Ocean Predict

SYMPOSIUM OP'24

In partnership with unesco Intergovernmental Oceanographic Commission

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

An operational system to forecast the plastic density in the Great Pacific Garbage Patch

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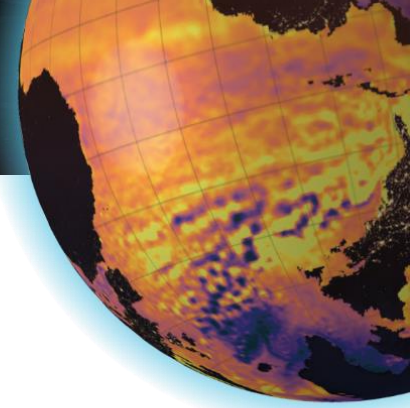
THE OCEAN CLEANUP™

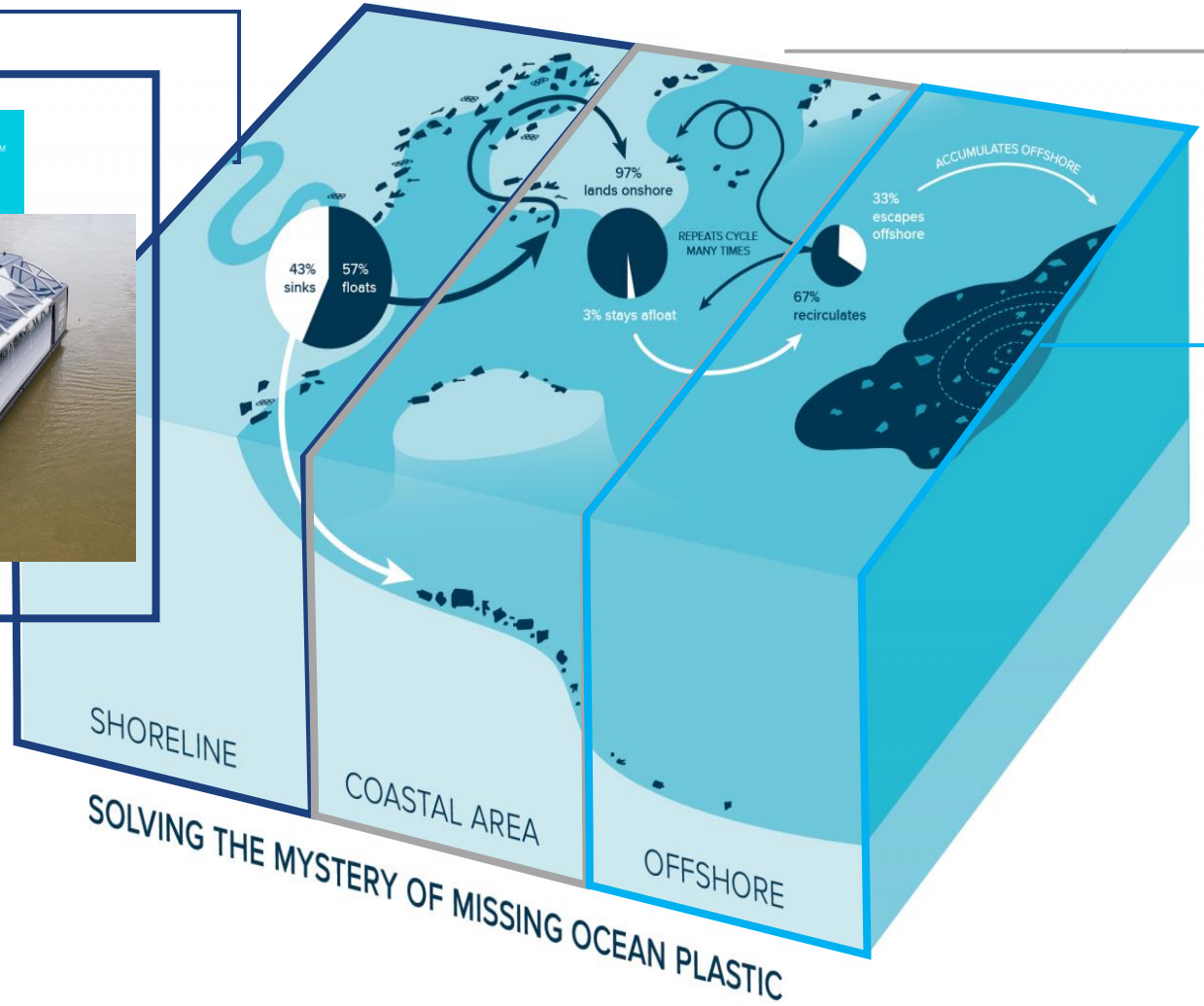


Outline

- Context
- Presentation of the TOC-OOFS operational system
- Model validation
- On-going and future developments

Ridding the oceans of plastics

INTERCEPTOR™

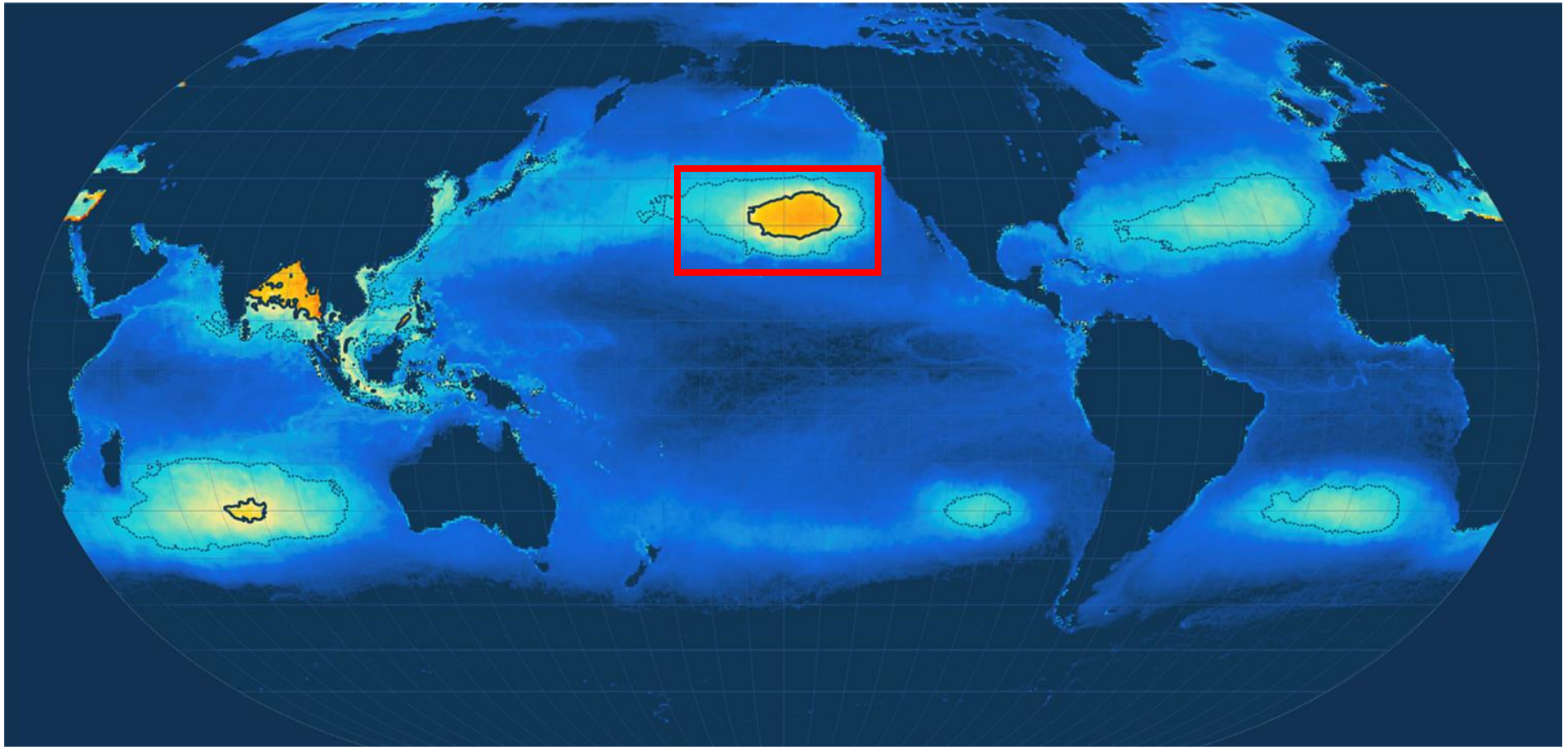


Beaching

SYSTEM 03

The Great Pacific Garbage Patch (GPGP)

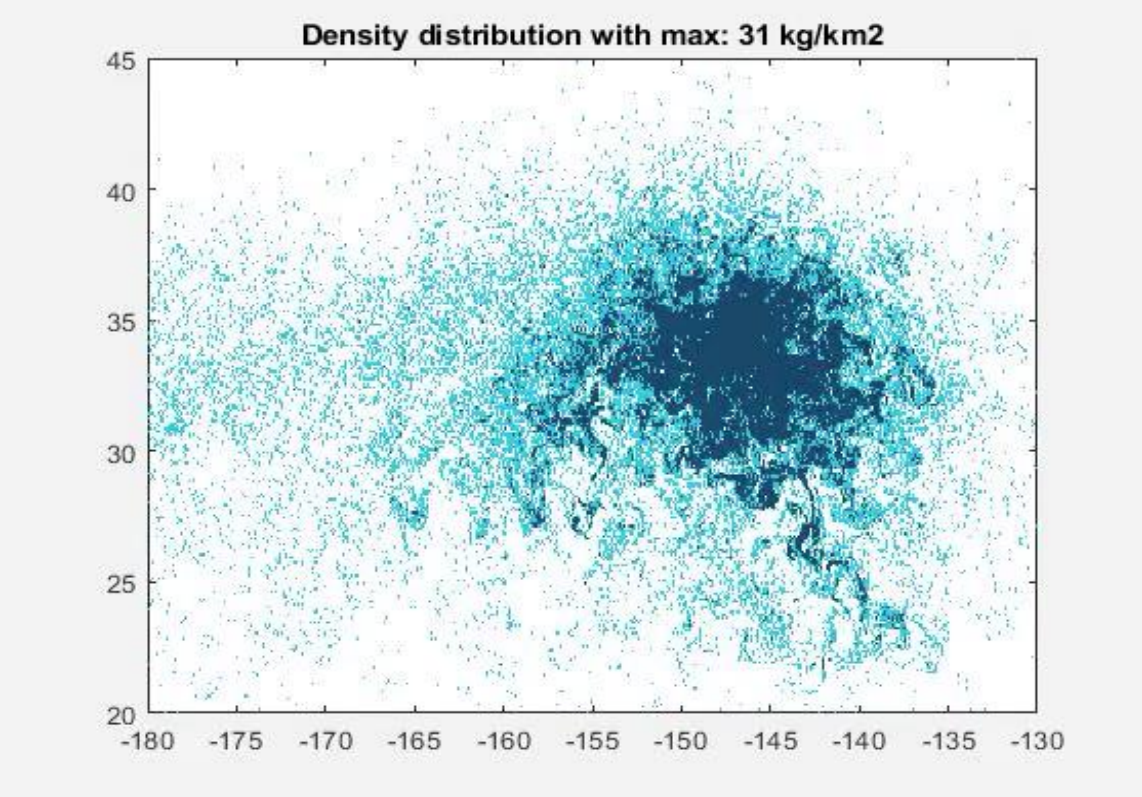
- Plastic accumulating in the North Pacific Gyre (*Lebreton et al., 2018*)

