Uncertainty analysis for the RadCalNet test sites at Baotou (BTCN, BTSN)

Lingling Ma[1], Yongguang Zhao[1], E. R. Woolliams[2], Caihong Dai[3], Ling Li[3], Ning Wang[1], Yaokai Liu[1], Caixia Gao[1]

1 Key Laboratory of Quantitative Remote Sensing Information Technology, Aerospace Information Research Institute, Chinese Academy of Sciences, Beijing, China
2 National Physical Laboratory, Hampton Road, Teddington, Middlesex, TW11 0LW, UK;
3 National Institute of Metrology, Beijing, China

Baotou RadCalNet Sites

- The Baotou site is located at the Ming'an township, Urad Front Banner, Bayannur prefecture, Inner Mongolia Autonomous Region, China (Li et al., 2015).
- There are two RadCalNet sites within the region, with BTCN at [40.8514°N, 109.6292°E] and BSCN at [40.8658°N, 109.6155°E].
- The aim of RadCalNet is to provide consistent top-of-atmosphere (TOA) reflectance products over several sites across the World to users through a common online portal (www.radcalnet.org/)

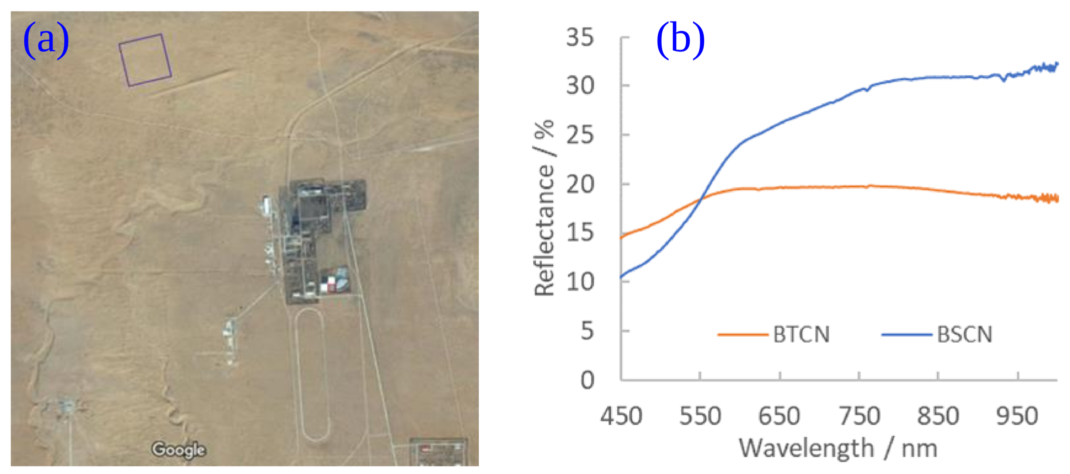

Figure 1. (a) The satellite image of the Baotou site; (b) the reflectance of BTCN and BSCN sites.

Site Instrumentation for RadCalNet

a) At the Baotou site, the surface reflected radiance is measured by a CR-250 spectrometer which covers the spectral region from 380 nm to 1080 nm, with a spectral resolution of 2 nm.
b) The spectrometers have nominally a 3° field of view and are mounted at a height of 2.5 m (BSCN) or 2.0 m (BTCN) , which observe the ground at nadir every 2 min.
c) Aerosol and water vapor content atmospheric parameters are obtained from the AERONET sun photometer, and an all sky imager has been also deployed at the Baotou site.
d) The spectrometers were calibrated traceably to SI at NIM.

