中国科学院空天信息创新研究院
Aerospace Information Research Institute,Chinese Academy of Sciences

Construction and Validation of TOA Reflectance Reference Model for Stable Land Surface Target- Using Golmud Gobi Site as an Example

Peilan Song[1,2], Lingling Ma[1], Yongguang Zhao[1],Ning Wang[1], Yaokai Liu[1], and Wan Li[1]

1 Key Laboratory of Quantitative Remote Sensing Information Technology, Aerospace Information Research Institute, Chinese Academy of Sciences, Beijing 100094, China;
2 School of Optoelectronics, University of Chinese Academy of Sciences, Beijing 100049, China

ABSTRACT

Using Golmud Gobi site as an example, this study provides a method to construct the top of atmosphere(TOA) reflectance model for inland stable targets. By analyzing the variation of TOA reflectance of inland stable targets caused by different factors, the TOA reflectance model of inland stable targets is established under the constraints of observation geometry and atmospheric parameters. The accuracy of the proposed model was evaluated by using Landsat8/OLI and Sentinel-2B /MSI observation data with high calibration accuracy. The model directly takes the inland stable targets as the calibration reference. It can not only provide the radiance reference value at the entrance pupil for the sensor to be calibrated, but also provide an angle conversion method for high-precision and high-frequency cross-calibration.

INTRODUCTION

Pseudo invariant calibration sites (PICSs) have the advantages of high surface reflectance, low latitude, low aerosol thickness, low cloud cover frequency and so on, so they are very suit for monitoring the stability of sensors. In recent years, the TOA reflectance variation and modeling of PICS have attracted the attention of many researchers and organizations including CEOS WGCV/IVOS. Algeria 3, Algeria 5, Libya 1, Libya 4, Mauritania 1 and Mauritania 2 were identified as pseudo invariant calibration sites during the CEOS IVOS-19 meeting in 2008. However, PICS are currently distributed in the Sahara Desert in North Africa and the Middle East. It is difficult to apply them to the Chinese land satellites, which are mostly imaged in China. Therefore, in order to meet the needs of radiation calibration in China, it is necessary to carry out research on site characteristics of relatively stable sites in China. Among them, the development of TOA reflectance model for site will be a key point in the research of site characteristics.

STUDY AREA

◆Geographical Coordinates:
36.411920°~36.456987°N;
94.197169°~94.252941°E
◆Site Area:5km × 5km
◆Average Elevation :2.8440km
◆Surface Reflectance: VIS > 0.15;
NIR > 0.3.

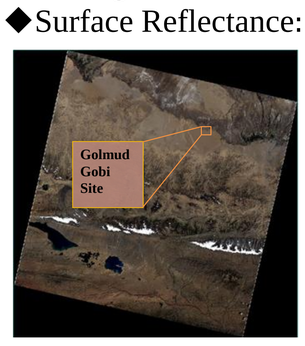

Figure 1 Landsat8 image over Golmud Gobi site on Jul. 23 2015.

DATA

◆ Image:
- ✓ Aqua/MODIS;
- ✓ Sentinel-2B/MSI;
- ✓ Landsat8/OLI.

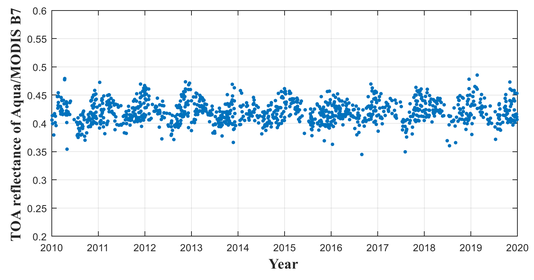

Figure 2 TOA reflectance time series data of MODIS over Golmud Gobi site.

◆ Atmosphere :
- ✓ ECMWF

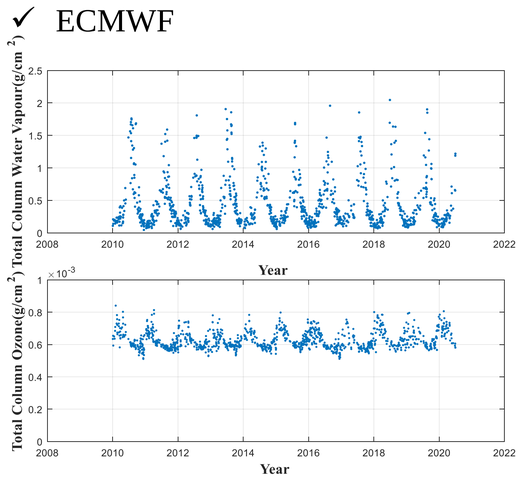

Figure 3 The seasonal changes of atmosphere in Golmud Gobi site from 2010 to 2020.

