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

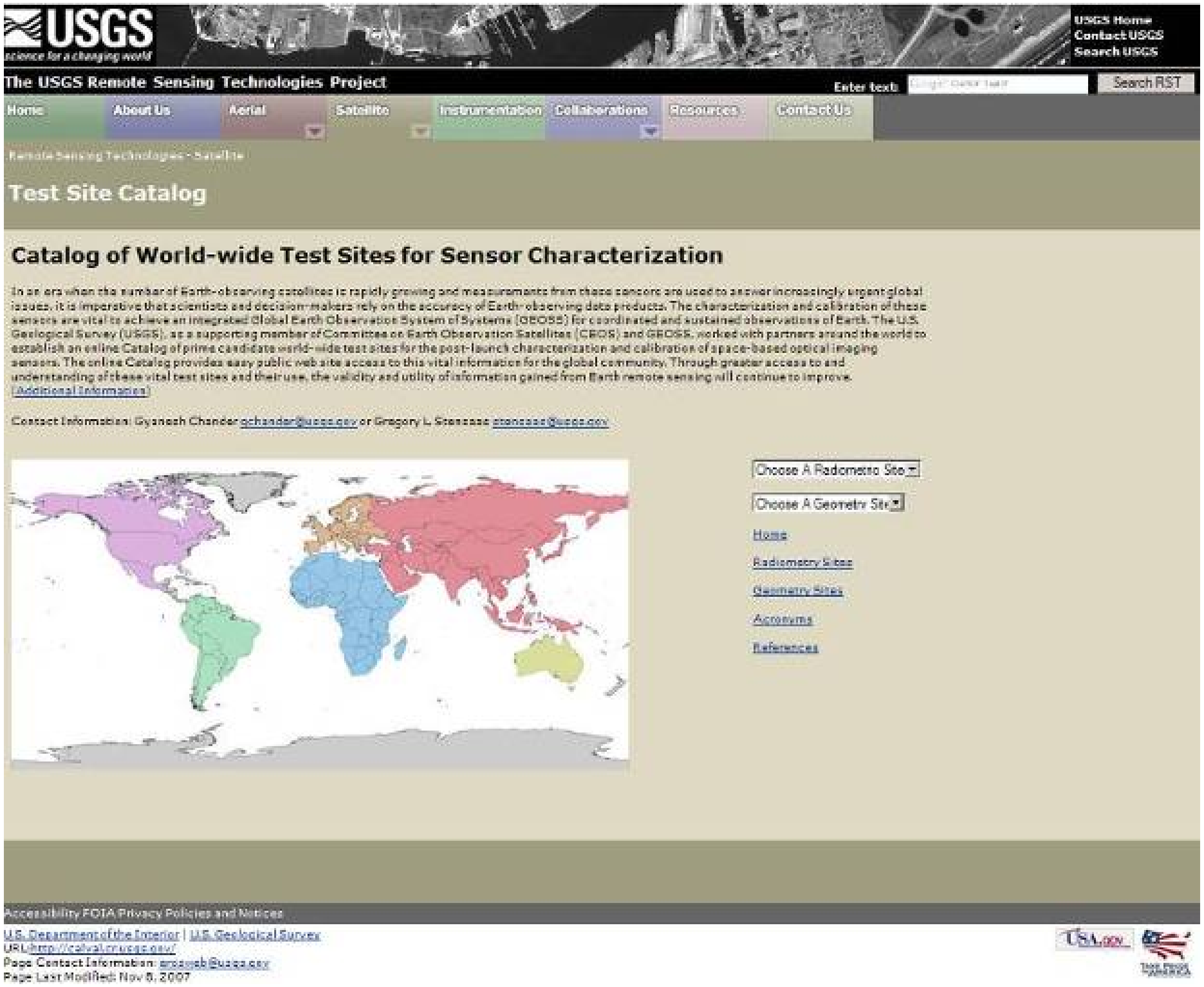
1) Algeria 3
2) Algeria 5
3) Amburla
4) Arabia 1
5) Arabia 2
6) Barreal Blanco
7) Bonneville Salt Flats
8) Dunhuang
9) Dunrobin
10) Egypt 1
11) Egypt 2
12) Ivanpah Playa
13) La Crau
14) Lake Frome
15) Libya 1
16) Libya 2
17) Libya 4
18) Lunar Lake Playa
19) Mali 1
20) Mauritania 1
21) Namib Desert 1
22) Namib Desert 2
23) Niger 1
24) Niger 2
25) Railroad Valley Playa
26) Rogers Dry Lake
27) Sechura Desert
28) Sonoran Desert
29) Sudan 1
30) Taklamakan Desert
31) Tinga Tingana
32) Uyuni Salt Flats
33) Warrabin
34) White Sands
35) Winton
36) Yemen Desert 1

