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The European harmonised bathymetry grid EMODnet Bathymetry

Introduction, outlook and contribution from German partners

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The EMODnet Bathymetry portal provides open and free access to the bathymetry of the European seas. This article presents the current status of the EMODnet Bathymetry project, its impact on the marine stakeholders, with examples from the German community, and provides an outlook to future developments.

EMODnet | HR-DTM | metadata | WMS
EMODnet | hochauflösendes DGM | Metadaten | Web-Map-Service

Das EMODnet-Bathymetrie-Portal bietet einen offenen und freien Zugang zur Bathymetrie der europäischen Meere. Dieser Artikel stellt den aktuellen Stand des EMODnet Bathymetrie-Projekts und seine Auswirkungen auf die marinen Akteure mit Beispielen aus der deutschen Community vor und gibt einen Ausblick auf zukünftige Entwicklungen.

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Intro

EMODnet Bathymetry is being developed in the framework of the European Marine Observation and Data Network (EMODnet) as initiated by the European Commission. EMODnet Bathymetry aims at facilitating the access to bathymetric data covering all the European seas and which are held by multiple organisations such as Hydrographic Offices, research organisations and private companies. In order to do so, the EMODnet Bathymetry portal (www.emodnet-bathymetry.eu) provides open and free access to the bathymetry of the European seas at 1/16 arc minute which is approximately 115 m resolution depending on latitude (EMODnet Bathymetry Consortium 2018), along with metadata of surveys and pre-gridded products held by the partners.

The original data sets themselves are not distributed without the consent of the data provider. Only the metadata are publicly available through services, giving clear information about the background survey data used for the digital terrain model (DTM), their access restrictions, if any, originators and distributors. The semi-distributed infrastructure of SeaDataNet facilitates requests from users to data providers with metadata harmonised and centralised in dedicated and controlled catalogues (Schaap and Lowry 2010).

Viewing and downloading services give users wide functionalities to interact with EMODnet DTM and all its constituents. They are also made available by means of OGC (Open Geospatial Consortium) web services (e.g. WMS, WFS, WCS, WMTS)

This article presents the current status of the EMODnet Bathymetry project, its impact on the marine stakeholders, with examples from the German community, and provides an outlook to future developments.

The user experience

The current EMODnet DTM, which was released at the end of September 2018, has a grid resolution of 1/16 arc minute × 1/16 arc minute (approximately 115 m width and 60 to 90 m height, depending on latitude). It contains approximately 12.3 billion grid nodes organised in 64 tiles. From all the data sources gathered (> 30,000), a total of 9,456 unique data set references have been sampled for use in the current common EMODnet DTM (see methodology below). This DTM is available free of charge for viewing and downloading, and for sharing by OGC web services from the EMODnet Bathymetry portal (Fig. 1). The OGC services include a recently published world baselayer (EBWBL) covering both water and land at a global scale (https://tiles.emodnet-bathymetry.eu).

On top of the EMODnet DTM, selected areas are covered with higher resolution DTMs (HR-DTMs), which again follow the same grid geometry, but then with resolutions of 1/32 to 1/512 arc minute, depending on the data policy of the data provider or prevailing national policy and physical constraints related to the limitations of the sen-

