CleanAtlantic

Tackling Marine Litter in the Atlantic Area

Final Report: WP 6: Mapping and modelling of marine litter

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INDEX

Report WP6 CleanAtlantic: Mapping and modelling of marine litter

1. Background

1. Action 55 of the RAP is set to "Develop sub-regional or regional maps of hotspots of floating litter, based on mapping of circulation of floating masses of marine litter, and identification of hotspots of accumulation on coastal areas and the role of prevailing currents and winds." Under the Interreg Atlantic Area project CleanAtlantic, a group of modelling specialists together with marine litter experts have taken up the challenge of contributing to the aim of Action 55.

2.- As part of the project CleanAtlantic, the modelling group developed a Lagrangian transport tool, MOHID Lagrangian. This tool can be applied to forecast the formation of retention areas (hotspots) with the highest probability for litter accumulation in any particular region. The abilities of this open source Lagrangian tool include its easy implementation, robustness, computing efficiency that simulates millions of particles in short times, the capacity to use any Eulerian circulation fields from other models, as well as the ability to simulate different types of Lagrangian particles. This modelling methodology, with this Lagrangian tool, can be applied in different geographical areas where meteorological and hydrodynamic modelling capabilities are in place.

3.- Applying this methodology, simulations were performed with a number of particles with statistical significance (in the order of millions of simulated tracers) for a simulated time long enough to cover different marine / atmospheric phenomena (minimum of two years). The simulations included global (North Atlantic), regional (domains that include one, or several, countries) and local domains (domains with points of interest at the regional level). The tracers used in the simulations were 3 different types of marine litter (i.e., different densities).

4. The capabilities of the models to predict the origin of marine litter accumulated on the seafloor and coastal areas were assessed and the connection of major rivers with sinks of marine litter was studied. The concentration/dispersion maps of marine litter originated from land (rivers and ports) or sea (maritime traffic and aquaculture) are shown separately.

5.- The local domains also serve as validation for the model methodology used, as they present well-controlled, documented, and confined industrial activities. In situ monitoring and modelling work with mussel pegs (or stoppers), derived from local aquaculture in a region of northern Spain, was carried out to study the influence of this type of marine waste on this coastal area, which is serving in parallel as a validation process for the model architecture used in the project.

Objective:

The aim of this WP is to develop sub regional or regional maps of hotspots of floating litter, based on models mapping of circulation of floating masses of marine litter, and identification of hotspots of accumulation on coastal areas and the role of prevailing currents and winds.

Partners:

IST, CETMAR, INTECMAR, USC, IEO, DGRM, DROTA, IFREMER, CEDRE, CEFAS, IMI, ARDITI

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2. Summary of activities

The objective of this WP -coordinated by the IST and USC- is fully aligned with the collective action no.55 of the OSPAR Regional Plan, which aimed to develop sub regional or regional maps of hotspots of floating litter. These maps were based on mapping of circulation of floating masses of marine litter, identification of hotspots of accumulation on coastal areas and the role of prevailing currents and winds. Contributing to this collective action, the project had developed a Lagrangian transport model tool applicable to all the regions to forecast the formation of retention areas (hotspots) with highest probability for litter accumulation.

The results obtained had completed with the information gathered through surveys with sea professionals (accumulation on coastal areas, snagging sites, and dumping grounds) and local authorities (for coastal accumulation) coming from WP 4, 5 and 7. The capabilities of the models to predict the origin of marine litter accumulated on coastal areas has been assessed and the connection of major rivers with sinks of marine litter has been studied. When appropriate, model has been calibrated by matching real and predicted marine litter accumulation's locations on the shoreline. The area of influence of land and sea based marine litter sources has been assessed and different scenarios of reduction has been evaluated. Partners from the 5 AA countries with modelling expertise had contributed. The partners involved have a long tradition of collaboration with the maritime and fishing sectors in their regions and have worked in previous initiatives dealing with marine litter management, which assure a smooth interaction and strong involvement of these stakeholders.

This WP had five main actions whose objectives are described below:

Action 6.1.- A review of the state-of-the-art of marine litter and debris model parameterization had carried out taking into consideration its nature, size and main processes affecting its deposition, fragmentation, and buoyancy. Recent literature related to marine litter application has been summarized in order to produce sound results in this rapidly developing scientific topic. Solid base and comprehensive methodology for modelling based in state-of-the-art numerical models had contribute to development of forecasting tools that will facilitate management actions such removal of marine litter from hotspots. The results of the literature review on marine litter modelling and conceptual model of marine litter dynamics and processes involved in its degradation and buoyancy variation were the basis for developing the Lagrangian modelling tool.

Actions 6.2.- The equations describing marine litter processes and evolution has been programmed in an open source Lagrangian transport model that can use hydrodynamic results from ocean, regional or coastal models. The Lagrangian modelling tool (including marine litter processes) has been applied across all study areas based on a Lagrangian transport model. Any user with access to the results of the hydrodynamic and wave models can run the model. The modelling tool facilitated the identification of areas of marine litter accumulation and the establishment of management actions such removal of marine litter from hotspots.

Action 6.3.- Hotspots - accumulation areas- has been mapped using hydrodynamic and wave models, the marine litter modelling tool developed in 6.2, and the connectivity between sources and accumulation areas. Litter has been modelled as passive tracers transported by currents and through the available circulation models resulting in a network of connected areas. The identification of areas of marine litter accumulation will facilitate the establishment of management actions such removal of marine litter bringing it to levels that are not detrimental to ecosystem function and biodiversity.