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

http://calval.cr.usgs.gov/sites_catalog_map.php



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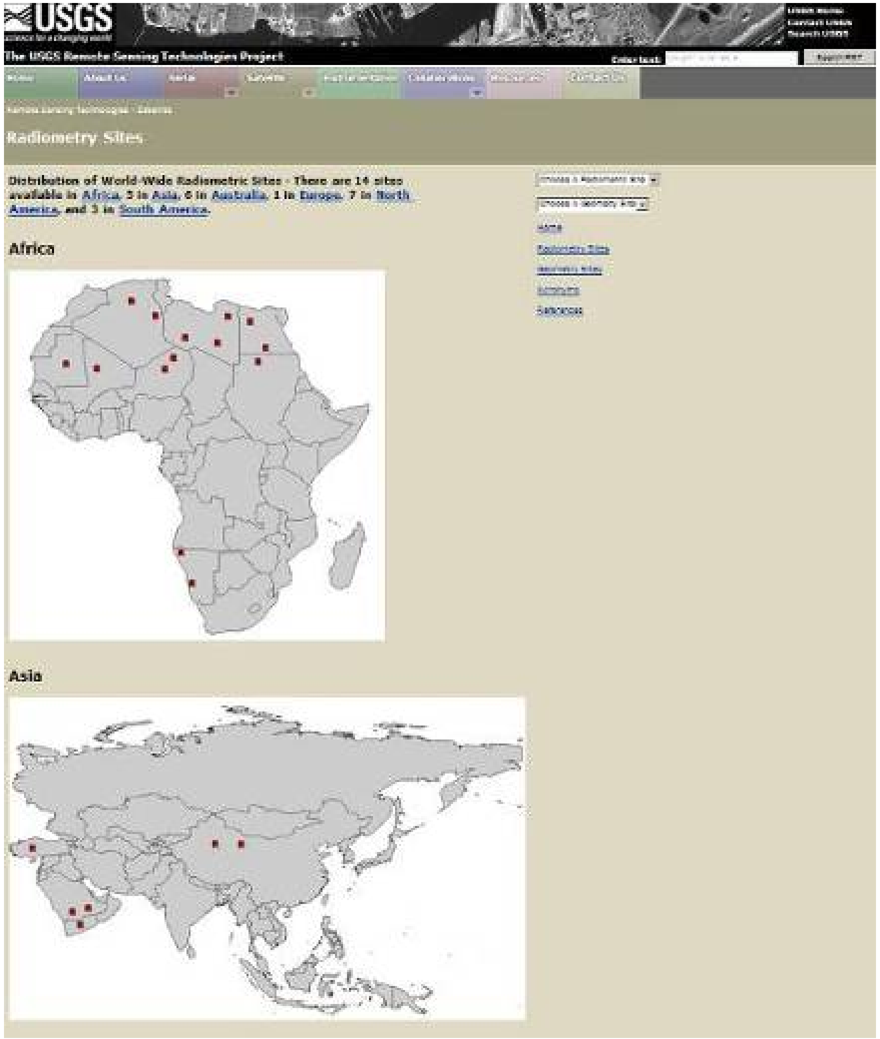
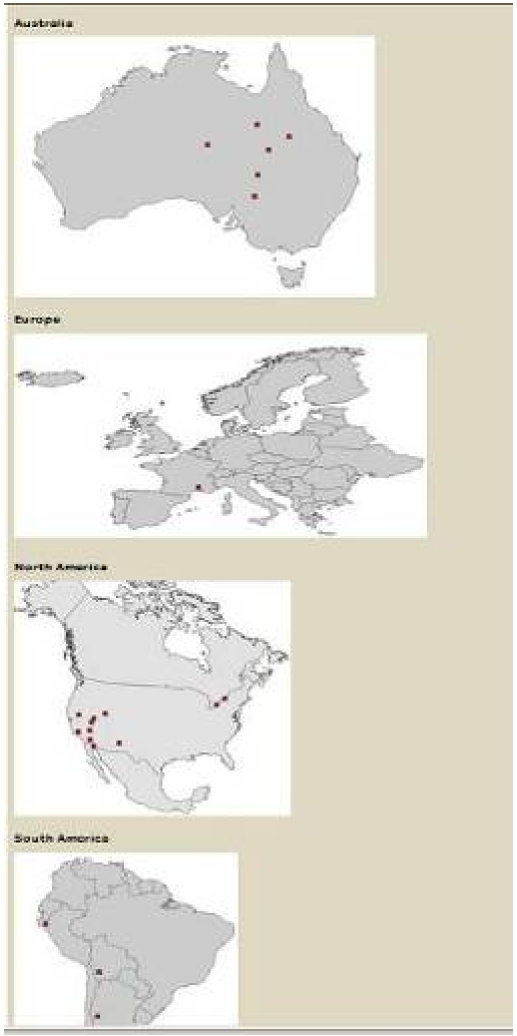
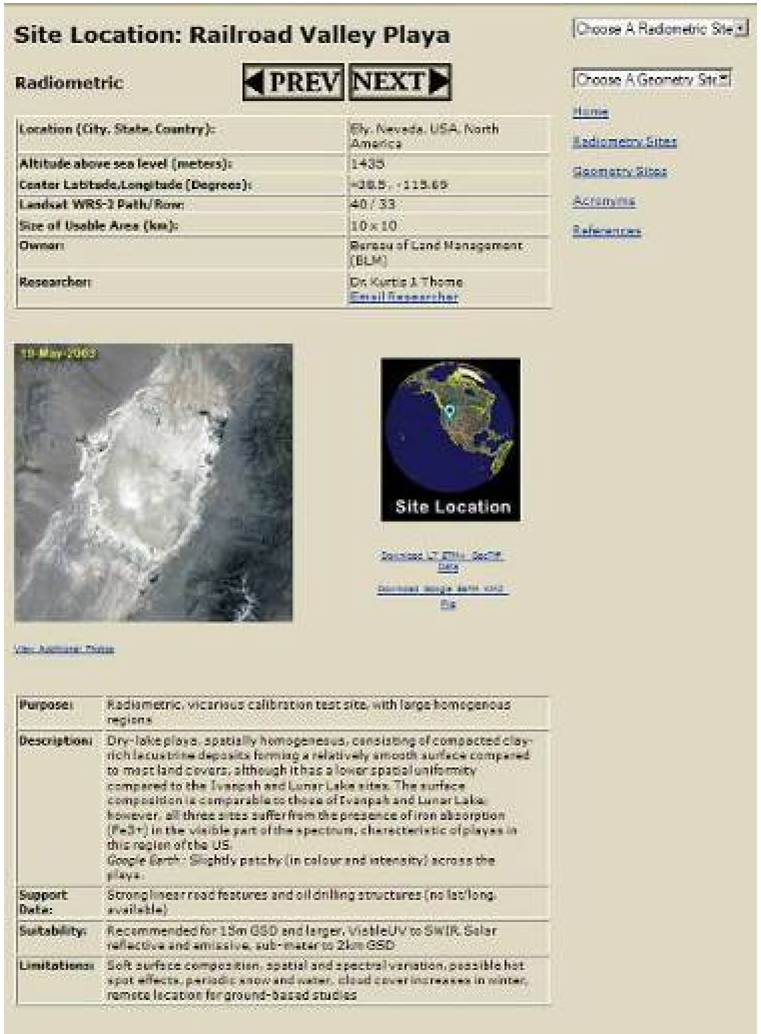
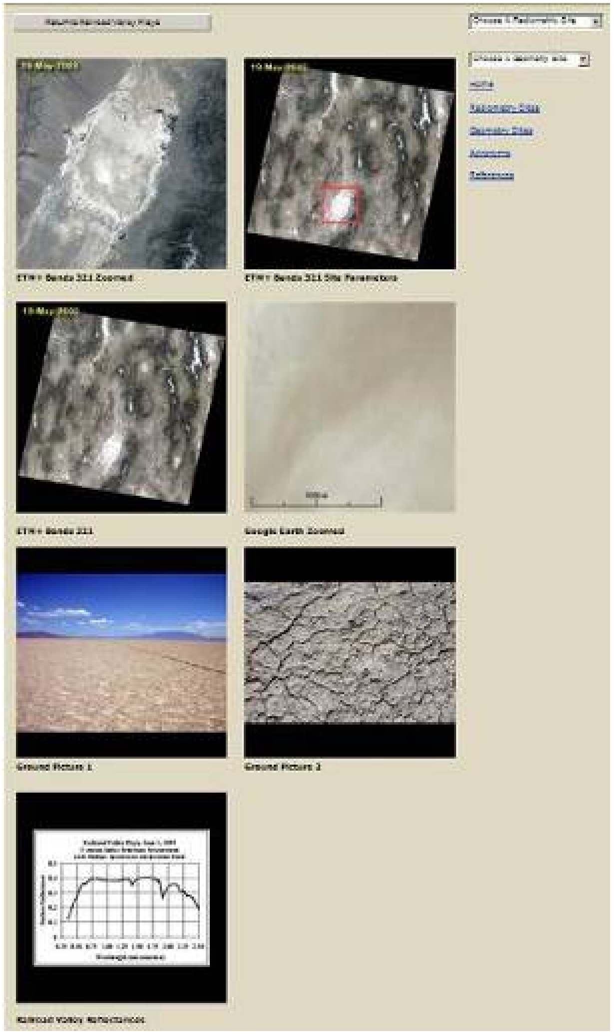
Radiometry Sites





