CHANGES IN THE ECOSYSTEM STRUCTURE OF THE ALGAE SARGASSUM IN THE TROPICAL ATLANTIC OCEAN

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WHAT IS SARGASSUM ?

- **Brown seaweed**, most of them are benthic.
- Two species of Sargassum involded are pelagic (**free floating**) : **Sargassum natans** and **Sargassum fluitans**.
- Growth: mainly **influenced** by **irradiance**, **sea temperature** and **nutrient** (nitrate, phosphate, iron, [*Gao and McKinley, 1994*])
- **Usually found** in the **Sargasso Sea** and the **Gulf of Mexico**.

Left : **Sargassum natans** and right : **Sargassum fluitans**. [Photo by *J. Francks]*

PROBLEMATIC

West Indies, Caribbean and West Africa event's since 2011 : **Unprecedented amounts and mass strandings of Sargassum.**

Negative impacts for marine ecosystems, biology, water quality, health of the population and tourism.

RECENT STUDIES **:** North Equatorial Recirculation Region of the Atlantic Ocean (**NERR**, located between the North Equatorial Counter Current and the equator) is **one new tank of Sargassum.**

2012

2013

2014

2015

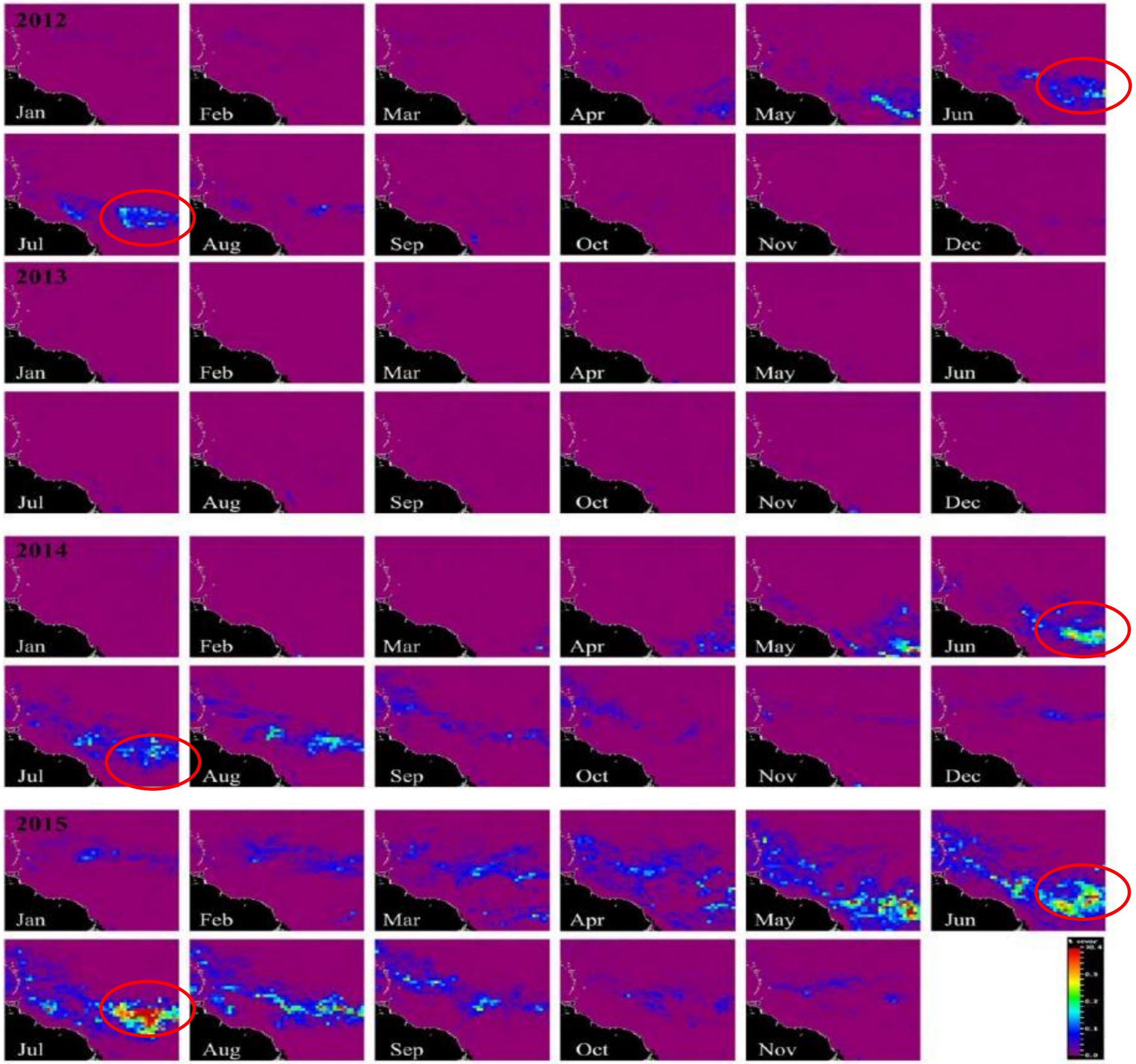


Fig1 : Monthly mean distribution maps show Sargassum area coverage (MODIS)

