TUZ GÖLÜ: NEW ABSOLUTE RADIOMETRIC CALIBRATION TEST SITE

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ABSTRACT:

Calibration, absolute radiometric calibration in specific, is an important process for continuity and reliability of optical satellite data, since it puts the data on a standard scale and makes it compatible and comparable with the data acquired from different sensors. Therefore, the importance of performing a calibration campaign increased significantly. Being aware of this significance, TUBITAK UZAY (Space Technologies Research Institute, The Scientific and Technological Research Council of Turkey), by taking advantage of having such a suitable site in the country, decided to establish a new absolute radiometric calibration test site on Tuz Gölü (Salt Lake) for the calibration and validation requirements of cal/val community in general and of the country, specifically. In order to evaluate the usability of the site and determine the most usable area, we first compiled a list of properties that a calibration/validation test site should have. We have seen that Tuz Gölü fulfils most of those requirements. Later, we performed homogeneity analysis using Getis Statistics on MODIS satellite images of July and August 2004-2007. As a result of analysis, we obtained approximate usable area to be 324.026 km^2. We also observed that, the longer duration the region is covered with water, the more homogeneous it is. The site will be visited annually and further analysis and field studies will be conducted. The test site is considered to be useful to scientists all over the world.

1. INTRODUCTION

Calibration is an important process for continuity, reliability and, hence, widespread use of satellite images from different sensors for earth observation applications. Although calibration has been performed before launch in most cases, on-orbit calibration should be done especially for the stable radiometric calibration which plays a critical role in consistent long period data analysis, because the characteristics of camera electronics, optics and detectors can shift over time. Absolute radiometric calibration puts the data on a standard scale and makes it compatible and comparable with the data acquired from different sensors.

For absolute radiometric calibration reflectance-, irradiance-, and radiance-based techniques were developed at the University of Arizona in late 1980s. The main advantage of these methods is that they provide another effective way of calibration in addition to preflight and onboard calibration methods.

The reflectance based technique known as vicarious calibration depends on measurements of the surface reflectance of a test site at the time of sensor overpass. Therefore; scene acquisition time and satellite attitude should be determined for the satellite for the specific test field. At the same time of the scene acquisition, ground data collection is performed by field spectrometers and atmospheric parameters are measured to obtain reflectance, BRDF, aerosol loading, aerosol size distribution, column ozone, column water vapor etc. From these measurements top of the atmosphere radiance at the sensor within its spectral bands are computed. Sensor DN values and at-sensor-radiance is then used to calculate radiometric calibration parameters.

Up to date, many such test campaigns in different regions were held and the requirements of this process were reported in the literature. Especially CEOS (Committee on Earth Observation Satellites) WGCV (Working Group on Calibration and Validation) listed out the requirements and started for the standardization studies (best practices) of calibration test sites including characterization, methodology, and instrumentation to be helpful to the cal/val researchers. Also, USGS prepared a catalogue of World-wide test sites for sensor characterization (Chander, 2008) and (Goryl, and Danne, 2008) introduced cal/val portal which is also very useful for the cal/val community.

In this article, a study towards establishing a new absolute radiometric calibration test site, Tuz Gölü, specifically, initial studies done to assess its usability is presented. Firstly site selection criteria will be mentioned in Section 2. General information about Tuz Gölü and its characteristics will be evaluated as mentioned in the key properties list of CEOS WGCV template, in Section 3. In Section 4, the analysis of homogeneity, an important criteria for determining the test site on the lake, will be given. Homogeneity analysis, also taking into consideration monthly water coverage, will be presented. Finally, conclusions will be given in the last section.

2. SITE SELECTION CRITERIA

Considering test site selection criteria stated by cal/val community up to date (Morain, and Budge, 2004; Teillet et. al., 2007; Thome, 2002; Scott et. al., 1996), the following list has been compiled:

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1. A high-reflectance results in higher signal-to-noise ratio (SNR) which, in return, increases overall accuracy.
2. The higher the spatial uniformity of the area, the lesser the effects of generalizing the reflectance data to the size of the full test site.
3. Spectral uniformity of the site eases the calibration procedure.
4. Temporal uniformity of the site eases the calibration procedure.
5. The site should have little or no vegetation that can deteriorate spectral and temporal uniformity.
6. Higher elevation reduces the error due to aerosols.
7. A Lambertian site surface is preferable since it decreases errors caused by different solar and view geometry.
8. High probability of cloud free days provides more time for calibration studies.
9. A longer distance to densely populated areas and/or industrial facilities decreases the effect of anthropogenic aerosols.
10. A location far from the seas or other large water bodies minimizes the influence of atmospheric water vapor.
11. Having a site in an arid region minimizes probability of precipitation and this in turn may change the surface BRDF. Also, in arid regions, the probability of a cloudy weather is minimum.
12. Having a large site minimizes the unwanted effects of scattering of light from areas outside the target area.
13. Easy access to the site is an advantage.
14. Instrumented test sites are preferable.

