NET4mPLASTIC PROJECT

WP4 – Act.3 + Numerical modelling

D 4.3.3

Better knowledge on MP diffusion after extreme events, emanation of the EWS

June 30th, 2022 - Version 1

Project Acronym	NET4mPLASTIC
Project ID Number	10046722
Project Title	New Technologies for macro and Microplastic Detection and Analysis in the Adriatic Basin
Priority Axis	3
Specific objective	3.3
Work Package Number	4
Work Package Title	Demonstration activities: testing and improvement of developed methodologies
Activity Number	4.3
Activity Title	Numerical simulations
Partner in Charge	Regione Marche
Partners involved	University of Ferrara, IZSAM, University of Split
Status	Final
Distribution	Public

CONTRIBUTING PARTNERS	REGIONE MARCHE, UNIVERSITY OF FERRARA, IZSAM, UNIVERSITY OF SPLIT

Data	Vers	Prep	Resp	Appr	Rev	Comment
30/06/2022	1	Regione Marche	Regione Marche		Final	

Table of Contents

Table of Figures

Index of Tables

1 Introduction

This deliverable has a twofold scope: on the one hand to present the analysis on the potential role of extreme riverine events (i.e. floods and droughts) on the potential beaching of microplastics (section 2); on the other hand it provides a description of the operational model implemented during the project and of the NET4mPLASTICS Early Warning System (sections 3 and 4) The appendices are composted of some of the README files that explain the different steps of the operational model and that are save inside the folder structure of the computational machine where the model runs.

2 Extreme events analysis

The extreme event analysis is based on the river's discharges used as potential sources of microplastics in the climatological simulations. Specifically for each main rives droughts and floods have been identified and the potential beaching has been defined following the analysis done over the climatological runs for the identification of the accumulation sites. PS1 – Po delta and PS4 – Split are the only pilot sites for which observed daily values for stream flow were available for the simulated period. Instead for PS2 – Pescara only climatological data were available and hence the analysis can be consider as a rough description of the beaching processes during extreme events.

2.1 Pilot Site 1 – Po Delta

The Po Delta pilot site is dominated by the discharges from the Po river. In the NET4mPLASTIC implementation the Po river waters are divided into seven main branches: Maistra, Tramontana, Dritta, Scirocco, Tolle (divided into three minor branches), Gnocca (divided into two minor branches) and Goro (figure 1). The details of the implementation of the numerical model for PS1 can be found in deliverable 3.2.

From a seasonal point of view the Po river stream flow is characterized by two period of high discharge one in late spring (April) and one in early winter (November/December). On a daily base it present a significant variability with strong floods and droughts; in the period covered by the simulations the Po river stream flow ranged between 344 m^3/s

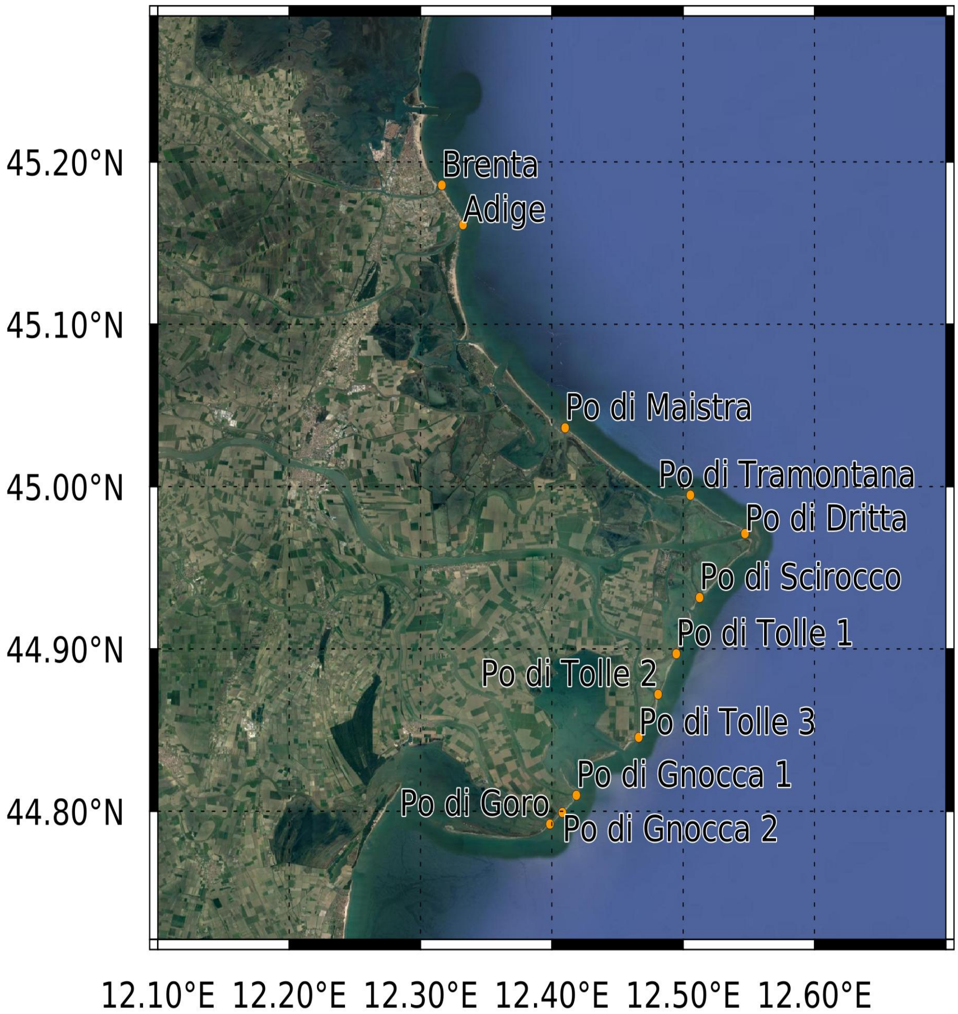

Figure 1: The Po river main *branches* used as inputs in the NET4mPLASTICS PS1 model implementation.

and 6149 m^3/s (figure 2). The straight line in figure 2 at the end of 2018 is due to a gap in the available data that was filled using a climatological analysis.

For the extreme events analysis the day of minimum and maximum stream flow were selected: respectively July 24th 2015 and November 29th 2016.

July 24th 2015 is characterized by a severe drought in the Po river with a daily stream flow average of 370 m^3/s, well below the seasonal mean. This is reflected in the distribution of potential beaching along the coast that shows generally low values and potential accumulation sites mostly south of the Adige river mouth (figure 3). Overall just

35% of all the released particles potentially beach within 20 days of release (table 1). Figure 3 also show how the vast majority of particles beach within the first day after release and anyway before 10 days. The lower panel of figure 3 shows that just a very low percentage of the particles that have been released from the Po river potentially beach, while only the Adige show higher values. The higher potential impact of the Adige river is connected to its higher stream flow values (146 m3/s) compared to the Po (it has to be kept in mind that the Po river stream flow at Pontelagoscuro is divided between the 7 main branches and that the Po di Dirtta (the branch that receive most of the water) has just 30% of the stream flow, that on July 24th 2015 is 110 m^3/s, hence lower that the Adige

The plots for the day with highest stream flow, November 29th 2016, are shown in figure 4. In contrast to July 24th 2015 the top left panel shows accumulations sites all along the coast with higher values below the Sacca di Goro in the southernmost part of the domain. In this case 40 % of the released particles beach, most of those within the first few days (top right panel in figure 4). The lower panel of figure 4 shows a significantly different behavior than the one in figure 3 with most of the beaching connected to the

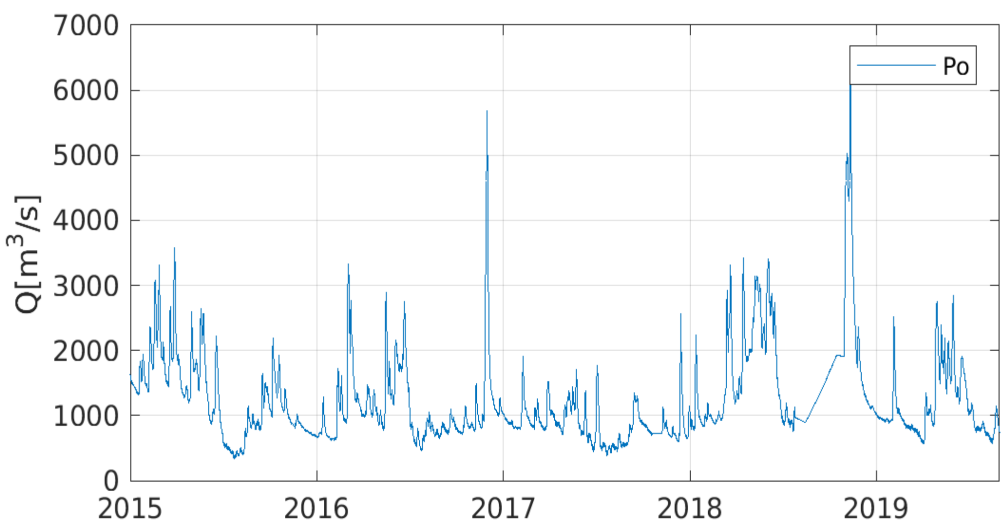

Figure 2: Hourly time series of the Po River stream flow in m3/s at Pontelagoscuro collected by ARPA Emilia Romagna.