[Wang et Hu, 2016]

WHAT IS CAUSING THE RECENT BLOOM AND STRANDING SARGASSUM SEAWEED IN THE TROPICAL ATLANTIC OCEAN ?

IS THE NERR A NEW « TANK » OF SARGASSUM ?
IF YES, WHY?

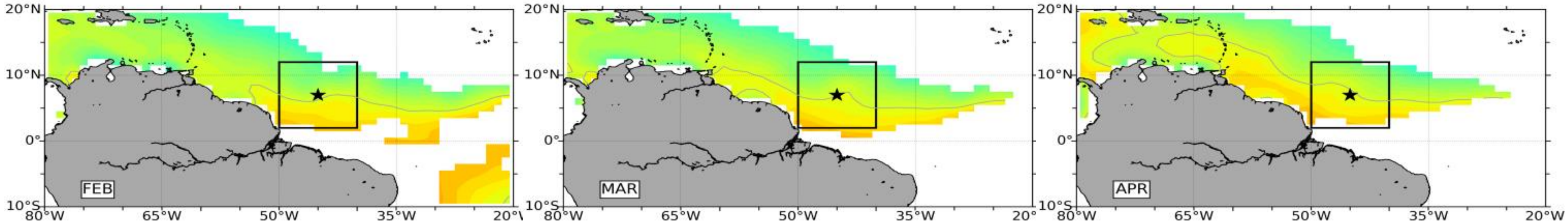
METHODOLOGY

■**Investigate climate trends or events** and their **potential feedback** on the recent bloom and mass strandings of the Sargassum.

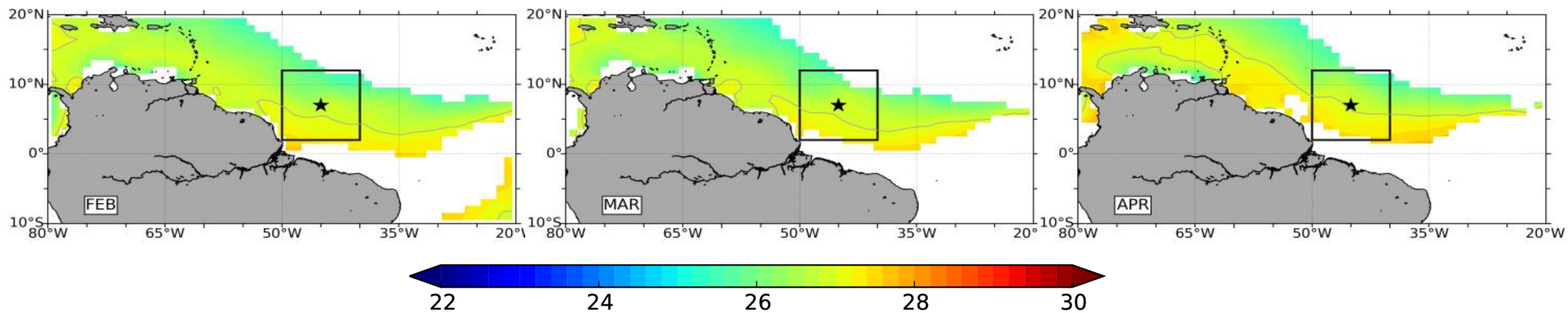
How ? By using firstly observational datasets of **hydrological parameters and seasonal climatology** of ocean conditions (ITCZ position, winds, SST, surface currents, rivers discharge, nutrients, Chlorophyll, climate indices),
that could potentially influence Sargassum production & distribution.

