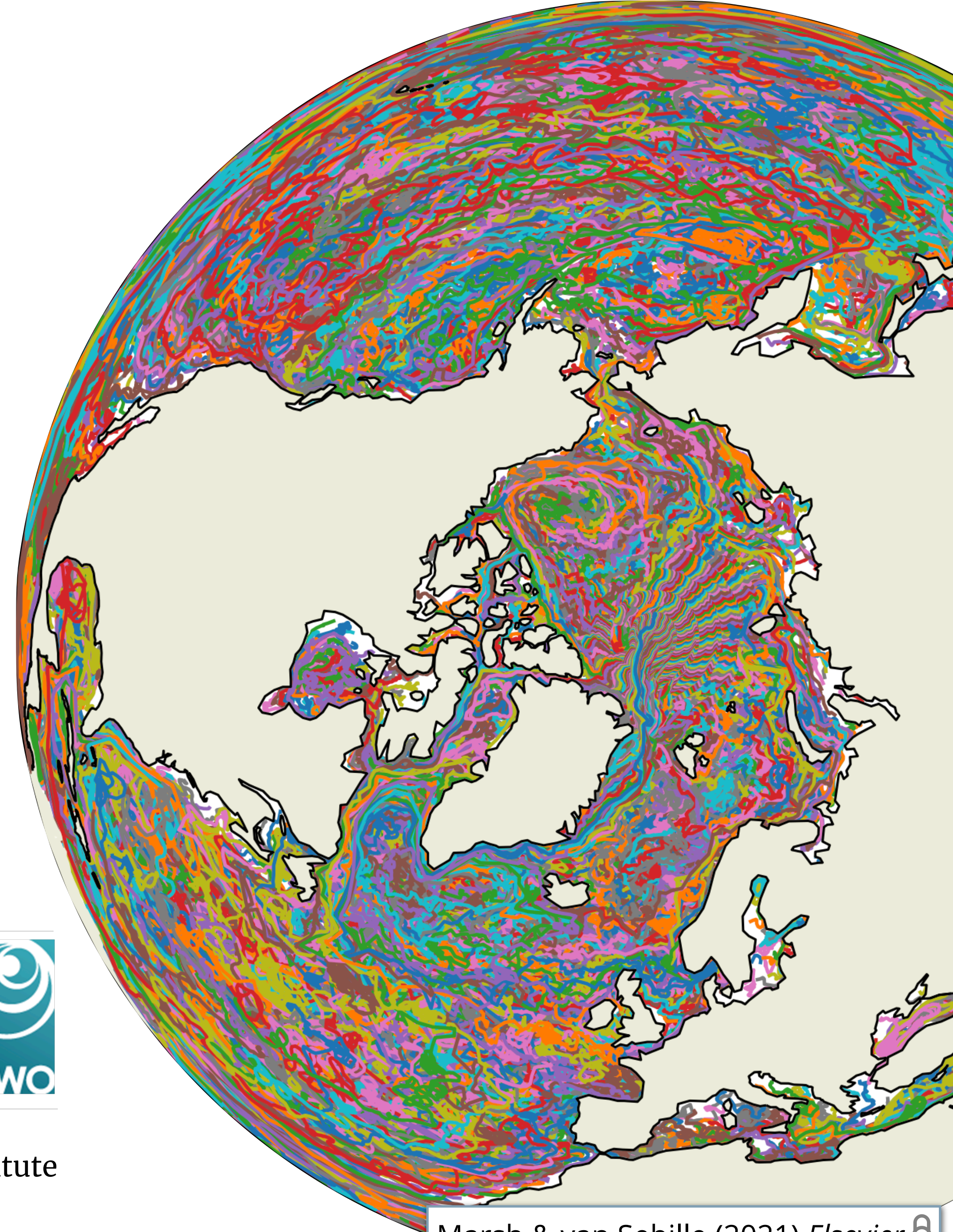


Whose plastic is that?

Using Bayesian Inference to attribute macroplastic sources and sinks

Erik van Sebille, and the oceanparcels.org/utrechtteam



Pacific Community
Communauté
du Pacifique

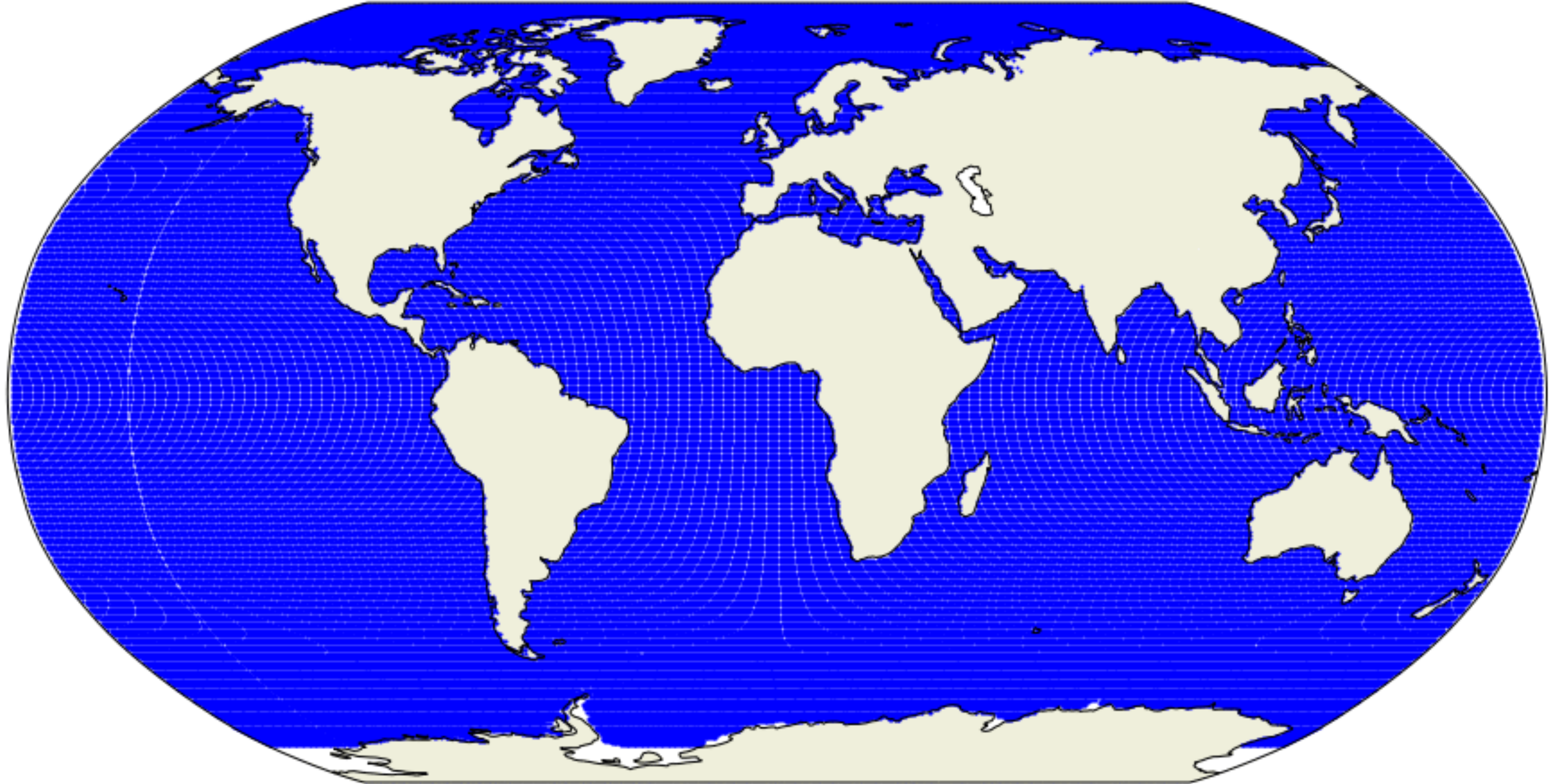


Institute for
Marine and Atmospheric
research Utrecht

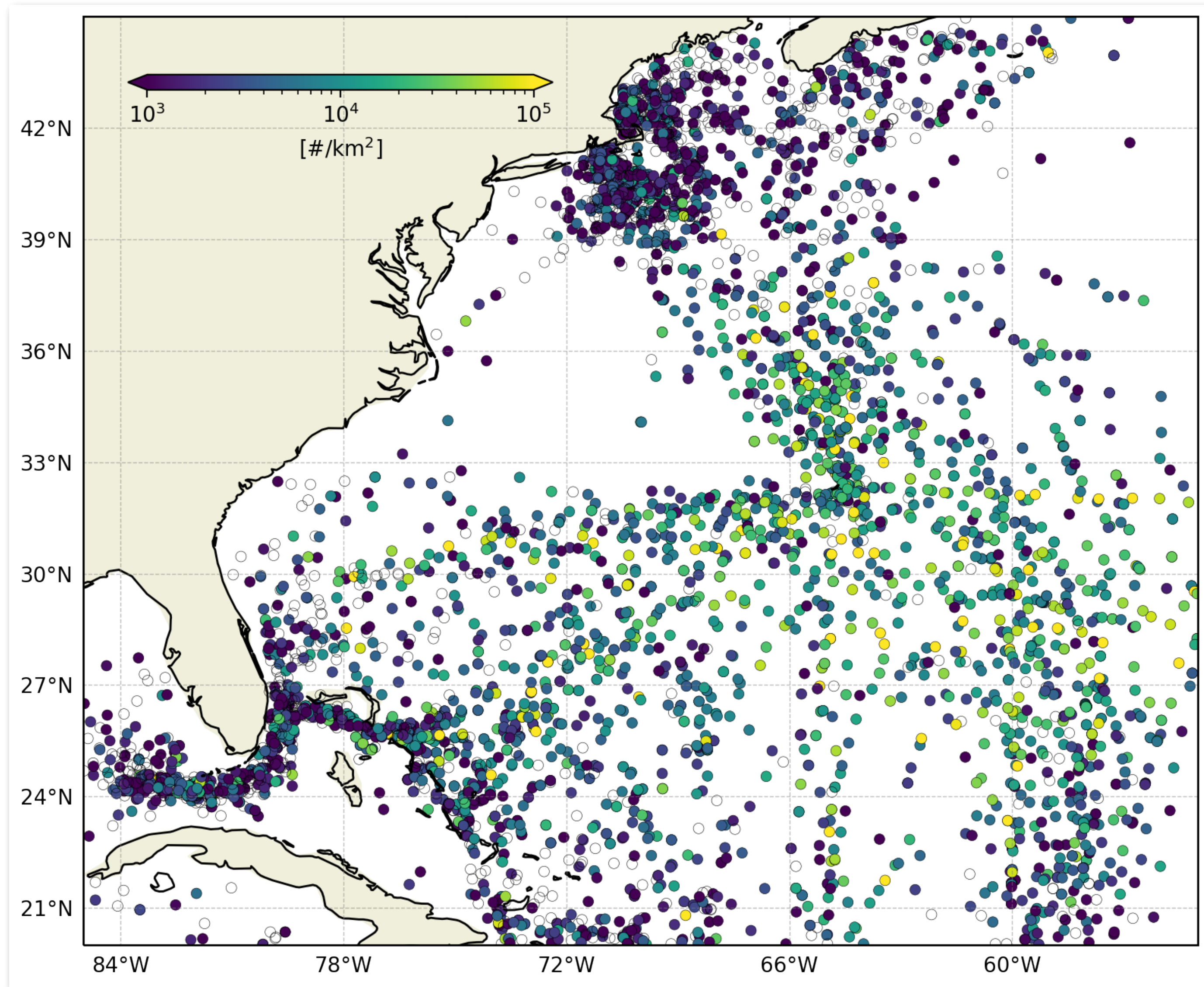
Freudenthal Institute

Simulating virtual particles at the surface of the ocean

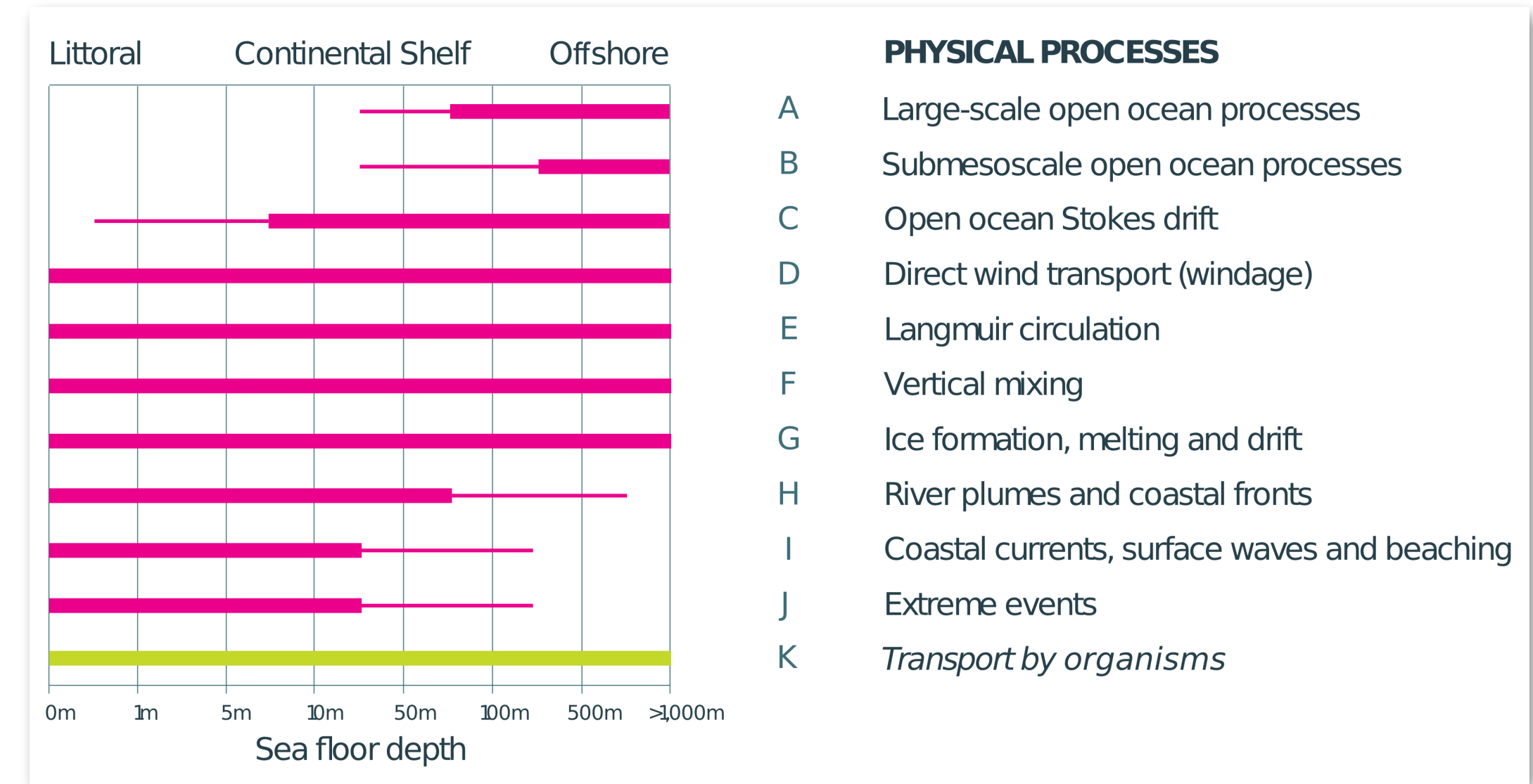
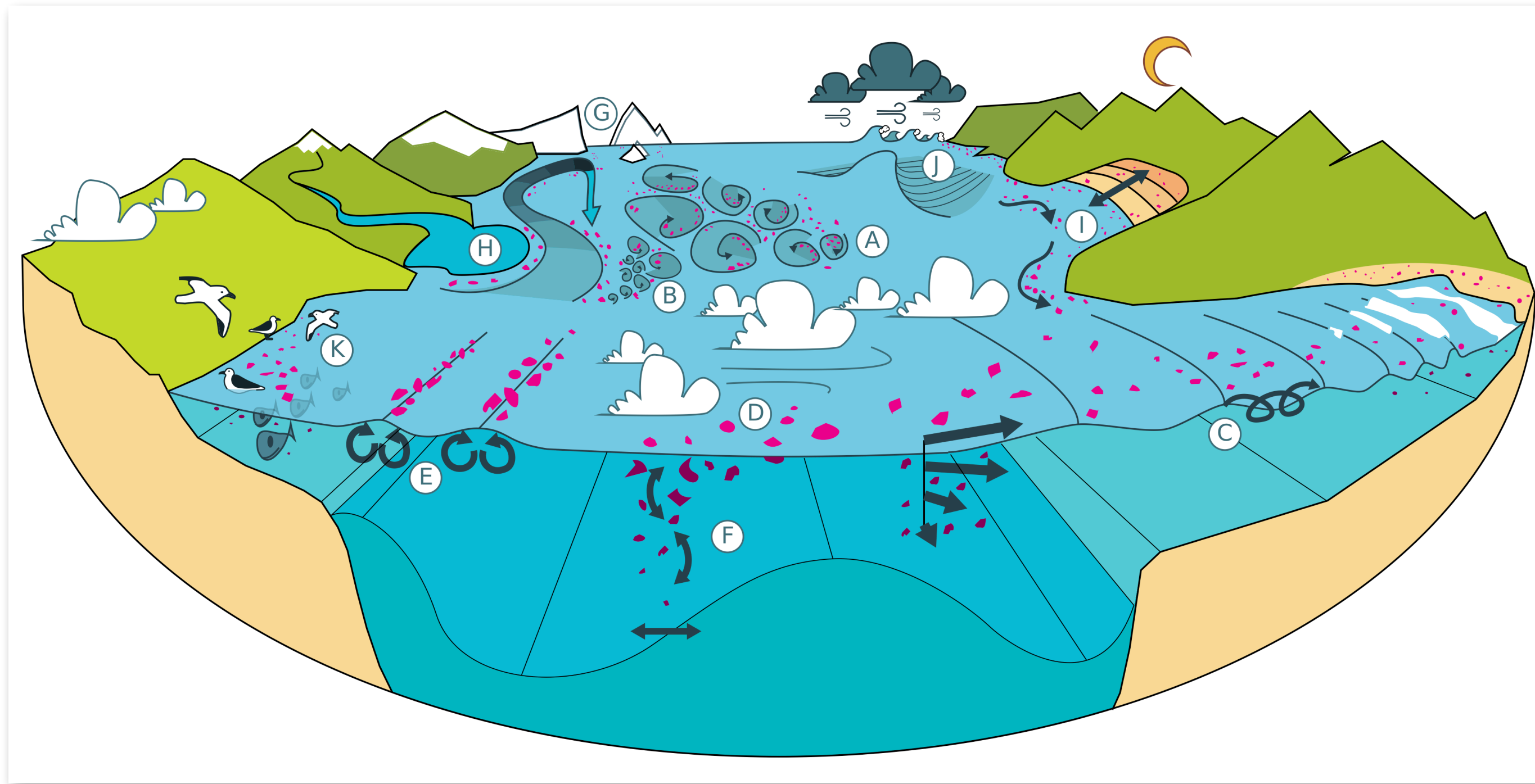
Particles in 1/12° NEMO surface fields at time 2000-01-03



