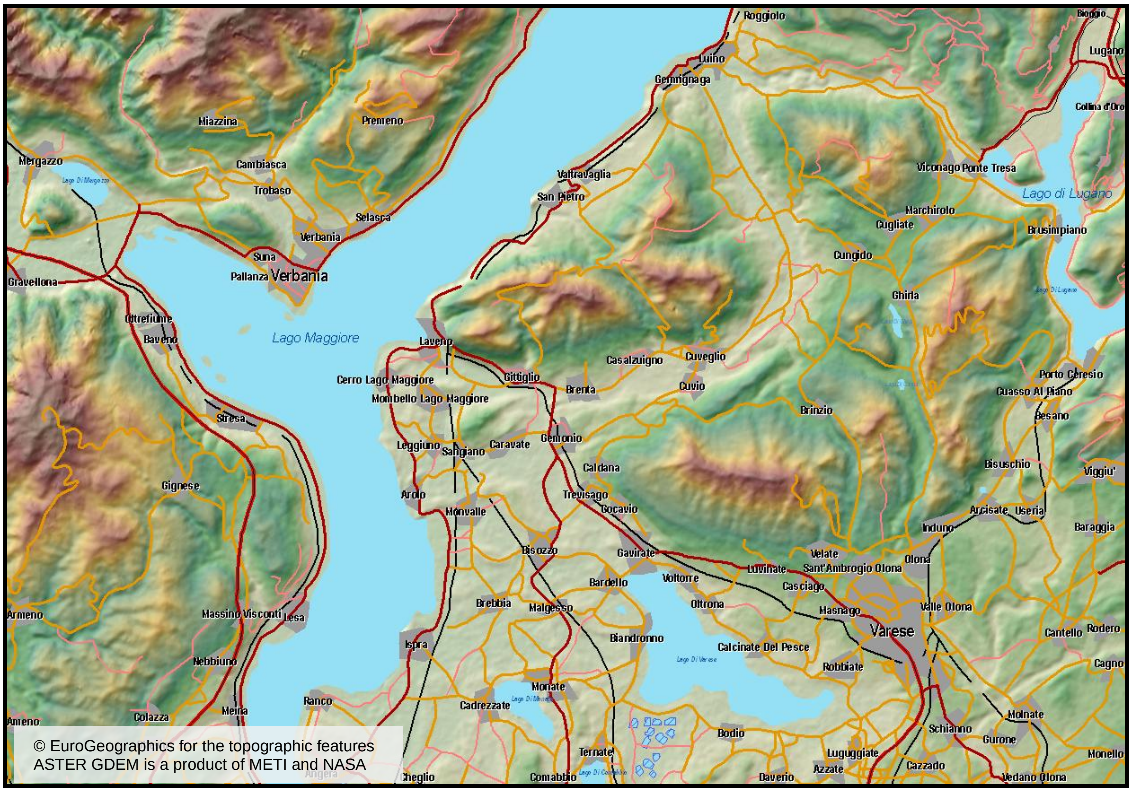
JRC Scientific and Technical Reports

Comparison Workshop on a European Digital Elevation Model

Co-organised by the GMES Bureau (EC, DG Enterprise and Industry) and the Institute for Environment and Sustainability (EC, DG Joint Research Centre), Stresa, Italy 5-6 May 2009

Katleen Miserez, Stephen Peedell, Peter Strobl, Hans Dufourmont, Jean Dusart



EUR 24128 EN - 2009

JRC
EUROPEAN COMMISSION

Institute for Environment and Sustainability

The mission of the JRC-IES is to provide scientific-technical support to the European Union's policies for the protection and sustainable development of the European and global environment.

European Commission
Joint Research Centre
Institute for Environment and Sustainability

Contact information
Contact: Jean Dusart
Address: Via E. Fermi, 2749, TP 262 - 21027 Ispra (VA), Italy
E-mail: jean.dusart@jrc.ec.europa.eu
Tel.: +39 0332 78 6703
Fax: +39 0332 78 6325
http://ies.jrc.ec.europa.eu/
http://www.jrc.ec.europa.eu/

JRC 56020

EUR 24128 EN
ISBN 978-92-79-14621-3
ISSN 1018-5593
DOI 10.2788/51490

Luxembourg: Publications Office of the European Union

Printed in Italy

Comparison Workshop on a European Digital Elevation Model

Co-organised by the GMES Bureau (EC, DG Enterprise and Industry) and the Institute for Environment and Sustainability (EC, DG Joint Research Centre), Stresa, Italy 5-6 May 2009

Executive summary

Background

Elevation data represent one of the most commonly used spatial data themes, with applications across a wide variety of domains. Elevation data are needed for GMES Services and are included in the Annex II of the INSPIRE Directive (2007/2/EC). Moreover, at the Pan-European level, elevation data are needed to support various territorial policies and applications. Various needs have been identified requiring different spatial and vertical resolution and specific accuracy. In addition there is an increasing need for a higher resolution accurate Digital Elevation Model (DEM) covering the European Continent.

In order to establish a comprehensive and detailed analysis of the current level of capability to create and deliver pan-European elevation data and associated services, the Global Monitoring for Environment and Security (GMES) Bureau and the Spatial Data Infrastructure Unit of the Joint Research Centre (JRC) have organised a workshop to bring together potential providers and end users.

The GMES initiative of the European Commission (EC) and the European Space Agency (ESA) is comprised of 3 components:

- A space component, providing an observational infrastructure for space-based data collection (Earth Observation Satellite).
- A GMES Services component which is comprised of a series of (Core) Services providing (reference) data and information common to a broad range of policy-relevant applications. GMES (Core) Services do provide input information for a number of (Downstream) Services, tailored to specific applications from global to local levels, and capable of combining and integrating (Core) Services data and information with more application-specific data.
- An *in-situ* component, providing information from a broad range of measurements on the earth's surface (including both territorial, marine and atmospheric measurements). These data are essential both to validate space born observations and to complement them.

The Directorate-General for Enterprise and Industry (DG ENTR) at the EC formulates and prepares the implementation of services to be set up in the context of the GMES initiative. The EC recognises the users as drivers for the identification and development of GMES services.

Scope of the workshop

The workshop was open to all data providers who have a European wall-to-wall DEM in their portfolio (minimum coverage: EU-27, desired coverage: European continent) or could at least contribute significant parts of such, be it from in-situ (including airborne) or space borne data observations. Both providers from public sector or from private sector were invited to participate in the exercise. Focus was on providers who can deliver solutions between now and the end of 2011.

Selected experts in the domain of DEM production methodologies and quality assurance have been invited by the workshop organisers to contribute with their expertise in the comparison exercise, whereas representatives from the user communities gave an overview of typical European use case requirements for a DEM.

In view of the potential development of such a GMES DEM service, the workshop has addressed the following:

- presentation of elevation data user requirements for key policy areas and applications
- provide an overview of existing products/solutions in relation to elevation data

- identify potential solutions for the establishment of a pan-European Digital Elevation Model (EU-DEM), representing a range of technologies;
- perform an initial comparison of alternative solutions, by gathering technical specifications, with reference to selected geographic test areas in Europe
- identify future developments in this domain, both in terms of evolving data capture capability and in terms of delivery to users (e.g. through web services)
- provide information related to data delivery and licensing.

1. Policy context

The GMES initiative

The Communication from the Commission "Global Monitoring for Environment and Security (GMES): we care for a safer planet" (COM(2008)748) addresses the need to develop GMES Services as the basis for Europe's autonomy in information provision worldwide. The objective of GMES is to provide, on a sustained and operational basis, reliable and timely services related to environmental and security issues in support of public policy needs. GMES is an EU-led initiative, in which the European Space Agency (ESA) implements the space component and the European Commission (EC) manages and coordinates actions for identifying and developing services.

The GMES programme is aiming at providing homogeneous geo-information services on global and European level (Core Services), as well as services which are focused on specific regional or thematic areas (Downstream Services). These services will rely on the three categories of data:

1. Space observation data, mainly to be provided by the GMES Space Component, i.e. the *Sentinels* series of satellite missions, complemented by various national satellite missions. The GMES Space Component is co-funded between the European Commission and the European Space Agency (ESA). A delegation agreement between the EC and ESA governs the data collection for the space component within the GMES context. The contributing space missions are providing data from both Member States' (MS) national. missions and international missions.

2. In-situ observation data, to be provided by a network of observation infrastructures organised in different themes on local, regional or national level. These networks are typically owned and governed by the Member States. The homogeneous and sustainable provision of these data poses a considerable challenge, which is going to be tackled under lead of the European Environment Agency (EEA).

3. Reference data, which fulfil a specific and complementary role as compared to the observation data, by providing a geographic or positional framework. These data are – amongst other - topographic data (including road networks, hydrography, Digital Elevation Models (DEM) etc…) and other data such as geological maps etc... The workshop was a first step towards the development of a European wide DEM, and will be an essential component in the development of a GMES Land Monitoring Core Service.

Land Monitoring Core Service

The Land Monitoring Core Service (LMCS) addresses a wide range of resources and policies at EU and international level (e.g. soils, water, agriculture, forestry, biodiversity, transport etc.). The land cover / land use (LC/LU) communities are diverse and have specific requirements. The common key user requirements are (i) an improved access to *in situ*, space and reference data, (ii) reliable and improved or enriched land cover and land cover change (LCC) data which are the basis for a multitude of applications related to environment, spatial planning, regional dynamics etc. Given the fact that users have or do not have their own capacities to process data, the LMCS should offer a portfolio of data and products with different levels of elaboration from pre-processed images to elaborated information.

Due to this diversity, the LMCS Implementation Group recommended a progressive and modular implementation and defined a two-steps approach, starting with multi-purpose products required by a large community of users (pre-processed images, reference data including DEM, LC/LU data…) and further extending the scope to more elaborated thematic products (e.g. water quality/quantity models, crop forecasts, environmental indicators etc.).

Digital Elevation Models, SRTM and GDEM

Elevation data are required across a broad set of application areas, each with different technical and usage requirements. From a generic point of view, one could state that there is a need for a continent-wide elevation dataset at a 25 to 50 meter posting, and at an overall vertical accuracy of approximately 5m.

Furthermore there seems to be a consensus that no single data source can provide fully consistent and complete pan-European coverage as of today. Whereas low resolution products need fusion with other data-sources anyhow (e.g. Shuttle Radar Topography Mission (SRTM) mission lacks data over areas above 60° N), the raw data sources used for high resolution products also suffer from gaps due to various reasons (cloud cover, missing data, source data specific characteristics such as layover and shadow, etc…). Nevertheless, from a theoretical point of view, it can be stated that sufficient data-sources do exist to produce a high quality consistent pan-European DEM in a short time frame.

Finally, there's little doubt about the fact that the broad usage of DEMs is still hampered by conditions and terms of use foreseen in licensing agreements, in combination with pricing mechanisms for the commercially available products, whereas the publicly and freely available alternative products show some serious drawbacks in quality, equally hampering a broad uptake in operational workflows.

It has been acknowledged that this actual situation has not dramatically changed since an earlier workshop on an EU-DEM, back in 2002. And yet, the need to be able to use a pan-European DEM for Community policies, whether it would be in the field of environment, regional dynamics or agriculture, continues to increase.

2. EU-DEM as reference data

Reference data[1] are information handled by data providers (institutional or commercial data providers) and recognised by a large community of users as basic spatial data to reference their (thematic) data upon (for example road networks, rivers and water bodies, administrative units and toponyms, etc..)[2].

Reference data are vital to GMES services (in particular Emergency Response, Land, and Security services) and to end-user applications in order to provide a) the basic geographic framework on top of which additional (thematic) spatial information can be produced and disclosed (e.g. LC/LU maps, asset maps and damage assessment maps in response to crisis) and b) the set of relationships between the geographical components that will allow building the assessments, analyses and monitoring from combinations of data sets.

Therefore, the implementation of an initial GMES Service for a geospatial reference data service element cross-cutting the different GMES services (Land, Emergency, Security in particular) has been considered of paramount importance. Given the fact that the context and availability of data, as well as the data sources are very different inside and outside the EU, their implementation will require multiple efforts before yielding a truly operational European Spatial Data Infrastructure. As such, the identified INSPIRE annex I data themes fulfil a predominant role in that context.

At the same time, the combination of aerial information from land cover databases (CORINE Land Cover (CLC), Urban Atlas, national land cover initiatives…) with linear information from the hydrographical network and with height and slope information from a DEM, will enable Community institutions and bodies and spatial data user communities in general to improve various types of spatial analyses including modelling of environmental impacts and modelling of regional dynamics. Hence the importance for EU-DEM data to be improved both in terms of access and quality at European level.

[1] Reference data fulfill 3 functional requirements: a) provide an unambiguous location for a user's information; b) enable the merging of data from various sources, and c) provide a geographic context to allow others to better understand the spatial information that is being presented.

