Interreg
Italy - Croatia
NET4mPLASTIC

EUROPEAN UNION

NET4mPLASTIC PROJECT

WP4 – Act. 3 - Numerical Simulations

D 4.3.2

"Development" of a model for the identification of plastic and MP sources and accumulation sites with the assessment of the modelling chain performance to be used for implementing the EWS and the integrated platform
(WP5)

7th April, 2021 - 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, UNIVERSITYU OF FERRARA, IZSAM, UNIVERSITY OF SPLIT

Data	Vers	Prep	Resp	Appr	Rev	Comment
07/04/2021	1	Regione MArche	Regione Marche		Final	

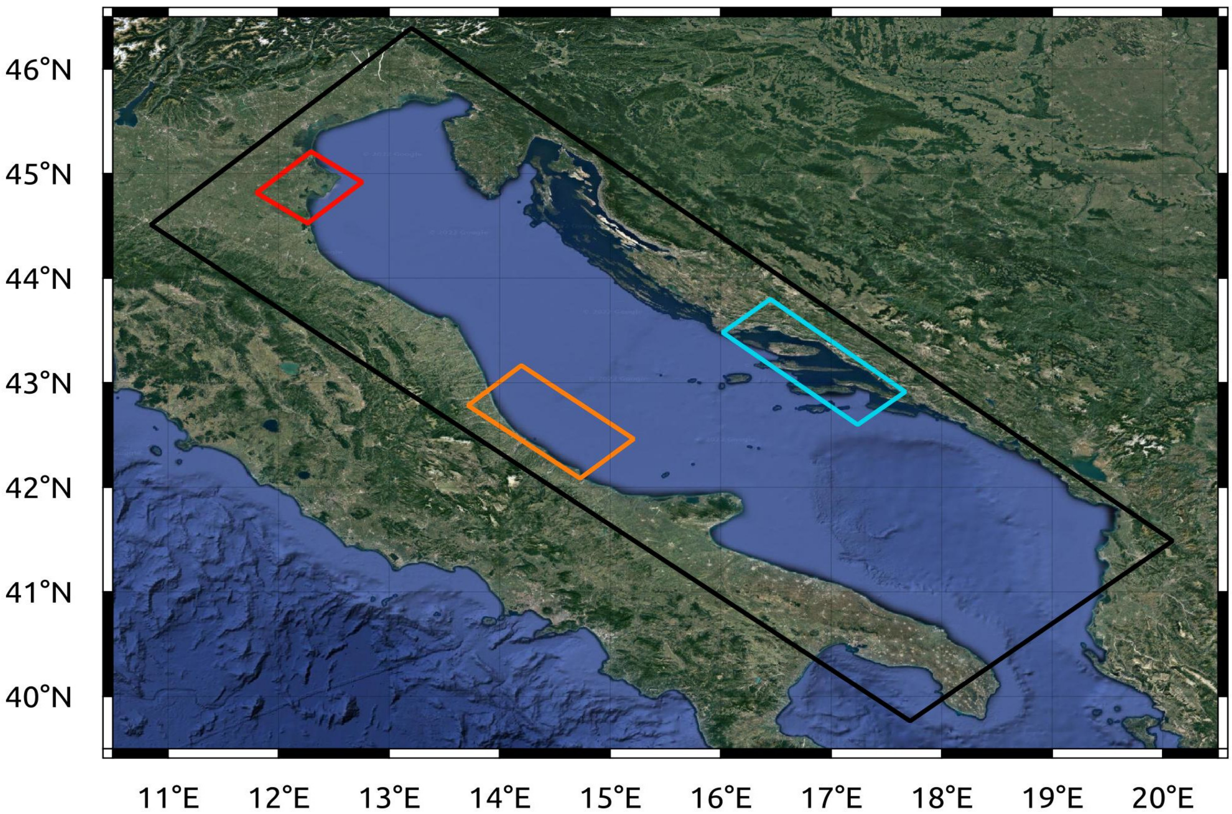
Table of Contents

Table of Figures

Index of Tables

1 Introduction

This deliverable describes the set up for the hydrodynamical and Lagrangian simulations of Pilot Sites 2 - Pescara, 4 – Split. Pilot site 1 – Po Delta implementation has been already presented in deliverable 3.2 “Implementation of the numerical model and first results obtained with a 3D transport model calibrated for microplastics”. Pilot site 3 Rijeka was not implemented due to the lack of input data, instead an Adriatic basin wide simulations was done using the rivers as the only source of microplastic, those simulations will be referred to as PSB. Figure 1 shows the location of PS1, PS2, PS3 and the whole domain of PSB. For all pilot sites the general set up is presented



along the main results. The two sections at the end of the document describe the definition developed for microplastic hazard due to riverine inputs that will be used in the Early Warning System (EWS) hazard definition and the main characteristics of the operational model that will be implemented.

As for the fist Pilot Site, the hydrodynamical simulations were 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, and McWilliams JC. 2003 and 2005) and implemented with the same configuration and set up (see D3.2 for details on the hydrodynamical model set up). The outputs of those runs were used as forcing for the Lagrangian model ICHTHYOP (Lett et al., 2008) that simulated the dispersion paths of microplastics released at the rivers mouths implemented in the hydrodynamical simulations. As described in details below only the major rivers were used.

Since the implementation of the two pilot sites (PS2 and PS4) is the same they will be described and discussed together below.

2 NET4mPLASTIC Pilot Sites 2 and 4 implementation

2.1 Grid generation

Both grids were generated with the Matlab tools developed for the Regional Ocean Modeling System and available on the model page repositories (see www.myroms.org). Each grid was developed to adjust to the characteristics of each pilot site and to find an optimal balance between computational coast and horizontal resolution.

2.1.1 PS2 – Pescara grid

The second Pilot Site (location shown as the orange box in figure 1; grid details shown in figure 2) is located along the coast surrounding Pescara, in the south-western part of the Adriatic Sea. It is a site characterized by low sandy coasts with high human impacts due to big cities located along the coast and popular touristic locations. The grid for PS2 (figure 2) was centered on the city of Pescara and stretches along the coast for 65 km north and 70 km south, this way it covers the three major rivers located in the area

