UN-GGIM EUROPE

UNITED NATIONS COMMITEE OF EXPERTS ON GLOBAL GEOSPATIAL INFORMATION MANAGEMENT

Core Spatial Data Theme ‘Elevation’ Recommendation for Content

Working Group A - Deliverable of Task 1.b

Version 1.0- 2019-08-26

Version History

Version number	Date	Modified by	Comments
1.0	2019.08.26	WG A	Consolidated draft, for review by geographical and statistical community

Warning: in the following parts of this document, the paragraphs written in grey e.g. "This document has annexes containing more detailed explanations " are common to all core spatial data themes; they aim to provide context and objectives of core data. The paragraphs written in black are specific to core spatial data theme Elevation.

Content

1 Executive Summary

In September 2015 the countries of the United Nations adopted the 2030 Agenda for Sustainable Development; a set of goals to end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development agenda. Each goal has specific targets to be achieved over the next 15 years. The 17 Sustainable Development Goals (SDGs) of the 2030 Agenda are supported by 169 targets and 230 indicators.

Geospatial data supports the measuring, achieving and monitoring of many of the goals and targets set by the 2030 Agenda. The 2030 Agenda demands new data acquisition and integration approaches to improve the availability, quality, timeliness and disaggregation of data. Goal 17 explicitly emphasizes the need for developing capacities and partnerships. In this context the success of the 2030 Agenda depends on senior administrators owning and leading the geospatial efforts in their respective countries.

In Europe, building on the INSPIRE Directive redirecting the focus on a cohesive spatial data infrastructure without gaps in content and discrepancies in quality, stakeholders are working on geospatial standardization and increasing richness of data through Core Data Recommendations for Content that correspond to the first phase of WGA work program. Core data is primarily meant for fulfilling the common user requirements related to SDGs in Member States and European institutions.

Elevation is part of the basic geographic equipment of a country. Elevation influences propagation of physical phenomena (such as water flow, wind, air or water pollution, visibility, waves) but also ecosystems or urban spreading. In addition, it is required to derive other data, such as orthoimages or drainage basins.

Several products are necessary to cover the wide range of user requirements. For each level of detail, it is recommended to supply both a DTM (Digital Terrain Model) and a DSM (Digital Surface Model). Elevation data is required at large and medium scale on whole land territory. In addition, most detailed data is necessary on hot spots, such as urban areas or flood risk zones.

Focus is on land territory. However, it is also advised to provide a coarse (medium scale) DTM on territorial waters. Bathymetry of rivers would also be quite useful but unfortunately, is difficult to achieve as efficient production methods are currently missing. Research and knowledge exchange are encouraged as consideration for future.

Main quality criteria are the vertical accuracy (depending on level of detail) and the production frequency: this production frequency has been fixed as 3 years for large and medium scale data and as 6 years for the detailed DTM and DSM because they require more production efforts.

DTM and DSM should be provided using current grid formats and standardised Coordinate Reference Systems. Other formats (Lidar point cloud, TIN) might be considered in future.

2 Foreword

2.1 Document purpose and structure

2.1.1 Purpose

This document provides the main characteristics of core data for theme Elevation with focus on the recommendation for content. This document aims to help decision makers (from governments, data producers, national coordination bodies, etc.) to define their policy regarding the improvement of existing data and production of new geospatial data. It addresses digital data.

This document has Annexes containing more detailed explanations targeting the technical people who will be in charge of implementing or adapting core data recommendations (e.g. for production purpose, as source of other standards, etc.).

2.1.2 Structure

The executive summary synthesizes the main conclusions of the Working Group A (WG A) process and results to develop the recommendation for content. It is meant mainly for high level decision makers.

The foreword reminds the general context of core data, the first step achieved by WG A (i.e. selecting core data themes), and it explains the general principles set by WG A to develop the recommendations for content of core data specifications for all selected themes.

The 'recommendation for content' document itself includes four chapters:

- Overview: it provides the general scope of the theme and describes the main use cases addressed;
- Data content: it provides the main characteristics of the recommended content, such as the list of core features and attributes (for vector data), as well as data capture and quality rules;
- Other recommendations: e.g. Coordinate Reference System, Metadata, Delivery;
- Considerations for future: this chapter addresses some key trends or significant user requirements that cannot be considered as core today but that might be considered in future.

The 'recommendation for content' document is meant for medium level decision makers. It is written in natural and not too technical language.

The technical explanations included in annexes describe the relationship between the recommendation for content and the corresponding INSPIRE specification, and contain any other appropriate information useful for this theme.

2.2 Core data context

2.2.1 Rationale for core data

The following background of harmonised pan-European data was identified.[1]

Authoritative geospatial data are used to support both the implementation of public policies and the development of downstream services. Moreover, geospatial data are required to be homogenous to enable the implementation of public policies in a coherent and coordinated way among countries and at regional or global level. Likewise, significant opportunities exist if services developed by industry can be exploited without requiring country specific adaptation.