Variability below the gyre scale



The physical oceanography of the transport of floating marine debris



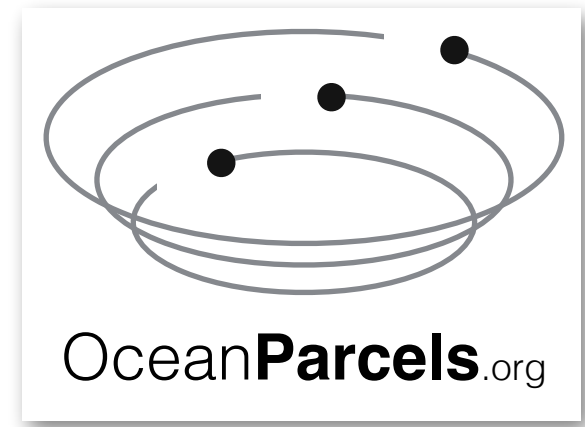
Institute for Marine and Atmospheric research Utrecht

Freudenthal Institute

van Sebille, Aliani, Law, Maximenko, Alsina, Bagaev, Bergmann, Chapron, Chubarenko, C3zar, Delandmeter, Egger, Fox-Kemper, Garaba, Goddijn-Murphy, Hardesty, Hoffman, Isobe, Jongedijk, Kaandorp, Khatmullina, Koelmans, Kukulka, Laufk3tter, Lebreton, Lobelle, Maes, Martinez-Vicente, Morales Maqueda, Poulain-Zarcos, Rodr3guez, Ryan, Shank, Shim, Suaria, Thiel, van den Bremer & Wichmann (2020) *Environmental Research Letters*

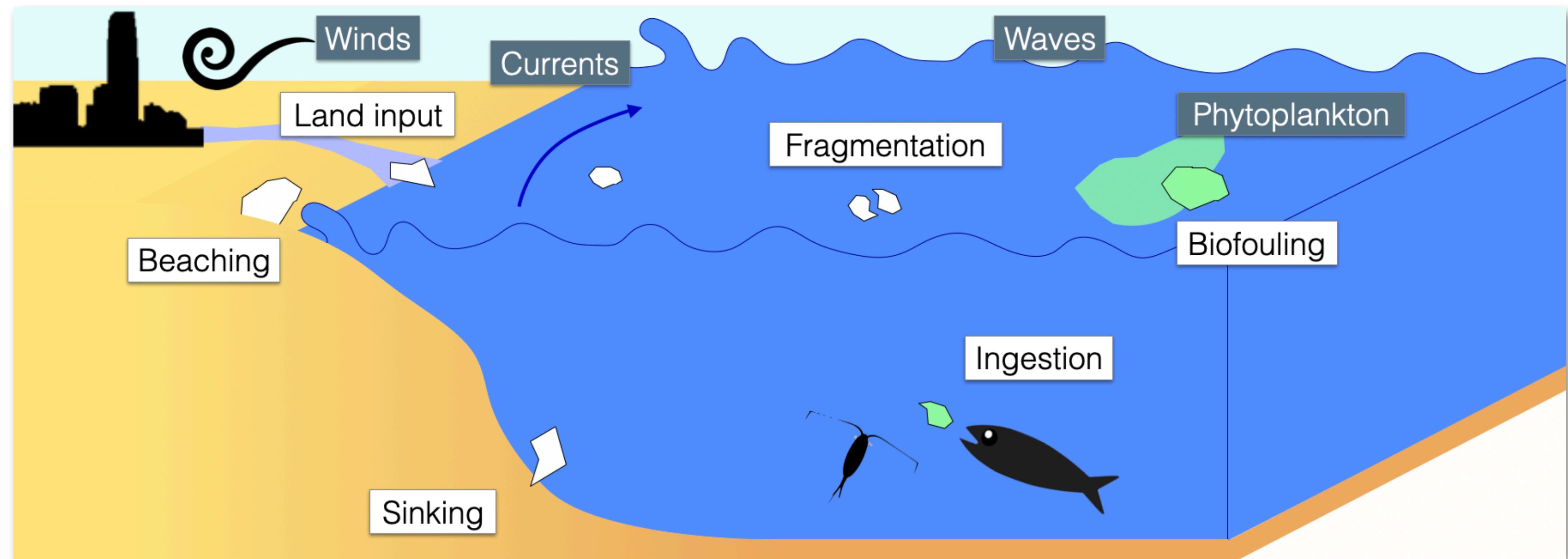
Virtual particles: Lagrangian analysis in an ocean model

- Lagrangian Ocean Analysis: Tracking virtual particles in 3D
- Parcels: *"Probably A Really Computationally Efficient Lagrangian Simulator"*
- A set of **python classes and methods** to build Lagrangian models



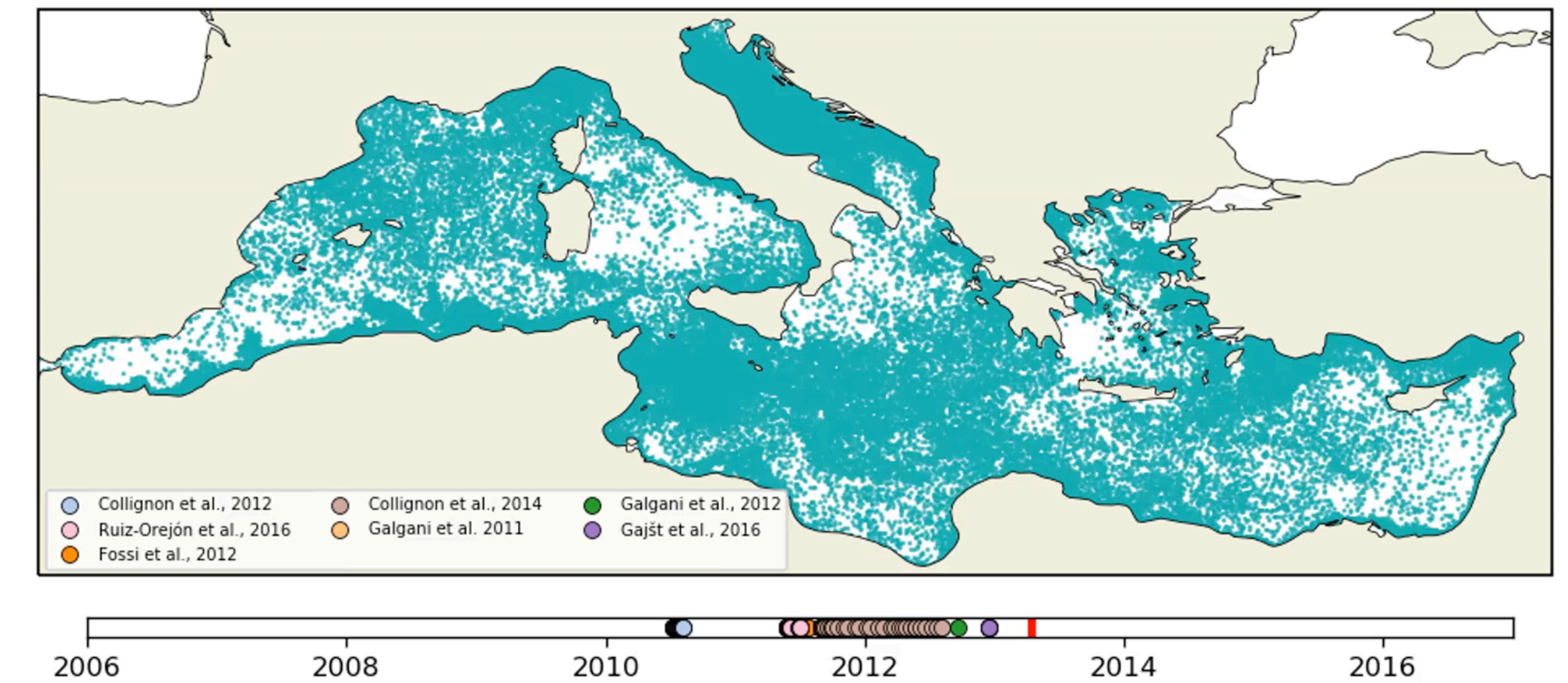
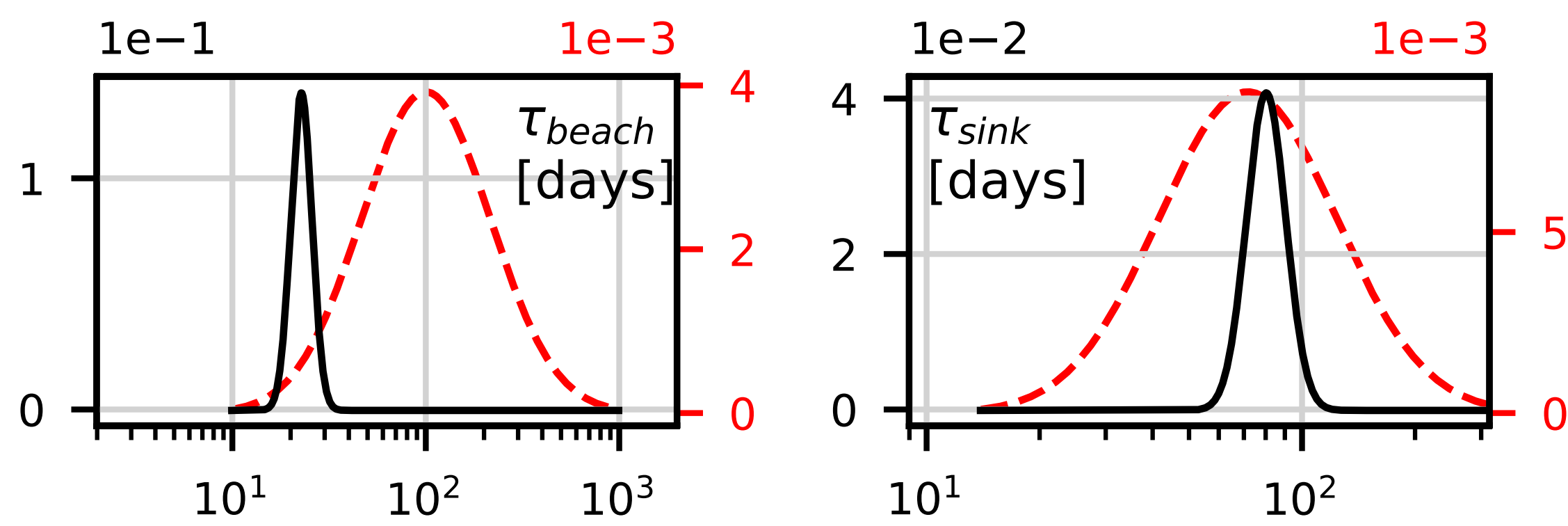
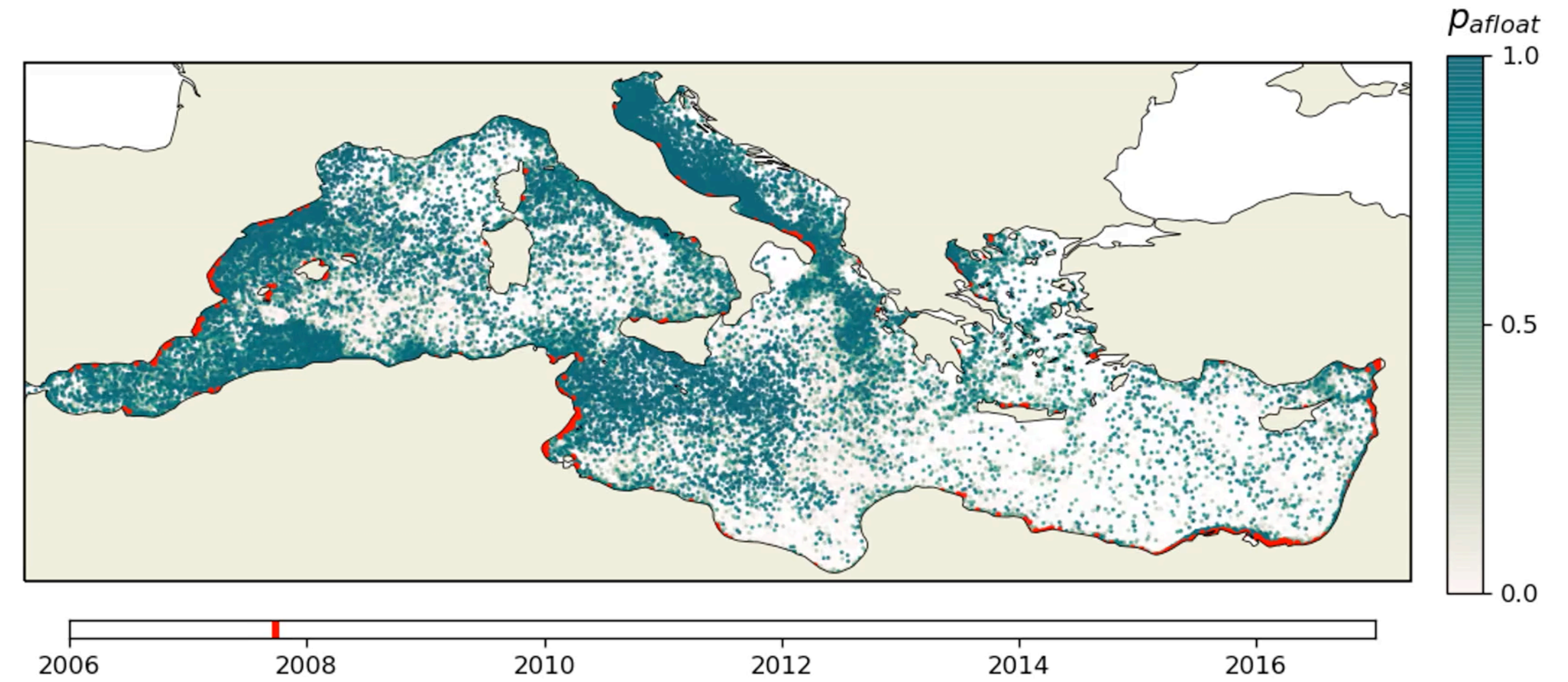
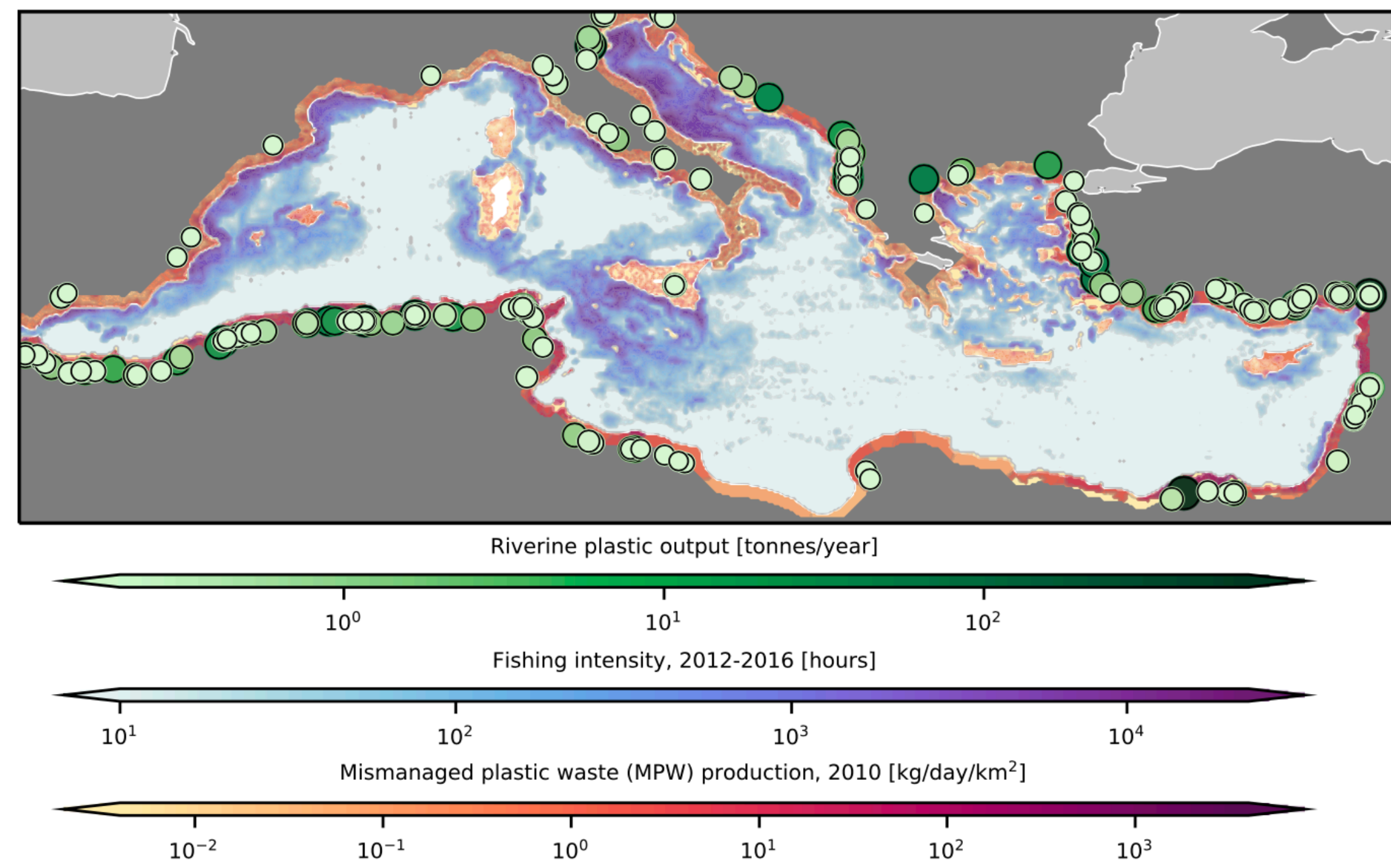
- Incorporate **'behaviour'**

