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| **Author(s):** | Matias Alday G. (matias.alday@ifremer.fr) |
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# 1 Bathymetric data

## 1.1 Coastlines

Coastline polygons taken from OpenSteetMap:

- Projection: WGS84
- Last update: 2018-06-10 09:33.
- Source: http://openstreetmapdata.com/data/land-polygons

These polygons define the mean high water spring, which means that their elevation should be placed above sea mean waver level according to local tide conditions. Source files only have Lon Lat info, no elevation provided.

The following comparison is done with respect to a coastline file which integrates SHOM data and other non-specified sources (file provided by F. Ardhuin: **france_more5.line**).

In addition, coastline polygons from GSHHS version 2.3.7 where reviewed, but no contrast is done with them since their resolution is clearly coarser than the OpenSteetMap polygons.

- Source: http://www.soest.hawaii.edu/wessel/gshhg

### 1.1.1 Features along the French coast

Review of some differences between coastlines sources. This will help to decide what elements keep of insert in the final coastline polygon of the model (at least for features along the French coast).

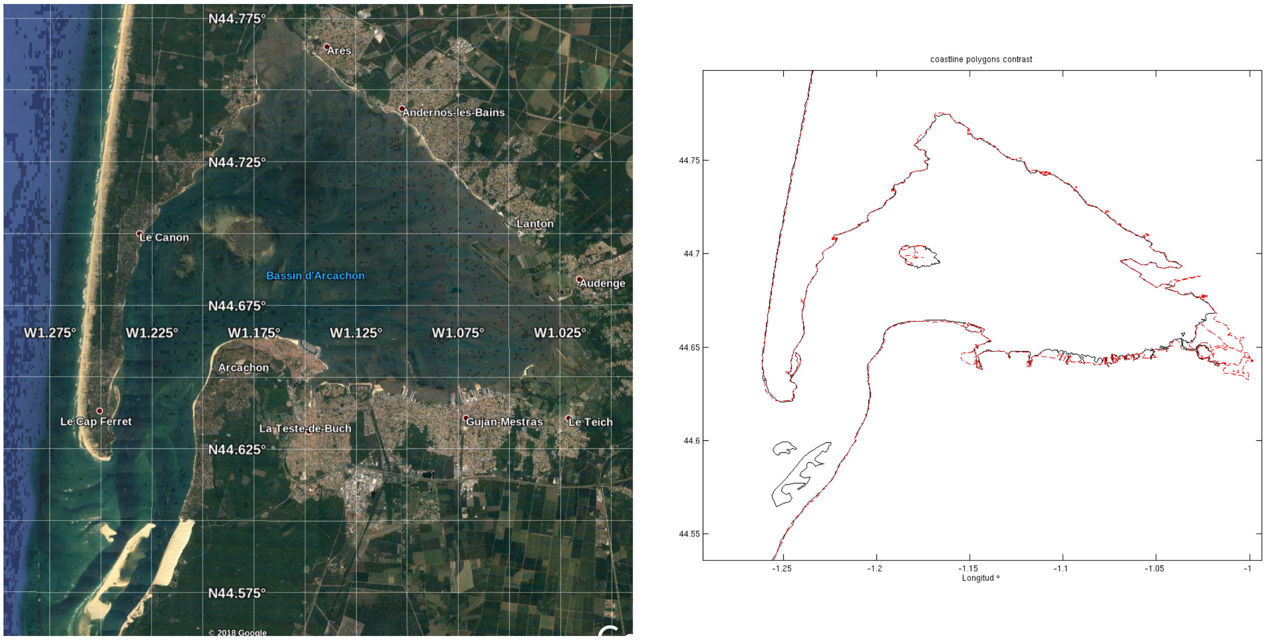


**Figure 1: Coastline contrast at Bassin d'Arcachon.**
Obs.: OpenStreetMap coastline in black.

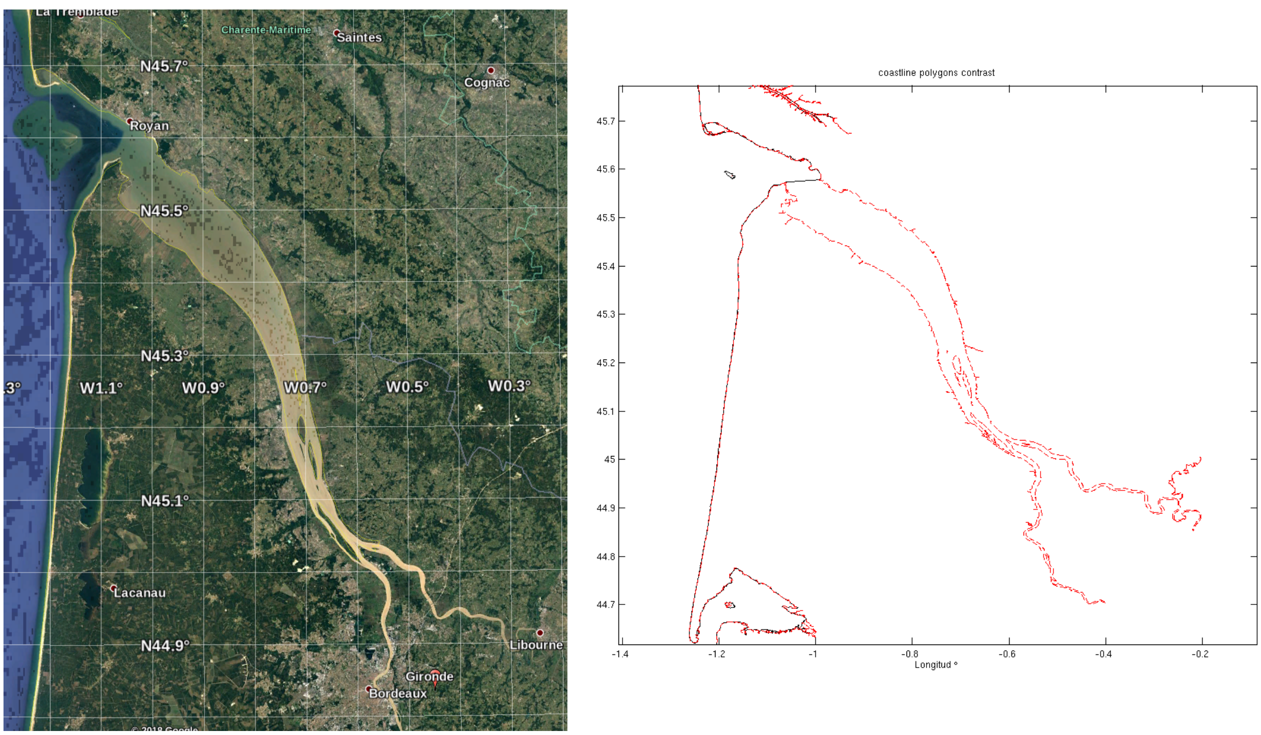


**Figure 2: Coastline contrast at Gironde.**
Obs.: OpenStreetMap coastline in black.

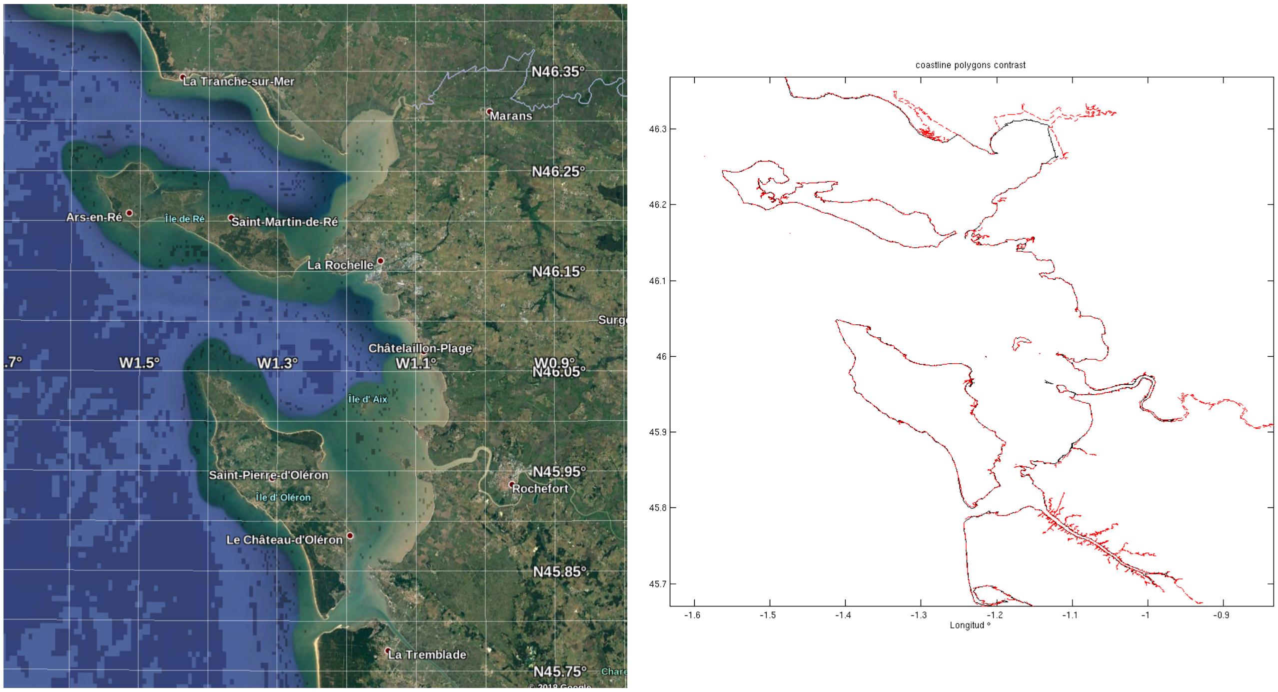


**Figure 3: Coastline contrast at La Rochelle.**
Obs.: OpenStreetMap coastline in black.

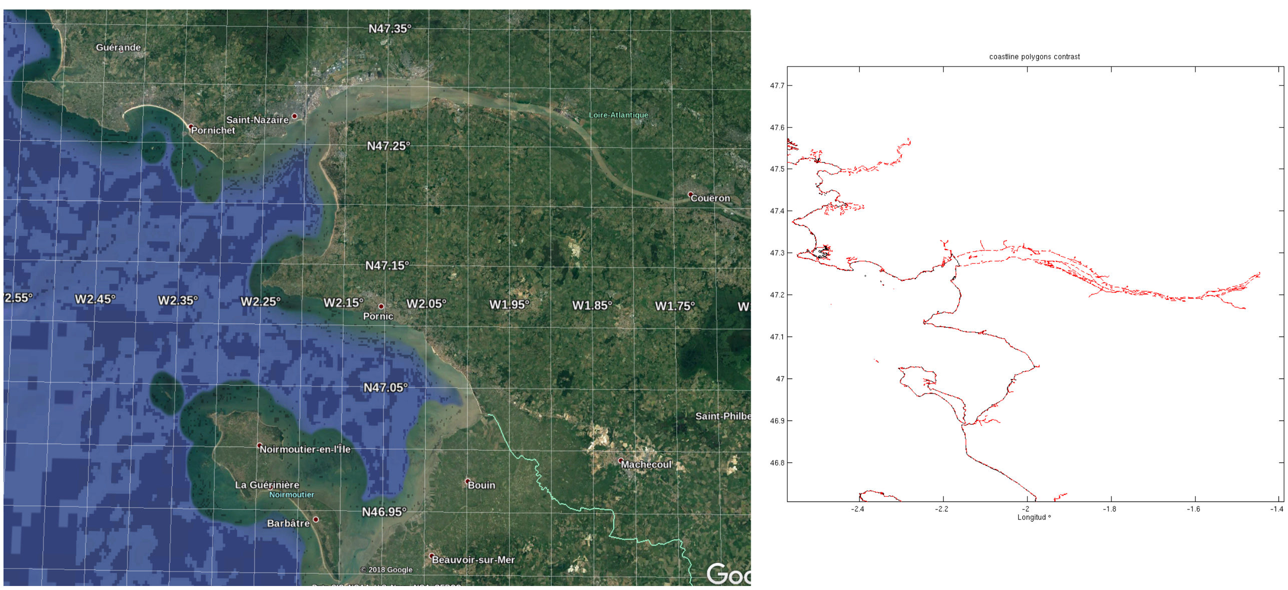


**Figure 4: Coastline contrast at Saint Nazaire**
Obs.: OpenStreetMap coastline in black.

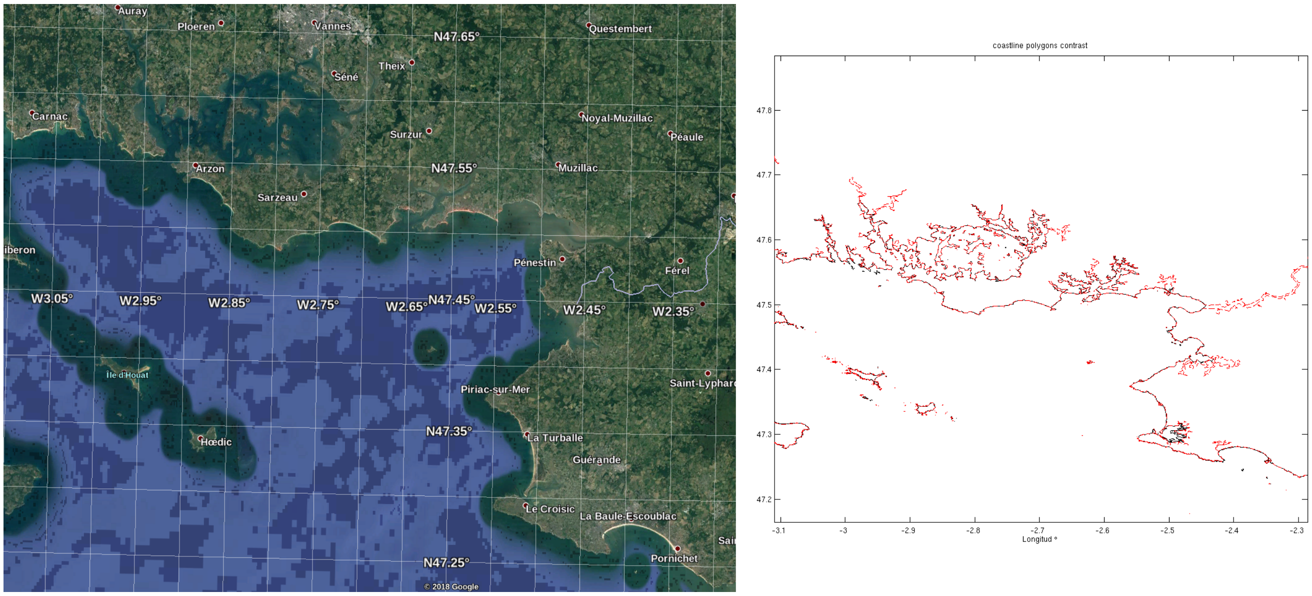


Figure 5: Coastline contrast at Penestin.

Obs.: OpenStreetMap coastline in black.

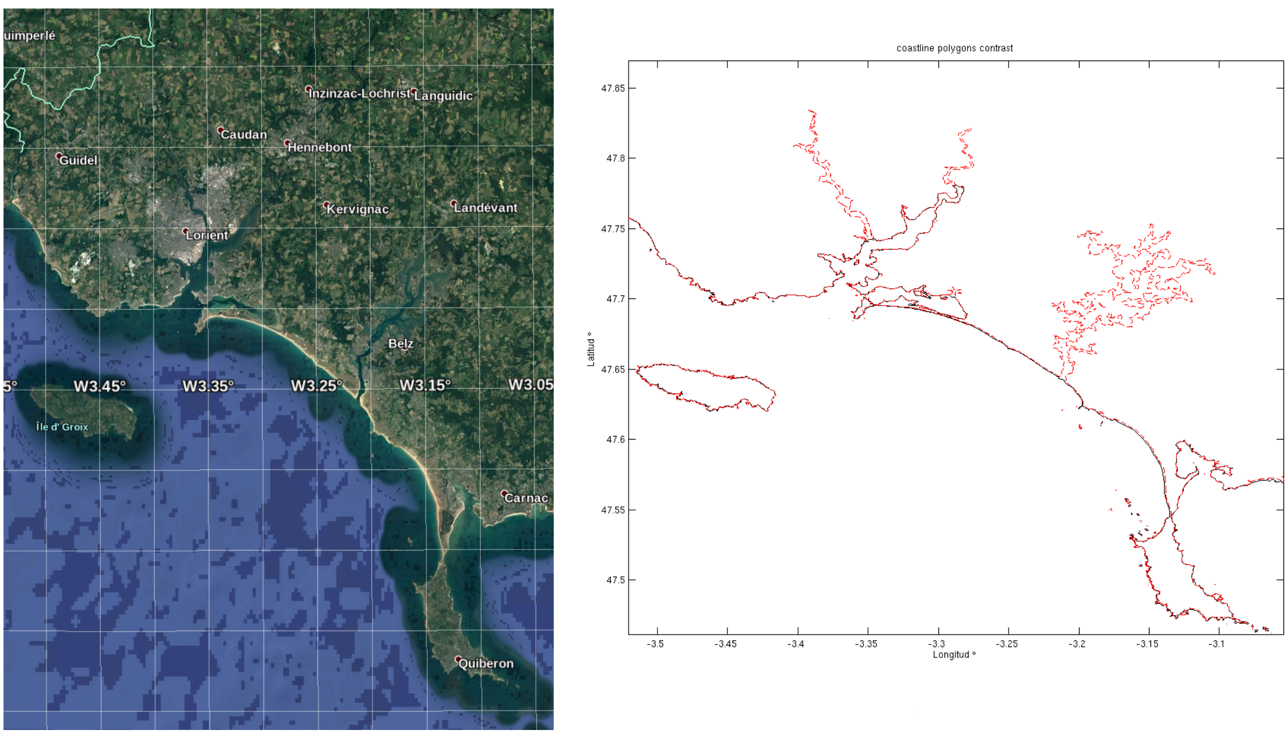


Figure 6: Coastline contrast at Lorient.