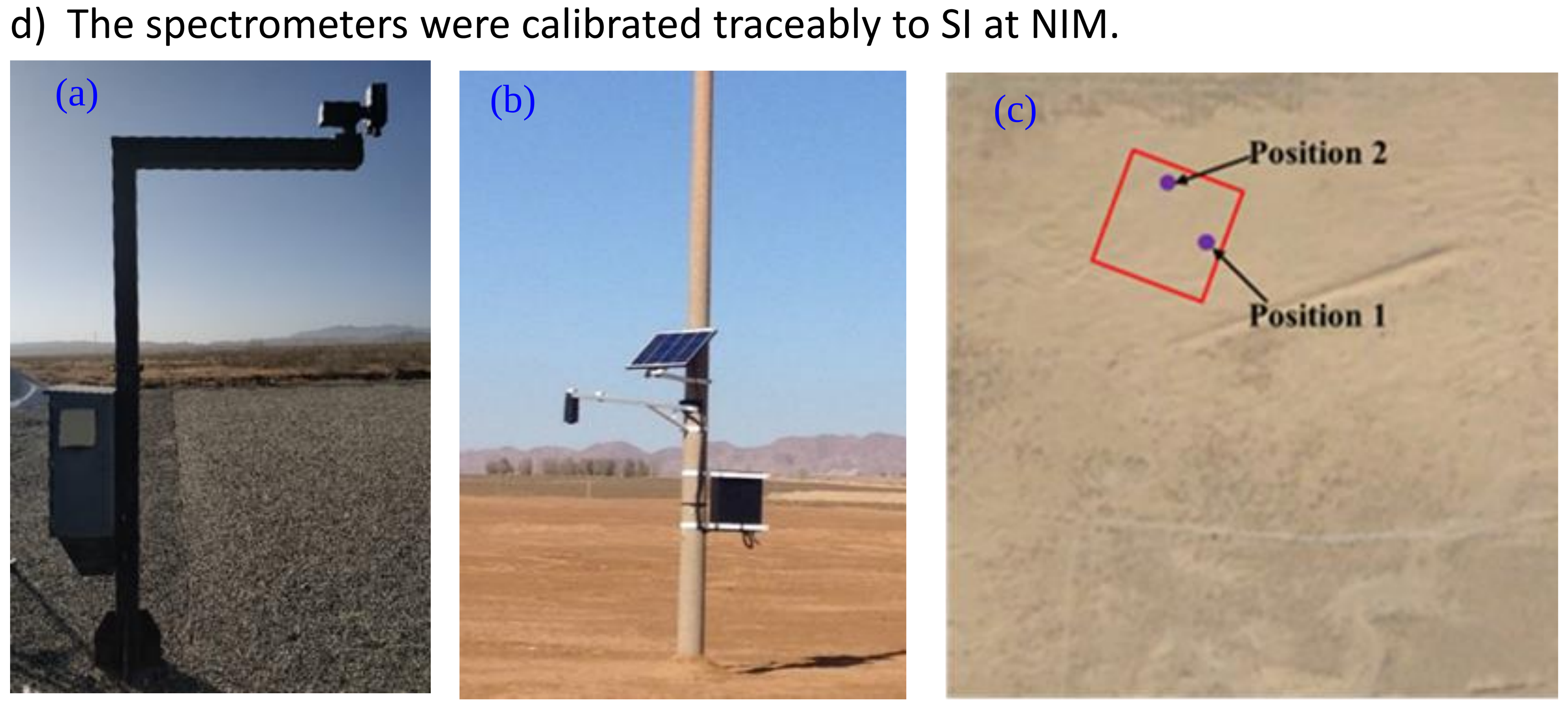

Figure 2. Automatic observation systems of ground reflected radiance in the Baotou site. (a) Observation system on grey target; (b) observation system on sandy site; (c) the positions of the two spectrometers on sandy site.

A Metrological Approach

To convert the observed radiance into reflectance, and to propagate reflectance to TOA, atmospheric radiative transfer must be considered. Figure 3 gives a simplified (ignoring multiple scattering) visualization of the relevant light paths.

