



Microwaves and Radar Institute

TanDEM-X

30m Edited DEM

Product Description

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DOCUMENT CHANGE CONTROL

This document is under configuration control. Latest changes to the document are listed first.

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1 Introduction

The TanDEM-X 30m Edited Digital Elevation Model (EDEM) is a product developed at the Microwaves and Radar Institute of the German Aerospace Center (DLR), in the frame of the activities of the TanDEM-X mission. The goal is a gap-free DEM in 30m spacing which includes landcover, quality and edition layers. The EDEM and its layers have been derived from the global TanDEM-X DEM Product and the TanDEM-X bistatic interferometric synthetic aperture radar (InSAR) data, acquired between 2011 and 2015 in stripmap single polarization (HH) mode. Moreover, a colored hill-shade preview of the EDEM is included for visual inspection purposes. For display purposes some layers are color-coded or present a low resolution preview with legend. Furthermore, a kmz and xml are included to include all information that could be useful.

1.1 Purpose

The purpose of this document is to describe the TanDEM-X 30m EDEM product, its layers and format.

1.2 Scope

The current document includes the product description and raster format of the TanDEM-X 30m EDEM product and its layers.

2 Documents

2.1 List of Abbreviations

The following symbols and acronyms have been used.

Symbol	Description
TDX	TanDEM-X
DEM	Digital Elevation Model
EDEM	Edited Digital Elevation Model
EDM	Editing Mask
FNF	Forest/Non-Forest
WBL	Water Body Layer
LC	Land Cover
LCM	Land Cover Map
HSD	Hill Shade Display
HEM	Height Error Map
QL	Quicklook

2.2 Applicable Documents

The following documents are fully applicable together with this document.

	Document
[AD1]	License agreement regarding the use of the edited 30m TanDEM-X DEM

2.3 Reference Documents

The following references have been used for preparing the document on hand.

	Document
[RD1]	C. González, M. Bachmann, J.L. Bueso-Bello, P. Rizzoli, M. Zink. A Fully Automatic Algorithm for Editing the TanDEM-X Global DEM. Remote Sensing. 2020; 12(23):3961. https://doi.org/10.3390/rs12233961
[RD2]	B. Wessel. TanDEM-X Ground Segment – DEM Products Specification Document. Tech. rep. TD-GS-PS-0021. Public Document, Issue 3.2. German Aerospace Center (DLR), Nov. 2019
[RD3]	J.L. Bueso-Bello, M. Martone, C. González, F. Sica, P. Valdo, P. Posovszky, A. Pulella, P. Rizzoli. The Global Water Body Layer from TanDEM-X Interferometric SAR Data. Remote Sensing. 2021; 13 (24):5069. https://doi.org/10.3390/rs13245069
[RD4]	M. Martone, P. Rizzoli, C. Wecklich, C. González, J.L. Bueso-Bello, P. Valdo, D. Schulze, M. Zink, G. Krieger, A. Moreira. The global forest/non-forest map from TanDEM-X interferometric SAR data. Remote Sensing of Environment. 2018; 205 :352-373.
[RD5]	ALOS Global Digital Surface Model ”ALOS World 3D - 30m (AW3D30)” Credit: Courtesy of the Japan Aerospace Exploration Agency (JAXA) https://www.eorc.jaxa.jp/ALOS/en/dataset/aw3d30/aw3d30_e.htm
[RD6]	NASADEM by NASA, Shuttle Radar Topography Mission (SRTM) Credit: Courtesy of NASA/JPL-Caltech https://www.earthdata.nasa.gov/esds/competitive-programs/measures/nasadem
[RD7]	Digital LiDAR-Terrain Models of Spain, Andorra, Gibraltar Digital LiDAR-Terrain Models of Austria Credit: Courtesy of Sonny, sonny7@gmail.com https://www.opendataportal.at/katalog/de/dataset
[RD8]	Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid Credit: Courtesy of Commonwealth of Australia (Geoscience Australia). Geoscience Australia, Canberra. https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search/metadata/89644
[RD9]	Reference Elevation Model of Antarctica (REMA) Credit: Courtesy of Polar Geospatial Center (PGC) at the University of Minnesota https://www.pgc.umn.edu/data/rema/ I.M, Howat, et al. 2019: The Reference Elevation Model of Antarctica, The Cryosphere https://doi.org/10.5194/tc-13-665-2019 [27.06.2022]
[RD10]	ArcticDEM digital surface model (DSM) of the Arctic Credit: Courtesy of Polar Geospatial Center (PGC) at the University of Minnesota National Geospatial-Intelligence Agency, National Reconnaissance Office (NGA-NSF) https://www.pgc.umn.edu/data/arcticdem/ Mosaics: Porter, Claire, et al., 2018, “ArcticDEM, Version 3” https://doi.org/10.7910/DVN/OHHUKH , Harvard Dataverse [18.07.2023]
[RD11]	Coastline of Greenland shapefile G250k from 14.08.2015 / downloaded 25.07.2023 courtesy of GEUS Geological Survey of Denmark and Greenland date of data. GEUS disclaims any errors in data.

3 TanDEM-X 30m Edited DEM Product

3.1 Usage Policy

The license terms [AD1] for the use of the TanDEM-X 30m Edited DEM products are automatically accepted by registering for downloading the data. The license is granted only for scientific and non-commercial purposes.

