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 4

Reporting Period: 01/10/2023 – 31/12/2023

The European Marine Observation and Data Network (EMODnet) is financed by the European Union under Regulation (EU) 2021/1139 of the European Parliament and of the Council of 7 July 2021 establishing the European Maritime, Fisheries and Aquaculture Fund and its predecessor, Regulation (EU) No. 508/2014 of the European Parliament and of the Council of 15 May 2014 on the European Maritime and Fisheries Fund.

Contents

1. Highlights in this quarter

- **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 again from 42153 to 42369 CDI entries, while the number of Composite DTM entries increased from 277 to 279. New CDI entries for bathymetry survey data sets were contributed by 6 data providers, originating from Italy, France, Latvia, Netherlands (2), and Ireland. In the coming quarter more 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. For Satellite Derived Bathymetry, 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. Its production will start soon.

- **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:**

  As follow-up to the plenary meeting and workshop, that was held in Brest – France, 25-26 September 2023, IFREMER has finalised the deliverable D3.1 which provides guidance information for using the latest release of the Collaborative Virtual Environment (CVE) as part of the production workflow for generating the new EMODnet DTM. This Deliverable is provided as Annex to this progress report.

  The data gathering activities will be completed in the coming months with more CDIs and CDTM submissions, whereby also the pre-processing of the associated data, using GLOBE and following EMODnet methodology, to 1/32 * 1/32 gridded data sets will take place for transfer of the gridded data sets to Regional Coordinators. A workshop has been planned for regional coordinators together with core partners in April 2024 for monitoring and discussing the RDTM generation process. The workshop will be hosted by GGSgc in France.

- **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 at 23rd 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:**
  As indicated under Task 2 and Task 3, a lot of 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 in the second half of 2024 for publishing the planned 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 was done so far by sending an updated document to JIRA which was then processed by the EMODnet Secretariate. Recently, EODnet Bathymetry has received logon details for direct access to the EMODnet CMS (Drupal) for performing maintenance activities. This will be tested and in near future used 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. Representatives of the Regional Sea Conventions have also been informed about the EMODnet progress and products during the successful EMODnet Open Conference which was held from 29 – 30 November 2023 in Brussels – Belgium.

- **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 practice, the EMODnet DTM is considered as the European contribution to Seabed 2030 and as such fully integrated into the GEBCO DTM. This is strengthened by the fact that George Spoelstra (GGSgc) and Federica Foglini (CNR), both members of the EMODnet Bathymetry consortium, act as Chair and Vice-Chair of the GEBCO subcommittee TSCOM (Technical Subcommittee on Ocean Mapping). During the EMODnet Jamboree a meeting of the Bathymetry consortium took place, which included an online dialogue with GEBCO and SeaBed 2030 senior staff about the cooperation and synergies and also how to arrange that data from European data providers will go through EMODnet to GEBCO and SeaBed 2030. This dialogue will be followed up.

- **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. The number of visits and downloads of the full DTM products has increased very considerably in the reporting period, which is most probably due to the EMODnet Open Conference and the promotion around this event. The user feedback is at a regular level 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 23rd 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 Bathymetry plenary meeting took place during the EMODnet Jamboree to remind partners of the production schedule for the new product releases and for an online dialogue with GEBCO and SeaBed 2030 as mentioned under Task 7. Shom and MARIS prepared the Q3-2023 progress report which was reviewed and accepted by the EU CINEA. Preparations are ongoing for the Interim Annual Report which will be submitted during February 2024.

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,c,d	M4, M7, M10, M13	
D1.2: Annual Interim report	WP1	M12	In progress		
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: Training Workshop for data pre-processing and metadata population	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		This will continue in the coming Months till M15

D2.4: Pre-processed composite DTMs and included in Sextant service	WP2	M12	Underway		This will continue in the coming Months till M15
D2.5: Satellite Derived Bathymetry data sets and included in Sextant Service	WP2	M12	Underway		This will continue in the coming Months till M15
D3.1: Upgraded guideline of EMODnet methodology for DTM production, including using prototype CVE	WP3	M9	Delivered	M10	Attached as Annex to this Progress Report
D3.2i: Upgraded Globe software	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
D3.3i: Training and intercalibration Workshop	WP3	M11	Has been re-scheduled to better fit the latest planning for production of DTM		Workshop of Regional Coordinators and Integrator at M16
D3.4i: Processed and pre-gridded data sets as input for RDTMs	WP3	M14			
D3.5i: Regional DTMs with common resolution of 1/16 arc minutes grid	WP3	M17			
D3.6i: Best version HR DTMs for coastal waters and hotspots	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	
D4.3i: CVE optimised for reginal coordinators	WP4	M14			
D4.4i: Globe software + GGSGC workbench upgraded with extra functionality	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
EM-869 Bathymetry to provide metadata records relevant to the Ocean Hackathon 2023	Resolved	No update was provided from Bathymetry. Sorry.		17/11/2023
EM-905 Geoserver 2x server side request forgery issues	Resolved (Bathymetry side)	Bathy has an updated version (2.4.1)		10/12/2023

