CEOS WGCV#21 Report: Terrain mapping sub-group (TMSG)

Jan-Peter Muller

Chair, CEOS Sub-group on Terrain mapping from satellites

http://wgcv.ceos.org/

MODIS & MISR science team member (NASA EOS Project)

Overview

- "Terrain Mapping from satellites" Sub-Group (TMSG)
  - Objectives
  - Justification
- Programmatic status
- Scientific status of DEM production & validation activities
  - SRTM (IfSAR)
  - ICESAT (lidar)
  - ASTER (stereo)
- Programmatic plans
- Recommendations to CEOS WGCV21 for consideration for CEOS Plenary arising from Portland workshop
- Proposed replacement wording for Action Plan

CEOS WGCV Terrain Mapping

- **What is the mission of this sub-group?**
  - **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 prepare recommendations for the establishment of a global ground control point network. (CEOS-ISPRS)**
  - **To consider how orbit validation could be developed (CEOS-ISPRS)**
  - **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.**

WGCV-TMSG:Justification

- Georeferencing and subsequent ortho-rectification of all space-based land products requires a global terrain data-set
- Atmospheric correction also requires terrain to correct for path radiance as well as self-shadowing in rugged regions
- Studies of mountainous environments require terrain data for the following example applications:
  - surface spectral BRDF/albedo retrievals (and subsequent land surface biophysical parameters)
  - Monitoring of glacier areal coverage
- Terrain data required for monitoring changes in elevation due to:
  - Deforestation and Afforestation
  - Surface mining activities
  - Urbanisation
  - Differential SAR interferometry for mm-level solid earth surface deformation (e.g. volcanoes, earthquakes, domestic subsidence)

Programmatic Status

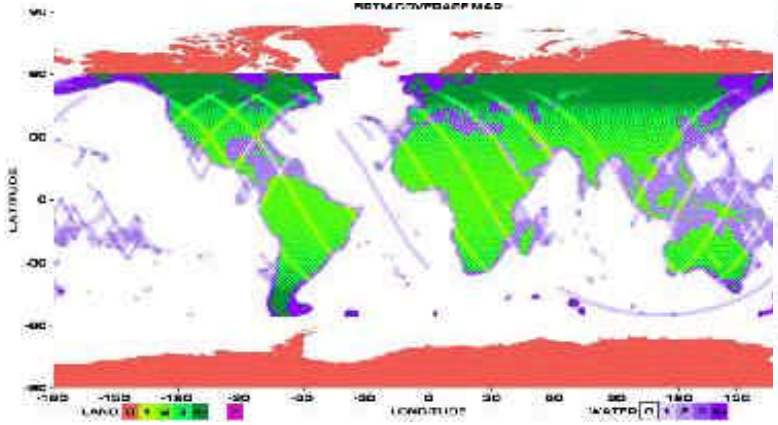
- **Workshop held prior to ISPRS meeting on "IfSAR and Lidar" in Portland, OR, USA on 16 June 2003**
  - **Reviewed global DEM production and distribution issues from SRTM, validation activities for SRTM, ASTER and ICESAT**
  - **Discussed over-arching requirements for test sites**
  - **Agreed on 3 new European (Snowdonia, UK; Barcelona, SP; Aix-en-Provence, FR; Bavaria, D) and 1 additional US test site (Puget Sound)**
  - **Started liaison with SPOT-5 HRS (ISPRS sponsored) DEM validation campaign for Barcelona, Bavaria and existing test site over Aix-en-Provence, FR**
  - **Discussed "Best Practice Dossier" and agreed to hold a subsequent meeting to focus on evaluation methods and statistics**
- **Membership of Sub-Group includes invited senior technical experts from civilian, military and commercial organisations.**

SRTM Context

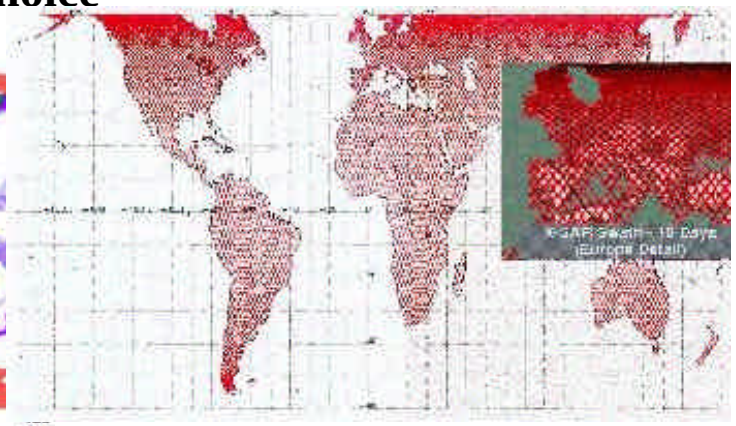
- C-SRTM data (C-band/JPL and X-band DLR/ASI) collected in February 2000 for 80% of land surface (60ºN-56ºS)
- NASA processed all C-band data in 1º x 1º tiles and delivered these to NIMA in 12/02
- All 3” C-SRTM DEMs being placed in the public domain
- DLR processing all X-band data but only available for accepted PIs of data grant. All other users required to purchase DEM at 100€/15 arc-minute tile (1,600€/1º tile).
- “Bleeding edge” technology particularly regarding orbit and attitude restitution resulted in substantial delays in the systematic processing of DEMs

C- and X-SRTM Coverage

- Accuracy predicted to be a function of the number of imagings. Evaluation not yet performed
- C-SRTM coverage complete (except for radar shadow gaps) for 60ºN-56ºS)
- X-SAR coverage mainly single-look except for orbit crossovers and near the latitudinal extremes
- X-SRTM coverage only some 30% of C-SRTM. X-SAR includes 1" DEM, Height Error Matrix and SAR backscatter
- X-SAR DEMs released on WGS84 ellipsoid requiring user to correct to local geoid of their own choice



