

The Development of Chinese Radiometric Benchmark Satellite (CRABS)

Peng Zhang¹, Chuanrong Li², Naimeng Lu¹, Lei Ding³, Xiaobing Zheng⁴, Xin Ye⁵, Xiuqing Hu¹, Lingling Ma⁵

1 National Satellite Meteorological Center (NSMC), CMA

2 Academy of OPTO-Electronics (AOE), CAS

3 Shanghai Institute of Technical Physics (SITP), CAS

4 Hefei Institute of Physical Science (HIPS), CAS

5 Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP), CAS



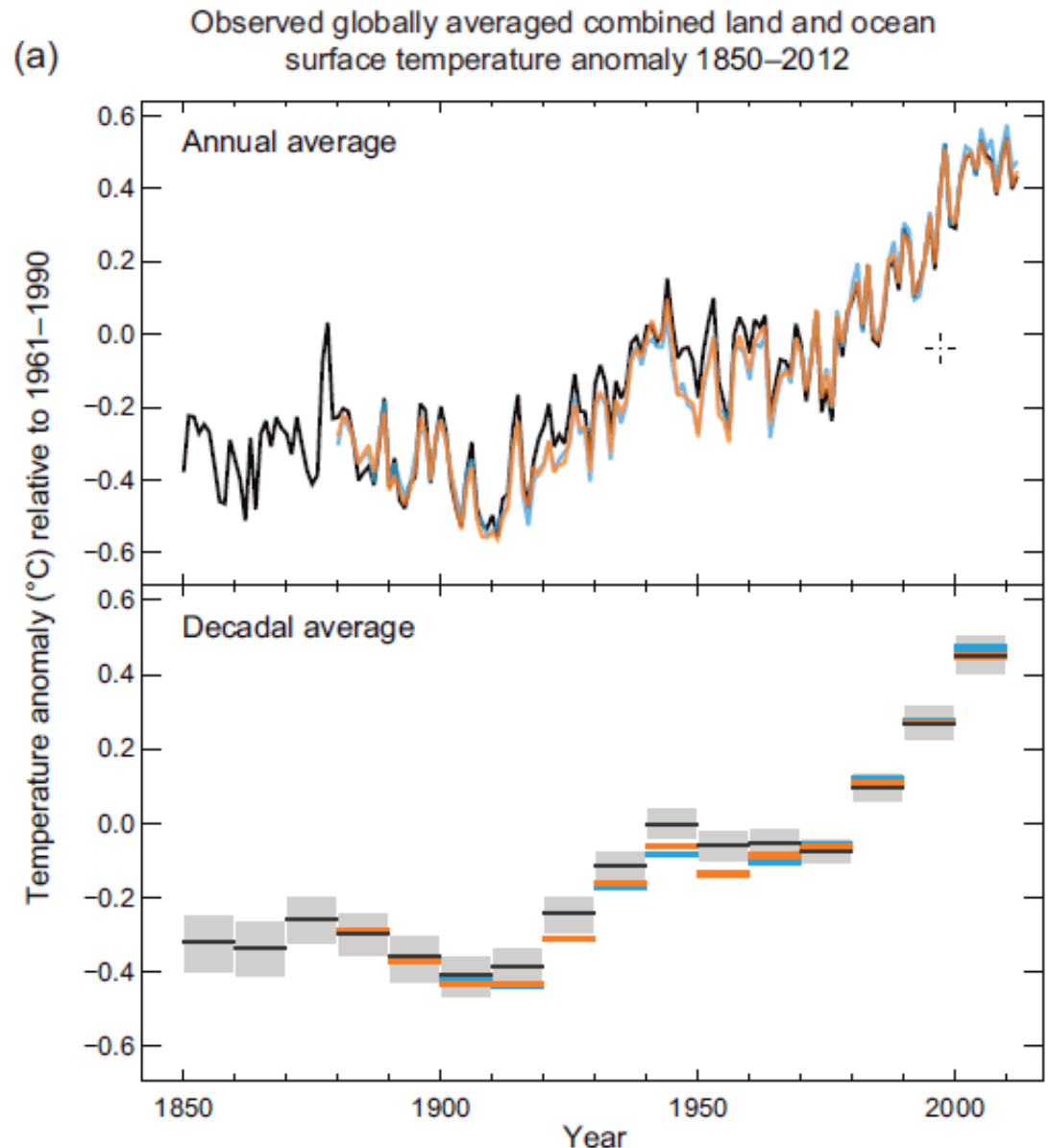
Outlines

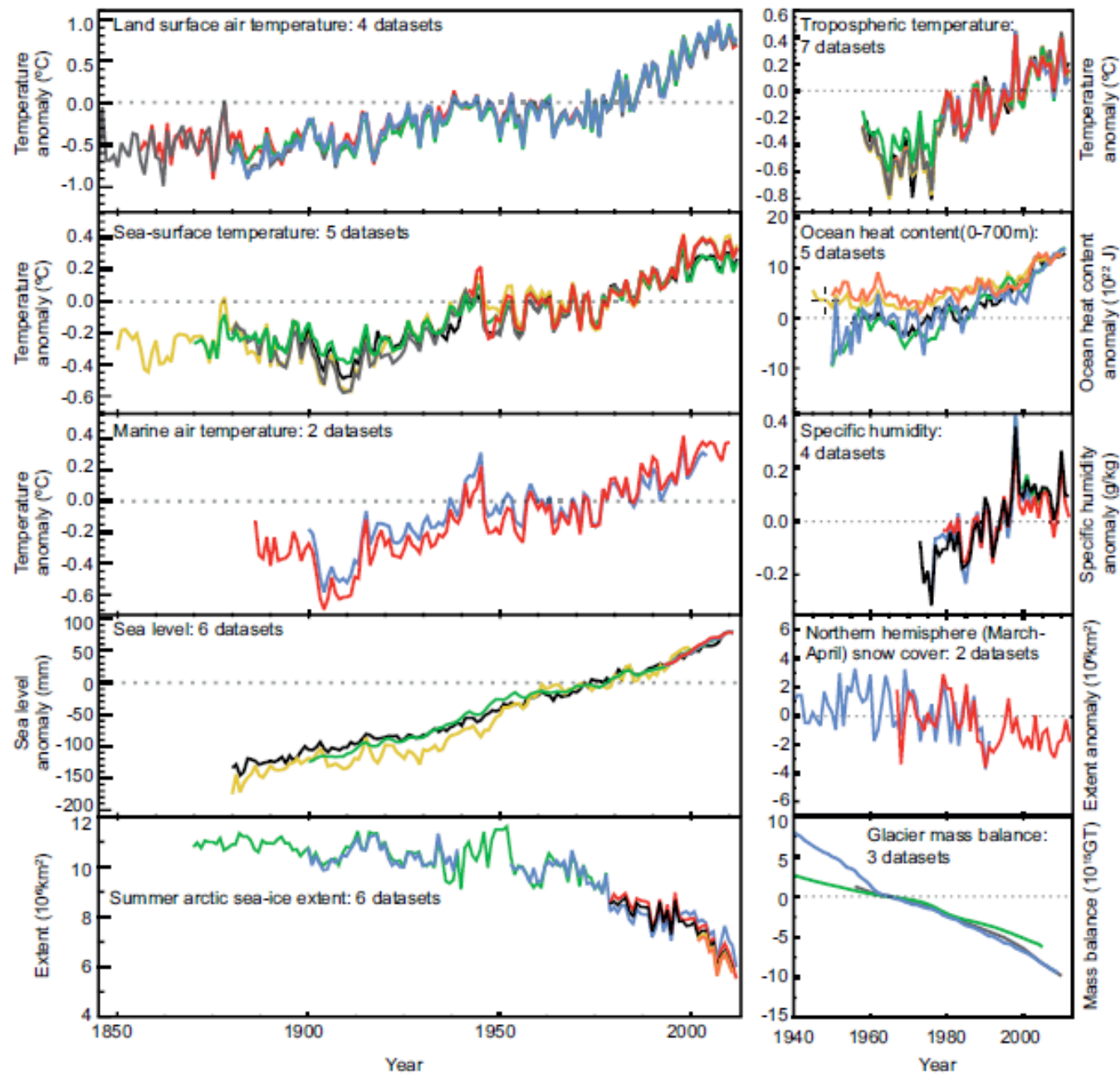
- ❑ **CRABS General Introduction**
- ❑ **SI-Traceable Standard in Phase A**
- ❑ **Prototype Instrument in Phase B**
- ❑ **Other Related Activities**
- ❑ **Discussion and Suggestion**

1. CRABS General Introduction

- Weather Satellite to Climate Satellite
- CEOS, CGMS response to GCOS
- Multiple On-orbit Instruments
- Historical Satellite Data Records

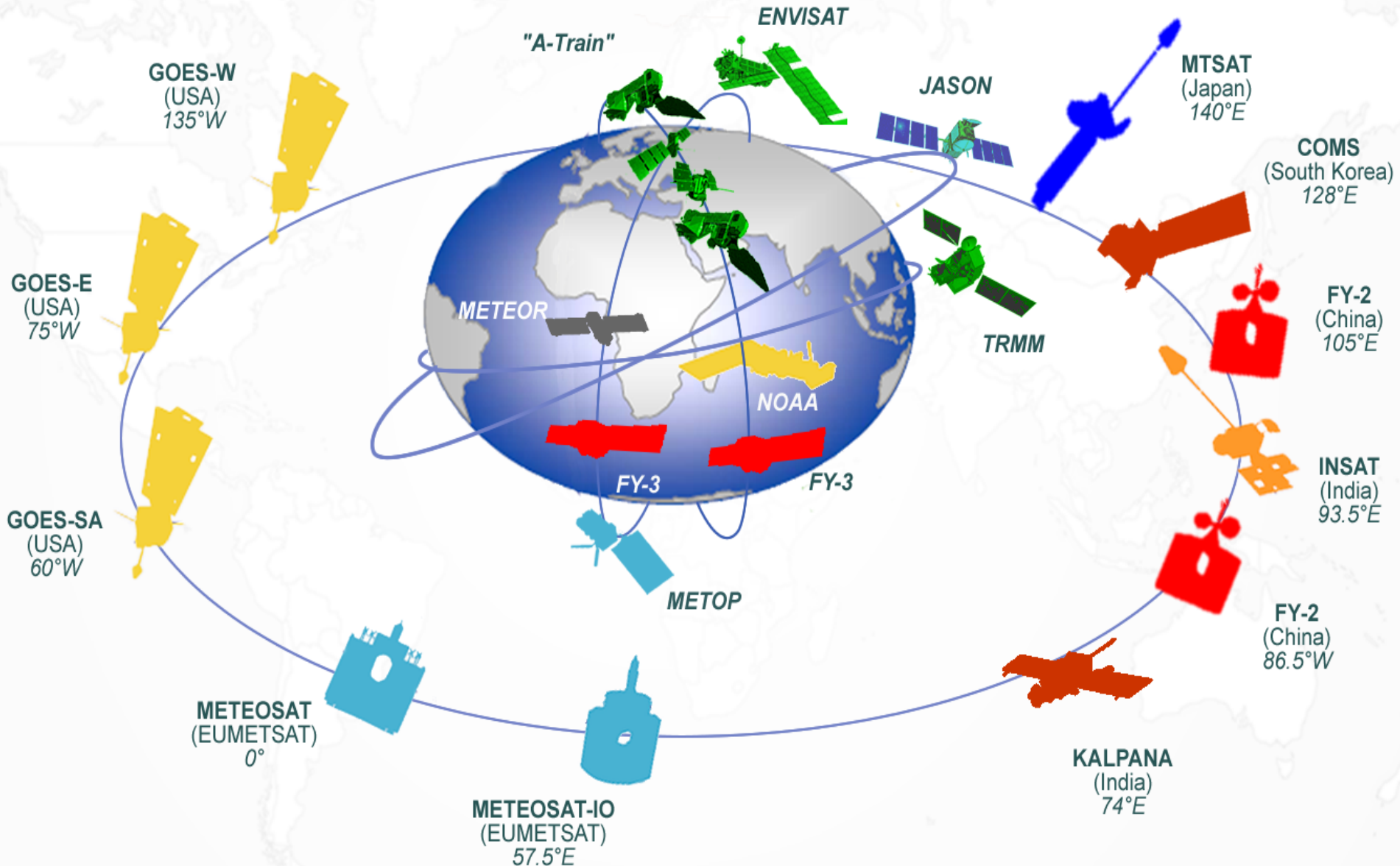
**SI-Traceable Space-based
Climate Observing System**





IPCC AR5, 2013

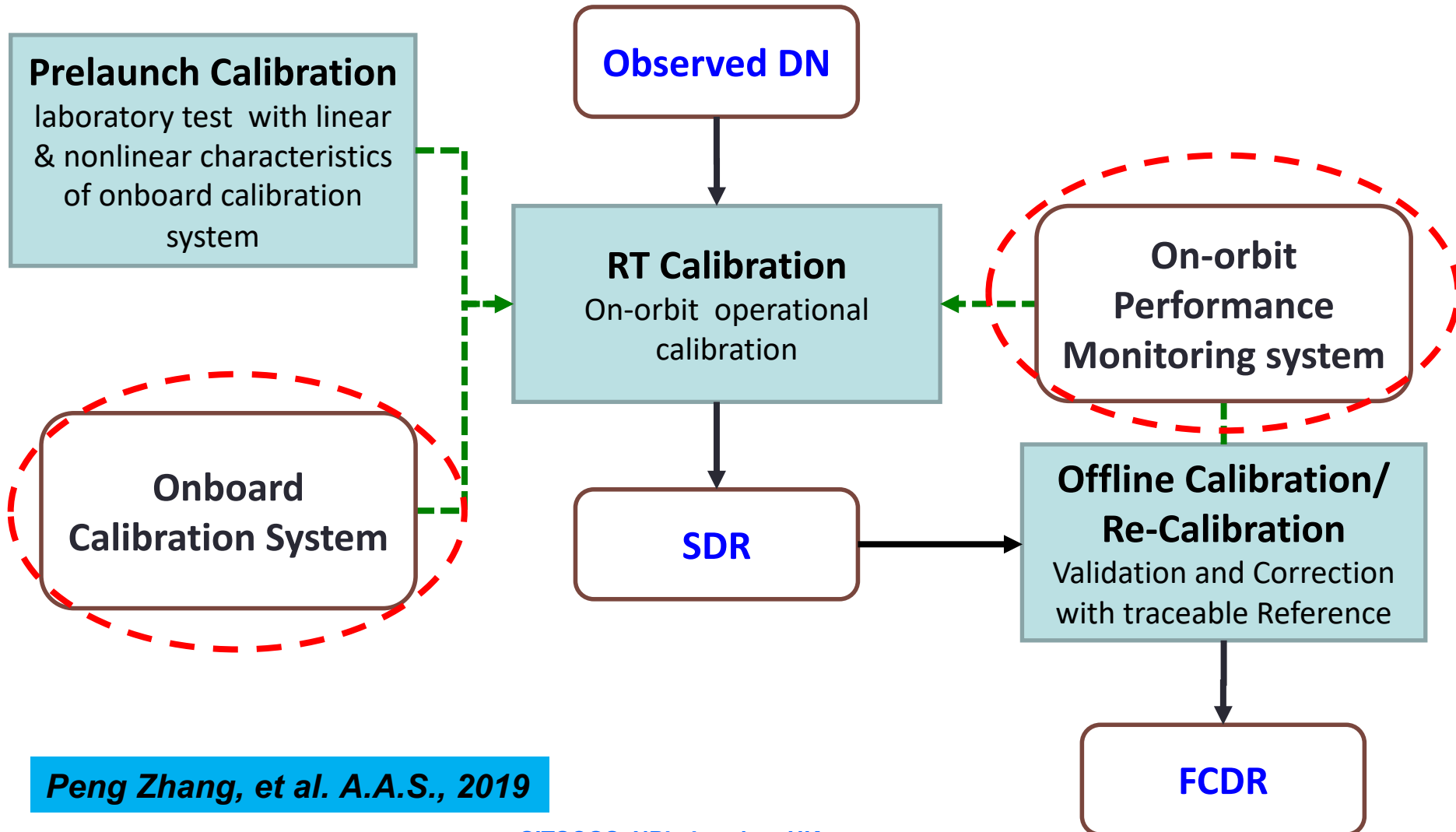
WMO Space-based Global Observing System



Near Future Satellites (from NOAA report)



Calibration Procedure



Peng Zhang, et al. A.A.S., 2019

Earth Observation Satellites in China

Mission	Chinese	Purpose	Abbr.
■ recoverable remote-sensing satellites		Land satellite	
■ DongFangHong	东方红	Telecommunications and broadcasting satellites	DFH Series
■ ShiJian	实践	scientific research and technological experiment satellites	SJ Series
■ BeiDou	北斗	navigation and positioning satellites	BD Series
■ ShenZhou	神舟	Experimental spacecraft	SZ Series
■ FengYun	风云	Meteorological satellites	FY Series
■ ZiYuan	资源	Earth resource satellites	ZY Series CBERS
■ HaiYang	海洋	Marine Satellites	HY Series
■ HuangJing	环境	Environment and disaster monitoring and forecasting	HJ Series
■ GaoFeng	高分	Earth Observation Mission	GF Series
■ TanSat	碳卫星	R & D: Carbon Dioxide	-----

