中国科学院空天信息创新研究院
Aerospace Information Research Institute (AIR)
Chinese Academy of Sciences (CAS)

Spectrum Earth

Targeting GEO’s Needs, Integrating Multi-source Data, and Lowering Barriers of Application

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Content

1. Working Experience with GEO
2. GEO’ s Goals and Vision
3. Features and Advantages of Spectrum Earth
4. Progress of China GEO Cooperation Initiative

Working Experience with GEO

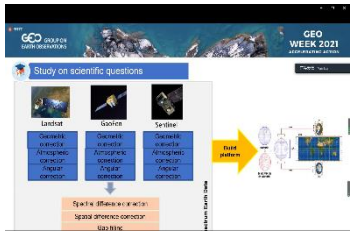
Assist leaders to participate GEO events

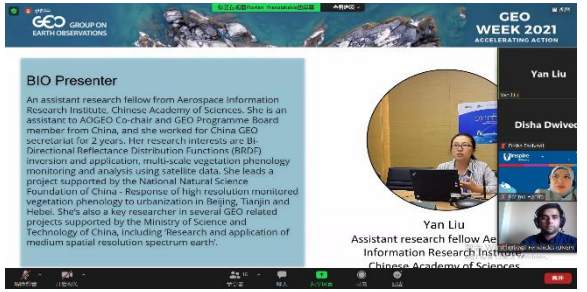
GEO plenaries, ExCom meetings, PB meetings

Participate in organizing GEO and AOGEO events

3 AOGEO Workshops and 1 joint side event with EuroGEO

S&T exchanges





AOGEO Training Workshop, Youth Track in 2021 GEO week, etc

International Communication Platform

Multi-stakeholders communication platform

S&T communication with world top experts;

Scientific research address actual needs.

GEO's Goals and Vision

Data Providers

Research Teams

Research Teams
Organizations
Institutions
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Decision Makers

Earth Observations

Satellites

Drones

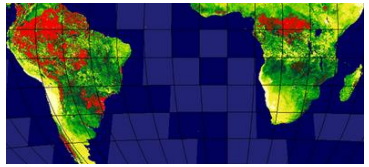
In-situ

Spectrum information is the fundament of accurate quantitative inversion.

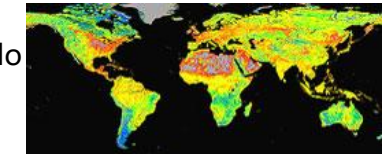
Model Inversion

The Earth Surface Parameters

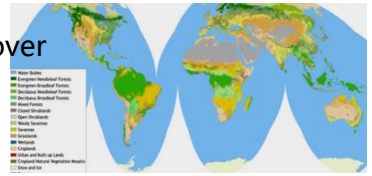
LAI



Albedo



Landcover



etc

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GEO Engagement Priorities

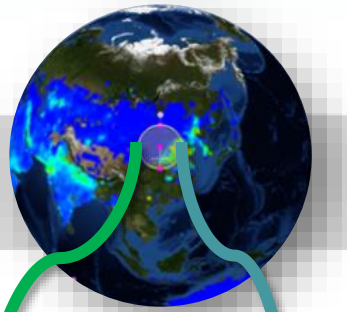
Features and Advantages of Spectrum Earth

Natural Earth

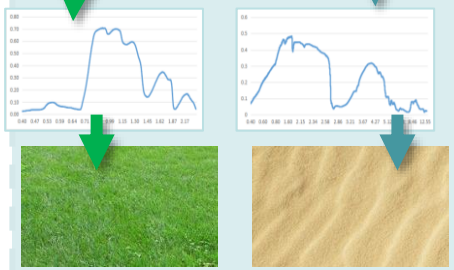
- Objective Existence
- Natural and Artificial Objects

Image Earth

- Directly Shot by Remote Sensing



Spectrum Earth



Spectrum is the unique "fingerprint" of land surface and core information that satellite can capture

Knowledge Earth

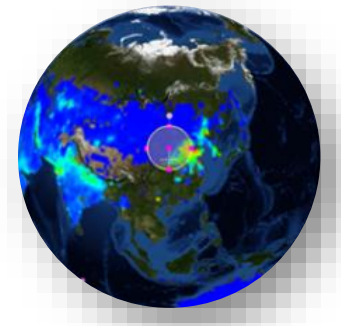
- Information-Knowledge
- Multi-level integration

GEO Engagement Priorities

- Comprehensive: Multispectral, multiscale, temporal continuous satellite observed spectrum data of the earth's surface;
- Quantitative: Standard radiation, space, time of the earth's surface;
- Continuous: Full coverage, continuous time, spectral normalization.

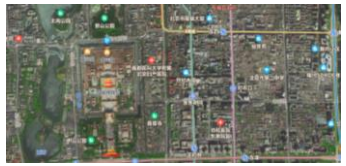
Features and Advantages of Spectrum Earth

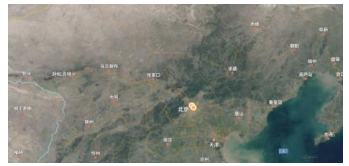
Ideal Spectrum Earth：Full and continues information in multiple dimensions



Spectrum Earth

Spatial Dimension



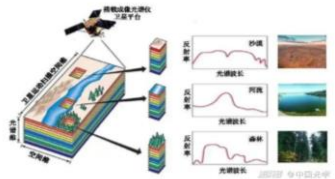


Serves applications that needs different spatial details

Temporal Dimension

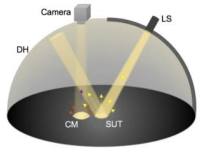

Meet the needs of observing changes in different time periods.

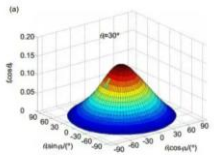
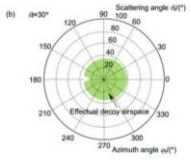
Spectral Dimension



Fully reflect spectrum details.

