Baotou Comprehensive Cal & Val Site

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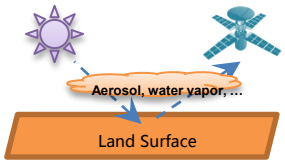
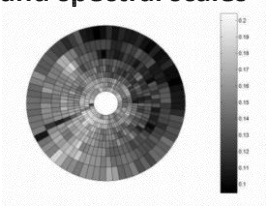
Technology challenges in Cal&Val for RS sensors

Calibration Accuracy

atmosphere

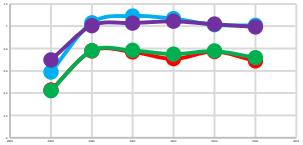


Mismatching in temporal, spatial, angular and spectral scales



Benchmark Consistence

Sensor degradation



Reliable ground targets

Product Quality Traceability

Comprehensive targets for various product quality assessment

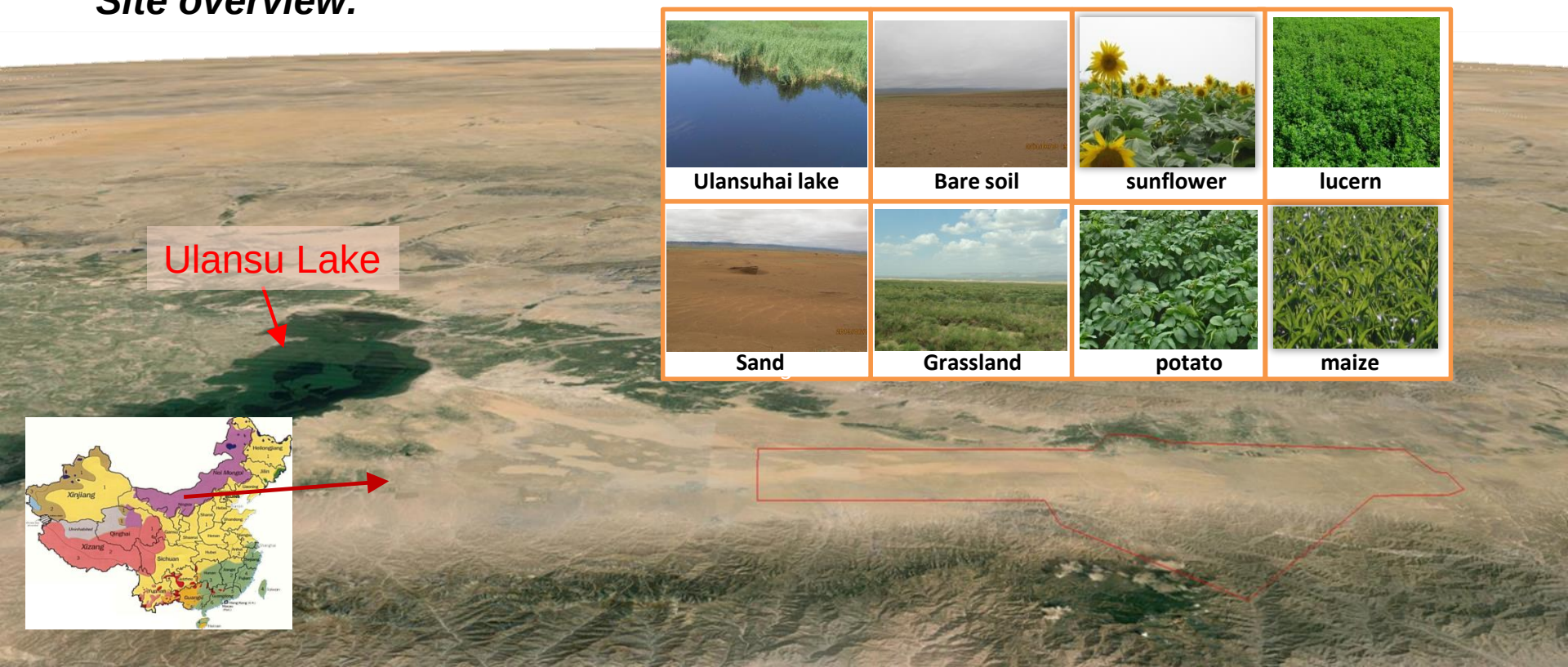
Baotou Cal&Val site

- High-stable ground standard targets
- High-accuracy stepwise Cal&Val system
- High-frequency automated radiometric calibration

Baotou comprehensive Cal&Val site

- Located in Inner Mongolia, China, 50km away from Baotou city.
- A flat area of approximately 300km^2, about 1270m above sea level.
- Land cover: Sand, bare soil, grass, lake, various agriculture(maize, sunflower, lucern, potato, etc.).
- Features a cold semi-arid climate.

Site overview:



Baotou comprehensive Cal&Val site

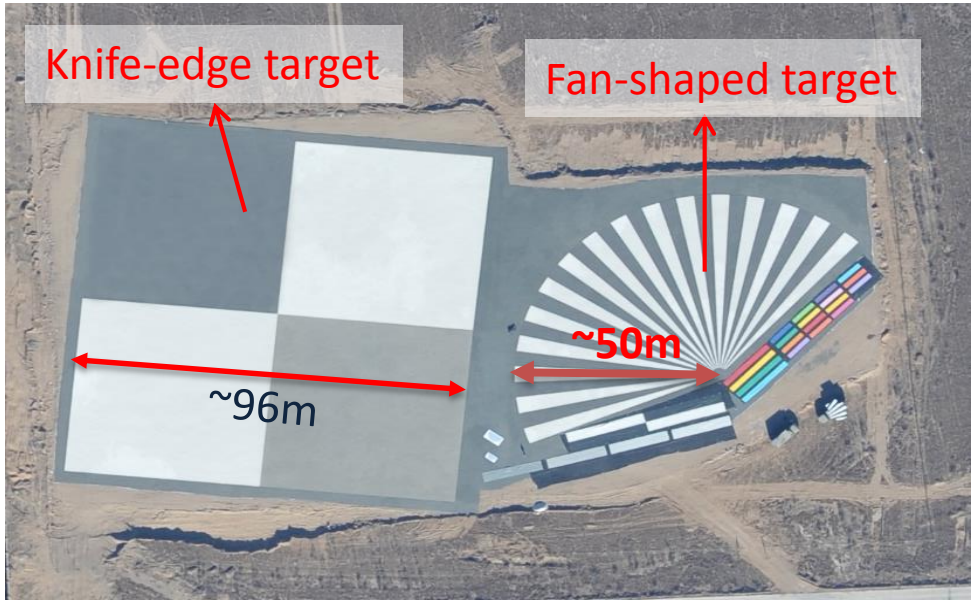
➢ 1. Ground standard targets

1.1 Artificial Permanent Targets

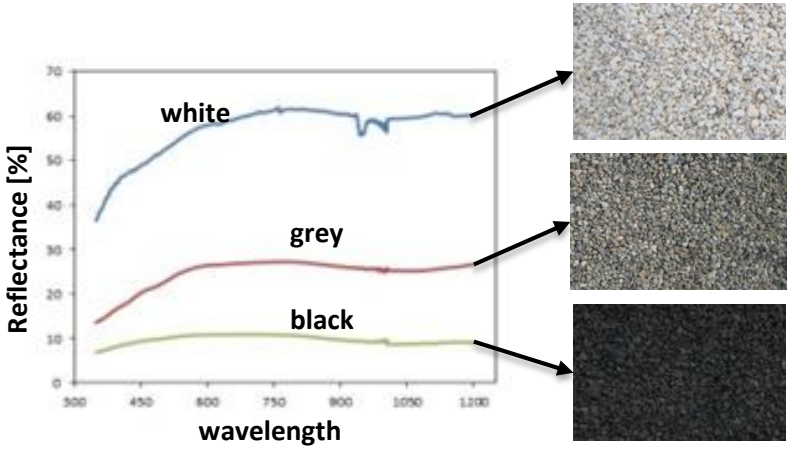
Optical edge and fan-shape target

Dedicated to radiometric calibration and spatial performance assessment:

