# *CEOS WGCV#25 Report: Terrain mapping sub-group (TMSG)*


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**HRSC CoI (ESA Mars Express)**

# 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.**
- **What is the relevance of TMSG to GEOSS 10-year Implementation Plan?**
  - **Six out of the Nine Societal Benefit areas state an urgent need for global topographic information of the highest possible quality, reliability and in some cases resolution (particularly disasters).**
  - **It could be argued that the other 3 areas (weather, biodiversity, ecosystems) have not yet thought through about the role of topography**
  - **Most of the mapping requirements are NOT discussed but need to be included**

# *Overview*

- **Programmatic status**
  - **2005/6 activities**
  - **Future activities**
- **Scientific status of DEM production & validation activities**
  - **Overview (coarse and medium-scale production and validation)**
  - **ESA merged DEM (GETASSE30) for MERIS/AATSR land processing**
  - **ICESAT-GLAS**
  - **ASTER**
  - **C- and X-SRTM (IfSAR)**
  - **SPOT5**
  - **DUDES**
- **Programmatic status and plans**
  - **WGISS/WGCV WTF**
  - **WGISS/ICEDS prototype**
- **Recommendations from CEOS WGCV #24 which were agreed by CEOS Plenary #18 (London, 11/05) : status**

# Programmatic Status - 2005/6 activities

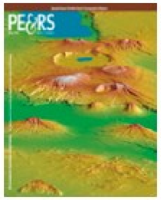
- Sub-group meeting held on 2 December 2005 at ESRIN immediately following the FRINGE 2006 (technical material to follow)
- Special Issue of *Photogrammetric Engineering and Remote Sensing* on "The Shuttle Radar Topography Mission – Data Validation and Applications". Edited by Dean Gesch (EDC), JPM (UCL), Tom Farr (JPL) in March 2006.
- SRTM conference (of the same title) was held at the USGS National Mapping Centre, Reston, Virginia, USA from 14-16 June 2005. Workshop co-sponsored by USGS, NASA, NGA, ISPRS and CEOS-WGCV. 183 attendees from 18 countries. Extremely positive feedback from attendees.
- Conference web-site includes final programme, all abstracts and presentations http://edc.usgs.gov/conferences/SRTM/
- News article in AGU EOS Transactions on final SRTM V2 release and above activities (see later)
- No progress on obtaining 30m SRTM-DEMs for all TMSG test-sites for WTF.
- Significant progress on EO Data Portal - CEOS-WGISS ICEDS
  - Addition of SRTM land-water mask and global C-SAR amplitude masks
  - Addition of inter-comparison pull-down menu facilities

# Special Issue on SRTM Validation



**PE&RS March 2006**

VOLUME 72, NUMBER 3
PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING
JOURNAL OF THE AMERICAN SOCIETY FOR PHOTOGRAMMETRY AND REMOTE SENSING




**The Shuttle Radar Topography Mission (SRTM), flown aboard Space Shuttle,** Endeavour in February 2000, acquired elevation measurements for nearly all of Earth's landmass between 60°N and 56°S latitudes. SRTM data were used to generate this view of the Crater Highlands along the East African Rift in Tanzania. Landforms are depicted with colored height and shaded relief, using a vertical exaggeration of 2X and a southwestwardly look direction.

Lake Eyasi is depicted in blue at the top of the image, and a smaller lake occurs in Ngorongoro Crater. Near the image center, elevations peak at 3648 meters at Mount Loolmalasin, about 2800 meters above the adjacent rift valley. The view continues forward to Mount Longido and the Meto Hills.

Tectonics, volcanism, landslides, erosion and deposition - and their interactions - are all very evident in this view. For many areas of the world SRTM data provide the fi rst detailed three-dimensional observation of landforms at regional scales.

SRTM data are available from the United States Geological Survey at http://edc.usgs.gov/products/elevation.html.

Additional information about the SRTM project is available at http://www.jpl.nasa.gov/srtm/.

This image and an extended caption are available at http://photojournal.jpl.nasa.gov/catalog/PIA06669.
Image by Robert Crippen, NASA/JPL.

## Foreword



## Highlight Article



## Columns & Updates

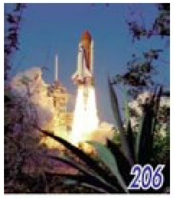


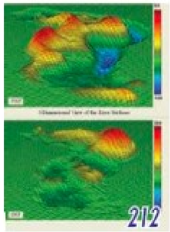
## Announcements



## Departments








American Society for Photogrammetry and Remote Sensing 05/09/2006 10:19 AM

**PE&RS March 2006**

VOLUME 72, NUMBER 3
PHOTOGRAMMETRIC ENGINEERING & REMOTE SENSING
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## Peer-Reviewed Articles (Click the linked titles to see the full abstract)



Data editing requirements, procedures and assessments carried out by the National Geospatial-Intelligence Agency to produce fi nished SRTM DTED® and related products disseminated to the U.S. Government and the public at large.



A detailed description documenting the results of SRTM validation for absolute geolocation error, absolute height error, and relative height error.



Validation of SRTM data products and assessment of possible improvements by their combination.



Calculated terrain parameters computed from the SRTM mission generally correlate with those computed from the National Elevation Data Set, but systematic differences refl ect the collection methods and true resolution of the data.



An evaluation of SRTM C-band DEMs in various terrain by comparison with coincident ground and canopy top elevation data obtained from the Laser Vegetation Imaging Scanner.



Validation of SRTM C-band DEMs Using Ice, Cloud, and Land Elevation Satellite (ICESat) data.



Production of a landscape scale map of mean tree height using SRTM data, and deriving height and biomass relationships based on field data.



Analyzing SRTM water surface elevation data to assess the capacity of interferometric radar for future water surface missions.



SRTM models provide an opportunity to scan areas not yet surveyed archaeologically on a supra-regional scale.

Top Home

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# Outreach to the Geophysics Community

Eos, Vol. 87, No. 18, 2 May 2006

## NEWS

### New Products From the Shuttle Radar Topography Mission

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New data products with broad applicability to the Earth sciences are now available from the Shuttle Radar Topography Mission (SRTM). SRTM, a joint project of the National Geospatial-Intelligence Agency (NGA) and NASA, flew aboard the Space Shuttle Endeavour on an 11-day mission in February 2000 with the goal of collecting a near-global data set of high-resolution elevation data [*Farr and Kobrick*, 2000]. Data from the mission have been available to researchers for several years, but newly available products offer enhanced usability and applicability.

Final products include elevation data resulting from a substantial editing effort by the NGA in which water bodies and coastlines were well defined and data artifacts known as spikes and wells (single pixel errors) were removed. This second version of the SRTM data set, also referred to as 'finished' data, represents a significant improvement over earlier versions that had nonflat water bodies, poorly defined coastlines, and numerous noise artifacts. The edited data are available at a one-arc-second resolution (approximately 30 meters) for the United States and its territories, and at a three-arc-second resolution (approximately 90 meters) for non-U.S. areas.

The data can be freely downloaded in 1° by 1° tiles in a simple binary raster format (see ftp://e0srp01u.ecs.nasa.gov/srtm/version2/). The data may also be acquired by purchasing a DVD in several different formats for a nominal cost (see http://eros.usgs.gov/products/elevation.html), or by downloading user-defined areas from the U.S. Geological Survey's (USGS) seamless data distribution system (see http://seamless.usgs.gov/).

In addition to the edited elevation data, the vector format water body and coastline mask derived by NGA during the editing process is also available. The SRTM Water Body Data (SWBD) is a 30-meter resolution near-global map of oceans and inland water bodies derived from radar data and Landsat data [*Slater et al.*, 2006]. The SWBD is available for download and on DVD at the same sources as the SRTM elevation data.

SRTM30, a near-global elevation model at a resolution of 30 arc-seconds (approximately one kilometer), is another SRTM data product that has been recently upgraded. SRTM30 has been enhanced by incorporating the edited version of SRTM elevation data in combination with the widely used USGS GTOPO30 global elevation model [*Gesch et al.*, 1999]. As with the other new SRTM data products, SRTM30 can be freely downloaded (see ftp://e0srp01u.ecs.nasa.gov/srtm/version2/SRTM30/).

In addition to the updated SRTM data products, new documentation and recent research results are also available, serving as helpful resources for the SRTM data user community. The Jet Propulsion Laboratory (Pasadena, Calif.) has released a detailed report [*Rodriguez et al.*, 2005] on the accuracy and quality of SRTM data (see http://www2.jpl.nasa.gov/srtm/SRTM_D31639.pdf).

Results from many recent investigations using SRTM data were presented at an SRTM data validation and applications workshop held in Reston, Va., in June 2005. Most of the 60 oral and poster presentations given at the workshop are available for viewing and/or

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download at the workshop Web site (http://edc.usgs.gov/conferences/SRTM/). The workshop covered a wide variety of topics, including horizontal and vertical accuracy of SRTM data, comparison of SRTM elevation data with other types of elevation data, comparison of Digital Elevation Models (DEMs) derived from SRTM C-band radar data with those from X-band radar data in terms of accuracy and spatial resolution, and applications of SRTM data and derived products. Several papers presented at the workshop have also been published in a special SRTM issue of *Photogrammetric Engineering & Remote Sensing* [*Gesch et al.*, 2006] (see http://www.asprs.org/publications/pers/2006journal/march/index.html).

#### *References*


Farr, T. G., and M. Kobrick (2000), Shuttle Radar Topography Mission produces a wealth of data, *Eos Trans. AGU, 81*(48), 583, 585.

Gesch, D., K. Verdin, and S. Greenlee (1999), New land surface digital elevation model covers the Earth, *Eos Trans. AGU, 80*(6), 69–70.

Gesch, D. B., J.-P. Muller, and T. G. Farr (2006), Foreword: The Shuttle Radar Topography Mission—Data validation and applications, *Photogramm. Eng. Remote Sens.*, *72*, 233–235.

Rodriguez, E., C. S. Morris, J. E. Belz, E. C. Chapin, J. M. Martin, W. Daffer, and S. Hensley (2005), An assessment of the SRTM topographic products, *Tech. Rep. JPL D-31639*, 143 pp., Jet Propul. Lab., Pasadena, Calif.

Slater, J. A., G. Garvey, C. Johnston, J. Haase, B. Heady, G. Kroenung, and J. Little (2006), The SRTM data "finishing" process and products, *Photogramm. Eng. Remote Sens.*, *72*, 237–247.


—Dean Gesch, U.S. Geological Survey, Sioux Falls, S.D.; E-mail: gesch@usgs.gov; Tom Farr, Jet Propulsion Laboratory, Pasadena, Calif.; James Slater, National Geospatial-Intelligence Agency, Reston, Va.; Jan-Peter Muller, University College London, London, U.K.; and Sally Cook, U.S. Geological Survey, Reston, Va.

# Programmatic Status - future activities

- TMSG working meeting planned for ISPRS Commission IV Symposium (Goa, India, September 2006)
- CEOS-WGISS EO Data Portal project currently working towards
  - Addition of edited 3” SRTM DEMs (both WMS and WCS)
  - Addition of NASA-GSFC-cascaded ICESAT-GLAS profiles
  - Addition of Landsat 5 mosaic (Dr Nevin Bryant, JPL)
  - Extraction of GCP WFS-WCS database (subject to funding) for GRID-enabled automated geocoding and orthocorrection
- In concert with ISPRS, plan to revisit international standards for specification of orbital elements
- In concert with the Global Mapping project, plan to co-ordinate the validation of 1:1M scale digital mapping using satellite data
- In concert with the relevant national and international bodies, plan to make a push on the creation of an OGC-compliant global Ground Control Points from global mosaiced Landsat and SPOT5 datasets

# Status of spaceborne DEMs - Coarse resolution production and validation

- **USGS-EDC-GTOPO30 and NOAA-NGDC/CEOS-GLOBE1 (30”≈1km) from Best Available Data (primarily US-NGA DTED1/0 and US-NGA-DCW) released in the mid-1990s. Detailed QA performed by NASA EOS-DEM Science WG. GTOPO30 operationally used for NASA-EOS processing. New v2 released in 2004. NOT VALIDATED.**
- **ERS-derived Radar Altimetry Corrected Elevation (ACE) at 30” (≈1km) developed under ESA funding by P. Berry (de Montfort University). NOT VALIDATED.**
- **SRTM30 - merger of unedited SRTM (averaged from 1->3->30”) with GTOPO30. NOT VALIDATED.**
- **GETASSE30 - ESA-ESTEC (M. Bouvet) : merger of ACE-SRTM30-EGM96. Used operationally for MERIS data processing. See later for details. NOT VALIDATED.**
- **ICESAT: major problems with 2 out of 3 lidars for global data acquisition. Data acquisition limited to 1-2 month acquisitions, 3 times/year. However, significant improvement in polar landmass heights for Greenland and Antarctica and substantial new data on vegetation/biomass. Validation started (Special Issue of Geophysical Research Letters, September 2005)**

# Status of spaceborne DEMs - Medium Resolution (30-90m) production

- ERS-tandem IfSAR (raw data acquired primarily in 1995/6) global coverage. Few national DEMs produced (UK-LANDMAP, Switzerland-SARMAP, Italy-Telespazio). Limited by atmospheric WV refraction effects although PS solution feasible if sufficient scenes are available (mostly Europe). No dedicated DEM processing project. Limited validation.
- SRTM (X-: DLR/ASI; C- NASA/DoD). Near global coverage (80% of landmass). Extensive validation performed and current status reported in AGU-EOS 2 May 06.
- ASTER. Stereo coverage based on individual requests and limited processing duty cycle. After 5 years, most of the Earth's surface is covered in cloud-free stereo acquisitions but limited processing capabilities at EDC (2-3 DEMs/day) have restricted available relative DEMs. Increasing number of low-cost ASTER-DEM commercial software. Cost (COFUS) of ASTER level 1 data still issue for large-scale systematic DEM production. JPM is negotiating TMSG access to ASTER-DSMs for test sites.
- SPOT-5 (and SPOT1-4). IGN/SPOT working on global commercial 10m DEM but no report since 6/04. JPM is negotiateng access for TMSG to SPOT5-DSMs for TMSG test site areas.
- ALOS (PRISM). GSI plan to contribute test sites in Asia. JPM has tried to negotiate access for TMSG to PRISM-DSMs. Hopes that WGCV-WGISS Plenary discussions can move this (stalled) process forward.

# Status of spaceborne DEMs - Medium Resolution (30-90m) validation

- ERS-tandem IfSAR - validation results in public domain limited to UK-LANDMAP project http://www.landmap.ac.uk and TMSG web-site presentations
- SRTM (X-: DLR/ASI; C- NASA/DoD). Consensus that SRTM-DEMs from X- and C- meet DTED-2 specification for height (Zrms≤8m) dependent on radar penetration of vegetation/built settlements. See more details later
- ASTER. USGS tests indicate that RMSExyz<<30m with 9≤RMSEz≤20m depending on date of acquisition, accuracy of orbital modelling and quality of GCPs. See more details later
- ICESAT: For flat, non-vegetated areas intercomparison with (6-foot footprint) airborne lidar DEM shows: 0.1±0.22m. See more details later.

# TMSG Update

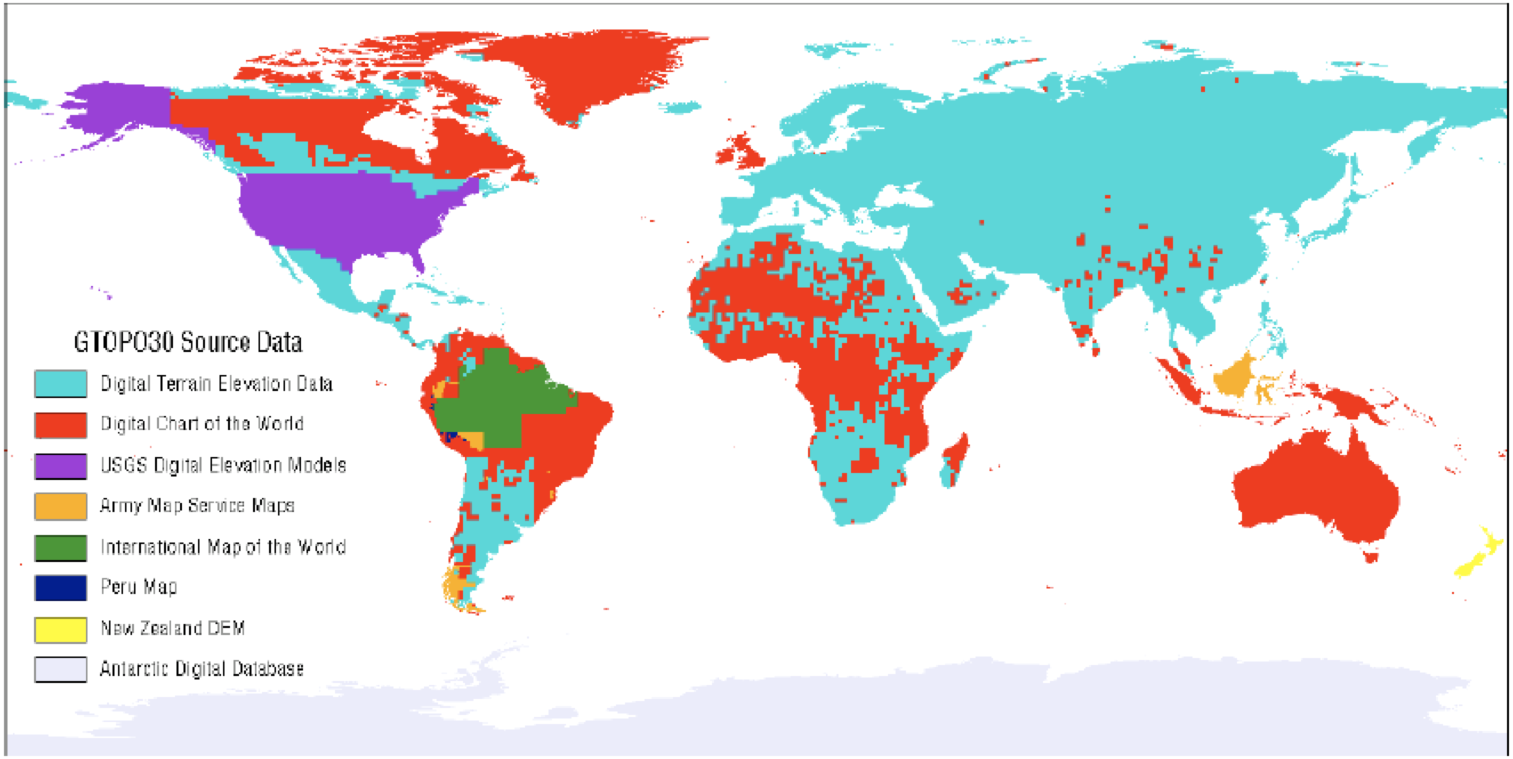
- TMSG working meeting held on the afternoon of 2/12/05 at ESA-ESRIN (immediately after FRINGE05) which discussed
  - TMSG test-sites: expansion to include sites in Africa, Asia and South America
  - Known issues web-site : planning issues
  - Best practice document revisited
  - Recent progress on spaceborne DEMs (SPOT5, X+ERS-tandem of Italy/Switzerland)
  - Quality assessment of GETASSE30 DEM employed by ESA for all systematic EO processing
  - Global GCP extraction from EO high resolution datasets (e.g. Landsat, ERS-IQL, SPOT, SRTM-amplitude)