Projects on Space-based Radiometric Benchmark

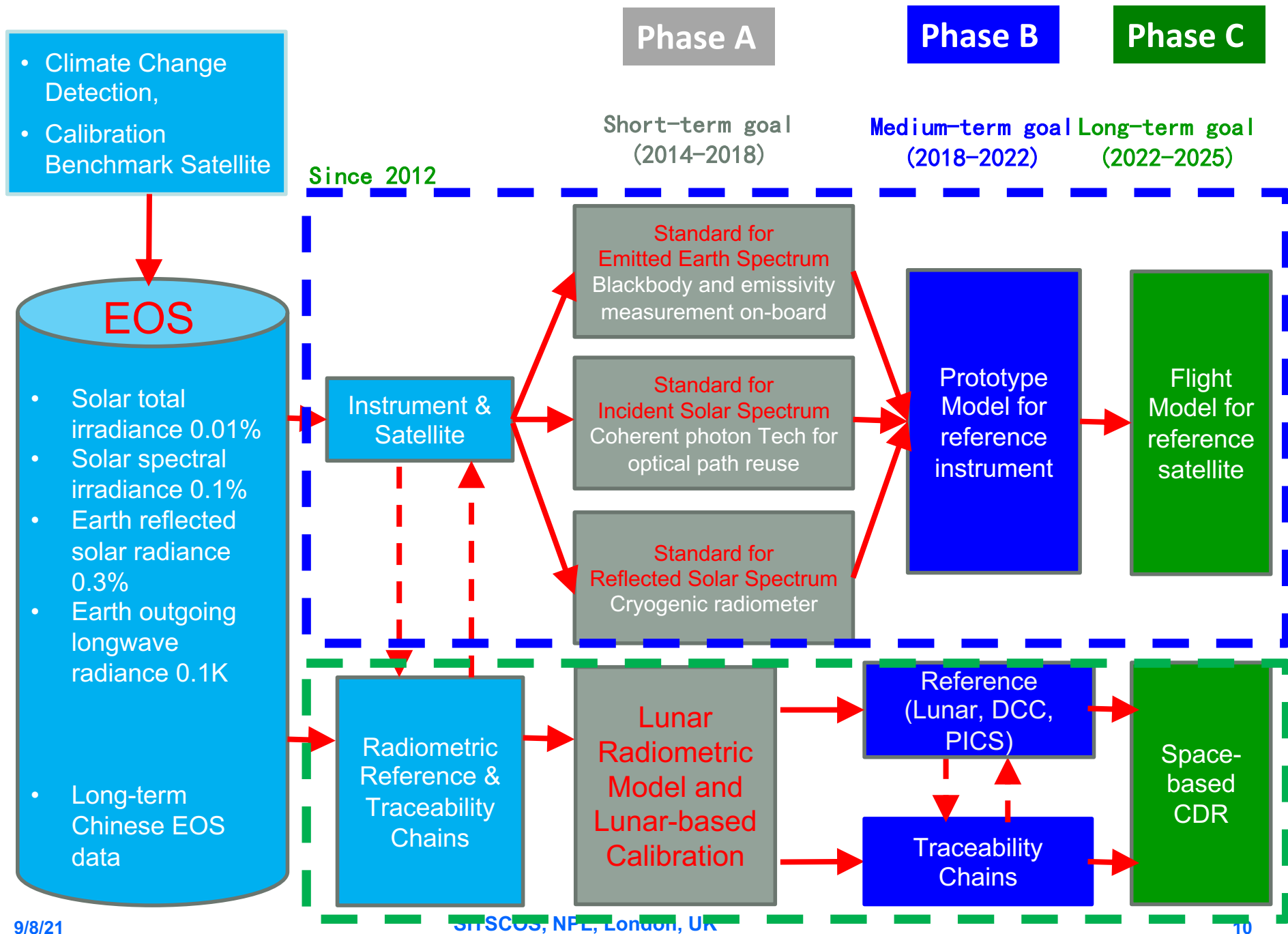
Founded by

- **National High Technology Research & Development Program of China (863 program) before 2018**
- **National Key R&D Program of China after 2018**



Goal

- **Chinese SI-traceable Radiometric Benchmark Satellite (CRBS)**
- **Retrospective Calibration of Historical Chinese EO Satellite Data (RICH-CEOS)**



2. SI-Traceable Standard in Phase A

Phase A (20 million RMB)

- National High Technology Research & Development Program of China (863 program)

Standard for
Emitted Earth Spectrum
Blackbody and emissivity
measurement on-board



Shanghai Institute of Technical Physics (SITP), CAS

Standard for
Incident Solar Spectrum
Coherent photon Tech for
optical path reuse



Anhui Institute of Optics and Fine Mechanics
(AIOFM), CAS

Standard for
Reflected Solar Spectrum
Cryogenic radiometer



Changchun Institute of Optics, Fine Mechanics
and Physics (CIOMP), CAS

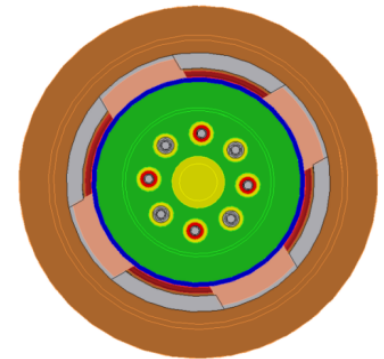
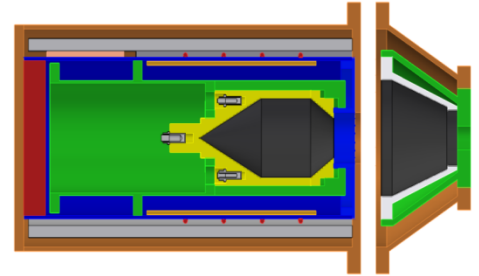
Lunar Radiometric
Model and Lunar-
based Calibration



National Satellite Meteorological Center (NSMC),
CMA

Standard for Emittted Earth Spectrum

- ✧ The black body uses a cavity structure to construct the main body of the radiation source with a diameter of 50mm.
- ✧ **On-orbit Absolute Radiance Standard cavity blackbody using four miniature phase change cells (Water, gallium melting, gallium based alloys, organic matter)** to establish an accurate temperature scale from 270K, to 350K at uncertainty of 10 mK (K=2);
- ✧ The temperature scale at each miniature phase change cells is transferred to four high-precision platinum resistors which measures the temperature throughout the blackbody cavity .
- ✧ On-orbit cavity emissivity using a Heated Halo source that allows the FTS to measure the broadband spectral emissivity of the IR calibrator to better than $\leq 4 \times 10^{-3}$ (K=2) ;
- ✧ Systematic specification requirement: emissivity better than 0.997, temperature control stability better than 0.01K, temperance accuracy better than 0.15K (K=2).

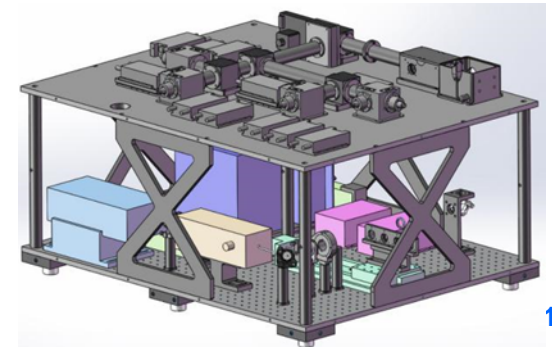


(Seeing Ding's report)

Standard for Incident Solar Spectrum

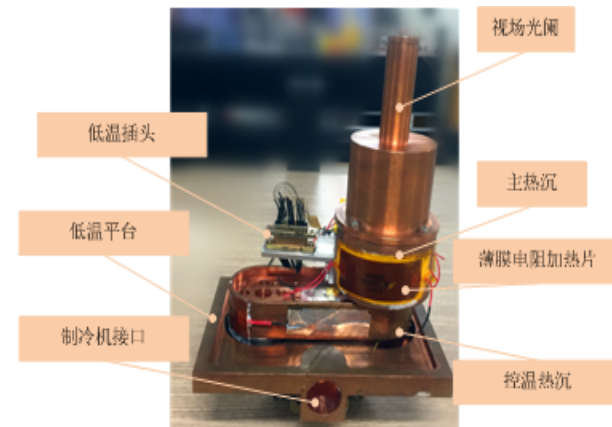
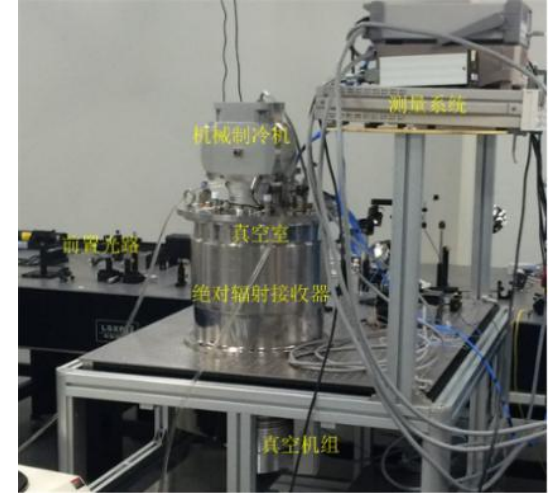
- ✧ Providing reference standards and metrology for photon counting community, which can be used to calibrate detection efficiency of photon counting detectors and retrieve spectral radiance of observation object.
- ✧ Integrated design of correlated photons source and radiometric observation, including the same stop, field, telescope and dispersive optical path, using scanning mirror to switch self-calibration and observation modes.
- ✧ We obtained an absolute spectral responsivity uncertainty of the correlated method of 0.29% ($k=1$) and spectral calibration uncertainty of 0.08nm.
- ✧ **Self-calibration prototype based on correlated photons technique** operates in the range from 430nm to 1000nm, spectral band of 8, spectral resolution of 4.0nm -14.5nm.
- ✧ Comparison with a conventionally calibrated transfer detector tied to AIOFM high accuracy cryogenic radiometer, the two independent calibration techniques differ by 0.24%, within the established uncertainty of comparison.

(Seeing Zheng's report)



Standard for Reflected Solar Spectrum

- ✧ The prototype of **the space-borne cryogenic absolute radiometer based on the electrical substitution principle** is developed. It consists of absolute radiation detector, electrical control system, mechanical cryocooler, vacuum unit, the front light path.
- ✧ The Space Cryogenic Absolute Radiometer is used as the primary standard for establishing the traceable power benchmark on satellite. The solar and the multispectral transmission radiometer is the secondary standard to establish the solar spectrum radiation benchmark.
- ✧ The measurement uncertainty of the Space Cryogenic Absolute Radiometer benchmark is better than 0.03%.
- ✧ The working temperature of the Space Cryogenic Absolute Radiometer arrives at 20K.
- ✧ spectrum range: 300nm~2500nm.
- ✧ The uncertainty of the solar spectrum radiation benchmark: 0.2% (<1600nm)和 0.5%(≥1600nm).
- ✧ The resolution: 3 ~ 5nm(300 ~ 1100nm), 10nm(>1100nm).



(Seeing Ye's report)

3. Prototype Instrument in Phase B

Phase B

- National Key R&D Program of China (300 million RMB)
- Chinese FY Satellite Program
- Chinese HY Satellite Program
- Chinese ZY Satellite Program

Prototype Model
for Benchmark
Instrument



Shanghai Institute of Technical Physics (SITP), CAS



Anhui Institute of Optics and Fine
Mechanics (AIOFM), CAS



Changchun Institute of Optics, Fine Mechanics
and Physics (CIOMP), CAS

Historic Satellite
Data Re-
Calibration



National Satellite Meteorological Center
(NSMC), CMA

Radiometric
Reference
(Lunar, DCC, PICS)
& Traceability
Chains



Academy of OPTO-Electronics (AOE), CAS

SI-Traceable Instrument in IR (Prototype)

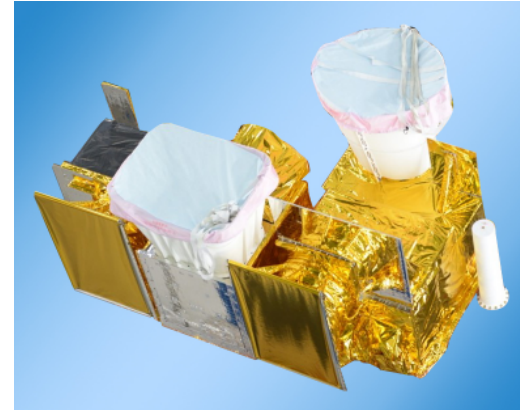
Emitted Earth Spectrum Instrument requirements are as follows

- ✧ Spectral Range: $600\text{ cm}^{-1}\sim 2700\text{ cm}^{-1}$.
- ✧ Spectral Resolution: 0.5 cm^{-1} unapodized.
- ✧ IFOV: 17 km.
- ✧ NedT: better than 0.1 K(@270K).
- ✧ Systematic calibration Uncertainty: better than 0.2 K(radiance), 2ppm(spectral).
- ✧ BB emissivity : greater than 0.999.

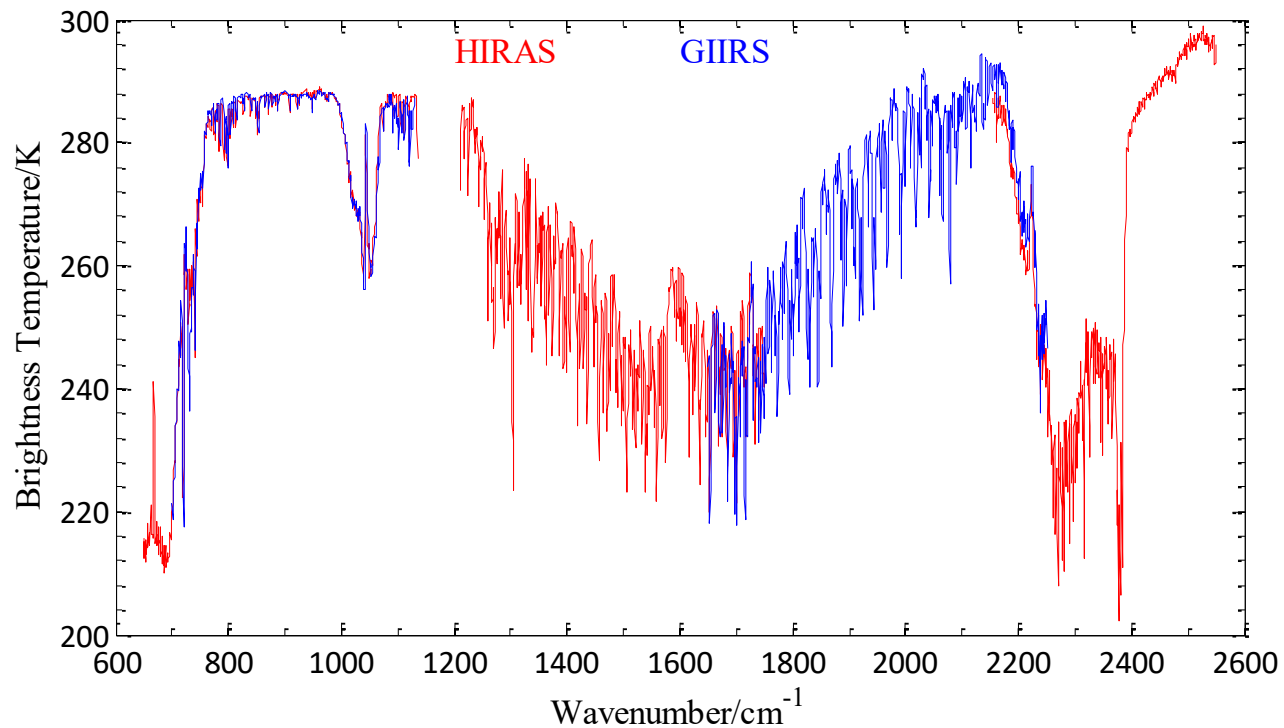
Interim Performance: On-orbit FTS instruments



