CEOS-WGCV Terrain Mapping Sub-group: Current Status and GEO DA-09-03d update

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Point-of-Contact, GEOSS Task DA-09-03d
Chairperson, CEOS-WGCV Sub-group on Terrain mapping from satellites
Chairperson, ISPRS Commission IV WG on "Global DEM Interoperability"
Vice-Chair, UK JISC Geospatial Working Group (2002-2008)

Head, Imaging Group
Professor of Image Understanding and Remote Sensing
HRSC Science Team Member (ESA Mars Express 2003)
Stereo Panoramic Camera Science Team Member (ESA EXOMARS)
MODIS & MISR Science Team Member (NASA EOS Project)
TerraSAR-X and TANDEM-X science team member (DLR-Astrium)

** Partially supported by BNSC-Qinetiq under the ICP3 programme*

CEOS WGCV Terrain Mapping

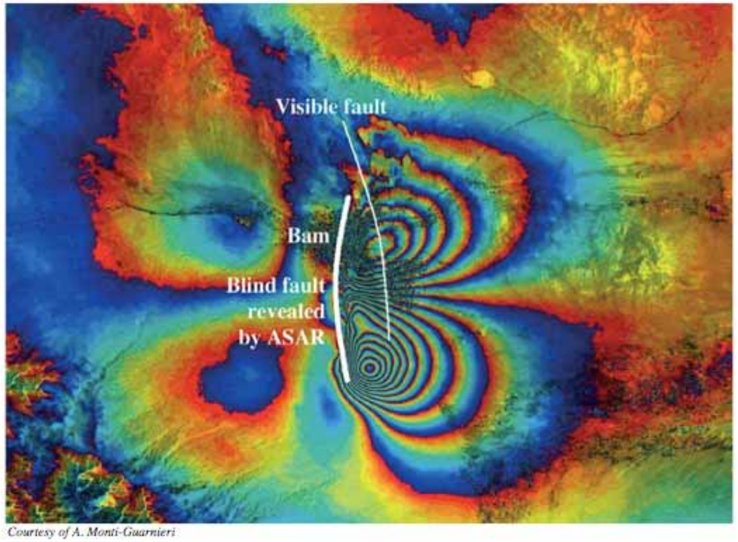
- **What is the mission of the Terrain Mapping Sub-Group (TMSG)?**
  - **To ensure that characteristics of digital terrain models produced from Earth Observation sensors at global and regional scale are well understood and that products are validated and used for appropriate applications.**
- **What are the specific objectives of this group?**
  - **To develop specifications for the generation of '*standardised terrain surface products with known accuracy*' from similar sensing systems in the context of data continuity,**
  - **to specify evaluation methods and statistics which give transparent information about the *quality and heritage of terrain models*.**
  - **To update the current dossier of test sites and identify new sites, particularly to satisfy the cal/val requirements of future missions and generally improve access to validation data sets.**
  - **To keep an up to date record of the current status of sensors which produce data for terrain mapping and of the DEMs available.**
  - **To produce a DEM requirements document with a science rationale, taking into account the output from SRTM.**

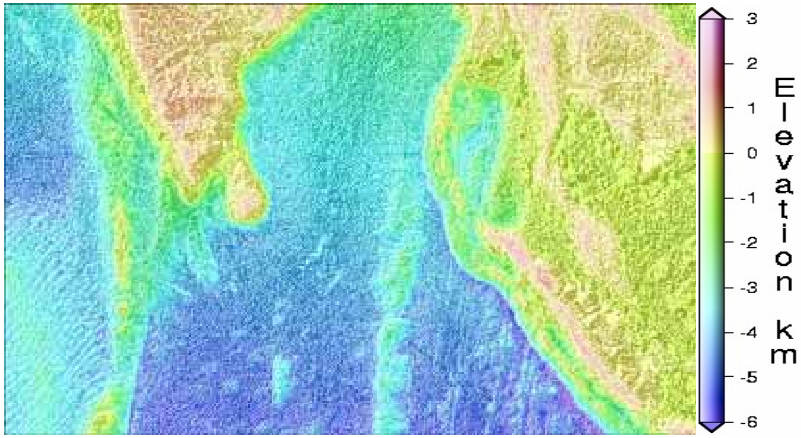
Overview

- Why does GEO need global topography/bathymmetry?
- What is GEO Task DA-09-03d?
- Global ASTER Project (METI-NASA)
- Validation of ASTER GDEM Version 1: Highlights of the CEOS-GEO-ISPRS workshop at IGARSS 2009
- DEMqis: A QA4EO-compliant quality reporting system (BNSC:UCL-Nottingham)
- Next Steps with ASTER GDEM V2 (supplied by METI/USGS/NASA)
- "Plan B" for Global DEM: use of ALOS PRISM+PALSAR (Supplied by T. Tadono, JAXA)
- GMTED 2010 (supplied by J. Danielson, D. Gesch, USGS)
- Status and plans for GEO Task DA-09-03d
- CEOS Plenary resolutions

Why does GEO need global topography/bathymmetry?

- ***Global DEM required for 6 of the 9 societal benefit areas identified by the 10 year Implementation Plan of GEOSS***
- ***Natural disasters all require detailed knowledge of topography***
  - *either directly for volcanic dome monitoring, flood inunadtion areal predictions, landslides*
  - *or for downstream EO processing, e.g. InSAR for earthquake monitoring and possible prediction*
- ***Poor bathymmetric and topography knowledge hinders tsunami forecasts***
- ***Tsunami a main spur for GEO implementation***





2' (≈4km) Smith, Walter H.F., and David T. Sandwell, 1997 "Global Sea Floor Topography from Satellite Altimetry and Ship Depth Soundings", Science, 277, 1956-1962, 1997

30m height "flood-fill" based on SRTM-DTED1® 3" (≈90m)

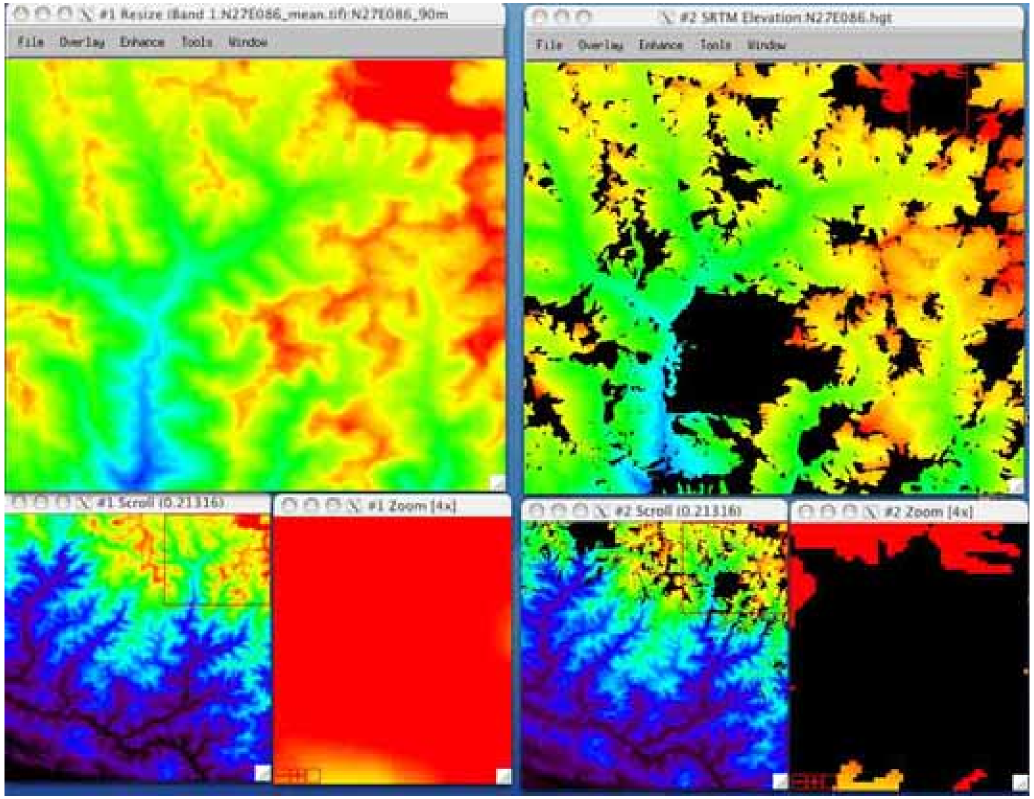
GEO Task DA-09-03d : Global DEM

- ***Supported by BNSC-CEOS with Point of Contact: Prof. J-P Muller (CEOS-WGCV) and WGISS activities reported by W. Cudlip (BNSC delegate)***
- ***Objectives are to***
  - **Facilitate interoperability among Digital Elevation Model (DEM) data sets with the goal of producing a global, coordinated and integrated 30m DEM of the Earth's land surface and continental shelves**
    - » **Originally envisaged ASTER GDEM to form the land part of this global 30m DEM**
    - » **Continental shelf bathymmetry less of a major issue, as appears to be SAR solution**
  - **This DEM database should be embedded into a consistent, high accuracy, and long term stable geodetic reference frame for Earth observation.**
- ***Planned activities include:***
  - **Successive open calls for validation of ASTER GDEM quality (12/08, 3/10) and presentation of results through online proceedings of workshops, subsequent peer review journals.**
  - **Open display of ASTER GDEM quality through the CEOS-WGISS ICEDS (3/10).**
  - **Open display of errors and artifacts through a "Known Product Issues" web service (3/10).**
  - **Promotion of continental shelf bathymetry acquisition starting in north polar region through ESA/CSA MORSE programme (6/10).**
- 40 members involved in Task (UK, US, AU, DE, FR, IT, ES, JP, CN, KR, WMO, OGC)
- Contributes towards 6 of the SBAs with Disaster monitoring most important

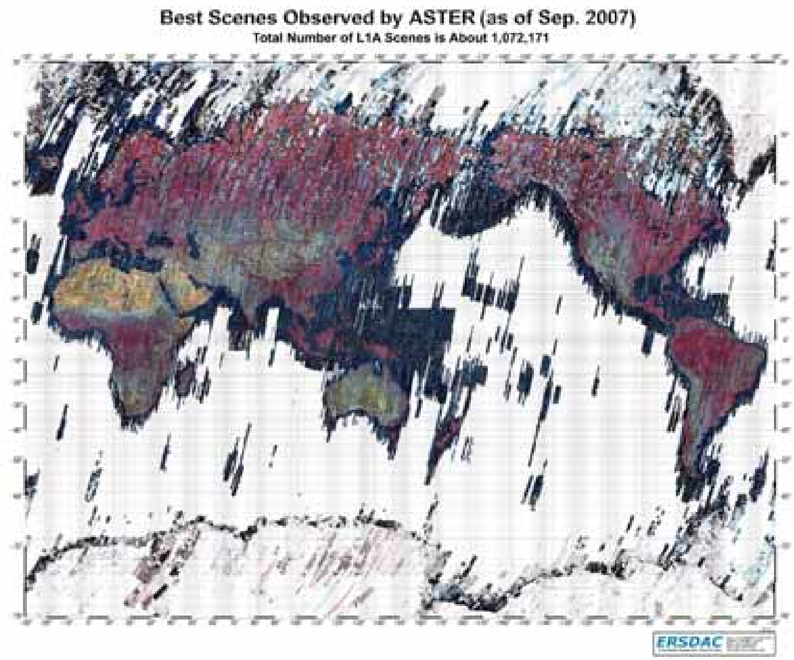
経済産業省 Ministry of Economy, Trade and Industry

ASTER Global DEM Project

Stacked ASTER SRTM



- **203 scenes used**
- **No holes for ASTER DEM**
- **Many large holes for SRTM**



- 22,895 1° x 1º tiles
- 83° N to 83° S
- 10 m Zrms
- 29/6/2009 release

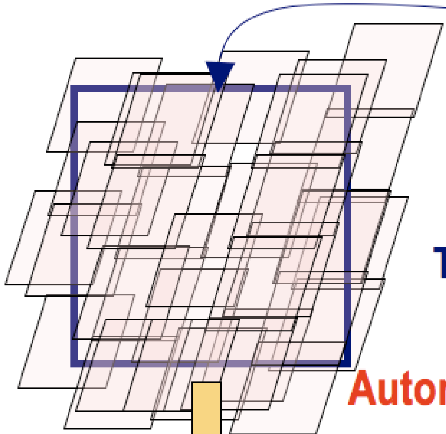
USGS
science for a changing world

Land Processes
Distributed Active Archive Center

NASA

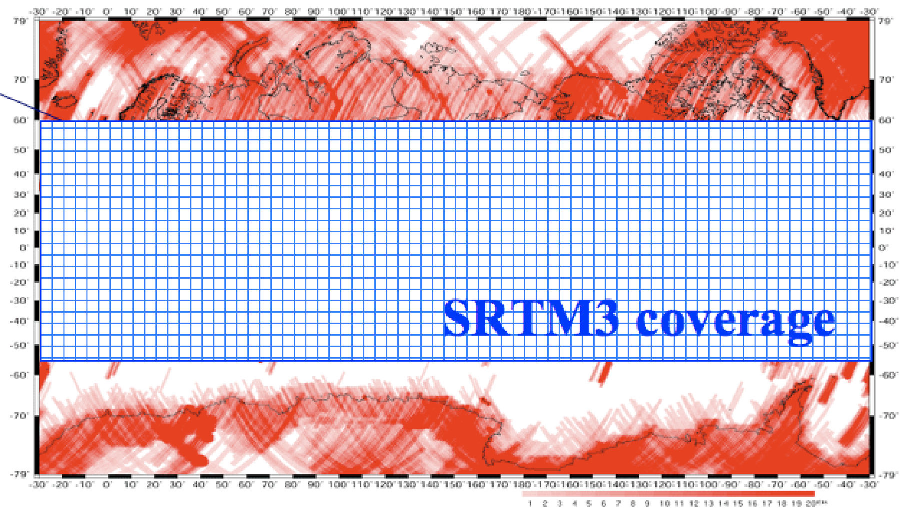
Methodology

1. Stereo-correlate entire ~ 1.5 million scene ASTER Archive; 2. Cloud mask to remove cloudy pixels;
3. Stack all DEMS & remove residual bad values and outliers; 4. Partition data into 1° x 1° tiles ---



ASTER scene
(60km x 60km)

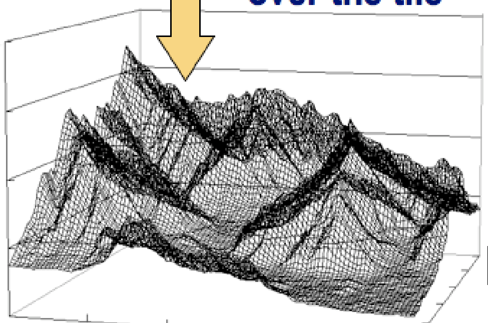
Tile (1 arc degree square)



ASTER coverage (~1.5 million scenes in summer 2008)
Deeper red indicates more data accumulated.

Automated processing

Generation of a seamless tile of DEM using all ASTER data ever acquired over the tile



A seamless Tile of DEM

Global coverage

ASTER GDEM

Contribution to GEOSS

Both US and Japan committed to contribute to GEOSS at Capetown Summit 2007.

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METI Ministry of Economy, Trade and Industry

SILC
Sensor Information Laboratory Corp.

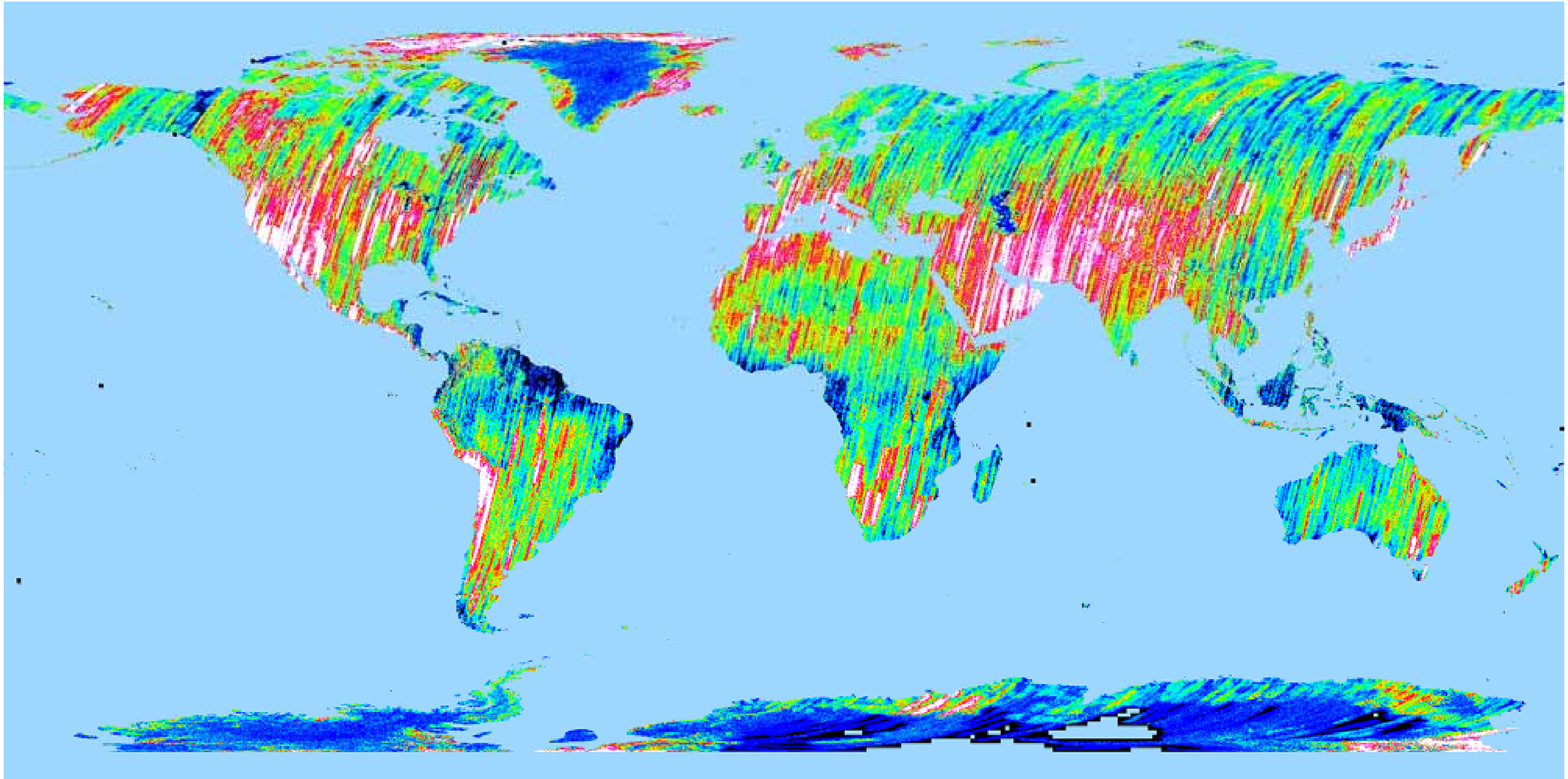
*Status-Overview : GEO DA-09-03d: Global DEM assessment**

- For conterminous U.S. component, 934 CONUS tiles have been compared to NED and SRTM1 DEMs.
- Absolute vertical accuracy were measured using 13,300 "GCPs on benchmarks" from the National Geodetic Survey.
- For non-US areas, USGS released an "Announcement of Collaborative Opportunity" on 2-Dec-08 with a closing date for proposals of 7-Jan-09. JPM circulated AOC around WGCV-TMSG and GEO task group. 21 non-US groups submitted validation results by 21 March 2009
- India and Thailand both made inquiries but did not submit a formal proposal in the right timescales
- JPM evaluated ASTER GDEM quality for 5 tiles (maximum permitted), 4 of which were over CEOS-WGCV test sites
- Around 1% of the total 22,495 tiles have been evaluated by these 21 groups outside of the US and around 3% by NGA and USGS
- USGS released a joint validation report with the limited distribution of ASTER GDEM on 29 June 2009

Status-Overview : GEO DA-09-03d: Global DEM : continuing roadblocks

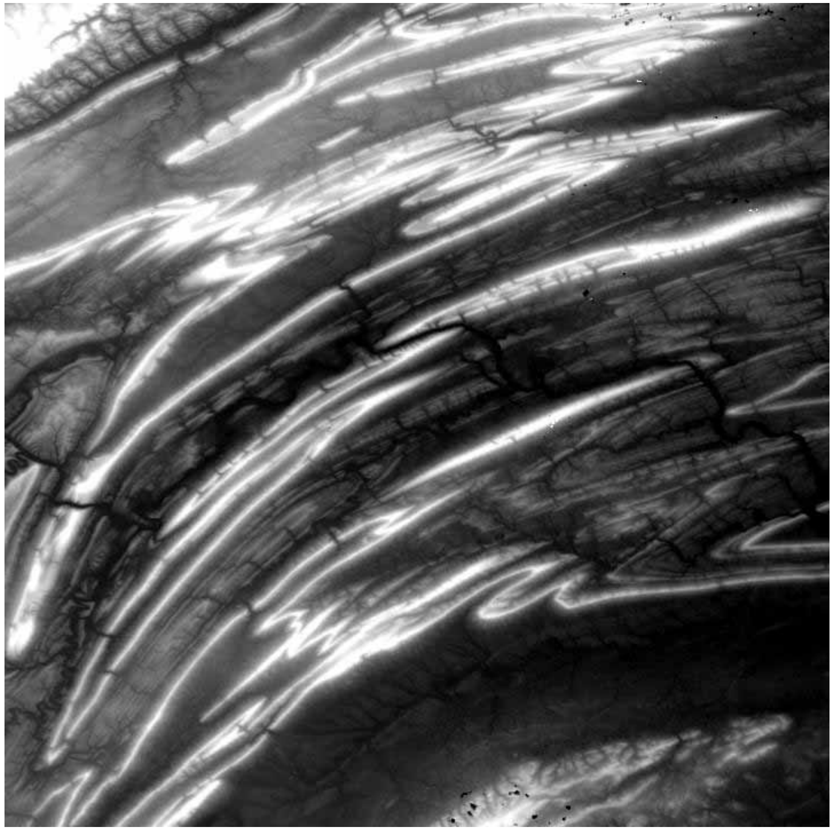
- **Current METI/NASA release policy states limits on the maximum number of tiles permitted for each order although all data will be free. USGS/NASA will allow 1,000 tiles at a time, ERSDAC 100 tiles for each order**
- **This limitation is due to previous ASTER data policy and infrastructure limitations which do not allow anonymous ftp (as for SRTM)**
- **Only 1º x 1º tiles to be released to registered users through ERSDAC and USGS-EDC**
- **During CEOS-GEO-ISPRS workshop at IGARSS09 on 17 July 2009 in Cape Town, Hato-san (ASTER GDS Manager) announced that an updated version would be generated but timescales were then unknown (see later)**

GDEM Stacking Number

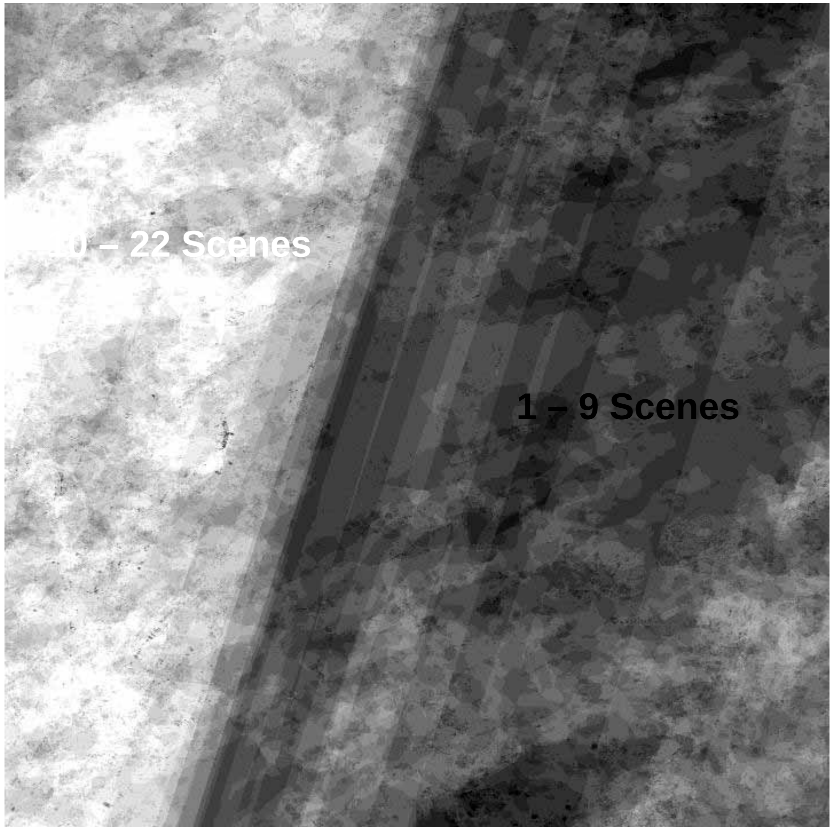


N.B. Experience suggests that accuracy linearly relates to stacking number.

