CleanAtlantic

Tackling marine litter in the Atlantic Area

Modelling and marine litter

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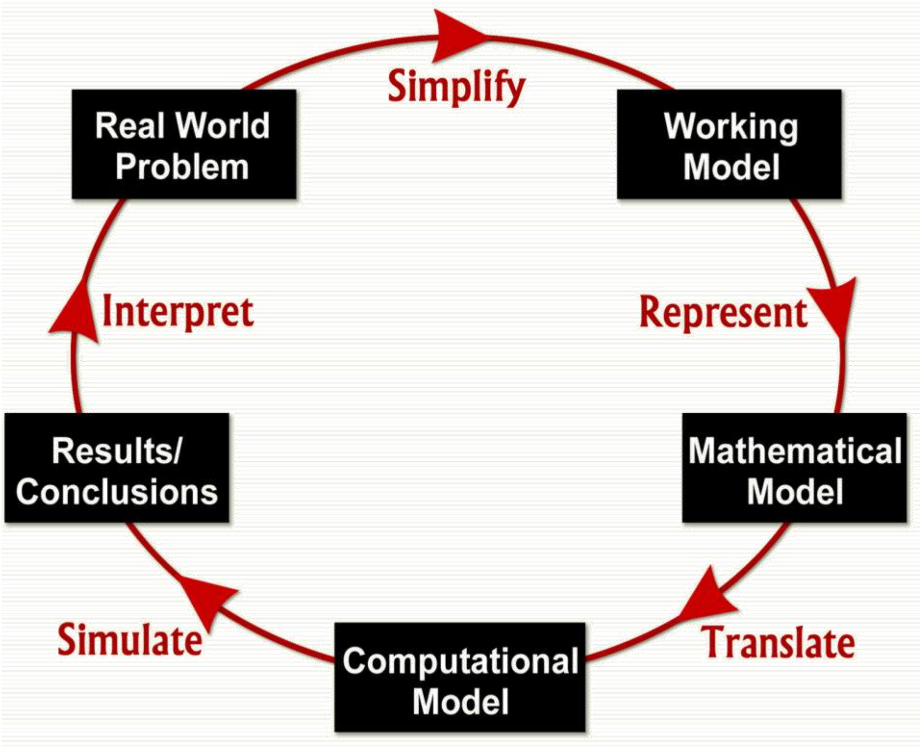
1. Introduction

What is a mathematical model?

It is an attempt to study a real problems in mathematical terms.



Why modelling is used?

1. Obtain knowledge
2. Test changes in a system
3. Aid decisión making

2. The real world problem

We have millions of tons of marine litter in the ocean and more marine llitter coming from human activities.

We want to clean it, but:

1) We can't clean the entire ocean and coastal waters.

2) We do not know the future state of the marine litter and their consequences.

We have a problem, we want to address it and we need to make decisions.

3. Working model

Variables
- Position
- Size
- Density
- …

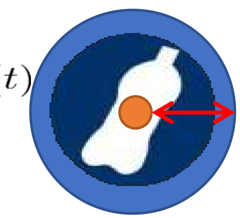
Processes.
- Transport by currents
- Waves
- Diffusion
- Wind
- Sinking
- Degradation
- Beaching
- ..

$\mathbf{r}(t)$

Complexity

$\mathbf{r}(t)$

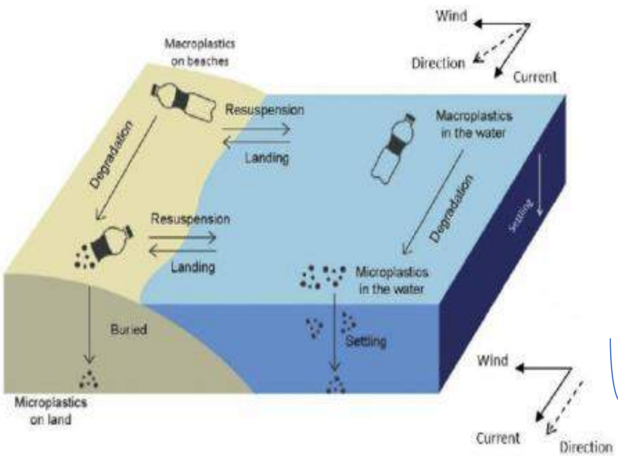
$R(t)$



ρ_p

4. Mathematical Model

- We have to translate into maths language, the working model of the marine litter: the variables describing the marine litter particle, their process and interactions to obtain the trayectory of the marine litter



Variables

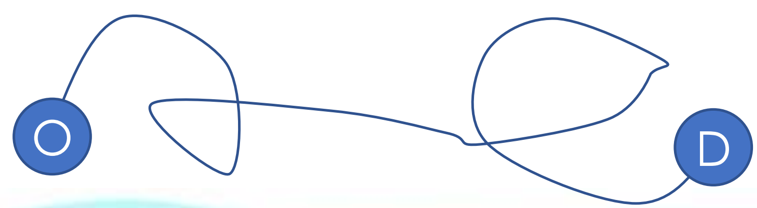
$$
\begin{aligned}
position &\rightarrow \mathbf{r_p}(t) \\
size &\rightarrow R(t) \\
density &\rightarrow \rho_p(t) \\
\dots
\end{aligned}
$$

$$\mathbf{r}(t) = (\mathbf{r_p}(t), R(t), \rho_p(t))$$

Processes

$$
\begin{aligned}
currents &\rightarrow \mathbf{v}(\mathbf{r_p}(t), t) \\
windage &\rightarrow \mathbf{v_f}(\mathbf{r_p}(t), t) K(\sqrt{\tfrac{A}{W}}) \\
diffusion &\rightarrow (2 * rand - 1)\sqrt{\tfrac{2D}{dt}} \\
waves &\rightarrow \mathbf{v}_s d(\mathbf{r_p}(t), t) * C_d \\
\dots
\end{aligned}
$$

$$\frac{d\mathbf{r}}{dt} = \mathbf{v}(\mathbf{r}(t), t) + \mathbf{v_f} K(\sqrt{\frac{A}{W}}) + (2 * rand - 1)\sqrt{\frac{2D}{dt}} + \mathbf{v}_s d * C_d + \dots$$



4. Computational model: Simulation of scenarios

- We can't simulate everything

- Imposibility to know all the initial conditions for the marine litter.

- We have to simulate a set of preselected configurations of some marine litter types.

- We need millions of trayectories which are harder to interpretate.

- **We require quantities sumarizing the obtained information.**
  - **Concentration maps – hot spots**

J.-H. Yoon et al. / Marine Pollution Bulletin 60 (2010) 448–463

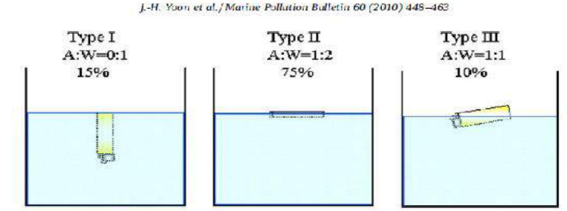


Fig. 1. Types of floating lighters. Percentages indicate the percentage among the 150 samples of lighters obtained from field surveys.

