Dataset of Multi-satellite Synchronous and Collaborative Observation in Zhangye (2013)

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Abstract: With more and more Earth Observation (EO) satellites on-orbit operation, it is especially important to conduct the experiment of multi-satellite synchronous and collaborative observation with ground synchronous measurement. And it is quite valuable for the research on the radiation normalization of multi-source EO data, validation of satellite products, inversion and scaling, supported by precise satellite sensors planning and control technology. In June 2013, we conducted a multi-satellite synchronous and collaborative observation with synchronous ground in-situ experiment in suburbs of Zhangye city. The terrain Features in this area are diverse (Including urban areas, mountains, deserts, forests and crop fields), which can meet the requirements of the synchronous experiment. Satellites sensors and ground instruments are used to perform synchronous and collaborative observation. Synchronous EO data and ground in-situ data are obtained including 10 satellites, 22 sensors and 3 types of ground observation instruments. In this paper, the synchronous observation dataset in Zhangye is introduced in detail including the measurement aim and method, data processing procedures and results, and data available range.

Keywords: Satellites synchronous and collaborative observation; Multi-satellite radiometric normalization; Joint satellite-ground observation; Zhangye experimental area

1 Introduction

Remote sensing (RS) data obtained from Earth Observation (EO) satellites has been widely used in many fields. As the quantity and category of Earth observation satellites increases, the spatial coverage is getting more broad, the temporal extent is more consistent and the spectral and spatial resolution is higher[1]. In recent years, with the development of technol-

ogy and economy, the amount of satellites on orbit increases gradually and satellite performance continues to improve. Because the needs of EO applications are more diverse and complex, single or single-type satellite is difficult to complete the continuous observation of moving or periodical changing targets. It can meet the requirements to harness satellite sensor planning algorithm to schedule multiple, multi-orbit satellites. Coordinating multiple satellites with different trans-pass time and different types of sensors can get EO data for interested ground targets. Then these EO image data is transmitted to the ground control center to meet different application requirements after analysis, interpretation and processing. S. Burrow Bridge[2] studied the ground monitoring and control issues of multiple satellites, and carried out a detailed argument of ground control optimized and reasonable distribution of resources. Al. Globus[3] established a Earth observation scheduling model by considering the priority problems of ground observation targets and constraints of sensor observations,. He Renjie[4–5] put satellite time windows constraints in the planning and scheduling by taking satellite mission planning as a multiple machines scheduling problem. Bai Baocun[6–8] established a synthesis task programming model by analysis the multi-task synthesis in multi-satellite observation.

In the experiment, EO data is acquired by multiple satellites and the ground instruments is used to do synchronous observation in the same region. Based on the synchronous and collaborative observation data with measured atmospheric data on the same day, atmospheric correction for high precision observation images can be carried out. Variations of calibration coefficient and performance can be detected by synchronous measurements of surface spectral sensors. For multi-satellite radiation normalization, data accuracy of radiation normalization can be detected according to synchronous data. Thus normalized standard data products can be produced and a reliable guarantee for later quantitative application can be provided. Specified information of the synchronous and collaborative observation dataset and the basic theory and demonstration of data reliability for data development are introduced in the paper.

The dataset of the multi-satellite synchronous observation experiment[9] in Zhangye district was acquired by the joint efforts of several satellite data centers and research units.

2 Metadata of Dataset

The detailed metadata information of the multi-satellite synchronous and collaborative observation in Zhangye district (2013), including dataset name, short name, authors, geographical area, spatial resolution, data published time, data sharing platform, contents of data sets, publisher and editor in charge, etc., are listed in Table 1.

3 Methods

The dataset of multi-satellite synchronous and collaborative observation in Zhangye region (2013) is acquired under the strict constraints of ground-satellite synchronization. The main contents of the dataset includes: ground measured spectral data, measured atmospheric data, diffuse-to-global ratio measurement data, and satellite EO data as well.

