COMPARISON OF RADIOMETRIC GAIN OF OPTICAL SATELLITE SENSORS USING TUZ GOLU RADIOMETRICALLY CALIBRATED TEST SITE

H. Özen[1]*, N. Fox*[2]*, A. Deadman*[2]*, I. Behnert*[2]*, P.Harris*[2]*, S. Gürbüz*[1]*, L. Yuan*[3]*, D. Griffith*[4]*, M. Kaewmanee*[5]*, A. Prakobya*[5]*, C. Musana*[5]*, F. Ponzoni*[6]*, D. Lee*[7]*, Y. Lee*[7]*, Y. Boucher*[8]*, F. Viallefont*[8]*, P. Rolland*[8]*, D. Helder*[9]*, L. Leigh*[9]*, K. Thome*[10]*, S. Sterckx*[11]*, E. Knaeps*[11]*, D. Raeymaekers*[11] *and P. Henry*[12]

[1] *TUBITAK UZAY, METU Campus, 06531 Ankara, Turkey; (hilal.ozen, sevgi.gurbuz)@uzay.tubitak.gov.tr*

[2] *NPL, TW11 0LW Teddington Middlesex, UK; (nigel.fox, andrew.deadman)@npl.co.uk*

[3] *CMA, No.46, Zhongguancun Nandajie, Haidian District, Beijing, China; liyuan@cma.gov.cn*

[4] *CSIR, Moreletta St, Silverton 0184, South Africa; dgriffith@csir.co.za*

[5] *GISTDA, Chaeng Wattana Road, Lak Si, Bangkok 10210, Thailand; (mkaewmanee, amornprk, chaichat)@eoc.gistda.or.th*

[6] *INPE, 12630-000 Cachoeira Paulista, Sao Paulo, Brazil; flavio@dsr.inpe.br*

[7] *KARI, 115 Gwahanno Yuseong Daejeon, Korea; (dglee, yhlee@kari.re.kr)*

[8] *ONERA, BP74025, 2 Avenue Edouard Belin, FR-31055 Toulouse, France; (yannick.boucher, francoise.viallefont, philippe.rolland)@onera.fr*

[9] *SDSU, Electrical Engineering, Brookings, SD 57007, USA; (dennis.helder, larry.leigh)@sdstate.edu*

[10] *NASA, Goddard Space Flight Center, Greenbelt, Maryland 20771, USA; kurtis.thome@nasa.gov*

[11] *VITO, Boeretang 200 BE-2400 MOL, Belgium; (sindy.sterckx, els.knaeps, dries.raymaekers)@vito.be*

[12] *CNES, 18 Avenue Edouard Belin, 31401 Toulouse, France; patrice.henry@cnes.fr*

Keywords: Remote Sensing, Satellite, Sensor, Calibration, Comparison

Pre-flight radiometric calibration is critical to ensure that sensors can demonstrate that they meet their design performance specification. However, following launch it is critical that this performance is verified and in particular that the radiometric accuracy is validated or if necessary corrected. As Earth observation data becomes widely used it becomes increasingly important that data from each satellite sensor can be relied upon in the short and longer term and any potential biases between sensors can be removed. This post-launch calibration/validation is thus recognized as a key activity by all satellite operators. There are various methods available for carrying out this post-launch vicarious calibration but one of the most common and generic approaches is to use a dedicated and characterised "test site". In such a method, ground based measurements of surface reflectance/radiance using similar solar illumination angles and sensor view angles (or at least corrected for these) is propagated to the top of the atmosphere (TOA) using a radiative transfer code. For the highest accuracy, surface measurements should be made within a few minutes of the satellite overpass and the characteristics of the atmosphere at that time also measured, particularly its optical depth.

The Tuz Gölü salt lake in Turkey (Fig. 1) is a LANDNET site [1, 2]. It is endorsed by CEOS as a standard reference site for radiometric calibration of optical satellite sensors. Tuz gölü is a salt lake located about 150 km. southeast from Ankara (38.50° N, 33.20° E). The Tuz Gölü basin is permanent endorheic in an arid plateau in Central Anatolia. It is a bright natural target, free of vegetation. It has an area of 1.964 km^2 and is 907 m above the sea level. It is extremely saline and during the summer up to 95% of water in the lake dries up and exposes an average of 30-80 cm thick salt layer. It is in a sparsely populated region with low aerosol content [3, 4]. The Tuz gölü salt lake test site is temporarily instrumented during field campaigns and is maintained by TUBITAK UZAY.