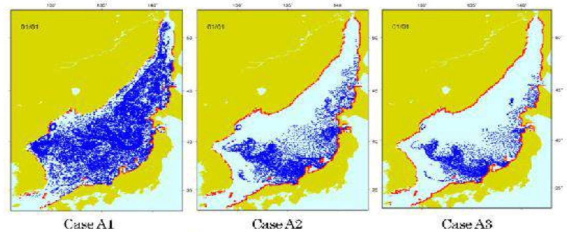
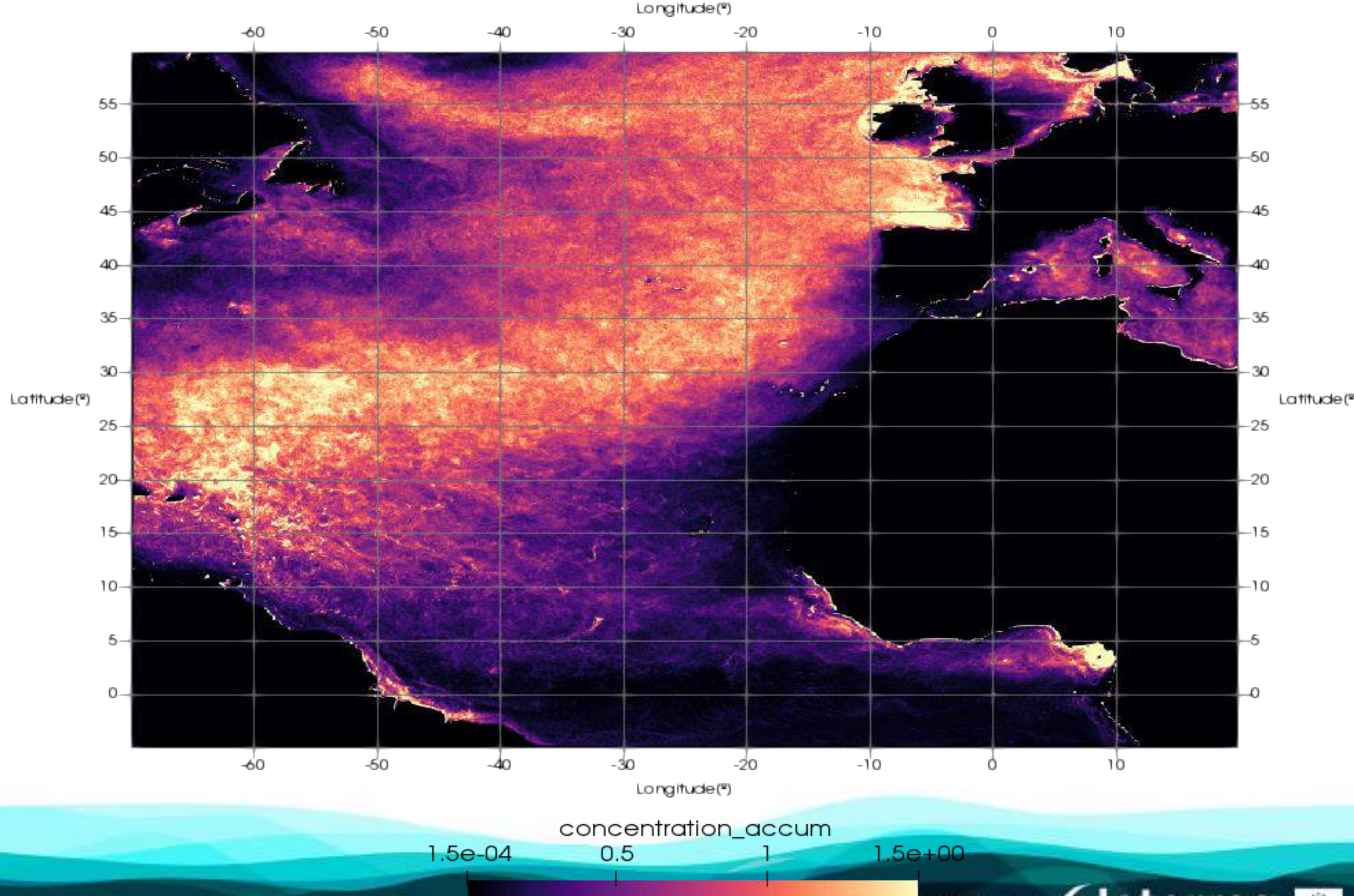


Fig. 2. Distributions of particles after 1 year for Cases A1–A3. The blue color and red points indicate floating and beached particles, respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

