	H	200	1.6	2.0	2.0°
6	118.75±1.1	H	200	1.6	2.0	2.0°
7	118.75±2.5	H	200	1.6	2.0	2.0°
8	118.75±3.0	H	1000	1.0	2.0	2.0°
9	118.75±5.0	H	2000	1.0	2.0	2.0°
10	150.0	V	1500	1.0	1.3	1.1°
11	183.31±1	H	500	1.0	1.3	1.1°
12	183.31±1.8	H	700	1.0	1.3	1.1°
13	183.31±3	H	1000	1.0	1.3	1.1°
14	183.31±4.5	H	2000	1.0	1.3	1.1°
15	183.31±7	H	2000	1.0	1.3	1.1°



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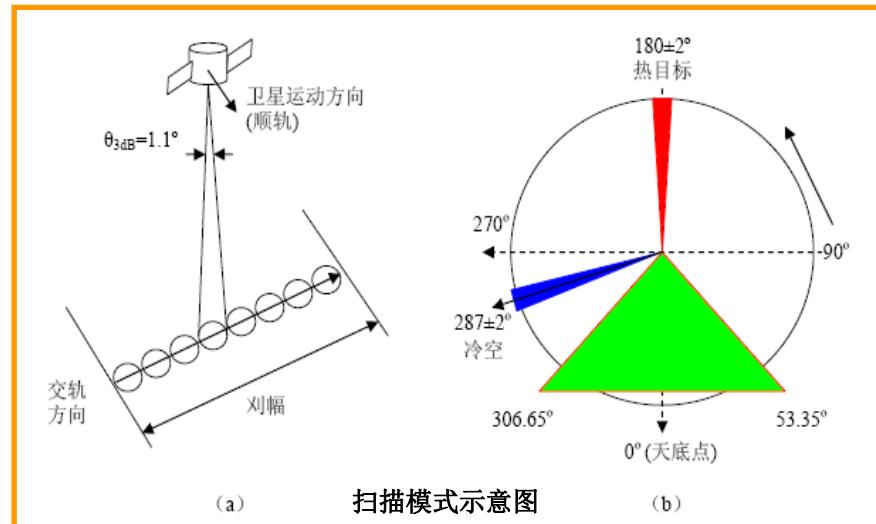


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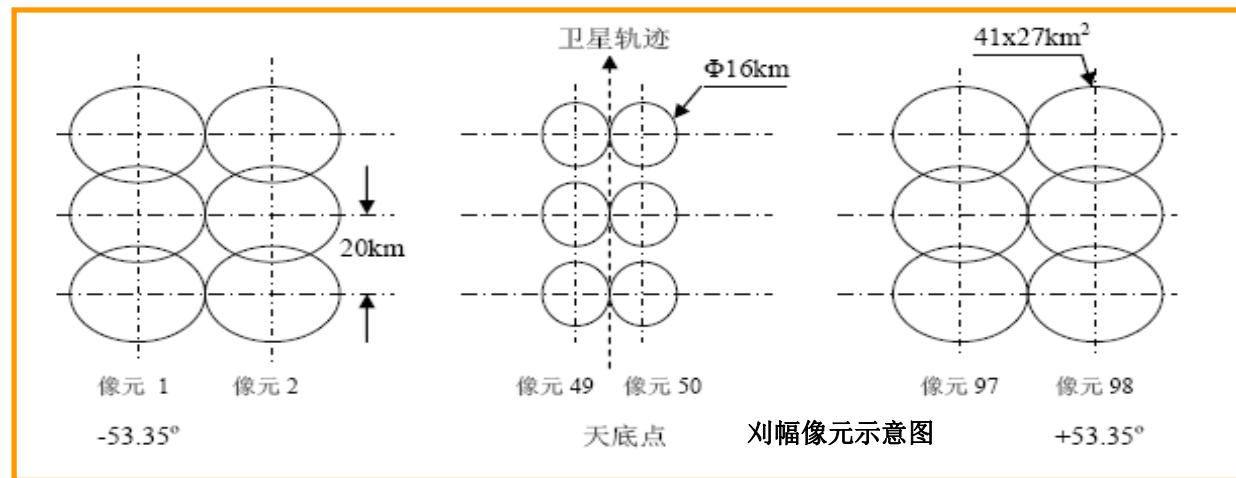
一、FY-3D MWHS II 简介

仪器由中科院国家空间科学中心研制

- 刃幅宽度: 2645 km;
- 像元数: 每条扫描线有98个像元;
- 刃幅间隔: 20km;
- 空间分辨率: 通道1-9的星下点分辨率约为25km, 通道10-11的星下点分辨率约为15km。



