Coastal Ocean Continuum in surface Topography Observations

Hydrodynamic modeling in the Gironde estuary and over the shelf of the Bay of Biscay and of the Gulf of Tonkin

N. Ayoub, F. Lyard, M. Herrmann, G. Charria, P. Marsaleix,
P. De Mey, V. Piton, A. Ayouche, F. Toublanc, D.T. Nguyen,
S. Barbot, S. Theetten, D. Allain, T. Duhaut

1. Tides in the Gironde and Seine estuaries
2. On-going modeling effort in the Gulf of Tonkin and lower Red River delta
3. Impact of tides on the small-scales dynamics over the shelf (Bay of Biscay)
4. Internal tides
5. Concluding remarks

1. Hydrodynamical modelling of estuarine and coastal systems

1.1 Objectives

- Provide a numerical platform to the SWOT project to simulate water levels in estuaries

- Provide *good* boundary conditions in terms of water, salt (and matter) transports for coastal models

- Characterize the time variability of the water level in estuaries and the underlying physical processes (tides, river flow, interactions tides-river flow, response to atmospheric forcing, etc.)
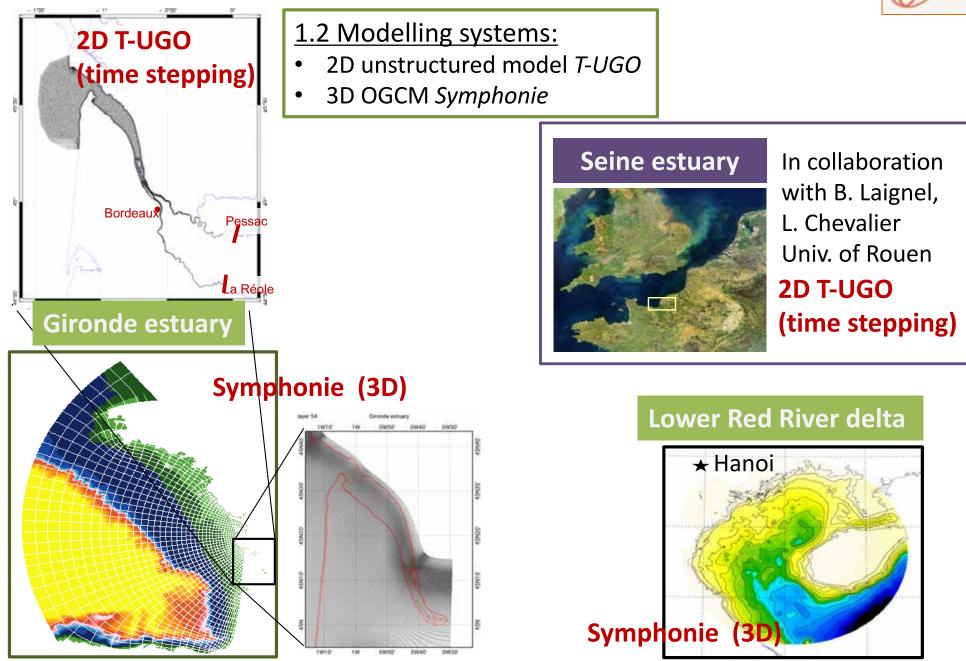
Not in this project:
- Analyze the observability with SWOT data of the estuaries water level (feed the SWOT HR simulator)

- Conclude on the possibility to reconstruct fresh water transport from the river to the ocean using SWOT data