- Wave effects
- Biofouling
- Sinking
- Fragmentation
- Beaching
- Ingestion?

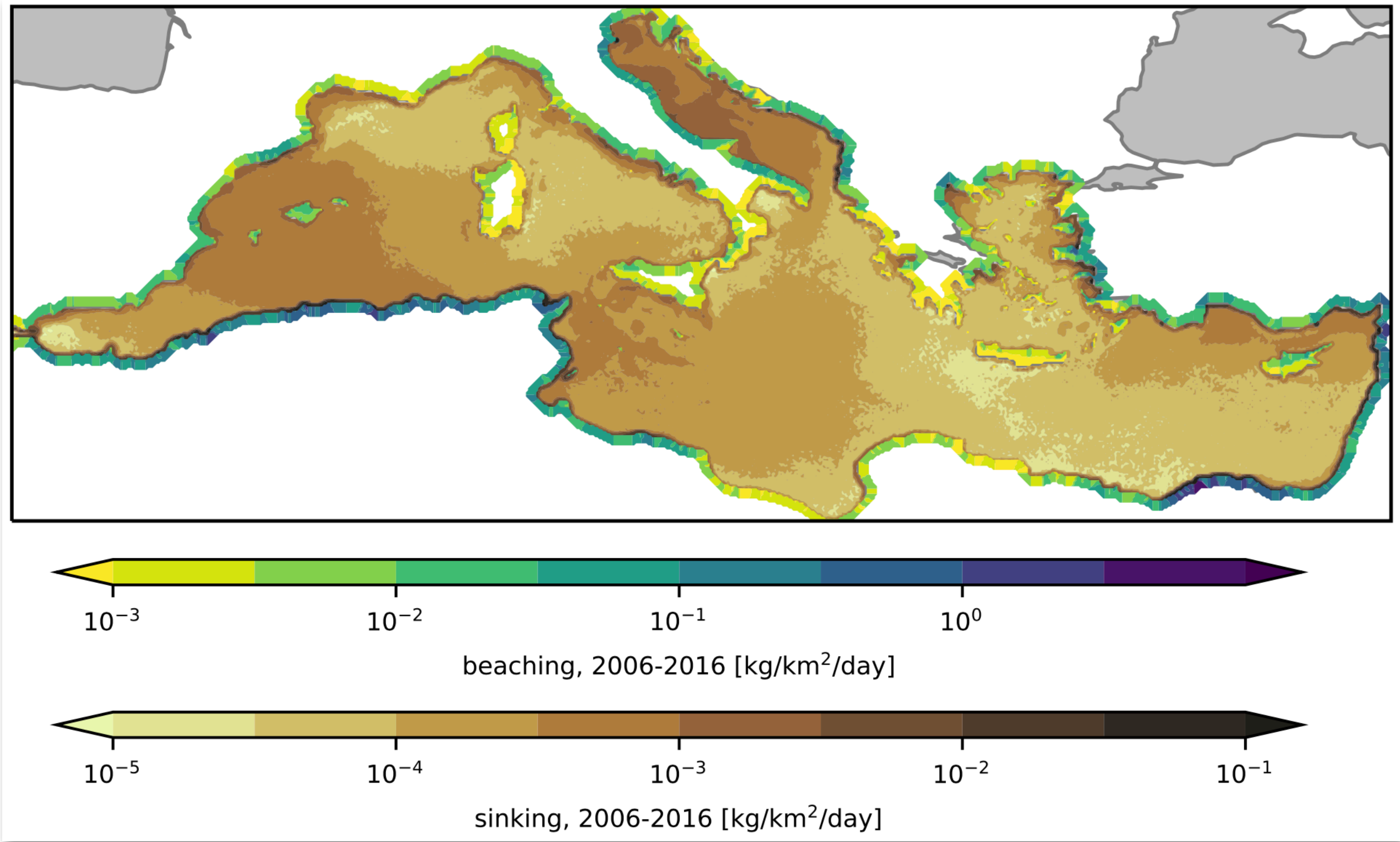


- **Parameterise** with lab- and field studies

The plastic budget in the Mediterranean using Bayesian parameter estimation

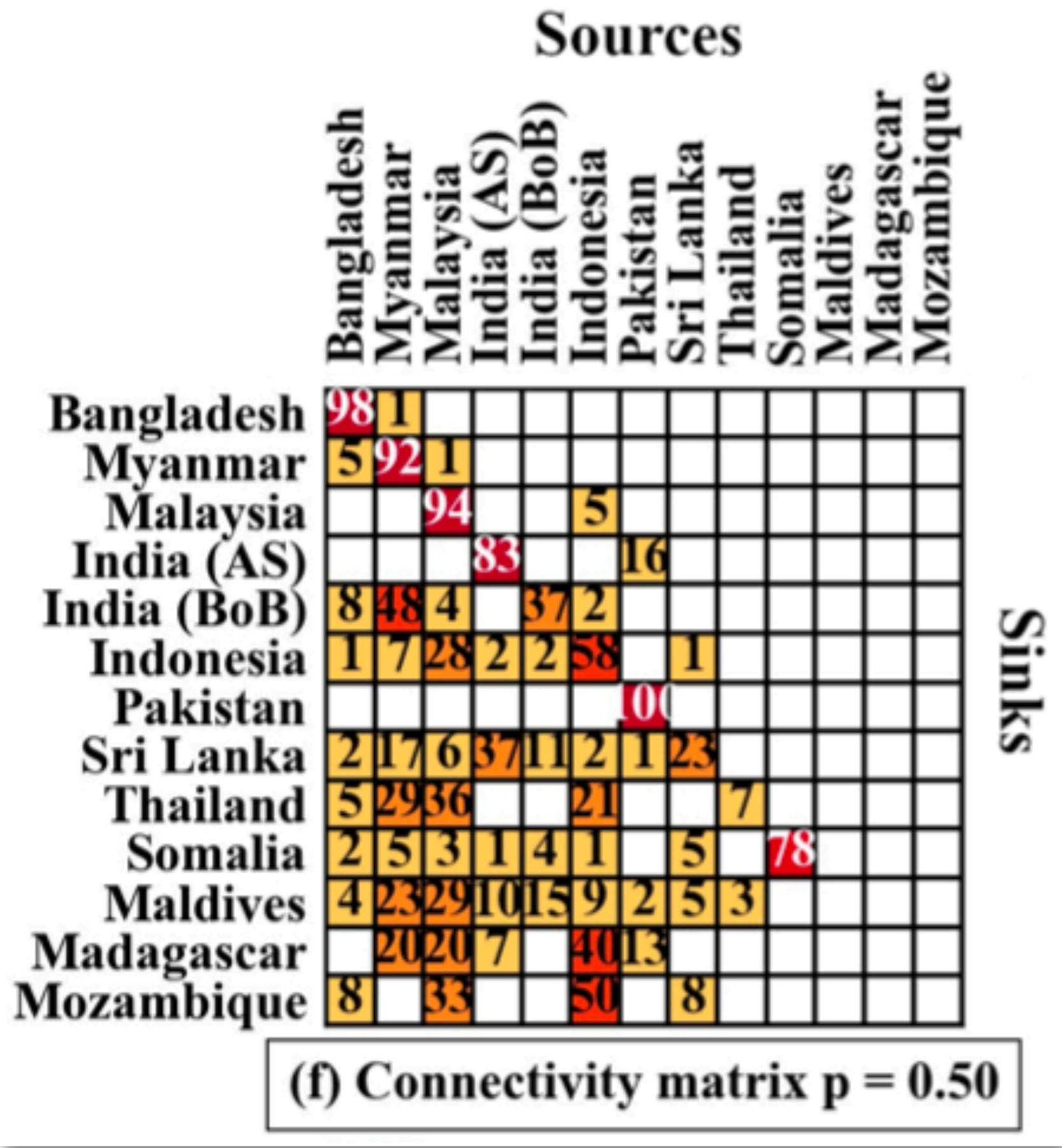
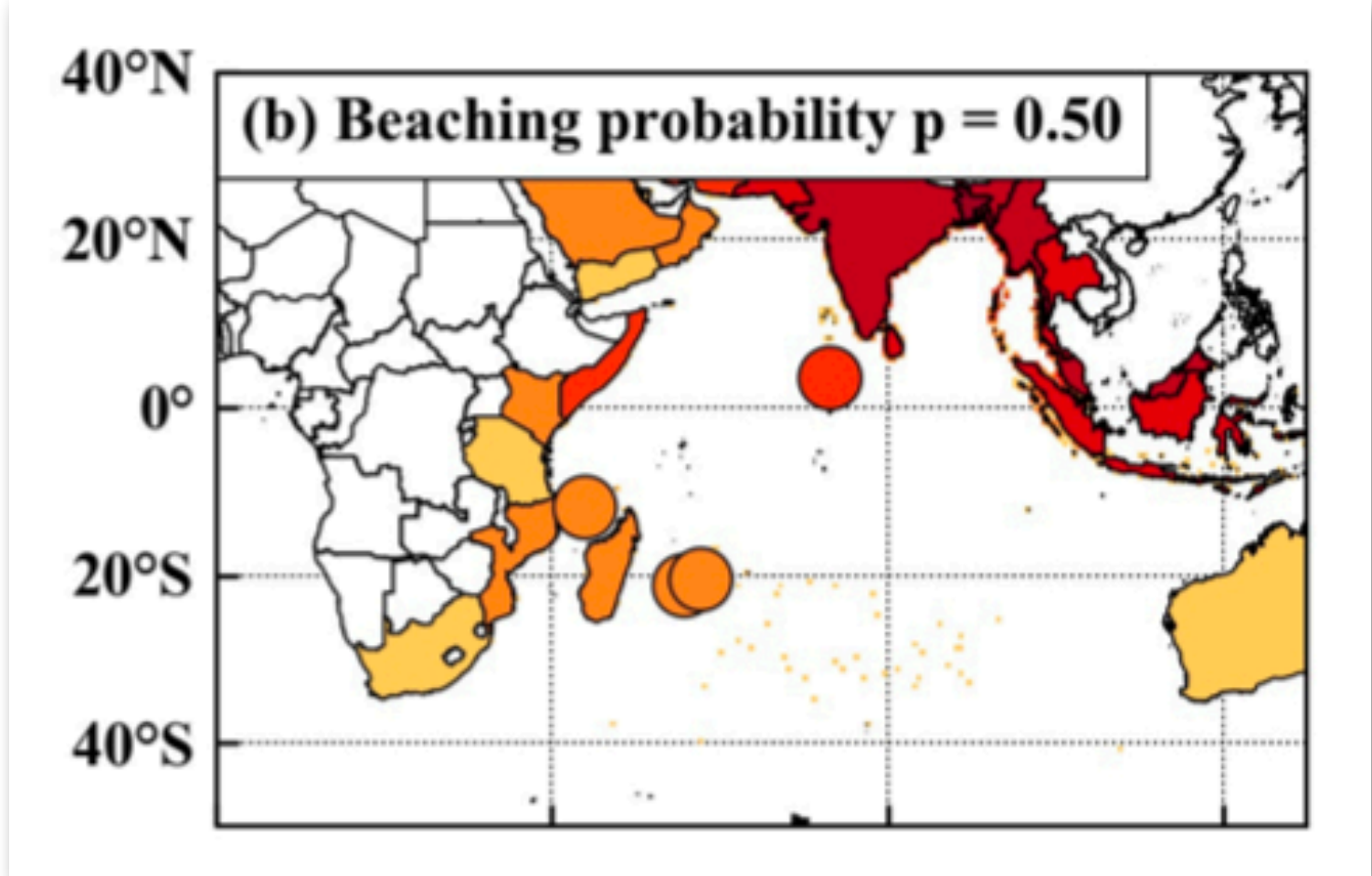
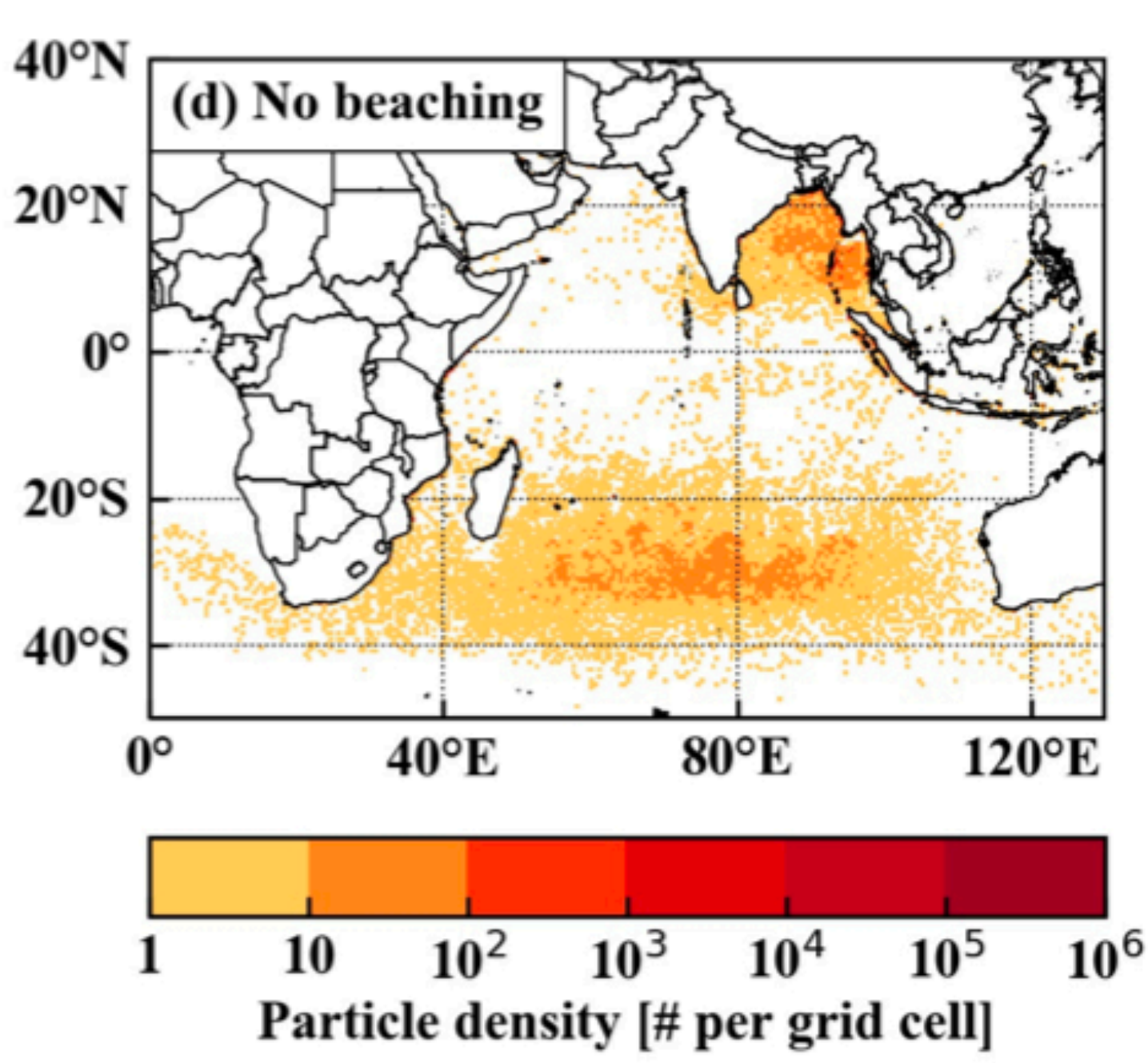