MWHS II型实物图片

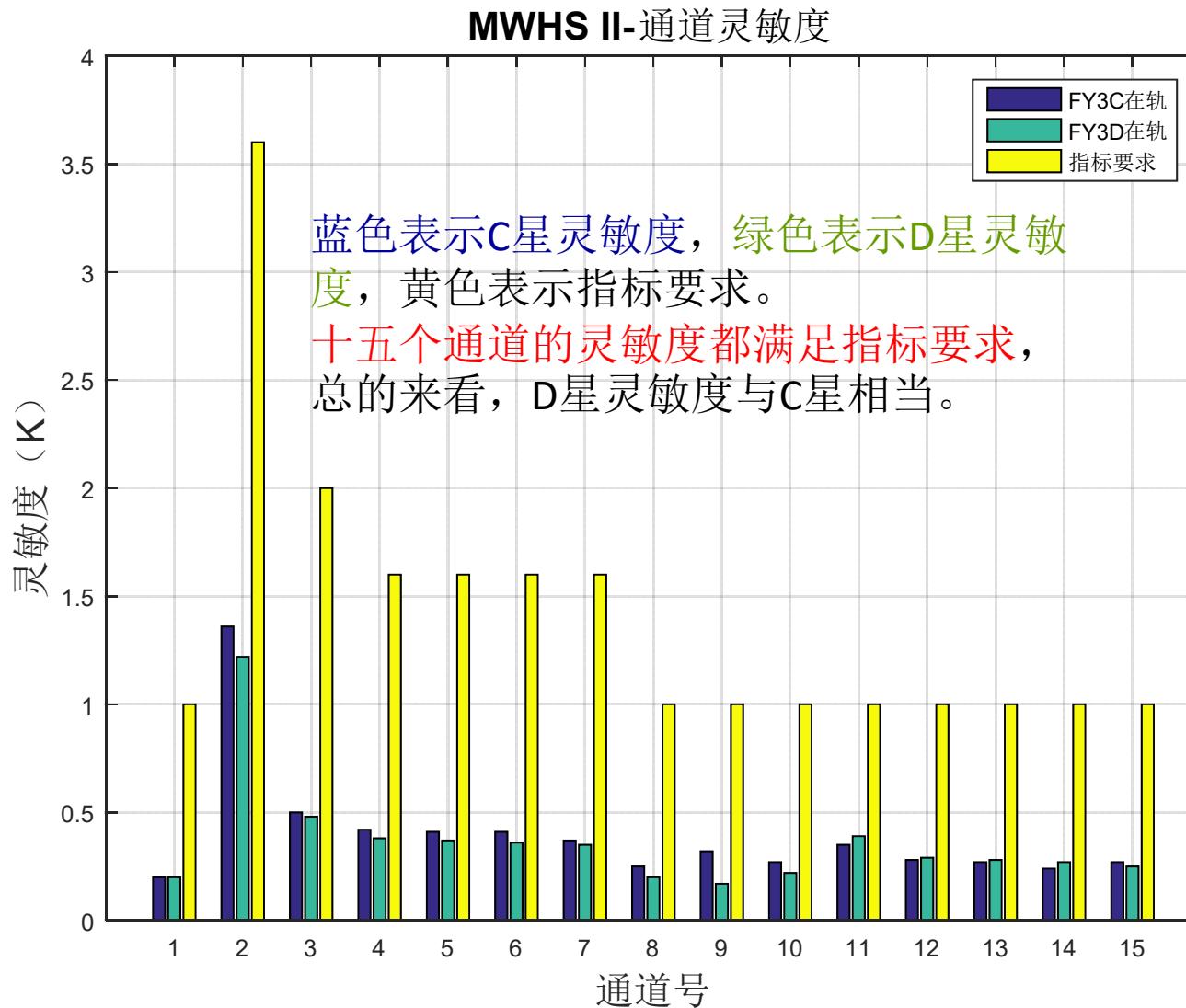


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二、FY-3D MWHS II 在轨性能评价



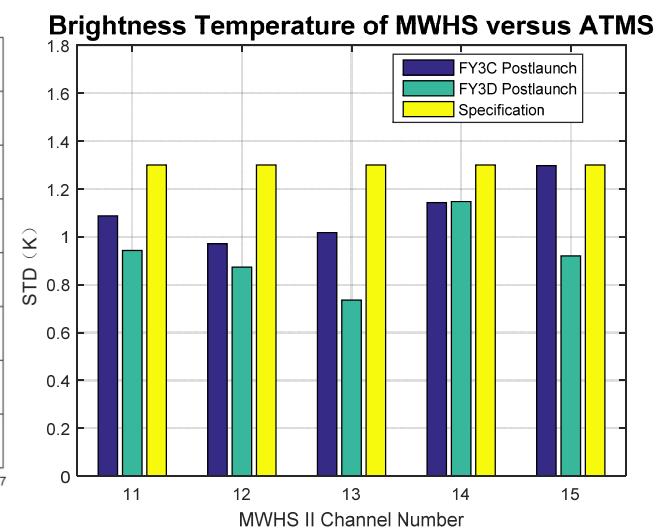
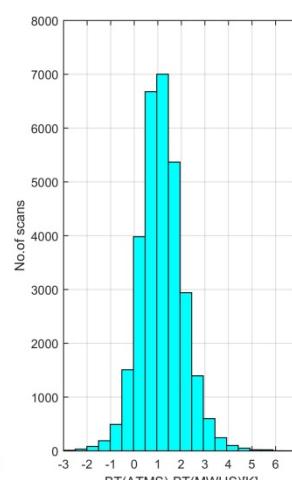
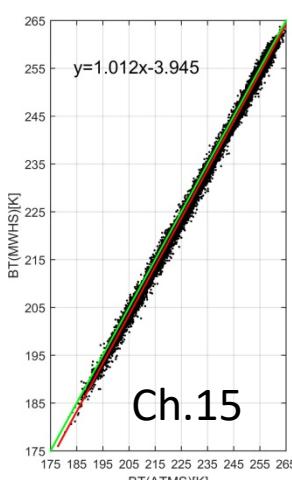
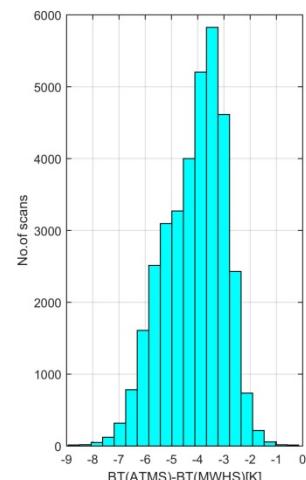
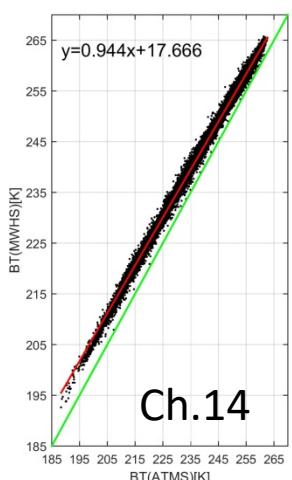
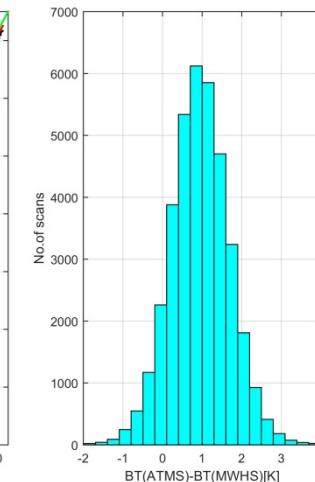
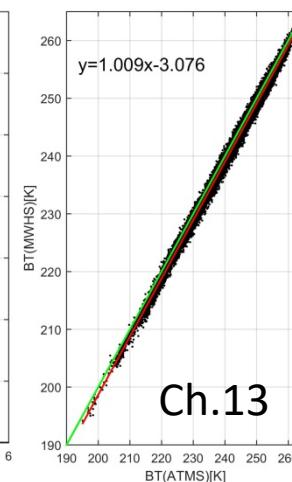
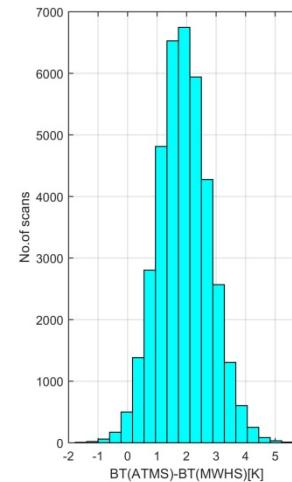
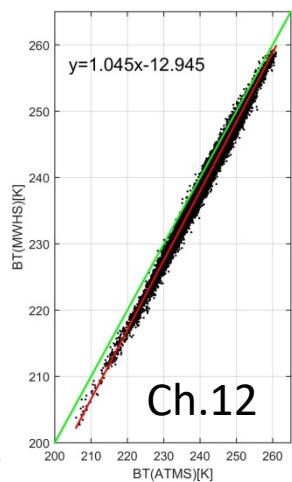
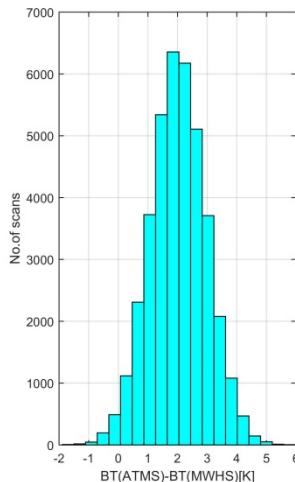
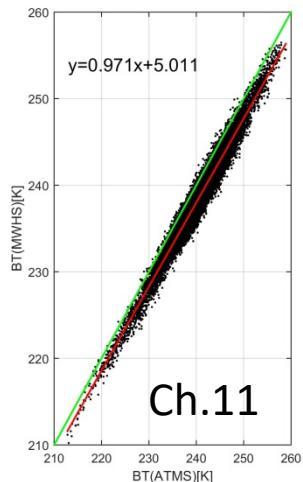
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二、FY-3D MWHS II 在轨性能评价

定标精度-交叉比对



由于谐波干扰的影响，通道14的偏差较大。



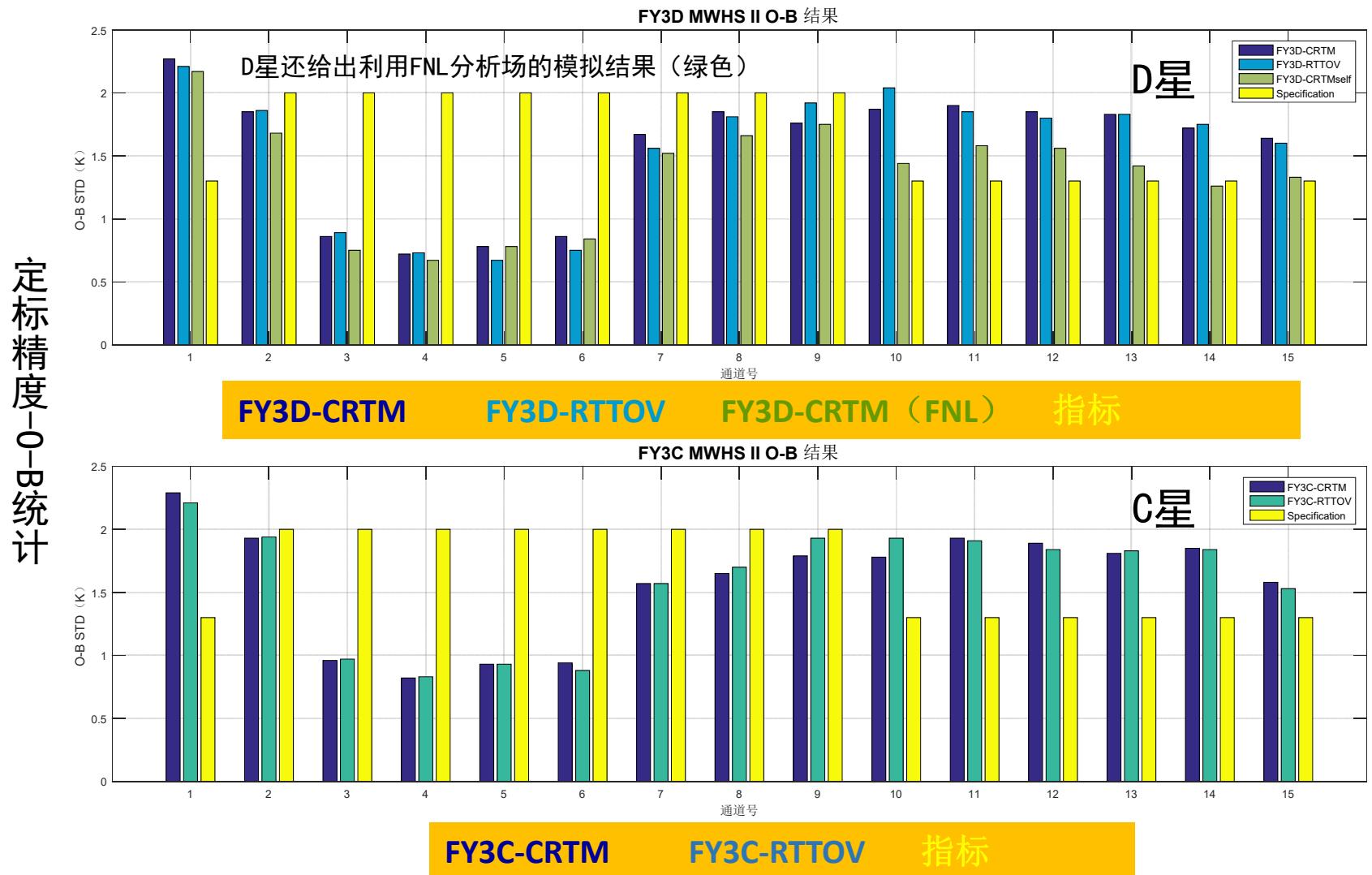
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蓝色表示C星结果，绿色表示D星结果，黄色表示指标要求。
与ATMS可比的183GHz五个湿度探测通道满足指标。



