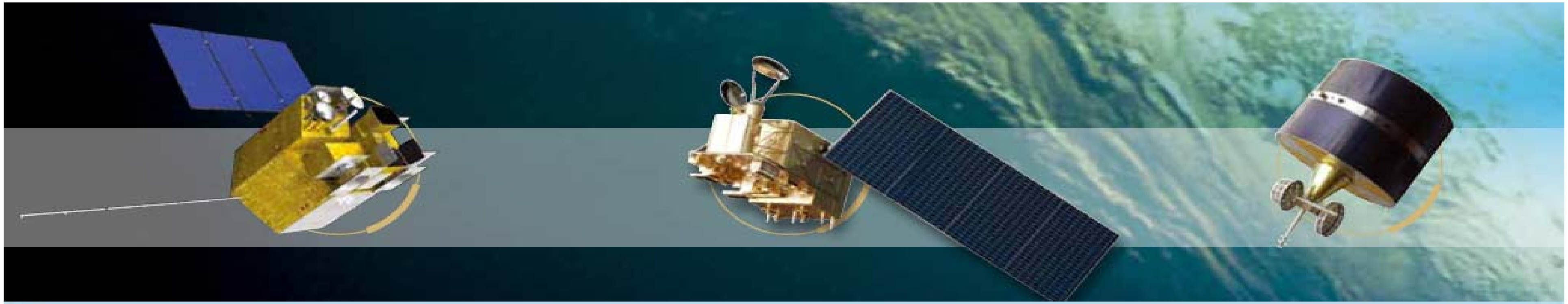

CMA Applications of Radiative Transfer Model in Product Generation and Sensor Monitoring

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Chunqiang Wu, Juyang Hu, Min Min, Wengguang Bai,
Ling Sun, Fangli Dou, Yong Zhang, Yang Guo, Dawei An,
Chengli Qi, Shengli Wu, Miao Zhang, Hui Liu, Xiaoqing Li
Lin Chen, Yuan Li, Liqing Hu

Outline

- Background
- Model Development
- Calibration and validation
- Sensor Monitoring
- Product generation and validation

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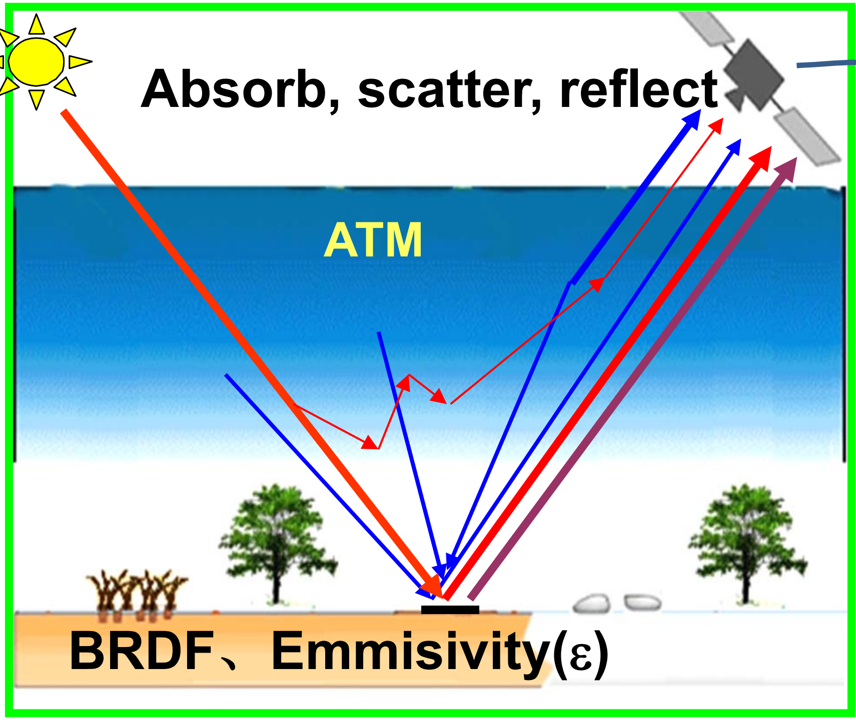
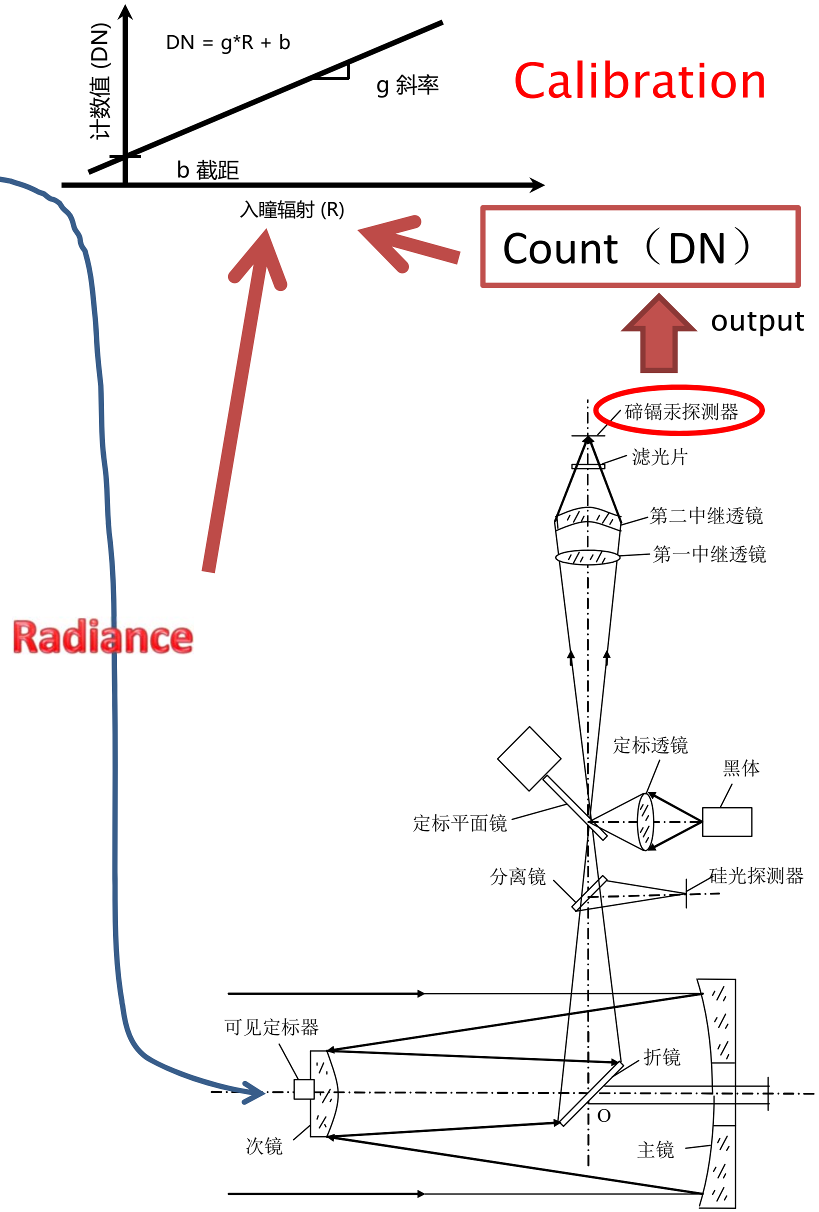
Satellite Measurement and Calibration



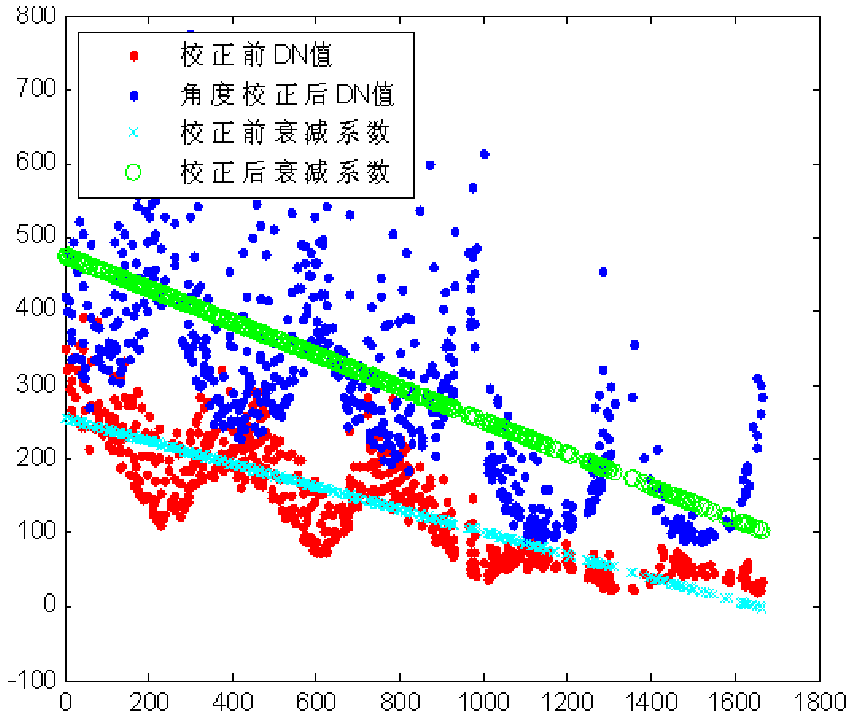


Radiative Transfer Eq:

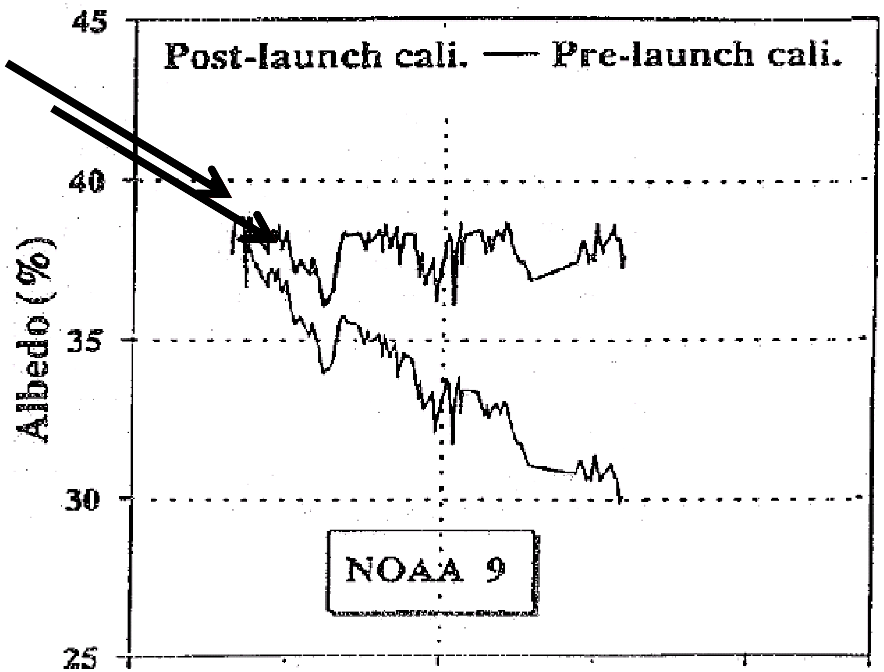
$$
\begin{aligned}
B_i(T_i) = {} & \varepsilon_i B_i(T_s)\tau_i \\
& + (1-\varepsilon_i)(R_{atm\_i}\downarrow + R^s_{atm\_i}\downarrow)\tau_i \\
& + R_{atm\_i}\uparrow + R^s_{atm\_i}\uparrow + \rho_{bi} R^s_i \tau_i
\end{aligned}
$$

Problem of Space Sensors：

（1） The calibration system is not good enough；
（2） No absolute calibration system, no reference；
（3） Not good enough with the stability；

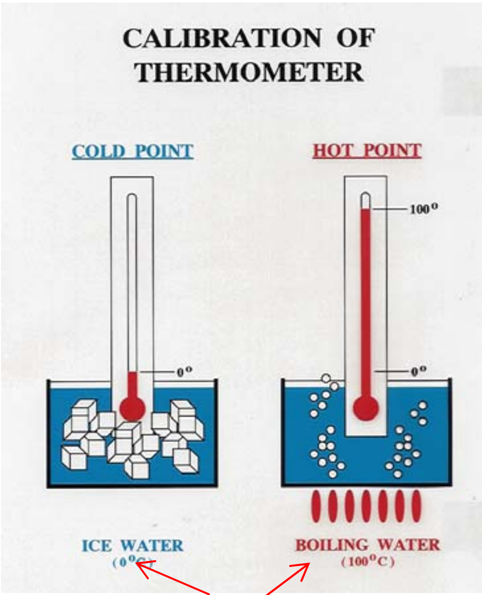


Attenuation of FY-1 reflect Channels in 5 years

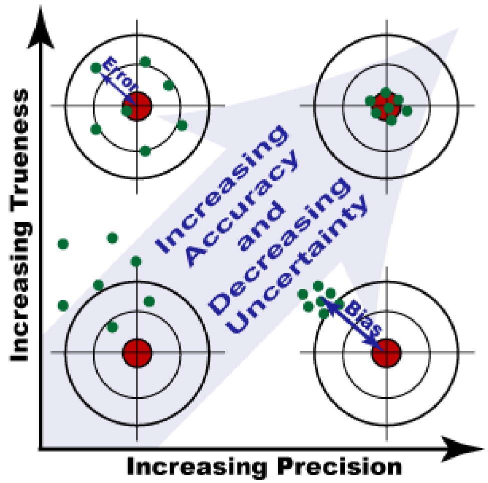


Attenuation of NOAA reflect Channels in 3 years

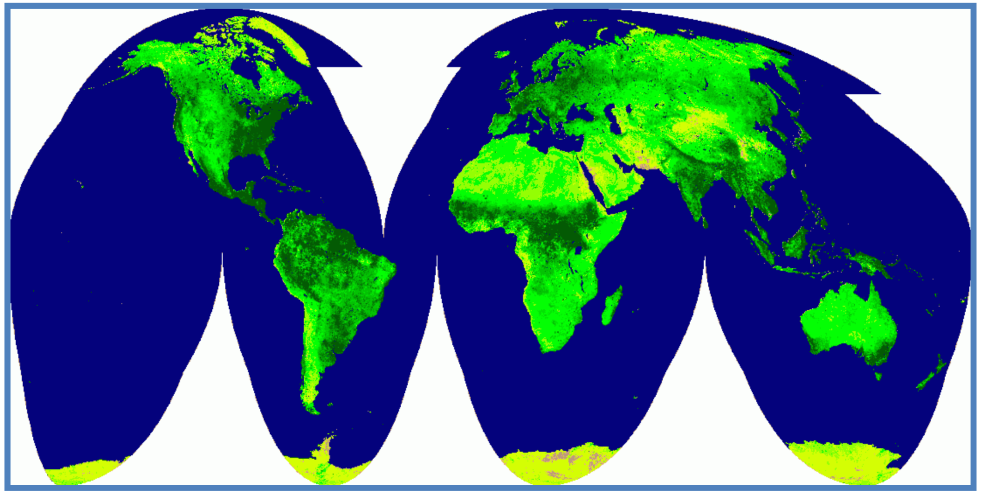
Calibration: to Improve Satellite Data quality