Po di Scirocco, Tolle and Gnocca in the central part of the delta and of Goro and Gnocca all the way to the southern part of the domain.

The values for mean daily stream flow, number of released particles and potentially beached particles (absolute and percentage) are show in table 1.

This analysis show that during events of high discharge not only the total number of potentially beached particles is higher than during normal events but also the percentage of potentially beached particles significantly increase. Moreover the distribution along the coast is different with high discharges resulting a broader distribution of sites of potential accumulation along the central part of the delta and all the way to the southern coast.

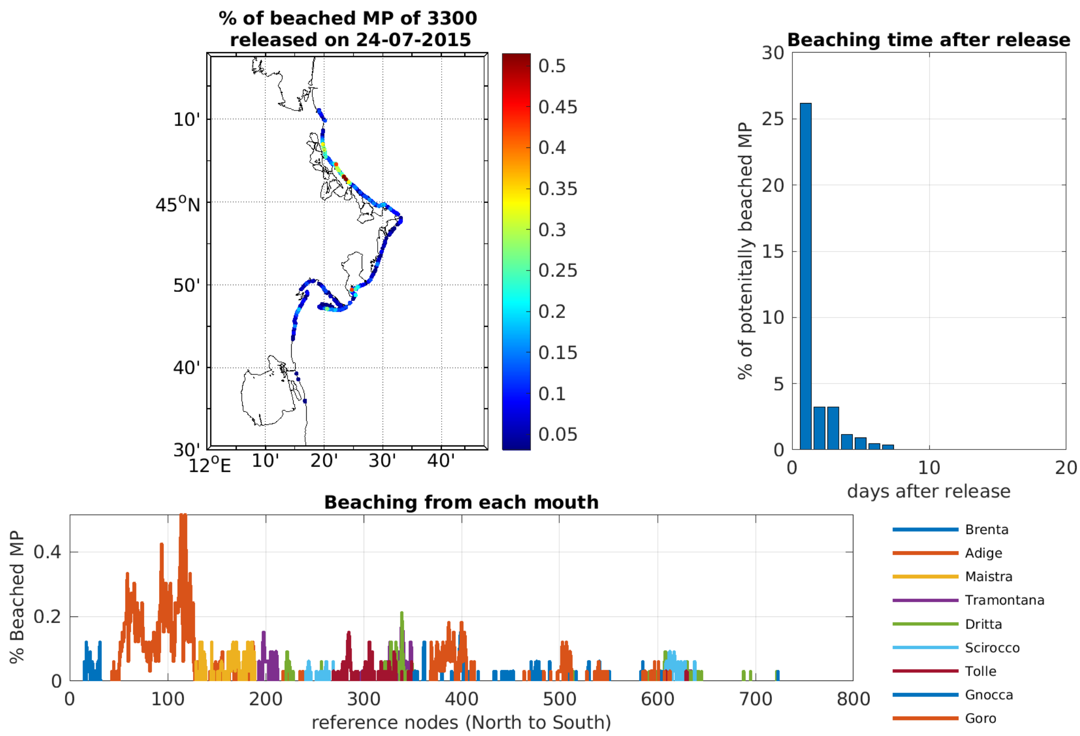

Figure 3: The distribution of potential beaching for the day of lowest Po river stream flow (24/07/2015). Top right panel: distribution along the coasts on each reference cells; top left panel: potential beaching timing after release; bottom panel: potential beaching along the coast divided by each mouth of origin.

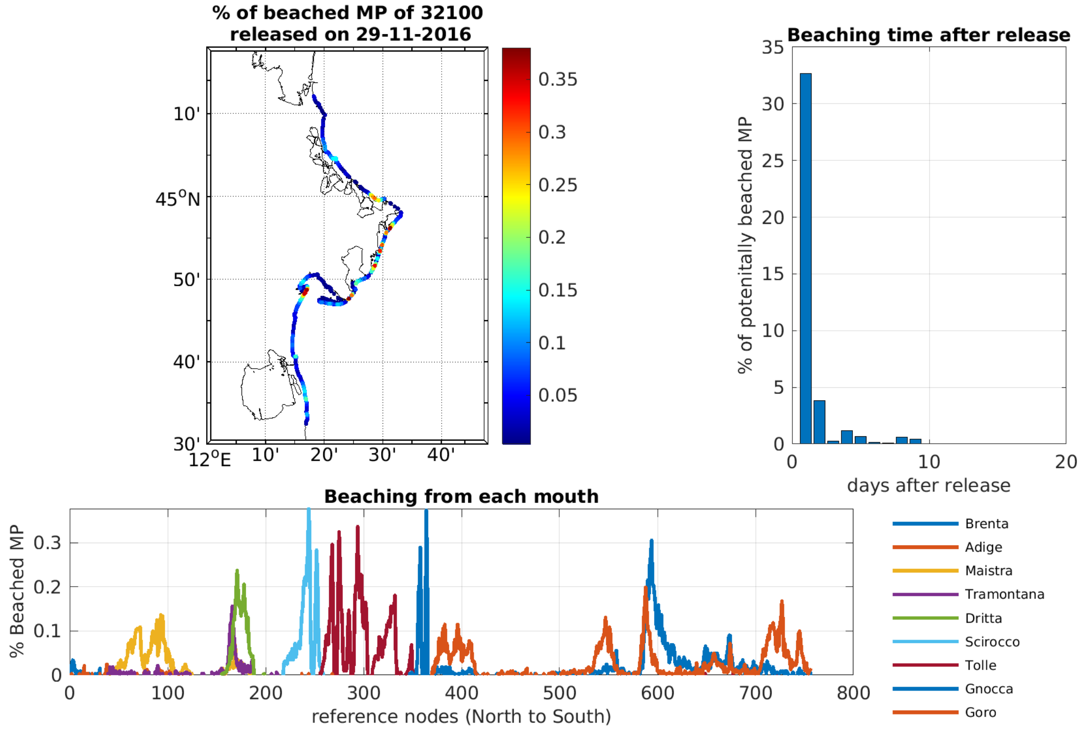

Figure 4: The distribution of potential beaching for the day of highest Po river stream flow (29/11/2016). Top right panel: distribution along the coasts on each reference cells; top left panel: potential beaching timing after release; bottom panel: potential beaching along the coast divided by each mouth of origin.

Table 1: the statistics for potential beaching and discharges for the days of maximum and minimum Po river stream flow during the period covered by the PS1 simulations.

Date	Daily mean streamflow [m3/s]	Released particles	Potentially beached particles [abs]	Potentially beached particles [percent]
24/06/2015	370	8352	1173	35.4%
29/11/2016	5564	32100	12839	40.0%

2.2 Pilot Site 2 – Pescara

In contrast to PS1 and PS4 for the Pescara Pilot Site during the project it was not possible to find data of hourly or daily discharges for its three main rivers (figure 5), consequently a climatological time series of riverine discharges was used (figure 7). Hence the analysis of extreme events is somewhat limited. In order to give a general overview it was decided to use the Pescara river as reference and to select two representative day, one for the minimum discharge (August 15ht 2015) and one for the maximum discharge (April 15th 2017). It has to be kept in mind that in the case of the Pescara river the range of climatological discharges is very narrow, spanning from 35 m^3/s and 59 m^3/s.