5. Global escenarios: Atlantic area



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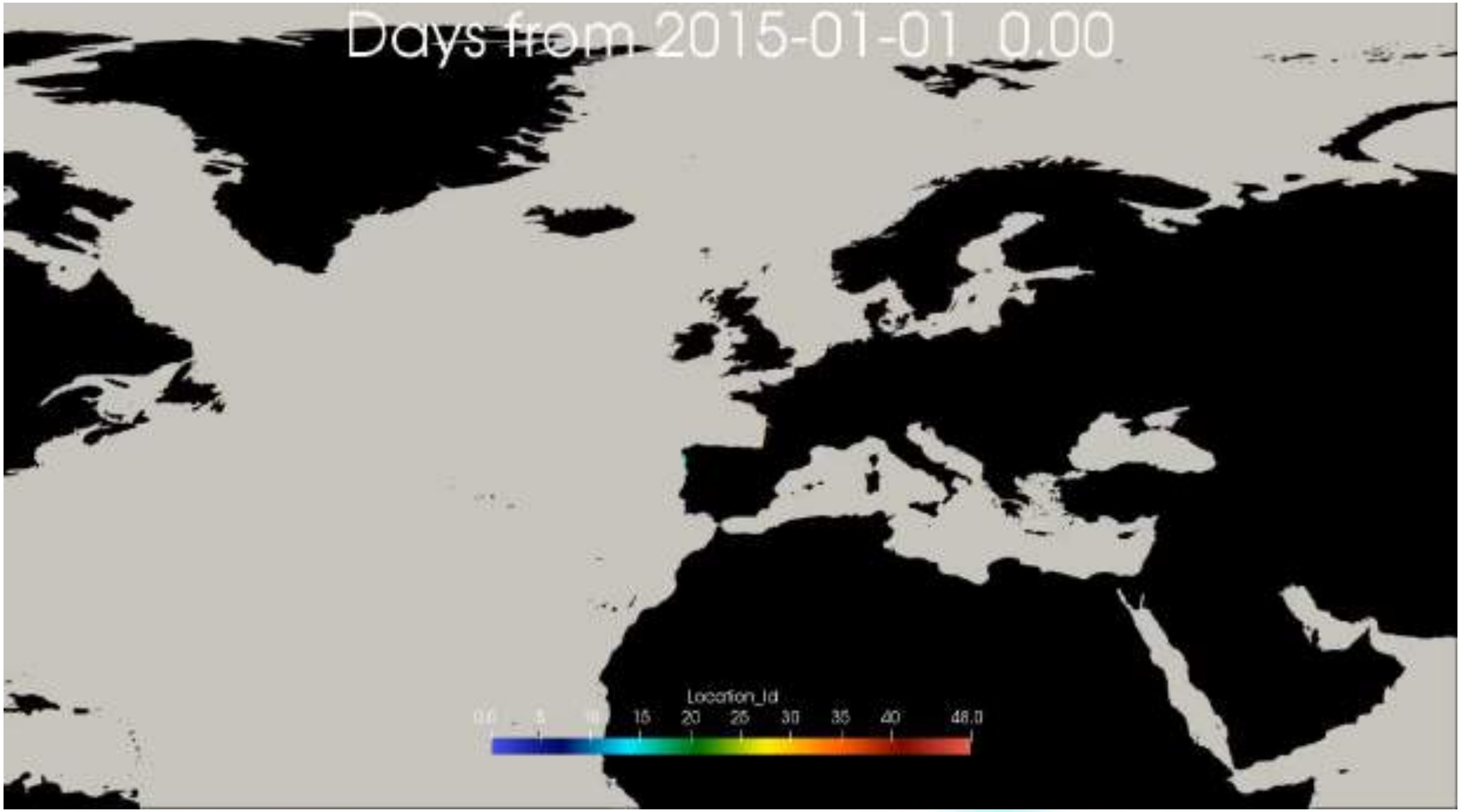
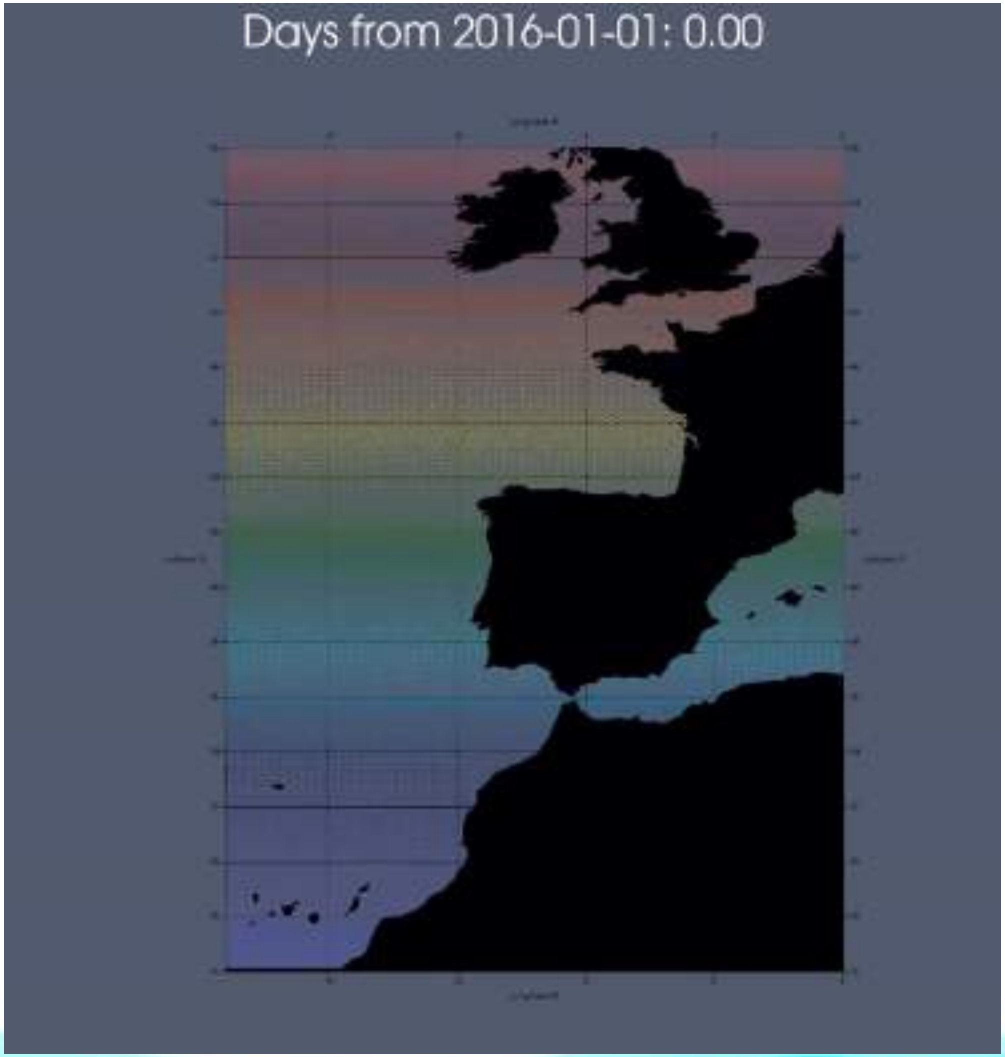
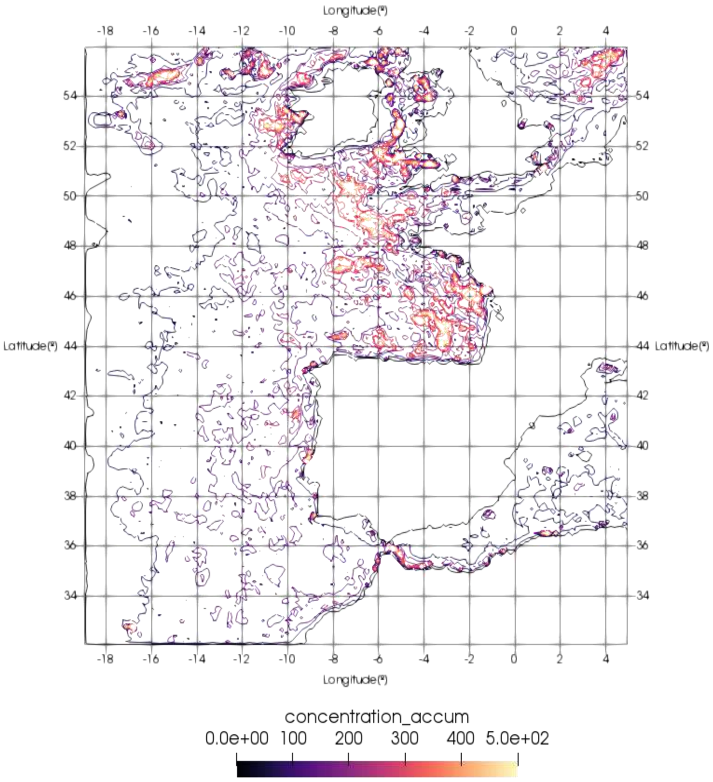
6. Regional escenarios: rivers emission

