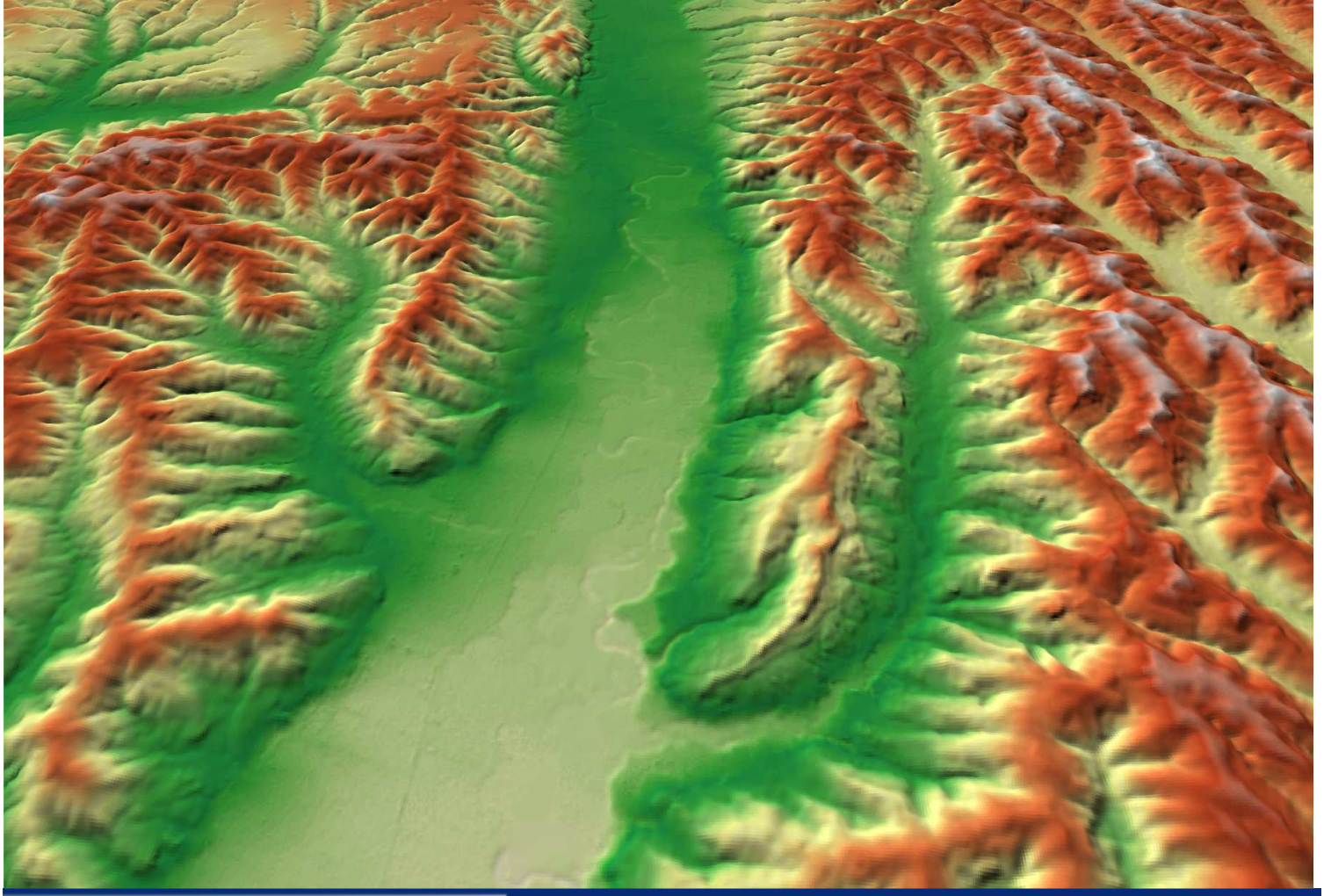

WorldDEM DTM$_{lite}$

Technical Product Specification

Version 1.1

AIRBUS DEFENCE AND SPACE
Intelligence

AIRBUS

Table of Contents

Table of Contents 2
List of Figures 3
List of Tables 3
Abbreviations 4
References 4
1 Introduction 5
1.1 WorldDEM™ as Data Basis 5
1.2 Scope 5
2 WorldDEM DTM$_{lite}$ Product Definition and Specification 6
2.1 Technical Summary 7
2.2 Accuracy 7
2.3 Pixel Spacing 8
2.4 Format 8
2.5 Projection 8
2.6 Coverage 8
3 WorldDEM DTM$_{lite}$ Production Process 9
3.1 Database 9
3.2 Processing Steps 10
3.2.1 Removal of Surface Structures 10
3.2.2 Hydro-enforcement 12
3.2.3 Post-processing and packaging 12
3.2.4 Quality Control 12
4 Packaging 13
4.1 Naming Convention 13
4.2 Additional datasets 13
4.2.1 Metadata 13
4.3 Product File Structure 14

List of Figures

Figure 2-1: WorldDEM DTM$_{lite}$ 6
Figure 3-1: WorldDEM DTM$_{lite}$ main processing steps 10
Figure 3-2: Removal of surface structures - main processing steps 10
Figure 3-3: Urban flattening. Left: WorldDEM, right: WorldDEM DTM$_{lite}$ 11
Figure 3-4: Forest smoothing: Left: WorldDEM, right: WorldDEM DTM$_{lite}$ 11
Figure 4-1: Product File Structure 14

List of Tables

Table 2-1: Overview of Product Definition 7
Table 2-2: Pixel Spacing Depending on Latitude 8
Table 4-1: Naming Convention 13

Abbreviations

Abbreviation	Description
AoI	Area of Interest
CE90	Circular error (90% confidence level)
DEM	Digital Elevation Model
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DSM	Digital Surface Model
DTM	Digital Terrain Model
EGM2008	Earth Gravitational Model 2008
GeoTIFF	Tag Image File Format - geocoded
HR	High Resolution
LE90	Linear Error (90% confidence level)
SAR	Synthetic Aperture Radar
VHR	Very High Resolution
WGS84-G1150	World Geodetic System1984
XML	eXtensible Markup Language

References

The following Reference Documents were used during the preparation phase of this document (latest available version applicable):

