

Continent-wide DEM Creation for the European Union

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Abstract – This paper presents a new digital elevation model (DEM), called EU-DEM, which covers the 32 member countries and 6 cooperating countries of the European Environment Agency, named EEA38. Under the direction of the European Commission's Directorate-General for Enterprise and Industry and prime contractor Indra Espacio, Intermap Technologies® will create and deliver this middle-precision DEM to the European Commission as a new elevation data theme for its Earth Observation initiative GMES, and in particular to support the implementation of the Land Monitoring and Emergency Response services. The EU-DEM is currently created from a fusion of improved ASTER GDEM data with SRTM data supported by Intermap's high-precision NEXTMap® Europe dataset.

Keywords: GMES, Land Monitoring, Emergency Response, Digital Elevation Model (DEM), EU-DEM, NEXTMap, SRTM, ASTER GDEM

1. INTRODUCTION

With the entry into force of the Lisbon Treaty on 1 December 2009, the European Union has strengthened Europe's role in the world. The modifications and innovations regulated in the treaty include common environmental and safety issues and thus indirectly affect the European Union's contribution to the Global Earth Observation System of Systems called GMES (Global Monitoring for Environment and Security). One goal of GMES is to provide homogeneous geospatial data and downstream services on both a global and European level.

The challenges due to the lack of consistency, quality, coverage, currency, precision and licensing in the elevation datasets held by the legally mandated organizations, such as the National Mapping Agencies, present a formidable technical obstacle to their consideration as a pan-European elevation data source. The elevation model discussed in this paper, called EU-DEM, goes back to an open tendering procedure of the European Commission (EC). In mid 2009, the EC was looking for an inexpensive and quick solution for creating spatial reference data for Europe, which will be made available by a first GMES service. Initially, it will primarily serve nationwide hydrography and elevation data. Access to the data will be established through a new middleware service component, capable of serving GMES services and end-user applications linked-up to the INSPIRE geo-portal. Figure 1 illustrates the draft concept of that service. The project area (EEA38) covers a total area of about 5.84 million km² and is shown in Figure 2.

As part of a multi-national consortium led by Indra Espacio, Intermap undertakes an innovative fusion of the ASTER GDEM (Advanced Spaceborne Thermal Emission and Reflection Radiometer) and SRTM (Shuttle Radar Topography Mission) for the generation of this new, hybrid EU-DEM. Intermap Technologies' more precise NEXTMap Europe elevation data (Mercer, 2009) is used for the accuracy improvement of the satellite data during the data fusion process.

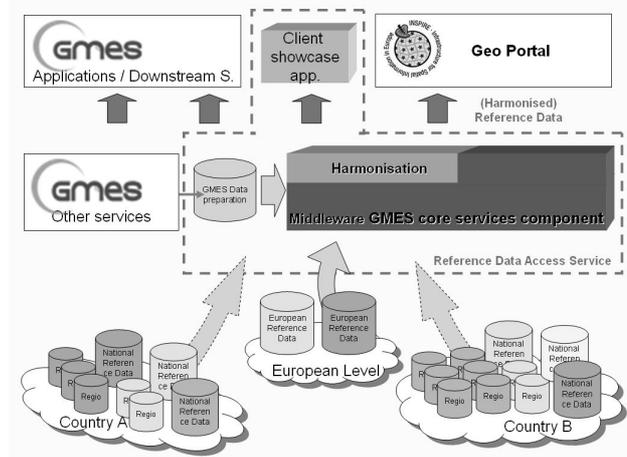


Figure 1. Overall draft concept of the initial GMES reference data access service (European Commission, 2009)

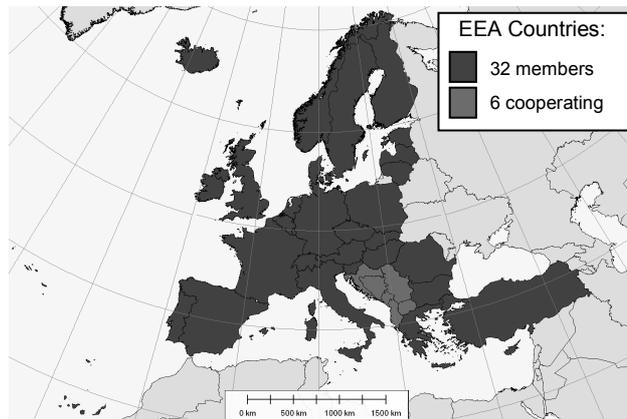


Figure 2. Coverage of the EU-DEM (EEA38)