To acknowledge the scientists who have generated and provided the Edited DEM and its layers, we request that users include the corresponding bibliographic citations in their work. Following references shall be cited:

RD1 C. González, M. Bachmann, J.L. Bueso-Bello, P. Rizzoli, M. Zink. A Fully Automatic Algorithm for Editing the TanDEM-X Global DEM. *Remote Sensing*. 2020; 12(23):3961. <https://doi.org/10.3390/rs12233961>

RD3 J.L. Bueso-Bello, M. Martone, C. González, F. Sica, P. Valdo, P. Posovszky, A. Pulella, P. Rizzoli. The Global Water Body Layer from TanDEM-X Interferometric SAR Data. *Remote Sensing*. 2021; 13 (24):5069. <https://doi.org/10.3390/rs13245069>

RD4 M. Martone, P. Rizzoli, C. Wecklich, C. González, J.L. Bueso-Bello, P. Valdo, D. Schulze, M. Zink, G. Krieger, A. Moreira. The global forest/non-forest map from TanDEM-X interferometric SAR data. *Remote Sensing of Environment*. 2018; 205 : 352-373.

3.2 Product Overview

The TanDEM-X 30m EDEM dataset includes:

- The global EDEM in 30m spacing and two different vertical datums:
 - WGS84 Ellipsoid
 - Geoid EGM 2008
- Auxiliary layers
 - Land cover map (LCM): Forest, Land, Water classes
 - Editing mask (EDM)
 - Height error map (HEM)
- Previews
 - Hill shade display (HSD) color & shade
 - Image display with legend Quicklooks (QL) for each layer.
 - EDM kmz overlay and legend
- Support
 - xsd files
- Metadata and statistics as xml
- downsized HSD

The products are partitioned in geocells ($1^\circ \times 1^\circ$ latitude/longitude) as described in [RD2]. The Edited DEM and its layers as well as the hillshade display are available as raster datasets in GeoTIFF or cloud optimized GeoTIFF (COG) format (deflate compressed, with different bit depth) with a ground resolution at the equator of $30 \text{ m} \times 30 \text{ m}$, which corresponds to $1 \text{ arcsec} \times 1 \text{ arcsec}$ in latitude/longitude.

3.2.1 Naming Convention

The file naming convention of the TanDEM-X 30m Edited DEM geocells refers to the latitude and longitude value of the lower left or southwest corner pixel of a product. The prefix string in the file base name has the general form:

”TDM1_tttt_nn_BbbXxxx” (e.g. TDM1_EDEM_10_N22E040.zip).

The main tif files have a suffix with the general form:

”TDM1_tttt_nn_BbbXxxx_FFFF_CCC.tif” (e.g. TDM1_EDEM_10_N22E040_EDEM_W84.tif)

and the tif Auxfiles as well as preview:

”TDM1_tttt_nn_BbbXxxx_FFF.tif” (e.g. TDM1_EDEM_10_N22E040_EDM.tif)

The meaning of the letter codes is given in Table 1.

Table 1: Naming convention for the TanDEM-X 30m EDEM products.

Letter	Meaning	Example
tttt	Product type, i.e. EDEM	EDEM
nn	Spacing, 10: original spacing, 1 arcsec grid	10 (1 arcsec 30m at equator)
B	“N” if the center of southwest corner pixel of a tile is on the Equator or north of it. “S” if it is south of the Equator	N
bb	2-digit latitude value of the center of the southwest corner pixel of a tile in degrees	22
X	“E” if the center of the southwest corner pixel of a tile is in the eastern hemisphere, “W” in the west one. If the center of the southwest corner pixel of the tile is exactly at 0° longitude, this is “E”. If the center of the southwest corner pixel is exactly at $\pm 180^\circ$ longitude, this is “W”	W
xxx	3-digit longitude value of the center of the southwest corner pixel of a tile in degrees	040
FFFF FFF FFF	Layer type Auxiliary files types are: EDM (editing mask) LCM (land cover map) Preview HSD (hillshade display)	EDEM
CCC	Used vertical datum for the main product	W84

3.2.2 Format, Coordinate System and Grid

Format

The main used format is GeoTIFF / cloud optimized GeoTIFF (COG). The raster data are compressed with DEFLATE algorithm and *band* interleaved. This format allows for ingesting metadata, as well as the geo-coordinates in each file header. The number of bands as well as the depth of the raster vary depending on the type of layer or product. Additional metadata are provided as xml file, as well as quicklook images in png format. A kmz is included as well, which displays the edition mask and its legend.

Coordinate System

Horizontal datum: The WGS84 horizontal datum is maintained from the unedited version and described by EPSG: 4326.

Vertical Datum: The EDEM product is written in two vertical coordinates systems (VCS):

- WGS 84 Ellipsoid, described by EPSG: 4979
- EGM 2008 Geoid, described by EPSG: 3855

Warning: horizontal re-projection of the digital elevation model should consider ellipsoid VCS since projections are defined over the ellipsoid.

Extent, Pixel Spacing and Grid

The extent, pixel spacing and grid used for the TanDEM-X 30m EDEM product are derived from the unedited product. The products are partitioned in geocells with an extent of $1^\circ \times 1^\circ$ in latitude and longitude coordinates for latitudes comprised between 0° - 60° North/South. Between 60° - 80° North/South latitudes the geocells have an extent of $1^\circ \times 2^\circ$. Above 80° North/South latitudes the geocells have an extent of $1^\circ \times 4^\circ$. The pixel spacing in latitude direction towards the poles is constant at 1 arcsec, while the pixel spacing in longitudinal direction varies. The pixel spacing in longitude varies due to two factors: the amount of degrees contained in a geocell and the variation of the number of pixels in longitude varying with respect to the latitude. The grid considers a single pixel overlap with the neighbouring geocells.

A detailed description can be found in the TanDEM-X DEM product specification document [RD2].

3.3 Product Generation

The TanDEM-X 30m Edited DEM and its layers have been derived from the global TanDEM-X DEM Product and the bistatic interferometric synthetic aperture radar (InSAR) data, acquired between 2011 and 2015 in stripmap single polarization (HH) mode.

