CEOS-WGCV36 Terrain Mapping Sub-group: Current Status and GEO IN-02-C2.1 report

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Stereo Panoramic Camera Science Team Member (ESA EXOMARS)
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ISRIC World Soil Information

*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 SRTM.

TMSG Modus Operandi

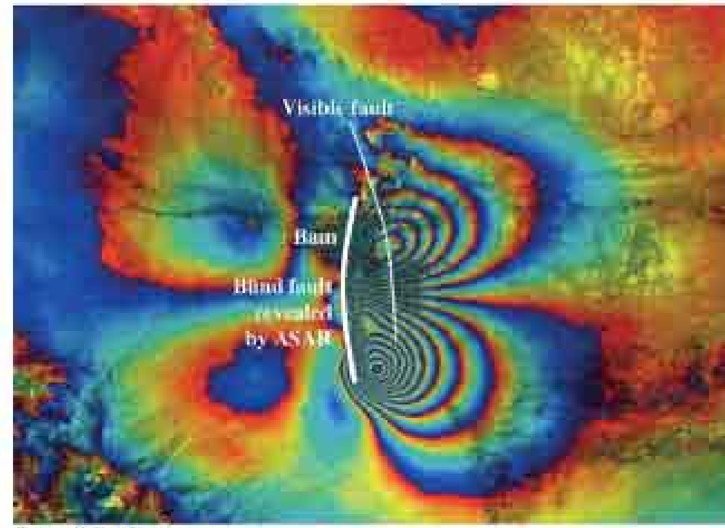
- Terrain mapping SG linked to ISPRS IV/3 on "Global DEM interoperability" and GEO task IN-02-C2.1 on "Global DEM"
- Annual technical workshops as part of an international conference
  - IGARSS09, Cape Town , South Africa, July 2009
  - ISPRS Commission IV Symposium, Orlando, FL, 16-18 November 2010
  - 2011 symposium had to be abandoned due to Japanese tsunami
  - Special session at ISPRS Congress, Melbourne, 26 August – 2 September 2012
- News announcements as and when there is relevant news (e.g. release of the ASTER GDEM v2)
- Emails to collect inputs for WGCV #36 (57 on email list, 9 responses in total)
- Everything done on a "best efforts" basis with minimal funding so limited ambitions at present to meet specific objectives
- JPM planned to step down in 6/2013 after more than 13 years in the post. Hannes Reuter (ISRIC World Soil Information) agreed to become Vice-Chair and has received affirmation/support by Dutch Space Agency. However, there is now some uncertainty as HR moving to EC
- UK Space Agency able to provide partial support for travel. UKSA will be launching new Applications programme in 2013 with possibility of small amounts of funding QA4EO showcase. Mtg on 20.5.13 to discuss

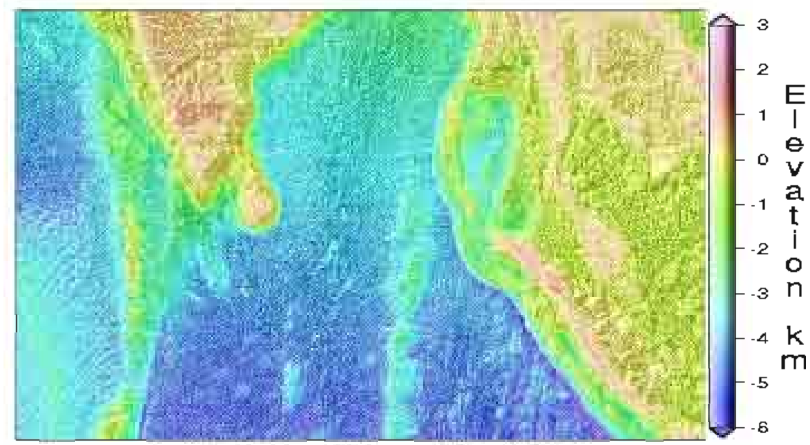
Overview

- Why does GEO need global topography/bathymmetry?
- Current State-of-the-art in DEM production & quality assessment
  - SRTM Version 3 (supplied by B. Crippen, JPL, USA)
  - TanDEM-X DEM generation status (provided by M. Zink, DLR)
  - Greenland Bedrock/Continental shelf bathymetry (supplied by J. Bamber, University of Bristol, UK)
  - A new dataset of Antarctica surface-elevation, ice thickness and bed/continental shelf topography (supplied by P. Fretwell, M. Pritchard, BAS, UK)
  - Euro-Maps 3D – a Transnational, High-Resolution Digital Surface Model based on IRS-3P (supplied by Euromap-GAF, D)
  - National Aerospace Institute of Spain (INTA) report on preparation for TanDEM-X validation activities in Spain (supplied by Enrique Nicolás Gesé & Pablo Sánchez Gámez, INTA, Spain)
- Future mission: ESA BIOMASS of 3D vegetation structure & subsurface bedrock topography
- UN meeting on global DEM harmonisation (report supplied by Vice-Chair H. Reuter, ISRIC)
- QA4EO showcases
- Status of tasks in IN-02-C2.1 Global DEM
- Next steps and recommendations for CEOS Plenary for global topography and bathymetry

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 2005-2015***
- ***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***





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)

GDEM
Filling the Voids of
SRTM NASA Version 3
(Also: the SRTM-GDEM STAR)

Robert E. Crippen
NASA Jet Propulsion Laboratory
Pasadena, California, USA

ASTER Science Team Meeting
Pasadena, California USA
December 2012

~

… Mergers of the SRTM and ASTER GDEM (et al.) global elevation models under NASA's MEaSUREs Program*

2008-2013: "SRTM NASA Version 3"

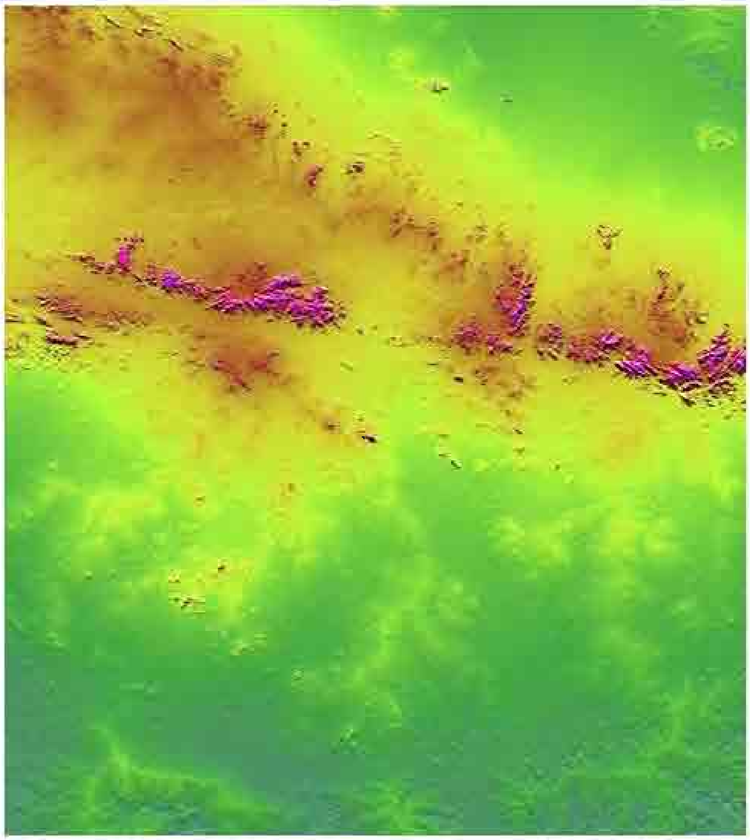
2013-2018: "NASADEM"
2016?

* MEaSUREs:
"Making Earth System Data Records for Use in Research Environments"

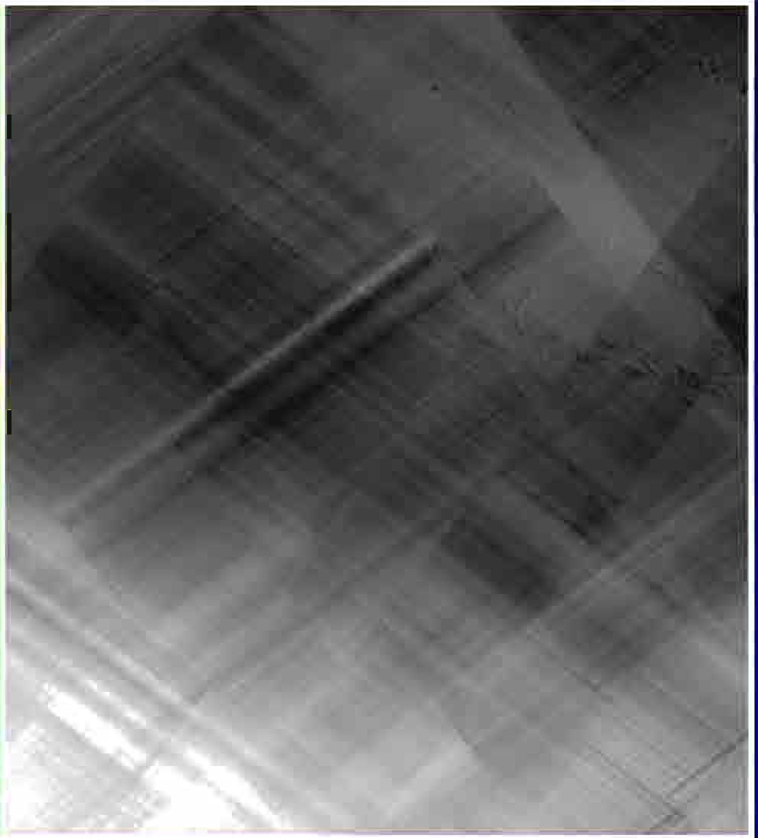
NASADEM: Complete reprocessing of SRTM for fewer voids and better block adjustments.

ICESat Corrections of SRTM:

Derived from Individual Data Takes



SRTM Topography



Composite of Corrections

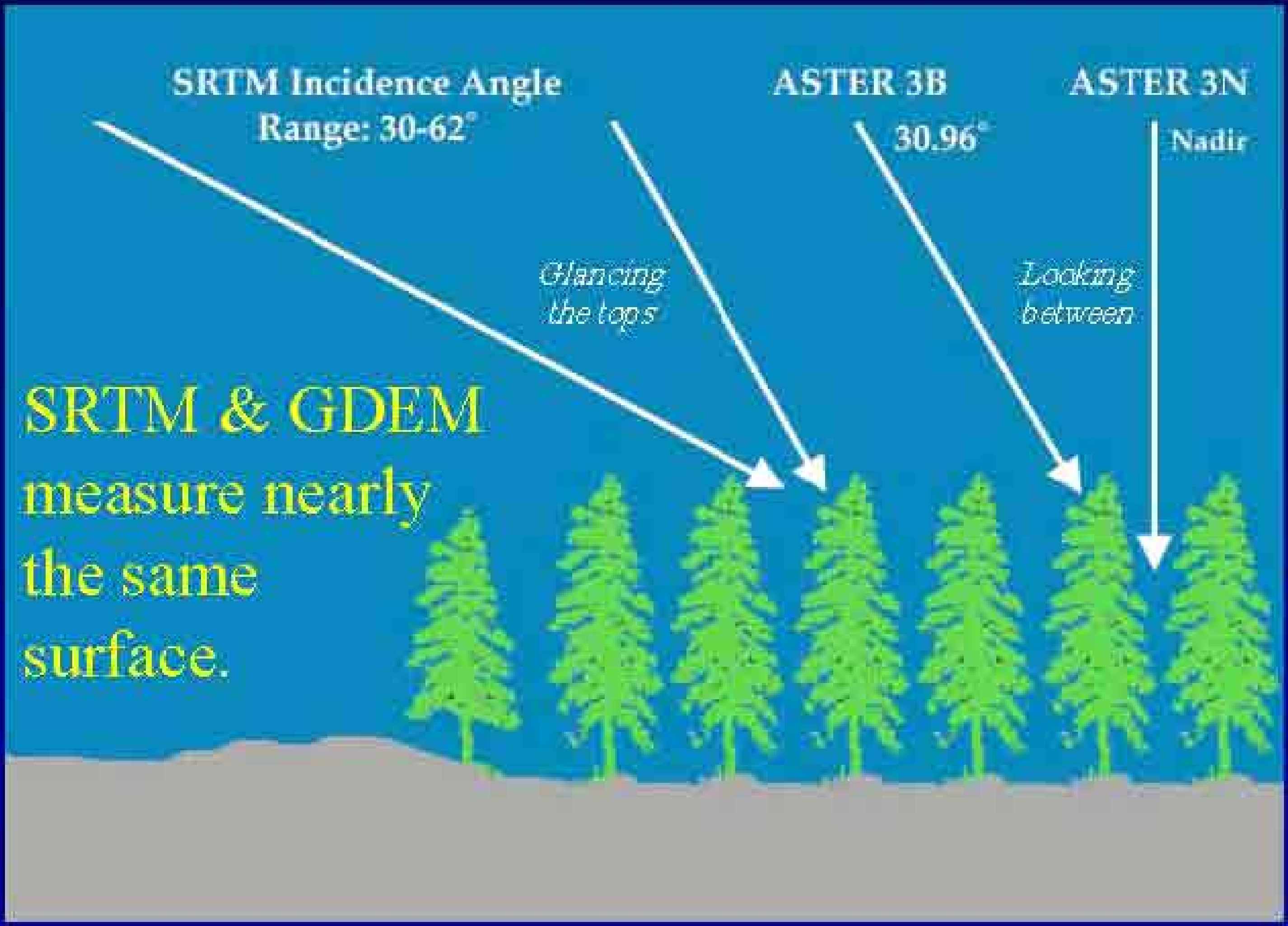
Uluru, Australia

INPUT DATA

SRTM v1 & v2 1-arc-second DEM (“30 meter”)
ASTER GDEM2 1-arc-second DEM
GMTED2010 7.5-arc-second DEM (USGS)

GDEM “NUM” file (source type & scene count)
SRTM “NUM” data (non-void SRTM swath count)
SWBD (SRTM water body mask as used in v2)

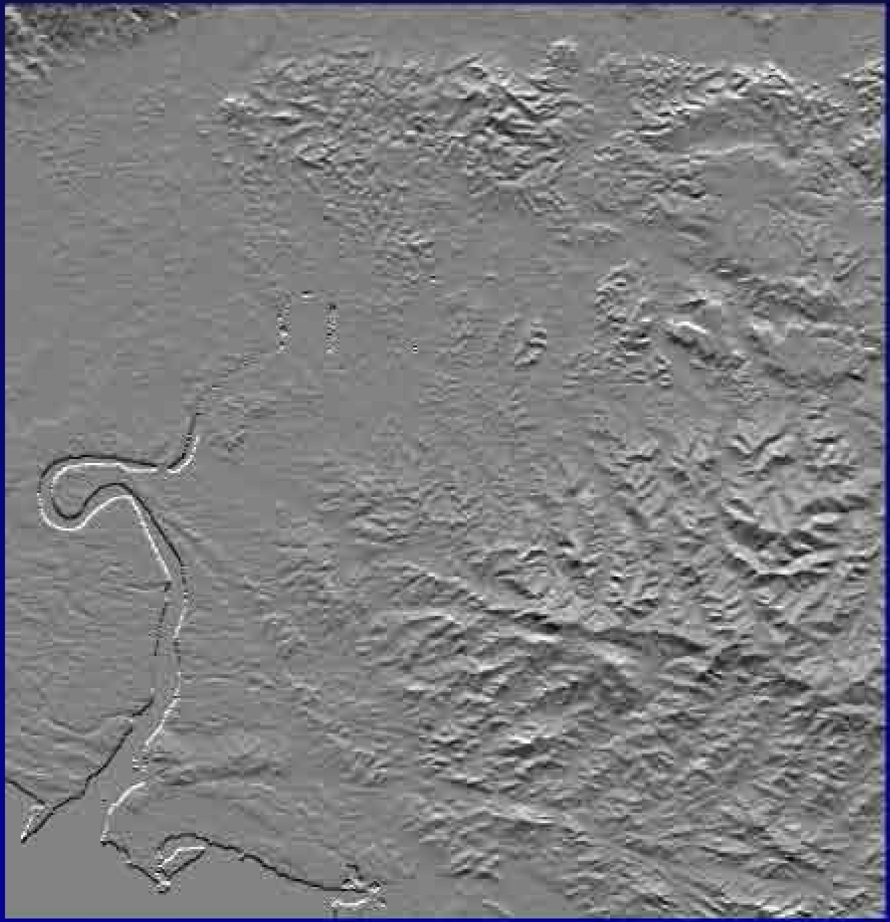
Forest Penetration: Radar versus VNIR

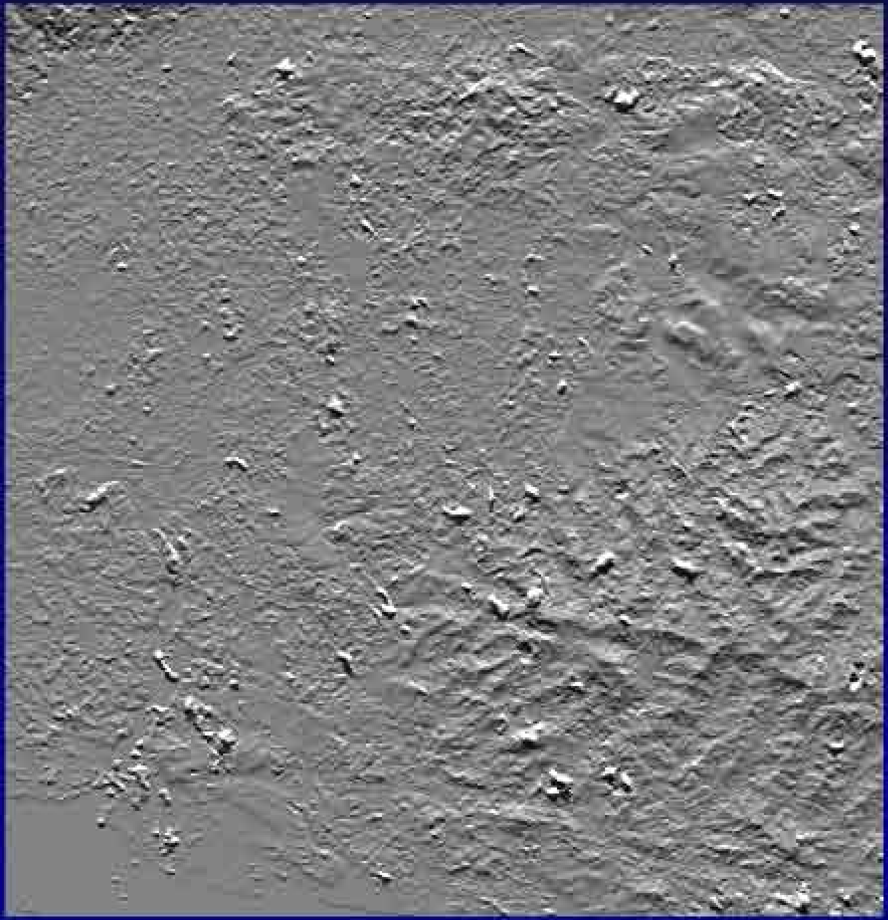


Geometry Matters! ...much as it does for your eyes.

Not Just Wavelength.

Preference given to SRTM over GDEM2





SRTM 1AS

Very consistent quality,
but with voids in difficult terrain.

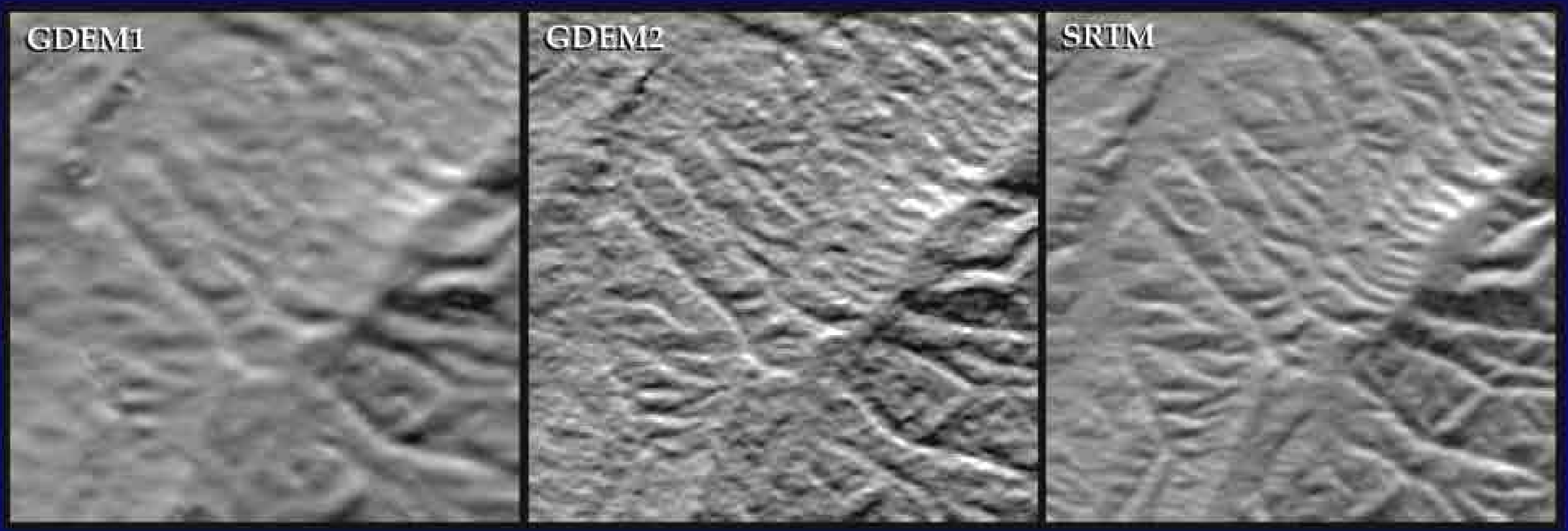
Panama

9.1 N 79.0 W
918 x 884

GDEM2

Variable quality,
especially in cloud-prone areas.

Resolution and Noise: Appearance matches Statistics

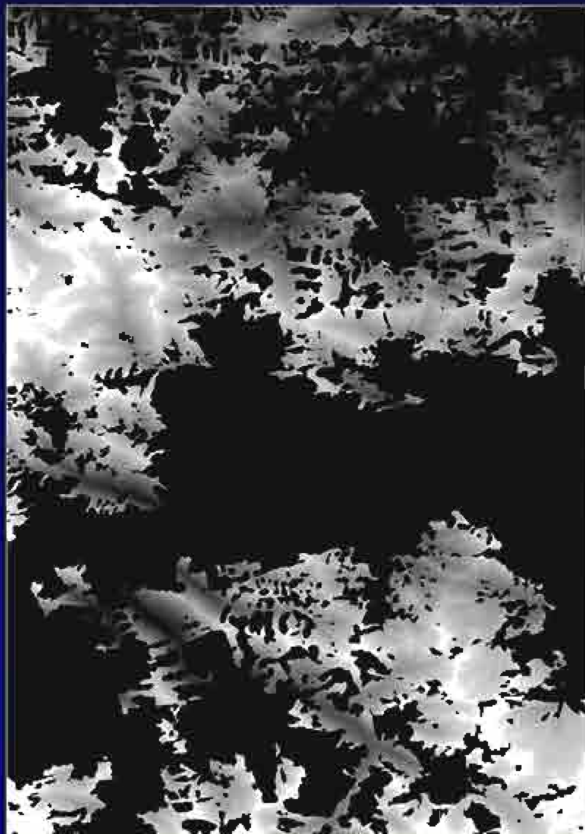


	GDEM1 9x9 kernel	GDEM2 5x5 kernel	SRTM
Res =	121 m	82 m	77 m
Noise =	7.76	7.81	4.46

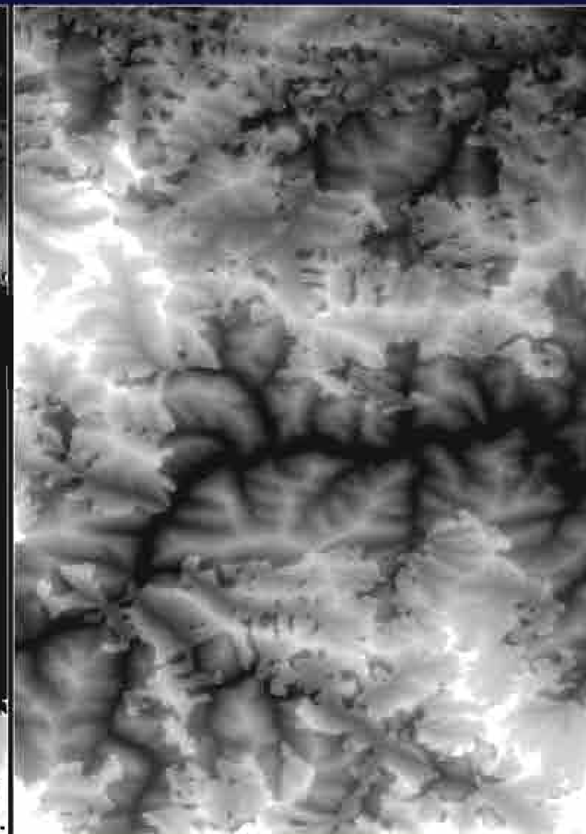
West Virginia: Keyser-Romney area

But at its best, GDEM2 nearly matches SRTM 1-arc-second data.

Void Fill Quality



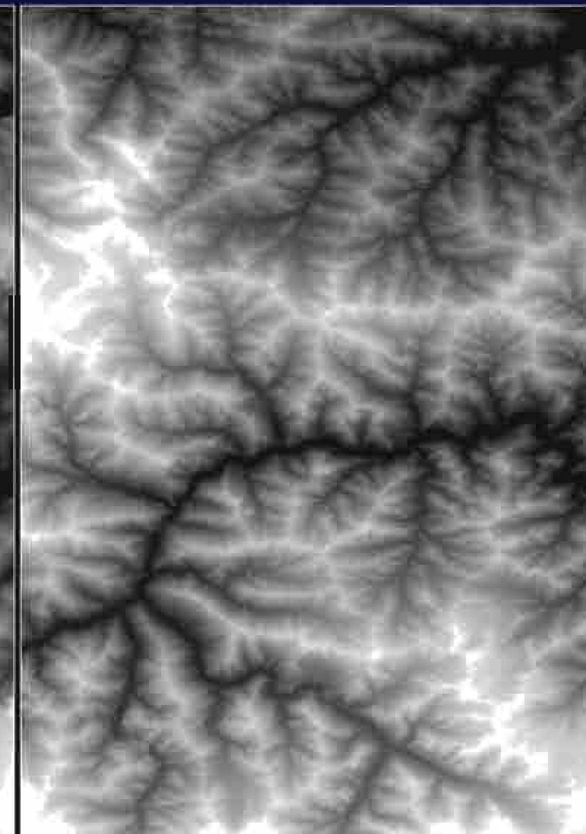
SRTM with Voids



CGIAR DEM

Disjointed Merger
(> 500 m)

(Uses no ASTER data)



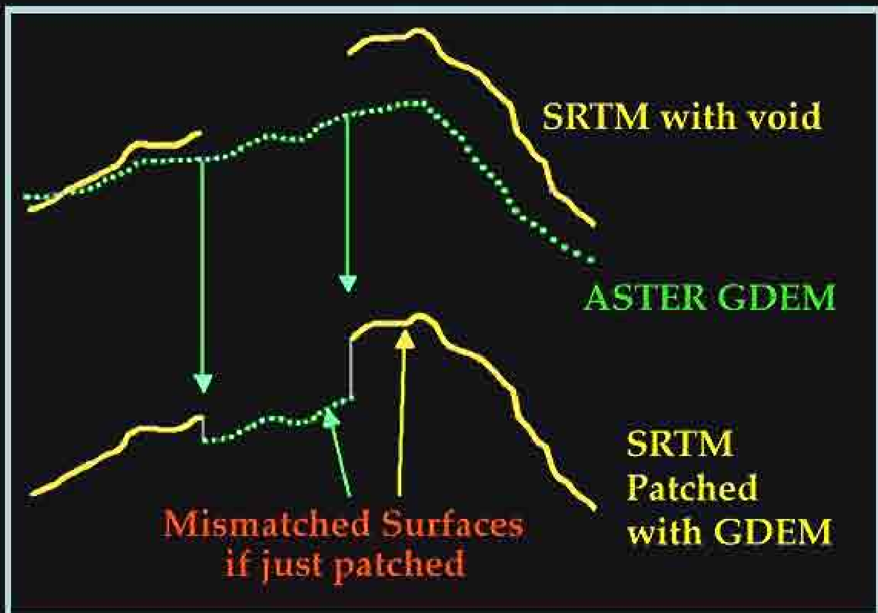
SRTM with GDEM

Smooth Merger

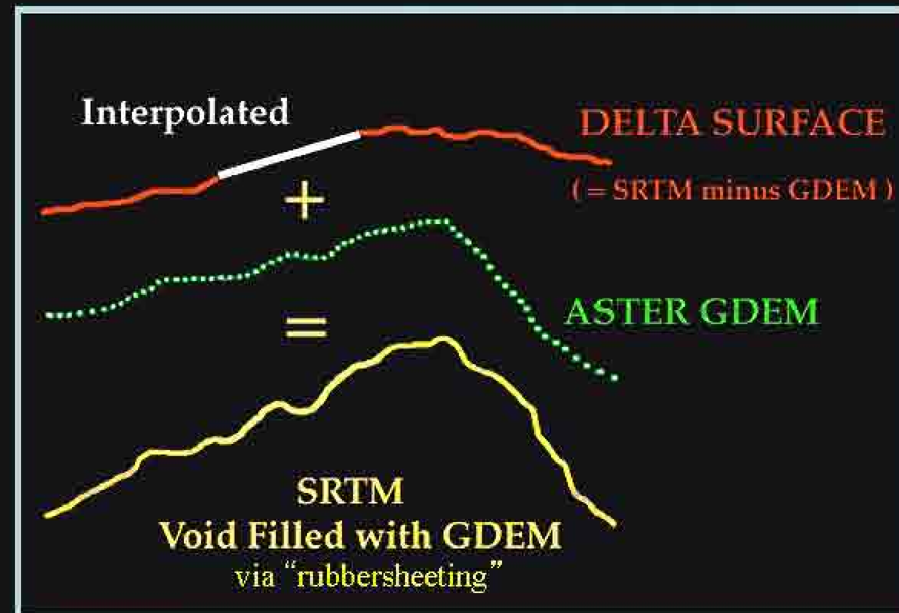
N36 E78: Southwest China

Void Filling via Delta Surface Fill Method

DEM = GDEM + Interpolated (SRTM - GDEM)
where necessary



Void Filling via Patching



Void Filling via Delta Surface

Modified from Grohman et al., 2006

Delta Surface Fill

Where SRTM is not void:

DEM = GDEM + (SRTM – GDEM)

DEM = SRTM

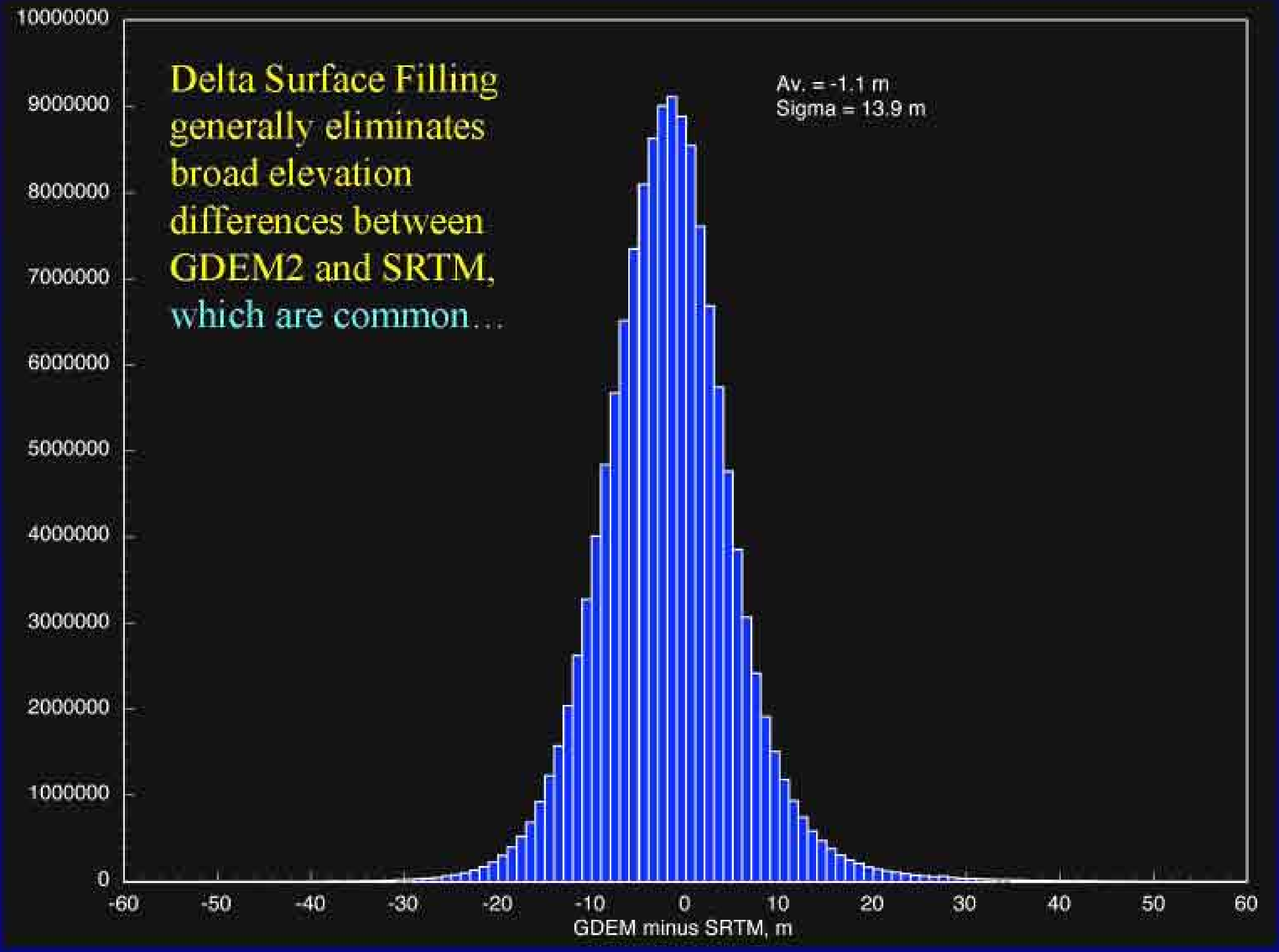
No interpolation necessary.
Result is exactly SRTM.

