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The Time-Lapse Digital Elevation Models Difference for Change Detection of Earth's Topography

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Aim:
To highlight the mostly omitted option of using global DEMs for change detection in the topography

Objectives:
- ❑ Subtract SRTM from Copernicus DEM;
- ❑ Apply an ArcMap tool „Focal Statistics”
- ❑ Study and fine-tune settings of the tool „Focal Statistics,” and comment on the results

Scope:
- Australian desert aeolian erosion
- Bali, Indonesia vulcano
- Zonguldak, Turkiye earthworks, and land subsidence
- Brunei Darussalam forest depletion

Note on DEM's vertical accuracy characterisation

Unlike the majority of studies on the accuracy of DEMs, here, the accuracy of DEM is interpreted:

1. The variance of the error of the pixel's elevation is composed of a sum of variances of three statistically independent variables:

$$\sigma_{DEM}^2 = \sigma_I^2 + \sigma_E^2 + \sigma_T^2$$

where: Indices '*I*', '*E*', and '*T*' denote the type of error source:

I – Instrument,
E – Environment,
T – Target.

Note on DEM's vertical accuracy characterisation

2. Instrument-induced errors are due to the limited accuracy of surveying instruments (LiDAR, InSAR, leveling instrument)
3. Refraction, vegetation cover, moisture, clouds, and shadows;
4. Target error can be expressed as:

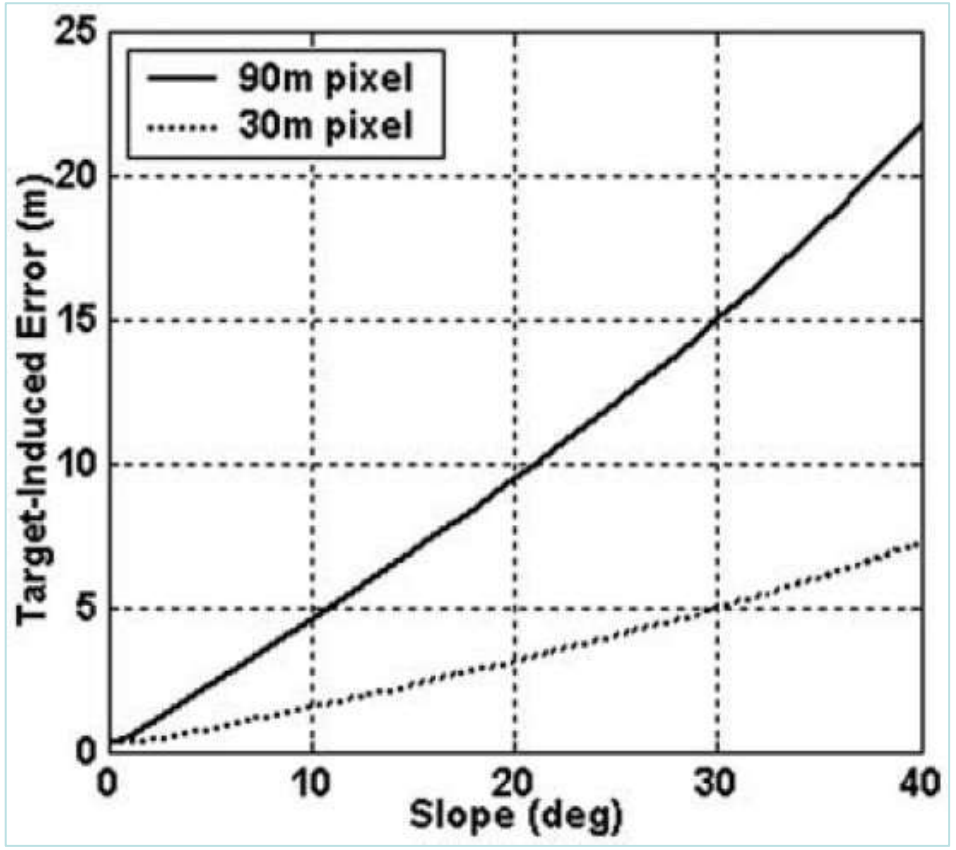
$$\sigma_T^2 = \frac{d^2 tan^2(\mathrm{s}) + q^2}{12}$$

d – Pixel size [m],
s – Slope[deg]
q – Quantization level

Note on DEM's vertical accuracy characterisation

$$\sigma^2 = \frac{d^2 tan^2(s)}{12}$$

d – Pixel size [m],
s – Slope[deg]