Online Catalogue Example: Railroad Valley Playa, North America





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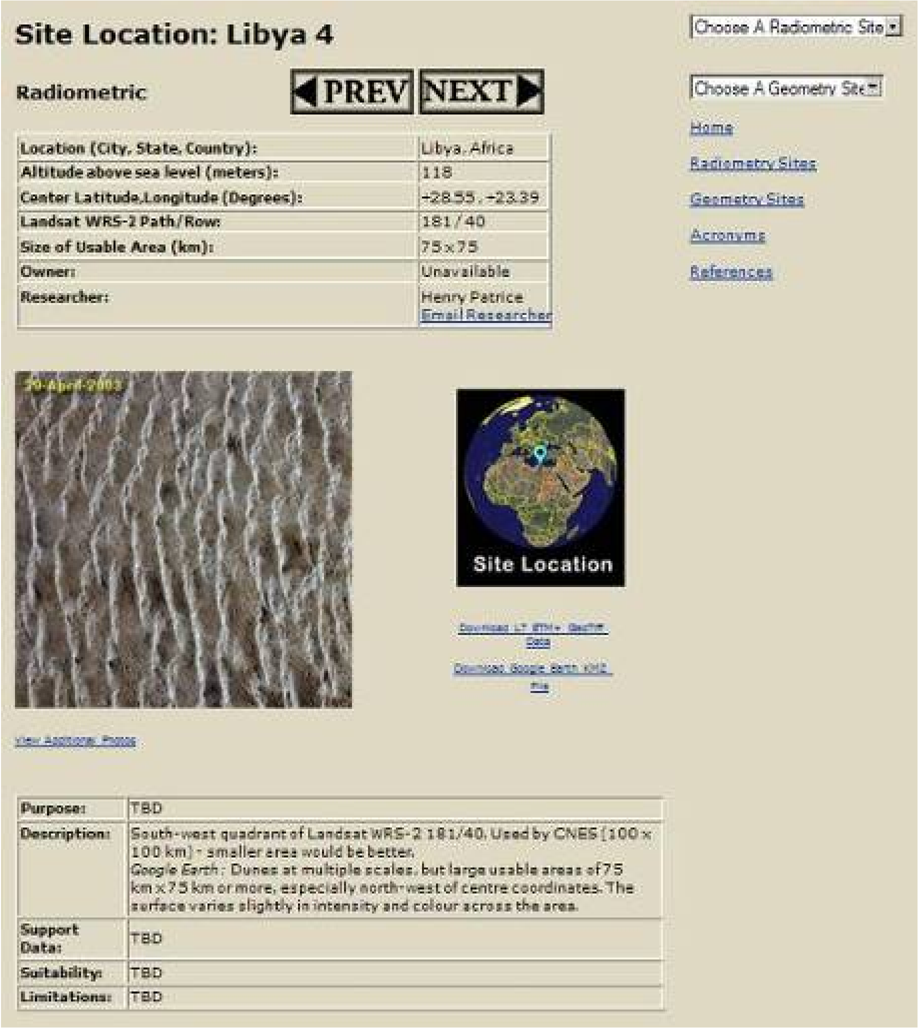
Online Catalogue Example: Libya 4, Africa



Site Location: Libya 4

Choose A Radiometric Site

Choose A Geometry Site

Radiometric PREV NEXT

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

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Radiometry Sites

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29-April-2002

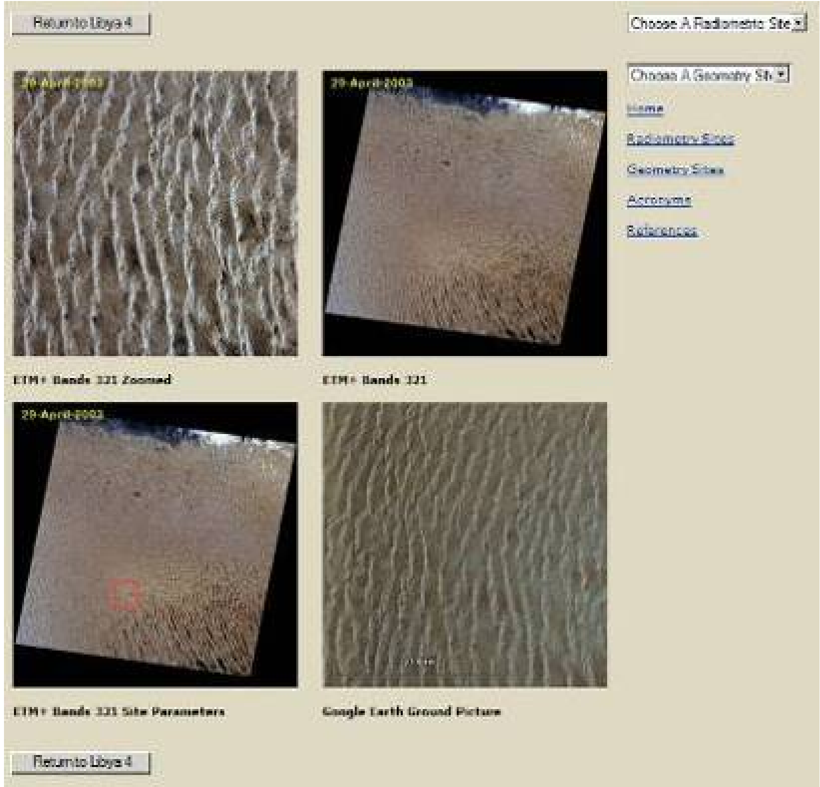
Site Location

Download L7 ETM+ GeoTiff Data

Download Google Earth KMZ File

View Additional Photos

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



Return to Libya 4

Choose A Radiometric Site

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29-April-2002

ETM+ Bands 321 Zoomed

29-April-2002

ETM+ Bands 321

29-April-2002

ETM+ Bands 321 Site Parameters

Google Earth Ground Picture

Return to Libya 4

Online Catalogue Example: Dunhuang, Asia

Site Location: Dunhuang

Radiometric PREV NEXT

Location (City, State, Country):	Dunhuang, Gobi Desert, Gansu Province, China, Asia
Altitude above sea level (meters):	1220
Center Latitude,Longitude (Degrees):	+40.13 , +94.34
Landsat WRS-2 Path/Row:	137 / 32
Size of Usable Area (km):	25 x 25
Owner:	Unavailable
Researcher:	Unavailable

