Catalog of World-wide Test Sites for Sensor Characterization

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Outline

- Introduction
- Site Selection Criteria
- Online Test Site catalog
- Provisional Calibration Site Categorizations
- Summary
- Proposed Future Plans
Context

- 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:
  - Reliability of supply
  - Consistent data quality
  - Plug-and-play capability

- Consistent data quality implies the adherence of data to appropriate standards of fidelity to the underlying physical quantities (reflectance, temperature, etc.) that they measure.

- These well-calibrated data then assure the accuracy and enhance the intercomparability that enables the use of advanced Earth observation technologies to address societal benefits.
Scope of test sites

- Test sites are core to any future QA/QC strategy
- Test sites provide a convenient means of obtaining information to verify sensor performance
- Test sites are the only practical means of deriving knowledge on biases between sensors
- Test sites allow, at some level, a means of bridging anticipated data gaps caused by lack of measurement continuity, due to lack of co-existent in-flight sensors
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 to address global societal benefits.
Characteristics of sensors which can benefit from test sites

- Gain
- Linearity
- Stability
- MTF
- Uniformity (Flat field)
- Stray light (Adjacency effects)
- Polarization
- Spectral
- SNR
- Algorithms

- Geo location
- Camera model
- Band-to-band
Test site as a reference standard!

- For example in the context of radiometric gain: Internal Calibrator, Solar Diffuser, Rayleigh scattering, clouds, sun-glint are all equally applicable methods.
  - Test sites and their use is really a methodology which in turn is one of many potential methods.
- In that context, test sites become a means to achieve an objective and should really be defined as “reference standards” to facilitate an activity.
Prime Candidate Earth Target Types

- **Including only playa (dry lakebed), salt flat, and desert sand sites**

- Snow fields are excluded primarily because high surface reflectances are more sensitive to variations in atmospheric particle size distribution and because they are usually located at latitudes characterized by high solar zenith angles.

- Vegetation targets are excluded because they are subject to phenological changes as well as strong reflectance anisotropy effects.

- Water targets are excluded because low surface reflectances are more sensitive to atmospheric path radiance and because of sun glint.

- Other target types (uniform cloud cover, atmospheric scattering, ocean glint) are excluded because more specialized analysis is required, not in keeping with operational use of benchmark test sites.
Well-Established Site Selection Criteria

- **High spatial uniformity over a large area (within 3 %)**
  - Minimize misregistration and adjacency effects
- **Surface reflectance greater than 0.3**
  - To provide higher SNR and reduce uncertainty due to atmosphere
- **Flat spectral reflectance**
  - Reduce uncertainties due to different RSR
- **Temporally invariant surface properties (within 2 %)**
  - To reduce BRDF, spectral, surface reflectance effects
- **Horizontal surface with nearly lambertian reflectance**
  - Minimize uncertainty due to different solar illumination and observation geometry
- **At high altitude, far from ocean, urban, and industrial areas**
  - Minimize aerosol loading and atmospheric water vapor
- **In arid regions with low probability of cloud cover**
  - Minimize precipitation that could change soil moisture
## Initial List of 36 Test Sites for Consideration

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Distribution of 36 Radiometric Sites
Online test site catalog

- 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

- Each of the calibration site pages contains the same fields for easy review
  - These fields include location, terrain elevation, center latitude/longitude, 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
  - satellite images of the test site
  - previous/next button
  - sample Landsat images and Google KMZ files
Catalog of World-wide Test Sites for Sensor Characterization

In an era when the number of Earth-observing satellites is rapidly growing and measurements from these sensors are used to address increasingly urgent global issues, it is imperative that scientists and decision-makers 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 the GEOSS, works with partners around the world to establish an online Catalog of prime candidate world-wide test sites for the pre-launch characterization and calibration of space-based optical imaging sensors. The online Catalog provides easy public web site access to the vital information for the global community. Through greater access to and understanding of these test sites and their use, the validity and utility of information gained from Earth remote-sensing will continue to improve.

