Aerospace Information Research Institute(AIR)
Chinese Academy of Sciences(CAS)

Calibration and production validation (Cal&Val) of hyperspectral sensors onboard China's hyperspectral missions

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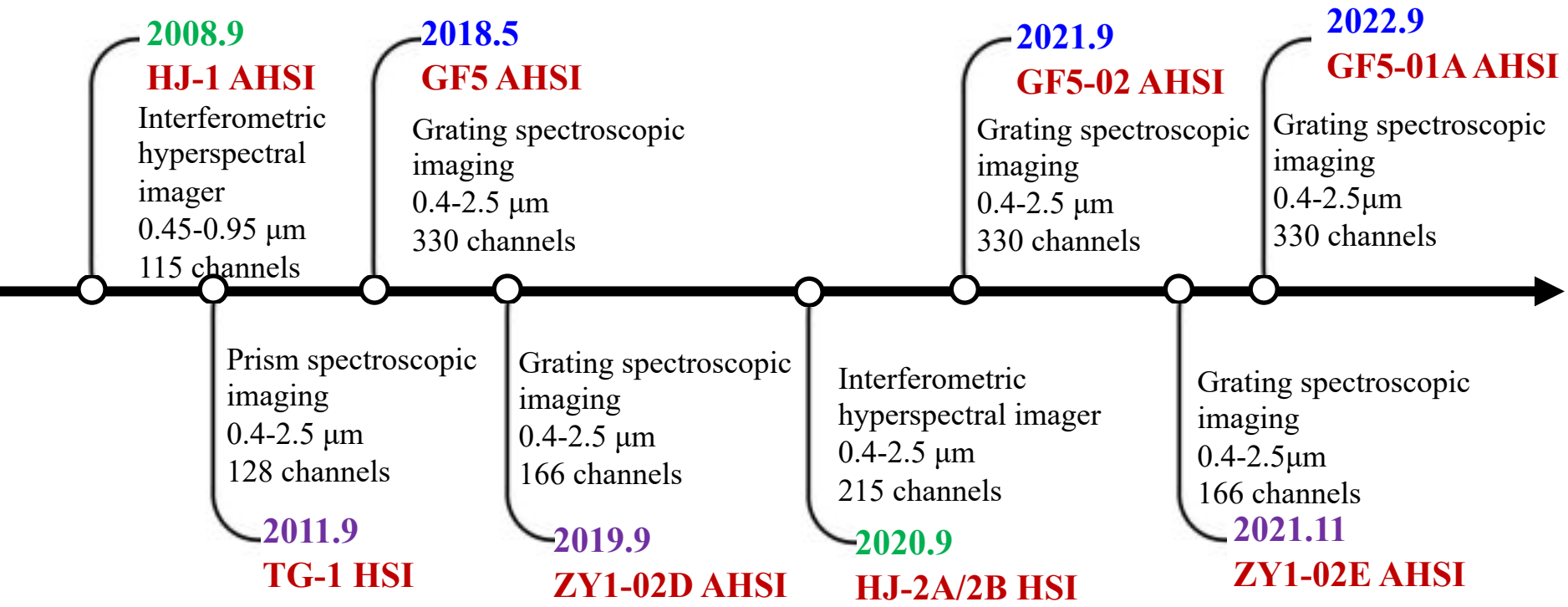
Outline

1. Introduction of China's hyperspectral satellite mission
2. Hyperspectral data product processing - taking GF5-02 as an example
3. Absolute radiometric calibration for hyperspectral satellite mission
4. Validation of calibration results and application cases
5. Conclusion

1. Introduction of China's hyperspectral satellite mission

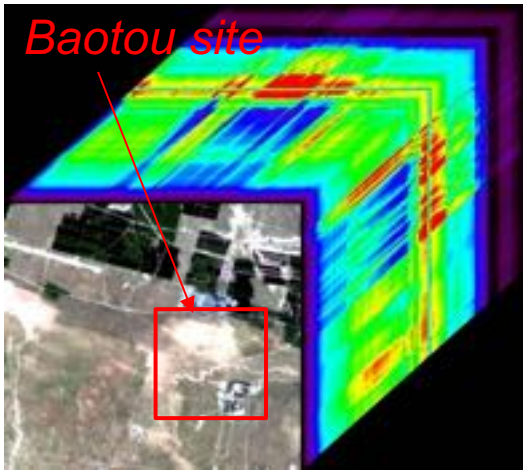
- In the past two decades, China's spaceborne hyperspectral mission has been developing continuously, and a series of hyperspectral satellites have been successfully designed and launched, such as the Huanjing (HJ) hyperspectral series, Tiangong (TG)-1 hyperspectral sensor, Gaofen (GF) hyperspectral series, and Ziyuan (ZY) hyperspectral series.



2. Hyperspectral data product processing - taking GF5-02 as an example

- Taking the GF5-02 hyperspectral mission as an example, the hyperspectral preprocessing system is introduced in this presentation.
- GF5-02 was launched on September 7, 2021, the Advanced Hyper Spectrum Imager (AHSI) is one of the main sensors for terrestrial high resolution remote sensing.
- It cooperates with GF5 satellite for observation in the morning and afternoon, but unfortunately, GF5 satellite has stopped working.
- GF5-01A , another satellite with the AHSI will be launched in December of this year to replace the GF5 satellite.

	GF5-02	GF5-01A
GSD	30 m	30 m
Spectral range	0.4-2.5 μm	0.4-2.5 μm
Spectral resolution	VNIR ≦ 5 nm; SWIR ≦ 10 nm	VNIR ≦ 5 nm; SWIR ≦ 10 nm
Spectral calibration accuracy (LED)	VNIR：≦0.5nm；SWIR：≦1.0nm	VNIR：≦0.5nm；SWIR：≦1.0nm
Swath	60 km	60 km
Bands	330(VNIR:150，SWIR: 180)	330 (VNIR and SWIR)
Revisit period	51 days (no side-looking)	51 days (no side-looking)



GF5-02 AHSI image
(2021/11/8)

2. Hyperspectral data product processing - taking GF5-02 as an example

☐ AHSI data product processing

- GF5-02 AHSI comprises the following levels of processed hyperspectral data product : L0 product, L1 product, and L2 product.
- The calibration subsystem supports the production of AHSI hyperspectral data products by providing relative radiometric calibration coefficients, absolute radiometric calibration coefficients, geometric correction parameters, etc.
- The validation and application subsystem carries out the validation and quantitative application of AHSI hyperspectral data products.

