Inter-Calibration Activities of NSMC/CMA

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Topic

- Fengyun Series: Chinese Meteorological Satellite Program and Payloads
- Earth-based reference sites and field experiments
- Calibration activities for FY1C/D: on-orbit calibration
- Calibration activities for FY2C/D: on-orbit calibration
- Calibration activities for FY3: pre-launch calibration

Contributors for this material:

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1. Fengyun Series: Chinese Meteorological Satellite Program and Payloads

- Current and next generation polar system and geostationary system of Chinese Meteorological Satellites will be introduced briefly

- The properties of payloads on FY1C/D, FY2C/D and FY3A are specified

Chinese Meteorological Satellite: FY Series

Polar System

FY
|
1A
1B
1C
1D

First Generation

FY
|
3A
3B
3C
↓
3H

Second Generation

Geostationary System

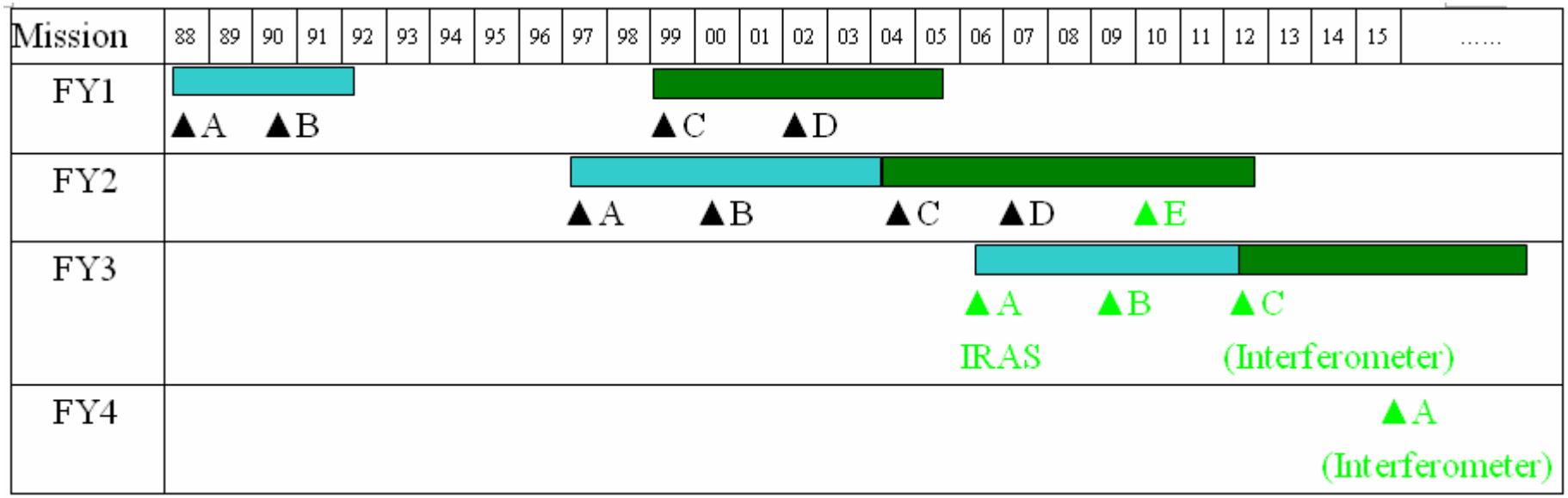
First Generation

FY
|
2A
2B
2C
2D
2E

Second Generation

FY
|
4

Schedule of FY Series



- **FY1A/B/C/D was launched on Sept. 7, 1988; Sept. 3, 1990; May 10, 1999; May 15, 2002 separately**
- **FY2A/B/C/D was launched on June 10, 1997; June 25, 2000; Oct. 18, 2004; Dec. 8, 2006 spearately**
- **FY3A has been postponed to second half of 2007**
- **In this presentation, on-orbit calibration for FY1C/D, FY2C/D, pre-launch calibration for FY3A are introduced**

The Specifications of the payload on FY-1C/D

Channel Number	Spectral Range	Spectral Property	Purpose
1	0.58 ~ 0.68	VIS	Day time image
2	0.84 ~ 0.89	NIR	
3	3.55 ~ 3.95	MTIR Window	Forest fire, the surface properties of cloud, land and ocean
4	10.3 ~ 11.3	FTIR Split Window	Cloud, land and SST
5	11.5 ~ 12.5		
6	1.58 ~ 1.64	NIR	Ice/snow
7	0.43 ~ 0.48	VIS	Ocean color
8	0.48 ~ 0.53		
9	0.53 ~ 0.58		
10	0.900 ~ 0.965	NIR	Troposphere water vapor and cloud

The Specifications of the payload on FY-2C/D

	Visible	Infrared 1	Infrared 2	Infrared 3	Water Vapor
Wavelength(μm)	0.55-0.90	10.3-11.3	11.5-12.5	3.5-4.0	6.3-7.6
Resolution (Km)	1.25	5	5	5	5
FOV (microrad)	35	140	140	140	140
Scan Line	2500_4	2500	2500	2500	2500
Detector	Si-photo-diode	HgCdTe	HgCdTe	HgCdTe	HgCdTe
Noise Performance	S/N=1.5 (albedo=0.5%) S/N=50 (albedo=95%)	NE Δ T < 0.4K-0.2K(300K)	NE Δ T < 0.4K-0.2K(300K)	NE Δ T < 0.4K-0.2K(300K)	NE Δ T < 0.6-0.5k(260K)
Quantification Scale	6 bits	10 bits	10 bits	10 bits	8 bits
Scan step angle	140 microrad (N-S scanning)	140 microrad (N-S scanning)	140 microrad (N-S scanning)	140 microrad (N-S scanning)	140 microrad (N-S scanning)
Frame time	30 minutes	30 minutes	30 minutes	30 minutes	30 minutes

Payloads onboard on FY-3

Abbreviation	*Instrument Full Name*
VIRR	Visible and InfraRed Radiometer
IRAS	InfraRed Atmospheric Sounder
MWTS	MicroWave Temperature Sounder
MWHS	MicroWave Humidity Sounder
MERSI	MEdium Resolution Spectral Imager
SBUS	Solar Backscatter Ultraviolet Sounder
TOU	Total Ozone Unit
MWRI	Microwave Radiation Imager
SIM	Solar Irradiation Monitor
ERM	Earth Radiation Measurement
SEM	Space Environment Monitor

Basic Information for Each Instrument

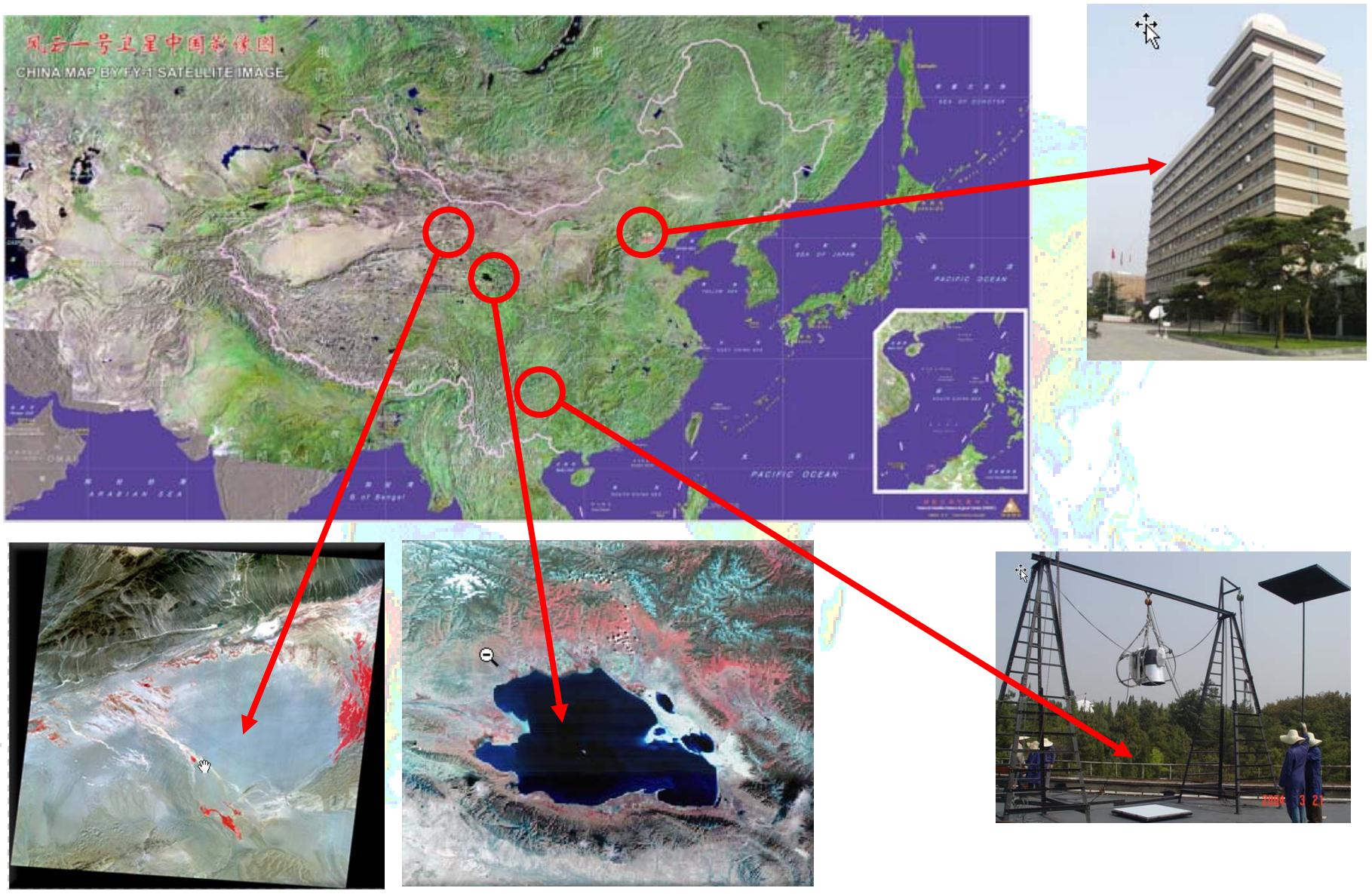
Name of Instrument	Number of Channels	Spectral range	Field of Views /line	Spatial Resoluation at Sub point (km)
VIRR	10	0.43 – 12.5 μ m	2048	1.1
IRAS	26	0.69 – 15.5 μ m	56	17
MWTS	4	50 – 57 GHz	15	50/75
MWHS	5	150 – 183 GHz	90	15
MERSI	20	0.41 – 12.5 μ m	2048/8192	1.1/250
SBUS	12	252 – 280 nm	240	70/10
TOU	6	309 – 361 nm	31	50
MWRI	6	10.65 – 150 GHz	240	15-70
ASI	TBD			

http://www.nsmc.cma.gov.cn

2. Earth-based reference sites and field experiments

- Four Earth-based reference sites in China are introduced
- Field campaigns on Dunhuang Desert site and Qinghai Lake site are summarized
- Long term BRDF properties of Dunhuang Gebi Desert site are analysed

