Tuz Gölü site Characteristics

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1. Introduction

An international team of remote sensing calibration experts, representing space agencies from 10 different countries, conducted a two week field campaign at Tuz Golu, Turkey in August, 2010 sponsored by the Committee on Earth Observation Satellites (CEOS). While the campaign focused on surface reflectance factor measurement, five specific CEOS objectives were being addressed: evaluating differences in field instrument primary calibrations, evaluating difference in field characterization methodologies and possible establishment of best practices, perform a multi-sensor absolute calibration comparison, identification of minimum and ideal instrumentation / characterization for use as a reference standard, and formal characterization of the Tuz Gölü absolute calibration site. This paper will focus on the latter component. An evaluation of the temporal, spatial and directional dependencies of the surface reflectance of the Tuz Gölü salt flat will be presented. Also, an evaluation of the optical atmospheric stability of the site was conducted.

2. Field Reflectance Characterization

A scouting team from Tubitak Uzay identified a section of the dry Tuz Gölü salt lake that offered good overall spectral uniformity and ease of access. The location was then divided into nine measurement sites, eight 300 x 100 meters in size and one larger 1000 x 1000 meter site as seen in Figure 1. Each site was measured multiple times over 9 days, by multiple groups working as independent teams. The salt flat is highly reflective in the visual wavelengths (nearly 60%) but drops off in reflectance in the short wave infrared (less than 10%) as shown in Figure 2. Each team was tasked with measuring one of the 9 sites each day, with the desire for each team to measure all nine sites over the course of the nine day campaign. This, in turn,

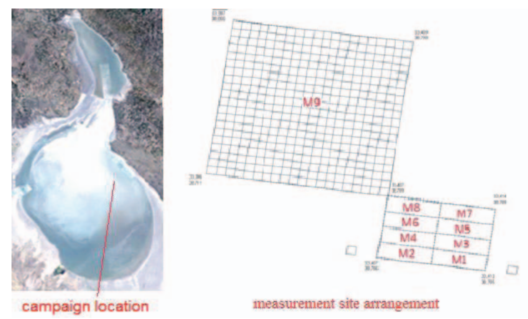

Figure 1: Tuz Gölü site location

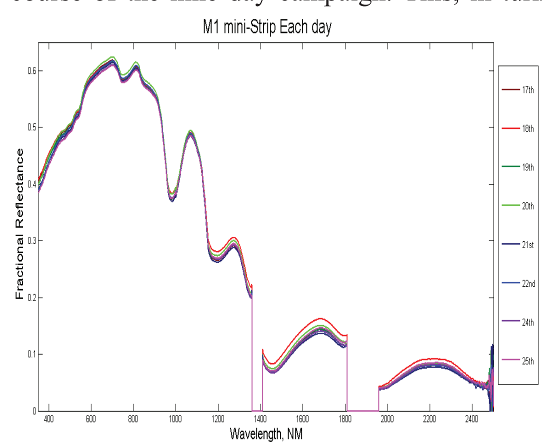

Figure 2: Tuz Gölü Absolute Reflectance

provided a wealth of data to evaluate the temporal and spatial reflectance variability of the site.

One such set of measurements made by the team from South Dakota State University also consisted of the repeated measurement of a 30 x 5 meter mini-strip just to the south of the M1 site. The measurements where completed 8 of the 9 days at exactly the same time and location each day. The measurement scheme involved the taking of 30 spectra "in motion". The purpose of these measurements was to get a better understanding of the surface variability, by removing as many variables as possible, such as atmospheric and solar illumination changes. The means of each day as it differed from the overall average is seen in Figure 3. The standard deviation of the daily means of all the data taken over this M1 mini-strip (shown as dotted lines) is under +/- 0.01. When taken in consideration that some of this deviation comes from the repeatability error of taking the data, the M1 site shows remarkable stability over the 9 day campaign.