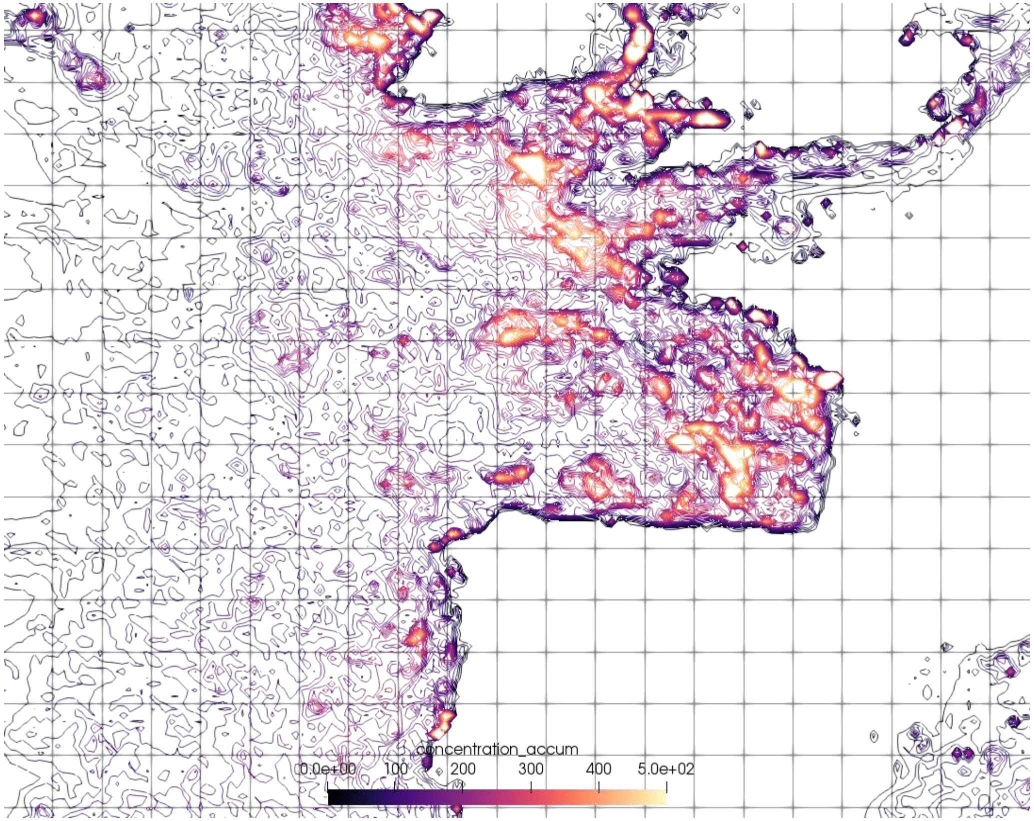


6. Regional scenarios

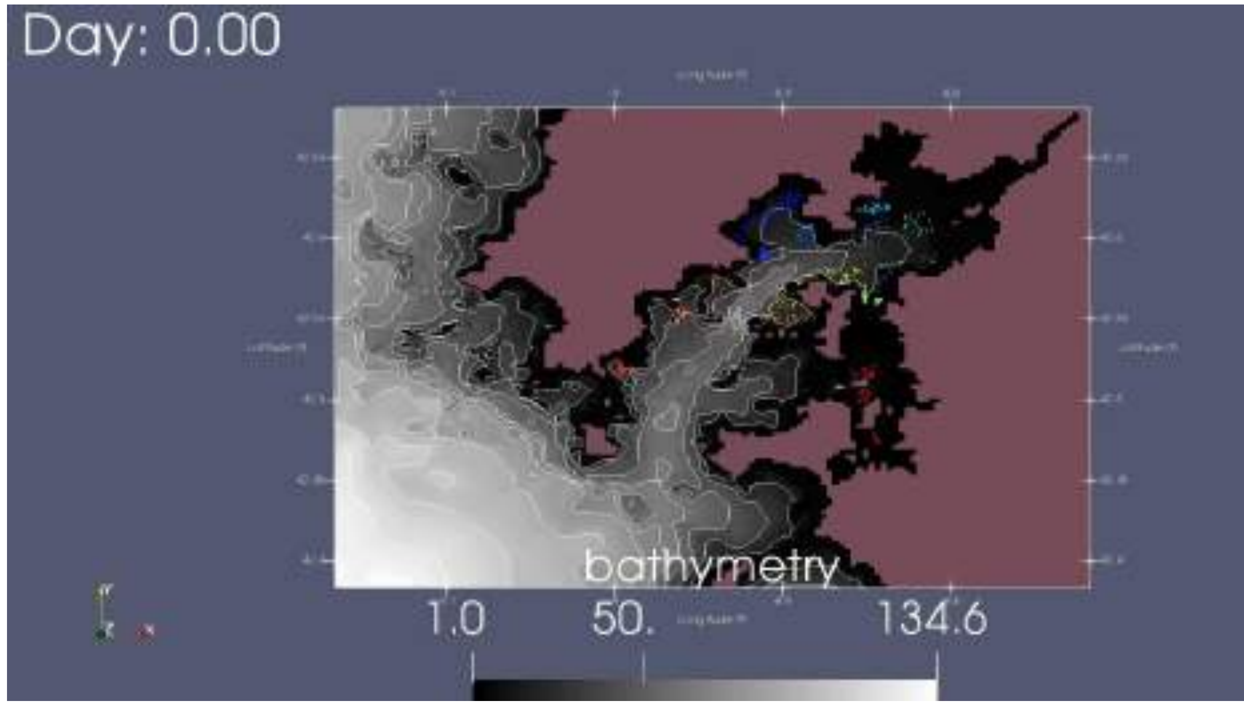


Concentration maps: hot spots

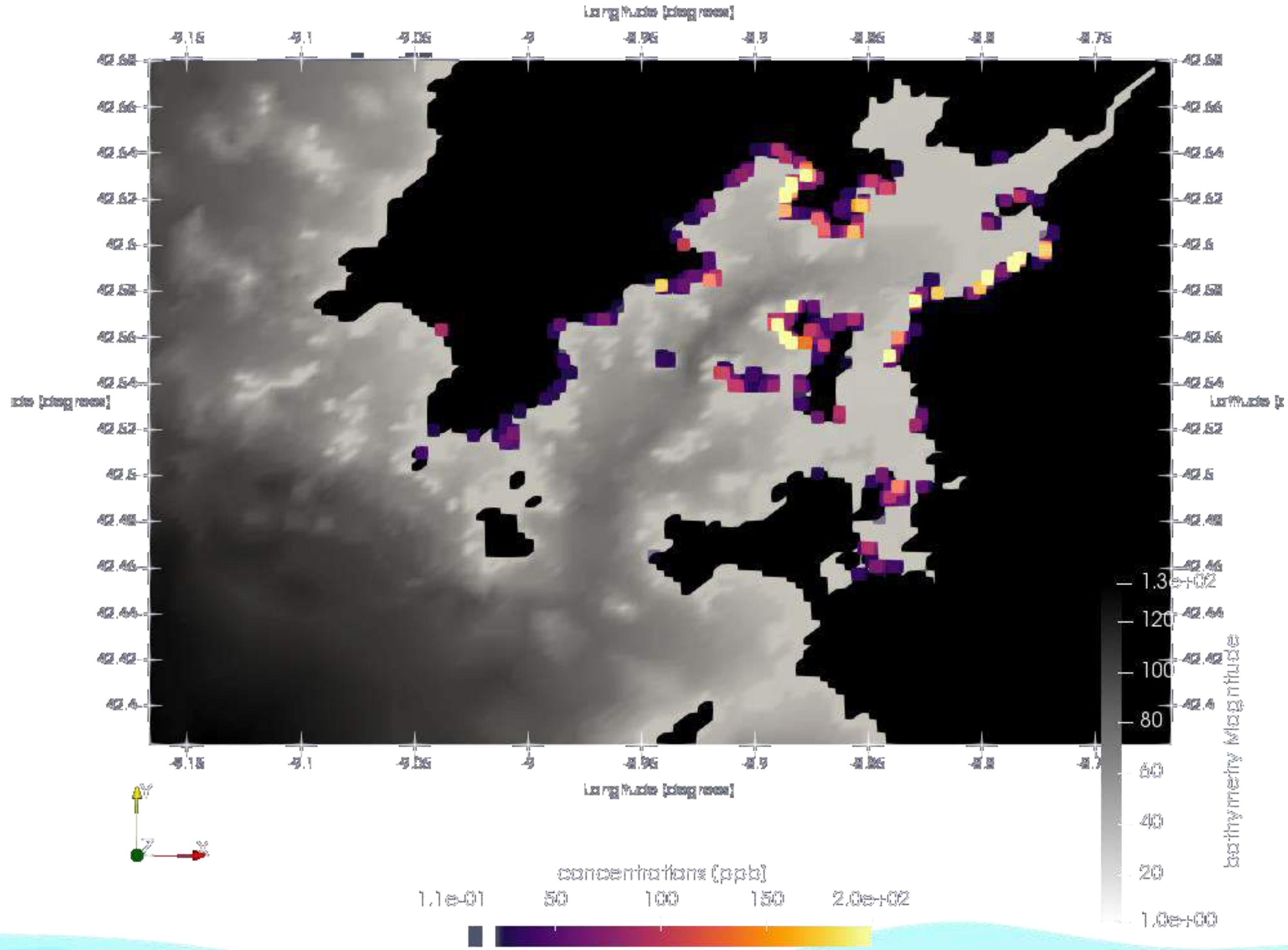




Local escenarios: Mussel pegs - Arousa



Local escenarios: Mussel pegs - arousa



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Conclusions

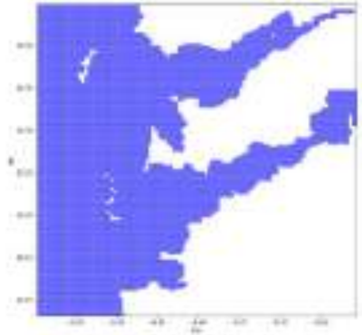
•Our work inside the CleanAtlantic Project is to make mathematical models to describe the motion of marine litter. and translate it to computational code.

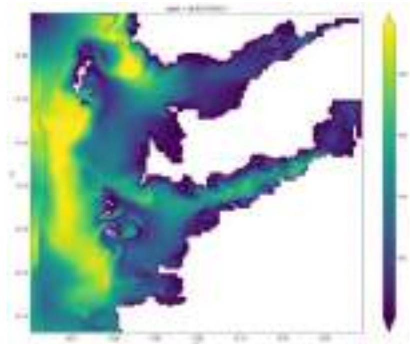
•We simulate different escenarios at different scales to provide useful information about concentration of marine litter to aid for decision making.

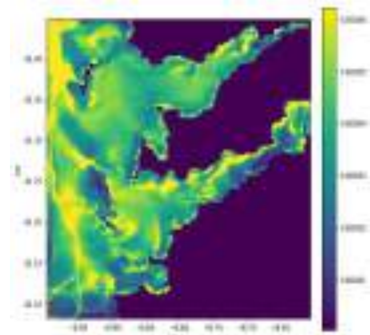
5. Medidas Lagrangianas

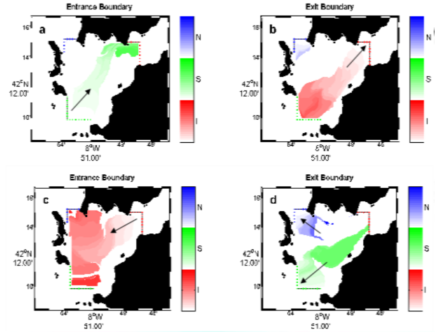
- **Medidas que utilicen toda la información integrada de las trayectorias de los de los escenarios simulados.**

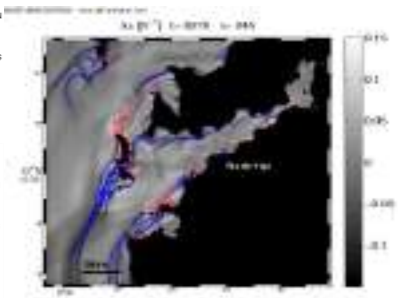
- **Mapas de densidad**: Observar en que regiones(celdas) hay más cantidad de basura acumulada: Hotpots.
- **Probabilidad**: Probabilidad de que la basura marina que haya tenido su origen en un punto alcance un determinado destino.
- **Time residence**: Tiempo que la basura marina en una determina región.
- **Dispersión absoluta**: Cuantificar la dispersion de la basura partiendo de su lugar de origen.
- **Barreras del transporte**: Identificar aquellas regiones con una dinámica similar y ver donde no hay intercambio de masas de agua.
- **Mapas Lagrangianos sinópticos(SLM):** Medir el ratio de escape de las partículas o basura marina para una región dada.
- **Matrices de connectividad:** Observar como es el intercambio de particulas entre regiones para ver su conexión. Por ejemplo, el agua que va de una ría a otra.



