Tidal and Storm Surge Modeling

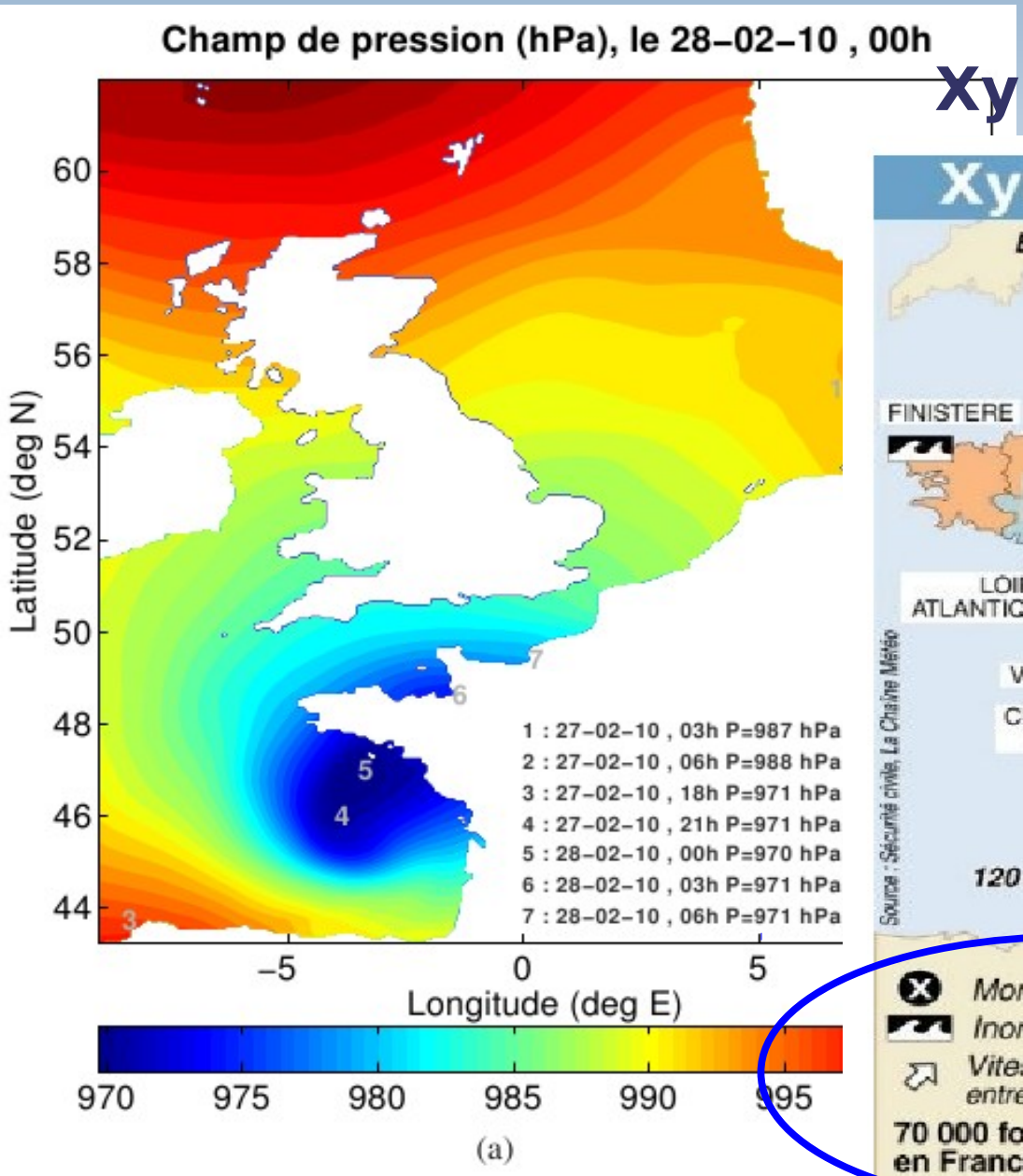
The HOMONIM project

Flav Gouillon,

A. Pasquet, R. Baraille, S. Correard, D. Jourdan

LOMW, 2013

Storm surges in France



Xynthia, the deadly storm

What is the HOMONIM project?

- **Operational tidal and storm surge modeling system in the Atlantic and Mediterranean Sea**

- **The French ministry for ecology, sustainable development and territory planning with its department for the prevention of risks needs:**
  - **To better anticipate marine environmental risks**
  - **To improve the understanding of the processes involve in storm surge phenomenon**
  - **An operational system to predict extreme events**

- **The main objectives are to better understand/characterized and to improve the prediction of those events**

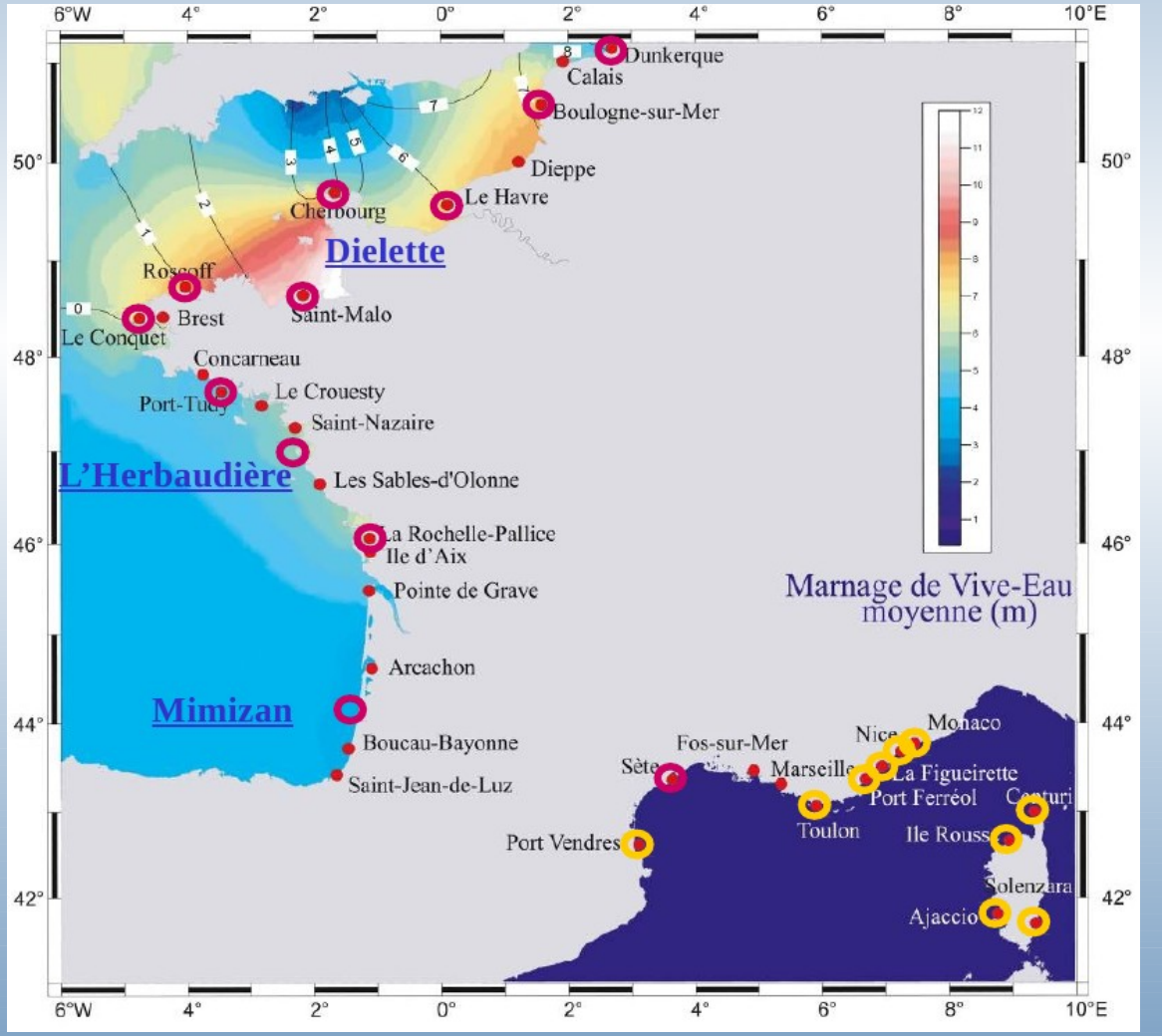
- **The project has started in June 2012 and will last until 2015**
- **The SHOM 'competes' against EDF/LNHE (Telemac2D)**

Objectives of the project

1st Objective: Better understand and characterized events

- Knowledge of past extreme events via historical water level analysis (statistical and numerical)

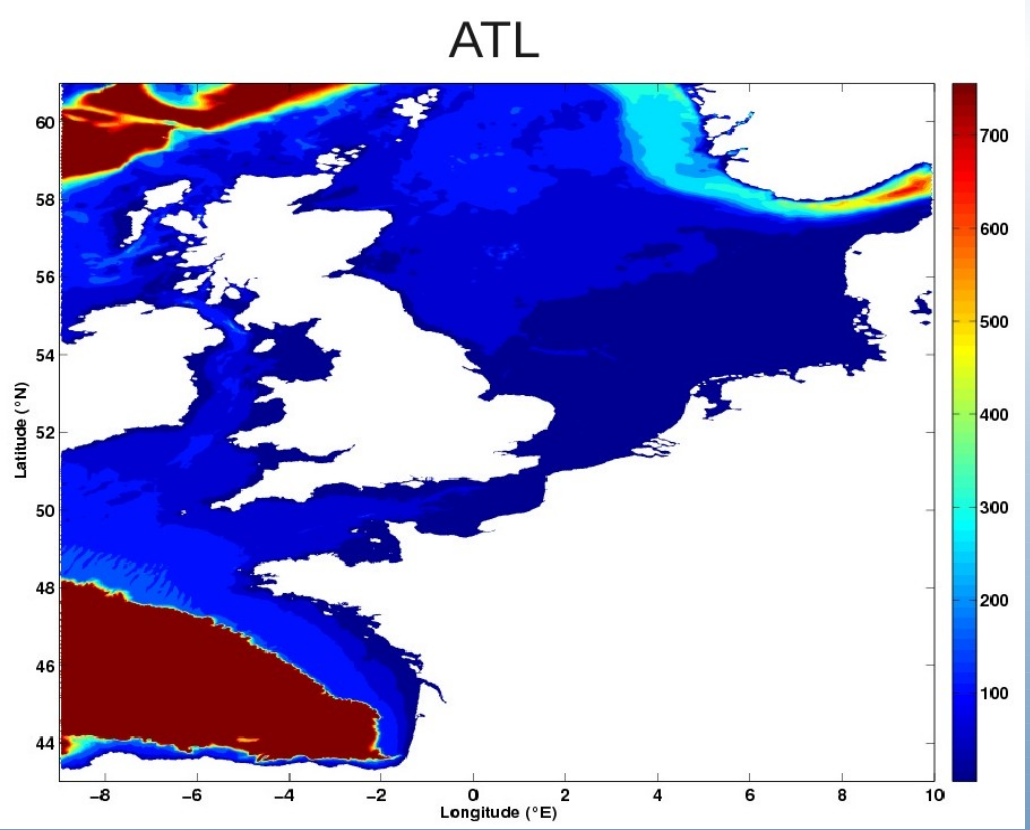
- Exploit and consolidate the existing observational network

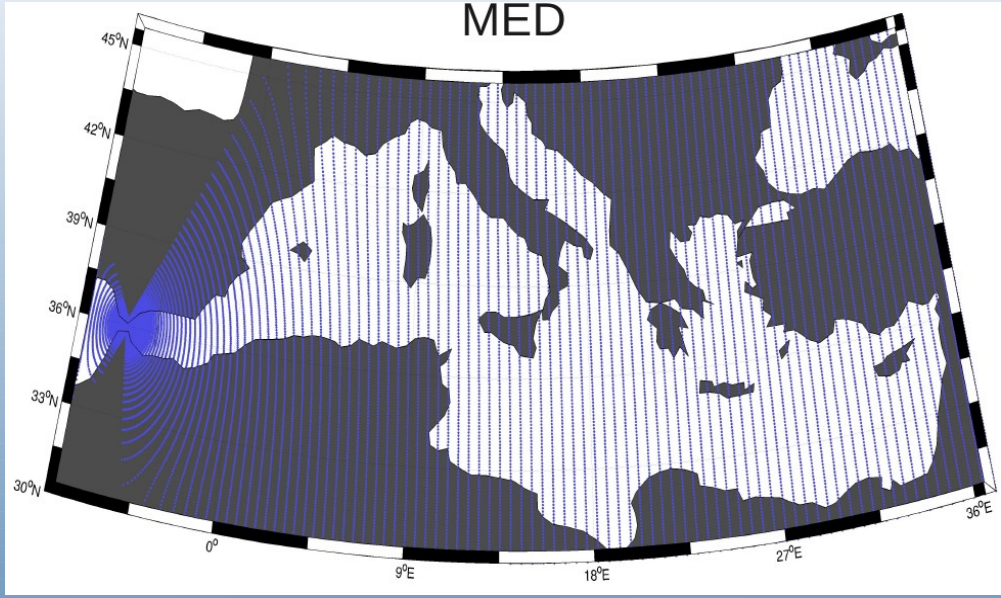


Objectives of the projet

2nd Objective: Improve storm surge modeling/prediction

- Adapt or develop existing models of ATL and MED into operational predicting system
- Modeling of the sea state
- Modeling a 2D/3D ocean





2D Modeling – how to reach the objectives ?