(atmospheric aerosols & dust not considered at this stage)

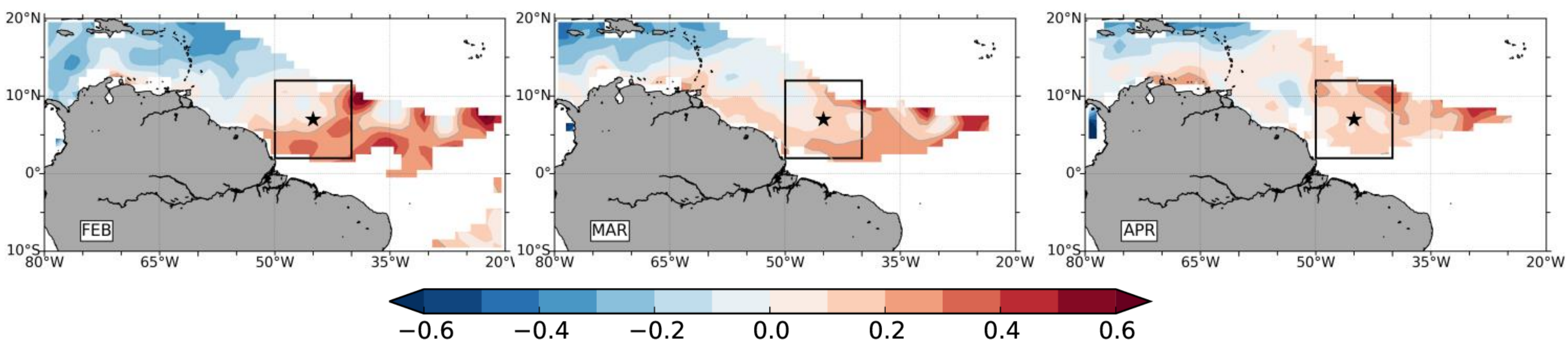
SST [°C] – YEARS NO SARGASSUM BLOOM EVENT (2006-2008-2009-2013)



SST [°C] – YEARS SARGASSUM BLOOM EVENT (2011-2012-2014-2015)



SST [°C] difference – YEARS NO SARGASSUM BLOOM minus YEARS SARGASSUM BLOOM



⇒ Sargassum in the NERR seems associated with negative SST anomalies.

Different situation in the Carribeans (but Caribbeans are not a « tank » but a stranding area).

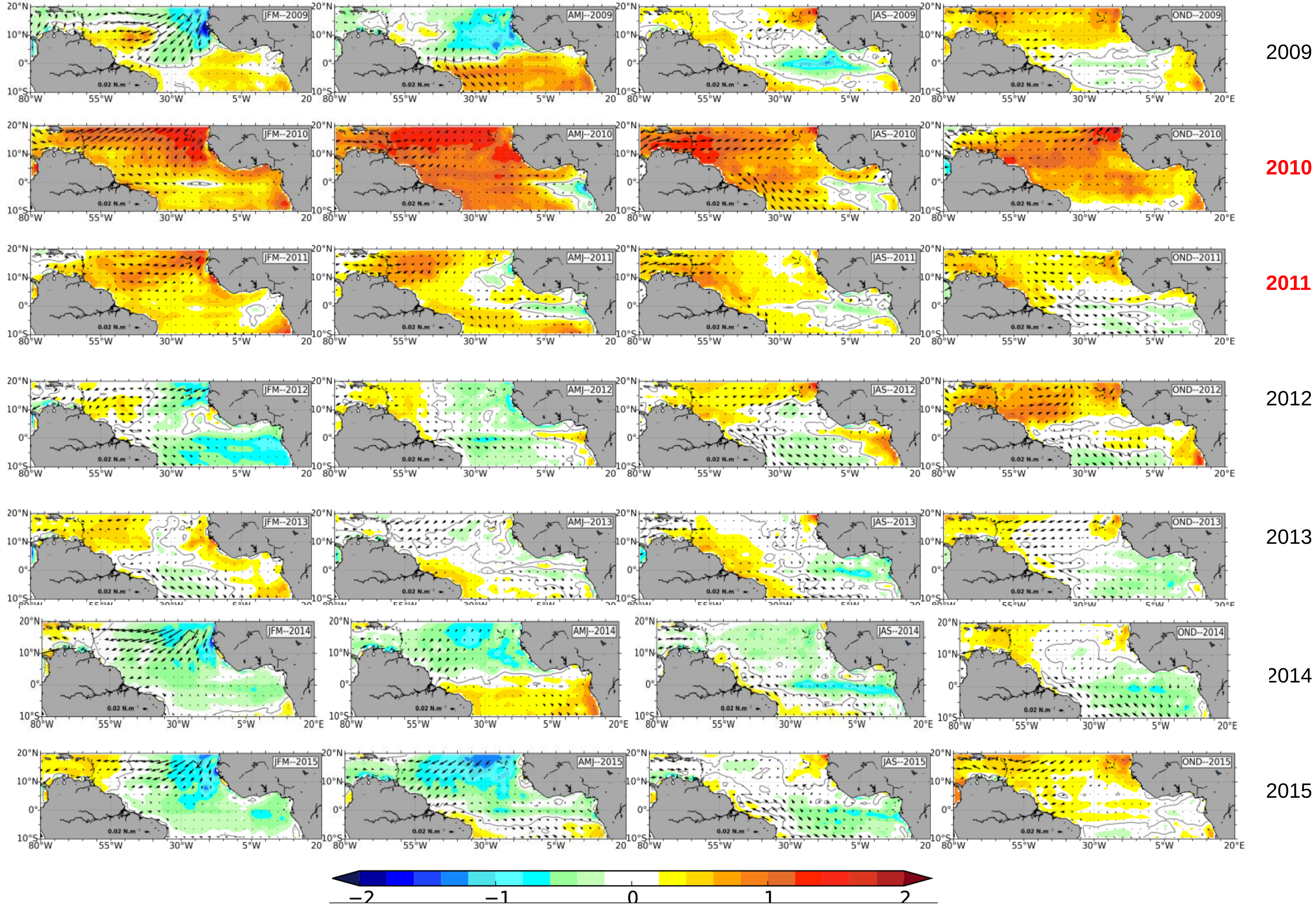
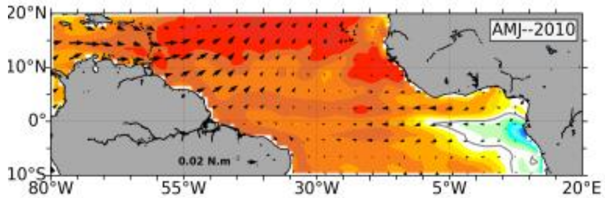
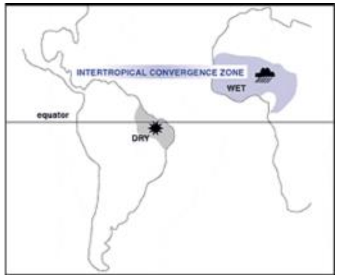


