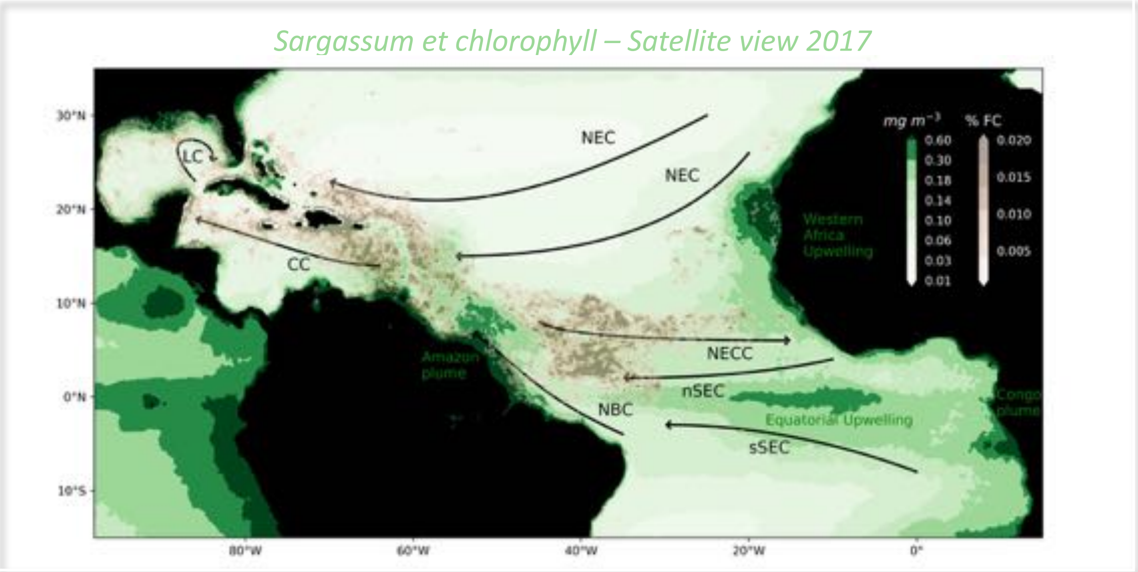
Evolution of the riverine nutrient export to the Tropical Atlantic over the last 15 years:

Is there a link with Sargassum proliferation?

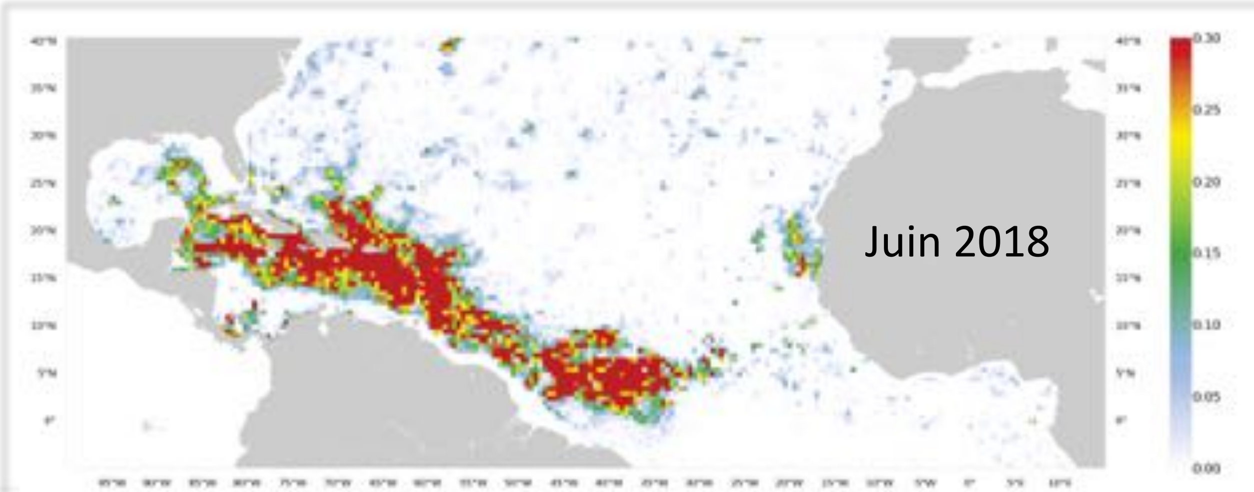


Julien Jouanno
IRD-LEGOS, Toulouse

with L. Berline, R. Benshila, J-S. Moquet, M.H. Radenac, C.K. Tchamabi, G. Morvan, R. Sosa, T. Thibaut, F. Diaz, W. Podlejski, T. Changeux, F. Menard, C. Chevalier, A. Soulie, J-M. Martinez, Hybam Team,…

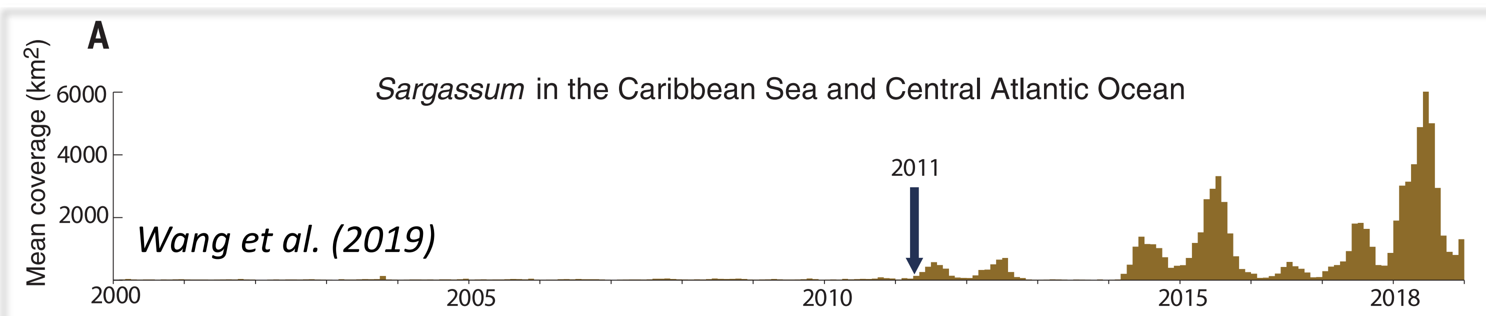
Context

A large scale phenomenon



MODIS Sargassum observations – SAREDA/CNES (Berline et al. 2021)

Large interannual fluctuations in the *Sargassum* biomass



Wang et al. (2019)

