FY-3D/MERSI-II commission test

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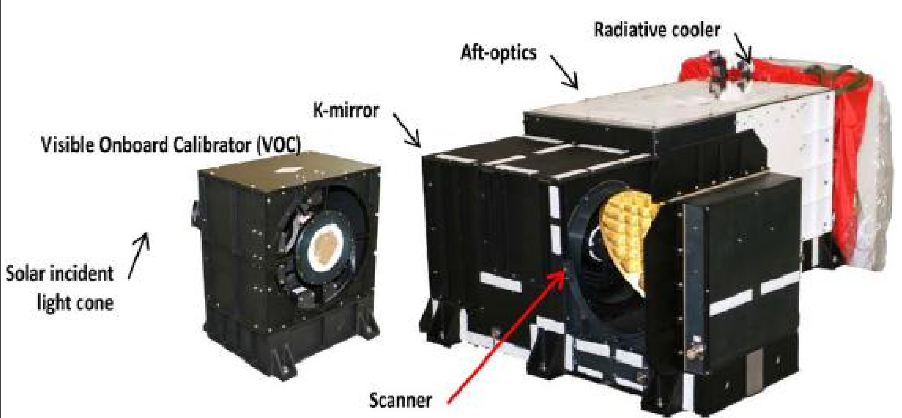
NSMC

Outline

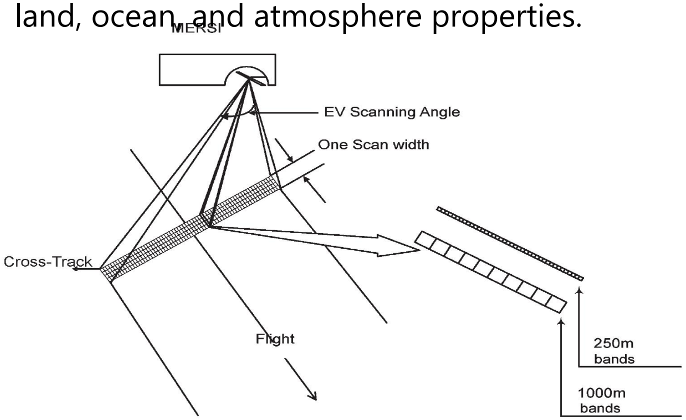
- Overview of MERSI and its Evolution
- New features and improvements of MERSI II
- MERSI II in-flight CAL/VAL
  - GSICS multiple and integrated VCs
  - CRCS ground-based validation
- Summary

MERSI I on FY-3A/3B/3C

Parameters	Specification
Earth scanning	±55.1degree±0.1
Quantization	12 bits
Scanner speed	40 rotation/minute
Scanning stability	<0.5 IFOV (1000m)
Sampling pixel of each scan	2048(1000m bands) , 8192(250m bands)
Scanner Pointing accuracy	120 ±30 arcseconds, 1 (±100m at nadir)
Response Degradation rate	<20%/3 years
Spectral Characterization Accuracy	Bias of Center wavelength< 10%* width, out of band< 3%
Inter-band Co-registration	<0.3pixels
Restore of saturation	≤6 pixels(1000m) within 2 km of entering *Ltyp* regime
Bright Target Recovery	≤24pixels(250m)
MTF	≥0.27(1000m) , ≥0.25(250m)
Radiometric Calibration accuracy	Visible bands <7%; Thermal band<1k(270k)
Detector consistency within one band	unconsistency≤5-7%



- **20 spectral bands with a total of 350 detectors located on 4 focal plane assemblies (FPA).**
  - 19 reflective solar bands (RSB): bands 1-19, 0.4~2.1um
  - 1 thermal emissive bands (TEB): band 5, 10-12.5 um
- **Two spatial resolutions (nadir): 250 m(1-5), and 1 km(6-20).**
- **Scan angle range: ±55° (from nadir)**
  - A swath of 10 km (along-track) by 2900 km (nadir along-scan)
  - Global coverage in 1 day
- **One-sided 45° scan mirror with one K- mirror (de-rotation)**
  - 1.5 second each scan
- **Comprehensive applications**
  - Near 20 science data products for studies of the Earth's land, ocean, and atmosphere properties.



MERSI→MERSI-II

Continuity and Evolution

MERSI-II Improvements:

- Cover all bands in FY-3A/B/C MERSI and VIRR
- Five more IR bands
- Cirrus cloud band 1.38μm
- Water vapor bands In NIR and 7.2μm
- Two IR split windows with 250m spatial resolution
- Higher accuracy from onboard calibration

Band	MERSI-II	MERSI-I	VIIRS	SLSTR	OLCI
1	0.470	0.470	DNB		
2	0.550	0.550	√	√	
3	0.650	0.650	√	√	
4	0.865	0.865	√	√	
5	1.38	×	×	√	
6	1.64	1.640	√	√	
7	2.13	2.130	√	√	
8	0.412	0.412	√	×	√
9	0.443	0.443	√	×	√
10	0.490	0.490	√	×	√
11	0.555	0.520		×	√
12	0.670	0.565	√	×	√
13	0.709	0.650		×	√
14	0.746	0.685	√	×	
15	0.865	0.765	√	×	√
16	0.905	0.865	×	×	√
17	0.936	0.905	×	×	√
18	0.940	0.940	×	×	
19	1.03	0.980	×	×	√
20	3.8	1.030	√	√	
21	4.05	×	√	×	
22	7.2	×	×	×	
23	8.550	×	√	×	
24	10.8	11.25	√	√	
25	12.0		√		

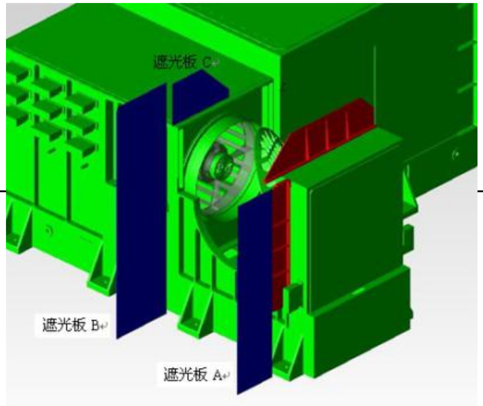
□ 250 m
□ 1000 m

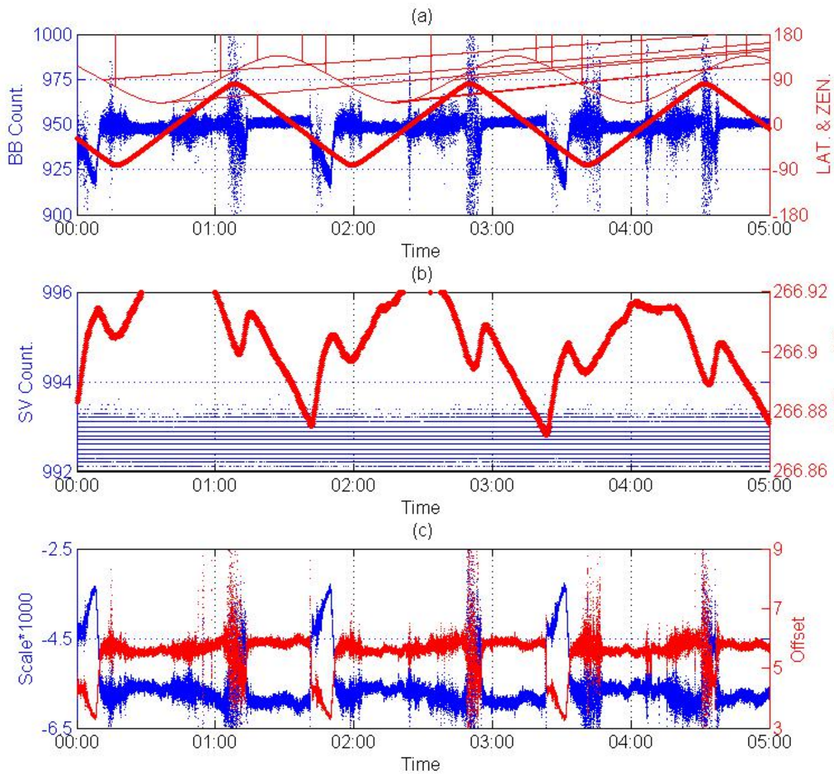
New features and improvements of MERSI II

- More Baffle to decrease straylight contamination: have been installed on the head of the instrument to further prevent contamination from solar illumination.
- OBCBB structure improvements to enhance emissivity and temperature uniformity, new capability on warm up and cool down (WUCD)
- New capability for Moon Observation Maneuver: By changing the scan timing sequence, MERSI II has a moon observation mode, which can achieve the initiative moon observation and calibration ability.
- RSB VOC improvements to reduce self-degaradaiotn :To minimize SIS degradation and its associated effects due to solar exposure, a shutter door is mounted on the solar incident light cone and is kept closed except during solar calibration events. The spectra of the standard trap detectors are also adjusted to better characterize changes in MERIS RSBs.

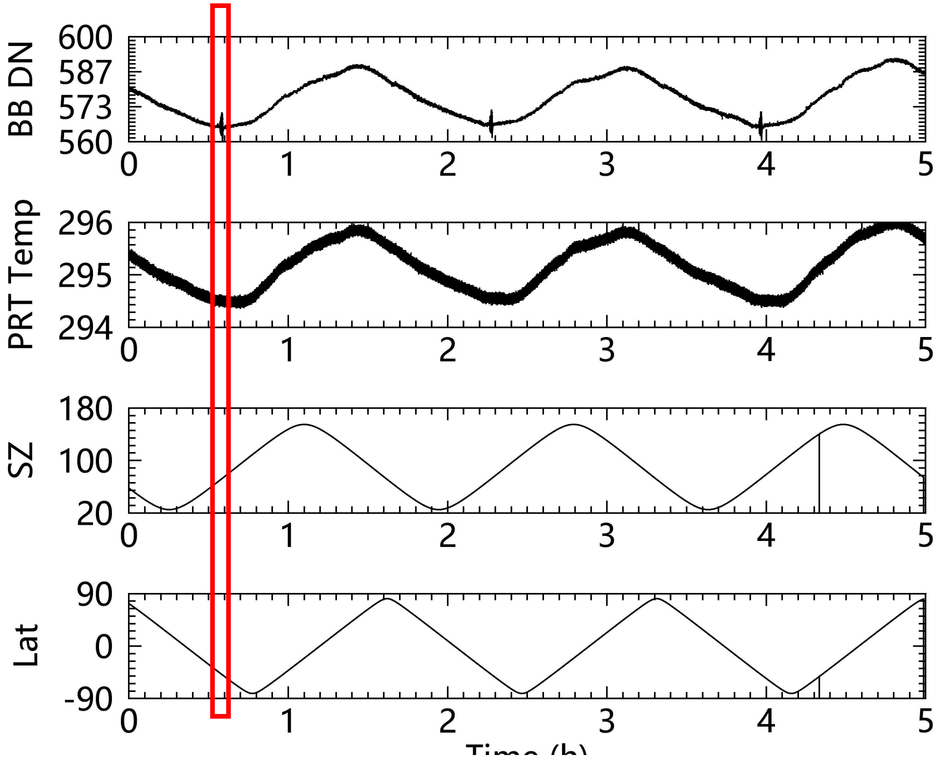
More Baffle, Decrease solar contamination