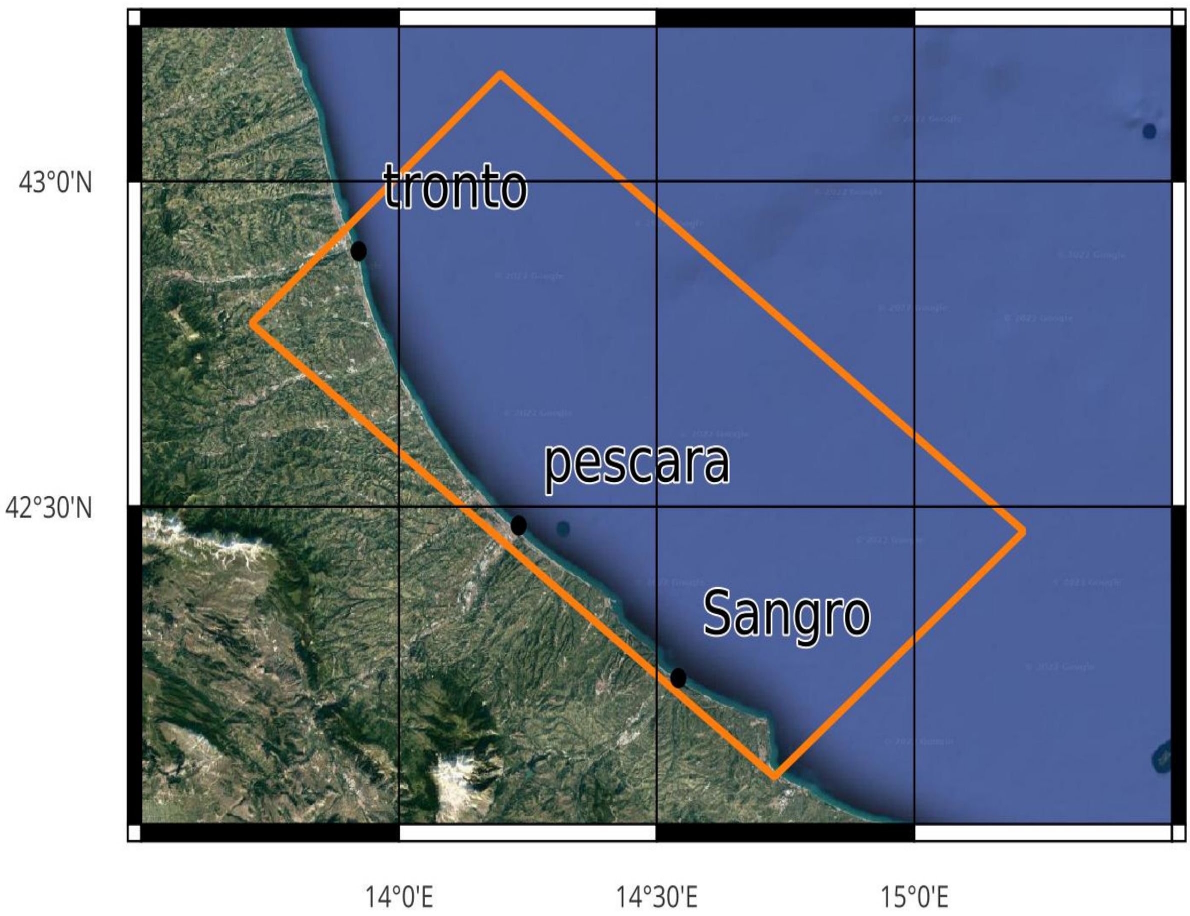

Figure 5: The PS2 - Pescara pilot site and the three rivers used as inputs for the simulations

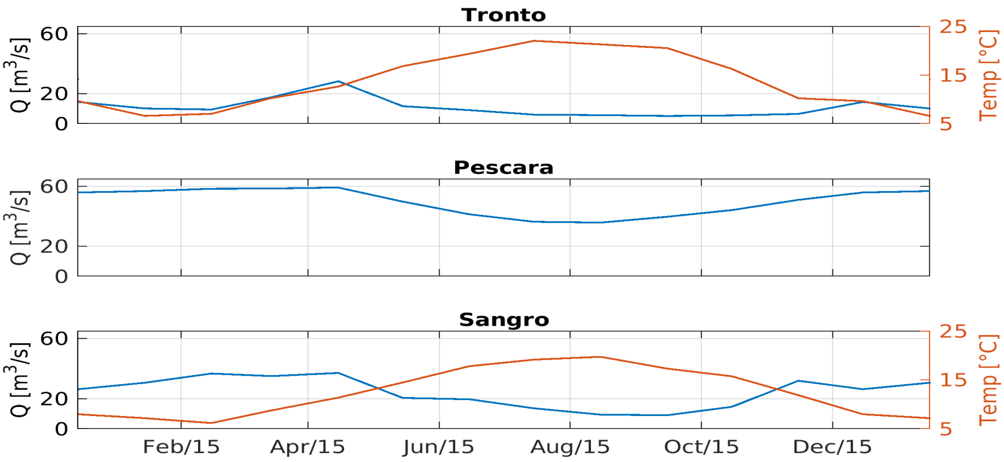

Figure 6: The climatological forcing used as riverine inputs for PS2

The distribution of potentially beached microplastics is similar in the two events with fewer affected areas in low discharges (figure 8, top left panel) and more, mostly

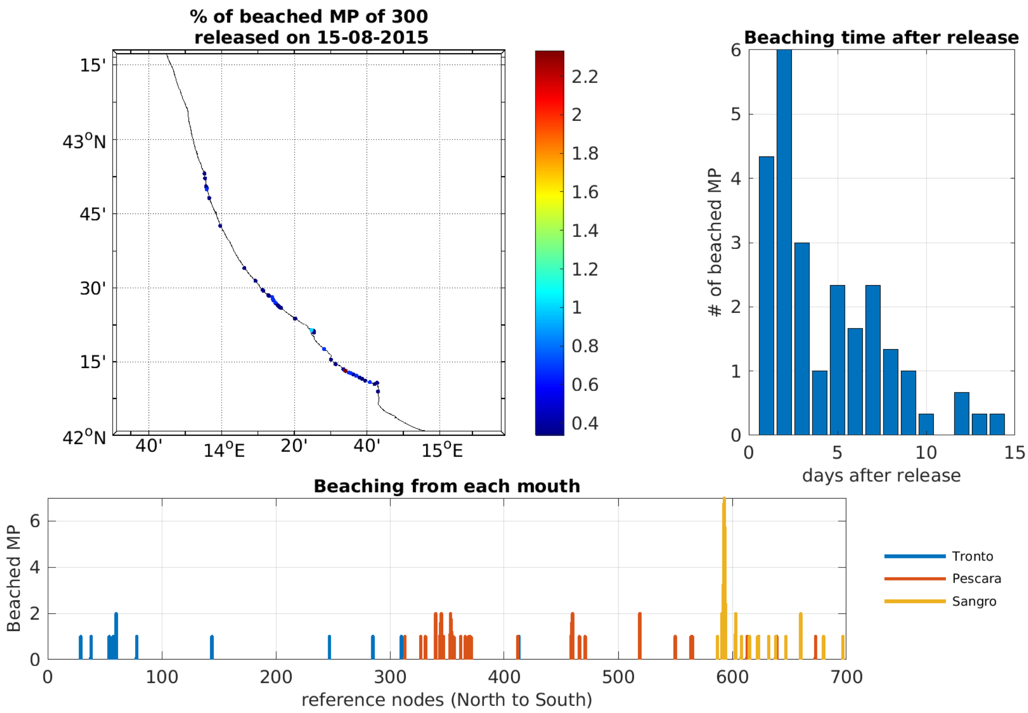

Figure 7: The distribution of potential beaching for the day of *lowest* Pescara river stream flow (15/08/2015). Top right panel: distribution along the coasts on each reference cells; top left panel: potential beaching timing after release; bottom panel: potential beaching along the coast divided by each mouth of origin.

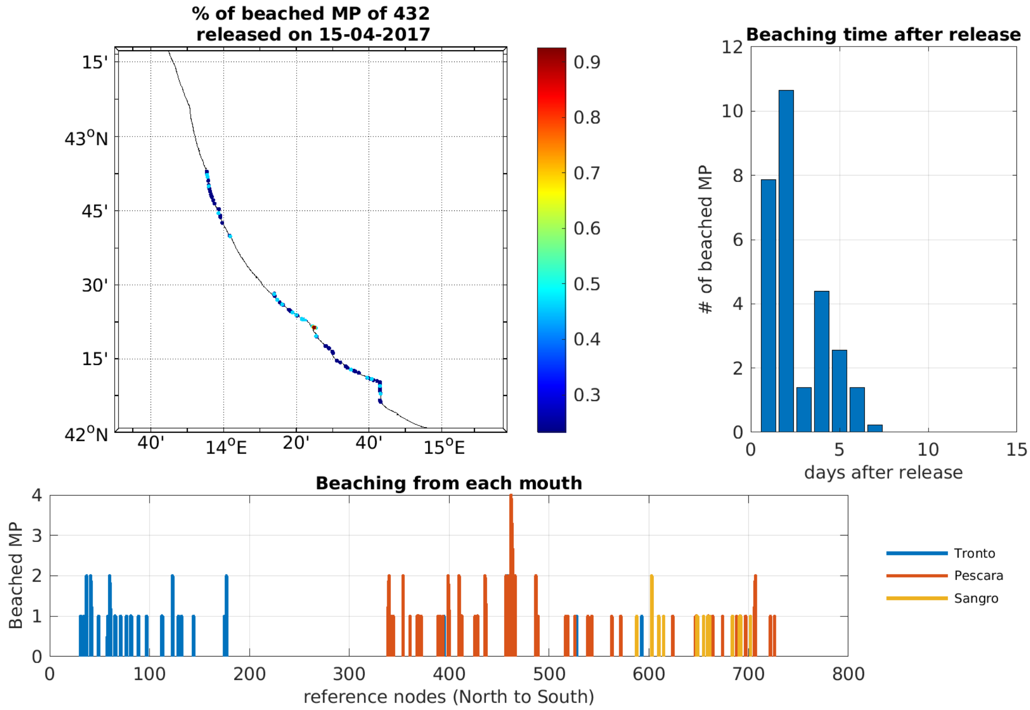

Figure 8: The distribution of potential beaching for the day of lowest Pescara river stream flow (15/08/2015). Top right panel: distribution along the coasts on each reference cells; top left panel: potential beaching timing after release; bottom panel: potential beaching along the coast divided by each mouth of origin.

located in the coastlines just south of each river mouth, for high discharges (figure 9, top left panel). The potential beaching timing is similar in both cases with most of the beaching occurring in the first 5 days; in the case of high discharges particle beach within 10 days while for low discharges there can be longer beaching time up to 15 days. The lower panel of figures 8 and 9 shows the distribution along the coast of beaching sites. Once again it is clear how most of the potential beaching is located close to each river mouth.

Table 3 shows how the two cases have similar values of potentially beached particles in percentage, pointing to the fact that the two cases show similar behaviour. This is mostly connected to the small range in the climatological discharges.

Table 2: the statistics for potential beaching and discharges for the days of maximum and minimum Pescara river climatological stream flow during the period covered by the PS2 simulations.

