MOHIDing Workshop – 7-8 June, 2018 – Lisbon, Portugal

*Transport of Floating Marine Litter in the coastal area of the south-eastern Bay of Biscay: a Lagrangian approach using modelling and observations**

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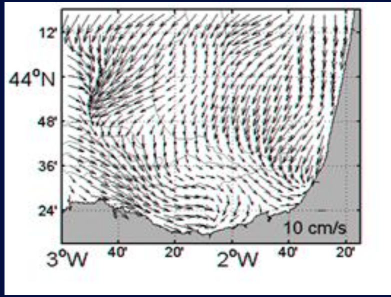
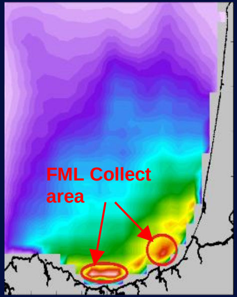
* submitted in Journal of Operational Oceanography





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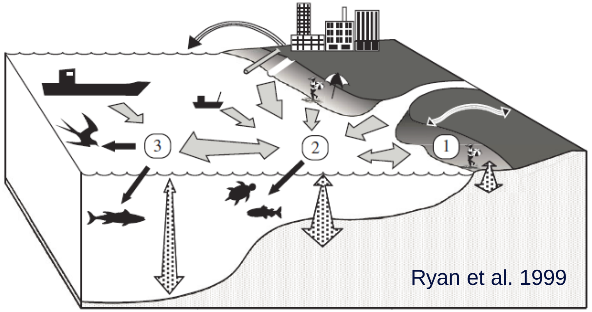
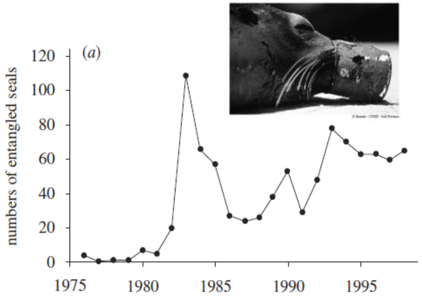
Introduction

The Marine Litter issue

- Marine litter is one of the main ocean pollutions related to human activities
  - **Plastic**, fishing nets, sanitary wastes, etc.
  - **4.8 to 12.7 Mt of marine litter** in the ocean every year (Jambeck et al., 2015)
  - **Plastic waste** = 60-80% of world's litter → **10% ends up into the oceans** (Derraik 2002)
  - Main inputs: **beaches, rivers, storm water runoff, wastewater discharges** (Ryan et al. 1999)
  - UNEP 2005: 15% beach onshore (1), 15% drift in the surface ocean (2),
    70% sink toward the deeper ocean after drifting in the surface layer (3)
- Many impacts
  - **Environment & Ecology**
    - **Ingestion by fishes, turtles, marine mammals** + **entanglement**, impede fish movement
    - **Contaminant fixation** on plastic wastes (e.g. bacteria), degradation toward **microplastic**
  - **Economy**
    - Touristic activities, recreational use of beaches
    - Obstacles for navigation
    - Significant **cost of litter collection** onshore/offshore → **~350 M€/year** for EU coasts
- Marine Strategy Framework Directive targets marine litter (Directive 2008/56/CE)
  - Good ecological state to be reached in 2020
  - **Descriptor #10 → Marine litter**





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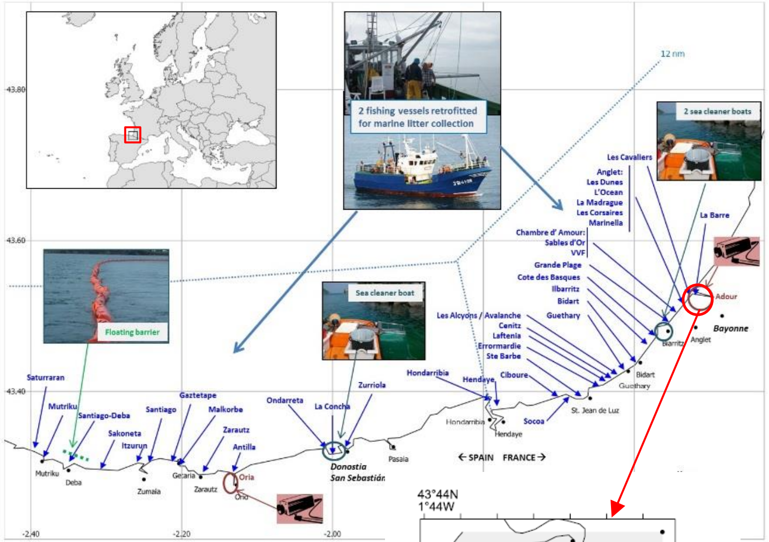
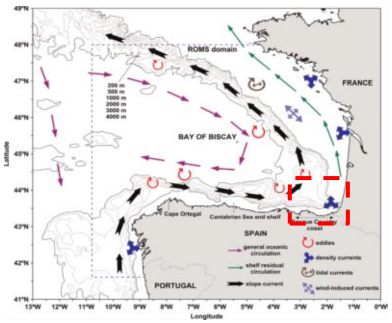
Introduction

