The Amazon River seen from the Ocean

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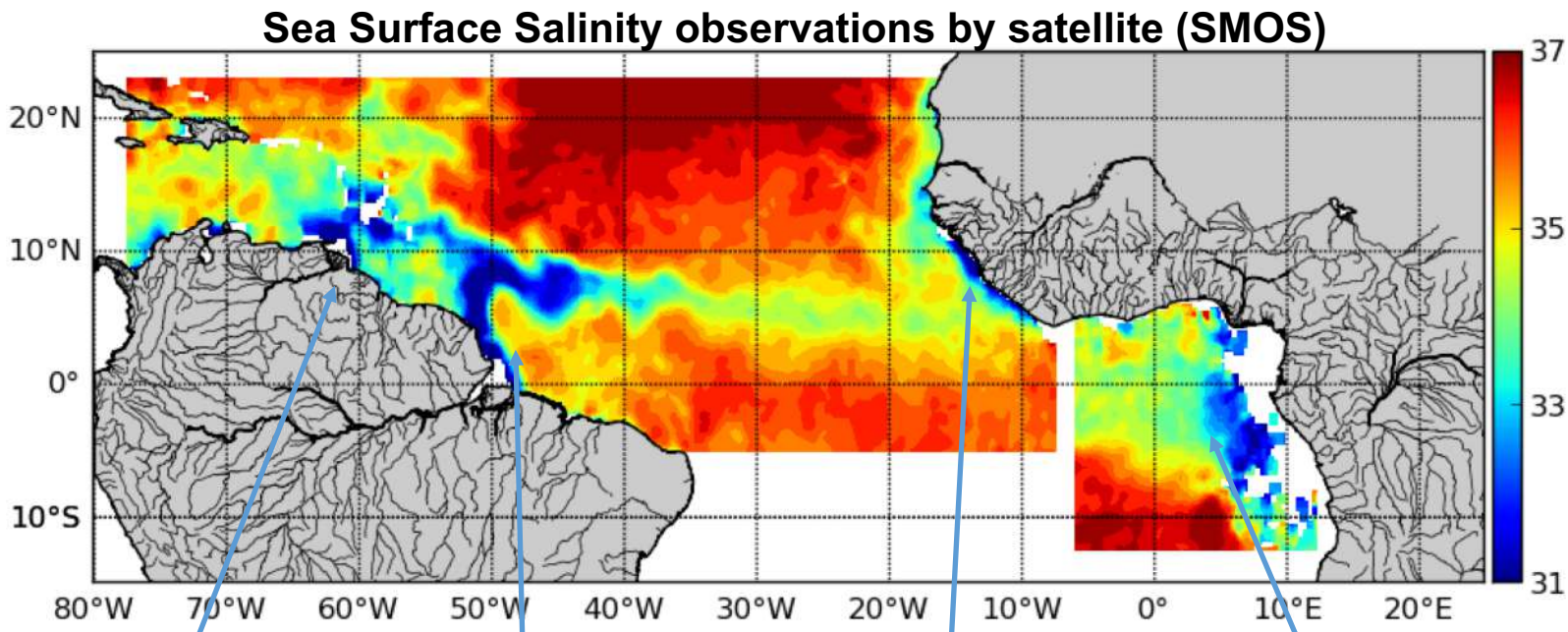
Meeting HYBAM – September 2019

A synoptic influence on the upper ocean salinity



Orinoco (35000 m³/s)

Amazon (210000 m³/s)

Sierra Leone rivers

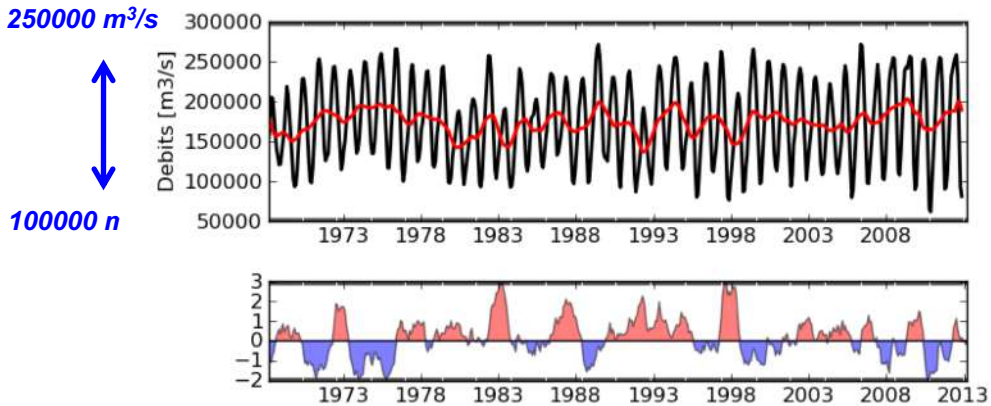
Congo+Niger (42000 + 6500 m³/s)

The tropical Atlantic receives the three world's largest rivers

20% of the worldwide runoff

Large tropical rivers are sensitive to climate variability and anthropic pressure

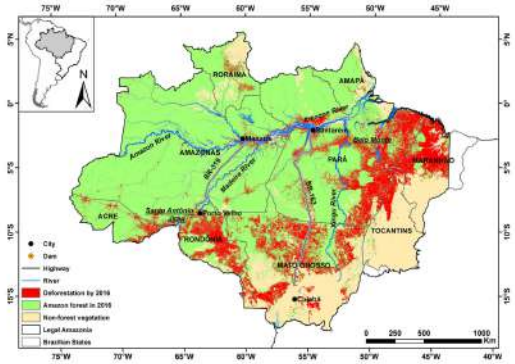
- **Seasonal and interannual variability**

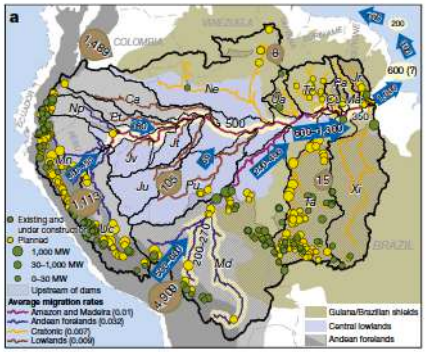


Amazon (Obidos, Hybam)

ENSO index

- **Land use / urbanisation / dams**





Latrubesse, Nature, 2017

Variability at the river-end of:
- freshwater flux
- nutrients
- contaminants (e.g. plastics)

Impacts of the Tropical rivers (mean, variability, changes) on the ocean ?

