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

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Point-of-Contact, GEOSS Task DA-09-03d
Chairperson, CEOS-WGCV Sub-group on Terrain mapping from satellites
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Head, Imaging Group
Professor of Image Understanding and Remote Sensing
HRSC Science Team Member (ESA Mars Express 2003)
Stereo Panoramic Camera Science Team Member (ESA EXOMARS)
MODIS & MISR Science Team Member (NASA EOS Project)
TerraSAR-X and TANDEM-X science team member (DLR-Astrium)

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

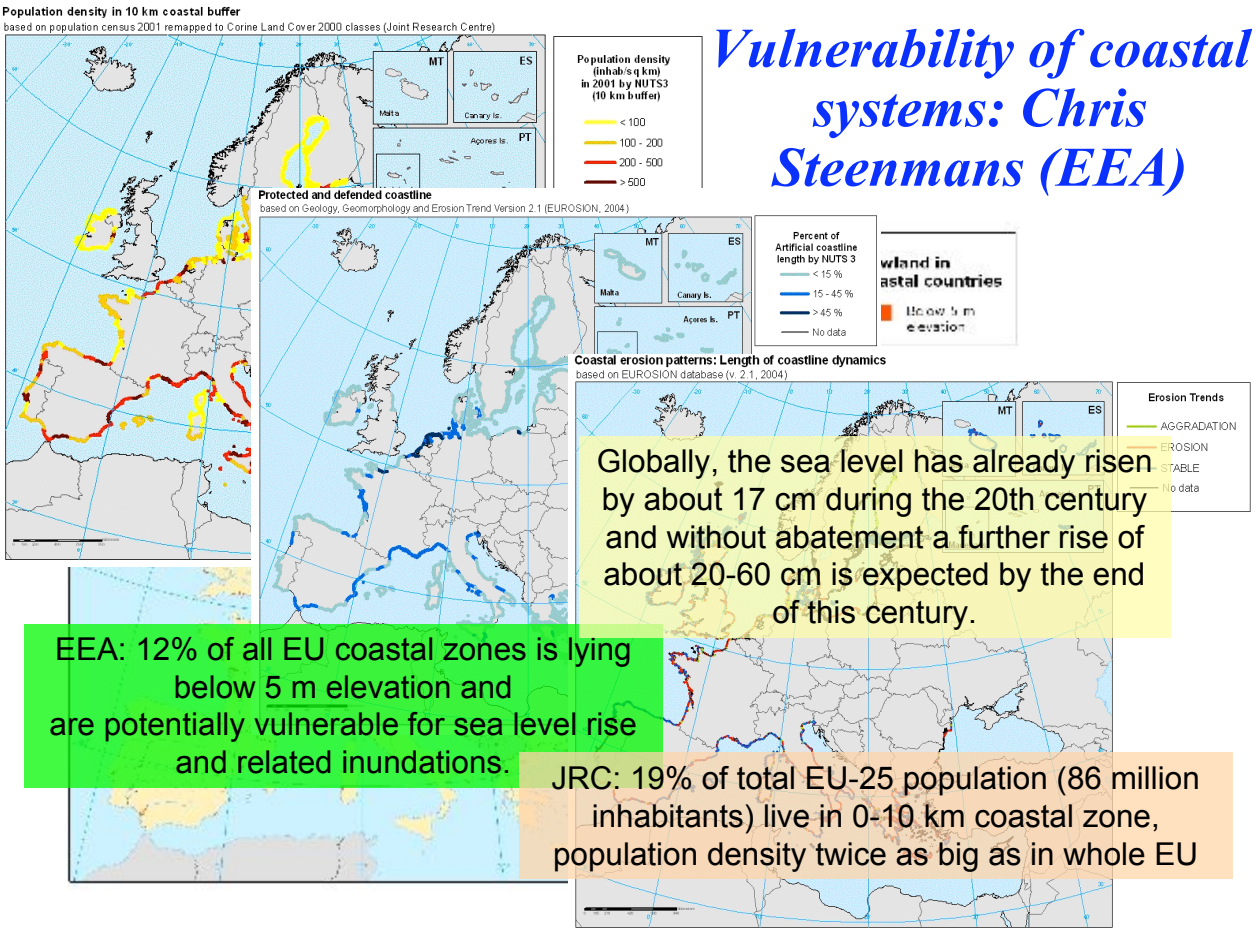
CEOS WGCV Terrain Mapping

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

Overview

- **Highlights of EEA user requirements and current spaceborne DEM solutions to the needs of the European Union, report on a workshop held in Stresa, Italy on 5-6 May 2009**
- **Why does GEO need global topography/bathymmetry?**
- **What is GEO Task DA-09-03d?**
- **Global ASTER Project (METI-NASA)**
- **Current status of ASTER GDEM**
- **Status and plans for GEO Task DA-09-03d**
- **Key issues concerning bathymmetry**
- **Outstanding issues: Gap-filling, Validation and Dissemination**
- **Recap on CEOS Plenary resolutions and actions arising**

Vulnerability of coastal systems: Chris Steenmans (EEA)

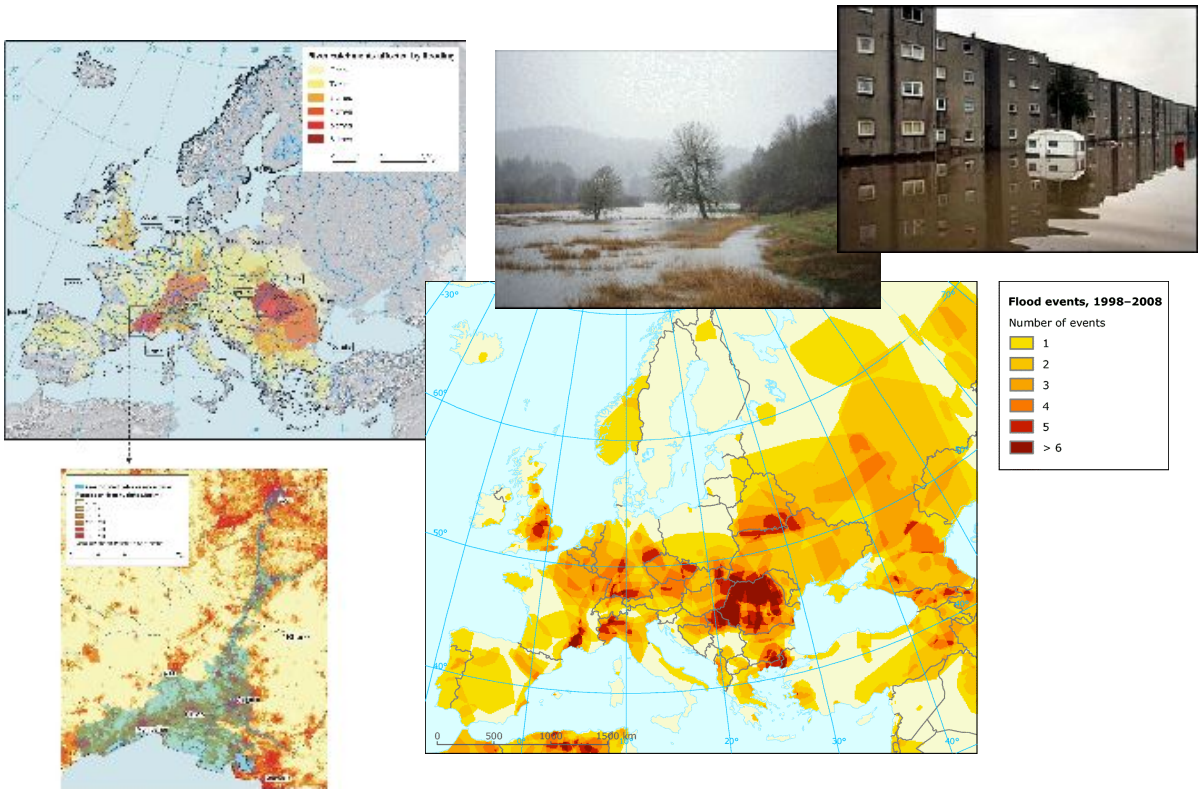


Globally, the sea level has already risen by about 17 cm during the 20th century and without abatement a further rise of about 20-60 cm is expected by the end of this century.

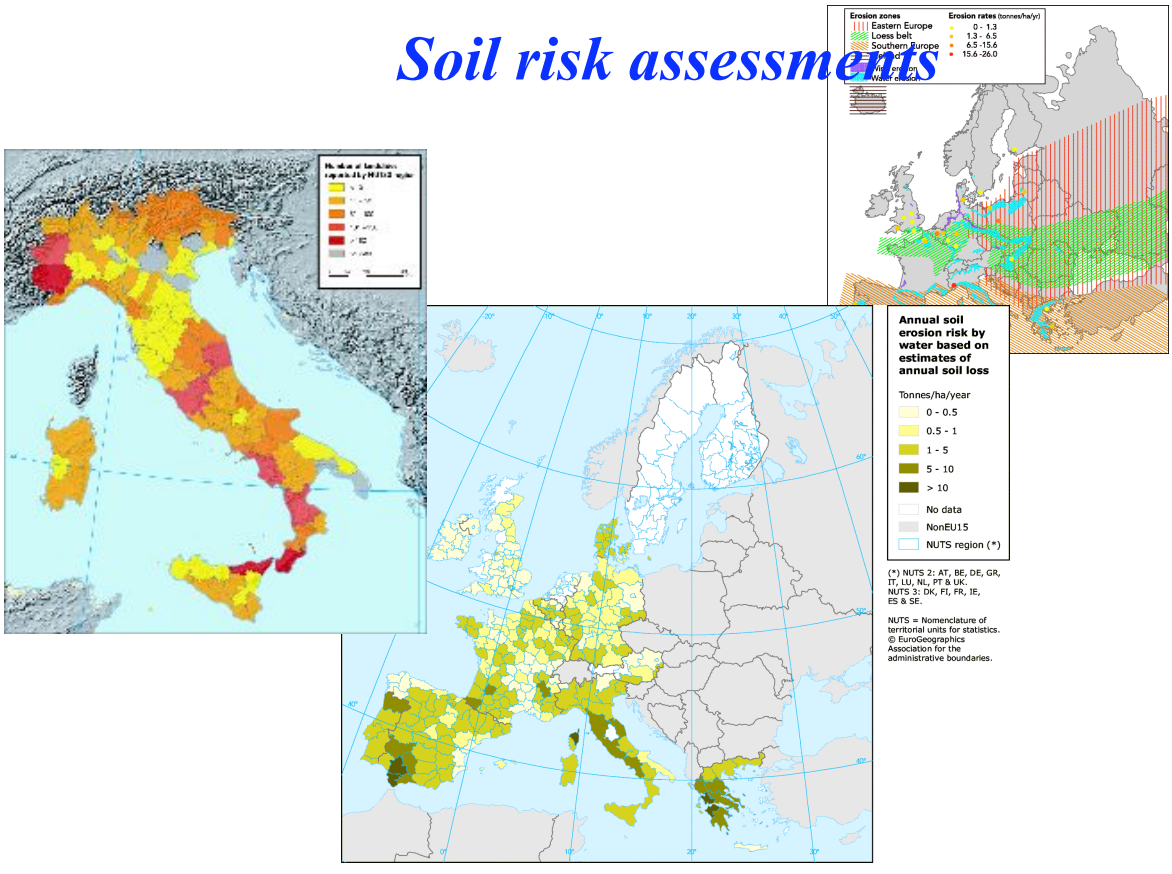
EEA: 12% of all EU coastal zones is lying below 5 m elevation and are potentially vulnerable for sea level rise and related inundations.

