Impact of the tides, wind and shelf circulation on the Gironde river plume dynamics

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Outline

Introduction: context and area of study

Modelling configuration

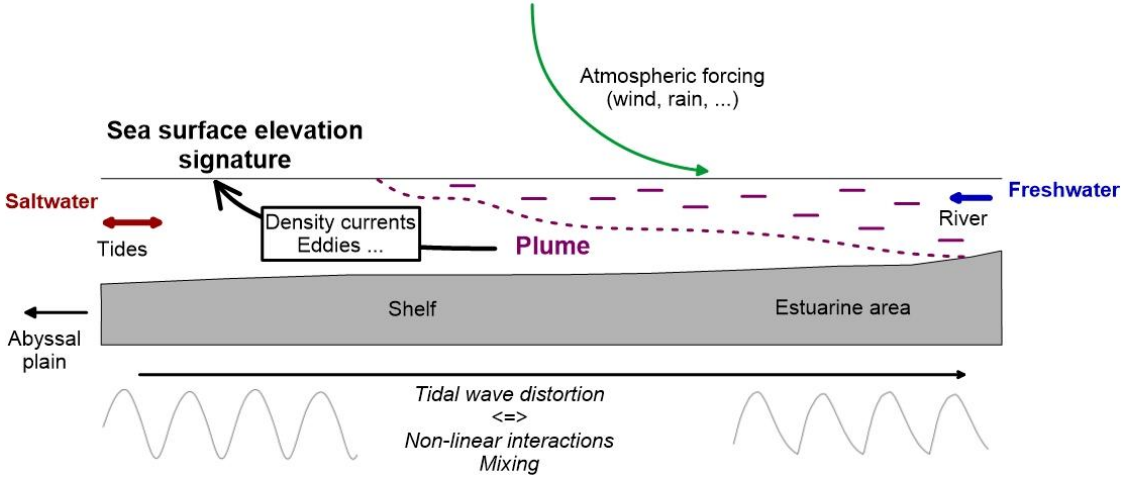
Elements of validation

Plume seasonality, stratification and small scale features

Conclusions

Perspectives

Introduction



Plume = ocean - estuary interface

Tides

River discharge

Coastal circulation

Wind

How do these forcings interact to forme the plume?

What are the characteristics and dynamics of this plume?

What is the signature of these phenomena on the sea surface height?

Bay of Biscay

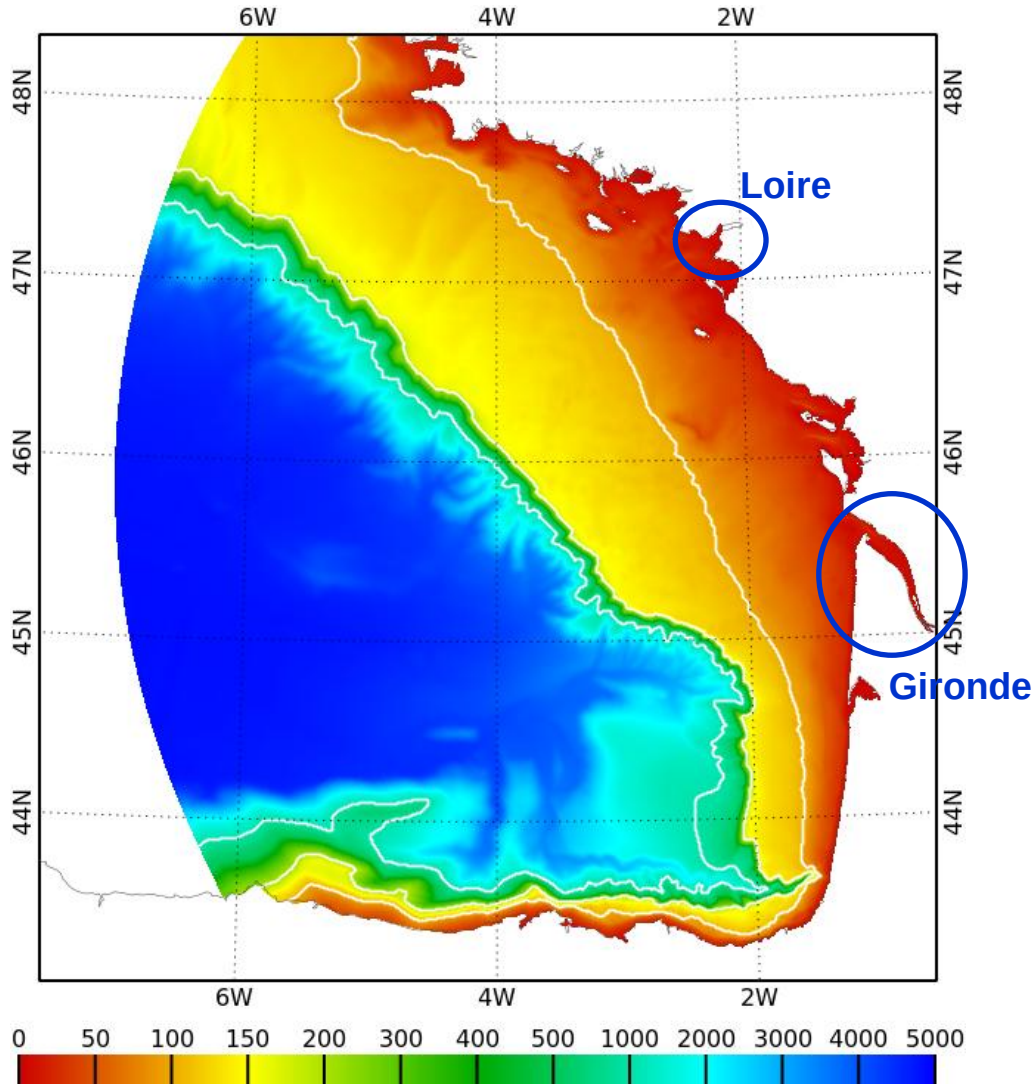
Large continental shelf in the north (Armorican shelf), decreasing width towards the south (Aquitaine shelf)

Narrow continental shelf along the Cantabrian coast

Strong bathymetric gradients over the Armorican and Cantabrian slopes

Abyssal plain ~4500m deep

Two major freshwater inputs: Loire and **Gironde**



Bathymetry of the Bay of Biscay.
In white : 100, 200 and 1000m isobaths.

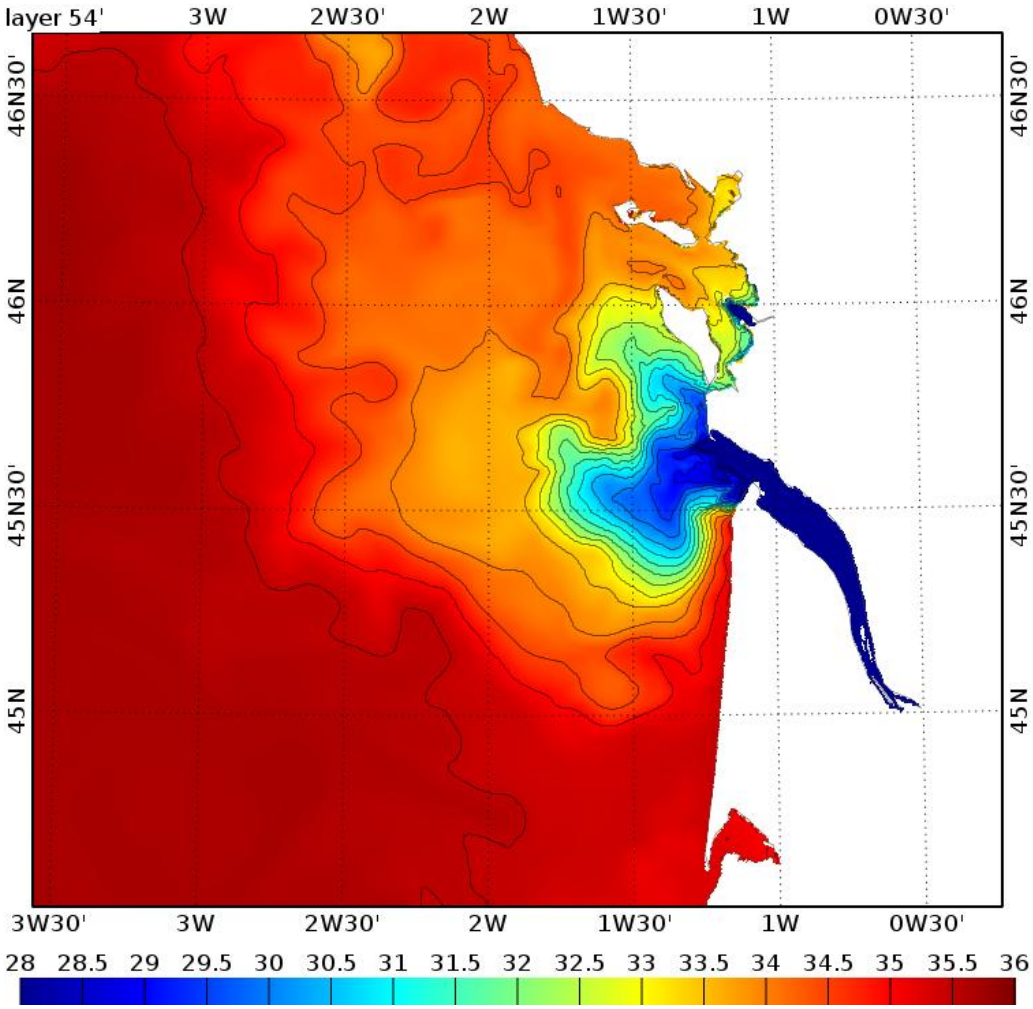
What do we know about shelf circulation and the Gironde plume?

On the shelf circulation:

- anticyclonic in summer
- cyclonic in winter
- combination of winds, tides and density gradients (salinity/temperature)

On the Gironde plume:

- spreading northward and along-shore in winter
- spreading offshore or southwards when the river discharge is reduced and dominant winds are SE oriented



Modelled sea surface salinity (daily mean, psu)
05/30/2012

Modelling configuration: BOBSHELF

Variable horizontal resolution
- 3km at the oceanic open boundary
- 800m on the shelf
- less than 300m in the Gironde estuary and Pertuis Charentais

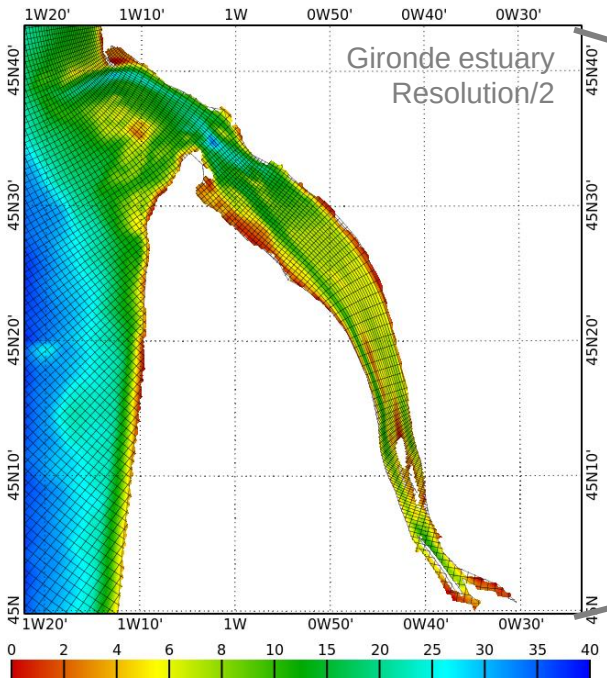
55 sigma levels

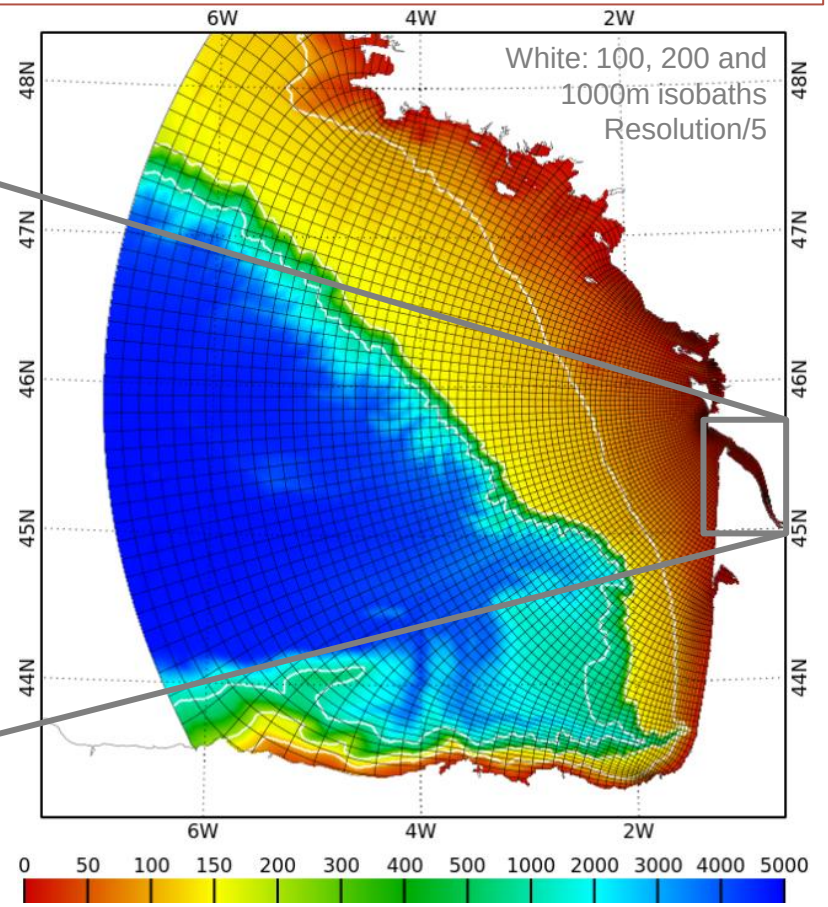
Atmospheric forcing: ECMWF operational analyses
(switching now to AROME)