Action 6.4.- The fate of litter released from land-based sources on different areas has been assessed using the Lagrangian Litter Tool (6.2) and the paths of each source has been analysed. Maps showed which rivers and coasts contribute more to marine litter. Simulations have been carried out assuming continuous and discrete emissions to account for the river discharge events. Maps were made showing the main rivers and coastal areas that contribute to the accumulation of marine litter in the Atlantic area under different hydrodynamic circulation regimes and river discharge conditions. An improved knowledge of the impact areas associated to each source of marine litter will enable better understanding of the best prevention and mitigation measures and policies for reducing the amount of litter reaching a certain coastal or marine area.

Actions 6.5.- The Atlantic area is subject to ocean activities such as heavy maritime traffic, including merchant shipping and fishing vessels. Ocean and coastal circulation can transport the generated litter to the coast or to the open ocean. This action characterized the paths followed by this litter and the accumulation areas influenced by the seasonal hydrodynamic variations in the Atlantic Area. Influence maps of oceanic sources were made according to the main maritime routes and the main European ports.

Action 6.6.- In this action, the impact of potential mitigation measures was assessed with the application of the marine litter transport model tool. Simulations were evaluated considering the reduction of marine litter sources.

The activities of these actions were completed during the first part of the project. During the **extension of the project**, the following tasks were planned and carried out:

Task 1 - Test different critical stresses for resuspension of the plastics.

Task 2 - Beaching maps for all rivers and for each river individually.

Task 3 - Test different scenarios with different particle density increase rates (as an approximation of biofouling).

Task 4 – Interactive web platform to assess sources of marine litter.

Task 5 - Estimation of the location of marine litter hotspots in the Spanish Atlantic regions using a Lagrangian hydrodynamic model and replicate this methodology for France and Portugal demarcations.

Task 6 - K-Means clustering technic applied to discover the typical distribution of beaching litter.

3. Results and deliverables

Task 1 - Test different critical stresses for resuspension of the plastics.

MOHID LAGRANGIAN TOOL: improvements

As a result of the collaboration between IST and USC, a Lagrangian transport tool, MOHID Lagrangian (*Figure 1*) has been developed. This tool can be applied to forecast the formation of retention areas (hotspots) with the highest probability for litter accumulation in any region. The abilities of this open source lagrangian tool include its easy implementation, robustness, computing efficiency that simulates millions of particles in short times, the capacity to use any Eulerian circulation fields from other models, as well as the ability to simulate different types of lagrangian particles. This modelling methodology, with this Lagrangian tool, can be applied in different geographical areas where meteorological and hydrodynamic modelling capabilities are in place.

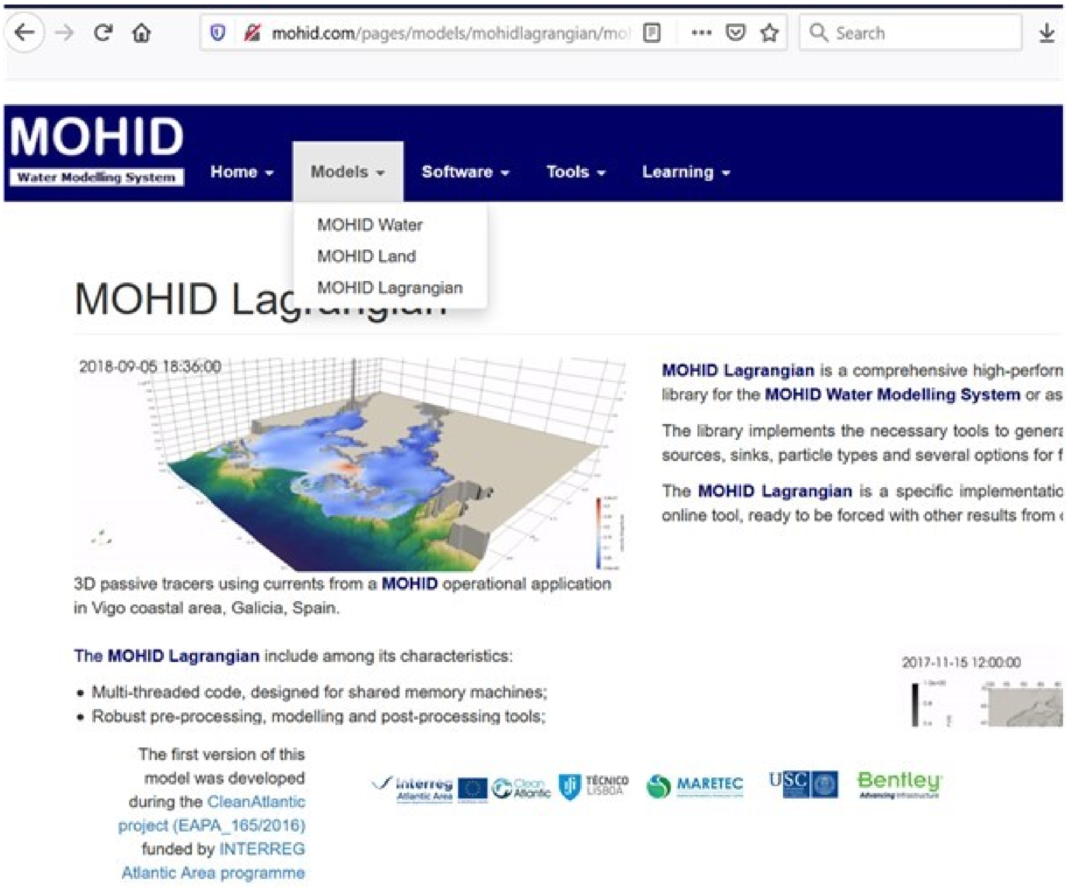

Figure 1. Lagrangian tool can be accessed in http://mohid.com as well as all the available information about its installation and features.