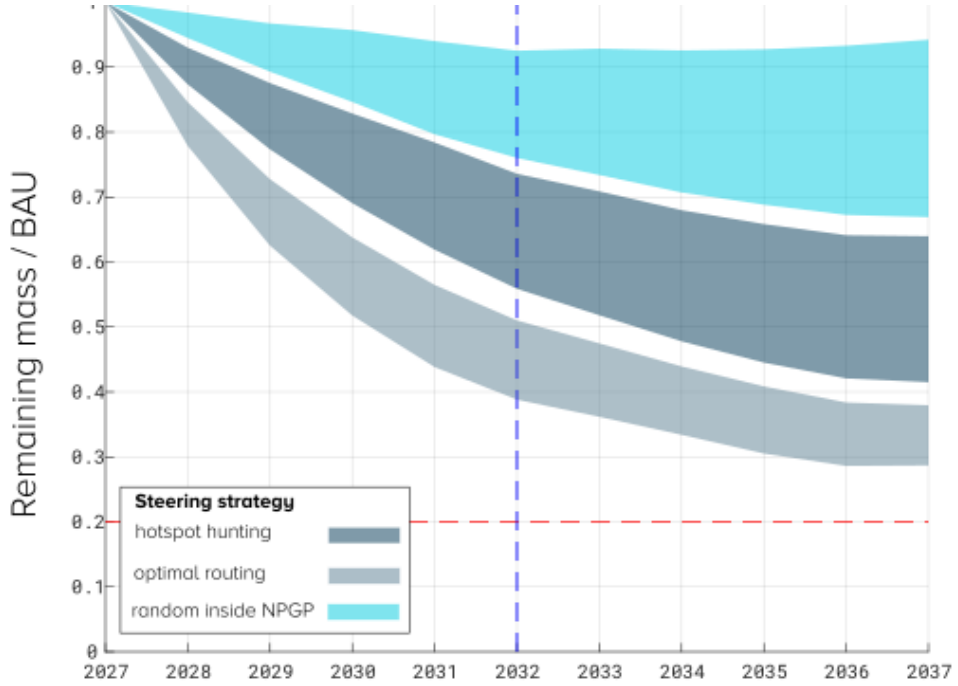


Lebreton et al. "Evidence that the Great Pacific Garbage Patch is rapidlyaccumulating plastic", *Sci. Rep.* (2018)

Cleaning the GPGP

- Because of its heterogeneity, cleaning this plastic can be greatly enhanced with a proper steering strategy (*Sainte-Rose et al., in prep.*).





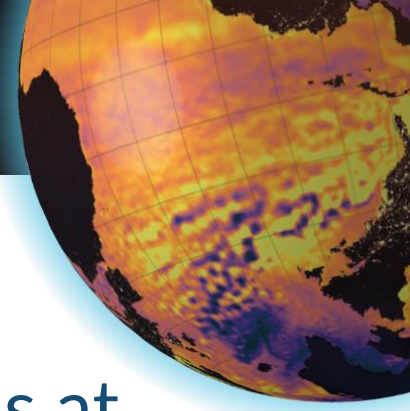
Need for an operational system

- Global and regional operational forecast systems already exist for:
  - ocean circulation
  - wind
  - ocean waves
  - biogeochemistry
  - ~~floating plastics~~

- Floating plastics, a peculiar passive Lagrangian tracer:
  - for its transport: inertial effects, wave-induced drift, wind induced leeway-drift…
  - for its diversity: polymers ranging from 0.2 to 1 in density ratios with sea-water, different shapes and sizes.
  - for its sources: linked to various anthropogenic activities (consumer products, fishing, aquaculture) (*Lebreton et al. 2022*)
  - for its fate: interaction with the coastline, degradation, fragmentation, bio-fouling, sedimentation, re-suspension etc (*van Sebille et al., 2020*)…

van Sebille et al. "The physical oceanography of the transport of floating marine debris" *Environ. Res. Lett.* (2020)

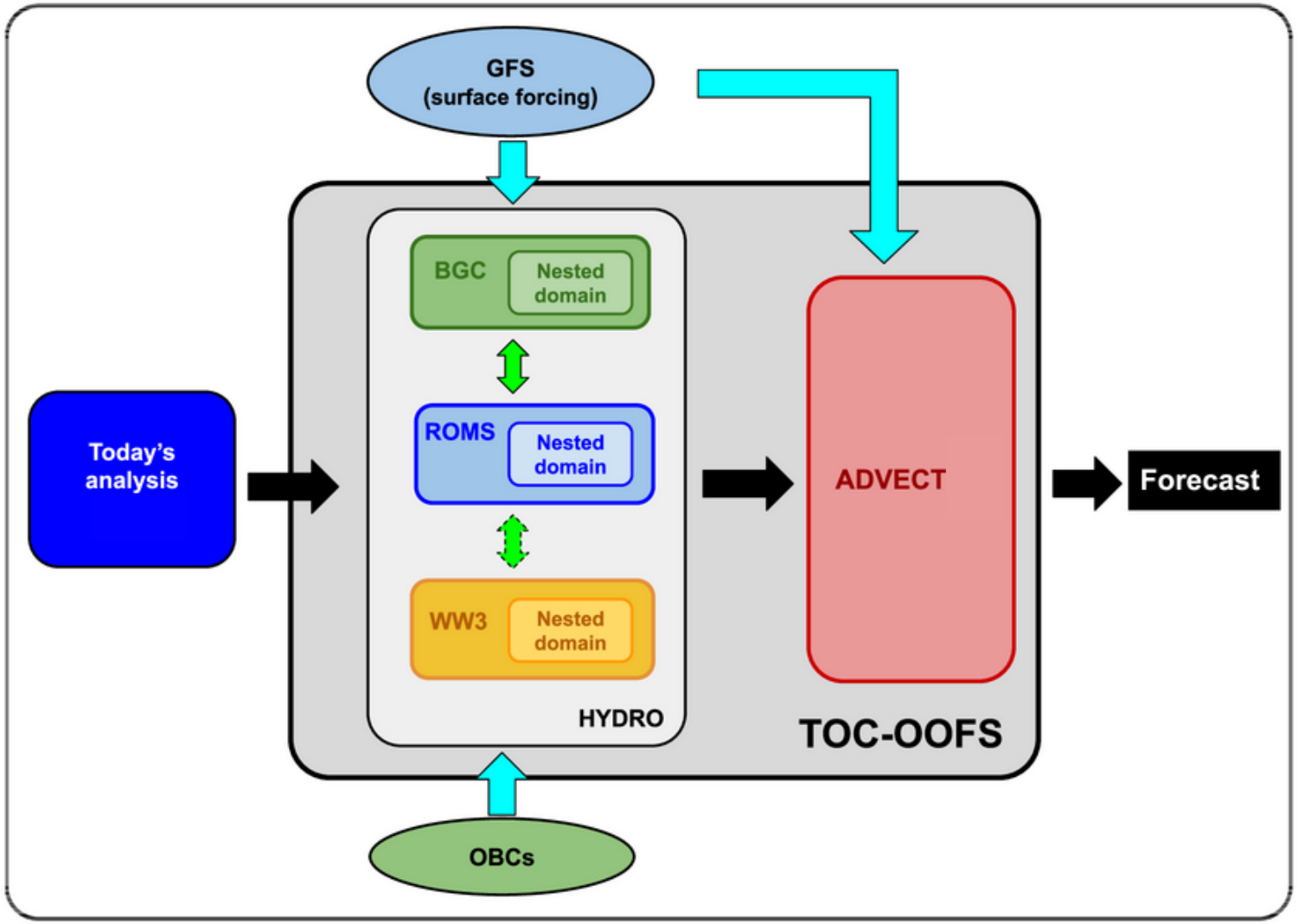
Lebreton et al. "Industrialised fishing nations largely contribute to floating plastic pollution in the North Pacific subtropical gyre" *Sci. Rep.* (2022)