Where SRTM contains a void:

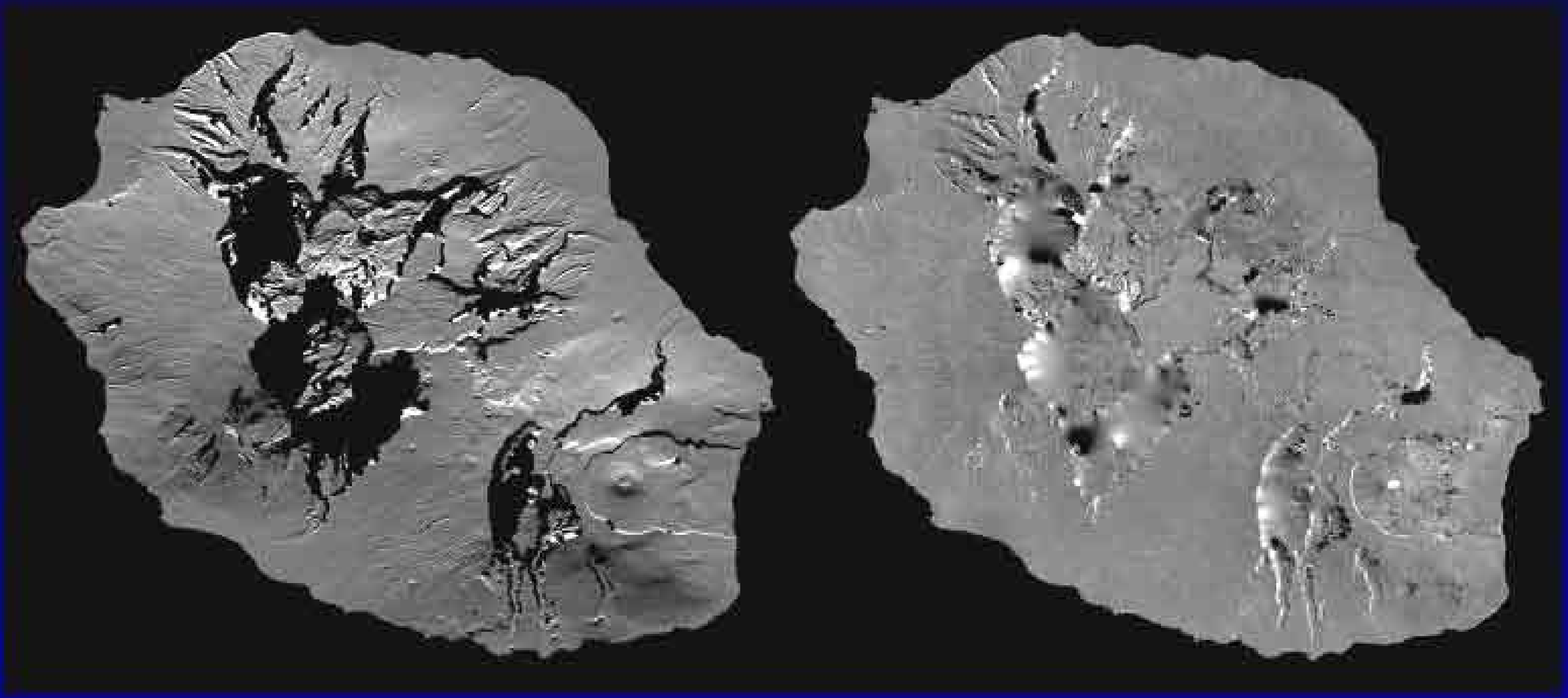
DEM = GDEM + interpolated (SRTM – GDEM)

DEM = GDEM plus its estimated
(interpolated)
difference from SRTM
across the void.

GDEM is used to estimate
the missing SRTM DEM.


Delta Surface Filling
generally eliminates
broad elevation
differences between
GDEM2 and SRTM,
which are common…
Av. = -1.1 m
Sigma = 13.9 m
10000000
9000000
8000000
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
GDEM minus SRTM, m

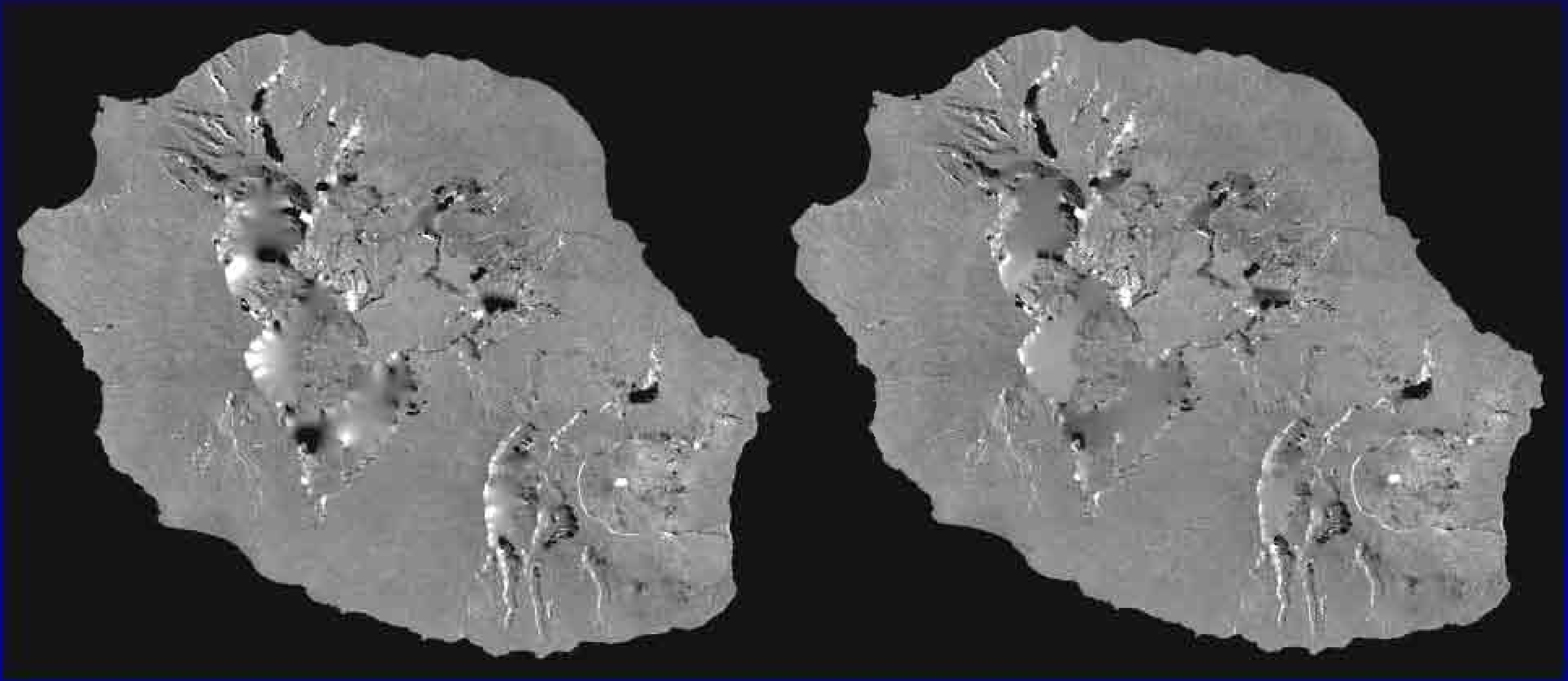
Delta Surface Fill: Reunion Island



SRTM Shaded Relief
with voids

SRTM – GDEM
Delta Surface Filled
via edge growing using 16-way
Inverse Distance Weighting

Delta Surface Fill: Reunion Island



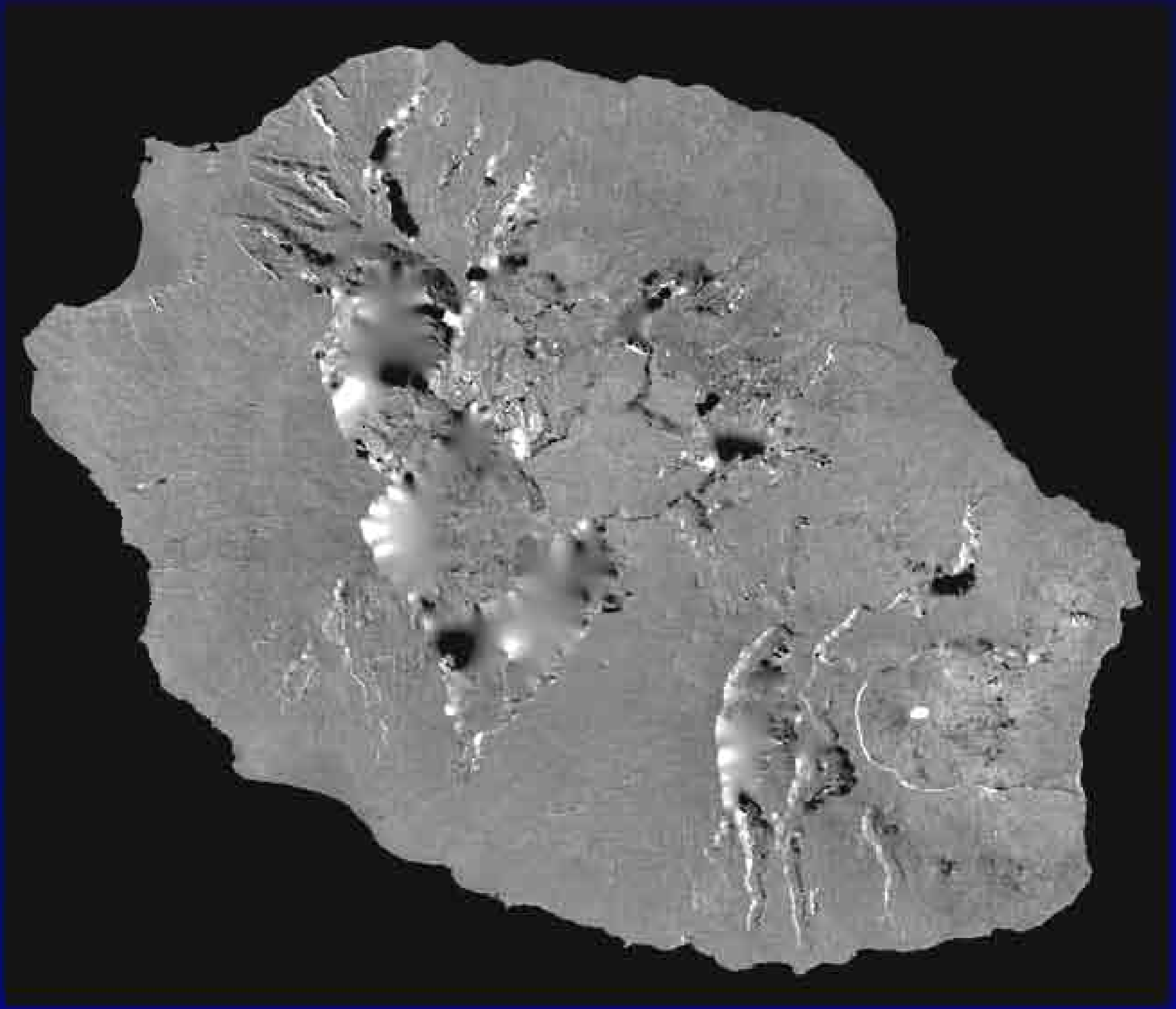
Inverse of Distance

Inverse of Square-Root-of-Distance
(Flattens the Fill Centers)

SRTM – GDEM Delta Surface Filled

via Edge Growing using 16-way Inverse SQRT Distance Weighting (IDW) interpolation

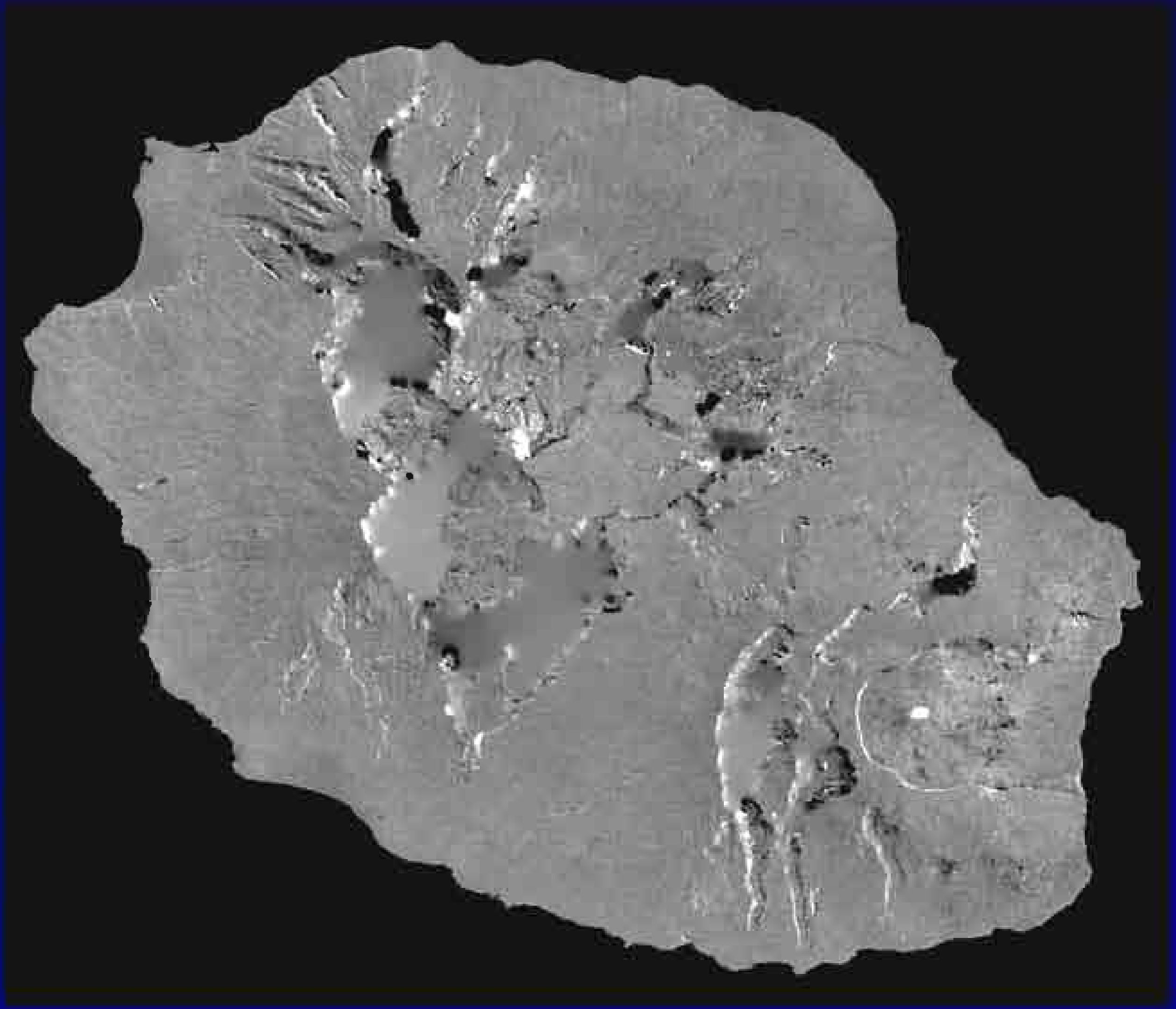
Inverse Distance Weighting



SRTM – GDEM Delta Surface Filled

via Edge Growing using 16-way Inverse Distance Weighting interpolation

Inverse SQRT Distance Weighting

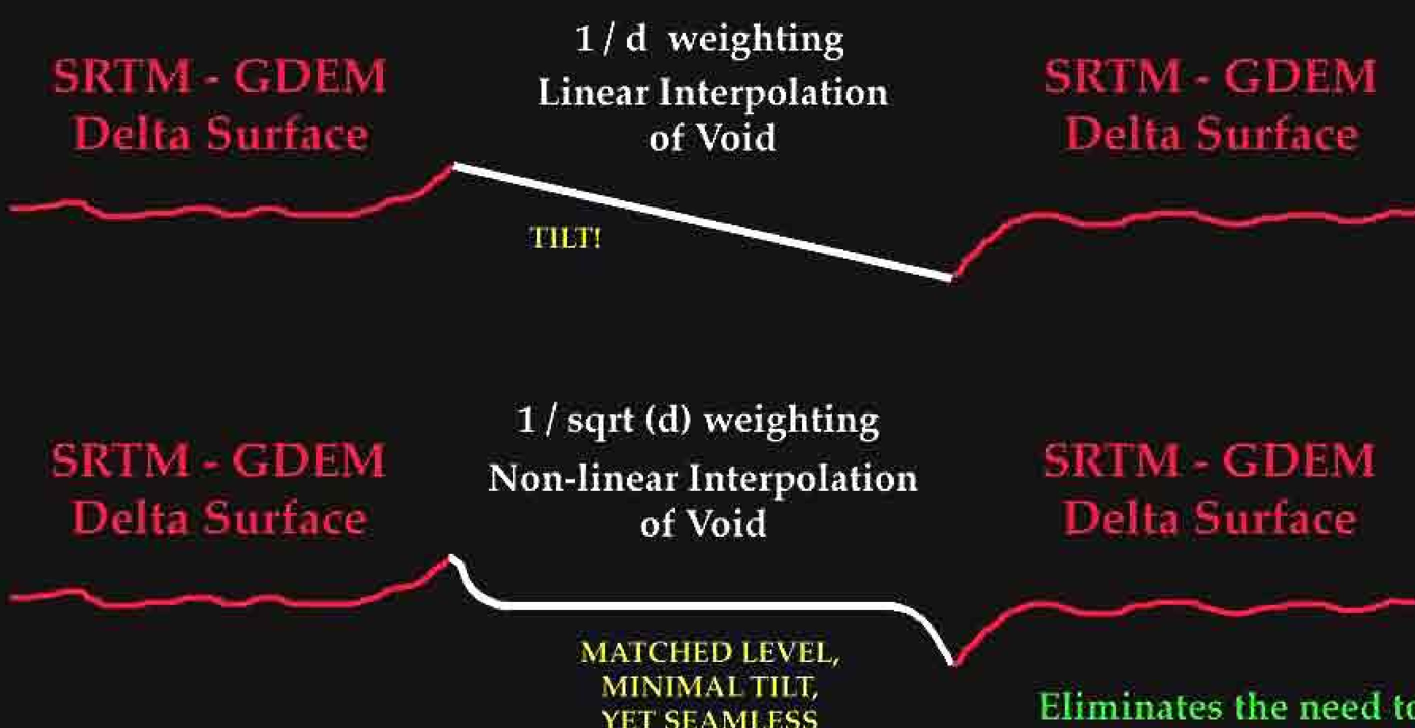


SRTM – GDEM Delta Surface Filled

via Edge Growing using 16-way Inverse SQRT Distance Weighting interpolation

Interpolation of the Delta Surface

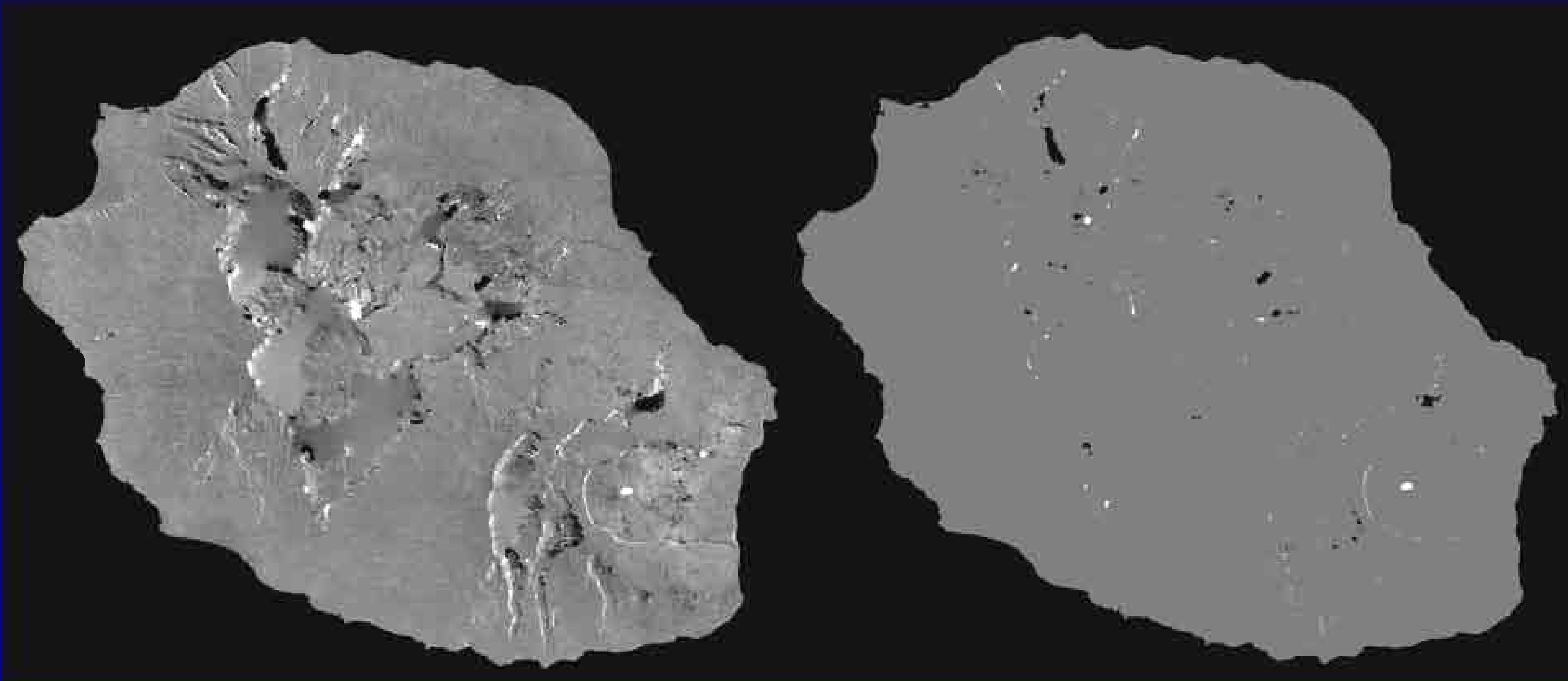
is designed to avoid tilt of GDEM, and yet match the local levels of SRTM and GDEM and match their edges seamlessly:



(Transect profiles)

Eliminates the need to otherwise equalize the local SRTM and GDEM average elevations.

Glitch Removal: Reunion Island

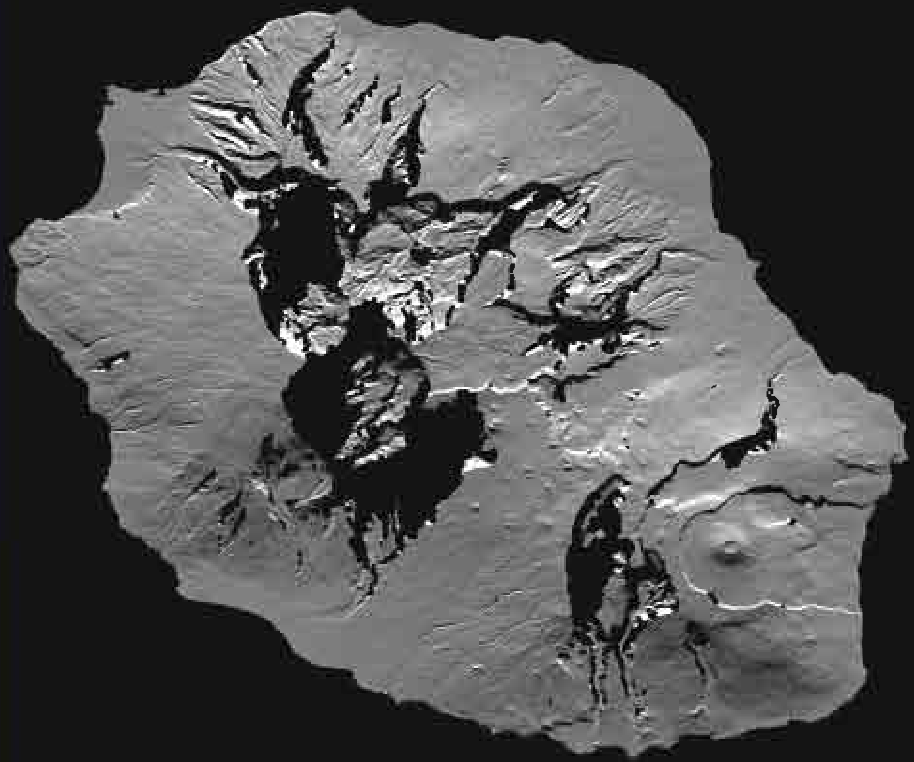


Delta Surface Fill (DSF)

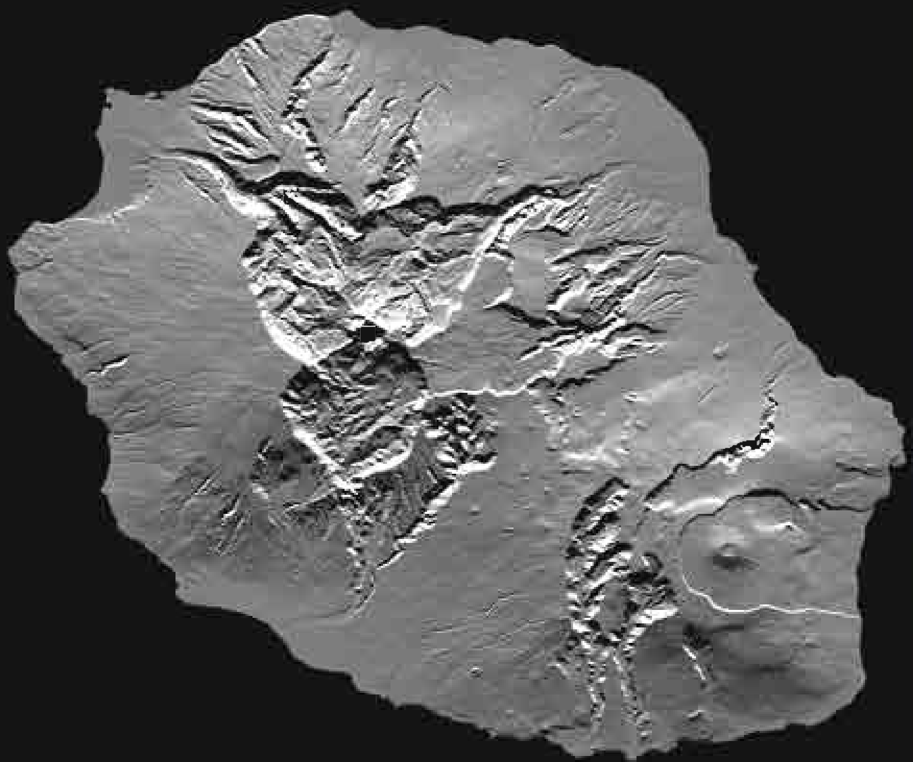
Threshold of DSF at +/- 80 m

Areas exceeding threshold are replaced with GMTED2010 7.5-arc-second DEM using Delta Surface Fill method.

