How accurate (and usable) is GDEM? (A statistical assessment of GDEM using LiDAR data)

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GDEM v1.0[1]

- Global 30 m DEM created by stereo-correlating the **1.3 million-scene ASTER archive of optical images**;
- Produced jointly by **METI** (Japan) and **NASA**;
- Covering almost 98% of Earth's land surface;
- Version 1 publicly released on **June 29th 2009**;

[1] http://www.gdem.aster.ersdac.or.jp

Research question

How to assess accuracy

of a gridded elevation product (DEM)?

(which aspects to look at?

how to test them?)

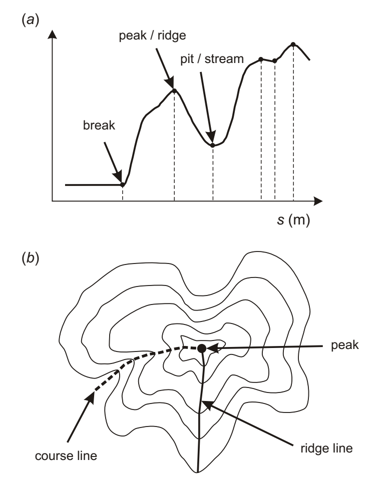
Connected work I

- Guth, P.L., 2010. *"Geomorphometric comparison of ASTER DEM and SRTM"*. Join Symposium of ISPRS Technical Commission IV, Orlando, FL, p. 10.
- Hayakawa, Y.S., T. Oguchi and Z. Lin. 2008. *"Comparison of new and existing global digital elevation models: ASTER G-DEM and SRTM-3"*. Geophys. Res. Lett., 35(17), L17404.
- Hirt, C., Filmer, M.S., Featherstone, W.E., 2010. *"Comparison and validation of the recent freely available ASTER-GDEM ver1, SRTM ver4.1 and GEODATA DEM-9S ver3 digital elevation models over Australia"*. Australian Journal of Earth Sciences, 57(3): 337–347.

Connected work II

- Reuter, H.I. and Nelson, A. and Strobl, P. and Mehl, W. and Jarvis, A. 2009. *"A first assessment of Aster GDEM tiles for absolute accuracy, relative accuracy and terrain parameters"*. Geoscience and Remote Sensing Symposium, 2009 IEEE International, IGARSS 2009, Vol 5., p. 240.
- Toutin, T. 2008. *"ASTER DEMs for geomatic and geoscientific applications: a review"*. Int. J. Remote Sens., 29(7), 1855–1875.

Land surface elements



Land surface smoothness

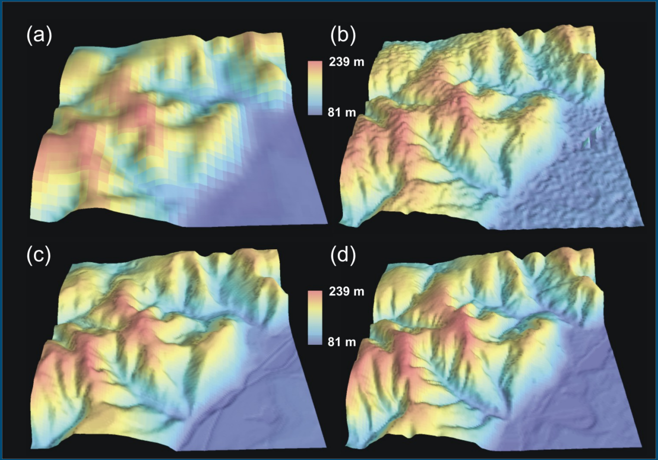


Figure: (a) 90 m resolution SRTM DEM, (b) 30 m resolution SRTM DEM, (c) 1:50,000 topo-map, and (d) 1:5000 topo-map.

Variogram comparison

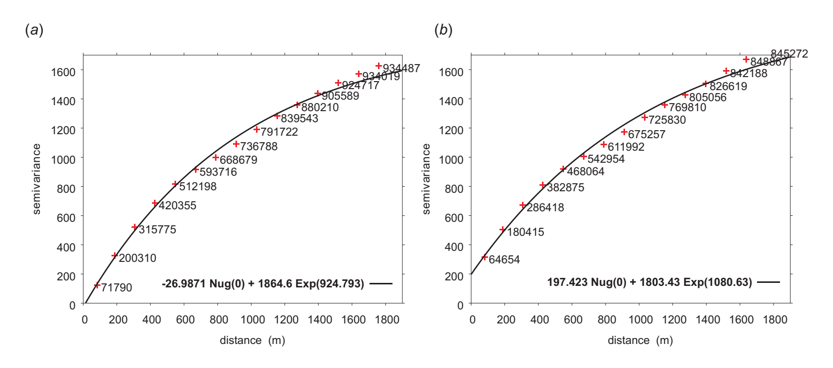


Figure: (left) field-sampled heights and (right) SRTM DEM. The SRTM DEM shows much higher nugget (197), i.e.unrealistic surface roughness.