The LCM in the product includes land cover (LC) classes such as water, forest and land. The LCM have been derived sequentially from the global data set of quicklook images, characterized by a ground resolution of 50 m x 50 m, in order to limit the computational burden. For classification purposes several observables, systematically provided by the TanDEM-X system, have been exploited, such as the calibrated amplitude, the bistatic coherence and the DEM height information. Once the LC classes have been estimated over several input scenes (covering an area of about 30 km × 50 km), they have been merged through a mosaicking process. In particular, for editing the TanDEM-X DEM product a complex weighted approach on the water detection over the single scenes has been considered and a Water Body Layer (WBL) has been estimated [RD3]. Then the LC mosaics were interpolated to the output grid (30m x 30m, at the equator) and combined into one multiple LC class map.

The WBL and the voids of the TanDEM-X DEM product in 30m have been used to define the water areas to be flattened and the gaps to be filled with an external reference DEM or an adequate interpolation technique. In addition, the different editing strategies and used reference DEMs are noted in the editing mask (EDM). Additionally, the standard deviation of the estimated relative height accuracy of the single pixels on the unedited TanDEM-X DEM product is given in the HEM layer.

Moreover, a colored hill-shade preview of the EDEM is included for visual inspection. For display purposes some layers are color-coded or present a preview QL. Furthermore, a kmz and xml are included for information completeness.

3.3.1 DEM editing

The DEM editing takes care of two main aspects: filling voids (0.11% of the landmasses) and flattening water surfaces. For this purpose, a dedicated framework has been designed in order to organize and optimize the processing steps [RD1]. The high-level flow-chart of the automatic editing is depicted in Figure 1.

Starting with TanDEM-X DEM product an overlap correction is first made. Then the TanDEM-X WBL, described in the next section 3.3.2, is considered in order to discriminate between the areas to be filled and the areas to be flattened. Here the gaps and water surfaces are further classified into different types in order to choose the most appropriate editing approach. Water has been classified into rivers, lakes and ocean, while voids were grouped and classified by size and water neighbouring classes.

The main gap filling approach is the *Stable Delta Surface Interpolation* which considers an external reference DEM and an estimation of the reliability of the vicinity of the gap to derive a height drift mask. Then a delta surface plane is estimated where an interpolation over the gap and the areas corresponding to the height drift is performed. The interpolation is then smoothed and the delta surface is added to the external reference DEM. The gap and height drift areas are then substituted with these interpolated smoothed heights.

When there is no external reference DEM available an *Inverse Distance Weighting* interpolation is directly performed. This works over small gaps or where the vicinity of the gap is not noisy and presents low-relief topography. In the case of Antarctica, where no reference was available smoothing process has been applied before the interpolation.

The used references are listed under [RD5-RD10]. In particular, some few gaps of the TanDEM-X DEMs over the Antarctica Peninsula and neighbouring islands were overlapping with gaps in the reference REMA DEM. In these cases an interpolation was meaningless. To patch the reference REMA DEM, single TanDEM-X acquisitions were processed, the corresponding DEMs generated, recursively calibrated as well as mosaicked with respect to the reference REMA DEM. This patched reference REMA DEM has then been used in the same way as the other external reference DEMs. Information about the single acquisitions used for patching the reference REMA DEM, can be found on the xml file as shown in Figure 9.

Different water flattening approaches depending on the kind of water body were considered. For the ocean, the level of water is considered to be at 0m geoid height. Over lakes the flattening has been estimated considering a cut value on the distribution of the height of the 2 pixel shoreline, in order to avoid considering outliers. The estimated level of the lake is considered to be the value that equals the lowest height for which one fourth of the maximal frequency on the distribution is given. The undulation of the geoid is considered as well. Rivers have been edited with a pixel by pixel approach, that takes into account 2 pixel shoreline on the vicinity of the pixel itself and considers the 30th percentile of this value to fill the river pixel. Moreover, rivers have been smoothed in order to mitigate noise effects.

Finally, an editing mask is generated pixel-wise, indicating whether the pixel has or has not been edited. In case the editing was applied, the editing mask carries information such as which algorithm was applied and which external reference DEM was used, among others. More details on the editing mask are described in Section 3.4.3.

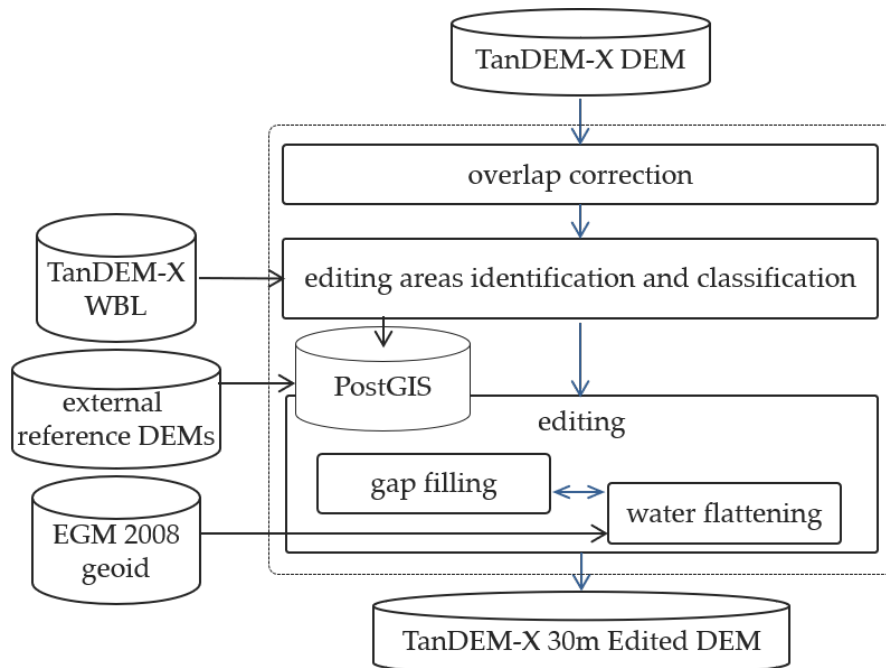


Figure 1: High-level flow chart of the developed automatic framework for DEM editing.