[2] A good example is provided in some of the Northern European MS, where efforts have been made to ensure that throughout the various levels of public authorities, the same spatial data are being used as reference data, so as: a) to avoid duplication of data collection; b) to facilitate any combination of thematic spatial data, and c) to ensure continuous updating of these reference data by taking onboard the necessary changes as produced by authorities responsible for specific spatial object categories, forming subsets of the overall (topographic) set of reference data.

3. Background and Rationale

3.1 What is a Digital Elevation Model?

A Digital Elevation Model (DEM) can be defined as a digital file holding the elevation values of a collection of points for a given area. There are no unique definition about the type of elevation stored in a DEM as highlighted for example in [Maune, 2001, Appendix B] and [Li et al., 2005, p.9]. In this document, we use the term DEM in the sense of a generic term for elevation data in all its various forms. If the measured elevations are those of the firm ground (bare earth z-values), a DEM is called a digital terrain (elevation) model or DTM (or more precisely DTEM since DTMs sometimes refer to other variables than elevation). When the measured elevation is that of the top surface of objects (natural or man-made) occurring above the firm ground, a DEM is called a Digital Surface (elevation) Model or DSM.

DEM elevations of lakes and rivers normally imply the water surface (bathymetry refers to depths below the water surface). DEMs can be represented as raster data where each pixel gets a value proportional to an elevation. DEMs are created by collecting or interpolating elevations at a number of known positions. The elevations add a z-value to the ground's x and y horizontal coordinates. The spacing between the elevations points (i.e. their density) directly effects the accuracy of a DEM.

3.2 The INSPIRE Specification on Geographical Grid Systems

A grid typically uses a matrix of n x m cells spanned by 2 axes. As a result, a grid cell can be referenced by a sequence of integer values (one for each axis) that represent the position of the reference cell along each of the axes of the grid. See CV_GridCoordinate as specified by ISO 19123 (ISO 19123, Geographic Information – Schema for coverage geometry and functions (ISO 19123:2005), 17/06/2009).

The grid – proposed as the multipurpose Pan-European standard – is based on the ETRS89 Lambert Azimuthal Equal Area coordinate reference system (INSPIRE Specification on Geographical Grid Systems – Guidelines: http://inspire.jrc.ec.europa.eu/documents/Data_Specifications/INSPIRE_Specification_GGS_v3.0.pdf) with the centre of the projection at the point 52° N, 10° E and false northing: Y_0 = 3210000 m, false easting: X_0 = 4321000 m (CRS identifier in INSPIRE: ETRS89-LAEA). The grid is designated as Grid_ETRS89-LAEA. For identification of an individual resolution level the cell size in metres is appended to the name. The origin of Grid_ETRS89-LAEA coincides with the false origin of the ETRS89-LAEA coordinate reference system (Y=0, X=0).

The grid is defined as a hierarchical one in metric coordinates to the power of 10. The resolution of the grid is 1m, 10m, 100m, 1000m, 10,000m, 100,000m. The grid orientation is south-north, west-east. The reference point of a grid cell for grids based on ETRS89-LAEA is the lower left corner of the grid cell.

The difference in resolution between the different hierarchical levels of the proposed decimal grid system is rather large. For some applications, it might be necessary to insert additional levels in between. This could be done by simply dividing a grid into 4 equally spaced sub cells. Thus, a grid with a distance of 1 km could be divided into cells of 500 m length. A second level could be introduced by dividing each cell again into 4 equally sized cells of 250 m length. A next sub division would lead to grid cells of 125 m length. This is already close to the next lower hierarchical level of the decimal grid, and therefore not supported. This method of sub dividing a grid is called quad-tree, as each cell is divided into 4 quarters. The graphical representation of the grid structure when traversing the grid from its root cell to its smallest sub cell results in a tree structure with 4 branches at each level. [Wirthmann, A. et al]

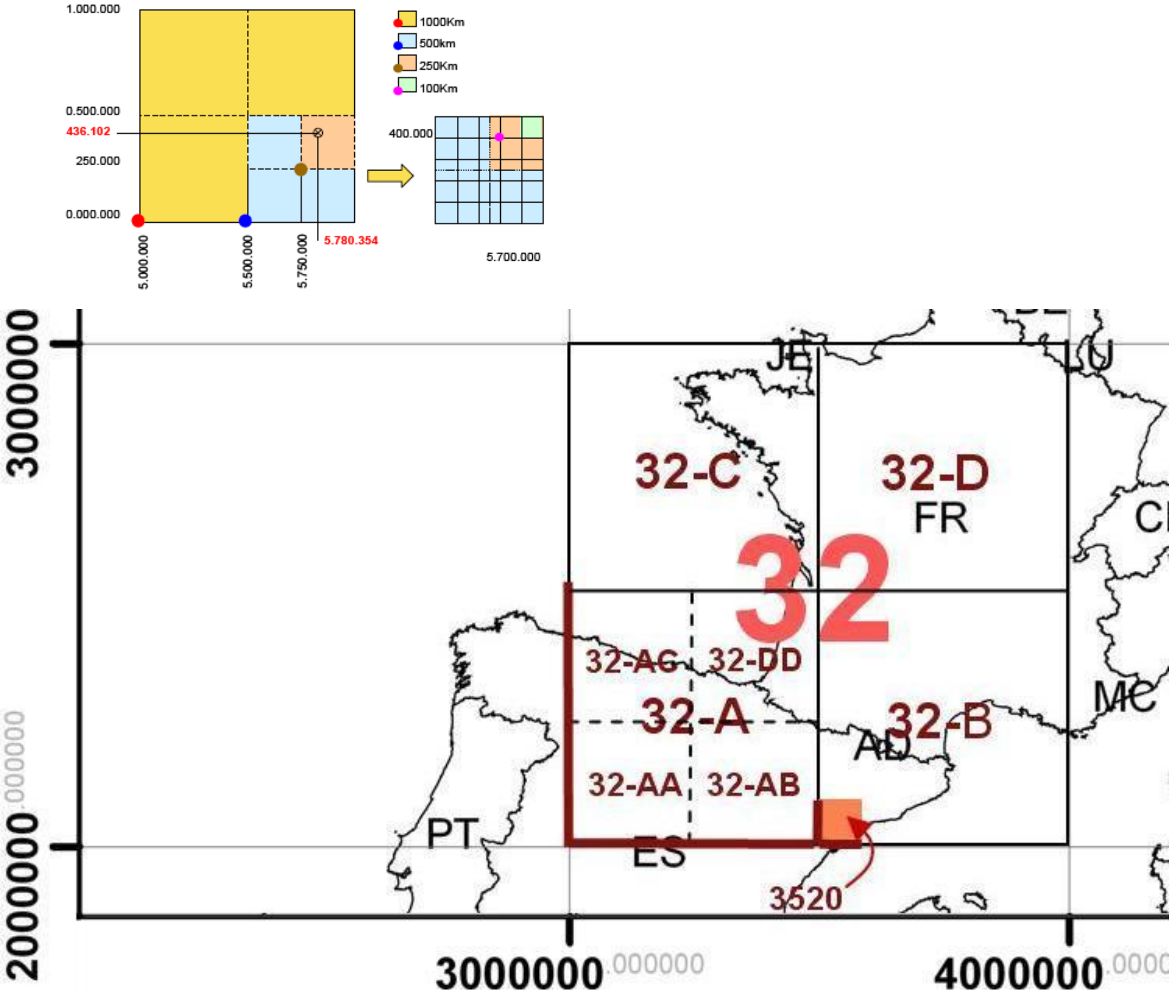


Figure 1: Quad-tree subdivision

Level	Cell Size	Cell Code Scheme	Cell Code Example
19	1000 km	xy	32
18	500 km	xy-q	32-A
17	250 km	xy-qq	32-AB
16	100 km	xxyy	3320
…			
5	25 m	xxxxxyyyyy-qq	3346720658-DC
…			
1	1 m	xxxxxxxyyyyyyy	33467652065889

Figure 2 Coding system

3.3 Evolution of European Coverage and Requirements

A first workshop on EURODEM was organised by the EC and ESA in Brussels on 15th February 2002, at which requirements of European Institutions were presented as well as products and solutions available from National Mapping Agencies and industry providers. At that time, expectations for a pan-European DEM centred on 2 levels of spatial resolution – 90x90m and 30x30m. Since that time, data from the Space Shuttle Radar Topography Mission (SRTM) [Farr and Kobrick, 2000], which flew in February 2000, have become available (from late 2004 for edited and validated data), and have addressed many requirements at these resolutions. In Europe, SRTM data at resolution 30x30m are only available (via DLR's EOWEB Portal) for restricted orbit strips and are priced at 400 euro per 0.25° x 0.25° tile.

Considerable effort has been undertaken within JRC to coordinate and apply our technical expertise to validate and enhance the raw SRTM data, and to generate derived datasets – including catchments and hydrographic networks, of which the CCM (Catchment Characterisation and Modelling) is one example. Based on the experience gained in the use of SRTM data and the maturity of requirements that have evolved through their widespread application, attention is now focussed on the feasibility of a more accurate and detailed pan-European DEM. Several initiatives may now allow pan-European coverage at approximately 30x30m resolution, with higher resolution feasible in selected areas.

In parallel, extensive elevation data acquisition is taking place through aerial-photogrammetric techniques and traditional field survey – however the scope for adopting a hybrid approach to combining field, aerial and space sources is limited by the difficulties in establishing a consistent end product.

3.4 Current Global/Continental DEM Coverage

Existing coverages that are available almost globally are distributed by the United States Geological Survey (USGS), see http://eros.usgs.gov/products/elevation.htm. The main global or nearly global elevation data are in increasing resolution order:

- The coarsest resolution data set is a global 1-km digital raster data derived from a variety of raster and vector sources and has been available for several years (GTOPO30). The resulting heterogeneity in the quality of this data set is impacting on all derived layers and is a critical issue since no information on the spatial distribution of the accuracy is available. It is expected that the elevation data are a mixture between terrain and surface elevations.
- The Shuttle Radar Topography Mission (SRTM) successfully collected Interferometric Synthetic Aperture Radar (IFSAR) data over 80 percent of the landmass of the Earth between 60 degrees North and 56 degrees South latitudes in February 2000. Two elevation data sets are distributed.
    - DSM with 1 arc second resolution (approximating to 30m by 30m at the equator). The data exists at this resolution between 60 degrees North and 56 degrees South latitudes, processed from X-band. Although it is distributed on-line, upon payment, it is not as comprehensive in its coverage or as freely available as for the United States. The reasons for this and the possibility of accessing this source in the future should be investigated – a significant caveat is that coverage is unlikely to be completed for the pan-European area of interest, even below 60 degrees North.
    - DSM with 3 arc second resolution (about 90m by 90m at the equator) freely distributed between 60 degrees North and 56 degrees South latitudes. This unique data set is the sole nearly global source of surface elevation data derived from the same sensor (and at the same date). However, it is a surface elevation model only and does not cover the whole territory of the European Union.
- Commercial ventures. At the present time, we are aware of several initiatives providing potential pan-European coverage at resolutions equivalent to up to DTED Level 4 (5m x 5m).
    - SPOT Reference 3D

Co-produced by SPOT Image and IGN France, comprising a DTED level 2 DEM. The Reference 3D product includes an orthoimage from the HRS Sensor, whilst the SPOT DEM Precision product has the DEM plus Quality Control layer and SPOT DEM is the DEM layer only.

- InterMap NextMap
  NextMap Europe is a mapping initiative of InterMap Technologies, offering both DSM and DTM products at 5m resolution. Having begun with the UK, this programme has now covered DE and is forecast to cover AT, BE, CZ, DK, FR, DE, IE, IT, LU, NL, PT, ES and CH.
- EuroGeographics EURODEM Initiative
- TANDEM-X
  TANDEM stands for TerraSar Add-On for Digital Elevation Measurements, scheduled to begin operation in 2009 as a mission of DLR and EADS-Astrium.

4. Requirements

4.1 Applications

Digital Elevation Models are used across many different application areas, including, but not limited to:

- Remote Sensing
    - Parametric geo-coding of aerial photos and satellite images
    - Atmospheric correction of aerial photos and satellite images
    - Terrain and BRDF correction of aerial photos and satellite images
- Environmental Monitoring
    - Land monitoring
    - Mapping and characterisation of drainage networks and catchments
    - Hydrological modelling
    - Noise modelling
- Agriculture
    - Monitoring of CAP inventory and control measures
    - Monitoring of crop production and yield estimates
- Landscape Analysis
    - Landscape characterisation and automated extraction of landform elements
    - Visualisation
- Hazards and Security
    - Landslides, avalanches and erosion
    - Flood risk modelling and damage assessment
    - Civil protection
- Soil Science
    - Monitoring and assessment of soil threats (e.g. soil erosion)
    - Prediction of soil properties for different applications (hydrology, crop yield forecasting)
- Climatology and Meteorology
- Vegetation Mapping and Habitat Suitability
- Telecommunications and Utilities
- Navigation

Covering policy areas including the Water Framework Directive, Noise Directive, Birds and Habitats Directive, Soil Thematic Strategy, Agriculture/CAP, Enlargement (in particular support to Land Administration infrastructures such as land registry development), Emergency Response services … So far, only land based requirements are expressed – the requirements and specifications for bathymetry need to be elaborated.

