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The Chinese Radiometric Calibration Site for Remote Sensing Satellite

Summary and purpose of paper

To provide the information on the measure and construction of radiometric calibration site of remote sensing satellites in China.

The Chinese Radiometric Calibration Site for Remote Sensing Satellites

1. BACKGROUND

Along with quantitative application development of satellite remote sensing technology, the need of high-accuracy radiometric calibration of satellite sensor is increasing.

The radiometric calibration of on-board satellite sensor is restricted for a long time; thus a vicarious method of radiometric calibration on test site is used. It is an available method for improving calibration accuracy. Since 1970's, NASA and Optical Science Center, Arizona University U.S, and CNES and INRA France, have made the absolute radiometric calibration method research in ground-based test site. In recent years the establishment of China Radiometric Calibration Site and the radiometric calibration method research have been taken by some scientists and organizations in China.

2. BASIC THEORY OF THE RADIOMETRIC CALIBRATION OF THE TEST SITE

Basic concept of the radiometric calibration on ground-based test site is: to select a flat, optical characteristic uniform and stable test site as observation target, then to make the synchronous satellite-ground observations with measurement instruments. Inputting the measured data into the ground-based system makes the radiant transfer calculation later. An incidence aperture apparent radiance or apparent reflectance of the in-flight satellite sensor is obtained. A calibration coefficient is obtained by the comparisons of apparent radiance with the observation count of satellite sensor's waveband. Thus a process of absolute radiometric calibration is achieved. For different spectral waveband of satellite sensors, the measurement items and physics model in the radiometric calibration is different.

A. Visible and near infrared spectral wavebands

For visible and near infrared wavebands, the in-flight passive satellite sensor incepts the signal of reflective radiance from the earth-atmosphere system that is relative to the solar irradiance. In the synchronous satellite-ground observations, the ground-based measurements of test site include bi-direction reflectance (ρ_s) from targets and solar irradiance (E_s), atmospheric optical parameters and meteorological parameters etc. And a satellite synchronous observation image of the same surface target area is obtained. Based on geometry and angle of view of the sun and satellite during satellite overpass as well as the spectral response of sensors etc., the radiant transfer calculation is made and the satellite incidence aperture apparent radiance is obtained then. A formula is as following:

$$L = \frac{\rho_s}{\pi} E_s \cdot \tau + L_p \qquad (1)$$

τ: atmospheric transmittance , L_p: atmospheric path radiance

In general, observation value of satellite sensor is presented by appearance reflectance ρ* , it is as

$$\rho^* = \frac{\pi L}{E_o \mu_s} \qquad (2)$$

E_0 : extra-atmospheric solar irradiance, $\mu_{s:}$ cosine of solar zenith

The quantitative relation between calculated spectral radiance and count value (c_i) by satellite sensor is as:

$$L = (a_1 c_1 + a_2) A \qquad (3)$$

a_1 and a_2 are calibration coefficients on board , A is vicarious calibration coefficient by ground test site.

B. Thermal infrared waveband

For the thermal infrared band with wavelength longer than 3 micron, it incepts the radiance signal from the earth-atmosphere system itself. For this waveband, the test site with an uniform temperature distribution and clear water body is proper. In satellite-ground synchronous observations, the ground-based measurements of test site include water surface temperature (T_s), emissivity(ε), spectral radiance (B_s), atmospheric optical parameters and meteorological parameters etc.. And a satellite synchronous observation image of same target area is obtained. Based on geometry and angle of view of the sun and satellite during satellite overpass, as well as the spectral response of sensors etc, the radiant transfer calculation is made. A satellite incidence aperture apparent radiance is obtained. The formula is following as:

$$I = B_s \cdot \tau(P_s) - \int_{p_0}^{P_s} B(p) \partial\tau(p) / \partial p dp \qquad (4)$$

$$B_s = \varepsilon B(P_s) + (1-\varepsilon) L_a$$

τ(P_s): atmospheric transmittance , P_s and P_0: atmospheric pressure at ground level and top atmosphere level, L_a: the downward radiance obtained at ground, B_s and B(p) are the Planck functions at ground surface and pressure P respectively.

The quantitative relation between the incidence aperture radiance I and count value c_i of satellite sensor is as:

$$L = (b_1 c_1 + b_2) \beta \qquad (5)$$

$b_1$and b_2 are calibration coefficients on board , β is vicarious calibration coefficient of infrared band on ground test site.

3. TEST SITE

In order to achieve a high accuracy of radiometric calibration, the following are important.