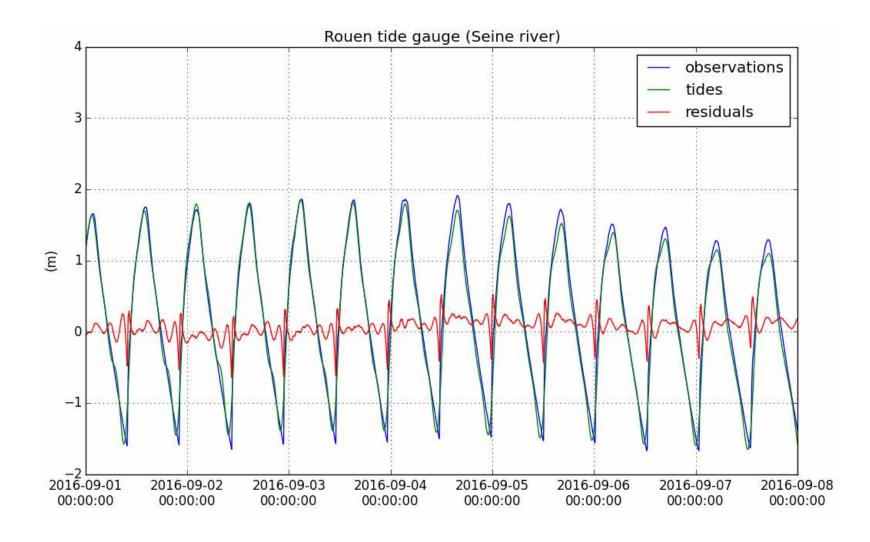# 1. Hydrodynamical modelling of estuarine and coastal systems

1.2 Modelling systems:
- 2D unstructured model *T-UGO*
- 3D OGCM *Symphonie*

2D T-UGO (time stepping)

Bordeaux

Pessac

La Réole

Gironde estuary

Symphonie (3D)

Seine estuary

In collaboration with B. Laignel, L. Chevalier Univ. of Rouen

2D T-UGO (time stepping)

Lower Red River delta

★ Hanoi

Symphonie (3D)

Tidal anomalies in estuaries
> deficient harmonic method to analyze/predict tides
> low tides not modified in spring/neap cycle
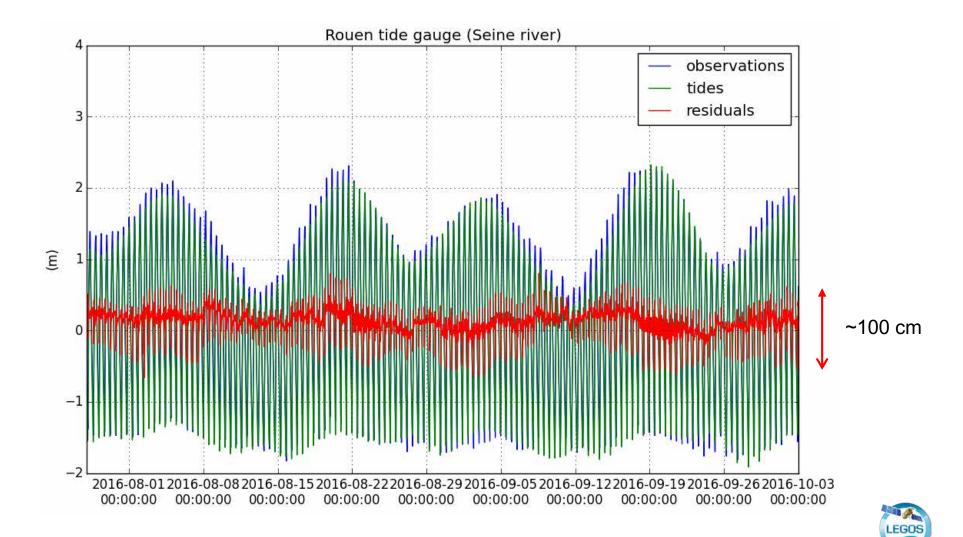> tide modulation by river discharge fluctuations (increase of tidal residual)

Rouen tide gauge (Seine river)