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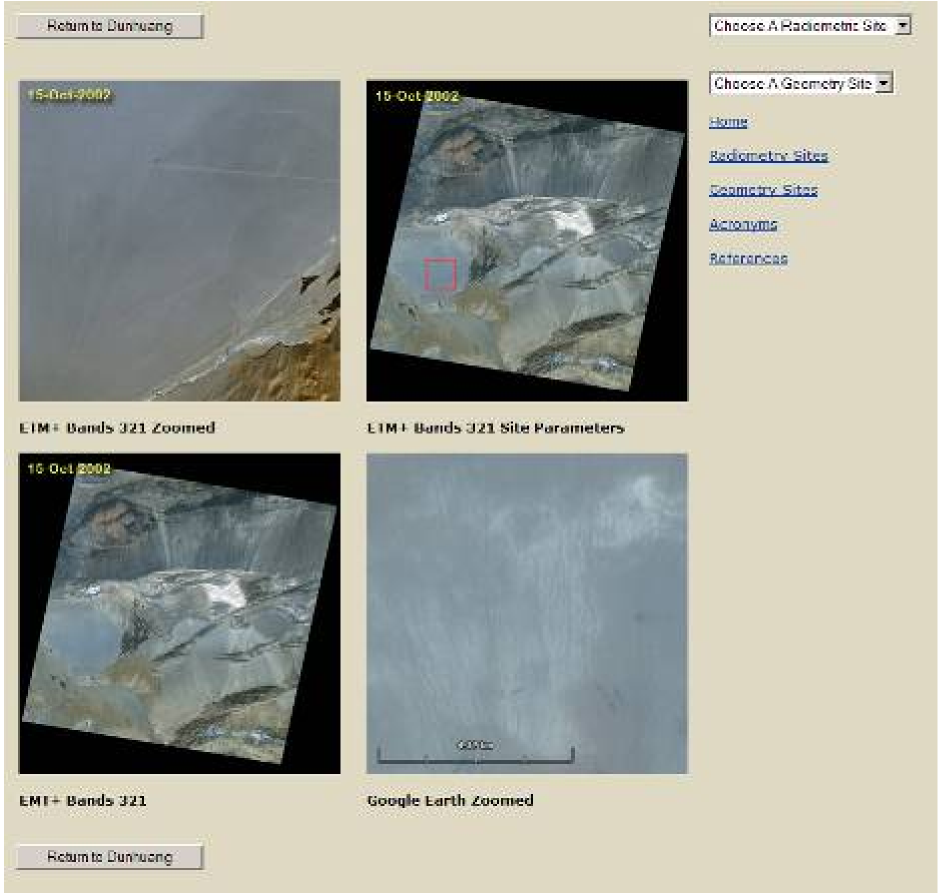
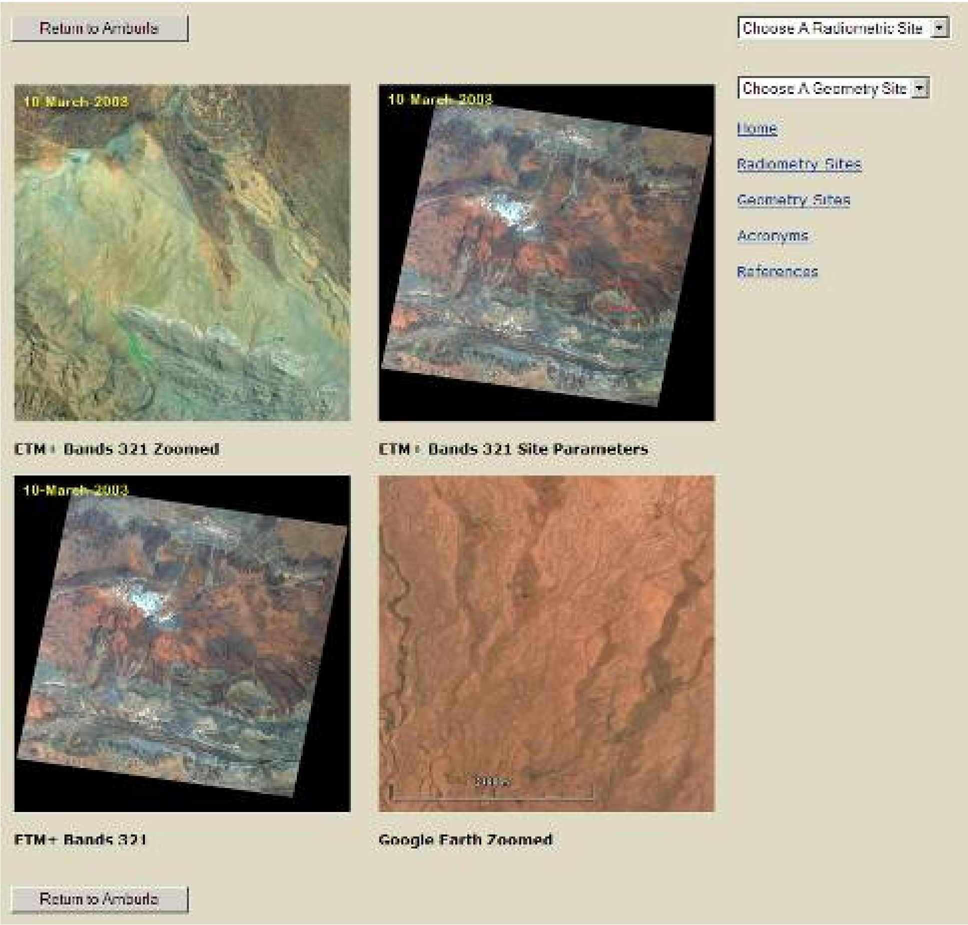
15-Oct-2002