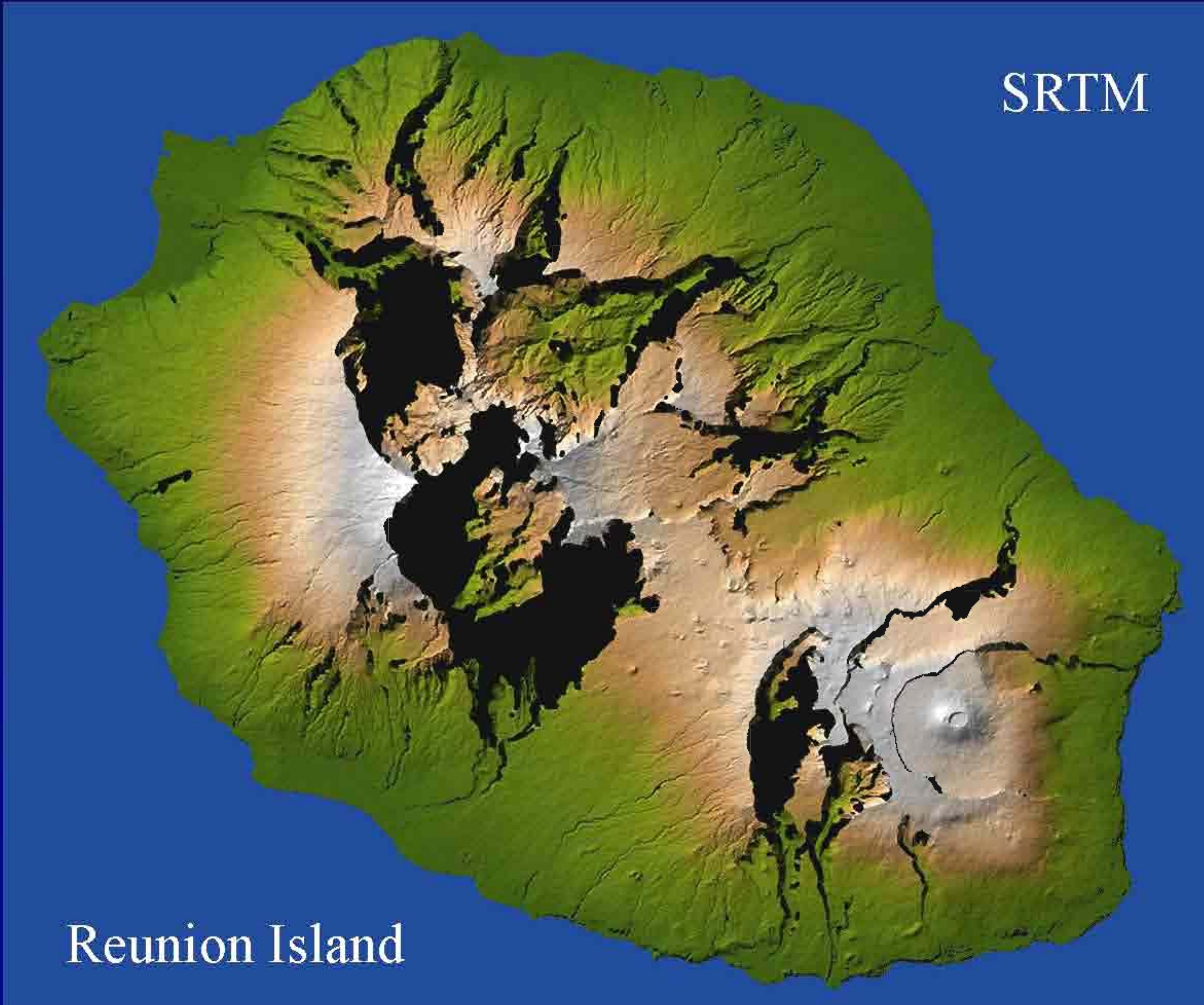
Reunion Island: Voids Filled

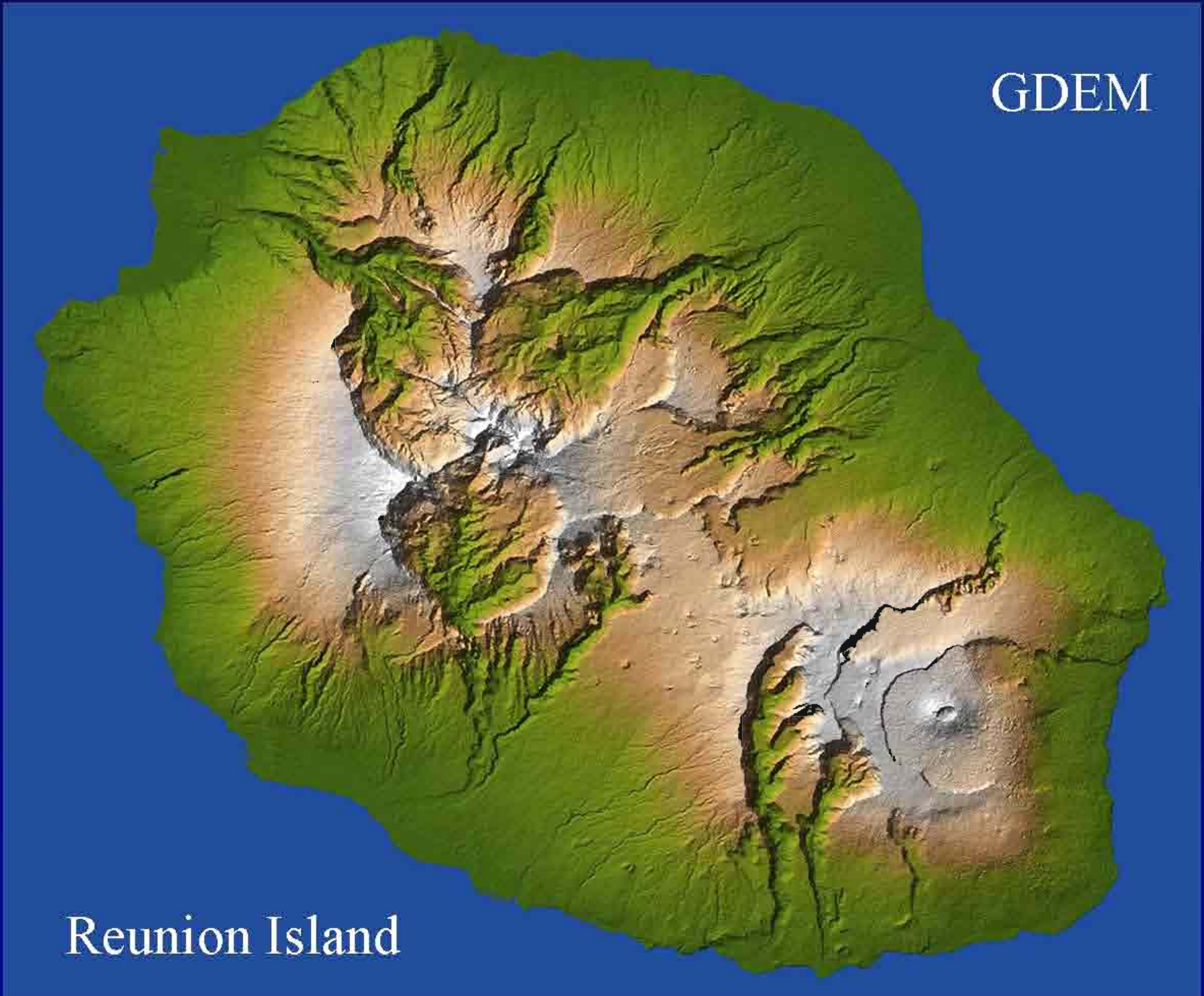


SRTM with Voids



SRTM with GDEM
(and GMTED)


SRTM
Reunion Island


GDEM
Reunion Island


SRTM V3
Reunion Island

Southeast Panama: Shorelines and Clouds

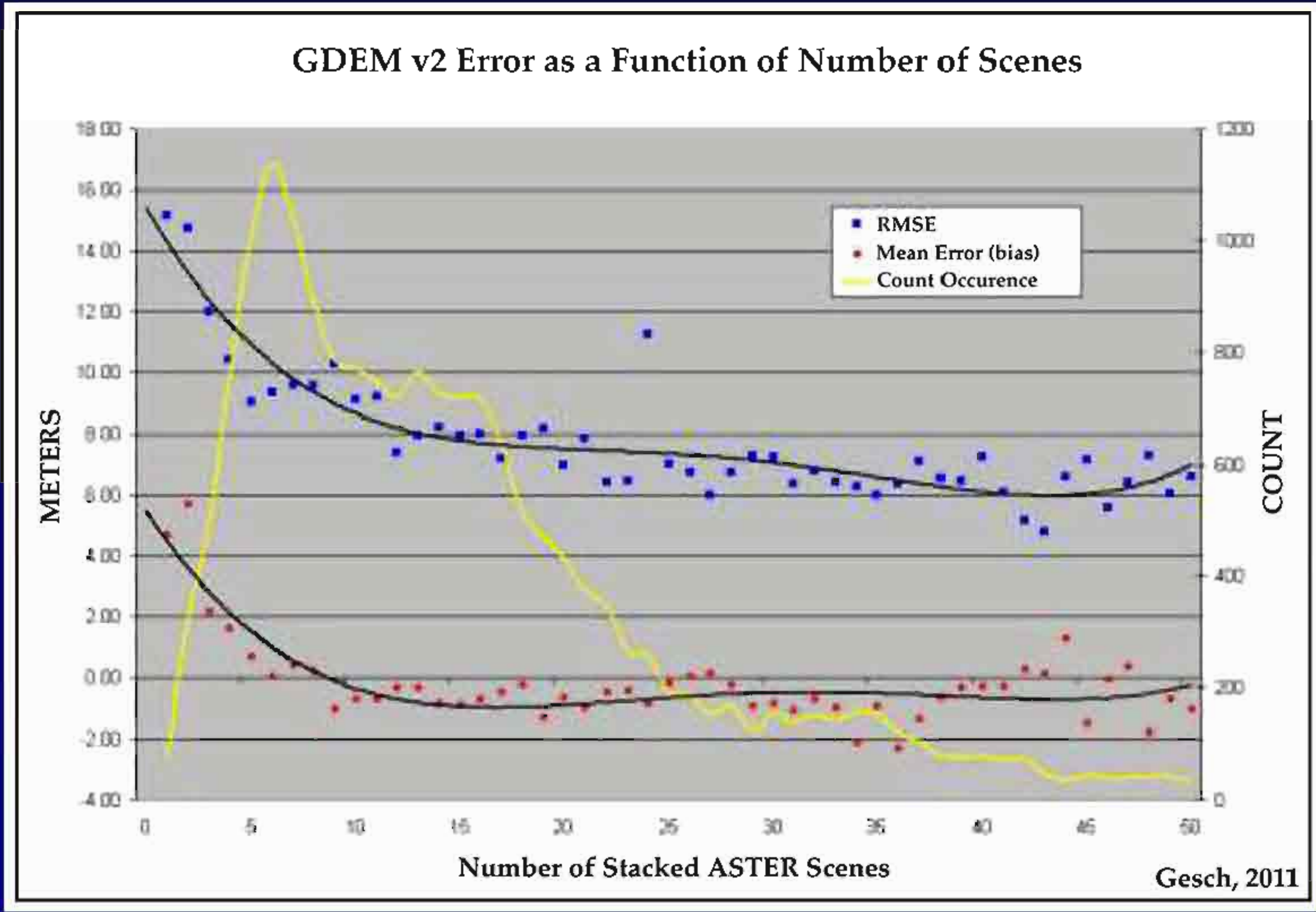
SRTM
Voids &
Water Mask Errors

GDEM
Clouds &
Shoreline Errors

SRTM Version 3
Looks Good

Cloud Removal
from GDEM
and thus from NASADEM

Using the NUM value does <u>NOT</u> work.



GDEM quality generally increases with repetitive measurements.

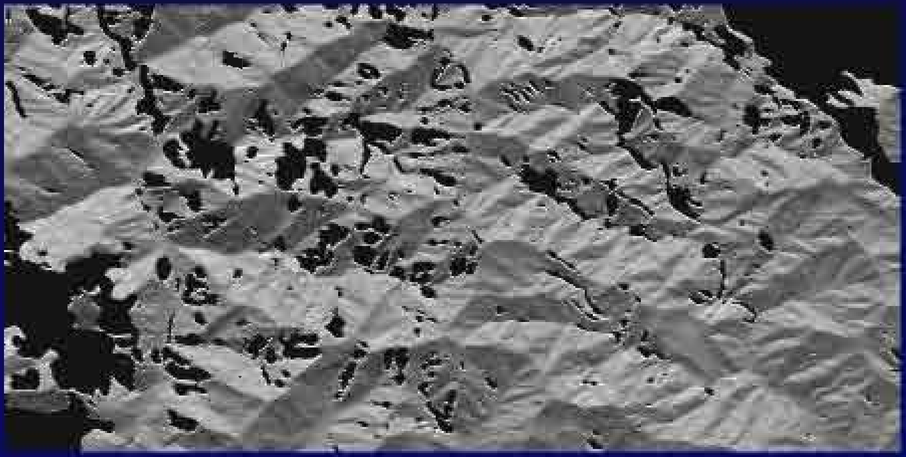
HOWEVER, this is a NOT a practical predictive tool at a given location:
e.g. a one-scene ASTER DEM could be ~correct,
while a stack of ten may be measuring heights of persistent clouds.

Cloud Removal
REQUIRES
Cloud Detection

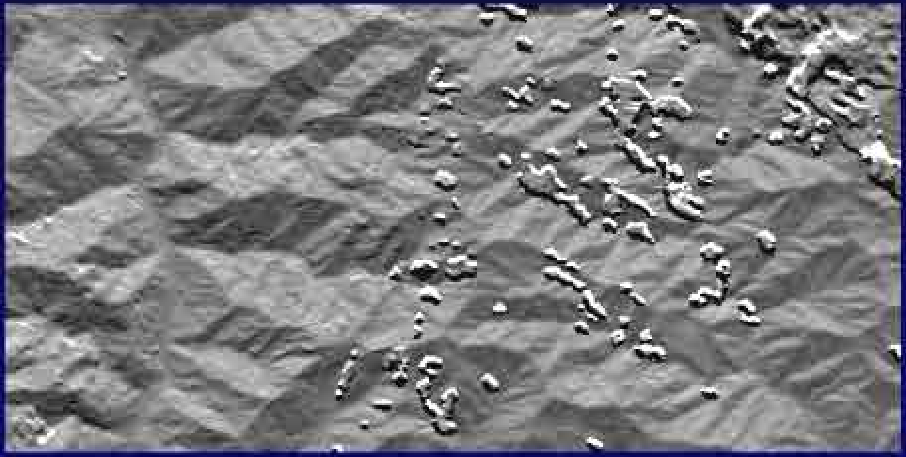
(rather than error probabilities)

Example in Sichuan, China

Some voids in SRTM are Clouds in GDEM2

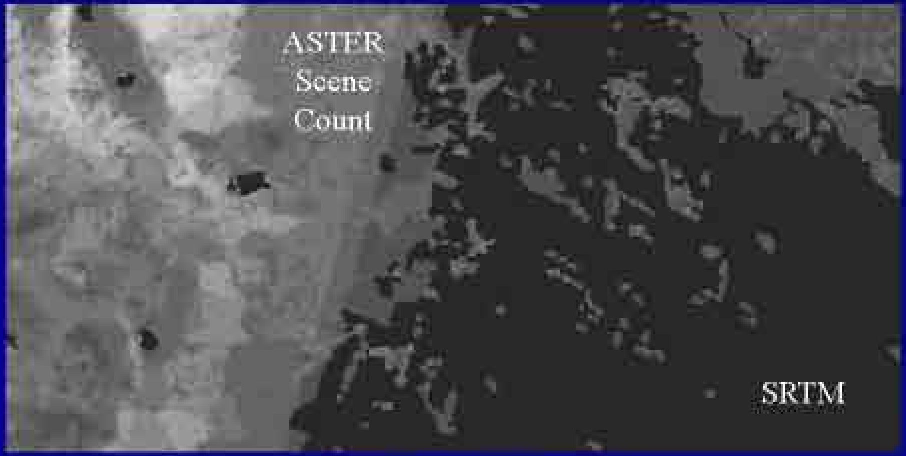


SRTM Shaded



GDEM2 Shaded

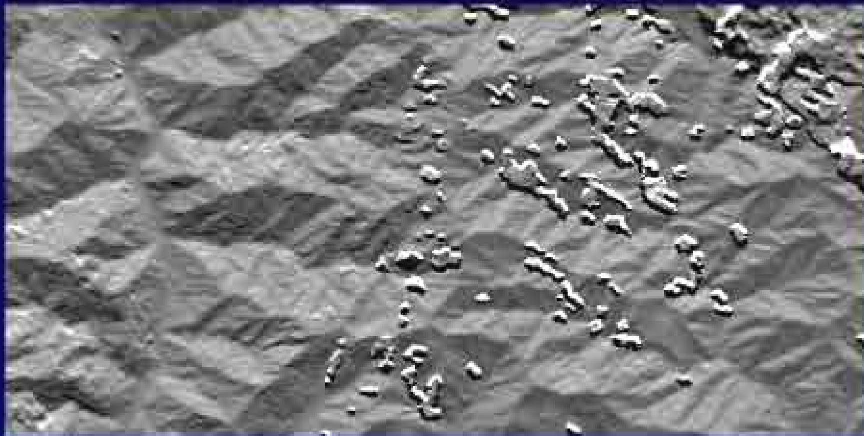
Because…



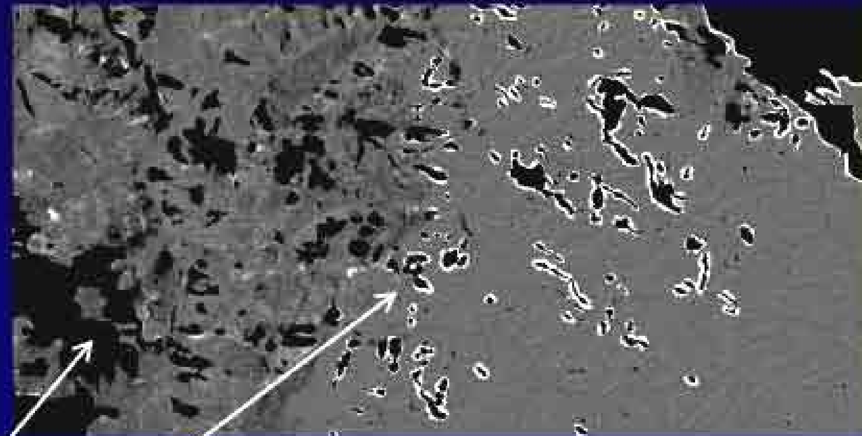
GDEM2 NUM File

GDEM = <u>Good ASTER</u>, but if not <u>then SRTM</u>, but if not <u>then bad ASTER</u>.

Clouds are revealed by the Delta Surface



GDEM2 Shaded



GDEM2-SRTM Delta Surface
(before filling)
showing SRTM Voids (Black)

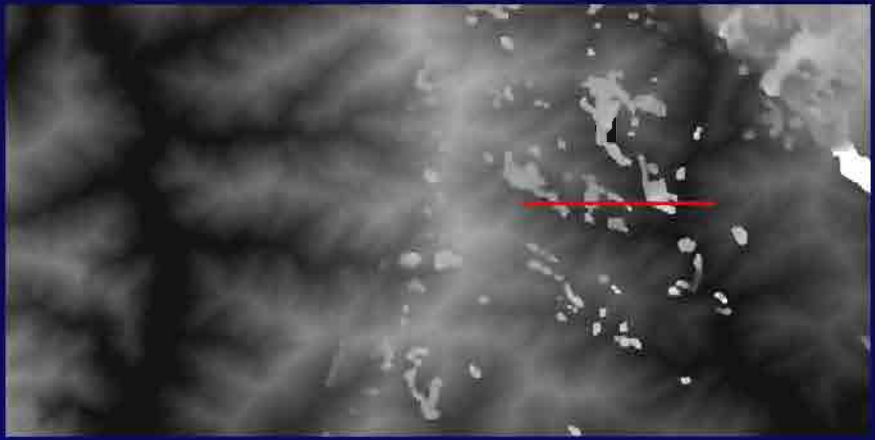
Clouds in GDEM2 form halos around SRTM voids in the Delta Surface.

GDEM2 non-cloud elevations form NO halos around SRTM voids.

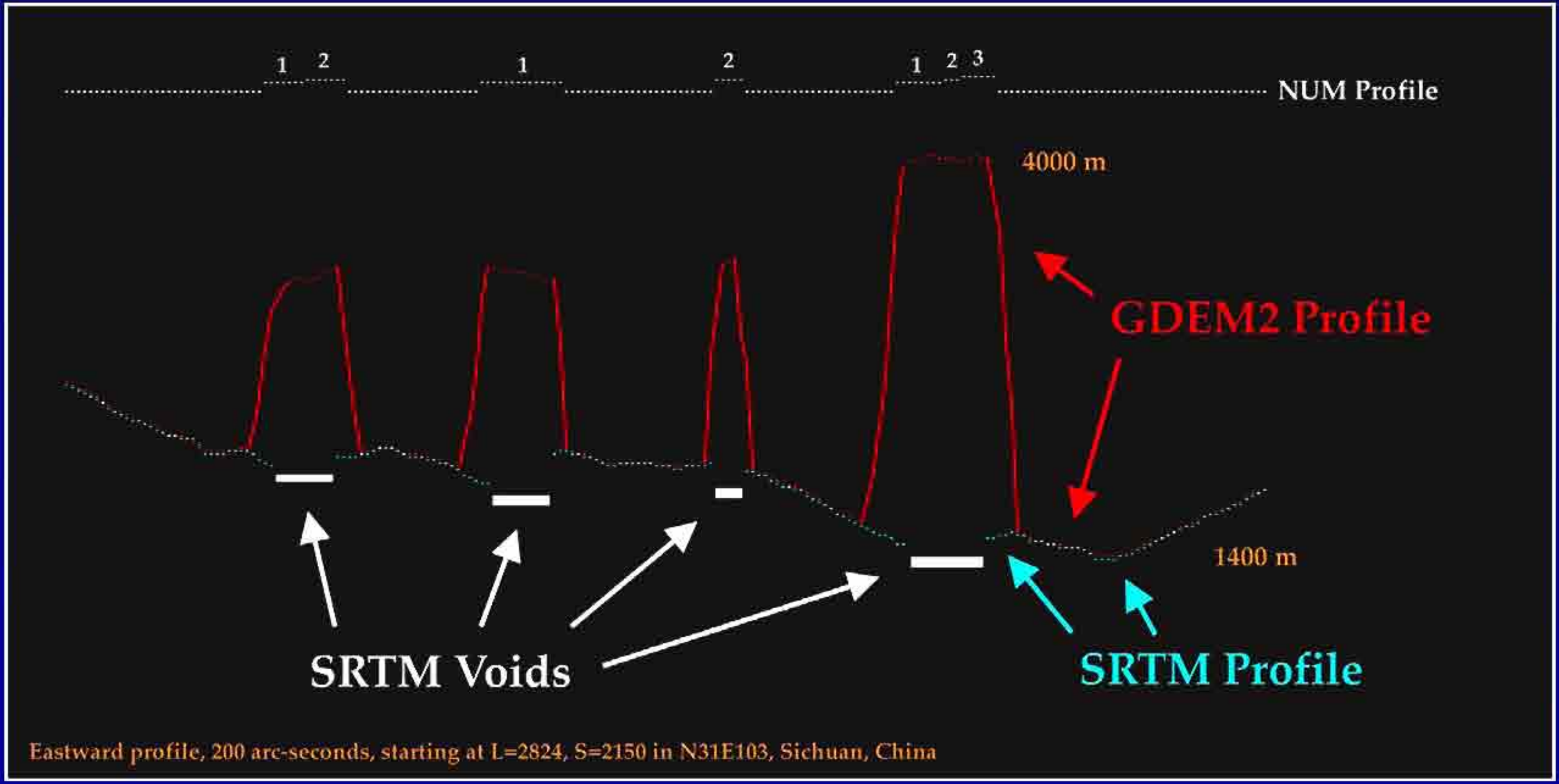
This works because we can use the SRTM 1-arc-second data.
Its voids are smaller than the voids in the SRTM 3-arc-second data that was used in GDEM.
The halos are the overlap of the SRTM 1AS data with clouds in the ASTER fill of SRTM 3AS voids.

Profile View:

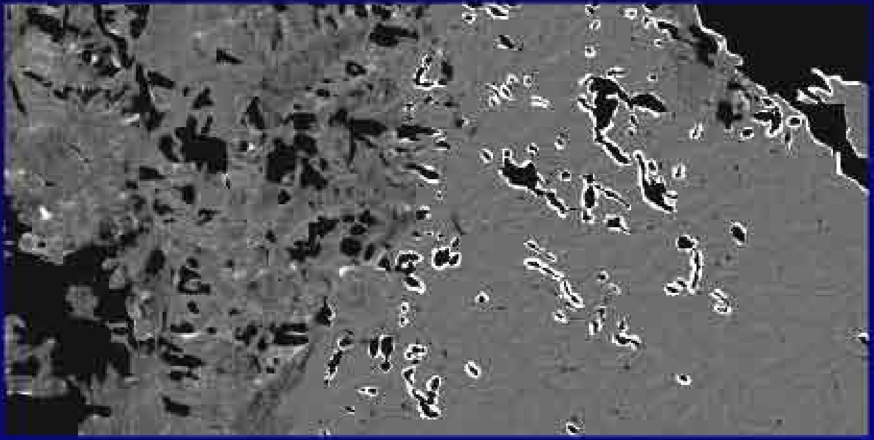
GDEM clouds filling
SRTM voids,
but with overlap (halos).



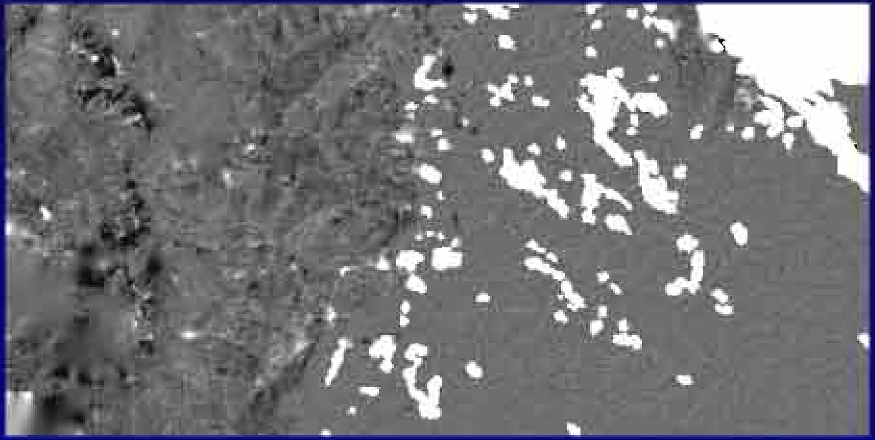
GDEM Height as Brightness



The Delta Surface as a cloud detector



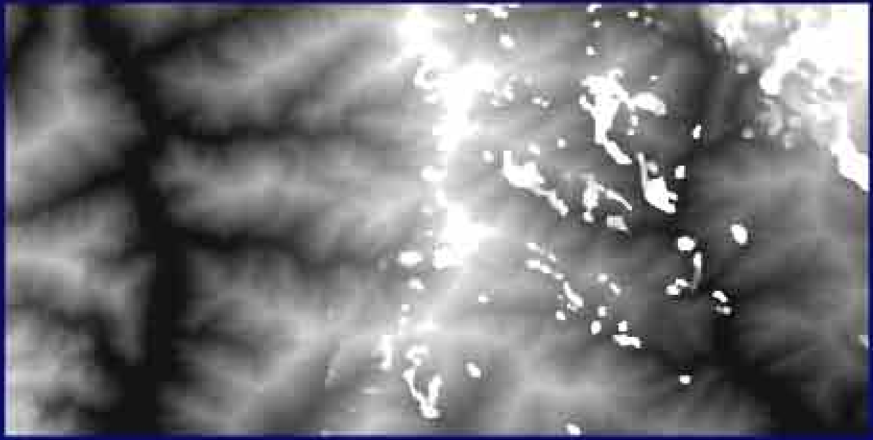
Delta Surface without Fill



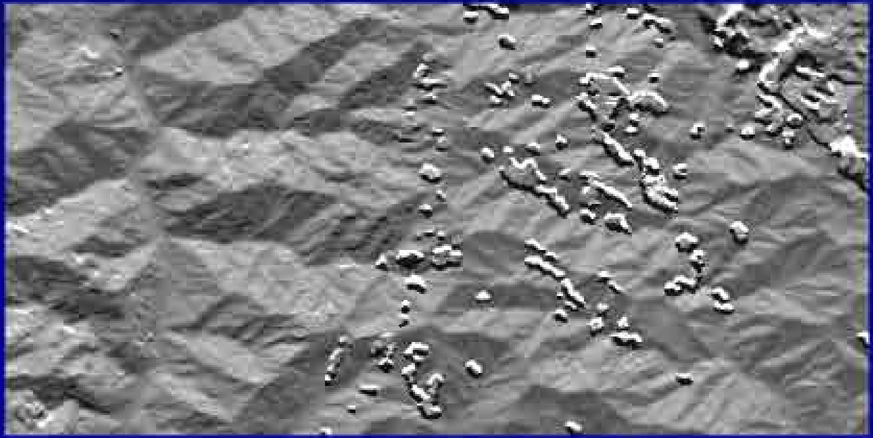
Delta Surface Filled = Error Mask

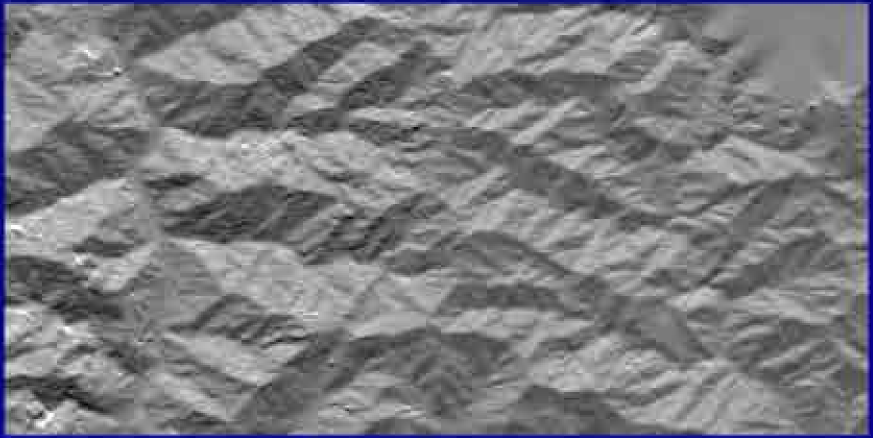
Anomalous areas
within voids
are then rejected
as GDEM fill
of SRTM.

Replace rejected GDEM with GMTED using DSF



GDEM2 Height as Brightness ⟶ Clouds Suppressed





GDEM2 Shaded ⟶ Clouds Suppressed

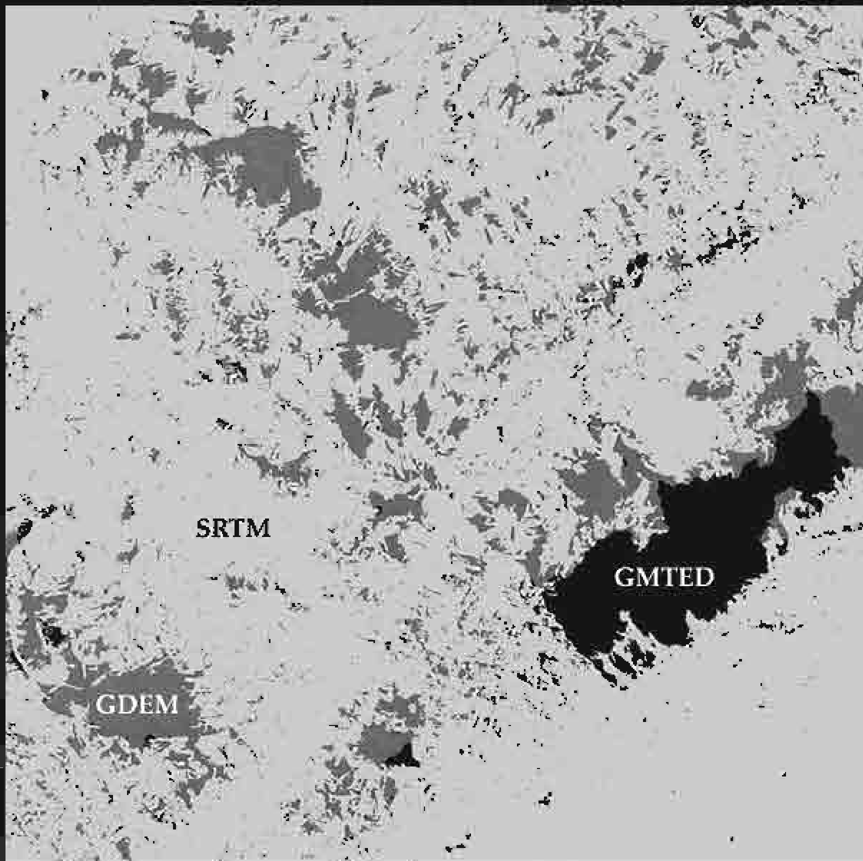
Method works well, especially for spatially small clouds.

