RADCALNET

Analysis and Correction of Adjacent Effect in Radiometric Calibration over Baotou Artificial Targets

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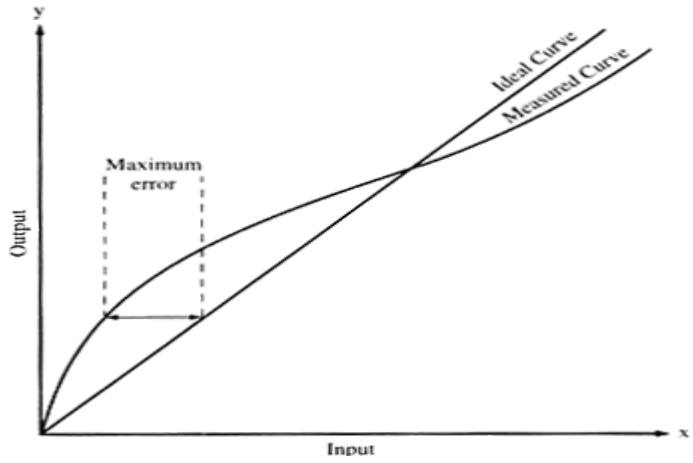
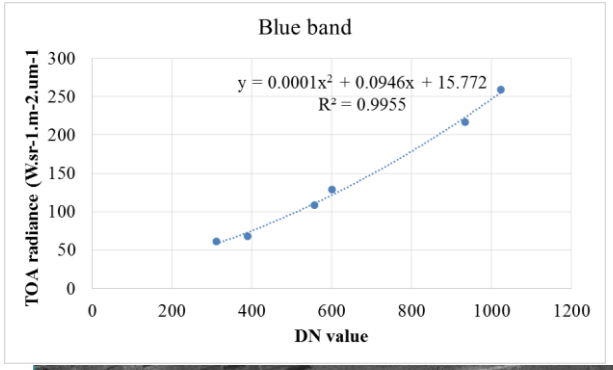
OUTLINES

1. Adjacent effect analysis for the artificial targets
2. Adjacent effect correction methods
3. Preliminary demonstration of ZY3-01 and Sentinel-2a
4. Conclusions

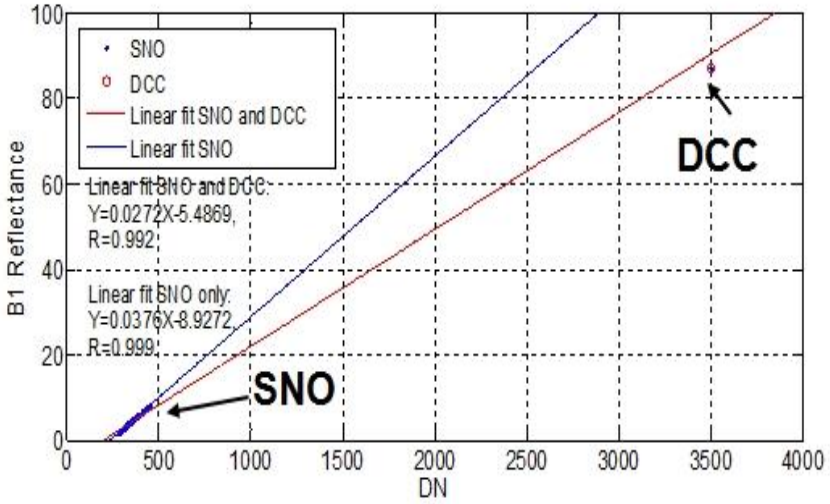
Sources of adjacent effect in radiometric calibration

1. Non-linear sensor responsivity

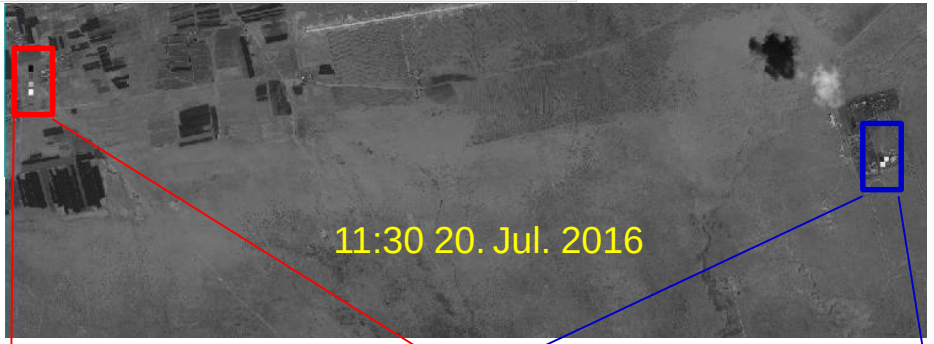




ZY3-02(GSD：5.8m for multi-spec bands)



FY-3C/MERSI
(provided by Chen, CMA)



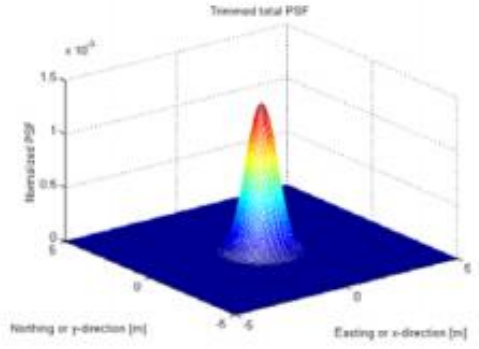
Sources of adjacent effect in radiometric calibration

2. Adjacent effect

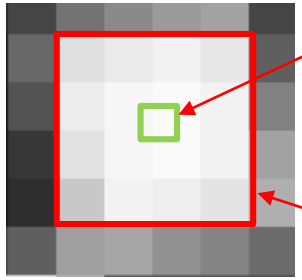
(1) The **point spread function** (PSF) of the imaging system is a Gaussian-like function, so the radiometric response of each pixel in the image will be influenced by surrounding pixels' incident radiances.

