# Recent Progress of BaoTou Comprehensive Cal&Val Site

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# Outline

(1)
- Overview of the Baotou site

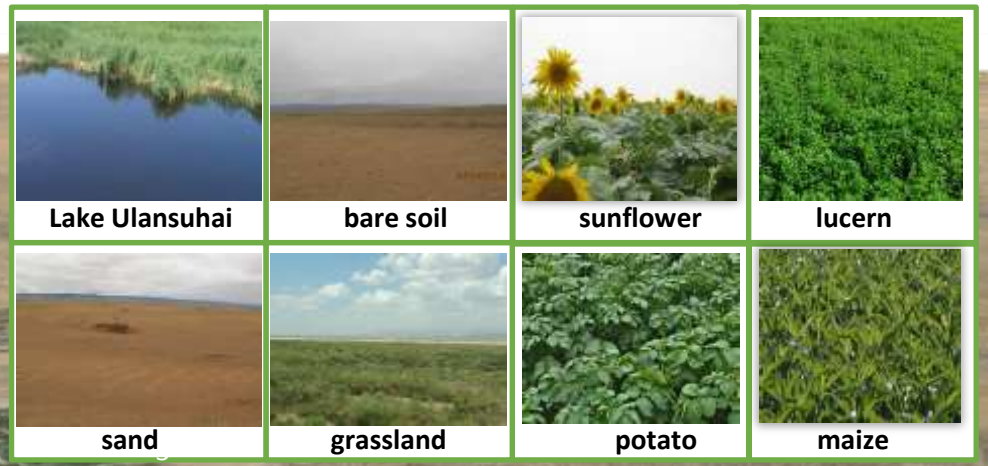
(2)
- Progress in automatic calibration

(3)
- Great events of  Baotou site

# Overview of the Baotou site

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

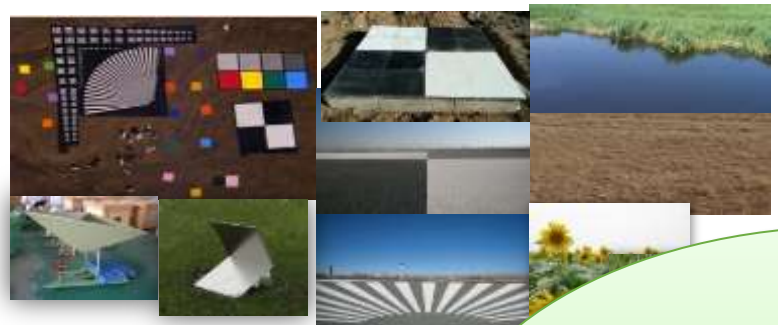
***Site overview:***




Lake Ulansuhai

# Overview of the Baotou site

## Comprehensive surface targets
with artificial targets and natural scenes reasonably matching



Artificial portable targets

Artificial permanent target

## Stepwise Cal&Val technical system

Airborne standard sensors

Ground test equipment

- **Advanced Cal&Val system**
- **Great contribution to RS applications**
- **International platform for R&D**

## Data processing and quality evaluation system

## Automatic in-situ calibration system

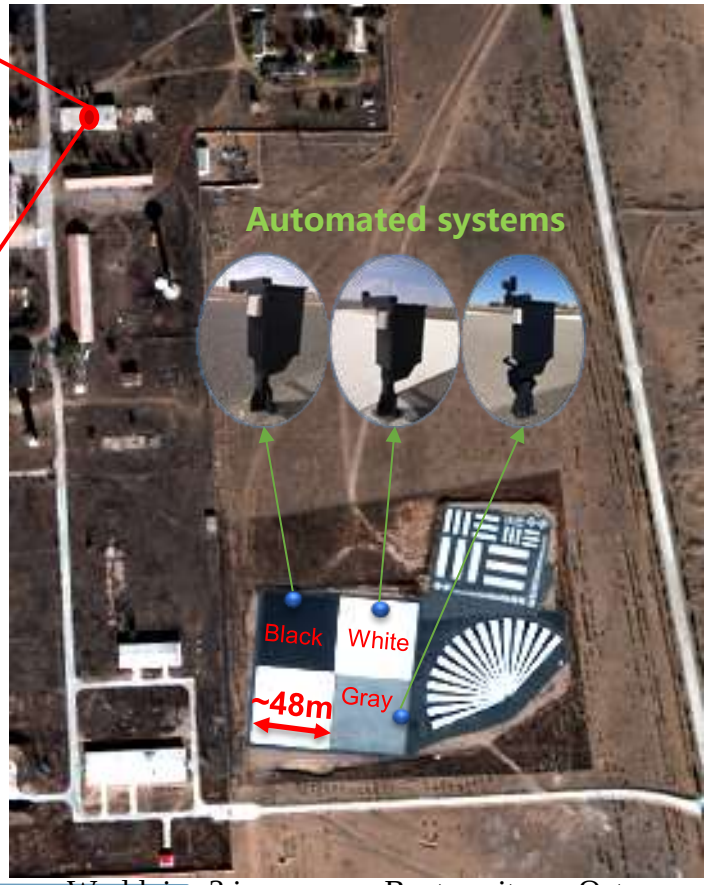
# Progress in automatic calibration

- Accomplished automated surface spectrum measurement system

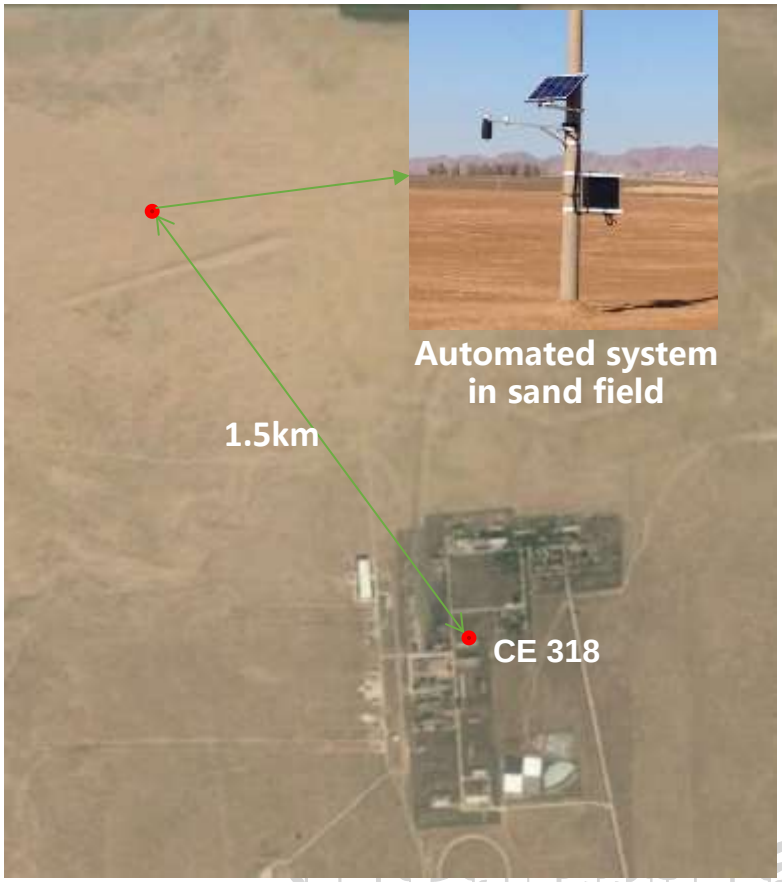
✓ **As one of the four demonstration sites of the Radiometric Calibration Network (RadCalNet), four automated systems with identical spectroradiometer configurations were set up on the black, white and gray artificial permanent targets, and the sand field.**

