National Oceanography Centre · cnes · NOAA · EUMETSAT · NASA · OSU Oregon State University · University of New Hampshire · esa

IRD Institut de recherche pour le développement · LEGOS · LA

→ 8th COASTAL ALTIMETRY WORKSHOP

23—24 October 2014 | Lake Constance | Germany

Coastal altimetry: its potential for very high resolution tide modelling in the Gulf of Guinea.

[1,2]ONGUENE R., [2]Lyard F., [3]Marsaleix P., [2]Birol F., [3]Duhaut T., [2]ALLAIN D.

[1]The UIT Douala-Cameroon ; [2]LEGOS/[3]LA Toulouse-France

Contact: raphael.onguene@legos.obs-mip.fr ; ziongra@yahoo.fr

•Outline

- **1. The study area, & Research question**

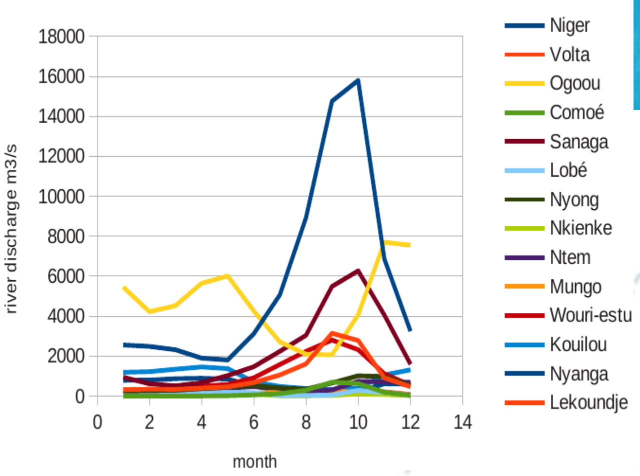
- **2. Some field surveys, T-UGOm Grid and**
- **altrimetry track positions**