# *ESA merged DEM (GETASSE30) for MERIS/AATSR land processing*

**Information courtesy of**

**Marc Bouvet, ESA-ESTEC**

# GTOPO30 used by NASA EOS processing chain - source DEMs

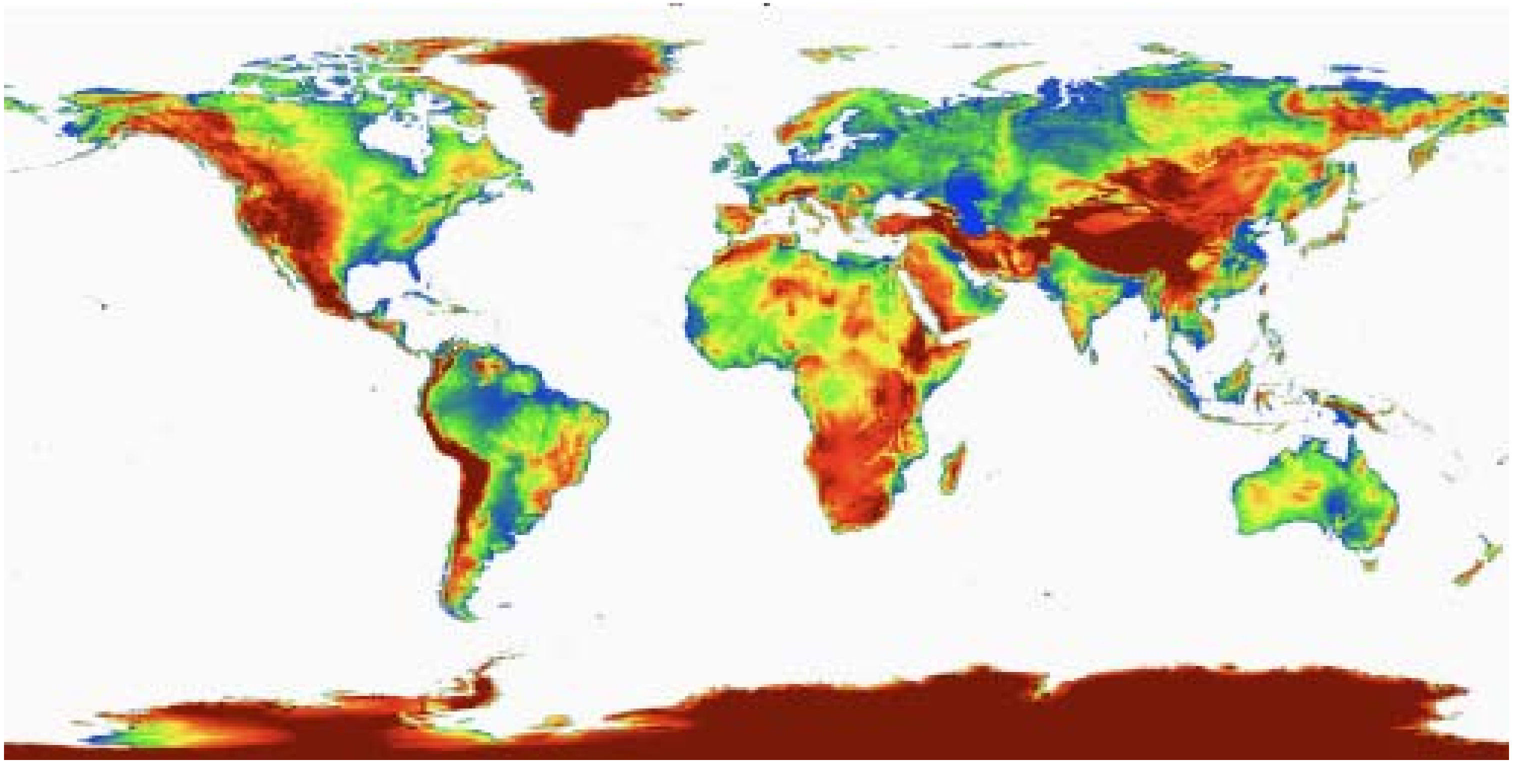


# SRTM component of Unedited SRTM30

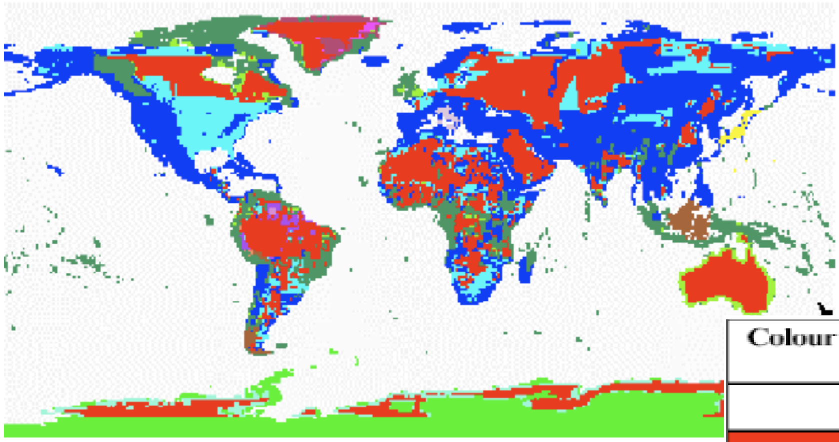
Complete 30” (≈1km) DEM can be downloaded from

ftp://edcftp.cr.usgs.gov/pub/data/srtm/SRTM30/SRTM30.tar

# Modified GTOPO30 using ERS Radar Altimetry Corrected Elevation (ACE) used by ESA for processing chain

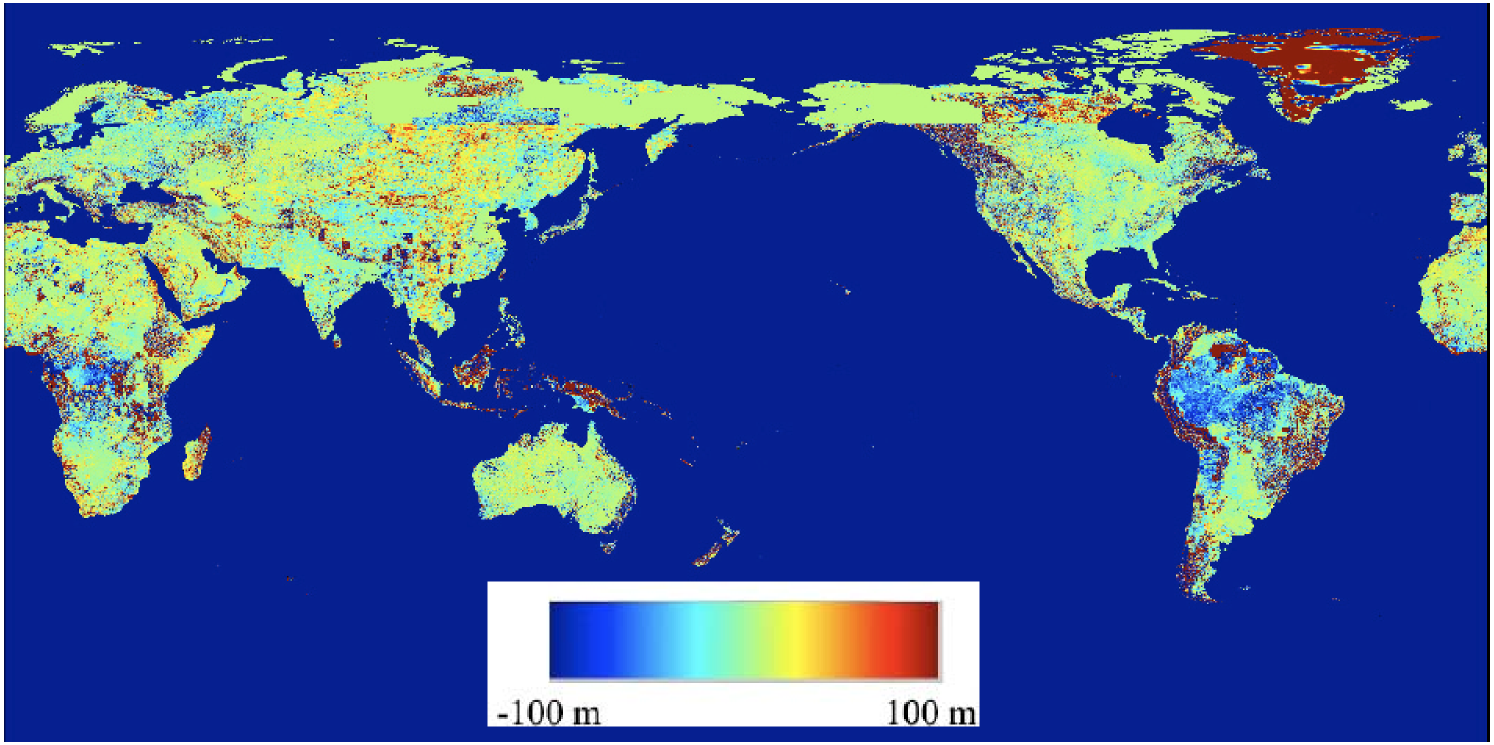


# ACE source regions




| Colour | No. Of 1° Tiles | Data Source |
|---|---|---|
| | 39375 | Ocean |
| | 7270 | Altimeter Derived DEM |
| | 7079 | DTED non-shifted |
| | 2340 | DTED shifted |
| | 2992 | DCW developed by DMA, converted to 30" grid by USGS, non-shifted |
| | 415 | DCW developed by DMA, converted to 30" grid by USGS, shifted |
| | 73 | DEM of Japan, from GSI non-shifted |
| | 48 | DEM for Italy, at high resolution from SGN, converted to 30" grid by NGDC |
| | 61 | DEM of New Zealand at 500m gridded by LCR, reprojected to 30" by USGS non-shifted |
| | 208 | DEM of Greenland by Zwally (and others)/NSIDC, converted to 30" by JPL non-shifted |
| | 39 | DEM of Greenland by Zwally (and others)/NSIDC, converted to 30" by JPL shifted |
| | 231 | Army Map Service 1:1, 000, 000-scale maps, digitized by GSI, gridded by USGS non-shifted |
| | 2 | Army Map Service 1:1, 000, 000-scale maps, digitized by GSI, gridded by USGS shifted |
| | 95 | International Map of the World 1:1, 000, 000-scale maps for part of Brazil adapted by GSI, gridded by USGS non-shifted |
| | 11 | International Map of the World 1:1, 000, 000-scale maps for part of Brazil adapted by GSI, gridded by USGS shifted |
| | 5 | Peru 1:1, 000, 000-scale maps for part of Peru by the Ministerio de Guerra of Peru, adapted by GSI, gridded by USGS non-shifted |
| | 4556 | SCAR Antarctic Digital Database, converted by USGS, repaired by NGDC non-shifted |

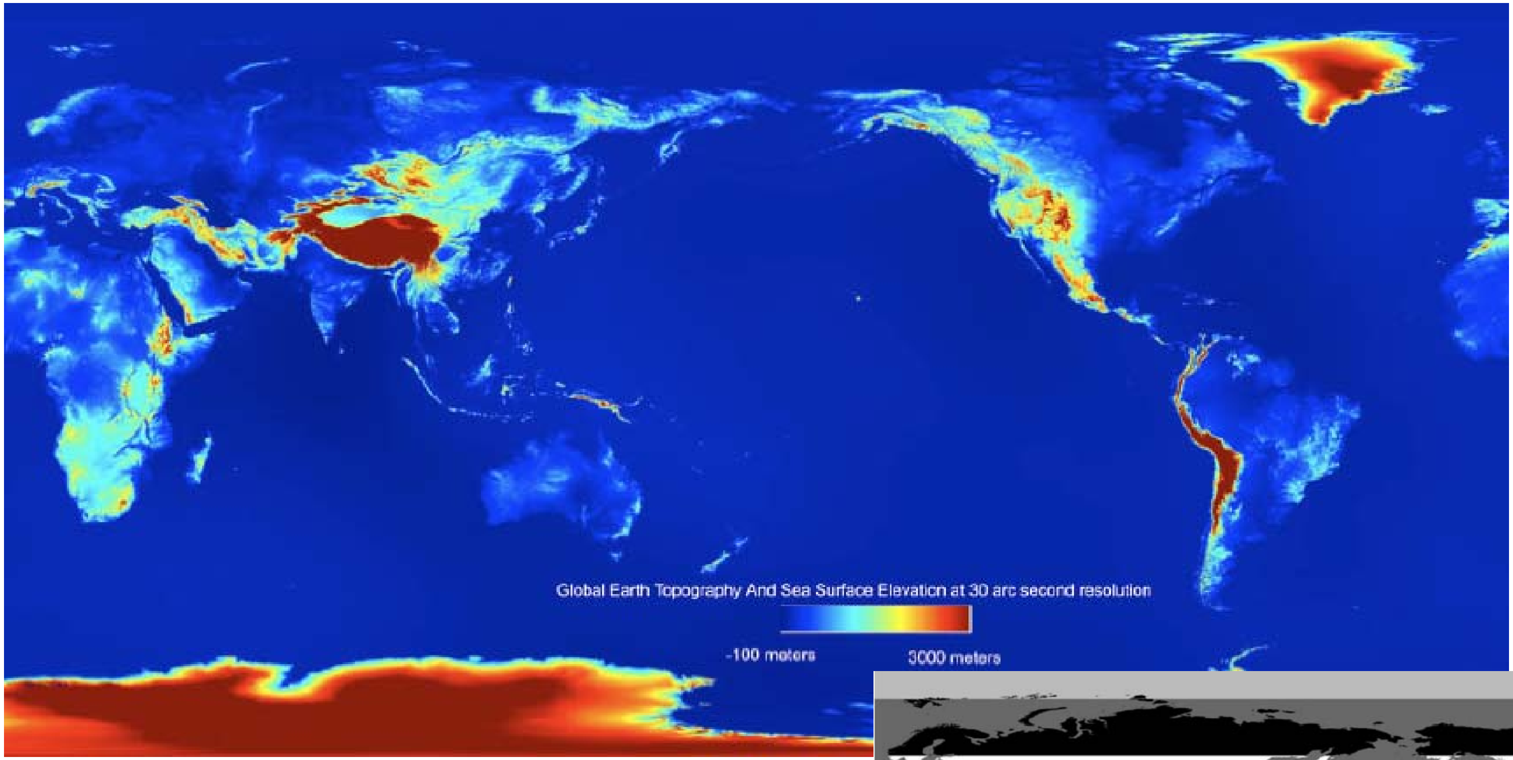
# *ACE-SRTM30 height differences*

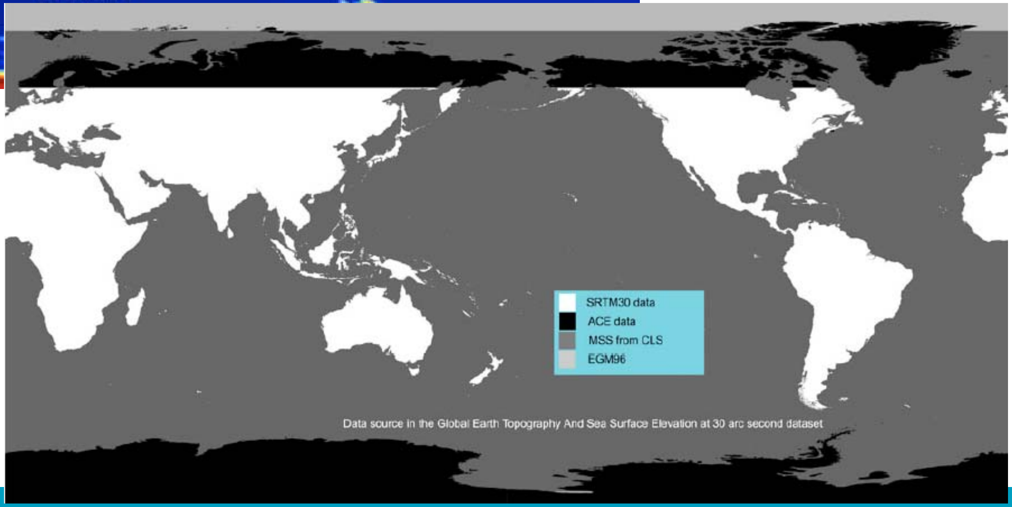



N.B. There are a number of noticeable features here:

- ACE is lower than SRTM30 for tropical forested areas, probably because the RA penetrates through the dense vegetated canopy
- There is a line at 60ºN associated with the changeover from SRTM-sourced to DTED-sourced regions
- ACE is considerably higher (≤300m) than the best available DEM from the Danish Geophysical Institute

# GETASSE30 DEM used for MERIS land surface and atmospheric data processing



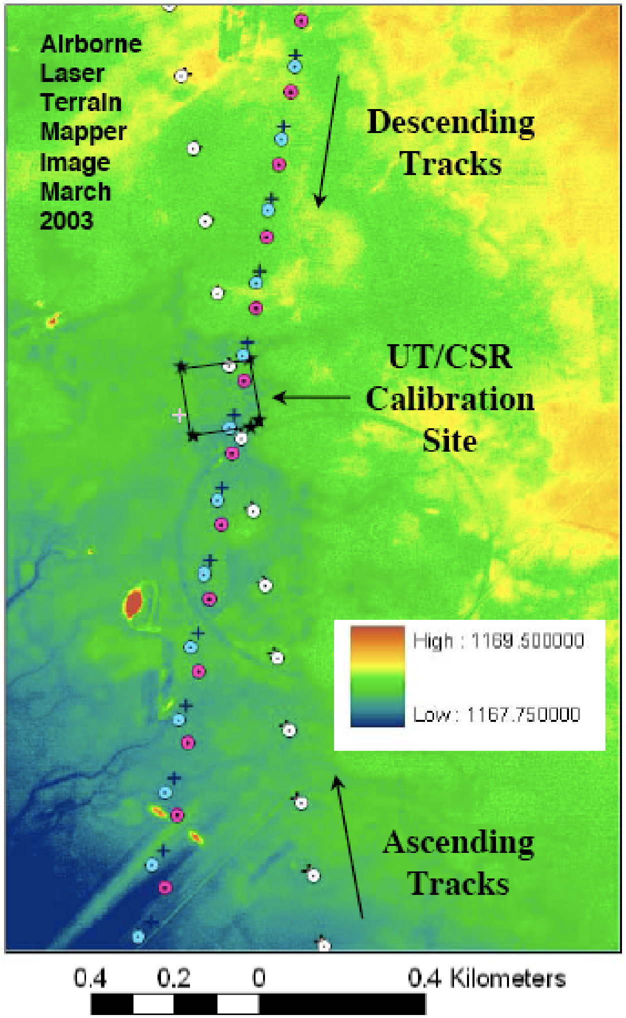
# Future requirements for validation

- All global-scale products from NASA and ESA instruments are orthorectified using DIFFERENT DEMs with differences of up to several hundred metres
- The GTOPO30 and SRTM3 DEMs have been extensively validated and this validation documented
- However, no such validation has yet been performed of SRTM30, especially of the latest edited version of the DEM
- No validations have yet been performed of GETASSE30v2 which includes the edited SRTM30 which has many artifacts
- There are no current "Known Issues" documentation of what impact the use of GTOPO30 or GETASSE30 artifacts has on derived global-scale land surface products
- There is an urgent need for NASA and ESA to validate these new DEMs and ensure interoperability between global-scale products in high relief areas (such as Greenland) as well as tropical areas to ensure that when data products may be merged in future, DEM artifacts will not dominate the signal