Fig 3 : Spatial distributions of seasonal SST [C] and wind stress direction anomalies [N.m] related to 1993-2015 (per three months periods). The zero isoline isotherms is represented in gray line.



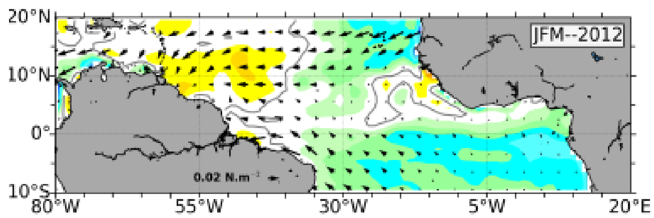
Anomalously high SSTs in 2010 and early 2011
may have induced optimal temperature
for Sargassum maximum growing in parts of the basin.

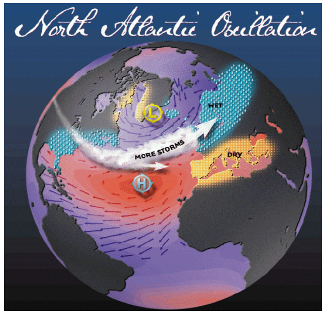
High AMO index <=>
warm SSTs



These anomalously high SSTs related to
anomalously high Atlantic Multidecadal Oscillation (AMO) index
and North Atlantic Oscillation (NAO) anomalously negative index
[Lefèvre et al., 2013, Servain et al., 2014].

NAO index << 0 <=>
warm SSTs & weak trade winds





Since 2012, cooling trend especially in the eastern basin!
⇔stronger winds ?
⇔More vertical mixing ?
⇔More subsurface nutrient ?
=> Analysis of AMO, NAO index, heat balance and subsurface nutrients variability need to be made.