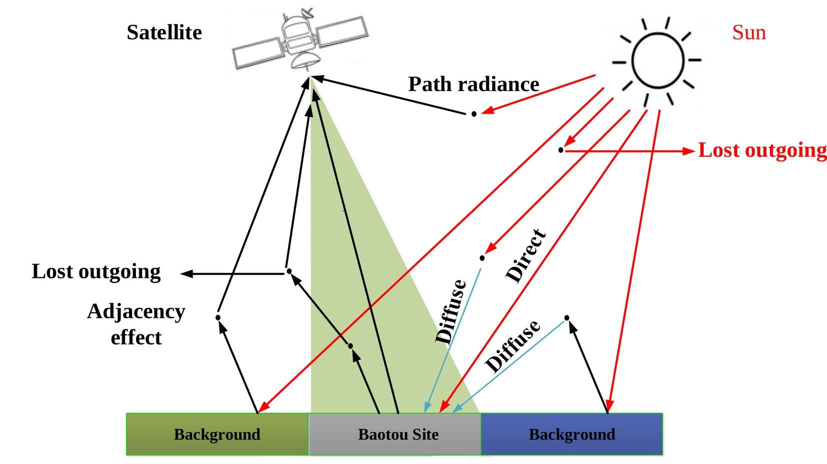

Figure 3. Light paths for radiation from the site

The uncertainty tree diagram was used to show the sources of uncertainty that affect the Baotou measurements of ground spectral reflectance.