Susquehanna Test Site



Prototype ASTER GDEM



Number of Scenes Used to Produce Prototype ASTER GDEM

Global DEM Interoperability: ASTER GDEM: Initial Assessment over the CEOS-WGCV-TMSG test sites in Europe and China

Jan-Peter Muller, Shih-Yuan Lin**

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Point-of-Contact, GEOSS Task DA-09-03d*

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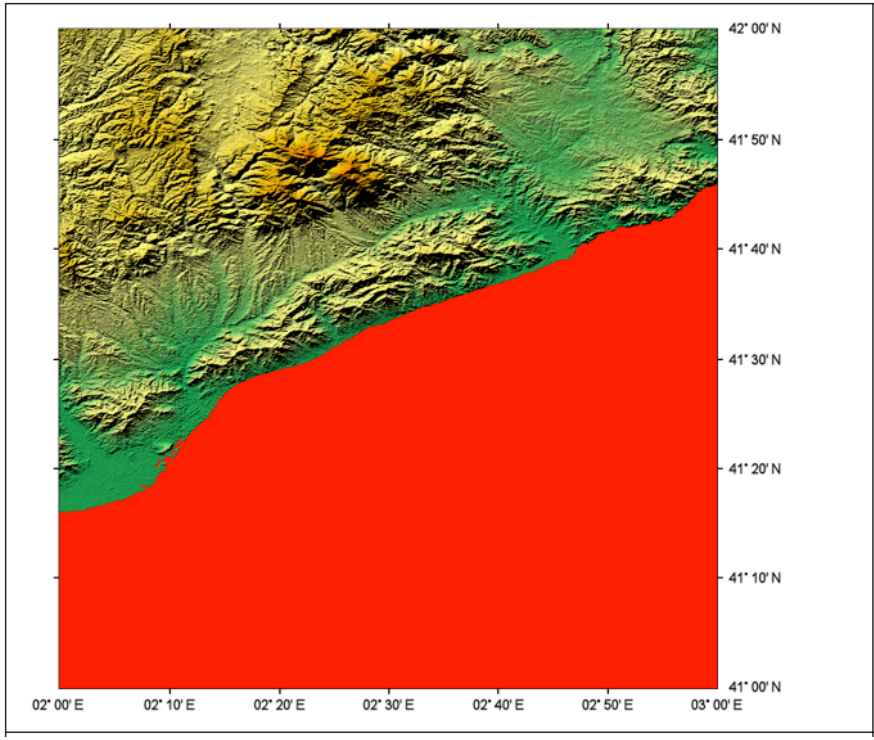
** Partially supported by BNSC under the ICP3 programme*

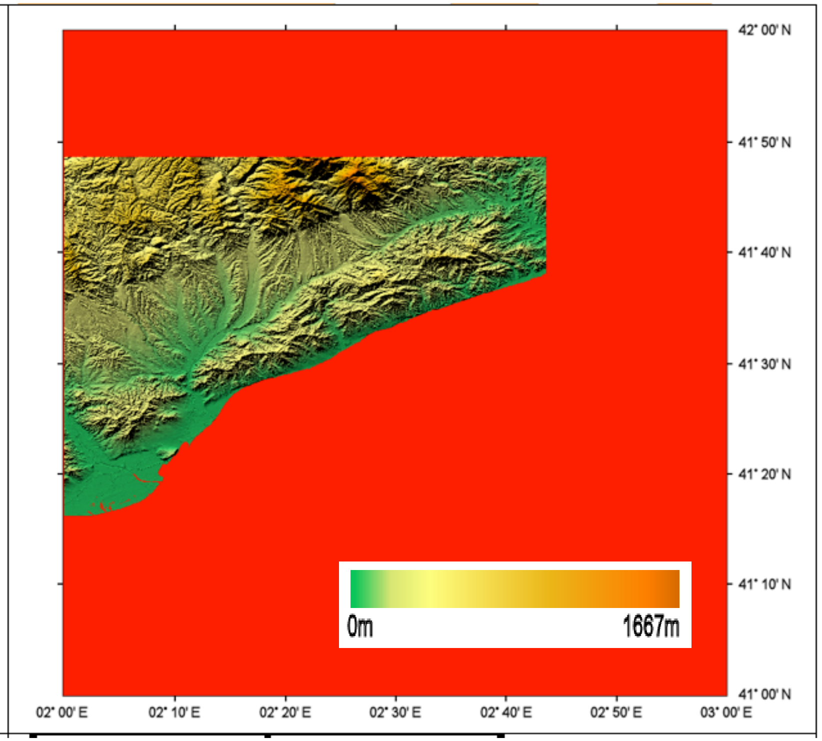
***many thanks to K Kitmitto (MIMAS), L.Gong (CSB)*

CEOS-WGCV-TMSG test sites assessed

- **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, UK**
  3-5ºW, 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 (NOT USED)**
  -121.397 to -123.897ºW, 46.364-48.864ºN
  forest, urban, wetlands

ASTER intercomparison with ICC DTM : Barcelona (1)

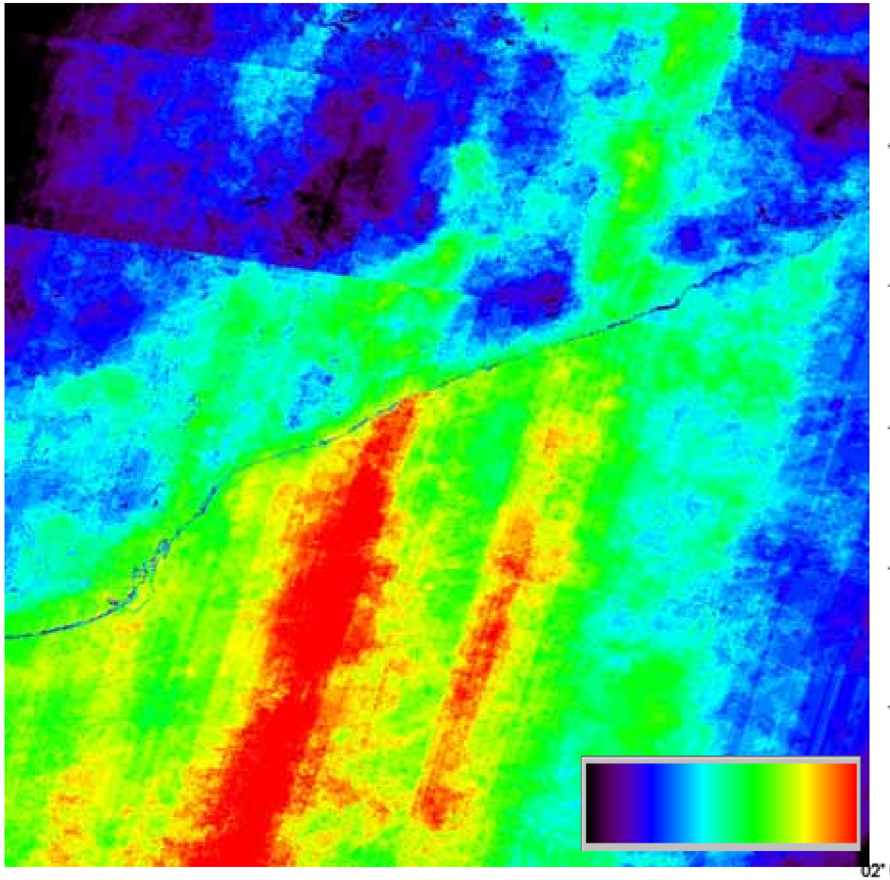




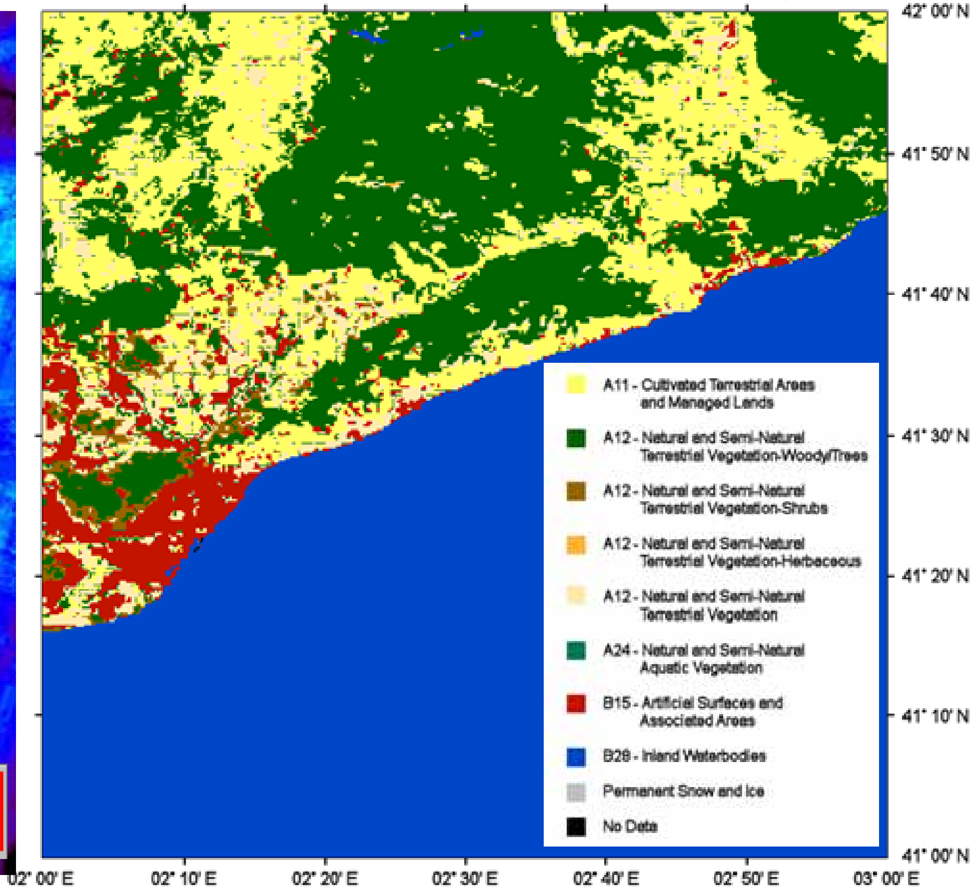
ASTER at 1 arc-seconds

ICC resampled to 1”

ASTER intercomparison with ICC DTM and GLC2000 Land Cover: Barcelona(2)

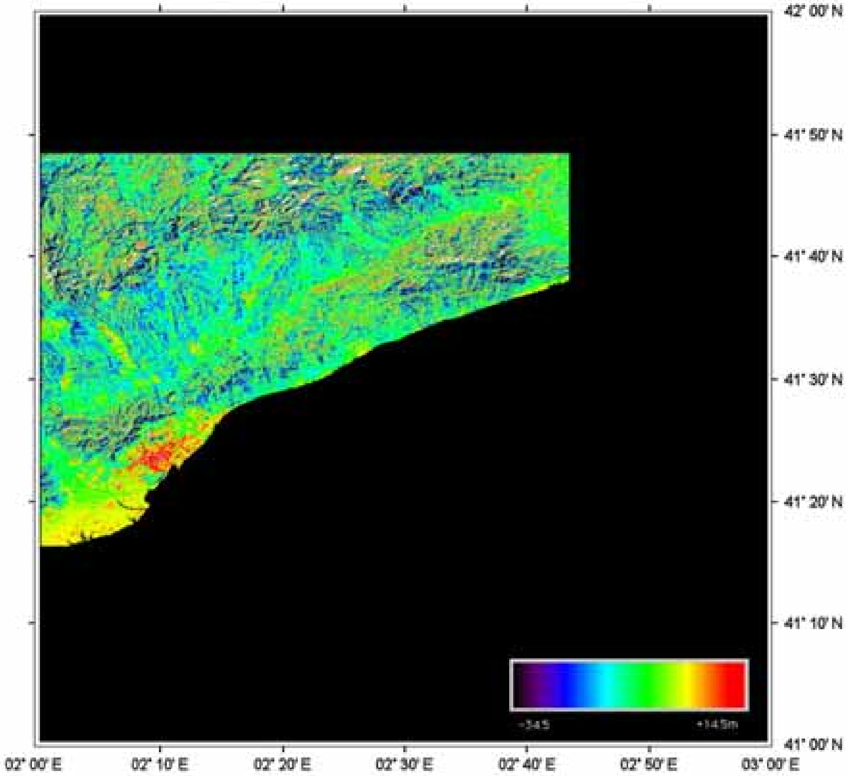


Stacking Number (1-54)



GLC2000 resampled to 1”

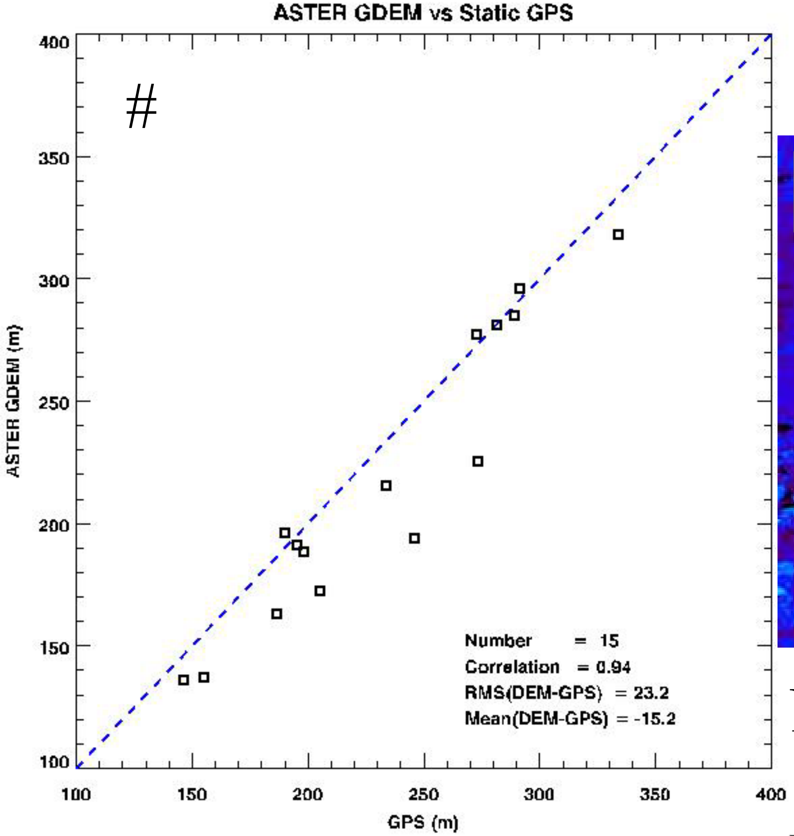
ASTER-ICC DEM height difference

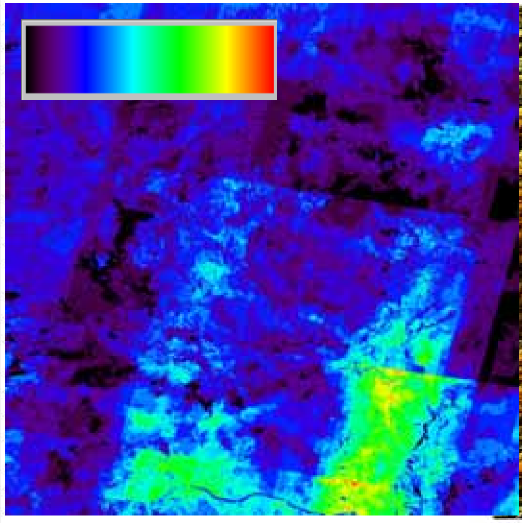


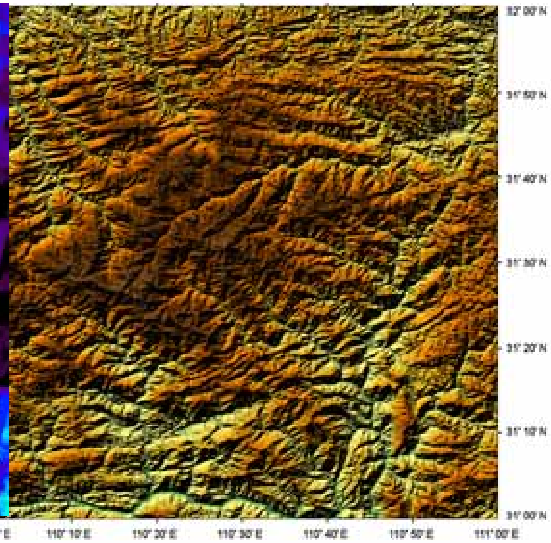
Largest negative height difference in downtown urban area. Still indication of topographic shifts

Minimum	Maximum	Mean	Standard Deviation	RMSE	Land cover class	% of Land cover Class
-243.347	105.582	-8.688	11.243	14.209	All	25.3%
-130.577	88.030	-11.090	8.893	14.215	A11-Cultivated Terrestrial Areas and Managed Lands	6.5%
-243.347	105.582	-8.194	13.586	15.866	A12-Natural and Semi-Natural Terrestrial Vegetation-Woody/Trees	10.5%
-67.203	36.786	-11.539	9.704	15.077	A12-Natural and Semi-Natural Terrestrial Vegetation-Shrubs	1.0%
-41.012	16.213	-18.662	10.011	21.175	A12-Natural and Semi-Natural Terrestrial Vegetation-Herbaceous	0.0%
-114.895	77.297	-9.712	8.636	12.996	A12-Natural and Semi-Natural Terrestrial Vegetation	3.3%
N/A	N/A	N/A	N/A	N/A	A24-Natural and Semi-Natural Aquatic Vegetation	0.0%
-127.141	64.932	-5.521	9.062	10.611	B15-Artificial Surfaces and Associated Areas	3.4%
-40.970	11.530	-0.106	1.258	1.263	B28-Inland Waterbodies	0.7%

ASTER inter-comparison for China (1)







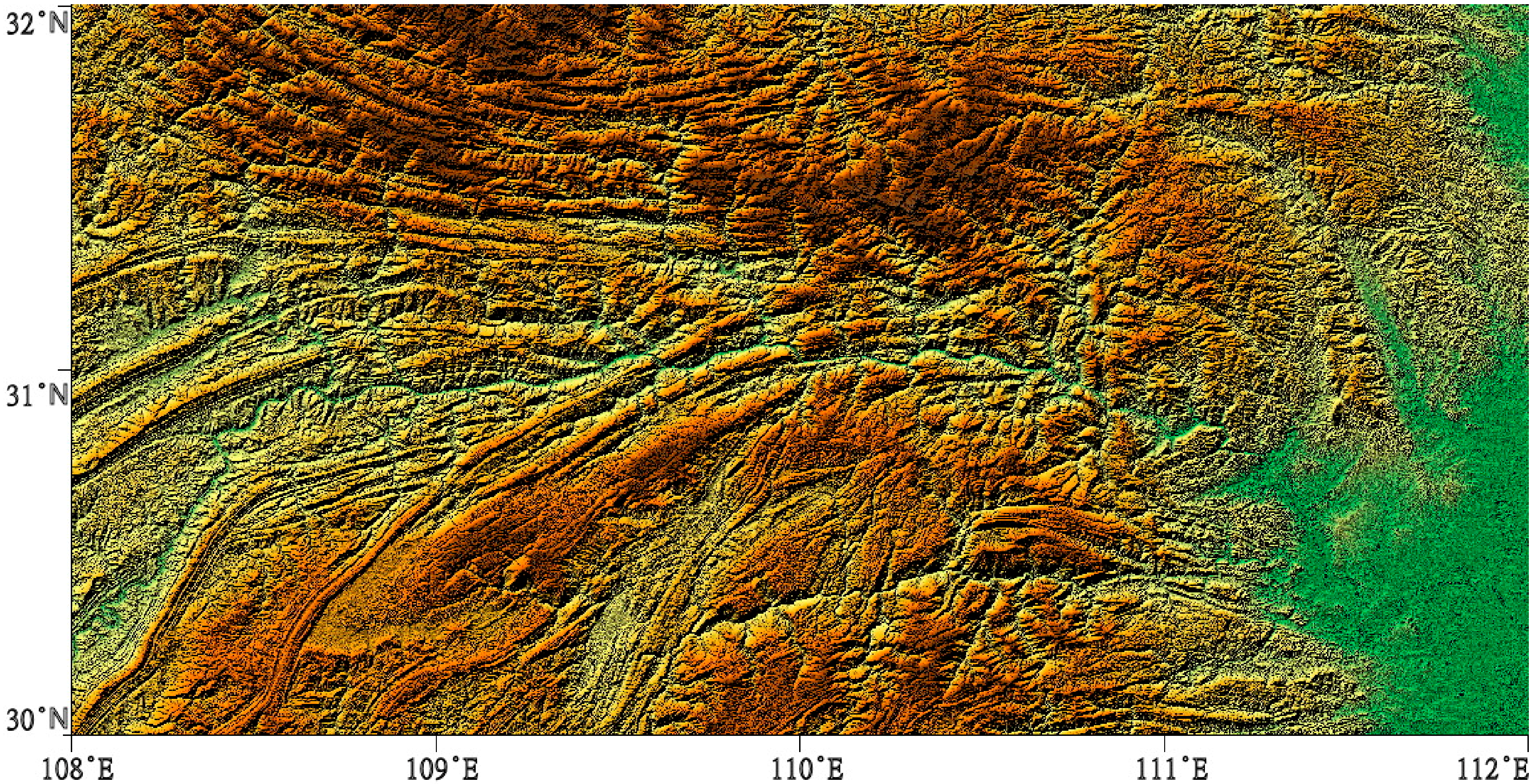
NUMB (0-16 range) N31E110 cell

Minimum	Maximum	Mean	Standard Deviation	RMSE	Land cover class	% of Land cover Class
-598.4117	588.2874	-0.8835	38.7811	38.2586	All	100%
-449.6283	388.3965	-1.9291	30.7005	30.6784	A11-Cultivated Terrestrial Areas and Managed Lands	30.00%
-598.4117	588.2874	-0.1675	42.7544	42.5062	A12-Natural and Semi-Natural Terrestrial Vegetation-Woody/Trees	57.40%
-492.6981	444.2789	-1.8396	37.1318	37.1413	A12-Natural and Semi-Natural Terrestrial Vegetation-Shrubs	12.20%
-215.4204	87.0000	-2.3945	20.7468	20.8688	A12-Natural and Semi-Natural Terrestrial Vegetation-Herbaceous	0.20%
-46.0093	80.4022	18.0907	21.2755	27.9181	B15-Artificial Surfaces and Associated Areas	0.01%
-211.3181	142.8655	9.1473	28.7320	30.0996	Inland Waterbodies	0.19%

N.B. Much larger standard deviation but smaller bias but topography much rougher than UK

Zhenhong Li (Glasgow University), Yingbing Li, Peng Li (Wuhan University)

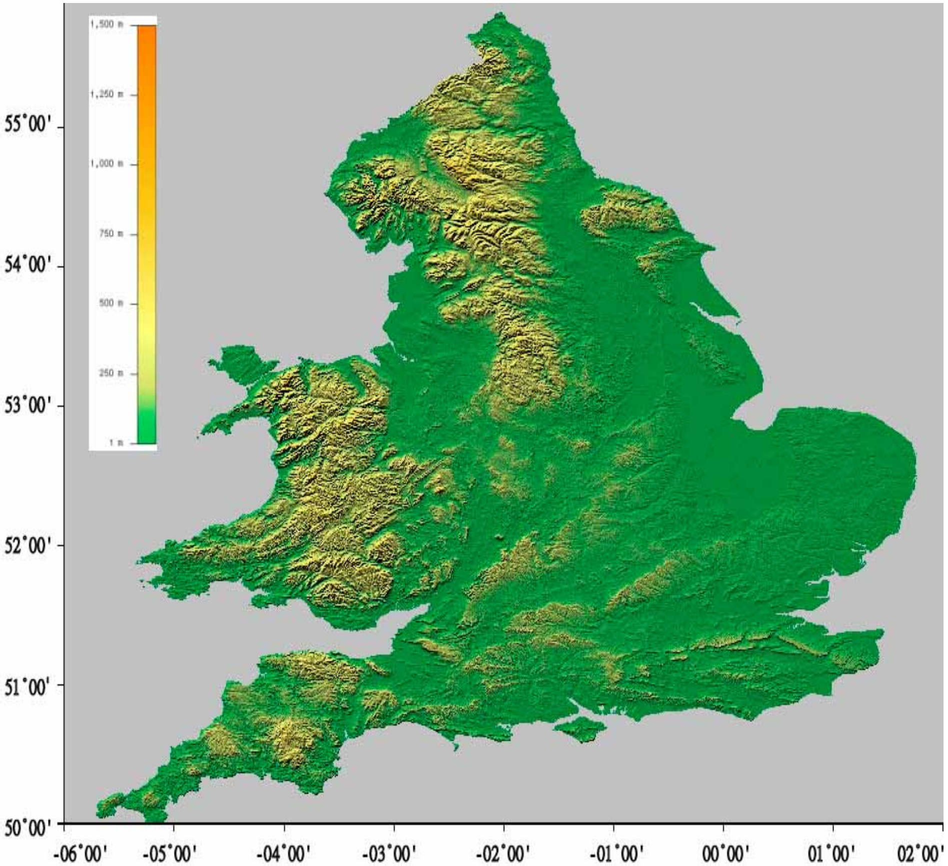
ASTER inter-comparison for China (2): 3G



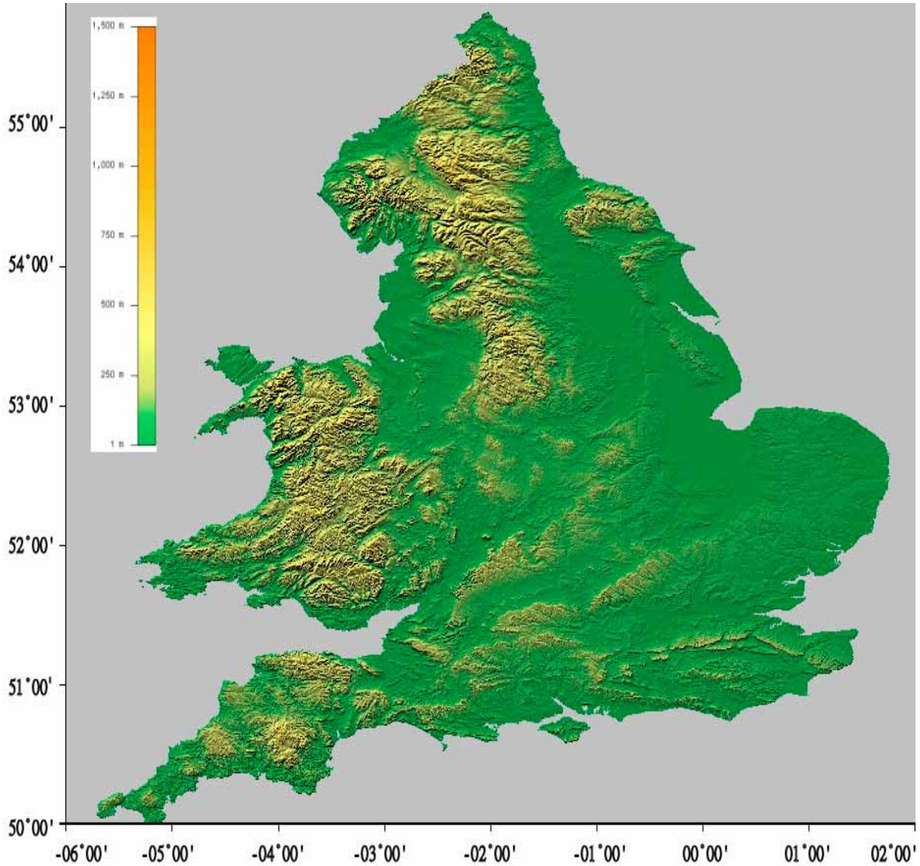
ASTER-CNED** ALL points 3G area
-4.12 ± 35.94 for 101, 052, 840 points

** analysis performed by G. Lixia (CSB)

UK Intercomparison of ASTER, with BlueSky DTM



ASTER DEM at 1 arc-seconds
Zrms=10m



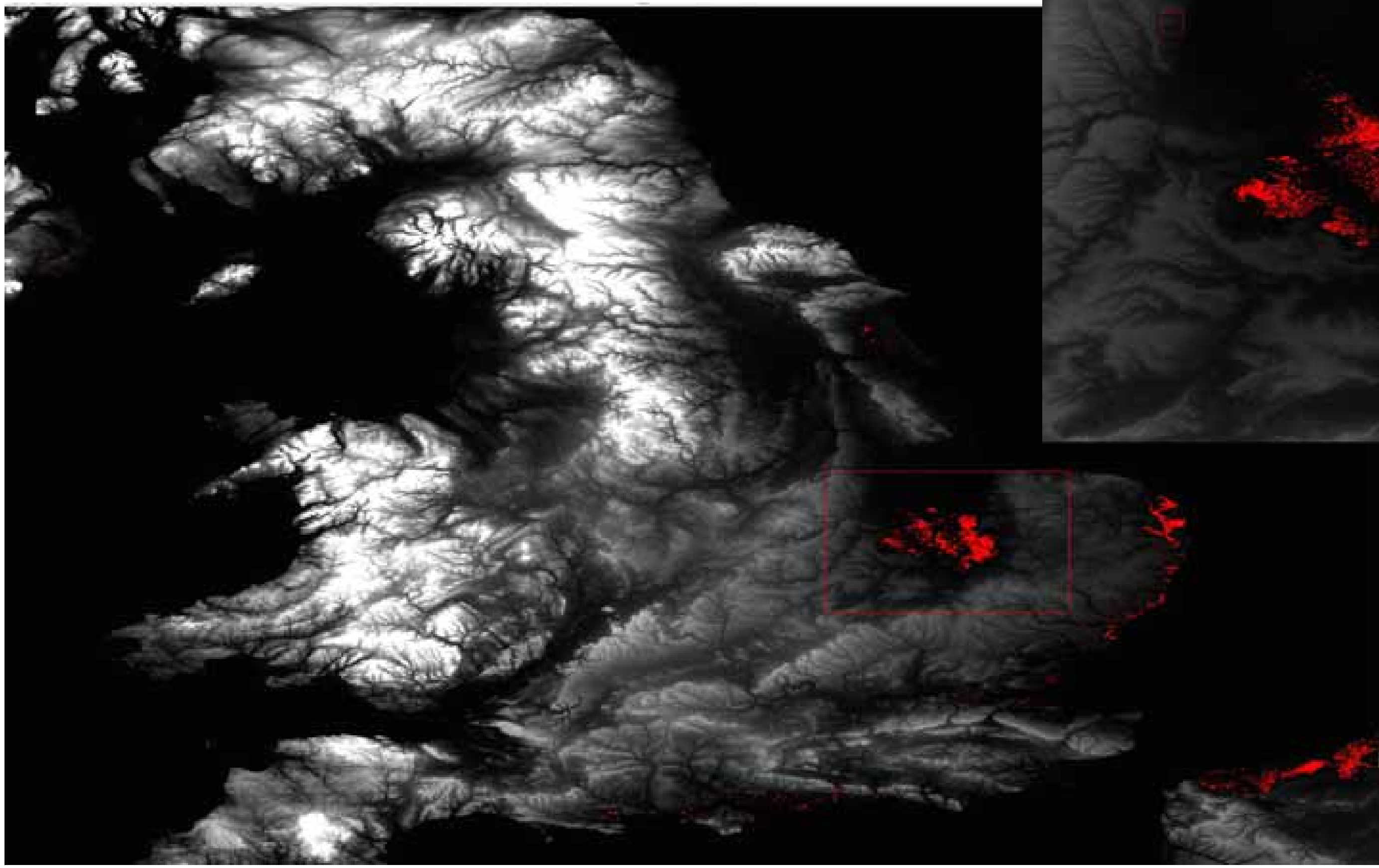
BlueSky DTM resampled to 1”
Zrms= 1.5m

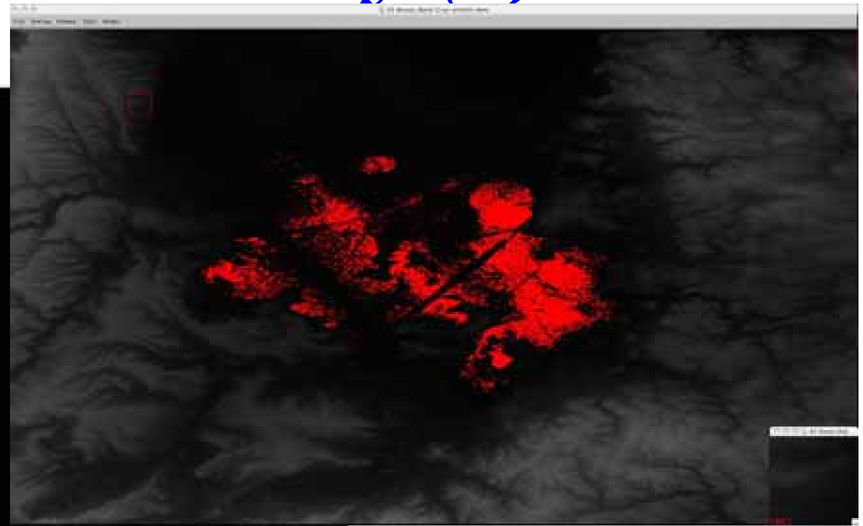
UK Intercomparison of ASTER, SRTM with BlueSky (1)