The INSPIRE Directive has set up the legal and technical framework for harmonisation of the existing data related to the themes in annexes I, II and III. INSPIRE specifications provide common data models that ensure a first step towards interoperability, however ensuring homogeneous content is outside their scope, as they contain no indication about levels of detail, very few recommendations about quality, and as most features and attributes are "voidable", i.e. to be supplied if available or derivable at reasonable cost.

This background led the UN-GGIM: Europe Regional Committee to setup in 2014 the Working Group A on Core Data to deal with core data content and quality, production issues, funding and data availability.

Recommendations for content of core data will complement INSPIRE data specifications by defining the priorities on the core content that is encouraged to be made available in Europe in order to fulfil the main user requirements that are common to many countries, with focus on the SDG related ones.

Core data availability may be ensured either through upgrading of existing data when feasible or through production of new data when necessary.

2.2.2 Core data scope

In its first phase, WG A selected core data themes according to the following criteria: core data is the geospatial data that is the most useful, either directly or indirectly, to analyse, to achieve and to monitor the Sustainable Development Goals.

Among the 34 INSPIRE data themes, 14 have been considered as core including theme Elevation.

More information about the selection process and results may be found in document 'Core Data Scope - Working Group A - First Deliverable of Task 1.a - Version 1.2' on http://un-ggim-europe.org/content/wg-a-core-data

[1] Extract from the Report by the Preparatory Committee on the establishment of the UN-GGIM: Europe Regional Committee, European Commission Ref. Ares(2014)1491140 - 09/05/2014.

2.3 Document objectives and principles

2.3.1 Encouraging content availability

This deliverable provides recommendations for national governments and data producers, aiming to help them to define their priorities for enriching existing data or producing new data. This deliverable is meant mainly for data producers, however it defines the recommended result and target but not the production process.

2.3.2 Complementing INSPIRE

Core data specifications are built upon INSPIRE data specifications. On one hand, they often simplify INSPIRE by selecting core feature types and attributes and by restricting or clarifying the scope; On the other hand, they enrich INSPIRE by recommending specific levels of detail, quality rules and sometimes data model extensions. Besides, the INSPIRE common terminology is thoroughly used for naming core features and attributes.

Regarding the levels of detail, the ELF (European Location Framework) project terminology has been used. The ELF levels of detail are the following: Global, Regional, Master level 2, Master level 1, Master level 0. These terms are defined in the glossary.

Regarding delivery, core data may be supplied according to several ways. It is expected that, very often, the core data recommendations will be used to enrich and upgrade existing products. In this case, core data will be available through these improved products. Core data may also be delivered through INSPIRE conditions (specifications and services).

2.3.3 Status of core data recommendations

This document contains recommendations that are not legally binding. However, some recommendations are more important than others. This order is indicated as follow:

Core Recommendation X

It is first priority recommendation, considered as both necessary and achievable in principle. Ideally, it should encourage involved stakeholders to launch short-term actions (typically within a couple of years).

Core recommendations are usually addressing only technical aspects and are meant for the organisations in charge of producing this theme. The set of core recommendations defines the basic expectations on core data.

Good Practice X

It is second priority recommendation; if adopted, it will provide significant added value to core data; it indicates a relevant trend to be adopted as much as possible. It encourages involved stakeholders to take these recommendations into account in long term, if not possible in short term.

NOTE: some of these good practices may be quite easy to achieve and are already effective in some countries whereas some others may be more difficult to achieve. This is typically the case when these good practice recommendations involve other stakeholders in addition to the organisations in charge of producing this theme, and when they address not only technical aspects but also legal or organisational ones.

A “core data set” should contain the minimum data defined by the core recommendations (and ideally also by the good practices) of this deliverable but may of course contain more and/or better information.

2.4 Abbreviations

CRS	Coordinate Reference System
DSM	Digital Surface Model
DTM	Digital Terrain Model
EL	INSPIRE theme Elevation
ELF	European Location Framework
HY	INSPIRE theme Hydrography
LoD	Level of Detail
OGC	Open Geospatial Consortium
OI	INSPIRE theme Ortho-imagery
SDG	Sustainable Development Goal
TIN	Triangular Irregular Network
UN-GGIM	United Nations initiative on Global Geospatial Information Management
WG A	(UN-GGIM: Europe) Working Group on Core data

2.5 Glossary

2.5.1 Levels of detail

Global	Level of detail defined by ELF: data to be used generally at scales between 1: 500 000 and 1: 1 000 000, i.e. mainly at international level
Regional	Level of detail defined by ELF: data to be used generally at scales between 1: 100 000 and 1: 500 000; data mainly for national or regional (European or cross-border) actions.
Master level 2	Level of detail defined by ELF: data to be used generally at scales between 1: 25 000 and 1: 100 000); data mainly for regional (sub-national) actions.
Master level 1	Level of detail defined by ELF: data to be used generally at scales between 1: 5 000 and 1: 25 000; data mainly for local level actions.
Master level 0	Level of detail defined by ELF: data to be used generally at scales larger than 1: 5 000; typically, data at cadastral map level, mainly for local level actions.

NOTE: the above definitions are indicative; in practice, detailed data (Master levels) may also be required also by national, European or international users.

