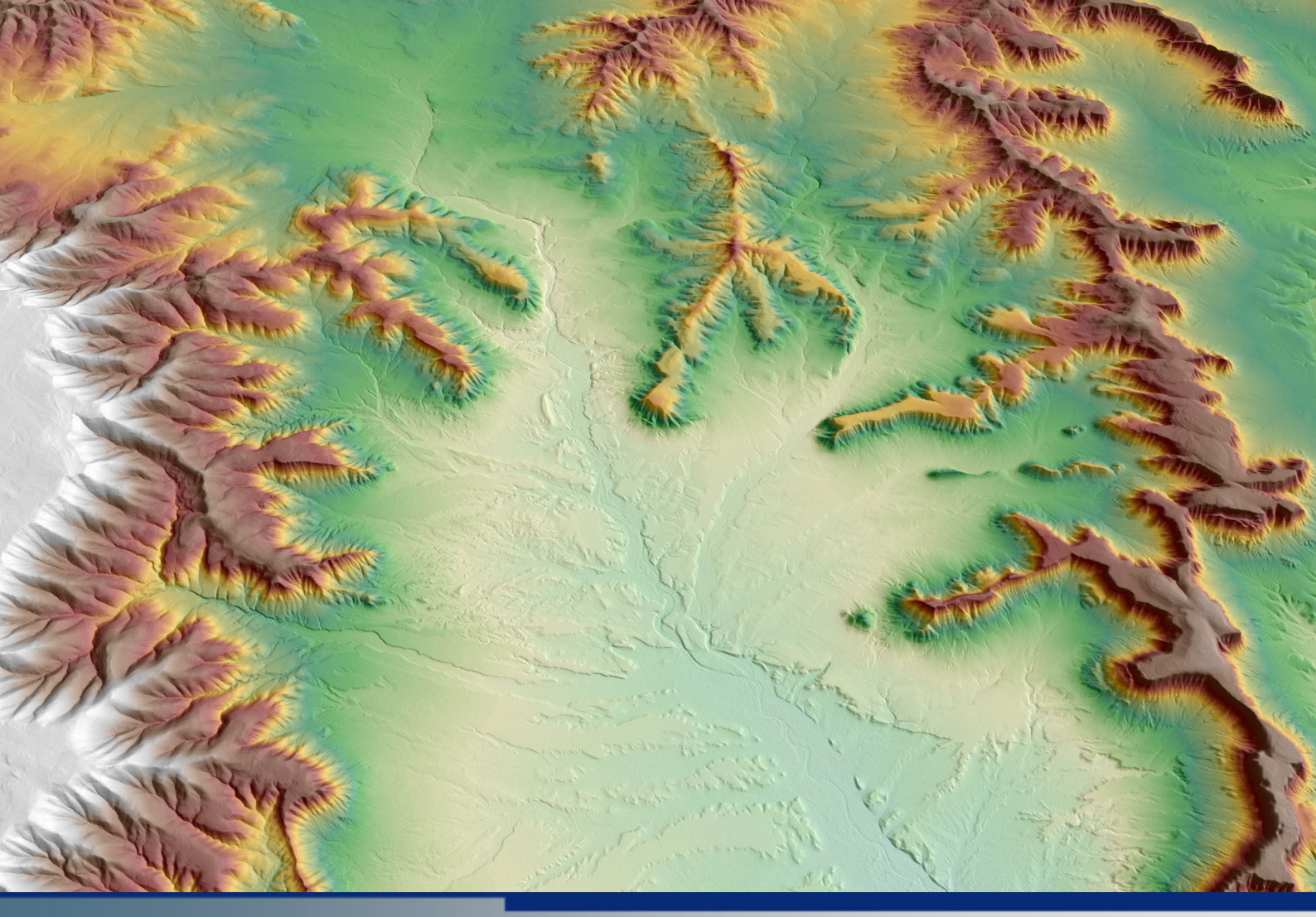

WorldDEM4Ortho

Technical Product Specification

Version 1.4

AIRBUS DEFENCE AND SPACE
Intelligence

AIRBUS

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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
LE90	Linear Error (90% confidence level)
SAR	Synthetic Aperture Radar
WGS84-G1150	World Geodetic System1984
XML	eXtensible Markup Language

References

The following Reference Documents were used during 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

1 Introduction

WorldDEM4Ortho is an elevation information layer optimized for orthorectification of high-resolution (HR) and very high resolution (VHR) optical and radar images. It is the most homogenous and accurate elevation model for orthorectification on a global scale.

