The Introduction of Earth Radiation Budget Measurements on Chinese FY-3 Series Satellites

Qiu Hong，Qi Jin，Zhang Peng , Zhang Yan and Hu Liqin

National Satellite Meteorological Center, CMA, Beijing, China

Hong xiaoju

Shanghai Institute of Technical Physics, CAS, Shanghai, China

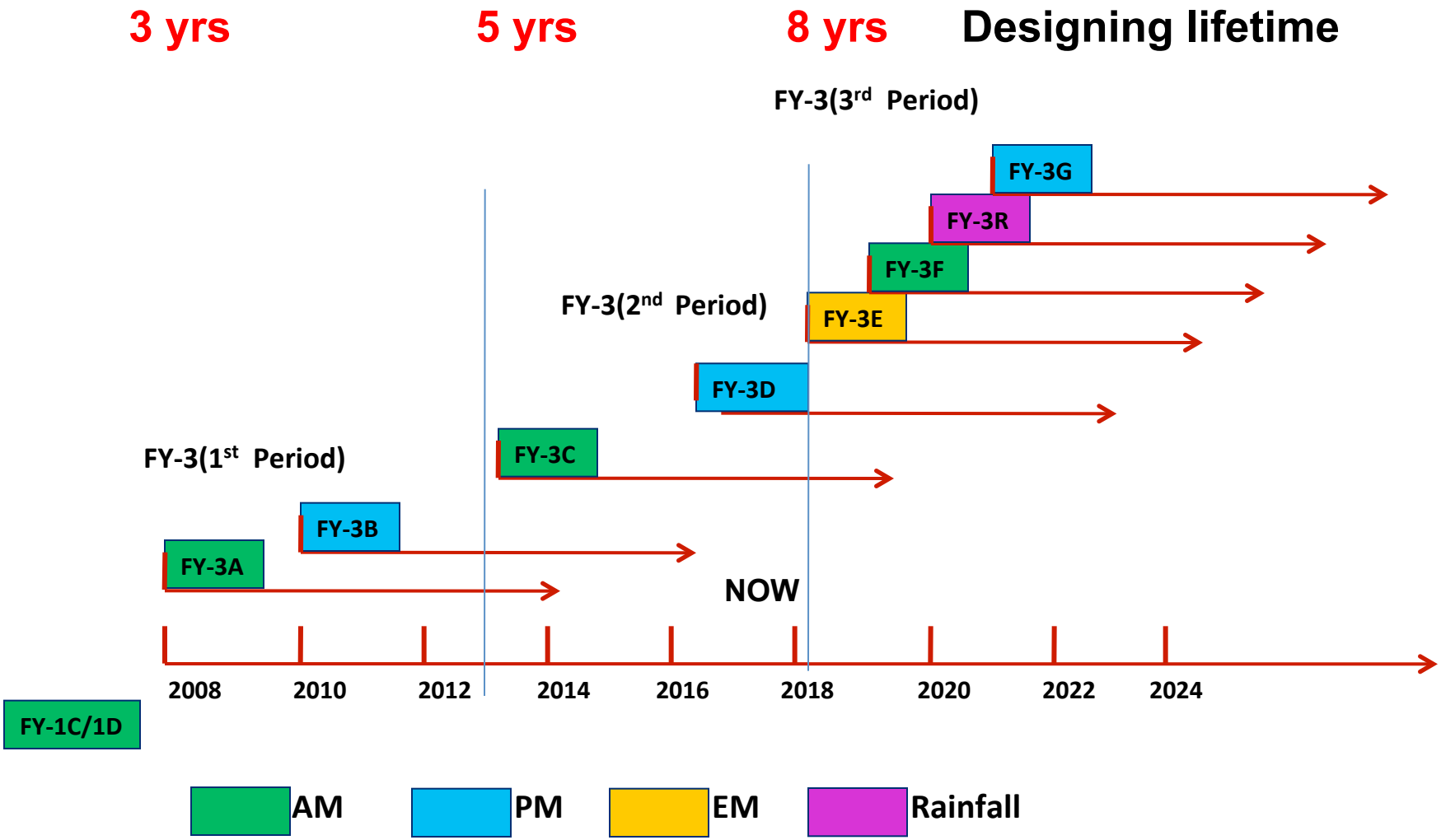
qiuhong@cma.gov.cn

Oct. 20, 2016

Outline

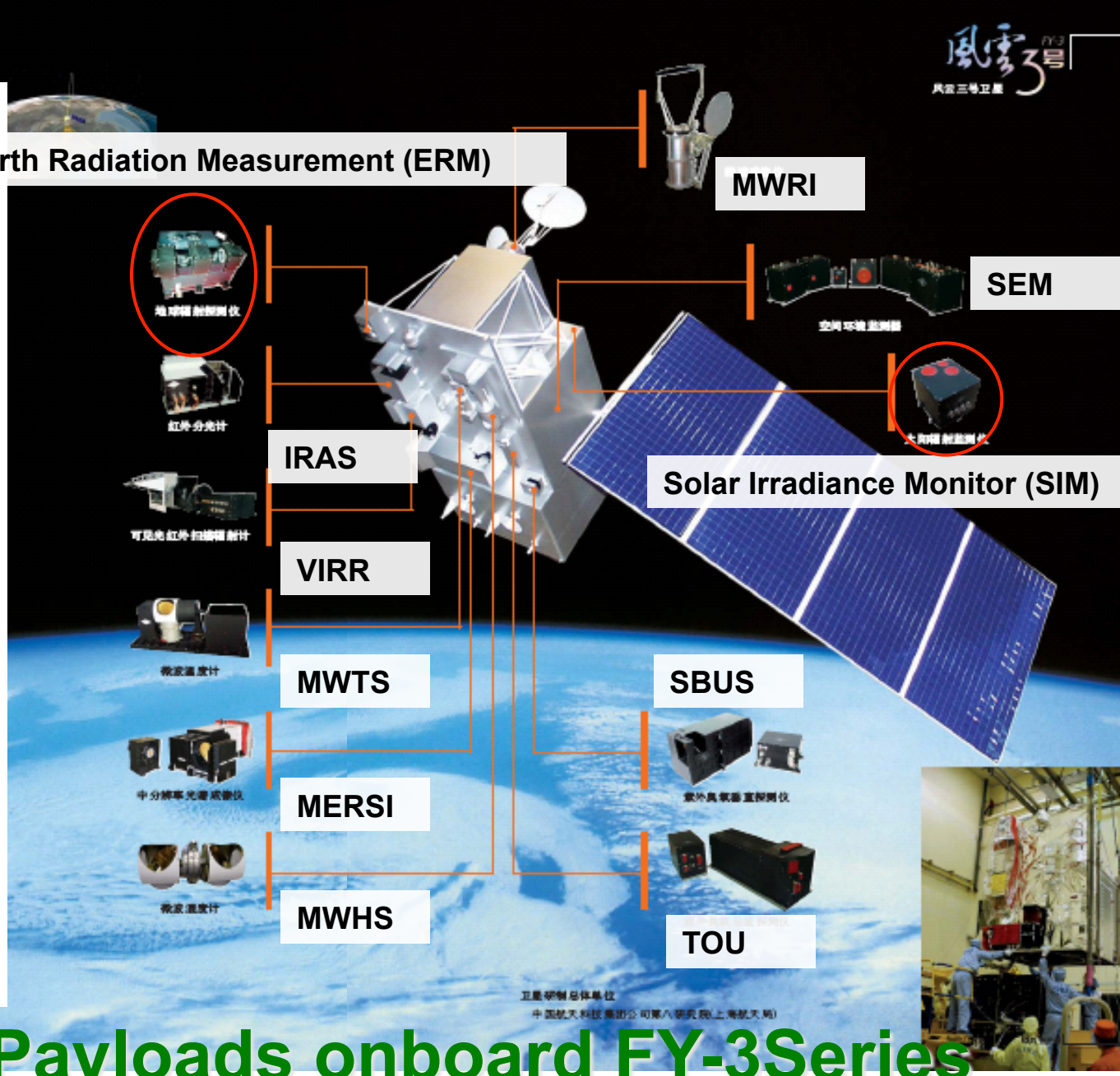
- *The Chinese Second Generation Polar Orbit Meteorological Satellites(FY-3series)*
- *Earth Radiation Budget Measurements on Current FY-3 Satellites*
- *Radiometric Calibration of the ERM*
- *Validation to FY-3/ERMs*
- *ERM on Next Period of FY-3 satellites*

The Route of FY-3 Series Satellites



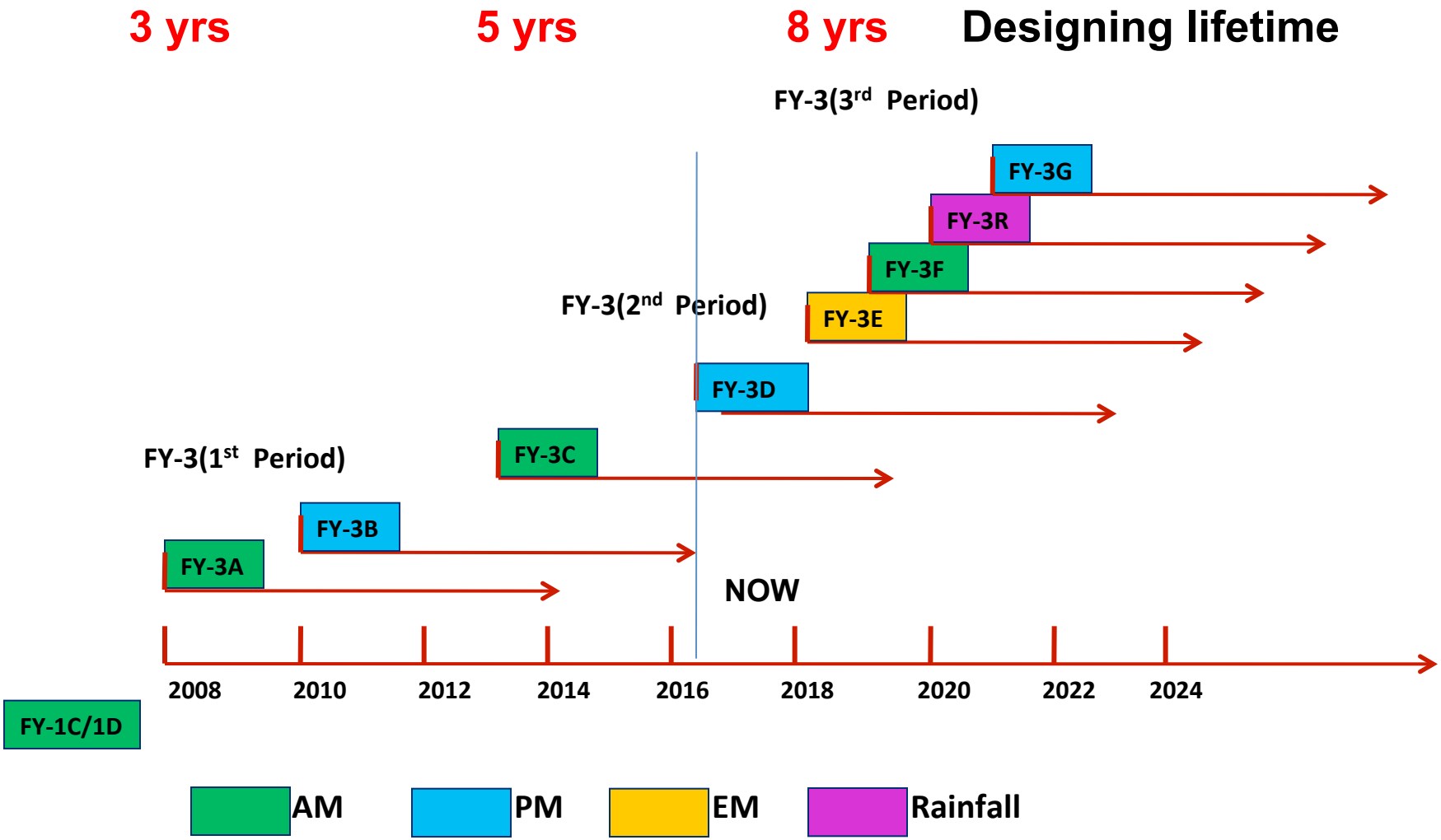
FY-3 Series Satellite

- Orbit type: near polar sun-synchronous
- Orbit altitude: 836km
- Orbit inclination angle: 98.75°
- Revisit time: 5.5 days
- Orbit maintenance eccentricity: ≤0.0015
- Descending node local time: 10:20 (morning orbit)
- Ascending node local time: 13:40 (Afternoon orbit)