RD-01 DLR Document: TD-GS-PS-0021; DEM Products Specification Document, Version 3.1, 05.08.2016

RD-02 WorldDEM Technical Product Specification, Airbus Defence and Space, Intelligence

RD-03 WorldDEM4Ortho Technical Product Specification (Version 1.4)

1 Introduction

WorldDEM DTM$_{lite}$ is an automatically generated global digital terrain model (DTM) derived from the WorldDEM™ product, offered by Airbus Defence and Space [RD-02].

WorldDEM DTM$_{lite}$ is the only global digital terrain model covering seamlessly and homogeneously the entire land surface of the Earth at an unrivalled resolution of 24 meters meeting high quality standards.

WorldDEM DTM$_{lite}$ constitutes an off-the-shelf automated alternative to the WorldDEM DTM, which is semi-manually edited, and only produced on demand. Like the WorldDEM DTM, the WorldDEM DTM$_{lite}$ profits from the high precision of the WorldDEM product which serves as input to the automated process.

1.1 WorldDEM™ as Data Basis

The WorldDEM™ products are based on the radar satellite data acquired during the TanDEM-X Mission, which is funded by a Public Private Partnership between the German Aerospace Centre (DLR) and Airbus Defence and Space.

The primary goal of the mission was the generation of a worldwide (97% of global landmass), consistent, and high precision Digital Surface Model (DSM) based on SAR interferometry. The two satellites TerraSAR-X and TanDEM-X operate as a single-pass SAR interferometer (InSAR), using the bi-static InSAR StripMap mode. At least two complete coverages of the Earth's surface are used to generate the DSM product. The data acquisition started in January 2011 and was complete by mid-2015.

1.2 Scope

This document describes the specification and format of the WorldDEM DTM$_{lite}$ product. It provides a description of the processing steps, the characteristics of the product as well as the delivery formats.