# *ICESAT-GLAS assessment*

**Thanks to Bob Schutz (UTA) and Dave Harding (NASA-GSFC)**

# White Sands Space Harbor (WSSH)

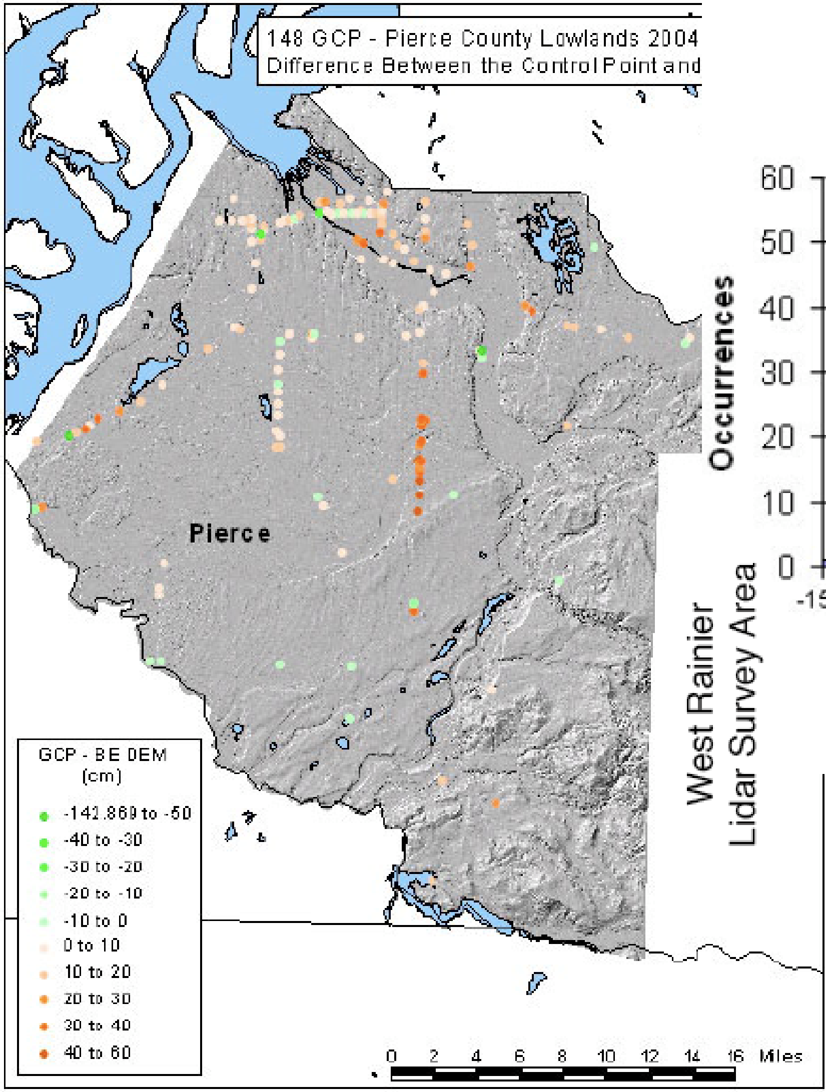


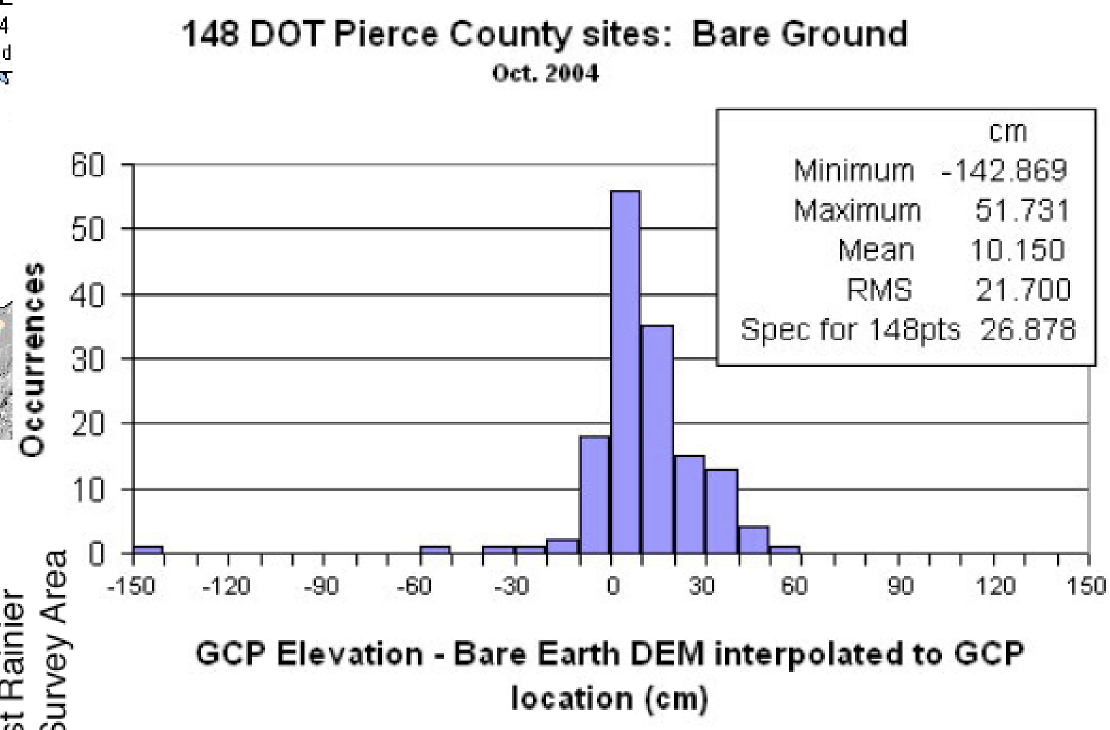

- WSSH area used for ICESat Cal/Val
- University of Texas Optech Airborne Laser Terrain Mapper used in March 2003 to create "lidar" refererence surface
- Area shown is 1.5 km x 2.5 km
- Elevation varies from 1169.5 m (red) to 1167.75 m (blue)
- No vegetation

# WSSH Elevation Comparisons

- Lidar - SRTM
  - Mean = - 37.8 cm, RMS = 182.1 cm (67,517 points)
- ICESat – Lidar (near nadir points, ~ 0.3° from nadir)
  - 2a: mean = - 4.3 cm, RMS = 12.2 cm
  - 3a: mean = -6.6 cm, RMS = 10.5 cm
- ICESat – SRTM
  - 2a: mean = - 25.1 cm, RMS = 171.9 cm
- Are SRTM differences caused by elevation change between the 2000 flight of SRTM and 2003-2004 measurements of ICESat?

# Western Pierce County Bald Earth DEM Validation Using 148 WA DOT Survey Points



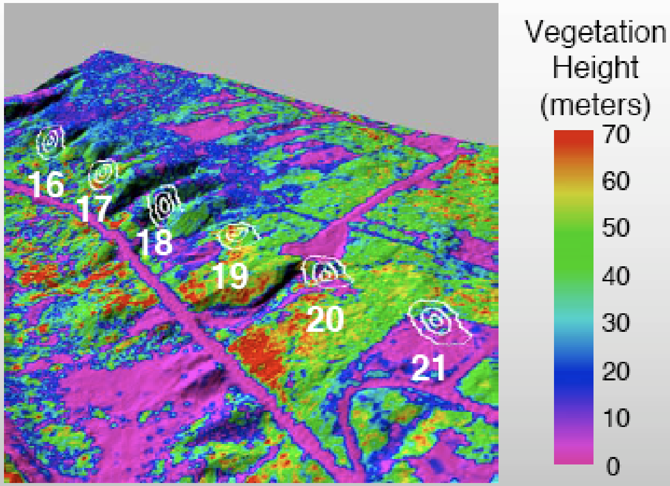

Flat, Non-vegetated Areas

Mean elevation difference = 10 cm

RMSE = 22 cm

(from D. Martinez, PSRC)

# Comparison to ICESat Received Echo Waveforms



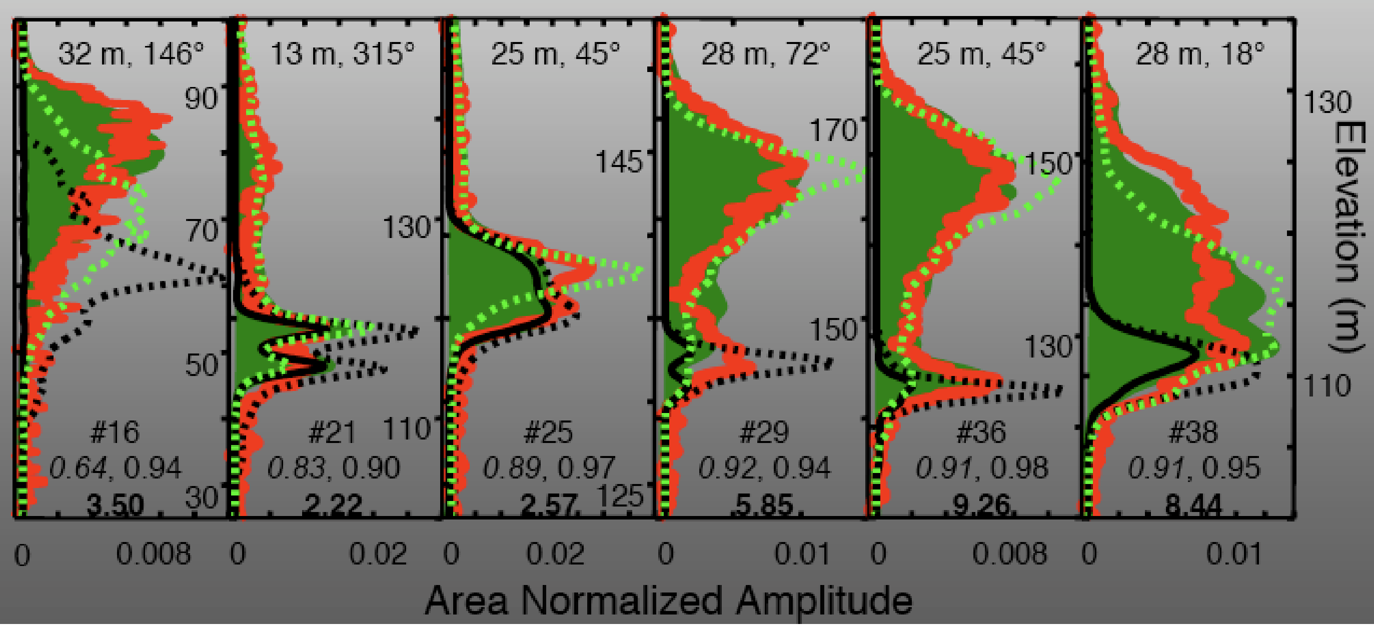

GLAS instrument model applied to TerraPoint airborne swath-mapping laser altimeter data.

Harding and Carabajal, GRL, 2005

**Received echo**

**Model at location of best match**

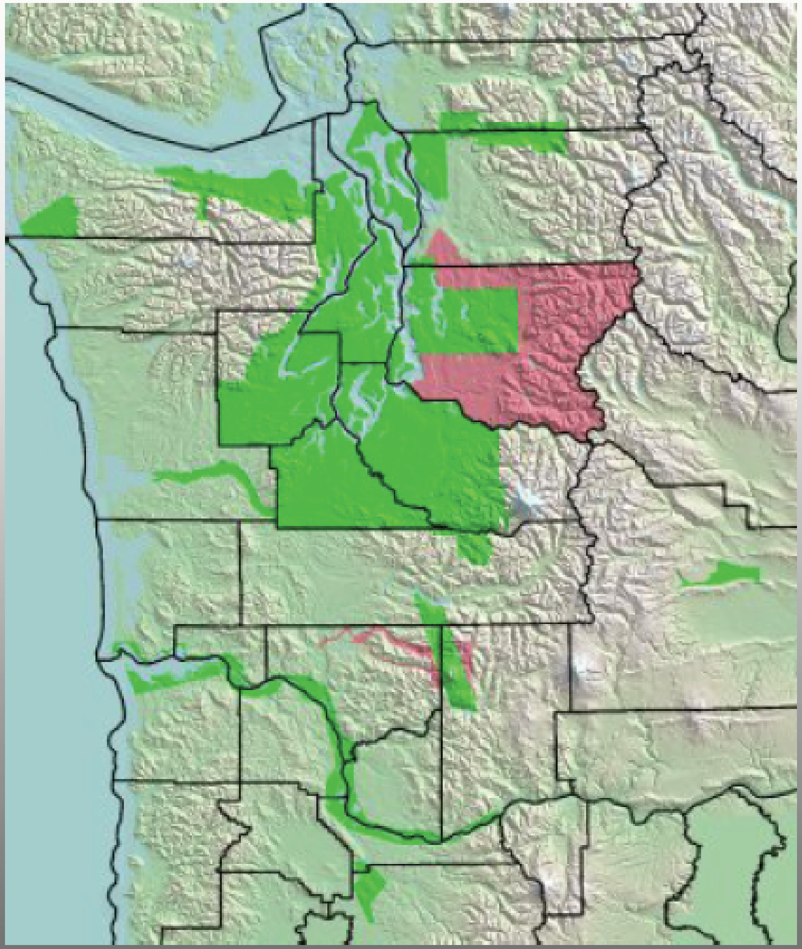
**Ground contribution**



# Future research with ICESAT

- Understand the relationship between lidar waveforms and tree canopy 3D architecture
- Understand radar penetration depths (from C, X and in future L-band interferometry) and relate these to lidar waveforms and 3D canp[y architecture
- NASA-GSFC plan to add all ICESAT-GLAS tracks to CEOS-ICEDS EO Data Portal (Status unknown)
- Exploit rich airborne lidar DSM/DTM (and in future airborne lidar waveform) for other spaceborne-derived DEMs in CEOS test site in Puget Sound (see next slide)

# Puget Sound Lidar Consortium (PSLC)



Puget Sound Lidar Consortium

Other public surveys (limited canopy data)

**Public-domain high-resolution topography**

- Airborne lidar swath mapping
- http://www.pugetsoundlidar.org
- http://core2.gsfc.nasa.gov/lidar/terrapoint

- **Federal-local multi-agency collaboration**
  - Local counties and municipalities
  - Regional transportation council
  - USGS & NASA
- **Contract with TerraPoint, LLC**
  - Competitively selected commercial vendor
  - 2000-05 Jan-March leaf-off data acquisition
  - ~15,000 sq km of Puget Lowland mapped
  - 1 pulse per sq m = 15 billion laser pulses
  - Up to 4 discrete returns per laser pulse
  - Return intensity for more recent mapping
  - Deliverables:

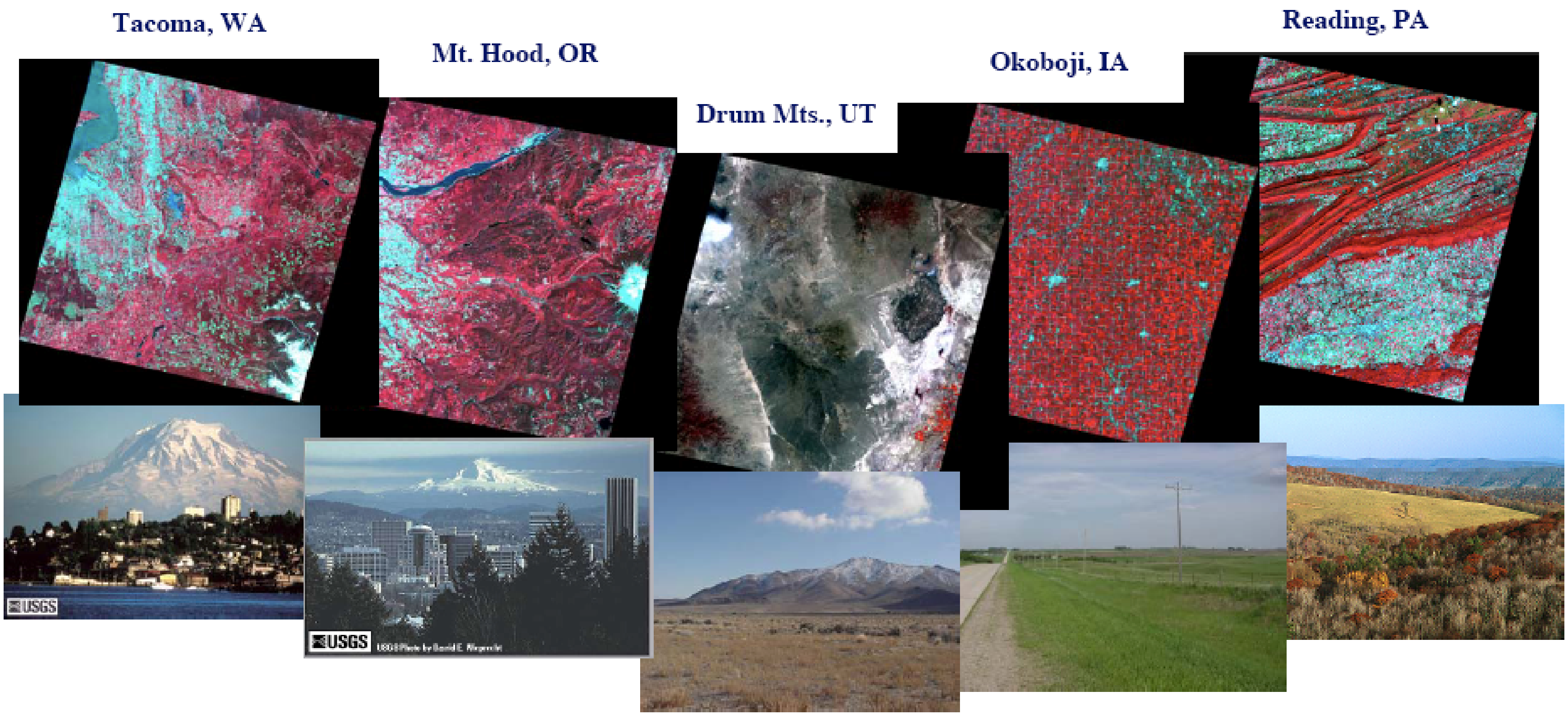
    classified point cloud (ground, canopy, buildings)

    highest surface and bald Earth DEMs (1.8 m grid)