SST IN THE NEW « TANK » AREA: NERR

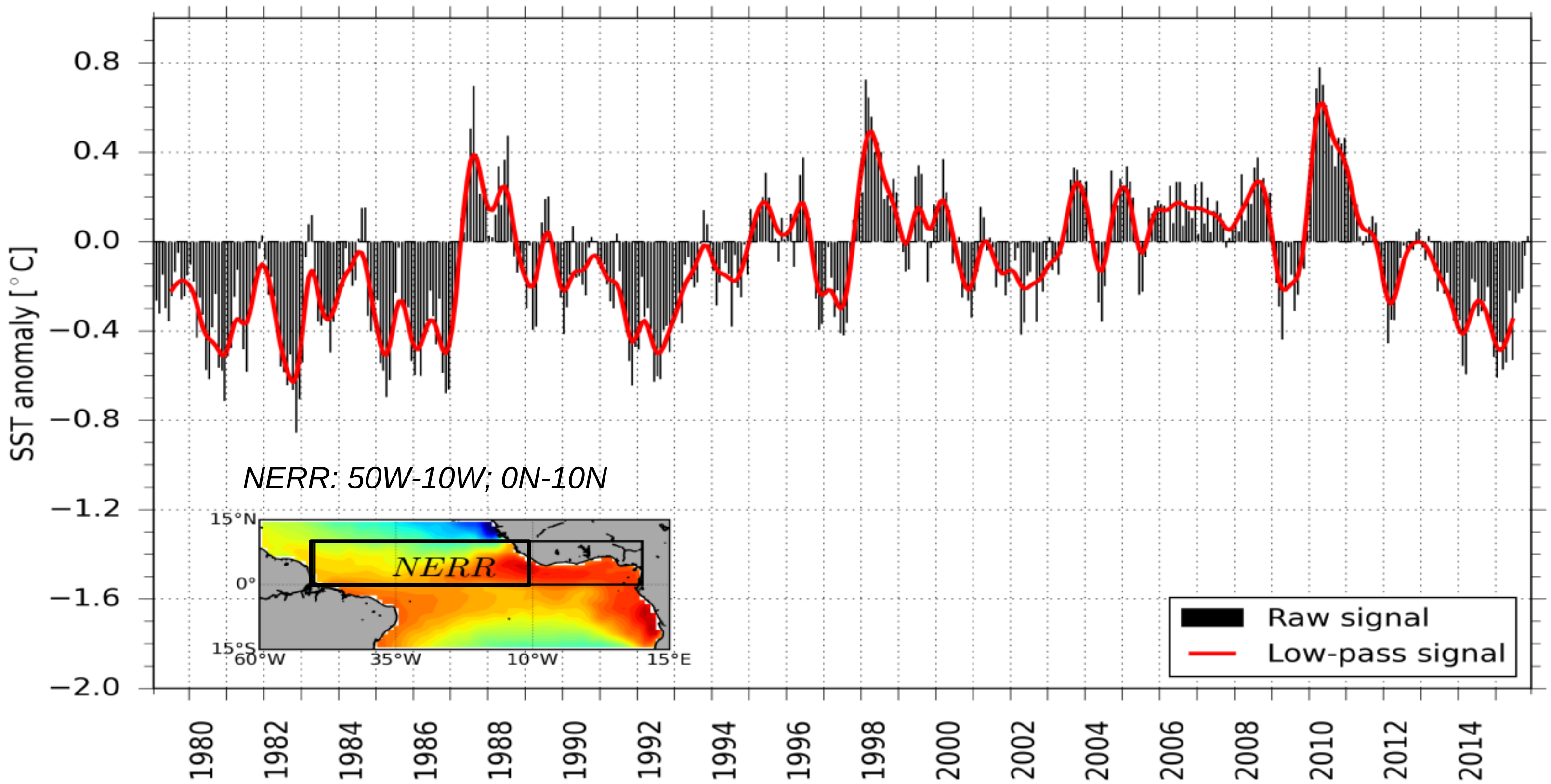
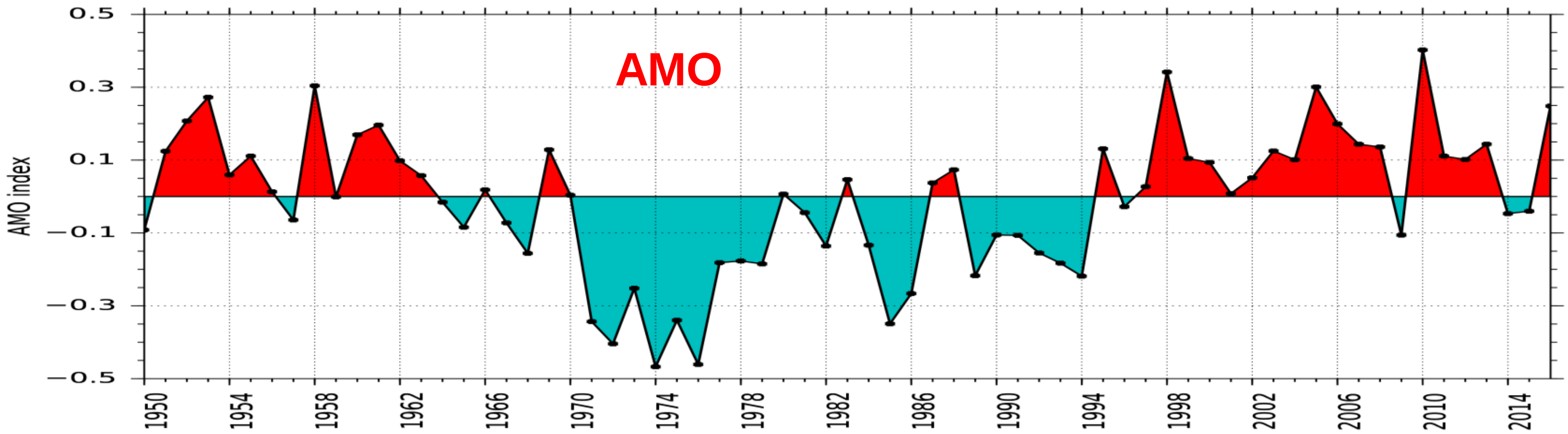