1. Accurate temporal and spatial representation of storm surge processes

- validate the tide (storm surge interactions, OB forcing, model resolution at the coast, bottom friction)
- Wind stress (sea state added or not)
- Added value of 3D configuration

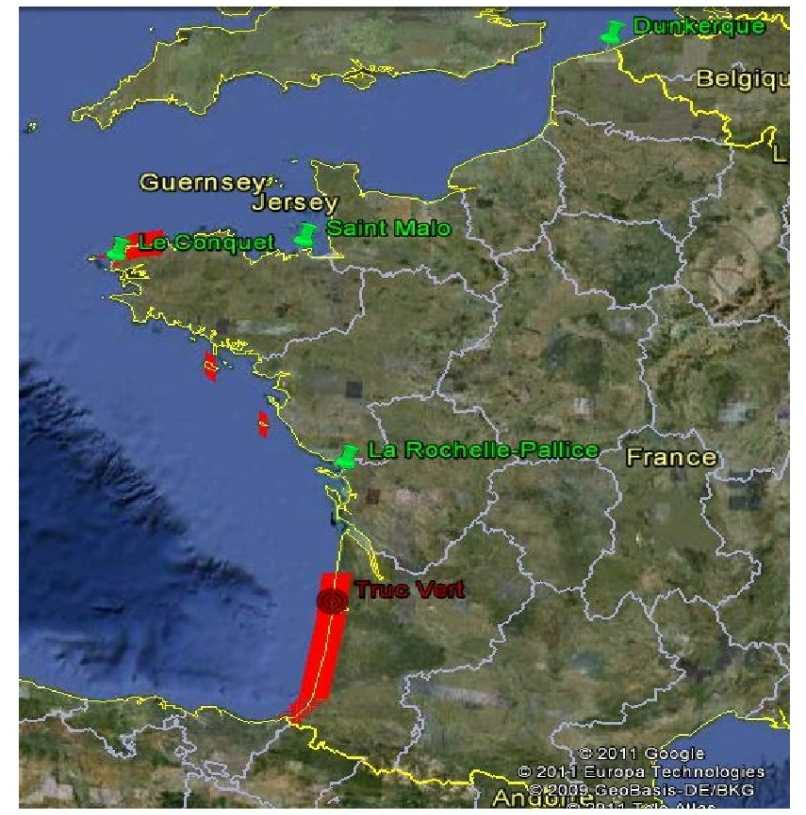
2. Evaluate performance of the different configurations

- Methodology to validate the tide that allows for sensivity studies
- Météo-France protocole of validation to intercompare the models
    - 1 year tidal run validation
    - 1 year full model validation
    - 11 short storm events (10 days)
    - statistical scores on 18 tidal gauges for ATL, 10 for MED
    - computational cost

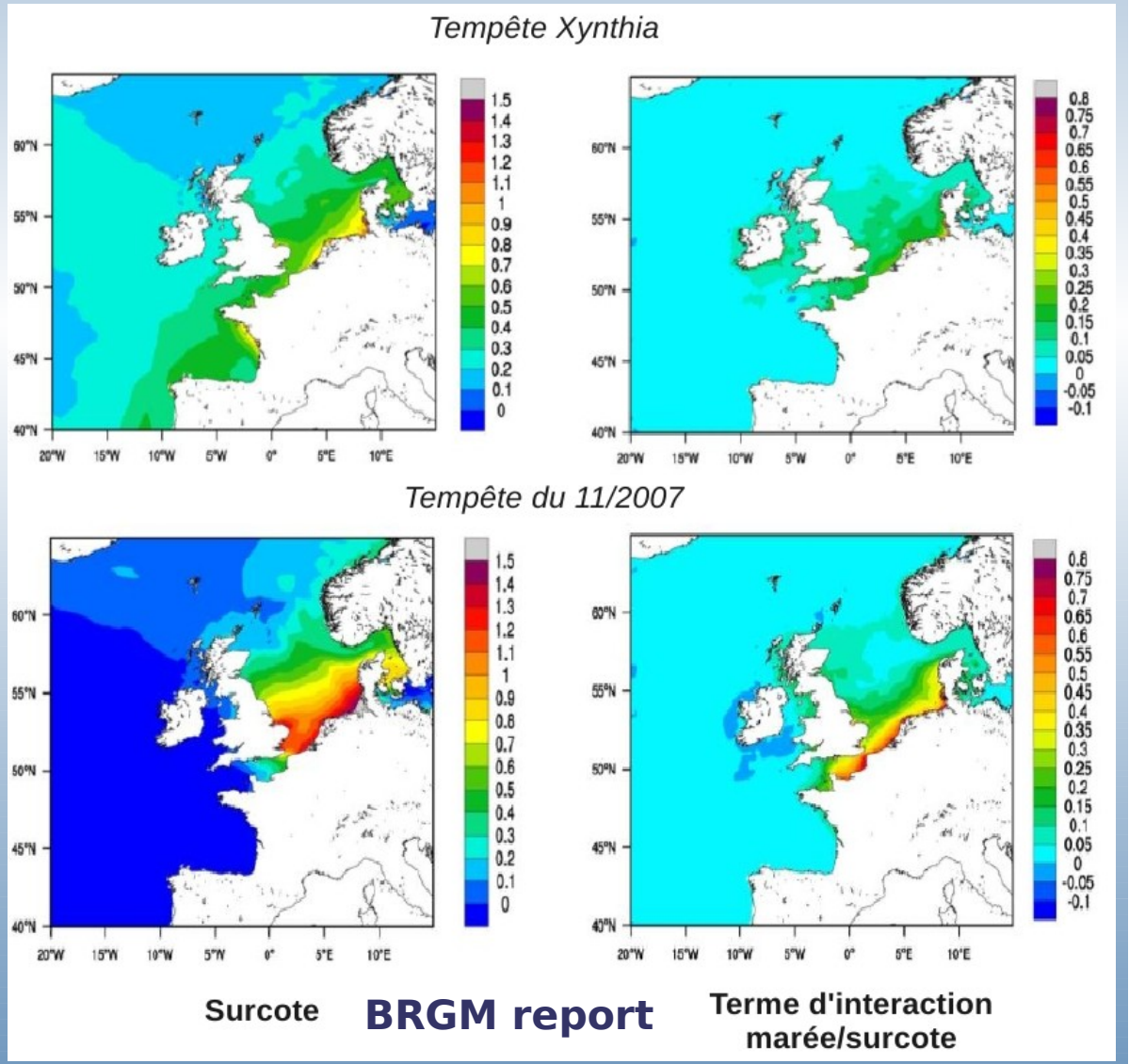
2D Modeling - how to reach the objectives ?

1. Accurate temporal and spatial representation of storm surge processes

- spatial/temporal forcing resolution O(~10cm)
- tide O(10% to 50% of surge)
- sea state O(10% to 20% of surge)

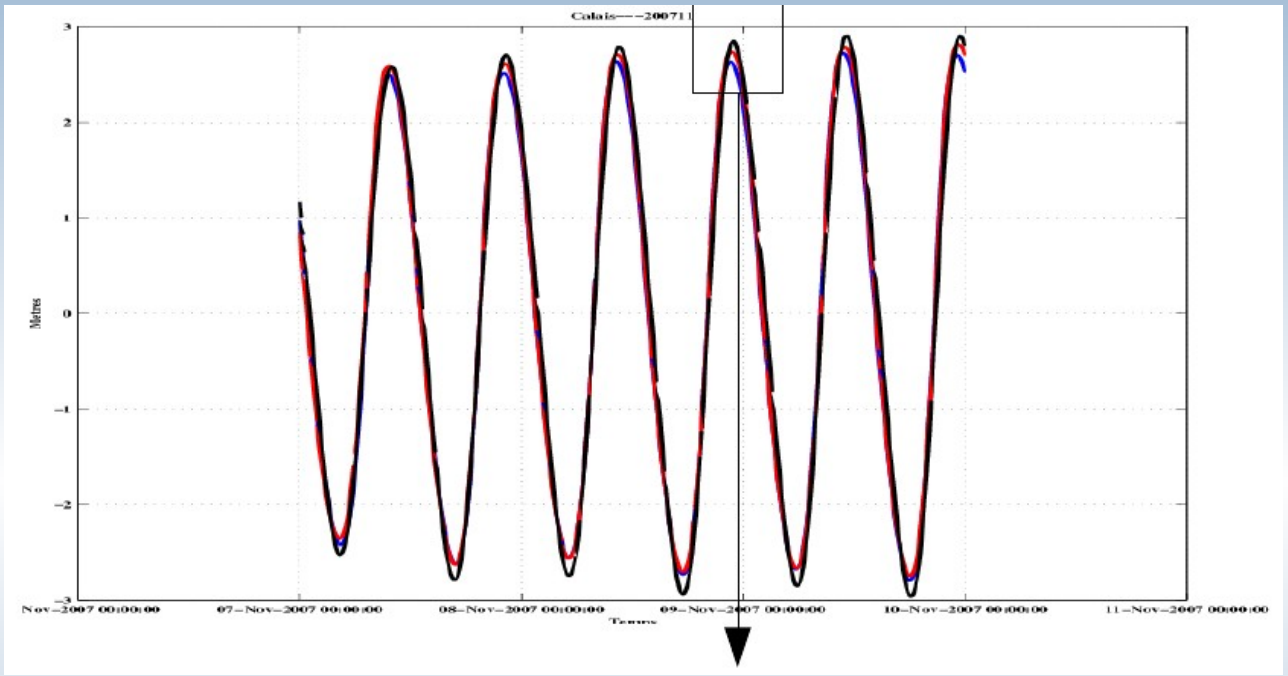


Locations where interactions between tides and storm surge are negligible



2D Modeling - how to reach the objectives ?

Tidal validation : Error = $SSH_{simulated}$ – $SSH_{Observed}$



Model

Tidal forcing

Prediction

Error due to tidal forcing (accuracy, number of tidal constituents)

