# THE NEW TANDEM-X DEM CHANGE MAPS PRODUCT

*Marie Lachaise, Carolina González, Paola Rizzoli,*
*Barbara Schweißhelm, Manfred Zink*

German Aerospace Center (DLR)
Münchener Str. 20, 82234 Oberpfaffenhofen, Germany
Marie.Lachaise@dlr.de

## ABSTRACT

The Earth is a very dynamic system and the topographic height of its landmass changes over time, especially in forested areas, glaciers, permafrost regions or where human activities take place. After the TanDEM-X mission provided a first global DEM of unprecedented quality in 2016, a new complete coverage of the Earth's landmass was acquired mainly between 2017 and 2020. This data is used to create another global DEM. In addition to providing more up-to-date elevation information, these new acquisitions also provide a great dataset to show the changes that have occurred in the few years between the two global datasets. The new product - the TanDEM-X DEM Change Maps - will be produced in 30m and 90m postings and will focus on showing these changes between the first global TanDEM-X DEM and the newly acquired time-tagged DEM scenes. It will also include the in-house automatically edited TanDEM-X DEM.

***Index Terms***— TanDEM-X, digital elevation model, DEM changes, terrain changes.

## 1. INTRODUCTION

The TanDEM-X mission flies two very similar satellites in a close formation that has provided bistatic interferometric imaging for digital elevation models since 2010. During the first five years of the mission, two coverages of the entire landmass of the Earth were acquired. With these data, the first global TanDEM-X DEM was created and released in 2016. It is the first global product with such accuracy and consistent quality [1,2]. During its generation, it became clear that at this level of accuracy, elevation differences between interferometric SAR data acquired at different time periods are visible. Indeed, changes in glaciers or forests, but also agricultural activities or infrastructural changes leave well visible traces in the X-band DEMs.

Therefore, in 2017, the TanDEM-X mission decided to acquire an additional complete coverage of the Earth's landmass. The goal was to create an independent dataset within a well-defined period from 2017 to 2020 to observe topographic changes. This data will be used to create a new global digital elevation model - the TanDEM-X DEM 2020. It will provide more up-to-date elevation information and will be available in 2024.

During the interferometric processing that generates the Change Raw DEMs [3], this second, more recent global dataset is compared to the first DEM version and changes over time are assessed. In this way, human-induced changes due to mines or large infrastructure projects, but also the melting of glaciers and ice sheets or deforestation activities are made visible. The observation and quantification of these processes on a global scale is not only highly interesting for science, but also shows the dramatic effects of climate change and provides stakeholders with information that is of utmost importance for decision-making processes. Therefore, complementary to and independent of the TanDEM-X DEM 2020 generation, another new product - the TanDEM-X DEM Change Maps - is being created that focuses on showing these DEM changes in the newly acquired data on a global scale. The specificity of this product is that the newly acquired overlapping DEMs are not mosaicked together before calculating the difference, as it is the case with TanDEM-X DEM 2020, so that the crucial temporal information is preserved.

After a brief description of the features and limitations of TanDEM-X DEM 2020 in terms of change detection, this paper will focus on the description of the new product: the TanDEM-X DEM Change Maps.

## 2. TANDEM-X DEM 2020

### 2.1. Product characteristics

The TanDEM-X DEM 2020 will be the second global DEM of the TanDEM-X mission. It will be produced with the newly acquired dataset and is thus clearly separated in time from the first global DEM [4]. It should be noted that although the huge majority of the data was acquired between 2017 and 2022, some data is still being acquired (2022) to fill some gaps. It technically follows the same product

format specifications as the original TanDEM-X DEM [5]. It will also be provided at 12m, 30m, and 90m and is expected to have similar absolute horizontal and vertical accuracies (see Table 1).

| DEM Product | Posting | Absolute Horizontal Accuracy CE90 | Absolute Vertical Accuracy LE90 | Relative Vertical Accuracy 90% linear point-to-point error | Coverage |
|---|---|---|---|---|---|
| TanDEM-X DEM (standard product) | 0.4 arcsec (~12 m @ equator) | Specified: < 10 m Measured: < 2 m | < 10 m Measured: < 2 m | 2 m (slope ≤ 20%) 4 m (slope > 20%) | Global |
| TanDEM-X DEM 2020 (2nd temporal DEM) | 0.4 arcsec (~12 m @ equator) | < 10 m | < 10 m expected similar to DEM (< 2 m) | Not specified | Global acquisitions (with local gaps.) |

