SDGSAT-1 Data Users Handbook (Draft)

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Table of Signatures

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Document Summary

The SDGSAT-1 Users Handbook is prepared by the International Research Center of Big Data for Sustainable Development Goals (CBAS). The purpose of this handbook is to provide a basic understanding and associated reference material for the Sustainable Development Science Satellite 1 (SDGSAT-1) observatory and its scientific data products. This handbook records the situation of SDGSAT-1, technical specifications, data format, etc. to serve the scientific application of SDGSAT-1.

(1) Terminology explanation

Auxiliary data: describes the auxiliary information that is helpful in the SDGSAT-1 data processing. Specifically, it refers to the non-image parts that are related to the parameters of payloads when transmitted from satellite.

Metadata: describes the data structure, data domain and relationship. Specifically, it refers to the information recorded in the *meta.xml* file.

Browse image: downscaled image with a suffix of browse.png.

Thumbnail: a compressed image representation with a suffix of thumb.png.

UTC: Coordinated Universal Time, the primary time standard by which the world regulates clocks and time.

TIS: Thermal Infrared Spectrometer.

MII: Multispectral Imager for Inshore.

GIU: Glimmer Imager for Urbanization.

(2) Except for special instructions, all the time in the documents refers to the UTC.

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1. Introduction of SDGSAT-1

1.1 Background of Satellite Development

The implementation of the UN 2030 Agenda for Sustainable Development (2030 Agenda) faces several challenges such as lacking of data and insufficient processing methods. As an efficient means of data acquisition for research, earth observation can widely, dynamically and objectively monitor the Earth, and detect the Earth's environmental parameters related to land, ocean, atmosphere, and human activities. It can provide dynamic, multi-scale and periodic information that is closely related to the Earth's surface environment and resources for the Sustainable Development Goals (SDGs).

The Sustainable Development Science Satellite 1 (SDGSAT-1) is the first science satellite in the world dedicated to serving the 2030 Agenda, and the first Earth science satellite of the Chinese Academy of Sciences. To meet the requirements of monitoring, evaluating and researching on indicators of SDGs, SDGSAT-1 aims to depict traces of anthropic activities by synergetic observation of its triple payloads, i.e., Thermal Infrared Spectrometer (TIS), Glimmer Imager for Urbanization (GIU) and Multispectral Imager for Inshore (MII). The TIS can explore the spatial distribution of thermal radiance of land surface, the GIU can detect various night lights in urban and rural areas with various intensity, as well as to retrieve urban aerosols at night. The MII can monitor the coastal environment. The triple payloads work in day or/and night observing modes, facilitating the realization of global SDGs and the study of the SDG indicators related to human-nature interaction.

SDGSAT-1 was developed by the Big Earth Data Science Engineering Program (CASEarth), a Strategic Priority Research Program of the Chinese Academy of Sciences (CAS). It is the first satellite in the series of the Sustainable Development Science Satellites constructed by the International Research Center of Big Data for Sustainable Development Goals (CBAS).

1.2 Scientific Objectives

The scientific objectives of SDGSAT-1 are to detect the parameters related to the interactions between human activities and the Earth environment, convert integrated detection data to SDGs application information, and explore the correlation and coupling with human activities and natural environment related indicators. By taking full advantages of SDGSAT-1 in macroscopic, dynamic, large-range, multi-payload and day-night collaborative acquisitions of the Earth's surface, the environmental changes and evolution rules mainly caused by human activities can be learned, such as urbanization level (SDG11), human settlement patterns (SDG2 and SDG6), energy consumption (SDG13) and coastal ecology (SDG14 and SDG15). In addition, new detection methods for surface environmental elements under weak light conditions such as night light or moonlight can be explored to serve for the fields related to SDGs.

Figure 1.1 The SDGSAT-1 was successfully launched in China

Figure 1.2 SDGSAT-1 was successfully entered to the designated orbit

At 10:19, November 5, 2021 (Beijing standard time), SDGSAT-1 was launched by Long March 6 rocket from the Taiyuan Satellite Launch Center, Shanxi province, China. The satellite was successfully sent to the designated orbit and attitude, with solar panels deployed (Figures 1.1 and 1.2). On December 20, 2021, the first batch of images taken by the satellite were unveiled in Beijing, China, including GIU, MII and TIS images upon Yangtze River Delta, Shandong Peninsula, Namtso lake in Tibet, Aksu City of Xinjiang Province, Beijing City, Shanghai City, and Paris of France, etc. On May 27, 2022, the orbit operation conditions of the satellite were evaluated and thereafter the satellite entered into its trial operation phase.