Tidal forcing: T-UGOm « tailored » solution

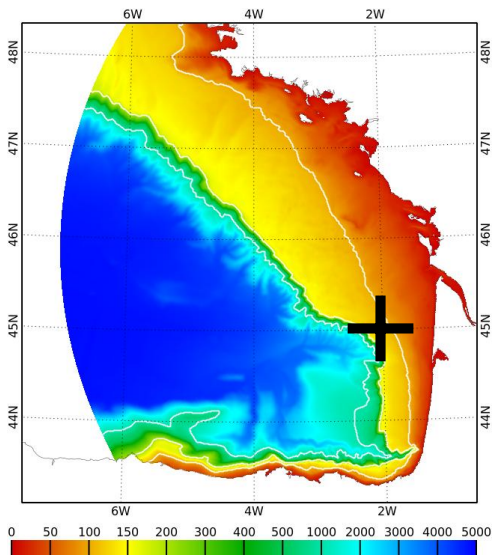
OGCM forcing: Mercator-ocean products (IBI)

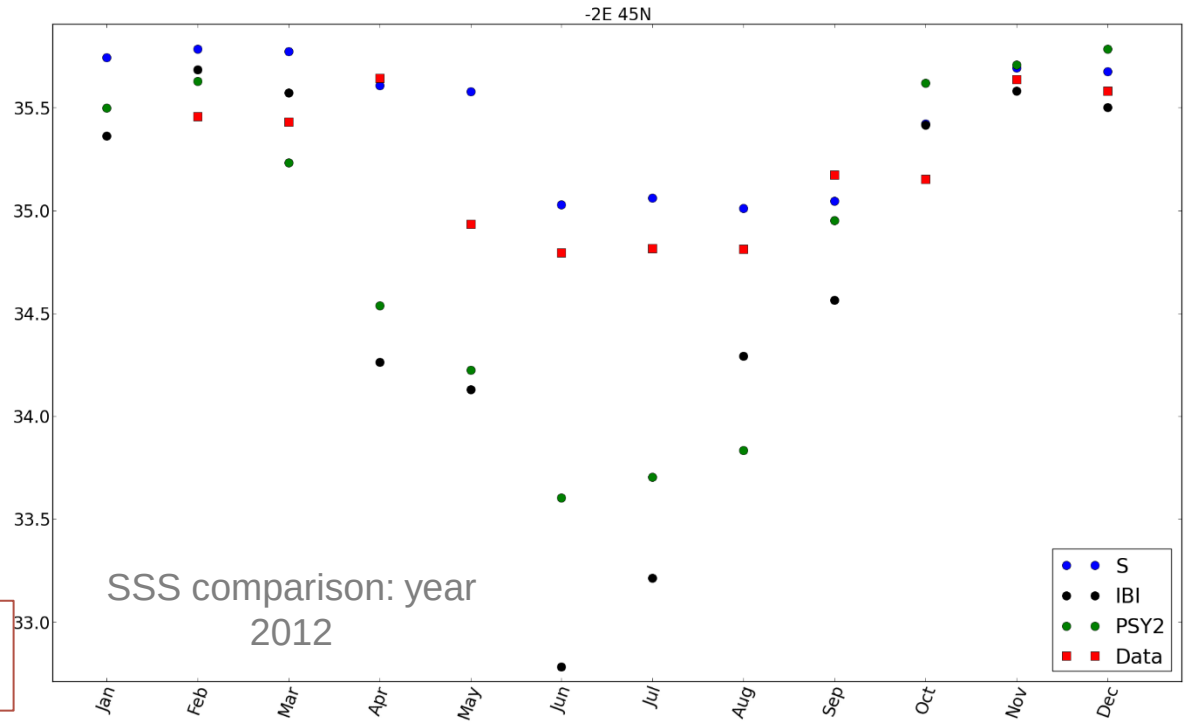
Representation of multi temporal and spatial scales, from the deep plain to shallow waters





Validation elements: large scale SSS





SSS comparison: year 2012

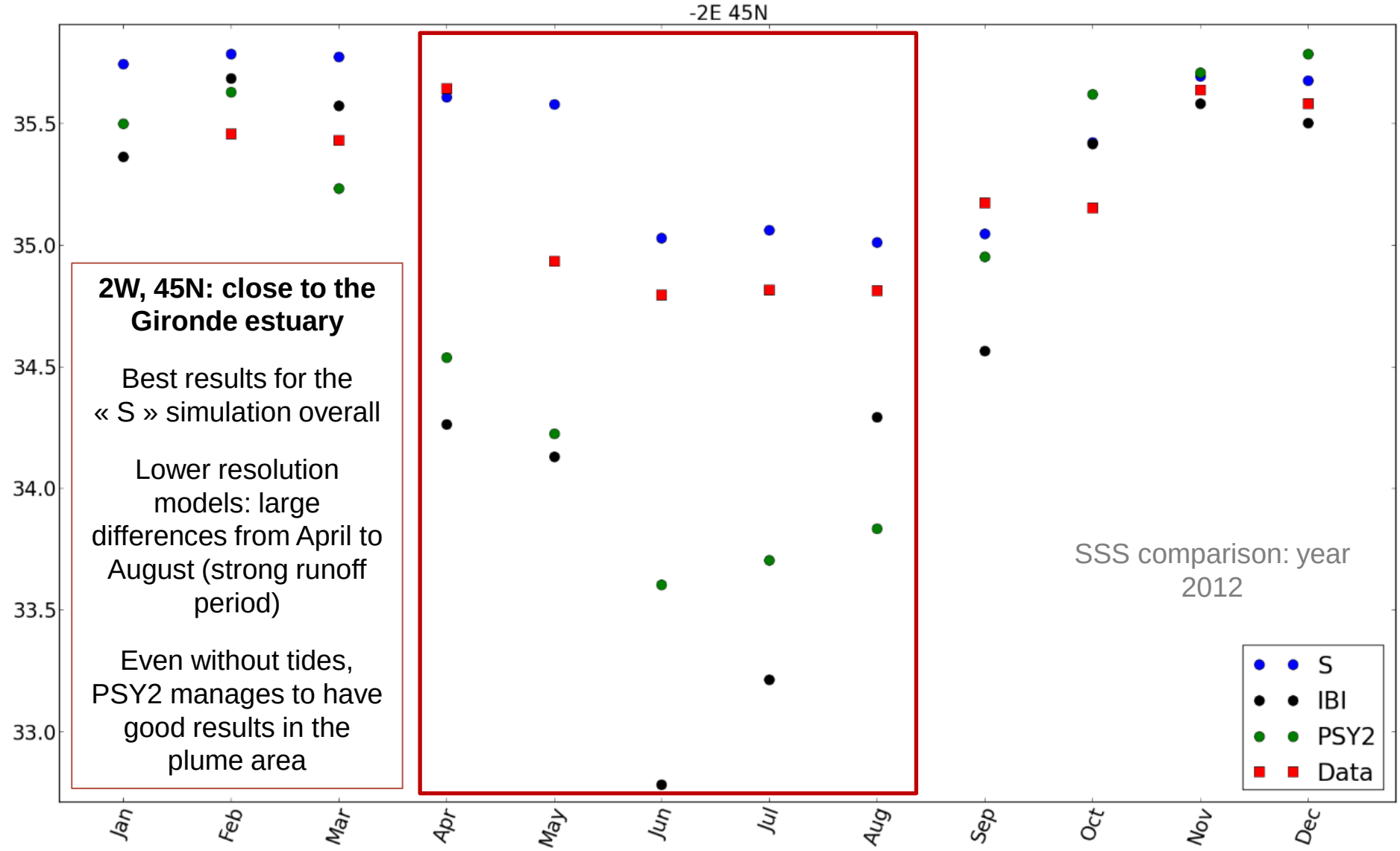
Data: gridded SSS database LOCEAN-LEGOS (Reverdin, Kestenare)

PSY2 = PSY2V4 model (Mercator-Ocean)
Assimilation, no tides,1/12°

IBI = IBI operational model (Mercator-Ocean)
No assimilation, tides, 1/36°

S = Symphonie model, BOBSHELF configuration
No assimilation, tides

Validation elements: large scale SSS



2W, 45N: close to the Gironde estuary

Best results for the « S » simulation overall

Lower resolution models: large differences from April to August (strong runoff period)

Even without tides, PSY2 manages to have good results in the plume area

Seasonality of the Gironde plume

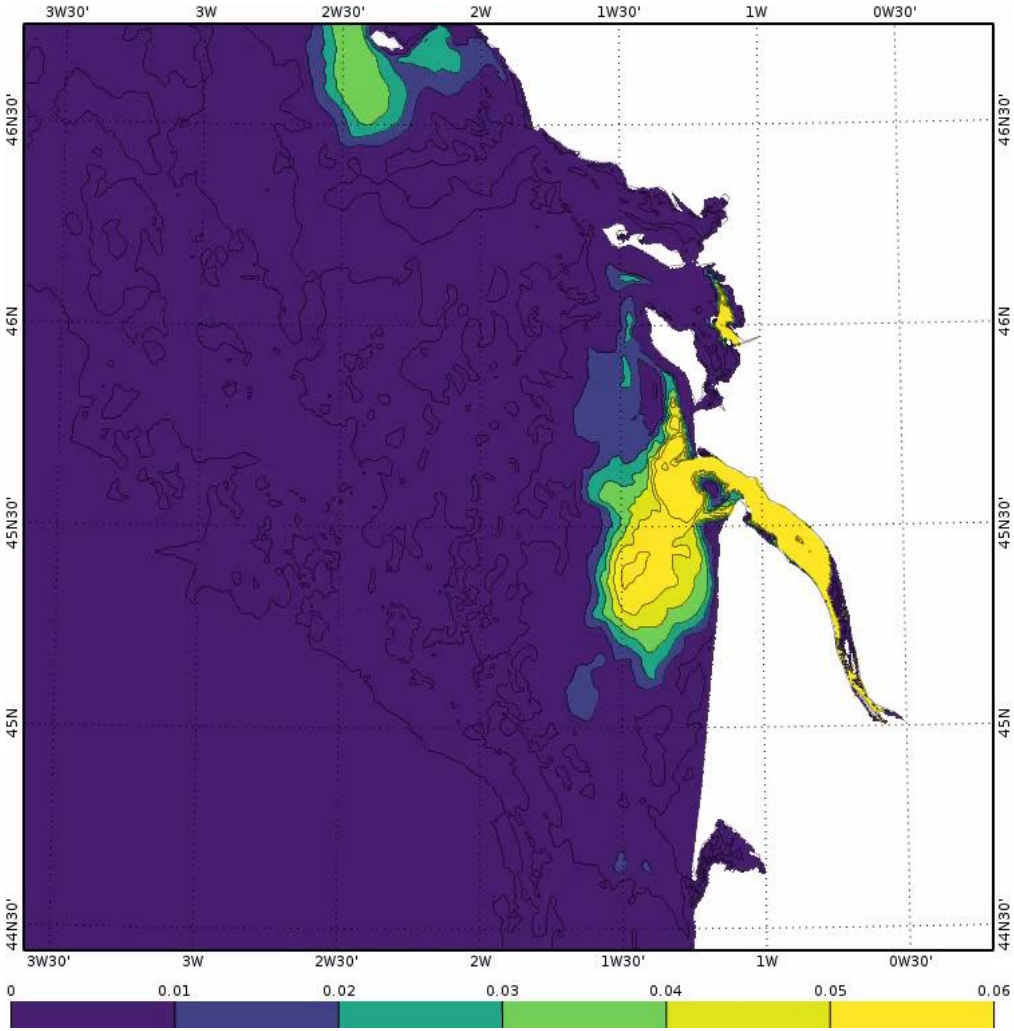
« Stratification index »
(Hansen & Rattray, 1996)