Observation Angle Dimension

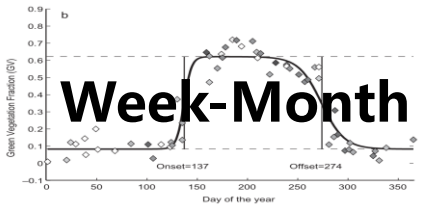
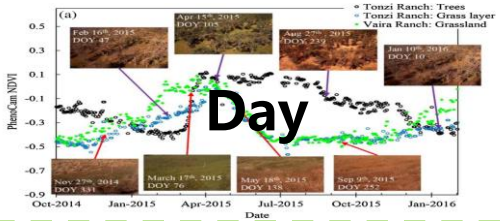
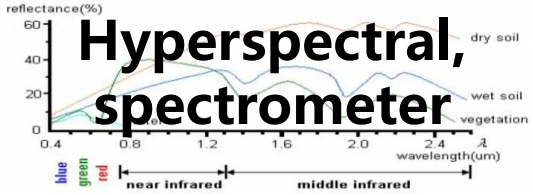
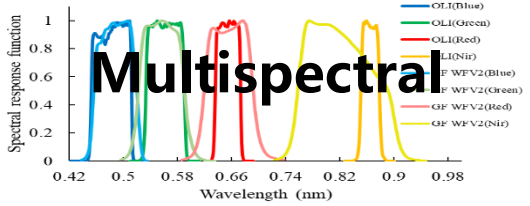
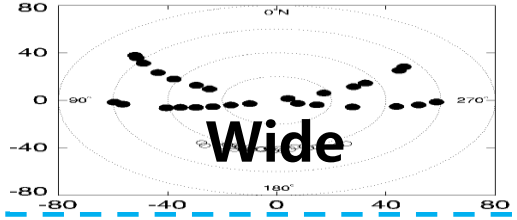
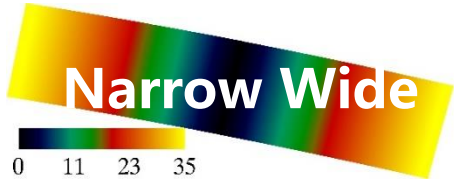


Support energy balance, surface structure analysis.

Features and Advantages of Spectrum Earth

Reality: A single satellite or sensor can realize near-completeness in a certain dimension.

Spatial Dimension			
Temporal Dimension			
Spectral Dimension			
Observation Angle’ s Dimension			

Features and Advantages of Spectrum Earth

- **The ideal spectral earth is a complex and huge scientific research and engineering system, which is difficult to realize in short time.**
- **Seek a suitable start for technical research and system development.**
  - Pressing needs in local and international community, especially in GEO.
  - Enough satellite data.
  - On a certain technical basis.
- **Gradually realize the multi-dimensional integrity and continuity of land surface spectrum information.**

Features and Advantages of Spectrum Earth

Global environmental problems are becoming increasingly prominent, while low-resolution data is difficult to satisfy demands.

Typical Problems: Climate Change， ozone layer destruction, biodiversity reduction, acid rain spread, forest loss, land desertification, air pollution, water pollution, marine pollution, solid waste pollution.

MODIS（500m）

Sentinel-2（10m）

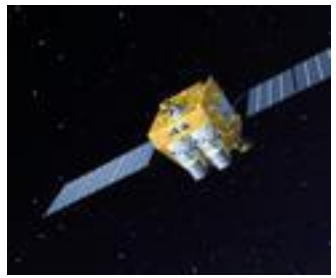
Since low-resolution data cannot capture the detailed changes of the surface, medium-resolution data is urgently needed to provide information support!

Features and Advantages of Spectrum Earth

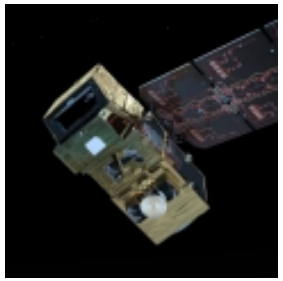
Global earth observation has entered the era of medium-resolution era.

At present, there are more than 20 medium-resolution satellites in orbit around the world.

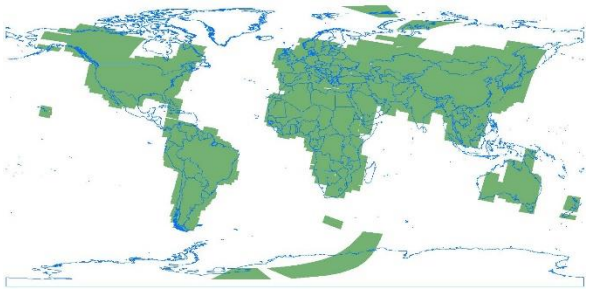
ZY Satellites



Gaofen Series Satellites



Sentinel Satellites



Gaofen WFV Satellite Data Coverage Map

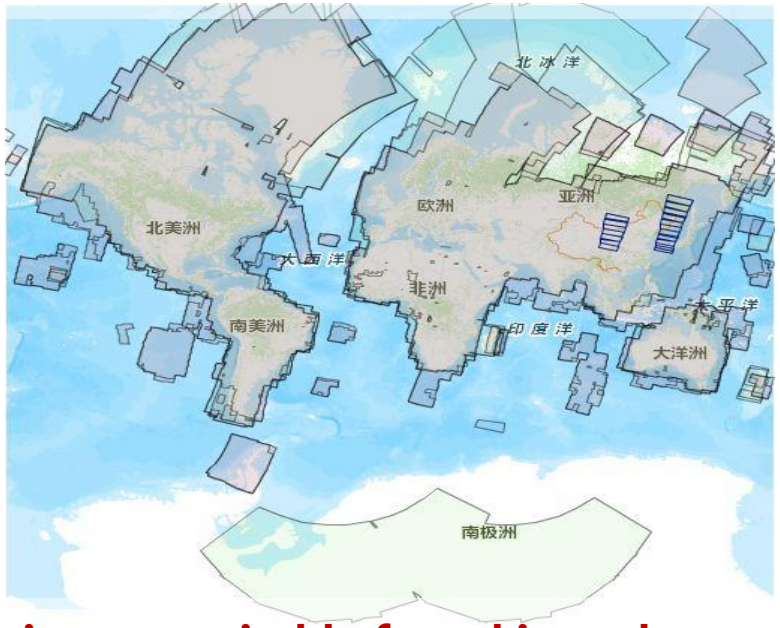
Series	Satellite	Country
Ziyuan Series	ZY 02C/D ZY 04	China
Gaofen Series	GF-1A/B/C/D GF-3/4/6	China
Domestic commercial satellite series	beijing-1 Jilin-1	China
LandSat	LandSat-8	America
Sentinel Series	Sentinel-2A/B	EU
SPOT Series	SPOT-6…	France

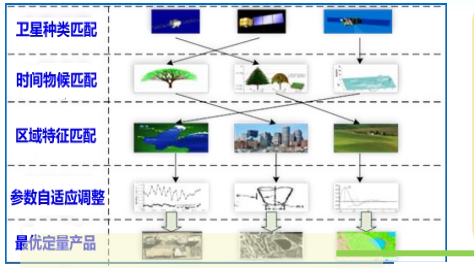
There are numerous types and large quantities of medium-resolution satellite data, difficult in processing and short of global spatiotemporally continuous medium-resolution data product set, which cannot meet the needs of fine monitoring of the global environment.