Earth-based reference sites and field experiments



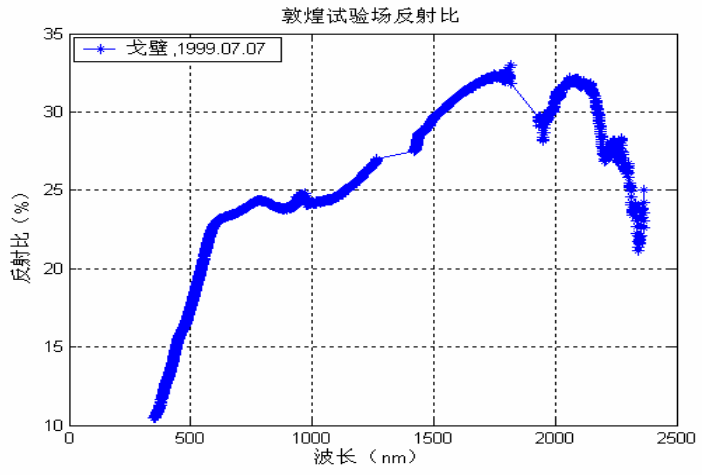
Four Earth-based reference sites in China

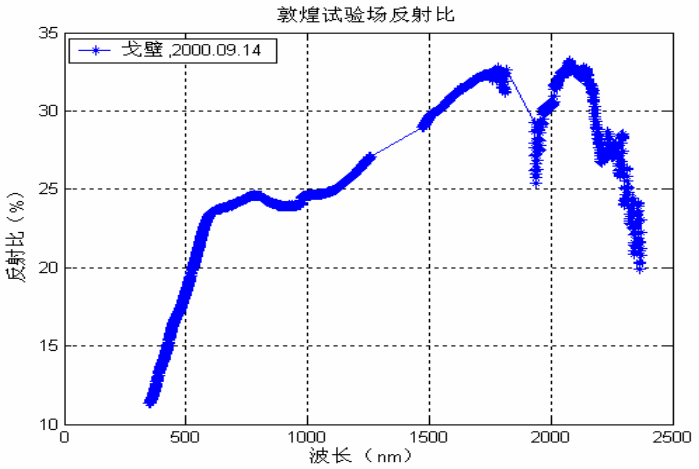
Site	Characteristic	Location	Purpose
Dunhuang	Gebi Desert, homogenous surface, dry atmosphere, and high visibility	40° 10′ N, 94° 20′ E Elevation: 1176 m	On-orbit calibration for VNIR band
Qinghai	Lake, Good Lambertian feature, dry atmosphere, and high visibility	36° 45′ N, 100° 20′ E Elevation: 3196 m	On-orbit calibration for TIR band
Beijing	Laboratory on the top of NSMC build	116.46° N, 39.92° E Elevation: 48 m	• Validation for the calculation from radiation transfer code with very high spectral resolution • Benchmark measurements
Lijiang	Local meteorological observation station, dry atmosphere, high visibility	100.25° N, 26.86° E Elevation: 2300 m	Pre-launch calibration for VNIR band of engineering and flight model

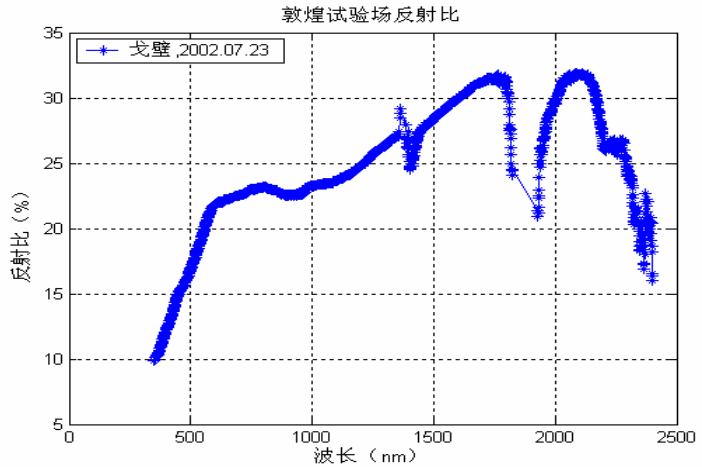
Sight of Dunhuang Gebi desert

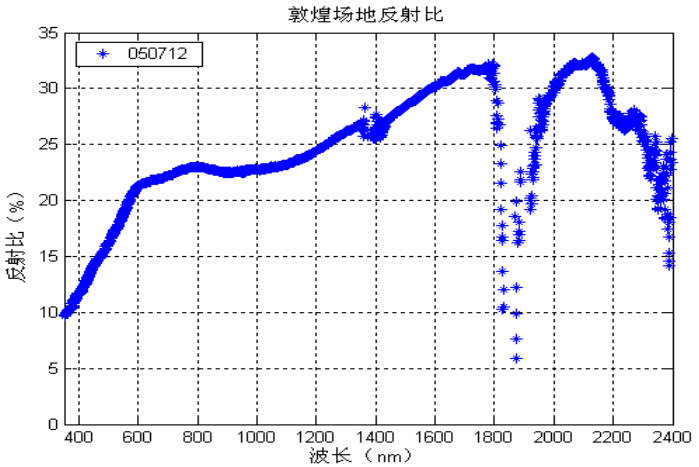
4 years of reflectivity in Dunhuang site

- show very good stability
- reflectivity define as the ratio of desert surface and reference board

