中国科学院光电研究院
ACADEMY OF OPTO-ELECTRONICS,CHINESE ACADEMY OF SCIENCES

UAV-based Remote Sensing Payload Comprehensive Validation System

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Project PI

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Outline

1. Background
2. System Overview
3. Inflight Calibration & Performance Assessment
4. Future Plan

1. Background

Trend of Earth observation systems:

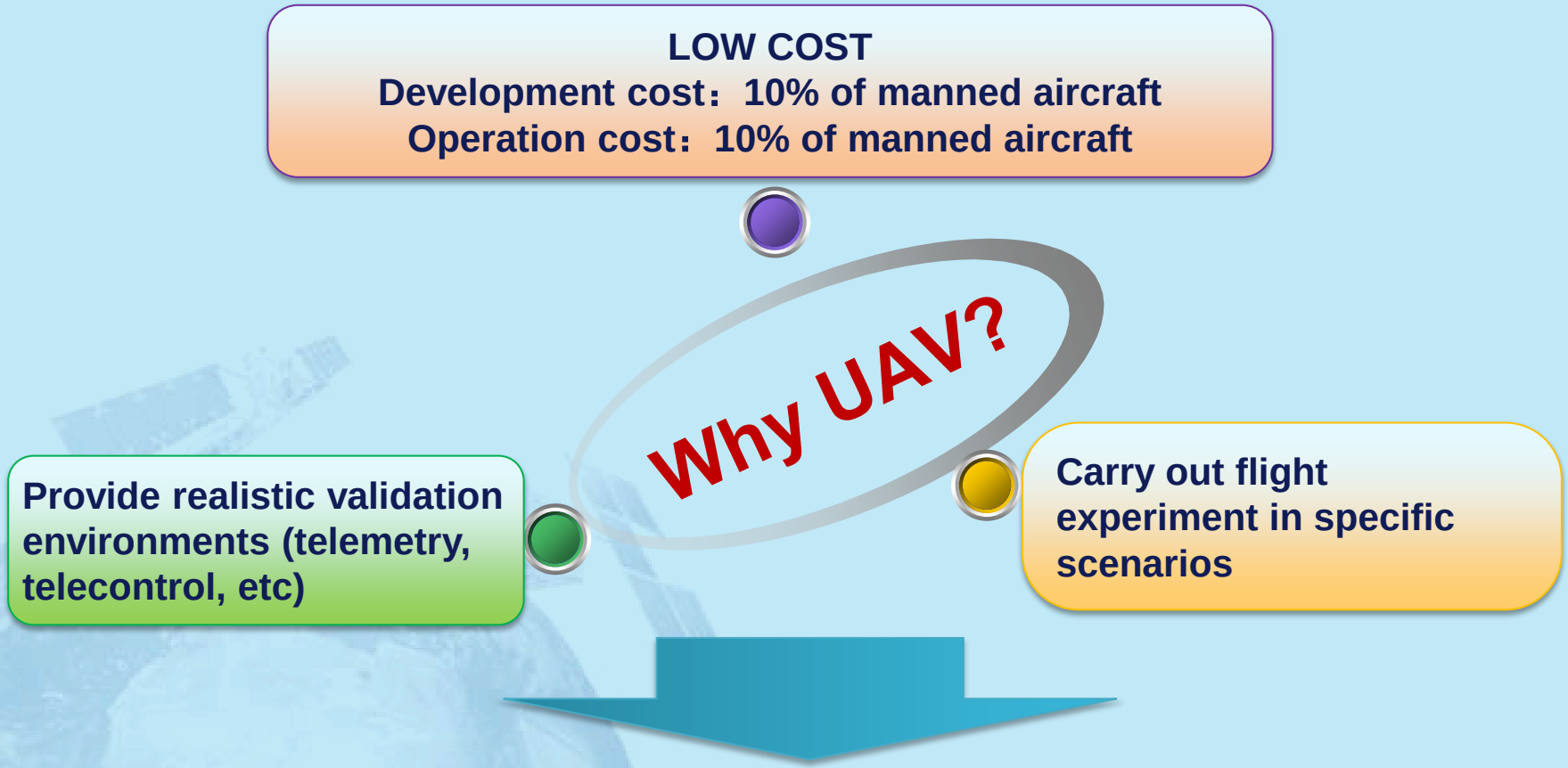
Quantitative remote sensing application

International standardization of data quality assessment and data sharing

Pre-launch Cal &Val demand

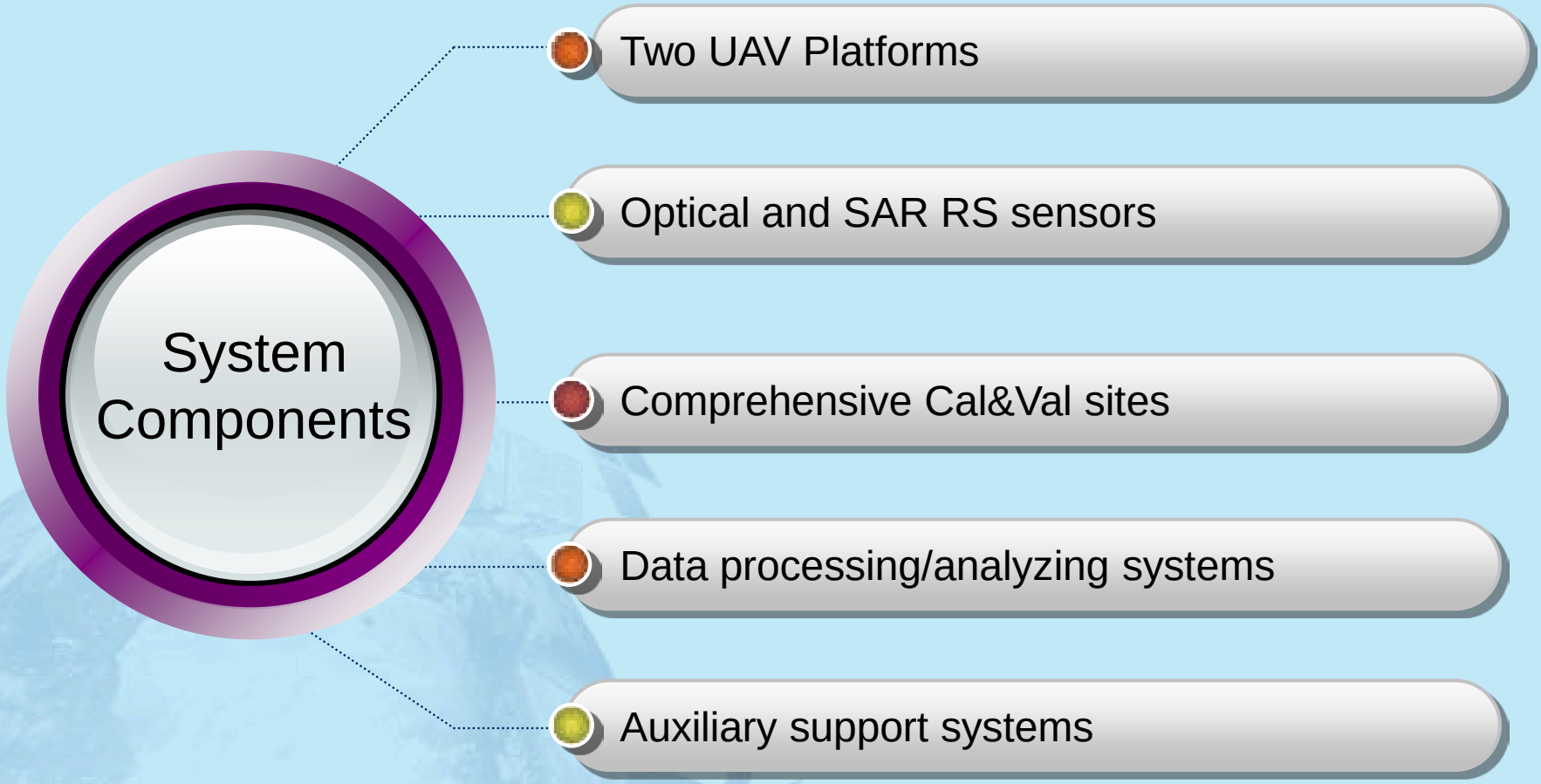
Monitoring of payload performance in system operation period