Table 1 Summary of ZYCOLDATA-2013 metadata

Items	Description
Dataset full name	Dataset of multi-satellite synchronous collaborative observation in Zhangye district (2013)
Dataset short name	ZYCOLDATA-2013
Authors	Li, G. Q. L-5718-2016, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Ligq@radi.ac.cn Zhang, H. L-5733-2016, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, haozhang@ceode.ac.cn Xie, J. B. L-6473-2016, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, jbxie@ceode.ac.cn Yuan, F. Y. L-7263-2016, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, fyyuan@ceode.ac.cn Li, H.W. L-5922-2016, Central South University, haiwei6583@163.com Qian, J. M. D-6692-2017, National Satellite Meteorological Centre, qianjm@cma.gov.cn Wan, W. D-4616-2017, Chinese Centre for Resources Satellite Data and Application, wanwei829@163.com Ma, G. B. L-6180-2016, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, gbma@ceode.ac.cn
Geographical region	38°22′34″N−39°02′34″ N, 99°59′57″E−100°51′42″ E Study area located nearby Zhangye city, Gansu Province and most of the landscape is alluvial plain
Time	2013
Temporal resolution	daily
Spatial resolution	15 m−1,000 m
Data format	.hdf, .tif, xls, .kmz, .zip Number of files 30
Data Size	18.5 GB
Data files	The dataset consists of 4 parts: Earth Observation data, ground measured spectral data, measured Diffuse-to-global ratio data, atmospheric observation data. 1. 201306-microtopsII.xls, this is the atmospheric observation data，data size is 248 KB 2. 20130612Reflection.rar, this is the ground measured spectral data ,data size is 7.43 MB 3. 201306-MZB processing results.xls, this is the measured Diffuse-to-global ratio data, data size is 403 KB 4. Earth Observation data by 10 satellites collaborative observation, data size is about 18.5 GB and data filenames are shown in Table 2
Foundations	Ministry of Science and Technology of P. R. China (2013AA12A300); Beijing Government (501-01-2012-800004-15); Chinese Academy of Sciences (131C11KYSB20160061)
Data Publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn/
Address	Address: No.11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	The term of the **Data** from the Global Change Research Data Publishing and Repository is the definition of metadata, dataset (data product), and data paper (published through *Journal of Global Change Data & Discovery*). The **Data** sharing policy includes: (1) the **Data** is openly available and can be easily to be downloaded through internet for all; (2) end users are encouraged to use the **Data** subject to citation; (3) users, who are value added provider services, are welcome to redistribute the *Data* subject to written permission from the GCdataPR Editorial Office for the **Data** redistribution license; (4) for database or new dataset developers who use the **Data** to compile new dataset, the "ten per cent principal" should be followed, that is, the picked records from the **Data** should not surpass 10% of the new dataset, and the data records source should be clearly noticed in the suitable place in the new dataset[10]

3.1 Synchronous Observation Planning

Multi-satellite synchronous and collaborative observation is one of the multi-satellite coordinating and planning modes. There are three commonly used synchronous modes: (1) Several satellites take images in the same place at the same time; (2) Several satellites take images at different locations at the same time; (3) Several satellites take images at the same

place at different time. In this project we use the first synchronous mode. Seven cruising observation satellites and three task-oriented observation satellites are used in the synchronous observation. In order to determine the exact time of simultaneous observation, task-oriented observation satellites are requested to make observation planning.

According to the on-orbit simulation of three task-oriented observation satellites on June 1, 2013, it is possible to do synchronous observation for several satellites at the study area in Zhangye city, Gansu province, China. Considering the result of satellite on-orbit simulation and ground measurement requirements, this study area has ideal conditions. So this synchronous observation experiment is designed and done (Figure 1).

3.2 Satellites Synchronous Observation Data

After the process of synchronous observation planning and satellite observation tasks submission, 10 satellites with 22 sensors were used to obtain EO image data for the study area between 11:00 to 12:00 on June 13, 2013.
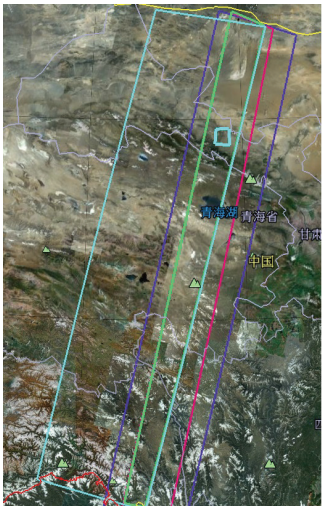

Figure 1   Multi-satellite Synchronous planning example (Light blue line: SPOT5 observation extent; dark blue line: THEOS observation extent; pink line: SJ9 observation extent; green line: the overlay extent of three satellites)