The accuracy of the difference of two DEMs

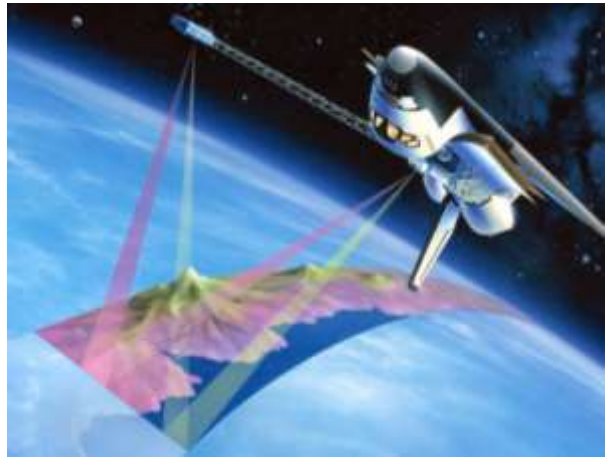
The variance of the difference between two statistically independent variables with a known variance of their errors **σ^2(DEM1)** and **σ^2(DEM2)** can be expressed as:

$$\sigma^2_{dDEM} = \sigma^2_{DEM1} + \sigma^2_{DEM2}$$

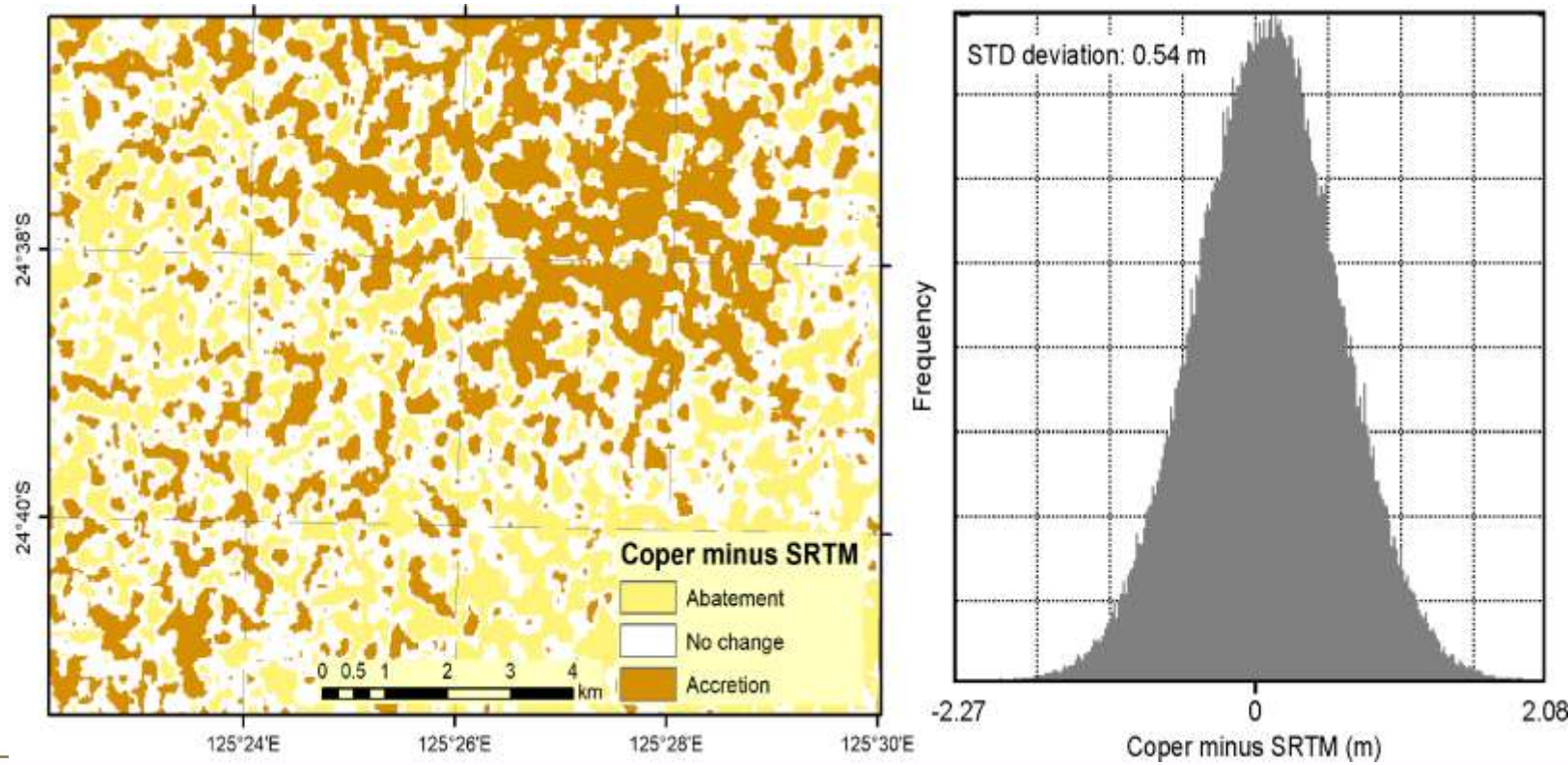
About the DEMs used

