Barotropic tidal modelling : sensitivity to bottom drag

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SHOM
L'océan à la carte

Introduction

- **Increasing needs for resolving coastal processes, for example to prevent natural risks (storm surges, marine submersion)**

- **Specific numerical implementations at the SHOM for coastal modelling : wetting and drying, non-linear free surface, tidal potential, boundary conditions**

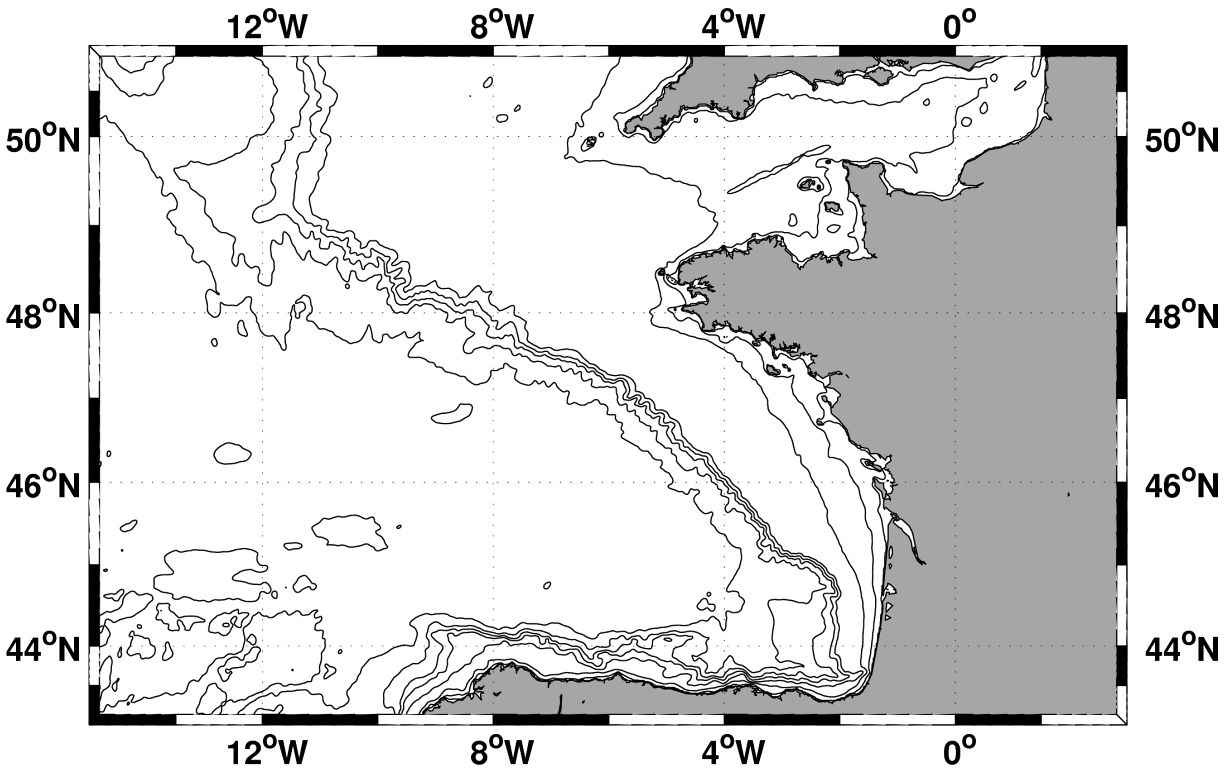
- **Storm surges modelling and representation of tidal dynamics with HYCOM recently evaluated (*Pineau-Guillou*, 2009)**

Model configuration

- **HYCOM in a pure barotropic configuration (one isopycnal layer)**

- **1 minute horizontal resolution**

- **Sea-surface elevations and 2D velocities (from the NEA2004 tidal atlas) prescribed along the open boundaries for 14 tidal constituents : M2, S2, N2, K2, K1, O1, P1, Q1, M4, MS4, MN4, 2N2, M3 and M6**



Possible improvements

- **Bathymetry**
- **Boundary conditions**
- **Bottom drag**

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- Bathymetry
- Boundary conditions
- **Bottom drag**

  → quadratic law : $\vec{\tau} = C_D |\vec{u}| \vec{u}$

  → C_D often constant for global modelling (generally between 2.5×10^{-3} and 3.0×10^{-3})

  → Need for a more physically consistent friction coefficient computation in coastal areas

Possible improvements

Vertical mean of turbulent velocity profile

- **Considering the whole water column :**

$$u(z)\ \alpha\ \ln\left(\frac{z}{z_0}\right),\ z_0 < z < H \quad \rightarrow \quad C_D = \left(\frac{\kappa}{\ln\left(\frac{H}{z_0}\right) - 1} \right)^2$$

κ : Von Karman's constant
z_0 : bottom roughness
H : water height

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- **Considering a limited bottom boundary layer (not yet tested) :**

$$\left.\begin{aligned} u(z)\ \alpha\ \ln\left(\frac{z}{z_0}\right),\ z_0<z<H_{bbl} \\ u(z)=u(H_{bbl}),\ H_{bbl}<z<H \end{aligned}\right\} \quad \rightarrow \quad C_D=\left(\frac{\kappa H}{H\ln\left(\frac{H_{bbl}}{z_0}\right)-H_{bbl}}\right)^2$$