**Table 1:** TanDEM-X DEM (original product) and TanDEM-X DEM 2020 specifications

However, most of the Earth's landmass was only covered once, which means that the TanDEM-X DEM 2020 will have some limitations compared to the original DEM. First, it may contain some gaps due to missing observations or scenes of inappropriate quality. Second, the relative height accuracy will be less homogeneous as the SNR varies due to the antenna pattern. It should be noted that better and stronger noise filtering is performed during interferometric processing to minimize this effect [6]. Finally, there may be local errors due to residual phase unwrapping errors, shadows and layover, or artifacts originating from the processed reference DEM used for interferometric processing [7].

### 2.2. Limitations for change detection between DEMs

The original TanDEM-X DEM results from the average of several scenes taken at different times. Furthermore, the mosaicking algorithm aims to determine the highest quality for each pixel in the mosaic by selecting input pixels to be considered on a pixel-by-pixel basis [8]. Which pixels from which scene were considered for averaging and mosaicking cannot be traced. Therefore, the DEM pixels do not have a proper timestamp.

The TanDEM-X DEM 2020 is generated using the same approach and therefore has the same limitations regarding a unique timestamp for a single pixel. In addition, it will not be available until 2024 and will not provide direct DEM differences. Finally, like the first TanDEM-X DEM, it will not be edited at first.

## 3. TANDEM-X DEM CHANGE MAPS

### 3.1. Motivation

Terrain change detection is a very important topic and is very useful in various fields such as mining, glaciology, and forest monitoring and helps to understand climatic changes. As explained before, the TanDEM-X DEM 2020 is not really suitable for terrain change detection. Indeed, a processed reference DEM is required for comparison, and a unique time stamp per pixel is needed for further analysis of the measurements.

Therefore, we are aiming for a new product that will provide terrain changes on a global scale. This product will also be based on the Change Raw DEMs created from the dataset collected between 2017 and 2022.

### 3.2. Product characteristics

The TanDEM-X DEM Change Maps product shows the DEM changes between the newly acquired data (processed into Change Raw DEMs) and the original edited TanDEM-X DEM used in the interferometric processing.

This product is of great interest for many scientific applications. Note that the TanDEM-X DEM products are currently available to the scientific community through a standard announcement of opportunity process and submission of a scientific proposal. The 90-meter version is freely available for scientific purposes, and it is planned to make the TanDEM-X DEM Change Maps available at the 30m and 90m levels in a similar manner by the end of 2022.

At least the following layers are foreseen for the DEM Change Maps:

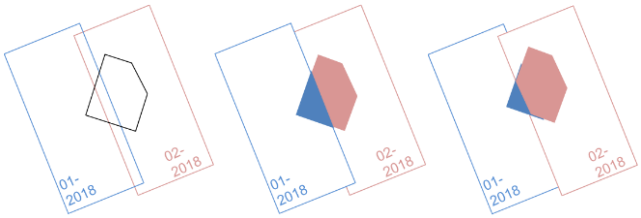
- 2 DEM Change Maps with date layers (first and latest DEM changes).
- 2 Change Indication masks
- Edited TanDEM-X DEM (the first global DEM).
- DEM Edited Mask
- HEM

*3.2.1. First and latest DEM Change Maps*

The main purpose of this product is to provide DEM change maps where the pixel being compared to has a unique timestamp. Therefore, two change maps are generated: one with the change of the oldest pixel – or first DEM change - in the new dataset in question, and another with the change of the newest pixel used – or latest DEM change - (see Figure 1). Thus, the two maps differ when there are multiple coverages. In the case of a single coverage, both maps contain the same information. Users must be aware that a given elevation change measured in the DEM change maps corresponds to a topographic change with respect to the global TanDEM-X DEM on the one hand, but cannot be associated with a corresponding physical height change of the same magnitude on the other hand. This is due to the fact that the reference TanDEM-X DEM reflects an averaged elevation derived from the combination of different images, possibly acquired over a period of several years. This aspect has to be considered especially over vegetated and snow-covered regions.

