Status of TanDEM-X DEM Calibration and Mosaicking towards the TanDEM-X DEM

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Abstract

With begin of 2013 DEM production started with the generation of the Intermediate TanDEM-X DEM (IDEM) for selected science and commercial test sites. This paper gives an overview of the Intermediate DEM production that took place from end of 2012 until July 2013. It describes the DEM production process and the lessons learnt by the IDEM phase. Since autumn 2013 the final DEM generation has begun in flat areas.

1 Introduction

For the global TanDEM-X DEM the whole world will be acquired by at least two coverages [1]. To span the time for final DEM generation the idea was to generate first TanDEM-X DEMs solely of the first coverage which was acquired from December 2010 to March 2012. The interferometric processing of the data within the *Integrated TanDEM-X Processor* (ITP) goes more or less in line with the data acquisition. So its processing of the first coverage was completed in summer 2012. These data were continuously quality controlled by the last module in the processing chain the *DEM Mosaicking and Calibration Processor* (MCP). Among others Raw DEMs with phase unwrapping errors resp. need for reprocessing will be flagged and tie- and ground control point for the DEM calibration will be extracted. The so-called Intermediate DEMs serve several tasks. First of all its production was initiated to set the last DEM workflows around the MCP in full operation to start with the learning curve in DEM generation. During DEM calibration and mosaicking processing, the single interferometric DEM scenes are oriented [2] and merged together. Additionally, science and commercial users should benefit from first impressions of the quality of the data. This paper gives an overview of the Intermediate DEM production that took place from end of 2012 until July 2013.

2 Intermediate DEM Production

The first coverage was mainly acquired with a small baseline and with a larger height of ambiguity around 40-50m which result in some phase unwrapping errors. These phase unwrapping errors are reduced later on by applying the dual-baseline phase unwrapping method [3]. This method needs as prerequisite the second coverage acquisition. The final DEM will consist by at least two coverages. These coverages are used on the one hand to resolve phase unwrapping errors within reprocessing and on the other hand to ensure a low noise level even for difficult areas like forests and steep terrain to meet the performance goal [4].

2.1 Aim

The main aim was to set the MCP in operation. This comprises firstly the DEM calibration and secondly the DEM mosaicking processor with its corresponding quality control, processing system (psm) and operating tools (OT). But also the archiving of the DEMs in the product libray (PL) and the EOWeb upload is affected.

2.2 Regional IDEM processing

On selected science and commercial test sites the first coverage was mosaicked into first DEMs according to the DEM Product Specification [4]. Hereby 1754 completed IDEM geo-cells referring to a complete first coverage were generated. Their distribution is displayed in **Figure 1**. The coverage of those cells can also be downloaded as kml (https://tandemx-science.dlr.de).

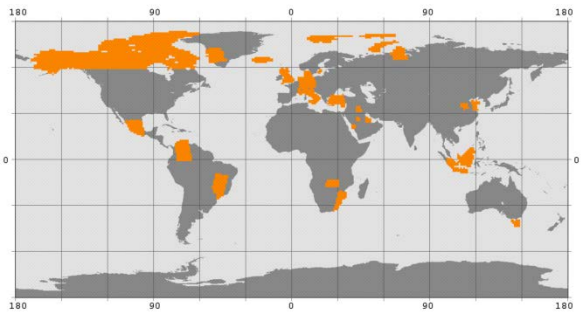

Figure 1: IDEM availability world-wide (final status from 2013-08-22).