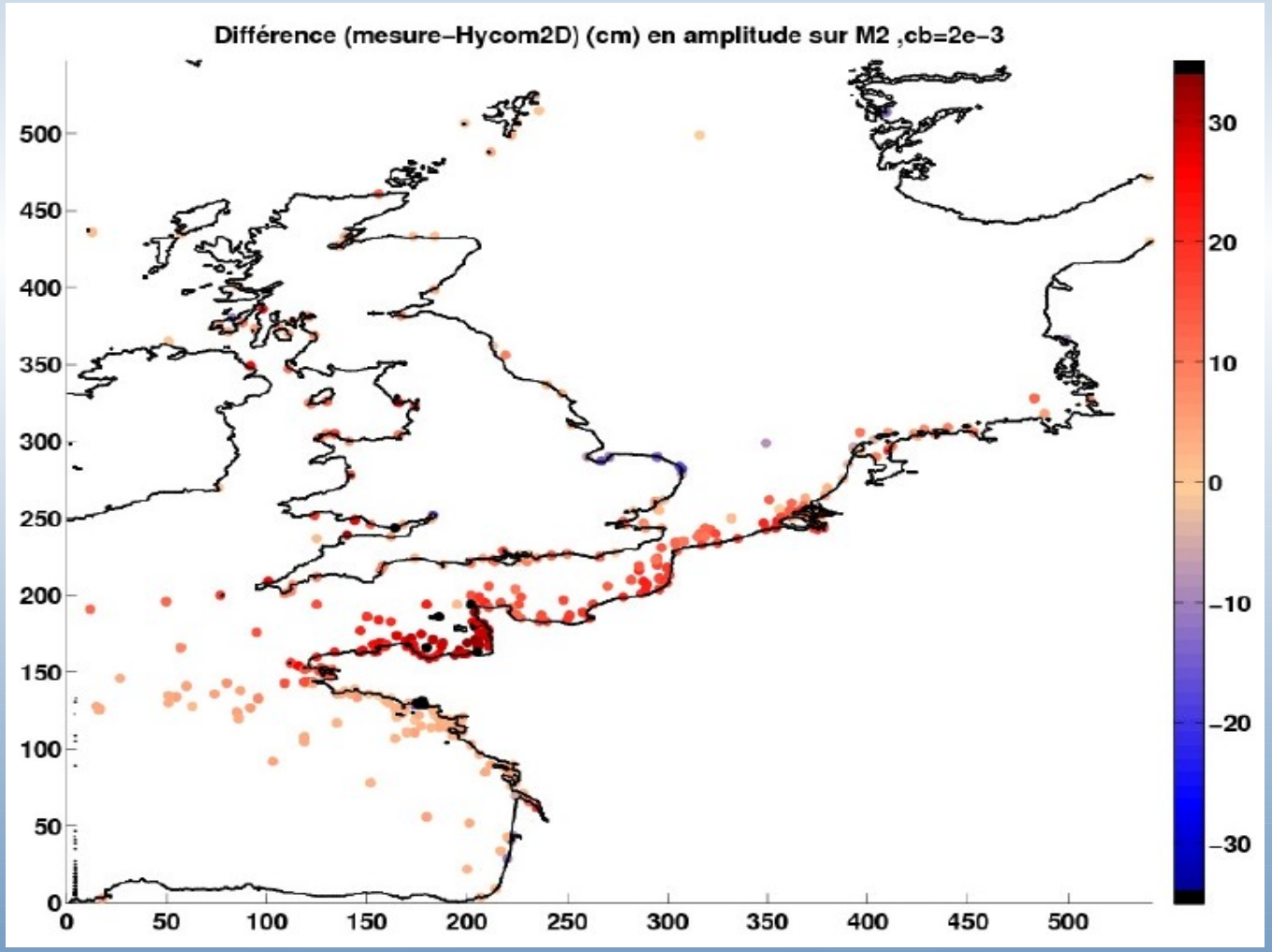
Error due to the model configuration (resolution, friction,...)

Tools to evaluate and quantify those errors

2D Modeling - how to reach the objectives ?

- SHOM Harmonic analysis and predicting tool: MAS
- 500 tidal gauges available (RONIM)
- re-create time series at specific points with *N* tidal constituents

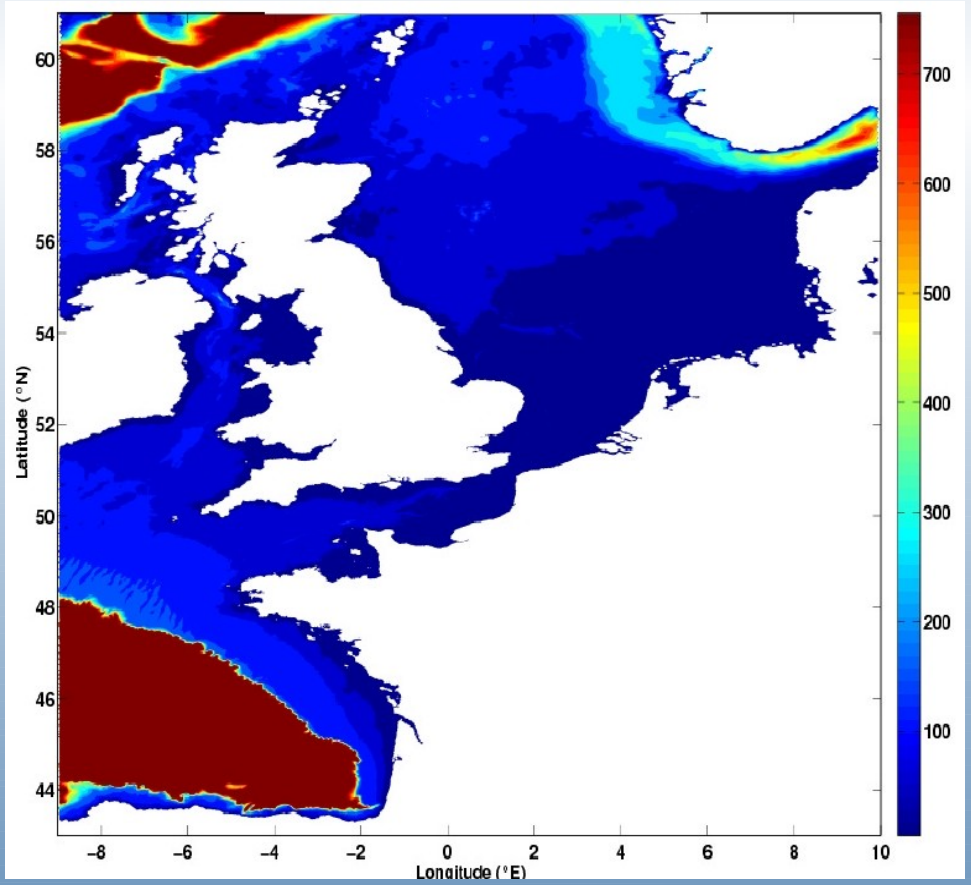
Method to validate and intercompare sensitivity runs



2D Modeling – Atlantic (ATL)

HYCOM configuration

- LEGOS Bathymetry
- Arpege/Aladin atmospheric forcing



Sensitivity tests

1- TIDE

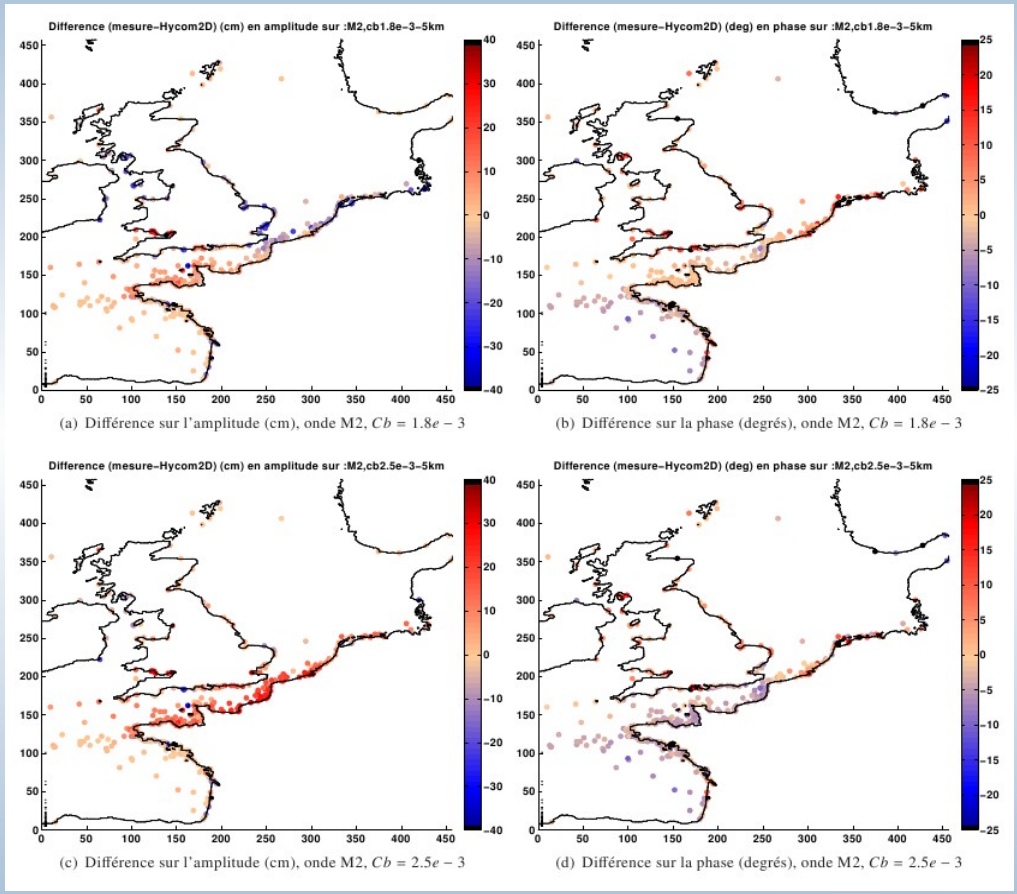
- tidal forcing (LEGOS *vs.* TOPEX)
- model resolution (5km, 2km, curvi)
- bottom friciton
- open boundary (SSH, U, V)
- local tidal potential

2- STORM SURGE

- wind stress parameterization

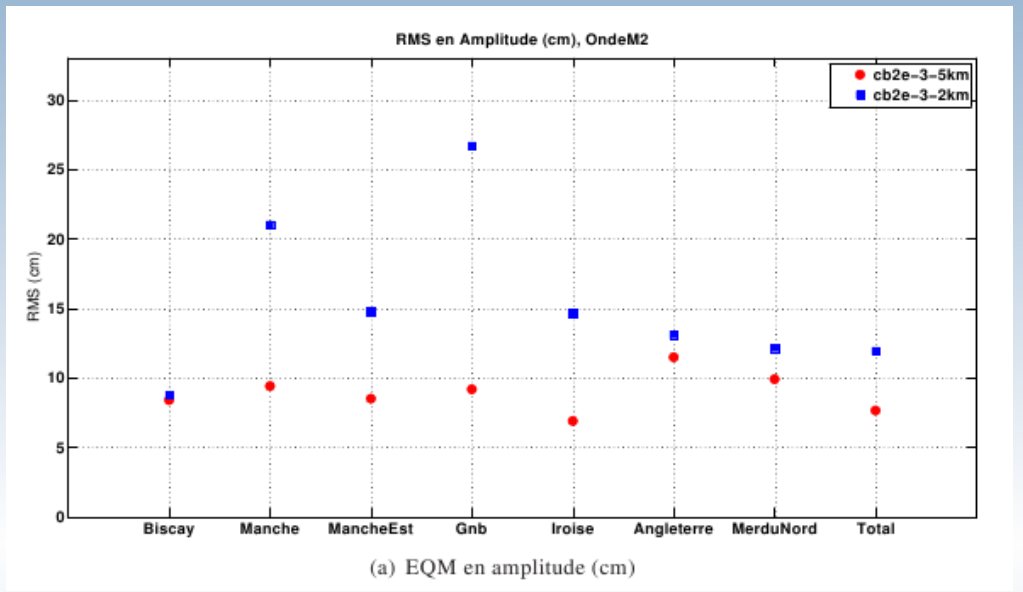
2D Modeling – ATL - TIDE

Results on uniform grids

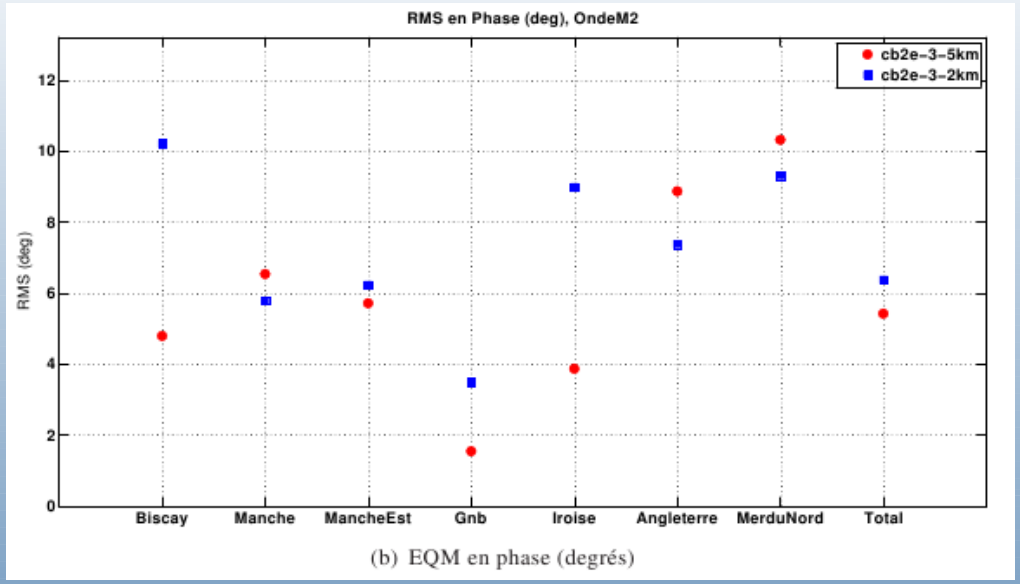


(a) Différence sur l'amplitude (cm), onde M2, $Cb = 1.8e-3$ (b) Différence sur la phase (degrés), onde M2, $Cb = 1.8e-3$