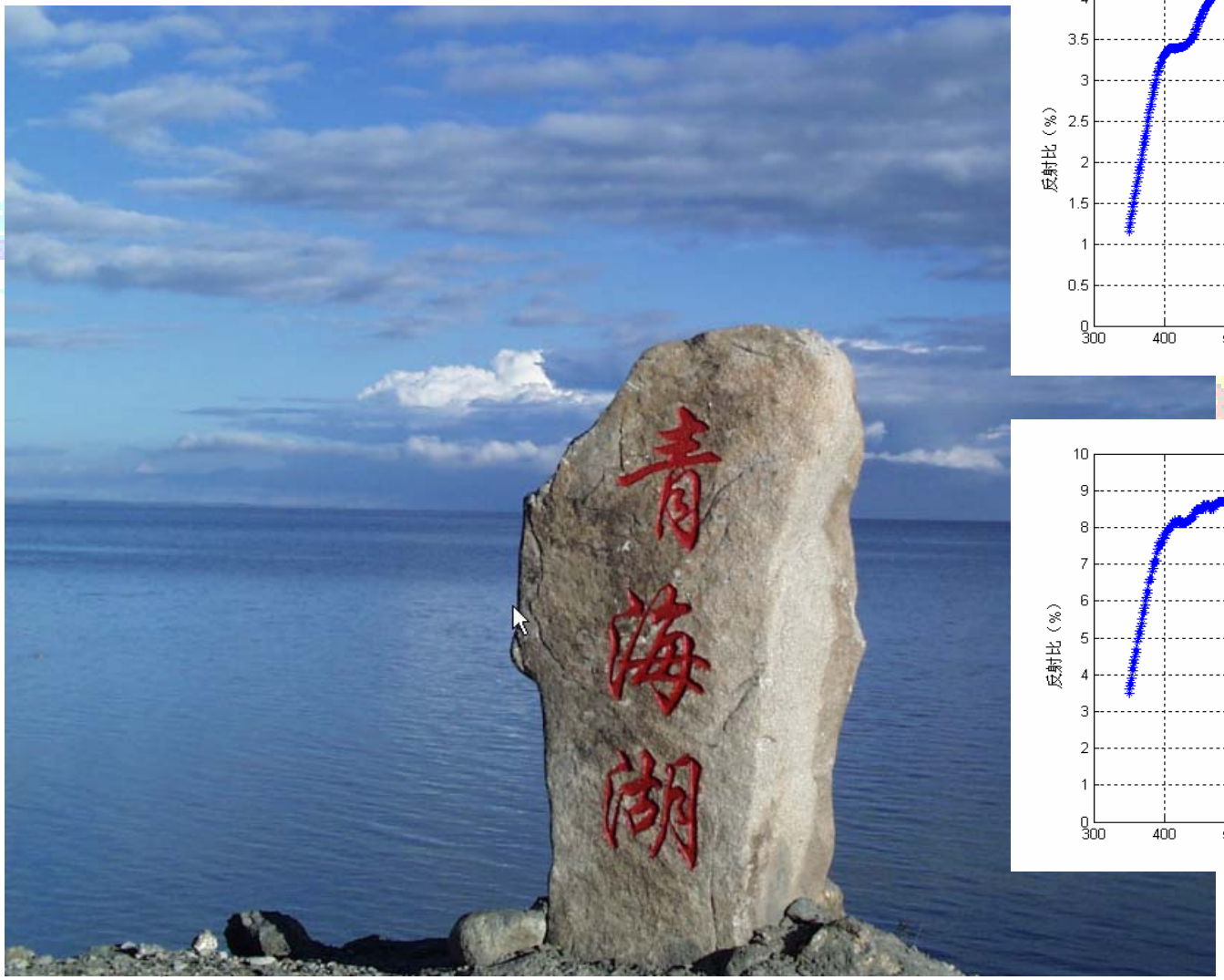


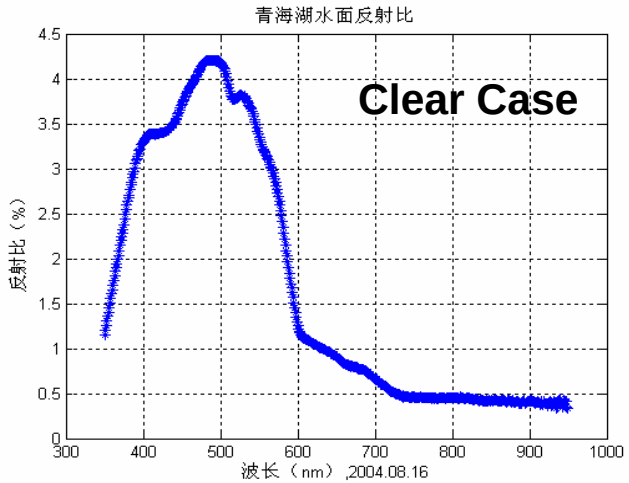




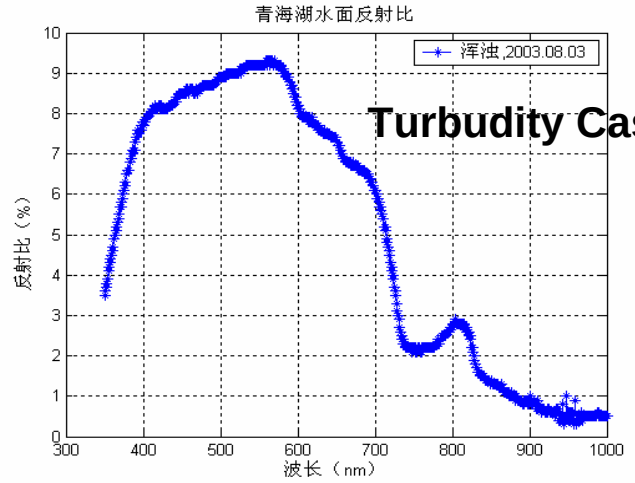


Sight of Qinghai Lake





Clear Case



Turbudity Case

Depth of Lake: 20 m

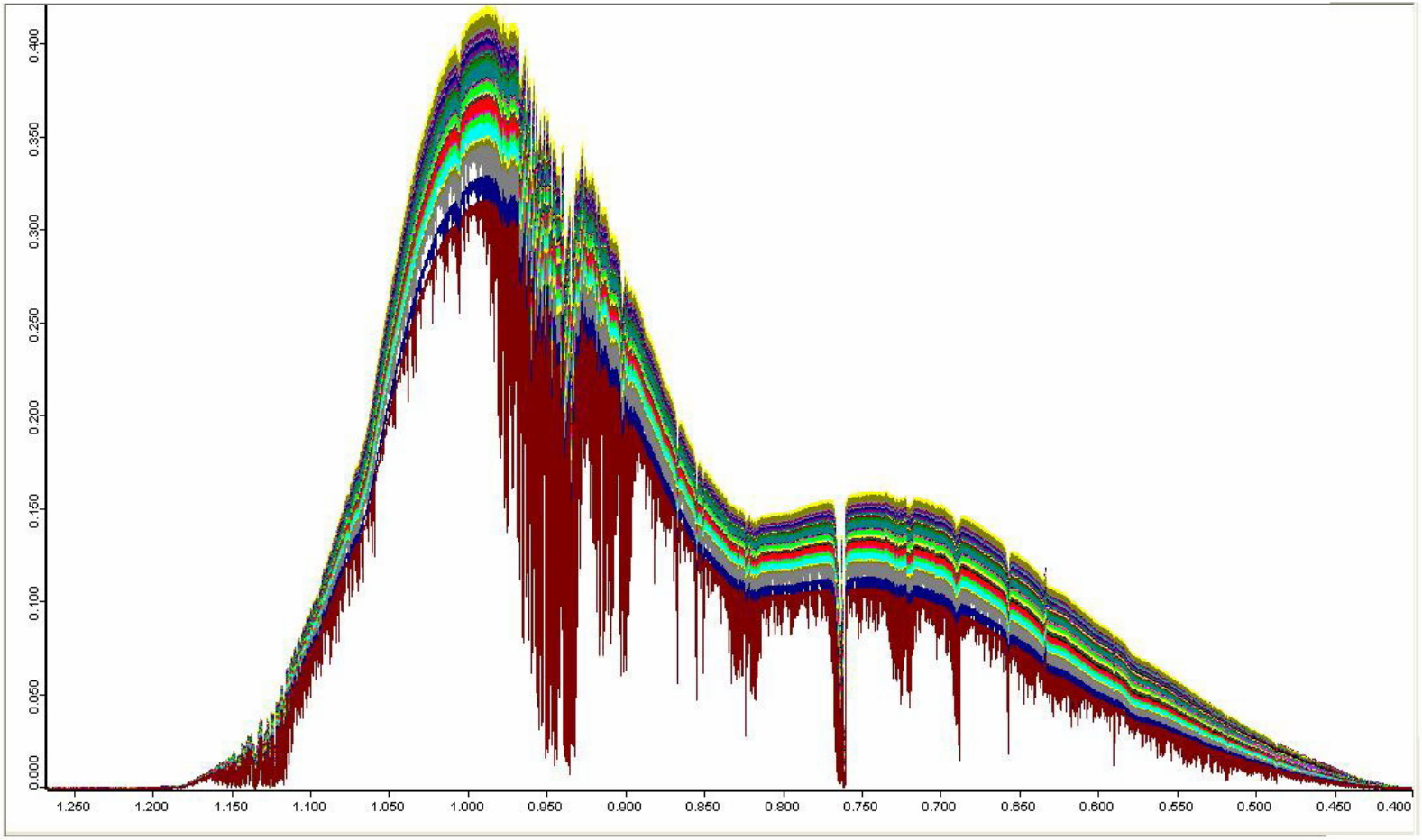
Sight of Beijing Atmospheric Spectrum Observation Laboratory

Ground-base measurement in very high spectral resolution with Bruker

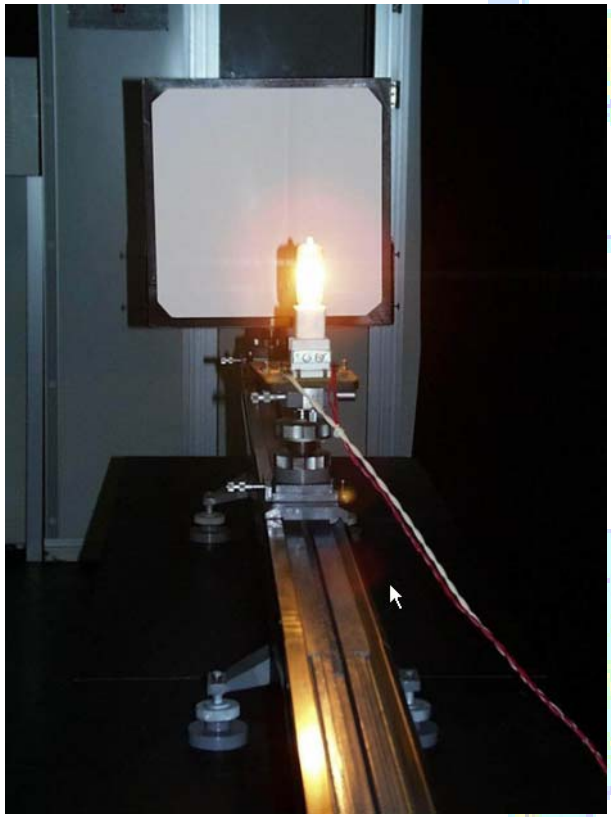
大气观测实验室竣工图

400 – 1150 nm solar spectrum at the surface measured by Bruker

Beijing, Jan, 2007



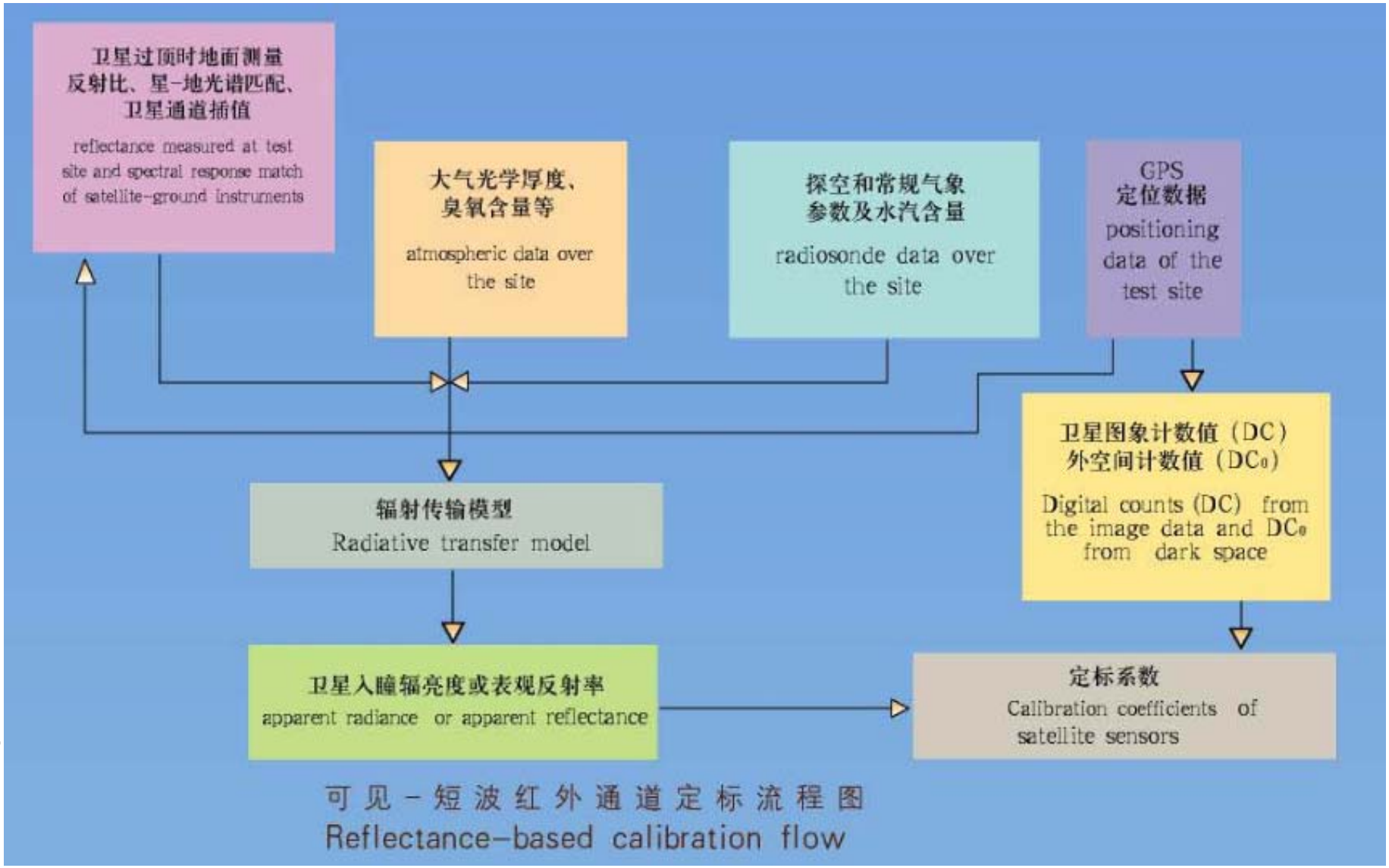
Benchmark measurements in Beijing Atmospheric Spectrum Observation Laboratory