Presentation of TOC-OOFS

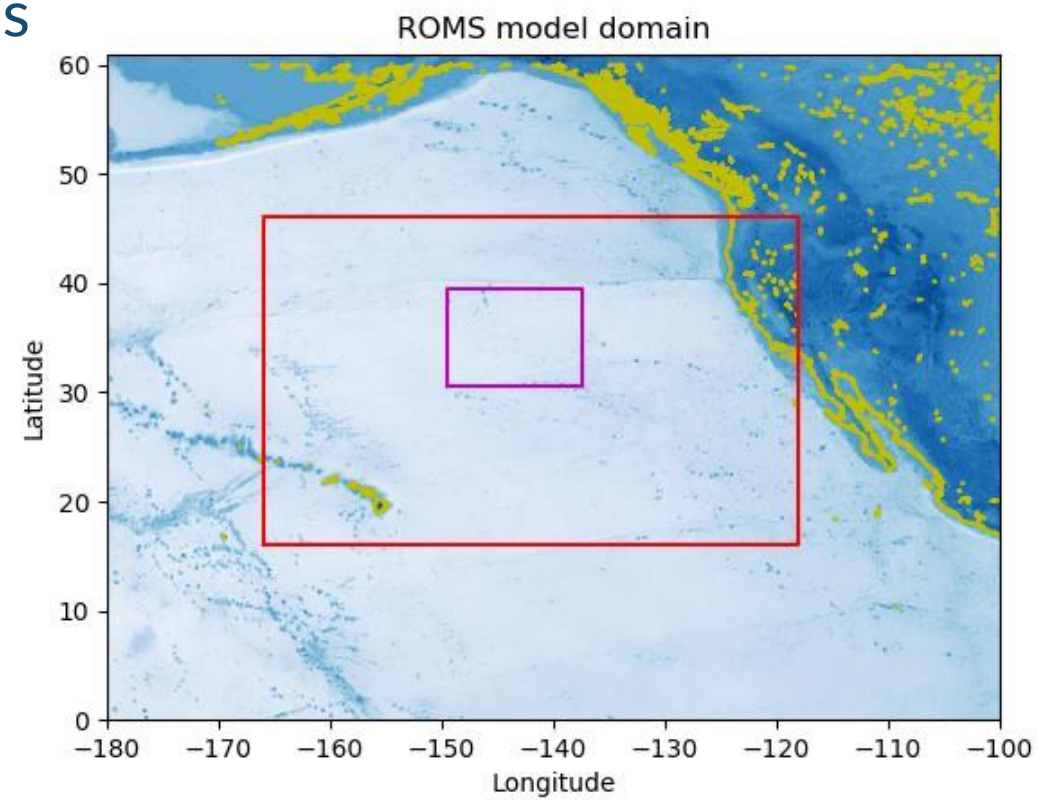
- TOC-OOFS is an operational forecast system (6 days) that aims at driving decision-making for the ships to steer the cleanup systems in the most plastic dense locations based on:
  - global and regional circulation models (HYCOM / NEMO – for the global models and a ROMS regional model).
  - global and regional wave model (WW3) to allow for wave-induced drift computations.
  - global wind model (GFS) for wind-induced transport.
  - regional Chl-A ROMS bio-geochemical model.
  - global plastic dispersal (ADVECT).

TOC-OOFS under the hood



ROMS regional circulation model

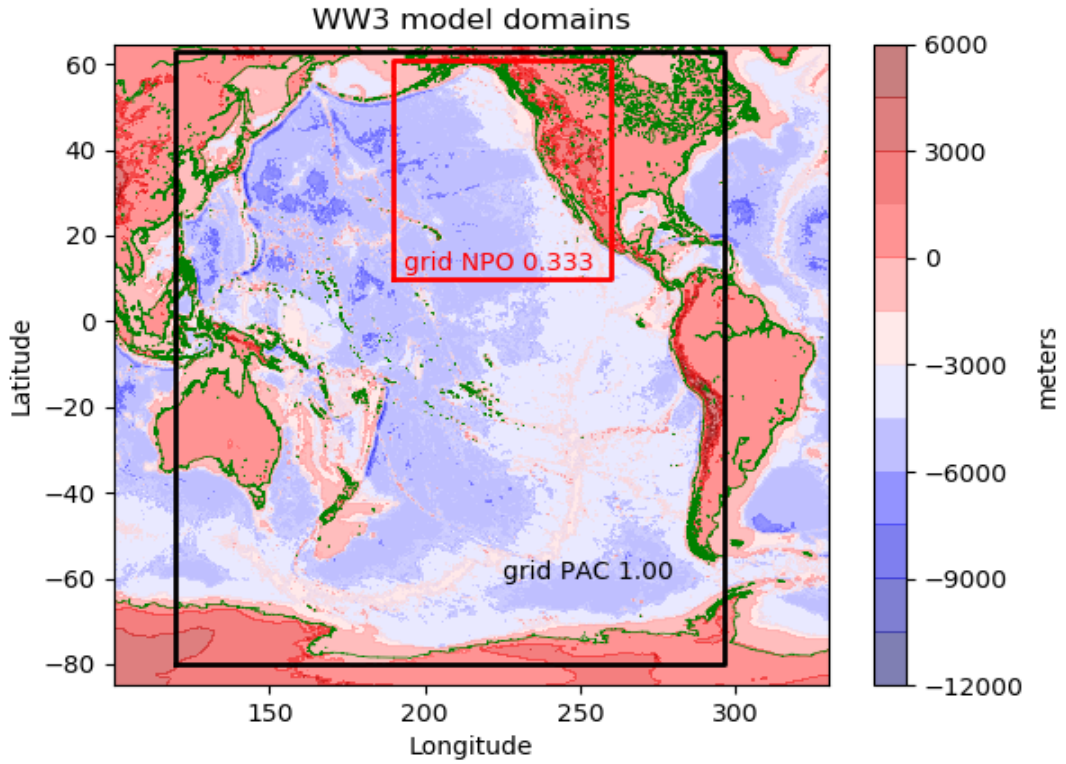
- Surface forcing bulk fluxes computed from:
  - 3-hourly Climate Forecast System Reanalysis (CFSR) data during 5.5 years hindcast
  - 3-hourly Global Forecast System (GFS) for nowcast and forecast
- Open boundary conditions:
  - 6-hourly global NEMO /HYCOM
  - Grid resolution: 1/12° and nested 1/36°



WW3 wave model

- Hindcast simulations: for analysis purpose (*Wrenger et al., 2020)*
  - 10 years starting on 2010-Jan-01
  - surface forcing: 6-hourly CFSR winds
  - 2 grids: larger grid spans the entire Pacific Ocean with resolution of 1 degree and nested grid spans only the GPGP area with resolution of ⅓ of degree

- Forecast Simulations:
  - Starting on 2019-Jan-01
  - Surface forcing: 3-hourly GFS winds
  - Larger grid has ½ degree resolution and nested grid has ¼ degree resolution
  - the simulations are NOT coupled to ROMS and no data assimilation is being used.

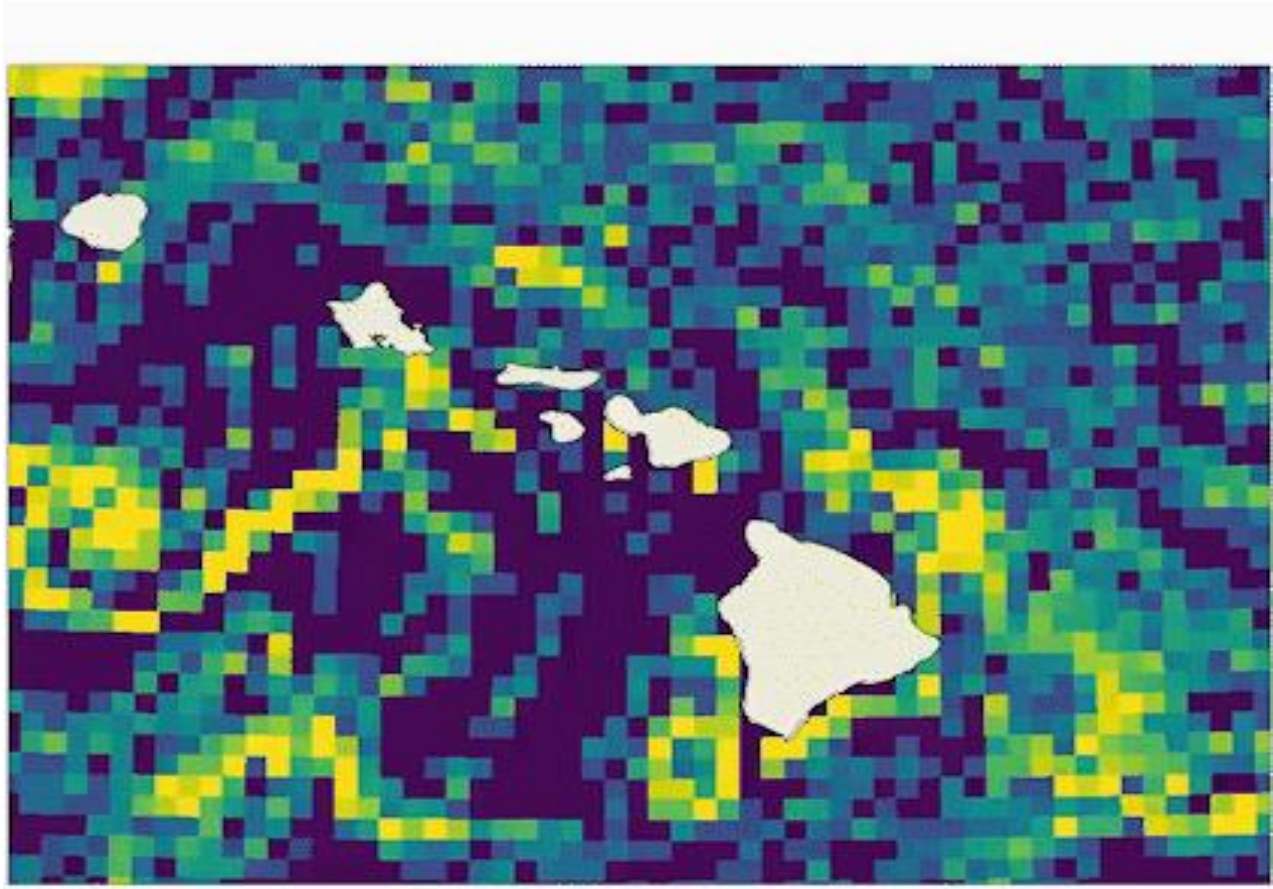


Wrenger et al. "Waves in the Great Pacific Garbage Patch", OMAE (2020)