3. T-UGOm 2DH spectral equations and parametrisation

- **4. Results**
- **5. Conclusions and future works**

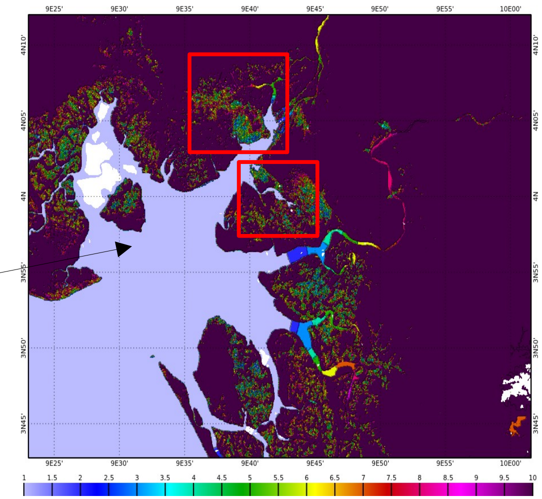
The study area

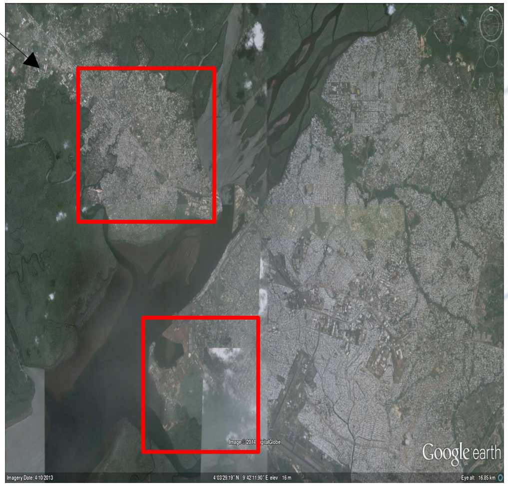
Large coastal erosion in Benin



Latitude : 3°30'S - 6°50'N
Longitude: 0°30'W - 10°E

Tropical and Equatorial climate conditions





Marine Flooding and high salinity intrusion

• The main research questions

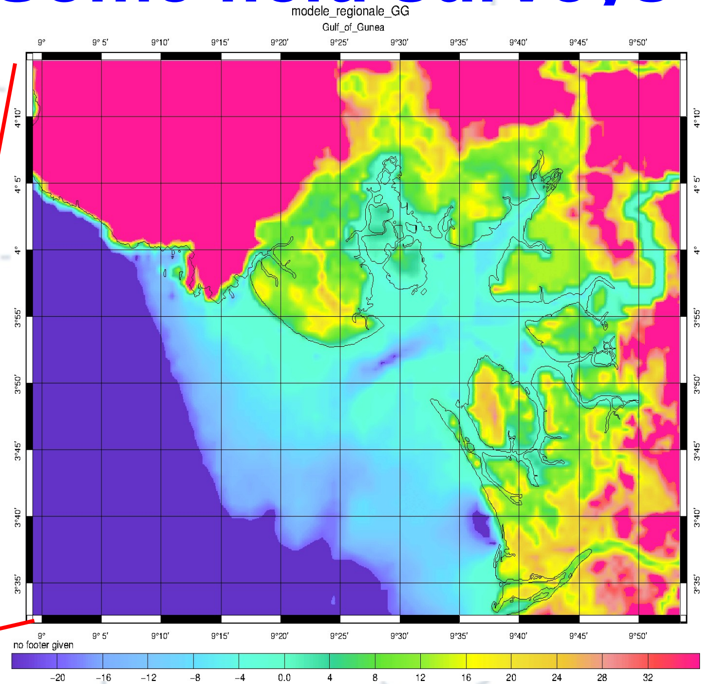
How do the air-sea fluxes interact with the Coastal circulation in the Gulf of Guinea taking into account the climate change and anthropogenic activities ?

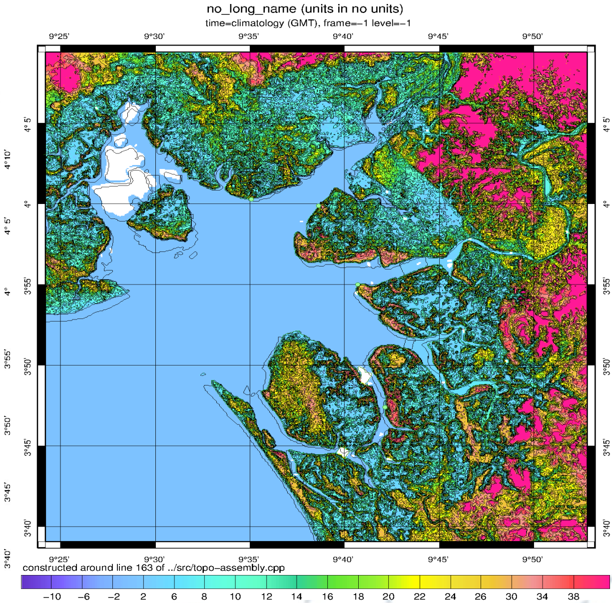
What can be the potential of coastal altimetry to answer to the question?

The first step is tide modeling.

