Study of salinity in the Casamance estuary: modelling and observations

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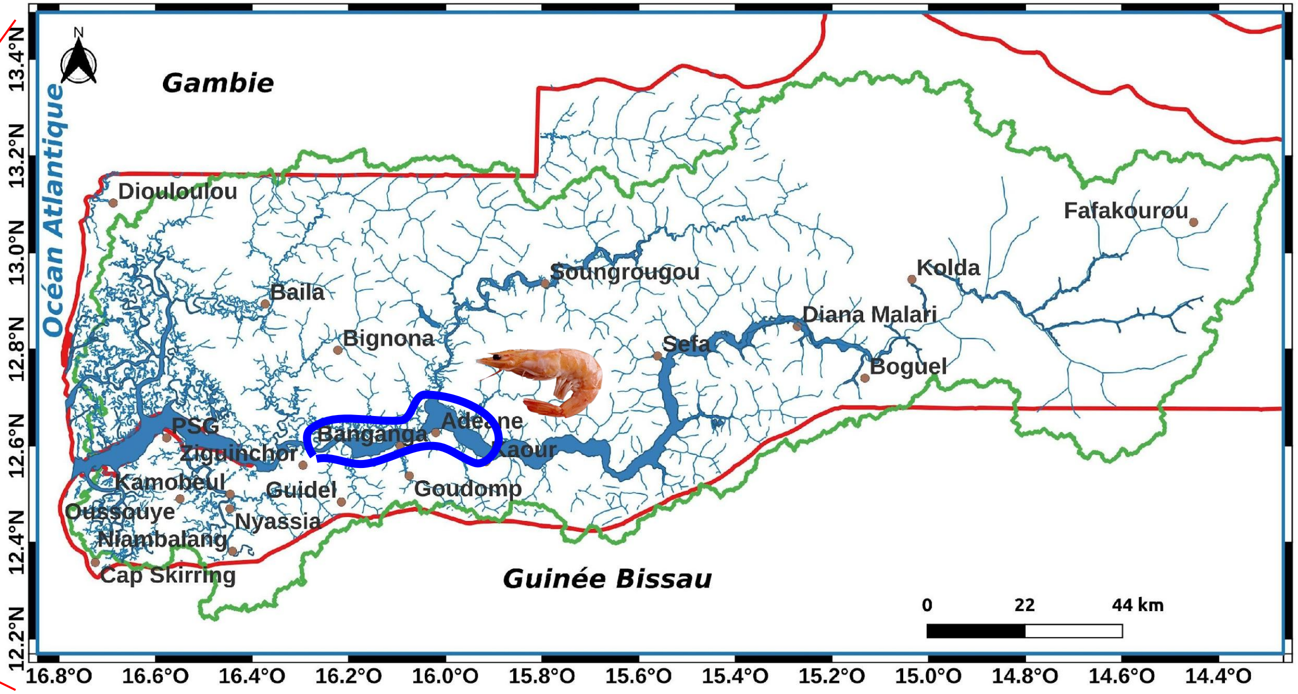
Characteristics of the Casamance estuary

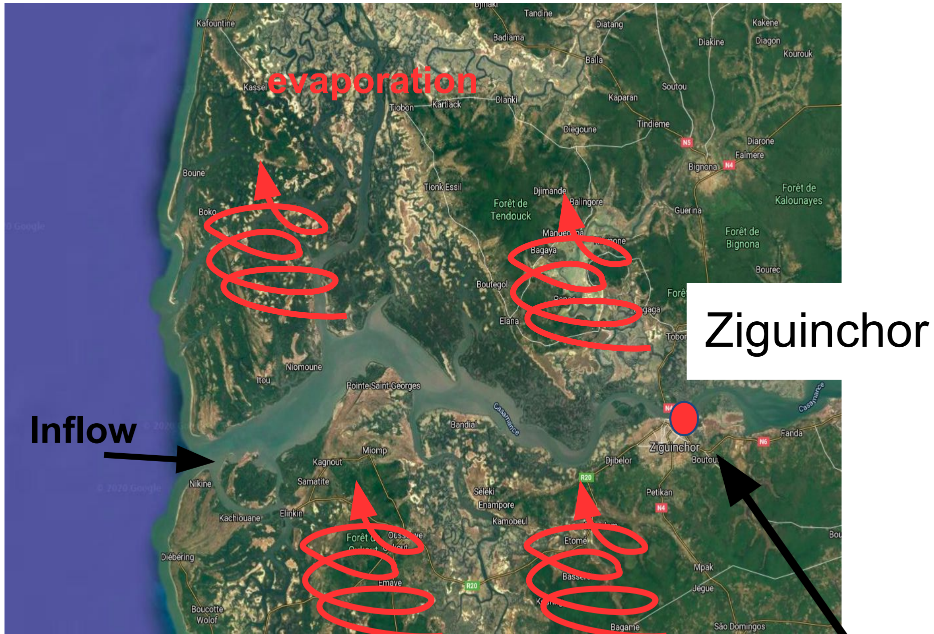


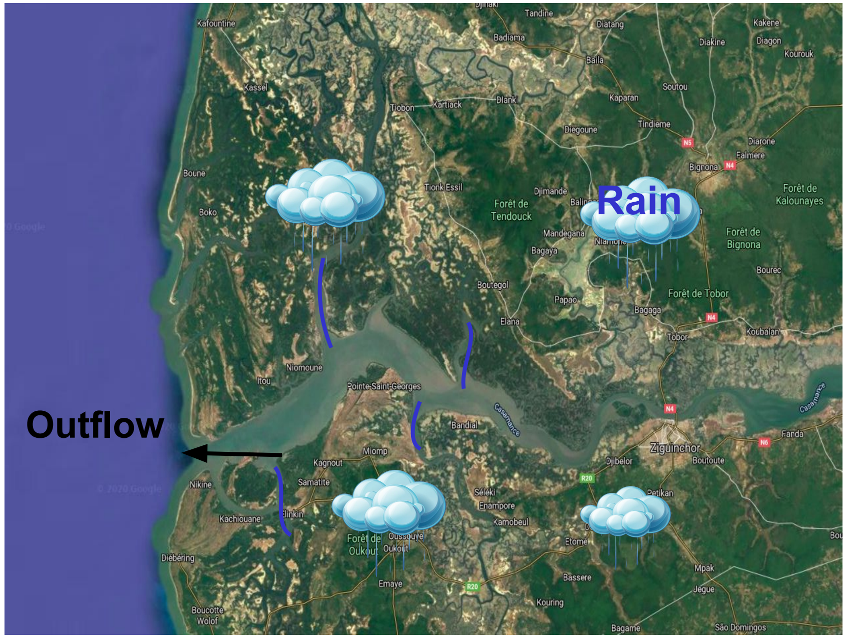
- located in south Senegal, ~350 km long
- Mangrove
- rice paddy fields
- shrimp fisheries
- Tourism
- rainy season in june-october

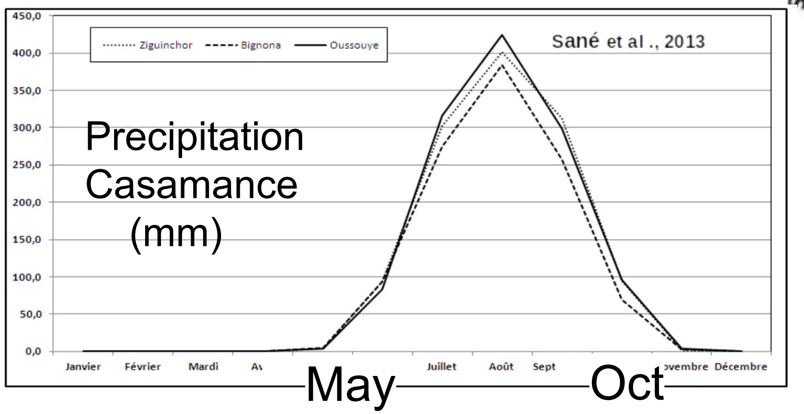
Characteristics of the Casamance estuary