Great improvement around Day/Night terminator



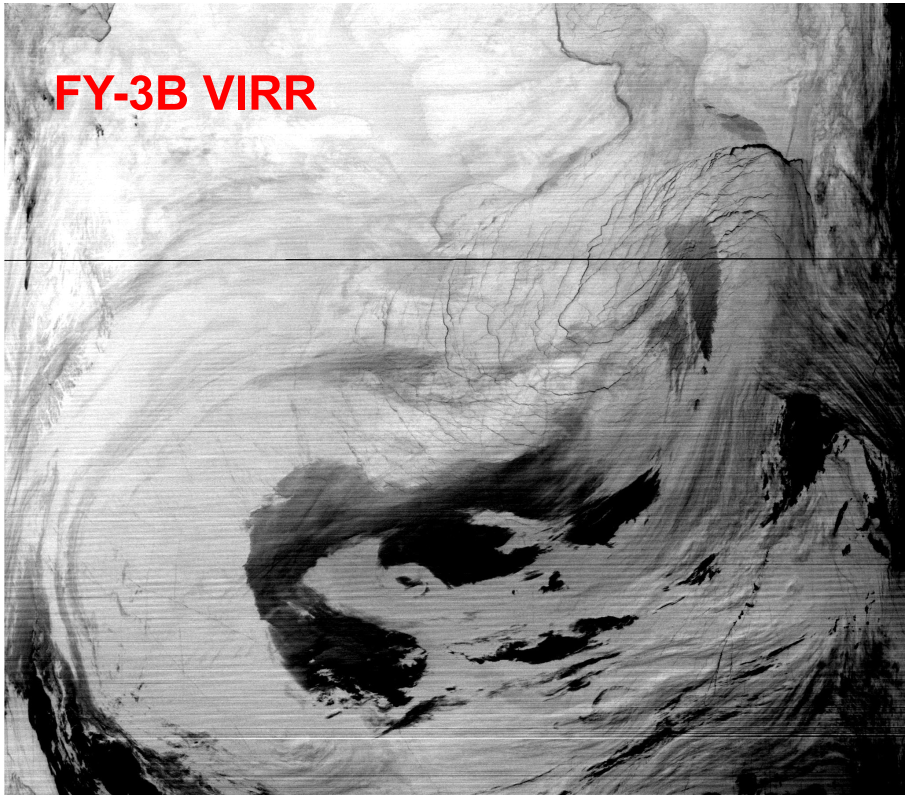


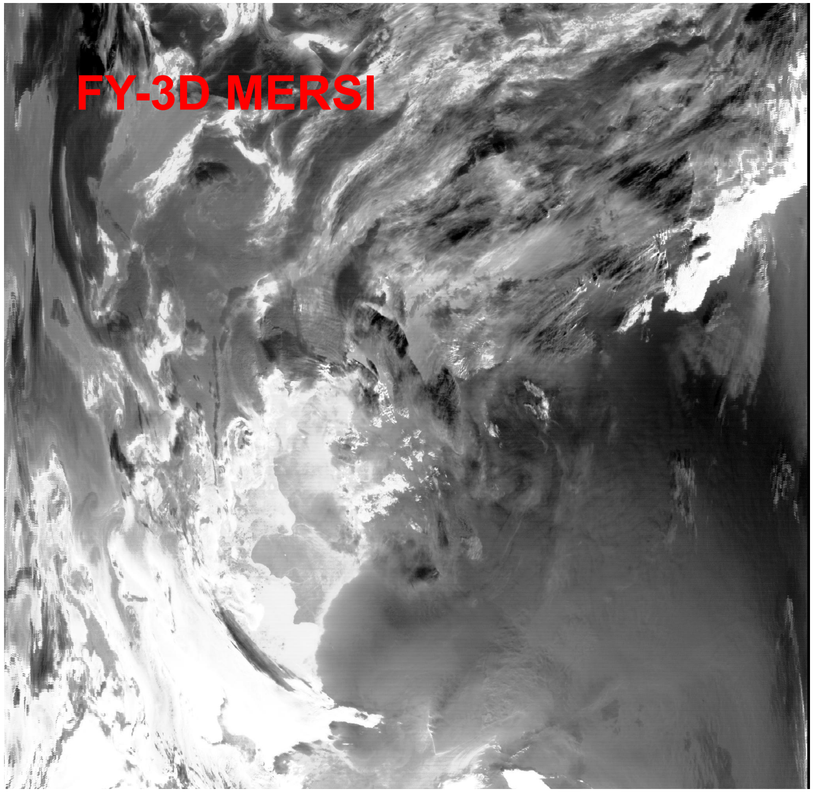
FY-3B/VIRR 3.8um BB DN Contamination(20180103)



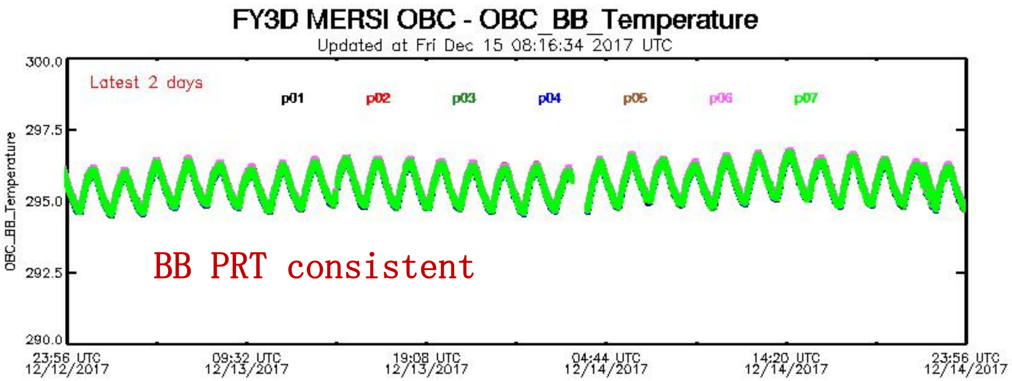
FY-3D MERSI 3.8um BB Signal Less contamination（20180103）

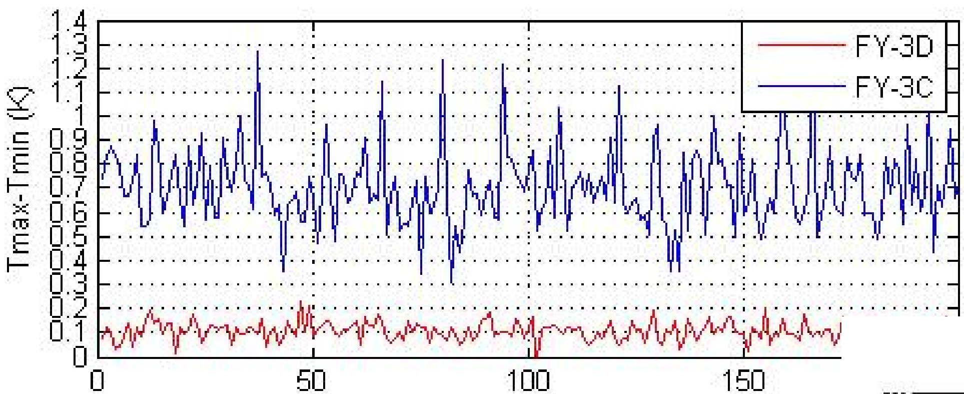
VIRR/MERSI-II Image around Terminator

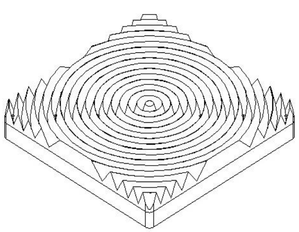




BB performance with warming-up and cooling-down function



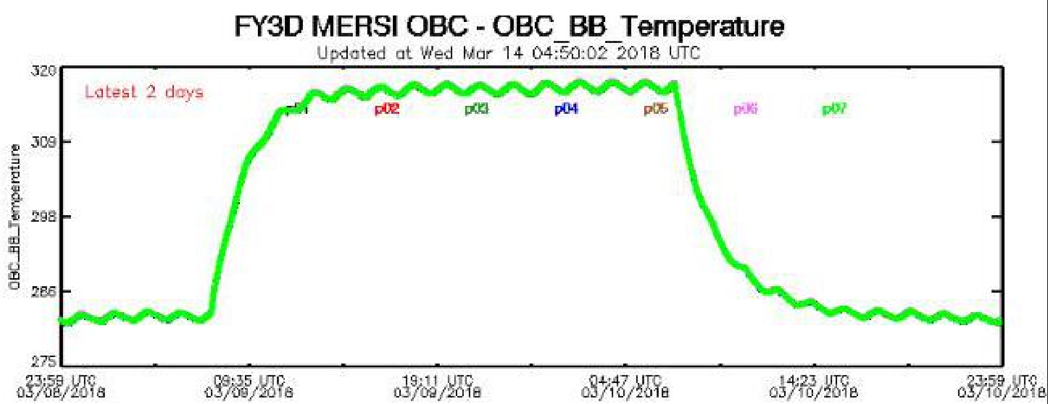




Thickness increased
Included angle decreased
Effective emissivity increased
Uniformity increased

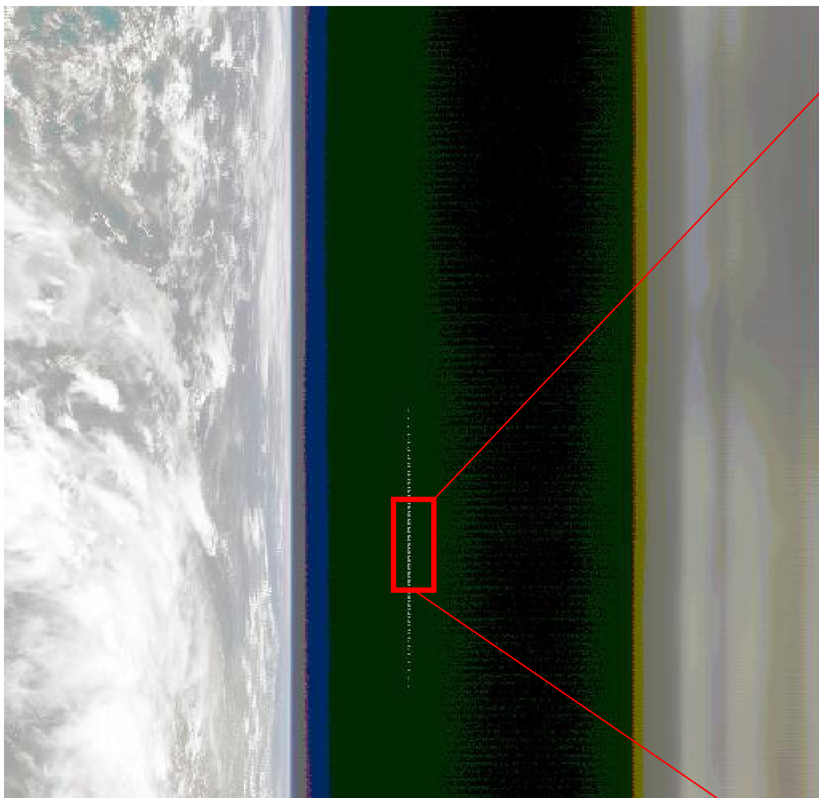
- **temperature uniformity**
  PRT thermometer consistence is less than 0.2K（Max-Min）， mean STD less than 0.1K;
- **BB temperature variation function**
  Range: 282K ~317K
  Goal: Nonlinear check on orbit

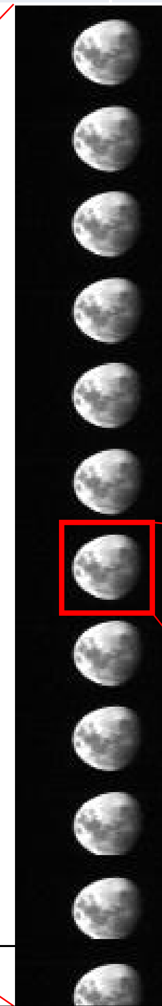
BB Warming-up and cool down

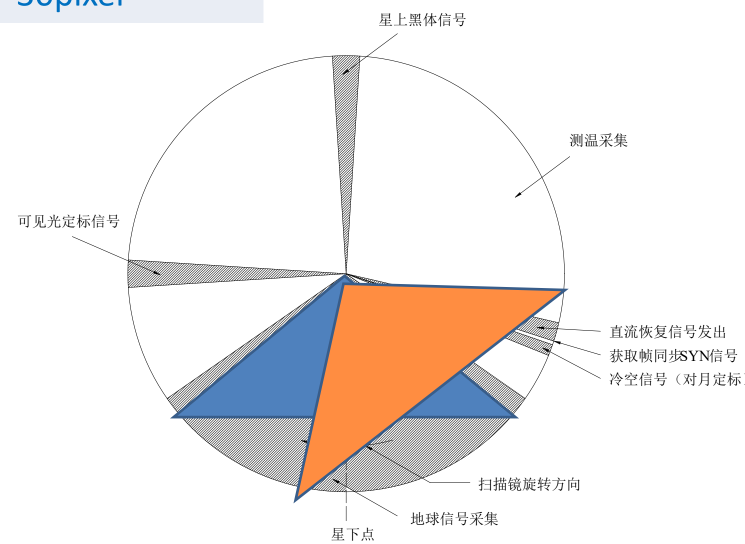


Moon Observation Maneuver

Date	Time	Phase	Size
2017-12-28	05:26:02~05:29:42	145° ~152°	30*30pixel
2017-12-29	06:06:22~06:07:12	26° ~27°	30*30pixel