2. Main Technical Specifications of SDGSAT-1

2.1 Features of Design

The SDGSAT-1 was designed to have a Sun-synchronous orbit and be equipped with three payloads – Thermal Infrared Spectrometer (TIS), Glimmer Imager for Urbanization (GIU) and Multispectral Imager for Inshore (MII). By working in ‘Thermal Infrared + Multispectral’, ‘Thermal Infrared + Glimmer’ and single-payload observation modes in orbit, SDGSAT-1 can collect multiple types of datasets through synergetic observations day and night. To ensure data quality, SDGSAT-1 has various calibration modes, such as side slithering calibration, blackbody and cold sky calibration, vicarious calibration, and cross calibration. Its design life is 3 years.

2.2 Orbit

The orbit of the SDGSAT-1 is circular, near polar and sun-synchronous (Figure 2.1). SDGSAT-1 flies at an altitude of 505 km (ranges from 500 km to 510 km) with inclination angle of 97.5°. The descending node of SDGSAT-1 is 9:30 AM, with the circling time around 90 minutes. It can circle the Earth 14 to 15 rounds per day, and the revisit period is about 11 days.

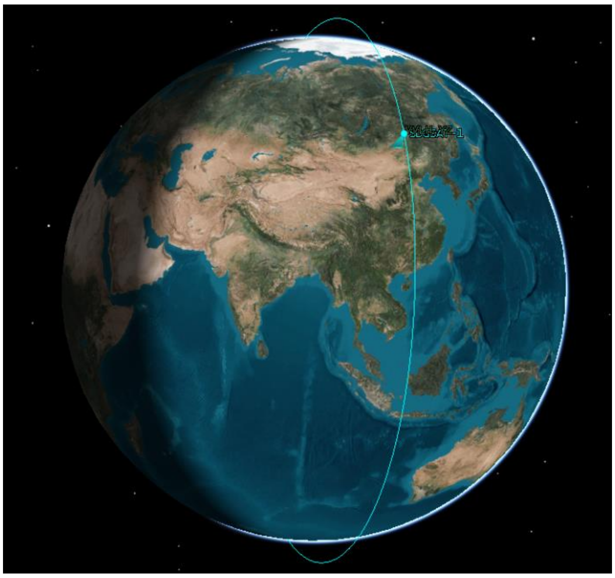

Figure 2.1 Diagram of the orbit of SDGSAT-1

The tracks of satellite nadir points of SDGSAT-1 are shown in Figure 2.2. The swath width is 300 km at nadir. Except for the general observation mode targeted to global SDGs, the SDGSAT-1 also has an emergency response mode for major natural disasters, as well as an extended mode for polar areas to strengthen the ability of polar observation. Within the imaging range, the MII works at daytime and shuts down at night, the GIU works at night and shuts down at daytime, and the TIS can operate all day long.

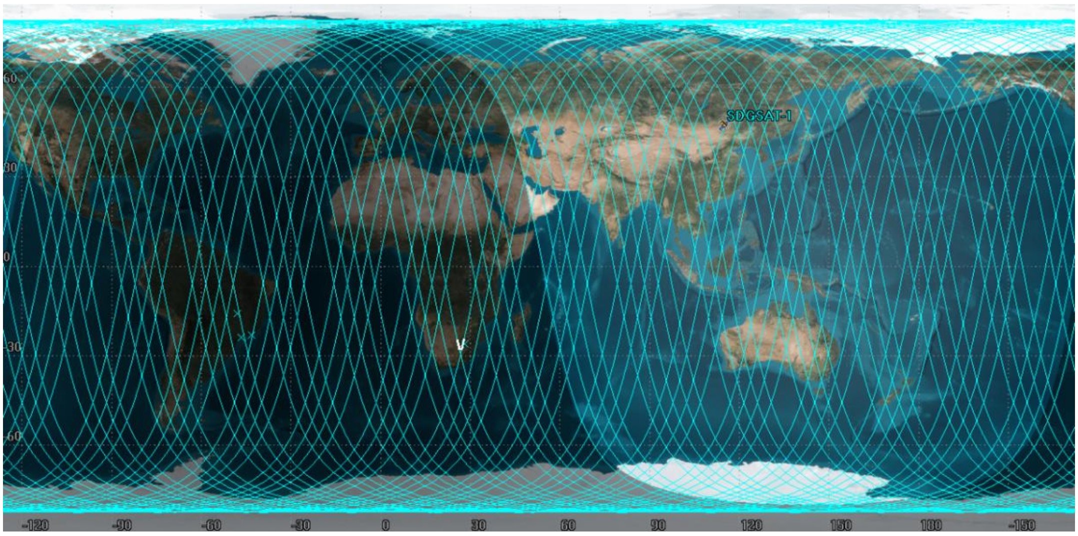

Figure 2.2 Tracks of satellite nadir points of SDGSAT-1

2.3 Technical Specifications

The technical specifications of the triple payloads (i.e., MII, GIU and TIS) of SDGSAT-1 are listed in Table 2.1.

