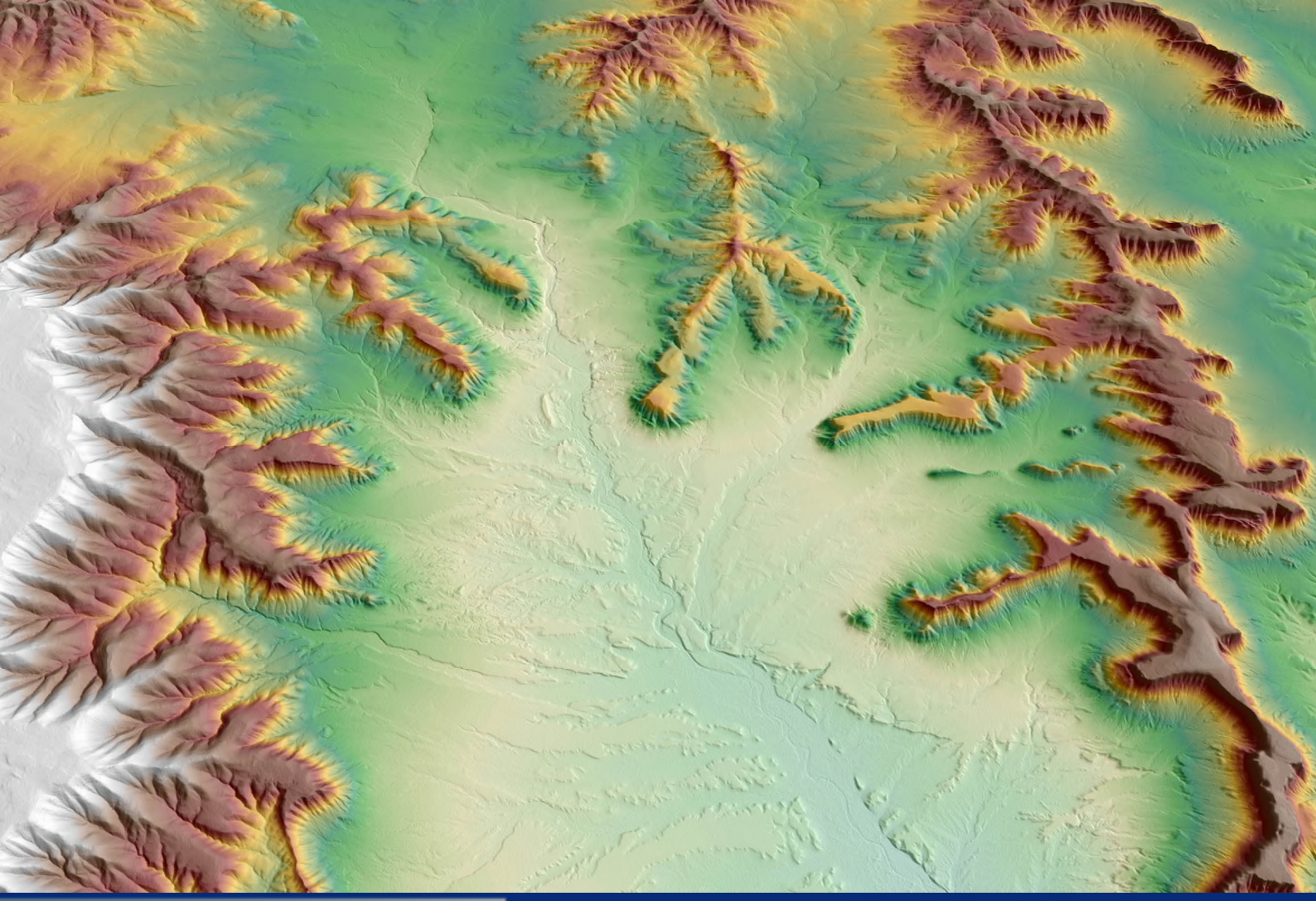

WorldDEM4Ortho
(Version 2)

Technical Product Specification

Issue 1.1

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
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)

RD-04 DEM Quality Analysis: Generation of DEM Performance Mask

1 Introduction

WorldDEM4Ortho (Version 2) is an elevation information layer optimized for the 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 which covers the entire land surface of the Earth. In comparison to earlier versions of the product, WorldDEM4Ortho Version 2 features increased homogeneity and improved processing of specific land cover classes, such as urban areas and vegetated areas.