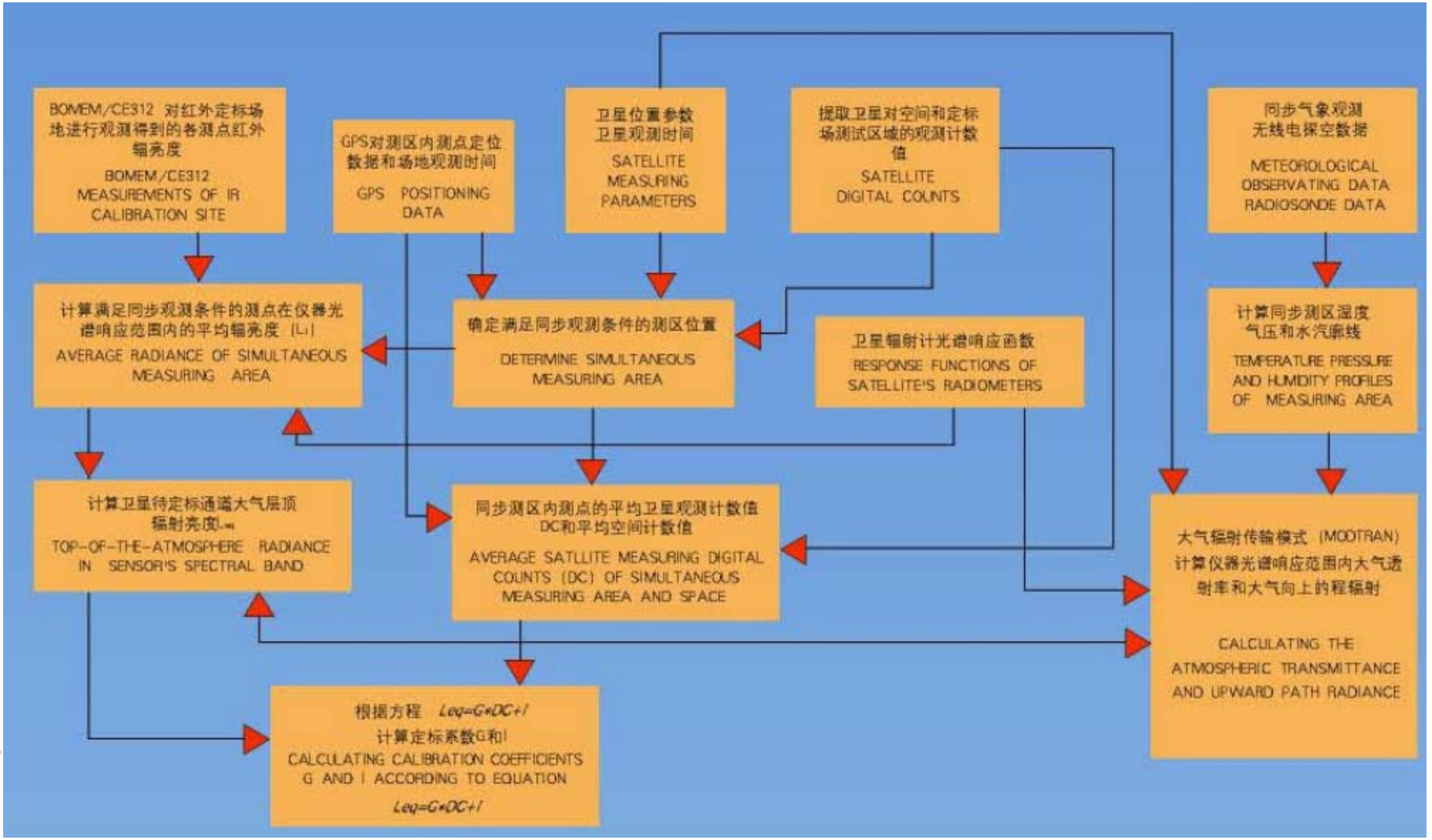
Reference Lamp

Integral Sphere

Reference Board


卫星过顶时地面测量
反射比、星-地光谱匹配、
卫星通道插值
reflectance measured at test site and spectral response match of satellite-ground instruments
大气光学厚度、
臭氧含量等
atmospheric data over the site
探空和常规气象
参数及水汽含量
radiosonde data over the site
GPS
定位数据
positioning data of the test site
卫星图象计数值（DC）
外空间计数值（DC0）
Digital counts (DC) from the image data and DC0 from dark space
辐射传输模型
Radiative transfer model
卫星入瞳辐亮度或表观反射率
apparent radiance or apparent reflectance
定标系数
Calibration coefficients of satellite sensors
可见-短波红外通道定标流程图
Reflectance-based calibration flow

Calibration flow for thermal channels



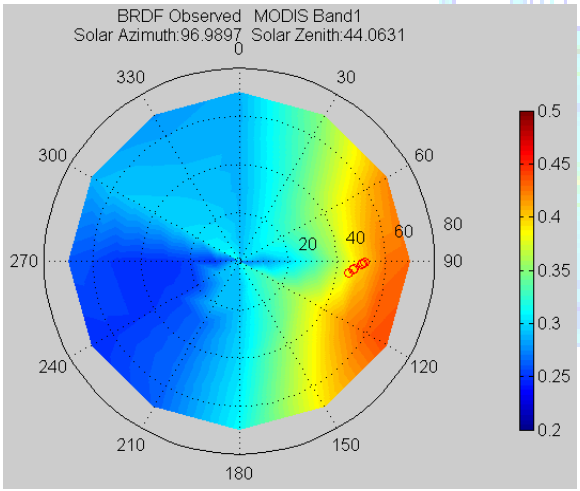
List of the field campaign for recent years:

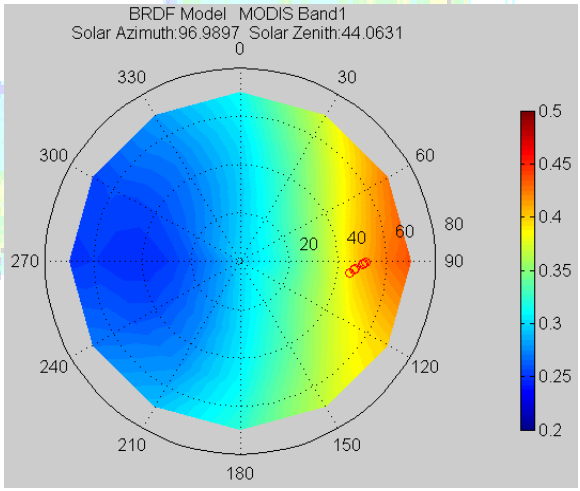
Field Campaign	Calibration Purpose	Camaign Site
1999	FY-1C, FY-2B	Dunhuang site
2000	FY-1C, CBERS-01	Dunhuang site and Qinhai Lake
2001	FY-1C, FY-2B	Qinhai Lake
2002	FY-1D/1C, FY-2B, HY-1, NOAA-17	Dunhuang site
2003	FY-1D/1C, FY-2B, HY-1	Qinhai Lake
2004	FY-1D, FY-2B, CBERS-02	Qinhai Lake
2005	FY-1D, FY-2C, MODIS	Dunhuang site and Qinhai Lake