Table 2.1 Technical specifications of SDGSAT-1

Orbit/Sensor	Parameter	Specification
Orbit	Type	Sun-synchronous
	Altitude	505 km
	Inclination	97.5°
TIS	Swath Width	300 km
	Spectral Bands	8.0~10.5 μm 10.3~11.3 μm 11.5~12.5 μm
	Spatial Resolution	30 m
GIU	Swath Width	300 km
	Spectral Bands	P: 444~910 nm (PL/PH) B: 424~526 nm G: 506~612 nm R: 600~894 nm
	Spatial Resolution	P (PL/PH): 10 m, Color (RGB): 40 m
MII	Spectral Bands	B1: 374 nm~427 nm B2: 410 nm~467 nm B3: 457 nm~529 nm B4: 510 nm~597 nm B5: 618 nm~696 nm B6: 744 nm~813 nm B7: 798 nm~911 nm
	Spatial Resolution	10 m

The GIU and MII of SDGSAT-1 use a multimode design sharing with the same optical path to realize imaging through switching the optical path between day and night. The GIU is the first multi-color night-time light imager in the world, including a panchromatic band and three multi-color bands (RGB), with spatial resolutions of 10 m and 40 m, respectively. The MII includes seven multispectral bands with 10-m spatial resolution, a wide swath width and high signal-to-noise ratios (SNRs) and can take an elaborate coastal observation. Main specifications of the SDGSAT-1 GIU/MII are shown in Table 2.2.

Table 2.2 Main specifications of SDGSAT-1 GIU/MII

Parameter		Specification
SNR of GIU	City main road	≥ 50 (Panchromatic and RGB, $1.0\times10^{-2}W/m^2/sr$)
	Urban residential district	≥ 10 (Panchromatic and RGB, $1.6\times10^{-3}W/m^2/sr$)
	Polar moon	≥ 10 (Panchromatic, $3\times10^{-5}W/m^2/sr$)
	Dynamic range of the same scene	≥ 60 dB
SNR of MII		B1 ≥ 130, B2~B6 ≥ 150 (reflectance = 0.3, solar zenith angle ≥ 30°)
Static/Dynamic MTF		≥ 0.23/0.10
Radiometric Calibration Accuracy		Relative radiometric calibration: ≤ 2% Absolute radiometric calibration: ≤ 5%
Quantization		≥ 12 bits
Bit Rate		≤ 400 Mbps

TIS is a new design with three bands, featured with a wide swath width (300 km), a high spatial resolution (30 m), a high dynamic range (220~340 K), and a high detection sensitivity (0.2K@300K). Main specifications of TIS of are listed in Table 2.3.

Table 2.3 Main specifications of SDGSAT-1 TIS

Parameter	Specification
Noise Equivalent Temperature Difference (NETD)	0.2K@300K
Dynamic Range	220K~340K
Static/Dynamic MTF	≥ 0.17/0.1@30m resolution (satellite nadir)
Radiometric Calibration Accuracy	Absolute radiometric calibration: ≤1K@300K, Relative radiometric calibration: 5%
Quantization	≥ 12 bits
Bit rate	Peak value ≤ 230 Mbps Mean value ≤ 70 Mbps
Calibration	Full field-of-view blackbody calibration
Scanning Accuracy	⩽ 6″ (objects, 3σ)

2.4 Illustration of Spectral Responses

(1) TIS

The TIS includes three bands, each of which is composed of four Charge Coupled Devices (CCDs). Figure 2.3 shows the relative spectral response (RSR) of each TIS band.