Tidal anomalies in estuaries

> deficient harmonic method to analyze/predict tides

> **low tides not modified in spring/neap cycle**

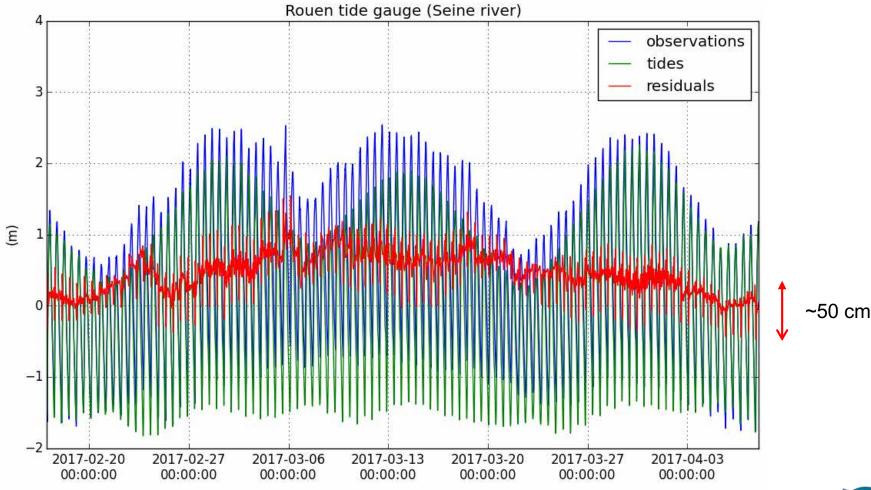> tide modulation by river discharge fluctuations (increase of tidal residual)

Rouen tide gauge (Seine river)

Tidal anomalies in estuaries
> deficient harmonic method to analyze/predict tides
> low tides not modified in spring/neap cycle
> **tide modulation by river discharge fluctuations (increase of tidal residuals)**
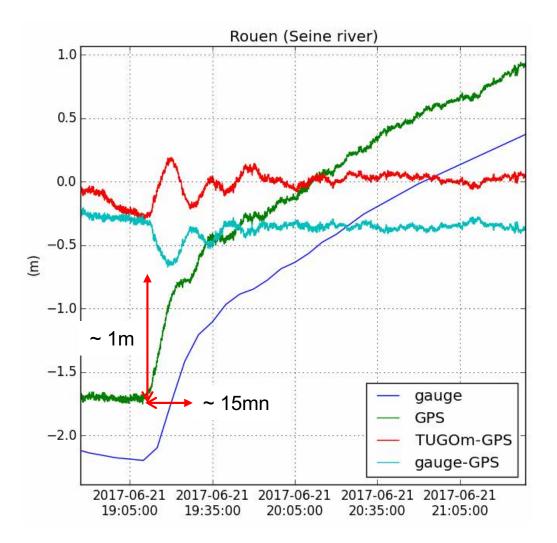

Rouen tide gauge (Seine river)

~50 cm

Tidal modelling/corrections accuracy issues
> rapid change of level at ebb/flood transition
> needs data assimilation (tide gauges)
> with 1 mn time sampling (local resonance oscillation not captured at 5 mn sampling)

Rouen (Seine river)

Tidal modelling accuracy
> rapid change of level at ebb/flood transition
> needs data assimilation (tide gauges)
> with 1 mn time sampling (local resonance oscillation not captured at 5 mn sampling)
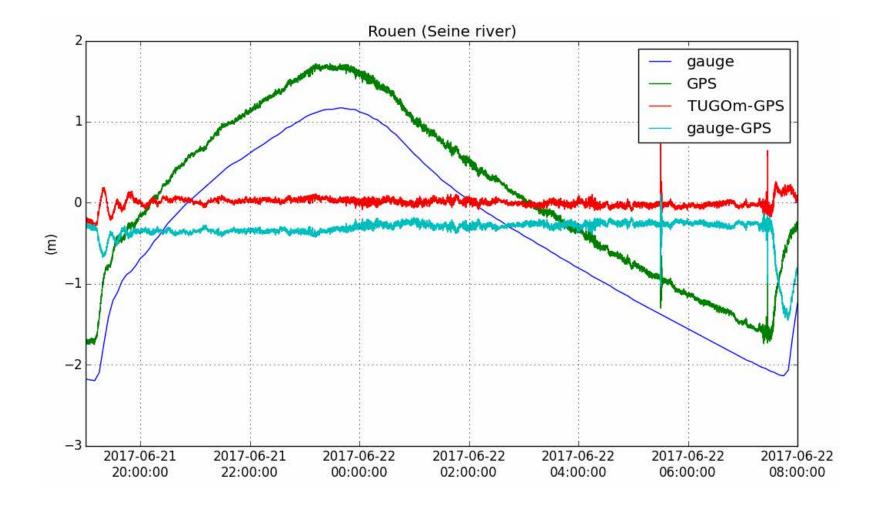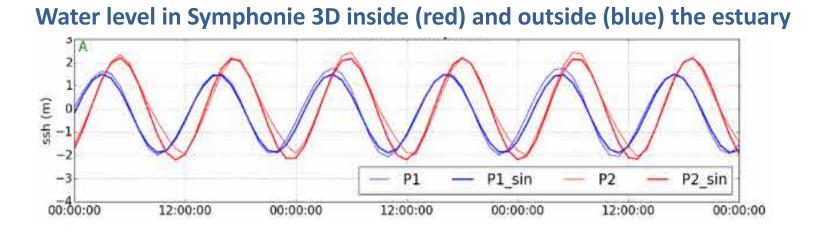

