CEOS-WGCV38 Terrain Mapping Sub-group: Current Status and GEO IN-02-C2.1 report

Jan-Peter Muller

j.muller@ucl.ac.uk

Point-of-Contact, GEOSS Task IN-02

Chairperson, CEOS-WGCV Sub-group on Terrain mapping from satellites

Chairperson, ISPRS Commission IV WG on "Global DEM Interoperability"

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 UK Space Agency*

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 current space assets.**

TMSG Modus Operandi

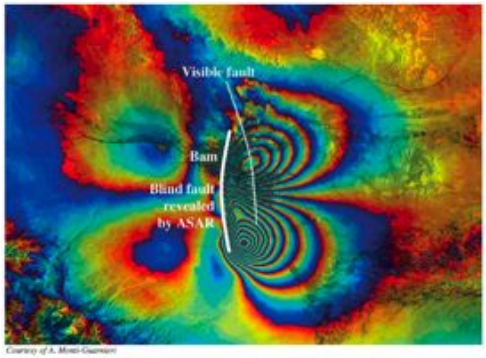
- Terrain mapping SG linked to ISPRS IV/3 on "Global DEM interoperability" and GEO task IN-02-C2.1 on "Global DEM"
- Annual technical workshops as part of an international conference
  - ISPRS Commission IV Symposium, Orlando, FL, 16-18 November 2010
  - 2011 symposium had to be abandoned due to Japanese tsunami
  - Special session at ISPRS Congress, Melbourne, 26 August – 2 September 2012
  - Invited talk & sessions at ISPRS Comm.IV Symposium, Suzhou, 18-20 May 2014
  - Planned invited sessions at IGARSS 2015 in Milan, Italy, 26-31 July 2014
- News announcements as and when there is relevant news (included news on the release of the SRTM v3, TanDEM-X AO in December 2013)
- Emails to collect inputs for WGCV #38 (59 on email list, 5 responses in total)
- Everything done on a "best efforts" basis with minimal funding so limited ambitions at present to meet specific objectives
- JPM continuing in role as Chair until he finds replacement. Exit strategy under discussion with UK Space Agency and able to provide some support.
- Key goals are the generation of higher spatial resolution spaceborne DEMs (and bathymetric DEMs) and derived DTMs for next generation sensors
- Keen to move forward with studying impacts of DEM uncertainties on derived LPV, IVOS and SAR products

Overview

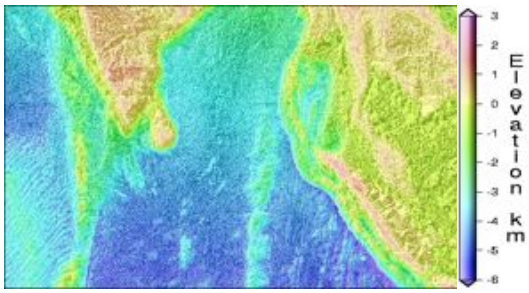
- Why does GEO need global topography/bathymmetry?
- Current State-of-the-art in DEM production & quality assessment
  - Status of 30m ASTER GDEM (provided by Mike Abrams, JPL)
  - Status of 5m "ALOS World 3D" (AW3D) (provided by Takeo Tadono, JAXA)
  - President Obama release of 1 arc-second SRTM DEMs (material provided by Bob Crippen & Mike Kobrick, JPL)
  - Preliminary assessment of TanDEM-X i-DEM over CEOS-WGCV test site
- Status of tasks in IN-02-C2.1 Global DEM
- Forward Look – collaboration between SGs

Why does GEO need global topography/ bathymmetry?

- ***Global DEM required for 6 of the 9 societal benefit areas identified by the Implementation Plan of GEOSS 2005-2015, and for 2015-2025***
- ***Natural disasters all require detailed knowledge of topography***
  - ***either directly for volcanic dome monitoring, flood inundation areal predictions, landslides***
  - ***or for downstream EO processing, e.g. InSAR for earthquake monitoring and possible prediction***
- ***Poor bathymetric and topography knowledge hinders tsunami forecasts***
- ***Tsunami a main spur for GEO implementation***



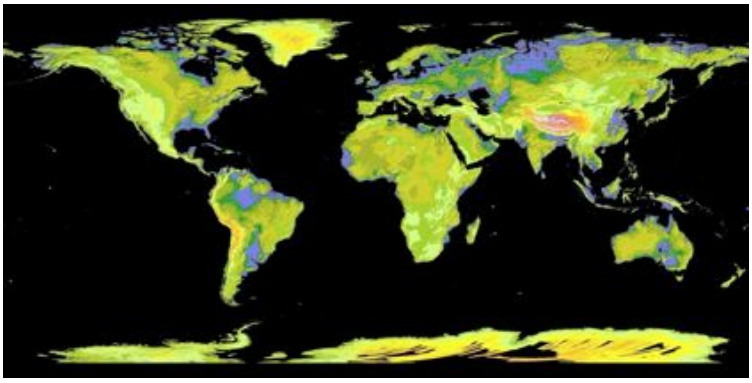
30m height "flood-fill" based on SRTM-DTED1® 3" (≈90m)



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

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
Global Digital Elevation Model (GDEM) Version 3

- Global – 83N to 83S– 30m DEM available free to all users
- Version 1 released June 2009, Version 2 released October 2011
- 30 million 1x1 degree tiles distributed
- Version 3 planned for release Fall 2015
  - Will include land-water mask
  - Will include data plane identifying water bodies as ocean, lake or river
  - Further removal of artifacts
  - Addition of 3 years of stereo data to fill in holes over perennially cloudy areas



Precise Global Digital 3D Map "ALOS World 3D" (AW3D)

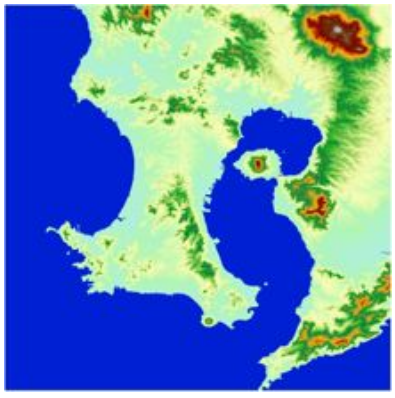
New Global DEM Dataset Generation by ALOS PRISM

September 30, 2014

Takeo Tadono
Earth Observation Research Center (EORC)
Japan Aerospace Exploration Agency (JAXA)
tadono.takeo@jaxa.jp

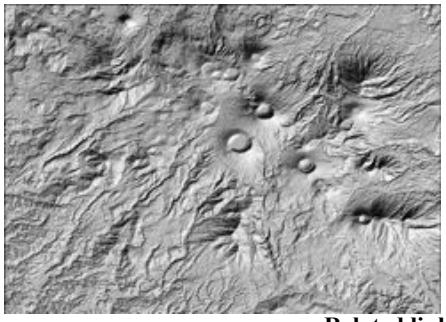
"ALOS World 3D" (AW3D)

The Japan Aerospace Exploration Agency (JAXA) is starting to process the precise global digital 3D map using some 3 million data images acquired by the Panchromatic Remote sensing Instrument for Stereo Mapping (PRISM) onboard the Advanced Land Observing Satellite *"DAICHI"* (ALOS).



The digital 3D map consists of a DEM (or DSM) and ortho-rectified images (ORI) that indicate geolocation. DEM is compiled this time has a five meters in spatial resolution with five meters height accuracy (RMSE) that enables us to express land terrain all over the world. Hence its strong character will prove useful in various areas including mapping, damage prediction of a natural disaster, water resource research etc.

The global 3D map processing will be completed by March 2016. JAXA will commission the compiling work, and service provision to NTT DATA Corporation and Remote Sensing Technology Center of Japan (RESTEC).



In order to popularize the utilization of the 3D map data, JAXA is also preparing global DEM with lower spatial resolution (of about 30 meters under the current plan) to publish it as soon as it is ready. It will be available free of charge for any users. We expect that the 3D map will contribute to the expansion of satellite data utilizations and the industrial promotion, science and research activities as well as the Group on Earth Observations (GEO).

Related links
JAXA AW3D: http://www.eorc.jaxa.jp/ALOS/en/aw3d/index_e.htm
AW3D NTT DATA and RESTEC: http://alos-world3d.jp/en/index.html
Sample movies of the digital 3D map: http://www.youtube.com/watch?v=pZg78PXnlQc

Advanced Land Observing Satellite (ALOS, "DAICHI")

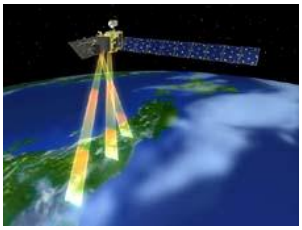
✓ **Operation**

24 Jan. 2006 by H-2A Rocket #8
12 May 2011 Mission ended
~22 Apr. 2011: Low Load Mode (LLM)
> 1,934 days=**5.3 years > 12 mil. scenes**

✓ **Objectives**

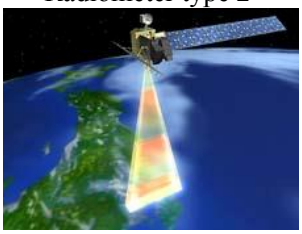
- Cartography (1/25,000 scale)
- Regional environmental monitoring
- Disaster monitoring, *etc.*

PRISM
Panchromatic Remote sensing Instrument for Stereo Mapping



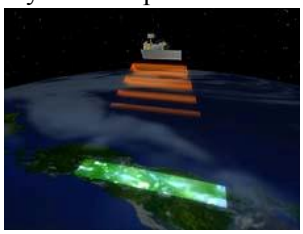
PRISM can acquire **triplet stereo** imageries by nadir-, forward-, and backward-radiometers with **2.5 m spatial resolution in 35 km swath**.

