



**EMODnet**



European Marine  
Observation and  
Data Network

# **EMODnet Thematic Lot n°1 – Bathymetry**

**EASME/EMFF/2019/1.3.1.9/Lot1/SI2.836043**

**Start date of the project: 20/12/2022 (24 months)**

**Centralisation Phase**

## **Quarterly Progress Report 3**

**Reporting Period: 01/07/2023 – 30/09/2023**



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# 1. Highlights in this quarter

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- **Task 1 - Maintain and improve a common method of access to data held in repositories:**

During the reporting period, the number of survey data sets has increased considerably from 41574 to 42153 CDI entries, while the number of Composite DTM entries stayed at 277. New CDI entries for bathymetry survey data sets were contributed by 5 data providers, in particular with a large submission of 588 survey data sets by Marine Institute (Ireland) as an associate partner. Partner Ifremer has reviewed its data policy for survey data sets gathered in EEZ of other international countries. It has decided to publish only data sets for which diplomatic approval has been received. As a result, Ifremer has de-activated 46 CDI data sets from the current catalogue. In the coming months new CDI and CDTM entries are expected from many regular data providers as a deadline has been set for the current contract for finalising gathering and population early 2024. Next to survey data sets and composite DTMs, this will also concern producing and including more Satellite Derived Bathymetry (SDB) files. This will focus on selected coastal areas without survey coverage in the Baltic, where feasible. Also, a cooperation has been established between partners EOMAP (Germany), expert in SDB, and GST (Denmark), that SDB data will be used in addition to single and multibeam surveys of GST for generating a new CDTM for the Danish waters on a 50 meters grid. This CDTM will serve GST as a national public product and also be input for EMODnet Bathymetry.

- **Task 2 - Construct products from one or more data sources that provide users with information about the distribution and quality of parameters in time and space:**

A plenary meeting was held in Brest – France, 25-26 September 2023, and has focused on data providers and regional coordinators activities. As part of the meeting, a series of workshops on Ifremer’s software GLOBE, Sextant and Mikado and CORONIS interpolation techniques took place with tutorials and hands-on training sessions. This served to inform all consortium partners about latest developments and functions of these software packages and to train them in using these. This is not only necessary for picking up new functionality, but also because there are regularly personnel changes in the EMODnet Bathymetry team. In addition, Ifremer presented and demonstrated the latest release of the Collaborative Virtual Environment (CVE) which is now at such a mature level that will be integrated in the production workflow for generating the new EMODnet DTM. More information about the CVE will be given in Deliverable D3.1 which will be finalised and distributed end of October 2023 as follow-up to the Workshop demonstration and discussion.

The following detailed agenda has been agreed with the partners with respect to deadlines towards the update of the full EMODnet Bathymetry DTM with its associated components:

Until February 2024: Data Providers:

- gathering and populating new CDI entries for survey data and new Sextant entries for CDTM data sets, also including SDB data sets
- completing Quality Info (QI) in existing CDI and Sextant entries, where missing, following list of Shom
- pre-processing new CDI and Sextant data sets, using GLOBE and following EMODnet methodology, to 1/32 \* 1/32 gridded data sets for transfer to Regional Coordinators

From February to July 2024: Regional Coordinators

- joining Workshop in February 2024 for discussing the RDTM generation process

- contact with data providers to learn about and get hold of relevant new data sets
- get hold of the Collaborative Virtual Environment (CVE) for reviewing previous RDTM releases and for making annotations of issues
- working with local GLOBE to update and improve their RDTM at 1/16 \* 1/16 arc minutes with new data, better interpolations, correcting previous errors, etc
- loading the draft new RDTMs in the CVE in June 2024 for review by all Regional Coordinators and the Integrator, identifying and discussing remaining issues
- finalising the RDTMs for hand-over to the Integrator