Features and Advantages of Spectrum Earth

Developing Spectrum Earth to improve global data efficiency

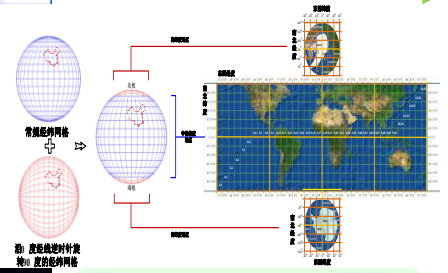
The medium-resolution data of Gaofen series has developed an efficient global coverage capability. In November 2019, CNSA announced open sharing of China's Gaofen data with 16-meter resolution.





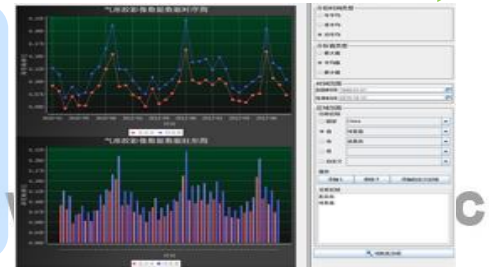
Improve the level of application technology

Improve global/ large-scale monitoring capabilities



Improve multi-source data processing and application capabilities

Improve multi-temporal monitoring capabilities

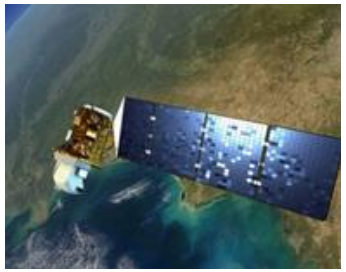


Spectrum Earth is most suitable for taking advantage of medium-resolution remote sensing data resources including Gaofen, Landsat and Sentinel 2 series satellites.

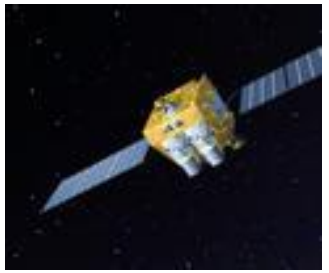
Features and Advantages of Spectrum Earth

Seek a suitable start for technical research and system development

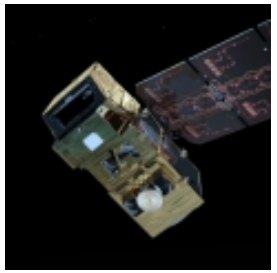
Medium-resolution



Landsat Series



Gaofen Series



Sentinel Satellite

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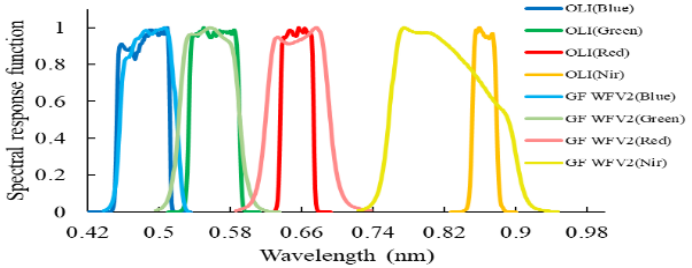
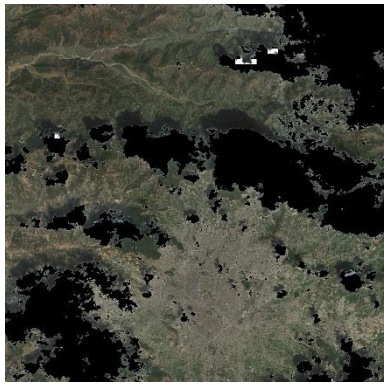
Multi-spectrum



Spatiotemporal continuity



Features and Advantages of Spectrum Earth

Some Problems in the Large-scale Application of GEO Worldwide

- Many types of loads and large differences in application accuracy;
- High threshold for back-end users' application.

Some Problems in the Globalized Application of Gaofen data

- The value of overseas application needs to be improved;
- Connection with international technology system needs to be improved.

Solutions Put forward by Several Countries

- **Optical Data Centre (ODC, Australia)**
  Focusing on solving geometric problems
- **Analysis Ready Data (ARD, CEOS)**
  Single-load data product, application- oriented
- **Spectrum Earth (SE, China)**
  Focusing on solving problems such as multi-load, multi-temporal and massive data
- **Data Information system (DAIS)**
  Information and product production

Spectrum Earth was proposed in "China's Plan for Implementing GEOSS (2016-2025)"

Progress of China GEO Cooperation Initiative

Research on Development of Medium Spatial Resolution of Spectrum Earth and its Application Technology

Dec 1st, 2020- Dec 1st, 2023

Key R&D Program of the Ministry of Science and Technology

Key projects of intergovernmental scientific and technological innovation cooperation

Overseas Cooperation Teams: **Geoscience Australia** **International Centre for integrated Mountain Development**

