Catalog of World-wide Test Sites for Sensor Characterization

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U.S. Department of the Interior
U.S. Geological Survey
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
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Distribution of 36 Radiometric Sites

7

1

5

3

14

6
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 GEOSS, works with partners around the world to establish an online Catalog of prime candidate world-wide test sites for the post-launch characterization and operational use of Earth observation systems. The online Catalog provides easy public web site access to this vital information for the global community. 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.

[Catalog of World-wide Test Sites for Sensor Characterization]
Radiometry Sites

Distribution of World Wide Radiometric Sites: There are 14 sites available in Africa, 3 in Asia, 6 in Australia, 1 in Europe, 2 in North America, and 1 in South America.
Online Catalogue Example: Railroad Valley Playa, North America

Site Location: Railroad Valley Playa

Radiometric:

<table>
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<th>Location (City, State, Country):</th>
<th>Washoe, Nevada, USA, North America</th>
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<tr>
<td>Landcover with Bath Size:</td>
<td>60 x 60</td>
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<tr>
<td>Size of Visible Area (km^2):</td>
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Owner: Bureau of Land Management (BLM)

Researcher: UNAVCO A. H. Home, Small Researcher

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

Description: Dry lake playa, spatially homogeneous, consisting of compacted clay-rich lacustrine deposits forming a relatively smooth surface comprised of mud and mud cracks. Although a lower spatial uniformity compared to the Owens Lake and Lunar Lake sites, the surface composition is comparable to those of Owens and Lunar Lake playas; however, some areas show differences in the presence of iron absorption (Fe3+) in the visible part of the spectrum, characteristic of deposited fines in this region of the US. Google Earth: Slightly patchy (in colour and intensity) across the playa.

Support Data: Clearing linear road features and oil drilling structures (no filling available)

Suitability: Recommended for 30m GSD super/super, VaccineUV to SWIR, Solar reflective and emissive, full-mater to 24m GSD

Limitations: Soft surface conditions, seasonal and spectral variation, possible hot spot effects, periodic areas and cracks, cloud cover increases in winter, remote location for ground-based studies
## Online Catalogue Example: Libya 4, Africa

### Site Location: Libya 4

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<td>Researcher:</td>
<td>Heny Patrice</td>
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</tr>
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</table>

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 30 km scale; but large usable areas of 75 km x 75 km or more, especially north-west of center 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

Program:

Description:
Located in the Gobi Desert in north-west China, about 35 km west of the city of Dunhuang (Gansu Province, China). The location is situated on a shallow fan delta. The site consists of a sand dune whose altitudes range from approximately 400 m to 600 m. The surface contains some surface terraces and is covered by a flat, sandy surface. The site is located near a river and a lake, which provide water for irrigation and livestock. The site is surrounded by a desert landscape, with sand dunes and rocky outcrops. The site is accessible by road and is well suited for scientific research.

Supporting Data:

Suitability:

Limitations:

Google Earth Image:

Reference:

References:

Choices for Location:

Choose a Radiometric Site:
Choose a Geometric Site:

Google Earth Image:

Choose a Radiometric Site:
Choose a Geometric Site:

Online Catalogue Example:

Dunhuang, Asia

USGS
# Online Catalogue Example: Amburla, Australia

**Site Location: Amburla**

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<tr>
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**Purpose:** TBD

**Description:** An arid desert site located on a flat plain characterized by a red soil with sparse vegetation of Mitchell grass. Ideal for evapotranspiration and soil water flux studies. Predominantly arid climate with occasional rain events. The site is monitored to monitor the effects of climate change on vegetation and soil moisture.

**Support Data:** TBD

**Suitability:** TBD

**Limitations:** TBD

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Google Earth: Various drainage patterns, small ranges of colours and intensities. The most sensible part is limited to a small area approximately 1 km (N-W) by 2 km (E-S).
Online Catalogue Example: La Crau, Europe

Site Location: La Crau

Location (City, State, Country): La Crau, France, Europe
Altitude above sea level (metres): 28
Coast Latitude,Longitude (Degrees): 43.87, 4.97
Landuse WRS-2 Path/Row: 196/30
Size of Usable Area (km²): 1.3
Owner: Unavailable
Researchers: Herve Patrice

Purpose: TBD
Description: This area has a thin pebbly soil with very sparse vegetation cover. About 30 km north-west of Marseille, not far from the Mediterranean, as possibility of atmospheric water vapour and aerosol problems. Source: framework for Calibration and Validation of Earth Observation (FNCVEO) web site, http://www.eca.esa.int/calibration/radiometry/in-flight/miscrep).
Support Data: TBD
Suitability: TBD
Limitations: TBD

Choose a Radometric Site
Choose a Geometry Site

Return to La Crau

FTM Bands 3/2/1 22 June 2003
FTM Bands 3/2/1 22 June 2003

FTM Bands 3/2/1 Site Parameters
Google Earth Ground Picture

View Additional Photos

Supporting Site Details
SiteNotes: SiteNotes form c005

Harmonize Infrared Maps

USGS
Site Location: Barreal Blanco

Purpose: TBD

Description: Located in northwest Argentina in Provincia de San Juan. Used on 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 16km x 20km in pixels on a 100-200nm ETM+ containing a 4,640 20m ground sites on a 0.1-0.190 arc. 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 homogenous brightness may be prone to saturation at high sun. Uniform areas are limited to 0.3 km x 0.5 km or less, but there are several such areas.

Support Value: TBD

Suitability: TBD

Limitations: TBD
GCPs

51 GCPs selected over Brookings, SD area

72 GCPs selected over Morrison, CO area
Acronyms

BLM Bureau of Land Management
CEOS Committee on Earth Observation Satellites
CNES Centre National d’Etudes spatiales (French)
DOI Department of Interior
DOQQ Digital Orthorectified Quarter Quad
EROS Earth Resources Observation and Science
ETM+ Enhanced Thematic Mapper Plus
G Geometric Site
GEOSS Global Earth Observation System of Systems
L7 Landsat 7
NASA National Aeronautics And Space Administration
NIR Near Infrared
R Radiometric Site
SAIC Science Application International Corporation
SNIR Short Wave Infrared
TBD To Be Determined
USGS United States Geological Survey
VNIR Visible Near Infrared
WGCV Working Group for Calibration and Validation
WRS Worldwide Reference System
References


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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CEOS WGCV Subgroups

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

- Infrared and Visible Optical Systems (IVOS)
  Dr. Nigel Fox (NPL)

- Terrain Mapping (TMSG)
  Prof. Jan-Peter Muller (UCL)

- Synthetic Aperture Radar (SAR)
  Dr. Satish Srivastava (CSA)

- Microwave Sensors (MSSG)
  Christopher Buck (ESA)

- Land Product Validation (LPV)
  Dr. Fred Baret (CNES)

- Atmospheric Chemistry (AC)
  Dr. Bojan Bojkov (UMBC/NASA)
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 (fqy@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 of 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 (eg. 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