In line with the criteria listed above, generally deserts and salt lakes are preferable radiometric calibration sites. The Railroad Valley in Nevada, USA, the La Crau test site in France, Ivanpah Playa in Nevada, USA, White Sands Missile Range in New Mexico, USA, Lake Frome in Australia, Uyuni Salt Flats in Bolivia are among such sites.

3. TUZ GÖLÜ

In this section, while presenting the information about Tuz Gölü test site, CEOS WGCV template for cal/val sites will be taken as a guideline.

Core Site / Description of the Site:

Tuz Gölü, a permanent endorheic lake, is located in the arid central plateau of Turkey in Central Anatolia (Figure 1). Being a natural reserve area, the site is a salt flat at an elevation of 905 m above the sea level. The evaporates are mainly halite and gypsum, with minor amounts of polyhalite and coelestine (Camur, et al., 1996). There is virtually no vegetation in the salt flat but it is surrounded by arable fields and salt-steppes. There are salt mines and saltwork pools operating at the margins of the lake.

The suitable area selection analysis was conducted by using the MODIS (LPDAAC, 2007) satellite images of July and August (2004-2006), which is the most suitable period for the site, for calibration studies. In Figure 2, the red region is 324.026 km^2 and illustrates available homogenous area throughout July-August. The yellow region has an area of 195.092 km^2 and gives an idea about regions which are likely to be dry, in July-August period. Thanks to the large size of the area, the lake can be used for calibration/validation of satellites with sensors from low to high resolution. The method used for determining the usable area is described in the next section.

Figure 1: Location map of Tuz Gölü salt lake, Turkey on Europe Map (Map courtesy of www.map-of-europe.us/, image courtesy of GLCF).

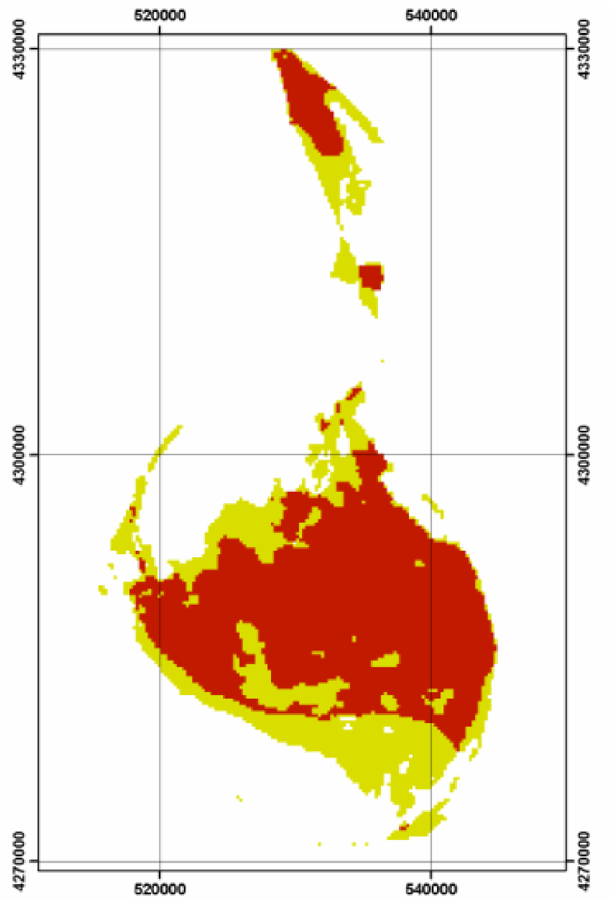

Figure 2: Suitable area for calibration.

These regions were visited during our first field study on September, 2007 (Figure 3).

Figure 3: A view from a homogeneous region on the lake.

Current Status of the Site:

TUBITAK UZAY will be organizing field campaigns at Tuz Gölü during summer period each year. Site will be temporarily instrumented during campaigns. The maintenance of the site is funded by TUBITAK and the first campaign is planned to be held during August 2008.