C-SRTM DEM Coverage



X-SRTM DEM Coverage

SRTM Distribution Issues

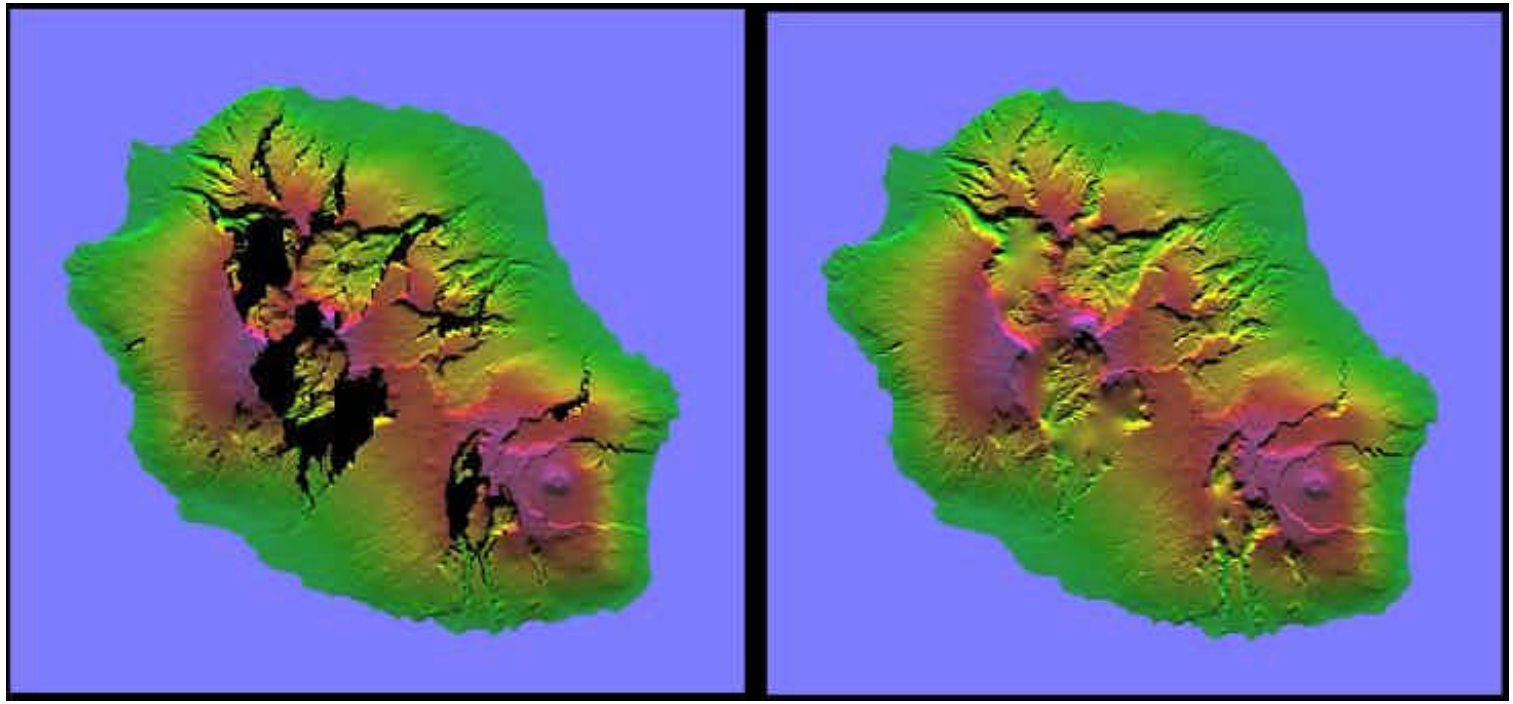
- C-SRTM DEM (only) 3 arc-second (90m) postings (NASA format) for 80% of land surface on WGS84 geoid is being placed in the public domain to be completed by 12/2004. 1” data (30m) unedited DEM only for the conterminous USA (lower 48 states) available NOW.
- Initial release of unedited (no correction for water bodies,gaps filled due to radar shadows, SAR processing artefacts) continental DEMs from USGS at http://seamless.usgs.gov
  - North and South America available NOW
  - Western Eurasia and Africa due 1-Dec-03
  - Eastern Eurasia due 1-Feb-04
- NIMA contractors working on editing and verification using in-house NIMA assets prior to NIMA releasing under a restricted license an official DTED-2 product.
- Edited version of South America at DTED-1 (3”) due for release shortly from USGS with other continents coming later (schedule unknown). Referred to as Version 2
- 30” (1km) updated version of GTOPO30 released on 20-Aug-03 and available for free download at ftp://edcftp.cr.usgs.gov/pub/data/srtm/SRTM30