Other issues…

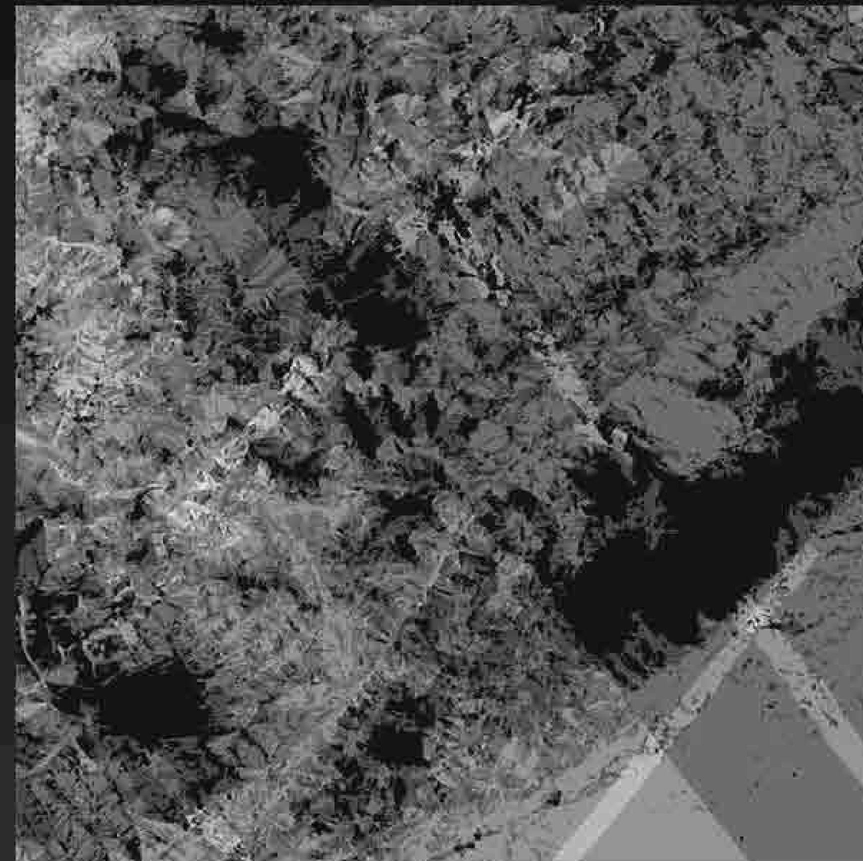
NASADEM "NUM" File

1 = NGA water-masked void → → NGA Water Mask → Refined Water Mask
2 = NGA water-masked non-void →
5 = GDEM elevation is 0 in SRTM void → → → → → → →
11 = NGA interpolated SRTM (small void fills)
21 = GMTED
31 = SRTM Fill Mystery Data (NGA via GDEM)
51 = National Elevation Dataset (NED)
52 = NED via GDEM
53 = NED Alaska via GDEM
71 = Canada DEM
72 = Canada DEM via GDEM
100 = ASTER Scene Count is 0
101-200 = ASTER Scene Count (stop count at 100)
201-255 = SRTM Swath Count (max at ~23)

View of SRTM Version 3 “NUM” File



Not contrast stretched

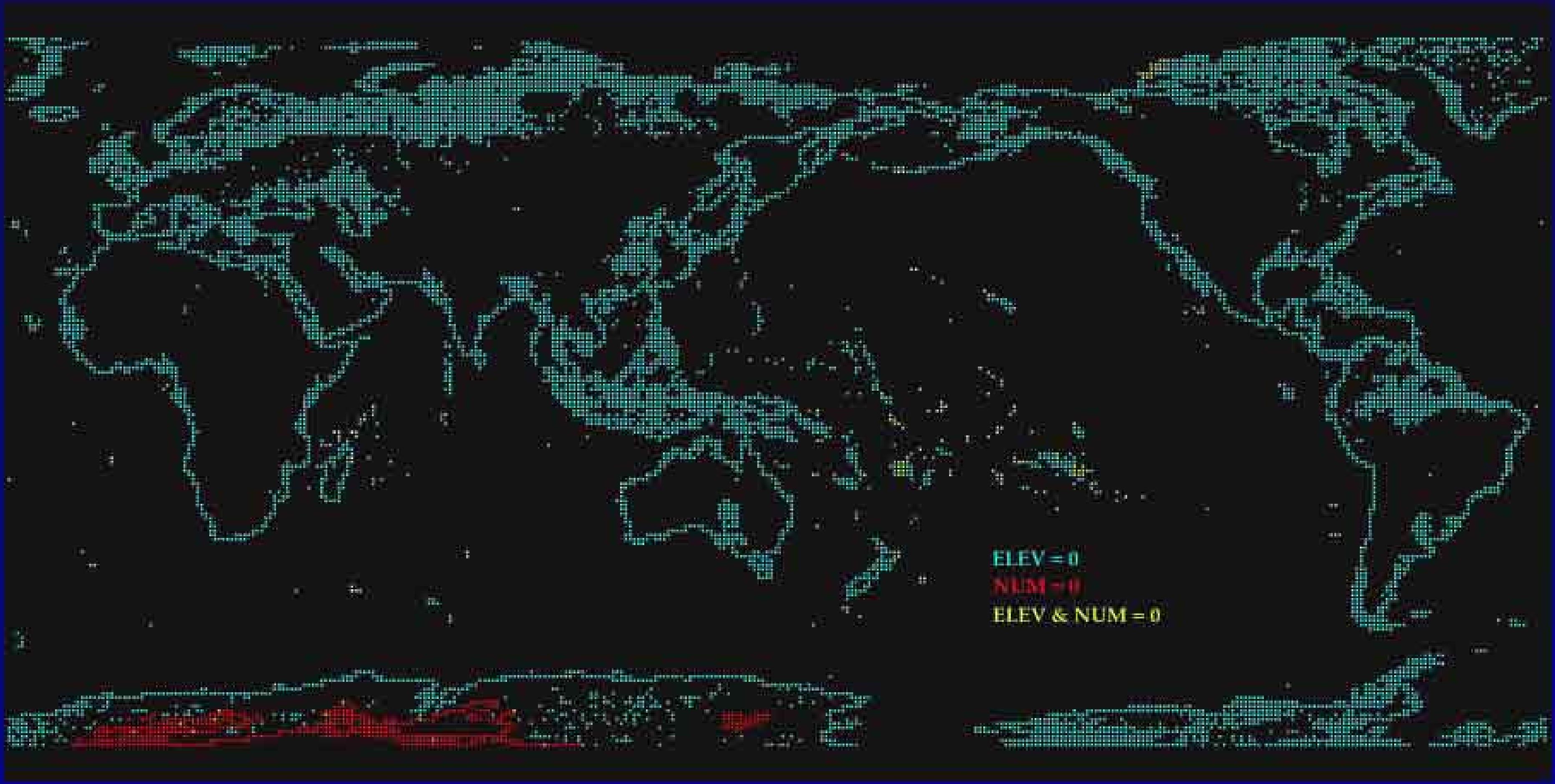


SRTM count stretched.
(swaths evident)

N31E103 (China)

Map of GDEM: Elevation = 0 and/or NUM = 0

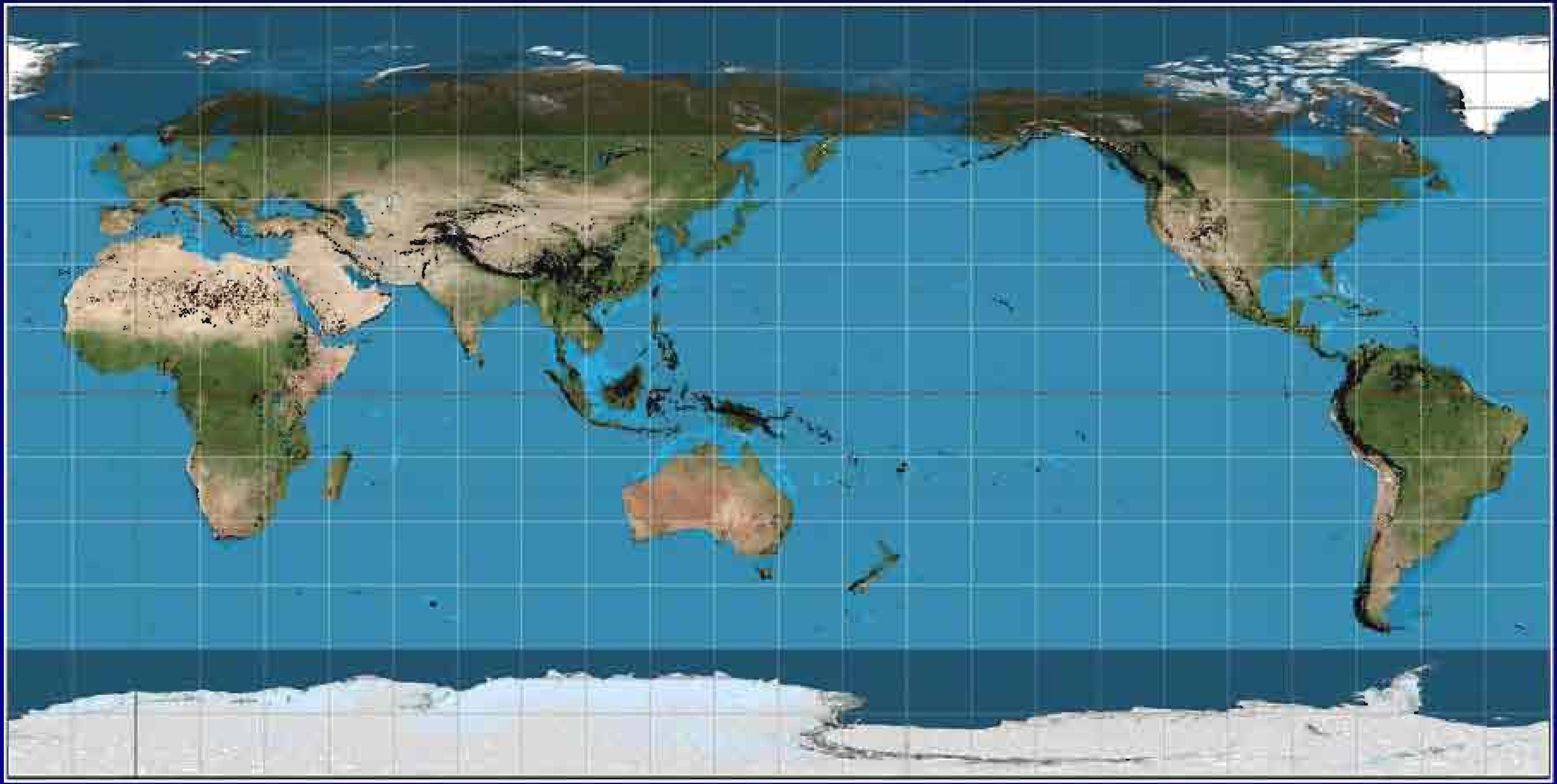
...for glitch detection



Rarotonga, Cook Islands. (S22W160)

Quad found to be defective: Sea level = 182 m and has no ASTER elevations.

SRTM-GDEM STAR



Areas (black) where GDEM was rejected as SRTM fill due to inconsistency with SRTM elevations (+/- 80m)

Replaced with GMTED or NED

Summary

- An SRTM / GDEM merged 1-arc-second DEM has been completed (October 2012) and will made generally available (mid 2013), at 3-arc-second postings …and it's free.

- The DEM various includes void, shoreline, cloud, glitch, and source-differential elevation fixes.

- The *long awaited (but imminent)* SRTM-GDEM STAR is a by-product of SRTM Version 3.

THE END

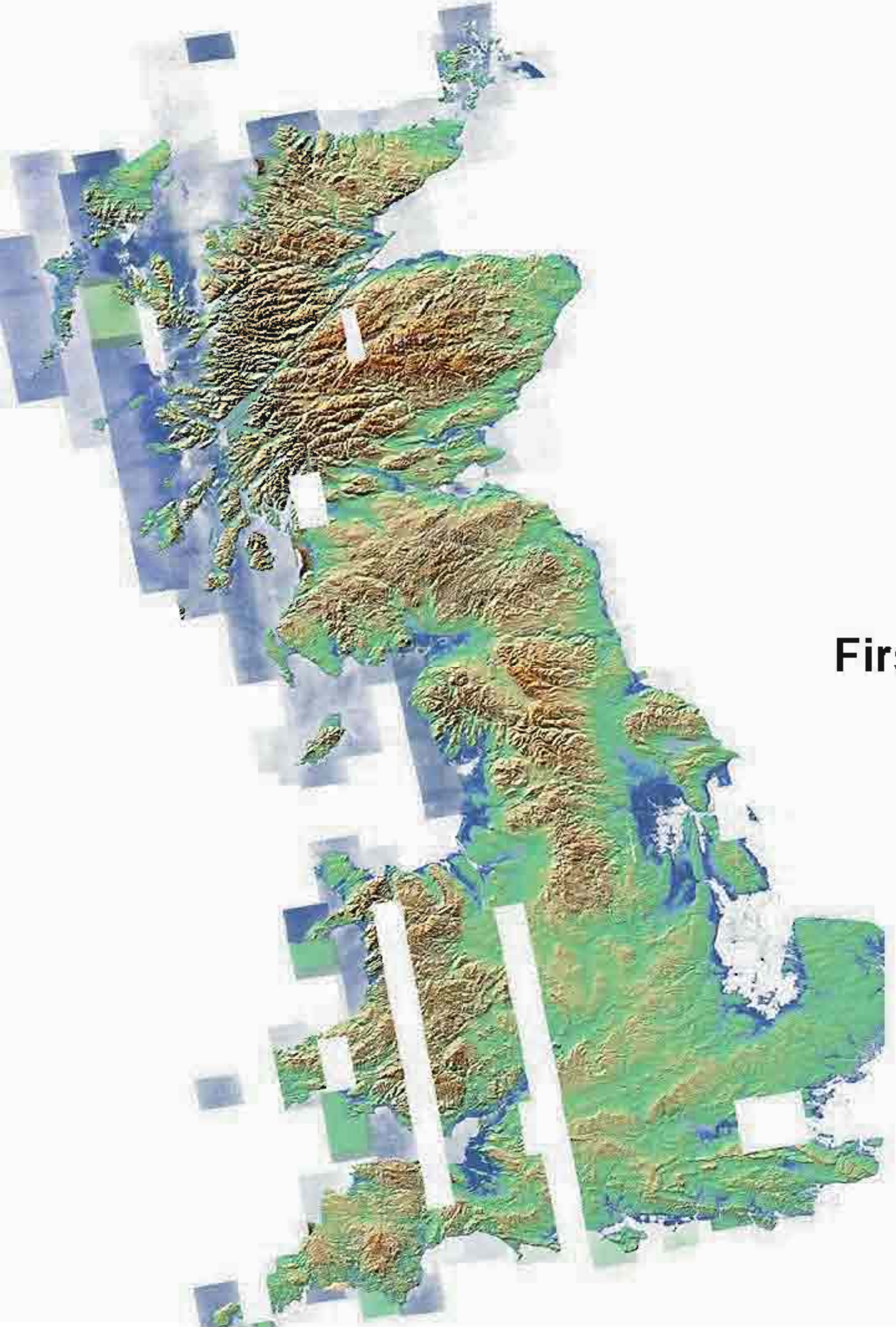
TanDEM-X DEM Generation Status
Manfred Zink, DLR

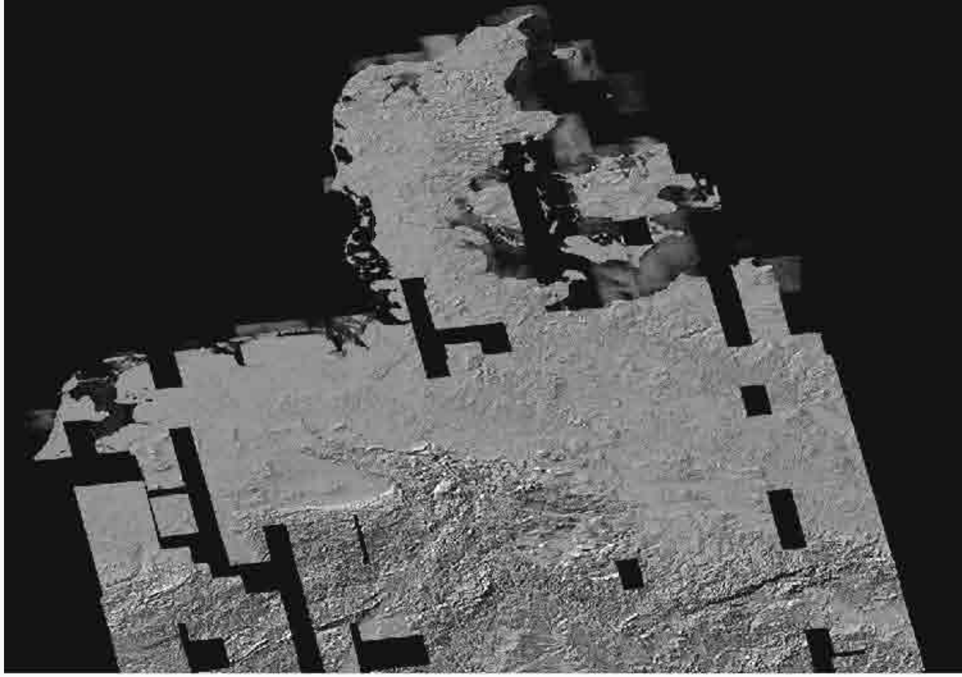
DLR

Mission Status

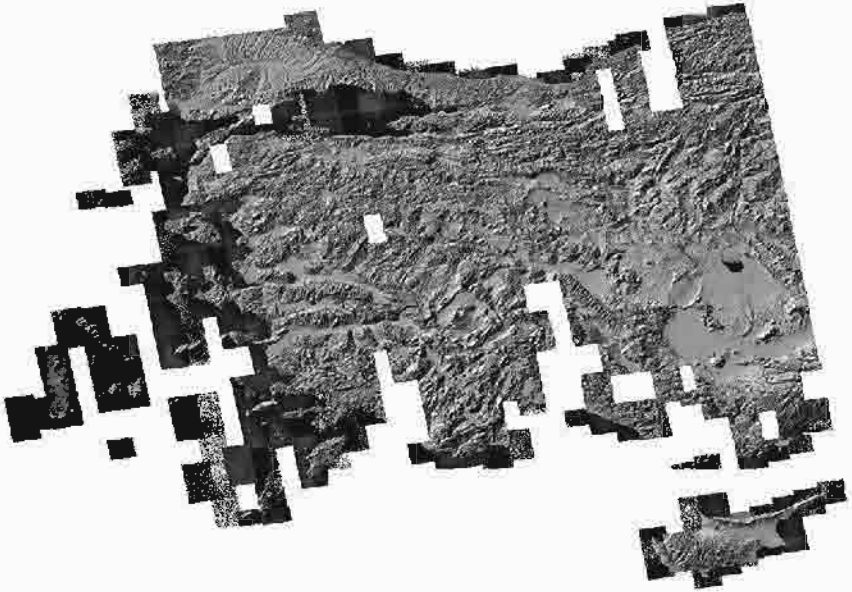
- Second global acquisition finished
- Currently first acquisition of Antarctica and recovery of gaps
- Starting from August acquisitions over difficult terrain from opposite viewing geometry
- Intermediate DEMs (based on first coverage only) to become available mid June 2013 for specific regions
- Final DEM delivery to commence early 2014

DLR





First IDEM Samples



4th TerraSAR-X / TanDEM-X Science Team Meeting

June 10 – 14, 2013 @ DLR, Oberpfaffenhofen

- Status & results presentations
- Planning for the 3rd TanDEM-X acquisition phase:
- Splinter groups will define:
  - Acquisition Mode (DRA, long baseline across/along InSAR)
  - Test site definition (e.g. super test sites)
  - Time schedule

https://tandemx-science.dlr.de/

Upcoming TanDEM-X Announcements of Opportunity

- Intermediate DEM
- global DEM CoSSC

planned to be issued mid July 2013

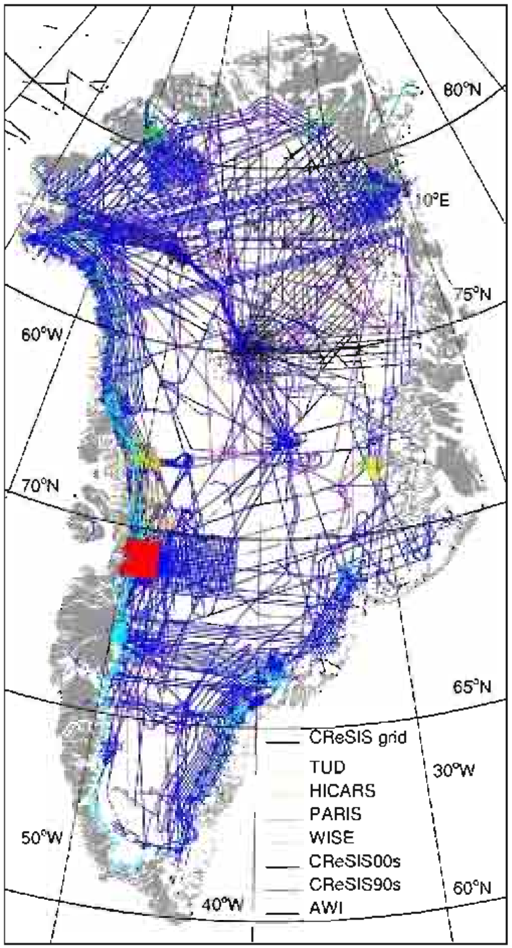
DLR

Jonathan Bamber§

School of Geographical Sciences
University of Bristol, UK

Compiled by Jan-Peter Muller, UCL-MSSL from
Bamber et al., A new bed elevation dataset for Greenland. The Cryosphere, 7, 499–510, 2013

Input datasets into Bedrock topography

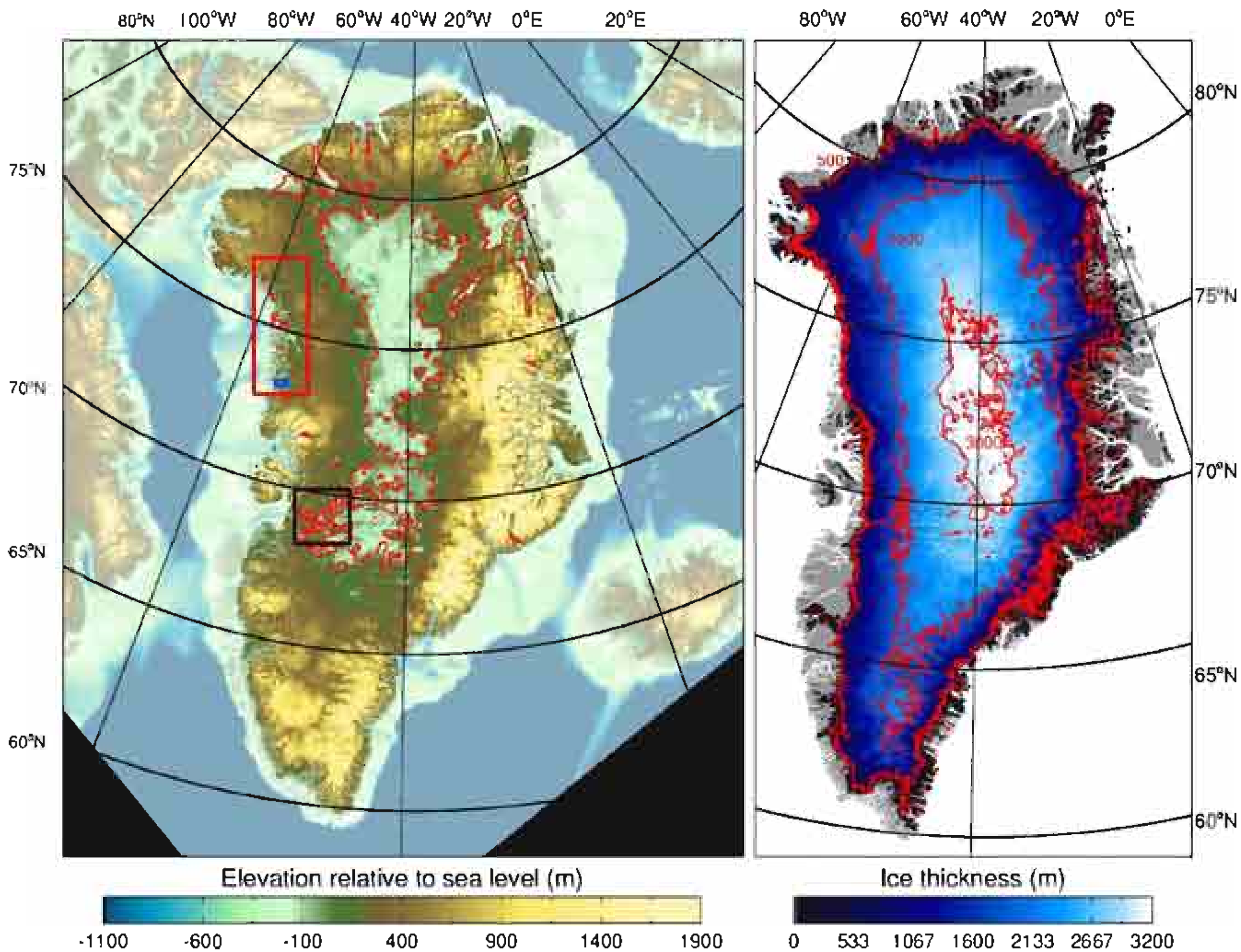


Airborne data sources used in this study.

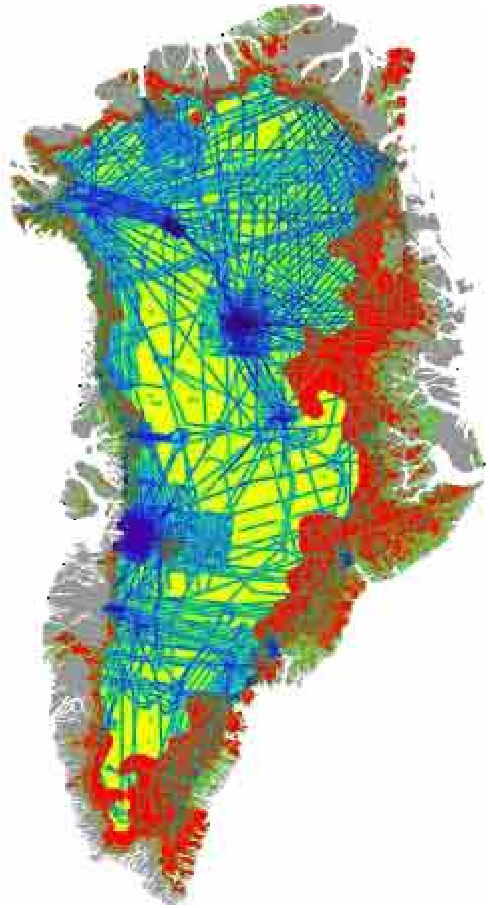
Source	Time period	Reference	Line kilometres used
CReSIS	1993–2012	Gogineni et al. (2001)	337 650
Alfred Wegener Institute	1996–1999, 2004, 2010	Nixdorf et al. (1999)	58 350
Warm Ice Sounding Explorer	2008–2010		13 180
Pathfinder Advanced Radar Ice Sounder	2009	Raney (2010)	5880
High Capability Radar Sounder	2011	Peters et al. (2007, 2005)	5270
Technical University of Denmark	1970s	Bamber et al. (2001b)	70*

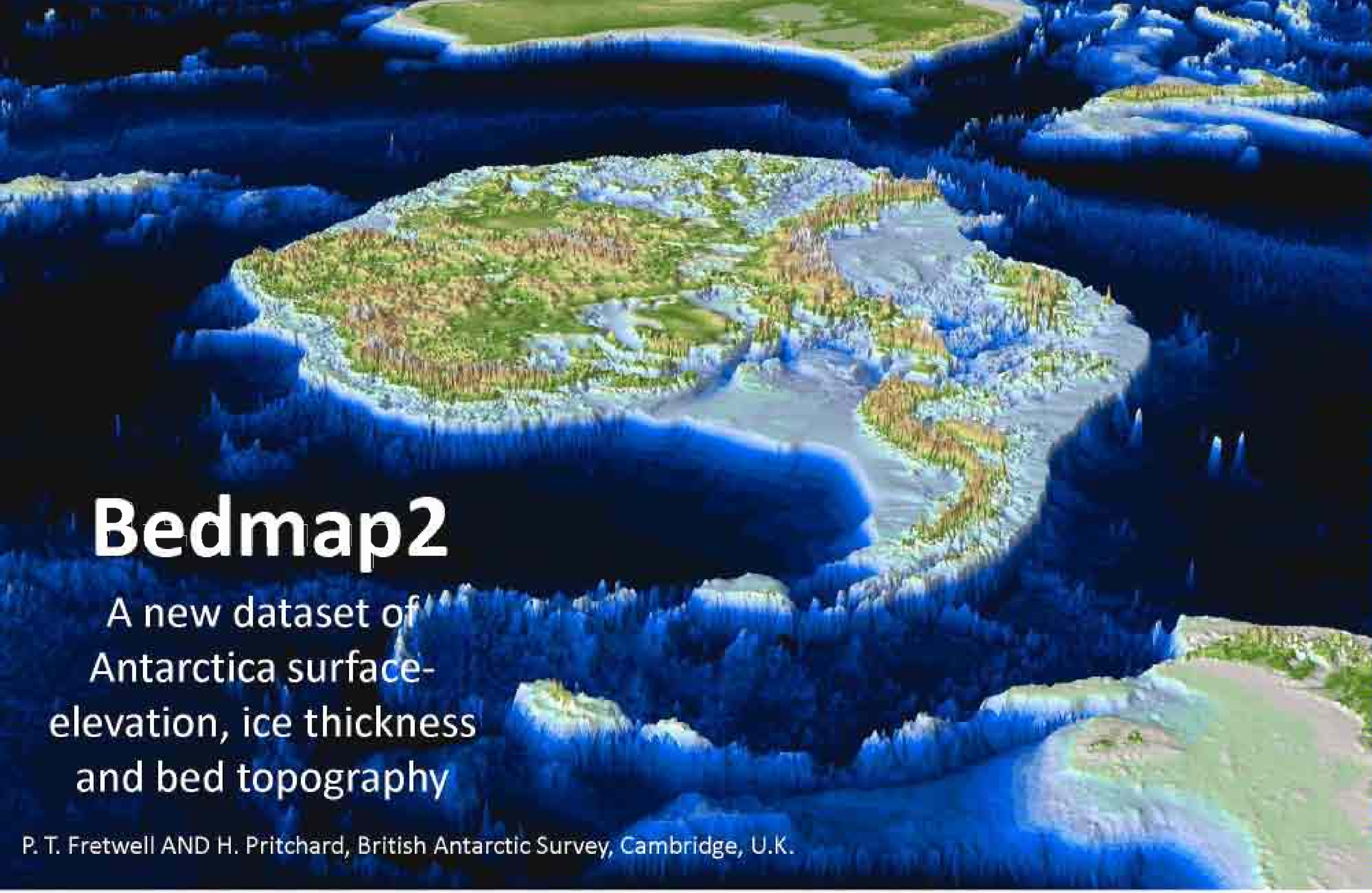
Approximately 30 000 km of line km were flown by TUD, but we only used these data if no other, more recent, observations were available. Hence the lower number shown

Resultant BSEM & ITEM



Uncertainties in elevation values



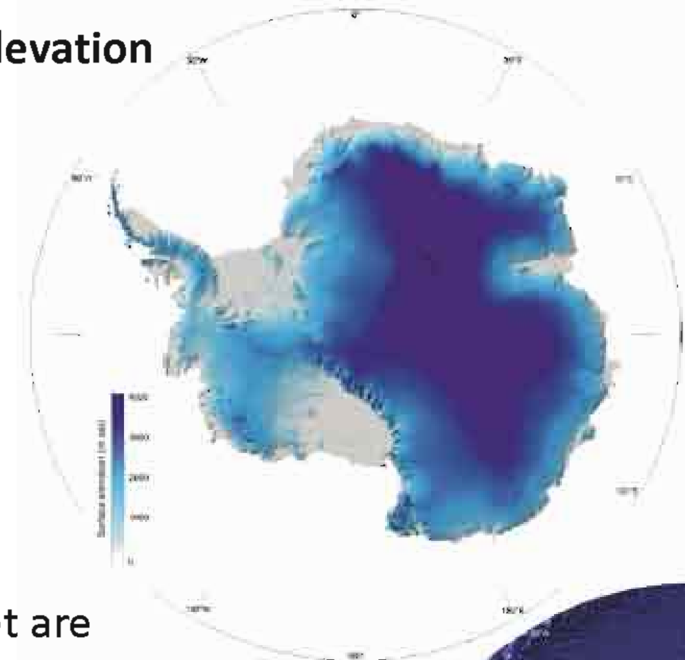


Bedmap2

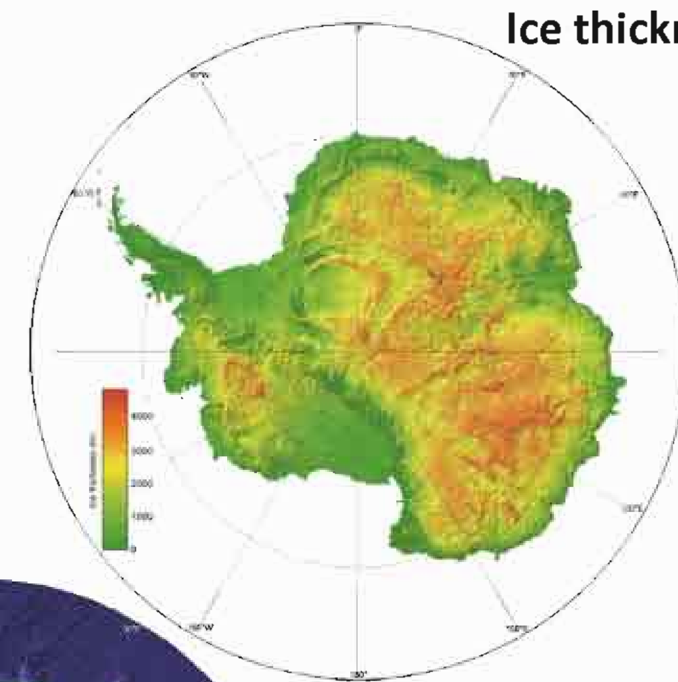
A new dataset of Antarctica surface-elevation, ice thickness and bed topography

P. T. Fretwell AND H. Pritchard, British Antarctic Survey, Cambridge, U.K.

Surface elevation

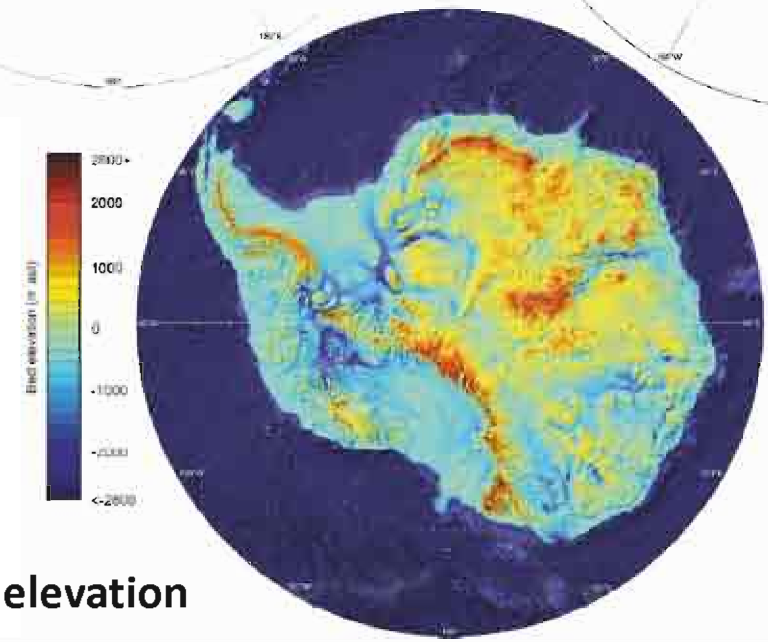


Ice thickness



The three dataset are the culmination of a major data collection effort by the Antarctic science community.