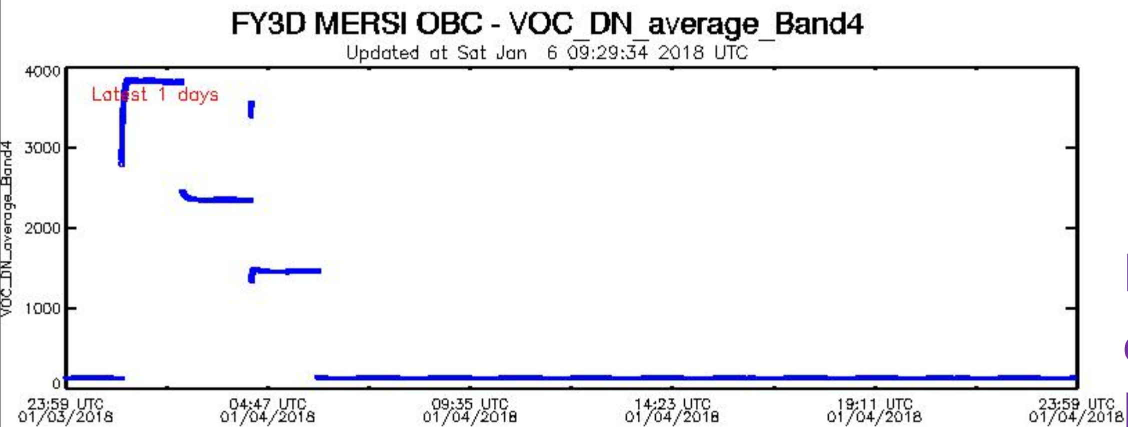


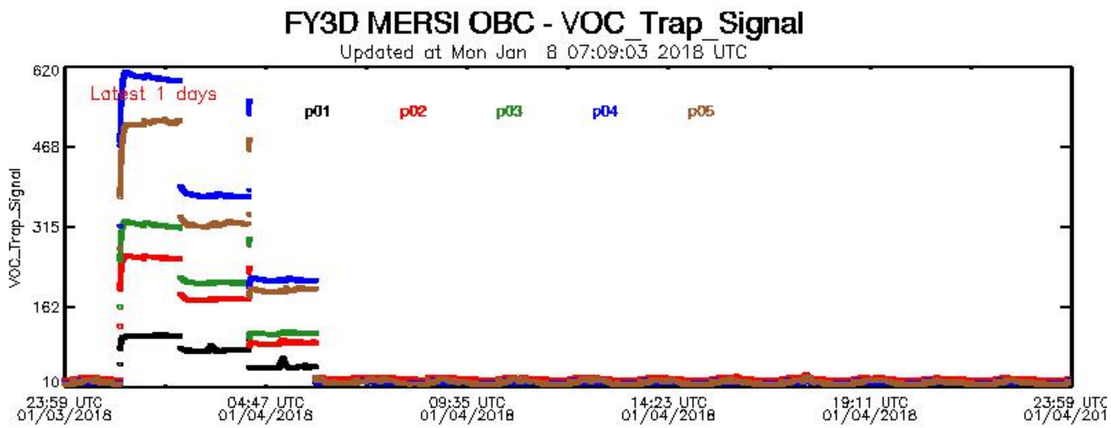


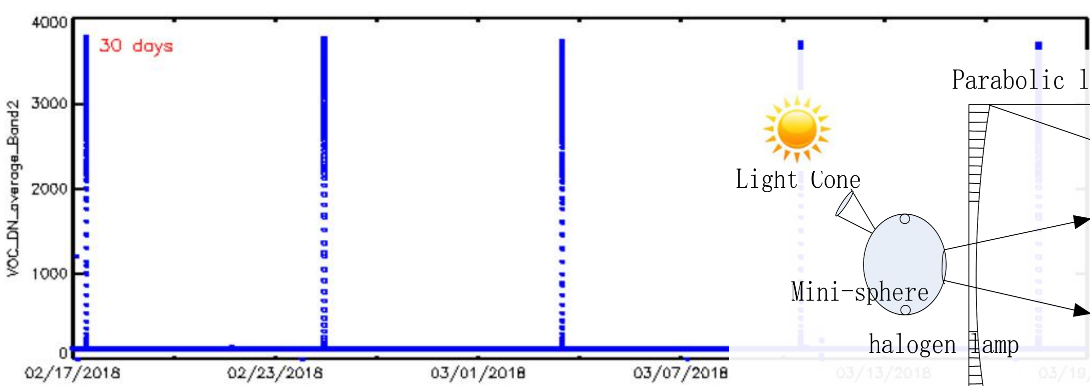
Moon observation by changing the scan timing sequence

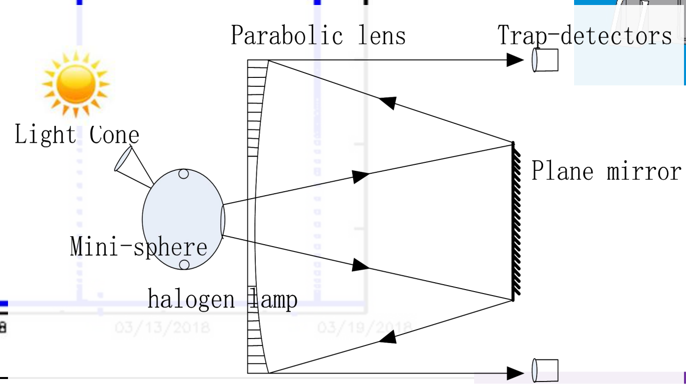
Visible onboard calibrator(VOC)

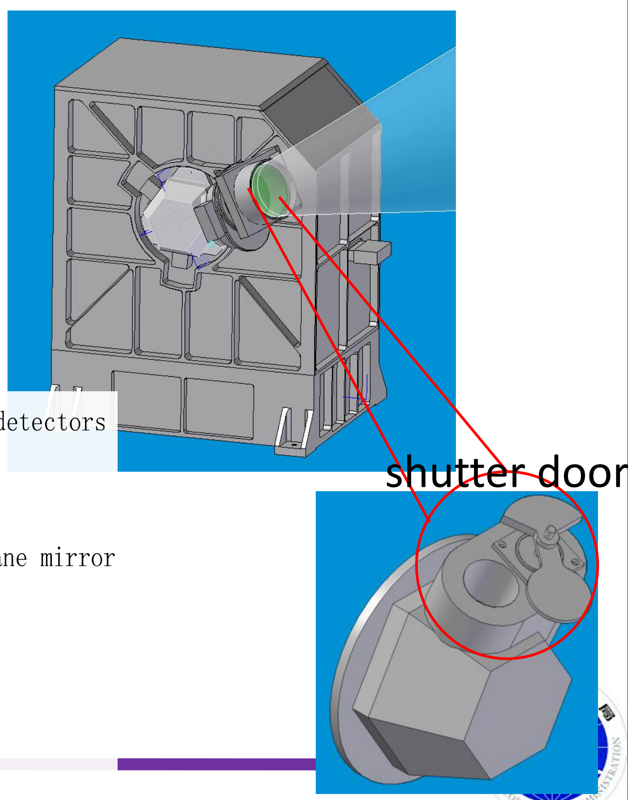
Lamps and shutter door alternative opening periodicaly, four radiance level from inside lamps and sun.









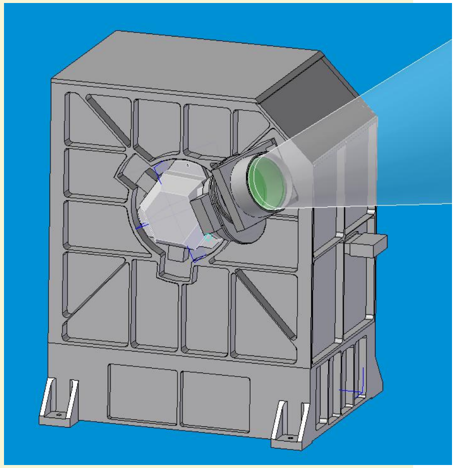


Inflight calibration and validation:RSBs

Multiple methods are used for RSBs CAL/VAL

Visible onboard calibrator(VOC) ----------Just for reference

- scheduled every week based on lamp or sunlight
- degradation monitoring



Multi-Vicarious calibration(not ground-based)

- multi-site calibration:desert, snow, gobi, lake, sea
- intercalibration with reference sensors: MODIS, VIIRS, GOME
- DCC
- Moon

CRCS Ground-based validation

- in-situ measurement at Chinese Radiometric Calibration Site(CRCS) Dunhuang
- independent validation for MERSI II

Inflight calibration and validation:TEBs

OBCBB for CAL, multi-VC for VAL

Blackbody onboard calibration

- a concentric ring V-groove blackbody (282K) .
- space view (SV) provides offset measures
- calibrated every scan

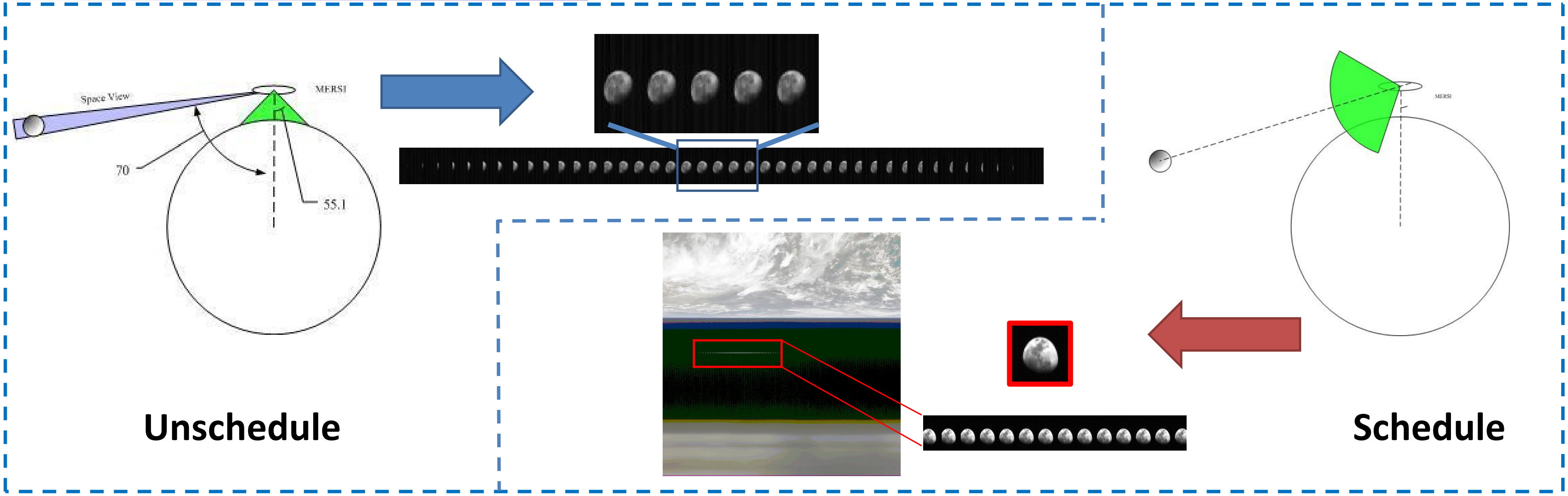
GSICS intercalibration

- intercalibration with reference sensors: IASI, CRIS, HIRAS
- Only for validation

CRCS Ground-based validation

- in-situ measurement at CRCS Dunhuang and Qinghai Lake
- independent validation for MERSI II

Multiple VCs for CAL/VAL: Moon



Interband Calibration

$$k_{water} = \frac{I_{water-Model}}{I_{window-Model}} \cdot \frac{Es_{window}}{Es_{water}} \cdot \frac{\omega_{window}}{\omega_{water}} \cdot \frac{\sum_{moon}\left(DN_{window} - DC_{window}\right)}{\sum_{moon}\left(DN_{water} - DC_{water}\right)} \cdot k_{window}$$

Absolute Calibration

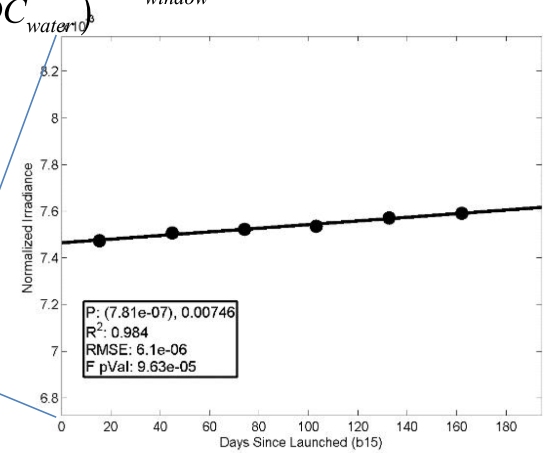
$$k = \frac{I_{moon}}{\omega_{pixel} Es / \pi \sum_{moon}\left(DN - DN_0\right)}$$