Unedited GTOPO30v2 coverage

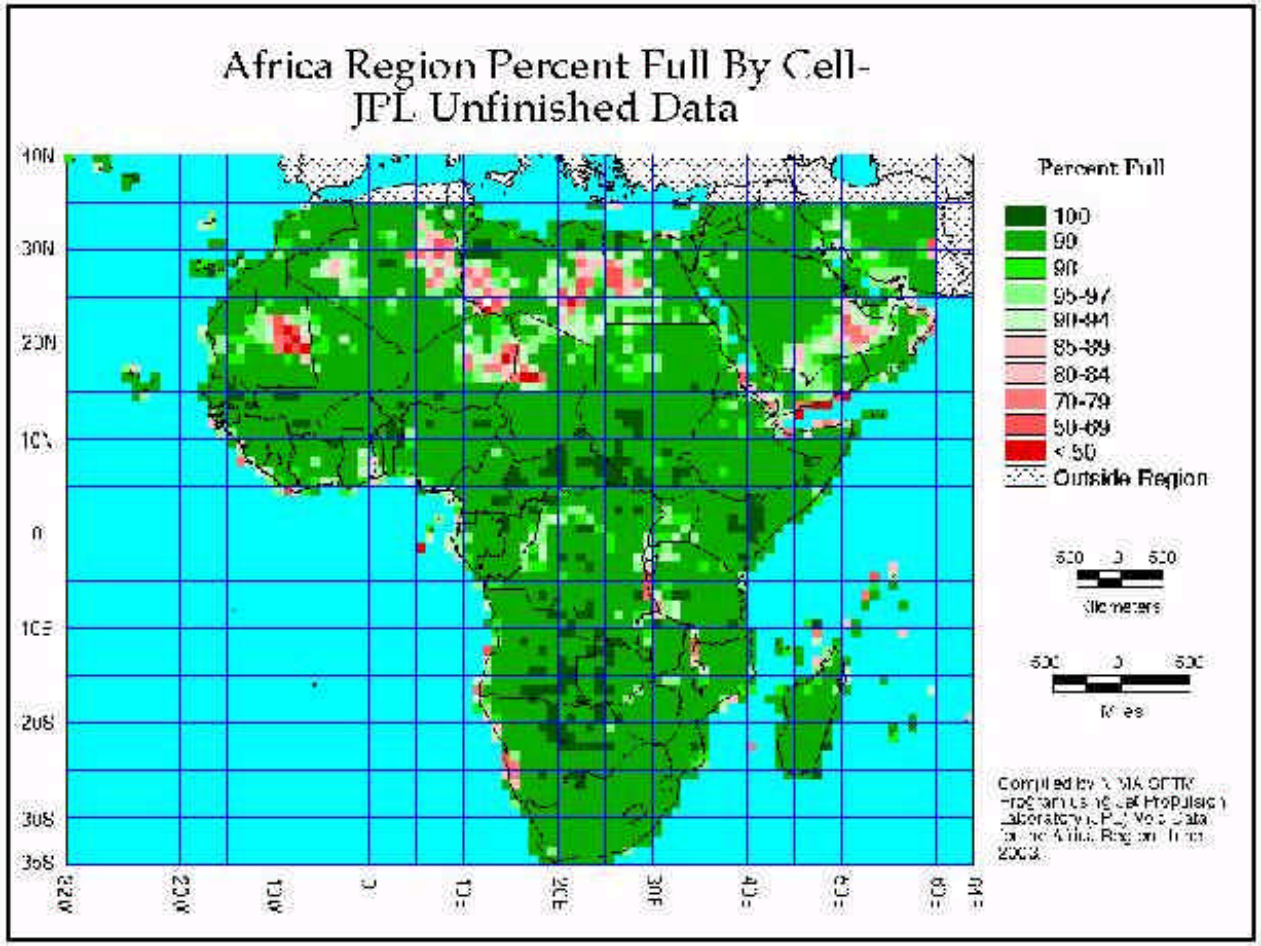
Complete DEM can be downloaded from

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

Example of data voids - radar shadows



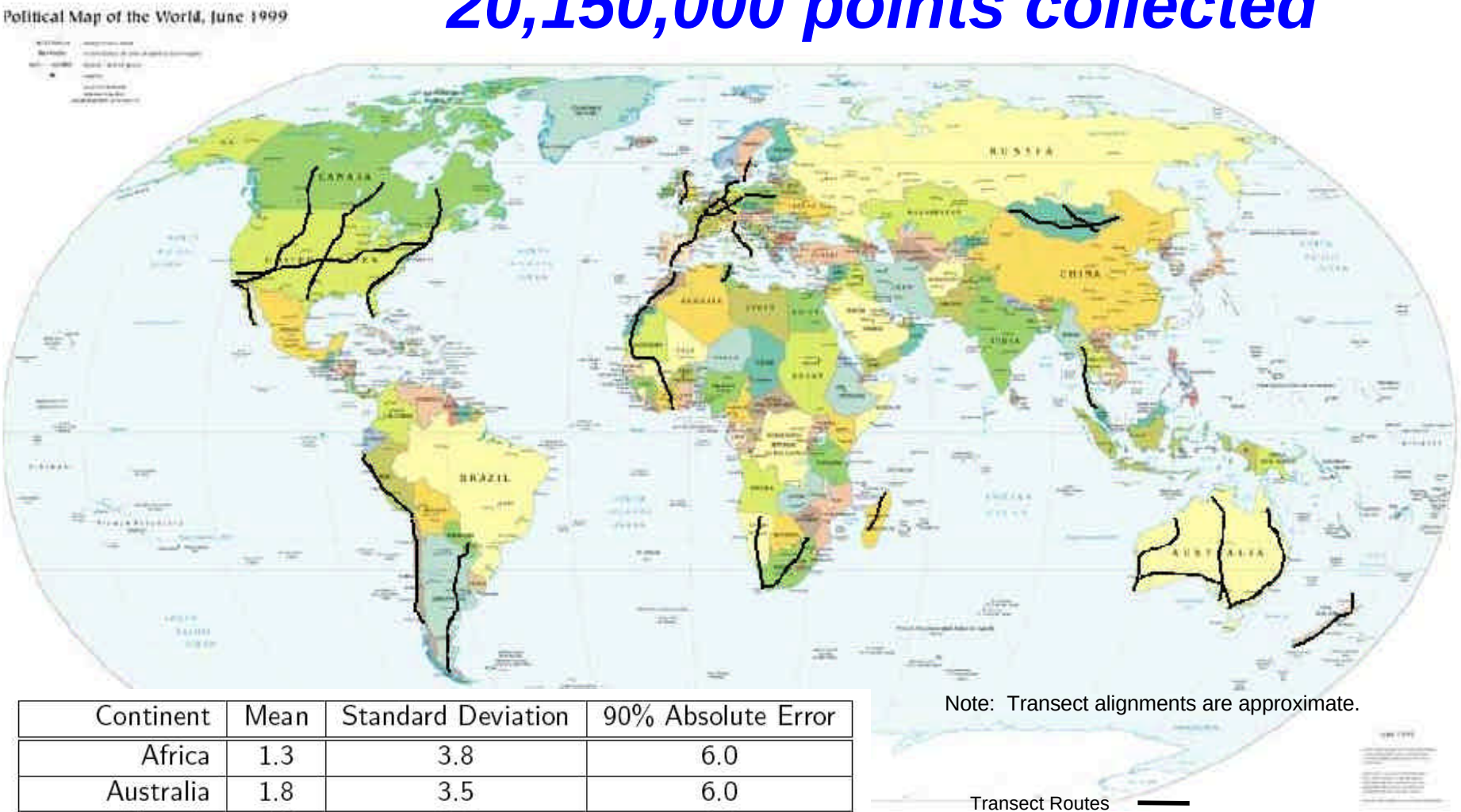
SRTM data voids - loss of coherence (e.g.sand)



Overall Quality Assessment

- NIMA contracted JPL to produce continental transects using kinematic GPS
- NIMA compared SRTM DEM against in-house Ground Control Points
- NIMA compared SRTM DEM against in-house DTED-1
- Overall showed that errors were <<16m (90% LE)

SRTM TRANSECTS - 20,150,000 points collected



Continent	Mean	Standard Deviation	90% Absolute Error
Africa	1.3	3.8	6.0
Australia	1.8	3.5	6.0
Eurasia	-0.7	3.7	6.6
North America	0.1	4.0	6.5
New Zealand	1.4	5.9	10.0
South America	1.7	4.1	7.5

Note: Transect alignments are approximate.

Transect Routes

2 Aug 2001

COMPARISON OF SRTM ELEVATIONS WITH PHOTOGRAMMETRIC GROUND CONTROL

CELL STATISTICS FOR (GCP – SRTM) ELEVATION DIFFERENCES (METRES)
AGGREGATED FOR EACH CONTINENT

	AFRICA	AUSTRALIA	EURASIA-E	EURASIA-W	N. AMERICA	S. AMERICA
No. of Cells w/ GCPs*	2,396	168	1,943	1,957	1,857	644
Mean of Mean Differences	-1.9	-1.8	-0.4	0.6	-0.2	-2.0
Median of Mean Differences	-1.9	-1.4	-0.4	0.6	0.0	-2.1
Mean of 90% Elev. Difference Errors	5.5	6.5	8.2	6.0	6.0	7.0
Mean of RMS Elev. Differences	4.4	4.7	5.7	4.4	4.3	5.5

* Includes only cells with 6 or more GCPs.

COMPARISON OF SRTM DTED® WITH REFERENCE DTED®

CELL STATISTICS FOR (REFERENCE DTED – SRTM DTED) ELEVATION DIFFERENCES (METRES) AGGREGATED FOR EACH CONTINENT

	AFRICA	AUSTRALIA	EURASIA-E	EURASIA-W	N. AMERICA	S. AMERICA
No. of Cells w/ Reference DTED	234	355	102	184	146	10
Mean of Mean Differences	-1.4	2.2	1.9	-0.6	1.6	-8.0
Median of Mean Differences	-1.1	2.0	1.9	-0.3	1.8	-7.8
Mean of 90% Elev. Difference Errors	6.7	7.0	10.1	7.0	8.4	8.6
Mean of RMS Elev. Differences	4.9	5.1	7.1	4.8	6.1	10.1