FY-3/HIRAS 0.2-0.7K

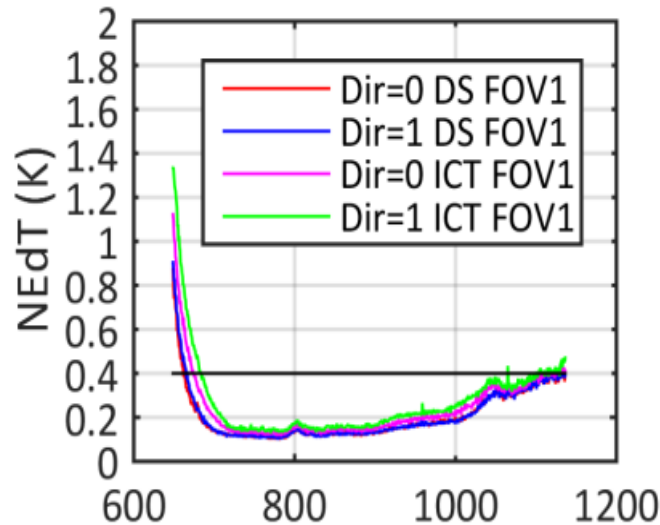


FY-4/GIIRS 0.5-1K

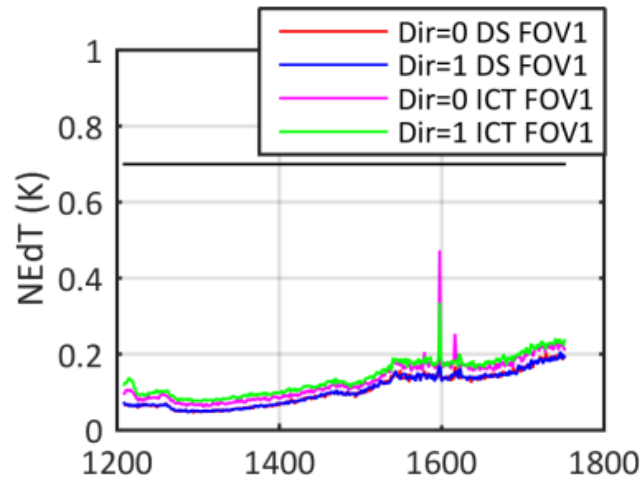


HIRAS performance and validation

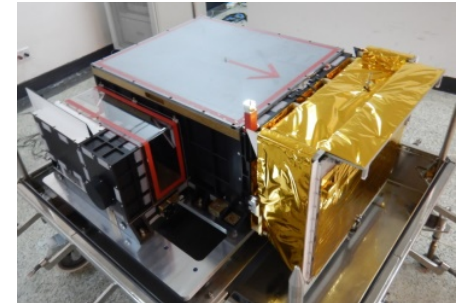
LW @ 0.625cm⁻¹ Res



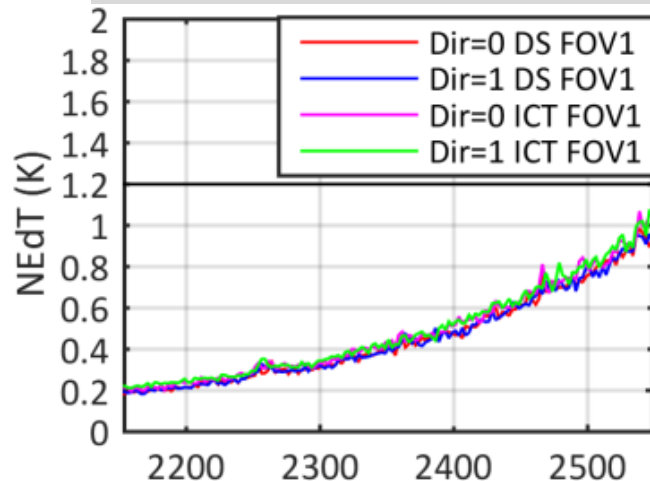
MW @ 1.25cm⁻¹ Res



NEdT



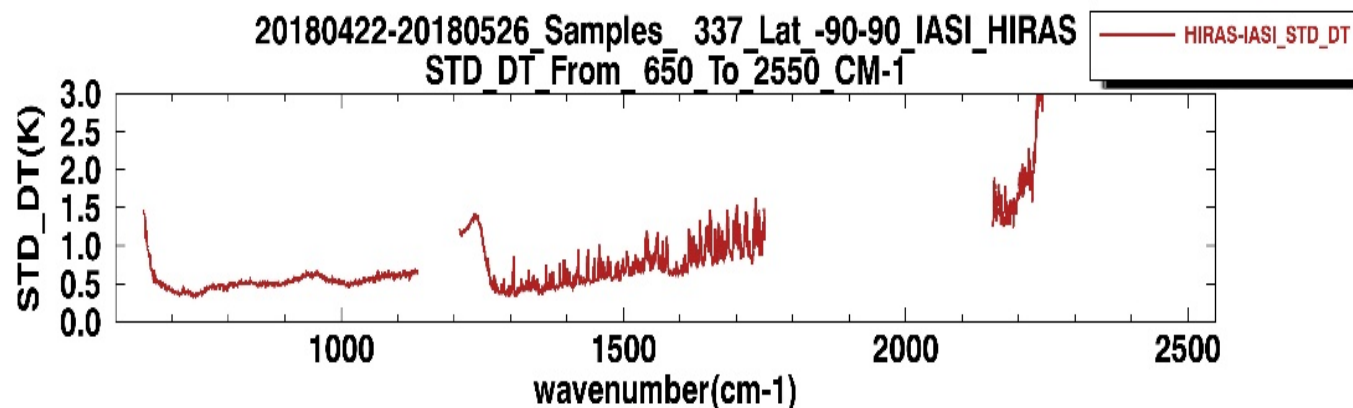
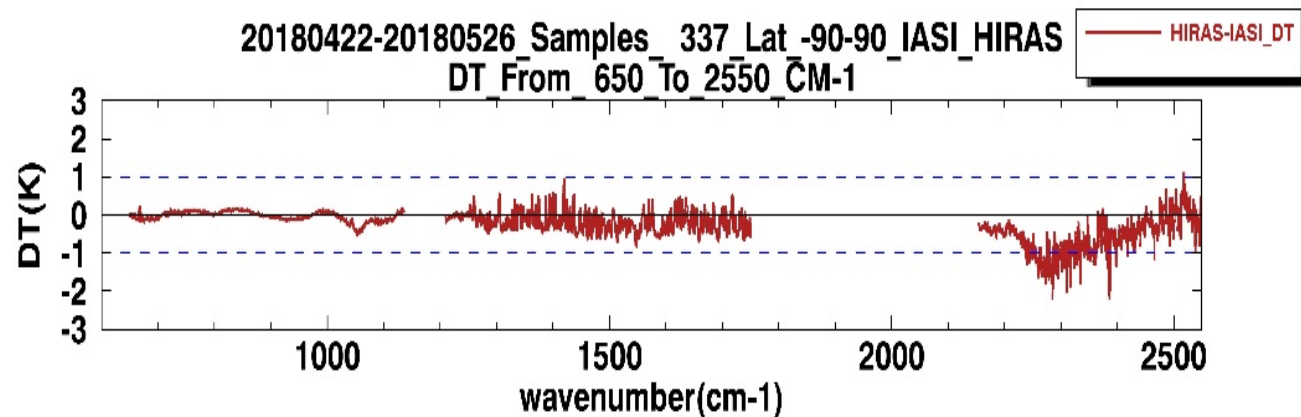
SW @ 2.5cm⁻¹ Res



Noise performance: derived from DS and ICT measurements

- **NEdTs derived from DS and ICT are consistent.**
- **NEdTs in forward and reverse sweep direction are consistent.**
- **Meet requirements.**

Calibration bias with respect to IASI



- Data:2018.04.22-2018.05.26 17 days
- LW bt bias better than 0.5K, MW bt bias less than 0.7K;
- LW bias std less than 0.5K, MW bias std in 0.5~1K, SW window and weak absorption region meet 0.5K ;

SI Traceable Instrument in RSB (Prototype)

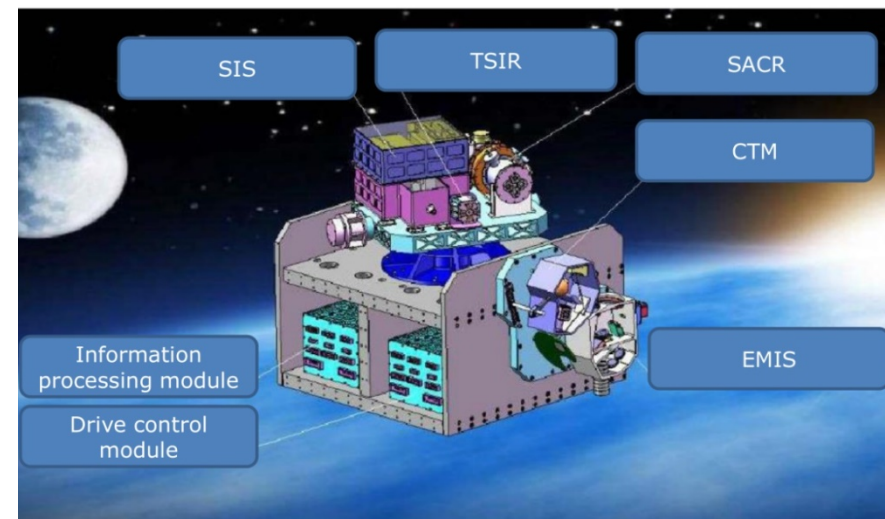
Total Solar Irradiance	0.2 μ m - 35 μ m, Absolute uncertainty: 0.05%
Incident Solar Spectrum	380 nm - 2500 nm, Spectral resolution: 3 nm(380-1000 nm), 8nm(1000 - 2500 nm) Spectral precision: 0.1 nm - 0.3 nm, Self-calibration uncertainty: 0.2%, Absolute measurement uncertainty: 0.3%
Reflected Solar Spectrum	380 nm - 2350 nm, Spectral resolution: 10 nm, Spectral precision: 0.1 nm - 0.3 nm, Spatial resolution: 100 m, Coverage: 50 km, on-board radiance transfer uncertainty: 0.6%, Absolute spectral radiance measurement uncertainty: 1%

Space-borne SI-traceable instruments in RSB (Flight Model in 2025)

This system consists of 7 components: **Earth/moon imaging spectrometer (EMIS)**, **Solar irradiance spectro-radiometer (SIS)**, **Total solar irradiance radiometer (TSIR)**, Space-borne absolute cryogenic radiometer (SACR), Comparison transfer module (CTM), information processing module, and drive control module.

- Overall design technology of space-borne reference load in solar band
- Solar-earth-moon hyperspectral observation technique based on space cryogenic radiometer Correlation
- Photon self-calibrated solar absolute spectral irradiance observation technology
- Performance test and precision verification technology of the load principle prototype

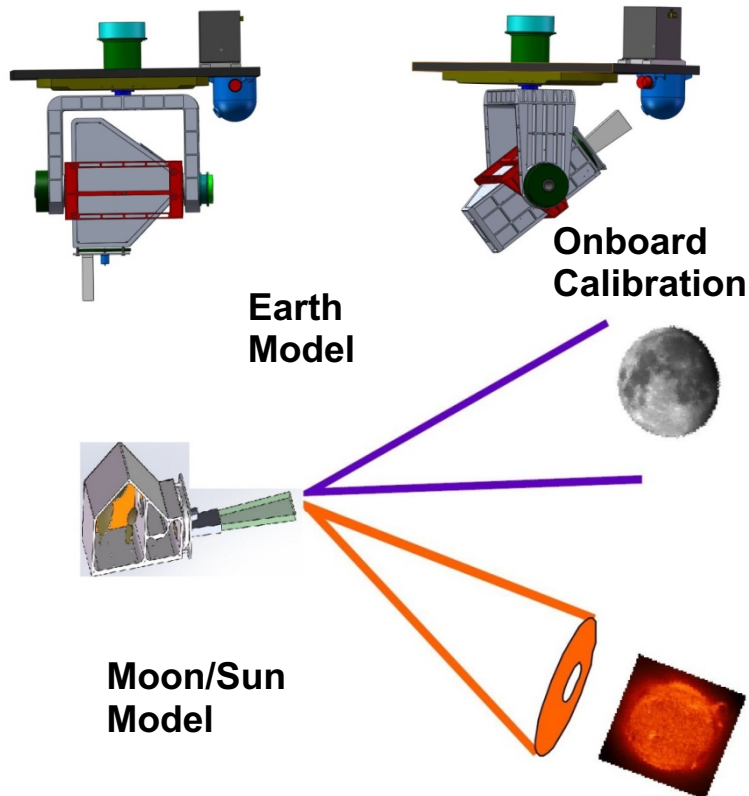
Concept Design



SI-traceable demo instrument on FY-3RM rainfall mission (2022)

LeSIRB-Lunar and Earth Spectral Imager Radiometry Benchmark

Mission Goal: Demonstration of SI traceability instrument and experiment for inter-calibration between current Fengyun satellite optical imagers to improve calibration accuracy



Parameter items	Specification	
Ground spatial resolution	250m	
Spectral resolution	4nm	
Spectral range	400nm~1060nm	
Ground Swath width	50Km	
S/N Ratio	>150	
Radiance Dynamic	Similar to MERSI-3	
MTF	$>0.2@f/f_{nyq}=1.0$	
Radiometric uncertainty	2%	
Spectral calibration	2nm	
Polarization sensitivity	<1%	
Observation Model	Earth/Lunar/Sun/Calibrator	

4. Other Related Activities

Retrospective Calibration of Historical Chinese Earth Observation Satellite Data (RICH-CEOS)

RICH-FY : Chinese Meteorological Satellites

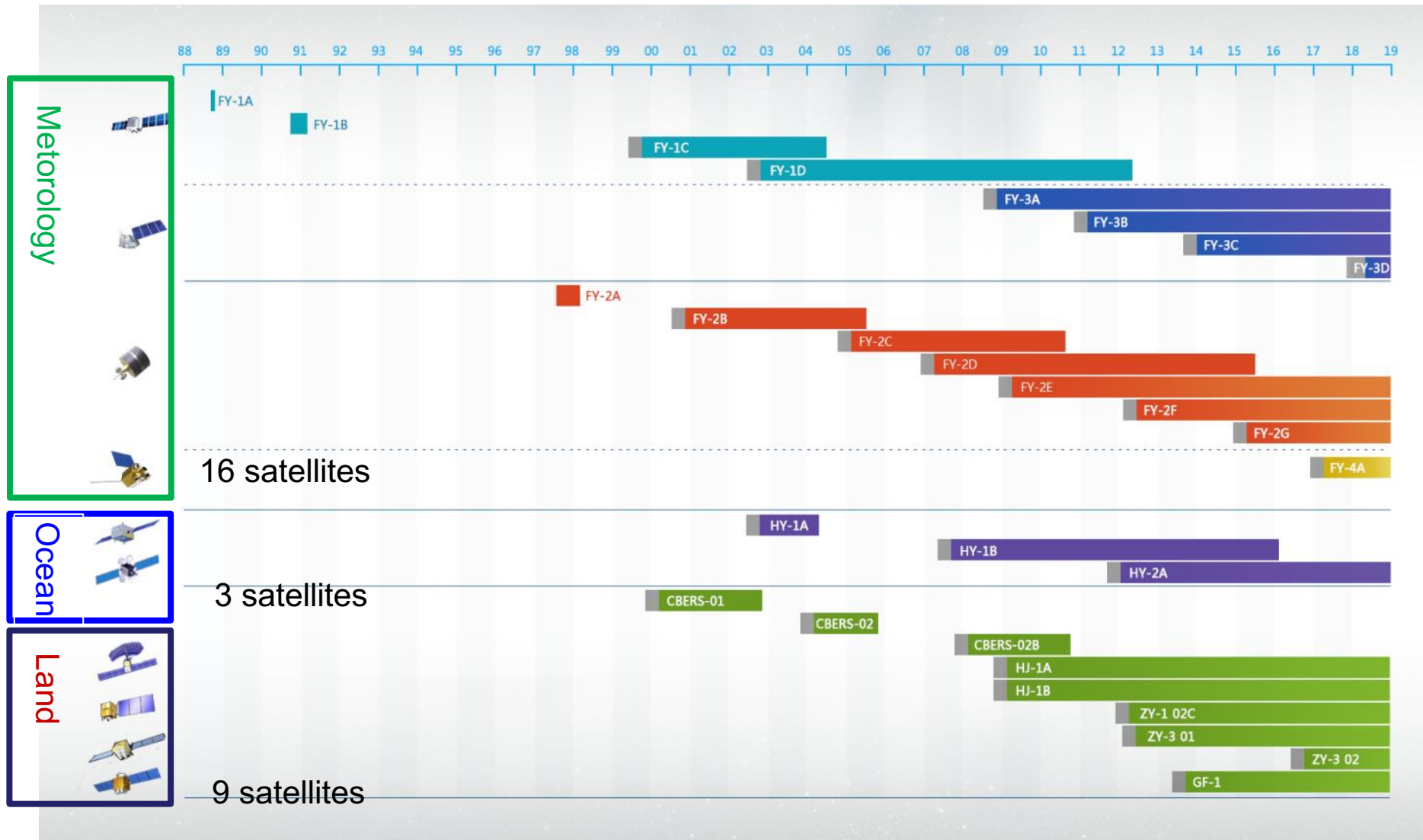
RICH-ZY : Chinese Land Resources Satellites

RICH-HY : Chinese Marine Satellites

18 institutions in
Earth observation and
navigation



Chinese Satellite Data number✓ quality?



Satellites and Instruments Related

Time scale is over 30y (1989~), including GEO and LEO meteorological, oceanic and land satellites. There are 27 satellites and 15 kinds of instruments, 5500TB in total, covering visible, near-infrared, short wave infrared, infrared and microwave. The spacial resolution covers from meters to dozens kilometers. The observation mode covers active and passive mode.