# ASTER DEM status and issues

**Thanks to Bryan Bailey (USGS-EDC)**

# Study Site Selection and Characteristics



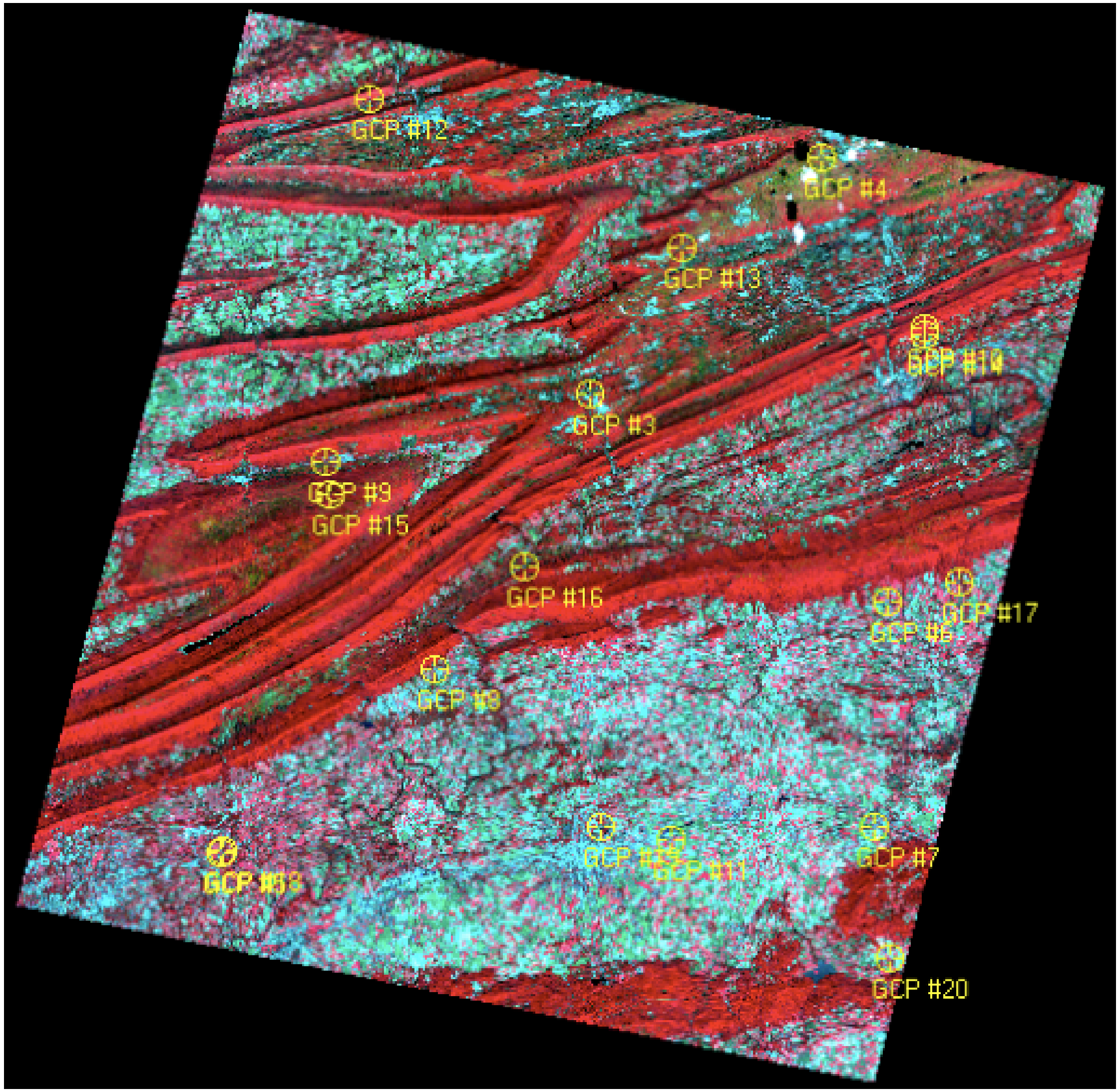

- Five sites selected
- Variable terrain
- Two ASTER scenes per site
- Early & recent dates
- Multiple pointing angles

USGS

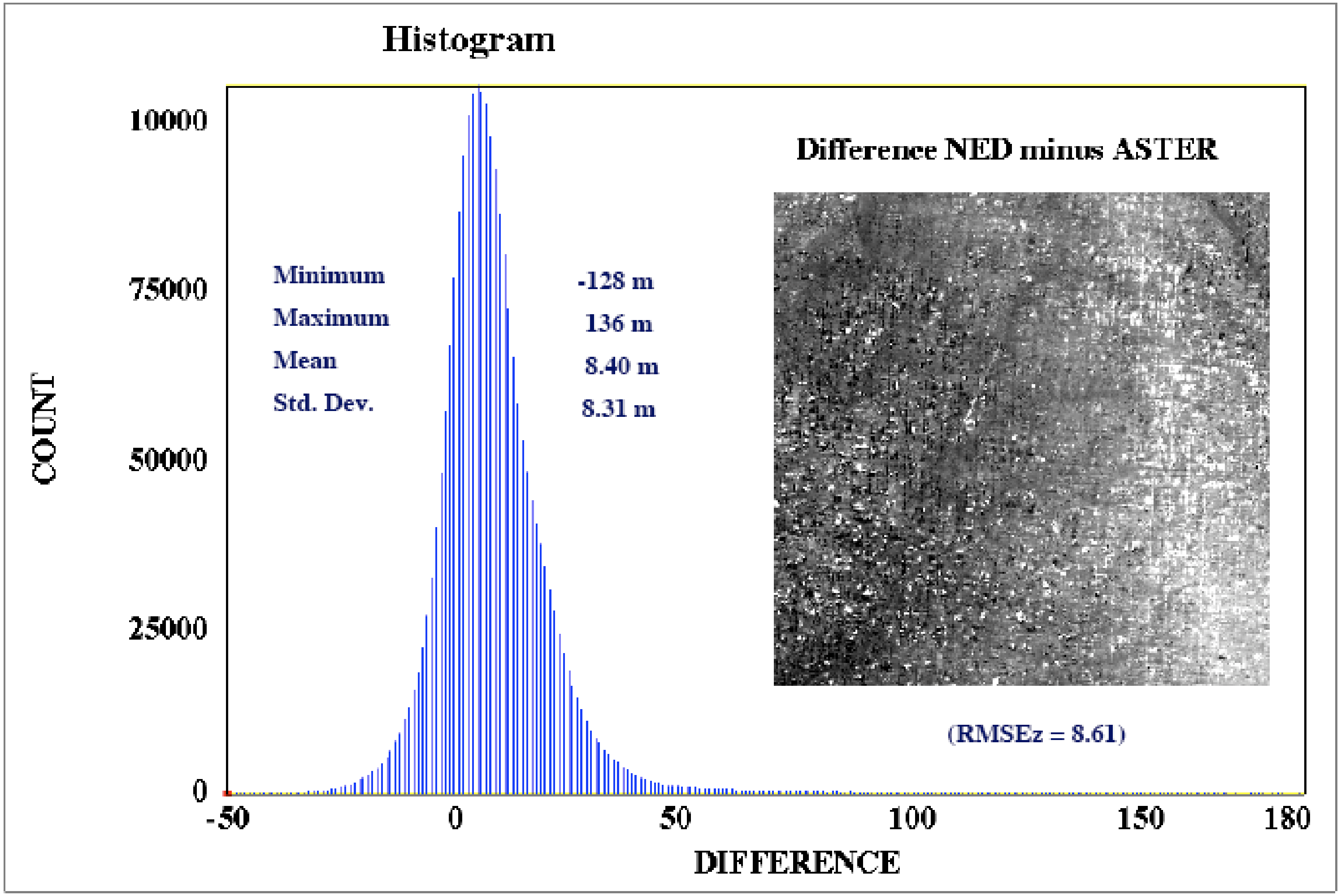
# General Methodology

- Generate DEM's from ASTER L1A data (30 m postings).
  - GDS and LP DAAC produced DEM's per our request.
  - We produced DEM's using SILCAST and AsterDTM software.
- Assess horizontal accuracies.
  - Used USGS orthophoto quads and topo maps to determine x-y offsets.
  - Calculate statistics to determine RMSEx and RMSEy values.
- Assess vertical accuracies.
  - Used USGS National Elevation Data (NED) as primary reference data.
  - Produced NED - ASTER DEM "difference" images.
  - Calculated means and standard deviations on all difference images.
  - Calculated RMSEz values from 25 randomly selected and evenly distributed points within each difference image.

# Typical Ground Control Point Distribution



# Image Statistics Derived from Difference Image



# Vertical Accuracies by DEM Generation System

| Software System | | X | Y | Z | | | | Z | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RMSEx | RMSEy | Mean | Std Dev | RMSEz | | Mean | Std Dev | RMSEz |
| SILC Early | | 16.98 | 14.08 | 10.46 | 15.40 | 14.36 | | 7.04 | 13.89 | 11.64 |
| SILC Recent | | 22.76 | 15.53 | 3.63 | 12.38 | 8.92 | | | | |
| GDS Early | | 50.71 | 10.60 | 9.68 | 14.23 | 14.00 | | 10.13 | 15.87 | 15.68 |
| GDS Recent | | 95.55 | 17.39 | 10.58 | 17.51 | 17.36 | | | | |
| SulSoft Early | | 20.66 | 21.99 | 24.47 | 18.69 | 18.97 | | 22.70 | 20.33 | 18.99 |
| SulSoft Recent | | 65.46 | 23.85 | 20.92 | 21.97 | 19.00 | | | | |
| DAAC Early | | 68.03 | 23.13 | 17.71 | 21.66 | 26.77 | | 20.73 | 25.22 | 31.18 |
| DAAC Recent | | 104.36 | 28.16 | 23.76 | 28.78 | 35.58 | | | | |

* Recent S/W enhancements implemented by GDS, SulSoft, and LP DAAC since completion of this study may improve some results shown in this table.

# Vertical Accuracies Compared: SRTM vs. ASTER DEM's

| ASTER (SilCast) | | | | |
|---|---|---|---|---|
| | | Z | | |
| Test Site | Acquisition Date | Mean | Std Dev | RMSEz |
| Drum Mountains, UT | 31-Jul-00 | -8.83 | 11.17 | 11.29 |
| Mt Hood, OR | 24-Sep-02 | -21.79 | 15.91 | 20.02 |
| Okoboji, IA | 31-Aug-01 | 11.49 | 18.85 | 15.02 |
| Reading, PA | 05-Oct-01 | -8.14 | 15.93 | 15.27 |
| Tacoma, WA | 28-Jun-00 | 2.03 | 15.15 | 10.22 |
| | Average (Abs) | 10.46 | 15.40 | 14.36 |
| Drum Mountains, UT | 20-Mar-04 | 0.15 | 8.78 | 8.78 |
| Mt Hood, OR | 27-Jul-04 | -3.97 | 18.84 | 9.73 |
| Okoboji, IA | 22-Oct-03 | -3.93 | 9.68 | 9.23 |
| Reading, PA | 06-May-04 | 4.61 | 11.67 | 8.50 |
| Tacoma, WA | 05-Jun-03 | 5.49 | 12.94 | 8.35 |
| | Average (Abs) | 3.63 | 12.38 | 8.92 |

| SRTM | | | | |
|---|---|---|---|---|
| | | Z | | |
| Test Site | Acquisition Date | Mean | Std Dev | RMSEz |
| Drum Mountains, UT | N/A | -2.20 | 2.95 | 2.78 |
| Mt Hood, OR | " | -13.80 | 14.23 | 16.83 |
| Okoboji, IA | " | 4.71 | 1.78 | 4.83 |
| Reading, PA | " | -5.63 | 6.25 | 8.02 |
| Tacoma, WA | " | -1.99 | 10.75 | 7.91 |
| | Average (Abs) | 5.67 | 7.19 | 8.07 |

# *Future ASTER research*

- **Understand source of mean difference bias and relate this to land surface cover and orbital errors**
- **Investigate how accurately relative ASTER-DEMs can be corrected using SRTM-90m data**
- **Study error characteristics of ASTER vs SRTM to understand whether ASTER-DEMs can be used to fill in gaps in SRTM-DEM coverage**
- **Add ASTER-DEMs to CEOS-ICEDS EO Data Portal coverages (completed)**

# *C- and X-band SRTM issues*

**Thanks to Paul Salamonowicz (NGA) and Marian Werner (DLR)**

# SRTM Accuracy Goals

- **SRTM Accuracy Design Goals at 90% Probability Level:**
  - Absolute Horizontal (AH) = 20 m
  - Absolute Vertical (AV) = 16 m
  - Random Vertical = 8m → Relative Vertical (RV) = 11 m

- **The accuracies associated with SRTM are defined as follows:**
  - **Absolute Horizontal (AH)** - 2-D horizontal error value such that if any point in the DTED cell or sub-cell is selected at random there is a 90% probability that its true horizontal position is within the AH value of a given position
  - **Absolute Vertical (AV) –** 1-D vertical error value such that if any point in the DTED cell or sub-cell is selected at random there is a 90% probability that the true elevation is within the AV value of the given elevation
  - **Relative Vertical (RV)** - 1-D vertical error such that if any two points in the DTED cell or sub-cell are selected at random there is a 90% probability that the true difference in elevation between them is within the RV value of the computed difference in elevation.
  - NOTE: Relative Horizontal (RH) error estimates are not provided for SRTM DTED® because it is difficult to measure with the coarse resolution data

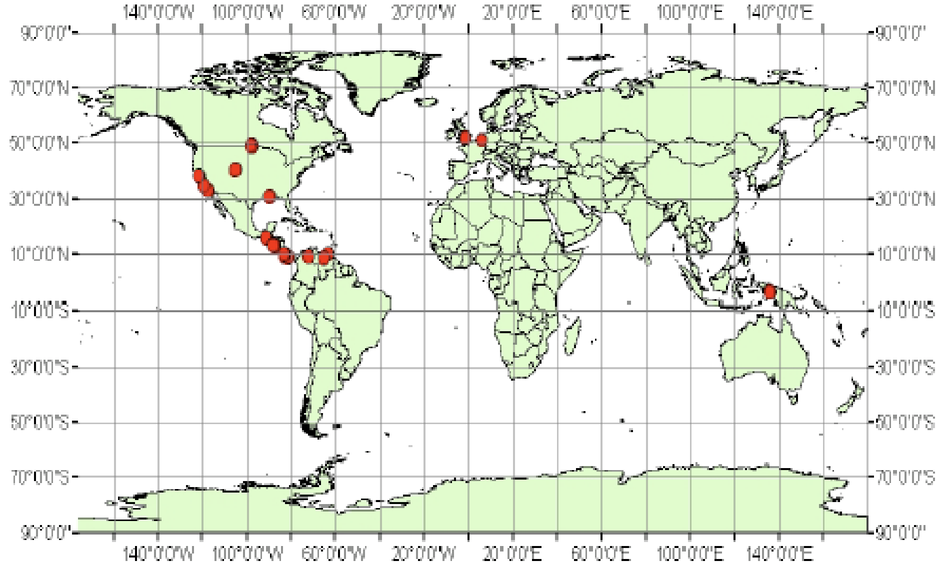
# Overview of SRTM Products

- **Digital Terrain Elevation Data - Level 2® (DTED-2®)**
  - Consists of cells covering a 1° x 1° geographical area
  - Post spacing: 1” x 1” between equator and 50° latitude, 1” x 2” above 50° latitude
  - Vertical Reference: Mean Sea Level (MSL)
  - Provides cell wide error predictions at the 90% confidence level for: AH, AV, RH

- **Terrain Height Error Data (THED)**
  - Attempt to provide error estimates at a finer resolution than those provided with the DTED®
  - Provides an estimate of the elevation random error per post
  - Includes metadata known as Vertical Systematic Error Model (VSEM)
    - VSEM divides a cell into 64 sub-cells (8 x 8)
      - Each sub-cell covers 7.5’ x 7.5’ and contains 450 x 450 posts
    - VSEM Provides (at the 90% confidence level):
      - A representative random error per sub-cell
      - An estimate of the distance over which the error is correlated
      - An estimate of the long-wavelength (systematic) error
    - Based on the estimated errors above, the VSEM also provides an estimate of the absolute vertical (AV) and relative vertical (RV) errors on both a cell and sub-cell basis.

# ▶ Ground Truth Data

- **Elevation Ground Truth**
  - Star-3i X-band IFSAR
    - 10 meter or 5 meter post spacing
    - Vertical Accuracy =1,2,3 m (1σ)
    - Horizontal Accuracy = 2.5 m (1σ)
  - 152 samples
  - Each sample covers approx. 1 sub-cell
  - Cover 21 unique geographic areas




Star-3i Data Samples

- **Land Classification Data**
  - The Global Land Cover 2000 (GLC2000)
    - The GLC 2000 was created as part of a project by the European Commission titled Global Environment Information System (GEIS)
    - Land cover classification was generated from SPOT-4 VEGETATION sensor
      - Contains Blue, Red, NIR, and SWIR channels
    - Worldwide data collected in 14 months from 1 November 1999 – 31 December 2000
    - The USGS/EROS Data Center participated in the classification of the data over North America.
    - More information on the dataset can be found at http://www.gvm.jrc.it/glc2000

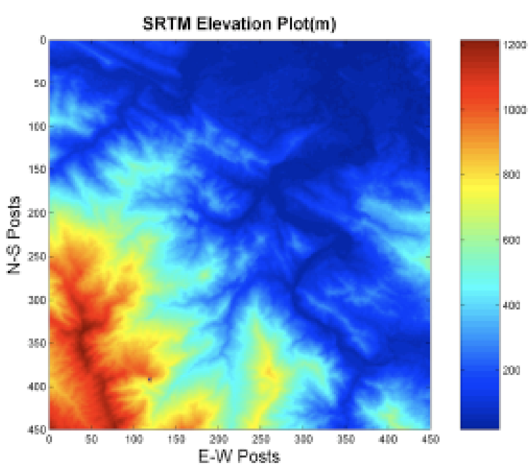
Reference: "Global Land Cover 2000 database. European Commission, Joint Research Centre, 003. http://www.gvm.jrc.it/glc2000."