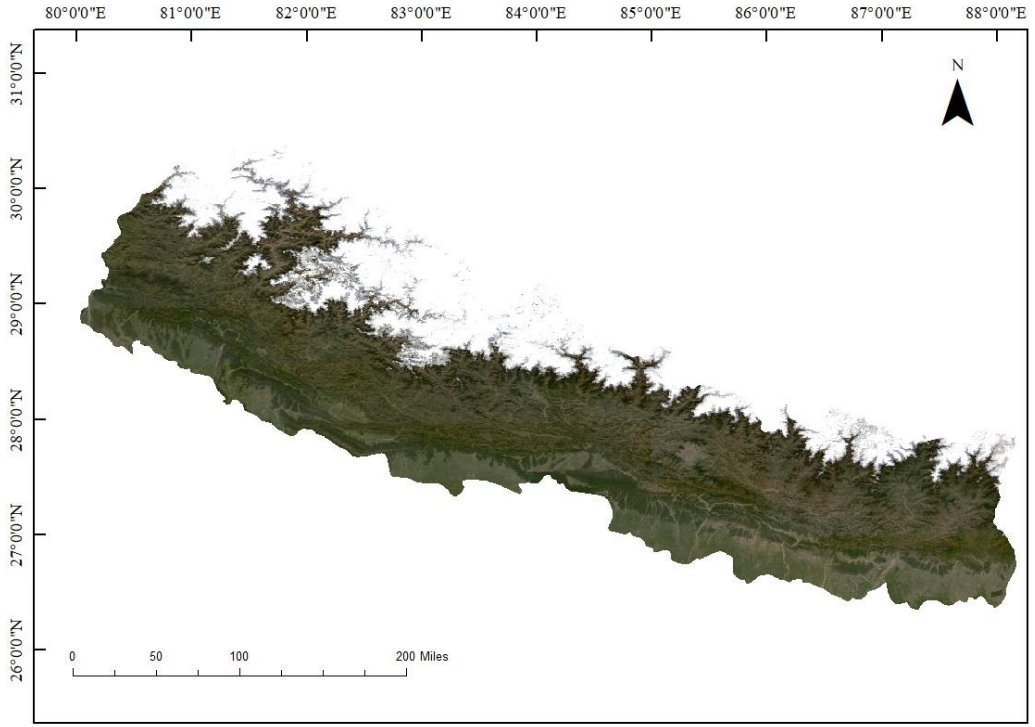
Research Areas: **Australia, Nepal, France, Cambodia–Taking into account both ecosystem diversity and GEO activity**

Research Tasks:

1. **Multispectral Data Processing Technology System of Spectrum Earth;**
2. **Expanding Technology from Multispectral Images to Hyperspectral Images;**
3. **Research and Development of 10-meter level Spectrum Earth platform;**
4. **Application and Demonstration based on Spectrum Earth.**

Progress of China GEO Cooperation Initiative

Challenges



Basic Situation

- High Altitude
- Complex Terrain
- Monsoon Climate

Facing Challenges

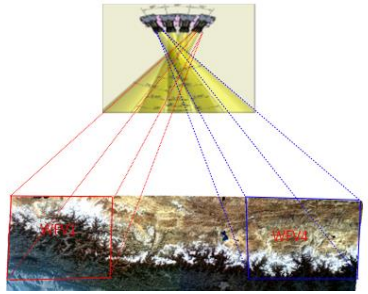
- Cloudy and snowy, high requirements for cloud and snow recognition accuracy;
- Difficult to obtain effective observations at any scale during the rainy season;
- Parts of the region most of the time are covered by clouds or thick aerosols;

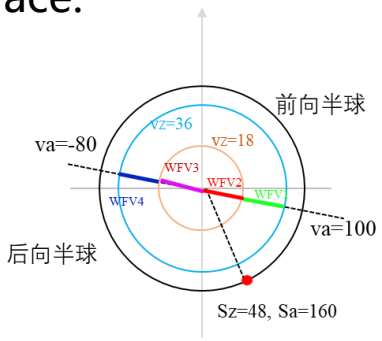
Progress of China GEO Cooperation Initiative

Incorporating low-resolution information into surface reflectance angle normalization.

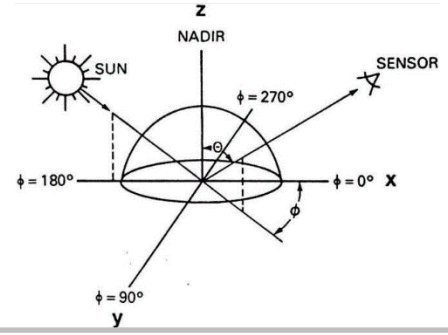
Existing Problems

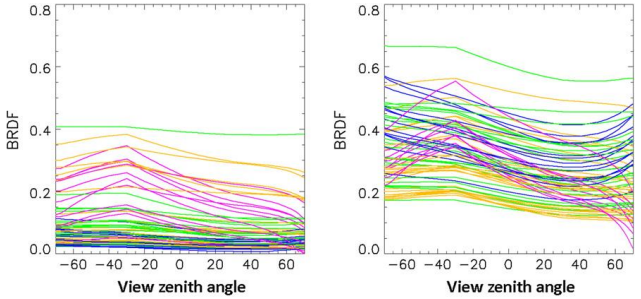
1. The GF-1 wide-field imager has a larger field of view, but its multi-angle observation capability cannot fully describe the anisotropic reflection characteristics of the surface.





2. There are many factors affecting the anisotropic reflection characteristics, and the reflection anisotropy characteristics of different structures of the surface are quite different.





Solutions

The low-resolution surface reflection anisotropy feature product is introduced to analyze the distribution characteristics of the anisotropic reflection feature, extract the prior knowledge of the surface anisotropic reflection, and realize the angle normalization of the reflectance data of the GF-1 wide-field imager.

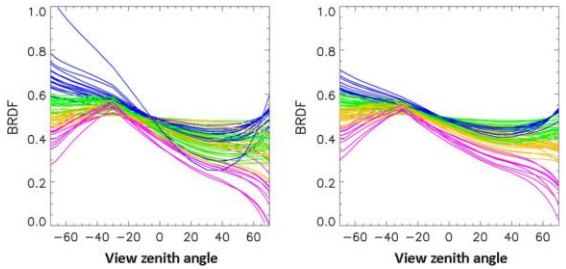
Achieving consistency and comparability of observational angles of data

Progress of China GEO Cooperation Initiative

Incorporating low-resolution information into surface reflectance angle normalization.

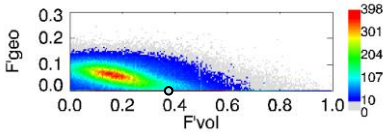
Algorithm Scheme

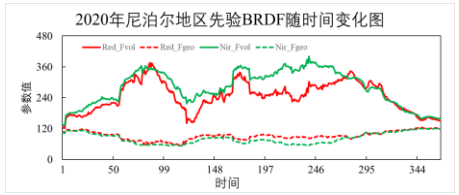
1. Kernel driver model parameter normalization



The normalized BRDF is more regular, which facilitates the extraction of prior knowledge

2. The extraction of prior BRDF knowledge





$$F'(i,j) = (k*i, k*j) - \frac{k}{2}$$

$$F = \sum_{i=1}^{s_{max}} \sum_{j=1}^{L_{max}} F'(i,j) \times n(i,j)/n$$

The extracted prior BRDF can represent most pixels' anisotropic reflection features. Prior knowledge changes significantly over time.