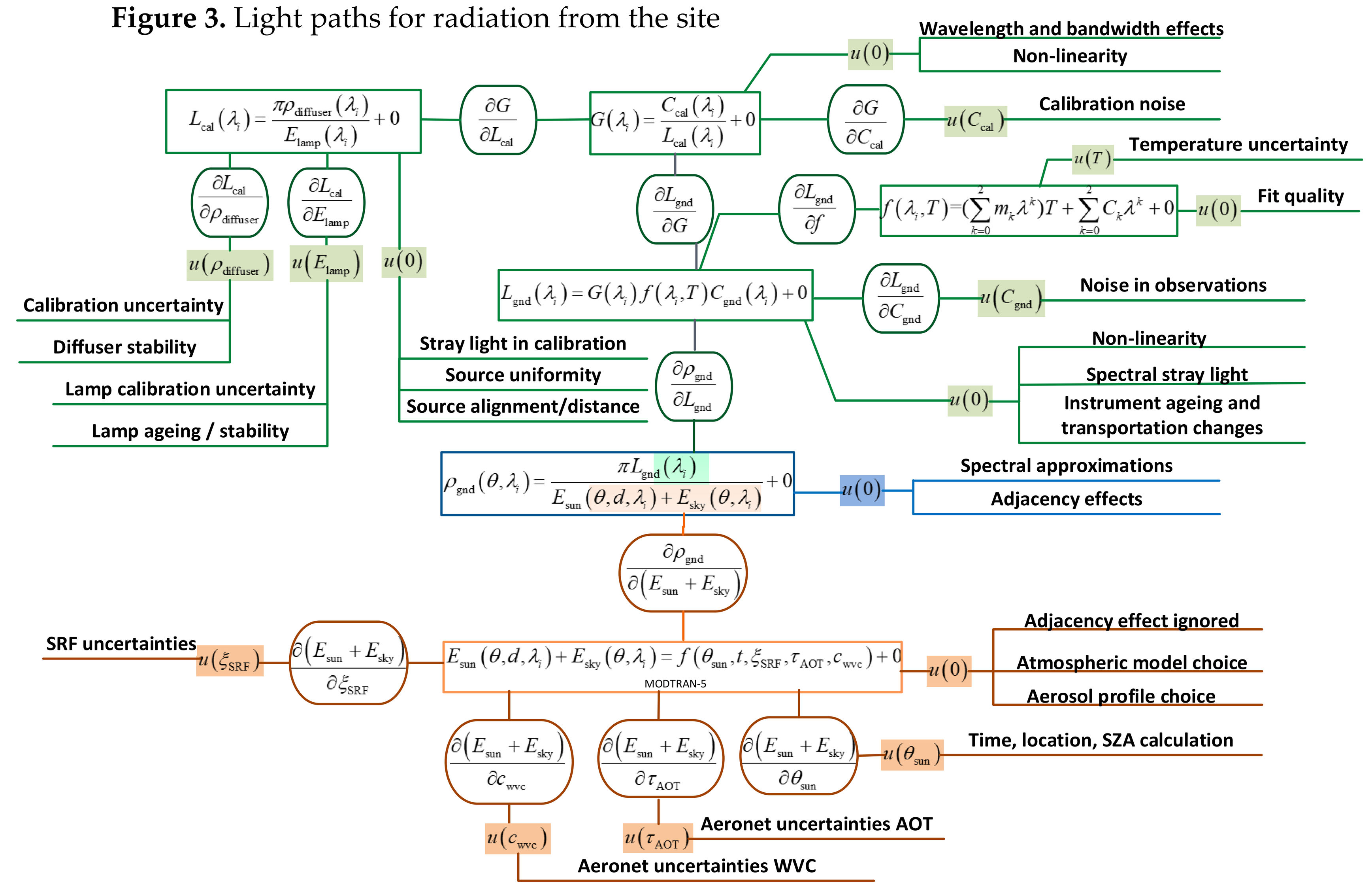

Figure 4. Uncertainty tree diagram for the Baotou measurements of ground spectral reflectance.

Recommendations for the workshop

- As satellite uncertainties improve, ground reference sites need higher quality links to SI and robust uncertainty budgets.
- A metrological approach supports the development of robust uncertainty budgets and collaborations between metrology institutes and the EO community are beneficial.
- Work is needed to develop uncertainty analysis for combining multiple comparisons and for trend analysis.

Conclusions

- An example of a metrological uncertainty analysis for a RadCalNet site was shown in this poster, and the determination of ground reflectance and TOA reflectance for the Baotou BTCN and BSCN sites was described. The RadCalNet TOA reflectance product can be well used for the satellite calibration with comprehensive uncertainty budget.
- For the first time, we considered the error correlation structures for each uncertainty component within the uncertainty transfer chain of Baotou BOA and TOA reflectance.
- The uncertainties of the official RadCalNet TOA product for BTCN and BSCN are estimated to be approximately 7 % and 4 %–5 %, respectively. The uncertainty will be reduced when the influence of adjacency effects considered to be eliminated

Results: Uncertainty Budget

① Laboratory calibration of field spectrometer

Spectral Calibration and radiometric calibration of the spectrometers used at BTCN and BSCN were carried out using a mercury line source and a lamp illuminated diffuser panel in NIM, respectively.

- ✓ **Spectral calibration**
- ✓ **Lamp-diffuser panel radiance source**
- ✓ **Spectrometer noise during calibration**
- ✓ **Source non-uniformity**
- ✓ **Spectrometer nonlinearity、dark signal, external and internal stray light, et al.**