Site Location

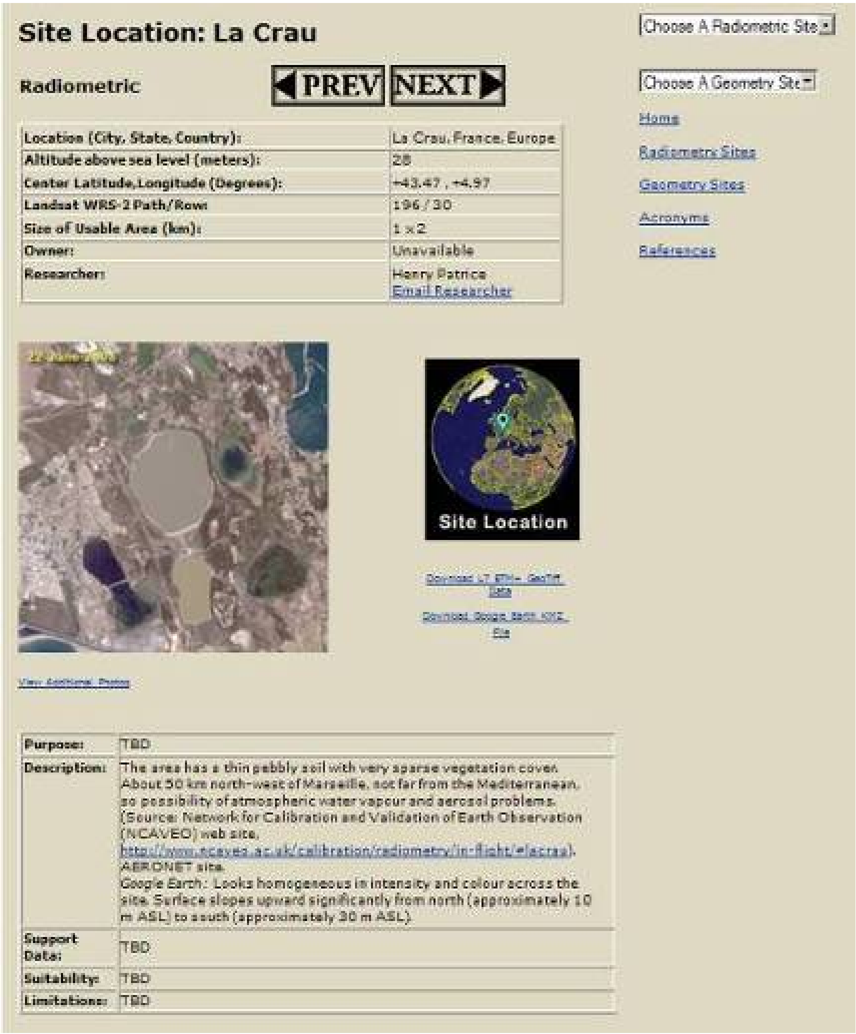
Purpose:	TBD
Description:	Located in the Gobi desert in north-west China, about 35 km west of the city of Dunhuang (Gansu Province). The calibration area is situated on a stabilised alluvial fan. The area used for vicarious calibration measurements is approximately 400 m x 400 m in the centre of the fan and the surface comprises cemented gravels, with no vegetation. Sources of meteorological data for the site include the Dunhuang-PAM automated weather station, which is part of the Asian Automatic Weather Station Network. Atmospheric aerosols over the site are typical of a rural continental location, although some larger particles were observed, possibly influx from the sand dunes to the north-west. Sandstorms affect the site on around 8 days per annum and atmospheric dust is a significant factor on around 60 days per annum. (Source: Network for Calibration and Validation of Earth Observation (NCAVEO) web site. http://www.ncaveo.ac.uk/calibration/radiometry/in-flight/#dunhuang) AERONET site. Google Earth: Looks very uniform in intensity and colour, especially in Google Maps satellite imagery, which shows more detail.
Support Data:	TBD
Suitability:	TBD
Limitations:	TBD

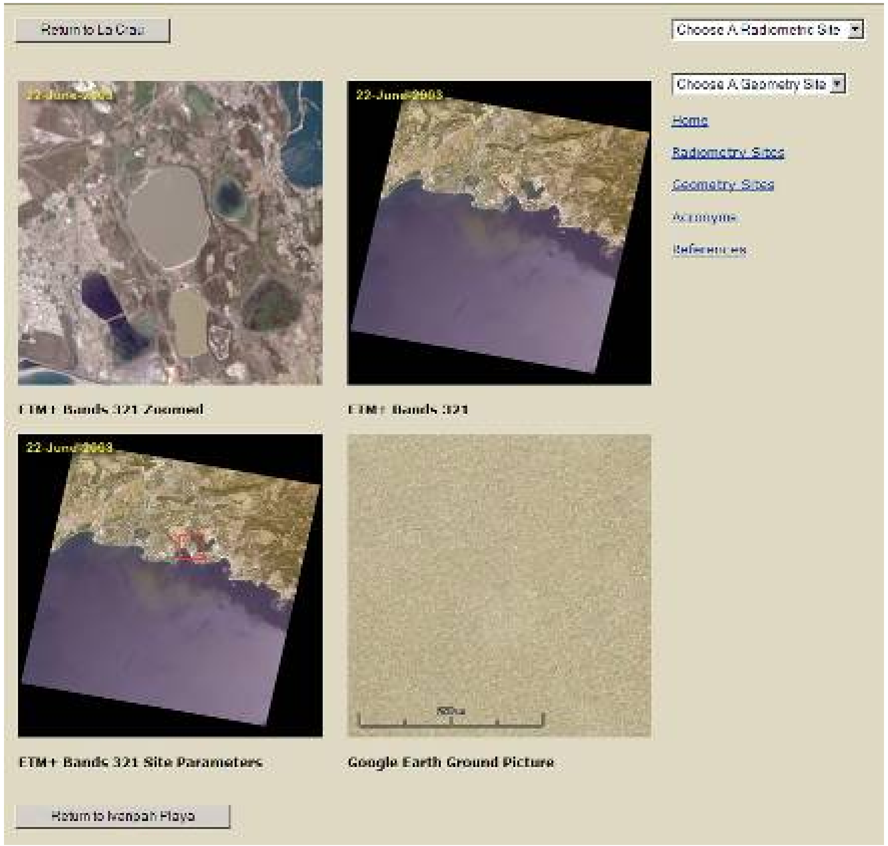


Online Catalogue Example: Amburla, Australia



Online Catalogue Example:
La Crau, Europe





Online Catalogue Example:
Barreal Blanco, South America

Site Location: Barreal Blanco

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Radiometric PREV NEXT

Location (City, State, Country):	Barreal Blanco, San Juan, Argentina, South America
Altitude above sea level (meters):	1872
Center Latitude,Longitude (Degrees):	-31.96 , -69.45
Landsat WRS-2 Path/Row:	232 / 82
Size of Usable Area (km):	0.5 x 0.5
Owner:	Unavailable
Researcher:	Unavailable

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 16x4 20-m pixels on a 100-280 axis. ETM+ consisted of a 16x4 30-m pixel site on a 010-190 axis. 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 favourable in the Southern Hemisphere in January. *Google Earth* : Small homogeneous bright site. 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 Data:	TBD
Suitability:	TBD
Limitations:	TBD