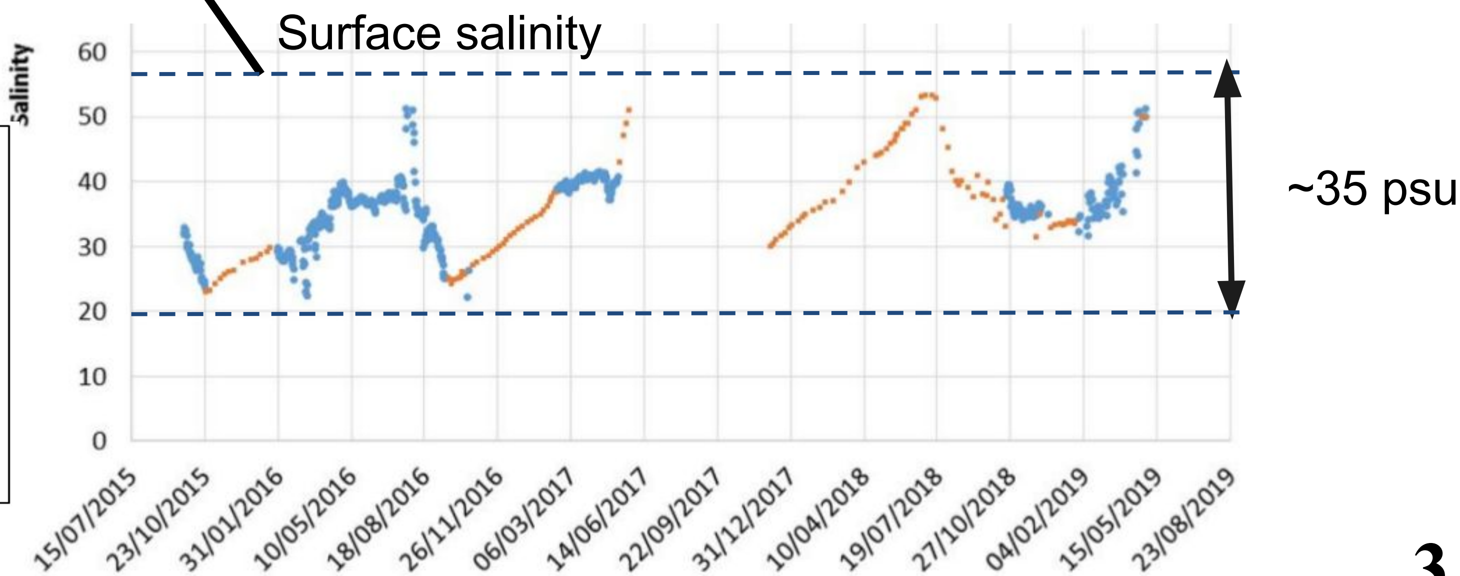
Dry season (November-July) : inverse estuary

Rainy season (August-Oct) : positive estuary









Objectives of the study

General objective:

Study the salinity variability in Casamance and understand the physical mechanisms using numerical modeling and available observations

Specifically:

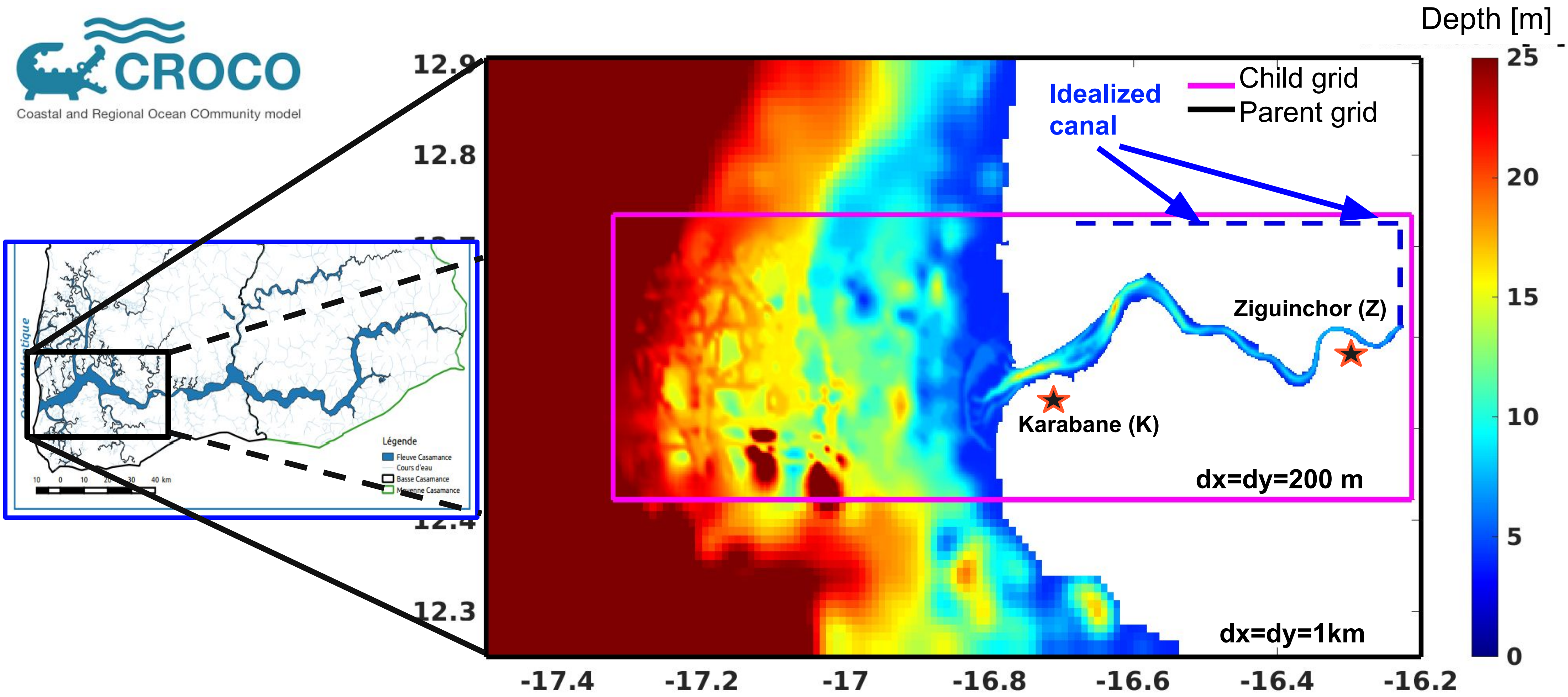
1) Caracterize the tidal hydrodynamics

2) Observe the salinity vertical and longitudinal structure in west Casamance

3) Model the salinity variations and study its different forcings

CROCO model configuration

Coastal and Regional Ocean COmmunity model



- west part of Casamance
- 1 km (parent grid), 200 m (AGRIF zoom)
- 10 vertical levels
- tidal forcing : TPXO7 global model

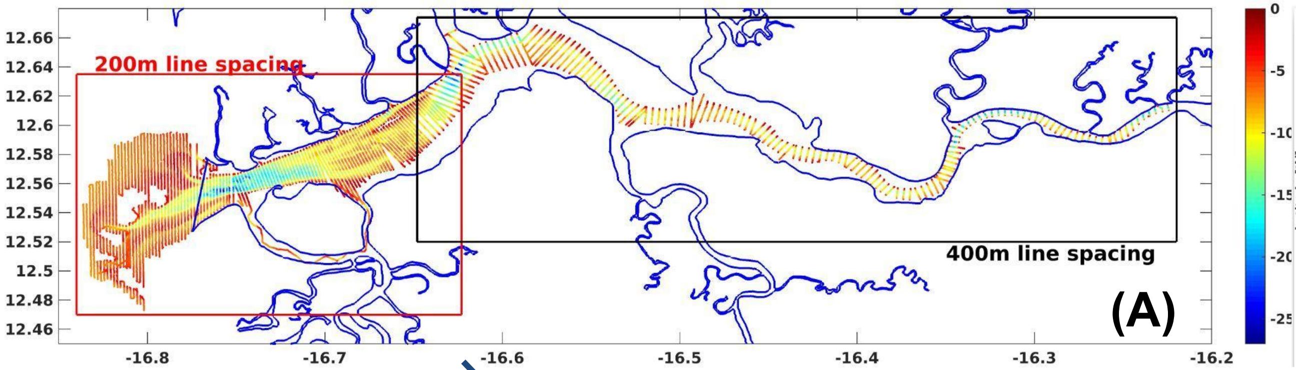
  Egbert & Erofeeva, 2002

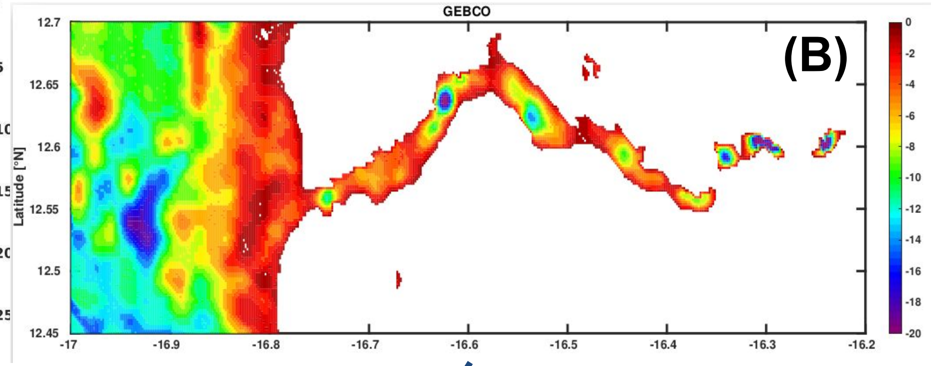
- open boundary forcing: WOA
- Wind : Quikscat climatology 2000-2009
- Idealized canal at landward extremity of estuary (rectilinear, constant depth=4m)