From August to December 2024: Integrator + Shom + MARIS

- working on the overall integration of the RDTMs into a consistent EMODnet DTM
- preparing the source reference layer, checking and correcting any missing CDI and Sextant references
- making the new DTM ready for publishing as downloadable tiles in multiple formats, OGC services, and completing product metadata in Sextant
- preparing the MSL version of the DTM and tiles using the LAT-MSL conversions from the GTSM model from Deltares
- making the 3D version of the EMODnet DTM together with CORONIS
- integrating the new EMODnet DTM into the Central Portal – Products Catalogue and Map Viewer service
- preparing report of findings

Annex 1 gives a short report on the RTD activities of CORONIS for improved interpolation techniques and of Deltares for possibly using deep-learning for extrapolating missing bathymetry, e.g. in estuaries, and further progress of Deltares with updating the EMODnet Bathymetry product on best-estimate coastlines for Europe.

- **Task 3 - Develop procedures for machine-to-machine connections to data and data products:**

The migration from the thematic Bathymetry portal to the EMODnet Central Portal has been finalised and the new Central Portal was launched on the 23<sup>rd</sup> January 2023, while the publishing of the EMODnet Bathymetry website was halted at the same date.

EMODnet Bathymetry now continues to operate and maintain several catalogue services and web services, which are being harvested and/or directly feeding the Central Portal services. The services are following INSPIRE principles and their operations are being monitored from the Central Portal with good results.

EMODnet Bathymetry is regularly testing the functionality of the Central Portal and following up feedback from users. This is aimed at spotting possible bugs in the back-office systems of EMODnet Bathymetry or at the front-office interfaces of the Central Portal. Any identified bugs are reported to JIRA for further action. Also, shortcomings or requests for improved functionality are being gathered from internal consortium testing and following user feedback and these are submitted to the CP team through JIRA and/or at TWG meetings as wishes for future developments. Most will be directed towards optimisation of functionalities, while also additional functionalities might come forward.

- **Task 4 - Contribute data, data products and content to a central portal that allows users to find, view and download data and data products:**

Activities have taken place in the previous contract for arranging the migration from the thematic portal to a Central Portal. This was originally done around the 2020 EMODnet DTM version, followed in April 2023 with the new 2022 DTM version. This procedure will be followed again end of 2024 for publishing the 2024 products of EMODnet Bathymetry.

- **Task 5 - Contributing content to dedicated spaces in Central Portal:**

Each thematic has its own dedicated space at the Central Portal where it publishes its so-called 'narrative'. The maintenance is done by sending an updated document to JIRA which is then processed by the EMODnet Secretariate. At the latest TWG it was announced that thematic lots will get more direct access to the EMODnet CMS (Drupal) for performing maintenance activities. EMODnet Bathymetry team will look into this and use its CMS account for providing new and updated content, where required and appropriate.

- **Task 6 - Ensure the involvement of regional sea conventions:**

Secretariats of the Regional Sea Conventions are kept up-to-date of the EMODnet Bathymetry services, inter alia through regional partners. The 2022 EMODnet bathymetry full grid release, launched in April 2023, provides a good opportunity to reinforce the good relationships with the secretariats of the Regional Sea Conventions who are kept up-to-date of the EMODnet Bathymetry services and products, and where possible, engaged in wider promotion and contributing to mobilising more potential data providers and product users.

- **Task 7: Contribute to the implementation of EU legislation and broader initiatives for open data:**

On a global scale, good synergy is continued with GEBCO and the Seabed 2030 project. In this context, George Spoelstra (GGSgc) and Federica Fogliani (CNR), both members of the EMODnet Bathymetry consortium, act as Chair and Vice-Chair of the GEBCO subcommittee TSCOM (Technical Subcommittee on Ocean Mapping). One of their targets is to promote adoption of the metadata – data management practices in GEBCO and Seabed 2030, following SeaDataNet CDI standards and services, as applied by EMODnet Bathymetry. Also, the collaboration with IHO is continued and leads to data contributions by several other national hydrographic services beyond the consortium partners. In practice, the EMODnet DTM is considered as the European contribution to Seabed 2030 and as such fully integrated into the GEBCO DTM.