AVNIR-2
Advanced Visible and Near-Infrared Radiometer type 2



AVNIR-2 can observe with **10 m resolution in 70 km swath**, and it can be changed the observation area by pointing capability within +/-44 deg. in across track.

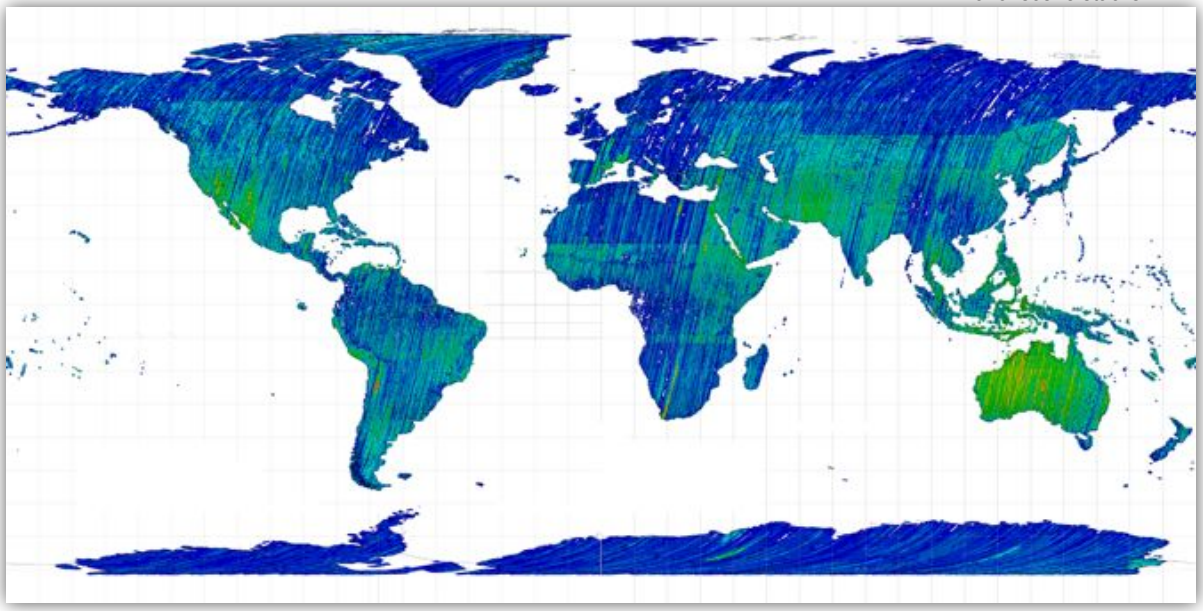
PALSAR
Phased Array type L-band Synthetic Aperture Radar



PALSAR can acquire the data in not only daytime but also nighttime as well as cloudy and rainy whether conditions.

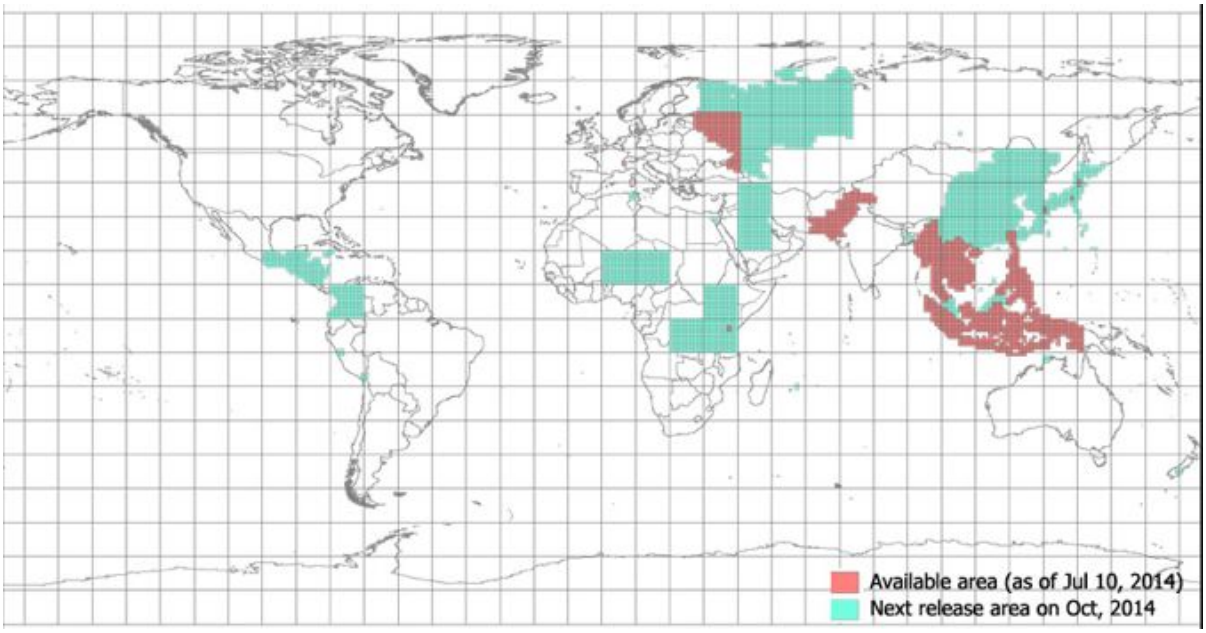
PRISM Data Acquisition Result

- **Global archive of PRISM stereo scenes (35km x 35km)**
  - Over 1 million stereo or triplet sets with cloud level < 30 % / scene in global
  - There are still remaining cloud covered areas



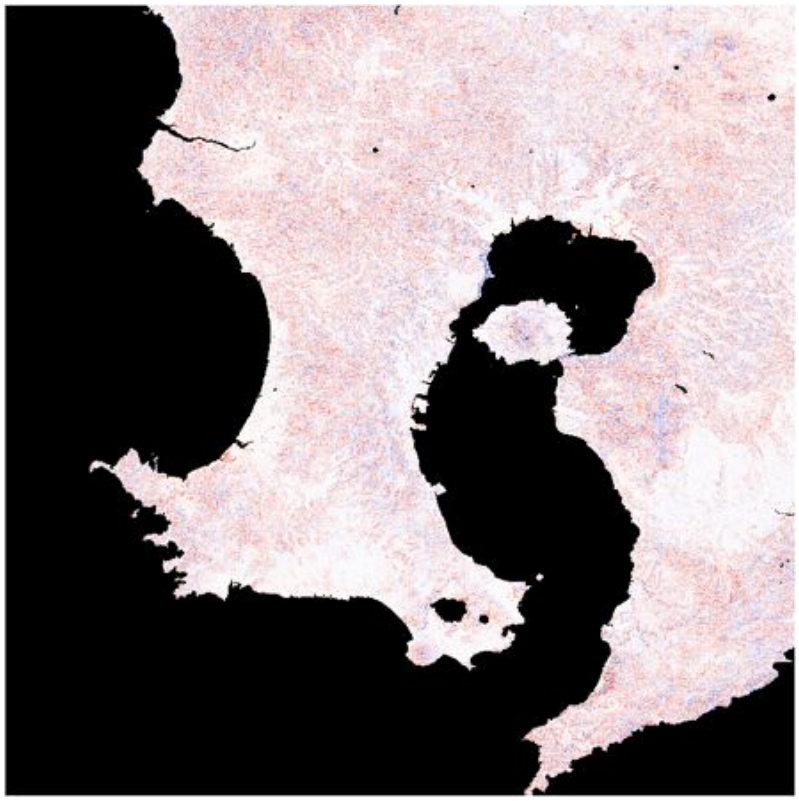
Distribution of PRISM stereo scene archives (cloud level < 30%)

Processing Status of AW3D Product



Processing status of AW3D 5m DEM tiles (as of July 10, 2014)

Validation of AW3D 5m DSM



Difference image (PRISM/DSM minus SRTM Ver.3 3-arcsec)

N031E130

Stats of height validation with 289 CPs

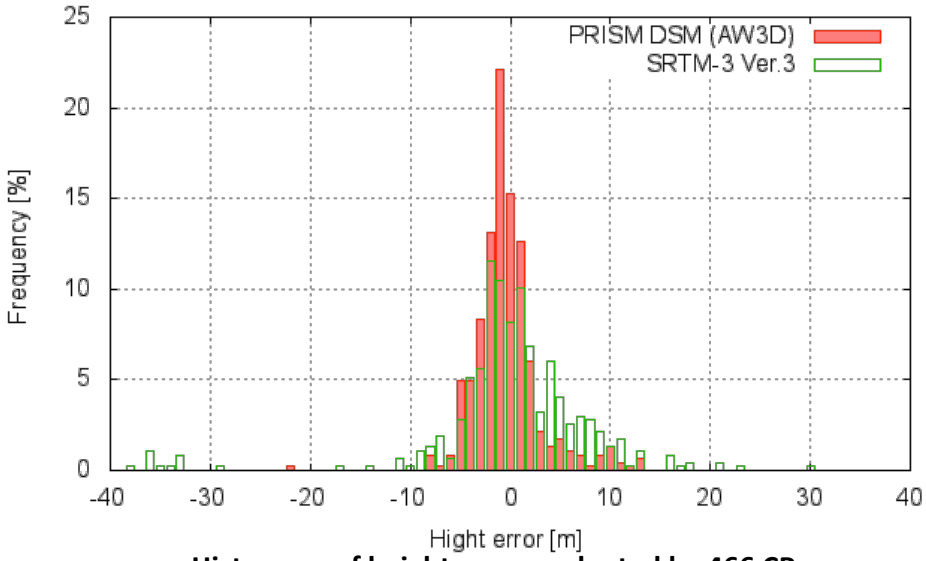
Dataset	Ave [m]	STDEV [m]	RMSE [m]
AW3D	-1.69	2.04	2.65
SRTM v.3	-1.68	8.23	8.39