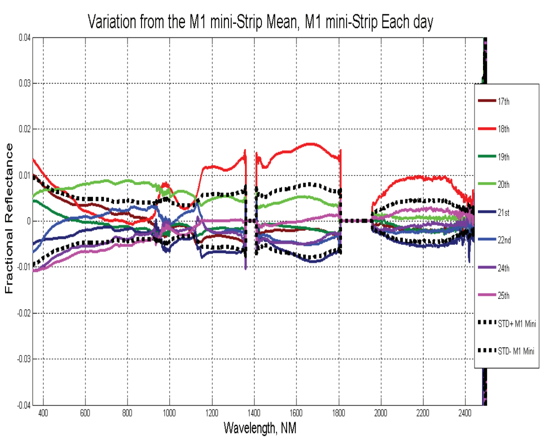

Figure 3: Tuz Gölü Reflectance M1 Variation

3. BRF effects

NPL operated the GRASS (Gonio-Radiometric Spectrometer System) [1] to determine the Bidirectional Reflectance Factor (BRF) effects of Tuz Gölü reference test site at two locations near the sampled sites. The BRF measurements were performed in the timeframe of the satellite overpasses to be used as input to the Radioactive Transfer Code in the vicarious calibration process, where a full sequence of measurements at viewing angles: 10º, 20º, 30º takes 10 minutes. The spectrometer used with the goniometer system operated over the spectral range 400-1300 nm. In addition, BRF measurements were recorded during one night using a floodlight supplied by ONERA to record the BRF effects of the site under constant illumination conditions.

The results show that there are dramatic changes in BRF for small changes in solar zenith angle of approximately 0.25 reflectance factor at 650nm over a 30 degree change in measurement angle, as seen in figure 4. This could be the result of

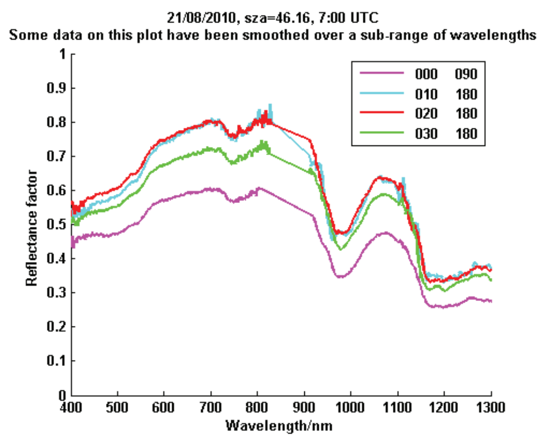

Figure 4: Tuz Gölü BRDF measurements

the surface structure of the salt flat.

4. Spatial Uniformity Characterization

Spatial uniformity of reflectance is one of the most important aspects of an absolute calibration site. Uniformity not only reduces the number of measurements needed but also reduces the error resulting from interpolation or averaging. One method to assess the uniformity is to calculate the first and second order statistics of a collection of points within a measurement area. This gives a model for the reflectance uncertainty if the area is represented as a flat surface with the reflectance equal to the sample mean. An example of the results obtained is shown in Figure 2.

The data taken by the SDSU team over the course of the campaign was examined. These sets were used due to the spatial and temporal coverage of the data. The data covered M sites 1-6 and 8, and was taken between 10:50 – 12:00 local time over 9 days. The measurements including taking 100 spectra "in motion" along four transects, resulting in 400 spectra. The mean of this data is plotted as its difference from the mean of the M1 mini-strip. We can see that the M1 mini-strip is a bit higher in reflectance than other areas studied. Also note that the overall standard deviation of

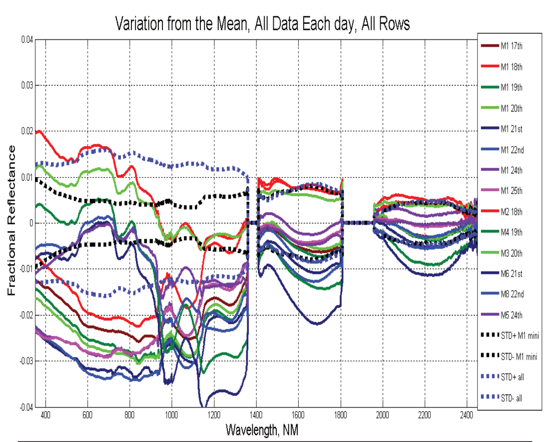

Figure 5: Tuz Gölü Reflectance Variation

the means of all the sites collected (dotted blue lines) only marginally increases in the shortwave lengths to a value below 0.02 reflectance units, while still maintaining a value less than 0.01 in the longer wavelengths, as seen in figure 5.

