QA4EO-WGCV-IVO-CLP-XXX Draft

A procedure for establishing a "land-based" reference standard test-site

QA4EO-WGCV-IVO-CLP-XXX

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1 Abstract

This document describes the procedure that should be followed to establish a new "reference test site" for the calibration and validation of radiometric gain of a land surface imager. This procedure is written following the key guidelines of QA4EO (Quality Assurance Framework for Earth Observation) http:QA4EO.org. The procedure was established based on a consolidation of published "best practise" and tested using the Tuz Gölü site in Turkey as a case study. This procedure is applicable to "test sites" for sensors operating in the solar reflective spectral region (350-2500 nm) and includes all sensor scales - footprint and spatial resolutions.

2 Scope

There are many potential Earth targets that can be used as "reference sites" to support the post-launch radiometric calibration of space-based imagers in VNIR (visible and near infrared and SWIR (short wave infrared) regions of the spectrum, with more than 30 in regular usage[1]. However, recognising the need to prioritise within this number, whilst not seeking to limit the identification and establishment of new candidates, CEOS WGCV IVOS has established, and is currently refining criteria to categorise sites according to their suitability for particular applications. In particular, it has identified a set of eight, which are *"instrumented reference standard test sites"* with routine surface measurements and that it has called "Landnet":

- **Railroad Valley Playa**, NV, USA, North America
- **Ivanpah**, NV/CA, USA, North America
- **LSpec Frenchman Flat**, NV, USA, North America
- **La Crau**, France, Europe
- **Dunhuang**, Gobi Desert, Gansu Province, China, Asia
- **Negev**, Southern Israel, Asia

[1] Teillet P.M., Barsi J. A., Chander G., and Thome K. J., 2007. Prime Candidate Earths Targets for the Post-Launch Radiometric Calibration of Space-Based Optical Imaging Instruments, in Proceedings of SPIE, Vol 6677.

- **Tuz Gölü**, Central Anatolia, Turkey, Asia
- **Dome C**, Antarctica

It has also established a set of five "*pseudo invariant desert sites*" but these are not easily visited and so the procedure for their identification is different and not covered by all aspects of this document.

It is intended that the above CEOS endorsed "reference standard test-sites" will become the principle focus for calibration and validation of the international EO Cal/Val community. Ideally, CEOS requires at least ten instrumented sites. This procedure sets out a process for its "user" to identify and establish a "test site" that has the potential to be endorsed by CEOS.

The following broad selection criteria have been recommended [2] [3] [4] and accepted by the community and summarised below in Table 1. The evaluation of a potential site against these criteria forms the basis of this procedure.

Tuz Gölü, which is a relatively new reference site, is used throughout this procedure as a case study to illustrate the process.

Table 1: Cal/Val criteria used in the selection process of a new test site

Item number	Criteria
1	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.
2	A high-reflectance results in higher signal-to-noise ratio (SNR) that, in return, increases the overall accuracy.
3	Spectral uniformity of the site eases the calibration procedure.
4	Temporal uniformity of the site eases the calibration procedure.

[2] Morain S., and Budge M. A., 2004. *Post-Launch Calibration of Satellite Sensors,* ISPRS Book Series – Volume 2, pp.181-187.

[3] Thome, K., 2002. Paper on the ISPRS Commission I Mid-Term Symposium in conjunction with Pecora 15/Land Satellite Information IV Conference "Ground look radiometric calibration approaches for remote sensing imagers in the solar reflective", Denver, CO USA. http://www.isprs.org/commission1/proceedings02/paper/00039.pdf .

[4] Scott, K. P., Thome, K., Brownlee, M. R., 1996. Evaluation of the Railroad Valley playa for use in vicarious calibration. *Proceedings of SPIE*, vol. 2818, pp. 158-166.

5	A Lambertian site surface is preferable since it decreases errors caused by different solar and view geometry.
6	The site should have little or no vegetation that can deteriorate spectral and temporal uniformity.
7	Higher elevation reduces the error due to unknown aerosol vertical distribution and the aerosol loading is minimized; the aerosol loading is less critical for higher altitude.
8	High probability of cloud free days provides more time for the calibration studies.
9	A longer distance to densely populated areas and/or industrial facilities decreases the effect of anthropogenic absorbing aerosols.
10	A location far from the seas or other large water bodies minimizes the influence of atmospheric water vapour, which can be characterized by a high variability.
11	Having a large site minimizes the unwanted effects of scattering of light from the neighbouring area outside the target area.
12	Easy access to the site is an advantage for the measurement campaigns.
13	Instrumented test sites with routine measurements are preferable.