Note
- No major issues
- Observation time differences (*i.e.* forest and vegetation changes)

■ Masks due to clouds, in-land water, and sea areas

Difference
+50m
+/-0m
-50m

Validation Result of AW3D 5m DSM



Histogram of height error evaluated by 466 CPs

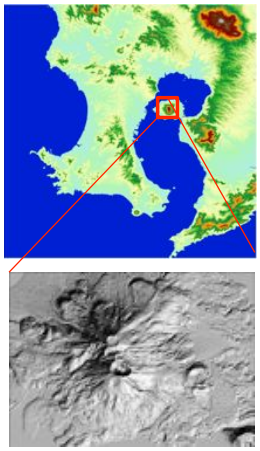
Stats of height validation with 466 CPs in five tiles

Dataset	Ave [m]	STDEV [m]	RMSE [m]
AW3D	-0.43	3.38	3.40
SRTM v.3*	0.11	7.99	7.98

* reference

Conclusions
- Data processing status is on schedule
- The height accuracy achieved 3.40 m (RMSE)
- The remaining cloud masks are issues

Specification of "ALOS World 3D" Product



DSM (N031E130)
5 m spacing

Contents and definitions of "AW3D" Dataset (Level 1)

	Dataset Name	Contents
1	Precise DSM Dataset	Area: Global land area within 82 deg. of N/S latitudes Horizontal spacing: 0.15arcsec (approx. 5 m) Management: 1 deg. tile of lat/long, approx. 22,000 tiles in total Contents: – DSM file (DSM): 5 m (RMSE) in height accuracy – Mask file (MSK) – Stack number file (STK) – Header information (HDR) – Scene list (LST) – Quality assurance information (QAI)
2	ORI Dataset	Ortho rectified image of PRISM nadir-looking Horizontal spacing: 0.075arcsec (approx. 2.5 m) Management: Individual scene unit Contents: – Ortho rectified image for nadir (ORI): 5 m (RMSE) in geolocation accuracy – Header information (OHR)
3	Correlation Coefficient Image (CCI)*	The averaged correlation coefficient distribution image of available stereo pairs in scene-bases. Definition: The index shows image matching quality *e.g.* a correlation coefficient for the aerial correlation matching.

* An intermediate product

- A low-resolution DSM dataset (30 m spacing, TBD) with same height accuracy (5 m) will be opened to the public free of charge as soon as it is ready.

"ALOS World 3D" Product Level

	Level 1	Level 2	Level 3
Type	DSM Digital Surface Model	DSM Digital Surface Model	DTM Digital Terrain model
Coverage	Global (land)		
Unit	Tile (1 degree x 1 degree) Mesh (0.2 degree x 0.2 degree) AOI*	AOI*	AOI*
Resolution	5m (Please ask for other resolution)		
Horizontal Accuracy	5m (RMSE)		
Vertical Accuracy	5m (RMSE)		
Coordinate system	Geographic Lat/Lon (ITRF97[GRS80]) (Please ask for UTM)		
Format	GeoTIFF		
Image files	DSM (elevation in meter, 16bit integer), Mask image	DSM (elevation in meter, 16bit integer**), Mask image	TBD
Height type	Ellipsoid height	Ellipsoid height or Elevation (height above sea level)	Ellipsoid height or Elevation (height above sea level)
Minimum sales area (AOI)	400km^2	400km^2	400km^2

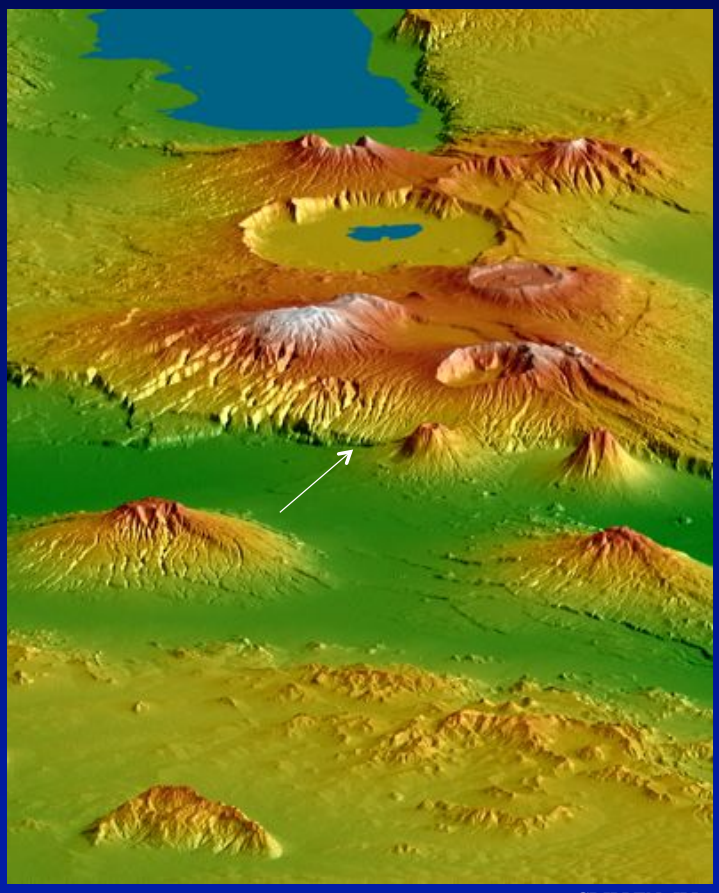
***: Single polygon with 4 or more vertices. Each side: 10km or more. Each angle: 90degrees or more.**
****: Please ask for float.**

- Sample DSM datasets are available on **http://alos-world3d.jp/en/index.html**
- Contact by E-mail to: **data@restec.or.jp**

Release of (most of) SRTM 30m elevation data for Africa

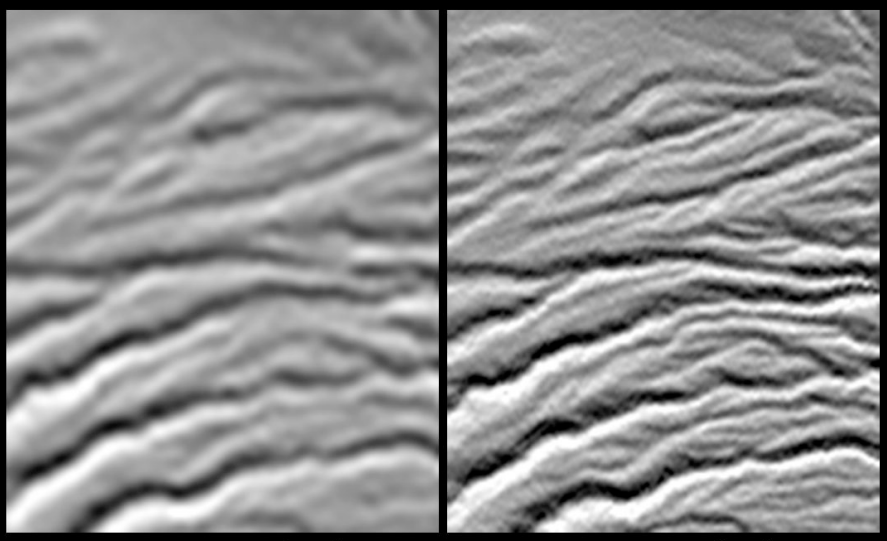
90m versus 30m comparison site (next slide): Crater Highlands, Tanzania

JPL Photojournal Image
PIA06669



CRIPPEN, JPL

Shuttle Radar Topography Mission (SRTM)
Digital Elevation Model (DEM)
Shaded Relief Images