Methodology : bathymetric data

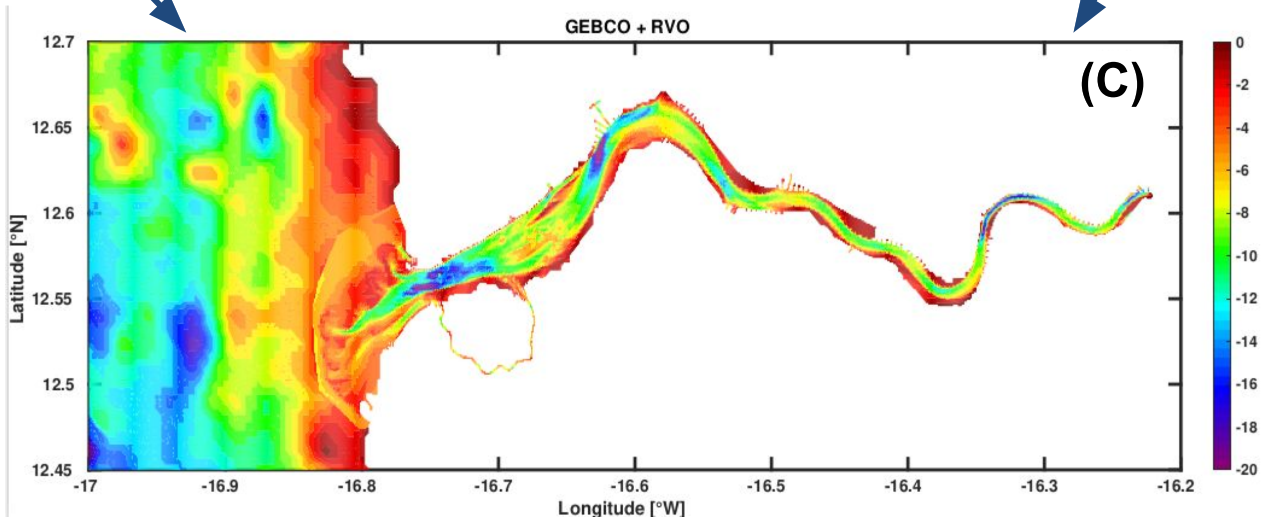
RVO bathymetry (2012) between the mouth and Ziguinchor (400 m between 2 transverse lines) (Brak et al., 2013)

Bathymetry from the GEBCO database
Resolution: ~400 m

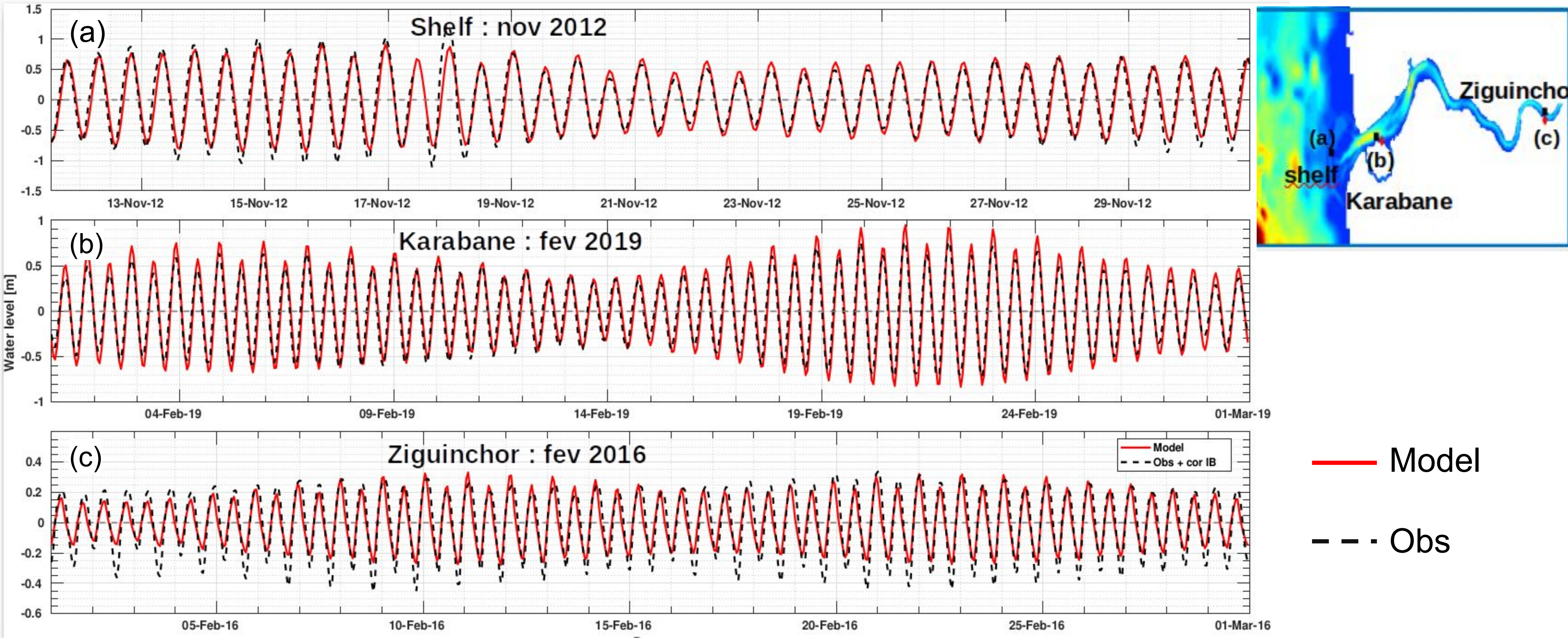




Merging of the two datasets and interpolation on 100 m grid



Tidal elevation



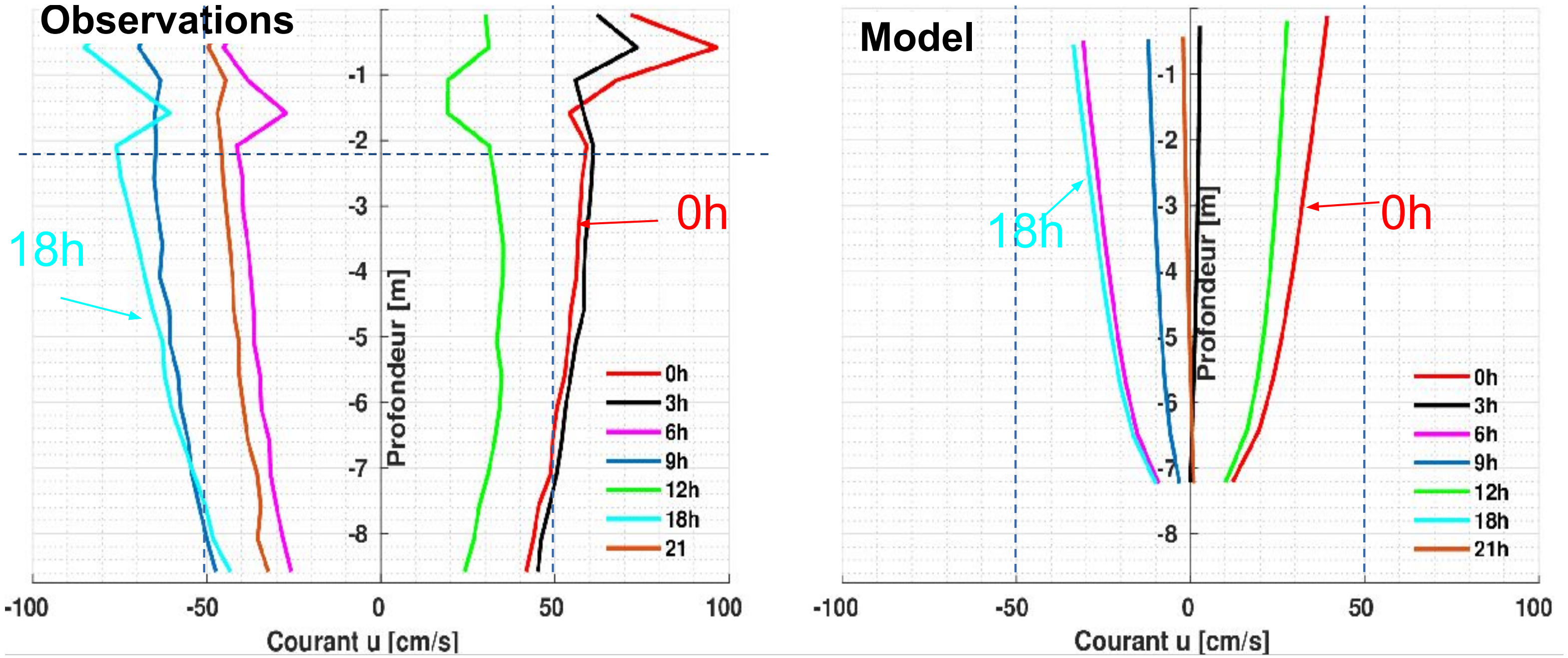
- Calibration of the model logarithmic bottom friction to fit observations
- Model/data good agreement at Karabane and “shelf”
- Underestimation of model sea level and strong asymmetry at Ziguinchor

Tidal currents

Evaluation of zonal (longitudinal) currents in Ziguinchor
(21/11/2021; Machu & Capet, pers. com.)

