HOW CAN THE TANDEM-X DIGITAL ELEVATION MODEL SUPPORT TERRESTRIAL IMPACT CRATER STUDIES?

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Introduction: Between December 2010 and March 2015 the German Aerospace Center (DLR) operated the X-band radar satellites TerraSAR-X (TSX) and TanDEM-X (TDX) in close formation as a single-pass SAR interferometer. One of the mission's purposes during this phase was data acquisition in bistatic mode over the entire Earth's land surface. These data are processed to finally yield a global digital elevation model (DEM) with unprecedented accuracy [1]. Its performance will considerably exceed the currently existing terrestrial DEMs, e.g. from SRTM in 2000. Both its global coverage and high accuracy makes it a unique data source for the studies of terrestrial impact structures.

TanDEM-X Mission Status: Interferometric data acquisition for DEM generation started with two global coverages in the timeframe December 2010 – March 2013. This was followed by two mappings of Antarctica, interleaved with gap filling activities and a period from August 2013 – April 2014 during which the satellite configuration was re-adjusted to allow imaging of difficult terrain with opposite viewing geometry. By early 2015, all acquisitions had been accomplished [2].

In a single orbit the maximum time devoted to DEM-related stripmap acquisitions with a swath width of 30 km amounted to about 300 sec, equivalent to a total orbital length of 2250 km. These data needed to be divided into individual scenes, so-called Raw DEMs, of ~30×50 km^2 extent. This occurred in an automatic processing chain which consists of two main components: the first for producing the required Raw DEMs and the second for finally generating the DEM tiles from the Raw DEMs. About 500000 Raw DEMs have been generated from slightly more than 4 years of TanDEM-X in-orbit operations as a single-pass interferometer.

TanDEM-X DEM Status: Each DEM tile has a size of about 110×110 km^2. With a total of about 20000 tiles the global coverage requirement will be achieved. As of May 2015 65% of Earth's land masses are available as final DEM. The associated >10000 DEM tiles fully meet the requirements (Table 1) with the absolute vertical accuracy even exceeding the specifications by a factor 10. This excellent performance can be attributed to the high quality of the two SAR instruments, the sophisticated acquisition planning and quality monitoring scheme together with a complex but well working calibration, processing and mosaicking environment. It is expected that the complete TanDEM-X DEM will be available by mid 2016. DEM access for scientific purposes will be granted via an AO proposal scheme.

Parameter	Requirement
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.

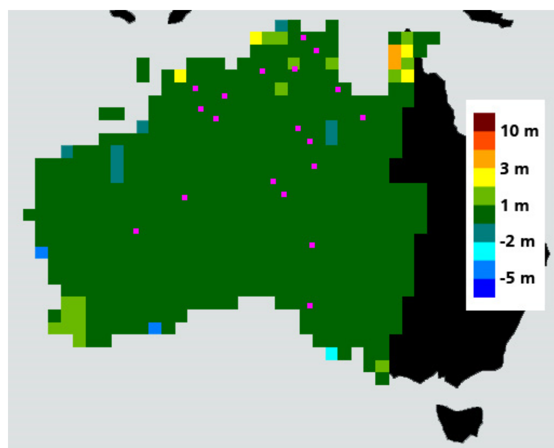

Fig. 1: Absolute height error for the DEM tiles covering Australia as derived from comparison with ICESat points (status: March 2014). The pink squares denote the locations of confirmed impact structures from the Earth Impact Database (modified from [3]).

Impact Structures in TanDEM-X Raw DEMs: The configuration of the processor generating the Raw DEMs permitted the generation of raw scenes with an accuracy already very close to the specification of the final DEM [4]. Therefore, in the absence of DEM tiles, we started our studies of impact structures using Raw DEMs. Early results confirmed the excellent quality of this dataset [5]. Meanwhile we continued a systematic investigation of all confirmed impact structures from the Earth Impact database (EID) at the Planetary and Space Science Centre of the University of New Brunswick/Canada.

As of July 2015, of the 188 database entries 85 are expected to show a surface imprint (not counting those which are fully submerged). Most of this sample could be mapped using 1-2 TanDEM-X Raw DEMs (Fig. 2). A few required mosaicking of up to 9 individual scenes and only 6 have to await the availability of the DEM tiles because of their large diameters. The smallest unambiguously detected structure is Aouelloul with a diameter of 390 m. Its rim clearly sticks out of the surrounding terrain as expected for a simple crater.