Cimel CE318

Data processing server

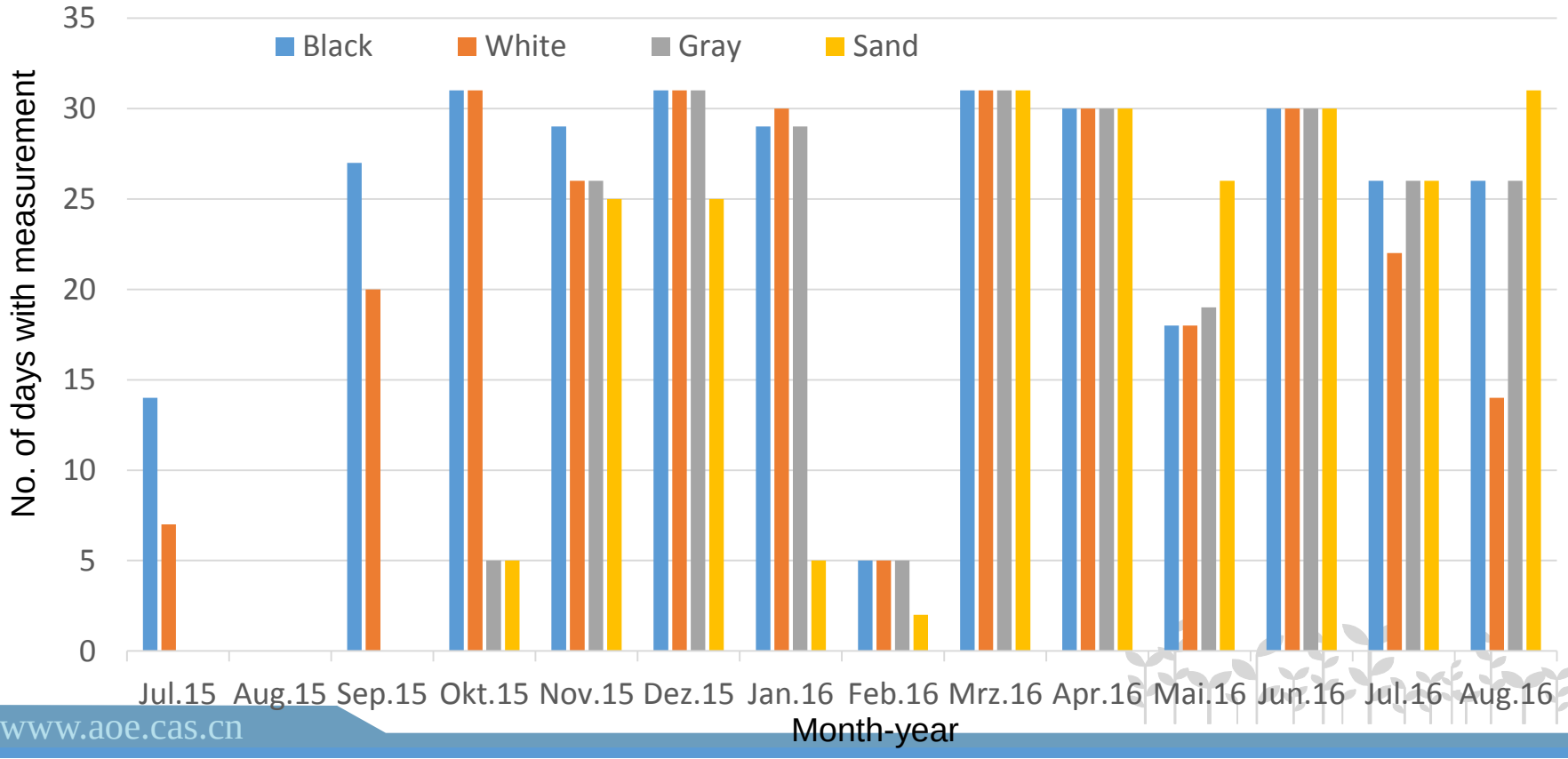



Worldview3 image over Baotou site on Oct. 27, 2015. (Band 5/3/2)



# Progress in automatic calibration

- Essential data collection by automated surface spectrum measurement system
  - ✓ Essential data of the site has been collected for several years.
  - ✓ Measuring the surface feature with high temporal resolution (2 min) from 8:30 to 16:30 local time, and supporting data self-checking and teletransmission.



# Progress in automatic calibration

- ✓ To meet the requirement of RadCalNet portal, the surface reflectance is retrieved from the observed reflected radiance and the measured atmospheric parameters, with the help of atmospheric radiative transfer model (MODTRAN);
- ✓ Automated system only observes surface at fixed point. Because of the heterogeneity of the target, the reflectance should be corrected according to the historical surface measurement.