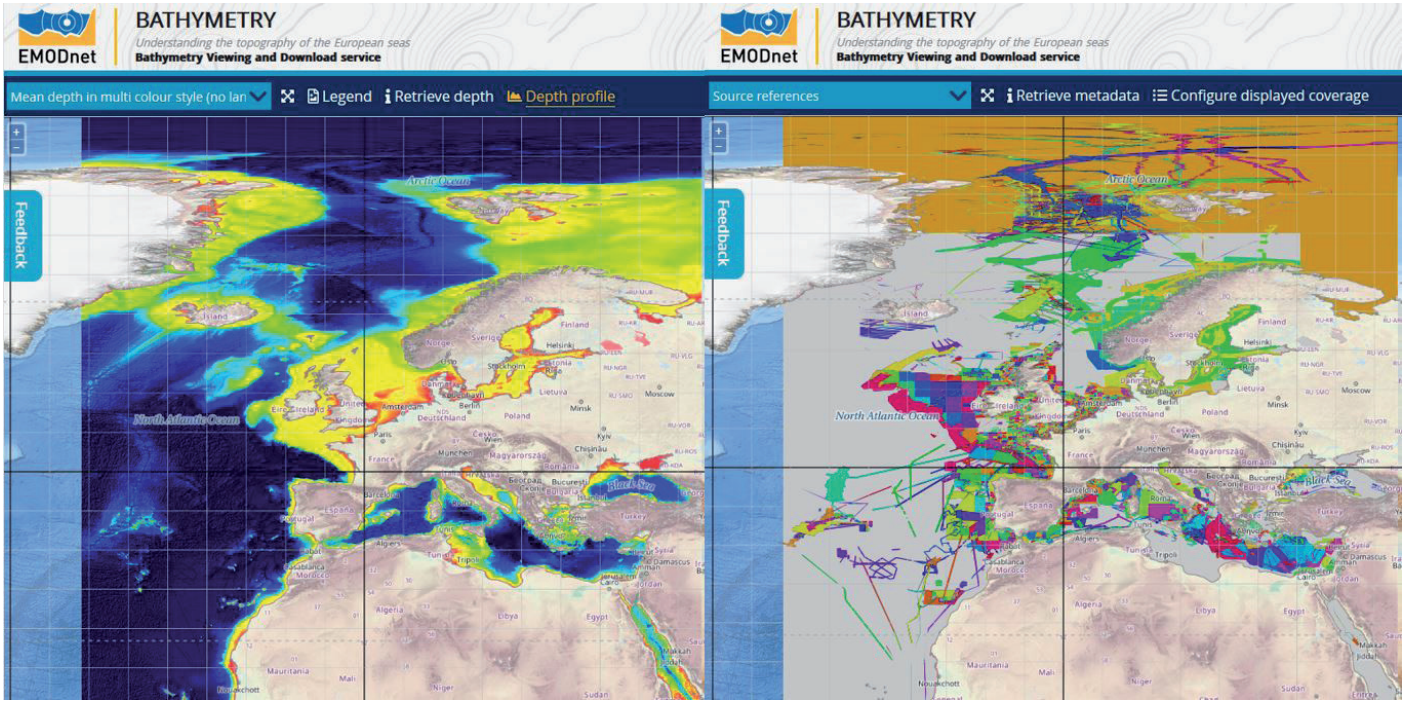

Fig. 1: Overview of the EMODnet bathymetry portal (https://portal.emodnet-bathymetry.eu) showing the bathymetric DTM at 1/16th arc minute resolution (left) along with the coverages of the source data (right)

sor during the acquisition. Generally, HR-DTMs are covering areas of particular interests such as, for example, canyons, sea mounts, hydraulic sand dunes and coastal areas. For the North Sea, for example, the German HR-DTMs are based in harmony with the DGM-W grids (Digitales Geländemodell des Wasserlaufs). These digital terrain models have been developed in cooperation between the German Waterways and Shipping Agencies and the German Federal Maritime and Hydrographic Agency. The DGM-W grids show the German estuaries of the Elbe, the Weser and the Ems with their individual bathymetric profile of tidal flats, inlets and shoals. These grids are a compilation of multibeam echo sounder data, single-beam echo sounder data and LiDAR data.

Describing source data is a key element for both the aggregation of individual data sources within the DTM and the interrogation and use of individual data by users through the data portal. Since the early stages of EMODnet Bathymetry, a strong relationship with the Pan-European SeaDataNet network and infrastructure has been established. SeaDataNet's primary goal is the development of a standardised, distributed system for managing the large and diverse data sets collected by oceanographic fleets and automatic observation systems across various scientific themes. The key element in the realisation of such a distributed system includes common metadata standards for the expression of data ownership, data acquisition and processing, communication and quality assurance. This includes the use of XML and international standards, such as ISO 19115 – 19139, and more importantly shared (and commonly defined) vocabularies. These are all managed in close collaboration between EMODnet Bathymetry, SeaDataNet, OGC, ISO, W3C, within the definitions set by the INSPIRE Directive 2007/2/EC.

The benefits that EMODnet Bathymetry is getting from this tight collaboration with SeaDataNet reside in the explicit expression of lineage (origin), data quality, history and distribution conditions of the data sources. The SeaDataNet Common Data Index (CDI) infrastructure and metadata standards with its network of distributed data centres have been adopted and adapted by EMODnet Bathymetry to provide an integrated and harmonised overview and access to bathymetric surveys that are gathered by the project (Fig. 2).