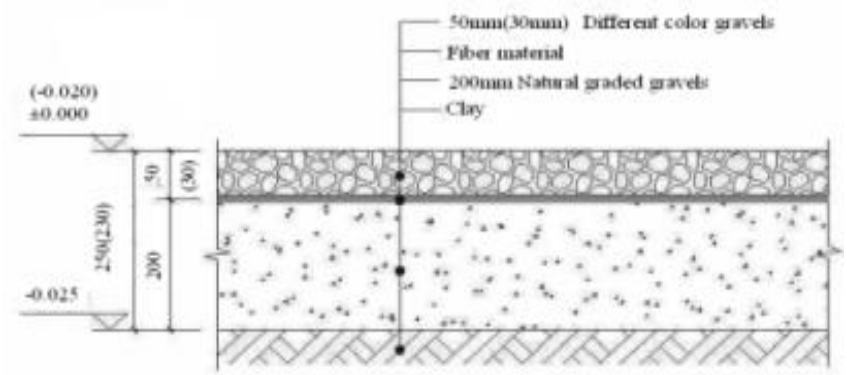
- **High-stable**: made of natural gravels
- **Wide-range**: three grey-scale
- **Well-uniform**: each block filled with the same gravels



Aerial image of the optical artificial permanent targets



Gravel (size<1.5cm)



Baotou comprehensive Cal&Val site

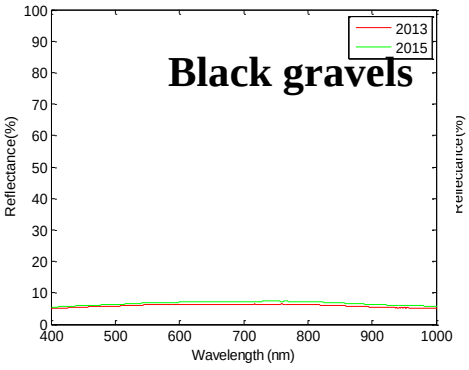
➢ 1. Ground standard targets

1.1 Artificial Permanent Targets

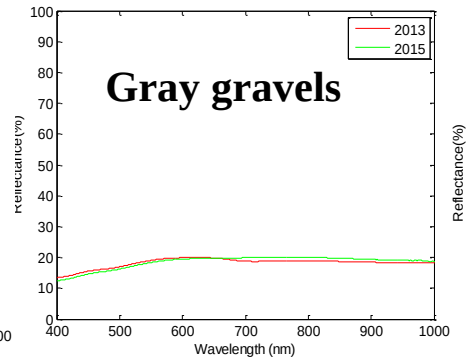
Optical edge and fan-shape target

The construction of these targets was finished at the end of October, 2013. Degradations of each target were evaluated by the measurements of cleaned gravels from 2013 to 2015.

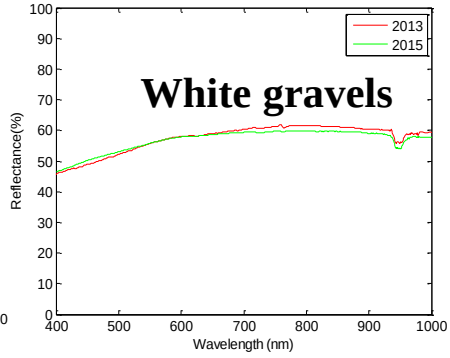
Reflectance measurement (SZA=60º)



Relative spectral reflectance difference: 6.9%/year.



Relative spectral reflectance difference: 0.22%/year.



Relative spectral reflectance difference: -2.5%/year

Baotou comprehensive Cal&Val site

➢ 1. Ground standard targets

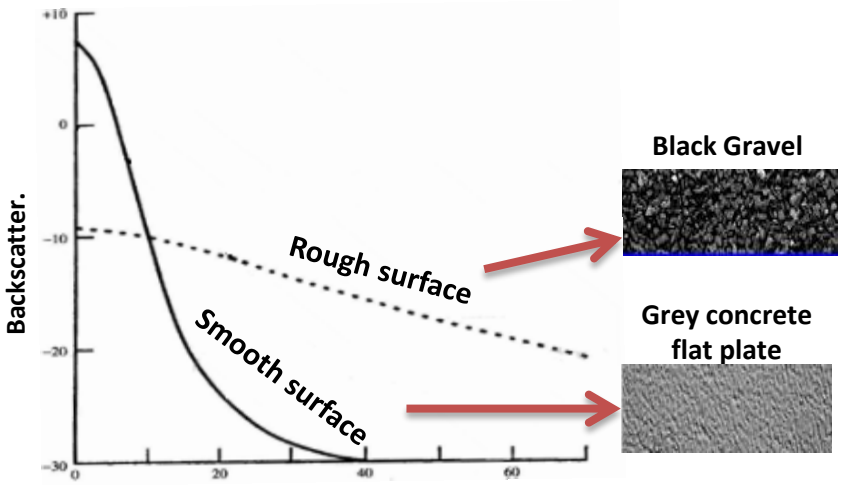
1.1 Artificial Permanent Targets

Microwave/optical bar-pattern target

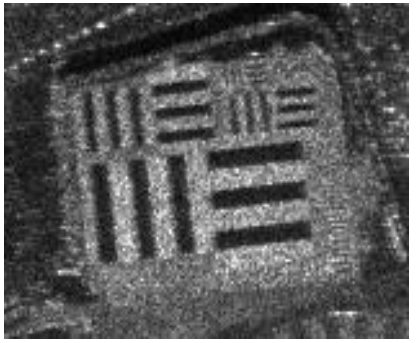
Black gravel and grey concrete flat plate with different roughness were exploited to construct the target for both microwave and optical image resolution assessment.

Finished construction by the end of September, 2014

Intensity contrast between bars and the background is realized by their roughness difference