3 Terminology

The reflectance terminology that is in common usage within the EO community has been defined by Schaepman-Strub (2006)[5]. Some of the key terms used in this document are listed below:

BRF (Bidirectional Reflectance Factor): is given by the ratio of the reflected radiant flux from the surface area *dA* to the reflected radiant flux from an ideal and diffuse surface of the same area *dA* under identical view geometry and single direction illumination. The BRF can be expressed as π * BRDF.

[5] Schaepman-Strub G., Schaepman M.E., Painter T.H., Dangel S., and Martochik J.V. 2006. Reflectance quantities in optical remote sensing – definitions and case studies. Remote Sensing of Environment, 103, pp. 27-42

BRDF (Bidirectional Reflectance Distribution Function): describes the scattering of a parallel beam of incident light from one direction in the hemisphere into another direction in the hemisphere.

Metrological Traceability: *property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations each contributing to the measurement uncertainty.*

The abbreviated term 'traceability' is widely used for "metrological traceability" as well as for other concepts, such as "sample traceability" or "document traceability" or "instrument traceability", where the history ('trace') of an item is meant. It is, therefore, recommended to include an appropriate prefix to ensure the meaning is clear.

Quality Indicator: *a means of providing "a user" of a product, (which is the result of a process) sufficient information to assess its suitability for a particular application. This "information" should be based on a quantitative assessment of its traceability to an agreed reference standard (ideally SI).*

Quality Control: is the process and or activities employed to ensure *products* or *services* are designed and produced to meet or exceed customer specified requirements.

Reference: *can be a definition of a measurement unit through its practical realization, or a measurement procedure, or a measurement standard.*

It should be noted that although this allows a very flexible interpretation, it is important to ensure that appropriate consideration is given to the:

- criticality of the process in the overall application
- level of accuracy required
- need for interoperability

Reference standard: Measurement standard designated for the calibration of other measurement standards for quantities of a given kind in a given organization or at a given location.

Reference test site: A site to be used for the post-flight calibration of the remote sensors fulfilling the selection criteria outlined in Table 1 (to be refined by CEOS WGCV IVOS).

Reflectance Factor: is the ratio of the radiant flux reflected by a surface to that reflected into the same reflected-beam geometry and wavelength range by an ideal (lossless) and diffuse (Lambertian) standard surface, irradiated under the same conditions. Reflectance factors have values under 1.

Vicarious calibration: Refers to the post-launch calibration of a satellite using techniques, which make use of a natural or artificial target on the Earth's surface.

4 Introduction/Context

This document provides a methodology to identify and assess the suitability of new land "reference test sites", e.g. snow, desert and salt-lakes, based on the selection criteria described in Table 1. Such test sites would be suitable to validate and/or calibrate the radiometric gains and offsets of sensor in the post-launch environment. This will allow correlation with those determined during pre-flight calibration and also an evaluation of change following any potential degradation due to launch or during flight. Such sites will also be used as "common targets" to evaluate "biases" between different in-flight sensors viewing the same target in near simultaneity. In principle they can also be used to link datasets and sensors separated in time, including timescales of many years, if the characterisation procedures are sufficiently robust.

To be endorsed by CEOS, a reference standard test site must have *routine ground-based measurements* with traceability to SI standards. This facilitates the establishment of a *Quality Indicator* for the data products delivered by the remote sensing instrument. SI traceability can be established through a number of routes including reference standard sources for radiance and irradiance and artifacts for reflectance. All instrumentation used must have documented evidence of its traceability and associated uncertainty.

Not all of the 8 *CEOS instrumented reference standard test sites* have permanent ground-based measurements. This is generally due to their remoteness and lack of on-site personnel and budgetary constraints. However, there is some progress towards automation of instrumentation and this is to be encouraged[6].

The regularity of site characterisation and deployment of instrumentation depends on the sites temporal variability and ideally should be carried out at the time of a satellite overpass for the best accuracy. However, as a minimum, test site characteristics should be evaluated on an annual basis.

In conclusion there are two main issues, which drive the assessment of suitability of a "reference test site":

- *Stability in time* of the basic spectral shape (reflectance factor, BRDF) and the reflectance value over the spectral range of interest

- *Spatial uniformity* of reflectance in relation to the needs of the spatial resolution of the imager.