ADVECT model

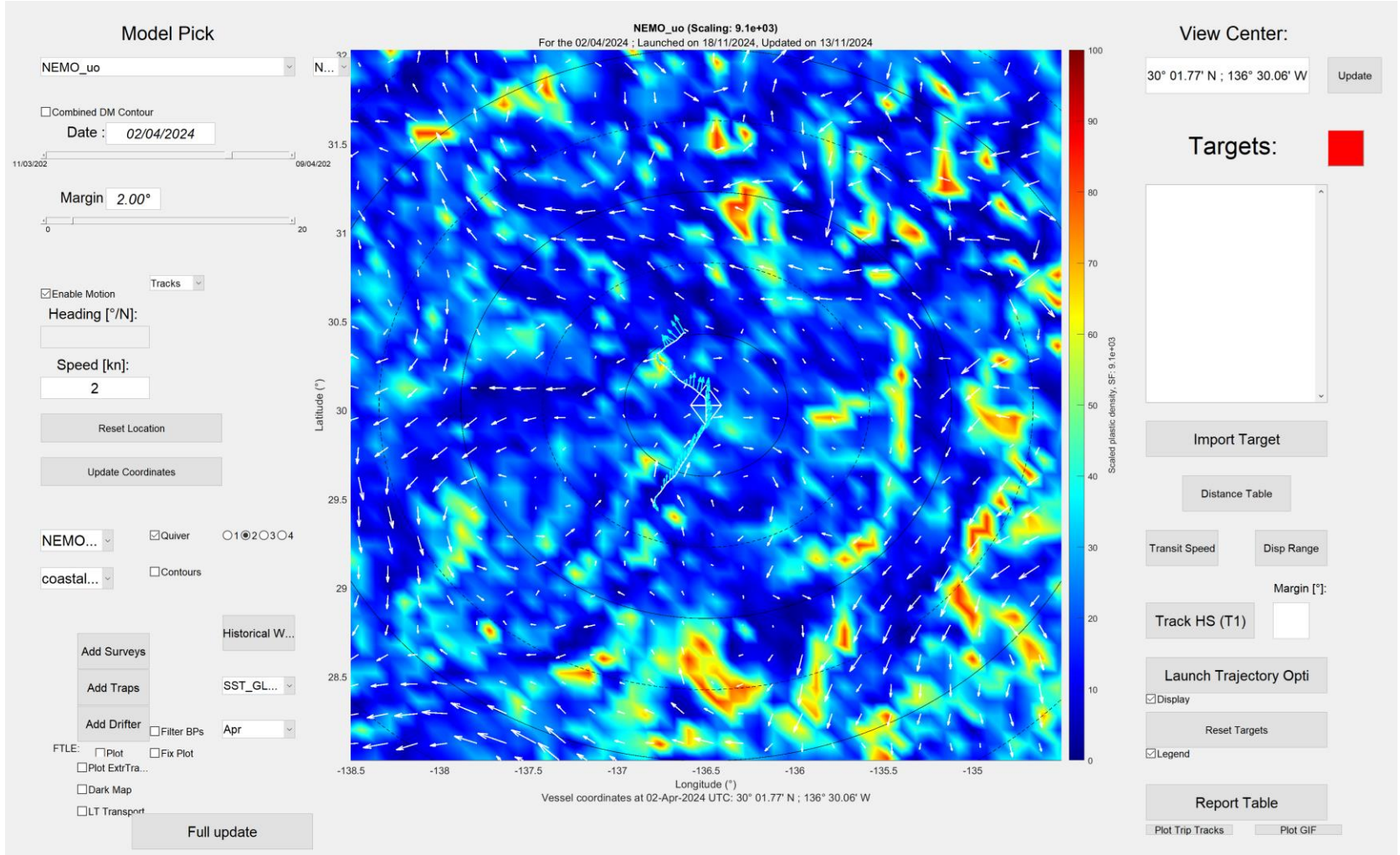
- 3D - Lagrangian plastic dispersal model (*Klink et al., 2021*):
  - global model
  - sea-surface current
  - wave-induced drift
  - windage
  - fate of plastics: beaching / sinking
  - OpenCL implementation (GPU ready)
  - Open source:

  github.com/TheOceanCleanupAlgorithms/ADVECT
- Model setup:
  - spin-up since 1993
  - coastal particle sources

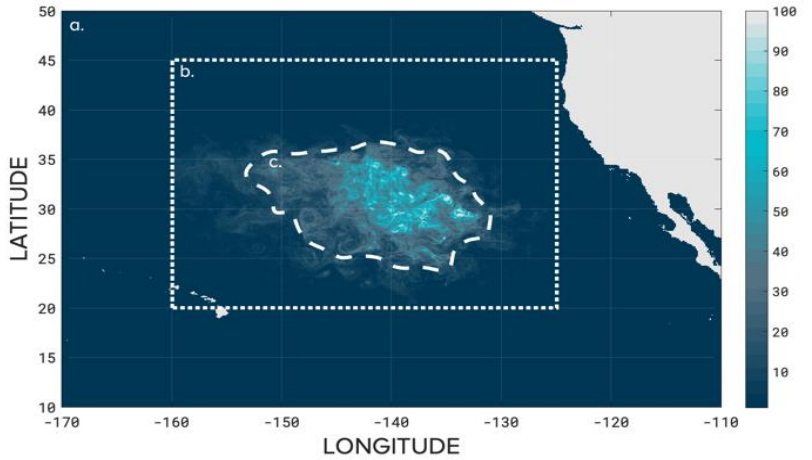


Klink, D., A. Peytavin, and L. Lebreton. "Size Dependent Transport of Floating Plastics Modeled in the Global Ocean. Front." *Mar. Sci* 9 (2022): 903134.

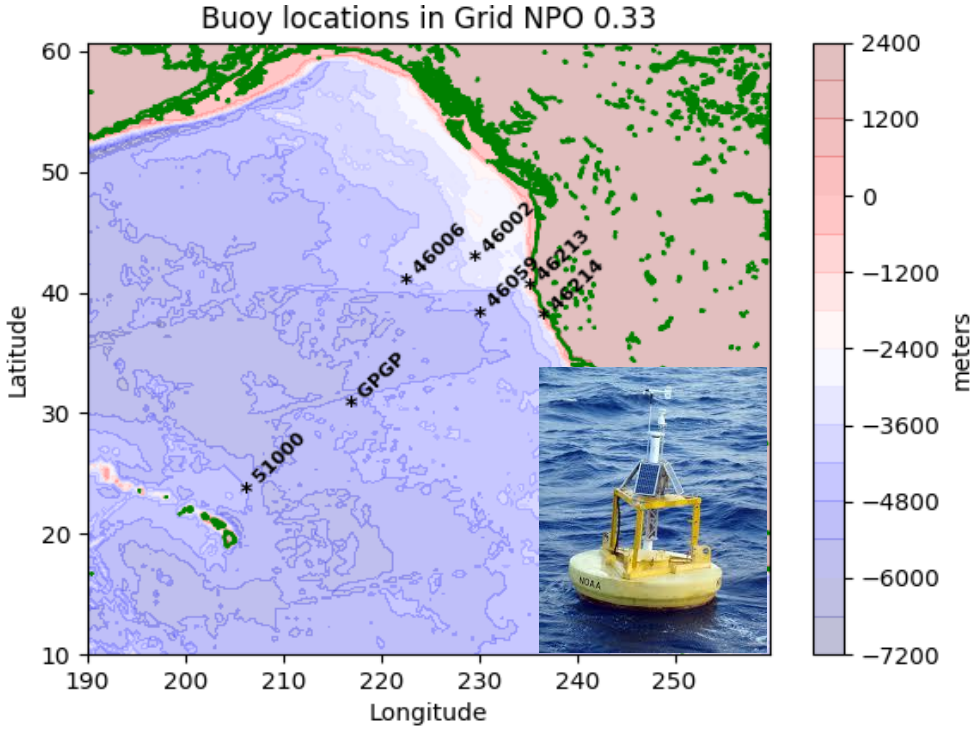
Visualization interface (Plasty)

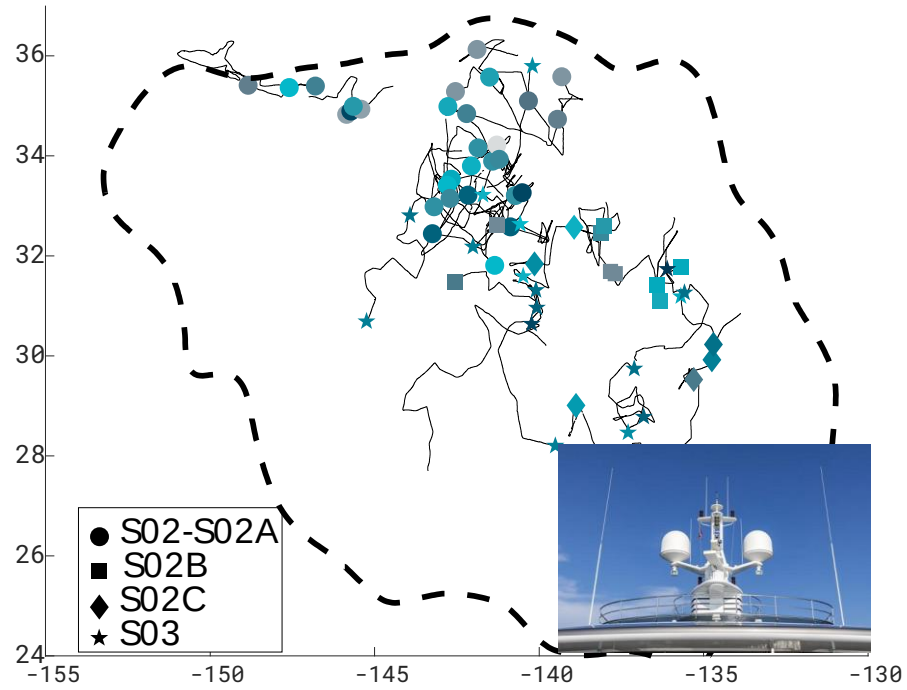


Model validations



- Scarce ground truth data in the GPGP.
- Historical data from NOAA buoys; 2021-2024 data collected by S02-S03 (wind, waves and plastics) (*Sainte-Rose et al, Wrenger et al. 2020*).