MOHID Lagrangian tool was designed to cope with extremely large scenarios (planetary scale), extremely large calendars and extremely large tracer collections. Squared with the design goal of maintaining a material description, i.e., actual trajectories of tracers are considered, not a stochastic description of an ensemble of tracers, high-performance implementation was the only solution. As such the numerical core is implemented in Fortran 2015+, taking full advantage of the fast language with parallel support and available compiler optimizations across platforms, while still maintaining a modern object-oriented model. The pre-processing and post-processing tools are written in Python, enabling users to make quick adaptations if required.

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Supported input data is NetCDF-CF, enabling direct consumption of datasets published in online warehouses and servers. Data sets can include vectorial fields such as current, wave and wind velocity, or scalar fields such as salinity, temperature, density and other properties. Output format is raw binary vtu files, with indexation. This allows for the direct use of highly optimized packages such as Paraview to explore and treat the results, that can comprise tens of millions of tracers. The post processing suite enables the computation of spatial and temporal averages of any quantity, tracer filtering by state, arbitrary shape binning and direct plot/map output and publication.

A full set of documentation is available, as well as self-contained cases, ready to run in one click, both for Windows and Linux platforms. Precompiled binaries are distributed for Windows, allowing the user to download, and run. The project is CMake based, enabling advanced users to produce compilation projects if desired, in a fully cross-platform manner.

A given case is set-up using a structured and self-documenting xml file, describing all the initial conditions, parameters and options required. Primitive support for volumes, shapes, emission rates, movement and type of tracer sources is embedded, with full support for arbitrary geometries given as input data.

Passive, basic tracers are conceptualized as an immaterial point with quantities such as velocity. Complex, material tracers are derived from this concept, adding mass, concentration, state, process constants (degradation rates, susceptibility coefficients, etc).

The general equation of motion that describe the tracer trajectory is:

$$\frac{dx_i}{dt} = v_i(x_i(t), t) + D \qquad \text{Eq.1}$$

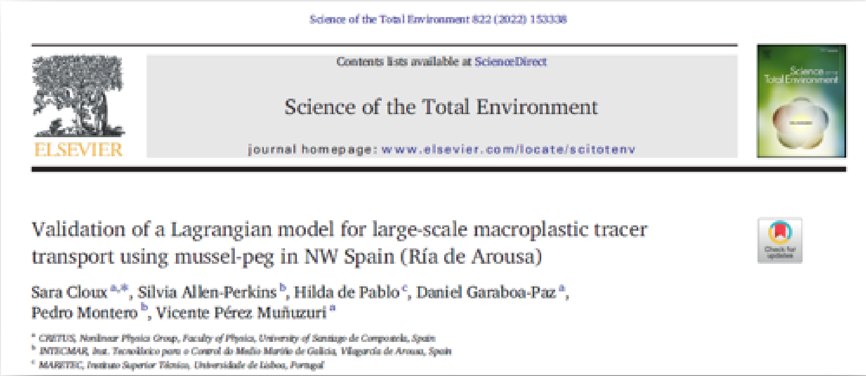
Where v_i is the velocity of the flow field at a time instant t and D is the diffusion term. The horizontal diffusion term is modeled using random velocities while the tracer travels a given mixing length, proportional to the resolution of the flow velocity field $v_i(x_i(t), t)$ and its ability to resolve motion scales.

$$D_i = rand_i\sqrt{|\Delta r_i| \cdot k} \qquad \text{Eq.2}$$

Where $rand_i$ are random velocities in the interval [-1,1] following a uniform distribution. k is the diffusion coefficient expressed in m/s2 and is set to 1, and $|\Delta r_i| = v_i/dt\ |$, is the distance traveled by a particle during a step dt, assuming the velocity is constant during the step.

The available integrators are first (Euler), second (multi-step Euler) and forth (Runge Kuta) order. Due to the kernel oriented description of the physical processes that each tracer is subjected to, implementing new processes is trivial, as well as implementing new integrators. Available kernels include general advective dynamics, diffusion, beaching, resuspension, linear degradation, buoyancy, Stokes drift and windage.

In the scope of the project, a study to validate the results of the Lagrangian model resulted in a scientific publication. This study developed by (Cloux et al., 2022) (**attached document**: **paper Cloux et al_ 2022.pdf**) tested the reliability of the model by comparing simulation data with beach monitoring data from Ria de Arousa (Galicia, NW Spain). The model was used to track the transport of marine debris over time in the Rias, estimate its accumulation along the Galician coast, and compare it with monitoring data. Despite the increasing availability of in situ monitoring data, this valuable information hardly explains the trajectory and origin of marine litter but simply indicates the areas where it is found at a given time and where it may accumulate (the fate).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Validation of a Lagrangian model for large-scale macroplastic tracer transport using mussel-peg in NW Spain (Ría de Arousa)

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Figure 2. Paper: Cloux, S., Allen-Perkins, S., de Pablo, H., Garaboa-Paz, D., Montero, P., Pérez-Muñuzuri, V., 2022. Validation of a lagrangian Model for Large-Scale Macroplastic Tracer Transport Using Mussel-Peg in Nw Spain (Ría De Arousa). Science of The Total Environment. https://doi.org/10.2139/ssrn.3967923.

Regarding improvements, the following were added to the MOHIDLagrangian model:

i) Correction of the fall velocity of particles as a function of buoyancy.

The previous method contained incorrect assumptions on the velocity to be used for buoyancy calculation. In this case the tracer velocity was being used instead of the ambient velocity. Combined with other errors in the equations, tracers took a long time to be deposited when compared to the literature.