- **Task 8 - Monitor quality / performance and deal with user feedback:**

The overall performance of the portal and its services is continuously measured and its results are reported in the separate indicators spreadsheet. It demonstrates that Bathymetry and its services and products continue to be quite popular. Despite the fact that the number of visits and download of the full DTM products remains high, there has been a decrease compared to the previous reporting quarter. An explanation is that the 2022 DTM was published in the first Quarter of 2023, which supported with promotion gave a lot of extra traffic which has now gone down to regular levels. The user feedback is at the same level as earlier reporting both on the quality of the DTM product and the usability of the portal. Answers are directly provided to the users.

- **Task 9 - Maintain the existing thematic web portal for a maximum of six months from the start of the project:**

The earlier EMODnet Bathymetry portal was maintained till 23<sup>rd</sup> January 2023 when the actual migration was finalised. The Central Portal is now the shop-window, while EMODnet Bathymetry is maintaining the operation and maintenance of the various Bathymetry catalogues and web services that feed into the Central Portal.

- **Project management:**

A plenary meeting (25th and 26th of September 2023) has been organised with dedicated workshops (see task 2), also discussing best practices in bathymetric data processing and management along with recent development for the benefit of the consortium (interpolation, data science and AI).

Shom and MARIS prepared the Q2-2023 progress report which was reviewed and accepted by the EU CINEA.

Milestone/Deliverable in numerical order	WP	Date due	Status (To do/ Delivered/ Delayed)	Date delivered	If Delayed: reason for delay and expected delivery date
D1.1: Quarterly concise progress reports	WP1	M4, M7, M10, M13, M16, M19, M24,	Delivered D1.1a,b	M4, M7, M10	
D1.2: Annual Interim report	WP1	M12			
D1.3: Final report	WP1	M24			
D1.4: Plan for service continuity, incl. docs and sources	WP1	M24			
D2.1: Upgraded guidelines for data pre-processing and population of metadata	WP2	M6	Delivered	M6	See Annex 1
D2.2i: <i>Training Workshop for data pre-processing and metadata population</i>	WP2	M9	Delivered as part of meeting 25-26 Sept 2023 in Brest - France	M9	
D2.3: Pre-processed survey data sets and included in CDI Service	WP2	M12	Underway		
D2.4: Pre-processed composite DTMs and	WP2	M12	Underway		

included in Sextant service					
D2.5: Satellite Derived Bathymetry data sets and included in Sextant Service	WP2	M12	Underway		
D3.1: Upgraded guideline of EMODnet methodology for DTM production, including using prototype CVE	WP3	M9	Delayed		M10 – report as follow-up to Workshop demonstration and discussion
<i>D3.2i: Upgraded Globe software</i>	WP3	M9	Delivered and presented at meeting 25-26 Sept 2023 in Brest - France	M9	Note that Globe is regularly updated upon request and made available publicly
<i>D3.3i: Training and intercalibration Workshop</i>	WP3	M11	Will be delayed		M14-M15: Shifted to better fit in the latest planning for DTM production; will be Workshop of Regional Coordinators and Integrator
<i>D3.4i: Processed and pre-gridded data sets as input for RDTMs</i>	WP3	M14			
<i>D3.5i: Regional DTMs with common resolution of 1/16 arc minutes grid</i>	WP3	M17			
<i>D3.6i: Best version HR DTMs for coastal waters and hotspots</i>	WP3	M20			
D3.7: New EMODnet DTM incl Quality Index and loaded in EMODnet web services for viewing and downloading	WP3	M23			
D3.8: HR-DTMs loaded as separate layer in EMODnet web services for viewing and downloading	WP3	M23			