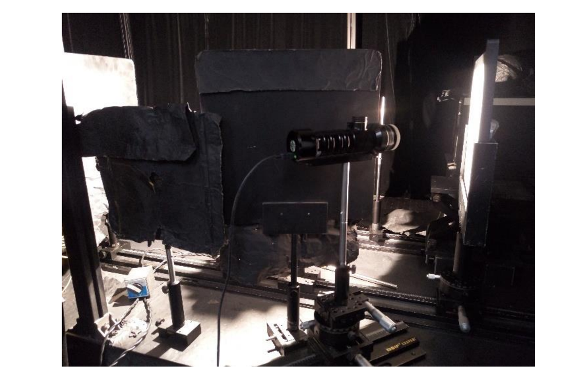

Figure 5. Lamp-diffuser panel radiance source

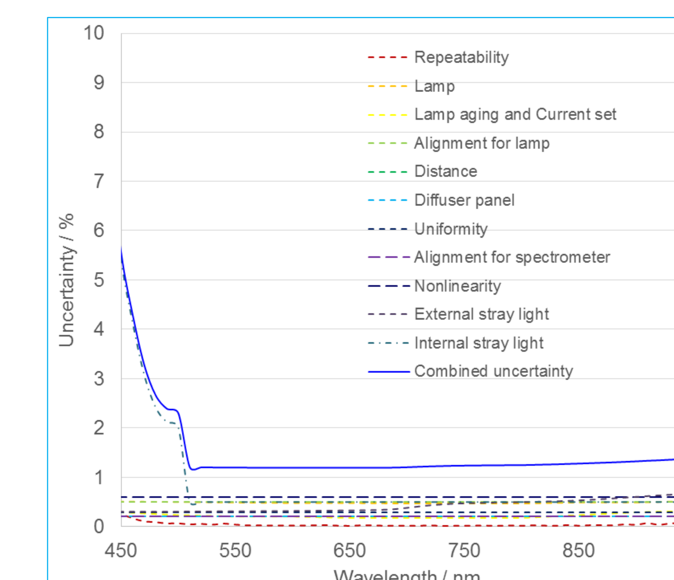

Figure 6. The uncertainty associated with laboratory calibration

② Field measurement of radiance

- **Spectrometer temperature stability**: temperature sensitivity tests were performed using a thermal chamber while the instrument viewed a stable radiance source. **A gain correction equation** was determined for the site through fitting to experimental data.

$$f(\lambda;T) = (m_0 + m_1\lambda + m_2\lambda^2)T + (c_0 + c_1\lambda + c_2\lambda^2)$$

- **Noise during field measurements**
- **Spectrometer stability**

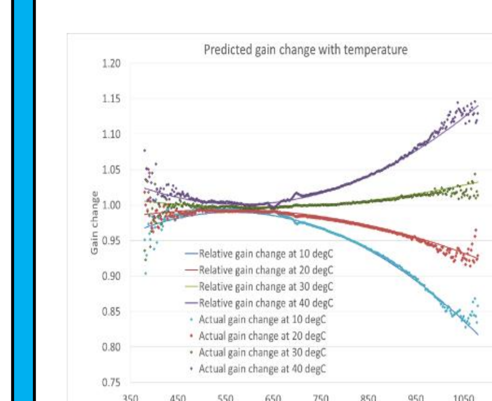

Figure 7. Predicted gain change with temperature

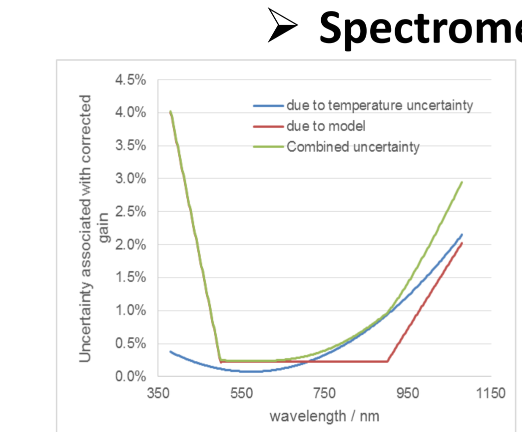

Figure 8. The uncertainty associated with temperature correction

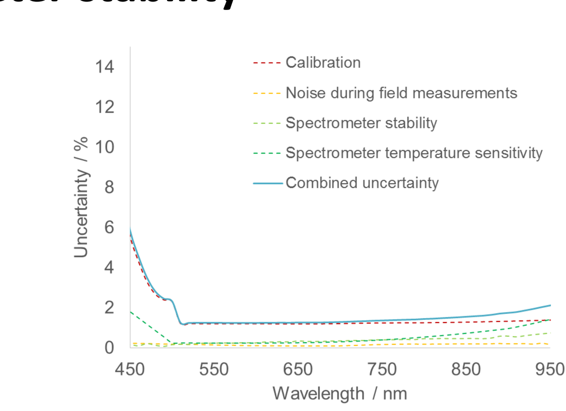

Figure 9. The uncertainty associated with field measurement of radiance

③ Field measurement of ground reflectance

Monte Carlo analysis techniques were used to determine the sensitivity analysis of MODTRAN-5 to atmospheric conditions.