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
EM806 Increase zoom level for coastline	pending	Action to be undertaken by CP to increase the zoom level. Pre-tiled level already existing	27/06/2023	
EM766 EMODnet Baselayer is using WebMercator tileset in EPSG4326 projection	Resolved	Use of the appropriate tileset is suggested from Bathy. New version developed and tested. Now active.	12/04/2023	27/10/203
EM703 Bathymetry narrative update	pending	One series of update in the narrative done. Ticket left opened as a new series should come shortly	03/01/2023	
EM774 GetFeatureInfo shows unnecessary RGB info for HR depth and natural colors	Resolved	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	20/10/2023
EM805 EMODnet Bathymetry land topography cache issue	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	27/06/2023	14/08/2023

		clear out the CP cache frequently. Investigation on the best clearing cache frequency is undergoing		

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 up again to normal numbers.
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 product downloads has increased very considerably, and is very large. Most probably, the EMODnet Open Conference has contributed to this very considerable rise in downloads, not only of the HRDTMs and DTRM tiles, but also of the Satellite Derived Coastlines package. Also, the number of WMS - WFS requests has increased very much, while it was already very high.
3. Internal and external organisations supplying/approached to supply data and data products within this quarter	CDI catalogue service	Several data providers have submitted new entries, while others are working to meet the deadlines of the contract
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 is slowly decreasing to be around 120, while end of the year it went lower. 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 quartely numbers are reasonable as the bathymety narrative is a static story. See the earlier remark under

views and percentage of returning visitors		5.1.This quarter the numbers are circa 14% higher than the previous quarter, most probably as a result of the EMODnet Open Conference.

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].

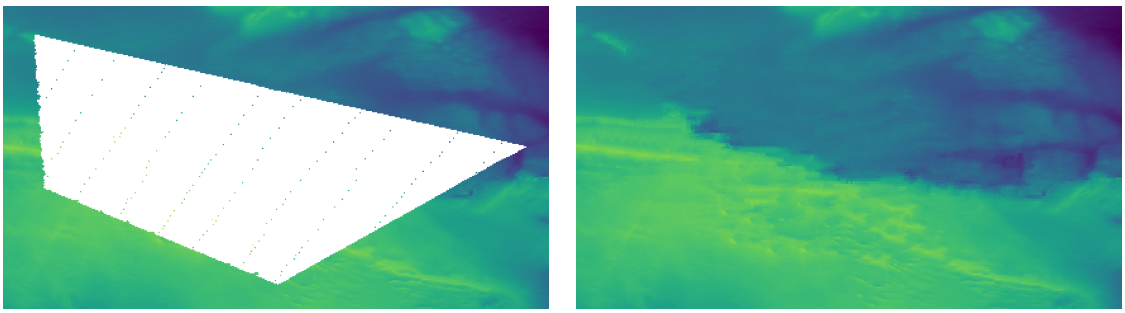


Figure 1. Sample of the new gradient-preserving inpainting algorithm: on the left you can find the original DTM, with unknown cells in white, and on the right the result of the proposed algorithm.

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

[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.

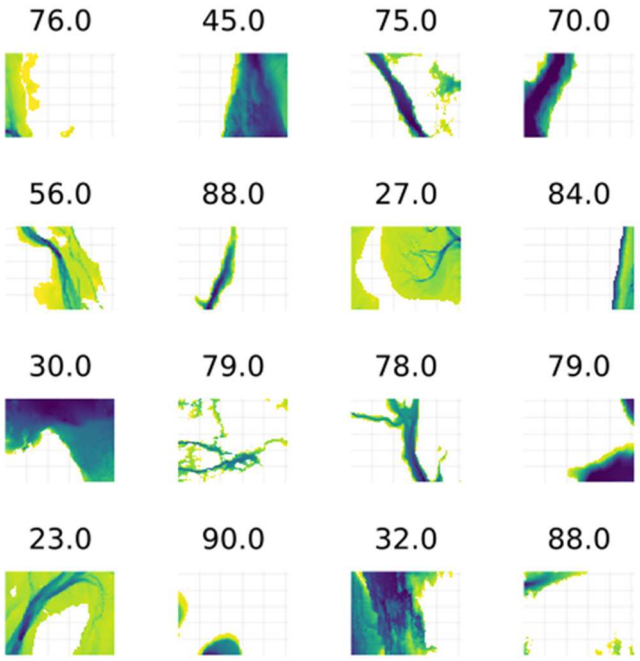
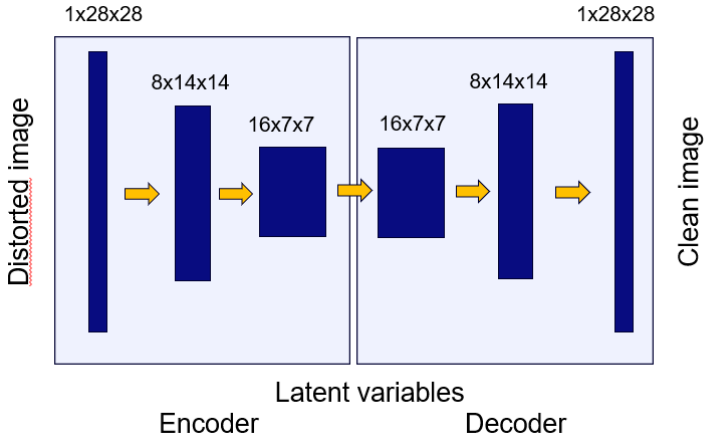