90-meter pixels 30-meter pixels

Stream erosion patterns,
Crater Highlands, Tanzania

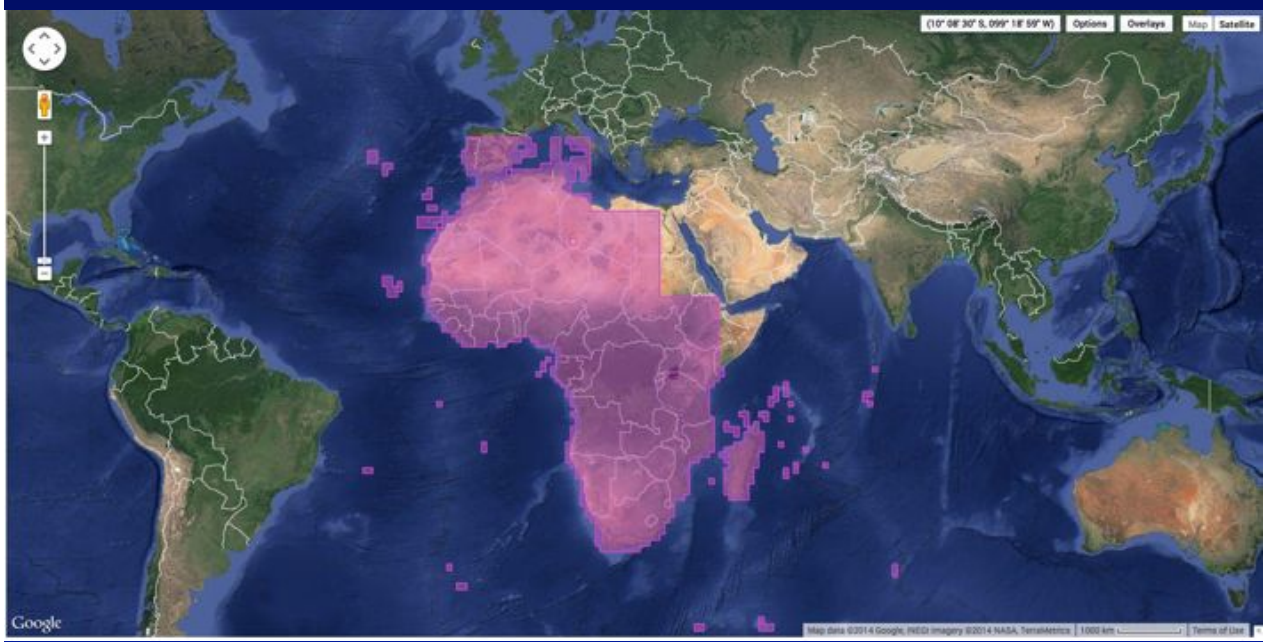
N

Area Size = 5220 x 4320 meters

Location = South 2.93 East 35.92

CRIPPEN, JPL

Coverage of SRTM3 release



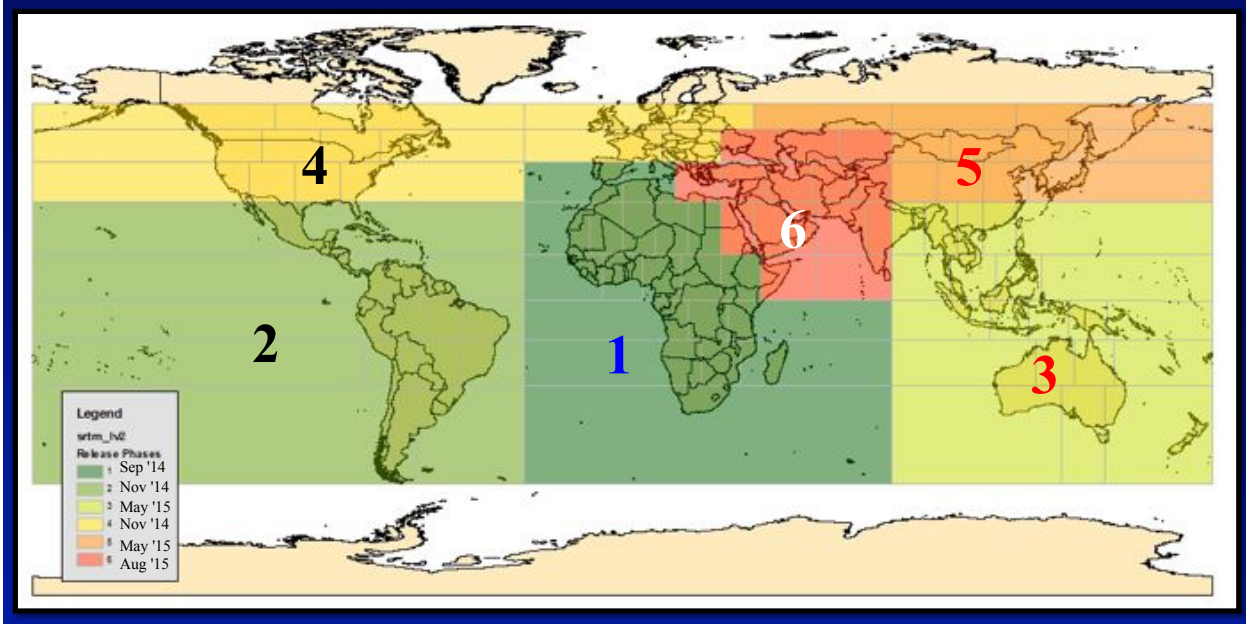
SRTM 1” (≈30m) first data release ordered by President Obama and announced at the World Climate Summit at the UN on 23.9.14

Relevant text from White house

Releasing Powerful New Data to Enable Planning for Resilience

To empower local authorities to better plan for the impacts of severe environmental changes such as drought, glacial retreat, flooding, landslides, coastal storm surges, agricultural stresses, and challenges concerning public health, today the National Aeronautics and Space Administration (NASA), the National Geospatial-intelligence Agency (NGA), and the U.S. Geological Survey (USGS), as part of an ongoing commitment to open data and international data sharing through the inter-governmental Group on Earth Observations, will release a collection of higher-resolution elevation datasets for Africa. Datasets covering other global regions will be made available within one year, with the next release of data providing more accurate elevation information for Mexico, Central and South America, and the Caribbean. Until now, elevation data for Africa were freely and publicly available only at 90-meter resolution. The datasets being released today, and during the course of the next year —which are based on data collected by sensors designed by an international partnership and carried on the U.S. Space Shuttle—resolve to 30-meters and will be used worldwide to improve environmental monitoring, climate change research including sea-level rise impact assessments, and local decision support. These datasets are being made available via a user-friendly interface on USGS's Earth Explorer website. With a commitment from the Secure World Foundation, and in collaboration with the Committee on Earth Observation Satellites, USGS, NOAA, and NASA plan to offer online training and regional workshops to further enable users to take advantage of these data resources.

SRTM2 Release Phases 1 - 6



TanDEM-X: Science Activities

Irena Hajnsek[1/2], Manfred Zink[1] and Thomas Busche[1]

1 Microwaves and Radar Institute, DLR
2 Institute of Environmental Engineering, ETH

Oberpfaffenhofen, Feb 2014

Announcements of Opportunity

Science Opportunities for the following products:

Announcements (release date, closing date)

- **Intermediate DEM** (from first global coverage, difficult terrain excluded, for selected regions only) **5.12.13, 14.3.14**
- **CoSSC** from the global DEM acquisition **5.12.13, 14.3.14**

- **TanDEM-X DEM** **Summer 2014??**

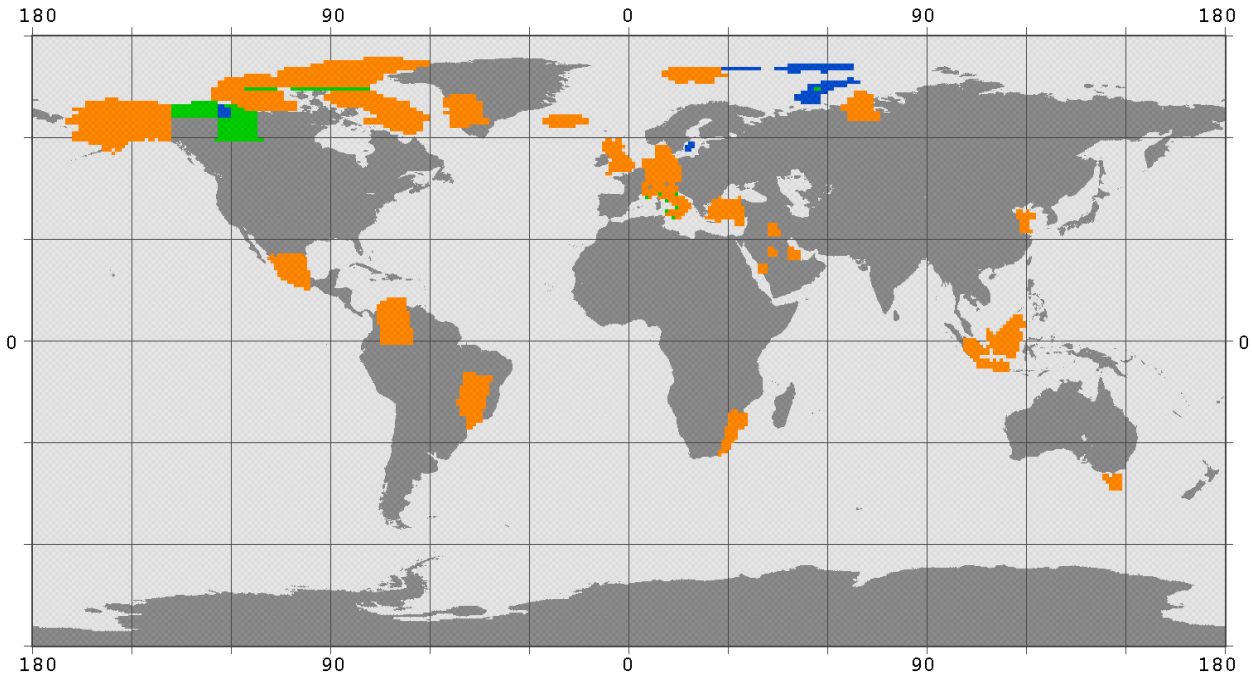
DEM Products for Scientific Use
Intermediate DEM (no global coverage)