Table 2   Metadata of multi-satellite synchronous observation dataset in Zhangye

No.	Satellite	Sensor	Product level	Name of data file	Entry	Data volume
1	TERRA	MODIS	02\03	TERRA_*.hdf	4	1.77 GB
2	AQUA	MODIS	02\03	AQUA_*.hdf	4	2.08 GB
3	FY2D	VISSR		FY2D_*.hdf	4	834 MB
4	FY2E	VISSR		FY2E_*.hdf	4	834 MB
5	FY2F	VISSR		FY2F_*.hdf	4	834 MB
6	FY3A	MERSI	L1	FY3A_MERSI*.hdf	15	4.58 GB
		MWHSX	L1	FY3A_MWHSX*.hdf	8	114 MB
		TOUXX	L1	FY3A_TOUXX*.hdf	9	16.7 MB
		VIRRX	L1	FY3A_VIRRX*.hdf	10	711 MB
7	FY3B	ERBMX	L2	FY3B_ERBMX*.hdf	14	199 MB
		ERMXX	L1	FY3B_ERBMXX*.hdf	8	67.3 MB
		IRASX	L1	FY3B_IRASX*.hdf	8	103 MB
		MERSI	L1	FY3B_MERSI*.hdf	12	4.21 GB
		MWHSX	L1	FY3B_MWHSX*.hdf	9	128 MB
		MWRIA	L1	FY3B_MWRIA*.hdf	1	26.7 MB
		MWRI	L1	FY3B_MWRID*.hdf	4	107 MB
		MWTSX	L1	FY3B_MWTSX*.hdf	13	5.77 MB
		TOUXX	L1	FY3B_TOUXX*.hdf	9	17.4 MB
		VIRRX	L1	FY3B_VIRRX*.hdf	6	426 MB
8	HJ1B	CCD2	L2	HJ1B-CCD2*.tar.gz	2	1.72 GB
9	SPOT5	HRG2	1A	SPOT5.rar	2	694 MB
10	THEOS	MS&PAN	1A	*-TH201300074*.rar	3	1.11 GB

3.3 Ground Measured Spectral Data

For remote sensing research, it needs suitable spectrometers for field application in order to study the reflectance spectrum of visible and near-infrared for a variety of different objects in the field under natural conditions. We used ASD Fileldspec Pro FR (referred to as ASD FR) full spectrum portable optical spectrum analyzer, which was made in American ASD (Analytical Spectral Devices) company. The spectral range of the spectrometer is between 350−2,500 nm, including: VNIR (350−1,020 nm), SWIR1 (1,020−1,800 nm) and SWIR2 (1,800−2,500 nm) (Table 3).

Table 3 Main technique parameters of ASD FR spectrometer

Technique parameters	Indexes
Degree of linearity	±1%
Wavelength accuracy	±1 nm@700 nm
Wavelength repeatability	As a result of 0.3 nm at calibration temperature ± 10 °C range
Spectral resolution	3 nm@700 nm, 10 nm@1,400 nm and 2,100 nm
Sample interval	1.4 nm, and 2 nm in the range of 350−1,000 nm and 1,000−2,500 nm correspondingly
Scanning time	Fixed scanning time is 0.1 second; Max average spectrum reaches to 31,800 times
Equivalent noise radiation	UV/VNIR(ultraviolet to near infrared)1.4×10^{-9} W/(cm^2·nm·sr)@700 nm NIR(near infrared) 2.4×10^{-9} W/(cm^2·nm·sr)@1,400 nm NIR(near infrared) 8.8×10^{-9} W/(cm^2·nm·sr)@2,100 nm

Notes: @700 nm signifies700 nm, the rest remaining the same.

ASD FR continuous spectrometer has two measuring modes: Raw data measurement modes and reflectance/reference sheet measurement mode.

In the raw data measurement mode, the spectrum measurement, display and store is mainly the raw digital signal. Under the reflectance/reference sheet measurement mode, the measurement, display and storage is automatically normalized to the spectrum on the latest measuring reference signals, and its value is the relative reflectance factor[11]. In this experiment the measurement mode, "reference board-ground-reference board", was used. The surface albedo (ρ_g) could be calculated:

$$\rho_g = \frac{V_g(\lambda)}{V_p(\lambda)}\rho_p \tag{1}$$

Where, $V_g(\lambda)$ is the measured spectral curves of DN values for sampling the landmark point.