Contact Information: Susannah Chandley (susannah@usgs.gov) or Gregory J. Grenier (grenier@usgs.gov)
Radiometry Sites

Distribution of World Wide Radiometric Sites: There are 14 sites available in Africa, 5 in Asia, 6 in Australia, 1 in Europe, 2 in North America, and 2 in South America.
Online Catalogue Example: Railroad Valley Playa, North America

Site Location: Railroad Valley Playa

Radiometric

- **Location (City, State, Country):** Winnemucca, Nevada, USA, North America
- **Altitude above sea level (meters):** 1430
- **Center Latitude, Longitude (Degrees):** 39.2850, -117.619
- **Ground View Width in Feet/Distance:** 60 x 60
- **Size in Square Area (km²):** 10 x 10
- **Owner:** Bureau of Land Management (BLM)
- **Researcher:** UC Iruma A. Ibrham

**Purpose:** Radiometric, vicarious calibration test site, with large homogeneous regions

**Description:** Dry lake playa, sparsely vegetated, consisting of compacted clay-rich substrates which forms a relatively smooth surface compared to most land covers. Although it is a lower spatial uniformity compared to the Evans and Lunar Lake sites, the surface composition is comparable to those of Evans and Lunar Lake; however, all three sites suffer from the presence of iron absorption (FeIII) in the visible part of the spectrum, characteristic displayed in the region of the VIVISAT/Google Earth - Slightly patchy (in colour and intensity) across the playa.

**Support Data:** Clear linear road features and 3D terrain structures (no cutting, available)

**Suitability:** Recommended for 30m GSD and larger, VIs shown vs. SWIR, Solar reflective and emissive, sub-meter to 25m GSD

**Limitations:** Soft surface, vegetation spotty and spectral variation, possible hot spot effects, periodic area and color, cloud cover increases in winter, remote location for ground-based studies
Online Catalogue Example: Libya 4, Africa

Site Location: Libya 4

Radiometric

Location (City, State, Country): Libya, Africa
Altitude above sea level (meters): 118
Center Latitude: -28.55, Longitude: -23.39
Landsat WRS-2 Path/Row: 181/40
Size of Usable Area (km²): 75x75
Owner:Unavailable
Researcher: Henry Patrice

Purpose:
TBD

Description:
South-west quadrant of Landsat WRS-2 181/40. Used by CNES (100 x 100 km) - smaller area would be better. Google Earth: Dunes at multiple scales, but large usable areas of 75 km x 75 km or more, especially north west of centre coordinates. The surface varies slightly in intensity and colour across the area.

Support Data:
TBD

Suitability:
TBD

Limitations:
TBD
### Online Catalogue Example: Dunhuang, Asia

#### Site Location: Dunhuang

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**Purpose:**

Located in the Gobi Desert in north-west China, about 35 km west of the city of Dunhuang (Gansu Province). The calibration area is situated on a relatively flat plain. The area has a significant solar contribution as the surface temperature is approximately 400 m - 4000 m in the centre of the fan and the surface forms a large area under the desert's vegetation. Sufficient meteorological data for the site include the Dunhuang-DAM automated weather station which is part of the Asian Automatic Weather Station network. Atmospheric stresses over the site are typical of a desert environment, although there are larger perturbations more dominant, possibly reflecting the semi-arid nature of the north-west.バンドット in the area results in significant solar load on around 60 days per annum. Source: Network for Calibration and Validation of Earth Observation (NCV/EO) at the USGS.

**Support:**

TBD

**S suitability:**

TBD

**Limitations:**

TBD

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**Site Location**

15 Oct 2002

**LIT-I Bands 321 Zoomed**

15 Oct 2002

**LIT-I Bands 321 Site Parameters**

15 Oct 2002

**Google Earth Zoomed**
Online Catalogue Example: Amburla, Australia

Site Location: Amburla

Radiometric

Location (City, State, Country): Amburla, Northern Territory, Australia
Altitude above sea level (meters): 626
Center Latitude, Longitude (Degrees): 12.385, 133.119
Landmark: 30 km NW of Alice Springs
Owner: Unavailable
Research: Unavailable

10 March 2008

CTM - Bands 321 Zoomed
CTM - Bands 321 Site Parameters

10 March 2008

FTM - Bands 321
Google Earth Zoomed

Purpose: TBD
Description: An arid desert site located on a flat plain characterised by a red gravelly loam soil covered with a thick layer of dust. Small sand dunes are found in some areas. The site is covered with a sparse grass vegetation, and the area is prone to occasional flooding. The site is used for scientific research.