While the CDI is used as the basis for the description of individual bathymetric surveys, the EMODnet Bathymetry team is also conscious that some data providers want to provide gridded products composed from multiple sources, also known as composite grids. Hence, the EMODnet bathymetry community has adopted and adapted the SeaDataNet Sextant catalogue service, in order for data providers to provide details about Composite DTMs. This is known as the CPRD index (CPRD stands for composite product). The Sextant metadata files also follow the ISO 19115 – 19139 metadata standards and are supported by SeaDataNet controlled vocabularies.

Underlying methodology and technology

EMODnet Bathymetry deals with heterogeneous bathymetric data, provided by multiple providers, various sensors, various ages and survey quality. In

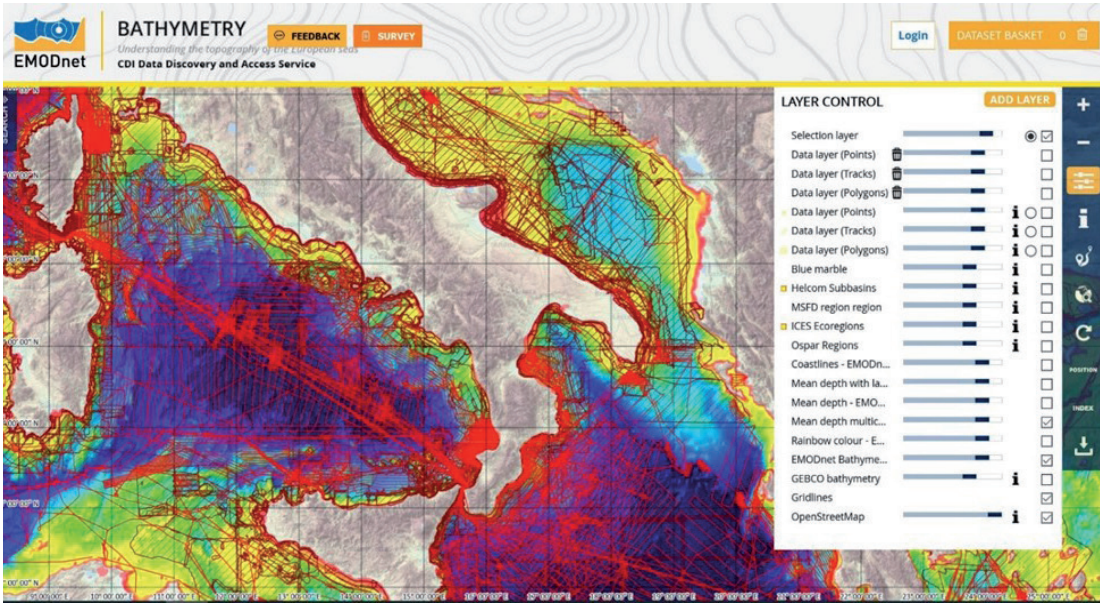

Fig. 2: Example of survey coverage. Individual polygons or polylines indicate a specific survey which is associated to standard metadata (see text), including a reference to the data originator and/or the data distributor

order to overcome this diversity, an effective and adapted data management system has been designed in accordance with international standards and common practice. The full EMODnet Bathymetry processing chain, including metadata generation and data sampling, is illustrated in Fig. 3. It reads from the top, where post-processed source data (i.e. data that have undergone a full hydrographic workflow) are described (metadata production) and sampled using dedicated software. Metadata are made available for cataloguing (CDI and CPRD as introduced earlier). Sampled data are made available for validation/quality check and compilation in a regional DTM, prior to the integration in the complete DTM and display on the web portal.

The EMODnet Bathymetry consortium benefits from a wide panel of expertise and resources from the semi-distributed network of 49 directly contributing organisations. By semi-distributed network, one understands two main ideas. First, data sources are always being held by the originating organisation, which can freely decide how they can put into effect their national or organisational data policy relative to the distribution to end users. Only metadata and the associated viewing/downloading services are being commonly centralised. For data participating in the DTM, source data are being sampled at the common DTM grid resolution (associated with a commonly agreed cell geometry, see below). Second, roles of the contributors are distributed amongst data providers, regional basin coordinators and DTM/Portal integrator. While the data providers have direct access to the source data, they also have a detailed knowledge of the conditions in which they have been acquired and processed. Their role is to process data (hydrographic workflow), prepare the metadata and down sample the post-processed source data. This information is then used by one or more of the twelve basin coordinators in order to aggregate the data and compose a DTM over their area of responsibility (BSH is responsible for the North Sea). Through this process, a feedback loop enables a first level of quality analysis. All the basin coordinators provide their compilation to the DTM/Portal integrator who makes sure they all fit together coherently and all convey associated data attributes (soundings density, main contributor, minimum and maximum water depth, standard deviation per grid cell) and lineage to the metadata. Through this second check, the quality assurance of the DTM product is further ensured.