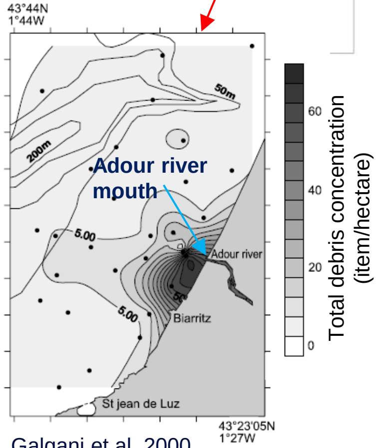
LIFE LEMA project

- Funded by the EU LIFE program. Duration: 2016-2019
- Objectives
  - **Support FML management by local authorities** → collection operations, source identification, collected waste valorization
  - Improve **knowledge about FML** dynamics in the **coastal area** → **Metocean** tools
  - Improve **offshore collection efficiency** → Fishing vessels, FML hotspot targeting, routing optimization
  - Anticipate **onshore arrivals**
- Focus on
  - **Macro-litter** (typical size > 20 cm)
  - **Floating** Marine Litter → Coastal area
  - **Beached** Marine Litter → Nearshore/Onshore areas
  - Study area: **SE Bay of Biscay** (Spain/France)
- Methodology applied offshore and near coast
  - **Fishing boats** used for FML collection
  - **FML observations & analysis** (video monitoring, remote imagery)
  - **Surface transport** study: **observation** (HF Radar, drifters) and **model**





Ferrer et al. 2009



Galgani et al. 2000

Introduction

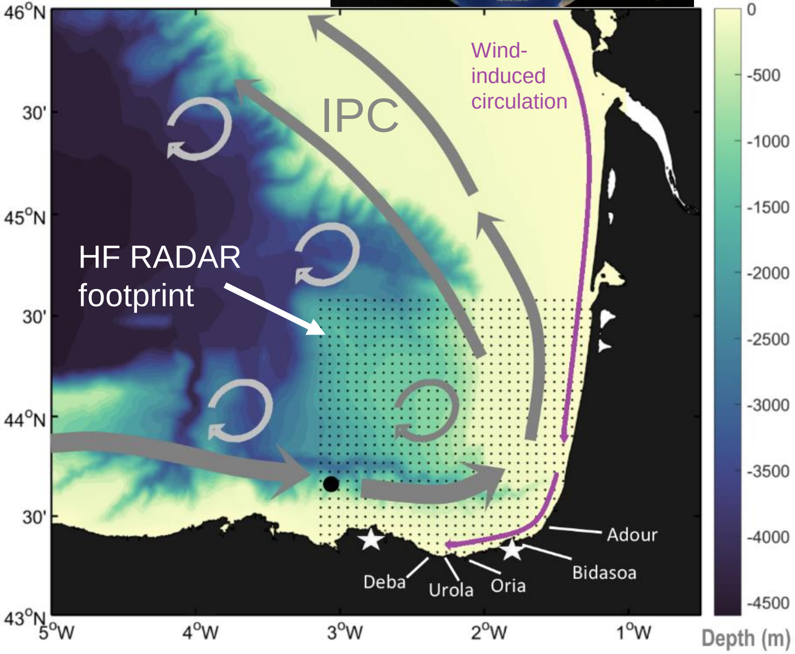
South-Eastern Bay of Biscay

- **Coastal area**
  - Sharp bathymetry, with numerous canyons
  - Shallow shelf (~200 m)
- **Dynamics**
  - **Iberian Poleward Current (IPC)**, a density-driven slope current
  - High **seasonal** variability
    - → toward East (North) along the Spanish (French) coast in Winter
    - → reversed flow in Summer, intensity 3 times weaker

  (Le Cann and Serpete 2009; Charria et al. 2013)
- **Wind-induced circulation**
  - **Inner shelf circulation mainly driven by wind**
  - Same direction IPC in autumn and winter
  - Southward and Westward in Spring and Summer

  (Solabarrieta et al. 2015)
- **Continental inflow**
  - **1 main river and 4 secondary rivers** in the area with high seasonal flow variability
  - Mean flows variyng between 1000m^3.s^{-1} (Adour) to 100m^3.s^{-1} for the others

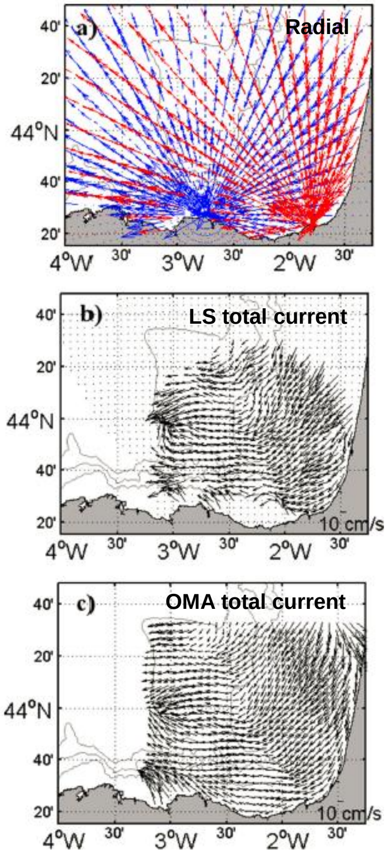
  (Ferrer et al. 2009)