Context

Seasonality

- Transport and growth from the **central Tropical Atlantic**
- **Key role of the ITCZ area** (maintenance of a pool of Sargassum)
  Wang et al. 2019, Johns et al. 2020, Berline et al 2020

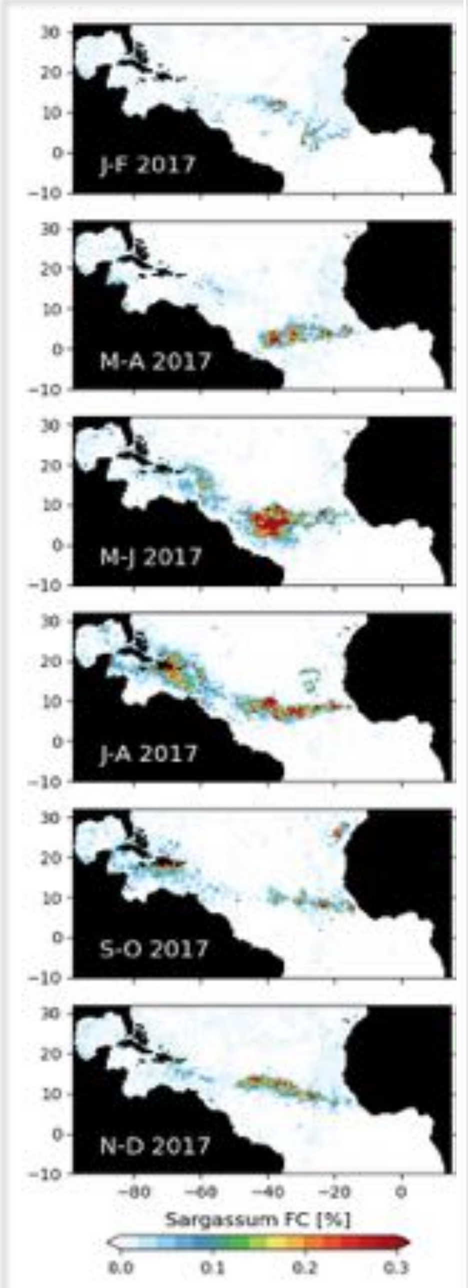
Few certainties

Regime shift from 2011

- Warm surface T° in 2010 *Djakoure et al. 2017*
- Transport anomaly in 2010 NAO-- *Johns et al. 2020*
- Amazon nutrients inputs *Wang et al. 2019, Djakoure et al. 2017*

Interannual variability

- Amazon *Wang et al. 2019*
- Dust (Iron fertilization) *Wang et al. 2019*
- Upper ocean dynamics (upwelling, turbulence, wind) *Johns et al. 2020*



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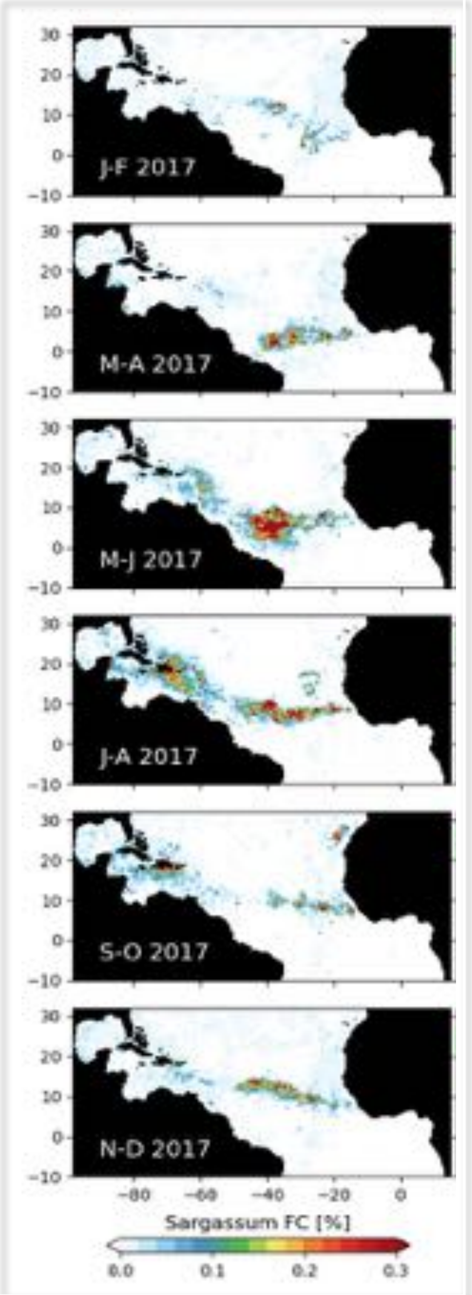


Contribution of the Amazon

ECOLOGY · 04 JULY 2019 **nature**

Huge algal mat spanning an ocean is visible from space

Deforestation in the Amazon has helped to fuel the growth of a seaweed blanket that exceeded 20 million tonnes in 2018.

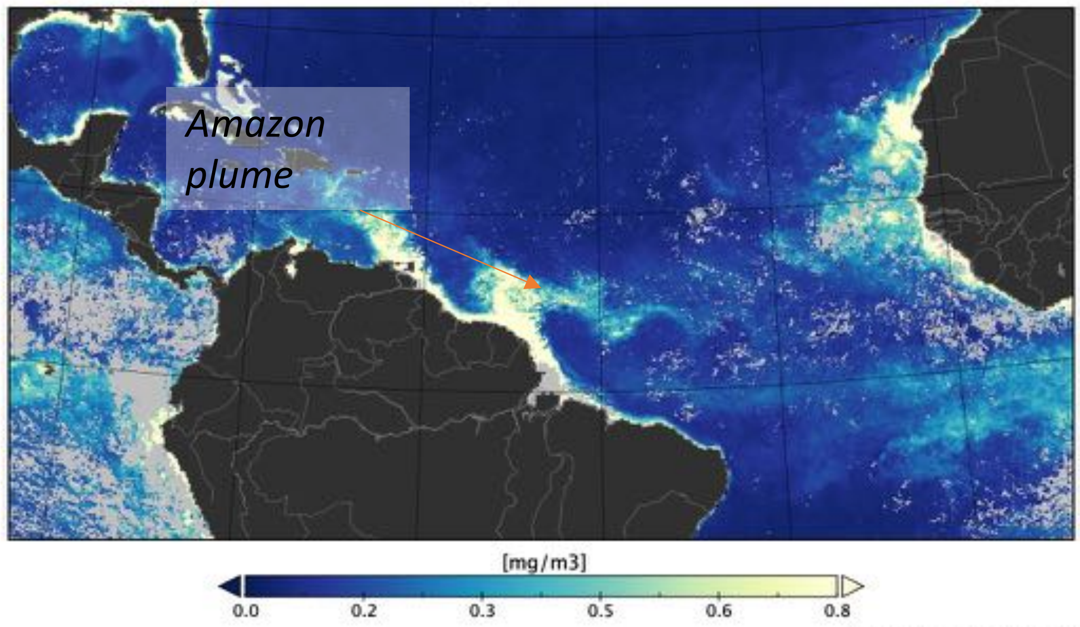
Science

The team thinks those years of high nutrient outflows may have helped to trigger the growth of *Sargassum* in a part of the ocean where it had never proliferated before.