Payloads onboard FY-3Series Satellite in the first period

The Route of FY-3 Series Satellites



The Payloads on 2nd Period of FY-3satellites

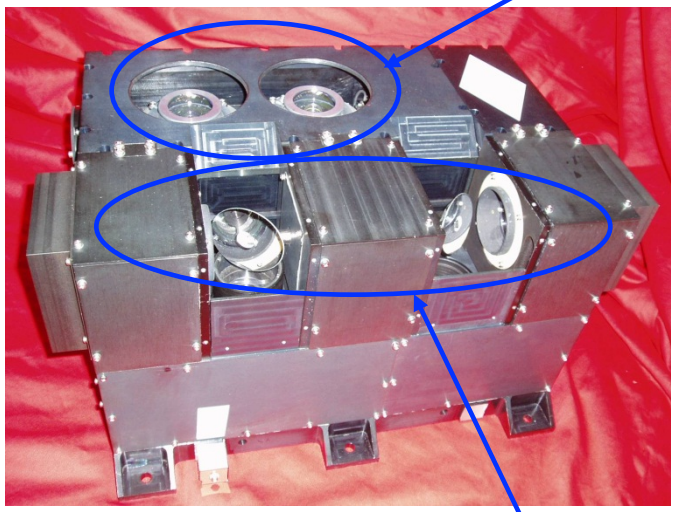
N0.	Sensor	Satellite / Sensor	FY-3C AM Satellite	FY-3D PM Satellite
		Scheduled Launch Date	2013	2016
1	Optical Imagers	MERSIVIRR	✓	MERSI(ONLY)
2	Passive Microwave Sensors	MWTS	√	√
		MWHS	√	√
		MWRI		√
3	Occultation Sounder	GNOS	√	√
4	Ozone	TOU	√	
		SBUS	✓	
5	Hyperspectral Sensors	HIRAS	IRAS	√
		GAS (Greenhouse Gases Absorption Spectrometer)		✓
6	ERB Observation Sensor Suite	ERM	✓	
		SIM	√	
7	Space Weather Sensor Suite	SEM	√	✓
		Wide Angle Aurora Imager		
		Ionosphere photometer		✓
		Solar X-EUV Imager		✓

Outline

- The Chinese Second Generation Polar Orbit Meteorological Satellites(FY-3series)
- *Earth Radiation Budget Instruments on Current FY-3 Satellites*
- *Radiometric Calibration Design of the ERMs*
- *Validation to FY-3/ERMs*
- *ERM on Next Period of FY-3 satellites*

The Earth Radiation Measurement (ERM)s on Current FY-3 Series

WFOV NonScanner Channels



The photo of ERM on FY-3A/B/C

NFOV Scanner Channels

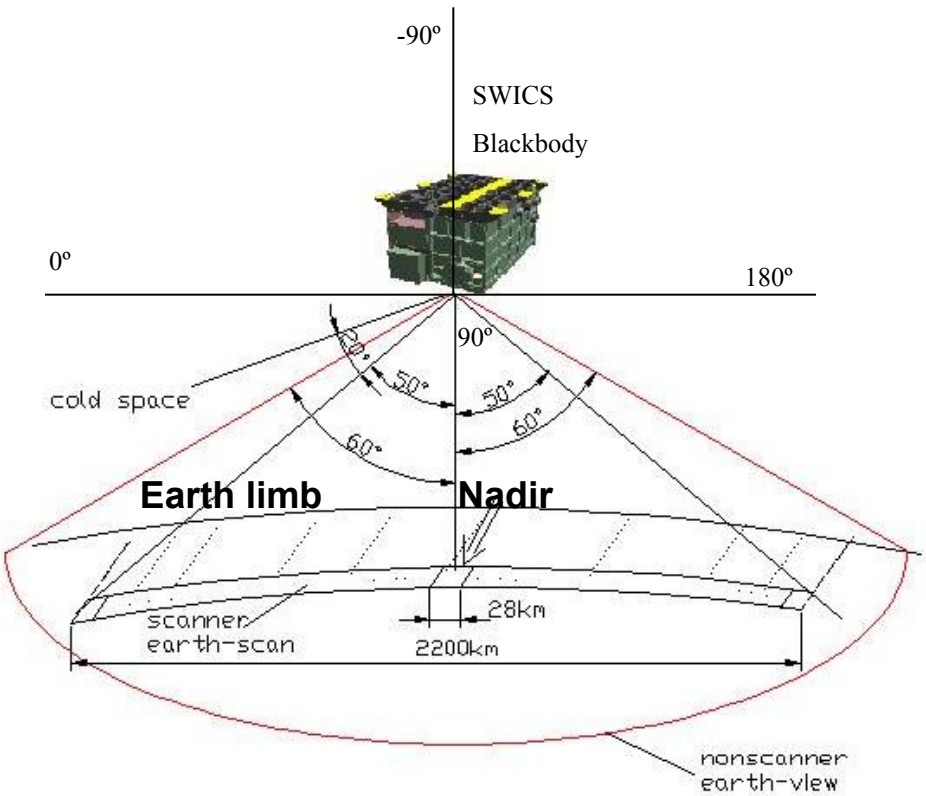
The Specifications of ERM NonScanner(WFOV)

Channel	0.2～>3.8μm	0.2～50μm
FOV	120°	120°
Dynamic range	0～370$Wm^{-2}Sr^{-1}$	0～500$Wm^{-2}Sr^{-1}$
accuracy *	1%	0.8%(0.5%)
Noise	0.4$Wm^{-2}Sr^{-1}$	0.4$Wm^{-2}Sr^{-1}$
Long-term stability in 2(5) years **	< 1%	< 1%

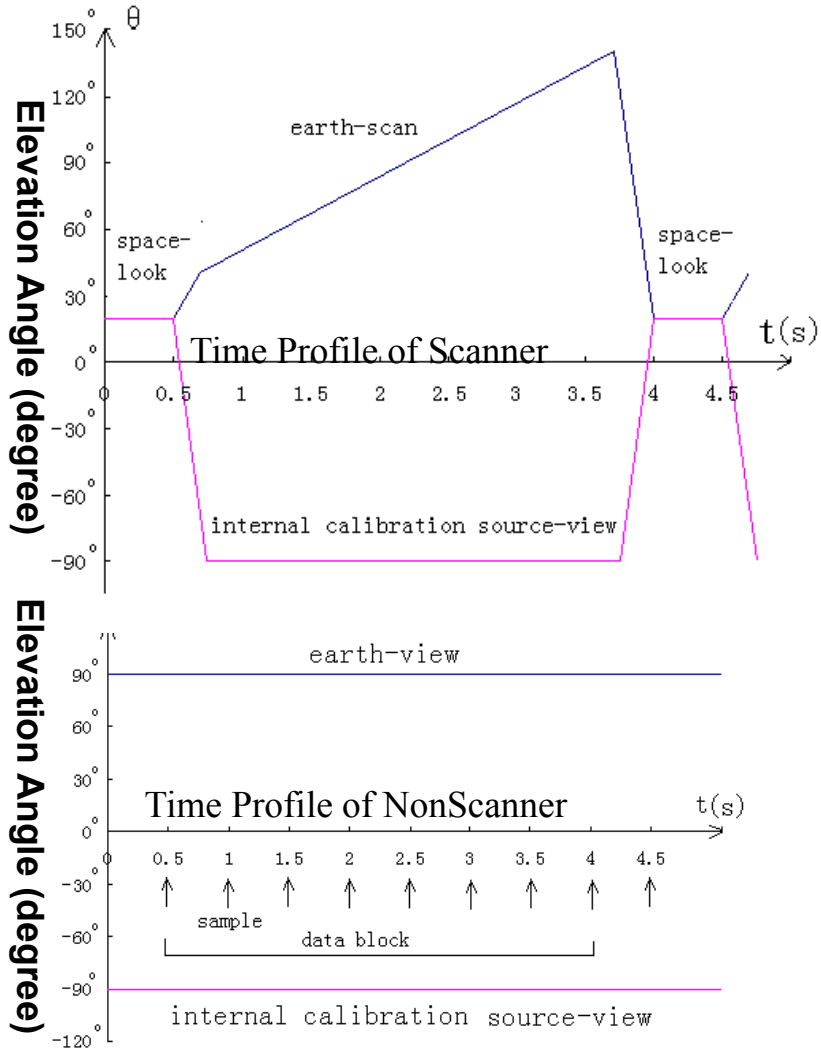
The Specifications of ERM Scanner(NFOV)

Channel	0.2～>3.8μm	0.2～50μm
FOV	2°×2°	2°×2°
Scanning range	±50°	±50°
Dynamic range	0～370$Wm^{-2}Sr^{-1}$	0～500$Wm^{-2}Sr^{-1}$
accuracy *	1%	0.8%(0.5%)
Noise	0.4$Wm^{-2}Sr^{-1}$	0.4$Wm^{-2}Sr^{-1}$
Long-term stability in 2 (5)years **	< 1%	< 1%

ERM Scanning Characteristics



The Scanning Characteristics of ERM NFOV Scanner (black) and WFOV Non-Scanner (purple).

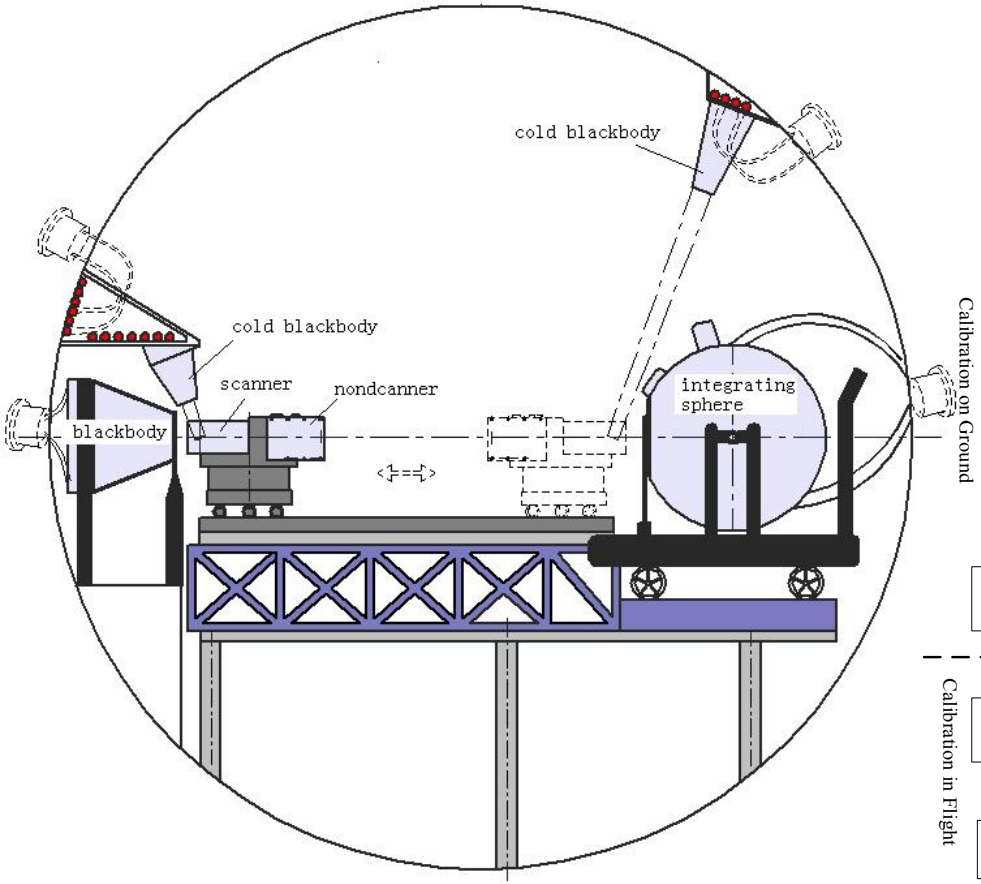


The time profile of NFOV Scanner (up) and WFOV NonScanner (down) for earth view (black) and internal calibration source view (purple)