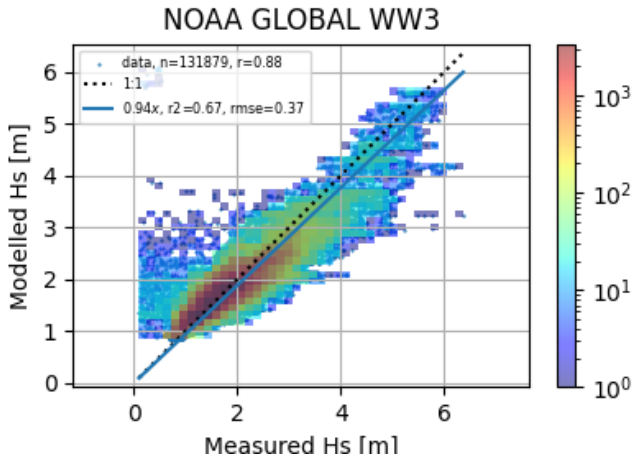


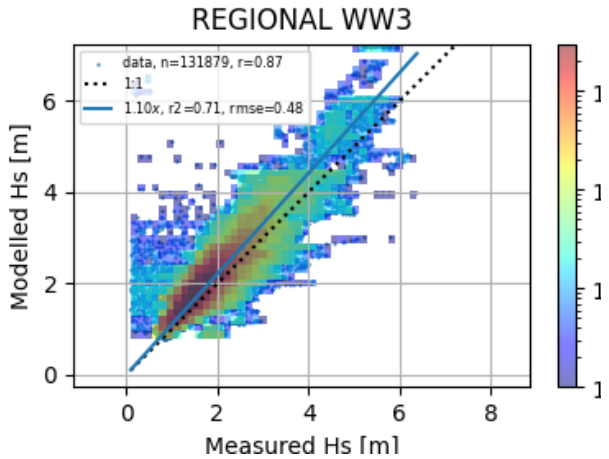


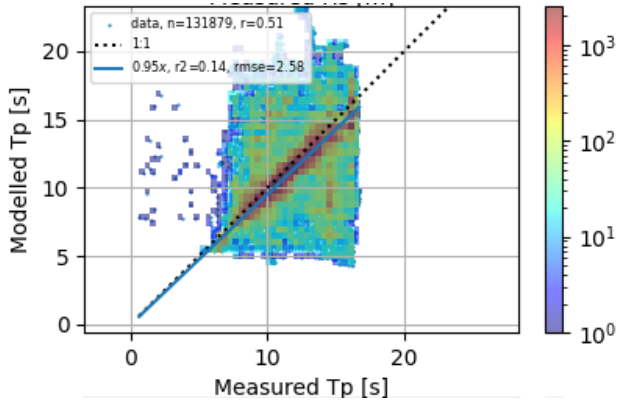
Sainte-Rose et al. "Monitoring and performance evaluation of plastic cleanup systems (Part i): description of the experimental campaign", OMAE (2020)

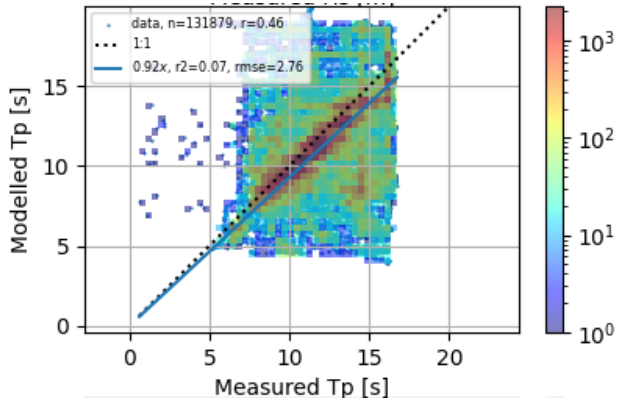
Wave model validation

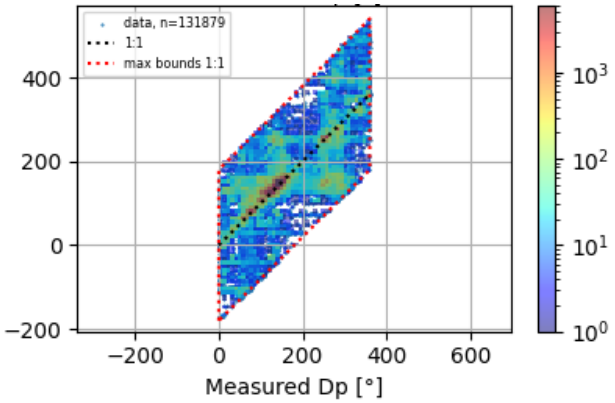
- Bulk wave properties from inside the GPGP from vessels data

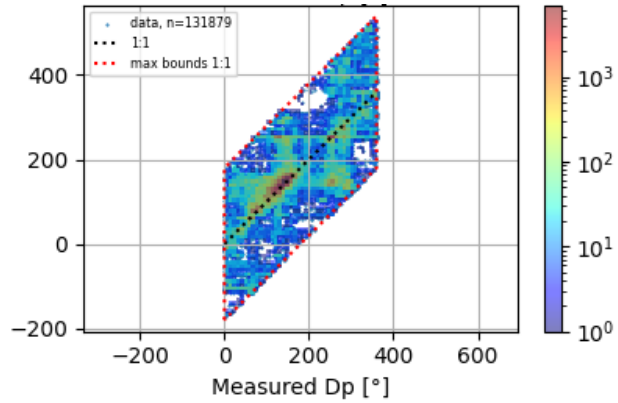






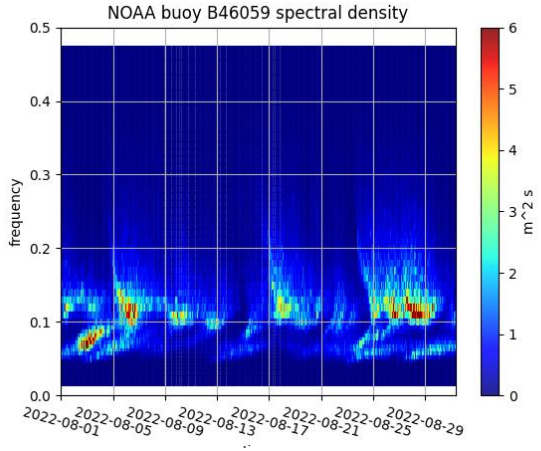


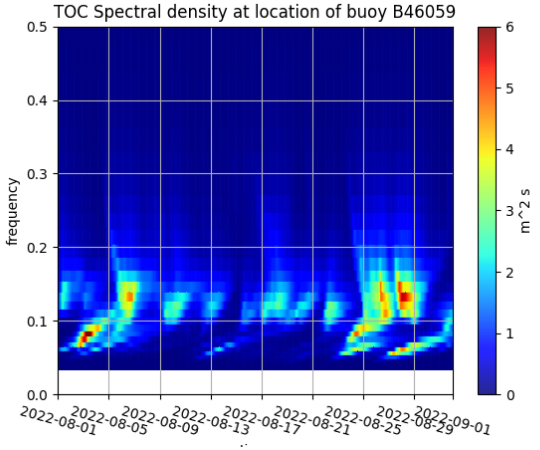


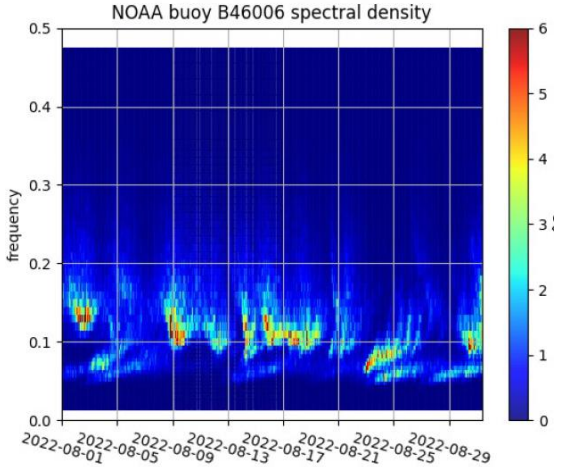


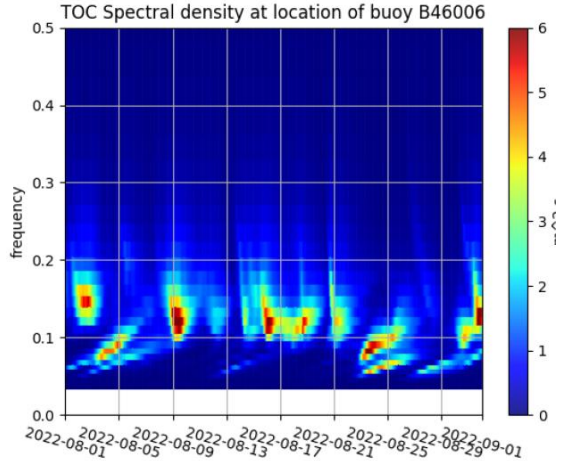
Wave model validation

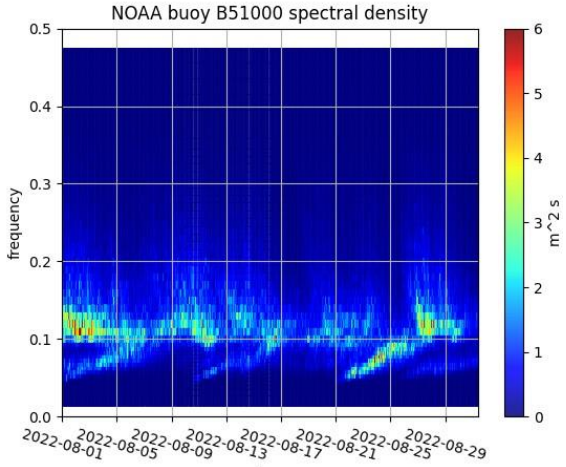
- 1D - spectral wave energy from NOAA buoys