Degradation mornitoring

$$k(t) = p \cdot t + k_0$$

Results

Band	p	k0	F-Value	k(2017-4-26)	Reletive difference （%）
3	3.35E-06	0.02237	0.006	0.02291	2.4
4	3.09E-06	0.02241	0.003	0.02291	2.2
12	1.13E-06	0.008279	0.027	0.008462	2.2
15	7.81E-07	0.007464	0.000	0.007591	1.7
19	2.45E-05	0.05062	0.007	0.05459	7.8

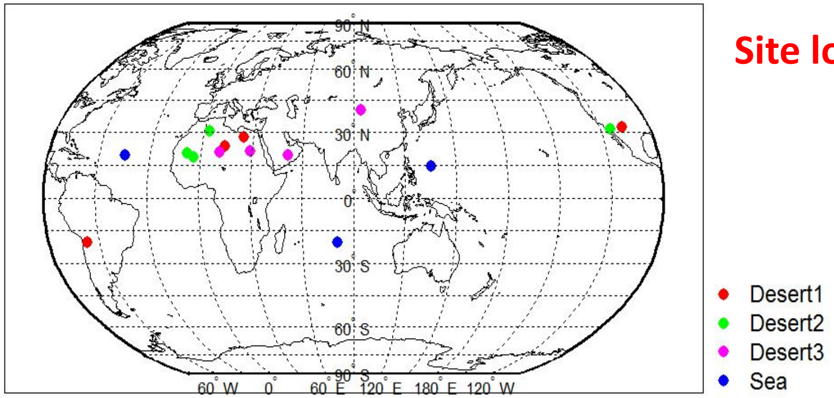


Courtesy of Ronghua Wu

Multiple VCs for CAL/VAL: Multi-site

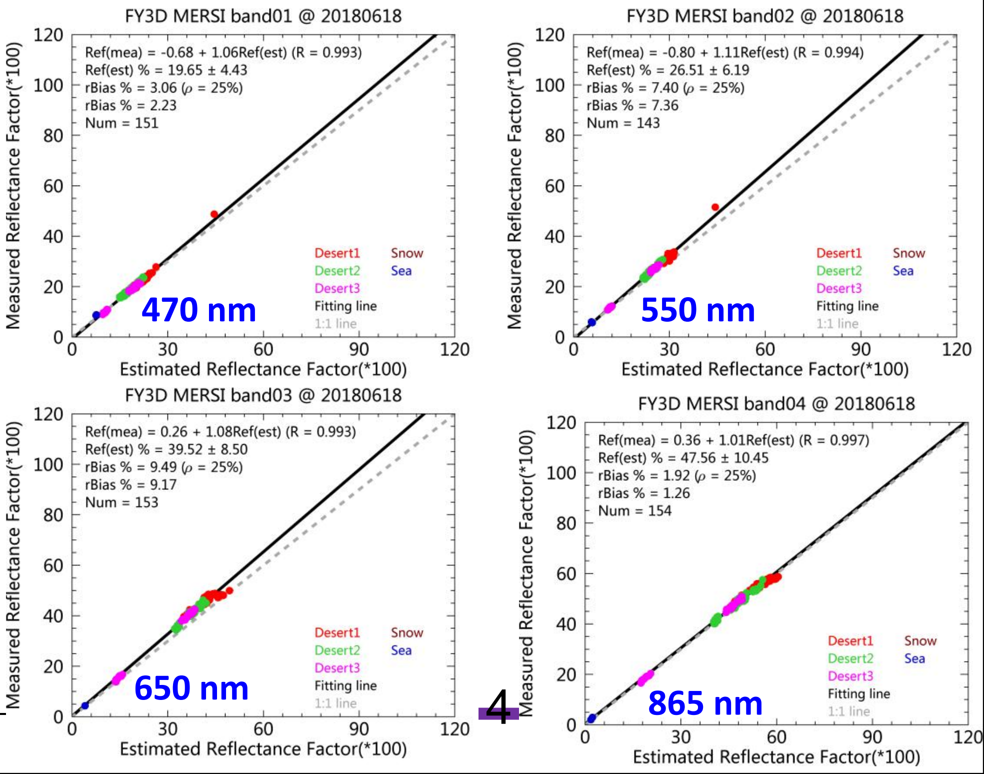
- **Calibration Reference：** 6S RTM simulations
- Multiple stable earth targets (MST) are used, to reduce the calibration uncertainty.
  - 12 desert and salt lake targets
    - Higher brightness: WhiteSands, Uyuni Salt Flats, Libya1, Libya4, Mali
    - Moderate brightness : Algeria5, Mauritania2, Sonora, Arabia2
    - Lower brightness : Niger2, Sudan1, Dunhuang
  - 3 dark sea targets
    - AtlanticN, IndianOcean, PacificN1

Courtesy of Ling Wang

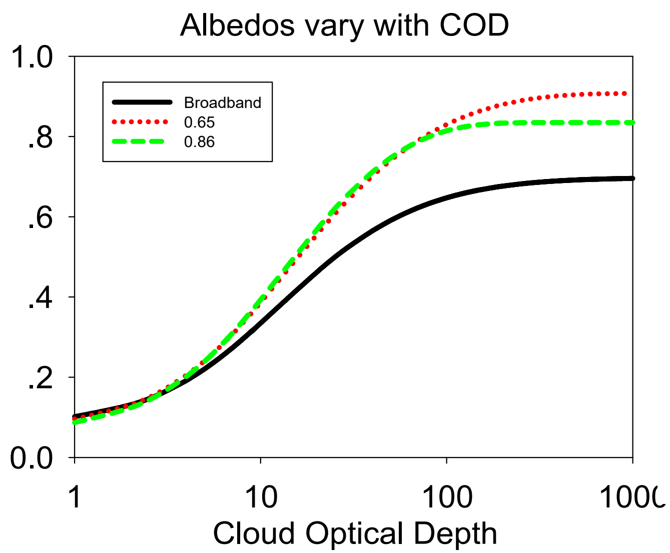


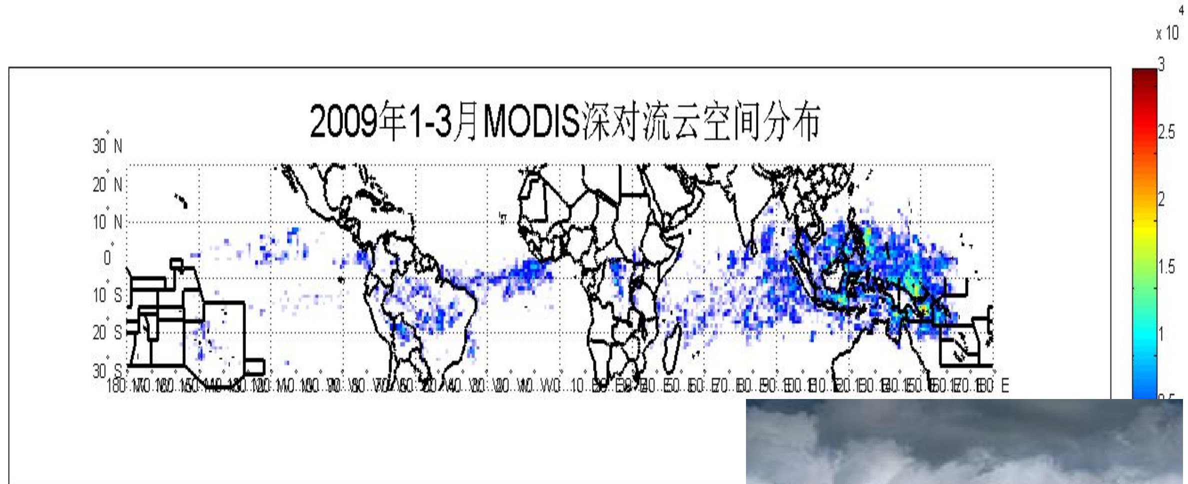
Site location

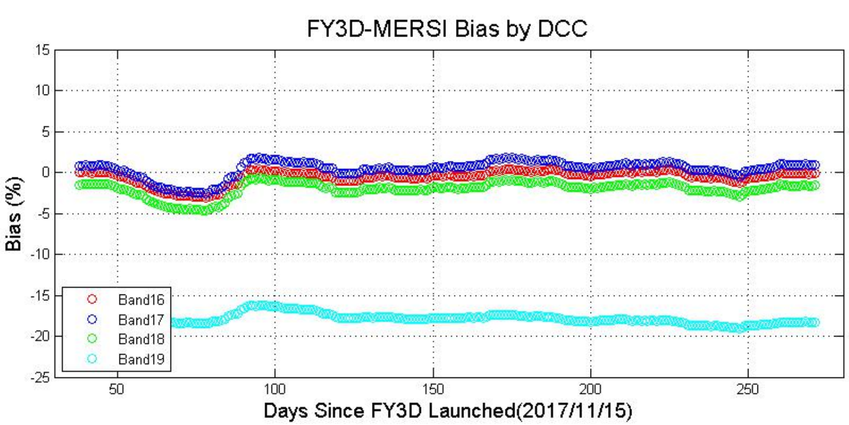
MST calibration examples for FY-3D MERSI2

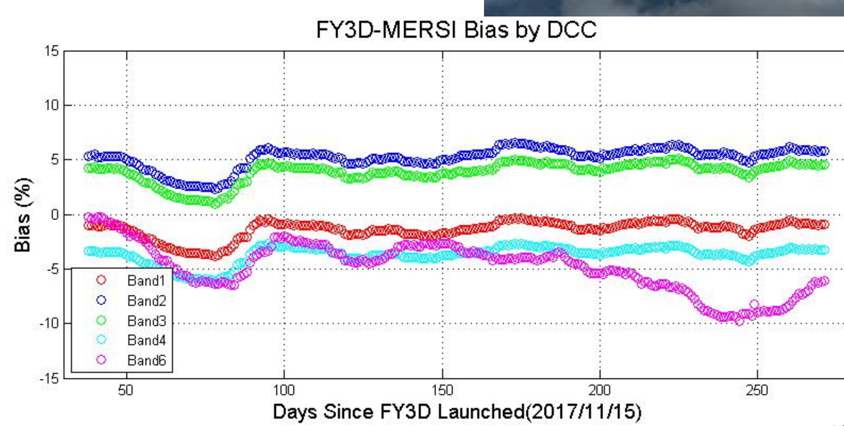


Multiple VCs for CAL/VAL: DCC





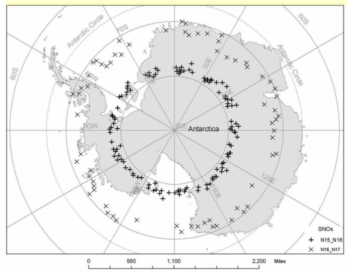


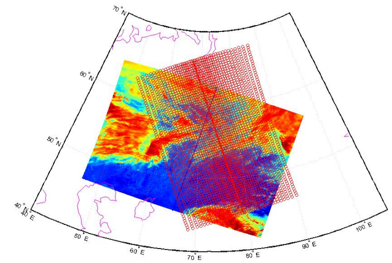


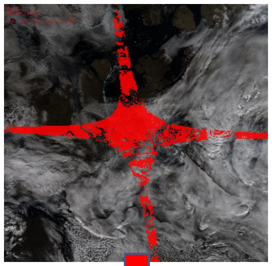
Courtesy of Lin Chen

Multiple VCs for CAL/VAL: SNO/SNOx

Nadir Track → SNO/SNOx Prediction → Geo collocation → Filtering







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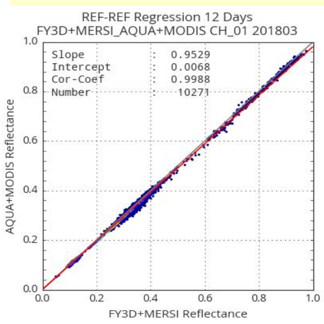
Comparison



RSB Reference sensor:

MODIS, VIIRS, GOME

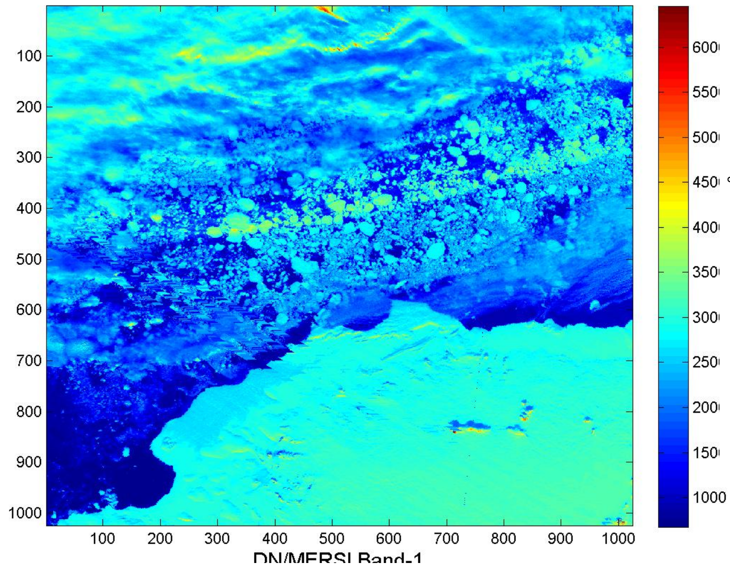
TEB Reference sensor:

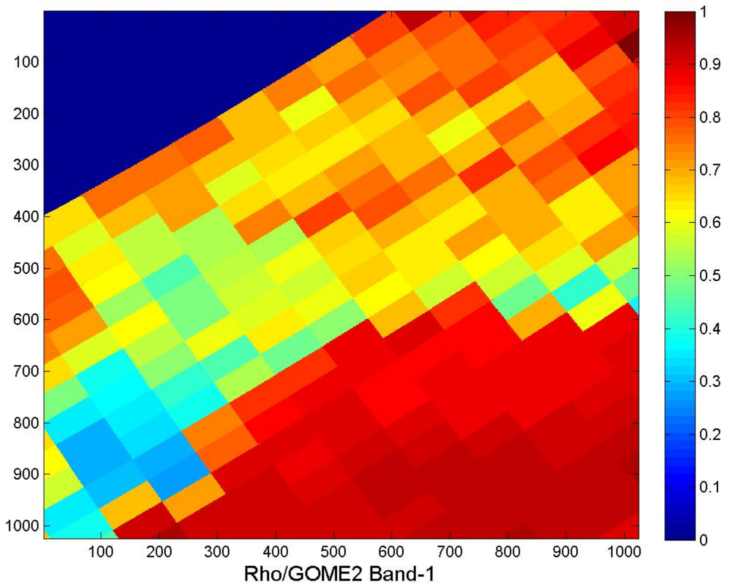
IASI, CrIS, MODIS

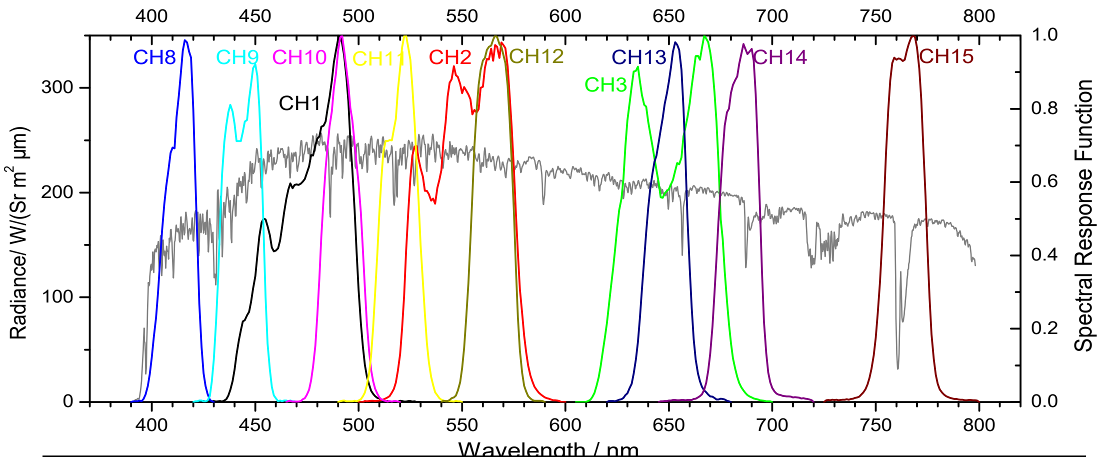
Collocation Criteria

- Observation time difference check
  $| t_{FY3} - t_{ref} | < dt_{max}$
- Satellite zenith angle difference check
  $| \cos(SZA_{ref}) / \cos(SZA_{FY3}) - 1 | <$ MaxRate_OptPathDiff
- Environment uniformity check
  STDV(FY3 DNs in ENV_BOX) < MaxSTDV
- Normality check
  | MEAN(FOV_BOX) − MEAN(ENV_BOX) | × 9 / STDV(ENV_BOX) < Gaussian

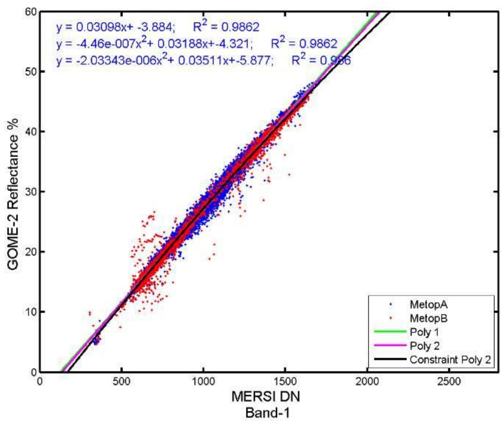
Iner-Cal between MERSI II and GOME-2







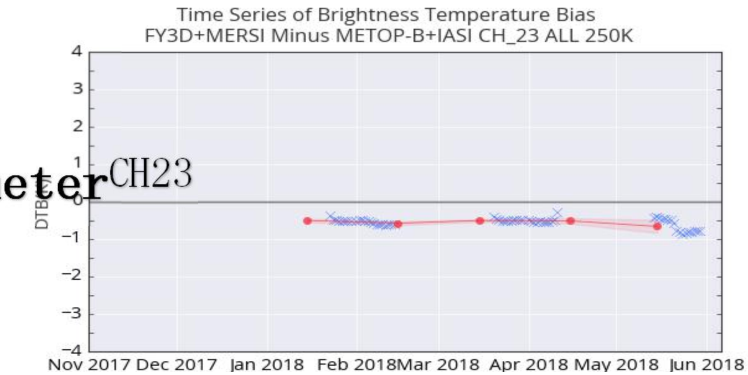
Band	Cal_Slope	Reflectance Uncertainty	Spatial Uncertainty	Total Uncertainty
1	0.0002669	0.16	0.72	0.74
2	0.0002677	0.15	0.89	0.91
3	0.0002508	0.14	0.98	0.99
8	0.0002384	0.18	0.68	0.70
9	0.0002232	0.23	0.69	0.73
10	0.0002065	0.21	0.78	0.81
11	0.0002102			
12	0.0002016			
13	0.0002063			
14	0.0001806			
15	0.0001871			

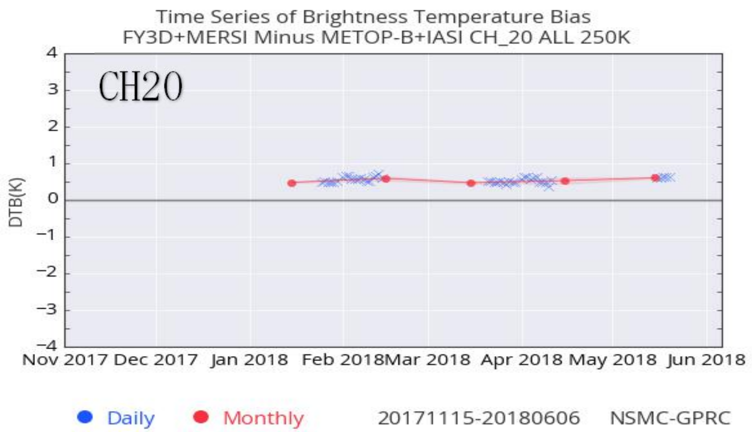


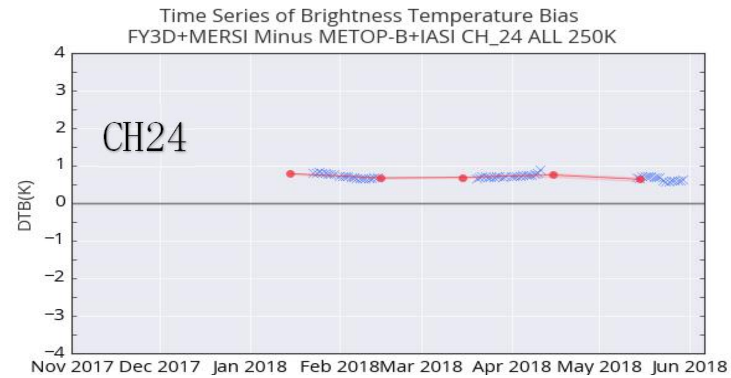
Iner-Cal between MERSI II and IASI

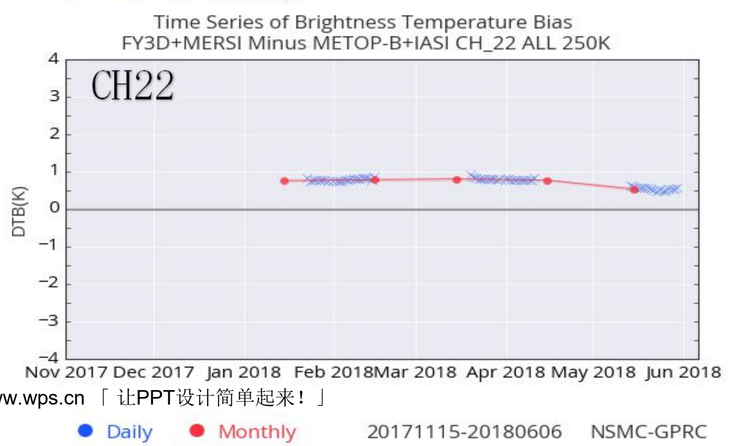
SNO use IASI-B as reference

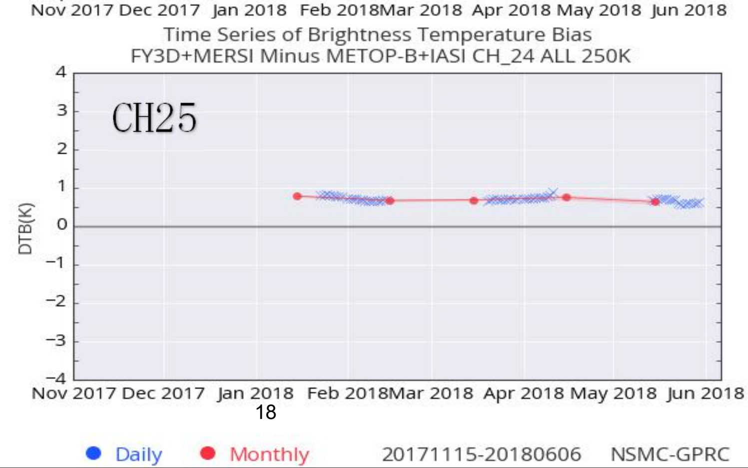
TB Bias@250K is about 0.5K~1K, based on prelaunch emissivity and nonlinear parameter







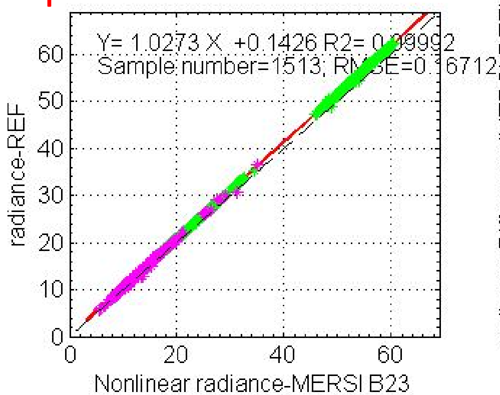


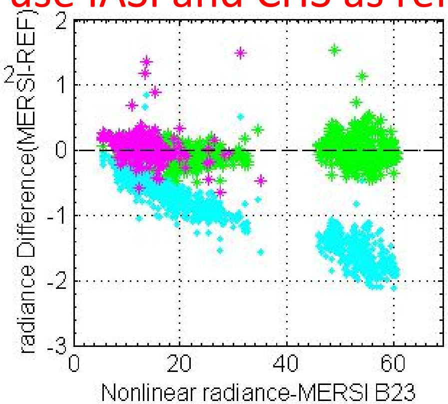


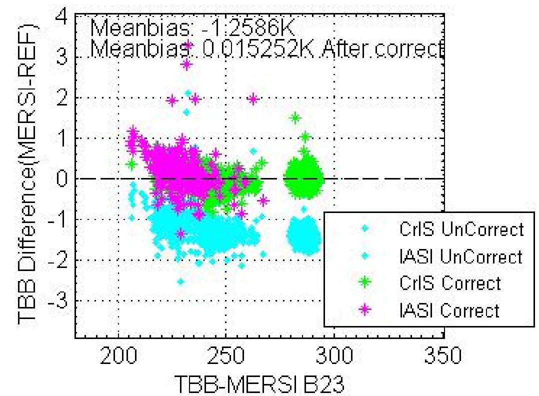
Iner-Cal between MERSI and HIRAS

collaboration of intercalibration in the different and same platform.