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 (Version 2) Product

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

2.1 Description

The WorldDEM4Ortho is in fact a hybrid digital elevation model. Superstructures such as urban building areas as well as small objects (e.g. power pylons) and trees, small groups of trees and gallery forests are levelled down to approximate bare ground. In these areas the WorldDEM4Ortho is a Digital Terrain Model (DTM) -like product. Vegetated areas including large forest areas and bare soil are represented as digital surface model with moderate smoothing.

The product is based on the semi-automatically and manually edited WorldDEM™ and its Auxiliary Layers (s. RD-01, RD-02). WorldDEM is free of void and artefact areas and represents the best available input data on a global scale.

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: areas north of 84°N are 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 **) ****)		2.5 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 originating from DTM_{lite} as described above

**) 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.

3 WorldDEM4Ortho (Version 2) Production Process

3.1 Database

WorldDEM4Ortho is a product based on the manually edited WorldDEM and its Auxiliary Layers (s. RD-01, RD-02). Ancillary elevation models[1] were used during the production of WorldDEM to create a digital surface model that is free from voids and artefacts.

Additionally, ancillary forest map data[2] were used to support the delineation of vegetated areas (see chapter 3.2).

The WorldDEM product is an edited DSM produced based on the $WorldDEM_{core}$ product. The main editing steps of the DSM include the following elements:

- 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 enhance licensed data material (void filling):

- 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
- 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
- GMTED2010 Elevation Data retrieved from http://earthexplorer.usgs.gov/ produced by the U.S. Geological Survey, https://lta.cr.usgs.gov/sites/default/files/Data%20Citation_1.pdf
- 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.
- ALOS World 3D-30m (AW3D30) provided by Japan Aerospace Exploration Agency (JAXA)

[2] 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

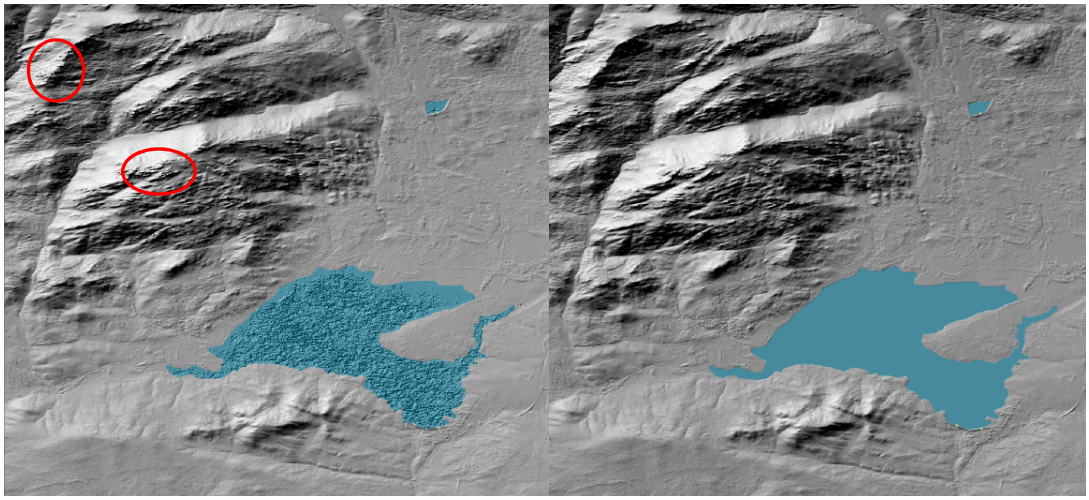

Figure 3-1: Water editing (blue), infills (red circles). Left: WorldDEM$_{core}$, Right: WorldDEM

3.2 Processing Steps

This chapter describes the basic processing steps performed to generate WorldDEM4Ortho.

3.2.1 Urban built-up areas

Urban built-up areas in the WorldDEM dataset used as input show buildings and other structures. For WorldDEM4Ortho, urban structures are removed and bare ground information is visible instead.

This urban flattening is required to allow the generation of orthorectified images without disturbances on ground structures (e.g. roads) and also on building structures.

This editing step is done via automated processing and under consideration of the existing WorldDEM4Ortho urban classification information.

