The Global TanDEM-X Digital Elevation Model and the Terrestrial Impact Crater Record

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Introduction

TanDEM-X provides a very accurate digital elevation model (DEM) of the entire terrestrial land surface. It has been generated from data acquired by the German TanDEM-X mission between December 2010 and March 2015. The TanDEM-X mission consists of two identical X-band radar satellites which have been operated by the German Aerospace Center (DLR) in close formation as a single-pass SAR interferometer [1]. The global TanDEM-X DEM achieves the requirements listed in Table 1 with a considerable fraction of the data even exceeding the vertical accuracy by almost an order of magnitude.

The DEM is delivered in tiles, each having a size of about 110 × 110 km². About 20000 tiles are required for achieving global coverage. By mid-2016 the TanDEM-X DEM exists for more than 90% of the land surface with completion being expected for the 2nd half of this year.

Parameter	Requirement
Coverage	Global
Pixel spacing (independent pixel)	12 m
Absolute vertical accuracy (90% linear error)	10 m
Relative vertical accuracy (90% linear point-to-point error)	2 m (slope < 20%) 4 m (slope > 20%)

Table 1: TanDEM-X DEM requirements.

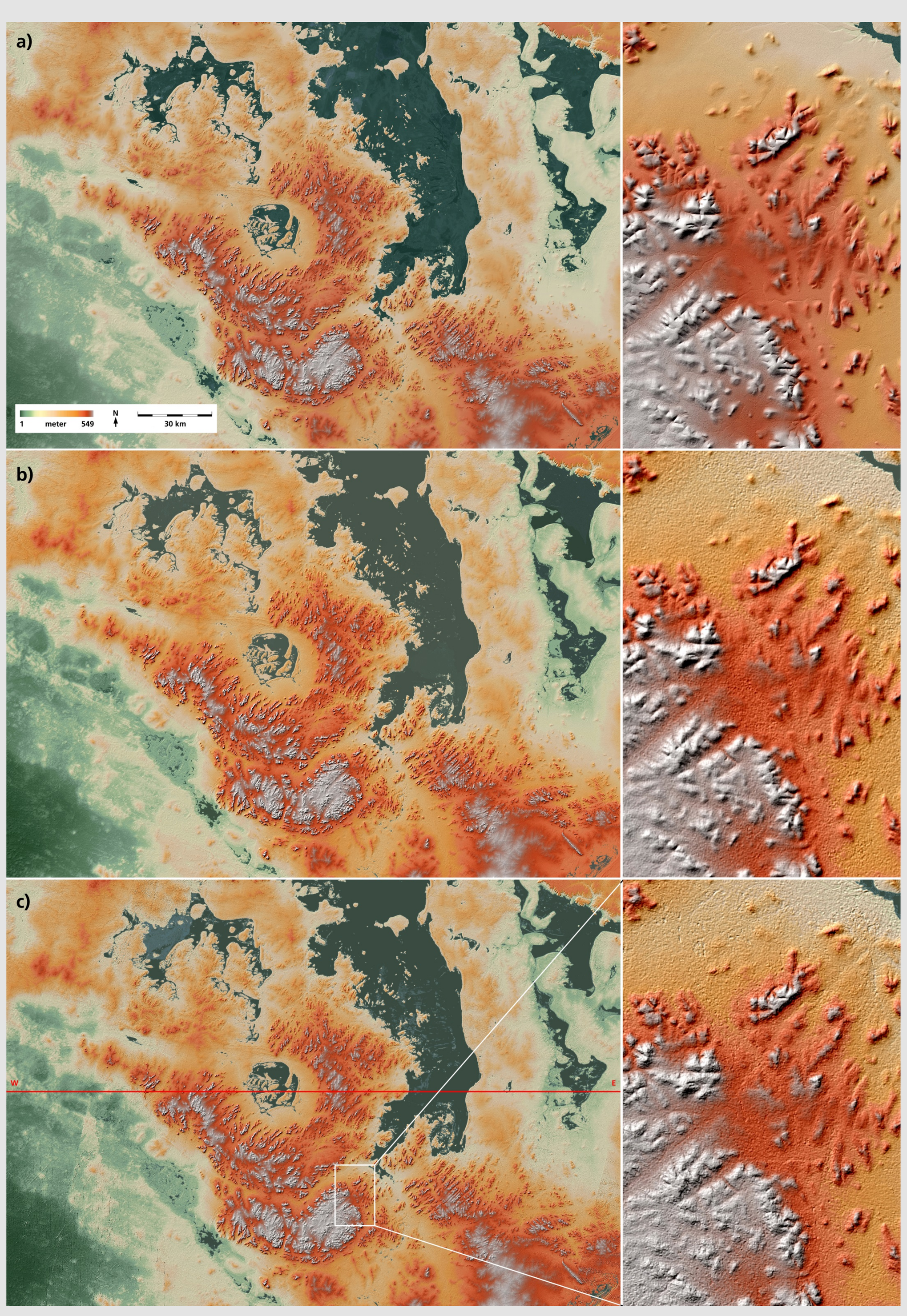


Fig. 5: Acraman as seen in hillshaded mosaics of DEMs from TanDEM-X (a), SRTM (b) and ASTER (c). The inset shows a part of Acraman at ~50% TanDEM-X resolution.

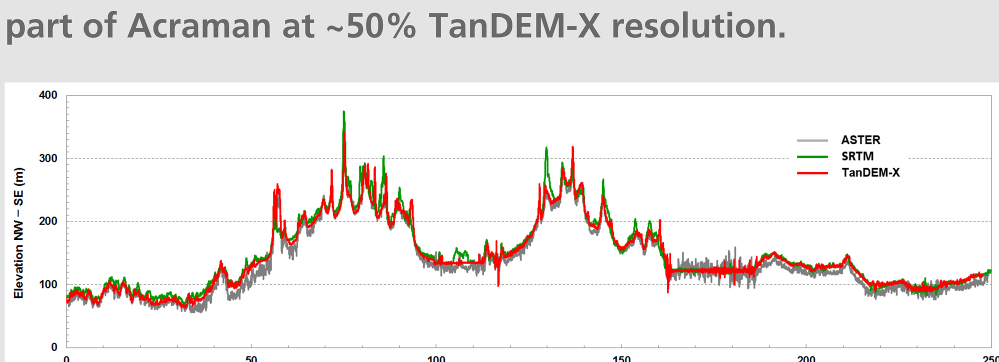


Fig. 6: W-E profiles through Acraman from TanDEM-X, SRTM and ASTER. The location of the profile is denoted by the red horizontal line in Fig. 5c.

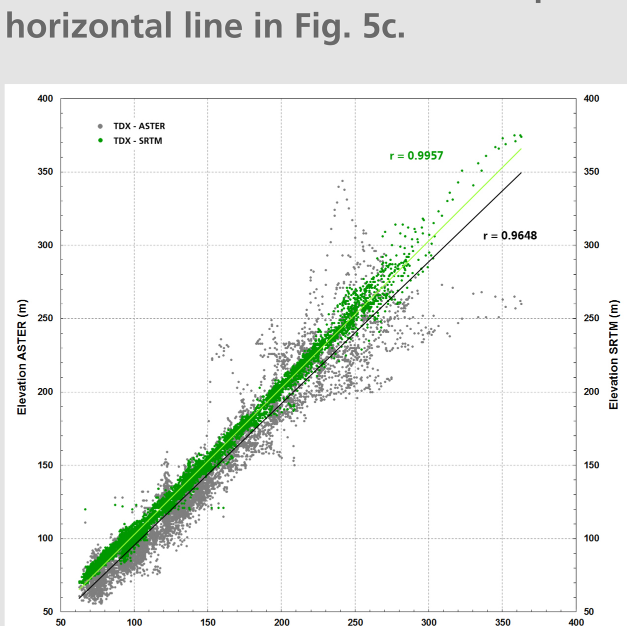


Fig. 7: Correlation between TanDEM-X elevation with that from SRTM and ASTER for the profile in Fig. 6.

TanDEM-X DEM and Impact Craters

Its global coverage and high accuracy make the DEM a unique data source for remote sensing studies of terrestrial impact structures. In the past years we have investigated what can be learned from the DEM for craters of various types and preservation status [2].