JRC: 19% of total EU-25 population (86 million inhabitants) live in 0-10 km coastal zone, population density twice as big as in whole EU

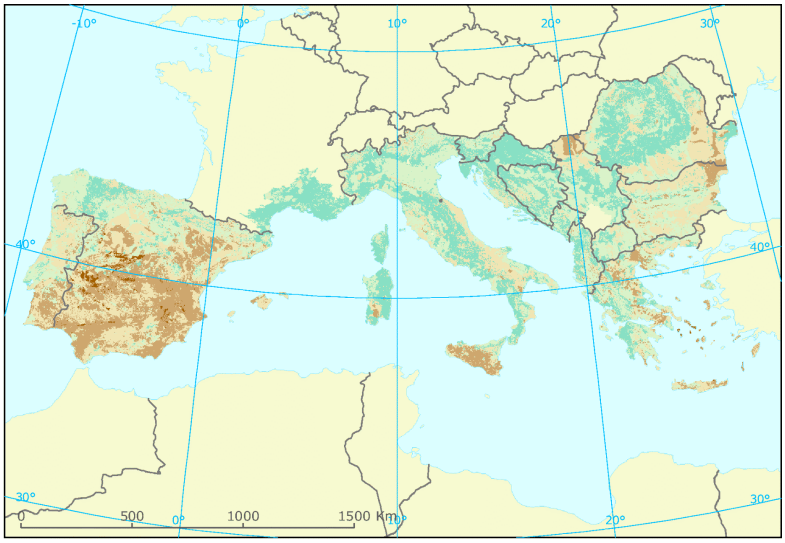
Climate change impact and adaptation



Soil risk assessments



Sensitivity to Desertification

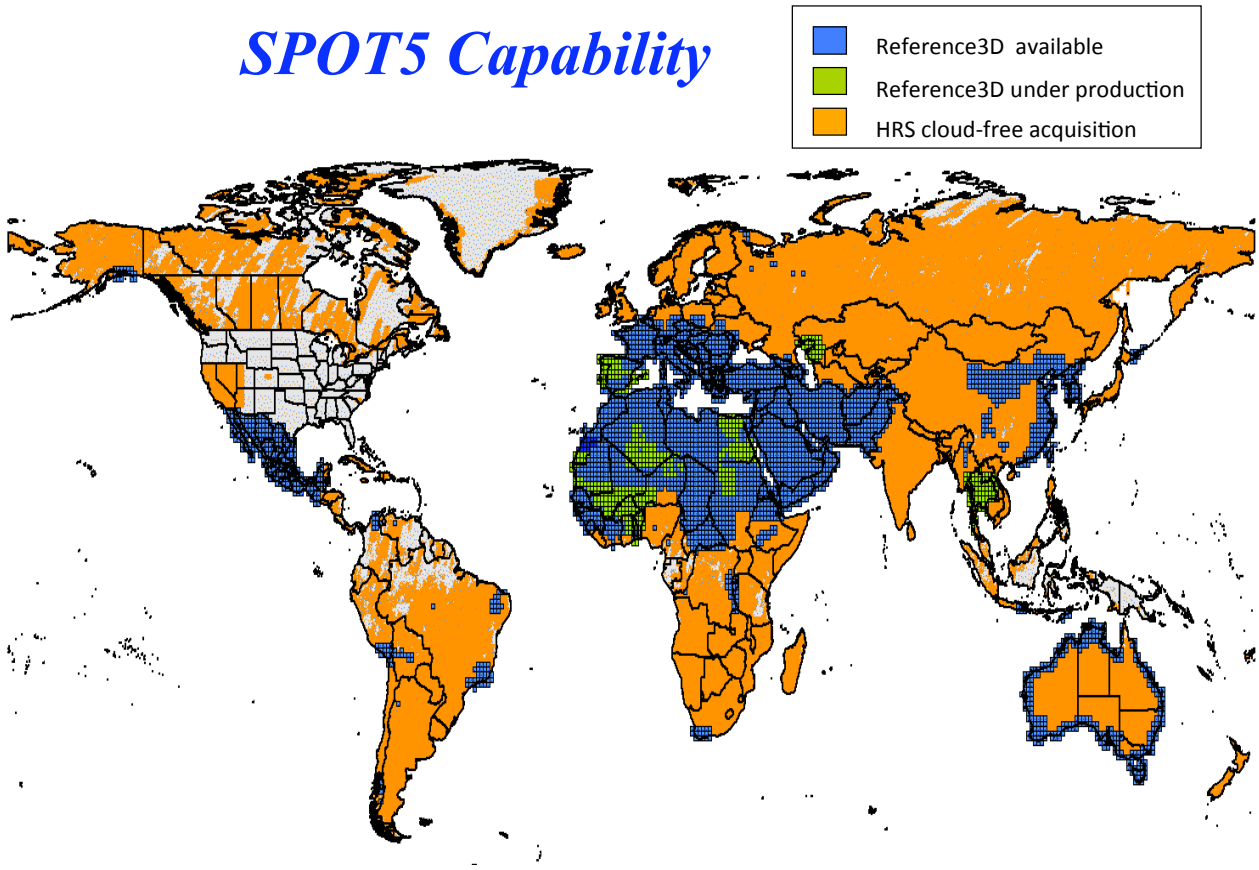


Index of sensitivity to desertification (SDI), 2008

- < 1.2 Non affected areas or very low sensitive areas to desertification
- 1.2 - 1.3 Low sensitive areas to desertification
- 1.3 - 1.4 Medium sensitive areas to desertification
- 1.4 - 1.6 Sensitive areas to desertification
- > 1.6 Very sensitive areas to desertification

European Environment Agency

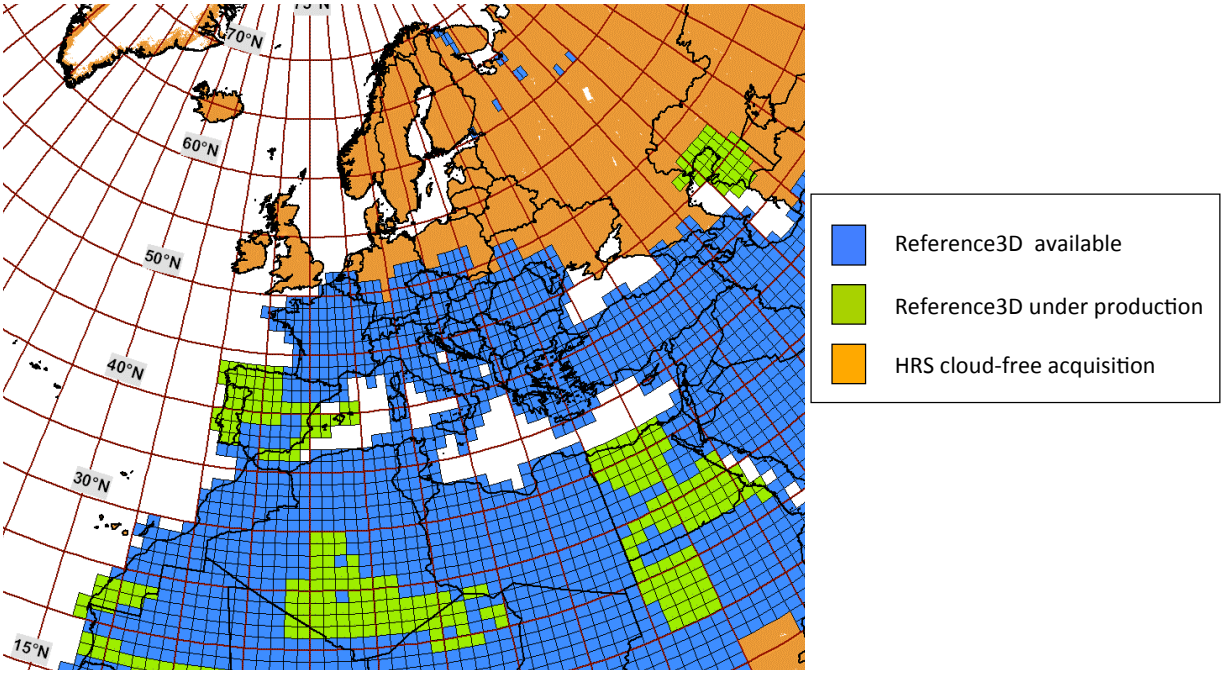
SPOT5 Capability



Thanks to Marc Bernard, SPOT Image

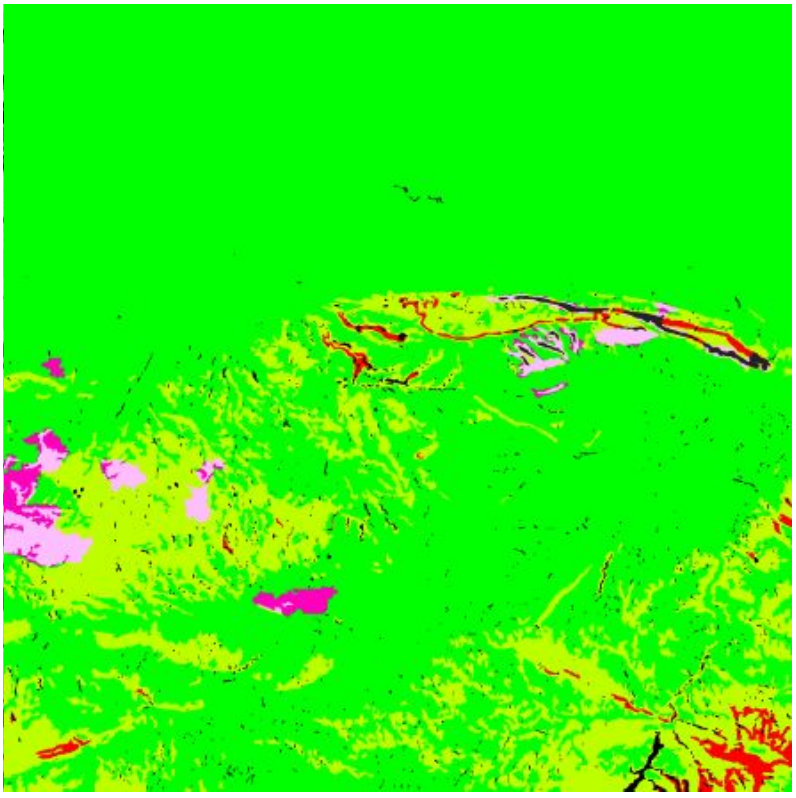
Pan European Capability

Ref3D coverage of continental EU 27 as of May 2009: 2.54 M km² / 4.31 M km²



Thanks to Marc Bernard, SPOT Image

Reference3D® v2 : Vertical Accuracy Masks



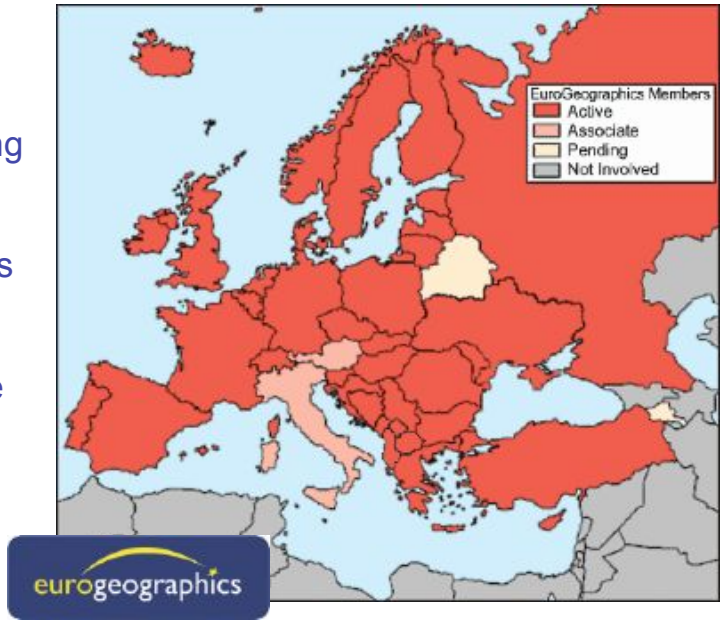
This raster mask gives the vertical accuracy, as deemed by the producer, within separate classes.