Data receiving system

Ground data processing subsystem

L0 level
- Data parser
- Data scene

L1 level
- Dark signal correction
- Relative response correction
- FPM to FPM correction
- Geometry correction

L2 level
- Fine geometric correction
- Cartographic geometry process
- Data archiving

Calibration subsystem
- ✓ Onboard calibration data processing
- ✓ Vicarious calibration
- ✓ Geometry correction

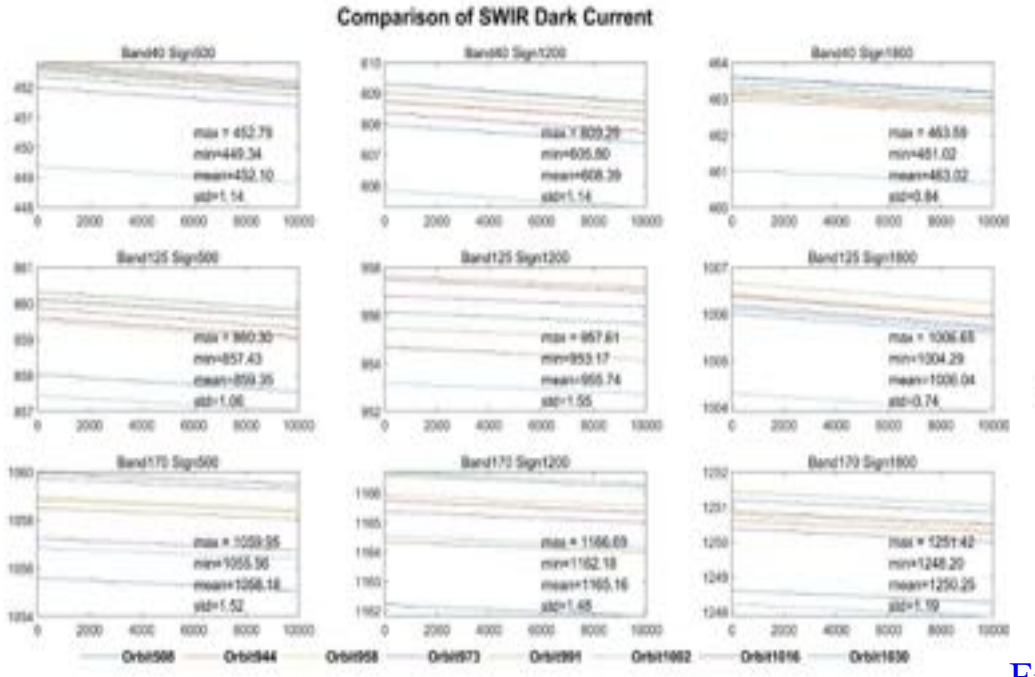
Application and validation subsystem

Others | Mineral explora-tion | NPP | VI | Surface reflectance

2. Hyperspectral data product processing - taking GF5-02 as an example

☐ Dark signal correction

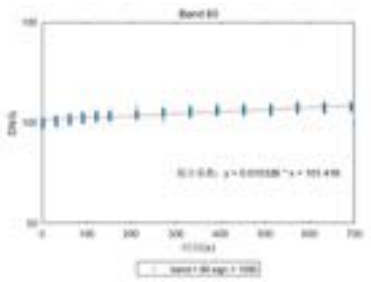
- According to in-orbit deep sea observation data at night, the dark signal changes with time after the AHSI camera is turned on.
- In order to accurately describe the dark signal changes and correct the dark signal, a time-varying dark signal model is established, and the model error is within 1 DN value.



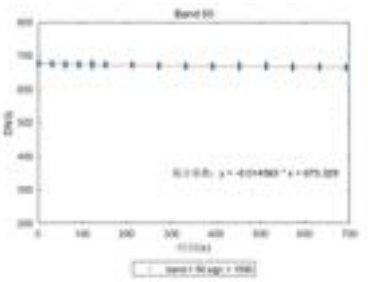
Dark current variation with time (average result of 10 lines)

Model $\boldsymbol{DN_{dark} = f(t - t_0)}$

where t_0 is startup time, t is the imaging time.



VNIR
（B80，detector 1000）



SWIR
（B50，detector 1000）

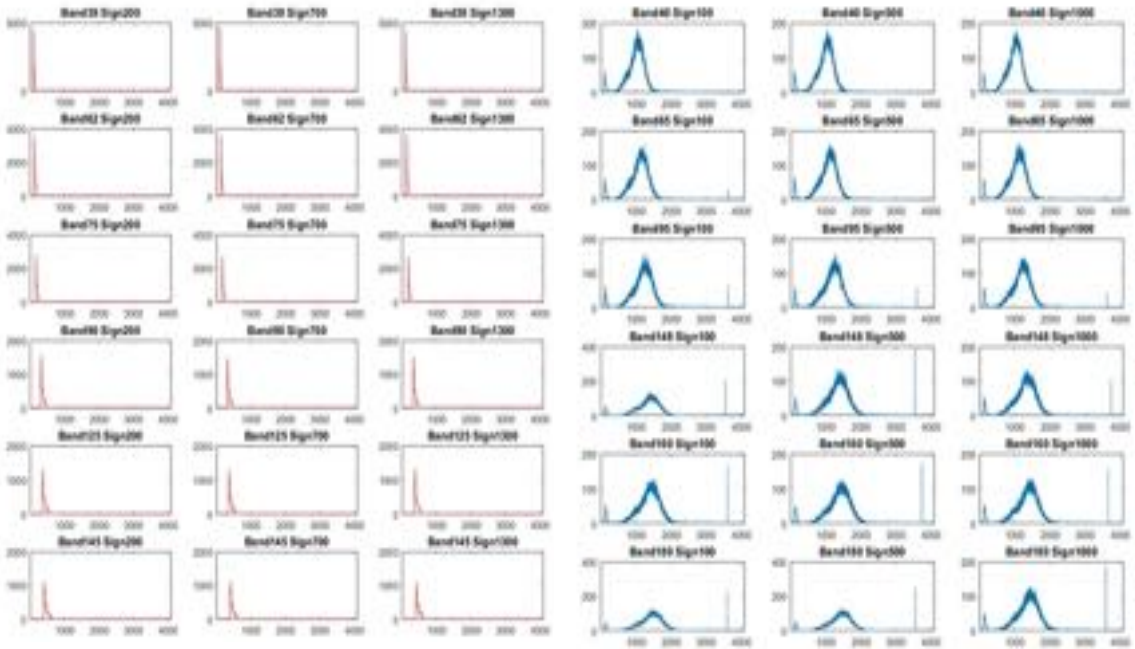
Fitting results of dark signal time-varying model of AHSI camera

2. Hyperspectral data product processing - taking GF5-02 as an example

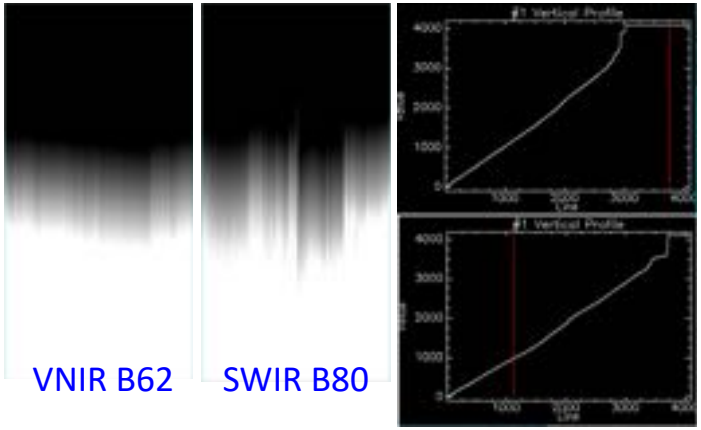
☐ Relative response correction

- Histogram statistics method based on all available uncalibrated images（spanning more than a month） were used to calculate relative gain values for detectors.
- The relative gain values for detectors were determined by matching the histograms of different detectors.