(c) Différence sur l'amplitude (cm), onde M2, $Cb = 2.5e-3$ (d) Différence sur la phase (degrés), onde M2, $Cb = 2.5e-3$



(a) EQM en amplitude (cm)



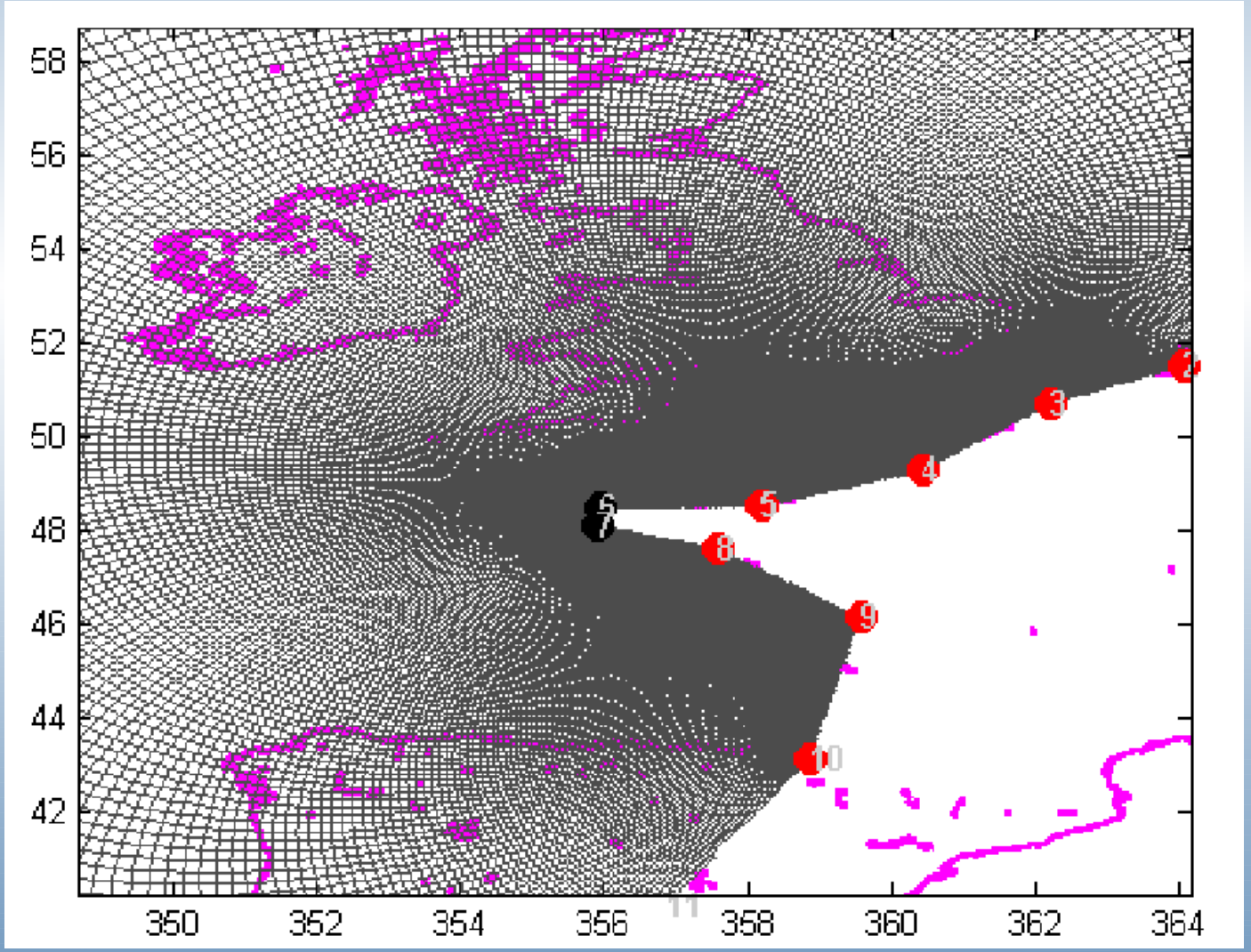
(b) EQM en phase (degrés)

1) Add resolution the coast?
2) Need to adjust the bottom friction?

2D Modeling – ATL

Adding model resolution

- matlab interface to generate orthogonal curvilinear grid (using the GRIDGEN software, *Sakov* 2009)

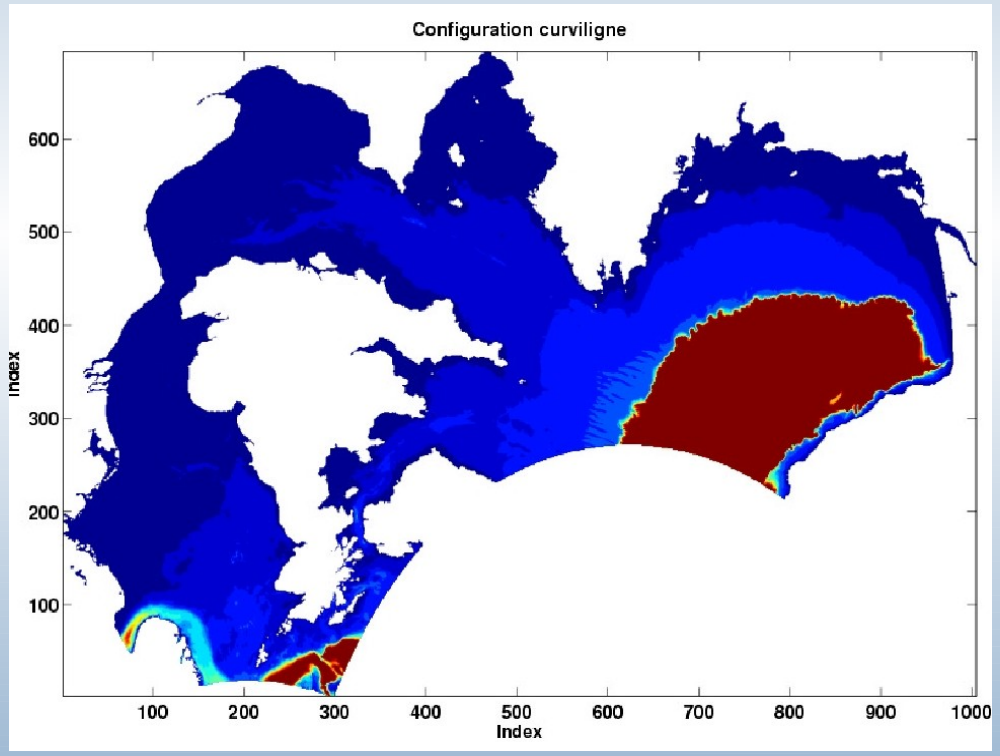


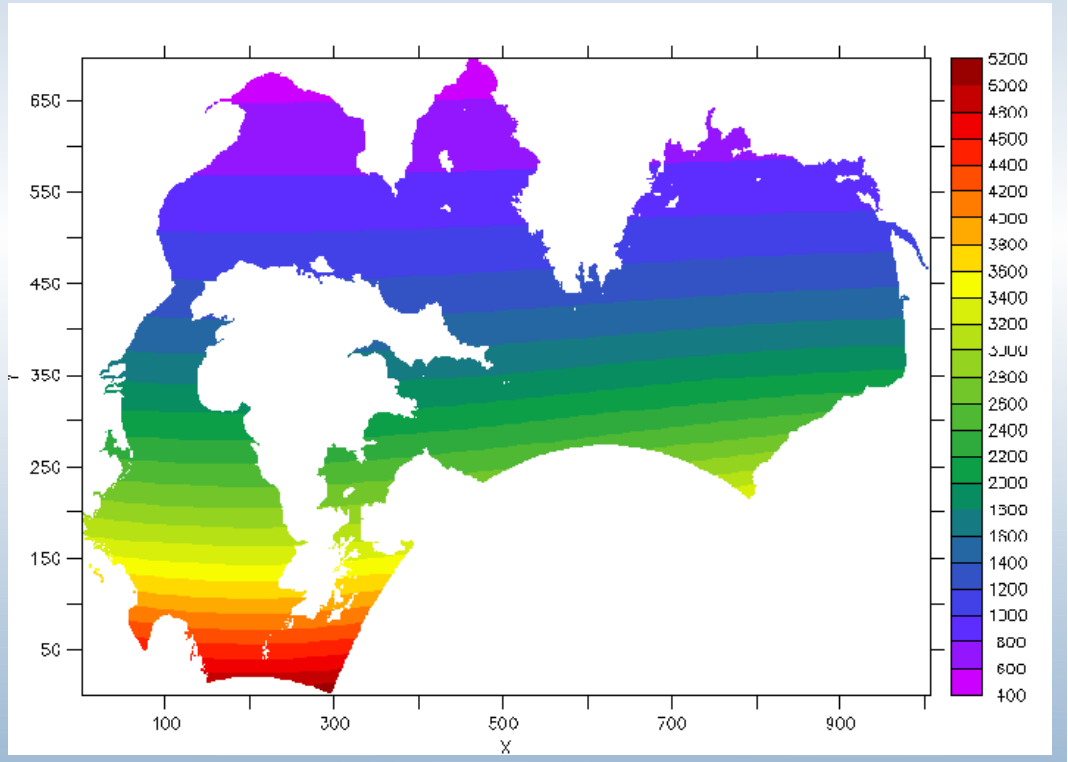
2D Modeling – ATL - TIDE

Sensitivity to model resolution

- matlab interface to generate orthogonal curvilinear grid
- Tools to make generalized mercator grid (2 poles)