WorldDEM4Ortho is a digital elevation model based on the WorldDEM product offered by Airbus Defence and Space (DS) which covers the entire land surface of the Earth.

1.1 WorldDEM4Ortho 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 operation of the satellites in orbit, the data acquisition as well as the interferometric processing of the data is performed by DLR. Airbus Defence and Space is refining the processed data and has the commercial exploitation rights of the WorldDEM data.

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 DEM 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 WorldDEM4Ortho product. It provides a description of the processing steps, the characteristics of the product as well as the delivery formats.

2 WorldDEM4Ortho Product

WorldDEM4Ortho is a digital elevation model (DEM) specified as elevation information input for orthorectification processes.

2.1 Description

The product is derived from the unedited WorldDEM, called "$WorldDEM_{core}$" and its Auxiliary Layers (s. RD 01, RD 02) by automatic processing. Urban areas are levelled down to ground level, approximately. In these areas the WorldDEM4Ortho is a Digital Terrain Model (DTM) -like product. This approach is applied to avoid artefacts in the resulting orthorectified optical and radar images. All other areas are represented by the object's surface, thus, in these areas the dataset is a Digital Surface Model (DSM).

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.

This provided data is checked for data set completeness, the technical specification of the product content as well as for visual consistency to guarantee that the automated process corrected all identified issues within the data.

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 WorldDEM4Ortho 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 2-1.

Table 2-1: 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 WorldDEM4Ortho product is available as 32-bit floating data in GeoTIFF format. NoData values (-32767.0) are used for points where the elevation information could not be determined. The product is partitioned in 1° x 1° geocells, which is the standard delivery unit.

2.5 Projection

The WorldDEM4Ortho 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. Small islands and atolls might not be reflected properly. For clarification: The North Pole is not part of the product as there is no land mass present.

2.7 Summary

Table 2-2: 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 *) **) ***)		< 4 m (LE90%)
Relative Vertical Accuracy *) **) ***)		< 2 m (slope ≤ 20% LE90%) < 4 m (slope > 20% LE90%) (90% linear point-to-point error within an area of 1° x 1°)
Absolute Horizontal Accuracy **) ***)		< 6 m (CE90%)

*) Excluding urban areas which are “DTM-like-areas” as described above
**) Excluding area of Antarctica and Greenland
***) 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.

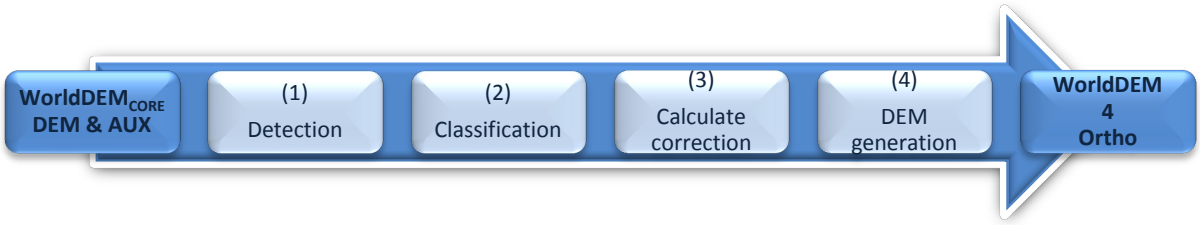
3 WorldDEM4Ortho Production Process

3.1 Database

WorldDEM4Ortho is a product based on WorldDEM$_{core}$ and its Auxiliary data (s. RD-01, RD-02). Additionally, ancillary elevation models[1] are used to fill-in in case of larger voids (see Chapter 3.3.1).

3.2 Processing Steps

WorldDEM4Ortho production process is performed automatically in the following steps. In distinction from the WorldDEM product, manual editing is not applied.



1. Detection of areas (patches) where processing is required.
2. Classification of areas identified in step 1 (see chapter 3.3):
   a. **Terrain**: areas of radar layover, foreshortening and shadowing, radar artefacts (spikes and wells), voids.