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二、FY-3D MWHS II 在轨性能评价



统计2018年3月21-25日全球南北纬45°间洋面晴空区O-B，结果表明：C星和D星误差相当；

118GHz八个温度探测通道均满足指标要求；窗区和吸收线远翼通道受地表模型精度影响，湿度通道受背景场精度影响，O-B方法评估仅供参考。



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FY3D MWHSII 在轨测试指标符合情况

序号	项目名称	技术指标要求	测试结果	符合情况
1	对地扫描张角	$\pm(53.35^\circ \pm 0.1^\circ)$	$106.765 \pm 0.015^\circ$	符合
2	对地观测点	98点	98点	符合
3	扫描周期	2667ms	2667ms	符合

通道	中心频率(GHz)	动态范围指标	动态范围	灵敏度指标	灵敏度	定标精度指标	定标误差	符合情况
1	89.0	0~10	1.64~4.74	1.0	0.20	1.3	0.945	符合
2	118.75 ± 0.08	0~10	1.61~4.89	3.6	1.22	2.0	1.516	符合
3	118.75 ± 0.2	0~10	1.62~5.75	2.0	0.48	2.0	0.985	符合
4	118.75 ± 0.3	0~10	1.99~5.6	1.6	0.38	2.0	1.037	符合
5	118.75 ± 0.8	0~10	1.61~5.12	1.6	0.37	2.0	0.936	符合
6	118.75 ± 1.1	0~10	1.6 ~5.19	1.6	0.36	2.0	0.933	符合
7	118.75 ± 2.5	0~10	1.41~4.88	1.6	0.35	2.0	0.914	符合
8	118.75 ± 3.0	0~10	1.25~4.66	1.0	0.20	2.0	0.883	符合
9	118.75 ± 5.0	0~10	3.65~8.87	1.0	0.17	2.0	0.861	符合
10	150.0	0~10	1.77~5.74	1.0	0.22	1.3	0.888	符合
11	183.31 ± 1	0~10	1.58~5.43	1.0	0.39	1.3	0.918	符合
12	183.31 ± 1.8	0~10	1.72~5.7	1.0	0.29	1.3	0.880	符合
13	183.31 ± 3	0~10	1.11~4.93	1.0	0.28	1.3	0.877	符合
14	183.31 ± 4.5	0~10	3.78~8.92	1.0	0.27	1.3	0.986	符合
15	183.31 ± 7	0~10	1.2 ~7.72	1.0	0.25	1.3	0.934	符合



三、FY-3D MWHS II L1数据格式及使用指南

FY-3D微波湿度计—型I数据科学数据集

科学数据集				
分组名称	科学数据集名		科学数据集英文描述	科学数据集中文描述
Geolocation Fields	SDS1	Latitude	Latitude in WGS84	纬度
	SDS2	Longitude	Longitude in WGS84	经度
	SDS3	SolarAzimuth	Solar Azimuth	太阳方位角
	SDS4	SolarZenith	Solar Zenith	太阳天顶角
	SDS5	SensorAzimuth	Sensor Azimuth	仪器方位角
	SDS6	SensorZenith	Sensor Zenith	仪器天顶角
	SDS7	Scnlin_daycnt	Scan Line Time (day count)	扫描线对地观测起始时刻天计数
	SDS8	Scnlin_ms cnt	Scan Line Time (milliseconds count)	扫描线对地观测起始时刻毫秒计数
	SDS9	Pixel_View_Angle	Pixel View Angle	对地观测起始终止角
	SDS10	DEM	Digital Elevation Model	数字地表高程
	SDS11	LandSeaMask	Land Sea Mask	海陆掩码
	SDS12	LandCover	Land Cover	陆地覆盖类型
Data Fields	SDS13	Earth_Obs_BT	Earth Observation Brightness Temperature	对地观测亮温
QA Fields	SDS14	QA_Scan_Flag	QA Flag for Scanline	扫描线预处理质量标识
	SDS15	QA_Ch_Flag	QA Flag for Channel Data Integrity	通道数据完整性质量标识
	SDS16	QA_Score	Earth Observation Brightness Temperature Quality Score	观测亮温质量评分

L1数据中表征维数的参数说明

参数名称	说明
npixel	98个扫描成像点数
nscans	每轨扫描线条数
nchannel	15个通道



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三、FY-3D MWHS II L1数据格式及使用指南

定标后对地观测亮温

	0	1	2	3	4	5	6
0	272.99765	270.92538	270.7772	270.87717	269.3741	269.47968	268.84293
1	272.80508	271.44504	271.60602	270.9336	270.3263	269.93716	268.93024
2	271.70618	271.2446	271.15662	270.42227	270.21793	269.48962	267.86435
3	272.2107	271.12936	271.35077	270.86505	269.424	268.69626	266.5122
4	272.5658	271.88538	272.23	270.6334	269.09933	267.3196	265.78497
5	273.16995	272.1804	271.87802	270.80457	268.6526	266.31488	264.65747
6	273.35068	273.10226	272.64417	270.49057	267.2877	265.32162	263.97293
7	273.60785	273.05304	273.02686	269.9769	266.24594	263.78445	262.31015
8	274.01205	272.5619	271.57767	268.12518	264.5783	261.74316	260.29968
9	274.04718	272.22522	270.8417	266.33585	264.15222	261.71872	260.618
10	274.67868	271.7452	268.84634	265.7311	263.29657	262.69254	261.68475
11	274.36774	270.9092	268.19437	265.9758	265.3708	264.3933	263.16837
12	274.2353	271.5484	268.83243	266.80045	266.5656	266.14554	264.82867
13	275.27145	272.3068	269.8713	268.39603	268.12823	267.21564	266.63895
14	275.3361	272.7438	270.02957	269.26382	268.25665	267.3412	266.73462
15	275.1298	272.7213	270.9022	269.76675	269.43796	267.78348	268.22726
16	275.45502	273.5727	271.47632	270.61932	269.5796	268.91254	269.20258
17	274.903	273.72922	271.72775	270.34592	269.55365	268.9781	269.20654
18	275.48425	273.9086	272.7709	271.01636	270.44073	270.1133	269.35184
19	275.00076	273.82816	272.47266	271.30728	271.53412	270.77414	269.2722
20	275.44455	274.17914	273.5648	272.2756	272.40997	271.9593	270.64072
21	275.9862	273.76218	273.73563	273.34116	273.4434	273.73196	272.4466
22	276.52573	274.79654	274.2764	274.0968	273.70456	273.77725	272.8017
23	276.18536	274.88794	274.6139	274.5601	273.95175	273.03815	272.863
24	276.45212	275.0938	274.66782	275.04163	273.72717	272.0751	271.8061
25	276.6099	275.49814	275.6252	274.36758	273.60785	272.3254	271.25546

存储格式: [nchannel × nsamples × npixel]



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四、FY-3D MWHS II L1数据读取程序说明

L1级数据的“QA”中存储了描述MWHS II定标亮温质量的三个科学数据集

The screenshot shows a file browser on the left and three table viewers on the right.

File Browser (Left):

- FY3D_MWHSX_GBAL_L1_20180123_0906_015KM_MS
- Data
 - Earth_Obs_BT
- Geolocation
 - DEM
 - LandCover
 - LandSeaMask
 - Latitude
 - Longitude
 - Pixel_View_Angle
 - Scnlin_daycnt
 - Scnlin_ms cnt
 - SensorAzimuth
 - SensorZenith
 - SolarAzimuth
 - SolarZenith
- QA
 - QA_Ch_Flag
 - QA_Scan_Flag
 - QA_Score

A red circle highlights the QA folder.