Figure 2 Sample of generated tiles meant for training and testing the network

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.



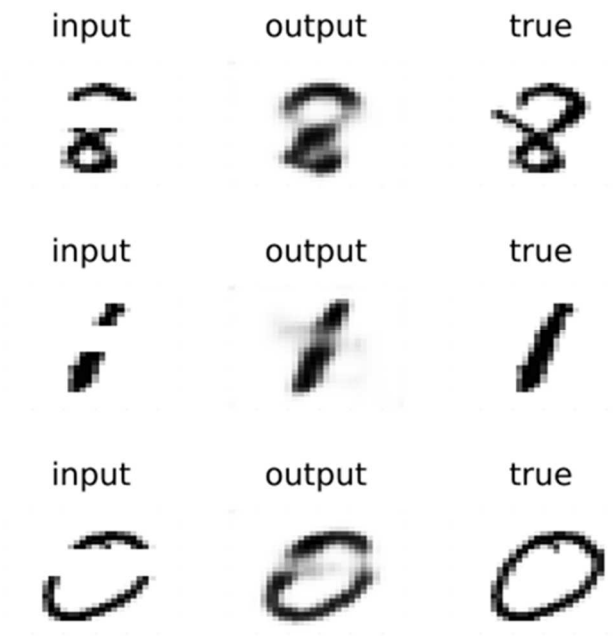


Figure 3 Diagram with example set-up of an auto-encoder (top) and example filling gaps for digits of the famous MNIST dataset.

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.

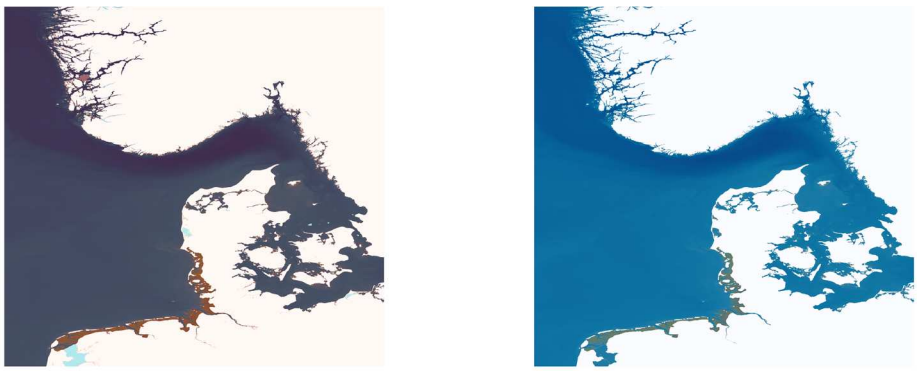


Figure 4 Current land-sea mask (left) and satellite derived land-sea mask

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.

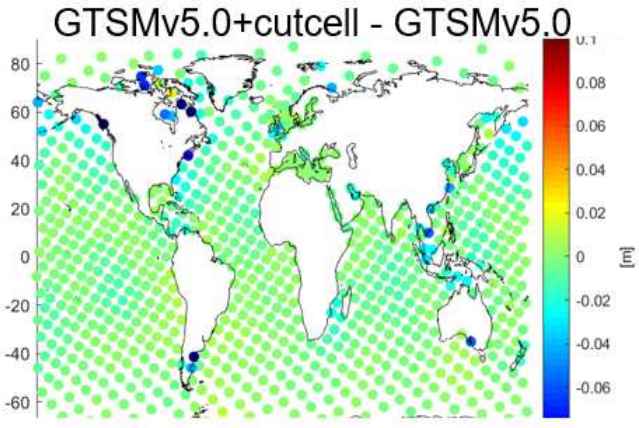


Figure 5 Change in accuracy resulting from application of the cut-cell method. Negative values indicate improvements.