WIKIPÉDIA

Recent studies have found three likely drivers of nutrient influx linked to increasing *Sargassum* biomass: an increase in nutrient output from the Amazon River, increased nutrients in the Gulf of Mexico, and coastal upwelling off the West African Coast which transfers deep nutrient-rich waters to the upper water column where sargassum resides

Contribution of the Amazon



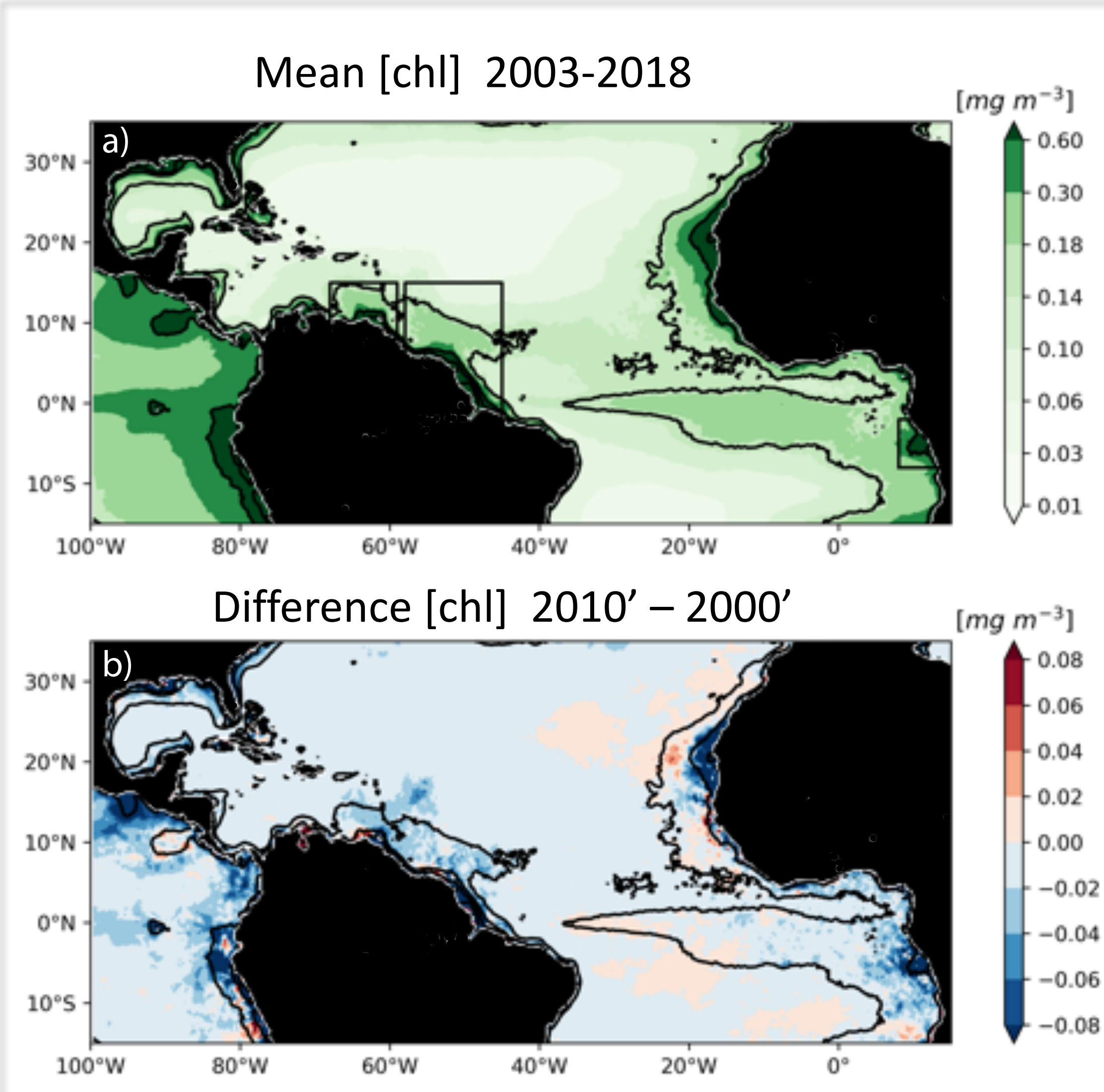
Satellite image of surface chl-a
(proxy for the phytoplancton activity)

- **20%** of the world river discharge
- **Large scale impact** on the productivity of the Tropical Atlantic
- **Strong anthropic pressure** on the Amazon basin(deforestation, intensive agriculture, urbanization, massive construction of dams)

Contribution of the Amazon

Result I
no increase in phytoplanktonic productivity in the plumes over the last 20 years

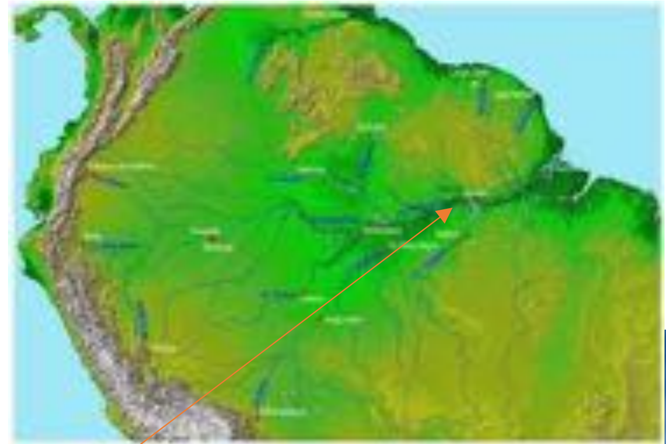
Not consistent with the assumption of fertilization by rivers