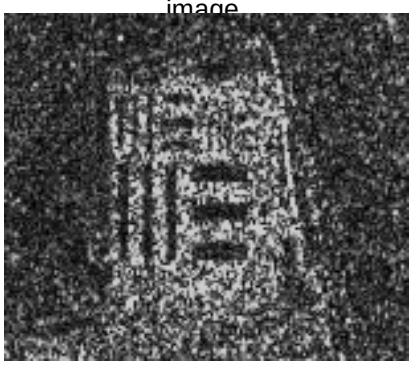


2014/10/13 GF-2 PAN image



2014/10/19 C-band airborne SAR image

2014/10/17 airborne SWIR image



2014/10/22 KOMPSAT-5 SAR image

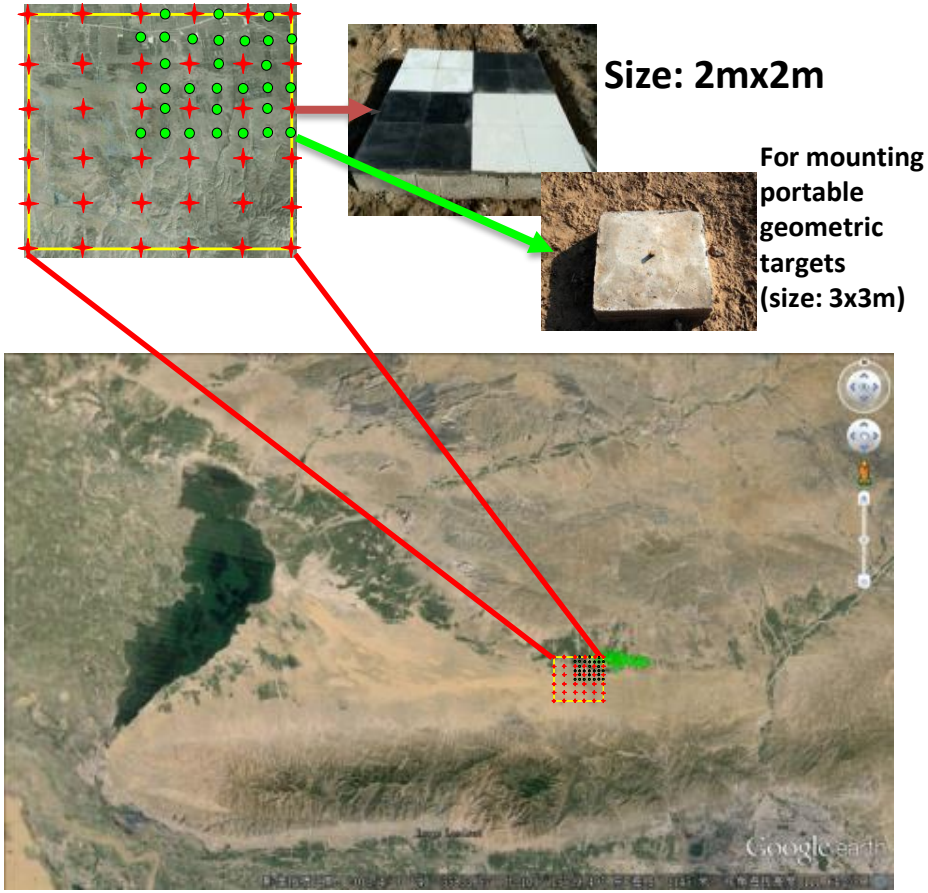
Baotou comprehensive Cal&Val site

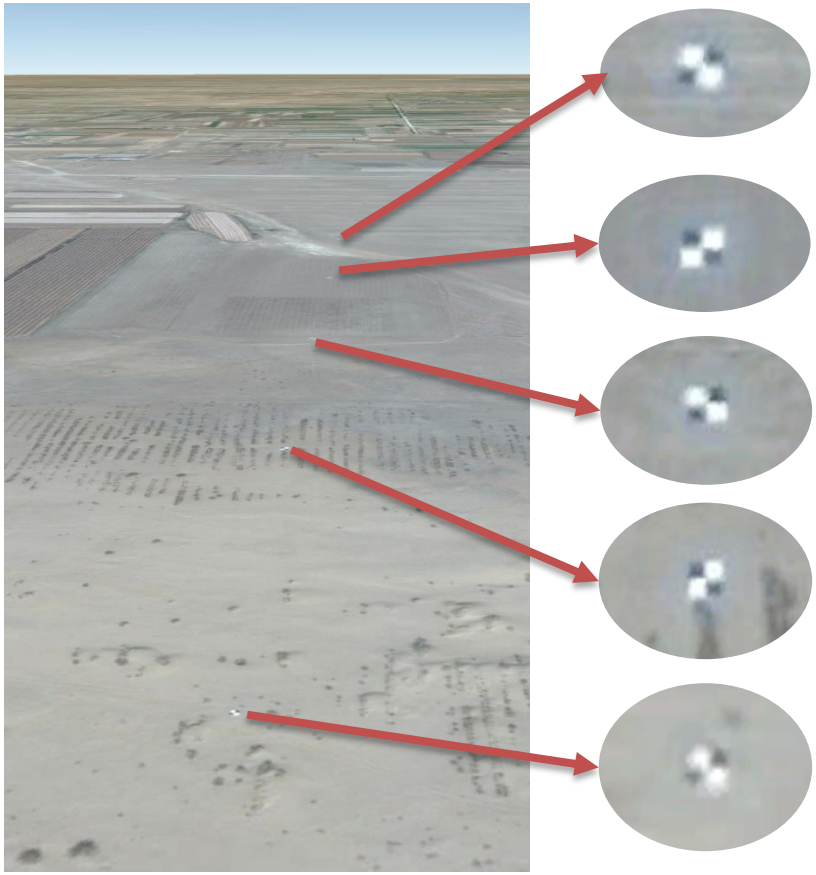
➢ 1. Ground standard targets

1.1 Artificial Permanent Targets

Geometric control points

75 geometric control points with positional accuracy of 2cm(horizontal), 4cm (vertical).





GCP Google Earth image(from Digital Global, 0.5m)

Baotou comprehensive Cal&Val site

➢ 1. Ground standard targets

1.1 Artificial Permanent Targets

SAR corner reflector base

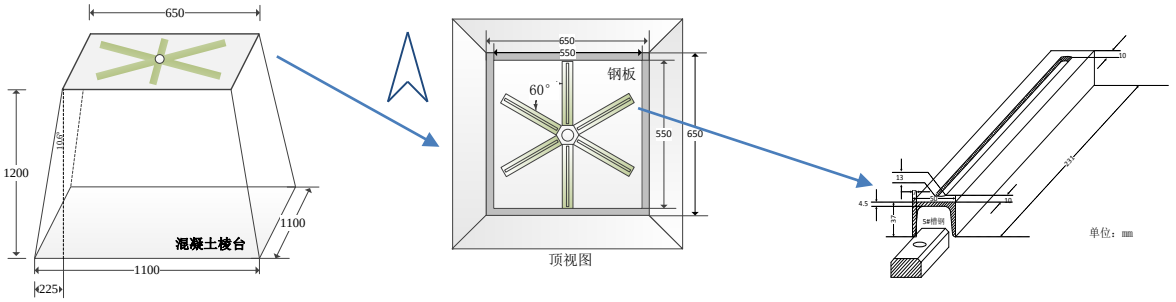
Distribution direction (east-west) is 95° to North, with compromise of transportation convenience and SAR flight direction:

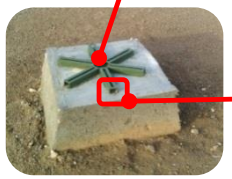
$$\beta = \arcsin\frac{\pm\cos\alpha}{\cos\xi} \approx 10^\circ$$

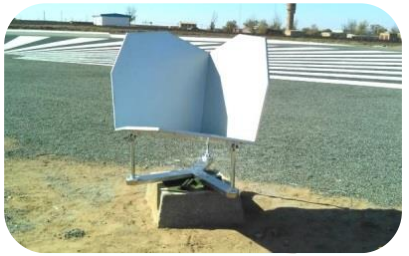
β : Azimuth
α : Latitude
ξ : Inclination

Satellite	Inclination
TerraSAR	97.44°
Radarsat-2	98.6°
Sentinel-1	98.18°
SkyMed	97.86°
HJ-1-C	97.37°

For quickly deploying corner reflectors and avoiding repeated measurement of position information







Baotou comprehensive Cal&Val site

➢ 1. Ground standard targets

1.2 Artificial Portable Targets

Optical

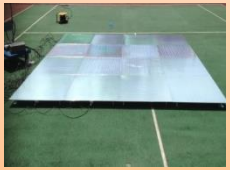
Knife-edge

Color targets

Fan-shaped

Array of point source targets

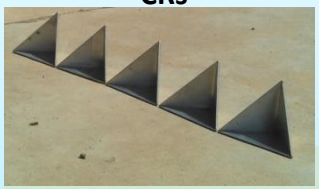
Grayscale



Low-emissivity Target(4mx4m)