Users should be aware that the editing process is an automated approach and the quality of the edition relies on the accuracy of the external reference DEMs. For details on the editing process of the TanDEM-X DEM products, please refer to [RD1].

3.3.2 Water

Water bodies typically appear as dark areas within the interferometric coherence, since the bistatic signal decorrelates almost completely. This aspect makes the coherence a reliable indicator of the presence of water on the ground. Therefore, for the generation of the TanDEM-X WBL, the bistatic coherence was used as sole input feature for performing the classification task. In particular, for each input scene, first the two-dimensional gradient of the coherence was computed and then a Scharr transformation was applied in order to highlight the gradient edges. At this point, the well-established watershed algorithm was used for image segmentation. This is a non-parametric contour detection method, which, starting from user-defined markers, treats pixels values as a local topography. It then floods basins starting from the markers, until basins attributed to different markers meet on watershed lines. Such markers, also called seeds, are here set by taking values of the interferometric coherence close to the theoretical bias. The output is a set of closed contour lines which delineates the borders between regions with different characteristics. The contoured regions, where the water seeds were initially placed, are finally identified as water bodies. Then the TanDEM-X WBL class was obtained based on a two-step weighted logical mosaicking process of overlapping TDX acquisitions. The water class has been then interpolated on the final grid. To address possible interpolation inaccuracies, pixels that could be considered as gap that are neighbour of water, with a mean distance below 1.4 pixels, are also considered to be water in the WBL.

Differently, permanent and temporary water layers were obtained by simply counting water occurrences within those overlapping TDX images used in the mosaicking process to generate the TanDEM-X WBL. For each water body, the areas identified as water in all overlapping images are indicated as permanent water. Other areas, identified as water only in some of the available images (mainly due to temporal or seasonal changes or to the presence of frozen water), are classified as temporary water. For further details on the method, please refer to [RD3].

The water bodies were estimated over all land surfaces where water detection with the available TanDEM-X DEM acquisitions was possible. Therefore, the estimation of water in general for the Antarctica has been excluded, since all acquisitions have been made in winter time and coastal areas are characterized by the presence of sea ice. Over Greenland, water detection was performed, but only the classes permanent and temporary water were estimated, and no WBL is calculated from TanDEM-X acquisitions for DEM editing purposes. The WBL in both cases considers a shapefile that delimitates the shoreline of Antarctica and Greenland respectively [RD11].

3.3.3 Forest

The volume correlation factor quantifies the amount of decorrelation due to multiple scattering within a volume, which typically occurs in presence of vegetation. This quantity is directly derived from the interferometric coherence and used as main input feature for the identification of vegetated areas. For this purpose, a fuzzy multi-clustering classification approach, which takes into account the geometric acquisition configuration for the definition of the cluster centers, is individually applied to each acquired scene. A certain variability of the interferometric coherence in X-band has been observed among different forest types, mainly due to changes in forest structure, density and tree height. This leads to an adjustment of the algorithm settings, and in particular to the derivation of different cluster centers, depending on the considered type of forest. A weighted mosaicking process of the single scene estimations has been performed and the derived global product has been published in 50m resolution. For further details on the method, please refer to [RD4]. These mosaics have been interpolated to fit the grid of the LCM product.

3.4 TanDEM-X 30m Edited DEM Layers Description

This section presents the detailed description of each layer as well as the delivery format and supplementary metadata .

3.4.1 TanDEM-X 30m Edited DEM

The TanDEM-X 30m EDEM is the main product and is given in two vertical coordinate Systems (VCS):

- Ellipsoid as W84
- Geoid 2008 as EGM

The rasters give the height information on the respective VCS in linear meters and are written as float with 32 bits in one band. As all GeoTIFFs in the product, they are compressed with DEFLATE algorithm and *band* interleaved. In the following, the geocell S46W074 over fjords in Patagonia is going to be used as an example for displaying the different quicklooks or color-coded layers. Figure 2 shows the EDEM previews QL in png format for both VCS.