3.4 Ground Measured Atmospheric Data

The ground atmospheric data was measured by using Microtops sun photometer made in United States Solar Light Company, which is one of handheld spectrophotometers used by many researchers around the world. The Microtops is a handheld 5-channel sun photometer. According to different purposes, users can choose the channel wavelength when purchase (such as observations of ozone and water vapor observation, select 300, 305.5, 312.5, 940, 1,020 nm). Each is equipped with a narrowband filter and as a 2.5° field angle. By choosing a different wavelength, AOD, total amount of direct solar radiation, ozone and water vapor can be measured.

　　Assume that the aerosol particle size distributions satisfy Runge (Junge) distribution, according to formula (2), and Angstrom coefficient α atmospheric turbidity coefficient β was calculated by using aerosol optical depth over any two-channel ($\tau_{a\lambda}$), based on which deduced the aerosol optical thickness at 550 nm wavelength.

$$\tau_{a\lambda} = \beta\lambda^{-a} \tag{2}$$

3.5 Diffuse-to-global Ratio Measurement Data

The portable spectrometer for measuring diffuse-to-global ratio in experiment area is made by American SVC Company, which is a widely used spectrometer. The SVC spectrometer has three commonly used models, GER1500, GER3700 and HR-1024. Its specific parameters are shown in Table 4.

Table 4　Key technique parameters of HR-1024 spectrometer

Basic specifications	Indexes
Spectral measurement range	350−2,500 nm
The channel number	1,024 tunnel
Instrument weight	3.1 kg
Spectral resolution	≤3.2 nm (350−1,050 nm)
	≤8.5 nm (1,000−1,900 nm)
	≤6.5 nm (1,900−2,500 nm)
Scanning time	Minimum 1 ms
Field angle	14° and 4° standard can choose prepositional 25° optical fiber field lens
Size of instrument	220 mm×290 mm×80 mm
Data format	16 bits
Wavelength repeatability	±1 nm
Dark current	Automatic or manual
Power	12V VDC battery
Mode of operation	Portable, back or tripod fixing
The work environment	Temperature −10−40°C, humidity 10%−90% RH

　　The instrument used to measure the diffuse-to-global ratio is shown in Figure 2. The diffuse radiation is measured when the tripod ball shade light above the black hole. Otherwise, the global radiation is measured. The diffuse-to-global ratio is directly calculated by the value of the blocking ratio of total solar radiation and diffuse solar radiation, as follows:

$$a = 2L_2 / (L_1 + L_3) \tag{3}$$

Where, L_2 is the value of blocking diffuse reflection; L_1 and L_3 is the value of twice nearest global radiation without blocking.

4 Dataset Compositions, Quality Control and Validation

The dataset of multi-satellite synchronous and collaborative observation in Zhangye region (2013) includes 4 parts: Satellite datasets, ground spectral datasets, diffuse-to-global ratio data sets, atmospheric datasets.

　　1) Surface albedo.zip is the ground synchronous spectral data. Its data size is 8.02 MB.

The wavelength-dependent surface measured reflectivity curves are shown as Figure 3.

2) Atmospheric data.zip is the measured atmospheric data. Its quantity is 248 KB. AOT at 550nm wavelength varying over time is shown in Figure 4. The vertical line in the figure represents the transit time.

3) Diffuse-to-global ratio.zip is the measured diffuse-to-global data. Its data size is 403 KB. The wavelength-dependent diffuse-to-global curves are shown as Figure 5.

4) The satellite EO data consists of 10 satellites, which original data size is 18.5 GB. The EO data products are received, processing, and provided by satellite data centers.