Buoyancy in the model is computed following (Haider and Levenspiel, 1999):

$$Buoyancy = \sqrt{-2 * g * \left(\frac{shapeFactor}{cd}\right)} \qquad \text{Eq.3}$$

Where shapeFactor is used to account for tracer shapes transitioning from a sphere to a disk:

$$shapeFactor = 6 * \frac{V}{4 * A} \qquad \text{Eq.4}$$

Where V and A stand for tracer volume and area respectively.

cd represents the drag coefficient:

$$cd = \frac{24}{Re} * (1 + 0.173 * Re^{0.657}) + \frac{0.413}{1 + 16300 * Re^{-1.09}} \qquad \text{Eq.5}$$

And Reynolds Re is computed as:

$$Re = \frac{max\left(abs(v, 1E-8)\right) * l}{kv} \qquad \text{Eq.6}$$

Where v stands for the characteristic velocity of the tracer, *l* the characteristic length and *kv* the viscosity.

ii) Calculation of bottom velocity

As gridded results include vertical layers in the order of tens up to hundreds of meters where a single velocity value is used. With this implementation velocity decreases following a parabolic decrease of velocity from the centre of a vertical layer of results towards the bottom, producing more realistic velocity values.

iii) Critical shear stress for resuspension

A user can now also define variables such as critical shear stress for resuspension of tracers, which enables the study of scenarios when the type of tracers and bottom of the ocean are unknown.

Task 2 - Beaching maps for all rivers and for each river individually.

Another powerful feature of this model is its parameterization of beaching. The state variable LI(t), or land interaction, for each particle is defined based on the type of cell it is on in a set of particle trajectories *ri*. To do this, we need to consider the land interaction mask (*LIM*) obtained from the current field, which has values ranging from -1 to 2. Non-missing value (missing values refer to mesh points where no value has been assigned) cells are considered as water wc, missing value cells are considered as land (*lc*), adjacent cells to missing cells above a set threshold height are considered as beach cells (*bc*), and cells below the threshold are considered as seafloor cells dc. The threshold is set by the user in the simulation settings. Cell values are categorized as it is shown in Figure 3a.

Once the scalar Land-Interaction-Mask field (LIM) is obtained (see Figure 3), the Land-Interaction for each particle at each time instant is calculated as follows:

$$LI(t)_i = LIM(r(t)_i) \qquad \text{Eq.7}$$

Considering a i-particle with an associated *LI* value that causes it to become trapped on land, as shown in Figure 3b, the beaching process is computed based on a velocity reduction factor. When a particle is beached, its factor reduces its current speed to 0. The velocity reduction factor is obtained using the following equation:

$$f_v(LI) = b_w(LI) \cdot r_w \qquad \text{Eq.8}$$

with b_w a beach quadratic weight in the range [0,1] that weights how deep a particle is in a beach cell.

$$b_w(LI) = 1 - \left(\frac{LI - b_{min}}{b_{max} - b_{min}}\right)^2 \qquad \text{Eq.9}$$

and r_w is the probability of particles to become beached. Thus, even in a 2D simulation, it is crucial to have a 3D mesh or bathymetry that enables us to calculate the Interaction Mask (*LIM*) accurately.

a) b)

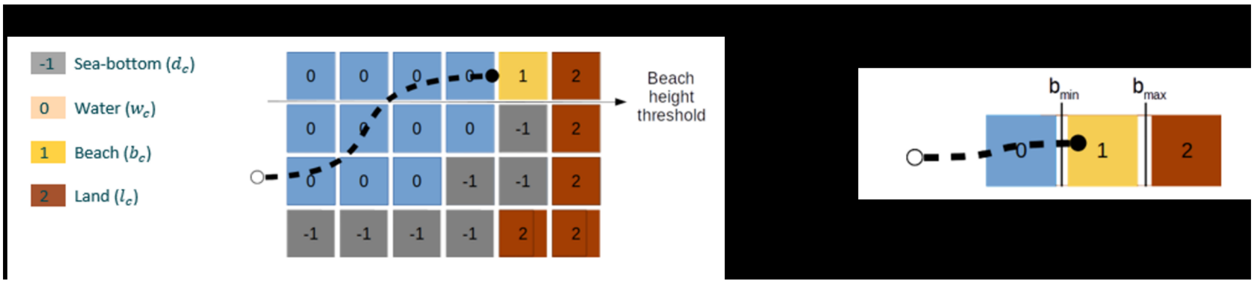


Figure 3. Beaching process implemented in MOHID-Lagrangian model. a) Assignment of the Land-Mask Interface values (LIM). b) Beaching scenario where a particle moves from water to beach.

This way, it is possible to set a threshold depth value above which the particle becomes stranded, as well as a probability for particle beaching. With these parameters, different accumulation scenarios can be modeled. Cloux et al., (2022) observed that in many cases it is hard to establish a beaching factor r_w for some regions, while in other cases, the real exposure to the beach may not be well described in the simulation. Beaches may have a complicated orography (stones, algae, etc) that can influence the retention of floating particles, and these may not be well reproduced in the simulated coastline. However, it was not possible to establish a linear relationship between the beaching factors that fit well with one beach or another.

Another additional feature of this model is the ability to separate the accumulations on the output grid, meaning that the influence of each emission source can be evaluated separately. The output grid is chosen by the user and can be defined in various ways. In this study, the output grid covers the North Atlantic Ocean domain. In the validation study, the output grid consisted of narrow segments that reproduce the coastline. The model counts the number of particles that pass through each cell of the mesh throughout the entire simulation period, resulting in both a count and a concentration in the area of each respective mesh cell. MOHID-Lagrangian supports various types of emission points, including box, sphere, point, lines, KMZ-polygon, XY-polygon, and position time series. Therefore, we can configure the type of emission.

The methodology for mapping beaching zones in the North Atlantic Ocean area (*Figure 4* right) .was similar to that used in the first part of the CleanAtlantic project to determine the areas most likely to accumulate litter in the open ocean (*Figure 4* left).