A similar mask provides the absolute horizontal accuracy of the orthoimage.

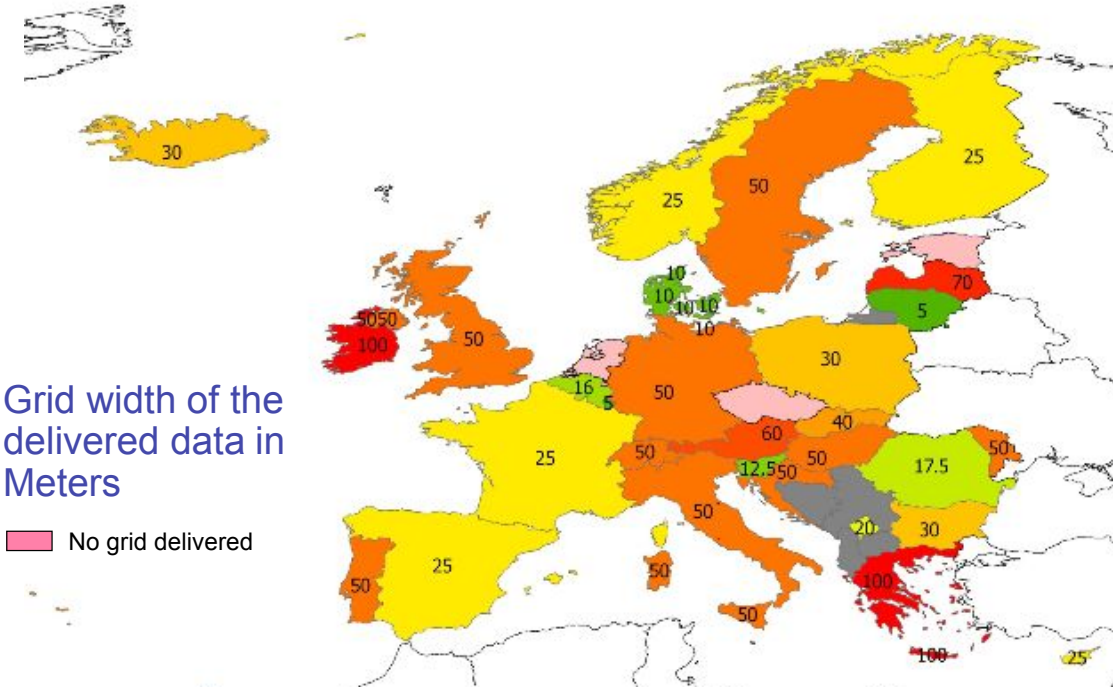
Thanks to Marc Bernard, SPOT Image

What is EuroGeographics ?

- EuroGeographics represents nearly all European National Mapping and Cadastral Agencies (NMCAs)
- Currently EuroGeographics has 52 members from 43 countries.
- Together the members are building the European Spatial Data Infrastructure (ESDI)



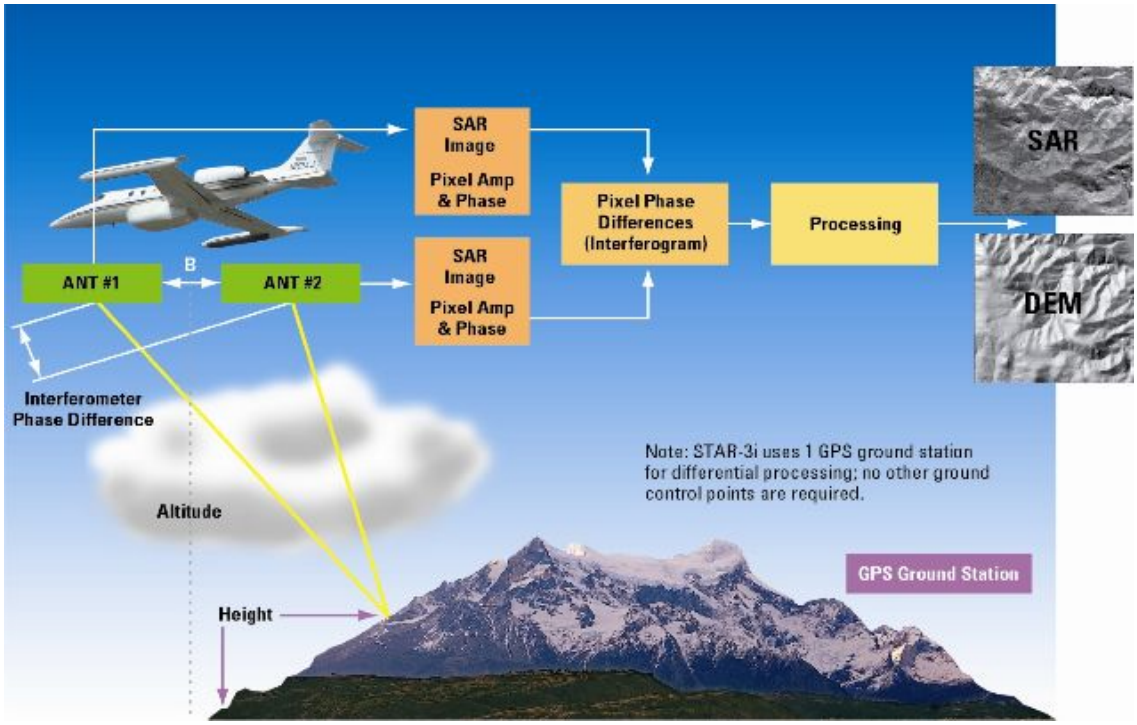
Grid DTM data employed for EU-DEM



Grid width of the delivered data in Meters

No grid delivered

IFSAR Data Acquisition



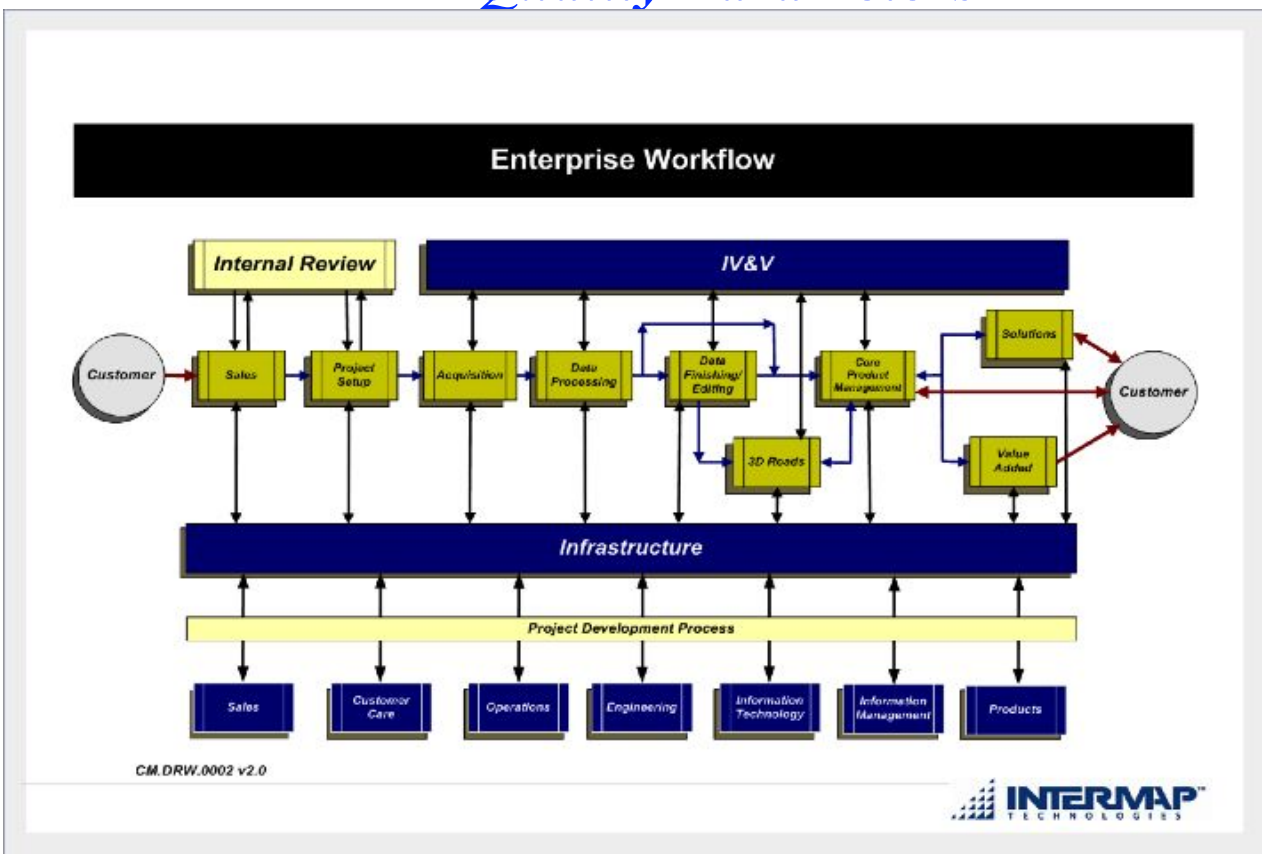
INTERMAP TECHNOLOGIES

Quality Parameters

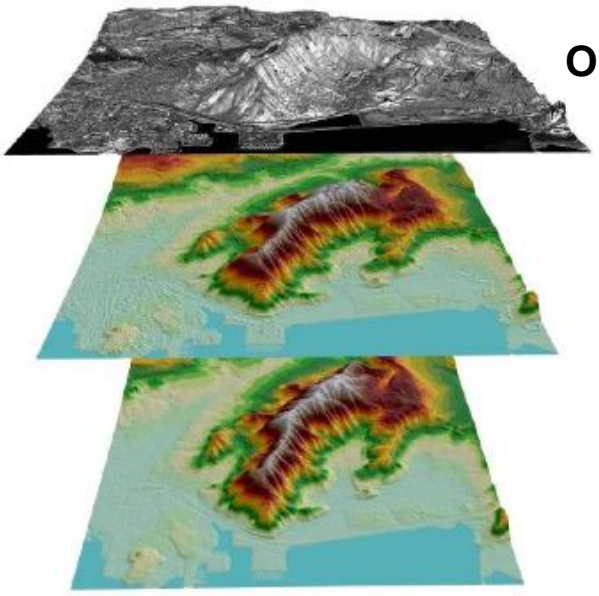
- Vertical accuracy characteristics
  - **NEXTMap Level II Product vertical accuracy is better than 1-metre RMSE in unobstructed areas with slopes less than 10 degrees. Using Linear Error 95% of the data is accurate to 2 metres.**
- Horizontal accuracy
  - **NEXTMap Level II Product horizontal accuracy is better than 2-metres RMSE in unobstructed areas with slope less than 10 degrees. Using Circular Error 95% of the data is accurate to 4 metres.**