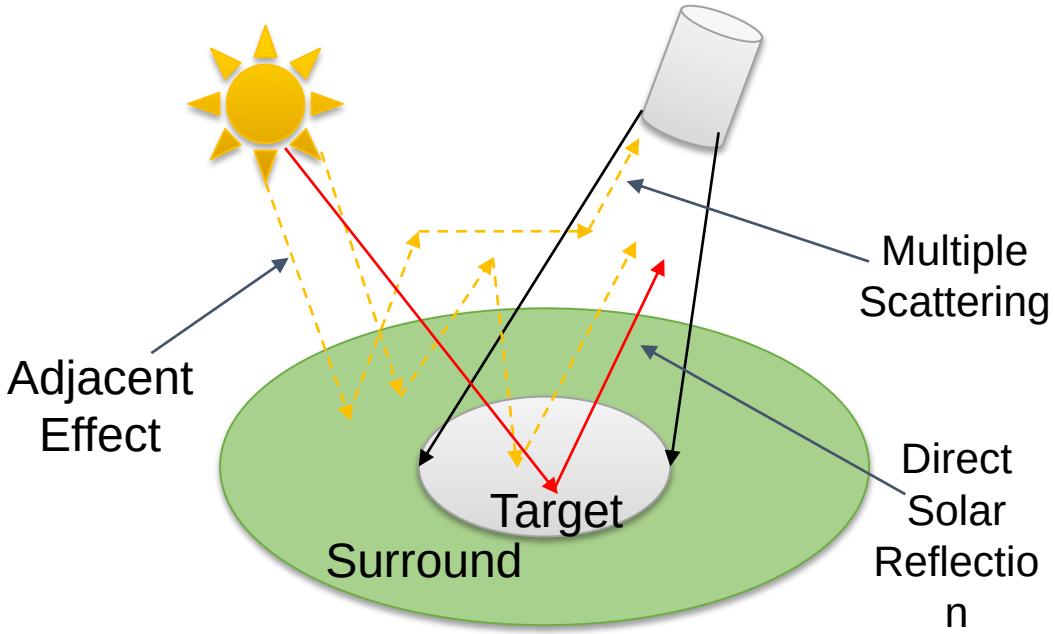
(2) The radiation occurs multiple scattering among surface and atmosphere, so radiometric response of the sensor to a target pixel will contain diffused energy from surrounding surface and atmosphere.

$$L^{*}(x,y) = \iint_{0,0}^{m,n} PSF_{sensor+Atm}(x_i, y_j) * L_{target+background}(x_i, y_j)dxdy$$