Date	Daily mean streamflow [m3/s]	Released particles	Potentially beached particles [abs]	Potentially beached particles [percent]
15/08/2015	35.8	300	74	24.6%
15/04/2016	59.2	432	123	28.5%

2.3 Pilot Site 4 – Split

For Pilot Site 4 – Split it was possible to use observed data for stream flow over the whole duration of the simulations. For the extreme event analysis the selection of the events was done only on the Neretva river since it is by far the most important freshwater contributor of the area. Two days were selected for low (September 30th 2015) and high discharges (March 22nd 2018).

The main difference between the two selected days is the amount of coast potenitally impacted. During low discharges (figure 10) just the mainland coast and the Paljesac Penisula are affected by potential beaching, while during high discharges (figure 11) most of the coast of the study site are impacted. The timing of beaching (right panels in figures 10 and 11, is similar with most of the beaching happening during the first day after release and lower values lasting up to 20 days.

Even if the absolute number of beaching is different (since it is proportional to stream flow) the percentage values are close (table 4).

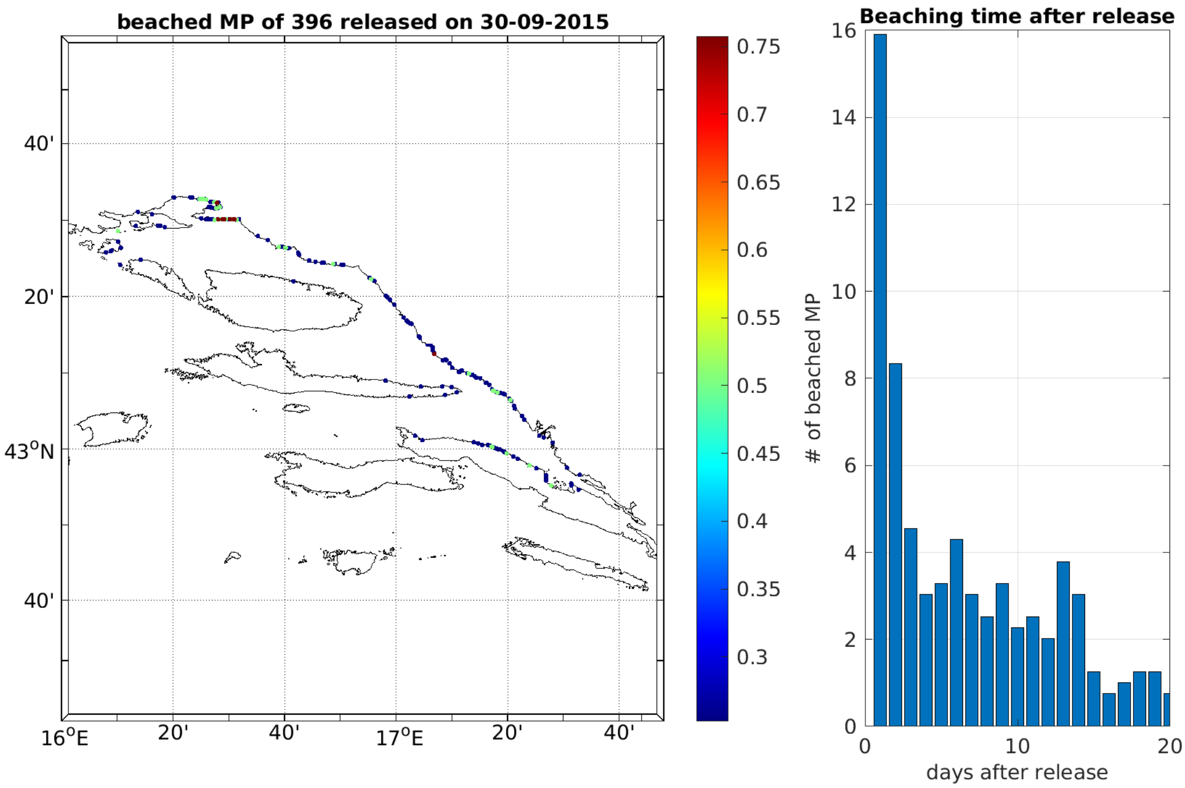

Figure 9: The distribution of potential beaching for the day of lowest Neretva river stream flow (30/09/2015). Top right panel: distribution along the coasts on each reference cells; top left panel: potential beaching timing after release; bottom panel: potential beaching along the coast divided by each mouth of origin.

Table 3: the statistics for potential beaching and discharges for the days of maximum and minimum *Neretva* river stream flow during the period covered by the PS3 simulations.

Date	Daily mean streamflow [m3/s]	Released particles	Potentially beached particles [abs]	Potentially beached particles [percent]
30/09/2015	52.9	396	272	63.7%
22/03/2018	1452	6180	3404	55.1%

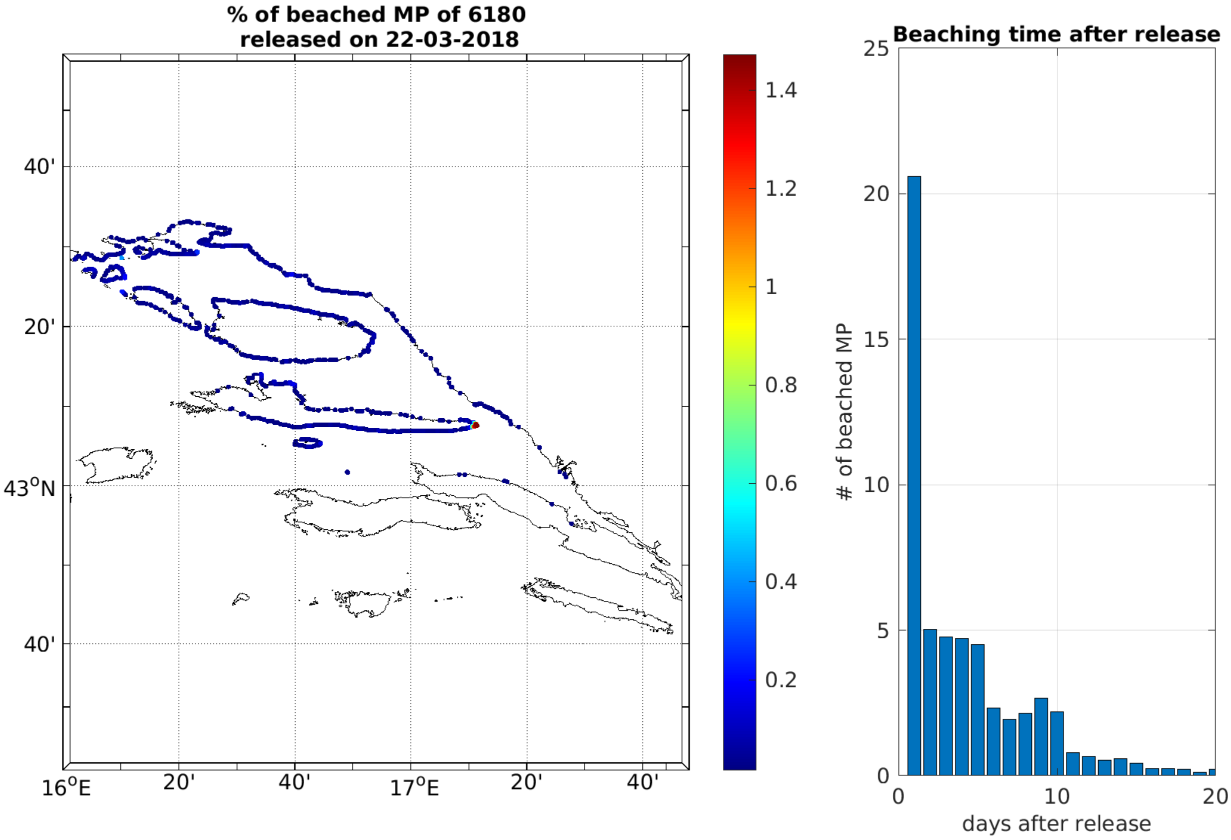

Figure 10: The distribution of potential beaching for the day of lowest Neretva river stream flow (22/03/2018). Top right panel: distribution along the coasts on each reference cells; top left panel: potential beaching timing after release; bottom panel: potential beaching along the coast divided by each mouth of origin.

3 Early Warning System

The Early Warning System (EWS) developed for NET4mPLASTIC aims to provide information on a daily base on the potential risk of impacts due to microplastic of riverine origin. The EWS was implemented on PS1 – Po Delta to verify its sustainability from a management point of view. The EWS will produce a daily bulletin of areas potentially at risk of beaching, targeted to all stakeholders identified in the frame of NET4mPLASTIC.

The EWS is based on an operational modeling chain derived from the one used for the climatological simulations described in deliverables D4.3.1 and D4.3.2. In section 3.1 a general description of the modeling chain implementation is provided while in section 3.2 the EWS and the risk classes are described.