Simple calculation to estimate the plume extension:

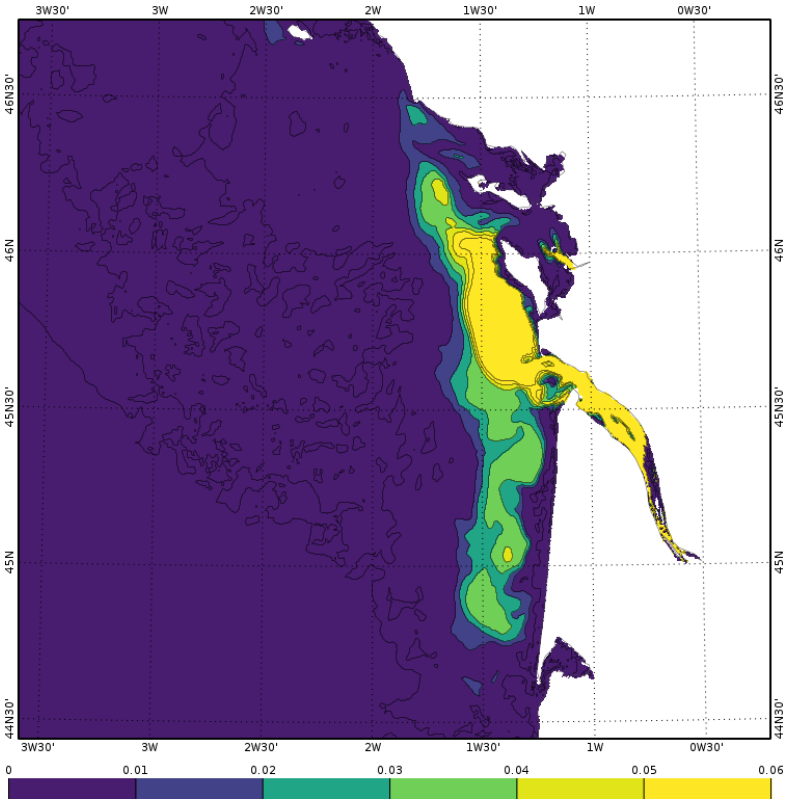
$$stratif = \frac{S_{bot} - S_{surf}}{\overline{S_z}}$$

stratif > 0.1 => in the plume

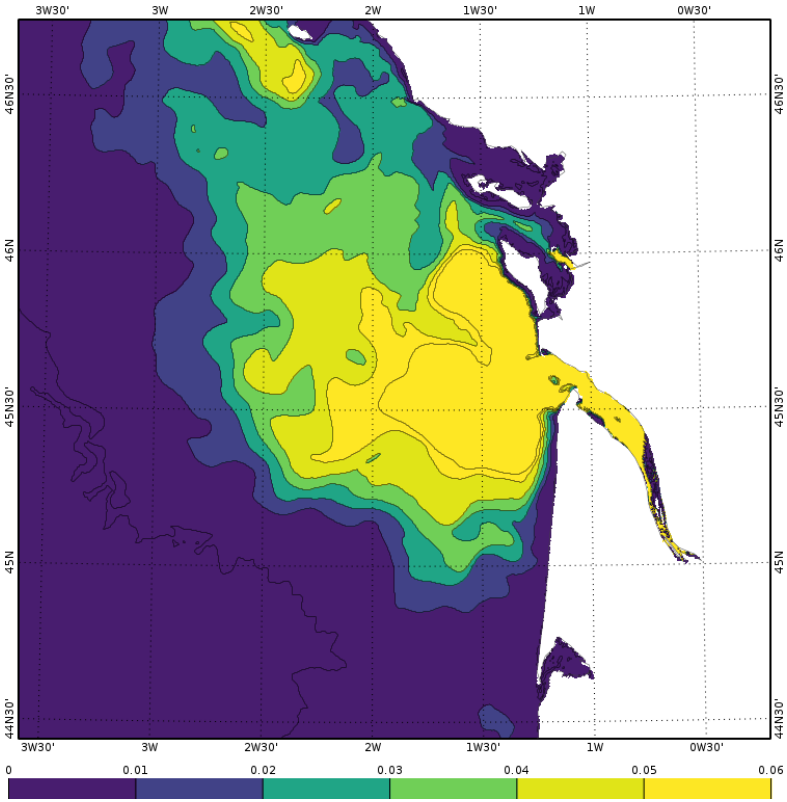
Calculated from daily averages of the salinity



Seasonality of the Gironde plume



01/15/2012

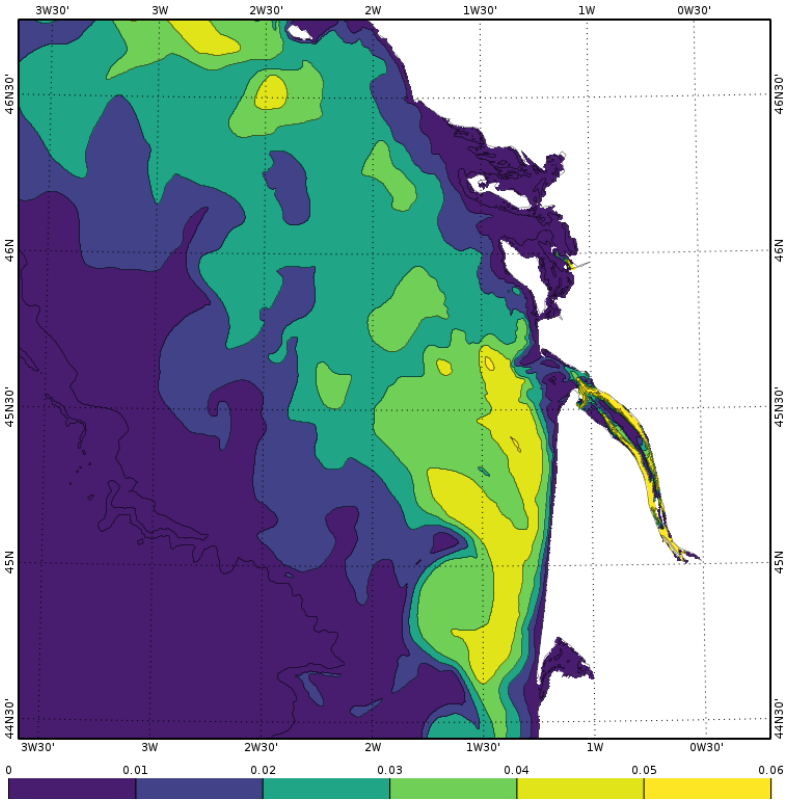


05/30/2012

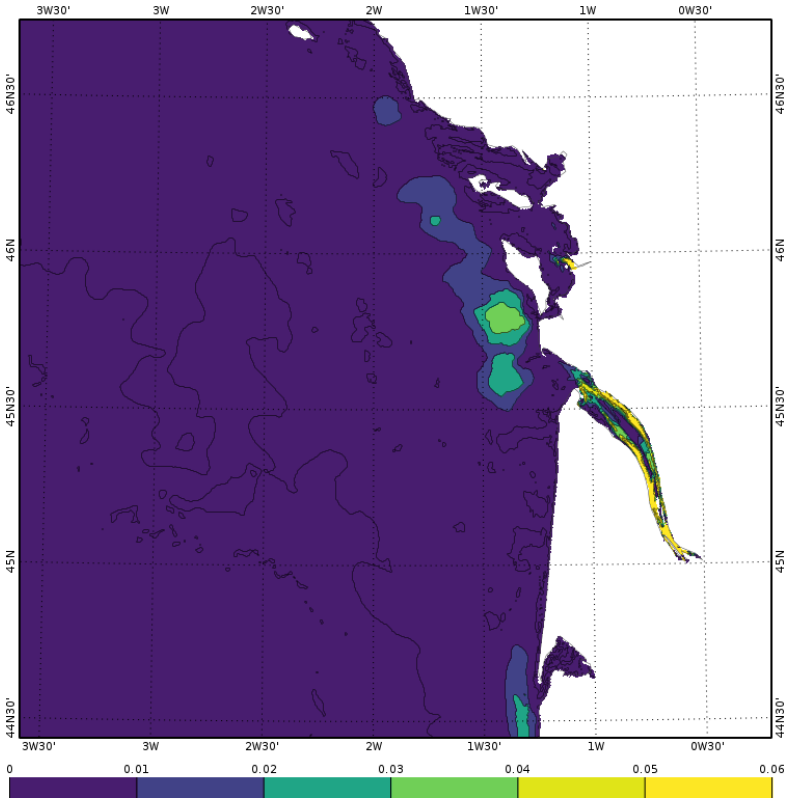
Winter
Plume propagation: mostly northward
Constrained along the coast, small offshore extension
Strong stratification values

Spring
Plume propagation: northward and seaward
More extended offshore
Strong stratification values