[1] Data resources used to enhance licensed data material (void filling):

- ALOS World 3D-30m (AW3D30) provided by Japan Aerospace Exploration Agency (JAXA)
- ASTER Global Digital Elevation Map retrieved from https://asterweb.jpl.nasa.gov/gdem.asp, NASA/METI/AIST/Japan Space Systems, and U.S./Japan ASTER Science Team
- NASA LP DAAC, 2013, NASA Shuttle Radar Topography Mission Global 1 arc second, Version 3.0. NASA EOSDIS Land Processes DAAC, 2013 USGS Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota (https://lpdaac.usgs.gov), accessed May 2nd 2017 at https://doi.org/10.5067/MEaSUREs/SRTM/SRTMGL1.003.
- STRM Digital Elevation Data retrieved from http://earthexplorer.usgs.gov/ and from http://srtm.csi.cgiar.org/
  U.S. Geological Survey, https://lta.cr.usgs.gov/sites/default/files/Data%20Citation_1.pdf
- For Greenland: Greenland Mapping Project (GIMP) Digital Elevation Model retrieved from https://bpcrc.osu.edu/gdg/data/gimpdem
  Howat, I., A. Negrete, and B. Smith. 2015. MEaSURES Greenland Ice Mapping Project (GIMP) Digital Elevation Model, Version 1. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: http://dx.doi.org/10.5067/NV34YUIXLP9W.
- For Alaska: USGS NED 2 retrieved from https://www.sciencebase.gov/catalog/item/56954d4ee4b039675d006037
  U.S. Geological Survey, Department of the Interior/USGS
- For Canada: Canadian Digital Elevation Data retrieved from http://geogratis.gc.ca/site/eng/extraction
  Natural Resources Canada, http://open.canada.ca/en/open-government-licence-canada
- For Iceland: Free Digital Data retrieved from http://www.lmi.is/en/stafraen-gogn/
  National Land Survey of Iceland, http://www.lmi.is/wp-content/uploads/2013/10/licenceNLSI.pdf
- For Scandinavia and Russia: Free Digital Data retrieved from http://viewfinderpanoramas.org/index.html
  Viewfinder Panoramas,
  Jonathan de Ferranti, Developed Digital Elevation Models based on data collected by the 2000 Shuttle Radar Topography Mission, retrieved at http://viewfinderpanoramas.org/dem3.html
- For Antarctica: Antarctic Mapping Project Digital Elevation Model, retrieved from https://nsidc.org/data/nsidc-0082, Liu, H., K. C. Jezek, B. Li, and Z. Zhao. 2015. Radarsat Antarctic Mapping Project Digital Elevation Model, Version 2. [subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center.

b. **Hydrology**: water ponds (lakes, reservoirs), rivers and coastal water

c. **Urban areas**: dense urban areas, single buildings including streets; urban areas with trees are partial included.

3. Correction of the classified areas:

   a. Small voids and artefacts of any category are interpolated considering the surrounding pixels.

   b. For terrain-based artefacts and larger voids are filled with ancillary DEM data.

   c. Water based artefacts are flattened onto a single water level derived from shoreline pixels. Coastal water is set to sea level 0. Rivers are stepped with a flow following the surrounding shorelines (no hydrological enforcement).

   d. Areas classified as “urban” are levelled to ground approximately (“DTM-like-area”) as in large and dense urban areas often no reliable ground information can be determined.

4. Implementation of all replacement patches into the $WorldDEM_{core}$ followed by post-editing filter operations.

The generation of the WorldDEM4Ortho product is performed on geocell basis. After that an edge matching procedure is implemented to match the adjacent geocells against each other (due to different pixel spacing no edge matching possible between the different latitude zones as specified in table 2-1).

3.3 WorldDEM4Ortho Processing Specification

In this chapter the processing rules applied to the identified classes are described in the categories “terrain”, “hydrology” and “urban area”.

3.3.1 Terrain Feature Processing

The terrain editing comprises the correction of terrain artifacts caused by SAR specific characteristics or DSM processing. The processing rules applied during the terrain processing are summarized in the following table.