Figure 1. Location of Tuz Gölü salt lake LANDNET site

This paper will present the results of a cross comparison of satellite image derived values of TOA reflectance over the measurement site with those determined from the atmospheric propagated ground based measurements collectedduring the CEOS Land Comparison 13-27 August, 2010. Different sensors with different overpass times and different spatial and spectral characteristics collected on different days over the same site are directly compared. This analysis is based on an aggregated set of ground-based measurements (from 11 international teams) which included variations of sampling strategy, BRDF, atmospheric parameters and carried out following the principles of QA4EO [5, 6, 7] (Fig. 2).

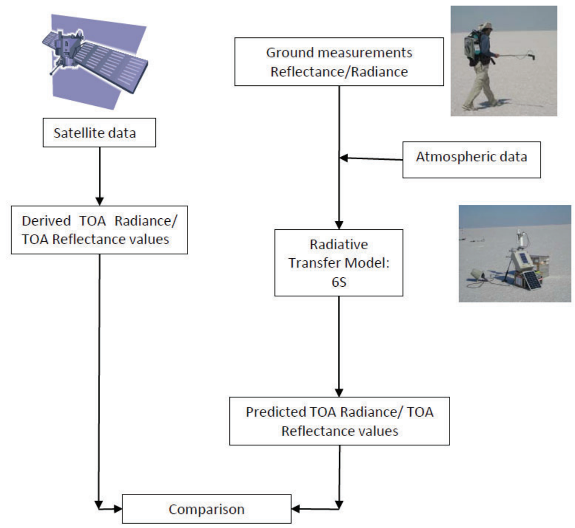

Figure 2. Flowchart representing the cross comparison methodology

1. METHODOLOGY

During the CEOS Land Comparison 2010, images from different optical sensors were acquired over the Tuz Gölü salt lake. These images were compared with the ground measurements taken during the CEOS Land Comparison 2010. The comparison methodology used is presented in the flowchart in Figure 2. Satellite images are acquired over the measurement site at Tuz Gölü test site at the same time the ground measurements are conducted (Fig. 3a). The TOA reflectances are derived from these images. The measurement site consists of eight areas of the size of 100 m x 300 m and an area of the size of 1 km x 1 km (Fig. 3b). These areas are measured by 11 different teams alternately [8]. For this study a mean value of the ground measurements is obtained over six areas of the size of 100 m x 300 m representing the measurement site as enclosed in red in Figure 3. Afterwards, TOA reflectances are simulated from ground measurement reflectance data together with the atmospheric data by running a radiative transfer code. In this analysis, the 6S (Second Simulation of a Satellite Signal in the Solar Spectrum) radiative transfer code is used [9]. Finally, the percent differences of the TOA reflectances are calculated for comparison.

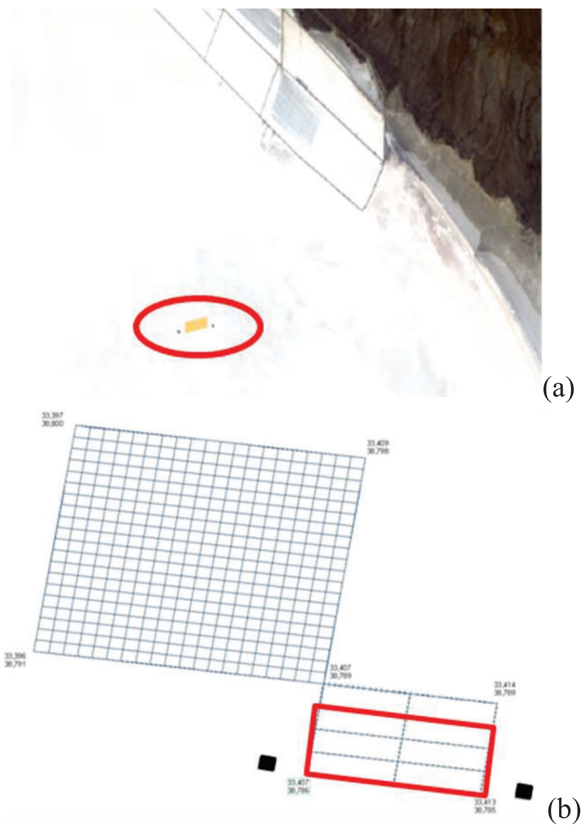

Figure 3. Representative measurement area of the site enclosed in red: a) on THEOS image acquired on August 19th, 2010; b) on map sketch with eight areas of the size of 100 m x 300 m, an area of the size of 1 km x 1km and two 50 m x 50 m tarpaulins