Contribution of the Amazon

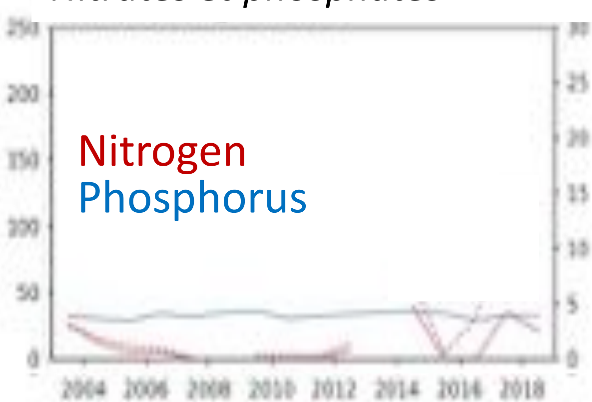
Result II

No massive increase in nitrogen and phosphorus inputs in the last 20 years

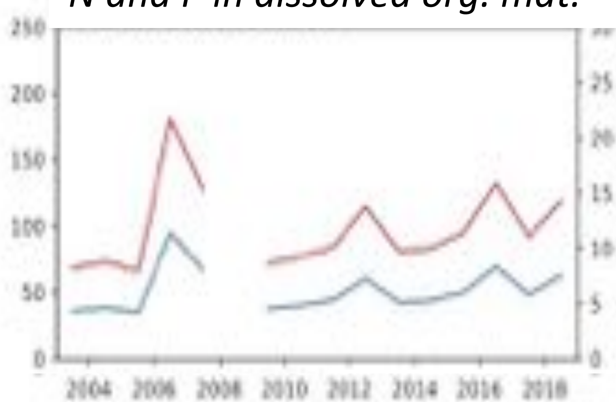


Nutrient flows measured monthly in Obidos since 2003 by the ORE HYBAM Observatory (IRD)

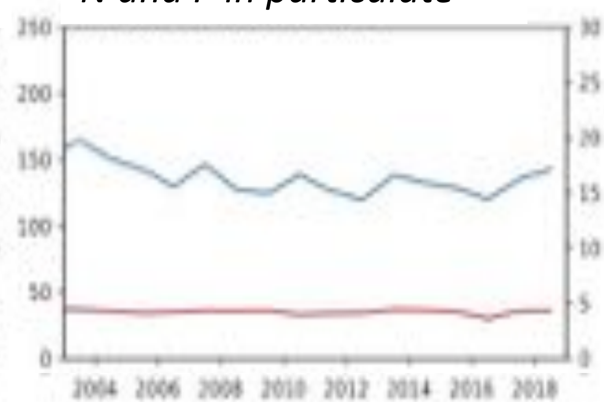
Nitrates et phosphates



N and P in dissolved org. mat.