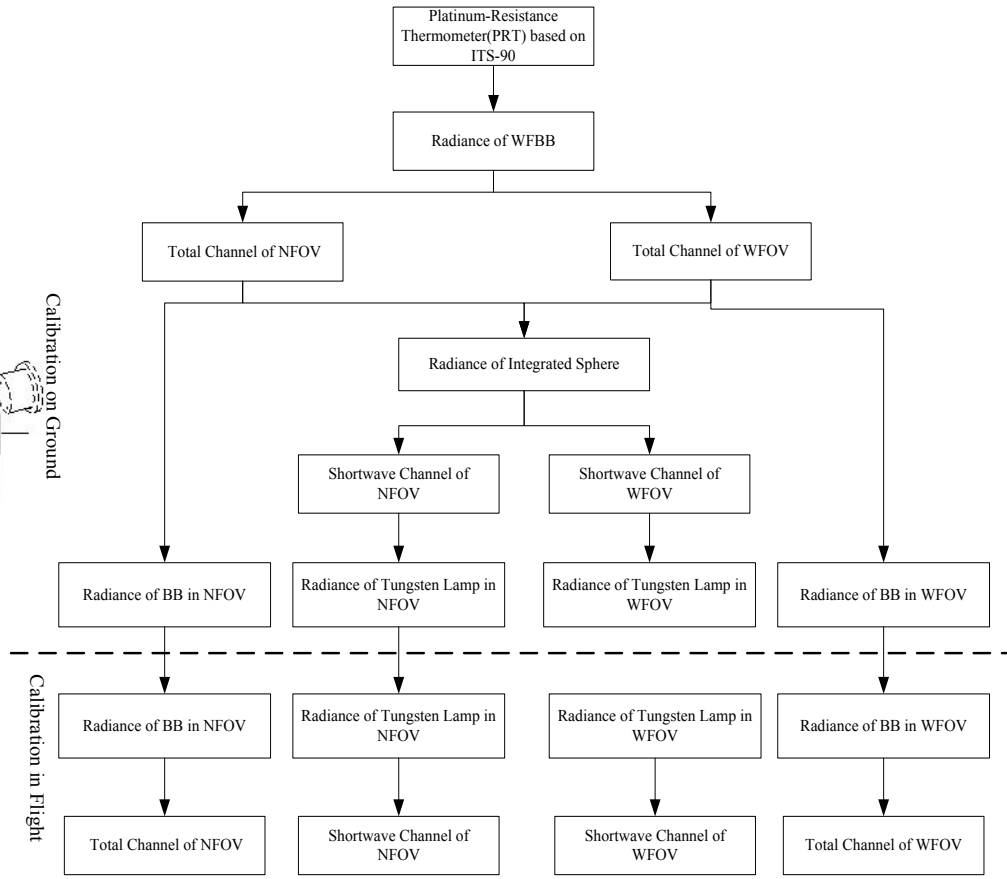
Outline

- The Chinese Second Generation Polar Orbit Meteorological Satellites(FY-3series)
- Earth Radiation Budget Instruments on Current FY-3 Satellites
- *Radiometric Calibration Design of the ERMs*
- *Validation to FY-3/ERMs*
- *ERM on Next Period of FY-3 satellites*

The Radiative Calibration of ERM



ERM Radiative Calibration Chamber at Ground

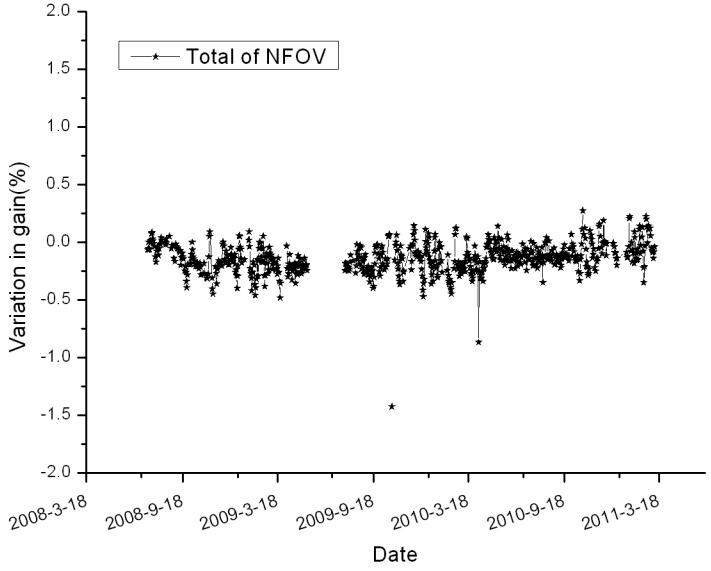


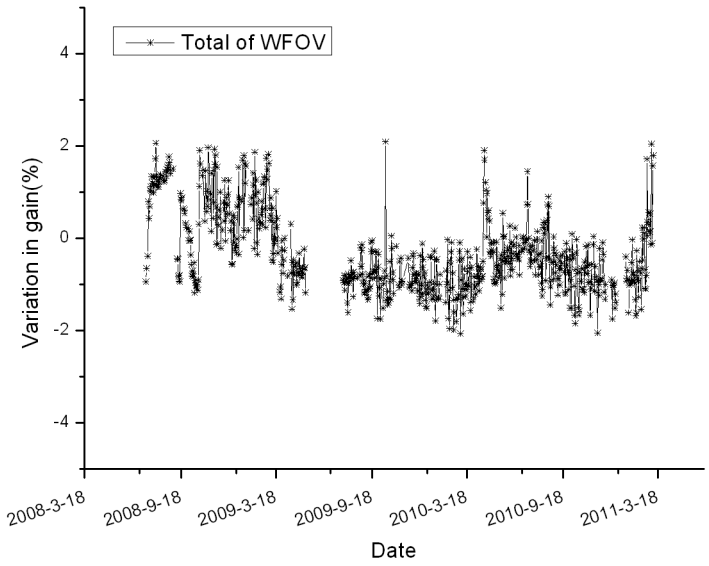
The flow chart of ERM Radiative Calibration

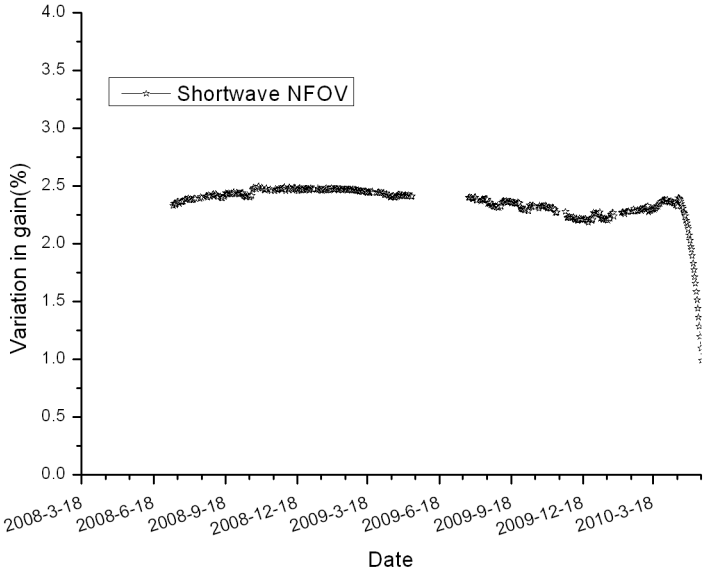
Outline

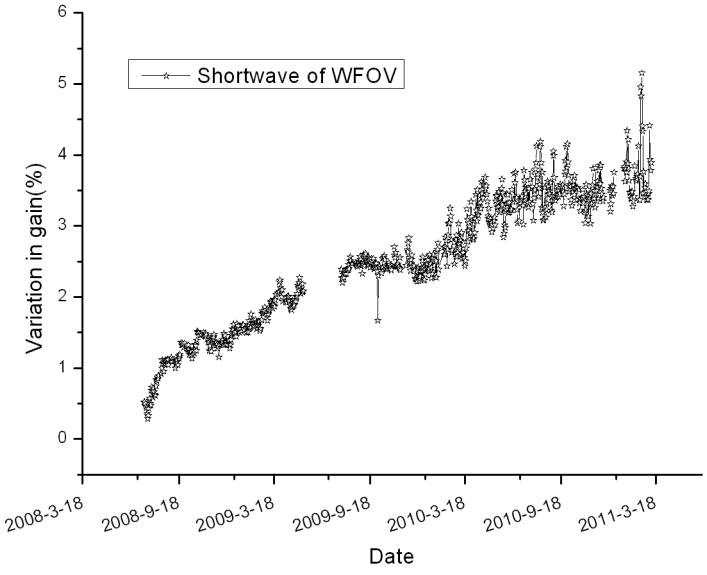
- The Chinese Second Generation Polar Orbit Meteorological Satellites(FY-3series)
- Earth Radiation Budget Instruments on Current FY-3 Satellites
- Radiometric Calibration Design of the ERMs
- *The stability of ERMs on orbit*
- *Validation to FY-3/ERMs*
- *ERM on Next Period of FY-3 satellites*