Seasonality of the Gironde plume



07/30/2012

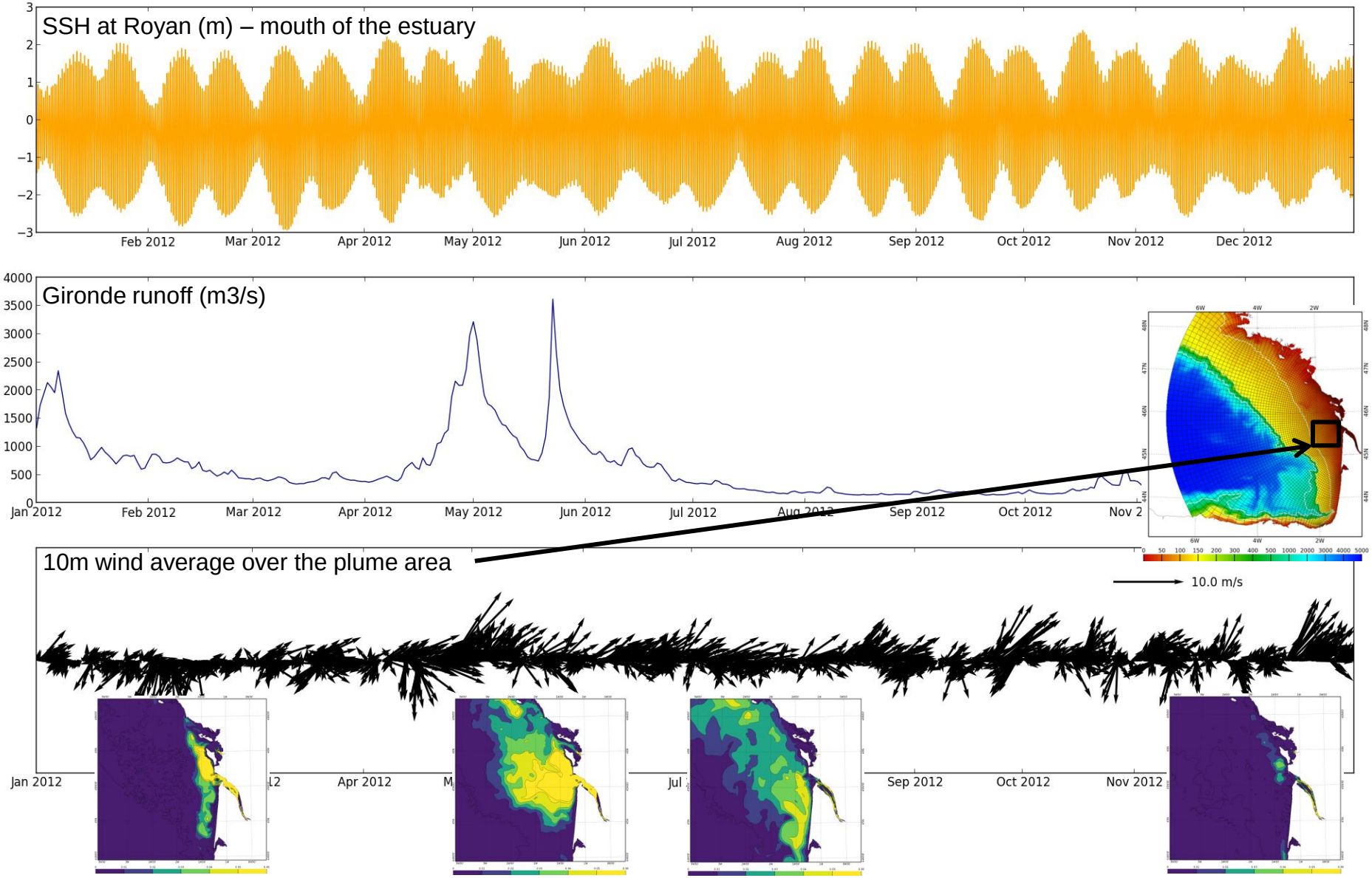


11/30/2012

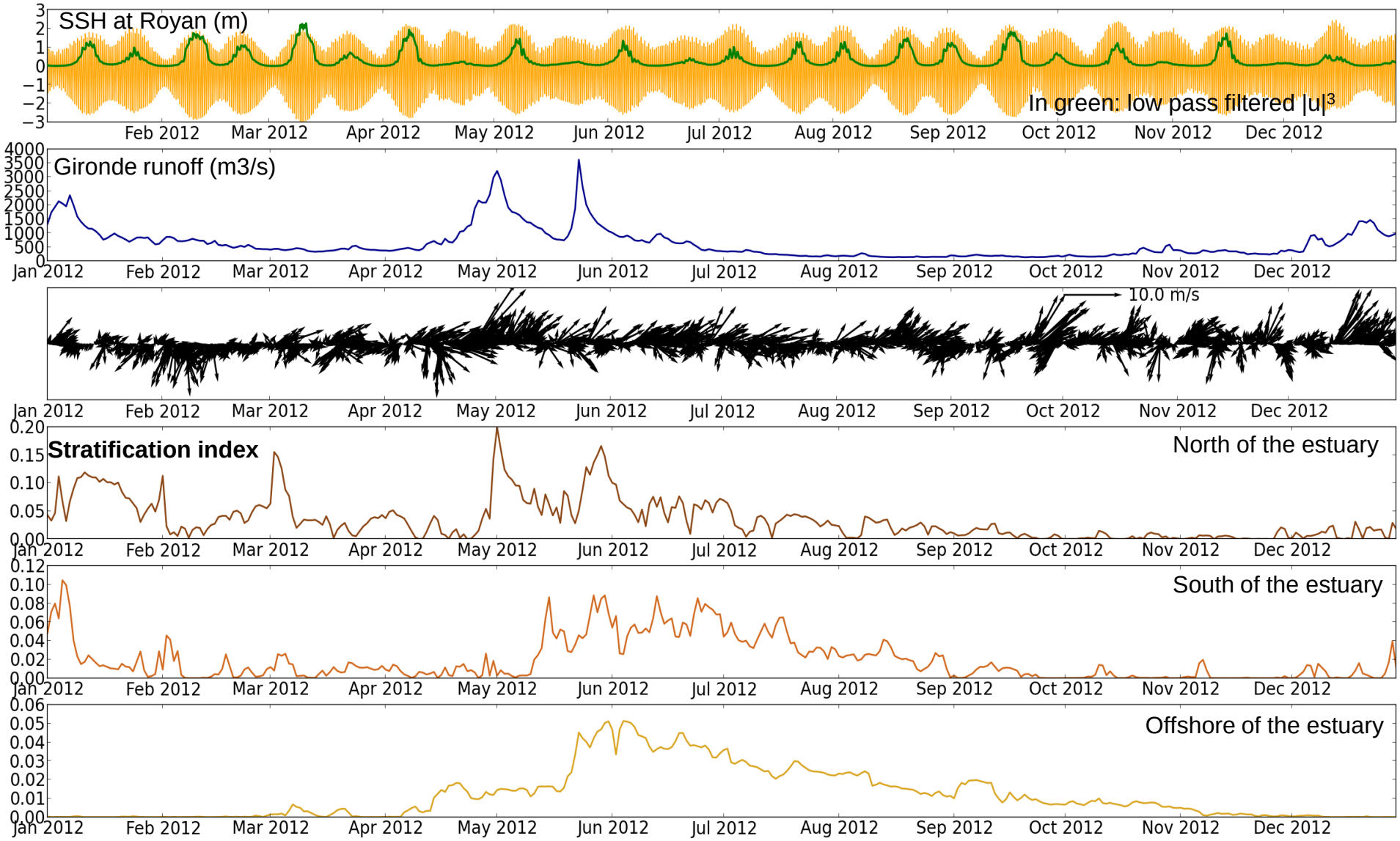
Summer
Plume propagation: northward and southward (connexion with the Loire plume?)
Offshore extension reduced

Autumn
Plume propagation: northward
Overall small plume extension
Low stratification values

Tides, runoff and wind



Stratification response to forcings



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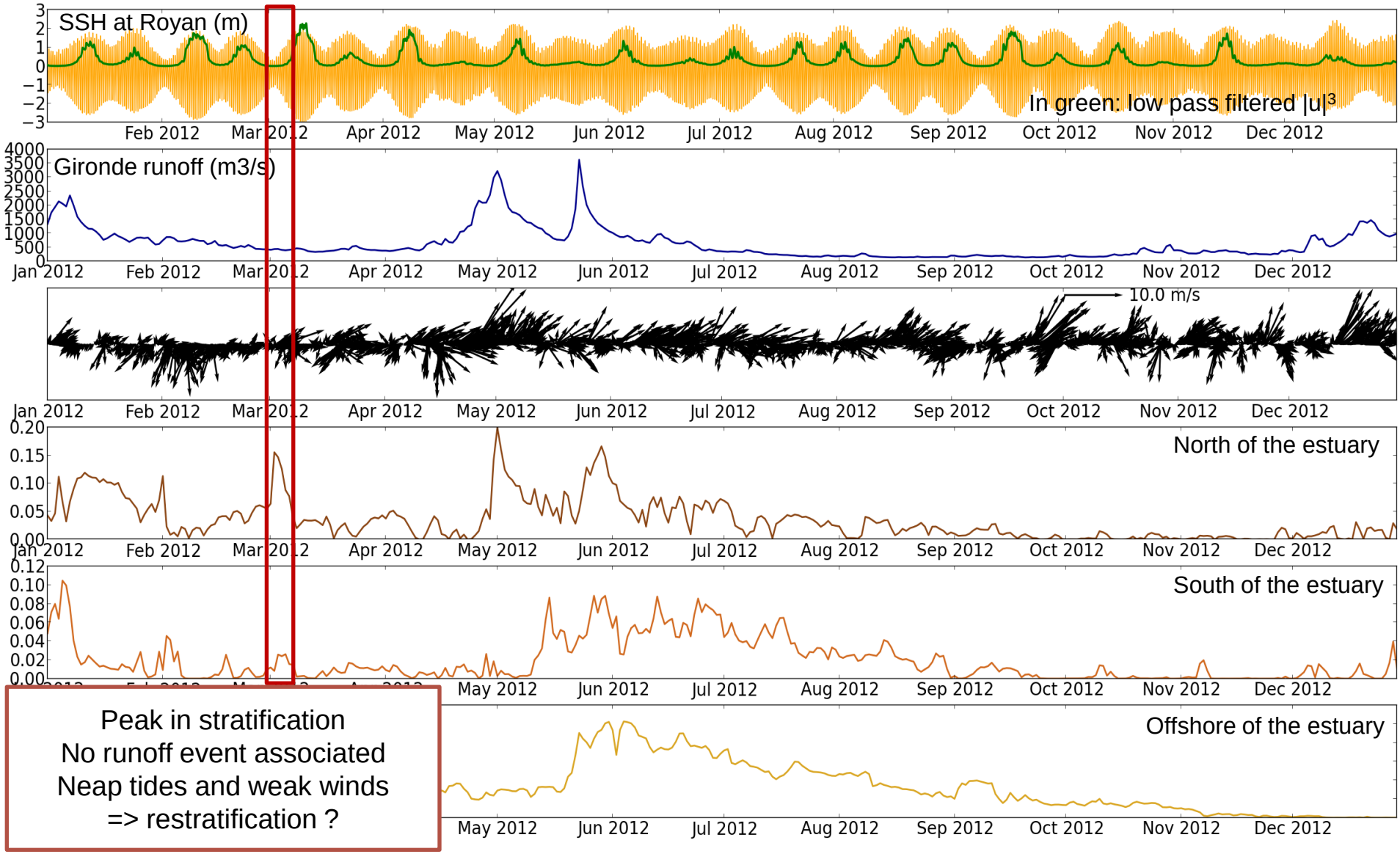
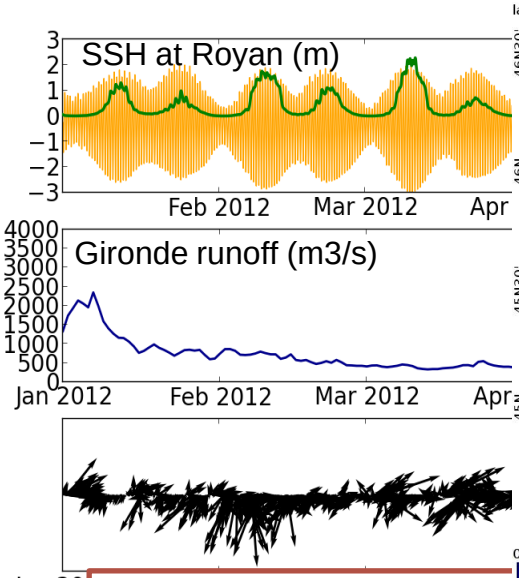
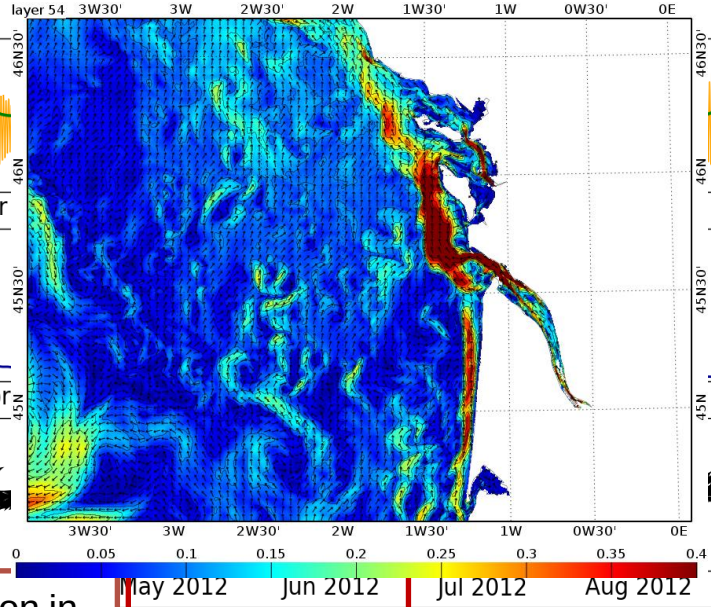
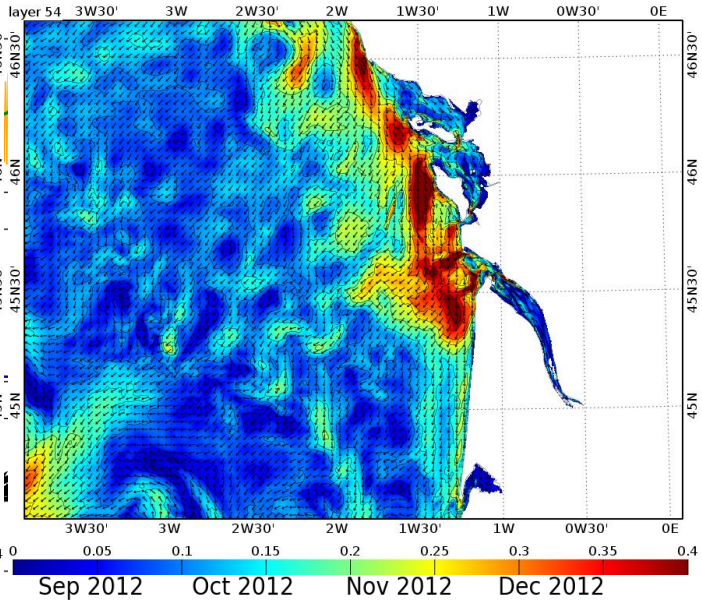