3. Angle normalization

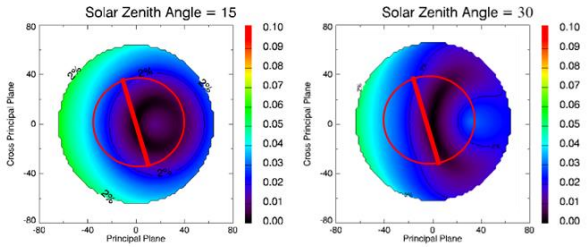
$$NBAR_{\lambda}^{sensor}\left(\theta_v = 0, \theta_s = \frac{\theta_s^{TM} + \theta_s^{ETM+}}{2}\right) = c(\lambda) \times \rho_{\lambda}^{Landsat}\left(\theta_v^{sensor}, \theta_s^{sensor}\right)$$

$$c(\lambda) = \frac{\hat{\rho}_{\lambda}^{MODIS}\left(\theta_v = 0, \theta_s = \frac{\theta_s^{TM} + \theta_s^{ETM+}}{2}\right)}{\rho_{\lambda}^{MODIS}\left(\theta_v^{sensor}, \theta_s^{sensor}\right)}$$

Angle normalization is performed by simulating the relationship between directional reflectance and real observations

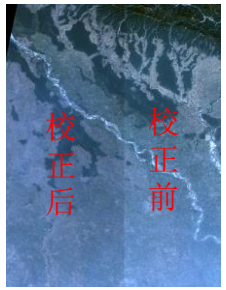
Results Evaluation

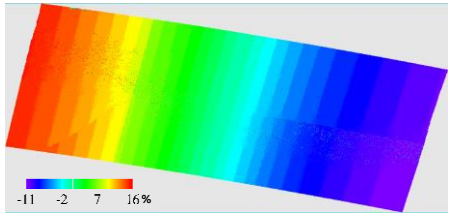
1. Applicability evaluation of prior BRDF



Simulation data validation showed that the prior BRDF had a good correction effect on the GF-1 WFV observation plane (RMSE<0.02).

2. Normalized evaluation of GF1-WFV reflectance





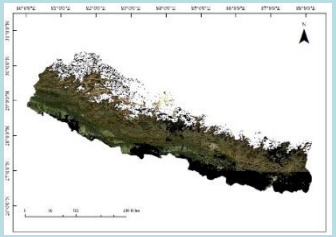
The reflectance before and after normalization is significantly different, and the maximum relative difference can reach 16%. The reflectance after normalization has a high consistency with that of Landsat (NIR RMSE<0.056).

Progress of China GEO Cooperation Initiative

Reconstruction of monthly reflectance data in cloudy and rainy regions

Problems

Lack of spatiotemporal continuous low-resolution reflectance products to assist in data reconstruction

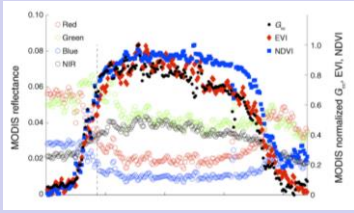


February 2020, black represents missing data

- The limited 10-meter-level clear sky data is difficult to meet the input requirements of traditional data fusion algorithms.
- Affected by the thick aerosol in the mountains, it is impossible to use the cloud mask data to realize automatic screening of clear sky data.

Some areas of Nepal, all observations of Gaofen 1 in January 2020, black represents missing data

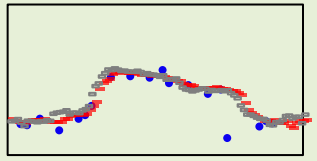
Commonly used data reconstruction methods operate independently on a single band, but lack consideration of the correlation between multiple bands



Solutions

- NBAR is one of the most widely used reflectance products, often used as auxiliary data for medium-resolution scale data reconstruction.
- Synergistic use of angular reflectance and NBAR to improve the available data in the reconstruction algorithm, and taking into account surface time changes, quantitatively imputation for missing data.

- Using pixels' time series changes in the whole growing season to reconstruct data from the time dimension, realize the reconstruction of spatiotemporal continuous data over a long period of time
- Compare the 10-meter-level data with the low-resolution time curve, and remove the thick aerosol data through outlier analysis.



Aiming at the characteristics of mainly vegetation coverage in Nepal, the vegetation index is used as a unified index to search for similar pixels in the spatiotemporal window to achieve multi-band collaborative reconstruction.

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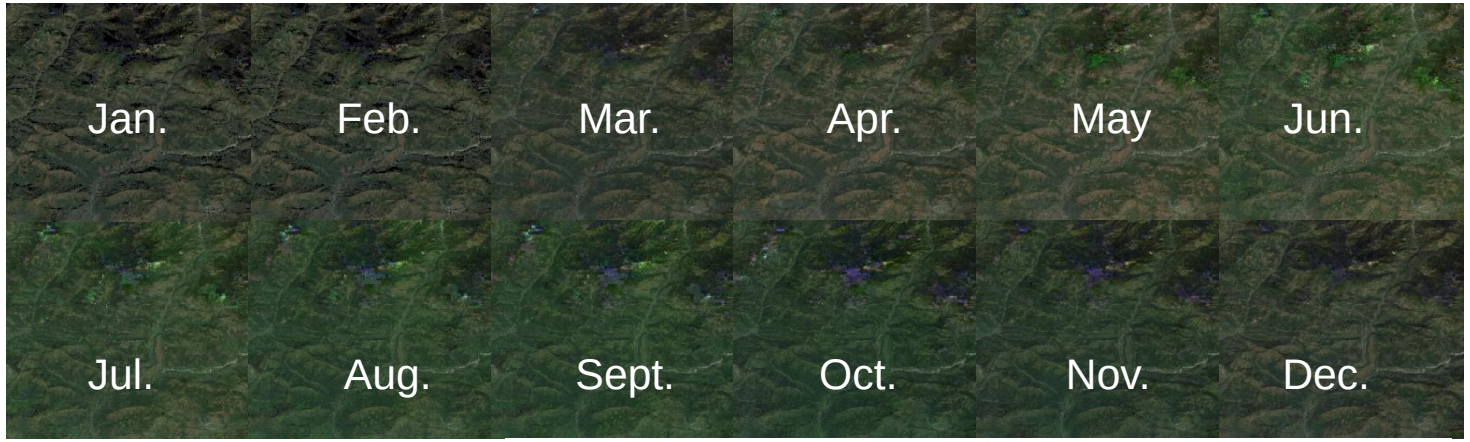
Reconstruction of monthly reflectance data in cloudy and rainy regions

Medium Resolution Scale

- Effectively filling in missing clear sky data.
- With time series information, the effect of thick aerosols on reflectance is mitigated.
- The accuracy is close to that of traditional data fusion algorithms （Pearson’ s r~0.95, RMSE ~0.04）
- There is no need to manually filter input data, enabling automated processing of large areas
- In areas with long-term cloud coverage caused by terrain, the algorithm needs to be further improved.