Referent land surface model

The referent LSM

can be produced using significantly

more accurate measurements

(e.g. upscaled LiDAR measurements)

Statistical framework

Proposed framework for assessment of DEM accuracy:

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- **Accuracy of absolute elevations** (absolute error);
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- **Accuracy of surface roughness** (i.e. representation of the short-range variation);
- User's satisfaction;

Absolute accuracy

Absolute error of a DEM is commonly derived as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (z^{GDEM} - z)^2}{N-1}} \qquad (1)$$

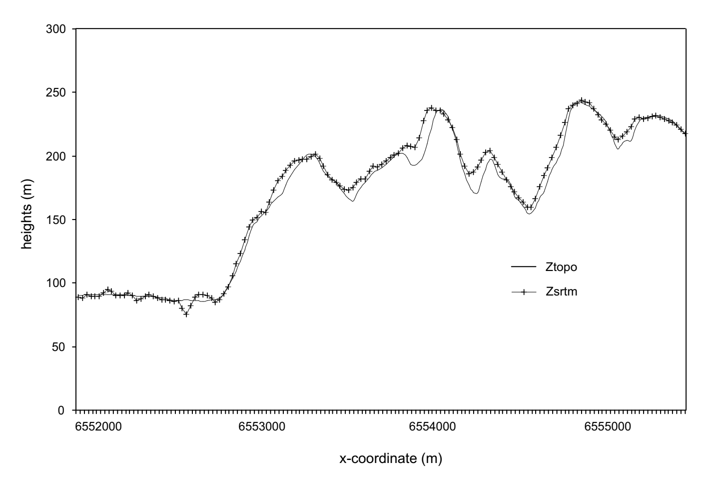
Target elevation can also be modeled as a function of the true elevation:

$$z^{GDEM} = f(z) \qquad (2)$$

R-square indicates how much of variability in true elevations (total sum of squares — SSTO) can be explained by the target DEM (residual sum of squares — SSE):

$$R^2 = 1 - \frac{SSE}{SSTO} \qquad (3)$$

Comparing elevations



Hydrological features

Spatial accuracy of stream networks can be assessed by comparing the buffer distance maps for stream networks derived using the same settings but different DEMs as inputs.
As with absolute elevations, the accuracy can be evaluated by fitting a regression model and then looking at R-square values and statistical significance for buffer distance maps.

Surface roughness

Surface roughness is the local variation of values in a search radius. There are many ideas on how to derive this parameter. Here, we have decided to evaluate surface roughness using two standard measures:

1. **Difference in the variogram parameters** — especially in the range and nugget parameters — fitted using (randomly) sampled elevation data. This is a global measure.
2. **Difference in the local variance** derived using a 7×7 search-window. This is a local measure.

Case studies

Four small case studies in areas of variable relief and forest canopy:

- Booschord (Netherlands),
- Calabria (Italy),
- Fishcamp (USA),
- Zlatibor (Serbia),

For each case study we have prepared a 30 m LiDAR DEM and GDEM.

Software used

All processing has been implemented in the R+SAGA/FWTools framework:

- **R** $>$ v2.12 including a list of packages;
- Tinn-R v2.3 (code editor);
- SAGA GIS v2.0.7 — a light GIS (not available under Mac OS!);
- FWTools v2.4 — a list of utilities to handle spatial data; GRASS GIS v6.4.

The R script can be obtained at
`http://geomorphometry.org/content/gdem-assessment`

Example

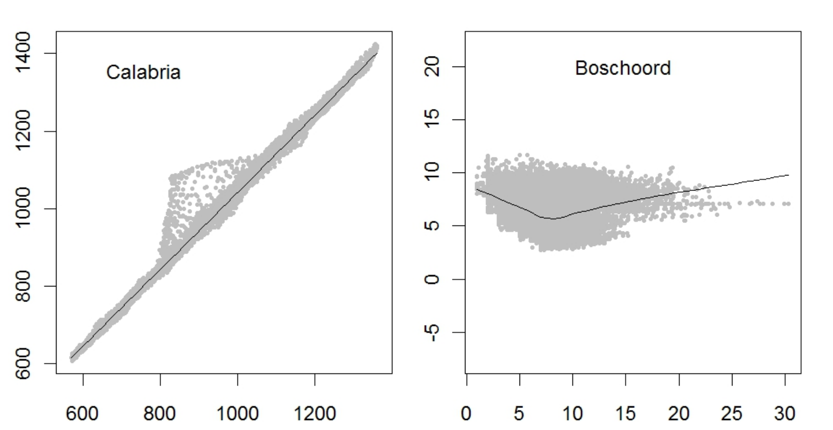
```
> library(maptools); library(gstat); library(rgdal)
> # Download the datasets:
> data.url <- "http://geomorphometry.org/system/files/GDEM_assessment.zip"
> download.file(data.url, destfile="GDEM_assessment.zip")
> unzip("GDEM_assessment.zip")
...
> str(grid.list[[j]]@data)

  'data.frame':   15000 obs. of  2 variables:
   $ zlatibor_LDEM: num  1010 1010 1008 1007 1005 ...
   $ zlatibor_GDEM: num  997 1000 1000 1000 998 ...
```