H_{bbl} : bottom boundary layer thickness

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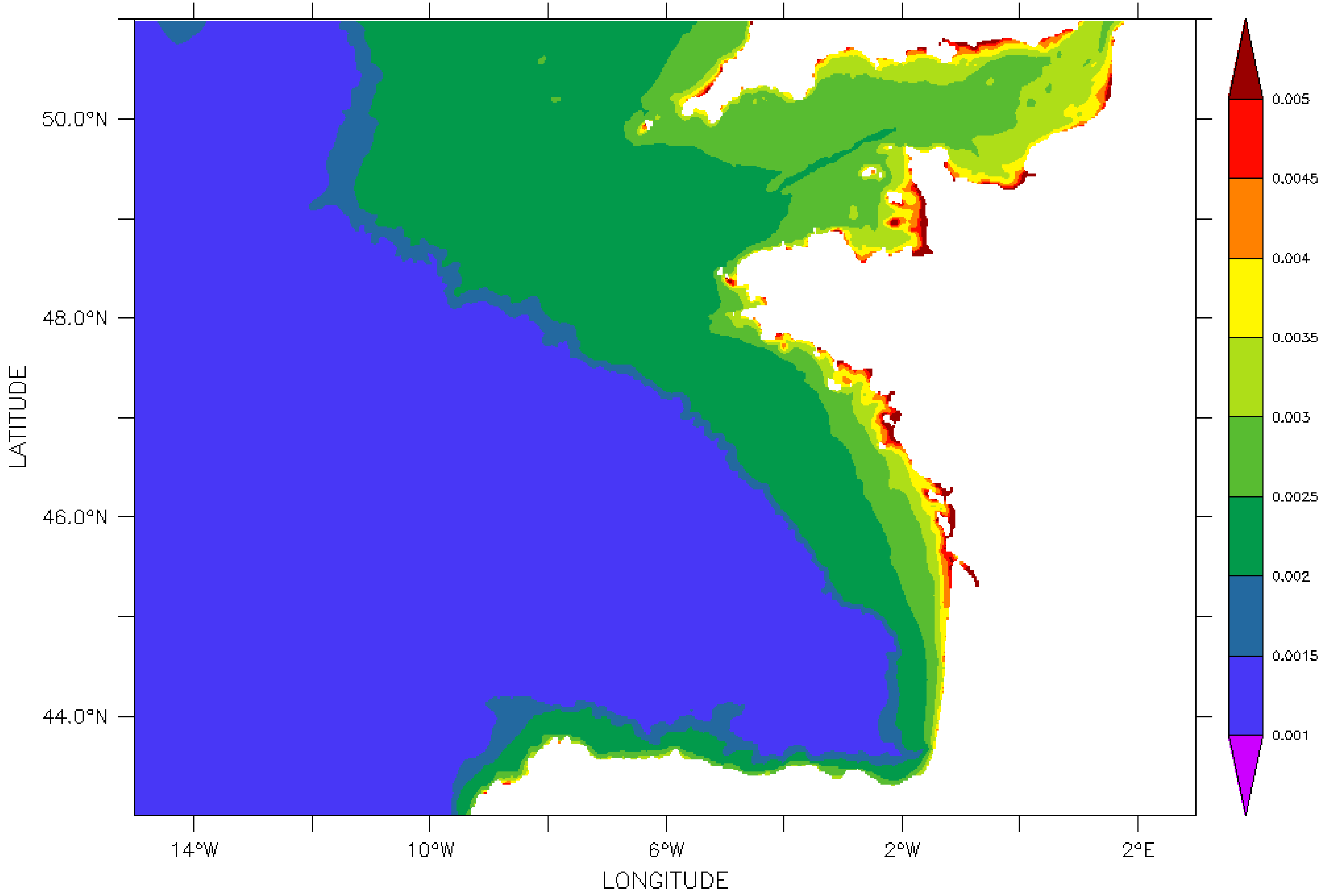
→ **Time- and space-dependent friction coefficient**

Possible improvements



Mean bottom friction coefficient for z_0 = 11 mm

First results

Method :

- **Harmonic analysis of times series of sea surface elevations**
- **Comparison with tide gauges observations (for each tidal constituent) :**

$$rms = rms\left(\left|A_{obs}e^{i\varphi_{obs}} - A_{mod}e^{i\varphi_{mod}}\right|\right)$$

A_{obs} , φ_{obs} : Amplitude and phase of tide gauges observations

A_{mod} , φ_{mod} : Amplitude and phase of the nearest model point

First results

Global results : 202 stations

C_D=0.0025

M2 rms = 13.57 cm
S2 rms = 8.60 cm

C_D=0.003

M2 rms = 12.04 cm
S2 rms = 8.45 cm

Logarithmic C_D with z_0=11mm

M2 rms = 9.80 cm
S2 rms = 6.56 cm

Results for the English Channel : 113 stations

C_D=0.0025

M2 rms = 16.68 cm
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Future works

- **Use of seabed nature and form to obtain a spatially-varying bottom roughness**

- **Implementation of a ripple predictor (time-varying bottom roughness)**

- **Implementation of parametrizations of 3D effects on barotropic dynamics : energy conversion from the barotropic mode to the baroclinic modes**

- **Waves impact : completely different physical approach for bottom friction because of its non-stationarity and its impact on seabed in very shallow waters**

Future works

- **Developments of data assimilation methods to find parameters linked to bottom friction : tide gauges (sea surface heights) and HF radars (surface velocity currents)**

- **Quantification of the critical density of observations to constrain hydrodynamical models**

- **Analysis in terms of physical processes**

Conclusion

- **Tidal dynamics very sensitive to bottom drag representation**
- **Constant bottom friction coefficient inadequate for regional or coastal tidal modelling**
- **More important impacts of bottom drag formulation in shallow waters**