卫星	仪器	波长 m	波段	分辨率 m	开始日期-结束日期
CBERS-01	CCD	0.45--0.89	5	20m	1999.10.14-2002.10
	IMSS	0.5-12.5	4	78m/156m	1999.10.14-2002.10
	WFI	0.63-0.89	2	258m	1999.10.14-2002.10
CBERS-02	CCD	0.45--0.89	5	20m	2003.10.21 - 2005.10
	IMSS	0.5-12.5	4	78m/156m	2003.10.21 - 2005.10
	WFI	0.63-0.89	2	258m	2003.10.21 - 2005.10
CBERS-02B	CCD	0.45--0.89	5	20m	2007.9.19-2010.9
	WFI	0.63-0.89	2	258m	2007.9.19-2010.9
	HR	0.5-0.8	1	2.36	2007.9.19-2010.9
HJ-1A	CCD	0.43-0.90	4	30	2008.9.6-□
	HSI	0.45-0.95	115	100	2008.9.6-□
HJ-1B	CCD	0.43-0.90	4	30	2008.9.6-□
	IRS	0.75-12.5	4	720	2008.9.6-□
ZY-1 02C	PMS	0.51-0.89	4	5/10	2011.12.22-□
	HR	0.50-0.89	1	2.36	2011.12.22-□
ZY-3 01	MUX	0.45-0.89	4	6	2012.1.9-□
	TLC	0.50-0.80	1	3.5	2012.1.9-□
ZY-3 02	MUX	0.45-0.89	4	5.8	2016.5.30-□
	PAN	0.50-0.80	1	2.5	2016.5.30-□
GF-1	PMS	0.45-0.89	5	2/8	2013.4.26-□
	WV	0.45-0.89	4	16	2013.4.26-□

ZY : 9 satellites and 5 instruments

HY : 5 satellites and 3 instruments

卫星 Satellite	遥感仪器 Instrument	波段范围 Wavelength	通道数 Bands	空间分辨 Resolution	资料开始服务时间（卫星发射时间）-- Start date- end date
HY-1A	COCTS	0.402 - 12.5 μm	10	1.1 km	2002.05.29 (2002.05.15) - 2004.03.30 (2004.03.30)
	CZI	0.433 - 0.695 μm	4	250 m	
HY-1B	COCTS	0.402 - 12.5 μm	10	1.1 km	2007.04.15 (2007.04.11) - 2016.01.23 (2016.01.23)
	CZI	0.433 - 0.695 μm	4	250 m	
HY-2A	雷达高度计 RA	13.58 GHz, 5.25 GHz	2 频段	25 km	2011.10.01 (2011.08.16) - 今
	微波散射计 SM	13.256GHz	1 频段, 双极化	50km	
	微波辐射计 RM	6.6-37.0GHz	5 频段, 双极化	25-100 km	
HY-1C	COCTS	0.402 - 12.5 μm	10	1.1km	计划 2018 年 9 月
	CZI	0.420 - 0.890 μm	4	50m	
	UVI	0.345-0.395 μm	2	550m	
HY-2B	雷达高度计 RA	13.58 GHz, 5.25 GHz	2 频段	25 km	计划 2018 年 10 月
	微波散射计 SM	13.256GHz	1 频段, 双极化	50km	
	微波辐射计 RM	6.6-37.0GHz	5 频段, 双极化	25-100 km	

FY : 13 satellites and 7 instruments

卫星 Satellite	遥感仪器 Instrument	波段范围 Wavelength	通道数 Bands	空间分辨率 Resolution	资料开始服务时间 (卫星发射时间) – 资料结束服务时间 (卫星退役时间) Start date- end date
FY-1A	VIRR	0.48 – 12.5 μm	5	1.1 km	1988.9.8 (1988.9.7) – 1988.10.17 (1988.10.17)
FY-1B	VIRR	0.48 – 12.5 μm	5	1.1 km	1990.9.3 (1990.9.3) – 1991.2.15 (1991.2.15)
FY-1C	VIRR	0.43 – 12.5 μm	10	1.1 km	1999.5.10 (1999.5.10) – 2004.4.26 (2004.4.26)
FY-1D	VIRR	0.43 – 12.5 μm	10	1.1 km	2002.5.15 (2002.5.15) – 2012.4.1 (2012.4.1)
FY-2A	VISSR	0.5 – 12.5 μm	3	1.25 km, 5 km	1997.6.10 (1997.6.10) – 1998.2.12 (1998.2.12)
FY-2B	VISSR	0.5 – 12.5 μm	3	1.25 km, 5 km	2000.7.19 (2000.6.25) – 2005.6.2 (2005.6.2)
FY-2C	VISSR	0.5 – 12.5 μm	5	1.25 km, 5 km	2004.10.27 (2004.10.19) – 2010.8.2 (2010.8.2)
FY-2D	VISSR	0.5 – 12.5 μm	5	1.25 km, 5 km	2006.12.19 (2006.12.8) – 2015.6.30 (2015.6.30)
FY-2E	VISSR	0.5 – 12.5 μm	5	1.25 km, 5 km	2009.2.17 (2008.12.23) – 今
FY-2G	VISSR	0.5 – 12.5 μm	5	1.25 km, 5 km	2015.6.3 (2014.12.31) – 今
FY-3A	VIRR 2	0.43 – 12.5 μm	10	1.1 km	2008.5.29 (2008.5.27) – 2018.3.6 (2018.3.6)
	MERSI 1	0.41 – 11.25 μm	20	250 m, 1 km	2008.6.2 (2008.5.27) – 2018.2.11 (2018.3.6)
	IRAS	0.69 – 1.64 μm 3.76 – 14.95 μm	26	17 km	2008.6.26 (2008.5.27) – 2016.8.13 (2018.3.6)
	MWTS 1	50 – 57 GHz	4	50 – 60 km	2008.6.8 (2008.5.27) – 2013.5.6 (2018.3.6)
	MWHS 1	150 GHz, 183 GHz	5	15 km	2008.5.31 (2008.5.27) – 2016.8.13 (2018.3.6)
	MWRI	10 – 89 GHz	10	12 – 75 km	2008.6.6 (2008.5.27) – 2010.5.18 (2018.3.6)
FY-3B	VIRR 2	0.43 – 12.5 μm	10	1.1 km	2010.11.18 (2010.11.5) – 今
	MERSI 1	0.41 – 11.25 μm	20	250 m, 1 km	2010.11.18 (2010.11.5) – 今
	IRAS	0.69 – 1.64, 3.76 – 14.95 μm	26	17 km	2010.11.18 (2010.11.5) – 今
	MWTS 1	50 – 57 GHz	4	50 – 60 km	2010.11.18 (2010.11.5) – 2014.2.21
	MWHS 1	150 GHz, 183 GHz	5	15 km	2010.11.18 (2010.11.5) – 今
	MWRI	10 – 89 GHz	10	12 – 75 km	2010.11.18 (2010.11.5) – 今
FY-3C	VIRR 2	0.43 – 12.5 μm	10	1.1 km	2013.9.25 (2013.9.23) – 今
	MERSI 1	0.41 – 11.25 μm	20	250 m, 1 km	2013.9.30 (2013.9.23) – 2015.5.30
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	MWTS 2	50 – 57 GHz	4	50 – 60 km	2013.9.30 (2013.9.23) – 今
	MWHS 2	150 GHz, 183 GHz	5	15 km	2013.9.30 (2013.9.23) – 今
	MWRI	10 – 89 GHz	10	12 – 75 km	2013.9.29 (2013.9.23) – 今

Difficulty 1: On-board calibration design for Current FY

Spectral band	On-board calibration	Instrument	uncertainties
UV bands	Sun + diffuse reflector Mercury lamp + solar continuous spectrum	TOU/FY-3 SBUS/FY-3	1) State change before and after launch 2) Attenuation of diffuse reflector
Visible and NIR bands	VOC: small integrating sphere with diameter of 6 cm, light beam expanding system, trap detector	MERSI/FY-3	1) State change before and after launch 2) Degradation
	Moon observation	MERSI/FY-3C	Moon model accuracy
	Tungsten halogen lamp	ERM/FY-3	1) State change before and after launch 2) Degradation
	Absolute radiometer	SIM/FY-3	1) State change before and after launch 2) Degradation
Infrared bands	Onboard blackbody + space view	VISSR/FY-2 VIRR/FY-3 MERSI/FY-3 IRAS/FY-3	1) State change before and after launch 2) Blackbody temperature control accuracy 3) Accuracy and changes in blackbody emissivity 4) Extent of the cold space contaminated by radiation
	Onboard blackbody (two temperature points)	ERM/FY-3	1) State change before and after launch 2) Blackbody temperature control accuracy 3) Accuracy and changes in blackbody emissivity
Microwave bands	Onboard blackbody + space view	MWTS/FY-3 MWHs/FY-3 MWRI/FY-3	1) State change before and after launch 2) Blackbody temperature control accuracy 3) Accuracy and changes in blackbody emissivity 4) Extent of the cold space contaminated by radiation

Large change before and after launch, poor in-orbit stability

- International: visible 2%, infrared 0.2K, stability <1%
- Domestic: visible 7-10%, infrared 1-1.5K, stability?

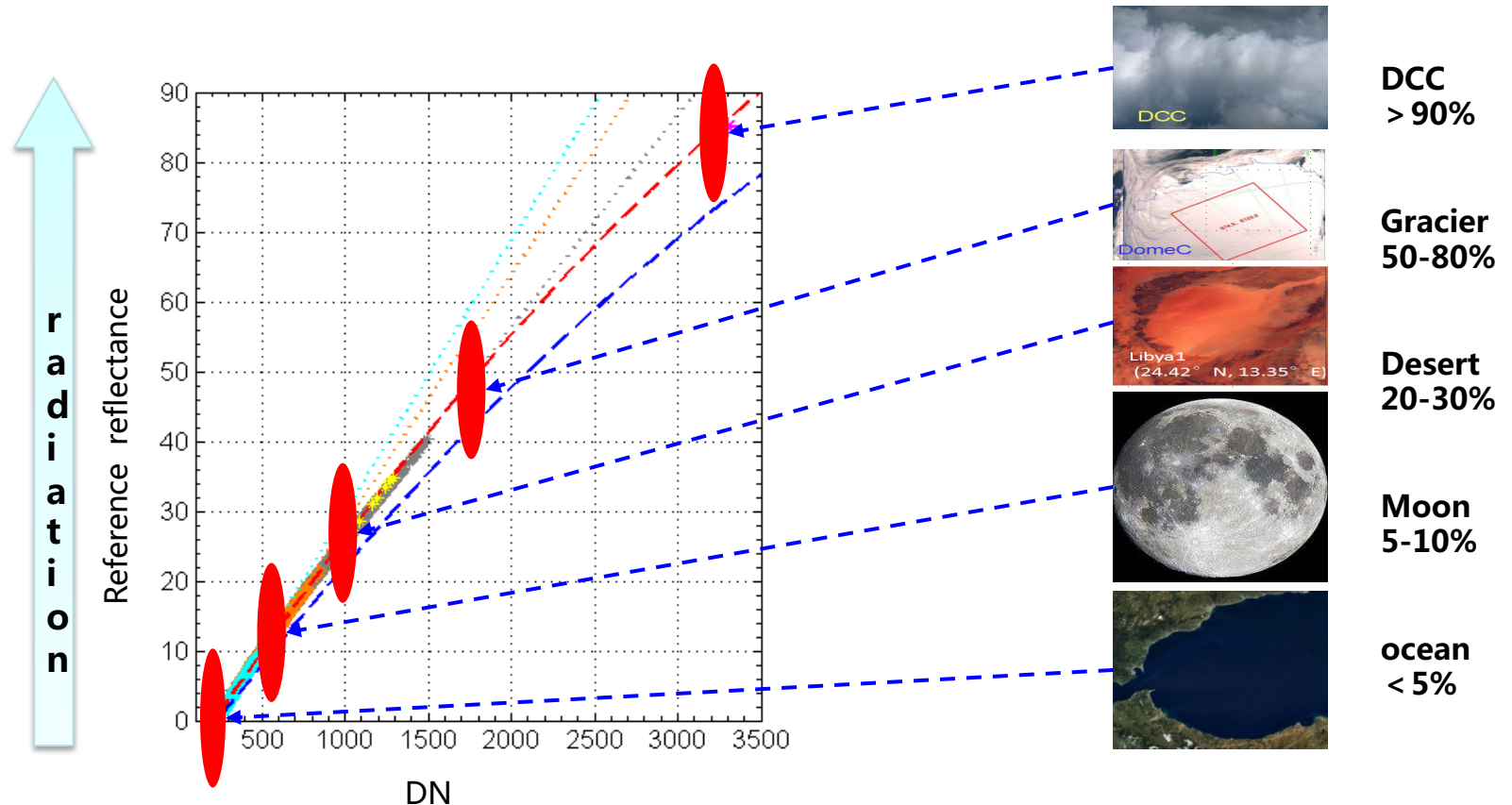
Difficulty 2: Instrument Nonlinearity Performance

(Prelaunch Vaccum Calibration for MW)

CH	1	2	3	4	5	6	7	8	9	10	11	12
Fre. (GHz)	23.8	31.4	50.3	51.76	52.8	53.596 ±0.115	54.4	54.9 4	55.5	F0=57. 29	f0±0.322 2±0.217	f0±0.322 2±0.048
SNPP ATMS (K)	0.3	0.4	0.1	-0.08	-0.05	-0.08	0.07	0.1	0.1	0.4	0.4	0.4
FY-3D MWTS MWHS (K)			-0.48	-0.99	-0.73	-0.59	-0.65	-0.64	-0.58	-0.80	-0.82	-0.80

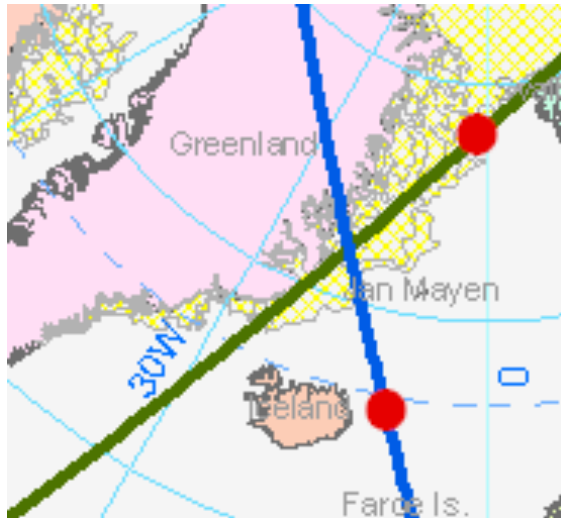
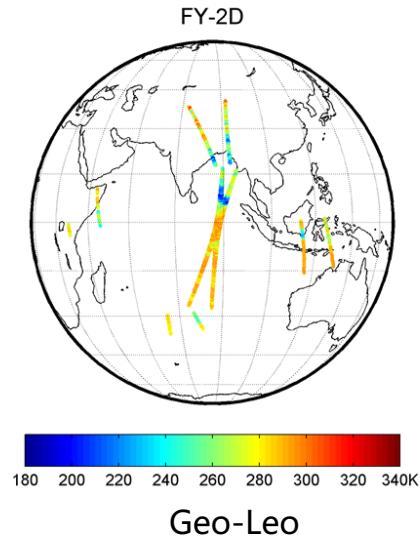
CH	13	14	15	16	17	18	19	20	21	22
Fre. (GHz)	f0±0.3222± 0.022	f0±0.3222± 0.010	f0±0.3222± 0.0045	88.2	165.5	183.31±7	183.31±4.5	183.31±3	183.31±1.8	183.31±1
SNPP ATMS (K)	0.5	0.4	0.5	0.2	0.4	0.2	0.2	0.2	0.3	0.3
FY-3D MWTS MWHS (K)	-0.96	-0.75	-0.58	2.7	0.9	3.4	1.9	0.9	0.2	0.5

Solution 1: Calibration Monitoring with multi PICTs



Solution 2: Calibration Monitoring with reference Instrument

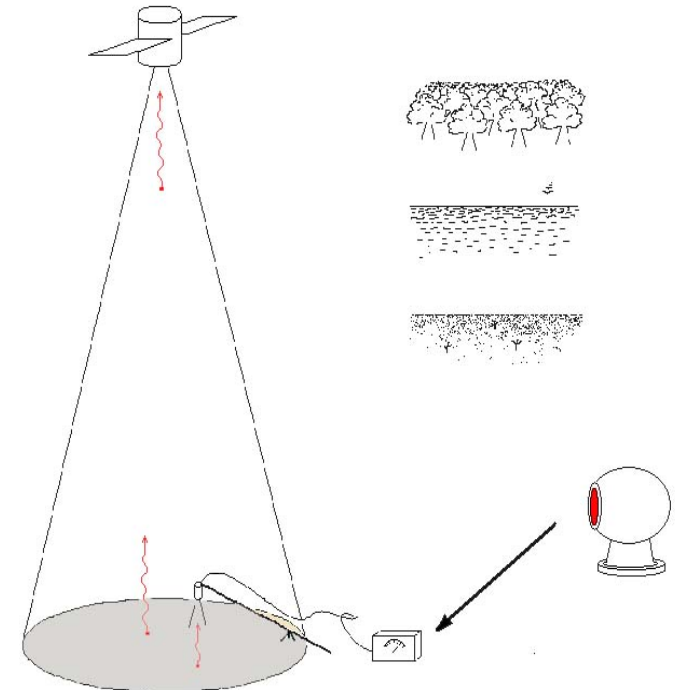
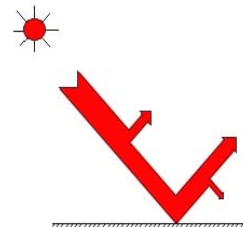
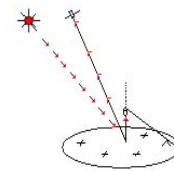
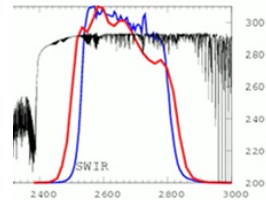
(Traceability/Consistence)