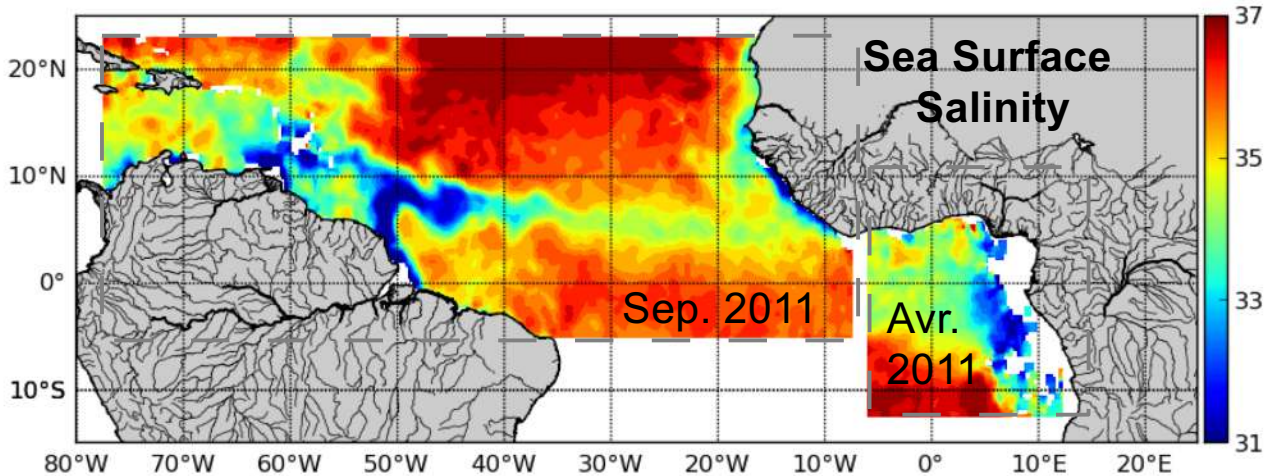
- Ocean dynamics and regional climate
- Biogeochemistry – biology
- Contamination

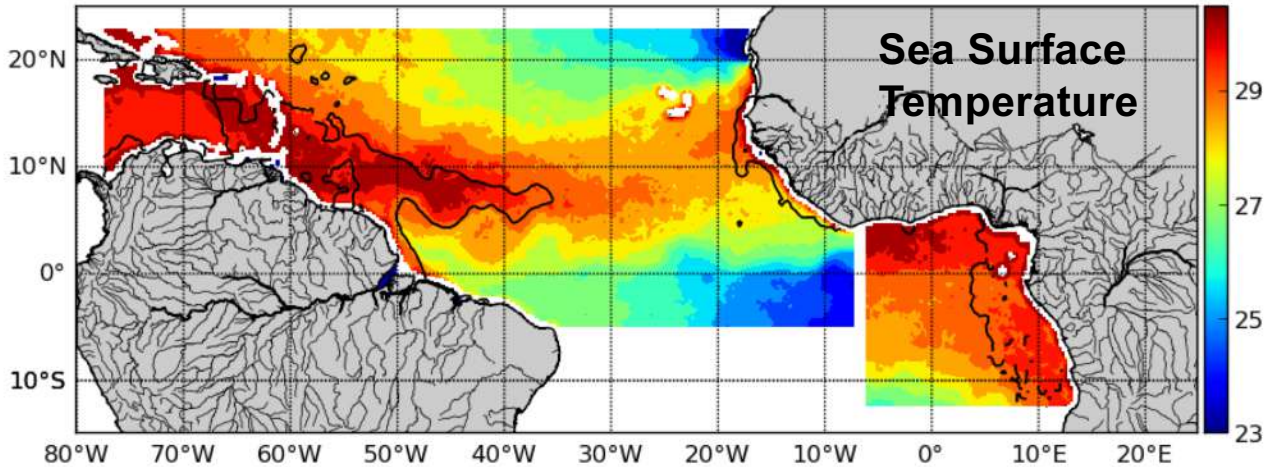
Which :

✓ Tools ?
✓ Useful hydrological data used by the oceanographers ?
✓ Missing information ?

Overview of the different impacts of the Amazon river on the Tropical Atlantic Ocean

Modulation of the sea surface temperatures and heat content





Modulation of the sea surface temperatures and heat content

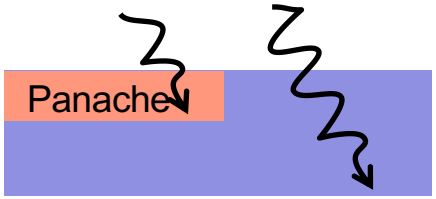
Mechanisms

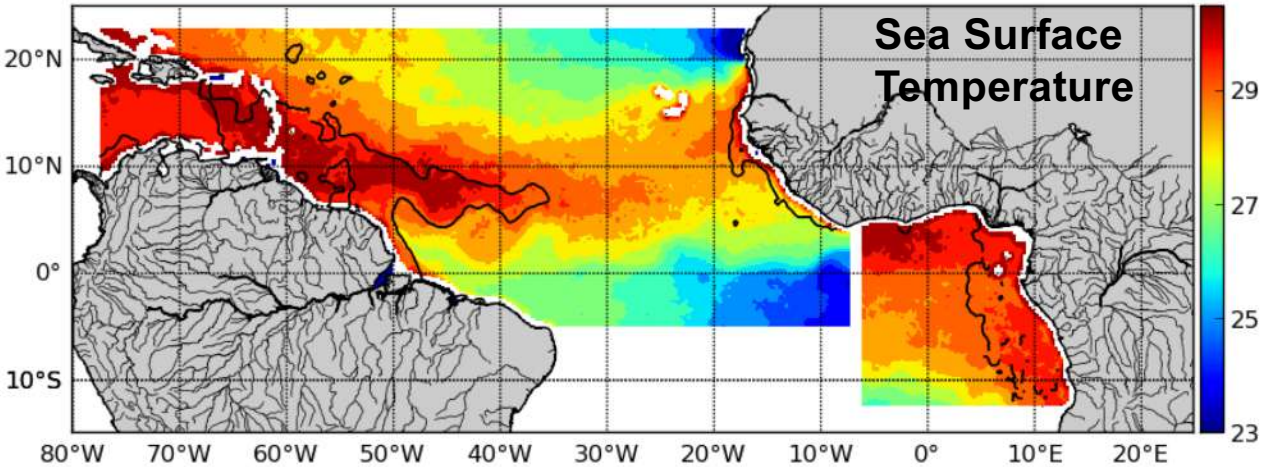
1. Large density gradient between the plume and subsurface waters

→ Limits the vertical mixing and maintains the warm waters at the surface
[e.g., Pailler et al. ,1999, Foltz et al. 2009, Balagaru 2012]

2. Phytoplankton and dissolved organic matter

→ Capture the solar radiation in the upper meters
[Murtugudde et al, 2002, Newinger and Toumi 2015]