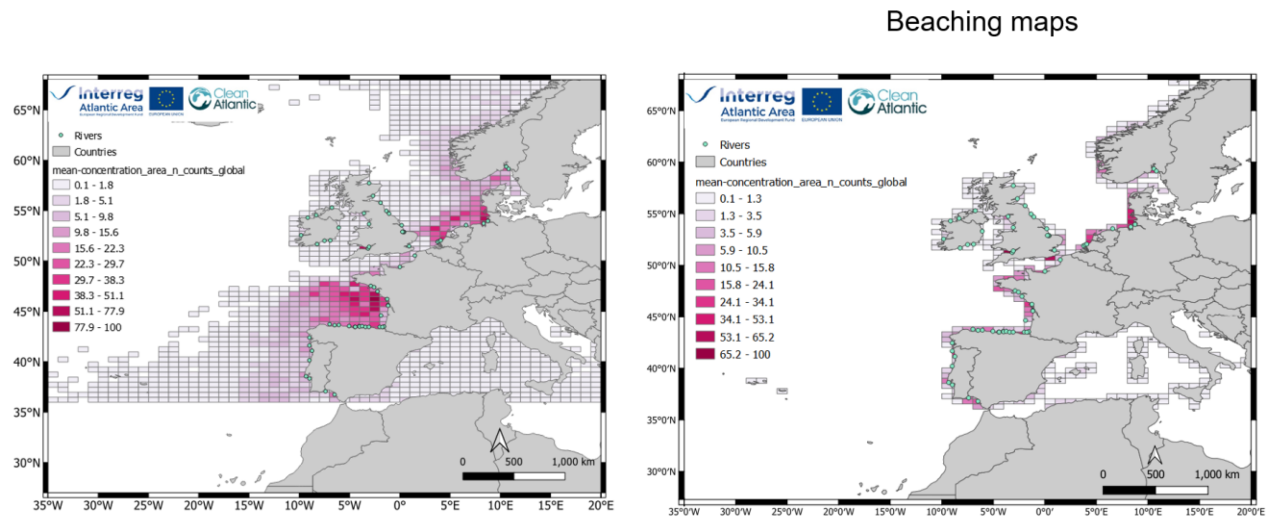


Figure 4. Areas most likely to accumulate marine litter in the open ocean (left) and beaching areas (right). Darker colours indicate greater accumulation.

Note that these new surface maps only indicate the model cells closest to land, with the greatest accumulation of particles. In order to map areas in more detail, it would be necessary to use local models with higher resolution, more precise Eulerian conditions and include typical coastal processes (waves, more precise bathymetry, wind, among others).

These new maps were drawn up taking into account 64 European rivers simultaneously, as well as for each river individually.

A folder containing these maps, in shapefile and .png formats, is attached (**attached document: CleanAtlantic_beaching.rar**).

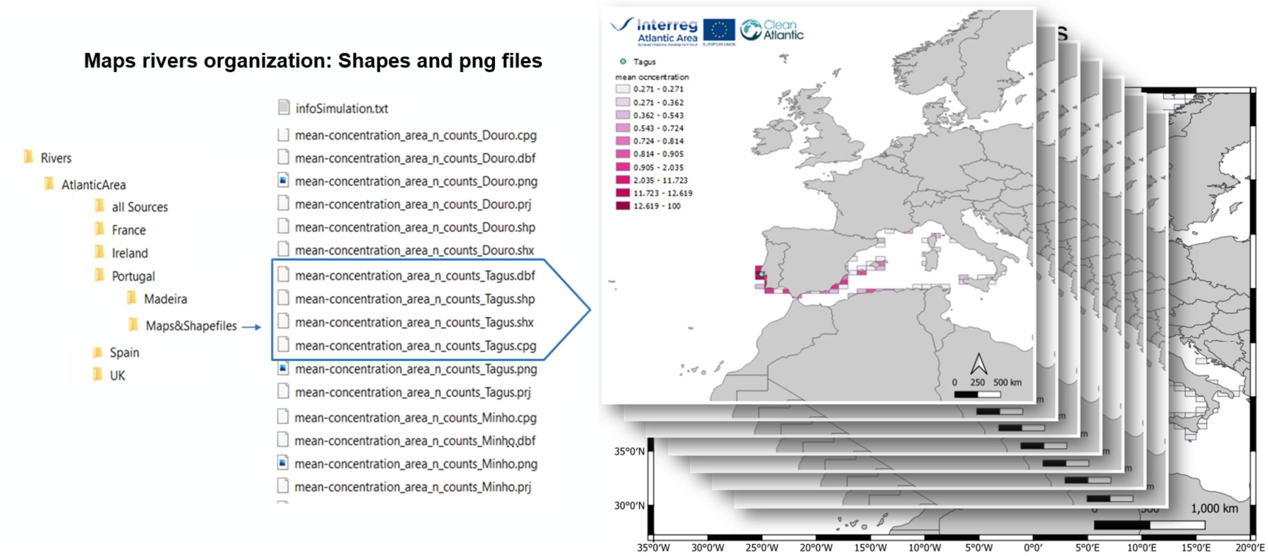


Figure 5. Files and beaching maps.

Task 3 - Test different scenarios with different particle density increase rates (as an approximation of biofouling)

New features and improvements made in MOHIDLagrangian during CleanAtlantic interreg project.