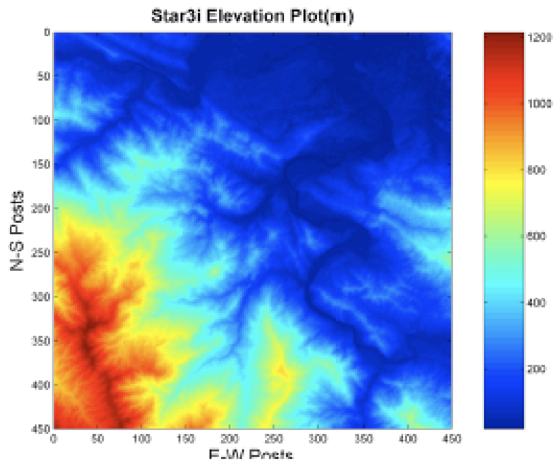
# DTED-2® Analysis

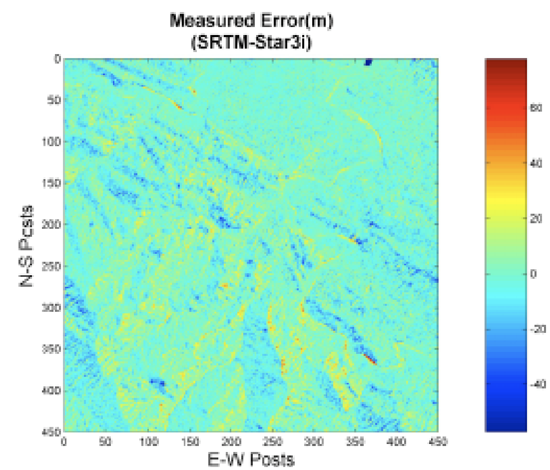
Error estimates at 90% Probability Level

## Sample of a Poor Sub-Cell: Panama – GT3N09W082C5V1

| | Pre Horizontal Adjustment | | | | Post Horizontal Adjustment Shift X:-21m Shift Y: -6m | | | |
|---|---|---|---|---|---|---|---|---|
| | LW /Bias (m) | RRE (m) | AV (m) | RV (m) | LW /Bias (m) | RRE (m) | AV (m) | RV (m) |
| Predicted | 4.9 | 6.9 | 8.5 | 9.7 | 4.9 | 6.9 | 8.5 | 9.7 |
| Measured | 3.0 | 15.1 | 15.6 | 21.1 | 2.1 | 12.2 | 12.2 | 16.9 |



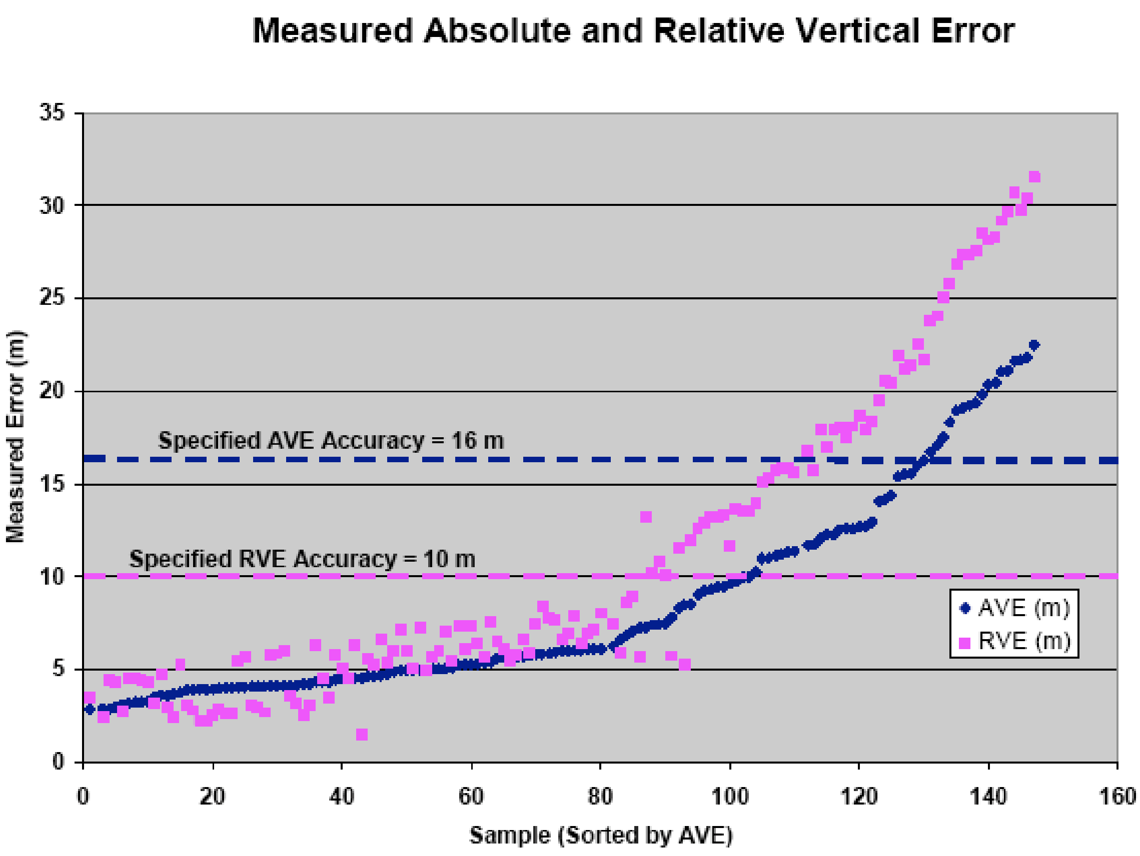



# DTED-2® Vertical Accuracy Results

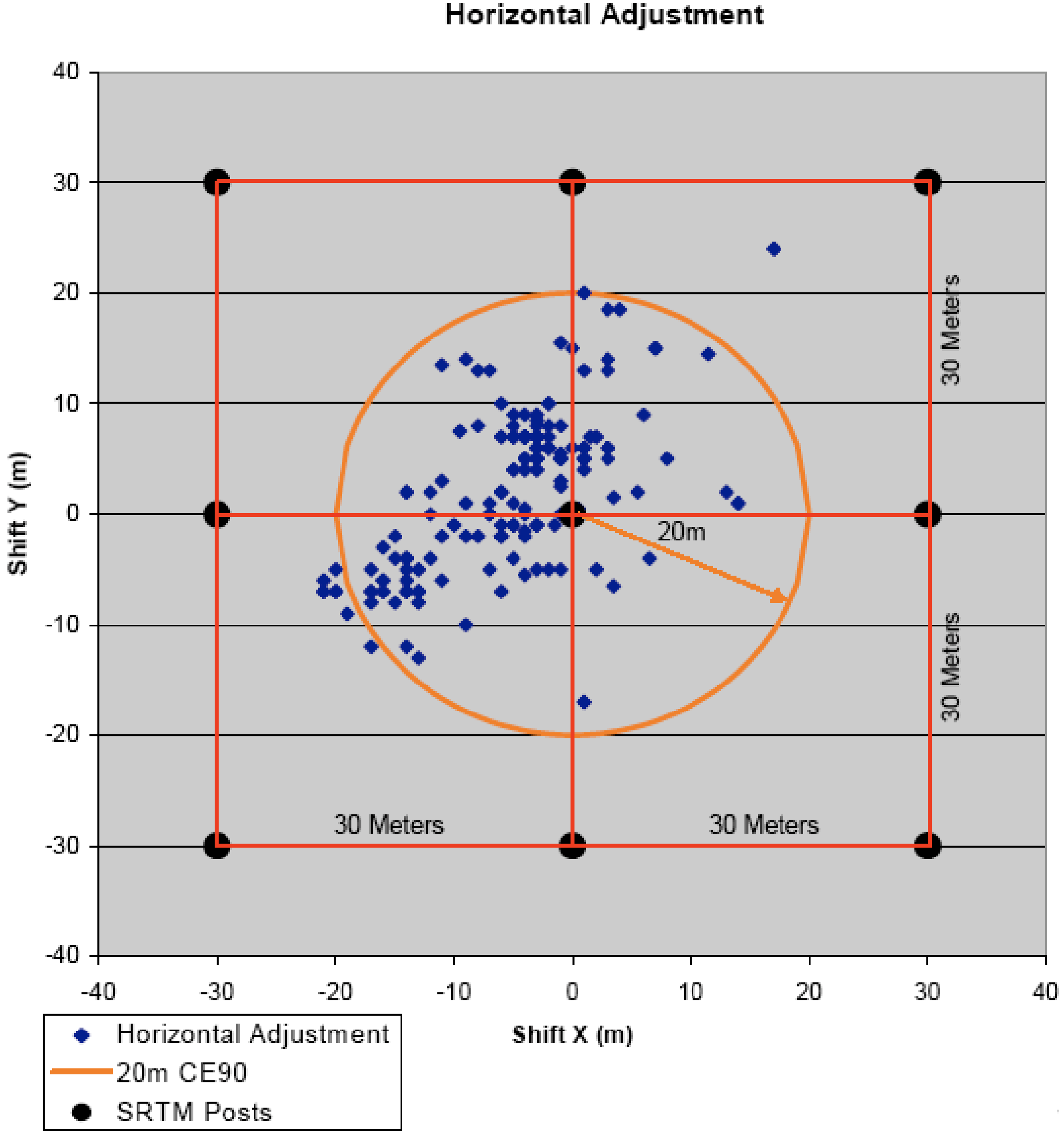
- The measured AV for the various samples show that most of them (88%) meet the SRTM specification
- Only 60% of the RV meet the specification

Note: Many of the samples used in this study are from regions that make IFSAR collection difficult



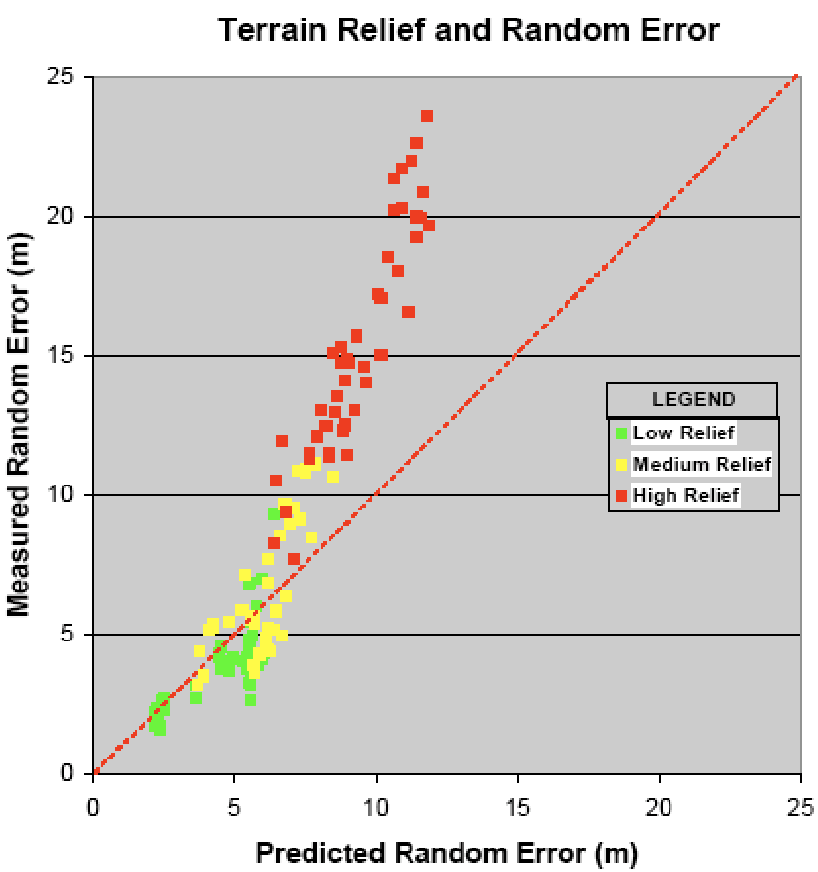
# DTED-2® Horizontal Accuracy Results

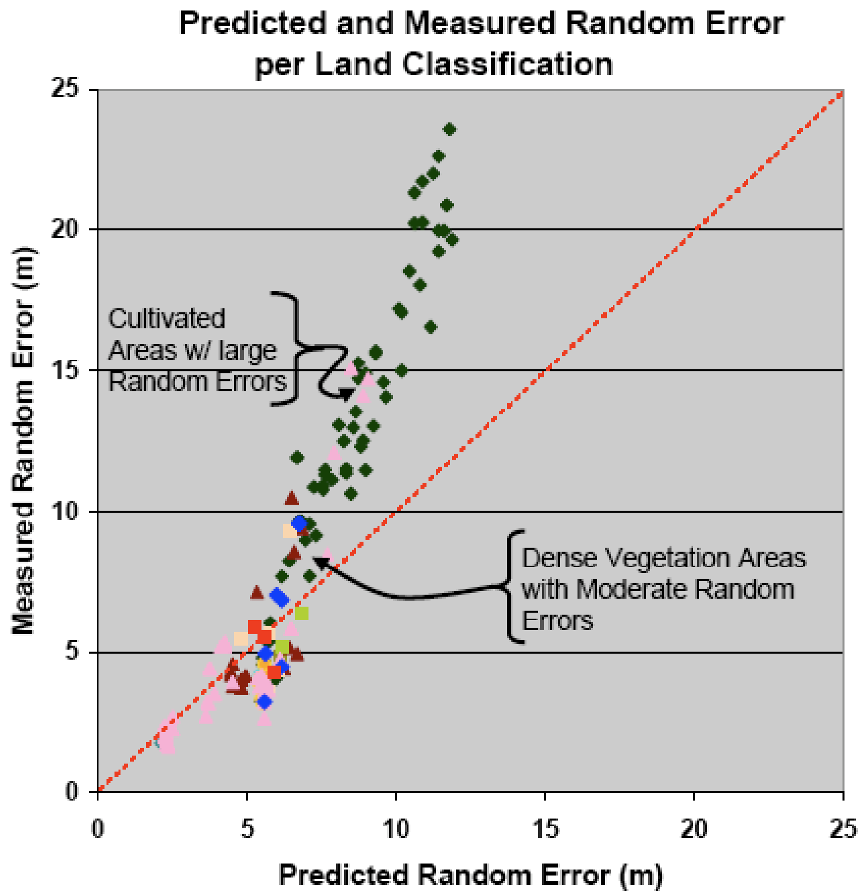
- Quality of the horizontal positioning of the SRTM data is very good
- Design spec for absolute horizontal accuracy was 20 meters at the 90% confidence interval
- The measured horizontal shifts are well within this value



# SRTM / THED Error Analysis

Comparison of the random error plot based on terrain and based on land classification



# Representative Sample

Average accuracy results for our sample at the 90% probability level

| | Random | AV (m) | RV (m) | Global Percentage |
|---|---|---|---|---|
| Overall | 8.11 | 8.38 | 10.90 | 100.00 |
| Low Relief | 3.69 | 4.79 | 5.04 | 67.03 |
| Mid Relief | 6.36 | 6.64 | 8.76 | 25.69 |
| High Relief | 15.46 | 15.18 | 21.36 | 7.28 |

- Using global percentages for relief to normalize SRTM accuracies based on the results of this study yields the following global accuracy estimate:

  **AV = 6.0 m RV = 7.2 m Random = 5.2 m**

- These compare well to the JPL results averaged across continents:

  **AV = 6.8 m RV = 6.9 m**

# Validation: SRTM / X-SAR DEM over Germany

## (Navigation Point Height) – (SRTM Height)

| flat terrain | | | | |
|---|---|---|---|---|
| | **number** | μ | σ | **RMS** |
| forested areas | 2329 | -6.20 | 6.74 | 9.16 |
| urban areas | 1683 | -2.63 | 4.10 | 4.87 |
| open landscape | **20786** | **-0.94** | 4.31 | **4.41** |
| Σ | 24798 | -1.55 | 4.84 | 5.08 |
| **moderate relief** | | | | |
| | **number** | μ | σ | **RMS** |
| forested areas | 1970 | -1.98 | 7.60 | 7.86 |
| urban areas | 725 | -1.14 | 4.86 | 5.00 |
| open landscape | **8000** | **+0.15** | 4.54 | **4.54** |
| Σ | 10695 | -0.33 | 5.33 | 5.34 |
| **highlands** | | | | |
| | **number** | μ | σ | **RMS** |
| forested areas | 2272 | -4.43 | 8.62 | 9.69 |
| urban areas | 766 | -1.04 | 5.29 | 5.39 |
| open landscape | **7693** | **-0.74** | 5.36 | **5.41** |
| Σ | 10731 | -1.54 | 6.37 | 6.55 |

Tab. 1: SRTM DEM validation against navigation points in the western part of Germany

**Reference Data:**

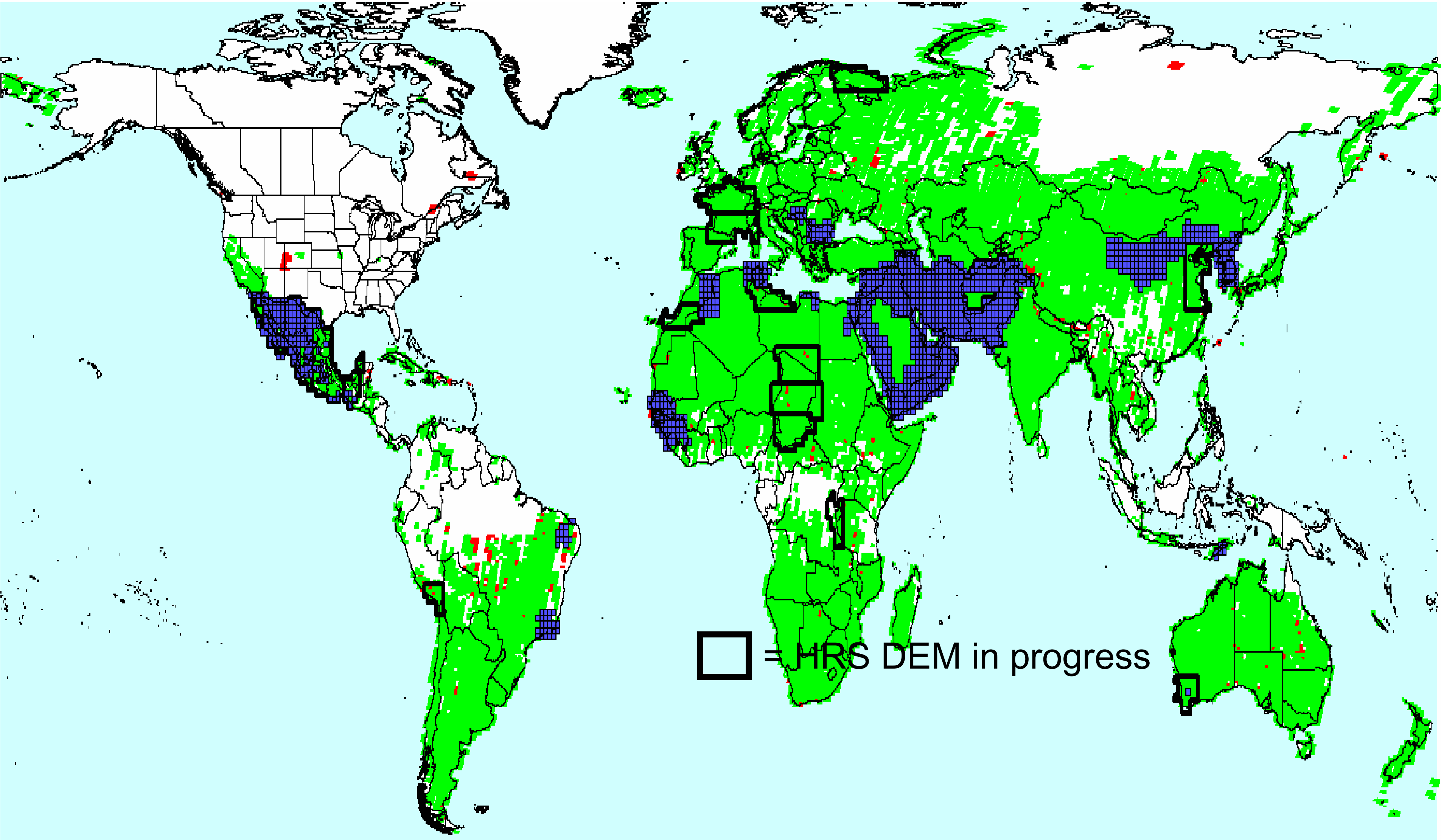
- 46231 Navigation Points (NPs), provided by AMilGeo Euskirchen, Germany
- Test area: western part of Germany 1000 km x 300 km
- The mean of the SRTM heights is in good accordance to the NPs for open landscape
- Urban and forested areas show the expected bias (= mean difference between surface and terrain height)
- Standard deviations correspond to the height errors induced by the uncompensated boom oscillations
- PDF of tree heights => higher RMS values for forested areas