2 WorldDEM DTM$_{lite}$ Product Definition and Specification

WorldDEM DTM$_{lite}$ is an automatically generated digital terrain model (DTM) globally describing the surface of the Earth regardless of tall vegetation or man-made structures.

The product is based on the digital surface model WorldDEM™ as well as ancillary layers. WorldDEM™ is an edited product, free of void and artefact areas and represents the best available input DSM on a global scale. As supporting data the WorldDEM$_{core,}$ auxiliary files and forest layers are used. For more detail on the auxiliary layers see section 3.

Using the information contained in the WorldDEM™ and the mentioned ancillary layers, the surface structures (non-terrain structures) from the DSM such as built-up areas, forests, as well as selected smaller surface elements with a vertical component (e.g. power pylons, small groups of trees) are levelled down to approximate bare Earth elevation while preserving terrain characteristics (see chapter 3).

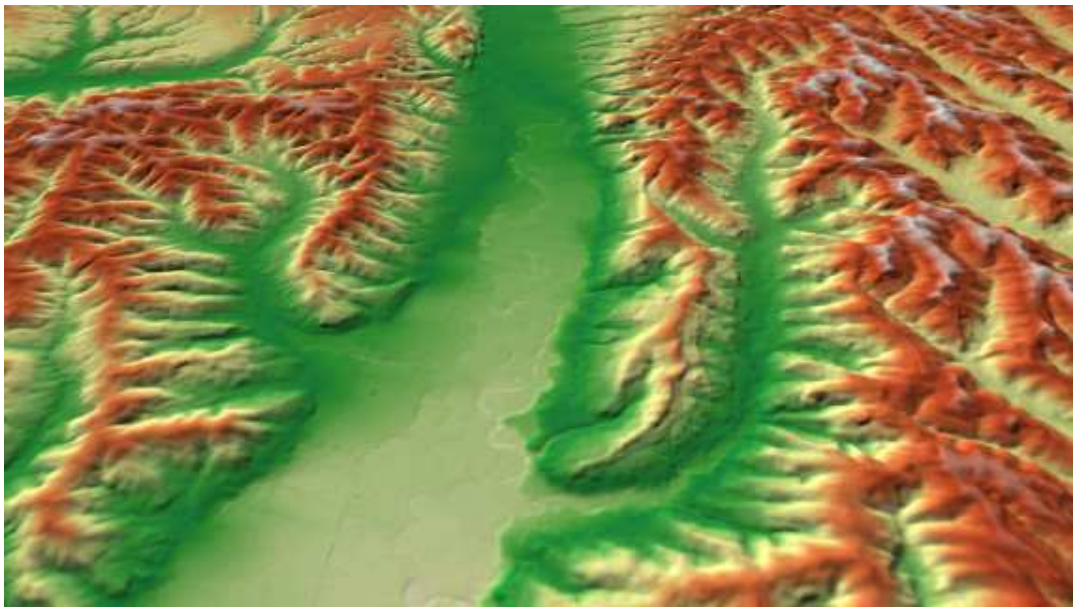

Figure 2-1: WorldDEM DTM$_{lite}$

2.1 Technical Summary

Table 2-1: Overview of Product Definition

Specification Parameter		Value
File format		GeoTIFF
Data type		32 Bit, floating
NoData value		-32767.0
Projection		Geographic Coordinates
Coordinate Reference System	Horizontal	WGS84-G1150
	Vertical	EGM2008
Pixel spacing		0.8 arcsec (approx. 24 m)
Vertical Unit		Meter
Absolute Vertical Accuracy *) ***)		2.5 m (90% linear error)
Relative Vertical Accuracy **) ***)		< 4 m (90% linear point-to-point error within an area of 1° x 1°)
Absolute Horizontal Accuracy *) **) ***)		< 6 m (90% circular error)

*) Based on validation results using ICESat GLAS reference points, excluding parts with permanent snow/ice cover of Antarctica and Greenland (physical reflection properties differ between WorldDEM and reference data).