It should be noted that some jumps may occur between adjacent acquisitions if the two acquisition dates are separated by several months. In fact, a finer calibration is performed within the datatake but not between adjacent

datatakes to preserve the possible large-scale terrain changes [9].




(a) (b) (c)

**Figure 1:** First and latest DEM change maps: (a) Two adjacent scenes taken at different times, where the terrain has changed across both scenes; (b) DEM change map - first change: the pixels of the oldest acquisition are taken in the overlap area; while for the (c) DEM change map - latest change, the pixels of the newest data are selected in the common area.

*3.2.2. Change Indication Masks*

The change indication masks are intended to provide information about possible terrain changes and their reliability based on local characteristics of the edited reference DEM and Change Raw DEM scenes. They are not a substitute for a thorough temporal elevation change analysis.

*3.2.3. Edited TanDEM-X DEM*

The (first) global TanDEM-X DEM is unprocessed, i.e., it is the pure result of interferometric SAR processing and subsequent mosaicking. Residual gaps resulting from unprocessable data, for example, are still present and water surfaces appear noisy. The global TanDEM-X DEM is edited fully automatically by filling gaps and flattening water surfaces [7]. A corresponding editing mask indicates the edited regions. This edited DEM also served as a reference for the interferometric processing of the Change Raw DEMs used for the previously mentioned TanDEM-X DEM 2020.

## 4. CONCLUSION

This paper summarized the features of the TanDEM-X DEM 2020 and its limitations in change detection. Therefore, this paper introduces a new product - TanDEM-X DEM Change Maps - that provides clearer information about the terrain changes that have occurred in the last five to ten years.