2.5.2 Other terms

bathymetry	Elevation of Earth surface in waterbodies
depth	*Elevation* property measured along a plumb line in a direction coincident to Earth's gravity field (downwards) [INSPIRE]
Digital Surface Model (DSM)	Surface describing the three dimensional shape of the Earth's surface, including all static features placed on it. NOTE 1: in theory, temporary phenomena (such as cars, trucks) should not form part of the surface, but due to the technical difficulties in removing them some of these features may also be present in the surface. NOTE 2: Vegetation, buildings and bridges are examples of static features. [adapted from INSPIRE]
Digital Terrain Model (DTM)	Surface describing the three dimensional shape of the Earth's bare surface, excluding as possible any other features placed on it.
elevation	Elevation is vertically-constrained dimensional property of a spatial object consisting of an absolute measure referenced to a well-defined surface which is commonly taken as origin (e.g. geoid or water level) and based on the gravity field of Earth [UN-GGIM: Europe WG A]
height	*Elevation* property measured along a plumb line in a direction opposite to Earth's gravity field (upwards) [INSPIRE]
vertical accuracy	Root mean square error of the Z coordinate

2.6 Reference documents

INSPIRE Data Specification on Elevation – Technical Guidelines 3.1:
http://inspire.ec.europa.eu/id/document/tg/el

3 Overview

3.1 General scope

Definition: Elevation is vertically-constrained dimensional property of a spatial object consisting of an absolute measure referenced to a well-defined surface which is commonly taken as origin (e.g. geoid or water level) and based on the gravity field of earth. Core theme elevation includes terrestrial elevation and bathymetry.

Description: The main purpose of digital elevation data is to provide an elevation property with reference to a specified origin (vertical reference or datum). This property may be height (when the value is measured opposite to the gravity field of the Earth) or depth (when the value is measured in the direction of the gravity field) [adapted from INSPIRE Feature Catalogue].

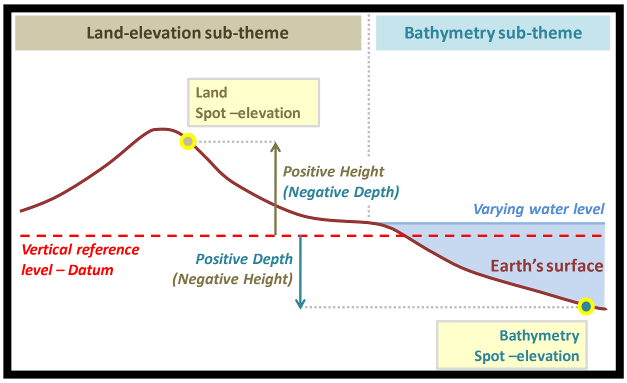

Figure 1: illustration of height and depth properties

Elevation data may be provided according to various representations, such as grid data, contour lines, TIN (Triangular Irregular Networks) or point clouds.

In practice, elevation data may be related to the bare terrain – in this case, it may be represented by a DTM (Digital Terrain Model) – or it may be related to the terrain with its permanent covering features (trees, buildings) – in this case, it may be represented as a DSM (Digital Surface Model).

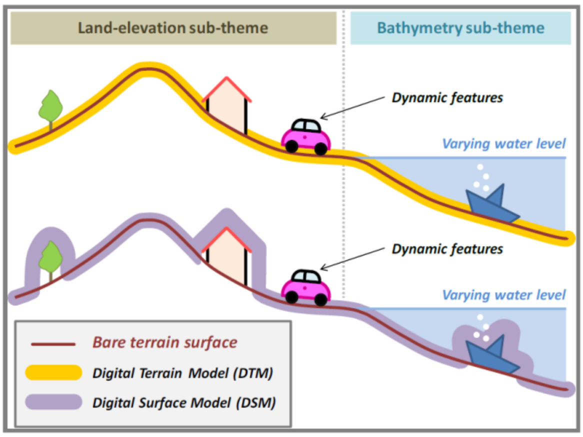

Figure 2: illustration of DTM and DSM

The scope of this core theme is restricting the scope of INSPIRE theme Elevation to Earth gravity properties. In addition, some priorities have been defined, mainly regarding the geographic coverage, levels of detail and types of representations. These priorities are documented in next chapters. More detailed comparison with INSPIRE is available in Annex A.