INTERMAP TECHNOLOGIES

Quality Parameters



NEXTMap Core Products



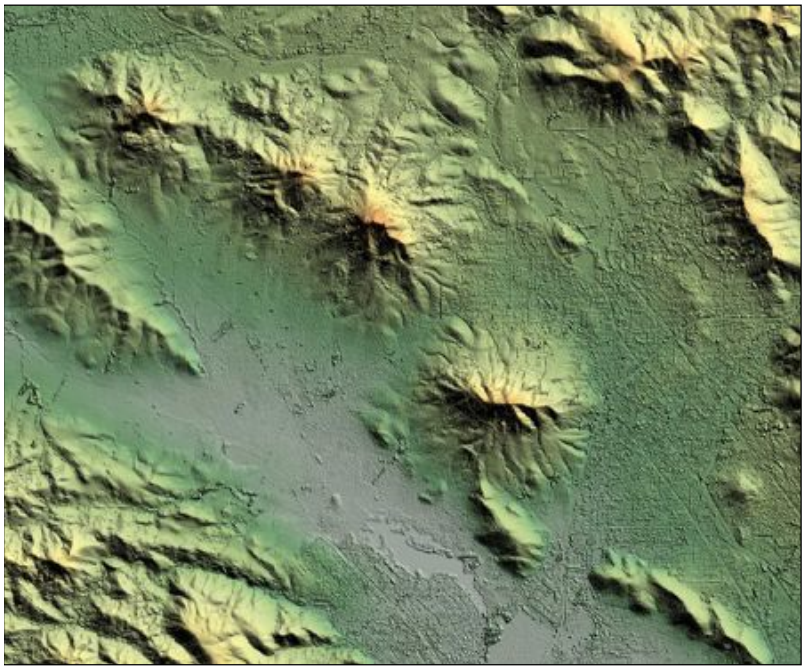
Orthorectified Radar Imagery

Digital Surface Model

Digital Terrain Model

INTERMAP TECHNOLOGIES

NEXTMap® Europe Core Products



Digital Surface Model

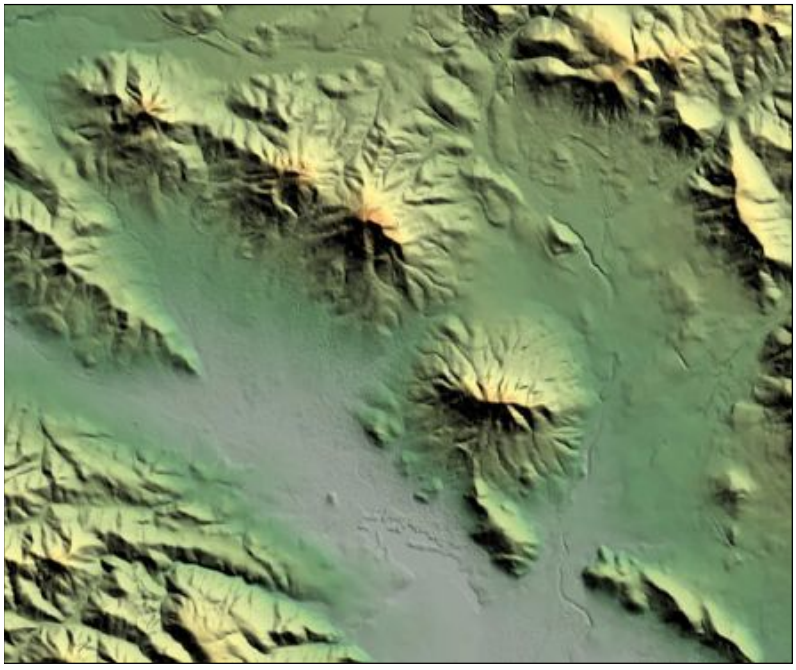
- **5 metre resolution**
- **1 metre RMSE vertical accuracy**

Accuracies are Defined for Unobstructed Areas of Slope < 10º

First surface reflection of radar signal. Includes natural and man-made features.

INTERMAP TECHNOLOGIES

NEXTMap® Europe Core Products



Digital Terrain Model

- **5 metre resolution**
- **1 metre RMSE vertical accuracy**

Accuracies are Defined for Unobstructed Areas of Slope < 10º

Automated and manual editing removes surface features

INTERMAP TECHNOLOGIES

NEXTMap® Europe Core Products

High accuracy image basemap

Orthorectified Radar Imagery

- **1.25 metre resolution**
- **2 metre horizontal accuracy**

INTERMAP TECHNOLOGIES

IRS-P5 Cartosat-1

Launched on May 5, 2005

In flight stereo viewing with 2.5 m resolution

Global coverage through Onboard Solid State Recorder

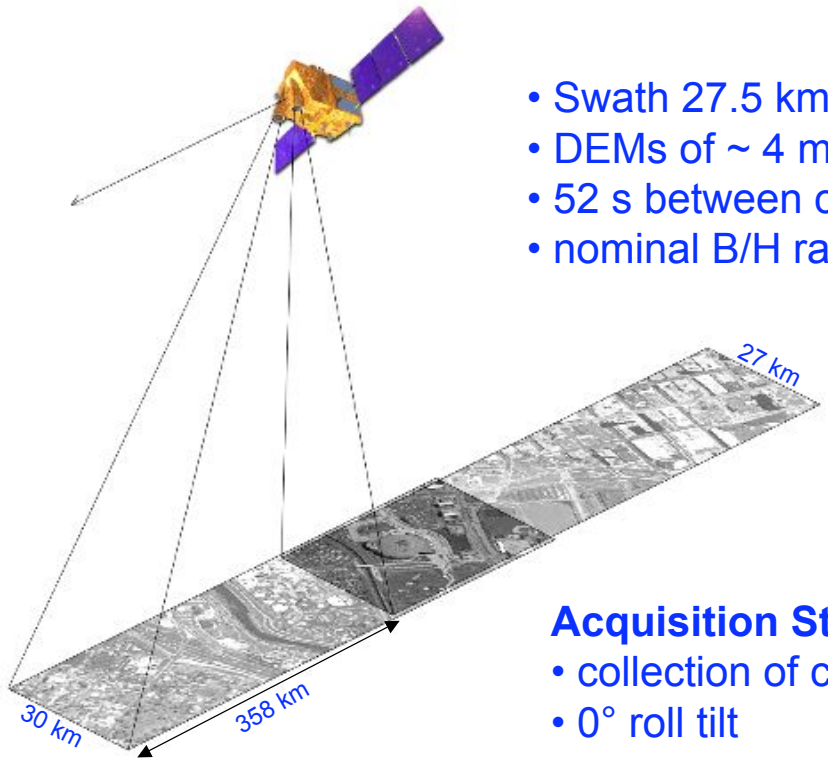
Minimum mission life of five years

IRS-P5 Cartosat-1 Fact Sheet

IRS-P5 has been launched into polar sun synchronous orbit on May 5, 2005. The satellite has two panchromatic cameras for in flight stereo viewing.

Sensor	PAN-Fore	PAN-Aft
Tilt Along Track	+26°	-5°
Spatial Resolution	2.5 m	2.5 m
Swath-width	30 km	27 km
Radiometric Resolution, Quantisation	10 bit	10 bit
Spectral coverage	500-850 nm	500-850 nm
CCD arrays (number of arrays * No. of elements)	1 * 12000	1 * 12000

IRS-P5 Stereo Data Acquisition

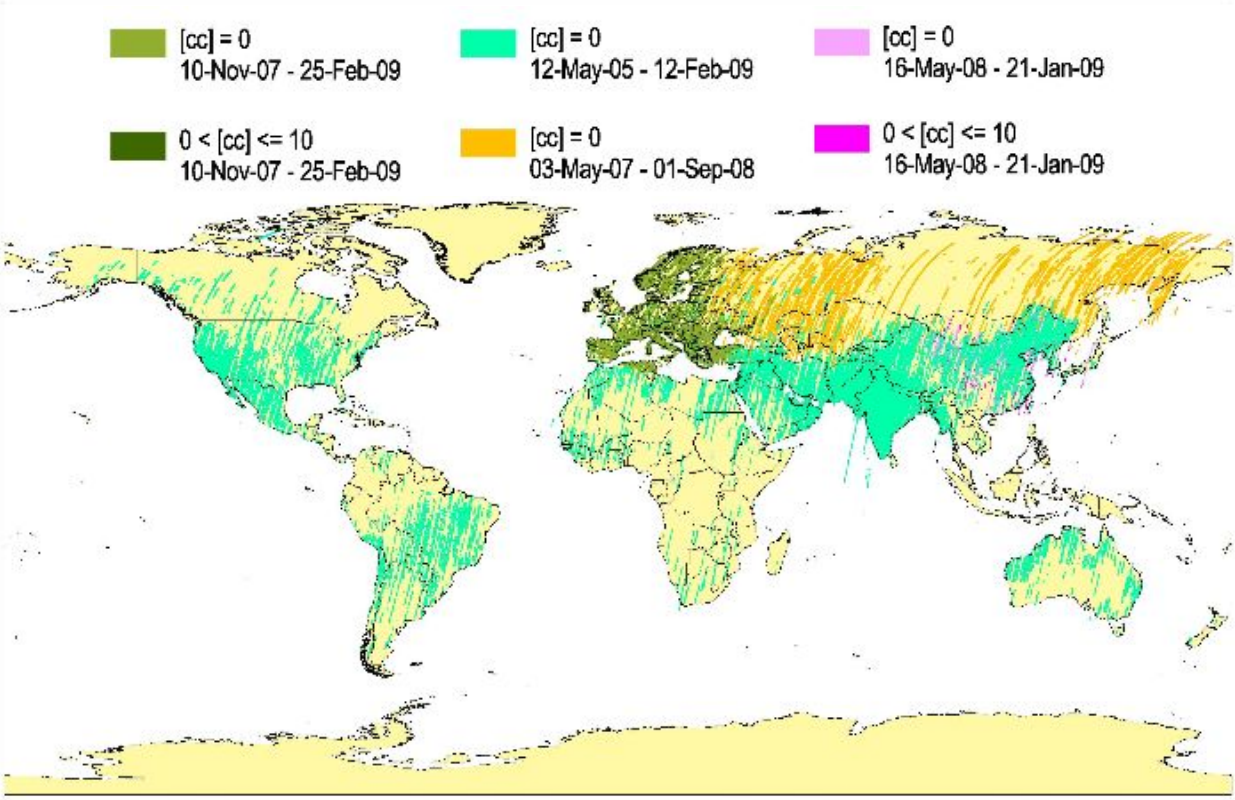


- Swath 27.5 km
- DEMs of ~ 4 m elevation accuracy
- 52 s between cameras ~ 358 km
- nominal B/H ratio 0.62