The plastic budget in the Mediterranean using Bayesian parameter estimation

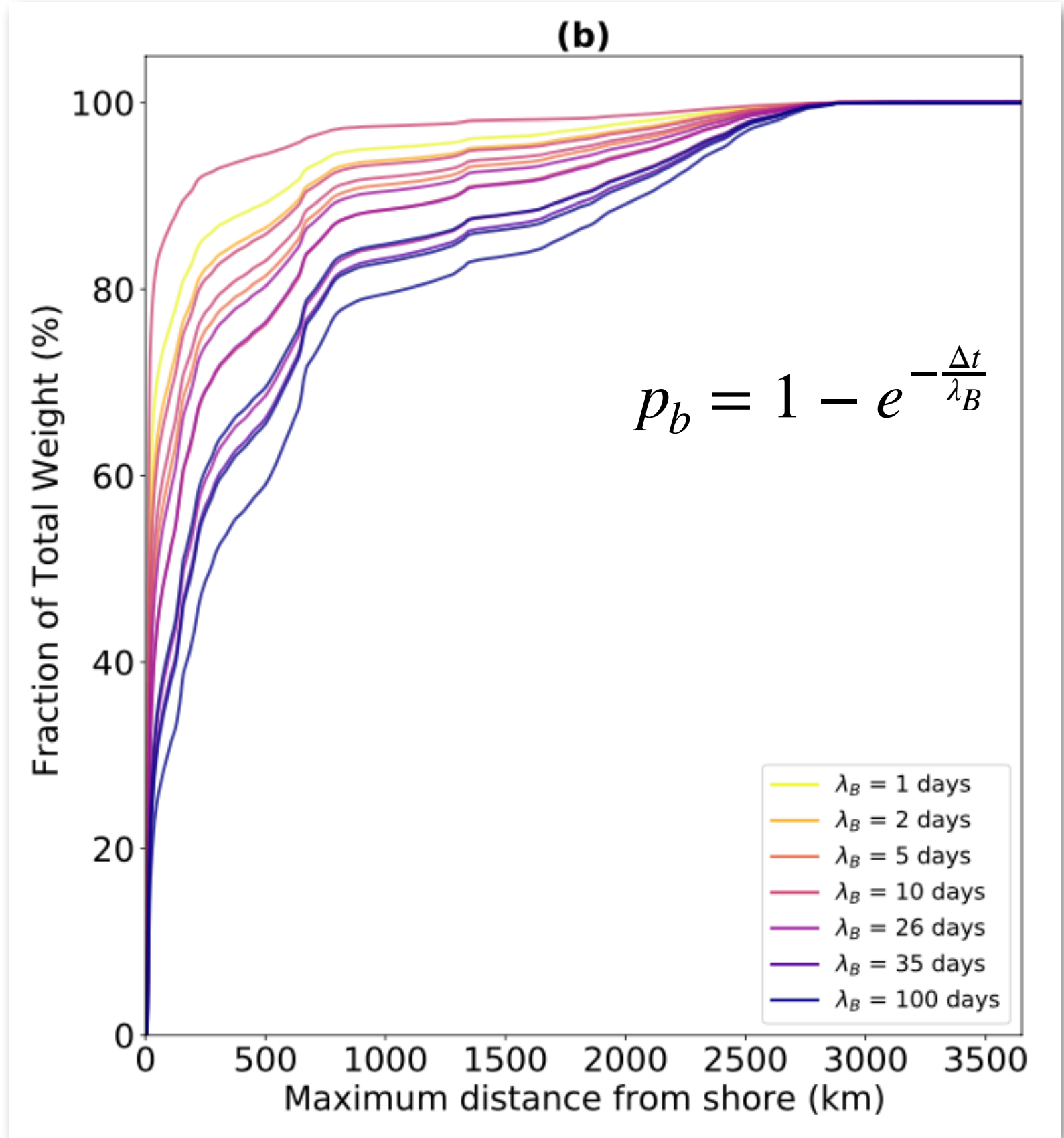
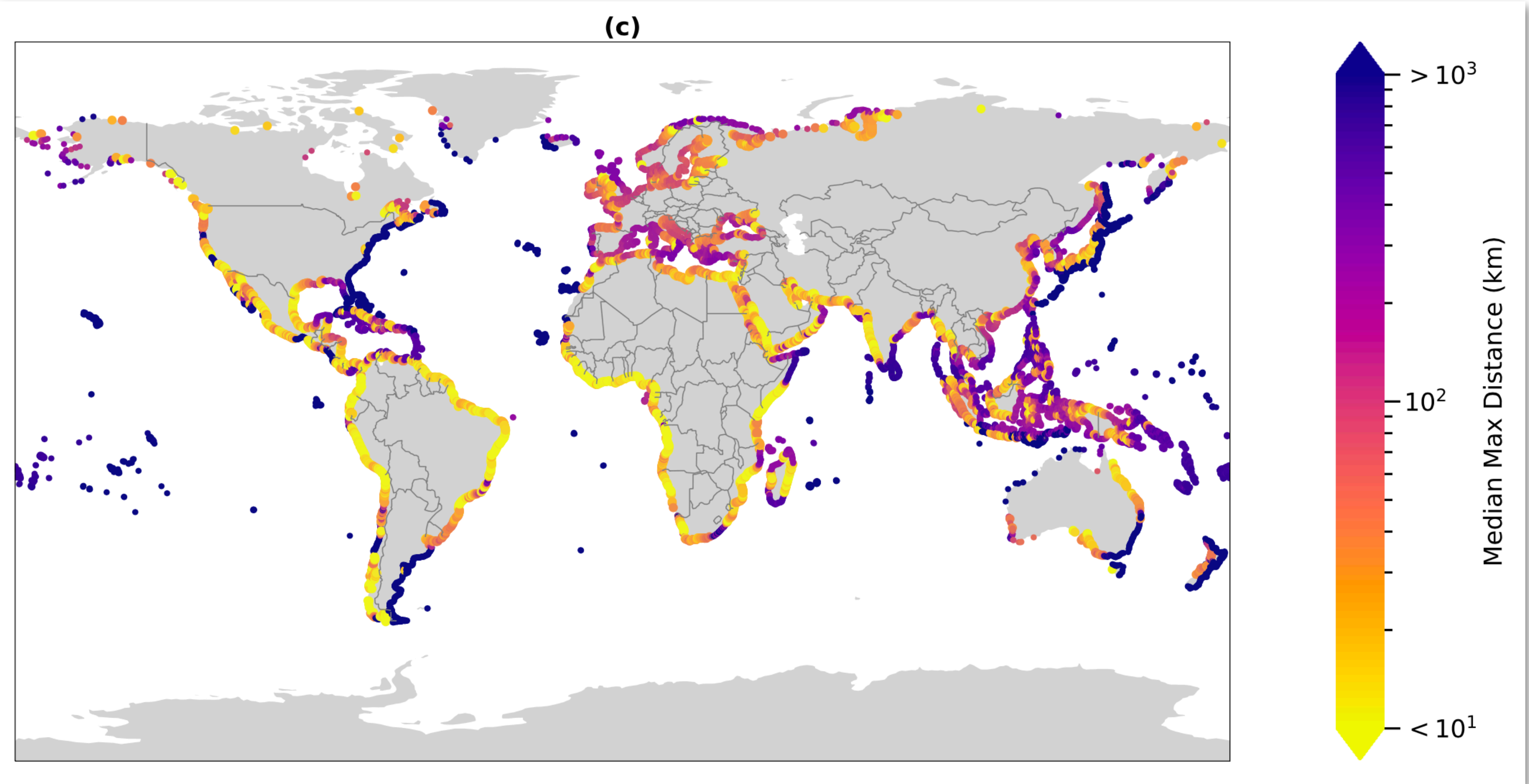


~50% beached | ~40% sunk | ~10% still afloat

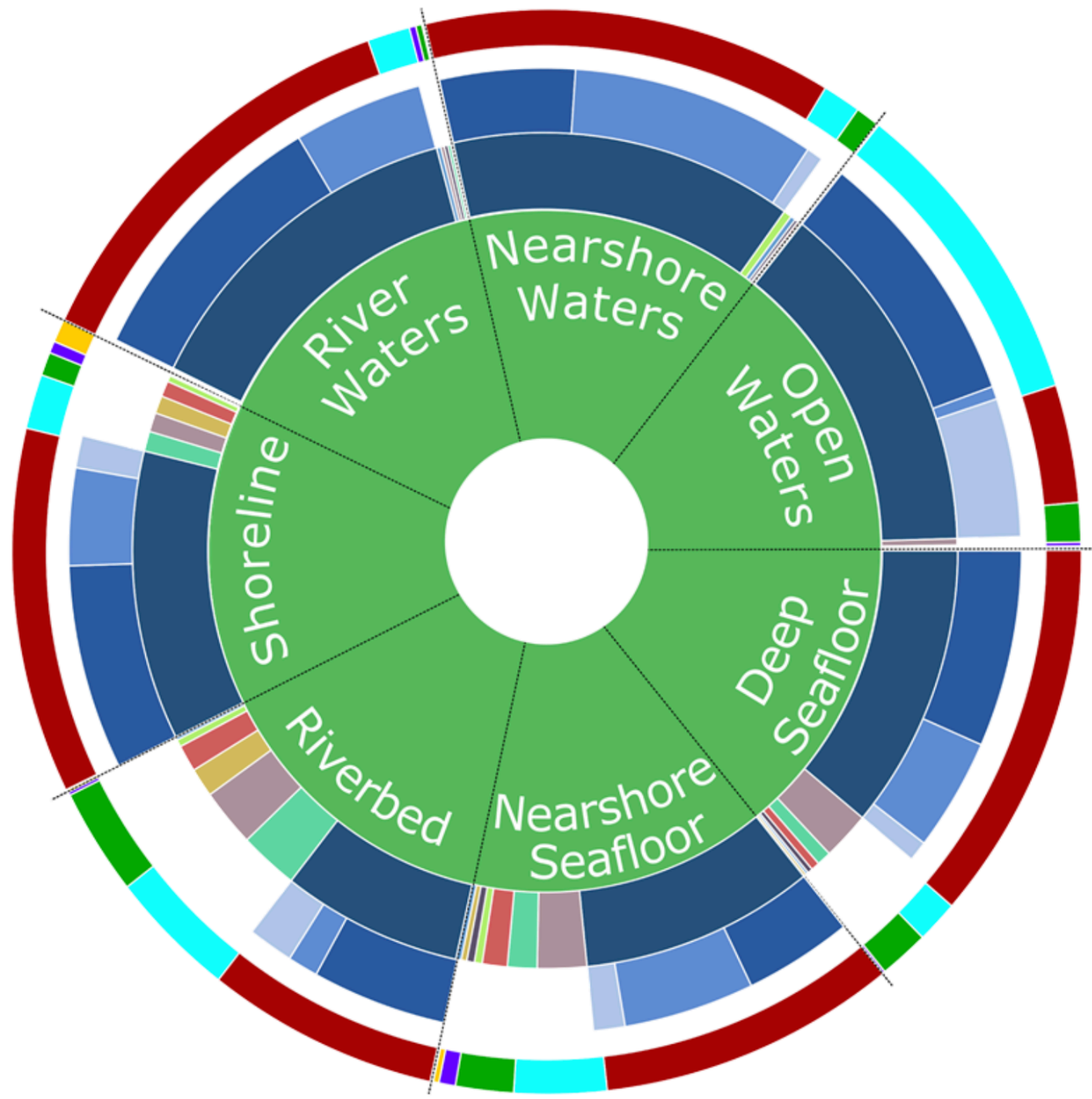
Most plastic that beaches is local?



Most plastic that starts nearshore stays nearshore?



Does consumer plastic stay near-shore?