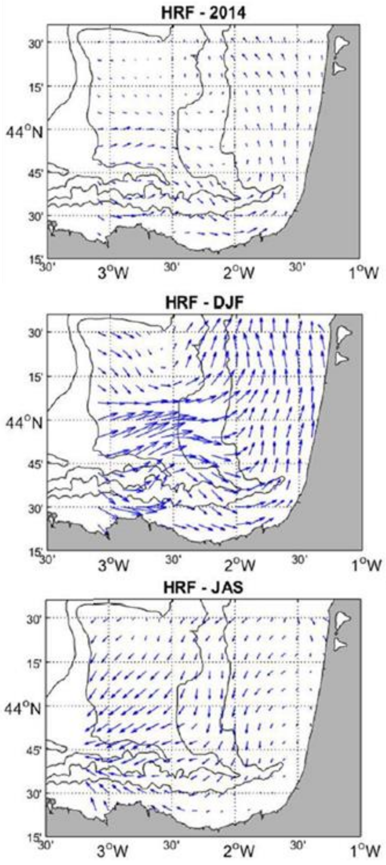
Data

Surface current fields from HF Radar system

- Euskalmet HFR system operated by AZTI Tecnalia
- Two antennas on the Spain north coast
- Data processing (see Rubio et al. 2017)
  - Least Square (LS) algorithm
  - OMA method
- Surface current fields
  - Current velocity components U,V
  - Area: [-3.2°E,-1.2°E], [43.27°N,44.58°N]
  - **Regular horizontal grid 5 x 5 km**
  - **Hourly data**



Rubio et al. 2017



OMA current annual/seasonal mean

Data

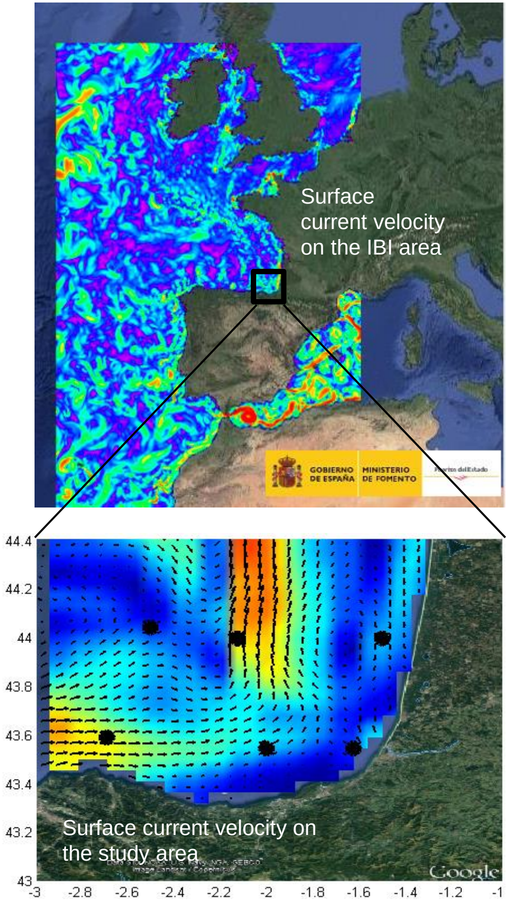
Surface current field from Copernicus model

- **IBI Ocean Analysis and Forecasting system**
  (CMEMS product: IBI_ANALYSIS_FORECAST_PHY_005_001_b)
  - NEMO hydrodynamic model forecast and analysis
  - Variables available: water level, currents, temperature, salinity

- Variable used: 3D or 2D surface current velocity field

- Model grid
  - Horizontal: **regular grid 2 x 2 km**
  - Vertical: 50 vertical layers (cartesian)

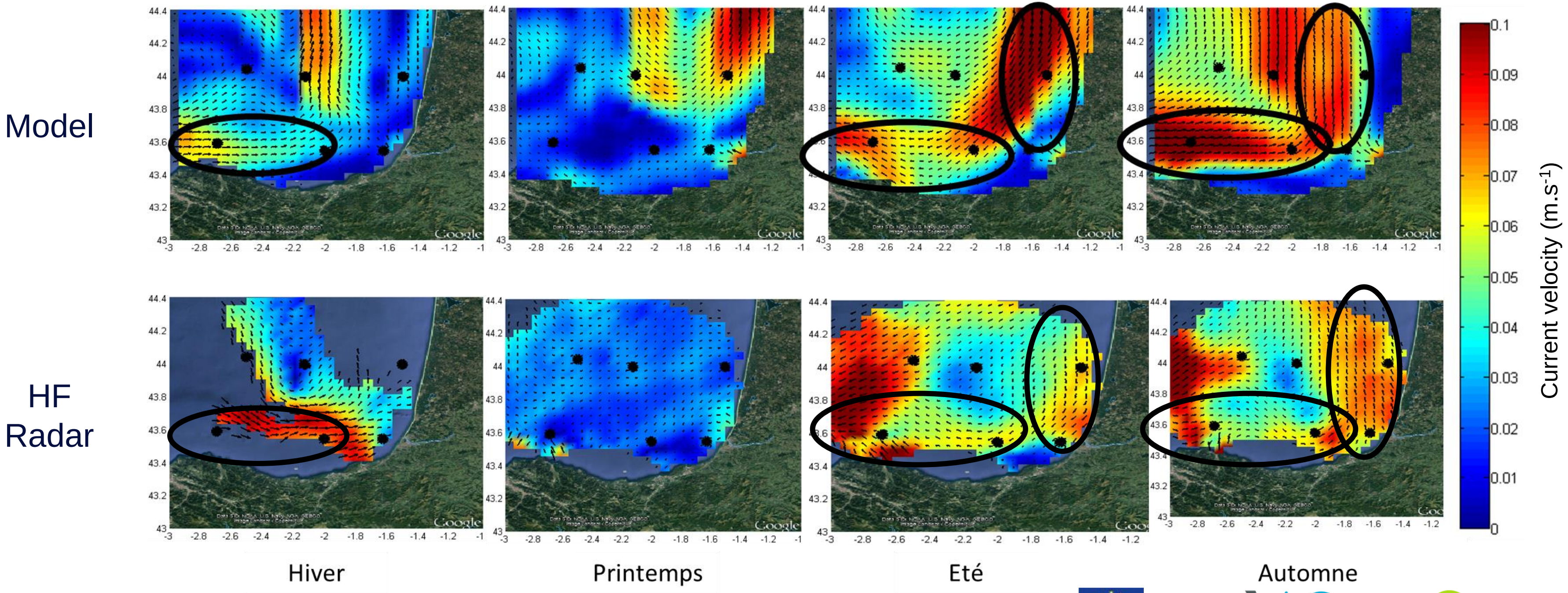
- Time step (hindcast data)
  - **Daily** 3D fields
  - **Hourly** 2D surface fields



