**GF1 WFV Surface Reflectance product manual**

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**1. Introduction**

As the field of Earth observation enters the era of big data, users of satellite remote sensing data not only hope for consistency in geometric positions of remote sensing data, but also put forward higher requirements for radiometric consistency of remote sensing data, in order to better carry out remote sensing data applications and information extraction. The Ready to use (RTU) product aims to lower the application threshold of satellite remote sensing data, freeing data users from the tedious work of finding, organizing, and processing data, and providing users with standardized higher level data products. The RTU product has features such as geometric standardization and radiometric normalization, making it easy to use directly. The GF1 WFV (Wide Field View) surface reflectance (SR) product belongs to the RTU product.

**Table 1. GF1 WFV data parameters**

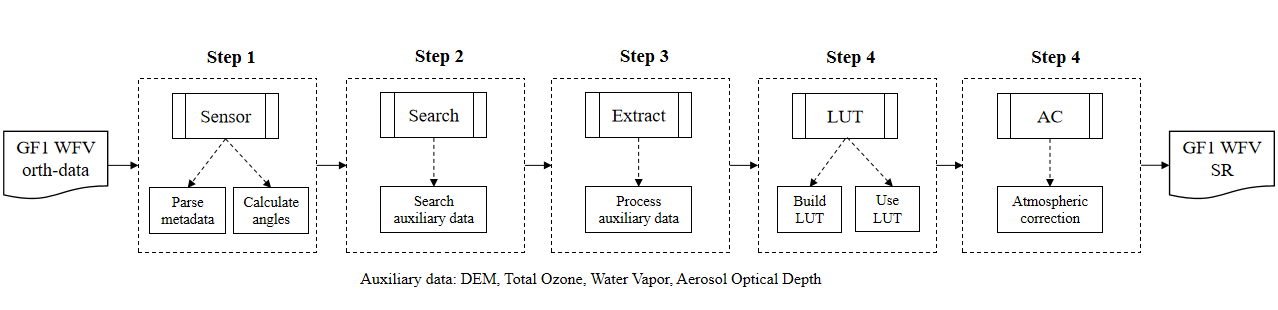
|  |  |  |  |
| --- | --- | --- | --- |
| **parameter** | **WFV camera** | | |
| **band** | **band NO.** | **band range/nm** |
| Spectral information | blue | 1 | 450～520 |
| green | 2 | 520～590 |
| red | 3 | 630～690 |
| Near infra-red (NIR) | 4 | 770～890 |
| Spatial resolution | 16m | | |
| Scene width | 800km (4 camera combinations) | | |
| Repeat coverage | 4 days | | |

GF1 WFV SR products are generated based on the GF1 WFV ortho-rectified data by the SR retrieval procedure (AirSR) and the GF1 WFV images received by the remote sensing satellite ground station of China. The L1-norm constrained least squares (L1LS) and a novel block adjustment method that considers the accuracy of GCPs are applied to ortho-rectify the GF1 WFV. AirSR is a surface reflectance retrieval algorithm for multi-source satellite remote sensing data developed by China remote sensing satellite ground station. On the basis of radiometric calibration, the surface reflectance products are obtained by atmospheric correction using 6S model, MODIS products (water vapor, ozone, aerosol optical depth), DEM, and other auxiliary data.

**2. Algorithm**

AirSR adopts a per-pixel atmospheric correction method based on the 6S radiative transfer model and MODIS AOD (Aerosol Optical Depth) spatial fusion. The MODIS AOD products used include MOD08D3, MOD09CMA, and MCD19A2, which are spatially fused using the Universal Kriging Method (UK) to obtain a complete coverage of AOD data. The required atmospheric water vapor content and ozone data are from MCD19A2 and MOD09CMG products, which can be downloaded from the MODIS product website (<https://ladsweb.modaps.eosdis.nasa.gov/archive/allData/>). AirSR also considers the influences of solar zenith angle and satellite observation zenith angle. Firstly, the auxiliary data is preprocessed to obtain input data such as water vapor, aerosol optical depth, ozone, and altitude required by the 6S model. Then, angle information such as solar zenith angle and satellite observation zenith angle are calculated. Then, the lookup table (LUT) is constructed based on the 6S model to obtain the atmospheric correction coefficient. Finally, on the basis of radiometric calibration, combined with the atmospheric correction (AC) coefficient lookup table, atmospheric correction is performed to obtain land surface reflectance.

AirSR consists of seven modules, including data input, Sensor, Search, Extract, LUT, AC, and results output, as shown in Fig.1.