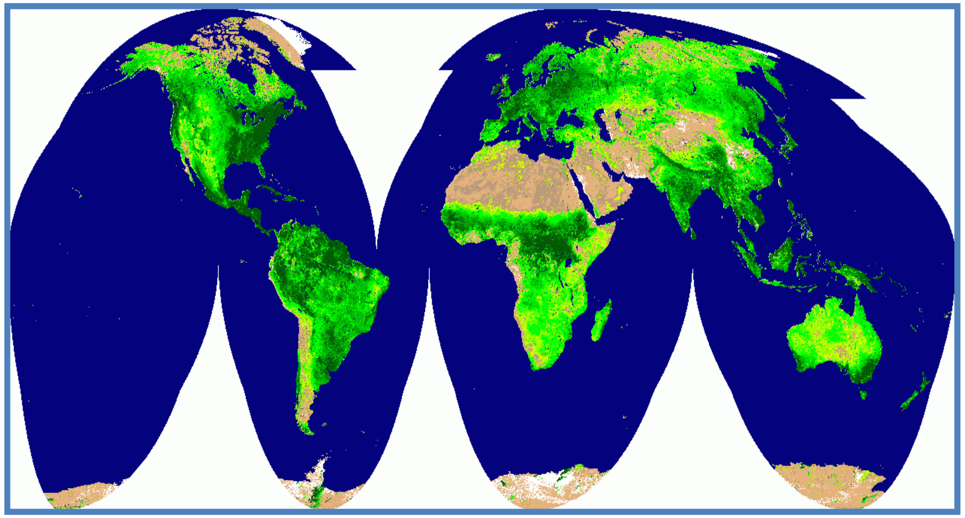


Reffence



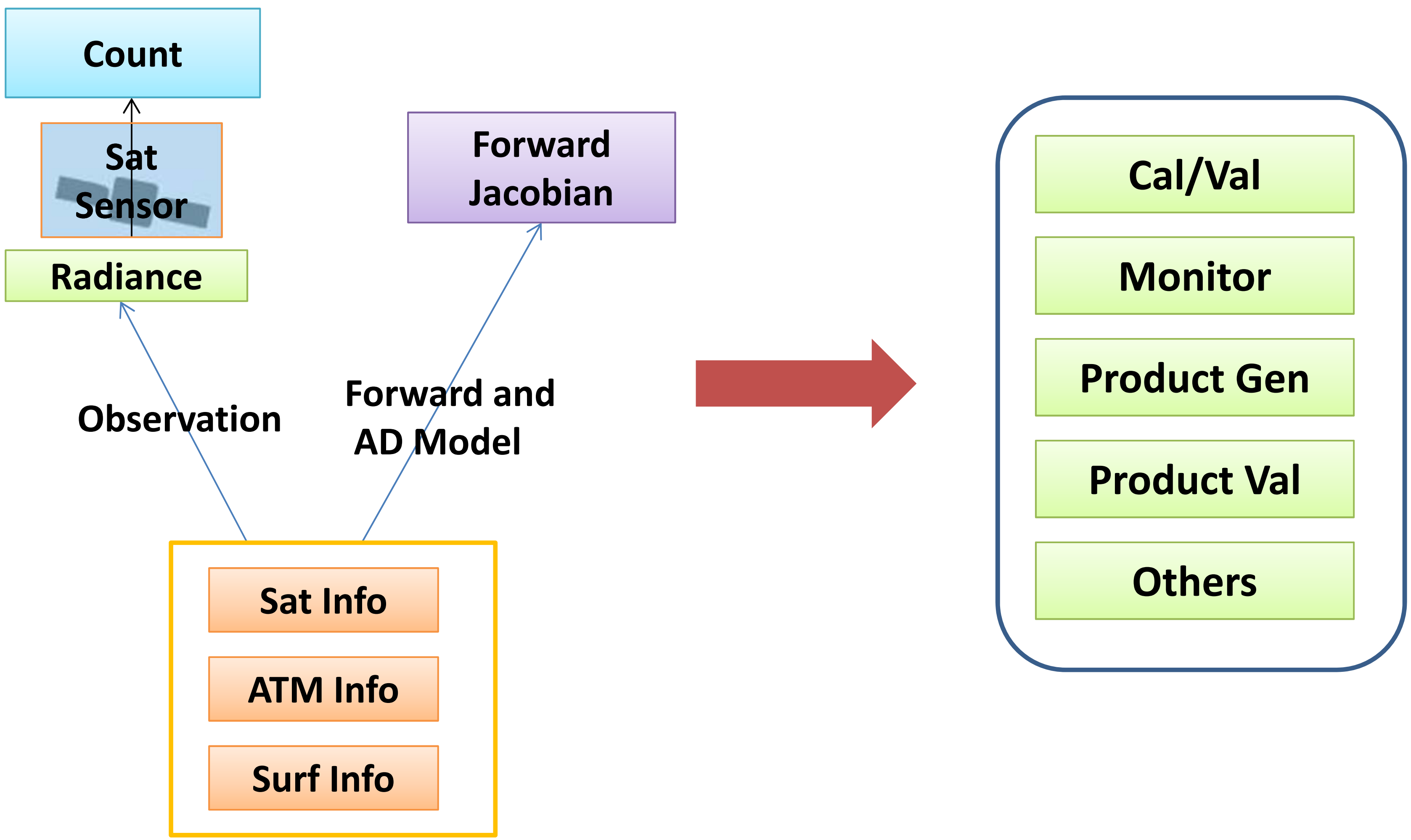
Before Correction





After Correction

The RTMs are widely used at NSMC



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Model Development

- **Models used at NSMC**

  RTTOV, CRTM, ARMS, LBLRTM, MonoRTM, 6S, ModTran, FYRTM…

- **Models in developing at NSMC**

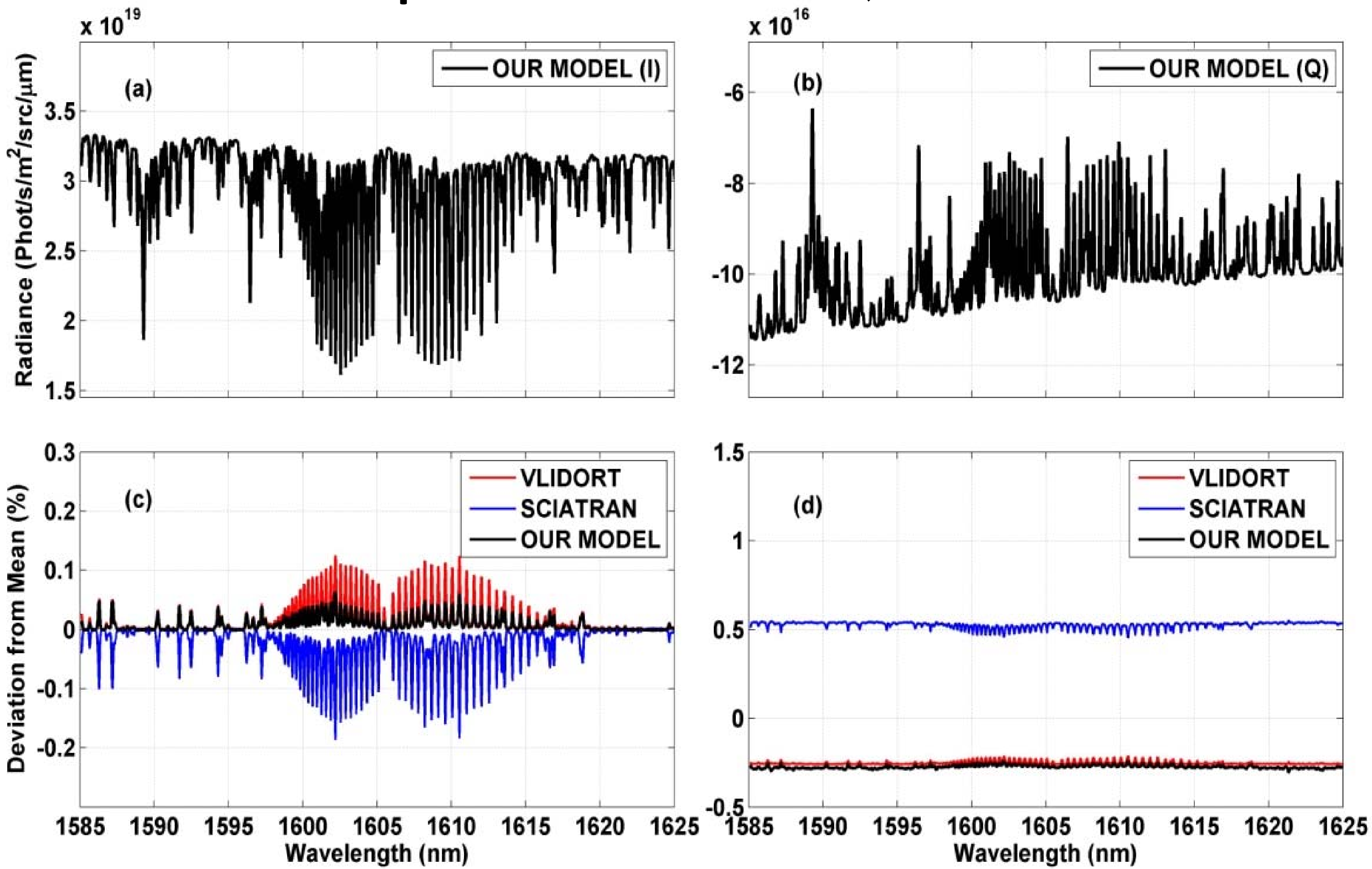
  Fast Model for High Spectral Radiance

  For lunar spectral irradiances

  For Cloud scattering

Near Infrared Spectral Calculation with Polarization

Compared with VLIDORT、SCIATRAN



Case1 Rayleigh (Rayleigh only, NNUM=4, SZA=60, VZA=0.0, SAZ=0, VAZ=180, PS=950, PLOC=0.9, SIGMA=0.05, ALBEDO=0.1, AOD=0.0, US STANDARD)

Simulation of TOA lunar spectral irradiances

Periodical Characteristics of Lunar Irradiance

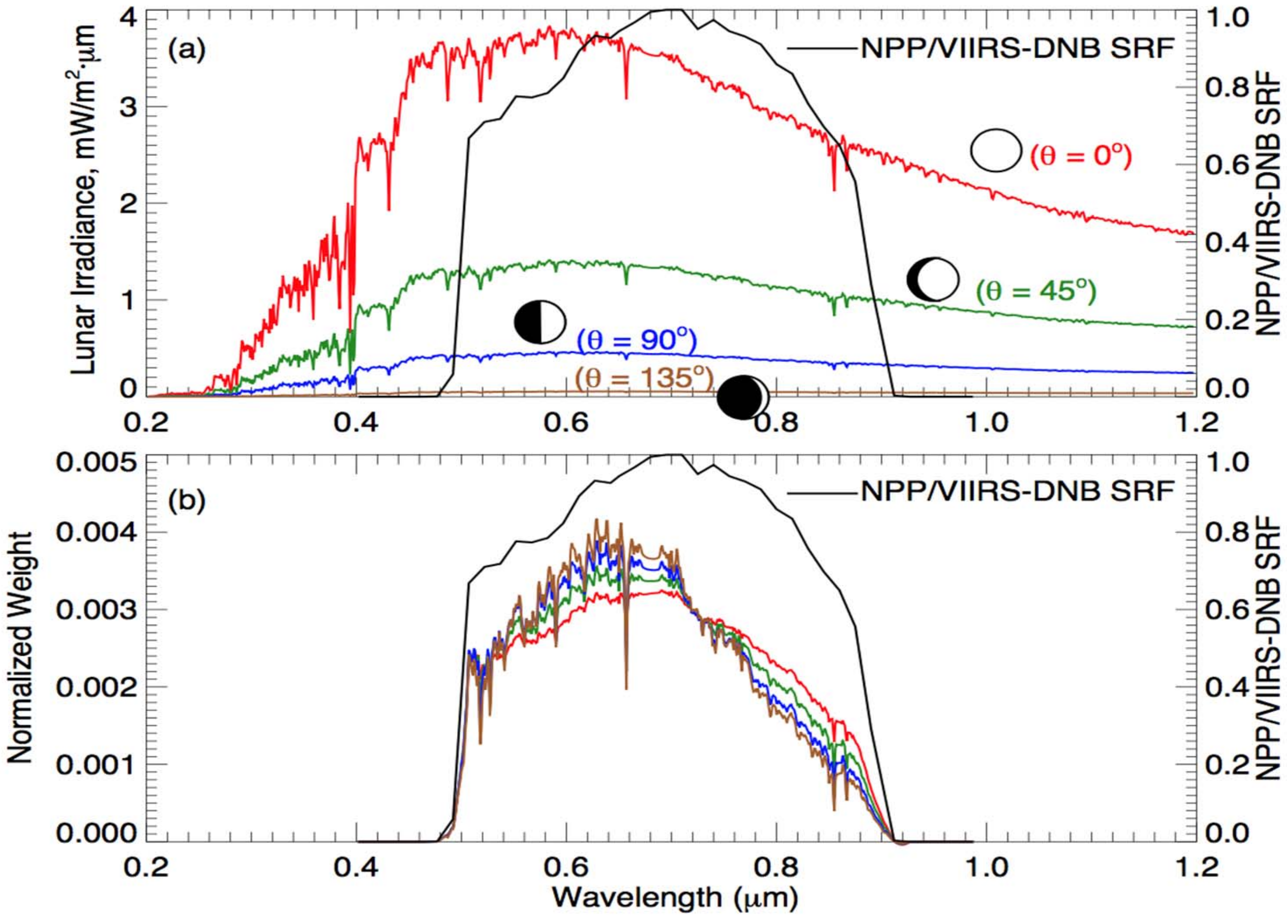


Figure 1. Simulated TOA lunar spectral irradiances at lunar phase angles =0°, 45°, 90°, and 135° and NPP/VIIRS-DNB SRF (black solid line) (a), and its corresponding normalized weighting values of DNB (b).

Min, et al, 2017. JGR

Modified 2.25µm Channel in Cloud remote sensing

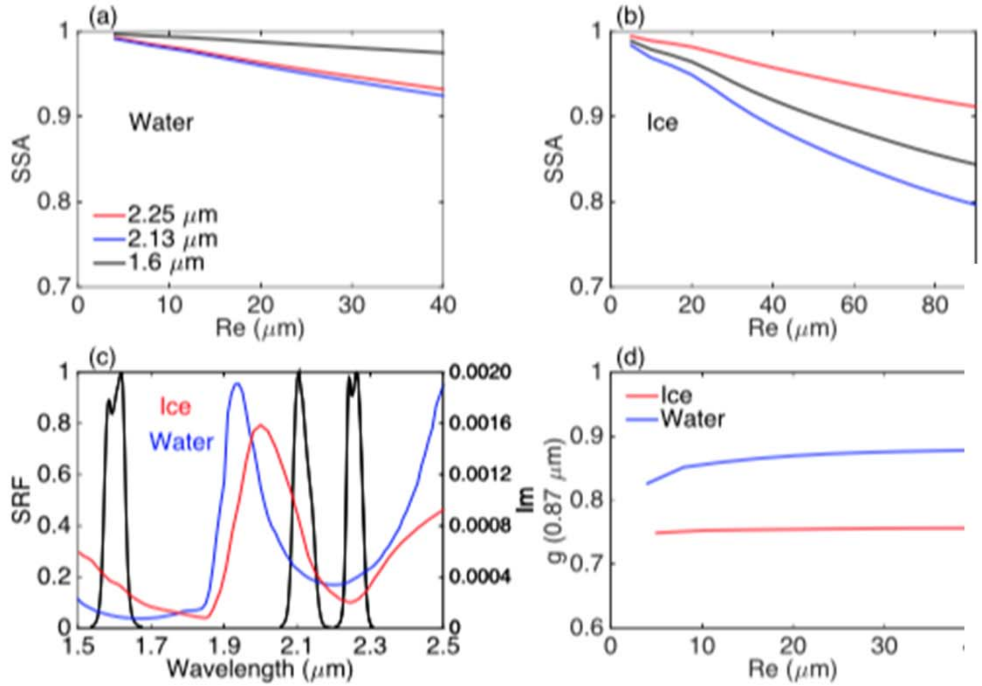


Fig. 1. Bulk SSA for (a) water and (b) ice clouds as a function of effecti particle radius. (c) Imaginary part of refractive indices (Im) for water and ic and the SRF of VIIRS 1.6- and 2.25-μm channels and the MODIS 2.13-μ channel. (d) Asymmetry factor (g) of water and ice clouds at the 0.87-μ channel.