1. Background



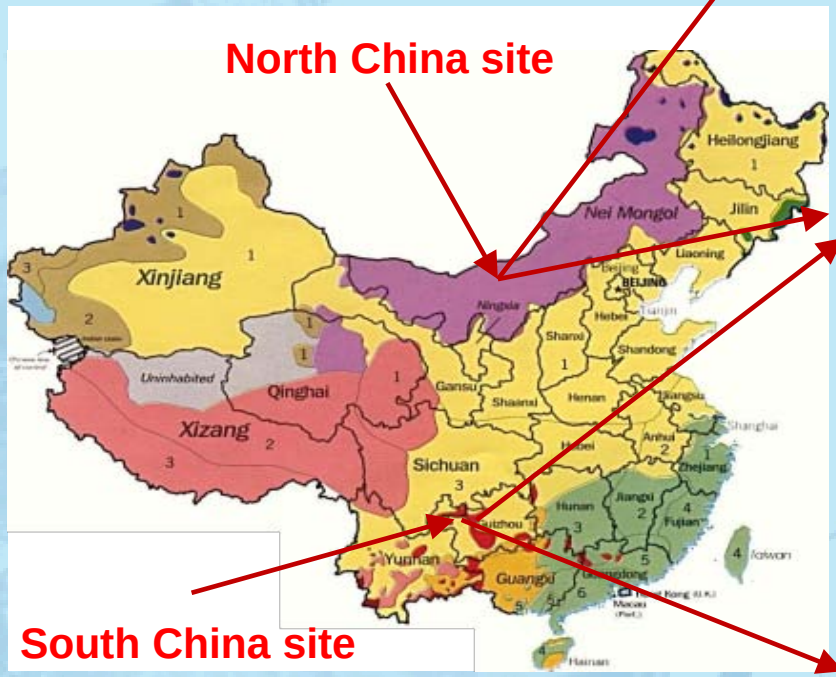
UAV-based Remote Sensing Payload Comprehensive Validation System

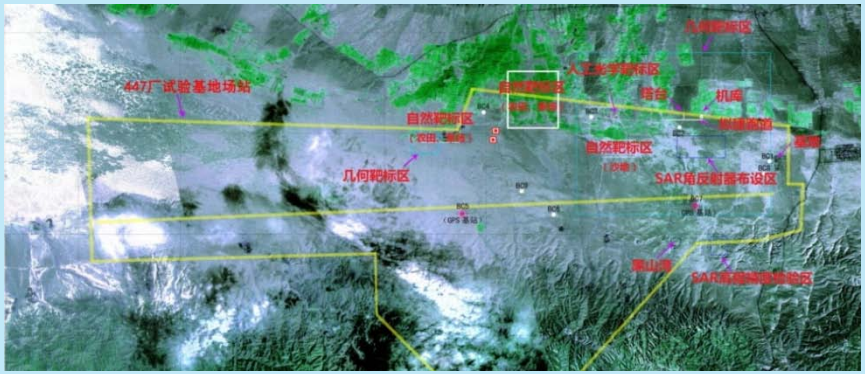
2. System Overview

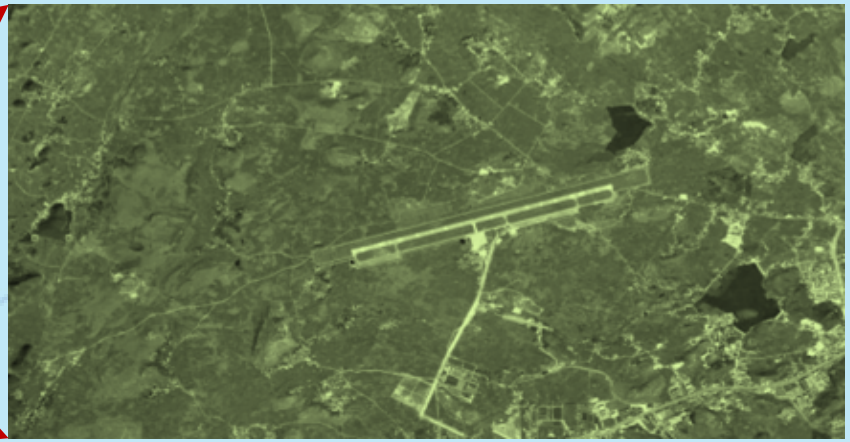


2. System Overview - The Comprehensive C&V Site

- Two comprehensive Cal&Val test sites were preliminarily established, which have different climate characteristics, various land cover types and topographic features.
- Now they are being further developed so as to support multi-grade validation of airborne and spaceborne sensors for stable and long-term operation.







2. System Overview - The Comprehensive C&V Site

- **Standard artificial and natural targets**

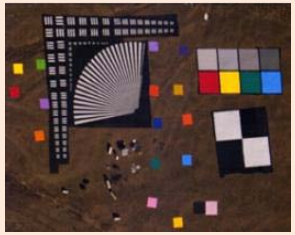
Knife-edge target

Fan-shaped target

Gray-scale target

Colored target

Three-bar target



Layout of targets

Optical targets

Trihedral Corner Reflector

Dihedral Corner Reflectors

Ku-band Active Transponder

SAR targets

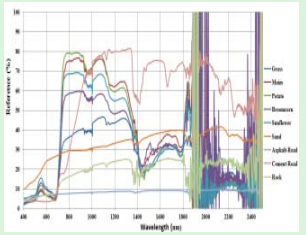
Rice

Maize

Potato

Sunflower

Surface parameters measurement



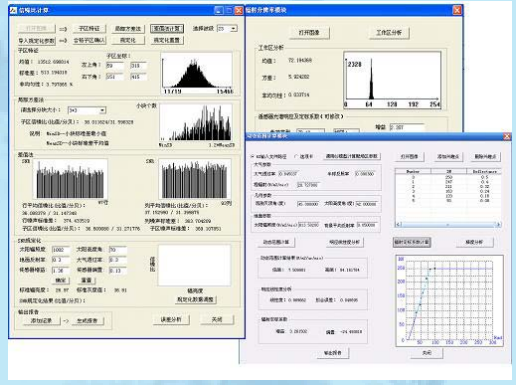
Spectral curves

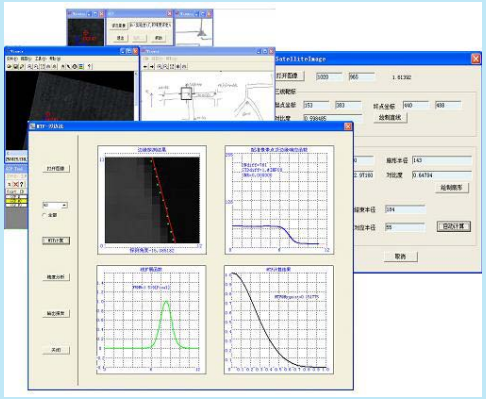
Natural ground targets

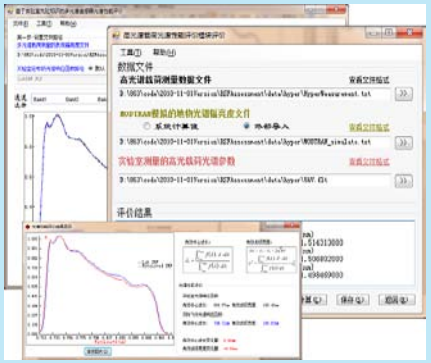
2. System Overview - Data processing/analyzing system

Data processing/analyzing system

Data processing	Radiometric performance assessment	Geometric Performance Assessment	Spectral Performance Assessment
• Radiometric correction • Geometric correction • Spectral correction • Reflectance retrieval • Vegetation index retrieval • SAR data processing	• Absolute radiometric calibration • Signal to Noise Ratio, SNR • Dynamic range • Response linear degree • Radiometric resolution, NEΔρ	• Ground resolution • MTF • Band registration precision	• Hyperspectral camera: central bandwidth; FWHM • Multispectral camera: spectral response function







3. Inflight Calibration & Performance Assessment

- **Flight campaigns**
  - **Nov 2010 Campaign**

    Airborne optical sensors in North China test site
  - **Jul 2011 Campaign**

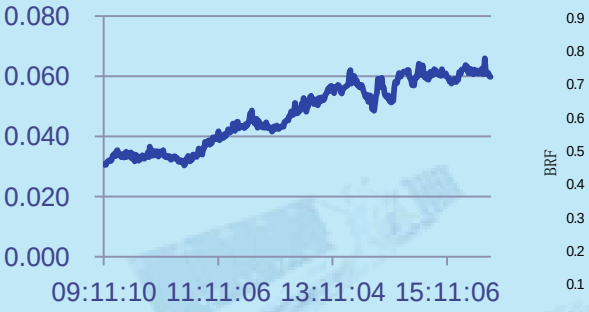
    Airborne optical and SAR sensors in South China test site
  - **Sep 2011 Campaign**