Contributors include 60 authors from 35 institutions in 14 countries



Bed elevation

Additional to the datasets, Bedmap2 provides a number of key statistics for scientists and policy makers

STATISTICS

Bedmap2 statistics

Area, volume and depth	
Number of ice thickness measurements	24.8 million
Number of survey campaigns	207
Number of cells in the final grids	3,490,207
Area including ice shelves (10^6 km^2)	13.924
Area excluding ice shelves (10^6 km^2)	12.295
Ice Volume including ice shelves (10^6 km^3)	26.92
Mean thickness including ice shelves (m)	1937
Mean thickness excluding ice shelves (m)	2126
Thickest ice (Astrolabe Subglacial Basin) (m)	4776
Deepest bed point (Byrd Glacier) (m)	-2870
Area below sea level (10^6 km^2)	5.50
Area below sea level as a % of the total grounded area	44.7
Potential sea-level equivalent (m)	58.3

Potential contribution to sea-level (m)

	Total potential contribution	Potential from ice grounded with a bed below sea-level
Antarctica	58.3 m	22.7 m
East Antarctic Ice Sheet	53.3 m	19.2 m
West Antarctic Ice Sheet	4.3 m	3.4 m
Antarctic Peninsula Ice Sheet	0.2 m	0.1 m

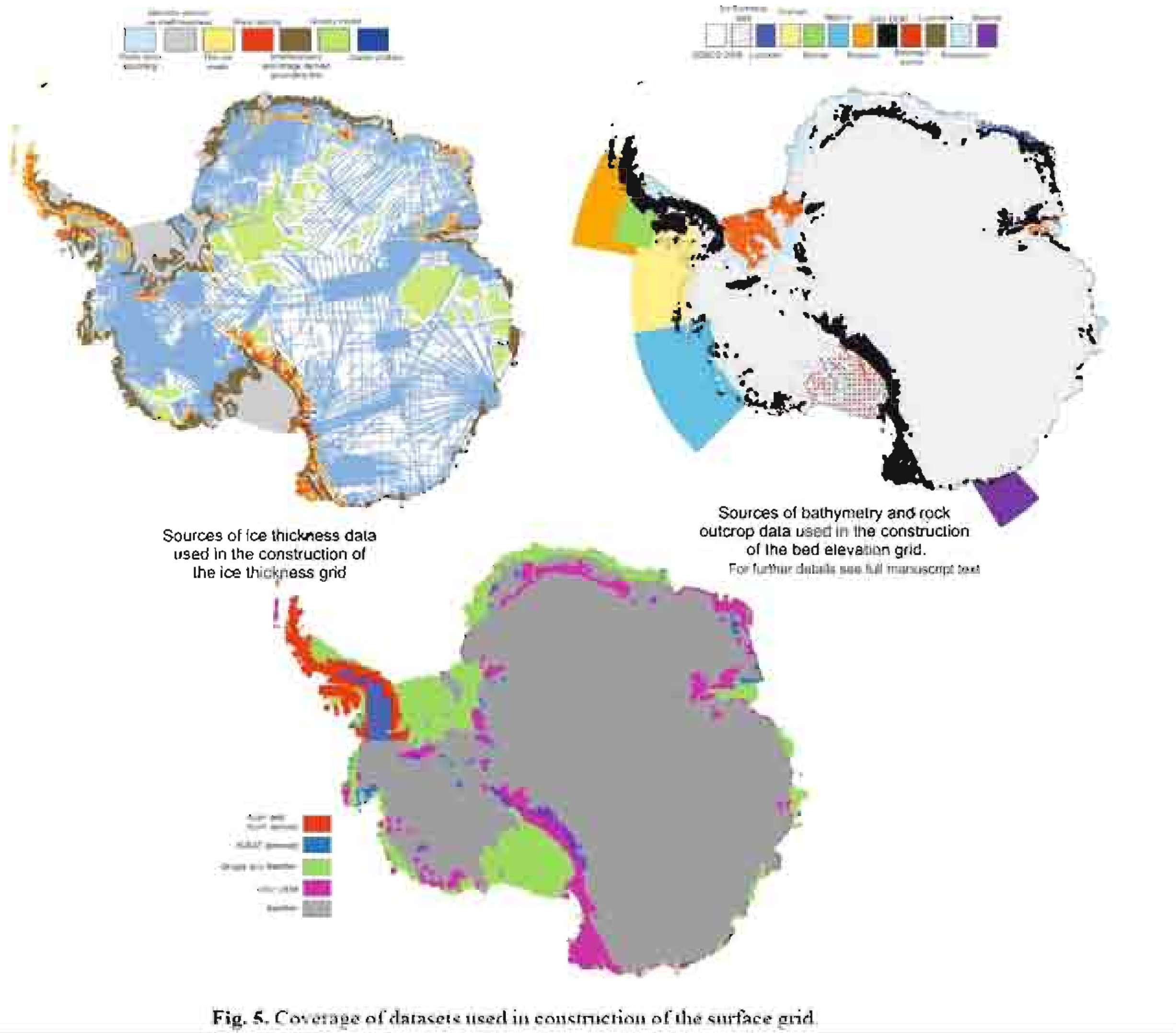
One important user group will be ice sheet modellers who need reliable bed topography to run models of ice sheets

The three datasets are complied from a wide range of different data sources, each with its own inherent uncertainties

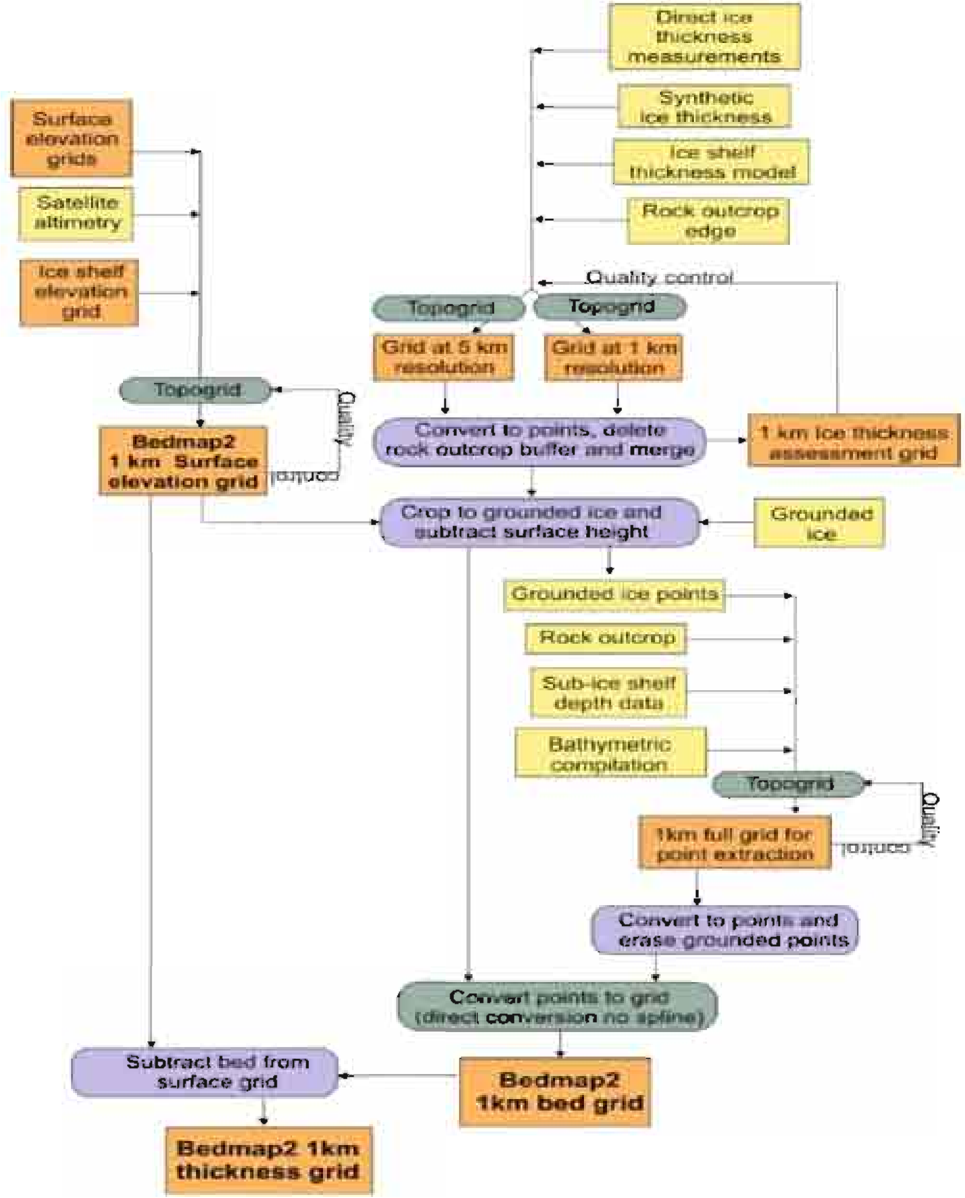
Data sources (ice thickness):
- •radio echo sounding, seismic,
- •satellite altimetry,
- •cartographic data,
- •synthetic data,
- •satellite gravity

Data sources (offshore):
- •gravity inversion,
- •gridded products,
- •swath bathymetry,
- •seismic (under ice shelves)

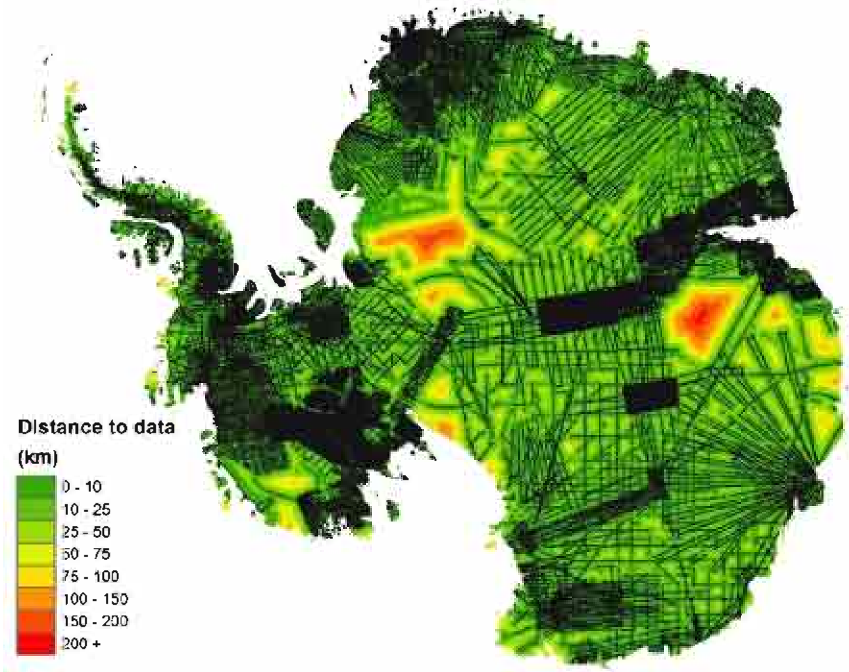
Data sources (surface grid)
- •Icesat satellite altimetry
- •Aster GDEM
- •Gridded products
- •Cartographic data

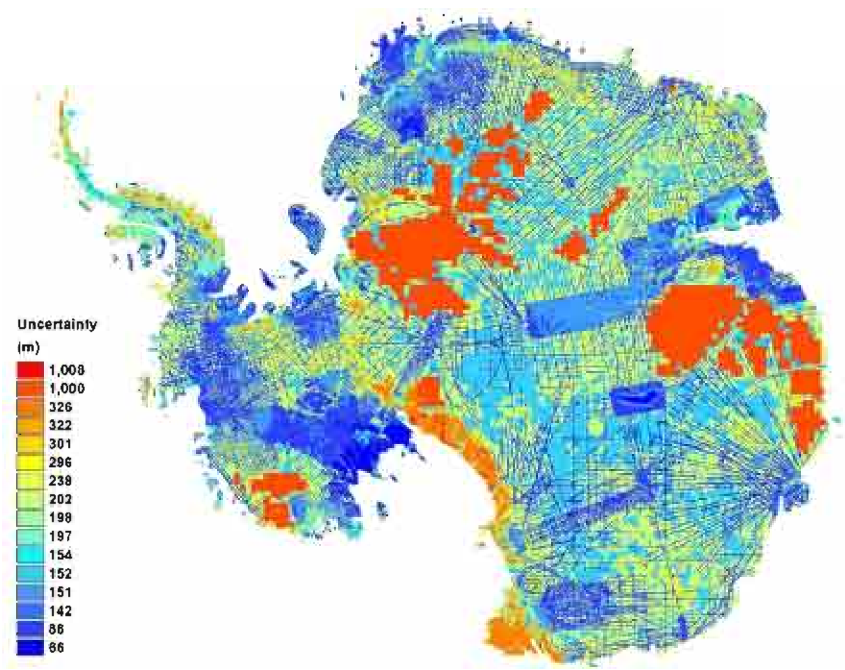


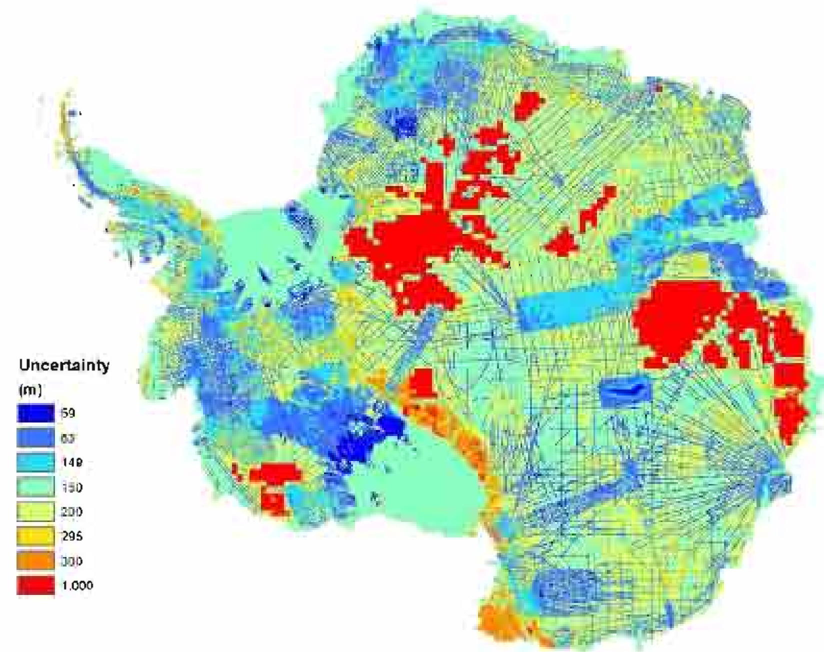
The complexity of the input data has resulted in a methodology that is by necessity complex



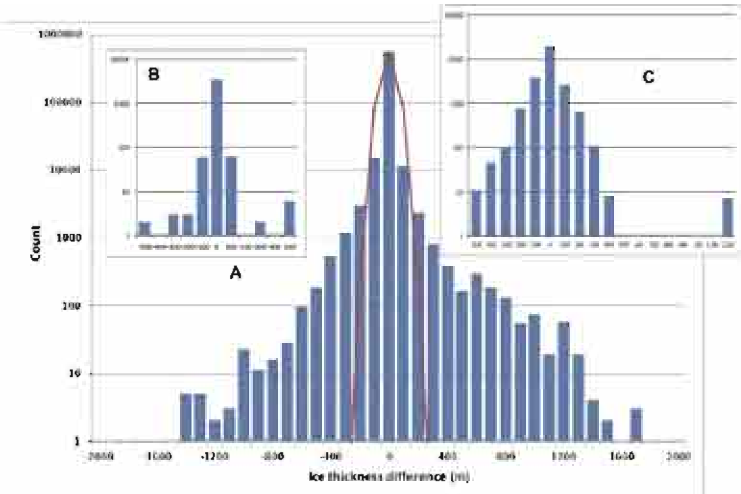
The resulting publication provides a number of grids which quantify the sources of uncertainty







As well as tabular data and graphs



Cross-over analysis

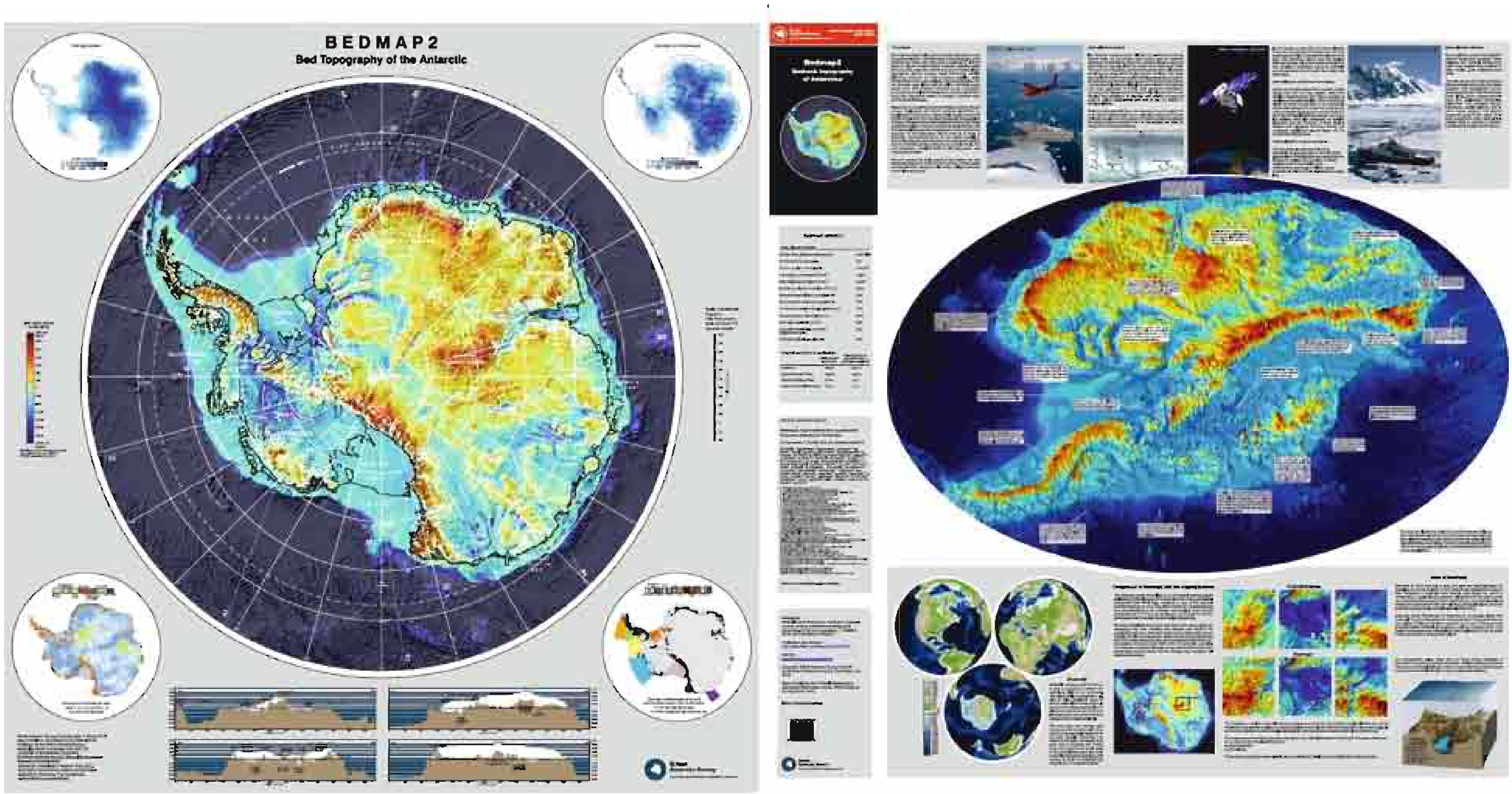
Table 6. Sources of uncertainty in Bedmap2 ice thickness uncertainty classes.

Uncertainty class	Cells with data Gridding uncertainty (±m)	Cells with data Overall uncertainty (measurement and gridding, ±m)	Cells without data Gridding uncertainty (±m)
1 (smooth)	30	59	150
2 (intermediate)	65	83	200
3 (rough)	140	149	295
4 (gravity-derived)	NA	1000	NA
5 (ice shelf)	NA	150	NA
6 (synthetic)	NA	NA	300

Table 3. Digital elevation models used in compilation of the Bedmap2 surface grid.

Source	Location (Fig. X)	Uncertainty estimate
ASTER	Antarctic Peninsula	±26 m, bias +3 m (Cook et al., 2012)
SPIRIT	Antarctic Peninsula	Within ±6 m of ICESat elevations for 90 % of the data in areas of good contrast (Korona et al., 2009)
Satellite radar and laser altimetry (Griggs and Bamber, 2011)	Ice shelves away from grounding zone	±15 m, bias 5 m
Satellite radar and laser altimetry (Bamber et al., 2009a)	East and West Antarctic ice sheet away from mountains	±23 m, bias <1 m
Satellite laser altimetry (Brenner et al., 2007)	Interior Antarctic Peninsula, some mountain and coastal areas	Estimate ranges from ±0.4 m, bias −0.4 m (relative to airborne laser scanning) to ±20 m, bias −24 m (relative to radar altimeter DEM over steeper slopes)
OSU DEM (Liu et al., 1999)	Mountain areas	±100 to 130 m

A new double sided map of the sub-surface topography has now been compiled that details some of the features of the publication and dataset



Details of the dataset, publication and resulting map are recorded below

Reference:

- Fretwell and Pritchard et al. Bedmap2: improved ice bed, surface and thickness datasets for Antarctica. 2013. The Cryosphere, 7, 375-393, 2013, doi:10.5194/tc-7-375-2013

Publication web address:

- http://www.the-cryosphere.net/7/375/2013/

website:

- www.antarctica.ac.uk/bedmap2

Map compiled by P.T. Fretwell, Mapping and Geographic Information Centre, British Antarctic Survey. March 2013.

ISBN 978-0-85665-205-9

Map available from Stanfords map shops: http://www.stanfords.co.uk/

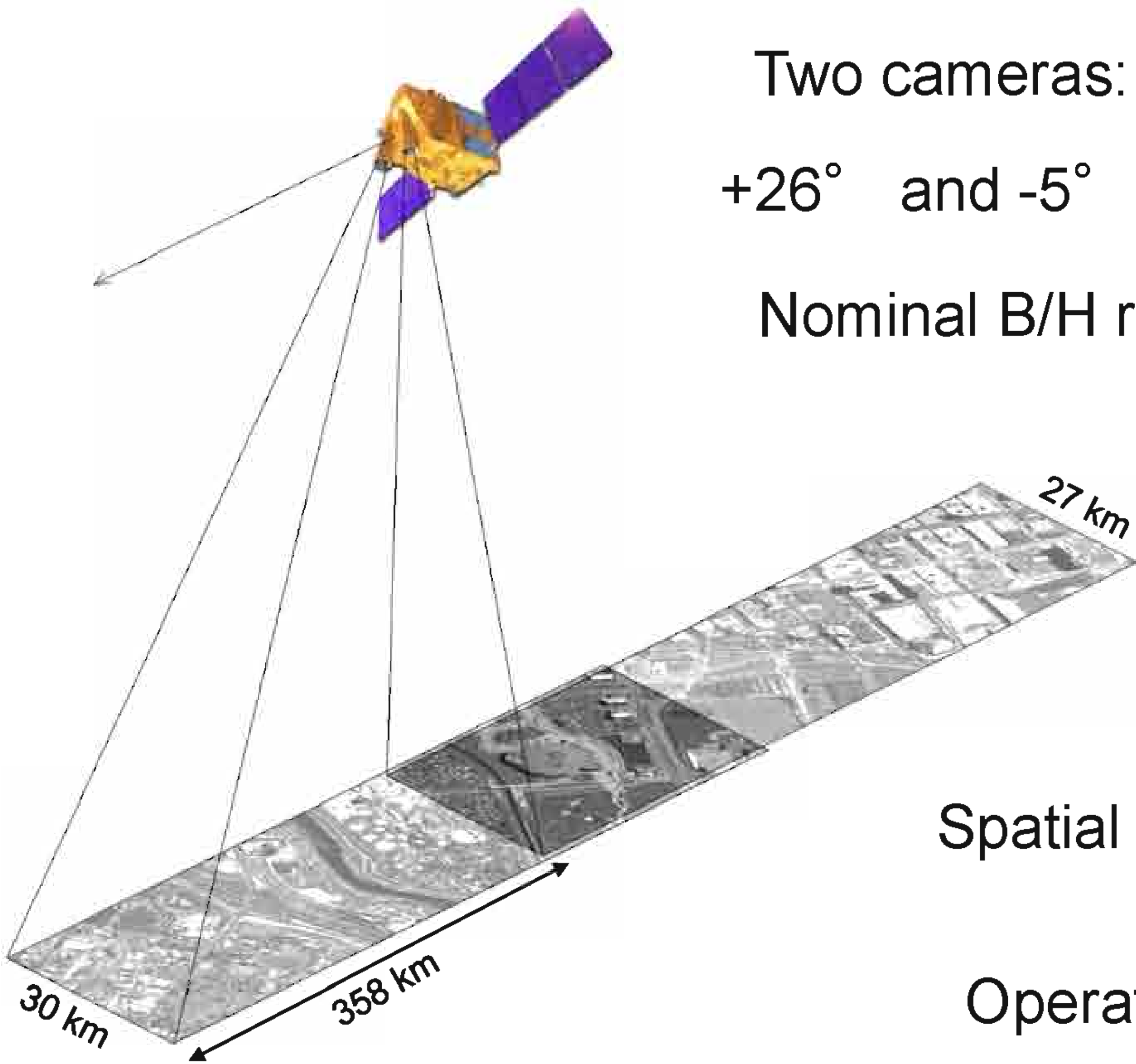
euromap

A GAF COMPANY

Satellitendaten-Vertriebsgesellschaft mbH

Euro-Maps 3D – a Transnational, High-Resolution Digital Surface Model

IRS-P5 Cartosat-1



Two cameras: PAN-Fore & PAN-Aft

+26° and -5° tilt along the track

Nominal B/H ratio 0.62

Swath 27 km

10 bit resolution

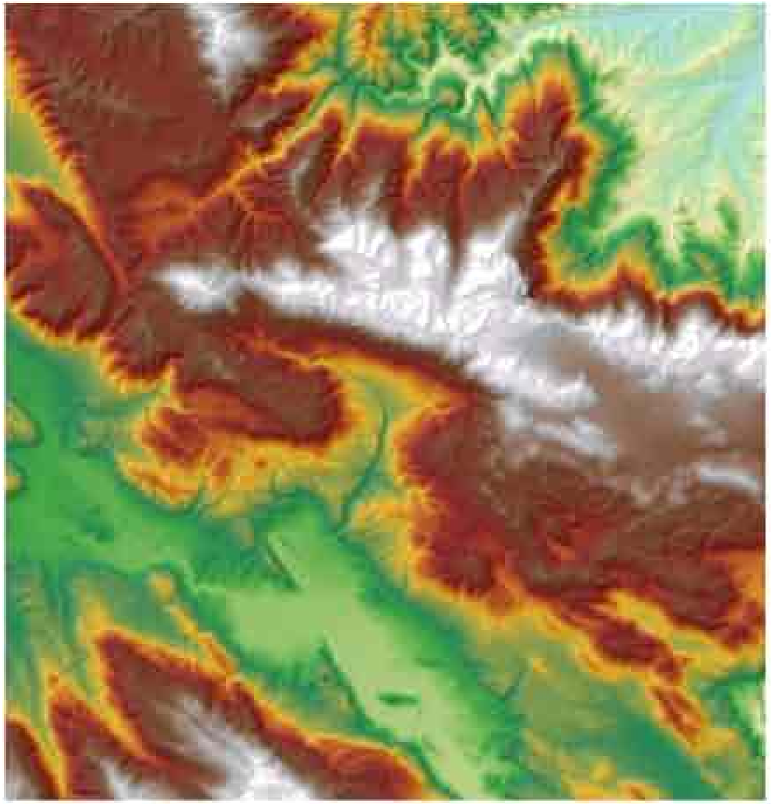
Spatial resolution 2.5 m

Operational since May 2005

Euro-Maps 3D

Product specifications:

Post spacing	5 m
Spatial reference system	UTM / WGS84
Height reference	EGM96
Vertical accuracy	LE90 5-10 m
Horizontal accuracy	CE90 5-10 m
Relative accuracy	LE90 <2.5 m
File Format	GeoTIFF (16-bit)
Scene-based DSM	27 km x 27 km
Mosaicked DSM	0.5° x 0.5° tiles
Base data	IRS-P5
Orthoimage pixel size	2.5 m

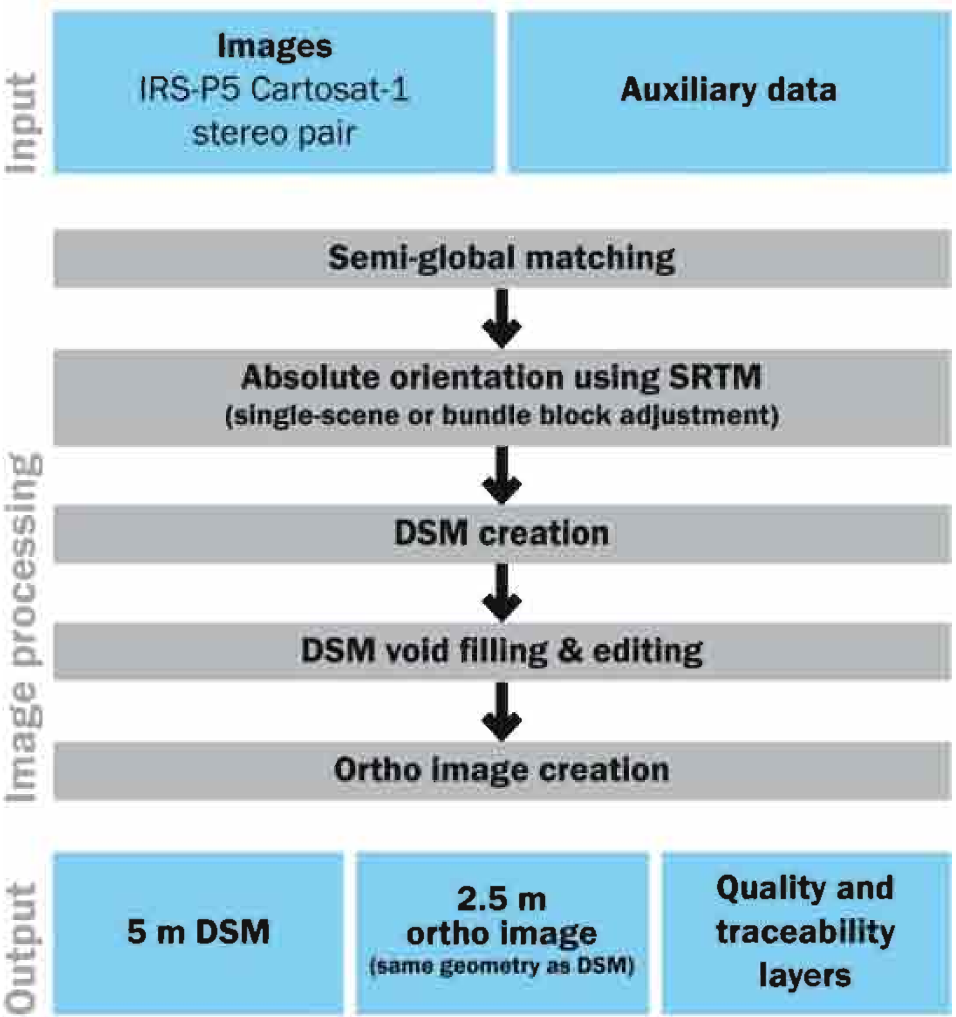


© 2013, Euromap, includes Antrix material

HRE80 and HREGP accuracy requirements are fulfilled

Production Workflow implemented at Euromap

Based on DLR/IMF developed Xdibias and Catena Software



Through a global georeferencing approach, the same accuracy is achieved worldwide for areas between 56° S and 60° N

Detailed and accurate representation of the surface is achieved by using a sophisticated and tailored algorithm

Product transparency and standard quality is guaranteed through several quality and traceability layers

Data

Production

Software

DLR

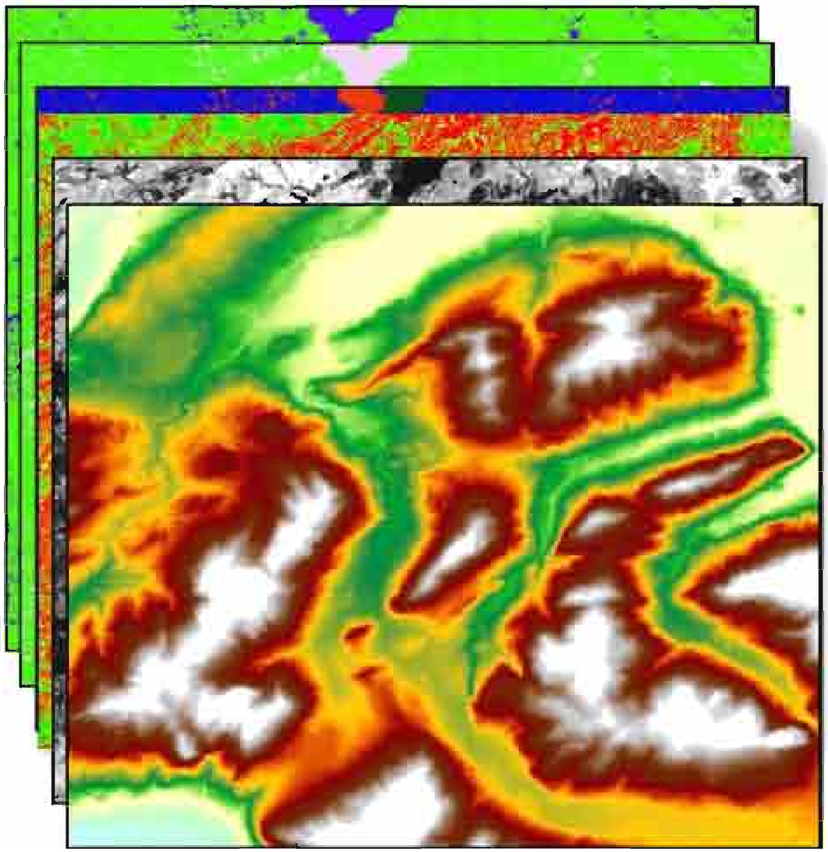
Development

GAF AG

Quality & Traceability Layers

Detailed additional information consisting of several pixel based quality and traceability layers also including an ortho layer