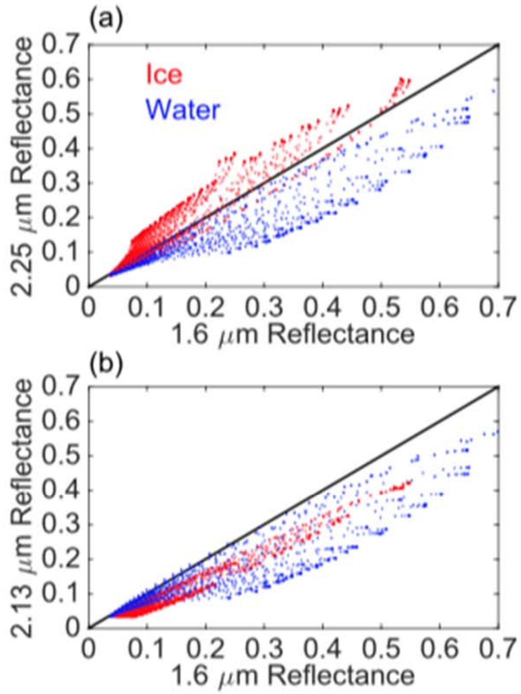
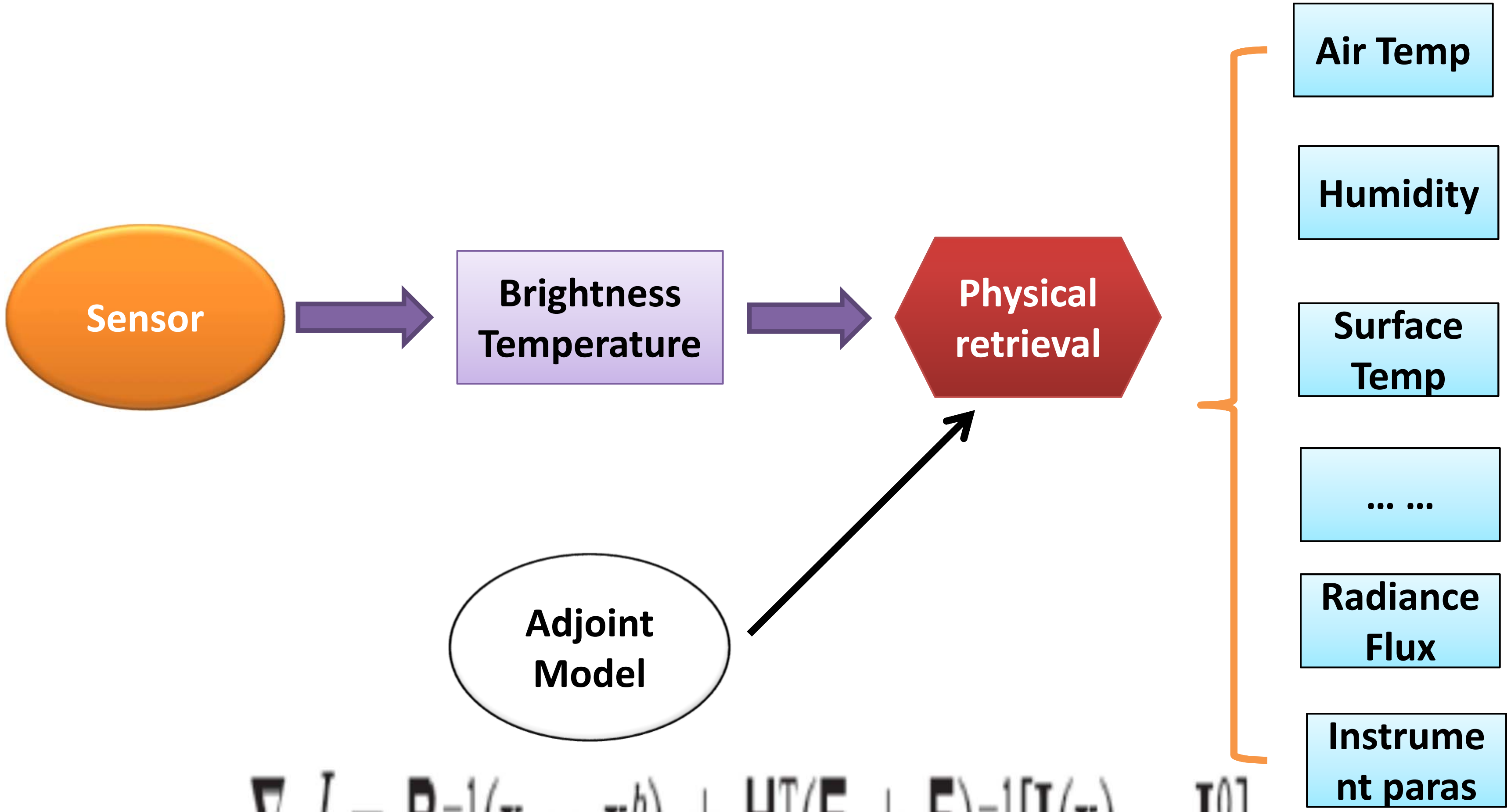


Fig. 4. Reflectances for ice and water clouds at a pair of NIR channels. (a) 1.6- and 2.25-μm channels. (b) 1.6- and 2.13-μm channels. The results are simulated at six sets of solar-satellite geometries, and cloud layers with large ranges of COT and CER are considered. Red and blue dots are for ice and water cloud layers, respectively.

Wang, et al., 2018. *IEEE Transactions on Geoscience and Remote Sensing*

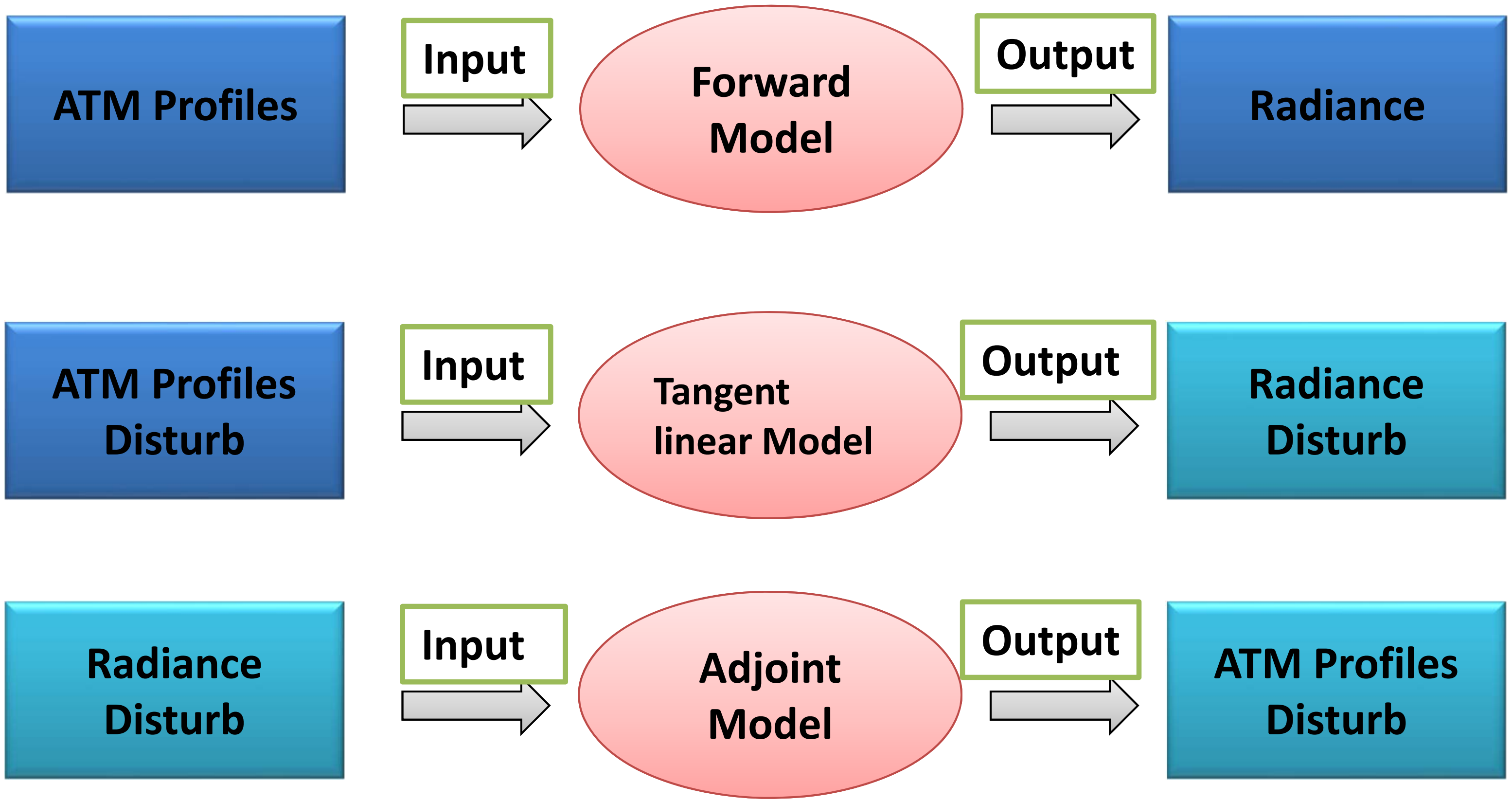
Why are the Adjoint Model Important?

- For physical retrievals



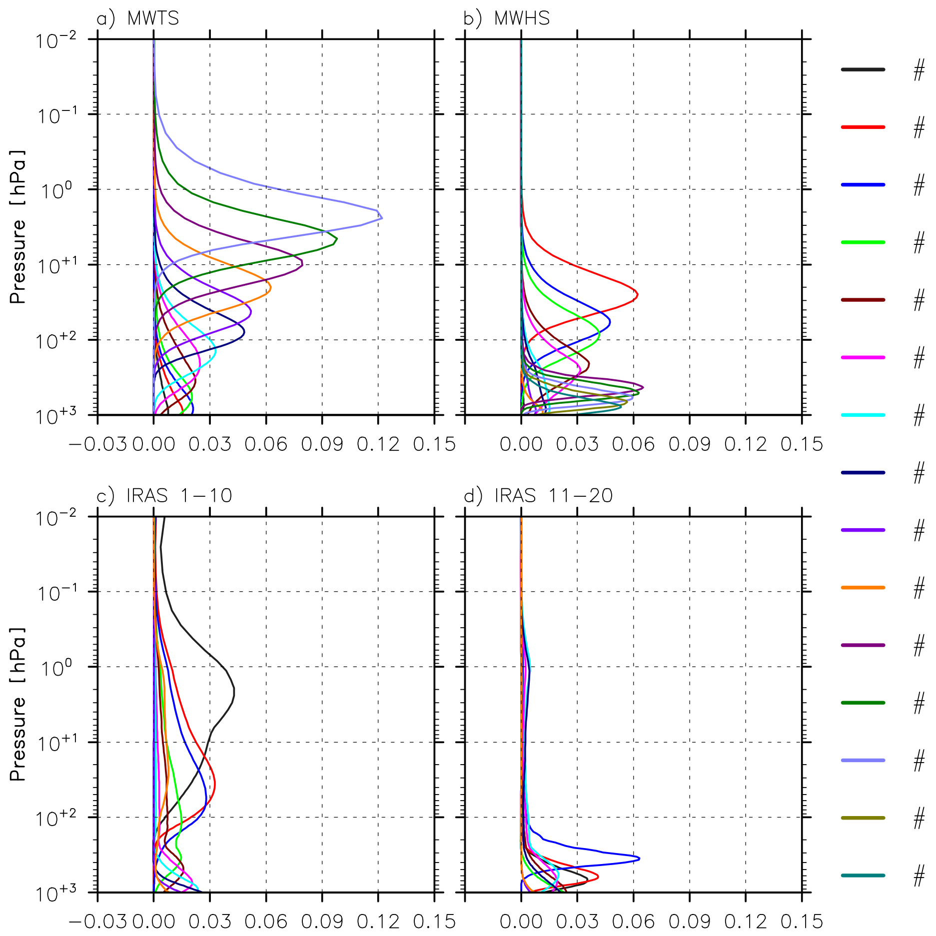
$$\nabla_x J = \mathbf{B}^{-1}(\mathrm{x} - \mathrm{x}^b) + \mathbf{H}^{\mathrm{T}}(\mathbf{E} + \mathbf{F})^{-1}[\mathrm{I}(\mathrm{x}) - \mathrm{I}^0],$$