Heights at zero metres Above Mean Sea Level

BlueSky resampled to 3 arc-seconds

UK Intercomparison of ASTER, SRTM with BlueSky (2)

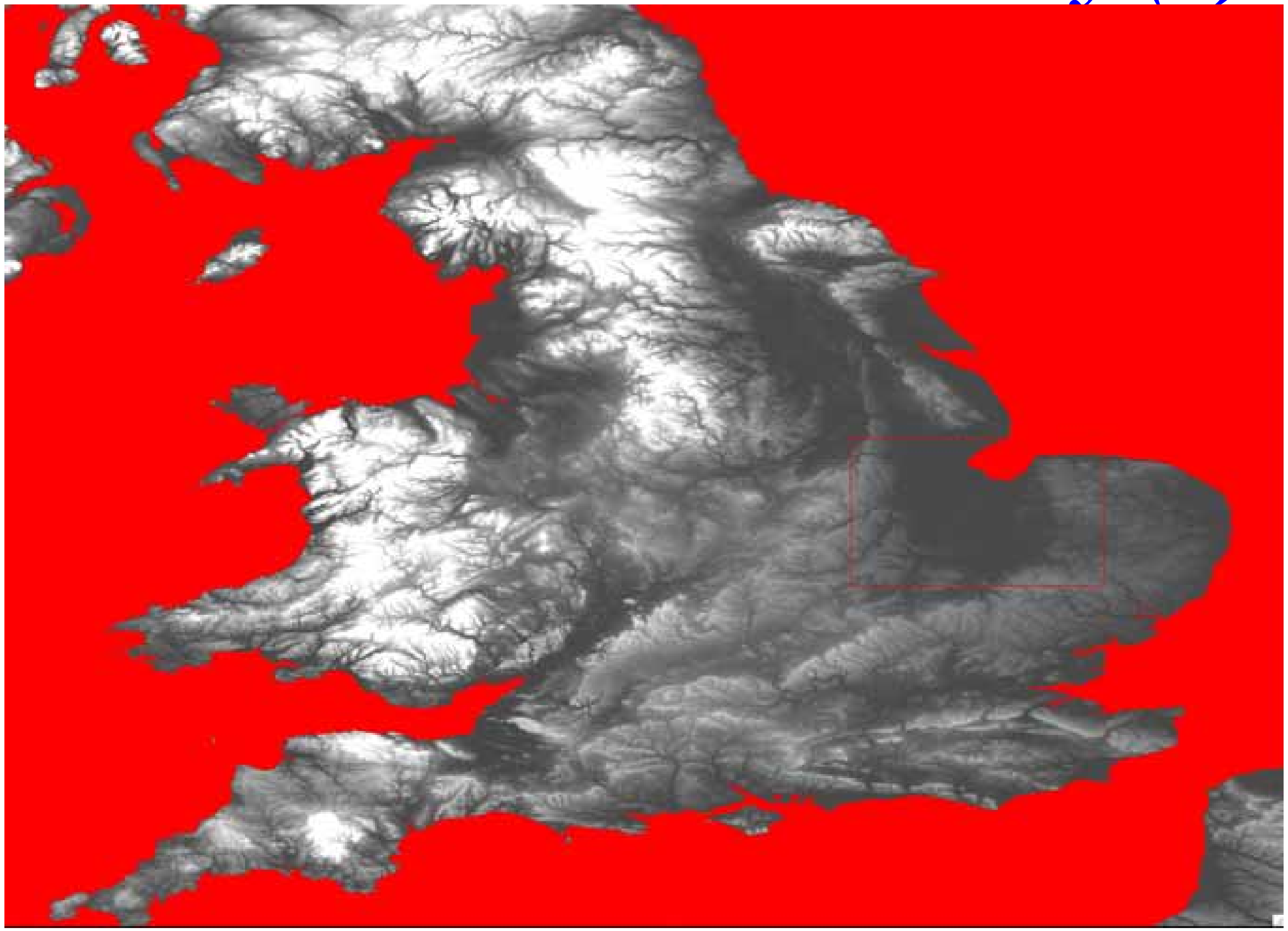




Heights at zero metres Above Mean Sea Level

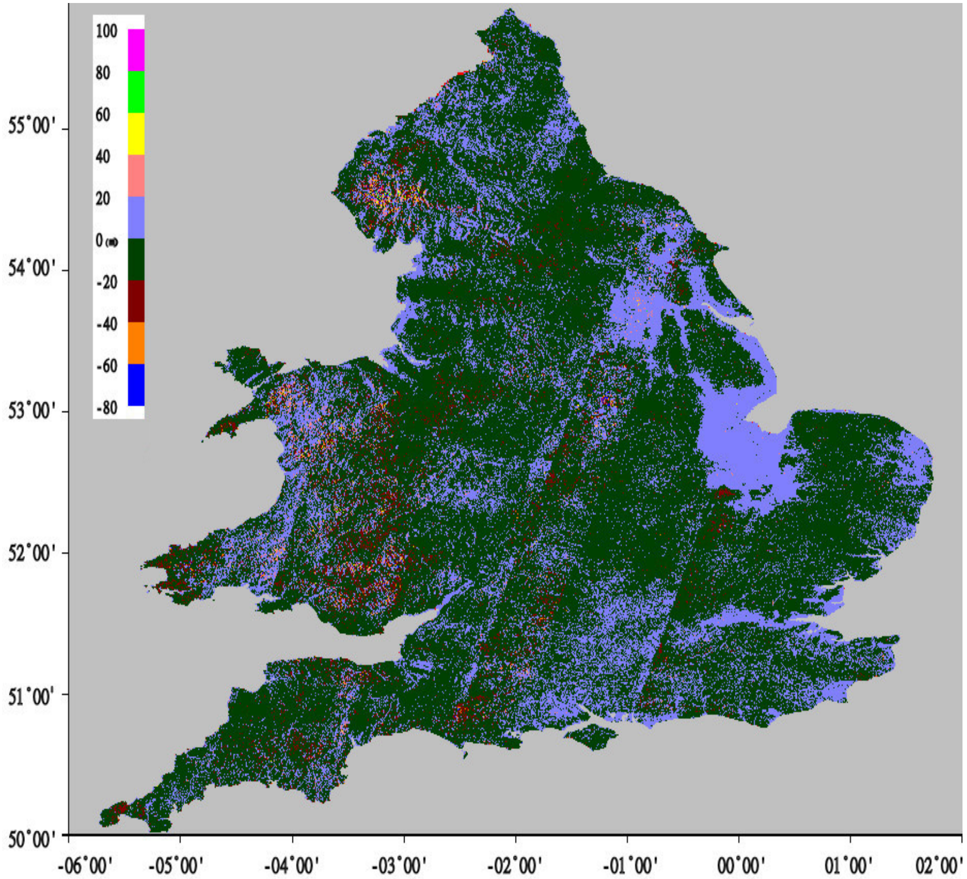
SRTM at 3 arc-seconds

UK Intercomparison of ASTER, SRTM with BlueSky (3)

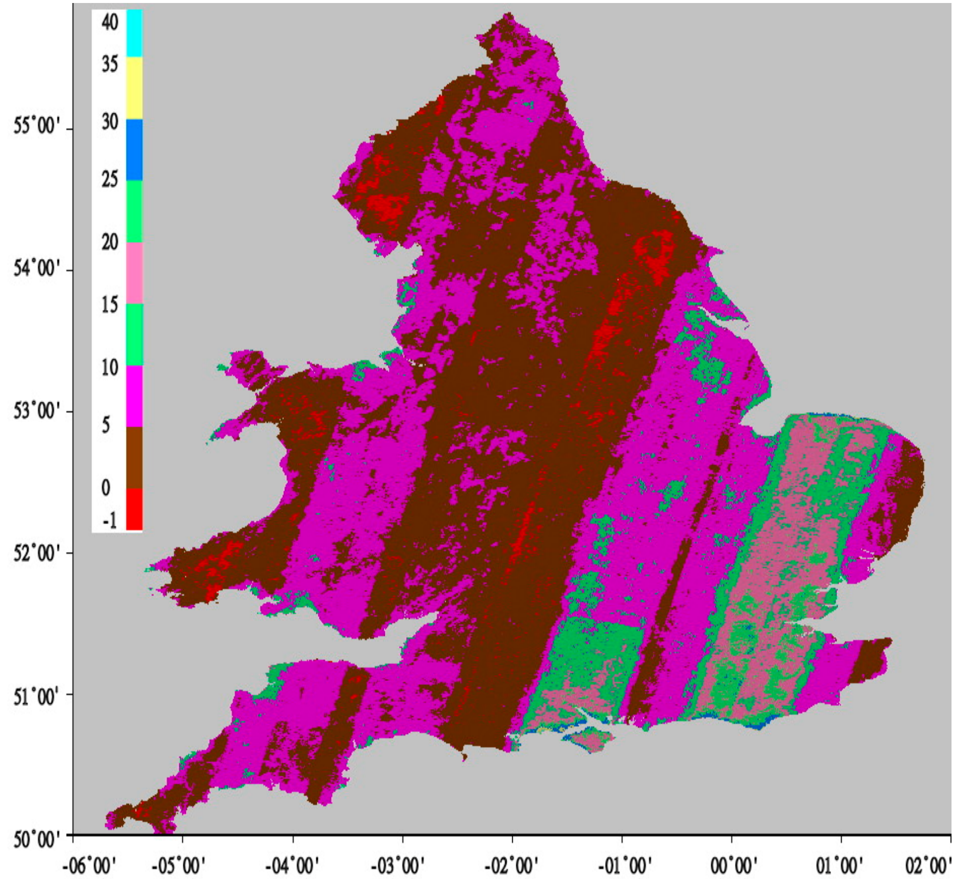


ASTER resampled to 3”. NO Heights at ≤0 metres above MSL

UK Intercomparison of ASTER, SRTM with BlueSky (5)



ASTER-BlueSky DEM at 1"



ASTER Stacking Number

ASTER-BlueSky at 3 arc-second (≈75m) for England and Wales

ASTER-BLUESKY	-4.651 m ± 11.232
SRTM-BLUESKY	1.081 m ± 8.612
ASTER-SRTM	-5.681 m ± 9.271

N.B. Overall ASTER heights lower than BlueSky (is this a datum issue?)
Height difference statistics do not (quite) meet global specification (10m RMS)

Validation of the ASTER GDEM over the United States: Comparison with SRTM, the USGS National Elevation Dataset, and GPS Benchmarks

Dean Gesch, Bryan Bailey, Norman Bliss, Jeff Danielson, Ken Duda, Gayla Evans, and Zheng Zhang

U.S. Geological Survey, Earth Resources Observation and Science Center (EROS), Sioux Falls, SD, USA

IEEE International Geoscience and Remote Sensing Symposium
July 12 – 17, 2009
Cape Town, South Africa
Special Session on Global DEM Interoperability: ASTER GDEM Initial Assessment

(ASTER GDEM is a product of METI and NASA)

Introduction / Validation Plan

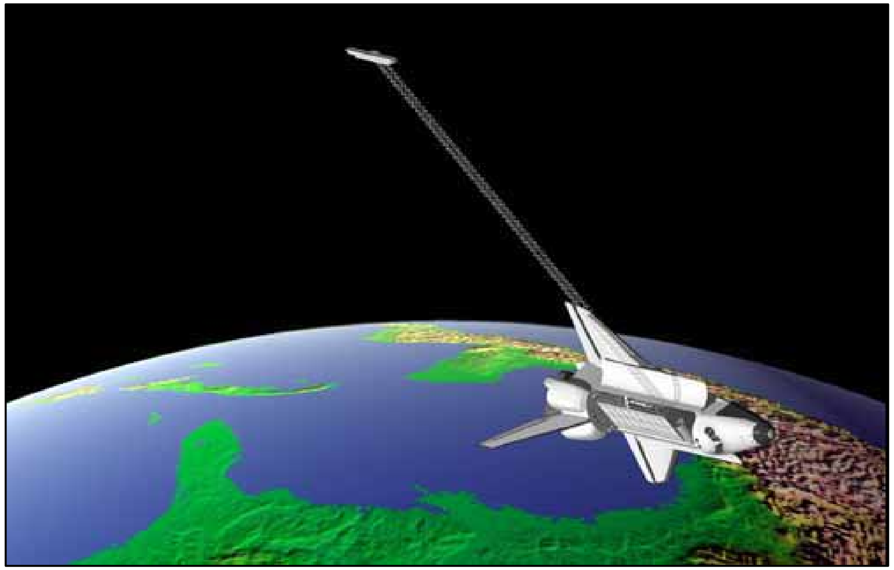
- **USGS evaluated 934 1°x1° GDEM tiles over the conterminous United States**
  - **Pixel-by-pixel comparison (differencing) with other raster DEMs: the USGS *National Elevation Dataset* (NED) and the *Shuttle Radar Topography Mission* (SRTM)**
  - **Absolute vertical accuracy measurement vs. high-accuracy geodetic control points**
  - **Analysis included consideration of land cover, relief, and number of ASTER scenes**
- **350 non-U.S. 1°x1° GDEM tiles evaluated by collaborators**

USGS

Raster-based Validation: Reference Data

National Elevation Dataset (NED)

- “Best available” bare earth elevation data of the United States
- Seamless data derived from topographic maps, lidar, and photogrammetric data
- Multi-resolution:
  - 1-arc-second (30 meters)
  - 1/3-arc-second (10 meters)
  - 1/9-arc-second (3 meters)



Shuttle Radar Topography Mission (SRTM)

- 1-arc-second (30-meter) elevation data derived from interferometric SAR data collected during an 11-day mission in February 2000
- “First return” (or “first reflective surface”) elevations
- 3-arc-second (90-meter) data available for non-U.S. areas

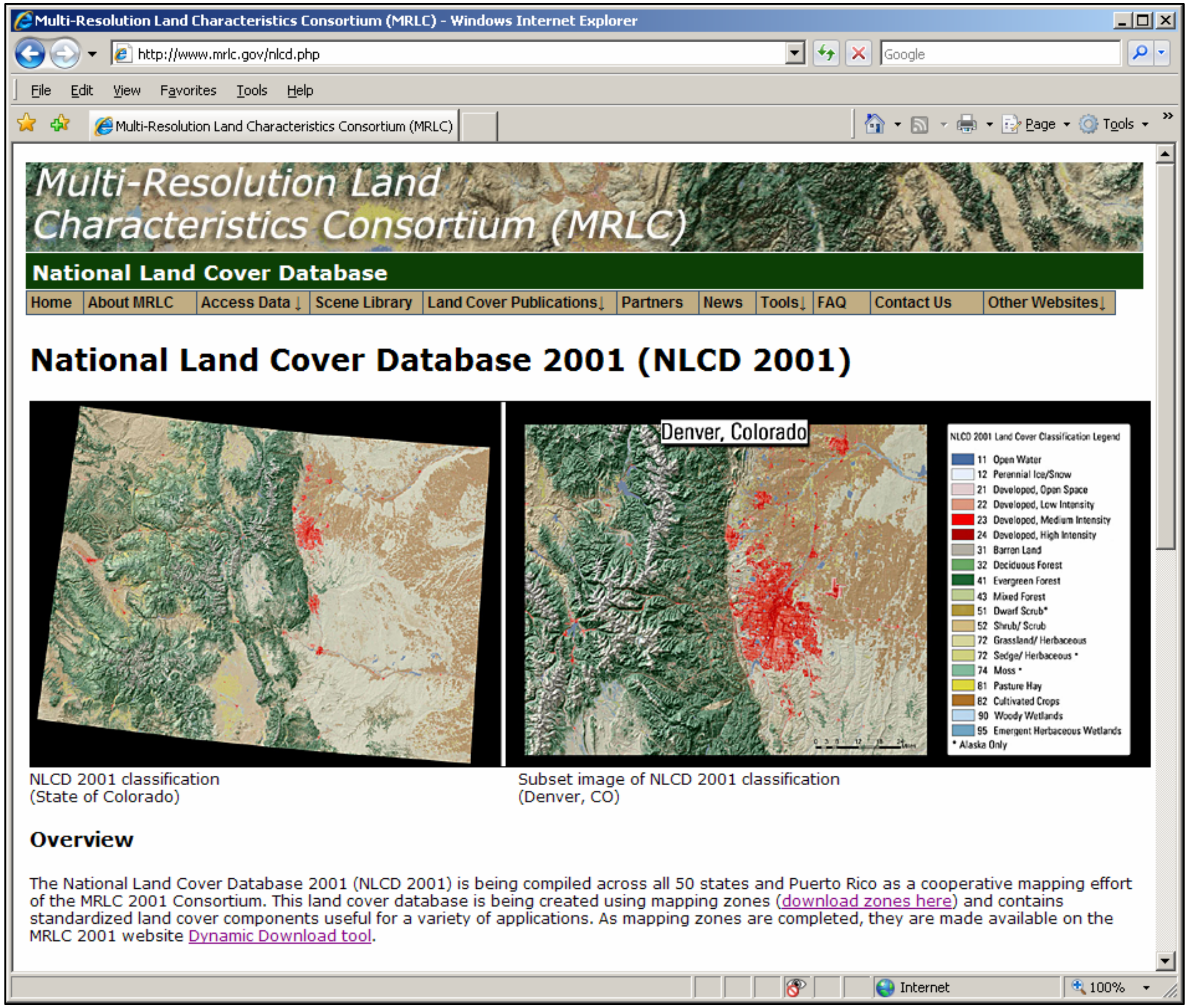
USGS

Raster-based Validation

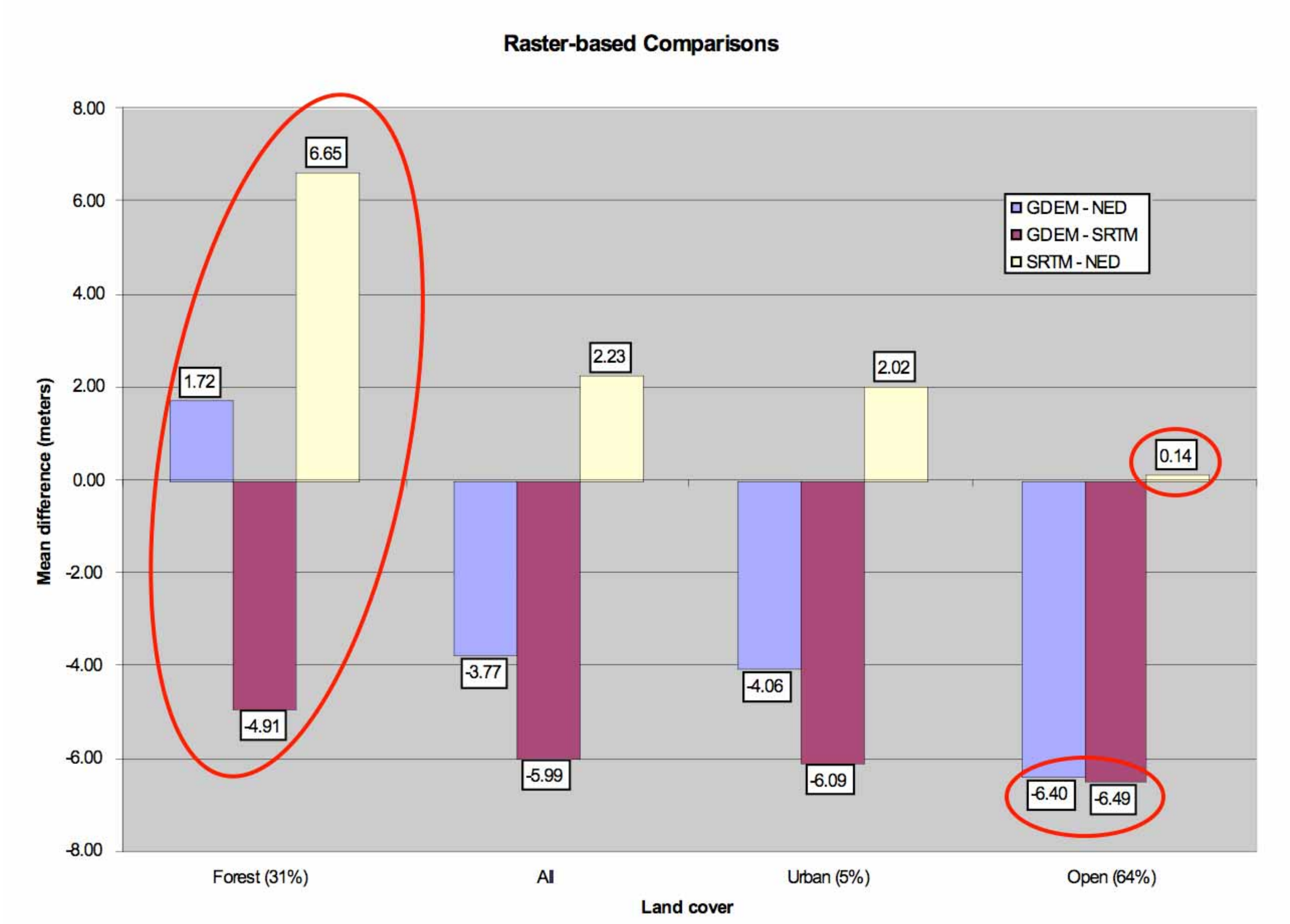
- **Elevation differencing:**
  - **GDEM minus NED**
  - **GDEM minus SRTM**
- **Difference statistics (in meters):**

Difference	Minimum	Maximum	*Mean*	Standard Deviation	*RMSE*	90% confidence	*95% confidence*
GDEM - NED	-717.1	3,934.0	*-3.77*	8.19	*10.46*	17.21	*20.50*
GDEM - SRTM	-649.0	3,935.0	*-5.99*	7.35	*9.94*	16.35	*19.48*
SRTM - NED	-596.6	933.6	2.23	4.50	6.32	10.40	12.39

Validation: Reference Data



- 30-meter land cover derived from Landsat data
- 19 classes:



Raster-based Comparisons
Mean difference (meters)
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
GDEM - NED
GDEM - SRTM
SRTM - NED
1.72
-4.91
6.65
-3.77
-5.99
2.23
-4.06
-6.09
2.02
-6.40
-6.49
0.14
Forest (31%)
All
Urban (5%)
Open (64%)
Land cover

Summary of Results

	Mean diff. (meters)	RMSE (meters)	95% confidence
GDEM - NED	-3.77	10.46	20.50
GDEM - SRTM	-5.99	9.94	19.48
GDEM abs. vert. acc.	-3.69	9.34	18.31

- **GDEM average relative vertical (point-to-point) accuracy: *approximately 4 meters***
- **GDEM slope uncertainty: *approximately 6.5 % (3.75 degrees)***

USGS

Evaluation of Samples of the Aster Global DEM Using STAR-3i Airborne Interferometric SAR Data

Bryan Mercer, Qiaoping Zhang, Michael Denbina

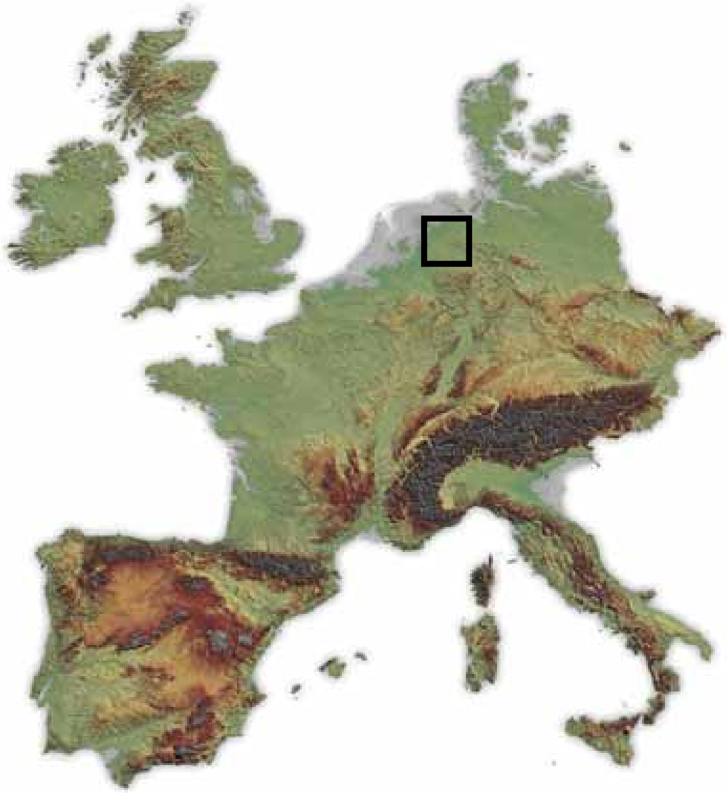
Intermap Technologies Corp., Calgary, Canada

IGARSS 2009 Capetown, South Africa July 17, 2009

The Reference Data Set: NEXTMap Europe – what is it?