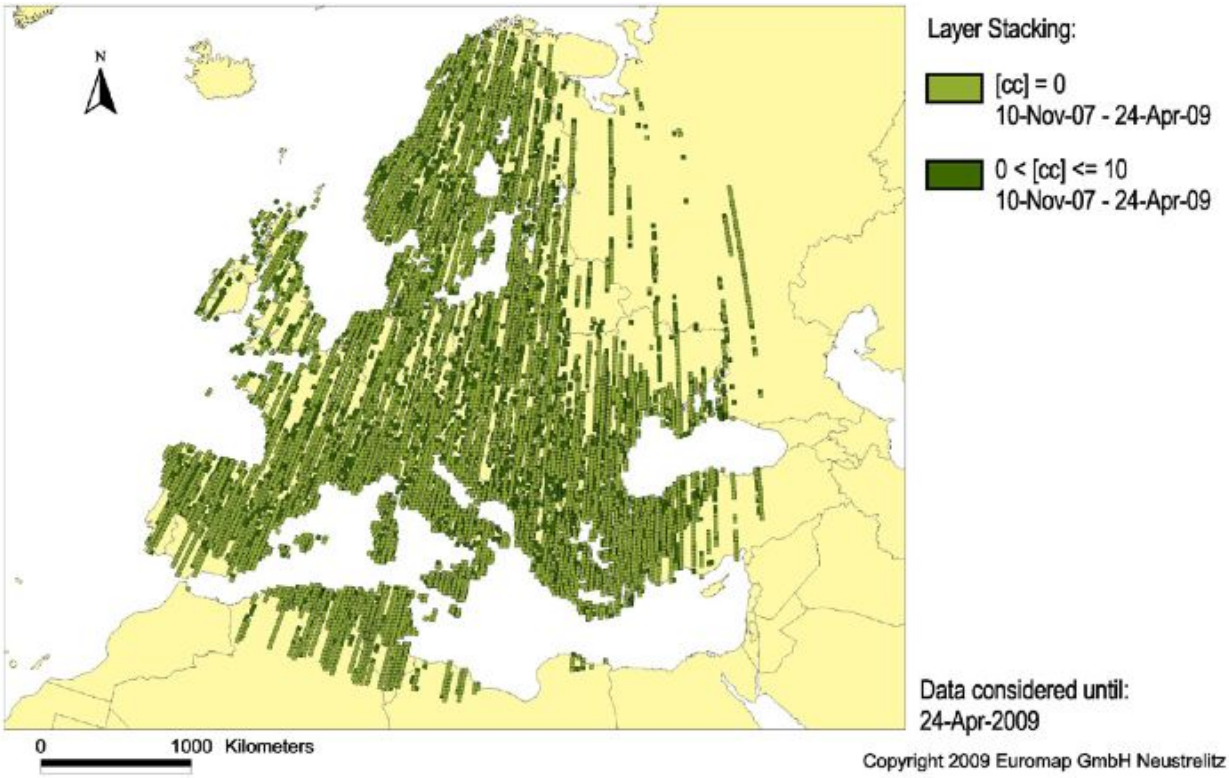
Acquisition Strategy

- collection of contiguous coverages
- 0° roll tilt

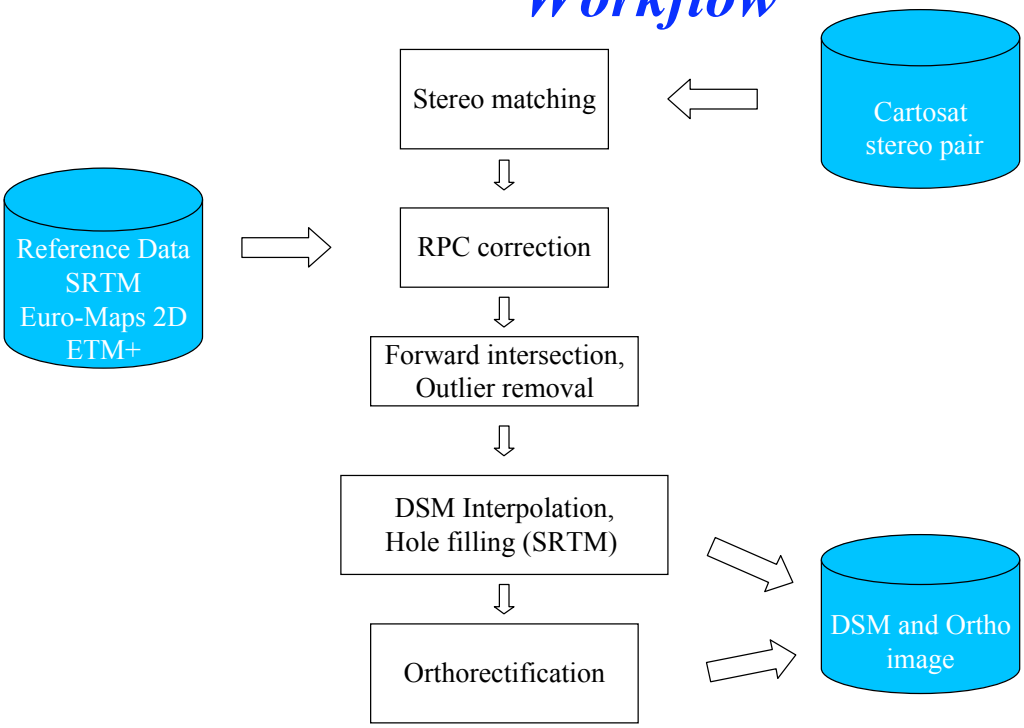
P5 Stereo Coverage



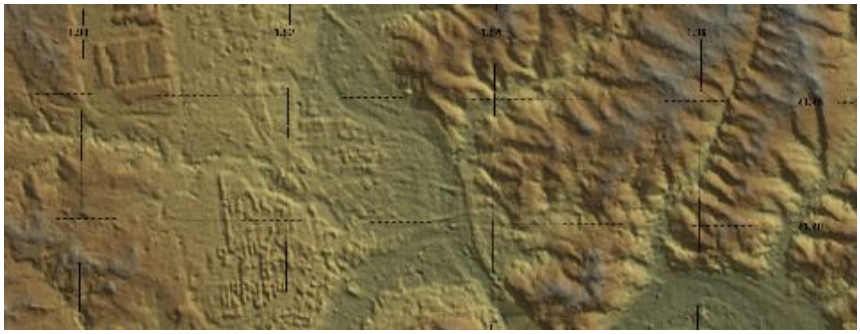
IRS-P5 Stereo Coverage – Cloud-free



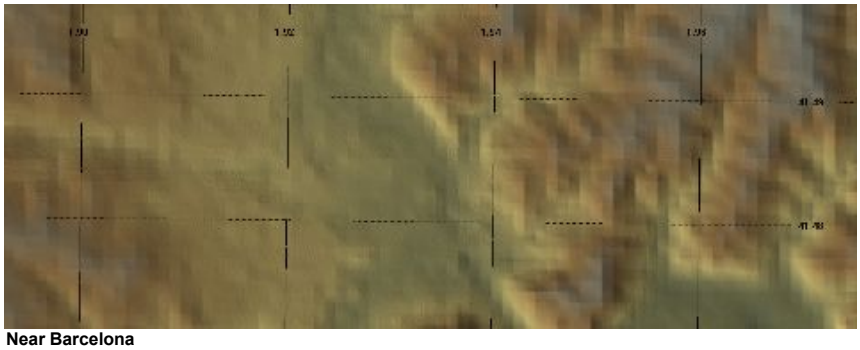
Production Methodology and Workflow



Detail of Cartosat-1 DEM



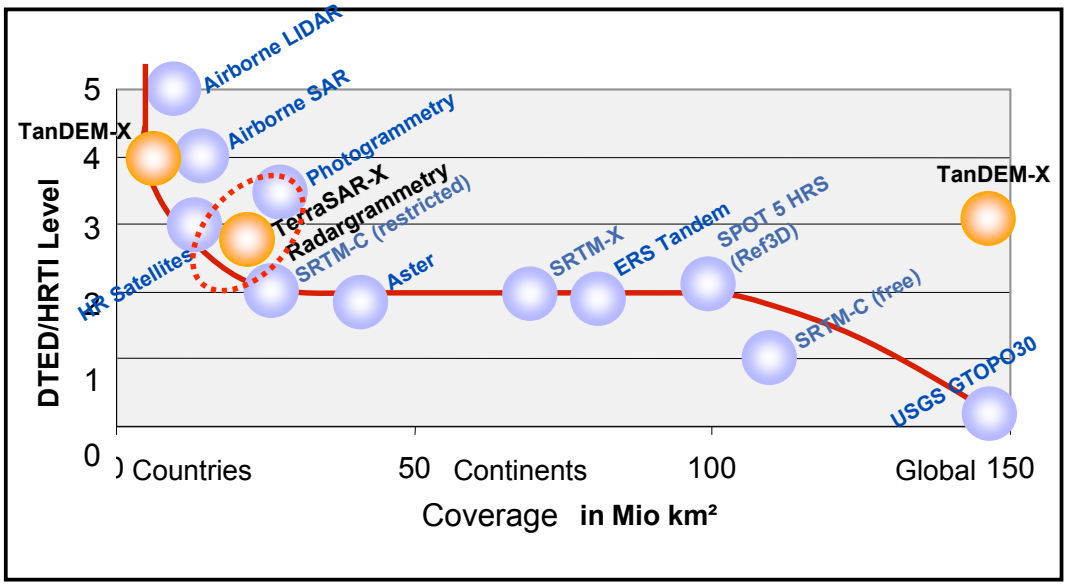
Cartosat-1 DEM, 10 m



SRTM-C DEM, 90 m

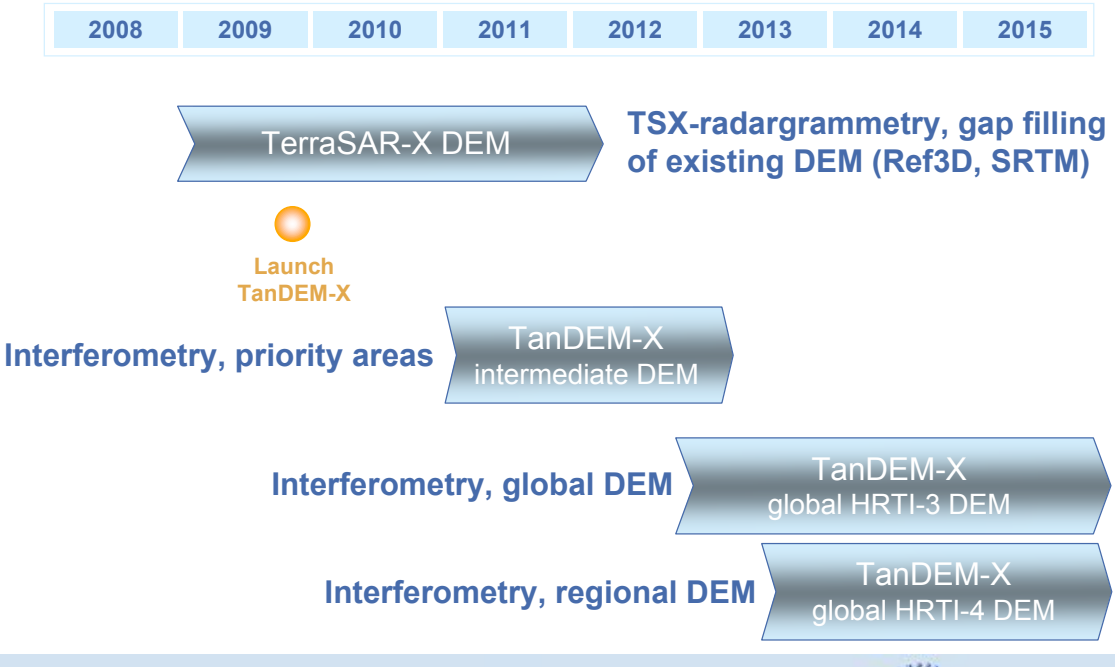
Near Barcelona

TerraSAR-X & TanDEM DEM Products & Services



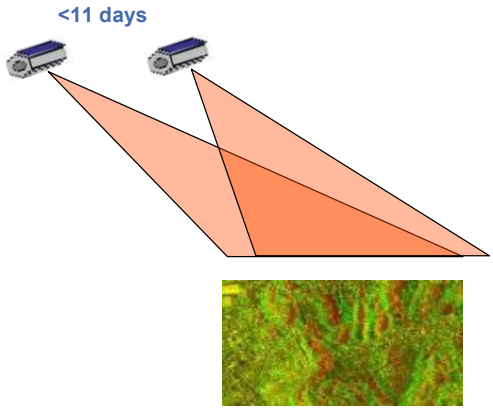
- TerraSAR-X radargrammetry: DTED level 3, regional coverage, on demand as of 2009
- TanDEM-X interferometry: DTED Level 3 (global) & DTED Level 4 (regional)

Infoterra GmbH DEM schedule



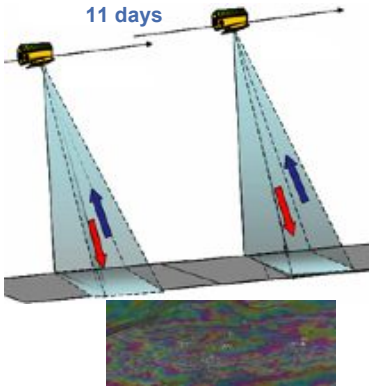
Extraction of Elevation Information using TerraSAR-X

Radargrammetry
(Stereo 3D reconstruction)



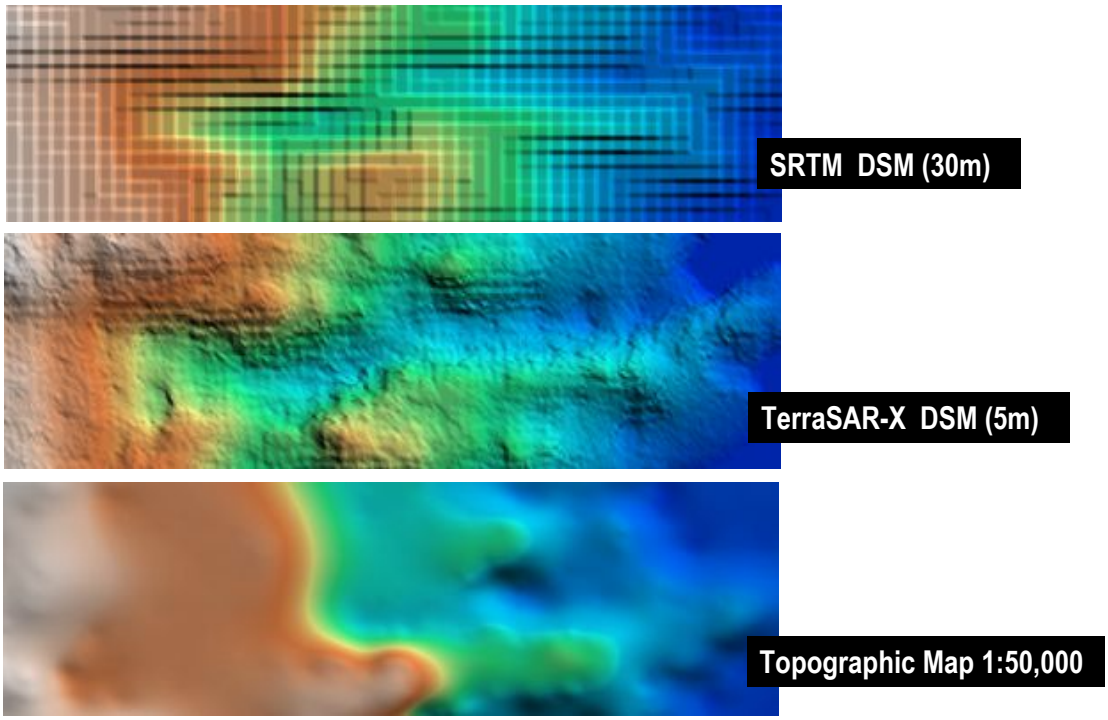
Utilization of two images with *different acquisition geometry* (intensity only)
→ less accurate

SAR Interferometry
(repeat pass INSAR)



Utilization of the *phase difference* of two images with the *same geometry*
→ more accurate, where feasible

Sample Results Digital Surface Model (DSM)



Preliminary Radargrammetric Specification

Digital Surface Model (DSM)

Method	Radargrammetry based on TerraSAR-X StripMap stereo pairs
Spacing	10 m (5 m on demand)
Abs. vertical accuracy	~ 5 – 10 m (90% linear error) depending on terrain
Relative vertical accuracy	tbd (point to point in 1° cell, 90%)
Horizontal accuracy	~ 5m (90% circular error)
Tile Size	1° x 1°
Data Format	16-bit floating GeoTiff, HRTI
Auxillary Metadata	xml-Format

(Specifications to be verified based on validation results)

Preliminary radargrammetric DEM Specifications