Two poles configuration : from hundred meters to kilometers

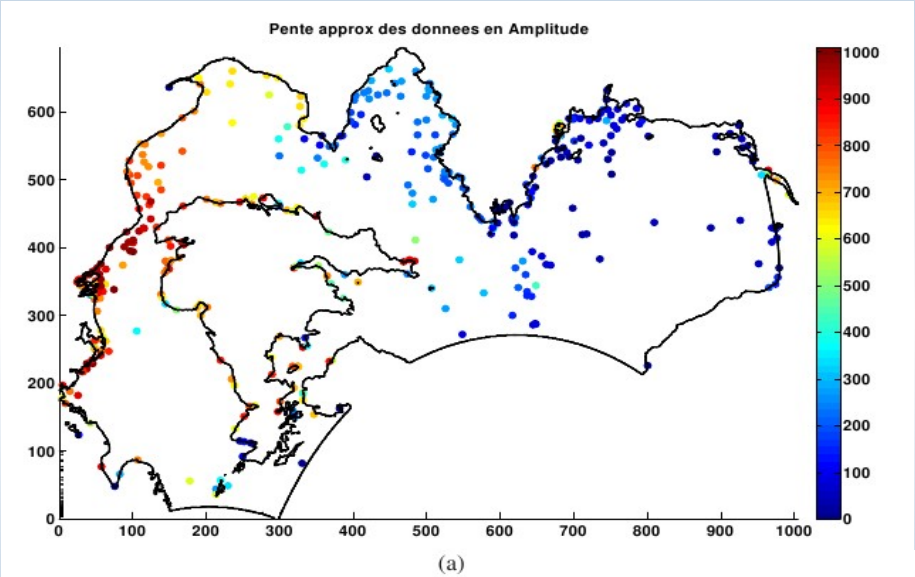


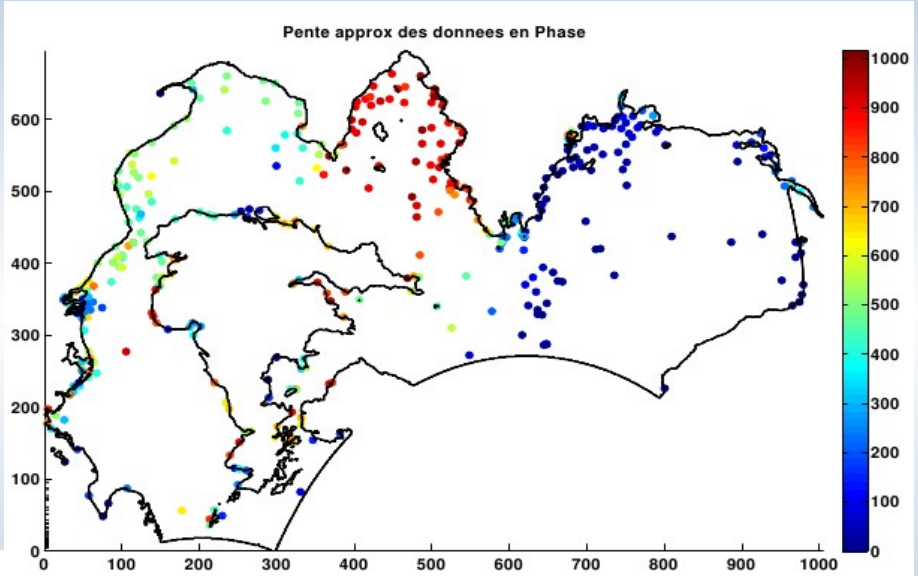


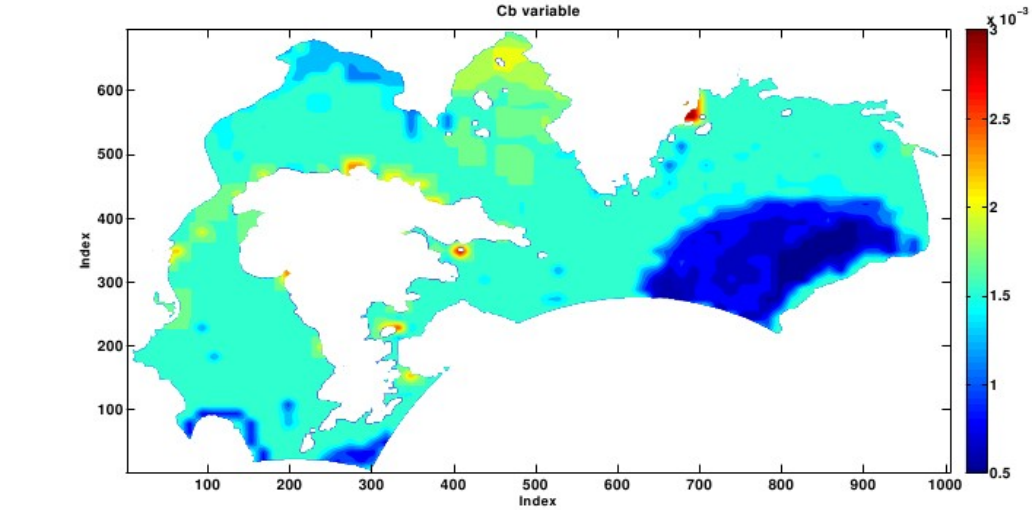
2D Modeling – ATL - TIDE

Sensitivity to bottom friction

- need for a spatial variable friction coefficient
- from bottom rugosity (sedimentology profile), amplitude and phase difference, and model numerical dissipation







2D Modeling – ATL - TIDE

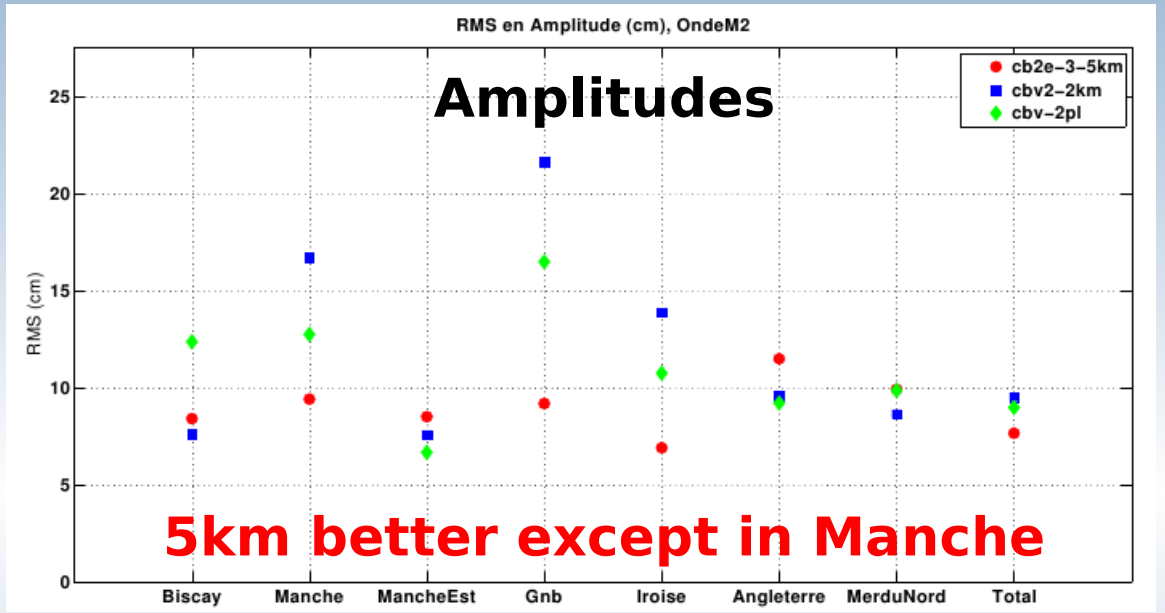
Results of 2 poles grid *vs.* uniform grid

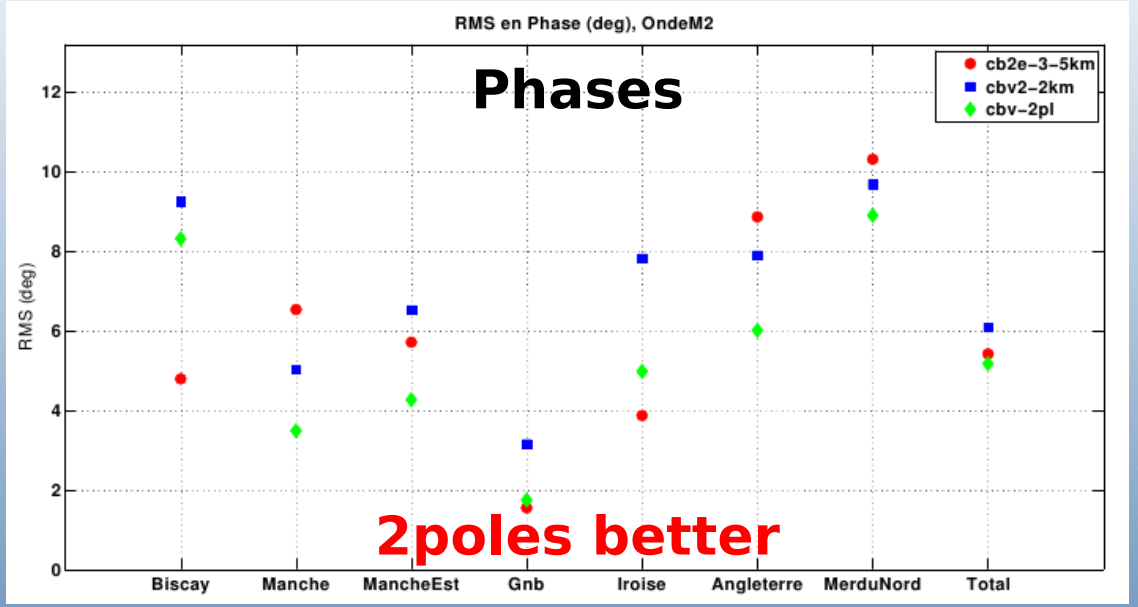
Phases are better with high resolution

Important sensitivity to bottom friciton and time step (model dissipation)

Score	MF	5km	2 poles
Error Amp (cm)	25.8	14.3	**10.8**
Error Pha (min)	25.2	18.3	**16.9**

We retain the 2 pole configuration

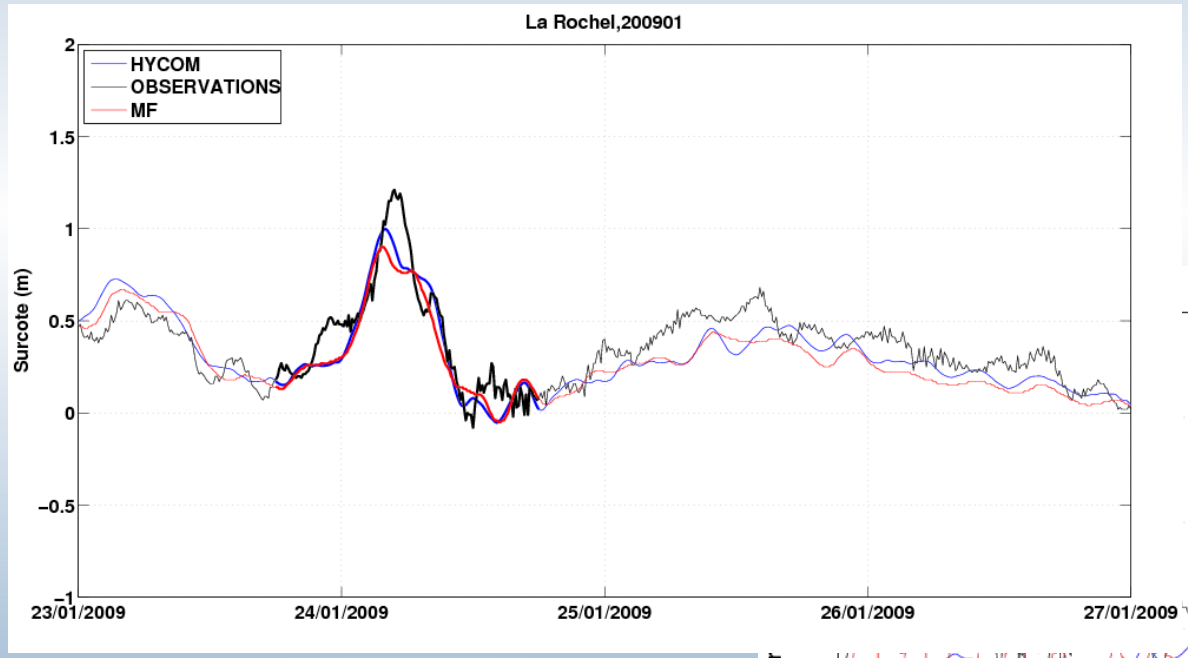


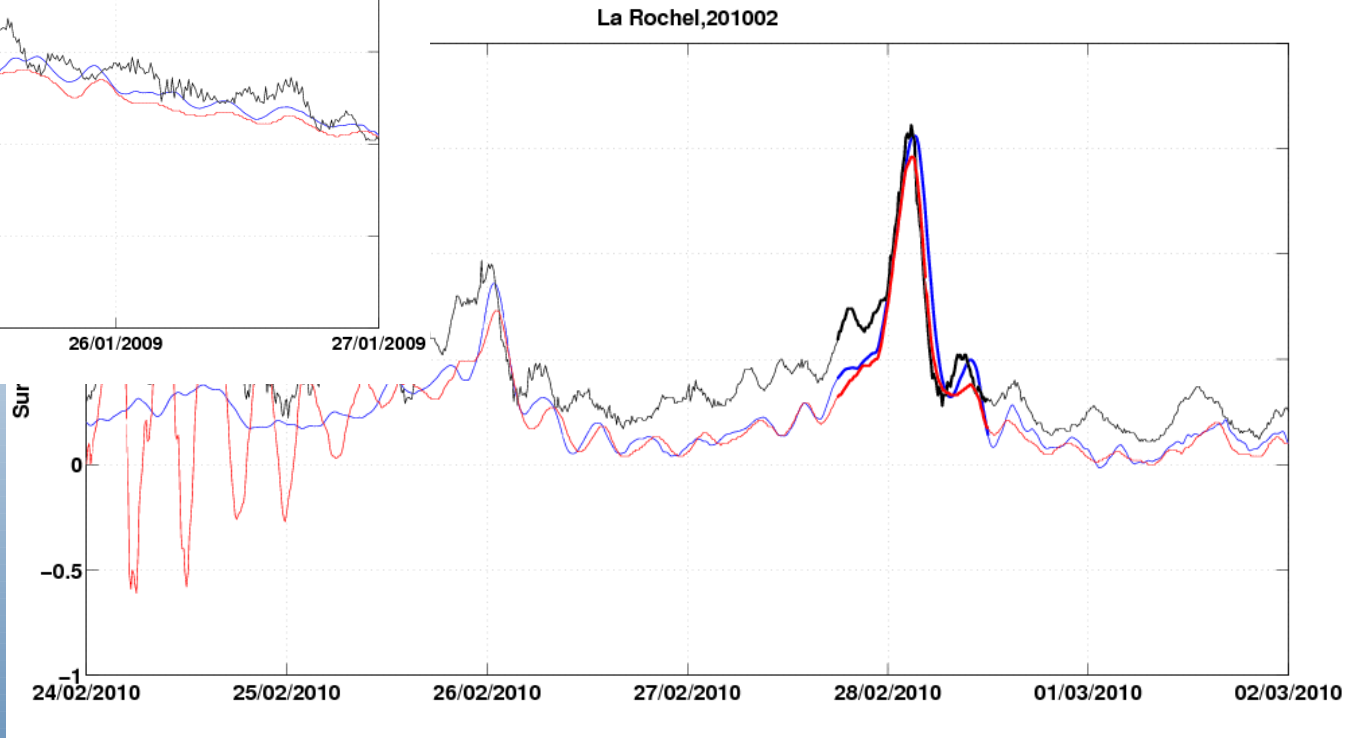


2D Modeling – ATL - SURGE

What wind stress parameterization?