N and P in particulate



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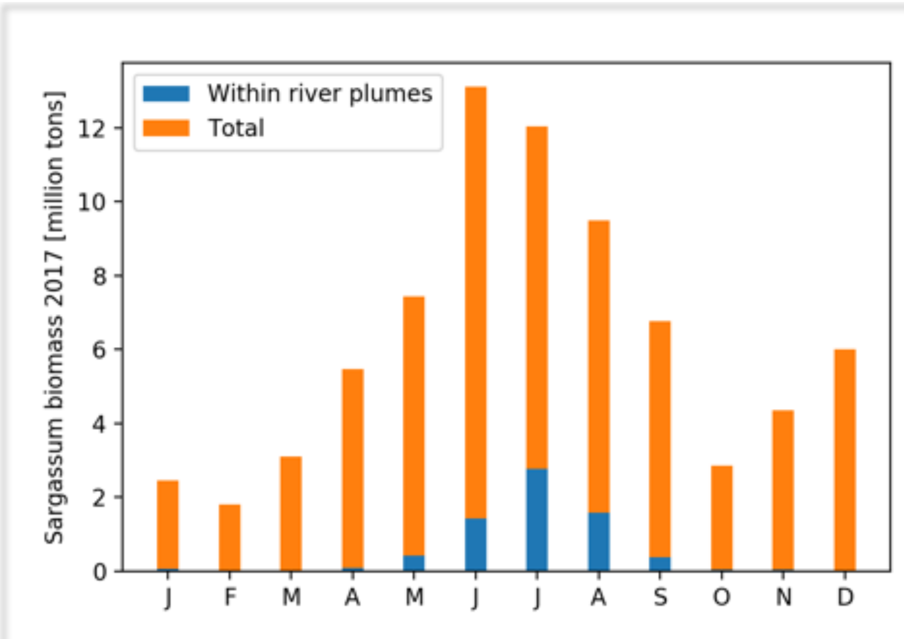
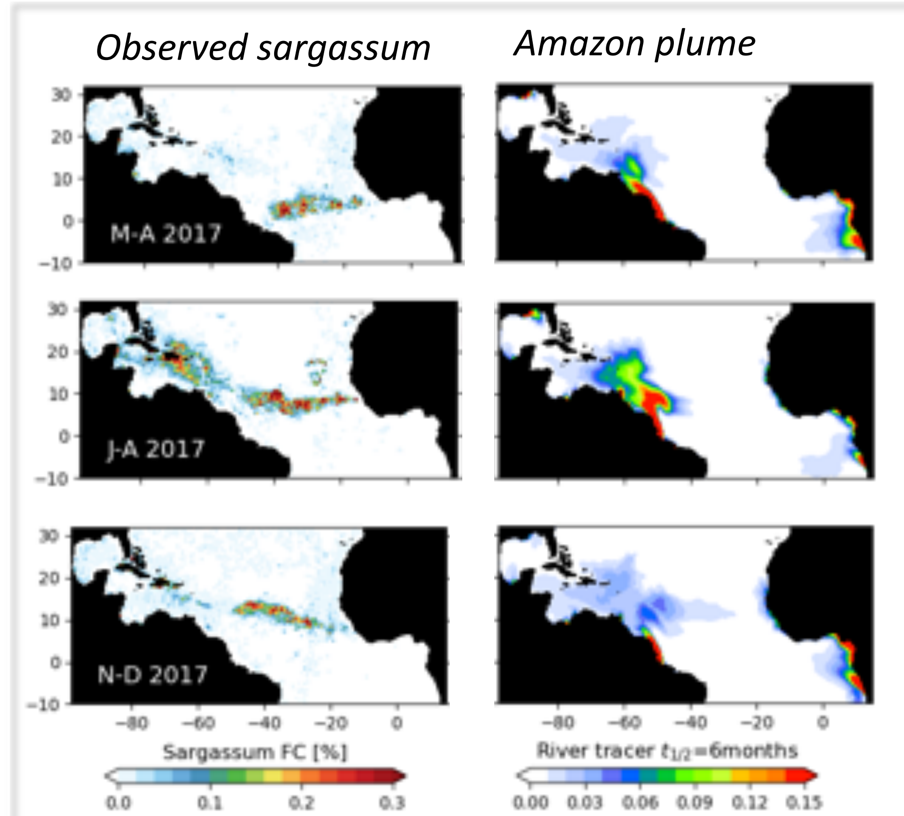
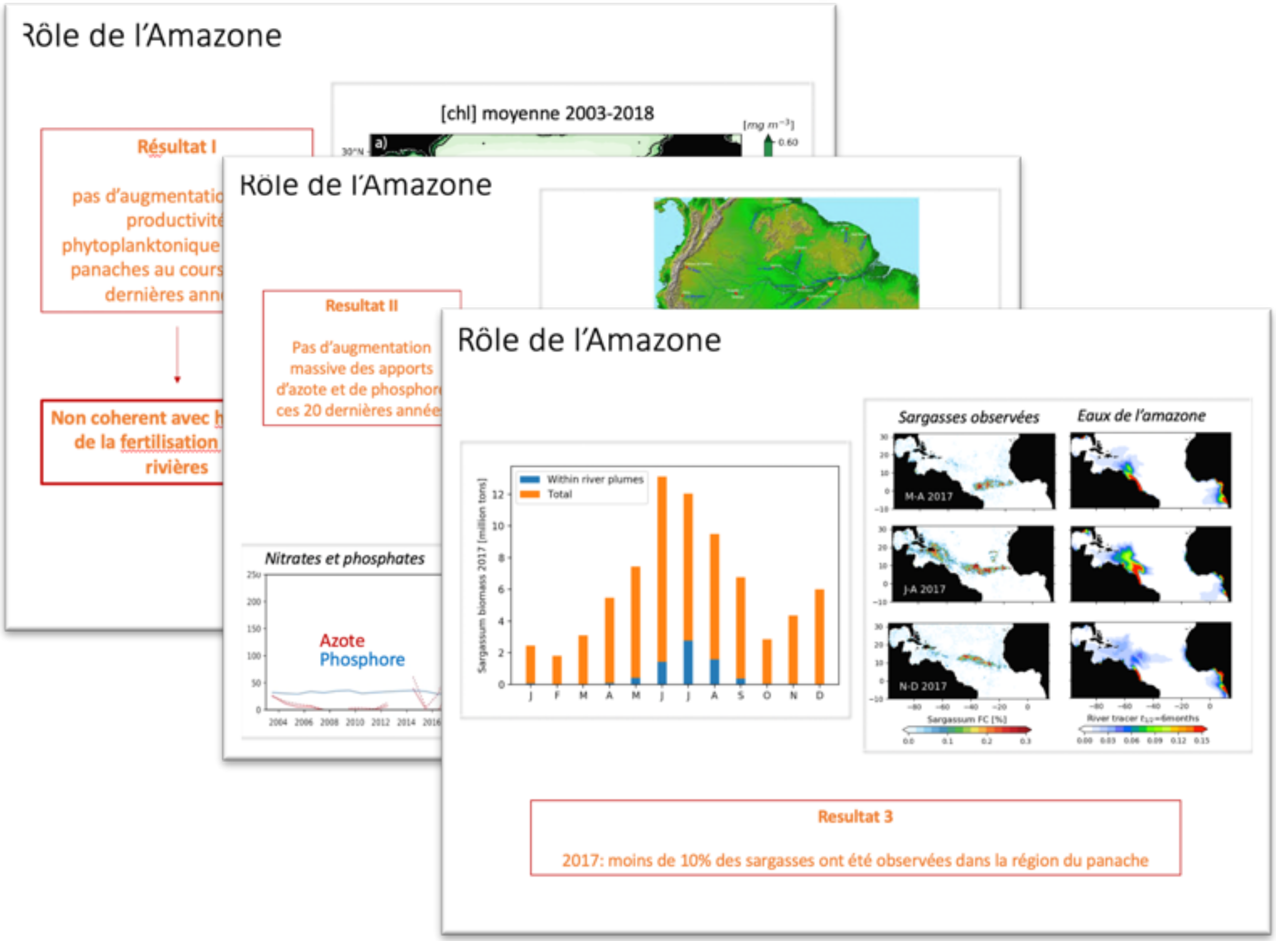




Result 3

2017: less than 10% of sargassum was observed in the plume area



These results are not consistent with the assumption that fertilization by rivers would play a key role on the different aspects of the proliferation (triggering, maintenance, year-to-year variability)

Observation

↓

Modelling

But criticisms can be made of each of these results:

- difficulty of the ocean colour algorithms to identify productivity in the plumes
- varying lability of the different nutrient inputs from the rivers
- different growth dynamics between phytopankton and *Sargassum*
- Obidos hydrological station far from the mouth
- etc…

Modelling strategy

Key ingredients to represent the distribution of Sargassum

Transport
currents, wave drift, windage

Growth
irradiance, T° , macronutrients (N,P), nutrients stored in the tissues

Mortality
grazing, Langmuir, stranding

Equation and parametrization

$$\frac{\partial C}{\partial t} = U_C - \phi_C$$

$$\frac{\partial N}{\partial t} = U_N - \phi_N$$

$$\frac{\partial P}{\partial t} = U_P - \phi_P$$

$$f(T) = e^{-\frac{1}{2}\left(\frac{T-Topt}{T_x-T}\right)^2}$$

$$f(I) = \frac{I}{I_{opt}} \cdot e^{\left(1-\frac{I}{I_{opt}}\right)}$$

$$f(Q_N) = \left(\frac{1-Q_{Nmin}/Q_N}{1-Q_{Nmin}/Q_{Nmax}}\right)$$

$$f(Q_P) = \left(\frac{1-Q_{Pmin}/Q_P}{1-Q_{Pmin}/Q_{Pmax}}\right)$$

$$\phi_{transport}(Nutrient) = -U \cdot \frac{\partial Nutrient}{\partial x} - V \cdot \frac{\partial Nutrient}{\partial y}$$