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[6] Czapla-Myers J.S., 2006. Automated ground-based methodology in support of vicarious calibration, PhD Thesis University of Arizona. There are two other reference test sites: La Crau, France, Europe and Lspec Frenchman Flat, NV, USA, North America with automated ground-based measurements.

Many of the sub-criteria have an impact on how the above are used or how they are evaluated.

5 Outcomes

The outcome from following this procedure will be sufficient information to complete a CEOS "reference standard - test site" registration form to enable the candidate site to be reviewed for its suitability for endorsement
http:www. calvalportal.ceos.org/CalValPortal/welcome.do

6 Inputs

The inputs to this procedure will be information derived from satellite imagery, meteorological archives and result of surface characterisation via ground-based teams.

7 Standards and Traceability

All instrumentation used to characterise the reference test site should have clear demonstrable traceability to SI units (radiance, irradiance) as appropriate. All characterisation should be carried out using a QA4EO endorsed method or with documentary evidence to enable it to be endorsed by QA4EO.

8 Process

The procedure is written to provide its reader with guidance on how to identify and establish a new reference test site to support the calibration and validation of radiometric gain of Land surface imagers. It has been developed following the experiences of those who have already established similar test-sites and in particular uses the new site, "Tuz Gölü" in Turkey, as a case study.

The following steps outline the overall set of tasks, which are required. Each will be expanded upon in this chapter:

- **Define the intended application and subsequent requirements driving the characteristics for the reference test site**

- **Preliminary Identification of a candidate test site** (satellite data analysis, and study of the Google Earth Maps)

- **Detailed "desk study" of candidate site** (annual usability of test-site, selection of specific test-site coordinates, access to the field campaign)

- **Site characterisation** (methodology, radiometric characterisation, atmospheric characterisation, data analysis)

- **Demonstration of site suitability** (comparison to existing established test sites, comparison to CEOS general criteria)

- **Submission for endorsement**

8.1 Define the intended application and subsequent requirements driving the characteristics for the reference test site

Before seeking to find or evaluate a "Test-site" it is essential to review all the applications (and their requirements) it is intended to be used for. In the context of this specific document, relating to radiometric gain, we need to consider sensor spatial resolution, (all sensors, only high, only medium, one particular sensor), footprint, sensor view orientation, accuracy required, regularity of use, spectral range to be covered and spectral resolution.

Case Study: Tuz Gölü, Turkey

In this case the objective was to find a site that was suitable for calibrating the radiometric gain of all land imager sensors from high to medium resolution with the highest accuracy possible. A secondary objective was for a site of relatively easy accessibility to Europe. A third objective was that the site should be suitable to be used to cross-compare performance and/develop instrumentation and methodologies used for ground based vicarious calibration.

8.2 Preliminary Identification of a candidate test site

Archived satellite imagery, including that from sources such as "Google Earth" provide a useful basis for preliminary screening, initially visually, or through some automated process with key selection criteria, e.g. brightness and area. In some cases, "local knowledge" of terrain can also provide a good starting point.

Following initial identification, more detailed screening using satellite imagery should be carried out to evaluate the sites suitability for the required task. Ideally this should use data from satellites with similar characteristics to that of the intended application. Any analysis, for example spatial uniformity should be carried out using an approved quantitative method where available, and appropriately documented.

Case Study: Tuz Gölü, Turkey

TU first identified the Tuz Gölü site through "local knowledge" and subsequently used satellite imagery (NIR and red spectral bands) initially MODIS followed by Landsat TM to evaluate its spatial uniformity. The Tuz Gölü site situated at 38 50°N, 33 20°E, is a salt lake which dries each summer. Its spatial uniformity was evaluated using Getis statistics [7].

8.3 Detailed "desk study" of candidate site

Following identification of a candidate test site a number of basic criteria need to be evaluated to ensure that it is appropriate to invest significant manpower on detailed characterisation.

8.3.1 Annual usability of test-site

For many test-sites there are periods of the year when its usability is at an optimum, due for example to meteorological conditions, and/or sun illumination angles (locational latitude). For some sites, the likelihood of poor conditions may mean it is unusable for periods of the year. The length and occurrence of these useable periods clearly impact on the overall value of the test site and the level of effort that should be expended. In contrast to this statement, a site with otherwise excellent properties but is only useable for one or two months of the year may justify more effort than one that is relatively poor but can be used for 12 months. This trade-off should be carried out based on the requirements specified in section 8.1.