The potentials of Adjoint Model

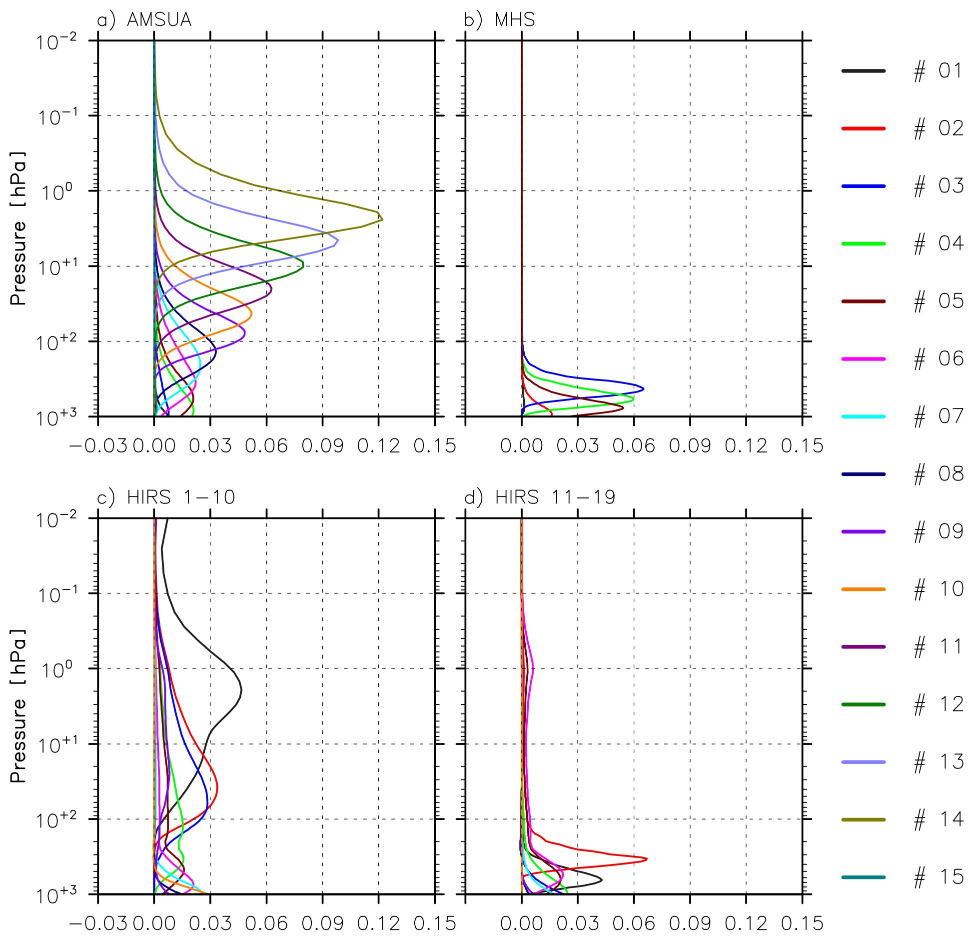


Temperature Jacobians for VASS

FY3C VASS



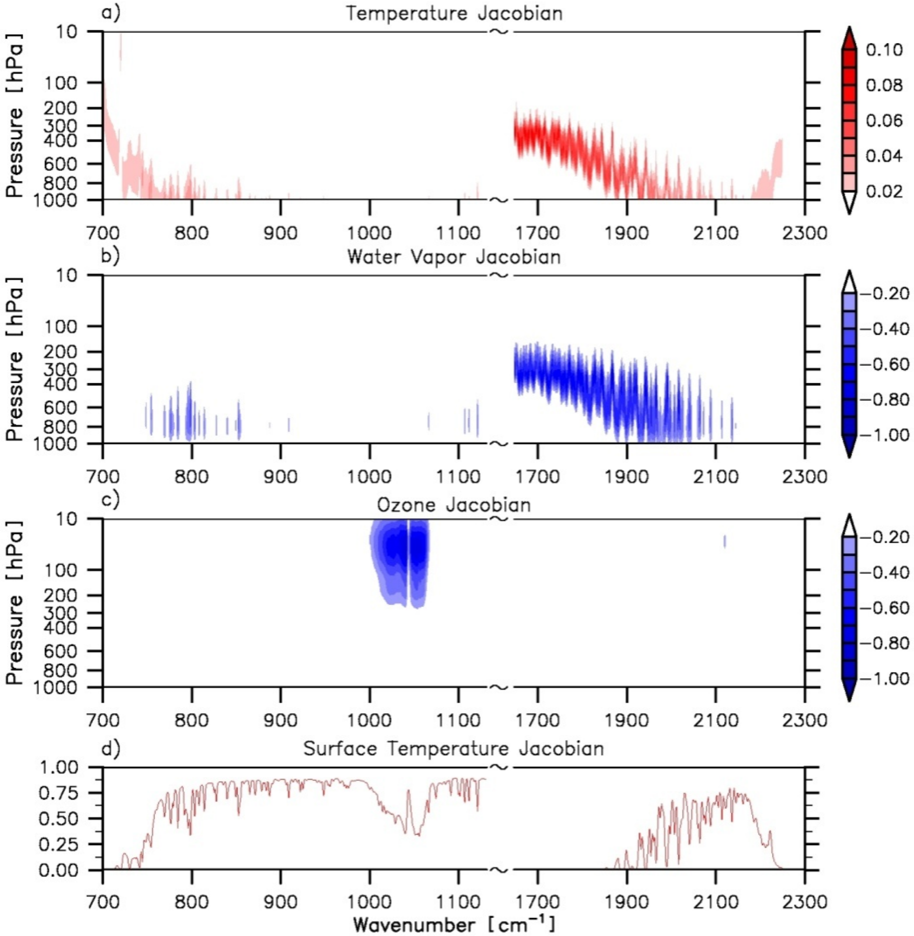
NA18 ATOVS



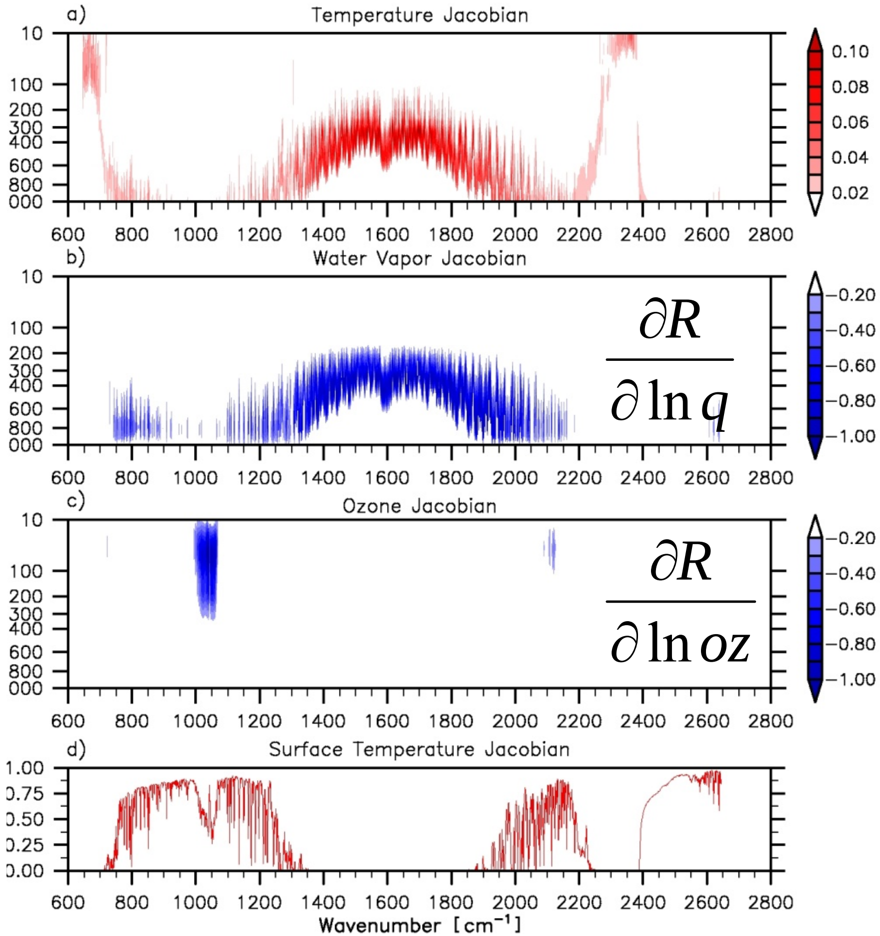
US Standard，IR EMIS=0.98，MW EMIS=0.68

Jacobians for FY-4 GIIRS

FYRTM/FY4 GIIRS



RTTOV/IASI



US Standard， IR EMIS=0.98

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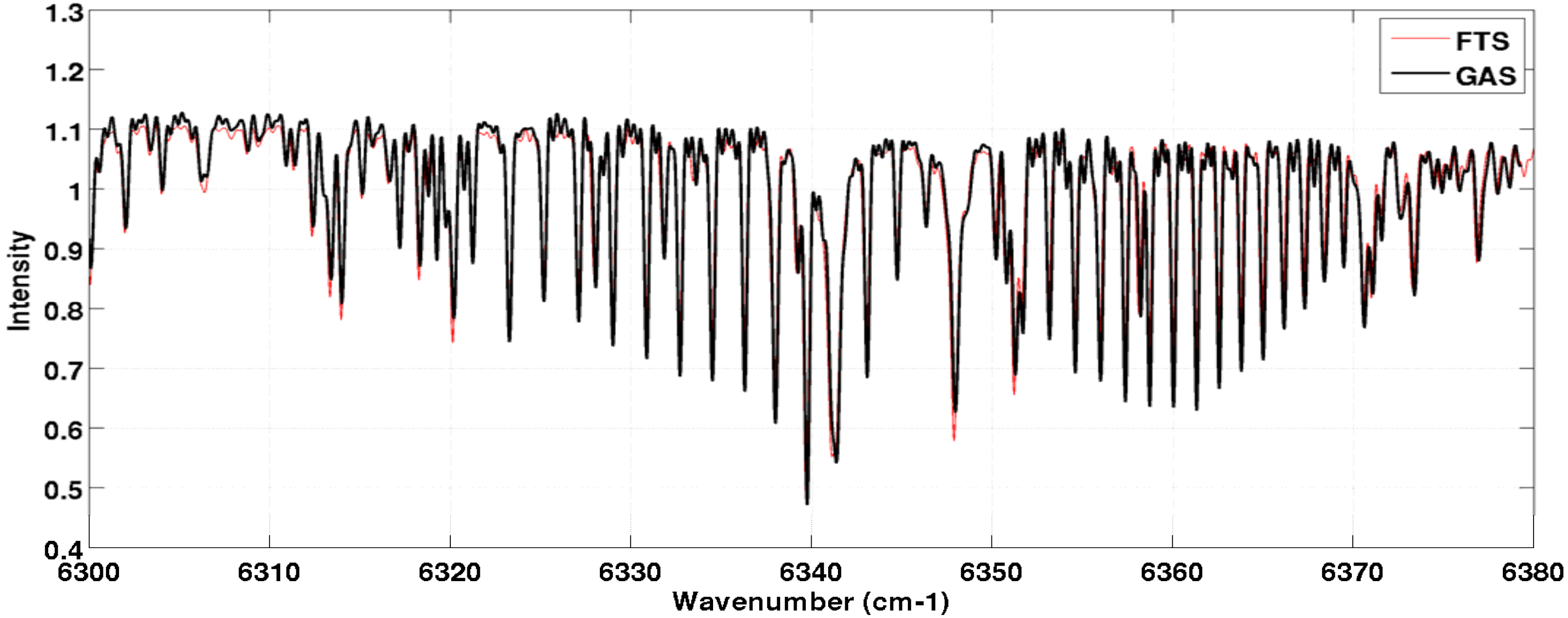
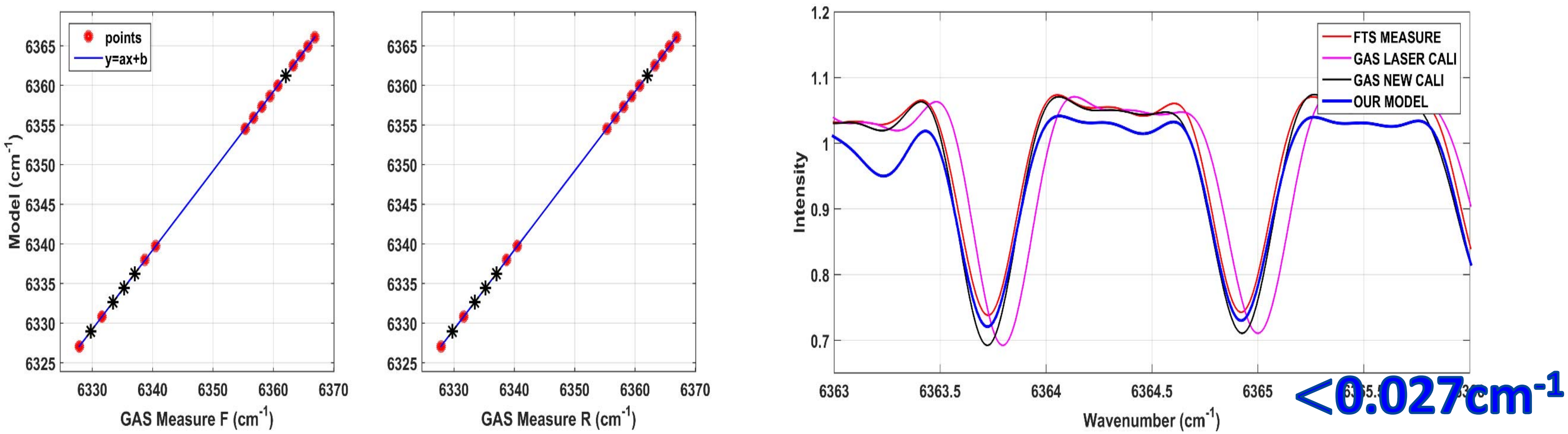
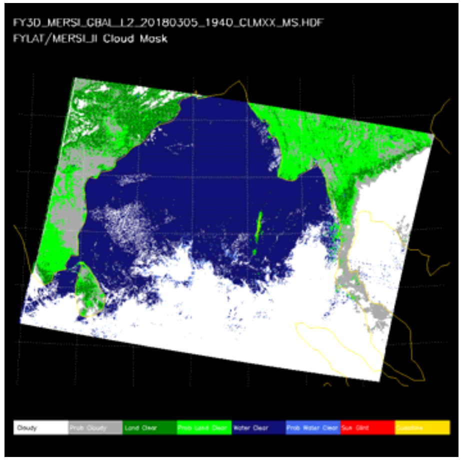
Cal/Val:　FY-3D GAS Spectrum in TVAC Test

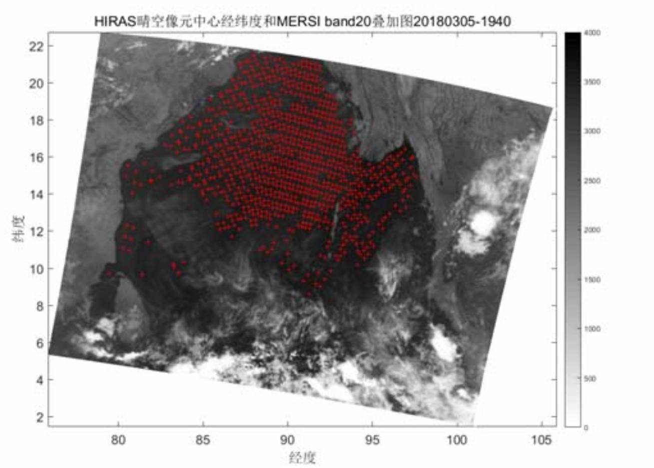




Cal/Val： To estimate FY-3D HIRAS Spectral Calibration Coefs

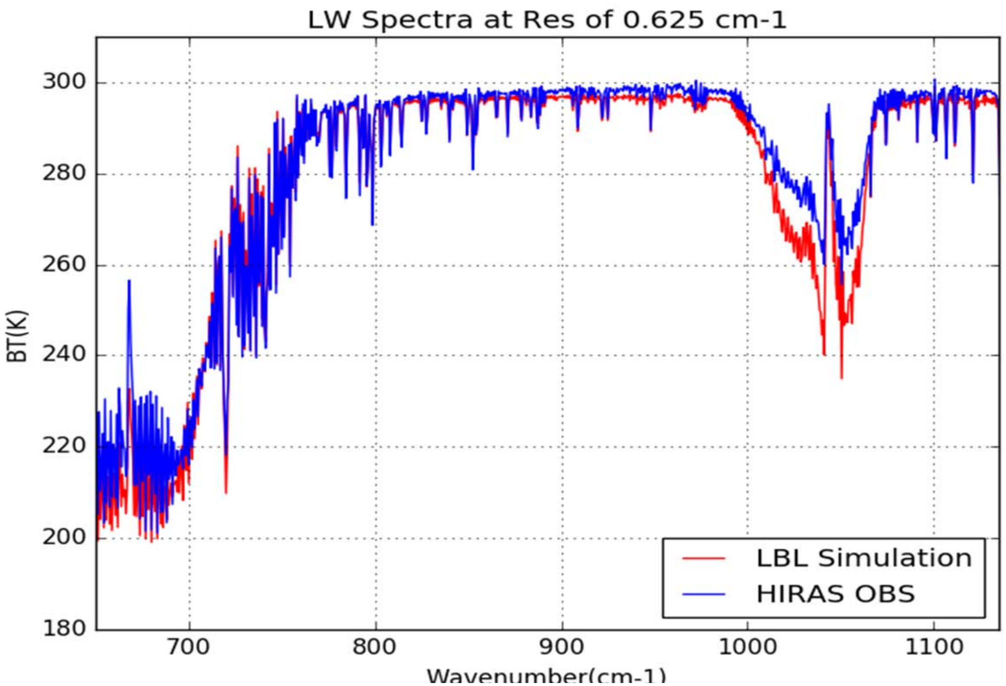
MERSI-II CloudMask



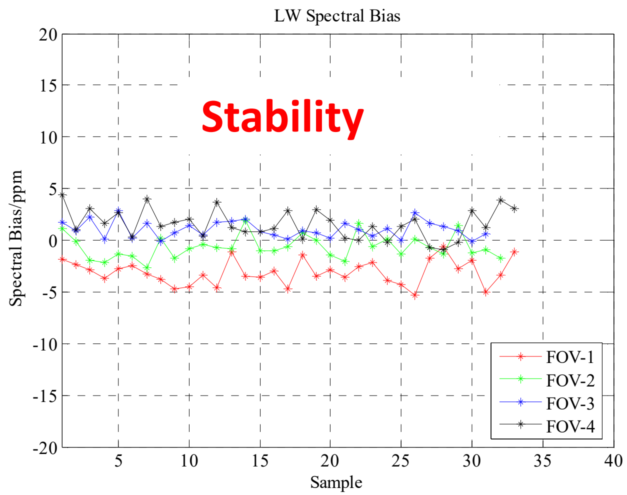


Clear pixels determined from MERSI cloudmask

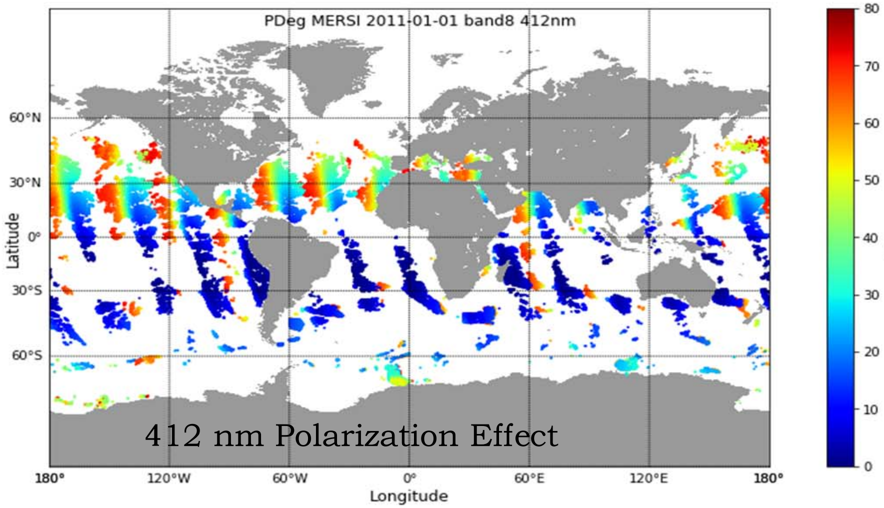
HIRAS OBS compared with LBLRTM simulation （LW）

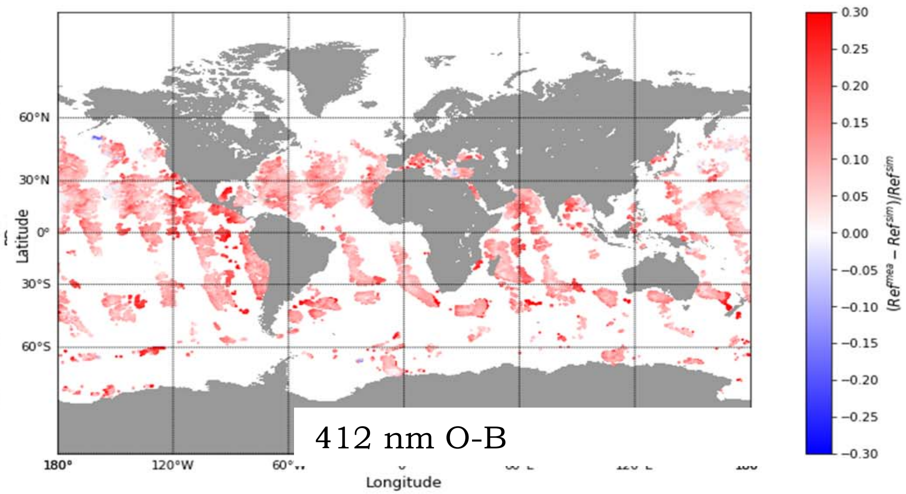


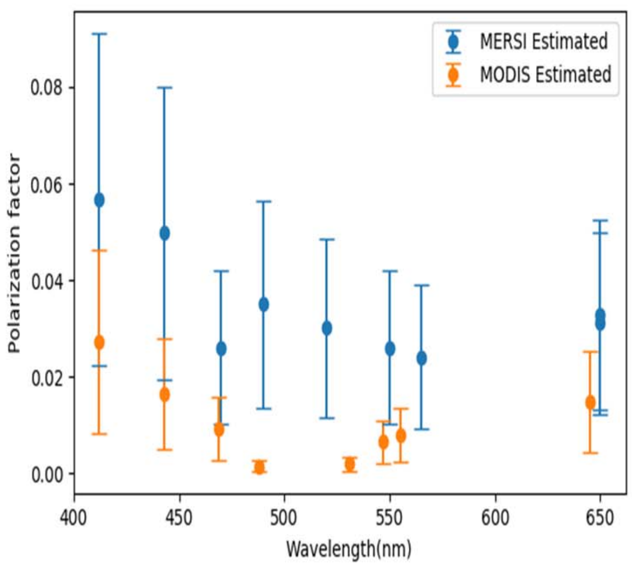
Frequency biases relative to LBLRTM will be derived; ILS & laser parameters may be adjusted