Table Viewers (Right):

- TableView - QA_Score - /QA/ - W:\FY3DMWHS\l1\DATA\2018\20180123\FY3D_MWHSX_GBAL_L1\QA\QA_Score
- TableView - QA_Scan_Flag - /QA/ - W:\FY3DMWHS\l1\DATA\2018\20180123\FY3D_MWHSX_GBAL_L1\QA\QA_Scan_Flag
- TableView - QA_Ch_Flag - /QA/ - W:\FY3DMWHS\l1\DATA\2018\20180123\FY3D_MWHSX_GBAL_L1\QA\QA_Ch_Flag

The QA_Score table data:

	0
0	100
1	100
2	100
3	100
4	100
5	100
6	100
7	100
8	100
9	100
10	100
11	100
12	100
13	100
14	100
15	100
16	100
17	100
18	100
19	100

The QA_Scan_Flag table data:

	0
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	0

The QA_Ch_Flag table data:

	0
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0



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四、FY-3D MWHS II L1数据读取程序说明

C语言高级函数版

调用函数: int status = ReadSDSHDFInt("Test.HDF", "/Group/DatasetName", Data);

只读: H5F_ACC_RDONLY

```
int ReadSDSHDFInt(const char *strFileName, const char *strSDSName, int* pData)
{
    herr_t status;
    hid_t hFileID1;
```

读写: H5F_ACC_RDWR

```
hFileID1=H5Fopen(strFileName, H5F_ACC_RDONLY, H5P_DEFAULT); //打开文件
```

```
if(hFileID1<0)
```

```
{
```

```
    printf("打开文件%s错误！\n",strFileName);
```

```
    return -1;
```

```
}
```

```
status = H5LTread_dataset_int(hFileID1, strSDSName, pData); //读取数据
```

```
if (status<0)
```

```
{
```

```
    H5FcloseshFileID1);
```

```
    return -3;
```

```
}
```

```
H5FcloseshFileID1); //关闭文件
```

```
return 0;
```

```
}
```

读取不同类型:

H5LTread_dataset_string

H5LTread_dataset_char

H5LTread_dataset_short

H5LTread_dataset_int

H5LTread_dataset_long

H5LTread_dataset_float

H5LTread_dataset_double



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四、FY-3D MWHS II L1数据读取程序说明

C语言底层函数版

```
int ReadL1(char* filename, char* datasetName, float *pData)
{
    hid_t file_id,dataset; //hid_t是自带的定义类型
    herr_t status;

    file_id = H5Fopen(filename, H5F_ACC_RDONLY, H5P_DEFAULT);
    if(file_id < 0)
    {
        printf("open %s error!\n",filename);
        return -1;
    }
    dataset = H5Dopen(file_id, datasetName,H5P_DEFAULT); //返回要读的数据集的id
    if(dataset < 0)
        return -1;

    status = H5Dread(dataset, H5T_NATIVE_FLOAT, H5S_ALL, H5S_ALL, H5P_DEFAULT, pData);
    if( status < 0 )
        return -1;
    H5Fclose(file_id);
    return 0;
}
```

读取不同的数据类型:

H5T_NATIVE_UCHAR
H5T_NATIVE_CHAR
H5T_NATIVE USHORT
H5T_NATIVE_SHORT
H5T_NATIVE_INT
H5T_NATIVE_UINT
H5T_NATIVE_FLOAT
H5T_NATIVE_DOUBLE



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四、FY-3D MWHS II L1数据读取程序说明

Python版

```
Import h5py
```

```
Fp = h5py.File(FileName, 'r')
```

```
Data = Fp[SDSName][:]
```

```
Fp.close()
```



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五、FY-3D MWHS II典型产品介绍

冰水厚度指数产品

降水检测产品

VASS大气廓线产品

MWHS II
业务产品



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风云三号D星GNOS



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全球导航卫星掩星探测仪 GNOS

GNOS是风云三号02批的新增有效载荷，它利用低轨FY-3卫星上的GNSS接收机，接收被地球大气层和电离层遮掩的GNSS信号，通过反演得到全球大气的折射率、温度、压强、湿度和电离层电子密度等参数。GNOS不但成功接收到GPS的掩星信号，而且成功接收到我国北斗卫星导航系统的掩星信号。GNOS探测具有高精度、高稳定性、高垂直分辨率、全天候、低成本等优点，可为数值天气预报业务、大气物理研究和气候研究提供全天候的数据，为空间天气研究和业务提供电离层监测数据。