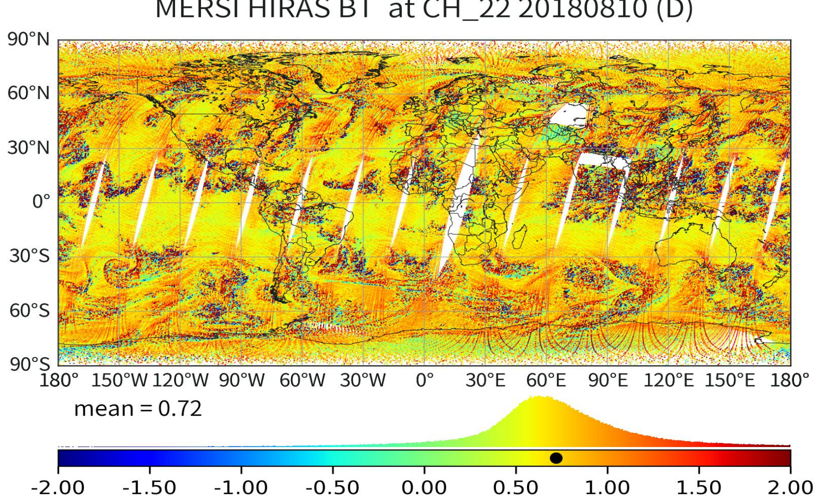
TEBs OBC paremeters correction use IASI and CrIS as reference



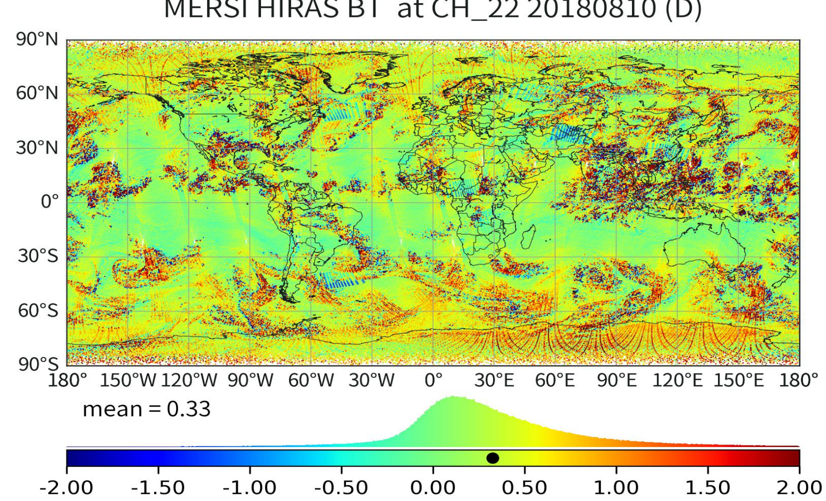




Before correction

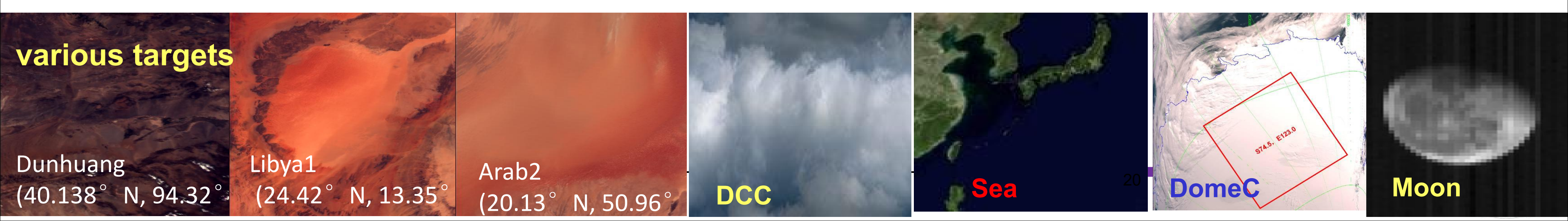


After correction



Comparison of various VC methods

Reflectance Dynamic	Method	Comparison	Applicable channels of MERSI II
High（>80%）	DCC	Merit：high stability, providing high brightness information, better performance in the absorption channel Demerit：saturation in ocean channels	1~7，16~19
Medium（<80%）	Multi-Site	Merit：multi-targets Demerit：seasonal variation affected by atmosphere and surface, unsuitable for absorption channels	1~19
	SNO_GOME	Merit：not rely on the atmosphere and surface observation, spectral differences can be ignored, providing medium reflectance targets for ocean channels; Demerit：Only suit for VIS channels	1~3，8~15
	SNO_MODIS	Merit：Do not rely on the atmosphere and surface observation	1~18
	SNO_VIIRS	Demerit：Need spectral correction	2~10、12、14、15
Low（<10%）	Moon	Merit：High stability Demerit：Accuracy depending on the moon model, low calibration frequency	1~20



Integrated Vicarious Calibration

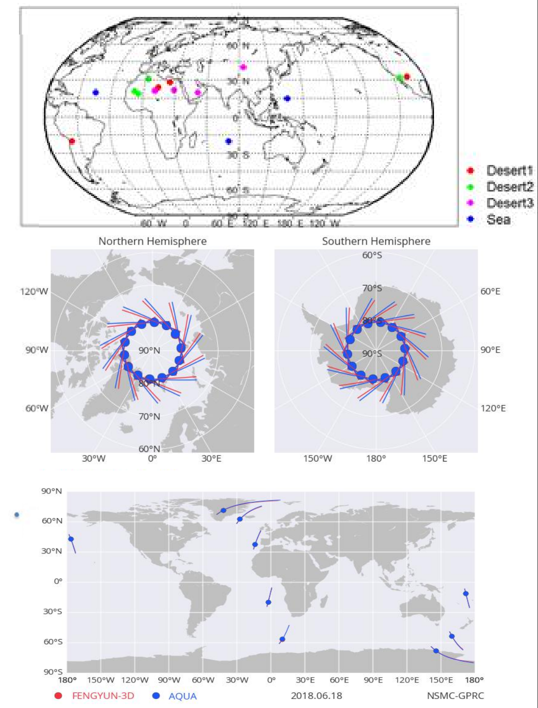
MERSI II use Integrated Vicarious Calibration method to perform Wide Dynamic calibration based on CMA GSICS GPRC

Important Steps:

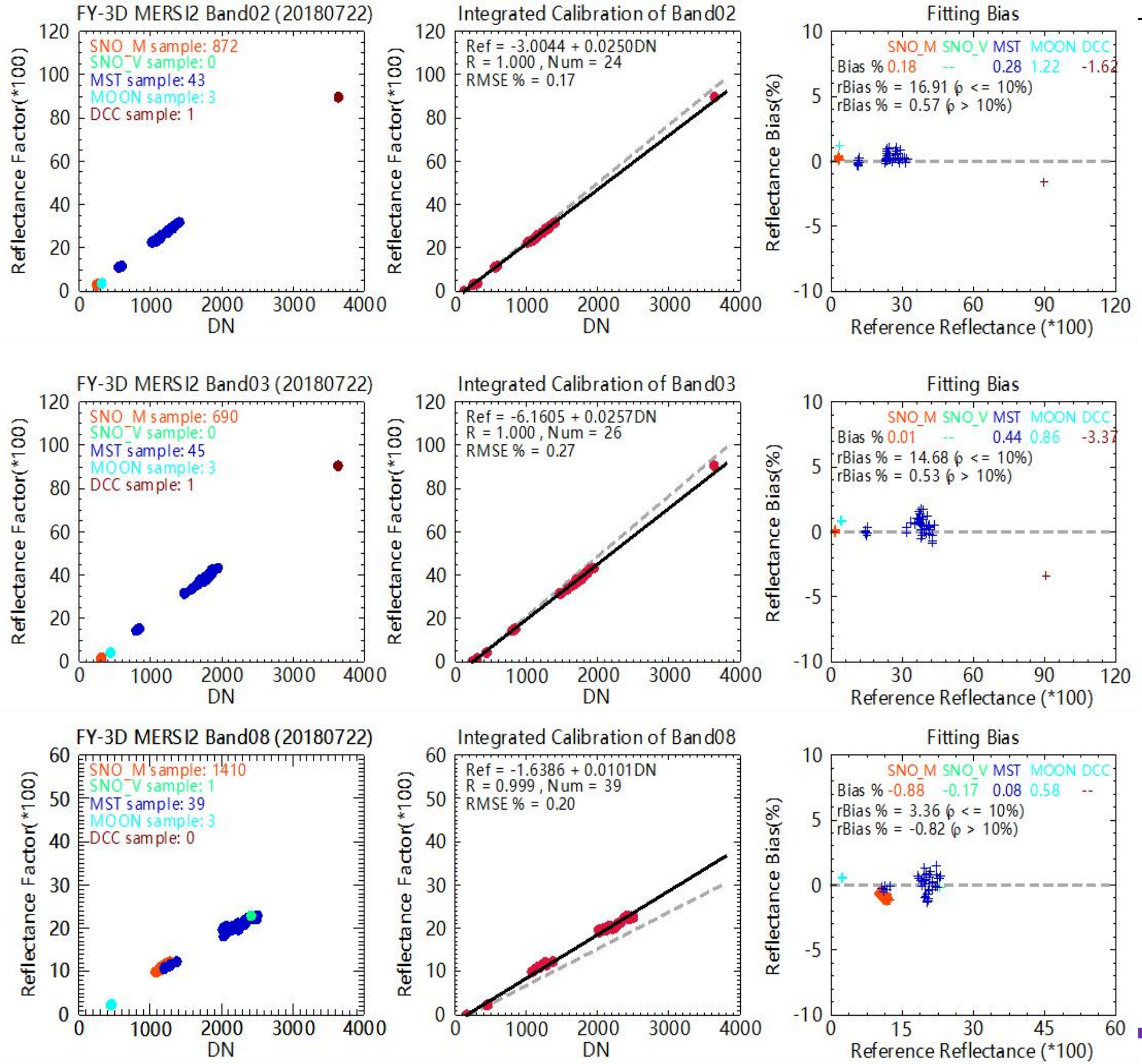
①**Multi-samples integration**：the sample is weighted integrated by piecewise averaging.

②**SV Seletion**：SV is a daily fixed cold space without stray light contamination at night.