3.1 Operational model description

The operational model chain is built on a simple structure so that it will be easily managed by the Regione Marche Staff (figure 12). The background idea is to have a

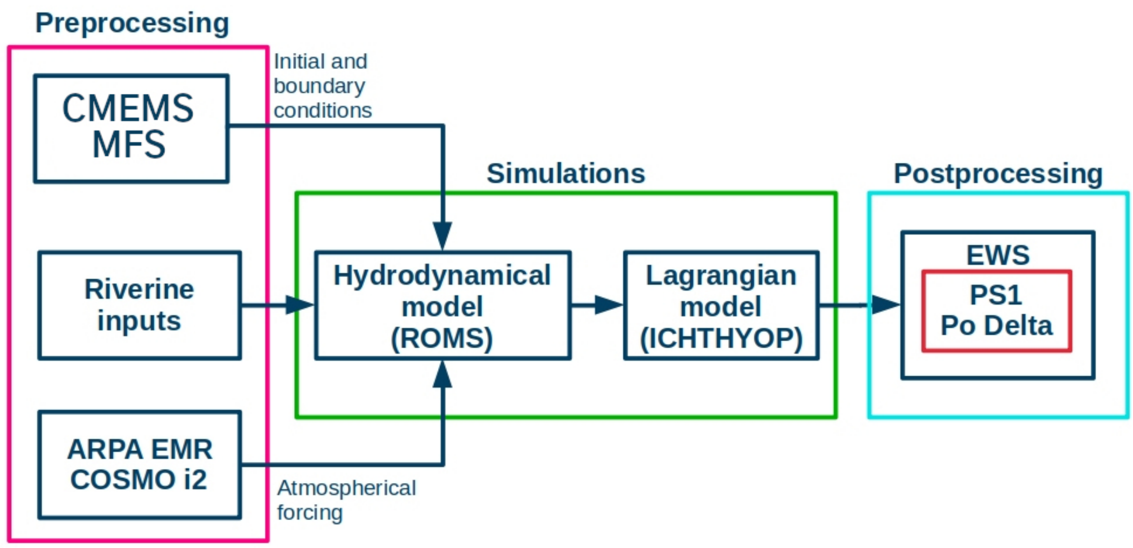

Figure 11: The operational modeling chain. The three main steps are pre-processing (red rectangle), simulations (green rectangle) and Post processing (blue rectangle).

linear modelling stream-flow so that if the chain stops for any reason (mostly for luck of data form the providers) the issue will be easy to find and fix even to non expert users. The operational chain is divided into three main steps:

- pre-processing: download of forcing data from external services and preparation of the forcing files;
- simulations: hydrodynamical and Lagrangian models run;
- post-processing: analysis of the simulations and production of the EWS data.

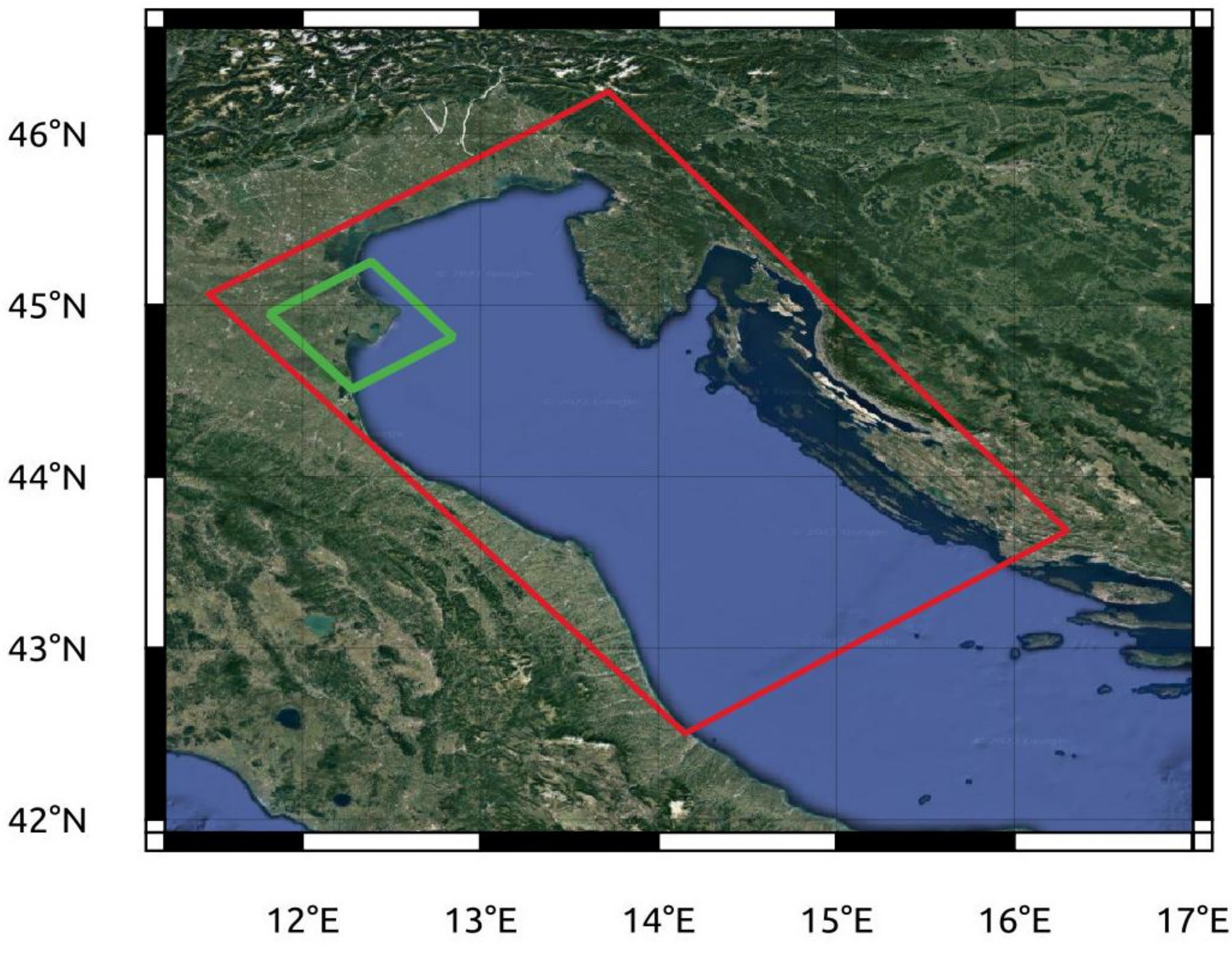

Figure 12: The ROMS nested grids used for the NET4mPLASTIC operational model. The red rectangle marks the limits of the 500 m parent grid, the green rectangle marks the limits of the 100 m child grid.

As requested by Regione Marche the whole modelling chain is implemented with open source programs and codes. This resulted in longer computational times but makes the operational chain free of proprietary codes and licenses. On the Regione Marche computational machine there is a README file (reproduced in appendix A) that list all the program and codes needed of the the operational chain.

The operational modelling chain uses the same numerical tools of the climatological simulations specifically:

- the hydrodynamical simulations are based on the Regional Ocean Modelling System (Haidvogel et al., 2000; Marchesiello et al., 2003; Peliz et al., 2003a and 2003b; Di Lorenzo, 2007; Dinniman et al., 2003; Budgell, 2005; Warner et al., 2005b; Wilkin et al., 2005, Shchepetkin AF). The implementation is the same of the climatological simulations (see D3.2 for details on the hydrodynamical model set up) apart from the nested grid approach (figure 13). It was necessary to use a nested approach since the boundary conditions are derived from the CMEMS MFS model that has an horizontal resolution of about 4 km in the northern Adriatic. In order to scale the gird correctly and reach the 100m horizontal resolution over the Po Delta an intermediate grid with 500m horizontal resolution was used. The nesting if fully two way, which means that the two grids exchange information at regular intervals in both directions.
- The Lagrangian model, as for the climatological analysis, is ICHTHYOP (Lett et al., 2008). The model is implemented only on the high resolution child grid and uses the hydrodynamical forcing from the ROMS outputs to simulate the transport of microplastics.

3.2 Folder structure

The operational model is implemented on a virtual computational machine in the Regione Marche server farm with a dedicates user (n4mp_op).

The folder structure is as follows:

- /home/n4mp_op
  - model:
    - ROMS: hydrodynamical model source
    - ichthyop: Lagrangian model source code
  - op_run: folder with the operational modeling
    - logs: log files for the operational master script
    - pos_p: post processing folder
      - logs: log files for post processing
      - oumat: post processing output matrices
      - EWS: early warning system files
    - pre_p: pre processing folder
      - bry: pre processing for boundary conditions
      - frc: preprocessing for initial conditions
      - ini: pre processing for initial conditions
      - lagr: pre processing for lagrangian model
      - riv: pre processing for rivers
    - run: folder where the models are run
      - logs: run logs files
      - in_roms: files to build and run roms
      - in_ichthyop: file to run ichthyop
  - sourceme: test file to add to the shell environment paths and variables to compile and run the models.
  - /inputMP/n4mp_op: external disc with all the input files
  - /outputMP/n4mp_op: external disc with all the output files.

3.3 The Operational master script

In order to keep the operational model as simple as possible, so that it can be managed by untrained users, the system is controlled through a single master script that calls several sub-processes in sequence for the pre-processing, running and post processing. The script produces a log file that can be used in case the operational model does not complete its daily cycle. The single processes run by the master scripts are described in the following three sections: pre-processing, simulations and post-processing

3.4 Pre-processing

During pre-processing all the files needed to run the hydrodynamical and Lagrangian models are produced. Specifically:

- atmospheric forcing fields:
- boundary and initial conditions
- riverine inputs
- Lagrangian drifters files

In order to speed up the pre-processing phase for each step (with the riverine inputs exception) a single file is created for each day. Then before running the hydrodynamical simulations only the needed forcing files are concatenated in a single file that is then read by the hydrodynamical model. This way input files are kept small in size and hence are faster to be read.