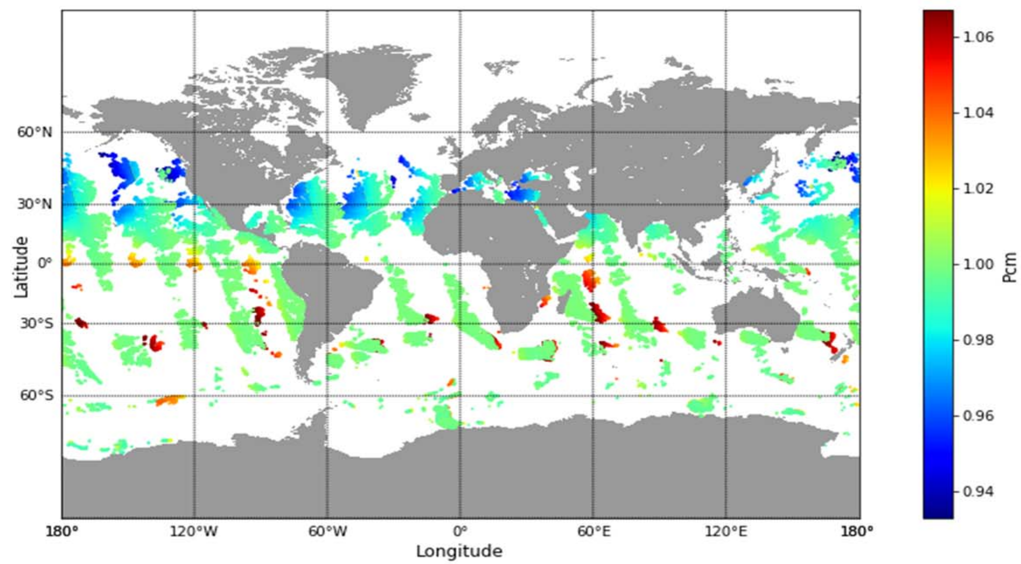
Cal/Val： Correction of Polarization effect for MERSI







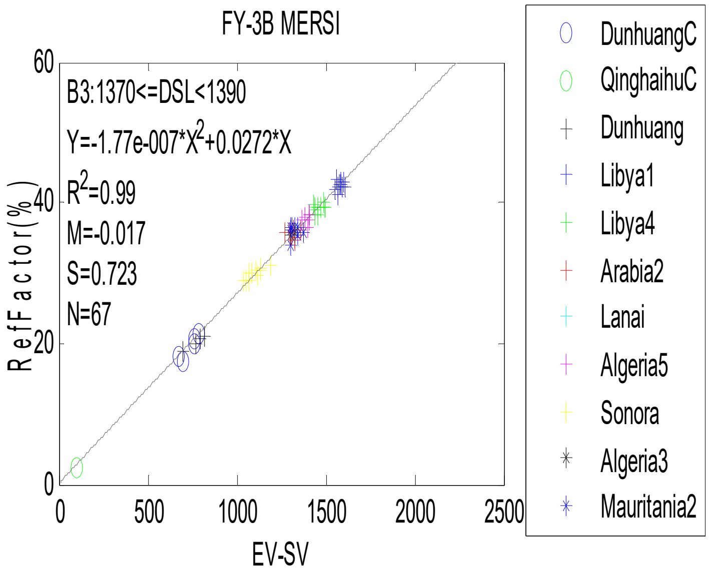
Polarization effect estimation



412 nm Magnitude of Polarization correction

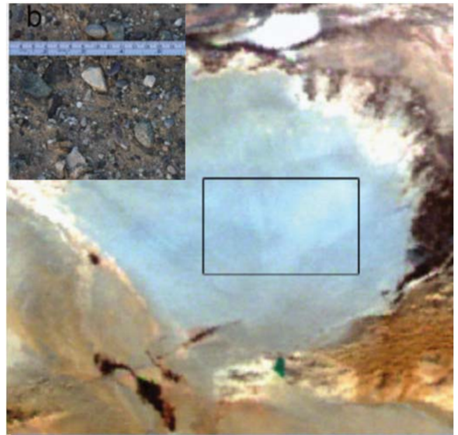
The polarization effect of FY-3 MERSI could be estimated using the simulation of FY-3 MERSI under the clear sky open sea pixels

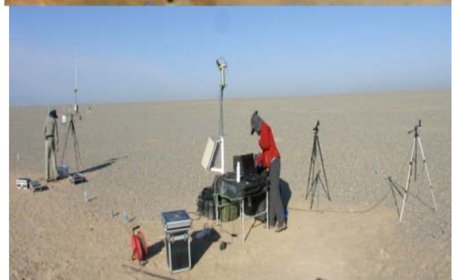
RTM + Campaign OBS for Cal/Val

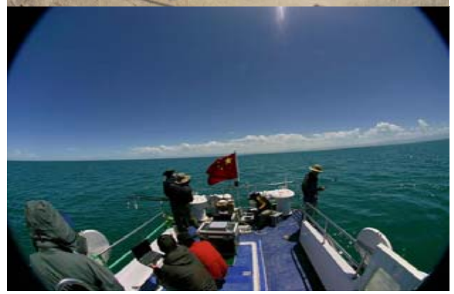


	Old	New
Surface	Lambert	BRDF
Scatter	Scalar	Vector
Trans	Band model	Mid-Res
Uncertainty	6%	3~5%

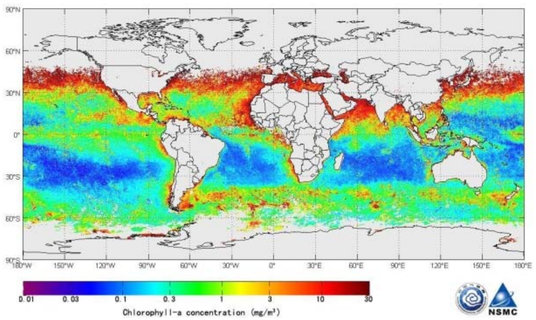
FY-3A MERSI

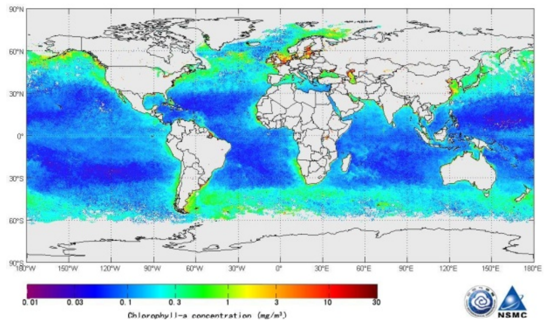




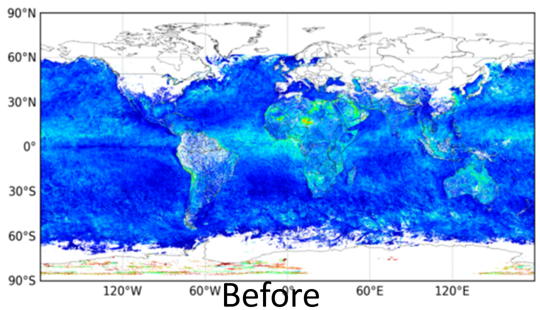


Sea Color

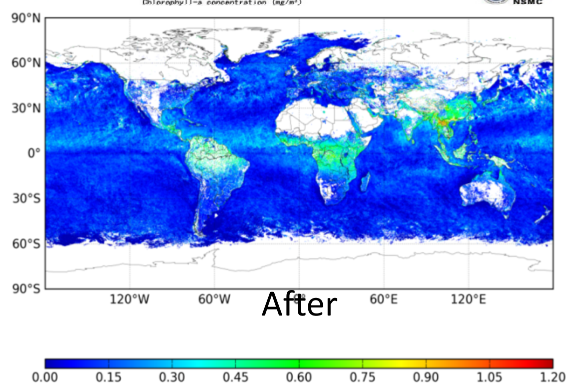




aerosol



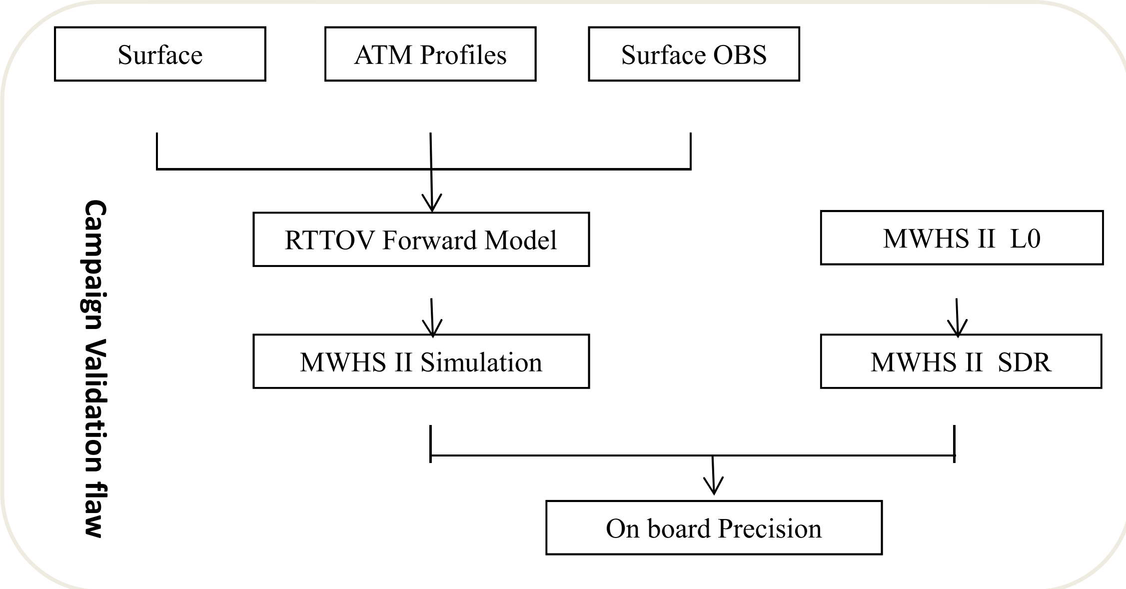
Before

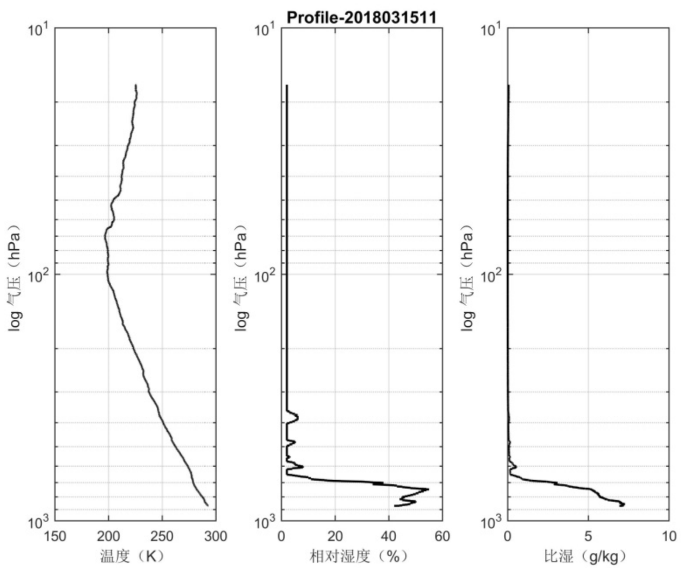


After

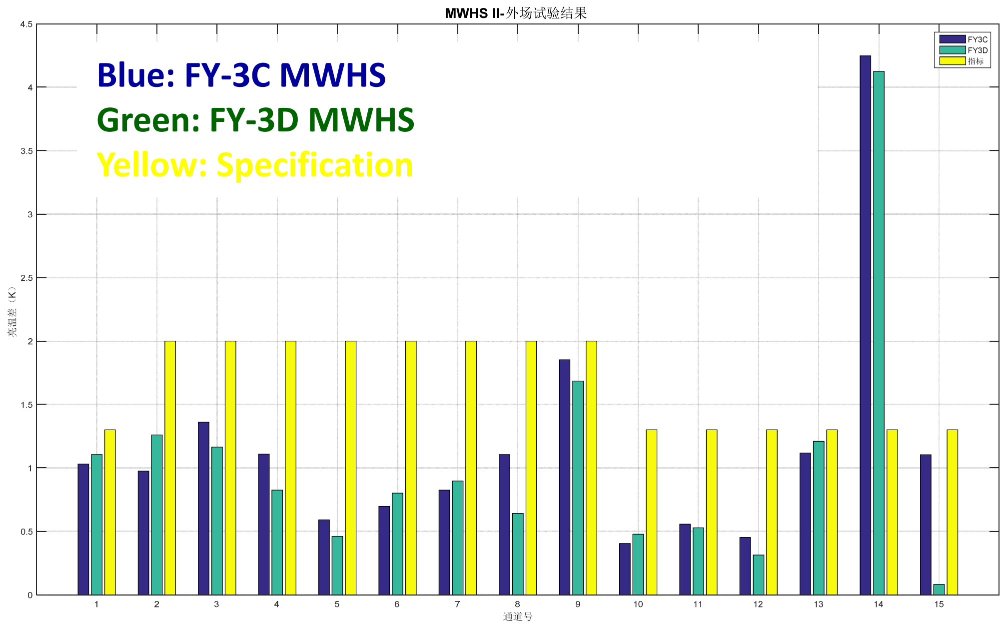
Cal/Val: campaign for FY-3c/d MWHS

过境普洱中心时刻 北京时	卫星编号	仪器天顶角（度）
2018/3/3 14:08:40.6	FENGYUN 3D	46.88
2018/3/3 23:06:56.5	FENGYUN 3C	15.1
2018/3/4 11:35:13.3	FENGYUN 3C	13.58
2018/3/5 11:16:20.6	FENGYUN 3C	22.65
2018/3/5 15:10:09.4	FENGYUN 3D	50.87
2018/3/6 14:51:58.5	FENGYUN 3D	25.58
2018/3/7 14:33:04.3	FENGYUN 3D	9.3
2018/3/8 3:01:21.0	FENGYUN 3D	10.49
2018/3/10 11:22:00.3	FENGYUN 3C	11.36
2018/3/12 14:38:37.1	FENGYUN 3D	1.81
2018/3/13 3:06:54.0	FENGYUN 3D	1.01
2018/3/14 22:59:22.4	FENGYUN 3C	1.44
2018/3/15 11:27:39.7	FENGYUN 3C	0.67





Sounding Profiles



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Flow Chart of RTM SAT-Simulator