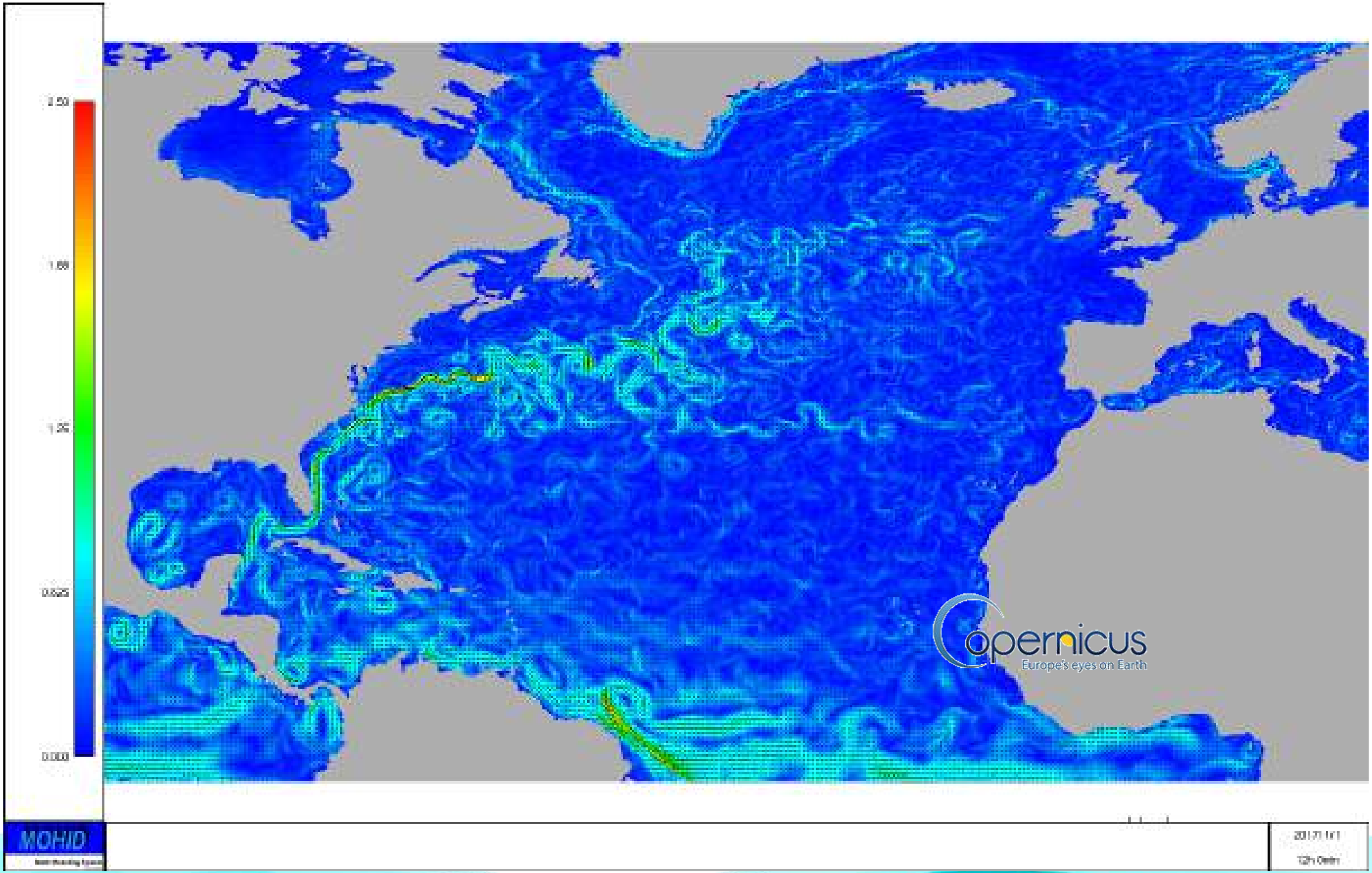






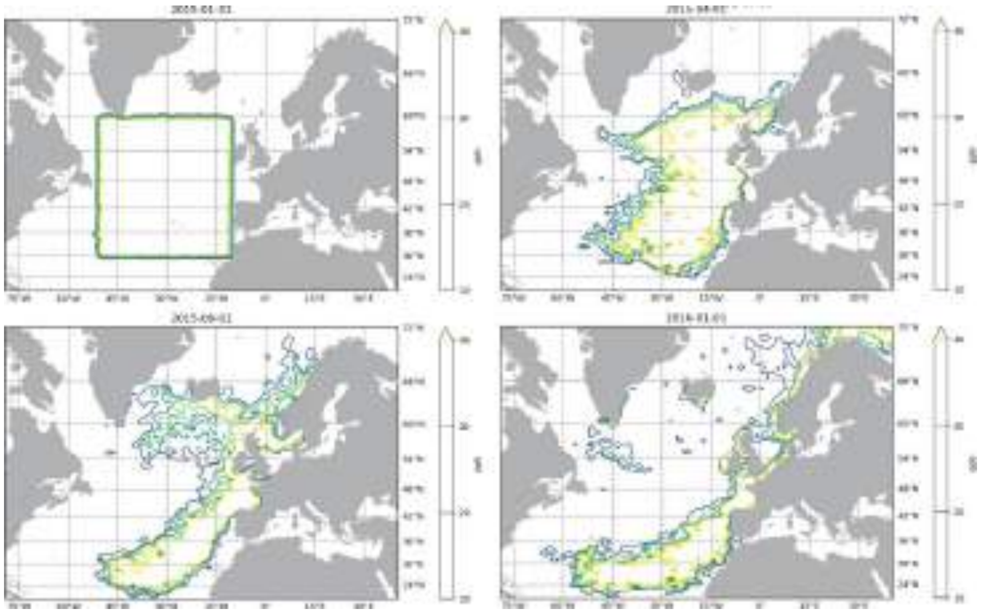


Global circulation models

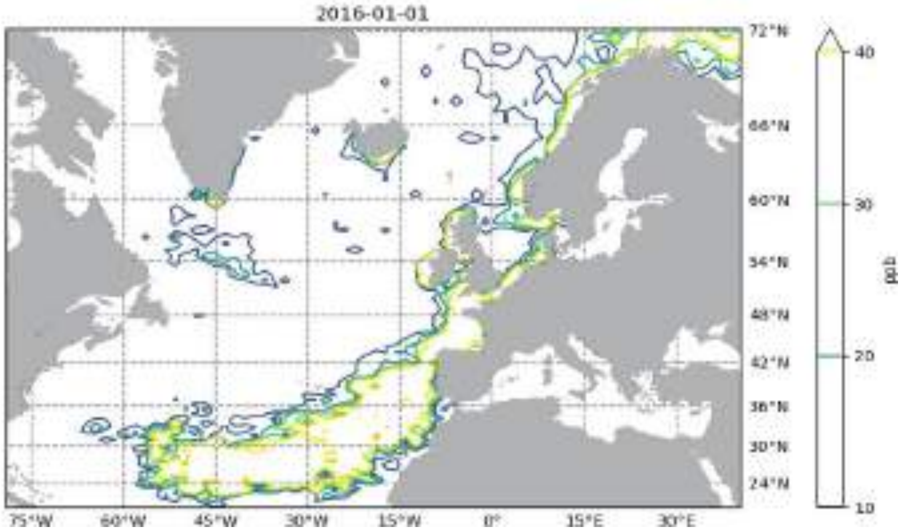


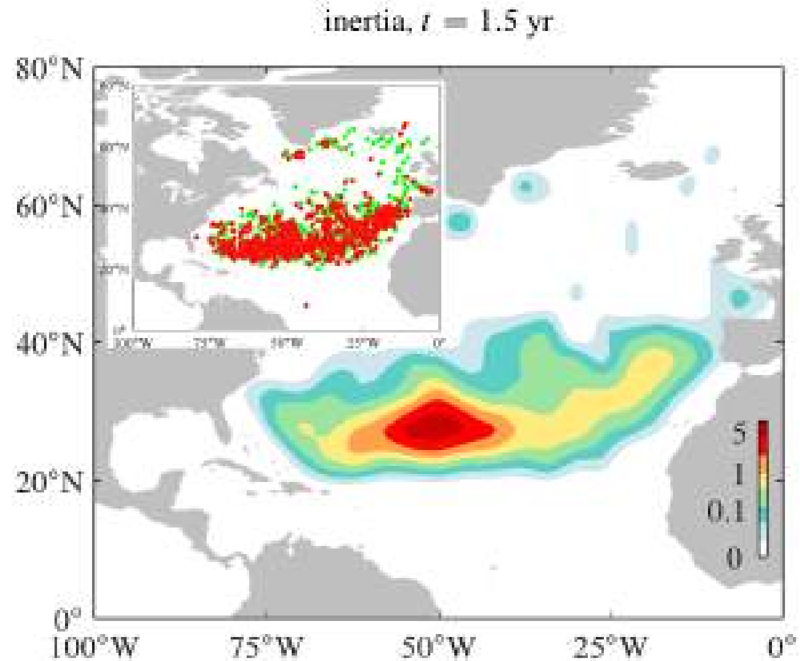
6. Regional escenarios

5.a Aproximación global: Hotspots