    Airborne optical and SAR sensors in North China test site

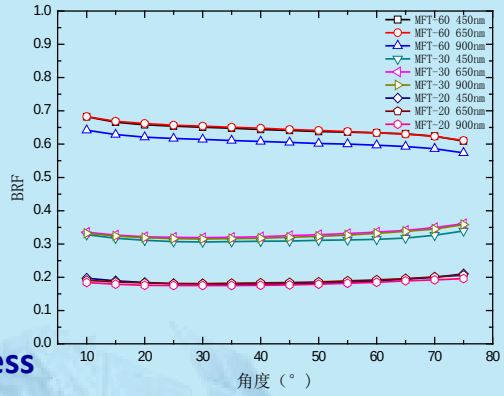
3. Inflight Calibration & Performance Assessment

- **Atmospheric and field measurements**

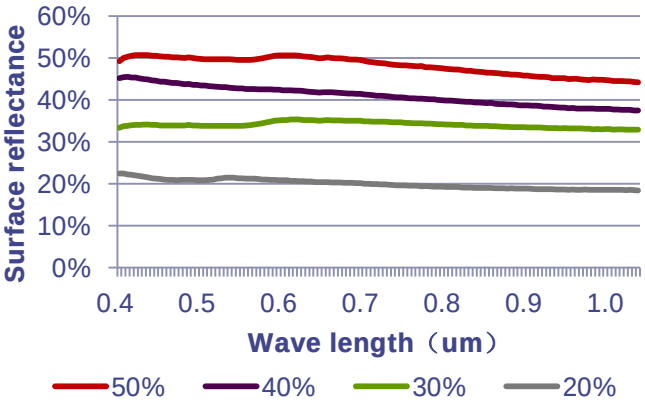
Spectral reflectance of targets were measured. The aerosol optical thickness data and meteorological profile above the test site were synchronously collected.

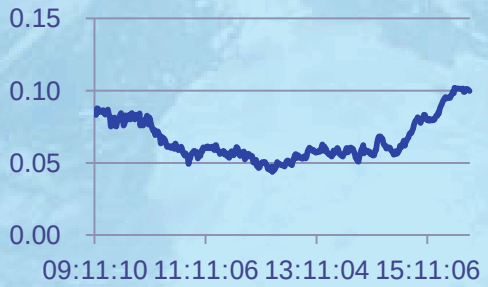


550nm aerosol optical thickness



BRF properties of targets



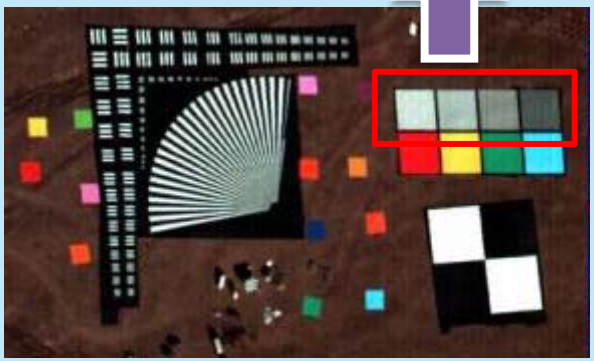


Moisture content

Radiosounding balloon

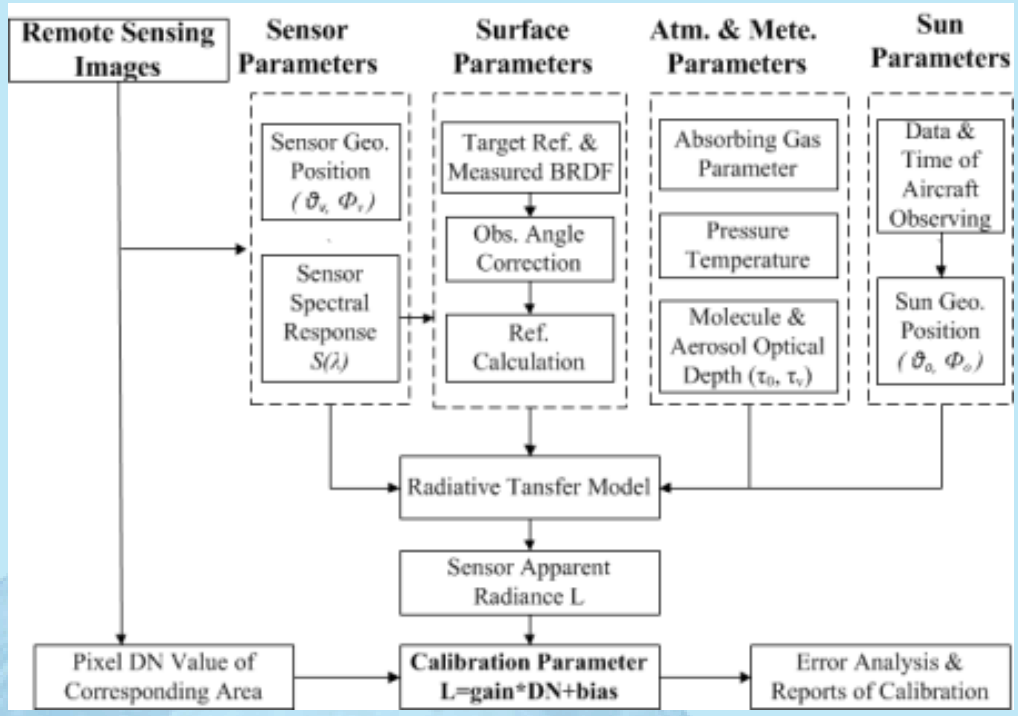
Automatic sun tracking photometer, CE318

Automatic weather station



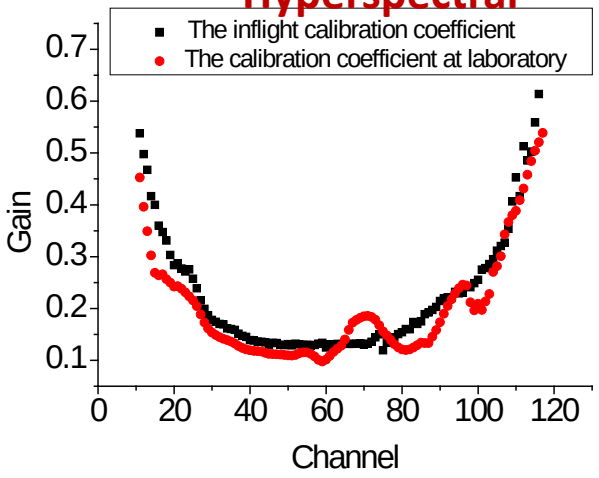
3. Inflight Calibration & Performance Assessment