Model-data comparison

Surface current fields: Eulerian comparison

- Copernicus model v.s. HF Radar velocity fields based on 3 years of data (2014-2015-2016)



Model-data comparison

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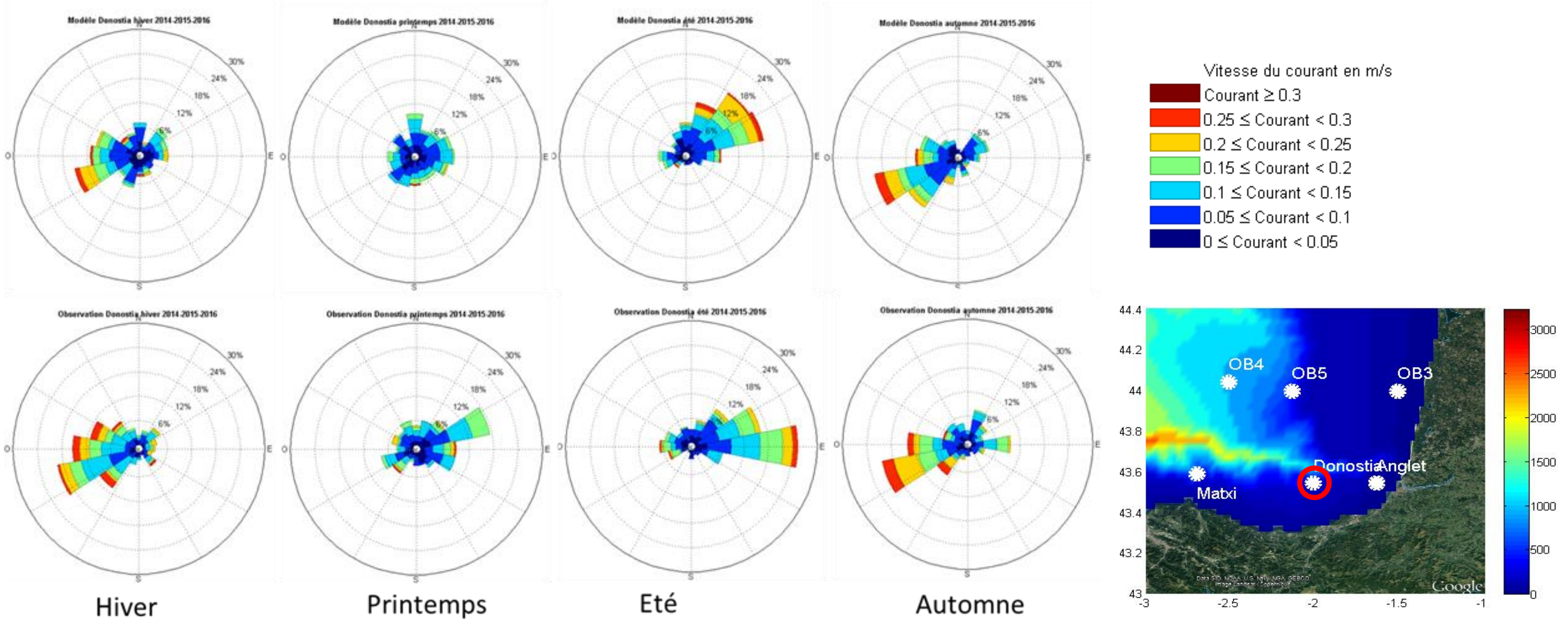
Model

HF Radar



Model-data comparison

Surface current fields: Eulerian comparison

- Copernicus model v.s. HF Radar velocity fields based on a 3 years control period (2014-2015-2016)

- Encouraging model-data agreement
  - Fair agreement in deep water
  - Reasonnable representation of the slope current
  - Several major seasonal patterns captured over the shelf

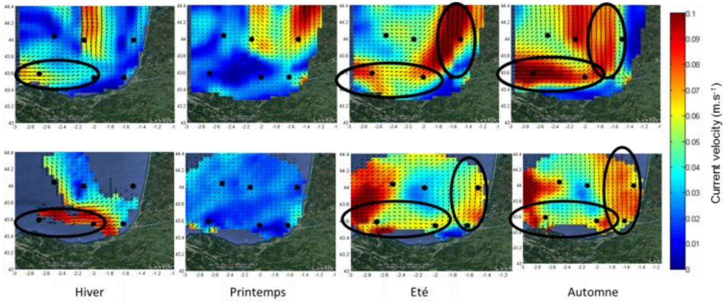
- However significant differences remain
  - Spring regime
  - Position and extension of the slope current
  - Important local differences over the inner shelf

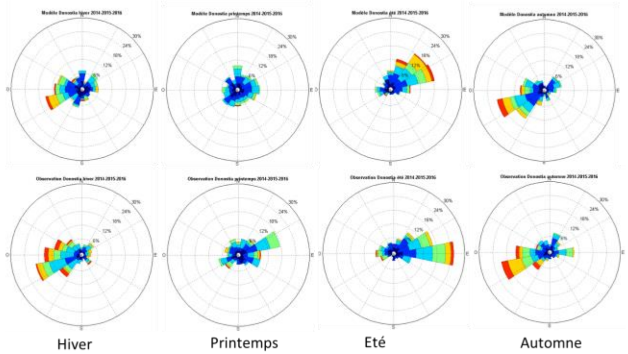
- Questions

  → What is the impact of these differences for the study of surface transport ?