Since key characteristics of the required technical specifications, particularly for very high resolution elevation data, will vary between application areas, a further analysis should be undertaken of requirements for the following, which could be done as part of the further consultation with Commission Services:

- Posting Spacing
- Vertical Accuracy
- Horizontal Accuracy
- Geographical Coverage
- Timeframe

4.2 Geographical Coverage

The core area to be covered is that of the current EU Member States (EU27) and enclosed territories (Kaliningrad, Oblast, Switzerland), Norway and United Kingdom dependencies in Europe (Channel

Islands, Isle of Man) and the small states of Monaco, Liechtenstein, Andorra and San Marino). However, given the importance of landscape features in defining the area of interest for many studies, this should be extended. One proposal would be to specify the combined extent of the EU27 and enclosed territories plus the International River Basin Districts (as defined under the Water Framework Directive) that intersect the EU27 and the accession countries territories. (Area1)

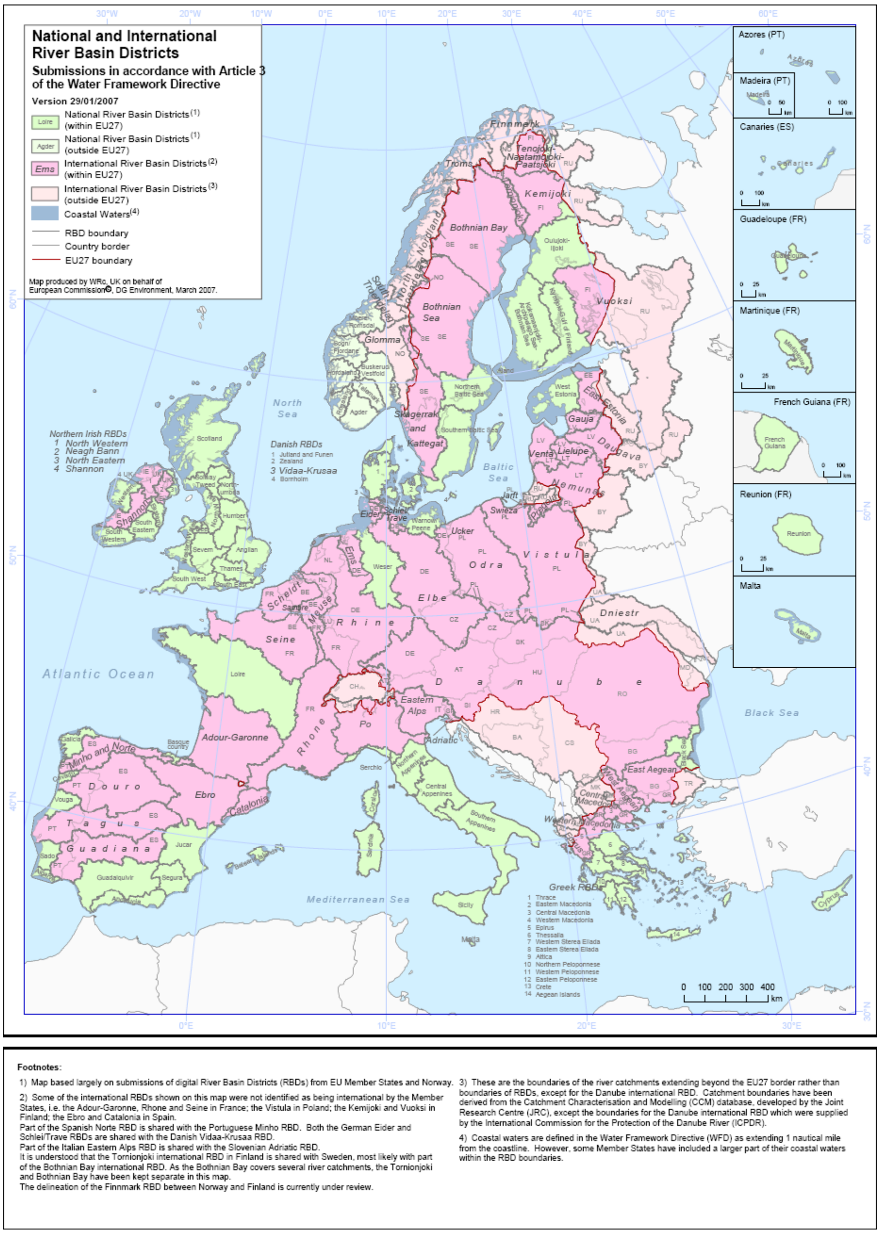


Figure 3 – Water Framework Directive River Basin Districts

The EU27 includes also the Départements Français D’Outre-Mer (DOM), i.e. Guadeloupe, Martinique, French Guyana and Réunion, and a proposed new status for the Caribbean Islands of Bonaire, Saba and Sint Eustatius will equally bring these territories to form part of the EU27. (Area2)

Alternatively the member countries (37 including collaborating countries) of the European Environment Agency could be defined as targeted geographic coverage. Again, it would seem appropriate to extend this coverage using the International River Basin Districts which, in this case, would include the border areas with Russia, Belarus, Ukraine and Moldova. This should be highlighted as the preferred option. (Area 3)

Figure 4 – EEA Member Countries

Since it is unlikely that any existing product will cover the proposed geographic extents, potential providers should be allowed to propose an initial geographic extent for immediate delivery and subsequent calendar for delivery of additional areas over a 1-2 year timeframe.

This proposed geographic extent, which corresponds also to the extent of the CORINE Land Cover 2006 and Image 2006 initiatives, is valid for the acquisition of a 1 arc second posting elevation dataset. Beyond this level of detail, acquisition will have to be targeted to priority areas although, as stated previously, the criteria for definition of such areas will vary over time and between applications.

The total geographic area defined as “pan-European” is 11.4m km2. The EU27 have an area of 4,324,782 km2.
For some applications, including agriculture, the geographic scope could be usefully extended to cover North Africa, Middle East and the CIS. (Area 3)

4.3 Sources

In addition to the space borne remotely sensed data sources (such as SRTM mentioned previously), various other platform categories are in use for the collection of elevation data, with several alternative technologies (e.g. LIDAR, SAR, SPOT HRS, stereo-photogrammetry etc.). Publicly funded bodies as well as commercial interests provide access to elevation data. For the purposes of EU-DEM, the underlying sources may be a mixture – the essential aspect will be the conformance to specifications and particular attention would be required for the appropriate harmonization of elevation information between areas with different source data.

4.4 Licensing

Licensing arrangements that maximize the potential applications of the data should be sought, and these licensing specifications are as important, if not more so, than the technical specifications of the

data themselves. Any licensing framework should at least reflect the data sharing principles of the INSPIRE Directive and subsequent implementing rules on data sharing (see Draft Regulation on INSPIRE Data and Service Sharing on:
http://inspire.jrc.ec.europa.eu/index.cfm/pageid/62). To the extent feasible one should consider how to deal with the GMES objective of full, free and open access as well.

Given the scope of the initiative to create a pan-European DEM, the need for flexibility and multi-purpose use and the potential impact on the market for elevation data, innovative arrangements for licensing should be investigated.

For the proposed pan-European 25m and 50m posting licensing should allow for unrestricted and timely unlimited use by the EU Institutions. The ultimate goal must be to provide such a product under a licensing scheme similar to that of SRTM3 or ASTER-GDEM.

For higher resolution elevation datasets, licensing terms should include:

- Unrestricted internal use within the EU Institutions, by employees, agents and contractors with a perpetual license.
- Right to disseminate internally within the EU Institutions, including the right to set up centralized database and geo-processing infrastructure providing internal access to the EU-DEM product without the need for external validation of requests.
- Possibility to install and use EU-DEM product at multiple geographical locations of the EU Institutions.
- Right to publish printed material, including hardcopy maps, incorporating the EU-DEM product, subject to acknowledgement of source and copyright.
- Right to distribute derived works subject to the condition that those derived works do not provide a basis for reverse engineering the EU-DEM product from them.
- Derived works to include ortho-images, perspective views, slope maps, vector based extracted features (roads, water features, catchment boundaries etc.).
- Right to publish visualization services (3D globes, hill shades, shaded elevation maps etc.) again subject to the provision that these do not provide a basis for reverse engineering the EU-DEM product from them.
- Right to use EU-DEM data temporarily outside the EU Institutions in the event of a major man-made or natural calamity.

Discussion is currently ongoing concerning a proposed GMES Data Policy.

The following issues may be relevant in discussing licensing:

- The “shelf-life” or “latency” of the EU-DEM data. As with all geographic information, EU-DEM data will initially have a high intrinsic value, which will fade over time, potentially allowing for a wider distribution without adversely affecting the business model of any data provider. This latency will differ between data sets – EU-DEM latency will be longer than, say, a high resolution satellite image. After an initial decrease in data value, there may be a subsequent phase in which the intrinsic value increases again as historical reference data.
- New methods of access, requiring innovation in licensing models. For example, we can expect the use of distributed geo-processing services to increase in the future, with EU-DEM potentially being one of the input datasets. For example, what arrangements should be in place to support a scenario where a University researcher runs a model hosted on a JRC server with EU-DEM data and obtains a result (such as an erosion risk map for a given area). Such scenarios are difficult to accommodate in classic end user license agreements.
- Reduced resolution data sets.

4.5 Data or Services?

As the capability of producing ever higher resolution and higher quality elevation information continues, and given the significant investment to collect, harmonise and maintain physical elevation datasets, we raise here the question as to whether 1 arc second resolution represents a threshold. Beyond this threshold it seems opportune to investigate the possibilities to acquire service capability, rather than a physical pan-European dataset, where high resolution data can be accessed on demand at the point of use and where new acquisitions can be programmed in a timely fashion, for specific areas, according to requirements.

5. Proposed Specifications

Detailed technical specifications should be developed once a decision has been made on the preferred overall approach and objectives. These specifications will combine parameters of resolution and accuracy, plus should also include licensing criteria.

A clear distinction should be made between DEM delivery as DTM or DSM. Delivery as a DSM is a minimum requirement; DTM generation from remotely sensed sources requires extensive manual editing and is therefore expensive. If the Terrain Model is delivered, a Digital Surface Model should be included (error fixing, certain terrain parameters require a DSM and not a Terrain Model).

A possible option exists to vary accuracy requirements according to inherent terrain (e.g. SPOT HRS which has lower elevation accuracy requirements in areas of high slope).

The following technical parameters indicate the desirable minimum specifications:

Product Specification A – EU-DEM Level 1
Grid spacing 100m
Horizontal accuracy <50m for 90%
Vertical accuracy absolute <30m for 90%
Vertical reference system EVRS89

Product Specification B – EU-DEM Level 2
Grid spacing 25m
Horizontal accuracy <10m for 90%
Vertical accuracy absolute <10m for 90%
Vertical reference system EVRS89

Product Specification C – EU-DEM Level 3
Grid spacing 10m
Horizontal accuracy <5m for 90%
Vertical accuracy absolute <2m for 90%
Vertical reference system EVRS89

Each DEM should be accompanied by the following quality layers:
- Footprints and identifiers of source data
- Water mask – any water body summing up to 10 pixels for the given resolution
- Correction mask – DEM artefacts corrected using external data with IDs referring to methods and used data
- Horizontal estimated error mask
- Vertical estimated error mask
- Validation mask – areas that do not meet the required specifications

EU-DEM should be compatible with the recommendations of the European Reference Grids Workshop and the INSPIRE technical implementing rules in particular the data specifications guidelines on Geographical Grid Systems and Coordinate Reference Systems. The main recommendations being:
- To adopt ETRS89 as geodetic datum and to express and store positions, as far as possible, in ellipsoidal coordinates, with the underlying GRS80 ellipsoid [ETRS89]
- To further adopt EVRF2000 for expressing practical heights (gravity-related)
- To identify coordinate reference systems and transformations in the format required by International Standard ISO 19111
- To adopt ETRS89 Lambert Azimuthal Equal Area coordinate reference system of 2001 [ETRS-LAEA], for spatial analysis and display
- To adopt ETRS89 Lambert Conic Conformal coordinate reference system of 2001 [ETRS-LCC] for conformal pan-European mapping at scales smaller or equal to 1:500,000

- To adopt ETRS89 Transverse Mercator coordinate reference systems [ETRS-TMzn], for European mapping minimising distortion of scale and direction given the total mapped area is smaller than 1000km x 1000km

Metadata

General Metadata at the product level should correspond to the specifications of ISO19115 international standard, Geographic Information – Metadata. A discovery-level profile corresponding to the INSPIRE Implementing Rules on Metadata should be provided according to the Commission Regulation on Metadata:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008R1205:EN:NOT

Source data footprint should also provide the link to a description of the source data corresponding to a profile of ISO19115 compliant with the INSPIRE Implementing Rule on Metadata.