We used the confirmed impacts of the Earth Impact Database (EID) as a reference sample, supplemented by recently discovered structures. For our studies we have access to DEM tiles for structures >50 km in diameter and to individual scenes where from the coregistered single look slant range complex (CoSSC) the so-called Raw DEMs, a TanDEM-X internal product, have been produced. Raw DEMs have an extent of ~30 × 50 km². About 570000 Raw DEMs have been generated from all acquisitions in single-pass interferometer configuration.

Covering the entire sample of impact craters with DEM tiles requires ~360 tiles. Random orientation of the structures relative to the tile boundaries can even for small craters require multiple tiles (Fig. 1).

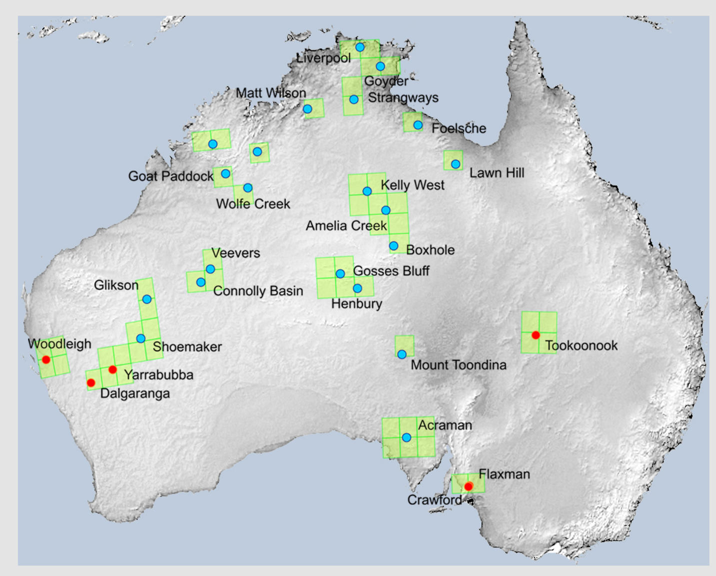


Fig. 1: Australian impact structures (blue dots: with surface topography, red dots: without surface topography) and corresponding DEM tiles (green boxes).