Sample distribution



Integrated Vicarious Calibration

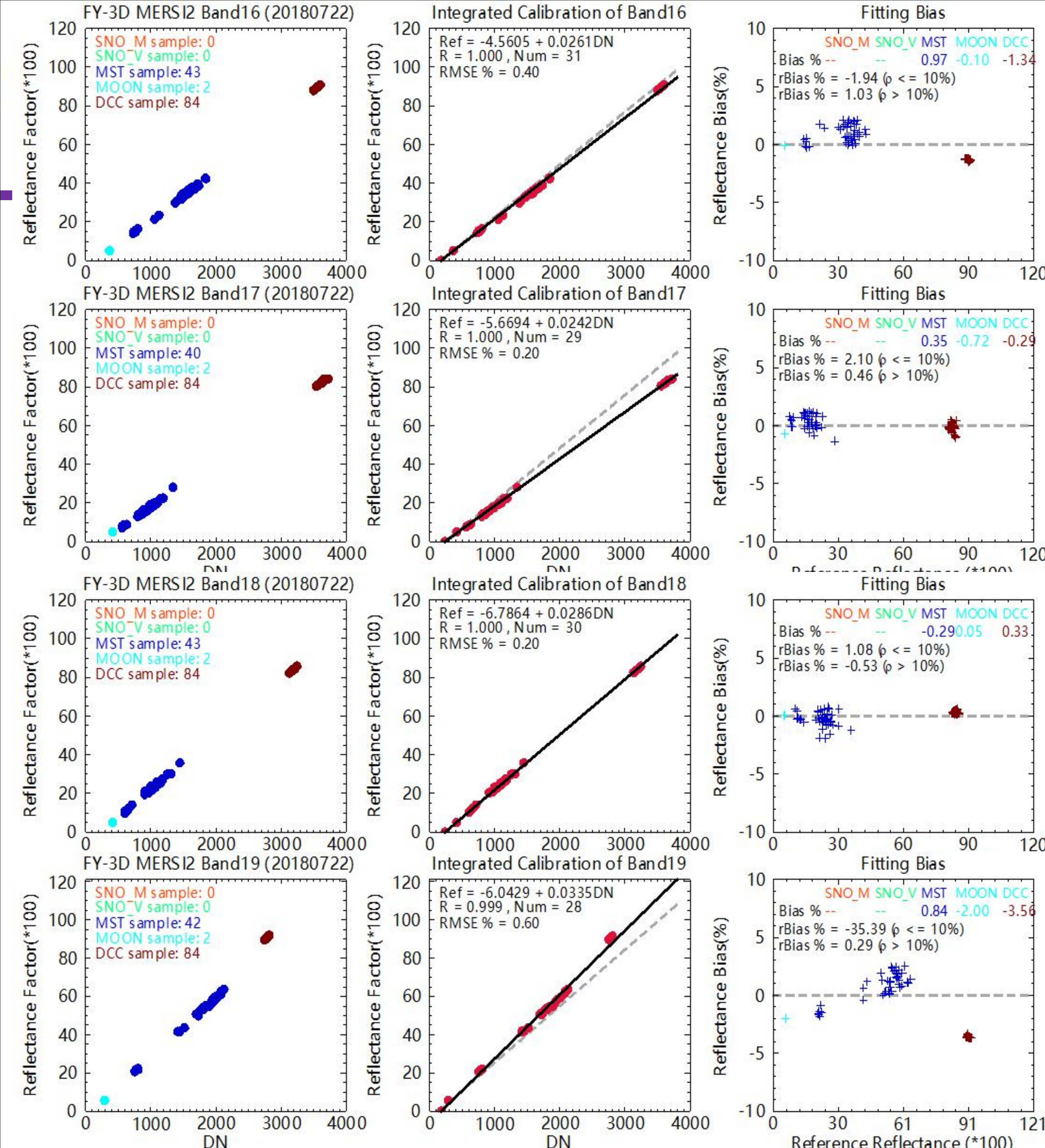


- **250m Visible bands**

Stable Targets: MST (Dunhuang , Libya1, Libya4, Arabia2, Lanai), DCC, Moon;

Reference Instrument: VIIRS MODIS GOME

Left: Distributions of various VC samples;
Mid: Distributions of integrated samples and weighted regression results;
Right: Distributions of residual biases



- **Near infrared bands**

Stable Targets: MST (Dunhuang , Libya1, Libya4, Arabia2, Lanai), DCC, Moon;

Reference Instrument: VIIRS MODIS

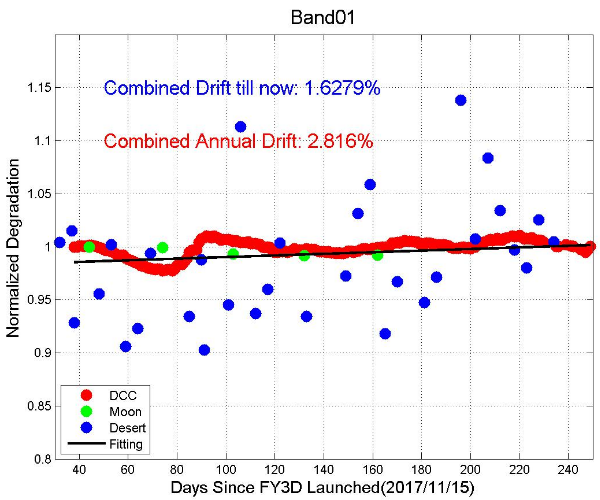
Left: Distributions of various VC samples;

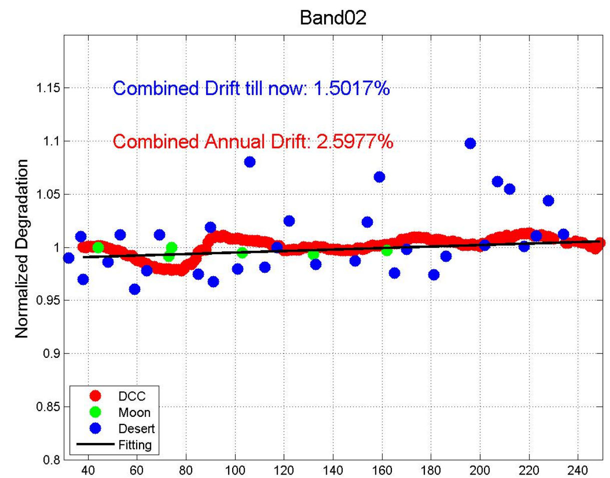
Mid: Distributions of integrated samples and weighted regression results;

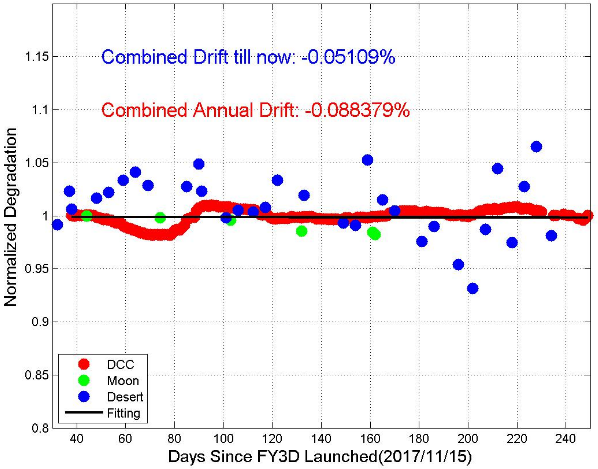
Right: Distributions of residual biases

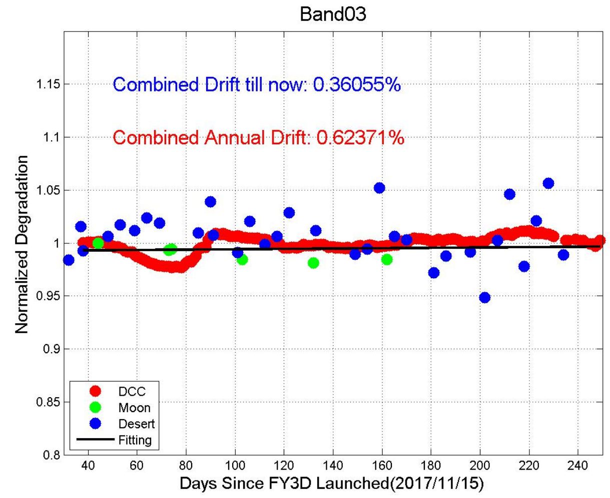
Combined Degradation Mornitoring

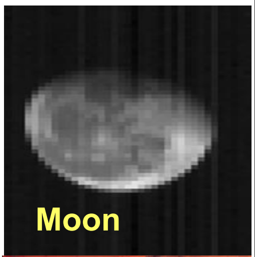
VIS 250m

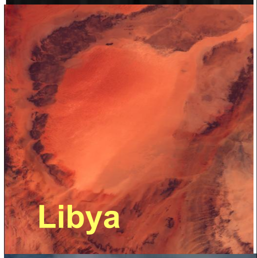




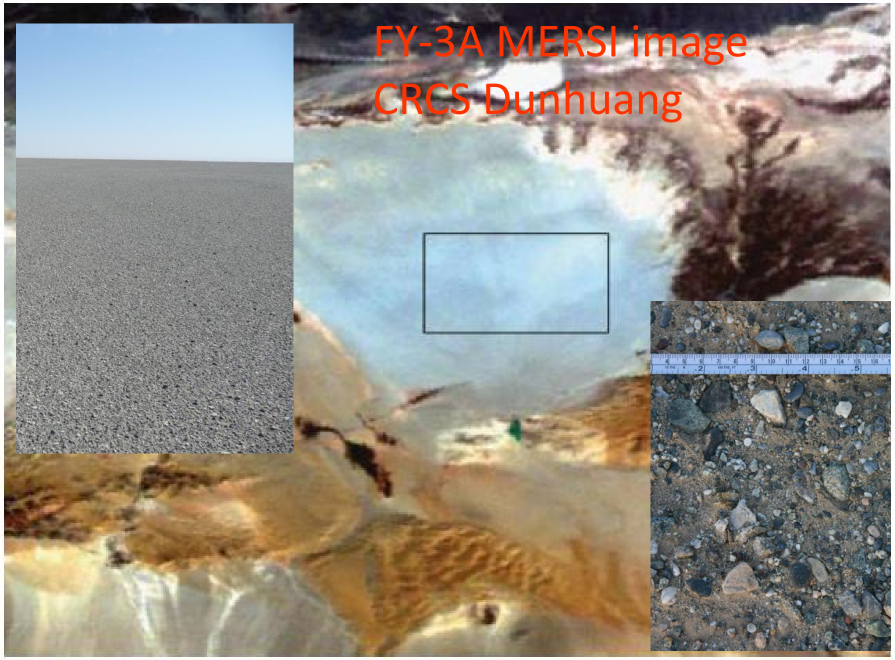




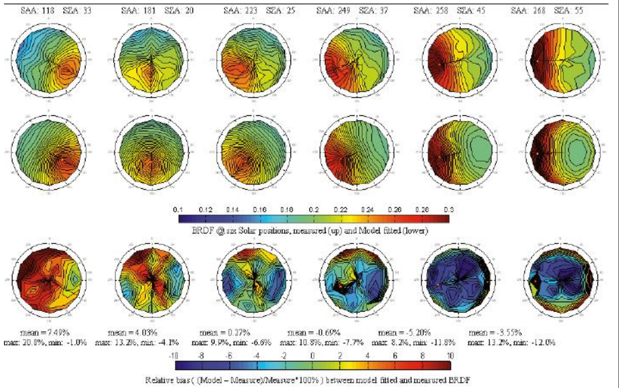


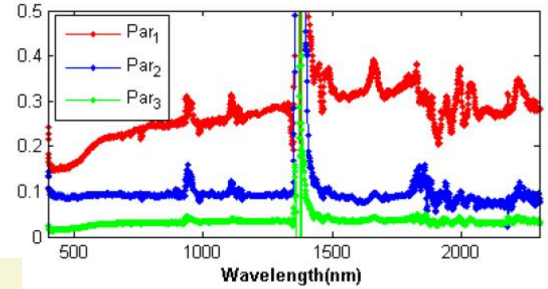


CRCS ground-based validation

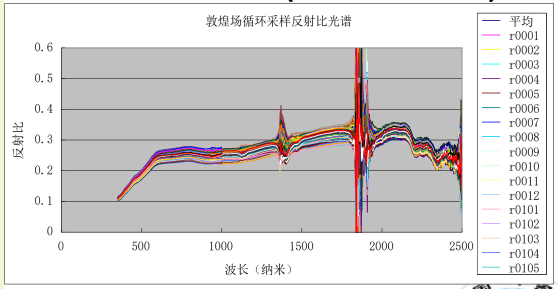


Surface spectral reflectance, aerosol optical property, and atmospheric profile are measured synchronously with the satellite overpass.





BRDF(AMBRALS)



Gobi surface combined with sandy soil and gravels, the mean diameter of the gravels is from 2cm to 5cm.

CRCS annual field campaign has been routinely carried out in summer.

The Dunhuang VC based on synchronous in-situ measurements used to be the baseline calibration approach for Chinese FY series satellites , but only the independent validation method from MERSI II

CRCS campaigns

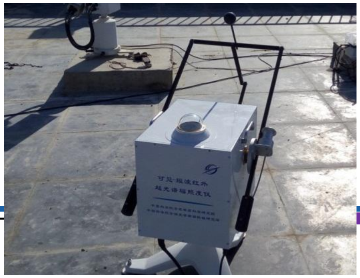
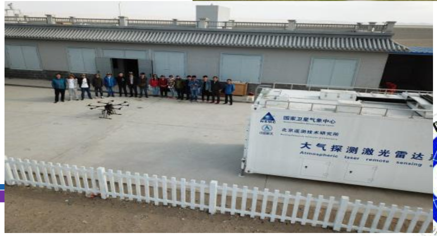
- Field campaigns is conducted at Dunhuang site and Qinghai Lake in May and Auguest 2018 for MERSI II test.