Fig 4 : SST anomalies [◦C] related to 1993 to 2015, box NERR [0◦N-10◦N; 50◦W-10◦ W] TropFlux dataset.

- 2010: High positive SST anomalies; decrease in 2011.
- 2012-2015 : Negative SST anomalies.

⇒ **Optimal weaker than usual temperatures for Sargassum growing since 2011 ?**

AMO AND NAO CLIMATE INDICES



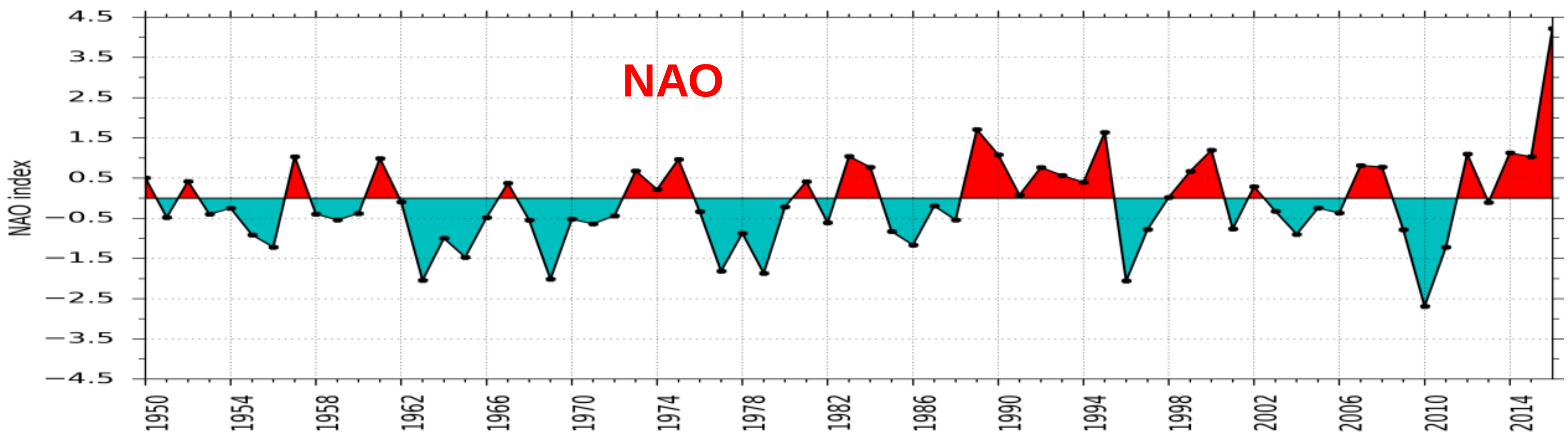


Fig 5 : Climate indices from 1950 to 2016: (top) AMO index average value from March to May and (bottom) NAO index average value from December to February [source: NOAA/AOML].

- *AMO positive phase => warmer SSTs and less precipitation in the Northeast Brazil.*
- *NAO positive phase => stronger tropical storms, cool waters and strong trade winds.*

AMO negative phase **2010-2015** *(but **2014**)* and NAO positive phase **2012-2015:**
=> cool waters & strong trade winds may induce more African dust onto the ocean, more vertical mixing, more subsurface nutrients.