VNIR SWIR



Histogram statistical results based on a large number of observation data

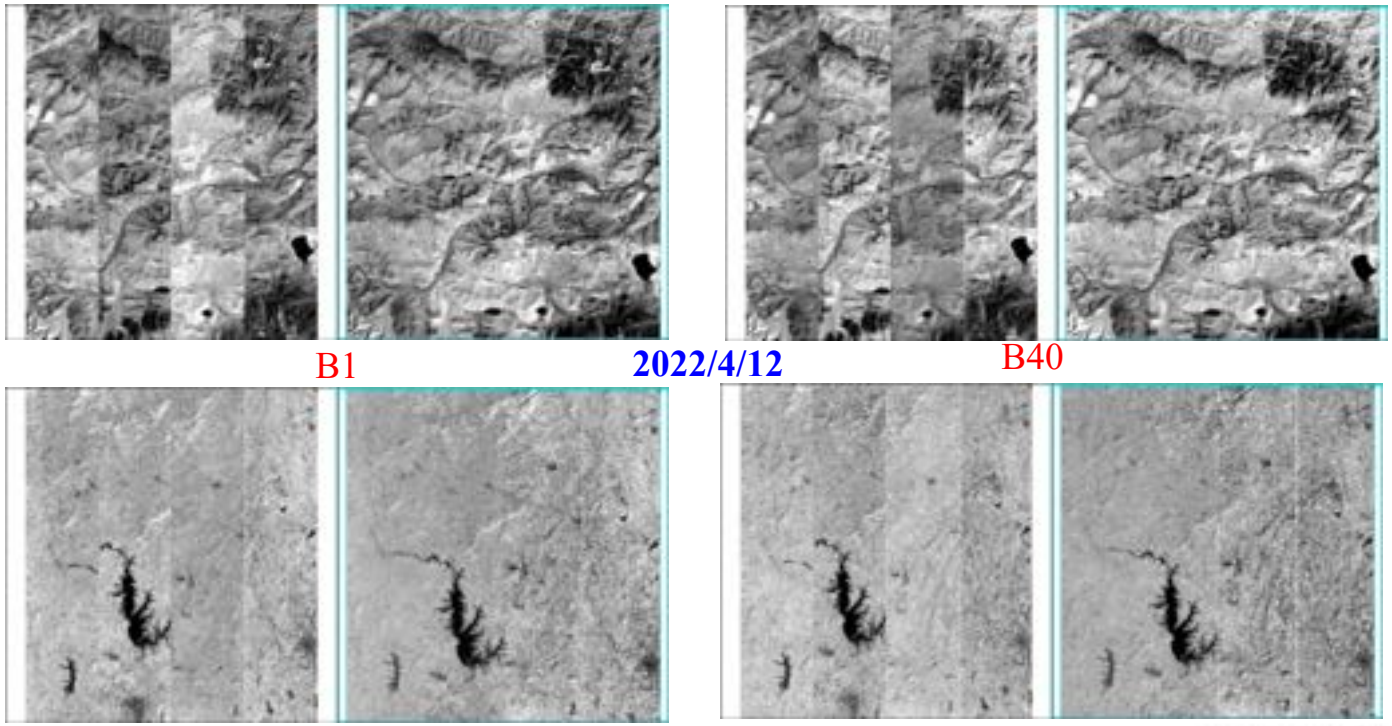


The look-up table based on histogram matching

2. Hyperspectral data product processing - taking GF5-02 as an example

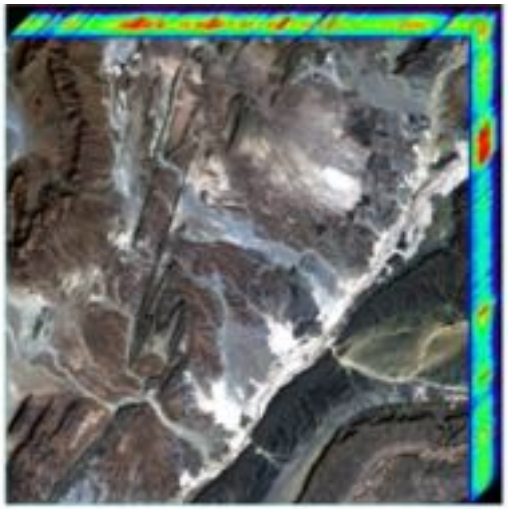
FPM to FPM correction

- The SWIR sensor has four different focal plane modules (FPM). After the relative response correction, the FPM to FPM correction was carried out to calculate the correction coefficients between different FPM.
- Based on the overlapping area data of different FPMs, the correction coefficients are obtained by linear fitting, which ensure the consistency between different FPMs.