For the detailed product metadata, ISO19115 Part 2: extensions for Imagery and Gridded Data, should be considered.

6. Workshop Proceedings

6.1 NEXTMap 40 (Geosys – Alain Killmayer)

6.1.1 Organisation Overview

Geosys is a private company created in 1987, with headquarters in Toulouse (France) and a subsidiary in Minneapolis (USA).

6.1.2 Background in Elevation Data Production

Geosys' technical capability has evolved from digitization of contour lines to airborne Radar technology. A major development in DEM production is their partnership with Intermap Technologies.

Current DEM products/services are:
- Mona Pro EUROPE (37 countries)
- NEXTMap 40 (18 countries)
- Specific acquisitions:
  - Radar satellite/airborne
  - Aerial autocorrelation

6.1.3 Pan European Capability

Source data, InterMap:
- Aerial IFSAR radar acquisitions: 3cm band
- Interferogram

Production methodology and workflow:

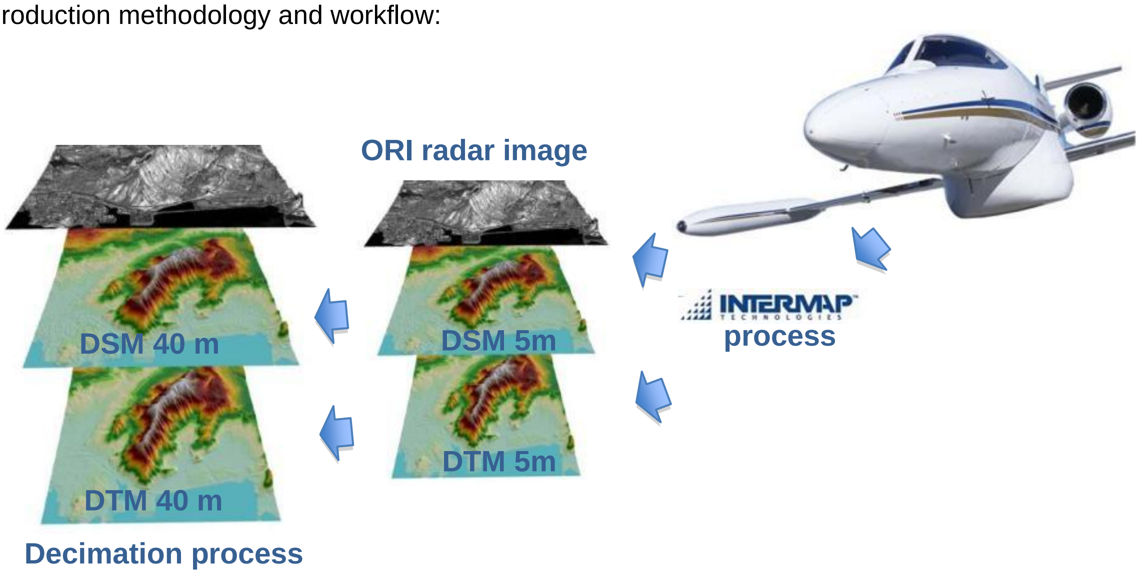


Figure 5 – Intermap Process

6.1.4 Quality Parameters

- Vertical accuracy characteristics

  Tested values at 95% confidence level:

2 meters on <10% slopes
6 meters on mountainous areas
- Horizontal accuracy
  Tested values at 95% confidence level:
  3 meters

1042 Vertical Check Points (VCP) were obtained through the German State agencies.

- NO surface treatment for DSM and vegetation and buildings cleaning for DTM
- Hydrological consistency and matching with hydrographical pattern
- Artefacts: radar artefacts (voids) interpolated and Z cross validated with ancillary data
- Ancillary data (Mona, IGN(s) and GCPs)
- Metadata provided
- Full consistency and homogeneity through EU territory, as the surveys were done independently to borders, and with the same method
- Quality assessment ISO 9001 V2000/validation procedures by Intermap QC department (IV-V)

6.1.5 EU-DEM Data Product Delivery

The data file format is BIL 32 bits (or other on request). Coordinate system is LAT LONG WGS84 (or any projection, ellipsoid, datum, on demand). An FTP/DVD delivery service is available.

6.1.6 Data Examples

Data examples for plains, lowlands, mountains were given. Areas above 60 degrees North are not available.

6.1.7 Licensing

There are different licensing models:
- Company license: fully open internal license, no life time limit
- Project license: limited for one specific project with fixed duration
- Multiple licenses: mutualisation

Compliance with INSPIRE Data and Service Sharing Implementing Rule and guidance document is claimed. Metadata is available.

Derived data is possible on demand (min max values layer or other posting).

Pricing models:
- A full company license is DSM 2,5€/sq km or DTM 3,5€/sq km
- Decreasing price per command area

6.1.8 Technical and Capacity Development

A forthcoming development envisaged to 2013 is the completion of EU community countries coverage.

6.2 NEXTMap Europe (Intermap Technologies – Hugh MacKay)

6.2.1 Organisation Overview

Intermap Technologies is enabling government agencies and commercial enterprises worldwide to quickly and affordably implement a wide range of geospatial solutions. Intermap is located in different places in Europe, America and Asia. The company is publicly traded in Toronto and London. The turnover is around $40 million USD, and there are over 600 employees. Intermap Technologies has 4 operational Airborne X-band Radar Mapping Systems and 1 L-band Radar System. Processes are ISO certified.

6.2.2 Background in Elevation Data Production

Evolution of technical capability
- Began commercial SAR mapping activities in 1983
- Began commercial IFSAR mapping activities in 1996

Major developments in DEM production
- Began production of single-pass IFSAR DEMs in 1997
- Began production of NEXTMap® DEMs in 2004
- SRTM Production and Void Fill
- High capacity IFSAR processing on multiple platforms
- ISO Standardized Processes and Production Workflow

Current DEM Product/Service
- NEXTMap Family of Products for Europe, USA, Australia and others

6.2.3 Pan European Capability

The NEXTMap Core Products are the Ortho-rectified Radar Imagery, the Digital Surface Model and the Digital Terrain Model.

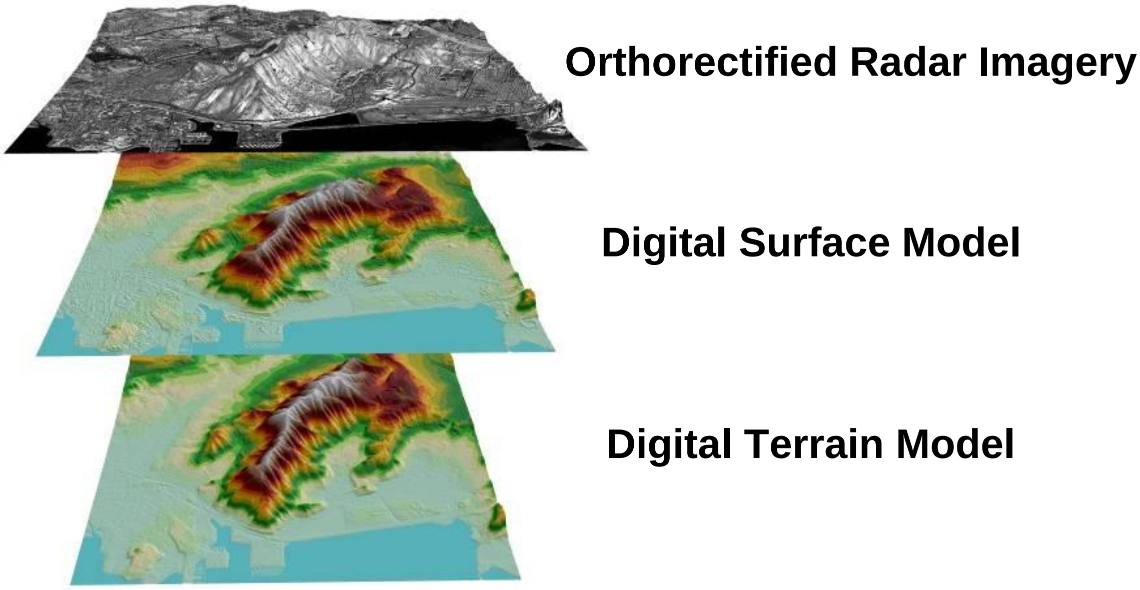


Figure 6 - NEXTMap Core Products

The NEXTMap® Europe Digital Surface Model had a 5-metre resolution and 1-metre RMSE vertical accuracy. It is the first surface reflection of radar signal and includes natural and man-made features.

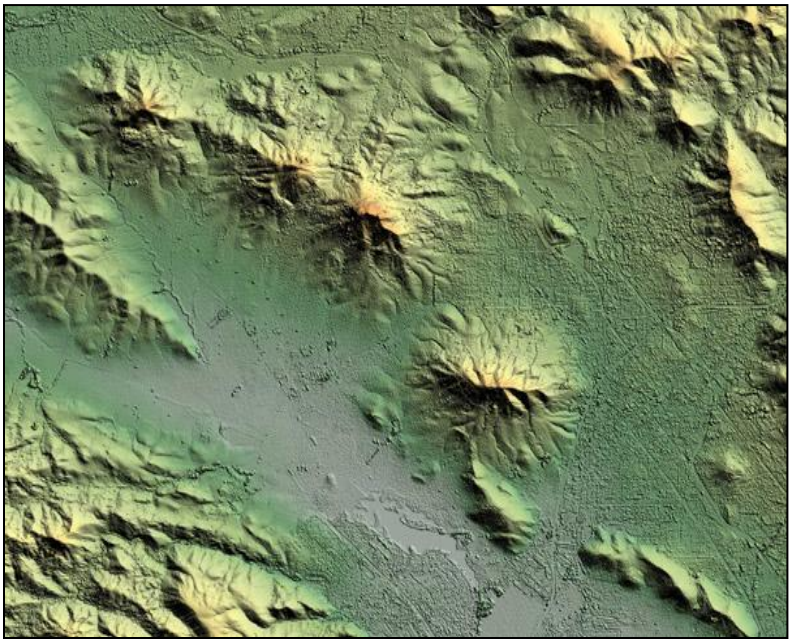


Figure 7 - NEXTMap® Europe Digital Surface Model

The NEXTMap® Europe Digital Terrain Model has a 5-metre resolution and 1-metre RMSE vertical accuracy. Automated and manual editing removes the surface features.

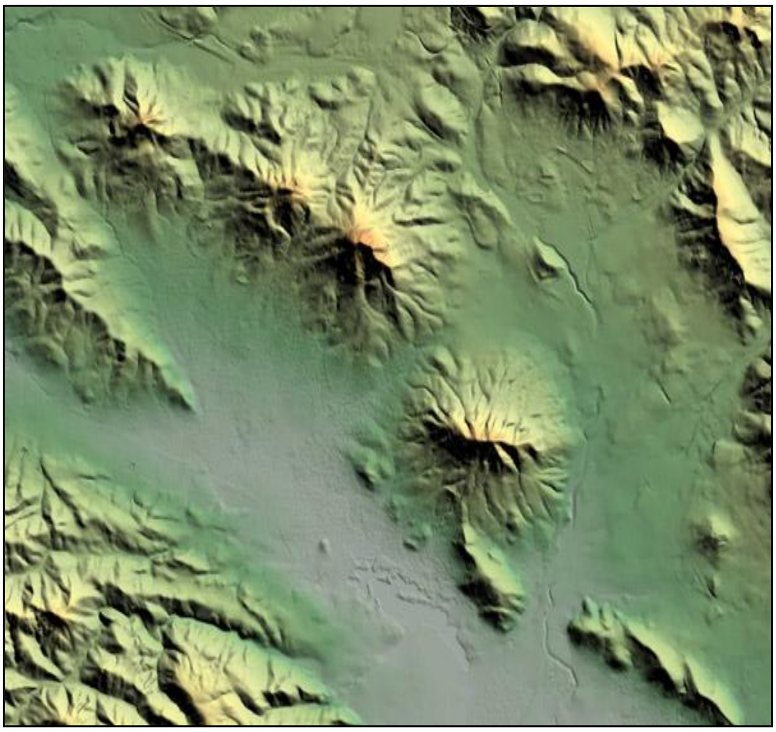


Figure 8 - NEXTMap® Europe Digital Terrain Model

The NEXTMap® Europe Ortho-rectified Radar Imagery has a 1.25-metre resolution and 2-metre horizontal accuracy. It is a high accuracy image base-map.