(a) The system PSF

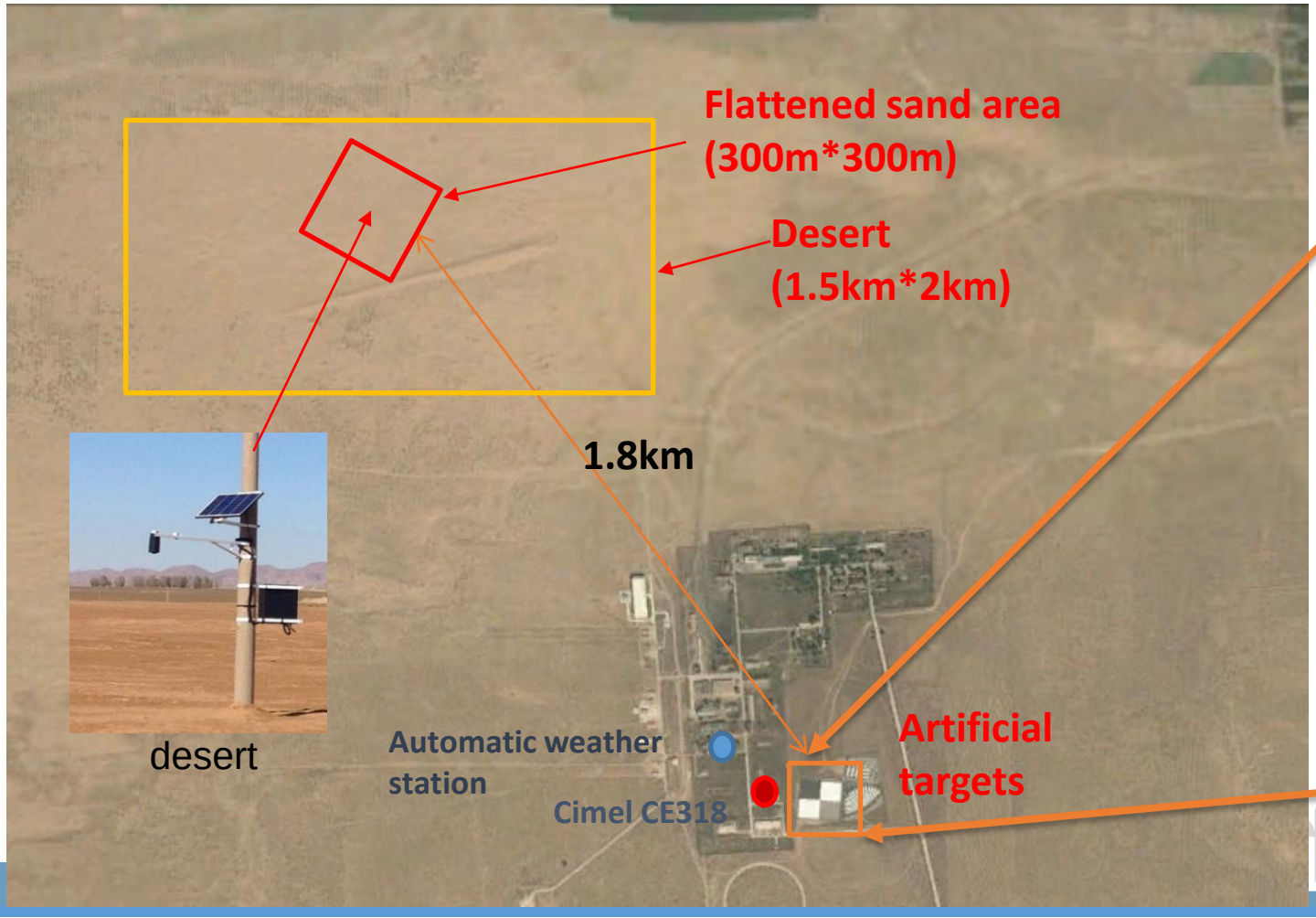




Incident radiance of the target pixel contains **multiple scattering besides direct solar reflection**

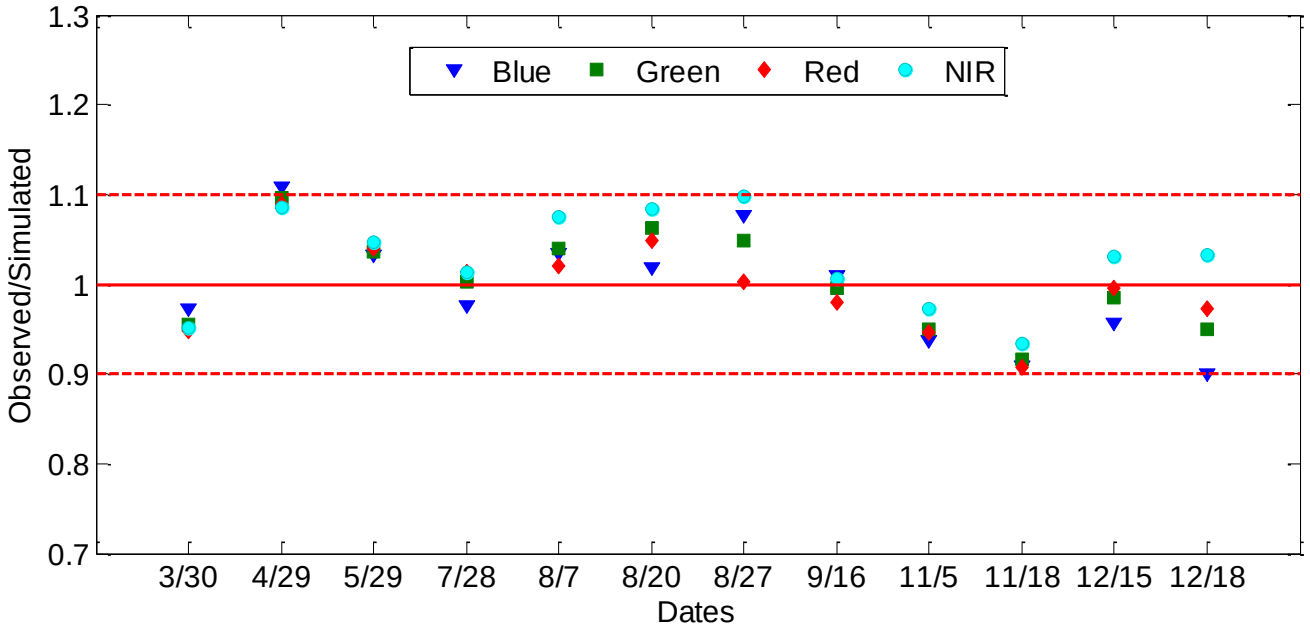
Targets in Baotou site overview

There are totally four automatic measurement systems over four targets with different reflectance, three of which are on artificial targets made of gravels sized 48*48m.
Another one is a sand target sized 300m*300m about 1.8km away from the artificial target region, which has good uniformity and flatness.



Phenomenon of adjacent effect in radiometric calibration over artificial targets

Sentinel-2a observed radiances vs. simulated TOA radiances based on the automatic measurements **for the desert**