$$K_h \cdot \nabla_h^2 Nutrient,$$

Numerical resolution

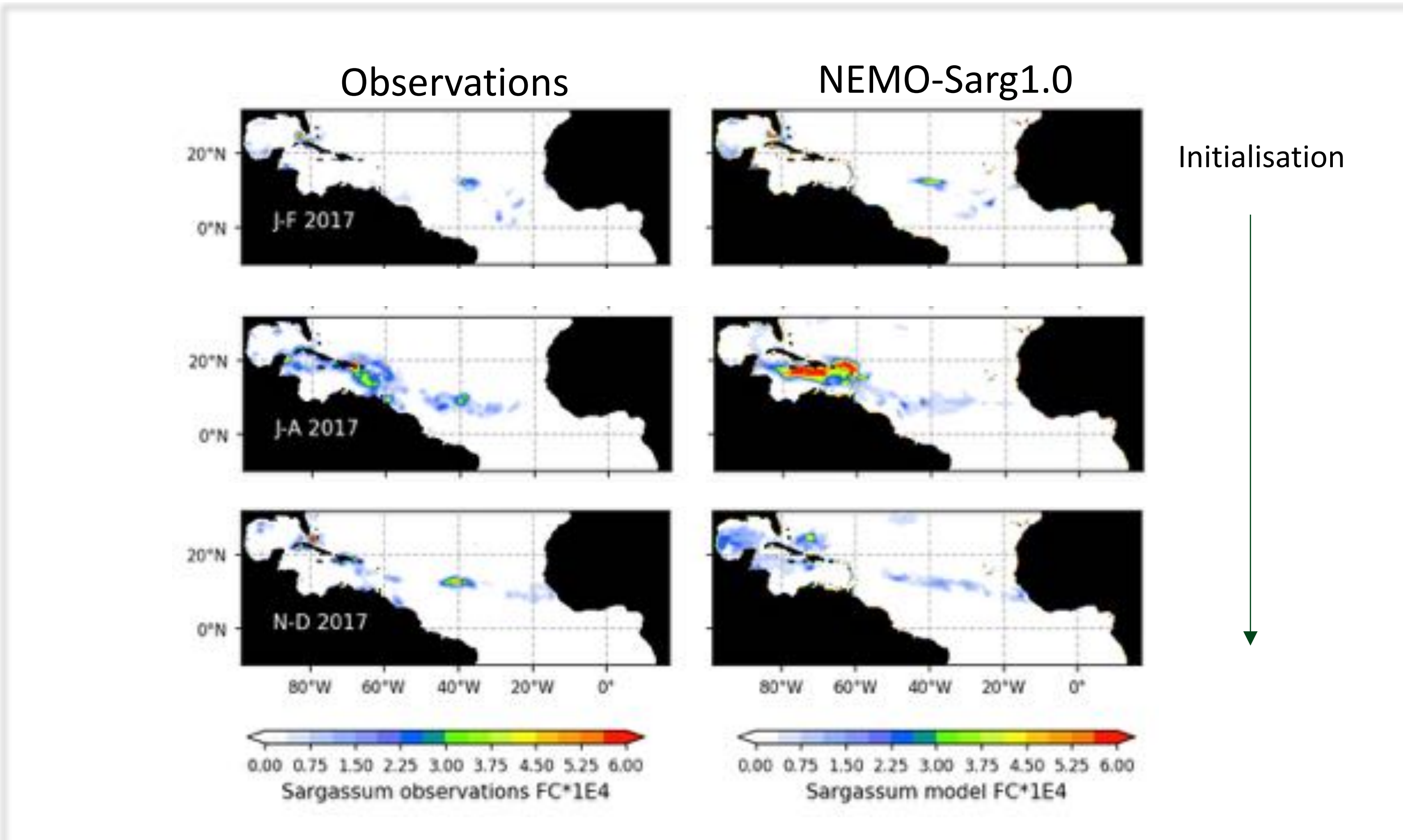
Numerical code NEMO-Sarg1.0
Jouanno et al. GMD 2021

General Eulerian approach, Tropical Atantic, 2D – surface layer (1m depth), ¼° resolution, not feedback to the biogeochemical model

Forcing currents, T, irradience, nutrients, obtained from reanalysis and physical-biogeochemical simulations (Radenac et al. 20)

Initial conditions satellite observations of Sargassum (MODIS, Berline et al. 2020)

Modelling : example of year 2017



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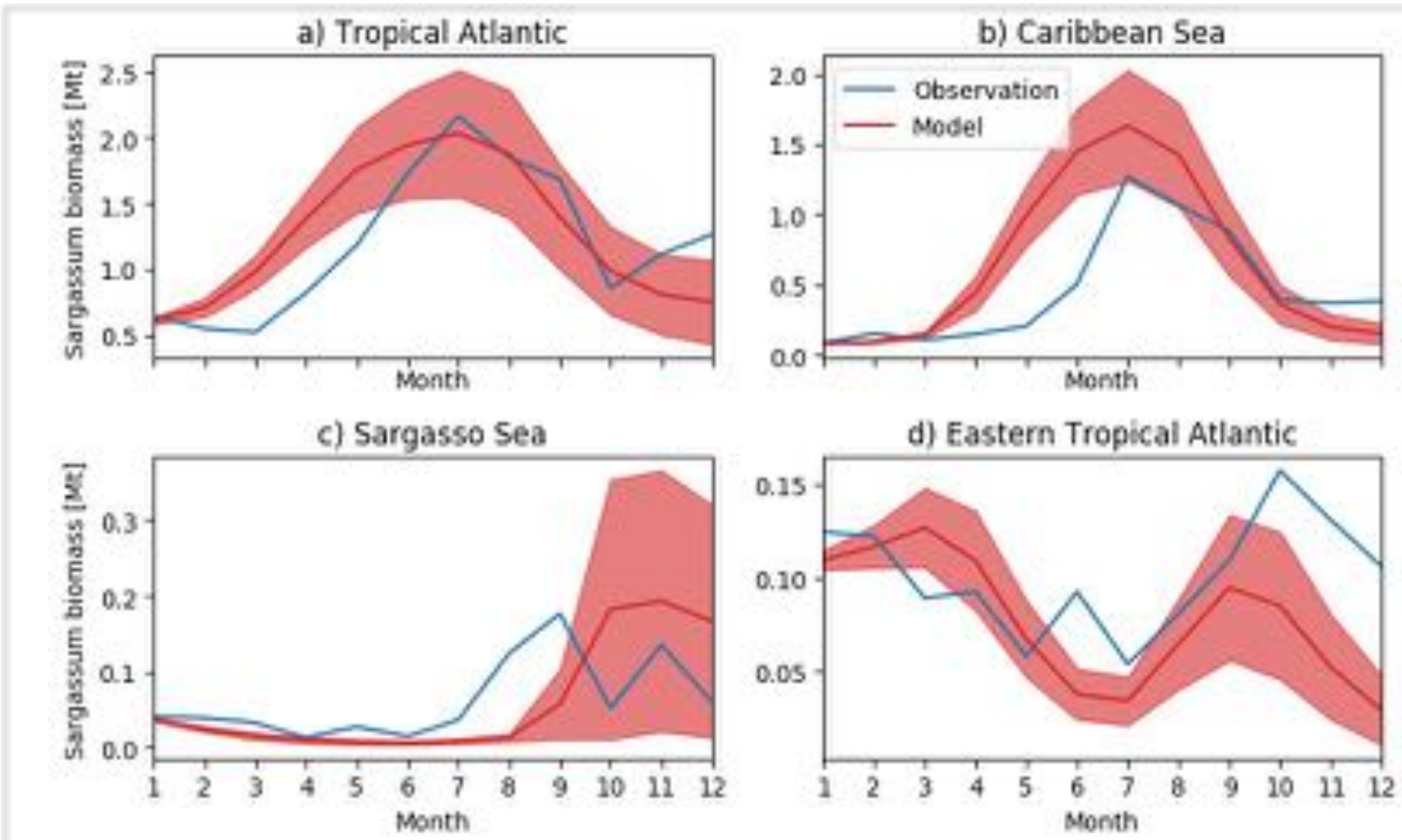