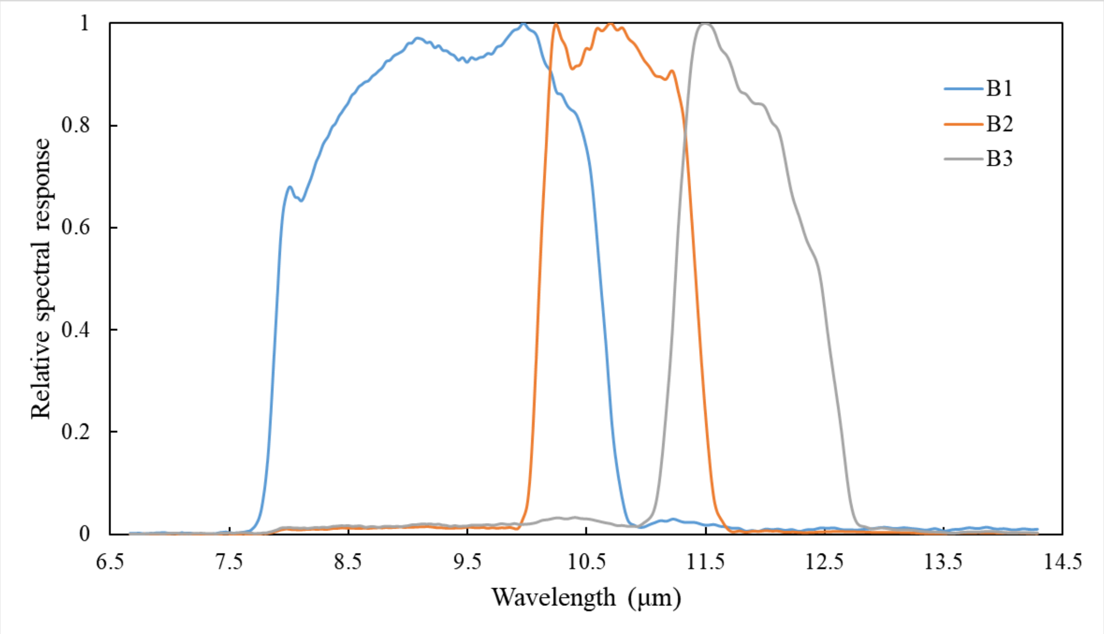

Figure 2.3 Spectral responses of SDGSAT-1 TIS bands

According to the relative spectral responses, the equivalent central wavelengths of the three TIS bands are shown in Table 2.4.

Table 2.4 The equivalent central wavelengths (μm) of SDGSAT-1 TIS bands

Band	B1	B2	B3
Equivalent central wavelength	9.35	10.73	11.72

(2) MII

The MII includes seven bands, each band is composed by sixteen Complementary Metal Oxide Semiconductors (CMOSs). Figure 2.4 shows the relative spectral response of MII.

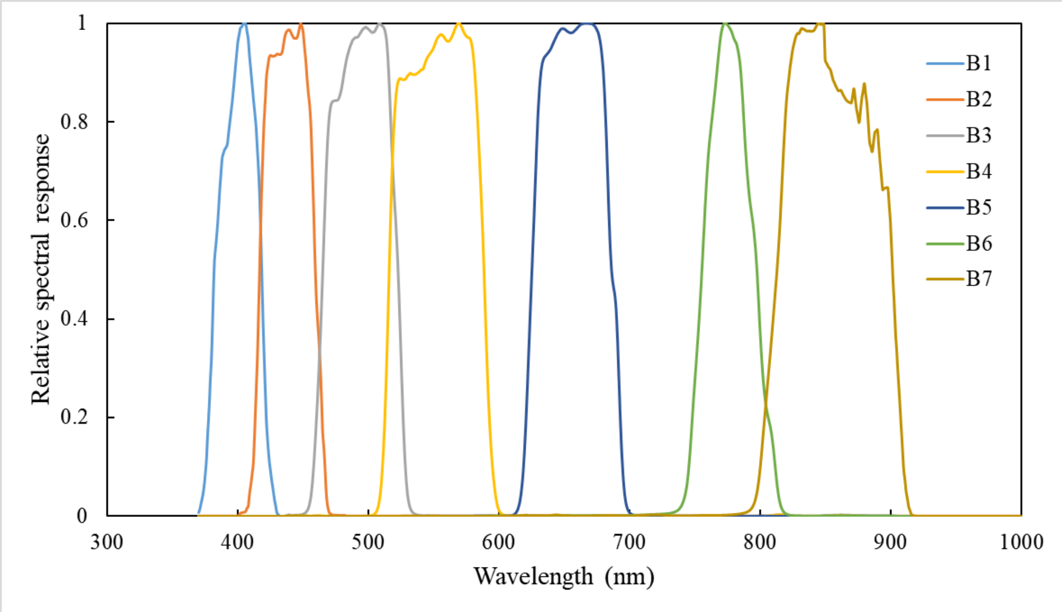

Figure 2.4 Spectral response of SDGSAT-1 MII bands

According to the relative spectral response, the equivalent central wavelengths of seven bands are shown in Table 2.5.