Table 3-1: Terrain Feature Processing

Feature	Procedure
Layover, Foreshortening (SAR specific features)	Patches of ≤ 16 pixels: • Interpolation considering pixels adjacent to the patch
	Patches of > 16 pixels: • Classification of layover areas using knowledge based operations • Replacement of identified areas using ancillary DEM data
Shadow (SAR specific feature)	Patches of ≤ 16 pixels: • Interpolation considering pixels adjacent to the patch
	Patches of > 16 pixels: • Classification of areas using iterative algorithms • Replacement of identified areas using ancillary DEM data

Feature	Procedure
Spikes & Wells	• Interpolation considering pixels adjacent to the patch

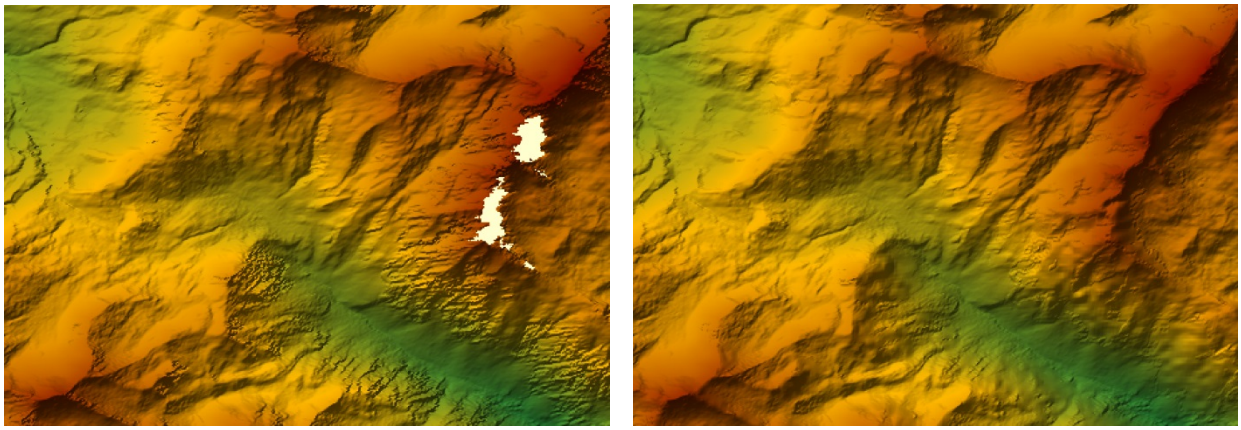


Figure 3-1: Void, layover and shadow areas (left), correction via infill of ancillary DEM data (right)

3.3.2 Hydrologic Feature Processing

In this process lakes (incl. reservoirs), rivers and oceans are considered according to the water portrayal in the used ancillary data (amplitude mosaic). Water surfaces not detectable as water are not considered as water and remain untreated, e.g. frozen water, narrow and small rivers, etc. In limited cases, an over-detection of water occurs.

Rivers are implemented with height levels oriented at the shoreline structure. This does not include a proper hydro-enforcement (runoff direction), e.g. no monotonic river flow is implemented.

Water height level in lakes or rivers is calculated geocell-individually. Thus, for trans-geocell lakes or rivers differences in water height levels arise at borders between two (or more) geocells. A border matching process provides homogeneous transition between the water levels on adjacent geocells.

The following table describes the hydrologic feature processing rules.

Table 3-2: Hydrologic Feature Processing

Feature	Procedure
Water basins	• Identification of basin extent • Levelling of identified area considering shoreline height values from DEM
Rivers	• Identification of river extent • Levelling of identified area considering shoreline height values from DEM • Terracing of rivers to adapt river course to terrain
Coastal water	• Identification of water extent • Levelling of identified area and set to sea level (0m)

3.3.3 Urban Area Processing

The content of the urban class is complex since all built-up elements have to be identified in the data (Table 3-3).

Urban structures not identified in the process will only be treated locally during the global smoothing filter process. The result will be a more rough appearance of the DEM.

Table 3-3 lists all urban structures and the procedure applied.

Table 3-3: Urban Feature Processing

Feature	Procedure
Large buildings	Smoothed to terrain level
Small buildings, suburbs	Smoothed to terrain level
Roads within built-up structures	No relevant change if already flat appearance
Overland roads	Slight smoothing
Railway structures	Flattening
Bridges	smoothing to ground / water level (exceptions may occur depending on size and bridge type)
Flat but sealed areas (parking lots etc.)	Slight smoothing
Sealed areas on airports (runways, aprons, taxiways)	Interpolation from adjacent non-sealed areas (including water ponds in airport areas)

4 Naming Convention

The file naming convention is standardized as follows:

WorldDEM_WDO_BB_YDD_EE_XGGG_HH

Example: WorldDEM_WDO_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.