As far as new features included in this lagrangian model, the following were implemented and tested:

1. Biofouling growth on marine debris such as plastics
2. Input of irregular and curvilinear gridded results.

iv) Biofouling growth on marine debris such as plastics

This feature applies mainly to lighter than water plastics that float in the ocean for long periods of time. As time goes by, biofouling will form around the pieces of plastic, starting with a biofilm which then enables other species to adhere to it. This includes species such as barnacles which feed on phytoplankton and use floating debris as anchor, thus making water (with phytoplankton) pass by them. As the biofilm and species like barnacles grow around the plastic, the combined density will increase and eventually, debris can start sinking to the bottom of the ocean.

For researchers to study the influence of biofouling in the sinking of marine debris such as plastics, a biofouling growth feature was included in MOHIDLagrangian code (freely available in this github repository). Because there is so few studies focussing on biofouling effects on sinking debris, a more general approach was considered. This would allow researchers to test different theories against any field data produced henceforth. As such, two methodologies were implemented for biofouling growth:

1. Constant growth rate
2. Biofouling growth rate as a function of phytoplankton in the surrounding water, whose values are provided by gridded results from model solutions such as those available in Marine Copernicus (CMEMS).

This feature allows users to model the growth of a biofilm using ambient concentrations of phytoplankton provided by gridded results in netcdf format. For this purpose, the MOHID WaterQuality module source code (freely available in this git repository) has been edited in such a way that MOHIDLagrangian can use it directly. MOHIDLagrangian also can read all the necessary water parameters from netcdf files, making it a versatile tool with potential for growth, as any number of methods can now be included if there are equations for it. The model also allows for a delay on the growth rate of biofouling (associated to species like barnacles) to include the time for a biofilm to grow before these species can adhere to marine debris.

v) Input of irregular and curvilinear gridded results

Because many models use irregular or curvilinear grids, MOHIDLagrangian was upgraded to include a reading capability of such grids. This allows for greater versatility of the model and intercomparison between different sources of model results, including from different modelling groups.

vi) Resuspension of marine debris

As sinking debris reach the bottom, erosion and deposition processes begin to gain importance and, for that reason, a suspension method was added to the MOHIDLagrangian model.

For the resuspension of Marine litter, the existing functions in the MOHIDWater numerical model were imported and adapted to the different characteristics of the Lagrangian model. The model was adapted to receive wave fields to simulate the shear stresses at the bottom caused by wave forces, and some features were added, such as the release of tracers near the bottom.

The resuspension process implemented is based on the work of Franz (2017) and a methodology described therein, which follows the work of (Soulsby and Clarke, 2005) – whose algorithm is described in its appendix A. Thus, the model considers the shear stress produced not only by waves, but also by bottom currents to calculate the resuspension of particles.

An important approximation used in the model is the density of the material accumulated with the debris. The methodology used was created for sandy areas, and therefore the model considers that the bottom is covered with sand with a density of 2650Kg/m^3 and that the amount of tracers deposited there is irrelevant in terms of mass. Roughness is calculated based on the work of van Rijn (2007a). For rocky areas another methodology would have to be implemented.

User settings are specified in the UsingMOHIDLagrangian.pptx file included in the github repository.

The biofouling process was also associated with resuspension, as biofouling was designed for marine litter which, with increased weight, sinks and becomes subject to these processes. The code accounts for a constant density of plastic but produces a weighted density between plastic and biofouling. The latter, being denser, will increase the combined density (plastic + biofouling). Then, as the vertical movement of the tracers takes buoyancy into account – which includes density – the tracers gain falling speed, approaching the bottom. From that point onwards, resuspension processes come into play and can transport sedimented plastics along the ocean floor.

An implementation file was also added to the github repository with the necessary settings for this type of implementation.

Task 4 – Interactive web platform to assess sources of marine litter.

As part of the CleanAtlantic project, a platform was created to make the results available http://cleanatlantic.maretec.org/

In the CleanAtlantic project, an online platform was created to visualise some of the results obtained in the project. The main cover of the platform includes information about the project as well as information about each of the partners that make up the consortium (Figure 6).

Figure 6. CleanAtlantic web platform when accessed for the first time.

The results refer to the simulation of emissions from the 64 rivers considered during the project. By clicking on the "i" it is possible to obtain all the information relating to this simulation, both the Eulerian fields and the Lagrangian implementation.

With this simulation, the areas of the North Atlantic Ocean most likely to accumulate marine litter were calculated. To do this, a study area was selected and divided into sub-areas.

The colour coding that appears in the visualisation of the results states: darker colours indicate the areas with the highest probability of marine litter accumulation. Clicking on each of these sub-areas shows a circular chart indicating which source(s) (rivers) carry the most particles (marine litter) in that predetermined sub-area (Figure 7).