Leo-Leo

Global data matching

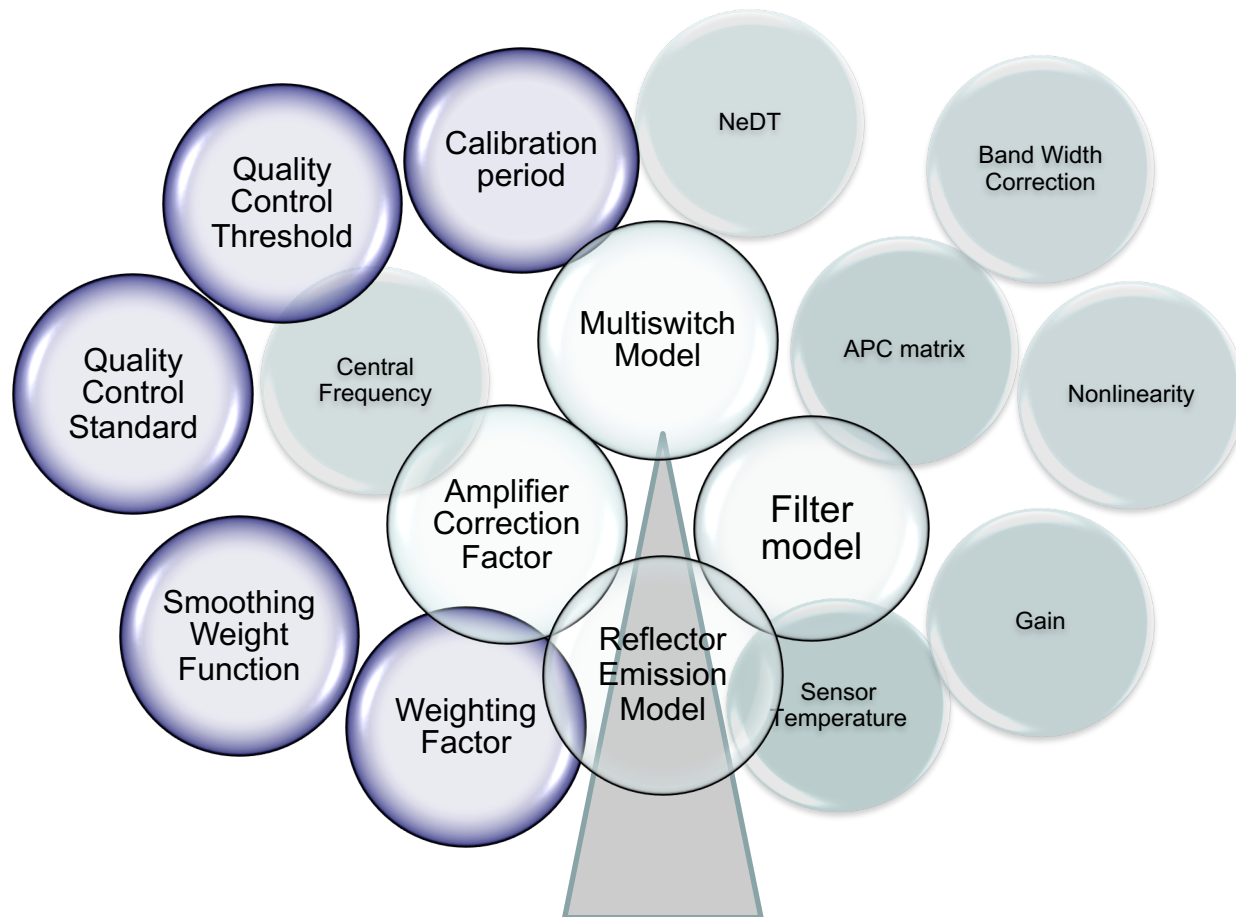
- Space
- Time
- Geometry
- Spectral



Solution 3: Simulated Physical Calibration Model

Passive Microwave Sensor

- Theoretical modeling
- Experiment testing
- Application testing and iteration improvement



Passive optical instruments: radiometric reference - natural stable targets (1/2)

Calibration targets	Accuracy	Reference
CRCS (China Remote Sensing Satellite Radiometric Calibration Site)	Reflectance: 15-30% Stability: 1-2% Directional effect: Yes Spectral: Smooth but not flat Accuracy: 3-5%	Hu et al, 2010 Chen et al, 2017
PICS (Pseudo Invariant Calibration Site)	Reflectance: 15~50% Stability: Directional effect: Yes Spectral: Accuracy: $3\% \pm 2\%$	H. Cosnefroy, 1996 Y. M. Govaerts, 2004 G. Chander, 2007 ; P. M. Teillet, 2007 Sun et al., 2012 Mishra et al., 2014 Wang et al., 2018
DCC (Deep convective cloud)	Reflectance: 80-90% Stability: 1-2% Directional effect : Yes Spectral: flat Accuracy: 3-5%	B. Fougnie ,2009 B. J. Sohn, 2009
Liquid Water Cloud (LWC)	Reflectance: 20-70% Stability: 3% Directional effect: obvious Spectral: flat Accuracy: 5%	Ham & Sohn , 2010 B.J. Soh , 2013

Passive optical instruments: radiometric reference - natural stable targets (2/2)

Calibration targets	Accuracy	Reference
Rayleigh Scattering	Reflectance: 5~10% Stability: 1~2% Directional effect: Yes Accuracy: 3~5%	E. Vermote, 1992 E. Dilligeard , 1997 O. Hagolle, 1999
Sun glint	Reflectance: 5~50% Stability: 1% Directional effect : Yes Accuracy: 1~2% High degree of polarization; Fat spectrum; Reflectance depends on observation geometry and sea surface roughness	C. Cox and W. Munk , 1954 ; B. Toubbé, 1999 ; O. Hagolle, 2004 ;
Snow	Reflectance: >90%(300-700 nm) Stability: 1.5% Directional effect: Yes Spectral: flat (<700) Accuracy: 2%	Masonis et al., 2001 Wu et al., 2009 Wang et al., 2019
Moon	Reflectance: ~7% Stability: 10 ⁻⁸ /year Directional effect: Yes Spectral: flat Uncertainty: 5-10% (ROLO)	Kieffer and Stone, 2005 Miller and Turner, 2009 Zhang, et al., 2017

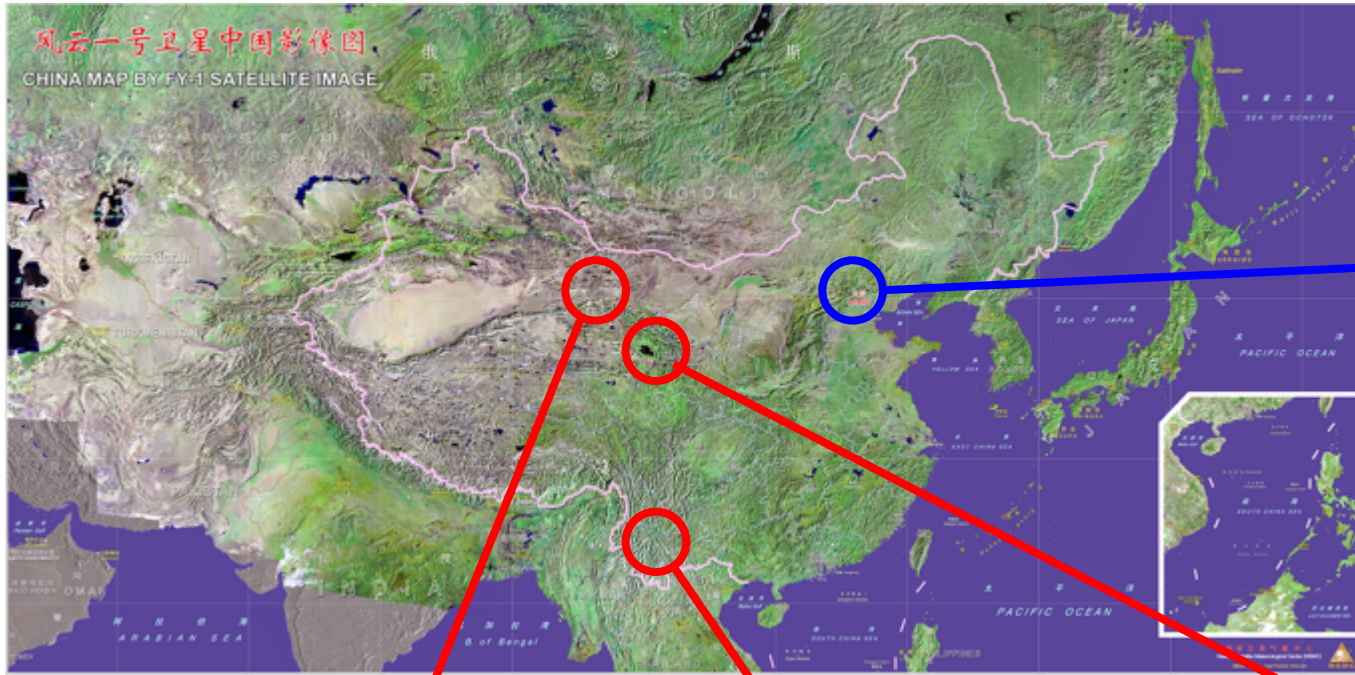
Passive optical instruments: radiometric reference – reference instrument

Reference instrument	Accuracy	Reference
HIRS	Stability: 0.2K Number of channels: 20 Accuracy: 0.5K;	L. Shi, 2013
IASI	Stability: 0.2K Spectral resolution: 0.25cm ⁻¹ Accuracy: 0.2K;	T. J. Hewison, 2013
AIRS	Stability: 0.2K Spectral resolution: 0.625cm ⁻¹ Accuracy: 0.2K;	L. Wang, 2011
CrIS	Stability: 0.2K Spectral resolution: 0.625cm ⁻¹ Accuracy: 0.2K;	Hui Xu, 2018 Likun Wang, 2017
MODIS	Stability: 0.1K/1% Number of channels: 36 Accuracy: 0.2K (IR); 2% (RSB)	A. K. Heidinger, 2002 X. J. Xiong, 2010; C. Cao, 2008
VIIRS	Stability: 0.1K/1% Number of channels: 36 Accuracy: 0.2K (IR); 2% (RSB)	

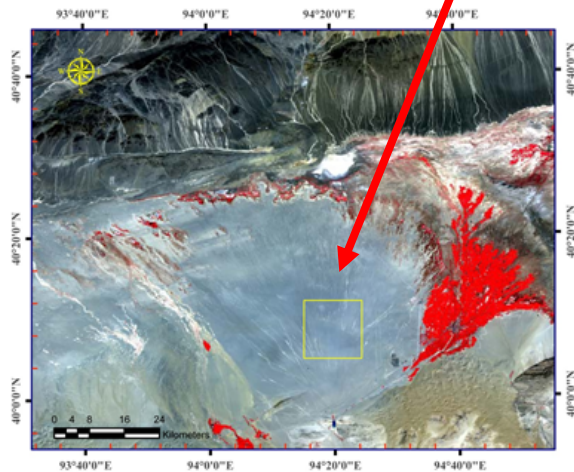
Passive Microwave Sensor: Radiation Reference

	Accuracy	Reference
ERA5	<2.5K	http://www.ecmwf.int/publications
GRUAN	0.6K,6%.	http://www.gruan.org
GNSS/OR	0.02%/5 yrs, 0.06 K/5 yrs。	Ho, S., et al. 2012: J. Geophys. Res., 117
GMI	Accuracy<0.4K , Stability < 0.2K.	Wentz,F.J.and D.Draper, J.Atmos.Oceanic Technol.,33
ATMS	Channel 3-15<0.75K Other Channel <1.0K	Weng, F., et. al. 2013: J. Geophys. Res. Atmos., 118
AMSU	0.5-1K	Cheng-Zhi, et al. 2016: CDR-ATBD
MHS	1K	EUMETSAT , MHS Level 1 PGS
SSM/I FCDR	0.5K	Wentz, F. J., 2013. SSM/I Version-7 Calibration Report
Cool Ocean Surface	0.27K/yr (18GHz)	Christopher S. Ruf , 2000. IEEE TGRS 38
Cold Space	2.72548±0.00057K , Peak wavelength 1.063mm , radiation intensity change <0.2%-0.3%。	Baikal of Baidu
Microwave Calibration Field (Simao)	Bt Change in 30d(Dry season)<0.4K ; Horizontal heterogeneity<0.15K 。	“Research on Key Technologies of Microwave Calibration Field” Project closing report , 2009

Chinese Radiometric Calibration Sites (CRCS)



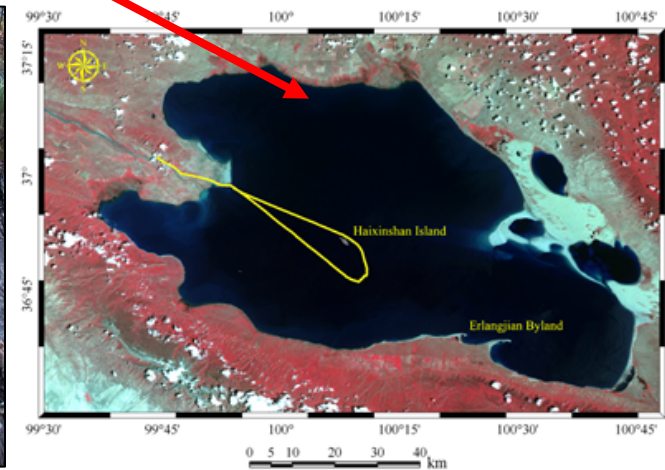
NSMC
Data processing center



Dunhuang Gobi (VNIR)

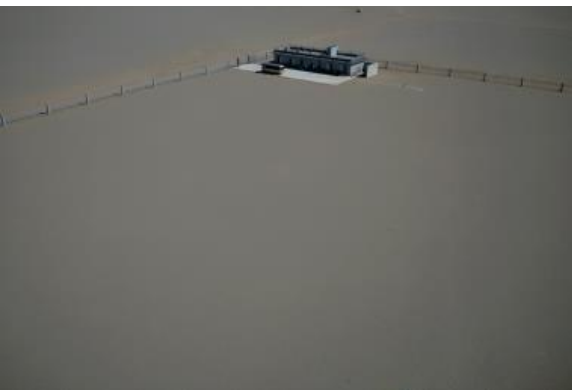
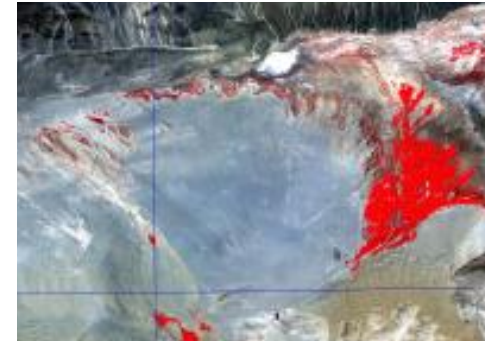
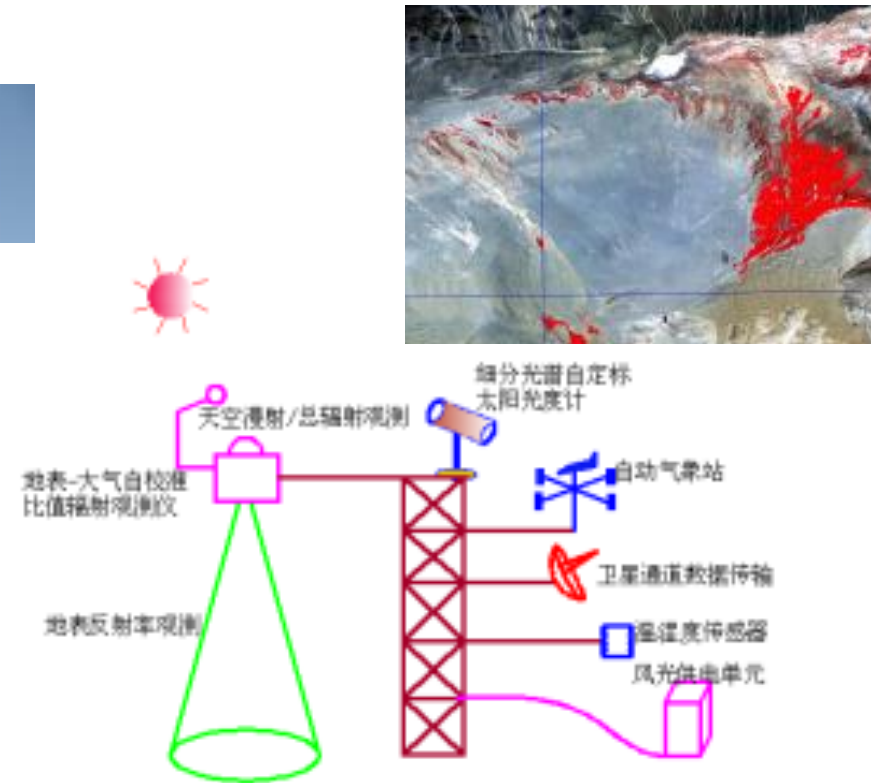