D3.9: Source reference layer in EMODnet web services to link to CDI and Sextant Catalogue services	WP3	M23			
D3.10: Refined best-estimate European digital coastlines in EMODnet web services for a range of vertical levels	WP3	M22			
D3.11: Updated Inventory of existing and ratified baselines and registered claims / disputes under UNCLOS, for European countries at the portal	WP3	M22			
D3.12: Methodology for assessing bathymetry between coastline and foreshore	WP3	M23			
D4.1: Standard machine-to-machine services delivered for common functionalities	WP4	M3	Delivered	Operational since M0	
D4.2: Dedicated machine-to-machine services adapted / delivered for special functionalities	WP4	M6	Delivered	Operational since M0	
<i>D4.3i: CVE optimised for regional coordinators</i>	WP4	M14			
<i>D4.4i: Globe software + GGSGC workbench upgraded with extra functionality</i>	WP4	When required	Following requests and suggestions		
D5.1: Operational Help-desk	WP5	continuously			
D5.2: Monitoring data about visits and usage	WP5	continuously			
D5.3: Promotional material and up-to-date	WP5	continuously			



thematic space at central portal					
D5.4: Presentations at relevant conferences	WP5	Regularly			

## 2. Identified issues: status and actions taken

[Provide an **overview of issues** identified by CINEA/ DG MARE/ Secretariat (Table A) in the past quarter - new as well as pending ones, the status of those issues, and actions taken to address them and/or roadmap with remaining actions planned to resolve the issues. In Table B, provide information about any issues and challenges identified by yourself.]

A. Priority issue(s) identified and communicated by CINEA/ DG MARE/ SECRETARIAT				
Priority issue	Status (Pending/ Resolved)	Action(s) taken/ remaining actions planned	Date due	Date resolved
<b>EM821 Bathymetry to send email address</b>	Resolved	Email address provided for access of the CMS		11/08/2023

B. Issues / challenges identified by the thematic assembly group itself				
Priority issue / challenge	Status (Pending/ Resolved)	Action(s) taken / remaining actions planned	Date due	Date resolved
<b>EM806 Increase zoom level for coastline</b>	pending	Action to be undertaken by CP to increase the zoom level. Pre-tiled level already existing	27/06/2023	
<b>EM766 EMODnet Baselayer is using WebMercator tileset in EPSG4326 projection</b>	pending	Use of the appropriate tileset is suggested from Bathy. Discussion undergoing for this implementation	12/04/2023	
<b>EM703 Bathymetry narrative update</b>	pending	One series of update in the narrative done. Ticket left opened as a new series should come shortly	03/01/2023	
<b>EM774 GetFeatureInfo shows unnecessary RGB info for HR depth and natural colors</b>	pending	Actions have been undertaken by CP team to use the appropriate field for display. Ticket is left open for REST service issue.	23/04/2023	
<b>EM805 EMODnet Bathymetry land topography cache issue</b>	Resolved	Updates of OSM have been done. Cached dataset from previous release of OSM have been cleared out. As OSM is continuously updated, it is suggested to clear out the CP cache frequently. Investigation on	27/06/2023	14/08/2023

		the best clearing cache frequency is undergoing		
<b>EM 861 Filter option for source reference layer shows empty list</b>	Resolved	Filtering option to be used on the Source Reference layer was not available. CP has corrected the issue.	25/09/2023	26/09/2023

### 3. Communication assets

[In Table A, list peer reviewed publications directly (co-)authored by consortium and project partners in the reporting period. In Table B, list all non-peer reviewed publications (co-)authored. In all cases, indicate the type of publication, provide the full reference incl. title, volume and issue etc., and whether the publication is open or closed access.]

A. (Co-)Authored peer-reviewed publications in the quarter					
Date of publication	Type of publication	Full reference	ISBN	DOI	Is it open access? Yes/No

B. Other/non-peer reviewed types of publications (co-)authored in the quarter					
Date of publication	Type of publication	Full reference	ISBN	DOI	Is it open access? Yes/No

For a compressive overview of publications referring to/making use of EMODnet data and/or data products, please consult Google Scholar.

## 4. Monitoring indicators

[Refer to the standardised monitoring tool, i.e. Europa Analytics, to complete the indicators excel template, and provide a short explanation in the table below on the numbers and trends for each indicator when possible/applicable. Indicate clearly if monitoring was carried out using tools other than Europa Analytics.]