DEM Product	Spatial Resolution Absolute	Horizontal Accuracy CE90	Absolute Vertical Accuracy LE90	Relative Vertical Accuracy
IDEM (intermediate DEM)	~12m (0.4 arcsec @ equator	<10m	<10m	Not specified
IDEM (1 arcsec)	~30 m (1 arcsec @ equator)	<10m	<10m	Not specified
IDEM (3 arcsec)	~90 m (3 arcsec @ equator)	<10m	<10m	Not specified

DLR

Mon Jul 8 05:51:11 2013

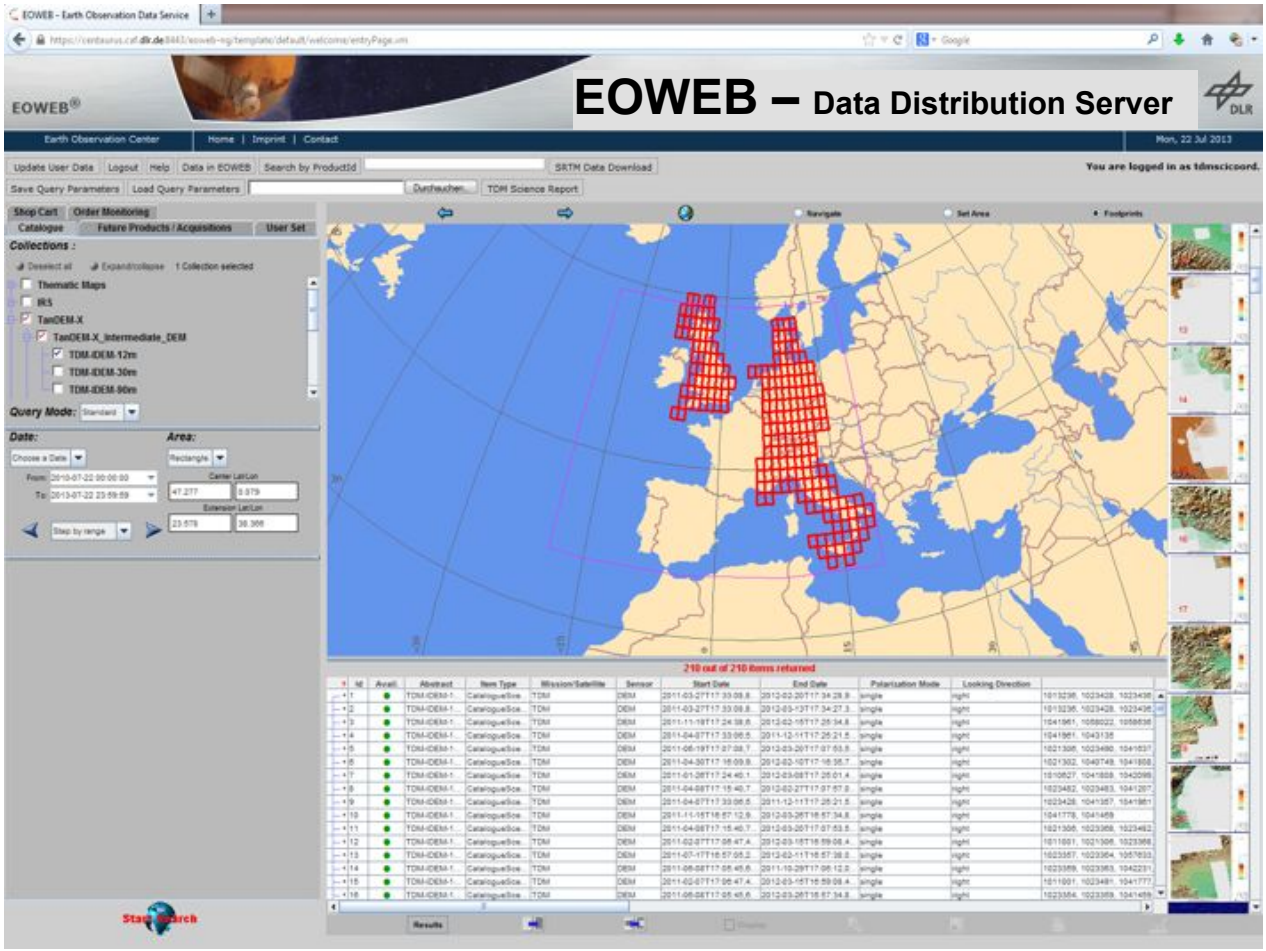
Intermediate DEM (IDEM): Distribution



Investigated area: ul-lr lon/lat -180 90 - 180 -90

Found cells: 2697
Total kbytes: 1517837008
Covered skm: 12656286.0

cell created
cell updated
cell archived
cell reloaded
cell deleted



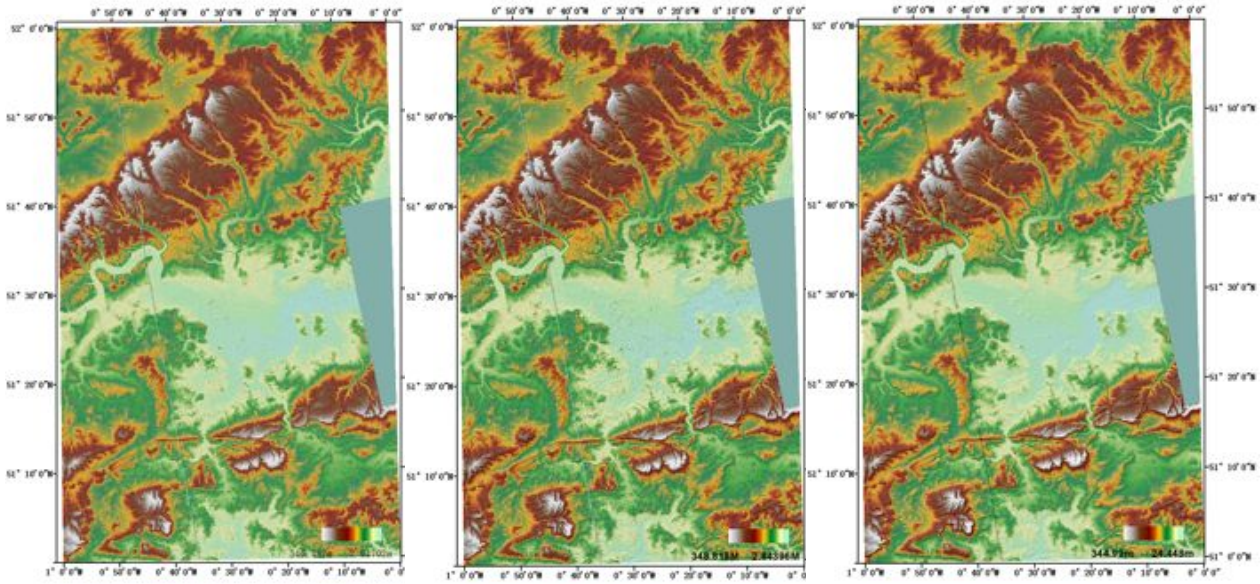
Preliminary assessment of TanDEM-X i-DEM over CEOS-WGCV test site

Jan-Peter Muller, Luyi Sun, Lang Feng

September 2014

MSSL/DEPARTMENT OF SPACE & CLIMATE PHYSICS

TDX IDEM, London, UK (N51W001)



12m TDX IDEM

30m TDX IDEM produced from 12m IDEM by averaging

90m TDX IDEM

Height Difference on water body compared with 30m BlueSky DTM – statistics before and after surface matching

Statistics of height difference on water body between 12m, 30m, 90m TDX and the reference BlueSky DTM before surface matching

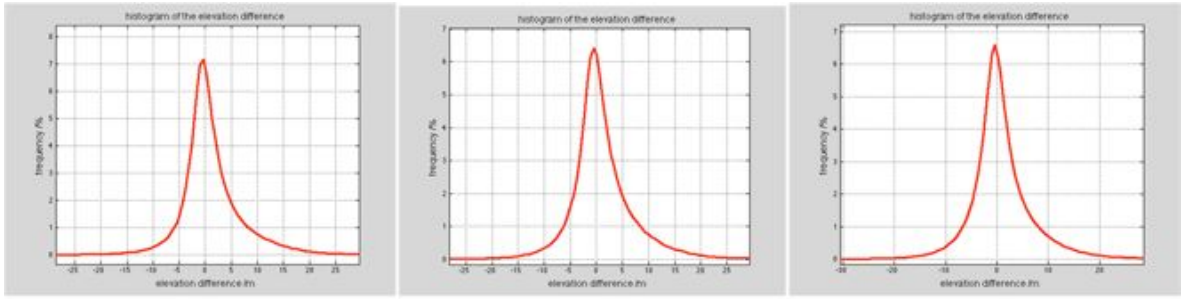
	12m TDX - BlueSky	30m TDX - BlueSky	90m TDX - Bluesky
Minimum (m)	0	0	0
Maximum (m)	64.7142	63.6962	60.9765
Mean (m)	47.5184	47.6065	47.5147
Standard deviation (m)	7.7035	7.2998	7.3462

Statistics of height difference on water body between 12m, 30m, 90m TDX and the reference BlueSky DTM after surface matching

	12m TDX - BlueSky	30m TDX - BlueSky	90m TDX - Bluesky
Minimum (m)	-21	-20.9702	-9.243
Maximum (m)	16.571	13.9416	14.0642
Mean (m)	0.72662	0.52334	0.45149
Standard deviation (m)	3.7724	3.4422	3.141