21-22/11/21

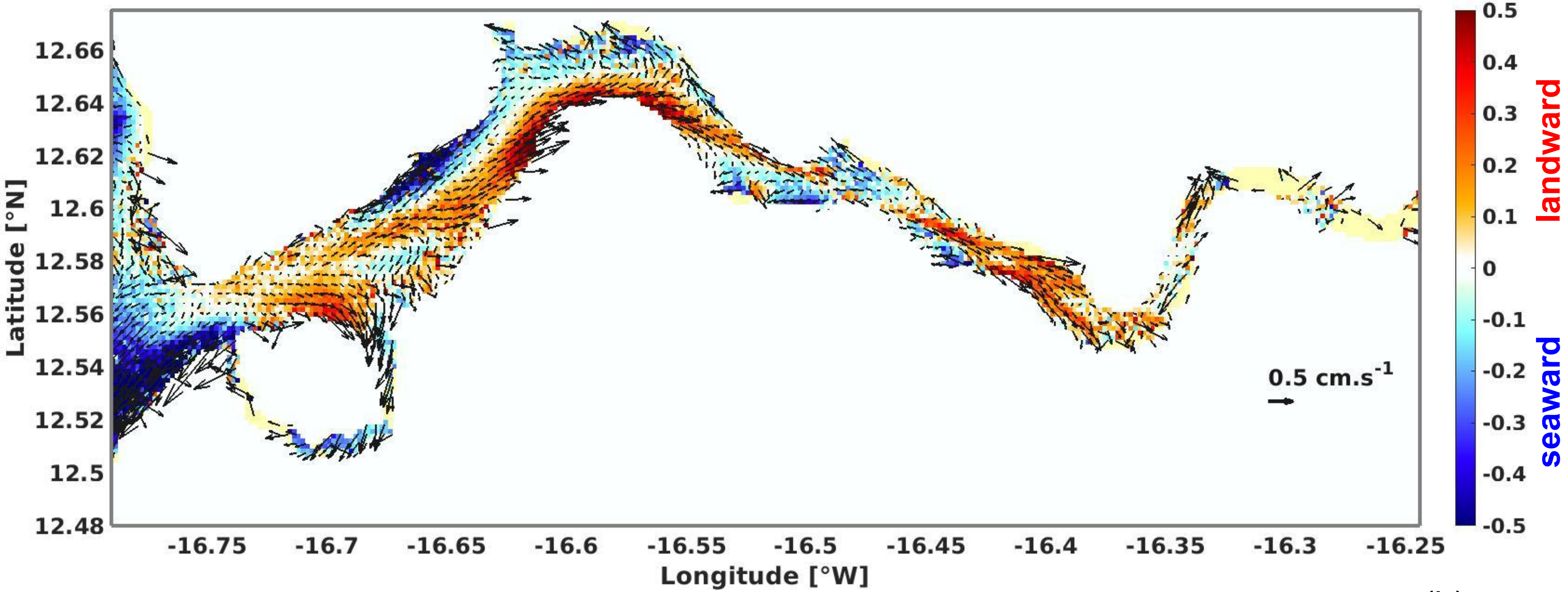
21-22/11/2021



- Temporal evolution and vertical structure of the current close to the observations
- underestimation of the current by ~ 50 %

Lagrangian circulation

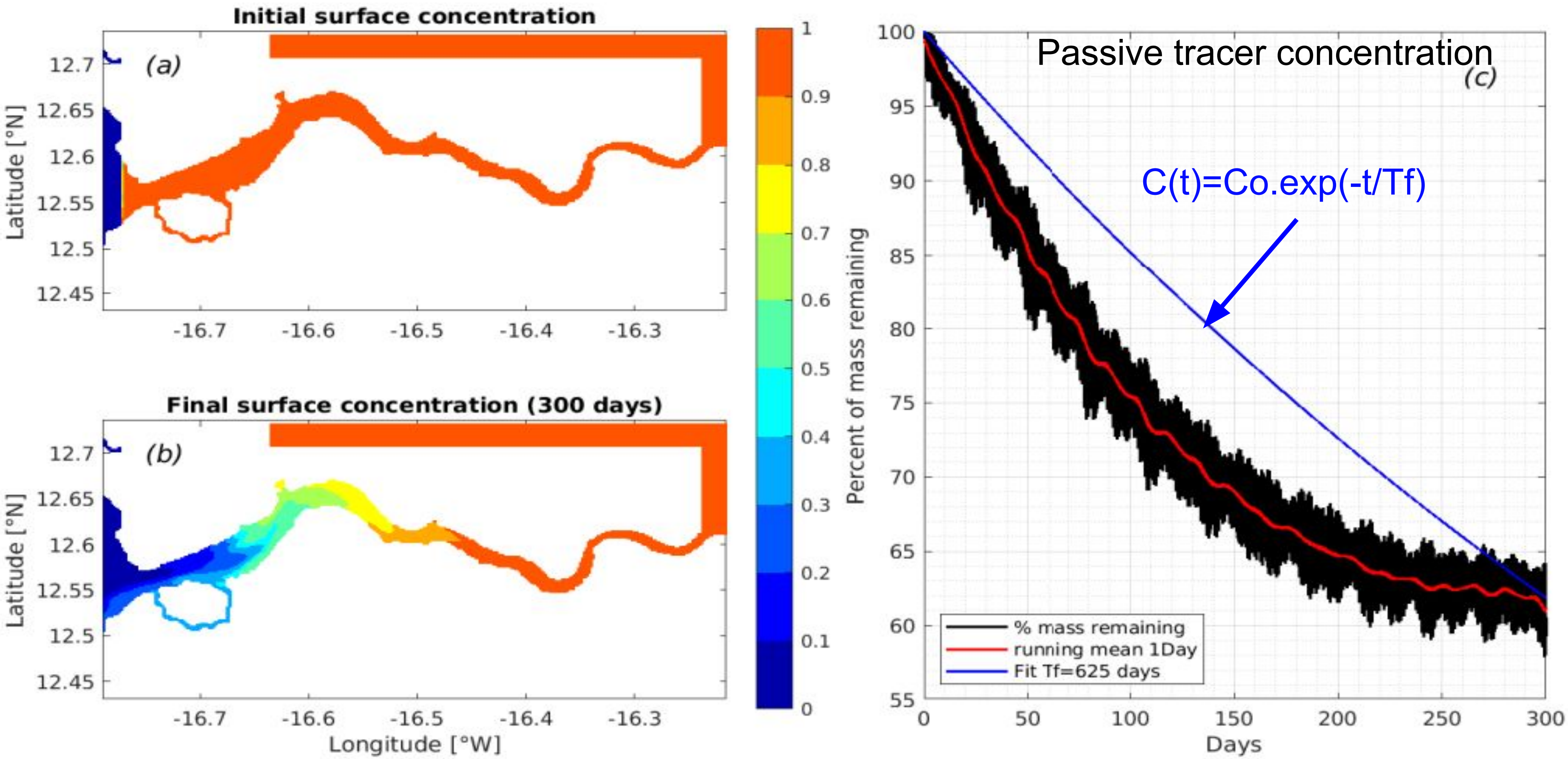
Lagrangian residual current (computed from the initial/final position of particles)



(b)

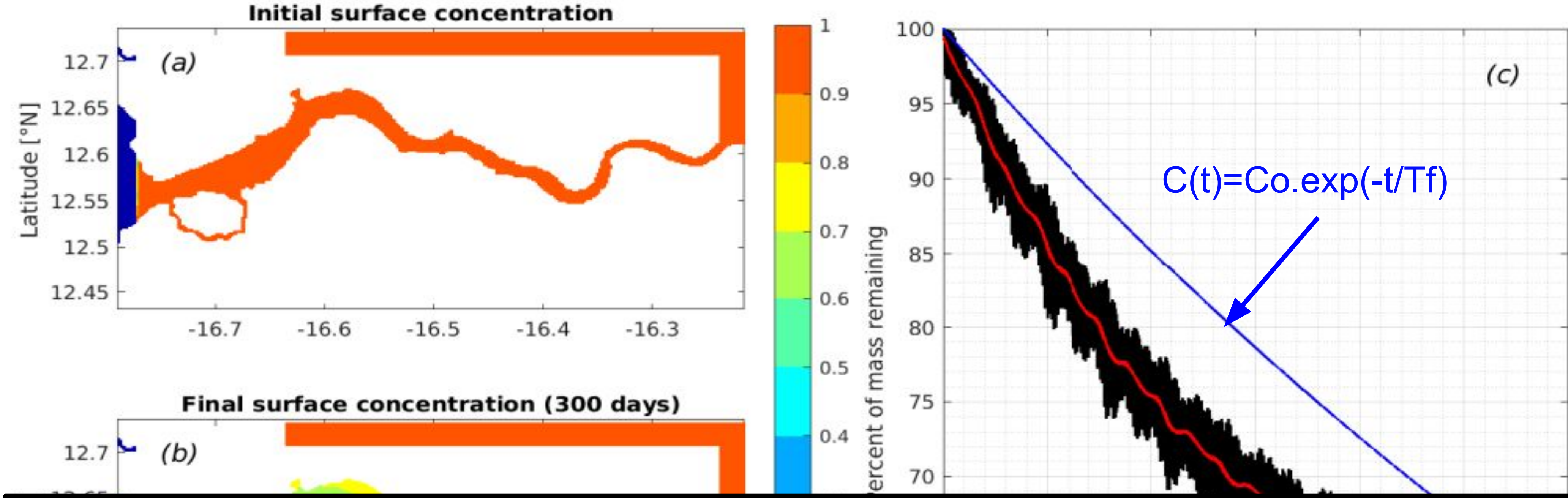
- Lagrangian particles launched at each grid point between January and May
- Residual current much weaker (~0.5 cm/s) than Eulerian (~ 5 cm/s) due to Stokes drift
- Complex pattern: offshoreward near river mouth, landward in estuary

Flushing time of the estuary (without runoff)



- Renewal time (Tf) estimated from the concentration of passive tracer in the estuary
- Tf~ 600 days, consistent with Lagrangian current magnitude : U~0.5 cm/s => T=L/U~1 year

Renewal time of the estuary



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Tides in the Casamance estuary: A modeling study