Key to all this methodology is standardisation and harmonisation of the methods and tools.

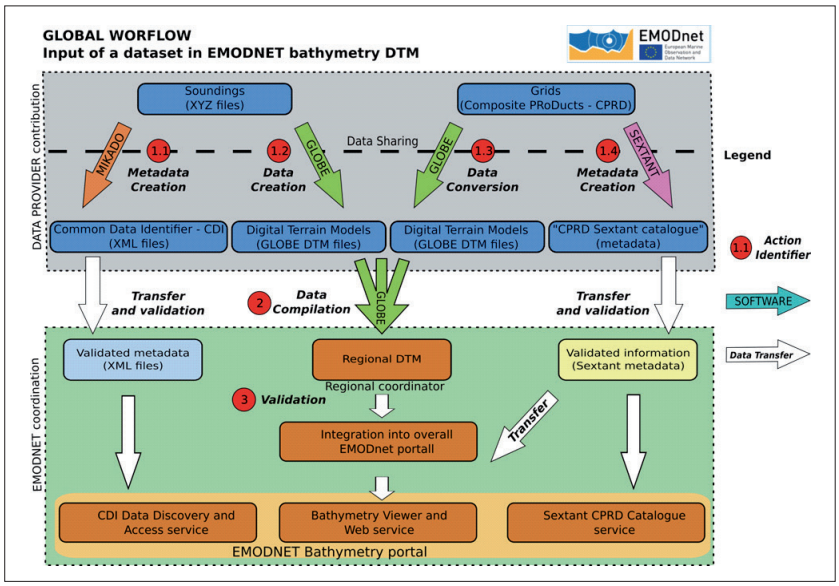

Fig. 3: Overall post-processed data and associated metadata workflow, including roles and actions of the partners of the project

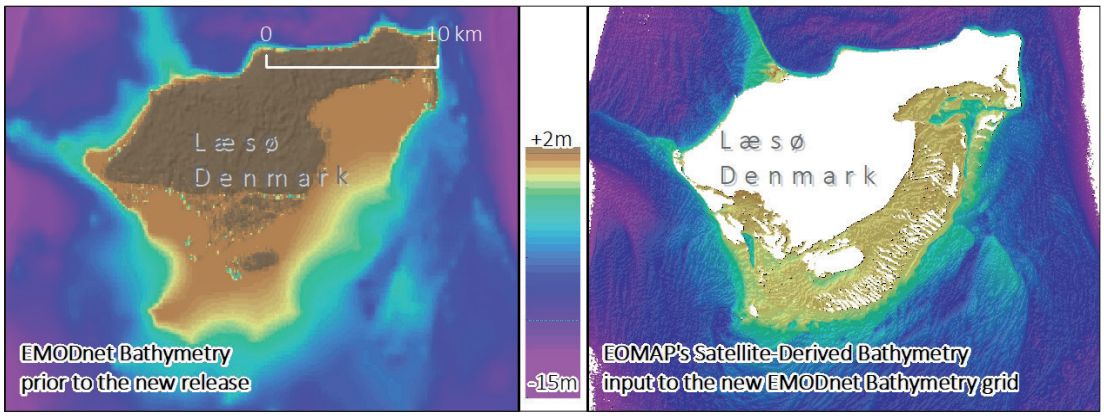

Fig. 4: EMODnet bathymetry prior to the latest release of EMODnet bathymetry (left) and the new dense bathymetric data input from EOMAP's satellite-derived bathymetry (right) which serves as input for the latest EMODnet bathymetry release. The image shows Læsø located in the Kattegat between Denmark and Sweden

Those have been earlier described when speaking about metadata. Concerning the bathymetric data, agreement has been reached amongst the data providers whose sampled data sets respect:

- the same horizontal and vertical references: horizontal coordinates are expressed as latitude, longitude, based on the WGS84 coordinate system (EPSG:4326), while for the vertical component, data are meant to be provided in metres relative to the lowest astronomical tide level (or a surface locally assimilated to it);
- sampling strategy: each grid cell is given at its centre, known as the grid node. Grid nodes are positioned in a unique way from the Greenwich meridian (0°) in longitude and the equator (0°) in latitude respectively as a multiple of the grid cell size plus half the cell size;
- the mean value of all soundings reported within the grid node, along with other attributes such as the minimum and maximum value, the number of soundings and the standard deviation are considered to provide enough information needed to estimate the local depth considering the targeted resolution.