3.2 Use cases

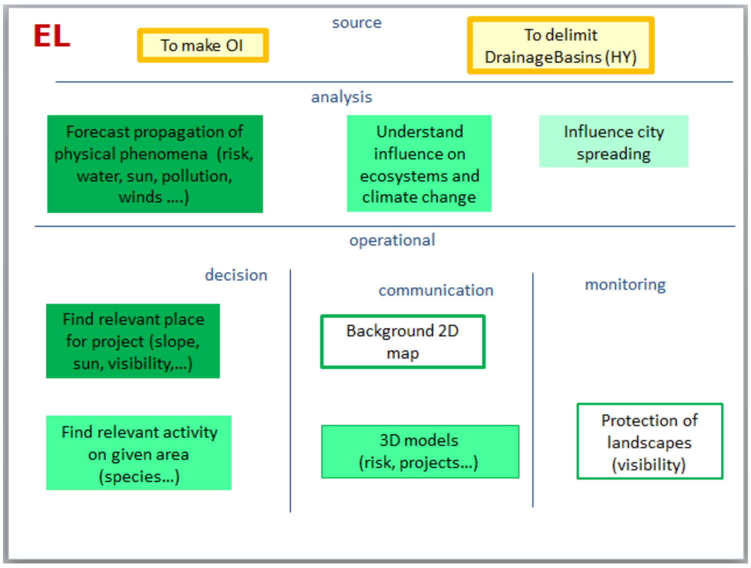

Figure 3: map of use cases for theme EL

Theme 'Elevation' is part of the basic geographic equipment of a country as it is necessary for the production of orthoimages (themselves of wide use) and to delimit Drainage Basins in theme 'Hydrography'. It is also useful for the coastline delimitation. Regarding cartography, elevation data improves 2D maps, by contour lines or by shading but its key use is for 3D models; these 3D models are themselves of wide use, for instance, to communicate about risk zones (to make people more aware), about a new construction project, for valorisation of a territory etc.

Elevation strongly influences key physical phenomena, namely water, air and light propagation. Elevation, being a physical value related to the gravity of Earth, determines the flow direction of liquids. The water flows from high to low so elevation data is required to forecast flood or pollution propagation but also to locate best place for new water pipes. Valleys and mountains facilitate or impede the air propagation so elevation data will be necessary to assess propagation of wind, of fire, of air pollution etc. and to find relevant place for wind turbines. The light may also be stopped by the terrain relief so elevation data is required to compute visibility or inter-visibility maps or to assess the sun potential of an area; it may also help to decide what are the relevant species (agriculture, forestry) for a given area, taking into account the sun exposure and other parameters. From Elevation data, slope data may be derived; slope is key information to decide on any new infrastructure as a terrain with a strong slope is generally not suitable for construction; consequently elevation helps to understand how a city may spread and therefore is quite necessary for spatial planning.

Elevation also influences natural phenomena and ecosystems; obviously, elevation data is required to delimit mountainous ecosystems; meteorological conditions vary quite a lot according to the elevation, therefore impacting flora and fauna; the climate change has different impacts on an area, according to its altitude.

4 Data content

4.1 Master level 0 elevation data

Core Recommendation 1

Member States should ensure the availability of a Digital Terrain Model and of a Digital Surface Model with following characteristics:

- ground pixel size (spatial resolution): 5 m or better

- frequency: 6 years or better

- vertical accuracy (Root Mean Square Error): around 0.5 m or better

- geographic extent: hot spots

NOTE 1: Hot spots should include at least areas prone to flood (i.e. areas around rivers and coastlines) and urban areas; detailed elevation data is useful in urban areas for the production of very high resolution orthoimages and for city 3D models.

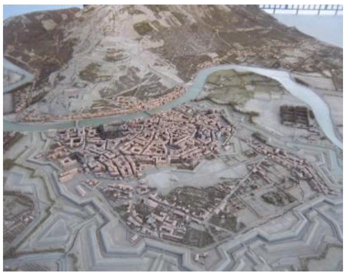

Figure 4: a 3D city model with orthoimages and 3D buildings wrapped on a DTM

NOTE 2: Some European countries are already producing Master level 0 elevation data on whole country. Though whole coverage is not considered as core, this should be encouraged when affordable.

NOTE 3: In practice, such elevation data has to be produced from LIDAR. Therefore, it is advised to produce bathymetric data on sea side up to 10 m depth that is the limit of LIDAR “visibility”. Nevertheless, it should be recognised there may be difficulties if waters are not calm and transparent enough, such as in estuaries

NOTE 4: Digital Surface Model is generally produced first and then the Digital Terrain Model is derived from it. The Digital Surface model is of great interest: it may provide a 3D view of a landscape and so, in urban areas, it may be a low cost alternative to vector 3D city model, enabling studies in many domains, such as urban planning, solar potential of roofs, etc. For instance, they are necessary for studies on wave propagation (location of new antenna, impact on human health) and they enable to easily detect changes (coastal area monitoring, …).

Digital Surface Model is not necessary on the sea part of littoral areas.

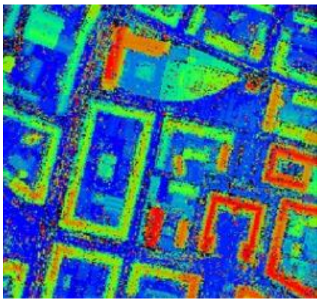

Figure 5: Urban Digital Elevation Model

NOTE 5: The resolution is 5 m is very minimum requirement. Grids with better resolution (2 m or even 1 m) are already produced by some European countries , this is a tend to be promoted.

NOTE 6: The vertical accuracy of 0,5 m is the average target and it may be adapted to the category of hot spots; typically, 50 cm may be enough for urban areas but better accuracy might be useful on areas prone to floods.