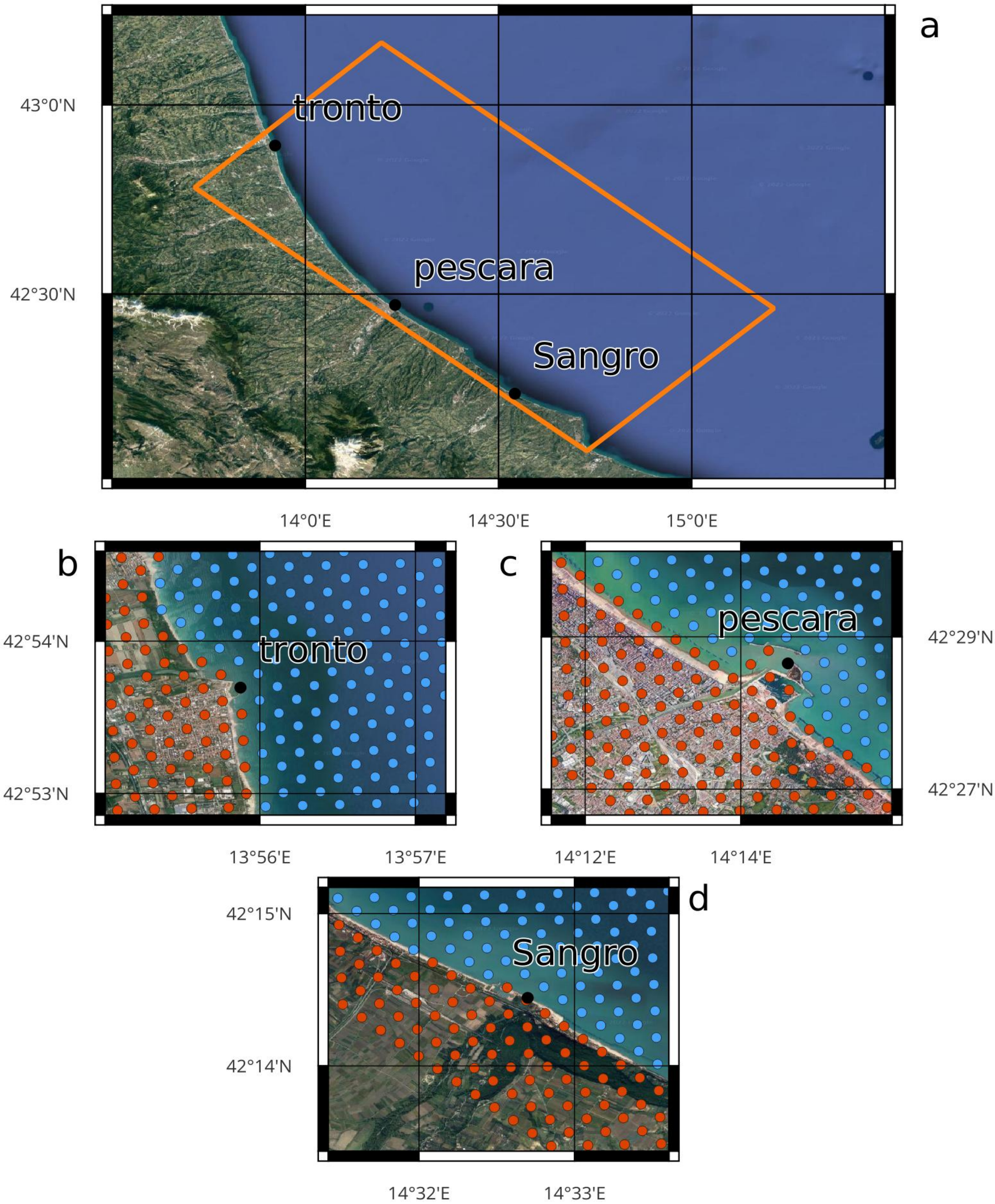


Figure 2: The PS2 - Pescara grid. Panel a shows the full grid limits and the location of the 3 main rivers (Pescara, Tronto and Sangro, marked with three black dots); panels b, c and d show in detail the location of each river and the relative land-sea mask.

(Pescara, Tronto and Sangro). In contrast to PS1 this grid has 3 open boundaries due to the coastline orientation. The grid horizontal resolution is 400 m, lower than PS1 100 m resolution, and 15 vertical layers with the same stretching as PS1. This lower horizontal resolution was necessary since PS2 covers a much wider area than PS1 and keeping a 100 m resolution would result in a significantly higher computational cost (i.e. the time required for each simulation) that would not be compatible with project timing constrains. The vertical discretization of the grid (both PS2 and PS4) are not shown in this deliverable since they follow the one defined for PS1.

2.1.2 PS4 – Split grid

PS4 Split grid (Icyan box in figure 1; grid details in figure 3) is located on the eastern side of the southern Adriatic in an area of and rocky coasts with several islands. The grid's northern and southern limits include the town of Split (at the northernmost edge) and the gulf just south of the Neretva river. Westward the grid extends for 62 km to include all the major islands and places the north-western corned on land so that only two boundaries (western and southern result open). As for PS2 the horizontal resolution is lower than PS1 (410m compared to 110 m) but with the same vertical sigma layers and same stretching parameters. This was again necessary in order to assure that the computational time of the hydrodynamical simulations was not excessive.

4 main rivers were included in the grid (from north to south): Jadro (figure 3b), Zrnovnica figure 3c), Cetina figure 3d) and Neretva (figure 3e). In the case of the Neretva it was possible to include in the grid mask a small channel of 5 km to represent the river mouth (the same approach used for the Po, Adige and Brenta rivers in PS1, see deliverable D3.2).