The best monthly observations of the Gaofen-1 satellite in 2020



Monthly reflectance after reconstruction in 2020

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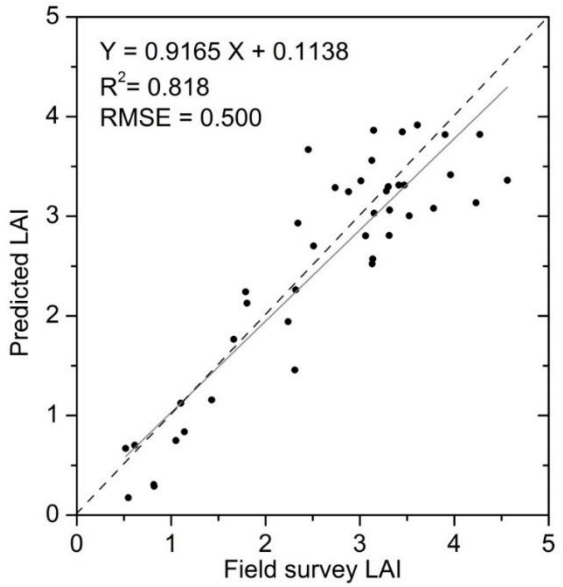
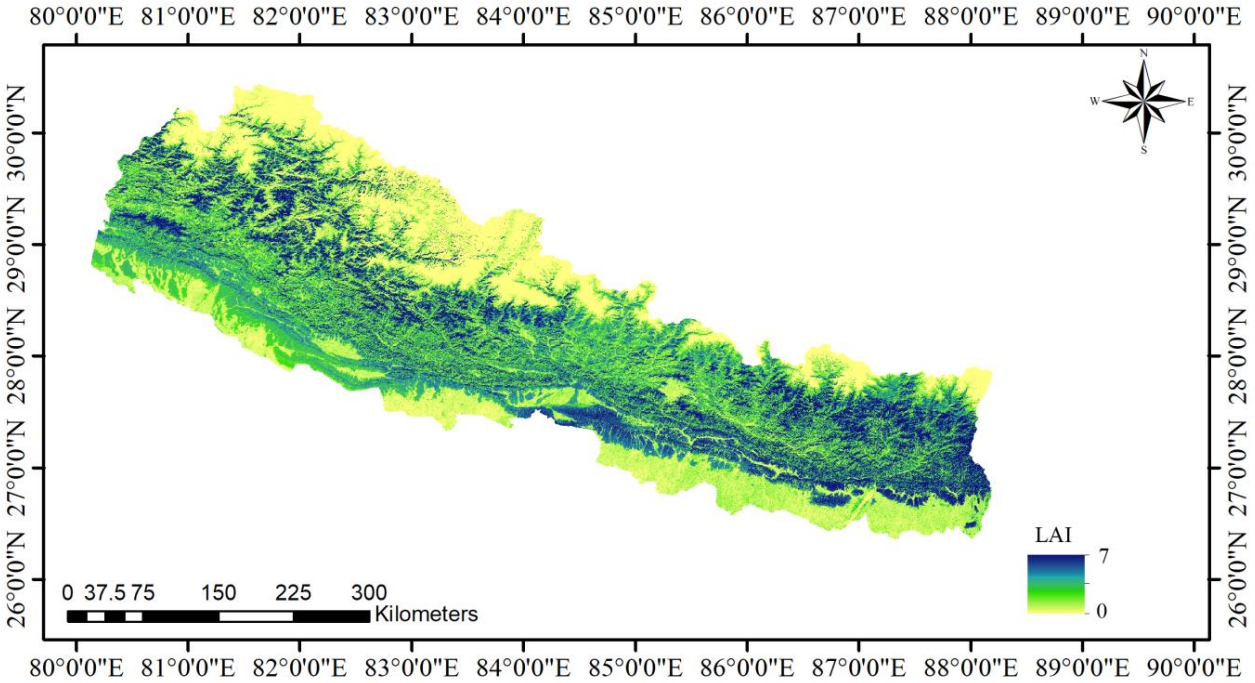
Application Demonstration of Ecological Environment factors Monitoring

Based on the spectrum earth data, using the self-developed LAI inversion algorithm (R2=0.818, RMSE=0.5) coupled with the PROSAIL radiative transmission model and the neural network model, the application demonstration of the leaf area index, a typical element of the ecological environment, was carried out in the whole area of Nepal.



Algorithm Accuracy Verification



Spatial distribution of LAI of typical elements of the ecological environment in Nepal in 2020