SAR

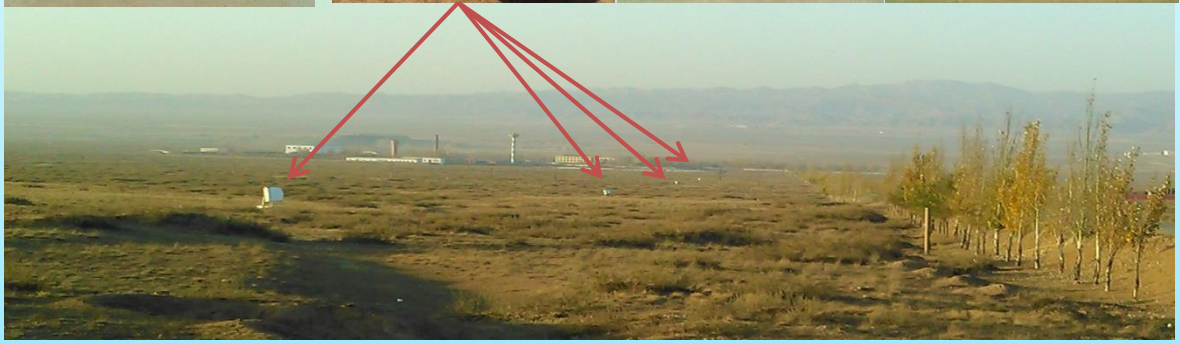
Triangular Trihedral CRs



Hexagonal Trihedral CRs

Dihedral Trihedral CRs

Bottom-extended Trihedral CRs



Square Trihedral CRs

➢ 1. Ground standard targets

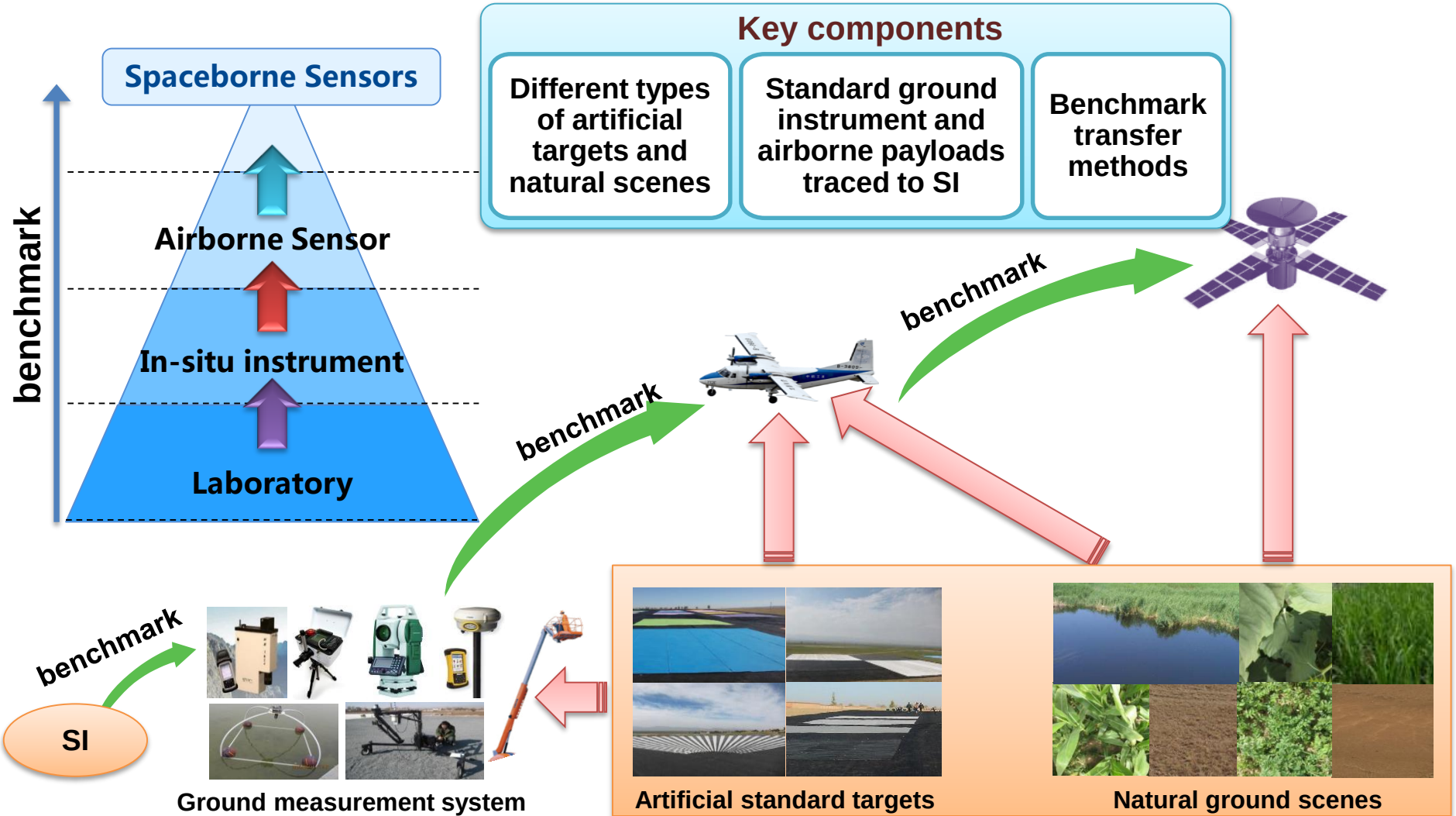
1.3 Natural Targets

For the cal/val of medium-resolution spaceborne sensors, large-size natural targets were built inside the Baotou site, including sand field (300m×300m), maize field (300m×300m), sunflower field (300m×300m).

Baotou comprehensive Cal&Val site

➢ 2. High-accuracy Stepwise Cal&Val system

The system aims to develop a chain that transfers the benchmark from laboratory to spaceborne sensors.

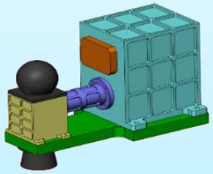


Baotou comprehensive Cal&Val site

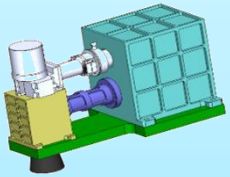
➢ 2. High-accuracy Stepwise Cal&Val system

In order to obtain the "truth" of ground scenes and targets, the Stepwise Cal&Val system are integrated and some standard payloads are still under-development.

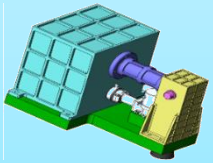
Ground hyperspectral imager



VNIR
400-1050nm
650 channels



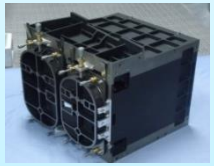
SWIR
1000-2500nm
300 channels



LWIR
8-12.5μm
150 channels

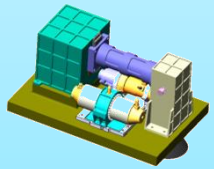
- **Cover the same spectral range**
- **Have more channels and higher resolution for ground imagers**
- **All have the self-calibration units**
- **Carry out the lab calibration traced to SI**