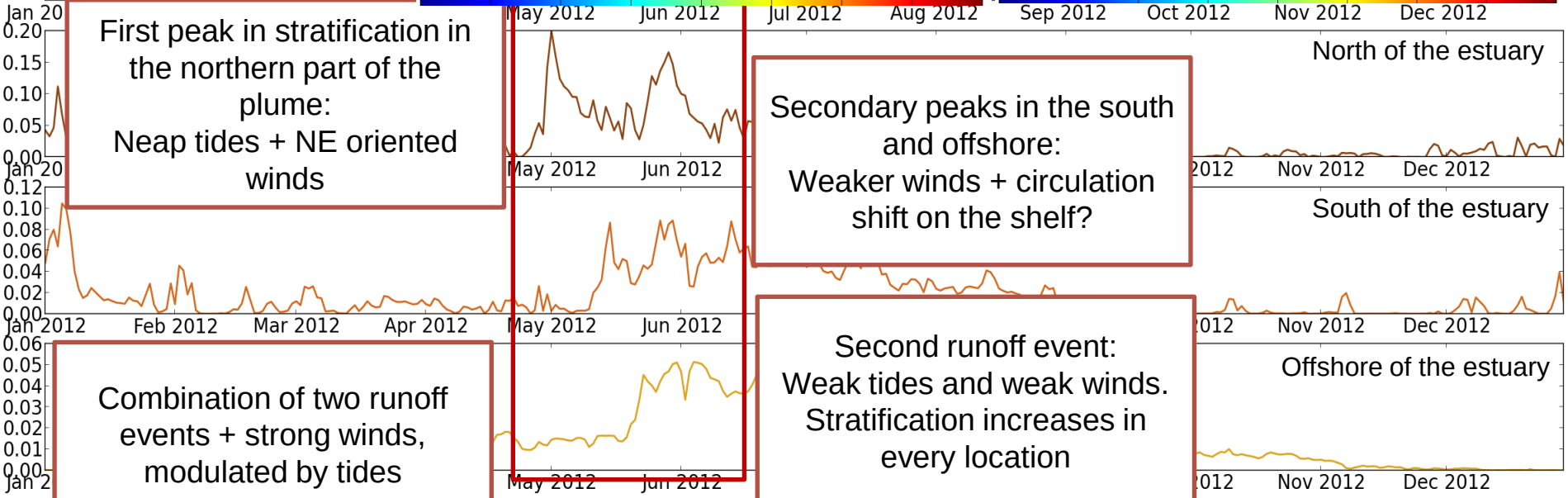
Peak in stratification
No runoff event associated
Neap tides and weak winds
=> restratification ?

Stratification response to forcings









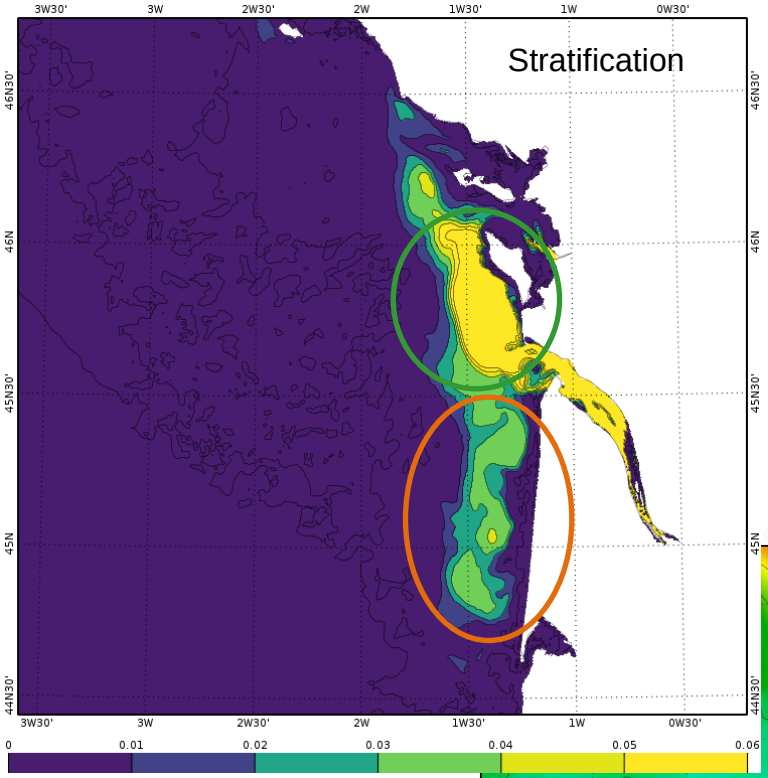
First peak in stratification in the northern part of the plume:
Neap tides + NE oriented winds

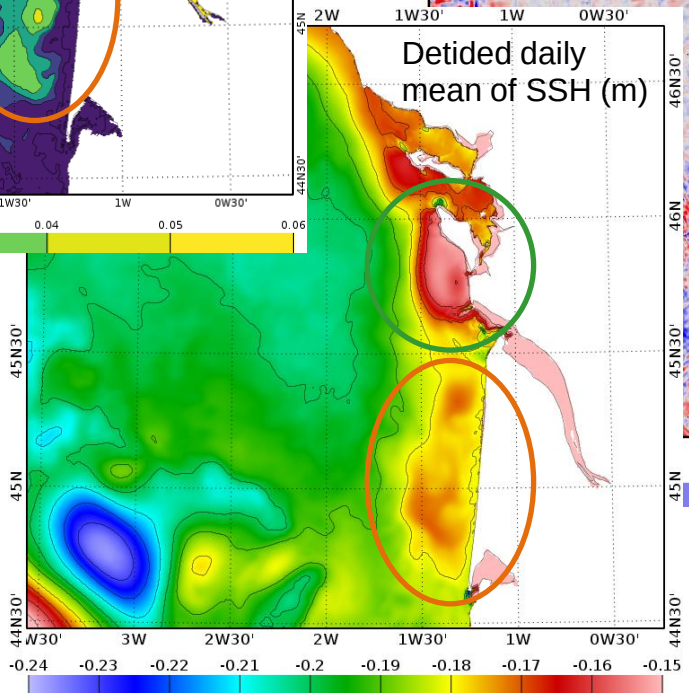
Secondary peaks in the south and offshore:
Weaker winds + circulation shift on the shelf?

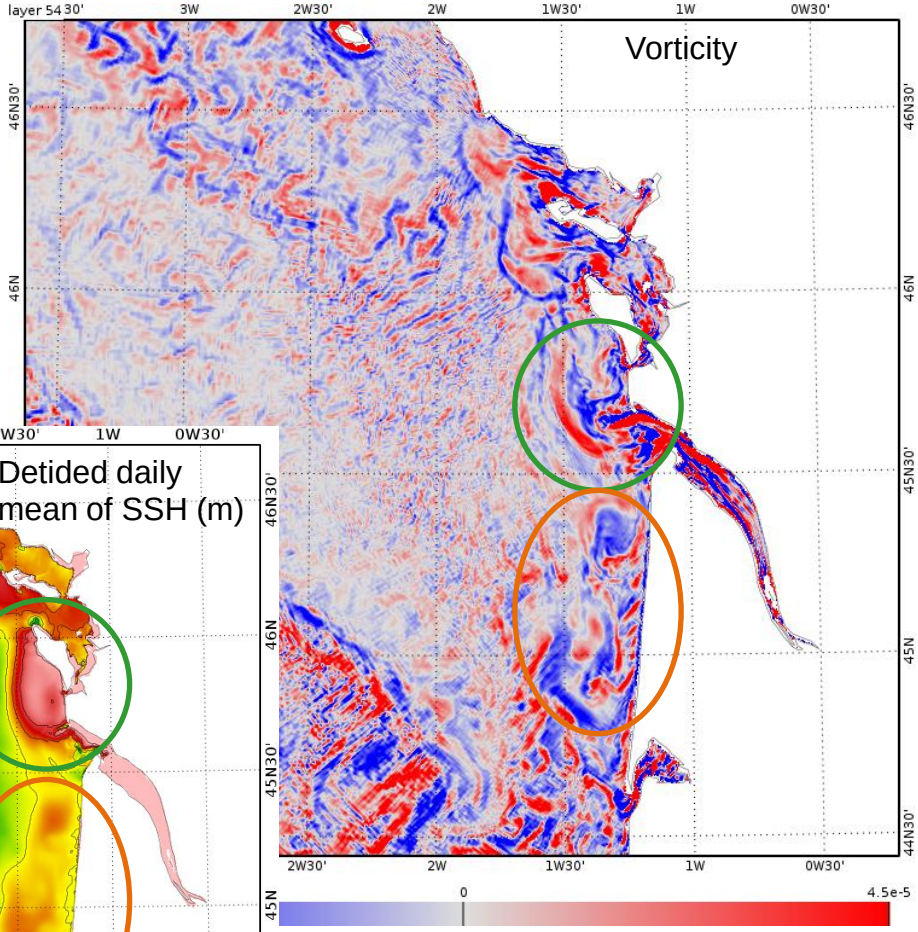
Combination of two runoff events + strong winds, modulated by tides

Second runoff event:
Weak tides and weak winds.
Stratification increases in every location