Material types

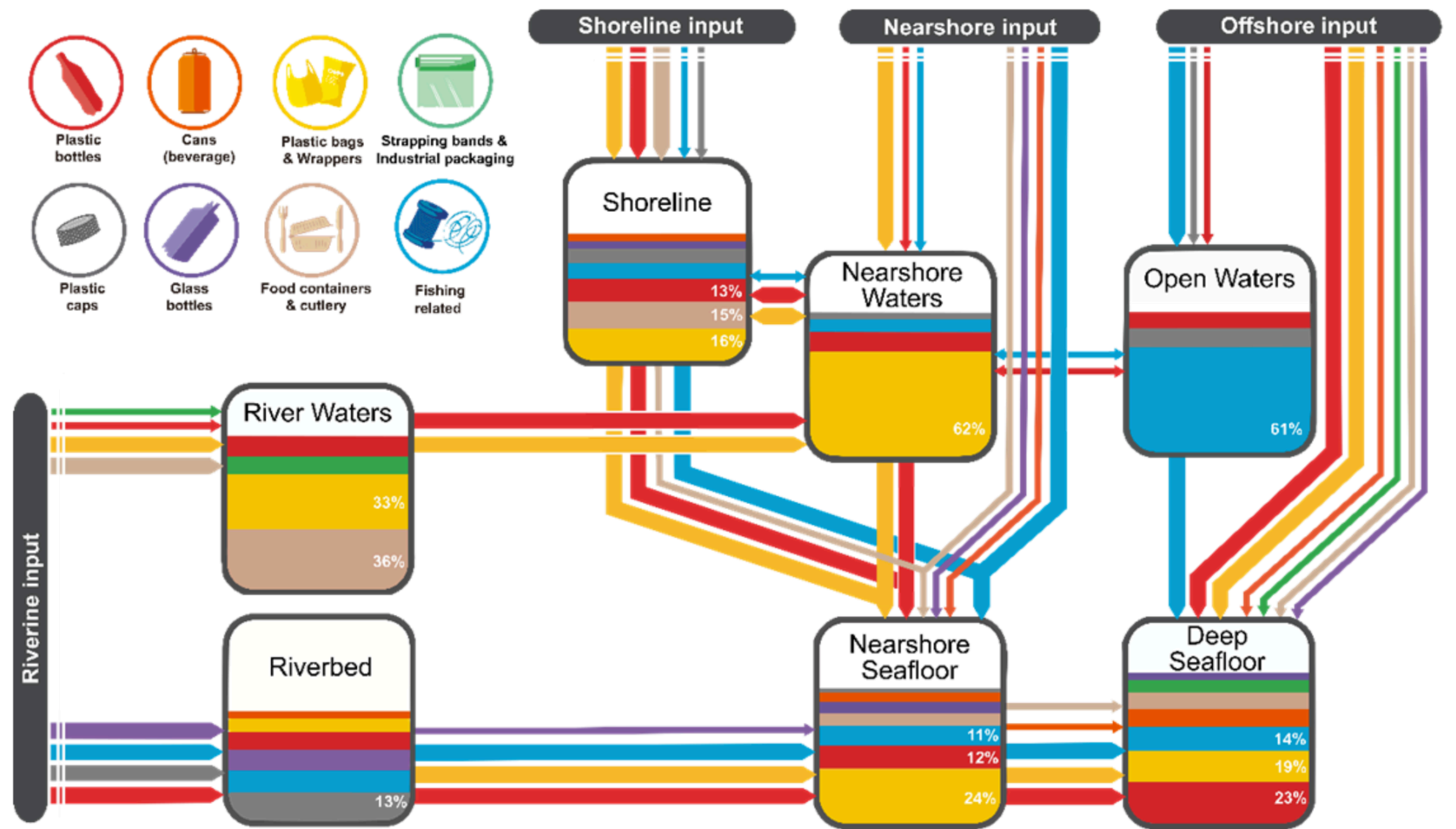
- Artificial polymers (plastic)
- Glass and ceramics
- Metal
- Paper and cardboard
- Cloth and textiles
- Others
- Rubber
- Processed wood

Origin

- Take-out Consumer
- Ocean & Waterway
- Industrial & Household
- Medical & Hygiene
- Smoking*


Plastic types

- Rigid
- Film
- Line

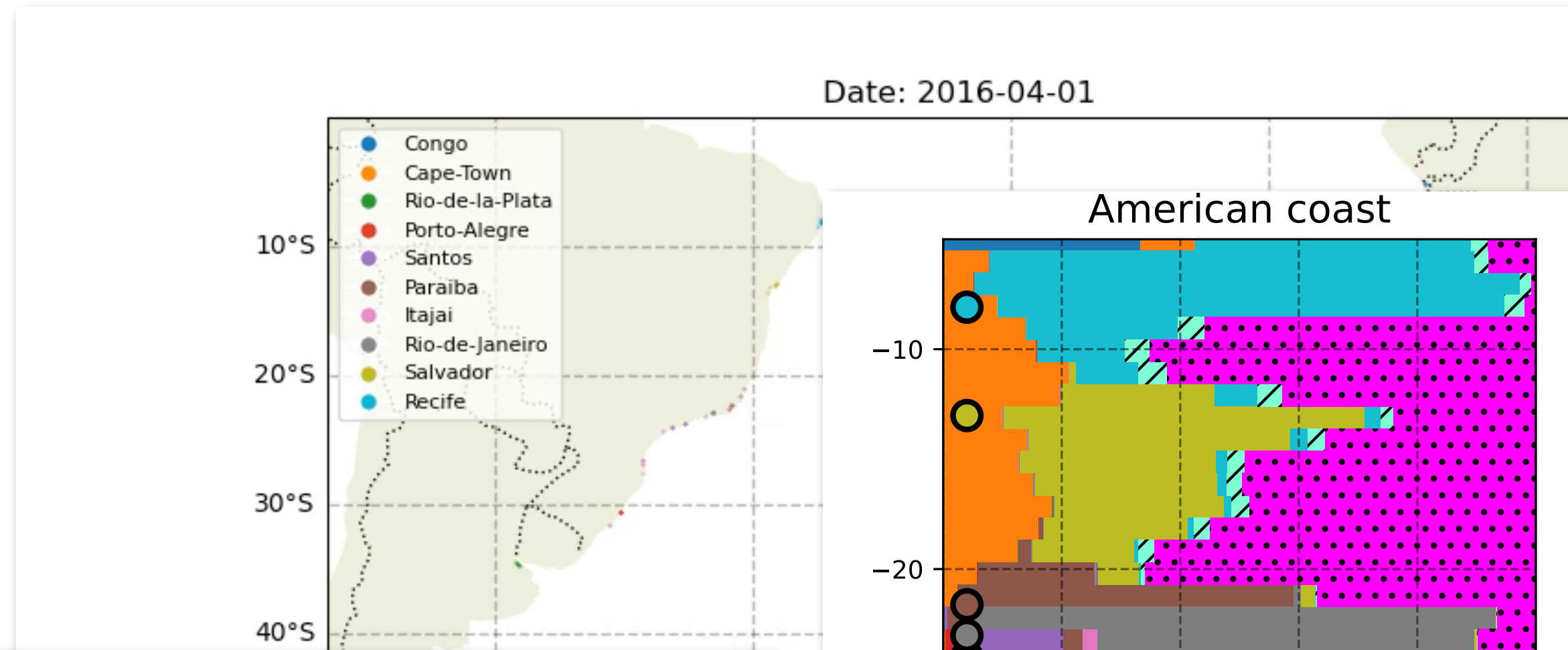
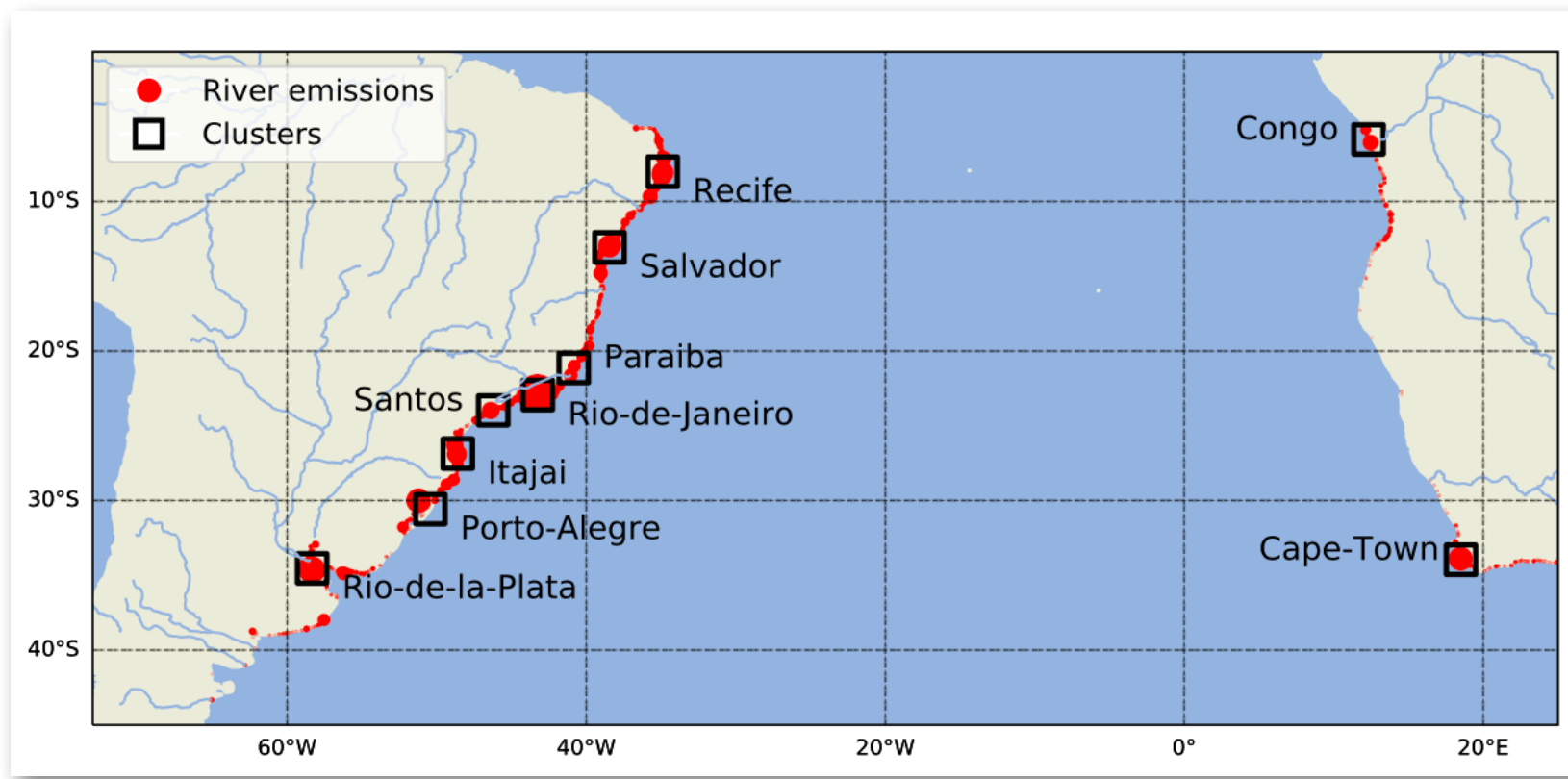


Morales-Caselles, Viejo, Martí, González-Fernández, Pragnell-Raasch, González-Gordillo, Montero, Arroyo, Hanke, Salvo, Basurko, Mallos, Lebreton, Echevarría, van Emmerik, Duarte, Gálvez, van Sebille, Galgani, García, Ross, Bartual, Ioakeimidis, Markalain, Isobe & Cózar (2021) *Nature Sustainability* 6

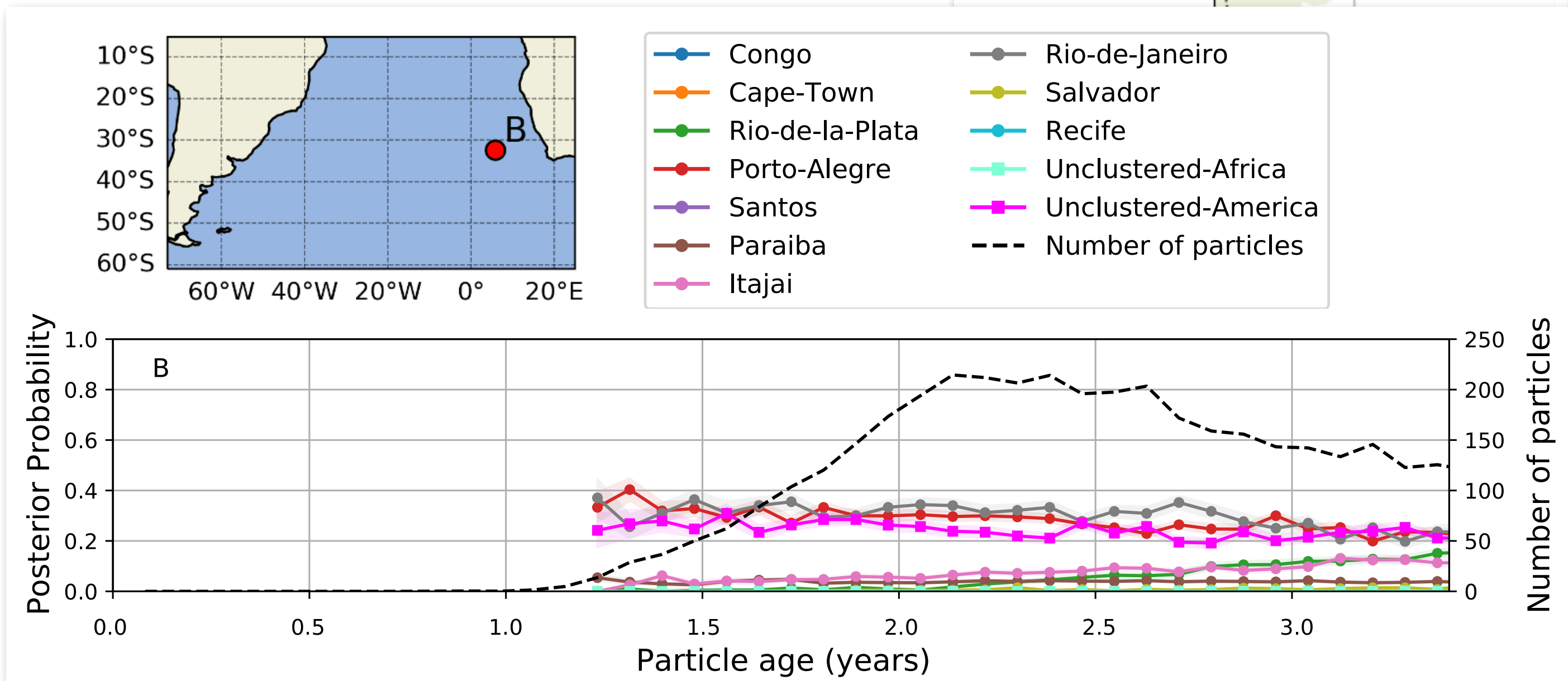
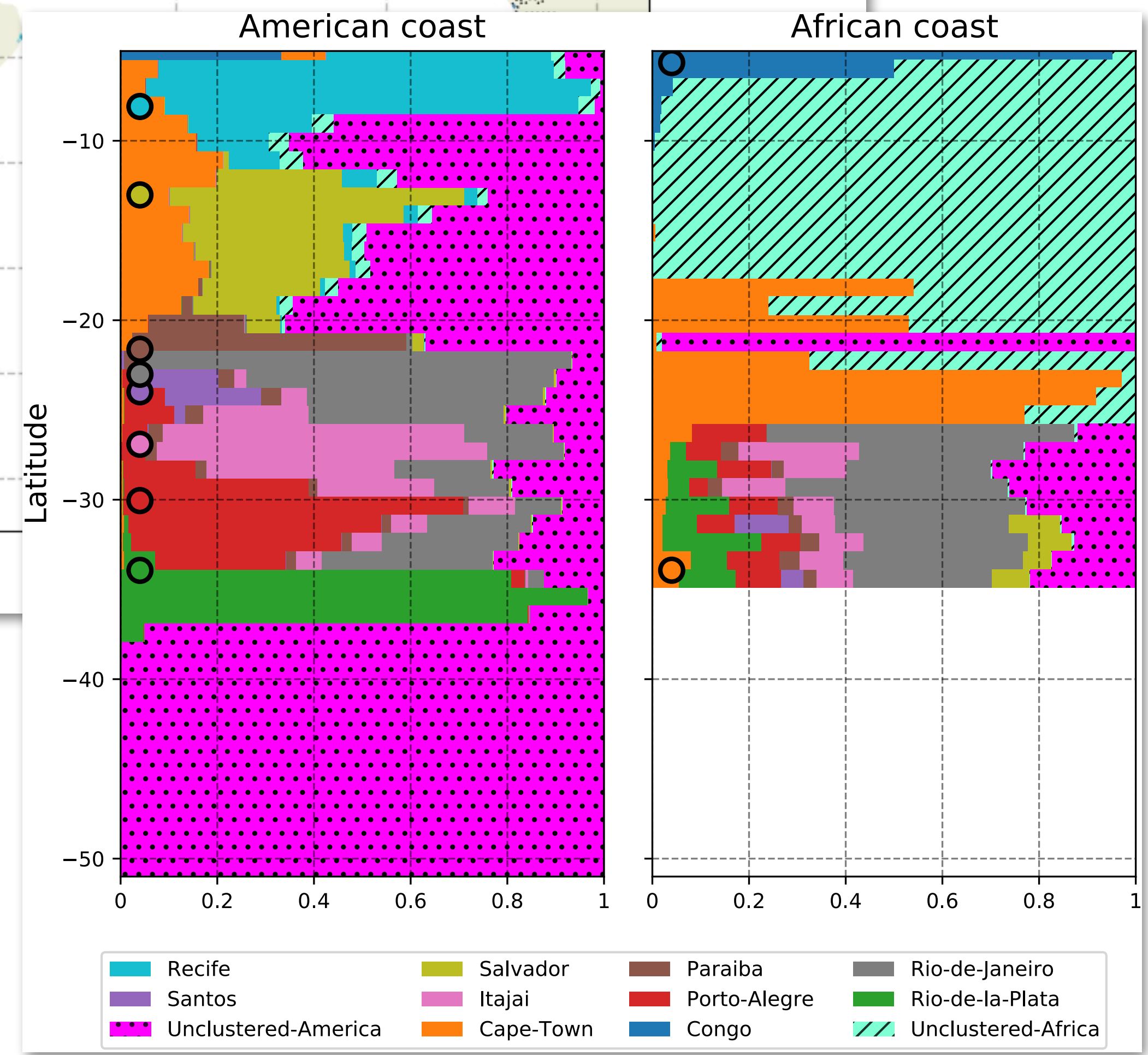
But *whose* plastic is that?