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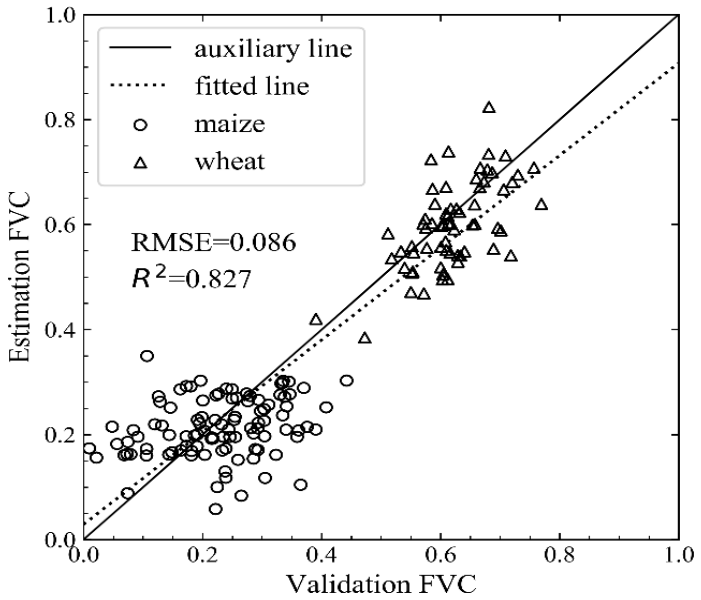
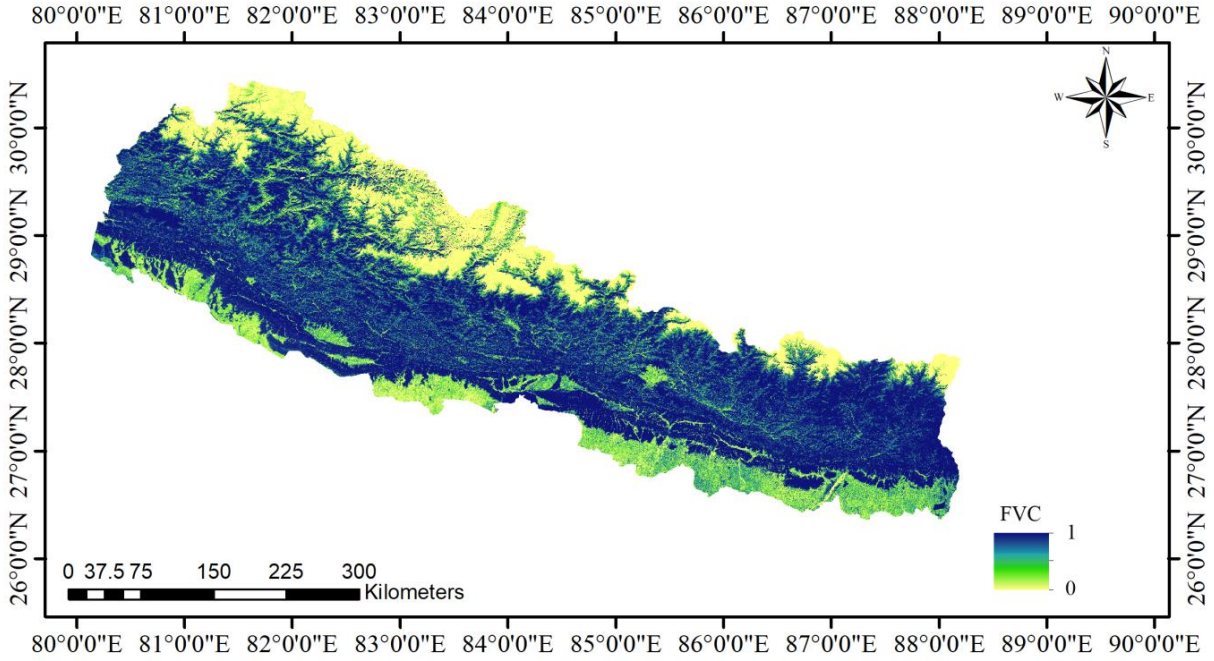
Application Demonstration of Ecological Environment factors Monitoring

Based on the spectrum earth data and the self-developed FVC inversion algorithm based on the pixel dichotomy model (R2=0.827, RMSE=0.086), an application demonstration of typical ecological environment elements-vegetation coverage was carried out in Nepal.



Algorithm Accuracy Verification



Spatial distribution of vegetation coverage of typical elements of the ecological environment in Nepal in 2020

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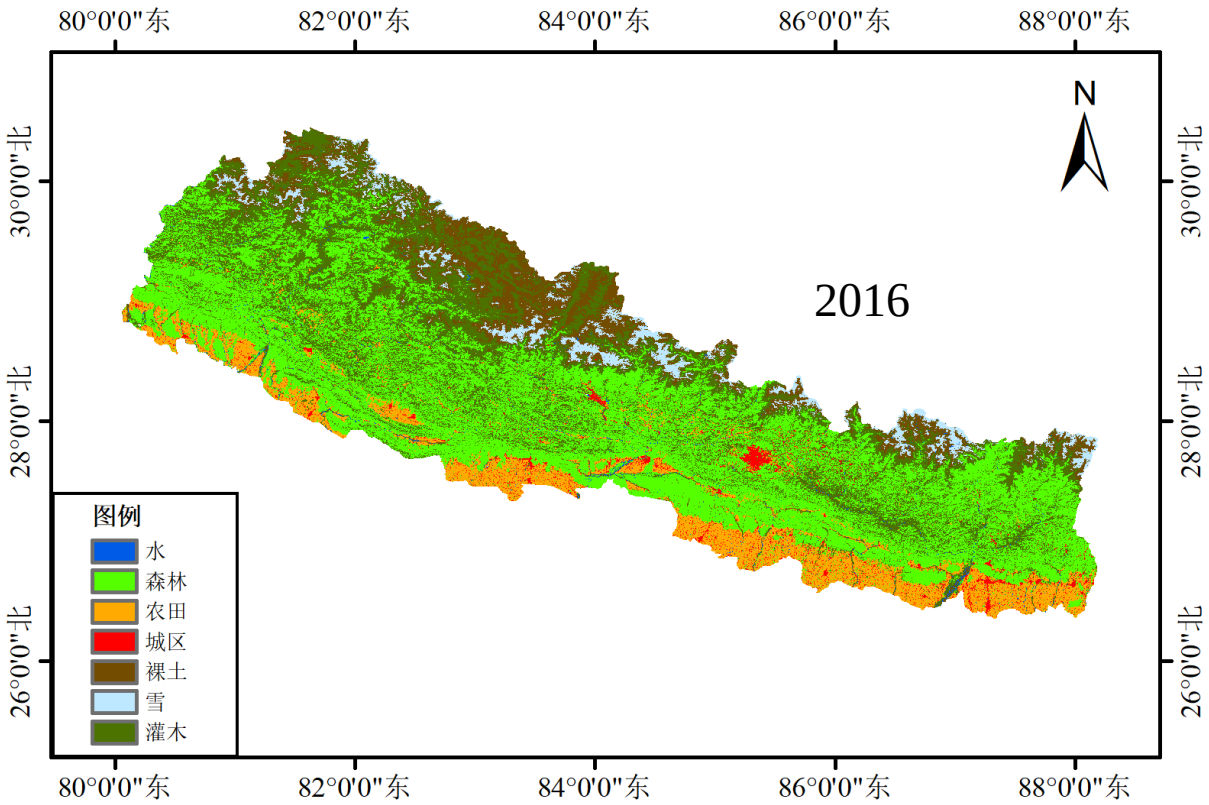
Application Demonstration of Land Cover Monitoring

Optimize the deep learning Unet model and establish the loss function of the inverse log-weighted cross-entropy of the type percentage.



The random sampling method is used for verification, and the classification accuracy is about 84%.