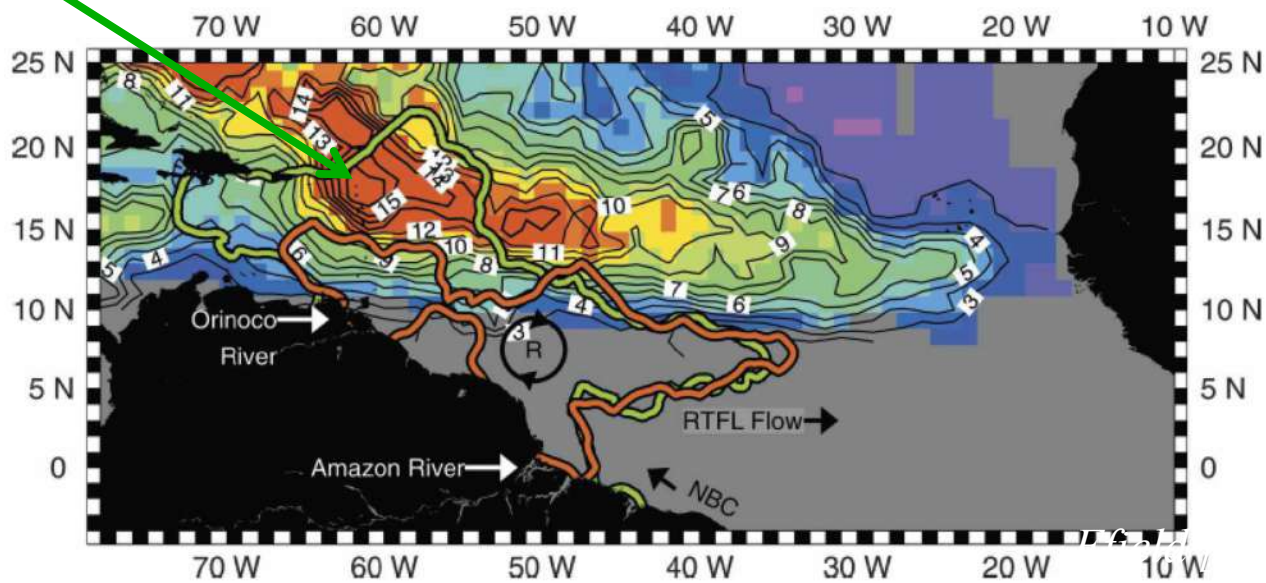




Possible impact on Tropical Cyclone intensification

Historical region of the plume

1960-2000 tropical storms and hurricanes paths

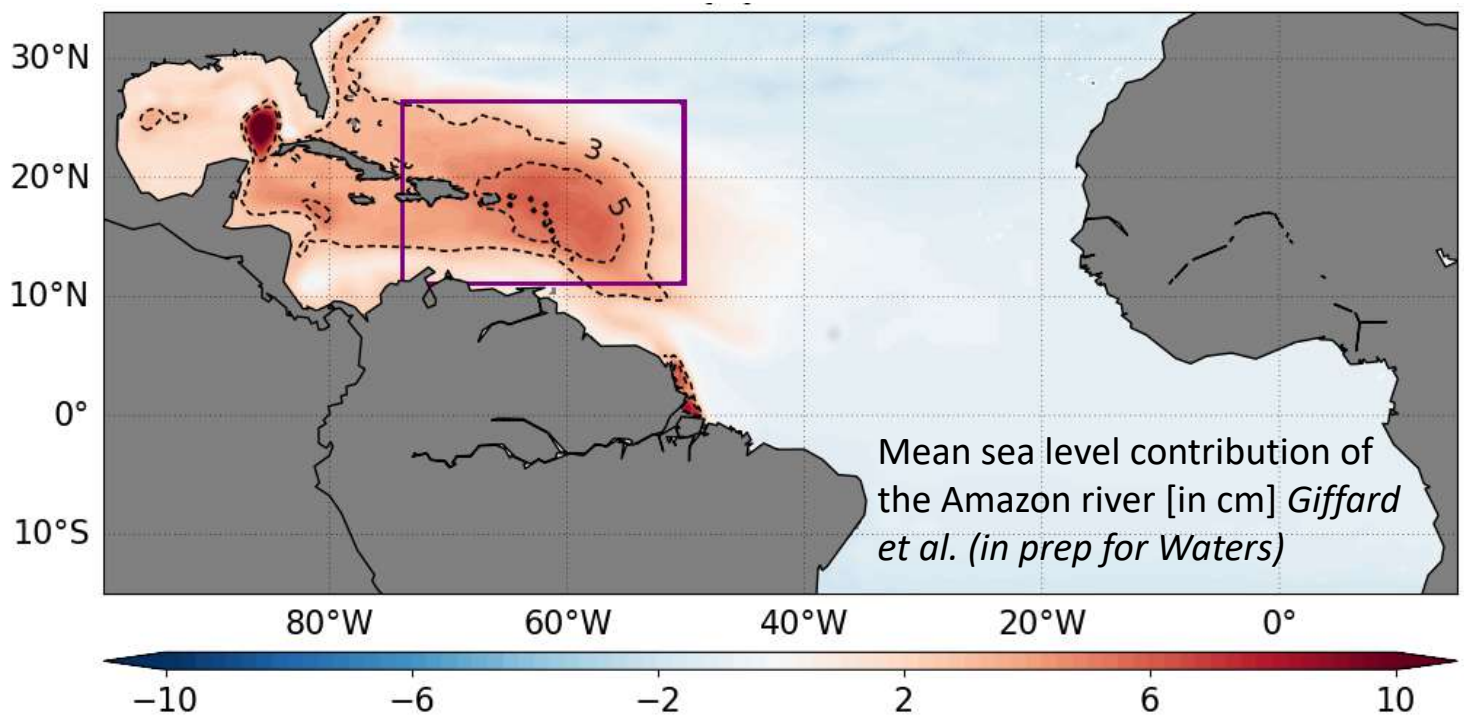


Ffield [2007] observed that 68% of all category 5 Atlantic hurricanes during the 1960-2000 time period passed directly over the historical region of the plume

→ Amazon and Orinoco : active players of TC intensification in the region ?