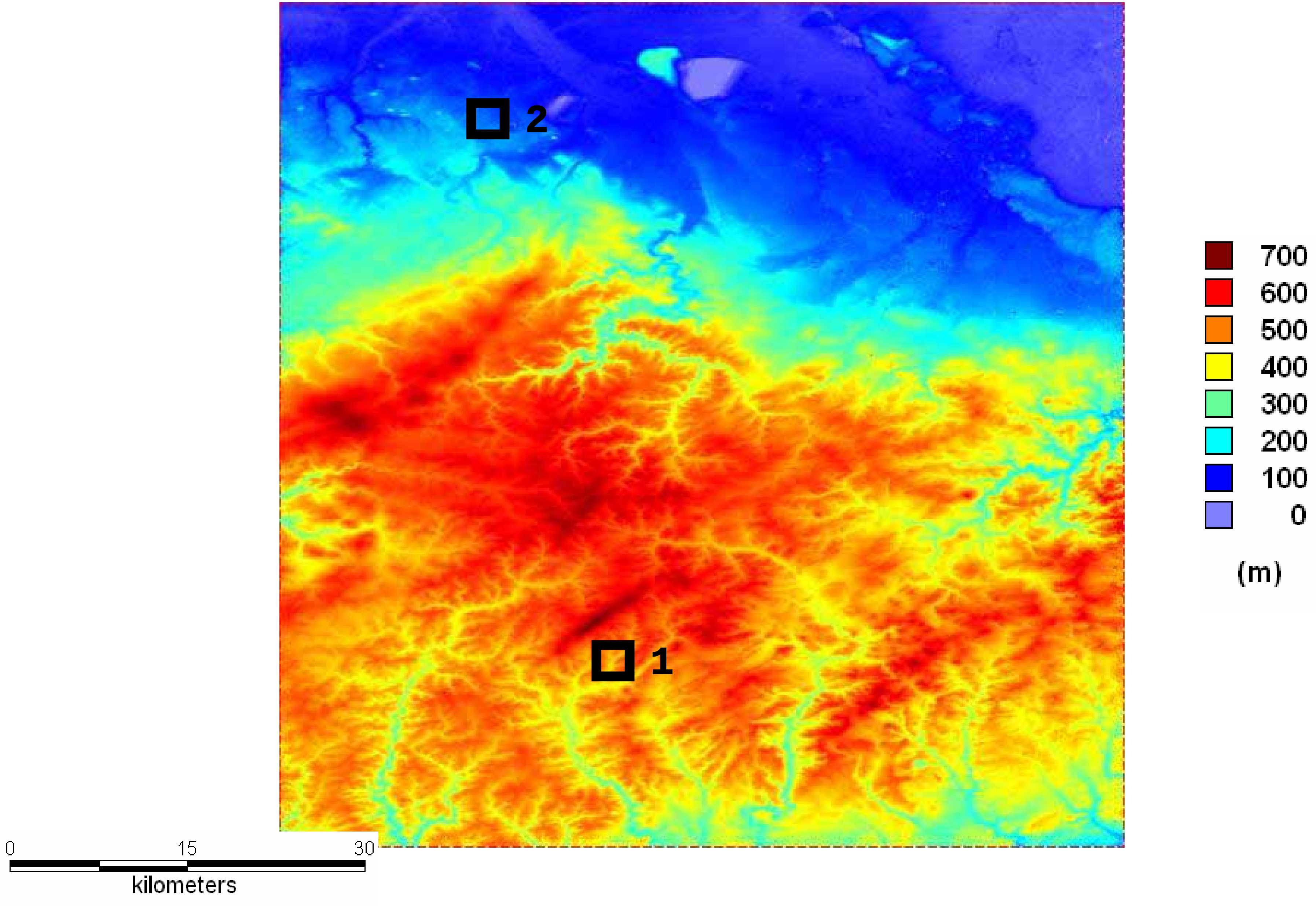
Specification	DSM	DTM	ORI
Sample Spacing	5 m	5 m	1.25 m
Accuracy (RMSE)*	1 m	1 m	<2m

* ...for bare, unobstructed, moderately sloped terrain

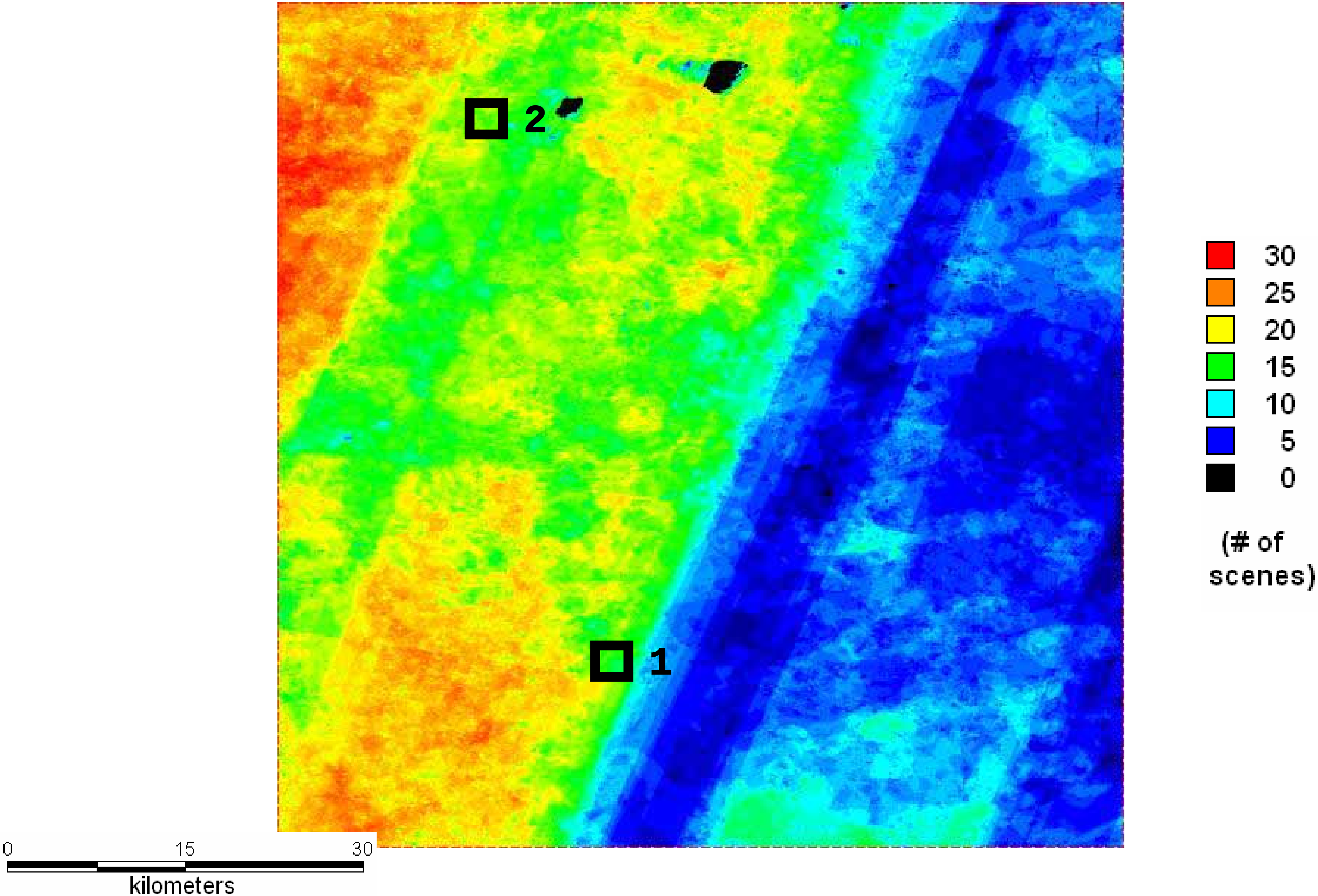


Difference Statistics (meters)	Germany	
	DSM	DTM
Mean	0.01	-0.16
Standard Dev'n	0.68	0.68
RMSE	0.68	0.69
95 Percentile	1.42	1.47
No. Check Pts.	690	690

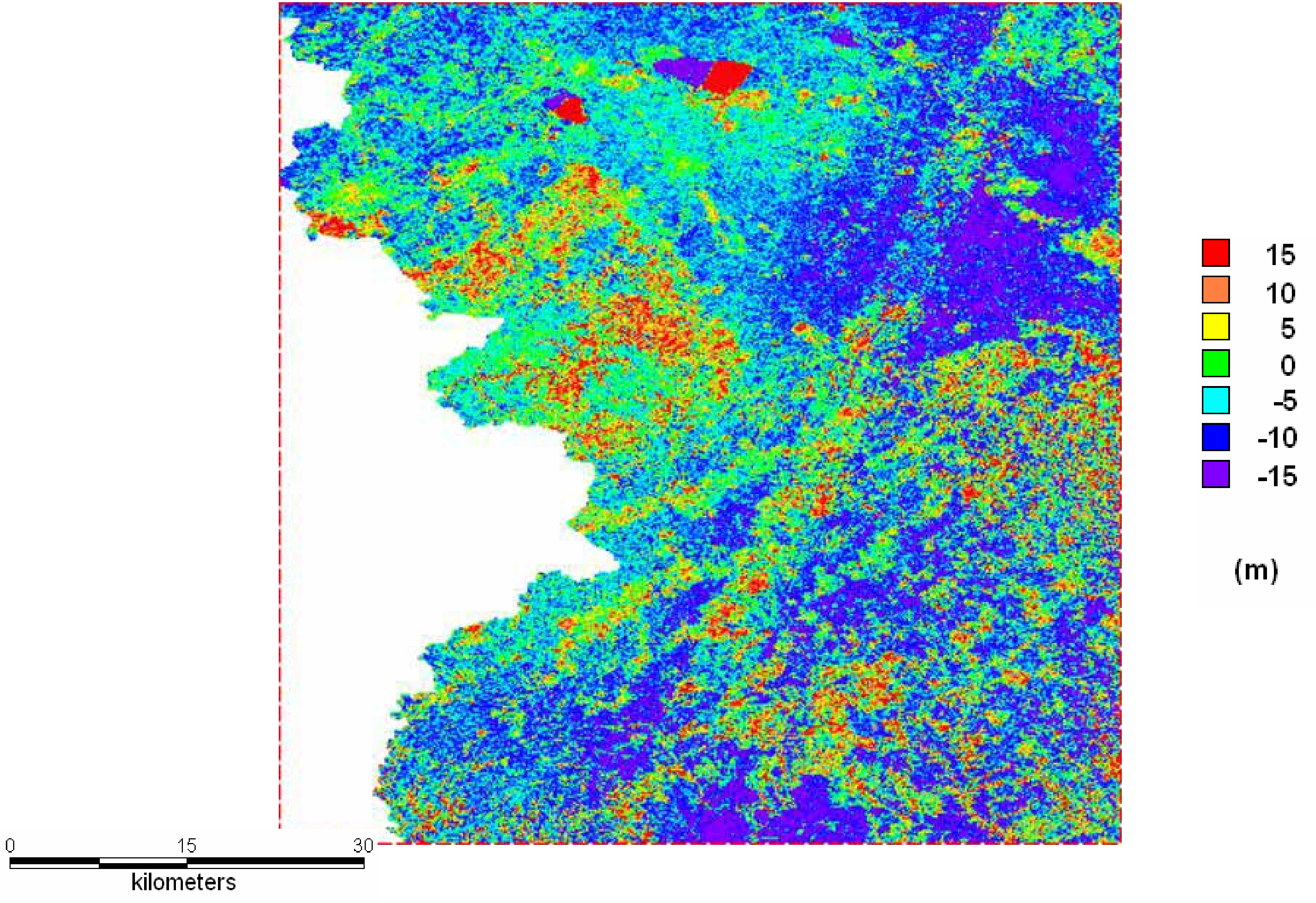
Aster Global DEM Showing Test Areas



Aster Global DEM – # of Aster Scenes



Difference: (Aster GDEM – Ref DTM)

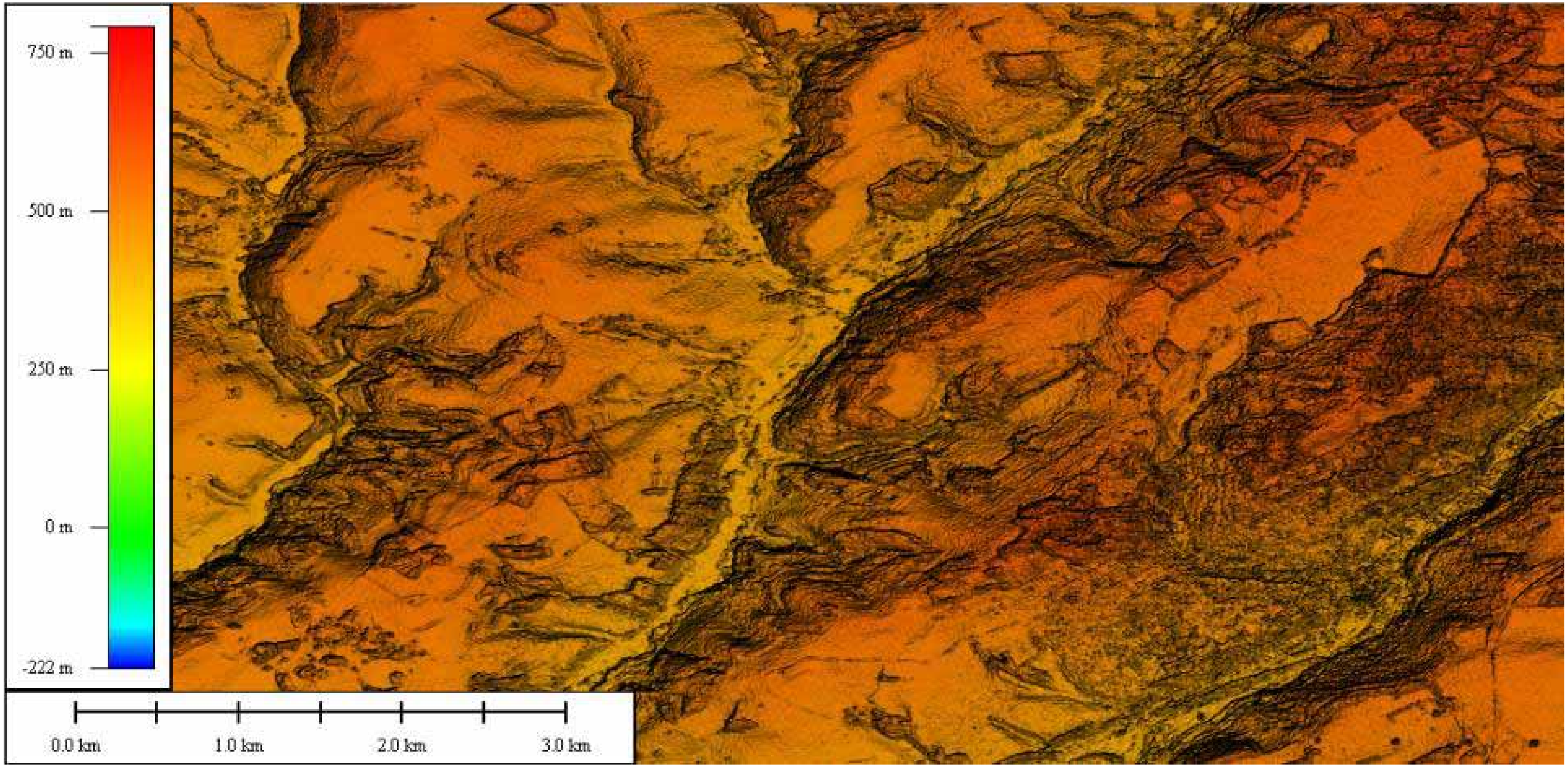


Error (Aster – ‘Truth’) Statistics

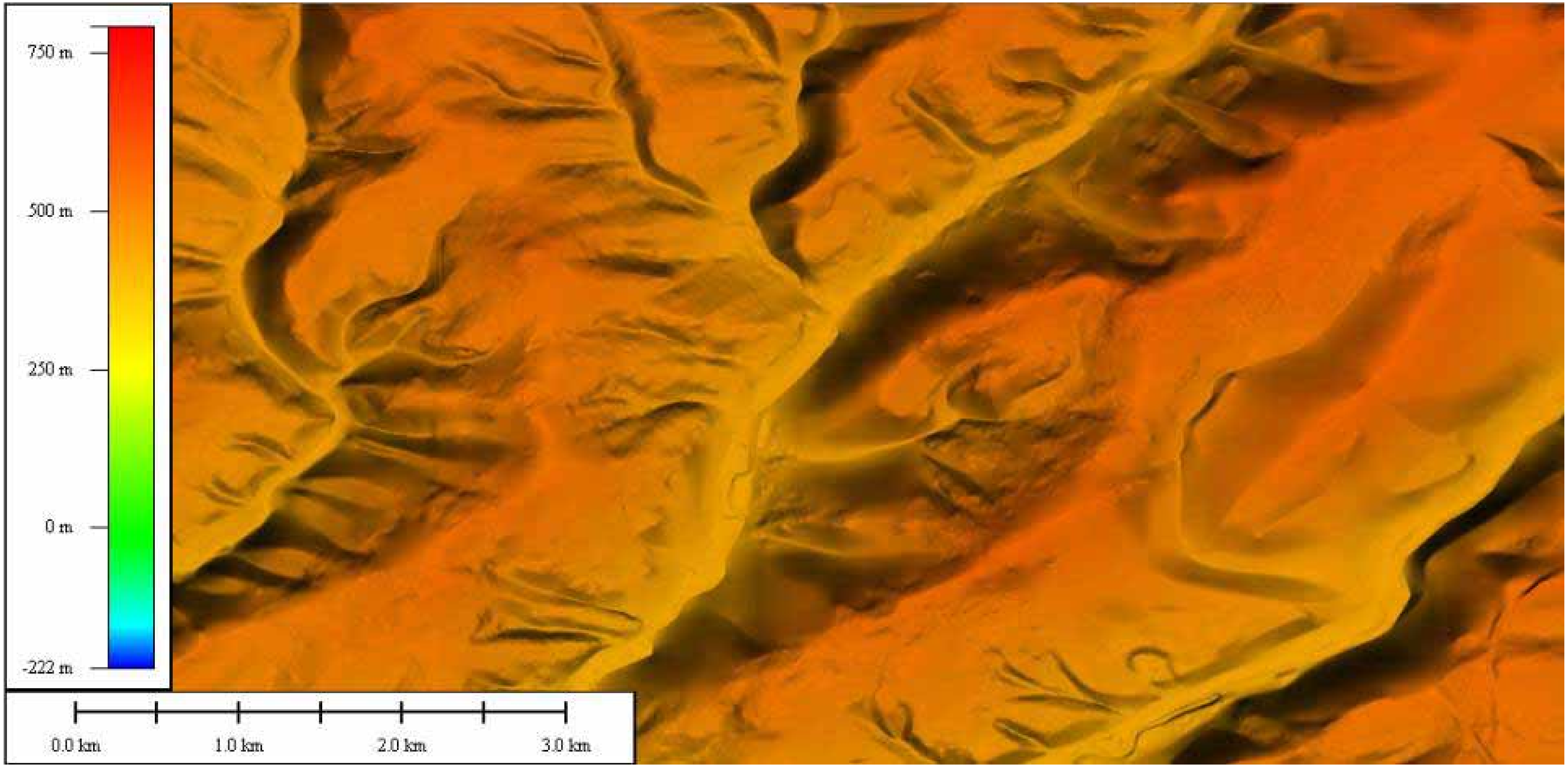
	Mean	Std. Dev.	RMSE	Min	Max
[Aster – Ref DSM] (all classes)	**-10.3 m**	**9.7 m**	**14.2 m**	**-251.2 m**	**410.5 m**
[Aster – Ref DSM] (‘bare / cropland’)	**-8.9 m**	**6.8 m**	**11.2 m**	**-93.9 m**	**230.8 m**
[Aster – Ref DSM] (slope <10°)	**-9.7 m**	**8.8 m**	**13.1 m**	**-238.9 m**	**410.5 m**
[Aster – CP] (36 Visual CP’s)	**-8.5 m**	**4.3 m**	**9.6 m**	**-1.9 m**	**-18.0 m**

Note: the high Min/Max values are due to clusters of bad data (‘blunders’) comprising about 0.5% of the total area. Blunder removal improves the standard deviation (all classes) by about 1.5 m.

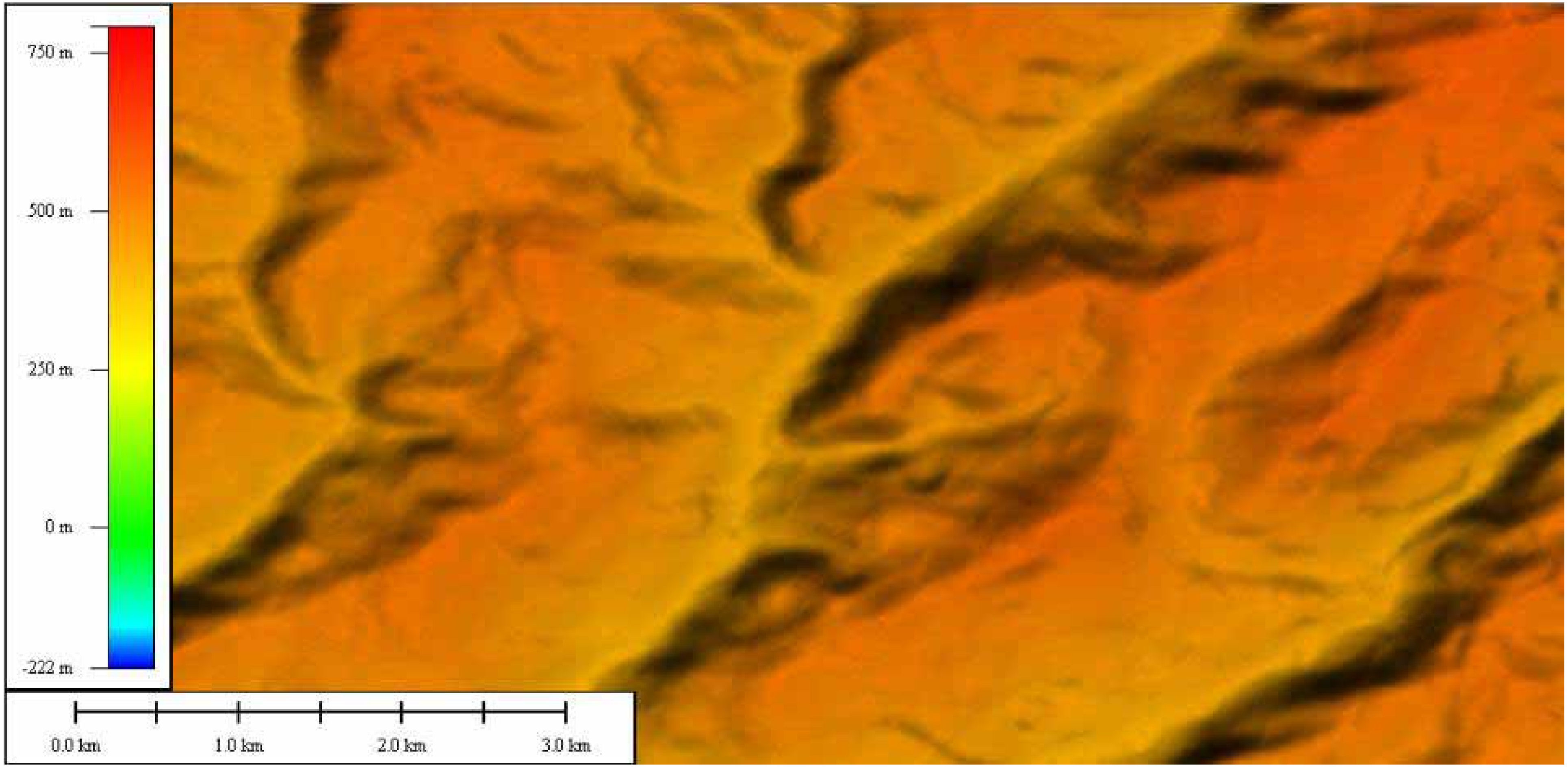
Area 1: Star-3i DSM



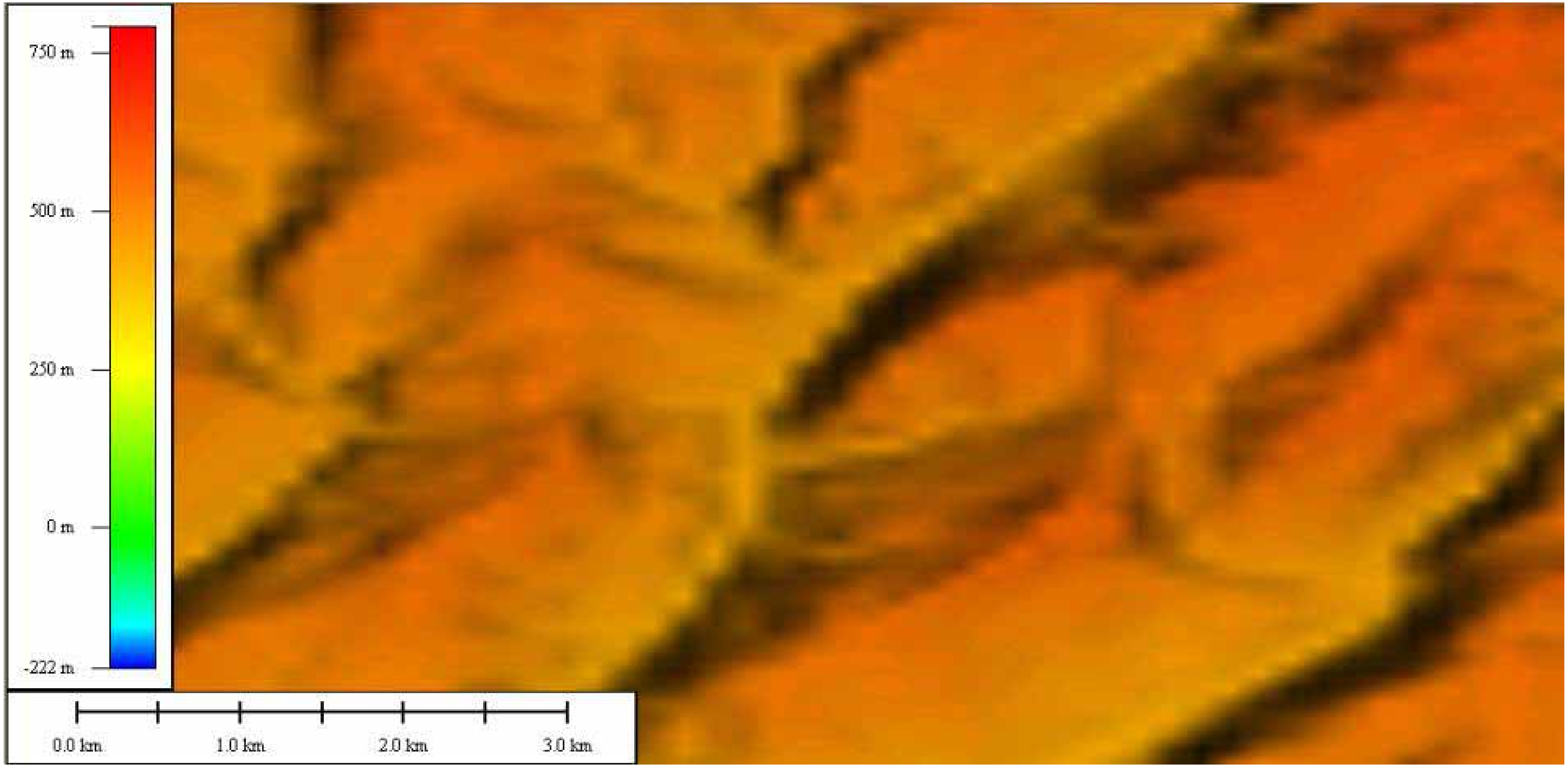
*Area 1: Star-3*i *DTM*



Area 1: Aster GDEM



Area 1: SRTM (90m)



DA-09-03d: Global DEM: Current Progress

- **Analysis of the results of the GEO-CEOS-ISPRS workshop and subsequent teleconferences suggest that version 1 of the ASTER GDEM is not "fit for purpose"**
- **Restrictions on redistribution from METI/USGS/NASA continue. The WCS service developed by Diping Li at George Mason University was closed down in a few days although his WMS service continues.**
- **However, it has been agreed that within an "intranet", that reporting of errors can use WMS displays**
- **The ASTER GDEM will no longer be employed in the data fusion project at JPL led by Mike Kobrick for filling gaps in SRTM3 (3"≈90m)**
- **Need to be able to quantify where artifacts exist. The UCL-Nottingham DEMqis (Quality Information Server) sponsored by BNSC and developed by Camilo Vargas will allow geographic, graphical and textual reports to be provided by members of the GEO task team, CEOS-WGCV-TMSG and ISPRS WG**
- **METI in collaboration with NASA/USGS will produce a Version 2 of ASTER GDEM. Subsequent discussions suggest that the main cause of poor quality, namely scene-to-scene co-registration, is not being addressed.**

BNSC-ICEDS DEM Quality Information Service (DEMqis)

Jan-Peter Muller, Camilo Vargas*

**jpm@mssl.ucl.ac.uk*

Point-of-Contact, GEOSS Task DA-07-01 and DA-09-03d
Chair, ISPRS WG IV/6 on "Global DEM Interoperability"
Chair, CEOS-WGCV Sub-group on Terrain mapping from satellites
Vice-Chair, UK JISC Geospatial Working Group (2002-2008)