4. HOMOGENEITY ANALYSIS

As mentioned previously, spatial homogeneity is one of the important criteria, having influence on the accuracy of the absolute calibration results. Homogeneity of the area, which can change over time, affects the site selection and also usability of the area. Therefore, a special focus on homogeneity will be given in this section.

For homogeneity analysis, the spatial autocorrelation, the degree of dependence between the pixels digital numbers associated with the pixel coordinate is used (Bannari et al., 2005). The clustering of similar digital numbers denotes positive autocorrelation while neighborhood of dissimilar values denotes negative autocorrelation. Global or local statistics are used to measure spatial autocorrelation. Getis statistics (Getis and Ord, 1992) is used as a local indicator which is an example of the local indicators of spatial association (LISA) (Bannari et al., 2005).

The statistics $G_i^*(d)$ for some chessboard distance (Gonzalez, 2002) d is defined as (Wulder and Boots, 1998):

$$G_i^*(d) = \frac{\sum_j w_{ij}(d)x_j}{\sum_j x_j} \qquad (1)$$

where $w_{ij}(d)$ = a spatial weight matrix

x_j = digital number attributed to the pixel location index j

i = target pixel location index

Let's define a set A, which contains the location indices of pixels which are within the chessboard distance d to the target pixel location i. For example if we choose all eight neighboring pixels ($d = 1$), this means A has nine elements including location index i. So;

If $j \in A$; $w_{ij} = 1$

Otherwise, $w_{ij} = 0$

Therefore; Equation (1) gives the ratio of the sum of the weighted DNs within the set of A to the sum of the DNs for the entire image (Wulder and Boots, 1998).

In the context of application to remote sensing digital images, a standard version of $G_i^*(d)$ is used by calculation of Z score standardized form [*].

(Bannari et al., 2005) used the following standardized formula obtained from Z score formula, to evaluate the homogeneity in Lunar Lake Playa, Nevada calibration test site.

$$G_i^*(d) = \frac{\sum_j w_{ij}(d)x_j - W_i * \bar{x}}{s\left[W_i * (n - W_i*)/(n-1)\right]^{1/2}} \qquad (2)$$

where $W_i* = \sum_j w_{ij}(d)$

$$\bar{x} = \frac{\sum_j x_j}{n}$$

$$s^2 = \frac{\sum_j x_j^{\,2}}{(n - (\bar{x})^2)}$$

The Getis Statistics, explained above, is conducted on Tuz Gölü calibration test site for homogeneity analysis using the NIR band of MODIS (LPDAAC, 2007) image taken on 20.07.2007 and d is taken as unity.

The resultant image showing Tuz Gölü homogeneity, calculated using Getis Statistics, is given in Figure 4. According to this statistics, if the target pixel and its neighborhood pixels have similar high values, Getis statistics gives a high value. If the target pixel and its neighborhood pixels have similar low values Getis statistics gives a low value (Wulder and Boots, 1998). Therefore; from the results, it is clear that there is a large

[*] Z score standardization is: $z = \frac{x - \mu}{\tau}$ where μ is the mean of x and τ is standard deviation of x.

homogenous area with high reflectance for absolute radiometric calibration.