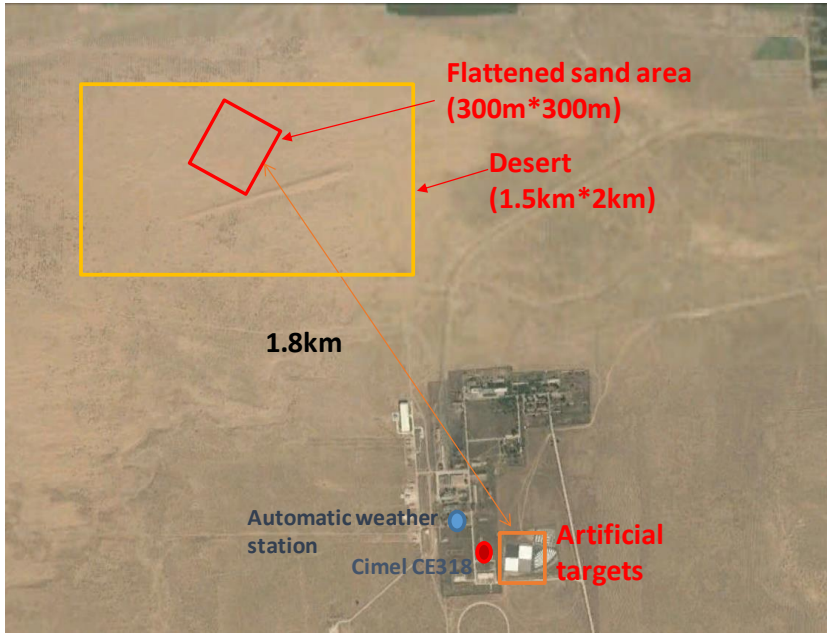


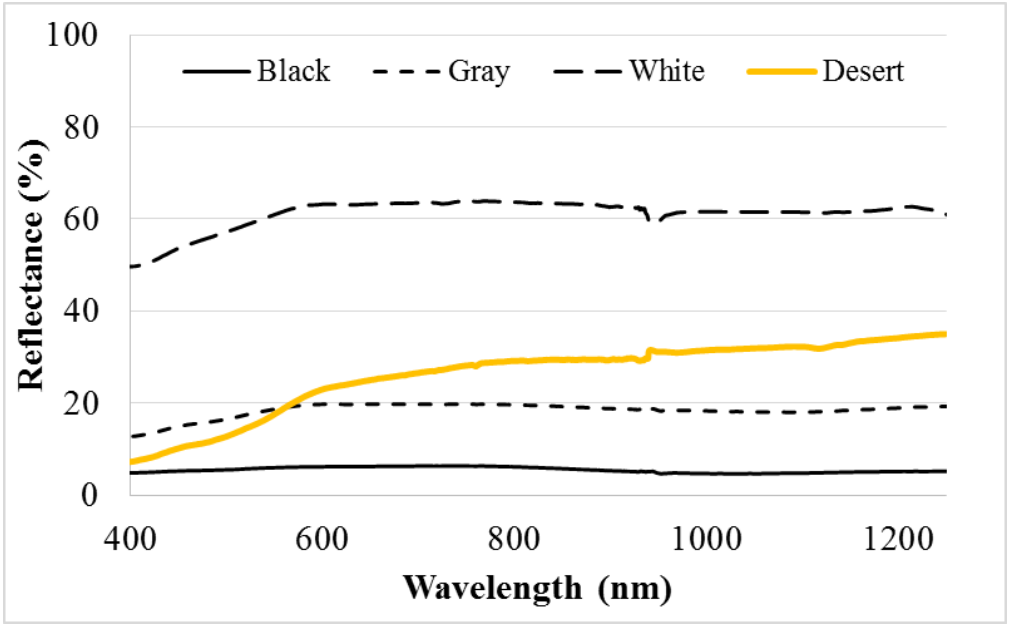
Twelve overpass days in 2016 are involved in the comparison. The satellite observed radiances and the simulated TOA radiances show mean differences of 5.2%, 4.4%, 3.8%, 5.1% for the blue, green, red, NIR band respectively.

The Sentinel-2a data test told a fact that satellite observations are rather consistent with simulations derived from ground automated measurement.

Analysis of adjacent effect of artificial targets

- The artificial targets on Baotou site have limited size (48m*48m of each), thus adjacent effect will play an important role for the targets when a 10m resolution satellite data is considered.
- The targets are mostly surrounded with desert, which spectral reflectance is close to black and gray targets' in blue band, while a rather large difference in NIR band, so the adjacent effect of black target should be less in shorter-wave band.
- The reflectance of gray target is close to the background ‘s(desert's reflectance), hence adjacent effect of the gray target should be most slight.





Ground measured spectral reflectances

Adjacent effect correction considering background reflectance

First idea:

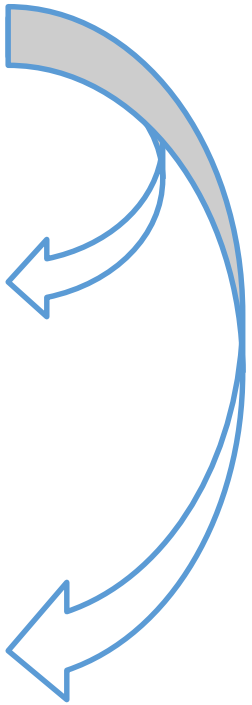
Consideration of background reflectance in the RTM simulation.

Optional:

Adjacent effect correction based on a statistical relations between limit-size artificial target and ideal scene.

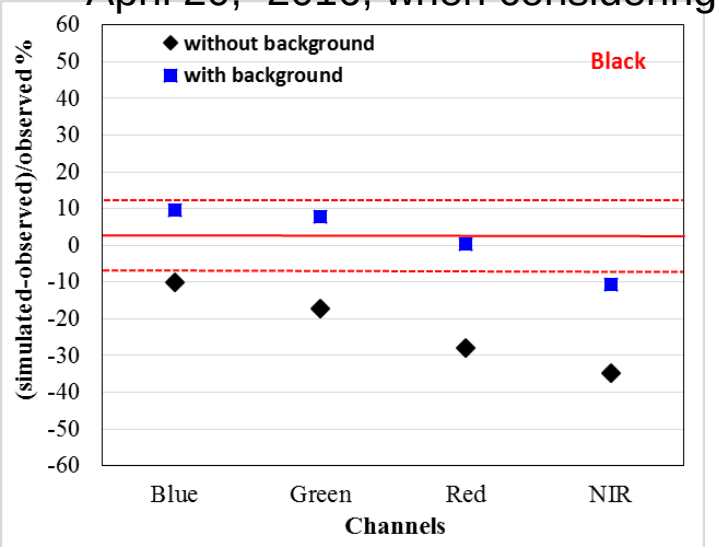
Optional:

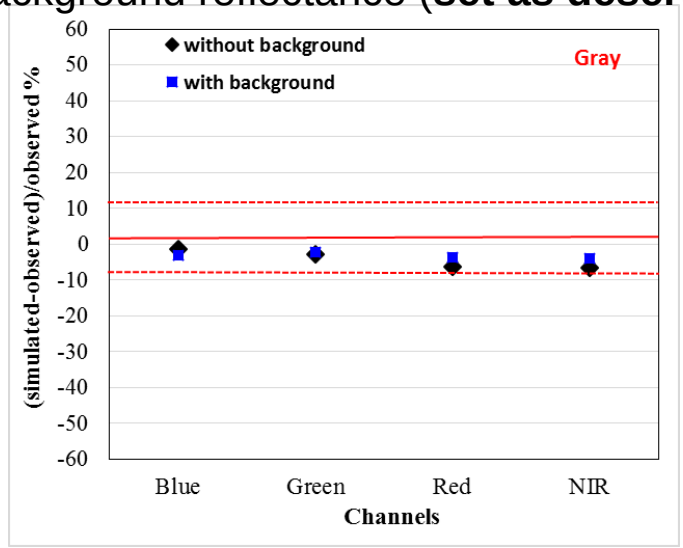
PSF correction according to sensor's characteristics



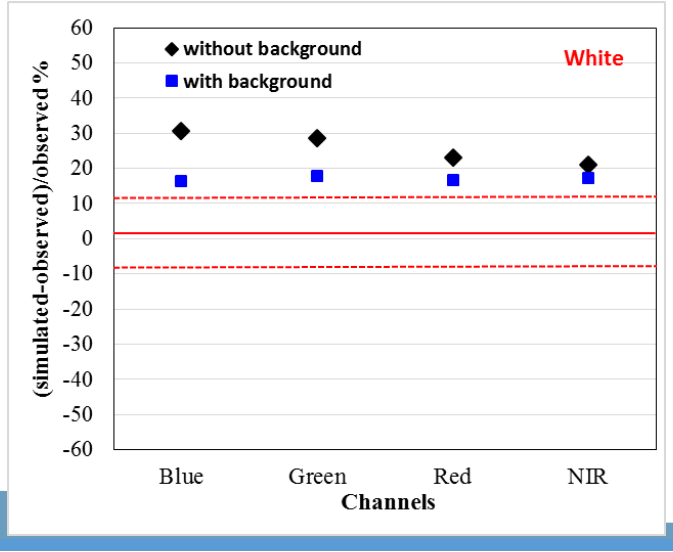
Demonstration of adjacent effect correction considering background reflectance

Comparison of RTM simulated TOA radiance with ZY3-01 (GSD:6m) observed radiance at April 20, 2016, when considering background reflectance (**set as desert reflectance**):





The black target and the white target obtain obvious improvement. While the improvement on gray target is relatively small due to close reflectance with the background desert.



The difference between simulation and observation for black target decreases when considering background reflectance. And the trend for 4 bands is rather consistent. This result indicates influence of the background on the observed radiance gets good compensation.

Demonstration of adjacent effect correction considering background reflectance

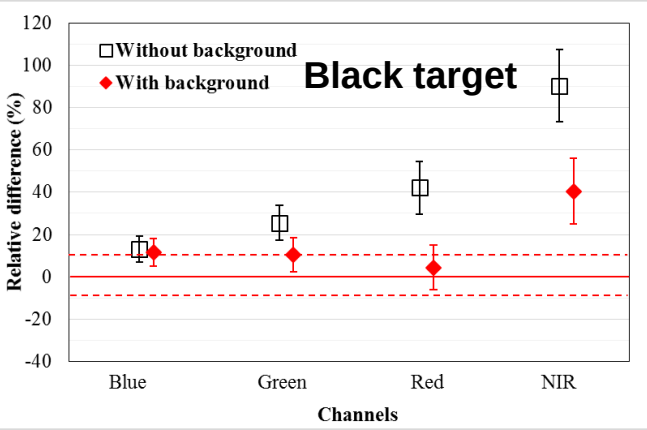
Taking Sentinel-2a data acquired in 2016 for example:

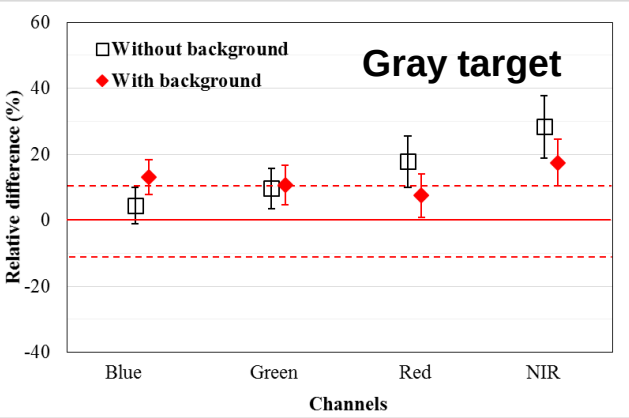
Sentinel-2a overpasses Baotou artificial targets

Date	AOT	WVC（gm/cm2）	Black	Gray	White
2016/3/30	0.2182	0.2425	√	√	√
2016/4/29	0.2262	0.4234	√	√	√
2016/5/29	0.1858	0.4234	√	√	√
2016/7/28	0.2023	1.7831	√	√	
2016/8/7	0.2472	1.8086		√	
2016/8/27	0.1885	1.2648	√		√
2016/9/16	0.2054	1.3988		√	
2016/11/5	0.2054	0.5305	√	√	√

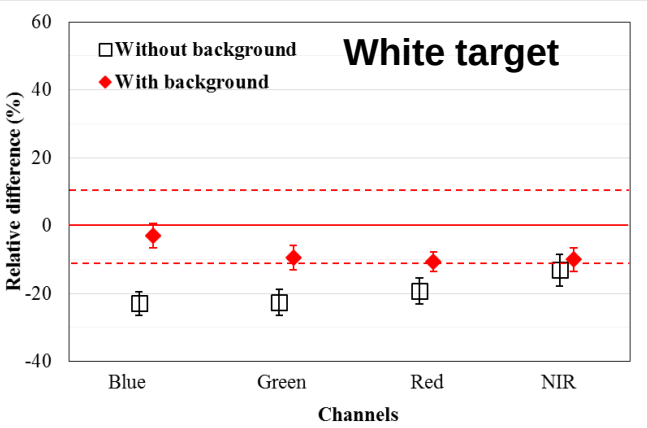
Demonstration of adjacent effect correction considering background reflectance

Preliminary comparisons between simulated TOA radiance with background consideration and observed TOA radiance for Sentinel-2a.