Airborne hyperspectral imager



VNIR
400-1050nm
300 channels

SWIR
1000-2500nm
170 channels



LWIR
8-12.5μm
75 channels

Total station and GPS

VIS-IR Field Spectrometers

LAI-2200C plant canopy analyzer

Overhead working platform

Photoelectric stabilized platform

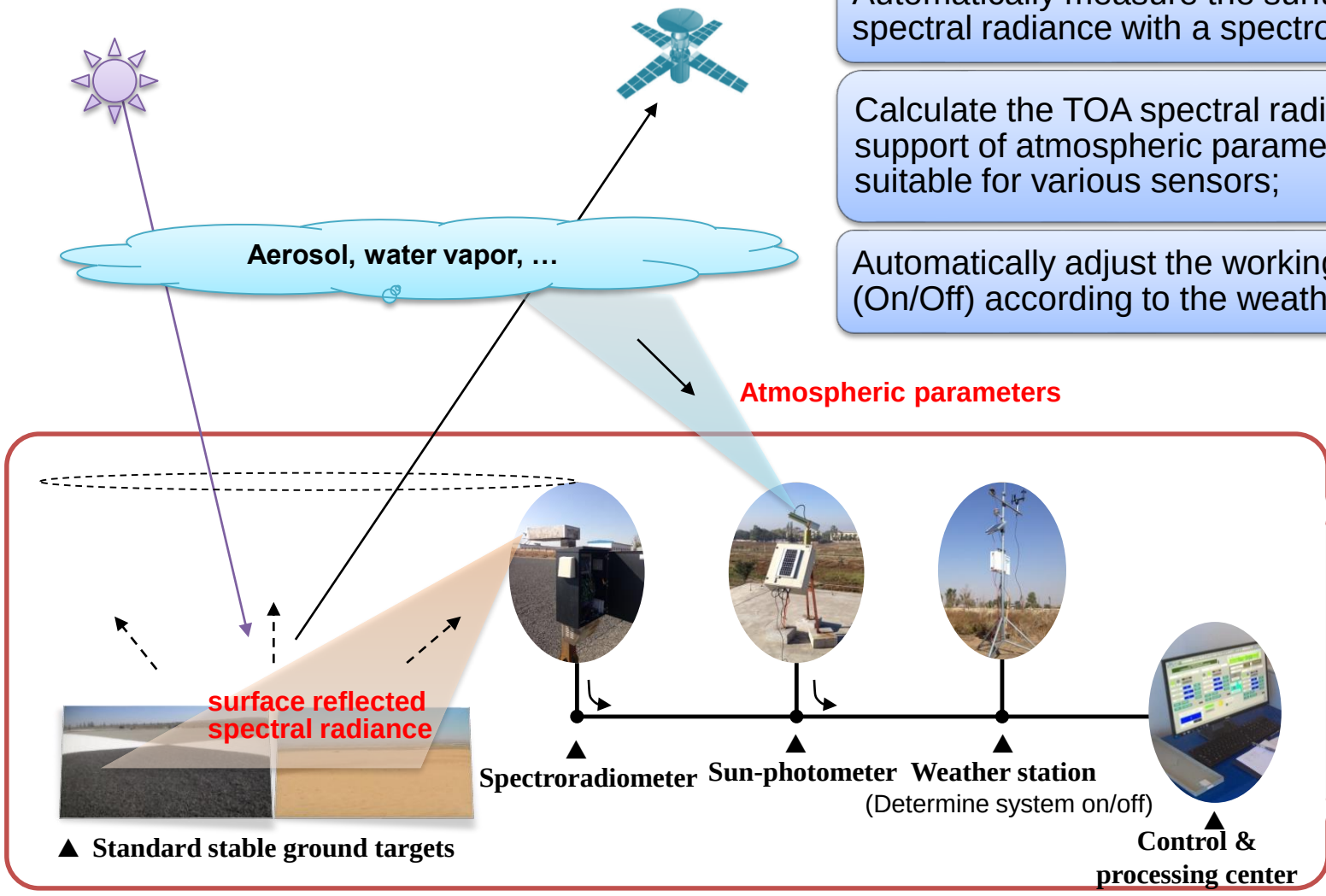
➢ 3. High-frequency automated radiometric calibration

Automated reflectance spectrum measurement system

Automatically measure the surface reflected spectral radiance with a spectroradiometer;

Calculate the TOA spectral radiance with the support of atmospheric parameters to be suitable for various sensors;

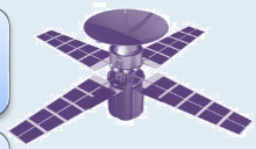
Automatically adjust the working status (On/Off) according to the weather condition.



Cal&Val Capability of the Baotou site

Automated radiometric calibration

- High resolution optical sensor
- Moderate resolution optical sensor
- High-resolution SAR



Performance assessment of spaceborne RS payloads

- Monitor the surface and atmosphere to infer the TOA spectral radiance
- As the key function contributed to RadCalNet

Baotou site

Capability

RS sensor testing based on aerial platform

- Panchromatic sensor
- Multi-/hyperspectral sensor
- Mid-infrared sensor
- Thermal-infrared sensor
- Synthetic aperture radar

Calibration

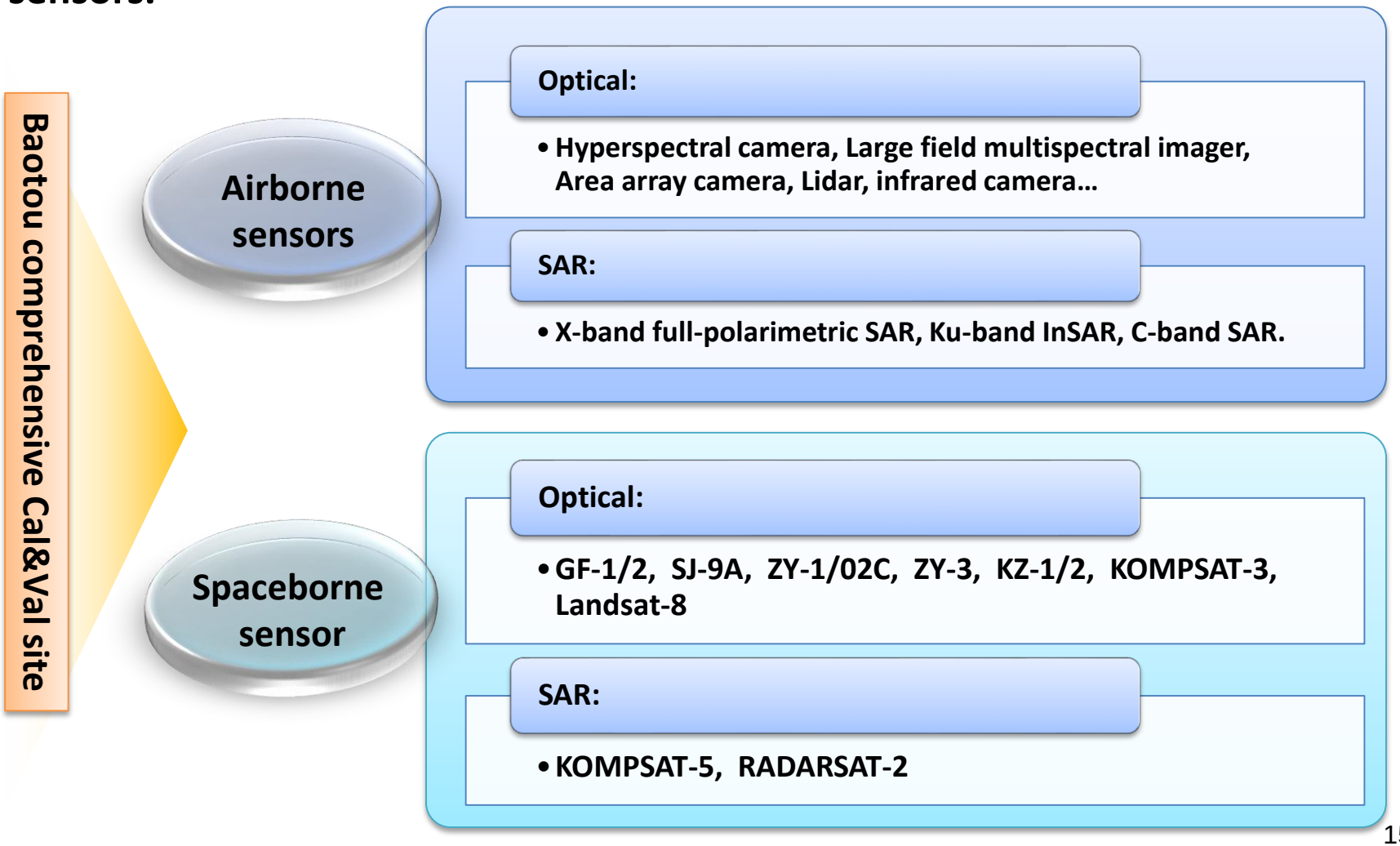
Performance assessment

Remote sensing product validation

- Surface basic characteristic product
- Surface ecology product
- Atmospheric and environmental characteristic product

Results of Cal&Val Campaigns

During 2009 to 2015, multiple scientific flight campaigns were carried out in Baotou site, including more than 11 airborne sensors and 12 spaceborne sensors.