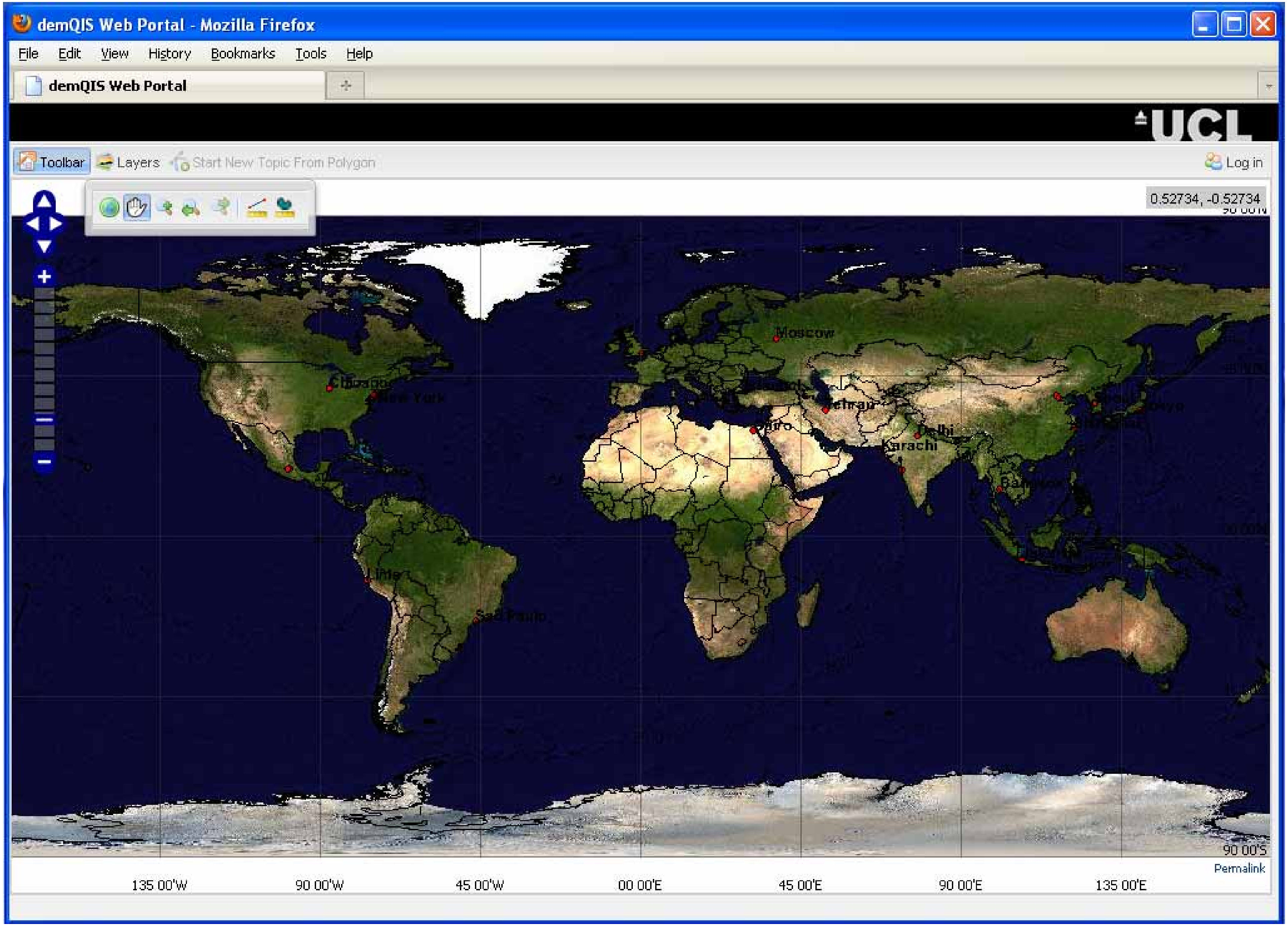
Head, Imaging Group
Director UK NASA RPIF
Professor of Image Understanding and Remote Sensing
HRSC Science Team Member (ESA Mars Express 2003)
Stereo Panoramic Camera Science Team Member (ESA EXOMARS)
MODIS & MISR Science Team Member (NASA EOS Project)
TerraSAR-X and TANDEM-X science team member (DLR-Astrium)

DEMqis: a prototype system for online analysis & sharing of scientific measurements

- **ICEDS Web-GIS developed for global Earth DEM at UCL as part of a CEOS-WGISS "EO Data Portal" in 2005 Open system using the University of Minnesota Map Server (UMMS), PostGreSQL but a proprietary GUI from Ionic Soft (now part of ERDAS Corp)**
- **DEMqis recently developed with BNSC support using OpenLayers for in house and cascaded WMS**
- **Users can identify "bad areas" and these can be linked to a moderated "wiki" in which text and/or images can be uploaded**
- **Users can display stack number mask layer to include areas where gaps have been filled as well as the number of input ASTER pixels**

DEMqis functions

- Display in-house SRTM and ASTER GDEM as well as link to WMS such as George Mason University
- Includes transparency to mix and match different datasets
- Includes flicker to allow two datasets to be compared (e.g. ASTER and SRTM)
- Includes change of overlay priority from one dataset to another
- Includes graphical outlining of areas where artifacts have been identified
- Allows descriptive information to be added and inserted into the PostGreSQL database
- Includes access to the underlying DTM (if available) to plot profiles
- Current system only available inside the MSSL firewall.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New York
Tehran
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Delhi
Karachi
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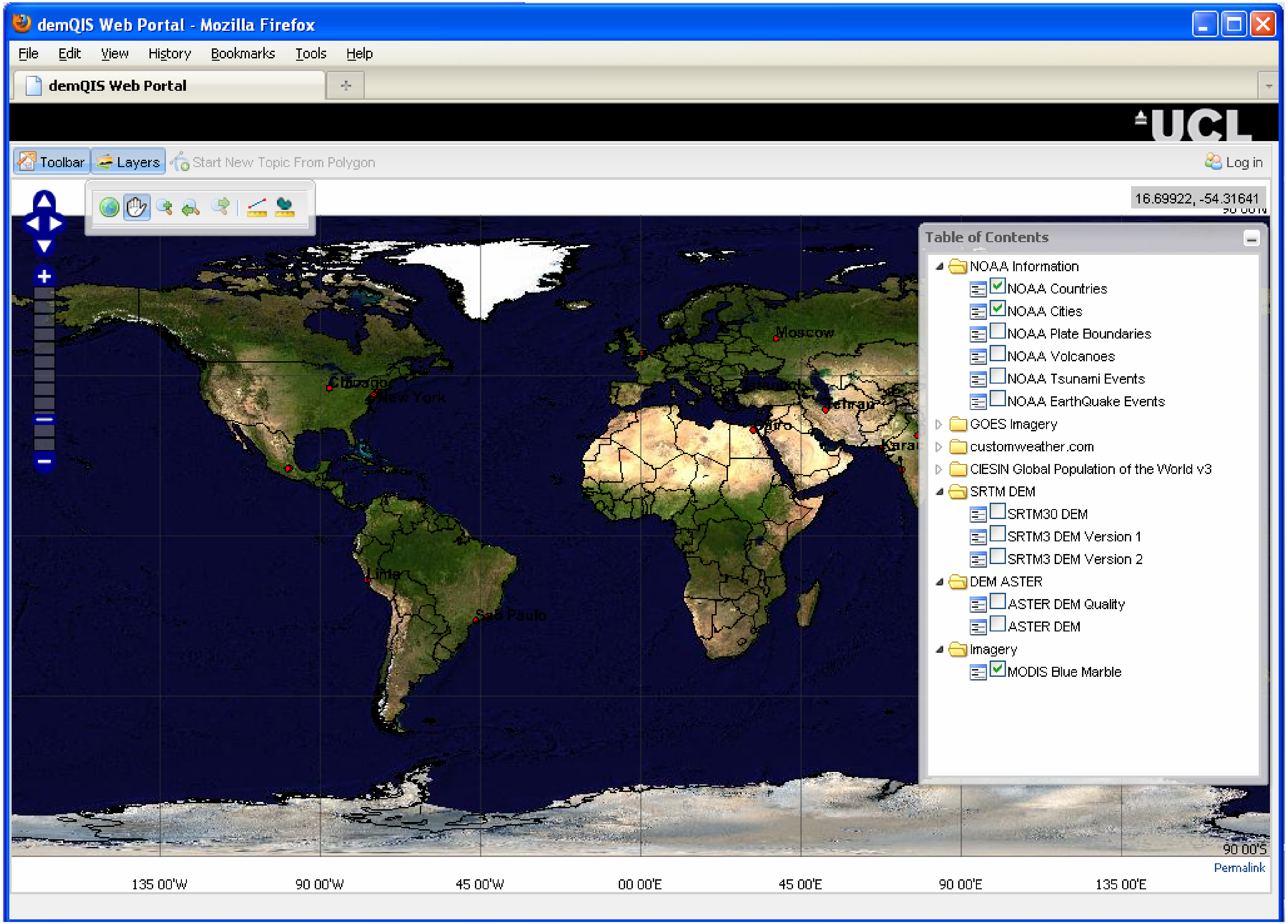
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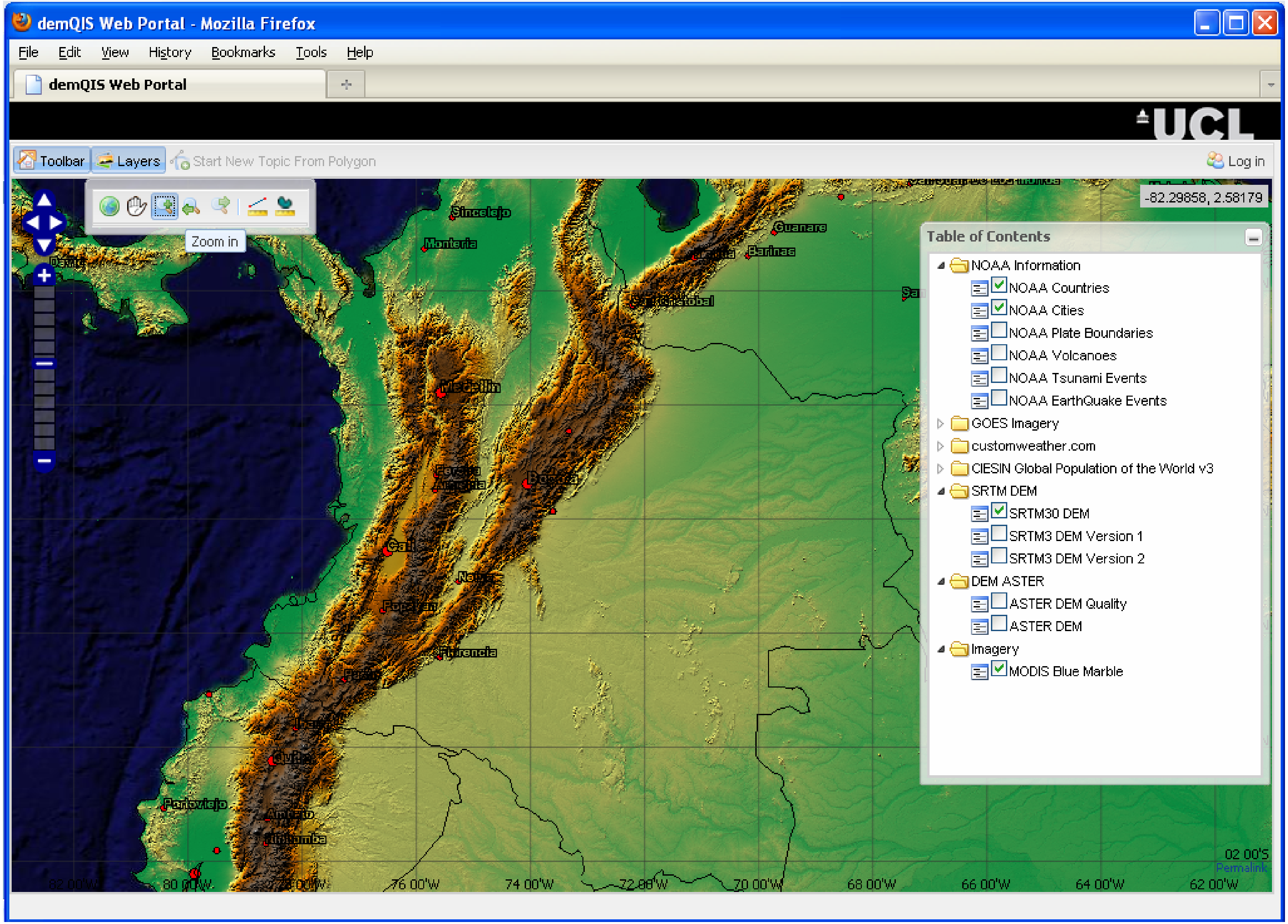
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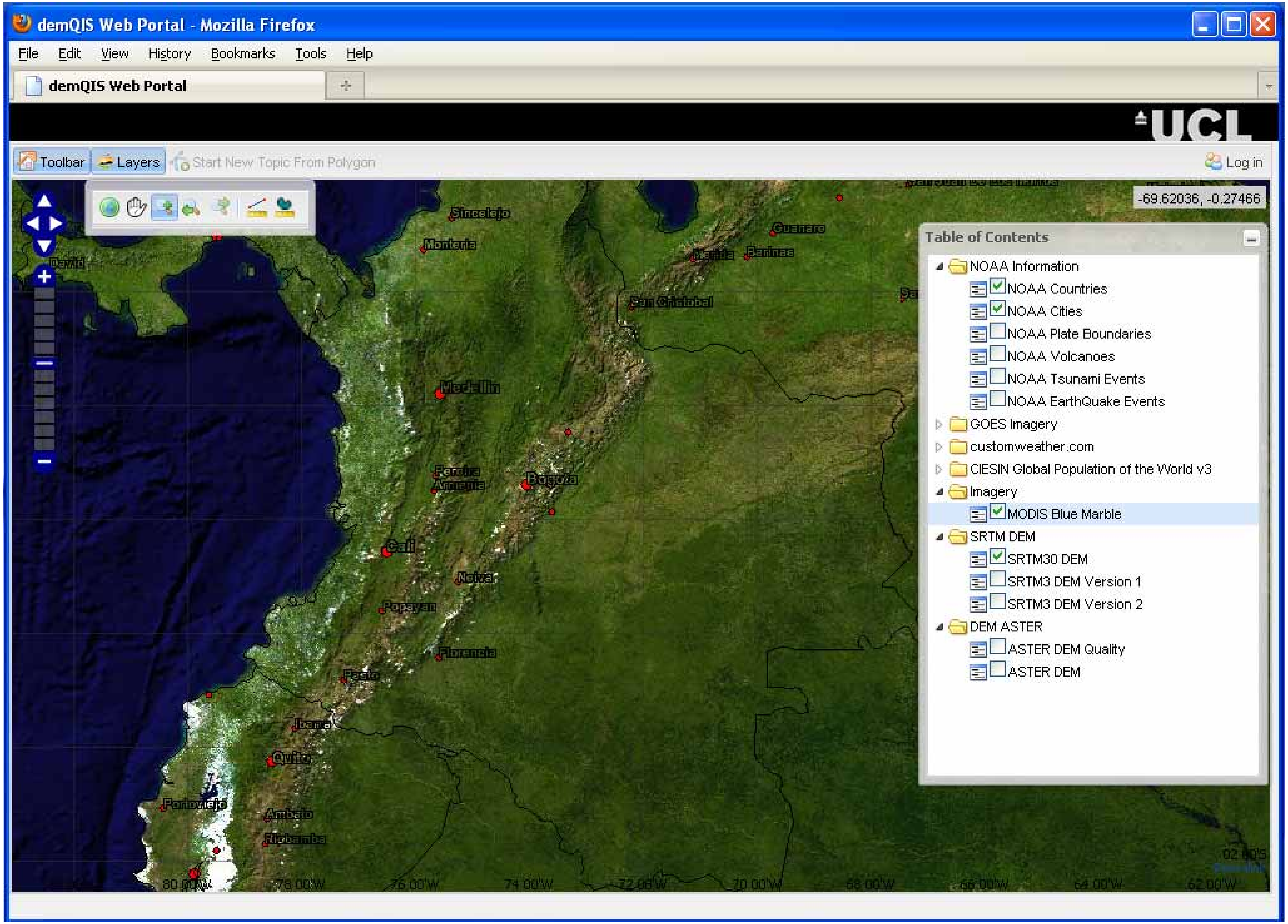
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San Cristobal
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Pereira
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Florencia
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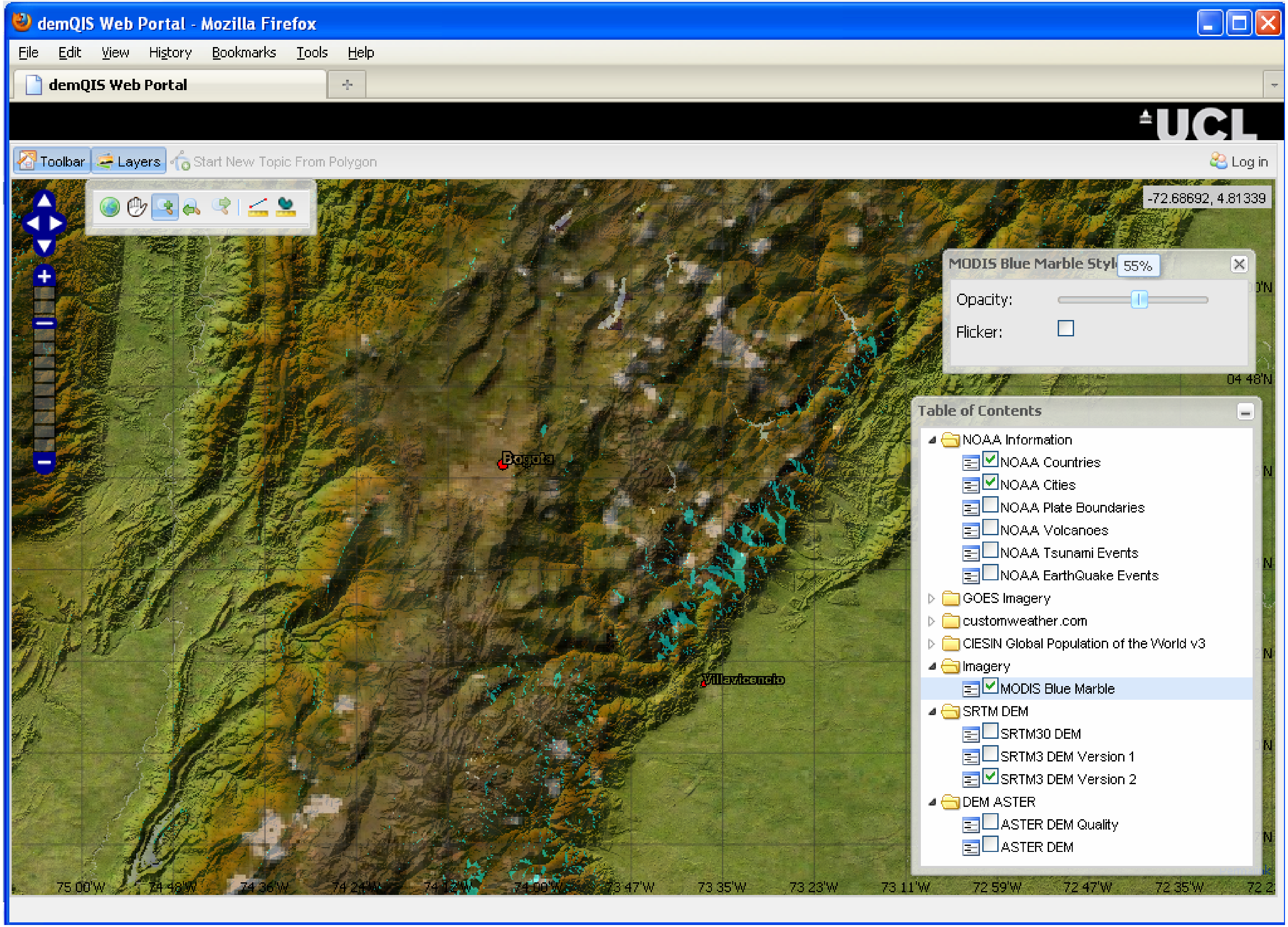
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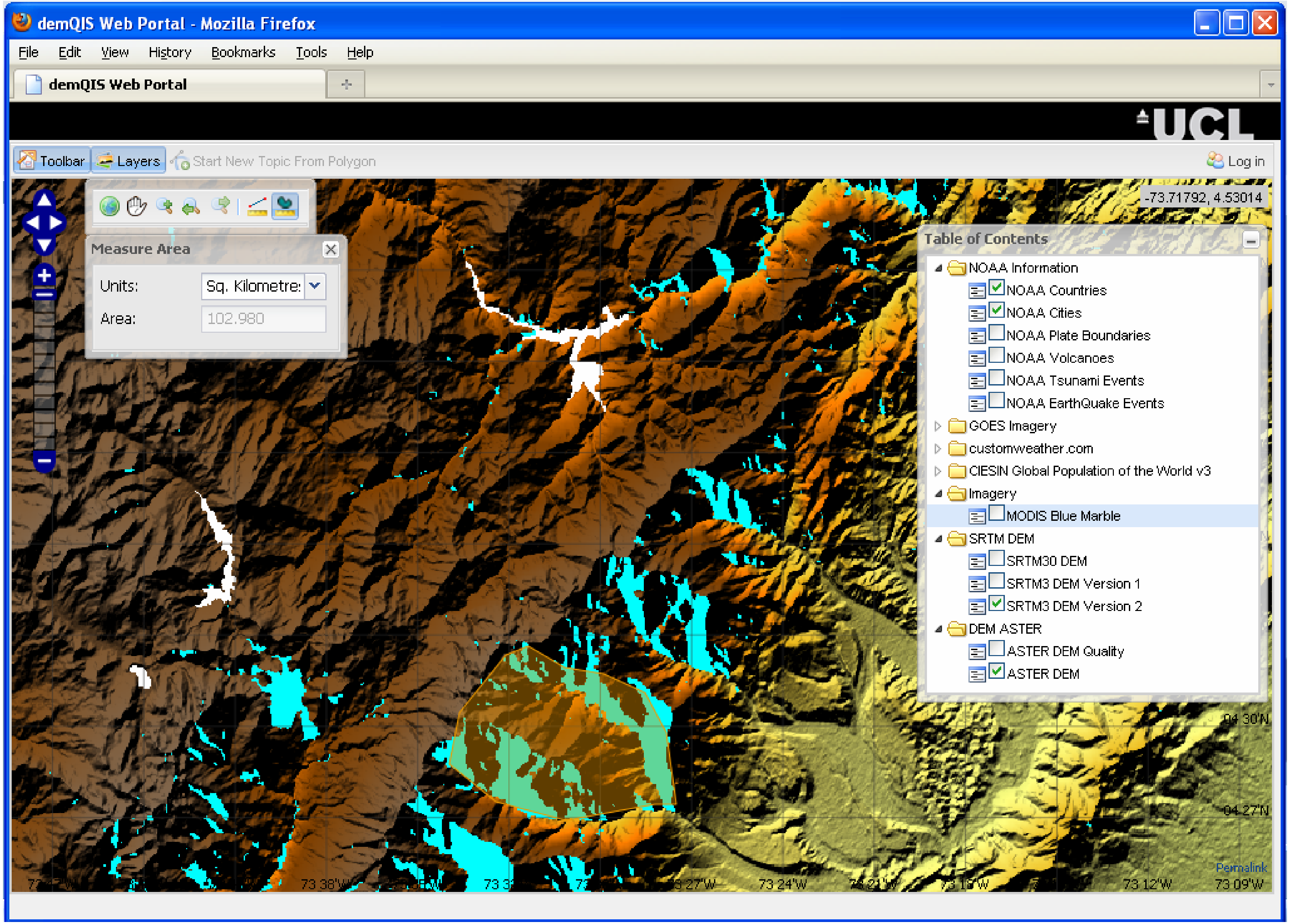
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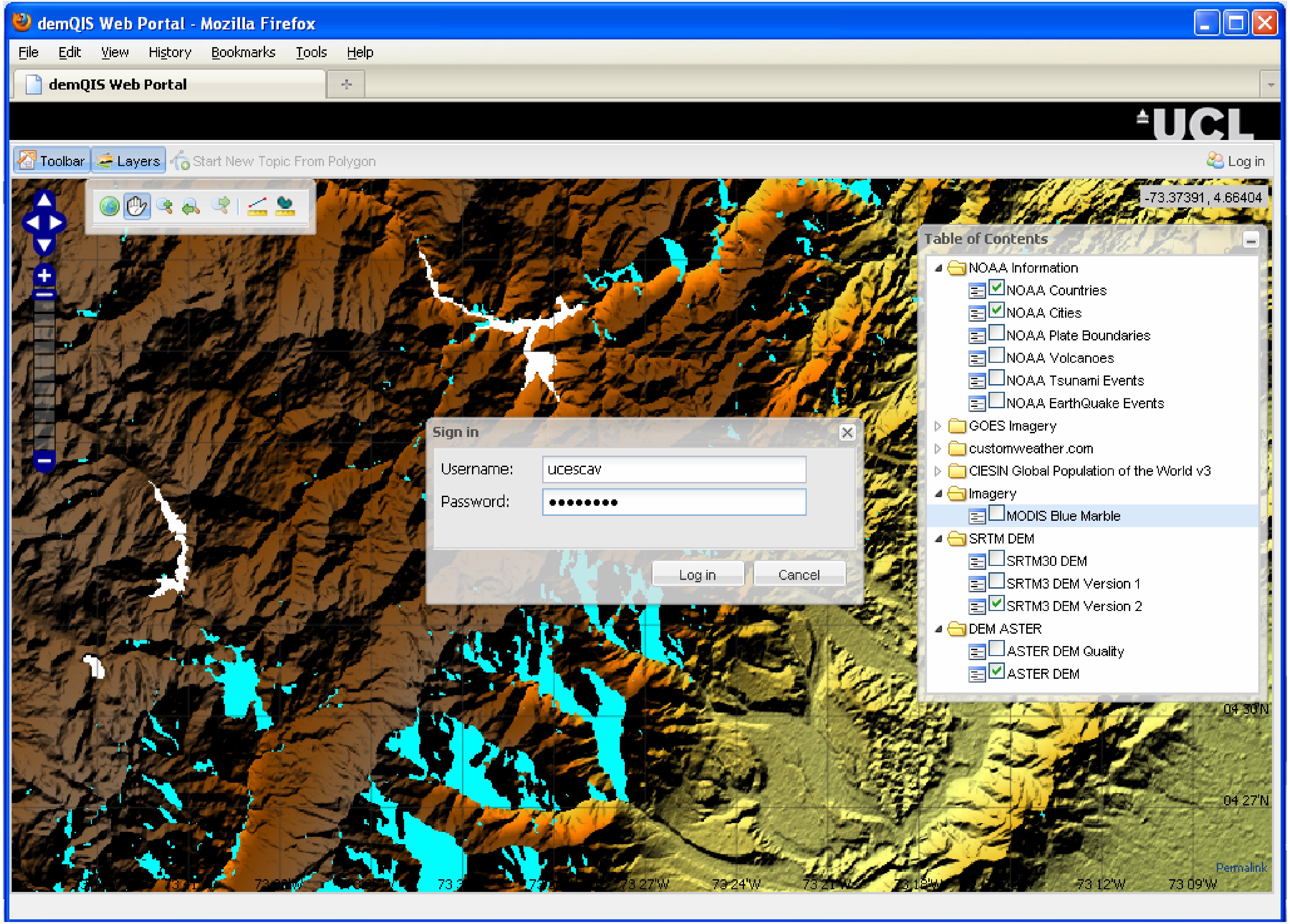
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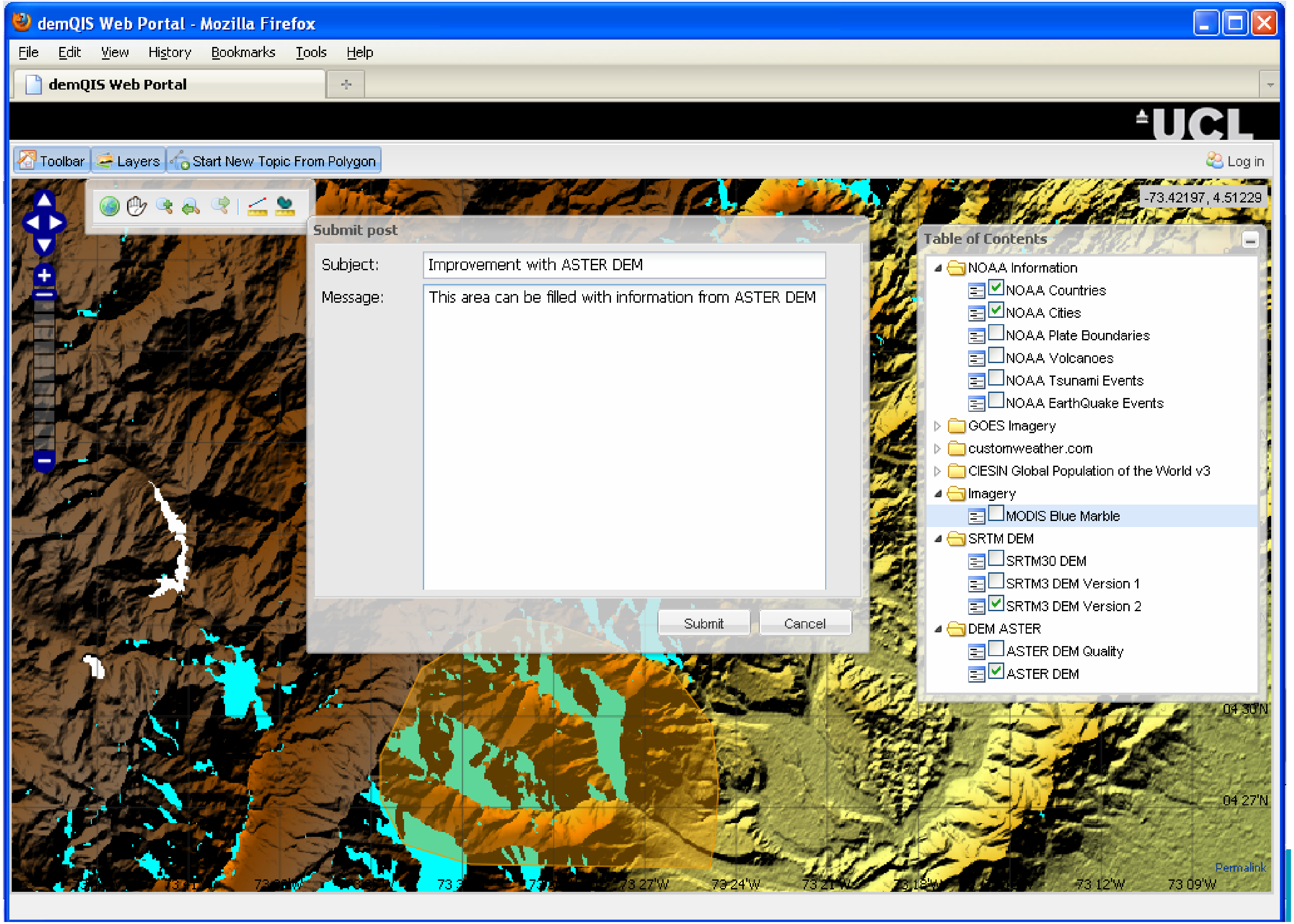
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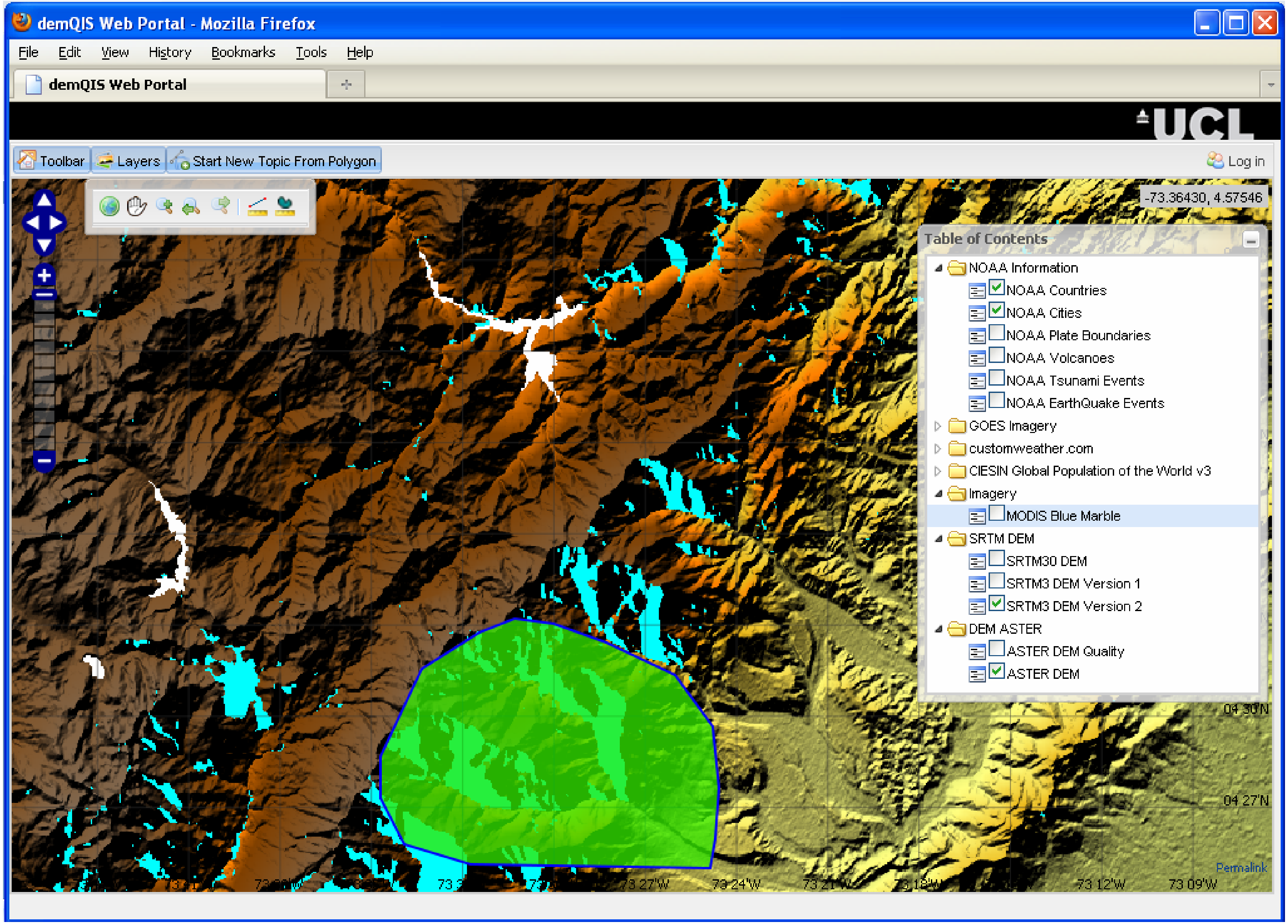
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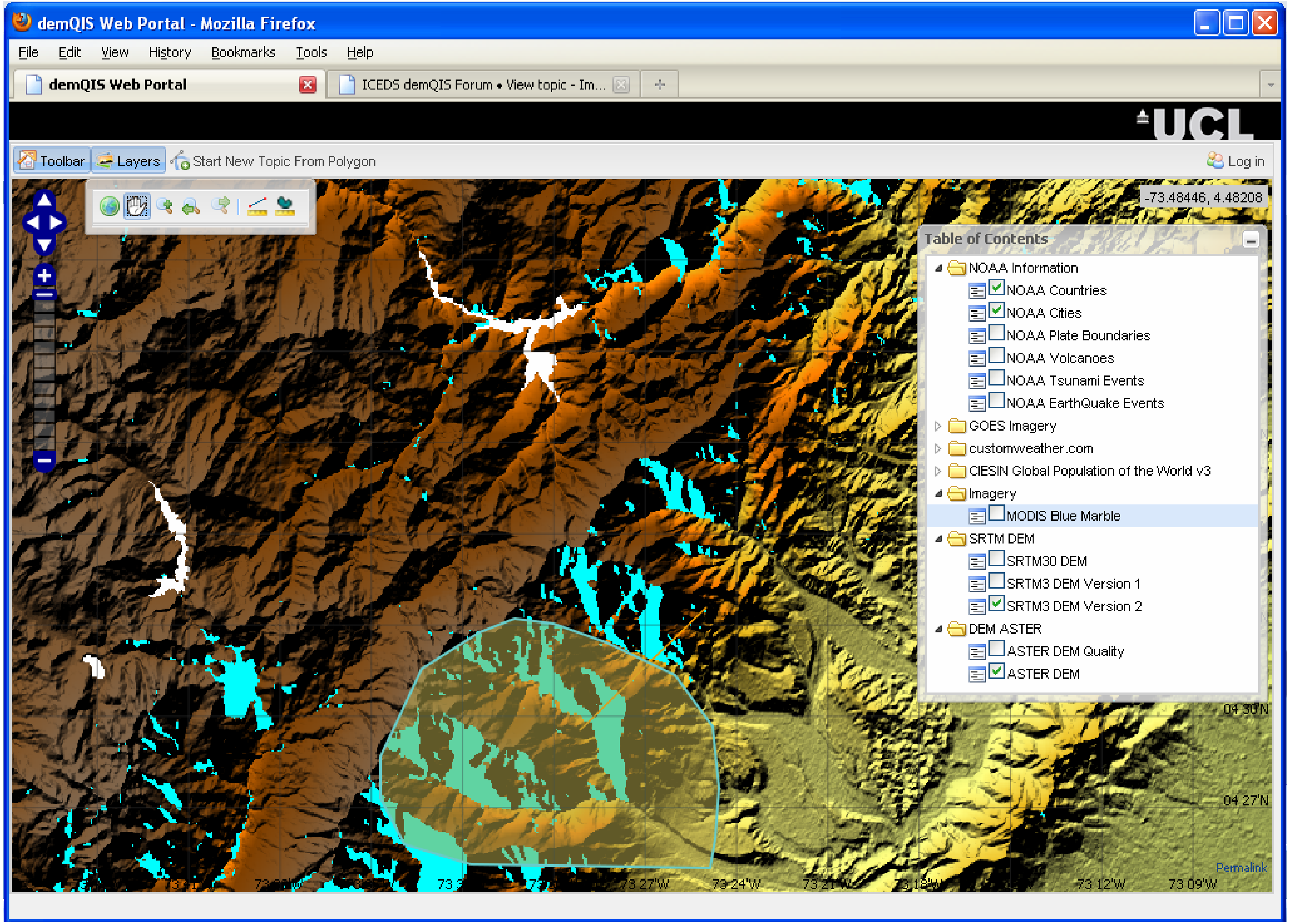
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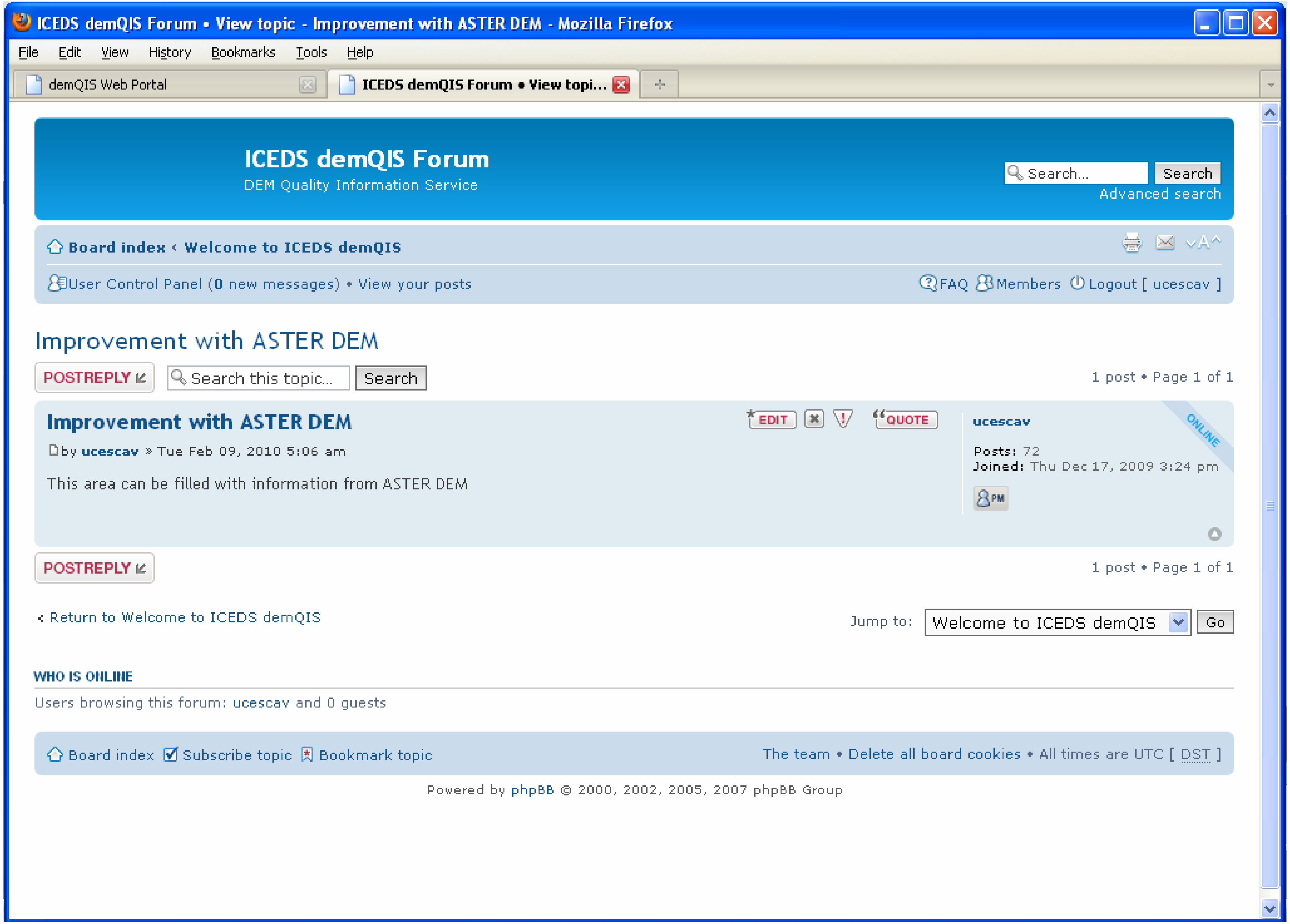
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DEM Quality Information Service
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Improvement with ASTER DEM
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Improvement with ASTER DEM
EDIT
QUOTE
by ucescav » Tue Feb 09, 2010 5:06 am
This area can be filled with information from ASTER DEM
ucescav
ONLINE
Posts: 72
Joined: Thu Dec 17, 2009 3:24 pm
PM
POSTREPLY
1 post • Page 1 of 1
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Welcome to ICEDS demQIS
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Users browsing this forum: ucescav and 0 guests
Board index
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DEMqis short-term Plans