Obs.: OpenStreetMap coastline in black.

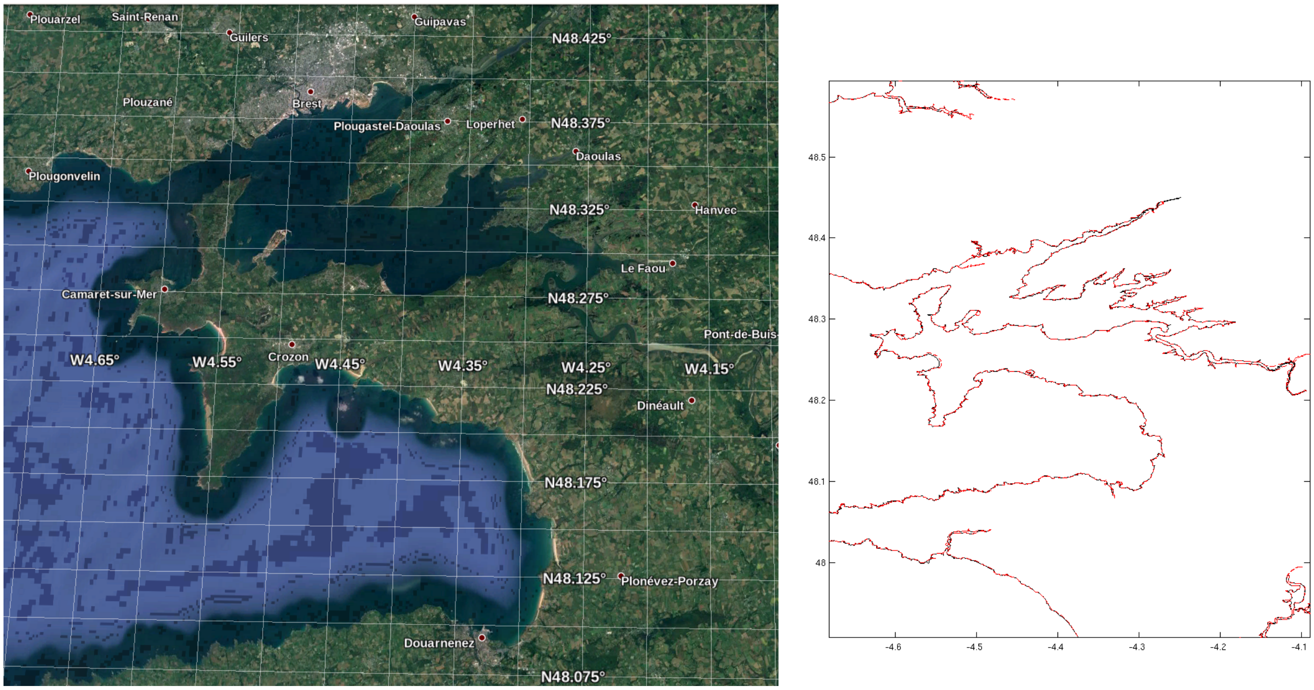


**Figure 7: Coastline contrast at Brest.**

Obs.: OpenStreetMap coastline in black.

### 1.1.2 Coastlines polygons pre-process

The pre-process sequence is aimed to reduce and modify the coastlines polygons before the mesh construction. The following elements where taken into account:

1) **Model domain:** Lon from-12 to 13.5, Lat from 36 to 63.

2) **Coastline for main polygon (Europe):** For example, two preliminary main polygons (European coast) where created. In the first one, French coastline provided by F. Ardhuin (mainly SHOM source) was inserted into the OpenStreetMap polygon, from ~(-3 Lon, 43.38 Lat) to ~(2.05 Lon, 51.025 Lat). Basically from Getxo(Spain) to Calais in France. In the second version, a set of insertions where made into the OpenstreetMap taken into account features from both coastlines sources (mainly following an analysis as described in 1.1.1).

3) **First Island filter:** All islands (polygons) with surface of less than 0.02 [$km^2$] (isosceles rectangle triangle with 200[m] side). Considering a maximum resolution of the mesh of ~200 [m] close to the coast. (See Figure 8, left image)

4) **Removing larger unused polygons:** Those features that are not part of the model domain. (See Figure 8, right image)

5) **Modifying main land polygon:** Deleting nodes within the model boundary and re-defining boundaries corner. (See Figure 9)

6) **Removing Island from specific areas:** This is done to perform a "bulk" action over small polygons in zones where high detail of the mesh is not needed.

After this pre-proces of the coastline sources, the amount of polygons to handle were reduced from ~70840 to ~15100.

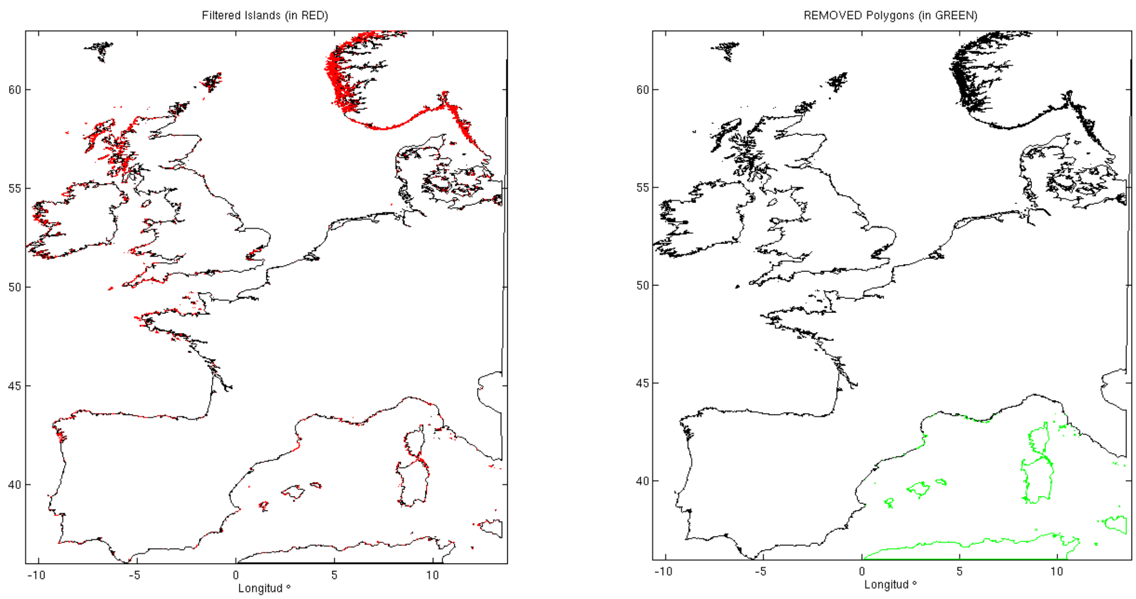

Figure 8: Islands filter and discarded polygons in pre-process.