**Fixed point reflectance retrieval**

$$\rho = \frac{\pi L_g}{E^{direct}_{solar} + E^{diffuse}_{sky} + E^{scat}_{sky}}$$

$\pi L_g$: Observed at-ground reflected radiance

$E^{direct}_{solar}$: Direct irradiance

$E^{diffuse}_{sky} + E^{scat}_{sky}$: Sky irradiance

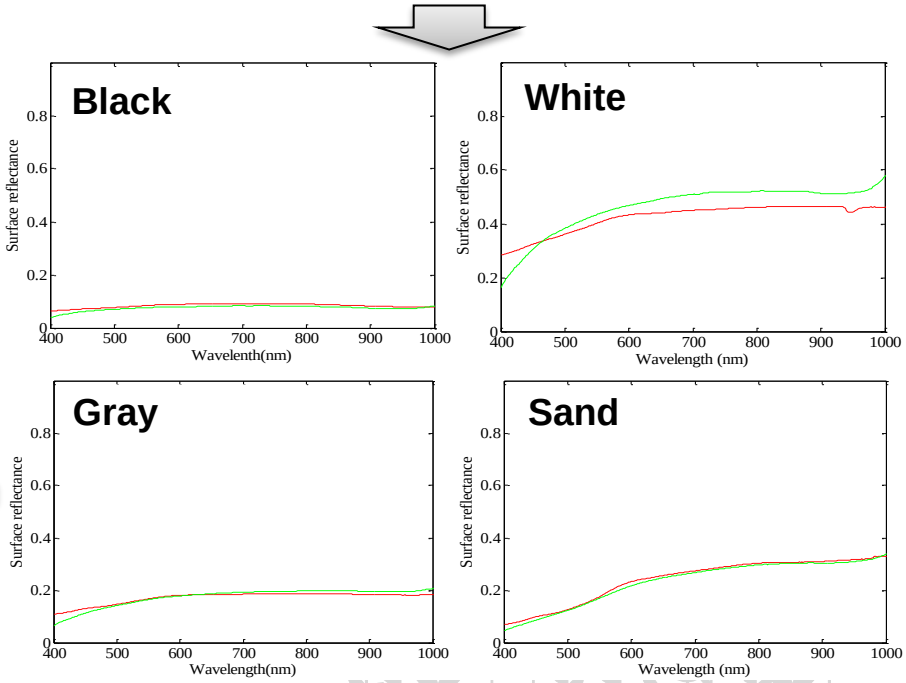
Calculated with MODTRAN and atmospheric parameters (AOT, water vapour, …)

**Spatial scaling effect correction**

$\rho^* = \rho S$ → Scaling coefficient

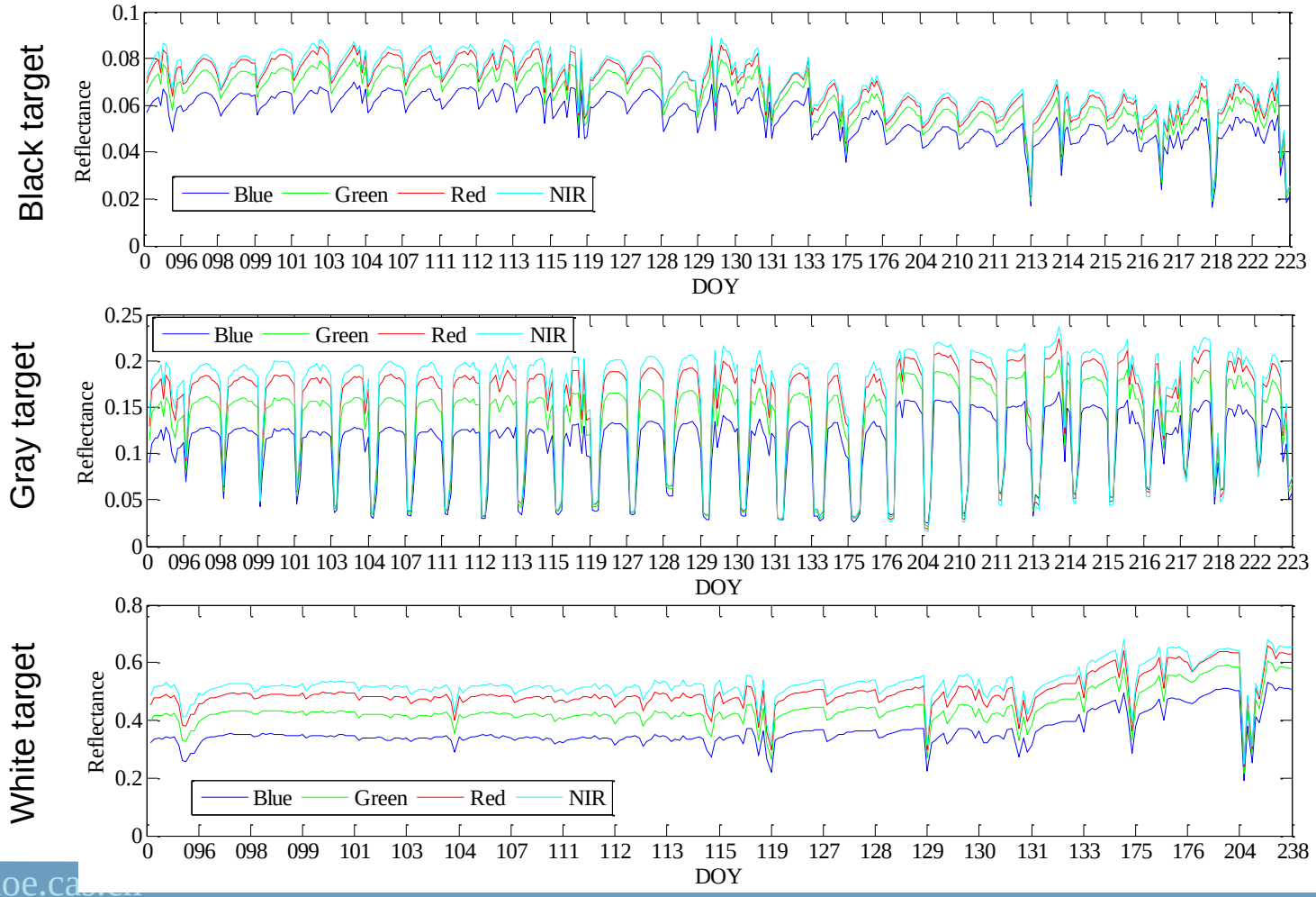
→ Fix point reflectance

Fixed point (green curves) V.S.
Area average (red curves)



# Progress in automatic calibration

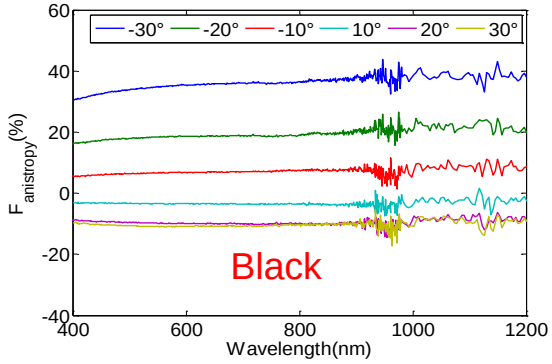
- 84 effective files following RadCalNet portal format have been generated and uploaded.
- Each file contains information for one day of one target. In the file, there are 13 records for observations at different time (9:00-15:00 local time, 2 values/hour).