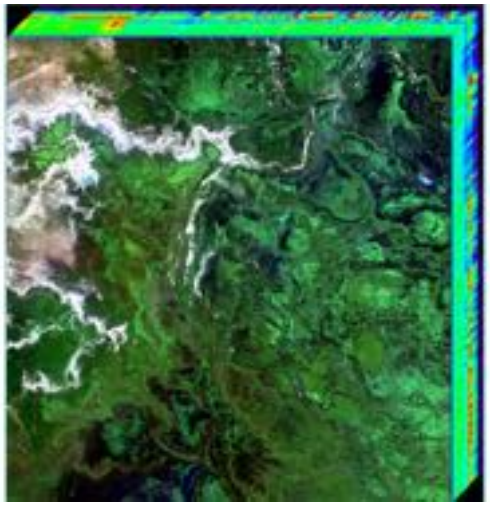


2. Hyperspectral data product processing - taking GF5-02 as an example

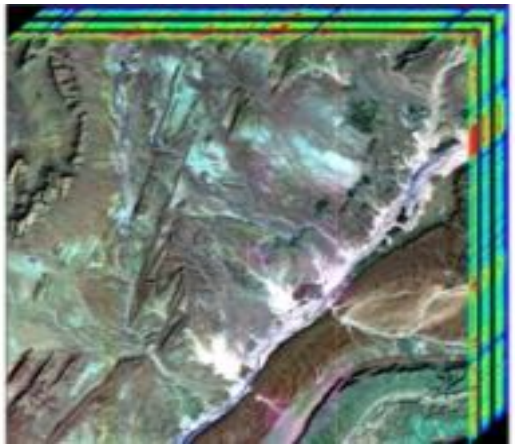
- GF5-02 data product



VNIR

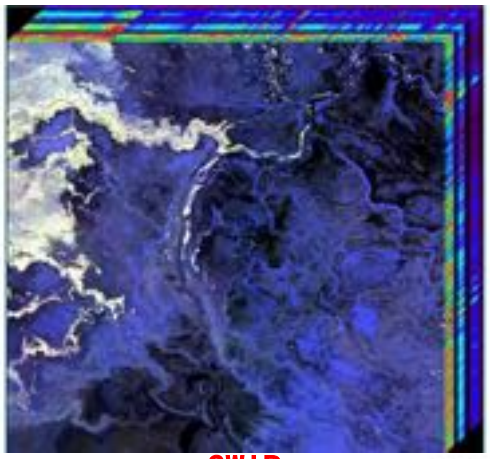


VNIR



SWIR

2021/12/09



SWIR

2022/01/29

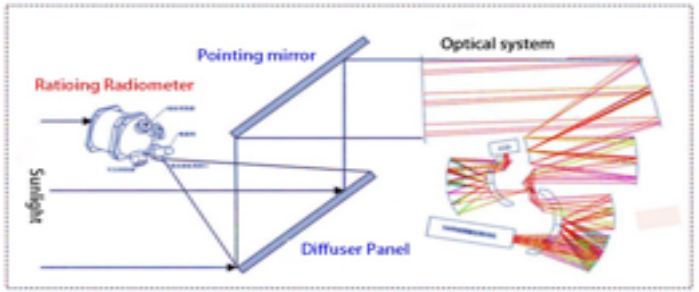
3. Absolute radiometric calibration for hyperspectral satellite mission

- **Onboard calibration**

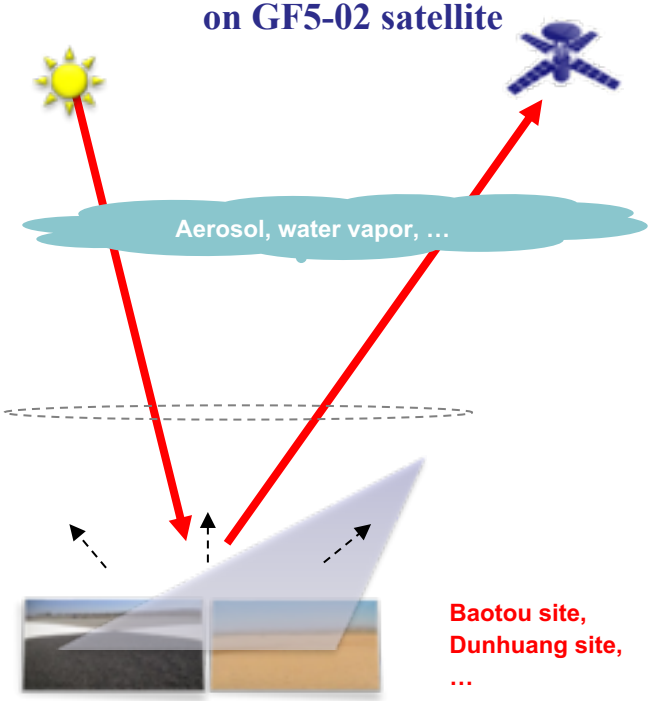
Onboard calibrator on GF5-02 satellite consists of a solar diffuser (SD) and a solar diffuser stability monitor (SDSM). Unfortunately, some factors lead to the inability to cover the full field of view of AHSI in the solar diffuser observation mode.

- **Vicarious calibration**

At present, vicarious calibration is the main way for the on-orbit calibration of China's spaceborne hyperspectral sensor. The ground reflectance and atmospheric parameters measured synchronously over Baotou site and Dunhuang site are used as the input to simulate the TOA radiance.



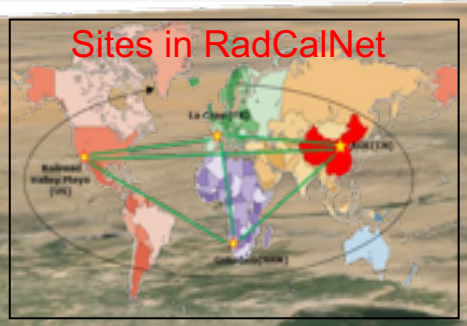
Onboard calibrator on GF5-02 satellite

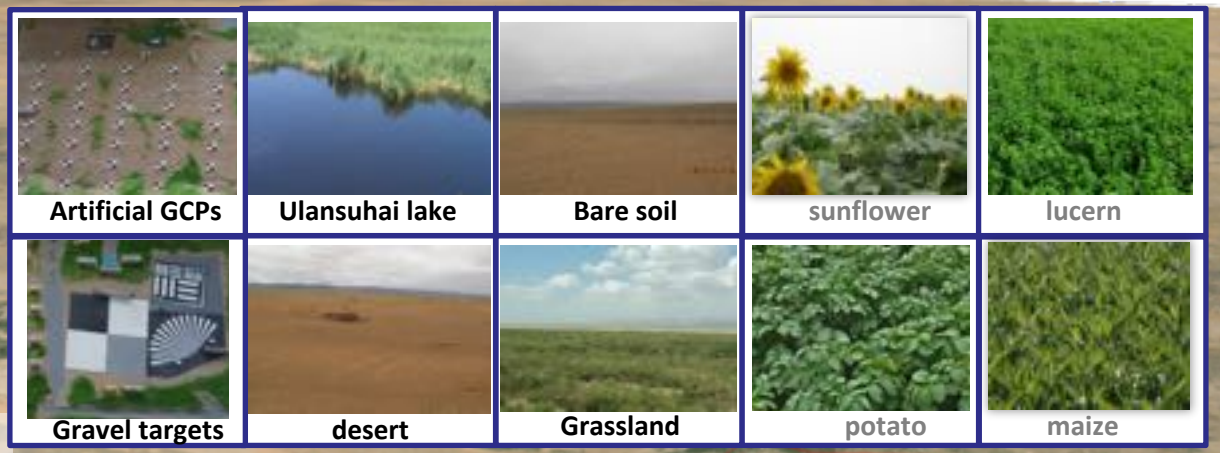


Standard stable ground targets

3. Absolute radiometric calibration for hyperspectral satellite mission

- The “National Calibration and Validation Site for High-Resolution Remote Sensors" of the MOST, China, is located in Inner Mongolia, China, 50 km away from Baotou.
- It consists of a flat area of approximately 300 km^2, about 1270 m above sea level, and multi-type typical natural scenes and various artificial targets in a single test site for HR sensor comprehensive calibration and evaluation.
- The Baotou site has been enrolled in the RadCalNet (Radiometric Calibration Network of Automated Instruments), which is making effort to provide a prototype of “global calibration” traceable to SI.