- *Cst*: not enough energy
- *Wu*:improve results of the actual Meteo-France model by 1 to 5cm only
- *Charnock Cst/Variable*: results were ok but problem with wave data
- *Makin*: reduce the wind stress if wind are too strong, results are good but preliminary





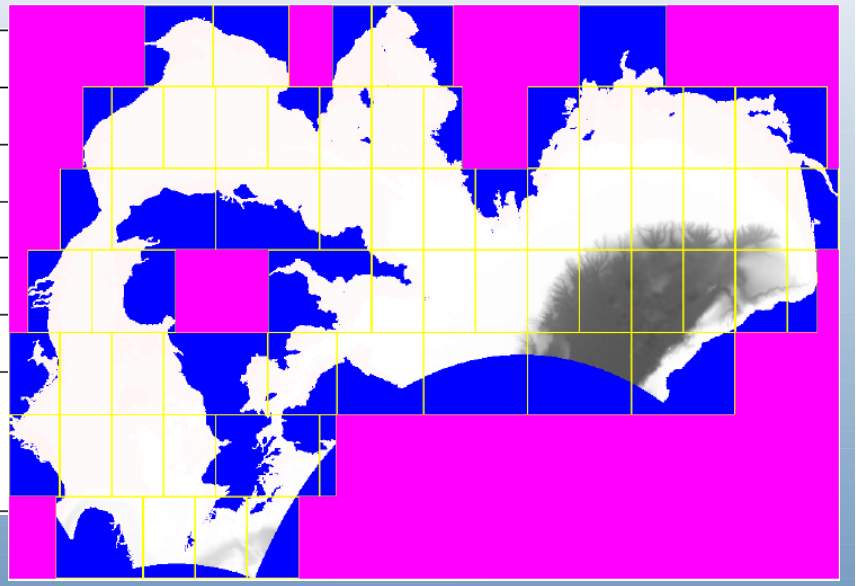
2D Modeling – ATL - SURGE

Global scores with Wu parameterization

Configuration	Amp Bias	Stand Dev	Err max	Err at peak	Phase Err
MF	-8.3	17.8	36.6	-15.6	-8.2
5km	**-7.9**	**17.1**	**35.4**	-16.2	-5.8
2poles	-8.4	**17.1**	35.8	**-15.8**	**-4.5**

Computational aspects

# of Procs	1	8	15	32	**63**	128	256
partitioning	1x1	6x2	12x2	8x7	**16x7**	22x11	18x27
Cost per iteration	1.1	0.35	0.23	0.093	**0.04**	0.023	0.018
Theoretical speed up	1	5.67	10.94	24.33	**48.66**	104.14	210.57
Measured speed up	1	3.14	4.78	11.82	**27.5**	47.8	61.1
Performance ratio	1	0.56	0.43	0.48	**0.56**	0.46	0.29
Launcher	mpirun ou srun	srun	mpirun	mpirun	**mpirun**	srun	srun



2D Modeling – ATL - SURGE

Conclusion for the ATL domain

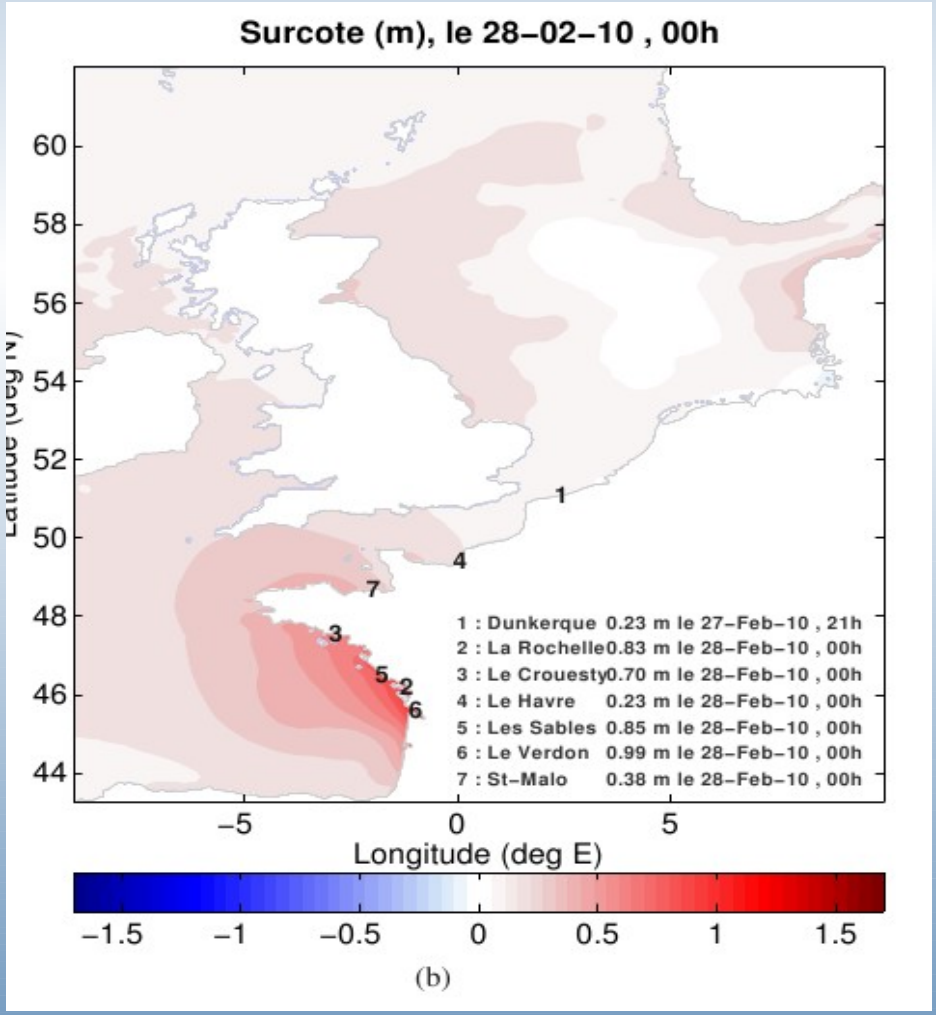
- Development of a simple and efficient curvilinear orthogonal grid generator

TIDE

- new methodology of validation
- good results compare to obs

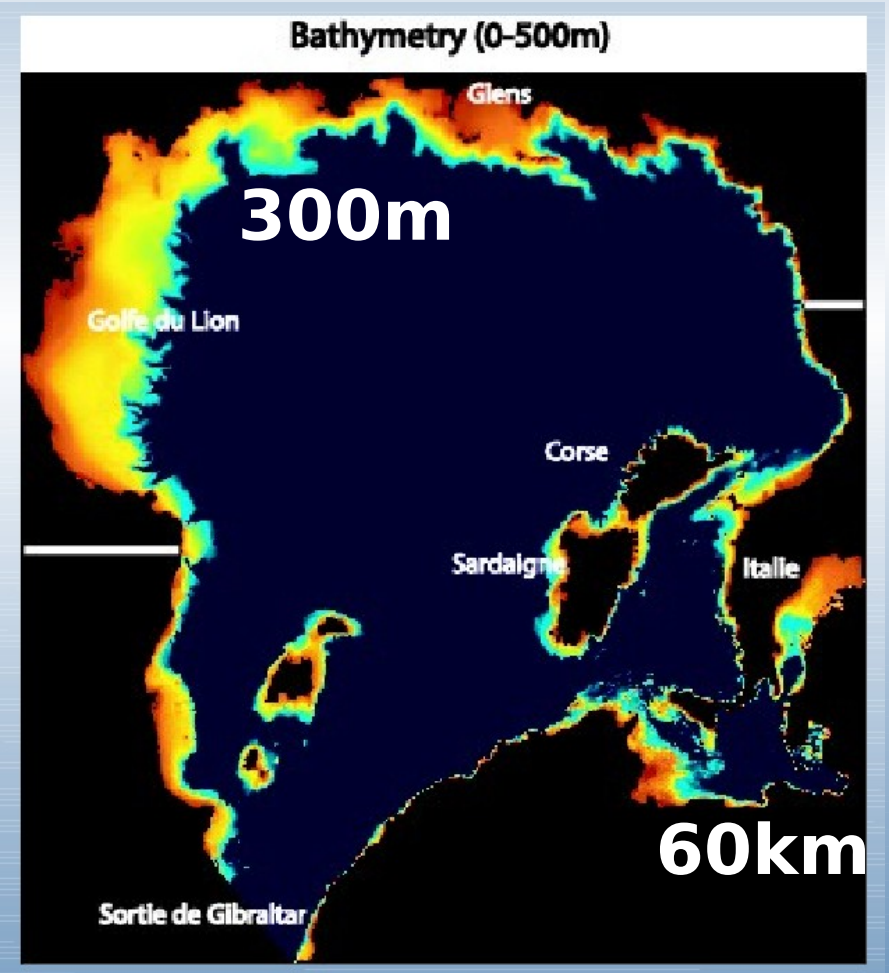
STORM SURGE

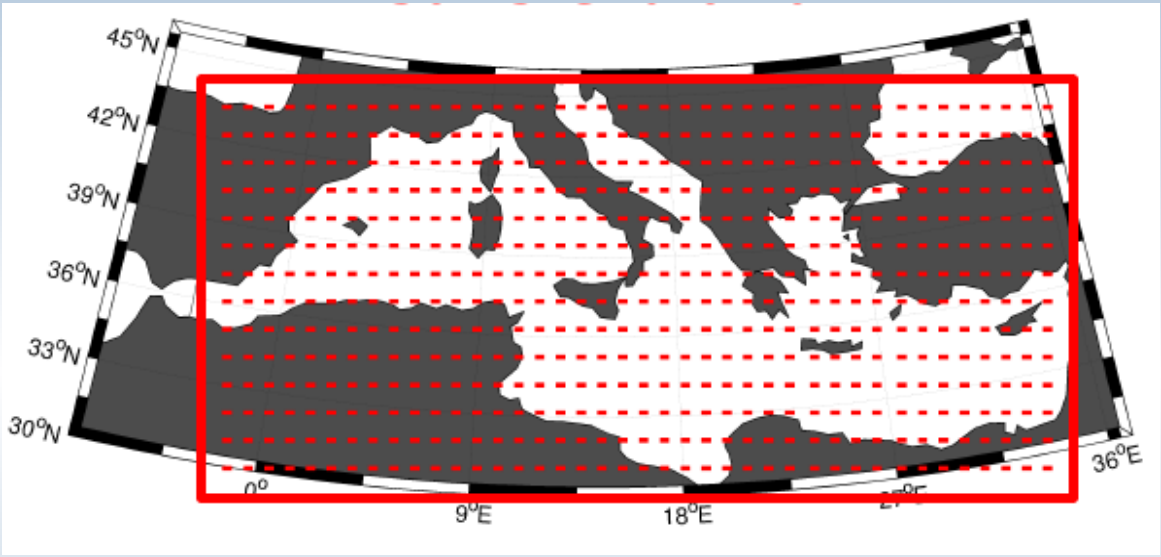
- Implementation of new wind stress parameterization
- Results are in good agreement with observations