- **Cal&Val of Optical sensors – Absolute radiometric calibration**

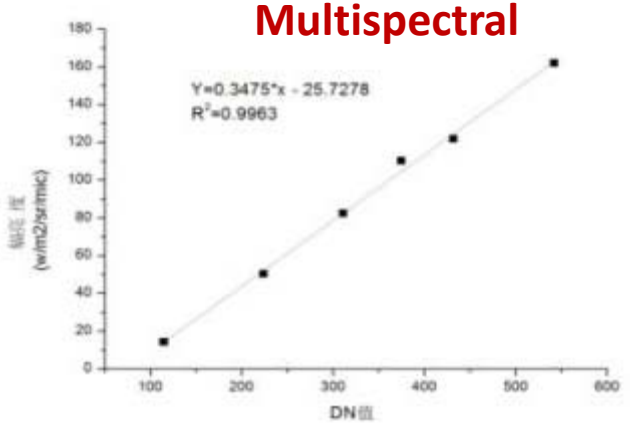


Flow chart of optical sensor radiometric calibration

Hyperspectral



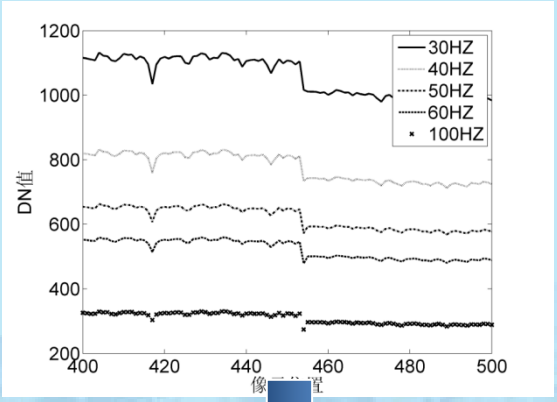
Multispectral

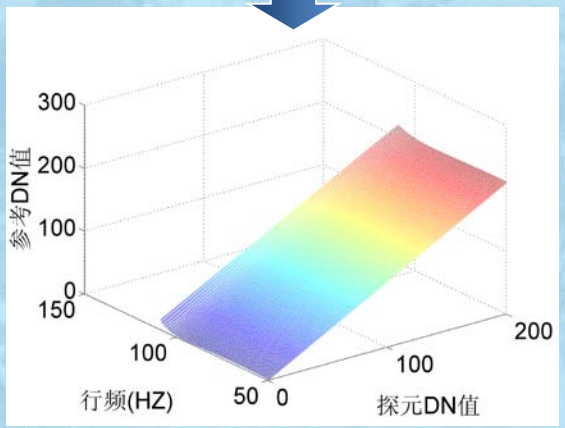


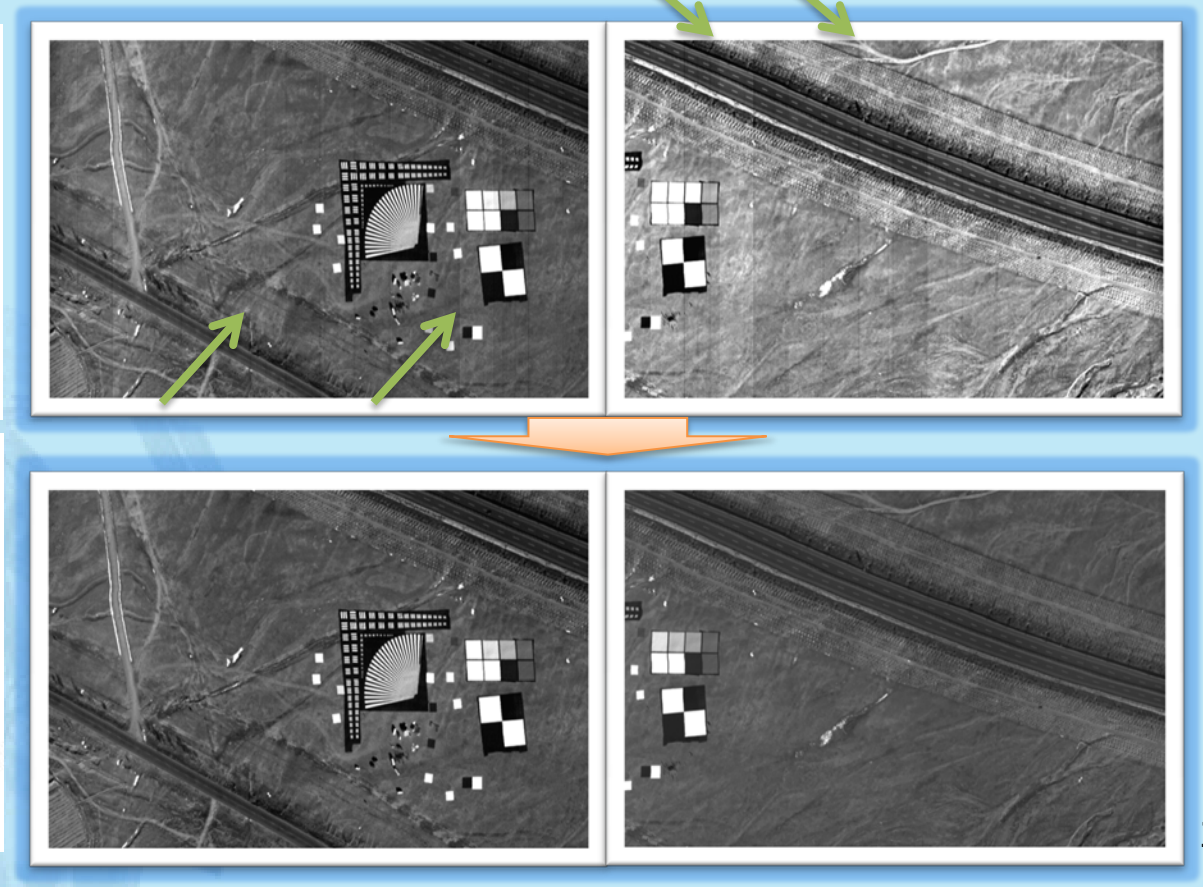
Radiometric calibration coefficients have very good linearity and the correlation coefficient reaches above 99%.

3. Inflight Calibration & Performance Assessment

- **Cal&Val of Optical sensors – Relative radiometric calibration**
  - **Because of the variation in velocity height ratio, the images of hyperspectral imager between adjacent flight strips lack of comparability for different surfaces.**
  - **A relative radiometric calibration method based on line frequency difference is proposed to solve this problem.**



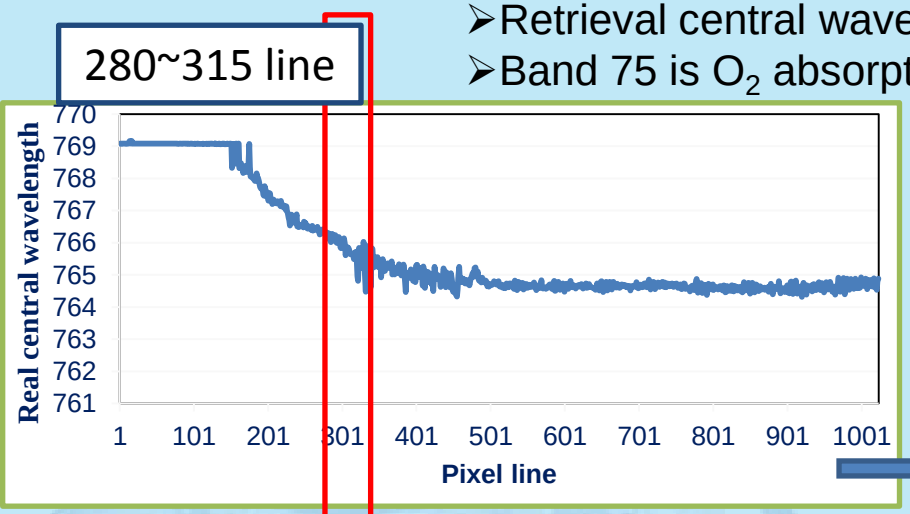


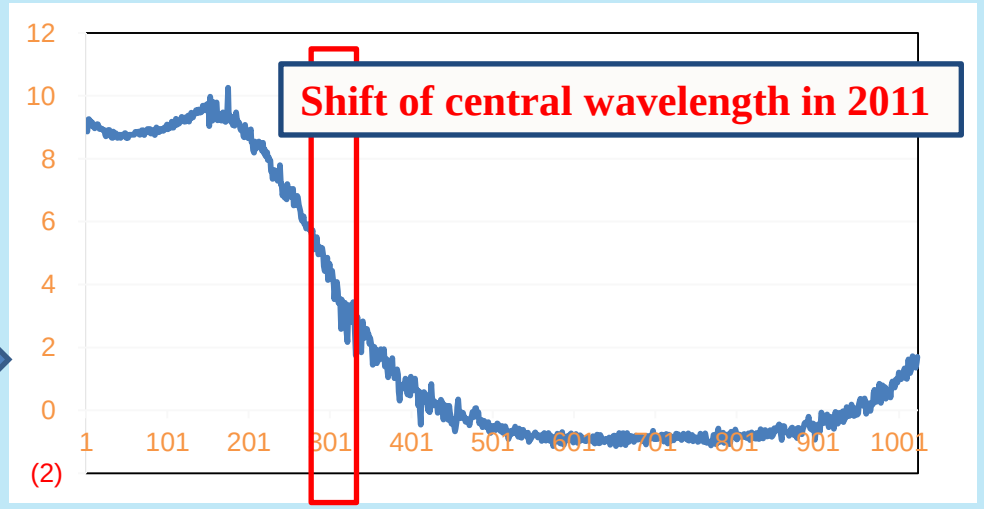


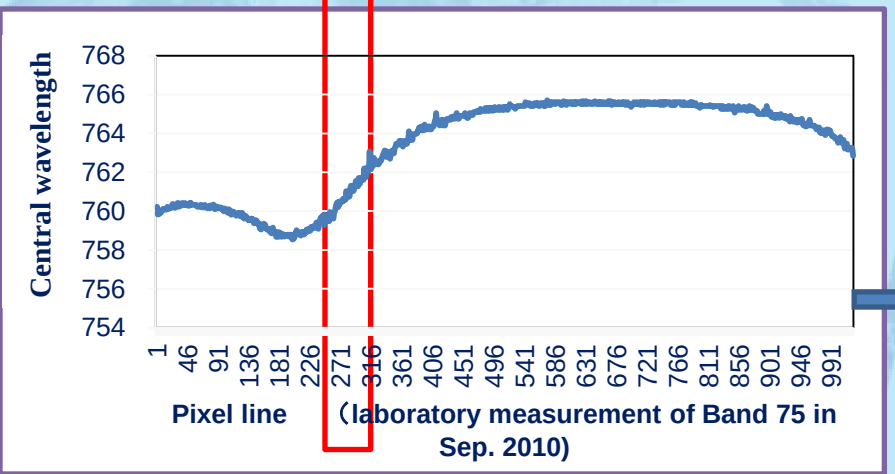
3. Inflight Calibration & Performance Assessment

- **Cal&Val of Optical sensors– Spectral calibration**
  - **Spectral calibration for hyperspectral sensor**

➢Retrieval central wavelength based on flight data in 2011.
➢Band 75 is O_2 absorption band.