METHODS

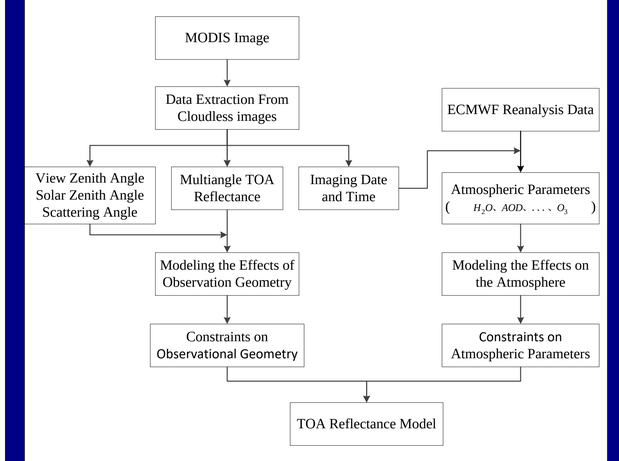

Figure 4 The construction method of TOA reflectance model

KEY RESULTS

◆Modeling the effects of observation geometry

✓ View zenith angle

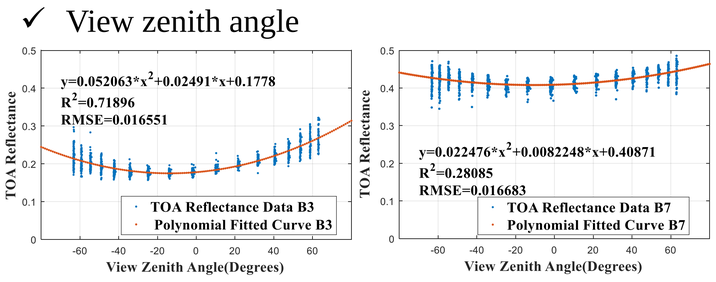

Figure 5 The Variation of TOA reflectance with view zenith angle over Golmud Gobi site from 2010 to 2020.

✓ Solar zenith angle

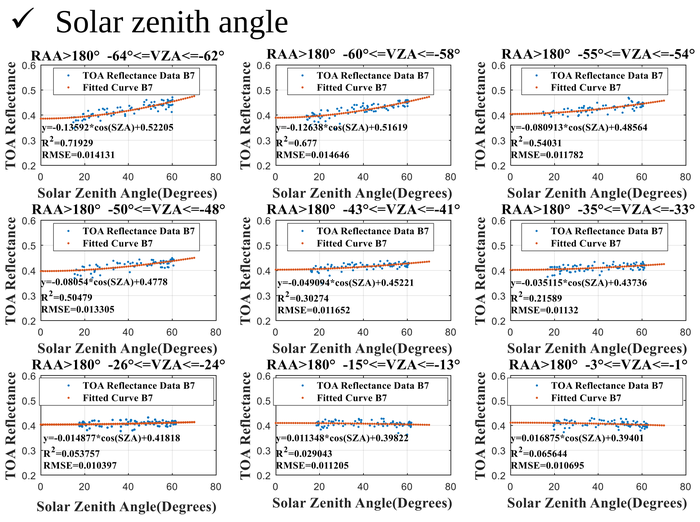

Figure 6 The Variation of TOA reflectance with solar zenith angle over Golmud Gobi site from 2010 to 2020.

✓ Scattering angle

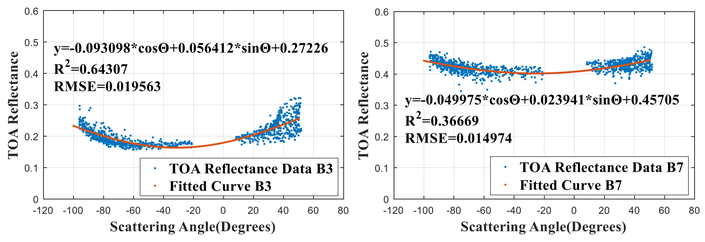

Figure 7 The Variation of TOA reflectance with scattering angle over Golmud Gobi site from 2010 to 2020.

◆Modeling Seasonal effects on the atmosphere

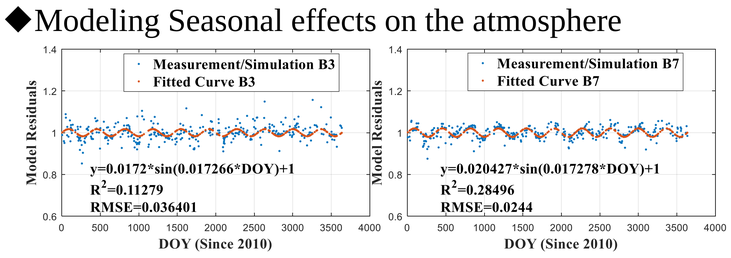

Figure 8 The model residuals change seasonally with the atmosphere after considering the influence of the observation geometry.