Table 2.5 The equivalent central wavelengths (nm) of SDGSAT-1 MII

Band	B1	B2	B3	B4	B5	B6	B7
Equivalent central wavelength	400.63	438.47	495.10	553.23	656.75	776.12	854.02

(3) GIU

The GIU includes a panchromatic band and three multi-color bands, Figure 2.5 shows the spectral response of GIU. P stands for panchromatic band, which contains three types of data: Panchromatic Low (PL), Panchromatic High (PH) and High Dynamic Range (HDR), where the HDR is the 50% weighted average of PL and PH data. The PL and PH share the same relative spectral response. RGB is the three multi-color bands.

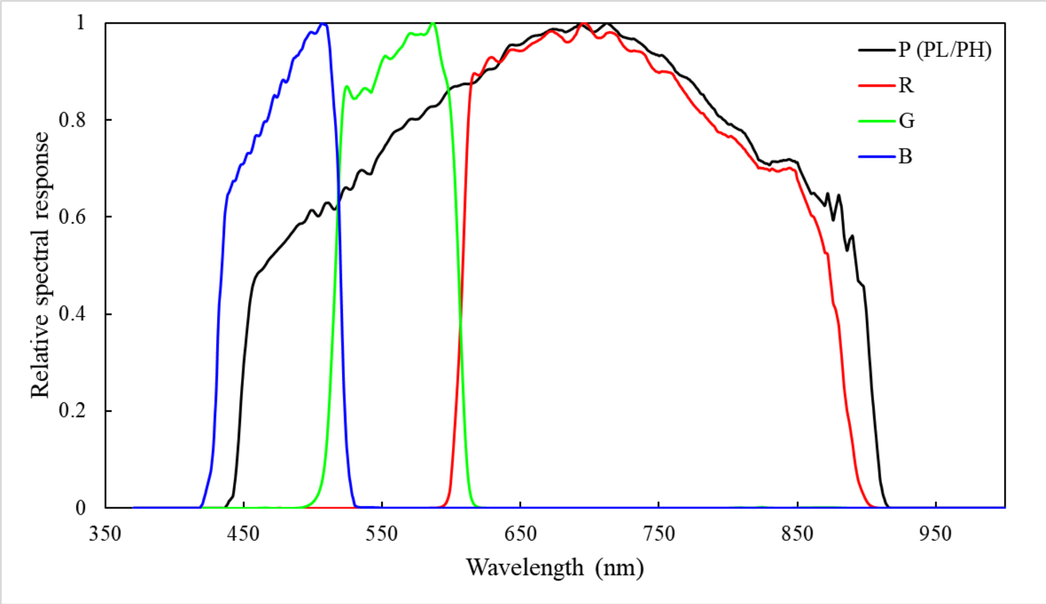

Figure 2.5 Spectral responses of SDGSAT-1 GIU bands

According to the spectral response, the equivalent central wavelengths of four bands are shown in Table 2.6.

Table 2.6 The equivalent central wavelengths (nm) of SDGSAT-1 GIU bands

Band	P	R	G	B
Equivalent central wavelength	680.72	734.25	561.20	478.87

2.5 Illustration of Calibration Coefficients

(1) TIS

TIS uses onboard black body temperatures for periodical calibration with frequency of about two weeks. The calibration coefficients are suitable for the L4A product after May 14, 2022. According to the evaluation results of periodical onboard calibration of TIS, the radiometric calibration coefficients (Gain and Bias) will be successively updated. With reference to the calibration coefficients, each pixel can be calibrated as follow:

$$L = \mathrm{DN} \times \mathrm{Gain} + \mathrm{Bias}$$

where L is the apparent radiance (W/m^2/sr/μm), DN is the digital number of the pixel, and Gain and Bias are the calibration coefficients. The calibration coefficients of Gain and Bias can be referred to Table 2.7, and the specific illustration is in the calibration file of SDGSAT-1 product (*calib.xml*).