The black target and the white target obtain obvious improvement. While the improvement on gray target is relatively small due to close reflectance with the background desert.



- After consideration of the background reflectance, the improvement on Sentinel-2a (10m) data is less than that on ZY3-01 (6m) data, probably because of their different spatial resolutions.

Adjacent effect correction method based on empirical relations

- In view of the facts that the desert is nearly not influenced by the adjacent effect and the similar instruments are used to acquire surface characteristics over artificial targets and desert, a statistical relations for a period of time between simulated TOA radiance of artificial targets and the desert is established, then apply these relations to do adjacent effect correction on the satellite observation values of artificial targets.

Automatic measurements

RTM → L_{desert}

RTM → $L_{targets}$

$L_{targets} = a * L_{desert} + b$

predict

$L'_{targets} = a * L'_{desert} + b$

Corrected target *L'*

Desert *L*
(without adjacent effect)

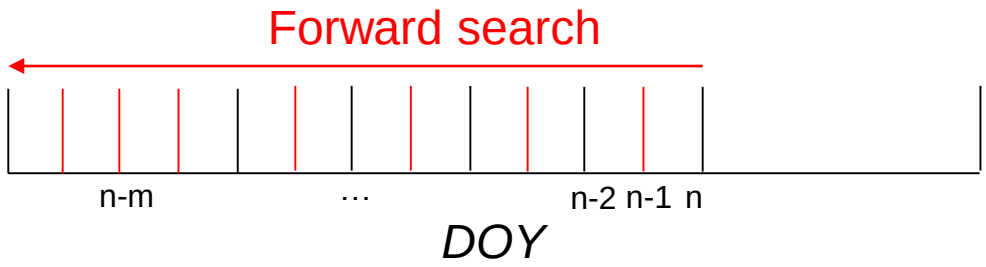
Assumptions

Radiometric characteristics of the sensor maintains stable when comparing the test day with the modeling days. This requires acquisition dates of the modeling data are close to the predicting date.

Adjacent effect correction method based on empirical relations

- Determine the empirical coefficients a & b:

➢ For a specified test day, search several days (modeling days) (e.g. 10 days) ahead of the test day, collect effect data recorded by the ground automated measurement system, and simulate TOA band radiance using in-situ measured atmospheric parameters.



➢ Using simulated desert TOA radiance and target TOA radiance of each day, fit out the coefficients a & b through least-squares regression.

➢ When the test day changes, the modeling days vary accordingly, and new ground measure data will update the values of a & b.

$$\begin{bmatrix} L_{target}^{0} \\ L_{target}^{1} \\ \cdots \\ L_{target}^{N} \end{bmatrix} = a \times \begin{bmatrix} L_{desert}^{0} \\ L_{desert}^{1} \\ \cdots \\ L_{desert}^{N} \end{bmatrix} + b$$

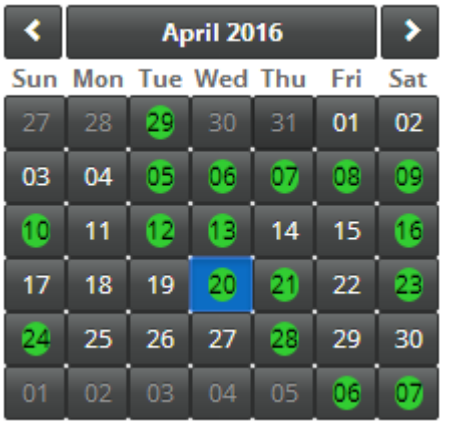
N is the No. of days.

- Apply the empirical relations to the test day, calculate artificial targets‘ TOA radiance according to desert’s TOA radiances simulation.

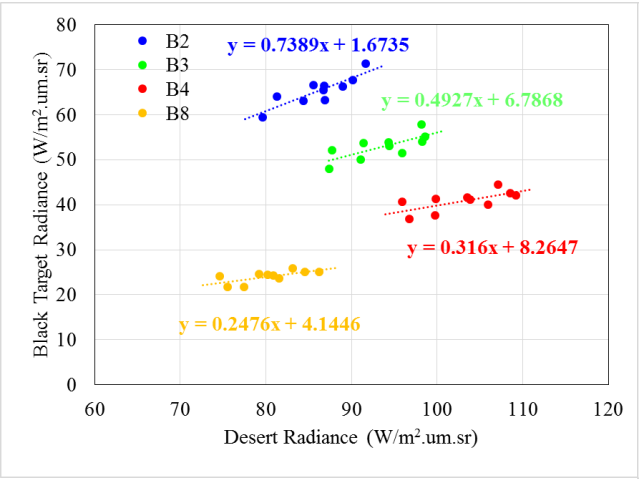
Adjacent effect correction method based on empirical relations

Sentinel-2a data test for example:

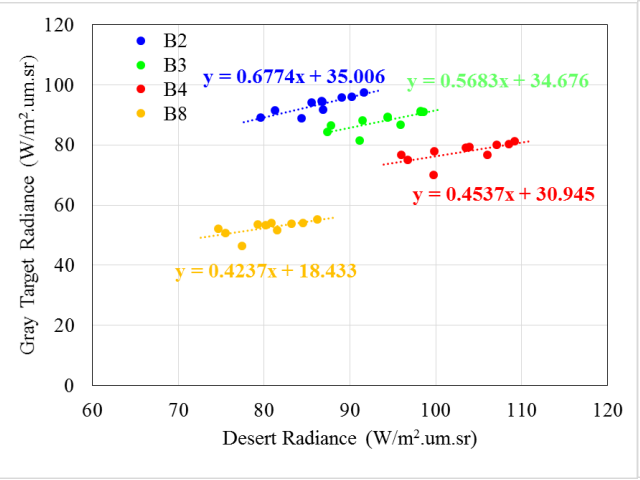
- Satellite data acquisition date is 2016-04-29.
- Collect valid data of ground automated measurement for the desert and artificial targets in the period from 2016-04-01 to 2016-04-28, and simulate corresponding TOA spectral radiance by MODTRAN.
- Solve the least-squares regression between artificial target radiances and sand target radiance to get the empirical coefficients a & b.