4.2 Master level 1 elevation data

Core Recommendation 2
Member States should ensure the availability of a Digital Terrain Model and of a Digital Surface Model with following characteristics:

- ground pixel size (spatial resolution): 10m

- frequency: 3 years or better

- vertical accuracy (Root Mean Square Error): 2 m or better

- geographic extent: whole land territory

NOTE 1: Master level 1 DTM aims to fulfil most of the use cases described in chapter 3.2 for applications at local level. It is the DTM to be used to produce the core reference orthoimage (pixel size between 20 cm and 1 m, accuracy better than 5 m: https://un-ggim-europe.org/wp-content/uploads/2019/04/UN-GGIM-Europe_WGA_Recommandation_Content_OI-v1.0.pdf).

It offers a good compromise between detailed information and user-friendly data (lack of artefacts, reasonable volume of data).

NOTE 2: As for Master level0, Digital Surface Model is generally produced first and then the Digital Terrain Model is derived from it. If the MNS is coming from sub-sampling of LIDAR clouds, it is recommended to use the maximum value of elevation.

NOTE 3: There is a wide range of use cases for Digital Surface Models: for the maintenance of vegetation along electric lines; used at various period of times, they enable to easily detect changes (update of topographic data). But above all, combined with a DTM and land cover, it enables to assess the biomass (e.g. volume of trees in a forest) what is a key information regarding energy (SDG 7) and climate change (SDG 13).

NOTE 4: In practice, Master level 1 DTM and DSM may be produced by stereo-plotting or automatic correlation. In case Master level 0 elevation data exist on whole territory, it may also be used to derive Master level 1 products. As for Master

4.3 Master level 2 elevation data

Core Recommendation 3
Member States should ensure the availability of a Digital Terrain Model and of a Digital Surface Model with following characteristics:

- ground pixel size (spatial resolution): 25 m (or better)

- frequency: 3 years or better

- vertical accuracy (Root Mean Square Error): 5 m or better

- geographic extent: whole land territory

NOTE 1: Master level 2 DTM and DSM aim to fulfil a wide range of use cases for applications at medium scales. It is the DTM to be used to produce the core high frequency orthoimage (pixel size 10 m –Sentinel-2 images: https://un-ggim-europe.org/wp-content/uploads/2019/04/UN-GGIM-Europe_WGA_Recommandation_Content_OI-v1.0.pdf).

NOTE 2: In practice, it is expected that Master level 2 data will be derived (by sub-sampling) from Master level 1 elevation data.

Good Practice 1
The availability of a Digital Terrain Model with following characteristics should be ensured:
- ground pixel size (spatial resolution): around 100 m
- vertical accuracy: a few meters, according to the depth
- geographic extent: sea regions with at least, territorial sea

NOTE 1: Territorial sea is the part of sea between the coastline and the baseline (up to 12 miles from coastline).

NOTE 2: DTM on sea is required for navigation, for cabling, for construction of wind turbines, for resource management (aquaculture, fisheries…) and for risk management (submersion).

NOTE 3: Current production methods enable to get good accuracy (better than 5 m) until depth around 100 m but coarser data (accuracy around 20 m or worse) in deeper waters.

NOTE 3: This good practice is already more or less achieved through the European product Emodnet Bathy. The efforts to consolidate and maintain such product should be encouraged.

4.4 Ground level

A key topic regarding elevation data is to define the "level" where the Ground should be captured. Issues occur in two main cases: inland waters (lakes and rivers) and bridges. This issue is common to all levels of detail but it is crucial in case of Master level 0 that aims to provide a very detailed view of elevation data.

Regarding inland waters, flood propagation studies would require bathymetric data (depth of water) whereas production of orthoimage requires the water surface (limit between air and water) level.

	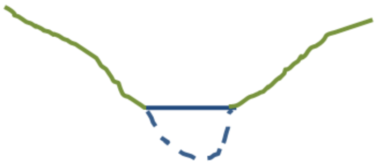	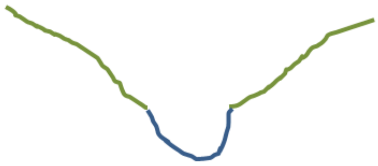
Real-world	Elevation data required for orthoimage production	Elevation data required for flood propagation studies

Figure 6: elevation data for inland waters

In theory, for DTM surfaces describing the floor of water bodies (e.g. the lake-floor or watercourse floor), the water bodies are not considered as part of the Earth's bare surface. Hence, they should be excluded from the DTM. However, in practice, bathymetric data of inland waters is currently considered as difficult to be captured.

Good Practice 2 It is advised to capture the elevation of the inland water surface. When relevant (i.e. on lakes and plain rivers), it should be ensured that the water surface is horizontal.

NOTE 1: good practice 1 applies for all levels of detail (Master level 0, Master level 1, Master level 2).

Regarding bridges (roads or railways above water), they should in theory, be considered as part of the Digital Surface Model but not of the Digital Terrain Model. However, in practice, it is generally easier to capture elevation data at the bridge surface level; in addition, considering that the terrain level is on the bridge surface is better to ensure continuity of the road or railway network on an orthoimage. On the other hand, a DTM with terrain level on the bridge surface is not fine for water flow propagation studies.