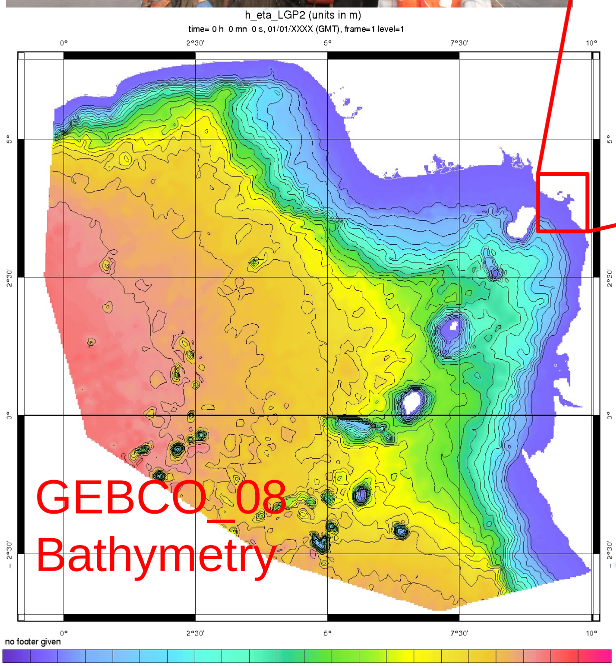
Some field surveys

- Bathymetry sounding January 2013





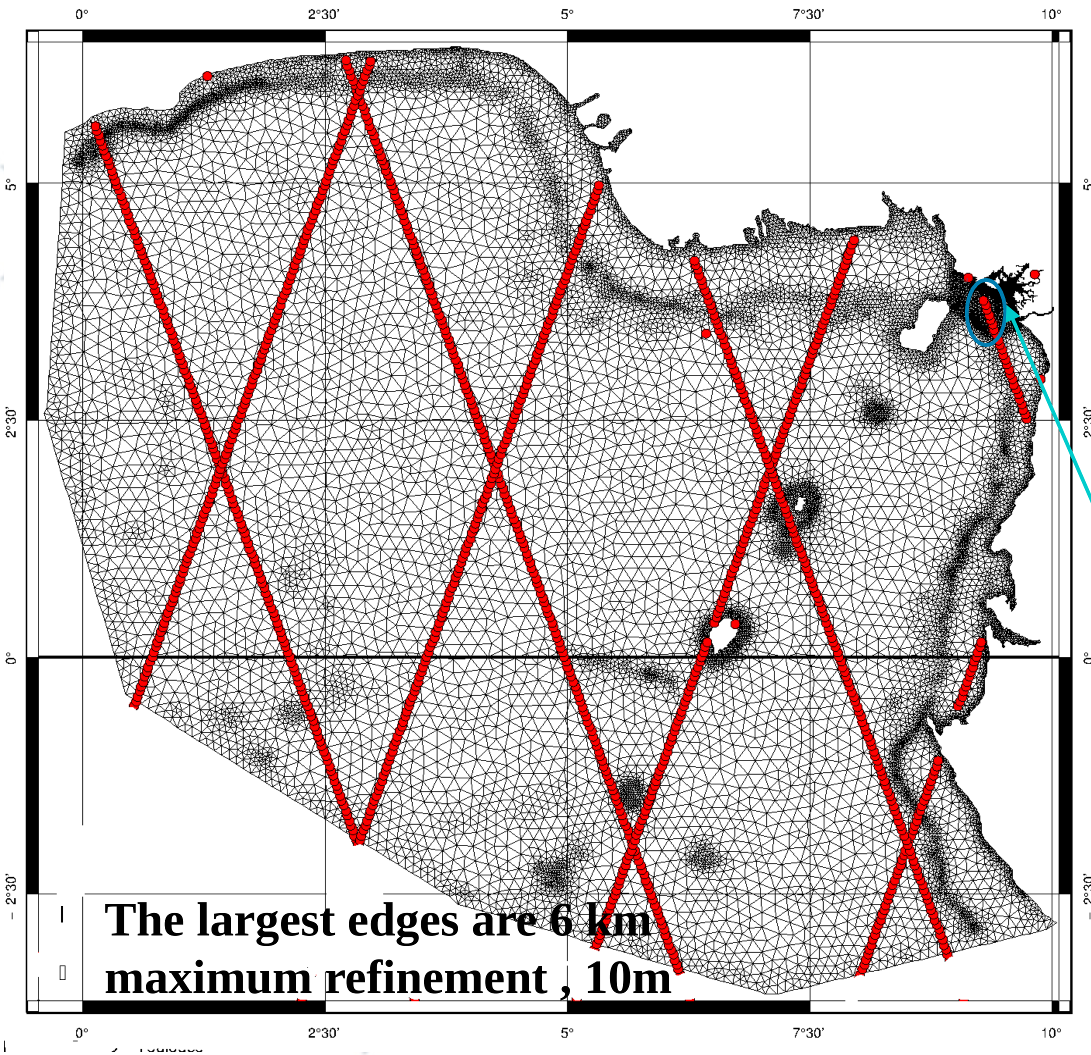
Cameroon estuary land elevation



GEBCO_08 Bathymetry

- **Bathymetry of the model = merge of bathymetry sounding and GEBCO_08, SRTM Land elevation**

T-UGOm GG grid and altrimetric tracks positions



- Missions T/P + J1+ J2
- Start :03/1993
- End : 03/2013
- Repeat Time: 9.916 days

- The CTOH computes and distributes tidal constants estimated from its along-track 1Hz sea level anomalies (SLA) products

- tidal constants are estimated directly by harmonic analysis of each single SLA time series (i.e. every 6.2km).

