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ONLINE CATALOG OF WORLD-WIDE TEST SITES FOR THE POST-LAUNCH CHARACTERIZATION AND CALIBRATION OF OPTICAL SENSORS

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ABSTRACT

In an era when the number of Earth-observing satellites is rapidly growing and measurements from these sensors are used to answer increasingly urgent global issues, it is imperative that scientists and decision-makers can rely on the accuracy of Earth-observing data products. The characterization and calibration of these sensors are vital to achieve an integrated Global Earth Observation System of Systems (GEOSS) for coordinated and sustained observations of Earth. The U.S. Geological Survey (USGS), as a supporting member of the Committee on Earth Observation Satellites (CEOS) and GEOSS, is working with partners around the world to establish an online catalog of prime candidate test sites for the post-launch characterization and calibration of space-based optical imaging sensors. The online catalog provides easy public Web site access to this vital information for the global community. This paper describes the catalog, the test sites, and the methodologies to use the test sites. It also provides information regarding access to the online catalog and plans for further development of the catalog in cooperation with calibration specialists from agencies and organizations around the world. Through greater access to and understanding of these vital test sites and their use, the validity and utility of information gained from Earth remote sensing will continue to improve.

Keywords – Test sites, Radiometric, Geometric, Spatial, Vicarious, Calibration, Remote Sensing

I. INTRODUCTION

With television, weather channels, Google Maps™ mapping service, and other day-to-day uses, satellite imagery has clearly become part of mainstream information society. Nevertheless, for most operational remote sensing applications, critical issues remain with respect to the consistency of quality in remotely sensed data.

Consistent data quality implies the adherence of data to appropriate standards of fidelity to the underlying physical quantities that they measure. These well-calibrated data then assure the accuracy and enhance the intercomparability that enables the development of advanced Earth observation technologies beneficial to user communities.

The use of test sites for post launch calibration has continued to expand. The U.S. Geological Survey (USGS) has put in place an online catalog of calibration test sites to provide easy public Web site access to this vital information for the global community. This paper further describes the catalog, the test sites, and the methodologies to use the test sites. It also provides information regarding access to the online catalog and plans for its further development in cooperation with calibration specialists from agencies and organizations around the world. The online catalog can be accessed at http://calval.cr.usgs.gov/sites_catalog_map.php

Need for a Global, Integrated Network of Calibration Sites

- ✓ User communities increasingly rely on information products from multiple satellite sensors.
- ✓ Better calibration can result from more postlaunch calibration, involving standardized measurement protocols, instrumentation, and processing.
- ✓ Field measurements remain resource-intensive activities.
- ✓ Less expensive complementary approaches can provide more frequent calibration updates and enable the monitoring of sensor performance trends, even without surface measurements.
- ✓ Future global monitoring systems, using increasingly complex constellations of satellites with multiple sensors, such as the Global Earth Observation System of Systems (GEOSS), will amplify the need for this initiative.

The online catalog builds on previous work[1] on the key considerations for site selection and provides a comprehensive list of 36 prime targets for consideration as benchmark sites for the radiometric calibration of space-based instruments. The list includes playa, desert sand, and salt flat sites only. Other test sites that have been used for radiometric calibration, such as snow/ice fields, uniform vegetation, and clouds, etc., are excluded because they are less amenable to systematic operational use[1].

II. WEBSITE LAYOUT

The layout is set up to help the user quickly locate the needed information available on the site. Drop-down menus list locations so the user may go straight to a specific site. A map with clickable links provides another way to go to sites. The maps include a world map, where the user selects a continent, and a map of each major continent. All of these maps are accessible throughout the catalog. The world map is shown in figure 1.

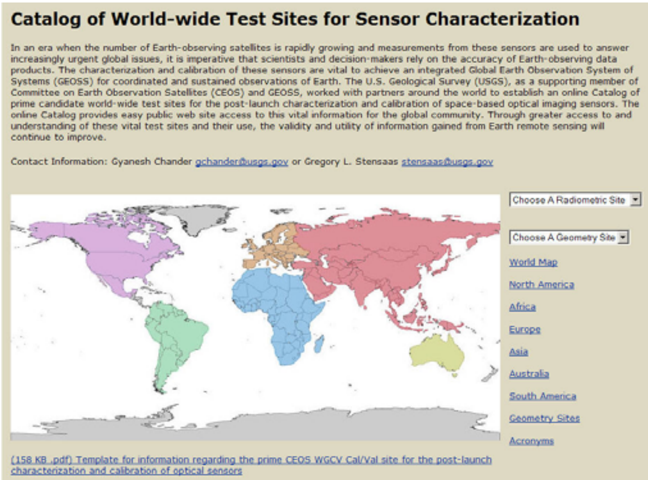


Figure 1. The worldwide test sites catalog for sensor characterization http://calval.cr.usgs.gov/sites_catalog_map.php

Each of the calibration site pages contains the same fields for easy review. These fields include location, terrain elevation, center latitude/longitude, Worldwide Reference System 2 (WRS-2) path/row, size of usable area, owner, researcher, purpose, description, support data, suitability, and limitations. Other features include a small image of the globe depicting the position of the site and a satellite image of the test site. Additional images are also available.