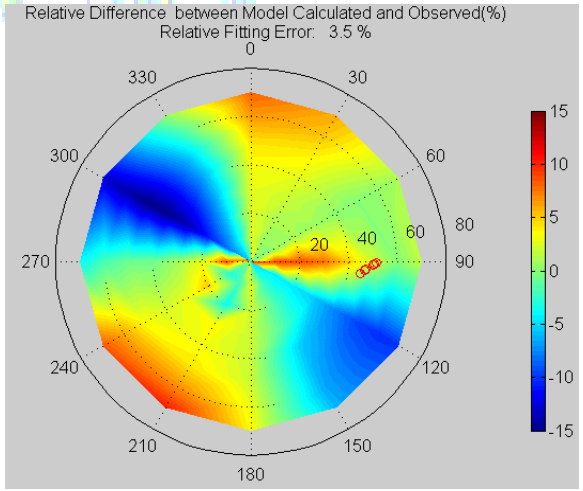
BRDF measurements of Gebi Desert

Goal: to reduce the BRDF impact on the reflectivity measurement

Dunhuang, 2002-07-23



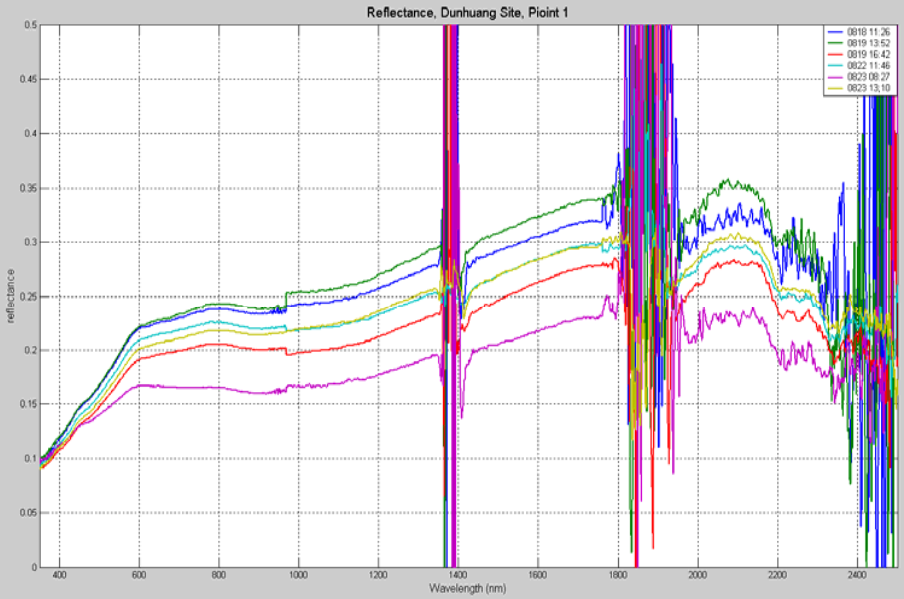




Simplified Portable Instrument for BRDF measurement

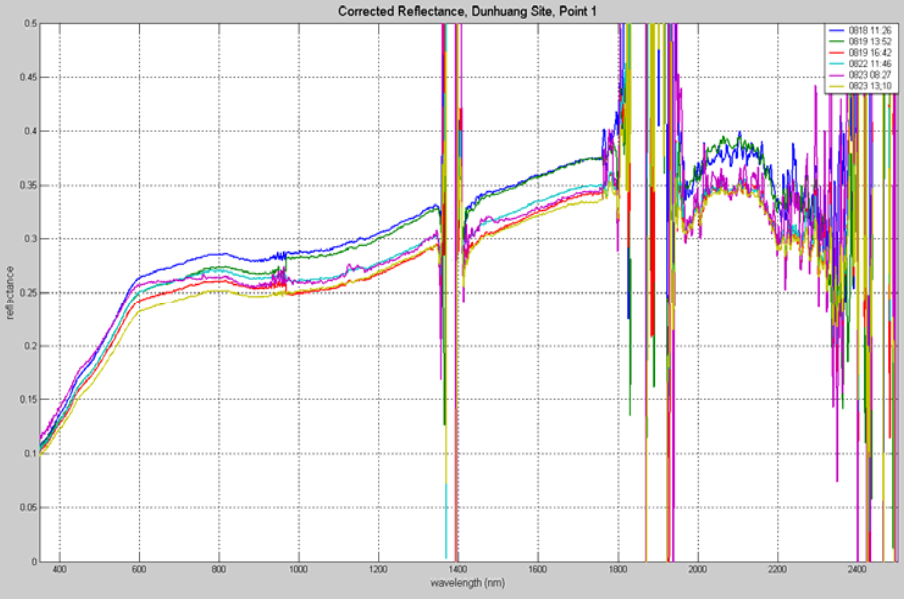
Same site in Dunhuang but different observation time

Reflectivity before BRDF correction



$$R(\theta_s, \theta_o, \varphi_s - \varphi_v) = f_{iso} + f_{vol} RossThick + f_{geo} LiSparse$$

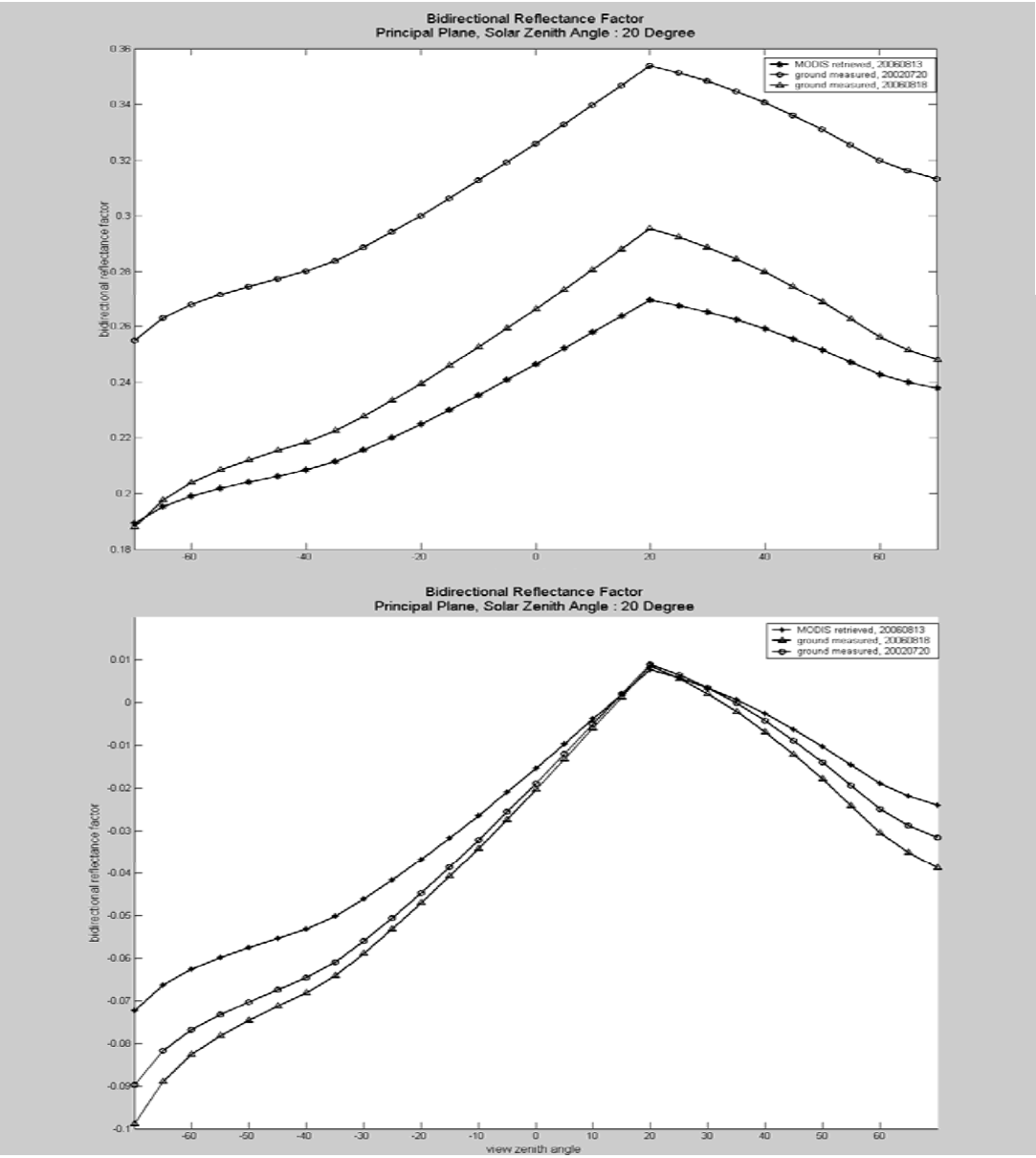
BRDF correct with MODIS AMBRALS model



Reflectivity after BRDF correction

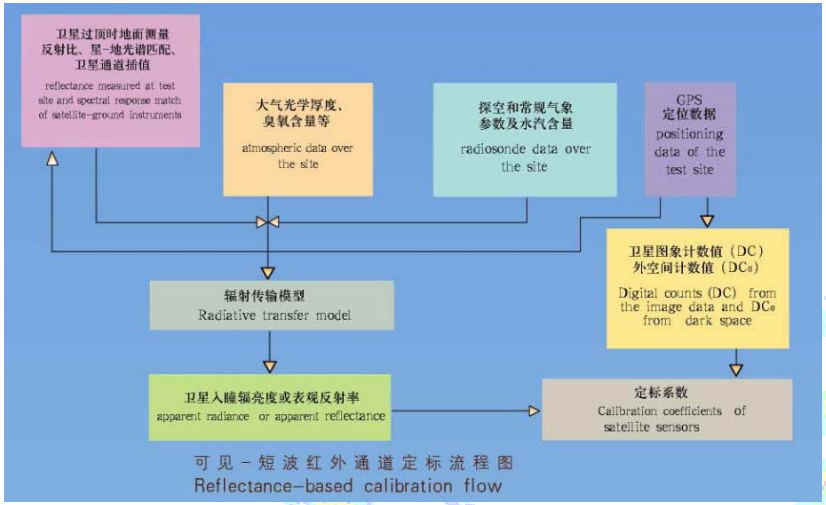
Bidirectional Reflectance Factor derived from AMBRAL model

By using of AMBRAL model, the amplitude factor has been removed from measured reflectivity. It can be seen the bidirectional reflectance factor keep stable from year 2002 to year 2006



3. Calibration activities for FY1C/D: on-orbit calibration

- The visible and near infrared channels are calibrated by pre-calibration and the Dunhuang site.
- The infrared channels are calibrated by the blackbody on-orbit.



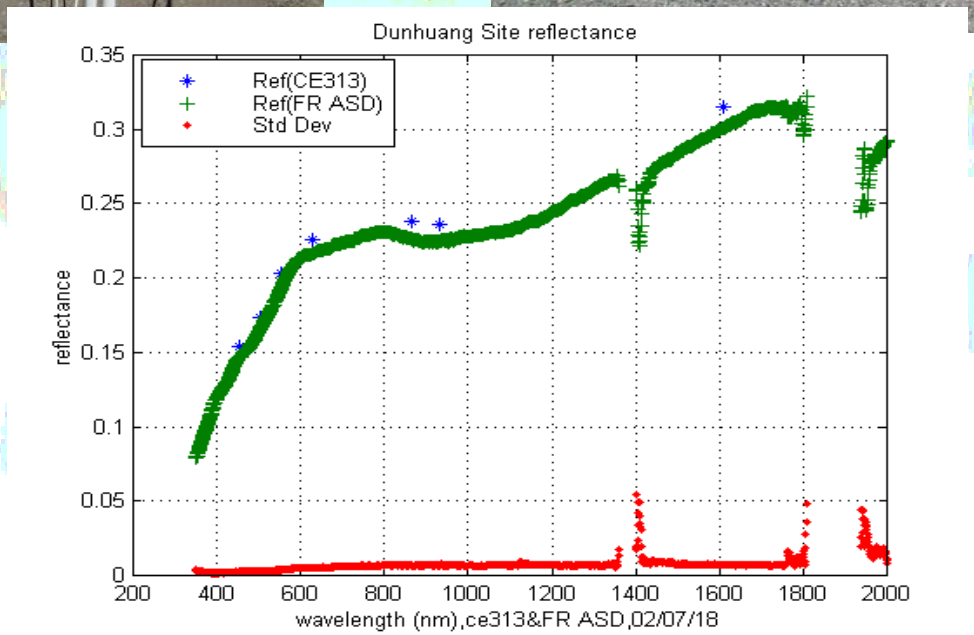
Corresponding to the requirement of reflectance-base calibration flow, each field campaign should perform both of the atmosphere and surface measurements