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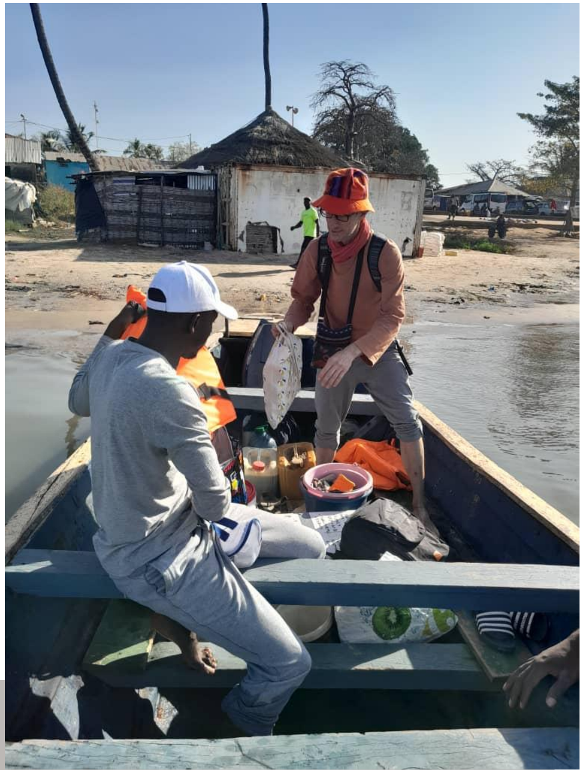
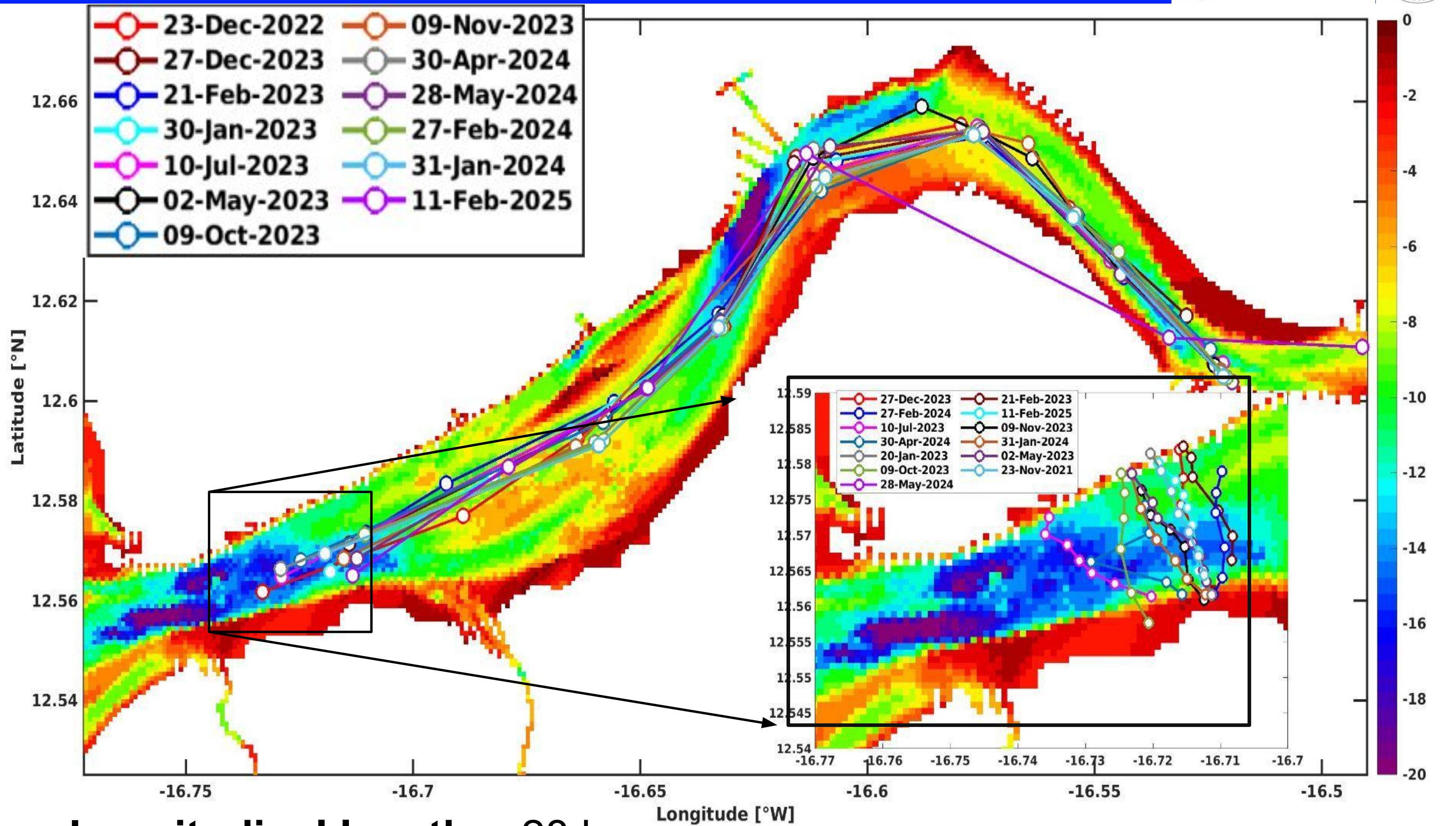
[c] UFR Sciences et Technologies Avancées (STA), Université Amadou Mahtar Mbow (UAM), Dakar, Senegal

In situ salinity analysis: Karabane-Pointe Saint George radial



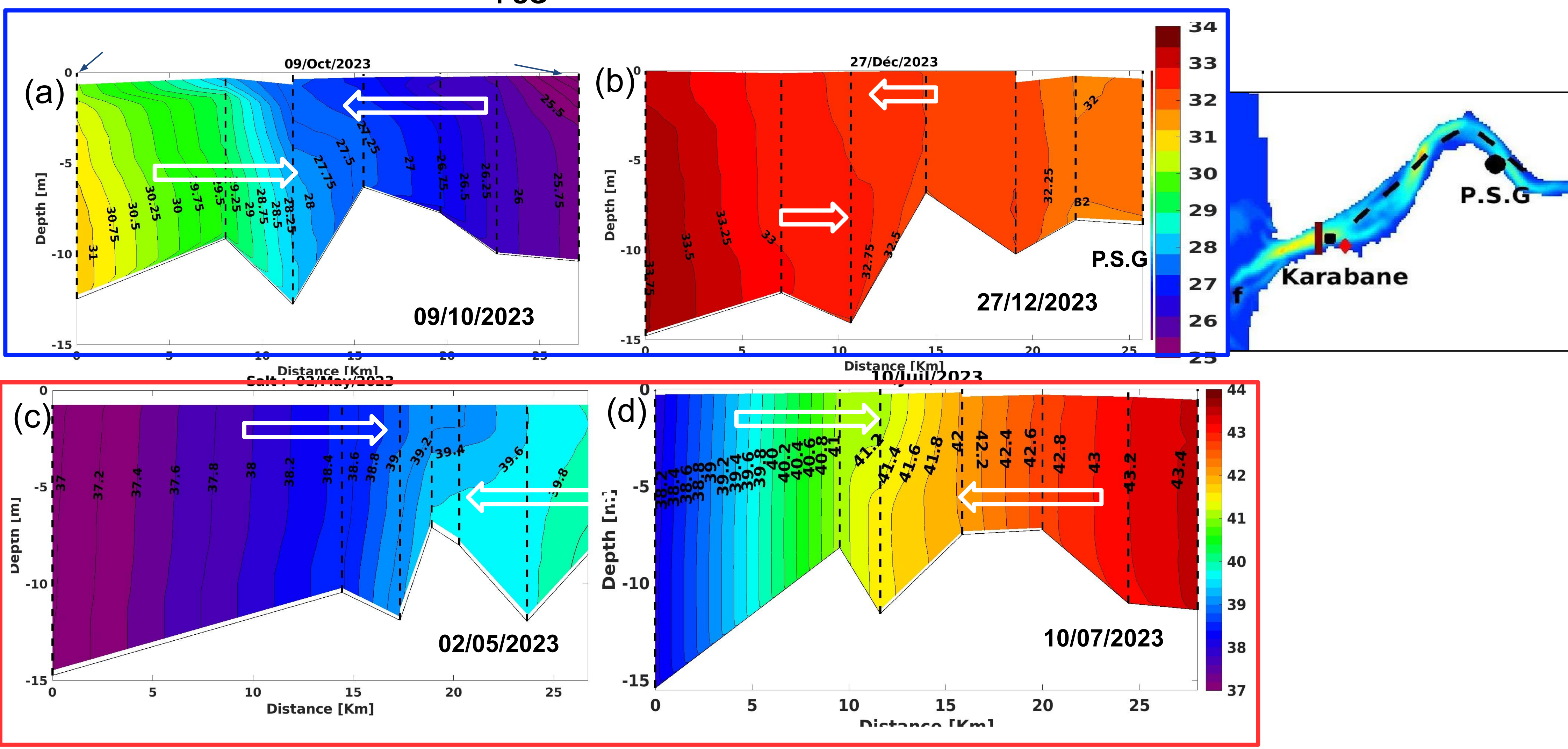


- **Longitudinal length:** ~28 km
- **Boat trips:** ~ once a month since december 2022
- **Parameters:** salinity, temperature, fluorescence, oxygen (surface/bottom)
- **Team** : B. Ndom, Y. Badji, A. Diouf, I. Ba (LOSEC); V. Echevin (LOCEAN), T. Brochier (UMMISCO); X. Capet (LOCEAN), E. Machu (LOPS) funding : ANR SOLAB, IRD