MSSL/DEPARTMENT OF SPACE & CLIMATE PHYSICS

Height Difference compared with 30m BlueSky DTM- histograms & statistics



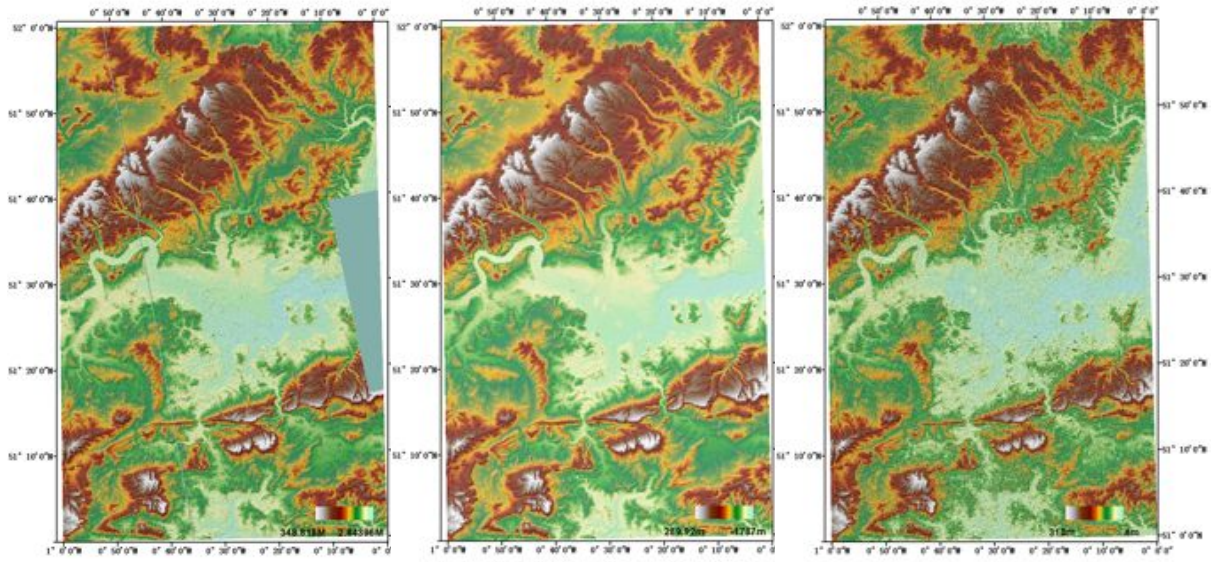
(a)12m TDX - 30m Bluesky (b) 30m TDX - 30m Bluesky (c) 90m TDX – 30m Bluesky

Histograms of height difference between 12m, 30m, 90m TDX and the reference BlueSky DTM

Table 1. Statistics of height difference

	12m TDX – 30m Bluesky	30m TDX – 30m Bluesky	90m TDX – 30m BlueSky
Minimum (m)	-28.7411	-27.9271	-30.4382
Maximum (m)	35.9167	35.1255	35.24
Mean (m)	1.178	1.0542	0.83294
Standard deviation (m)	6.0226	6.0836	6.1844

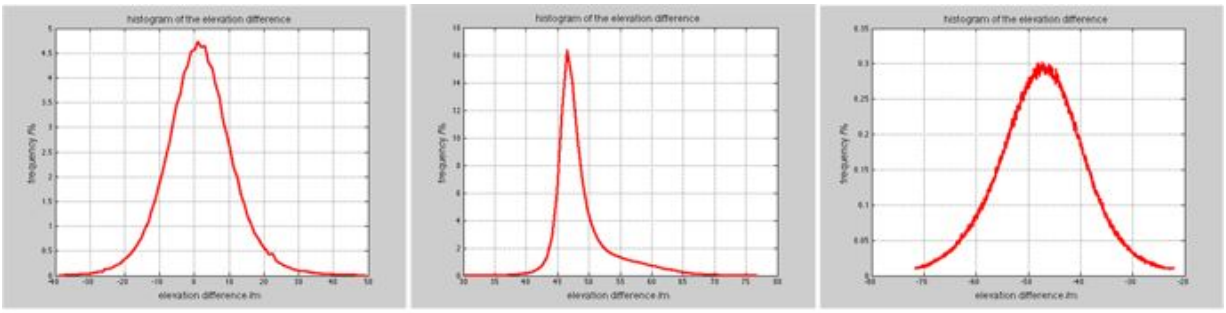
Comparison between ASTER GDEM v2, TDX IDEM and BlueSky DTM over London, UK (N51W001)



30m TDX IDEM | 30m BlueSky DTM | 30m ASTER GDEM v2

TDX IDEM and ASTER GDEM are re-projected to OSGB36 British National Grid.

Height Difference - histograms & statistics
BEFORE co-alignment using surface matching



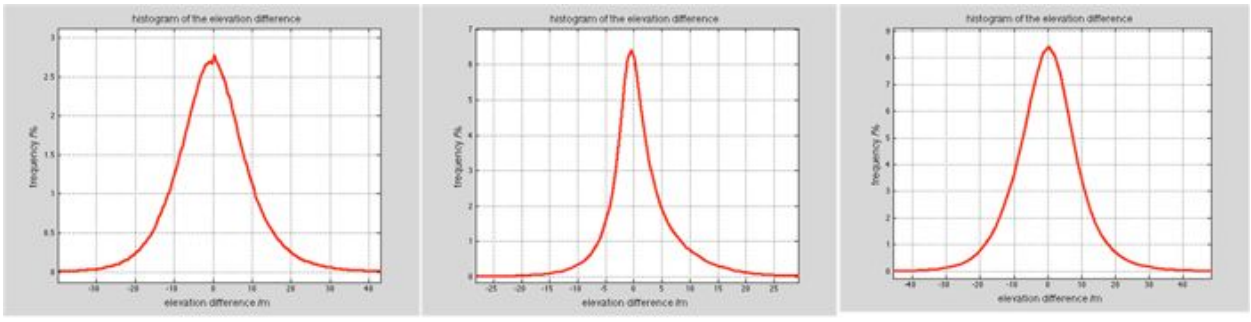
(a) 30m ASTER - 30m Bluesky (b) 30m TDX - 30m Bluesky (c) 30m ASTER - 30m TDX

Histograms of height difference between 30m ASTER GDEM, 30m TDX IDEM and 30m BlueSky DTM, all using the latter as reference DEM/DTM

Table 1. Statistics of height difference

	30m ASTER – 30m BlueSky	30m TDX – 30m BlueSky	30m ASTER – 30m TDX
Minimum (m)	-38.76	0	-71.6033
Maximum (m)	49.04	76.6161	0
Mean (m)	1.5099	48.7182	-46.391
Standard deviation (m)	9.7818	4.9713	10.7292

Height Difference - histograms & statistics
after surface matching



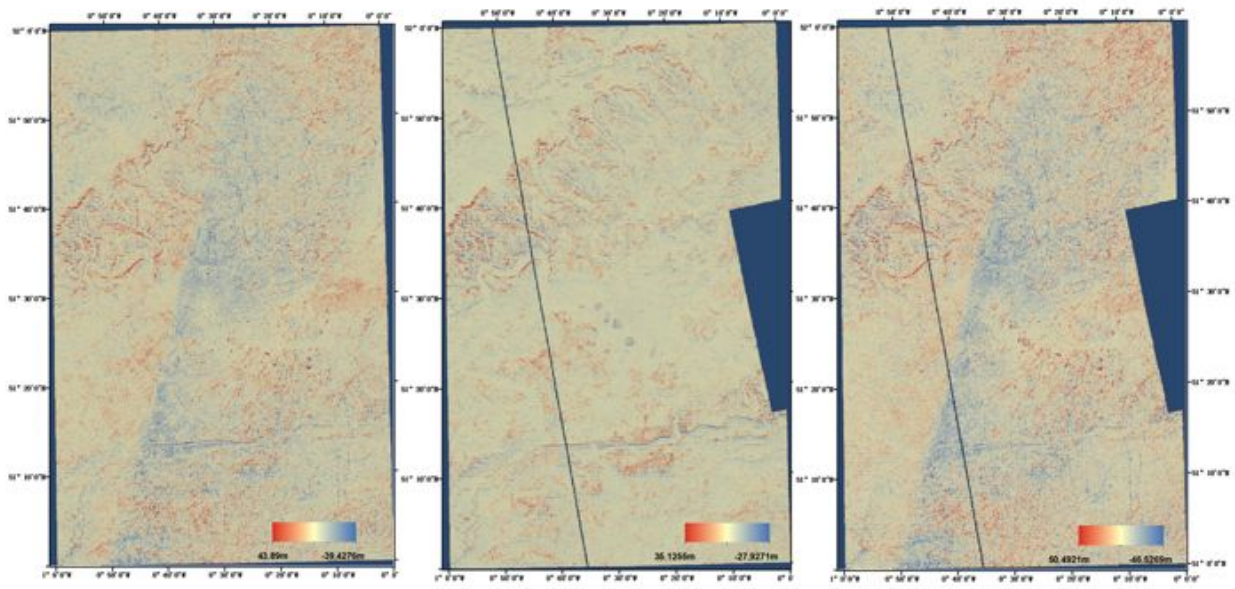
(a) 30m ASTER - 30m Bluesky (b) 30m TDX - 30m Bluesky (c) 30m ASTER - 30m TDX

Histograms of height difference between 30m ASTER GDEM, 30m TDX IDEM and 30m BlueSky DTM, all using the latter as reference DEM/DTM