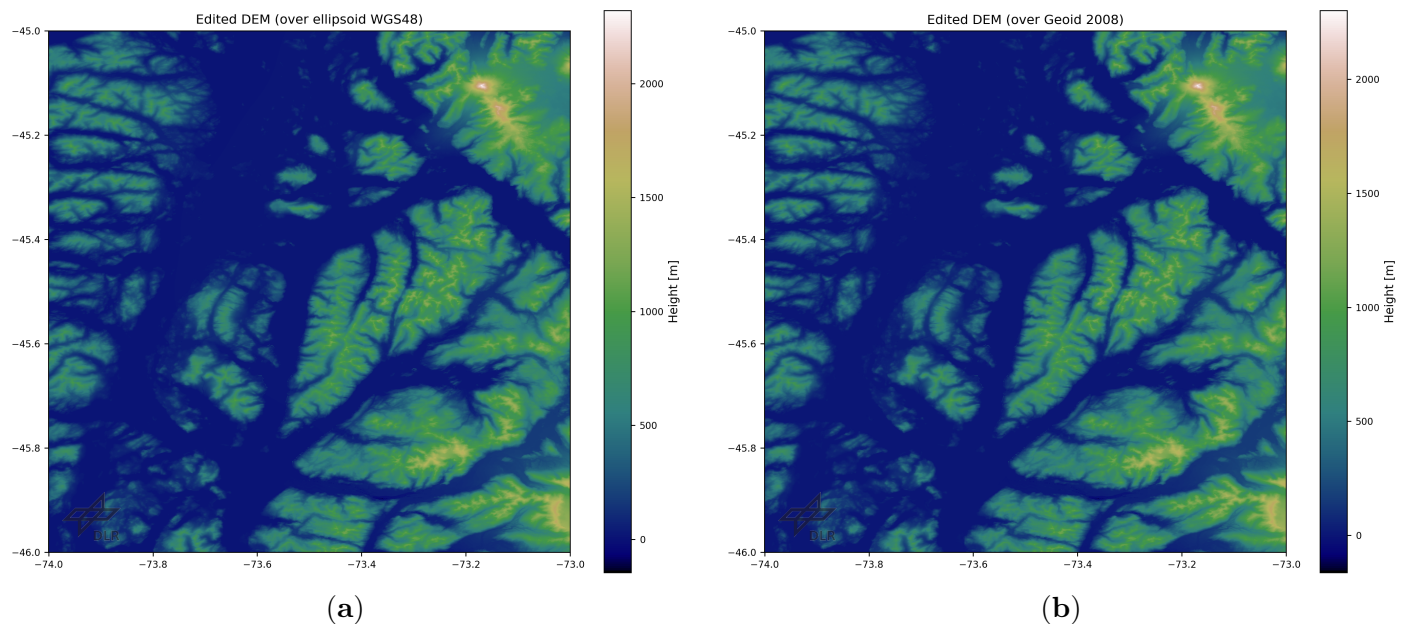


Figure 2: TanDEM-X 30 Edited DEM linear colored quicklook of geocell S46W074 over fjords in Patagonia (a) WGS84 (b) EGM 2008.

3.4.2 Hill Shade Display Preview

DEMs are difficult to interpret when displayed as linear values, details cannot be appreciated due to the extended dynamic range. A color-coded 3D representation of the terrain surface, with the sun's relative position taken into account for shading the image is considered for visualization purposes. The color-coded hill-shade displays are given as GeoTIFF raster files. In Figure 3 examples of hill-shade displayed (a) a mosaic over South America and (b) the geocell S46W074.

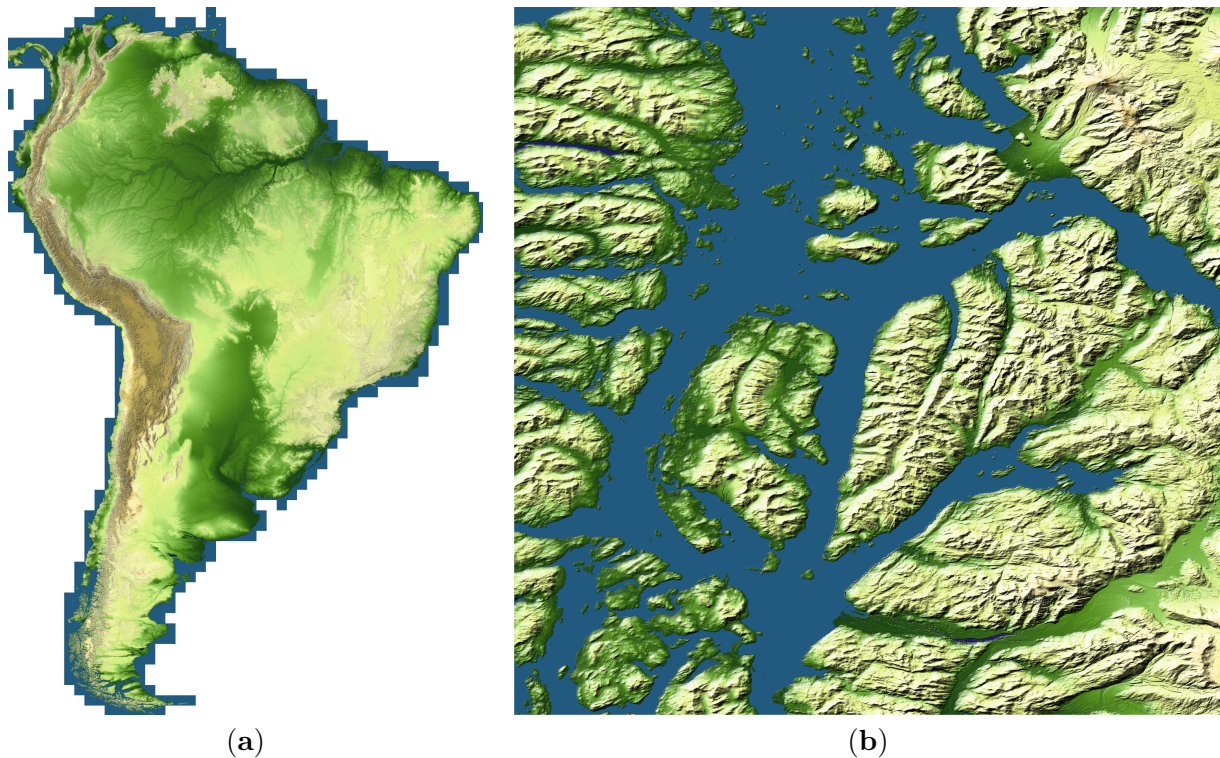


Figure 3: Color-coded hill shade display of the TanDEM-X 30m Edited DEM (a) over South America (b) example geocell: S46W074 fjords in Patagonia.

3.4.3 Editing Mask

The areas that have been edited are annotated as raster in the editing mask. The value for each pixel in the editing mask identifies a combination of the used edition algorithm and the external reference DEM, in the case of gaps filled with an external reference DEM. The annotated values in the editing mask are detailed in Table 2. The raster corresponds to an 8-bit colored-coded GeoTIFF. Figure 4 depicts an example of the editing mask over geocell S46W074.