In situ salinity analys

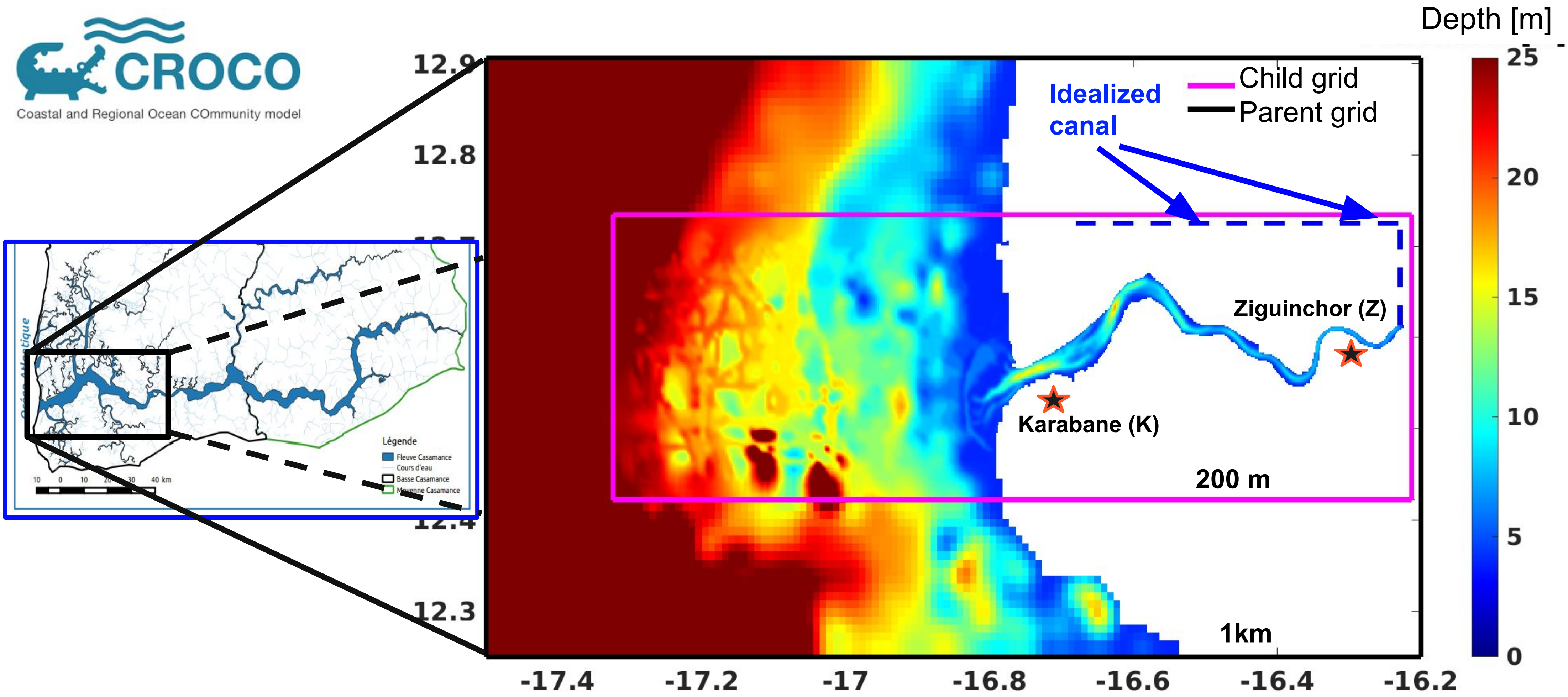
Karabane

PSG



- the salinity gradient increases seaward, characteristic of a positive estuary (oct and dec)
- isohaline slope indicated typical circulation of a positive estuary
- the seaward decrease in salinity is characteristic of an negative estuary
- isohaline slope indicated typical circulation of an inverse estuary

CROCO model configuration



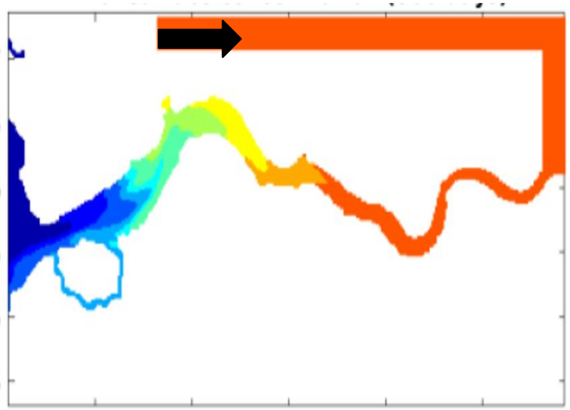
- west part of Casamance
- 1 km (parent grid), 200 m (AGRIF zoom)
- 10 vertical levels
- tidal forcing : TPXO7 global model

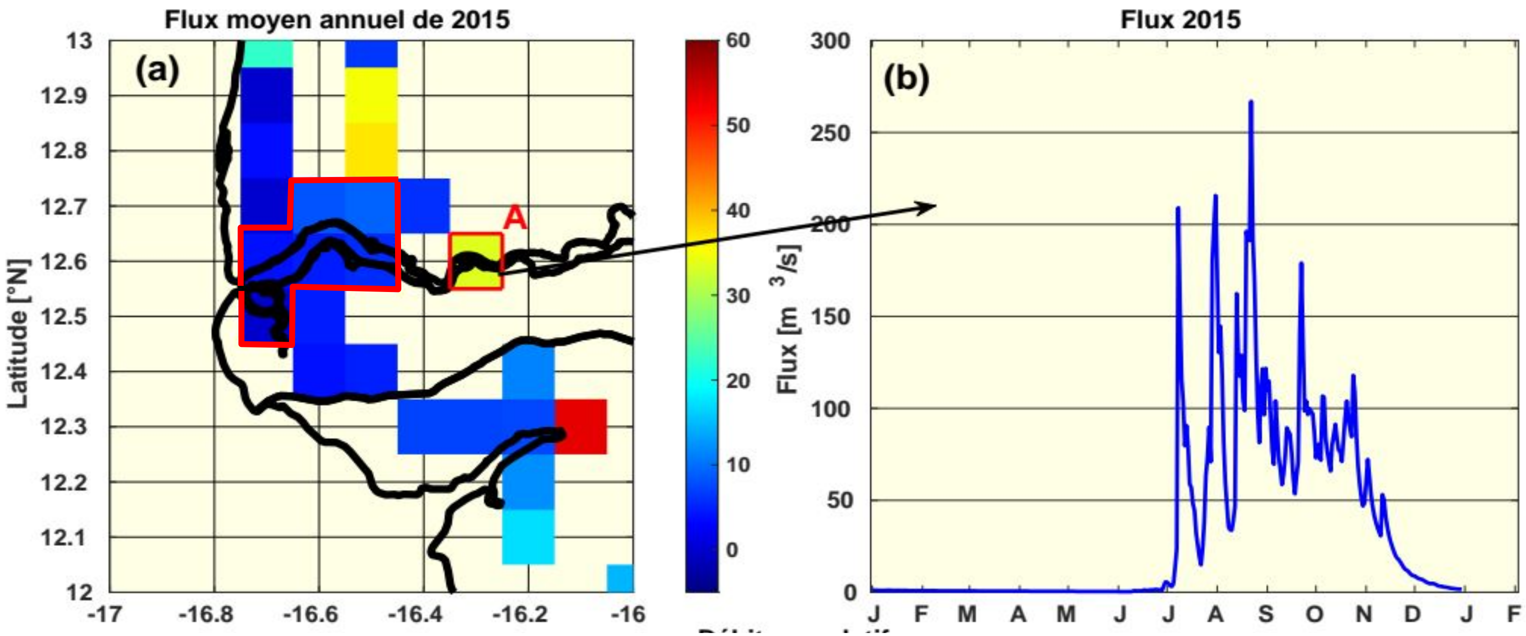
  Egbert & Erofeeva, 2002

- open boundary forcing: WOA
- **atmospheric forcing : ERA5 (bulk, hourly)**
- **GloFAS Runoff**
- Idealized canal at landward extremity of estuary (rectilinear, constant depth=4m)