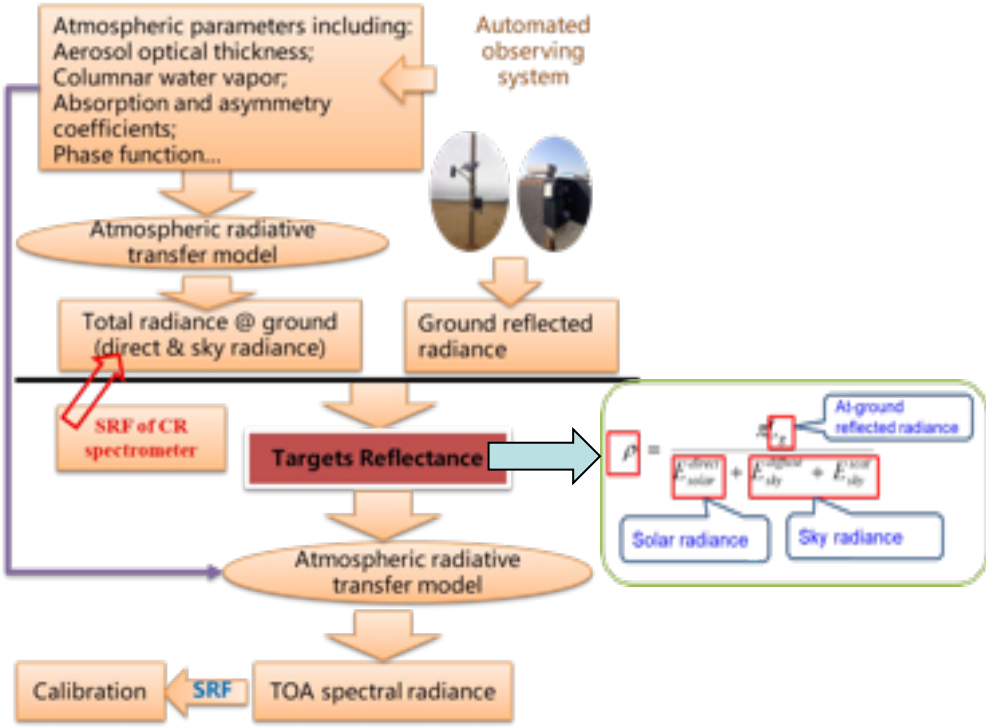


Ulansu Lake

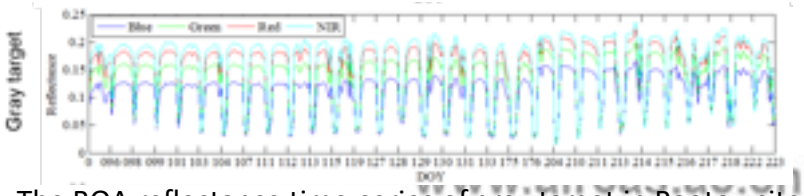
3. Absolute radiometric calibration for hyperspectral satellite mission

- In Baotou site, there are complete instrument system for surface spectral feature measurement and atmospheric parameter automatic measurement. The site is currently running. Automated radiometric calibration in Baotou site can collect data when satellite overpasses, acceptable atmospheric condition provided.

Equipments: Automatic spectral radiance measurement system, channel radiometer , automatic sunphotometer (CE318), automatic weather station, all-sky imager



The standard data processing flowchart

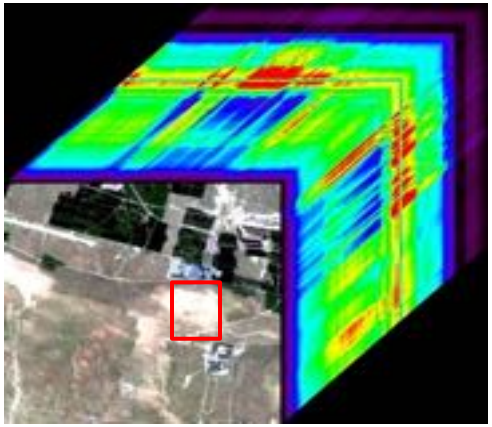


The BOA reflectance time-series of grey target in Baotou site

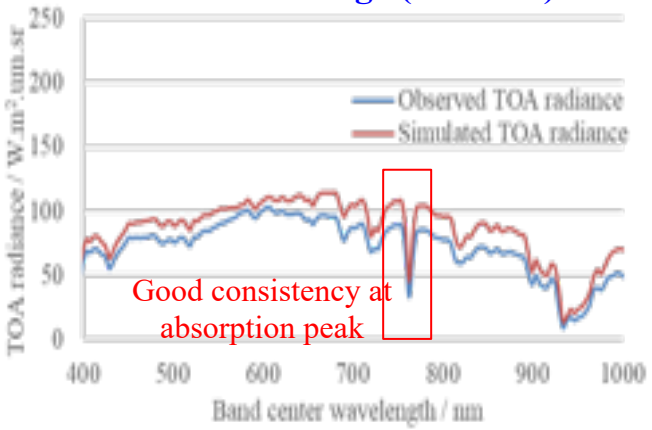
3. Absolute radiometric calibration for hyperspectral satellite mission

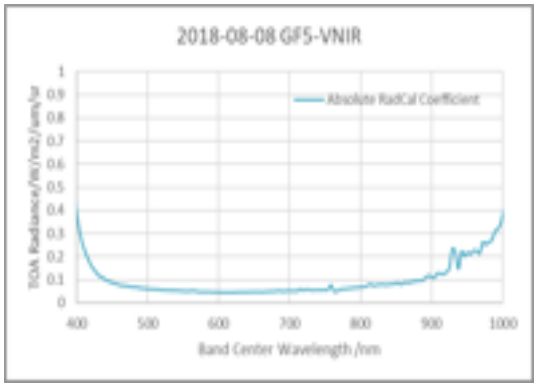
☐ Calibration results of AHS on-board GF5, ZY1E, and GF5-02 satellites

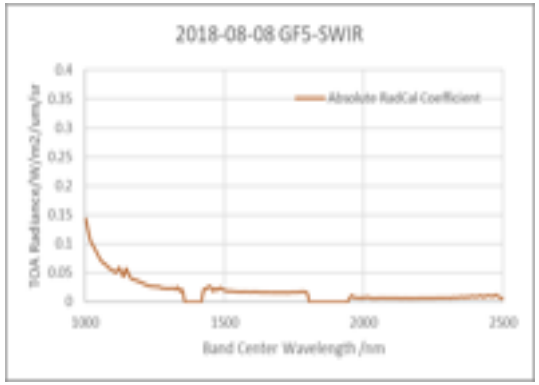
- The ground automatic measurement data of Baotou site is used in absolute radiometric calibration of AHSI sensors on-board GF5, ZY1E, and GF5-02 satellites.
- The spectral evaluation of AHSI sensors has also been done based on ground measurements over Baotou site.