Table 2: EDM mask values

Value	Group	Meaning
0		non edited
1	WBL	lake
2		river
3		ocean
4		water
5	void	Lidar void
6		SRTM void
7		AW3D30 1 void
8		NASADEM 1 void
9		AW3D30 2 void
10		NASADEM 2 void
11		AW3D30 3 void
22		REMA DEM void
24		Arctic DEM void
12	height drift	Lidar height drift
13		SRTM height drift
14		AW3D30 1 height drift
15		NASADEM 1 height drift
16		AW3D30 2 height drift
17		NASADEM 2 height drift
18		AW3D30 3 height drift
23		REMA DEM height drift
25		Arctic DEM height drift
19	interpolation	no reference void
20	value set to 0 geoid height	near ocean under geoid
21	mean value	tile overlap mean

3.4.4 Height Error Map

The height error map corresponding to the unedited TanDEM-X DEM is given. The raster is a 16-bit float GeoTIFF, with an invalid value set to -32767. Figure 5 shows the colored quicklook with legend of the HEM preview in png format for the geocell S46W074.

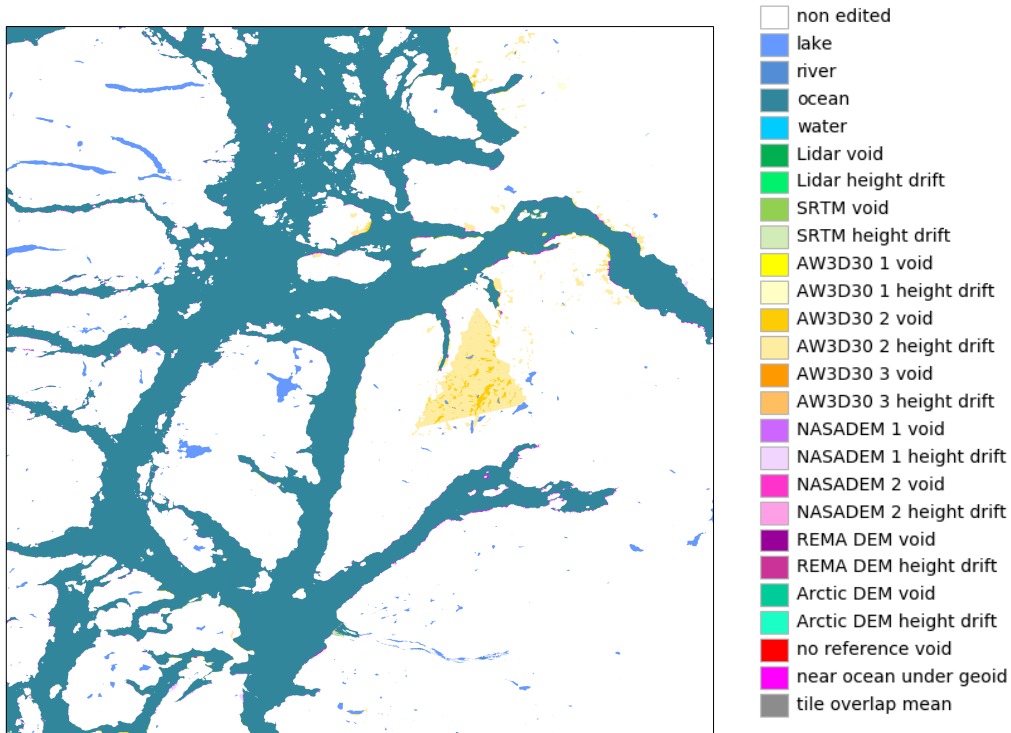


Figure 4: Color-coded editing mask with legend of the example geocell

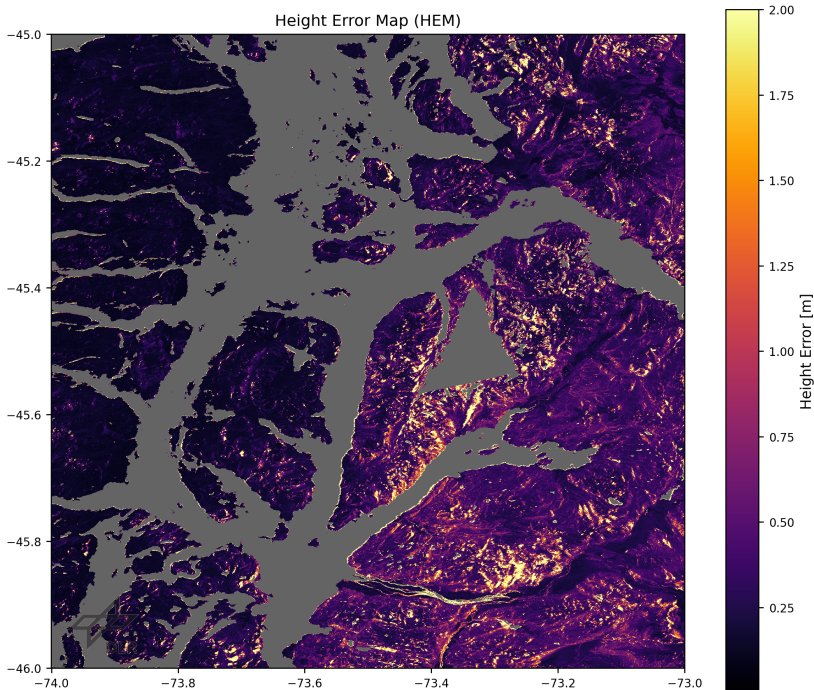


Figure 5: Color-coded quicklook with legend of the HEM

3.4.5 Land Cover Map

The LCM layer includes 3 LC classes: forest, land and water.

The LCM raster corresponds to an 8-bit colored-coded GeoTIFF with 2 bands. In the first band, the 3 above described LC classes can be found: 0: Invalids; 1: Forest; 2: Land; 3: Water. In the second band, information about the reliability of the water LC class is provided. 0: Invalids; 1: Temporary water; 2: Permanent water. Figure 6 shows the color-coded LCM (1st. band) of the LCM of the geocell S46W074.