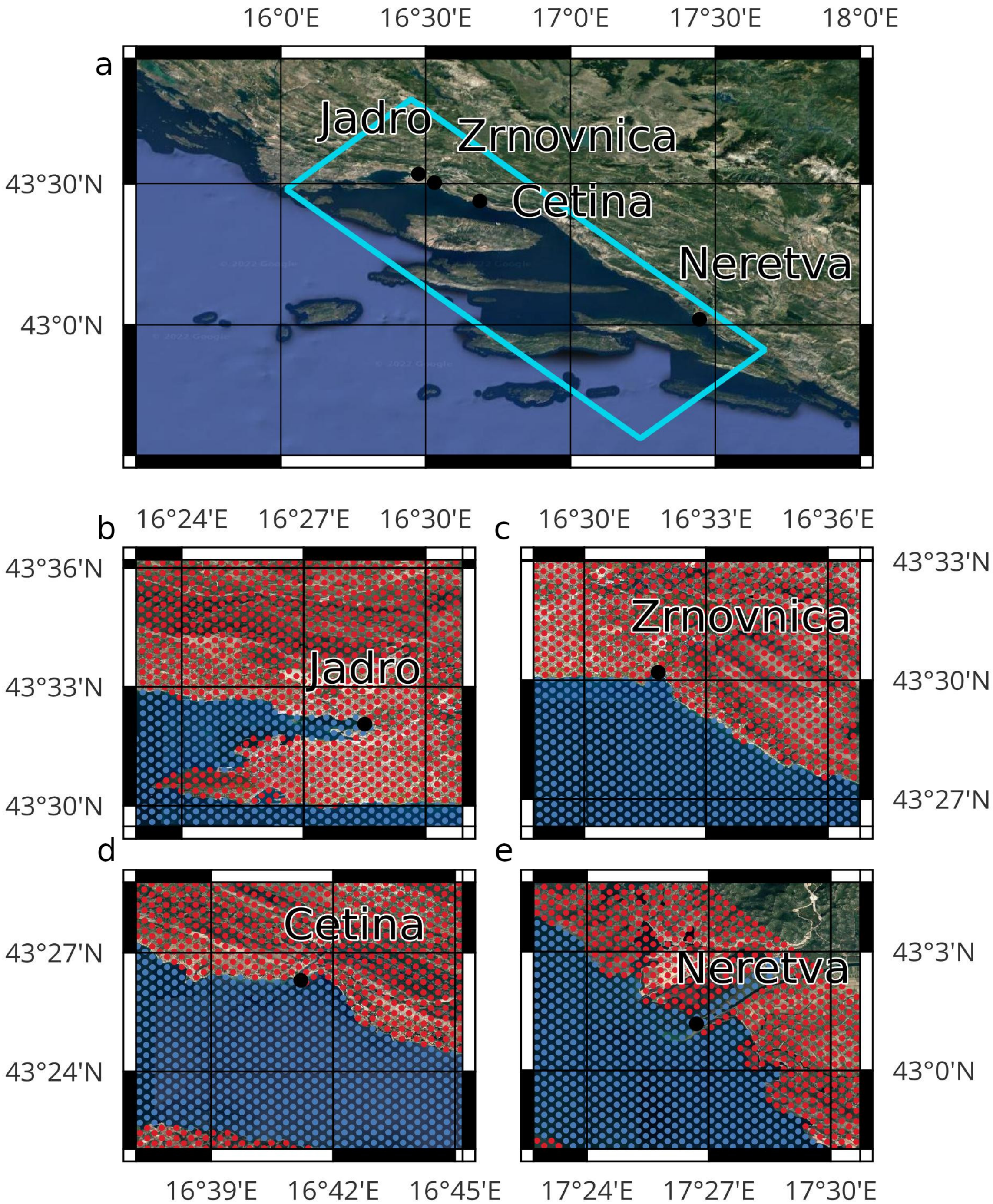
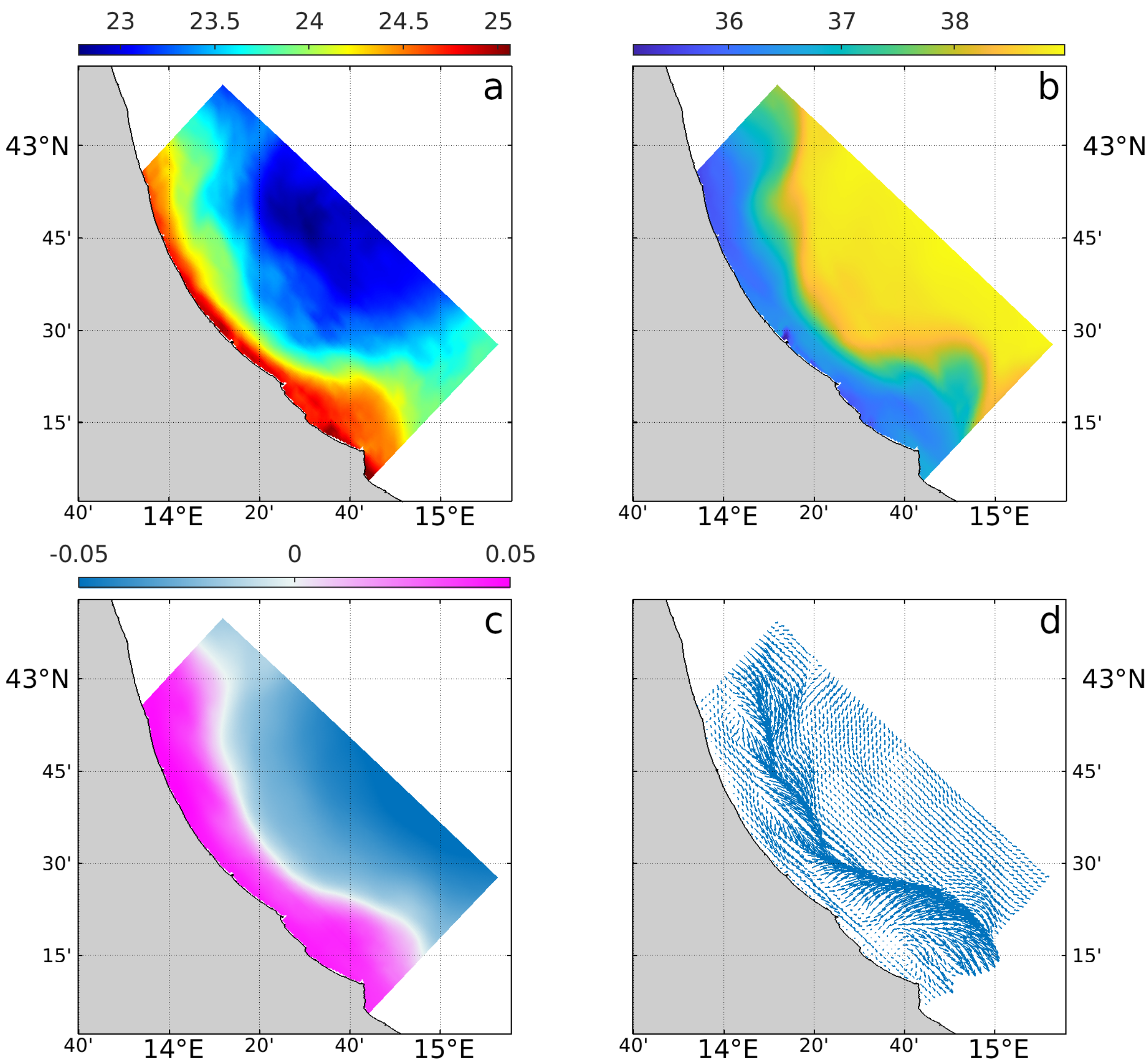


Figure 3: The PS4 – split grid. Top panel shows the grid limits and location of the 4 main rivers (Neretva, Cetina, Zrnovnica, Jadro, marked with black dots); Lower panels show the mask in proximity of each river mouth.

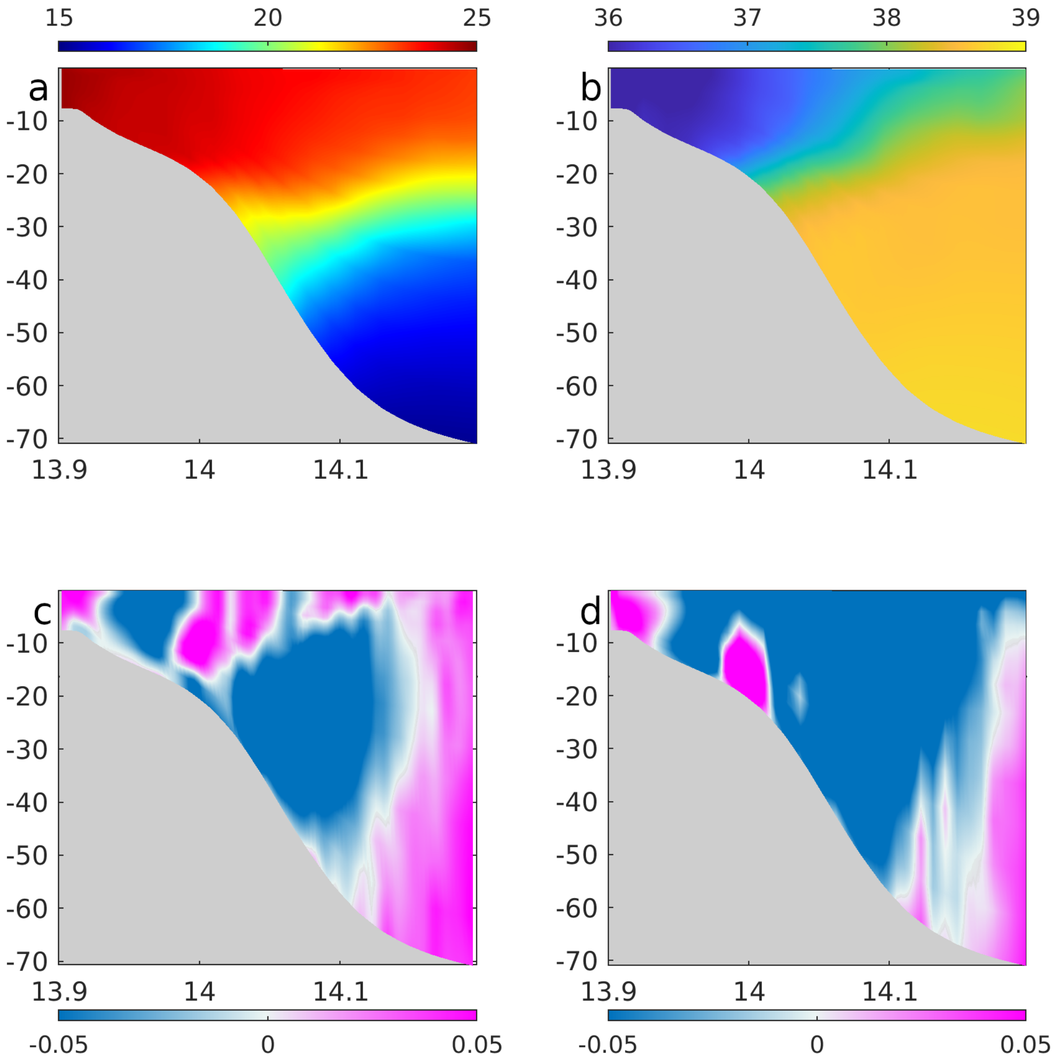
2.2 Initial and Boundary conditions

In order to maintain a consistent approach in all Pilot Sites, the same methodology of PS1 (see Deliverable D3.2) was used to define the initial and boundary conditions of PS2 and PS4. Initial conditions were obtained by interpolation over a target grid (either