The best solution would be to provide two options of the DTM, one for orthoimage production (with ground level on bridges) and one for hydrological purposes (with ground level under bridges, on water surface).

Good Practice 3 For DTM, at least for Master level 0, in areas prone to flood, where water flow studies are main use cases, data producers should "open the bridges", i.e. choose to capture the water surface level.

5 Other recommendations

5.1 Coordinate Reference System (CRS)

5.1.1 Land elevation data

The above recommendations and good practice apply to the elevation data related to Core Recommendations n° 1, n° 2 and n° 3. Core recommendation n° 1 relates to Master Level 0 DTM on hot spots, such as areas under flood risk and so including coastal zones with both land elevation data and bathymetry data along the shoreline.

Core Recommendation 4
For Master Level 0 data, the horizontal and vertical Coordinate Reference Systems used on the land should also be used on the sea part, for bathymetry data.

NOTE 1: In general, Master Level 0 DTM should be delivered as an integrated product (with some CRS) to enable efficient use for the flood risk management use case.

5.1.1.1 Horizontal reference system

Good Practice 4
Core data should be stored and managed in a CRS based on datum ETRS89 in areas within its geographical scope, either using geographic or projected coordinates.

NOTE 1: geographical scope of ETRS-89 excludes over-sea territories, such as Canary Islands or French Guyana or Madeira Islands and Azores Islands. In these cases, it is recommended to use a CRS based on ITRS (International Terrestrial Reference System).

NOTE 2: storing and managing data in CRS based on international datum facilitates the import of measures from modern sensors, ensures that data is managed in a well-maintained geodetic framework and of course, facilitates the export of data into international CRS (e.g. those mandated by INSPIRE).

5.1.1.2 Vertical reference system

Core Recommendation 5
It is recommended to use for the Z coordinate a gravity-related height.

NOTE 1: Elevation should be a physical value related to the gravity of Earth in order to enable determination of the liquid flow direction. Typically, height above ellipsoid is not considered as relevant.

Good Practice 5
For land territories, the Z coordinate should ideally be given in EVRS as vertical component of the Coordinate Reference System.

NOTE 1: EVRS states for European Vertical Reference System.

5.1.2 Bathymetry data

The above recommendations and good practice apply to the elevation data related to Good Practice n°1.

Good Practice 6
For the horizontal component, it is recommended to use as CRS geographic coordinates with any realisation of the International Terrestrial Reference System (ITRS), known as International Terrestrial Reference Frame (ITRF).

For bathymetry, the marine community generally uses CRS based on the WGS 84 datum. Regarding Master Level 2 DTM, WGS 84 can be considered as equivalent to any ITRS realisation, as deviations between them are negligible compared to data accuracy.

Good Practice 7
For the vertical component, Mean Sea Level (MSL) or Lowest Astronomical Tide (LAT) should be used as reference surface.

The EmodnetBathy product that is more or less implementing Good Practice n°1 is using LAT as reference surface.

5.2 Metadata

Good Practice 8
Core data should be documented by metadata for discovery and evaluation, as stated in the INSPIRE Technical Guidelines for metadata and for interoperability.

NOTE 1: this is an INSPIRE recommendation for the Member states belonging to the European Union (only the INSPIRE Implementing Rules are legally binding but the Technical Guidelines are considered necessary to make the European Spatial Data Infrastructure work in practice). For the other countries, this is a way to make their data easily manageable by transnational users.

NOTE 2: Organizations very often have discrepancies to what it is considered as a pure DTM or DSM. These discrepancies should be documented in metadata. Examples: temporally phenomena not totally filtered and excluded from DSM, any features placed on the Earth's bare not totally filtered and excluded from DTM, status of inland waterbodies and of bridges.

NOTE 3: INSPIRE metadata includes the lineage information. This metadata element should be filled, by documenting the source data and the production process, including the interpolation method. In case of heterogeneous production methods (and so heterogeneous quality), it may refer to ancillary quality maps or grids (e.g. source data, capture date, distance to nearest measure).

5.3 Delivery

It is expected that core data will be made available through improved existing products (or new products) or as INSPIRE data, and perhaps as specific core products (delivery issues still have to be investigated by the working group).

Core Recommendation 6
Core data should be made available under a few of the most current grid formats including georeferencing.

NOTE 1: current grid formats include public domain standard GeoTIFF and the OGC standards GMLJP2 that is geo-enabled JPEG2000. Lossless compression may be of interest in flat areas.

NOTE 2: elevation data may be provided through physical support or through on-line services, such as Web Coverage Service, that is one of the download option recommended by INSPIRE.

NOTE 3: other products may be derived from the core elevation DTM, such as contour lines, hypsometry, slope maps, etc. It is up to each Member state (or data producer) to decide on additional relevant external products.

6 Considerations for future

6.1 Inland water bathymetry

Inland water bathymetry would be quite useful to assess the amount of water available for irrigation and consumption, for fluvial navigation and for flood studies.