Table 2.7 Coefficients for absolute radiometric calibration of SDGSAT-1 TIS

Band	**Gain**	**Bias**
B1	0.003947	0.167126
B2	0.003946	0.124622
B3	0.005329	0.222530

(2) MII

The absolute calibration coefficients (Gain and Bias) of the MII sensor were derived from an imaging test on the calibration field in Dunhuang, Gansu Province, China, on December 14, 2021. These coefficients will be successively updated in the future. With reference to the calibration coefficients, each pixel can be calibrated as follow:

$$L = \mathrm{DN} \times \mathrm{Gain} + \mathrm{Bias}$$

where L is the apparent radiance (W/m^2/sr/μm), DN is the digital number of the pixel, and Gain and Bias are the calibration coefficients. The calibration coefficients of Gain and Bias can be referred to Table 2.8, and the specific illustration is in the calibration file of SDGSAT-1 product.

Table 2.8 Coefficients for absolute radiometric calibration of SDGSAT-1 MII

Band	Gain	Bias
B1	0.051560133	0
B2	0.036241353	0
B3	0.023316835	0
B4	0.015849666	0
B5	0.016096381	0
B6	0.019719039	0
B7	0.013811458	0

(3) GIU

The absolute calibration coefficients (Gain and Bias) of the GIU sensor were derived from an imaging test on the calibration field in Dunhuang, Gansu Province, China, on December 7, 2021. These coefficients will be successively updated in the future. With reference to the calibration coefficients, each band can be calibrated as follow:

$$L = \mathrm{DN} \times \mathrm{Gain} + \mathrm{Bias}$$

where L is the apparent radiance ($W/m^2/sr/\mu m$), DN is the digital number of the band after relative radiometric calibration, and Gain and Bias are the calibration coefficients. Bias means the average dark current when imaging ocean under the crescent condition. The calibration coefficients of Gain and Bias can be referred to Table 2.9, and the specific illustration is in the calibration file of SDGSAT-1 product.

Table 2.9 Coefficients for absolute radiometric calibration of SDGSAT1 GIU

Band	Gain	Bias
PL	0.00008832	0.0000167808
PH	0.00008757	0.0000183897
R	0.00001354	0.0000136754
G	0.00000507	0.000006084
B	0.0000099253	0.0000099253

2.6 Working Mode

Regular observation modes of the SDGSAT-1 include general nadir observation mode, side swing observation mode, and calibration observation mode.

2.6.1 General Nadir Observation Mode

General nadir observation mode is the most common mode, in which the push-broom sensor scans along the satellite nadir points to observe land and coasts, obtaining TIS, GIU and MII imagery. In this mode, the satellite points toward the zenith, and the swath scanning direction of the payloads is perpendicular to the flight direction of the satellite.

2.6.2 Side Observation Mode

Side observation mode is employed when the target to be observed is not within the swath using the general nadir observation mode, or the push-broom sensor cannot obtain the target at the satellite nadir in a short time. In such a case, the satellite needs to swing away from satellite nadir to timely observe the target.

(1) Polar region observation mode: Side swing 60° to observe the polar region, where winter for the North Pole and summer for the South Pole under the condition of 3/4 to the full moon and the lunar angle of altitude is larger than 20°. According to the requirement for detecting ice and snow in the polar night, 'TIS+GIU' is used in this mode.

(2) Hot-spot target observation mode: Side swing away from the satellite nadir point to observe the target, usually the swing angle is no more than ±30°, and the decrease in resolution in less than 1.5 times.

2.6.3 Calibration Observation Mode

The instrument will vary when the payload is launched into the orbit, therefore the onboard calibration is necessary. Calibration mode includes side slither calibration, blackbody and cold sky calibration, vicarious calibration, and cross calibration according to the different calibration sources.

(1) Side slithering calibration

In the side slithering calibration mode, the satellite rotates 90° yaw angle, so that the data array recorded in the payload changes from the vertical orbit direction to the horizontal orbit direction. In this way, the satellite flies over areas of the Earth's surface with relatively uniform reflectance, obtaining the calibration coefficients of individual detectors to improve the consistency between pixels.

(2) Black body and cold sky calibration

Black body and cold sky calibration mode is suited to the TIS. In the black body calibration (hot target calibration) and cold sky calibration (cold target calibration), the sensor rotates and points at the black body and deep space, respectively. This mode normally is used to evaluate the uncertainty of the absolute radiation of the payload, or detect the variation of gain and bias so as to assess the radiation stability.

(3) Vicarious calibration

The vicarious radiometric calibration can evaluate the real-time status of the sensor, taking into account the influence from atmospheric transmission and environment. This calibration will be conducted regularly during the orbit operation of the satellite to ensure the stability and reliability of the data quality. All three payloads (i.e., TIS, GUI and MII) need vicarious calibration.