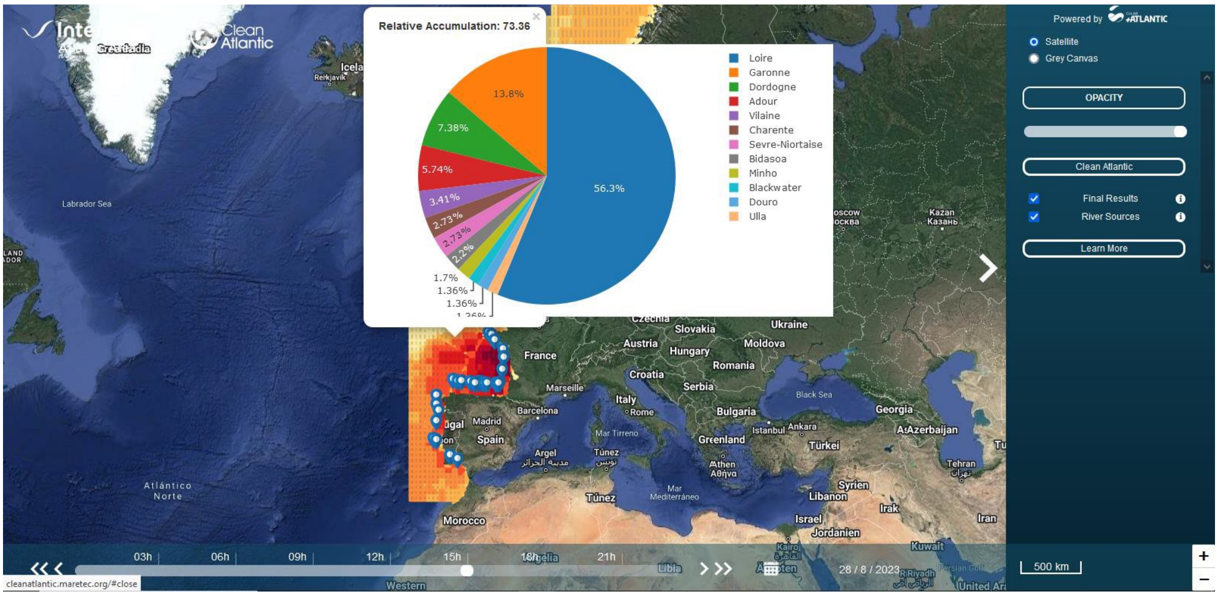


Figure 7. CleanAtlantic web platform showing the sources of the rivers, the areas most likely to accumulate particles in predefined cells and the contribution of each river to one of the defined cells.

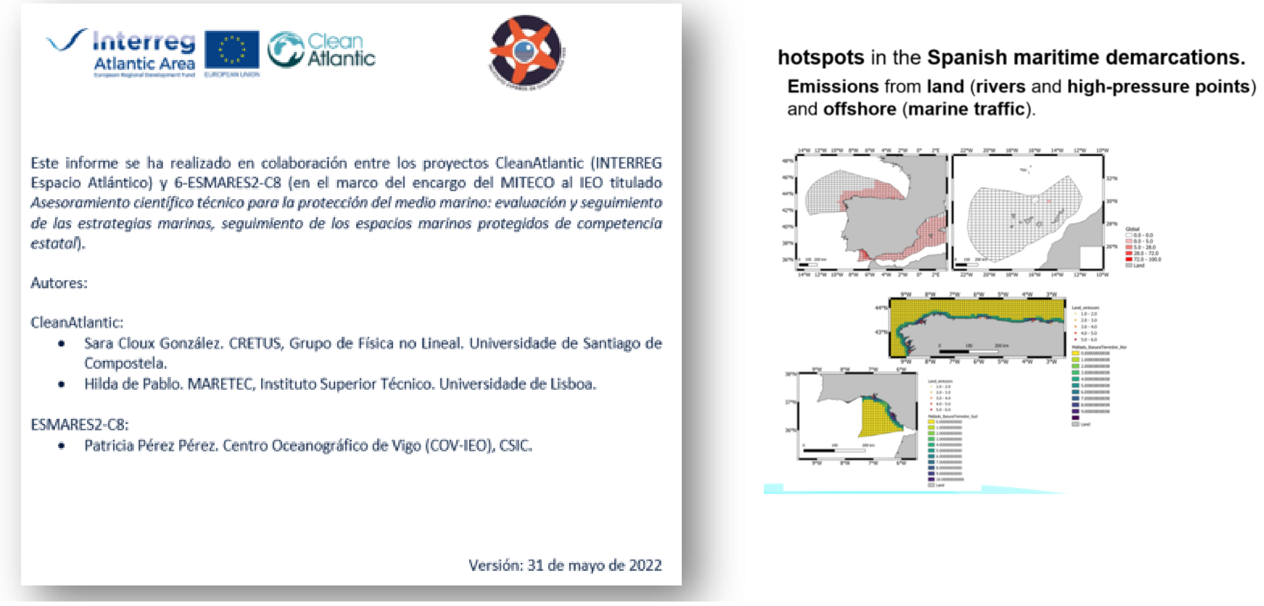
Task 5 - Estimation of the location of marine litter hotspots in the Spanish Atlantic regions using a Lagrangian hydrodynamic model and replicate this methodology for France and Portugal demarcations.

In 2018, the Ministry for Ecological Transition and the Demographic Challenge (MITECO) commissioned the Spanish Institute of Oceanography (IEO) under the title "Technical scientific advice for the protection of the marine environment: evaluation and monitoring of marine strategies, monitoring of protected marine areas of state competence". Chapter 8 of this assignment ("Chapter 8: Implementation and regular elaboration of monitoring and assessment of marine litter - Marine litter monitoring strategy") specifies the tasks related to descriptor 10 of the Marine Strategy Framework Directive (MSFD), marine litter. In addition to the work related to the status assessment required by the MSFD and other tasks related to the fulfilment of commitments acquired in regional conventions and reporting to the EC, the chapter also includes a task on the identification of marine litter accumulation areas (hotspots) in the Spanish demarcations (Task 6. Study of marine litter hotspots), which aims to address one of the measures included in the Programme of Measures of the first and second cycle of implementation of the MSFD.

In order to determine these accumulation areas or hotspots, in addition to making use of the results obtained in the monitoring strategies, the interest of using hydrodynamic models to help understand how the oceanic circulation patterns distribute marine litter in the Spanish demarcations was pointed out. To carry out this study, the Vigo Oceanographic Centre (COV-IEO) has had the collaboration of the CleanAtlantic project (INTERREG Atlantic Area). Within the framework of this project, the University of Santiago de Compostela and the Instituto Superior Técnico (University of Lisbon) developed a Lagrangian computational model that makes it possible to trace the movement of rubbish in the European Atlantic Ocean. Although the COV-IEO is also a partner of CleanAtlantic, in the framework of this particular activity, the work carried out by the

COV-IEO was carried out by the staff contracted for the MITECO assignment, precisely to respond to task 6. Thus, since July 2021, the COV-IEO has sent information and held regular meetings with these CleanAtlantic partners to decide on the conditions of the simulations, provide all the necessary data and produce this report. This report (Spanish version) is delivered as an annex (**annexed document: Report hotpots_ spanish demarcations_ES.pdf**) (Figure 8).