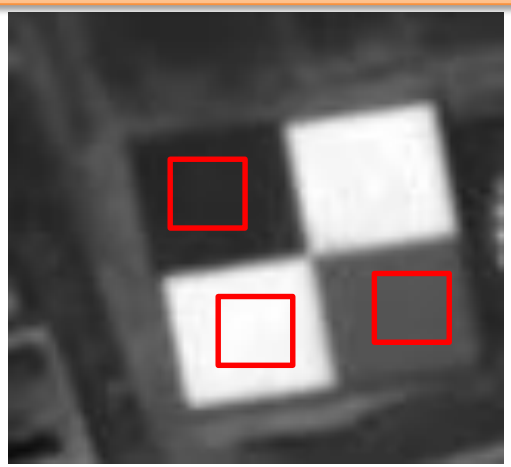


Results of Cal&Val Campaigns

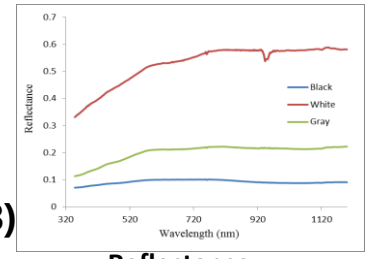
➢ Case1. Radiometric calibration in simultaneous mode

Baotou site has been greatly improved in a wide dynamic, stable, uniform ground standard targets for calibration. In addition, the sun photometer in this site joined the AERONET, providing quality-assured atmospheric data. Since WGCV-39 meeting, Baotou site has supported the in-orbit calibration of 8 Chinese high resolution satellite.

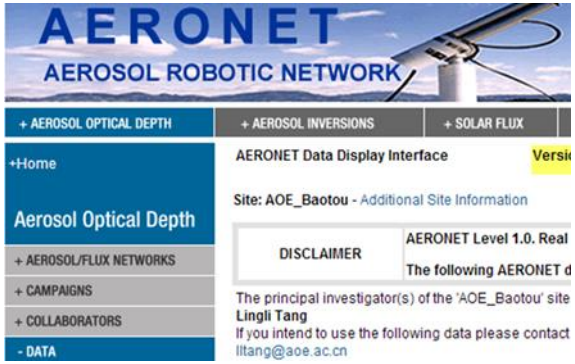
Case for the vicarious calibration of GF-1

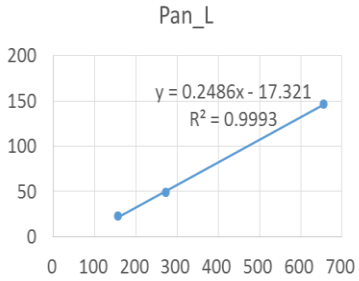


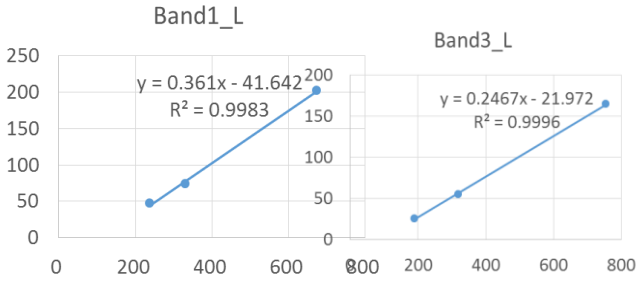
GF-1 image over Baotou site(2014-10-13)

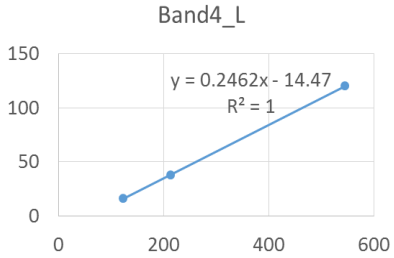


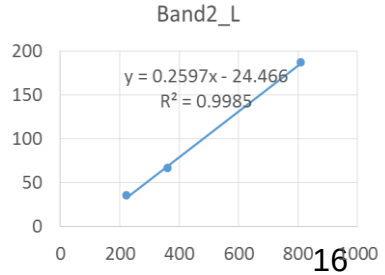
Reflectance











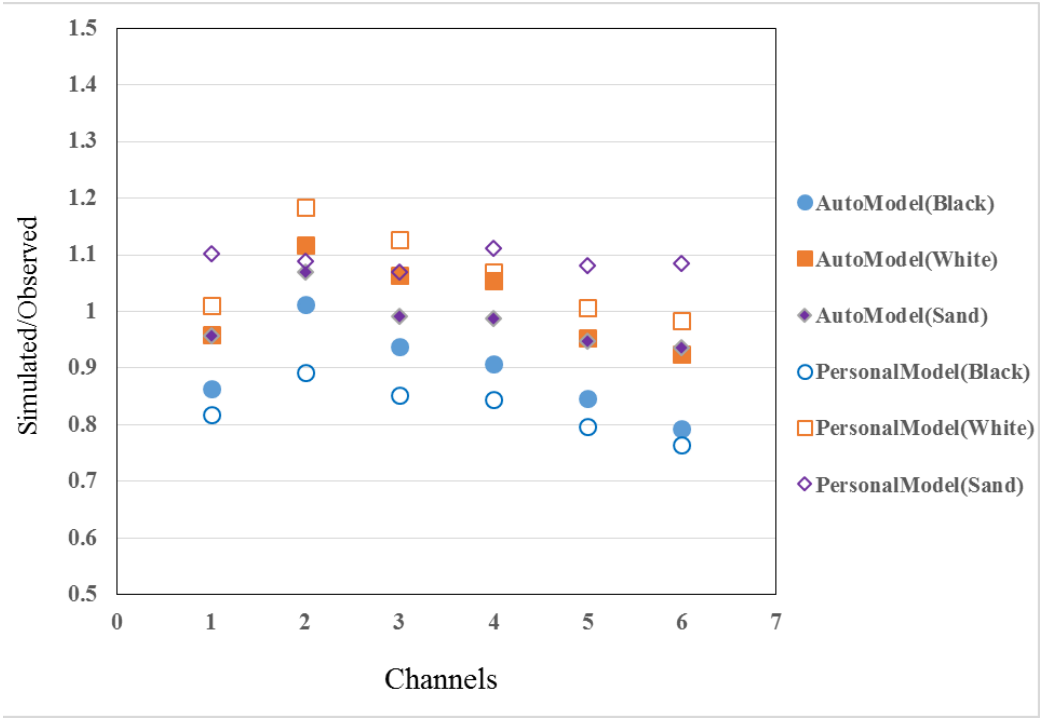
Results of Cal&Val Campaigns

➢ Case2. Radiometric calibration in automated mode

Case study: Simulation of TOA radiance for WorldView-3

WorldView-3 （RGB）

Date	2015-10-27
Time	03:41:48 UTC
SAA（°）	166.7
SZA(°)	54.3
VAA（°）	103.9
VZA(°)	12.3
AOD	0.0809
CWV(g/cm^2)	0.732

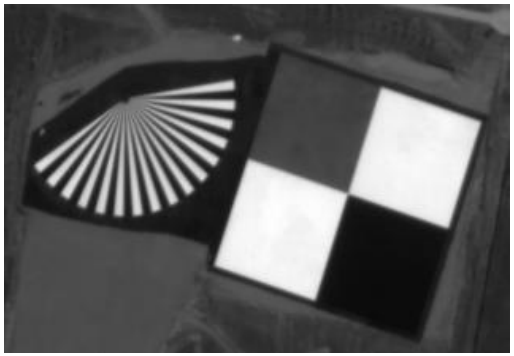


Radiometric calibration performances have been compared using WorldView-3 data. The results show a good consistence between simulated and observed values. It can also be concluded from the results that simulated values using auto mode are better than simultaneous mode due to the synchronous measurement error.