5 Discussion and Conclusion

5.1 Multi-satellite Synchronous Observation Data

The experiment of multi-satellite synchronous and collaborative observation harnessed multi-satellite and multi- sensor to observe the same study area. Before the experiment, a scientific satellite observation planning program was used to generate the executable observation plan. Multi-source Earth Observation data can be used for cross-calibration, cross-validation between different satellites, as well as verification of multi-satellite collaborative remote sensing retrieval products. It is quite difficult to perform the 10 satellites synchronous observation because the related satellites covers the major observational scale (15–1,000 m) and different observation spectrum (high spectrum, multispectral and panchromatic). And the dataset has po-

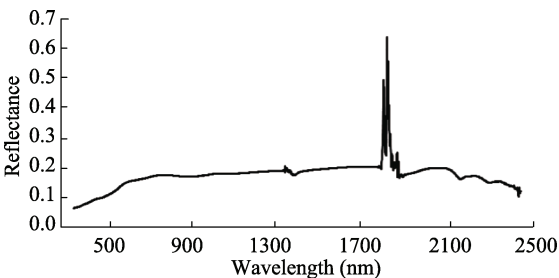**Figure 2**   Measuring instrument of diffuse-to-global ratio

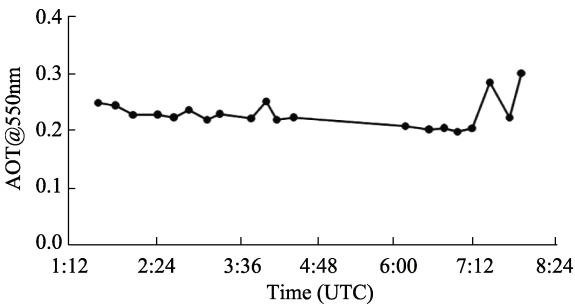
Figure 3   Ground measured spectrum

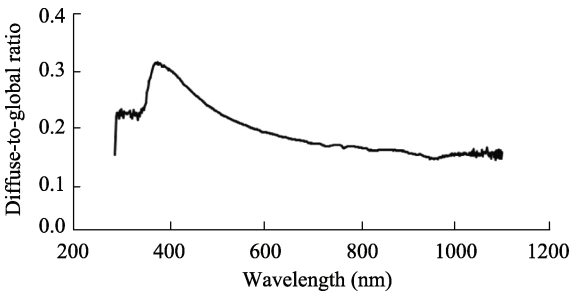**Figure 4**   AOT in 550 nm wavelength

Figure 5   The measured Diffuse-to-global ratio data

potential scientific value for research on multi-satellite synchronous observation and multi-satellite data fusion.

5.2 Ground Measured Spectral Data

The measured sites of ground spectral data are mainly located in the calibration regions, where the landscapes are plain, features uniform, and broaden vision. The measured spectral data can be combined with atmospheric data to calibrate the sensor and monitor sensor performance change. The cross calibration with multi-satellite, surface measurements of spectral data is required to calculate the spectral matching factor data. It can realize cross calibration among multi-satellite by using multi-satellite synchronous ground spectrum data. After atmospheric correction of the image, it can also be used to validate ground measured spectral data, in order to improve and perfect the correct results.

5.3 Atmosphere Data

The atmospheric data measuring stations are located mainly near the calibration sites. The main measurement data are as follows: AOT, moisture content and atmospheric pressure, etc. The atmospheric data is an indispensable input item for radiative transfer model, whose precise, to a certain extent, ensure the authenticity of the results. The atmospheric data are the entries for sensor's calibration as well as atmospheric correction. For using satellite image data to aerosol and water vapor retrieval, the measured atmospheric data can also verify the retrieval results.

5.4 Diffuse-to-global Ratio Data

The measuring site of diffuse-to-global ratio data is near the open region of the calibration site. The aim is to primarily reduce errors assumed in radiative transfer models. Comparing with the aerosol type assumptions, using the field measurements of diffuse-to-global ratio data is closer to the actual radiative transfer conditions. Combing the measured diffuse-to-global ratio data with radioactive transfer models, the irradiance method can be used for high precision sensor's calibration. In addition, based on variation field measurement curves of measured diffuse-to-global ratio along with time, the variation of atmospheric conditions can be acquired. When the curve of diffuse-to-global ratio vary dramatically, it signifies the variation of atmospheric conditions is huge. At this point, it needs to be analyzed according to specific purposes of research, to ensure that research results are true and reliable.

Author Contributions

Authors from RADI/CAS designed the multi-satellite synchronous and collaborative observation experiment, scheduled the satellite networking plan, and performed the in-situ survey. The author from CMA provided the FY series satellite image. The author from CRESDA provided the HJ satellite images.

Acknowledgements

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