In order to help all the contributors in their tasks, common tools are provided to help them producing metadata information (Ifremer's MIKADO and Ends And Bends software – www.seadatanet.org/Software) and for the preparation and manipulation of the sampled data sets (Ifremer's GLOBE software, Poncelet et al. 2020).

The German perspective

EMODnet-Bathymetry portal is formed by a European consortium of which three entities, BSH, EOMAP and MARUM are based in Germany.

EOMAP contributes to EMODnet bathymetry to fill shallow water bathymetric data gaps in areas where no survey data exist or those are not accessible to the project. EOMAP applies satellite-derived bathymetry technologies for that purposes (Hartmann et al. 2017; Hartmann and Heege 2020) and provided a total of 14,000 km² of dense shallow water bathymetric data, covering the Aegean Sea, Mediterranean coastal waters of Spain, Denmark, southern Italy, Croatia, Cyprus and parts of Libya. The provision of the satellite-derived bathymetry grid for the shallow water significantly increased the level of detail of coastal European waters (Fig. 4) and therefore is an important contribution for coastal and hydrodynamic modelling applications.

BSH contributes 119 additional data sets for the EMODnet 2020 project phase (currently undergoing), covering an area of ca. 3,100 km² in the North Sea and the Baltic Sea, including a new high-resolution DTM of the Jade area covering ca. 1,000 km² (Fig. 5). BSH is one of the first members of the EMODnet project and provided overall 1,132 data sets, including ten HR-DTMs since the first data collection in 2009. From 2014 to 2016 the BSH was basin coordinator for the Baltic Sea (since then transferred to the Swedish Maritime Administration). Since 2016, BSH has the role of the Basin Coordinator for the Greater North Sea, an area reaching to the Shetland Islands in the North and the English Channel in the West. The task is to

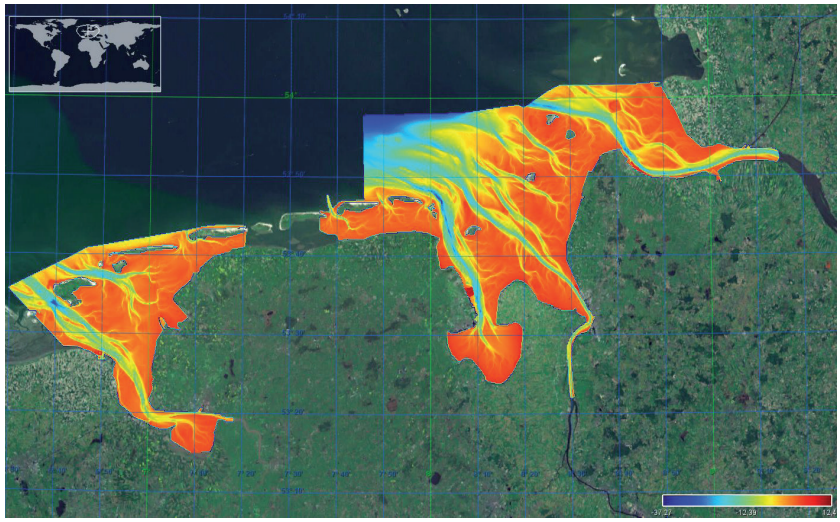

Fig. 5: High-resolution DTM »1850_North Sea – German Approaches DTM« available at very high spatial resolution