  → Can IBI model be used to simulate/forecast FML transport ?

→ **Use of a Lagrangian approach**



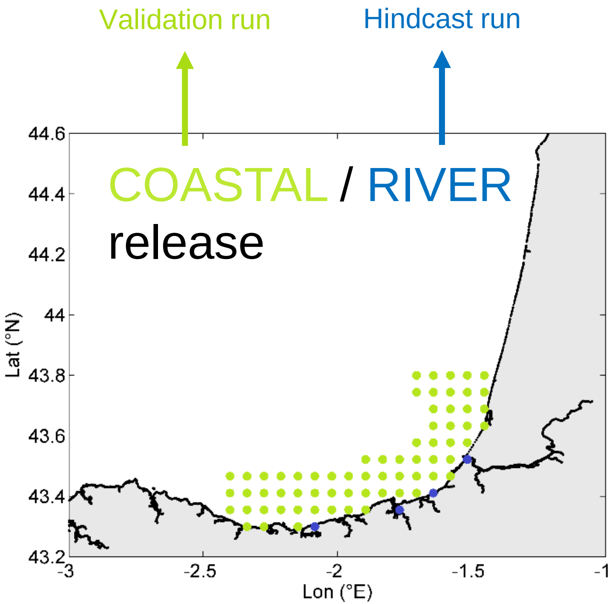


Lagrangian Transport Model

Lagrangian modelling of ocean surface transport

- **MOHID Water** modelling system (Martins et al. 2001; Braunschweig et al. 2004)
  Lagrangian transport module (Leitão 1996)
  - Main functionalities
    - 2D or 3D tracers advection by multiple current fields
    - Turbulent mixing effects: diffusion (Allen 1982) + dilution (volume increase)
    - Allows to account for direct wind effect at the surface
    - Properties transport (water quality, etc.)
- Implementation for this study
  - **2D advection by surface current** fields from HFR and Copernicus
  - Horizontal **diffusion** (hindcast run)
  - **Zero direct wind effect** on tracers
  - Without beaching process along the coast
- Tracers release
  - **Costal area release**: on a regularly spaced grid, 1 particle/hour
  - **Rivers mouth release**: in front of the 5 river mouths, depending on river flow

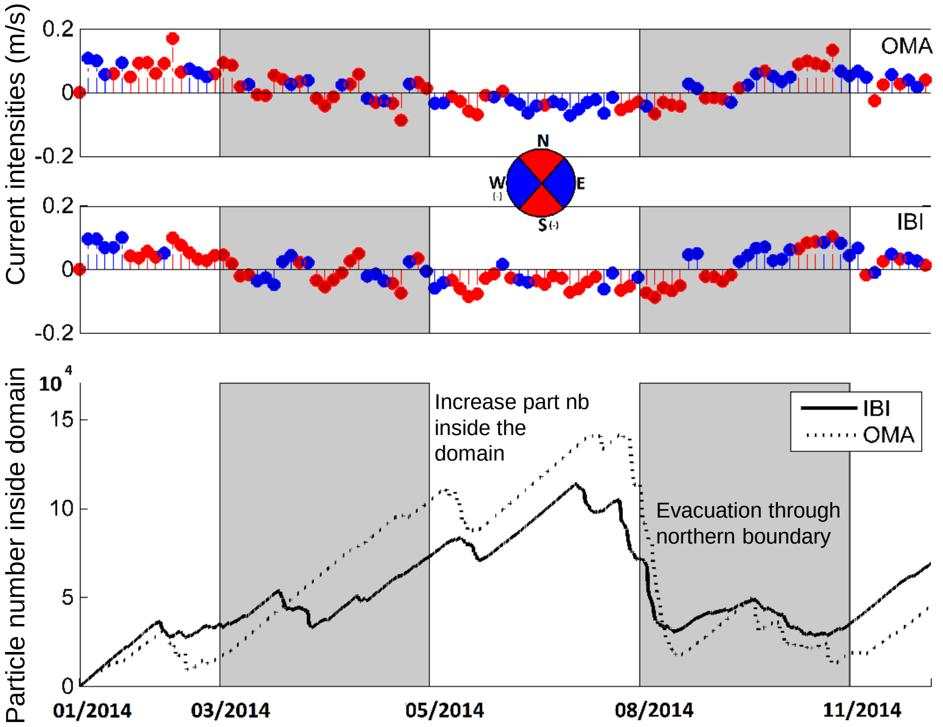
→ 5 years analysis simulation (2013-2017)



Validation run: CMEMS surface currents for Lagrangian transport simulations

Global tracers balance in/out the domain

- **Time evolution at the scale of the domain (COASTAL release)**
  - Comparable tendencies for the three years (2014-2016)
  - Remarkable **seasonal variability** for both runs
  - Higher particle **retention during spring and summer**
    - Effect of prevailing South and East current direction
    - **Retention along Spain coasts**
  - Important **domain flushing during autumn and winter seasons**
    - Northward surface current (IPC and wind) favour evacuation by northern domain boundary (along French coast)
  - More evacuation (retention) during winter (summer) with Copernicus forcings