- Surface reflectance measurement
  - ASD field spectroradiometer
  - CE313 field radiometers (simulated MERSI and VIRR's bands)
- Atmospheric characteristics measurement
  - Weather and radiosonde
  - Sunphotometer: AOD, transmittance
  - Lidar: AOD
- Calibration method:
  - Reflectance-based method
  - Irradiance-based method
  - Radiance-based method







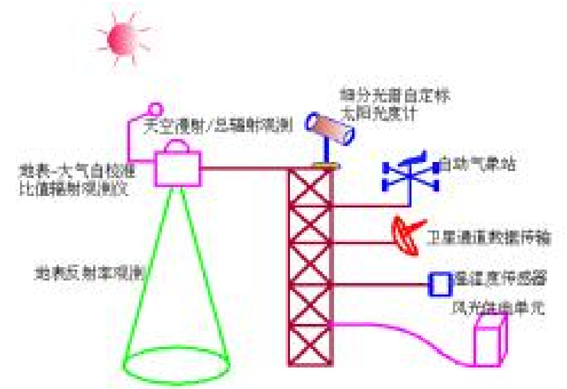



Ground-based Automatic Observation Systems

New field observing station at Dunhuang

Constructing field observing station, including

House,Observing field ,Instrument platforms,Power supply,Tower crane ,Road,Safeguard facilities



CRCS automatic measurement instruments II

Automated Test site Radiometer (ATR)

ground upwelling radiance

VIS-SWIR spectra-radiometer (VSSR)

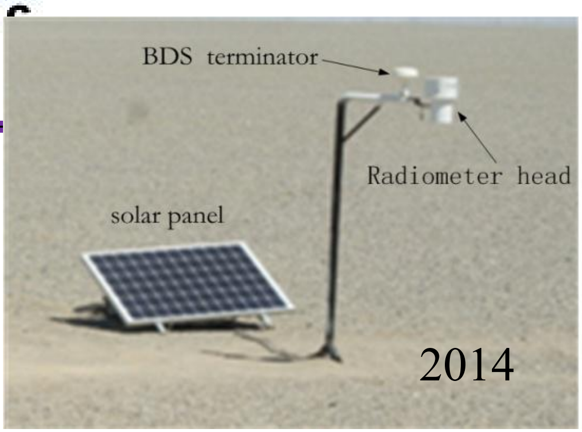
Total solar irradiance, diffused sky irradiance, directed solar irradiance

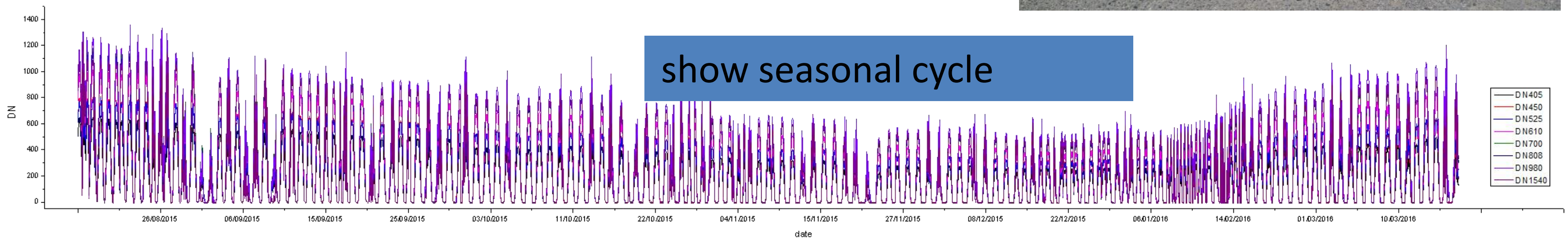
High-precision solar radiometer (HSR)

directed solar radiance for AOD

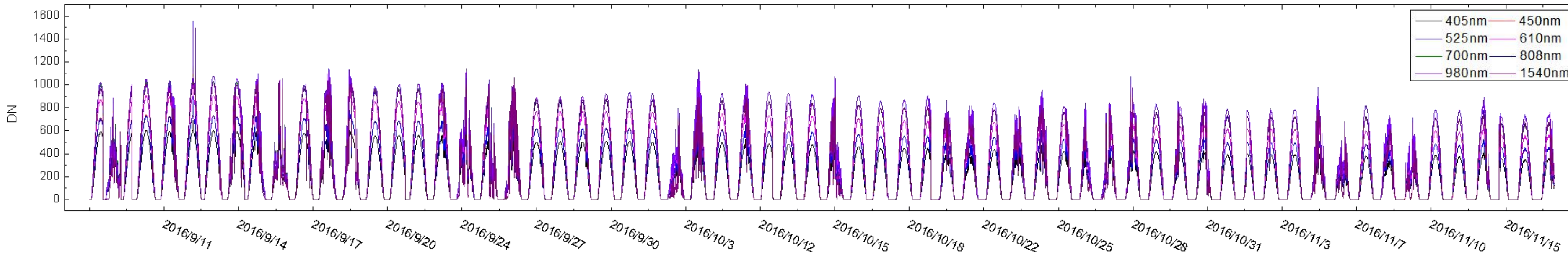
Automatic weather stations (AWS)

atmosphere&land surface temperature profiles



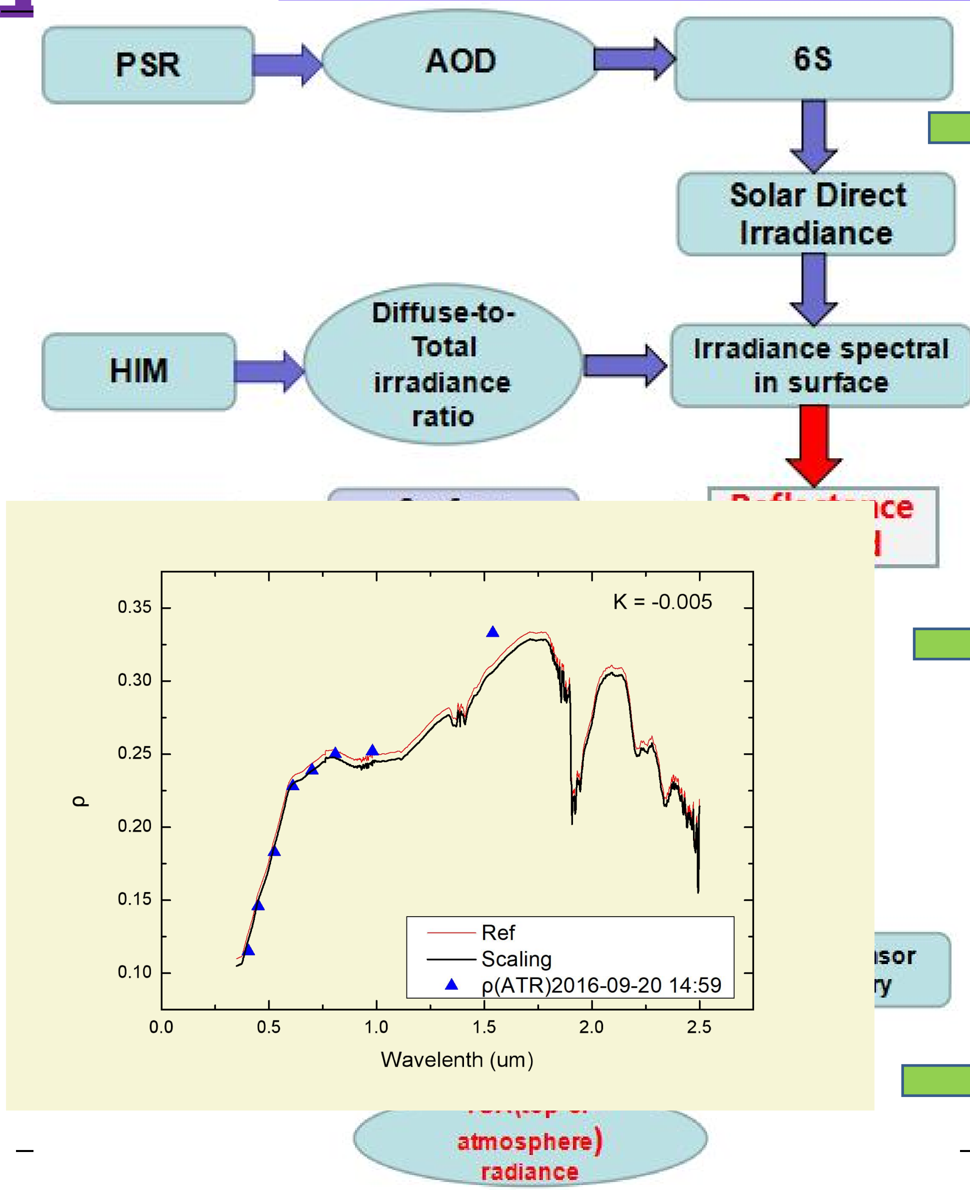


DNs measured by ATR from Aug, 2015 ~ Apr, 2016



DNs measured by ATR from Sep, 2016 ~ Nov, 2016

Radiometric calibration method based on automatic observation instruments on Dunhuang site



The surface Reflectance in band by PSR, NIM and ATR instruments

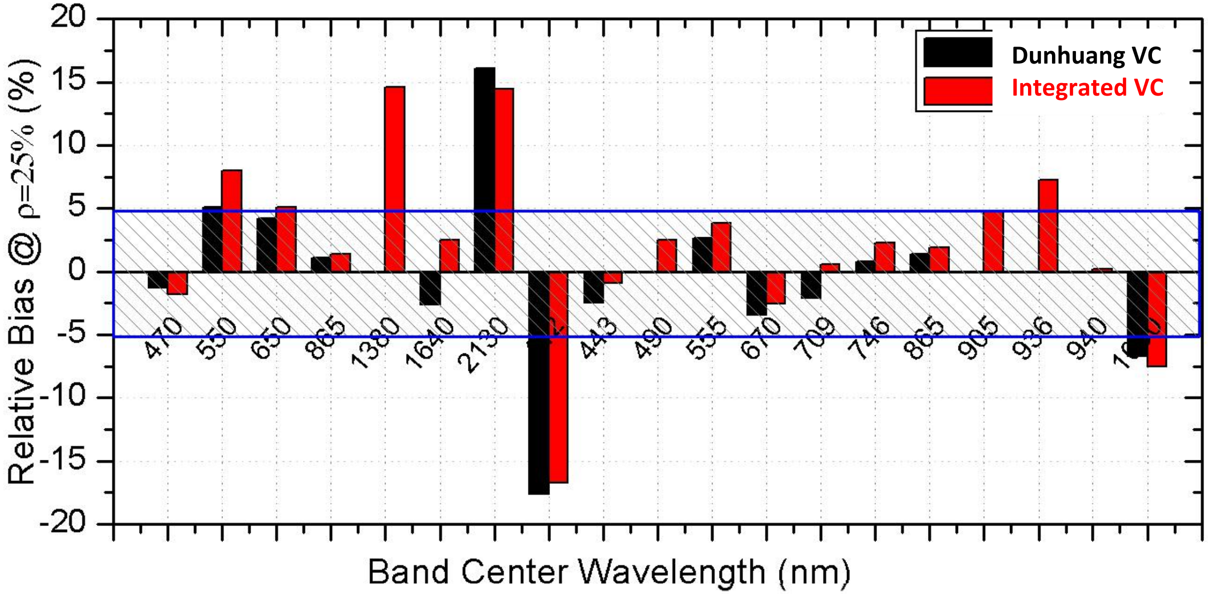
The surface Reflectance in band is scalled to Hyper-spectral reflectance at the satellite overpass time by a priori hyper-spectral reflectance(reference reflectance)

Calculation the TOA radiance and comparision to the satellite observation

Validation results comparsion

Prelaunch calibration On-orbit validation based on vicarious calibration (VC)

Prelaunch laboratory calibration perform well on-orbit, and the biases of most bands are within 5%. The two independent validation results show good consistency.



Validation results comparsion between integrated vicarious calibration (without insitu measurement) and Dunhuang site insitu calibration （2018.05）

band	Center Spectral nm	Integrated-VC %	Dunhuang Insitu VC %
1	470	-1.79	-1.28
2	550	7.99	5.09
3	650	5.14	4.22
4	865	1.37	1.12
5	1380	14.63	NaN
6	1640	2.47	-2.6
7	2130	14.42	16.08
8	412	-16.72	-17.63
9	443	-0.91	-2.48
10	490	2.49	-0.06
11	555	3.82	2.62
12	670	-2.52	-3.46
13	709	0.59	-2.11
14	746	2.27	0.83
15	865	1.92	1.36
16	905	4.74	NaN
17	936	7.22	NaN
18	940	0.19	NaN
19	1030	-7.52	-6.67

Summary

- FY-3D/MERSI-II has several significant improvements than previous MERSI-1 and all these functions work well on early orbit test.
- MERSI-II RSB key performance such as SNR and calibration accuracy are checked and comparable with pre-launch characterization/calibration. Prelaunch calibration show well performance on-orbit.
- Integrated Vicarious Calibration and Degradation Mornitoring based on multiple stable target are used for RSBs on-orbit calibration. So far, Most of RSBs are quite stable and no obvious degradation has been found.
- All the on-orbit calibration parameter are from prelaunch lab testing. It will be updated and the dataset will be reprosessed based on the new evaluation.

Thanks！

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