- **Members of the task team will be able to access the system if they provide a fixed IP address that can be registered at MSSL**
- **Plan to add capability to display transects and read-out height values in addition to existing readout of lat,lon values**
- **Allow sharing results with one, a few or everyone (Web 2.0 principle)**
- **System will continue to remain hidden behind the MSSL firewall until hardware in place which can cope with potential demand and funding in place…**
- **EU-FP7 opportunity in next round (Autumn 2010) to build a robust QA4EO server as well as create global DEM product**
- **No space agency has yet volunteered to support production of the Global DEM or its validation**

GROUP ON EARTH OBSERVATIONS

ASTER GDEM Project;
METI and NASA in Conjunction with ERSDAC and USGS

Update Plan for ASTER GDEM Version 2

Tetsushi Tachikawa
ERSDAC, JAPAN
tatikawa@ersdac.or.jp
March 1st, 2010

ERSDAC
Earth Remote Sensing Data Analysis Center

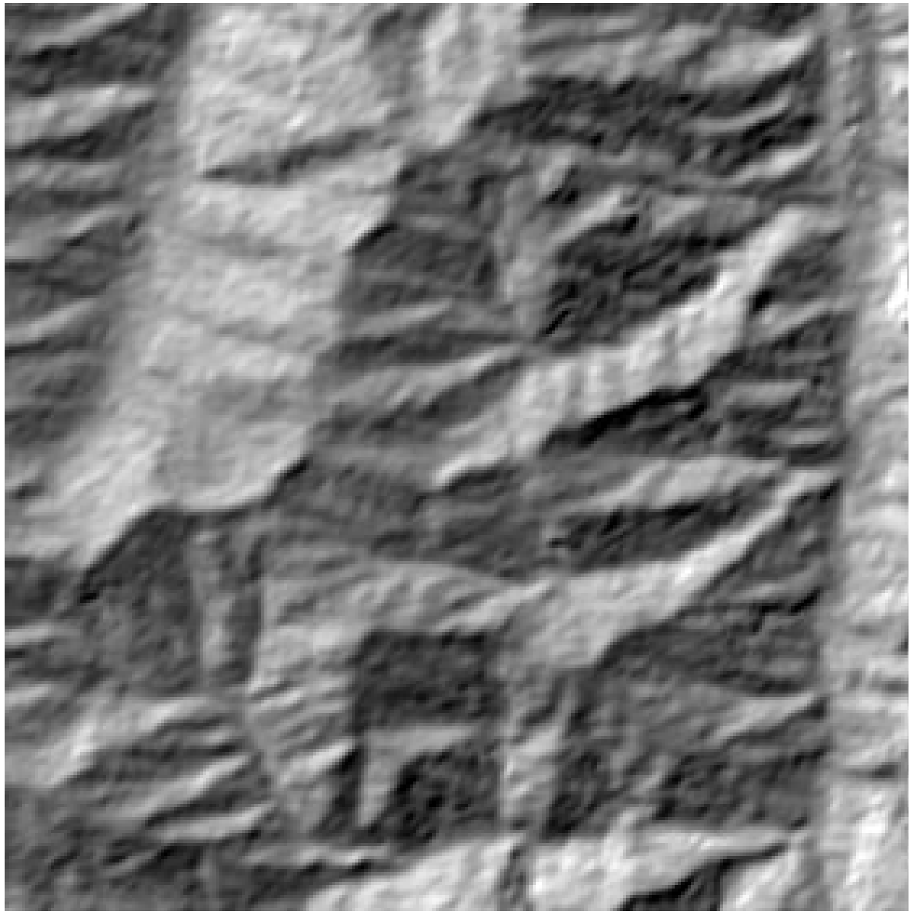
Updates Planned in GDEM Version2

- **New algorithm**
  - **Finer spatial resolution**
    The elevation is calculated by image matching of ASTER VNIR. The kernel size for image matching will change to 5 by 5 pixel from 9 by 9 pixel.
  - **Offset correction**
    Every DEM calculated by ASTER stereo pair has similar elevation offset. This -5m offset will be removed.
  - **Water body detection**
    Water body detection capability will enhance to 1km from 12km.

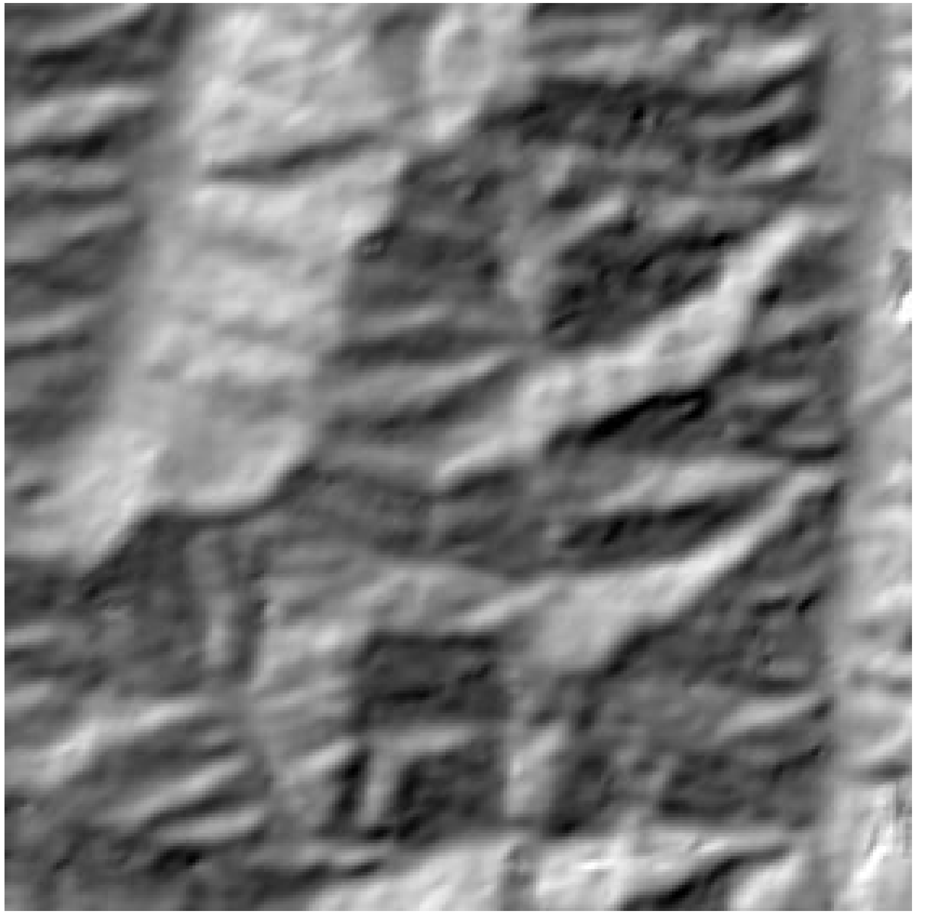
- **New observed data**
  - **Add recent ASTER observation data**
    GDEM version 2 will add ASTER data observed after September 2008 and expect to improve artifacts and anomalies by lack of ASTER data.

Spatial Resolution in Trial Version

Trial Version / Kernel=5x5pixel



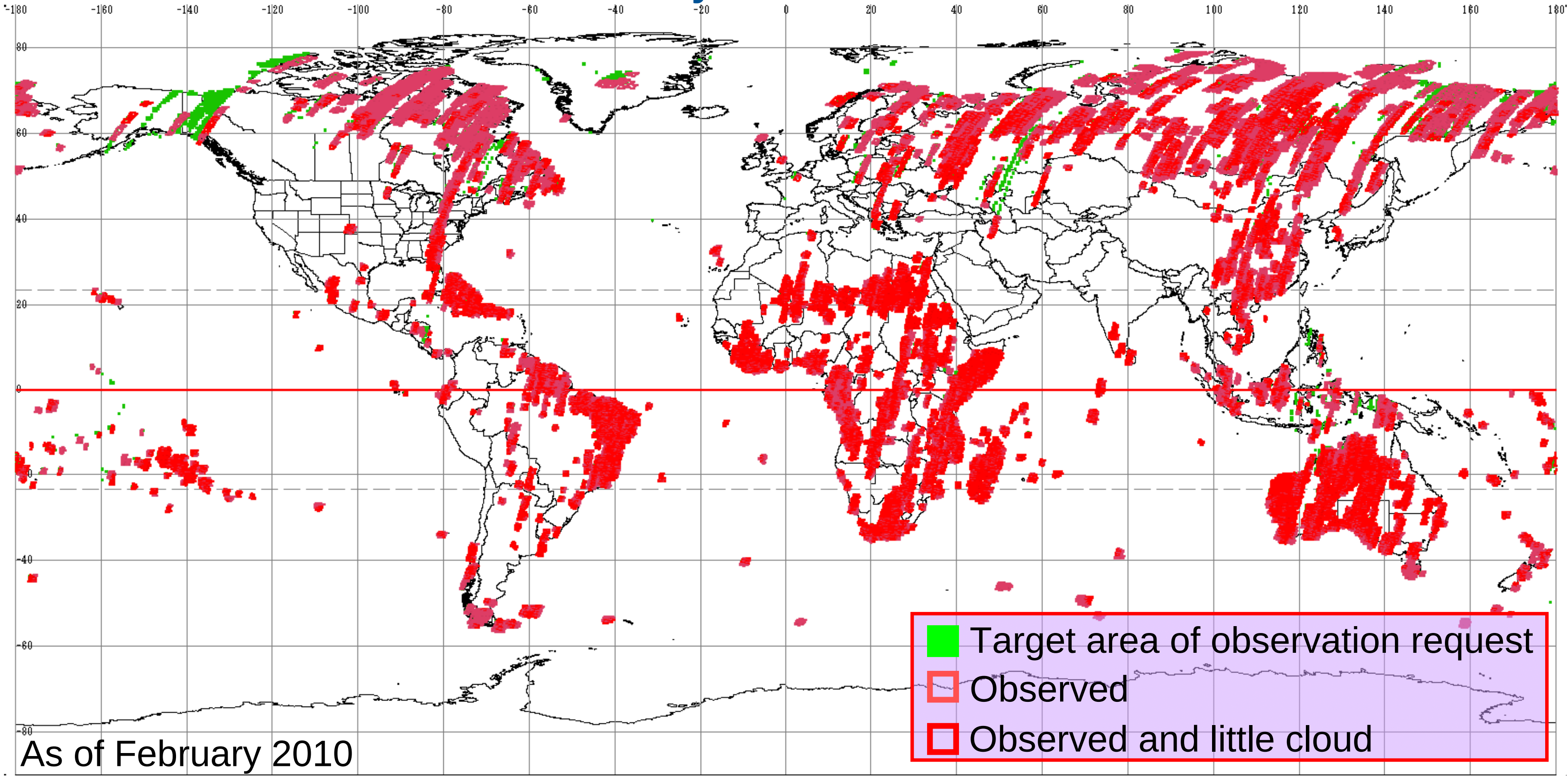
Present Version / Kernel=9x9pixel



The smaller kernel size, the finer spatial resolution

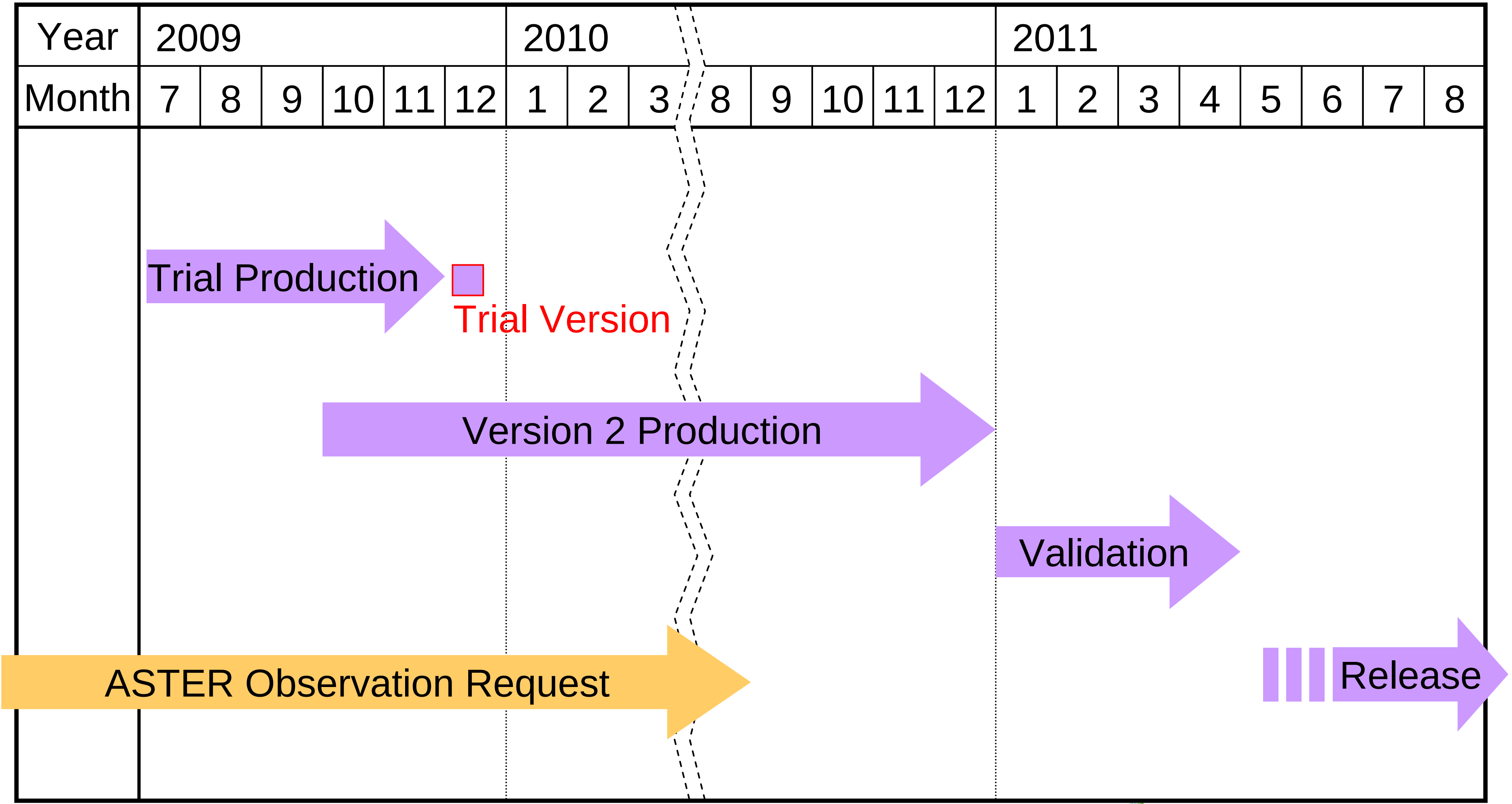
ASTER Observation Status for GDEM

The ASTER observation request was submitted for the area where observations was limited in January 2009.