Num	Number of stereo pairs used	
QC	Final quality assessment	
	0:	outside specs
	1:	within specs
Src	0:	Background
	1:	IRS-P5 Cartosat-1
	2:	SRTM
	3-9:	other DEMs
	10:	manually edited
	11:	water mask
	12-255:	reserved for other usages
Acv	Estimated vertical accuracy per pixel	
ORTHO	Orthorectified nadir image	
DEM	Derived DSM posted at 5m gridpoints	



Absolute Accuracy

Test site	Land cover/relief	LE90	CE90
Ankara	Urban, hilly	3.9	4.2
Kastamonu	Urban, hilly	3.4	2.2
Uzunköprü	Agriculture, flat	8.3	4.0
Aydin	Agriculture, forest, mountainous	5.5	5.9
Arles	Wetlands, agriculture, flat	2.6	9.4
Nebelhorn-north	Mountainous	3.9	4.6
Nebelhorn-south	Mountainous	4.1	5.8
Munich	Urban, agriculture, flat	6.3	4.3
Heidelberg	Forest, urban, agriculture, hilly	5.2	5.8
Koblenz	Forest, urban, open cast mining, hilly	7.1	5.6
Tunis	Urban, hilly	4.4	6.0
Le Kef 1	Dry, flat	3.9	5.7
Le Kef 2	Dry, flat	4.0	7.8
Sfax	Dry, very flat, salt lake	4.0	7.9
Gafsa	Dry, flat	3.6	7.4
Mlawa	Forest, agriculture, flat	8.4	5.1
Nowy Targ	Agriculture, forest, mountainous	6.4	7.4
Mostar	Agriculture, hilly	4.5	7.0
Trebinje	Agriculture, hilly	5.6	4.1
Relizane	Dry, flat	5.9	6.9
Gospic	Forest, hilly	8.4	3.1
Friedrichshafen	Agriculture, forest, flat	5.3	8.9

Tested and verified against GPS transects in 22 test sites

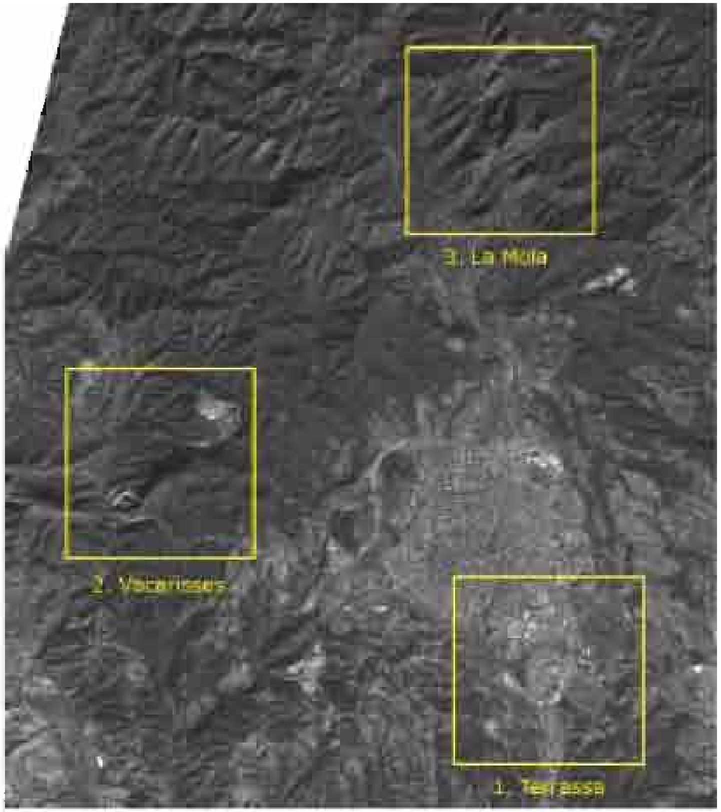
Mean lateral error CE90 of 6.7 m

Mean vertical error LE90 of 5.1 m

Uttenthaler, A., d'Angelo, P., Reinartz, P., Hass, P., Carl, S., Barner, F.;
A Concept for a Standardized DSM Product Automatically Derived from IRS-P5 Cartosat-1
German Aerospace Center (DLR), Remote Sensing Technology Institute, GAF AG and Euromap GmbH
Geospatial World Forum, Hyderabad, India, 21-Jan-2011

Absolute Accuracy

Tested and verified against LIDAR data in 3 test sites near Barcelona, Spain



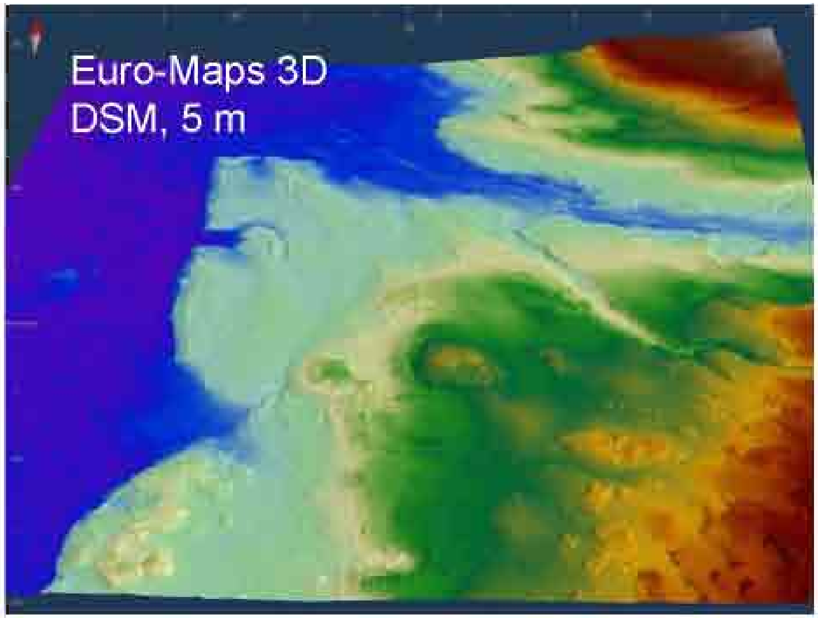
Test area	Mean	Med	Std	NMAD	AQ68	AQ95
Terrassa	0.03	0.00	3.44	2.07	2.29	6.83
Vacarisses	-0.16	0.07	4.05	2.80	2.97	7.45
La Mola	-1.21	-0.03	8.18	3.69	3.90	12.64
Field	0.19	0.13	1.99	1.25	1.31	3.90
Bridge	1.22	0.28	4.86	2.12	2.27	12.18
Industrial	-0.10	-0.10	3.11	2.33	2.49	6.19
Residential	0.49	-0.08	3.90	2.64	2.88	8.28
City	-0.56	-0.64	5.63	3.88	4.16	10.36

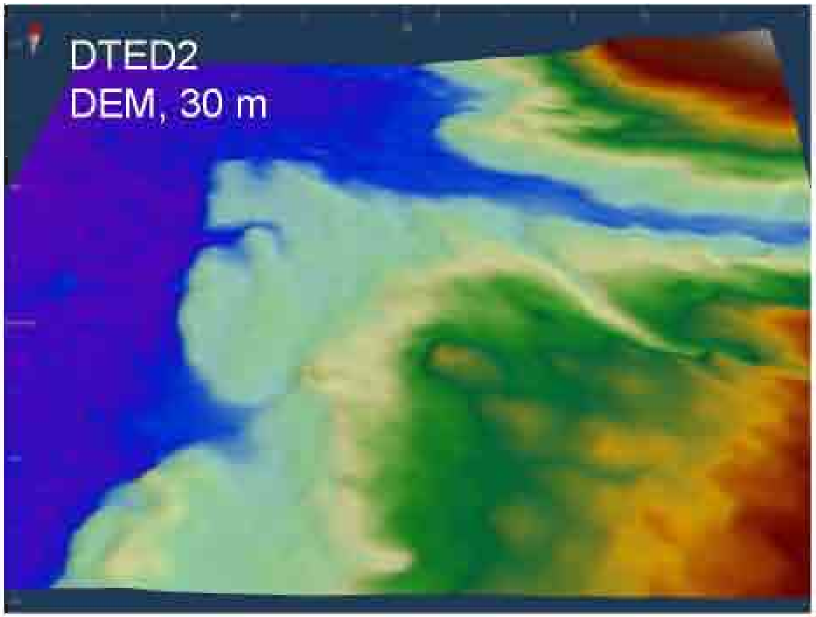
Table 3: Statistical evaluation of the euclidean distance between LIDAR reference points and the Cartosat-1 DSMs. The statistics for different landcover types were computed on the Terrassa area with the masks shown in Fig.2.

d'Angelo, Pablo und Reinartz, Peter (2011) *Semiglobal Matching Results on the ISPRS Stereo Matching Benchmark*.
Institute of Photogrammetry and GeoInformation, Leibniz Universität Hannover.
High-Resolution Earth Imaging for Geospatial Information, Hannover, Germany. ISSN 1682-1777

Level of Detail

Euro-Maps 3D shows more details in urban, forest and textured areas in comparison to DTED2 DEM





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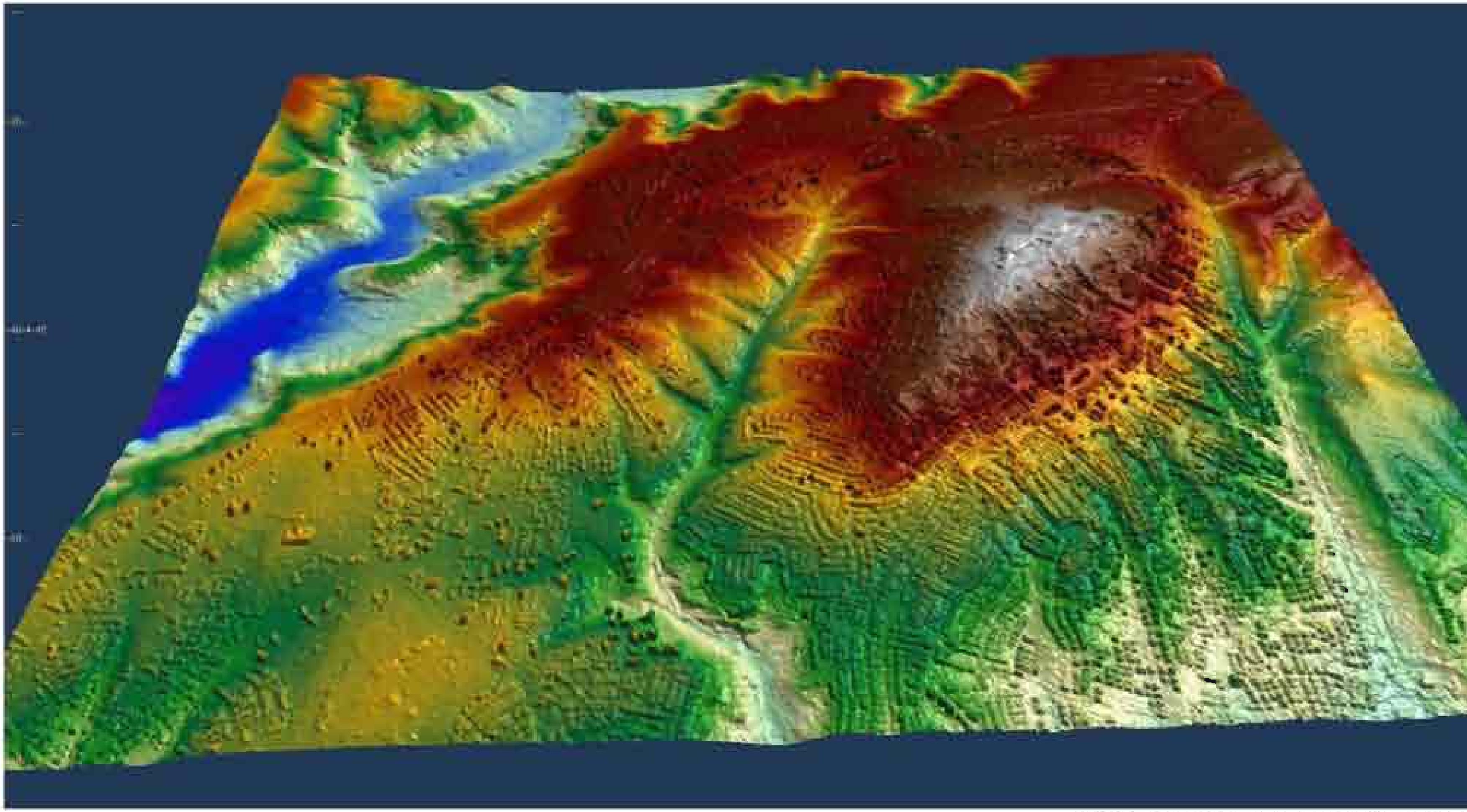
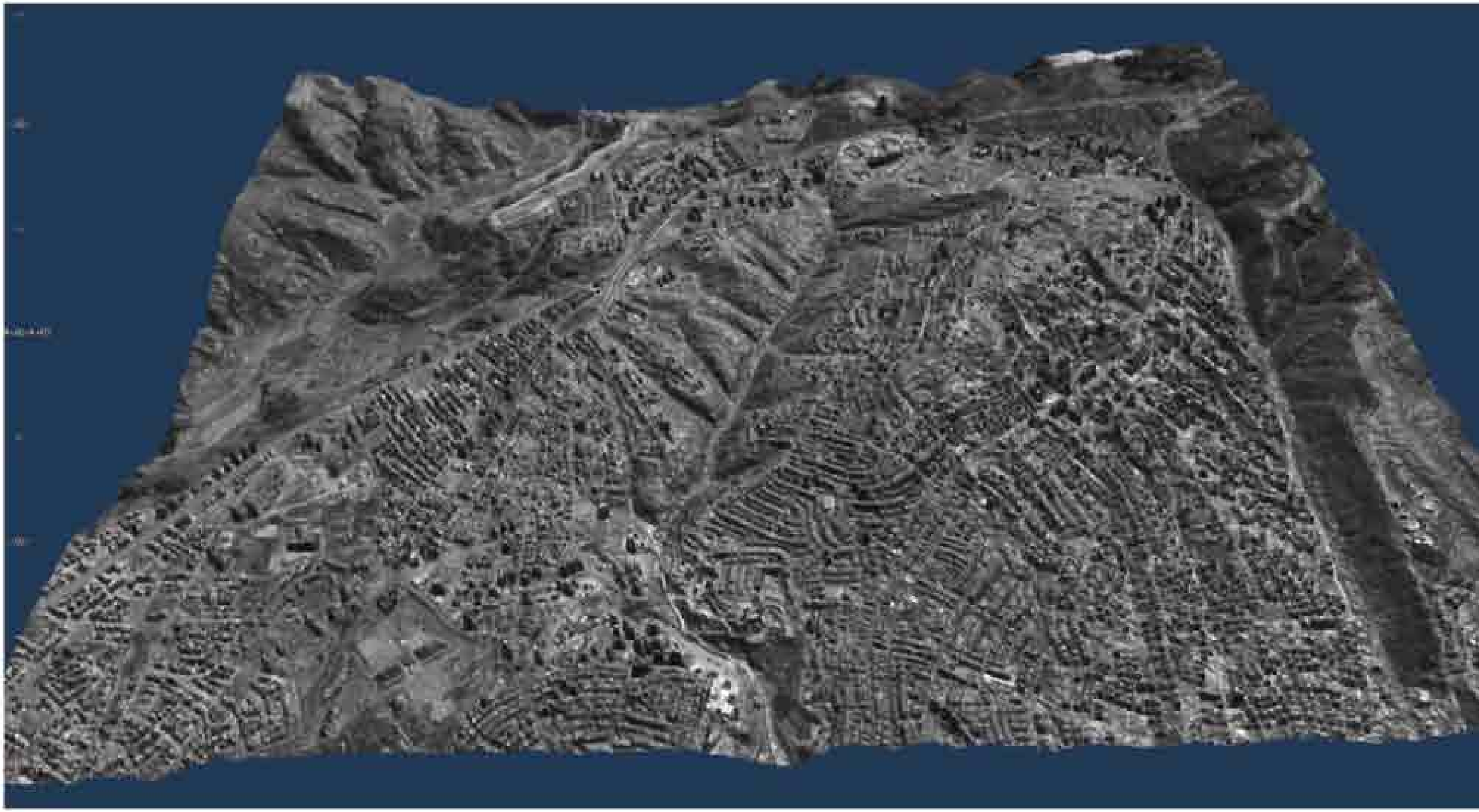
Turkey: Ankara in 3D

Euro Maps 3D



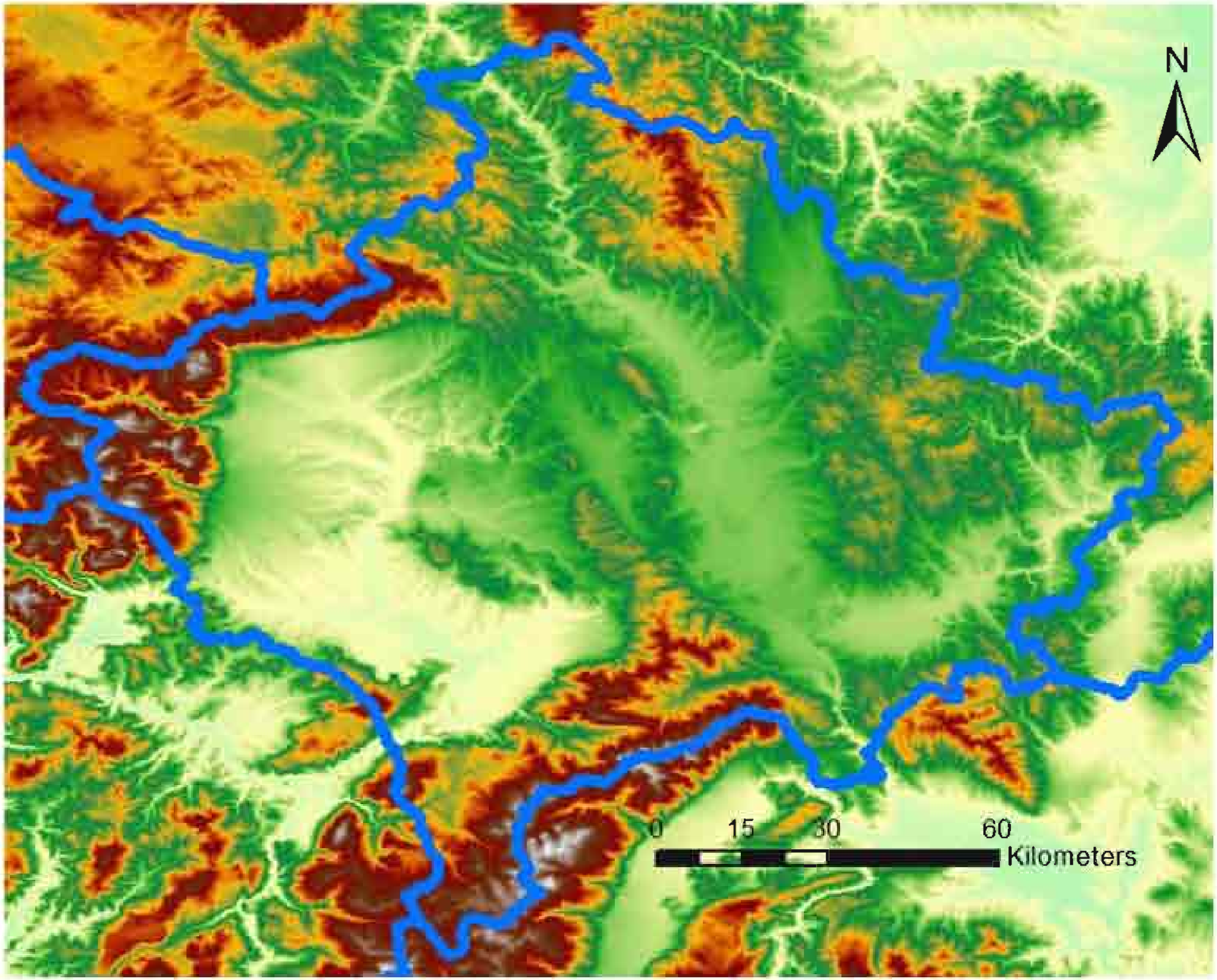
Euro-Maps 3D
with 5 m post spacing

Turkey: Ankara in 3D



2.5 m PAN-Aft Orthoimage of Ankara
draped over Euro-Maps 3D

Seamless Mosaic: Kosovo



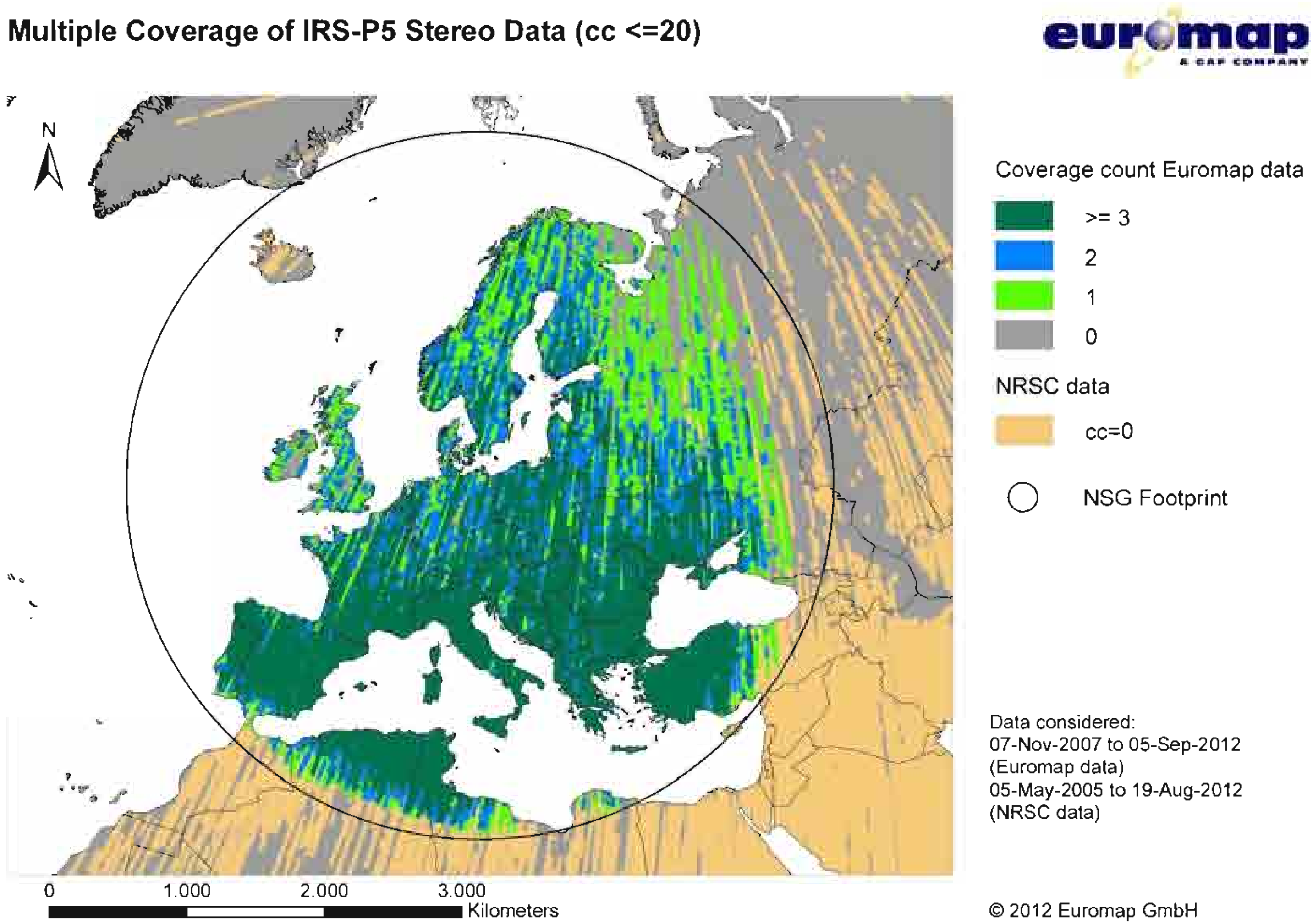
~ 130 stereo pairs

Multiple coverage of up to 8 stereo pairs

The pan-European, off-the-shelf DSM product will be continuously made available by Euromap

Other areas worldwide can be processed on request

European Cloud-free & DEM/ORI coverage and Price



The price per sq.km. is 4 € (4.50 € incl. ortho layer) for areas larger than 50,000 sq.km. and 7 € (7.50 € incl. ortho layer) for areas smaller than 50,000 sq.km. Countries completed to date include

Slovenia, Serbia, Macedonia, Kosovo, Greece, Albania

VALIDATION STUDIES OF TANDEM-X DATA

Global and Regional DEM benchmarking for reference DEM selection

6 months evolution

Enrique Nicolás / Pablo Gómez / Francisco Manuel Cabello
National Aerospace Institute of Spain (INTA).
Earth Observation, Remote Sensing and Atmosphere Department.
Observation Systems Area / Image Processing Laboratory.
nicolasge@inta.es

Main objectives: 6 months evolution

-Consolidation of TSAs – Ground truth finished:
- -9.760km of Z-tracks acquired (814.437 filtered points).
- -GCPs acquired with 3D accuracy below 0.15m (483 acquired).
- -Z-tracks in high relief. More than 151km in ridges between 1500-2500m ASL.

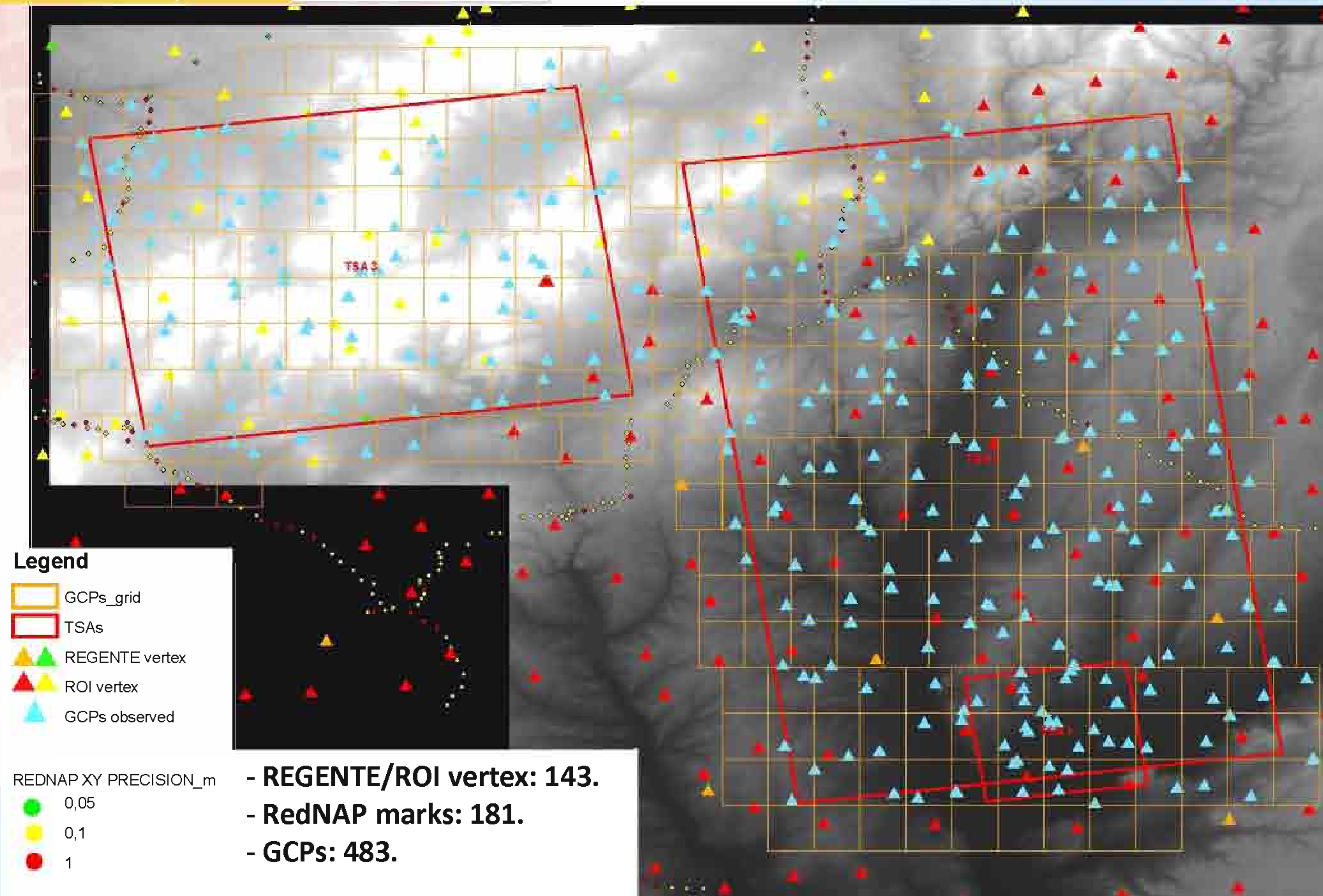
-DEMs analysis:
- -DEM benchmarking
  - -Free Global sources: SRTM / SRTMX / GDEMv1 / GDEMv2.
  - -Free National sources: IGN25 / PNOA5 (stereocorrelation) / **PNOA5_LiDAR**.
  - -Commercial sources: Intermap NextMap (5m) / Reference 3D.
  - -Restricted sources: DTED2 / CEGET.
- - Continuous DEM source selection for TanDEM-X DEMs validation.
- - New ground truth areas: INTA Dynamic Platform / N-1 Highway Synthetic Track.
- - Land cover influence in height error.

Best DEM

-TanDEM-X images acquisition (different geometric/polarimetric configuration):
- - 58 TanDEM-X SM products acquired (29 pairs).
- - Two ascendant orbits 71 and 162.
- - Different incidence angles between 20º and 40º.
- - Single polarization change VV or HH.