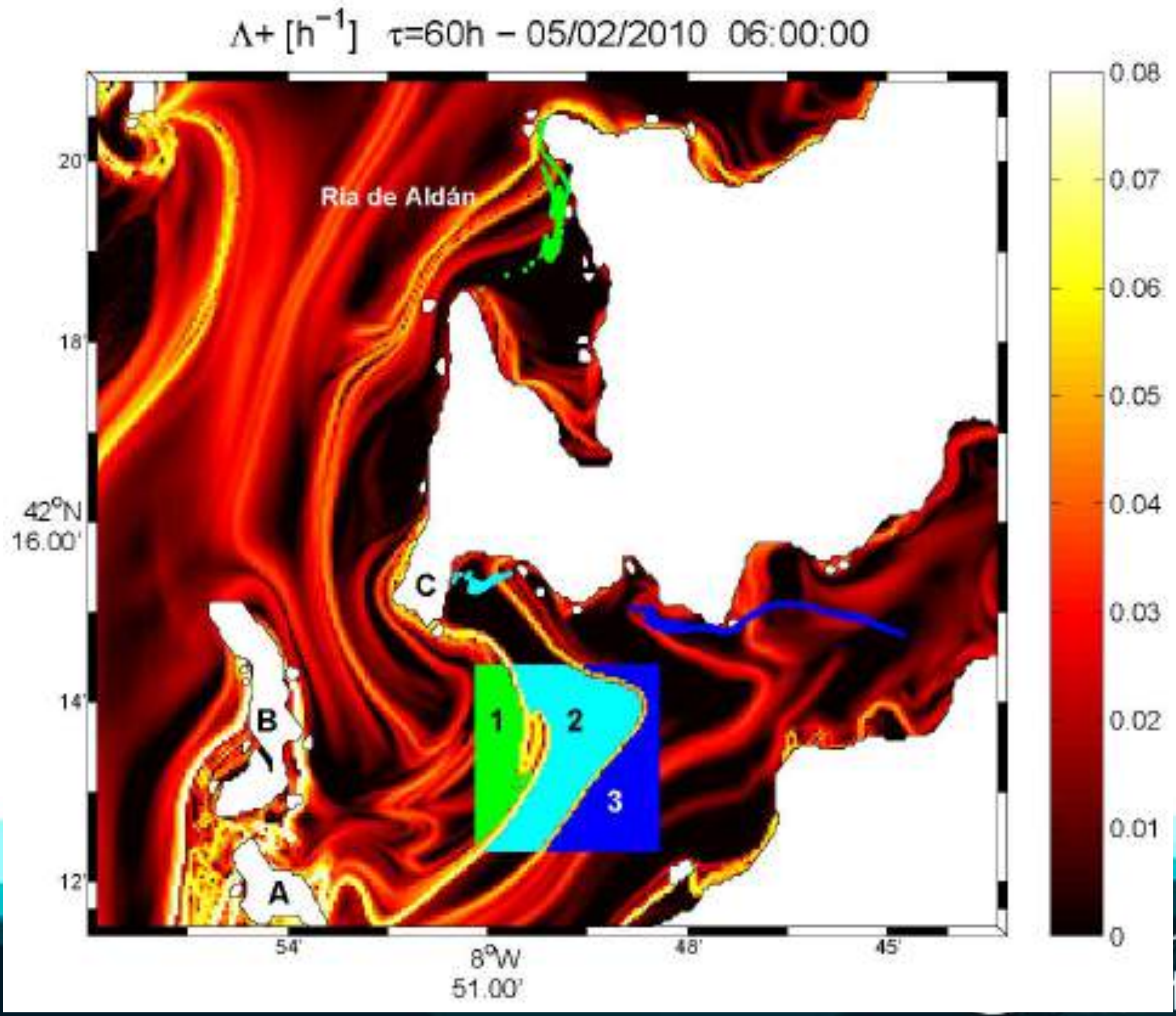
Preliminary results



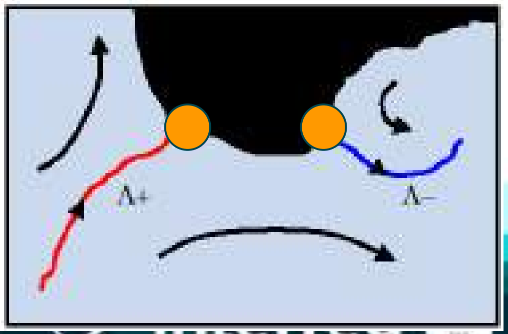


Beron-Vera, F. J., M. J. Olascoaga, and R. Lumpkin (2016), Inertia-induced accumulation of flotsam in the subtropical gyres, Geophys. Res. Lett., 43, 12,228–12,233,doi:10.1002/2016GL071443.