The Variation of Radiometric gains of ERM on FY-3A

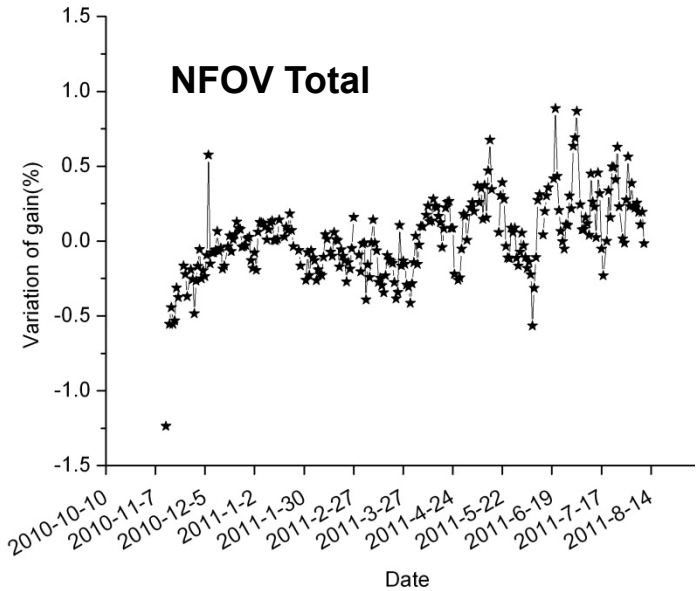


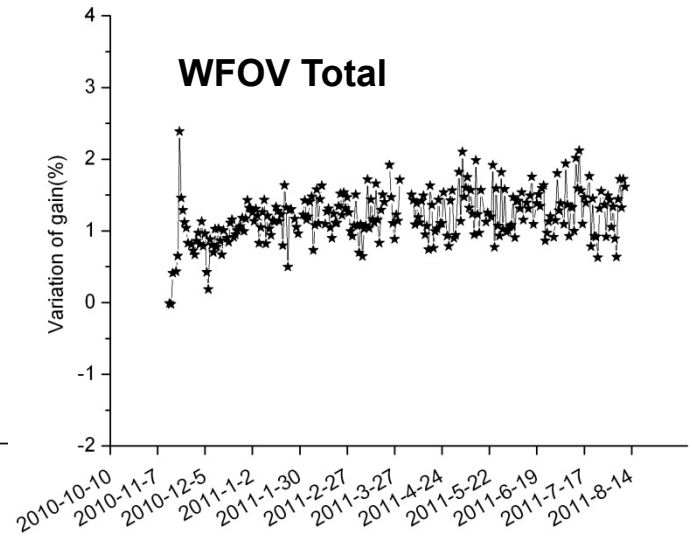


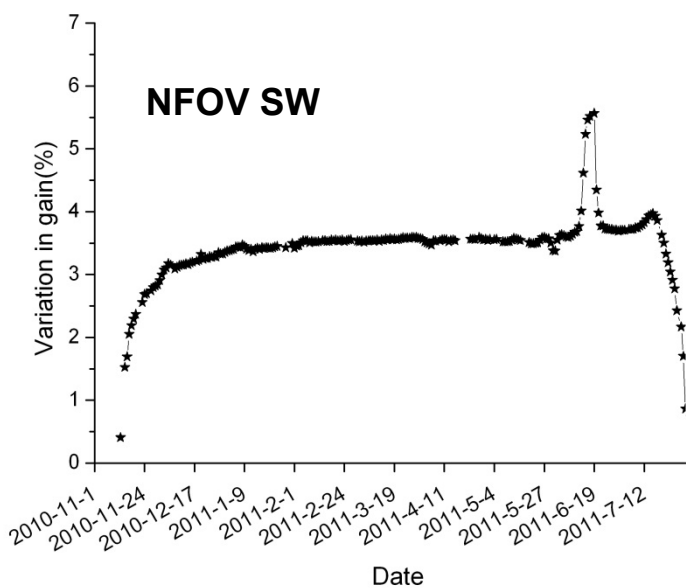


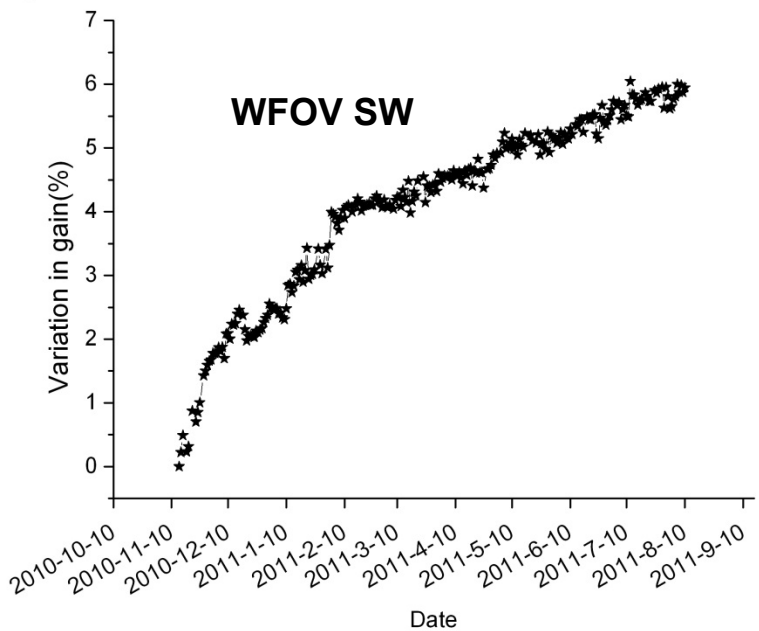


The Variation of Radiometric gains of ERM on FY-3B





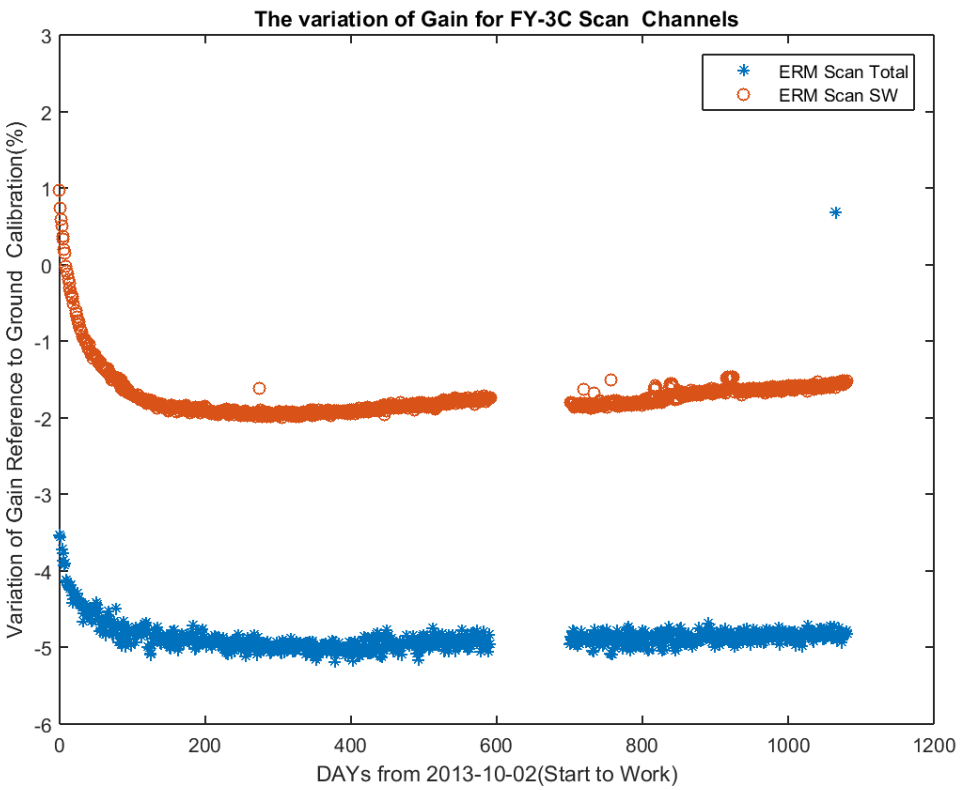




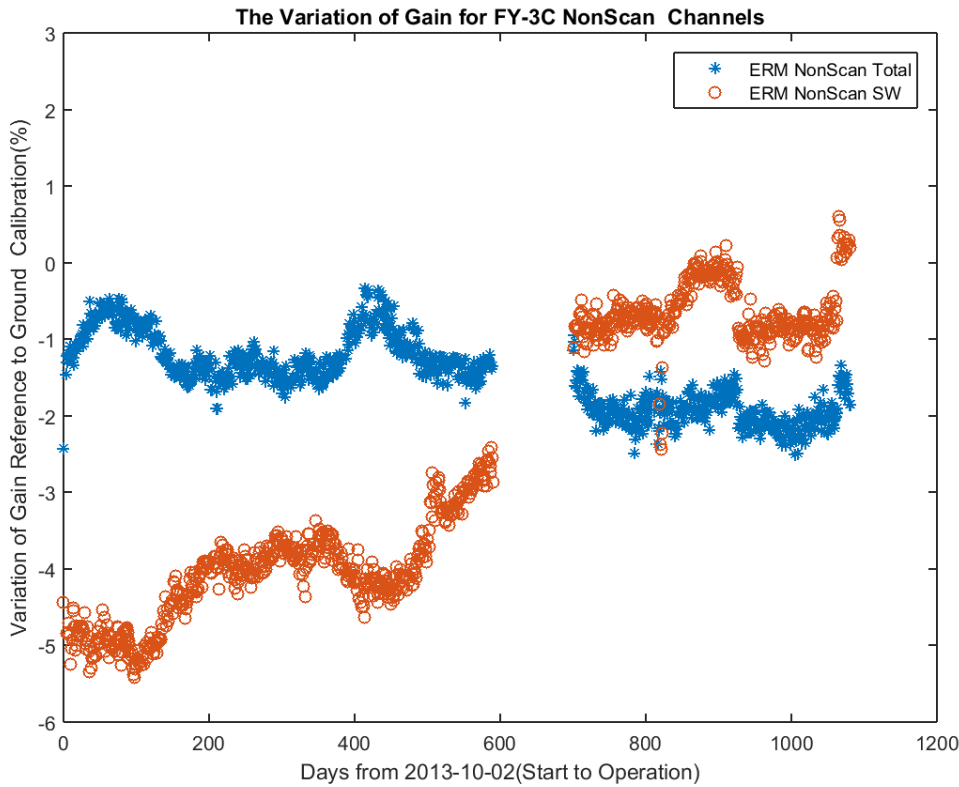
The Variation of Gains for NFOV Scanner

The Variation of Gains for WFOV NonScanner

The Variation of Radiometric gains of ERM on FY-3C



The Variation of Gains for NFOV Scanne

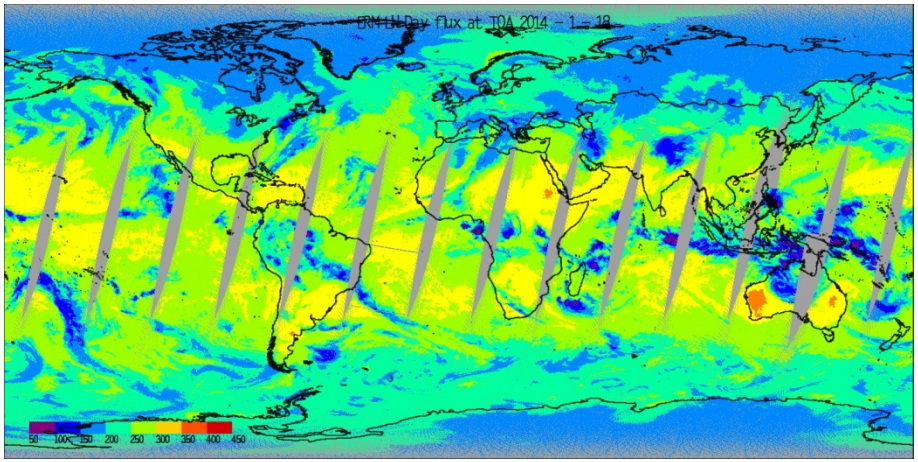


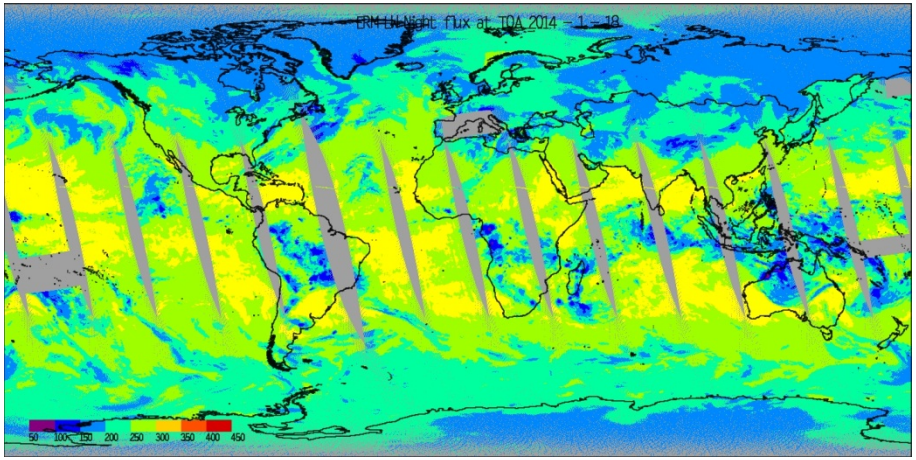
The Variation of Gains for WFOV NonScanner

Outline

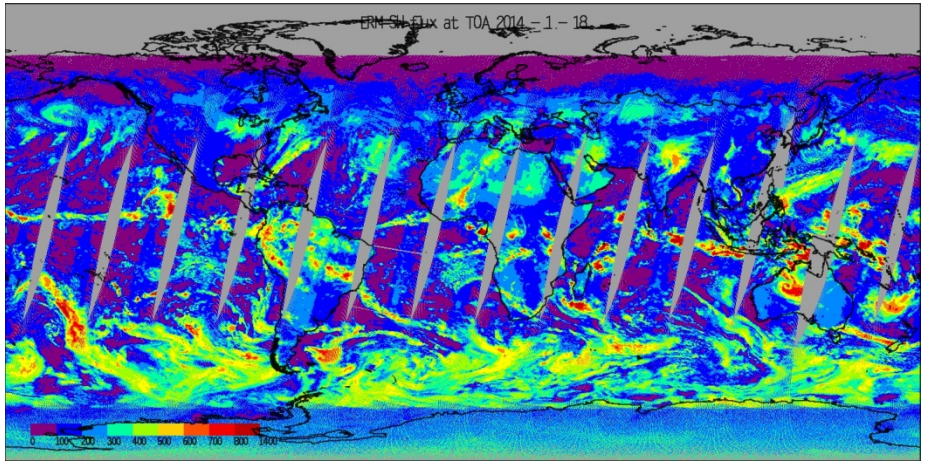
- The Chinese Second Generation Polar Orbit Meteorological Satellites(FY-3series)
- Earth Radiation Budget Instruments on Current FY-3 Satellites
- Radiometric Calibration Design of the ERMs
- The stability of ERMs on orbit
- *Validation to FY-3/ERMs*
- *ERM on Next Period of FY-3 satellites*

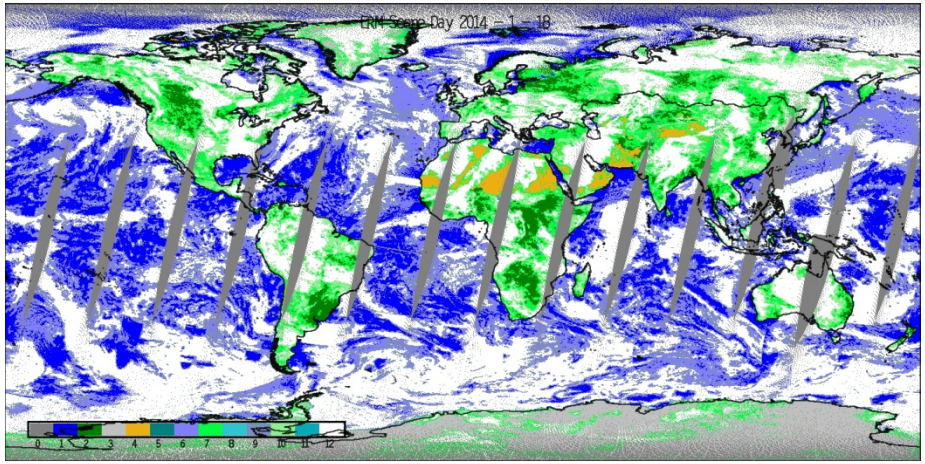
The LW and SW Flux at TOA from ERM on FY-3C





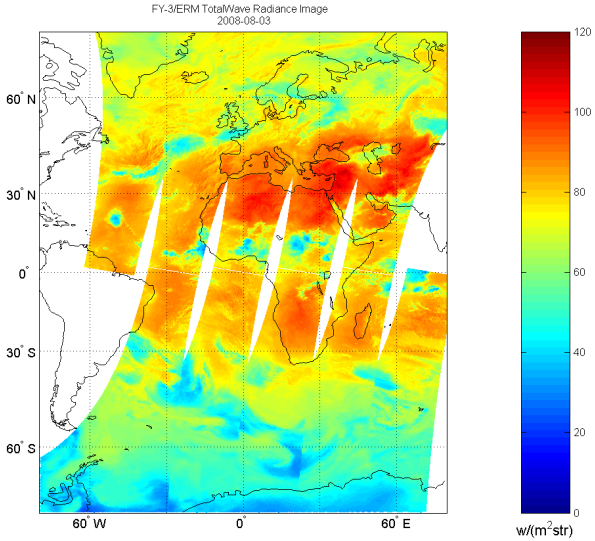
The upwards LW Flux at daytime (left) and nighttime（Jan.18 2014）