- **Shuttle Radar Topography Mission (SRTM)**
  - Data captured in February 2000
  - C-band used
  - Spatial resolution 1”
  - Instrument accuracy (one sigma) approx 2 m

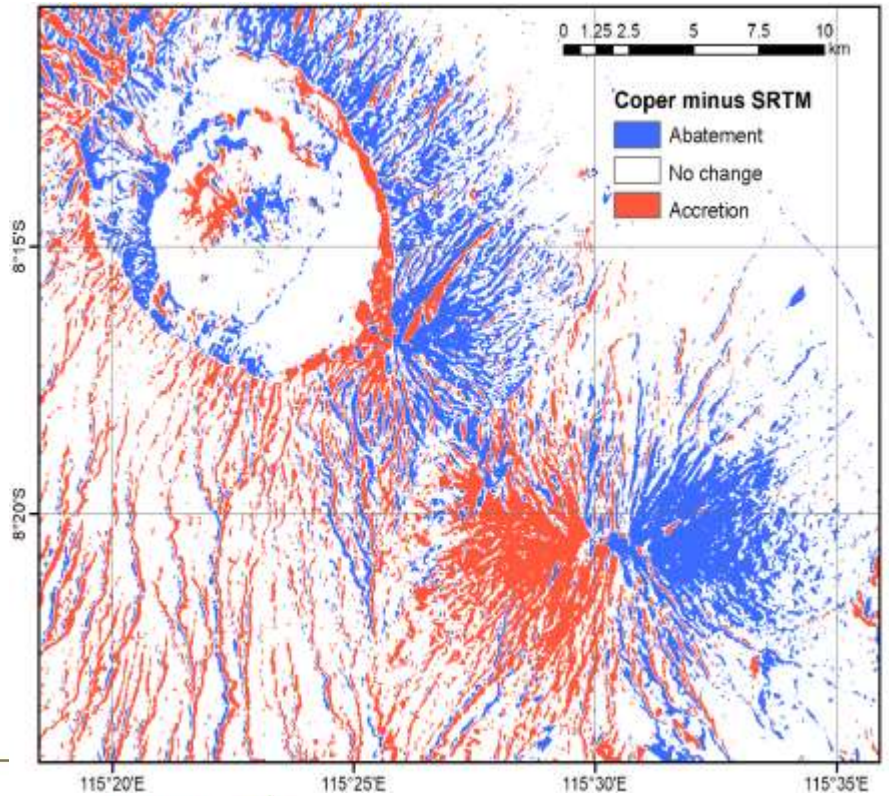
- **Copernicus DEM (edited WorldDEM data)**
  - Data captured dro 2011 – 2015
  - X-band used
  - Spatial resolution 1”
  - Instrument accuracy (one sigma) approx < 1 m