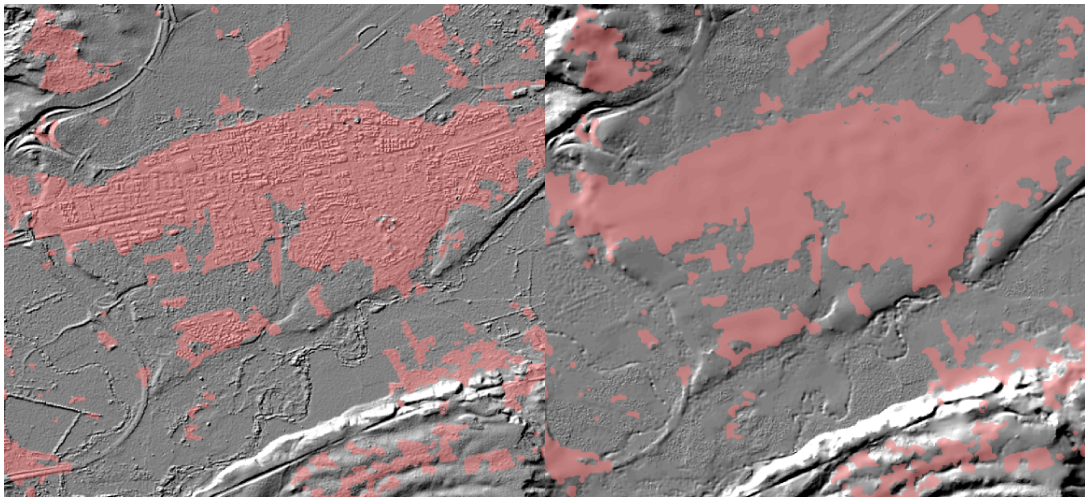

Figure 3-2: Urban flattening. Left: WorldDEM, right: WorldDEM4Ortho (Version 2)

3.2.2 Vegetation, open land, bare soil

Areas covered by larger and compact forest patches are slightly filtered to generate a smooth appearance of vegetation canopy.

This surface smoothing on vegetation canopies allows the generation of high resolution ortho imagery without blurring of visible vegetation structures, e.g. branches, leaves, etc.

Small forest patches as well as tree rows, e.g. alleys, gallery forests, are flattened down to ground level if their depth is less than approximately 60m.

Open land, including agricultural fields, as well as any type of bare soil are slightly smoothed analogue to larger forests.

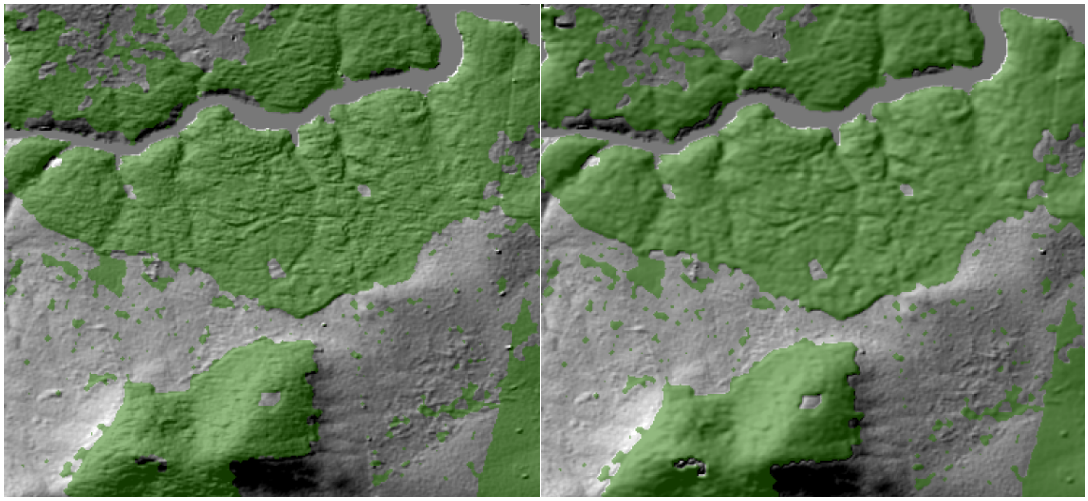

Figure 3-3: Forest smoothing: Left: WorldDEM, right: WorldDEM4Ortho (Version 2)

3.2.3 Roads and Railways (Linear Features)

Certain roads and railways are smoothed to remove DEM artefacts or non-artefacts like trees or buildings covering parts of the linear feature. These artefacts would disturb the appearance of linear features in the ortho images generated using WorldDEM4Ortho data.