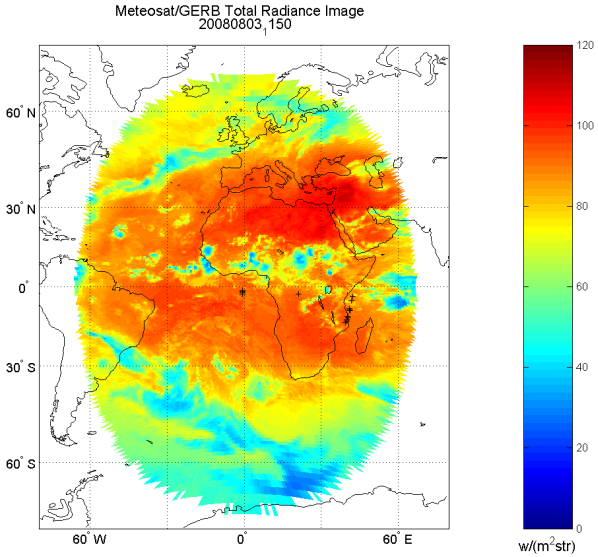


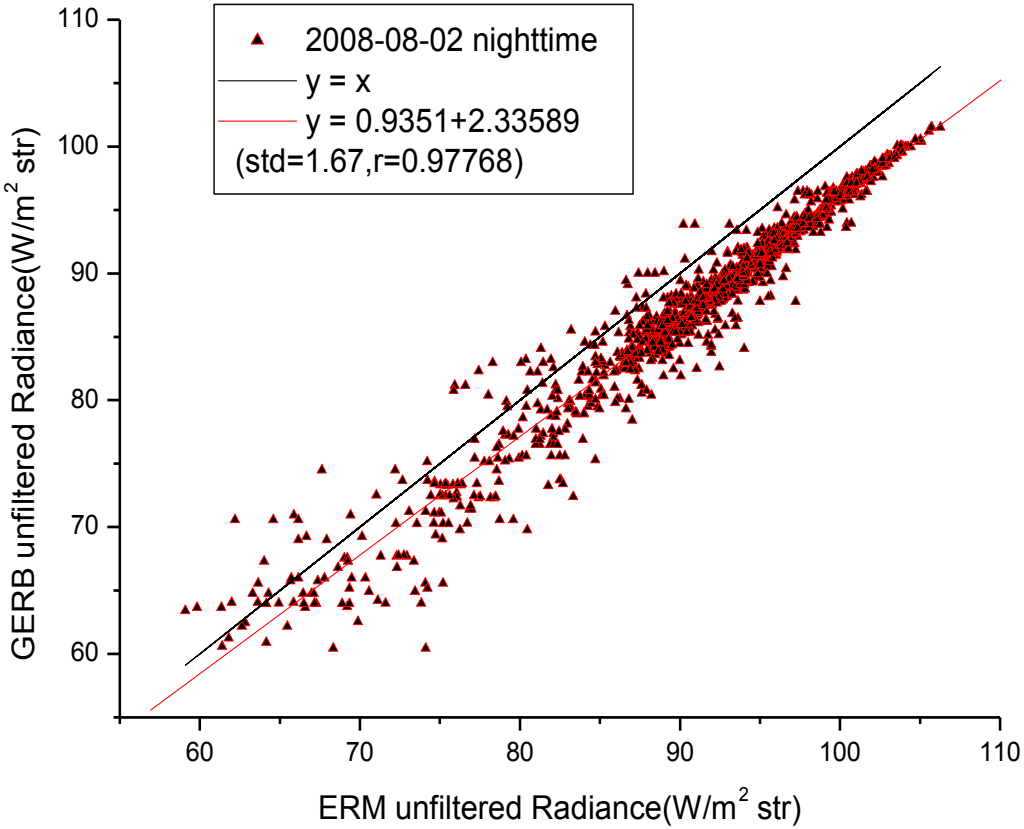


The upwards SW Flux at daytime (left) and Scene Type （Jan.18 2014）

Validation to ERM on FY-3A with GERB/L2 unfiltered radiance

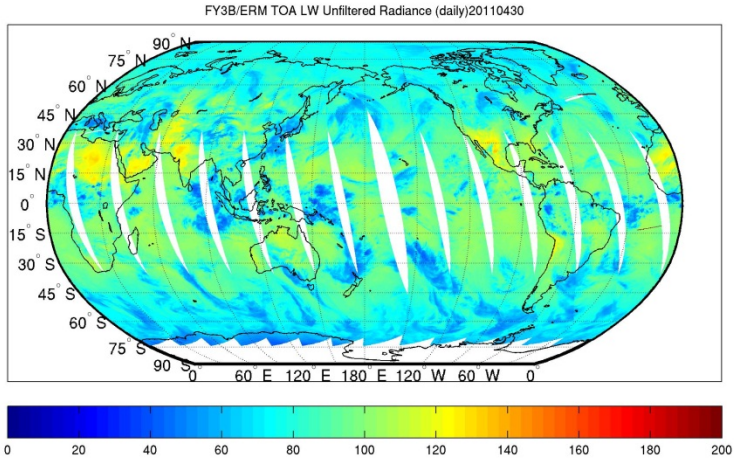




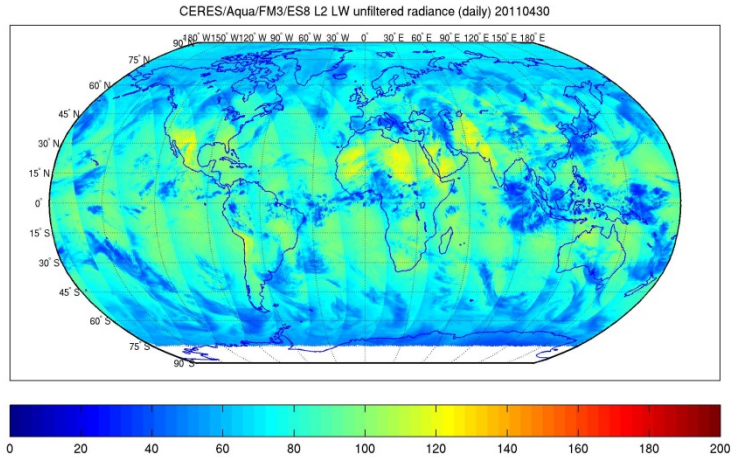


Validation of ERM on FY-3B
Comparing the earth radiance from ERM with Aqua/CERES

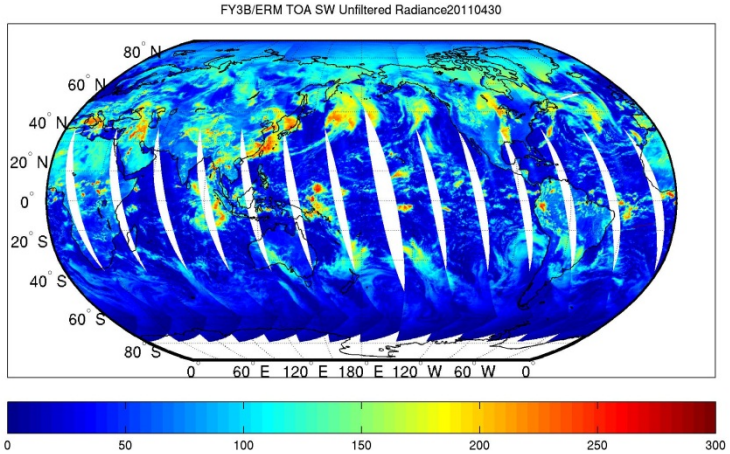
LW Unfiltered Radiance from ERM



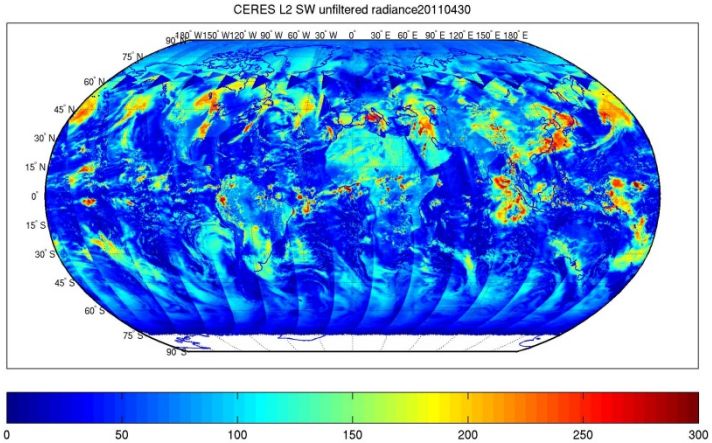
LW Unfiltered Radiance from CERES



SW Unfiltered Radiance from ERM

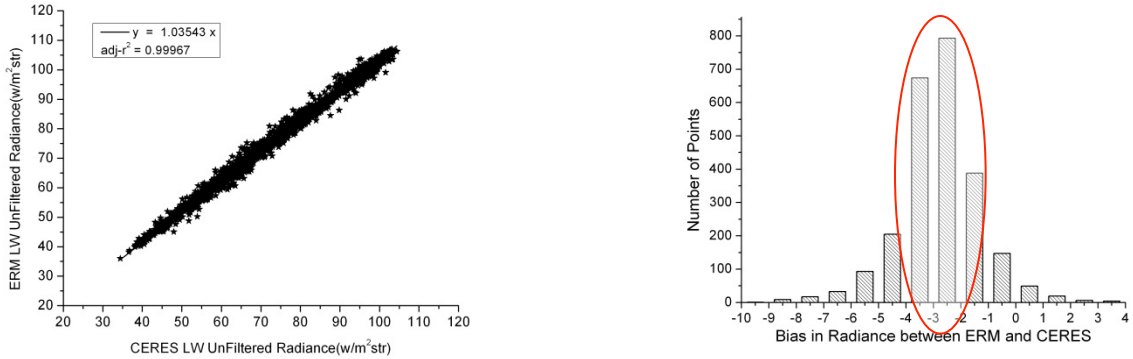


SW Unfiltered Radiance from CERES

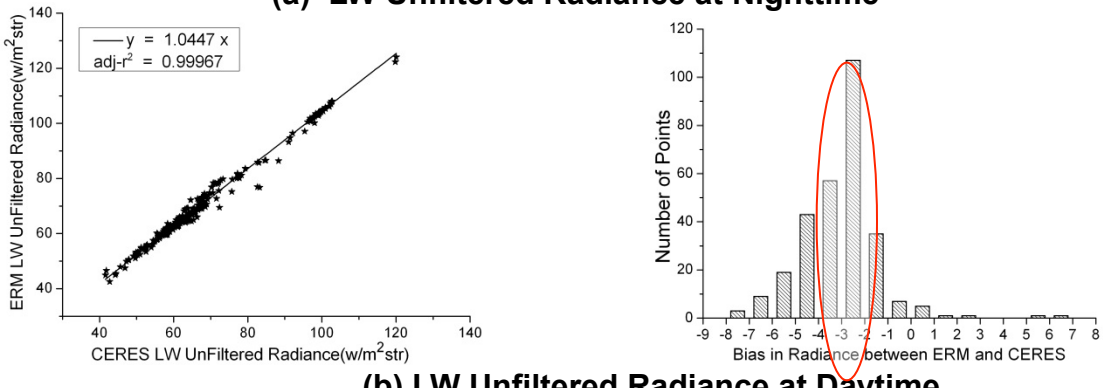


The LW and SW Unfiltered Radiance from ERM/FY-3B and Aqua/CERES (Apr.30th,2011)

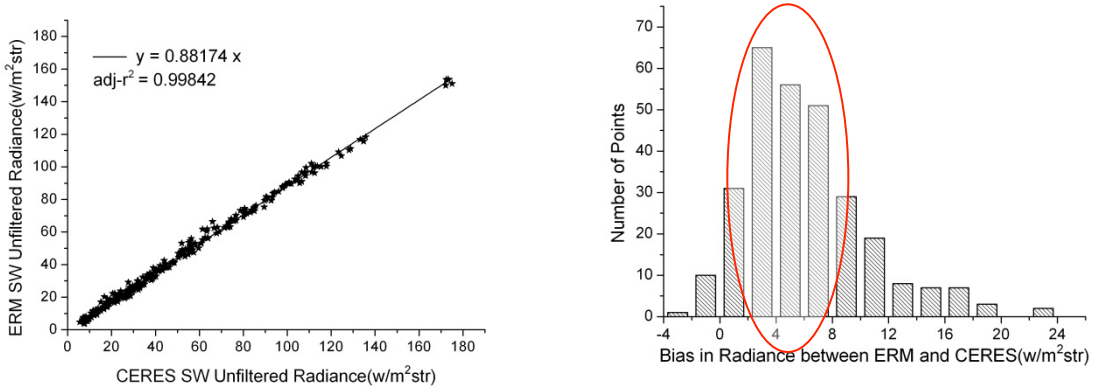
Comparison of SNO Observation between ERM and CERES