**Fig.1 Functional modules of AirSR**

Data input: including metadata and auxiliary data of satellite images

Sensor (step 1): The basic module for land surface reflectance retrieval, mainly includes metadata analysis and angle calculation.

Search (step 2): the search module for input data of atmospheric correction, including MODIS atmospheric data (aerosol optical depth, atmospheric water vapor content, ozone), and DEM.

Extract (step 3): the module for preprocessing aerosol optical depth, atmospheric water vapor content, ozone, and DEM data.

LUT (step 4): construction and use of lookup tables

AC (step 5): multi-process atmospheric correction

Results output: output of surface reflectance and metadata.

**3. Accuracy assessment**

The geometric accuracy of GF1 WFV surface reflectance inherits the geometric accuracy of the GF1 WFV ortho-rectified product. The absolute geometric accuracy of the GF1 WFV ortho-rectified product can achieve high accuracy within 0.5 pixels, and an independent assessment of the geometric accuracy is provided in the GQA file.

In order to carry out accuracy assessment of GF1 WFV surface reflectance products, field campaigns were conducted in Gansu, Inner Mongolia, Fujian, Hunan, Qinghai, and other places in China to collect field-measured land surface reflectance data of typical land cover types such as farmland, grassland, water, Gobi Desert, desert, bare land, and impervious surface. Accuracy validation results show the RMSE (Root Mean Square Error) is 2.30%, 2.29%, 3.44%, and 6.04% for bule, green, red, and NIR band of GF1 WFV, respectively.

**Table2. Validation results of GF1 WFV surface reflectance based on in-situ data (unit:%)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Day/sites/land cover** |  | **Blue** | **Green** | | **Red** | **NIR** | **RMSE** |
| 2019-09-13/Fujian, Nanping/rice field | *ρin situ* | 3.483 | 8.022 | 6.976 | | 39.844 | 4.404 |
| *ρretrieved* | 3.781 | 6.830 | 5.998 | | 31.179 |
| 2019-09-24/Gansu, Zhangye/oat field | *ρin situ* | 2.339 | 5.002 | 3.694 | | 51.476 | 5.639 |
| *ρretrieved* | 2.910 | 5.904 | 4.625 | | 40.286 |
| 2019-10-20/Hunan Zhuzhou/ Water | *ρin situ* | 2.793 | 3.589 | 1.447 | | 0.034 | 1.738 |
| *ρretrieved* | 2.983 | 4.944 | 2.988 | | 3.146 |
| 2019-09-15/Fujian Pingtan/ desert | *ρin situ* | 21.075 | 28.542 | 33.129 | | 36.836 | 1.176 |
| *ρretrieved* | 19.554 | 27.163 | 32.848 | | 35.720 |
| 2019-09-20/Gansu Jiayuguan**/**Gobi Desert | *ρin situ* | 14.208 | 19.079 | 23.537 | | 25.311 | 1.226 |
| *ρretrieved* | 13.644 | 18.133 | 22.658 | | 23.302 |
| 2019-09-22/Gansu Dunhuang**/**Gobi Desert | *ρin situ* | 17.411 | 21.253 | 23.390 | | 25.311 | 2.724 |
| *ρretrieved* | 15.022 | 18.566 | 21.296 | | 20.537 |
| 2022-07-25**/**Inner Mongolia Wuliangsu/bare land | *ρin situ* | 12.781 | 18.432 | 26.376 | | 31.515 | 1.690 |
| *ρretrieved* | 11.455 | 18.472 | 24.991 | | 28.731 |
| 2022-07-25**/**Inner Mongolia Wuliangsu/impervious surface | *ρin situ* | 16.150 | 19.445 | 22.409 | | 23.974 | 3.646 |
| *ρretrieved* | 11.030 | 16.318 | 18.388 | | 24.983 |