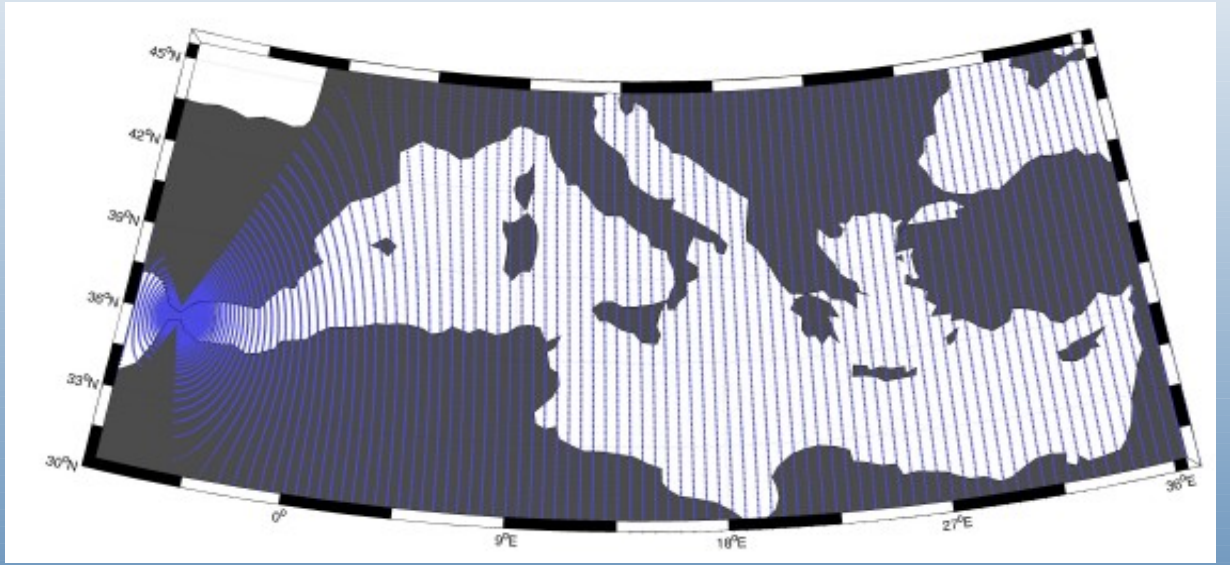


2D Modeling – Mediterranean (MED)

Difficult grid choice: different objectives and different processes







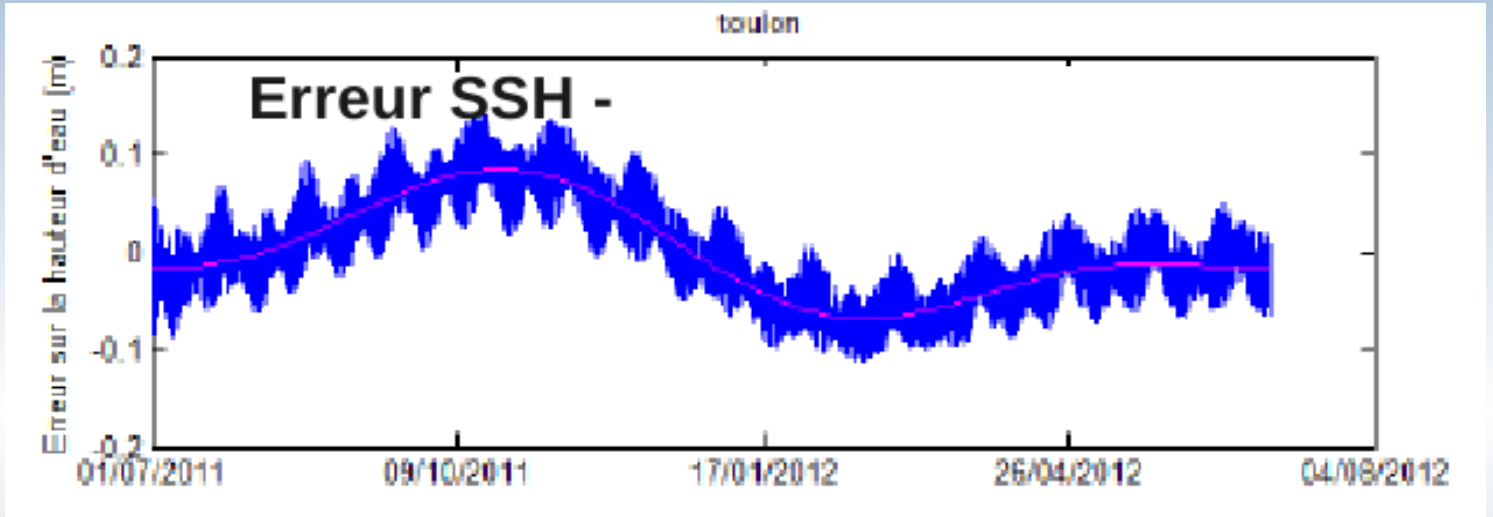
2D Modeling – MED

In order to get the 'optimal' configuration: sensitivity tests on :

- **Model horizontal resolution (2 poles)**
- **Bottom friction (variable)**
- **Tidal forcing (LEGOS)**
- **Open boundary forcing (SSH only)**
- **Number of tidal constituents (10)**

2D Modeling – MED - TIDE

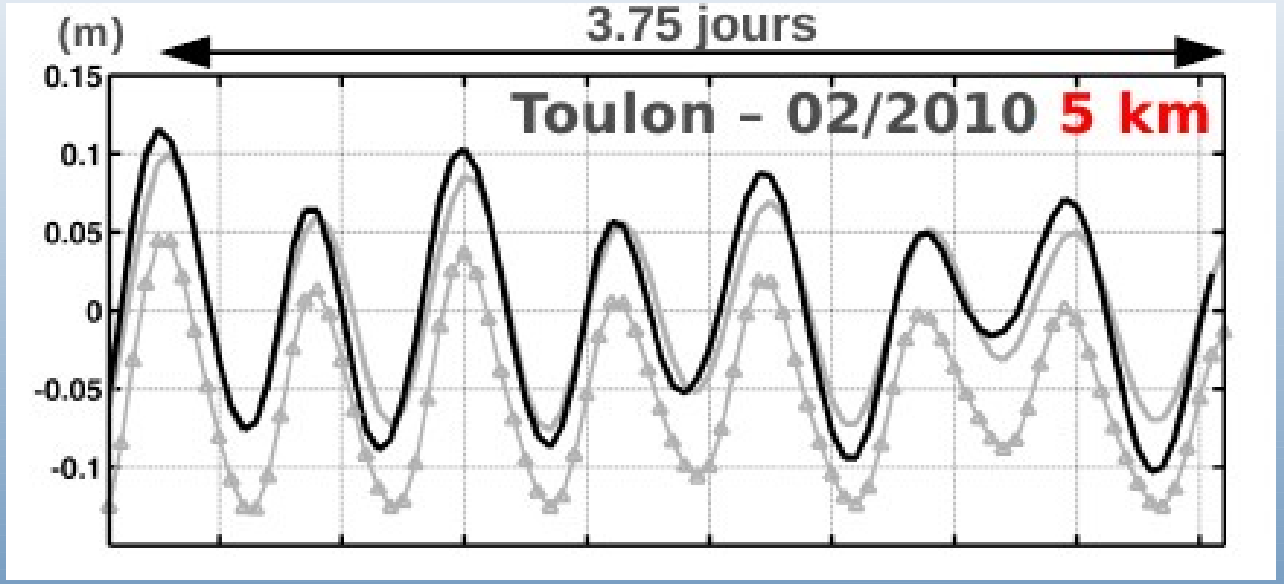
The role of steric effect in the MED
Validation with the MAS tool



Model

Obs with 143 tidal constituents

Obs with 8 tidal constituents

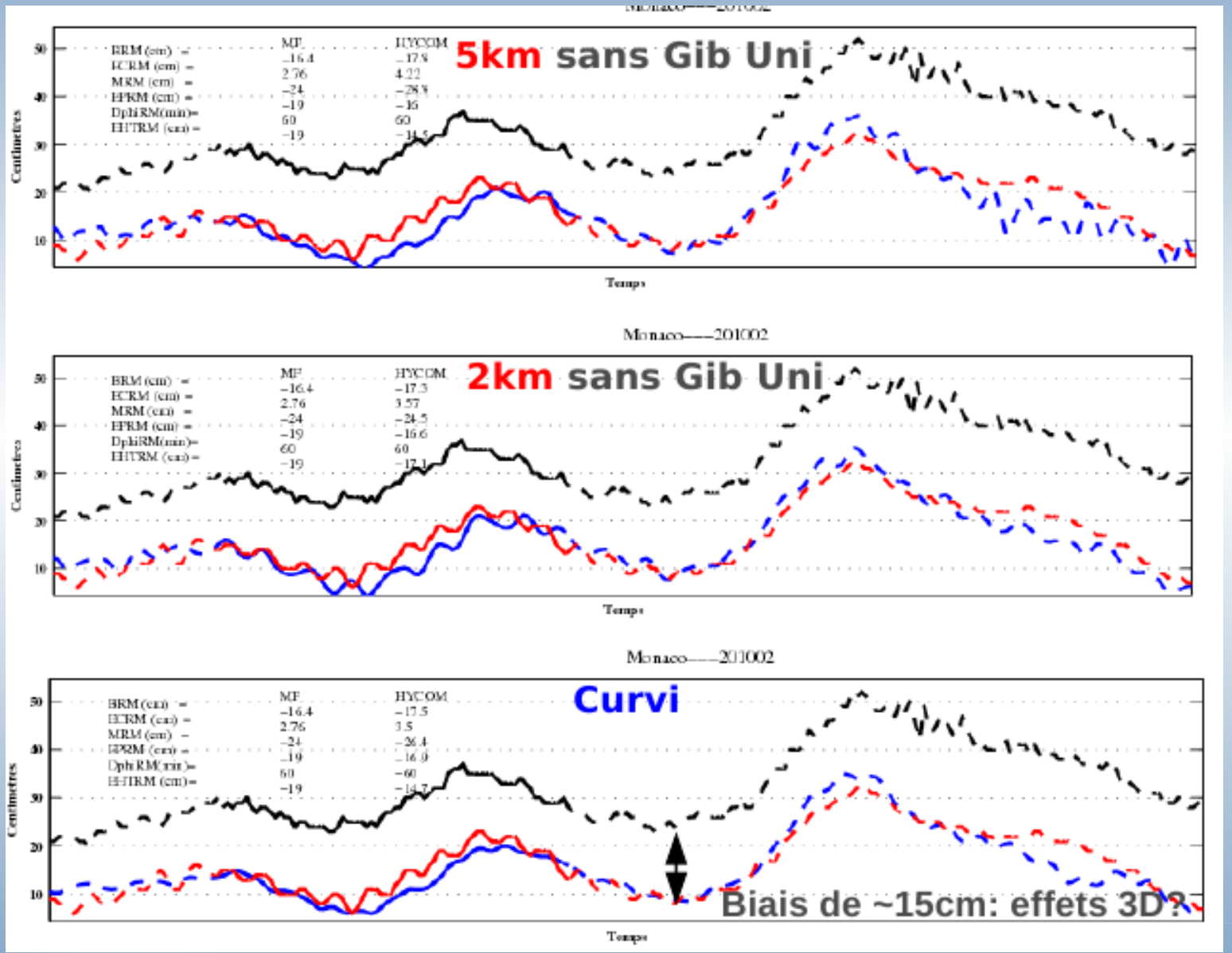


2D Modeling – MED - SURGE

Obs
HYCOM
MF

Weak impact of the resolution ? Run with 2 poles are being done to confirm...

How to explain this bias that occurs only for the 2010 storm ?



2D Modeling – MED

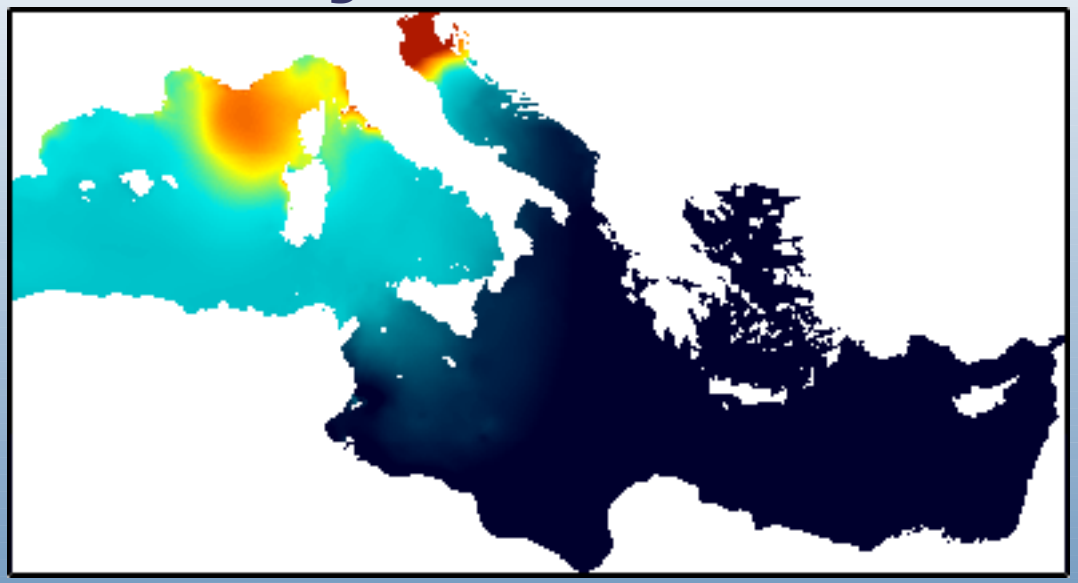
Conclusion

- Tidal amplitudes and phases compare well to observation
- Steric effect important and needs to be removed