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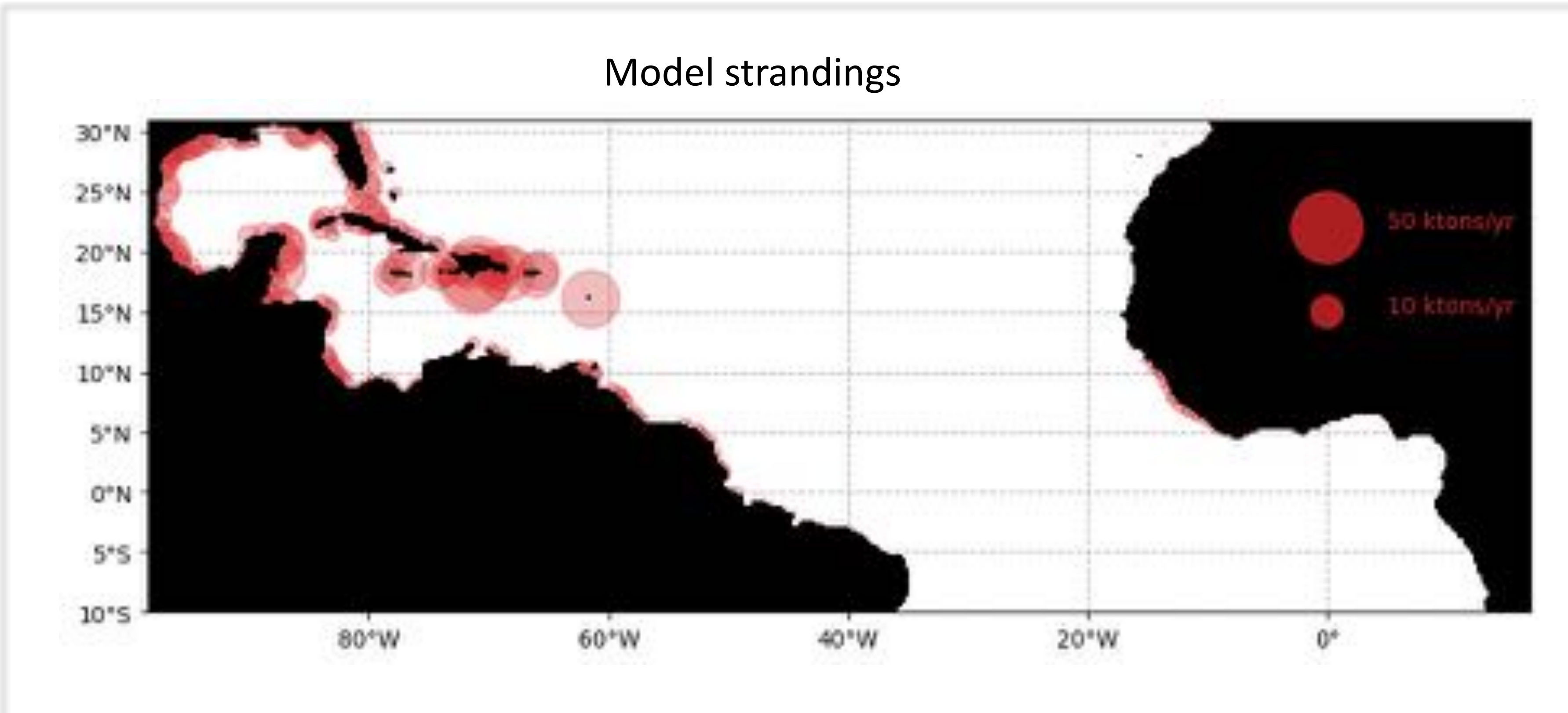
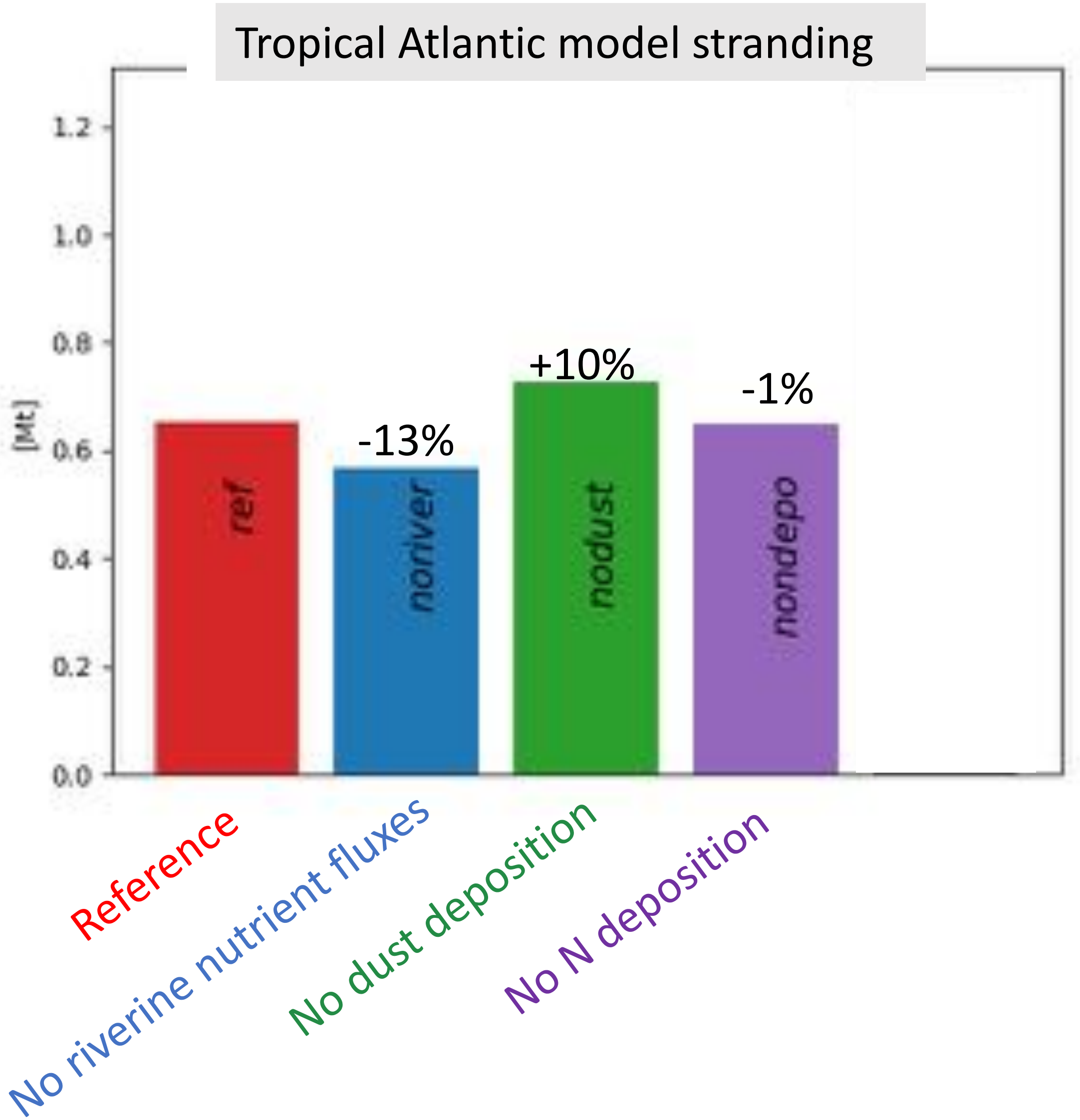