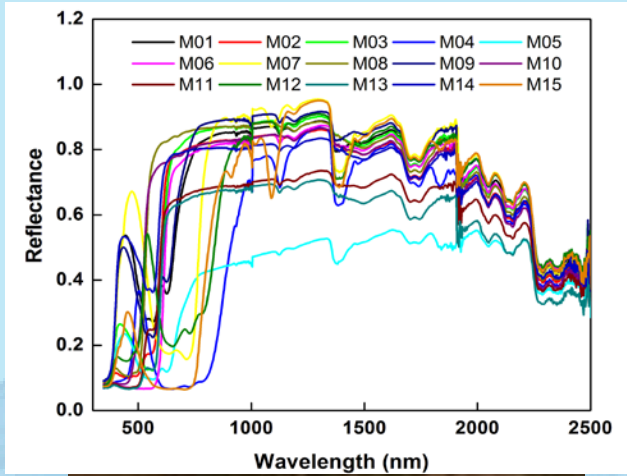


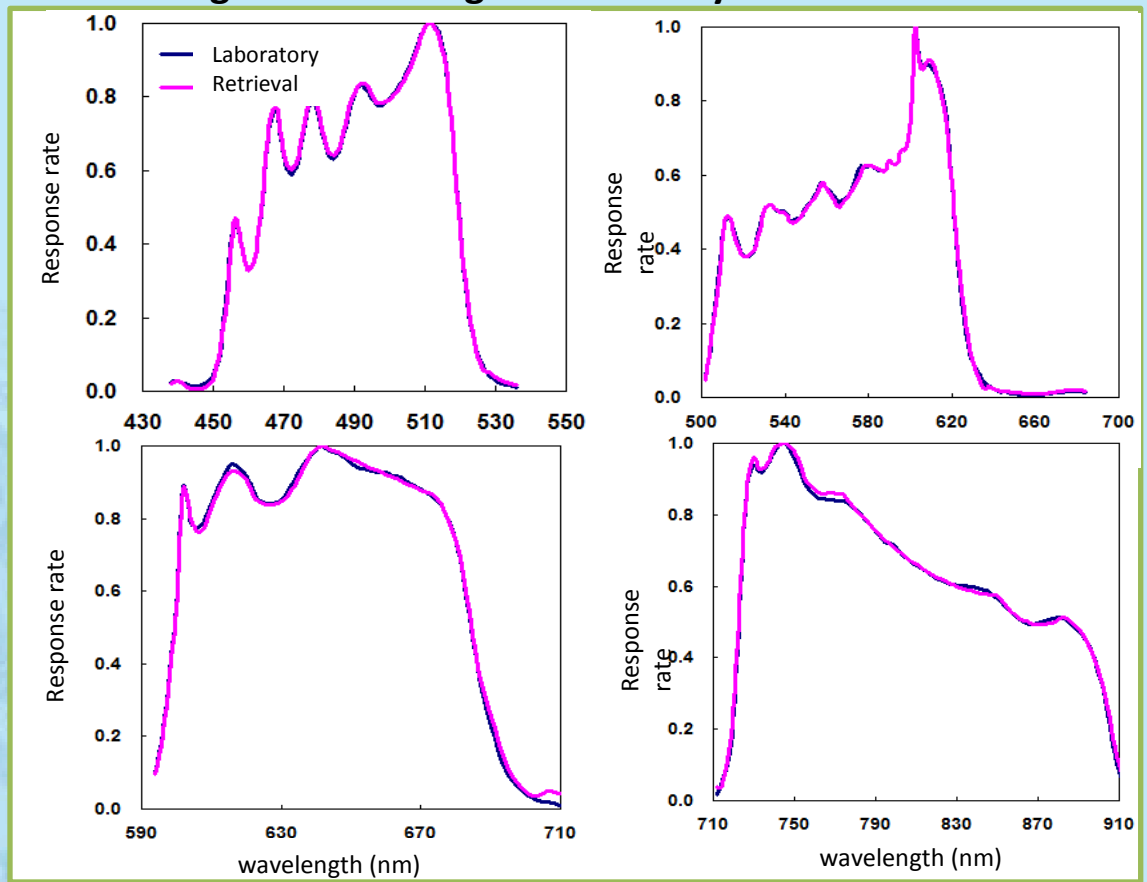


The shift of central wavelength is approximately 4~6nm compared to laboratory measurement.

3. Inflight Calibration & Performance Assessment

- **Cal&Val of Optical sensors– Spectral calibration**
  - **Spectral calibration for multispectral sensor**
    - **Difficulty: Solving of spectral response function faces ill-condition matrix**
    - **Solutions: The spectral reflectance of 15 multispectral targets were measured to add the number of equations; Piecewise fitting SRF according to laboratory measurements**



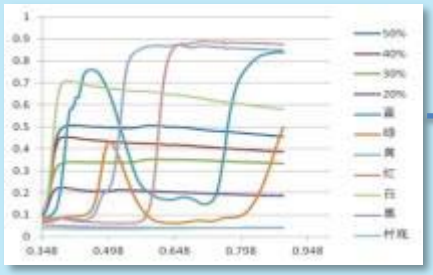


3. Inflight Calibration & Performance Assessment

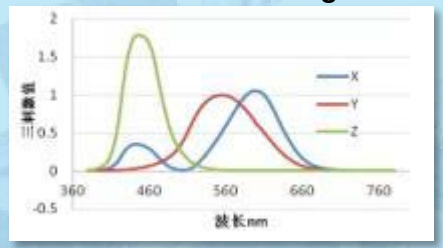
• Cal&Val of Optical sensors– True-color calibration

A general true color calibration model is proposed based on the physical mechanism of color generation, which can fully employed all spectral information in VNIR reflection zones of hyperspectral images.

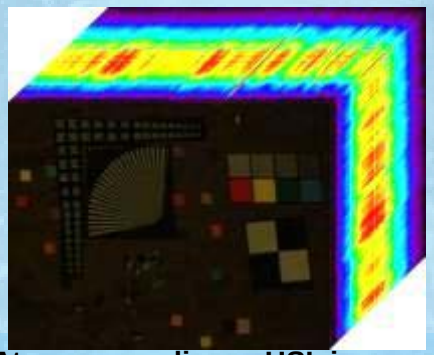
MODTRAN



In-situ measured spectral reflectance of the targets



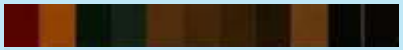
Human visual color matching function



At-sensor radiance HSI image

①

At-sensor ideal true color of the targets



②

Reconstructed true color of the targets & Images before true color correction

③

$$M_{RGB->R'G'B'} = \begin{bmatrix} 2.5635 & -0.3903 & -0.2178 \\ -0.1077 & 3.7997 & 0.5655 \\ 0.0416 & 0.2628 & 12.4262 \end{bmatrix}$$