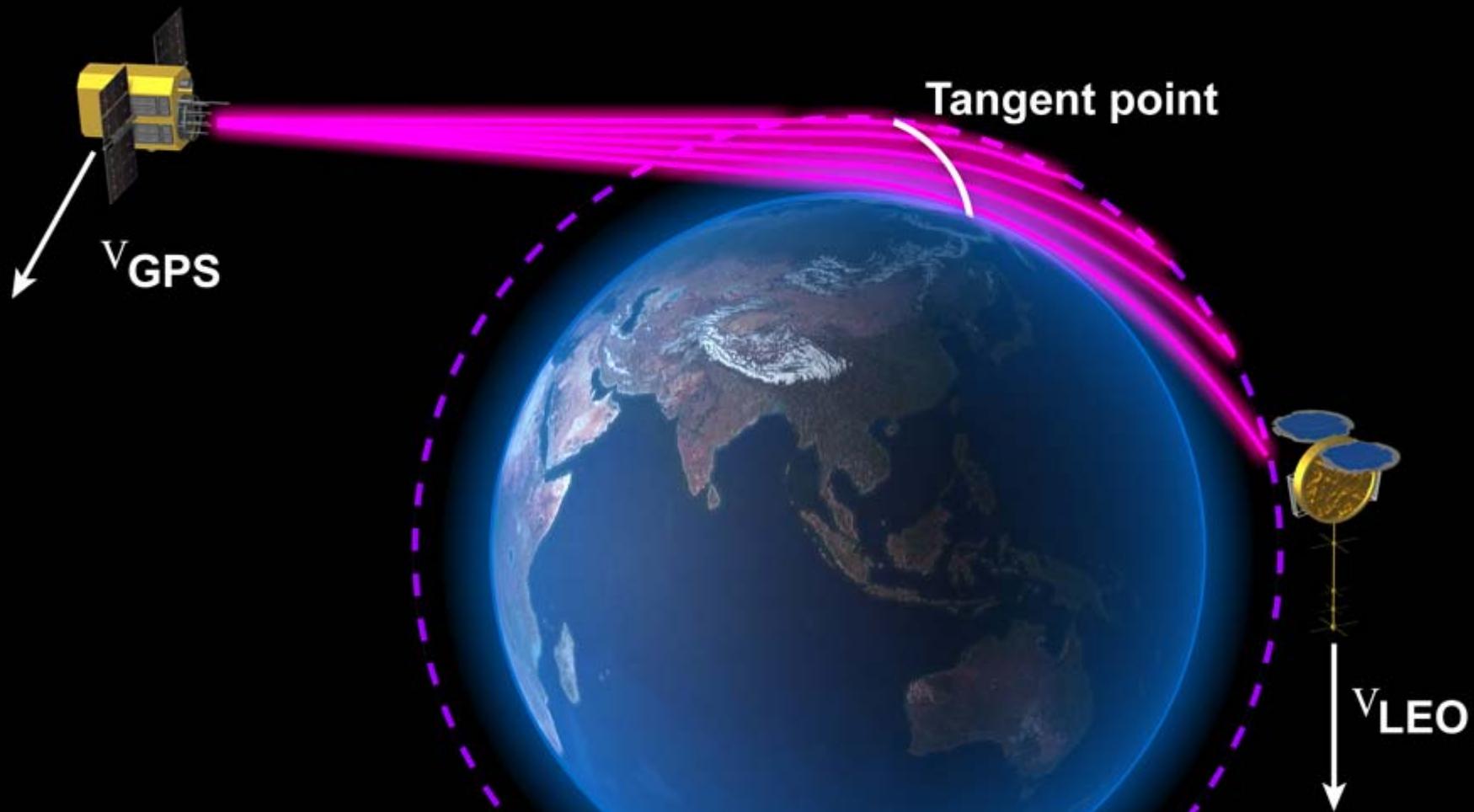


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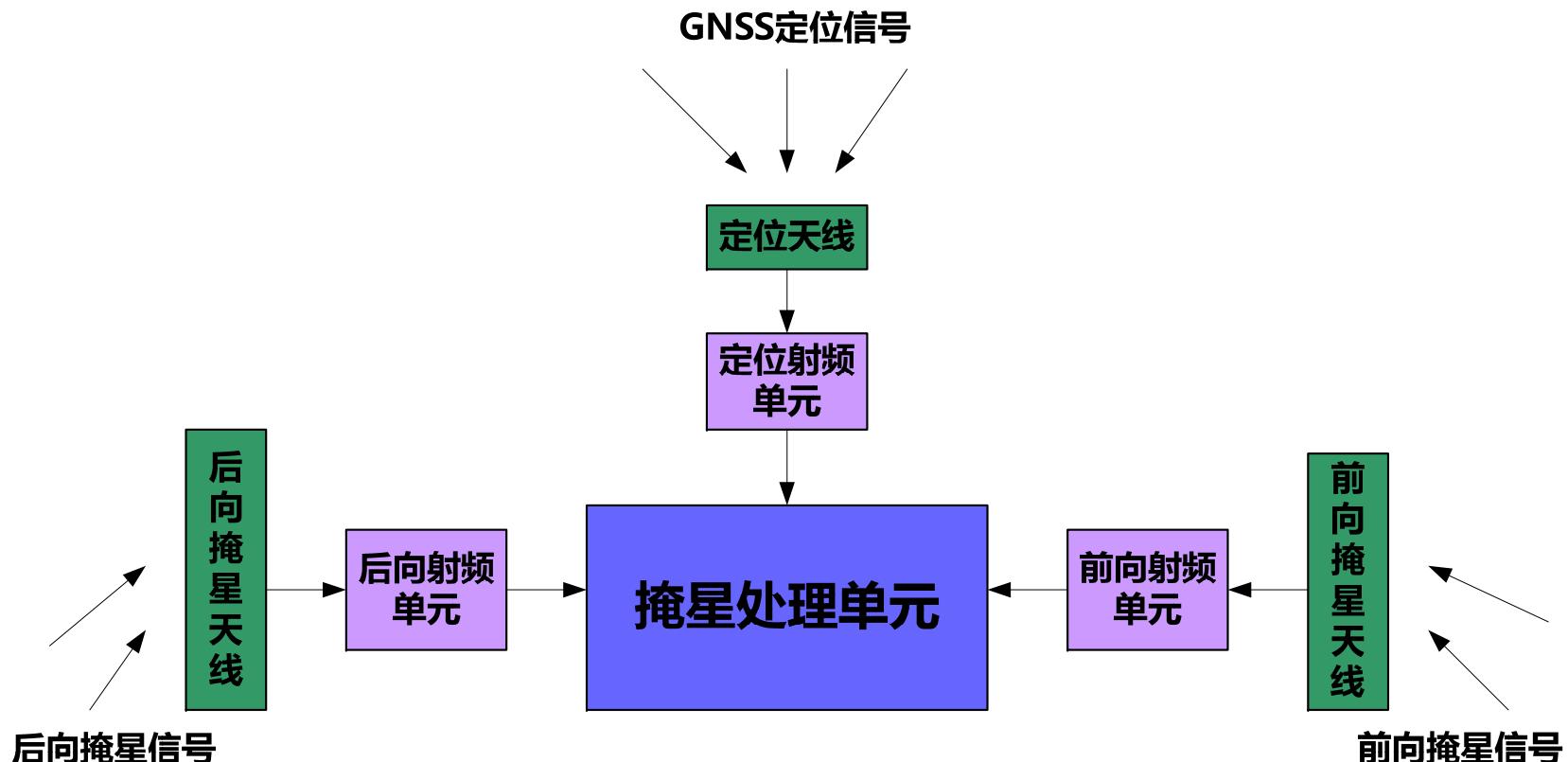


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Progression of Tangent Point for a Setting (desending) Occultation



GNOS仪器组成框图



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二、在轨性能评价

项目	技术指标要求	测试结果	指标符合性
接收机通道数	GPS 定位8, 掩星8; BDS 定位6, 掩星4;	9, 8, 6, 6	√
采样率	定位数据: 1Hz; 电离层数据: 1Hz; 大气闭环数据: 50Hz; 大气开环数据: 100Hz	增加BDS大气开环	√
伪距测量精度	≤30cm (RMS)	L1C: 10.5cm L2C: 15.5cm L2P: 10.6cm	√
载波相位测量精度	≤ 2mm (RMS)	L1C-L2C: 0.41mm L1C-L2P: 0.20mm	√
实时定位精度	≤10m (RMS)	7.28 m	√
实时测速精度	≤0.1m/s (RMS)	0.08 m/s	√
位置测量精度 (后处理)	<20cm	2.24 cm	√
速度测量精度 (后处理)	<0.2mm/s	18.73 μm/s	√



精密轨道

- GNOS L1数据（精密轨道）提供了一个时段的FY-3D卫星的精密轨道。产品内容包括时间、FY-3D卫星质心位置、质心速度、GNOS钟差。
- 用于计算大气附加相位、电离层附加相位。
- 命名：

FY3D_GNOSX_GBAL_L1_YYYYMMDD_HHMM PODXX_MS.SP3



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精密轨道

- 格式：SP3文本
- 文件头节有22行，含有文件版本号、轨道数据首历元的时间、数据历元间隔、文件中具有数据的卫星号、数据的精度指数及注释等。
- 数据记录节是由按一定历元间隔所给出的卫星位置（卫星速度）和卫星钟差等信息所组成。

```
FY3C_GNOSX_GBAL_L1_20140415_0146_PODXX_MS.SP3 x
++      0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
++      0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
++      0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
%c L cc GPS ccc cccc cccc cccc ccccc ccccc ccccc
%c cc cc ccc cccc cccc cccc ccccc ccccc ccccc
%f 1.2500000 1.025000000 0.00000000000 0.000000000000000
%f 0.0000000 0.000000000 0.00000000000 0.000000000000000
%i 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
/* Precise orbit for FY-3C using GNOS on 14105
/* LINE 2
/* LINE 3
/* LINE 4
* 2014 4 15 1 46 21.99990000
PL31 864.163331 683.071684 -7129.380889 999999.999999
VL31 45626.482490 -59563.741635 -179.067743 999999.999999
* 2014 4 15 1 46 22.99990000
PL31 868.725091 677.114618 -7129.395020 999999.999999
VL31 45608.687515 -59577.543095 -103.553125 999999.999999
* 2014 4 15 1 46 23.99990000
PL31 873.285066 671.156179 -7129.401599 999999.999999
VL31 45590.842599 -59591.279318 -28.038456 999999.999999
* 2014 4 15 1 46 24.99990000
PL31 877.843257 665.196365 -7129.400627 999999.999999
```

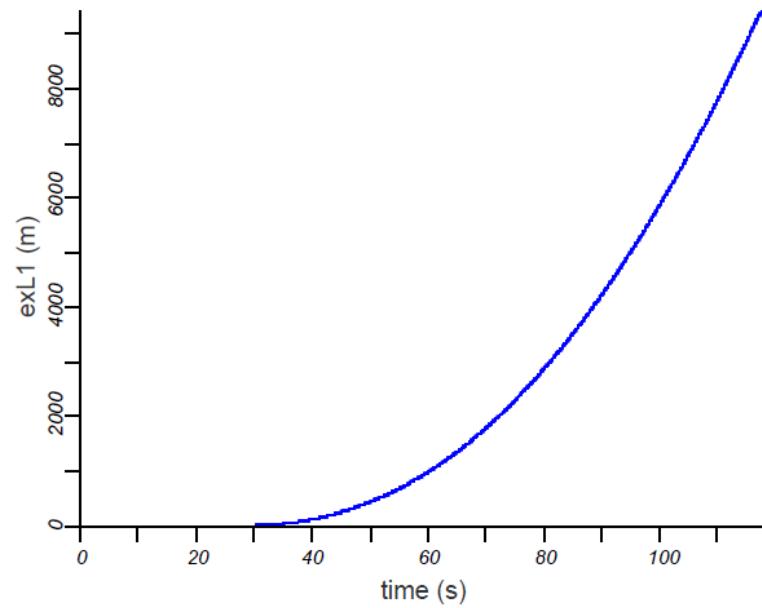


大气附加相位

- GNOS L1数据（大气附加相位）提供了单次掩星事件的大气附加相位及辅助数据。产品内容包括时间、掩星GNSS卫星号、掩星GNSS位置和速度、FY-3D卫星位置和速度、信噪比、掩星标识符。
- 用于计算大气弯曲角、折射率、密度、温度、湿度廓线。
- 命名：