The model reproduces the known stranding areas

Modelling : sensitivity to environmental forcing



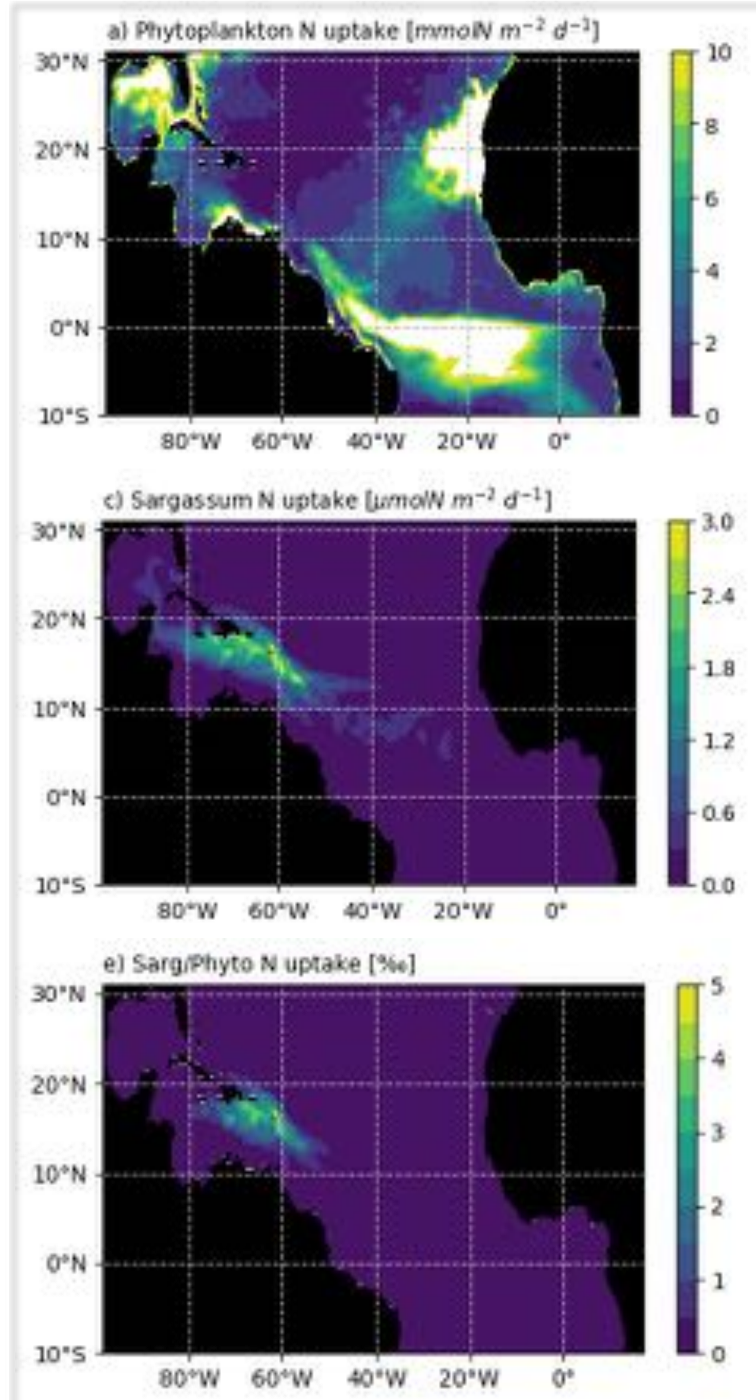
Main result : absence of riverine nutrients lead to about ~13% decrease of the strandings / biomass

Modelling

The Sargassum model is not coupled with the biogeochemical model : there is no opportunistic use / competition for nutrients between phytoplankton and sargassum

Comparison of nutrient uptake suggests this is a reasonable hypothesis :

$$\frac{\text{Sargassum N/P uptake}}{\text{Phytopankton N/P uptake}} < 5/1000$$



Conclusions

- **Role of the Amazon on the Sargassum proliferation probably overestimated**

Jouanno et al. (2021). Evolution of the riverine nutrient export to the Tropical Atlantic over the last 15 years: is there a link with Sargassum proliferation ?. Env. Res. Letters.

- **Development of a modelling platform: ability to represent seasonal distribution**

Jouanno, J, (2020). A NEMO-based model of Sargassum distribution in the Tropical Atlantic: description of the model and sensitivity analysis (NEMO-Sarg1.0), Geosci. Model Dev. Discuss, https://doi.org/10.5194/gmd-2020-383, in review, 2020.

- Processes responsible for interannual variability ?
- Seasonal forecasting ?

→ FORESEA

FOREcasting seasonal Sargassum Events in the Atlantic

https://sargassum-foresea.cnrs.fr