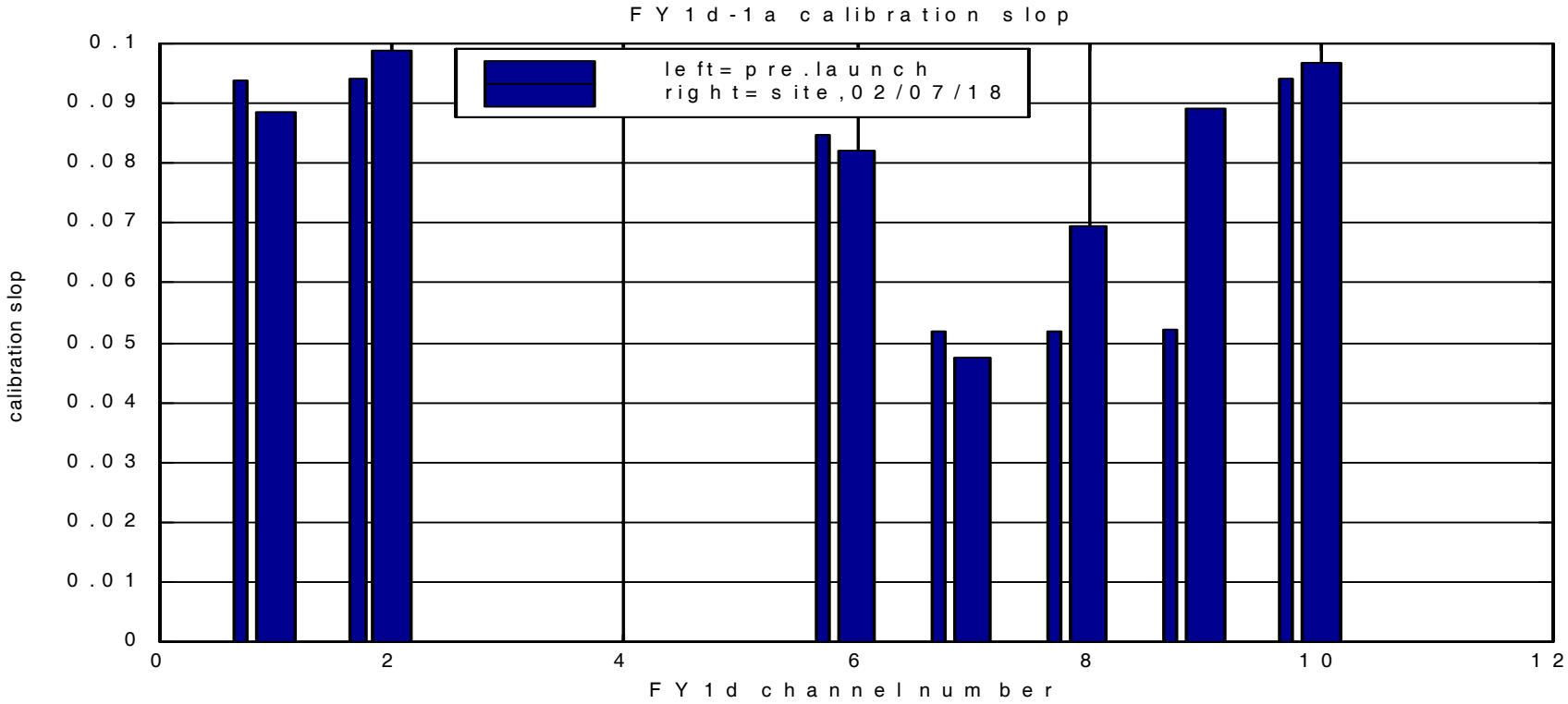
Pre-calibration in Lijiang Site

The Dunhuang site calibration

CE-318

FR ASD

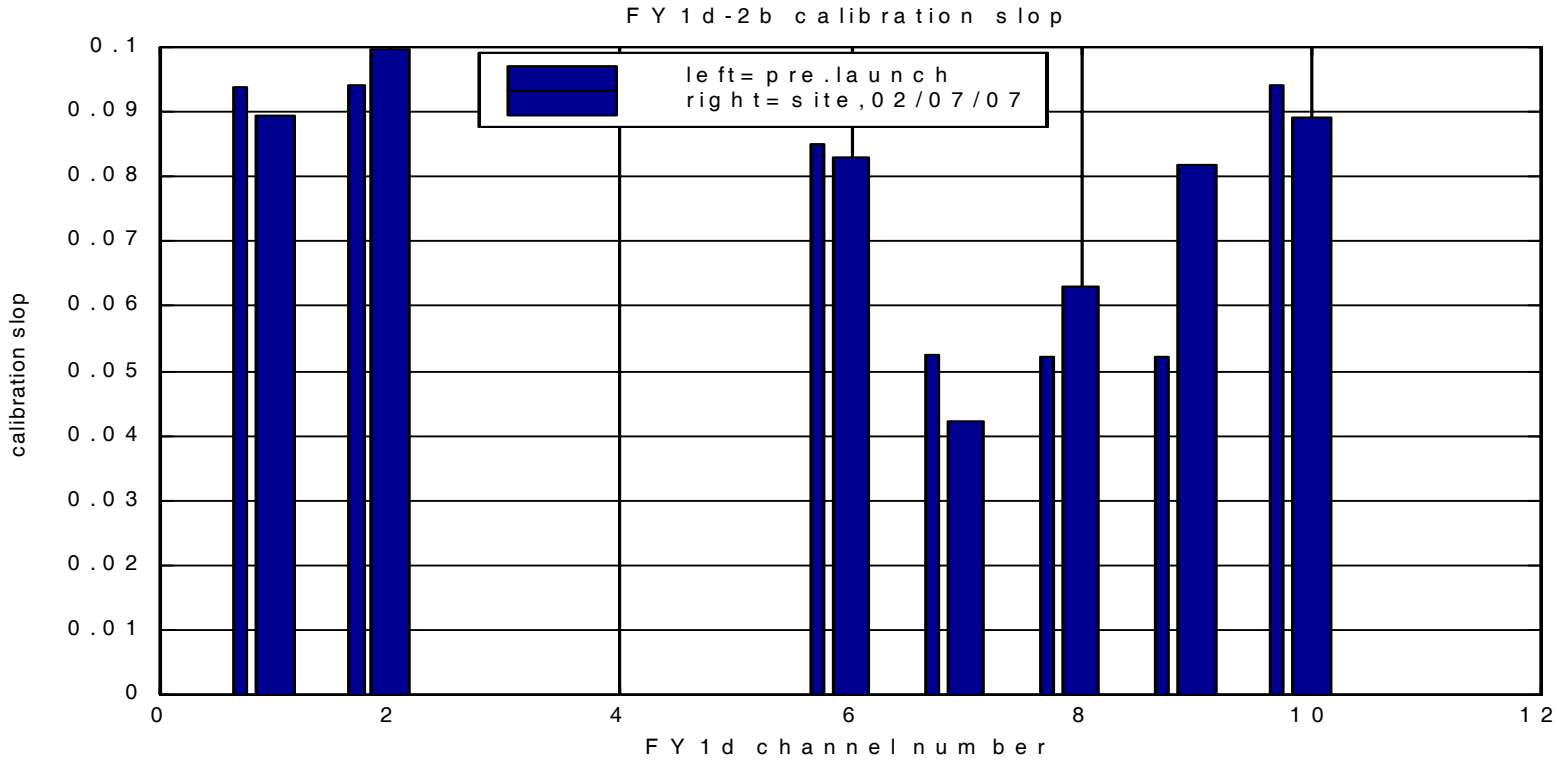




FY-1D (A) Calibration slopes for pre-launch and after- launch

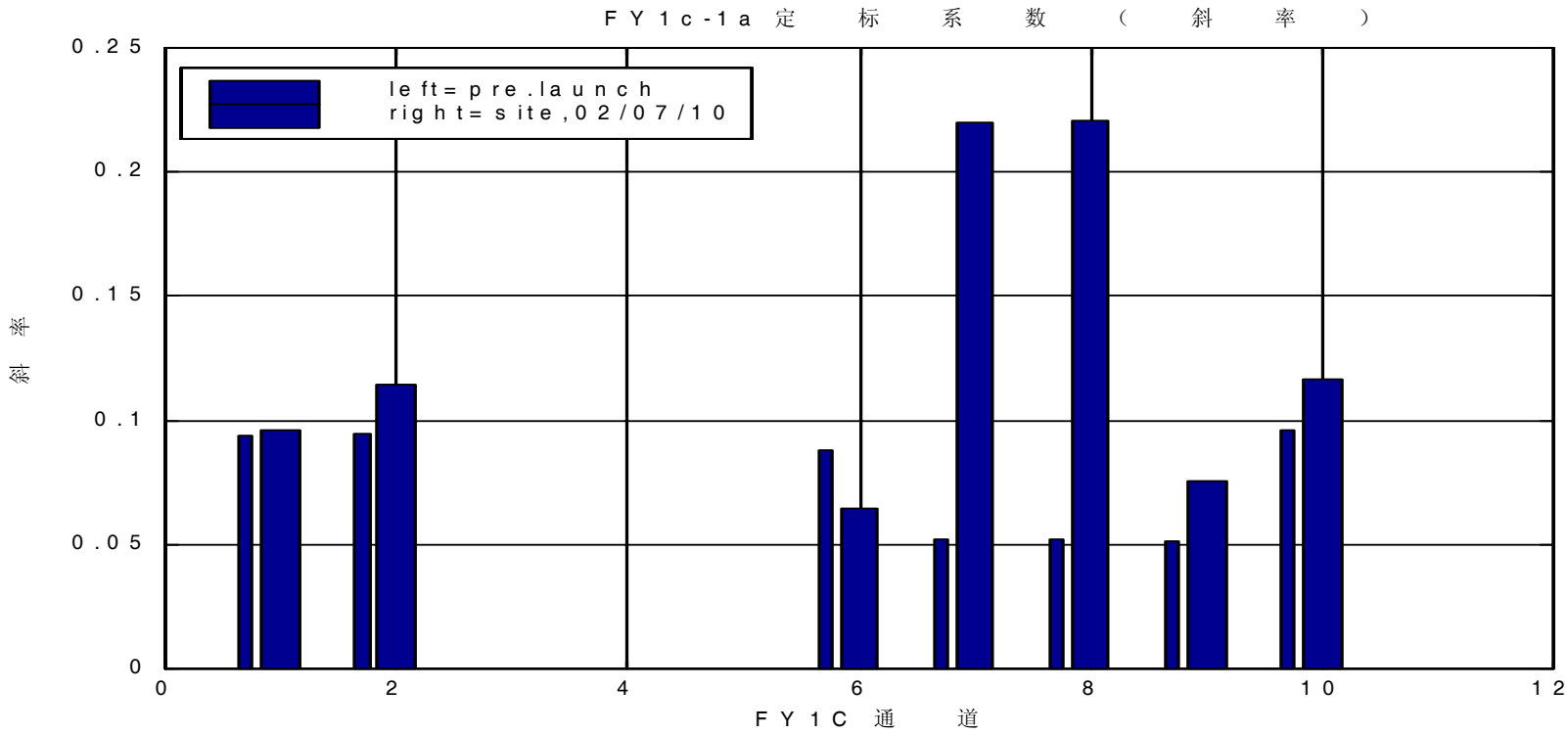
Analysis:

- In-flight calibrations show that the channels 1, 2, 6, 7, 10 of FY-1D (A) are well-agreed with pre-launch calibration.
- There is a large difference for the channel 8 and 9 even just after the launch of FY1D (year 2002).