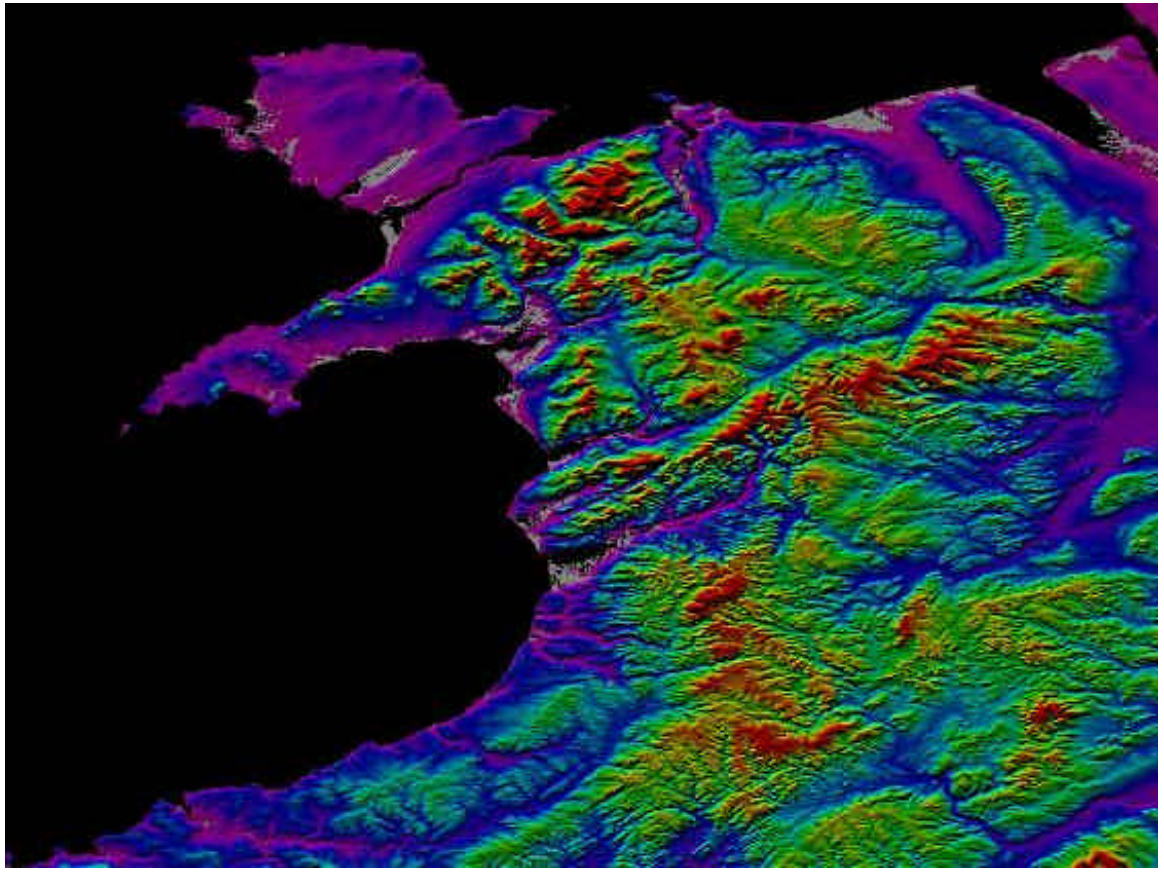
Objectives of validation study

- Quality assessment of the C-SRTM DEMs using "bare earth" DEMs, kinematic GPS and land cover information
- Assess whether they meet the design specification for DTED-1 (Zrms 18m)
- Assess planimetric height accuracy via intercomparisons with "bare earth" DEMs
- Interpret height differences in terms of topographic variables and land cover

Datasets

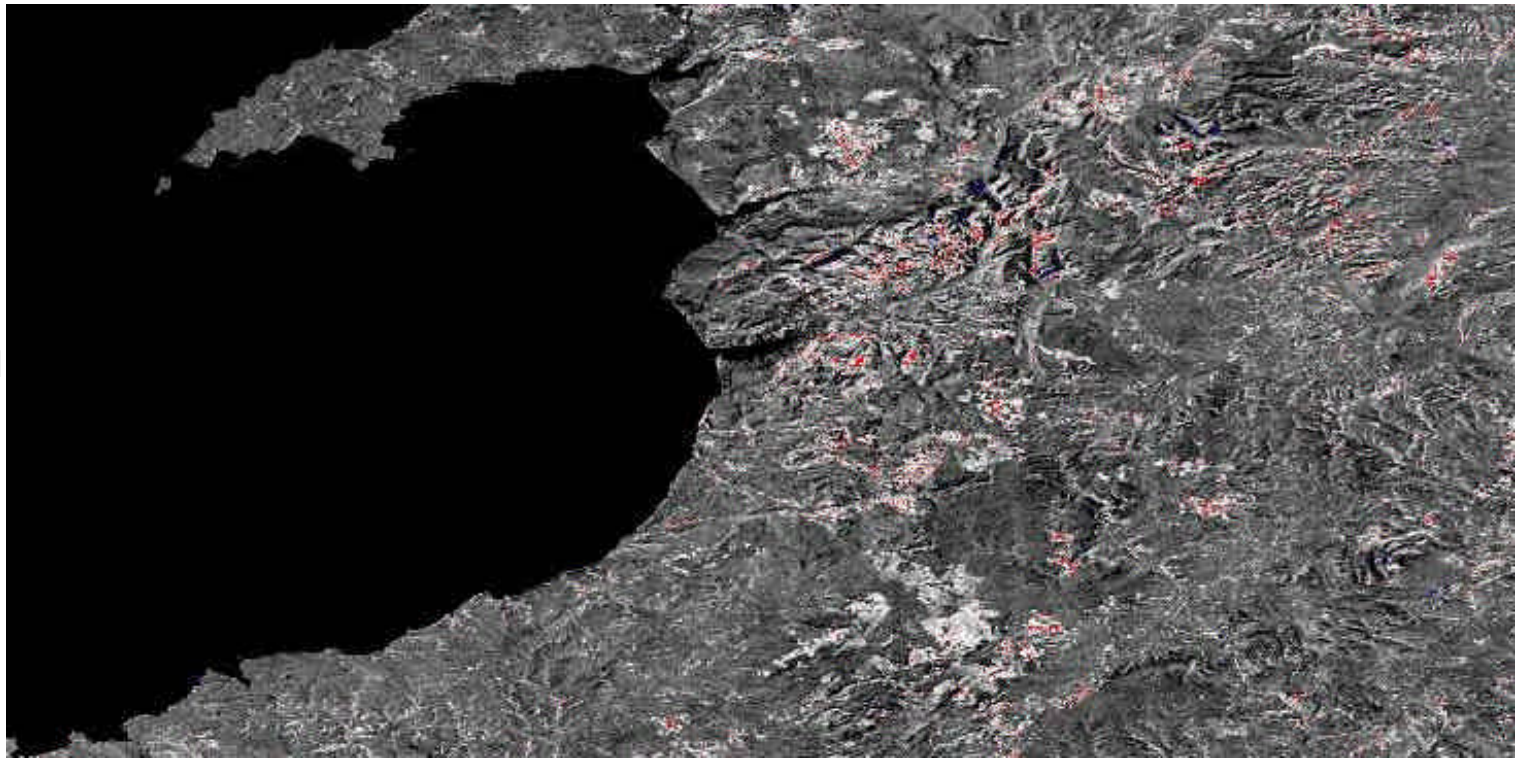
- CSRTM 3” DEMs made available by JPL under restricted license agreement
- XSRTM 1” DEMs available from DLR under PI data grant
- OS® PANORAMA 50m bare earth DTM available under restricted license to UK universities
- LANDMAP LANDSAT-7 ETM+ orthorectified mosaics
- LANDMAP kinematic GPS
- Both SRTM were NOT registered to OS® and required manual “warping” from 1-4 grid-points. Problem under investigation with JPL as results from other European test sites were even worse