Support Data: TBD
Suitability: TBD
Limitations: TBD

References:

Google Earth: Various drainage patterns, small ranges of colours and intensities. The most accessible part is limited to a small area approximately 2 km E-N to 2 km W-S.
Online Catalogue Example:
La Crau, Europe

Site Location: La Crau

Radiometric

| Location (City, State, Country): | La Crau, Franco-Europe |
| Altitude above sea level (meters): | 28 |
| Canister Latitude,Longitude (Degrees): | 43.47, -4.97 |
| Landsat WRS-2 Path/Row: | 196/30 |
| Size of Usable Area (km²): | 1 x 2 |
| Owner: | Unavailable |
| Researchers: | Henry Patrice |

Purpose: TBD

Support: TBD

Suitability: TBD

Limitations: TBD

References:

Home

Geometry Sites

Acronyms

AERONET site:
Google Earth: Looks homogeneous in intensity and colour across the site. Surface slopes upward significantly from north (approximately 10 m ASL) to south (approximately 30 m ASL).
Online Catalogue Example: Barreal Blanco, South America

Site Location: Barreal Blanco

Purpose: TBD
Description: Located in northwest Argentina in Provincia de San Juan. Used as a joint campaign with Argentina’s CONAE to calibrate the satellite instruments EO-1, ALI and Hyperion as well as Landsat-7’s ETM+ and Terra’s ASTER. The EO-1 and ASTER site measured L1 60 m and L1 20 m in pixels on a 100-200 km impact site on a 0.16 x 0.190 sq. The site was chosen because there was a need to calibrate the instruments on-board EO-1 immediately after the January launch and weather conditions are favorable in the Southern Hemisphere in January.

Google Earth: Small homogeneous bright area. May be prone to saturation at high sun. Uniform areas are limited to 0.5 km x 0.5 km or less, but there are several such areas.

Support Details: TBD
Suitability: TBD
Limitations: TBD

Barreal Blanco, South America
Geometry Sites
GCPs

51 GCPs selected over Brookings, SD area

72 GCPs selected over Morrison, CO area
Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<td>BLM</td>
<td>Bureau of Land Management</td>
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<td>Committee on Earth Observation Satellites</td>
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<td>Centre National d'Études Spatiales (French)</td>
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<td>Working Group for Calibration and Validation</td>
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<td>WRS</td>
<td>Worldwide Reference System</td>
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</table>
References


- "Template for information regarding the prime CESG07 WCWCC/CVIR site for the post-launch characterization and calibration of optical sensors." [PDF]


Calibration Site Categorizations

- **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.

- **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.

- **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.
## Provisional Calibration Site Categorizations

A=Absolute    I=Pseudo-Invariant    X=Cross-Calibration

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<td>164</td>
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</tbody>
</table>
CEOS WGCV Subgroups

WGCV Chair: Dr. Changyong Cao (NOAA/NESDIS)

- Infrared and Visible Optical Systems (IVOS)
  Dr. Nigel Fox (NPL)
- Synthetic Aperture Radar (SAR)
  Dr. Satish Srivastava (CSA)
- Land Product Validation (LPV)
  Dr. Fred Baret (CNES)
- Terrain Mapping (TMSG)
  Prof. Jan-Peter Muller (UCL)
- Microwave Sensors (MSSG)
  Christopher Buck (ESA)
- Synthetic Aperture Radar (SAR)
  Dr. Satish Srivastava (CSA)
- Land Product Validation (LPV)
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  Dr. Fred Baret (CNES)
CEOS IVOS-19 Test sites Discussion Summary

- **Two sets of test sites**
  1. Core “instrumented” sites
  2. “Invariant” sites

- **Special Methods**
  - Extraterrestrial (moon, stars)
  - Rayleigh Scattering
  - Sun Glint
  - Clouds
Core “Instrumented” IVOS Sites (Total=8)