Ideally the site should be cloud free, have low precipitation, low probability of complex aerosols (urban/maritime), high solar illumination angles. The meteorological data for a test site can be relatively easily analysed from a local meteorological service.

Of course the practical usability of a site might also be influenced by its propensity for change from anthropogenic origin. For example, do humans regularly visit it and if so for what purpose, e.g. some sites are protected by government agencies, some may be used for military training etc. If significant investment is to be committed to a site, a careful review of long-term ownership and planned usage is essential, to gauge likelihood of radiometric stability and also availability.

Since this procedure is specifically concerned with test-sites that are regularly instrumented, accessibility should also be considered to be an important criterion. For example the proximity of road access to the site will greatly facilitate the transportation of instrumentation and personnel for any required field characterisation.

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[7] Getis, A., and Ord, J.K., 1992. The Analysis of Spatial Association by Use of Distance Statistics. Geographical Analysis, 24(3), pp.189-206.

Case Study: Tuz Gölü, Turkey

Tuz Gölü is normally a salt lake, which dries to a salt surface for about three months during the summer. The meteorological data for this site, including average monthly rainfall and average monthly insolation time, was provided by Turkish State Meteorological Service and reviewed for the period 1987 to 2007. Based on this data, July-August is the optimum period for use as a "test site".

The geographical location of the site is far from the sea and any significant urban or industrial area. However, the commercial extraction of salt from the lake ensures good accessibility and also the prospect of accommodation, power and other logistics.

8.3.2 Selection of specific test-site coordinates

Satellite imagery with appropriate spatial uniformity criteria can be used to select potential test-sites. Even following the application of selection criteria within 8.2 there may be several options that could be selected for any one geographical location. For economic reasons this should be reduced to one for a particular geographical location. Adding constraint to the selection criteria such as spatial uniformity, and the use of higher resolution imagery is a first step, but ultimately candidate sites need to be visited and visually inspected.

Case Study: Tuz Gölü, Turkey

Potential areas, suitable for field characterisation, were selected based on a spatial uniformity study of remote sensing data (medium & high-resolution optical sensors: MODIS and Landsat) from July and August over the period 2004-2008.

In the case of Tuz Gölü, the spatial autocorrelation[8] method was used to check the spatial uniformity of the target area. *Spatial autocorrelation* is defined as the degree of dependence between the values of the same variable associated with locations close to each other. The analysis used Moran's I and Getis Ord local spatial statistical methods[9]. The output was a lake map with potential targets, which could be used for the vicarious calibration.

The selected areas were then visited by TU to check for other features/particularities, or surface vegetation. The visit discovered evidence of circular spots of about 1-1.5m produced by the evaporation process at the salt lake. These features needed consideration

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[8] Bannari, A., Omari, K., Teillet P.M., and Fedosejevs, G., 2005. Potential of Getis statistics to characterize the radiometric uniformity and stability of test sites used for the calibration of earth observation sensors. IEEE Transactions on Geoscience and Remote Sensing, 43(12), pp. 2918-2926.

[9] Morain S., and Budge M.A., 2004. Post-Launch Calibration of Satellite Sensors, ISPRS Book Series – Volume 2, pp.181-187.

in the sampling methodology selected for subsequent field campaigns. During field campaigns such features need to be individually characterised to assess their potential contribution to the overall spectral signature of the surface.

8.3.3 Access to the field campaign site

To avoid potential delays at the time of a site characterisation it is valuable to define an access route from the nearest road to the site. This should be carried out at the time of the site visit indicated in 8.3.2. Providing the terrain of the access routes is temporally stable this routes should be mapped using GPS and recorded. Care should be taken when selecting a route to ensure it is suitable for potentially heavily laden vehicles.

Case Study: Tuz Gölü, Turkey

Access ways to the selected areas from both satellite images and a field study were established and recorded using GPS. For this site, due to the nature of the soft ground, not all potential sites were accessible for vehicles and equipment and this formed part of the selection criteria.

8.4 Site Characterisation

To establish detailed characteristics of the site, particularly radiometric, requires a dedicated field campaign. The site characterisation needs to be carried out following CEOS recommended practises and in particular needs to use equipment appropriately calibrated traceable to SI units. Documentary evidence of the traceability of the equipment should be established and maintained and included/linked to any site characterisation report.