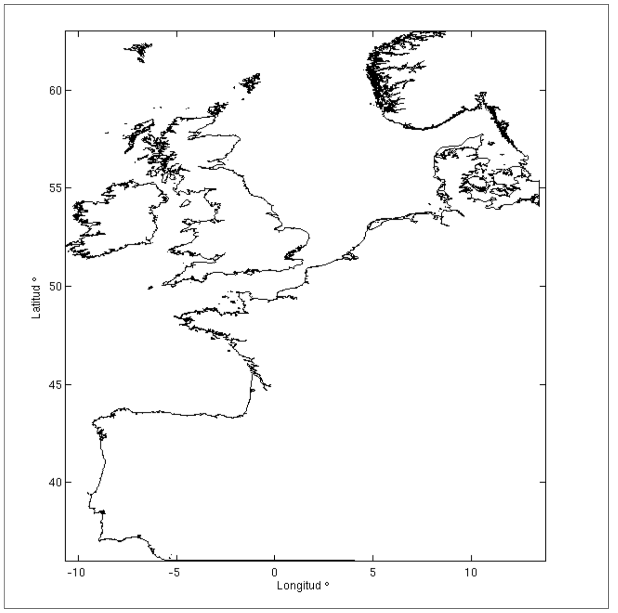


Figure 9: Final polygon selection after filters and modifications.

## 1.2 Depth data

### 1.2.1 Reviewed sources

Three bathymetric sources where analyzed:

1) **EMODnet:** Depth terrain model (DTM) which integrates several surveys along the French coast, the North sea and the North Atlantic (including high latitudes) from 41 partners, including SHOM as leading partner. The available data has a **resolution of 0.0021°** (1/8 arc minutes), the depth reference system is the Lowest Astronomical Tide. Data coverage includes the complete model domain, but it requires the ensemble different source files. For details go to: http://portal.emodnet-bathymetry.eu/ .

2) **HOMONIM:** DTM provided by SHOM (https://data.shom.fr), bathymetric variable named "MNT de façade Atlantic". The DTM **resolution is 0.001° (~ 111 m)**. Depth reference system can be selected: **Lowest Astronomical Tide** or **Mean sea level**. Data coverage is smaller than the model domain required for RESOURCECODE.

3) **NORGASUG:** Bathymetric data taken from xyz file provided by F. Arduhin. Spatial resolution seems uneven. Data coverage is smaller than the model domain required for RESOURCECODE. Depth reference system not

documented, but since this set was used in a previous project involving WW3, it is assumed that it is refered to Mean sea level.

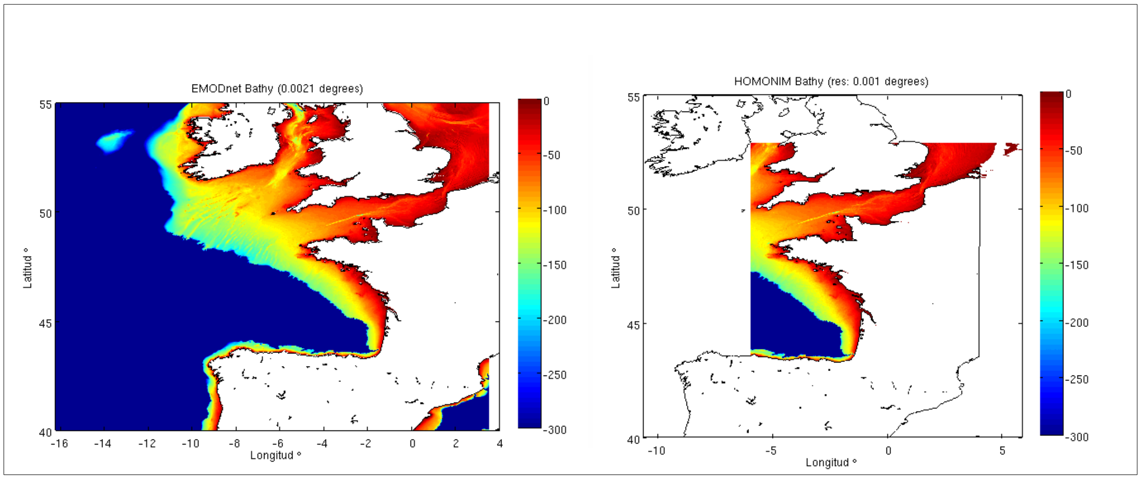


**Figure 10: EMODnet and HOMONIM bathymetry.**
Obs.: GSHHS coastline used as example only. EMODnet depth reference: Lowest tide level. HOMONIM depth reference: Mean sea level. Colorbar in meters.

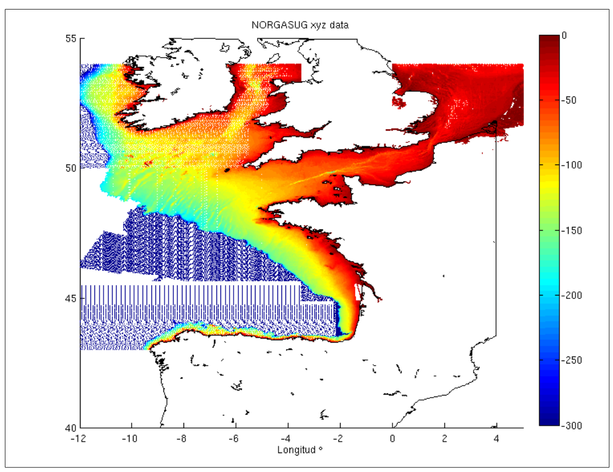


**Figure 11: NORGASUG bathymetry.**
Obs.: GSHHS coastline used as example only. Depth reference: probably Mean sea level. Colorbar in meters.

### 1.2.2 Integrated bathymetry

To integrate the bathymetry from EMODnet and HOMONIM (SHOM), all selected data was referred to the **lowest astronomical tide (LAT).** The complete HOMONIM data set was used, and EMODnet data completed the model domain outside the region covered by the HOMONIM bathymetry.

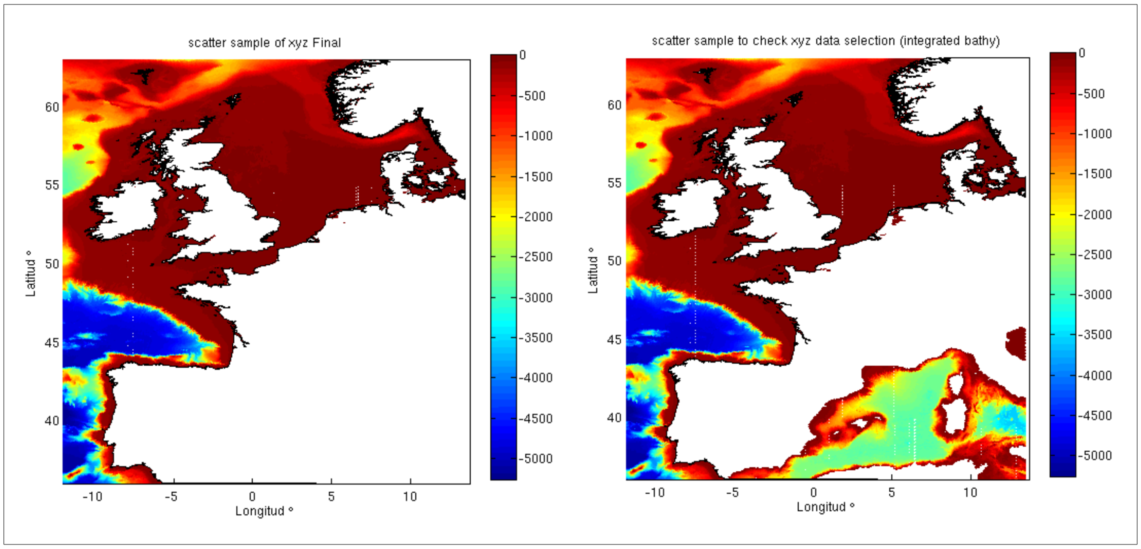


**Figure 12: EMODnet and HOMONIM integrated bathymetric data w/r to LAT.**
Obs.: Coastline polygons in black, as defined in 1.1.2, see Figure 9. Colorbar in [m].

### 1.2.3 Vertical datum change to mean sea water level (MSL)

Bathymetry data input in WW3 must be defined with respect to MSL, therefore a correction must be applied to the depths defined with respect LAT. According to the IHO (International Hydrographic Organization) a relation between the MSL and the LAT can be obtained using the harmonic constants derived from the analysis of previous observations. In this case, the harmonic constants were taken from the FES model output (2014).

The generic expression that relates LAT and MSL is of the form:

- **LAT = Z0 - (M2 + S2 + N2 + K1 + O1 + ...)**

**where: Z0 : mean sea level.**
**M2, S2, N2, K1, O1, etc.. : Harmonic components' amplitudes.**

FES's global model output has a resolution of 1/16°, and it provides a total of 34 tidal harmonics (amplitudes and phases). To use the expression defined above, over every node of the bathymetric grid, the harmonic amplitudes taken from FES where interpolated (linear interpolation) into the bathymetric grid (see Figure 13).