Example area: Snowdonia North Wales, UK - CSRTM DEM



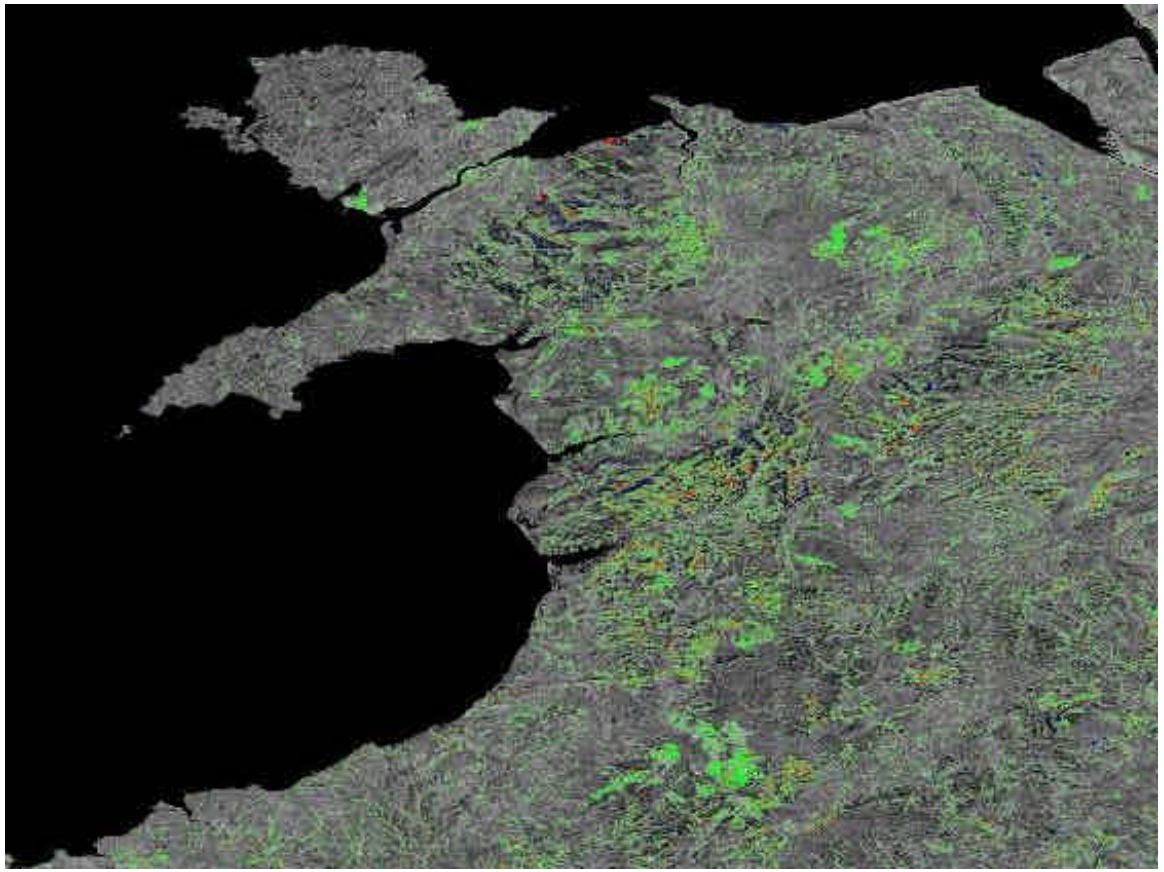
CSRTM-OS®
Red (>17m), Blue (<-17m)

Height differences
Dominated by:
Radar shadows,
Forest cover
1.22±4.13m overall
but for DEM
Differences
Excluding forest
And radar shadow
Is 1-2m!!

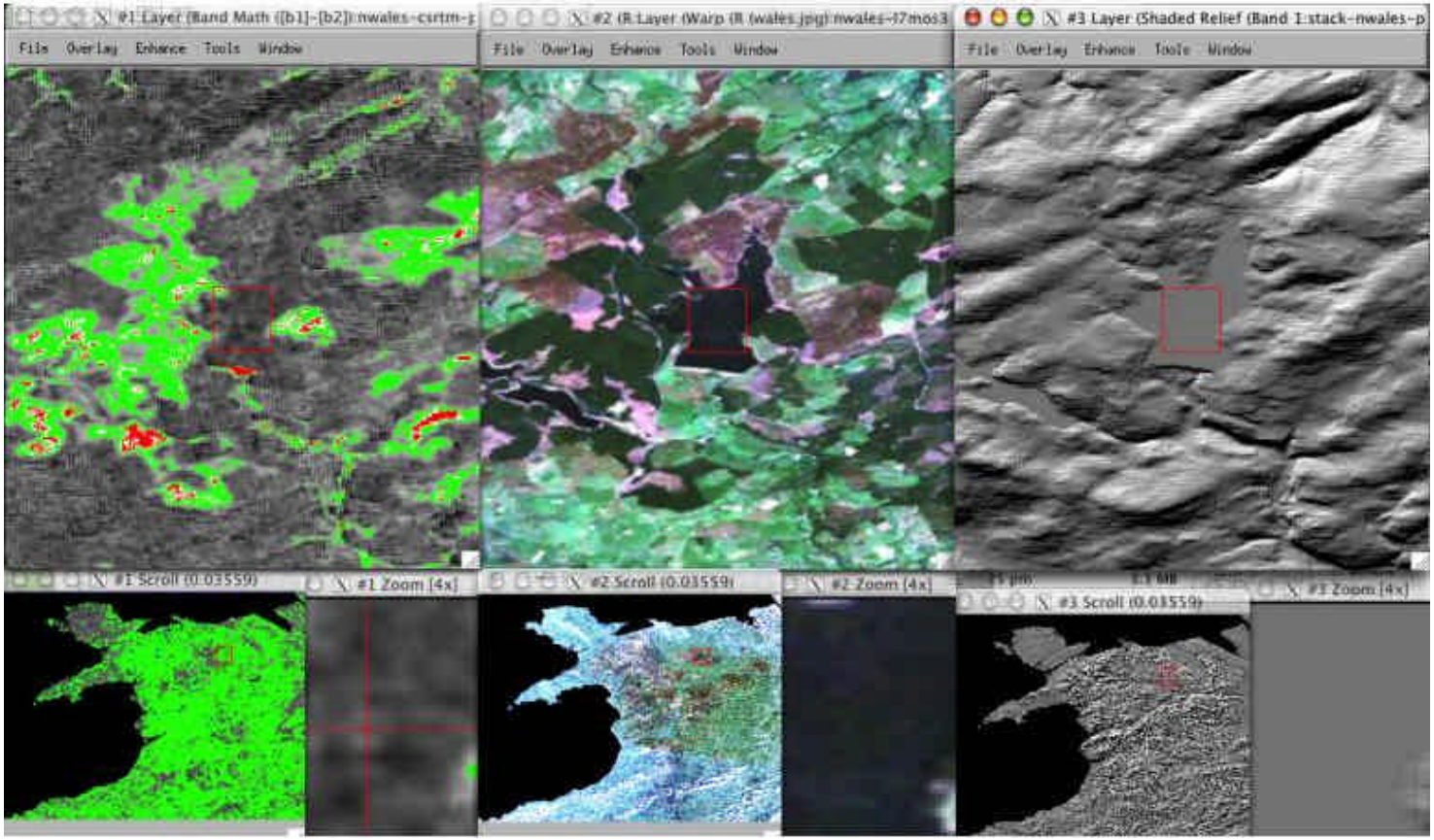


CSRTM-OS®
Green (9-16m)

Height differences
in this range are
closely linked to forest cover
In this region