In the next version, GDEM will add these ASTER data and expects to improve artifacts and anomalies due to the lack of ASTER observation.

Schedule for GDEM Version2



ASTER GDEM Project;
METI and NASA in Conjunction with ERSDAC and USGS

Advanced Land Observing Satellite (ALOS, “DAICHI”): potential for Global DEM

Takeo Tadono

JAXA, JAPAN

March 1st, 2010

ERSDAC
Earth Remote Sensing Data Analysis Center

✓ **Launch:**

Jan. 24, 2006 by H-2A Rocket #8

> 4 years in operation

✓ **Objectives:**

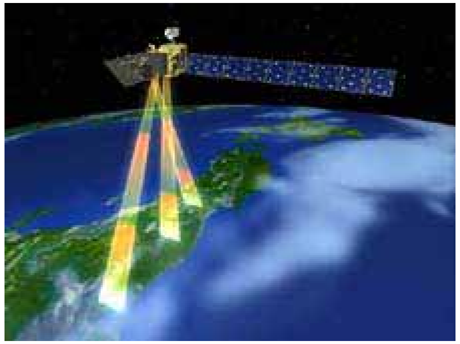
- Cartography (1/25,000 scale)
- Regional environmental monitoring
- Disaster monitoring, *etc.*

✓ **Three mission instruments:**

- PRISM, AVNIR-2, PALSAR

PRISM

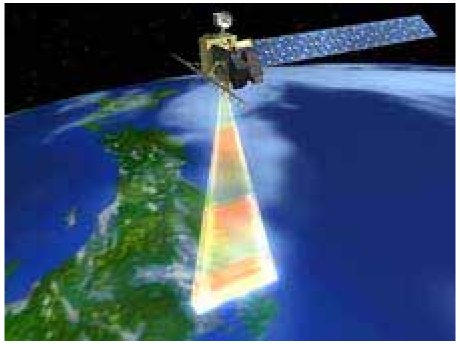
Panchromatic Remote sensing Instrument for Stereo Mapping



PRISM can acquire triplet stereo imageries by nadir-, forward, backward-looking radiometers with 2.5m spatial resolution and 35km wide swath.

AVNIR-2

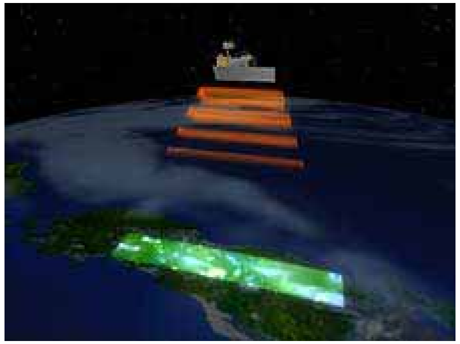
Advanced Visible and Near-Infrared Radiometer type 2



AVNIR-2 can observe with 10m resolution and 70km swath. The observation area can be changed by use of the pointing capability within ±44º across track.

PALSAR

Phased Array type L-band Synthetic Aperture Radar



PALSAR can acquire data night and day as well as in cloudy and rainy weather conditions.

Calibration Results of PALSAR

as of July 1, 2009

Radiometric calibration accuracy (common for all off-nadir angles)[1]		
Absolute accuracy		0.76dB (1σ) : Corner reflector 0.22dB (1σ) : Amazon Forest *
Noise equivalent sigma-naught		-34dB (FBD-HV) -32dB (FBD-HH) -29dB (FBS-HH)
Amplitude ratio of VV/HH for PLR		1.013 (0.062:1σ)
Phase difference of VV and HH for PLR		0.612deg (2.66deg:1σ)
Cross talk (PLR)		31.7dB
Resolution	Single look in azimuth	4.49m
	Range	9.6m (FBD, PLR, DSN)
	Range	4.8m (FBS)
Side lobes	In azimuth	-16.6dB
	In range	-12.6dB
	Two-dimensional	-8.6dB
Ambiguity	Azimuth	—
	Range	23dB
Geometric accuracy (common for all the incidence angles) [2]		
FBS, FBD, PLR, DSN		9.7m (RMS)
WB1, WB2		70m (RMS)

[1] Measurements of radiometric accuracy: Statistical analysis of the impulse response of the corner reflectors (CRs) at the calibration site and the responses from the Amazon rainforest. * Standard deviation of the incidence angle dependence of the gamma-naught measured for five off-nadirs (e.g. 9.9, 21.5, 34.3, 41.5, and 50.8 degrees). ** Gamma-naught: normalized radar cross section (NRCS or sigma-naught) divided by the cosine of incidence angle.**

[2] Measurements of geometric accuracy: Statistical evaluation of the worldwide CRs in total 572 and calculation of the root sum square of the distance between the position of the CRs, that are identified in the PALSAR image and obtained from the PALSAR geometric conversion formula, and its true location on the GRS80 that is calculated from the CR true measurement and the SAR observation geometry.

Calibration Results of PRISM/AVNIR-2

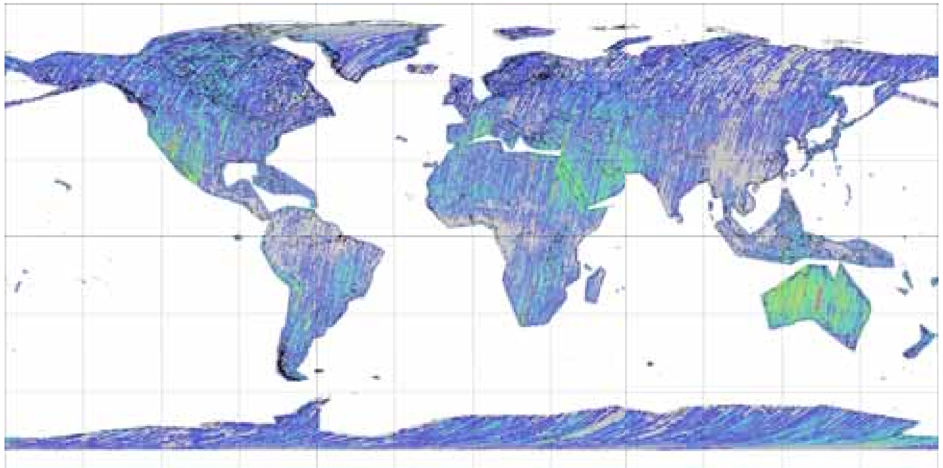
<table>
<tr><th>Standard Product</th><th>Previous results as of Sep. 29, 2007</th><th>Results as of July 1, 2009 (Public*)</th></tr>
<tr><td>PRISM
1B2</td><td>Geometry
Absolute Accuracy (RMS): using 1,390 GCPs
Pixel (X) Line (Y) Distance
Nadir 6.5m 7.3m 9.8m
Forward 8.0m 14.7m 16.7m
Backward 7.4m 16.6m 18.1m

Relative Accuracy (1σ)
3 radiometers 1.9m 2.3m 3.0m</td><td>Geometry (Jun. 22, 2007-Jun. 4, 2009)
Absolute Accuracy (RMS)
Pixel (X) Line (Y) Distance
Nadir 5.6m 5.3m 7.8m
using 5,499 GCPs, 586 scenes
Forward 4.9m 6.1m 7.8m
using 1,771 GCPs, 225 scenes
Backward 5.0m 7.1m 8.7m
using 4,839 GCPs, 525 scenes
Relative Accuracy (1σ)
3 radiometers 1.4m 1.8m 2.4m
CE90
Nadir 11.8m, Forward 12.4m, Backward 13.4m
Radiometry
Absolute accuracy: similar to that of AVNIR-2</td></tr>
<tr><td>AVNIR-2
1B2</td><td>Geometry (-41.5 to +41.5 deg. pointing)
Pixel (X) Line (Y) Distance
Absolute Accuracy (RMS) 106m 19m 108m
Relative Accuracy (1σ) 4m 4m 6m</td><td>Geometry (all period)
Absolute Accuracy (RMS)
Pixel (X) Line (Y) Distance
0 deg. pointing 71.1m <u>7.5m</u> 71.9m
+/-41.5 deg. 60.9m 96.6m 114.2m
Relative Accuracy (1σ) 3.4m <u>7.7m</u> <u>8.5m</u>
using 1,035 GCPs, 54 scenes
Radiometry (all period)
Absolute accuracy Band 1-3: 3.2%, Band4: 7.3%</td></tr>
</table>

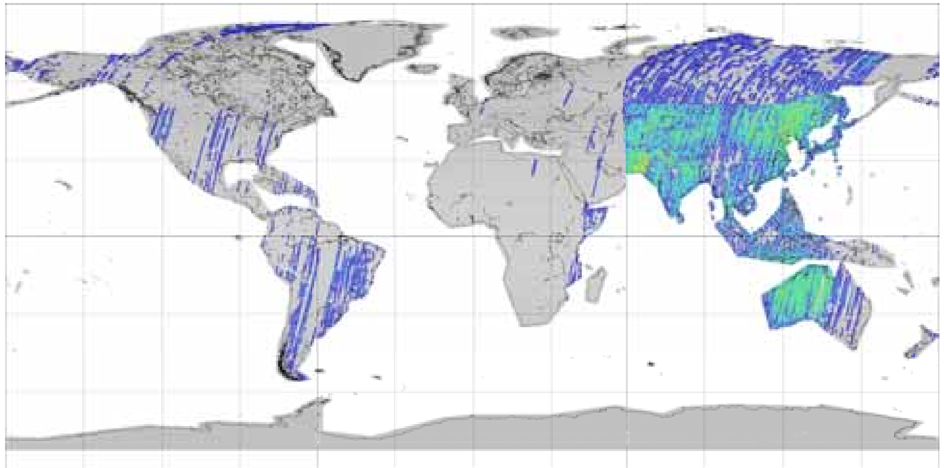
*** Latest ALOS calibration results (in English) can be found at http://www.eorc.jaxa.jp/hatoyama/satellite/data_tekyo_setsumei/alos_hyouka_e.html**

Acquisition Status of PRISM and AVNIR-2

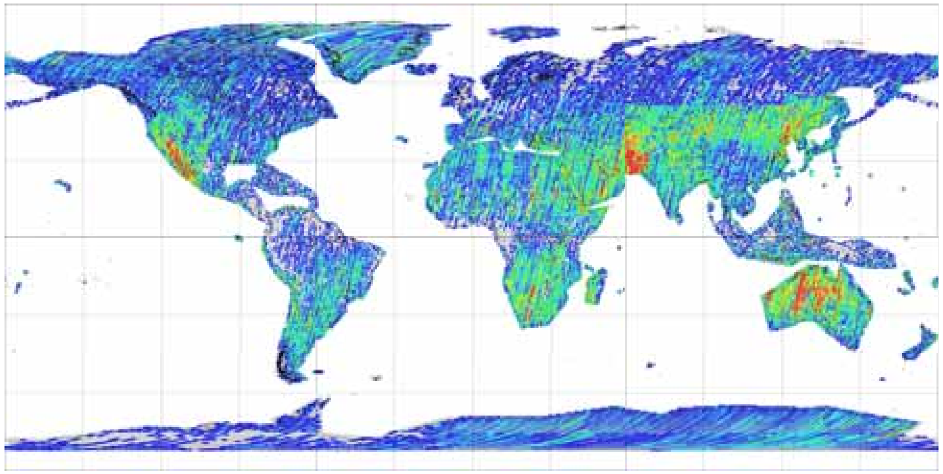
May 16, 2006 – Oct. 27, 2009



PRISM 35km (OB1) (Cloud cover: 0-2% / scene)



PRISM 70km (OB2) (Cloud cover: 0-2% / scene)



AVNIR-2 (Cloud cover: 0-2% / scene)

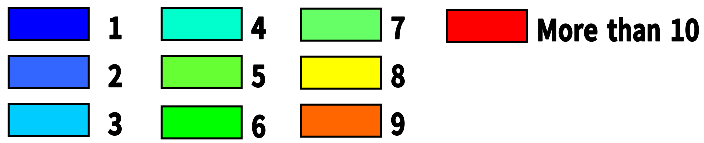


Image coverage map of PRISM and AVNIR-2 based on the basic observation scenario

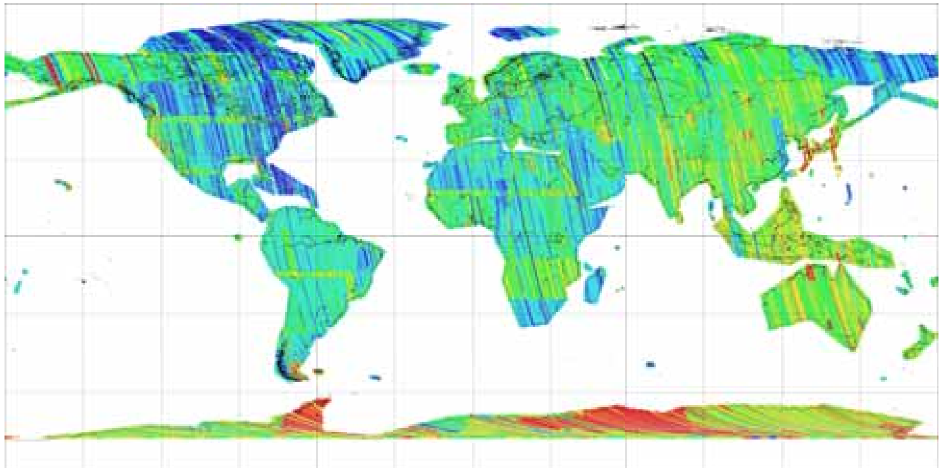
Spatial coverage: PRISM OB1 61 % with 0-2 % cloud cover in scene

OB1 75 % with 0-20 % cloud cover in scene

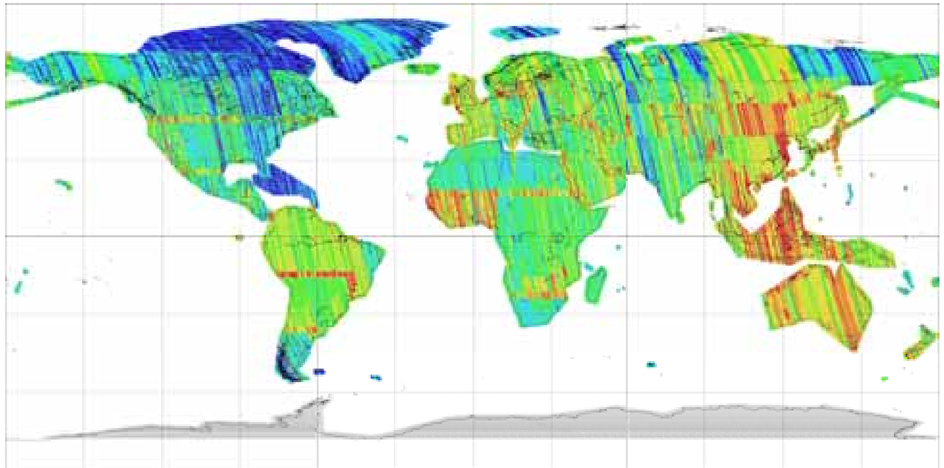
AVNIR-2 75 % (0-2%); 87 % (0-20%)

Acquisition Status of PALSAR

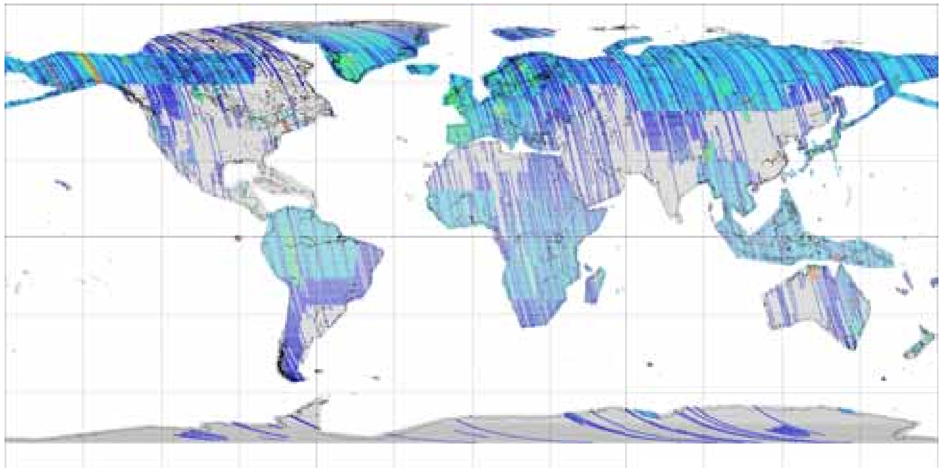
May 16, 2006 – Oct. 27, 2009



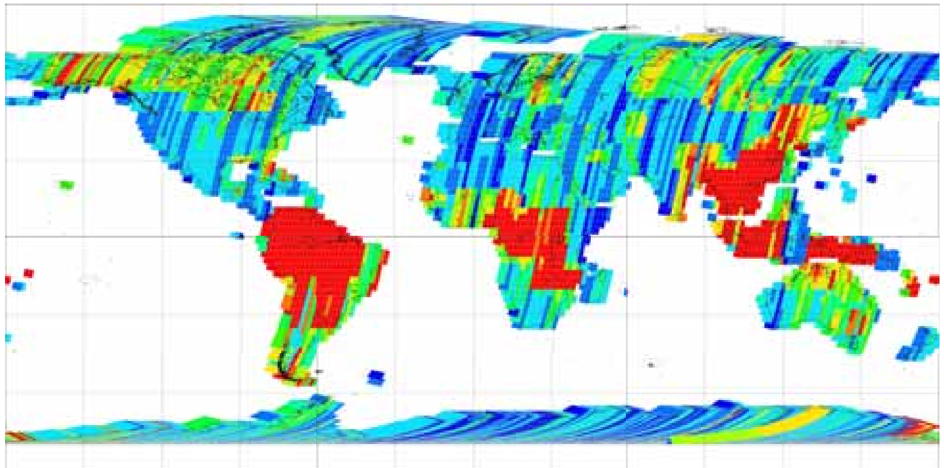
FBS Off-nadir:34.3deg (Asc.)



FBD Off-nadir:34.3deg (Asc.)



PLR Off-nadir:21.5deg (Asc., Selected areas)



WB1/WB2 Off-nadir:27.5deg (Desc.)

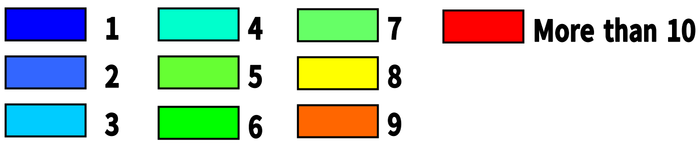
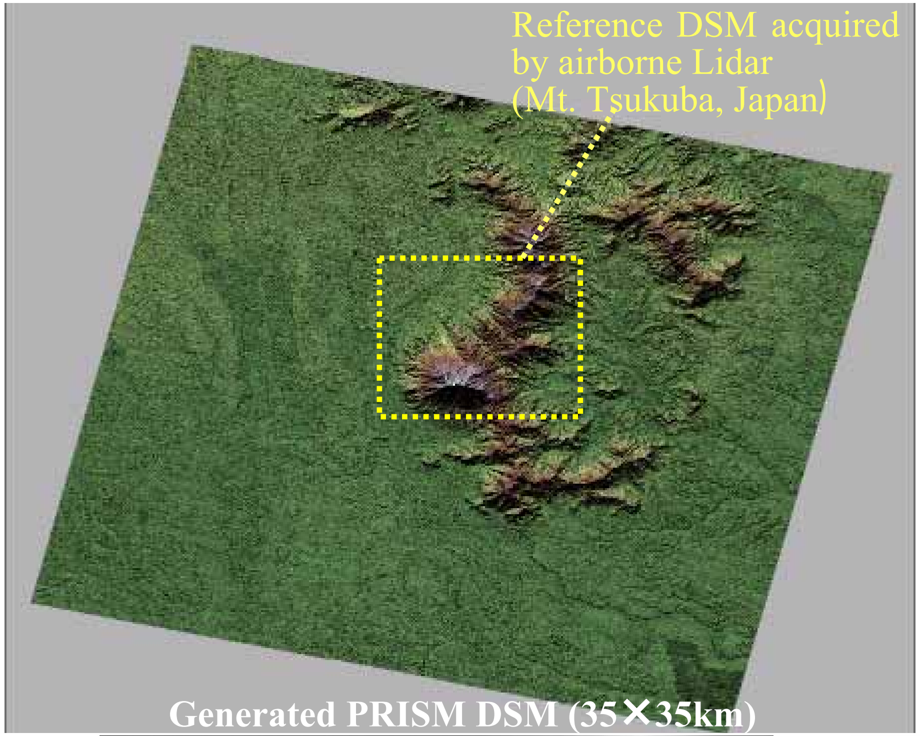
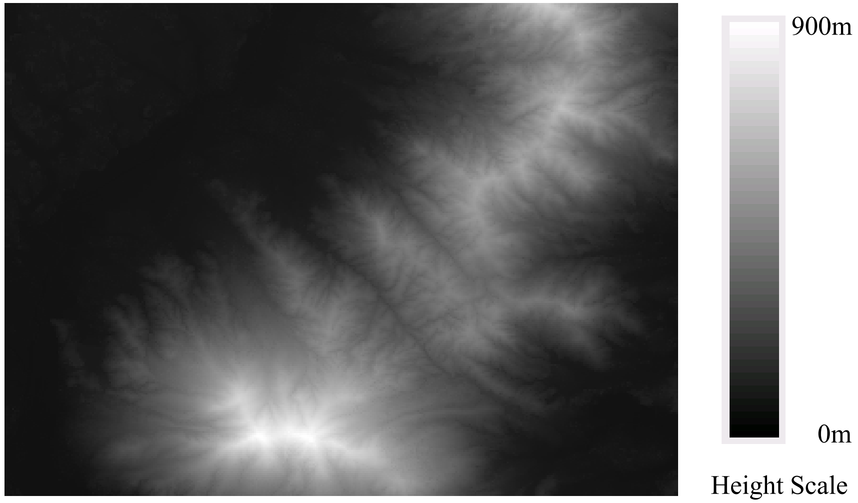


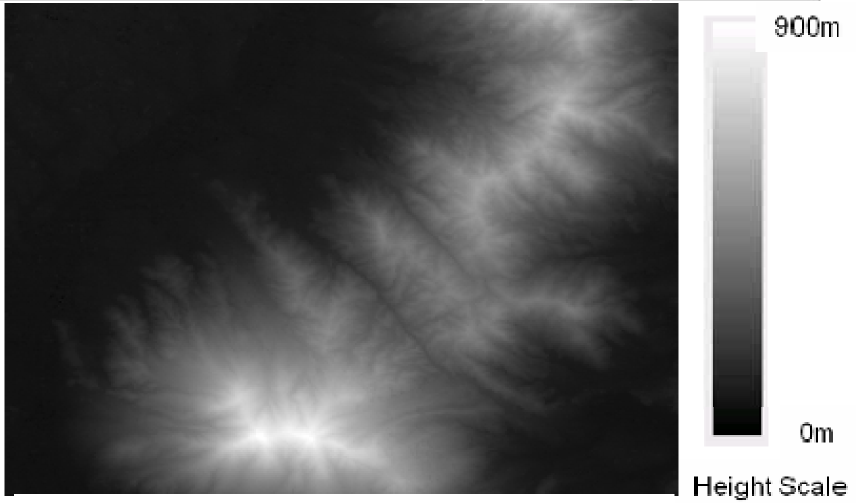
Image coverage maps of PALSAR based on
the basic observation scenario

PRISM Digital Surface Model (DSM)

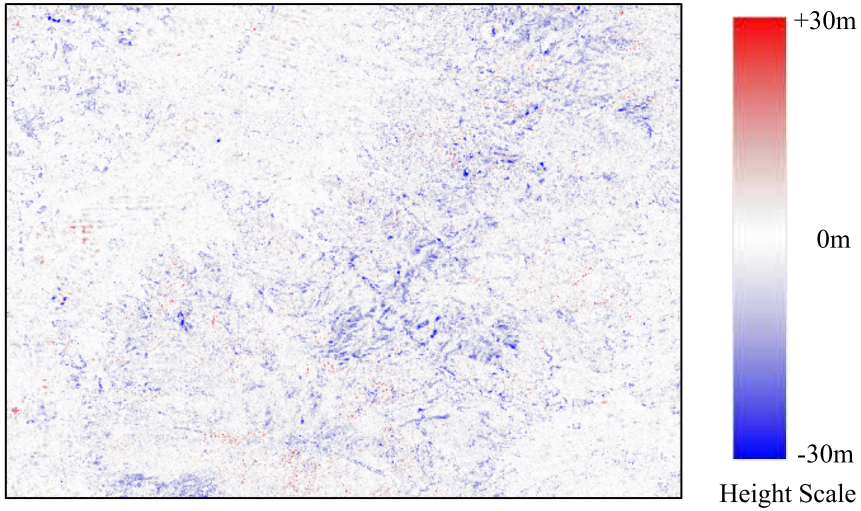




Reference DSM by Lidar onboard Cessna 206



Generated PRISM DSM (0.3 arc-sec, 8x8km)



Height difference = PRISM DSM − Lidar DSM (8x8km)

Validation – PRISM DSM

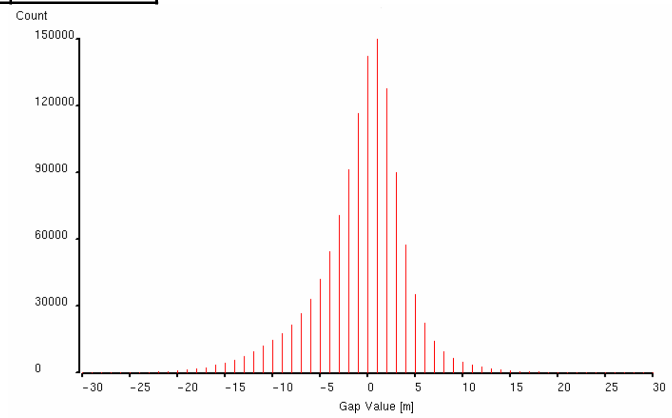
Statistics of PRISM DSM - Reference Lidar (whole area)

Site	Terrain	GCP	Points	Bias [m]	SD [m]	RMSE [m]	Max [m]	Min [m]
Mt.Tsukuba	Mountainous & Flat	42	1287801	-1.70	4.92	5.21	32	-73