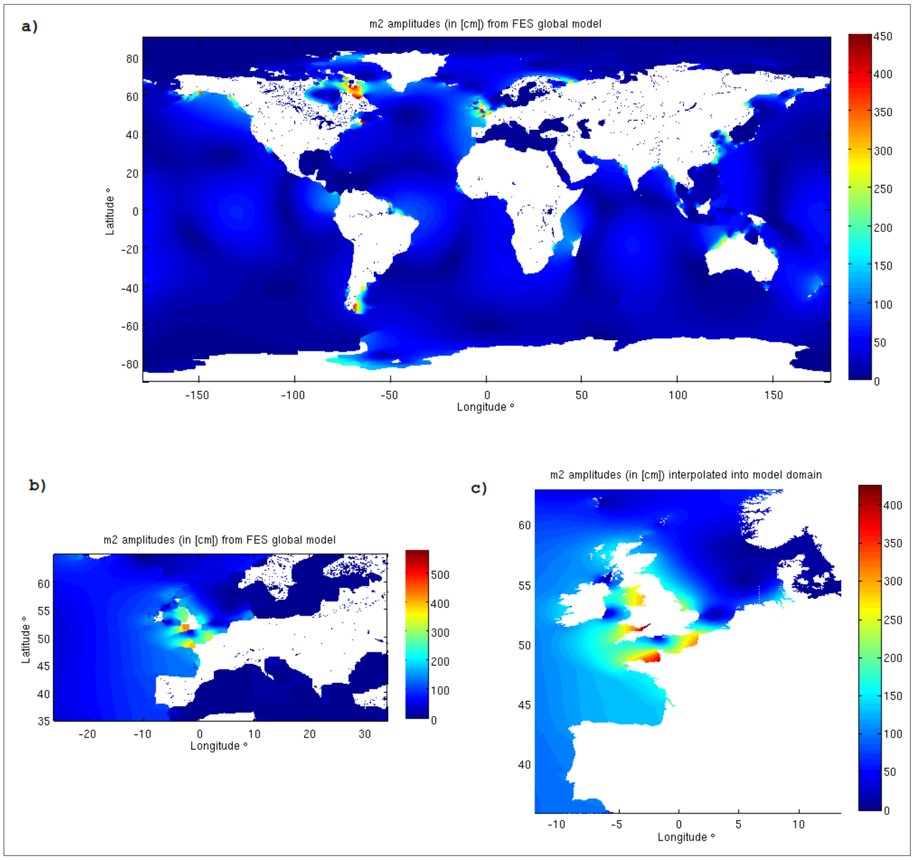


**Figure 13: M2 amplitude distribution and interpolation into bathymetric domain.**
Obs.: Colorbar in[cm].

To verify the use of the harmonic amplitudes in the vertical datum change(from LAT to MSL), a sensitivity analysis was done over the HOMONIM bathymetric domain. Since SHOM provides the data w/r MSL and LAT, it is possible to have an idea of how accurate the estimation of the depths transformed into MSL is. (Figure 14 and Figure 15)

In Figure 14 depths differences between the HOMONIM data w/r the MSL and LAT datum are shown in a), and the difference between the estimated MSL depths using M2, S2, N2, K1, O1 harmonic amplitudes and the HOMONIM bathymetry w/r to LAT is presented in b). From Figure 15 is possible to notice that the amount of tidal harmonics used is not enough to obtain the same depths in terms of the MSL as presented by SHOM. There are differences of about ~0.5 to 1 [m] along La Manche and the Atlantic French coast. When a total of 10 harmonics were used, depths differences along la Manche and the Pacific French coast varied between approx. -0.5 and 0.5 [m] (Figure 16) and overall differences are reduced(depth difference percentage =

-5.0280e-04%). Finally, when the total set of harmonics were used to transform LAT depths into MSL referenced depths, it urned out that the differences increased again (Figure 17).

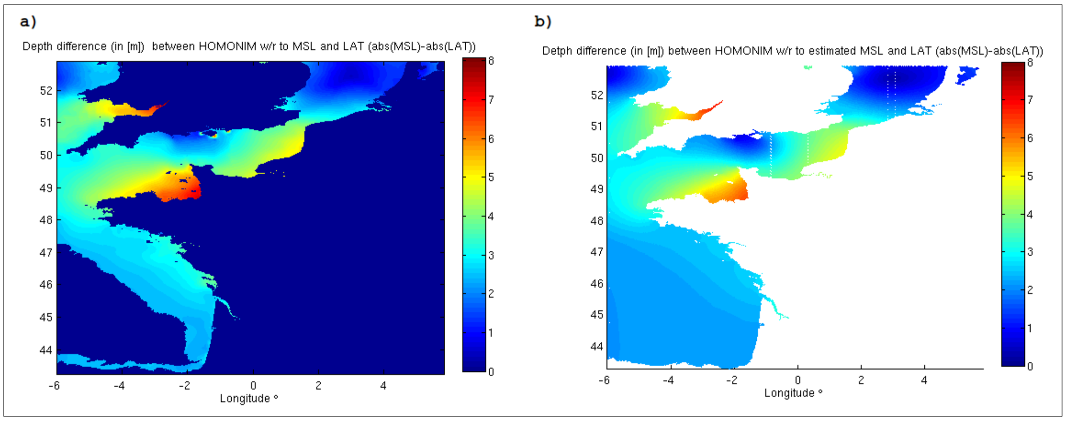


**Figure 14: Depth differences between MSL and LAT datum for HOMONIM.**
Obs.: Harmonics used in estimated MSL: M2, S2, N2, K1, O1. Colorbar in [m].

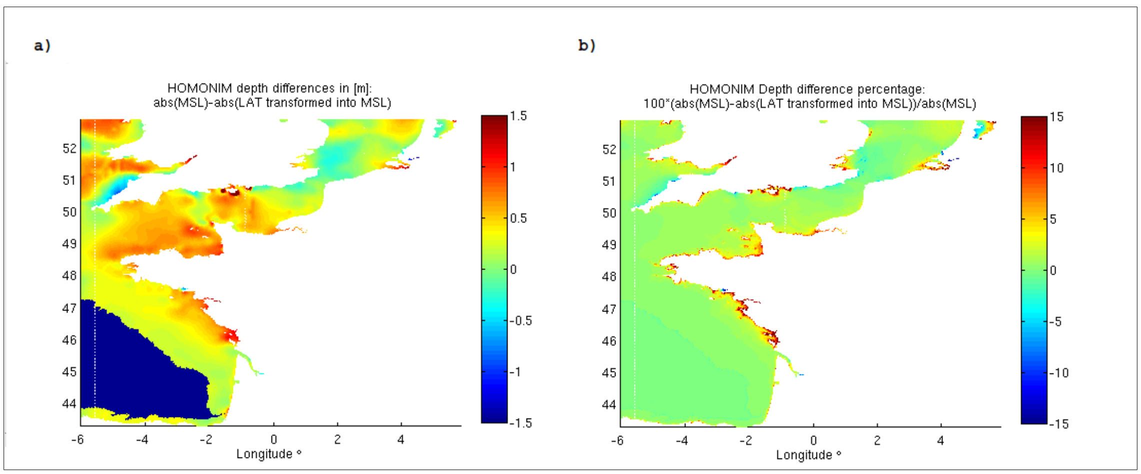


**Figure 15: MSL depth differences. 5 harmonics used: M2, S2, N2, K1, O1.**
Obs.: Percentage median = 0.0029%, Percentage mean = 0.0062%.