Comments on the progress indicators in the indicators spreadsheet		
Progress indicator	Means of collecting figures	Comment
1. Current status and coverage of total available thematic data A) Volume and coverage of available data	CDI catalogue service	There is a steady increase of CDIs.
What is your opinion on the data coverage within EMODnet for your thematic?	Considering population of CDI and Sextant catalogues	Overall, EMODnet Bathymetry has brought together an excellent data collection (CDIs and Composite DTMs), covering all European sea regions and compiled by 66 data providers.
B) Usage of data in this quarter	CDI RSM shopping ledger service	The number of downloaded CDIs went down dramatically. It seems that users are not finding the CDI service.
2. Current status and coverage of total number of data products A) Volume and coverage of available data products	Statistics from downloading at the Bathymetry system	The 2022 DTMs (Europe and Caribbean) and new HR-DTMs have been released in the first quarter of 2023. The coming year the number will be frozen till the new release of the 2024 DTM and HR-DTMs which is planned for end 2024.
B) Usage of data products in this quarter	Analysing download statistics	The number of DTM tile downloads has decreased considerably, but is still quite large. The new products were released in the first quarter which might have caused a more than average traffic in the following quarter. The number of WMS - WFS requests has decreased somewhat, but is still very high.
3. Internal and external organisations supplying/approached to supply data and data products within this quarter	CDI catalogue service	There are new entries as part of the new contract. There are also a lot of entries from the Marine Institute as associate partner. While IFREMER has reviewed its data policy resulting in de-activating a number of surveys in EEZ of other international countries for which he has not received diplomatic approval
4) Online 'Web' interfaces to access or view data	N.A.	No changes
5.1 Daily number of page views of EMODnet Thematic entry page	Europa Analytics	Daily number of page views of the Bathymetry narrative has decreased somewhat from around 160 to 120. This is the static content. Unfortunately, we cannot see how the bathymetry map layers and products are visited
5.2 Quarterly total number of visitors, page views, unique page	Europa Analytics	The quarterly numbers are reasonable as the bathymetry narrative is a static story. See the earlier remark under 5.1. These numbers are somewhat lower than in the previous

views and percentage of returning visitors		quarter as the effect of the new releases in 1st quarter is ebbing away.
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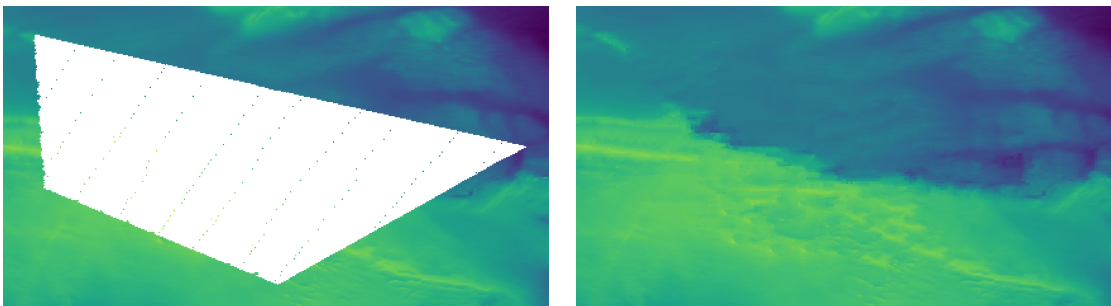
*The monitoring numbers reported as part of the progress monitoring of EMODnet performance are collected through Europa Analytics, unless reported otherwise.*

## 5. Annex 1 – Progress of Coronis and Deltares activities on interpolation, deep-learning, and best estimate coastlines

### Coronis - Improving interpolation techniques

In this first period of the new phase of the project Coronis has worked in two directions: (1) creating an interpolation method that allows preserving gradients and (2) improving the runtime of the current algorithms in the Python interpolation package.