**Table 3. Validation results of GF1 WFV surface reflectance based on in-situ data (continued, unit: %)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Day/sites/land cover** |  | **Blue** | **Green** | **Red** | **NIR** | **RMSE** |
| 2022-07-26**/**Inner Mongolia Wuliangsu/corn field | *ρin situ* | 3.424 | 6.044 | 4.647 | 44.460 | 2.562 |
| *ρretrieved* | 3.722 | 7.201 | 6.125 | 39.700 |
| 2022-07-26**/**Inner Mongolia Wuliangsu/bare land | *ρin situ* | 10.568 | 15.151 | 20.976 | 25.425 | 3.389 |
| *ρretrieved* | 12.013 | 18.951 | 25.135 | 28.908 |
| 2022-08-07/Qinghai Kunlunshan/desert | *ρin situ* | 10.258 | 13.243 | 15.740 | 16.781 | 3.584 |
| *ρretrieved* | 12.340 | 17.270 | 20.127 | 20.182 |
| 2022-08-09/Qinghai Chaka/Salt land | *ρin situ* | 44.016 | 45.351 | 46.173 | 46.689 | 5.845 |
| *ρretrieved* | 40.984 | 39.102 | 36.770 | 46.550 |
| 2022-08-09/Qinghai Chaka/grassland | *ρin situ* | 2.877 | 5.365 | 4.587 | 39.670 | 5.214 |
| *ρretrieved* | 6.941 | 9.544 | 7.960 | 31.685 |
| 2022-08-11/Qinghai Qilian/grassland | *ρin situ* | 1.202 | 3.102 | 2.511 | 40.801 | 7.363 |
| *ρretrieved* | 3.507 | 5.875 | 4.555 | 26.670 |
| 2022-08-12/Qinghai Qilian/grassland | *ρin situ* | 1.880 | 4.759 | 3.209 | 39.222 | 2.506 |
| *ρretrieved* | 4.080 | 7.924 | 5.902 | 37.486 |
| Band RMSE |  | 2.296 | 2.294 | 3.435 | 6.041 |  |

**4. product description**

The GF1 WFV land surface reflectance product is stored per scene in a file folder, consisting of surface reflectance, quality assessment (QA) files, and metadata.

* The naming convention for the file folder is: satellite\_sensor\_orbit\_acquisition date\_product type (SR), such as GF1\_WFV1\_054279\_20230522\_SR.
* Content of GF1 WFV surface reflectance product：It includes bands 1, 2, 3, and 4 (i.e. blue, green, red, and near infrared), and the naming convention is: satellite\_sensor\_orbit\_imaging date\_SR.TIF, such as GF1\_WFV1\_054279\_20230522\_SR.TIF. The spatial resolution of the image is 16 meters, and the projection coordinate system is WGS84 UTM. In order to reduce storage space, the surface reflectance results were changed from floating-point values to 16-bit integers by multiplying 10000, with a background fill value of -9999, and the lossless compression of LZW was performed.
* QA files：including PIXEL-QA, RADSAT-QA, and GQA (Geometric quality assessment)，the naming convention is: satellite\_sensor\_orbit\_imaging date\_SR\_PIXEL-QA/RADSAT-QA.TIF, or GQA.txt.

**Table 4 attributes of GF1 WFV RADSAT-QA**

|  |  |  |  |
| --- | --- | --- | --- |
| **Bit** | **Bit Value** | **Cumulative Sum** | **Description** |
| 0 | 1 | 1 | Data Fill Flag (0 valid data, 1 invalid data) |
| 1 | 2 | 3 | Band 1 Data Saturation Flag (0 valid data, 1 saturated data) |
| 2 | 4 | 7 | Band 2 Data Saturation Flag (0 valid data, 1 saturated data) |
| 3 | 8 | 15 | Band 3 Data Saturation Flag (0 valid data, 1 saturated data) |
| 4 | 16 | 31 | Band 4 Data Saturation Flag (0 valid data, 1 saturated data) |

* Metadata file（xml）: This includes information of the GF1 WFV SR product, such as satellites, sensors, imaging time, orbital numbers, geometric accuracy, projection, coordinates, calibration coefficients, solar zenith angle, and solar azimuth angle; and information on surface reflectance bands and QA bands, such as production time, production units, etc.
* Data access: all the products can be downloaded freely from https://zenodo.org/records/13917221.

**5. References**

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2. Long, T., Jiao, W., He, G., Wang, G. and Zhang, Z., 2023. Digital orthophoto map products and automated generation algorithms of Chinese optical satellites. National Remote Sensing Bulletin, 27, pp.635-650. (in Chinese) (For orthorectification product of GF1 WFV, https://www.ygxb.ac.cn/zh/article/doi/10.11834/jrs.20232041/)

3. She Wenqin, Zhang Zhaoming, Peng Yan, et al., 2023. GF-1 WFV surface reflectance product in China's land area, National Remote Sensing Bulletin, 27(9):1-13. (in Chinese) (For surface reflectance product of GF1 WFV, https://www.ygxb.ac.cn/zh/article/doi/10.11834/jrs.20222190/)

4. She Wenqin. A study on land surface reflectance retrieval from GF-1/6 WFV data. Dissertation of University of Chinese Academy of Sciences, 2023. (in Chinese) (For surface reflectance product of GF1 WFV, https://opac.las.ac.cn/F/?func=item-global&doc\_library=CAS01&doc\_number=001357166)

**Attachment 1 Example of metadata XML file**

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