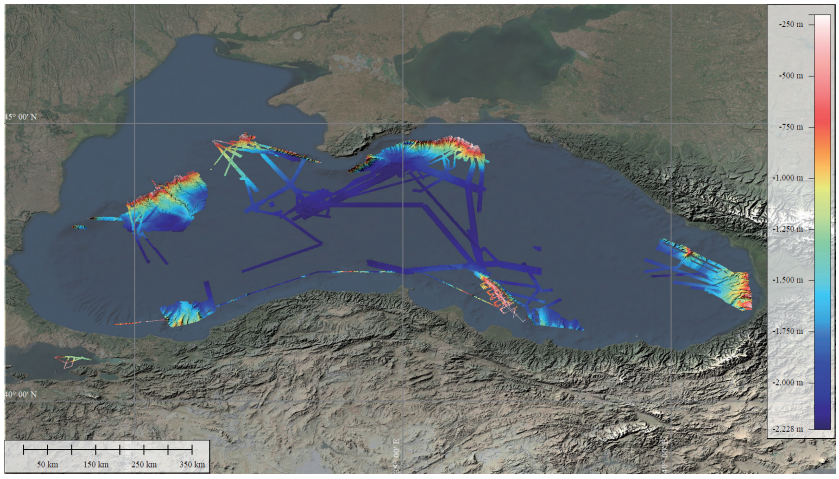

Fig. 6: German research community (MARUM and GEOMAR) contribution of processed bathymetry in the Black Sea

merge all data sets covering this area provided by the data providers.

The German marine geoscience research community acquired numerous hydroacoustic data within the European seas. Raw data sets are being archived by the BSH (www.bsh.de/EN/DATA/Oceanographic_Data_Center/Surveying_data/surveying_data_node.html). Within the EMODnet Bathymetry project the University of Bremen and MARUM have processed (full hydrographic processing including tidal, sound velocity correction, manual soundings editing and draft corrections), prepared metadata and sampled some of these data sets. More specifically, benefiting from two decades of strong interest in the Black Sea region, MARUM has shared their processed bathymetric data for the area (14 out of 16 survey cruises, see Fig. 6). Moreover, German bathymetric contribution has generated a number of scientific peer-reviewed papers such as Gutscher et al. (2017) in the Ionian Sea (Fig. 7), Loher et al. (2018) for the Calabrian Arc or the Gibraltar/Alboran Sea (Wienberg et al. 2013). The German research community has also been largely contributing to the Arctic area as part of a tight collaboration between EMODnet Bathymetry and the IBCAO community (Jakobsson et al. 2020).

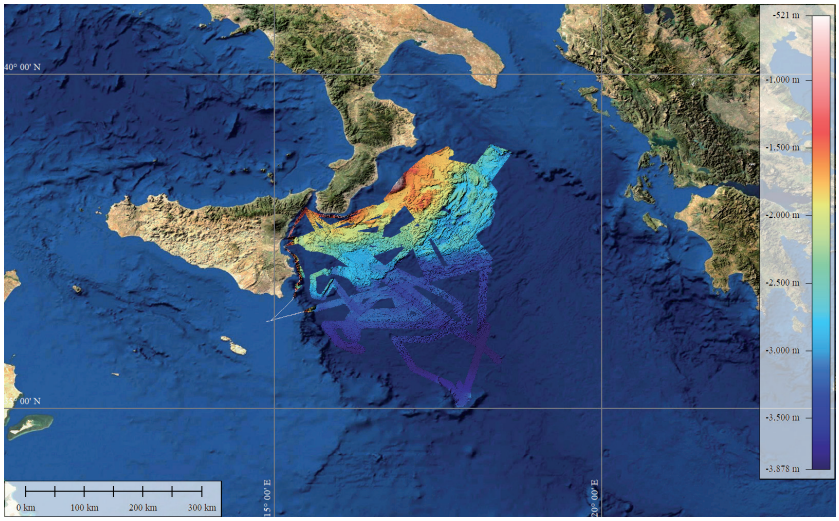

Fig. 7: High-resolution bathymetry contribution of the German research community in the Ionian Sea

Contribution to global bathymetric grids and regional programmes

As outlined above, since early years of the EMODnet Bathymetry programme, collaboration has been key factor for its development and success. Beyond the strong internal collaboration between contributors of the EMODnet consortium, as described earlier, EMODnet Bathymetry has also elaborated strong relations with several international actors.

The EMODnet DTM along with the description of the source bathymetric data enable contributing partners to fulfil their obligations against the INSPIRE Directive. Moreover, because the EMODnet DTM extends over national borders and that metadata are uniformly describing the data sources in a unique portal, user groups of similar interest have been selecting the EMODnet products as their main source of information. For example, both the North Sea Hydrographic Commission and the Baltic Sea Hydrographic Commission are using the bathymetric information originating from EMODnet as part of their Marine Spatial Data Infrastructure. This is also the case for the Baltic Environment Protection Commission (Jakobsson et al. 2019).