Radiometric Sites

The radiometric sites available at this time are on six of the seven continents. There are 14 sites available in Africa, 5 in Asia, 6 in Australia, 1 in Europe, 7 in North America, and 3 in South America. The distribution of the 36 radiometric sites around the world is portrayed in figure 2.

Figure 2. Distribution of the 36 radiometric sites around the world

Figure 3 shows an example screenshot of the La Crau site in Europe, and figure 4 shows a screenshot/example of the Lake Frome site in Australia.

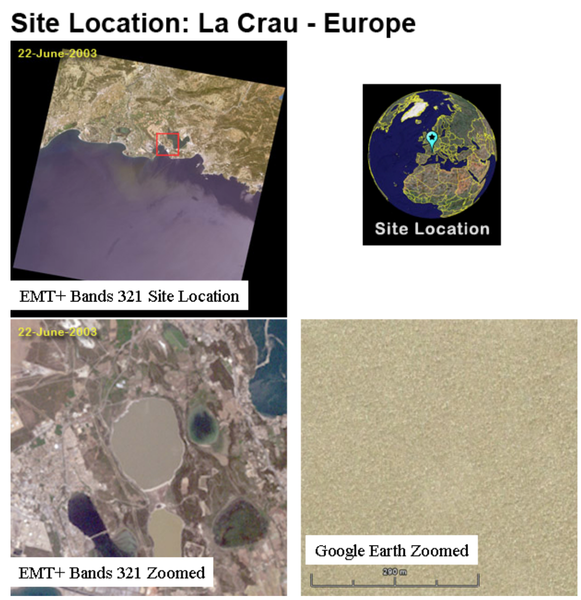
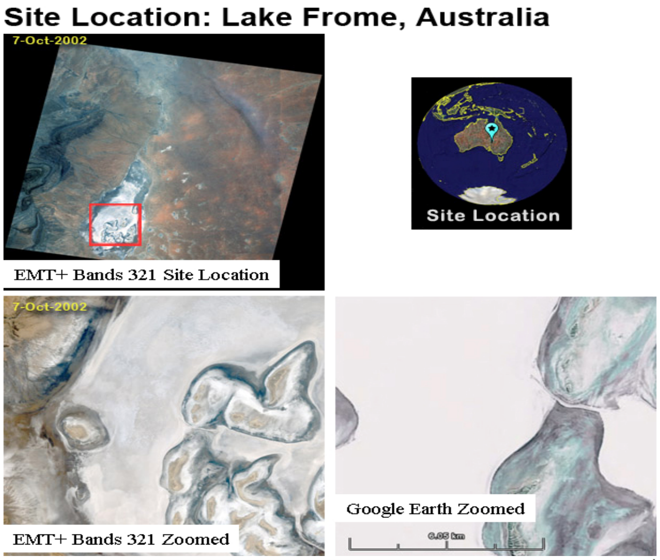


Figure 3. The La Crau site in Europe



Location (City, State, Country):	Lake Frome, South Australia, Australia
Altitude above sea level (meters):	3
Center Latitude, Longitude (Degrees):	-30.85 , +139.67
Landsat WRS-2 Path/Row:	97 / 81
Size of Usable Area (km):	10 x 10
Owner:	Unavailable
Researcher:	Unavailable

Figure 4. The Lake Frome site in Australia

Geometry Sites

The Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+) geometric supersites are all built by mosaicking panchromatic Digital Orthophoto Quarter-Quadrangles (DOQQs) that have been reduced in spatial resolution from 1 meter to 15 meters to match that of the ETM+ panchromatic band. DOQQs themselves are designed to meet the national map accuracy standards at 1:24,000 scale and have a horizontal root-mean-square accuracy of approximately 6 meters. The Landsat calibration team uses the term “supersite” for any WRS-2 path/row in which wall-to-wall coverage of DOQQs has been assembled for geometric/geodetic characterization and calibration purposes. The online catalog hosts 30 geometric supersites across the contiguous United States, as shown in figure 5.