Figure 9 - NEXTMap® Europe Ortho-rectified Radar Imagery

NEXTMap® Europe covers 15 entire countries and 2,200,000 million km2. It is a self-financed 50 million EUR program.

6.2.4 Quality Parameters

Vertical accuracy characteristics

- NEXTMap Level II Product vertical accuracy is better than 1-metre RMSE in unobstructed areas with slope less than 10 degrees. Using Linear Error 95% of the data is accurate to 2 metres.

Horizontal accuracy

- NEXTMap Level II Product horizontal accuracy is better than 2-metres RMSE in unobstructed areas with slope less than 10 degrees. Using Circular Error 95% of the data is accurate to 4 metres.

Surface treatment

- NEXTMap DSM captures first surface feature elevations such as vegetation and manmade structures
- NEXTMap DTM removes these features using automated and manual techniques in a stereo editing environment
- Water bodies are flattened to constant elevations in both the DSM and DTM

Hydrological consistency and matching with hydrographical patters

- Rivers are flattened in a stepping fashion to maintain hydrologic flow direction

Ancillary data

- Various ancillary data are used in the production process including available DEM source data, optical imagery, topographic maps, vector data layers and vertical check points

Artefacts

- IFSAR artefacts such as layover, shadow, saturation, de-correlation, motion ripples, image tones and brightness are eliminated
- Every reasonable effort is made to eliminate artefacts from ancillary data

Metadata

- Standard formats for metadata are supported to comply with widely recognized standards such as FGDC and INSPIRE
- Attributes include: Project Area, Version, Product Level, Acquisition Start/End Dates, Vertical Accuracy, Flight Height, Primary/Secondary Look Direction, Phase Unwrapper, Horizontal Datum, Vertical Datum, Projections, Ellipsoid, Spheroid, End User License, and more

Consistency of characteristics through EU territory
- NEXTMap Products are consistent throughout the EU territory

Quality assessment/validation procedures in production
- Field check and validation
- Intermap Quality System
- Independent Verification and Validation
- 3rd Party Validation Studies

6.2.5 EU-DEM Data Product Delivery

Data Model
- EVRS2000 (vertical), ETRS89 (horizontal)

Data File Format
- DSM and DTM: BIL, ArcGrid, ERDAS img, ArcASCII Grid, GeoTIFF 32 bit

Coordinate System
- Stored in geographic coordinates, delivery in many systems

Delivery Services Available
- Media and FTP, on-line Data Store

6.2.6 Data Examples

Data examples for mountains, lowlands and plains (partially) were provided. Areas above 60 degrees North are not available.

6.2.7 Licensing

Licensing model(s) description
- Perpetual Use License
- Project Use License
- Managed Accounts

Restrictions
- NEXTMap data cannot be distributed to 3rd Parties without the written consent of Intermap Technologies
- No distribution of derived products from which the NEXTMap DEM can be re-engineered

Pricing models
- DSM 25 EUR/sq km
- DTM 35 EUR/sq km

6.2.8 Technical and Capacity Development

- Expansion to full EU 27 and enclosed territories
- Expansion from Level II (1-metre vertical) to Level III (50-centimetre vertical)

- Simultaneous collection of X-band and polarimetric L-band
- 3D Road Vectors of Western Europe and USA

6.3 DEMs Derived from the IRS-P5 Cartosat-1 Inflight Stereo Mission (Euromap GmbH – Frithjof Barner)

6.3.1 Organisation Overview

Euromap has 13 employees and 8 temporary staff. The company does data reception, standard processing and image interpretation. It has 13 years experience in data distribution and is the exclusive distributor for IRS-P6 and IRS-P5. It is 100% subsidiary of GAF AG.

GAF AG has 140 permanent and 30 temporary staff. They have more than 20 years experience in remote sensing, software development and project management world wide. The company is involved in ortho processing, mosaicking, enhancement. They work with imagery, elevation and land cover data.

Telespazio is GAF’s sole shareholder.

The DLR Neustrelitz Ground Station is a DFD department. They have 60 staff, who are active in:
- Reception, pre-processing and archiving
- RS and image processing
- Navigation

They have three S/X-Band antennas Ø 7.3 m, 200 Mbps; L/S-Band Ø 4 m; and others.

Satellite data has been received since 1969, e.g.:
- PRIRODA (MOMS)
- IRS-1C/1D/P6/P5, IRS-P3 (MOS/WiFS)
- ERS-2 (X-SAR), TerraSAR-X
- Landsat 7, Meteosat, NOAA

The structure is as follows:

DLR is responsible for:
- Data reception at the Neustrelitz ground station
- DEM processor development at the Remote Sensing Technology Institute (IMF) in Oberpfaffenhofen

Euromap is responsible for:
- Archiving of raw data
- Development of processing chain linking data selection, DPGS, DEM processor, and archiving of DEM and intermediate products

GAFAG is responsible for:
- Evaluation of DEM and ortho products
- Consulting role

6.3.2 Background in Elevation Data Production

- IMF develops photogrammetric processes for over 20 years
- Focus on DEM generation from optical stereo data, fusing elevation models, and automated geo-referencing
- The flexible XDibias development environment for processors was devised by the IMF
- IMF participated in the ISPRS Cartosat-1 scientific assessment program, evaluated Spot-5 and ALOS data

GAF has extensive DEM experience

- as distributor of
  - SRTM X-Band products (60° N, 58° S)
  - MONA Pro DEM (Europe, North Africa)
  - SpotDEM / Reference 3D products
  - NEXTMap DSMs, DEMs (part of Europe, worldwide)
- in production, editing and quality control of DEMs
  - from optical HR and VHR sources
  - from radar sources
  - from various other sources (e.g. public maps)
- in merging different DEM sources to a quality-controlled "best-of" product

6.3.3 Pan European Capability

IRS-P5 Stereo Coverage – Cloud-free

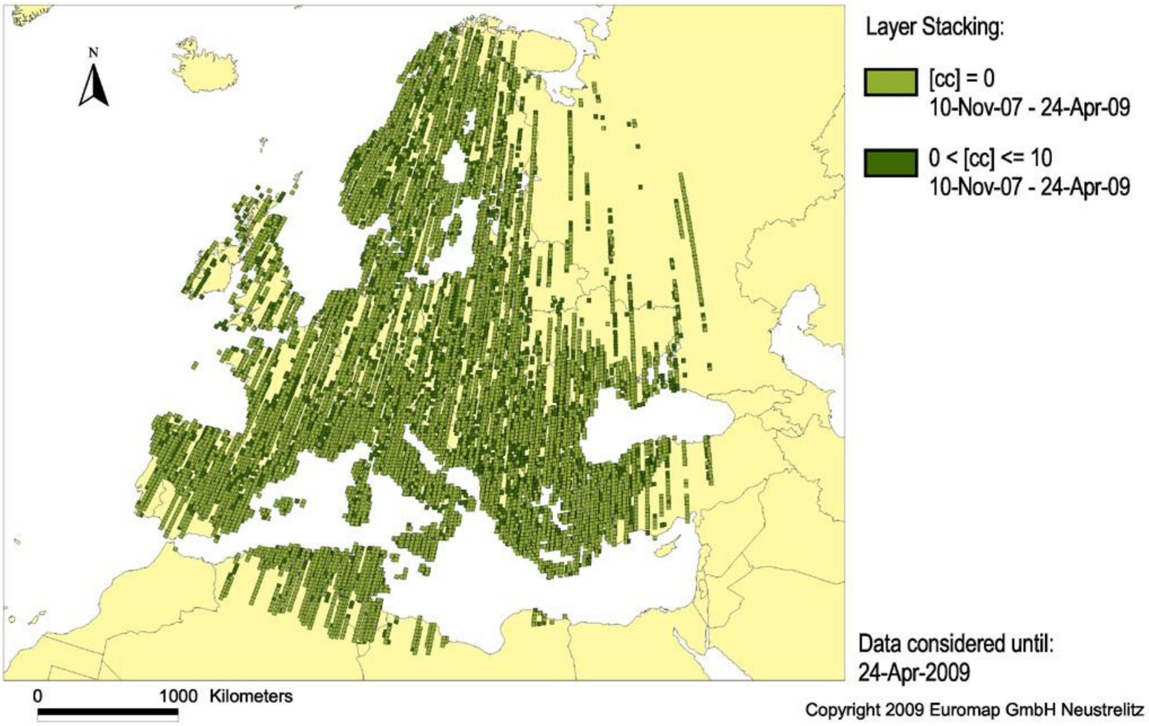


Figure 10 - IRS-P5 Stereo Coverage – Cloud-free

P5 Stereo Coverage

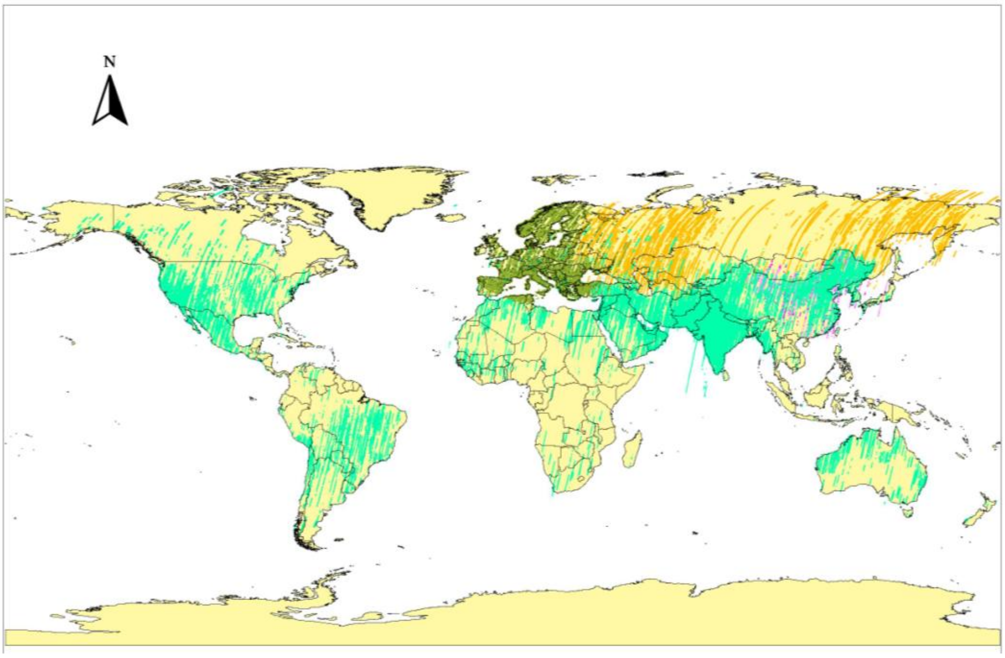
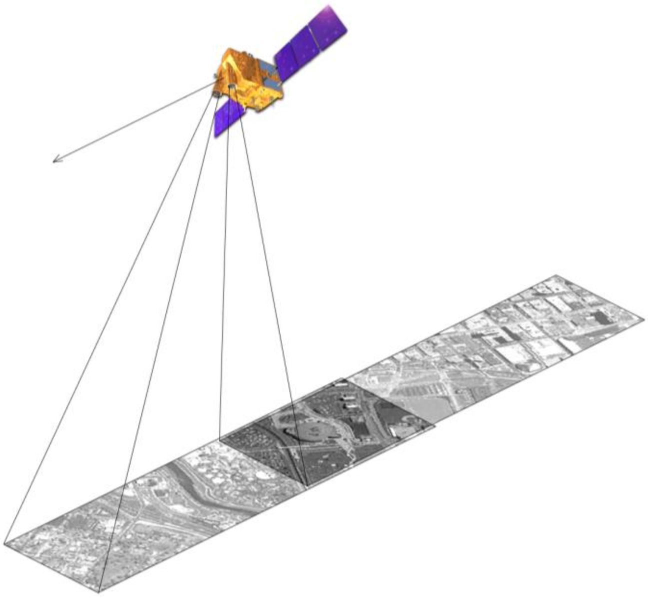


Figure 11 - P5 Stereo Coverage

IRS-P5 Cartosat-1 was launched on May 5, 2005. There is in flight stereo viewing with 2.5 m resolution. Through Onboard Solid State Recorder there is global coverage. The minimum mission life is five years. IRS-P5 has been launched into polar sun synchronous orbit. The satellite has two panchromatic cameras for in flight stereo viewing.