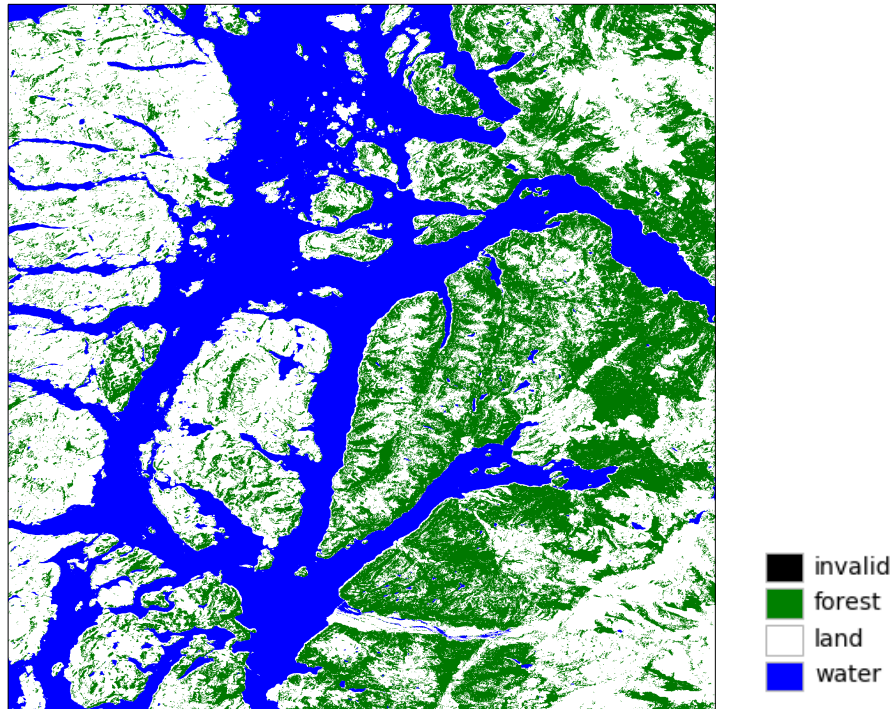


Figure 6: Color-coded land cover map with legend of the example geocell S46W074.

3.4.6 General

For visualization purposes one kmz of the product with the EDM as overlay has been chosen to be included in the delivery published product. As seen in Figure 7 this can be displayed on Google Earth together with its legend.

Figure 8 shows the files contained in the zip files of each single geocell, which are available for download. The XML structure from the global Tandem-X DEM product, detailed in [RD2], has been complemented with some additional parameters that resume the editing process. The xsd files describe the xml product and can be found in the support folder. Figure 9 shows the structure of the xsd file and the new branch added to the product. This describes the editing mask in percentages. Figure 10 shows the xsd extensions, apportioned with respect to the xsd provided in the TanDEM-X DEM product to allow for a comparison of the TanDEM-X 30m EDEM with the unedited TanDEM-X DEM product. In Figure 10 (b) the altitude coverage section of the xsd contains a statistical summary of the topographic heights in the considered geocell. The user should be aware that this section is given only with respect to the VCS WGS84 (ellipsoidal heights).