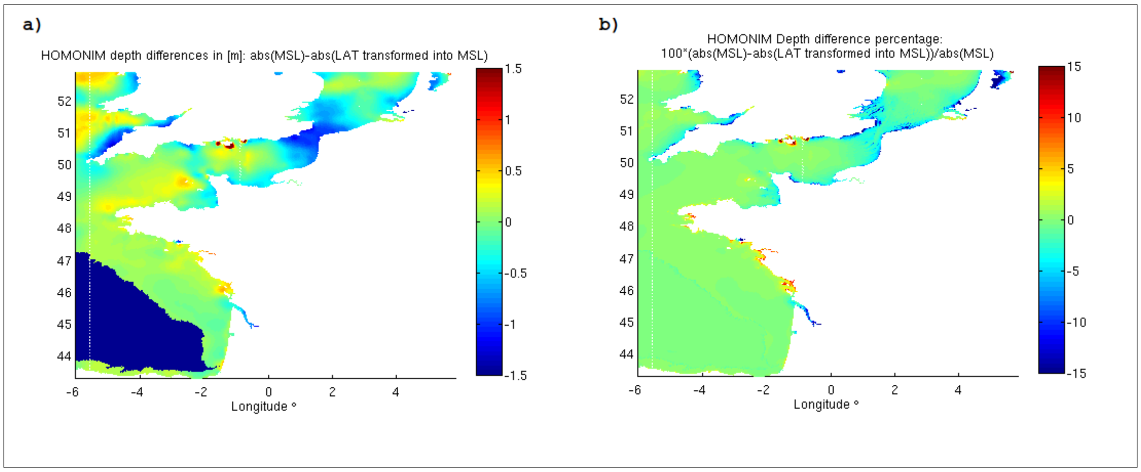


**Figure 16: MSL depth differences. 10 harmonics used: O1, K1, M2, S1, N2, K2, M4, MS4, MN4, M6.**

Obs.: Percentage median = -5.0280e-04%, Percentage mean = -0.0039%.

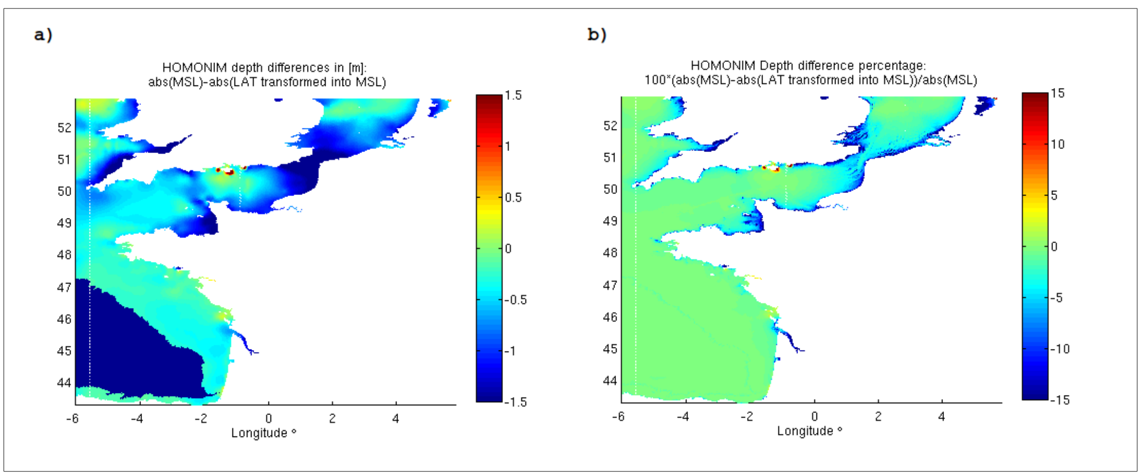


**Figure 17: MSL depth differences. 34 harmonics used.**

Obs.: Percentage median = -0.0043%, Percentage mean = -0.0145%.

# 2 Mesh construction

## 2.1 Subdomain tests

Sub-section of the complete model domain to test pre-process scripts aimed to simplify mesh generation (coarsening polygons, send small polygons to xyz bathy data, search and delete small angles from coastlines polygons).

This test mesh has a minimum triangle side ~200 [m] and a minimum timestep (for explicit scheme) of ~9.3 [s].

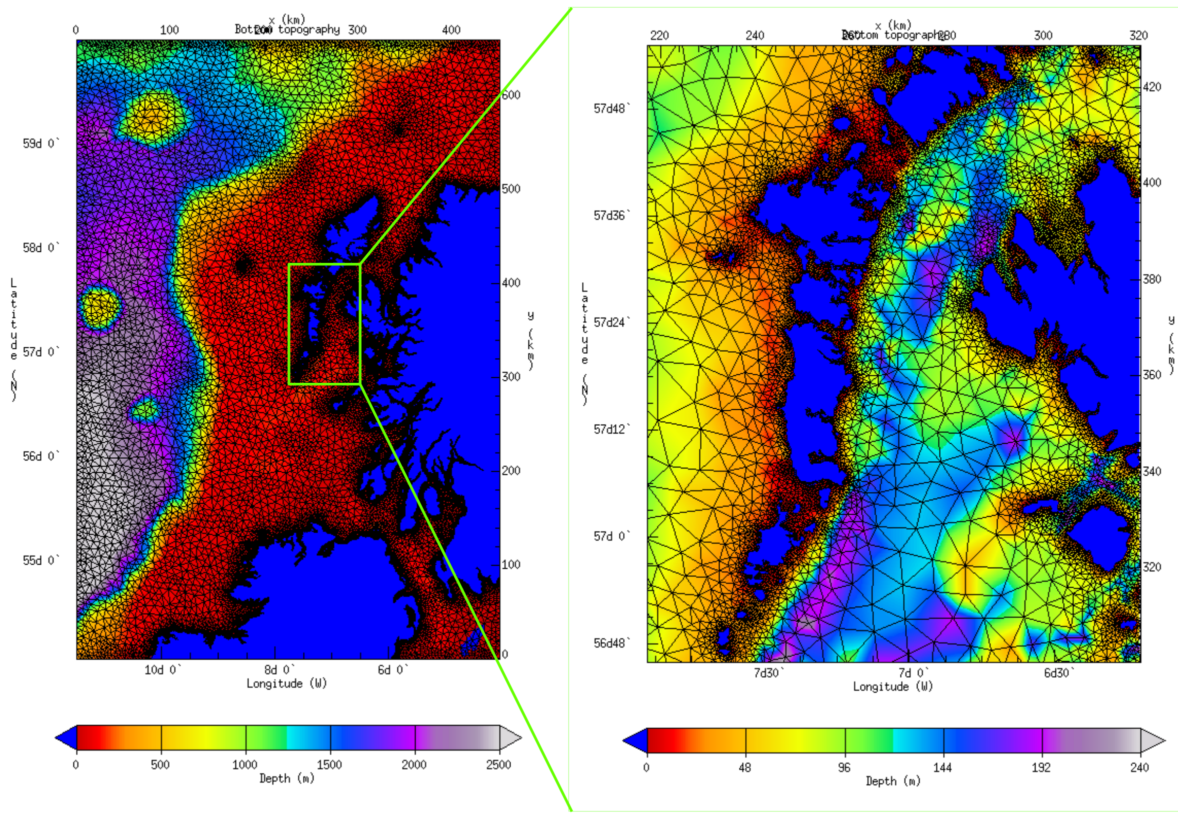


Figure 18: Subdomain mesh example.

## 2.2 Full domain tests

All tests are named Polymesh_full_test* to specify use of the full model domain.

### 2.2.1 Polymesh_full_test_04_coarse_NORWAY_ISLANDS_fixed_rand

Eastern boundary problems solved using the fixing scripts TEST.m and pick_and_crop_poly.m. Small port facilities and narrow rivers (and some inlets) removed along most of polygons. Brittany coast was kept as detailed as possible (more details than HOMERE and NORGASUG).

The following elements were taken into account in this mesh construction:

1. **SOURCE FILE FOR BATHY AND POLYGONS USED IN POLYMESH:**

   Coast_line_and_BATHY_corr_04_coarse_NORWAY_ISLANDS_V02.mat

2. **BATHY SOURCES AND TREATMENT:** Bathy taken from EMODnet and HOMONIM with respect to LAT(lowest astronomical tide).

   Data was integrated and changed to MSL vertical datum using 10 harmonics amplitudes: O1, K1, M2, S1, N2, K2, M4, MS4, MN4, M6 (should we verify a better set??)

3. **POLYGONS SOURCE AND TREATMENT:** Polygons taken from OpenStreetMap. Provider specifies that they are defined at the highest tide limit (horizontal datum WGS84):

   i.-A first filter was applied to the raw data to delete all polygons with less than 10 nodes or with an area smaller than 0.5*(200*200) / 10^6; (Area in km^2) (done with READ_Coastlines.m)

   ii.-Full resolution French coastline from NORGASUG inserted in the boundary polygon.

   iii.- A set of larger polygons were deleted from non interesting areas (Norway) to facilitate time step handling.

   iv.- **All polygons were assigned with an elevation z-coordinate (using tidal info from FES interpolated into the bathy data nodes, see the example in Figure 16).**

   v.- Coarsening of all polygons to 0.004 [deg] = ~ 400 [m] . This will result in a minimum node distance of triangle nodes of about ~200 [m] in some cases due to segment splitting in polymesh.

   vi.- All polygons with less than 10 nodes after coarsening are sent as xyz bathy data.

   vii.- 3 point search algorithm applied to decrease the number of small triangles in polygons (insel and rand).

   viii.- Extra coarsening applied to Norway coastlines (rand and islands) to avoid small time steps in that area (min node distance set to 0.012 [deg] = ~1.2 [km])

4. **MESH MIN TIME STEP (after node handling): 11.9 [s]**

Only 4 neighbors cleaning applied in IDL and some node movement done by hand (about 12 hours working on that).