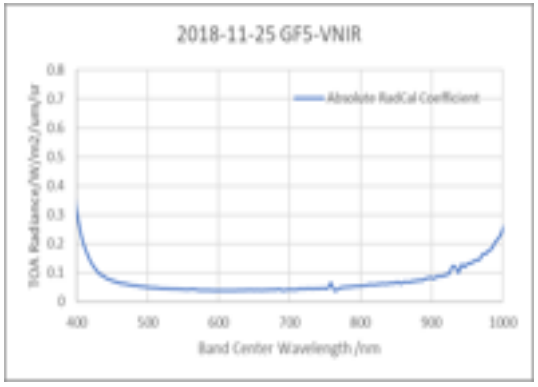


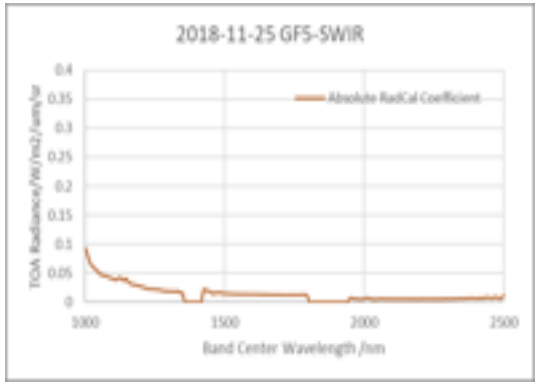
GF-5 AHSI image (2018/8/8)



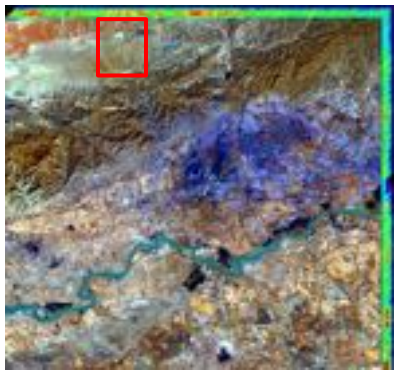




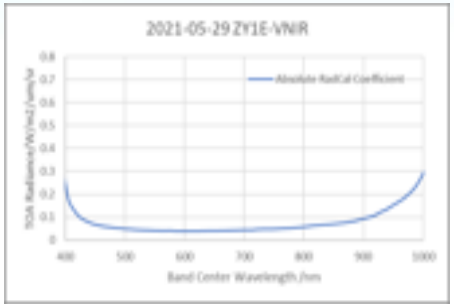


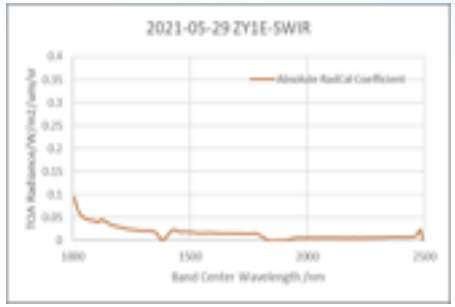


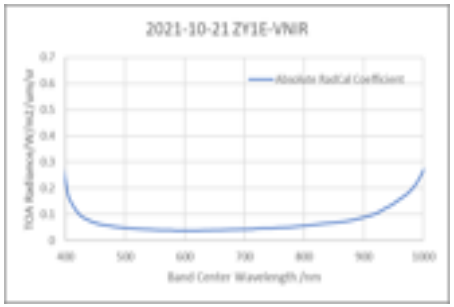
3. Absolute radiometric calibration for hyperspectral satellite mission

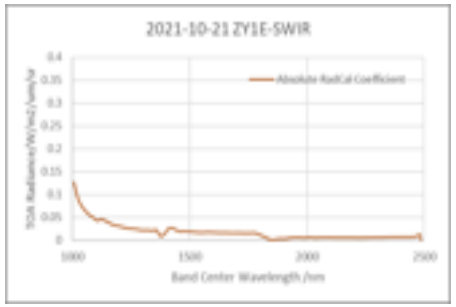


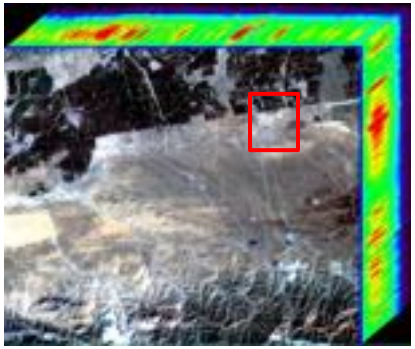
ZY1E AHSI image
(2021/10/21)



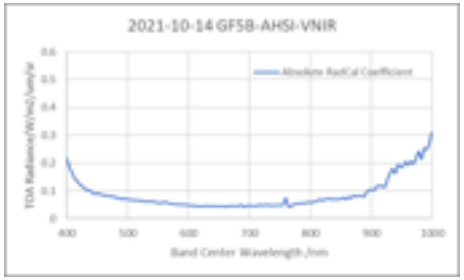


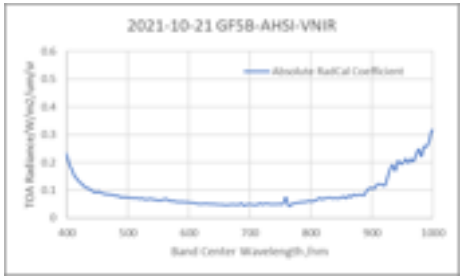






GF5-02 AHSI image
(2021/10/14)