Rouen (Seine river)

Water level in Symphonie 3D inside (red) and outside (blue) the estuary

Nguyen et al.

TUGO 2D

Water level
@ Trompeloup
17/03/2011

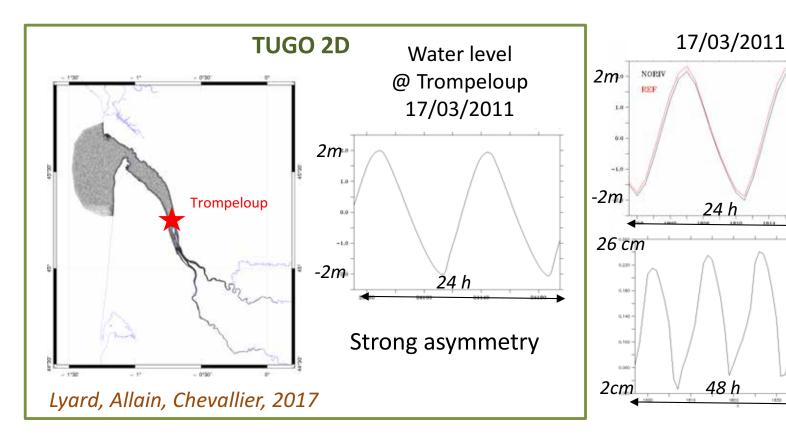Strong asymmetry

Lyard, Allain, Chevallier, 2017

17/03/2011

Symphonie

Water level
@ Trompeloup
with/without
river discharge

Difference of
water level
with/without
river discharge

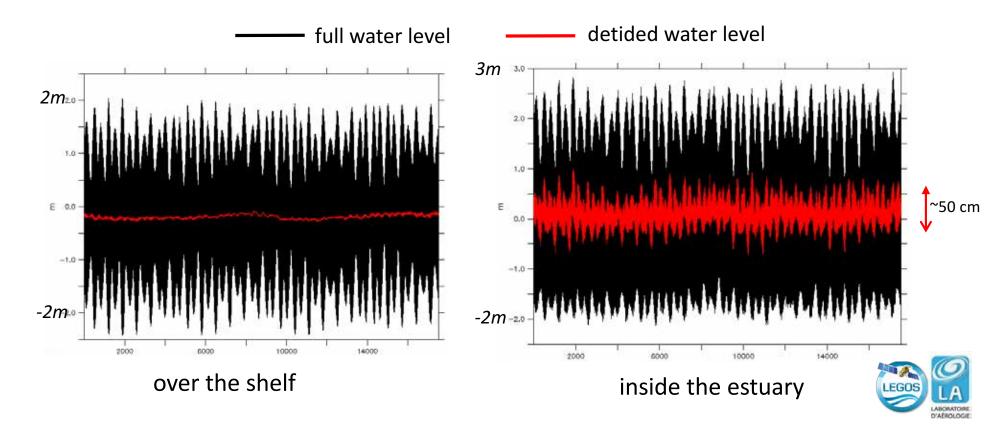## tides in Symphonie less asymmetric than in TUGO