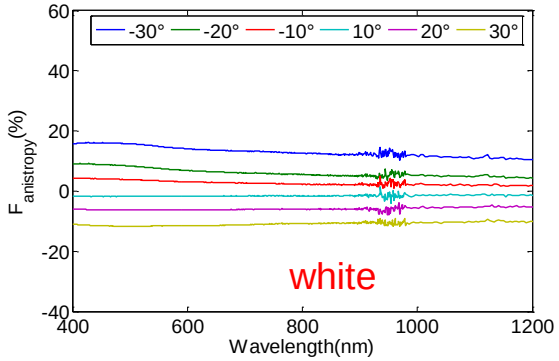


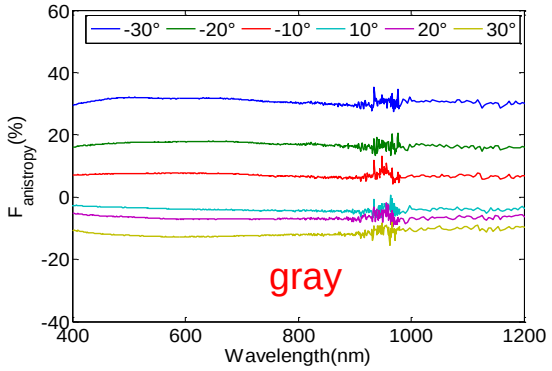
# Progress in automatic calibration

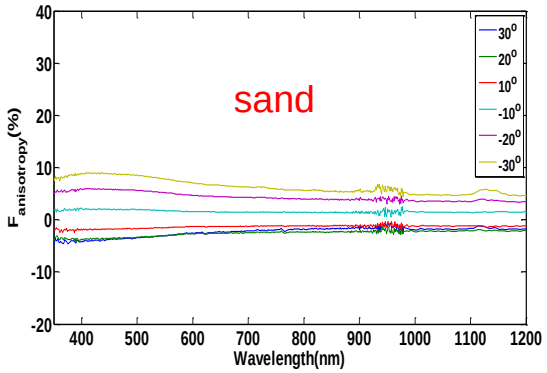
## ■ BRDF characteristics

- ✓ The artificial targets, which are paved by gravels, have much more obvious angular anisotropy than the sand field.
- ✓ With Ross-Li model, the BRDF effects can be well described. Therefore, after BRDF correction, the accuracy of calibration can be improved.




RMSE of BRDF model

- Black target: 0.24%(<10°); 0.46%(<30°)
- Gray target: 0.67%(<10°); 0.74%(<30°)
- White target: 0.95%(<10°); 2.03%(<30°)
- Sand target: 0.478%(<10°); 0.692%(<30°)

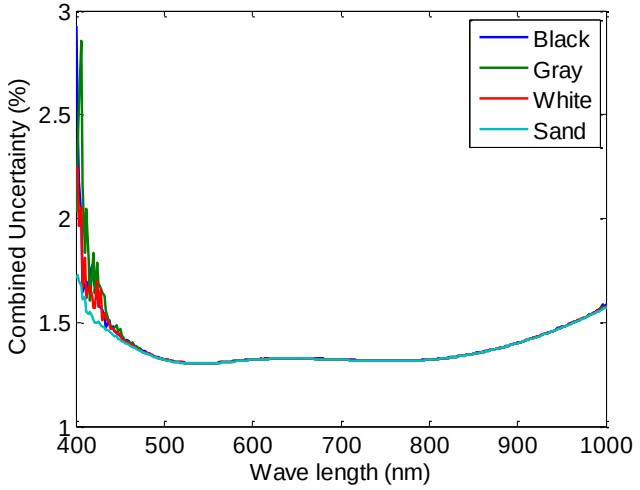
With BRDF correction, the angular effects may be reduced below 1% in most cases.

# Progress in automatic calibration

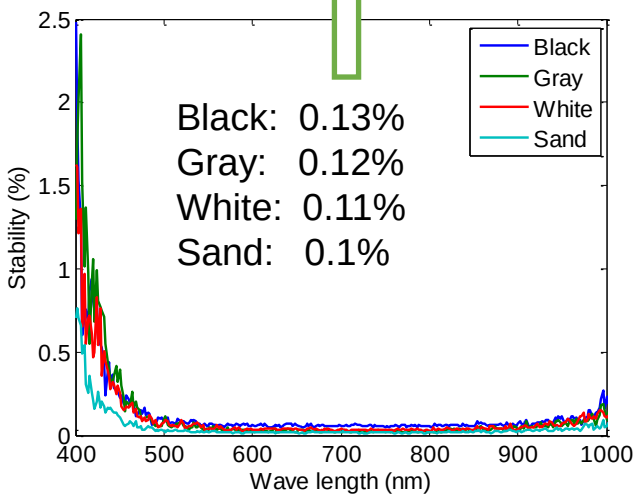
- ✓ The spectroradiometers used in the automated surface spectrum measurement system were calibrated in NIM (National Institute of Metrology, China).
- ✓ The overall uncertainty is reported to be lower than 2%. (k=1, traced to NIM).

## Uncertainty budget for lamp-panel system (NIM)

| Wavelength/nm | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
|---|---|---|---|---|---|---|---|---|
| Repeatability/% | 1 | 0.7 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.8 |
| Lamp/% | 0.8 | 0.6 | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.6 |
| Current % | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Alignment for lamp/% | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Distance % | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Diffuser pannel/% | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Uniformity /% | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Alignment for spectrometer/% | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| nonlinearity % | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Stray light /% | 0.8 | 0.7 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 |
| **Combined U/%(k=1)** | **1.84** | **1.56** | **1.32** | **1.32** | **1.32** | **1.32** | **1.4** | **1.57** |
| **Expanded U/% (k=2)** | **3.7** | **3.1** | **2.6** | **2.6** | **2.6** | **2.6** | **2.8** | **3.1** |




Overall uncertainty of 4 spectroradiometers



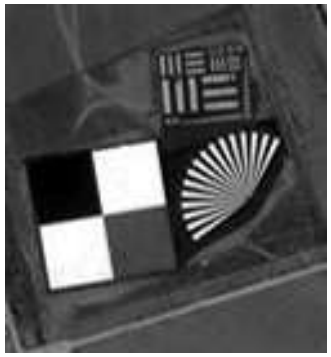

Stability of 4 spectroradiometers

# Demonstration on satellite calibration

Since the end of February 2016, when all the 4 systems at artificial targets and sand field were updated with same spectroradiometers， there have been 10 matchups for Landsat8, Sentinel-2a, ZY3, ZY-02C, GF-1, GF-2 and CBERS-4 satellites.