- If you find plastic at location x , then what is the probability that it came from source s ?
- Rephrase this question as $p(s | x)$ and use Bayes' theorem $p(s | x) \cdot p(x) = p(x | s) \cdot p(s)$
- Rewrite as $p(s | x) = \frac{p(x | s) \cdot p(s)}{p(x)}$
 - $p(x | s)$ -> **likelihood**: probability that plastic from source s arrives at location x
 - Can be computed from Lagrangian particle simulations from source s
 - $p(s)$ -> **prior**: probability that plastic comes from source s
 - Can be obtained from datasets like Meijer *et al* (2021 )
 - $p(x)$ -> 'normalising term': probability that *any* plastic is found at location x
 - Difficult to compute for 'open' system; assume $p(x) = \sum [p(x | s) \cdot p(s)]$

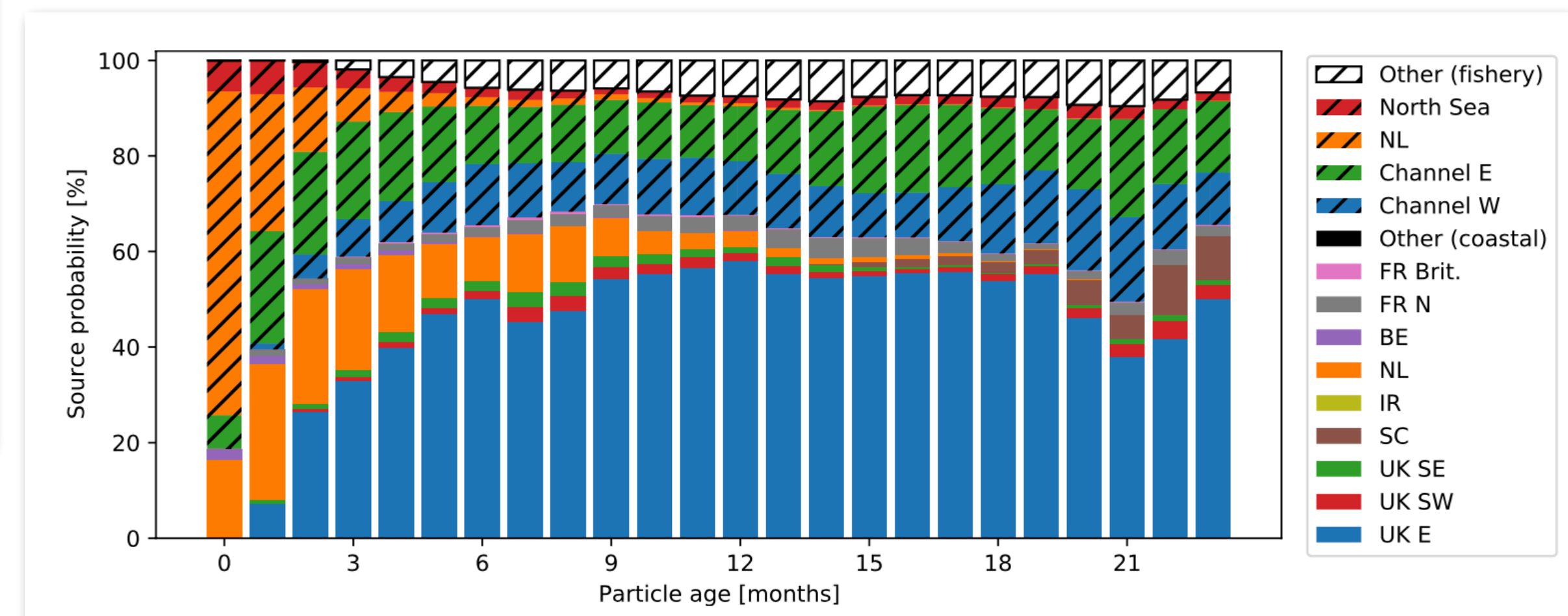
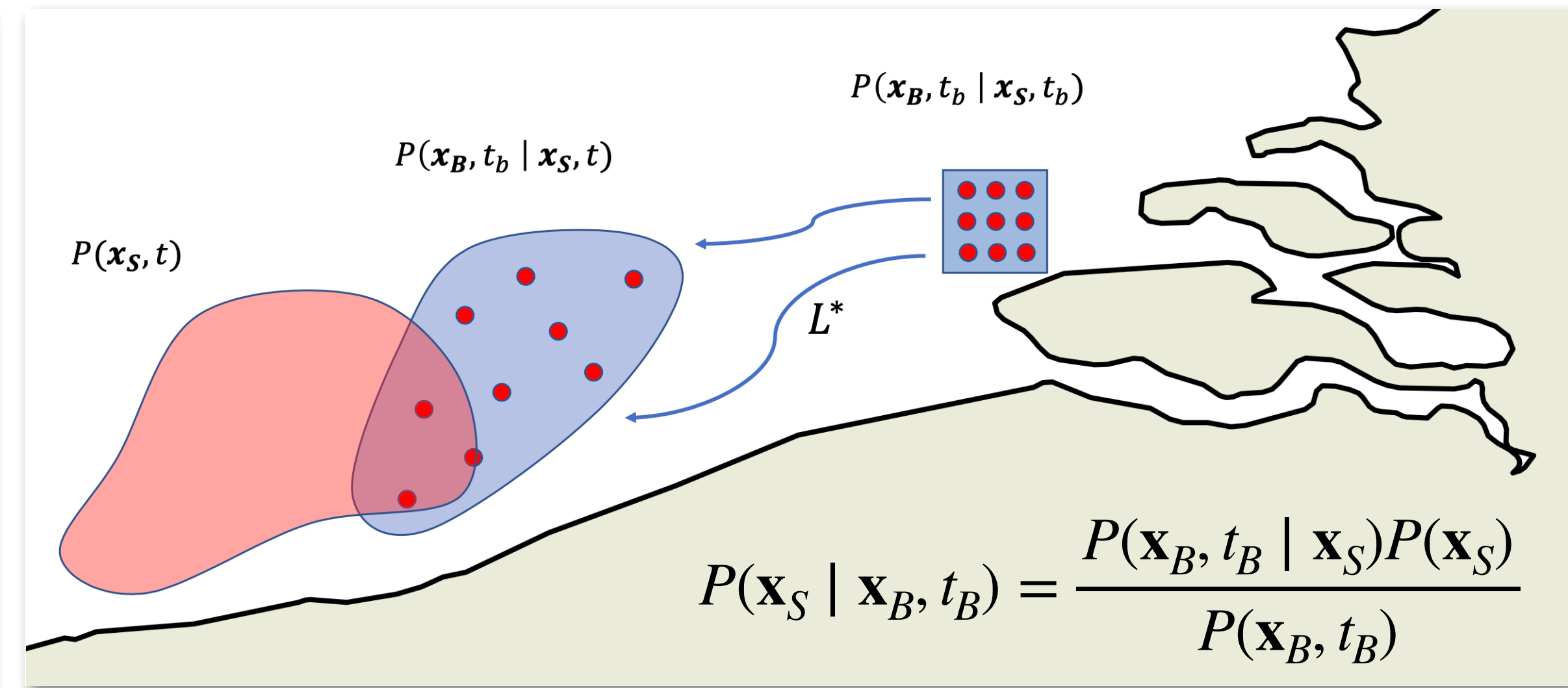
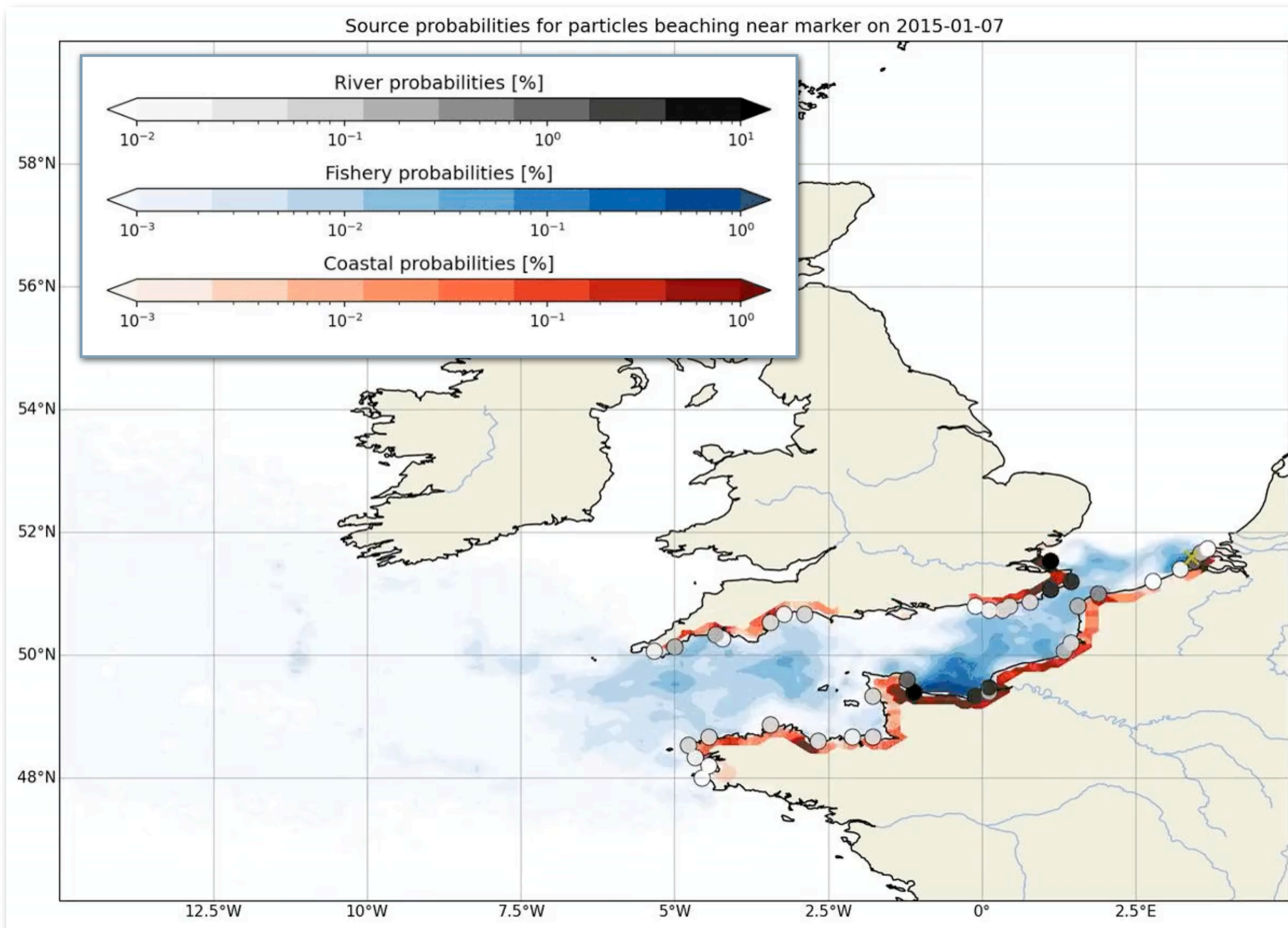
Using a Bayesian framework to distinguish South Atlantic riverine sources



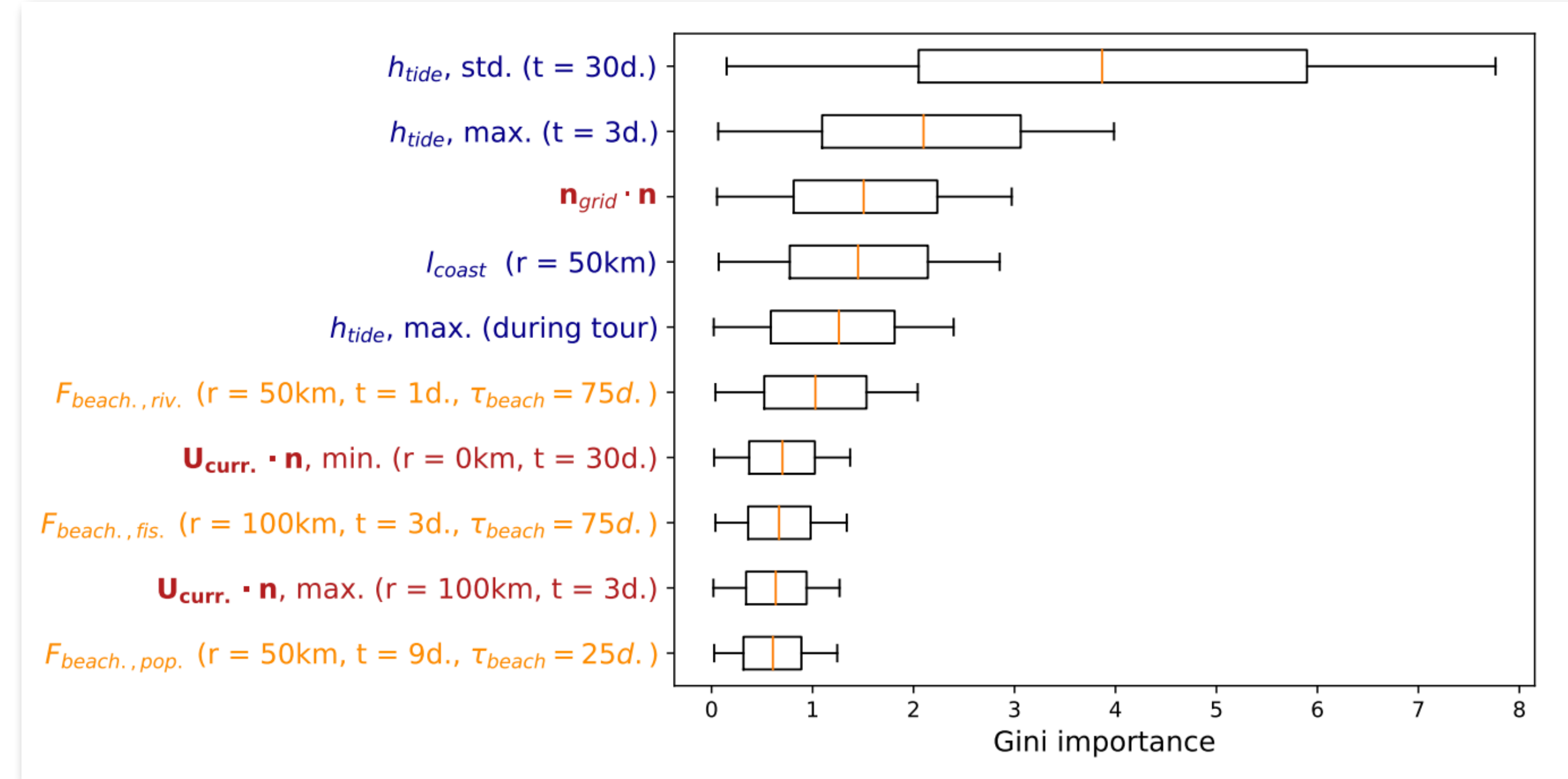
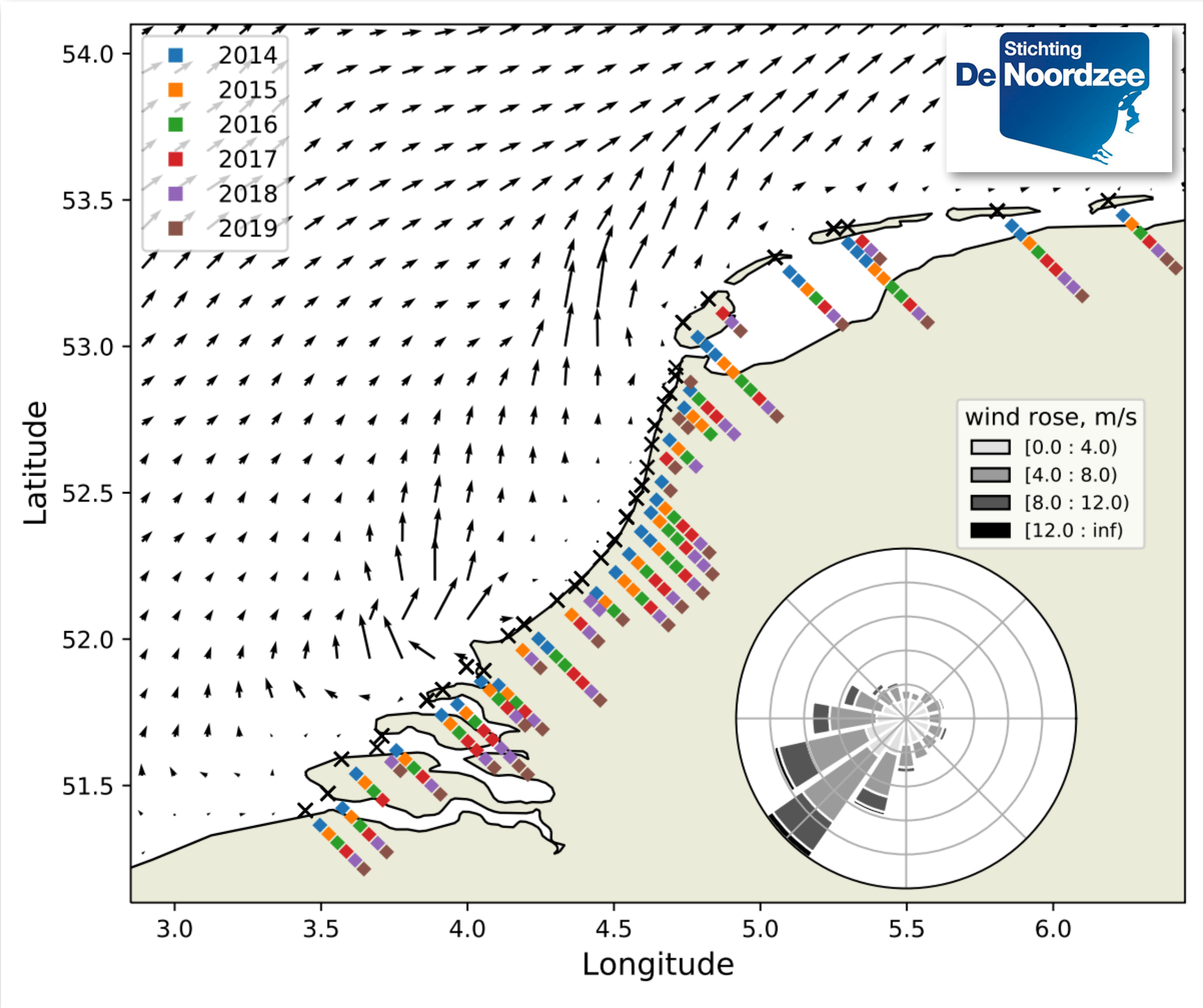
Date: 2016-04-01