- **Delivery content (final product):**
  - Height error mask
  - Waterbody mask
  - Source mask
  - Correlation (Disparity) mask
  - Editing mask (e.g. interpolated areas)
  - Shadow & Layover mask
  - Orthorectified image (from full performance image)
- **Optional**
  - Digital Terrain model (DTM)
  - Contour lines (from DTM, spacing tbd, depending on relief)
- **Minimum mapping size: 1 StripMap pair**

TanDEM-X DEM Characteristics

Digital Surface Model (DSM)

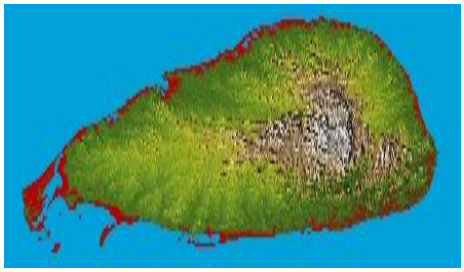
Method	Result of the dedicated TanDEM-X Mission acquisition scenario for global DEM: Two complete coverages of the earth plus additional acquisitions for difficult terrain
Spacing	~ 10 m (depending on location)
Accuracy	According to HRTI-3
Abs. vertical accuracy	~ 10 m (90% linear error)
Relative vertical accuracy	2m (slope <= 20%) 4m (slope > 20%) 90% linear point-to-point error within an area of 100 x 100 km
Horizontal accuracy	~ 10m (90% circular error)
Tile Size	1° x 1°
Data Format	16-bit floating GeoTiff, HRTI standard
Coordinate Systems	On user request
Geographic cpverade	Global, seamless coverage

Products Specification - Information layers

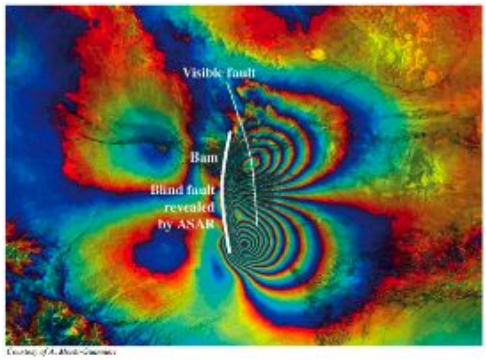
- **Delivery content (final product):**
  - Digital Surface Model (DSM), elevation values are ellipsoidal heights
  - Height error mask (values quantify the random (pixel-to-pixel) error)
  - Waterbody mask
  - Source mask
  - Correlation (Disparity) mask
  - Editing mask (e.g. interpolated areas)
  - Shadow & Layover mask
  - Orthorectified image
- **Optional**
  - Digital Terrain model (DTM)
  - Contour lines (from DTM, spacing tbd, depending on relief)
- **Minimum mapping size: 1 StripMap pair**

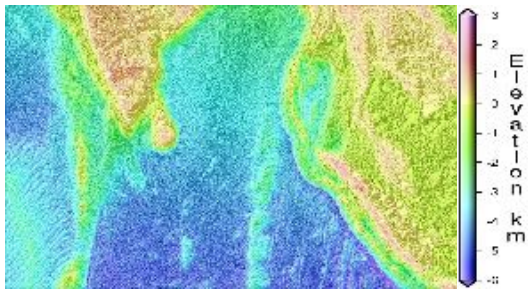
Why does GEO need global topography/bathymmetry?