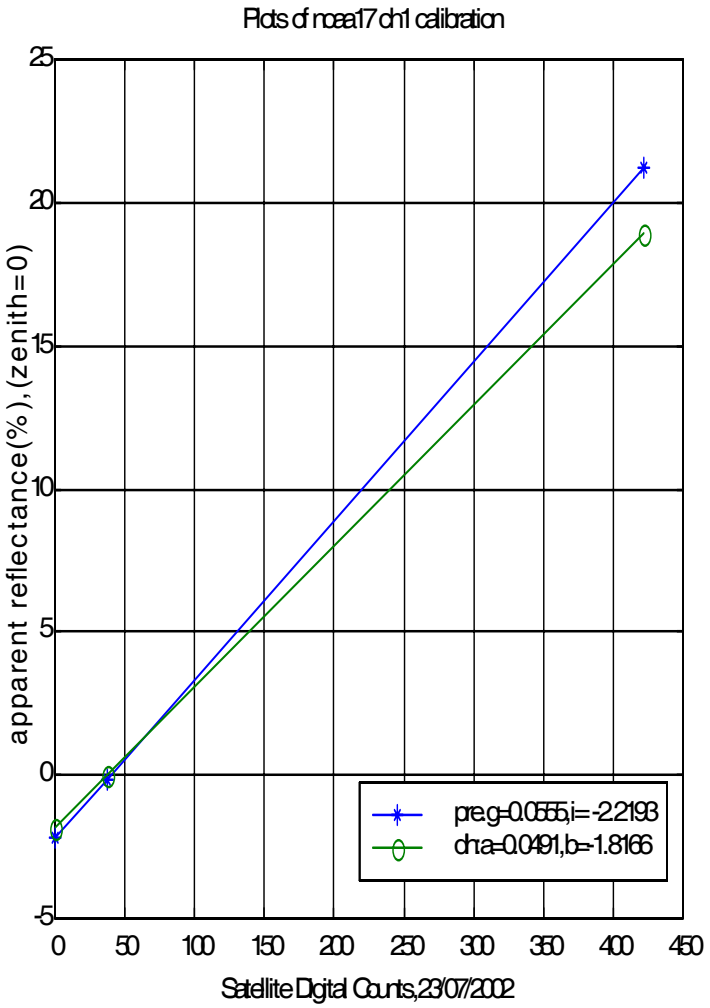
FY-1D (B) Calibration slopes for pre-launch and after

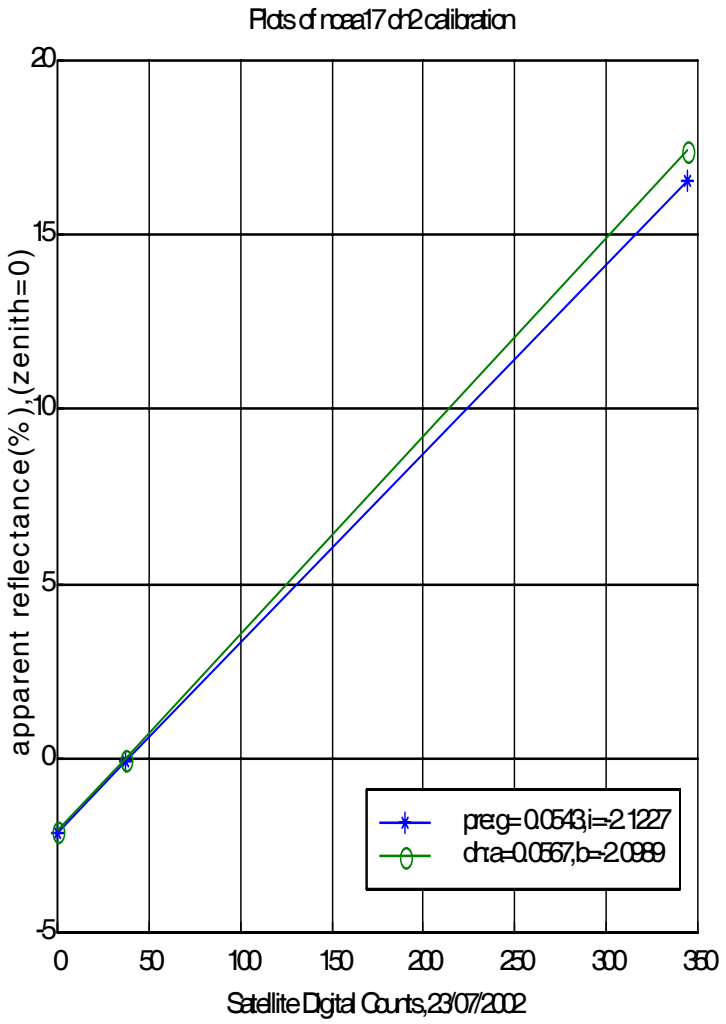
Analysis: In-flight calibration results show that the 4 channels (1, 2, 6, 10) of FY-1D (B) are well-agreed with pre-launch calibration except the channel 7, 8 and 9.



FY-1C (A) Calibration slopes for pre-launch and after- launch

Result：The calibration results show that the channels 1, 2, 6, 9, 10 of FY-1C(A) still agreed with pre-flight calibration while the exceptions are the channel 7 and 8. It shows that the attenuation of these 5 channels is slight even it is three years after the launch of FY1C. The attenuation of channel 7 and 8 is great.





Plot of of pre-launch calibration and in-flight for NOAA-17 CH 1 and 2

4. Calibration activities for FY2C/D: on-orbit calibration

- Pre-calibration
- The visible channels are calibrated by field calibration on Dunhuang Gebi desert site on-orbit
- The infrared channels are calibrated by inter-calibration with NOAA's infrared channels and by site-calibration on Qinghai lake on-orbit

Pre-launch Calibration

- The pre-launch calibration of visible channels of FY-2A/B/C/D are made on the field at Kunmin, Yunnan Province, the southwest of China. However, this site is not good enough since it is affected largely by the solar angle and atmospheric condition recently (close to urban area). Therefore, the current site has been move to Lijing.
- The pre-launch calibration of infrared channels are made in the vacuum container to simulate the space condition. The calibration is made with black body.

In-orbit Calibration of Visible Channels

- **Since there is no calibration designing boarding on FY2C/D, the on-orbit calibration of visible channel *FY-2C/D* is mainly relied on the absolute radiant calibration which is based on the field measurements at Dunhuang SITE.**

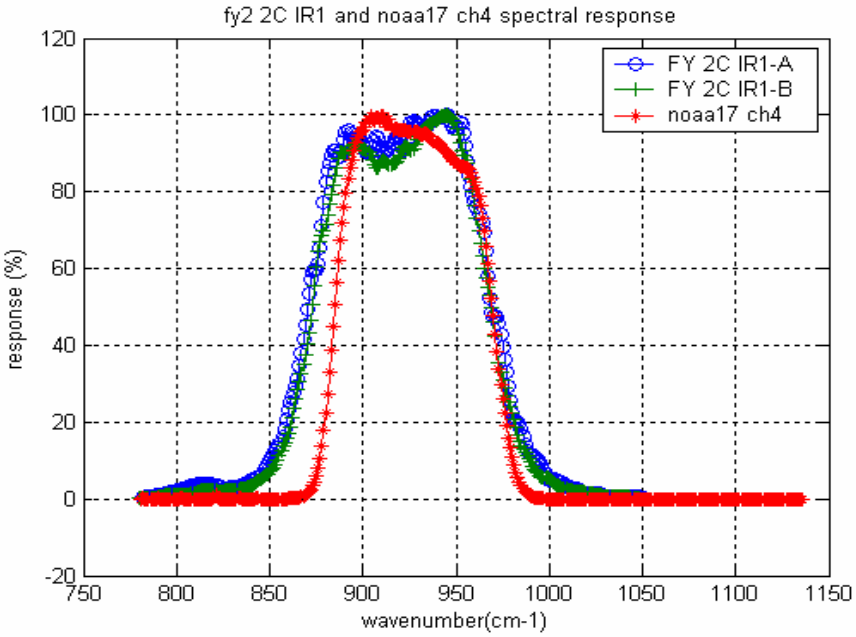
The inter-calibration of infrared channels

- **NOAA satellites have been selected as the reference for the inter-calibration of FY-2C/D payload.**
- **The GAC data from AVHRR channel 3, 4, 5 of NOAA-16, 17, 18 are used to perform the inter-calibration processing for the IR band 1, 2, 4 of FY-2C/D**
- **The channel 11, 12 (WV) of HIRS/3 of NOAA-17 are used to perform the inter-calibration processing for the WV channel of FY-2C/D.**

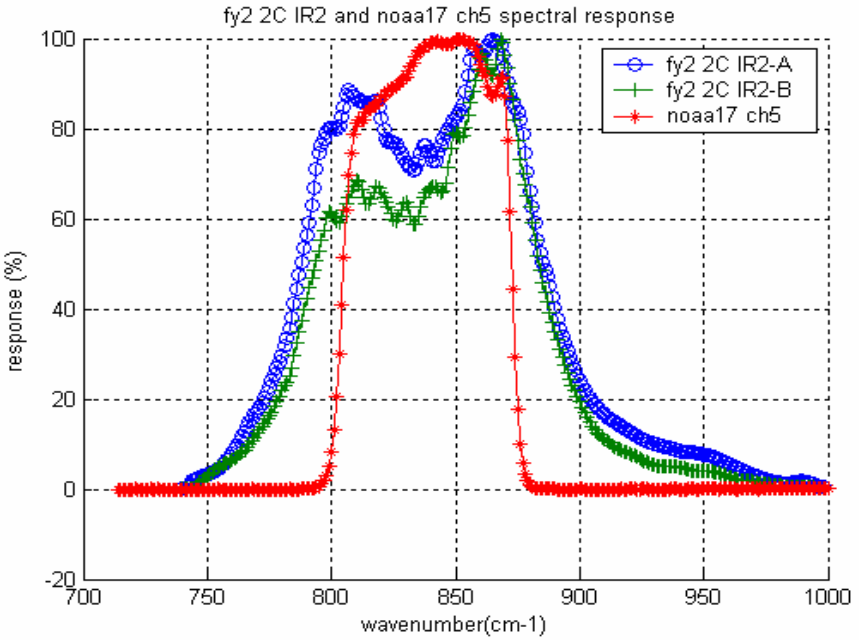
The inter-calibration of infrared channel