In order to maximise the benefit of site characterisation it should ideally be timed to suit the acquisition of a satellite sensor with operational characteristics similar to those specified in section 8.1. The selected sensor (s) should where possible have knowledge of its relative radiometric characteristics to that of an existing CEOS reference standard test site.

8.4.1 Methodology

The sites radiometric properties (reflectance/radiance) should be characterised using a CEOS recommended method with a sampling strategy optimised to suit the resolution of the intended sensors. This may require more than one sampling strategy.

In addition to spatial uniformity of reflectance/radiance the sites angular reflectance characteristic should be determined. Ideally the full BRDF of the surface should be determined for a range of sun illumination angles, that would be typical of those from expected satellite sensors.

In addition to radiometric characterisation the sites atmospheric parameters (aerosol loading, water vapour, temperature, pressure) should also be measured simultaneously using appropriate meteorological equipment.

Case Study: Tuz Gölü, Turkey

The measurement method and equipment were selected according to the reflectance-based methodology used by other research groups [10] [11]. This is described in more detail in the CEOS "best practise guide" on site characterisation, REFERENCE XXX

8.4.2 Surface Radiometric Characterisation

The reflectance factor of the test site surface is calculated from the radiance measurements performed with a portable spectroradiometer. Such measurements are usually made in comparative mode by alternately viewing a Lambertian reflecting panel of known reflectance illuminated by the Sun and the surface illuminated by the "same Sun". This measurement can of course only be made at specific locations at specific times and whilst some changes due to sun illumination angle variation can be accounted for by frequent cross-referencing to the panel, this relies on relatively small differences in the BRDF characteristics of the panel and the surface being measured.

It is thus important to define a sampling strategy optimised to minimise variation due to temporal changes in illumination whilst maximising the area under test i.e. as short a time as possible.

The size of the surface area to be sampled is selected depending on the imagers resolution (medium or high-resolution) and this surface should be oriented parallel to the satellite direction of travel. A test site 1 x 1 km could be used for a medium resolution imager (e.g. MERIS 300 m spatial resolution) and another site 80 x 300 m for a high-resolution imager (e.g. UK-DMC with a 32 m Ground Sample Distance - GSD). The size of the test site has to cover at least three pixels of the intended remote sensor and in addition be surrounded by an area of similar characteristics for at least a further two pixels to minimise adjacency effects due to imperfect optical imaging.

The sampling should take into consideration the features of the test reference site (cracks or spots) and the time required to sample the selected areas without having great variation in the illumination conditions (sun zenith/azimuth angles). For example at Railroad Valley, Nevada test site, the site characterisation over 1 x 1 km takes about one hour[12].

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[10] Slater P.N., S.F. Biggar, R.G.Holm, R.D. Jackson, Y.Mao, et al., 1987. Reflectance- and Radiance-Based Methods for the In-Flight Absolute Calibration of Multispectral Sensors, *Remote Sensing Environment*, 22, pp. 11-37.

[11] Thome K., 2004. Ground-look radiometric calibration approaches for remote sensing imagers in the solar reflective, CEOS-IVOS Workshop Calibration of multi sensors at RRV.

[12] As per reference 6.

Case Study: Tuz Gölü, Turkey

In the first field campaign, spectral radiance/reflectance measurements were performed using an ASD Fieldspec3 from TU and multi-angular measurements were performed using the GRASS (Gonio RAdiometric Spectrometer System)[13]. The selected surface was approximately 100 x 300 m, in order to match 10 pixels taking 3 samples for each of a high-resolution imager such as UK-DMC (32 m GSD). For the medium resolution imager MERIS and MODIS (300 m spatial resolution) 1 km x 1 km site will be used.

Different sampling strategies, including FOV of the spectrometer and frequency (ground spacing) were tested and had no influence on the determined spatial uniformity of the selected test site.

The variance in the measured value of the reflectance factor was about 0.02 of a 0.43 mean value over 420-520 nm and 0.03 of a 0.58 mean value over NIR.

This first field campaign selected an area, which excluded the 1-1.5m circular spot features of the salt-lake.

8.4.3 Atmospheric Characterisation

Since the ultimate aim of any test-site is to calibrate or validate the radiometric gain of a satellite, it is essential to have a full knowledge of any losses resulting from transmittance of the atmosphere. This can be calculated through use of a radiative transfer code (RTC) but this in turn is highly dependent on the inputs of a variety of parameters, which much be determined locally and at the time of use.