However, currently, this data is rarely available among European countries. Therefore, sharing experiences on test of potential production methods and research to find more efficient and affordable capture sensors and processes should be encouraged.

6.2 More efficient delivery formats

Delivery of elevation data through grids (for DTM and DSM) implies big volumes of data: information with similar level of detail could be provided using more efficient representations of elevation data, especially for large scale data. Lidar cloud points and/or TIN would be good candidates.

A potential scenario would be to deliver Lidar cloud points that have been filtered and classified (terrain/surface) and to offer this a service enabling users to derive the products they require, such as TIN.

Setting up of such services should be encouraged together with accompanying measures, such as assessment of existing client applications (and development of new ones if necessary) and user capacity building. Until now, only specific communities have necessary skills to handle TIN or point cloud data whereas most stakeholders consider it as not user-friendly.

7 Annex A: Relationship with INSPIRE

7.1 Data model

The UML models provided in this annex are only graphical illustrations of the core recommendations and of the good practices present in this document.

The recommendations for content are represented by highlighted the selected attributes in the following way:

Core recommendation

Good practice

The INSPIRE Data Specification propose a gridded data model for theme Elevation; this model is based on the concept of coverage. The INSPIRE data model is (likely) very useful for ensuring efficient and interoperable delivery of data, especially through Web Coverage Services that is one of the download options for INSPIRE coverage data.

However, the coverage data model provides almost no information about the required content of Elevation; this is why the UN-GGIM: Europe WG on core data is not proposing any data model for the elevation itself. The recommendations for content have been expressed in chapter 4 through defining the main characteristics, such as geometric resolution, vertical accuracy, frequency of production and geographic extent.

The following illustration is just displaying the expected core content taken from the INSPIRE coverage data model.

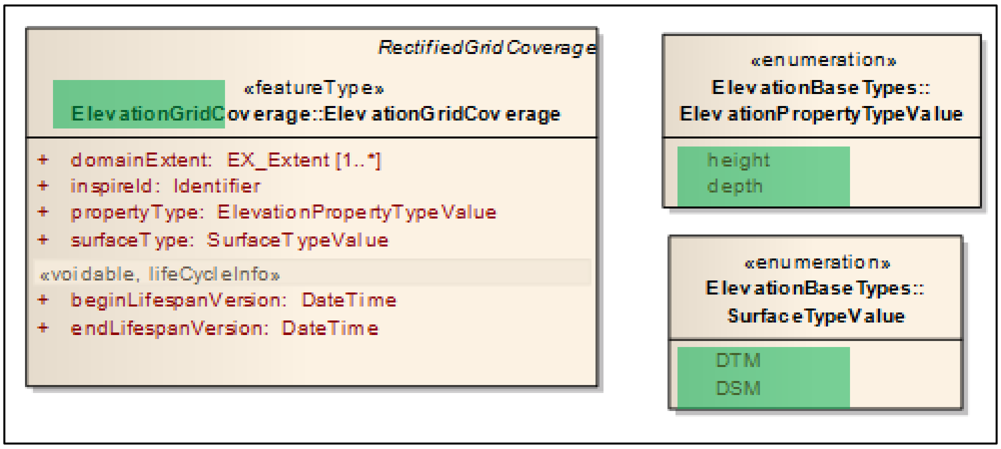

Figure 7: comparison between core data and INSPIRE coverage data model

NOTE 1: the coverage concept for grids includes the notion of a domain and of range. For core data and INSPIRE, the domain is a regular grid whereas the range is the set of values: elevation for each point of the grid.

NOTE 2: INSPIRE is also proposing data models for vector data (mainly contour lines) and for TIN; these data models are considered by core data as potential additional ways to deliver data. In both cases, INSPIRE and Un-GGIM: Europe have considered grid data as first priority.

7.2 Other topics

7.2.1 Scope

In INSPIRE, elevation is defined as "Vertically-constrained dimensional property of a spatial object consisting of an absolute measure referenced to a well-defined surface which is commonly taken as origin." For core data, the condition "**based on the gravity field of earth"** has been added to the definition.

However, INSPIRE (through its selection of mandated CRS) is also expected only gravity based measures of elevation as the UN-GGIM: Europe core data.

7.2.2 Data content

- Commonalities

INSPIRE offers coverage, vector and TIN data models but it is mandating the coverage representation for land elevation. The core data recommendation for content has also selected gridded data (DTM and DSM) as priority data for elevation.

- Differences

In general, INSPIRE being based on existing data, the INSPIRE data specification includes very limited requirement or even recommendation about the expected content of theme Elevation. The data specification are mainly providing well-documented data exchange "formats" ensuring minimum interoperability by enabling users to easily understand INSPIRE data. For instance, INSPIRE doesn't specify any spatial resolution and the geographic extent is by default "an area where a Member State has and/or exercises jurisdictional rights."

In opposite, core data states explicitly which levels of detail are expected and on which geographic extent. It also states which representation (DTM or DSM) is expected. This is summarized in the table below.