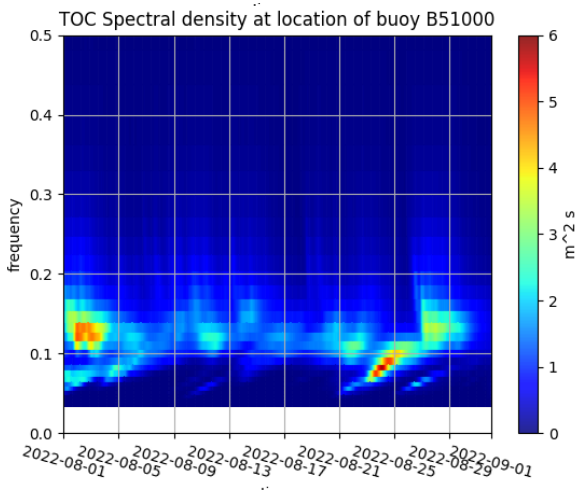


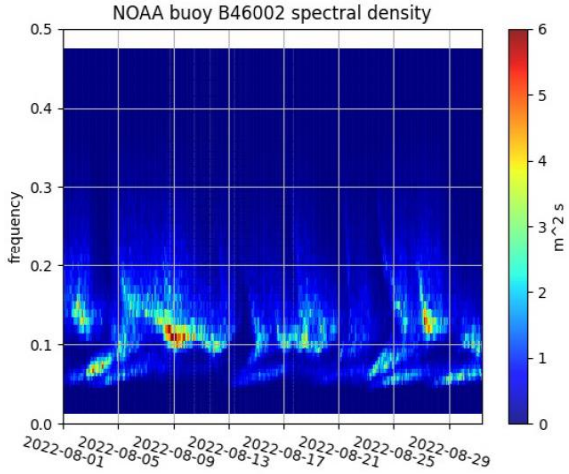


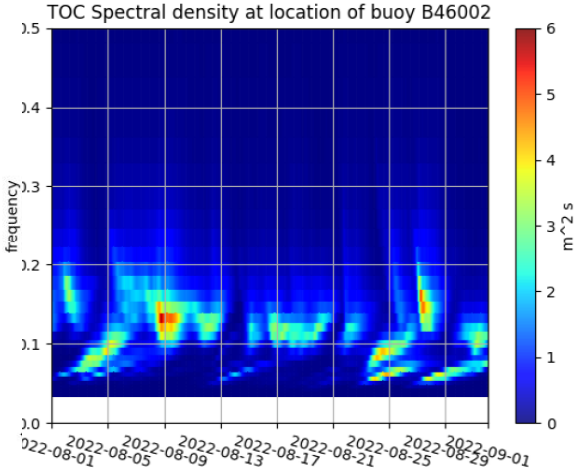






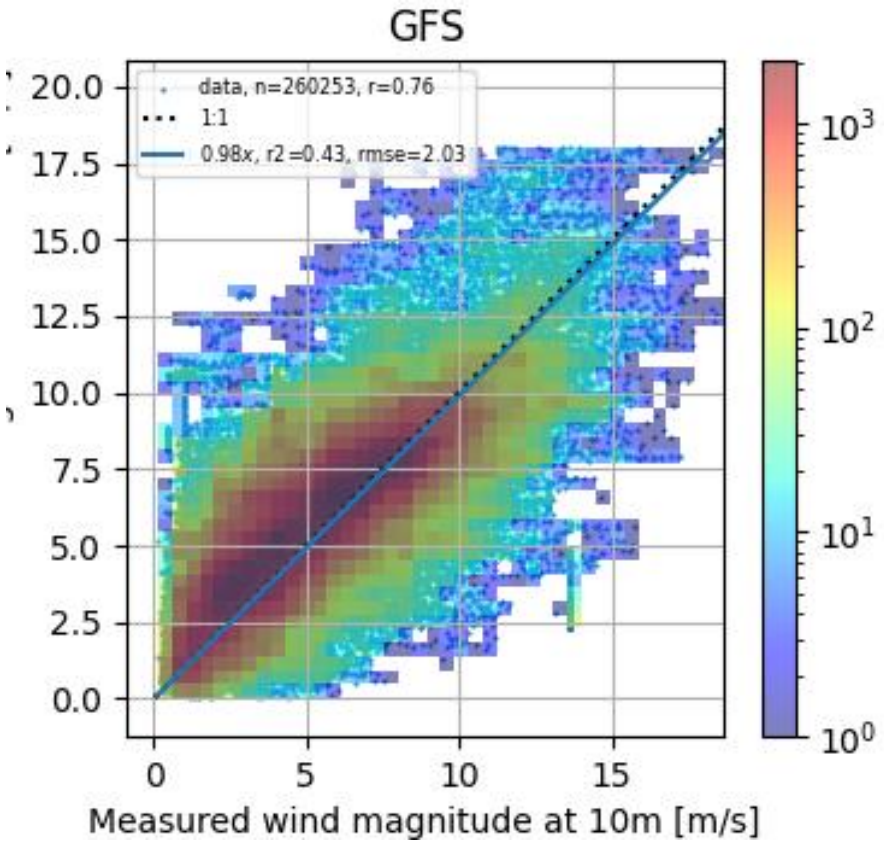


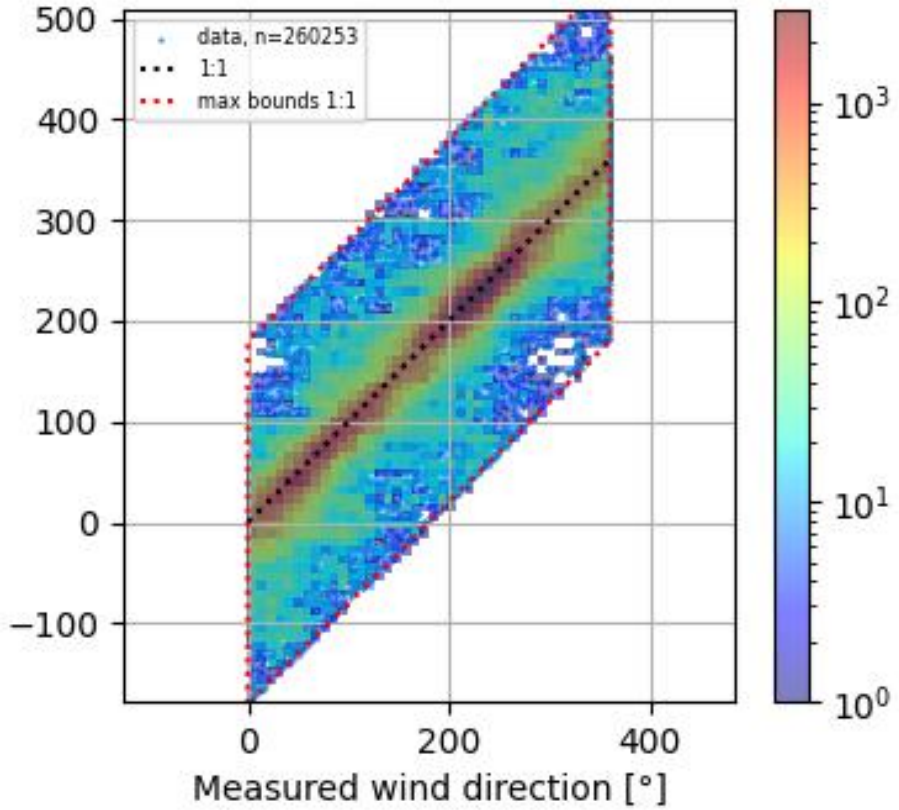




Wind model validation

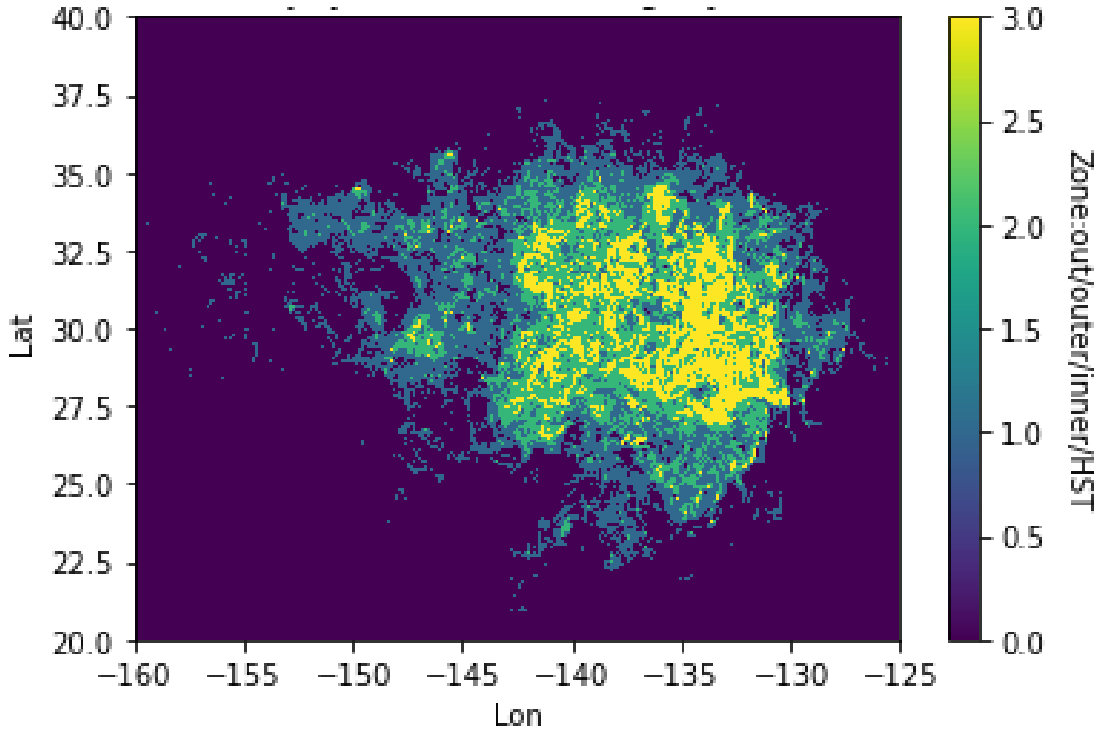
- Comparison with wind data from the vessel