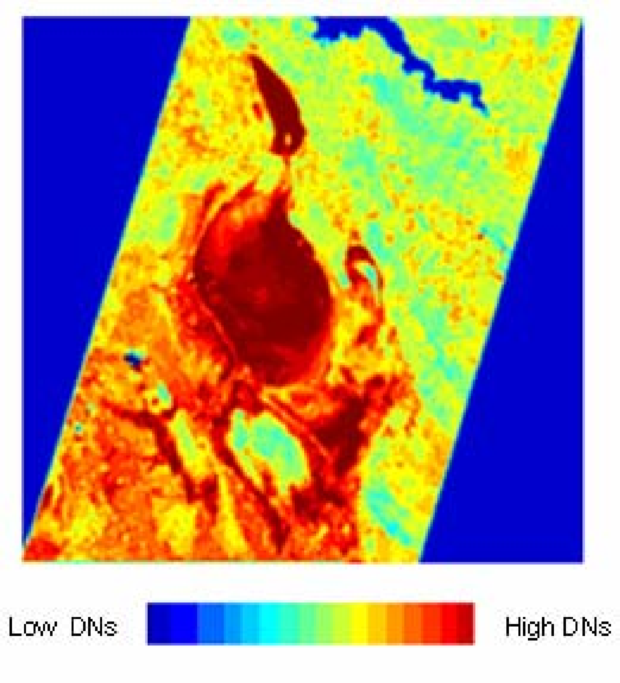

Figure 4: Getis statistics of MODIS (July, 2007), Band 2

Since water coverage of the lake changes along the year, we also performed some analysis to have an idea on how these changes affect the homogeneity of the area. If there is a relation between duration that the region is covered with water along the year and its homogeneity index, this may give us information about site homogeneity for the coming years. Therefore; firstly the regions that was covered with water with a duration ranging from 2 months to 8 months (Figure 5), was obtained using MODIS images (LPDAAC, 2007). Then for each region we calculated mean values attained to that area obtained from Getis statistics for July, 2007. Lastly, we looked at the correlation between the homogeneity index and the duration that region covered with water. Pearson's linear correlation coefficient, the measure of correlation valued between -1 and 1, was calculated as 0.9733 which means that there is a positive linear relation between two variables. Figure 6 shows the linear relationship given as follows:

$$y = 0.013.x + 0.087 \qquad (3)$$

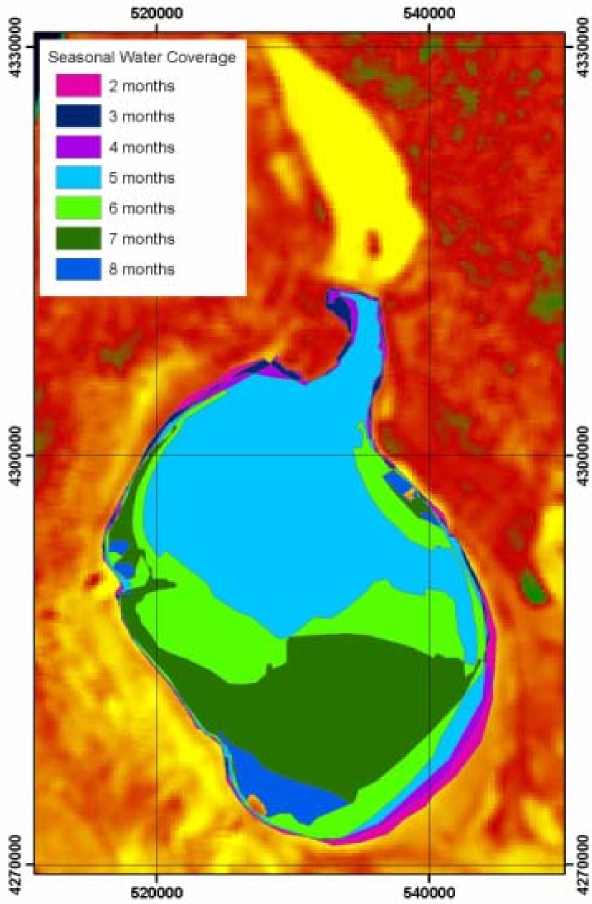

Figure 5: Seasonal water coverage in the year 2007

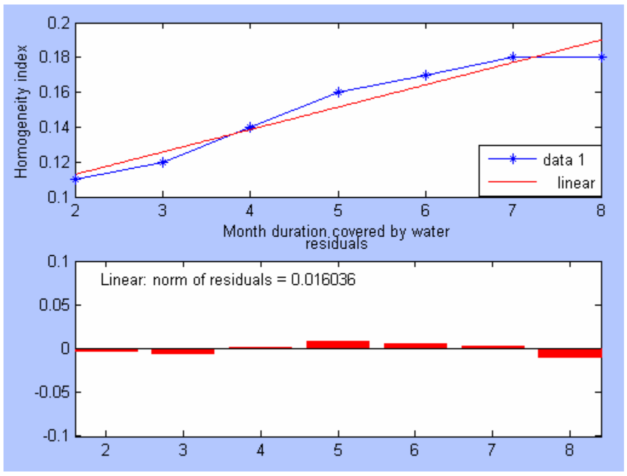

Figure 6: Homogeneity index relation with month duration covered by water

5. CONCLUSIONS

In this study, the suitability of Tuz Gölü as an absolute calibration/validation site for optical imagers of satellites has been evaluated. The results obtained are very promising.

Especially, the large extent of the spectrally homogenous region, high reflectance of the homogenous region, high accessibility and high elevation of the region are among the most salient features. We believe that, especially European users will find it very handy because of ease of access.

During the analysis, an interesting thing we observed was that, the longer a region is covered with water, the more homogenous it is. That phenomenon can be explained with homogenous distribution of salt with water. The studies including detailed field tests and analysis will be conducted annually and the site will be maintained in future.

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