**) Based on TanDEM-X coherence analysis, excluding parts with permanent snow/ice cover of Antarctica and Greenland (microstructure of regions with permanent snow/ice cover and signal penetration would lead to an overestimation of relative height error and are therefore excluded).

***) Due to the global coverage of the WorldDEM, all accuracy statistics and values stated in this document are calculated as an arithmetic mean on global level. Local deviations occur.

2.2 Accuracy

The accuracy is specified as absolute and relative accuracy.

Absolute accuracy values describe all random or systematic uncertainties of a pixel, in horizontal or vertical direction, with respect to the horizontal or vertical datum used. The errors are expressed as linear or circular error at a 90 percent confidence level and based on global product.

The **relative accuracy** describes the consistency of the digital elevation modelling. The relative accuracy is specified as uncertainty between two DEM pixels caused by random errors. The relative uncertainty is expressed as linear or circular error at a 90 percent confidence level.

The accuracy values for the WorldDEM DTM$_{lite}$ are displayed in Table 2-2. Due to the global coverage of the WorldDEM™, all accuracy statistics and values stated in this document are calculated as an arithmetic mean on global level. Local deviations occur.

2.3 Pixel Spacing

The default grid spacing of the WorldDEM DTM$_{lite}$ product is 0.8 arc seconds (approx. 24 m) in latitude direction. In longitude direction the pixel spacing depends on the latitude as listed in Table 2-2.

Table 2-2: Pixel Spacing Depending on Latitude

Zone	Latitude Band	Latitude Pixel Spacing	Longitude Pixel Spacing
I	0° - 50° North/South	0.8”	0.8”
II	50° - 60° North/South		1.2”
III	60° - 70° North/South		1.6”
IV	70° - 80° North/South		2.4”
V	80° - 85° North/South		4.0”
VI	85° - 90° North/South		8.0”

2.4 Format

The WorldDEM DTM$_{lite}$ product is available as 32-bit floating data in GeoTIFF format. The product is partitioned in 1° x 1° geocells. NoData values (-32767.0) are used for pixels outside the delivered Area of Interest.

2.5 Projection

The WorldDEM DTM$_{lite}$ is available in Geographic Coordinates; the horizontal reference datum is the World Geodetic System (WGS84-G1150) and the vertical reference datum is the Earth Gravitational Model 2008 (EGM2008).

2.6 Coverage

The whole landmass of the Earth is covered (~148.5Mkm²). Small islands and atolls might not be reflected properly. For clarification: areas north of 84°N are not part of the product as there is no land mass present.

3 WorldDEM DTM$_{lite}$ Production Process

The production process of the WorldDEM DTM$_{lite}$ is fully automated and self-calibrating. Urban areas as well as vegetated areas are levelled to ground. The delineation of those areas is carried out with a minimum number of external data to overcome the challenge of possible temporal decorrelation. An interactive quality control is applied to ensure the overall homogeneity and accuracy of WorldDEM DTM$_{lite}$.

3.1 Database

WorldDEM DTM$_{lite}$ is a product based on the manually edited WorldDEM™ (DSM) and its Quality Layers. Additional WorldDEM products (WorldDEM$_{core}$, WorldDEM4Ortho) as well as ancillary forest map data[1] were also used to support the process:

- WorldDEM™ – DEM (s. RD-02):
  - DEM – Digital Elevation Model
  - WBM – Water Body Mask
  - EDM – Editing Mask
- WorldDEM$_{core}$ – (s. RD-01):
  - DEM – Digital Elevation Model
  - HEM – Height Error Map
  - RLM – Reliability Mask
  - COV – Coverage Map
- WorldDEM4Ortho – (s. RD-03):
  - Classification Layer

Editing steps already included in the WorldDEM™ generation:

- Hydrological editing (flattening of water ponds, rivers, and oceans to height levels adapted to local topographic conditions)
- Airport editing (flattening of runways etc. to height levels adapted to local topographic conditions)
- Infill of external DEM datasets into void parts and into areas that are strongly disturbed by SAR specific artefacts
- Filtering of spikes and wells

[1] Data resources used to support the delineation of vegetation areas:

- ESA Climate Change Initiative - Land Cover project 2017
- Sexton, J. O., Song, X.-P., Feng, M., Noojipady, P., Anand, A., Huang, C., Kim, D.-H., Collins, K.M., Channan, S., DiMiceli, C., Townshend, J.R.G. (2013). Global, 30-m resolution continuous fields of tree cover: Landsat-based rescaling of MODIS Vegetation Continuous Fields with lidar-based estimates of error. International Journal of Digital Earth.
- Masanobu Shimada, Takuya Itoh, Takeshi Motooka, Manabu Watanabe, Shiraishi Tomohiro, Rajesh Thapa, and Richard Lucas, "New Global Forest/Non-forest Maps from ALOS PALSAR Data (2007-2010)", Remote Sensing of Environment, 155, pp. 13-31, December 2014. DOI=10.1016/j.rse.2014.04.014.; https://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm

3.2 Processing Steps

The processing steps behind the generation of the WorldDEM DTM$_{lite}$ are completely automated. Surface structures are removed while preserving the hydrological consistency of the input DSM data. An automated quality control step and the generation of the delivery package complete the process. This chapter outlines the basic processing steps.

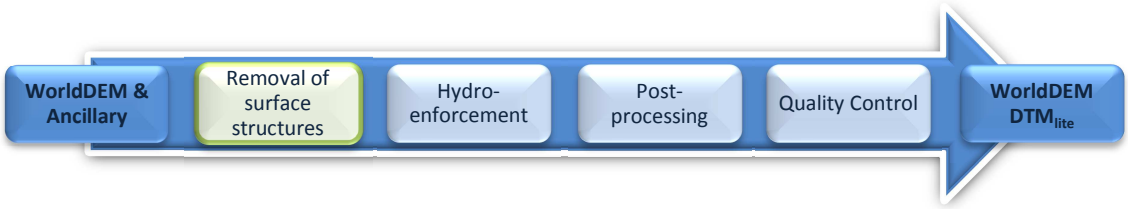

Figure 3-1: WorldDEM DTM$_{lite}$ main processing steps

3.2.1 Removal of Surface Structures

The automated process to remove surface structures uses the pixel and context information within the WorldDEM and the mentioned auxiliary data through its successive steps (Figure 3-2).

In a first step, the surface features are detected and assigned, depending on their thematic and geomorphologic characteristics, to different processing groups. Surface features at each group as well as terrain features are analyzed and characterized in order to calculate the parameters for the height correction processes, as well as specific class-related procedures. After the object height removal a homogenization of the areas is performed. Adapted filtering is applied depending on location taking into account the terrain and surface characteristics.

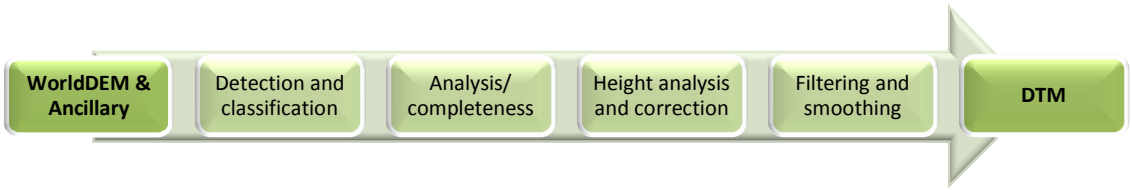

Figure 3-2: Removal of surface structures - main processing steps

The following surface features are removed:

- Built-up areas
    - Single buildings or spatial agglomeration of buildings and man-made features with a vertical component, e.g. apartments, commercial buildings, industrial installations, railway stations, gas stations, airport buildings and halls. Road and rail networks and service land are not included.

- Paved runway, taxiway and apron surfaces of large airports are already flattened to a consistent elevation during the editing process of the WorldDEM (RD-02).