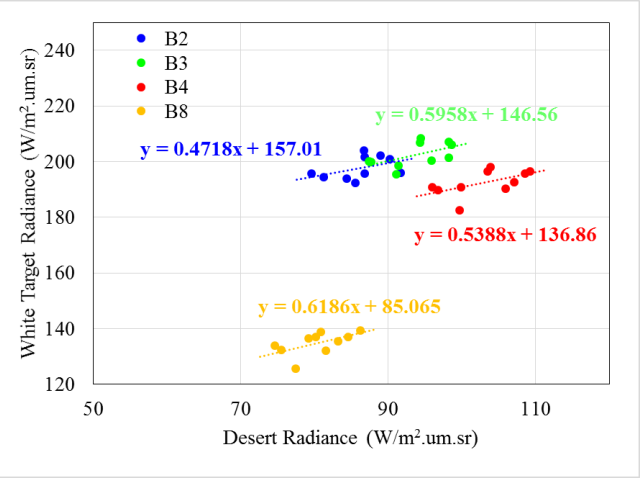
$$L_{targets} = a * L_{desert} + b$$



L_{desert} vs L_{black}



L_{desert} vs L_{gray}

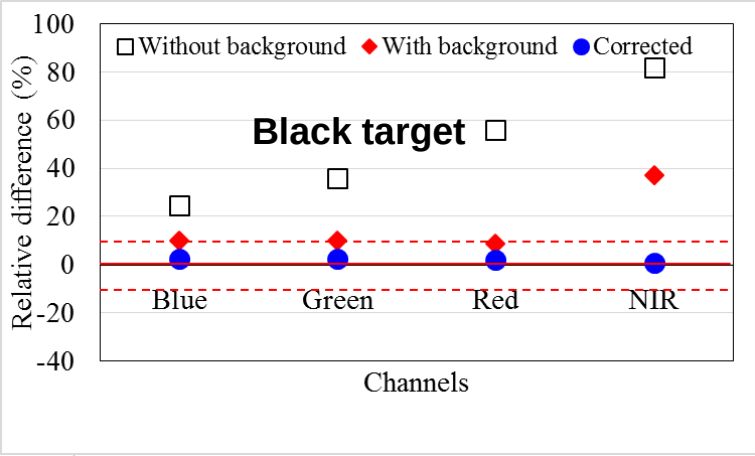


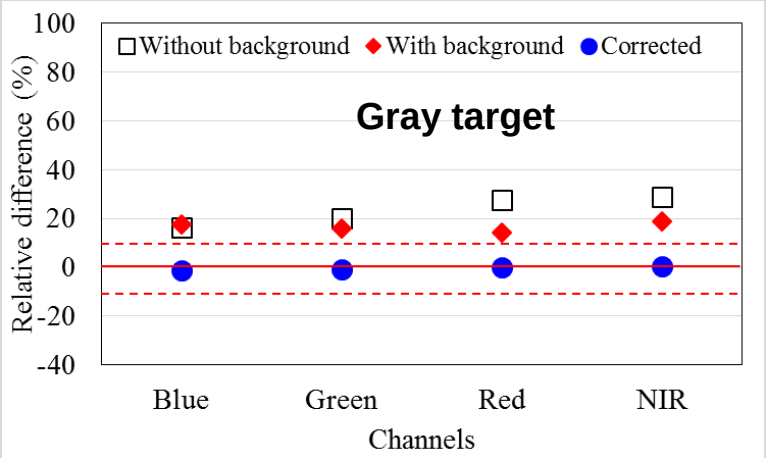
L_{desert} vs L_{white}

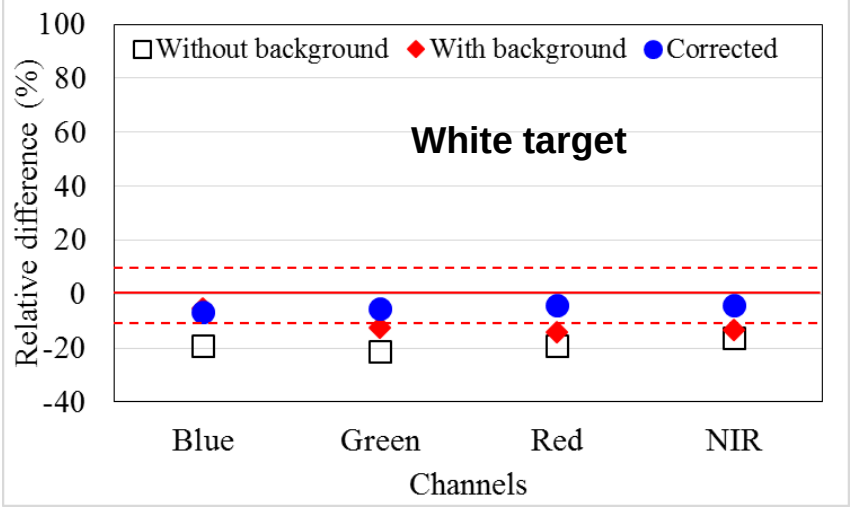
Calculation of a, b

Adjacent effect correction method based on empirical relations

Using the empirical coefficients (a & b) to correct the adjacent effect of Sentinel-2a observed data acquired over artificial targets on 2016-04-29.