Canopy Puer (MW)



Lake Qinghai (TIR)

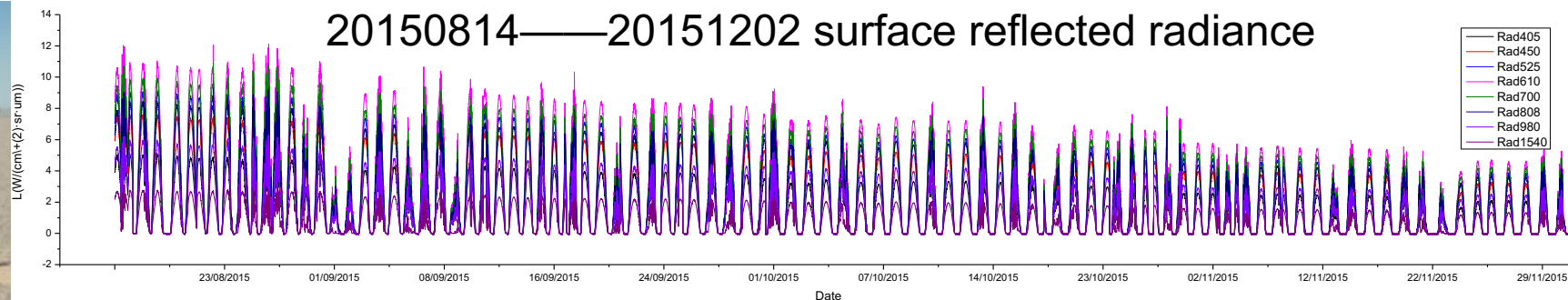
Dunhuang base for Automatic vicarious calibration was established in 2015



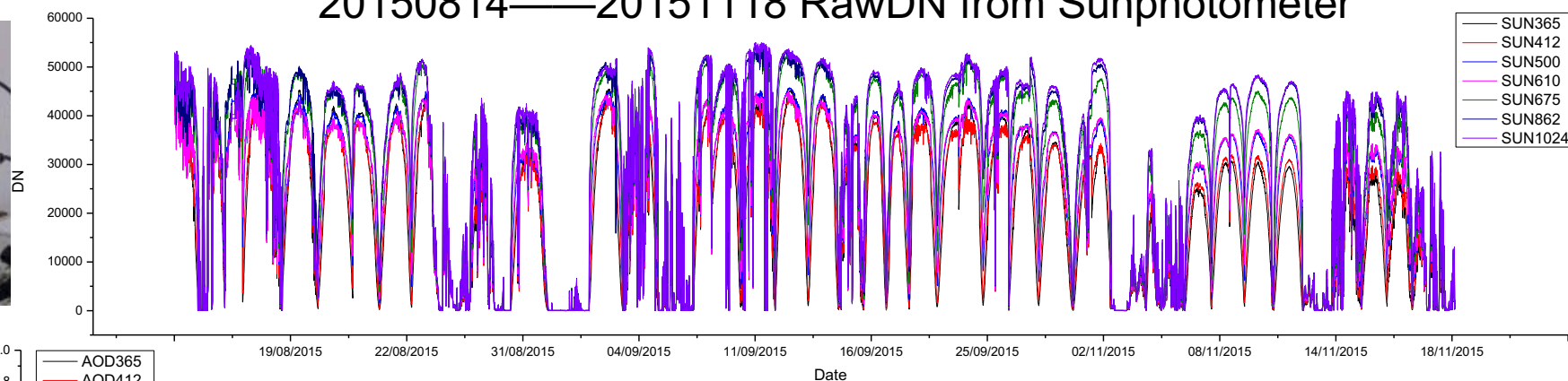
Long term Automatic continuous Measurement at Dunhuang site



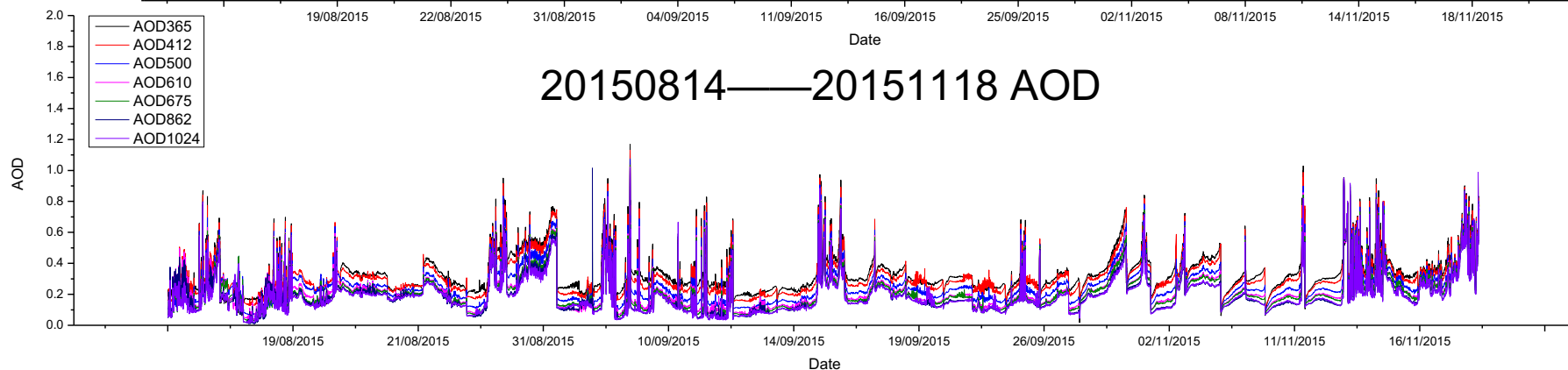
20150814—20151202 surface reflected radiance



20150814—20151118 RawDN from Sunphotometer



20150814—20151118 AOD



Overview of Dunhuang Site By UAV



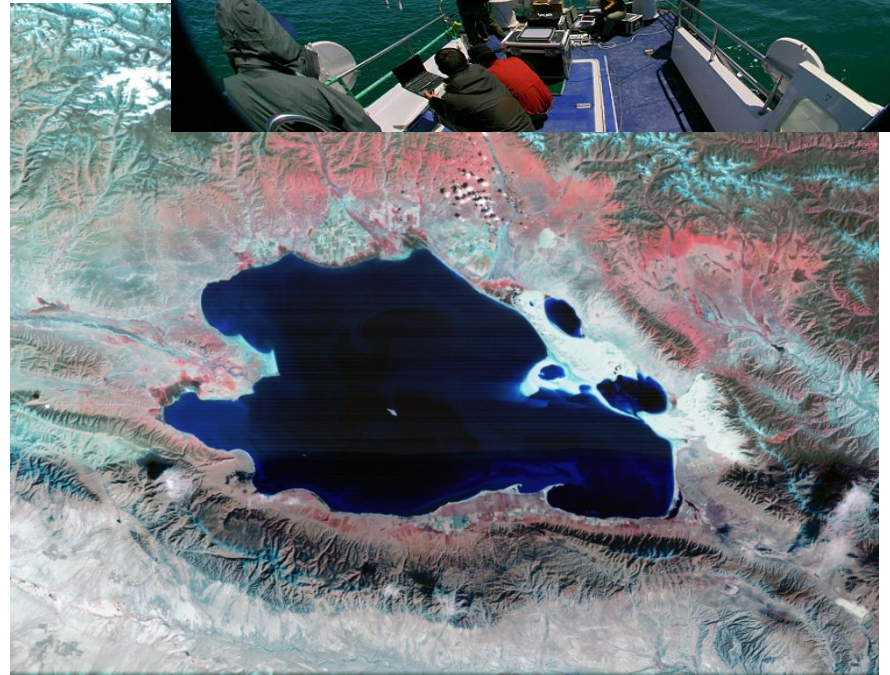
Buoy



Walking thermometer

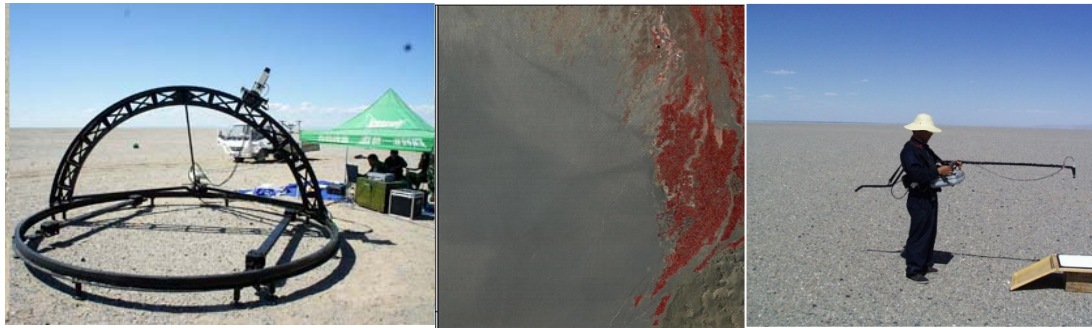


**IR Radiometer
IR981 (Left) VIR981
(Right)**

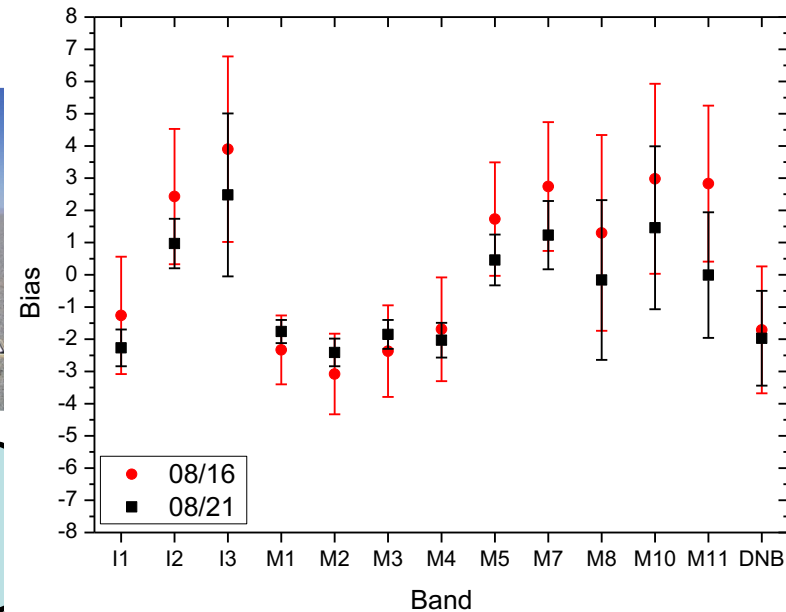


**Lake Qinghaihu for IR
calibration validation**

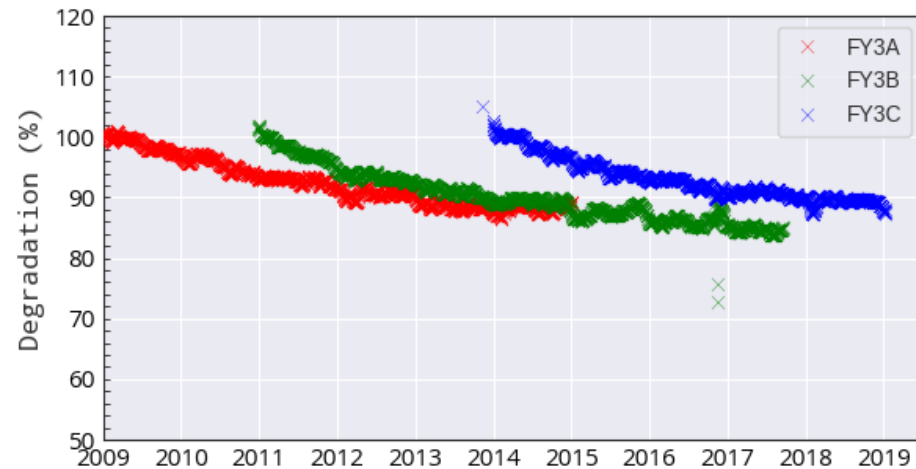
Dunhuang Cal/Val Site(CRCS)



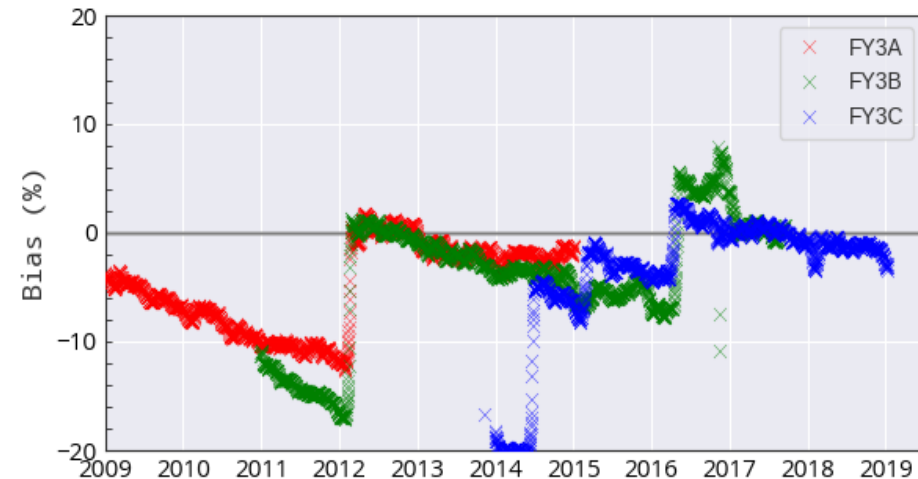
Since the 1990s, CRCS has been the main method operational used for RSB calibration of China remote sensing satellites



FY3ABC+VIRR CH_01 TimeSeries



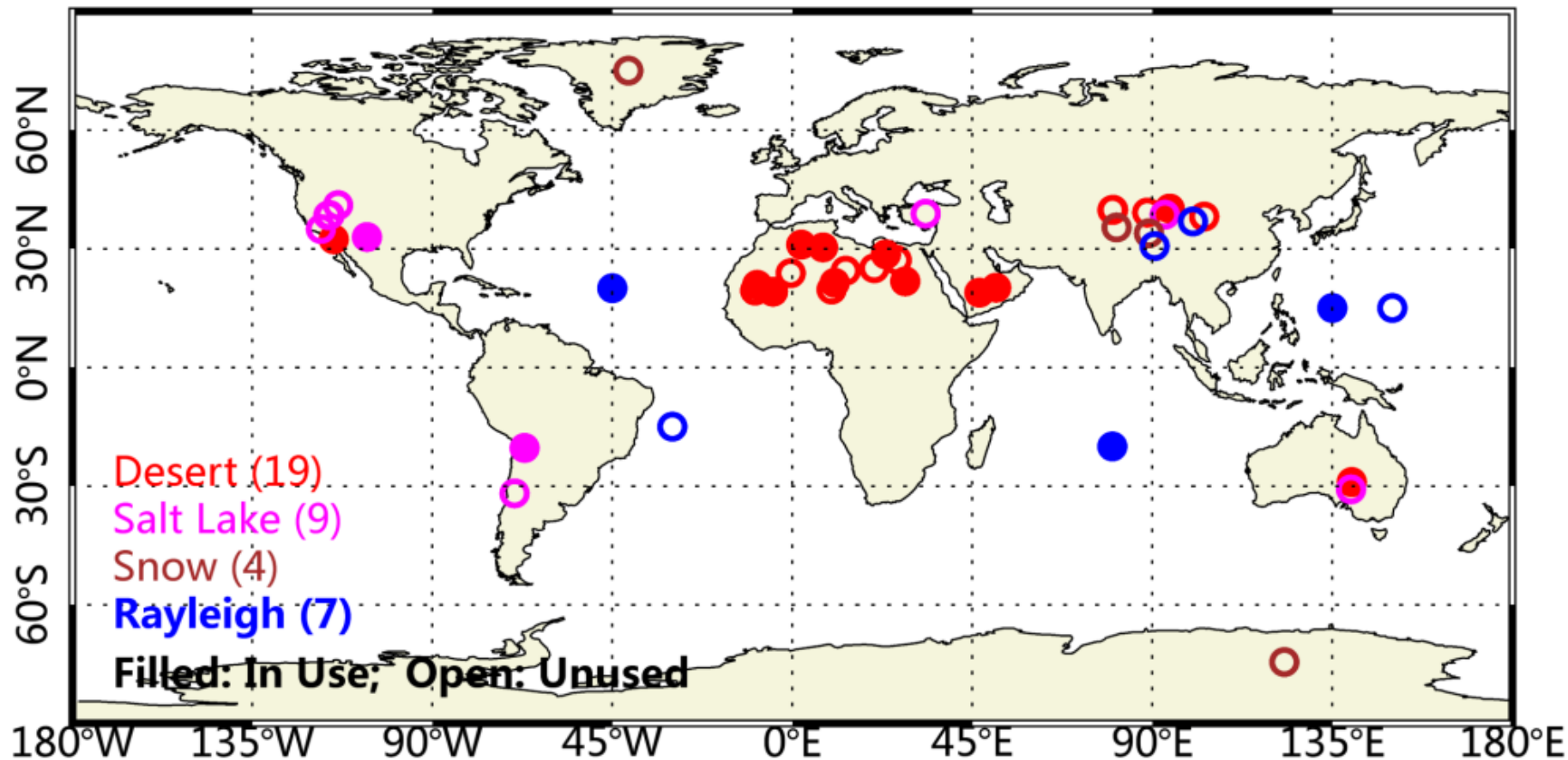
FY3ABC+VIRR CH_01 TimeSeries



Applied in RSB operational calibration updates of FY3A/B/C

Chen et al., 2017. IJRS

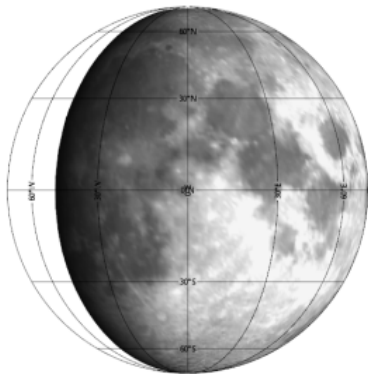
Pseudo-invariant sites (PICs)