ITCZ position at 30°W

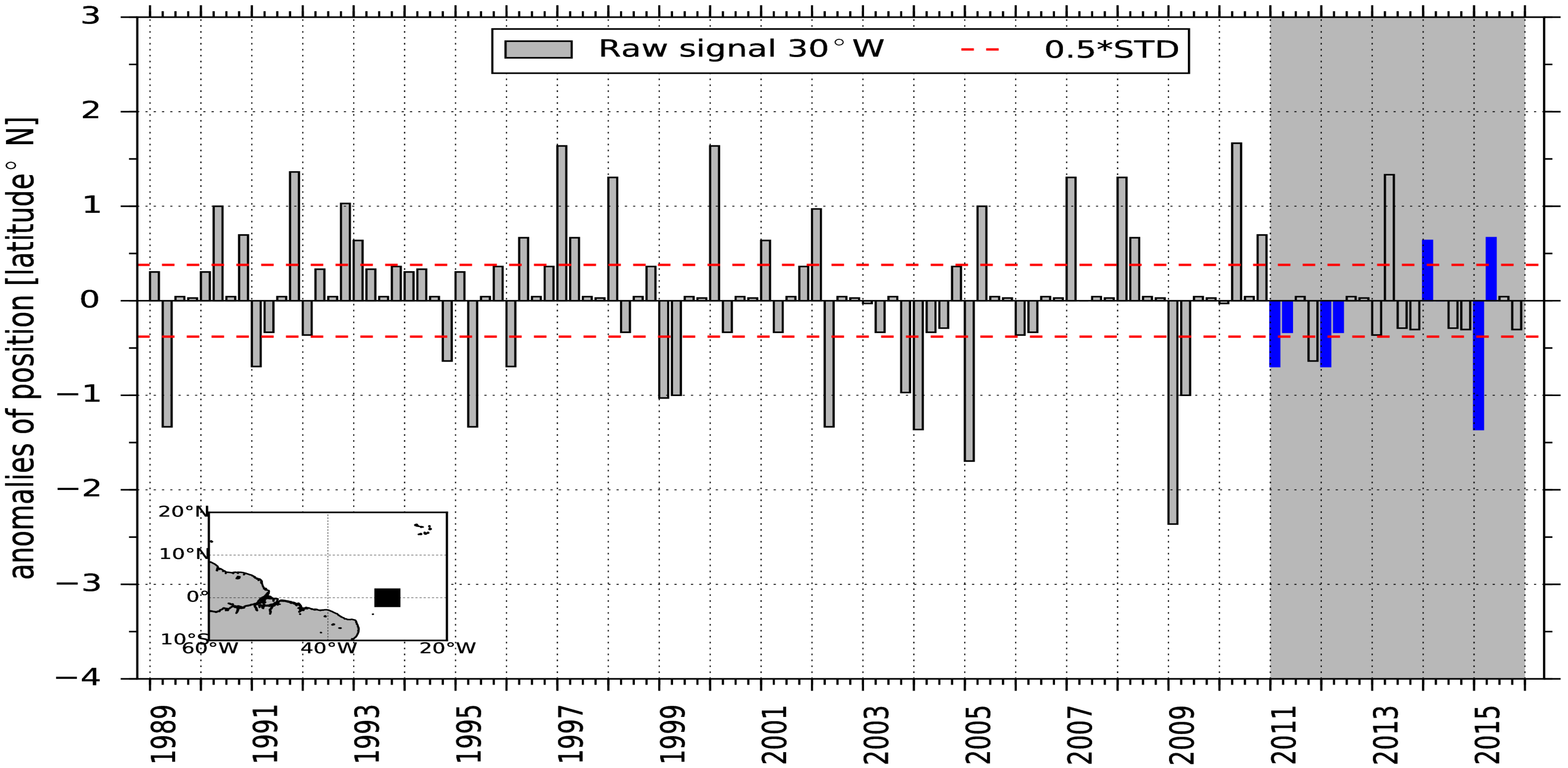
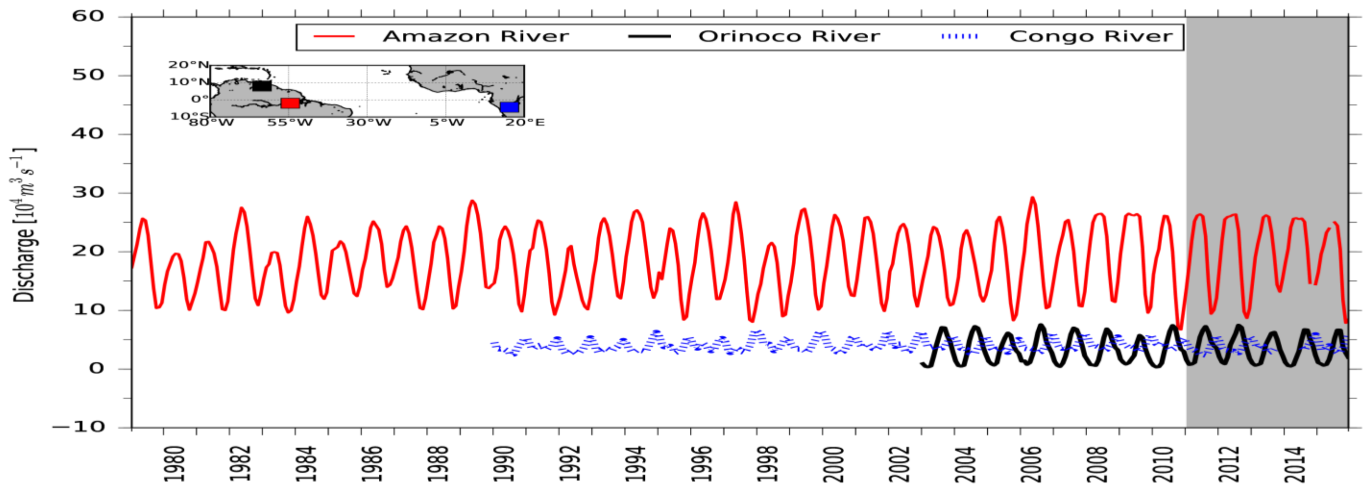