Sensor	PAN-Fore	PAN-Aft
Tilt Along Track	+26°	-5°
Spatial Resolution	2.5 m	2.5 m
Swath-width	30 km	27 km
Radiometric Resolution, Quantisation	10 bit	10 bit
Spectral coverage	500-850 nm	500-850 nm
CCD arrays (number of arrays * number of elements)	1 * 12000	1 * 12000

<u>IRS-P5 Stereo Data Acquisition</u>



- Swath 27.5 km
- DEMs of ~ 4 m elevation accuracy
- 52 s between cameras ~ 358 km
- Nominal B/H ratio 0.62

Acquisition Strategy

- Collection of contiguous coverages
- 0° roll tilt

Figure 12 – IRS-P5 Stereo data acquisition

Production Methodology and Workflow

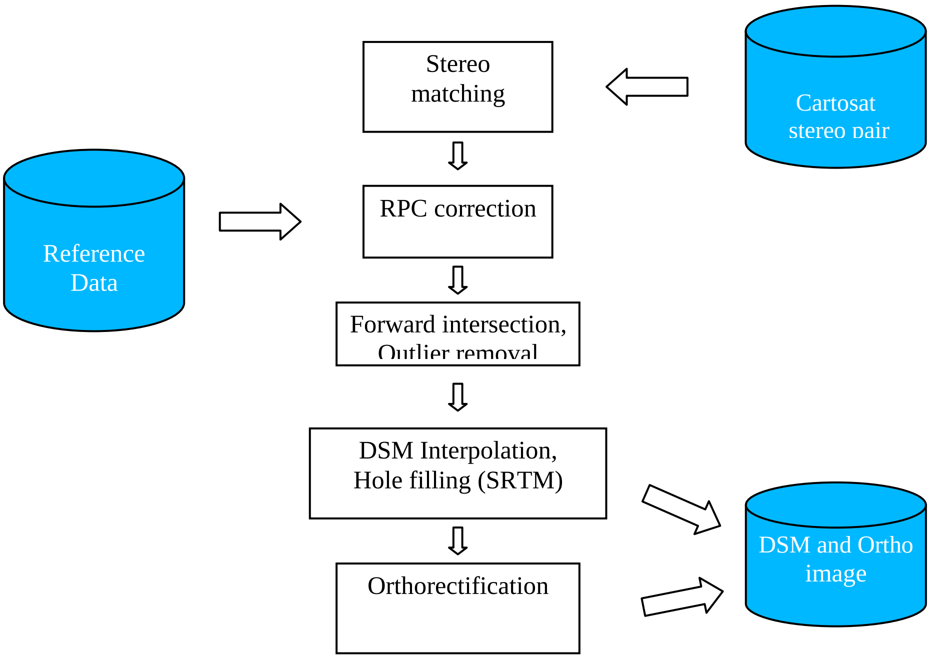


Figure 13 Production Methodology and Workflow

Image Matching

- Principle
  - Hierarchical LSM matching
  - Region growing on epipolar images with bidirectional LSM verification step

- Difficulties
  - Problems in homogeneous areas, shadows and clouds
  - Only two views – occlusions
    - Mountains, (Cities)

Geo-referencing Affine RPC correction

- Direct geo-referencing not accurate enough
  - Lateral accuracy of Cartosat-1 RPCs only approx. +/-250 m
  - Affine RPC correction with GCPs necessary

- Automatic GCP collection using reference image ETM+ (and DSM)
  - Large temporal difference (> 5 years)
  - Good GCP distribution not guaranteed
  - Lateral accuracy limited by used ETM+ mosaic based on GeoCover 2000 (~10-50 m)
  - Limited lateral accuracy may result in tilts in generated DSM

- But SRTM as reference more accurate (lateral accuracy < 10 m in Eurasia)

Geo-referencing by DSM alignment Affine RPC correction

- Use SRTM as the only ground control
  - Absolute lateral error (Eurasia) 8.8 m (CE 90)

- 3D Affine alignment of DSM against SRTM
  - Iterative outlier removal
  - Can handle local terrain changes and holes in reference DSM

- Estimate improved affine RPC correction
    - Robust, complete scene extend used
    - Improved orientation of both DSM and ortho-image

- Reference images still needed in flat areas
    - DSM alignment requires terrain

<u>DSM and Ortho-Image Generation</u>

- Forward intersection of mass points

- Gross outlier removal using SRTM as reference

- DSM interpolation
    - Interpolate small holes
    - Larger holes filled with SRTM using Delta Surface Fill

<u>Preliminary Specifications</u>

- DEM post spacing	10 m
- Spatial reference system	UTM/WGS84
- Height reference	EGM96
- DEM file format	GeoTIFF (16 bit)
- Ortho-image pixel size	2.5 m
- Metadata	XML
- Masks	filled with SRTM

The product will meet the following positional accuracy:
10 m CE90 horizontal
10 m LE90 vertical

Surface treatment
Vegetation and buildings included, DSM

6.3.4 Quality Parameters

Test results
- Barcelona: CE95 7.7 m horizontal
  LE95 3 m vertical (DLR)

Validation procedures in production
- manual check for shifts between adjacent orthos
- automatic correlation between adjacent orthos planned

6.3.5 EU-DEM Data Product Delivery

No information available.

6.3.6 Data Examples

DEM processor is not yet operational
- Tests are ongoing
- Semi Global Matching (faster, denser) under evaluation
- Packaging and formatting of products to be implemented

Areas above 60°
- Automated production depends on availability of ASTER GDEM (expected in June/July)
- Currently manually collected GCPs required

Sample data will be provided as soon as possible.

6.3.7 Licensing

Scene-based DEMs or scene-based DEM + Ortho
- Part of Euromap's GSC-DA offer to ESA
- Offered under the baseline license
- Extension to all other user groups requested in the GSC-DA tender is offered

Derived data can be used freely, as long as the DEM can not be reconstructed.

Pricing models
- Scene-based DEMs will be priced per scene
- 0.5° x 0.5° tiles of the mosaicked DEM will be priced per square kilometre
- Volume dependent
- Price depends on exact license conditions, which is open to negotiation

6.3.8 Technical and Capacity Development

Development of mosaic processor (DLR/IMF) to generate a consistent and seamless dataset
- Bundle block adjustment of adjacent Cartosat-1 scenes
- Creation of DSM and Ortho product with improved and consistent absolute orientation

Production of pan-European DEM in 0.5° x 0.5° tiles

6.4 EuroDEM (Federal Agency for Cartography and Geodesy/EuroGeographics – Michael Hovenbitzer)

6.4.1 Organisation Overview

EuroGeographics represents nearly all European National Mapping and Cadastral Agencies (NMCAs). Currently EuroGeographics has 52 members from 43 countries. Together the members are contributing to the set up of a European Spatial Data Infrastructure (ESDI).

EuroGeographics is a non-profit association that connects the work of its members, the National Mapping and Cadastral Agencies. The head office of EuroGeographics is located in Paris. EuroGeographics works with a small number of employees (<10) in the head office at the management of various products, projects and expert groups. The technical work on the product is done by the members. EuroGeographics is funded by its members. Some of their projects are partly funded by the EC.

6.4.2 Background in Elevation Data Production

The product management for EuroDEM was done by the Federal Agency for Cartography and Geodesy (BKG – Germany). BKG is well grounded in the harmonization of datasets, because of the federal structure of Germany. Since 2002 BKG worked at the harmonization of the German DTM out of 16 datasets from the federal states. The first version was finished in the year 2004.

6.4.3 Pan European Capability

The extent EuroDEM is the EU27, plus Croatia, Iceland, Kosovo, Moldova, Norway, Switzerland, … Grey areas are filled with SRTM data.

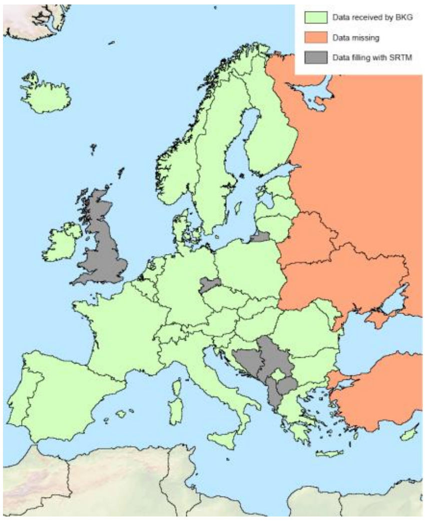


Figure 13 – EuroGeographics coverage

The product EuroDEM is a Digital Terrain Model (DTM). Exceptions are greater gap fillings, where SRTM data (DSM) was used.

Because EuroDEM is a mosaic of EuroGeographics' members national data the original datasets are acquired with different methods:

- Laserscanning

- Photogrammetry
- Digitalization of analog contour lines

Many countries are currently improving their national DTMs with very high accurate methodologies.

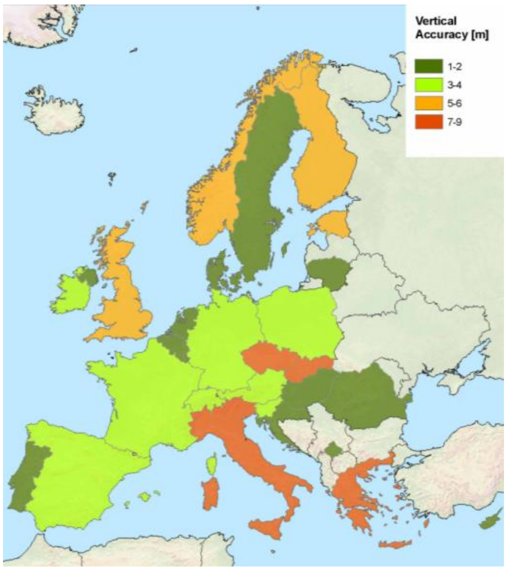


Figure 14 – Vertical accuracy of the DTM data of the EuroDEM countries

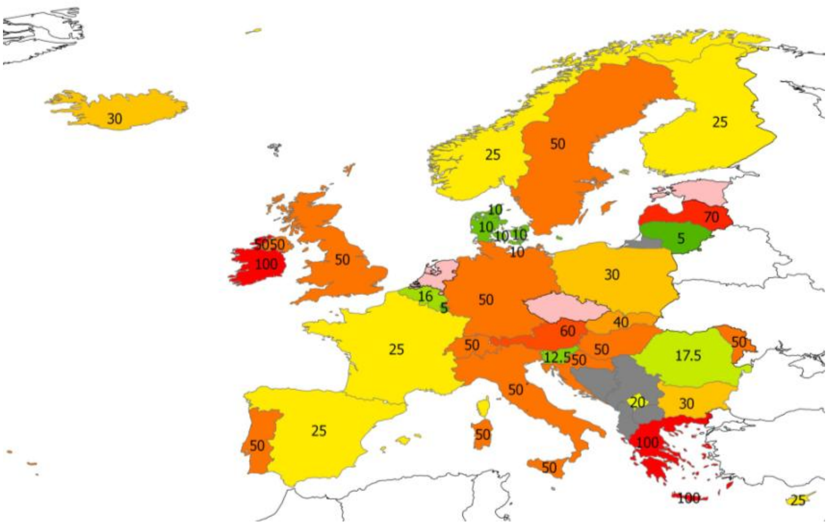


Figure 15 – Grid width of the delivered data in meters

The elevation data is transformed into a uniform projection and height system.
Differences from different dates and methods of data acquisition in overlaps at national boundaries are eliminated.

- Regions with great differences (errors) are cross-checked against contour lines of topographic maps or STRM-height values.
- Merging with an average algorithm regarding the distance to the national border of the member's state.

Subsequently there is a subdivision into tiles, compilation of regions and single countries.

The formats for delivery are created.

6.4.4 Quality Parameters

- Vertical accuracy	12 m (95% conf. level)
- Vertical resolution	heights in integer values
- Horizontal accuracy	~10 m (tests made)
- Horizontal resolution	2 arc seconds (~ 60 m)
- Surface treatment	includes no vegetation and buildings, except the SRTM areas
- Hydrological consistency	JRC tested EuroDEM data with good results
- Metadata	available (ISO 19113)

The quality control consists of checking the vertical accuracy with the points of the levelling network in Europe. The result was 6.0 RMSE.

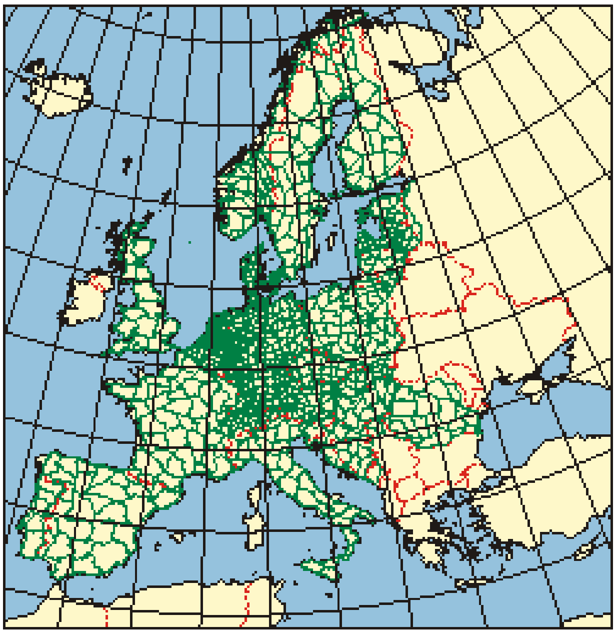


Figure 16 – Quality control EuroDEM

6.4.5 EU-DEM Data Product Delivery

EuroDEM can be delivered for the whole, displayed extent or partitioned in four regions:
- Northern Europe
- Western Europe
- Central Europe
- Eastern Europe

- Data formats	Esri Grid, Esri Ascii Grid, GeoTiff, Ascii XYZ
- Reference system	ETRS89
- Projection	no, geographical coordinates
- Height system	EVRS
- Services	download per FTP, other services planned

6.4.6 Data Examples

Data examples were provided for mountainous, plain, plateau area and above 60 degrees.