The atmospheric transmittance should be measured using a "sun-photometer" to determine the aerosol optical depth, and water vapour content. These measurements can be performed in automatic mode, with the added advantage that this will also lead to a site aerosol climatology record.

However, as a minimum this can be performed with the help of a handheld manual instrument sampling regularly during site radiometric measurements.

[13] Pegrum, H. M., N. Fox, E. Milton, et al., 2007. Development of the Gonio Radiometric Spectrometer System to conduct multi-angular measurements of terrestrial surfaces. 10th International Symposium on Physical Measurements in Remote Sensing (ISPMSRS'07), Vol. XXXVI, Part 7/C50, pages 488-492, ISPRS, Davos (CH). ISSN 1682-1777.

The dominant source of error for atmospheric transmittance comes from the aerosol optical depth measurement, and this is highly dependent on the pointing accuracy and the radiometric calibration[14].

Ideally an AERONET compliant sun-photometer would be stationed near to the site and for this an uncertainty in optical depth about ±0.01 of the average value for wavelengths greater than 440 nm and less than ±0.02 of the average value for shorter wavelengths can be achieved[15].

Similarly water vapour content can be determined from the 940 nm spectral band, with an uncertainty of 10% [16].

Additional meteorological data such as pressure, temperature should also be recorded and this is most easily achieved through an automatic weather station.

The instrumentation used to collect this data should be traceably calibrated and have sufficient accuracy and resolution that it does not limit the overall results of the site characterisation.

Case Study: Tuz Gölü, Turkey

For the first evaluation of Tuz Gölü the atmospheric parameters were measured manually with a MICROTOPS sunphotometer, and the variance associated with the measurement of the aerosol optical depth was less than 0.35% of the mean value.

Meteorological data was recorded by an automatic weather station.

8.4.4 Data Analysis

Measurements of the test-site should be performed on a number of days ideally varying the sample strategy and locations to ensure maximum variability in the measurement conditions. This should be performed in a systematic way to evaluate different parameters in turn, so as to ascribe uncertainty to each stage of the process and each parameter evaluated. The results for each day, spatial variability, etc should be determined independently and compared to other days to look for any residual trends or changing biases.

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[14] Holben, B.N., Eck, T.F., Slutsker, I. et al. 1998. AERONET – A federated instrument network and data archive for aerosol characterization. Remote Sensing Environment. 66, pp. 1-16.
[15] Holben, B.N., Tanre, D., et al. 2001. An emerging ground-based aerosol climatology: Aerosol Optical Depth from AERONET. J. Geophys. Res 106, pp. 12 067 –12 097.
[16] Halthore, R.N., Eck, T.F., Holben, B.N., Markham, B.L., 1997. Sunphotometric measurements of the atmospheric water vapour column abundance in the 940nm band. J. Geophys. Res. 102, pp. 4343-4352.

Finally if no trends are observed all results should be averaged and the mean value together with its standard deviation of the mean for each wavelength recorded. A full uncertainty budget should then be established to include additional common uncertainties such as instrument calibration and the variability of the atmosphere. Note: when using the site with a particular satellite acquisition, the exact atmospheric parameters measured at the time can and should be used. However, when providing "typical data" for the site, on the assumption that no major anomaly has occurred, it is best to take an average over the measurement campaign and indicate its variance.

Case Study: Tuz Gölü, Turkey

The results for Tuz Gölü are summarised in a test site summary document, which will be available on the Cal/Val portal in a short time.

8.5 Demonstration of site suitability

The results from the radiometric site characterisation should be reviewed and compared to those identified as "required" in section 8.1. If they do not meet the initial requirements the user should consider carefully if these initial target goals can be relaxed and/or if alternative locations in the same general area should be considered or of course if the site should simply be rejected.

8.5.1 Comparison to existing established test sites.

Following site characterisation, it is important to demonstrate consistency with existing test sites. This is most easily achieved through the mutual independent calibration of a satellite sensor and subsequent cross-comparison of the results. Such a process should ideally be planned in advance to ensure that the chosen sensor has or will be compared to a CEOS reference standard test site within the previous month (this time depends on an a-priori knowledge of the stability of the sensor and may be longer). Such coordination can best be carried out through the CEOS WGCV IVOS sub-group and ideally the intent to carry out such a comparison should also be registered in advance. This will enable appropriate support to be offered to the "test site team".