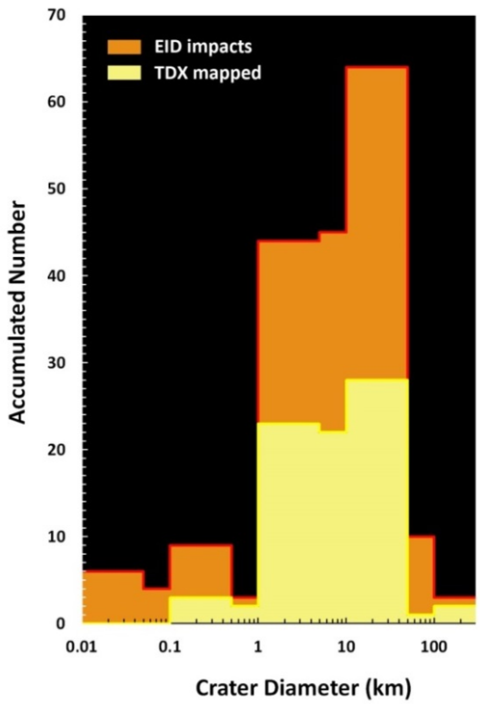

Fig. 2: EID database entries as a function of crater diameter and detections in the TDX RAW DEMs.

In addition to the Raw DEMs, we also analyzed the X-band amplitude signal in each scene. It depends both on radar illumination angle and surface properties such as, e.g. roughness. When combined with the DEM information, the resulting image could deliver morphological information which would remain unnoticed in DEM displays, e.g. drainage patterns (Fig. 3).

Our studies demonstrate the capabilities of the TanDEM-X DEM for studying the morphology of impact craters. Once the confirmed structures have been mapped, and it is understood how the DEM and crater parameters are interrelated, we plan to investigate whether algorithms can be developed for identifying previously unidentified impact structures in certain, well suited terrain.

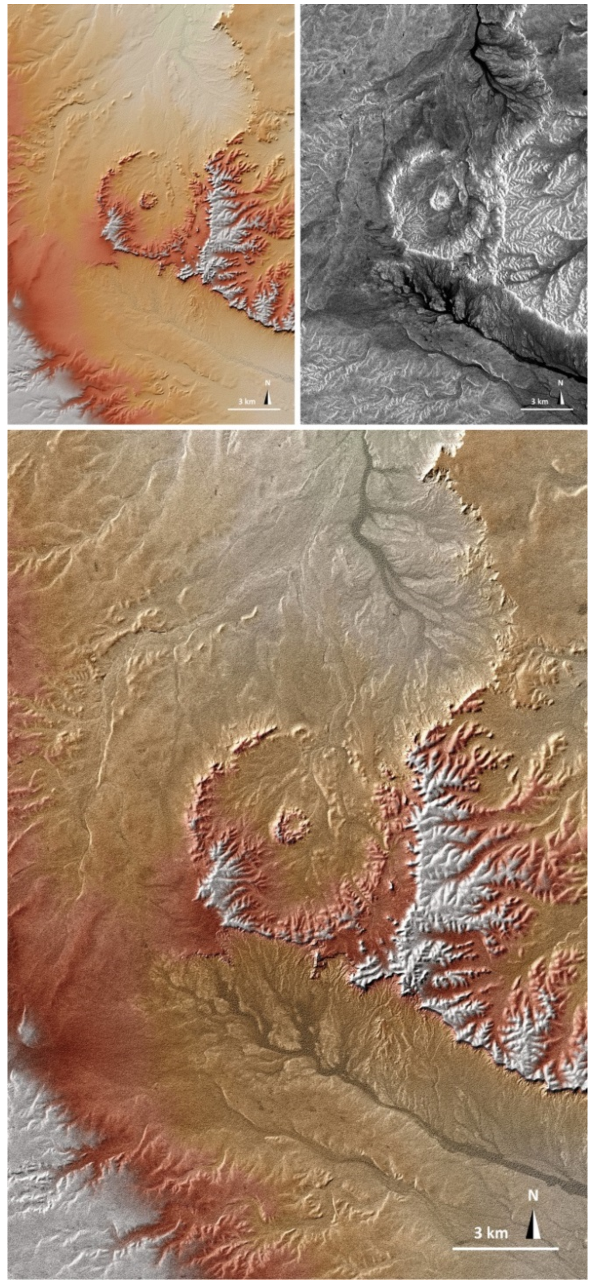

Fig. 3: Jebel Waqf as Suwwan as seen by TanDEM-X. Top left: hillshaded DEM data, illuminated with solar elevation = 45°, solar azimuth = 315°. Top right: X-band amplitude signal. Bottom: hillshaded DEM with underlying X-band amplitude signal.

References: [1] Krieger G. et al. (2013) *Acta Astronautica, 89,* 83-98. [2] Zink M. et al. (2015) *ISPRS Archives, XL-7/W3,* 1345-1352. [3] Zink M. et al. (2014) *IEEE GRSS, 2,* 8-23. [4] Rossi C. et al. (2012) *ISPRS Archives, XXXIV/B7,* 73-78. [5] Gottwald M. et al. (2015) *GSA SP518*, in print.