3.4.1.1 Atmospheric forcing

Data for the creation of the atmospherical forcing are derived from the 2.2 km implementation of the ARPA Emilia Romagna COSMO-LAMI model. The fields are retrieved each day by the Regione Marche Civil Protection service and uploaded to the computational machine used for the operational mode.

The pre-processing for those data is needed since the land sea mask of the COSMO data is not the same of the one used in ROMS, so in order to avoid issues with inconsistent fields each node of the COSMO land grid is substituted with the closest sea value.

3.4.1.2 Boundary and initial condition

Boundary and initial conditions for the hydrodynamical model are derived from data for the Mediterranean Sea Physics Analysis and Forecast (MFS) available form the European Copernicus Marine Services (www.marine.copernicus.eu). Data are downloaded automatically on a daily base and are first interpolated on the southern boundary of the parent grid (the only open boundary of the implementations). The MFS forecast includes the tidal forcing, hence it is unnecessary to impose tides on the model domain.

The initial conditions are computed just once a moth, 5 day before the end of each month. This is done not only to speed up the computational time but also to keep the solutions consistent within each month.

3.4.1.3 Riverine inputs

Riverine inputs are imposed on both grids, which is the common approach for nested grid. This way both grids can fully reproduce the plume dynamics in their domain and exchange consistent information on the nesting boundary.

Po is the only river for which are available real time data from the ARPA Emilia Romagna open data portal. Stream flow data from Pontelagoscuro ad downloaded at the beginning of each operational cycle and the input files are updated accordingly.

For most of the other rivers (i.e. the Foglia, Metauro, Esino, Musone, Potenza, Tronto and Neretva) climatological time series computed on available data are used. The other northern Adriatic rivers are scaled to the Po river discharge by using a monthly scaling factor computed on the daily ration between Adige and Po river discharges in the period 2013-2020. Figure 14 shows the original Adige time series (in red) and the one computed by scaling the Po river stream flow (in blue). This approach, while being affected by some errors in the estimation of flood periods, guarantee to have a realistic discharge for the minor rivers (i.e. Adige, Brenta, Isonzo, Piave and Tagliamento).

Since the model is run in forecast mode the riverine inputs between the last available observation and the end of the simulation are kept constant. This could result in an over or under estimation of inputs but it is still the most conservative approach available.

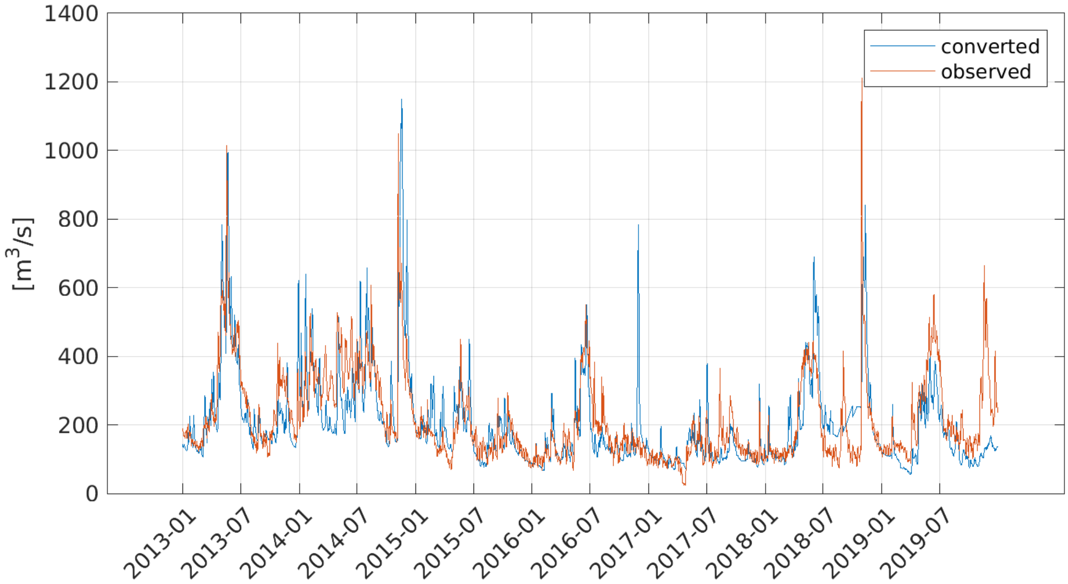

Figure 13: The observed Adige river stream flow at Boara Pisani (in red) and the one reconstructed by scaling the Po river discharge (in blue).

3.4.1.4 Lagrangian drifter files

The number of microplastic used for the Lagrangian simulations is scaled to the Po, Adige and Brenta hourly stream flow. As for the climatological run particles are placed on a straight line right in front of each river mouth.

3.5 Simulations

The operational model is structured over a monthly cycle (figure 15). At the beginning of each month the simulation is implemented with initial conditions set 5 days before. It is then run for 5 days of startup and then for 1 and a half day of forecast (the limit is imposed by the COSMO 2i forecast duration). Each following day is initialized using the first day of forecast computed the day before. Each first day of forecast is then stored to build a time series of hydrodynamical conditions.

For each daily forecast 5 Lagrangian simulations are run starting from day -5 to the current day. Each simulation is the analysed in post processing to compute the potential beaching of the current day.

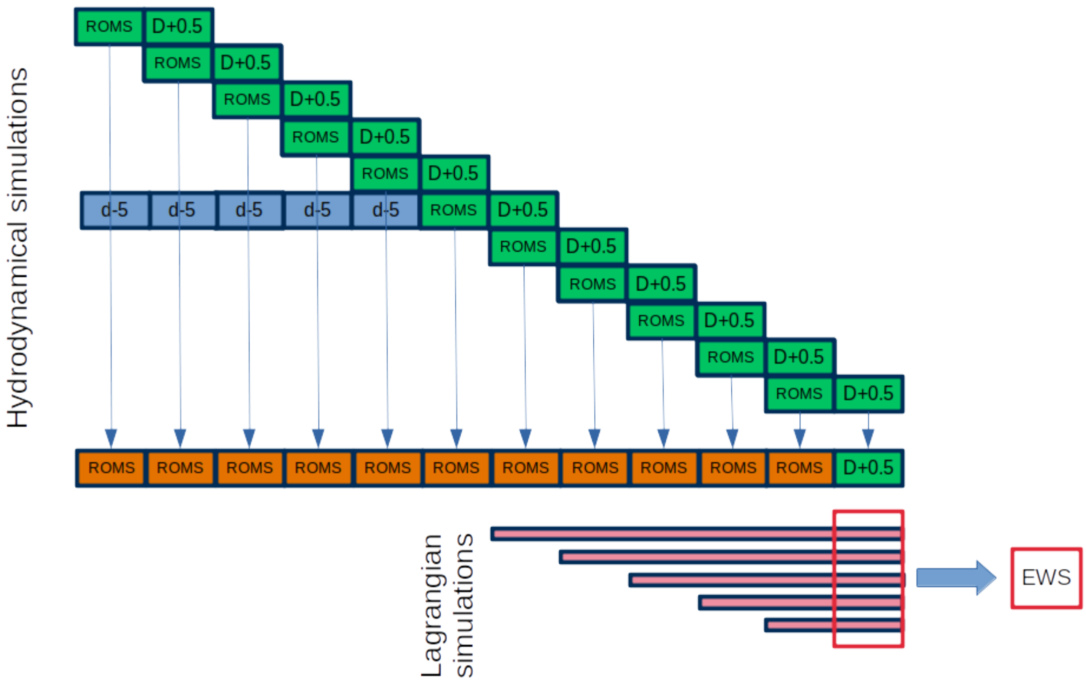

Figure 14: The operational modelling cycle. Each day the operational model runs a forecast simulation of 1.5 days (green boxes). The first day of each forecast is stored to build a time series of hydrodynamical conditions. 5 Lagrangian simulations are initialized for each day starting from day -5 to the current day, each simulation last until the end of the forecast. 5 days before the end of each month the model is reinitialized with 5 days of startup (light blue squares).

3.6 Post-Processing

Post processing is done following the procedure developed for the climatological simulations. A coastline was reconstructed following the hydrodynamical model mask (Figure 16, top left panel). This new coastline (that correctly represent the model coast) was then divided into segments of 200 m (twice the size of the horizontal grid cells) identified by a single point and contained into cells of equal size (Figure 16, top right panel). For each Lagrangian particle then is identified the closest point of passage during the whole simulation. If the particle passes closer than 200 m from the center of the segment it is considered as potentially beached and added to the potential beaching in that area. The results are plotted in a color scale either in absolute or percentage values.