◆TOA reflectance model

$$\rho^{sim}_{TOA,MODIS}(i)=\left(\frac{\left(a_{1,i}\cos\theta_v+a_{2,i}\right)\cos\theta_s+a_{3,i}\cos(\theta_v+a_{4,i})}{a_{5,i}\cos\Theta+a_{6,i}\sin\Theta+a_{7,i}}+a_{8,i}\right)\times\left(a_9\times\sin\left(\frac{2\pi}{365}\times DOY\right)+1\right)$$

✓ Constraints on observational geometry

(I)$-35^\circ<\theta_v<35^\circ$; (II)$-35^\circ<\theta_v-\theta_s<35^\circ$.

✓ Constraints on atmospheric parameters

Precipitation Type = 0; Snow Density < 0.16 g/cm³;
Total Could Cover < 0.8; Total AOD < 0.4(500nm);
Total CWV < 2.0 g/cm²

✓ Observation VS Simulation

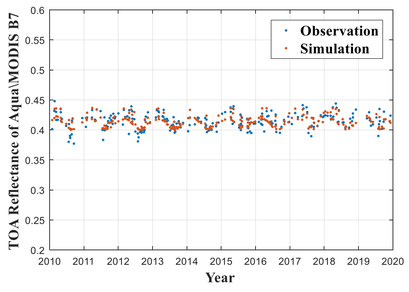

Figure 9 Comparison model simulation TOA reflectance and satellite observation TOA reflectance.

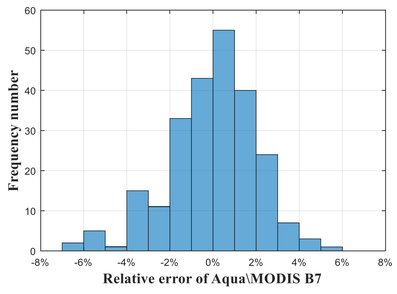

Figure 10 Relative error frequency number distribution histogram.

◆TOA reflectance model validation

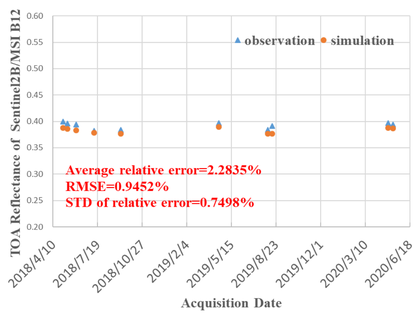

Figure 11 Comparison model simulation TOA reflectance and Sentinel2B/MSI B12 observation TOA reflectance.

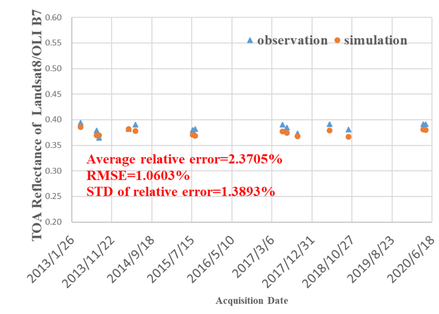

Figure 12 Comparison model simulation TOA reflectance and Landsat8/OLI B7 observation TOA reflectance.

CONCLUSIONS

- ◆ Using Golmud Gobi site as an example, the TOA reflectance reference model was constructed for inland stable targets. The model system deviation is less than -0.11%, and the root mean square error is less than 0.0083.
- ◆ The average relative errors between the simulated TOA reflectance and the observed TOA reflectance of Sentinel2B/MSI and Landsat8/OLI in Blue, Green, Red and NIR are less than 2.6811%. RMSE is within 0.0106. The standard deviation of relative error is not more than 1.7721%;
- ◆ The mode takes inland stable targets as the calibration datum, and the model input parameters are all from the satellite observation geometry, which avoids the site synchronous measurement. It can realize the absolute radiation calibration of satellite sensor with high efficiency and real time.

MAJOR REFERENCES

[1] Mishra N, Helder D, Angal A, et al. Absolute Calibration of Optical Satellite Sensors Using Libya 4 Pseudo Invariant Calibration Site[J]. Remote Sensing, 2014, 6(6):1327-1346.
[2] Raut B, Kaewmanee M, Angal A, et al. Empirical Absolute Calibration Model for Multiple Pseudo-Invariant Calibration Sites[J]. Remote Sensing, 2019, 11(9):1105-1125.
[3] Xingwei H, Xiaohu F, Qi H,et al. Cross-calibration of FY-3C medium resolution spectral imager in reflective bands[J]. Opticsand Precision Engineering, 2020, 28(7):1463-1470.