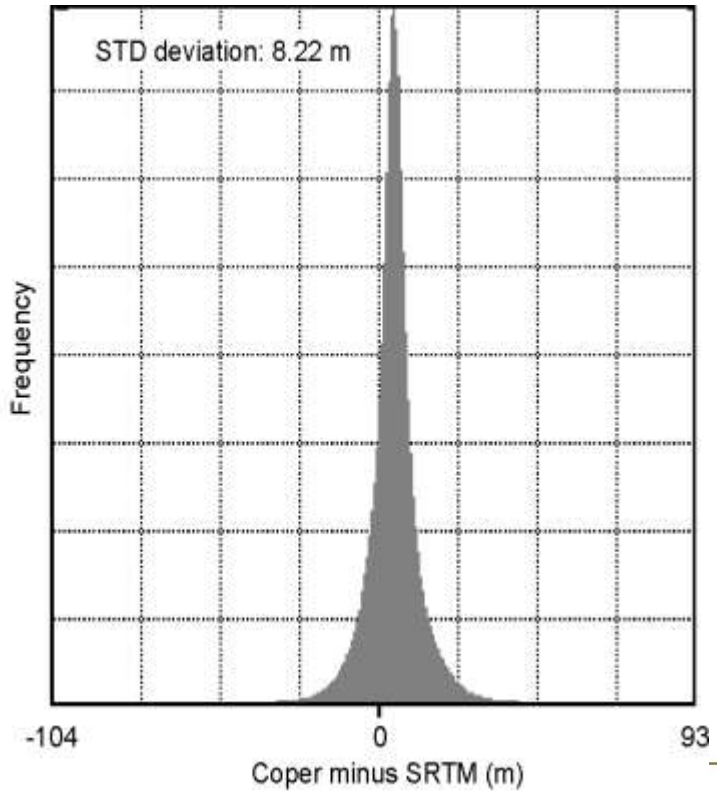


Coper *minus* SRTM over Australia's test sites. The discrepancies between both DEMs are caused by Aeolian erosion. The accretion almost perfectly balances the abatement. An averaging (7 x 7-pixel) filter was used to suppress the high-frequency noise.



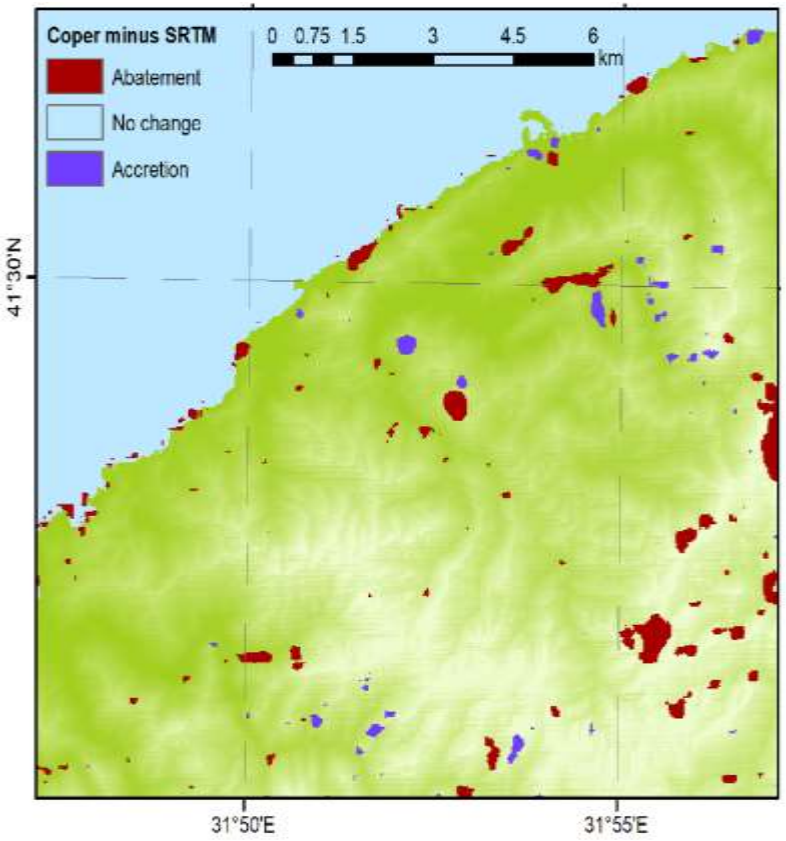
Coper minus SRTM over Bali's test sites. The water erosion causes discrepancies. Note accretion of the southwest slopes of the volcano and abatement on the northeast slopes, with the ridge of the volcanos forming a borderline between the accretion and abatement zones.