On the one hand, regarding the new interpolation method, we aim at developing a version of the method of Criminisi et al [1], usually devised for image processing, that is able to deal with DTMs as input. This method tries to fill in the unknown areas of an image by iteratively filling the gap with patches extracted from the known areas. The ordering of this filling process determines the final result, and by filling areas with large incident gradients first the result is a gradient-preserving filling. The development is still in a preliminary stage, but we presented a “proof of concept” for a specific dataset (see Figure 1). The satisfactory results obtained validate the choice of this algorithm, and we will implement a final version as part of the Python interpolation package [2].



**Figure 1. Sample of the new gradient-preserving inpainting algorithm: on the left you can find the original DTM, with unknown cells in white, and on the right the result of the proposed algorithm.**

On the other hand, regarding the improvements of execution speed, we aim at reimplementing some of the interpolation methods using GPU computing. Graphical Processing Units (GPUs) enable fast and massively parallel execution of some operations, such as convolutions. All the PDE-based inpainting methods developed during the previous phase of the project rely on convolutions on a fixed regular grid to solve the PDE guiding the interpolation. Therefore, we reimplemented one of the methods using the Taichi-lang package [3], which allows performing most of the processing on the GPU. For the moment, just one of the methods (CCST [4]) is implemented in the package, but we aim at implementing more in the coming months. Initial tests reveal that we can obtain results up to 7.5 times faster with the GPU implementation as compared with the CPU one. This initial implementation is in a development phase, and it is not yet on the main branch of the project. We also need to validate the speed improvements further with more variate datasets, hardware environments, etc.

Coronis also added another minor change that impacts the execution speed: a new termination criterion for PDE-based interpolants. In the previous termination criteria, the solver stopped iterating if, when comparing the current map with the one in the previous iteration, the global relative change was below a threshold. While theoretically correct, the unit-less meaning of this *global relative change* makes it difficult to tune for a

given dataset, which resulted many times in the solver executing more iterations than needed. Now, the user can stop the optimization/solving of the PDE when the maximum change of a single cell between the previous and current map is below a metric threshold based on the range of valid depths/elevations on the DTM. For instance, for a dataset containing a range of elevations from -10000 to 10000, a change of 1m is not relevant, and the solver should consider it got to a steady state when reaching this value. However, if the range of elevations is from 5 to 10, then 1 meter is a relevant change, and the method should continue iterating. This value can be set by the user directly, or as a percentage of the range of depths/elevations on the data, with this range being automatically computed by the method.

## References

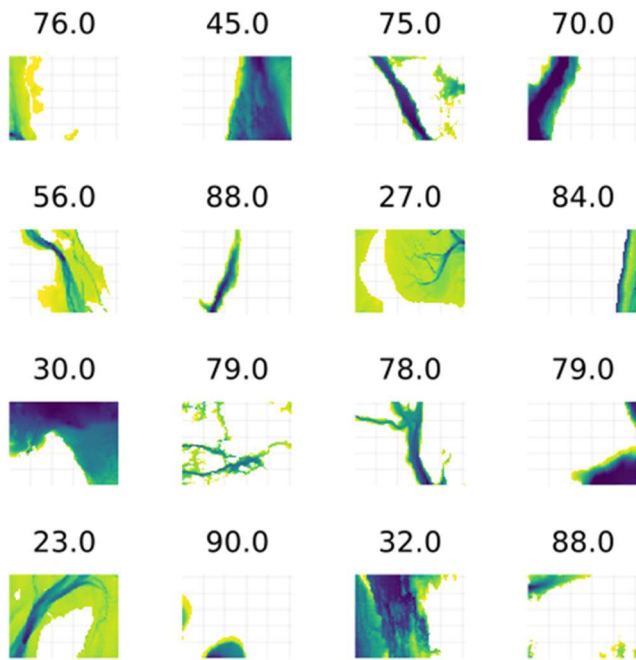
- [1] A. Criminisi, P. Perez and K. Toyama, "Region filling and object removal by exemplar-based image inpainting," in *IEEE Transactions on Image Processing*, vol. 13, no. 9, pp. 1200-1212, Sept. 2004, doi: 10.1109/TIP.2004.833105.
- [2] EMODnet Bathymetry Heightmap Interpolation Package. url: [https://github.com/coronis-computing/heightmap\\_interpolation](https://github.com/coronis-computing/heightmap_interpolation)
- [3] Yuanming Hu, Tzu-Mao Li, Luke Anderson, Jonathan Ragan-Kelley, and Frédo Durand. 2019. Taichi: a language for high-performance computation on spatially sparse data structures. *ACM Trans. Graph.* 38, 6, Article 201 (December 2019), 16 pages. <https://doi.org/10.1145/3355089.3356506>
- [4] Smith, W. H. F, and P. Wessel, 1990, Gridding with continuous curvature splines in tension, *Geophysics*, 55, 293-305.