FY3D_GNOSX_GBAL_L1_YYYYMMDD_HHMM_AE*##_MS.NC

FY3C_GNOSX_GBAL_L1_20131027_0626_AEG24_MS.NC
Excess Phase on L1 channel



大气附加相位

- FY-3D GNOS L1数据（大气附加相位）廓线数据结构

➤ 格式：NC

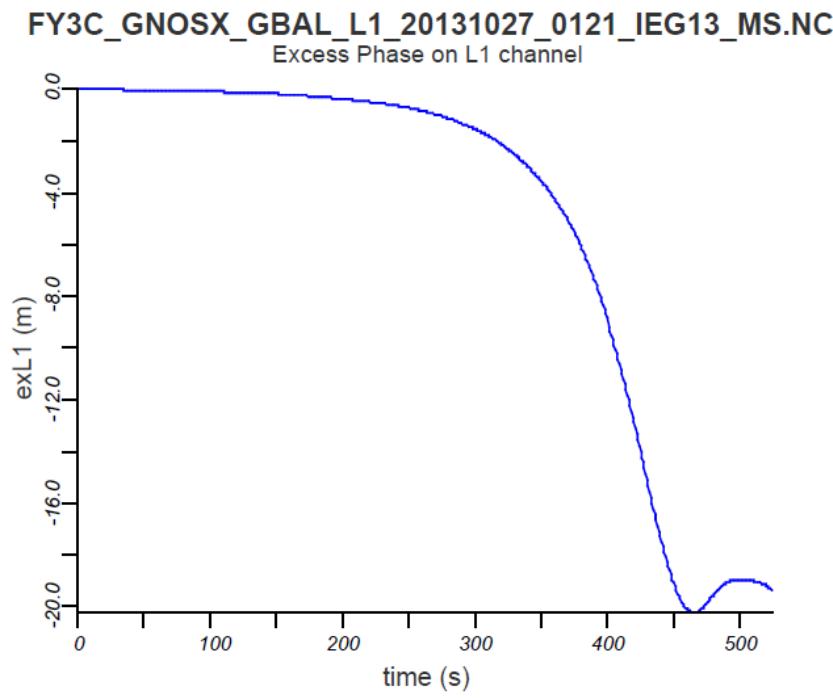
描述	属性名称	数据类型	单位	有效范围	填充值
L1通道CA码信噪比	caL1Snr	float	volts/volt	0, 65535	-999
L1通道P码信噪比	pL1Snr	float	volts/volt	0, 65535	-999
L2通道CA码信噪比	caL2Snr	float	volts/volt	0, 65535	-999
L2通道P码信噪比	pL2Snr	float	volts/volt	0, 65535	-999
开环相位模型	xndl	double	m	-2000000, 2000000	-9999999
开环相位大气模型	xndldd	double	m	-5000, 5000	-9999
开环伪距模型	xrng	double	m	-5000, 5000	-9999
开环相位残差	Dphs	double	m	-5000, 5000	-9999
掩星采样时间	time	float	s	0, 240	-999
经过电离层修正之后的附加相位	exLC	double	m	-10000, 10000	-99999
L1通道附加相位	exL1	double	m	-10000, 10000	-99999
L2通道附加相位	exL2	double	m	-10000, 10000	-99999
L2P通道附加相位	exL2P	double	m	-10000, 10000	-99999
L2C通道附加相位	exL2C	double	m	-10000, 10000	-99999
C1C2组合附加相位	exLC_C1C2	double	m	-10000, 10000	-99999
C1P2组合附加相位	exLC_C1P2	double	m	-10000, 10000	-99999
GNSS X坐标	xGnss	double	km	-26564, 26564	-99999
GNSS Y坐标	yGnss	double	km	-26564, 26564	-99999
GNSS Z坐标	zGnss	double	km	-26564, 26564	-99999
GNSS X速度	xdGnss	double	km/s	-5, 5	-999
GNSS Y速度	ydGnss	double	km/s	-5, 5	-999
GNSS Z速度	zdGnss	double	km/s	-5, 5	-999
LEO X坐标	xLeo	double	km	-7378, 7378	-9999
LEO Y坐标	yLeo	double	km	-7378, 7378	-9999
LEO Z坐标	zLeo	double	km	-7378, 7378	-9999
LEO X速度	xdLeo	double	km/s	-8, 8	-999
LEO Y速度	ydLeo	double	km/s	-8, 8	-999
LEO Z速度	zdLeo	double	km/s	-8, 8	-999



电离层附加相位

- GNOS L1数据（电离层附加相位）提供了单次掩星事件的电离层附加相位及辅助数据。产品内容包括时间、掩星GNSS卫星号、卫星位置和速度、FY-3D卫星位置和速度、信噪比、掩星标识符。
- 用于计算电离层电子密度廓线。
- 命名：

FY3D_GNOSX_GBAL_L1_YYYYMMDD_HHMM_IE*##_MS.NC



电离层附加相位

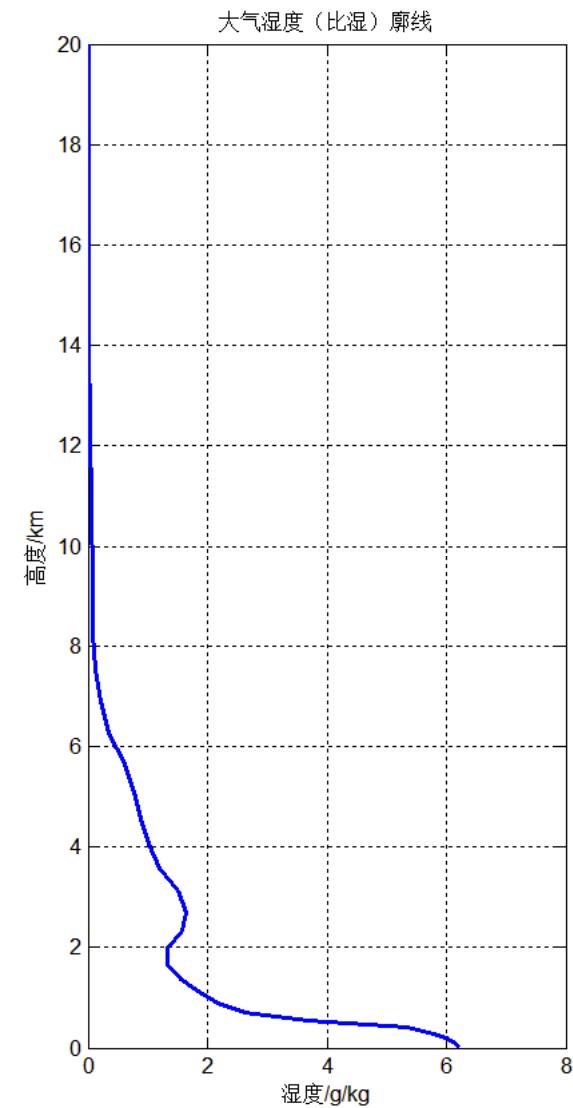
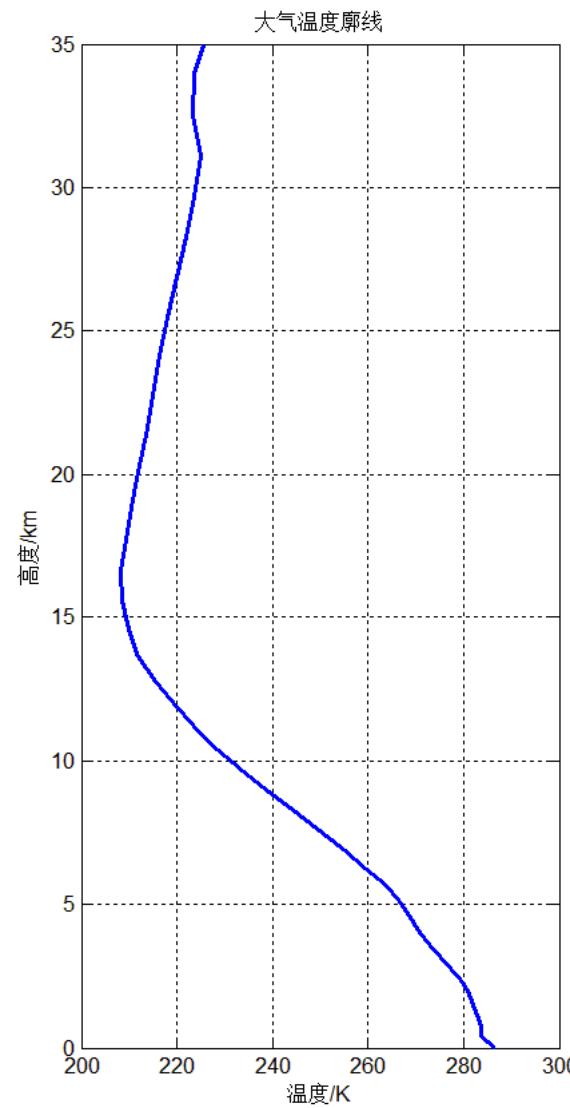
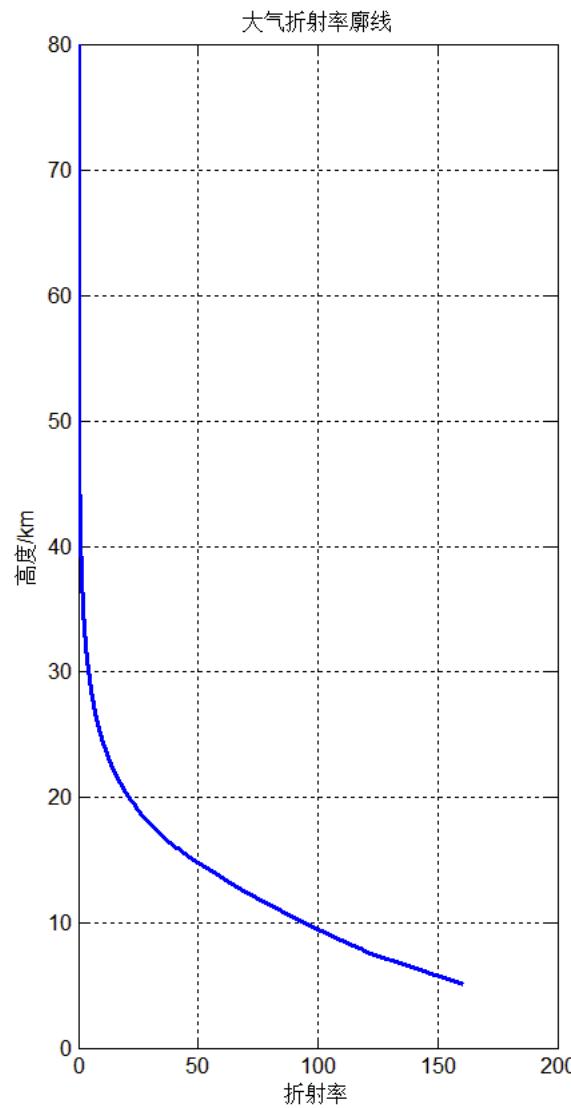
- FY-3D GNOS L1数据（电离层附加相位）廓线数据结构