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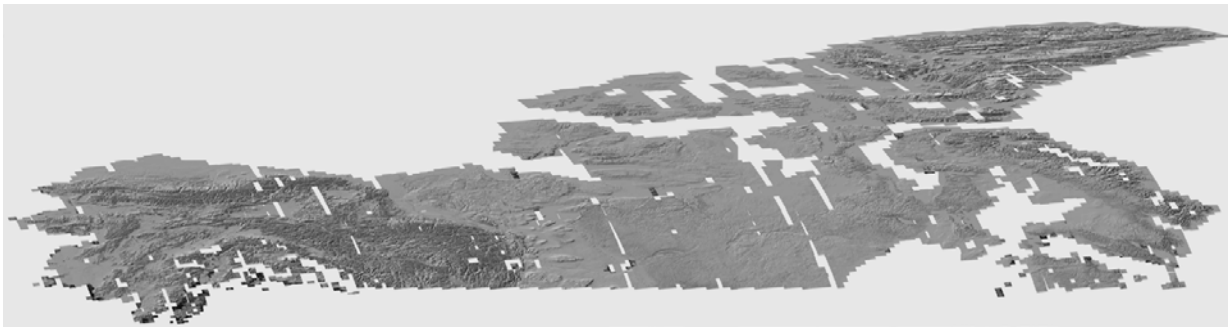
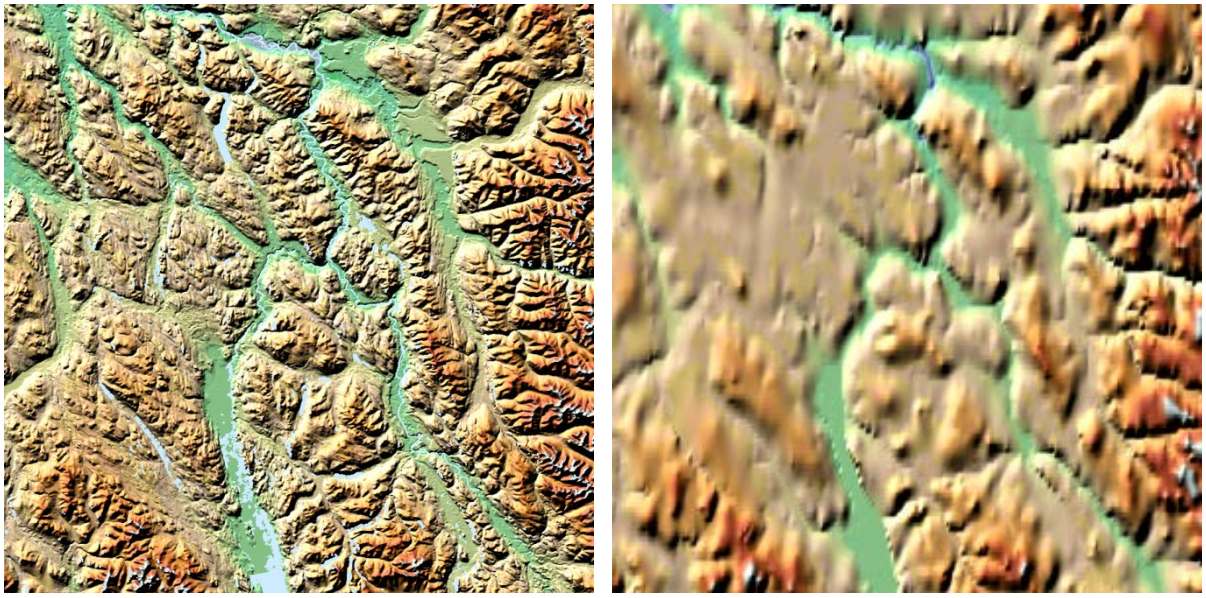


Figure 2: Quick look of TanDEM-X IDEM of Canada north of 60° latitude.



a) **b)**

Figure 3: Quick look of TanDEM-X IDEM tile N61W136 in Canada: a) DEM with water indication mask in light blue, b) GLOBE for tile N61W136.

DEMs over several different regions resp. landcover classes were generated: tropical (Columbia, Indonesia), subtropical (Sambia), coasts/islands (Island, Baffin Island/Canada), and even artic regions (Petermann glacier/Greenland). The IDEM Production ended in July 2013 with a systematic processing of Canada north of 60° latitude in preparation for the final DEM processing (**Figure 2**). The improvement in spatial resolution and height accuracy against the existing reference GLOBE is obvious (see **Figure 3**).

2.3 Features of IDEM

For the Intermediate DEM all DEM scenes with need for reprocessing were excluded. There are two mayor reasons for reprocessing: one is that phase unwrapping problems within undulated terrain or along rivers occur that could not be solved with single-baseline processing. On the other hand due to residual calibration errors some scenes could not be processed into their correct band. That leads to shifts in the order of multiples of half of the phase cycles (height of ambiguity), so called *π-ambiguities*. Both problems reaching an amount of around 20% of all data will be treated within the reprocessing - one by applying dual-baseline phase unwrapping and one by forcing to use the band corresponding to a reference height, usually the laser altimeter heights of ICESat [6].

The practice of omitting scenes indicated with the need for reprocessing lead to gaps in the Intermediate DEM - the more the terrain is undulated. Therefore, IDEM is predominately produced over flat terrain.

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2.4 Lessons learnt

In the following some points are discussed that came out during the IDEM production gearing towards an improved final DEM production:

- Improved quality control
- Load tests / MCP performance improvements
- Interdependences to other systems
- DEM calibration improvements
- Mosaicking improvements
- separated reprocessing workflow

Please note that these improvements solely concern the processing systems and not the quality of the data. The DEM quality has already been proven as very good [5].

The quality control (QC) was continuously improved e.g. with additional quick looks and reorganization of the html-based QC site. Each TanDEM-X DEM tile with its layers undergoes an individual, manual QC process. Besides the DEM several additional layers like amongst others the height error mask (HEM), the consistency mask, two amplitude mosaics and the water indication mask are created. In the mosaicking workflow also an evaluation of the results is performed. Therefore, the differences to SRTM, ICESat points and – if available - GPS tracks and high resolution reference DEMs are computed.

The load test in northern Canada showed already a good production environment for the IDEM and produced a complete data set of Northern Canada. But on the other hand still efforts had to be put into an optimal usage of the hardware resources. For the DEM mosaicking a further parallelization in calculating the mosaic tiles was needed. Also the calibration had to be further optimized by e.g. optimizing sorting algorithms for up to millions of ICESat control points within one calibration block that especially occur in the northern latitudes.

To avoid interdependences and interferences with the ITP also accessing to the same Raw DEM collection within the archive a pre-staging in delivering the data to the MCP and ITP was established.