- Important effect of model resolution from preliminary results of the 2 poles configuration...
- ... but increases sensitivity to bottom friction

- Same bias as in the ATL for the 2010 storm

Storm surge (0m to 0.4m) – 02/2010



Conclusion/Perspectives

- New methodology to validate the tides

- Simple graphic interface to generate curvilinear/uniform grids
- Variable bottom friction from sedimentology profile
- New wind stress parameterization

- Hycom tides and sea level during storm surge compare well to obs

- Results of ATL delivered to METEO-FRANCE last week
- Results of MED must be handed in a month

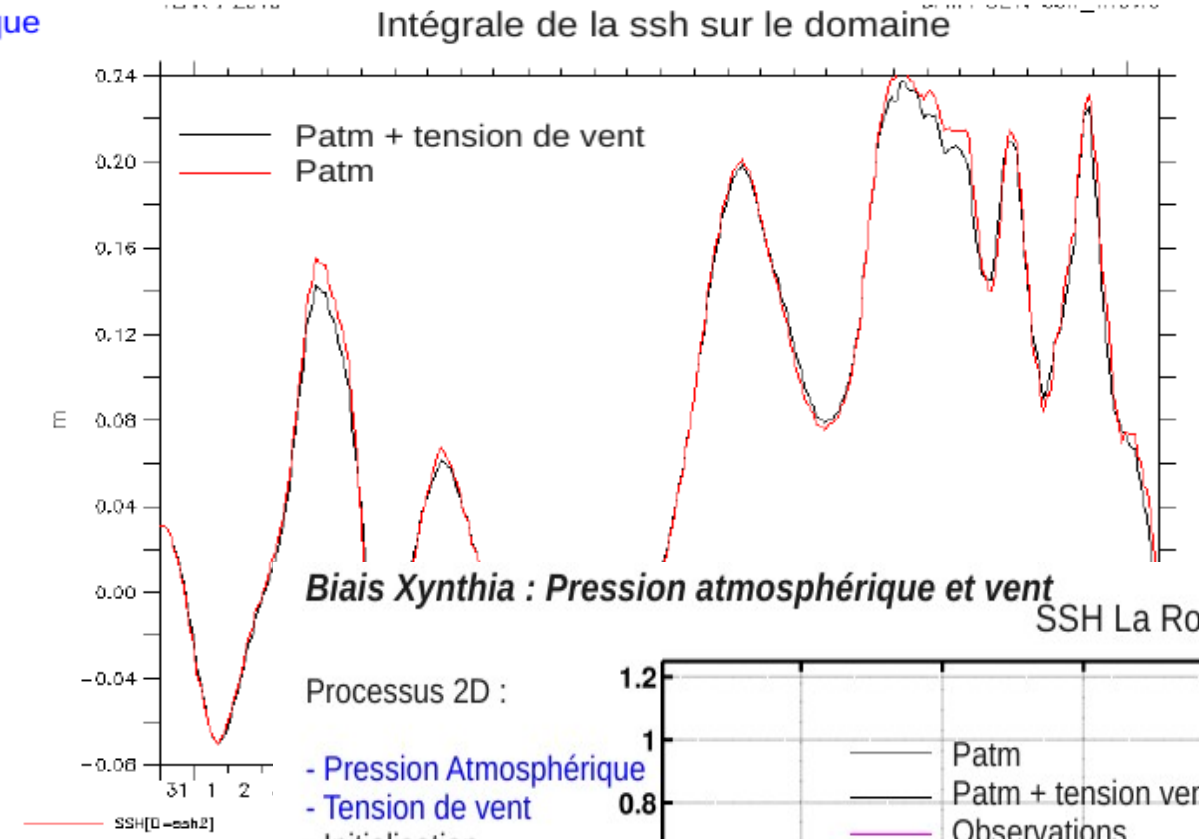
- Bias for the event of 2010 non-resolved as of now

2D Modeling – Bias ?

Porcessus expliquant le biais ?

Processus 2D :

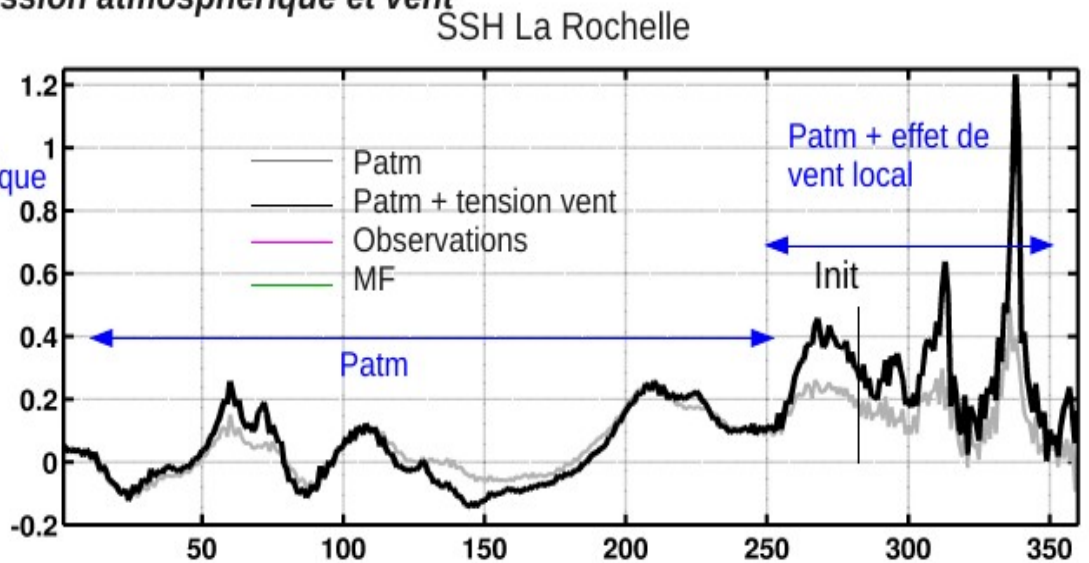
- Pression Atmosphérique
- Tension de vent
- Initialisation
- Effets non linéaires
- Wave set-up



Biais Xynthia : Pression atmosphérique et vent

Processus 2D :

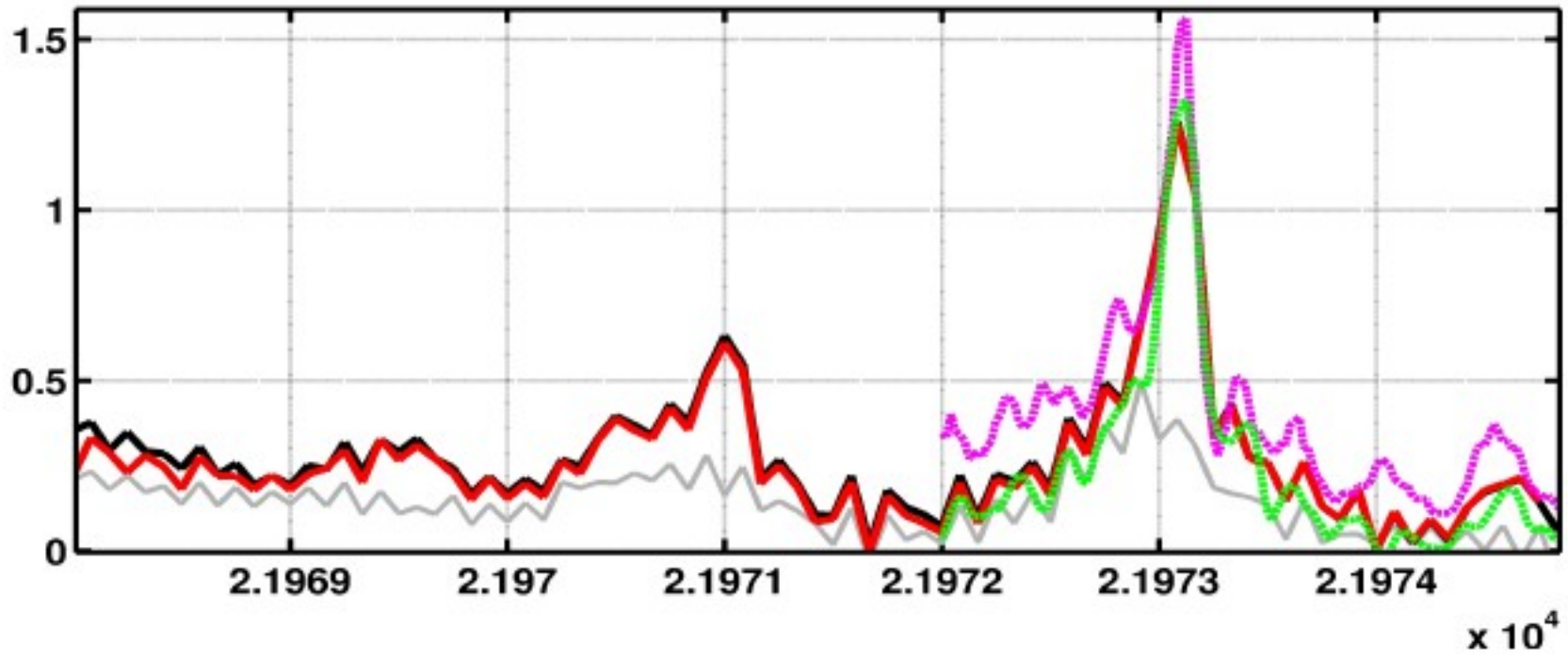
- Pression Atmosphérique
- Tension de vent
- Initialisation
- Effets non linéaires
- Wave set-up



2D Modeling – Bias ?

Processus 2D :

- Pression Atmosphérique
- Tension de vent
- Initialisation
- Effets non linéaires
- Wave set-up

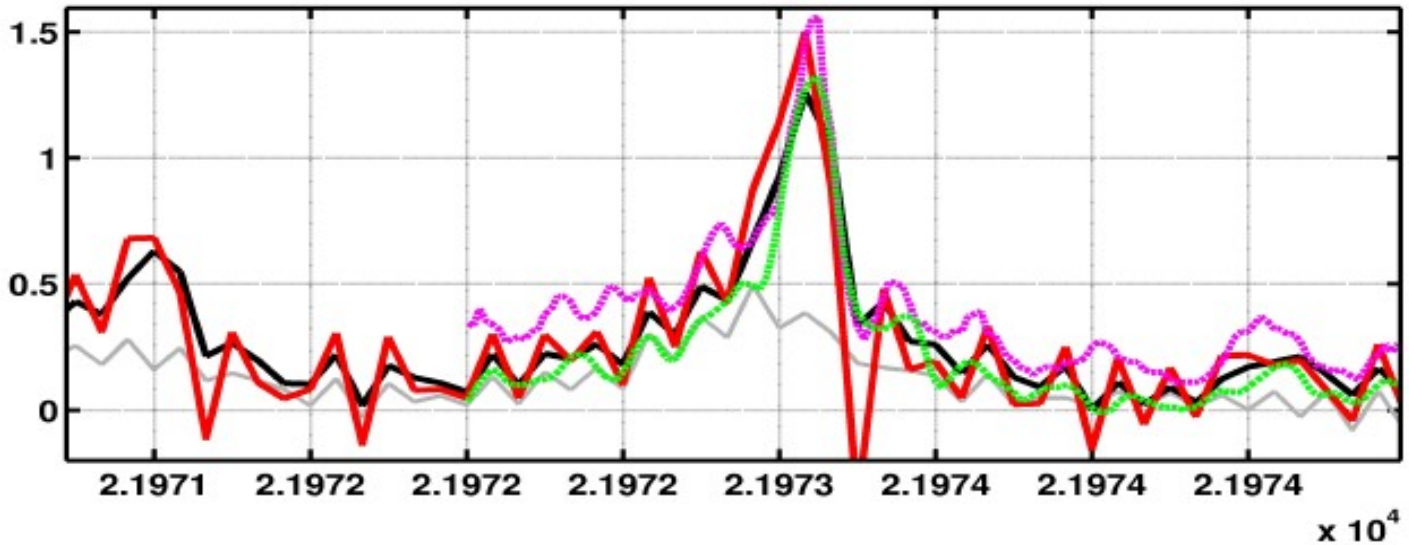


2D Modeling – Bias ?

Non linear effect of tides (run with no tides)

Processus 2D :

- Pression Atmosphérique
- Tension de vent
- Initialisation
- Effets non linéaires
- Wave set-up



3d effects ? A configuration show that it improved the solution but still some mass missing in the system...

link to the strong negative NAO index at that time?