Hernandez et al. (2016), Thèse M. Gevaudan

Impact on regional sea level

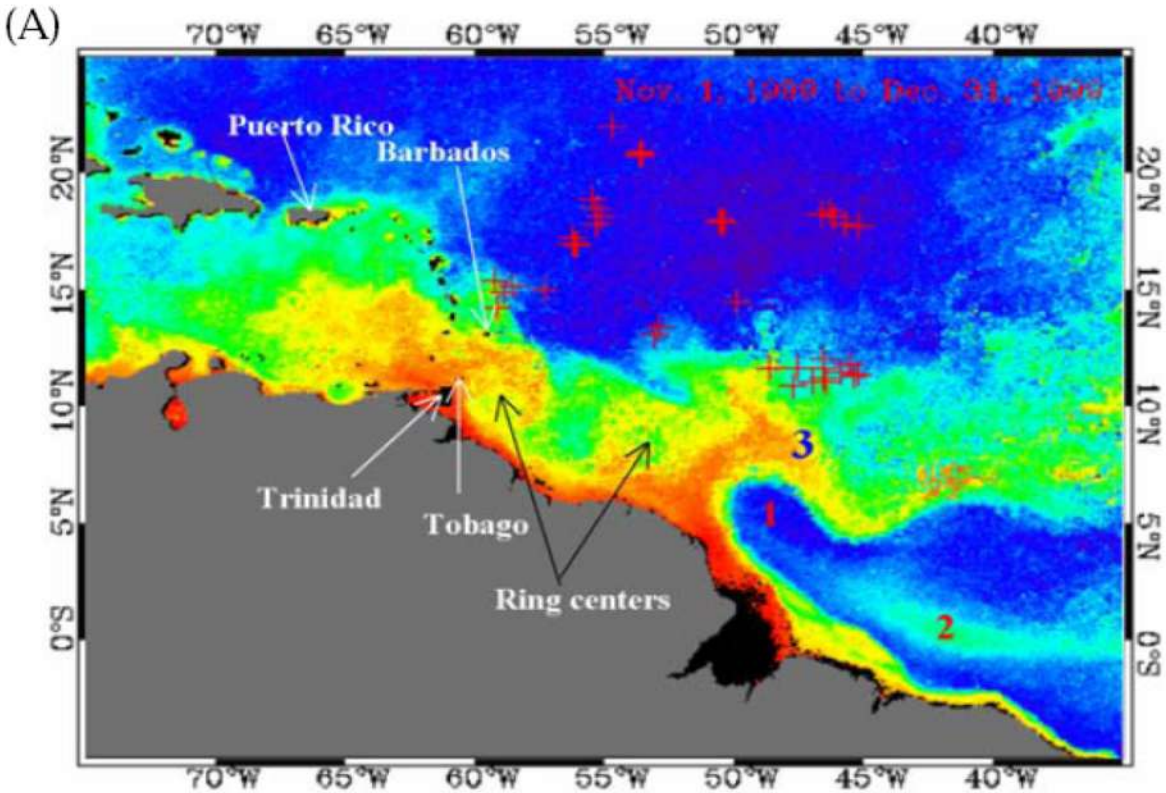


Mean sea level contribution of the Amazon river [in cm] *Giffard et al. (in prep for Waters)*

- The Amazon contributes to elevate the regional sea level (mainly through halosteric effect) > 10 cm near the mouth
  > 5cm in the Caribbean Sea

- How much the Amazon variability/changes contributes to regional sea level variability ?

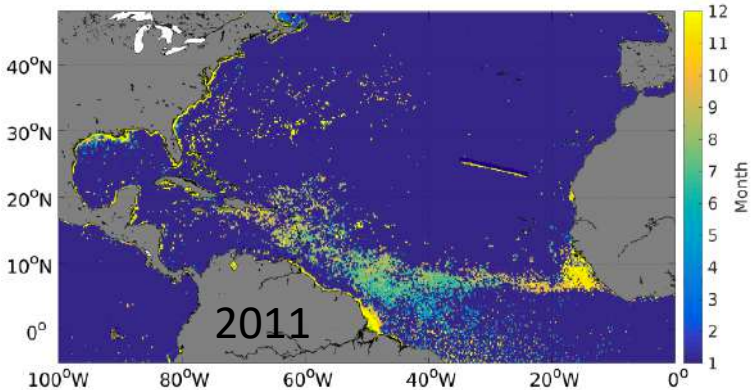
The Amazon plume: a highly productive environment

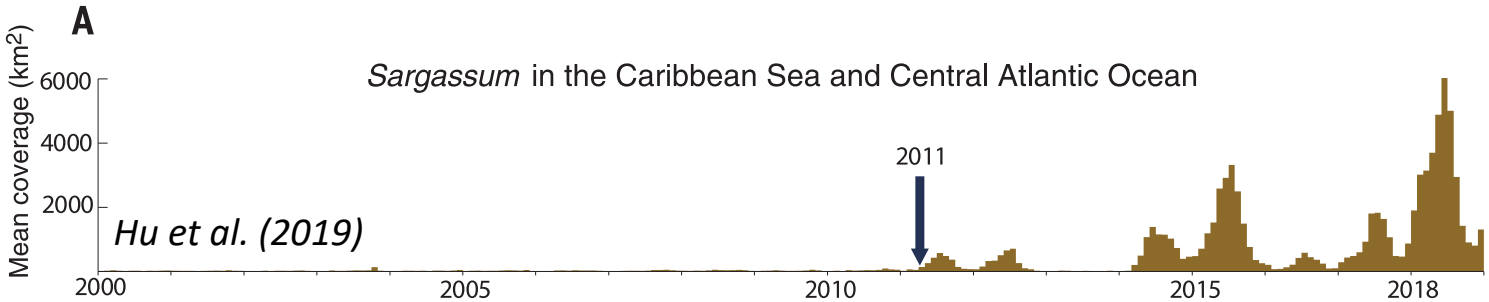


- CO2 sink (e.g. Subramaniam et al. 2008)
- Ecosystem structuration
- Feedback on the physics
  (modulation of the penetrative solar radiation)

Proliferation of Sargassum in the Tropical Atlantic since 2011

MODIS Sargassum Observation MODIS (L. Berline, A. Ody, MIO)





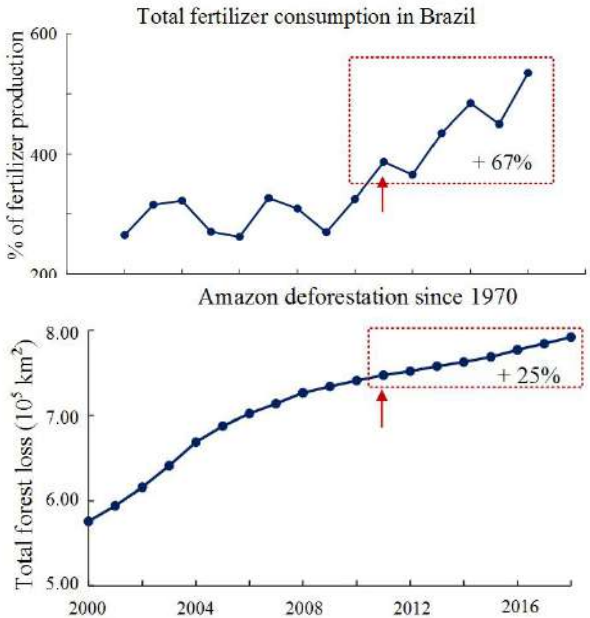
→ **Recent studies raised a possible role of the Amazon in the increase of the Sargassum biomass (e.g., Djakoure 2017, Hu et al. Science 2019)**

River plume may favor a productive environment :