The process to be followed for use of a test site to calibrate a satellite sensor is described in the CEOS "best practise" guide[17].

The results obtained following this comparison should be included within the documentation used to register a test site.

Case Study: Tuz Gölü, Turkey

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[17] CEOS "Best practice guide to a reference test site characterisation" is in progress.

The Tuz Gölü site was used to calibrate UK-DMC-1, which had also been calibrated using the Railroad Valley, Nevada (N38.497°, W115.690°) test site, which is endorsed by CEOS and has a long-standing history [18].

8.5.2 Comparison to CEOS general criteria

Before formal submission to CEOS for endorsement, a review of the sites characteristics compared to those specified by CEOS in Table 1 should be carried out as a checklist.

Case Study: Tuz Gölü, Turkey

Table 2 contains a summary of how Tuz Gölü fulfils the CEOS general criteria and its comparison to Railroad Valley, Nevada, an established reference test site.

Table 2: Cal/Val selection criteria determined for the Tuz Gölü test site

Item number	Ground based methods and instrumentation used to check the criteria
1	*ASD Spectroradiometer measurements* Tuz Gölü is spatially uniform with RMS < 2 % for a 300 * 100m target. RRV is characterised by a RMS approx. 3-5% in the VNIR for 1 * 1km
2	*ASD Spectroradiometer measurements* Tuz Gölü high values of RF ~0.40-0.58 for VNIR Railroad Valley with BRF ~ 0.25-0.45 for λ>450nm
3	*ASD Spectroradiometer measurements* Spectral range 350 – 2500 nm, showing uniformity in VNIR
4	*ASD Spectroradiometer measurements* for six days. The site is uniform in terms of six days period, 2008 field campaign The main temporal study has been done with MODIS satellite data.
5	*Multi-angular measurements of the site using the NPL GRASS to*

[18] As per reference 6.

	determine the BRDF of the surface.
6	*Site visit and Satellite data.* No vegetation exists over this site.
7	*NASA Shuttle Radar Topographic Mission, Digital Elevation Map* The elevation of the site is 907 m
8	*Weather Station data* 6 days & *Archived Data of Turkish State Meteorological Service* In July and August, most of the days are cloud-free.
9	*Satellite Data & GPS measurements* 105 km to Konya, 150 km to Ankara
10	*Satellite Data & Water Vapour Content from sunphotometer data 2008* The Salt Lake is located in the central part of Turkey at about 300 km from the Mediterranean Sea, 350 km from the Black Sea, and 580 km from the Aegean Sea. 6 days during 2008 field campaign shows a water vapour content daily mean ~1-1.6 cm with a normalised standard deviation less than 10%.
11	*Satellite data spatial statistics analysis* Usable area is in an ellipse shape surface with 16.96 km minor axis and 27.99 km major axis.
12	*Site visit* The site has many ways of access.
13	Temporarily instrumented with meteorological weather station and with a sunphotometer starting with 2009

8.4 Submission for endorsement

Once the site has been evaluated this information should be formally recorded on the "reference standard template" by following procedure QA4EO-WGCV-IVO-CSP-001. This procedure then indicates that the template should be submitted to CEOS WGCV IVOS for review.

9 Long term Evaluation of Performance

Once the site has been established and the template completed and submitted it is important to ensure that the site is regularly evaluated and records updated. These should be submitted to the Cal/Val portal where they will be linked to the database on test sites.

Satellite users and/or other research groups should where practical be encouraged to make use of the site and provide feedback on its performance from their perspective. In particular, independent ground teams can provide valuable insight through the application of alternate methodologies and instrumentation.

To maximise the sites usage and also to have continuous performance evaluation, it is recommended that the site be equipped with permanent autonomous instrumentation where possible and that this data be available on-line to any user for Cal/Val purposes.

If possible, an independent group should evaluate the sites ground characteristics.

10 Review of the Process

This procedure will be updated when CEOS IVOS has refined its site selection criteria and on the basis of comments from users as it put into practise.

11 Conclusion

This procedure has been established to provide guidance on establishing a "reference standard test-site" suitable for endorsement by CEOS. It is specifically intended for sites used to evaluate the radiometric gain of land surface imagers but can be adapted to suit other applications as needed.

It was largely written following the experiences gained from the establishment of a new test site in Turkey called Tuz Gölü, which is used as an example case study within the document.