Table 1. Statistics of height difference

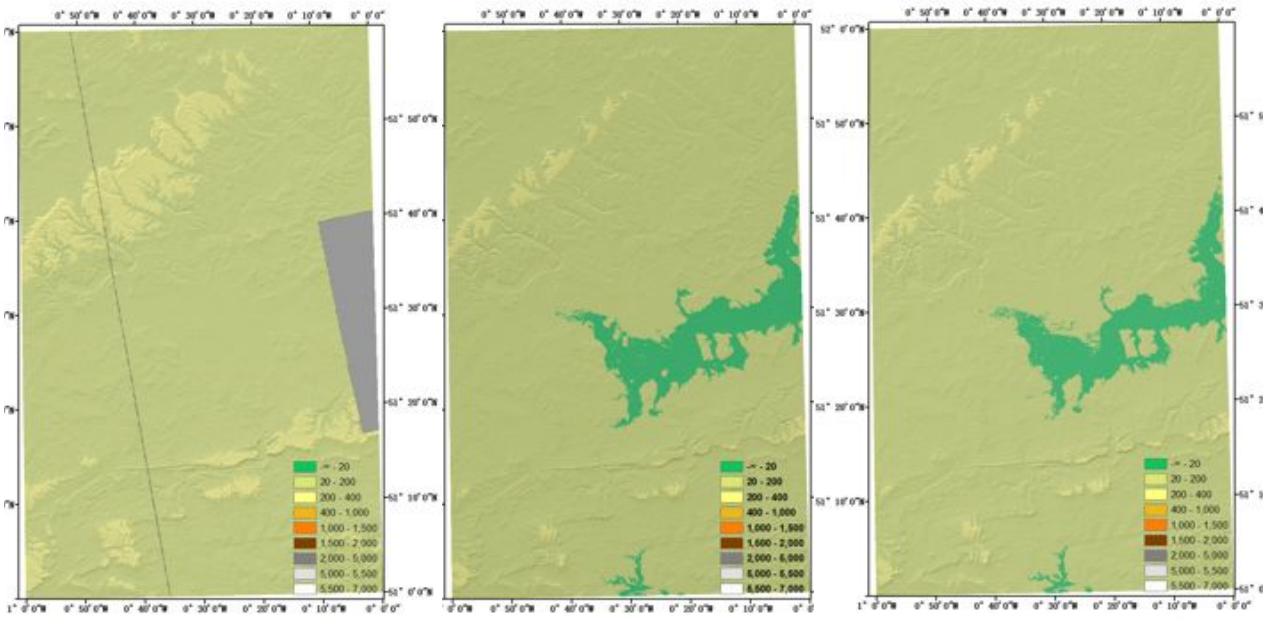
	ASTER - BlueSky	TDX - BlueSky	ASTER - TDX
Minimum (m)	-39.4276	-27.9271	-46.5269
Maximum (m)	43.89	35.1255	50.4921
Mean (m)	0.0064334	1.0542	0.094232
Standard deviation (m)	9.8377	6.0836	9.9626

Height Difference maps after surface matching



(a) 30m ASTER - 30m Bluesky (b) 30m TDX - 30m Bluesky (c) 30m ASTER - 30m TDX

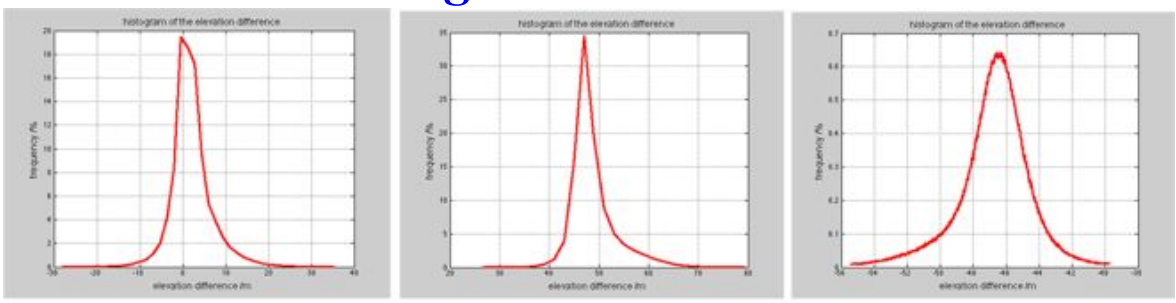
DEMs, London, UK (N51W001)



90m TDX IDEM 30m BlueSky DTM 90m SRTM-C DEM

Thames River doesn't appear on TDX IDEM due to height difference on the water body.

Height Difference before surface matching- histograms & statistics



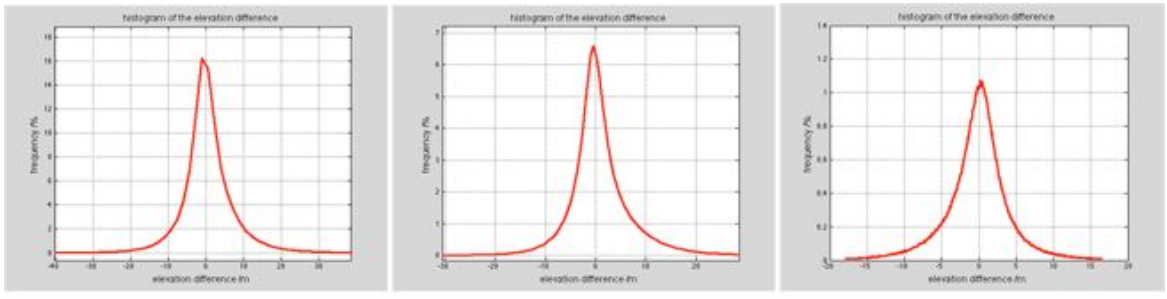
(a) 90m SRTM - 30m Bluesky (b) 90m TDX - 30m Bluesky (c) 90m SRTM - 90m TDX

Histograms of height difference between 90m SRTM-C DEM, 90m TDX IDEM and 30m BlueSky DTM

Table 1. Statistics of height difference

	90m SRTM – 30m BlueSky	90m TDX – 30m BlueSky	90m SRTM – 90m TDX
Minimum (m)	-27.88	0	-55.3804
Maximum (m)	35.04	79.0932	0
Mean (m)	1.9656	48.707	-45.912
Standard deviation (m)	4.9239	4.6935	6.5862

Height Difference AFTER surface matching histograms & statistics



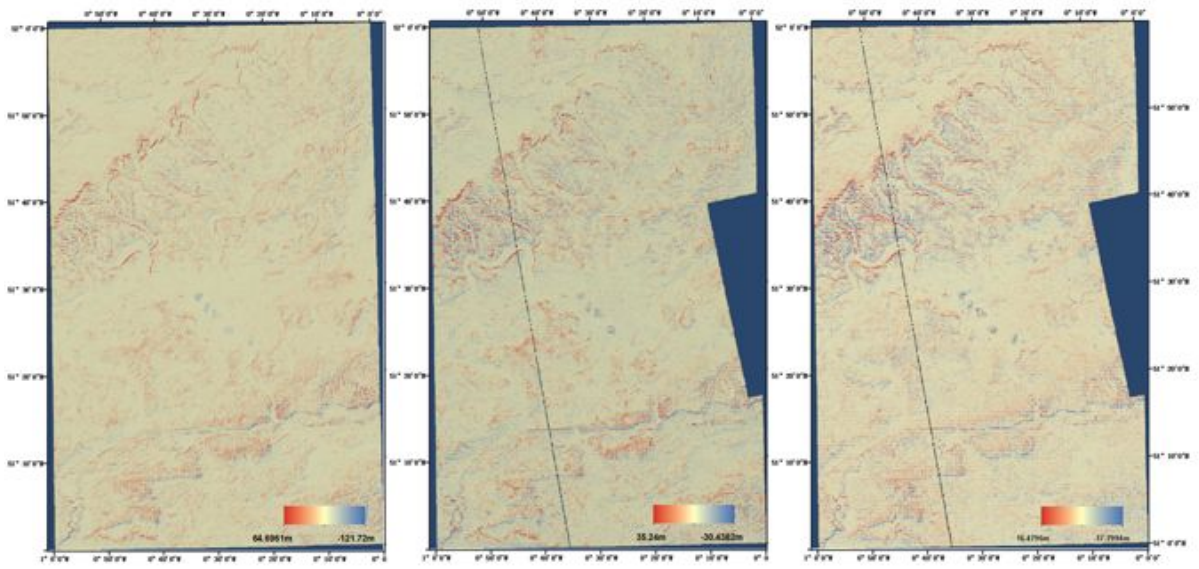
(a) 90m SRTM - 30m Bluesky (b) 90m TDX - 30m Bluesky (c) 90m SRTM - 90m TDX

Histograms of height difference between 90m SRTM-C DEM, 90m TDX IDEM and 30m BlueSky DTM

Table 1. Statistics of height difference

	90m SRTM – 30m BlueSky	90m TDX – 30m BlueSky	90m SRTM – 90m TDX
Minimum (m)	-121.72	-30.4382	-17.7994
Maximum (m)	64.6961	35.24	16.4796
Mean (m)	0.33065	0.83294	-0.21495
Standard deviation (m)	7.7563	6.1844	4.2438