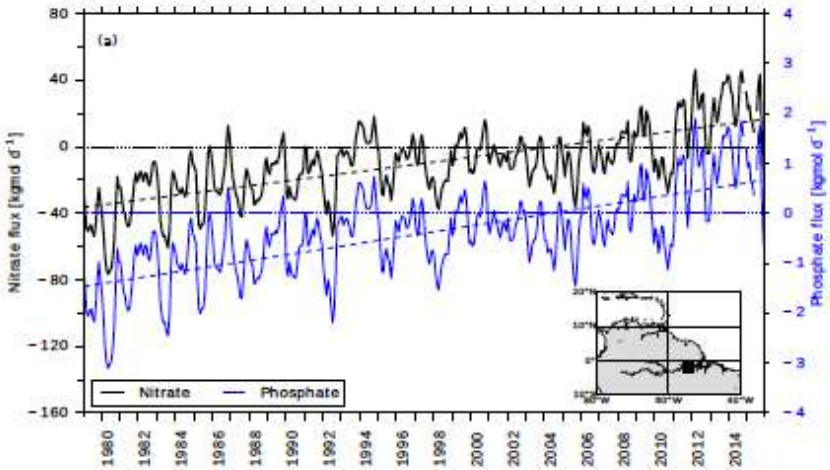
- Large nutrient input
- High stratification
- Among the warmest waters of the Tropical Atlantic

Proliferation of Sargassum in the Tropical Atlantic since 2011

Major argument : increase in the nutrient supply from the Amazon River



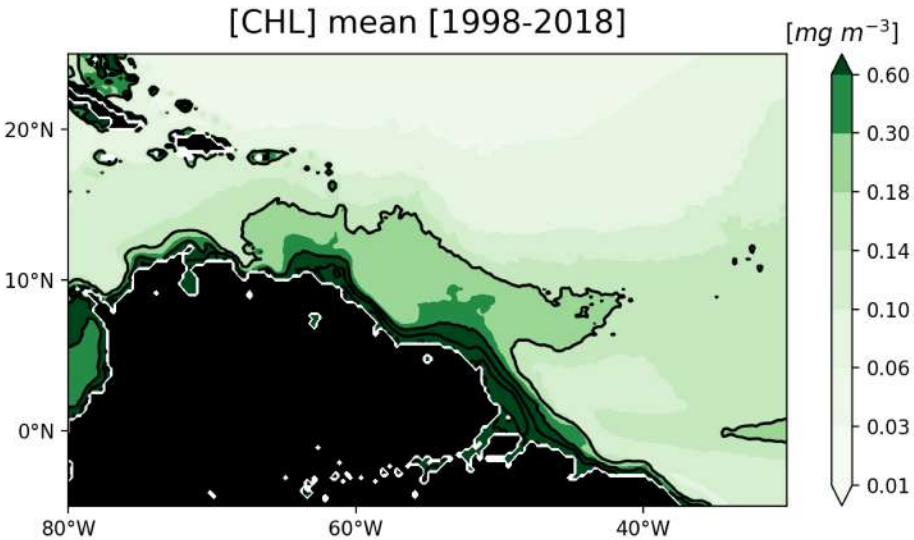
Wang et al. 2019

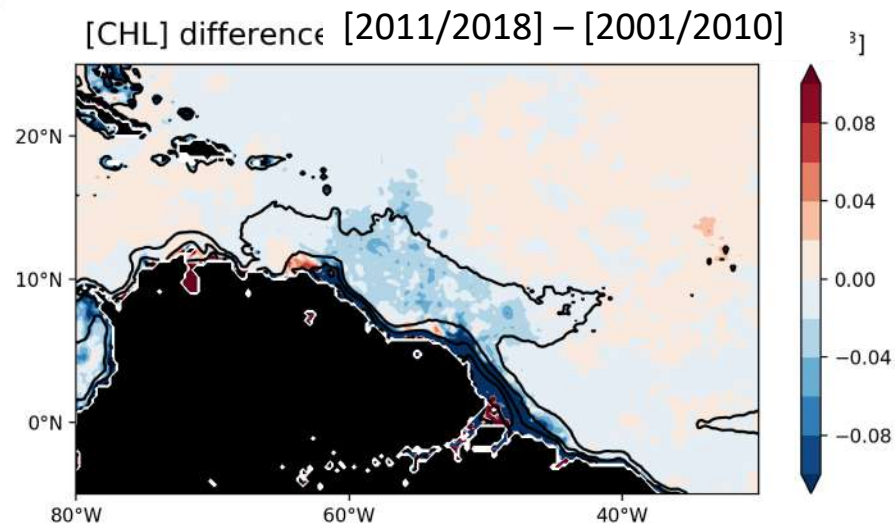


Nitrate and Phosphate anomalies from *Djakoure et al. (2017), Araujo et al. (2014)* estimated from on a statistical model and function of river runoff and population

→ But (to my knowledge) no direct measurements to confirm such changes

Proliferation of Sargassum in the Tropical Atlantic since 2011



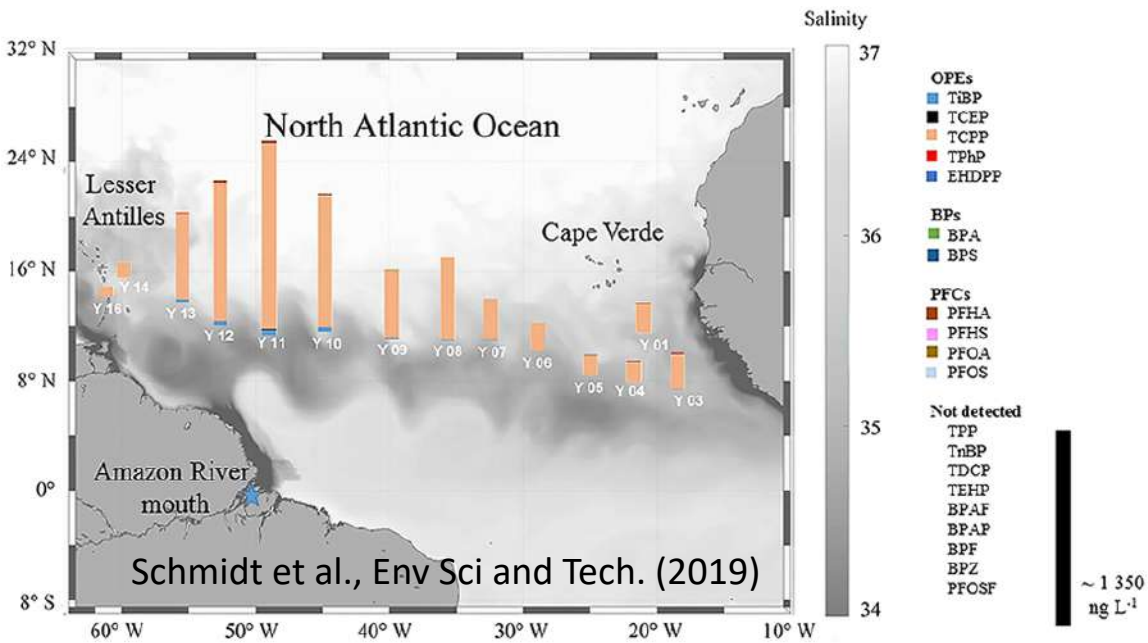


Decrease of [chl] in the Amazon plume area in the recent years (consistent between different ocean color products)

How can this be reconciled with a *possible increase* of N and P amazon load (as estimated by Araujo et al., Wang et al. 2019) ?