EMODnet Bathymetry also shares mutual complementary benefits with the International Hydrographic Organization (IHO) as a number of EMODnet contributors are themselves Hydrographic Offices and as the IHO sees the EMODnet Bathymetry products (DTM and data inventory) as an authoritative best estimate, trans-national digital bathymetric grid vital to the development of economic, scientific and environmental activities. This collaboration is embodied as part of the Memorandum of Understanding signed between the IHO and the European Commission in 2012. It is materialised through the full integration of the CDI/CPRD metadata inventory services in the IHO DCDB (Data Centre for Digital Bathymetry) viewer (https://maps.ngdc.noaa.gov/viewers/iho_dcdb) through OGC services, giving the possibility for any user to retrieve metadata information from European data holders and to be redirected to the EMODnet Bathymetry portal for further exploration.

Additionally, GEBCO and EMODnet communities mutually integrate their bathymetric grids (respectively at 115 and approximately 500 m horizontal resolution). Fig. 8 shows the geographical distribution of measured data sources composing the recent 2019 GEBCO release. Note that darker areas indicate regions without direct measurement. In these areas, the bathymetry is predicted from satellite altimetry (Smith and Sandwell 1994). One can see in Fig. 8 that the European seas have largely

been covered, despite some small areas (especially in the deep ocean) thanks to the contribution of the EMODnet Bathymetry DTM to the GEBCO grid. Note that where only altimetric derived approximation is available, EMODnet bathymetry DTM is filled from this information originating from the GEBCO grid.

Along with the substantial improvement of the worldwide bathymetric coverage, this collaboration has also two main advantages:

- The convergence of both bathymetric products for the European waters, hence minimising confusion for the users;
- Smoothing the interface between the areas of measured bathymetric data and the ones issued from altimetry extrapolation, in both products.

To be fully exhaustive concerning this aspect, EMODnet Bathymetry is an active supporter of the Seabed 2030 initiative (https://seabed2030.gebco.net) by sharing and promoting EMODnet methodology and federated infrastructure with central metadata and distributed data whereby data providers are well involved in the production of the DTM and well acknowledged for their contributions, hence further leveraging existing data and contributing to reach Seabed 2030 targeted goals.

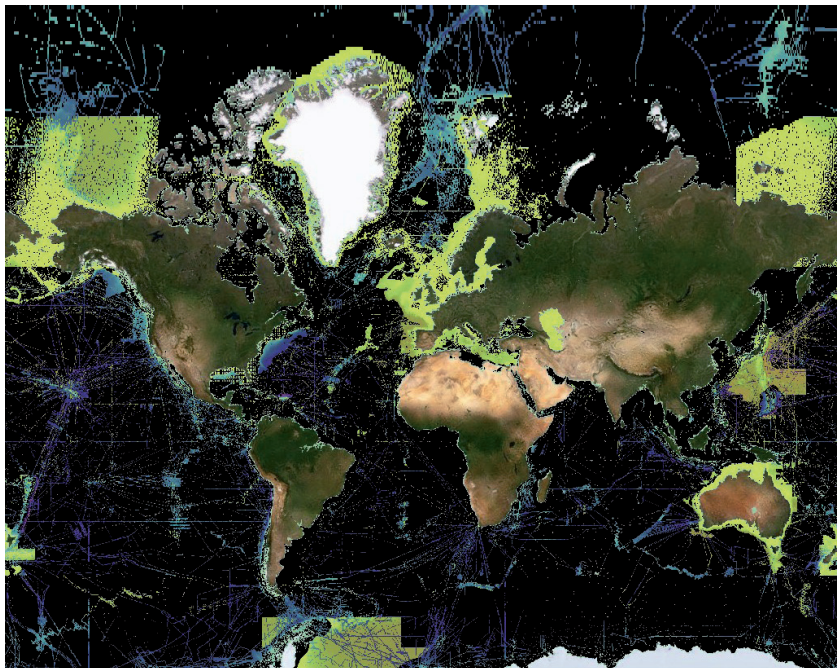

Fig. 8: Worldwide bathymetric coverage. Dark blue indicates areas where the bathymetry is being derived from altimetric signal. Other patches indicate where bathymetric data have been acquired using mostly acoustic sensors and data have been made known to the GEBCO community