(a) LW Unfiltered Radiance at Nighttime

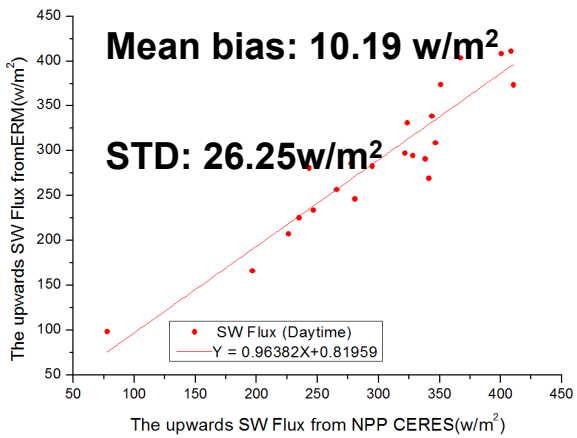


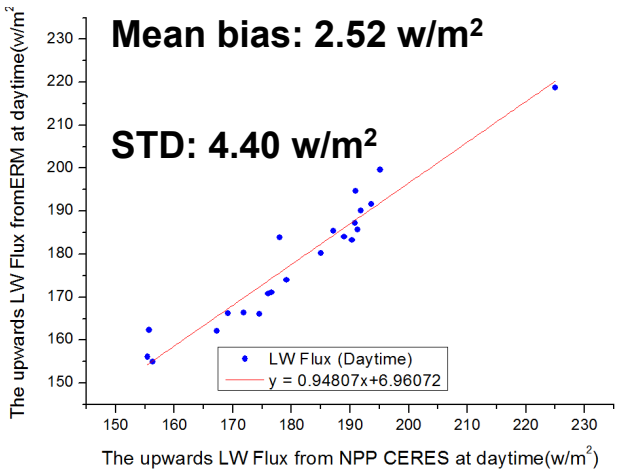
(b) LW Unfiltered Radiance at Daytime

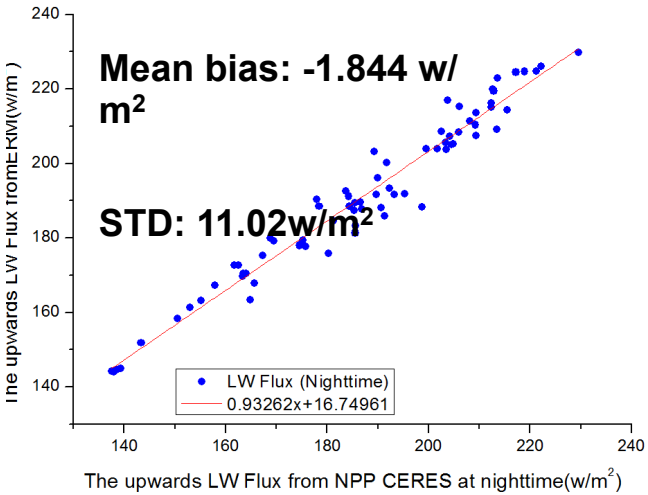


(c) SW Unfiltered Radiance at Daytime

Initial Comparison Between FY-3C/ERM and NPP/CERES







The comparison was carried out for the TOA upward LW and SW flux between FY-3C/ERM and that from NPP/CERES FM5 with the data from Mar.5 to Apr. 30,2014.

The comparisons Between ERM/FY-3C,GERB-3 and CERES/Terra at TOA

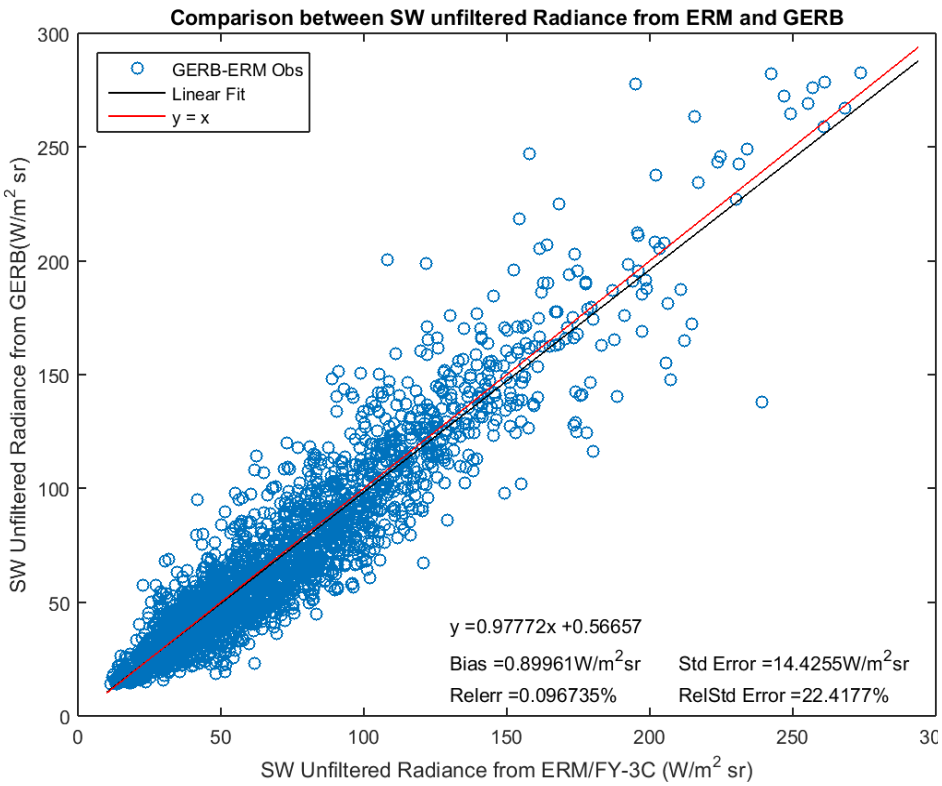
The two comparisons were made for ERM and GERB,CERES and GERB:

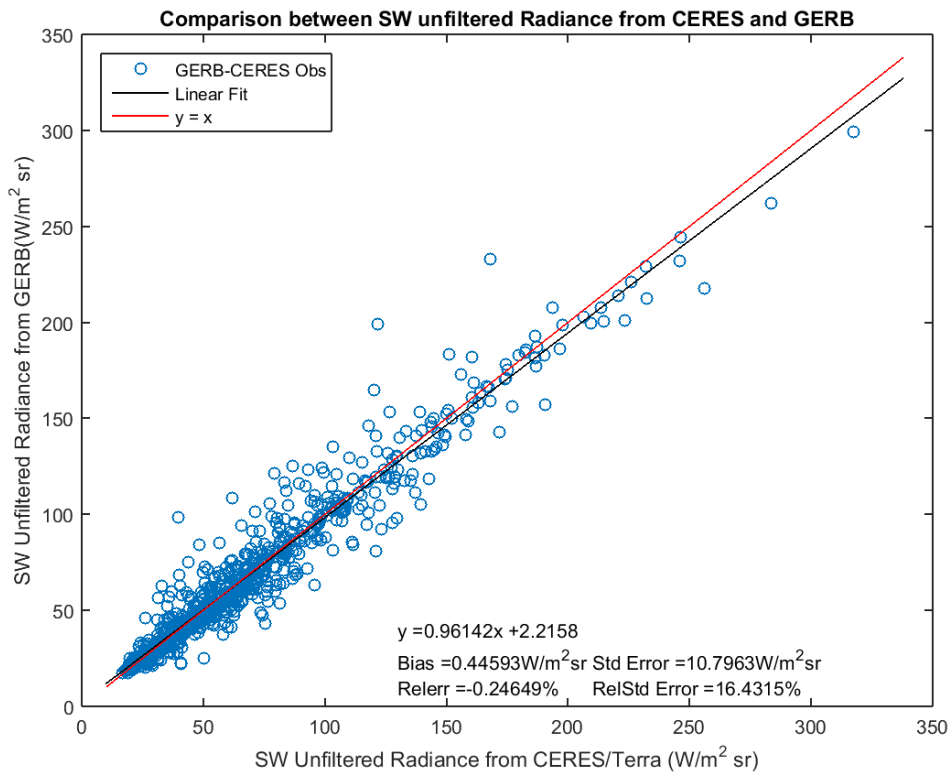
1. the observing time difference is less than 15min;
2. the viewing and solar zenith differences are less than 2°; the relative azimuth difference is less10°;
3. the SW and LW Unfiltered Radiance and Flux at TOA are averaged over 1°/lon and 1°/lat area for ERM,GERB-3 and CERES (CER-ES8-ED3).
4. Time range:

ERM and GERB :03 - 05,2016

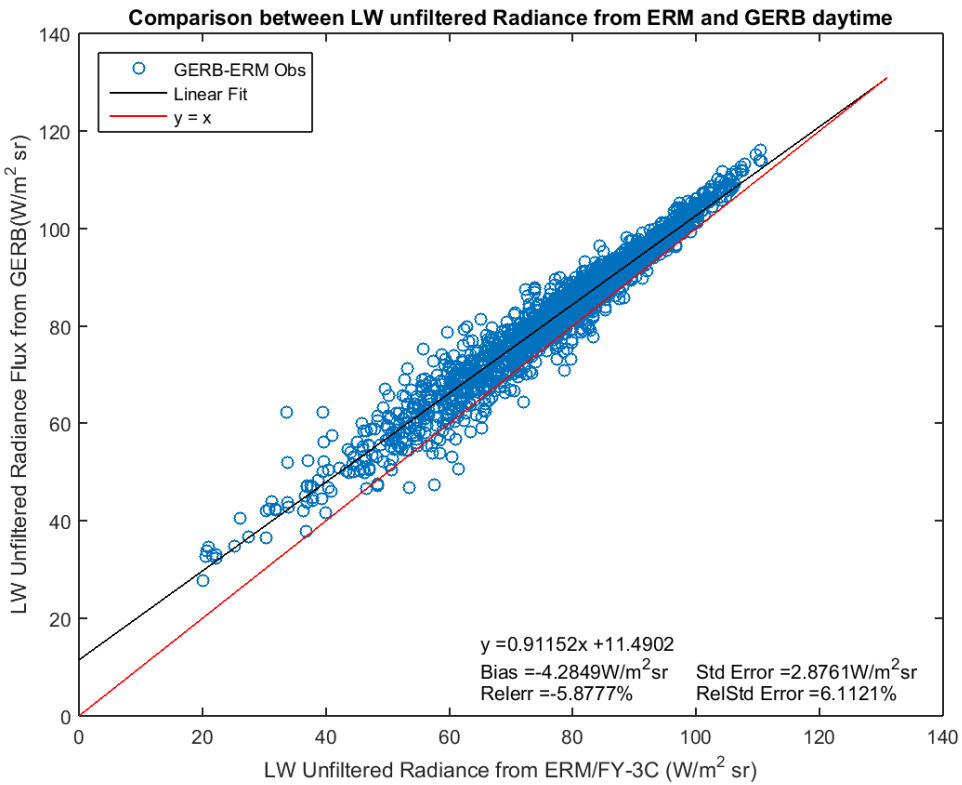
CERES and GERB: 08,2015

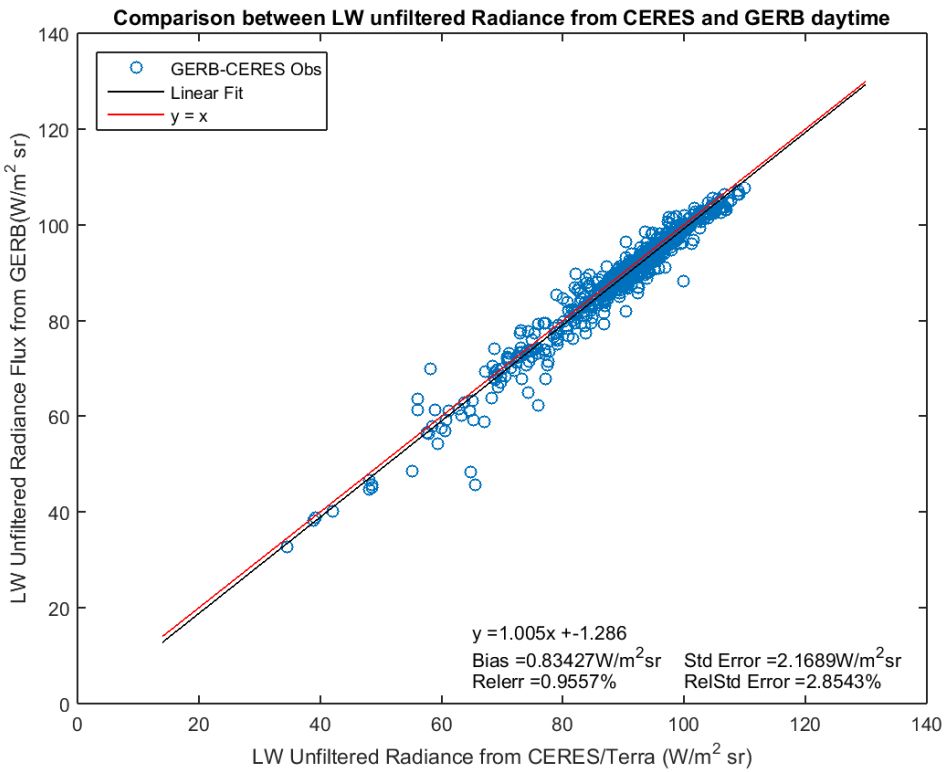
SW Unfiltered Radiance



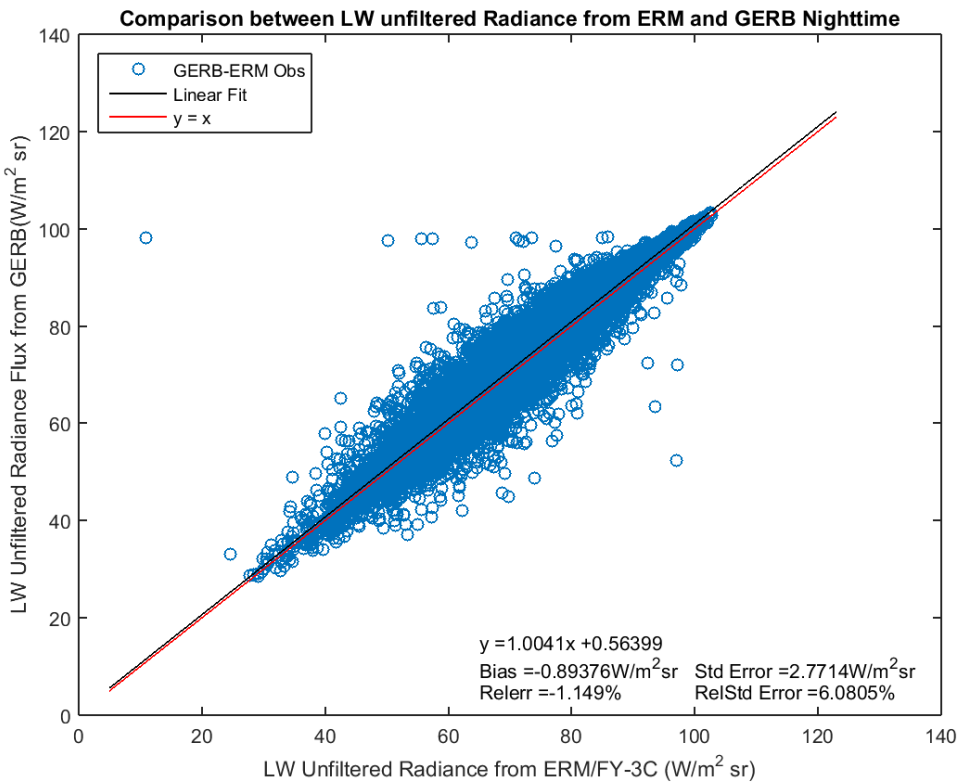


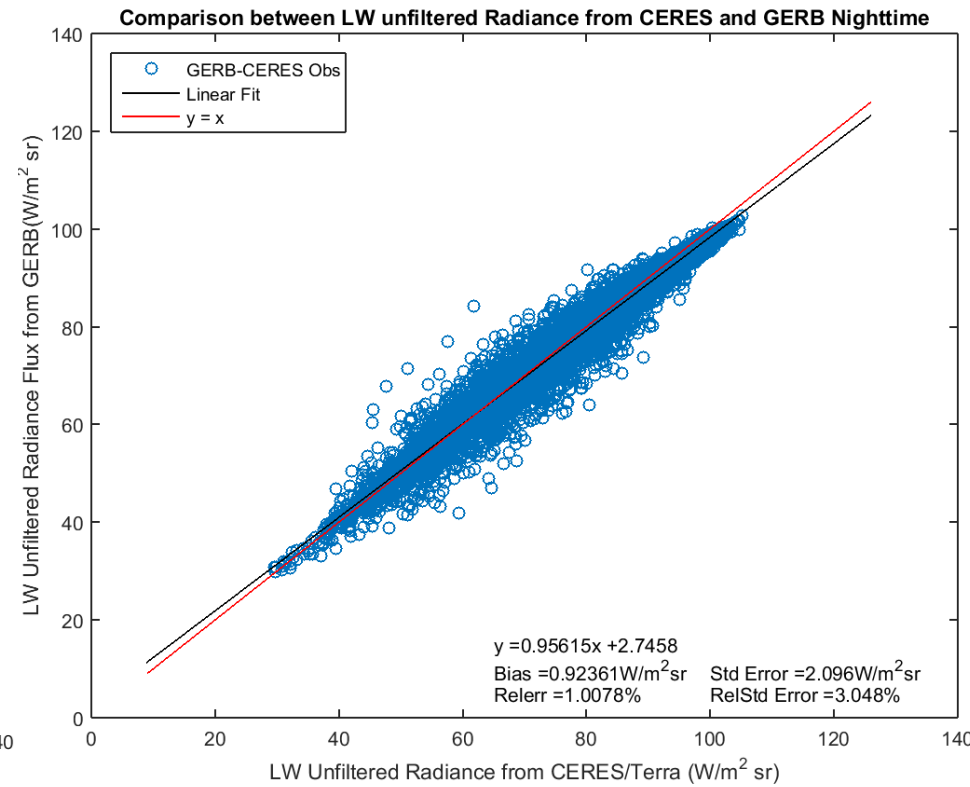
LW unfiltered Radiance at Daytime



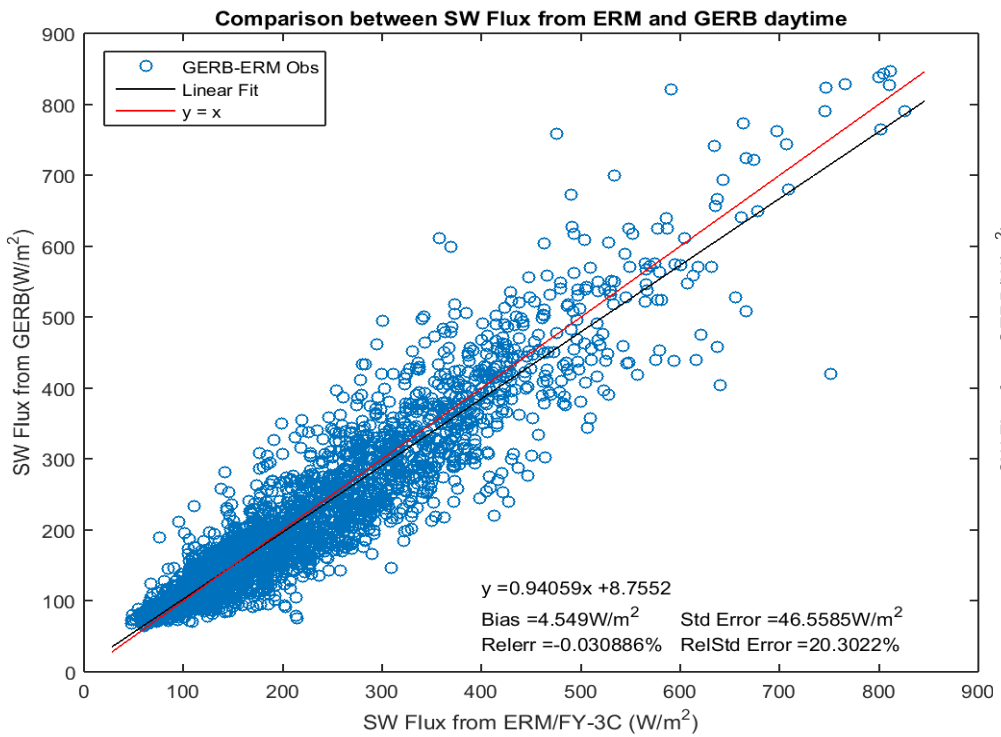


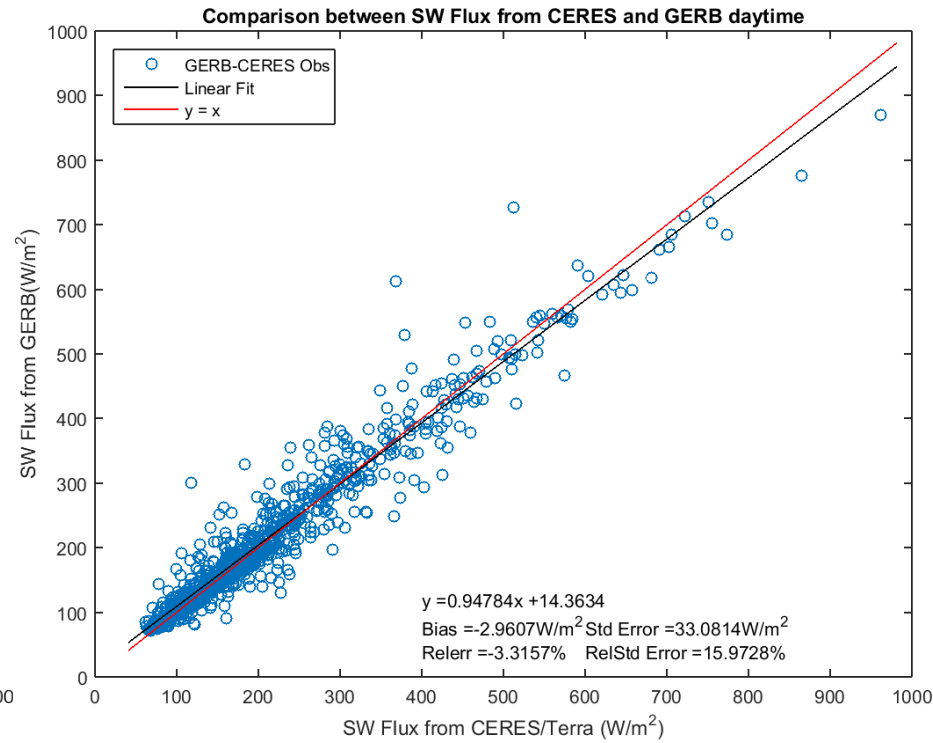
LW Unfiltered Radiance at Nighttime



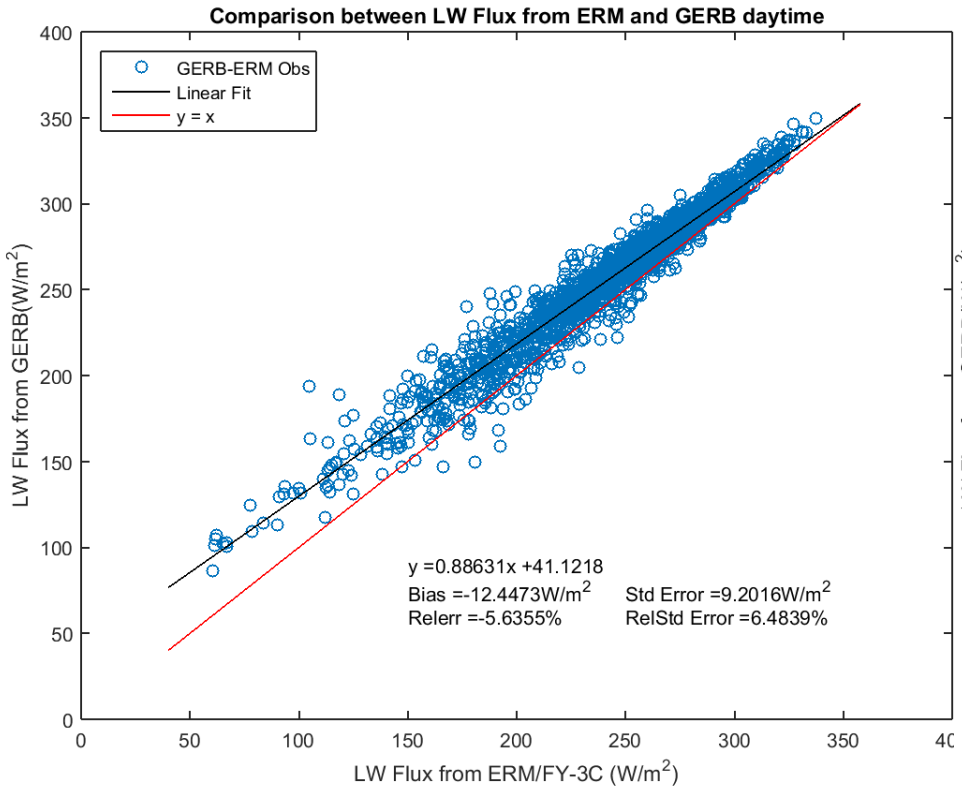


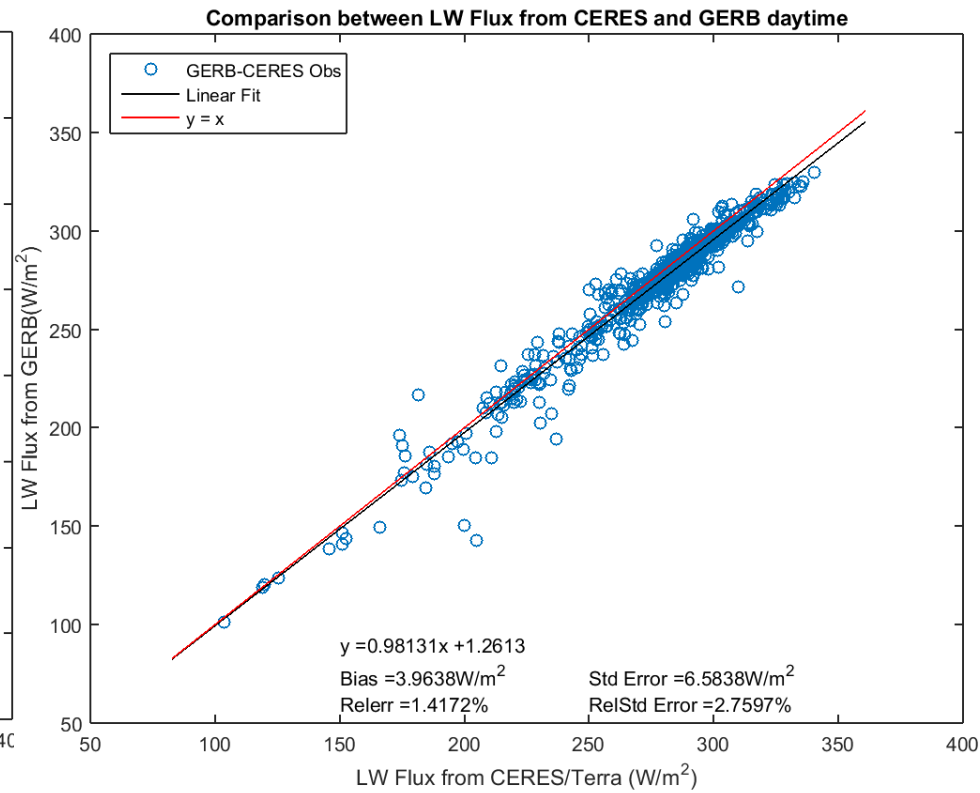
SW Flux upwards at TOA



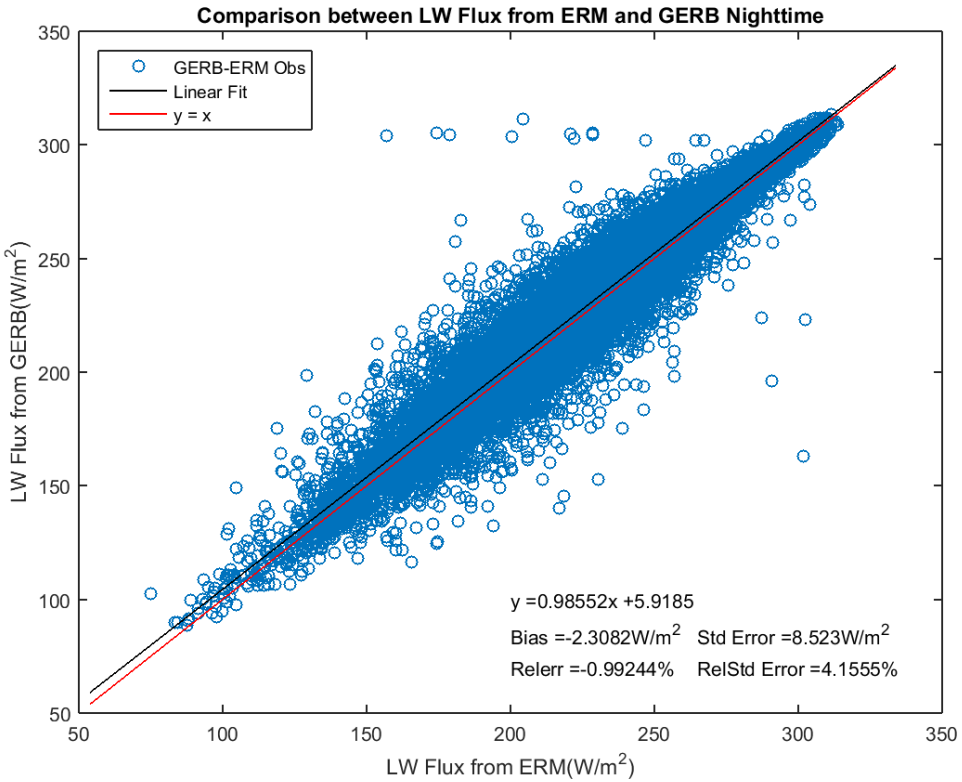


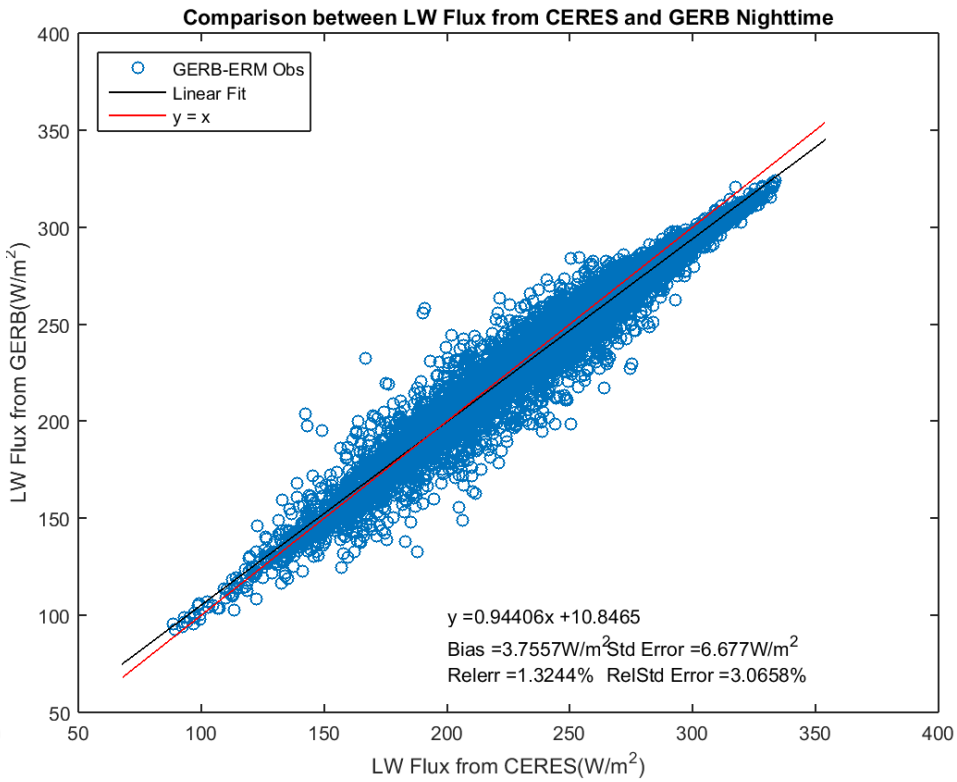
LW Flux upwards at TOA for Daytime





LW Flux upwards at TOA for Nighttime

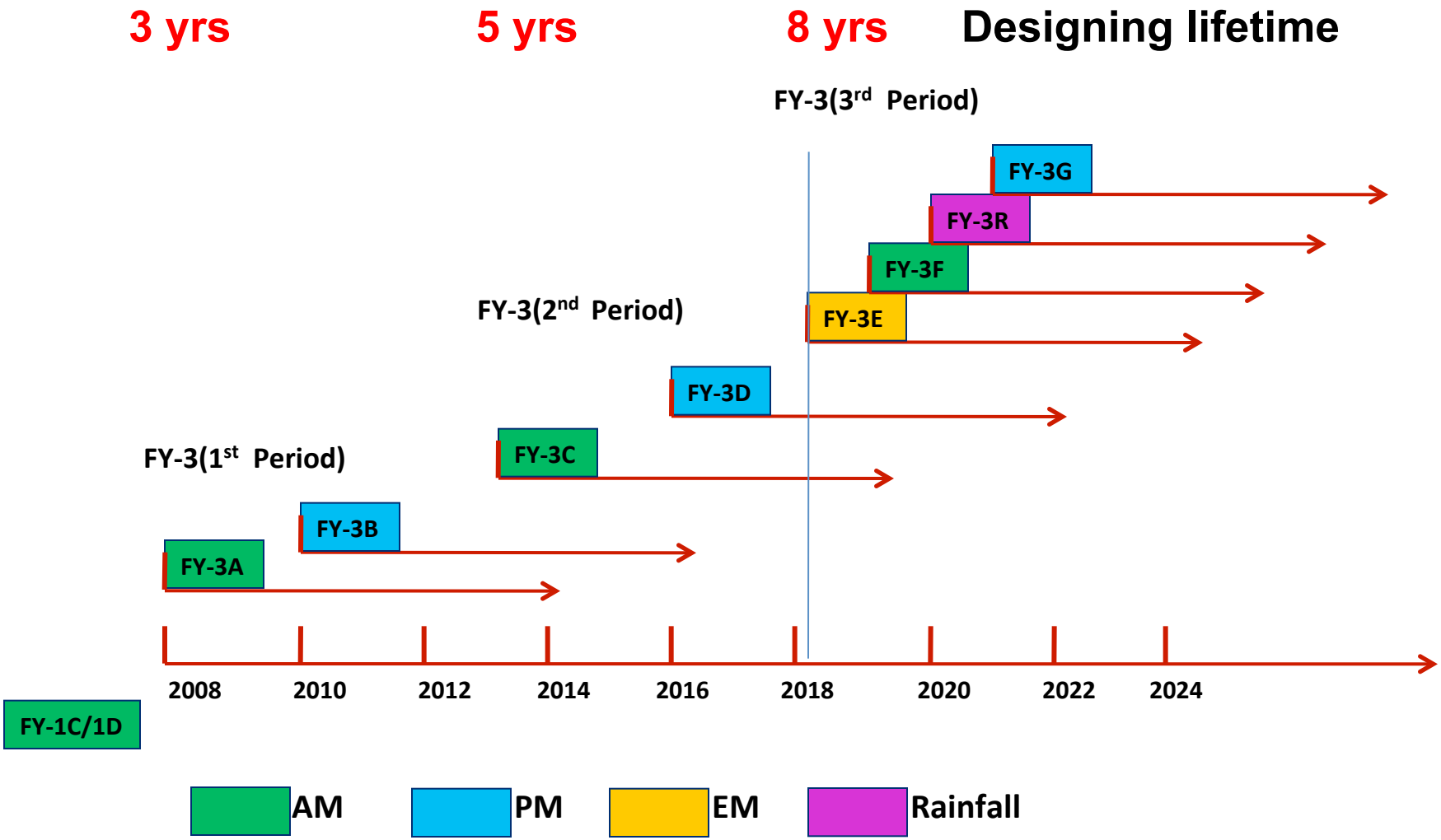




Outline

- The Chinese Second Generation Polar Orbit Meteorological Satellites(FY-3series)
- Earth Radiation Budget Instruments on Current FY-3 Satellites
- Radiometric Calibration Design of the ERMs
- The stability of ERMs on orbit
- *Validation to FY-3/ERMs*
- *ERM on Next Period of FY-3 satellites*

The Route of FY-3 Series Satellites



Payloads Configuration for FY-3E/F/G and Rainfall Mission

N0.	Sensor	Satellite / Sensor	FY-3E (05) EM Satellite	FY-3F (06) AM Satellite	FY-3G (07) PM Satellite	FY-3R (08) Rainfall Satellite
		Scheduled Launch Date	2018	2019	2021	2020
1	Optical Imagers	MERSI	√（III-Low Light）	√（III）	√（III）	√（III-Simplified）
2	Passive Microwave Sensors	MWTS	√	√	√	
		MWHS	√	√	√	
		MWRI		√	√	√
3	Occultation Sounder	GNOS	√	√	√	√
4	Active Microwave Sensors	WindRAD	√	√		
		Rainfall RAD				√
5	Hyperspectral Sensors	HIRAS	√	√	√	
		GAS (Greenhouse Gases Absorption Spectrometer)			√	