➤ 格式：NC

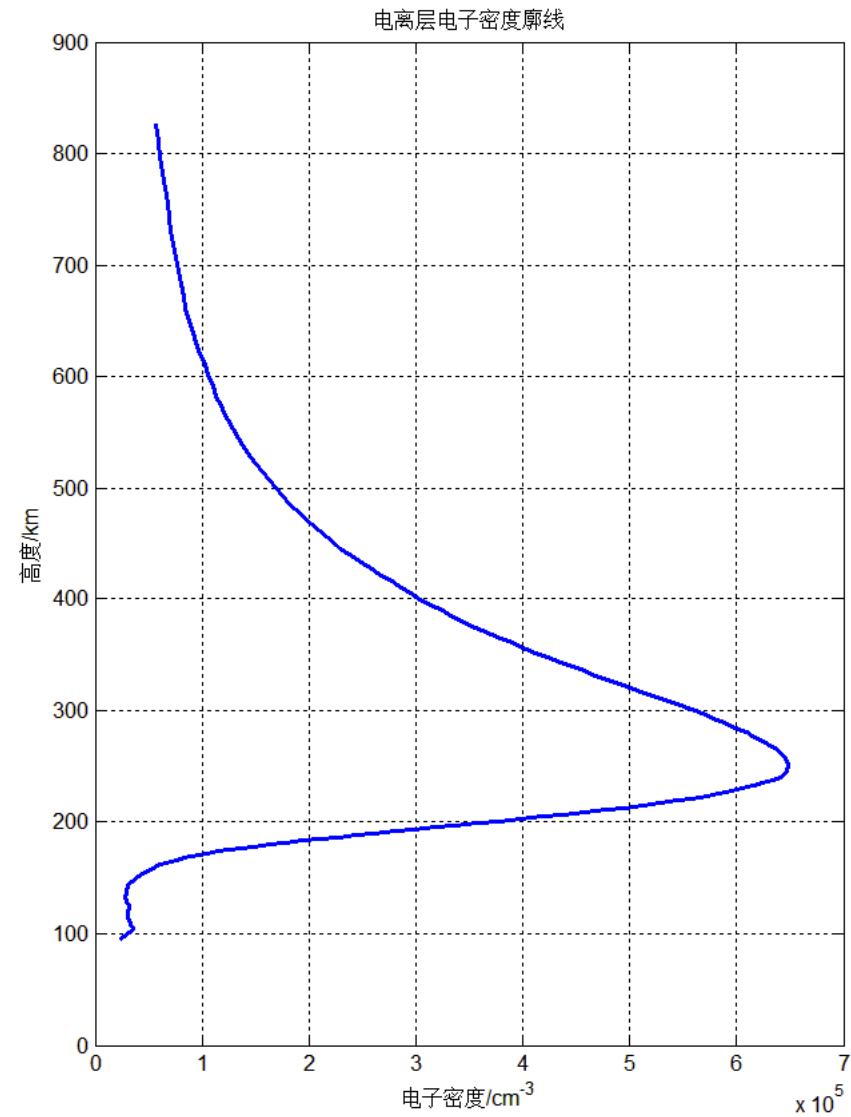
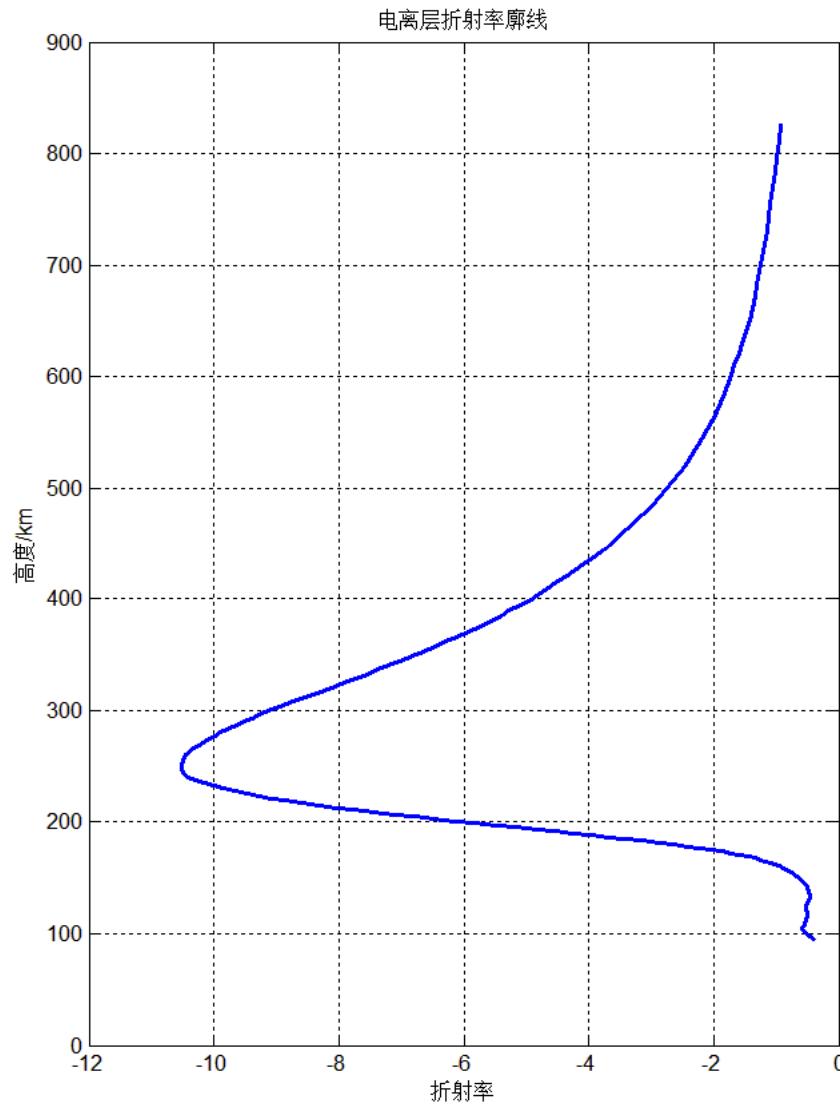
描述	属性名称	数据类型	单位	有效范围	填充值
L1通道CA码信噪比	caL1Snr	float	volts/volt	0, 65535	-999
L2通道P码信噪比	pL2Snr	float	volts/volt	0, 65535	-999
L2通道CA码信噪比	caL2Snr	float	volts/volt	0, 65535	-999
掩星采样时间	time	float	s	0, 1200	-999
L1通道附加相位	exL1	double	m	-5000, 5000	-9999
L2通道附加相位	exL2	double	m	-5000, 5000	-9999
GNSS X坐标	xGnss	double	km	-26564, 26564	-99999
GNSS Y坐标	yGnss	double	km	-26564, 26564	-99999
GNSS Z坐标	zGnss	double	km	-26564, 26564	-99999
GNSS X速度	xdGnss	double	km/s	-5, 5	-999
GNSS Y速度	ydGnss	double	km/s	-5, 5	-999
GNSS Z速度	zdGnss	double	km/s	-5, 5	-999
LEO X坐标	xLeo	double	km	-7378, 7378	-9999
LEO Y坐标	yLeo	double	km	-7378, 7378	-9999
LEO Z坐标	zLeo	double	km	-7378, 7378	-9999
LEO X速度	xdLeo	double	km/s	-8, 8	-999
LEO Y速度	ydLeo	double	km/s	-8, 8	-999
LEO Z速度	zdLeo	double	km/s	-8, 8	-999