→ **Knowledge gap on the riverine flux of nutrient** and ongoing changes of these fluxes

The Amazon River : a major source of organic plastic additives to the Tropical North Atlantic?



Schmidt et al., Env Sci and Tech. (2019)

M.I.O. Transatlantic Sargassum expedition in 2017

Sampling of **plastic additives** : organophosphate esters bisphénol, PFC (bio-accumulative and toxic)

→ Show that medium-/long-range contaminant transport occurs, most certainly facilitated by the highly stratified conditions offered by the river plume.

→ Consequences for ecosystems ?

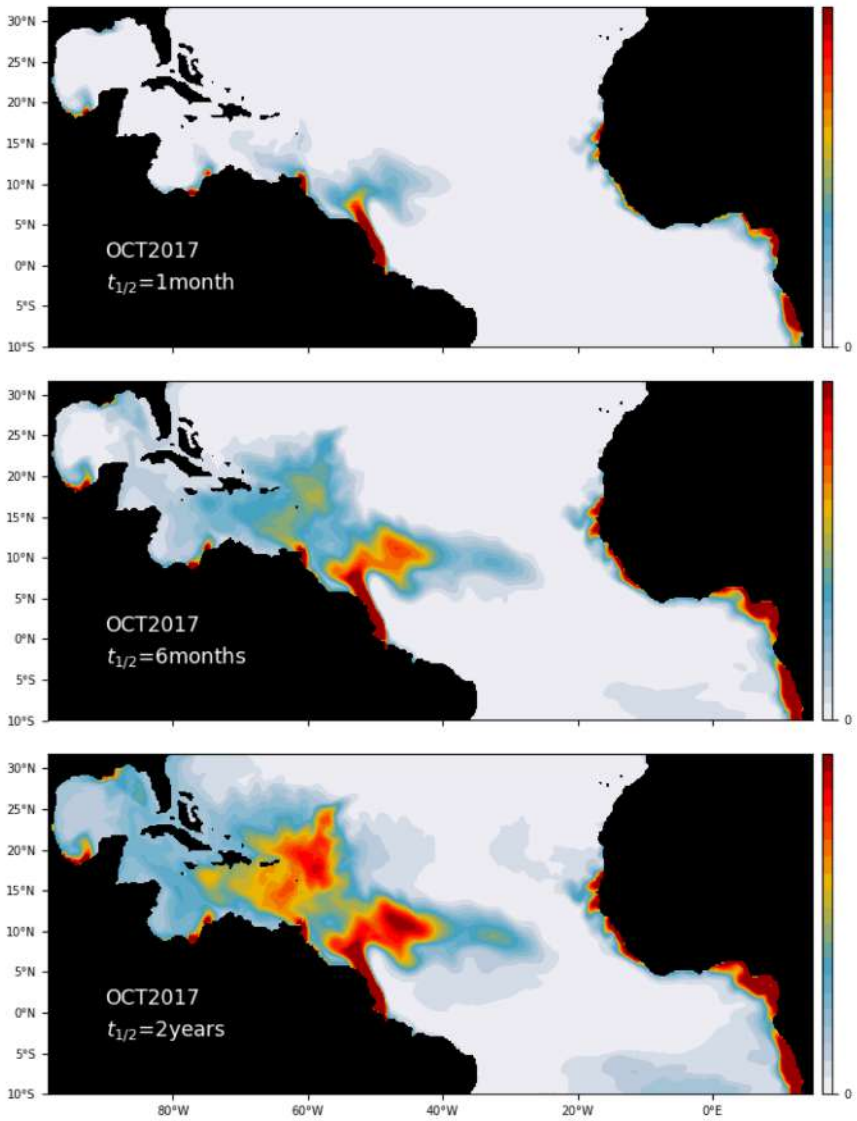
Which :

- ✓ Tools ?
- ✓ Useful hydrological data used by the oceanographers ?
- ✓ Missing information ?

Ocean Color and Sea Surface Salinity observations allow to partially map the extent and variability of the plume over the last decade

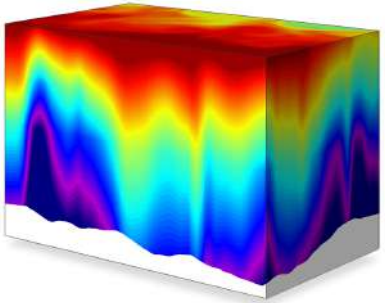
Modelling is required to investigate

- plume dynamics
- areas under influence of the Amazon waters
- processes controlling the variability
- projections
- Etc…