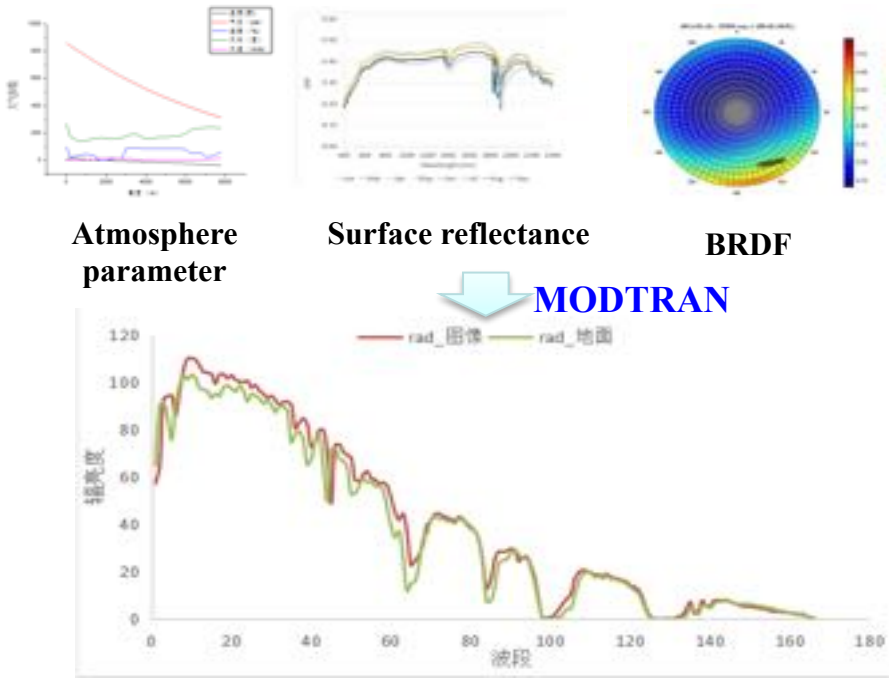




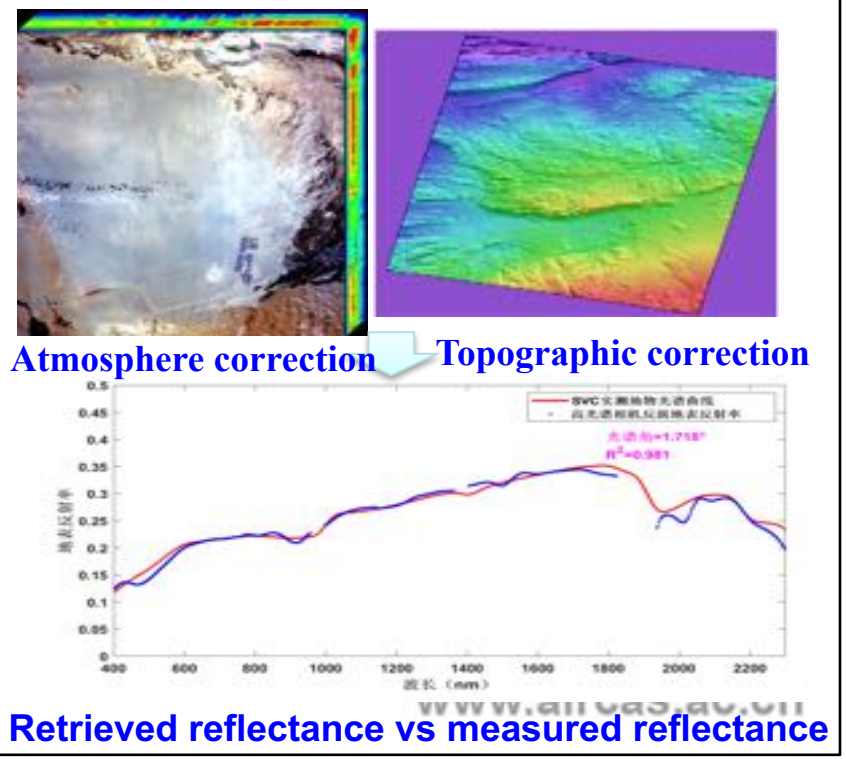
4. Validation of calibration results and application cases

☐ Validation of absolute radiometric calibration coefficients of ZY1E AHSI

- Based on the surface, atmospheric and BRDF data of Dunhuang site, MODTRAN is used to simulate the TOA radiance, which is compared with the observed radiance. The relative difference between them is within 10%;
- The retrieved reflectance is calculated through atmospheric correction and topographic correction. The retrieved reflectance is compared with ground measured reflectance. The spectral angle mapper (SAM) between them is 1.718, and the correlation coefficient is 0.981, indicating that the retrieved reflectance is very close to the measured reflectance.



Comparison of observed radiance and simulated radiance

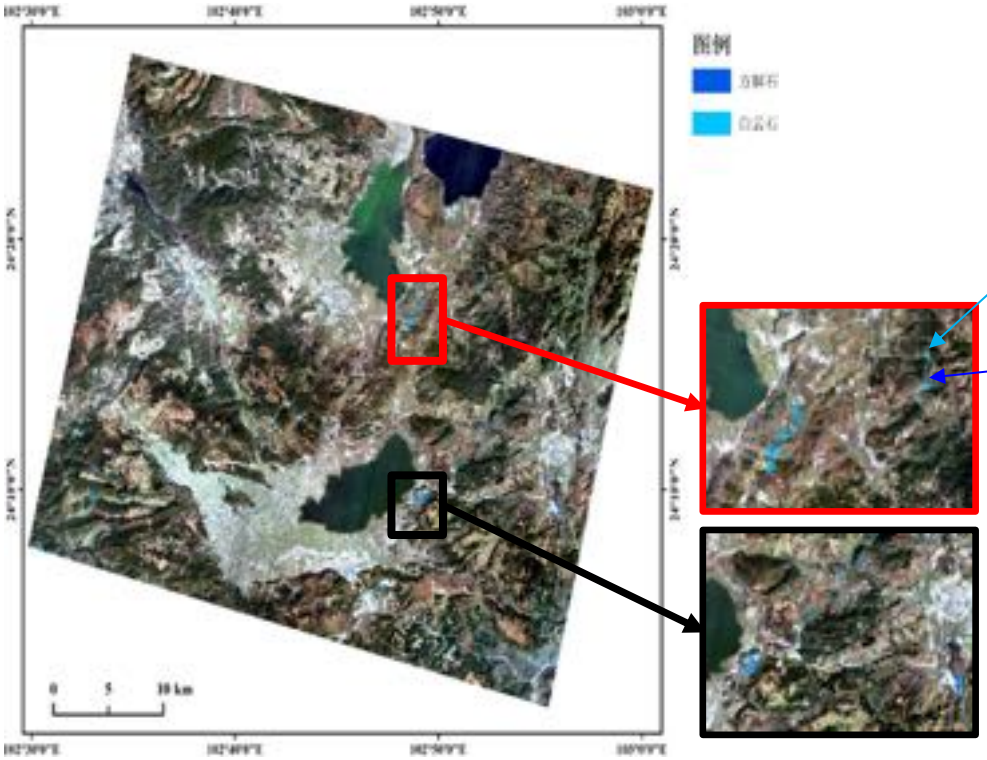


Retrieved reflectance vs measured reflectance

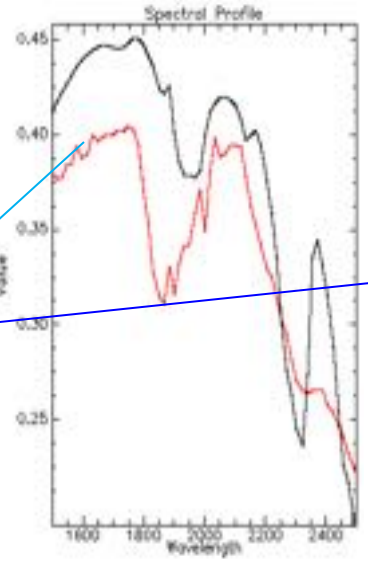
4. Validation of calibration results and application cases