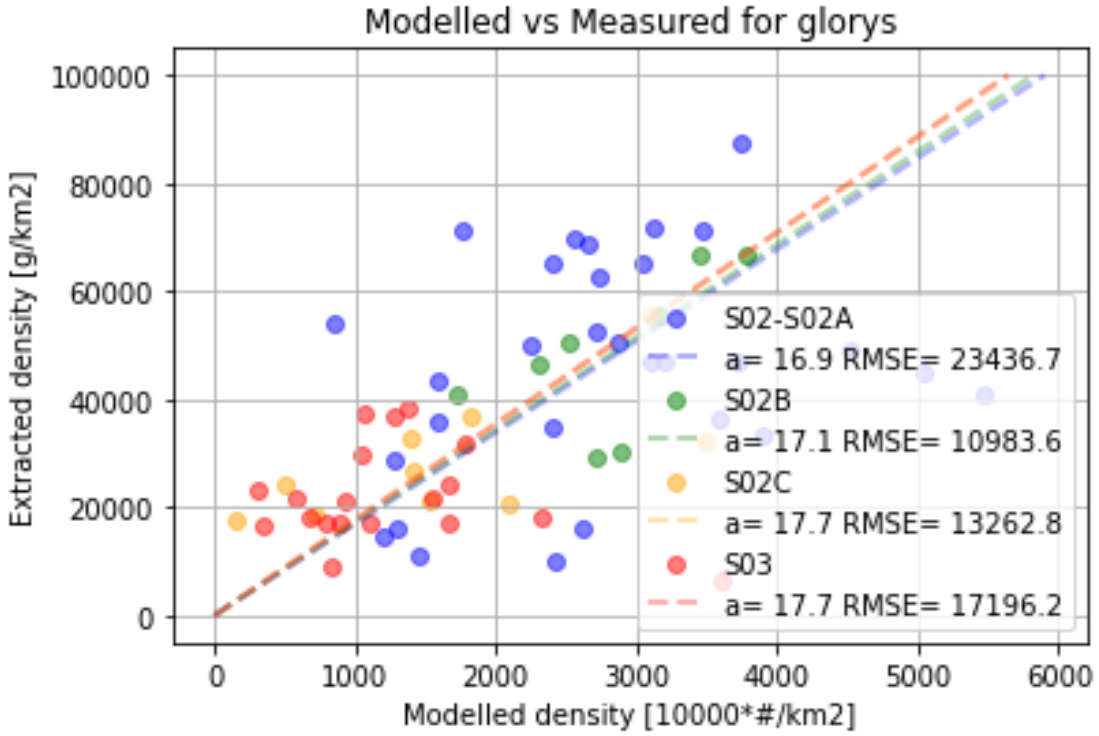




Plastic model validation

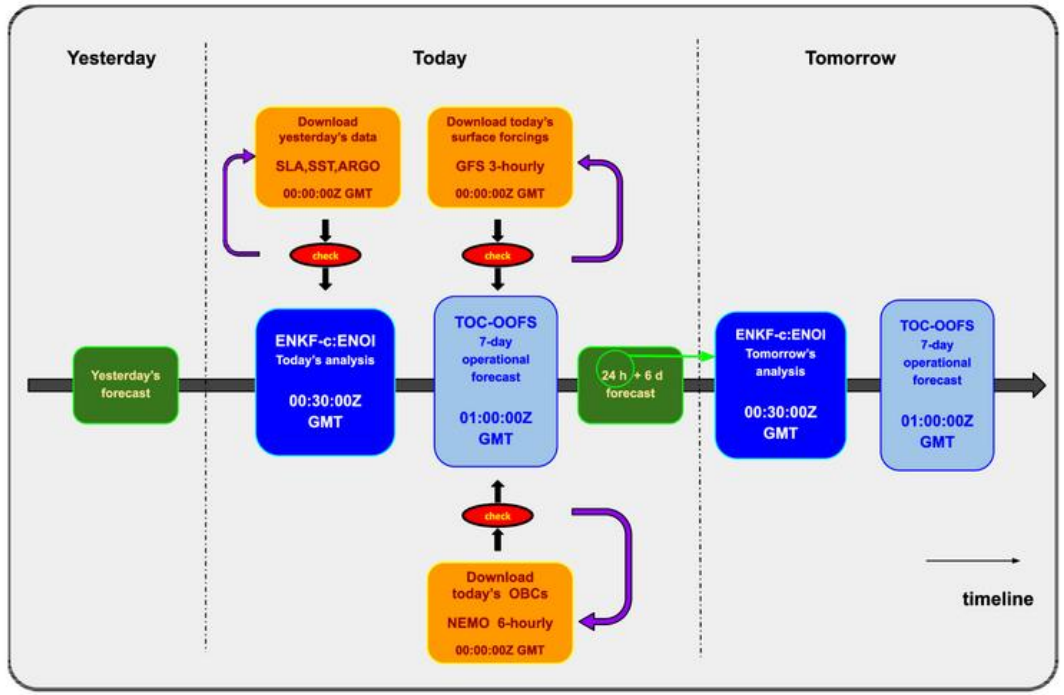
- Comparison between modeled and measured plastic surface densities (>1.5cm) from system extractions





On-going and future developments

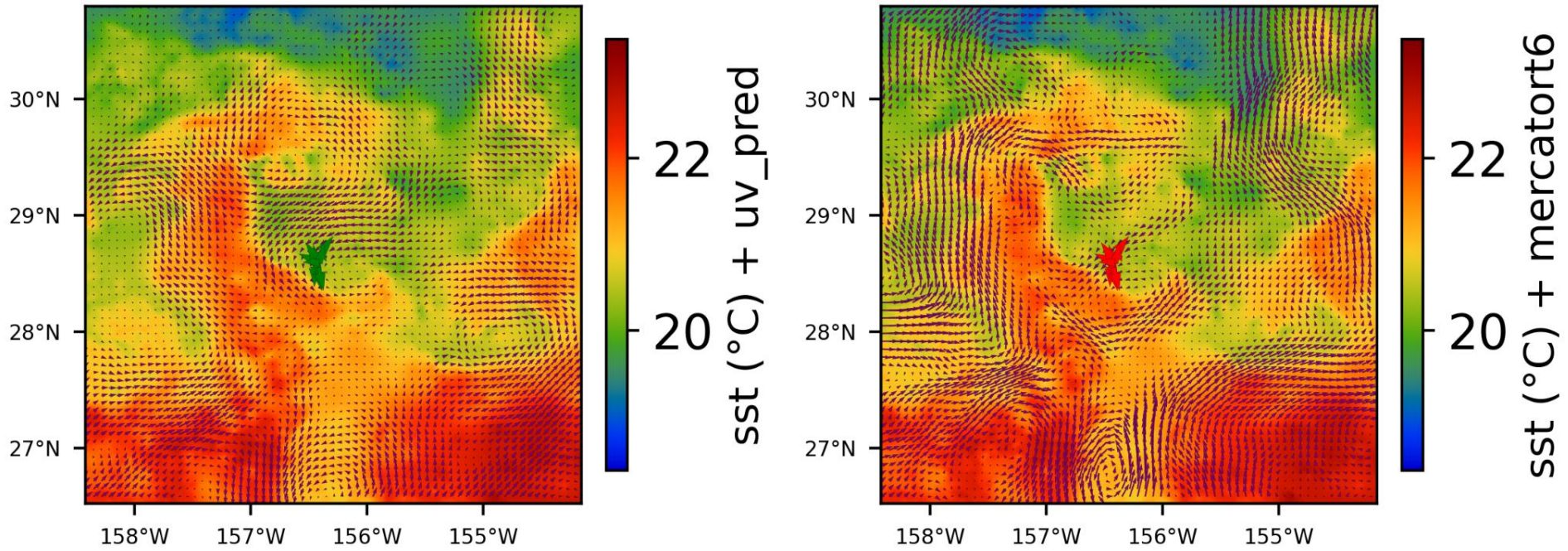
- Circulation model - assimilative ROMS:
  - two experiments (NEMO and HYCOM for background and OBC)
  - Ensemble Optimal Interpolation (*Sakov and Sandery, 2015*) of:
    - SLA: along-track L3 data from satelites Sentinel-6A, Jason-3, Sentinel-3A, Sentinel-3B, Saral/AltiKa, Cryosat-2, HY-2B
    - SST: ODYSSEA L3 data from satellite: polar orbiting (NOAA-18 & NOAAA-19/AVHRR, METOP-A/AVHRR, ENVISAT/AATSR, AQUA/AMSRE, TRMM/TMI) and geostationary (MSG/SEVIRI, GOES-11).



Sakov and Sandery. "Comparison of EnOI and EnKF regional ocean reanalysis systems", *Ocean Mod.* (2015)

On-going and future developments

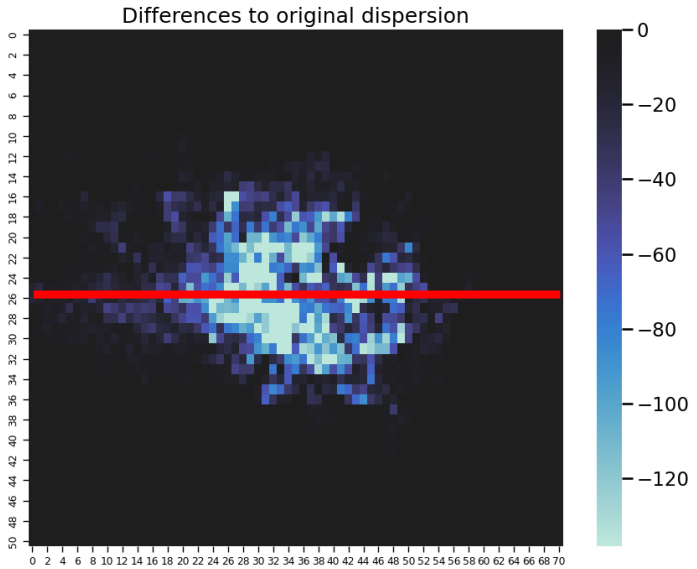
- Inclusion of Amphitrite HIRES v2.0 Neural-Network based circulation model (*Kugusheva et al., 2024*)