Vicarious calibration considers several influence factors, such as surface characteristics, atmospheric characteristics, etc. The calibration sites typically are flat and uniform places with high and smooth reflectance, such as desert, gobi, grassland, lake, ocean, snow, etc.

(4) Cross-calibration

Cross-calibration mode allows comparing each SDGSAT-1 payload with counterparts' onboard satellites such as Landsat-8, Sentinel-2, VIIRS, etc. The orbits of the SDGSAT-1 and other satellites are not the same and only their intersection will be taken for calibration. In this mode, when SDGSAT-1 runs through the orbit of another satellite, a sensor onboard SDGSAT-1 will point to the nadir and acquire data. Cross-validation mode can be applied to all three payloads (i.e., TIS, GIU and MII) of SDGSAT-by using orbit intersection opportunities.

3. SDGSAT-1 Data Product

3.1 Processing Level

The SDGSAT-1 data products include different Level-1, Level-2 and Level-4 data products. Level-1 product is a standard product based on the Level-0 product, after data processing such as relative radiometric correction, band registration, HDR fusion, etc. Level-2 product is based on the Level-1 product after geometric correction. Level-4 product is based on the Level-1 product after ortho-rectification using ground control points and Digital Elevation Model (DEM) and output with standardized format. Currently, only Level-4 product is available to users.

3.2 Product Naming Convention

A standard product includes image file, meta data file, browse image, and thumbnail. All the files are saved under the same catalogue in a compressed file. The naming convention is ProductID_L4A.zip, for example, KX10_GIU_20220207_E109.36_N19.03_202200014089_L4A.zip. The parameter specifications of standardized products are illustrated in Table 3.1.

Table 3.1 Parameter specifications of standardized products

Name Identification	Byte Length	Illustration
Satellite ID	4	SDGSAT-1 Satellite code: KX10
Payload ID	3	MII: Multispectral Imager for Inshore TIS: Thermal Infrared Spectrometer GIU: Glimmer Imager for Urbanization
Imaging Date	8	The date of the image, with the format of YYYYMMDD
Central Longitude	6	E/Wxxx.xx
Central Latitude	5	N/Sxx.xx
Task Number	12	This number corresponds to the production task number in the system
Product Level	3	L4A: Level-4 product

3.3 Level-4 Product

3.3.1 File Structure of Level-4 Product

(1) Image file

- TIS image file: Image file of 3 bands color composite with GeoTIFF format. Naming convention: ProductID_L4A.tif.
- MII image file: Image file of 7 bands composite from two cameras with GeoTIFF format. Naming convention: ProductID_L4A_A.tif, ProductID_L4A_B.tif, where A and B refer to different cameras.
- GIU image file: Four image files are saved separately for panchromatic and multicolor images and two cameras with GeoTIFF format, where panchromatic image includes three types of data: PH, PL and HDR, and multicolor image includes three RGB

bands. Naming convention: ProductID_L4A_A_LH.tif (panchromatic image), ProductID_L4A_B_RGB.tif (multicolor image), where A and B refer to different cameras.

(2) File of absolute calibration coefficients

ProductID_L4A.calib.xml.

(3) Product meta data file

ProductID_L4A.meta.xml.

(4) Product browse image

The file by downscaling 16 times of the original image, with a PNG format.

- TIS browse image: Image of 3 bands color composite. Naming convention: ProductID_L4A.browse.png.
- MII browse image: Image of 3 bands color composite (B5(R)/B4(G)/B3(B)) from two cameras. Naming convention: ProductID_L4A_A.browse.png, ProductID_L4A_B.browse.png, where A and B refer to different cameras.
- GIU browse image: Four image files are saved separately for panchromatic and multicolor images and two cameras. Naming convention: ProductID_L4A_A_LH.browse.png (panchromatic image) and ProductID_L4A_B_RGB.browse.png (multicolor image), where A and B refer to different cameras.

(5) Thumbnail

Image downscaled from browse image, with a size of 128×128 and a PNG format. The composite of bands accords with the browse image. Naming convention: ProductID_L4A_A.thumb.png and ProductID_L4A_B.thumb.png, where A and B refer to different cameras.

3.3.2 Metadata Illustration of Level-4 Product

A metadata file is for each product, and naming convention is ProductID_L4A.meta.xml. There are slightly differences between the meta data of the three payloads of SDGSAT-1. For instance, the metadata files of MII and TIS include cloud coverage ratio, and that of TIS also includes the statistics (maximum value, minimum value, mean value, and standard deviation) of each band. The meta data file produced at different periods of time also are slightly different.