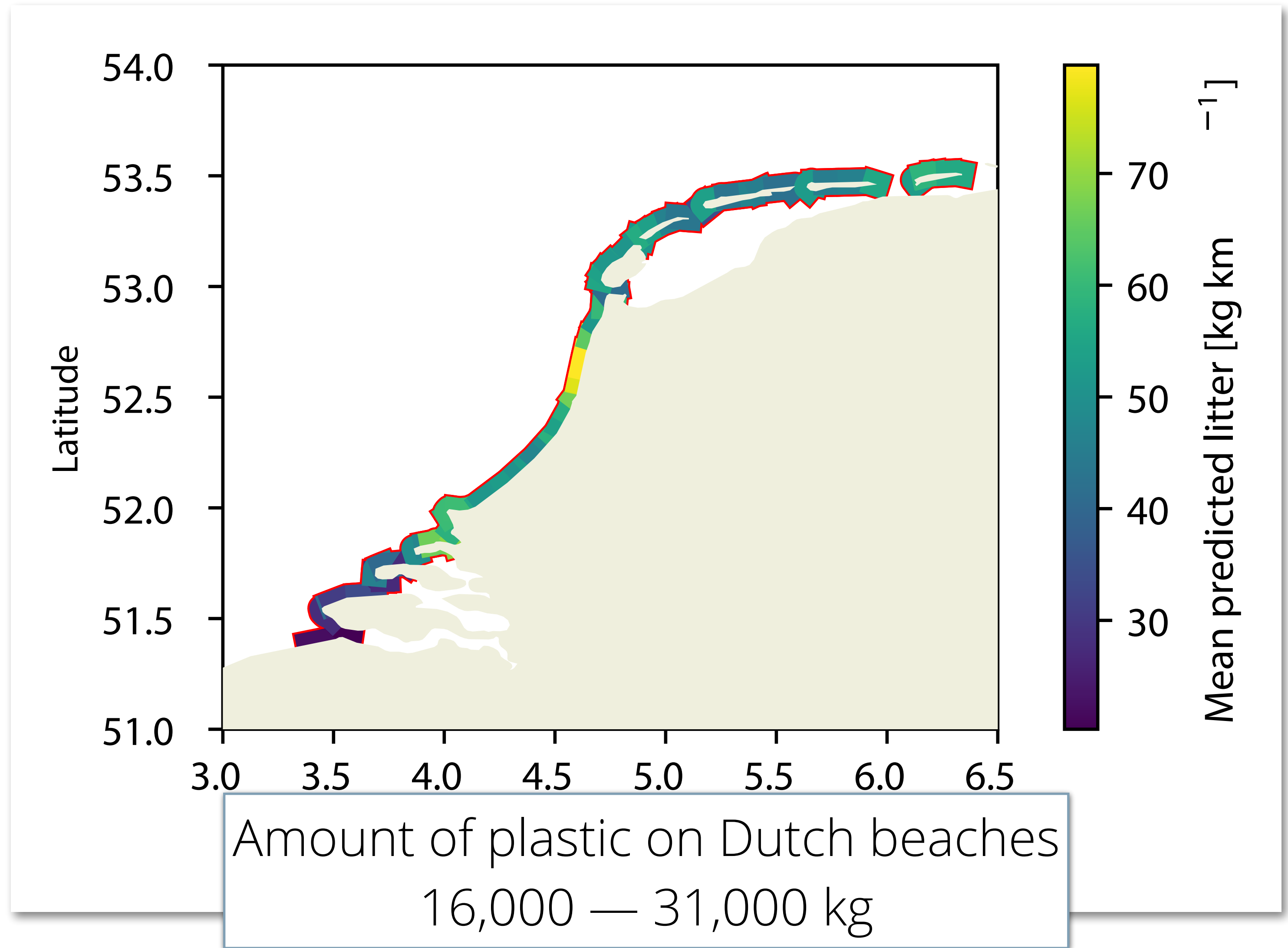
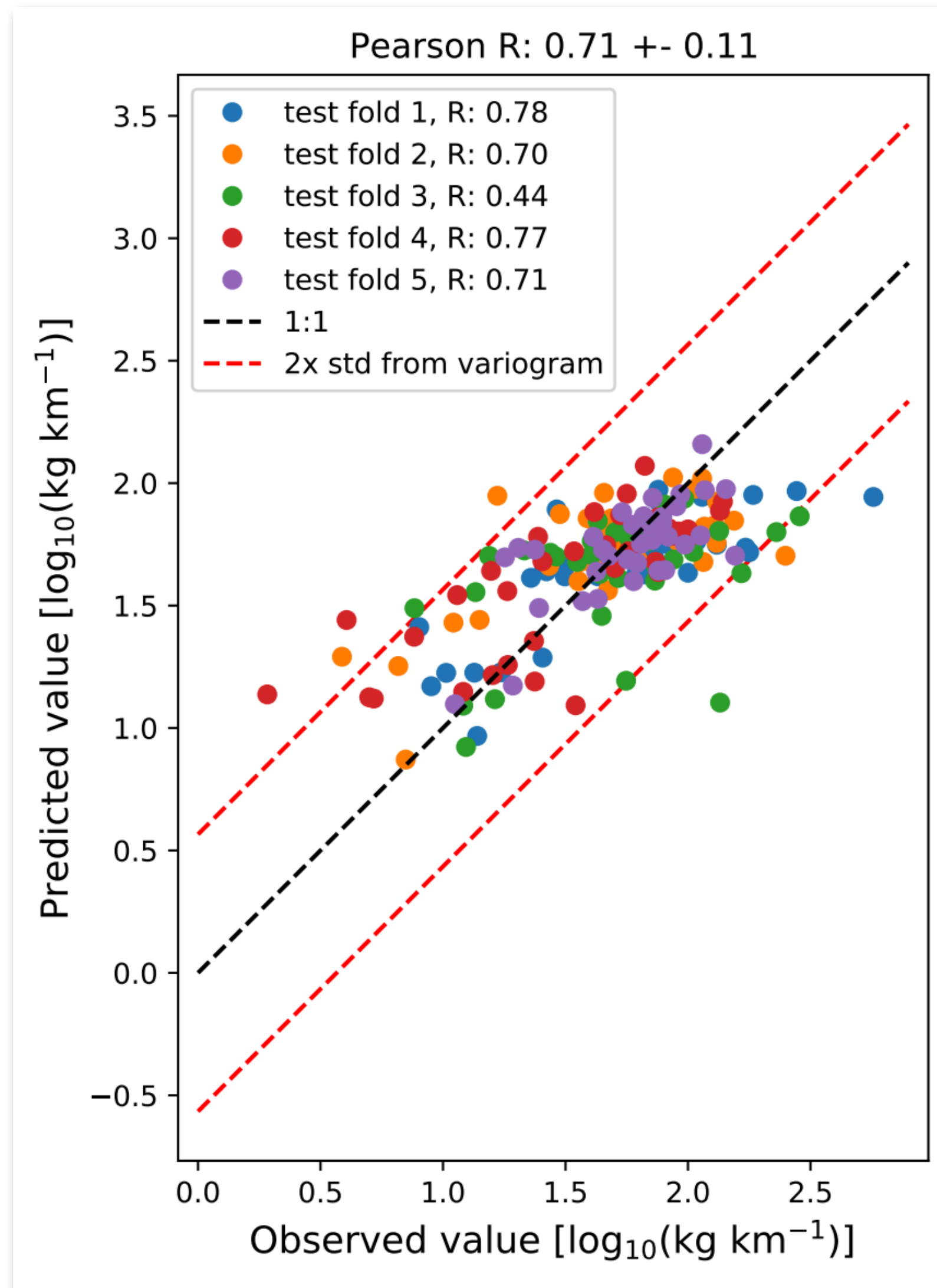
Bayesian Inference for source attribution



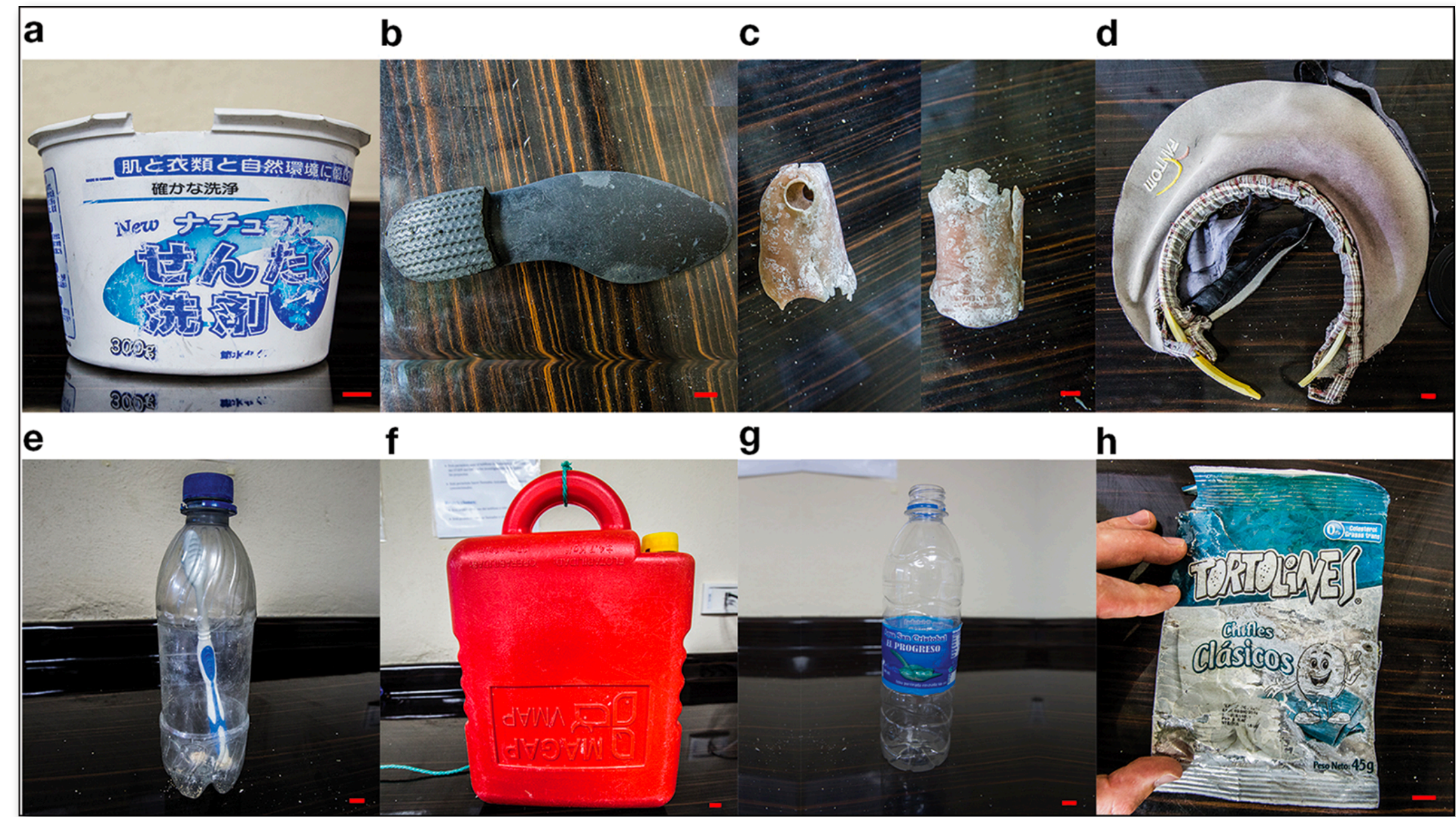
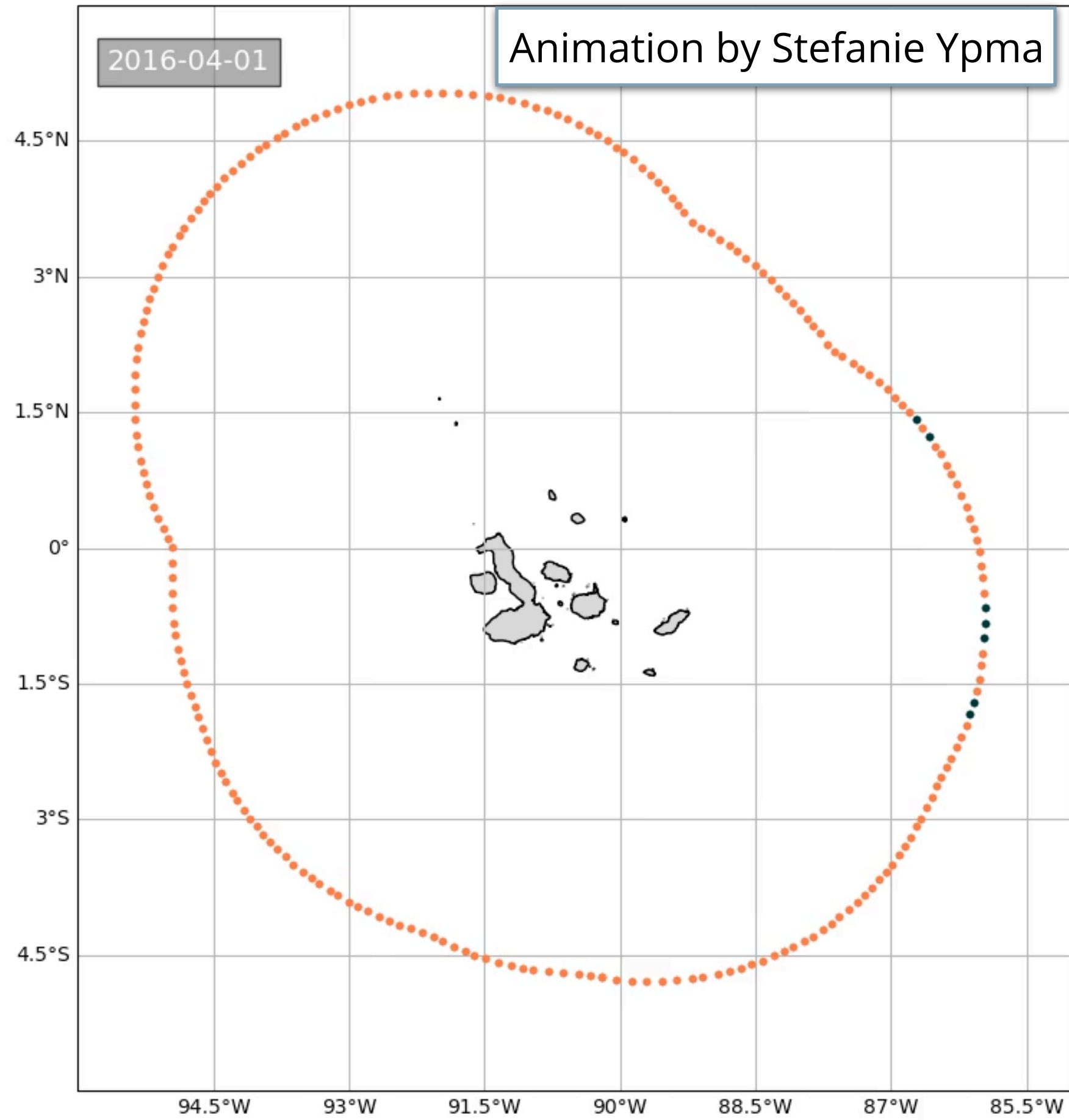
A Machine Learning approach to predict beaching on Dutch coastlines