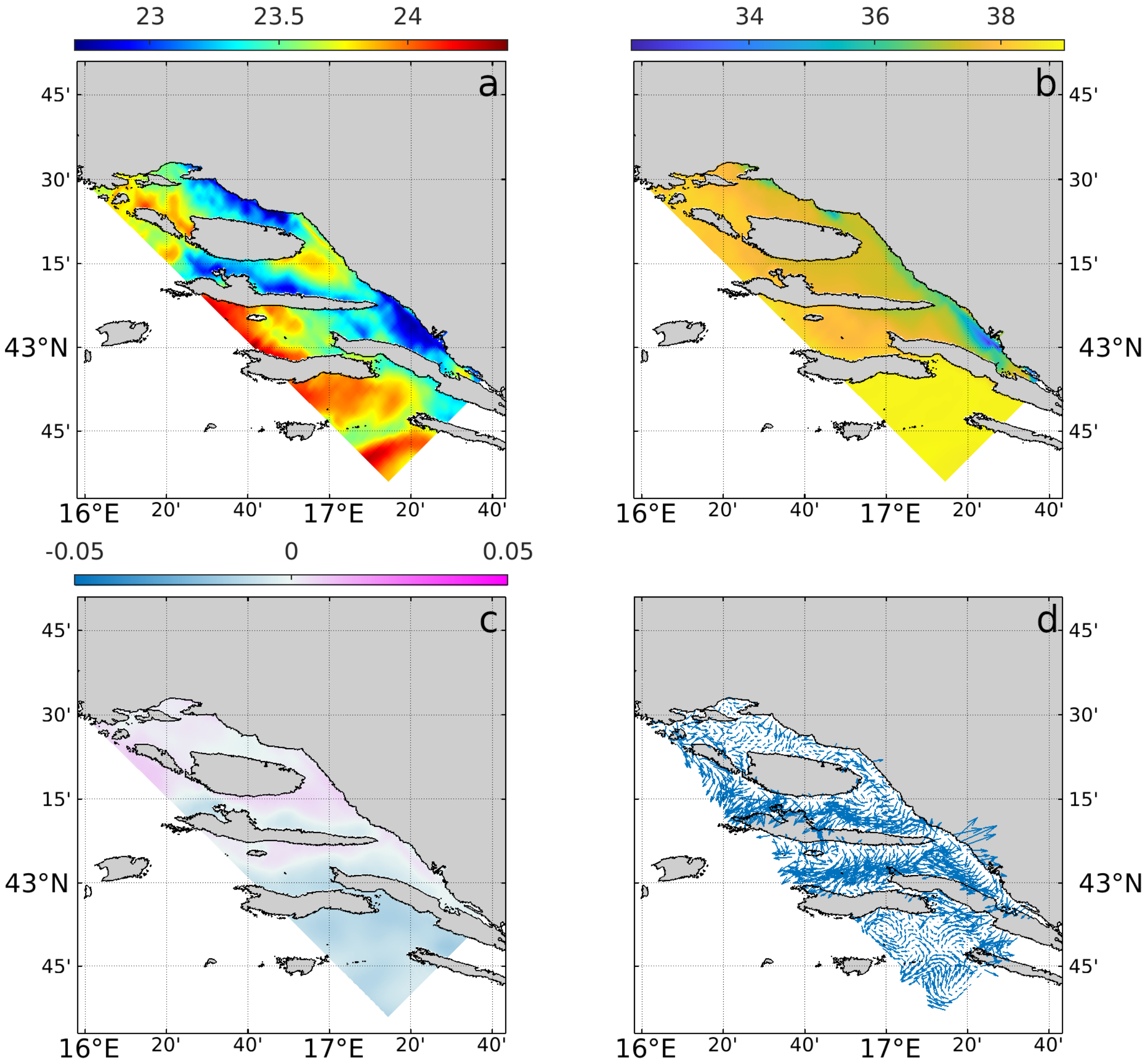
current (decimated by a factor 5).

PS2 or PS4) of temperature, salinity, free surface and zonal and meridional current fields from the Regione Marche Oil Spill Model. In figure 4 are shown the surface values (temperature, salinity, free surface elevation and currents) and in figure 5 the northern boundary, as an example of the boundary conditions, for PS2. The initial conditions clearly show the presence of the Western Adriatic Current (WAC) flowing southward



current. The gray area represent the transect seafloor.

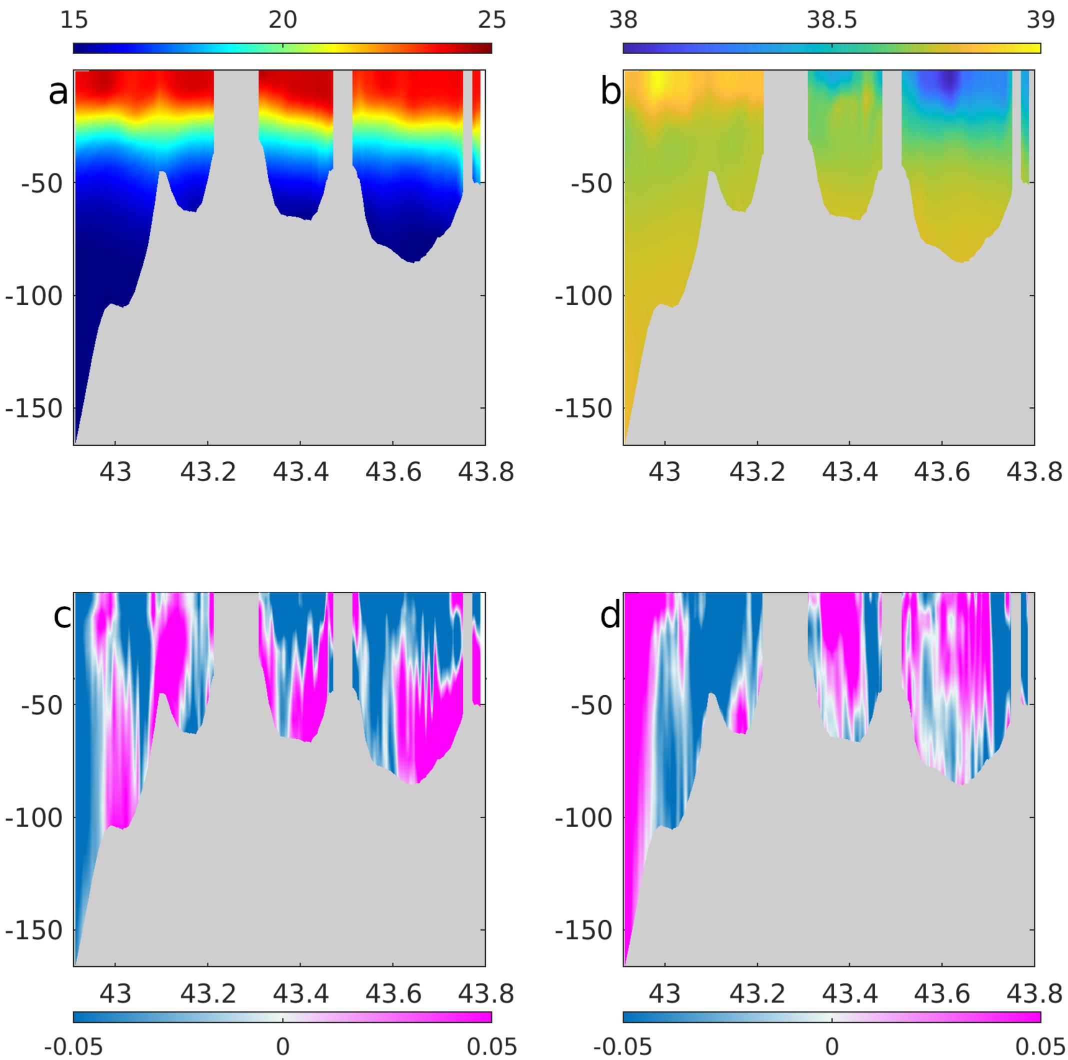
along the Italian coasts. This current is characterized by warmer and fresher waters(figure 4 a and b) that are mostly confined to a 30 m surface (figure 5 a and b) layer, progressively getting shallower moving off shore. The free surface and current



by a factor 5)

fields (figure 4 c and d and figure 5 c and d) are also correctly representing the typical local circulation present in the area at the beginning of September.