- tune the model parameters(bottom friction) ? the bathymetry ?
- sensitivity to upstream boundary conditions ?
- need to model the estuarine + river system ?
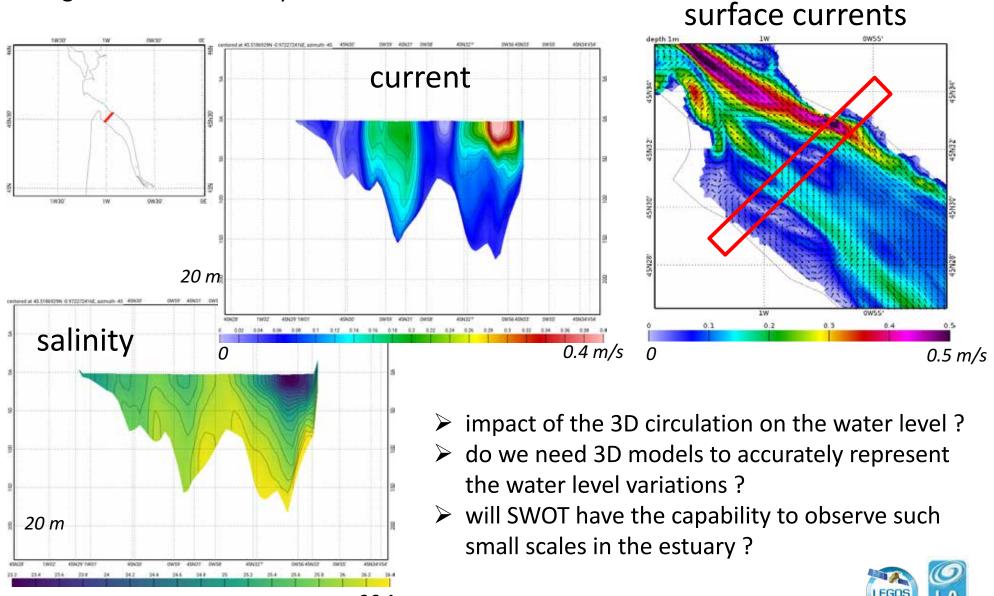
impact on tides analysis (and on detiding)

failure of the standard 'oceanic' method based on harmonic analysis

over the shelf   inside the estuary
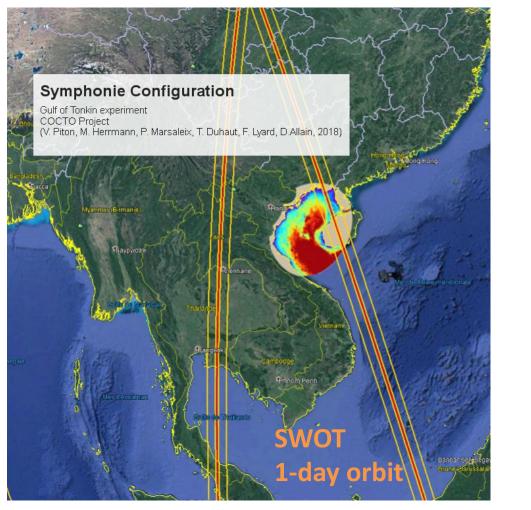
- well-marked stratification and significant vertical shear
- large seasonal variability
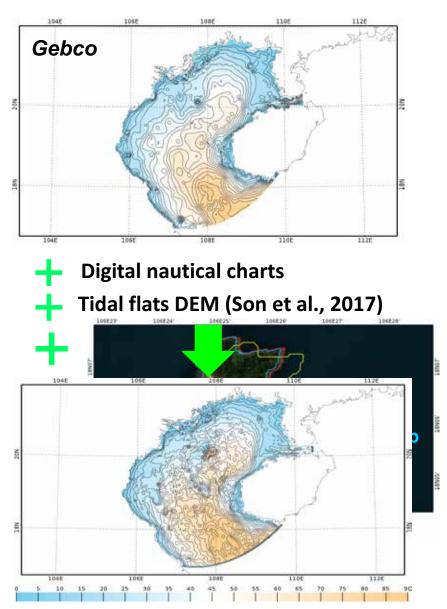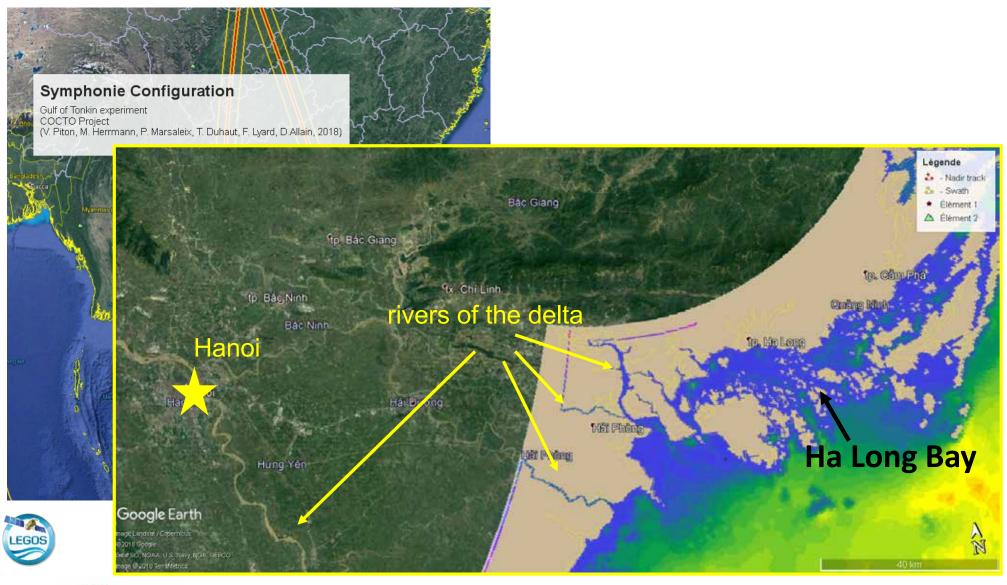
surface currents