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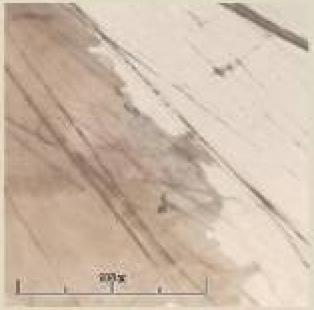
ETM+ Bands 321 Zoomed

ETM+ Bands 321

ETM+ Bands 321 Site Parameters



Google Earth Ground Picture

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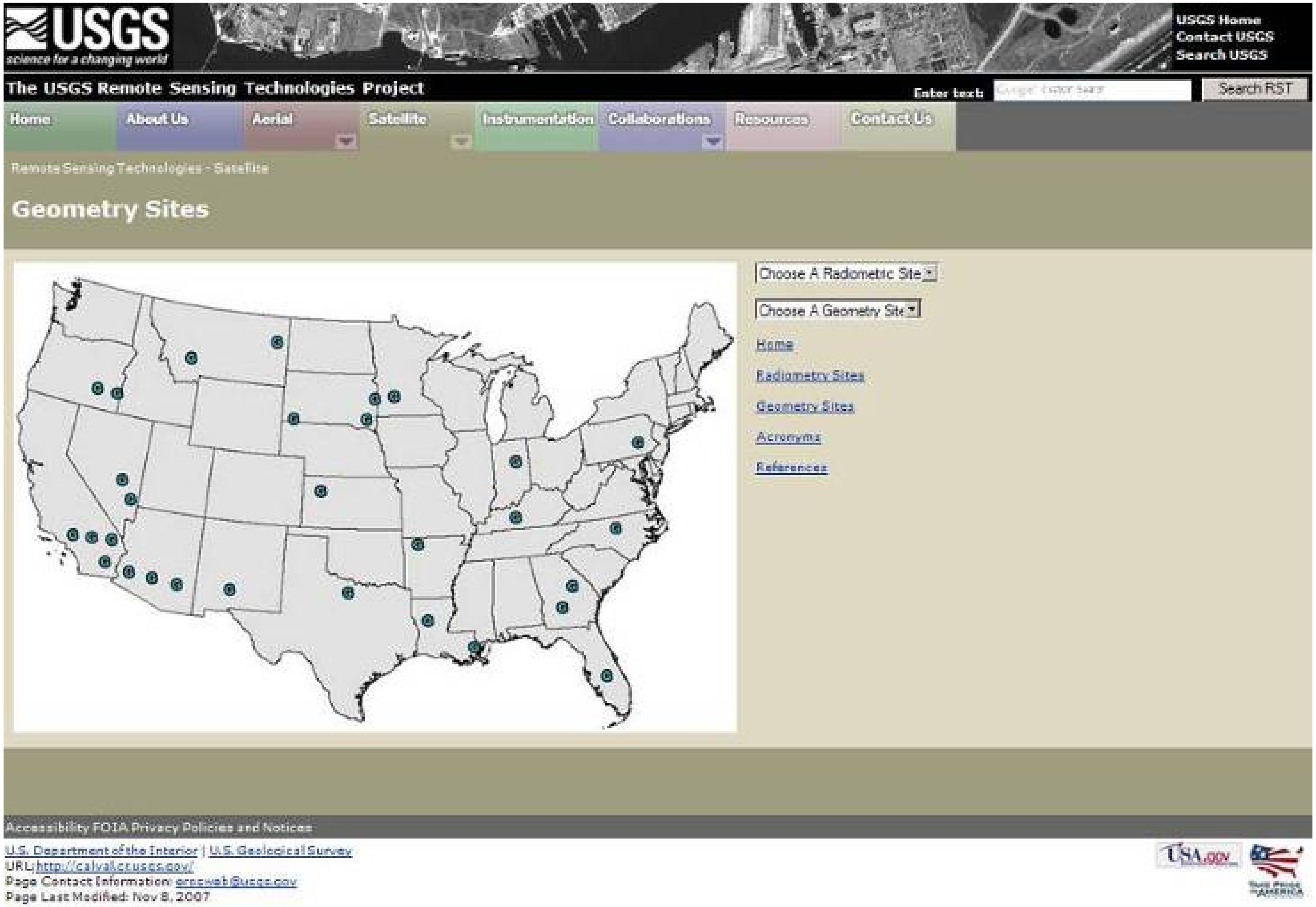
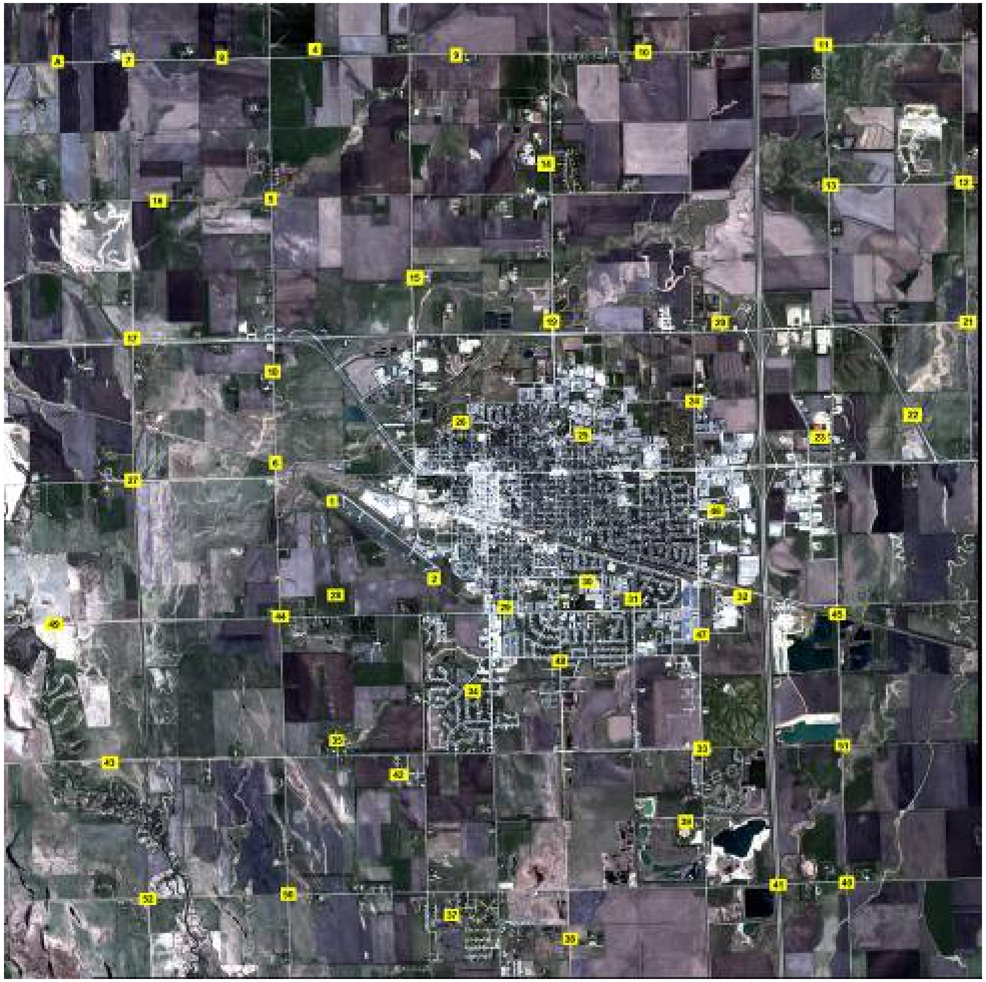
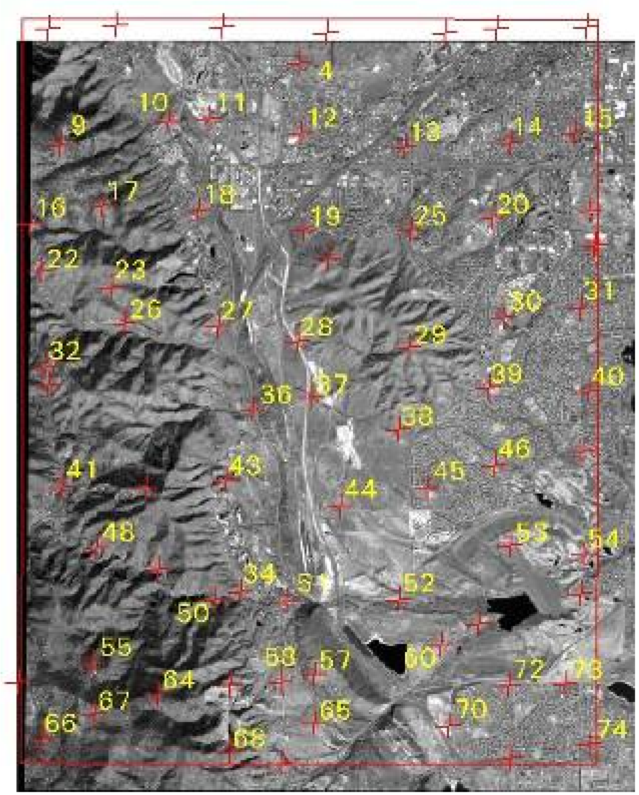
Geometry Sites