## **Deltares - Extrapolation of missing bathymetry with deep-learning**

During the previous release, the EMODnet gridded bathymetry was extended to Venice lagoon. This included several new datasets both from bathymetric surveys and from satellite derived bathymetry. It also became clear that even though a larger and larger fraction of the coastal waters is covered with every new release of the EMODnet gridded bathymetry, there are still numerous coastal regions where no high-quality data is available and where the water is not clear enough for satellite derived bathymetry. To fill these gaps, we proposed to develop a generative deep learning approach to fill the gaps, at least until these can be replaced by survey data.

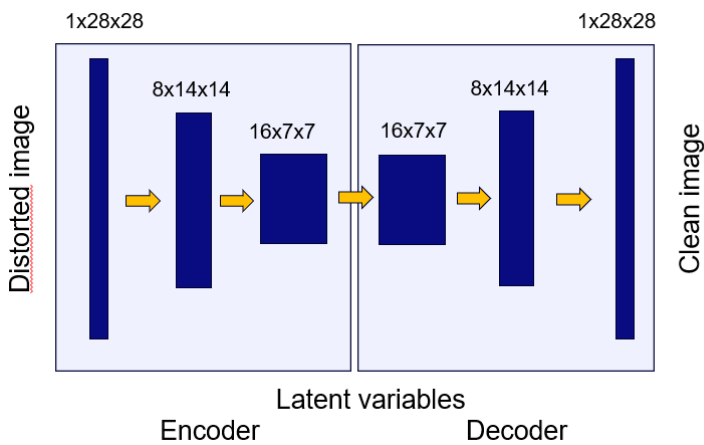
In recent months several preparations have been made to start the training of the deep learning model. Firstly, scripts were developed to generate tiles with training data. In this way new tiles can be generated at will, which will reduce the likelihood of over-fitting to the data. One of the next steps is to see if the quality index developed in EMODnet can be included as part of the training.





**Figure 2 Sample of generated tiles meant for training and testing the network**

The first approach being tested is a convolutional autoencoder. The figure below shows an example of this method applied to images of handwritten digits with a missing part of the image. The goal of the network in this example is to fill the gaps.



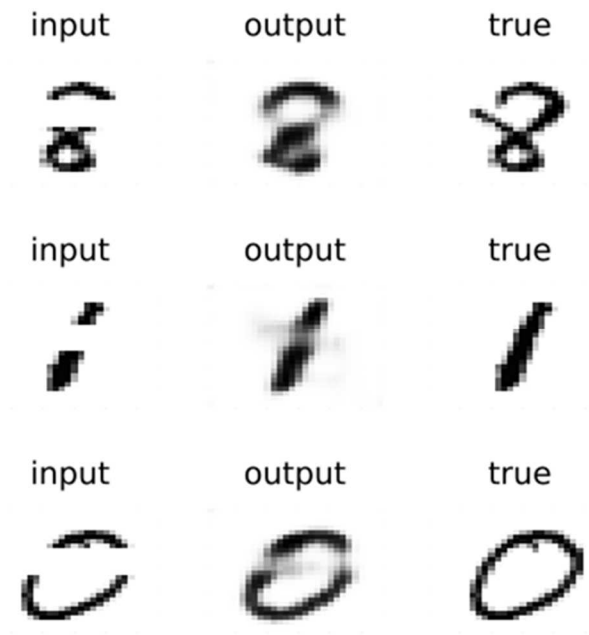


Figure 3 Diagram with example set-up of an auto-encoder (top) and example filling gaps for digits of the famous MNIST dataset.