# X- and C-SRTM DEM: Future Issues

- **JPL have completed editing the SRTM 3” (≈90m) DEM and USGS now distribute this using anonymous ftp**
- **JPL have completed the orthorectification of the SRTM SAR amplitude subsetted by orbit and by a 1º x 1º tile**
- **At the workshop, NASA and USGS requested that NGA release the SRTM 1” (≈30m) DEM as well as the THED. NGA responded by stating that the US had various bi-lateral agreements with countries around the globe which prevented this. The debate continues but it should be noted that Scott Hensley (JPL) showed that the true resolution of SRTM-1” was some 45-60m cf. 30m. Perhaps a compromise could be reached with data release at 2 arc-seconds?**
- **User’s priority (e.g. UN, GEOSS) is to fill gaps in SRTM coverage including above 60ºN and below 56ºS**
- **NASA has prioritised the re-processing of SRTM including X- and C- as well as ICESAT-GLAS rather than a new mission for these areas**
- **DLR have received the results of a national review and the proposed TANDEM-X (dual TerraSAR-X) will be funded (see later)**

# > 97 Mkm² of HRS cloud-free stereopairs (red = recent)

## SPOT 5 HRS DTED2 DEM + orthoimage ( >13M km² )



# *Independent accuracy assessments*

- ISPRS (International Society for Photogrammetry and Remote Sensing) **launched a "Study Team" in Nov 2002 to assess HRS accuracy. Final results were presented at the Istanbul ISPRS congress in July 2004.**

- DGIA (UK MoD) **found Reference3D fully compatible with DTED level 2 standard**

- SRTM - Reference3D **cross evaluation with** NGA **: full compatibility**

- JRC Ispra (European Commission) and FÖMI (Hungarian Mapping) **performed an in-depth assessement of Reference3D over Hungary, using "official" Hungarian data : RMSEz = 3.4m RMSExy = 5.75m**

# DEM Production with ERS Tandem and X-SRTM Data in Italy and Switzerland

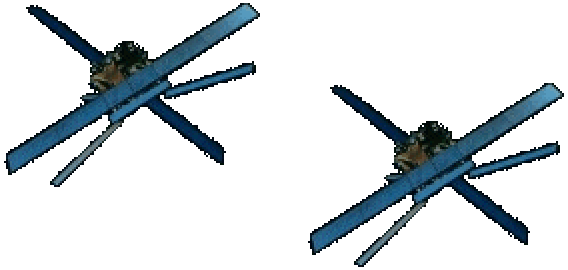
Frank Martin Seifert – ESA

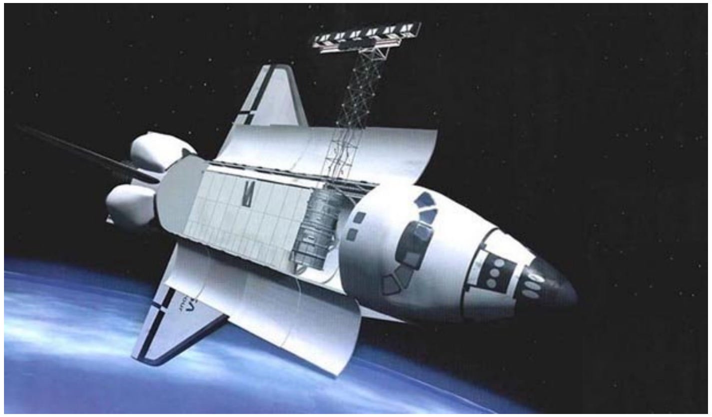
Mario Costantini – Telespazio

Paolo Pasquali – Sarmap

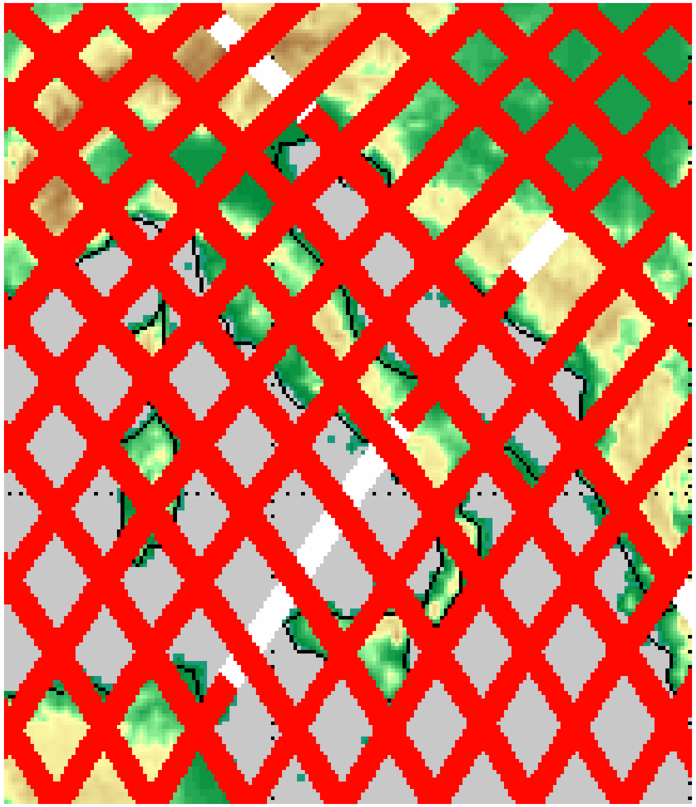
Rob Verhoeven – Synoptics

- DUDES Project
- ERS Tandem
- Validation Procedure
- Testsites
  - Italy
  - Belgium
  - Switzerland
- Conclusion



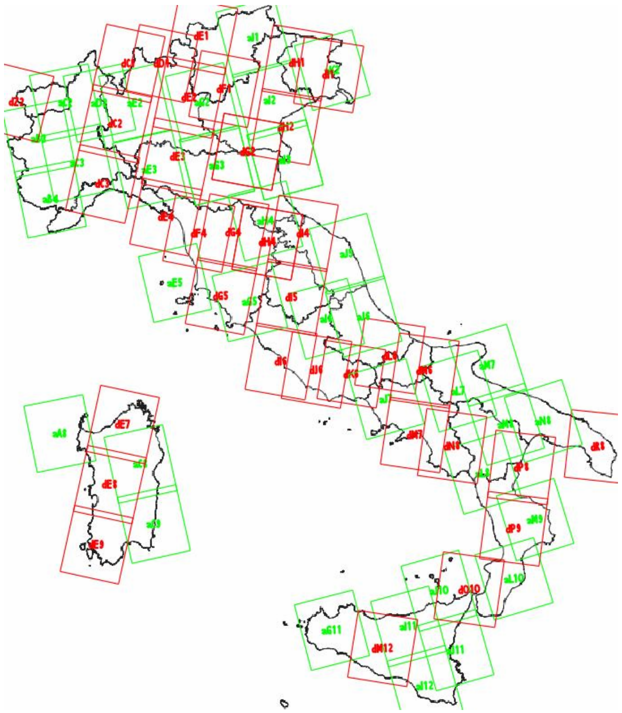


- SRTM-X from DLR and ASI
- ERS Tandem from ESA
- Merging of DEMs
  - Horizontal and vertical **systematic relative error** determination by comparison of the different DEMs
  - Horizontal and vertical **systematic absolute error** determination by minimum error norm assumption
  - DEM fusion: weighted average or wavelet approach



# ERS Tandem Mission

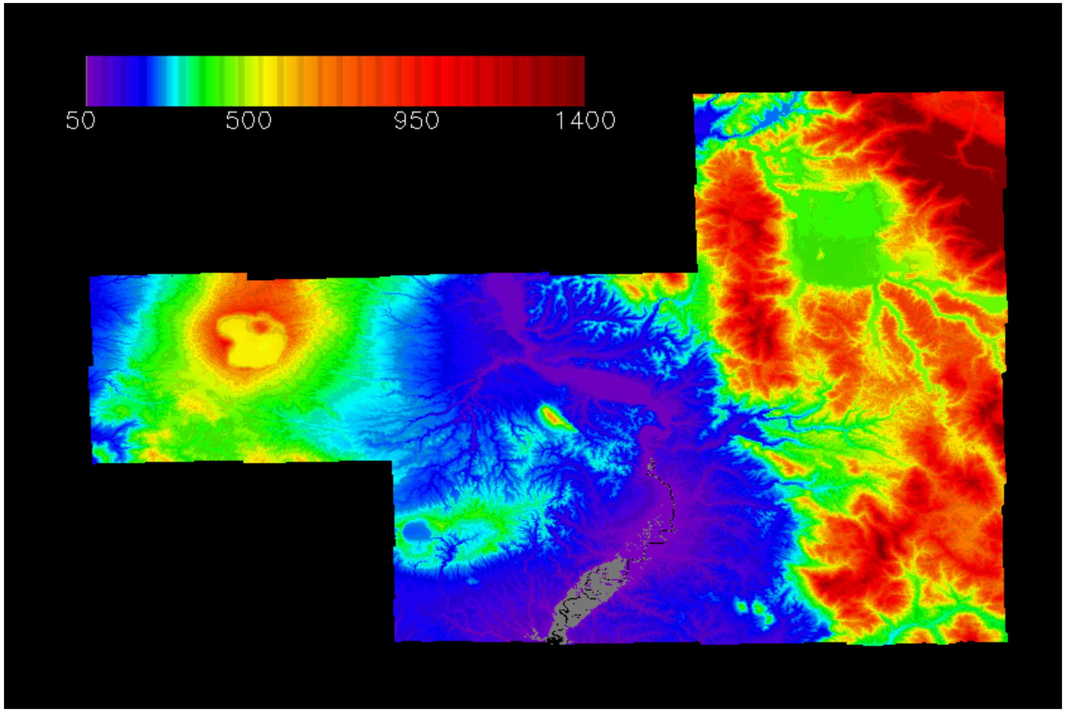
- C-band SAR 5.6 GHz
- 100 km swath width
- 23 deg incidence angle

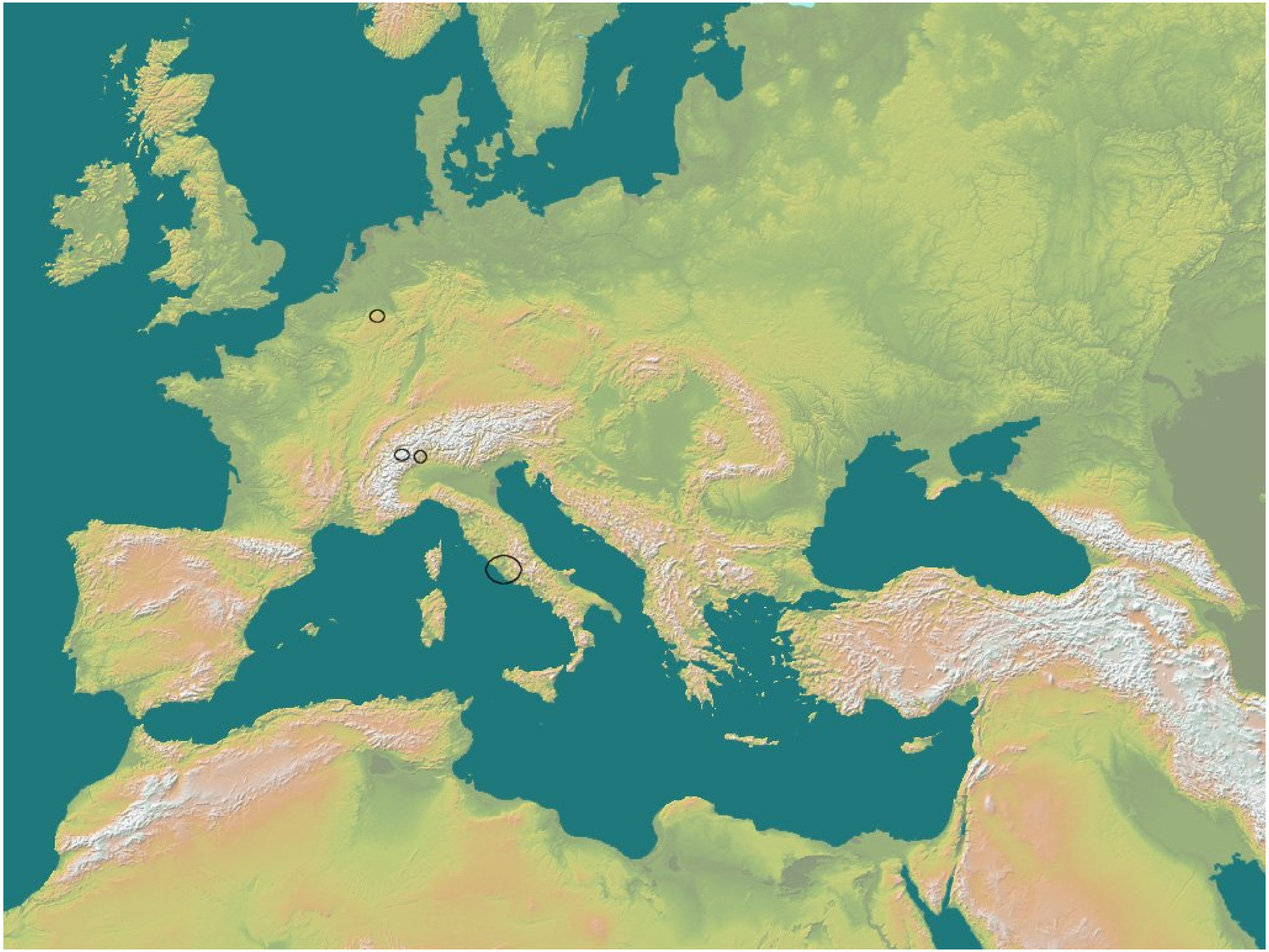
- One day repeat pass interferometry
- Baseline 0 – 1000 m
- June 1995 – July 1996
- 116000 Tandem pairs worldwide archived

# Validation procedure

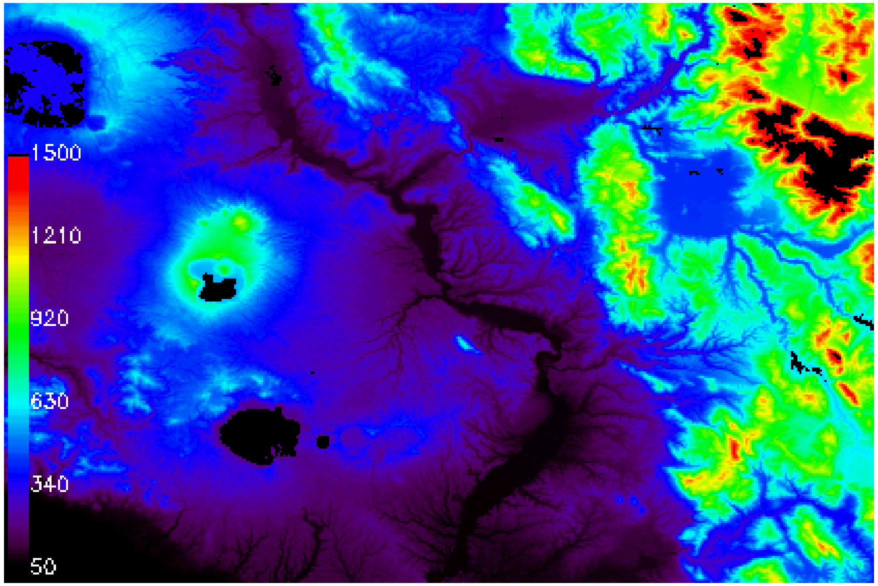
- Resampling to 30 m (resolution of HR-DEM)
- Validation through reference HR-DEM [IGM]
- Horizontal constant shift computation
- Vertical comparison with reference DEM

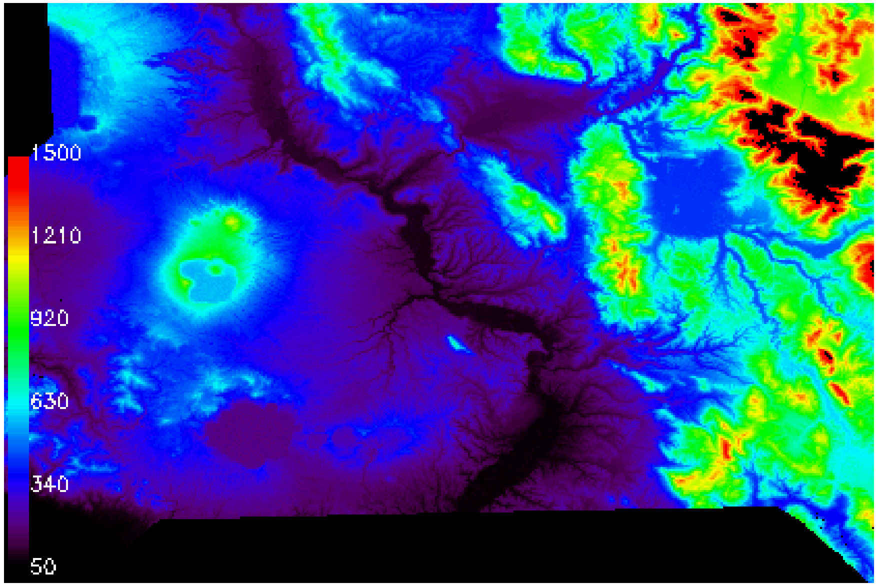


# Test Areas



# Italy: SRTM-3'' / DUDES

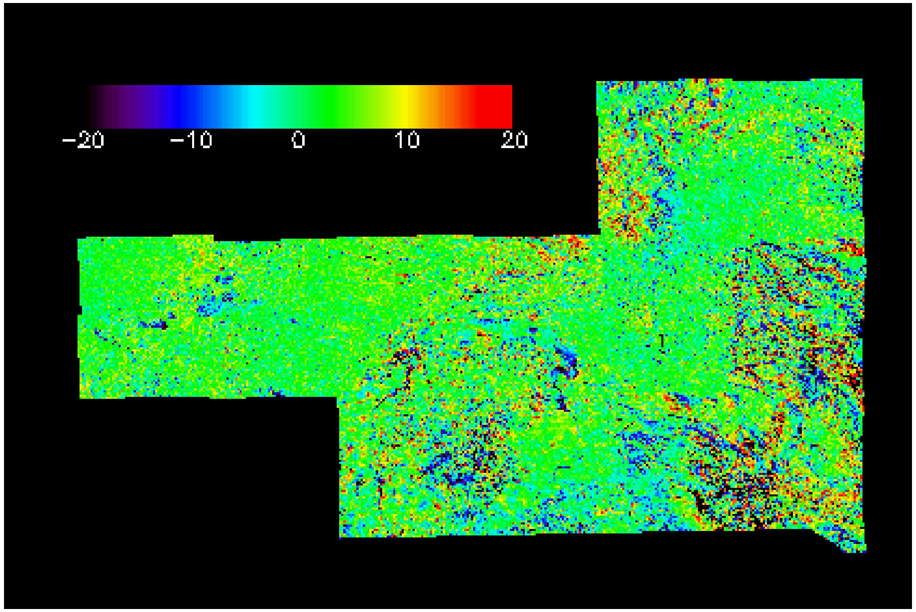



SRTM 90 co-registered with respect to the IGM HR DEM

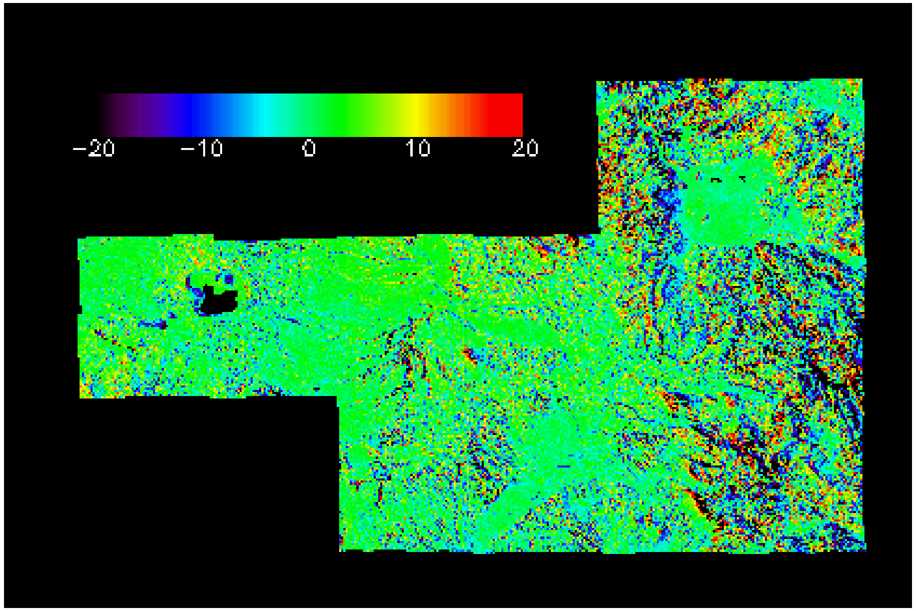
DUDES co-registered with respect to the IGM HR DEM