To select a fit test site, it should be flat and with uniform optical characteristic, stable and sufficient large. Besides, the clear-sky condition should often exist around the site. After the investigation and analysis on test sites, finally the DUN HUANG Gobi desert test site has been defined as the calibration test site for visible and near-infrared bands of satellite sensor, and the QINGHAI lake test site has been defined as the calibration test site of thermal infrared band of satellite sensor. It is also used for the calibration of lower reflectance object in visible and near-infrared band.

Table 1 Basic characteristic parameter at Dunhuang and Qinghai test site

DunHuang test site		QingHai lake test site	
Location:	at suburbs of DunHuang city, Gansu Province,Northwest China, 40°07′ N, 94°20′E .	Location:	at QingHai Province,China, 36°45′ N,100°20′E
Elevation:	1194m above sea level.	Elevation:	3196m above sea level.
Area:	30*30km^2.	Area:	4635km^2.
Character:	flat Gobi desert, small stone No vegetation in 20*20km^2. Reflectance 15% and 30% in visible and near infrared .	Character:	It is thin salt lake in the mainland Average depth 20 m, max depth 28m, the temperature change <1°C reflectance 5% -8% ,from 0.4-
Meteoric-parameter:	air pressure(hpa): 887.6 temperature(°C) : 9.5 Precipitation (mm) 34.1 relative humidity(%): 43.9 time of sunshine(hour): 3270.1 days of clear sky: 112.2 visibility(days/year, >10km): 288.2 days of no strong wind, cloud free, no floating dust and no sand storm 87.9	Meteoric-parameter:	air pressure(hpa): 686.6 temperature(°C) : 0.83 precipitation(mm) 434.5 relative humidity(%): 69.8 time of sunshine(hour): 2981.2 days of clear sky: 56.9 visibility(days/year, >10km): 358.1 days of no strong wind cloud free, no floating dust and no sand storm 43.7

Note: The information is in yearly average from 1984—1993.

4. MEASUREMENT EQUIPMENTS OF THE SITE

With the equipment and instrument importation and domestic technique development, a high accuracy ground measurement system has been established. Now the China Remote Sensing Satellite Radiometric Calibration Site possesses an advanced radiometric calibration technical system .

It includes:

- High spectral resolution and waveband measurement instruments for atmospheric optical characteristic
- High spectral resolution and waveband measurement instruments for ground optical characteristic
- High accuracy radiant standard , instrument calibration and standard transfer system
- High accuracy atmospheric parameter , environment parameter and meteorological observation instruments
- Location , communication and other support equipment

The parameters of primary instruments for the test site are as following :

A. Instruments for measuring ground and atmosphere optical characteristics:

Table 2 High spectral resolution instruments

FT-IR radiometer and Sun tracker	IFS120M A547/2m	Germany BRUKER Inc	range: 0.4—16.6um, resolution: 0.008cm-1
Spectroradiometer	TRIAX190	U.S. EG&G）	range : 0.4—5um , resolution: 0.3nm
FT spectroradiometer	MR154	Canada . Bomem Inc	range :0.7—15um, resolution: 1cm-1
Field radiometer	Fildspec FR	U.S. ASD	range :0.35—2.5um resolution: 3.5nm
Portable illuminometer	OL—754	U.S .LIBERO Inc	range: 0.2—1.6um resolution : 0.05nm
Field radiometer	VF921	China.	range :0.4—1.1um, resolution: 2.7nm
Short-wave IR radiometer	IR981	China.	range :1.3-2.5um, resolution: 6.4nm
Illuminometer	VIR981	China	range : 0.4—2.5um resolution : 20nm

Table 3 The waveband of measurement instruments

Automatic sun tracking photometer	CE318	France Cimel Inc.	8 channel (stand band) 440, 670 ,870 ,937 ,1020 870*3(polarization) special band 430-480 ,630-690 ,480-530, 770-890 ,530-580 ,840-890, 580-680 ,900-965 (nm)
Field radiometer	CE313-21	France	8 channel

		Cimel. Inc.	400-430,430-480,450-520, 480-530,530-580,520-590, 580-680,630-690(nm)
Field radiometer	CE313-23	France Cimel.Inc	6 channel 0.77-0.89,0.84-0.89,0.90-0.965, 1.55-1.75,1.58-1.64,2.08-2.35(μm)
Thermal infrared radiometer	CE312	France Cimel Inc.	5 channel 8.0-14.0, 8.2-9.2, 10.3-11.3, 10.5-12.5, 11.5-12.5(μm)
Infrared radiometer	CE312-1	France Cimel Inc	1 channel 3.55-3.93(μm)