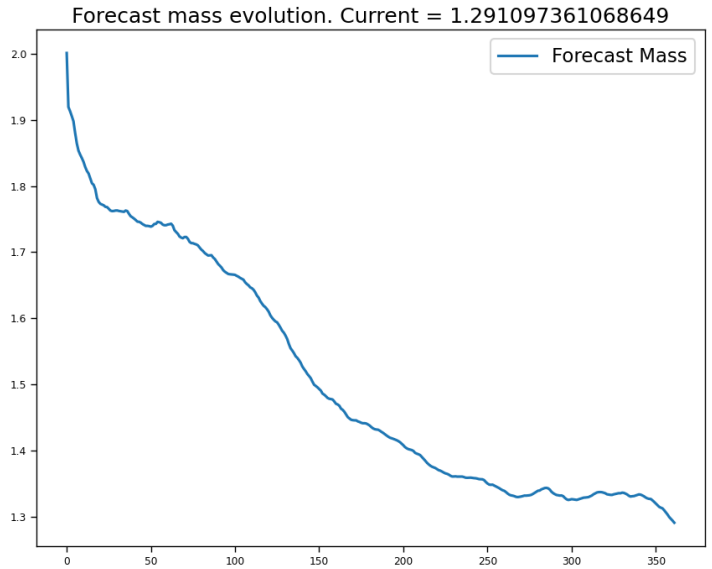


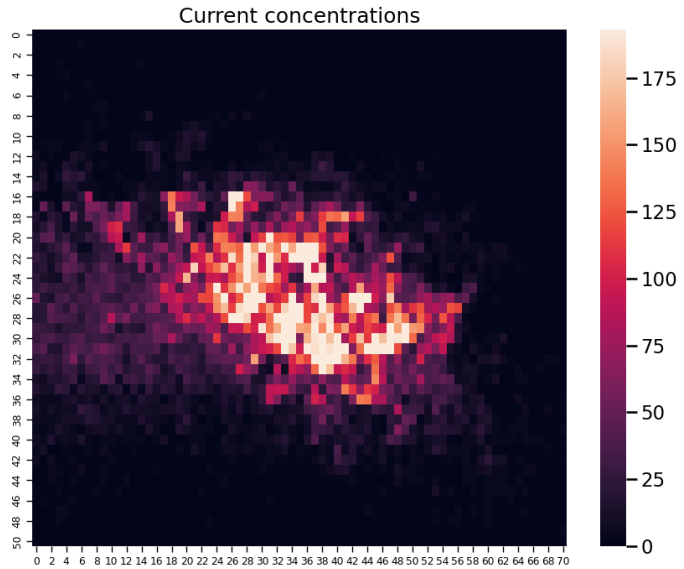
Kugusheva et al. "Ocean Satellite Data Fusion for High-Resolution Surface Current Maps", *Remote Sens.* (2024)

On-going and future developments

- Assimilative plastic dispersal model to take into account more frequent temporal and spatial plastic density measurements thanks to an Ensemble Kalman Filter (EnKF) based method (*Peytavin et al. 2021*).



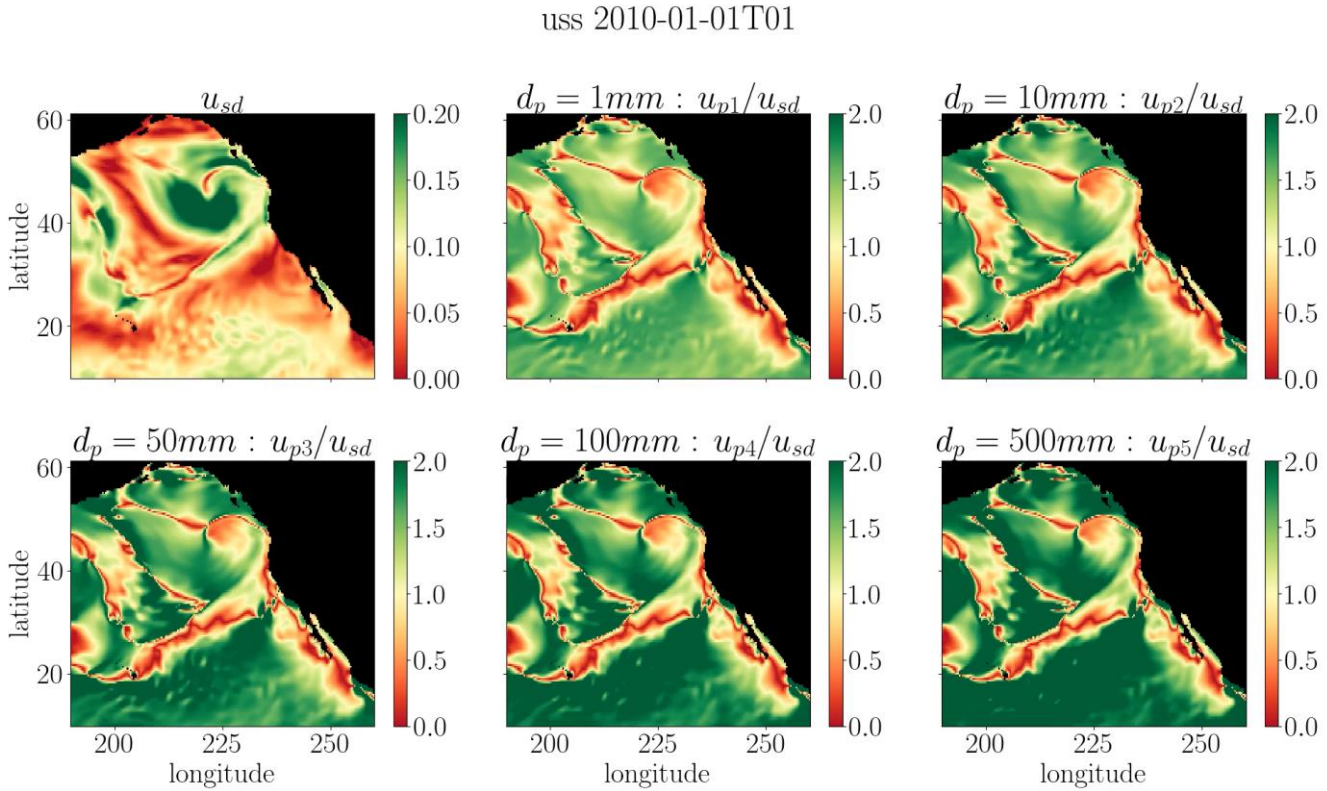




Peytavin et al. "Ocean Plastic Assimilator v0.2: assimilation of plastic concentration data into Lagrangian dispersion models", *Geosci. Mod. Dev.* (2021)

On-going and future developments

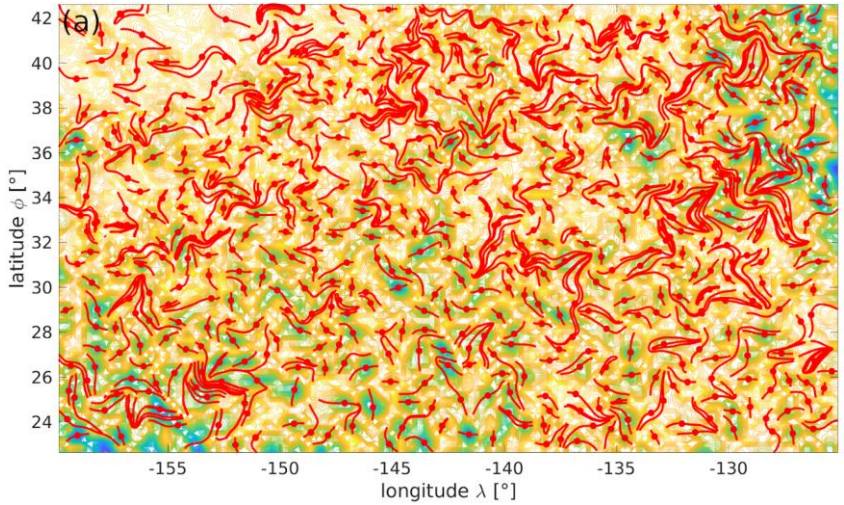
- Plastic transport:
  - size / density / shape dependent wave-induced drift (*Calvert et al., 2024*)

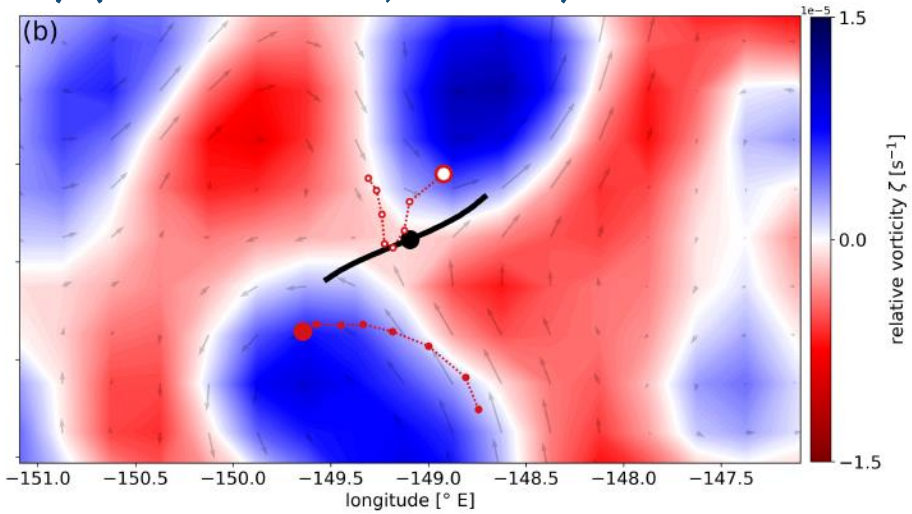


Calvert et al. " A Laboratory Study of the Effects of Size, Density, and Shape on the Wave-Induced Transport of Floating Marine Litter", *JGR: Oceans* (2024

On-going and future developments

- Eulerian diagnostics:
  - TRansient Attracting Profiles (TRAPs) (*Kunz et al., 2024)*





  - Finite Size Lyapunov Exponents (FSLEs)
- Lagrangian diagnostics:
  - drifters (GDP, SOFAR spotters, Maker Buoys – *Sainte-Rose et al. 2022*)

Kunz et al. "Transient Attracting Profiles in the Great Pacific Garbage Patch", *Ocean Science* (2024)

Sainte-Rose et al. "Persistency and surface convergence evidenced by two maker buoys in the great pacific garbage patch", *J. Mar. Sci. Eng.* (2023)

Conclusions and way-forward

- An operational system has been setup to map the plastics in the oceans and allow decision-making for an efficient cleanup.

- Some challenges remain in terms of validation:
  - sea-surface current
  - plastic densities

- Way forward:
  - larger temporal and spatial scale of ocean plastic measurements
  - higher resolution and assimilative circulation and plastic models

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