The Initial conditions for PS4 are shown in figure 6 (surface values) and in figure 7 (western boundary) and show a more complex dynamic than PS2 due to the presence



islands locations along the boundary.

of several islands in the area. Temperature values are not uniform but instead show colder areas inside the islands and toward the coast and warmer surface temperatures near the open sea. This distribution is coherent with the local dynamics inside the Croatian islands. A similar behavior can be seen for salinity that also shows the presence of coastal rivers with low coastal values.

In order to keep consistency between the pilot sites, the same initialization and start up method of PS1 was used for PS2 and PS4: each pilot site simulation was initialized on on September 1st 2014 and run with as spin up for 4 months (up to December 31st 2014). Then on January 1st 2015 the experimental run was initialized and run continuously untill August 28th 2019 (the last day of the Regione Marche's Oil spill model).

2.3 Atmospherical forcing and riverine inputs

ROMS is drive by different types of forcing and inputs. For PS2 and PS4 (following what was defined for PS1) atmospherical fluxes were computed starting from the hourly data of the ARPA Emilia Romagna SIMC – COSMO implementation with a 2.2 km horizontal resolution at 2 m height. The Surface fluxes and transfer of momentum were then computed through the bulk parametrization of Fairall et al. (1996, 2003). This is an adaptation of the algorithm developed in the COARE experiment (Coupled Ocean-Atmosphere Response Experiment) that computes surface fluxes of momentum, sensible heat, and latent heat at the Ocean-Air interface. An in depth description of the numerics can be found in Shchepetkin and McWilliams (2005) and in Haidvogle et al. 2008.

PS2 and PS4 hydrodynamical model implementation did not required a tidal forcing since tides are already included in the Regione Marche Oil Spill Model implementation and hence transferred to the child grids through the current fields.

2.3.1 PS2 – Pescara riverine inputs

PS2 riverine inputs were derived from climatological values available in literature (*Annali idrologici* published by the Italian "Istituto Superiore per la Protezione e la Ricerca

Ambientale" and available at www.isprambiente.gov.it). For the period 2014-2019 daily or monthly data for Pescara, Tronto and Sangro rivers were no available at the time of the implementation of the pilot site, hence a monthly climatology for stream flow and temperature (figure 8) was computed based on the data published in the *Annali idrologici* (table 1 summarize the periods periods used for each river). The temperature climatology computed for the Tronto river was also used for the Pescara, since no temperature data were available for the Pescara river and the two rivers present similar drainage basins; the value for salinity was set to 0 PSU. The three rivers present a similar distribution of mean discharge through the year with a winter and spring peak and lower values during summer (figure 8) in good agreement with the distribution of precipitation in the each drainage basin. Temperature presents values oscillating

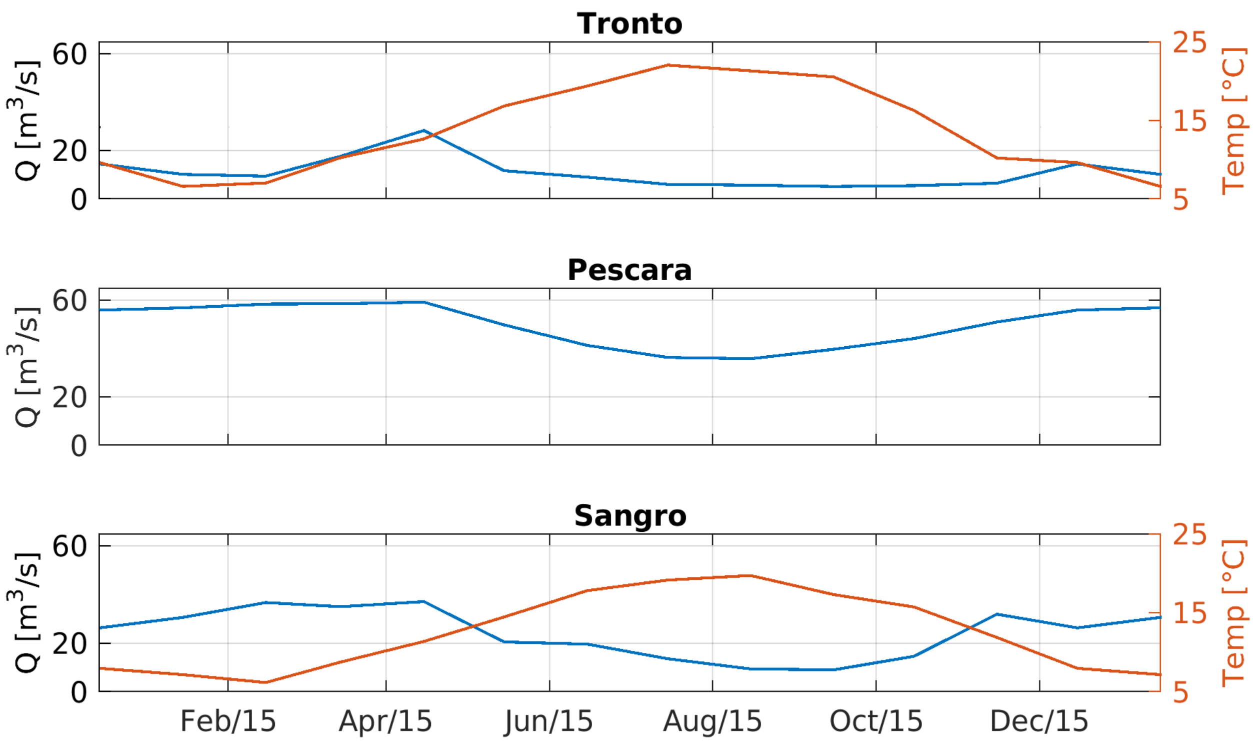


Figure 8: Climatological values of Tronto, Pescara and Sangro stream flow in m^3/s (blue line) and climatological temperature in °C (red line).

Table 1: The years of the stream flow and temperature date over which the climatologies for riverine inputs in PS2 were computed.

River	Streamflow data	Temperature data
Tronto	2005–2009	2003–2007
Pescara	1916–2010	N/A
Sangro	1976/1977/1978/1979/1993/1994/1996	2003–2007

between 5°C and 25°C with a single peak during summer and lower values during winter.