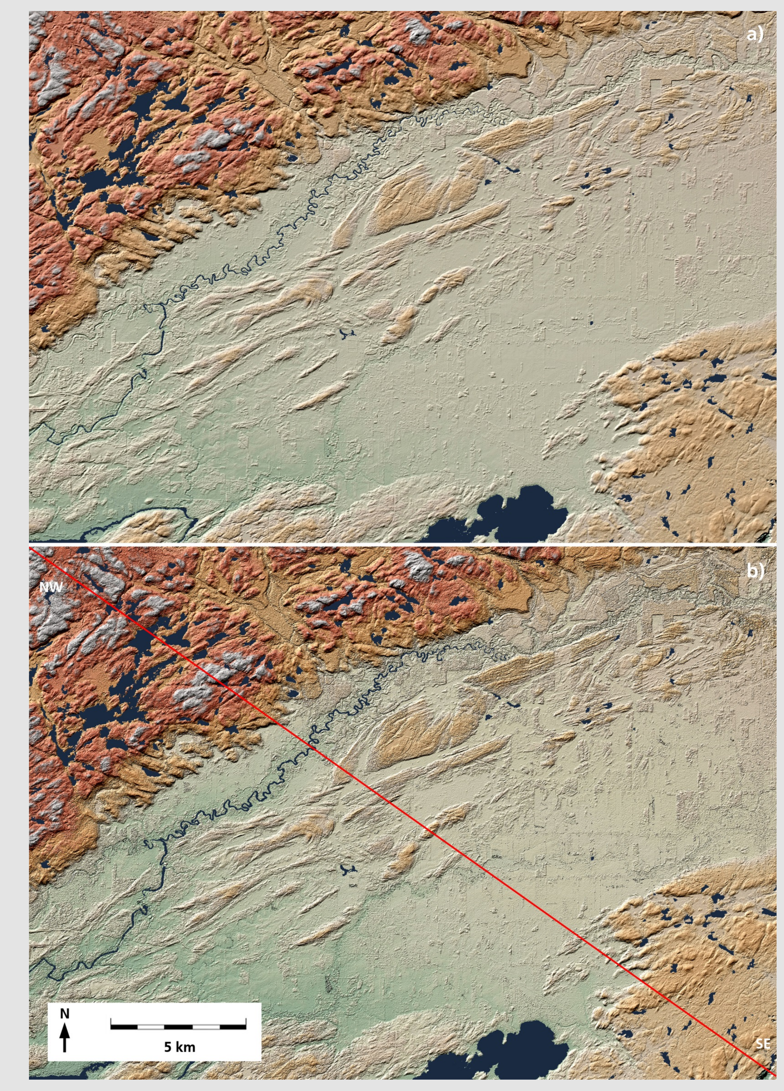


Fig. 2: Part of Sudbury as generated from a hillshaded mosaic of DEM tiles (a) and individual Raw DEMs (b). The red diagonal line illustrates the location of the profile in Fig. 3.

Raw DEM versus Final DEM

Even though Raw DEMs are the result of a single acquisition without having applied the elevation calibration of the final DEM generation, the interferometric processing chain ensures a Raw DEM accuracy which already comes close to that for the final DEM. Fig. 2 shows a section of Sudbury made from a mosaic of DEM tiles in comparison to a mosaic from Raw DEMs. The Raw DEM image displays almost all structures as the final DEM but with slightly higher elevation noise. Both DEM and Raw DEM trace the surface and not "bare Earth" because backscatter in the X-band occurs at the top of vegetation.

Elevation profiles through the scene in Fig. 2 are given in Fig. 3. Overall, final DEM and raw elevations correlate very well with an offset of -2.5 m for the raw DEM (Fig. 4). The raw elevations exhibit only very few outliers, mainly in areas with water bodies.

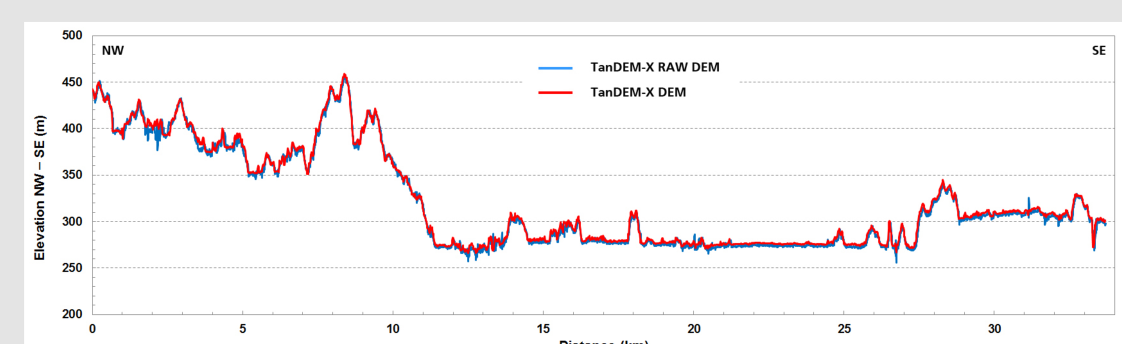
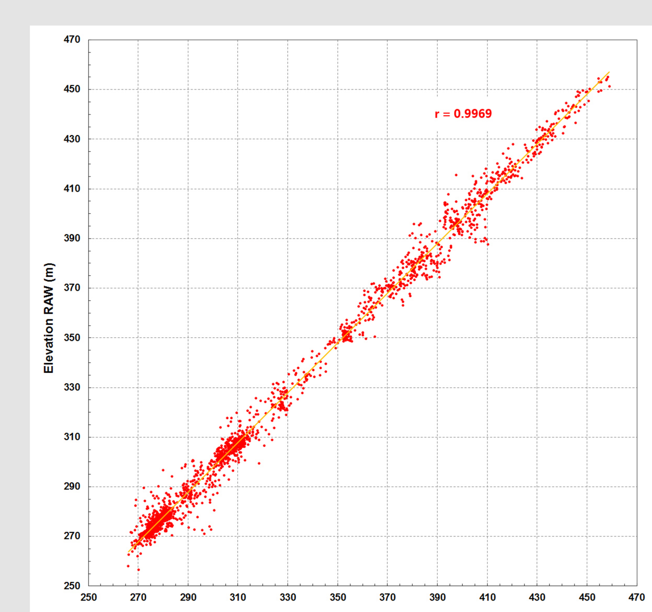


Fig. 3: NW-SE profiles through Sudbury from final DEM and Raw DEM elevations.