2. DATA SOURCES

Currently, no existing or upcoming elevation dataset completely meets the requirements with respect to coverage and accuracy. The challenges which are caused by the lack of consistency, coverage, topicality and accuracy of the elevation datasets are a massive problem in the timely delivery of pan-European elevation data. In order to overcome those challenges, including licensing restrictions, it was decided to use existing and easily available elevation data as sources for the new EU-DEM.

ASTER is a passive, multispectral remote sensing instrument, which has been in use since 1999 on the Terra satellite and providing coverage of the earth's surface except for the polar regions. The ASTER Global Digital Elevation Model (GDEM) was created by the Japanese Ministry of Economy, Trade and Industry (METI) and the National Aeronautics and Space

Agency (NASA) based on approximately 1.5 million individual scenes using stereo image correlation. The original GDEM is owned by METI and NASA, but has been made freely available for certain GEOSS applications since late June 2009 (JPL, n.d.).

In contrast, the SRTM data originates from an interferometric RADAR mission, taken with the Space Shuttle Endeavour during 11 days in February 2000. For further information about the SRTM data and its accuracy see Rodriguez et al. (2005).

For areas north of 60° latitude elevation data derived from Russian topographic maps and provided by the Joint Research Centre (JRC) of the EC are used as a substitute for the missing SRTM coverage.

The main product specifications for both source datasets and the fused EU-DEM are shown in Table 1.

Table 1. Main product specifications

Product name	GDEM	SRTM-3	EU-DEM
DEM type	DSM	DSM	DSM
File format	GeoTIFF signed 16bit	DTED1 signed 16bit	GeoTIFF 32bit float
Coordinates	geographic	geographic	geographic
Datum (X,Y)	WGS84	WGS84	ETRS89
Datum (Z)	WGS84	WGS84	EVRS
Geoid	EGM96	EGM96	EGG08
Tile size	1° x 1°	1° x 1°	1° x 1°
Grid spacing	1"	3"	1"
Coverage	83°N – 83°S	60°N – 56°S	EEA38
Accuracy (Z) [LE95]	~ 20 m	~ 14 m	< 14 m ^a
Accuracy (X,Y) [CE95]	~ 30 m	~ 10 m	~ 8 m ^a
Metadata	-	-	INSPIRE
Availability	since 2009	since 2003	in 2011

^a expected

The NEXTMap Europe elevation data also originates from an InSAR mapping campaign, realized by airborne radar systems developed and operated by Intermap Technologies and has been completely available since 2009. The DTM and DSM data cover 20 Western European countries at a consistent grid spacing of 0.15 arcseconds (< 5 m). The vertical and horizontal accuracies for unobstructed, low slope areas are 2 m (LE95) respectively 4 m (CE95).

3. METHOD OF EU-DEM CREATION

The innovative method applied for the creation of the EU-DEM combines the advantages of both digital surface models (DSMs), supported by the high accuracy of NEXTMap data (Figure. 3) and improved by a new hydrography dataset.

Figure 4 gives an overview over the high-level workflow of that EU-DEM creation.



Figure 3. Innovative fusion approach

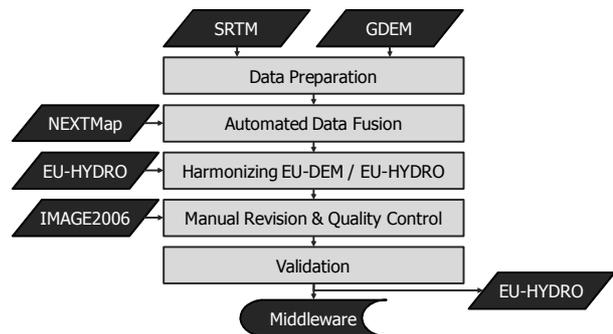


Figure 4. EU-DEM generation workflow

3.1 Data Preparation

The first step in the fusion workflow consists of the input data preparation. The following processing steps are performed before the data is merged:

1. Removal of areas in the GDEM that were generated by less than five scenes and covered by clouds
2. Conversion of the files into a 32bit binary format
3. Standardization of the grid spacing to 1" (SRTM and NEXTMap data)
4. Vertical datum transformation by replacing the EGM96 geoid by the latest EGG08
5. Restoration of the originally with SRTM filled voids in the GDEM
6. Identification and removal of extremely differing GDEM data

Note on step 1.) There is a relationship between the number of scenes that were used for the terrain modelling, and expected accuracy. Internal tests showed that this threshold is five, this means in areas comprising five or more scenes in general the GDEM is consistent. Therefore, for the EU-DEM generation all areas consisting of less than five scenes are excluded from the calculation.

Note on Step 5.) The voids in the GDEM were filled automatically with SRTM-3 v2 and v3 data. Since the two data sets were not adjusted vertically before the void filling, those areas often contain jumps in the elevation. Those areas are documented for each tile in a so called QA file and are restored before further processing.

Since various studies have shown that the GDEM data had both a horizontal and vertical displacement, this should also be corrected to improve accuracy. For this purpose, the individual GDEM tiles are correlated with the accurate NEXTMap Europe

data DOM (horizontal) and SRTM data (vertical). The offsets for each tile are corrected accordingly.

When verifying the vertical accuracy of the SRTM data using 8,300 vertical check points in unobstructed areas a mean error of 3m was found. Before fusion this bias is corrected.

3.2 Automated data fusion

The GDEM data (version 1) covers a larger extent than SRTM at a higher grid spacing. However, it still contains more artefacts which are described in the validation report by METI / ERSDAC et al. (2009) as "residual clouds", "bumps", "pits" and "mole runs". These artefacts are more pronounced in the flat terrain than in the mountains. SRTM data on the other hand, contains more voids in mountainous areas due to radar shadow.

By applying a terrain slope-dependent, weighted averaging method, both data sets are fused together. In areas of flat terrain a higher weight is on the SRTM data, whereas in areas with more relief the focus is rather on the GDEM. By this method, many of the above mentioned GDEM artefacts are eliminated and voids filled.

3.3 Harmonizing EU-DEM and hydrography layer

After the fusion water features are automatically edited in the EU-DEM as follows:

- ocean elevations are set to 0 m
- inland water bodies are flattened
- river elevations are both flattened and stepped to maintain a monotonic flow

Topologically consistent hydrography data, produced and provided by the Lithuanian project partner Aerogeodezijos Institutas (AGI), is automatically burnt into the 1,143 EU-DEM tiles. IMAGE2006 imagery data supported by ECRINS is mainly used as a base for this new hydrography dataset.

3.4 Manual Revision & Quality Control

In the next step all tiles are interactively controlled or corrected, using Intermap's proprietary 3D stereo Interferometric Editing Software (IES), which was successfully used for the NEXTMap production (Asselin, 2005). Additionally, any remaining pits, bumps and blunders are manually removed. IMAGE2006 colour imagery data is used in IES to guide the editors.

3.5 Validation

Finally, the accuracy of the EU-DEM is validated using various reference data sources. This includes not only (freely) available, trigonometric points but also LiDAR data and the above-mentioned NEXTMap data. Based on existing research results, a vertical accuracy of about 7 m RMSE is expected.

4. FIRST RESULTS

The following figures show an example from an area in Germany, covering an area of about 15 x 16 km² in the Bavarian Alps. Figure 6 shows the EU-DEM and Figures 5 and 7 show the input data used. For comparison Figure 8 presents the same area in the NEXTMap Europe DSM data.