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



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

GEO Task DA-09-03d : Global DEM

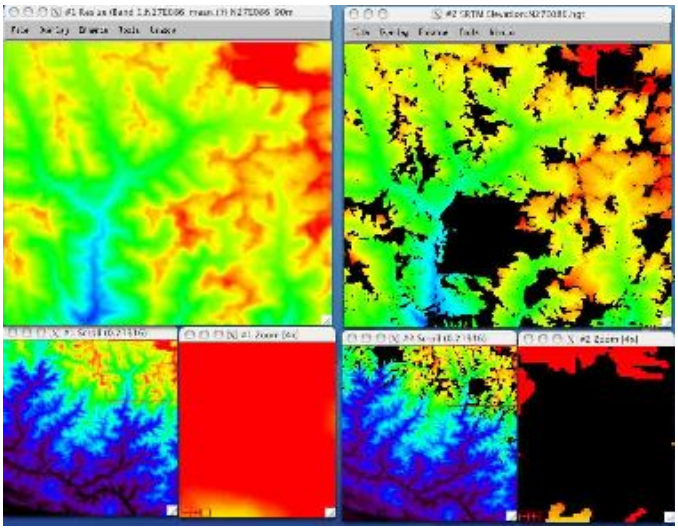
- ***Supported by BNSC-CEOS with Point of Contact: Prof. J-P Muller (CEOS-WGCV) and WGISS activities led by W. Cudlip (Qinetiq)***
- ***Objectives are to***
  - **Facilitate interoperability among Digital Elevation Model (DEM) data sets with the goal of producing a global, coordinated and integrated 30m DEM of the Earth's land surface and continental shelves**
    - » **Envisaged ASTER GDEM to form the land part of this global 30m DEM**
    - » **Continental shelf bathymmetry still a major issue, need for GEO pressure**
  - **This DEM database should be embedded into a consistent, high accuracy, and long term stable geodetic reference frame for Earth observation.**
- ***Planned activities include:***
  - **Successive open calls for validation of ASTER GDEM quality (12/08, 7/09, 6/10) and presentation of results through online proceedings of workshops, subsequent peer review journals.**
  - **Open display of ASTER GDEM quality through the CEOS-WGISS ICEDS (3/10).**
  - **Open display of errors and artifacts through "Known Product Issues" web service (3/11).**
  - **Promotion of continental shelf bathymetry acquisition starting in north polar region through ESA/CSA MORSE programme (6/10).**
- 40 members involved in Task (UK, US, AU, DE, FR, IT, ES, JP, CN, KR, WMO, OGC)

Joint US-Japan project to create a global 30m ASTER-DEM

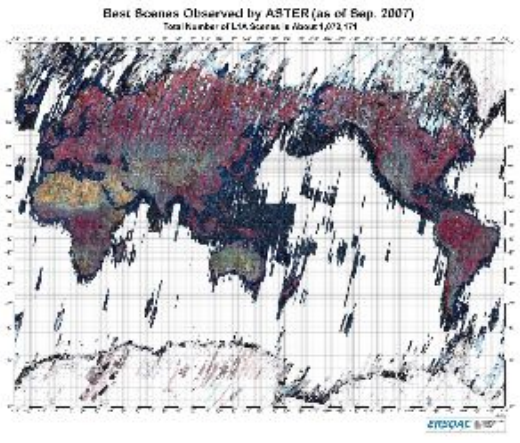
- **On 4 October 2007, updated on 21 February 2008, Bryan Bailey (Principal Remote Sensing Scientist, USGS, EDC) reported and I quote**
  - **"The National Aeronautics and Space Administration (NASA) and Japan's Ministry of Economy, Trade and Industry (METI), in cooperation with the U.S. Geological Survey (USGS) and METI's Earth Resources Data Analysis Center (ERSDAC), have announced plans to produce a global digital elevation model (DEM) from stereo data acquired during the past 8 years by Japan's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) that flies on the U.S. Terra spacecraft.**
  - **The ASTER Global DEM (GDEM) will have 30m postings, and it will cover land surfaces between 83N and 83S with estimated accuracies of 20 m at 95 % confidence for vertical data (elevation) and 30 m at 95 % confidence for horizontal data (geolocation).**
  - **METI and NASA have accepted an invitation from the Group on Earth Observations (GEO) to contribute the ASTER GDEM to the Global Earth Observing System of Systems (GEOSS), and it will be available at no cost to users from around the world.**
  - **At the GEO Summit in Cape Town, South Africa, last November, US Secretary Kempthorne and Japanese Minister Tokai announced the two countries' plans to produce the ASTER GDEM and contribute it to GEOSS.**
- **It is very likely that some (unknown number of) gaps will still exist due to persistent cloud cover or lack of contrast in the stereo images**

ASTER Global DEM Project Thanks to Bryan Bailey, EDC

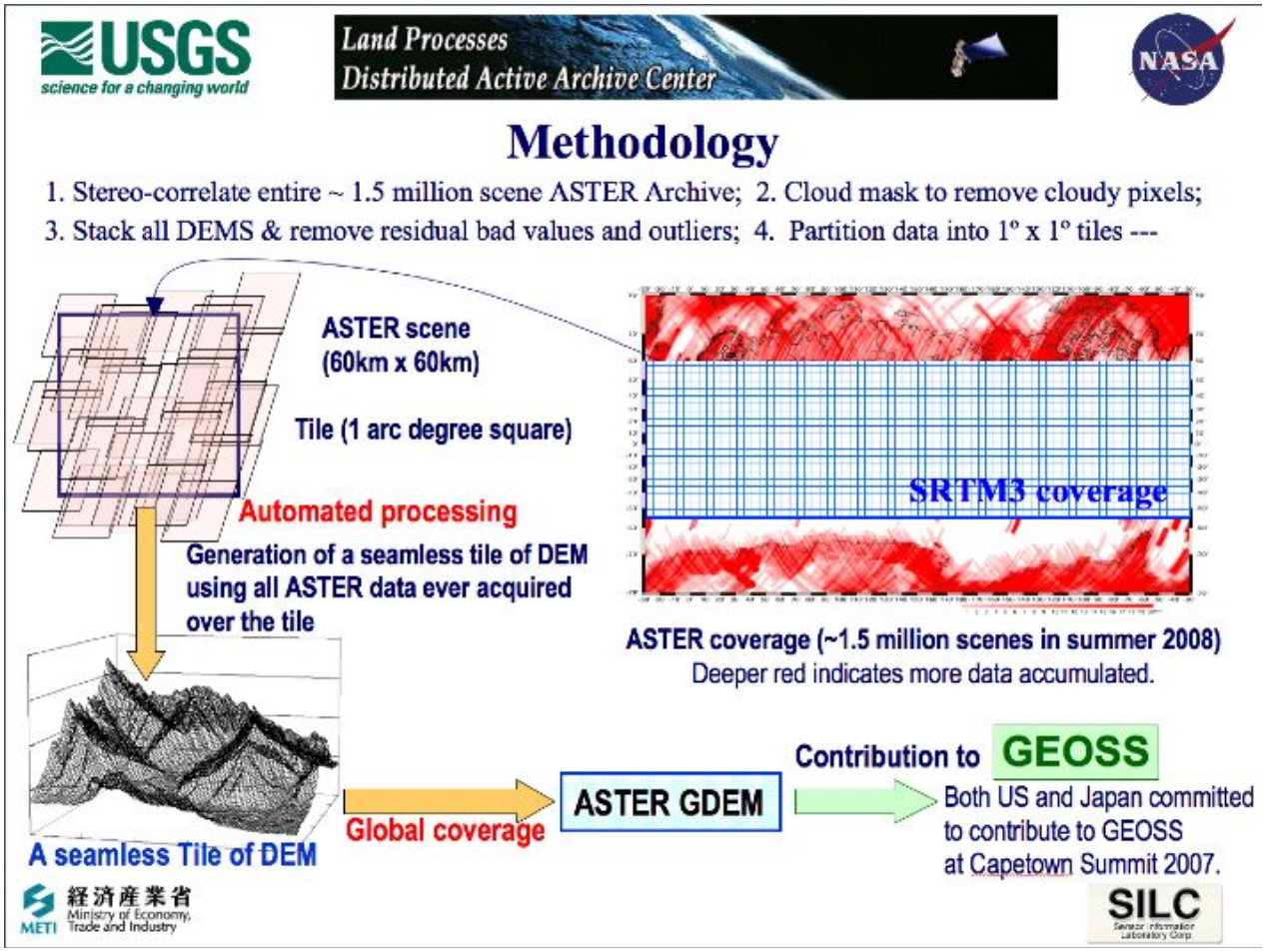
Stacked ASTER SRTM



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



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



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

- **For conterminous U.S. component, 934 CONUS tiles have been compared to NED and SRTM1 DEMs.**
- **Absolute vertical accuracy were measured using 13,300 "GCPs on benchmarks" from the National Geodetic Survey.**
- **For non-US areas, USGS released an "Announcement of Collaborative Opportunity" on 2-Dec-08 with a closing date for proposals of 7-Jan-09. JPM circulated AOC around WGCV-TMSG and GEO task group. 21 non-US groups submitted validation results by 21 March 2009**
- **India and Thailand both made inquiries but did not submit a formal proposal in the right timescales**
- **JPM evaluated ASTER GDEM quality for 5 tiles (maximum permitted), 4 of which were over CEOS-WGCV test sites**
- **Around 1% of the total 22,495 tiles have been evaluated by these 21 groups outside of the US and around 3% by NGA and USGS**
- **USGS hope to have joint validation report completed in the next few weeks for possible release of the ASTER GDEM no earlier than 1 June 2009**

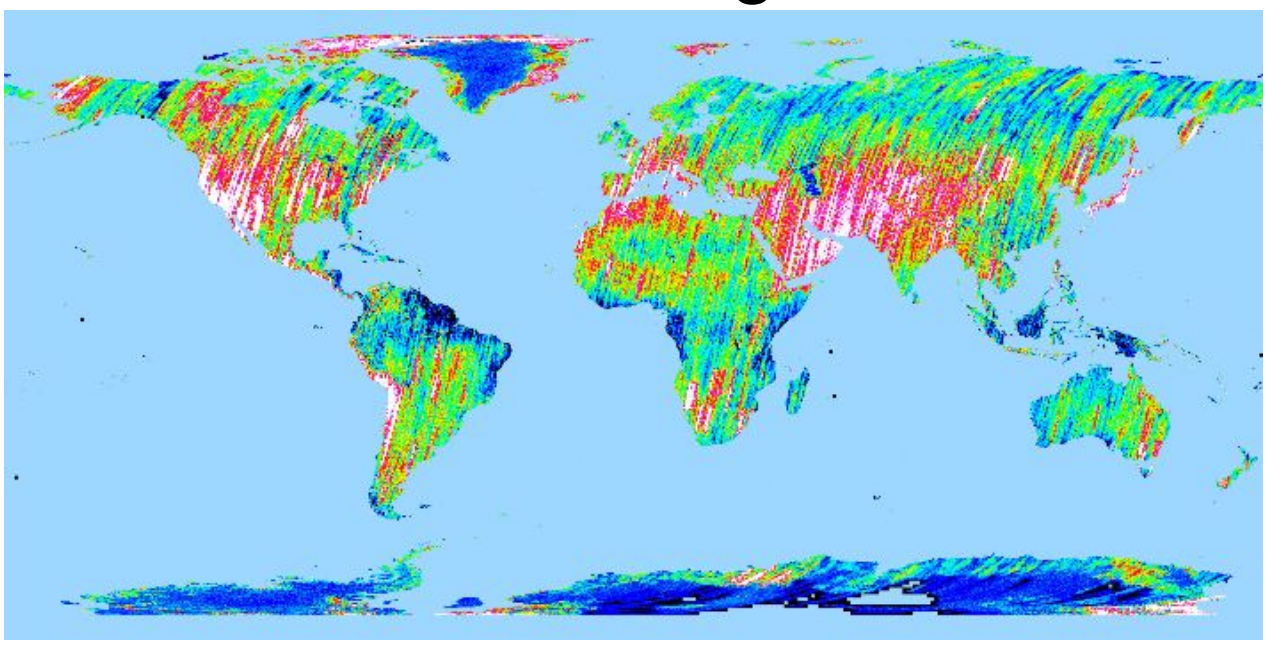
* thanks to Bryan Bailey for providing this in difficult circumstances