current

20 m

0   *0.4 m/s*

salinity

20 m

0   *0.5 m/s*

23.2   *26.4*

> ➤ impact of the 3D circulation on the water level ?
> ➤ do we need 3D models to accurately represent the water level variations ?
> ➤ will SWOT have the capability to observe such small scales in the estuary ?

2. On-going modelling efforts in the Gulf of Tonkin

Symphonie Configuration

Gulf of Tonkin experiment
COCTO Project
(V. Piton, M. Herrmann, P. Marsaleix, T. Duhaut, F. Lyard, D.Allain, 2018)

SWOT
1-day orbit

V. Piton et al., in prep.

Gebco

+ Digital nautical charts

+ Tidal flats DEM (Son et al., 2017)

+

Symphonie Configuration

Gulf of Tonkin experiment
COCTO Project
(V. Piton, M. Herrmann, P. Marsaleix, T. Duhaut, F. Lyard, D.Allain, 2018)
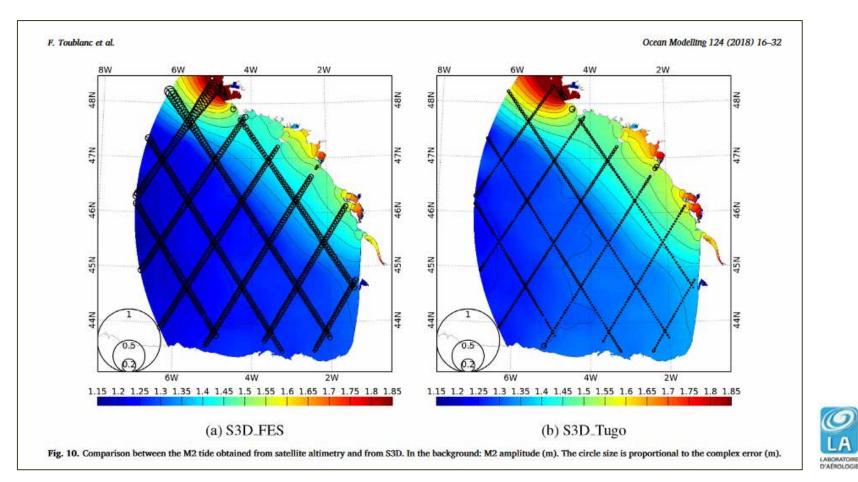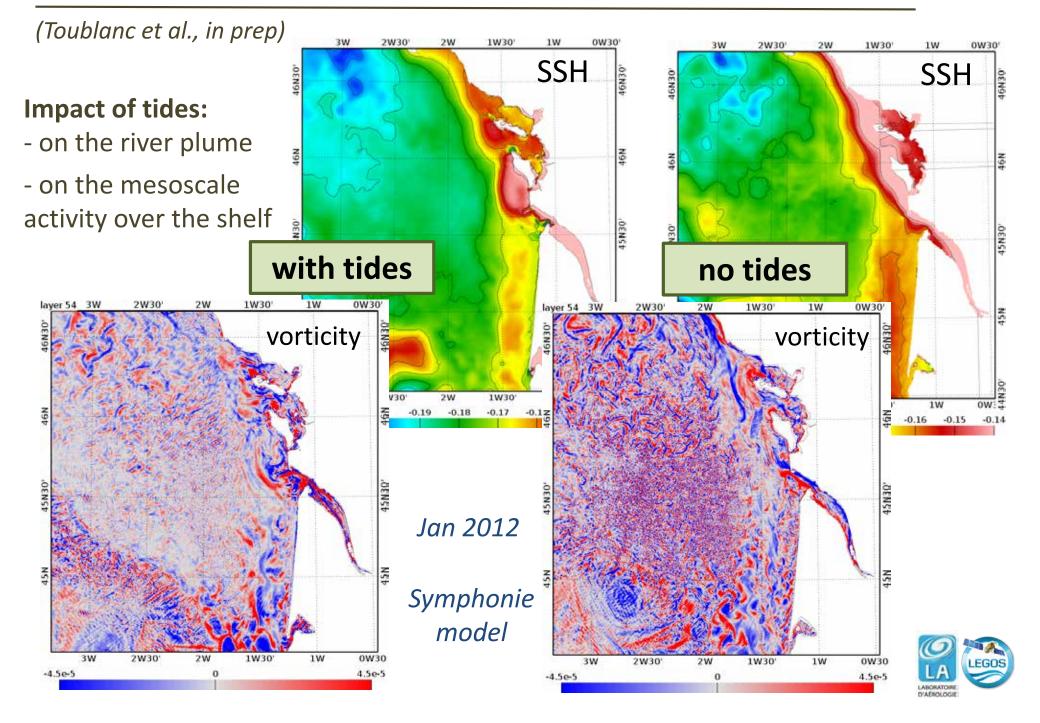
- assessment of the tides representation in the Symphonie model
- study of the impact of tidal open-boundary conditions

➡ Toublanc et al., Ocean Modeling, 2018
'Tidal downscaling from the open ocean to the coast:
a new approach applied to the Bay of Biscay'

Fig. 10. Comparison between the M2 tide obtained from satellite altimetry and from S3D. In the background: M2 amplitude (m). The circle size is proportional to the complex error (m).

3. Impact of tides on the small-scales dynamics over the shelf

(Toublanc et al., in prep)

Impact of tides:
- on the river plume
- on the mesoscale activity over the shelf
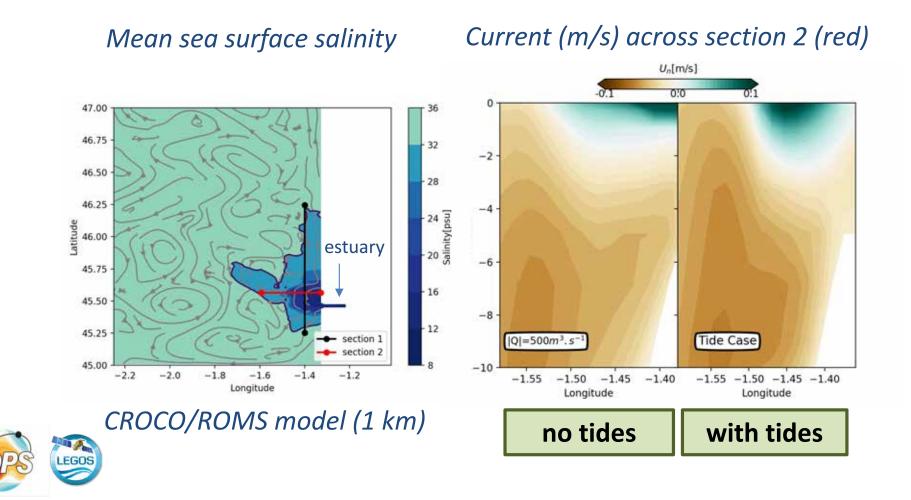