GCPs

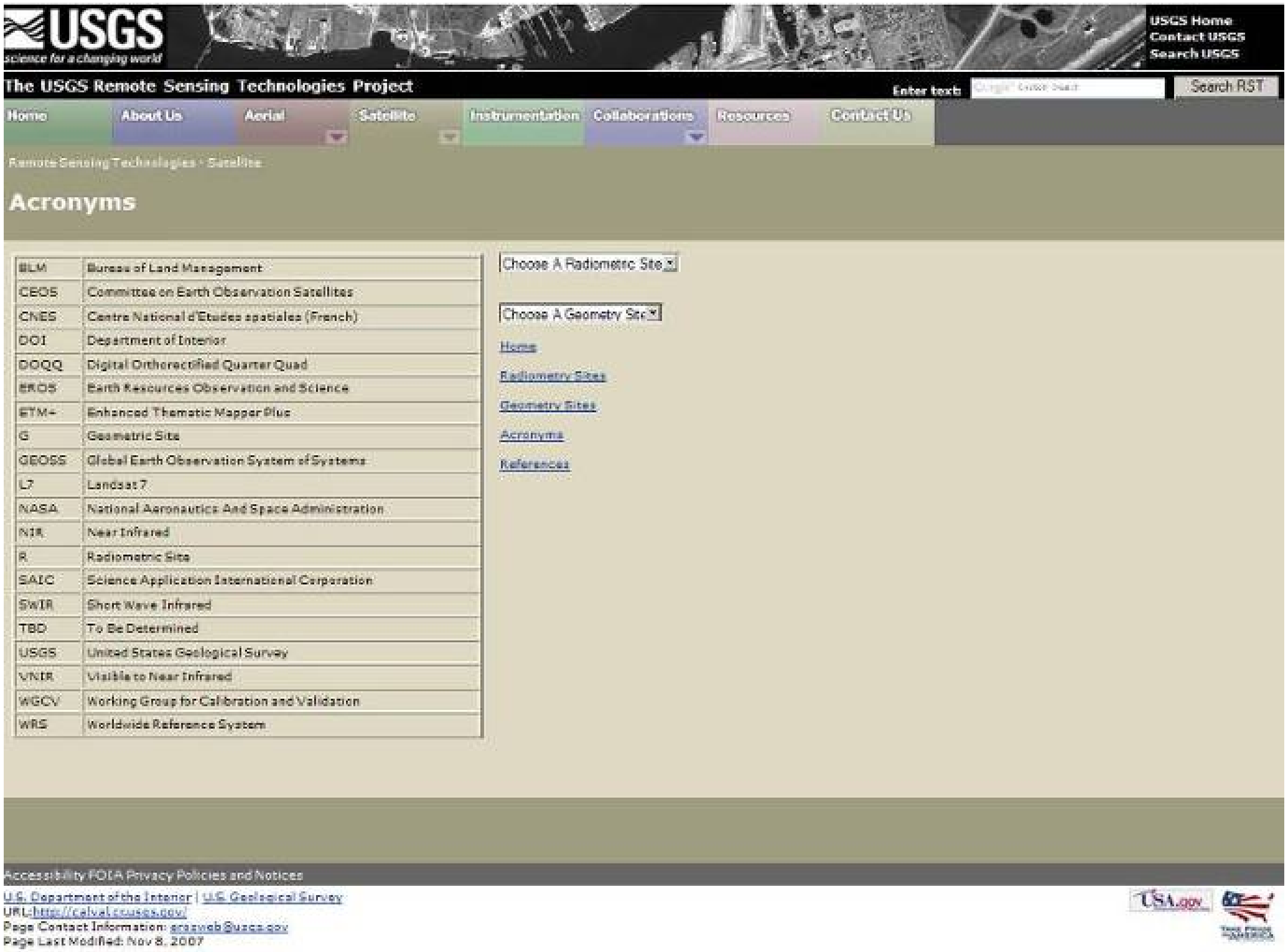


51 GCPs selected over Brookings, SD area



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
SWIR	Short Wave Infrared
TBD	To Be Determined
USGS	United States Geological Survey
VNIR	Visible to Near Infrared
WGCV	Working Group for Calibration and Validation
WRS	Worldwide Reference System