Fig. 4: Correlation among final DEM and Raw DEM elevations for the profile in Fig. 3.



TanDEM-X DEM versus Existing DEMs

Currently, the ASTER GDEM2 is the only available DEM with full global coverage and high independent pixel posting of 1" (equivalent to 30 m at equator). It is derived from stereo-optical imagery from ASTER onboard NASA's Terra platform. The 10-day Shuttle Radar Topography Mission (SRTM) in February 2000 is the source for two DEMs generated from X-band and C-band data, also exploiting the method of single-pass SAR interferometry. The C-band DEM has a pixel spacing of 1" and covers the land surfaces between 56°S and 60°N. Accuracy requirements of both DEMs are a factor of ~2-3 lower than for TanDEM-X. For the arctic region a regional DEM has been produced in the framework of ESA's PERMAFROST project [3]. It retrieved elevation information from various sources, e.g. topographic maps from the Soviet era. Pixel posting amounts to 90 m with unspecified elevation accuracy requirements.

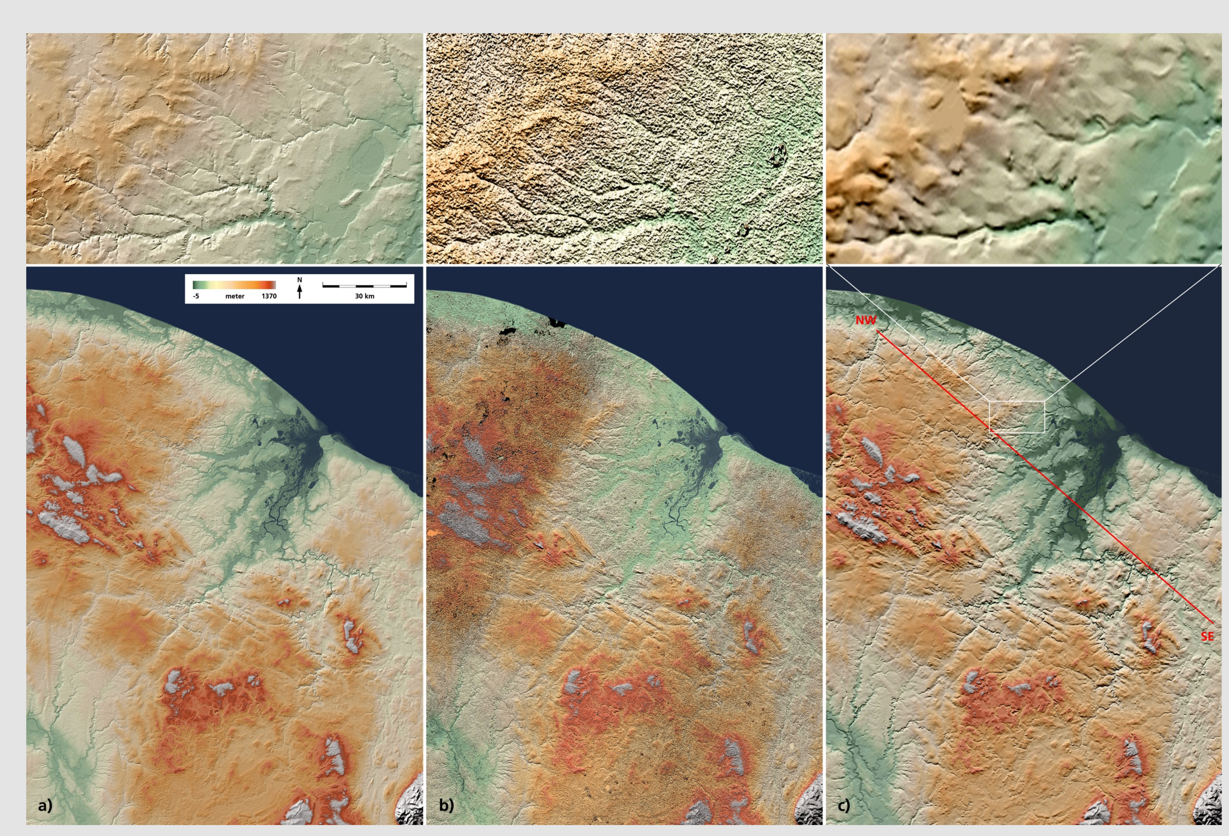


Fig. 8: The Kara site as seen in hillshaded mosaics of DEMs from TanDEM-X (a), ASTER (b) and PERMAFROST (c). The inset shows a part of Kara at ~50% TanDEM-X resolution.

Fig. 5-10 illustrate how the TanDEM-X final DEM compares with these DEMs in the cases of the large structures Acraman/Australia (Fig. 5-7) and Kara/Russia (Fig. 8-10).

Within specifications elevation data of all considered DEMs are compliant. ASTER displays larger noise with a higher fraction of outliers and artefacts. Both is obvious in the hillshaded maps, particularly for Kara, elevation profiles and correlation graphs. Offsets are obvious in the ASTER data but without a clear trend. In summary, agreement between TanDEM-X and ASTER exists when considering large scale topographic features but becomes worse on smaller scales.