Results: accuracy

Results of regression modeling (st.dev., R-square, RMSE):

- **Booschord**: 1.6 m, 0.01, 3.3 m
- **Calabria**: 171.3 m, .9941, 45.9 m
- **Fishcamp**: 111.1 m, .9915, 16.6 m
- **Zlatibor**: 37.7 m, .9656, 8.9 m

Elevations



Calabria
1400
1200
1000
800
600
600
800
1000
1200
Boschoord
20
15
10
5
0
-5
0
5
10
15
20
25
30

Stream networks

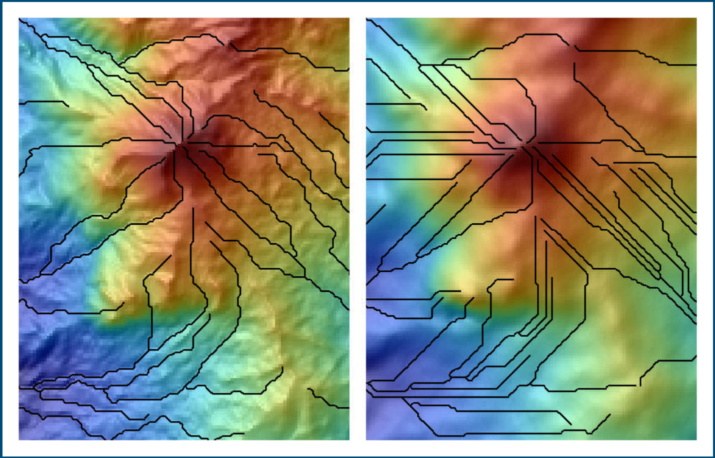


Figure: Calabria data set (left: LiDAR; right: GDEM).

STDEV (Calabria)

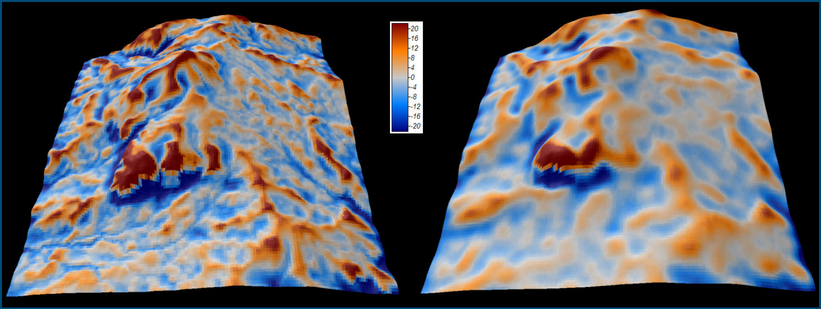
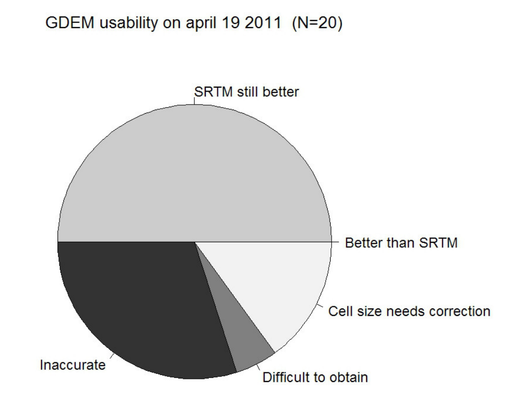


Figure: Standard deviation (surface roughness) derived using a 7 by 7 search window in SAGA GIS.

Variogram comparison (Calabria)

```
> vgm_LDEM.list[[2]]
  model        psill    range kappa
1   Nug     75.14568    0.000   0.0
2   Mat 150391.85522 2624.796   1.2
> vgm_GDEM.list[[2]]
  model        psill    range kappa
1   Nug     18.55683    0.000   0.0
2   Mat 199978.44320 3184.624   1.2
```

What do people think



Conclusions

- An adjusted R-square of >.995 could be used as the threshold level for a satisfactory fit between LiDAR and GDEM (this R-square corresponds to RMSE of <10 m in an area of medium relief e.g. with st.dev. in elevations of about 50–100 m).

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- By visually comparing DEMs for the four case studies, one can notice that GDEM often carries some artificial lines and ghost-like features.
- Analysis of the short-range variability helps determine effective grid cell size that more closely matches the true surface roughness.

Goodby GDEM, good morning TanDEM-X