1. Railroad Valley Playa, NV, USA, North America
   – Dr. Kurtis J. Thome (kthome@email.arizona.edu) – University of Arizona, USA
2. Ivanpah, NV/CA, USA, North America
   – Dr. Kurtis J. Thome (kthome@email.arizona.edu) – University of Arizona, USA
3. Lspec Frenchman Flat, NV, USA, North America
   – Mark C. Helmlinger (mark.helmlinger@ngc.com) – NGST, USA
4. La Crau, France, Europe
   – Patrice Henry (patrice.henry@cnes.fr) – CNES, France
5. Dunhuang, Gobi Desert, Gansu Province, China, Asia
   – Fu Qiaoyan (fgy@cresda.com) – CRESDA, China
6. Negev, Southern Israel, Asia
   – Arnon Karnieli (karnieli@bgu.ac.il) – Ben Gurion University, Israël
7. Tuz Golu, Central Anatolia, Turkey, Asia
   – Selime Gurol (selime.gurol@uzay.tubitak.gov.tr) – TUBITAK UZAY, Turkey
8. Dome C, Antartica
   – Dr. Stephen Warren (sgw@atmos.washington.edu) – University of Washington, USA
Core “Instrumented” IVOS Sites (Total=8)

Railroad Valley

Ivanpah

Lspec

La Crau

Dunhuang

Negev

Tuz Golu

Dome C
“Invariant” IVOS Sites (Total=5)

- Libya 1
- Algeria 3
- Algeria 5
- Mauritania 2
- Libya 4
Special Methods

Moon | Sun glint | Rayleigh | Clouds

Rayleigh Calibration Sites – Choice of oligotrophic areas with 2 years of SeaWiFS data made in 2001 with ACRI and LOV (CLIMZOO zones)
Terrain Mapping Subgroup (TMSG)

- Montagne Sainte-Victoire
  - France referred to as Aix-en-Provence
  - 5.528-5.685°E, 43.502-43.560°N
  - mixed arable, forest, limestone

- Barcelona, Spain
  - 1.5-2.75°E, 41.25-41.82°N
  - urban, mixed arable, forest

- North Wales,
  - UK3-5°W, 52-53.5°N
  - urban, pasture, forest

- Three Gorges, China
  - 108.252-111.302°E, 30.638-31.229°N
  - forest, arable, limstone shales

- Puget Sound, WA, USA
  - -121.397 to -123.897°W, 46.364-48.864°N
  - forest, urban, wetlands
Microwave Sensors Subgroup (MSSG)

- **Sandy desert** (e.g. Sahara)
  - Deep penetration depth, temporal stability of the Tb, underground structure TBD

- **Rocky/mixed desert** (e.g. Gobi)
  - Shallow penetration depth, azimuthal effects and vegetation

- **Rainforest** (Amazon)
  - Volume scatter, effects of rain cells on the canopy equivalent moisture TBD

- **Stable ocean areas**
  - Effects of the wind/salinity at L-band TBD

- **Antarctica**
  - Dry atmosphere, large penetration depth & temporally stable, low azimuthal anisotropy
Land Product Validation (LPV)

- CEOS Benchmark Land Multisite Analysis and Intercomparison of Products (BELMANIP)

- Map of sites covered by the groups represented in this paper (given on a global map of dominant surface types in each 1 x 1 cell (bare soil, water bodies, deciduous broadleaf forest, evergreen needleleaf forest, evergreen broadleaf forest, crops, grass)
Synthetic Aperture Radar (SAR)

- **International Amazon Rainforest Site**
  - A CEOS radiometric calibration reference site
  - Data routinely collected and analyzed for calibration satellites including RADARSATs
  - Radiometry of the site remains stable

- **Canadian Boreal Forest Site**
  - Radiometric characterization completed at C-band data
  - Site seasonally dependent
  - Can be used as a complimentary site to the Amazon radiometric accuracy

- **Calibration Transponder Sites**
Summary

- The test site catalog provides a comprehensive list of prime candidate terrestrial targets for consideration as benchmark sites for the postlaunch radiometric calibration of space-based optical sensors.

- The online test site catalog provides easy public Web site access to this vital information for the global community.

- The incompleteness of available information on even these prime test sites is an indication that much more coordination and documentation are still needed to facilitate the wider use of calibration test sites in remote sensing.
Proposed Future Plans

- Refine the selection of recommended primary sites
  - Gather complete site characterization data and information
  - Define core measurements (e.g., Instruments)
  - Develop protocols and fund pilot projects
  - Create a "calnet" or "landnet"

- Agencies should acquire and archive imagery of all primary sites
  - Develop online calibration data access infrastructure
  - Create tools to identify the potential co-incident image pairs

- Extend the list to include snow fields, vegetation targets and water targets

- Integrate the catalog into the CEOS EO Cal/Val portal

- Establish traceability chain for primary site data