Validation run: CMEMS surface currents for Lagrangian transport simulation

Normalized densities of particles

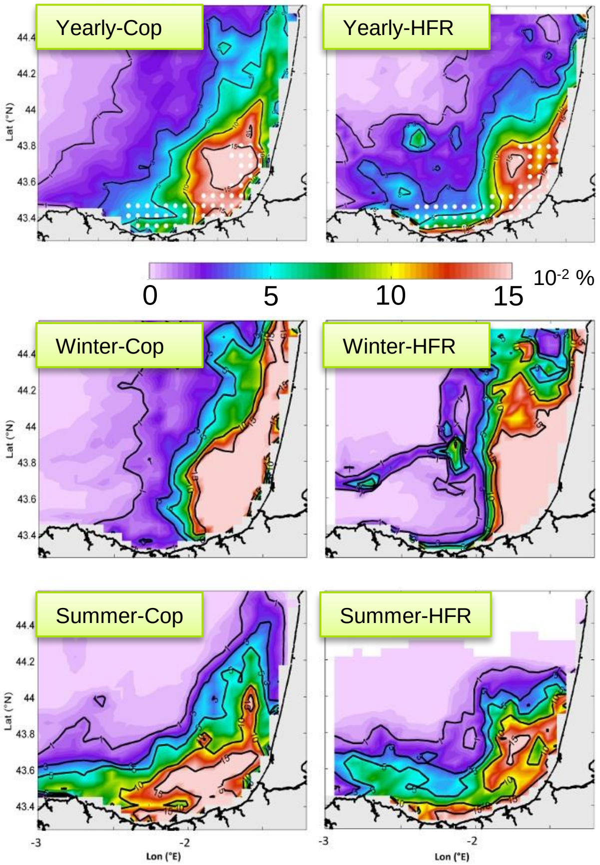
- **Averages over different timescales (COASTAL release)**

  - Yearly averaged in good agreement for both runs
  - Density values remain low (maximum 0,15%)
    → **No accumulation tendency**
    → **Maximum density in released area**
  - Particle **transport** is **northward in winter // southwestward in summer**
    → Conforts global balance

  - Normalized density inside a grid cell *(i,j)* is defined as:

$$\sigma(i,j,t) = \frac{n(i,j,t)}{N(t)}$$

with *N(t)* the total number of particles introduced from the beginning of the simulation to time *t*, and *n(i,j,t)* the numer of particles located in the grid cell *(i,j)* at time *t*

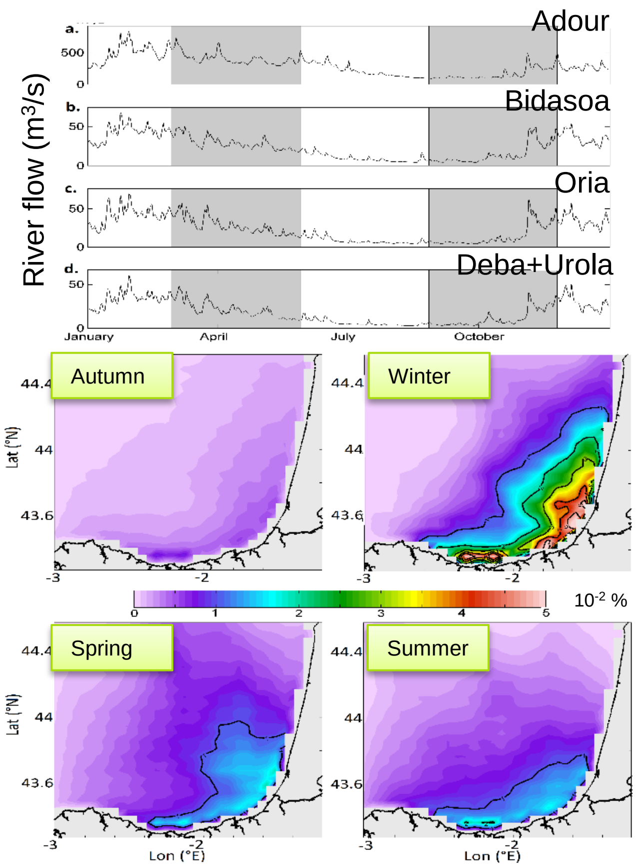


Characterization of surface transport patterns for FML introduced with continental outflows

Hindcast run analysis (RIVERS release)