3.3.3 Quantitative Inversion of Level-4 Product

(1) Converting radiance to apparent reflectance

In MII image, the radiance recorded in each pixel can be converted to apparent reflectance at the top of atmosphere ρ_P (short for apparent reflectance):

$$\rho_P = \frac{\pi \cdot L_\lambda \cdot d^2}{\mathrm{ESUN}_\lambda \cdot \cos(\theta s)}$$

where L_λ is spectral apparent radiance at the sensor's aperture at wavelength λ, which can be calculated by the calibration equations in Subsection 2.5; d is Earth-Sun distance in astronomical units; ESUN_λ is mean solar exoatmospheric irradiances at wavelength λ from Table 3.2; and θs is solar zenith angle in degrees.

Table 3.2 The spectral specifications of SDGSAT-1 MII bands

Band	Spectral response range (nm)	Band width (nm)	ESUN (W/m²/μm)
B1	374~427	53	1532.0
B2	410~467	57	1893.1
B3	457~529	72	1978.4
B4	510~597	87	1883.4
B5	618~696	78	1613.0
B6	744~813	69	1224.6
B7	798~911	113	993.51

ESUN of each band in Table 3.2 can be calculated as follows:

$$\mathrm{ESUN} = \frac{\int_{\mathrm{min\_}\lambda}^{\mathrm{max\_}\lambda} E(\lambda)S(\lambda)\mathrm{d}\lambda}{\int_{\mathrm{min\_}\lambda}^{\mathrm{max\_}\lambda} S(\lambda)\mathrm{d}\lambda}$$

where $E(\lambda)$ is exoatmospheric solar irradiances at wavelength λ, $S(\lambda)$ is the spectral response at wavelength λ, and min_λ and max_ λ are the minimum and maximum values of spectral response range, respectively (Table 3.2).

The squared distance between the Sun and Earth can be calculated as follows:

$$d^2 = 1.000423 + 0.032359 \cdot \sin(\theta) + 0.000086 \cdot \sin(2\theta)$$

$$- 0.008349 \cdot \cos(\theta) + 0.000115 \cdot \cos(2\theta)$$

where solar angle θ is defined as:

$$\theta = \frac{2\pi \cdot t}{364.2422}$$

$$t = J - J_0$$

$$J_0 = 79.6764 + 0.2422\times(\text{Year} - 1985) - \text{INT}\left(\frac{\text{Year} - 1985}{4}\right)$$

$$J = \text{INT}(30.6\times\text{Month} - C + 0.5) + \text{Day} + \frac{(\text{Hour}-8+\text{Minute}/60)-(\text{Longitude}/15)}{24}$$

where J is the Julian day, which is the continuous count of days since the beginning of the Julian period. For example, the Julian day of January 1 is 1, that of December 31 is 365 for the non-leap year, and 366 for the leap year. INT is the round operation, and C is calculated as follow:

$$C = \begin{cases} 30.6, & \text{Month} \le 2 \\ 31.8, & \text{Month} > 2 \text{ and Year/4} = \text{integer} \\ 32.8, & \text{Others} \end{cases}$$

The distance between the Sun and Earth can be simply estimated as in Table 3.3.

Table 3.3 Distance between the Sun and Earth (astronomical units)

Julian day	Distance	Julian day	Distance
1	0.9832	196	1.0165
15	0.9836	213	1.0149
32	0.9853	227	1.0128
46	0.9878	242	1.0092
60	0.9909	258	1.0057
74	0.9945	274	1.0011
91	0.9993	288	0.9972
106	1.0033	305	0.9925
121	1.0076	319	0.9892
135	1.0109	335	0.9860
152	1.0140	349	0.9843
166	1.0158	365	0.9833
182	1.0167		

(2) Converting radiance of TIS to temperature

The DN values of TIS can be converted to radiance using calibration coefficients which can be further converted to onboard effective temperature or brightness temperature by the Planck equation as follows:

$$T = \frac{10^6 \cdot hc/(k\lambda)}{\ln[2 \cdot 10^{24} \cdot hc^2/(L\lambda^5) + 1]}$$

where T is the brightness temperature (K), h is the Planck constant (6.626×10^{-34} J·s), c is the light speed (2.9979×10^{8} m/s), k is the Boltzmann constant (1.3806×10^{-23} J/K), and L is the radiance at wavelength λ (W/m^2/sr/μm).