2.3.2 PS4 – Split riverine inputs

4 rivers are present in the grid domain of PS4 (figure 3) the major of which is the Neretva, located in the southern most part of the domain, the other rivers are the Jadro, the Cetina and the Zrnovnica all located in the northern coast, toward the city of Split. The daily stream flow averages near the each river mouth, in m^3/s, were provided by the Croatian partners of NET4mPLASTIC in the project framework and cover the whole modeling period (figure 9). The Neretva is the most important fresh water input of the area with peak flood values up to 1405 m^3/s on March 22nd 2018 and an overall average of 250 m^3/s. The river present the typical bimodal distribution with two stream flow peaks in late autumn and late winter and drought values during summer; an exception of this is 2018 when high discharges are present during the whole winter period. The other rivers present much lower discharges with yearly average values below 15 m^3/s. It is of interest to now how most the minor rivers flood peaks are aligned with the peaks in the Neretva's stream flow. This is due to the rivers being geographically close to each other, hence experiencing the same type of forcing, and having similar drainage basing. It is significant to note that the Cetina river shows

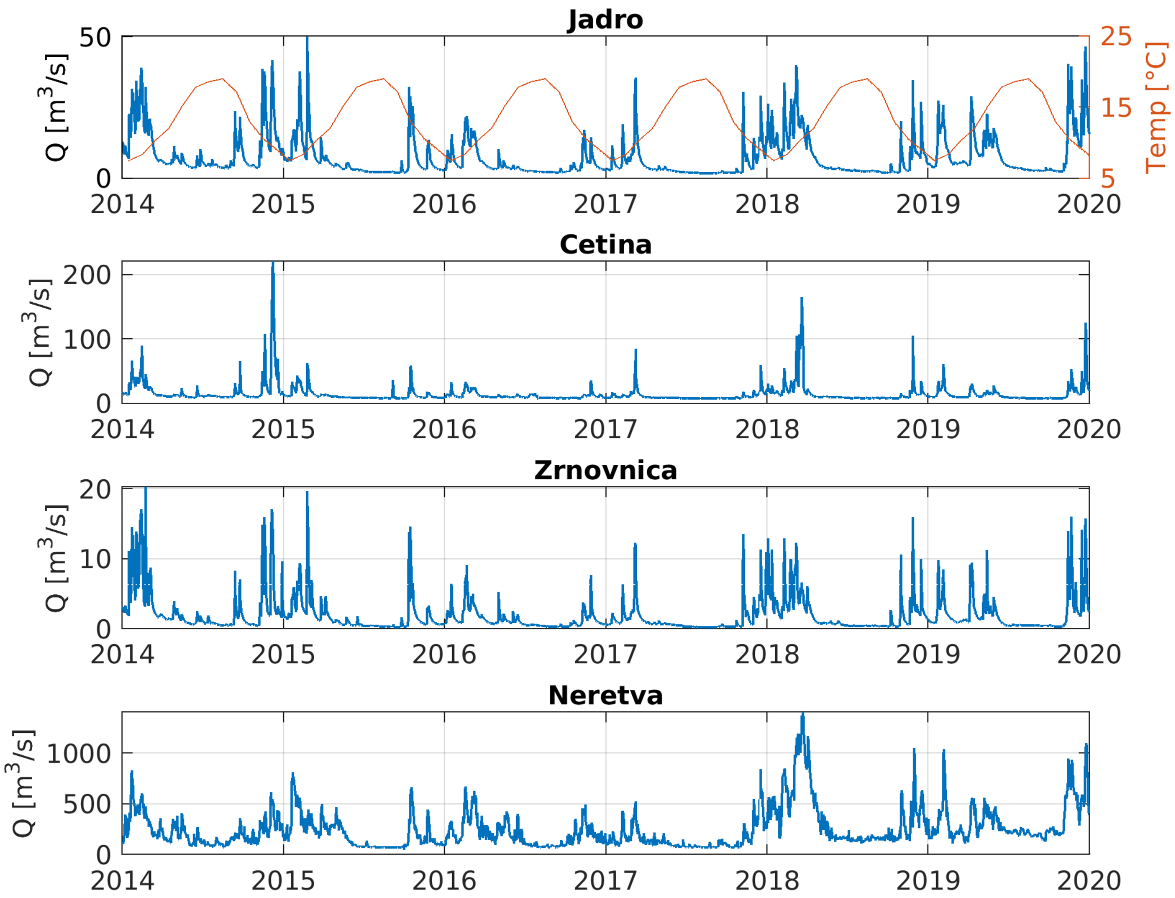


Figure 9: Stream flow values for Jadro, Cetina, Zrnovnica and Neretva rivers in m3/s (blue line). On the top panel is shown the climatological temperature used of all rivers of PS4 (red line).

significantly high flood events (close and over 100 m^3/s , up to 220 m^3/s on December 7th 2014) which potentially can have an important impact on the distribution of microplastics in the area surrounding the river mouth during flood events.

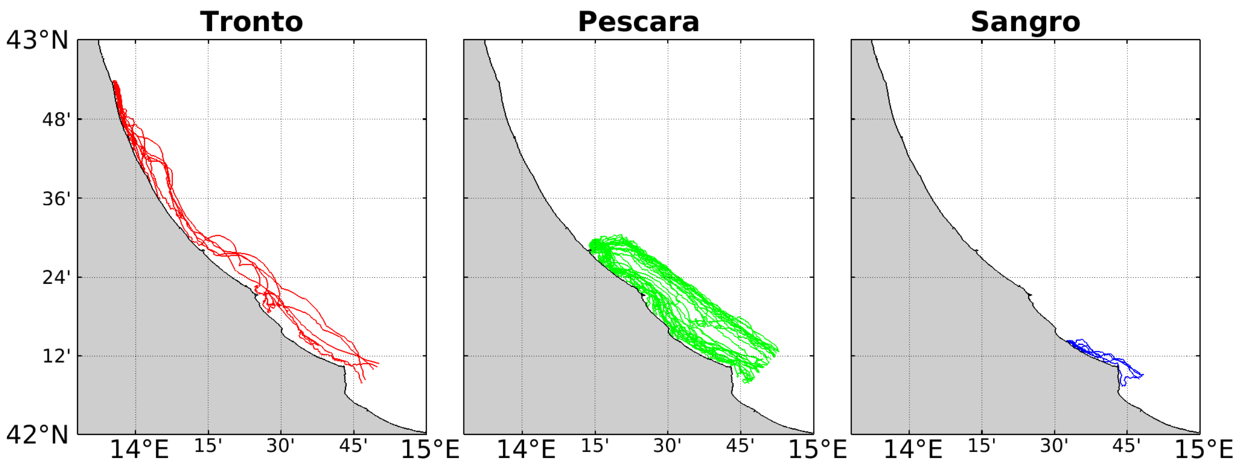
During the set up of the simulations the partners did not provide values for temperature, so temperature data between 2000 and 2006 for the closest available Adriatic rivers (Isonzo, Tagliamento, Piave, and Brenta, data collected by ARPA Veneto and ARPA

Friuli Venezia Giulia) were used to compute a monthly climatology (figure 9, red line in top panel).

2.4 Lagrangian simulations set up

The dispersal patterns and pathways for microplastics of riverine origin in each Pilot Site were done using the results of the hydrodynamical simulations (temperature, salinity and current fields) as forcing for the 3D Lagrangian model ICHTHYOP (Lett et al., 2008). The details of the Lagrangian simulation set up can be found in Deliverable 3.2.