RTMs：

CRTM, RTTOV, 6S etc

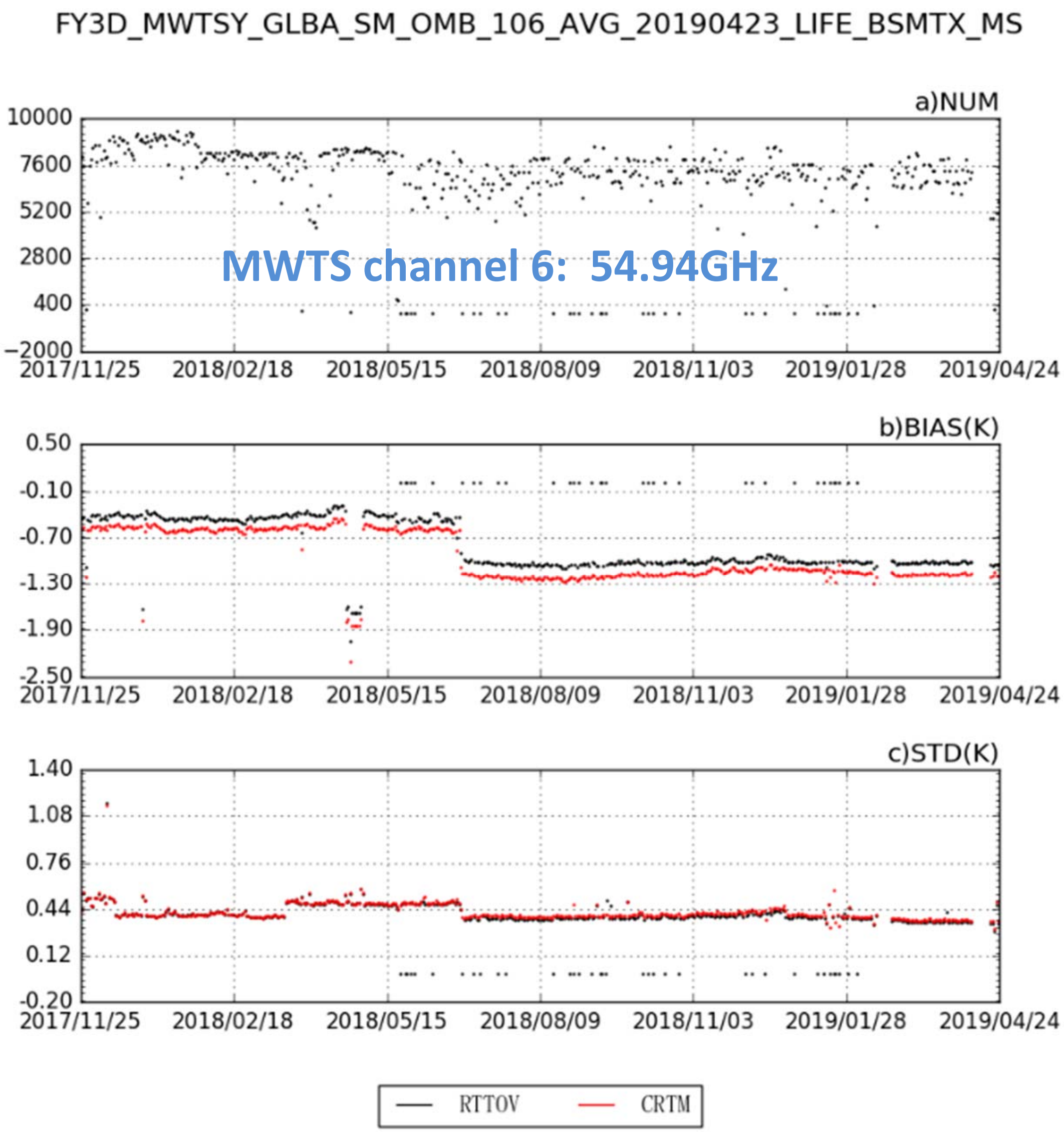
NWP：

FNL、 ERA 5、 CRA-40 etc

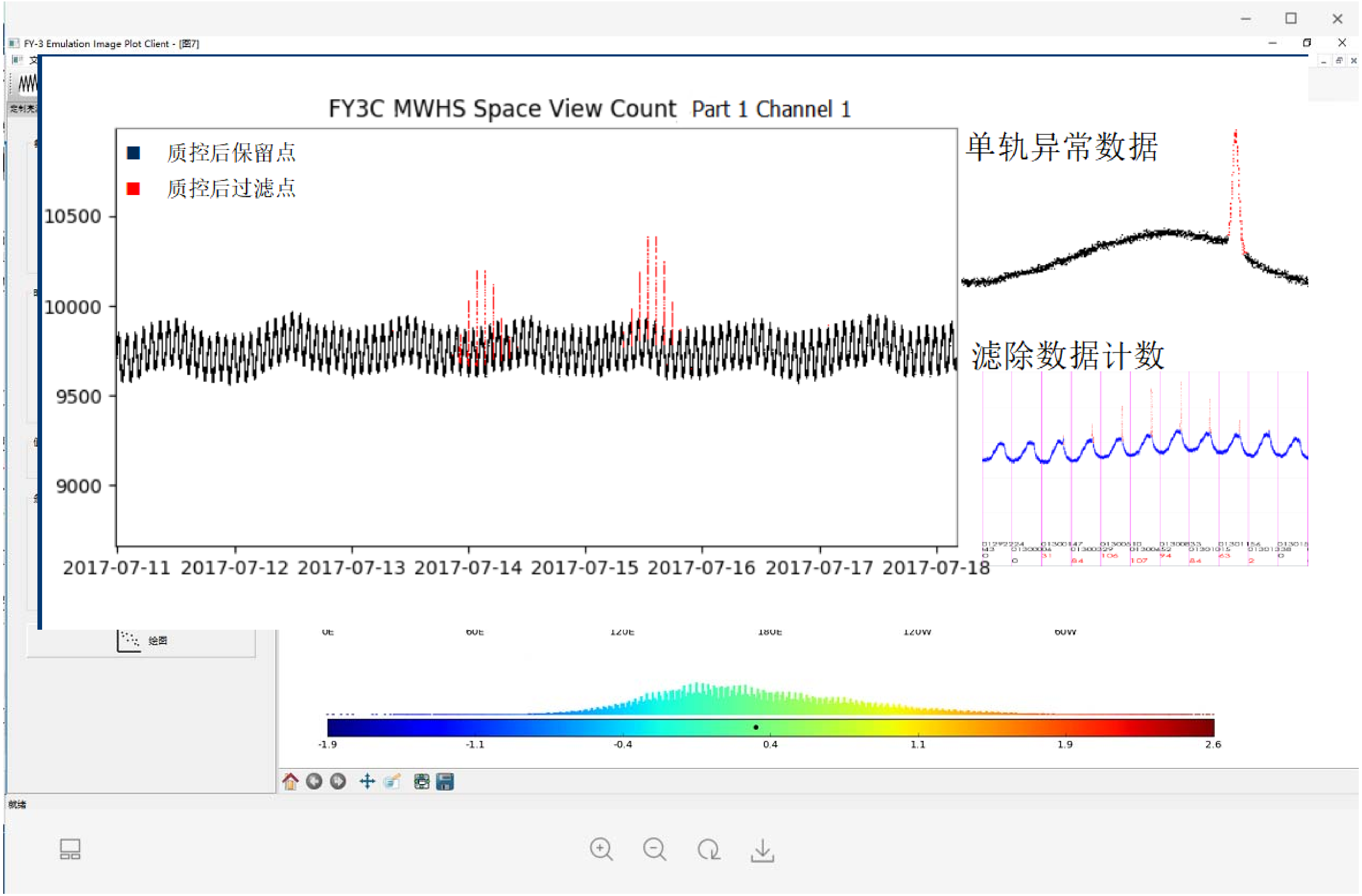
Clear Sky only

Monitoring instrumental performance using simulations

Web: : http://satellite.nsmc.org.cn

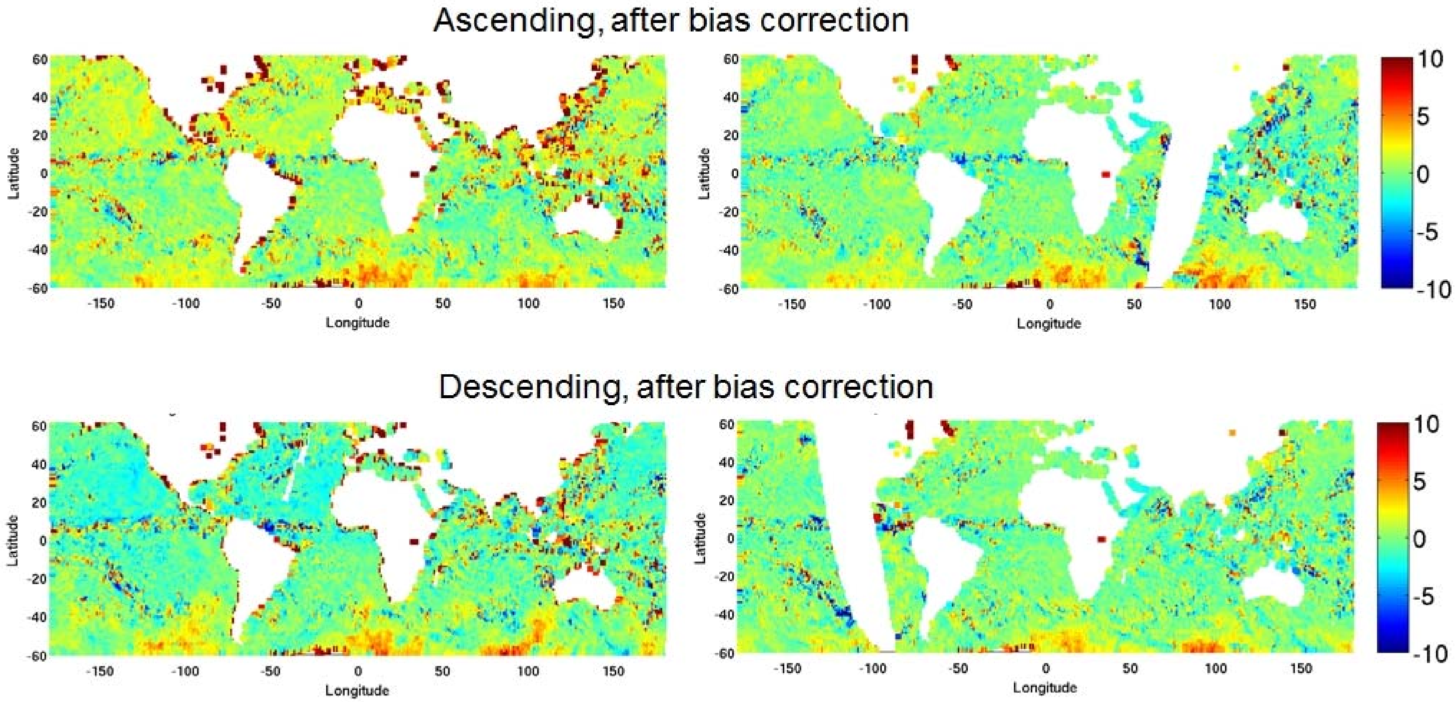


More details for the abnormal diagnosis



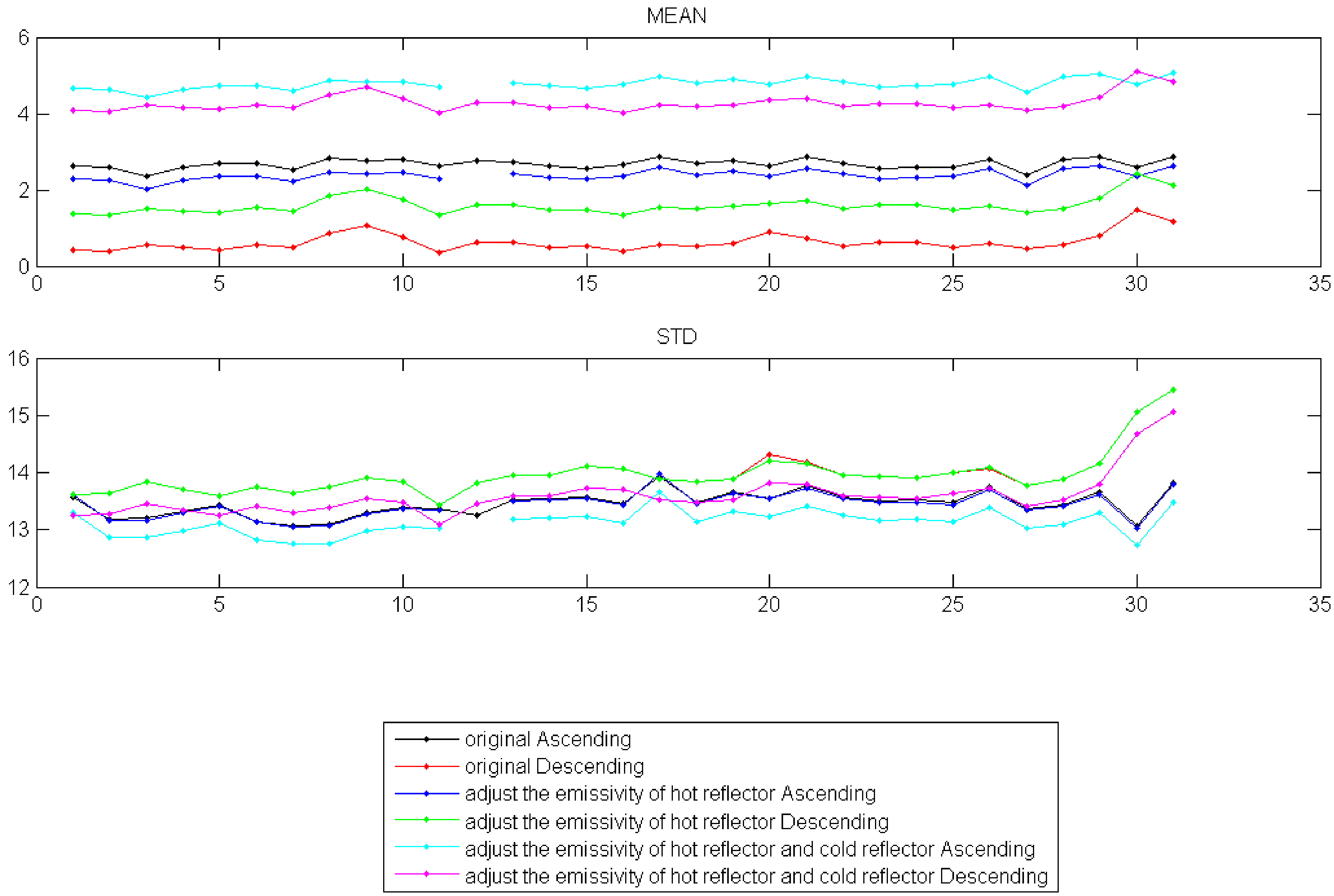
MWRI: Ascending/descending biases

MWRI; 18.7 GHz v **AMSR-2; 18.7 GHz v**

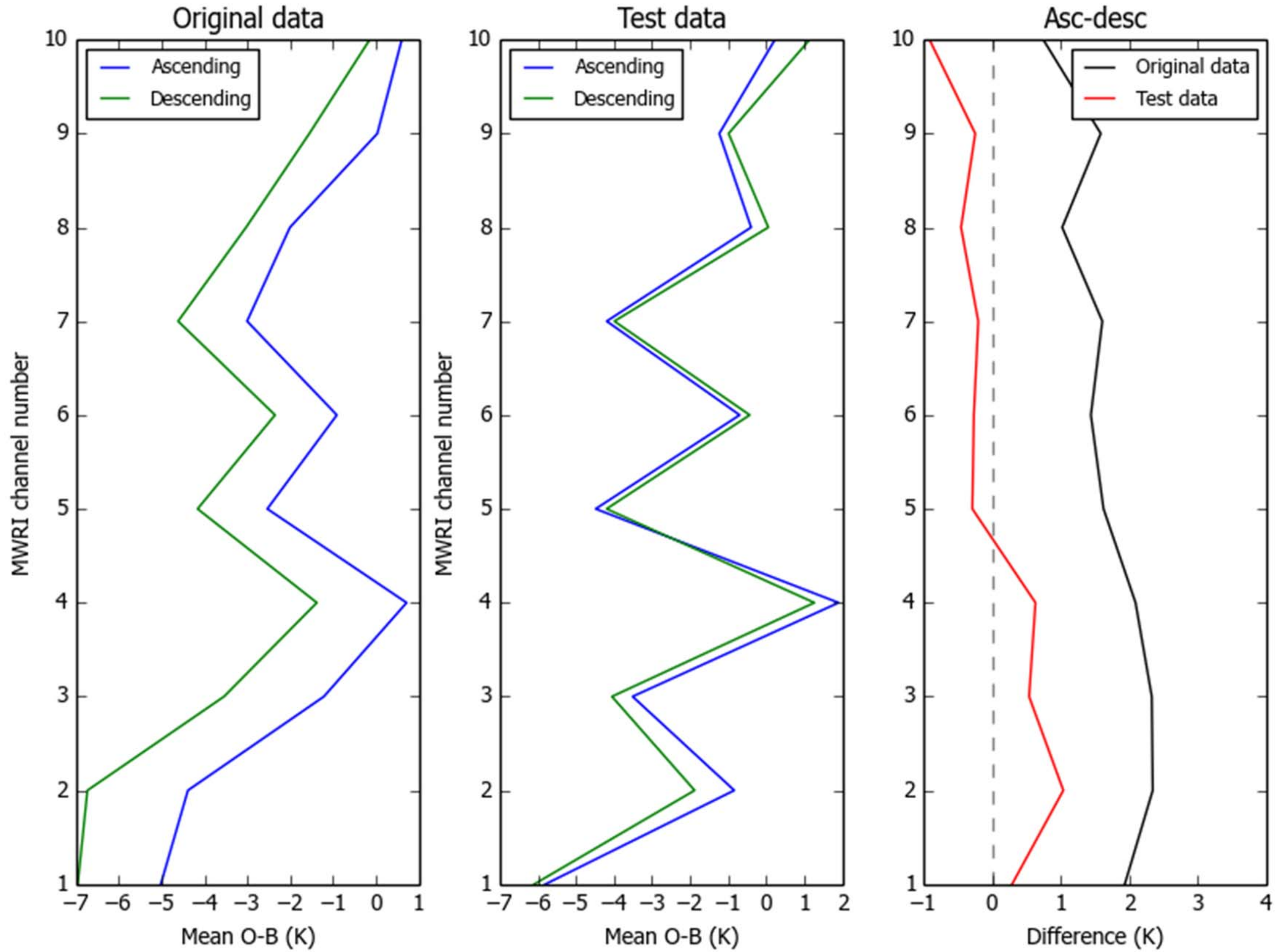


Mean (o-b), 8-12 June 2014

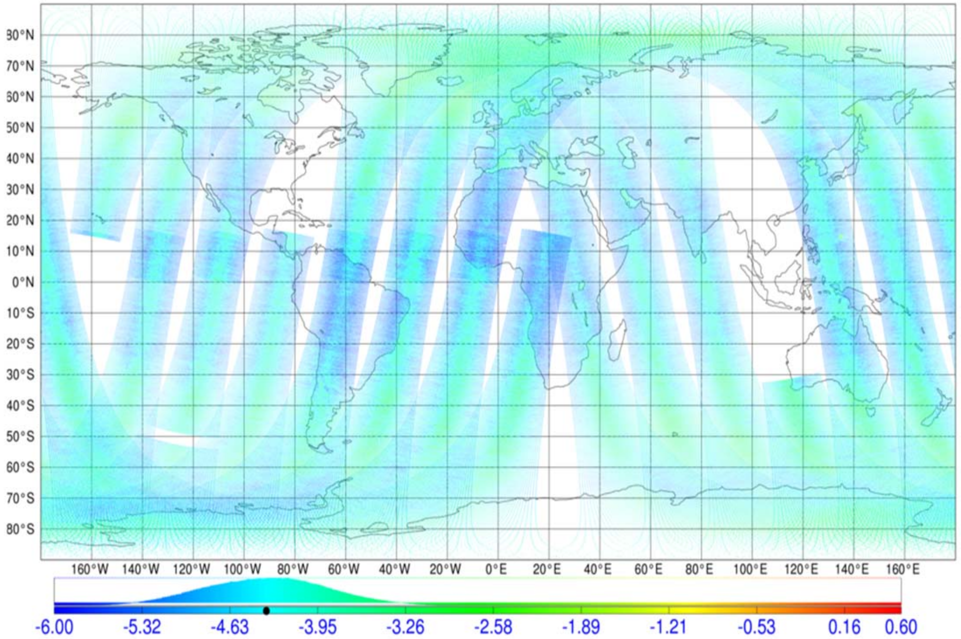
Statistics of MWRI O-B



The improved OMB for channels from UKMO

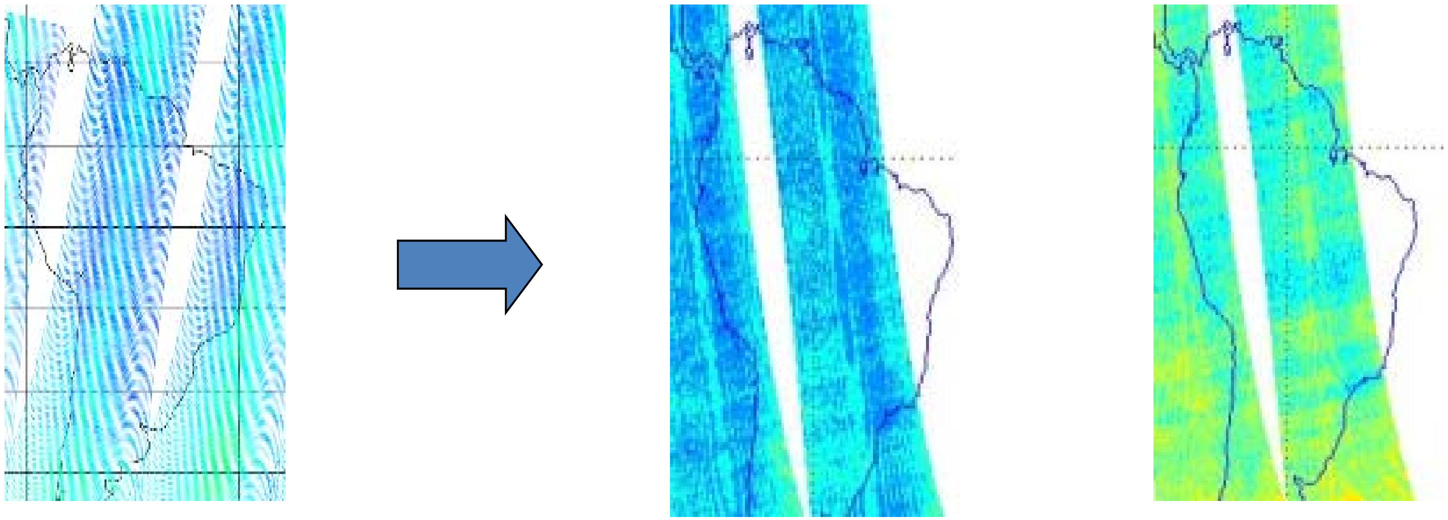


Surface Info in MWTS Sounding Channels

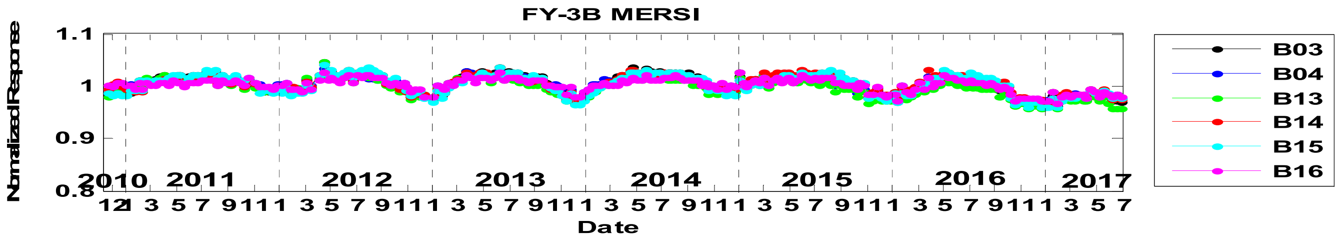


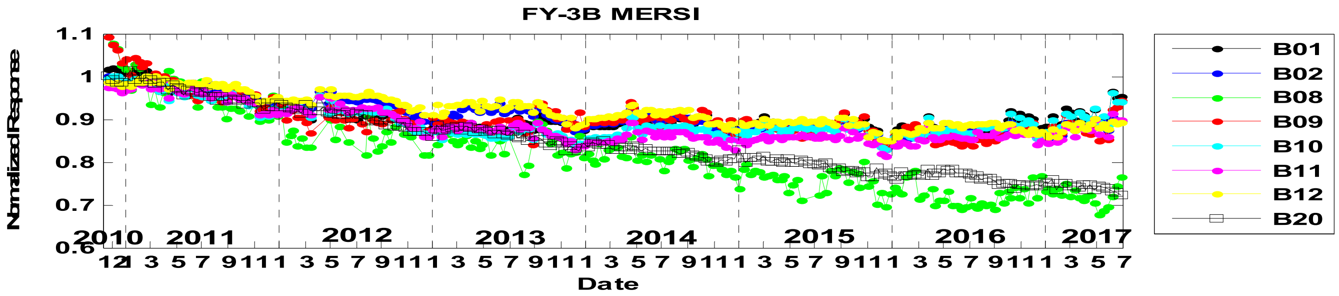
O-B of MWTS Sounding Channel, the Surface Information exists.

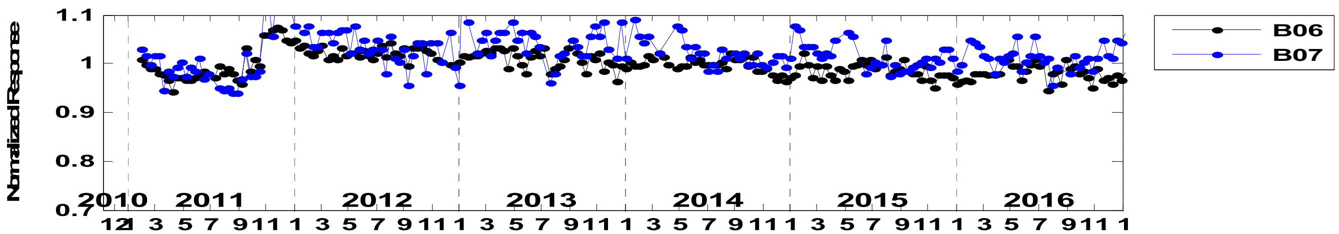
T=Tj+k(T1-Tj);j=5,6,7,8

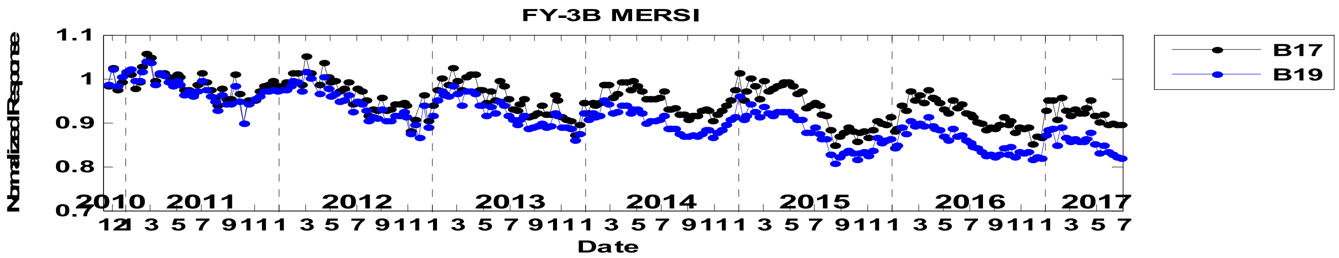


Monitoring of Reflected Channels of Imager