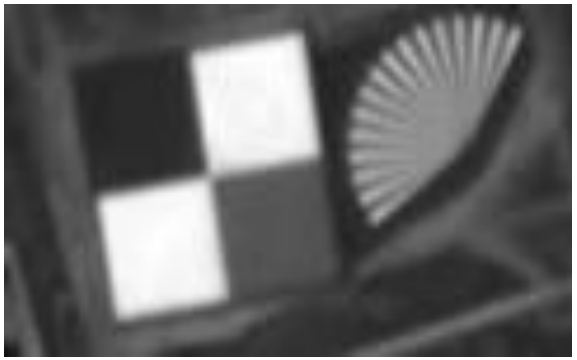
Results of Cal&Val Campaigns

➢ Case 3. Performance assessment for high-resolution optical sensors

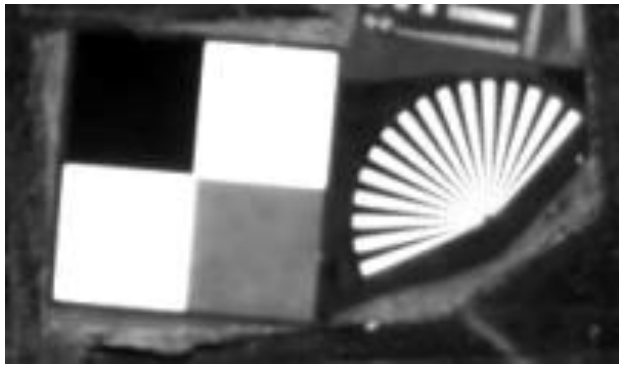
- **MTF**



KOMPSAT-3 panchromatic image



GF-1 panchromatic image
View zenith angle: 1.7°



GF-2 panchromatic image
View zenith angle: 8.86°

KOMPSAT (2014/8/14)	AOE's results	KARI's results
Along track	0.083	0.091
Cross track	0.105	0.106

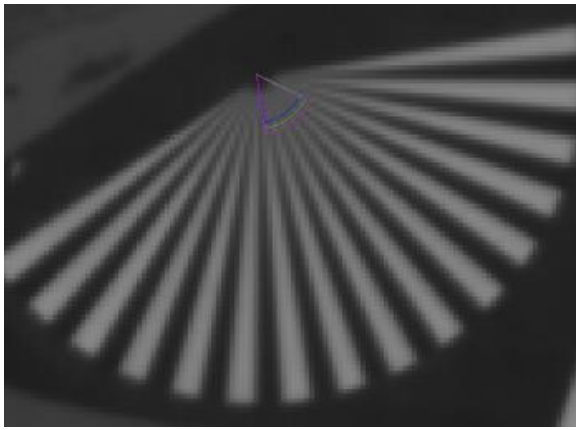
	GF-1 (2013/11/4)	GF-2 (2014/ 10/13)
Along track	0.0217	0.0722
Cross track	0.0467	0.0933

An improved "knife-edge" method was used, which has three aspects of improvements on the ISO 12233 method :

- **The use of the Fermi function for edge detection.**
- **Filter the ESF curves using S-G filter for noise suppression.**
- **Process LSF curve with Hamming window for avoiding spectral leakage and making more LSF central symmetry.**

➢ Case 3. Performance assessment for high-resolution optical sensors

- **Spatial resolution**



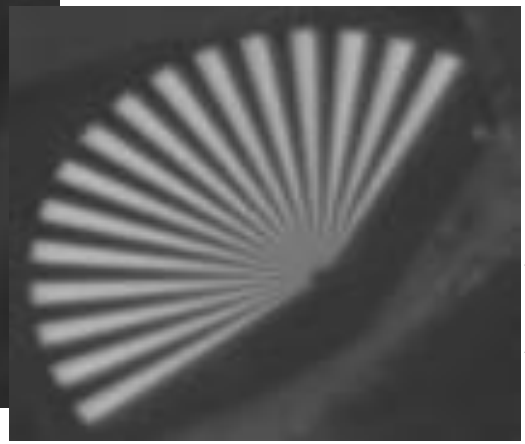
KOMPSAT-3 panchromatic image
on August 14, 2014

Automated detection algorithm for calculating resolution:

- Take the maximum radius of the target as a reference radius r_2.
- Select an area containing 5 white segments .
- Detect the number of white segment for a certain radius $r < r_2$ when DN differences between white and black segment<5, and the limited radius r_0 is acquire when number of white segment <4.
- Calculated resolution= $r_0 * \varphi$ (where φ is the angle of each segment).

	KOMPSAT-3(2014/8/14)
GSD	0.7m
Calculated resolution	0.79m
Visual resolution	0.73m

GF-1 panchromatic image
View zenith angle: 1.7°

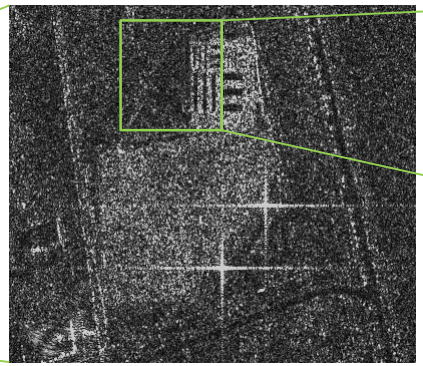


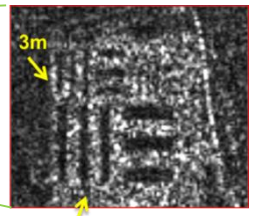
GF-2 panchromatic image
View zenith angle: 8.86°

	GF-1 (2013/11/4)	GF-2 (2014/10/13)
GSD	2m	1m
Calculated resolution	2.16 m	1.13m
Visual resolution	2.22m	1.05m

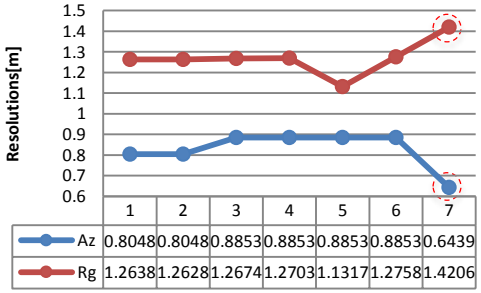
➢ Case 4. Image quality assessment for KOMPSAT-5 SAR

KOMPSAT-5 SAR image on October 22, 2014(HH)





The “image resolution” is better than 3m.

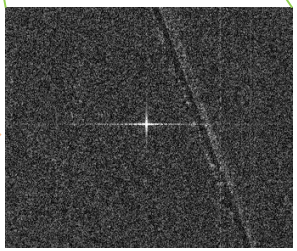


Nominal resolution:

- Ground range instrument geometric resolution:1.21m
- Azimuth instrument geometric resolution: 0.90m

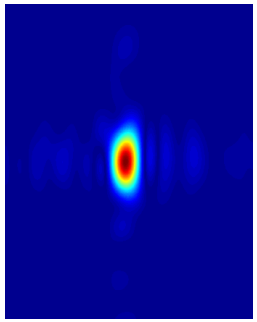
The resolution assessment results of the seven CRs are consist with each other except CR#7. The image of CR#7 is not a ideal point response image.