- 09 gauge points are located in the Cameroun Estuary

- **T-UGO**m (**T**oulouse **U**nstructured **G**rid **O**cean) model, for the barotropic 2D and 3D tide developed by LEGOS.
- - multi-discretisation capabilities (mostly LGP0, LGP1, NCP1, LGP2, continuous and discontinuous);
- - Finite volume and finite elements schemes;
- - explicit/semi-implicit tunable
- - Time step dynamical local sub-cycling
- - embedded 2D/3D spectral solver for tides, 2D sequential solver for tides;
- - combined with the **xscan software** with his convivial interface for pre and post processing.

- **The complex tidal equations for any astronomical tidal constituent:**

$$j\omega\alpha + \nabla \cdot hu = 0 \qquad \text{Eq.1}$$

$$j\omega\mathbf{u} + \mathbf{f} \times \mathbf{u} = -g\nabla(\alpha + \delta) + g\nabla\Pi - \mathbf{D}\mathbf{u} \qquad \text{Eq.2}$$

- where **j2** = -1 , **ω** is the tidal frequency in rad/s, **δ** the ocean bottom radial displacement, **α** the ocean tide elevation, **Π** the total tidal potential (i.e. astronomical plus loading/self-attraction potential), **D** the drag tensor, **f= 2Ωk** the Earth rotation vector and **g** the gravity constant.
- *For more details, see Lyard et al. (2006), Maraldi et al. (2007) and Le Bars et al. (2009).*

- **Bottom friction parametrisation of T-UGO 2DH model in GG**

- The mean vertical momentum diffusion:

$$\overline{F}_s = \frac{\rho}{H}\int_0^H \frac{\partial}{\partial z}\left(\mu \frac{\partial u}{\partial z}\right) dz = \frac{1}{H}\left(\tau_s - \tau_b\right) \quad (3)$$

- Where τ_s is the surface stress, τ_b the bottom stress and H the average depth

$$\tau_b = \rho \left\| u_{star} \right\| u_{star} \quad \text{with} \quad u_{star} = \sqrt{C_D}\,\overline{u}$$

Cushman-Roisin et al, (1997)

$$C_D = max\left[2.5x10^{-3}; k^2 \ln \frac{\Delta z_b}{z_0}\right]$$

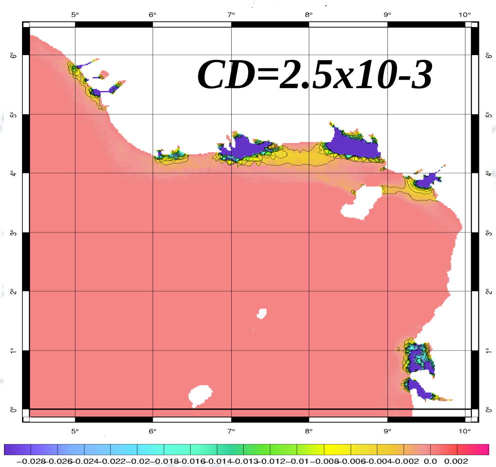
- *Sannino et al, (2004); C_D* is the drag coefficient

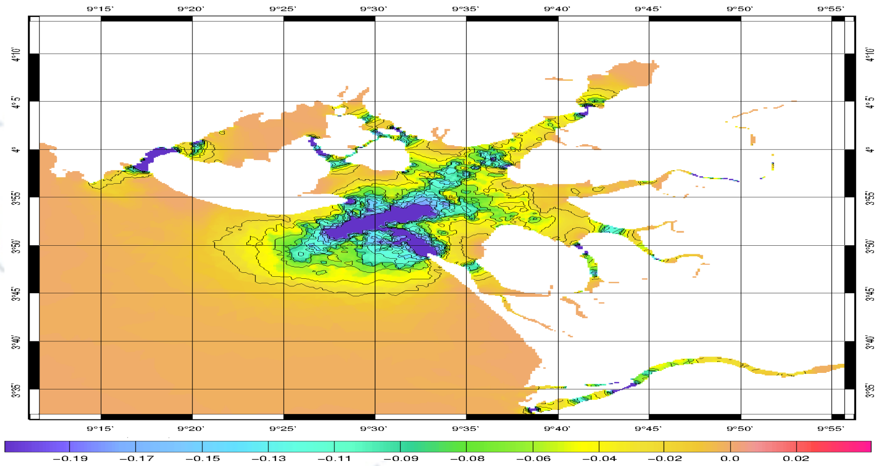
- Where **k, z0 , and Δzb** are respectively the **Von Karman constant**, **the roughness length**, and the **distance from the bottom to the deepest velocity grid point.**