The attenuation effect could be detected and corrected

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RTMs in Product Generation

- **Simulation – Look Up Tables**
- **FWD and AD/Jacobian Matrix in physical Retrievals**

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x}-\mathbf{x}_b)^T \mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}_b) + \frac{1}{2}(H(\mathbf{x})-\mathbf{y}^{obs})^T(\mathbf{O}+\mathbf{F})^{-1}(H(\mathbf{x})-\mathbf{y}^{obs})$$

$$J(\mathbf{x}_a) = \min_{\mathbf{x}} J(\mathbf{x}) \quad \forall \mathbf{x} \text{ near } \mathbf{x}_b$$

$\mathbf{x}$ – analysis variable

$\mathbf{x}_a$ – final analysis

$\mathbf{x}_b$ – background

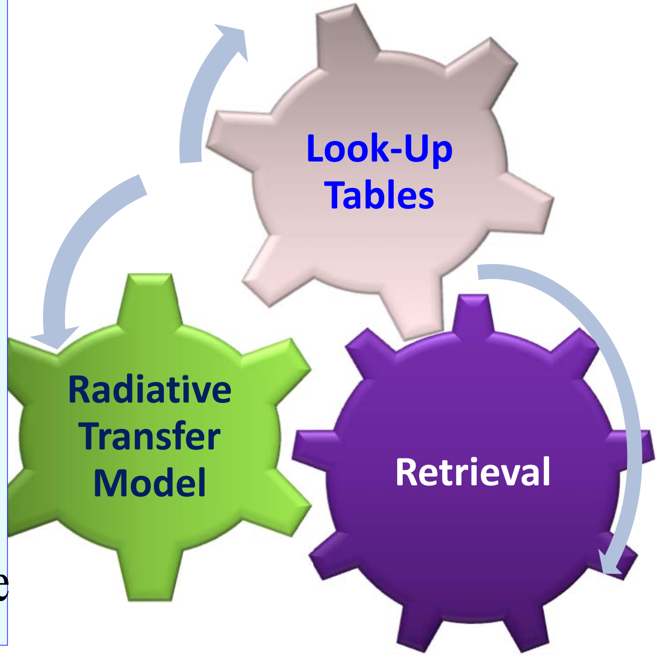
$\mathbf{B}$ – background error covariance

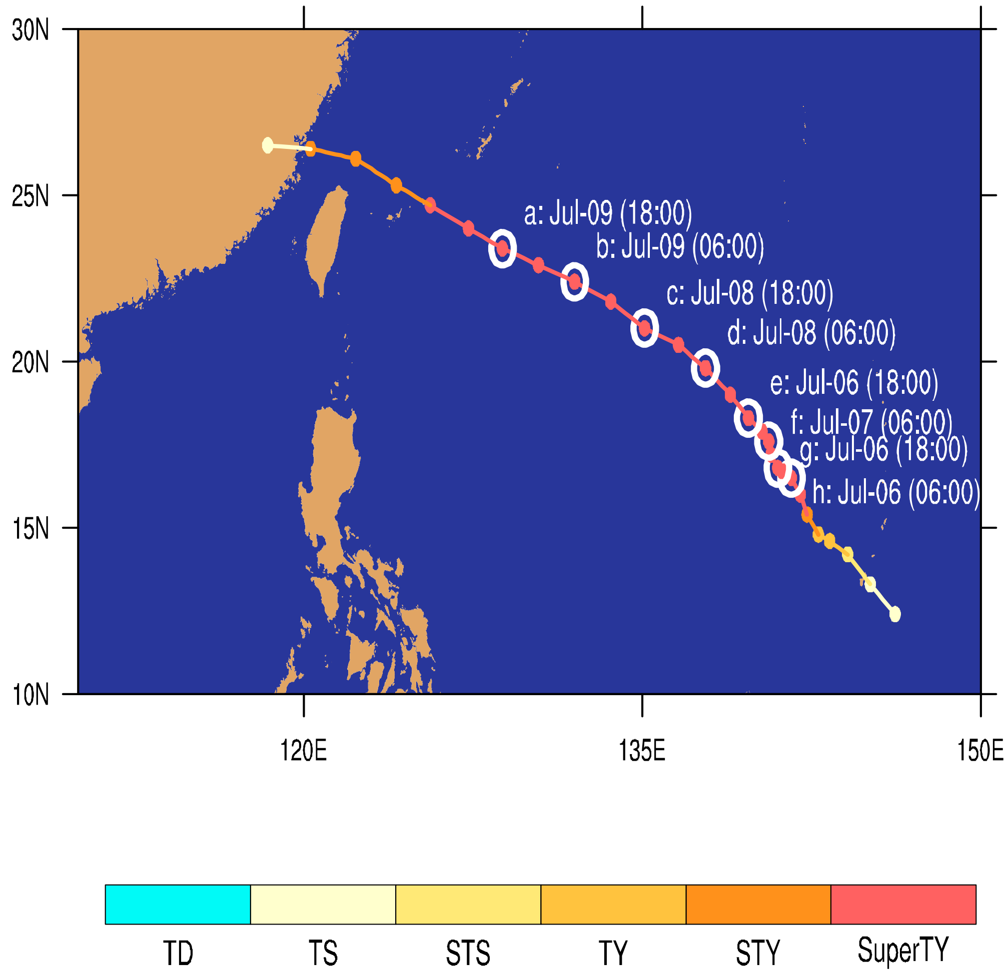
$\mathbf{y}^{obs}$ – observations

$\mathbf{O}$ – observation error covariance

H – observation operator

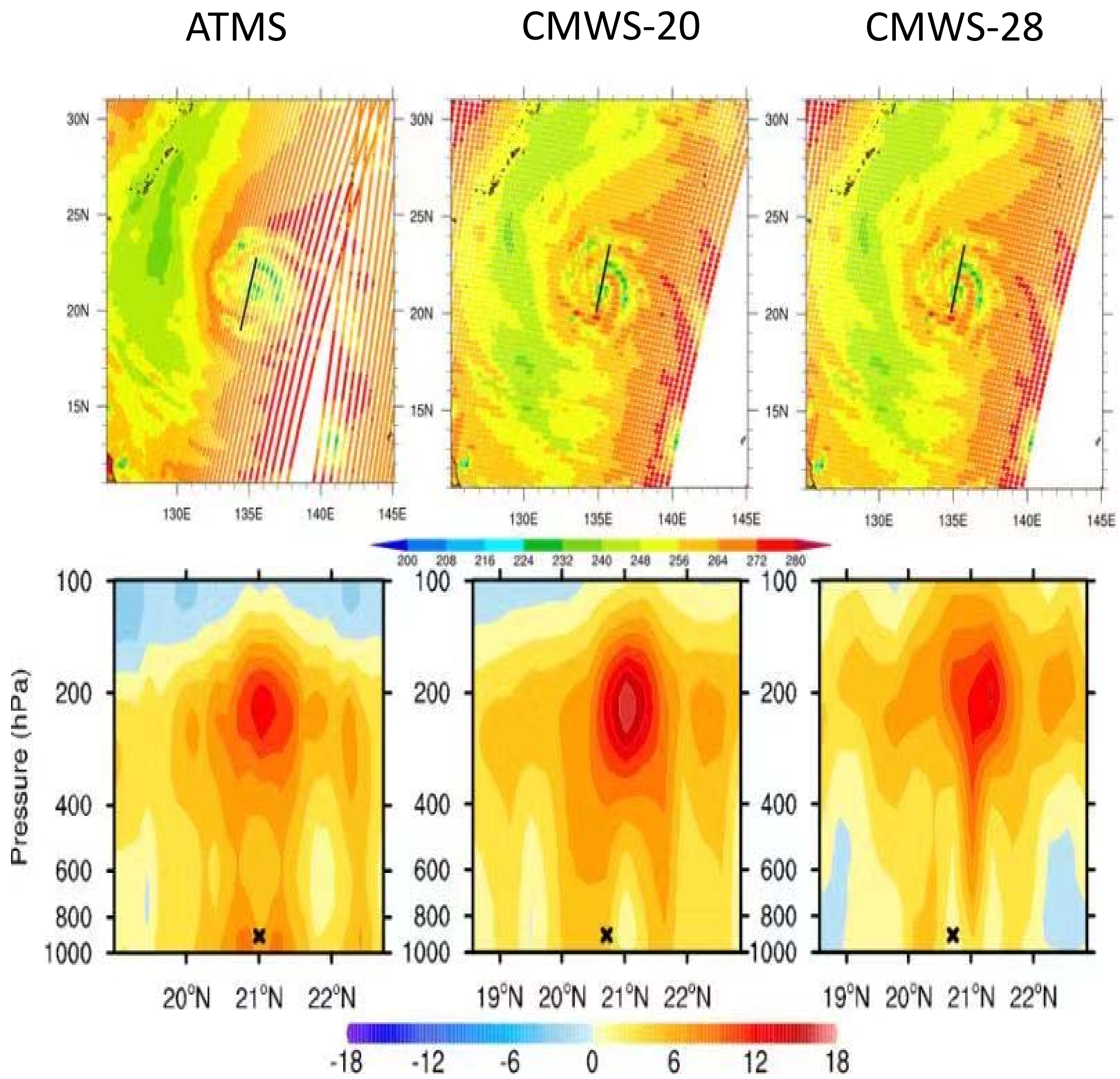
$\mathbf{F}$ – forward model error covariance