6.4.7 Licensing

EuroDEM is licensed on an annual basis and a minimum license period of 5 years.

EuroDEM	Minimum 5 years	Following years Annual fee
Single user usage right	130.000 € 0,03 € / km2	26.000 €
Unlimited usage right incl. Internet right	715.000 € 0,16 € / km2	143.000 €

6.4.8 Technical and Capacity Development

- EuroGeographics is developing their service infrastructure in the ESDIN project.
- Another goal of the ESDIN project is the data policy. They are launching a service product “EuroGeoNames” which uses a “freemium” model.
- EuroGeographics will monitor the user requirements of the pan-European DEM.
- The members will provide data in Annex II for INSPIRE (this will be affecting after 2016).

Options for a better EuroDEM are:

- EuroDEM30: To provide 30m resolution and 5m accuracy (based on update of the current EuroDEM), price level about same, few countries need to provide an update, possibility in 2010-2011
- EuroDEMmax: To provide hightest harmonized available accuracy in Europe (in forthcoming years) possible with co-operation with other commercial actors.

6.5 Reference3D (Spot Image – Marc Bernard)

6.5.1 Organisation Overview

- Company/consortium composition
  Reference3D is co-edited by Spot Image and IGN-France

- Geographical location
  France

- Structure (divisions, departments, staff)
  Spot Image: SME staffed with 220 people
  IGN: department in Toulouse (IGN Espace), staffed with 80 civil servants

- Principal operations devoted to DEM
  IGN: in charge of National French mapping and 3D database since … 1940.
  IGN Espace and Spot Image produce the Reference3D database since 2002.
  Reference3D coverages as of April 30th, 2009: 41+ millions km2

- Funding
  Stereo sensor on-board SPOT 5 was 46% funded by the French Government.
  Same for Reference3D production costs.
  Remaining funding should come from the market.

6.5.2 Background in Elevation Data Production

- Evolution of technical capability
  2003: 3-4 Millions km2 annual Ref3D production output
  2007: 8 Millions km2
  2010: 11 Millions km2

- Major developments in DEM production
  2002 and before: image matching for DEM extraction from aerial and space images

  2002-2003: definition of Ref3D specs with major users; embedded automatic tool to validate SPOT stereopairs; tasking of SPOT HRS stereopairs and triplets; in-flight calibration of HRS sensor; adaptation of block-adjustment and matching SWs to SPOT5 HRS; launch of Ref3D production

  2004-2007: automatic tie point measurements; automatic detection of artifact and suspicious areas using SRTM DTED1; use of ERS-1 & 2 altimeter as independent check points for Ref3D elevation data; implementation of DLD (Double-Line Drains) processing for riverbeds

  2008: re-processing of very large blocks to improve absolute horizontal accuracy (10mCE90); integrations of ICESAT data as independent source to detect blunders and check Ref3D elevations

  2009: starting the production of Reference3D v2

- Current DEM product/service overview
  On-line distribution of DEM, on-line distribution of Ref3D;
  On-line service for image orthorectification (from user image or Spot archive image)

6.5.3 Pan European Capability

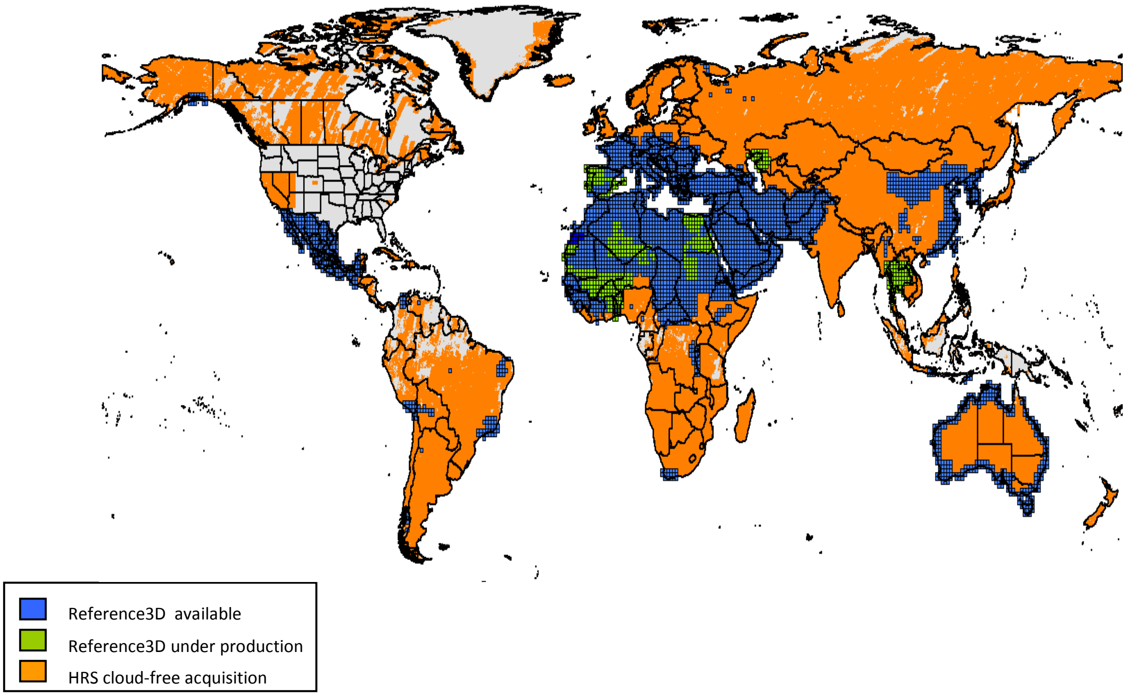


Figure 17 – Availability of Reference3D

What is Reference3D ?

Reference3D is a 3D package produced from SPOT 5 stereo data (HRS), especially designed for large area coverage. Uses range from mapping, GIS applications (forest, urban, agriculture, …) to military needs.

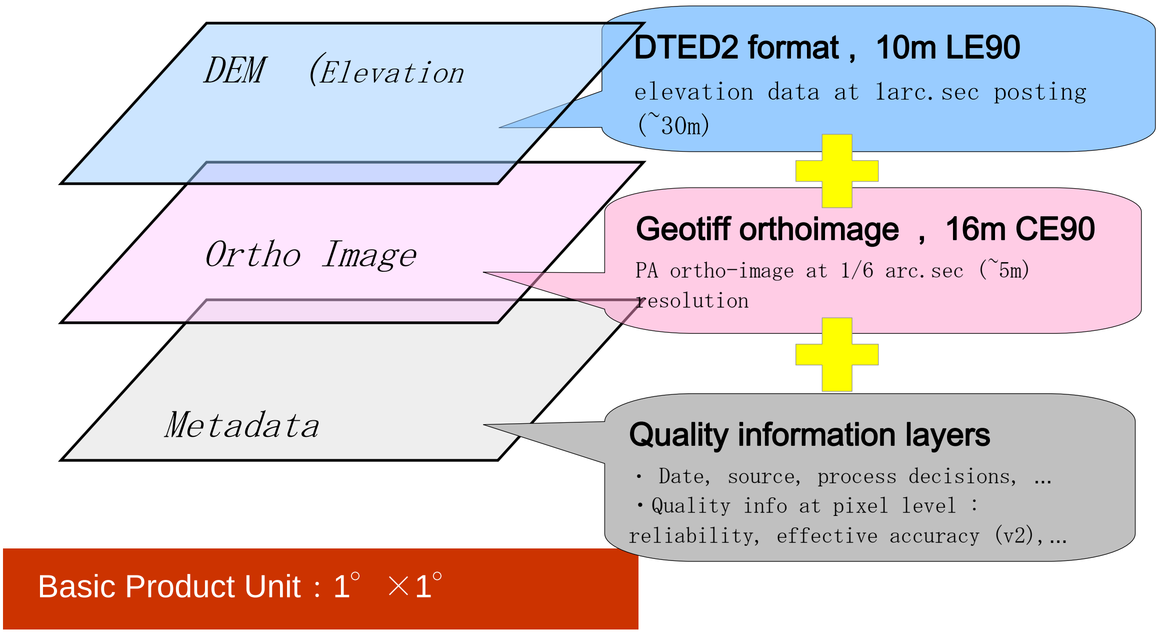


Figure 18 – Reference3D

DTED/HRTI equivalents available pan-EU

DTED level 2 (1 arc second below 50°N, 2 arc second in longitude for Northern Europe

Geographic Coverage
Current Ref3D coverage of EU27 is 2.54 M km2

Elevation Surface (DSM, DTM, Bathymetry)
First reflecting surface (DEM)
Bathymetry: none
DEM edited for seas, lakes and (option) rivers (DLD)

Sources
SPOT 5 HRS stereo pairs and/or

6.5.4 Quality Parameters

<u>Vertical accuracy characteristics</u>

Reference3D specs for absolute vertical accuracy
 10m LE90 for slopes < 20%
 18m LE90 for slopes between 20% and 40%
 30m LE90 for slopes above 40%
Other specs apply for relative accuracy
Effective vertical accuracy of Ref3D verified by major users: JRC (5.4m LE90 against Hungarian DEM), Bulgarian Cadastre Agency, NGA (2.3 to 7.2m LE90), French MoD, and other users in Germany, China, Japan, Australia, Oman, …

<u>Horizontal accuracy</u>

Reference3D spec for absolute horizontal accuracy is 15m CE90
Other spec applies for relative accuracy
Effective horizontal accuracy of Ref3D products measured by major users: JRC (12.1m CE90), Serbian Cadastre Agency, NGA (8.8m CE90), French MoD (3m to 10.1m CE90), and other users in Germany (better than 10m CE90), Japan, Australia, Oman, …

<u>Surface treatment</u>

Vegetation: none
Water bodies: DEM edited for seas, lakes and (option) rivers (DLD)
Buildings: none

<u>Hydrological consistency and matching with hydrographical pattern</u>

DEM edited for seas, lakes and rivers (DLD option)
DLD optional processing ensures a monotonous flow down of large rivers. A geoTIFF quality mask (MWa) records all editions linked with water bodies.

Additional specs for islands, cliffs and watersheds ensure good water basin delimitation and corresponding computations. The Ref3D ortho-image is greatly helpful at user level for delineation of fine water courses and other hydrological items. Ref3D is not adequate for “very-large-scale” uses e.g. fine design of irrigation network.

<u>Artefacts</u>

Semi-automatic detection and correction of artefacts. All editions recorded into a Quality Mask (MRe). No artifact above a given threshold. All remaining artefacts and suspicious areas (ie out of the specs) manually recorded into a specific Quality mask (MQu).

<u>Mosaicking procedures – Ancillary data, metadata</u>

A full set of metadata is available: sources, accuracy, process records, block adjustment residuals, external data used for void filling, estimated horizontal and vertical accuracy

Consistency of characteristics through EU territory

There is a full consistency, national borders do not impact Ref3D.

Quality assessment/validation procedures in production

There are four pillars to meet the specs:
- CNES carefully computes the orbital parameters of SPOT5, day after day.
- Quality insurance procedures in production benefit from 7 years of experience (some were painful). Spot Image is ISO 9001 certified.
- All Ref3D geocells are checked by French MoD within a devoted team (Paris).
- In-depth accuracy assessments are performed before and after use by major customers (JRC, NGA, several NMAs and MoDs, …)

6.5.5 EU-DEM Data Product Delivery

Data file format
Ref3D DEM format is DTED level 2
Product framing: 1°x1° geocell
Masks in GeoTIFF and DXF; Metadata in DIMAP/XML
Open documentation is available on-line.