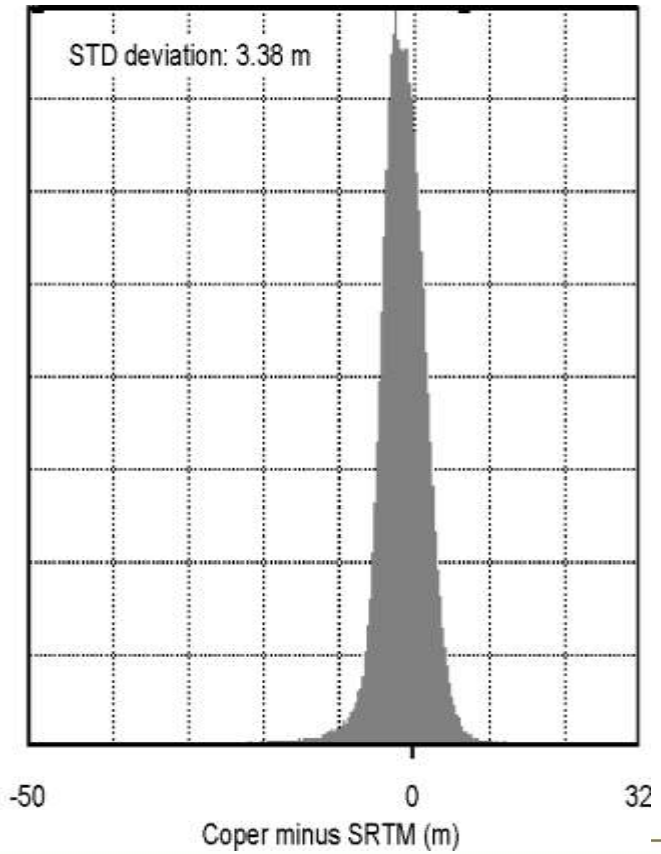




Note an asymmetry in the histogram. It is due to the new volcanic material delivered by the volcano.