True–color correction coefficient matrix

④

True–color correction

④

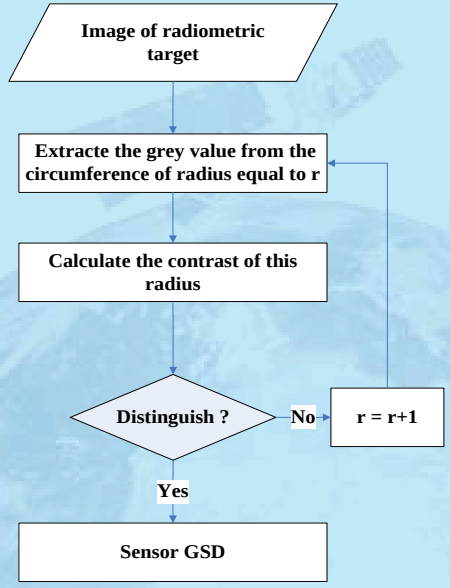
The corrected true-colored image

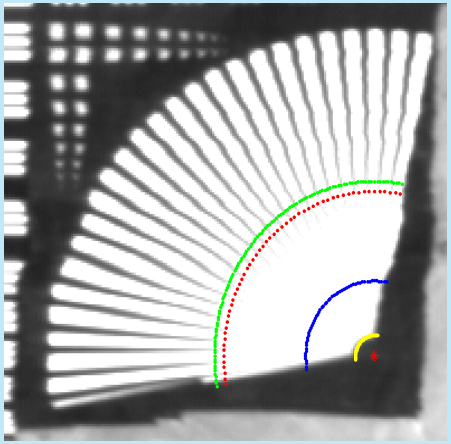
3. Inflight Calibration & Performance Assessment

- **Cal&Val of Optical sensors – Geometric performance**

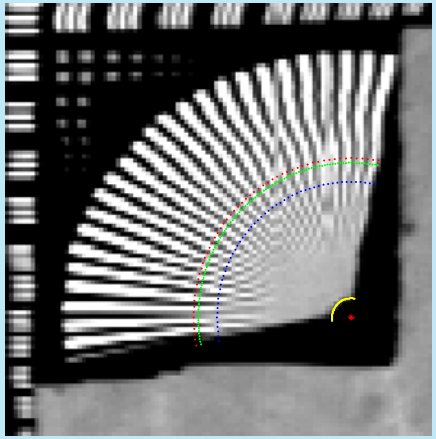
Ground resolution

Defined as the least ground distance or the least size of object that can be distinguished.





Panchromatic image in 2011



Hyperspectral image in 2011

- **Red line** denotes the location of ground resolution estimated by **our method**.
- **Blue line** denotes the location of **GSD**.
- **Green line** denotes the location of ground resolution estimated by **visual method**.

Camera		Calculated Resolution（m）	Visual resolution（m）	GSD（m）
Panchromatic		0.7941	0.8153	0.35
Multispectral	B1	0.8889	0.8178	0.70
	B2	0.7800	0.8083	0.70
	B3	0.8875	0.8428	0.70
	B4	0.7500	0.7750	0.70

3. Inflight Calibration & Performance Assessment

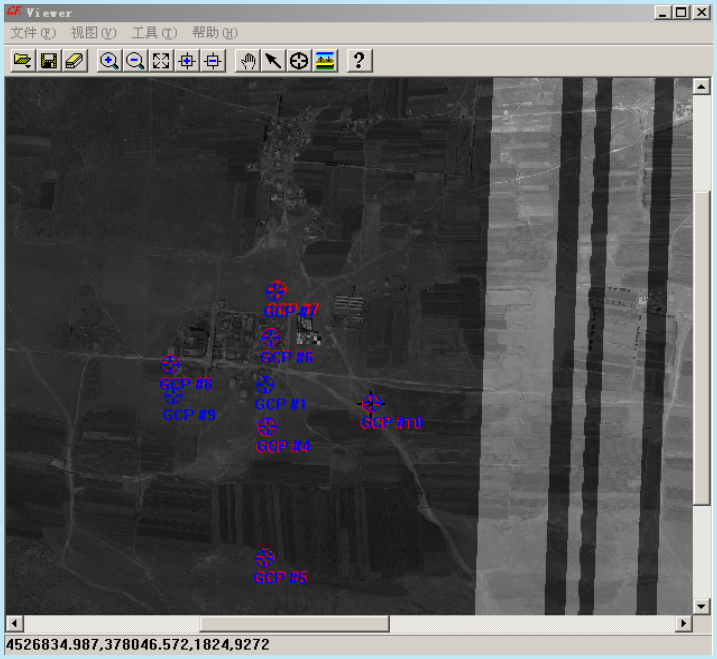
- **Cal&Val of Optical sensors – Geometric performance**

Geometric distortion

Geometric distortion evaluation result of panchromatic image in Sep. 2011 in Baotou city, China.

Data Type	External distortion Positioning error		Internal distortion	
	X-direction (m)	Y-direction (m)	Distance distortion (m)	Angle distortion (°)
Geometric coarse correction	22.106	155.295	14.859	167.16
Geometric precision correction	0.568	1.012	0.866	0.085

Geometric distortion evaluation module



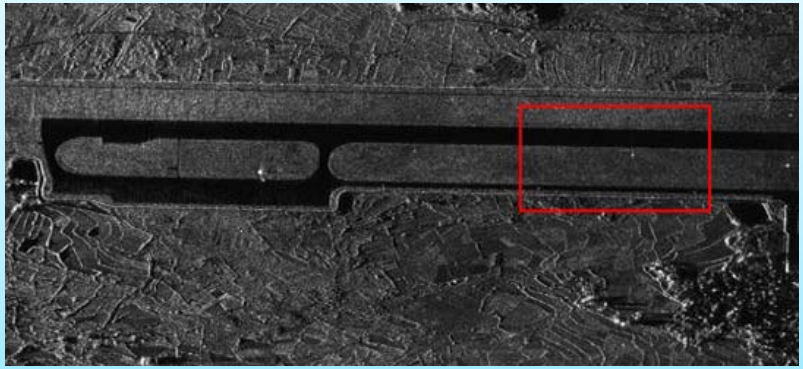
After geometric precision correction, the positioning accuracy can reach a meter-scale and the image distortion has also been corrected well.

3. Inflight Calibration & Performance Assessment

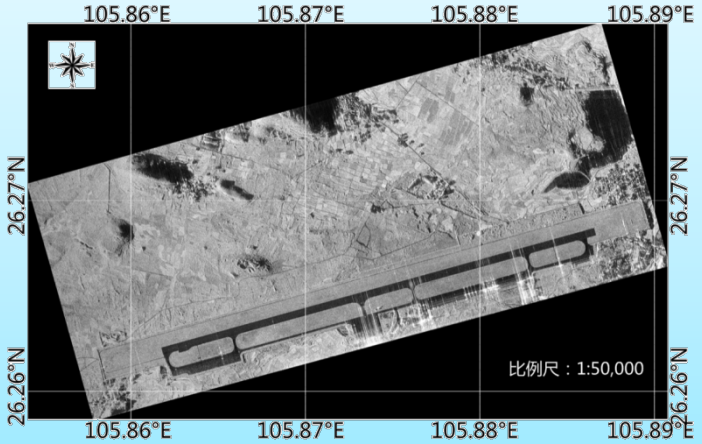
- **Cal&Val of SAR sensors – SAR data processing system**