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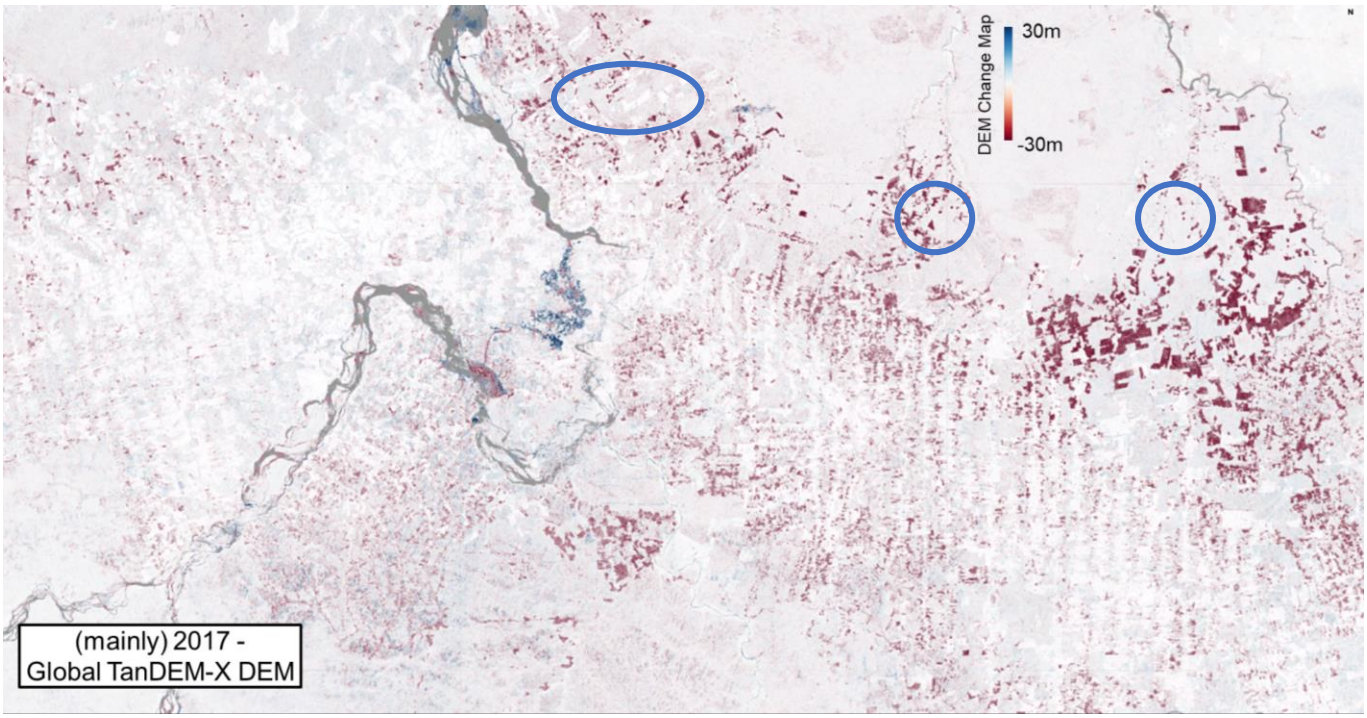
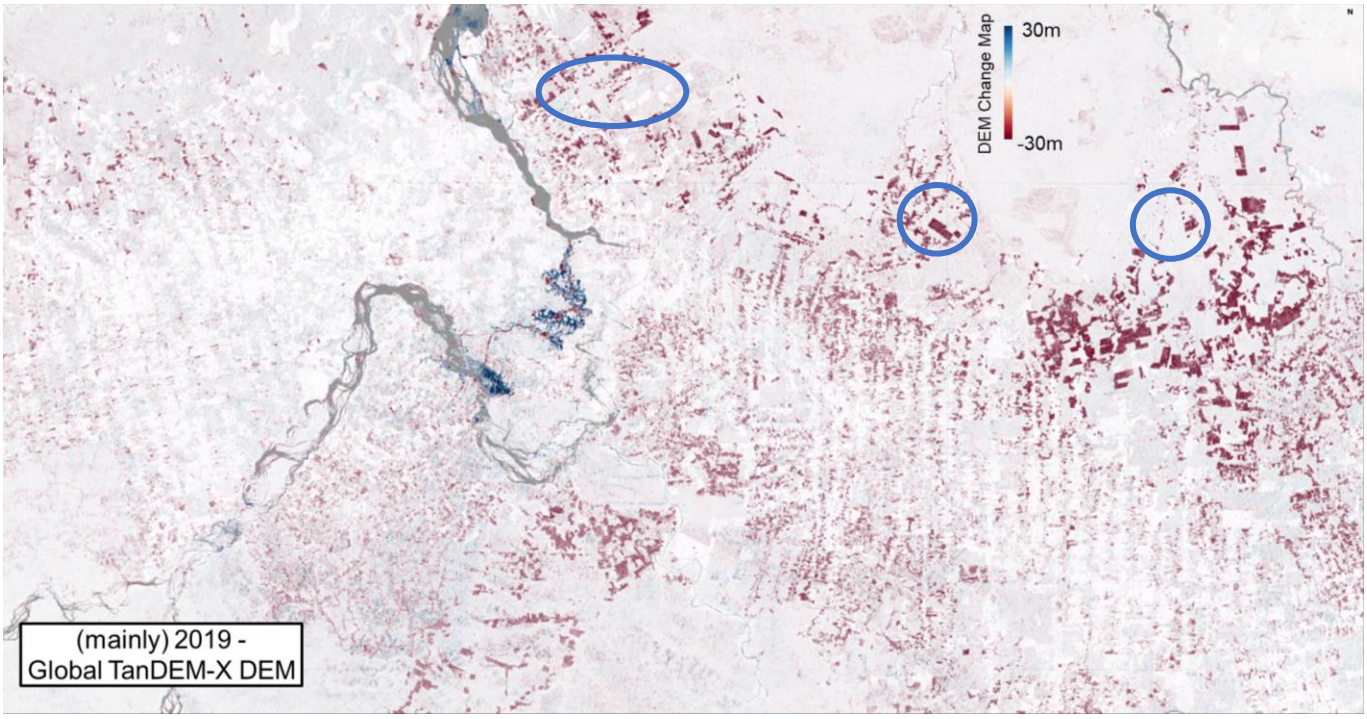



(a)




(b)

**Figure 2:** First and latest DEM change maps over some part of the rain forest in Brazil exhibiting the evolution of the deforestation: (a) DEM change map - first change: red regions depict areas that have been (probably) deforested between 2010/2015 and 2017; (b) DEM change map - latest change: this map depicts the DEM changes in acquisitions from 2019: the diminution of the forested areas between 2017 and 2019 can be clearly seen.