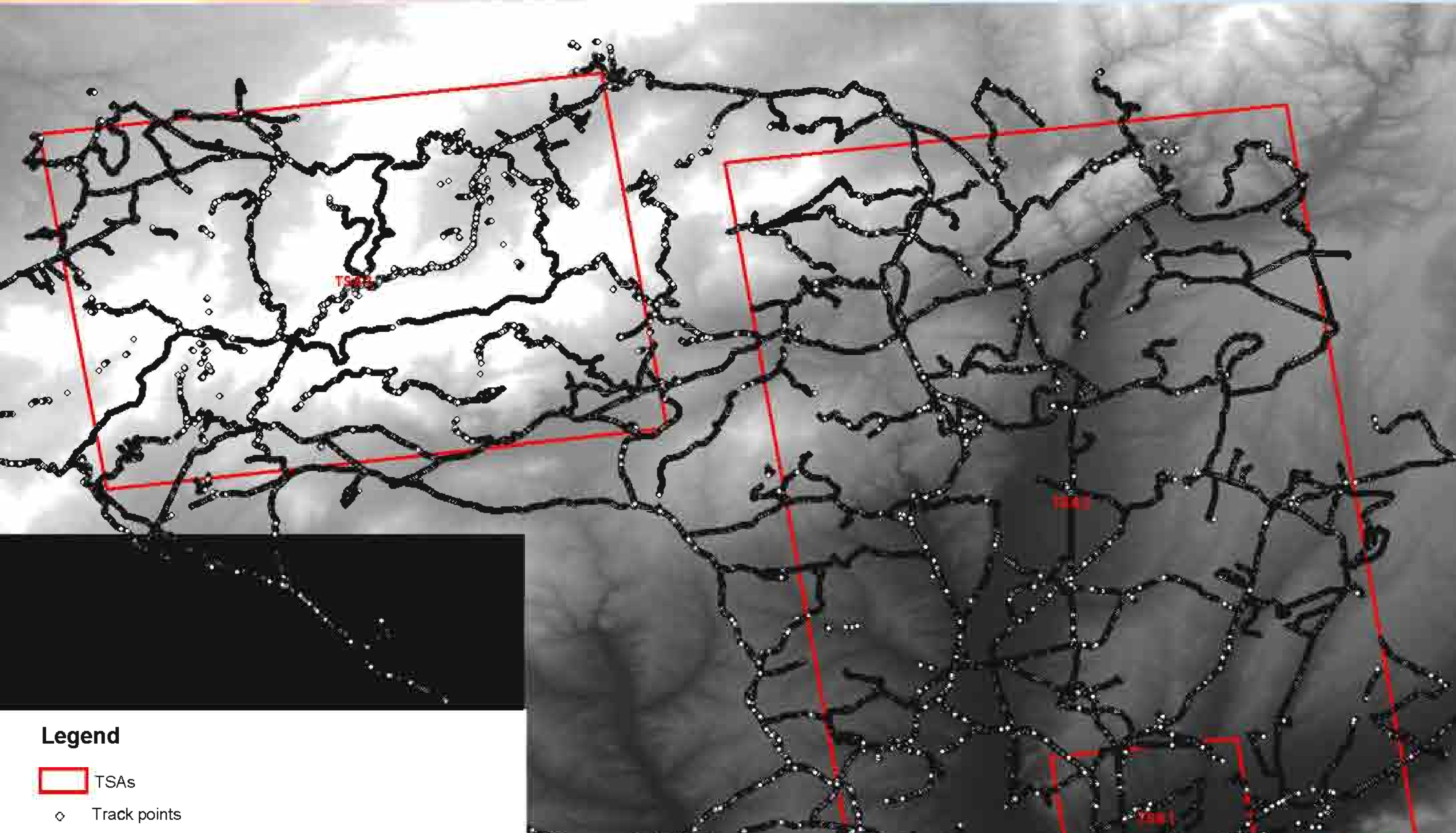
Ground truth data – Vertex, marks and GCPs

(Madrid region, Spain)



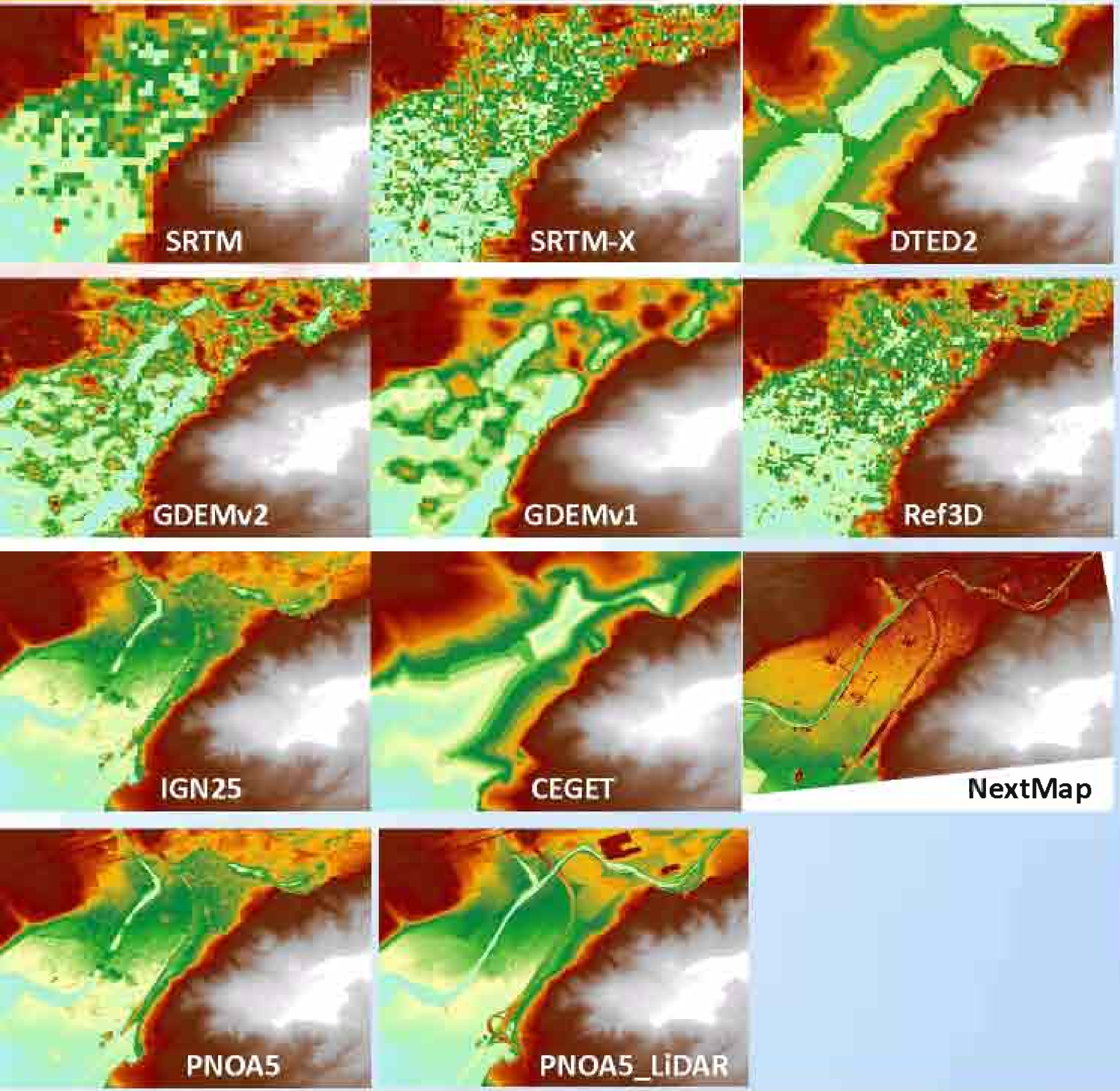
- REGENTE/ROI vertex: 143.
- RedNAP marks: 181.
- GCPs: 483.

Ground truth data – Z-Tracks
(Madrid region, Spain)



- Track points (filtered): 814.437
- Distance measured: 9.760 km.

QA of the continuous sources with discrete data. Benchmarking process

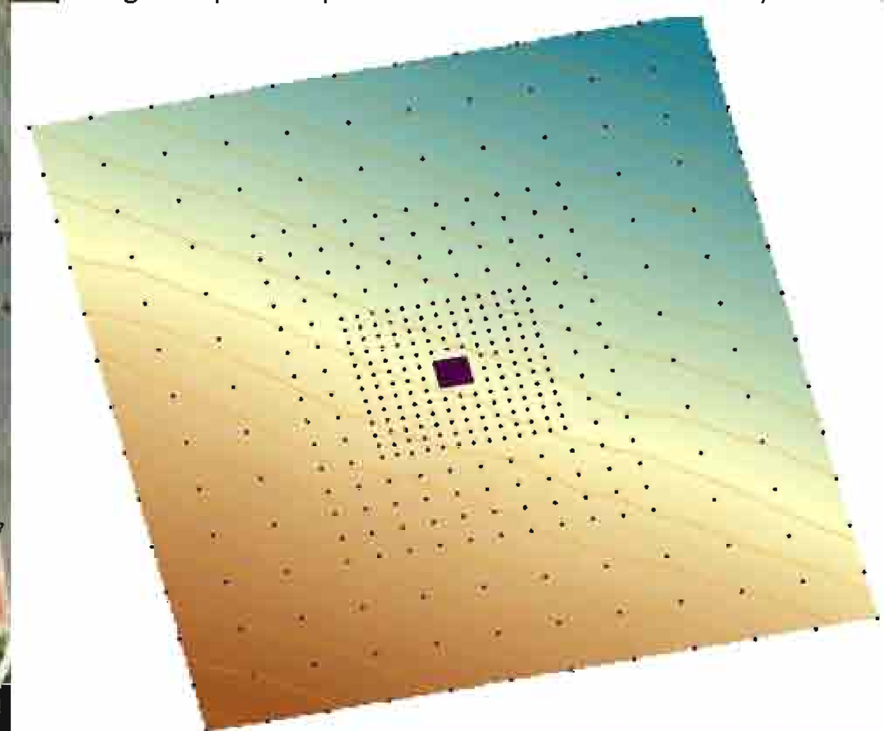


MDE	Coverage	GSD ~ m
SRTM	Global	90
SRTMX	Global	30
DTED2	Global	30
GDEMv1	Global	30
GDEMv2	Global	30
Ref3D	Global	30
IGN25	Regional	25
CEGET	Regional	10
NextMap5	Regional	5
PNOA5	Regional	5
PNOA_Lidar	Regional	5

QA : New ground truth / INTA Dynamic platform

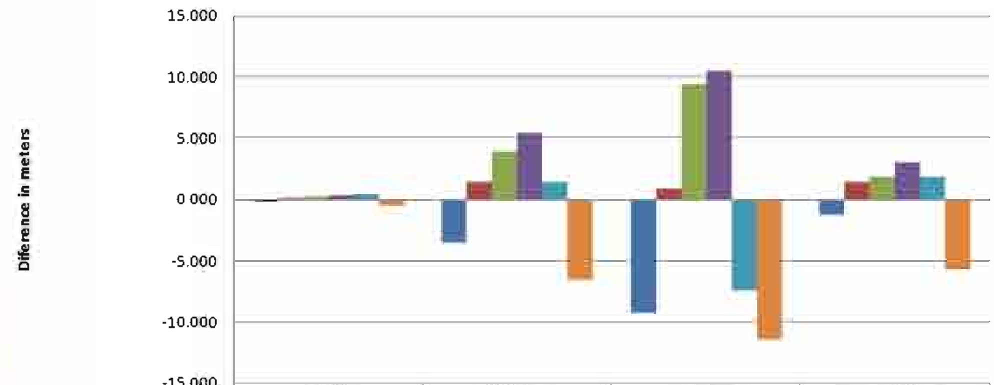
- Asphalt platform with a constant slope of 1% for water evacuation and a surface near to 6 Ha (build in 2003).
- GPS + TPS measured Grid of 517 points.
- Grid density:
  - 20m (DEM GSDs 90-25m)
  - 10m (DEM GSDs 25-10m)
  - 5m (DEM GSD 5m)
  - 1m (LiDAR Validation purposes)

Height map of the platform with countour lines every 20cm



QA : New ground truth / INTA Dynamic platform

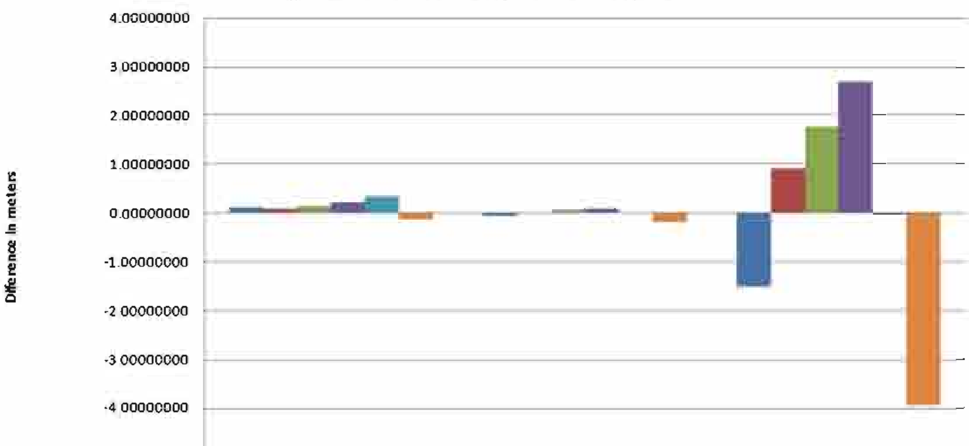
20M GRID - DIFFERENCE ANALYSIS



	IGN25	GDEM_V2	GDEM_V1	REFERENCE_3D
Average of the differences	-0.163	-3 561	-9.282	-1.238
Standard Deviation	0.176	1.453	0.899	1.410
RMS_z	0.240	3.856	9 353	1.879
LE90/LMAS	0.389	5.424	10 428	3 051
Max_difference	0 468	1 429	-7.403	1 860
Min_difference	-0.552	-6 516	-11.388	-5.679

- 5m grid
  - -PNOA5, PNOA5_LiDAR and Nextmap5.
  - -68 points used in the analysis.
  - -0,36 Ha.

5M GRID - DIFFERENCE ANALYSIS



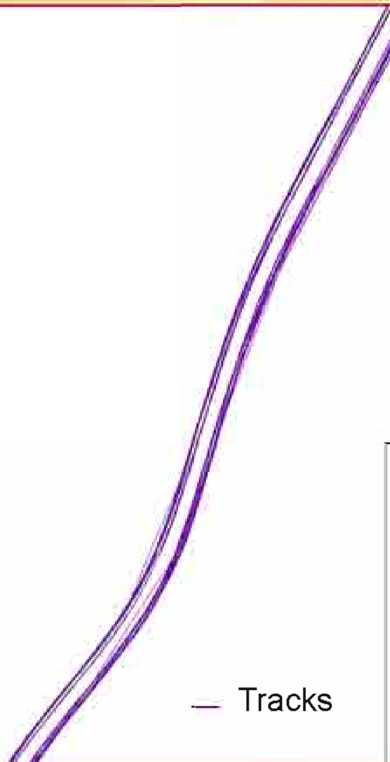
	PNOA5	PNOA5_LIDAR	NEXTMAP
Average of the differences	0.10747066	-0.06527535	-1.52189658
Standard Deviation	0 094728471	0.02881153	0.920679066
RMS_z	0.142577563	0.071443744	1.775538201
LE90/LMAS	0 23	0.10	2 70
Max_difference	0.349	0 010	-0.001
Min_difference	-0.132	-0 189	-3 939

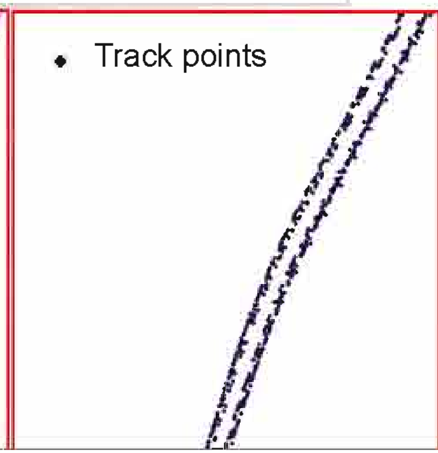
- 20m grid
  - -ASTER GDEM v1 and 2, IGN25, Ref3D.
  - -298 points used in the analysis.
  - -Area: 5,6 Ha.

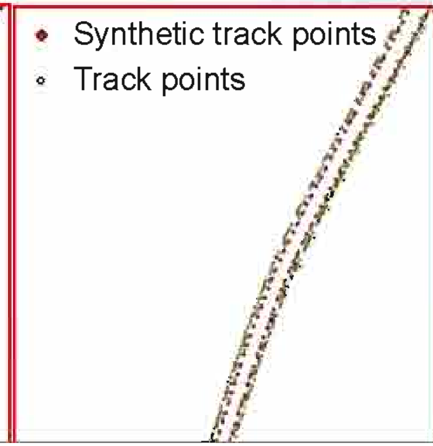
- The dynamic paltform was built in 2003. SRTM, SRTMX, CEGET and DTED2 cannot be evaluated due to the age (older than 2003) of the data used for their construction.

GOBIERNO DE ESPAÑA | MINISTERIO DE DEFENSA | SECRETARIA DE ESTADO DE DEFENSA | INTA Instituto Nacional de Técnica Aeroespacial

QA : New ground truth / Synthetic Z-Track
(A-1 Highway and Lozoya Valley Road)





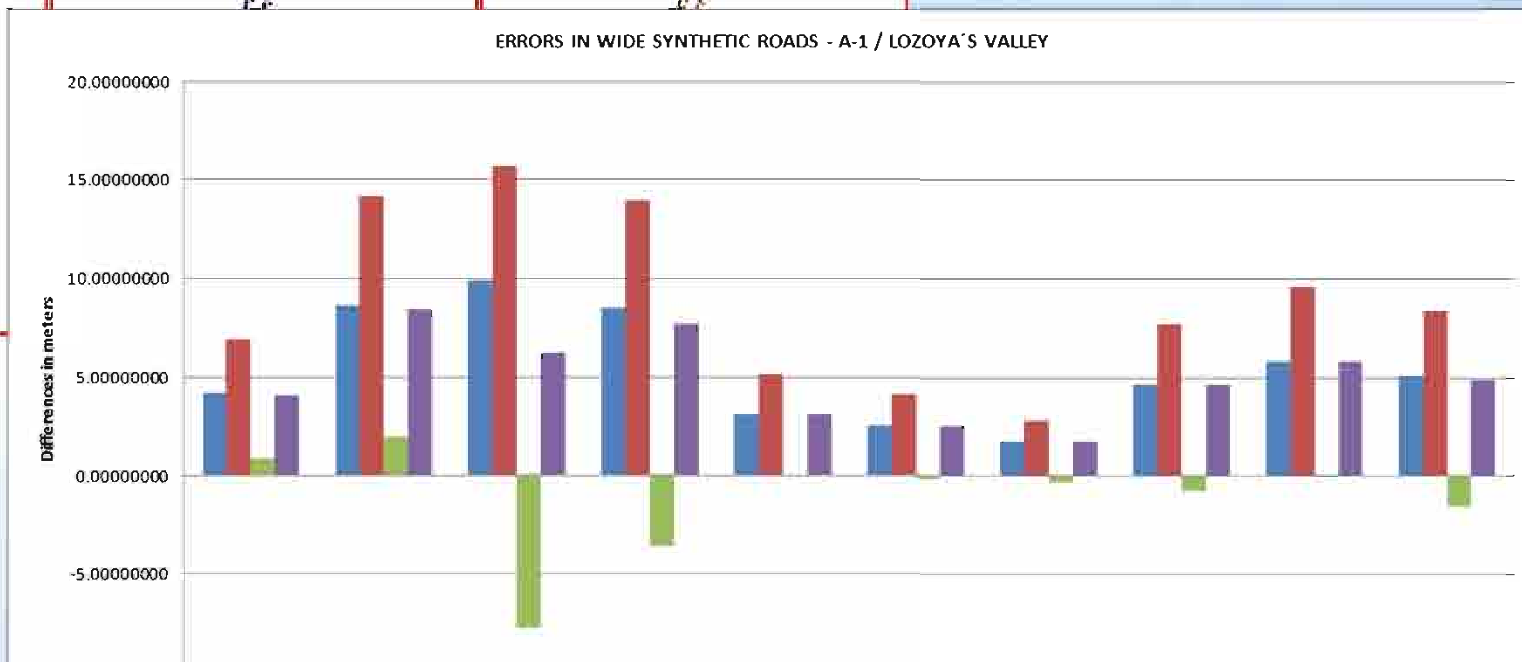


-More than 30 concurrent tracks (64.208 points).

-Extracted 1 synthetic point every 10m of road taking into account the nearest points (search radius = 10m, Z weighted mean in terms of distance).

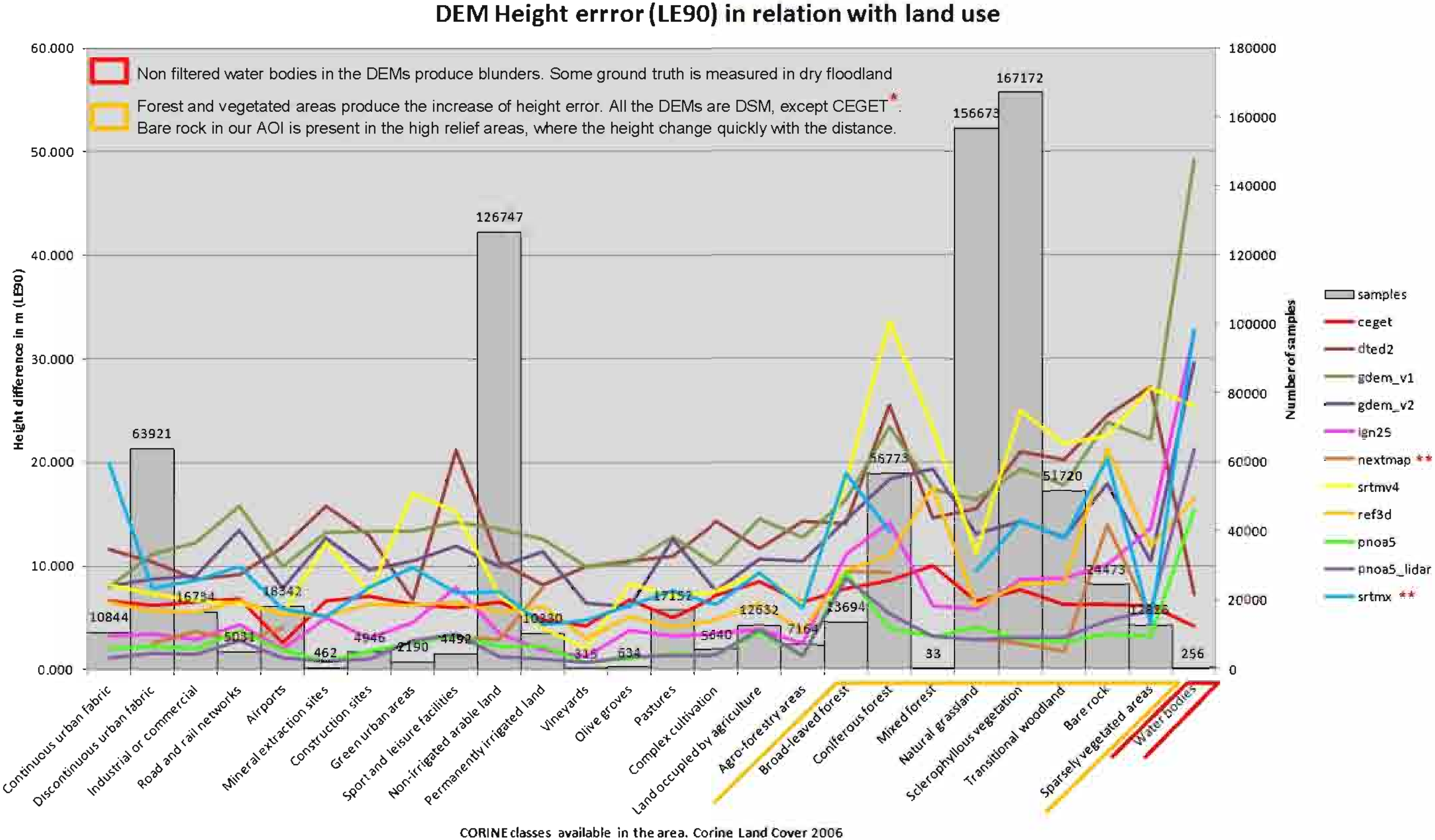
-Total of 10.749 points (107 km).

- NextMap5 non evaluated due to reduced coverage.



	CEGET	DTED2	GDEM1	GDEM2	IGN25	PNOA5	PNOA5_LIDAR	REF3D	SRTMV4	SRTMX
RMSZ	4.19199768	8.634649603	9.906350833	8.491888365	3.134209179	2.533828678	1.73414894	4.67267862	5.852829453	5.070978781
LMAS	6.90	14.22	15.71	13.98	5.16	4.17	2.86	7.69	9.63	8.36
DIF AVG	0.863196044	1.959055464	-7.7054803	-3.597148255	0.054881896	-0.11019733	-0.269421413	-0.694007014	-0.061677671	-1.504195629
STAND DEV	4.102153957	8.409453978	6.226895603	7.692738135	3.13372859	2.531431052	1.713172217	4.620847816	5.852504431	4.842727427

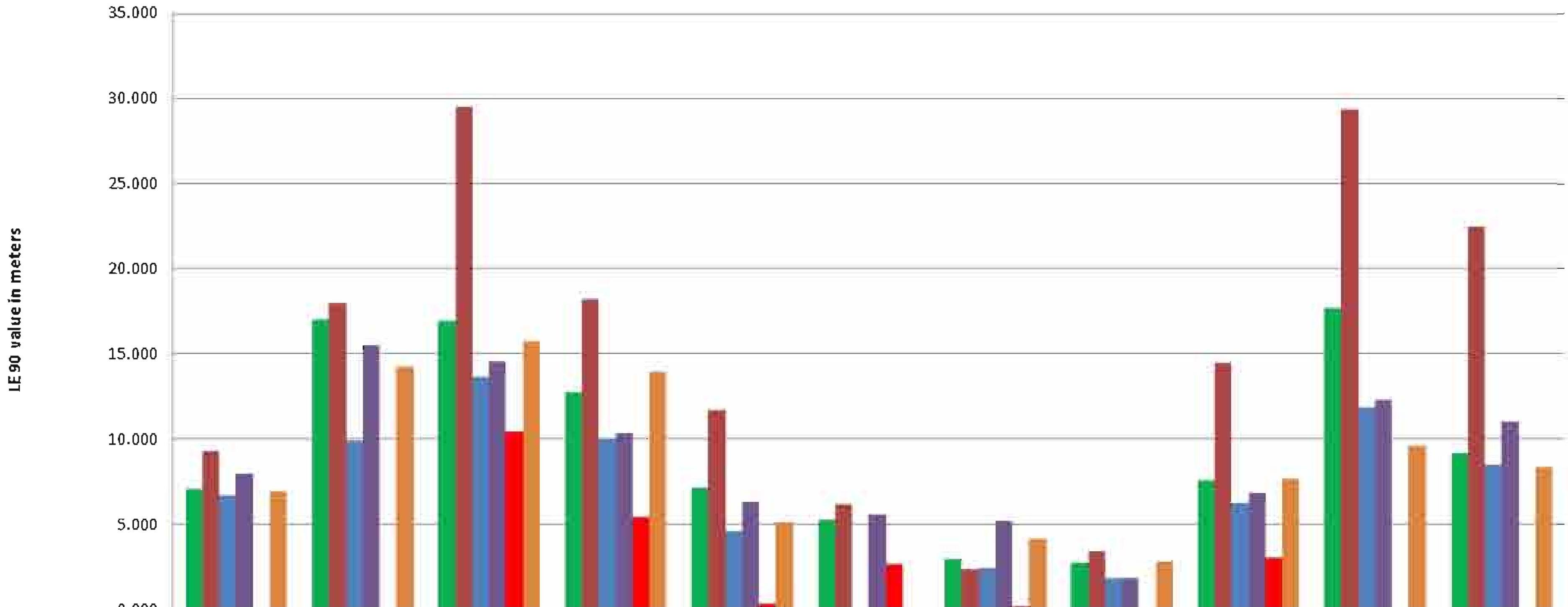
QA : Land cover influence in height error



*CEGET DEM is derived from cartography at 1:50.000 scale. The other DEMs are derived from Airborne or Spaceborne acquisitions.
**The number of samples for NEXTMap and SRTMX DEMs are lower or non-existant due to its reduced coverage.

QA - Benchmarking process - Results

LE90 analysis in terms of ground truth data used



	CEGET	DTED2	GDEM1	GDEM2	IGN25	NEXTMAP1	PNOA5	PNOA5_lidar	REF3d	SRTMV4	SRTMX
Z-Tracks	7.068	17.032	16.954	12.730	7.143	5.252	2.936	2.766	7.626	17.713	9.186
Geodetic vertex	9.299	18.004	29.469	18.182	11.746	6.157	2.358	3.426	14.505	29.348	22.478
RedNAP marks	6.683	9.936	13.632	10.013	4.625	0 *	2.482	1.879	6.248	11.863	8.475
GPS GCPs	7.993	15.505	14.514	10.334	6.369	5.556	5.200	1.839	6.871	12.287	11.065
Dynamic platform	0 *	0 *	10.428	5.424	0.389	2.700	0.229	0.102	3.051	0 *	0 *
Synthetic Z-Track	6.904	14.224	15.712	13.982	5.156	0 *	4.169	2.855	7.693	9.627	8.355

- Values equal to * are N/A data due to reduced coverage or age of the data older than 2003.
- An explanation for the differences in the case of Geodetic Vertex are the position of this marks in the terrain, usually in the top of hills, mountains or ridges where there are good visibility between them, but creates problems to the DEMs with higher GSD.

FUTURE

-Share our Ground truth database for Global/Regional DEM analysis/validation purposes.

-Process the TDX data and validate the DEMs extracted with different tools using our ground truth database (DSM).
- Height analysis.
- Slope analysis.
- Land cover analysis.

-Analyse the quality improvement between DEM extraction techniques.
- Single pass interferometry.
- Repeat pass interferometry.
- Radargrammetry.
- Multiple stereocorrelation.
- Stereocorrelation.

-Analyse the different DEM fusion techniques and explore new ones.

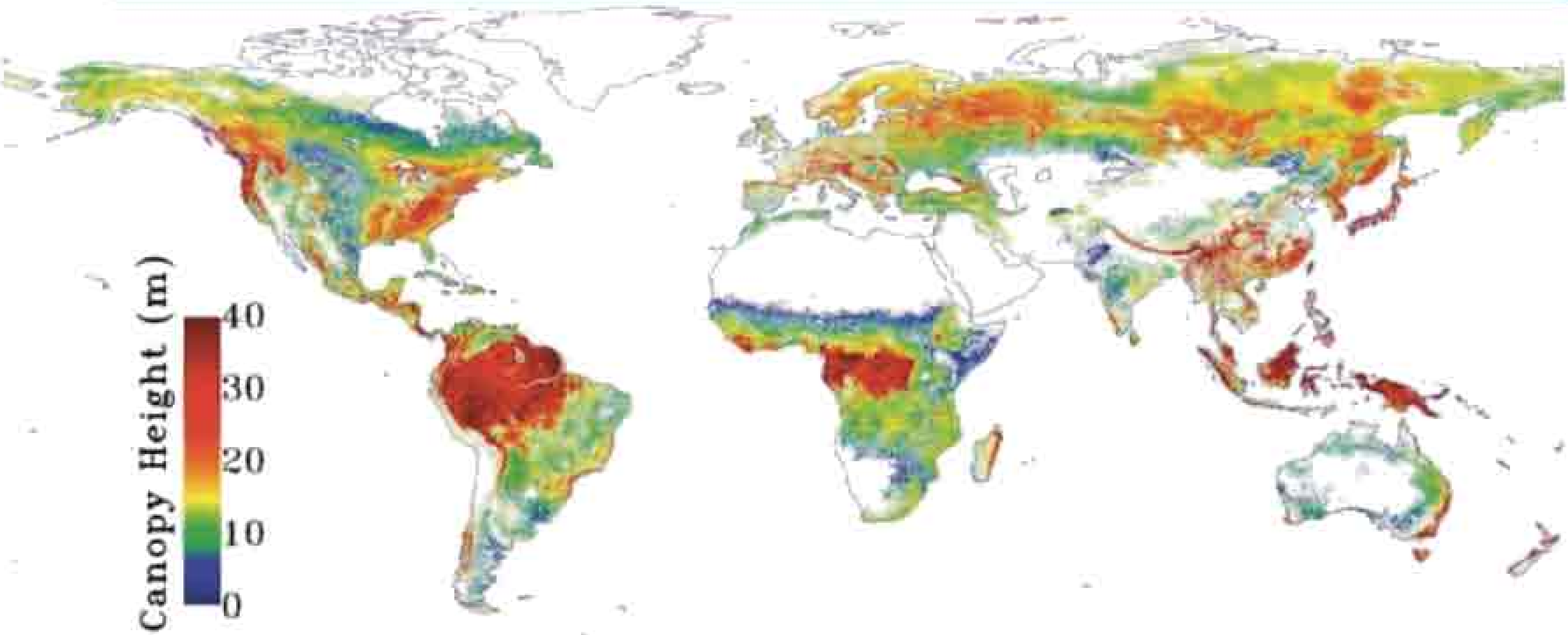
-Include new sources in the benchmarking process (Nextmap30, triple-stereo from Pleiades satellite…).