Level of Detail	Geographic extent	DTM	DSM
Master level 0	Hot spots (urban areas, areas prone to floods)	V	V (on land part)
Master level 1	Whole land territory	√	√
Master level 2	Whole land territory	V	V
	At least territorial waters (up to baseline)	V	

Regarding quality, INSPIRE gives some consistency rules between the vertical accuracy and the ground sample distance or spatial resolution [chapter 7.3 – table 11 and chapter 10.1.1 – table 7]. The quality recommendations of core data are respecting the consistency rules provided by INSPIRE.

Core data is also recommending a minimum update frequency for land elevation.

7.2.3 Data delivery

Regarding metadata, as INSPIRE, core data recommends to document the lineage and the discrepancies from pure DTM and DSM.

Regarding formats, INSPIRE offers several options for default encodings of theme Elevation, including TIFF and JPEG2000. The document "Core Spatial Data Theme Elevation - Recommendations for content" considers that these two encodings are relevant in principle but under the condition that the georeferencement is included in the format. This is why it is proposed to deliver Elevation data in GeoTIFF or in geo-enabled JPEG2000, such as GMLJP2.

8 Annex B: Methodology

Core data specifications have been elaborated based on one hand on user requirements (with focus on the ones related to SDG) and on the other hand on INSPIRE data specifications.

8.1.1 Understanding the issue

In a first step, WG A analysed the INSPIRE data specification and conducted some elevation expert interviews in order to understand the main **characteristics of elevation data products.**

These characteristics are the type of representation (grid, vector, TIN …), the geographic coverage, the level of detail and the production/maintenance frequency.

Regarding grid data, the level of detail is mainly provided through the spatial resolution (Ground Sample Distance or grid cell size) and the vertical accuracy.

A first conclusion was also that **several products (or families of products) are necessary to cover the wide range of user requirements.**

From this first phase, several potential candidates or hot topics (DTM and DSM at various LoD, DTM, bathymetry data) were identified.

8.1.2 Identifying the relevant products

Based on the identification of main topics, a questionnaire was sent to WG A members to get some idea of the European state-of-the-art: available elevation data and related use cases, on-going projects.

WG A has used an iterative process (shown in figure 8) to make decision about core Elevation data.

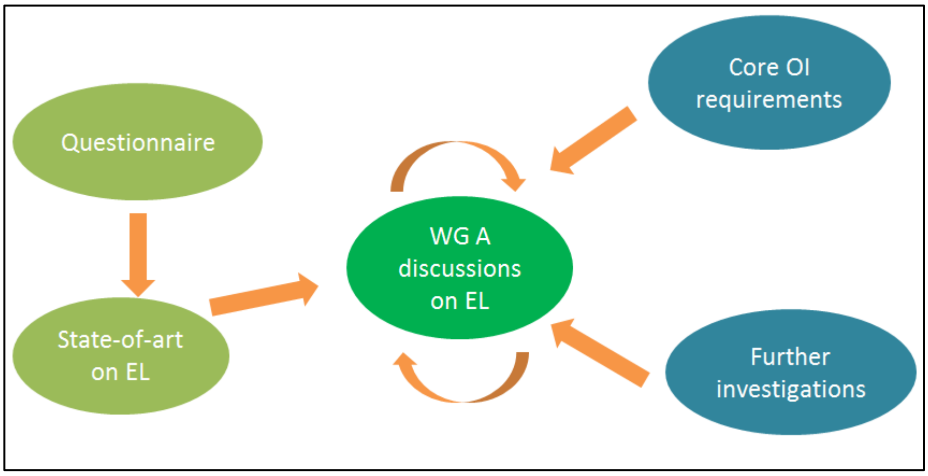

Figure 8: the iterative decision process

The main conclusions about Elevation data have been the following:

- There are clear user requirements for a very detailed DTM in hot spots (urban areas + flood risk zones); most European countries have produced or are producing such DTM. This is why WG A is recommending Master level 0.
- When a DTM exists, there is a big user interest to get also the associated DSM (e.g. for forestry studies); currently, **these DSM generally exist as first step in the DTM production**

but they are very often considered only as internal products. WG A is recommending making them available to users.

- On whole territory, most use cases are achievable – with more or less accuracy – with elevation grid data having a resolution between 10 m and 50 m.
- In parallel, WG A has elaborated the "Core spatial data theme Orthoimage – recommendations for content". The requirements for theme Orthoimage are summarised in following table. Because of these requirements, it was decided to include as EL core data both Master level 1 and Master level 2.

Orthoimage	Orthoimage status	Input DTM
Master level 1	Core	10m x 10 m grid/ Z accuracy 2 m
Master level 2	Good practice	50m x 50 m grid/ Z accuracy 5 m

- For the three levels of detail, DTM and DSM are very useful and look widely available (or easily feasible) in European countries; this is why they have been included as core recommendations.
- The set of the 3 levels of detail (Master level 0, Master level 1, Master level 2) should allow to derive the elevation data required by EUROCONTROL (areas 1 and 2) and by most of Copernicus services.