		OMS (Ozone Mapping Spectrometer)		√		
6	ERB Observation Sensor Suite	ERM		√		
		SIM	√	√		
		SSIM (Solar Spectral Irradiation Monitor)	√			
7	Space Weather Sensor Suite	SEM	√			
		Wide Angle Aurora Imager			√	
		Ionosphere photometer	√(Multi-angle)		√	
		Solar X-EUV Imager	√			

The Earth Radiation Budget instrument on Next FY-3 Morning Satellite

Earth Radiation Measurement -II (ERM-II)

The Specifications of ERM -II Scanner

Channel	0.2～5μm	5～50μm	0.2~100μm
FOV	2°×2°		
Scanning range	±56°±0.1°		
Dynamic range	0～280$Wm^{-2}Sr^{-1}$	0～120$Wm^{-2}Sr^{-1}$	0～400$Wm^{-2}Sr^{-1}$
accuracy	SW: 1% LW : 0.5%		
NeΔR	0.3$Wm^{-2}Sr^{-1}$	0.2$Wm^{-2}Sr^{-1}$	0.2$Wm^{-2}Sr^{-1}$
Long-term stability in 8 years	< 1.5%		

Improvements on ERM-II

1.It has an ability of the calibration with Solar and Lunar source.

2.A new long wave channel covering from 5 to 50μm is added to ERM-II to increase the observing abilities.

3.The radiometric noise is reduced through technical improvement.

Summary

- A brief introduction of Earth Radiation Measurement(ERM) from the FY-3A/B/C satellites;
- The stability of the ERMs on orbit were analyzed with internal calibration data, and it was shown that after the early time variation of gains, the detectors were becoming stable.
- The initial validations to ERM SW and LW unfiltered Radiance and flux at TOA with CERES and GERB data, the SW and LW data at nighttime are good, the errors in LW data seems a little larger.
- The new improved ERM instruments will be looking forward in the next period of FY-3 series satellites.

Thanks for your attention!