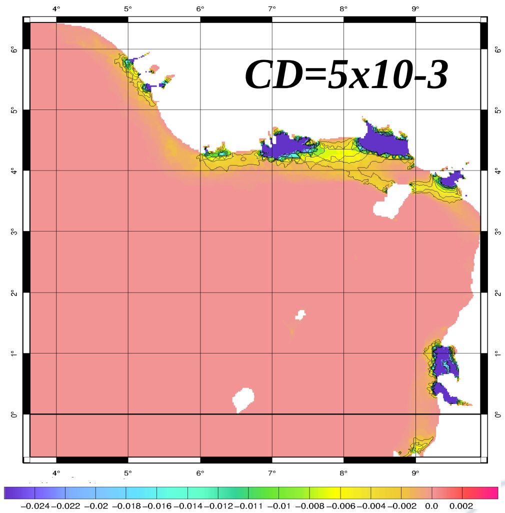
- **Without sediments properties We have done four sensitivity tests with :**

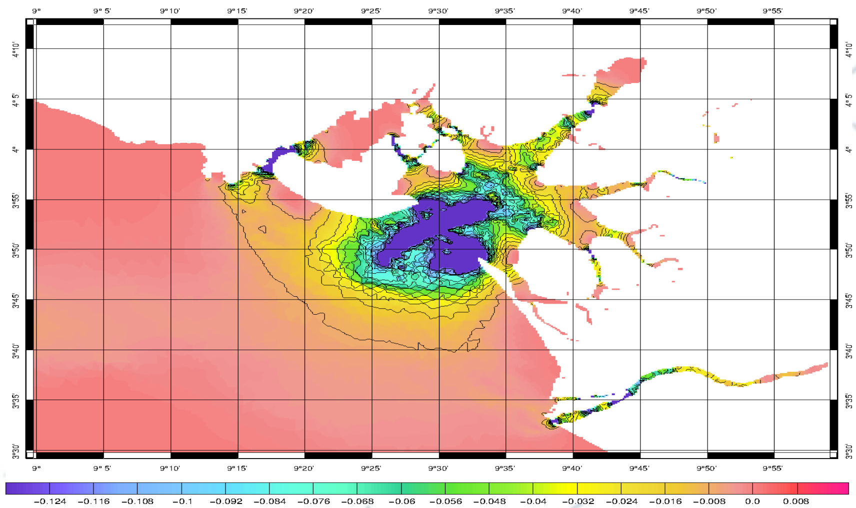
$$C_D = \left\{10^{-3}, 2.5x10^{-3}, 5x10^{-3}, 10^{-2}\right\}$$