Following procedures are required for the inter-calibration process

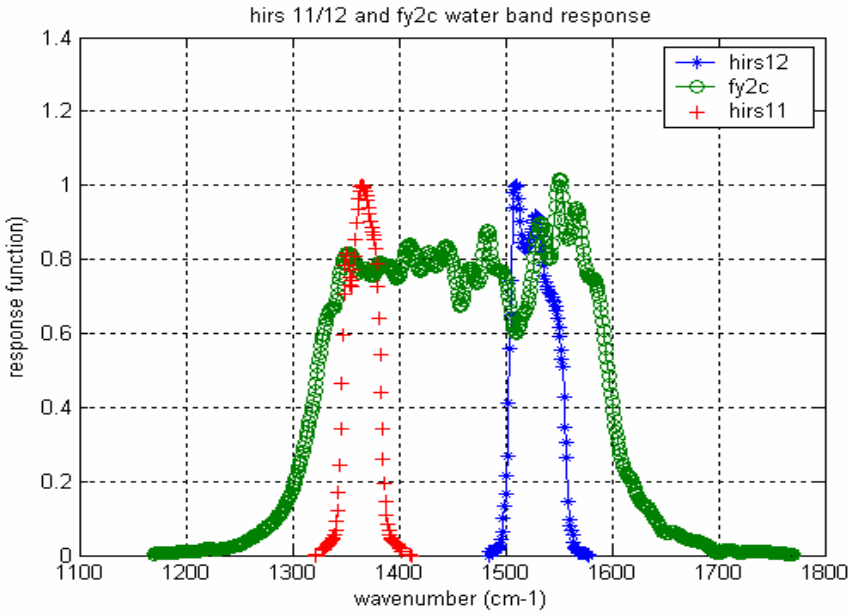
- **spectrum matching between different satellites**
- **time matching of different satellite data**
- **geometric matching for the observed radiance on the same target**
- **When the calibration coefficient from the higher resolution satellite is derived, the converted coefficients are required**



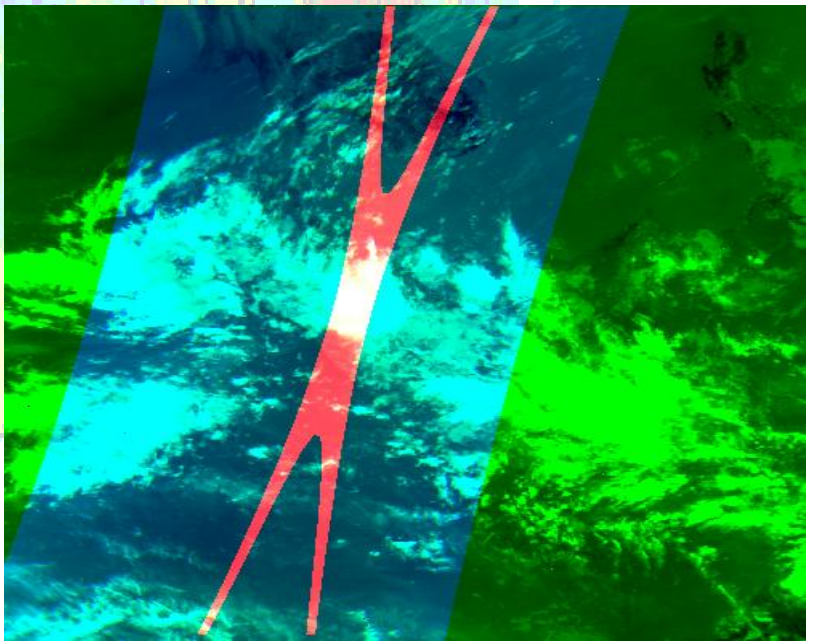
Schematic diagram of the response functions of ch4 and IR1 channel on board two satellites (NOAA–17 and FY–2C)



Schematic diagram of the response functions of ch5 and IR2 channel on board two satellites (NOAA–17 and FY–2C)

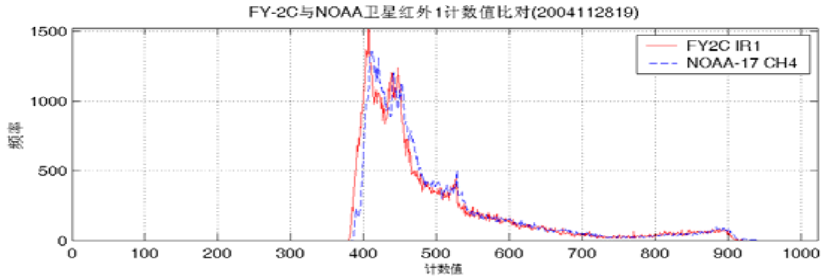


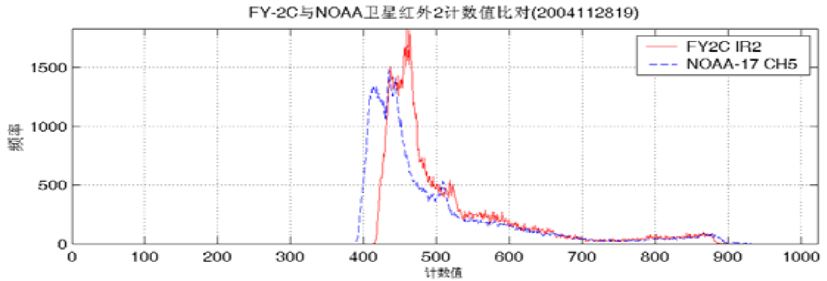
Schematic diagram of the response functions of WV channels on board two satellites (NOAA–17 HIRS/3 and FY–2C)

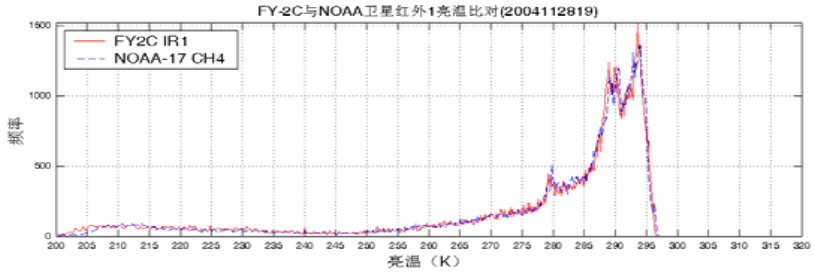


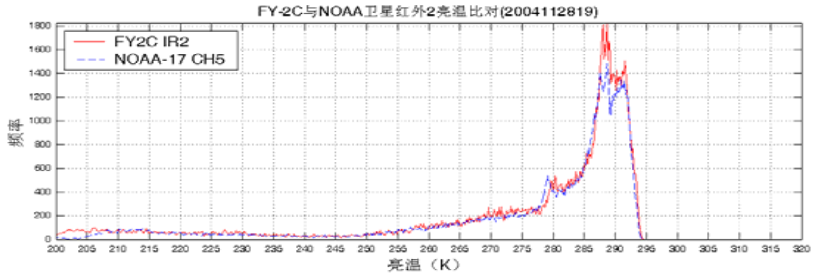
Sample zone (red area) for NOAA satellite passes the sub–point of FY–2C satellite

Analysis of DN and bright-temperature for FY-2C's IR1,IR2

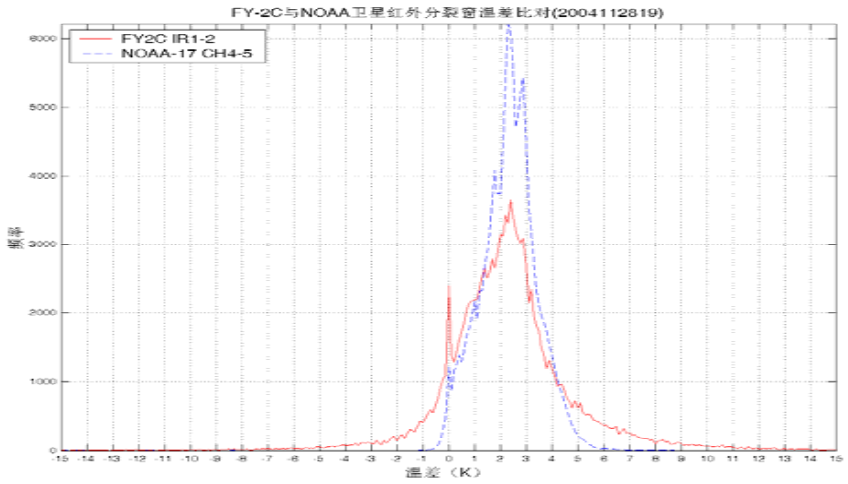








Analysis of IR1 & IR2 bright-temperature difference for FY-2C



5. Calibration activities for FY3: pre-launch calibration

- Pre-launch calibration has been done for all the flight models of FY3A payloads.
- The simulated data are using to develop the data pre-processing software for the payloads on FY3A, such as HIRS for IRAS, AMSU and AMSR for MWTS, MWHS and MWRI, AVHRR for VIRR, MODIS for MERSI.
- the data from SBUS and TOU-like instrument are not accessible in China. NSMC/CMA need assistance to have the space-base measurement of ultraviolet data as simulated data to test the algorithm.

Summarization

- The field calibration are very important to correct the pre-launch calibration for the current FY satellites because of the reliability of the pre-launch calibration and stability of payload before/after launch in China.
- The field calibration data are useful to monitor payload status variation and to update the in-flight calibration coefficient with temporal sequence for current FY satellites.
- By following the reflectance-based calibration flow, the field calibration experiments are successful to derive the in-flight calibration coefficient for the payloads, such as AVHRR-like sensors because of the ideal surface and atmosphere condition in Dunhuang site .
- GSICS will provide the chance to improve the calibration of FY series. On the other hand, the field site in China, the payloads on FY series extend the capability for other country satellites.

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Thank!