A Machine Learning approach to predict beaching on Dutch coastlines



Using numerical models to optimise beach clean-ups



Schofield, Wyles, Doherty, Donnelly, Jones & Porter (2020) *Antiquity*



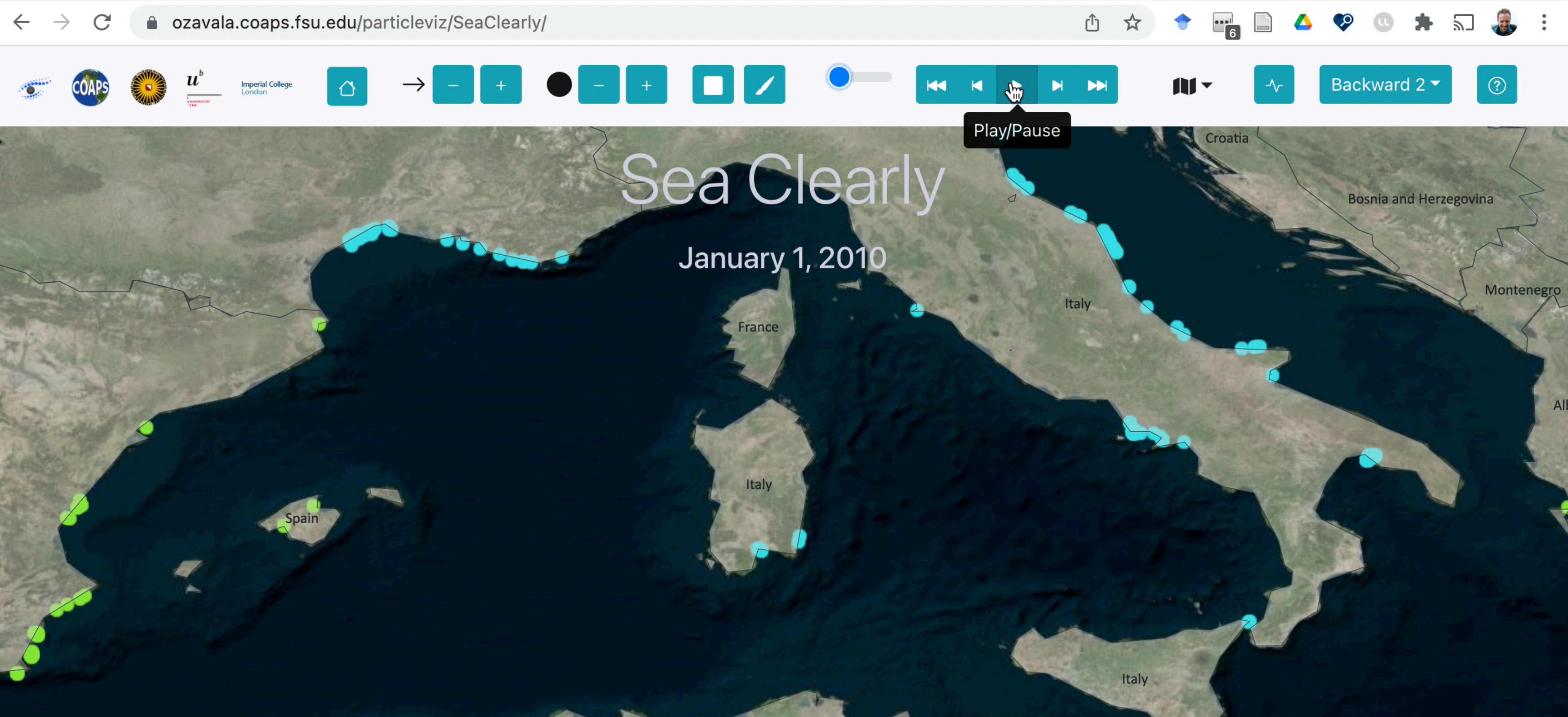
The goal: an app to predict when and where plastic beaches



Plastics as artefacts: identifying sources in LitterID workshops



The Blue-Cloud hackathon: predicting aquaculture exposure to pollution



Laura Gomez Navarro
Postdoctoral researcher

Cleo Jongedijk
PhD researcher

Delphine Lobelle
Postdoctoral researcher

Darshika Manral
PhD researcher

Victor Onink
PhD researcher

Claudio Pierard
PhD researcher

Joey Richardson
MSc student

Olmo Zavala-Romero
Postdoctoral researcher



Institute for Marine and Atmospheric research Utrecht

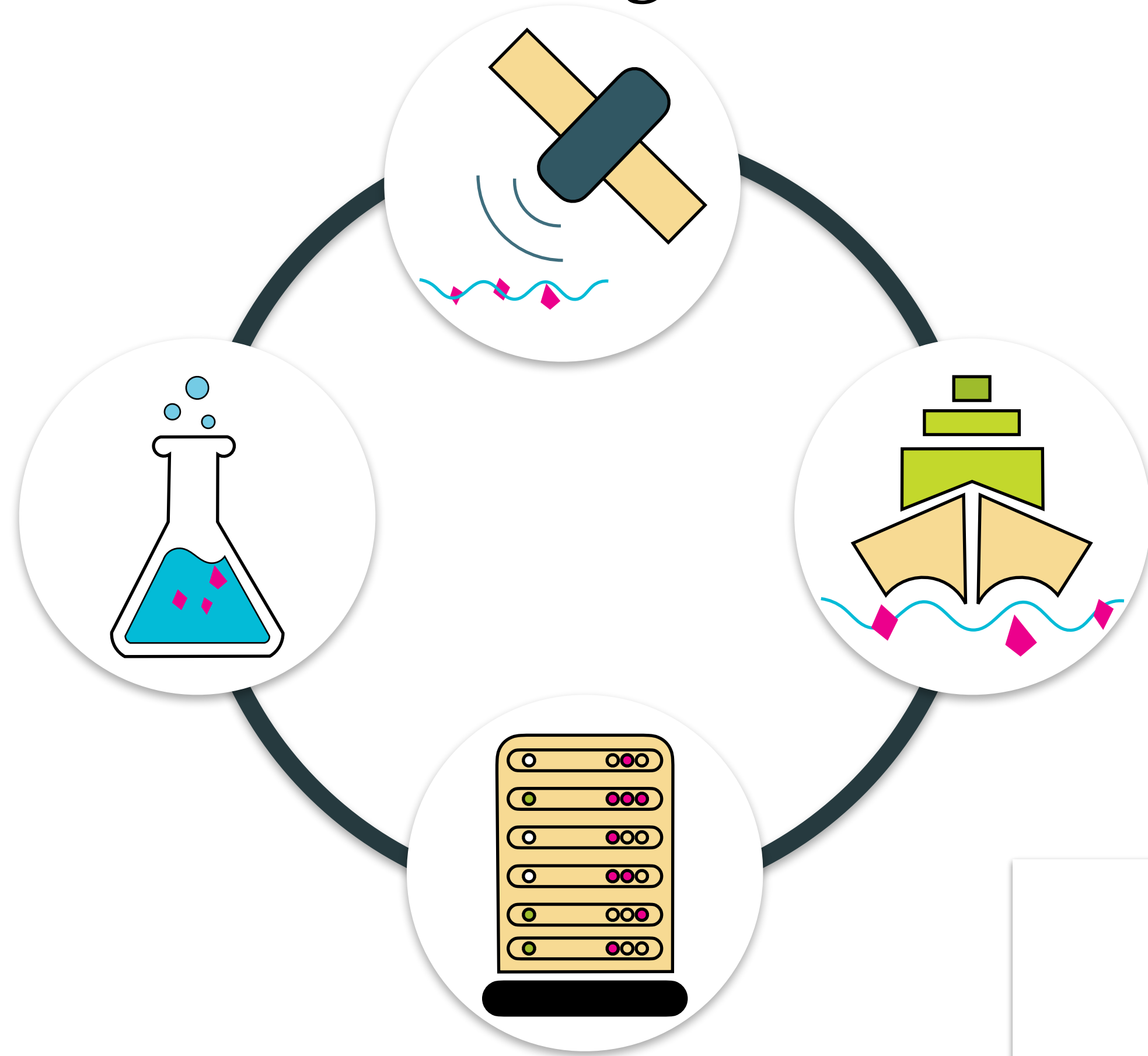
Freudenthal Institute

THE PARTICLE TRACKERS
IDEA: SEA CLEARLY

€25,000

Towards further evolving and giving outreach to the winning solution, promoting its uptake

We should work together and learn from each other

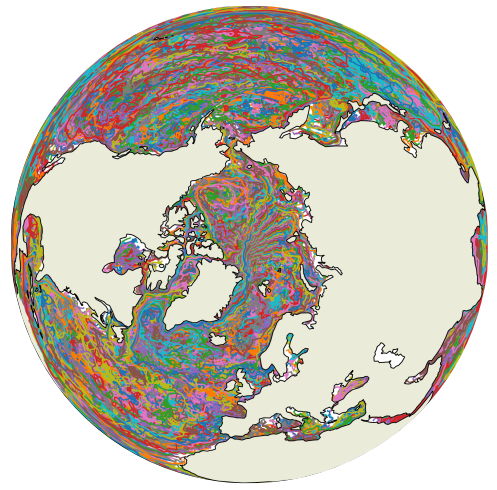


The plastic littering our ocean is an atrocity.
Society should be ashamed.

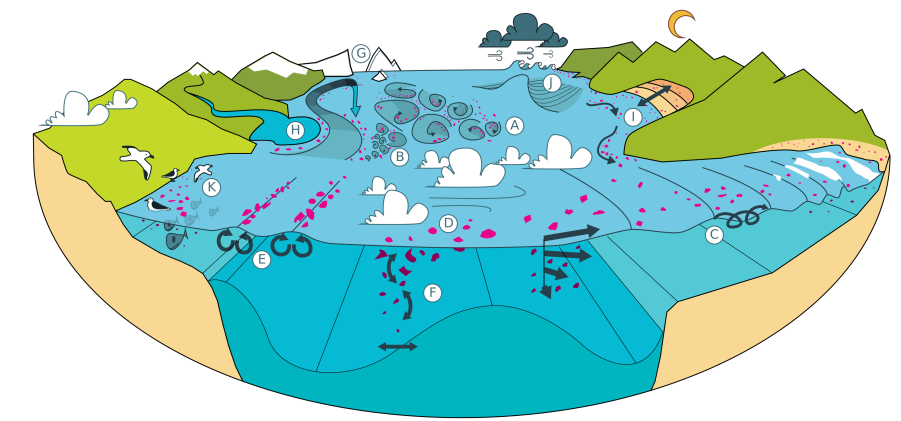
But at the same time, the plastic is a unique opportunity
to better understand how the ocean works.

Conclusions

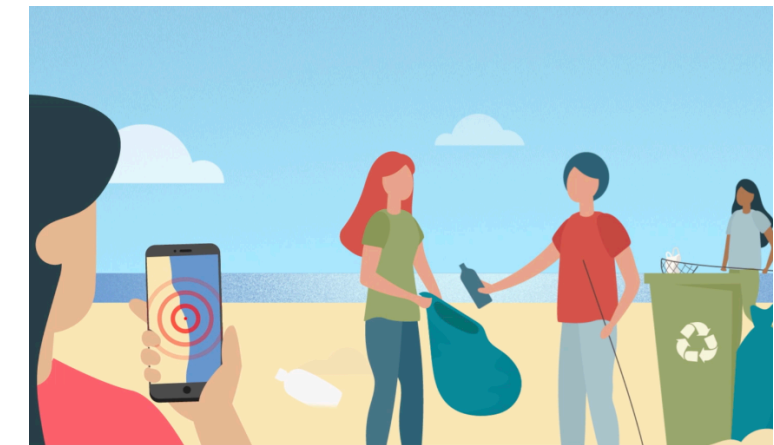
The ocean is no bathtub; it is in constant motion and full of small-scale eddies, which have a crucial role in the transport of plastic.



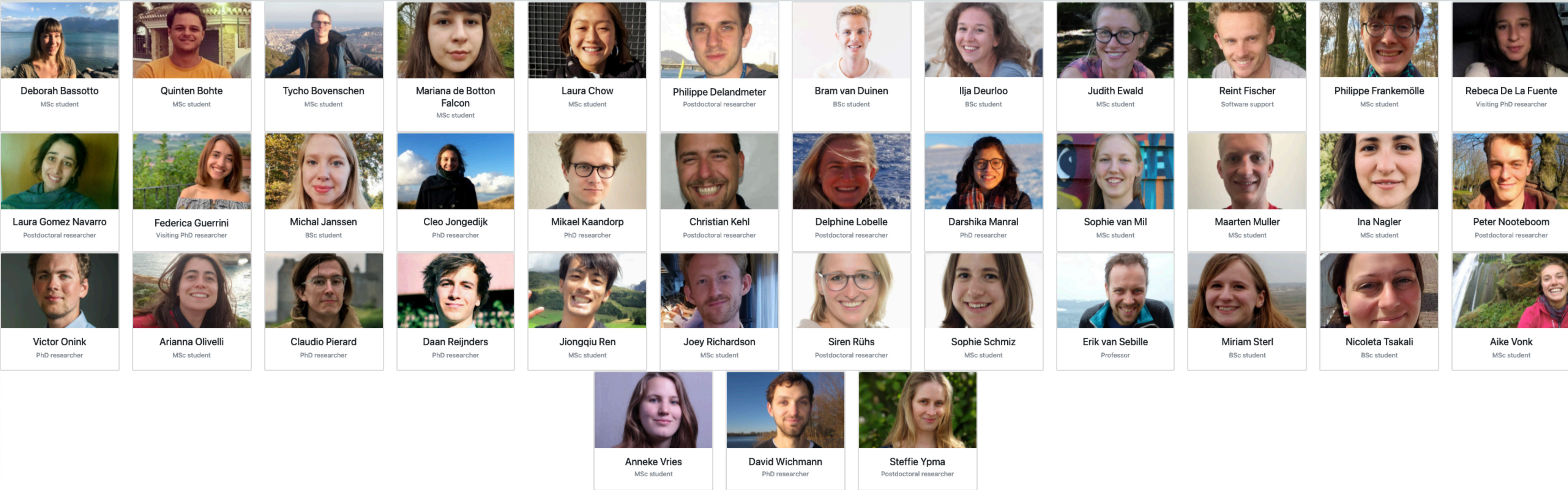
The challenge now is to capture additional (physical) processes such as beaching in the numerical models.



Accurate numerical models could be used to optimise clean-up strategies, and to 'play the blame game' through Bayesian Inference.



Thanks to the @UFollowtheOcean oceanparcels.org/utrechtteam



Institute for
Marine and Atmospheric
research Utrecht

Freudenthal Institute