As for the first pilot site only riverine inputs were considered as potential sources of microplastics since those are the main sources of microplastics identified in literature. Other sources (such as industrial plants, waste water treatment plants, ports and so on) are present in the pilot sites but no reliable data were available on discharges and concentrations. Given the characteristics of PS2 and PS4 each Lagrangian simulation was run for 15 days. This time span was defined based on the assumption that particles that are not beached in less than 15 days can be considered permanently in the water



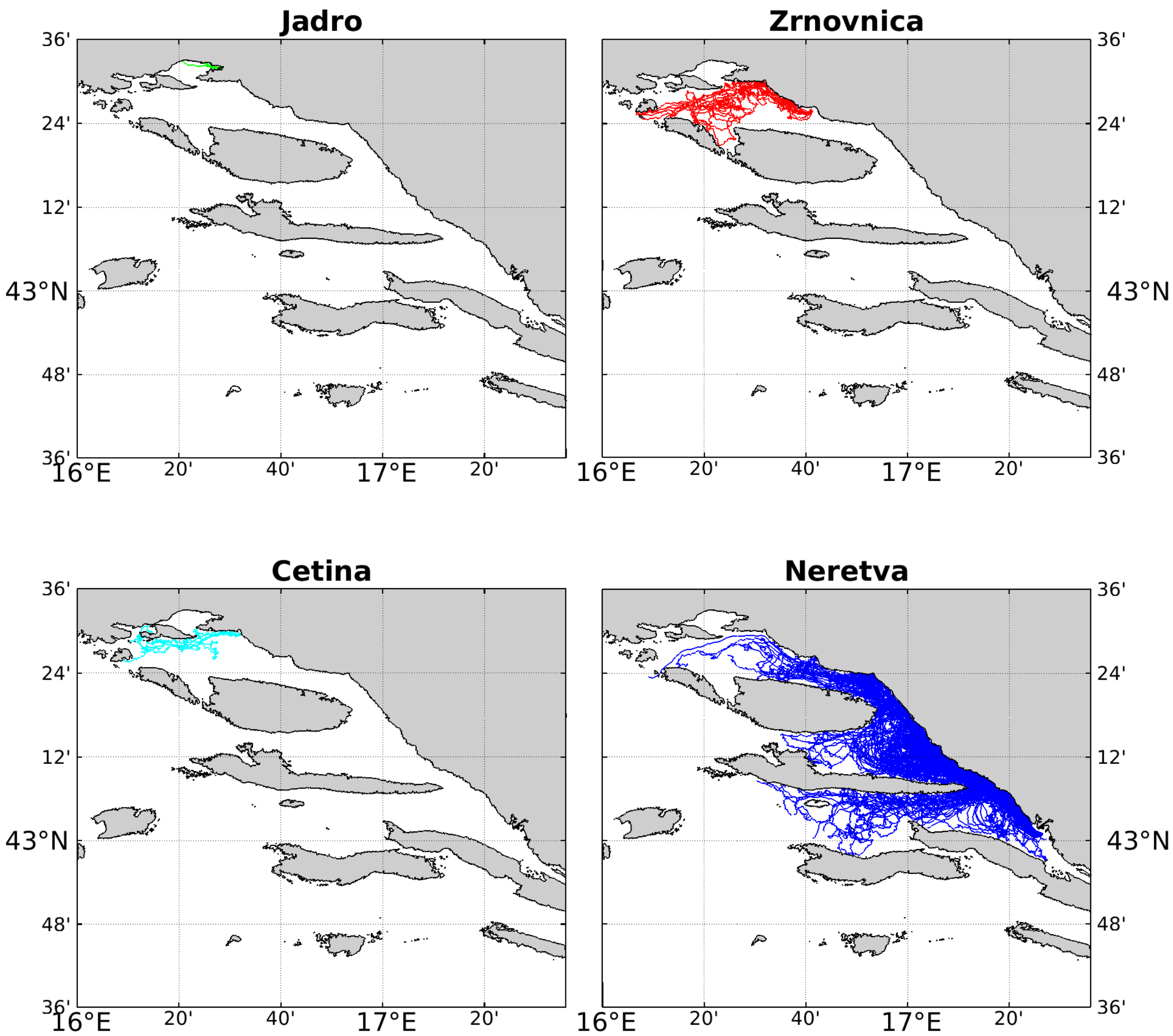


Figure 11: the microplastic dispersion pathways in PS4 for particles released on January 1st 2016 at 00:00 and 00:02. left top panel particles from Jadro river (in green), right top panel particles from Zrnovnica river (in green), right bottom panel particles from Cetina river (in cyan) and right bottom panel particles from Neretva river (in blue).

column. Figure 10 show an example (January 1st 2016, releases at 00:00 and 02:00) of the Lagrangian model outputs for PS2. Results are in line with the general circulation of the area which is strongly dominated by the southeasterly Western Adriatic Current. It is of interest to note that particles from each of the rivers are able to reach the southernmost grid limit, in the case of Tronto about 150 km from the river mouth. Figure11 show the Lagrangian results of PS4 (January 1st 2016, releases at 00:00 and 02:00). It is evident that the Neretva (lower right panel, blue lines) has a much broader impact that all the other rivers with particle released from its mouth that are able to reach the whole modeling domain in less than 15 days. The other rivers (Jadro, Cetina and Zrnovnica) have a much smaller impact mostly confined in the are close to each river mouth.

The simulations results have been processed to produce the accumulation maps following the methodology developed in D3.2.

3 Pilot Site B – Whole Adriatic

The basin wide Lagrangian simulations were implemented in place of Pilot Site 3 – Rijeka for which the needed data for model input were not provided by the project partners. To substitute PS3 it was decided to use the hydrodynamical results of the Regione Marche Oil Spill model as the inputs for a basin wide simulations of microplastic dispersion pathways and accumulation sites on a basin scale. In order to be consistent with the Oil Spill model physics the same riverine inputs were used for the Lagrangian model. It has to be noted that those partially differ from the sources used on PS1, PS2 and PS4 both in location and discharge magnitude (the riverine inputs of PSB are shown by the orange dots in figure 12). As for the other Pilot Sites the Lagrangian simulations were run from January 1st 2016 to August 28th 2019 with one simulation per day with two particles releases. Each simulation had a duration of 20 days that guarantees that most of the particles released would either be beached or be permanently in the open sea.

Figure 13 shows the simulations results for January 1st 2016. The strong impact of the Western Adriatic Current is clear since almost all of the particles released on the western side of the basin flow southward along the coast. It is interesting to not that on