Bridges crossing linear features are also smoothed to remove frequently occurring artefacts such as gaps, bumps, etc.

All linear features and implemented bridges are based on external line vector data (Open Street Map data).

The following table shows the categories of the implemented linear features.

Figure 3-4 and Figure 3-5 show the effects of linear features on the input WorldDEM data.

Table 3-1: Linear Feature Implementation

Linear Feature Category	Urban areas	Non-urban areas
Motorways	Smoothed	Smoothed
Trunks	Ignored due to urban flattening	Smoothed
Primay Roads	Ignored due to urban flattening	Smoothed
Railways (no tram or subways)	Ignored due to lack of coverage, especially in inner-urban stations or rail yards	Smoothed
Bridges crossing linear features	Smoothed for motorways	Smoothed for all linear features implemented in the DEM

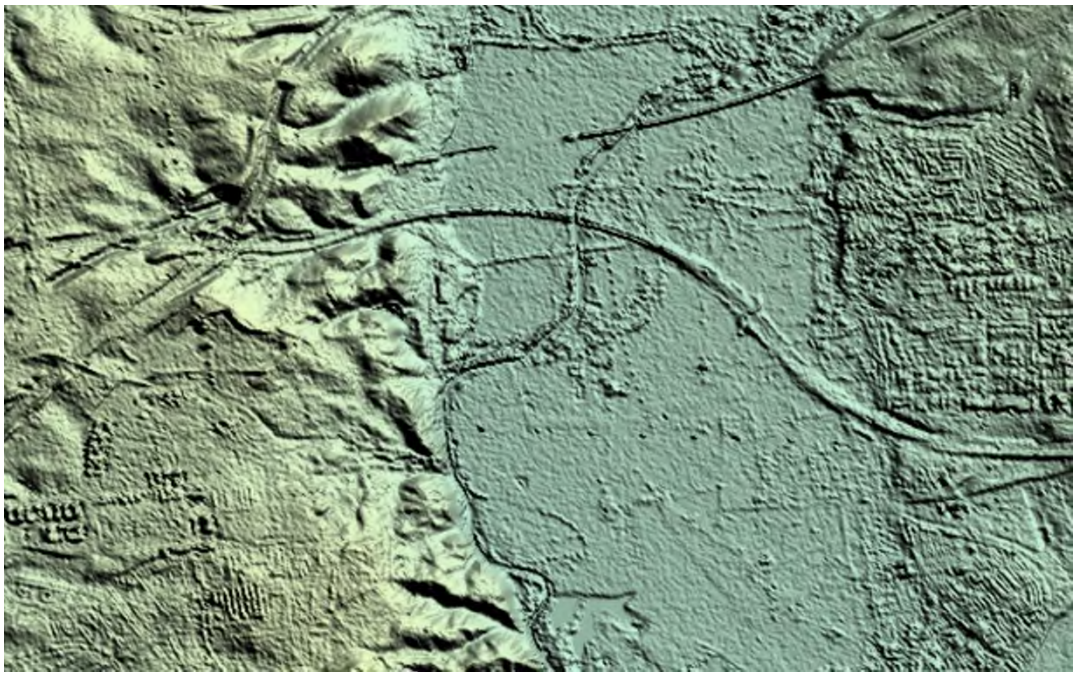

Figure 3-4: WorldDEM containing streets and railway

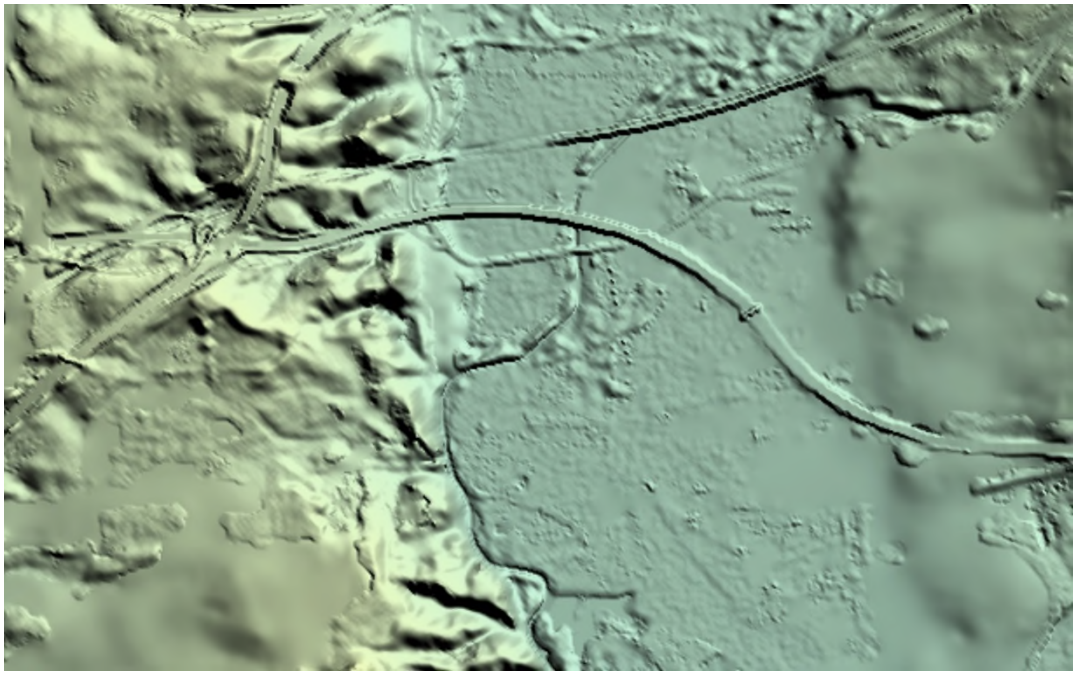

Figure 3-5: WorldDEM4Ortho (Version 2) containing smoothed streets and railways. Bridges crossing traffic lines are smoothed as well.

4 Annex

4.1 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)

4.2 Additional datasets

The following data is provided with the WorldDEM4Ortho 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.

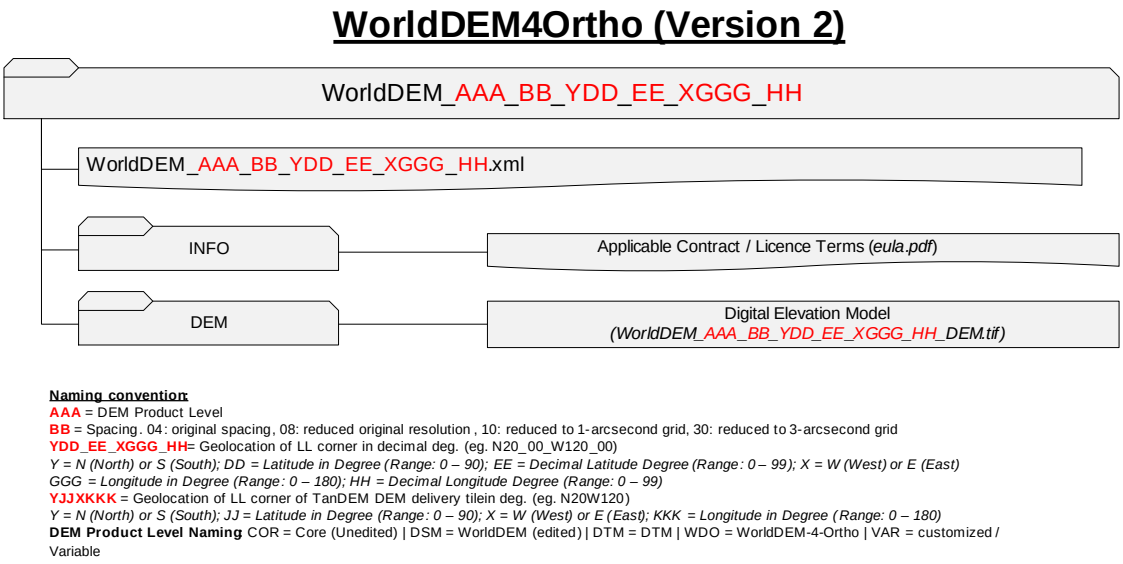

Figure 4-1: Product File Structure