As part of this study, a paper has been submitted and is currently being evaluated.



Este informe se ha realizado en colaboración entre los proyectos CleanAtlantic (INTERREG Espacio Atlántico) y 6-ESMARES2-C8 (en el marco del encargo del MITECO al IEO titulado *Asesoramiento científico técnico para la protección del medio marino: evaluación y seguimiento de las estrategias marinas, seguimiento de los espacios marinos protegidos de competencia estatal*).

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Versión: 31 de mayo de 2022

Figure 8. Report hotpots Spanish demarcations 2022.

The methodology used in this study was also applied to the demarcations of Portugal and France as part of the project.

The aim of these studies was to relate the dispersion/concentration of particles from different sources to different meteoceanographic phenomena. As an example, the following figure (Figure 9) shows the intensity of upwelling (bar graph) during the simulation period; the bars with negative values identify the predominance of upwelling. The lower graph (line graph, Figure 9) shows the percentage of accumulation of particles, from different sources (rivers), during the same simulated period and in a certain predefined area (in this case, northern Portugal). Comparing both graphs shows the relationship between upwelling (coastal upwelling) and the lower percentage of accumulated particles, mainly from the source closest to the predefined accumulation area. As the discharge of particles is superficial, upwelling causes these particles to separate from the coastal zone.

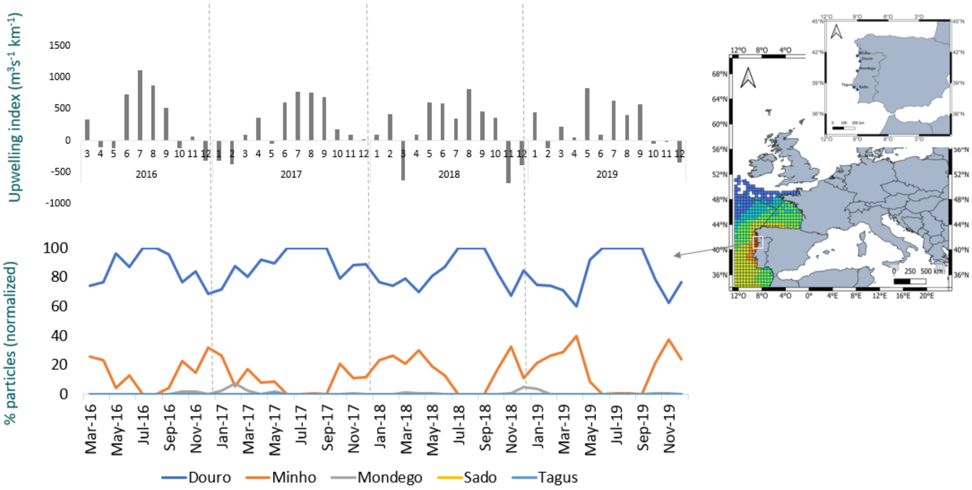

Figure 9. Portugal - Land emissions. Rivers (Sado Tagus, Douro, Mondego e Minho).

This same methodology was used, but now focusing on marine sources (the marine traffic lines). The emission of particles in this case was implemented by drawing lines in which Lagrangian particles were emitted at each given distance. The variation in the concentration of the percentage of (normalised) particles accumulated in each area depends on the meteoceanographic phenomena that dominate that area.

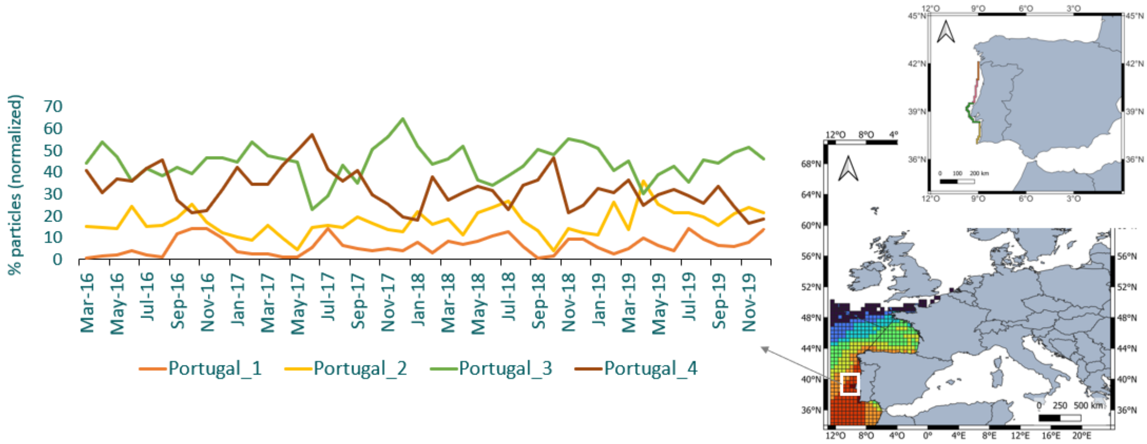

Figure 10. Portugal - Offshore emissions. Marine traffic

Task 6 - K-Means clustering technic applied to discover the typical distribution of beaching litter.

VIVENTE: podéis poner aquí un resumen del trabajo de Tito? Creo que ya había un documento sobre esto, pero no lo encuentro. Caso no consigas, dímelo que escribo alguna cosa siguiendo la lógica de las presentaciones (y el draft que me ha enviado Sara)

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