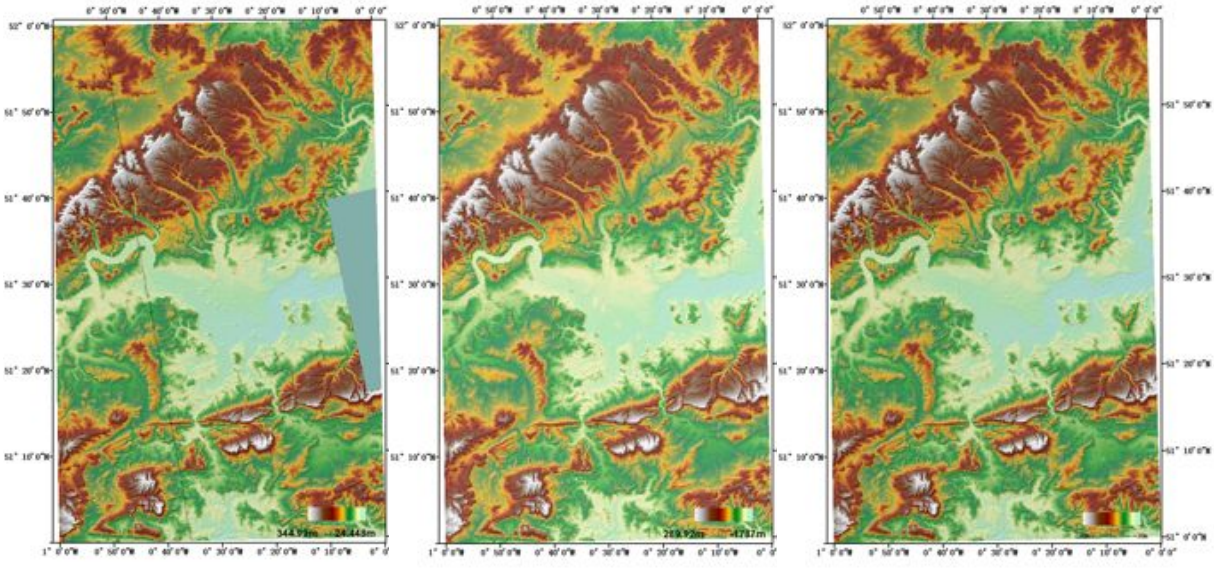
Height Difference maps AFTER surface matching



(a) 90m SRTM - 30m Bluesky (b) 90m TDX - 30m Bluesky (c) 90m SRTM - 90m TDX

N.B. Note the residual planimetric offsets still remaining

Comparison between SRTM-C, TDX IDEM, BlueSky DTM over London, UK (N51W001)

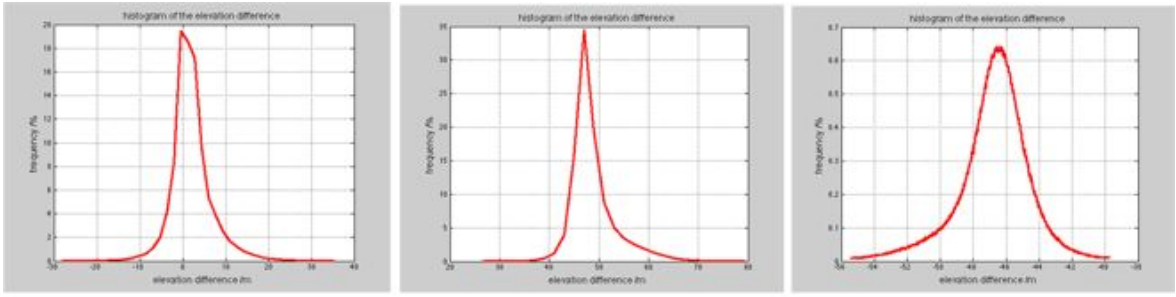


90m TDX IDEM

30m BlueSky DTM

90m SRTM-C DEM

Height Difference before surface matching- histograms & statistics



(a) 90m SRTM - 30m Bluesky (b) 90m TDX - 30m Bluesky (c) 90m SRTM - 90m TDX

Histograms of height difference between 90m SRTM-C DEM, 90m TDX IDEM and 30m BlueSky DTM

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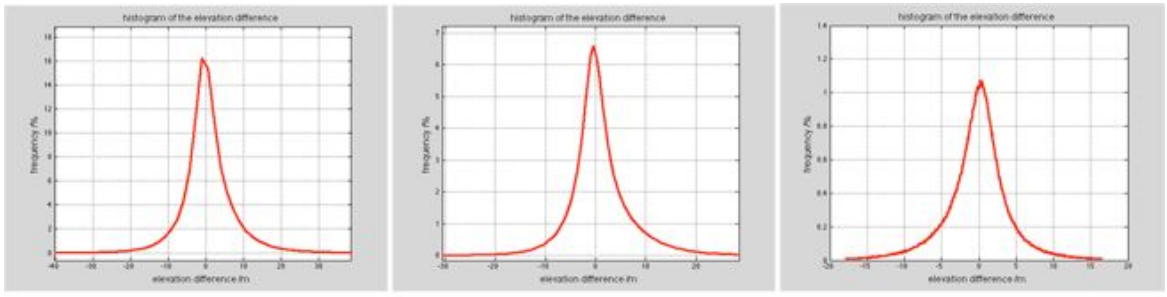
Height Difference after surface matching- histograms & statistics



(a) 90m SRTM - 30m Bluesky (b) 90m TDX - 30m Bluesky (c) 90m SRTM - 90m TDX

Histograms of height difference between 90m SRTM-C DEM, 90m TDX IDEM and 30m BlueSky DTM

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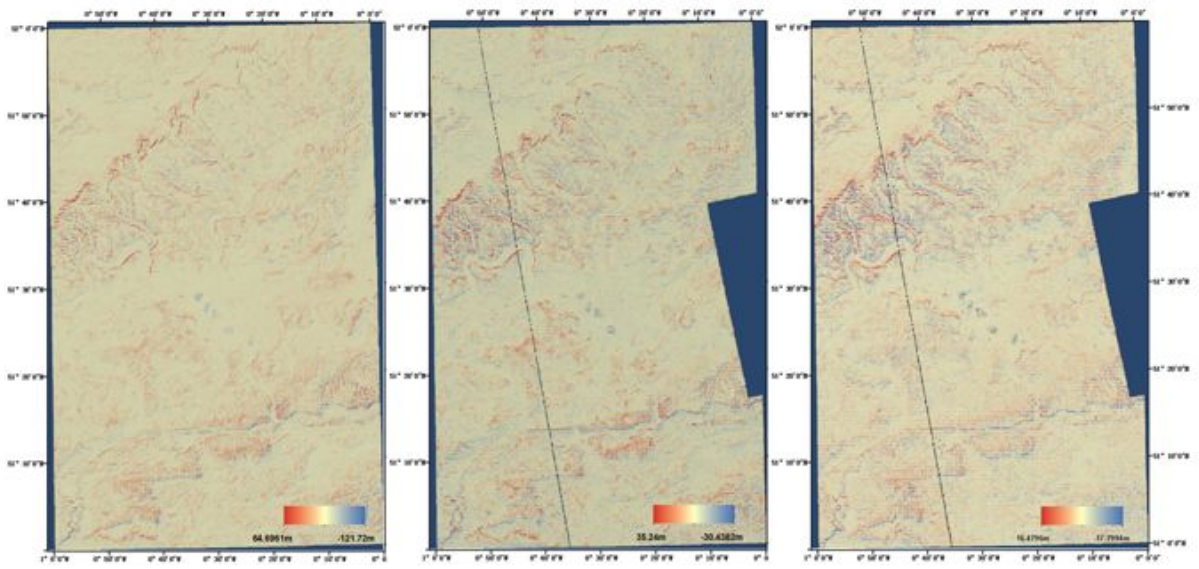
Height Difference maps after surface matching



(a) 90m SRTM - 30m Bluesky (b) 90m TDX - 30m Bluesky (c) 90m SRTM - 90m TDX

GEO Task IN-02: Global Datasets Role for Global DEM

- **IN-02 Earth datasets consist of 2 sub-tasks:**
  - **C1: Advances in Life-cycle Data Management**
  - **C2: Development of Regional/Global Information and Cross-cutting Datasets**
- **IN-02 Point of Contact: Mike Abrams (JPL, ASTER PI)**
- **Proposed on 1-Feb-14 to CEOS Executive Officer, Kerry Sawyer, that activity continue into the next 3 year implementation period under CEOS wing to cover**
  - **2014/15 release of SRTM V2 at 1 arc-second (≈30m)**
  - **≈2015 release of TanDEM-X DEM at 3 arc-seconds (≈90m)**
  - **2015/16 release of ALOS-PRISM DEM at 1 arc-seconds (≈30m)**
  - **2017 release of re-processed NASADEM at 1 arc-seconds (≈30m)**
  - **Unknown dates for creation of bathymetry of continental shelves using SAR & high resolution EO, once support is released**
- **Unsure what happened to this recommendation**

Forward Look – inter SG collaboration

- **TMSG would like to encourage interaction with other SGs, especially LPV, IVOS, SAR and AC**
- **TMSG will develop proposals with other SG chairs to look into collaborative projects and present one or more proposals at the DONM**
- **The primary aim is to quantify**
  - **what is the level of uncertainty that is required for elevation, slope, aspect, planimetry for different application areas**
  - **how "fit for purpose" existing global EO-DEMs are including recommendations for different application areas and whether "bare earth" or observable surface DEMs are acceptable**
  - **how uncertainty characterisation may be employed in retrievals for atmospheric composition, level-1 vicarious calibration, ocean-leaving radiance, snow/ice and land spectral BRDF**