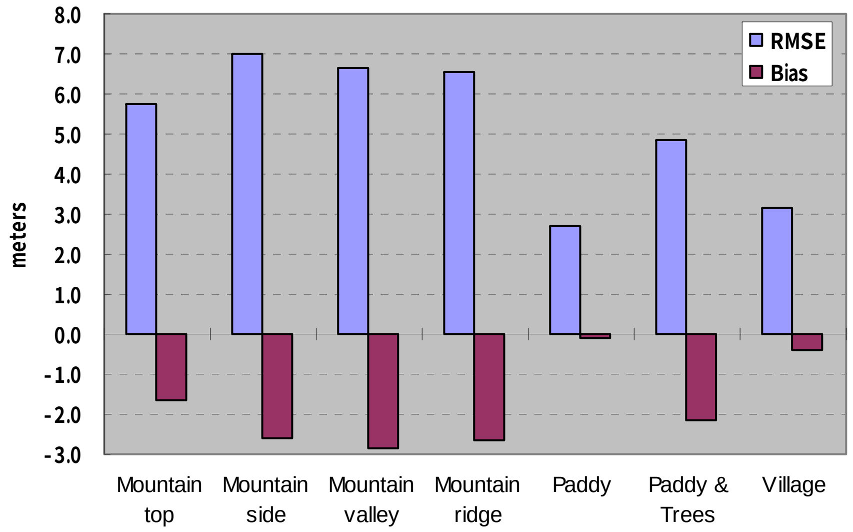
Statistics of PRISM DSM – Reference Lidar (individual land use and land cover)

Terrain	Points	Bias [m]	SD [m]	RMSE [m]	Max [m]	Min [m]
Mountain top *)	10000	-1.64	5.50	5.73	31	-38
Mountain side *)	10000	-2.59	6.49	6.99	24	-37
Mountain valley *)	10000	-2.85	6.02	6.66	20	-31
Mountain ridge *)	10000	-2.65	5.98	6.54	22	-55
Paddy	10000	-0.09	2.68	2.68	15	-17
Paddy & Trees	10000	-2.15	4.37	4.87	15	-32
Village	10000	-0.39	3.12	3.14	10	-22

*) Mountainous areas are including forests



Height differences (8x8km)



Validation of generated PRISM DSM for individual land cover (blue: RMSE, purple: bias error)

Results of analysis and validation

- Height accuracy (whole area) = 4.92m (1 σ), 5.21m (RMS)
- Except forest areas = 3.57m (RMS)

✓ Forest areas are including bias error

✓ The correlation coefficients may become high at the inside of boundaries (e.g. edges) of forests, buildings *etc.* It causes under estimations of the height > limitation of correlation matching

ADV=C
CEOS-WGCV

Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010)

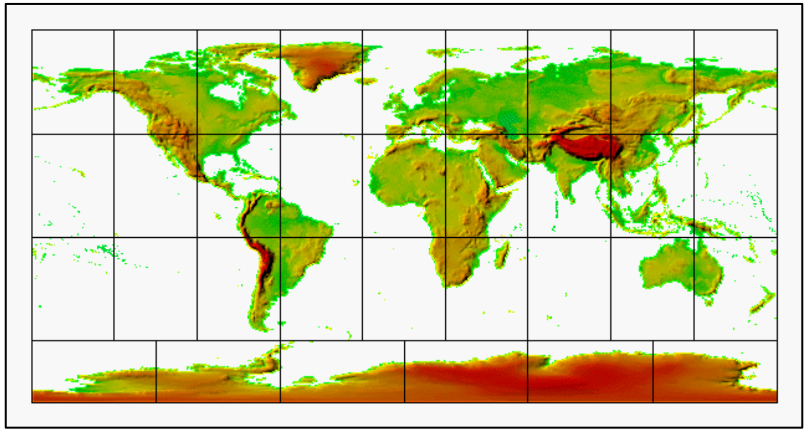
Jeffrey J. Danielson and Dean B. Gesch, U.S. Geological Survey (USGS), Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD, USA

Work performed with support from the National Geospatial-Intelligence Agency (NGA)

Presentation Section Outline

- **Existing Global Digital Elevation Sources**
  - **GTOPO30**
- **Global Multi-resolution Terrain Elevation Data 2010**
  - **Overview**
  - **Higher Resolution Data Sources**
  - **Products**
  - **Validation and Evaluation**
- **Conclusions**

GTOPO30 Global Elevation Model



http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html

- Widely used for climate modeling, land cover characterization, hydrologic modeling, and EOS satellite image product generation

- GTOPO30 continues to be a very popular product, averaging over 12,000 files downloaded each month

- **Dataset Information:**
  - **Stakeholder: U.S Geological Survey**
  - **Surface Type: Land Surface – Bare Earth**
  - **Horizontal Resolution: 30 arc-seconds (1 kilometer)**
  - **Vertical Unit: Integer Meter**
  - **Projection System: Geographic Lat / Long**
  - **Elevation Sources: 5 Vector and 3 Raster**
  - **Production Date: November 1996, Initial Release 1997**

Global Multi-resolution Terrain Elevation Data 2010

- **Primary Goal**
  - **To develop a fully global medium scale elevation model to replace and enhance GTOPO30. The new model has been generated at three separate resolutions (horizontal post spacings) of 30 arc-seconds (1 km), 15 arc-seconds (500 m), and 7.5 arc-seconds (250 m) from the best available higher resolution data sources.**

- **Elevation Data Sources**
  - **New Source Data:**
    - » **Shuttle Radar Topography Mission (SRTM) DTED 2®, 1 arc-second**
    - » **National Elevation Dataset (NED), 1 and 2 arc-seconds**
    - » **Canadian Digital Elevation Data (CDED), 0.75 and 3 arc-seconds**
    - » **Digital Terrain Elevation Data (DTED 1®), 3 arc-second**
    - » **SPOT5 Reference3D®, 15 arc-second**
    - » **Geoscience Laser Altimeter System (GLAS) / ICESat, 15 and 30 arc-seconds**
    - » **Radarsat Antarctica Mapping Project (RAMP) Ver. 2, 6 arc-second**
    - » **Australian GEODATA 9 arc-second DEM**

- **Metadata Compliant with FGDC Standards**
  - **Detailed spatially referenced metadata will be produced for all the datasets that constitute the global elevation model.**

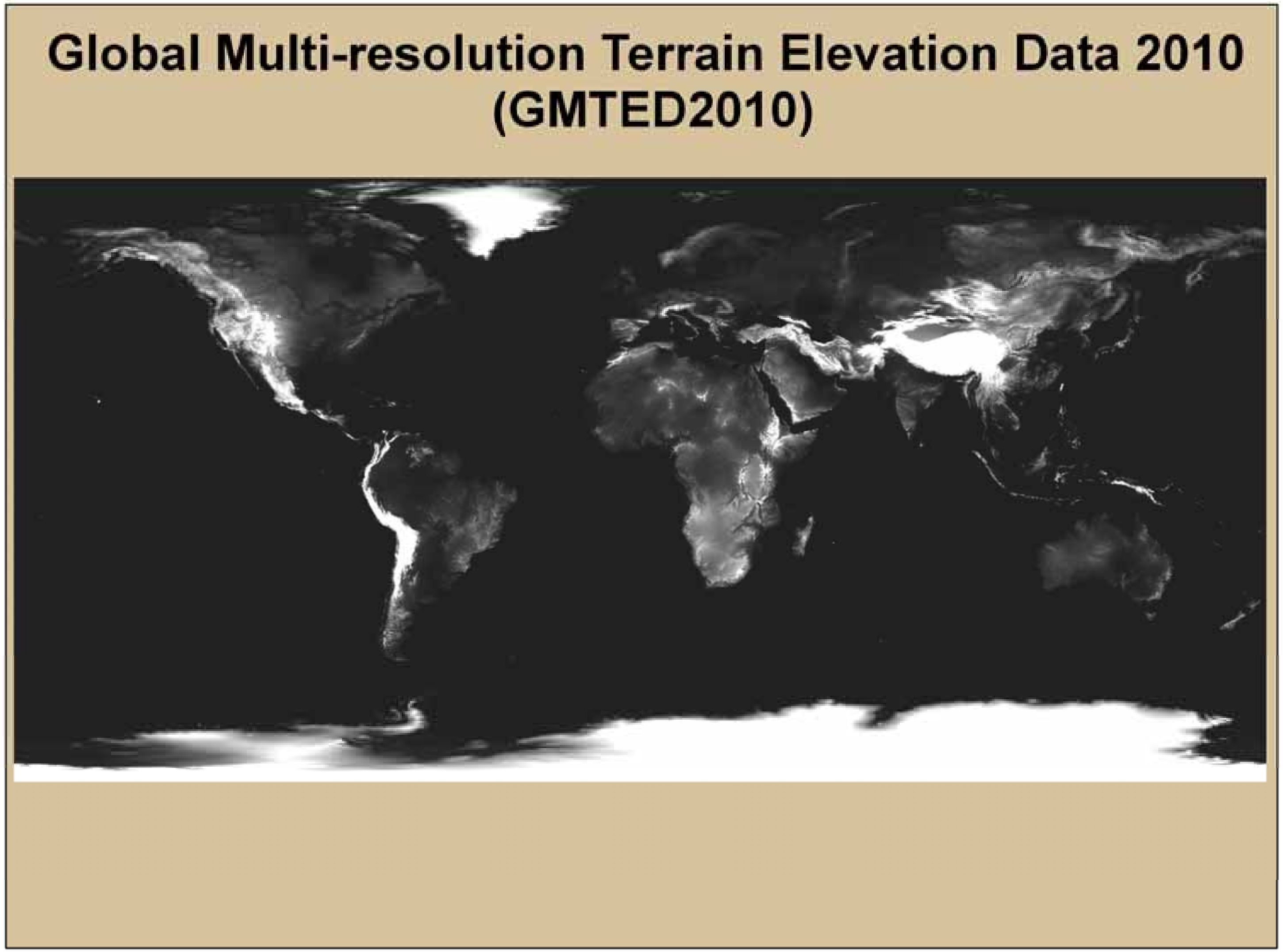
Input Data Sources: Shuttle Radar Topography Mission (SRTM) DTED 2® (void-filled) - 1 Arc-Second

- **Dataset Information:**
  - Stakeholder: National Geospatial-Intelligence Agency (NGA); NASA
  - Surface Type: Land Surface - Reflective
  - Horizontal Resolution: 1 arc-second
  - Vertical Unit: Integer Meter
  - Projection System: Geographic Lat / Long
  - Elevation Source: Shuttle Radar Topography Mission (SRTM) DTED 2 ® (void-filled), Limited Distribution (LIMDIS)
  - Source Date: February 2000

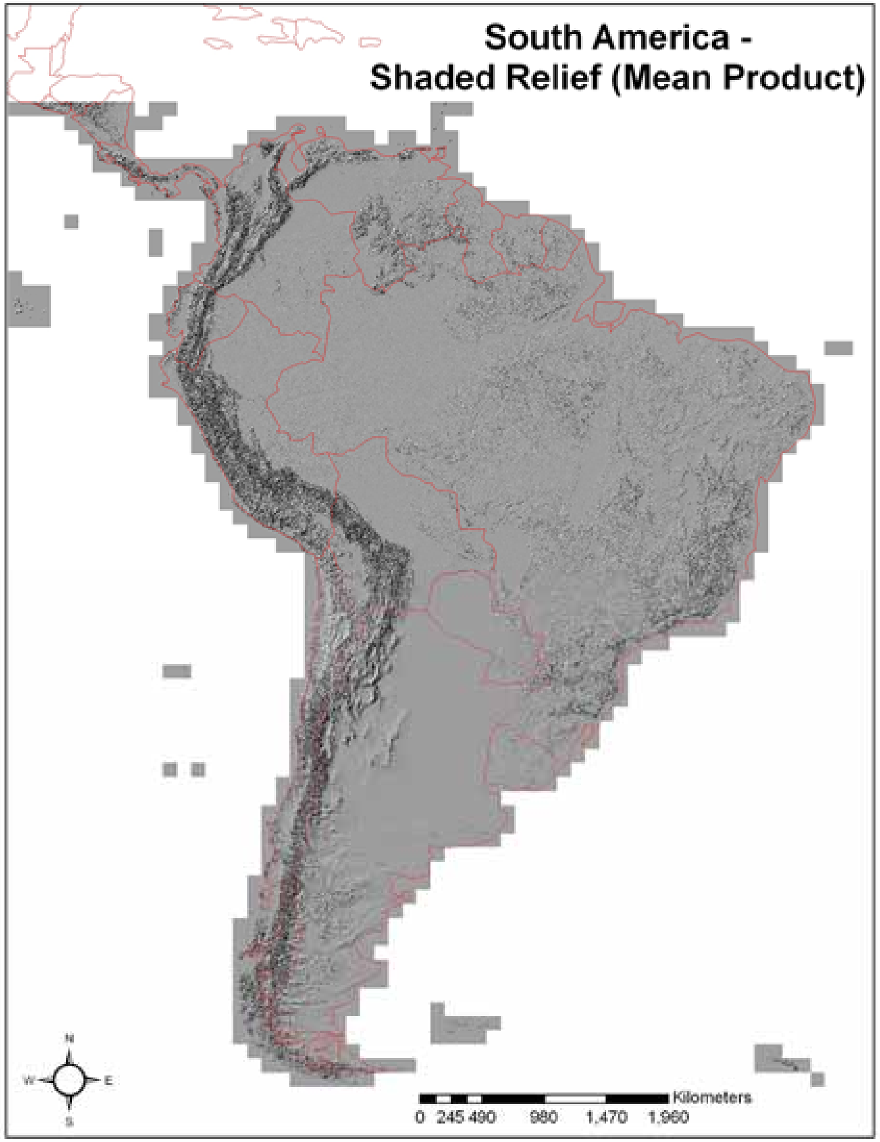
GMTED2010: Products

- **Products / Algorithms**
  - **Seven products generated at each resolution (7.5, 15, and 30 arc-seconds)**
    - » **Breakline Emphasis (Hydrologic Applications)**
      - **Breakline emphasis maintains the critical topographic features within the landscape by retaining any stream (minimum elevation) or ridge (maximum elevation) value that passes within the specified analysis window.**
    - » **Minimum Elevation Statistic (Stream Channel Identification)**
    - » **Maximum Elevation Statistic (Air Traffic Navigation Application)**
    - » **Mean Elevation Statistic (All-Purpose Visualization and Morphological Processing)**
    - » **Median Elevation Statistic**
    - » **Standard Deviation Statistic (Surface Texture / Roughness)**
    - » **Systematic Subsample**

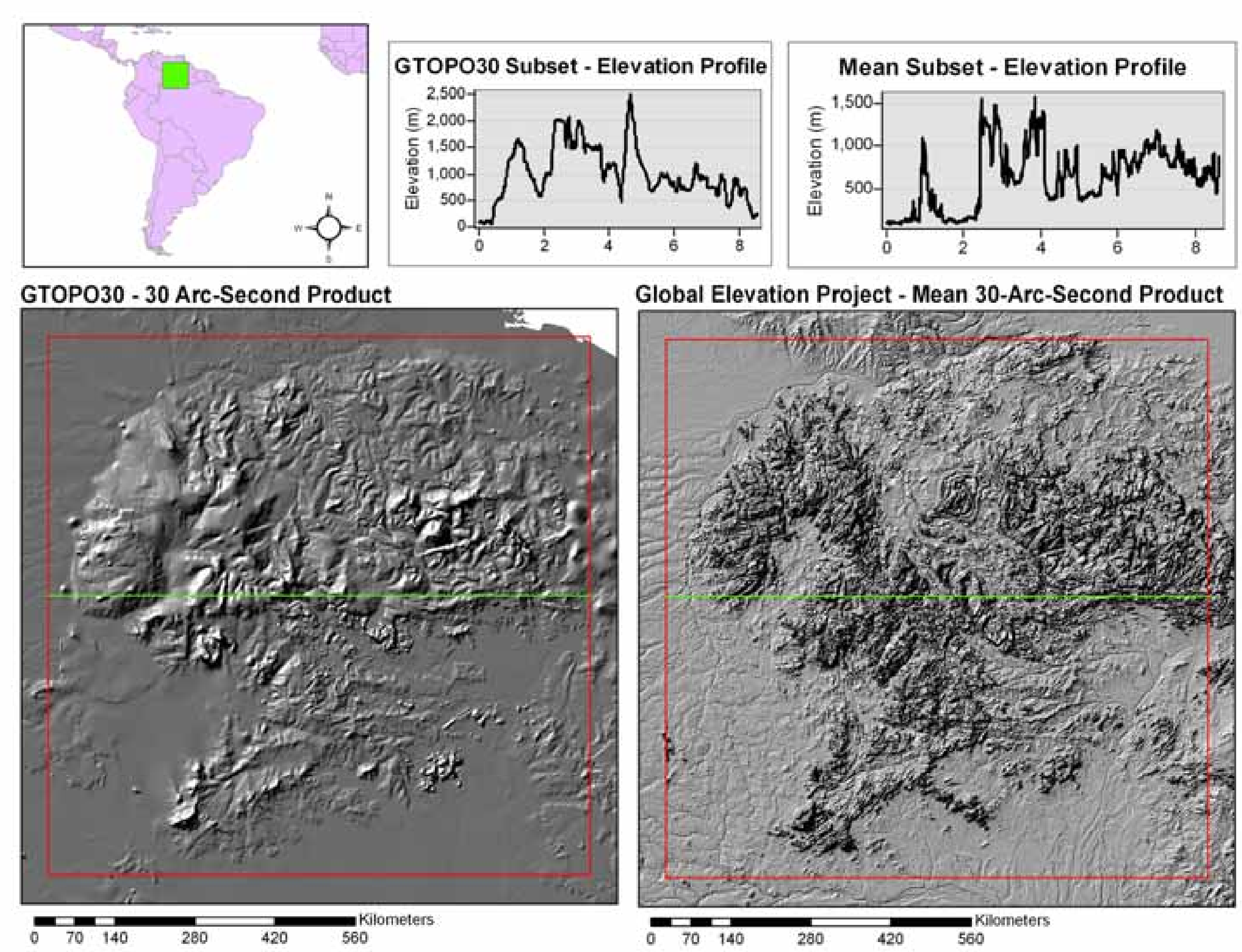
Global Multi-resolution Terrain Elevation Data 2010



South America



GTOPO30 and GMTED2010 Mean 30 Arc-Second Product Comparisons

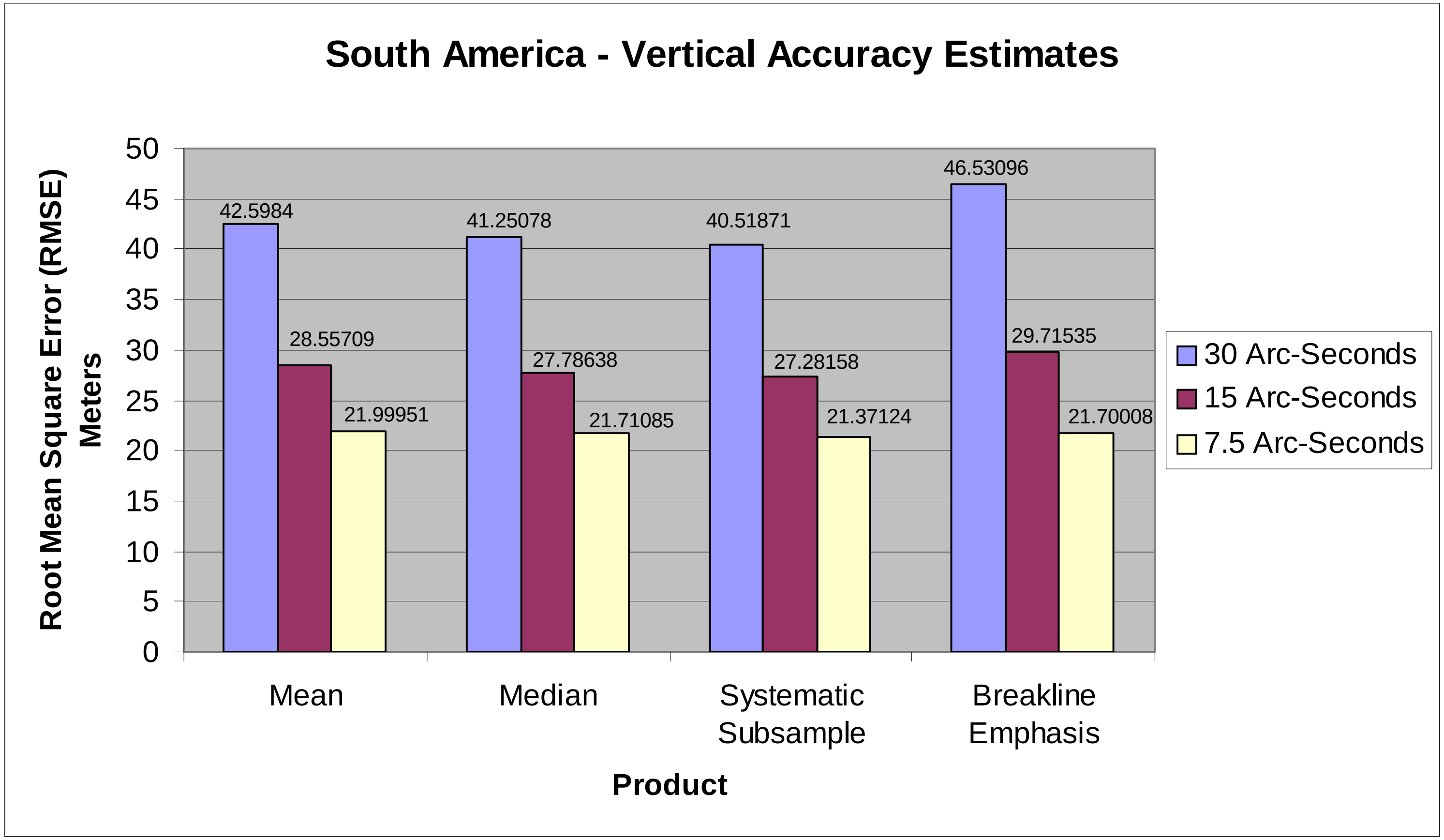


Validation and Evaluation Plans

- **Phase I – To be completed by March 31, 2010**
  - **Comparison of the original GTOPO30 with the new GMTED2010 30 arc-second mean product**
    - » **Image Subtraction (Pixel-Based Surface Difference Map)**
    - » **Elevation Profiles**
    - » **Cross-Validation Prediction**
    - » **Root Mean Square Error (RMSE)**
  - **Absolute vertical accuracy evaluation of the GMTED2010 with NGA geodetic and photogrammetric control points**
    - » **Elevation Profiles**
    - » **Cross-Validation Prediction**
    - » **RMSE**
- **Phase II – To be completed by October 31, 2010 (Based on the availability of a new global bare-earth ICESat point dataset)**
  - **Absolute vertical accuracy assessment of GMTED2010 with ICESat laser altimeter data**
    - » **Elevation Profiles**
    - » **RMSE**
- **Full Dataset Documentation**

Preliminary South America Validation

- **Comparison of GMTED2010 with the NGA photogrammetric control points**



South America– Vertical Accuracy Estimates

Conclusions

- **Upcoming Schedule:**
  - **GMTED2010 – Completed, March 31, 2010**
  - **GMTED2010 – Available by request after April 30, 2010 but public distribution online by June 30, 2010**
  - **GMTED2010 – Phase II validation with ICESat, October 31, 2010**

- **Summary and Benefits**
  - **Develop a fully global medium scale digital elevation model to replace and enhance GTOPO30.**
  - **Generate products at three separate resolutions (horizontal post spacings) of 30 arc-seconds (1-km), 15 arc-seconds (500-m), and 7.5 arc-seconds (250-m) from the best available data sources**
  - **Spatially referenced metadata will be produced for all datasets that constitute the global elevation model**
  - **Products will be made available to the public with no redistribution restrictions**

For More Information

USGS Topographic Sciences Home Page:
http://gisdata.usgs.net/topographic/

Email: daniels@usgs.gov
gesch@usgs.gov

Phone: 1-605-594-6148

*Activities planned in the next 6 months: GEO DA-09-03d: Global DEM **

- **The ICEDS-DEMqis service will be opened up to members of the CEOS, GEO and ISPRS communities**
- **ISPRS will release an evaluation of different cloud masking schemes for ALOS-PRISM and ASTER data which will be reported at….**
- **The ISPRS Commission IV Mid-Term Symposium will include sessions on Global DEM interoperability which will update the IGARSS09 results including an evaluation of the ASTER GDEM Version 1 summarising user inputs from the DEMqis wiki**
- **"Plan B" will be evaluated wrt either an alternative to ASTER GDEM as well as other possible sources for high latitude DEMs, particularly the ERS-tandem**
- **Further investigations into the best possible method for bathymmetric mapping will need to be made. Looking for a space agency to volunteer to support this (DLR?)**

Outstanding Issues (still) to resolve

- **How will more of the ASTER GDEM pixels be formally assessed? ICESAT-GLAS, ENVISAT-RA? Similar process also needed for SRTM and GDTEM2010.**
- **How will regions of poor quality data be identified in ASTER GDEM both in terms of missing data and areas affected by cloud cover? Need for continuing technical effort at identification**
- **How will these "voids" in the ASTER GDEM be filled? How best to engage CEOS-GEOSS space agency partners to contribute height pixels to a free and unrestricted global dataset at 30m? Need a space agency to take ownership of the final Global DEM creation**
- **How can we ensure that the ASTER GDEM receives the same intensive worldwide effort for validation that SRTM received? Need an agency (e.g. USGS) to provide resources to collate a large-scale validation exercise for ASTER GDEM V2 in association with the ASTER Science Team.**

Outstanding Issues (still) to resolve

- **How do we ensure that there is a similar level of effort for producing global bathymmetric data over continental shelves?**
  - **NOAA-NGDC are engaged in mapping extensive areas around the US coastline. USGS have demonstrated the fusion of such bathymetric and land DEMs**
  - **However, most other such bathymmetric data sources are extremely expensive (e.g. UKHO) and subject to © restrictions. How can agencies such as UKHO be persuaded that it is in their best interests to contribute? Space agencies to provide alternative source?**
  - **How does GEO persuade the oceanographic community that it is in their best interests to donate such proprietary data for the 9 SBAs agreed by the GEOSS ministers, especially that of natural disasters and hazards? Space agencies provide alternative**
  - **Or would it be more sensible for CEOS member agencies to consider space-based lidar depth sounding missions which also double up as vegetation canopy profiling system (e.g. NASA ICESAT-II), albeit the timescales here are late 2010s/early 2020s ESA have a mission study ITT at present. Recommendation needed to encourage interest by space agencies in developing spaceborne measurement systems for continental shelf bathymmetry as it is clear that existing organisations are not interested**

Follow-up on agreed CEOS Plenary recommendation

- **What steps are all space agencies taking to ensure their spaceborne DEM datasets are being made available to contribute to the agreed common goal? We have introduced this concept into WGCV Plenary BUT several organisations (JAXA, ISRO, SPOT Image) do not participate in WGCV plenaries**
- **In particular, what are DLR, SPOT Image, JAXA and ISRO doing to provide necessary DEM data? Request that at the CEOS Plenary, these space agencies are requested to provide an update either in writing or in the agency/institure report?**
- **Which space agency/agencies is/are volunteering to support the creation of this global 30m DEM?**
- **Which space agency/agencies is/are volunteering to support the validation of this global 30m DEM?**

Recommendation to CEOS Plenary

- **CEOS should encourage a space agency to take leadership of an evaluation of different spaceborne methods for acquiring 30m gridded bathymmetric measurements**
- **Bathymmetry is part of the Global DEM and extremely important for tsunami prediction (i.e. Disasters SBA). It is not currently represented in oceanographic organisations such as GEBCO that are mainly concerned about deep water low resolution (>>1km)**
- **Request that CEOS agencies to supply data (e.g. high resolution multispectral, very high resolution SAR (TSX, Cosmo-SkyMEd, Radarsat-2, NASA-NOAA SHOALS) that could be employed to evaluate different approaches for mapping continental shelves**