**Deltares – Updating and refining best-estimate European digital coastlines for a range of vertical levels**

Until now the satellite derived coastlines have not been used to determine the land-sea mask of the EMODnet gridded bathymetry. In this release, we aim to reduce the difference between the two datasets. This can potentially improve the EMODnet products in several ways. First, the satellite derived coastlines have a vertical level associated with them that can be used to reduce interpolation artefacts near the coast. Second, the LAT to MSL correction must use the land-sea mask of the gridded bathymetry, and more consistency can increase the accuracy. The figure below shows an example with some of the differences between the land-sea mask from the gridded bathymetry and the satellite derived coastline.



Figure 4 Current land-sea mask (left) and satellite derived land-sea mask

In the past few months several preparations for the sea-level/tide datasets for the next release have been performed. The Global Tide and Surge Model (GTSM) is at the core of the sea-level computations. Over the past years the quality of the model has steadily increased (see also figure below).

Year	version	developments	resolution	Std [cm] FES2014	Std [cm] coastalABC	Time [hr/5wk]
	gtsm1					
2015	gtsm2	Improved grid, SAL, improved IT diss	5km	9.3	25.4	5.35
2015	gtsm2_glossis		5km	11.3	25.1	5.33
2019	GTSMv3_codec	Improved grid and resolution Implementation of SLR	2.5/1.25km	7.6	18.3	23.72
2019	GTSMv3_cmip6 (CMIP6 climate projections)		2.5/1.25km	7.6	18.2	22.61
2020	GTSMv4.0 (EM66)	Improved bathy, calibration, Improved tidal potential	2.5/1.25km	6.3	17.4	21.08
2020	GTSMv4.0 + CA (EM64)		2.5/1.25km	4.6	15.7	20.11
2021	GTSMv4.1 (EM74)	Improved IT diss, Chezy re-tweaking, re-calibration XW	2.5/1.25km	5.8	16.8	18.58
2021	GTSMv4.1 + CA (EM75) (GLOSSIS)		2.5/1.25km	3.2	14.1	19.14
2022	GTSMv5.0 (GM42)	Improved grid (ortho), new bathy, improved ITfrict, cutcell (in development)	2km/800m	4.7	15.5	18.68
2023	GTSMv5.0 (GM42+cutcell)		2km/800m	4.2	12.8	19.23
2023	GTSMv5.0 + CA (-)		2km/800m	-	-	-
2020	FES2014 coastal stations				13.7	

Table 1 Development overview of GTSM

One development in GTSM is a new numerical method for grid-cells at the coast. The coastal cells can cross the coastline and thus overlap in part with land and in part with sea. The new ‘cut-cell’ method removes part of the coastal cells which improves the accuracy of the representation especially in narrow channels. The figure below shows the impact of the method on the accuracy compared to satellite derived tides. A few regions show marked improvements, with smaller improvements throughout the domain.

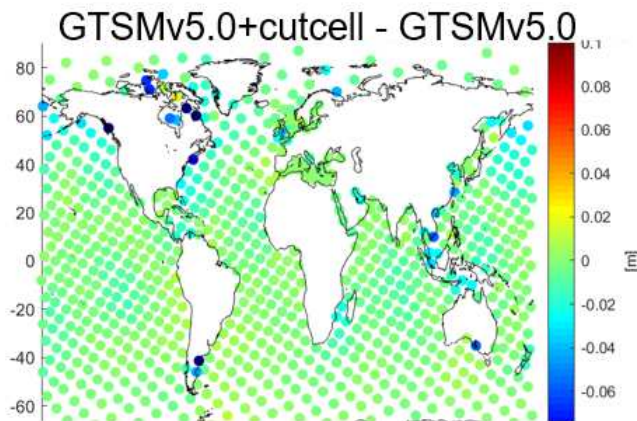


Figure 5 Change in accuracy resulting from application of the cut-cell method. Negative values indicate improvements.