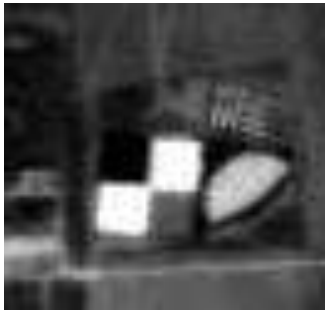
| Satellite | Date |
|---|---|
| Landsat8 | 04/21,05/07,06/08,06/24<br>07/26,08/04,08/27 |
| Sentinel-2a | 03/30, 04/29, 07/21 |
| CBERS-4 | 06/07 |
| GF-1 | 04/23,06/07,08/20 |
| GF-2 | 04/22 |
| ZY3 | 04/20 |
| ZY3-02 | 07/20 |
| ZY-02C | 04/16,04/19,04/22,04/25,04/28,05/12,<br>06/07 |

*GF1 (Pan:2m / MUX:8m)*
*Acquired date: 2016-06-07*

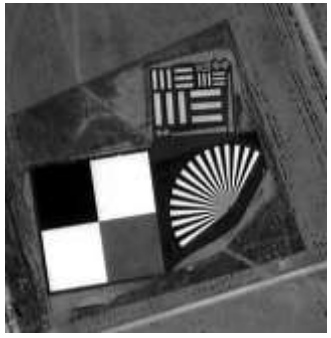


*ZY02C (Pan:5m / MUX:10m)*
*Acquired date: 2016-06-07*

*CEBRS04 (Pan:5m / MUX:10m)*
*Acquired date: 2016-06-07*



*GF2 (Pan:1m / MUX:4m)*
*Acquired date: 2016-04-22*



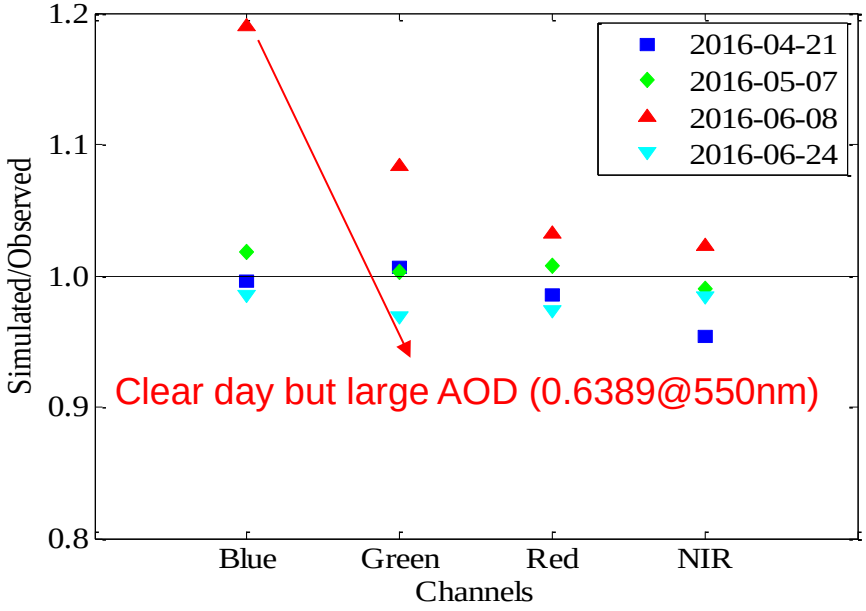
*ZY3 (Pan:2.1m / MUX:6m)*
*Acquired date: 2016-04-20*

*Landsat 8 (Pan:15m / MUX:30m)*
*Acquired date: 2016-06-24*

# Demonstration on satellite calibration

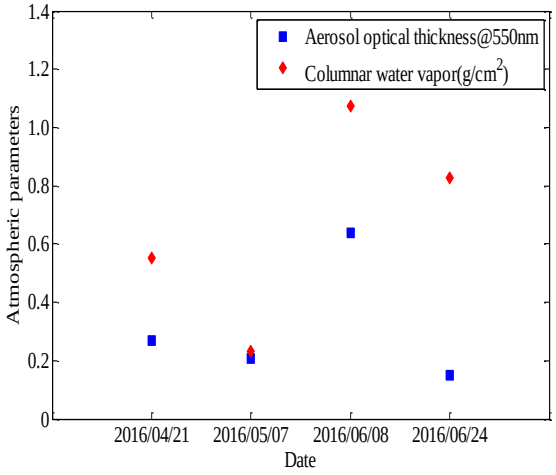
- Demonstration satellite in RadCalNet framework

✓ Average differences between simulated TOA radiance and observed TOA radiance are 4.8%, 1.5%, 0.0%, 1.2% for Blue, Green, Red, NIR band of OLI/Landsat8.