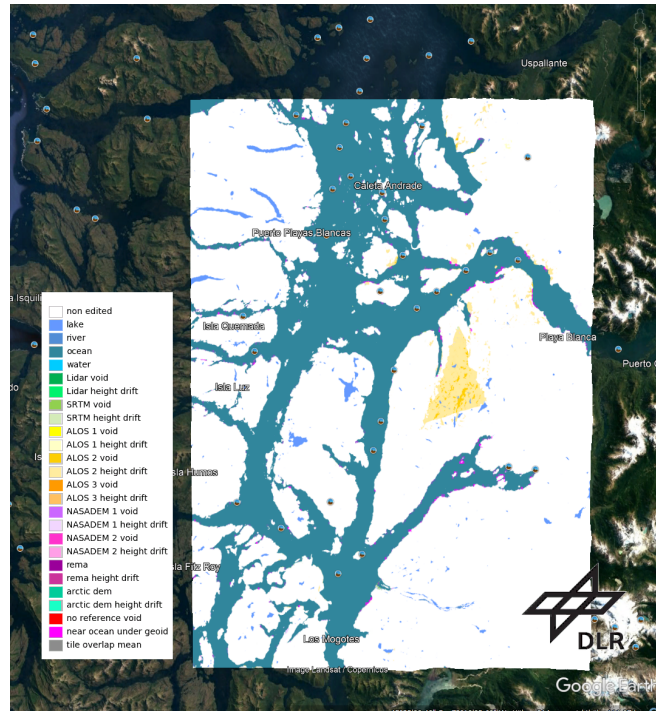


Figure 7: image of the kmz overlay of the EDM

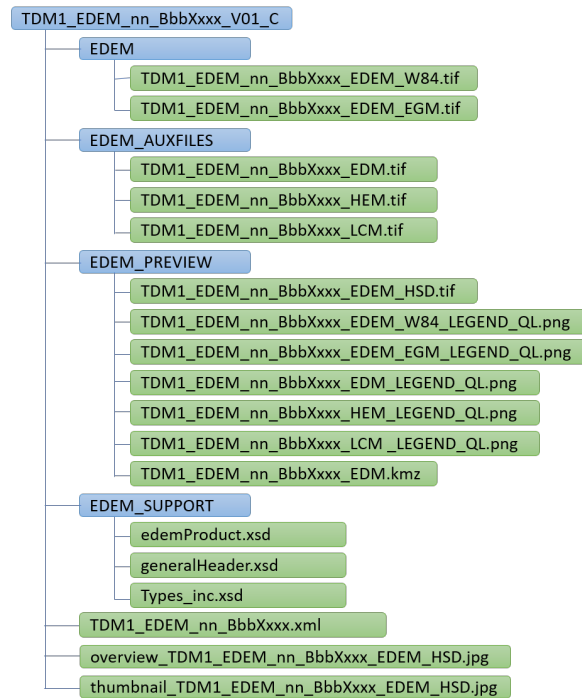


Figure 8: delivery folder

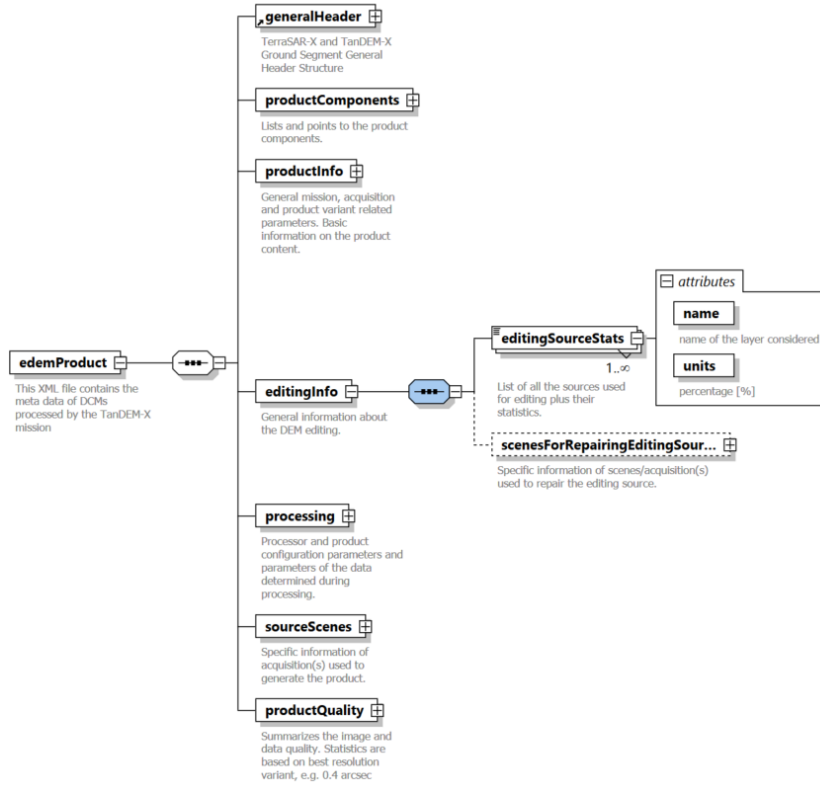


Figure 9: Overview of the xml structure (xsd) with the new branch editing information

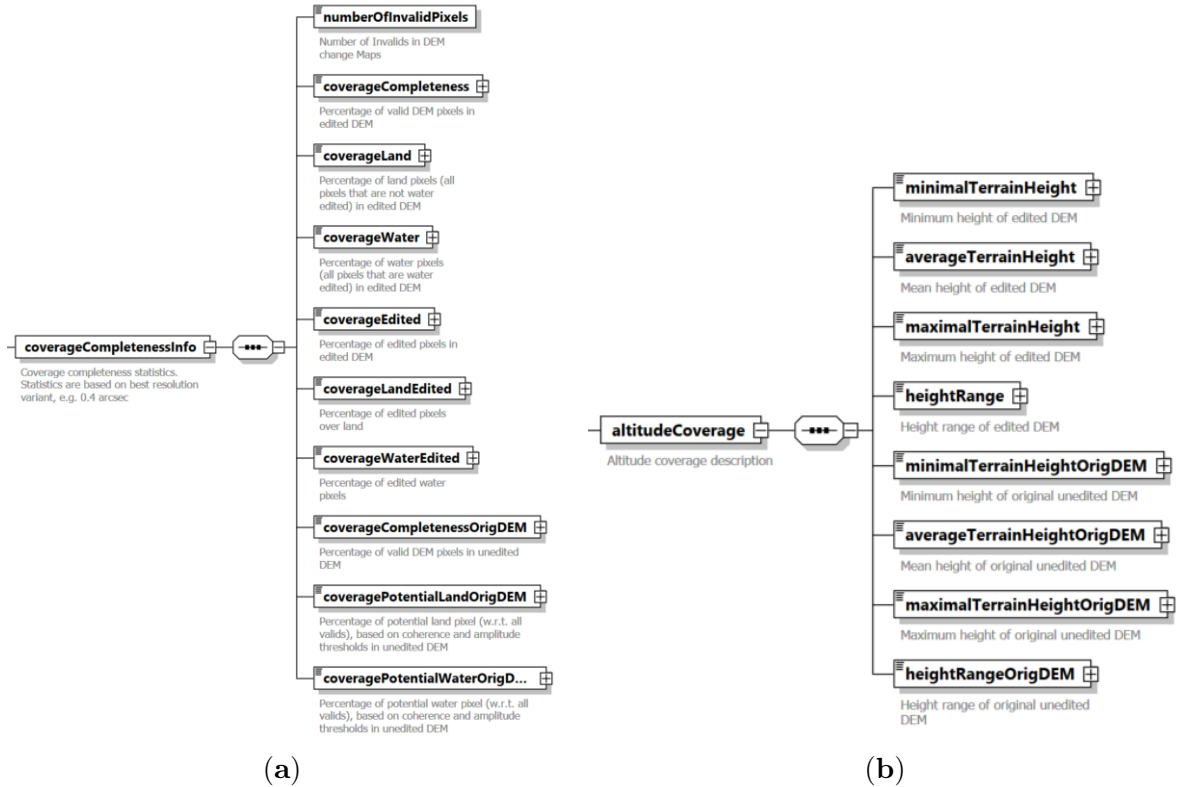


Figure 10: XML extensions under product info: (a) coverage completeness (b) altitude coverage.