Raw Data → Motion Compensation

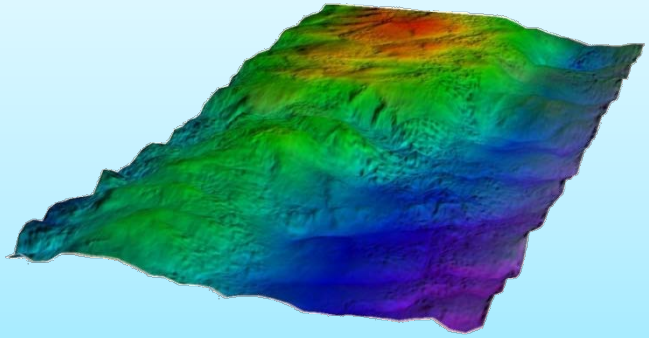
High resolution imaging processing



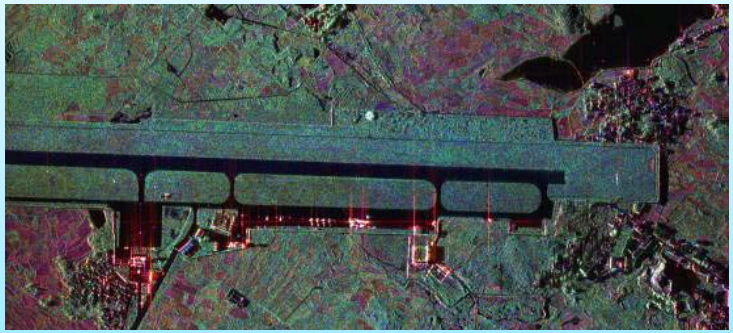
Radiometric and geometric processing



Interferometric Processing and DEM generation

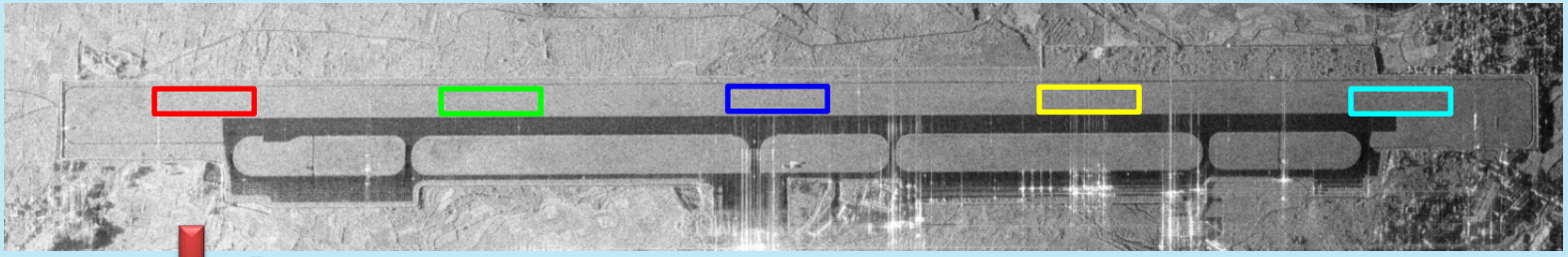


Polarimetric SAR data Processing and correction

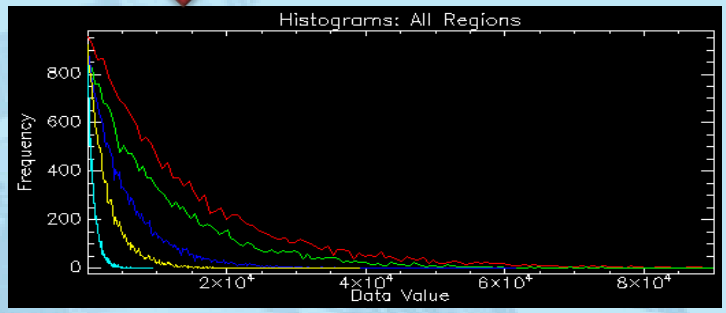


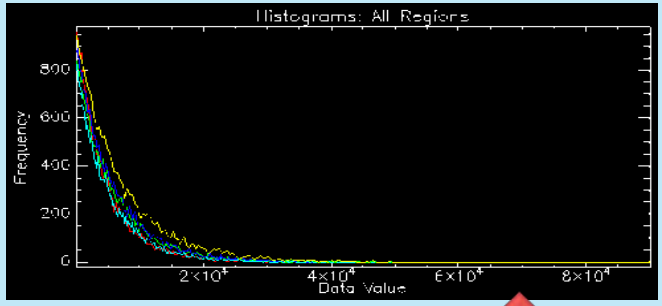
3. Inflight Calibration & Performance Assessment

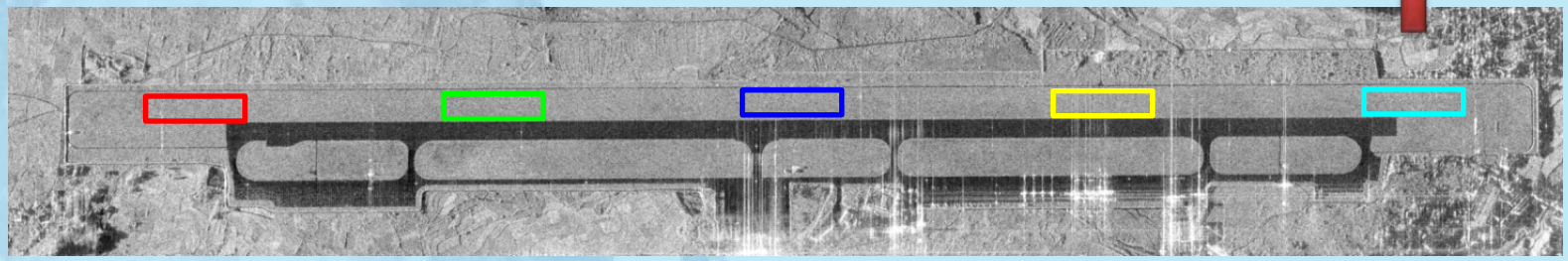
- **Cal&Val of SAR sensors – Relative radiometric calibration**



Before relative radiometric calibration





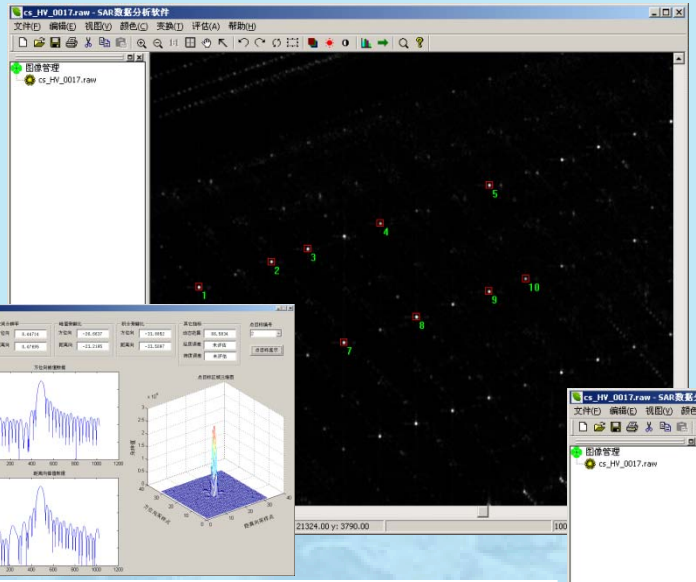


After relative radiometric calibration

3. Inflight Calibration & Performance Assessment

- **Cal&Val of SAR sensors – data analyzing system**

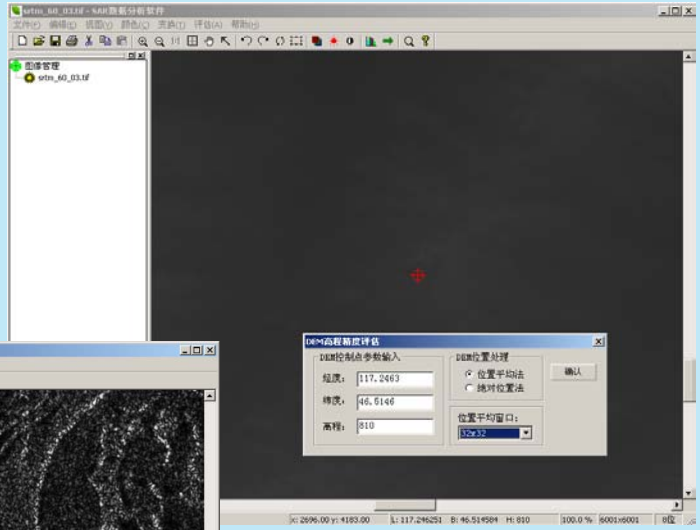
Point target analysis



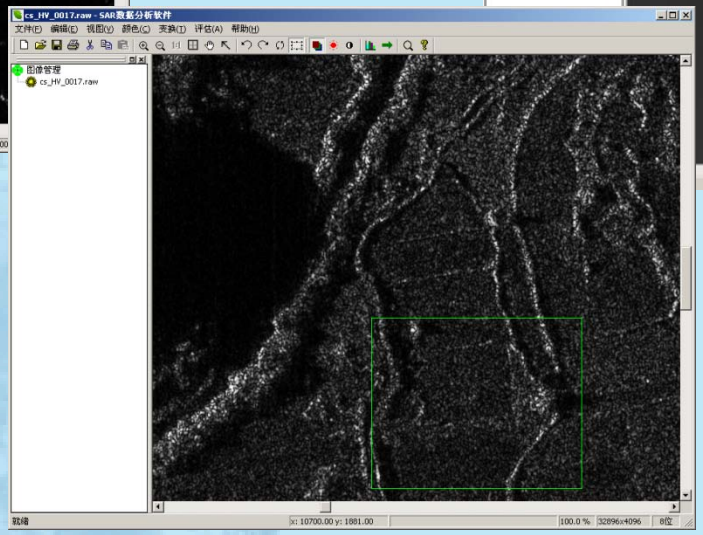
- Resolution
- PSLR(Peak Side Lobe Ratio)
- ISLR(Integrated Side Lobe Ratio)
- Dynamic range
- ….