References

USGS
science for a changing world

The USGS Remote Sensing Technologies Project

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Remote Sensing Technologies - Satellite

References

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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

#	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

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)

USGS

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

#	Site Name	Path	Row	Center Latitdue	Center Longitude
1	Algeria 3	192	39	30.32	7.66
2	Algeria 5	195	39	31.02	2.23
3	Amburla	103	76	-23.39	133.12
4	Arabia 1	164	47	18.88	46.76
5	Arabia 2	162	46	20.13	50.96
6	Barreal Blanco	232	82	-31.86	-69.45
7	Bonneville Salt Flats	39	32	41.00	-113.57
8	Dunhuang	137	32	40.13	94.34
9	Dunrobin	94	76	-22.67	146.13
10	Egypt 1	179	41	27.12	26.10
11	Egypt 2	177	44	22.94	28.79
12	Ivanpah Playa	39	35	35.57	-115.40
13	La Crau	196	30	43.47	4.97
14	Lake Frome	97	81	-30.85	139.67
15	Libya 1	187	43	24.42	13.35
16	Libya 2	182	43	25.05	20.48
17	Libya 4	181	40	28.55	23.39
18	Lunar Lake Playa	40	33	38.40	-115.99
19	Mali 1	198	47	19.12	-4.85
20	Mauritania 1	201	47	19.40	-9.30
21	Namib Desert 1	179	77	-24.98	15.27
22	Namib Desert 2	182	72	-17.33	12.05
23	Niger I	189	46	19.67	9.81
24	Niger 2	188	45	21.37	10.59
25	Railroad Valley Playa	40	33	38.50	-115.69
26	Rogers Dry Lake	41	36	34.96	-117.86
27	Sechura Desert	10	64	-5.90	-80.43
28	Sonoran Desert	38	38	32.35	-114.65
29	Sudan 1	177	45	21.74	28.22
30	Taklamakan Desert	146	32	39.83	80.17
31	Tinga Tingana	97	80	-29.00	139.86
32	Uyuni Salt Flats	233	74	-20.38	-66.95
33	Warrabin	95	78	-26.28	143.65
34	White Sands	33	37	32.92	-106.35
35	Winton	96	76	-22.52	142.94
36	Yemen Desert 1	164	48	16.87	47.55

#	Site Name	Path	Row	Center Latitude	Center Longitude
37	Dome C	89	113	-74.50	123.00
38	Tuz Golu	177	33	38.83	33.33
39	Algeria_1	196	44	23.80	-0.40
40	Algeria_2	197	42	26.09	-1.38
41	Algeria_4	193	39	30.04	5.59
42	Niger_3	190	45	21.57	7.96
43	Libya_3	180	44	23.15	23.10
44	Mauritania_2	201	46	20.85	-8.78
45	Lspec Frenchman Flat	40	34	36.81	-115.93
46	Negev, Southern Israel	174	39	30.11	35.01

THERMAL CALIBRATION SITES

#	Site Name	Path	Row
1	Lake Ontario	16	30
2	Lake Ontario	17	30
3	Lake Erie	18	30
4	Lake Tahoe	43	33
5	Salton Sea	39	37

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)

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“Invariant” IVOS Sites (Total=5)

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

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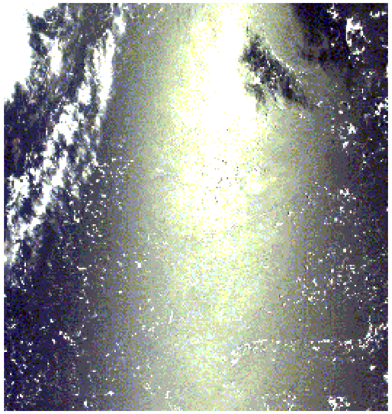
Special Methods

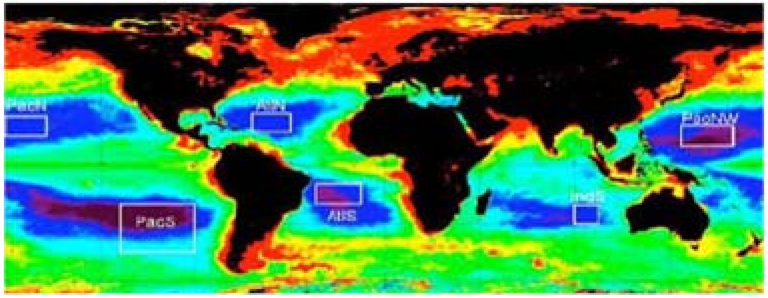
Moon



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)

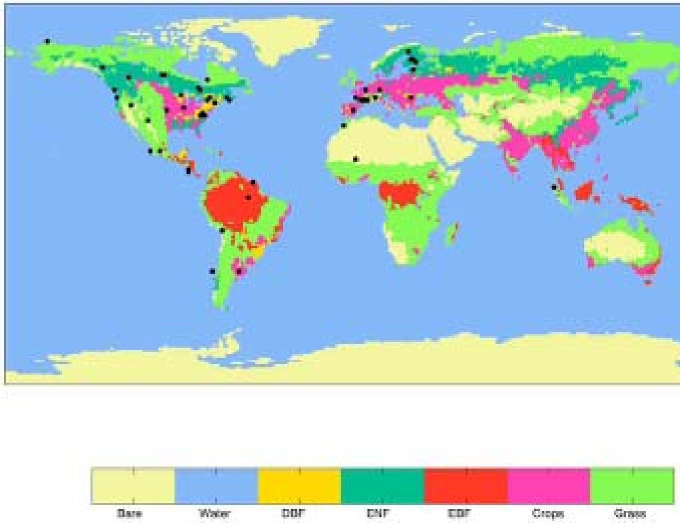
- **Montagne Sainte-Victoire**
  - France referred to as Aix-en-Provence
  - 5.528-5.685ºE, 43.502-43.560ºN
  - mixed arable, forest, limestone
- **Barcelona, Spain**
  - 1.5-2.75ºE, 41.25-41.82ºN
  - urban, mixed arable, forest
- **North Wales,**
  - UK3-5ºW, 52-53.5ºN
  - urban, pasture, forest
- **Three Gorges, China**
  - 108.252-111.302ºE, 30.638-31.229ºN
  - forest, arable, limstone shales
- **Puget Sound, WA, USA**
  - -121.397 to -123.897ºW, 46.364-48.864ºN
  - 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)
- http://lpvs.gsfc.nasa.gov/



- 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 calibratio 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 Amazc radiometric accuracy
- **Calibration Transponder Sites**

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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**