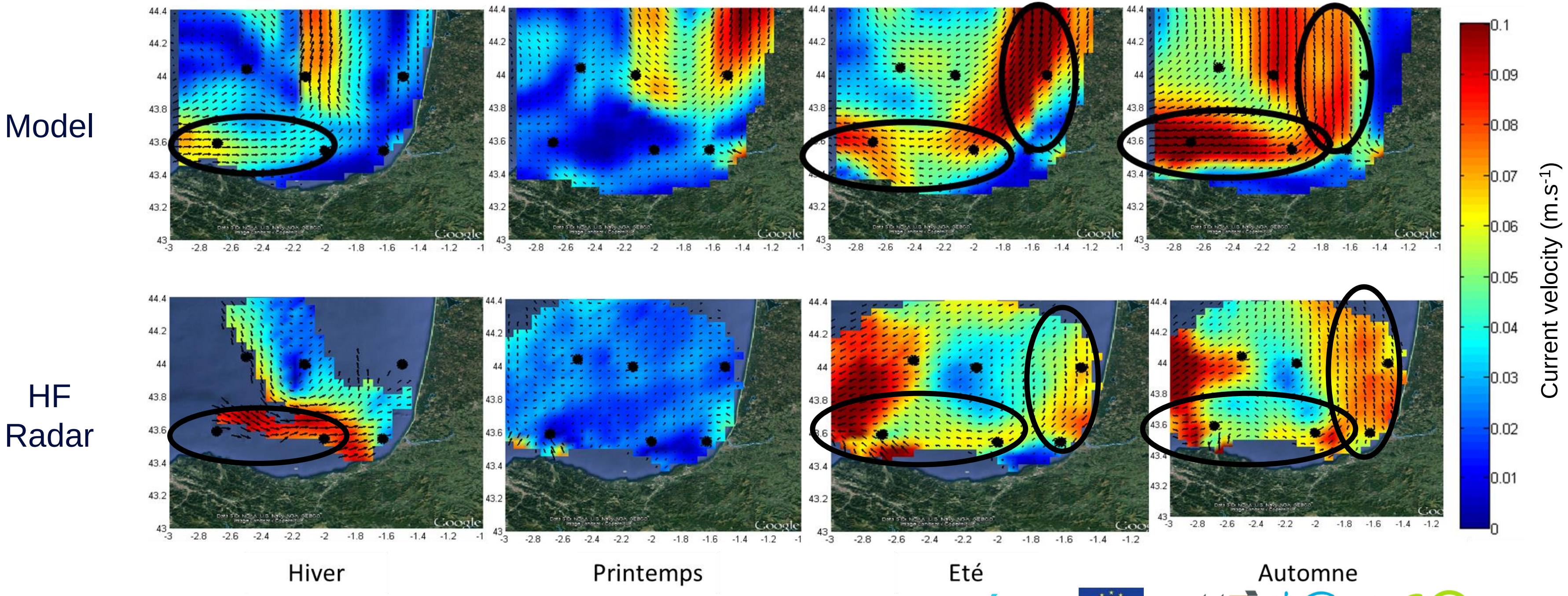
- **Seasonal average (5 years hindcast)**
  - Seasonal density patterns differ a lot
  - **Autumn: lowest density** → Limited outflow combined + **large evacuation capacity by IPC**
  - **Winter : highest densities**
    - Important continental outflows
    - Limited northward surface circulation along French coast (IPC more offshore)
  - **Spring/Summer: particles** concentrate in **south of the domain**
    - **Retention due to surface circulation** (mainly wind-induced) : Southward in North, low intensity in the SE corner
    - Higher accumulation in summer: comparable densities but much less outflows

→ Consistent results with **wind-induced circulation and slope current regimes**



Characterization of surface transport patterns for FML introduced with continental outflows

Surface current fields: Eulerian comparison

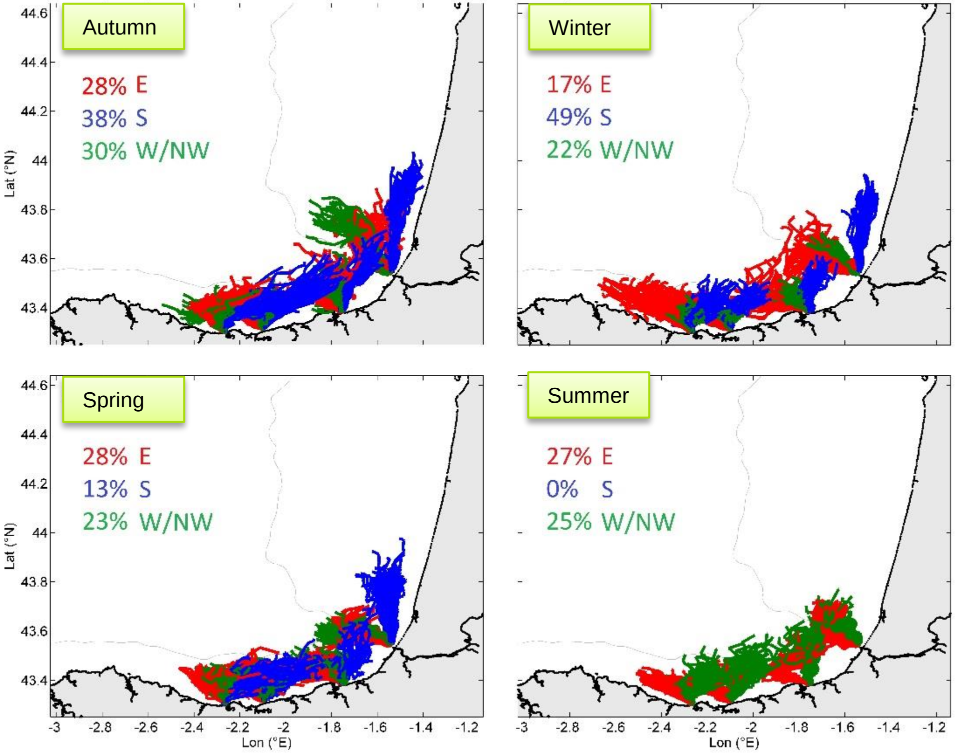


Characterization of surface transport patterns for FML introduced with continental outflows