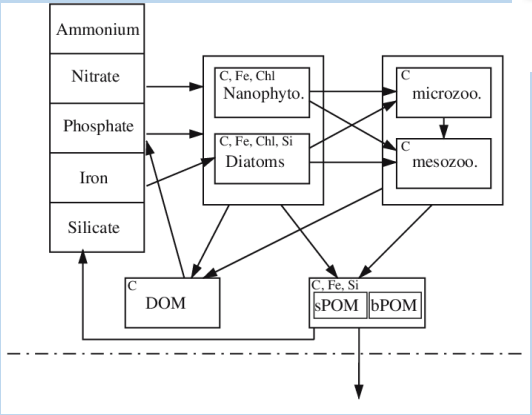
Modelling the Amazon plume

Lateral boundary conditions MERCATOR



River input

Atmospheric Forcing – ERAi or coupling with WRF

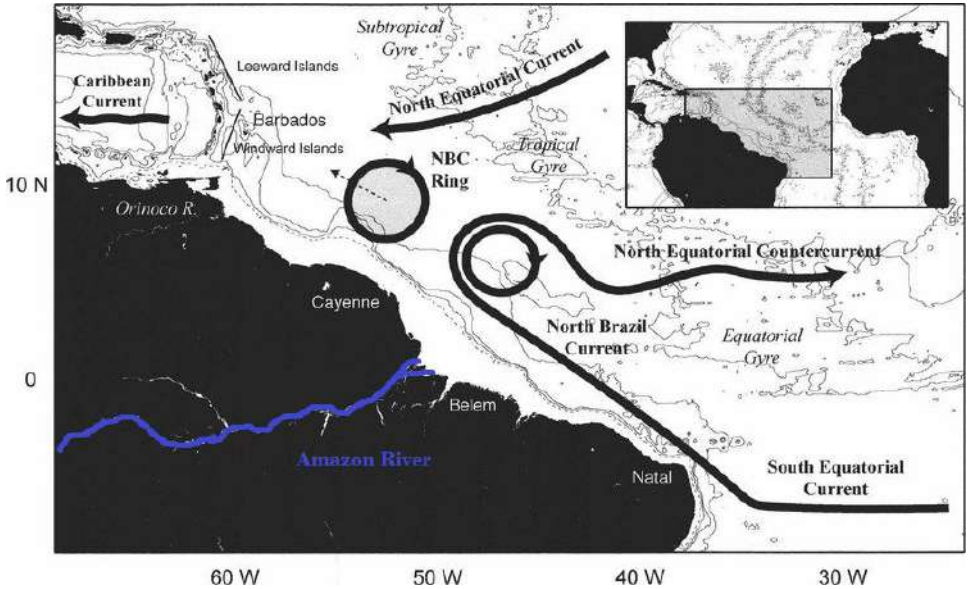


Ocean physics - NEMO

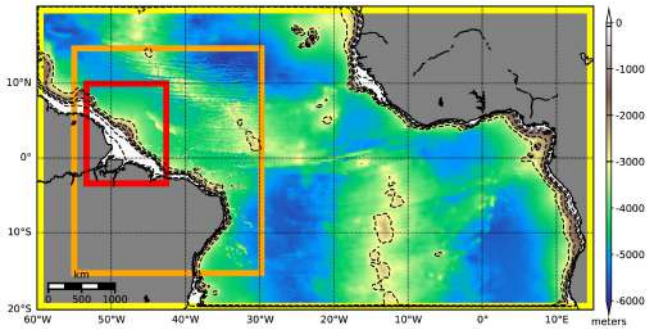
Ocean biogeochemistry PISCES

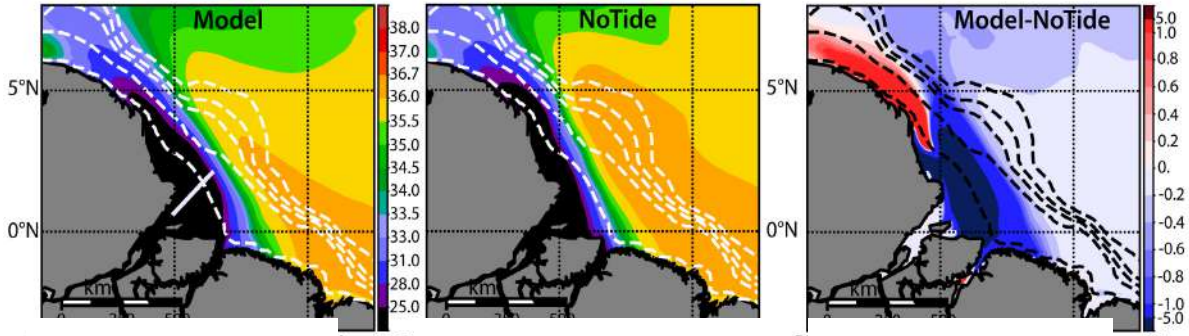
Typical integration periods :
1979-2017 for intermediate resolution (~25km)
2005-2017 for high resolution (~2km)

Modelling the Amazon plume



- Fine scale processes on the shelf (fronts, tides)
- Mesoscale dynamics in the retroflection area, TIWs
- Basin scale dynamics (MOC, equatorial variability)





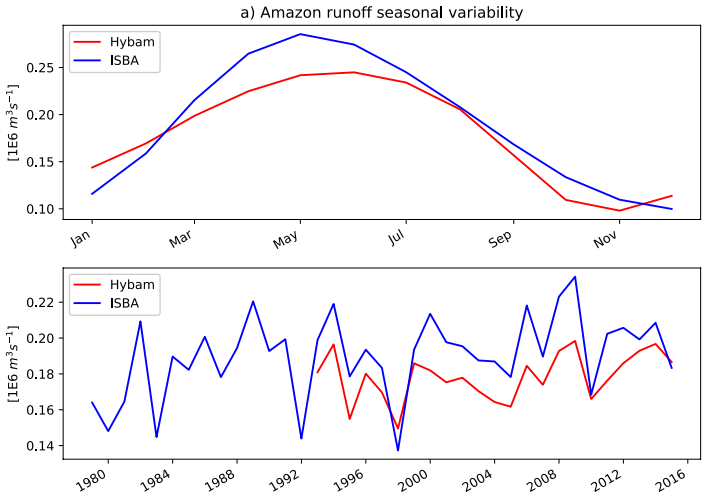
SSS (with tides) SSS (without tides) SSS difference

→ e.g. Tides influence the position and properties of the plume far off-shore (Ruault et al., submitted JGR)

Forcing the Amazon plume

Physics : **volume flux, temperature**

- Dai and Trenberth seasonal climatology
- HYBAM Obidos (+GRDC,ONS for the river end),Orinoco, Congo
- ISBA-CTRIP (Decharme et al. 2019)