Future developments of EMODnet Bathymetry

The EMODnet bathymetry community is avid of new developments that aim to improve either the bathymetric coverage of European waters, the collaboration between the different actors in the production phases or the experience that the user can have when using the generated product. For the first item, the use of satellite-derived bathymetry to improve the bathymetric knowledge of some areas has been innovative back in 2016. Evaluation of IceSat-2 data (Parrish et al. 2019), for example, or crowd source bathymetry, and their potential inclusion in next releases is under consideration. With respect to the second axis of innovation partner Ifremer is particularly active in the development of a virtual research environment using HPC Datarmor as a nodal processing point along with web processing services. Finally concerning the third point of innovation, Campos et al. (2020) illustrate works undertaken to investigate 3D raster simplification methods for large scale DTM, with the main aim of providing a fluid 3D view rendering directly accessible through recent web browsers (Fig. 9).

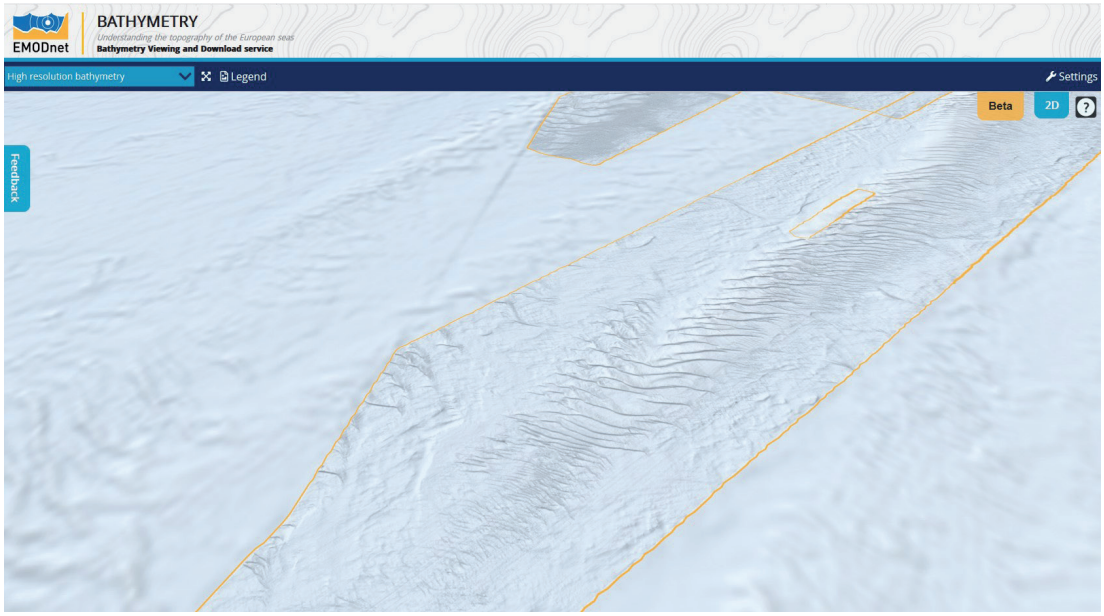

Fig. 9: 3D rendering of a HR DTM (orange layout) at the entrance of the Dover Strait

Conclusion

EMODnet bathymetry provides a unique inventory of bathymetric data describing the European waters. Thanks to the harmonisation of both metadata and data sampling mechanisms catalogues of existing data (CDI and CPRD) are available to the public along with 1/16 arc minute resolution DTM. These enable any user to fulfil most of his usage either by a direct use of the DTM or by requesting source data directly from the provider. The approach also allows international collaboration with regional and worldwide stakeholders such as the GEBCO/Seabed 2030. While, the EMODnet Bathymetry community keep following new developments (acquisition, processing and rendering), it also builds up on the gathering of a large community of experts. Therefore, we continue our invitation to potential survey data providers to contact us for cooperation in views of the improvement of resolution and coverage of the DTM product. //

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The EMODnet Bathymetry consortium is composed of 49 direct partners who are all associated to the results presented in this paper.

EMODnet Bathymetry is thankful to all the hydrographers and oceanographers who have patiently helped gathering bathymetric information contributing to our compilation. We hope our work further enhances the value of their effort.

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