Modeling of salinity: role of water discharge at the end of the canal

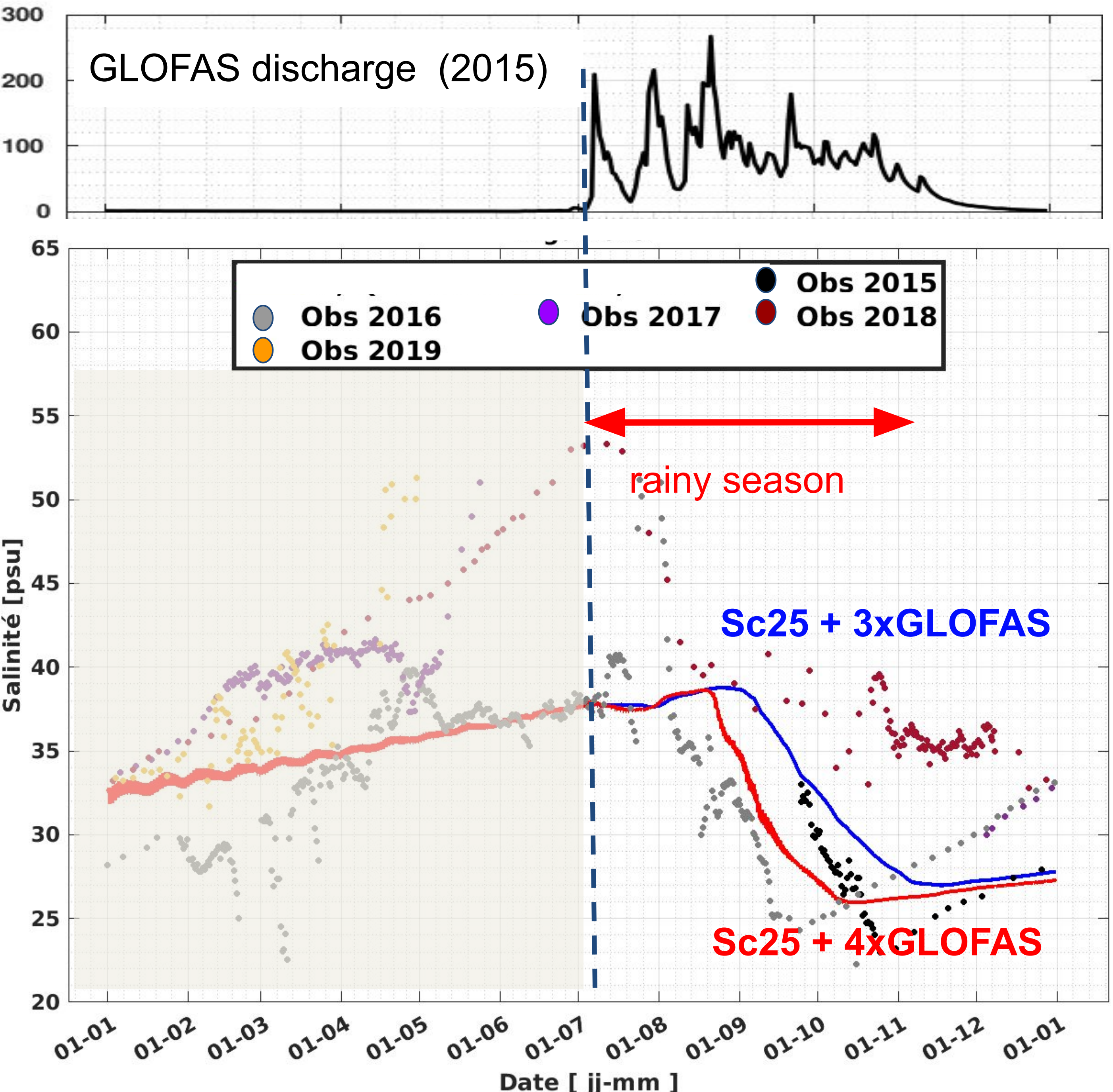
discharge Qc : GLOFAS





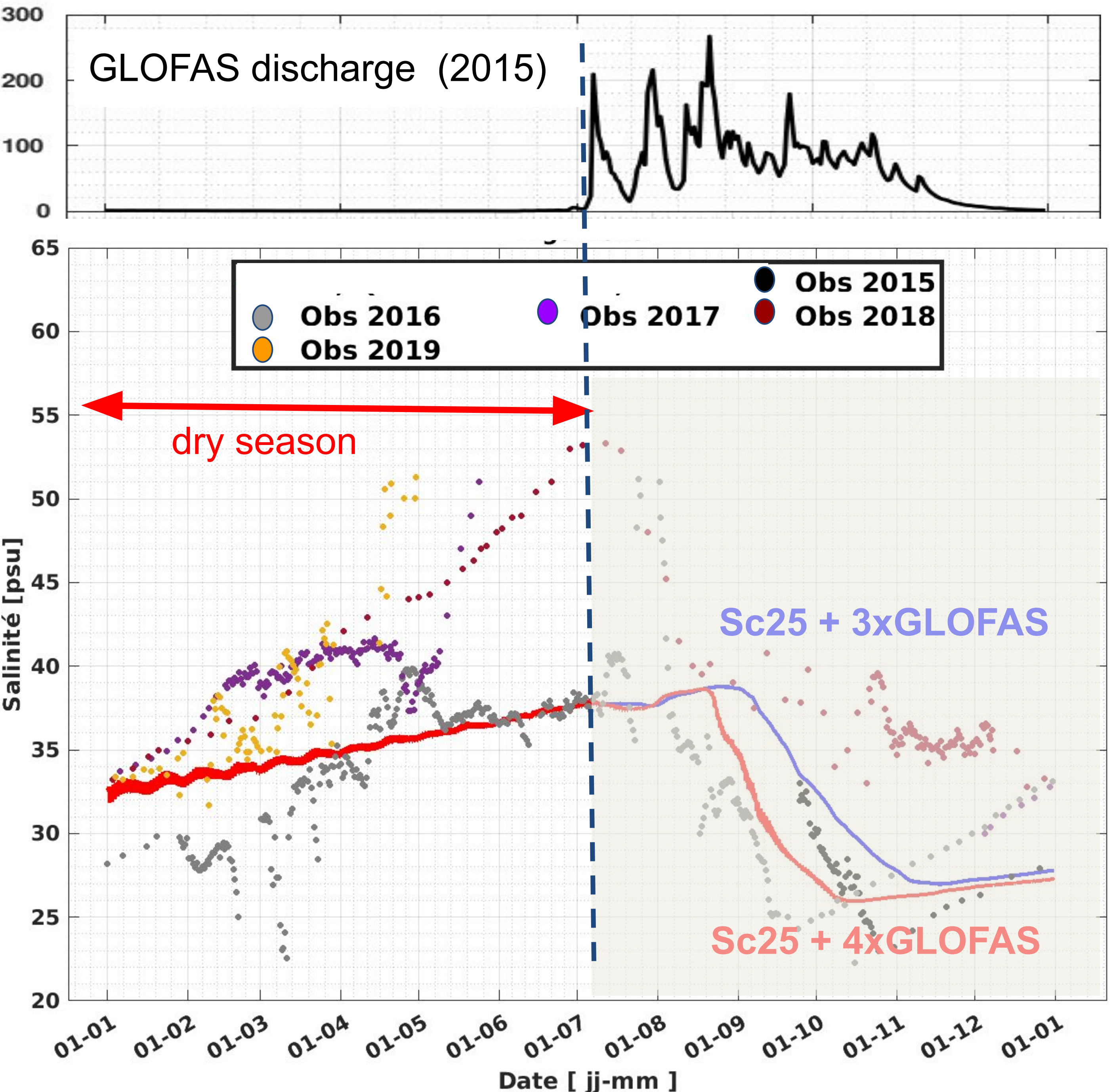
- GLOFAS: hydrological model forced by ERA5 precipitation (11 km resolution, daily)
- Discharge point in GLOFAS: water flux into water body: lake, sea, estuary
  => Discharge (Qc) near Ziguinchor **=** point A + other discharge points neglected
- Discharge of salted water: S= Sc
- Year 2015 is simulated

Influence of discharge (Qc) on salinity during rainy season



- **Sc=25 psu !**
- GLOFAS discharge at point A too low=> multiplied by 3-4
- Salinity decrease consistent with observations with Qc~3-4 GLOFAS
- Salinity decrease earlier and faster with Qc~ 4 x GLOFAS

Salinity evolution during the dry season



- Salinity weaker than observations
- underestimated salinity increase during the dry season
- Model evaporation~ observations (*Dacosta, 1989*)