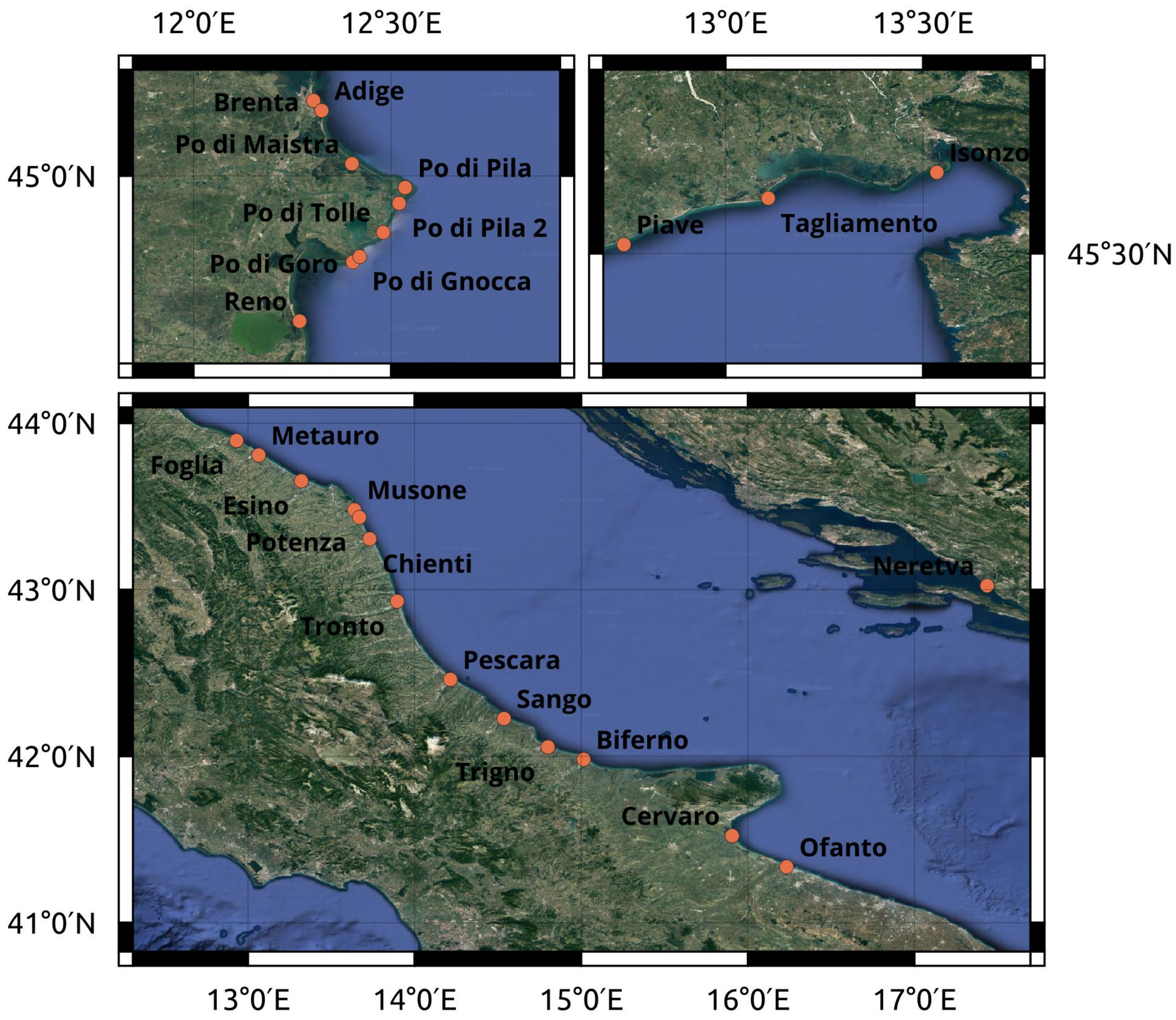


Figure 12: Location of the rivers used as microplastic inputs for PSB.

the Croatian side the only microplastic source is the Neretva river. This is consistent with the implementation of the Regione Marche Oil Spill model but it does not include the Cetina, the Jadro and the Zrnovnica rivers as PS4. Moreover given the lack of data it is probably not considering several potential sources along the eastern Adriatic coasts.

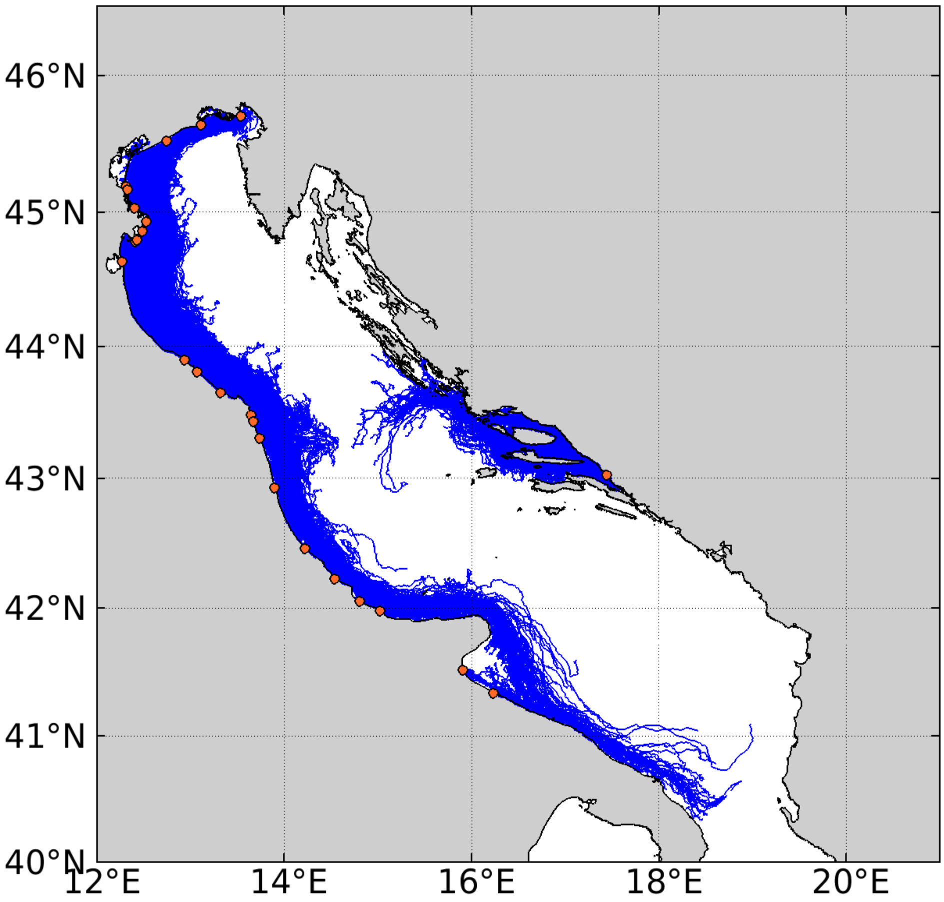


Figure 13: an example of the Lagrangian simulations output of pilot site B for particles released at 00:00 of January 1st 2016 (blue tracks). The orange dots mark the location of the river mouth considered as sources of microplastics.

4 Definition of microplastic hazard from riverine inputs

One of the expected results of NET4mPLASTICS is an Early Warning System (EWS) that will provide a daily bulletin of potential hazard for a Pilot Site. The definition of Hazard has hence a paramount role in the context of NET4mPLATIC. Hazard is generally defined as a quantification of any source of potential damage, harm or adverse health effects on something or someone. In other words it can be defined as the potential for harm or an adverse effect. In the context of NET4mPLASTIC the definition of hazard will be based on the analysis of the modeling results of each pilot site. The Lagrangian simulations analysis is based on the rsults of the daily runs. Each particle released is followed for 15 to 20 days (depending of the PS characteristics) and the number and location of particles considered as beached (i.e. a particle is considered as beached if it passes closer than a distance from coast set for each PS based on the horizontal grid resolution). This results in a series of daily maps that show the number of particles released from each river mouth that potentially beach in the modeling domain. This number do not represent and can not be converted to a microplastic concentration but can be considered as a measure of the potential hazard. In order to have a user friendly representation of the modelling results in the EWS the daily distribution map will be converted by categorizing each potential hazard on distribution percentiles computed on a seasonal base. This gives for each day and location an indication of how the daily potential hazard is compared to the average seasonal one. This aspect is discussed in details in D4.3.3.

5 Outline of the operational model for the Early Warning system

The Early Warning System will produce a daily bulletin of the potential hazard due to microplastics released from riverine inputs. The operational system will be implemented as a demonstrator on Pilot Site 1 – Po Delta and will start from same implementation of the PS1. The model will initialize the simulations form the Mediterranean Sea Physics Reanalysis operational model (MED MFC) data available on the Nucleus for European Modeling of the Ocean (NEMO) that uses a data assimilation variational scheme (OceanVAR) and is freely available form Copernicus Marine System repositories (www.marine.copernicus.eu). Those data will be used for initialization and boundary conditions. Riverine forcing (i.e. Po, Adige and Brenta riverine discharges) are obtain from the real time stream flow observations at Pontelagoscuro collected by ARPA EMR.

The Operational Model will be initialized on day -2 and run for two days as startup. Then on day 0 the forecast run will start and last for three days. After the model run the modeling output will be post processed to produce the distribution maps with the hazard values of the following two days. The model results will then be stored on the Regione Marche server farm.

6 Bibliography

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.

Firall CW, Bradley EF, Rogers DP, Edson JB and Young GS. 1996. Bulk parameterization of air-sea fluxes for tropical ocean-global atmosphere Coupled-Ocean Atmosphere Response Experiment, *J. Geophys. Res.*, **101**, 3747-3764.

Fairal CW, Bradley EF, Hare JE, Grachev AA and Edson JB. 2003. Bulk parameterization of air-sea fluxes: Updates and verification for the COARE algorithm. *J. Clim.*, **16 (4)** 571-591, doi: 10.1175/1520-0442(2003)016<0571:BPOASF>2.0.CO;2.

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