Slide courtesy of Fuzhong Weng

Thermal Structure from ATMS and CMWS

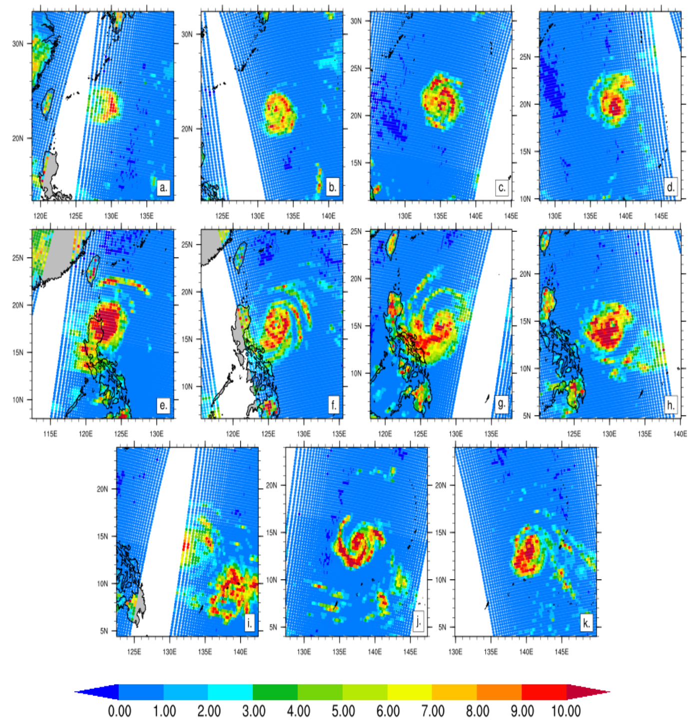


CMWS=MWTS+MWHS

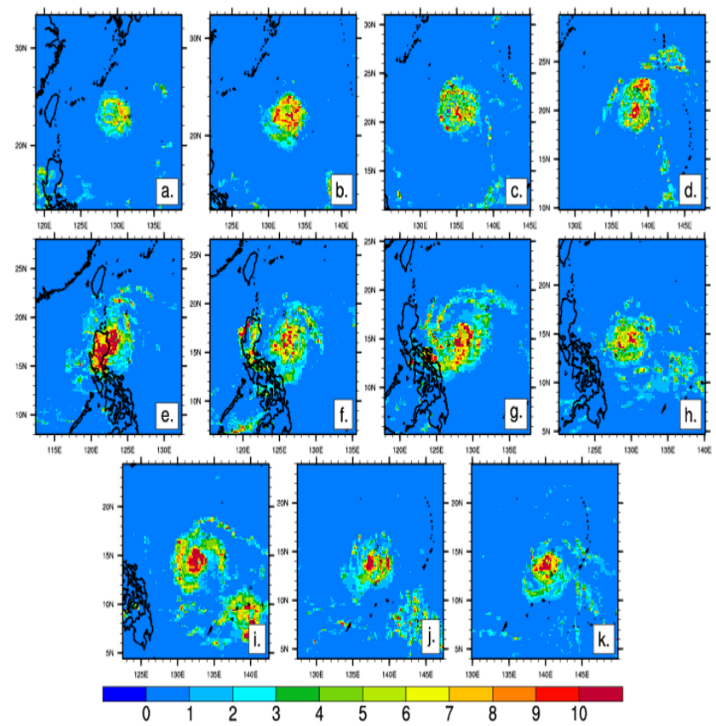
Slide courtesy of Fuzhong Weng

Typhoon Maria(玛利亚) and Mangkhut(山竹) Precipitation from FY-3 MWTS and MWHS

Precipitation from CMWS-28



Precipitation from CMORPH



FY3-CMWS-28 is combined from MWTS and MWHS
CMORPH stands for NOAA Climate Prediction Center Morphing Technique

Slide courtesy of Fuzhong Weng

Product Development： Infrared Total Precipitable Water Inversion

Input Data
（cloudmask,T639,satellite observations, observed geometric parameters）

↓

Data preprocessing
（NWP data spatio-temporal interpolation、surface emissivity estimation）

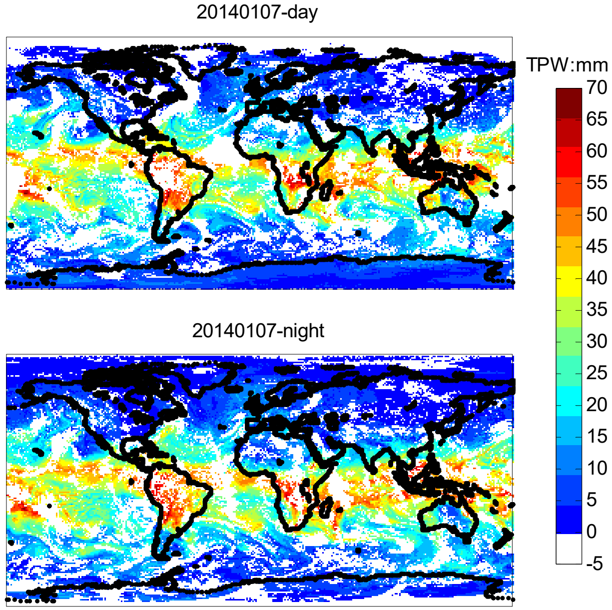
↓

RTTOV Simulation
(two split-window radiance, transmittance)

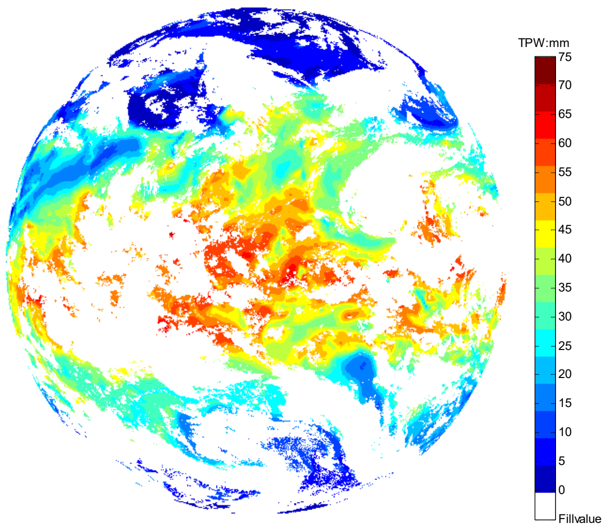
↓

Total Precipitable Water calculation
(coefficient calculation, TPW retrieval)

FY-3C VIRR TPW

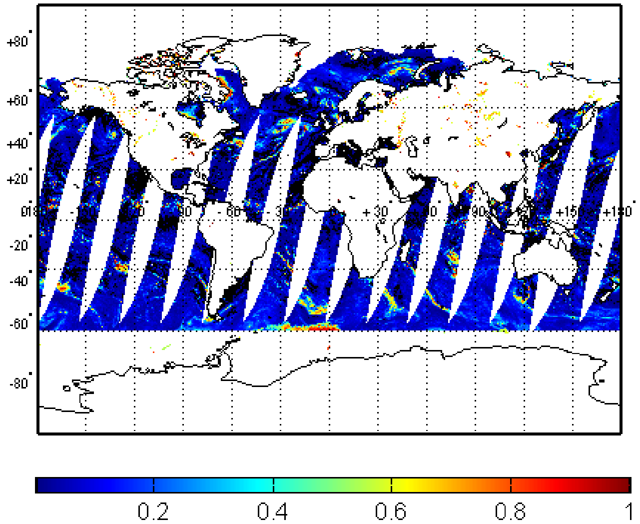


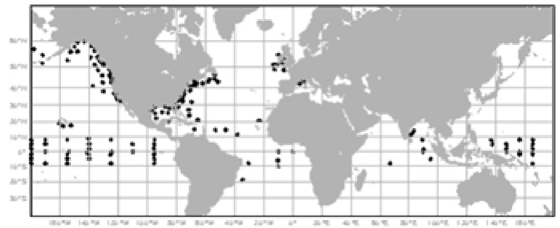
FY-2F TPW

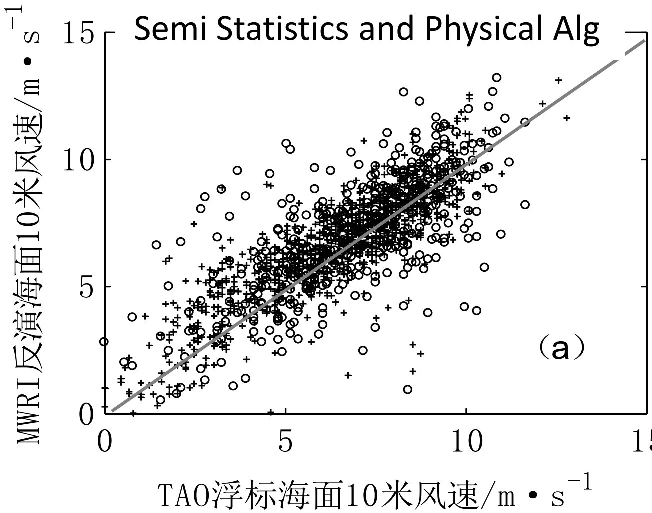


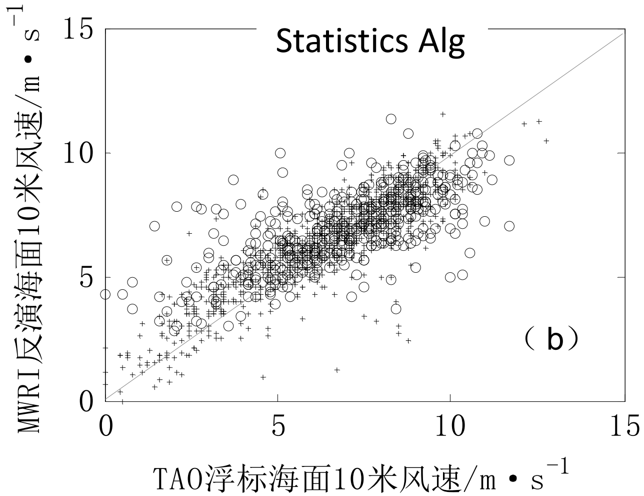
Product Development : Sea surface wind speed and cloud water retrieval algorithm

- Algorithm： Semi-Statistical-Physical Model
- D-Matrix coefficient training, based on atmospheric profile sample library and rapid radiation transfer model



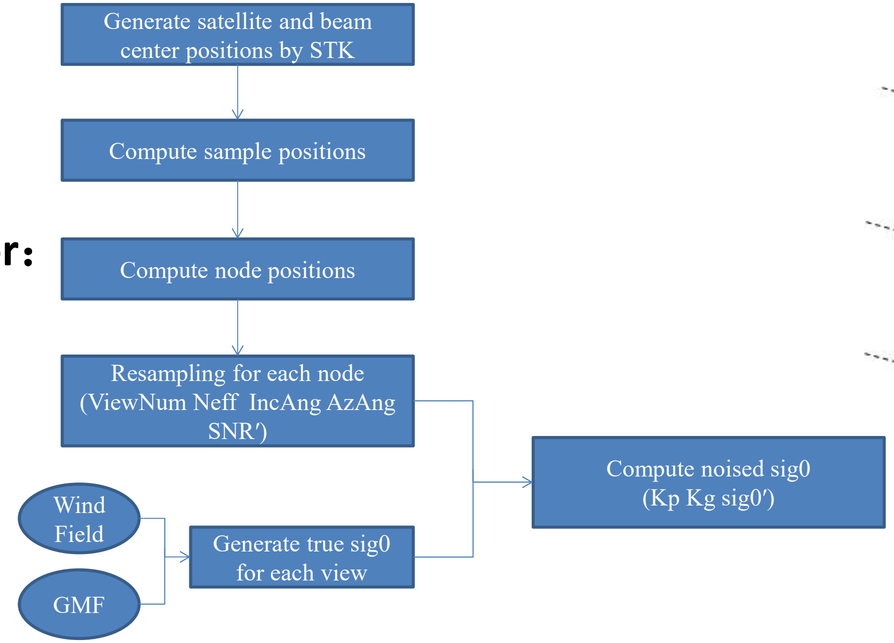


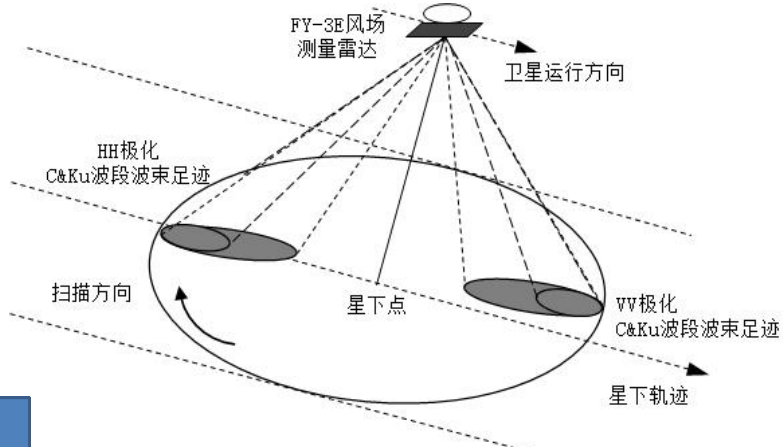




Product Development :Wind Profile Radar(simulator and products)

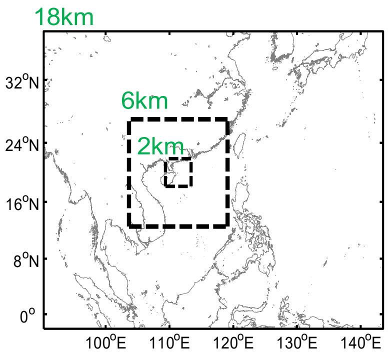
Simulator:

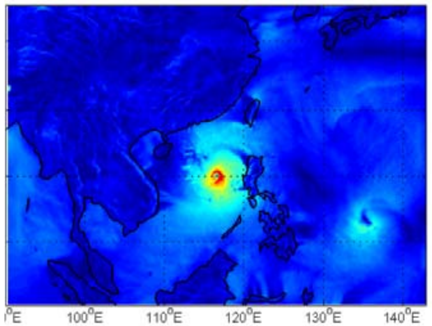


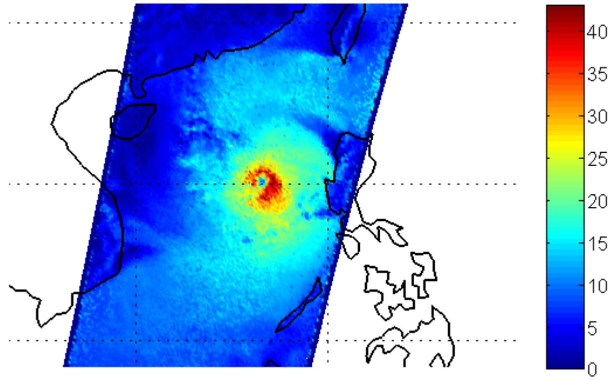


The WindRAD observation system is greatly different from the scattero-meter systems domestic and abroad: fan-beam, rotating scanning

Output: Wind field solution in Wind vector cell (WVC)







Typhoon wind field simulated by **WRF-ARW**

Inversion products of simulator

Way forward

- With the improved instrumental performance (NE∆T), and traceable radiometric measurements, FY series are becoming one of the important components of global observation to support the wide application.
- Any progress of RTMS for satellite instruments are expected and welcomed

Thank You!

谢谢！