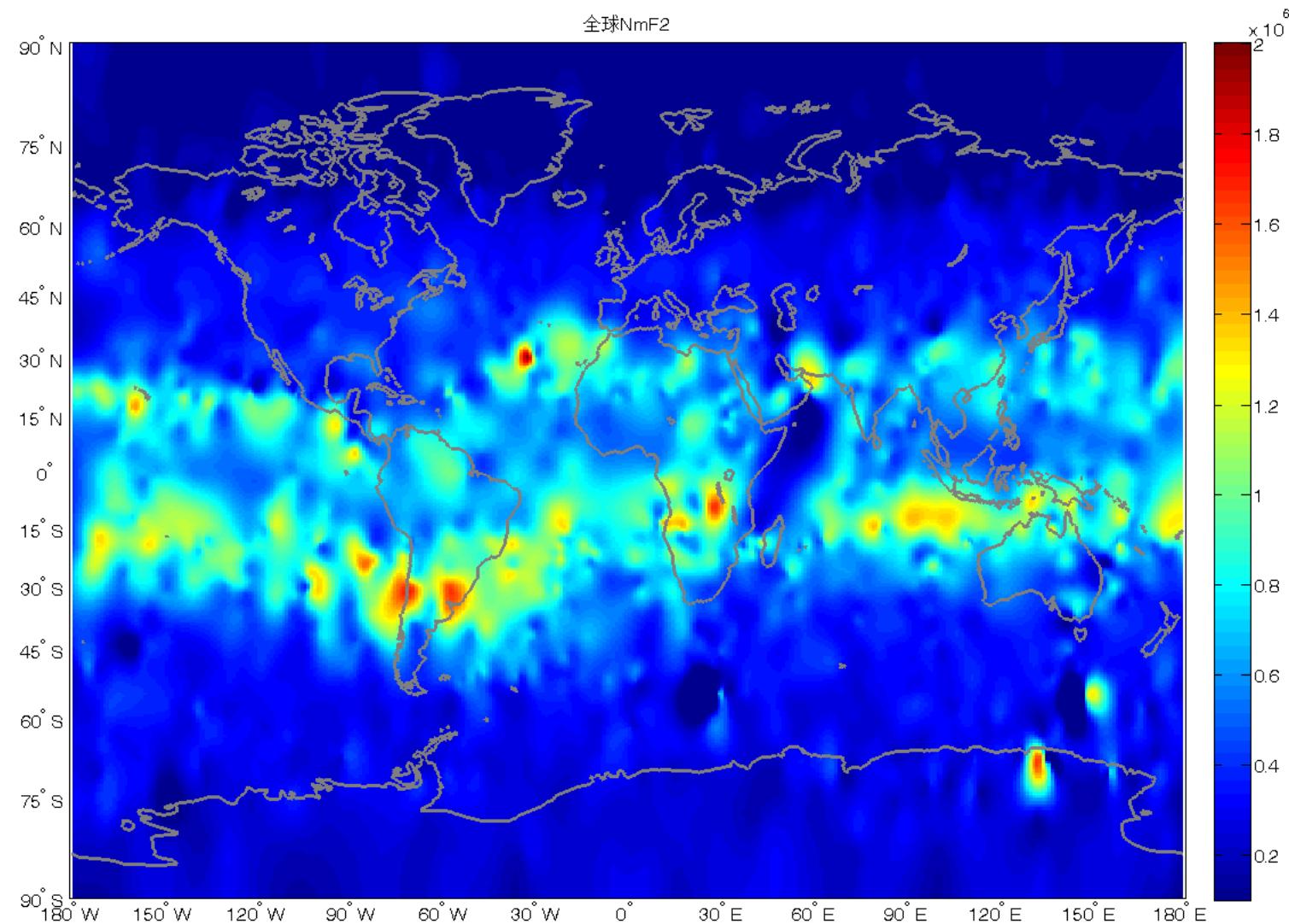
典型产品及应用——大气廓线



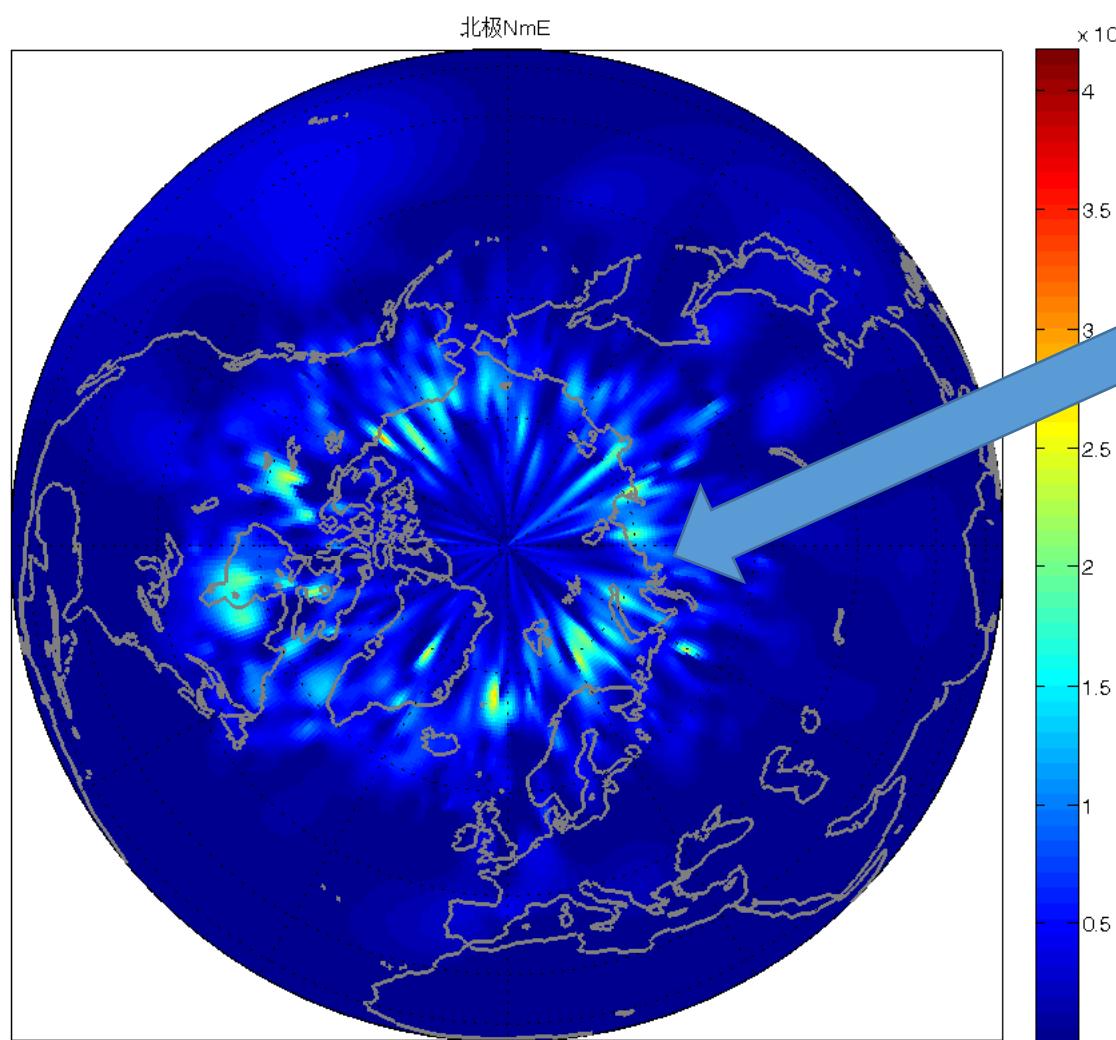
典型产品及应用——电离层廓线



典型产品及应用——全球电离层NmF2分布



典型产品及应用——北极电离层NmE分布



与极光卵的
分布对应

Thank you for your attention



Chinese Meteorological Administration



National Satellite Meteorological Center