Figure 5. Distribution of the 30 geometry sites across the contiguous United States

The mosaics are used to assess the geodetic accuracy of the ETM+ through ground control chip extraction. These results are then used to measure the ETM+ optical axis relative to the reference frames within the satellite bus and thus align sensor to satellite to ground. The mosaics themselves are used as a reference for measuring changes within the ETM+ scan mirror behavior. These changes are used to determine corrections to the scan mirror model.

The control assembled for each geometric test site extends beyond the 185-km (nominal) swath and length of a nominal 185 km Landsat WRS-2 scene, whereas radiometric calibration uses a specified area. Because of this difference, the online geometric template includes the four corner point latitudes/longitudes of each Landsat WRS-2 path/row, instead of the size of useable area. The remainder of the geometric template features the same links and fields.

Sample Data

Samples of Landsat data are made available for most of the test sites within the catalog. These data are provided as examples of the test site at Landsat scale. In the future, it is hoped that sample data from additional sensors can be provided to better illustrate these sites at other scales and resolutions, as well as in other spectral domains.

The L7 images are orthorectified GeoTiff image products, including radiometric and geometric precision correction as well as terrain correction. These products are produced to the cartographic projection parameters and technical parameters described below. The data were processed at the USGS Center for Earth Resources Observation and Science (EROS). The full resolution images can be downloaded from the Web site.

Sensor:	L7 ETM+
Product Level:	Orthorectified
Map Projection	UTM
Earth Ellipsoid	WGS84
Resampling	CC
Product Orientation	North Up
Product Format	GeoTiff
Output Media	FTP
Line Spacing	30 m
Pixel Spacing	30 m

Each of these images was chosen for the catalog from among the best cloud-free Landsat 7 images. To view all the scenes over the test sites acquired on different dates and by different satellites, use the USGS Global Visualization Viewer (GloVis) at http://glovis.usgs.gov.

The online catalog also offers a "quick look" capability for each site through the use of a KMZ file that can show the site and some of its characteristics in the popular and widely-available Google Earth™ mapping service. Each KMZ file contains the locations of each site with a border illustrating the size of the site. The KMZ file contains place marks for each site with a basic description and a link to the calibration site page. To learn about the Google Earth™ mapping service or to install it, go to http://earth.google.com. To use the KMZ file, open the Web site, go to File > Open, and select the KMZ file, or click on the small Google Earth™ icon (see figure 6) on each test site page.

Figure 6. Some of the North African radiometry sites available in KMZ files for use on the Google Earth™ mapping service

III. RADIOMETRIC SITE CATEGORIES

Radiometric test sites can be classified into three broad types: Absolute, Pseudo-Invariant, and Cross-Calibration.

Absolute Calibration (A)

An absolute calibration site is a location where *in situ* ground measurements of key physical parameters are acquired by calibrated ground instruments, allowing a detailed comparison of the ground instrument results to those of an orbiting sensor.

Although many satellite sensors are launched with well-characterized calibration sources, these sources change with time after launch. To perform absolute calibration of an orbiting sensor requires ground targets that are well-characterized. This approach attempts to measure the radiance seen by the sensor in orbit by *in situ* measurement of an absolute calibration site combined with a radiative transfer computation to predict the effects of transmission through the atmosphere.

An ideal absolute calibration site is exceptionally homogeneous over the spatial scale of an instrument pixel. Systematic surface measurements are made to characterize the site during instrument flyover. This limits calibration work to days when the satellite is collecting data over the test site. The maximum number of possible calibrations for a given test site during a given year for Landsat, which has a 16-day repeat cycle, is 22. Absolute calibrations are also dependent on favorable weather conditions, and the need for ground truth limits possible sites to those that are reasonably accessible. The difficulty of using absolute calibration sites is balanced by the relatively high accuracy of calibration that can be obtained.

Pseudo-Invariant Calibration (I)

A pseudo-invariant site is a location on the Earth's surface that is very stable both temporally and spatially over long periods of time and over significant spatial extent. These sites are typically located in desert regions that receive little rainfall and have few surface features.

The pseudo-invariant calibration sites are usually used to monitor the stability of the sensor over a long period of time. For sensors with no onboard calibrators, these sites provide an excellent source of information to study the sensor's behavior as a function of time.