Results 1/4

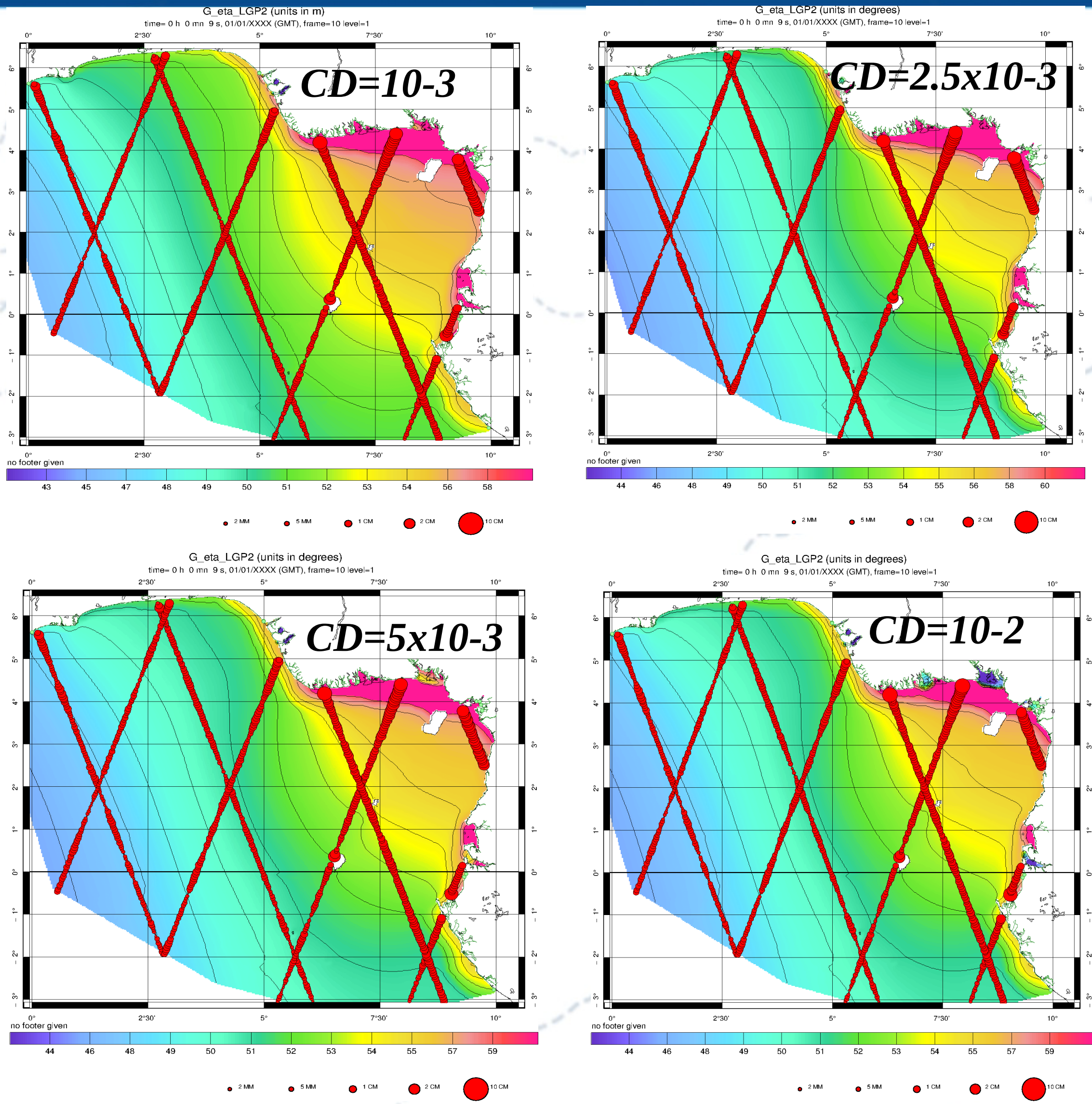








- **Bottom friction row in (W/m2) in GG area (in left), with the zoom in Cameroon Estuary (in rigth)**