BIOMASS Topography Mission

Jan-Peter Muller

Derived from ESA report (June 2012)

NASA global tree height map @ 1km

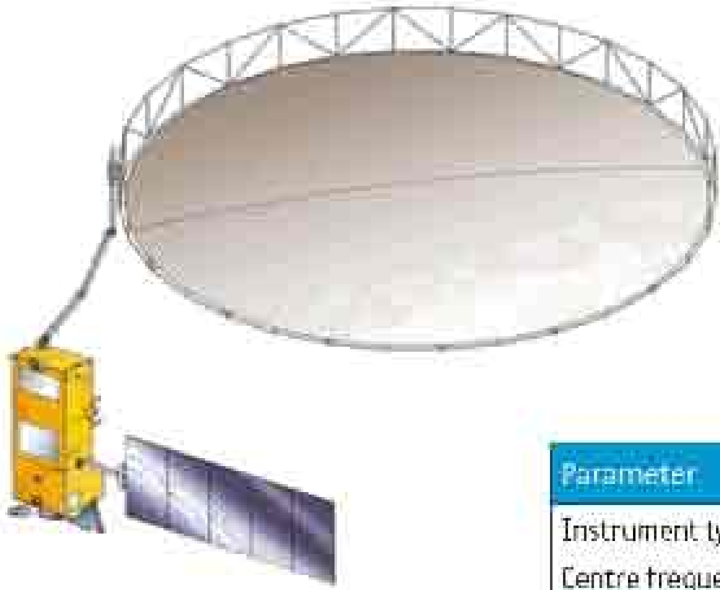


Marc Simard, JPL
http://www.nasa.gov/topics/earth/features/forest20120217.html

From MODIS imagery calibrated by ICESat data

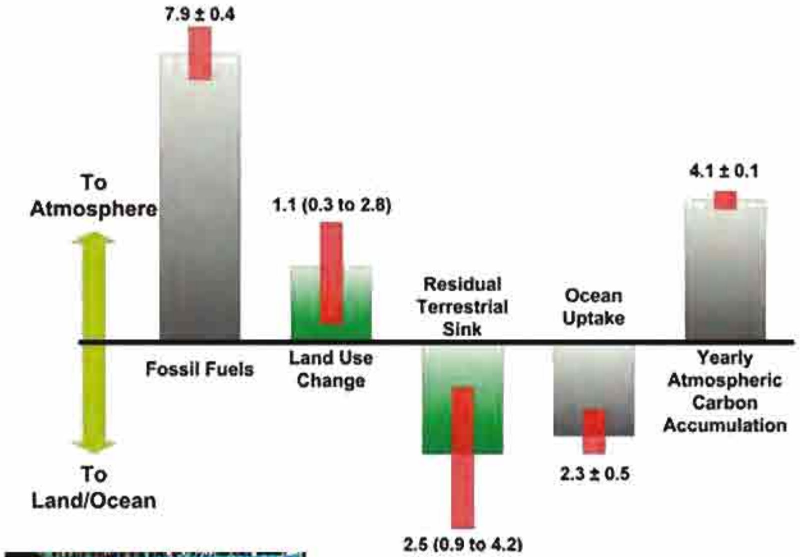
National Research FLAGSHIPS CSIRO

BIOMASS: ESA's Earth Explorer 7
P-band Topography mission (2020)

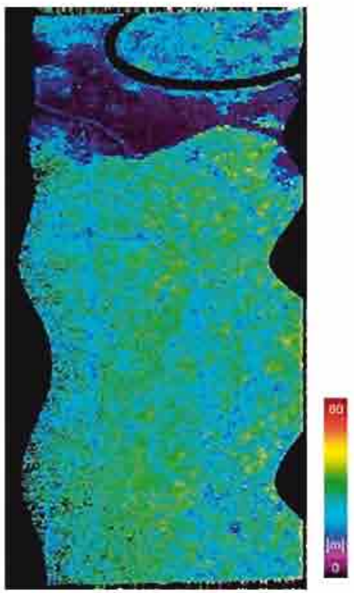


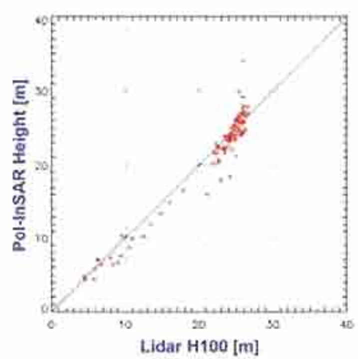
Parameter	Requirement
Instrument type	P-band synthetic aperture radar (SAR)
Centre frequency	435 MHz (P-band)
Bandwidth	≤6 MHz (ITU allocation)
Incidence angle (near)	Threshold: 23°; Target: 25°
Polarisation	Fully polarimetric
Cross-polarisation ratio	≤ -25 dB (threshold); ≤30 dB (goal)
Spatial resolution	≤60 m (across-track) × 50 m (along-track) (≥4 looks)
Swath	≥50–60 km
Noise equivalent σ^0	Threshold: ≤ 27 dB; Target: ≤ 30 dB
Total ambiguity ratio	≥20 dB
Radiometric stability	0.5 dB RMS
Absolute radiometric bias	1.0 dB
Dynamic range	30 dB

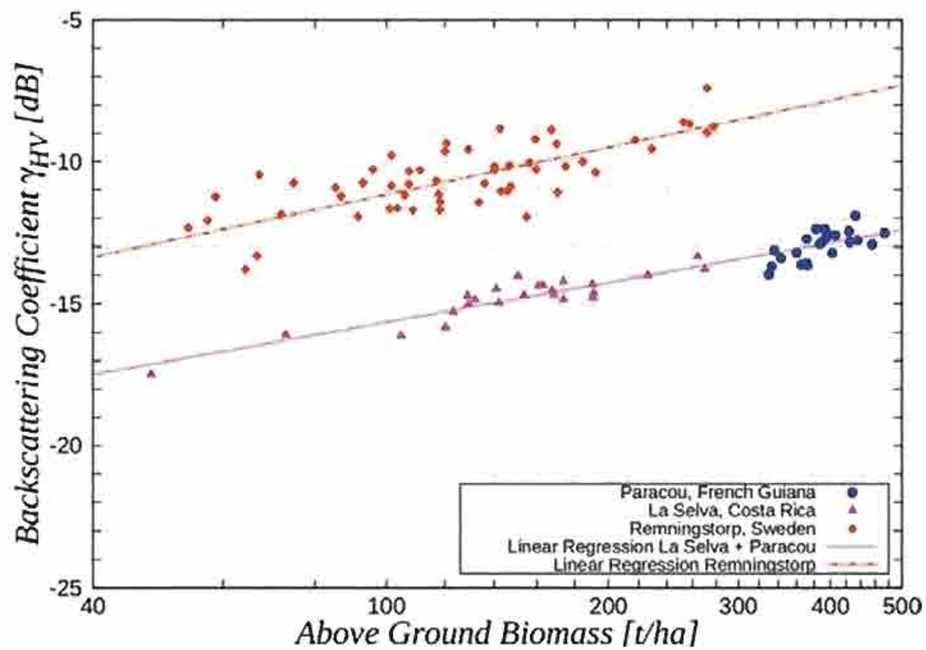
Biomass changes from P-Band backscatter



Biomass increment (TgC yr^{-1})	1990–1999	2000–2007
Boreal	117	120
Temperate	345	454
Tropical intact	1167	870
Tropical regrowth	1361	1497
All Tropics	2529	2367
Global	2991	2941

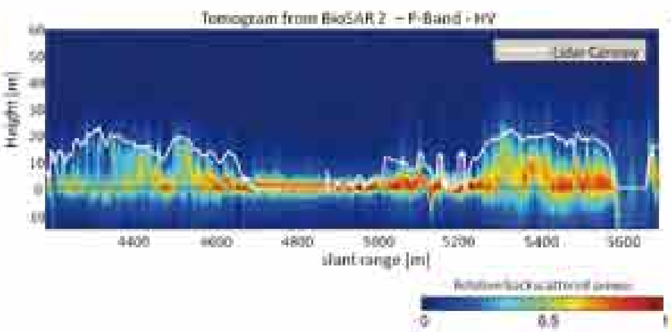


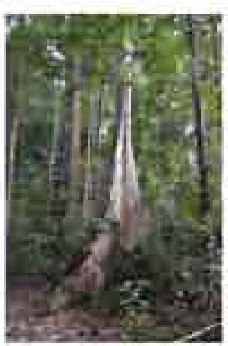


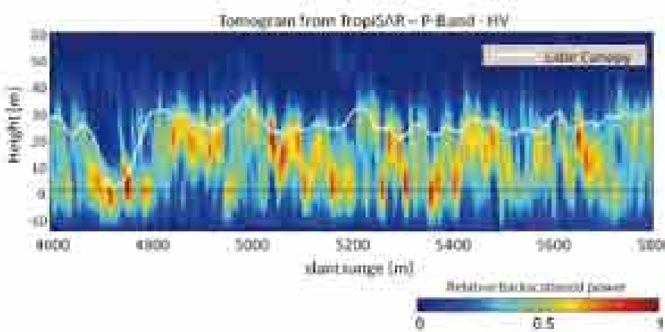


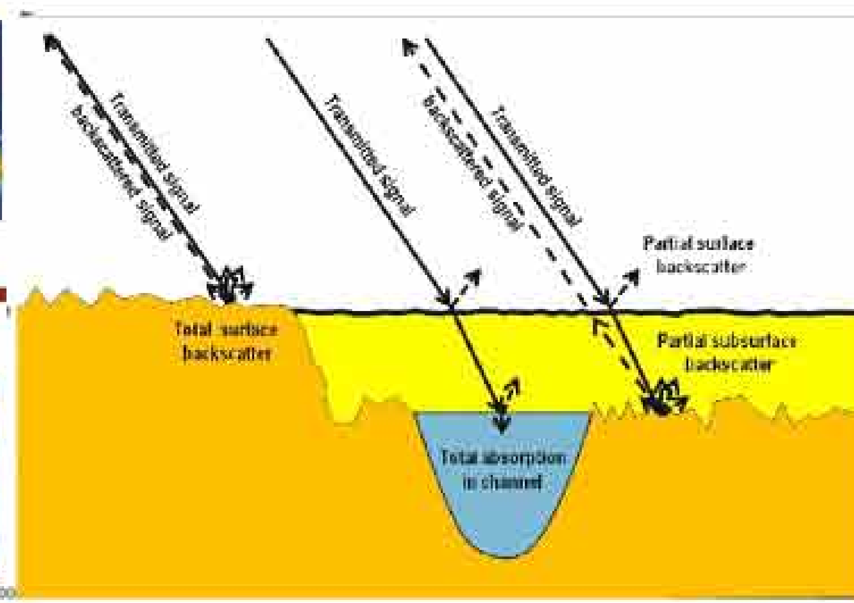
Exciting new Prospects from BIOMASS for Global Topography

- 3D structure of forests from P-band polarisation measurements
- Sub-surface Topography down to 40m over desert regions









GROUP ON EARTH OBSERVATIONS

GLOBAL SOIL PARTNERSHIP

Report on UN meeting in Geneva, CH on 11 March 2013

ISRIC World Soil Information

Hannes I. Reuter

UN Meeting Objectives: Common utilisation of a global high resolution DEM for the UN system

- The purpose of this DEM meeting was consultation, views and sharing current experience between the UN System entities on utilization of DEM data (OOSA, ITU, UNHCR, UNIDIR, UNEP, FAO, WB, IFRC) and commercial (ASTRIUM, ESRI) developments and scientific (ISRIC) in the area of DEM datasets using satellite sensors.

Future objectives

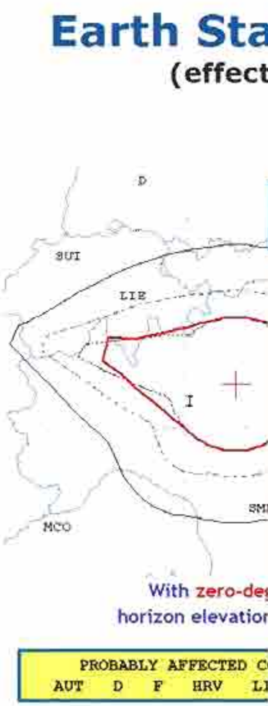
- a. avoidance of duplicate acquisition/purchasing;
- b. sharing of best practices on the use of DEM;
- c. pooling of financial resources to acquire coverage;
- d. opportunities for services such as data hosting, data processing;
- e. standardization of data processing and usage; and
- f. documentation and dissemination of best practices.

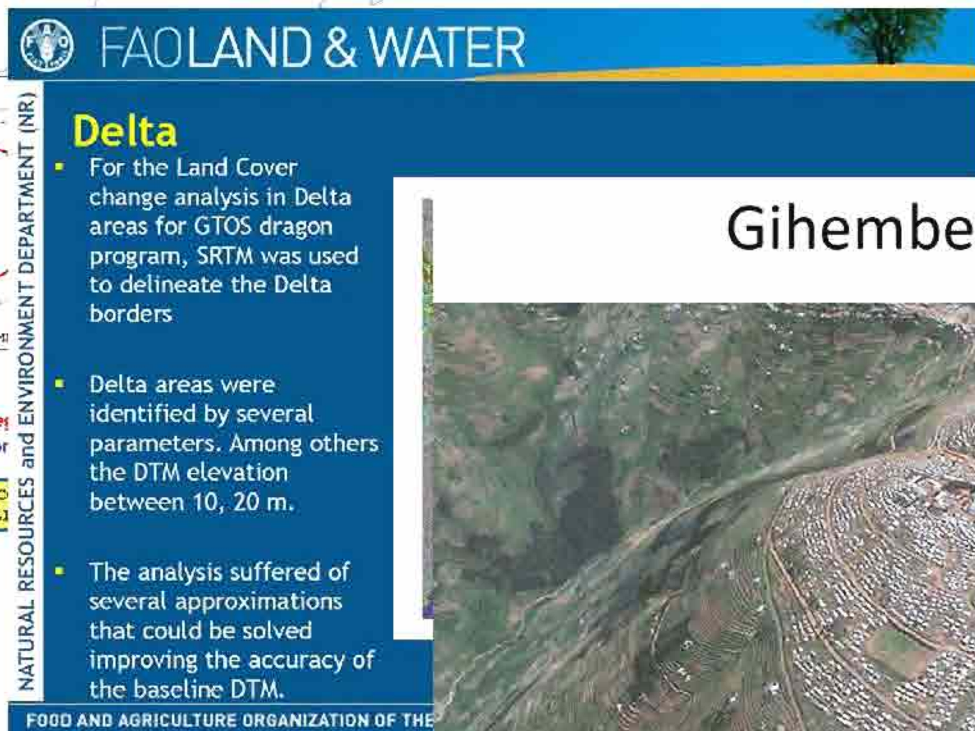
With respect to Terrain Mapping Subgroup

The issues related to data accuracy such as:

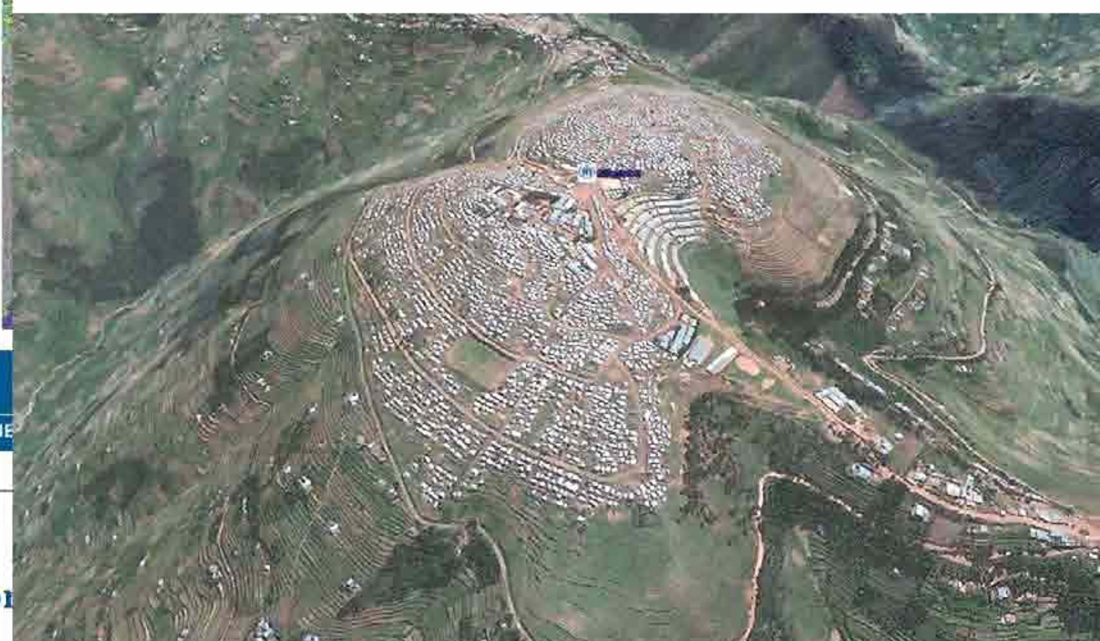
- a. sharing of test results;
- b. joint pilot projects for tests; and
- c. joint tests between providers and users.

Examples of DEM in the UN system





Gihembe - Rwanda

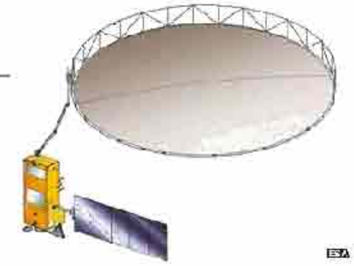


Vision for Terrain Mapping Subgroup

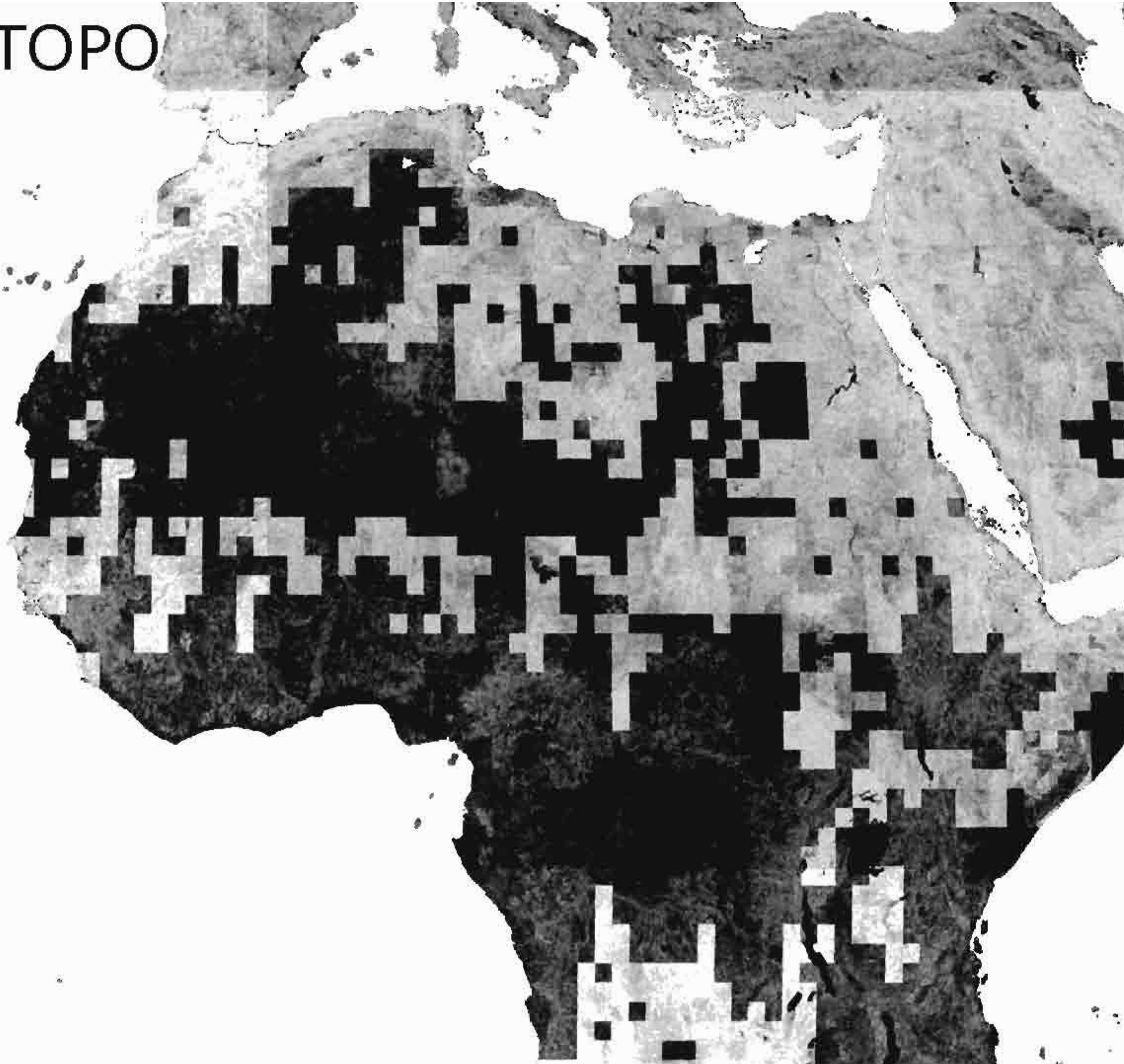
Vision is to provide time and space varying DEMs for the globe with spatial defined uncertainty.

- Land surfaces (e.g. 1970, 2010, different resolutions, biomass, erosion and hydrology modelling)
- Subsurface Water Surfaces (flooding, sea level)

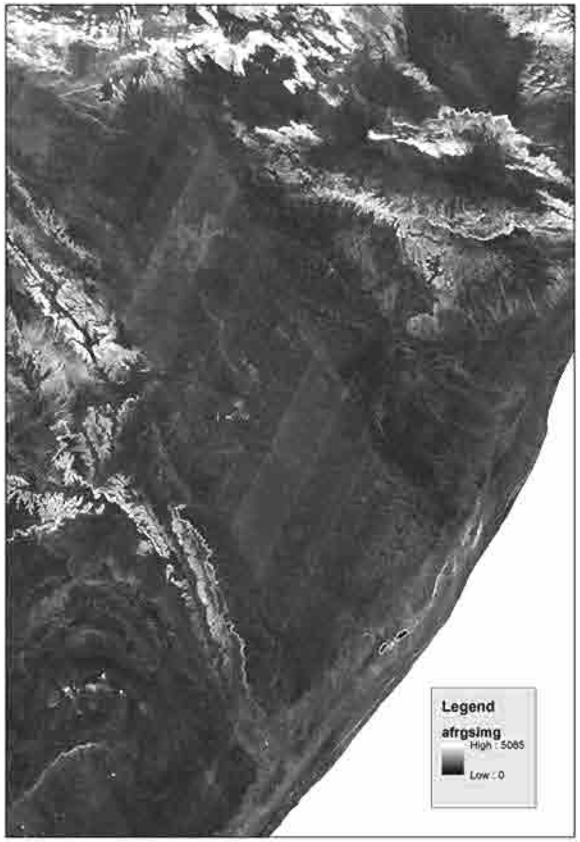
- Expand REFERENCE sites network (LiDar)
- Expand REFERENCE elevation/features

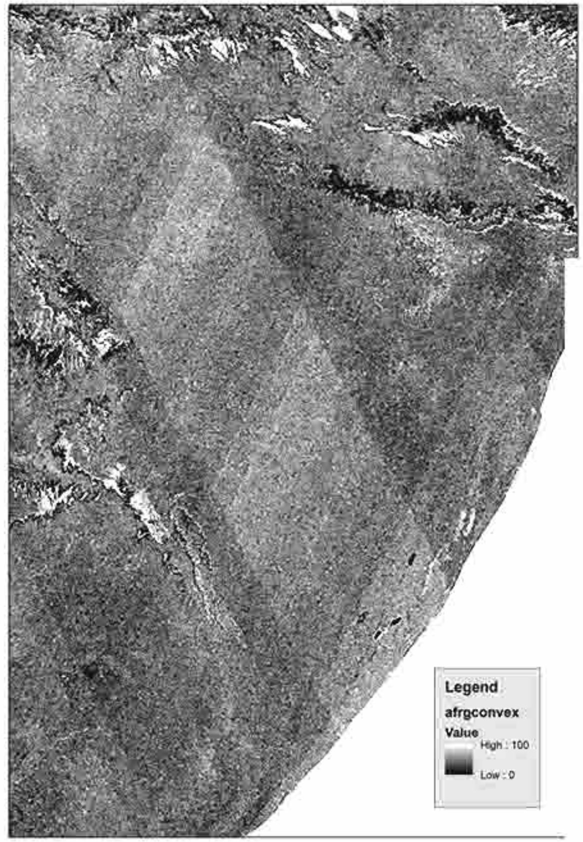


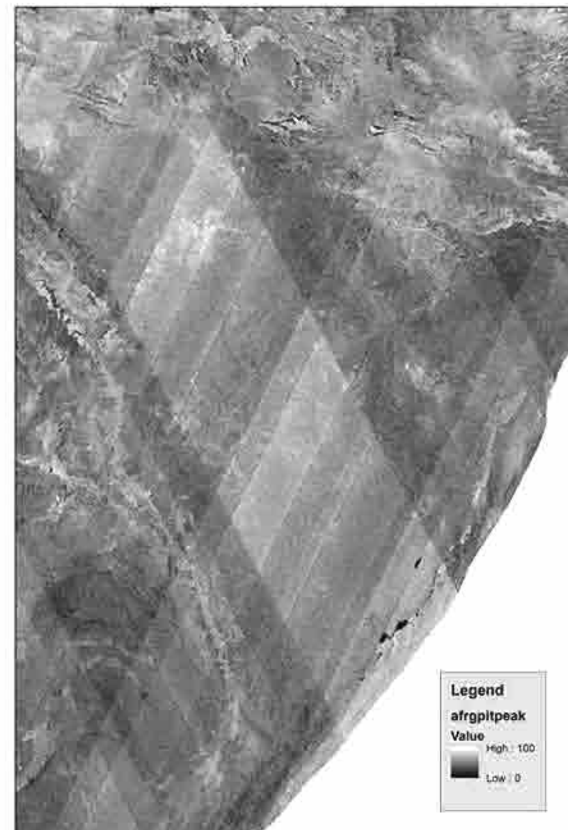
Africa GTOPO



SRTM


Legend
afrgsimg
High : 5085
Low : 0


Legend
afrgconvex
Value
High : 100
Low : 0


Legend
afrgpitpeak
Value
High : 100
Low : 0

ASTER GDEM V1

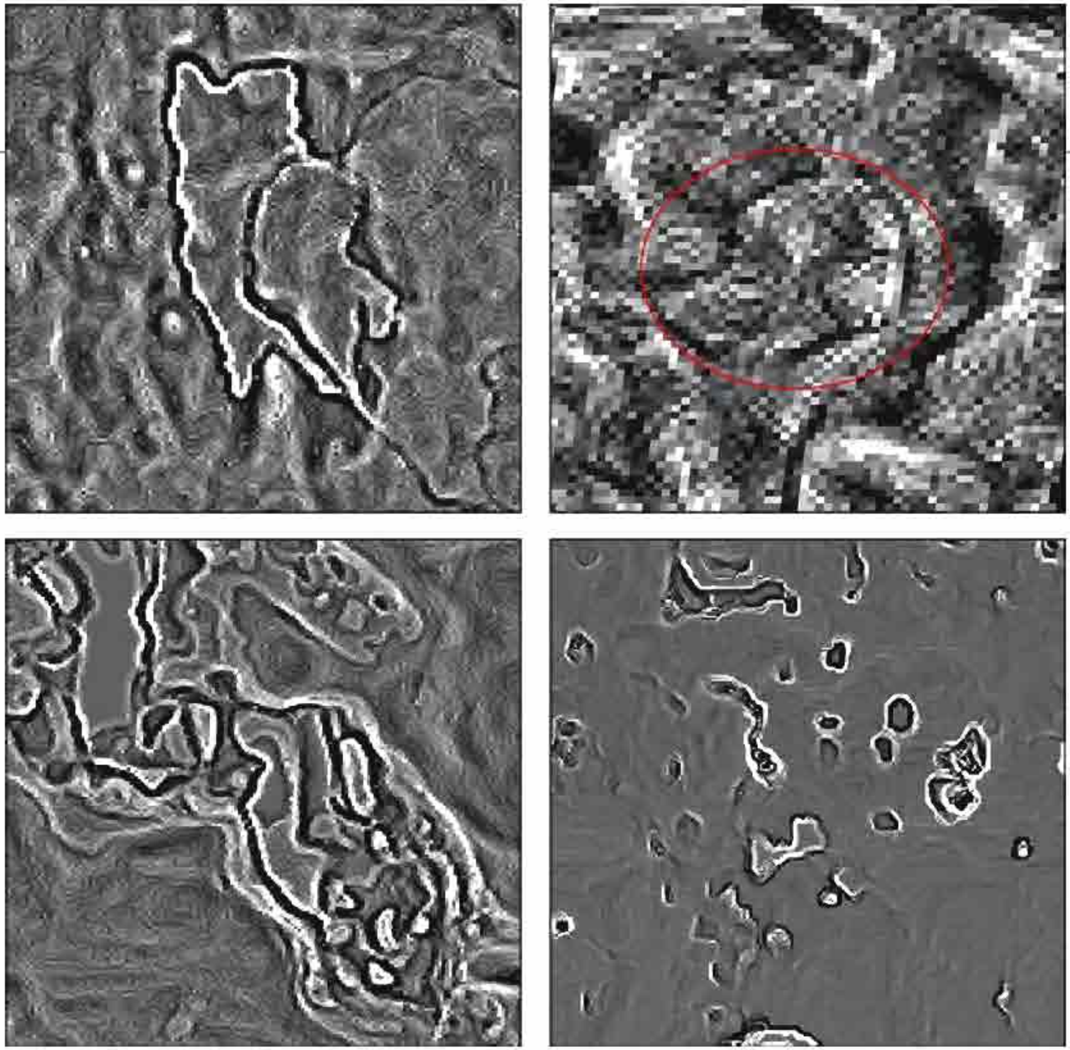


Figure 19 Example for artefacts in the N05W002(tl), N40E023 (tr), N45E008 (bl) and S02W079 (br) using profile curvature. Please note the black circle inside the red circle for N40E23, which coincidence with the cut lines

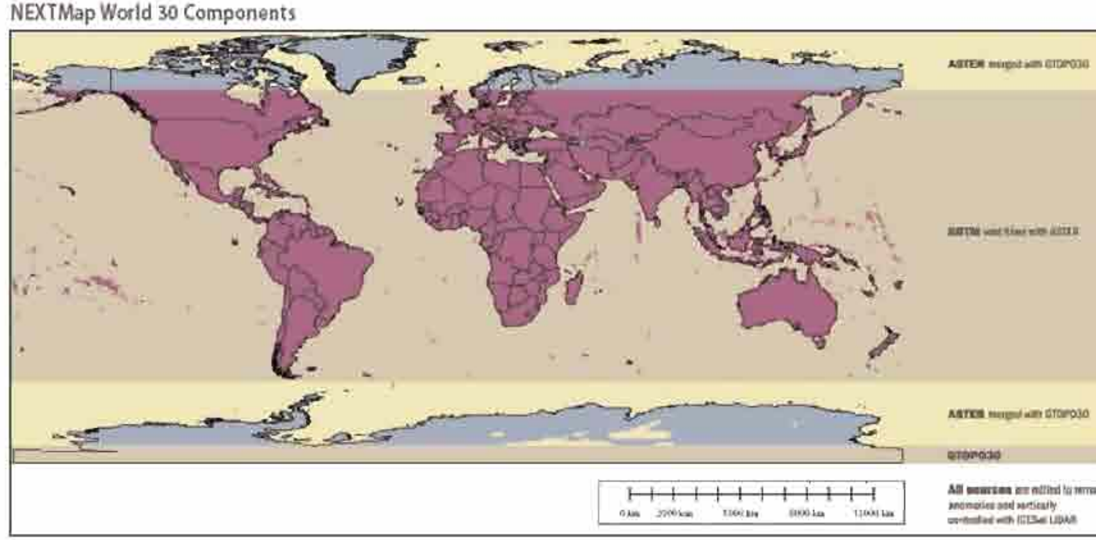
In ANY Digital Elevation Model you will find artefacts – you just need to know what to look for.

(Hint: no nice pictures of elevation)

Expand publicly available DEM/DSM

- Commercial products released but at costs way beyond the "dreams of Avalon"
- Astrium Global DEM product (from multiple sources inc. stereo Pleides, Spot7, TerraSAR-X)
- E.g. Elevation30 costs 2.3€/sq.km. (€345M)
- Elevation10 (5m Zrmse) costs 17€/sq.km. (€5.9B)

NEXTMap World 30 Components



QA4EO Showcase

- Most DEMs (except for SRTM & TanDEM-X) do NOT include a Quality Indicator (QIs). The one for ASTER GDEM is not "fit for purpose" as it does not correspond to any correlation on a per gridpoint basis with actual accuracy
- UN have recently adopted a commercial global DEM product from Astrium for all of their operations which does not appear to include QI on a per-gridpoint
- For spaceborne-derived bathymetry TMSG wish to demonstrate how including QIs can affect tsunami landfall predictions.
- EU-FP7-BASEMENT bid led by DLR spinoff unsuccessful to generate European continental bathymetry from space
- Proposed as a GEO ministerial video showcase but idea trashed by CEOS Chair today who demands only one video for all of the CEOS activities

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)
- Agreed activities to continue DA-09-03d within IN-02-C2 received public debate in a special session lasting 1.5 hours at ISPRS 2012 Congress in Melbourne, Australia on 2-Sep-12 which had more than 30 participants

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

- Global DEM fusion methods
- Temporal aspects of DEMs (as the DEMs become higher spatial resolution they become dynamic), e.g. time-tagging metadata
  - Vegetation
  - Mining
  - Ice-sheets
  - Urban
  - Landslides
  - Fracking
- Bare-earth DTM extraction methods? Link between land cover and bare earth DTMs
- Low contrast methods due to surface low surface roughness and desert (surface penetration)

GEO Task IN-02: Global Datasets Proposed activities for Global DEM

- Establishment of a global set of 3D GCPs and CCPs (Canopy Control Points)
  - ICESat from NASA-GSFC (waveform processed for retrieval of ToC (Top of Canopy) and Bare Earth (DTM))
  - Global Elevation testing facility (runways)
  - SRTM control data from Marc Simard (JPL)
- Creation of coastal zone 3D models including
  - (a) bathymetry of continental shelves;
  - (b) coastline;
  - (c) uniform co-ordinate reference system for merging land topography (France & US have exemplary projects in this area)
- Biomass retrieval from X, C & L as well as ICESat-II
- Polar areas have specific requirements
- Possibility of joining with Global land cover at 30m?

Global DEM for continental shelves and coastal zones: a new GEO sub-task

- EO visible/near-IR data can be employed to derive bathymetry for shallow water with low turbidity for depths up to 30m
- Turbidity is mapped from ocean colour sensors such as the ESA MERIS and could be used to decide when higher resolution systems such as LDCM or Sentinel-2 could be employed to map water depth
- EO SAR high resolution (1-3m) data can be employed to map how swell-wave patterns are transformed and these SAR amplitude images can then be inverted to provide bathymetry as demonstrated by Susanne Lehner and colleagues at DLR/OP
- Coastal zones, particularly those with wetlands are extremely difficult to map. Work needs to focus on use of higher resolution VIS/NIR and high-res SAR

Recommendation to CEOS Plenary

- CEOS should encourage the relevant space agencies to set-up Global test sites for (a) clearwater; (b) turbid water offshore bathymetric DEMs from EO sensors
- CEOS should encourage a space agency to take leadership of an evaluation of different spaceborne methods for acquiring 30m gridded bathymetric measurements
- Bathymetry 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 visible/NIR, very high resolution SAR (TSX, Cosmo-SkyMEd, Radarsat-2, NASA-NOAA SHOALS) that could be employed to evaluate different approaches for mapping continental shelves