OLI/Landsat8 image

Except for 8 Jun, AODs at other days are smaller than 0.3@550nm

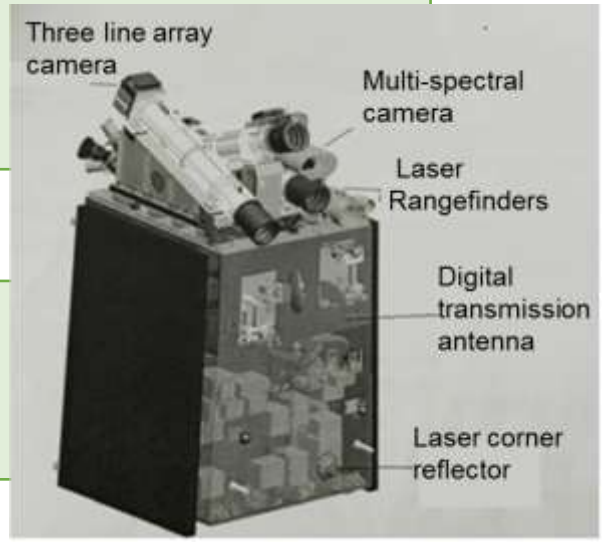


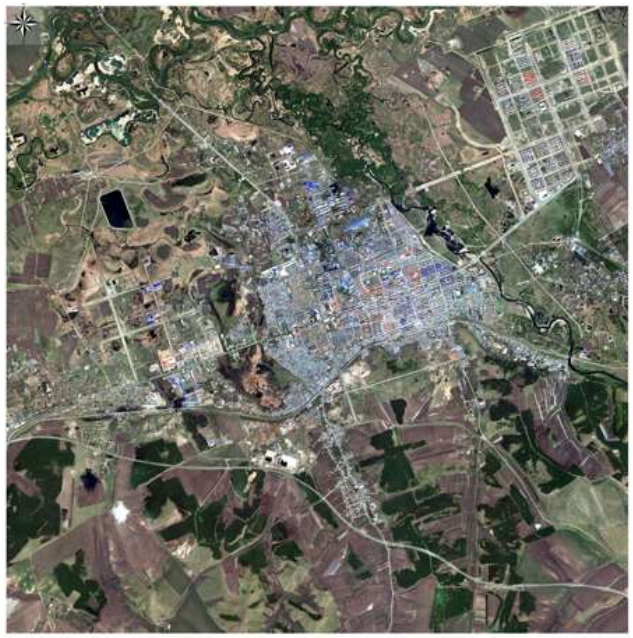
# Demonstration on satellite calibration

- Chinese high-resolution satellite---ZY3-02

- ZY3-02 satellite was launched on May 30, 2016, which is a new civilian high-resolution mapping satellite. It will join its predecessor ZY3-01 satellite (launched in 2012) in the same orbit to form a network and capture high-definition, 3D images and multispectral data.
- The on-orbit test was carried out over the Baotou site during July 15-25, 2016.

| Pan+MSS/ZY3-02 | | | | | |
|---|---|---|---|---|---|
| | Pan/ | B1 | B2 | B3 | B4 |
| Wavelength (um) | 0.5~0.8 | 0.45~ 0.52 | 0.52~ 0.59 | 0.63~ 0.69 | 0.77~0 .89 |
| Pixel size (m) | 2.1(NAD); 3.5 (FWD/B WC) | 6 | | | |
| swath width (km) | 51 | 51 | | | |
| revisit period (±32°, days) | 5 | 5 | | | |

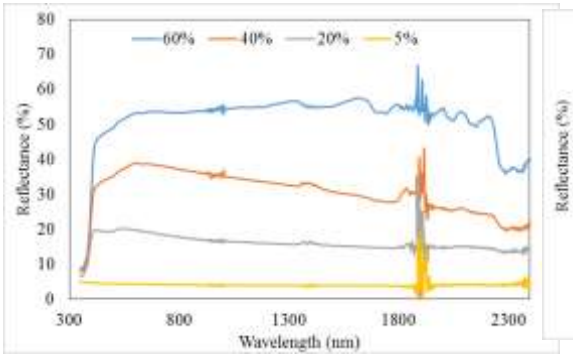


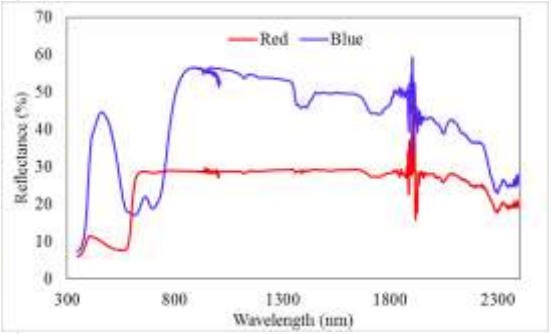
# Demonstration on satellite calibration

- Chinese high-resolution satellite---ZY3-02
  - **Measurement**
    - ✓ **Synchronous measurement: spectral reflectance for 3 permanent artificial targets and 6 portable targets;**
    - ✓ **Automatic measurement: spectral radiance for 3 permanent artificial targets and the sand field; atmospheric parameters.**