# Italy: Vertical differences



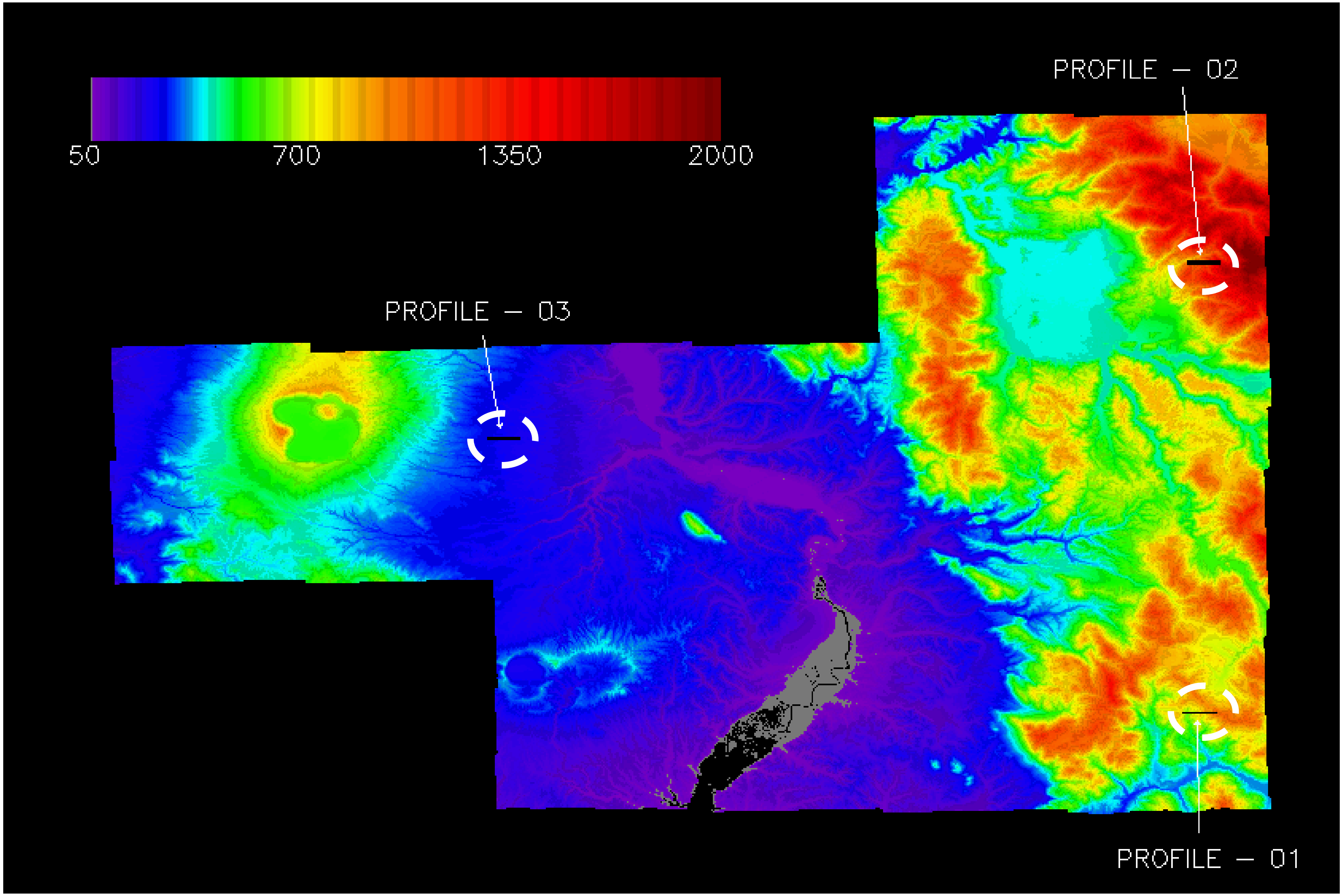

IGM - DUDES

IGM - SRTM 90

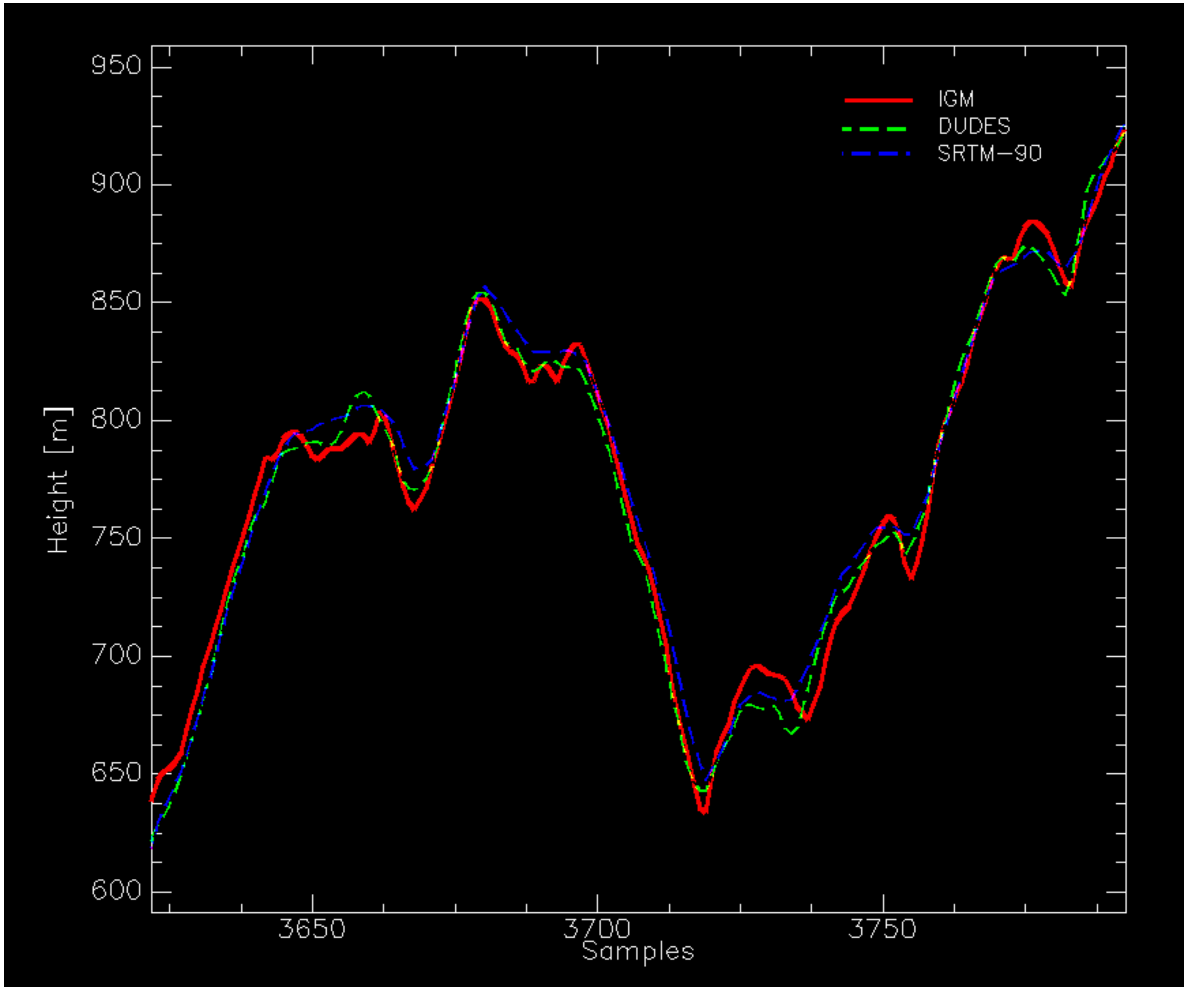



Stronger dependence on topography

# Italy: Vertical profiles



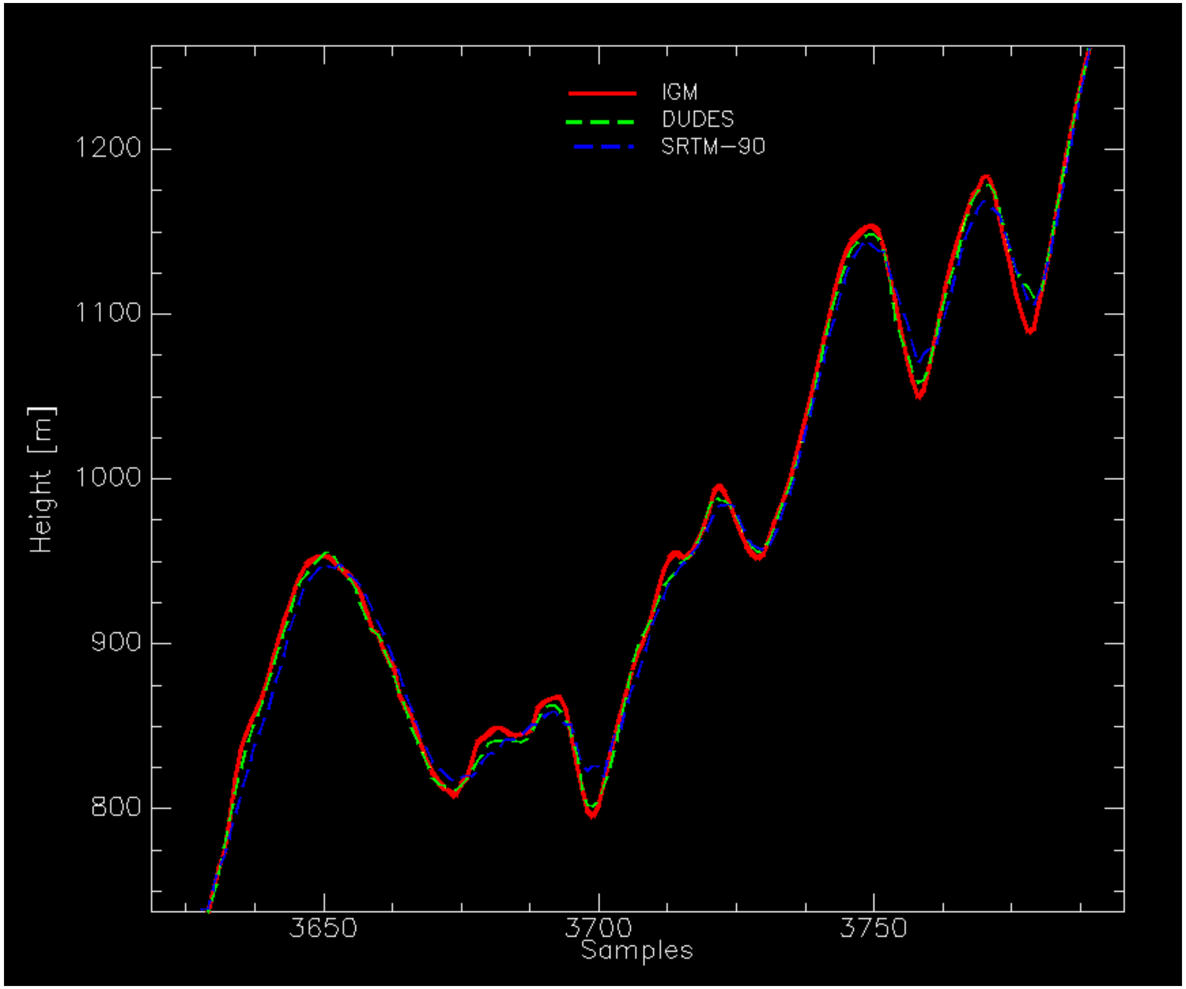
# Italy: Profile – 01




**Moderate Terrain**

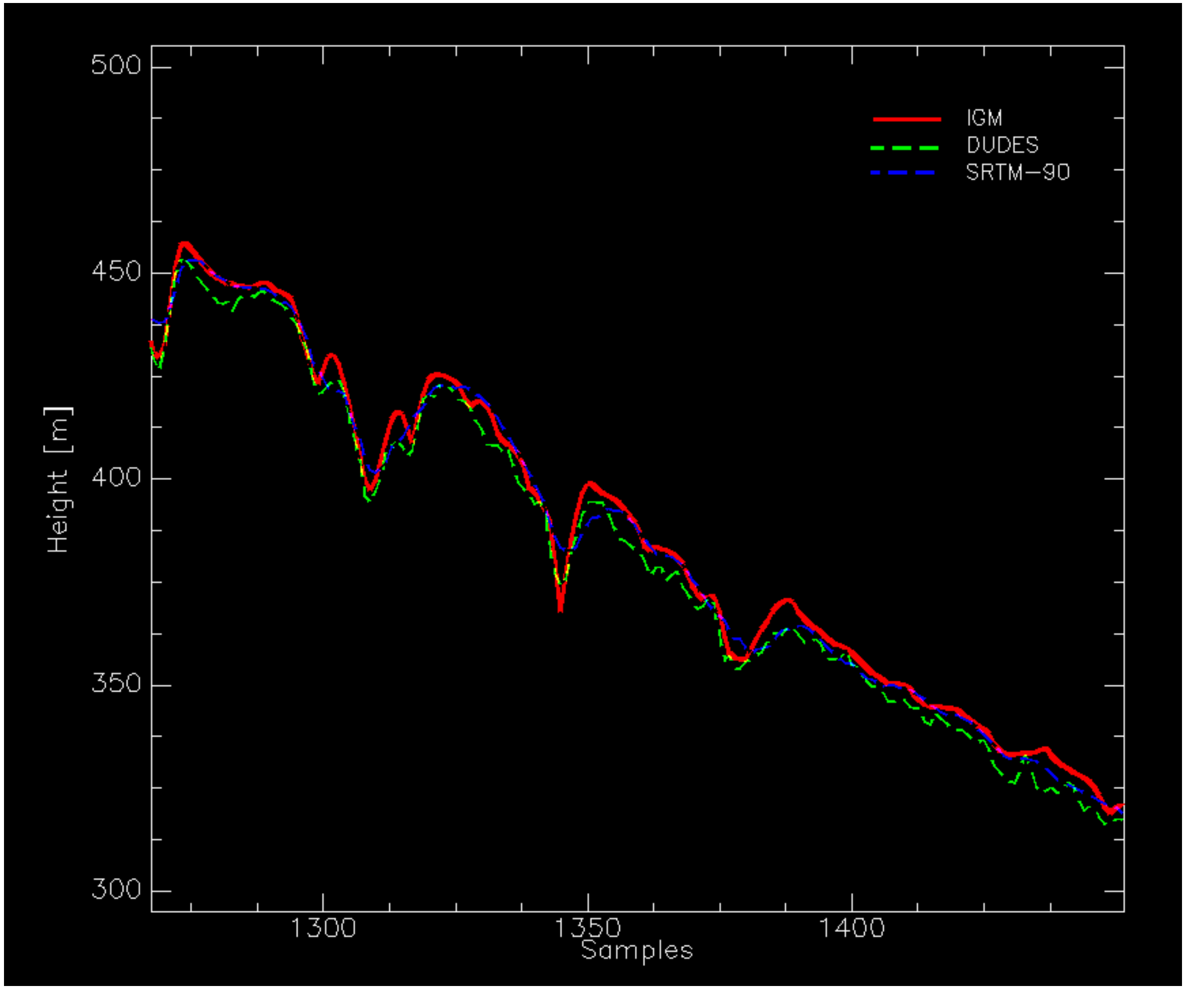
**SRTM-90 → Smooth profile**

# Profile – 02




**High Relief**

# Profile – 03




**Low relief**
**< 150 m**

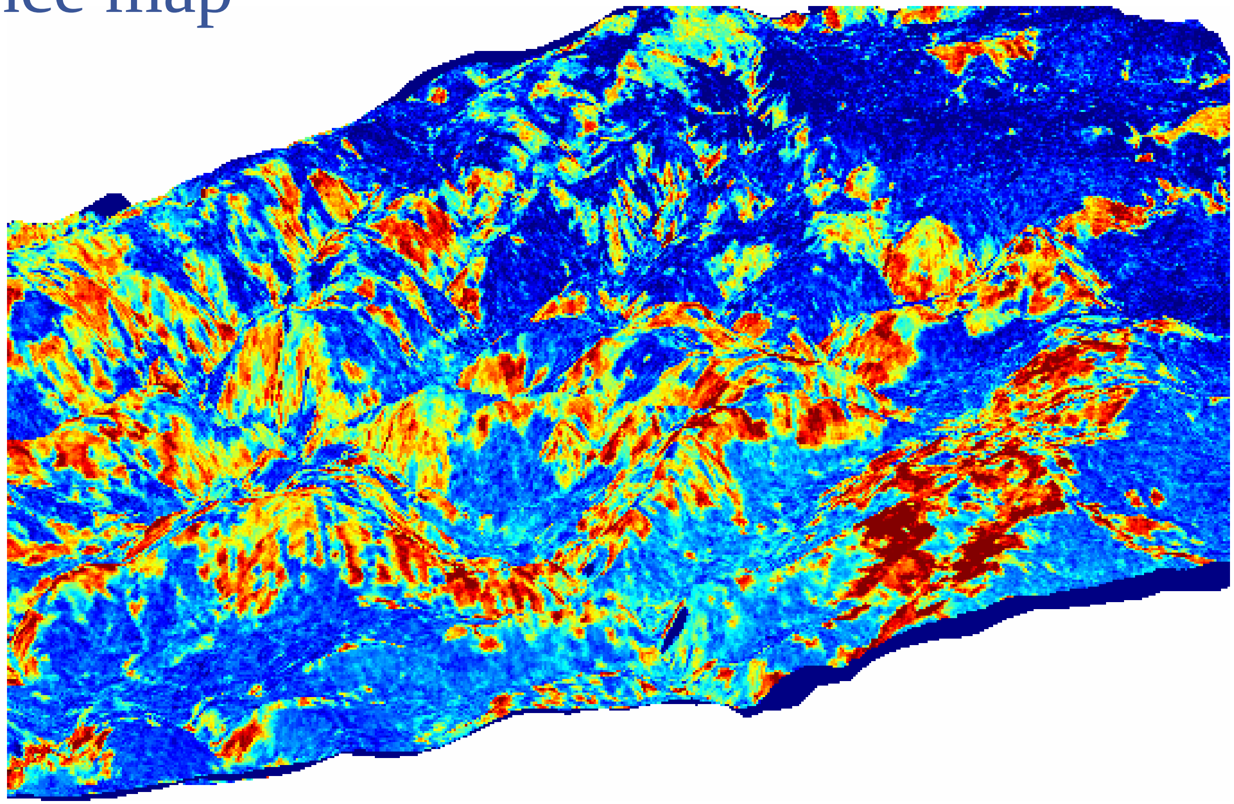
# Comparison with SRTM-C 3''