B. Radiant standard and standard transfer equipment

Table 4 Radiant standard and standard transfer equipment

High accurate radiant calibration system	cryorad Absolute radiometer Hamatsu	U.S	accuracy: 0.02%
Standard lamp calibration system	1000w quartz Halogen		range: 350-2500nm
Intergraph calibration system		China	Diameter: 500mm, out . ϕ85mm 1200, out ϕ 400mm
Reference panel		China	400*400mm, 500*500mm
Monochromator	sp-307	U.S	range: 0.35-13um
Blackbody source		China	ϕ120, t:273-343k ε: 0.995

C. Measurement Instruments for atmospheric and environmental parameter

Table 5 Instruments for meteorological and environmental parameter

automatic weather station		VATSALA , Finland	
Buoy		China	
Water thermometer		China	
Visibility instrument		U.S	0.03-60km
Soil Humidity ins..		U.S	range: 2%-100% Accuracy:2%
GPS	RTK	Canada	Location accuracy: 5mm
GPS	2000x	U.S	Location accuracy: 10m

D . Data processing, archive and information service sub-system

This sub-system is as a center of data collection, processing, archiving and information service for China Remote Sensing Satellite Radiometric Calibration Site. It is a system for the processing, archiving and service of the distributed data in a computer network. The center consists of a Web server based on a SQL server database and some micro-computers . Through Internet, the system exchanges information with the long-distance terminal in the radiometric calibration site and the related users. And through FDDI in National Satellite Meteorological Center, the system is also connected with the meteorological satellite data acquisition and processing system. Thus with the system, various meteorological satellite data can be direct obtained to support the radiometric calibration service of the in-flight satellite sensor. On the basis of network computer and system software, the system has integrated various data processing application software for the radiometric calibration. After a tried running of this software, an operation data processing and information service system of radiometric calibration would be formed.

5. FLOWCHART OF THE RADIOMETRIC CALIBRATION

According to satellite orbit parameters and technological characteristic as well as the observation mode of satellite sensor, the measuring equipment are used to confirm the synchronous satellite-ground observation program. In order to ensure the perfection and high quality of the observation, some rules of synchronous observation must be drawn..

Main task for data processing is as:

- Synchronous observational data correction at test site:

  Pre-processing of satellite observation data, calibration and correction of ground based measuring instruments, correction of spectral response and nonlinear of instruments, correction of Bi-direction reflectance of measured data etc.

- Data matching processing of satellite-ground observation:

  Observational time synchronous, pixel resolution matching, observational direction matching, location and registration of pixels and spectral response of instruments matching etc .

- Radioactive transfer code :

  Based on the radioactive transfer codes, such as Lowtran, 6S, Modtran, Fastcode, to develop the radiant transfer calculating code for fitting the radiometric calibration of China remote sensing satellite.

- Calibration coefficient calculating model :

  According to different status and in-orbit parameters of each satellite, it makes vicarious radiometric calibration for domestic satellites, and to develop calculating model of calibration coefficient for each domestic satellite. During June and August,

We made a synchronous observation for FY-1C and FY-2 meteorological satellites, and the calibration processing for FY-1C. We will do the radiometric calibration for CBERS satellite next year. In the near future the vicarious calibrations for the sensors of GMS-5, NOAA-15 and SPOT etc foreign satellites will be taken on China test site.

6. ACHIEVING OBJECT AND APPLICATION PROSPECTS FOR THE RADIOMETRIC CALIBRATION SITE

The projects of setting up a China radiometric calibration site and making related scientific researches will be finished in the end of 1999. With the site it is able to perform the vicarious calibration experiments for satellite sensors, then to execute radiometric calibration task. Firstly, it will make vicarious radiometric calibration for the meteorological satellite, resources satellite and other remote sensing platform of China. Besides, the site can also be used for the calibration of foreign satellites. The completion of the calibration site will improve the development of quantitative remote sensing technology. The technology system and the achievement made in scientific research of the radiometric calibration site of China have had a wide application prospects.

1. Combining closely the vicarious calibration on test site with the preflight

Calibration and the on-board calibration, which will improve the absolute calibration accuracy of satellite sensors. And it will enhance the extent and depth of the quantitative application of remote sensing data. It will also increase the social economical benefit with the application of remote sensing data.

2. The radiometric calibration on test site is an effective method for the monitoring of sensibility degeneration of satellite sensor.

3. The radiometric calibration on test site is helpful for the observation data matching among more satellite sensors and difference observation time. It will improve the comprehensive application of remote sensing data on climate research and environment monitoring. In addition, the radiometric calibration is also an important fashion for validating in orbit instrument performance and improving the development of remote sensing technology. The calibration site is also a radiometric measurement system that is in the lead of domestic remote sensing equipment and technology. This system will play an active role in the international co-operation on radiometric calibration technology.