synchronous spectrum measurement



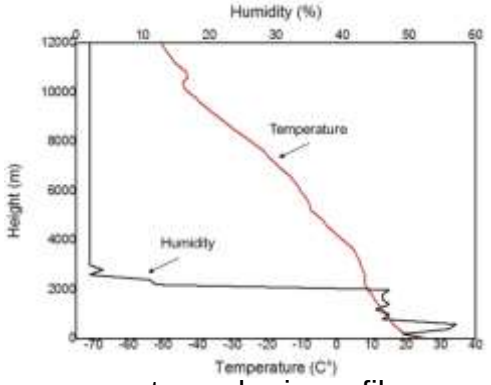

portable gray-scale targets



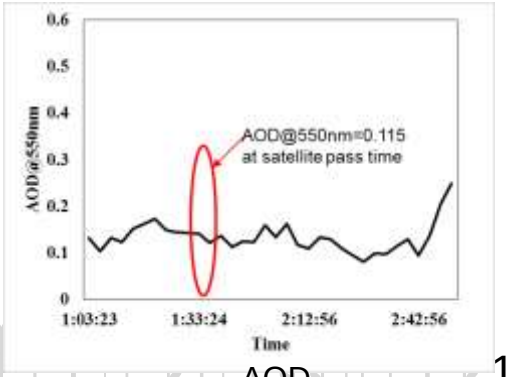

Portable colored targets

sunphotometer

atmospheric sounding



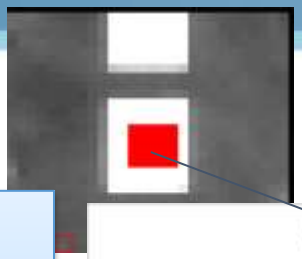

atmospheric profiles



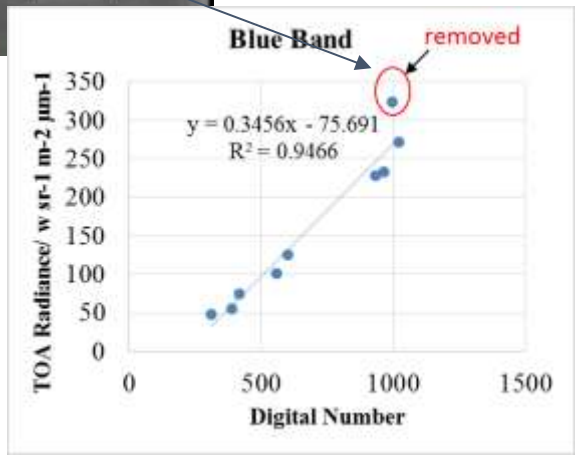

AOD

# Demonstration on satellite calibration

- Chinese high-resolution satellite---ZY3-02
  - ✓ Radiometric calibration



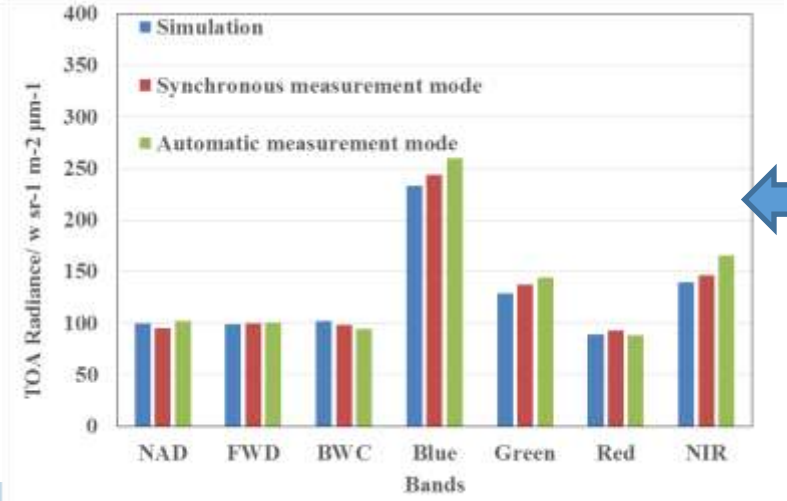
For saturation, the DN value of red region is filled with 977 by satellite agency

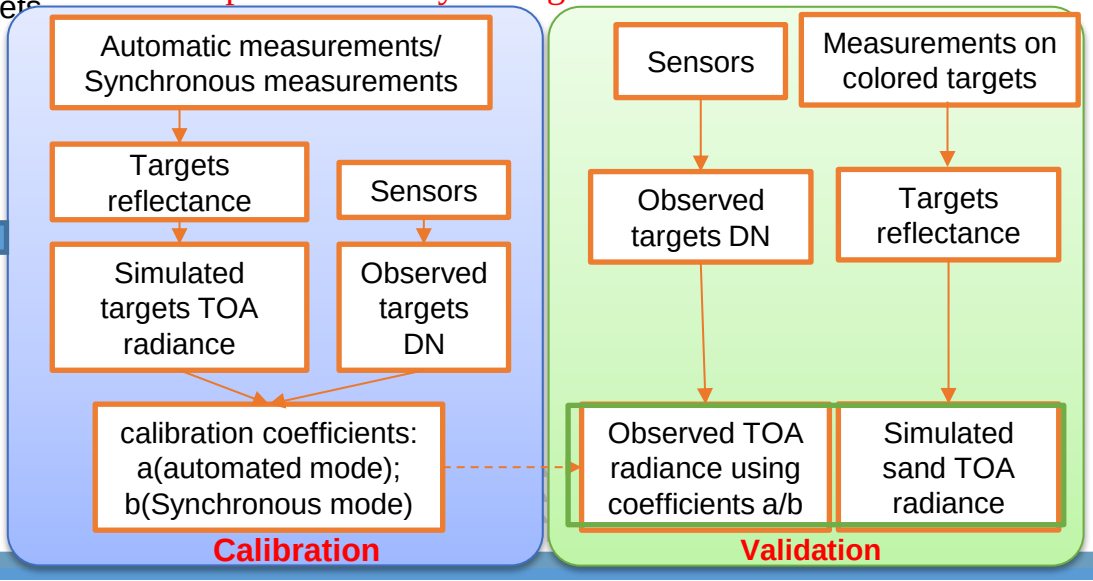



- The portable target of 60% reflectance shows saturation in the blue band image, so the corresponding point was removed when fitting calibration coefficient.
- Using 2 portable colored targets to validate calibration result based on 4 automated measurement systems, as well as calibration result based on all targets' synchronous measurement. Further Improvement is still necessary for automated calibration mode.

The response linearity were greater than 0.98 for all bands .

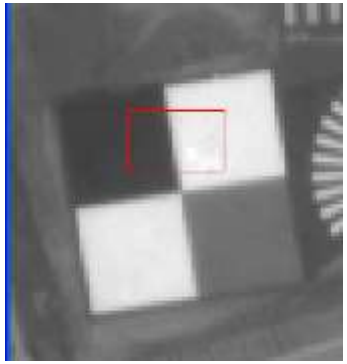
Validation results by using portal blue colored targets



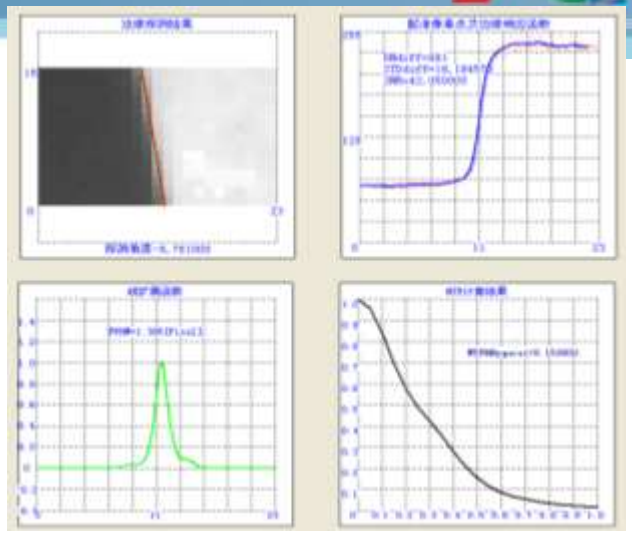
# Demonstration on satellite calibration