No.	Az. Res.（m）	Rg. Res.（m）	Az. PSLR（dB）	Rg. PSLR（dB）	Az. ISLR（dB）	Rg. ISLR（dB）	Dy. Range（dB）
1	0.2997	0.2707	-29.9001	-24.3671	-30.5193	-25.5551	85.8664
2	0.2997	0.2804	-31.7376	-21.9761	-29.8146	-24.7290	85.2708
3	0.3045	0.2804	-29.2417	-22.0863	-29.5731	-25.9416	86.4129
4	0.2997	0.2852	-30.0977	-32.3270	-28.4382	-25.0391	82.5886
5	0.2997	0.2852	-31.9878	-21.1309	-29.6991	-19.2911	85.4210
6	0.3190	0.2852	-27.9996	-26.5897	-28.1798	-27.0331	77.4594
7	0.3094	0.2900	-30.4414	-23.3795	-29.8154	-26.2518	86.1319
8	0.2997	0.2755	-28.2101	-24.5004	-30.2793	-25.8863	87.7243
9	0.2997	0.2804	-28.7574	-26.5284	-29.1662	-27.6142	84.7408
10	0.3094	0.2852	-28.8182	-22.7427	-29.9757	-24.0932	81.8551

DEM analysis



- DEM accuracy

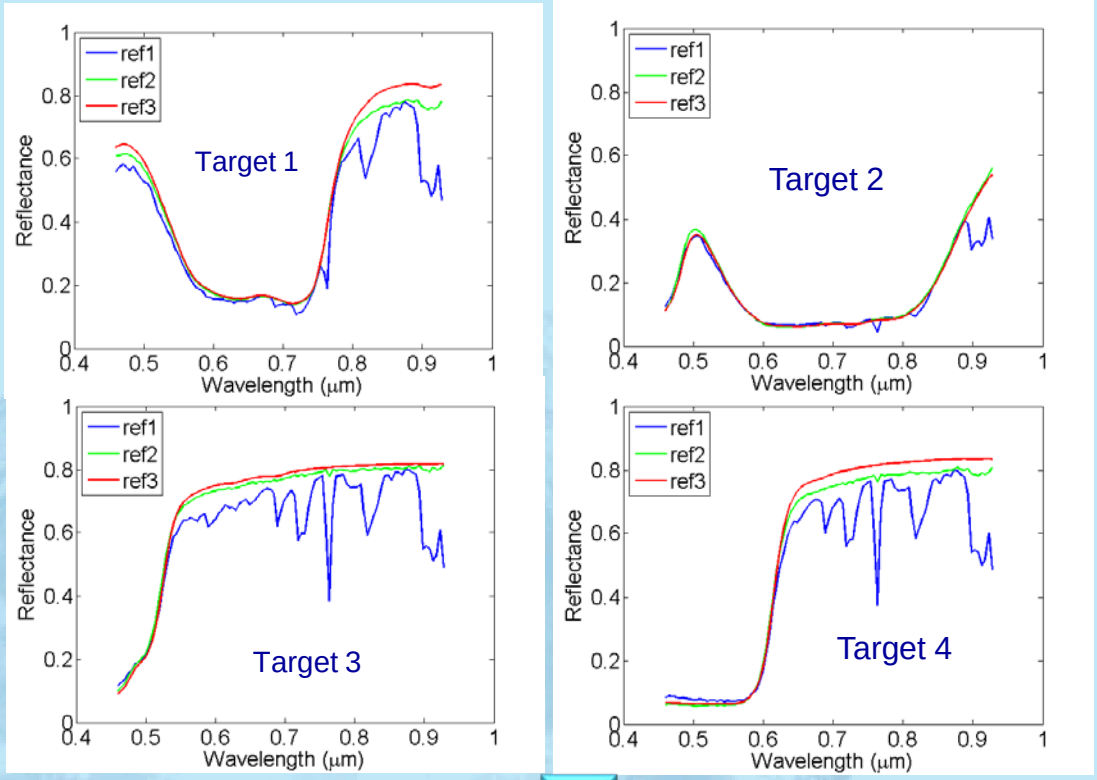


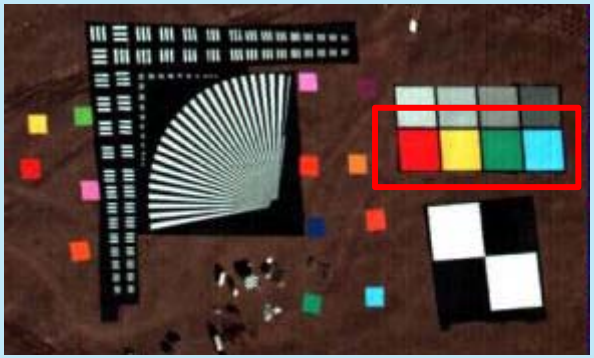
- ENL
- Radiometric resolution

Distributed target analysis

3. Inflight Calibration & Performance Assessment

- **Application performance – reflectance retrieval and validation**
  - **A Look Up Table (LUT) atmospheric correction model with adjacency effect correction was proposed to retrieve land surface reflectance.**





Colored targets in red frame

ref1: at-sensor reflectance without atmospheric correction

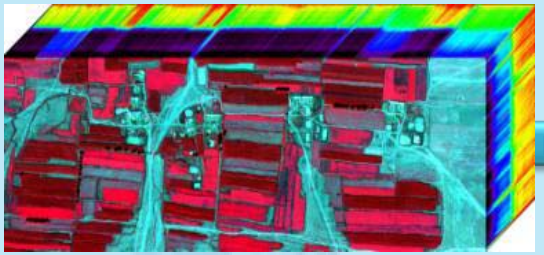
ref2: surface reflectance after atmospheric correction

ref3: field measured reflectance

It can be seen that the proposed method can eliminate the atmospheric effect well.

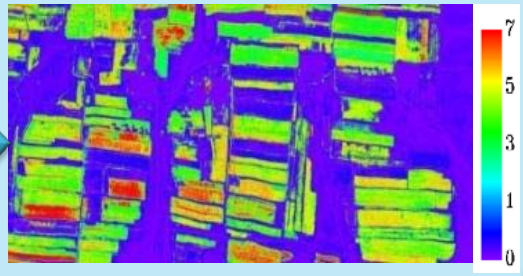
3. Inflight Calibration & Performance Assessment

- **Application performance – LAI retrieval and validation**
  - **Leaf Area Index (LAI) was retrieved from hyperspectral data according to the image classification.**



Airborne hyperspectral reflectance three-dimensional cube

Retrieve

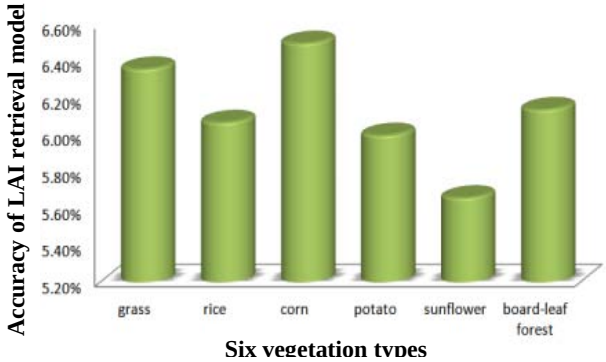


Result of LAI retrieved

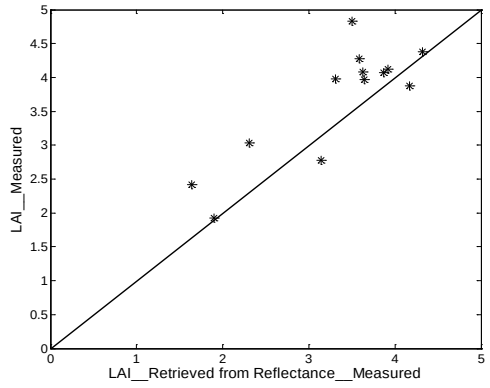
(1) Accuracy of LAI retrieval model is less than 7%.

(2) Validation results show that the retrieval error of LAI is approximately 21.7% with field measurement data.

(3) It might due to the retrieval error of reflectance, the saturation of NIR band with the increasing of LAI, the error of instruments.



Accuracy of LAI retrieval model for six vegetation types



Accuracy assessment using field measurements on Sep 3, 2011.

4. Future Plan

satellite

Airborne platform

Data process vehicle

Command vehicle

Dome C

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Baotou Comprehensive Cal&Val Site

Aircraft Hangar

Equipment store house

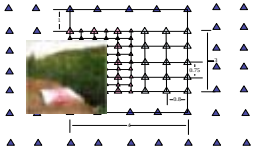
Tower

T&C vehicle

Real-time monitoring of flight status

Artificial target

Natural scene



Inflight and preflight geometric calibration


Thank you !