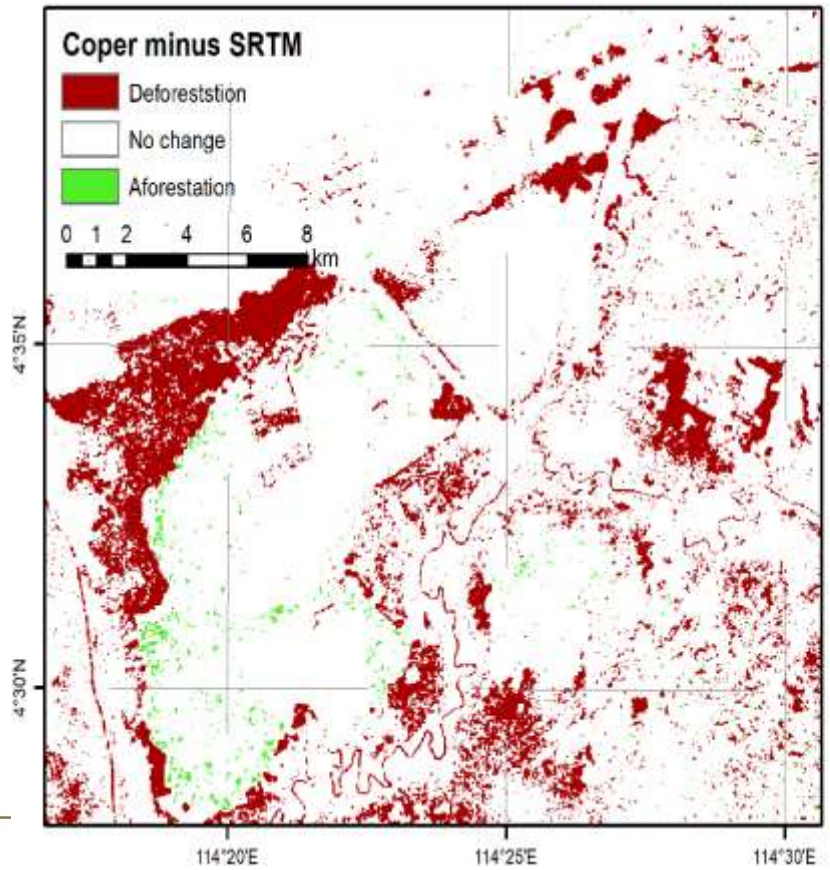
Raster of difference Coper minus SRTM over Zonguldak test sites. Open-cut mining operations are causing these discrepancies.

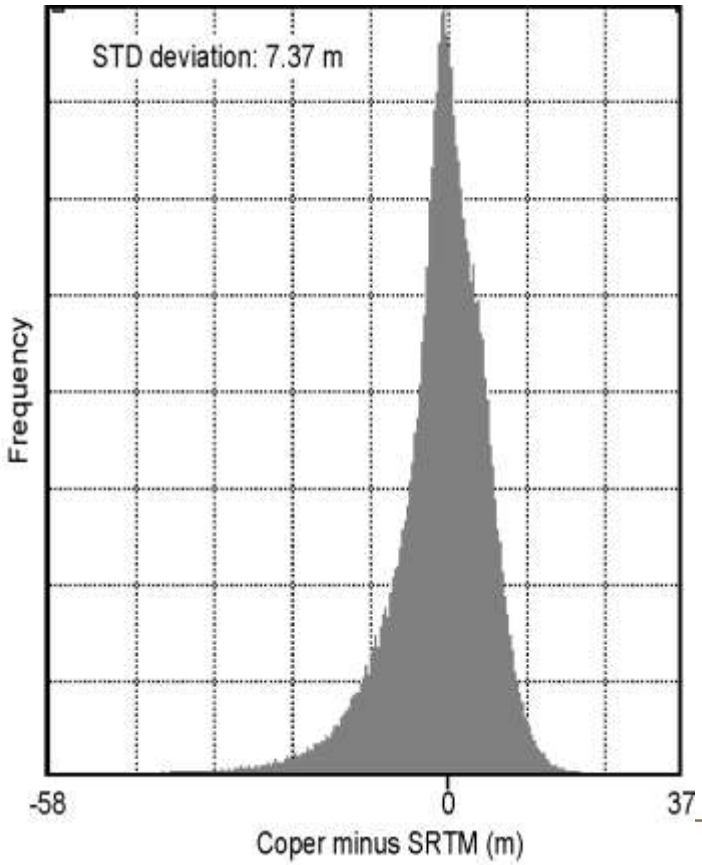




Note an asymmetry in the histogram.
It is due to the flattening of the landscape.

Coper minus SRTM over Brunei Darussalam's test sites. Forest depletion causes these discrepancies. Regrow of vegetation is minimal.





Conclusions

- It is possible to assess the topography and land cover changes using the difference between two with limited accuracy DEMs
- Given observable trends, this method can become one of the ways of monitoring changes in topography as standalone, and possibly as an input to multisource change monitoring systems of land cover
- The sensitivity of the method depends on the time lapse between DEMs' and the roughness of topography