Wind regime contribution

- **Seasonal average – Case RIVERS release**

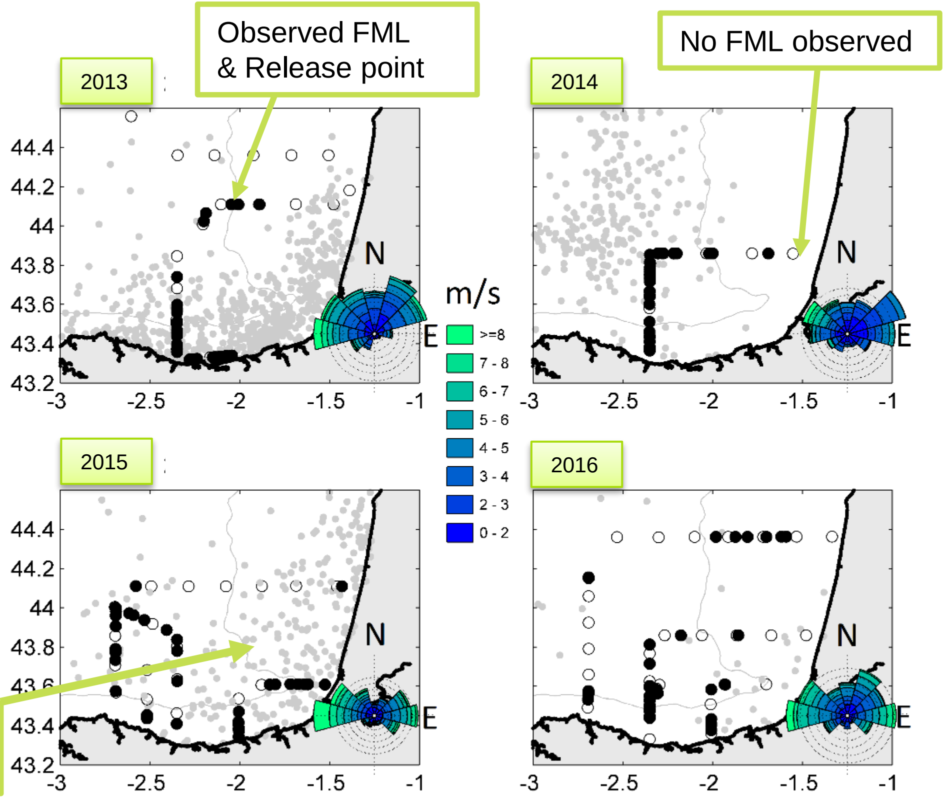
  - 3 days trajectories averaged over specific wind regime occurrences
  - **3 typical wind regimes**:
    - Westerly/North-Westerly → hot seasons
    - Easterly → intermediate seasons
    - Southerly → winter
  - **Southerly** wind very **rare in Summer**
  - **W/Nwesterly** and **Easterly** (less intense) winds **accentuate coastal accumulation**
  - Autumn/Winter **Southerly wind** and IPC **favour northward transport**



Characterization of surface transport patterns for FML introduced with continental outflows

Summer season transport prediction using FML observation data

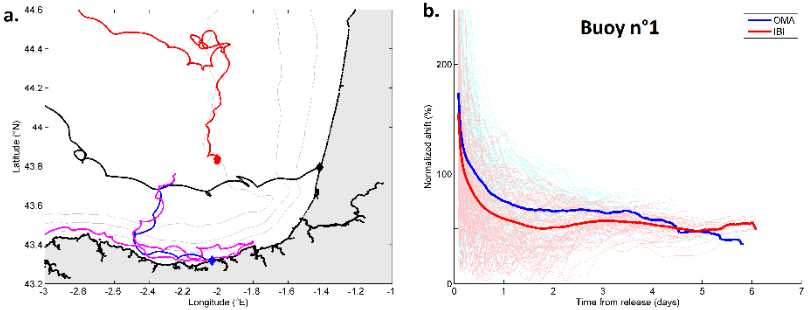
- Use of the model to investigate the fate of FML observed offshore
  - **4 years** with FML observations in summer from **JUVENA campaigns**
  - Initial release at observed point and river mouths
  - 1 month transport simulation
- Results
  - **Large inter-annual variability** of both FML quantities and transport
  - 2013: **critical** case with **accumulation along coast**
  - 2014 & 2016 : **no critical retention** thanks **to Easterly winds**
- Illustrate a possible operational use: targeting accumulation areas



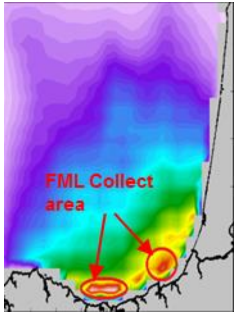
Conclusions

The support of Copernicus model for the study FML transport

- Eulerian and Lagrangian comparisons of Copernicus IBI and HFR surface currents gives encouraging results (3 years control period)
  - Results analysis and comparison based on **different diagnostics: 3 years test period**
  - Reasonable Copernicus/HFR results **global agreement**…
  - …but significant **local differences**, especially for the coastal release case



- **Copernicus IBI surface current to study transport in SE BoB**
  - **No specific permanent retention zone** in the coastal area
  - Transport pattern **highly seasonal**
    → **Autumn**: **evacuation** toward N along French coast
    → **Winter: accumulation** in the **SE corner** and in the **N** along French coast
    → **Spring/Summer : retention** in the S/SE region
  - Surface transport in **agreement with wind and IPC current patterns**
  - **Large summer variability** → wind variability



- Further work
  - **Downscaling** CMEMS & Further surface transport validation against observation
  - Work on **beaching parameterization**
  - **Operational implementation** to predict FML patches at sea

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Oceanography at coastal scales.
Modelling, coupling, observations and benefits from coastal research infrastructures
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Thanks for your attention !


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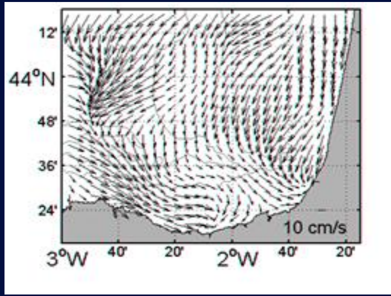

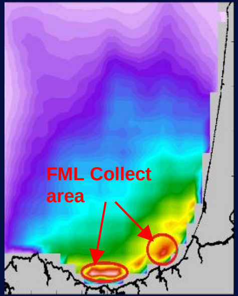

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