The original plan for DEM calibration was to calibrate the data takes as whole stripes within a continent-wide DEM calibration. This had to be discarded. Several practical reasons like availability of all data, the data volumes exceeding not only the calibration processor but also the delivery and pick-up system. Further the data takes begin arbitrarily so there was a need to cut them into reasonable manageable blocks. The size of one calibration block is now more oriented to a user-friendly size for the quality control containing around 1000 Raw DEMs. Tests confirmed that connecting different blocks works well and does not influence the accuracy. This is mainly due to the good accuracy of the ICESat points and a good connection by tie-points every 1,5km in along-track.

For the mosaicking several rules were set up to combine the different acquisitions best. Nevertheless, during the processing still few Raw DEMs are identified that decrease the quality. In those cases reruns are initiated and an internal MCP workflow to handle this procedure was established for calibration as well as for mosaicking.

The reprocessing workflow was originally part of the calibration workflow. At the end of the IDEM production a separate workflow was established, as it is not necessarily linked to DEM calibration. This new complex reprocessing workflow with seven subsystems involved was set into operations in summer 2013 as requisite for the start of the DEM production in August 2013. This workflow explicitly needs a complete coverage from the same orbit geometry for the requested area, because of the approach of dual-baseline phase unwrapping.

3 TanDEM-X DEM Production

In mid 2013 the (almost) complete first and second coverage were acquired and reprocessing of especially the first by help of the second coverage could be started. The processing strategy for the final TanDEM-X DEM foresees that flat regions, i.e. regions with no need for more than two coverages will be processed first. The acquisition of difficult terrain is still ongoing until mid 2014.

The operational processing of final TanDEM-X DEMs started with the flat western and middle part of Australia. The DEM calibration block outlines are oriented on data take borders (see **Figure 4a**). Whereas the outlines of the mosaicking blocks are orientated on geocells (see **Figure 4b**). After Australia the flat parts of Northern America and Russia were processed to final DEMs. **Figure 5** gives an overview of the DEM production status in April 2014.

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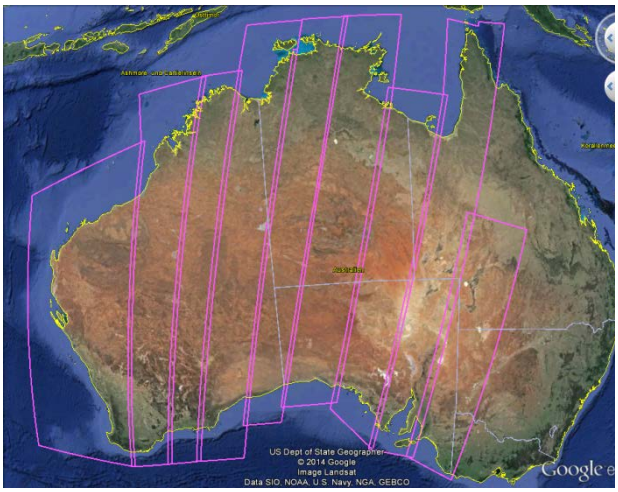
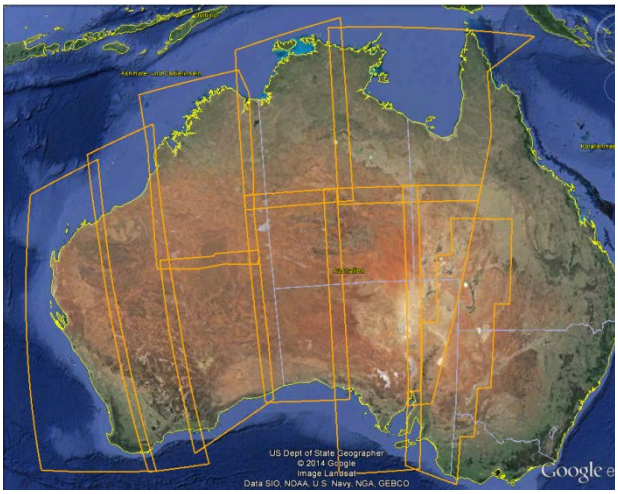


(a)



(b)

Figure 4: Overview of the DEM calibration blocks oriented on data takes in pink (a) and mosaicking blocks oriented on geocells in yellow (b) for Australia.

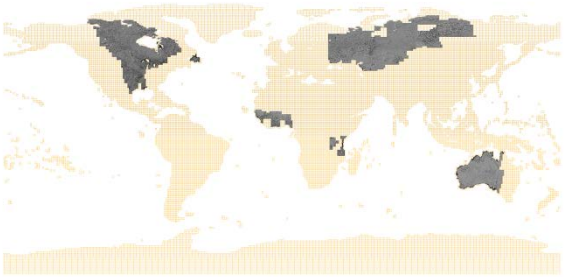


Figure 5: Overview of DEM production status in April 2014.

4 Conclusions

In this paper the processing and the status of the final Intermediate TanDEM-X DEM is presented. It gives an overview of the tests and system improvements on its way towards the final TanDEM-X DEM processing.

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