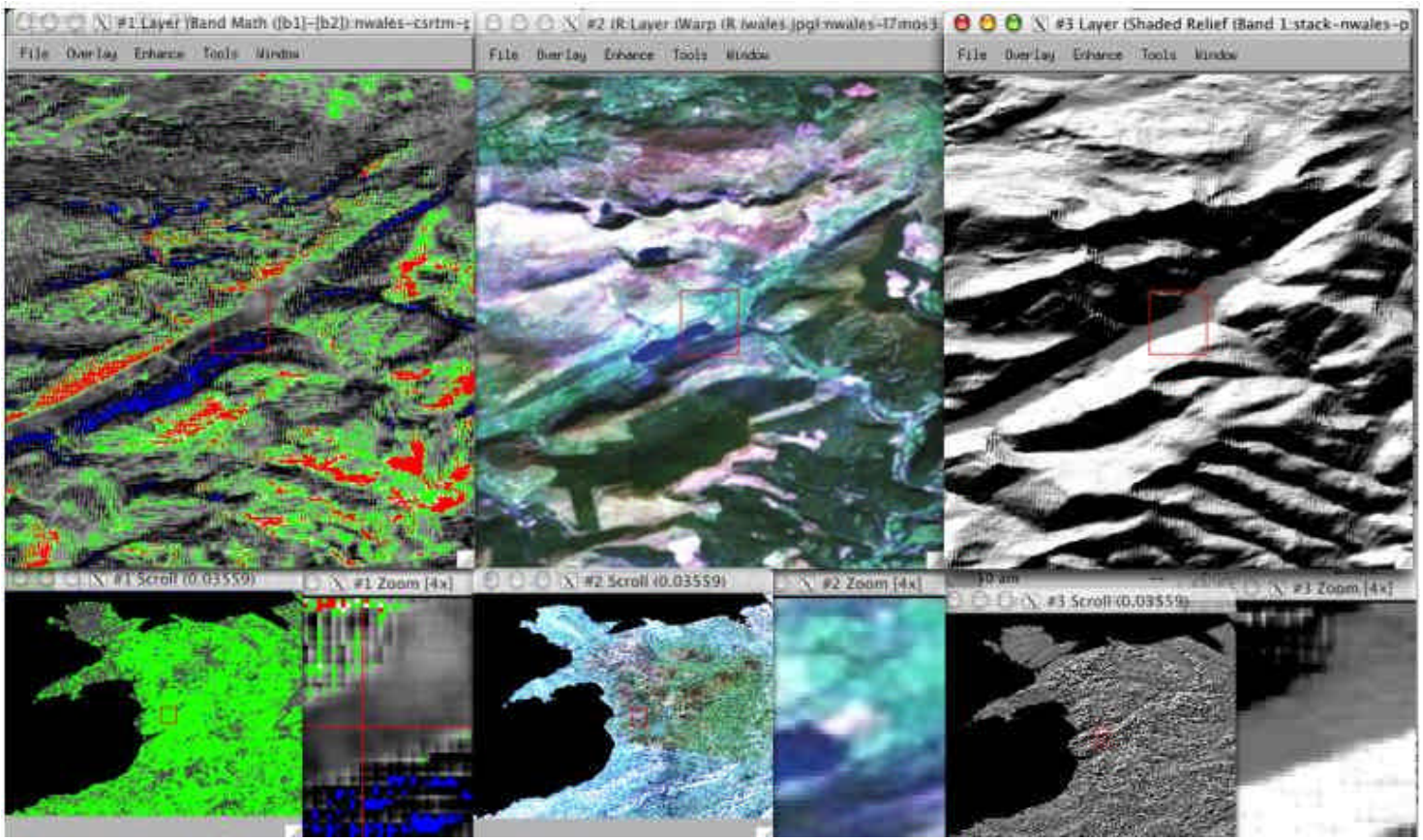


Example area showing impact of forest cover (Green=9-14m)



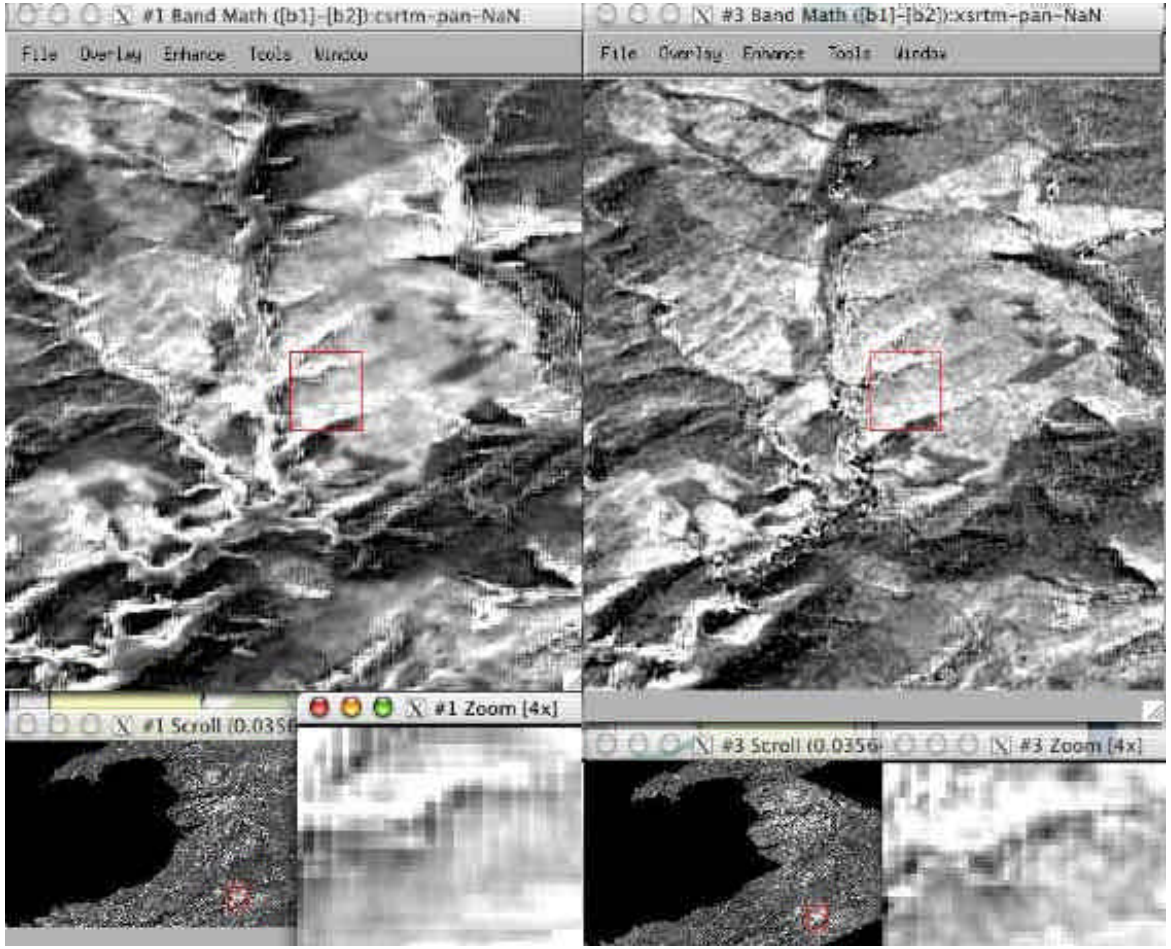
Example area showing impact of slope/aspect + forest cover

N.B. Limited examples of Slope/aspect effects. Cannot unscramble these due to impact of mosaicing of multiple “looks”