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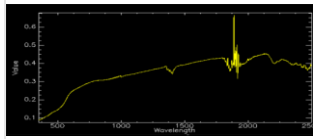
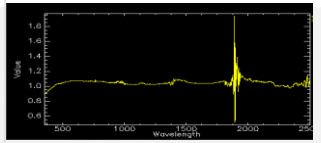
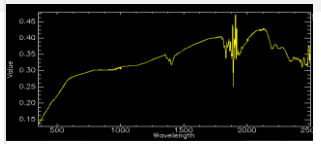
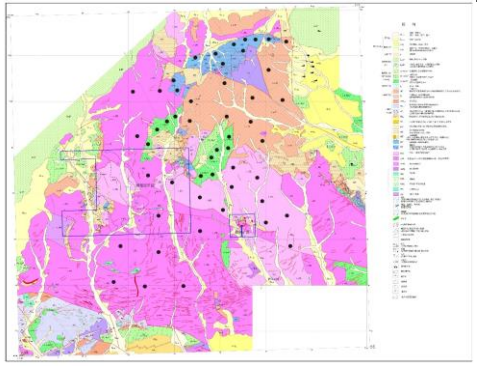
multispectral images to hyperspectral images

- Targeting the characteristics of the ground objects in the demonstration area, the spectrum information of typical ground objects, especially the mineral spectrum data, was collected, which provided data support for the expansion of hyperspectral images.
- The construction of the spectrum database of typical ground objects oriented to the target load is completed, which provides database support for the engineering of hyperspectral image expansion.

Measurement Type	Field Photos	Coordinate	measurement photo	Measurement spectrum	Spectrum analysis
brick red light yellow granite		N42.05685 E94.81883			2214nm吸收谷可能是铝羟基影响，2375nm处吸收谷是由于镁羟基造成。
light gray white plagiogranite		N42.31621 E95.07766			在全波段范围之内，反射率较高。该波谱曲线并未表现出明显的吸收特征。
offwhite biotite granite		N42.30281 E95.07905			2202nm/2260nm铝羟基特征吸收2350nm吸收谷，是 CO_3^{2-}特征吸收。



Sample collection from overseas demonstration areas

Sample collection from overseas demonstration areas

- The overseas sample collection area is mainly located in the north of West Urt, Sukhbaatar Province, with east longitude 112°30′ ~ 113°36′ and north latitude 46°51′ ~ 47°15′;
- A total of 52 sets of samples were collected, including granite, rhyolite porphyry, tuff, limestone and other samples.

There are over 1,300 hyperspectral data in spectra database, over 500 measured spectra, including 9 different types of ground objects such as water, wheat, soil, some plants, roads, granite, sloping beaches, and slate.

Spectrum collection and analysis in the domestic demonstration area

- The ground spectrum measurement of different rock ores is carried out in the demonstration area. The types of rock ores have dark and bright contrast changes from the overall tone, and the lithology types include different types of granite, slate, schist, and alluvial beaches.
- The measured spectra were collected for the main vegetation types around Hami. The main vegetation types were cotton, corn, and a small amount of grapes.

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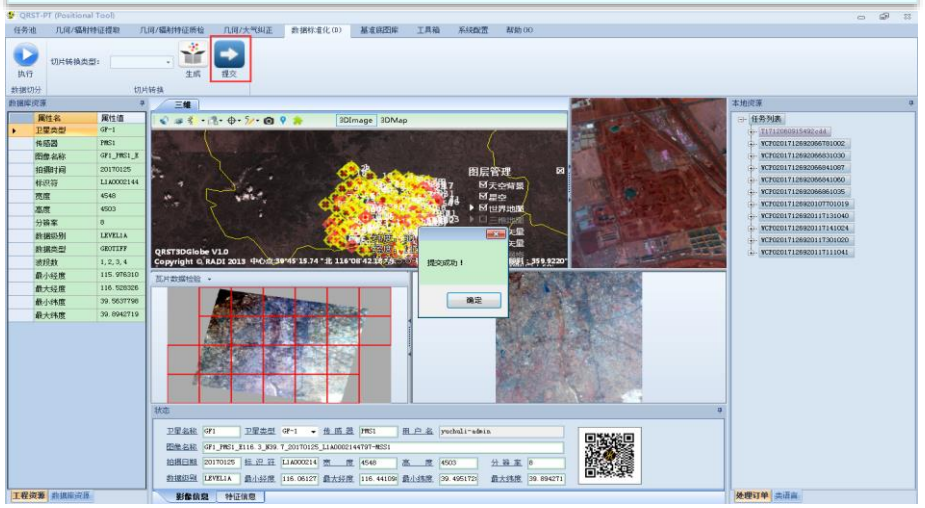
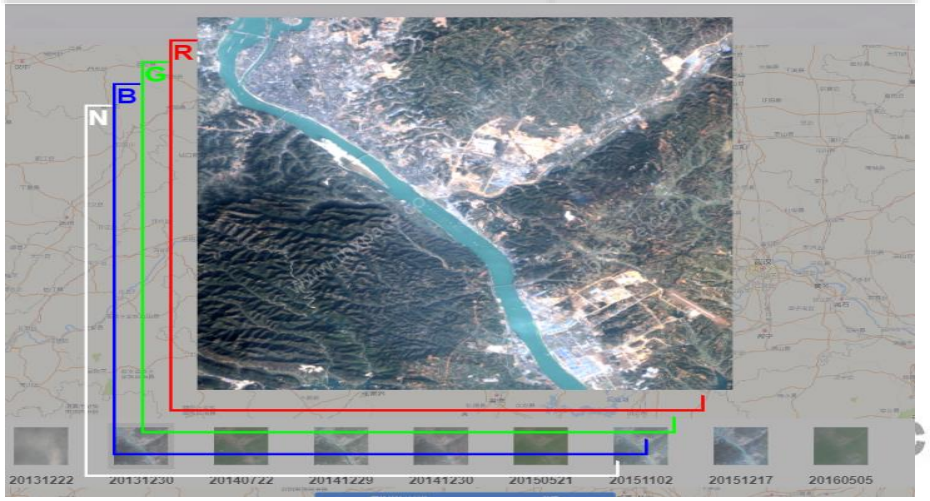
Platform research and development

For multi-source heterogeneous remote sensing satellite data, carry out the research and development of the spectrum earth platform data processing system, which can provide standardization, and normalization processing capabilities, and unify the radiation reference, geometric reference, and spatiotemporal resolution scale, data product specifications, etc., of multi-source heterogeneous remote sensing satellite data, support multi-source remote sensing satellite data application collaborative processing capabilities.

Normalize the image data obtained at different times to a specific time



Normalize the image data with different resolutions from different satellites to data blocks of standard pixel size.



Thank you!

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