- Chinese high-resolution satellite---ZY3-02



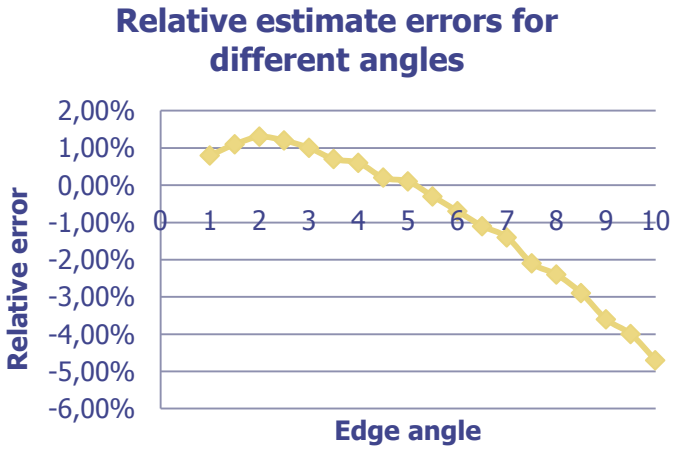
✓ MTF

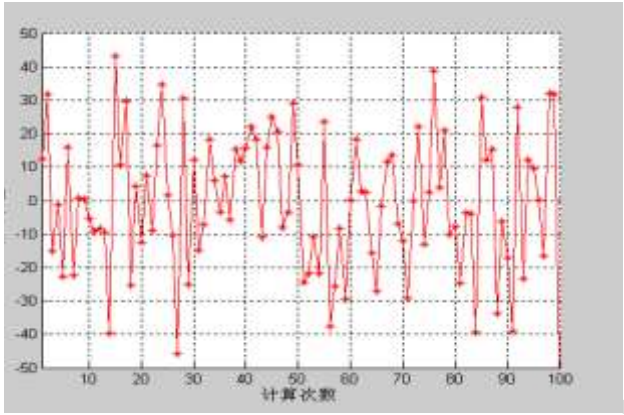
| | Calculation | Specification |
|---|---|---|
| Cross track | 0.153 | 0.1 |
| Along track | 0.103 | |



Error analysis results for 100 simulated images

| edge angle | SNR | MTF-ref | Mean of relative errors（100 times） | RMSE（100 times） | Error ＜10%（100 times） |
|---|---|---|---|---|---|
| -8.7610° | 42 | 0.15 | -0.83% | 20.76% | 38 |




Estimate errors of 100 simulated images

The error analysis indicates that influenced by factors such as black/white contrast, atmosphere and sensor noise, the SNR value when estimating MTF is only 42, and in addition the edge angle is larger than the recommended threshold 5°, so the current MTF evaluation may contain relatively no small uncertainty.

# Great Events

- In August 2016, the first workshop of the “National Calibration and Validation Site for High Resolution Remote Sensors” was held at Baotou. Representatives of all EO satellite operational agencies of China attended the workshop.


# Great Events

- The 28th IVOS meeting and the 5th RadCalNet meeting were hosted by Baotou site during July 18 to 21 2016. Nearly 30 worldwide scientists from NASA, NOAA, ESA, CNES, DLR, NPL, CSIRO, ONERA, GSJ, SDSU, etc, attended this meeting.






# Great Events

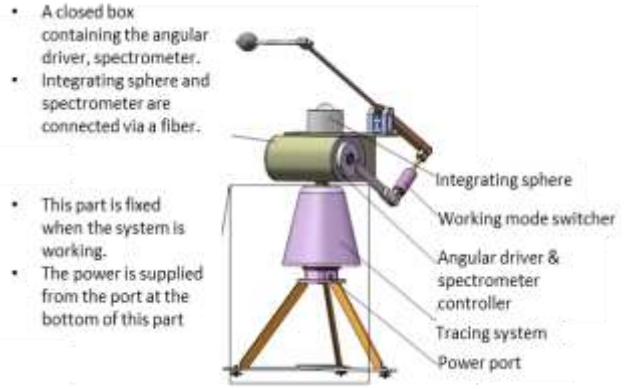
- After this meeting, on July 22, four scientists (Dr. Steffen Dransfeld from ESA, Dr. Françoise Viallefont-Robinet from ONERA, Dr. Esad Micijevic from USGS and Dr. Hirkazu Yamamoto from GSJ) visited the Baotou site.

# Future work

## ➢ To improve the calibration accuracy

- ✓ **Development of the local atmospheric model：** Explore the information from historical data to find the characteristics of the local atmosphere and surface. Study how to improve or correct the atmospheric radiative transfer model.

- ✓ **Development of automated measurement device for total/diffused sky irradiance,** providing observed total irradiance to replace the simulation value derived from MODTRAN in current system.



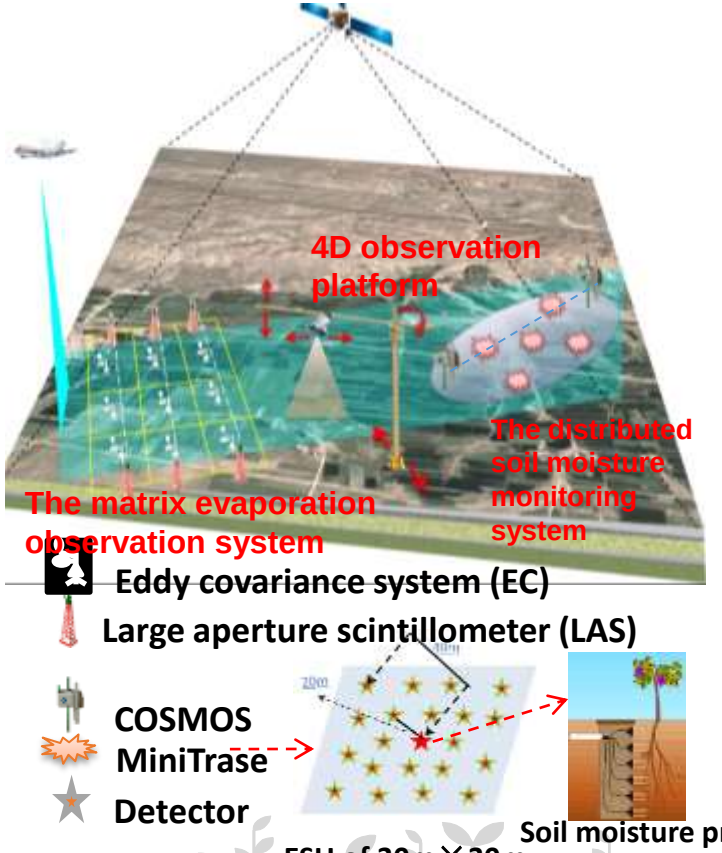

## ➢ To improve the operational capability

- ✓ Robust our system in operational running, especially the improvement of controlling and data processing software.
- ✓ Extension of spectrum range to SWIR domain.

# Future work

- **To Enhance the capability of land product validation based on the infrastructure of Baotou Site**

- ✓ Install evaporation, soil moisture observation equipment of Eddy covariance system (EC), Large aperture scintillometer (LAS) and TDRs, to realize the supporting capacity of land surface product modeling and validation;
- ✓ Study on the temporal, spatial, spectral and viewing angle matching technologies, decreasing significant scaling bias of step-wised validation.




**grass**

**crop** (maize, wheat, sunflower, melon)


Thank you !