Cross-Calibration (X)

A cross-calibration site is a location on the Earth's surface that contains large homogeneous regions that are viewable by two or more satellite sensors within a relatively short time period. Due to changes in sun angle and atmospheric content and condition, it is recommended that the time separation between images be measured in minutes, not hours, for this method to be effective. Also, with orbital differences between any two given sensors, some cross-calibration sites will not work as well as others. Users are advised to use caution and discernment in choosing sites that will work best for the sensors they are considering.

This cross-calibration approach involves comparison of near-simultaneous observations of the Earth's surface based on image statistics from large common areas within imagery from each of the sensors being compared. If the calibration of one of the sensors is well understood, it can be used as a baseline against which the other sensors are assessed. For sensors that have not been well-characterized, this method allows the most direct method for quantifying the differences in response between sensors, although not necessarily in terms of an absolute physical standard.

Any pair of images with relatively large, spatially homogenous regions can be cross-calibrated. Many of the catalog sites will work well with this method of calibration. Table 1 provides the provisional radiometry calibration site categorizations.

#	Site Name	WRS-2 Path	WRS-2 Row	Absolute Calibration (A)	Pseudo-Invariant Calibration (I)	Cross-Calibration (X)
1	Algeria 3	192	39		I	X
2	Algeria 5	195	39		I	X
3	Amburla	103	76	A		X
4	Arabia 1	164	47		I	X
5	Arabia 2	162	46		I	X
6	Barreal Blanco	232	82	A		X
7	Bonneville Salt Flats	39	32			X
8	Dunhuang	137	32	A		X
9	Dunrobin	94	76	A		X
10	Egypt 1	179	41		I	X
11	Egypt 2	177	44		I	X
12	Ivanpah Playa	39	35	A		X
13	La Crau	196	30	A		X
14	Lake Frome	97	81		I	X
15	Libya 1	187	43		I	X
16	Libya 2	182	43		I	X
17	Libya 4	181	40		I	X
18	Lunar Lake Playa	40	33	A		X
19	Mali 1	198	47			X
20	Mauritania 1	201	47		I	X
21	Namib Desert 1	179	77		I	X
22	Namib Desert 2	182	72		I	X
23	Niger I	189	46		I	X
24	Niger 2	188	45		I	X
25	Railroad Valley Playa	40	33	A		X
26	Rogers Dry Lake	41	36	A		X
27	Sechura Desert	10	64		I	X
28	Sonoran Desert	38	38		I	X
29	Sudan 1	177	45		I	X
30	Taklamakan Desert	146	32		I	X
31	Tinga Tingana	97	80	A		X
32	Uyuni Salt Flats	233	74		I	X
33	Warrabin	95	78	A		X
34	White Sands	33	37	A		X
35	Winton	96	76	A		X
36	Yemen Desert 1	164	48		I	X

Table 1. Provisional Calibration Site Categorizations

IV. ONGOING ACTIVITES

Due to the nature of the project, there is much information yet to be gathered for radiometric and geometric calibration sites to be used on the Web site. Gathering the needed information is dependent on the community and other calibration experts. The Web site will be maintained with the best and most current information.

The USGS will continue developing and improving this online catalog of test sites. Partners and collaborators from around the world are invited and encouraged to submit further detail on sites within the catalog and submit new sites for possible inclusion. Additional sample imagery over the various sites is also desired, along with ground information and other pertinent details that will aid in calibration.

Additionally, the USGS will work with others to further develop these calibration methods and to better describe these methods. Input from others in the field is strongly encouraged.

The USGS will also be adding additional geometric test sites with denser ground control for use with high-resolution satellites. Some of these sites will also be useful for characterizing and calibrating remote sensing gathered from airborne sensors. Opportunities for cross-calibration between satellite and airborne sensors are one area of great interest and promise.

Proposed Future Plans

- Refine the selection of recommended primary sites
- Gather complete site characterization data and information
- Acquire and archive imagery of all primary sites
- Develop online calibration data access infrastructure
- Establish traceability chain for primary site data
- Develop guidelines and establish certification mechanisms for meeting calibration standards
- Endorse and advocate compliance with calibration standards

V. CONCLUSION

The growing use of terrestrial targets for understanding satellite instrument performance has made them a key component of current and future postlaunch calibration strategies. The online catalog provides easy global public access to this vital information. Through greater access to and understanding of these vital test sites and their use, the validity and utility of information gained from Earth remote sensing will continue to improve. Through continued cooperation among the remote sensing agencies and organizations around the world on this catalog and on calibration methodologies, remote sensing data can be made more accurate, more useful, and more important to help develop an improved and sound understanding our world.

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Land Remote Sensing (LRS) Program and the Remote Sensing Technologies (RST) Project within LRS. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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