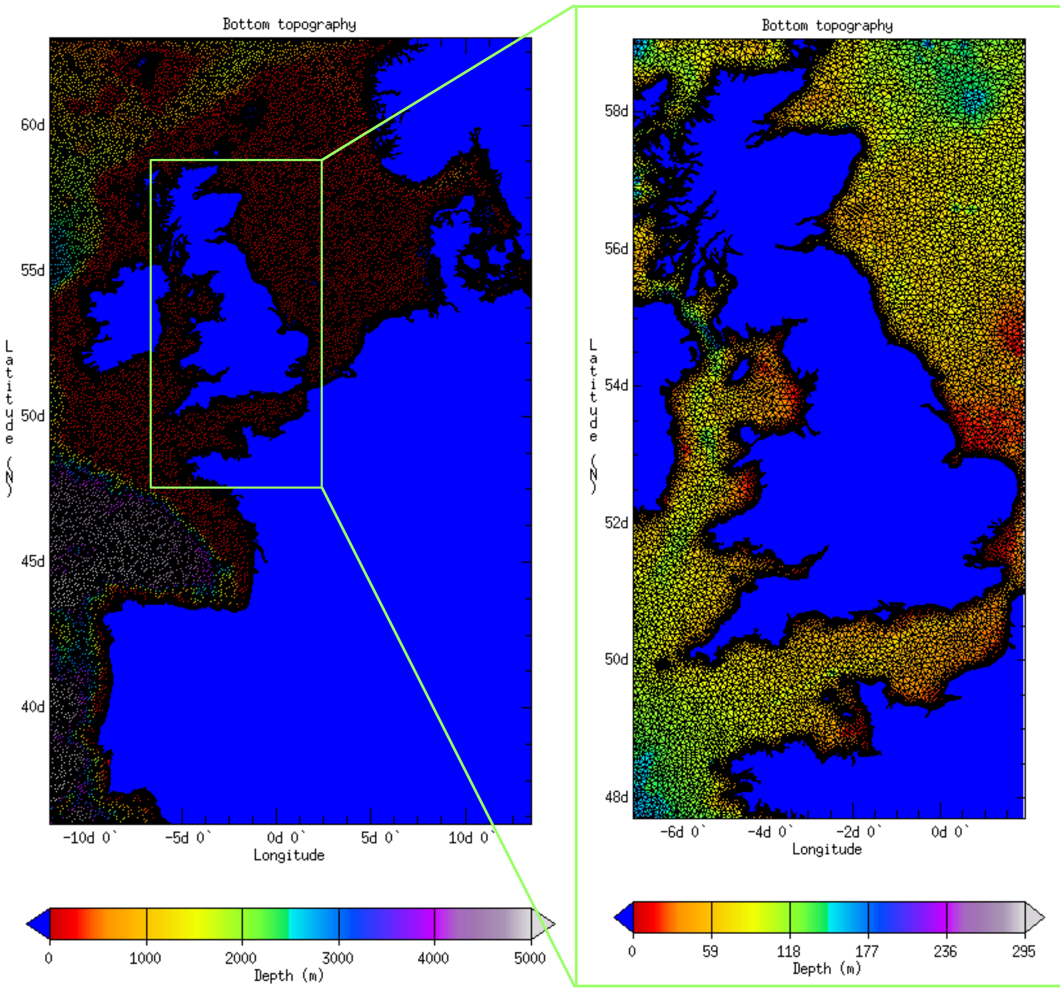


**Figure 19: Full domain mesh test: Polymesh_full_test_04_coarse_NORWAY_ISLANDS_fixed_rand.**

### 2.2.2 Polymesh_full_test_06_coarser_bound

In the following two examples, three main details have been solved in the polymesh configuration (meshin.nml). First of all, it was verified that when a maximum area is specified in PARAITER or PARAINIT (for example: PARAITER = 'YYa0.005jrpq30'), the refinement options, general and specified polygons, will not work. Hence, in order to keep control of the segments spliting (actually avoid too much spliting in order to have control of the minimum distance between nodes and avoid small triangles generation), the 'YY' option is kept in PARAITER and PARAINIT. Then , to keep control of the triangles growth with depth, instead of fixing a maximum area when calling triangle (as done in 2.2.1), the overall refinement was extened to larger depths and some sensitivity analysis was done regarding the maximum edge length allowed to define a convenient maximum triangle size. As an example, see meshin_V02.nml in (mesh shown in Figure 20):

/home/datawork-resourcecode/Model_Data/Polymesh_tests/Polymesh_full_test_06

The second element corrected, was the coarsening of part of the southern, western, and part of the northern boundaries to optimize the amount of total nodes.

Finally, the total amount of polygons has been updated. In this case, no filter of polygons was applied at the beginning of the coastline selection pipeline (READ_Coastlines.m), instead, all polygons filtering was done at the editing phase (coarsening, 3PS-alg, etc., applied with TEST.m). With this change in polygons selection and filtering, more details were obtanied in areas of interest, and all those polygons considered too small were sent to the xyz bathy data. With that approach, it is thought that more bathy details are kept in general, specially in shallow areas with several islands small islands (and where some refinement is used). This set of polygons and bathy can be found in Coast_line_and_BATHY.mat, Coast_line_and_BATHY_corr_01.mat, Coast_line_and_BATHY_corr02.mat, etc., at:

/home/datawork-resourcecode/Model_Data/Polymesh_tests/Polymesh_full_test_06

All .mat files with **_corr_**** ending, correspond to different states of polygons handling and correction (both islands and boundary polygon).

In this full domain test, different meshes were generated. Each one of them related to different satges of polygons correction. The following elements were taken into account in mesh construction:

1. **SOURCE FILE FOR BATHY AND POLYGONS USED IN POLYMESH:**

   Coast_line_and_BATHY_corr_**.mat

2. **BATHY SOURCES AND TREATMENT:** Bathy taken from EMODnet and HOMONIM with respect to LAT(lowest astronomical tide).

   Data was integrated and changed to MSL vertical datum using 10 harmonics amplitudes: O1, K1, M2, S1, N2, K2, M4, MS4, MN4, M6 (vertical datum verification in Figure 21)

3. **POLYGONS SOURCE AND TREATMENT:** Polygons taken from OpenStreetMap. Provider specifies that they are defined at the highest tide limit (horizontal datum WGS84):

   i.-The first filter to delete all polygons with less than 10 nodes or with an area smaller than 0.5*(200*200) / 10^6; (Area in km^2), was not applied to the raw data (with READ_Coastlines.m)

   ii.-Full resolution French coastline from NORGASUG inserted in the boundary polygon.

   iii.- A set of larger polygons were deleted from non interesting areas (Norway) to facilitate time step handling.

   iv.- **All polygons were assigned with an elevation z-coordinate (using tidal info from FES interpolated into the bathy data nodes, see the example in Figure 16).**

   v.- Coarsening of all polygons to 0.004 [deg] = ~ 400 [m] . This will result in a minimum node distance of triangle nodes of about ~200 [m] in some cases due to segment splitting in polymesh.

   vi.- all polygons with less than 6 nodes after coarsening are sent as xyz bathy data.

   vii.- 3 point search algorithm applied to decrease the number of small triangles in polygons (insel and rand).

   viii.- Extra coarsening applied to Norway and Denmark coastlines (rand and islands) to avoid small time steps in that area (min node distance set to 0.012 [deg] = ~1.2 [km])

4. **MESH MIN TIME STEP (after node handling): ~12 [s]**

   All meshes from this test were handled to get a ~12 [s] minimum time step.