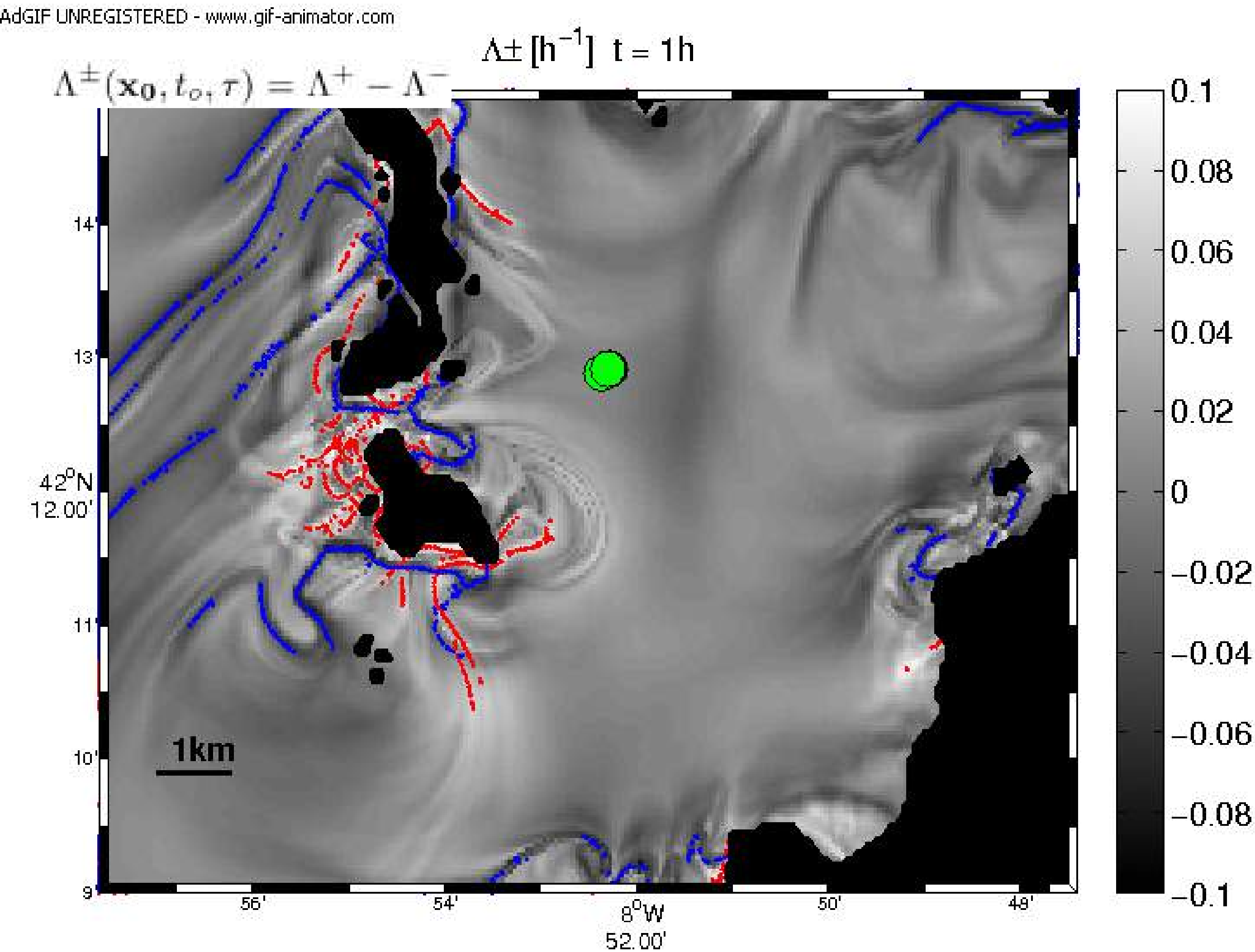
Lagrangian Coherent Structures in the Ria de Vigo – Visualize surface transport



- Repelling stable manifolds
- Indicate future separation of water bodies



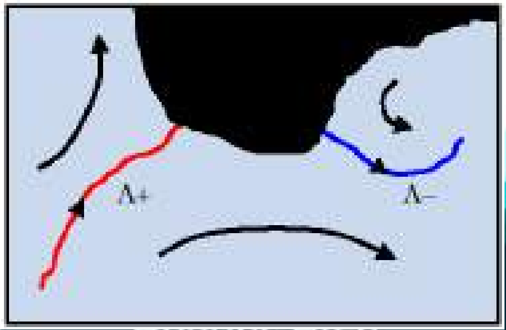
Validation with drifters – LCS from model. Transport barriers?



Repelling divergent LCS

Attracting convergent LCS

Drifter

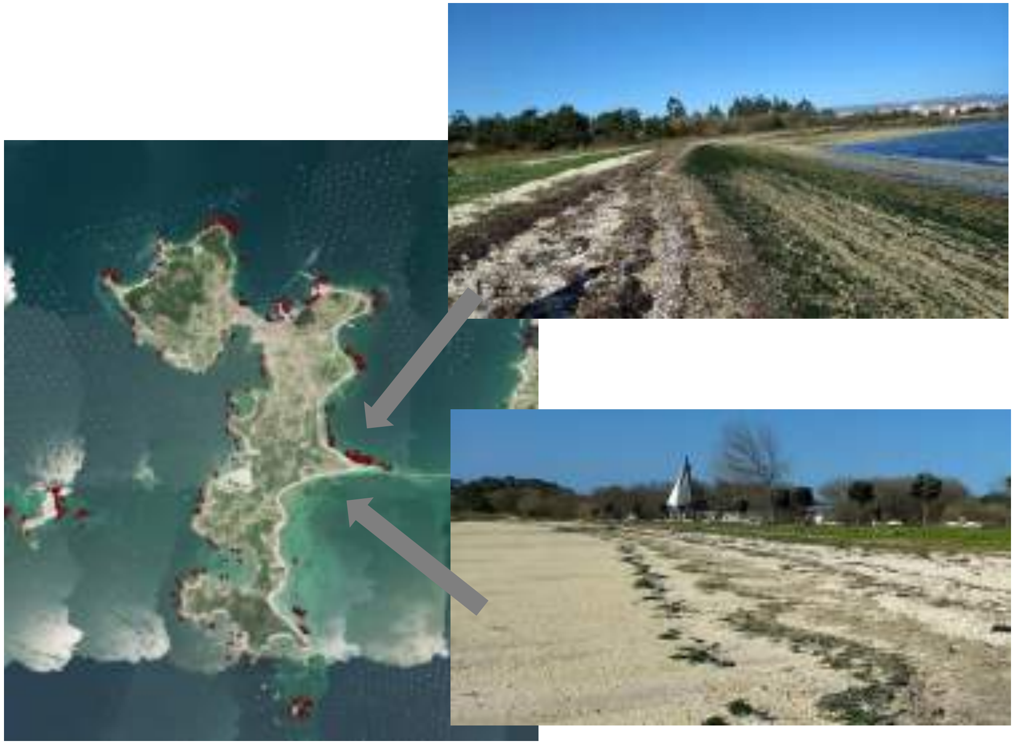


Model validation

First Guess to look for pilled-up areas.

An **accumulation map** will deliver before surveying the areas:

- Using the results of a **daily operational lagrangian** model
- Coast will be classified in **500 m long segments**



Model validation

- Mussel rafts in Galicia (NW Spain)
- Mussel ropes with pegs that break after extracting the mussels
- Pegs/debris end on beaches in Rias gallegas
- Known: Location and period of time for extraction
- Adding a gps to the pegs for a real-time validation
- Drifter buoys will also be released in different points.

5.b Estimación del origen: Integración backward

- **Realizar integraciones hacia atrás en el tiempo para estimar el origen de la basura marina.**

- **Origen: Áreas con un densidad de puntos significante de la integración hacia atrás.**

- **Non-coastal origin: Particles don't reach the coast: Estimate the contribution with a non-coastal origin (degradation, ships,…)**

- **Posibilidad de actuar en puntos concretos para limitar contaminación de determinadas áreas**

Conclusiones

- Dificultad para modelizar correctamente los macroplásticos. Es importante conocer su densidad, forma y evolución temporal de estas características
- La localización de hotspots en el fondo marino depende de factores como la vegetación, acumulación de piedras, etc.
- Considerando el tamaño del plástico mejora la modelización respecto a un tratamiento puramente Lagrangiano.
- CleanAtlantic desarrollará herramientas suficientes para la toma de decisiones; focos más contaminantes, localización de hotspots, etc.