This demonstrates that with a well devised sampling strategy, by measuring a small representative mini strip that you could approximate a reflectance factor for a larger foot print site, and potentially be within +/- 0.02 reflectance factors of the mean.

5. Atmosphere Optical Characterization

When doing a proper absolute calibration of a sensor, understanding the optical characteristics of the atmosphere is as critical as the knowledge of the surface reflectance. For this reason, a preliminary study of atmospheric stability was made, using a Cimel Automatic Sun Tracking Photometer provided by Tubitak Uzay in conjunction with Yankee Inc. Multi-Filter Rotating Shadow Band Radiometer (MFR) provided by SDSU. Data from the Cimel does show larger than expected variation in both the day to day and within day measurements. Similar results were demonstrated with the measurements taken with the MFR. Figure 6 shows higher atmospheric aerosol optical thickness (AOT) during the earlier part of campaign interval than expected ranging from 0.5 to 0.65 for the shorter 340 nm wavelengths. Also it shows substantial changes in AOT halfway through the campaign, dropping to between 0.15 and 0.3. The impacts of having an AOT that ranges from 0.65 to 0.15 for 380nm is the transmittance of the atmosphere ranges from 0.52 to 0.86. This clearly demonstrates the need for coincident measurements of the atmosphere at the time of overpass.

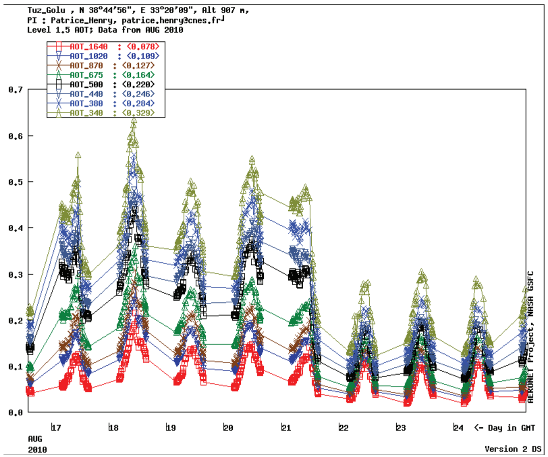

Figure 6: AOT loading during the campaign

In comparison a site used in Brookings, SD during the entire month of August, varies from 0.4 to 0.1, and has an average of 0.15 at 380nm. This results in a change in the transmittance of the atmosphere at 380nm between 0.67 and .90. Another site near Algodones Dunes in southwestern part of the USA has an AOT at 380nm varying from 0.2 to 0.05, or a transmittance value of 0.82 to 0.95.

6. Conclusion

The Tuz Gölü site does demonstrate some challenges for being used as an absolute calibration site. These include: spatial and temporal variability on the order of +/- 0.02, atmospheric transmittance variability on the order of between 0.52 and 0.86 at 380 nm, lower spectral reflectance levels of less than 0.10 in the longer wavelengths, and limitations on the site availability (only two month period in summer). But, with each successful campaign made at this location, these challenges are being overcome and site characteristics have become better understood and techniques for compensation are being devised. With proper techniques, instrumentation, and coincident data collection this site remains a viable candidate as a vicarious calibration site for optical imaging sensors.

[1] [Pegrum-Browning, H.M., Fox, N. and Milton, E. The NPL Gonio Radiometric Spectrometer System (GRASS), in Proceedings of the Remote Sensing and Photogrammetry Society Conference, University of Exeter 15-17 September 2008.