Coordinate system(s)
WGS84/EGM96 or EVRS/ETRS89
DEM commonly delivered in GeoTIFF, any projection, any system (linked with WGS84)

Services available
On-line ordering and delivery of DEM from Reference3D
On-line service for image ortho-rectification (based on Reference3D)

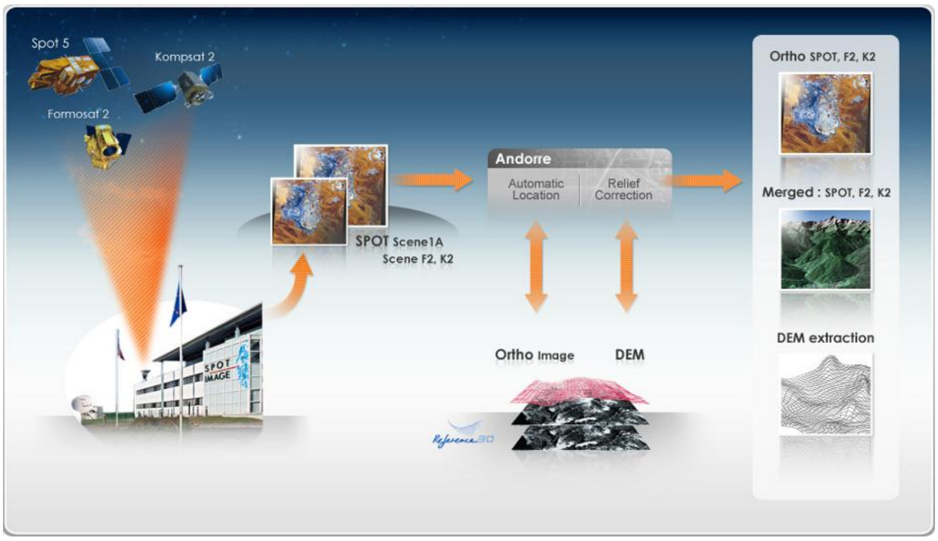


Figure 19 – Ortho-OnLine: the multi sensor orthorectification tool

6.5.6 Data Examples

Data examples for plains, lowlands, mountains and areas above 60 degrees North were given.

6.5.7 Licensing

A standard Reference3D license is available on the web site. A formal permission from the French government is needed.

Licensing is flexible, from a single user to large communities. Major users are granted customized licenses. There are many pricing schemes possible: global price, annual fees, project license, … Volume discounts are applied.

6.5.8 Technical and Capacity Development

Forthcoming developments envisaged: Reference3D v2
From 2008, the Ref3D production is based upon mass image modelling:

- Process very large image blocks (up to 15Mkm2) to refine absolute horizontal accuracy down to 10m CE90 and less
- Produce Ref3D v2 DEM with increased productivity (80+Mkm2 before 2014) with Accuracy Masks
- Upgrade existing 30m km2 Ref3D v1 into v2
- UE27 could be totally covered within 2010

The Ref3D v2 product

- Specifications are close to v1, with improvements and add-ons:
  - 2,50m colour ortho-image (to complement HRS Pan 5m)
  - Stronger involvement of IceSat measurements
  - Ref3D v2 includes a commitment in effective local accuracy (Accuracy Masks)
    - Planimetry: increased precision on most areas: 10m CE90
    - Altimetry: zonal precision indicators by range of values, cross-checkable with local slope
- Productivity gains are mandatory:
  - Improved matching process set up
  - Shared computations
  - More automatisation in the DEM cross-check/correction phase
  - More automatisation of the Masks' drawing process

Ref3D perspectives
2010-2011:

- European continent and main overseas covered with Ref3D v2
- including 2.50m colour ortho relevant to GMES core services
- Upon reception of adequate GCPs possible improvement of the commitment on absolute horizontal accuracy in XY down to 3m

From 2011:

- Improved absolute horizontal accuracy in XY up to 3m thanks to Pleiade local GCP units

6.6 ASTER Global DEM (NASA/Jet Propulsion Laboratory – Michael Abrams)

6.6.1 Organisation Overview

The consortium is composed of the U.S. National Aeronautics and Space Administration and Japan Ministry of Economy, Trade and Industry. Funding comes through government. The principal operations devoted to DEM are producing DEMs from individual ASTER scenes and distribution of a Global DEM.

6.6.2 Background in Elevation Data Production

Evolution of technical capability: Japan uses in-house developed software to produce scene DEMs, US uses COTS software. Currently DEMs are produced on demand for individual ASTER scenes.

6.6.3 Pan European Capability

- DTED/HRTI equivalents are available pan-EU
- Geographic coverage goes from 83N to 83S
- Elevation Surface (DEM)
- Sources are ASTER stereo pairs: along-track, 0.6 B/H, 15m pixels
- Global DEM is produced by contractor

6.6.4 Quality Parameters

- Vertical accuracy characteristics
  Tested values at 95% confidence level=20m
- Horizontal accuracy
  Tested values at 95% confidence level=30m
- Surface treatment
  Water bodies = 0
- Hydrological consistency and matching with hydrographical pattern
- Artefacts: TBR
- Mosaicking procedures
- Ancillary data, metadata:
  Number of images used for compilation per pixel; source of ill
- Quality assessment/validation procedures in production:
  A validation study is now being completed

6.6.5 EU-DEM Data Product Delivery

The DEM Output Format is GeoTIFF, signed 16 bits and 1m/DN. Referenced to the WGS/EGM96 geoid. Geographic latitude and longitude.

The coverage is from 83° N to 83° S. The data set consists of 22,895 1°x1° tiles.

6.6.6 Data Examples

Following example is an extract covering the area around Ispra (Italy)

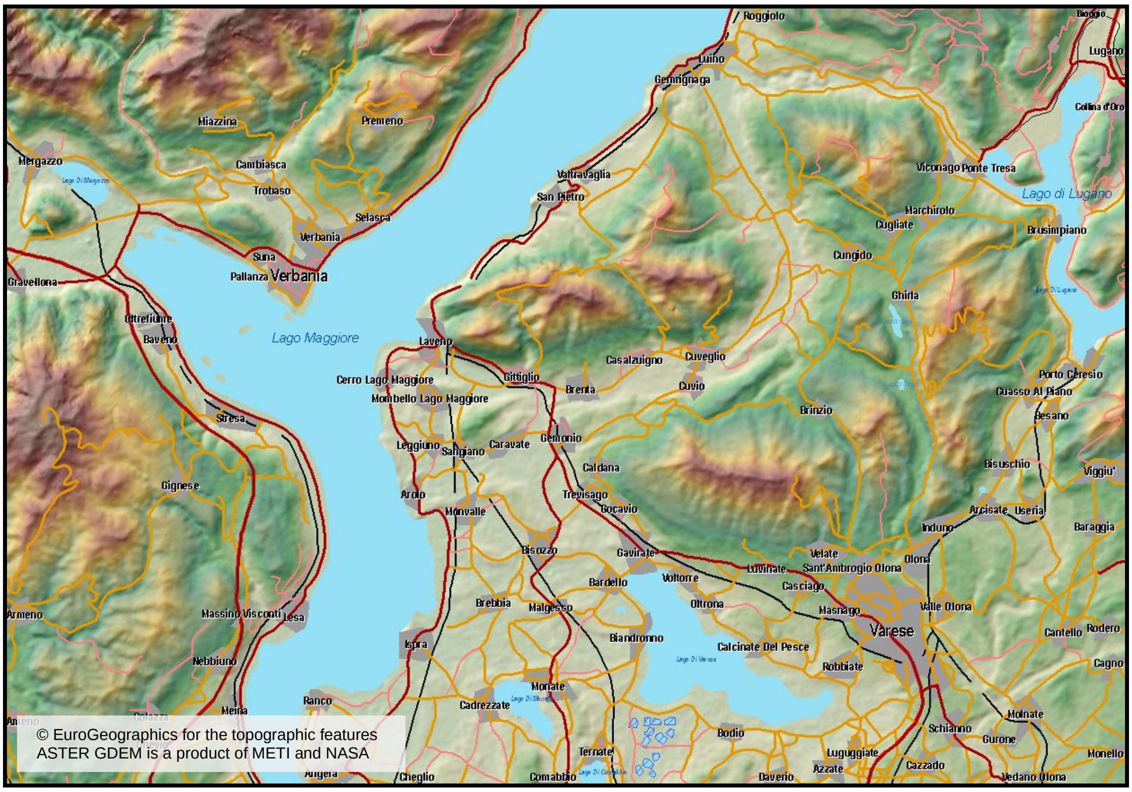


Figure 20: ASTER GDEM overlaid with EuroGeographics EuroRegionalMap data

6.6.7 Licensing

The data are available to all users. No secondary re-distribution will be required. There is no charge to all users.

6.6.8 Technical and Capacity Development

The public release of the full global data set was anticipated for June or July 2009. Data is available at no cost to all users in the spirit of the Global Earth Observing System of Systems (GEOSS). ASTER GDEM will initially be packaged in 1°x1° tiles, though “seamless” options may be considered in the future. The current plans are for data to be jointly released as a standard ASTER data product from:

- U.S. through Land Processes DAAC and EOS Data Gateway
- Japan through ERSDAC Ground Data System

7. Evaluation Sample Data

7.1 Description Sample Data

In order to assess the available data in more detail, four areas were identified and suggested to data providers. Each area covered 40km x 40km, represented in the Lambert Azimuthal Equal Area Projection, ETRS89 spheroid, which is one of the recommended reference systems for Europe.

Three basic topographic types were included, together with one area in high latitudes.

Study area 1 – Mountainous - Border Italy (Lombardia), Switzerland (Canton)

Study area 2 – Plain – Border Belgium, Holland

Study area 3 – Area above 60 degrees N - Border Norway, Sweden, Finland

Study area 4 – Plateau area – Border Slovenia, Italy

7.2 Evaluation Sample Data/Comparison sample Data

A detailed evaluation of the sample data will be done later by JRC.

8. Conclusions and Recommendations

The workshop confirmed that there is a need for a continent-wide elevation dataset at 25 m or 50 m posting, and at an overall vertical accuracy of around 5m. The workshop also pinpointed that some specific applications require more accurate information (e.g. hydrology e.g. flood, water management, but also agriculture etc.) which will require the access to another level of DEM resolution and accuracy, to be considered in a second step of development.

A single off the shelf solution for a fully consistent pan EU DEM at the required resolutions does not exist: all products suffer from some kind of drawback (incomplete coverage, varying levels of quality, appearance of artefacts etc.) Therefore a short term solution to provide an EU-DEM will need a processing of data from several sources. Along with the difficulties to provide a harmonised level of detail and accuracy under these boundary conditions, it is important to ensure a proper description of metadata accompanying the EU-DEM, (including information on data sources, methodologies and vertical as well as horizontal uncertainty estimates at pixel level).

Whilst mainly focusing on technical aspects, the workshop yielded some discussion on pricing and licensing – here there are still barriers to widespread use and considerable variation in the models used between providers. Strong reservations exist among European providers against releasing any product for public use. The mid resolution (down to 25m) is not the focus of current commercial activity. Therefore, if the EU intends to make available such a data set to the public it might have to procure it itself e.g. through the JRC. Such a step could also help to establish a freely accessible reference data set against which upcoming new products could be checked for their consistency.

In this context it should be noted that the ASTER GDEM has meanwhile been released, but there exist significant concerns on quality. Feeling of the JRC community is that these could be addressed by reprocessing (i.e. the problems are occurring as a result of the processing chain especially mosaicking) if the original ASTER DEM data were to be made available.

There is evidence of a shift towards web service based delivery of elevation data as a more appropriate model within an SDI context. Besides the obvious advantage of getting access to the most up to date versions of a data set, the service based approach would allow more flexible licensing schema’s as well, including the usage of a DEM without physical download of the data.

References

Far, T. and Kobrick, M., 2000. Shuttle Radar Topography Mission procedures a wealth of data. Amer. Geophys. Union Eos, 81 (48):583-585

Maune, D. (Ed.), 2001. Digital Elevation Model Technologies and Applications: The DEM Users Manual. American Society for Photogrammetry and Remote Sensing.

Wirthmann, A., Annoni, A., Bernard, L., Nowak, J., 2005. Proposal for a European Grid Coding System. European Reference Grids Workshop, 27-29 October 2003, Proceedings and Recommendations.

European Commission

EUR 24128 EN – Joint Research Centre – Institute for Environment and Sustainability

Title: **Comparison Workshop on a European Digital Elevation Model**
Authors: Katleen Miserez, Stephen Peedell, Peter Strobl, Hans Dufourmont, Jean Dusart

Luxembourg: Publications Office of the European Union
2009 – 46 pp. – 21 x 29.7 cm
EUR – Scientific and Technical Research series – ISSN 1018-5593
ISBN 978-92-79-14621-3
DOI 10.2788/51490

Abstract
This document is the report of the Comparison Workshop on a European Digital Elevation Model Co-organised by the GMES Bureau (EC, DG Enterprise and Industry) and the Institute for Environment and Sustainability (EC, DG Joint Research Centre), Stresa, Italy 5-6 May 2009.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

LB-NA-24128-EN-C

EUROPEAN COMMISSION

Publications Office
Publications.europa.eu

ISBN 978-92-79-14621-3