- Vegetation
  - Spatially enclosed canopy areas:
    - Areas covered by large and compact forest patches
    - Agriculture tree areas (e.g. palm tree plantations, fruit tree plantations)
  - Rows and small agglomerations of tall vegetation or single trees (e.g. alleys, gallery forests, hedges)

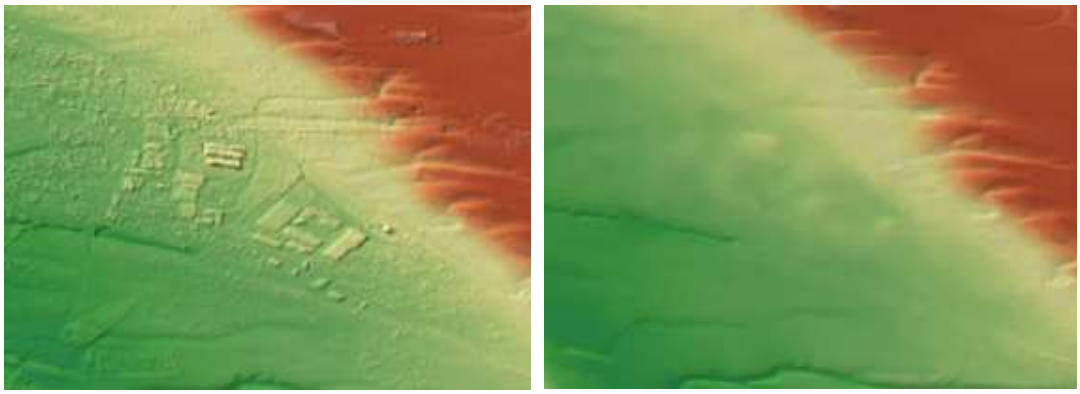

Figure 3-3: Urban flattening. Left: WorldDEM, right: WorldDEM DTM$_{lite}$

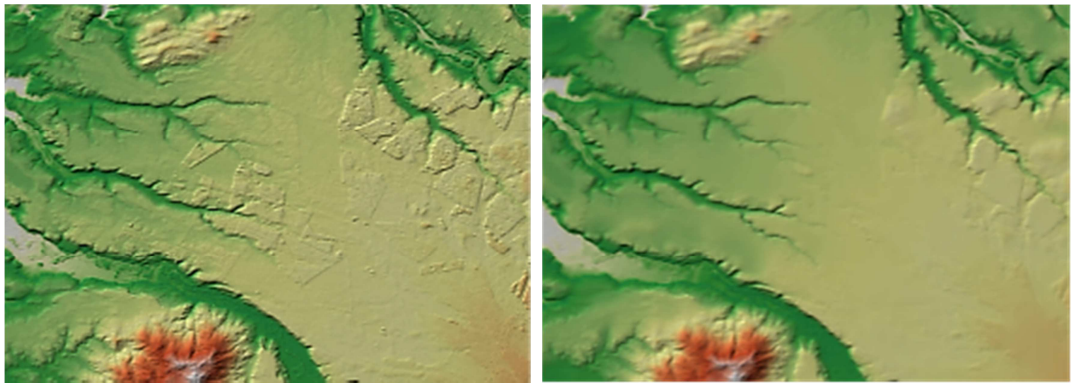

Figure 3-4: Forest smoothing: Left: WorldDEM, right: WorldDEM DTM$_{lite}$

Open land, including agricultural fields, as well as any type of bare soil remain untouched as these already have a proper terrain elevation.

3.2.2 Hydro-enforcement

This step consists of the reimplementation of DSM elevation values for the main hydro features and a shoreline check for identification and correction of hydrologically inconsistent pixels.

The editing of water bodies (hydro-enforcement) is an important processing step to achieve a high quality elevation model. This process is implemented in WorldDEM according to the WorldDEM™ editing specifications (RD-02). In WorldDEM DTM$_{lite}$ water surfaces elevations of the input WorldDEM DSM are preserved.

3.2.3 Post-processing and packaging

The grid spacing of the TanDEM-X/WorldDEM is 0.4 arc seconds in latitude, which equals approximately 12m (exactly 12.37m at the equator and 12.33m near the poles). In longitude, the pixel spacing depends on the latitude (RD-02). This resolution is kept through the production process and changed to 0.8 arc seconds in the last step.

The resampling process is tailored to ensure hydrological consistency.