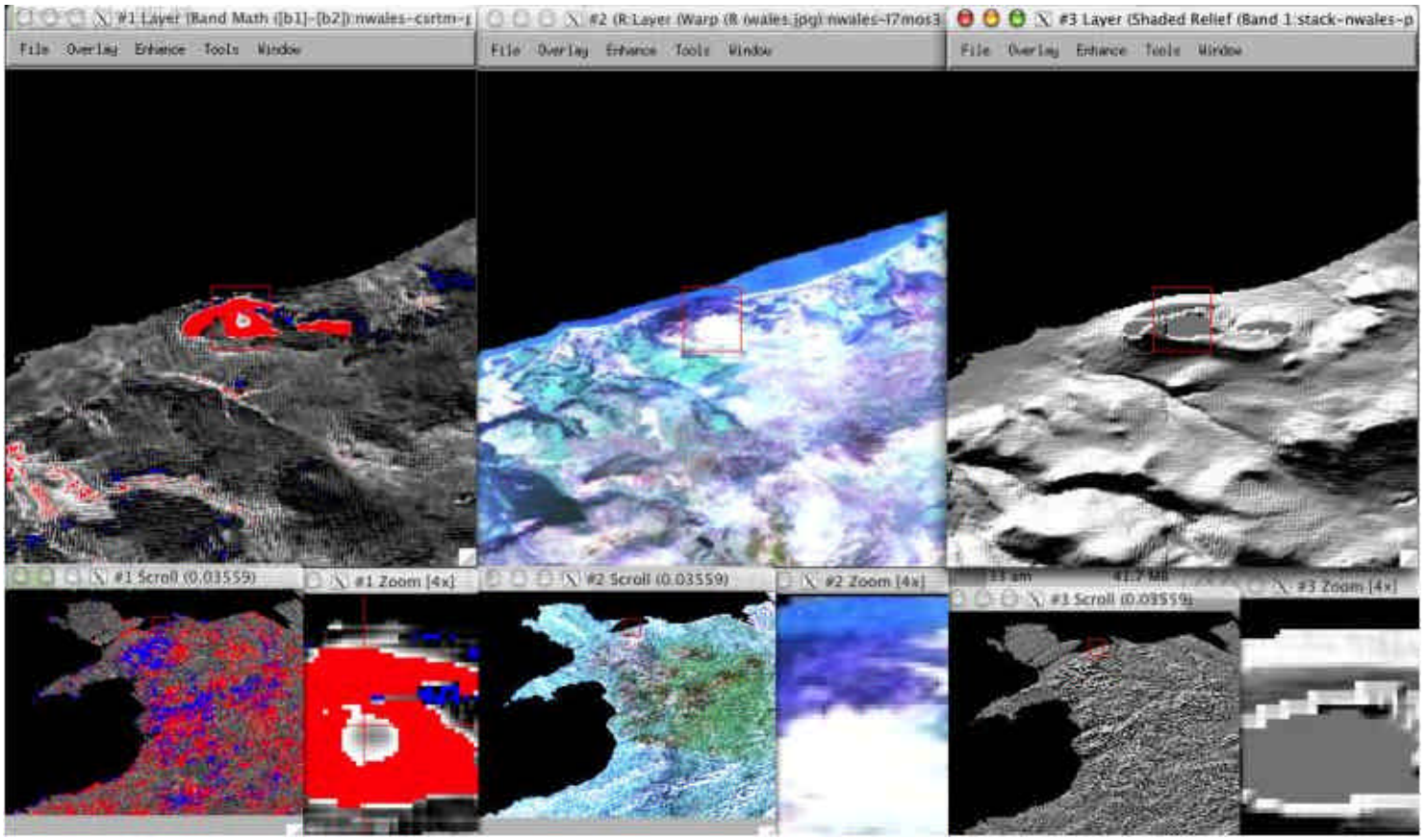


Intercomparison of CSRTM-OS® and XSRTM-OS®

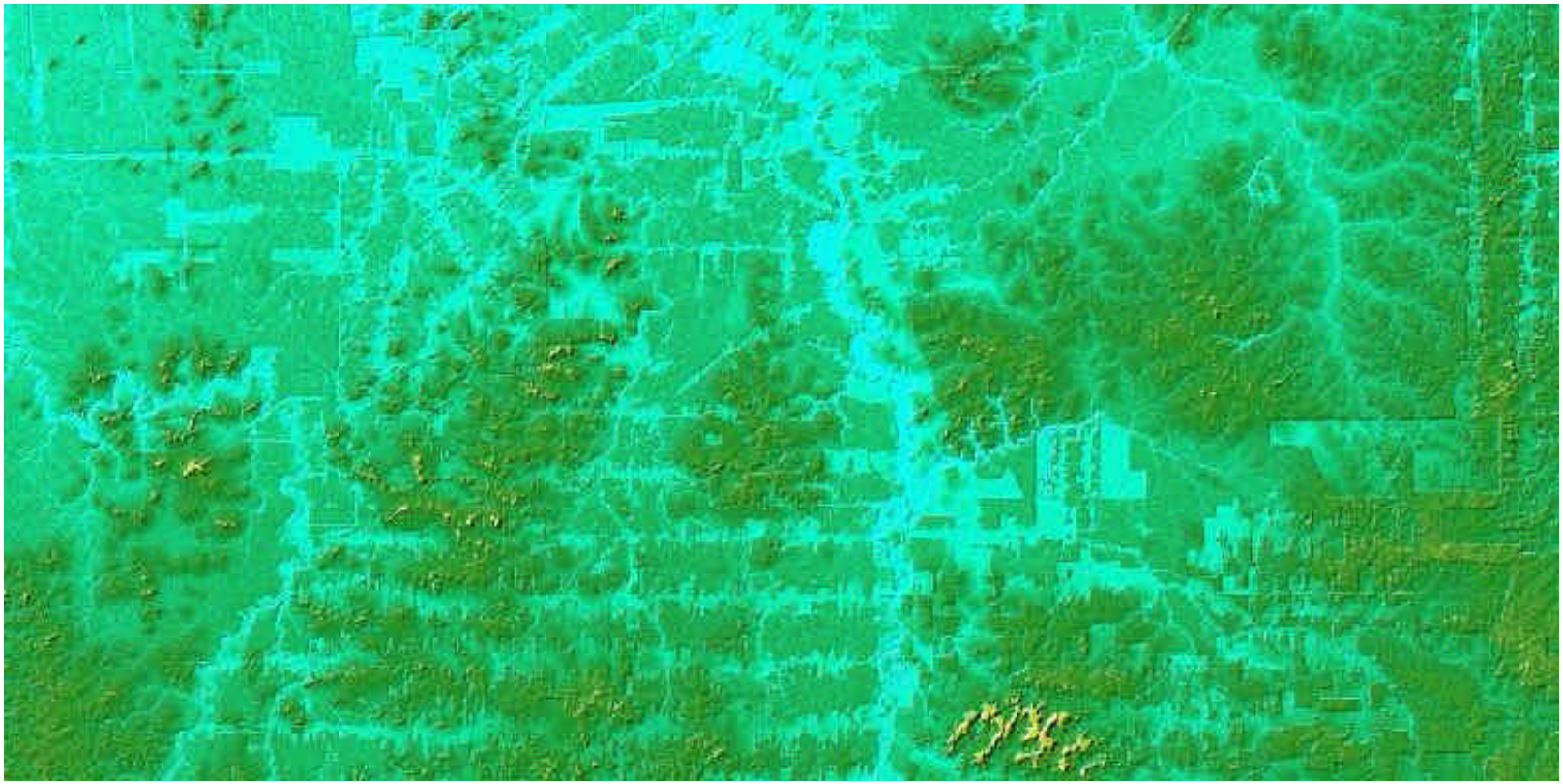
N.B. 1” XSRTM and 3” CSRTM differences with OS® DTM show little substantive differences. Little radar penetration at CSRTM. Further research needed with Lidar.