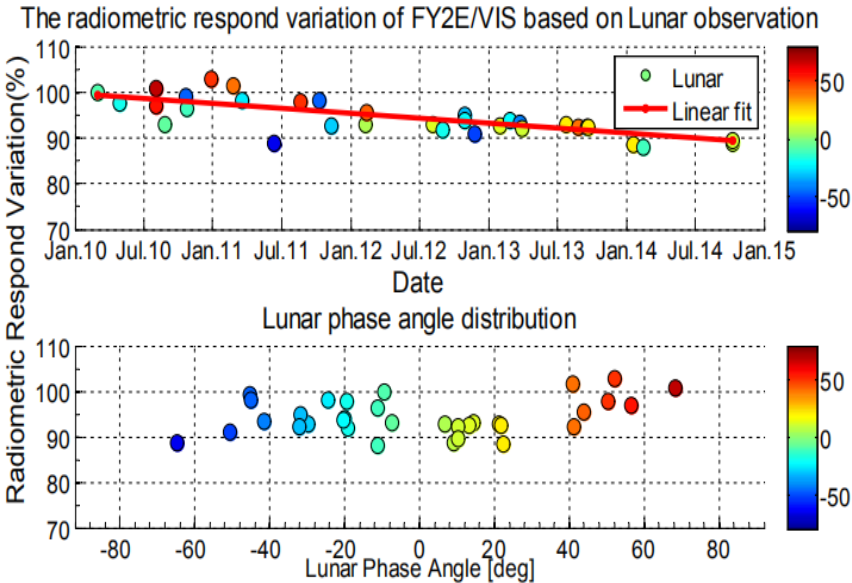
lunar irradiance model and calibration application (results from 863 project : space radiation measurement reference source development)



Lunar observation



Lunar simulation



Zhang, L., P. Zhang, X. Hu, L. Chen, and M. Min, (2017), A novel hyperspectral lunar irradiance model based on ROLO and mean equigonal albedo [J], optik, 142(2017), 657-664

L. Chen, P. Zhang*, R. H. Wu, et al., 2018: Monitoring of visible band radiometric response changes of Fengyun 2 geostationary meteorological satellite using the moon target. Journal of Remote Sensing, 22(2): 211-219.

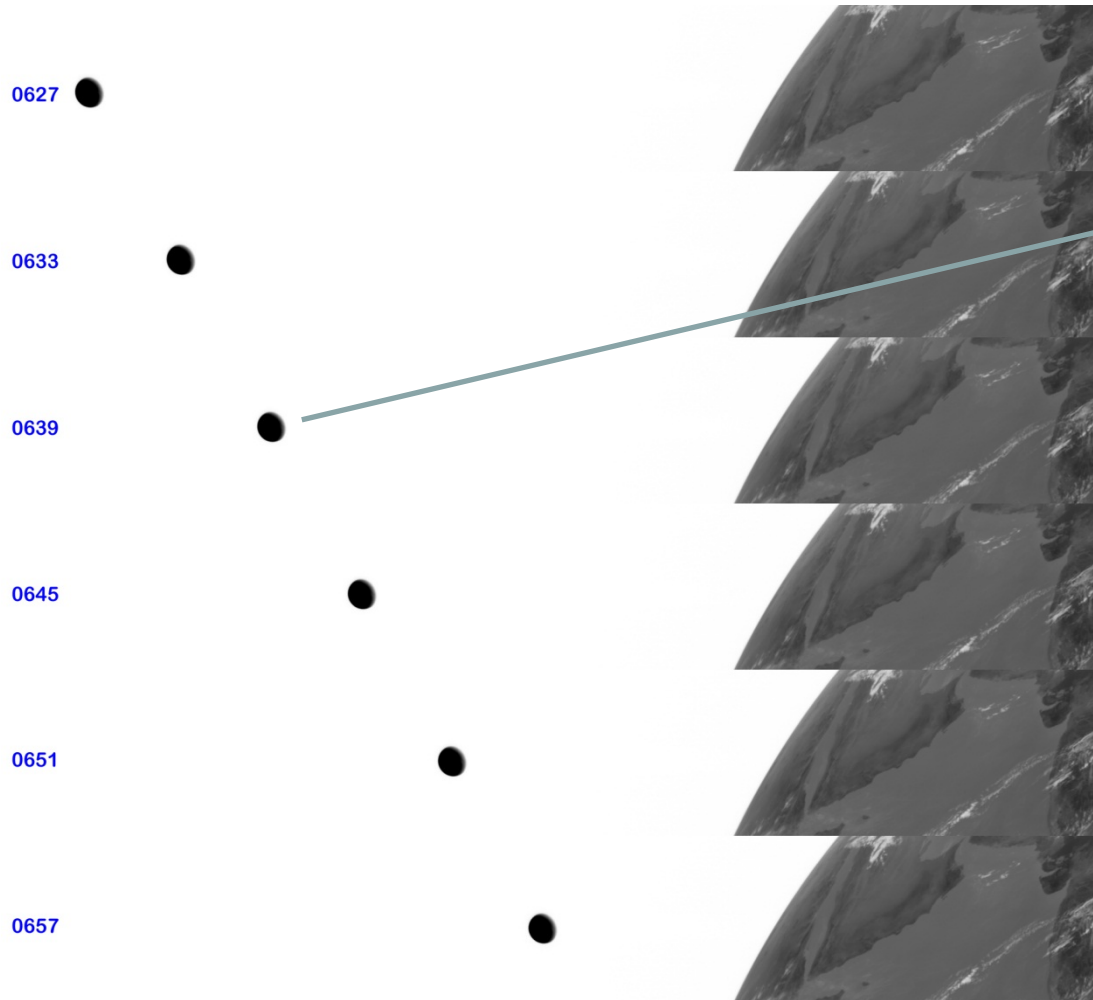
R. H. Wu,P. Zhang*,Z. D. Yang, et al., 2016. Remote Sensing Calibration and Tracking Monitoring Based on Lunar Reflectance [J].Journal of Remote Sensing,20(2):278–289

L. Zhang, P. Zhang, X. Q. Hu, et al., 2017, Lunar illuminance model comparison and ground-based moon observation verification [J]. Journal of Remotely Sensors, 21(6):864-870

2015 Dec.-2016 Mar., Ground-base lunar observation experiment in Lijiang



Lunar image observed by FY-2G on Feb. 7 2015 after changing observation area



Guiding satellite conducts
a lunar observation

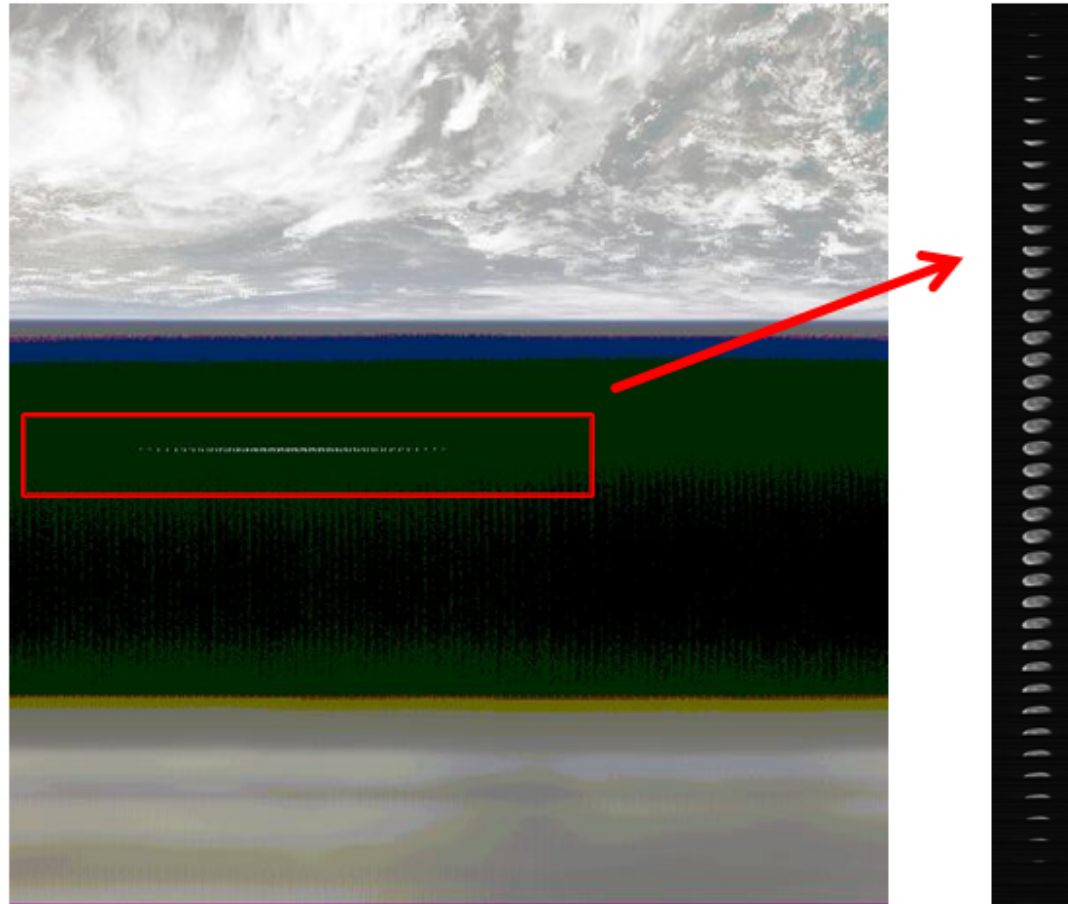


**Lei Yang (CMA): Moon prediction, registration and navigation
for FY satellite**

Matched Lunar Image

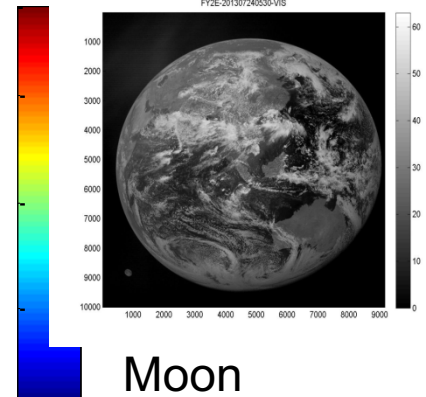
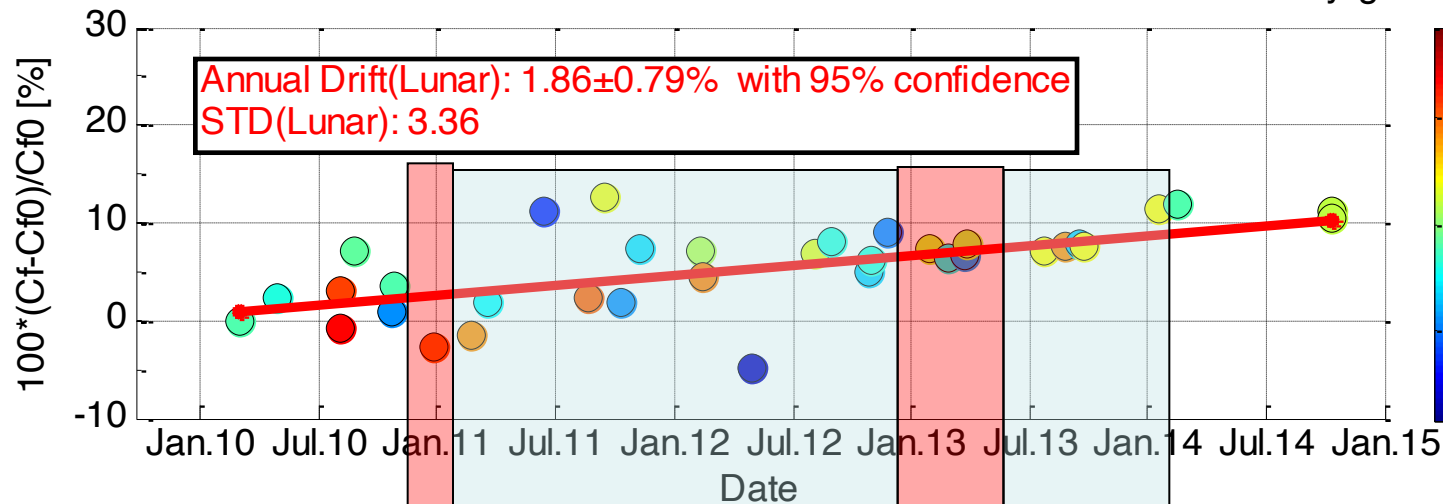
FY-3 visible band calibration

FY-3D lunar observation mode

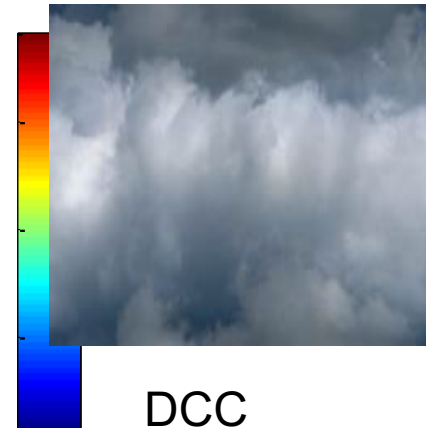
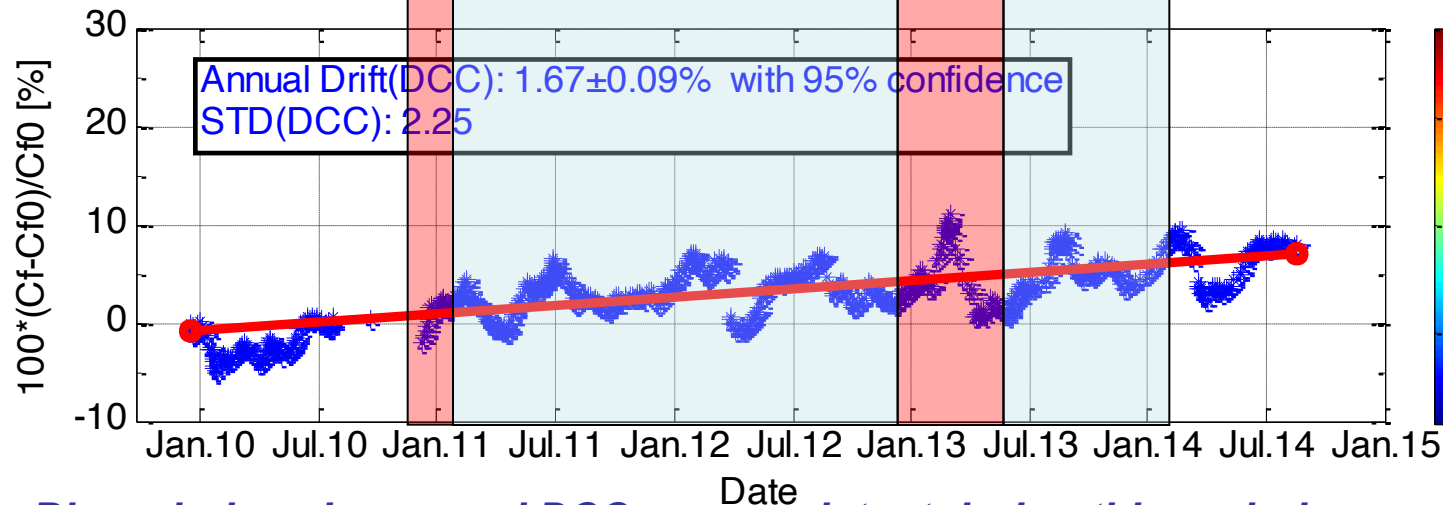