Fig. 9: NW-SE profiles through the Kara site from TanDEM-X, ASTER and PERMAFROST. The location of the profile is denoted by the red diagonal line in Fig. 8c.

SRTM usually agrees well with TanDEM-X. However, the superior spatial resolution of TanDEM-X due to the narrow pixel posting permits imaging fine topographic detail where SRTM fails to further resolve structures. As expected, SRTM appears as a low resolution version of TanDEM-X. PERMAFROST, in spite of its limiting wide pixel spacing, can be considered an alternative to ASTER in certain regions. Notably in the Russian Arctic the topographic maps (1:200000) were of high quality permitting reliable digitalization. On scales as used in Fig. 8 and 9 they correlate well with TanDEM-X. When zooming in to full scale TanDEM-X resolution, however, they fall short with fine detail becoming smeared out and lost.

In summary, remote sensing studies of impact crater morphologies can gain considerably when using the TanDEM-X DEM. The new dataset is also an interesting repository for finding new impact candidates. This challenging task, however, has to await further essential preparatory work.

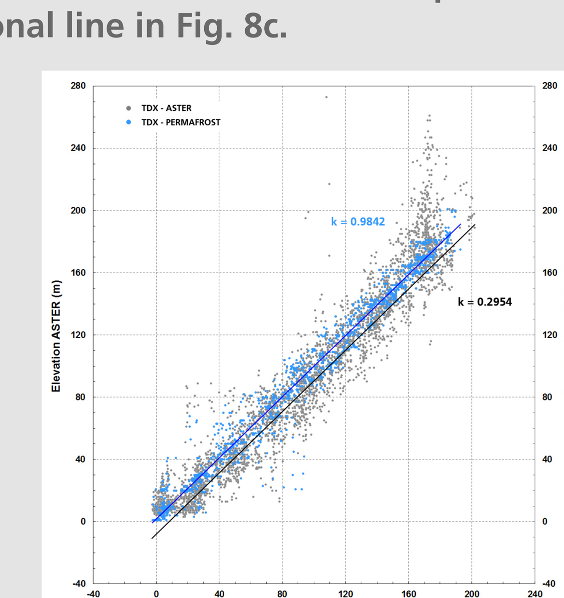


Fig. 10: Correlation between the TanDEM-X elevation with that from ASTER and PERMAFROST for the profile in Fig. 9.

[1]: Krieger et al., TanDEM-X: A radar interferometer with two formation-flying satellites. Acta Astronautica 89, 83-98, 2013.
[2]: Gottwald et al., Mapping terrestrial impact craters with the TanDEM-X DEM. in Osinski and Kring, eds., Large Meteorite Impacts and Planetary Evolution V, GSA SP518, 177-211, 2015.
[3]: Bartsch et al., ESA DUE Permafrost Final Report v2. Vienna University of Technology, 2012.

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