4 Early Warning System implementation

To make the results of the post processing easier to interpret instead of using the small cells as was done for the climatological analysis, the Po Delta coastline was divided into 17 areas generally divided by river mouths or topographical constrains (figure 18). For each area the total percentage of potential beaching is given by the sum of the values of all the cells that form that specific area. An example is provided in left panel of figure 16. A list of the areas and their geographical limits relative to the reference grid are provided in table 6

To provide an easier to understand classification of potential beaching the climatological results were used to compute the values of 5 beaching percentiles for each area on a

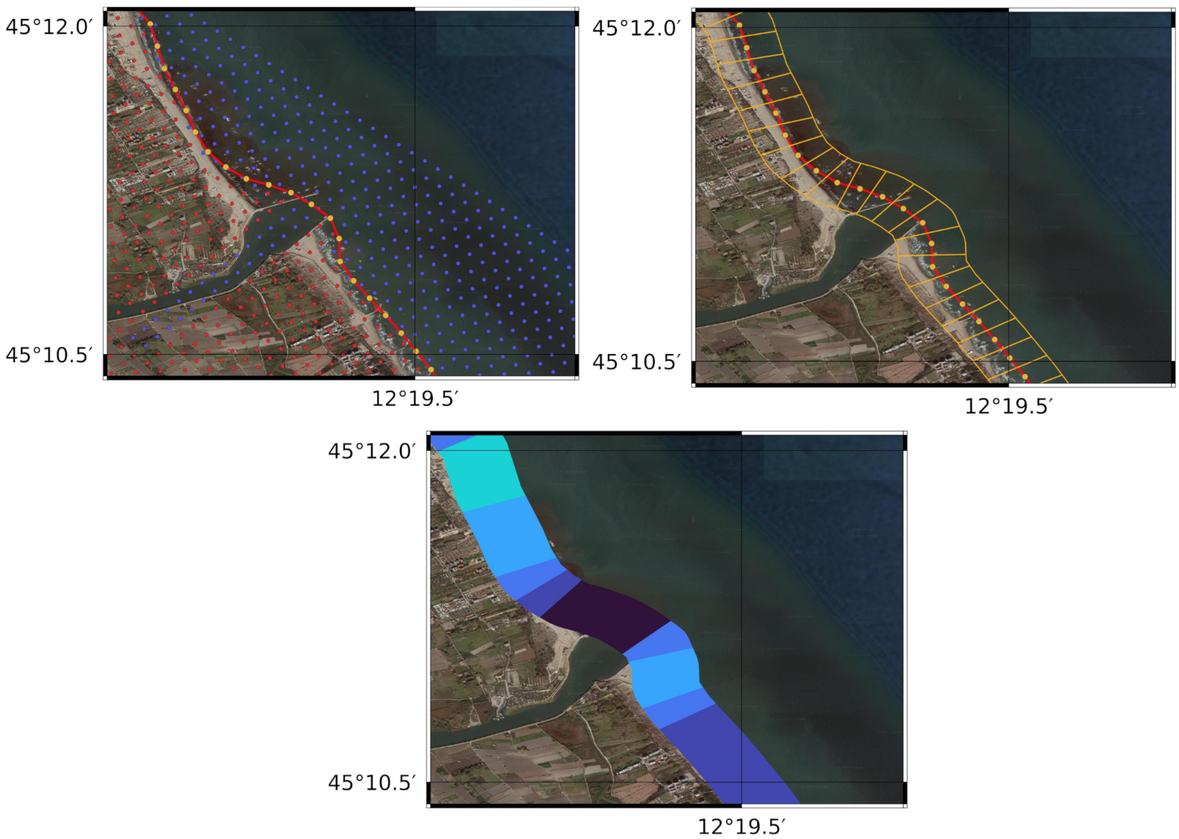

Figure 15: The reference grid used to count the number of potentially beached particles.

yearly and seasonal base. As an example the yearly percentiles for each are is shown in table 6. Table 6 shows the classes used in the EWS.

Figure 15 shows an example of output of the EWS for January 15th 2015 with each area classified based on the percentiles distribution.

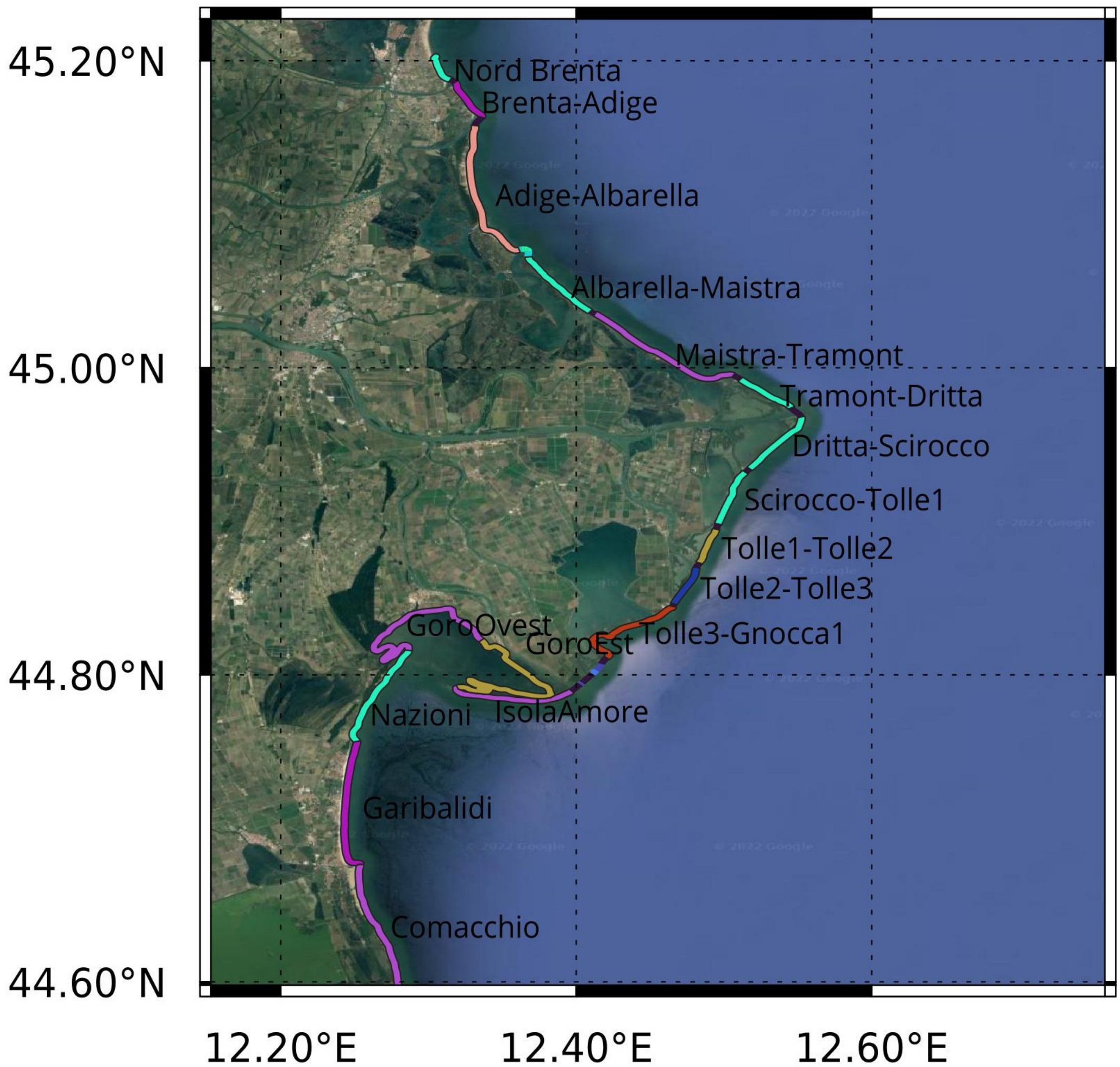

Figure 16: The 17 areas along the Po Delta coast used for the EWS

Area	Start	End	20th prc	40th prc	60th prc	80th prc	Max
Nord Brenta	1	12	0.016	0.048	0.104	0.104	0.571
Brenta Adige	15	31	0.019	0.053	0.101	0.101	0.429
Adige Albarella	36	90	0.463	0.914	1.451	1.451	3.668
Albarella Maistra	97	127	0.061	0.184	0.364	0.364	1.306
Maistra Tramontana	130	188	0.118	0.352	0.643	0.643	1.911
Tramontana Dritta	192	213	0.031	0.115	0.263	0.263	0.949
Dritta SCirocco	219	246	0.082	0.289	0.575	0.575	1.814
Scirocco Tolle01	249	270	0.066	0.202	0.380	0.380	1.588
Tolle01 Tolle 02	273	286	0.042	0.126	0.243	0.243	0.938
Tolle02 Tolle03	289	304	0.027	0.079	0.181	0.181	0.757
Tolle03 Gonocca01	306	350	0.194	0.491	0.855	0.855	2.897
Isola dell’Amore	369	414	0.082	0.271	0.609	0.609	2.589
Goro Est	415	504	0.024	0.080	0.180	0.180	1.087
Goro Ovest	505	585	0.056	0.231	0.583	0.583	3.415
Nazioni	586	626	0.072	0.371	1.037	1.037	5.843
Garibaldi	627	675	0.075	0.377	0.989	0.989	4.742
Comacchio	676	757	0.081	0.432	0.916	0.916	4.444

Table 4: The list of the Po delta area used in the EWS, the cell number identifying the beginning and end of each area and the percentiles used to define the risk classes.