Small scale features and SSH signature

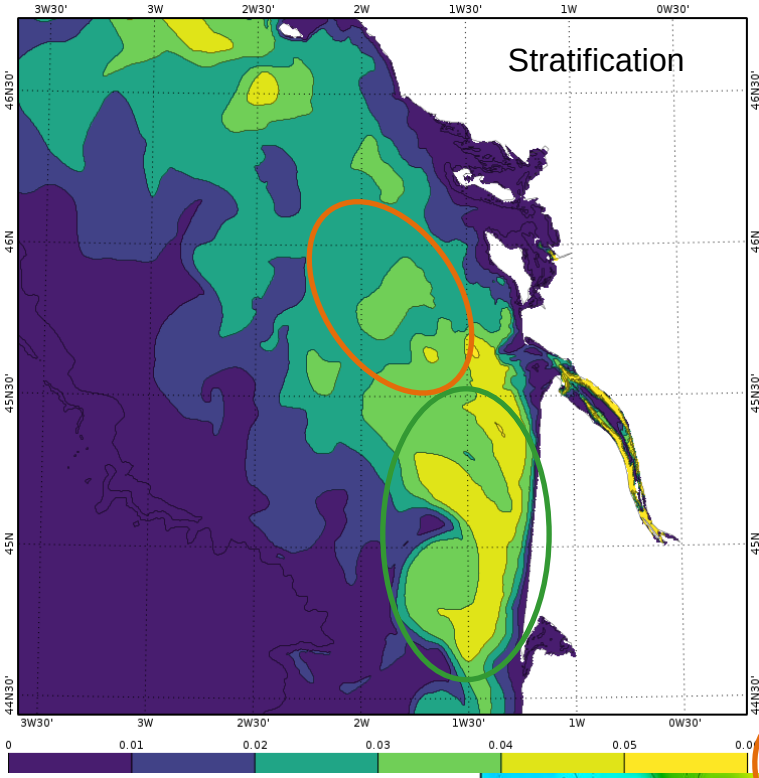


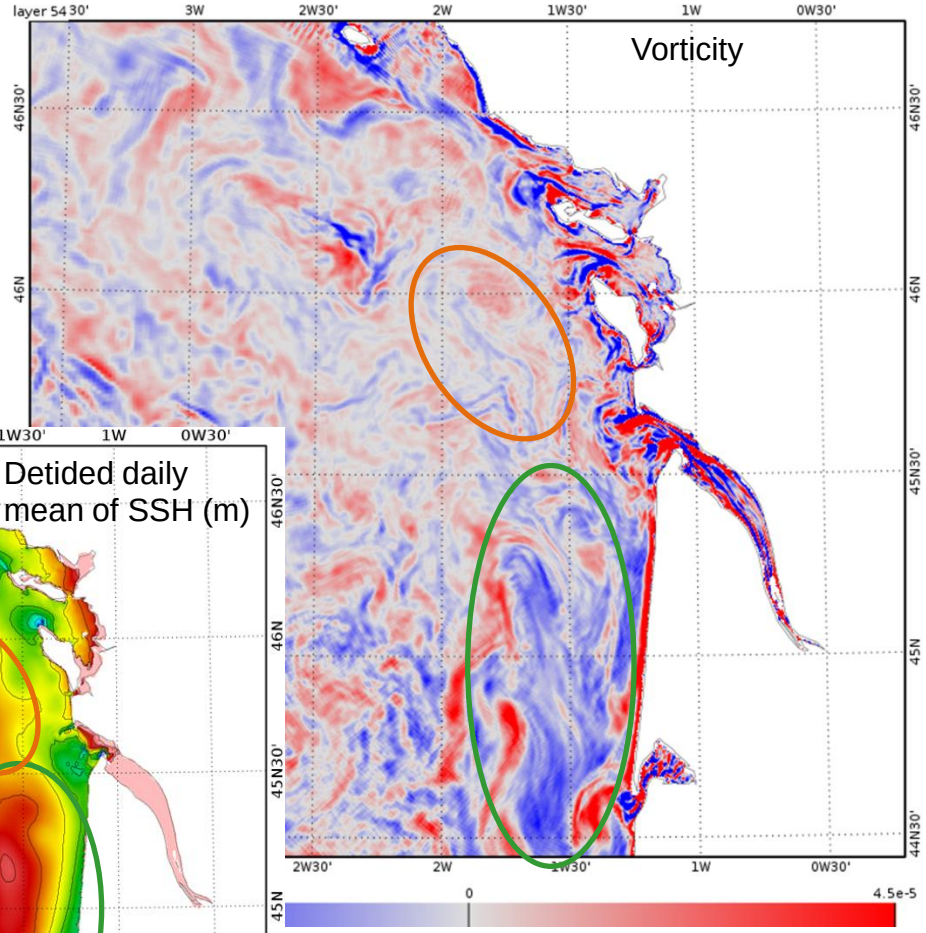


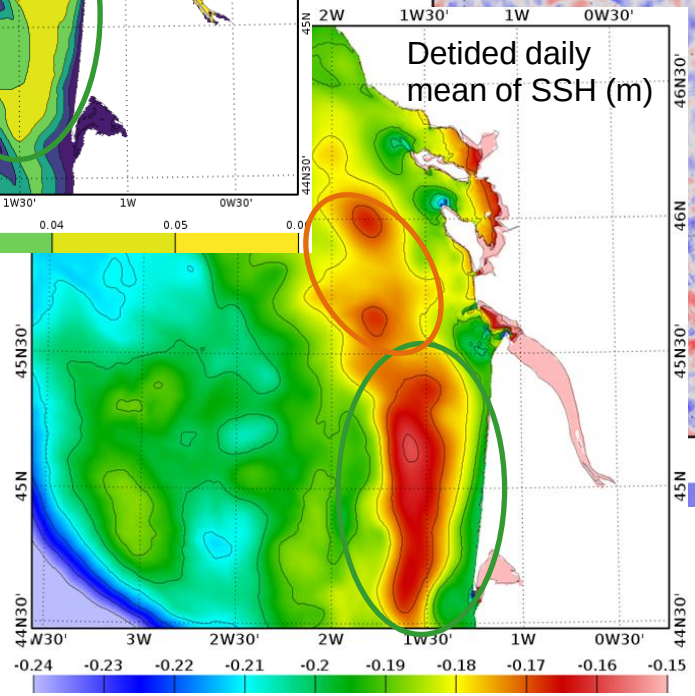


Winter (01/15/2012)

Small scale features and SSH signature







Summer (07/30/2012)

Conclusions and perspectives

Strong seasonality of the Gironde plume:

- constrained close to the coast in winter, progagating northward
- spreading seaward and southward from spring to the end of summer
- reduced extension in autumn (weak discharge in autumn 2012)

Stratification and freshwater pathways

- neap-spring tidal cycle modulation clearly observable
- stratification is always stronger in the northern part of the plume: dominant pathway
- strong relationship between wind, runoff events and stratification

=> Further investigation on these results: still ongoing work…

- quantification of the dependency to the different forcings (correlation)
- windstress = better estimation of the wind action
- can we really represent small scales on the shelf with our model?

=> Currently in progress:

Simulations forced with HR atmospheric forcing
=> impact on modelled plume dynamics?
=> impact on small scale phenomena?

Conclusions and perspectives

Original question: do the small structures associated with plume dynamics have a SSH signature?

- small scale structures (O(1km) to O(10 km)) observable in stratification and vorticity
- SSH signatures associated: a few centimeters

=> Planned for the future:

Wave forcing (WW3)

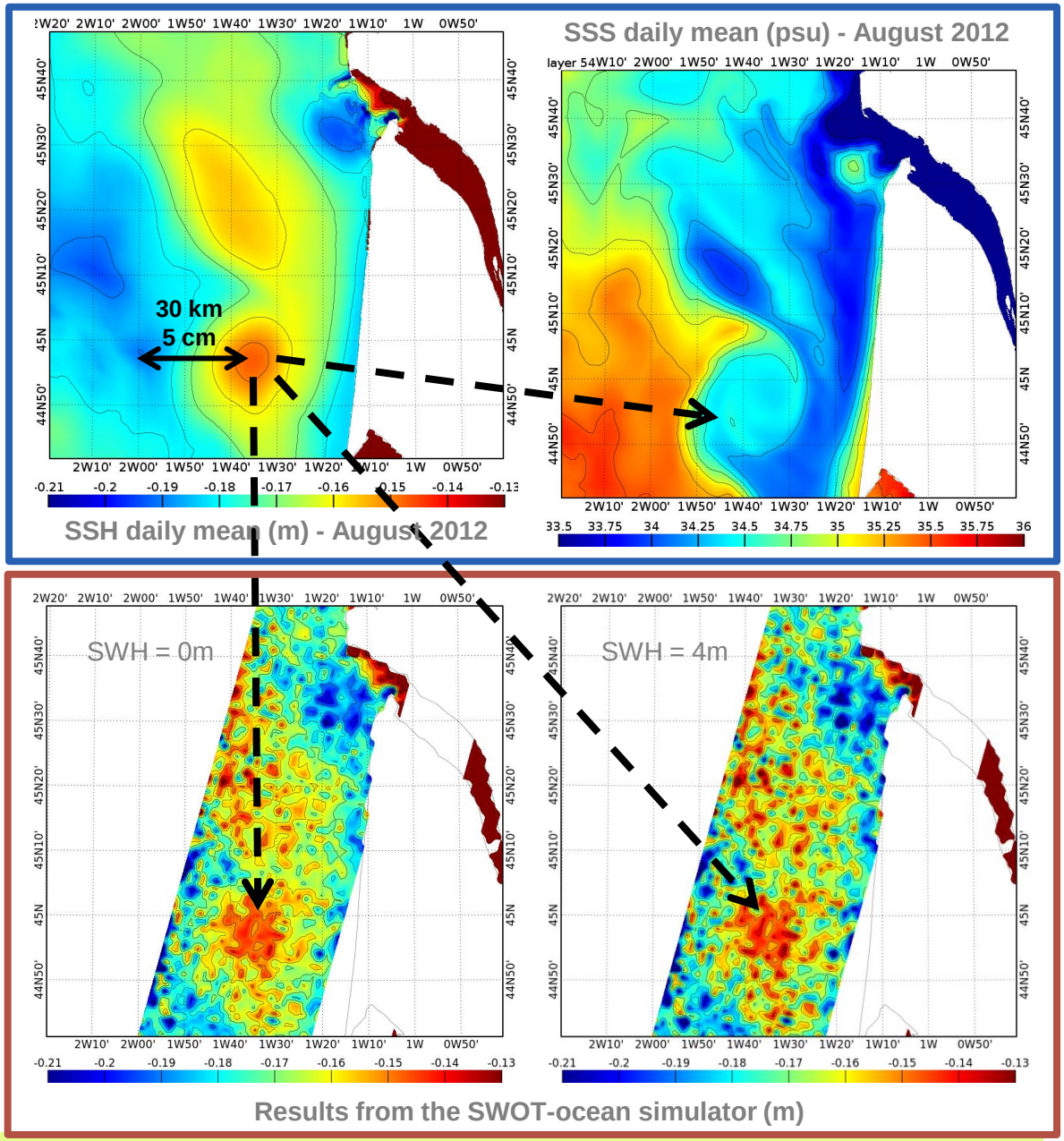
=> influence on the plume?

=> SSH signature and future SWOT observability?

Perspective: SWOT observability?

« Scenes » identification from 3D simulations:
- Plume-circulation interactions
- SSH signature
- Lasting more than 10 days

Estimation of the observability of these structures with the SWOT-ocean simulator



Future possible developments for the simulator:
- SSB induced by waves
- Spatio-temporal variability of the significant wave height

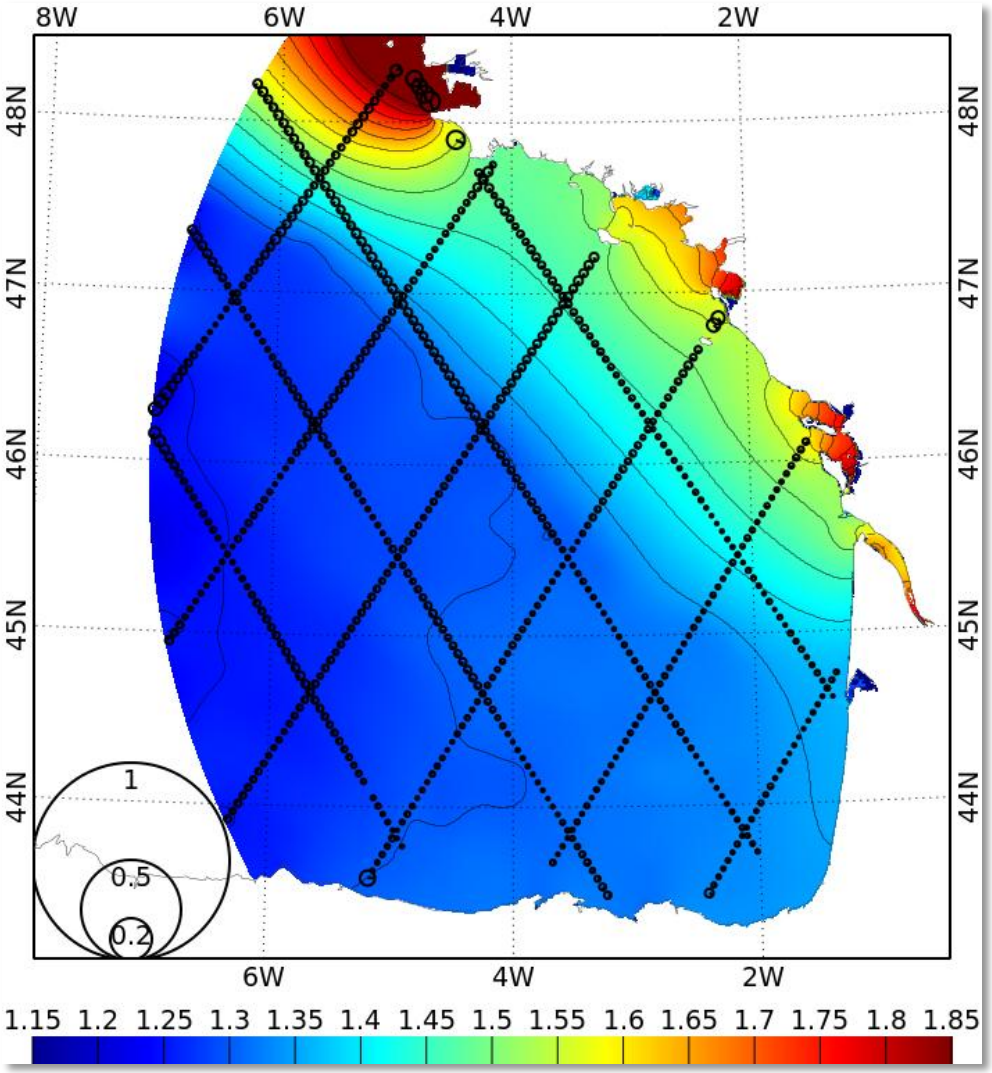
Thank you for your attention…

Validation elements: tides

Data: tidal harmonics extracted from satellite altimetry: X-Track products, CTOH-LEGOS
(Birol et al., 2016)

Average complex errors:

M2 = 1.84 cm
S2 = 1.55 cm
M4 = 1.11 cm
K1 = 1.42 cm



Comparison between satellite altimetry tidal harmonics and S3D for M2.
The circle size is proportional to the complex error.