Uncertainty sources:

- ✓ Reflected radiance
- ✓ AOT@550nm and CWV
- ✓ Aerosol type (rural vs. desert)
- ✓ Solar irradiance
- ✓ MODTRAN model
- ✓ Other sources：field environment…

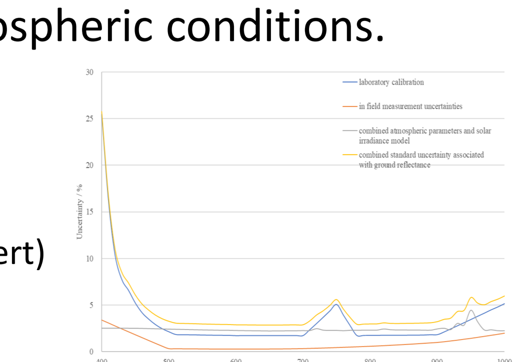

Figure 10. The combined uncertainty associated with ground reflectance.

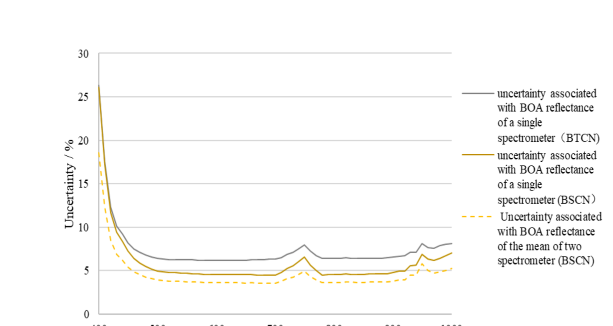

Figure 11. Uncertainty associated with the BOA reflectance.

④ Uncertainty Associated with Propagation to TOA

- This propagation to top of atmosphere is performed using MODTRAN-5.
- To determine the uncertainty associated with propagation to TOA reflectance, Monte Carlo analysis method was used.

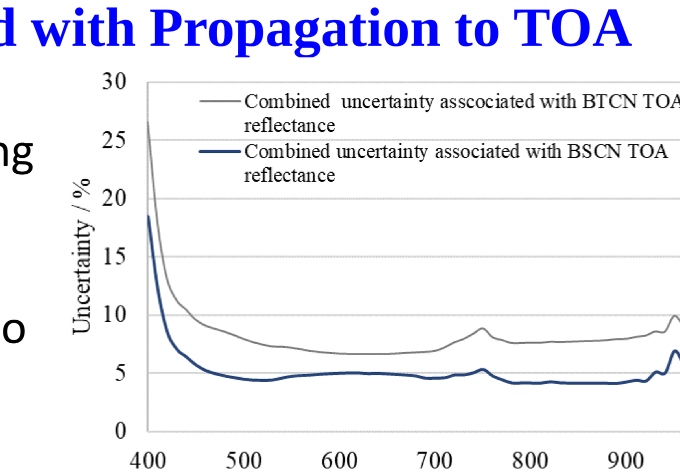

Figure 12. Uncertainty associated with the TOA reflectance.

Reference

[1] Ma L , Wang N , Liu Y , et al. An In-Flight Radiometric Calibration Method Considering Adjacency Effects for High-Resolution Optical Sensors Over Artificial Targets[J]. IEEE Transactions on Geoscience and Remote Sensing, 2021, PP(99):1-13.
[2] Ma L , Zhao Y , Woolliams E R , et al. Uncertainty Analysis for RadCalNet Instrumented Test Sites Using the Baotou Sites BTCN and BSCN as Examples[J]. Remote Sensing, 2020, 12(11):1696.
[3] Bouvet, M.; Thome, K.; Berthelot, B.; Bialek, A.; Czapla Myers, J.; Fox, N.P.; Goryl, P.; Henry, P.; Ma, L.; Marcq, S.; et al. RadCalNet: A Radiometric Calibration Network for Earth Observing Imagers Operating in the Visible to Shortwave Infrared Spectral Range. Remote Sens. 2019, 11, 2401.