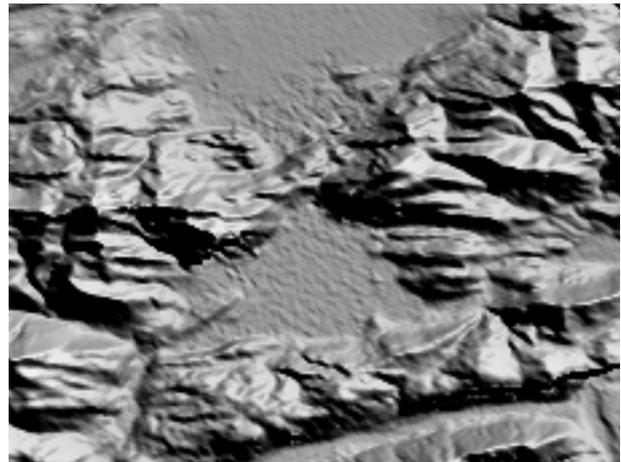


Figure 5. SRTM-3

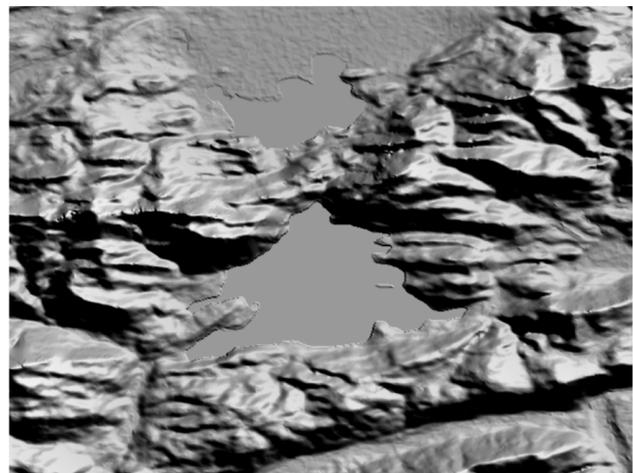


Figure 6. EU-DEM

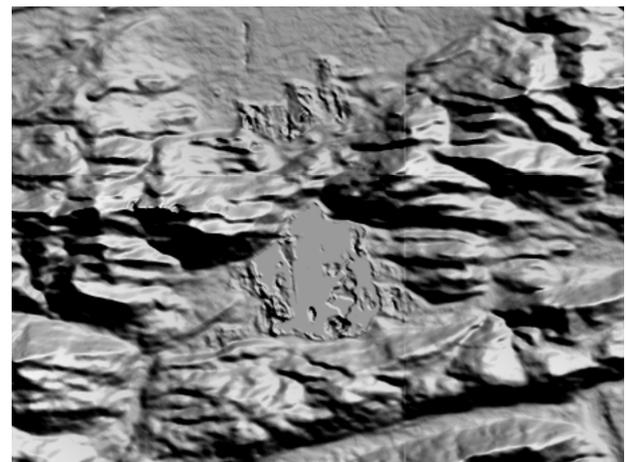


Figure 7. ASTER GDEM

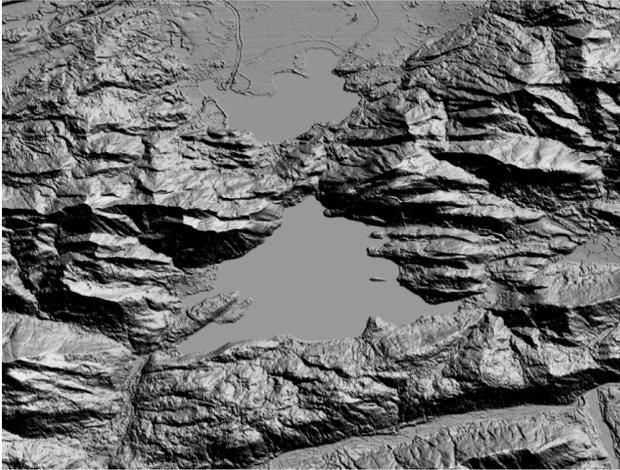


Figure 8. NEXTMap Europe DSM

5. OUTLOOK

The EU-DEM data is planned to become publicly available in 2011. The goal of this project is to establish a long-term basis for both European and global reference datasets which will become available nationwide in the near future. In addition to the EU-DEM, these also include the previously mentioned new hydrographical network data. Once developed, the initial GMES reference data access service as described in this paper also will become another component of the GEOSS.

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