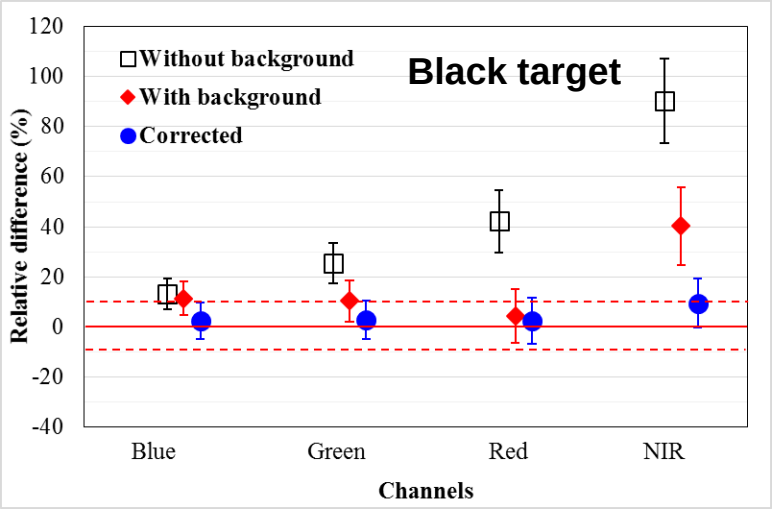


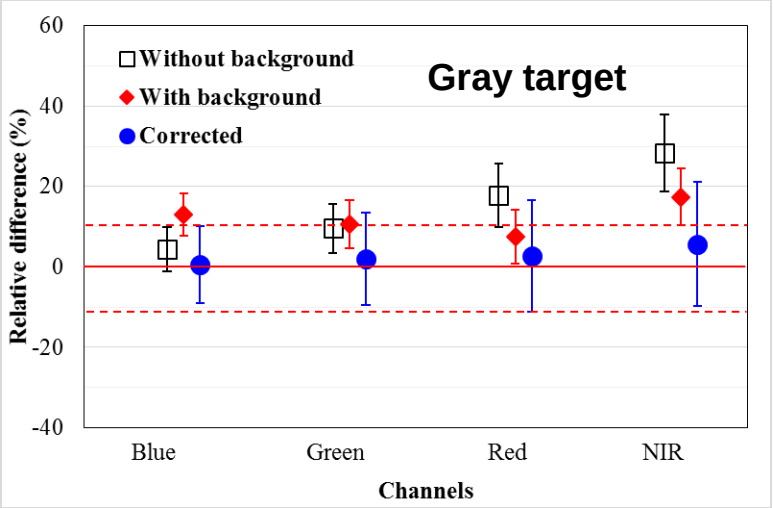


For empirical method, the relative mean difference after adjacent effect correction is 2.0%, 0.6%, -4.9 % for the three artificial targets, respectively.

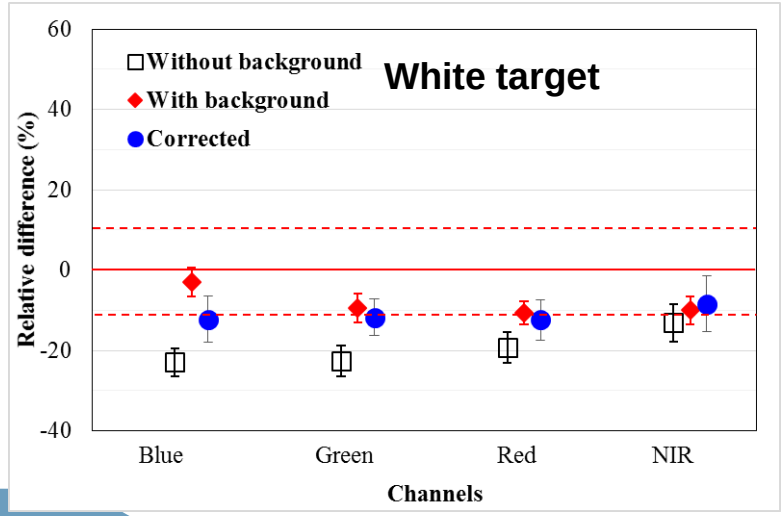
Demonstration of adjacent effect correction method

- Applying the adjacent effect correction methods to those Sentinel-2a data acquired in 2016, the observed TOA radiance and the simulated TOA radiance become much closer.





The data acquired at Sep.16 hasn't been included for large time span when modeling in empirical method.



For empirical method, the relative average difference after adjacency effect correction is 4.94%, 4.42%, -9.94 % for the three targets.

Conclusions:

- It is necessary to consider background reflectance when simulating the TOA radiance. However, because the land cover around the artificial targets is not pure desert, the appropriate background reflectance is to be further analyzed and determined, so as help to update the LUT of RadCalNet data center.
- A statistical relations is established between simulated TOA radiances of artificial targets and that of the desert so as to correct adjacent effect for artificial targets. This method is widely applicable for different sensors, but still has the following limitations:
  - ✓ The empirical relations should be updated dynamically with the time passing, which maybe not applicable for providing to the RadCalNet portal.
  - ✓ This method is developed on the assumption of the linear sensor response, so that the correction method can not catch the actual characteristics (curve response if existing) at the high and low regions of sensor' response.
- Restrictions on the GSD of the sensors is recommended, or new adjacent effect correction method based on PSF/MTF need to be added.


Thank you !