| Accuracy Measurements | Reference Spec. [m] | SRTM-C 3 arcsec | ERS | SRTM-X asc | SRTM-X desc | DUDES |
|---|---|---|---|---|---|---|
| **Misregistration w.r.t. HR-DEM** | | | | | | |
| Module of mean horiz. error | | 18.6 | 4.9 | 11.8 | 12.9 | 6.4 |
| Module of horiz. error st. dev. | | 4.4 | 14.7 | 4.4 | 3.1 | 8.2 |
| **Absolute horizontal circ. error (max 90% conf.)** | **< 20** | **21.9** | **23.2** | **15.6** | **16.6** | **14.6** |
| Relative horizontal circ. error (max 90% conf.) | **(< 15)** | 6.9 | 23.3 | 6.6 | 4.5 | 13.3 |
| **Difference w.r.t. HR-DEM** | | | | | | |
| Mean vertical error | | 0.2 | 0.5 | -4.2 | -3.1 | 2.5 |
| Vertical error st. dev | | 4.4 | 9.1 | 5.0 | 7.4 | 6.3 |
| **Absolute vertical error (max 90% conf.)** | **< 16** | **14.9** | **13.8** | **10.2** | **14.1** | **9.7** |
| **Relative vertical error (max 90% conf.) (slope < 20%)** | **< 6 - 10** | **6.0 (32% of total area)** | **10.2 (32% of total area)** | **5.8 (52% of total area)** | **6.7 (15% of total area)** | **8.2 (32% of total area)** |
| **Relative vertical error (max 90% conf.) (slope > 20%)** | **< 6 - 10** | **16.7 (68% of total area)** | **16.9 (68% of total area)** | **9.9 (48% of total area)** | **13.5 (85% of total area)** | **11.6 (68% of total area)** |

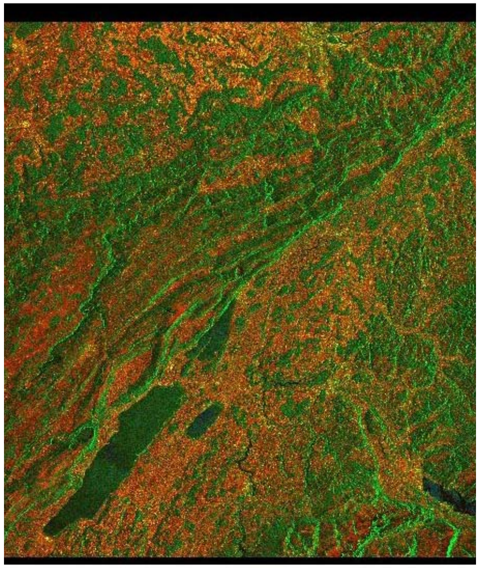
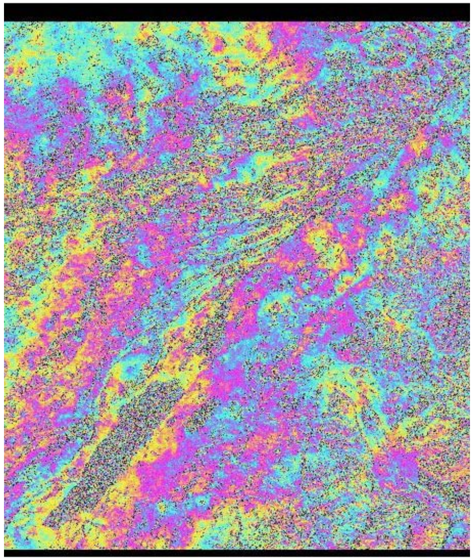
# SRTM-X Validation Results over Lazio test site

| Accuracy Measurements | SRTM Spec. | SRTM-X asc (old data old proc.) | SRTM-X asc (old data new proc.) | SRTM-X asc (new data new proc.) | SRTM-X desc old data old proc.) | SRTM-X desc (old data new proc.) | SRTM-X desc (new data new proc.) |
|---|---|---|---|---|---|---|---|
| **Misregistration w.r.t. HR DEM** | | | | | | | |
| **Absolute horizontal circ. error (max 90% conf.) [m]** | **< 20** | 15.6 | 15.9 | 12.7 | 16.6 | 15.5 | 19.6 |
| **Relative horizontal circ. error (max 90% conf.) [m]** | **< 15** | 6.6 | 5.5 | 5.2 | 4.5 | 3.4 | 3.6 |
| **Difference w.r.t. HR DEM** | | | | | | | |
| **Absolute vertical error (max 90% conf.) [m]** | **< 16** | 10.2 | 8.9 | 6.6 | 14.1 | 8.8 | 8.5 |
| **Relative vertical error (max 90% conf.) [m] (slope < 20%) (32% of the total area)** | **< 6** | 5.8 | 5.5 | 5.5 | 6.7 | 6.2 | 5.9 |
| **Relative vertical error (max 90% conf.) [m] (slope > 20%) (68% of the total area)** | **< 10** | 9.9 | 7.3 | 7.2 | 13.5 | 7.7 | 7.5 |

- SRTM maps top layer (e.g. canopy) while reference DTM 10,000 represents terrain surface
- Forest stands on top of hills are clearly visible in difference map

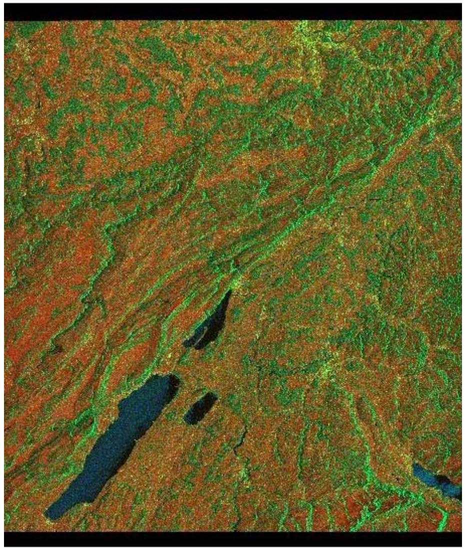
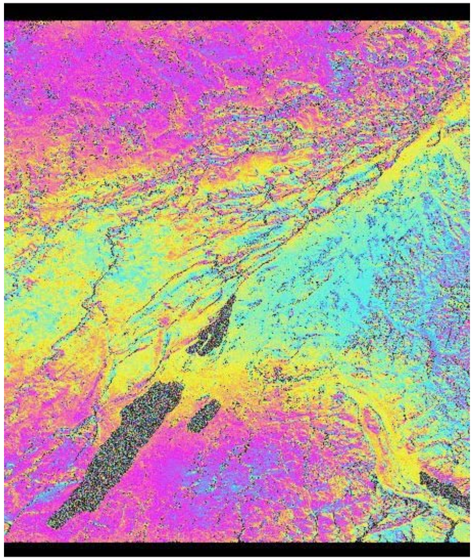


# Switzerland - Tandem

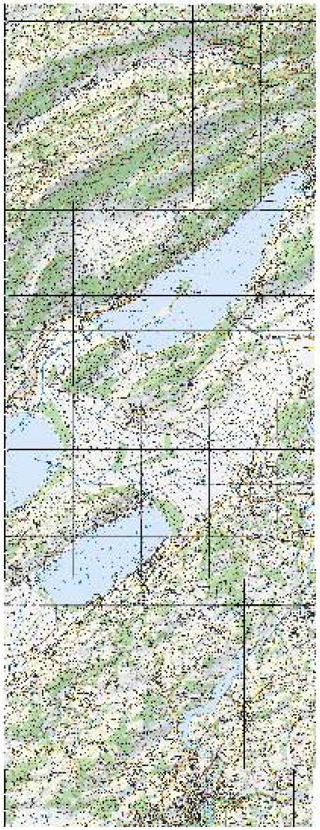
June 1995
127 m baseline

ILU and flattened Interferogram

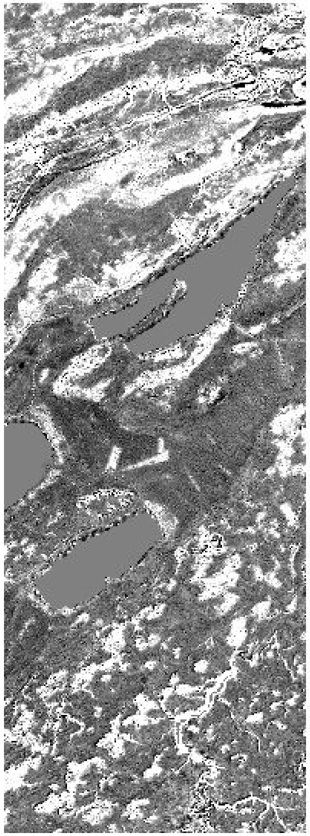



October 1995
114 m baseline

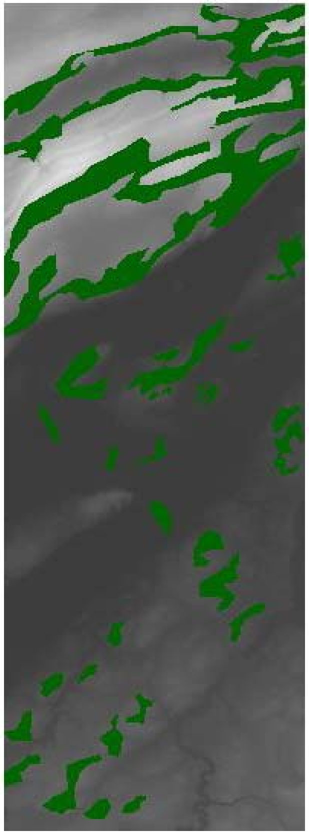
# Swiss example



Reference DEM



Reference DEM – DUDES DEM



DUDES DEM with Forest mask

| Accuracy Measurements | Reference Spec. [m] | DUDES Belgium | SRTM-C Swiss 1 | DUDES Swiss 1 | SRTM-C Italy | DUDES Italy |
|---|---|---|---|---|---|---|
| **Misregistration w.r.t. HR-DEM** | | | | | | |
| Module of mean horiz. error | | 98.4 | 100 | 0 | 18.6 | 6.4 |
| Module of horiz. error st. dev. | | 17.5 | | | 4.4 | 8.2 |
| **Absolute horizontal circ. error (max 90% conf.)** | **< 20** | **115.5** | | **0** | **21.9** | **14.6** |
| Relative horizontal circ. error (max 90% conf.) | **(< 15)** | 26.3 | | | 6.9 | 13.3 |
| **Difference w.r.t. HR-DEM** | | | | | | |
| Mean vertical error | | 3.0 | -2.7 | -2.5 | 0.2 | 2.5 |
| Vertical error st. dev | | 6.6 | 27.9 | 11.3 | 4.4 | 6.3 |
| **Absolute vertical error (max 90% conf.)** | **< 16** | **9.7** | **14.1** | **16.3** | **14.9** | **9.7** |
| **Relative vertical error (max 90% conf.) (slope < 20%)** | **< 6 - 10** | **8.0** | **12.0** | **14.8** | **6.0 (32% of total area)** | **8.2 (32% of total area)** |
| **Relative vertical error (max 90% conf.) (slope > 20%)** | **< 6 - 10** | | | | **16.7 (68% of total area)** | **11.6 (68% of total area)** |

## Conclusion:

- The DUDES approach demonstrated DTED-2 quality in most terrain by combining ERS Tanden and SRTM-X.
- DEM quality validated in co-operation with national authorities
- DUDES DEM proved to be better than DEMs from single sources.

# DEM accuracy definitions: Mario Constantini, Telespazio

| | |
|---|---|
| *DEM Horizontal Accuracy, Absolute* | Accuracy of the horizontal location of the DEM points caused by random and uncorrected systematic errors, expressed as the maximum absolute difference between the true and measured values with a 90% confidence level, i.e. excluding the 10% worst points. The definition is inspired to the DTED specifications (see [RD7]). |
| *DEM Horizontal Accuracy, Relative* | Accuracy of the horizontal location of the DEM points caused by random errors, expressed as the maximum absolute value of the unbiased difference between the true and measured values with a 90% confidence level, i.e. excluding the 10% worst points. The unbiased difference is evaluated by subtracting the difference between the true and measured values with an estimate of possible systematic terms. For example, this estimate can be obtained by means of a local average of the differences. The definition is inspired (but it is not identical) to the DTED specifications. (see [RD7]). |
| *DEM Vertical Accuracy, Absolute* | Accuracy of the height of the DEM points caused by random and uncorrected systematic errors, expressed as the maximum absolute difference between the true and measured values with a 90% confidence level, i.e. excluding the 10% worst points. The definition is inspired to the DTED specifications (see [RD7]). |
| *DEM Vertical Accuracy, Relative* | Accuracy of the height of the DEM points caused by random errors, expressed as the maximum absolute value of the unbiased difference between the true and measured values with a 90% confidence level, i.e. excluding the 10% worst points. The unbiased difference is evaluated by subtracting the difference between the true and measured values with an estimate of possible systematic terms. For example, this estimate can be obtained by means of a local average of the differences. The definition is inspired (but it is not identical) to the DTED specifications. (see [RD7]). |
| *Posting* | Pixel spacing |

# WGISS/WGCV Test Facility (WTF)

- Puget Sound test site populated with 30m SRTM (finished NGA-supplied called SRTM-DTED2®), all other NASA and ESA datasets and airborne lidar datasets
- All US WTF sites now have 1”(30m) SRTM-DTED2® and all non-US have 3”(90m) SRTM-DTED1®
- Would like to extend WTF to include
  - Other spaceborne DEM products (e.g. GETASSE30) for Puget Sound (e.g. SPOT-5, ERS-tandem, ALOS-PRISM)
  - Land cover information (US-NLCD at 30m, MODIS and GLC2000 at 1km and GlobCover at 300m)
  - Add other TMSG test sites in Europe (North Wales, Barcelona, Aix-en-Provence)
- How will this be supported as there are no committed resources and the future of transitioning WTF to an operational service is not agreed?
- This also applies to “Known Issues” which TMSG would like to kick-off using SRTM DEMs at EDC. However, it is hoped that the joint WGCV-WGISS Plenary can address this issue
- SRTM workshop strongly endorsed recommendation for establishment of “Known Issues” web-pages for SRTM

# Example of WTF datasets available

## Puget Sound, WA

N 47.6138 W 122.6478
UTM Zone: 10

Puget Sound itself is a body of water lying east of Admiralty Inlet, through which ocean waters reach inland some 50 mi from the Pacific Coast to provide all-weather ports for ocean-going ships at Seattle, Tacoma and Olympia. The waterwa a complex and intricate system of channels, inlets, estuaries, embayments and islands.

### DATA AVAILABLE

**Raw Data Available:**

**ETM+**

Thumbnail images of selected Landsat 7 ETM+ scenes covering the test site that have been processed to Level-1G and are available for preview. The full scene data are available as single-band images that have been Gzip-compressed for download.

- ETM+ Science Data User Handbook
- ETM+ Data

**SPOT VEGETATION**

Each SPOT files has 227 bands that correspond to 10-day NDVI composite images for the period of May 10, 1998 through August 31, 2004. These are ENVI image files with associated header recorders that specify number of lines and samples, datatype, projection parameters, etc.

- SPOT Readme
- Data

**DEM Data**

Subsets of digital elevation model (DEM) data derived from the Shuttle Radar Topographic Mission (SRTM) are available as DTED-2 in Geographic and UTM projections for sites in the United States, along with subsets from the National Elevation Data.

SRTM and NED Readme

- SRTM DTED-2
  - Geographic
  - UTM
- National Elevation Dataset (NED)
  - UTM

**MODIS** (not yet available

Spatial subsets of Terra MODIS 16-day vegetation indices at 1km resolution (MOD13A2) centered over the test site are available as Gzip-compressed HDF-EOS files.

MODIS Readme

- 2005

**ASTER** (not yet available)

Selected acquisitions of Terra ASTER data processed to Level-1B (at sensor radiances).

ASTER Readme

- 2005

**LIDAR**

- Data
- GSA Today
  - Cover
  - Article

**MERIS** (not yet available)

Spatial subsets of selected MERIS data providing coverage of approximately 200km by 200km centered over the core site that were acquired in 2003.

Readme

- 2003
  - Level-1b
  - Level 2

# WGISS EO Data Portal - Update on ICEDS wrt TMSG

- Drill-down to anywhere on the planet to scales of 1:25 000 (30m) for colourised hill-shaded SRTM-DEMs (unedited at present)
- Find out what archived DEM data is available for anywhere (e.g. NASA ASTER, courtesy of EDC) to fill gaps in SRTM DEMs
- Explore change (e.g. Landsat 5 to 7) using transparency and flicker and context (e.g. rivers, transportation networks) including SRTM-derived water features
- Interactive exploration of geographical relationships at the continental and global scale (e.g. sea-level rise impact of global population)
- http://iceds.ge.ucl.ac.uk

# Recommendations Agreed at Nov05 CEOS Plenary: TMSG

- Background: It has previously been agreed that spaceborne DEMs will be used preferentially for georadiometric processing of other EO data products. The existence of ACE and SRTM global DEM products is acknowledged. Current georadiometric processing at NASA uses non-EO data sources of dubious quality containing many artifacts. Current georadiometric processing at ESA uses an unvalidated DEM (GETASSE30)
- WGCV Requirement: Spaceborne DEMs should only be used for georadiometric processing if and only if their errors and artifacts have been fully characterised.
- Recommendation: CEOS recommends member space agencies evaluate the impact of using different sources, especially space-based DEMs for georadiometric processing of EO data products. CEOS further recommends that quantitative evaluation of spaceborne DEM products be performed and published as part of any future web infrastructure for validation.
- WGCV Follow-up Activities: TMSG offer to provide, with suitable resourcing, the error characterisation required of these spaceborne DEMs as well as examples of "Known Issues" with downstream products caused by errors in the DEMs used for georadiometric processing. Has there been any progress since 12/05 especially with regard to resourcing?