Example of landscape change from CSRTM-OS®: Mining

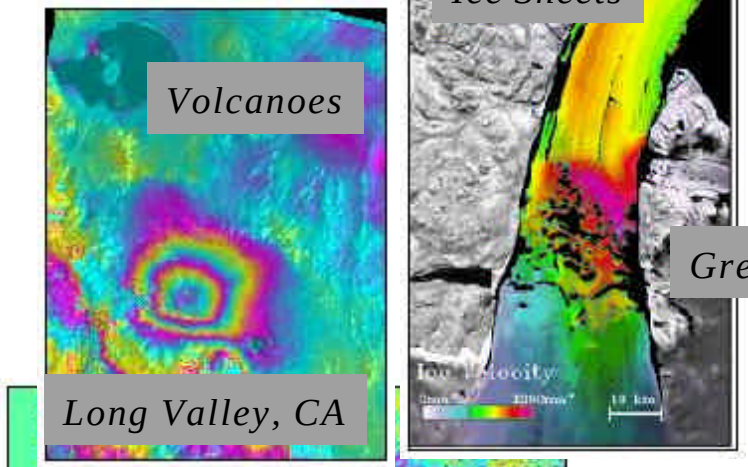


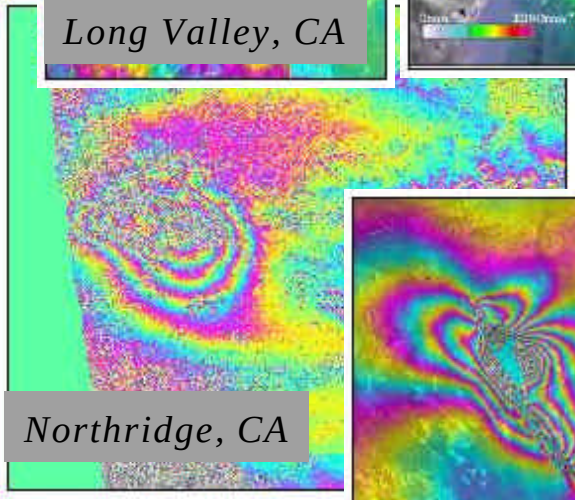
Example of deforestation from CSRTM over Rondonia, Brazil

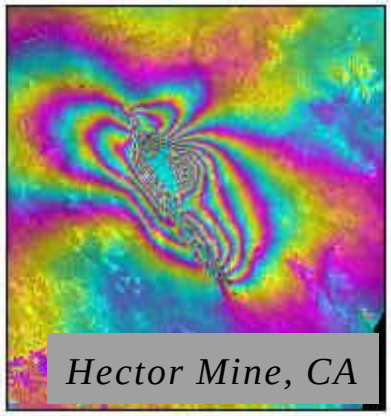


Example applications of SRTM for studies of mm change in earth land surface

Site-specific, Irregular Scalar Measurements

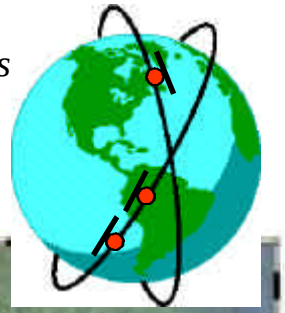


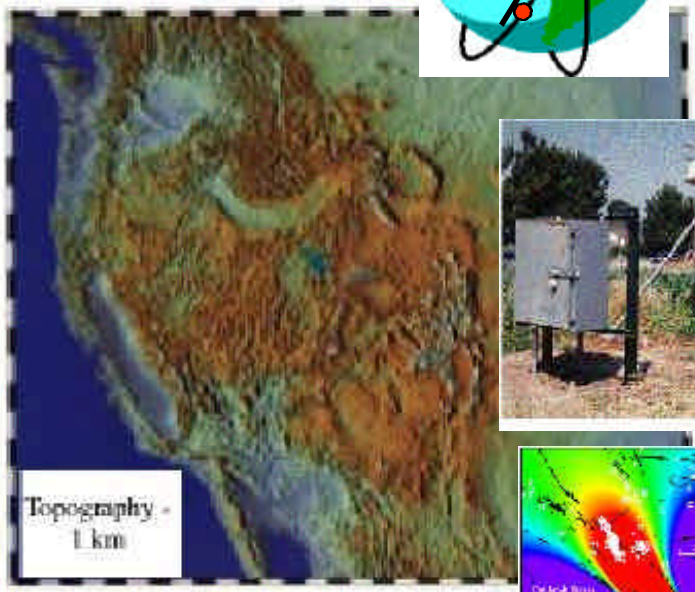




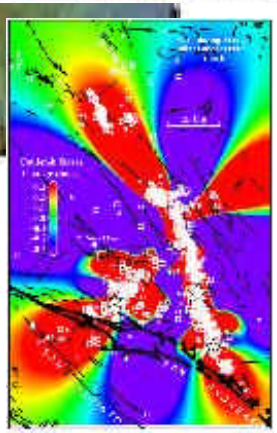
Earthquakes

Operational Constellations for Plate Boundary Scale Vector Measurements





PBO



Stress Change

Initial Conclusions

- C-SRTM and X-SRTM height differences similar for Snowdonia test site.
- CSRTM-OS® Mean difference = 1.22±4.23m
- XSRTM-OS® Mean difference = 0.26±6.12m
- Accuracy much higher than original specification (RMS=18m)
- Co-registration issues remain for CSRTM with national DEMs
- Problems of co-registration more severe for XSRTM due to use of GLOBE DEM for local phase unwrapping height offsets and phase flattening reference

Programmatic Plans

- Planned to hold next workshop in Rome on Monday, 1 December 2003 just prior to the ESA FRINGE03 meeting (2-5 December 03).
- Unfortunately ESA changed the dates of FRINGE03 so it will now start on 1 December (email dated 14/10). Will postpone workshop until tbd in 2004 possibly in conjunction with ISPRS 04 Congress in Istanbul or earlier if a suitable occasion arises
- Continuing interest in linking with WTF/WGISS activities (as well as LPV Sub-group) to provide easy web-access to test data-sets. Have attempted to request that LPV include test sites with rugged topography.
- Now propose that TMSG test sites be added to WTE and to try to persuade LPV to add these sites.
- Plan for Special Issue (Int. J. Rem. Sens.) on SRTM including both QA and applications planned to be edited by Farr, Kobrick, Gesch and Muller. Call to be issued shortly for publication in 2005.

Recommendations to CEOS Plenary

- CEOS to recommend worldwide use of SRTM DEMs, where available, to replace existing coarse data-sets for processing land and atmospheric data-sets at the earliest opportunity
- Spaceborne DEM data producers/suppliers should be encouraged to provide an on-line web-based method for users to report errors (artefacts, gross and local) that users find in such DEMs, together with location and/or extent, visual examples and statistical data
- TMSG requests funding support to set up a WGISS Test Facility with institutional support for the storage of terrain mapping reference and spaceborne DEM data for use by WGCV members