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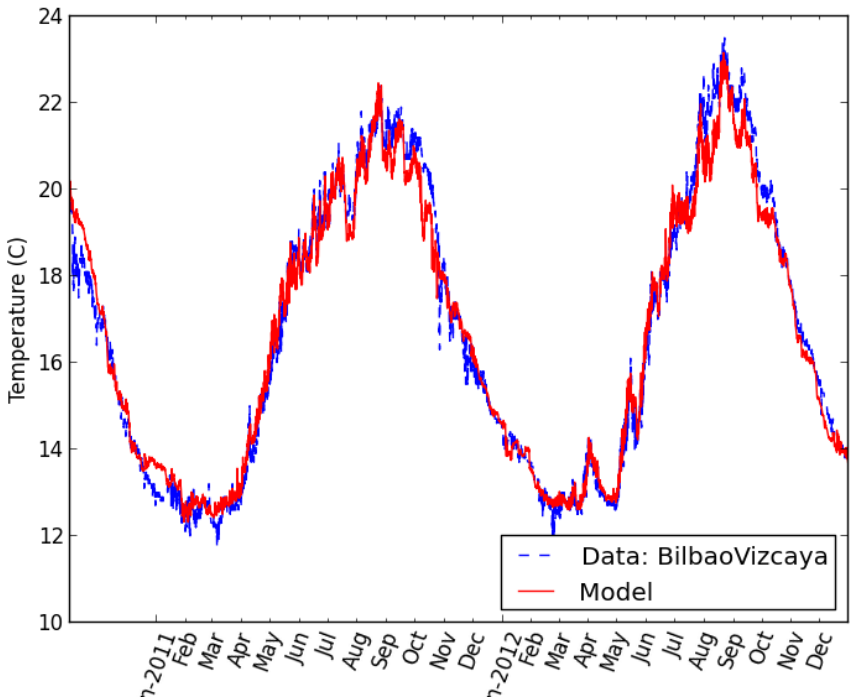
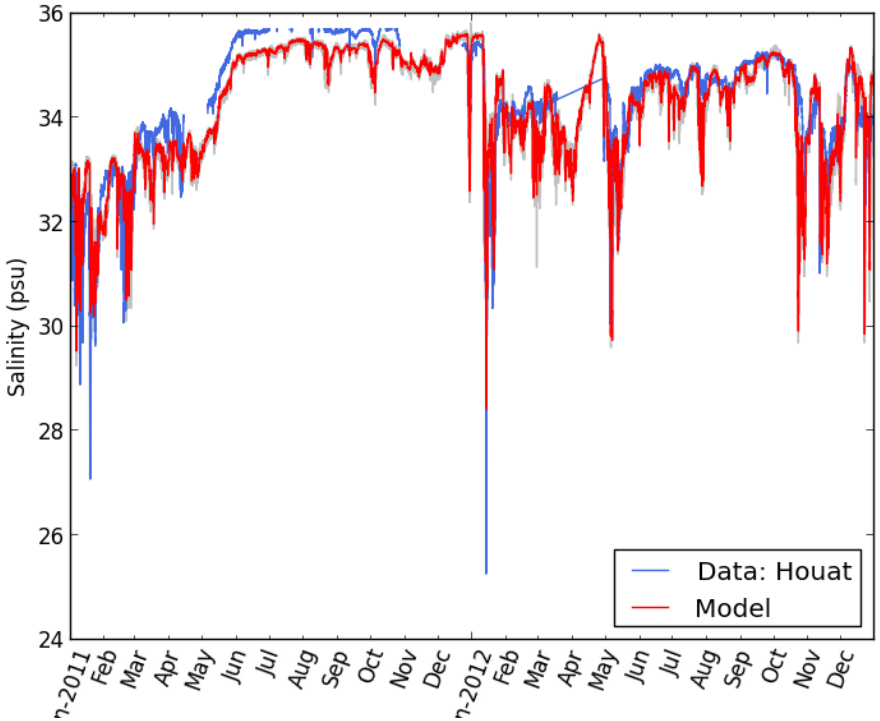
Validation elements: SSS and SST





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How to characterize the Gironde river plume?

Number diagnostics (Kourafalou et al., 1999)

- L = seaward extent of surface-advected plumes
- R = river plume number
- K = Kelvin number: classify buoyant discharges and river induced coastal currents

… For the Gironde estuary:

- L mean value estimated at 80 km (Po river: 85 km; Amazon river: 80-200 km; Columbia river: up to 400 km)
- K estimated at 4: same category as the Po river.
  K >> 1 = “linear dynamics and across-shore geostrophic balance” (Garvine, 1995)

Other diagnostics to study plume dynamics:

« Stratification index » (Hansen and Rattray, 1996)

Bottom minus surface salinity scaled by the vertical salinity mean
=> Tool for plume detection?

Transport calculations (Schiller et al., 2011)

Shelf transport of plume waters through different sections
=> Transport pathways

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Transport pathways

Freshwater transport through a section

From Schiller et al. (2011):

$$Q_f = \int \int_{-h}^{\eta} f_{wf} V dz dx$$

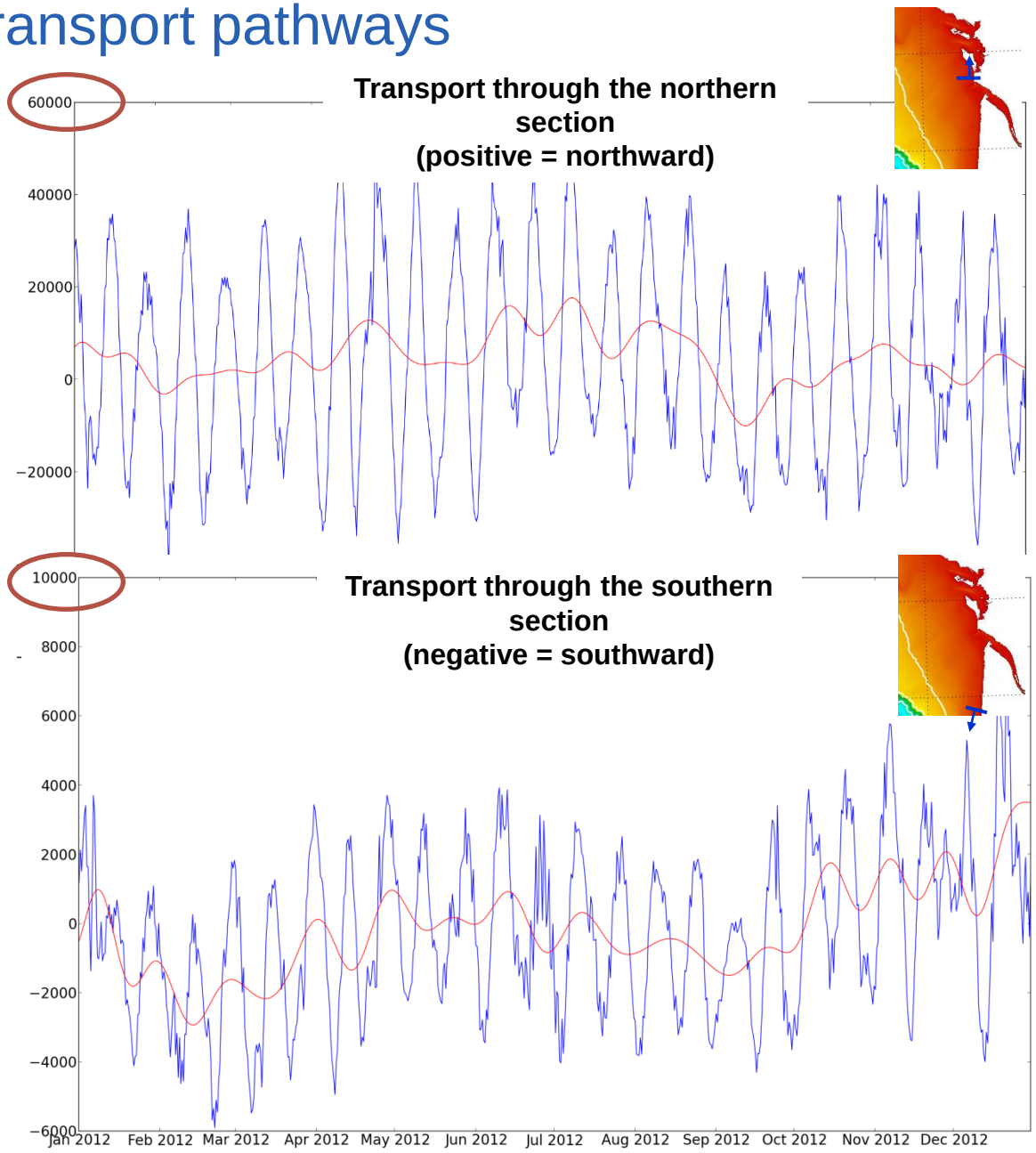
f_{wf} : freshwater fraction
V : cross-sectional velocity (m/s)

Different scales: transport much higher through the northern section

Strong tidal modulation at the spring/neap frequency (~15 days)

In red: very low-pass filtered series

Dominant transport = northward



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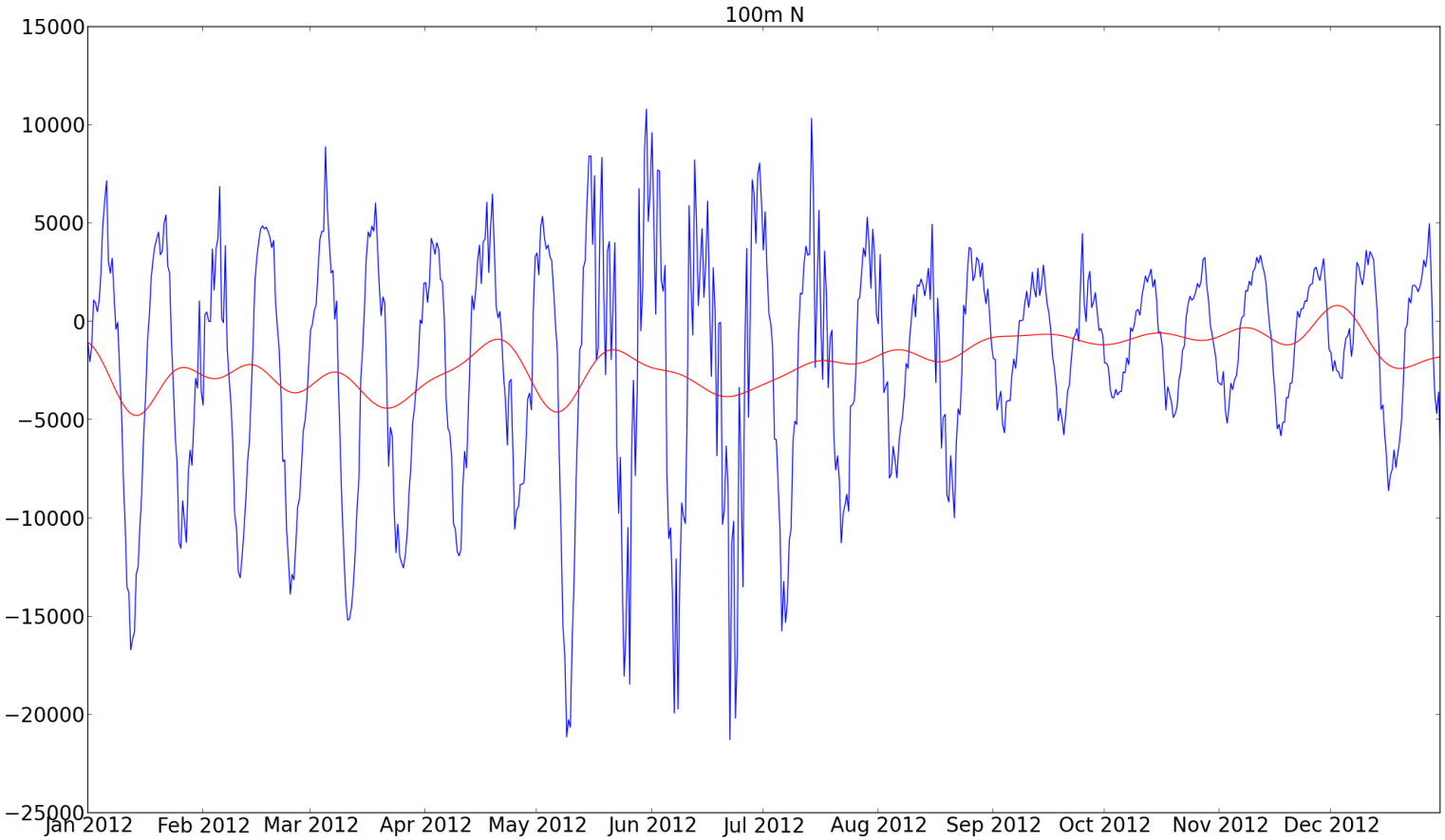
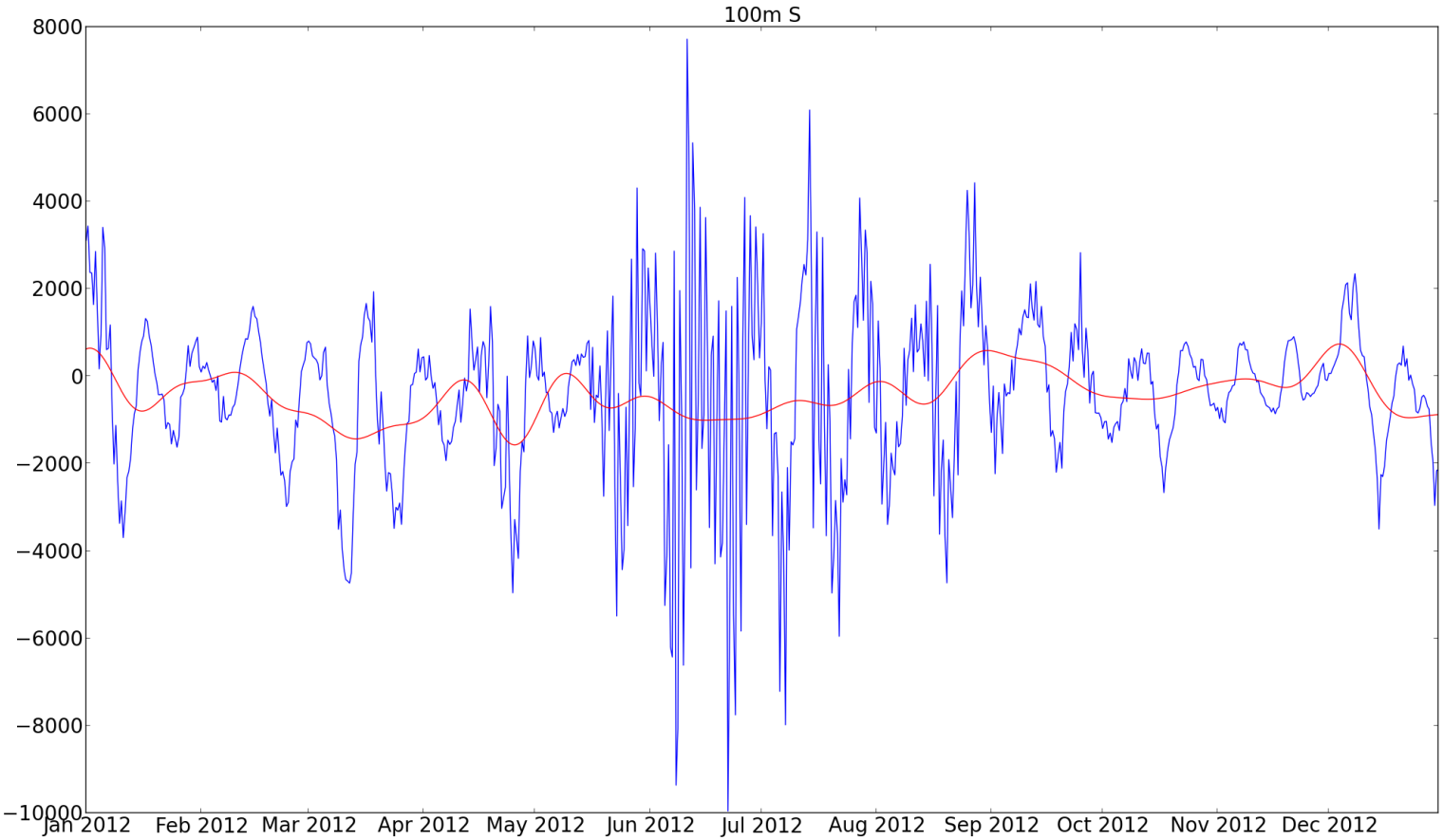
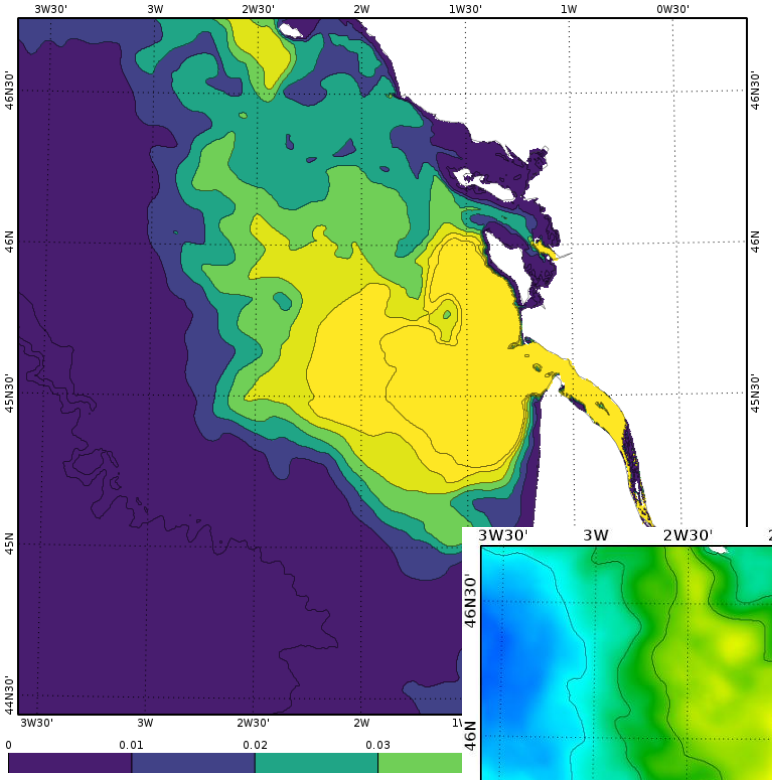
Transport pathways