=> advection is biased (residual current) in estuary

Salinity evolution during the dry season : role of the idealized canal

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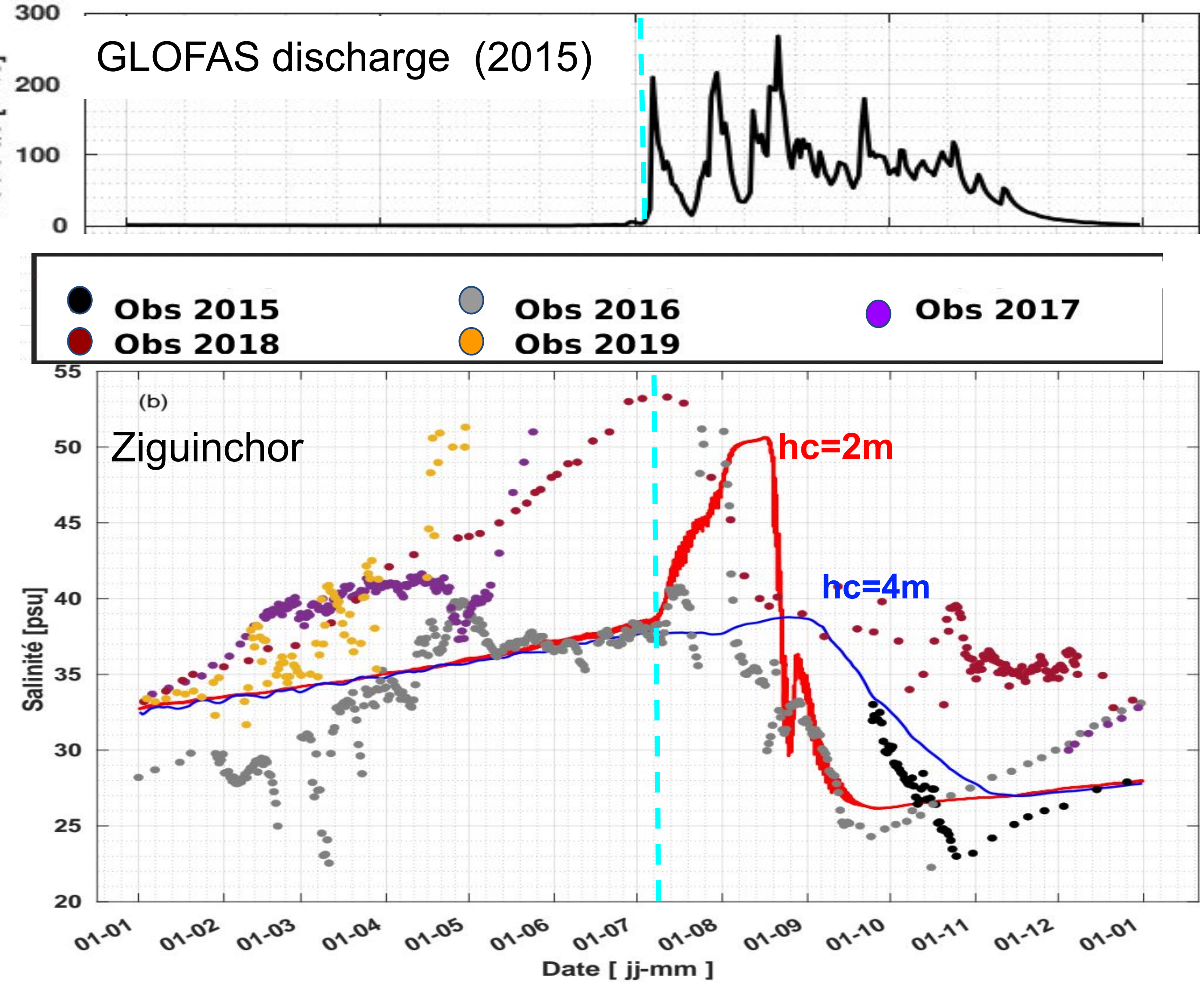
Influence of the canal depth (hc) on salinity at Ziguinchor

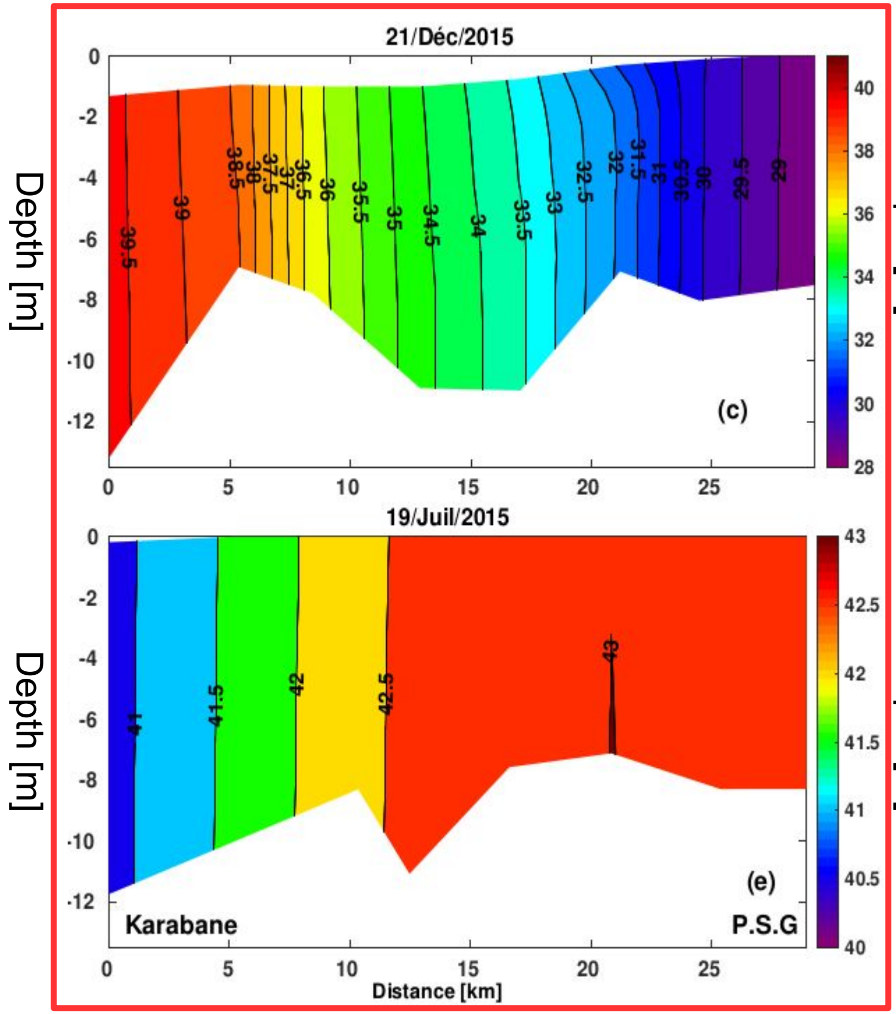


- **Qc = 3 GloFAS**
- slight change of salinity slope with hc=2m (June)
- strong increase of salinity at the start of rainy season (July-August) due to seaward transport of the canal salty waters

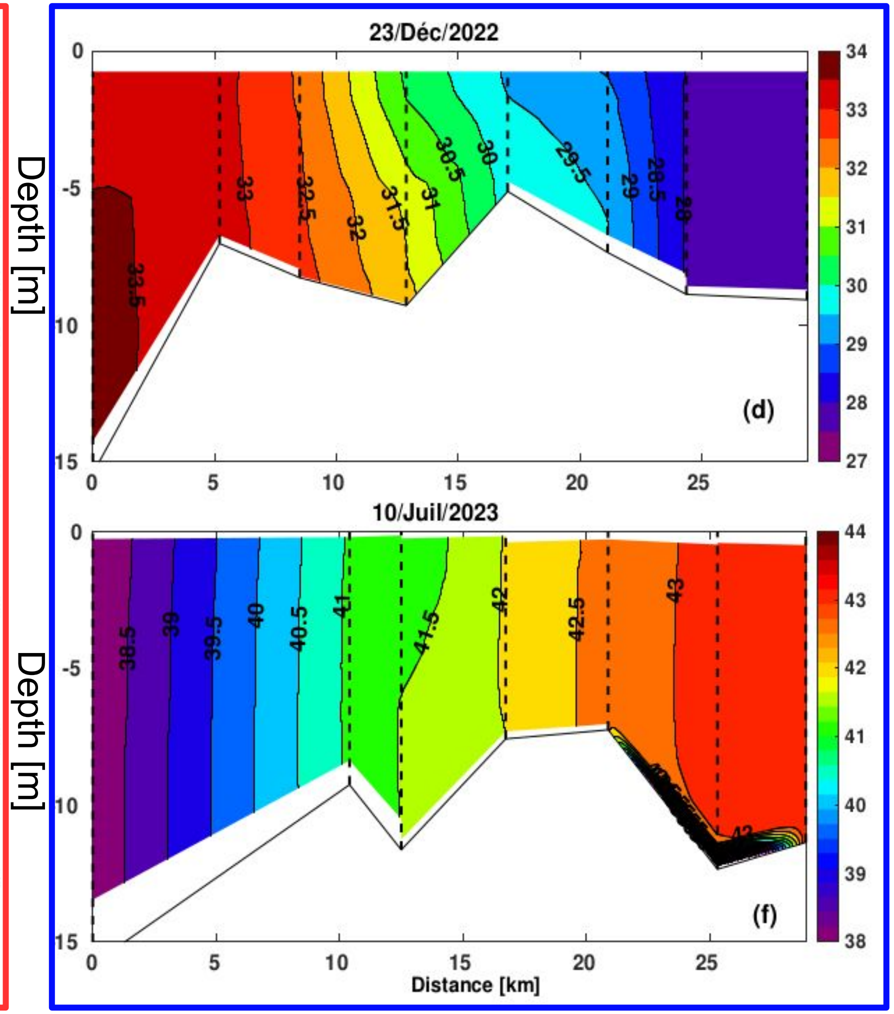
=> major role of topography in canal and in unrepresented eastern part of the estuary

Comparison of model salinity with longitudinal sections

Model



Observation



- Model qualitatively reproduces the observed salinity and longitudinal gradients
- Model is able to simulate the estuary negative and positive conditions

Conclusions and perspectives

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- The model allows a realistic representation of the tidal elevation but underestimates tidal currents
- The tidal Lagrangian circulation is slow (0.5 cm/s) leading to a renewal time of 600 days
- The model is able to simulate salinity inverse and normal conditions during 2015
- A realistic salinity is simulated during the rainy season with a discharge 3-4 times larger than GLOFAS and with a brackish salinity of 25 psu
- The salinity increase during the dry season is underestimated pointing to the need to improve the model upstream of the canal
- Perspectives: to extend the model domain using new bathymetric data (collaboration LIENSs lab.)



Thank you for your attention !