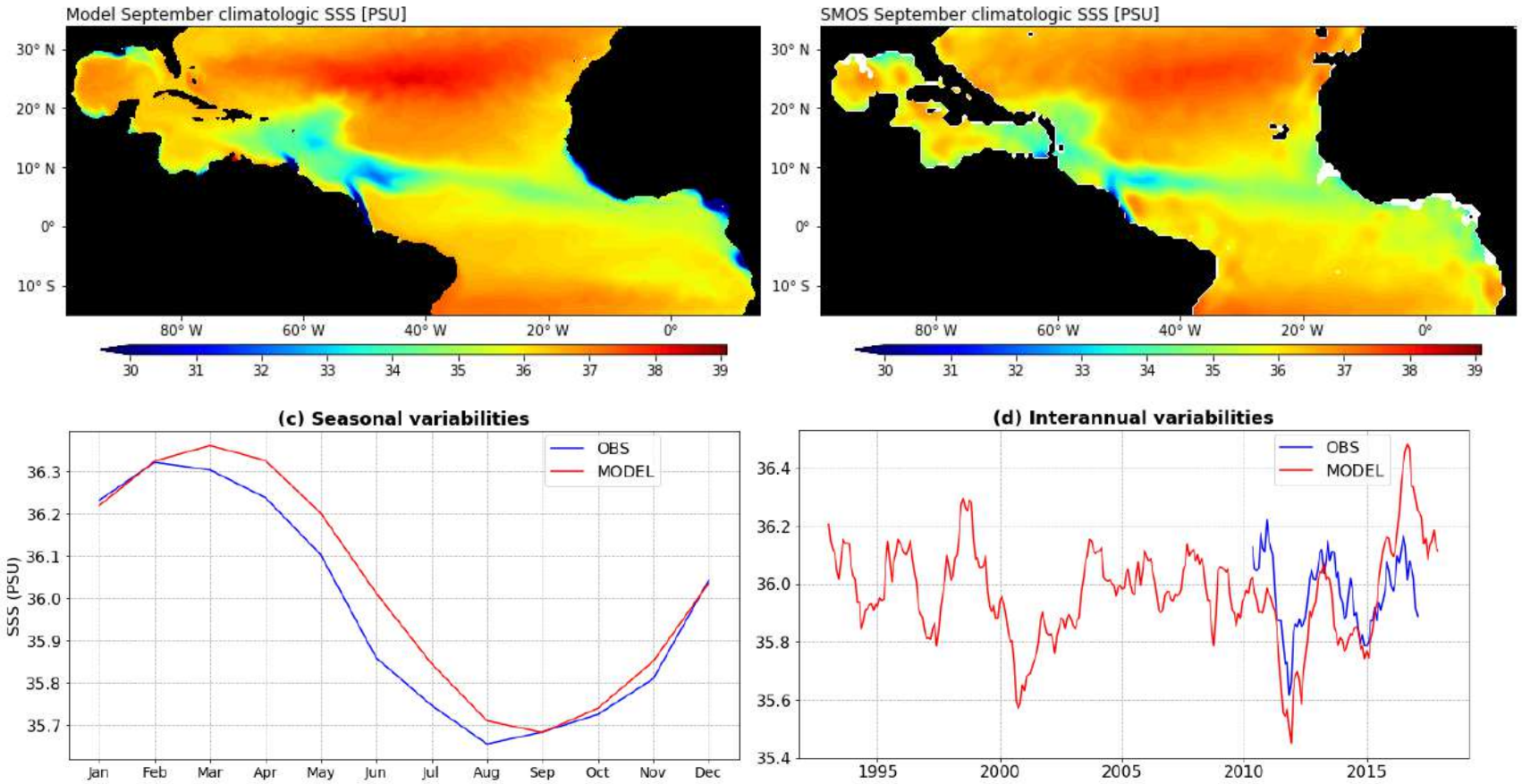


Biogeochemistry : **N, P, C (organic and inorganic), Alkalinity, Si, Fe**

- GLOBAL-NEWS2 data sets (Mayorga et al., 2010)
- Global Erosion Model (GEM) of Ludwig et al. (1996) for DIC and alkalinity
- Amazon forcing corrected/adjusted with scarce in-situ observations(Demaster and Pope 1996, Doherty et al. 2017, Richey et al. 1991)

→ **Large uncertainties on - the average concentrations**
- lability of the organic material
- seasonal and interannual variability (at the exception of Moreira-Turcq 2003)

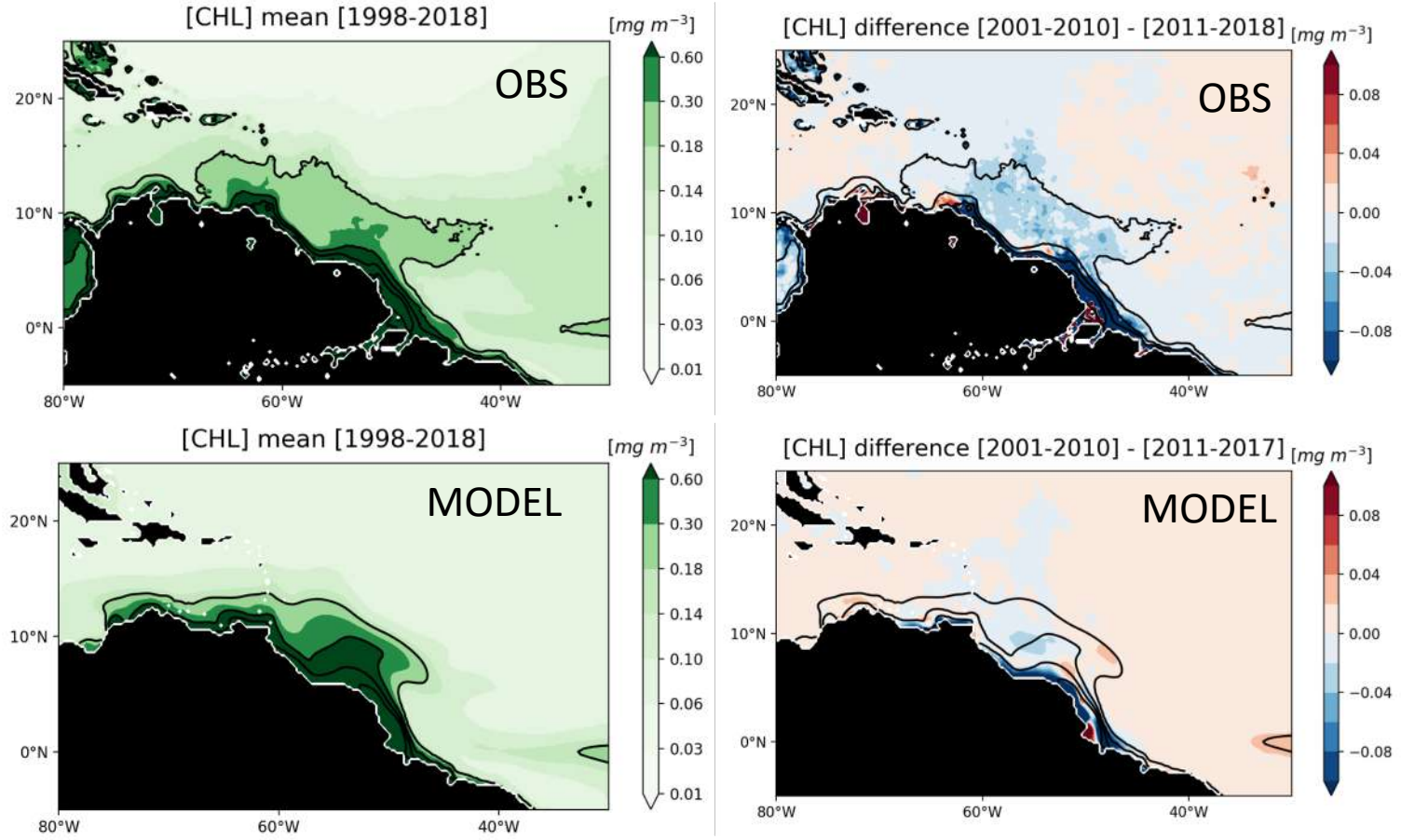
Representation of the plume



Mean, seasonal and interannual variability of the plume well represented

→ **Physical hydrological forcing is well constrained**

Representation of the « green » freshwater plume



Conclusions

The Amazon river is a major contributor to the functioning of the Tropical Atlantic Ocean

Physical hydrological forcing relatively well constrained (despite missing information near the river-end, or temperature information)

Challenge in understanding/representing the biogeochemical variability of the Amazon plume

→ Improve our representation of the biogeochemical process in the open ocean (e.g. diasotrophy) and on the shelf

→ Improve the biogeochemical forcing delivered by the Amazon (mean value, seasonal cycle, impact of floods, etc…)