2. RESULTS

When comparing images from different sensors, there are three advantages to using TOA reflectance instead of TOA radiance [10]. First, it removes the cosine effect of different solar zenith angles due to the time difference between data acquisitions. Second, TOA reflectance compensates for different values of the exo-atmospheric solar irradiance arising from spectral band differences. Third, the TOA reflectance corrects for the variation in the Earth-Sun distance between different data acquisition dates. These variations can be significant geographically and temporally. Different sensors with different overpass times and different spatial and spectral characteristics acquired images of the Tuz Gölü site on different days during the CEOS Land Comparison 2010. Therefore, in this study TOA reflectances are compared instead of TOA radiances. The ground measurements are used to predict the TOA reflectance values and compare them with the TOA reflectances derived from satellite data.

The TOA reflectance percent differences calculated for ENVISAT MERIS, ALOS AVNIR-2, EO-1 ALI, LANDSAT 5 TM, LANDSAT 7 ETM, THEOS and DEIMOS-1 satellite images are summarized in Figure 4. The TOA reflectance average percent difference between most of the satellite images agreed within 10% for acquisitions over Tuz Gölü site in the blue, green, red and NIR range of the spectrum. These results are preliminary and some work is ongoing to refine and quantify potential uncertainties in the atmospheric code.

3. CONCLUSION

The CEOS Land Comparison 2010 was conducted on 13-27 August, 2010 with the international participation of 11 different scientific ground measurement teams at the Tuz

Gölü test site. Concurrent, satellite images were acquired over the measurement site. These satellite images are collected from different sensors with different overpass times and different spatial and spectral characteristics on different days over the Tuz Gölü site. This paper summarizes the preliminary results of the cross-comparison of the ground measurements that are used to predict the TOA reflectance values and the TOA reflectances derived from satellite data.

4. ACKNOWLEDGEMENT

Authors also thank the agencies that have contributed with satellite data for the cross-comparison study and supporting the participation of the measurement teams. Finally, we would like to thank ESA for financially supporting the organization and analysis of results of this work.

5. REFERENCES

[1] CAL/VAL Portal: http://calvalportal.ceos.org

[2] USGS Test Site Catalog: http://calval.cr.usgs.gov/satellite/sites_catalog/

[3] Gürol, S., H. Özen, U. M. Leloğlu and E. Tunalı, "Tuz Gölü: new absolute radiometric calibration test site", *ISPRS 2008*, Beijing, China, 03-11 July 2008.

[4] Gürol, S., I. Behnert, H. Özen, A. Deadman, N. Fox, U. M. Leloğlu and H. Pegrum-Browning "Tuz Gölü: new CEOS reference standard test site for infrared visible optical sensors", *Canadian Journal of Remote Sensing*, Vol. 36, No. 5, pp. 553-565, 2010.

[5] http://www.QA4EO.org

[6] Behnert, I., A. Deadman, N. Fox, P. Harris, H. Özen, L. Yuan, D. Griffith, M. Kaewmanee, A. Prakobya, C. Musana, F. Ponzoni, D. Lee, Y. Lee, Y. Boucher, F. Viallefont, P. Rolland, D. Helder, L. Leigh, S. Sterckx, E. Knaeps and D. Raeymaekers, "CEOS Key comparison of techniques and instruments used for the vicarious calibration of Land surface imaging through a ground reference standard test site 2010", *Quality Assurance Framework for Earth Observation (QA4EO) documentation*, National Physical Laboratory, UK, 2011.

[7] Özen, H., N. Fox and A. Deadman, "CEOS Comparison of Satellite Imagers Using Tuz Gölü as a Reference Standard 2010", *Quality Assurance Framework for Earth Observation (QA4EO) documentation*, National Physical Laboratory, UK, 2012 (draft).

[8] Özen, H., N. Fox, U. M. Leloğlu, I. Behnert and A. Deadman, "The Tuz Gölü Field Campaign - an overview", *IEEE IGARSS 2011*, Vancouver, Canada, 24-29 July 2011.

[9] Vermote, E. F., D. Tanré, J. L. Deuzé, M., Herman and J. J. Morcette, "Second simulation of the satellite signal in the solar spectrum, 6S: An overview", *IEEE Transactions on Geoscience and Remote Sensing*, 35(3), 675-686, 1997.

[10] Haque, O., A. Sampath and G. Chander, "Radiometric and Geometric Assessment of the Data from RapidEye Constellation of Satellites", *JACIE Meeting*, Sioux Falls, USA, March 16-18, 2010.