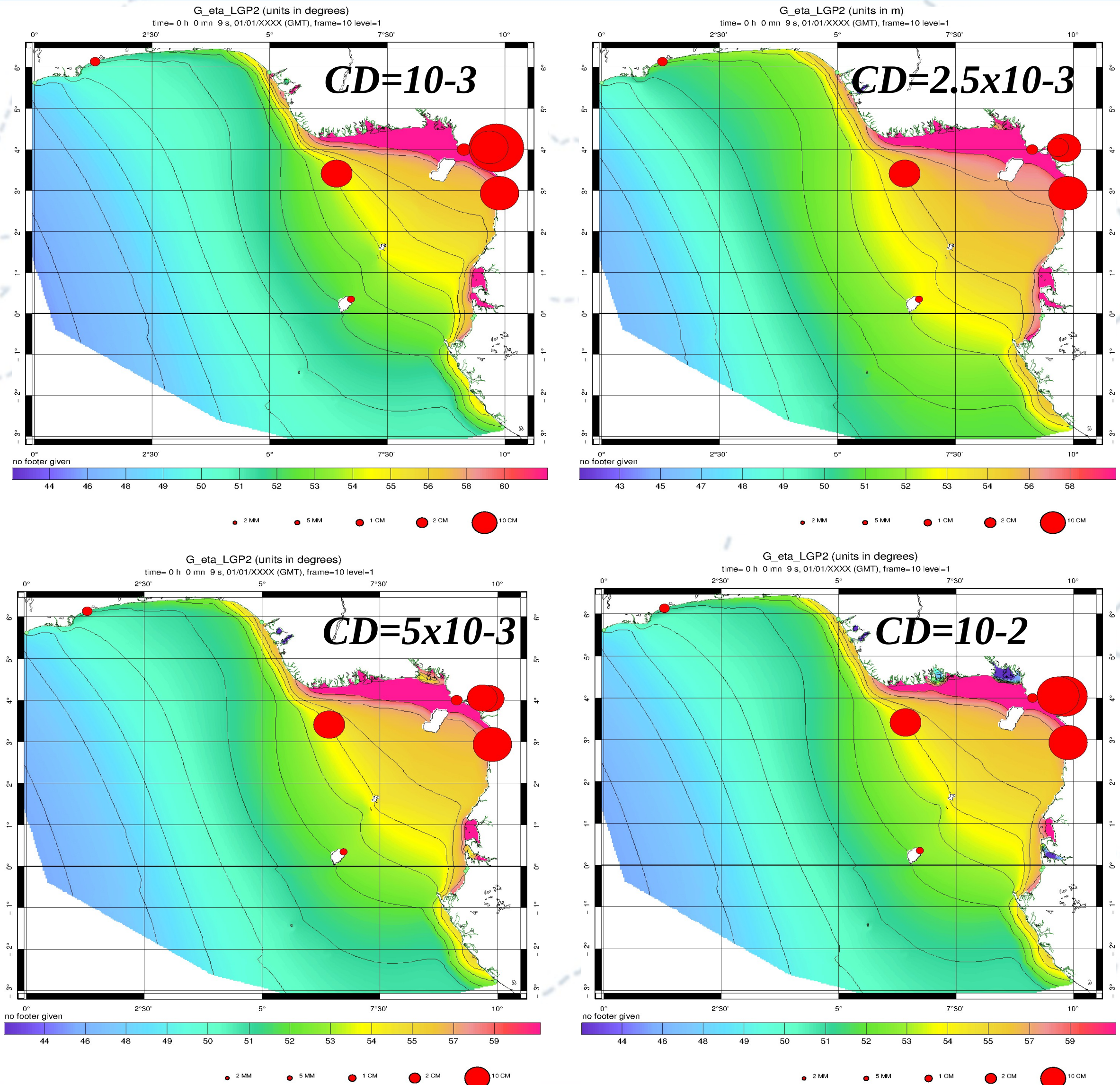
Results 2/4

$$\Delta z = A_{obs}\exp\left(j\rho_{obs}\right) - A_{mod}\exp\left(j\rho_{mod}\right)$$

- **M2 tide (in background)** **complex errors (Δz in red circle)** **between model and altimetry.**
- \- Error increases close to the coast.

\- M2 Tide is more amplified along the east coast than in the west.

- The same tidal altimetry data show also large biases with FES2004 and GOT4.7 models in coastal (>5 cm).
-