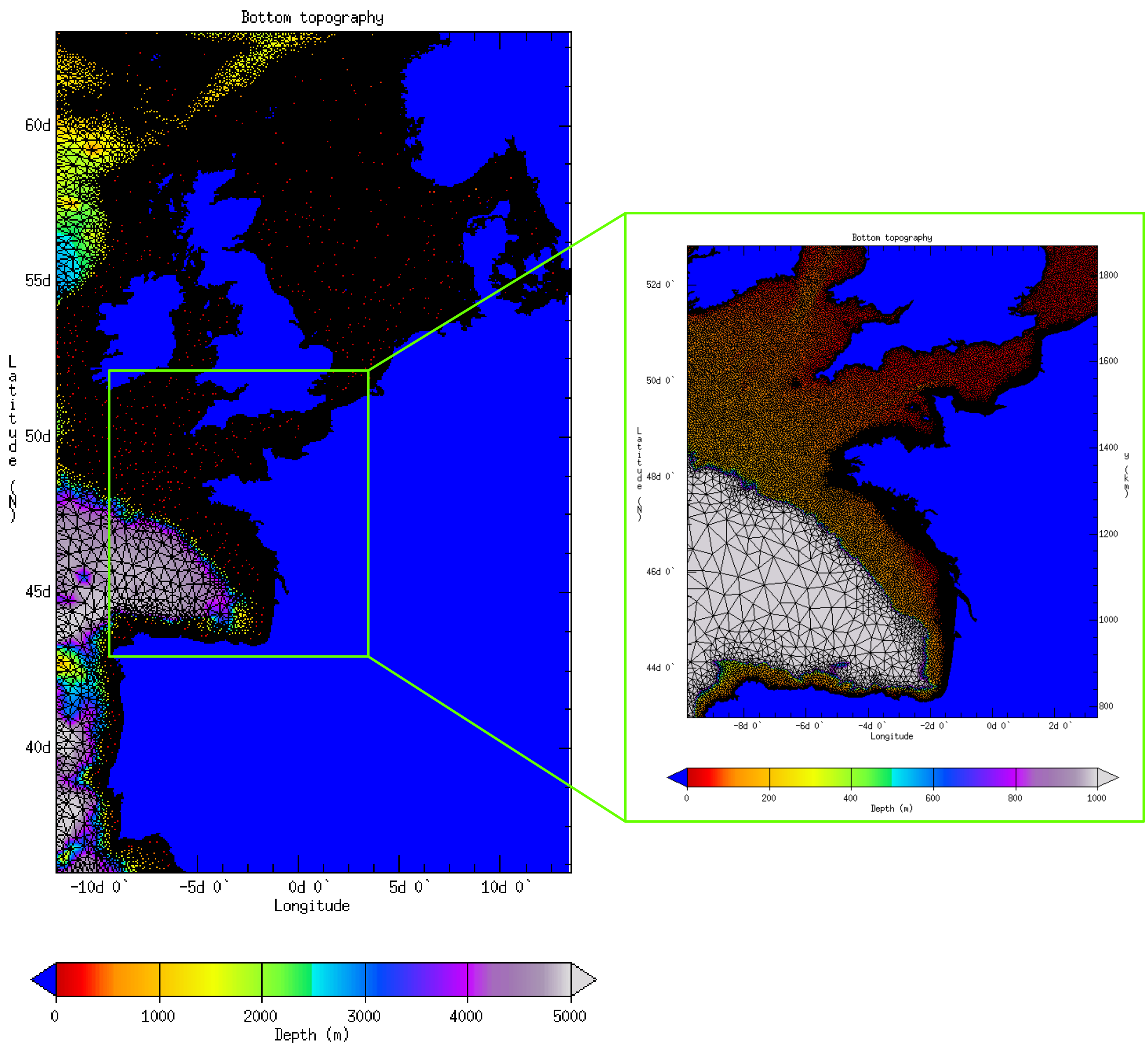


**Figure 20: Full domain mesh test: Polymesh_full_test_06_coarser_bound.**
Obs.: Taken from Polymesh_full_test_06, final_test_06_V02.msh.

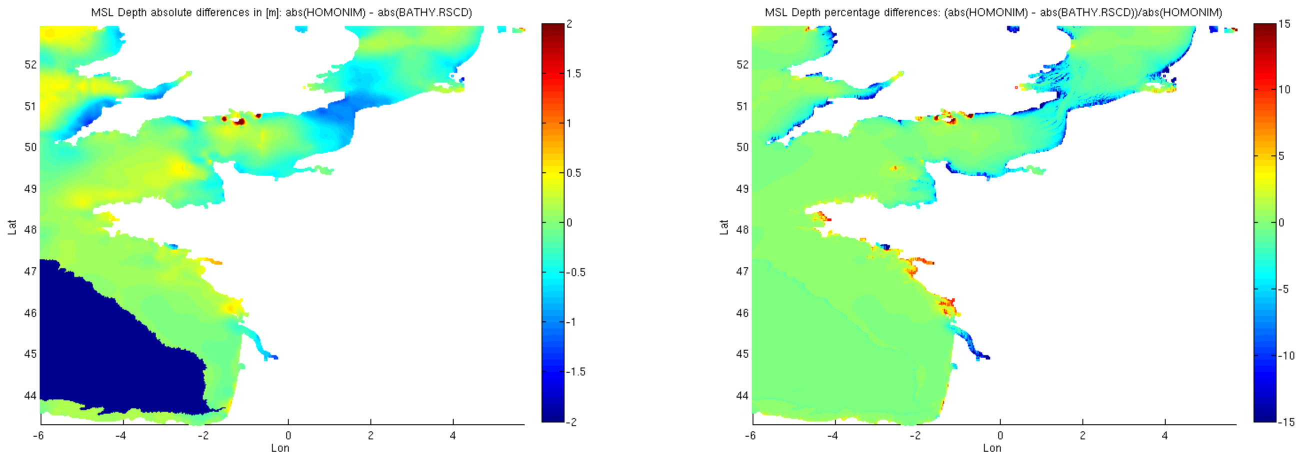


**Figure 21: Mid sea level check after bathy/polygons handling pipeline.**

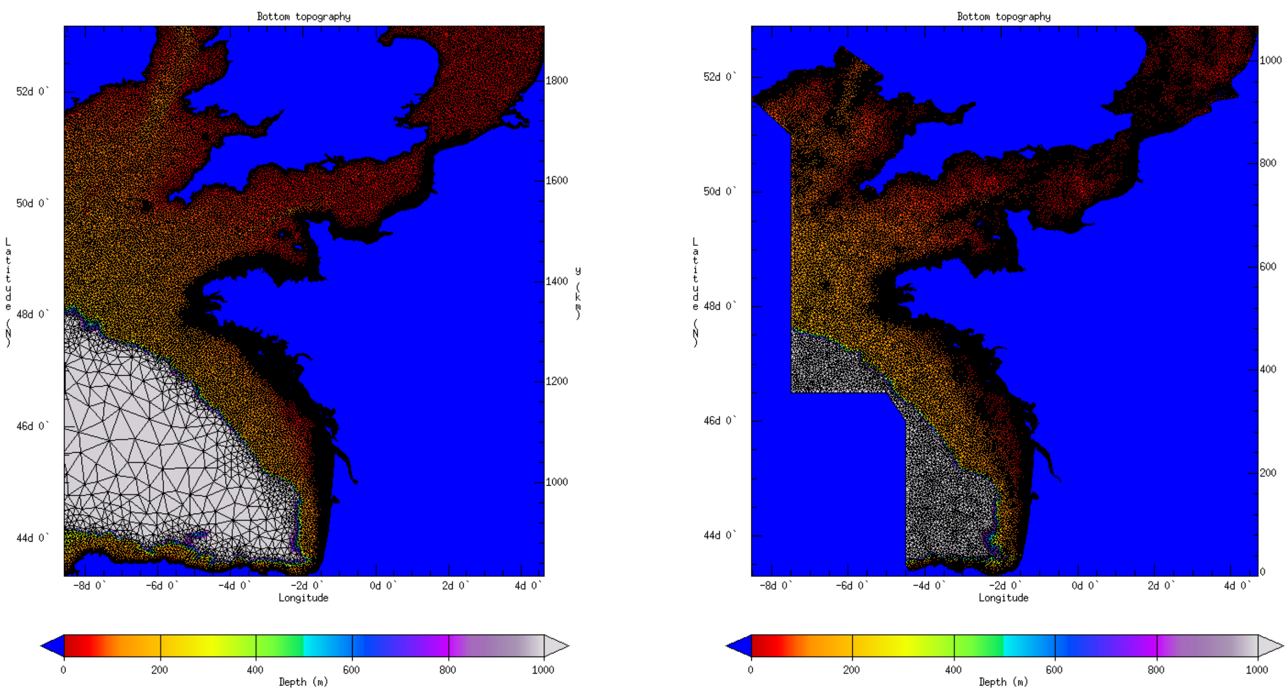


**Figure 22: Polymesh_full_test_06_coarser_bound contrast with NORGASUG mesh.**

Obs.: Left image taken from Polymesh_full_test_06, final_test_06_V02.msh.