Corner reflector

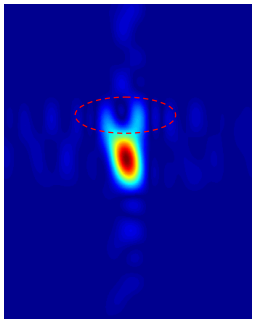


SAR image

CR #1



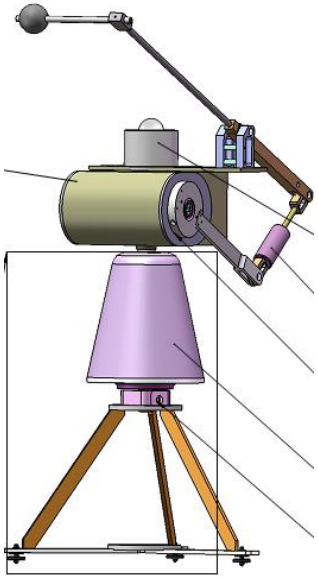
CR #7

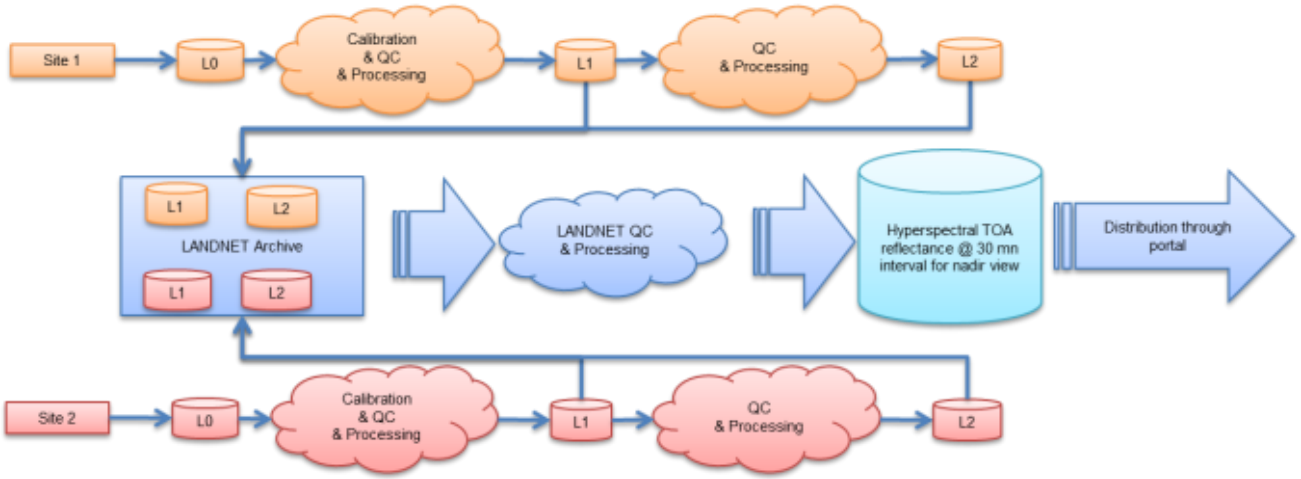


Way Forward

1. Continuously improve the capacity of automated radiometric calibration and contribute to the "global calibration" of EO through RADCALNET

- Enhance the function of automated measurement system to assure the stable operation.
- Develop sky total/diffused irradiance automated measurement and utilize historical in-situ measurement to improve the processing accuracy.
- Participate the RADCALNET activities, including the comparison of the auto-calibration among various sites, the improvement of uncertainty analysis method, and technique support for making guidelines or standards, so as to assure the consistency of automated radiometric calibration site network and promote RADCALNET to be an operational network.





Way Forward

soil

water

grass

crop (maize, wheat, sunflower, melon)

2. Enhance the capability of land product validation based on the infrastructure of Baotou Site

Have possessed

- Reflectance, Land surface temperature(LST), Vegetation coverage(VC), Leaf area index(LAI)

ground scenes

To be developed

- Albedo，Chlorophyll a+b, Photosynthetically active radiation(PAR), Biomass, Emissivity, Net radiation, Shortwave radiation, Long-wave radiation, Soil moisture, Evaporation, Aerosol optical depth(AOD).

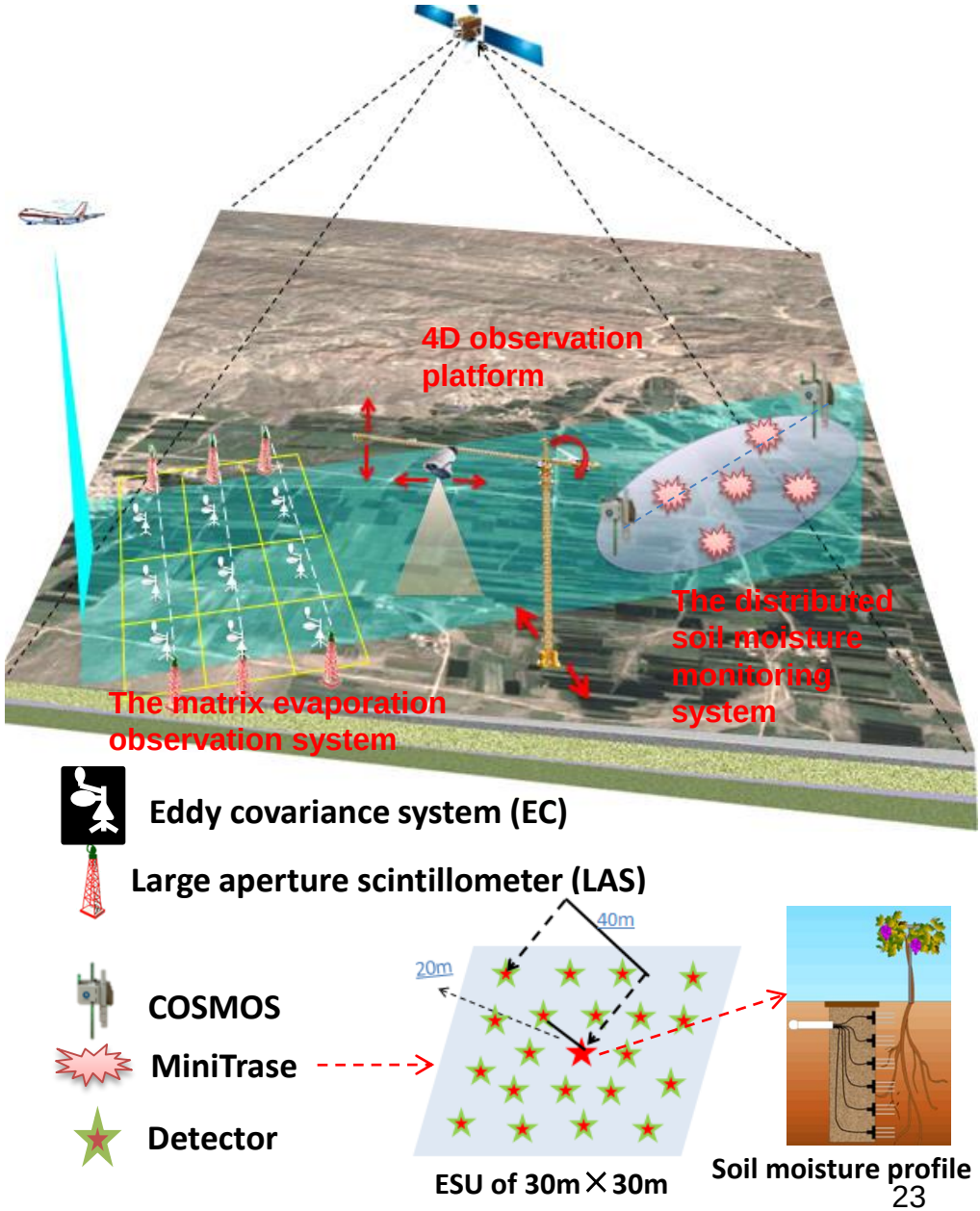
measurement instruments

quality control

Way Forward

Validation activities plan in 2016:

- Install evaporation observation equipment of Eddy covariance system (EC) and Large aperture scintillometer (LAS), to realize the supporting capacity of evaporation product validation;
- Install soil moisture observation equipments of MiniTrase, to realize the supporting capacity of soil moisture product validation;
- Aimed at the retrieved modeling and validation of Reflectance, VC, LAI, LST and Evaporation, a satellite-aircraft-ground synchronous hyperspectral payload test flight will be carried out in Baotou.
- Study on the temporal, spatial, spectral and viewing angle matching technologies, decreasing significant scaling bias of step-wised validation.




Thank you !