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

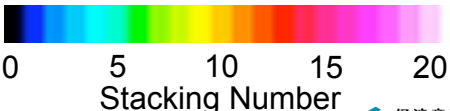
- ***My latest information, based on correspondence with our Japanese colleagues, would suggest that the decision to release (or not) the current version of the ASTER GDEM will be made during the ASTER Science Team meeting in Kyoto the week of June 8. If the decision is to release, then the actual release could occur prior to July 1.***
- **Current METI/NASA release policy states limits on the maximum number of tiles permitted for each order although all data will be free. USGS/NASA will allow 1,000 tiles at a time, ERSDAC 100 tiles for each order**
- **This limitation is due to previous ASTER data policy and infrastructure limitations which do not allow anonymous ftp (as for SRTM)**
- **Only 1º x 1º tiles to be released to registered users through ERSDAC and USGS-EDC. Conditions on subsequent use not known at present time**

** thanks to Bryan Bailey for providing this in difficult circumstances

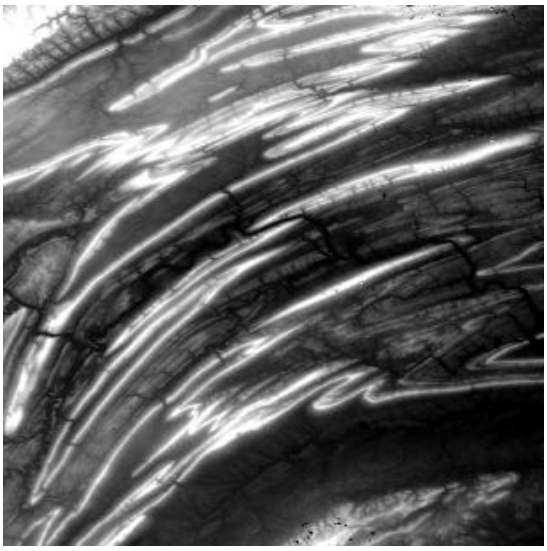
GDEM Stacking Number



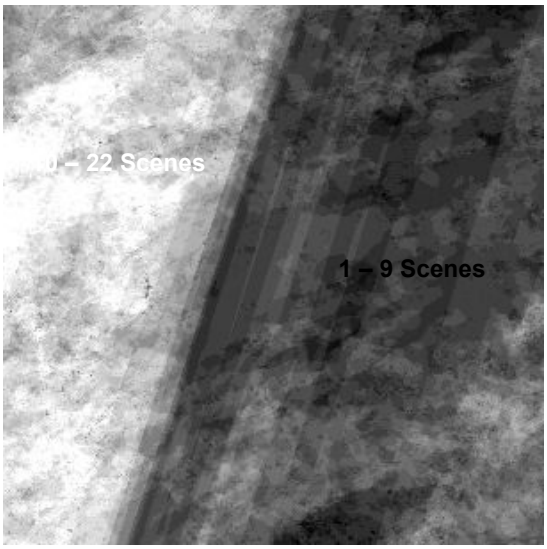
N.B. Experience suggests that accuracy linearly relates to stacking number.



Susquehanna Test Site



Prototype ASTER GDEM



Number of Scenes Used to Produce Prototype ASTER GDEM

CEOS-WGCV-TMSG test sites assessed

- **Montagne Sainte-Victoire, France**
  referred to as Aix-en-Provence
  5.528-5.685ºE, 43.502-43.560ºN
  mixed arable, forest, limestone
- **Barcelona, Spain**
  1.5-2.75ºE, 41.25-41.82ºN
  urban, mixed arable, forest
- **North Wales, UK**
  3-5ºW, 52-53.5ºN
  urban, pasture, forest
- **Three Gorges, China**
  108.252-111.302ºE, 30.638-31.229ºN
  forest, arable, limstone shales
- **Puget Sound, WA, USA (NOT USED)**
  -121.397 to -123.897ºW, 46.364-48.864ºN
  forest, urban, wetlands

N.B. screenshots from ICEDS extracts

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

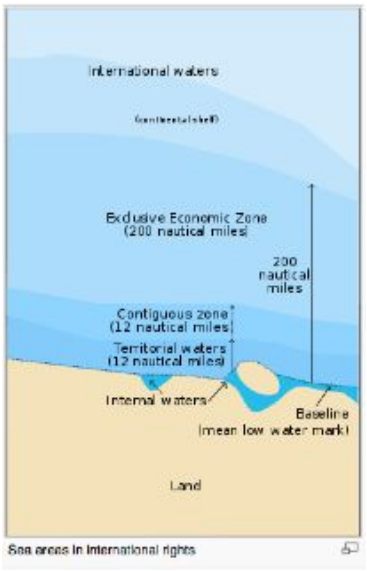
- **JPM has co-convened with Dean Gesch (USGS) a two session, 10-talk CEOS-GEO-ISPRS-IEEE workshop on 17 July 2009 on the ASTER GDEM validation to take place as part of IGARSS09 in Cape Town, South Africa from 13-17 July 2009**
- **Issue raised with Bailey & Abrams regarding this workshop and the associated papers and talks. Each AOC collaborator signed an agreement preventing them from releasing their results until the joint NASA/METI validation report is released. It was originally envisaged that the release would be 1 June 09 but events have prevented this deadline from being met.**
- **JPM has proposed that no papers be submitted to IGARSS09. Instead NASA/METI include all collaborators as co-authors and this joint report will then become the report on proceedings. Push for release before 17 July 09 so that agreement is honoured. Need assistance from WGCV Plenary on this.**
- **This session will include the launch of an international programme to perform further ASTER GDEM quality assessment and to launch a "user report" wiki**
- **It is rumoured (but not yet confirmed in writing) that SRTM-X 30m DEMs are due to be released by DLR. This can be used both for assessing ASTER GDEM as well as fill in poor ASTER GDEM values where these are shown**
- **UCL still plan to create a WMS of ASTER GDEM probably using existing GUI as well as a moderated "Known Issues" wiki**
- **all of these activities are subject to BNSC funding decisions to be made shortly**

GEO DA-09-03d: Global DEM : Next Steps(1)

- **Focus for land on FULL PUBLIC RELEASE of entire ASTER GDEM (22,895 tiles) via anonymous ftp with no limitations on the number of tiles or on any subsequent use (similar conditions to SRTM) to meet GEO data policy goals. Need CEOS support!**
- **WGCV Plenary support for WMS display of ASTER GDEM for inter-comparison with other datasets either at EDC and/or on ICEDS and/or elsewhere. This requires the removal of the restriction on re-distribution. Need CEOS assistance with this.**
- **Need investigation of feasibility of providing updates from other data sources as and when available so that we have a true shared community to contribute to Global DEM including credit being given at the pixel level to non-ASTER sources**
- **Need for global validation and assessment to determine those regions which need to be enhanced with other EO-derived DEMs. Focus initially on use of SRTM-X but also encourage NASA to release ICESAT-GLAS derived heights.**
- **Require support from CEOS member space agencies to provide missing or poor data quality (e.g. CNES/SPOT5, ISRO/Cartosat, JAXA/ALOS-PRISM) as well as TerraSAR-X stereo.**
- **DLR TANDEM-X unlikely within 2011 timescales. However, this will provide the next generation (DTED-3, 10m) DEM**

GEO DA-09-03d: Global DEM : Next Steps (2)

- **Requires massive mobilisation of resources for bathymmetric data acquisition, validation of entire datasets and data dissemination.**
- **Needs support from UN for countries to release data input to "Law of Sea" process. Treaty still a controversial issue in the US**
- **Christopher Fox (Director, NOAA-NGDC) to present a talk on behalf of JPM at GEBCO Brest meeting on Global DEM. Unfortunately due to schedule conflicts which cannot be changed, JPM cannot attend. Volunteers welcome!**
- **What role could EO play in bathymmetry sounding using lidar (e.g. NOAA SHOALS instrument from space)?**
- **Proselytise the value of this 30m DEM/bathymmetry dataset by showing example applications on the web and inviting the international community to provide further examples relevant to their own situation**



Possible source of non-US bathymmetric data: UN "Law of the Sea"

Outstanding Issues to resolve

- How will more of the ASTER GDEM pixels be formally assessed? ICESAT-GLAS? Similar process needed for SRTM.
- How will regions of poor quality data be identified in ASTER GDME both in terms of missing data which have been cosmetically filled and areas affected by cloud cover?
- How will these "voids" in the ASTER GDEM be filled? How many of the CEOS-GEOSS space agency partners are willing and able to contribute height pixels to a free and unrestricted global dataset at 30m?
- How can we ensure that the ASTER GDEM receives the same intensive worldwide effort for validation that SRTM received? Need a space agency to take ownership of the final Global DEM creation
- How do we ensure that there is a similar level of effort for producing global bathymmetric data over continental shelves?
  - NOAA-NGDC are engaged in mapping extensive areas around the US coastline. USGS have demonstrated the fusion of such bathymetric and land DEMs
  - However, most other such bathymmetric data sources are extremely expensive (e.g. UKHO) and subject to © restrictions. How can agencies such as UKHO be persuaded that it is in their best interests to contribute? Space agencies provide alternative source?
  - How does GEO persuade the oceanographic community that it is in their best interests to donate such proprietary data for the 9 SBAs agreed by the GEOSS ministers, especially that of natural disasters and hazards? Space agencies provide alternative
  - Or would it be more sensible for CEOS member agencies to consider space-based lidar depth sounding missions which also double up as vegetation canopy profiling system (e.g. NASA ICESAT-II), albeit the timescales here are late 2010s/early 2020s

GEO task DA-07-01 recommendations to CEOS Plenary

- Accept the GEO task DA-07-01 "Guidelines on Global DEM inter-operability" dated 15 August 2008 including the 30 recommendations and 15 actions contained therein.
- WGCV and WGISS welcomes the substantial progress made in recent years towards the provision of a global 30m Digital Elevation Model (DEM), although there are still deficiencies in coverage and in validation data. WGCV and WGISS also recognise the importance of DEMs for GEO societal benefit areas and downstream EO data services.
- Therefore it is recommended that CEOS member agencies agree to co-operate in the completion of a complete, gap-free and validated DEM by an agreed goal of June 2010 and no later than June 2011.
- This global DEM should include heights at 30m spacing over land based primarily on existing proven GDEMs, such as that based on data from the ASTER sensor and for bathymmetry down to depths of 30-40m on continental shelves including the production of a much more accurate coastline especially in the Arctic region.

Follow-up on agreed CEOS Plenary recommendation

- **What steps are all space agencies taking to ensure their spaceborne DEM datasets are being made available to contribute to the agreed common goal?**
- **In particular, what are DLR, SPOT Image, JAXA and ISRO doing to provide necessary DEM data? Request that at the CEOS Plenary, these space agencies are requested to provide an update?**
- **Which space agency/agencies is/are volunteering to support the creation of this global 30m DEM?**
- **Which space agency/agencies is/are volunteering to support the validation of this global 30m DEM?**