3.2.4 Quality Control

The production of the WorldDEM DTM$_{lite}$ is based on fully automated scripts applied to the WorldDEM data. Data quality of each produced geocell is ensured with the application of quality checks in respect to formal, statistical and visual consistency:

- Automated QC tools check for location, completeness and consistency.
- Interactive quality control on random datasets is also applied to ensure the overall homogeneity and accuracy of WorldDEM DTM$_{lite}$.

4 Packaging

The packaging process is done according to the product structure documented in the following sections.

4.1 Naming Convention

The file naming convention is standardized as follows:

WorldDEM_AAA_BB_YDD_EE_XGGG_HH

Example: WorldDEM_LIT_08_S33_00_E138_00

The bold letters are fixed and remain unchanged at all times. The other letters have the meanings as explained in Table 4-1. The file name always corresponds to the lower left corner coordinate (centre of Southwest pixel) of the AoI or bounding box corner, respectively.

Table 4-1: Naming Convention

Letter	Meaning
AAA	DEM Product: LIT = WorldDEM DTM$_{lite}$
BB	Pixel Spacing: 08: 0.8-arcsecond grid
YDD_EE_XGGG_HH	Geo-location of lower left corner in decimal degree e.g. N20_00_W120_00
Y	N (North) or S (South) hemisphere
DD	Latitude in Degree (Range: 0 - 90)
EE	Decimal Latitude Degree (Range: 0 - 99)
X	W (West) or E (East)
GGG	Longitude in Degree (Range: 0 - 180)
HH	Decimal Longitude Degree (Range: 0 - 99)

4.2 Additional datasets

The following data is provided with the WorldDEM DTM$_{lite}$ product.

4.2.1 Metadata

The metadata contains information on the input products, editing process, statistical parameters and general information for all delivered product components. The metadata is ISO 19115 compliant.

The Metadata is delivered as an xml-file.

4.3 Product File Structure

All product files are structured under the delivery folder (see Figure 4-1) as follows:

- **xml** file (Metadata)
- **INFO** folder containing the Applicable Contract / Licence Terms document (pdf)
- **DEM** folder containing elevation data (GeoTIFF)

For file naming convention see chapter 4.1.

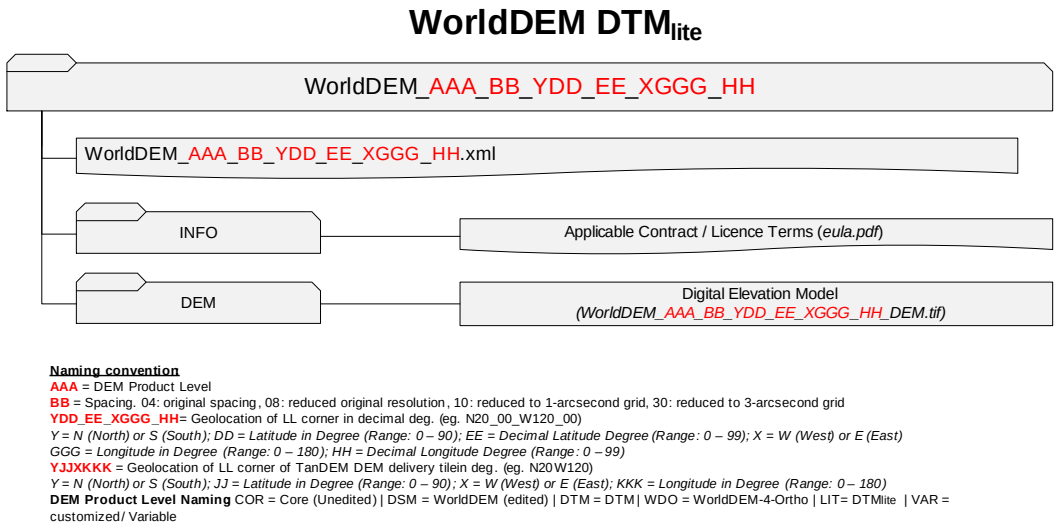

Figure 4-1: Product File Structure