R H Wu (CMA): Lunar data preparation for MERSI

The Variation of the Calibration coefficient at ROLO scale FY2E/VIS @ Straylight



The Variation of the Calibration coefficient of DCC for FY2E/VIS

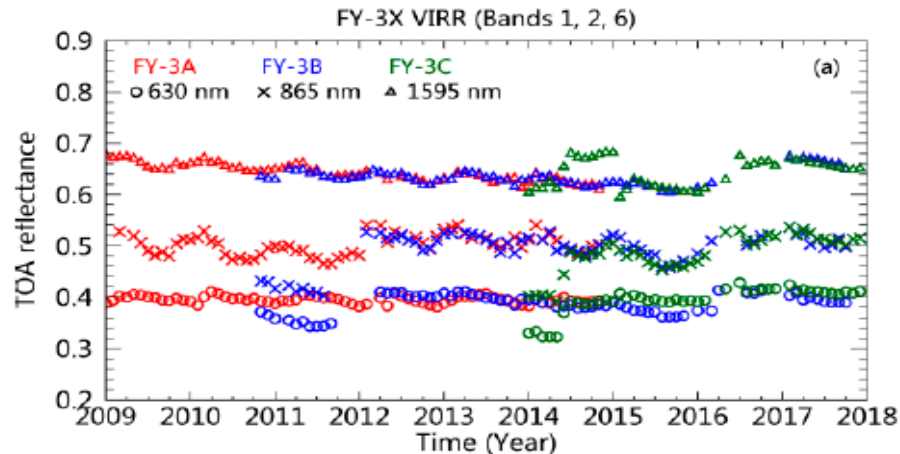


Blue window: Lunar and DCC are consistent during this period

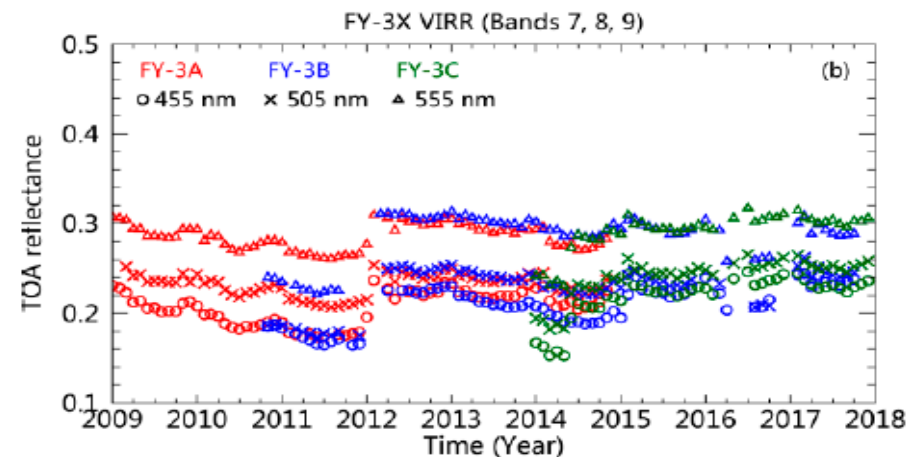
Red window: Lunar and DCC are not consistent

Line Chen(CMA): Lunar data preparation for FY-2

Re-Calibration of FY-3A/3B/3C VIRR RSB by Using PICS

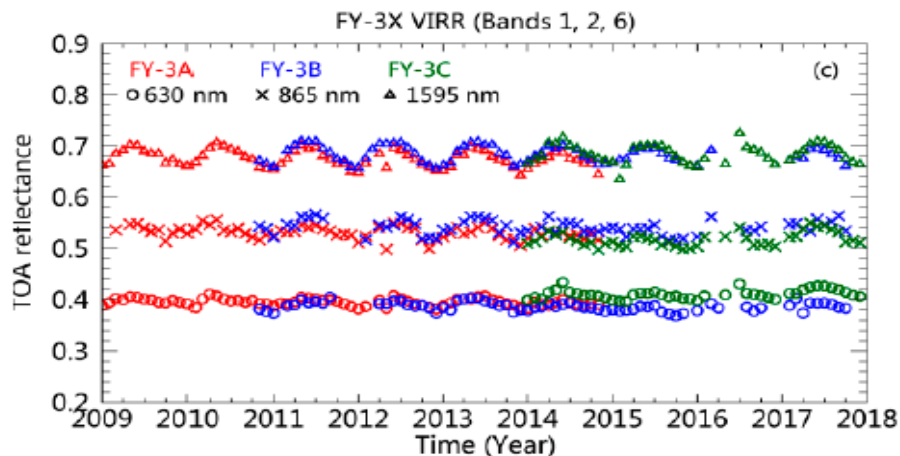


(a)

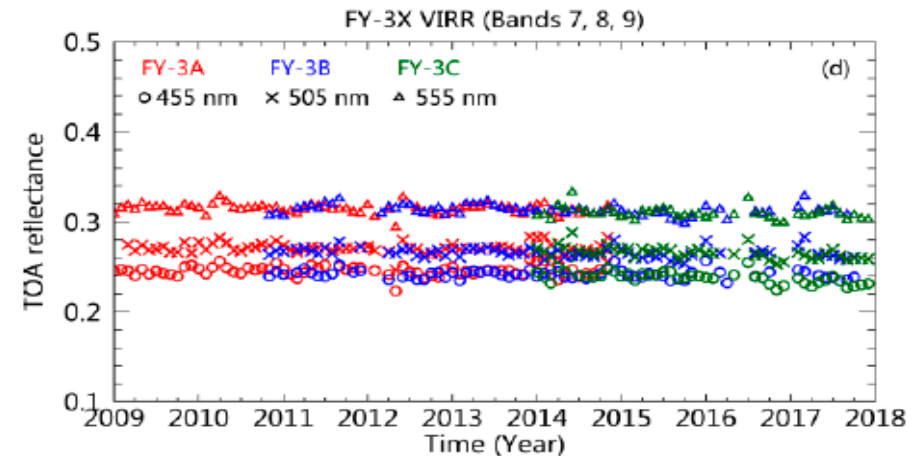


(b)

(a,b) Operational calibration results



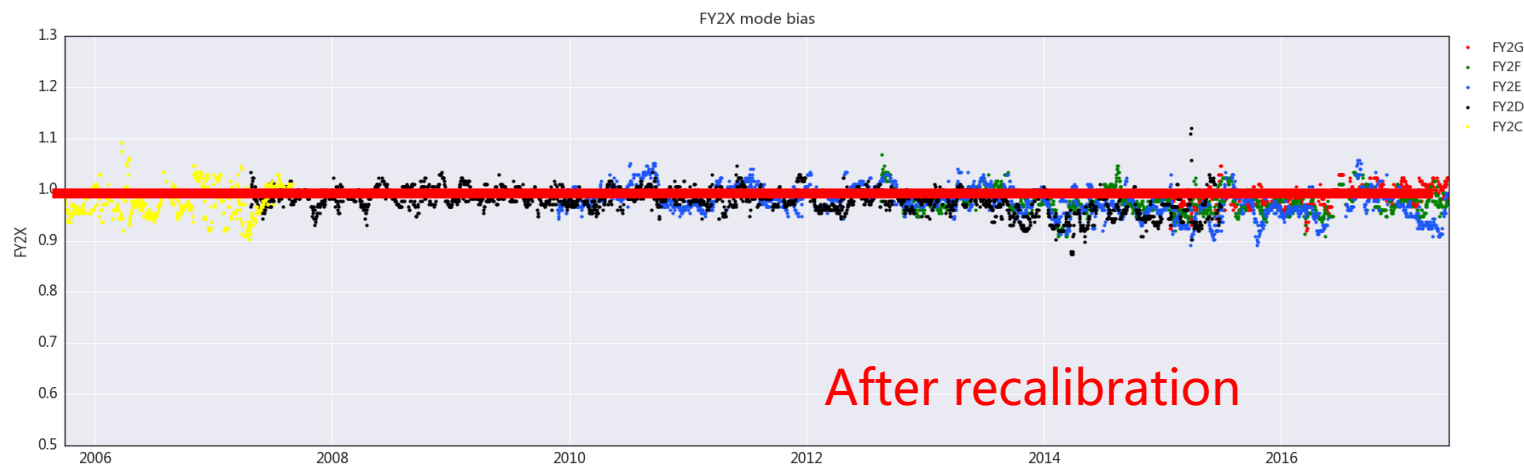
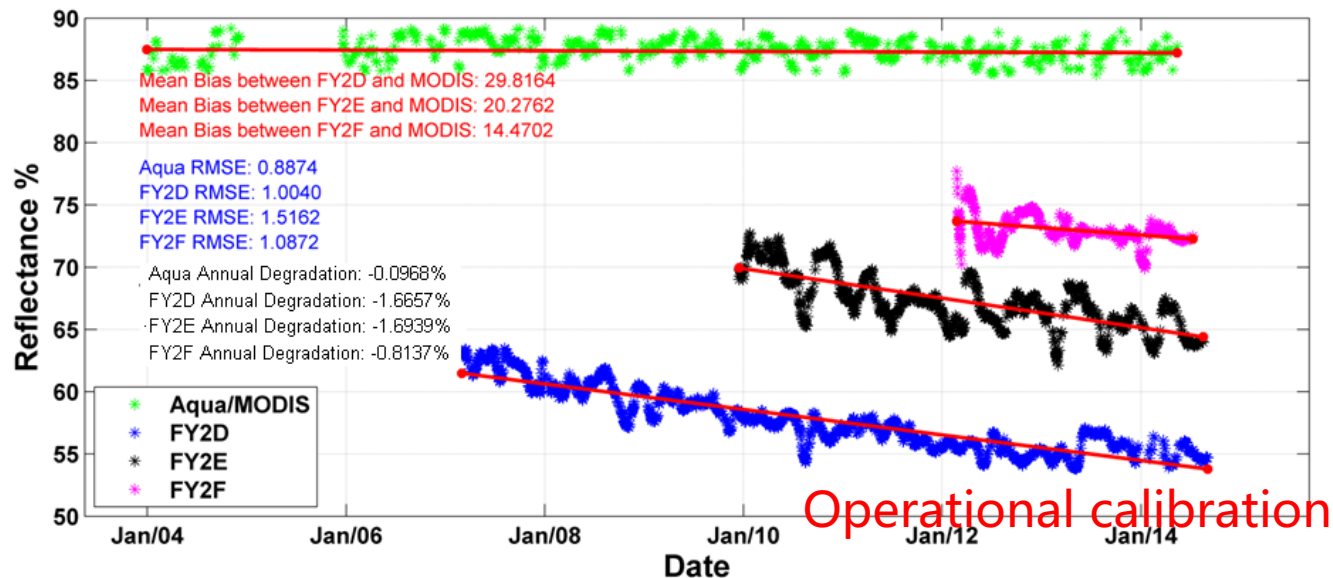
(c)



(d)

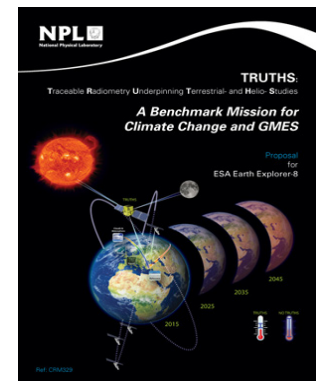
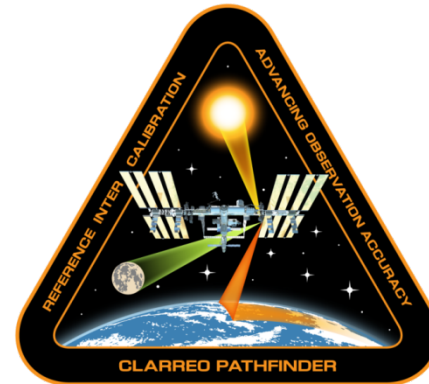
(c,d) recalibrated results using the MST calibration method

Re-Calibration of FY-2C/D/E/F/G VISSR RSB by Using DCC



5. Discussion and Suggestion

- ❑ SI-traceable reference satellite will benefit not only for Climate change monitoring, but also for EO satellites.
- ❑ International cooperation on satellite calibration and SI-traceable instruments and satellite is necessary.
- ❑ FCDR and TCDR from re-calibrated Chinese EOS data are expected to release in 2020 (version interim) and 2021 (version 1).
- ❑ To facilitate the harmonized data among the satellites, the Calibration Community Data (CCD) (such as the measured ICT, DCC, PICs, the Lunar by the instrument) should be defined, sampled and stored.



Second Joint GSICS/IVOS Lunar Calibration Workshop – China 2017

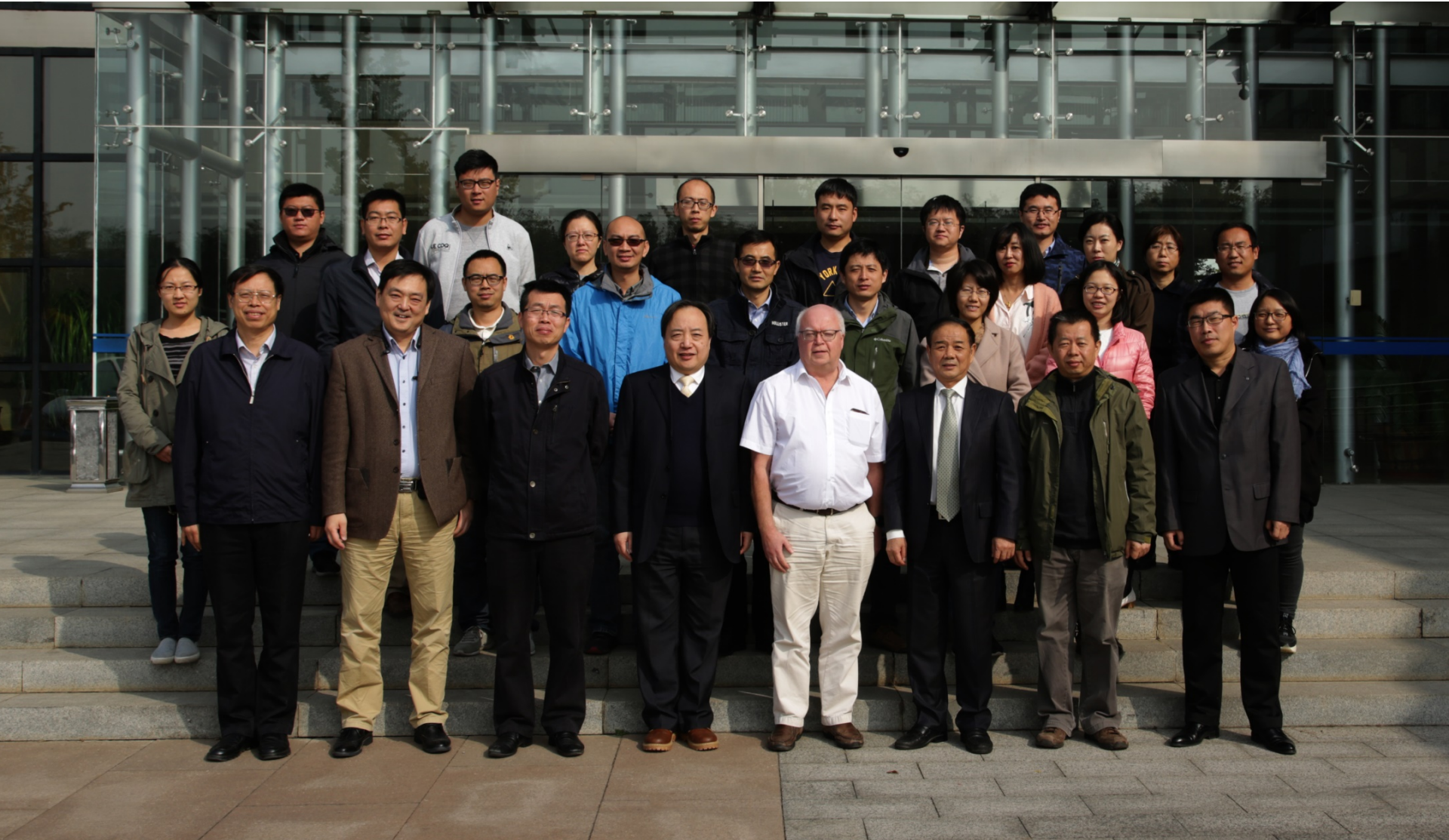


GSICS 2018 Annual Meeting



2018 Annual Meeting
March 19~23, 2018
Shanghai, China

Seminar on Benchmark Sensor – Beijing 2018





Together
For Better

谢

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