Results 3/4

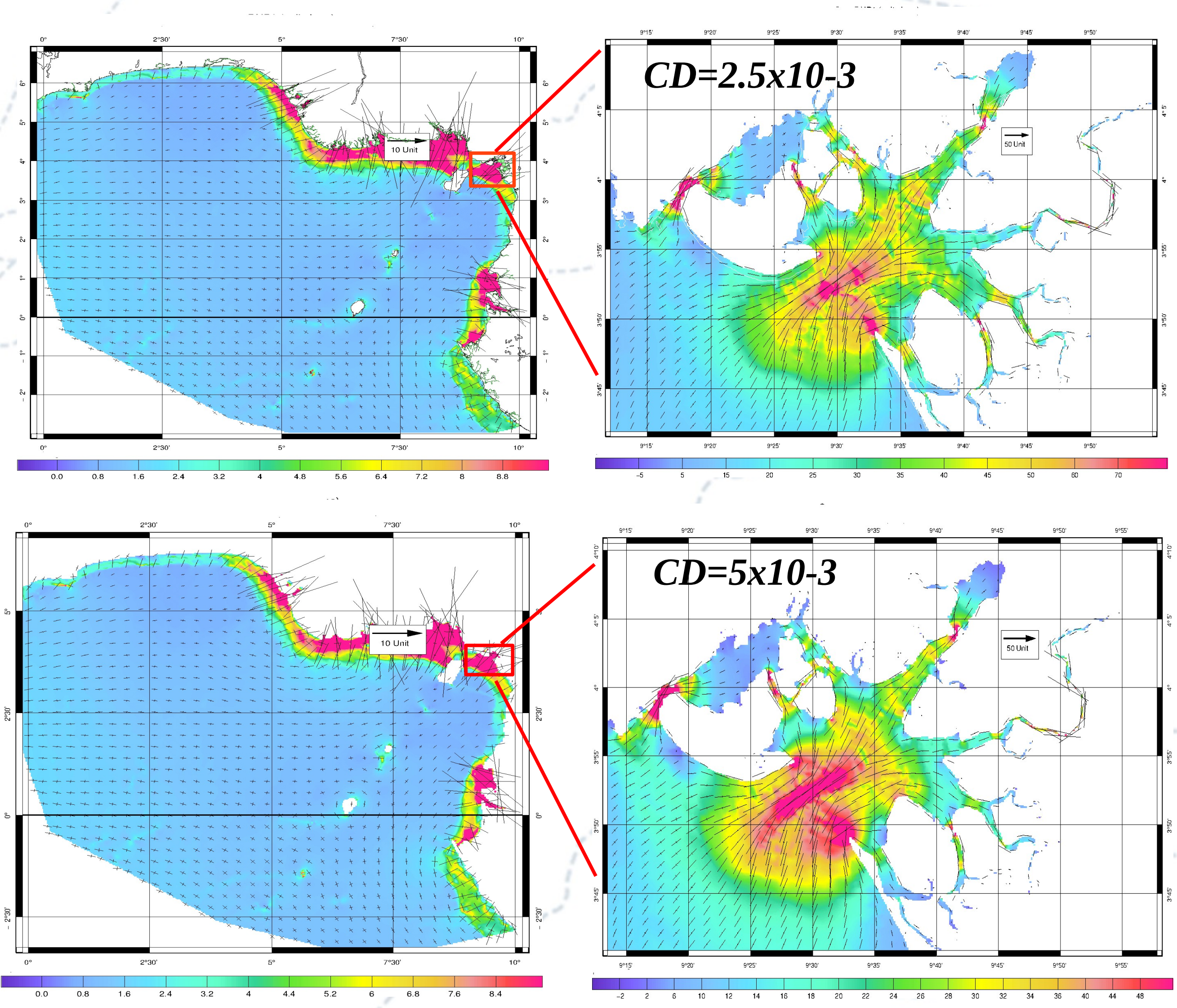
$$\Delta z = A_{obs} \exp\left(j\rho_{obs}\right) - A_{mod} \exp\left(j\rho_{mod}\right)$$

Complex errors (in red circle) between model and tidal gauge.

-The M2 tide error between GLOSS gauges and the model is 2.7 cm in Sao Tome (ST), SONARA harbor (PS) and Lome (LT).

-The large biases observed between the local tiges gauges are due to errors in erroneous time reference in the tide gauges. See ONGUENE et al, 2014a

- ***the best CD value is between 2.5x10-3 and 5x10-3.***



Results 4/4

- **Surface tidal current**
- -M2 tide surface currents represented by ellipses (in background,in cm/s) covering the Gulf of Guinea (left) & the zoomed map is the Cameroon estuary (rigth)

- -Surface currents are very sensitive to CD values in shallow water areas.

Conclusions

- Error between altimetry M2 Tide and model M2 in the Gulf of Guinea is 1 cm along the east coast and 2cm to the west coast, as in situ GLOSS data indicate errors of 1 cm.

- So the use of along track coastal altimetry data has an important potential to validate models in the coastal areas of the Gulf of Guinea.

-High resolution meshes helps us to reduce big biases between observations and models along the coasts of the Gulf of Guinea.

Future Works (1/2)

- - Install tide gauge measurements just under the pass T/P/J1/J2 N° 020 in the Cameroon estuary

  - Establish the link between sea level rise and coastal erosion using altimetry data, videos camera data install in coastal areas in (Benin, Senagal, Ghana and Cameroun) since 2013 and models

future works (2/2)

STEP 2 : S26_DOUALA26

Circulation model, forced by GLORYS MyOcean V2 (1992-2009) reanalysis, climatological rivers runoff, and tide FES2012 in Central Africa coastal area.

- Use the river discharges derived from altimetry as forcing to better model the interannual circulation in Gulf of Guinea

- Compare AVISO&CTOH SLA with model (DOUALA26)

- Compare altimetry Geostrophic currents with model (DOUALA26).

Thank you for your attention