Jan 2012

Symphonie model

4. Impact of tides on the river plume over the shelf

(PhD Thesis of A. Ayouche)

Processus study of the plume dynamics in idealized numerical experiments
➢ sensivity of the plume to tides, wind forcing, shelf bathymetry
➢ analysis of the instabilities that develop at the edge of the plume

Mean sea surface salinity

Current (m/s) across section 2 (red)

CROCO/ROMS model (1 km)

no tides   with tides
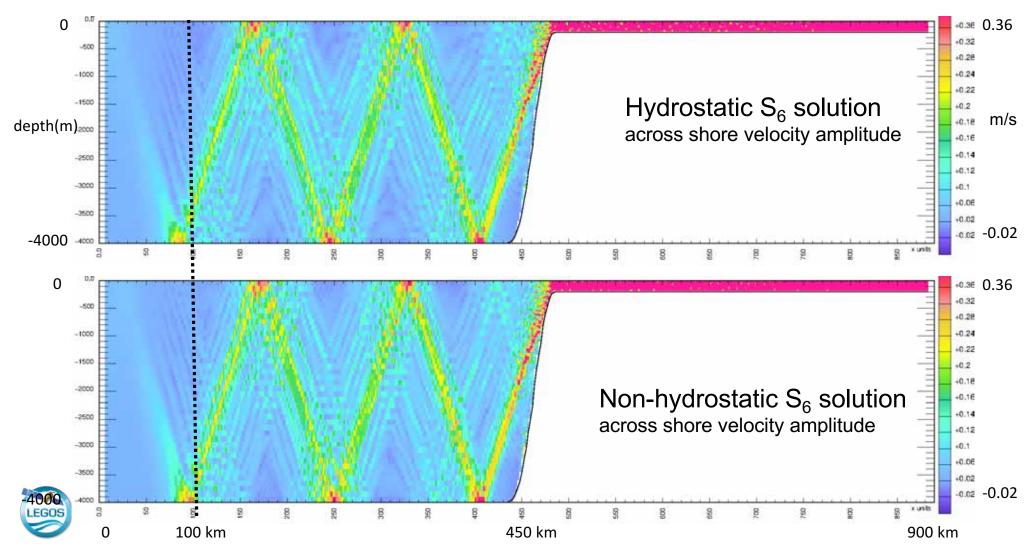
5. Internal tides

(PhD Thesis of S. Barbot)

Non-hydrostatic, 3D frequency-domain solver (T-UGOm)
> NH propagational effect proportional to squared frequency
> to investigate energy transfer from internal tides to internal waves (higher frequencies, solitons?) through non-linear processes

Hydrostatic S_6 solution
across shore velocity amplitude

Non-hydrostatic S_6 solution
across shore velocity amplitude

Concluding remarks

Tides in the estuaries from a numerical perspective
- strong asymmetry and non-stationarity
    - → a challenge for high precision modeling
    - → how to analyse/extract the tidal signal ?
- what is the benefit of 3D modeling for the modeling of water level variability ?
- which additional processes should we include in the models: surface waves, non-hydrostatic dynamics, hydro-sedimentary processes ?

Small scale dynamics over the shelf in the Bay of Biscay
- tides tend to reduce the small-scale activity
- impact of the tides on the plume shape (bulge, along- and cross-shore extensions)
- impact of the tides on the plume instabilities ?

Internal tides generated at the shelf break with 3D TUGO spectral model
- sensitivity tests in an idealized configuration (e.g NH vs H)
- realistic modeling in Bay of Biscay

2. On-going modelling efforts in the Gulf of Tonkin

in the perspective of modeling the sediments transport,
collection of in situ data to test the sediment model

SPRING TIDE

NEAP TIDE

Double core Estuarine Turbidity Maximum for S~ 20 and S~0.15

When S increase, thin layers of highly concentrated suspended particulate matter are formed.