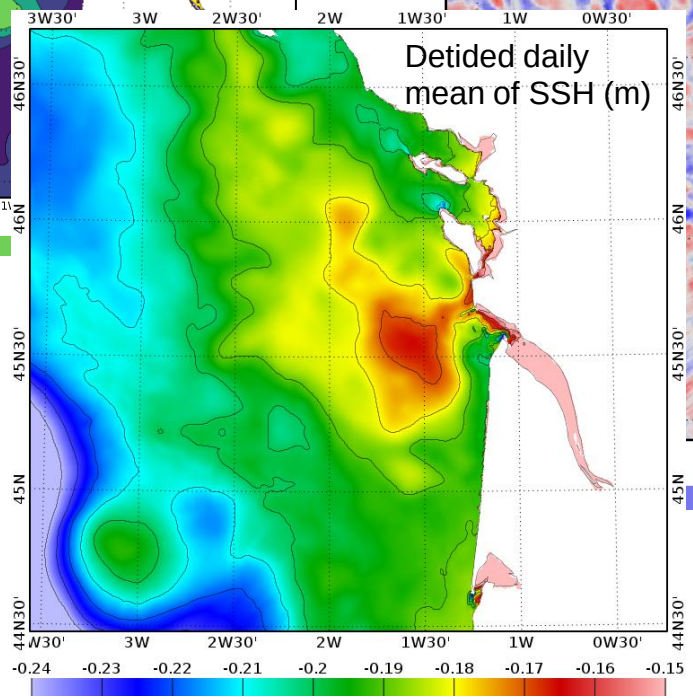


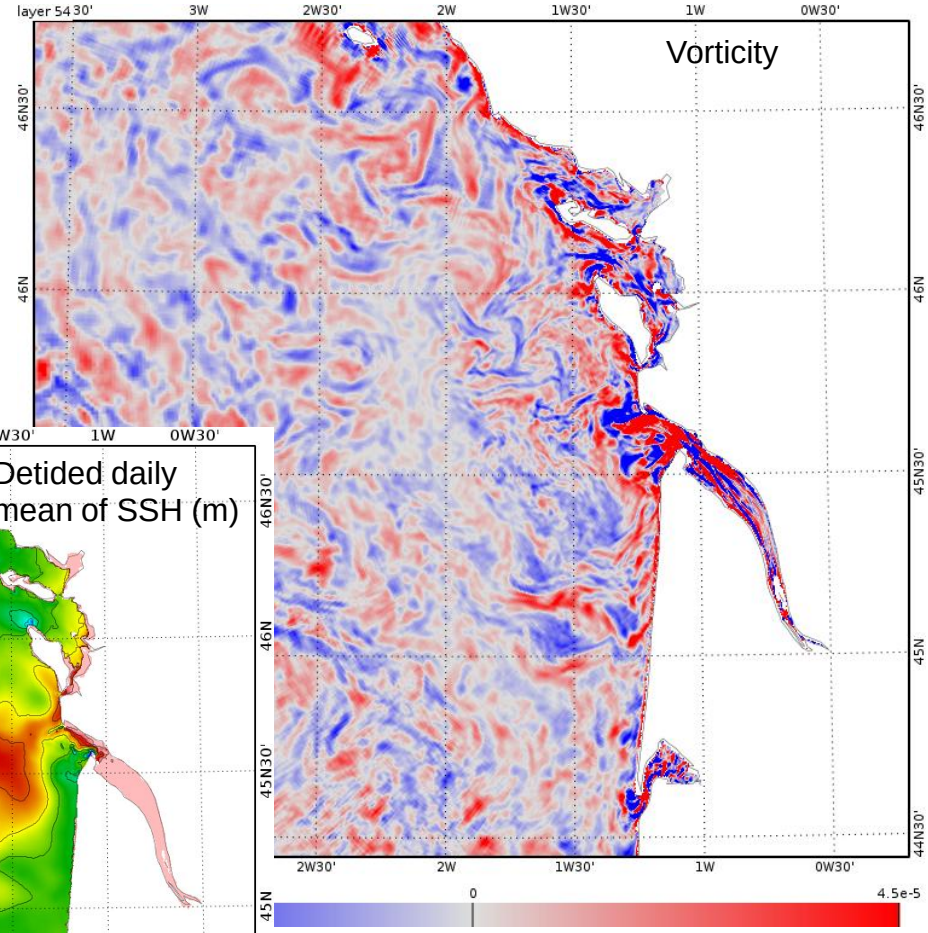
Transport pathways



Small scale features and SSH signature







Spring (05/30/2012)

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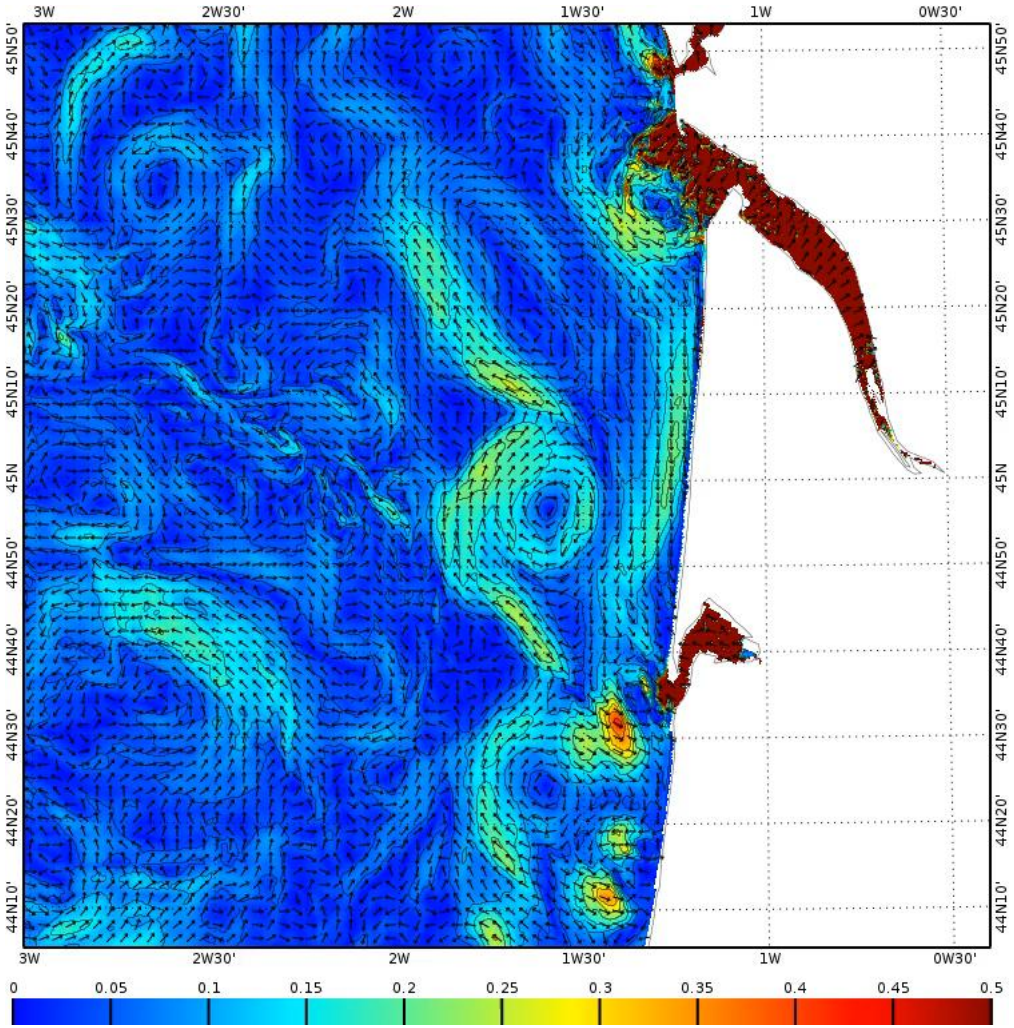
Geostrophic velocities



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