☐ Application case

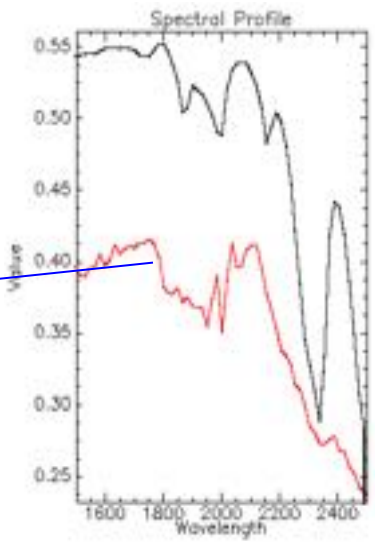
- Using the reflectance retrieved from hyperspectral image, the reflectance spectra of typical minerals were extracted, and the distribution map of rocky desertification minerals was drawn.



Distribution map of rocky desertification mineral types at Yunnan Research Area



Dolomite image spectrμm (red line) and USGS standard mineral spectrμm (black line)

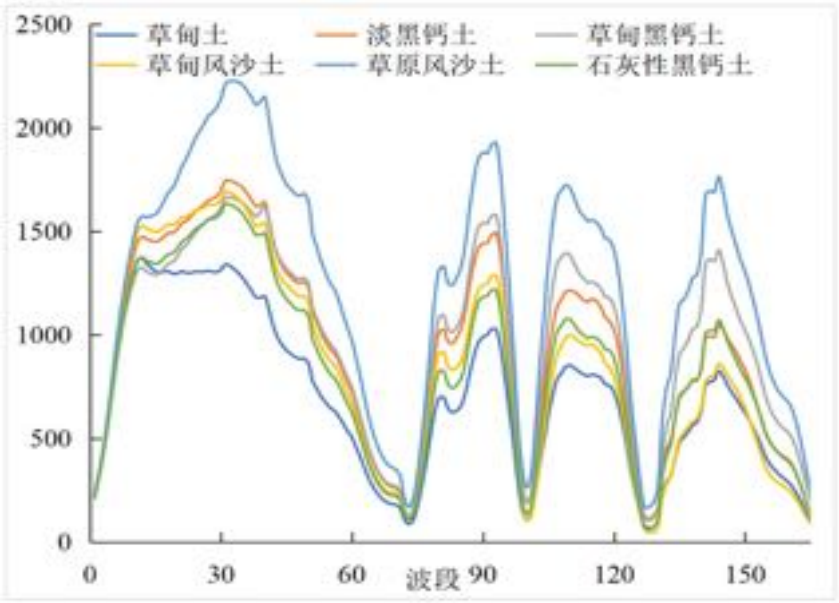


Calcite image spectrμm (red line) and USGS standard mineral spectrμm (black line)

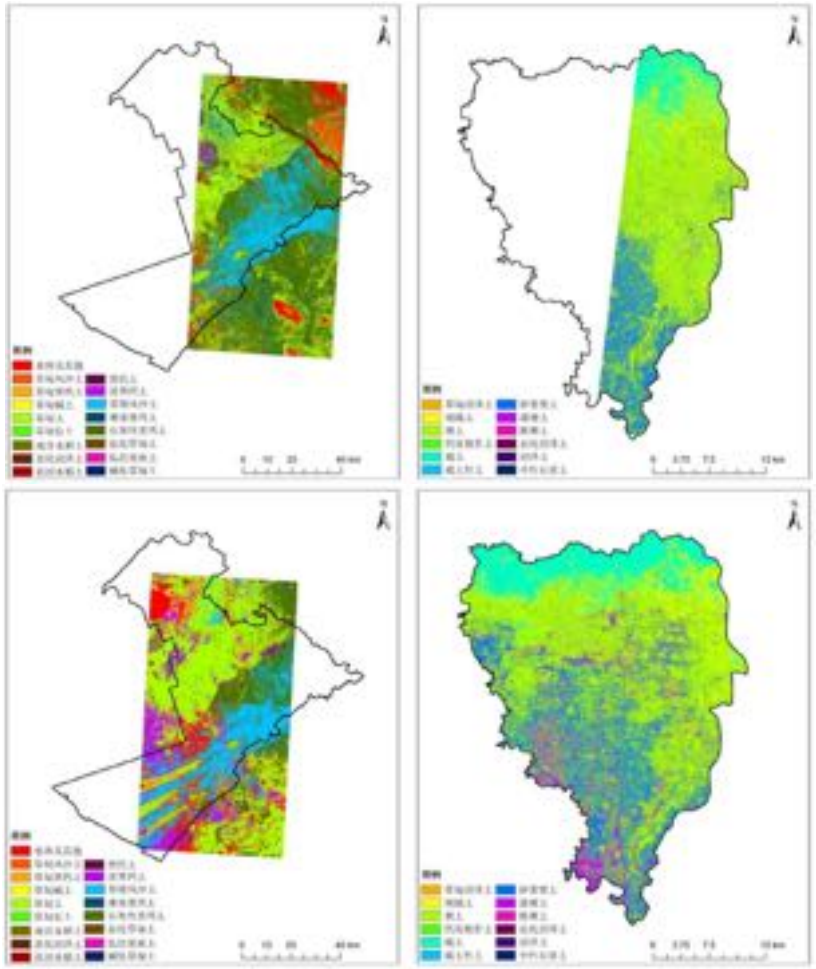
4. Validation of calibration results and application cases

☐ Application case

- The classification and distribution map of different soil types were made by using hyperspectral images.



Spectral curves of different soil types



Distribution map of different soil types based on hyperspectral data

5.Conclusions

(1) China had three AHSI sensors onboard hyperspectral missions in orbit, and a fourth mission (GF5-01A) to be launched in December this year. At present, the calibration of these AHSI sensor mainly depends on vicarious calibration.

(2) The calibration based on Baotou site and Dunhuang site has been carried out for many times, and the validation results show that the calibration results have good accuracy.

(3) The quantitative application based on hyperspectral data will continue to be carried out. Joint effort in calibration and validation will greatly improve the quality of hyperspectral data in the foreseeable future.

(4)More application cases are expected in the future and international cooperation in hyperspectral remote sensing in the future is worth looking forward to.

Thank you for your attention!

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