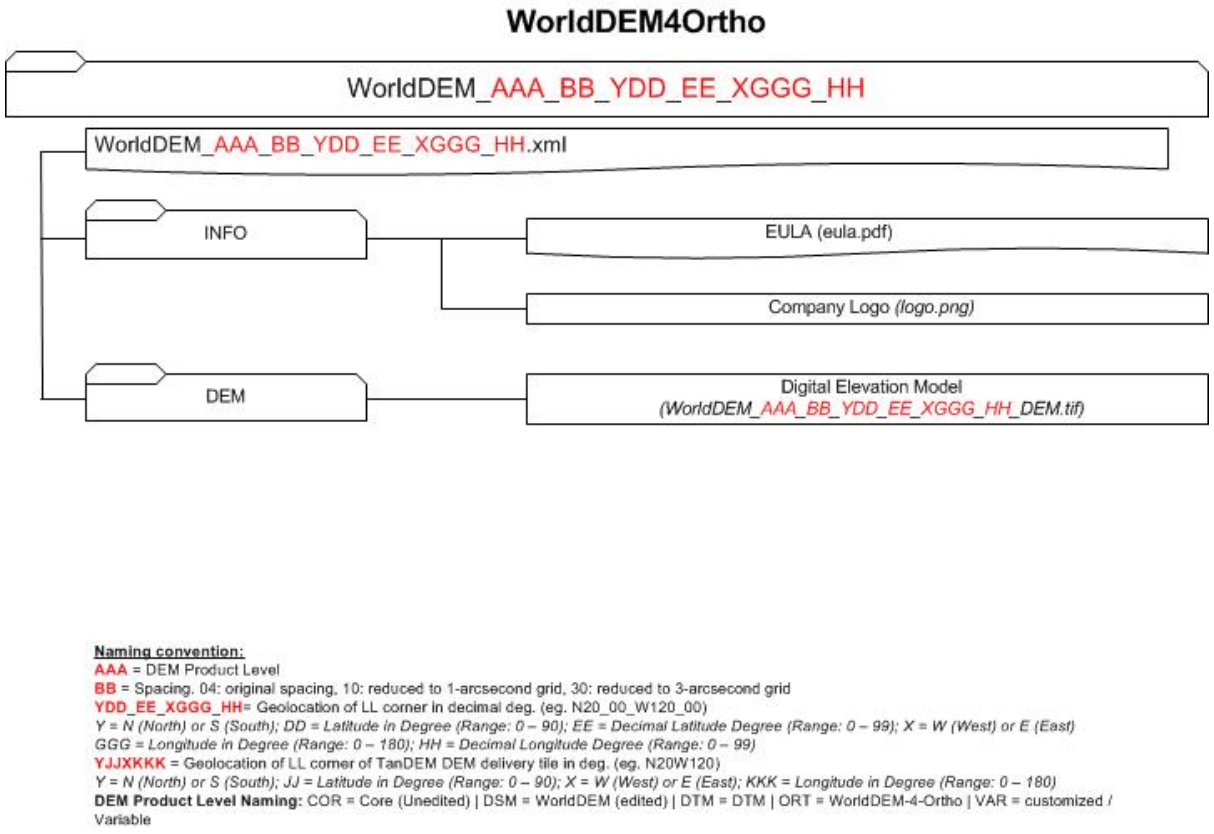
Table 4-1: Naming Convention

Letter	Meaning
WDO	DEM Product: • WDO = WorldDEM4Ortho
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)

5 Product File Structure

All product files are structured in the delivery folder (see Figure 5-1) as follows:

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



Naming convention:
AAA = DEM Product Level
BB = Spacing. 04: original spacing, 10: reduced to 1-arcsecond grid, 30: reduced to 3-arcsecond grid
YDD_EE_XGGG_HH= Geolocation of LL corner in decimal deg. (eg. N20_00_W120_00)
Y = N (North) or S (South); 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)
YJJXKKK = Geolocation of LL corner of TanDEM DEM delivery tile in deg. (eg. N20W120)
Y = N (North) or S (South); JJ = Latitude in Degree (Range: 0 – 90); X = W (West) or E (East); KKK = Longitude in Degree (Range: 0 – 180)
DEM Product Level Naming: COR = Core (Unedited) | DSM = WorldDEM (edited) | DTM = DTM | ORT = WorldDEM-4-Ortho | VAR = customized / Variable

Figure 5-1: Product File Structure