Class	Percentile	Description
0	0	No potential beaching
1	0–20	Very Low risk
2	20–40	Low risk
3	40–60	
4	60–80	High risk
5	80–100	Very high risk

Table 5: The percentile ranges and the risk classification used for the EWS

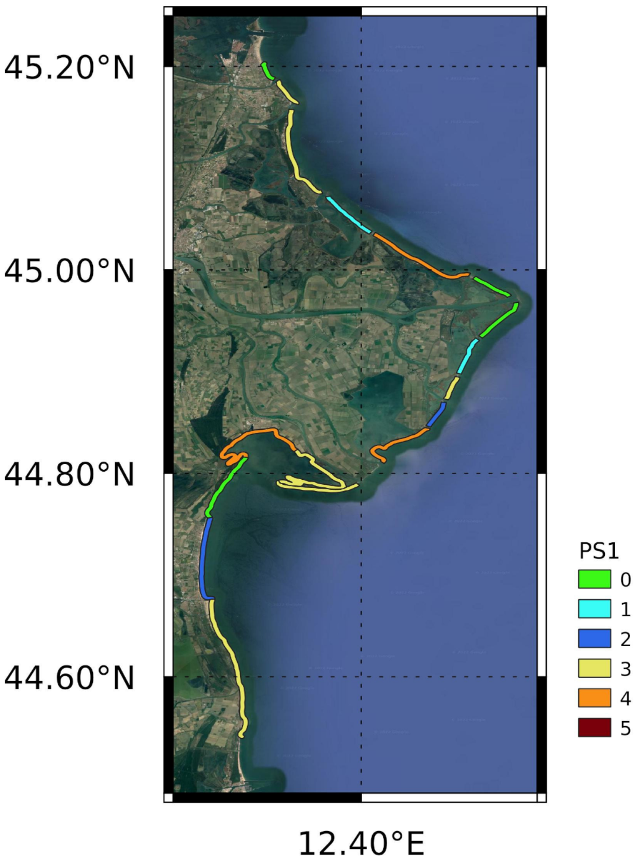

Figure 17: an example of EWS with results divided into risk classes.

5 Bilbiography

Budgell WP. 2005. Numerical simulation of ice-ocean variability in the Barents Sea region, *Ocean Dynamics*, DOI 10.1007/s10236-005-0008-3.

Budgell WP. 2005. Numerical simulation of ice-ocean variability in the Barents Sea region, *Ocean Dynamics*, DOI 10.1007/s10236-005-0008-3.

Di Lorenzo E. 2003. Seasonal dynamics of the surface circulation in the southern California Current System, *Deep-Sea Res., Part II*, **50**, 2371-2388.

Dinniman MS, Klinck JM, Smith O Jr. 2003: Cross shelf exchange in a model of the Ross Sea circulation and biogeochemistry, *Deep-Sea Res., Part II*, **50**, 3103-3120.

Haidvogel DB, Arango HG, Hedstrom K, Beckmann A, Malanotte-Rizzoli P, and Shchepetkin AF. 2000. Model evaluation experiments in the North Atlantic Basin: Simulations in nonlinear terrain-following coordinates, *Dyn. Atmos. Oceans*, **32**, 239-281.

Lett C., Verley P., Mullon C., Parada C., Brochier T., Penven P.,Blanke B., 2008. A Lagrangian tool for modelling ichthyoplankton dynamics. Environmental modelling and software. 23 (9), pp. 1210-1214.

Marchesiello P, McWilliams JC, and Shchepetkin A. 2003. Equilibrium structure and dynamics of the California Current System, *J. Phys. Oceanogr.*, 33, 753-783.

Peliz, A, Dubert J, Haidvogel DB, and Le Cann B. 2003. Generation and unstable evolution of a density-driven Eastern Poleward Current: The Iberian Poleward Current, *J. Geophys. Res.*, 108 (C8), 3268, doi:10.1029/2002JC001443

Shchepetkin AF, and McWilliams JC. 2003. A method for computing horizontal pressure-gradient force in an oceanic model with a nonaligned vertical coordinate, *J. Geophys. Res.*, 108 (C3), 3090, doi:10.1029/2001JC001047.

Shchepetkin AF, and McWilliams JC. 2005. The Regional Ocean Modeling System: A split-explicit, free-surface, topography following coordinates ocean model, *Ocean Modelling*, 9, 347-404.

Warner JC, Sherwood CR, Arango HG, and Signell RP. 2005. Performance of four turbulence closure methods implemented using a generic length scale method, *Ocean Modelling*, **8**, 81-113.

Wilkin JL, and Lanerolle L. 2005. Ocean Forecast and Analysis Models for Coastal Observatories, *in: Ocean Weather Forecasting, An Integrated View of Oceanography*, Springer, 577p., ISBN: 978-1-4020-3981-2

Appendix A

N4mP Operational Model set up.

In order to run the operationa chain needs several programs and tools.

Here is a list of all the packages that where installed. Most of those installations were done during the N4mP project by CNR-ISMAR

- FTP

  To install run from terminal:

  - yum ftp
- SUBVERSION

  This is needed to download the ROMS code

  To install run from terminal:

  - yum install mod_dev_svn subversion

  There was no need to configure it
- GFORTRAN v8.3.1

  There is no compiler on Centos so I had to install it and the one from the repositories is old. Some devtoolset had to be installed but keep in mind that it has to be specfied everytime a shell is open (throught he sourceme code)

  To install run from terminal:

  - yum install centos-release.scl-rh
  - yum install devtoolset-8-toolchain

  then add in sourceme

  - source scl_source enable devtoolset-8
- MPICH2 v3.3.2

  This is needed for parallelization of the code. I installed version 3.3.2

  To install run from terminal:

  - tar -xzvf mpich-3.3-2-tar-gz
  - ./configure --prefix=/opt/mpich2
  - make 2>&1 | tee m.txt

    - make install 2>&1 tee m.txt

- ZLIB

  To install run from terminal:

    - yum install zlib-devel

- HDF5 v1.12.0

  This library is needed to compile ROMS

    - tar -xzvf hdf5-X.Y.Z
    - make hdf5_build
    - cd hdf5_build
    - ../hdf5-X.Y.Z/configure --prefix=/opt/hdf5 --enable-fortran --enable-cxx
    - - make
    - - make check
    - - make install
    - - make check-install

  Check that the installation was done with zlib

    - (check in /opt/hdf5/lib/libhdf5.settings if I/O filters (external): deflate(zlib)

  otherwise netcdf-c will not install.

- NETCDF

  This library is needed to read and write model outputs. It needs a two step installation:

  - NETCDF-c 4.7.4
    - yum install m4 (if not present is needed)
    - CPPFLAGS=-I/opt/hdf5/include LDFLAGS=-L/opt/hdf5/lib ./configure --prefix=/opt/netcdf --disable-dap

      (--disable dap it is necessary because otherwise it does not complie. What it does is to disabel a part of curl.
    - - make check
    - - make install

  - NETCDF-Fortran 4.5.3
    - set environmental variables:
      - export CC=/path/to/cc
      - export FC=/path/to/gfortran
      - export F90=/path/to/gfortran
      - export F77=/path/to/gortran
      - LD_LIBRARY_PATH=/opt/netcdf/lib
      - CPPFLAGS=-I/opt/netcdf/include LDFLAGS=-L/opt/netcdf/lib ./configure --prefix=/opt/netcdf
      - make check
      - make install

- Added the EPEL repositories

  To install run from terminal:
    - yum install epel-release
    - yum update
- NCO tools

  Those are tools to manipulate NetCDF files. To install run from terminal:
    - yum install nco
- rsync

  Sincronization tool. To install run from terminal:
    - yum install rsync
- JAVA

  Needed to run ICHTHYOP. Install directly from repositories by running from terminal:
    - sudo yum install -java-11-openjdk-devel
- DNF

  Package needed to install octave netcdf
    - yum install dnf
- OCTVAVE

This program is needed in most of the pre and post processing. The program is called by terminal command octave. To install run from terminal:

- sudo yum install epel-release
- sudo yum install octave

T use netcdf in octave the following library has to be installed

- sudo yum -y install octave-netcdf

- WGRIB and WGRIB2

  Needed to convert GRIB to NetCDF. To install run from terminal:

  - sudo yum install wgrib
  - sudo yum install wgrib2

- CDO

  Those tools are needed to convert GRIB files to NetCDF. Specifically those are used to prepare the atmospherical forcing files (/inputMP/n4mp_op/frc).

  Those have several dependeincies:

  - EPEL
    - wget http://download-ib01.fedoraproject.org/pub/epel/epel-release-latest-7.noarch.rpm
    - sudo rpm -Uvh epel-release-latest-7.noarch.rpm
  - GRIB-API-DEVEL
    - sudo yum install -y grib_api-devel
    - yum groupinstall -y "Development Tools"

  To install run from terminal:

    - source sourceme (this is needed to set up the environmental variables needed for installation.
    - tar -xzvf cdo-xxx.tar.gz
    - sudo ./configure --with-netcdf=<netcdf-4 root dir> --with-hdf5=<HDF5 rott dir> --with-grib-api=<grib-api root dir>
    - ./configure --with-netcdf=/opt/netcdf --with-hdf5=/opt/hdf5
    - sudo make

- PYTHON 3

  Python3 is needed to run the motu client api to download data from CMEMS Services. To install run from terminal:

  - sudo dnf install python3