Fig 6 : Seasonal anomaly in the ITCZ position at 30°W, related to 1993-2015, from TropFlux dataset. The gray shaded band represents the years since when Sargassum events occur. JFM and AMM of Sargassum events 2011, 2012, 2014, 2015 are represented in blue.

- **ITCZ position**: latitude where the **meridional component of the wind**, at the **center of the Atlantic basin** (along 30°W), is **equal to zero** [*Hounsou-gbo et al, 2015*].

- **Negative phase** : ITCZ is located in its southernmost extent ⇔ increase of precipitation in the Northeastern Brazil & Amazon basin (ex : 2011, 2012, and 2015).

RIVERS DISCHARGE



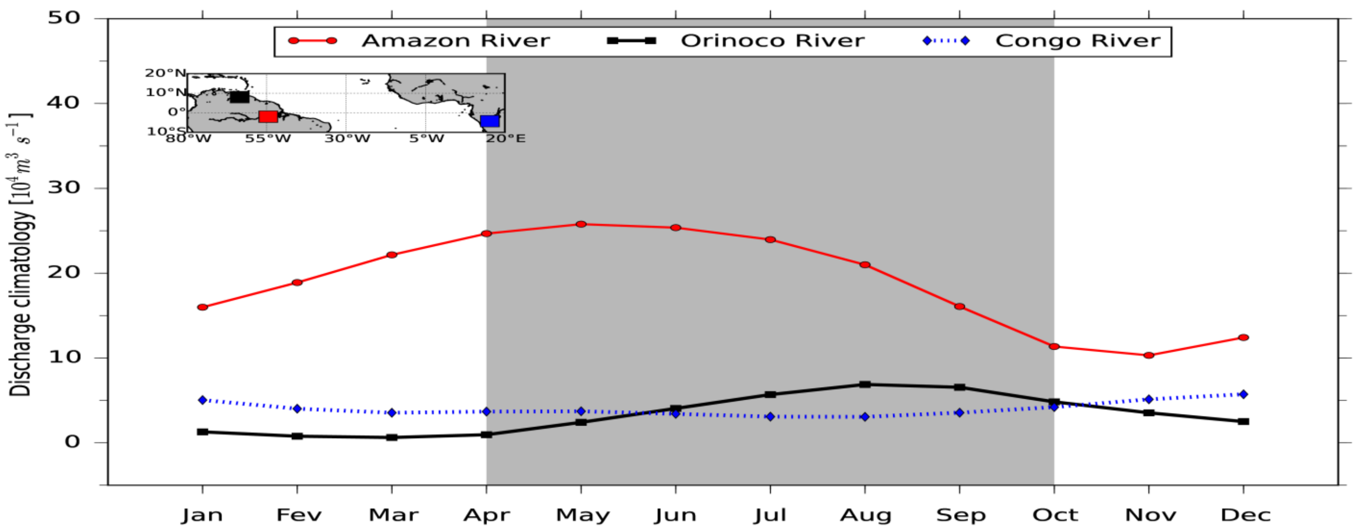


Fig 7 : Monthly mean and climatology of rivers discharge, related to 1993-2015, from HYBAM dataset. The gray shaded band represents the years and the months of Sargassum events.

- Amazon discharge : more variability for the minima than the maxima (2011-2015).

- Sargassum blooms and strandings occur during high flow & decreasing flow periods
    - of the Amazon River.

AMAZON RIVER DISCHARGE

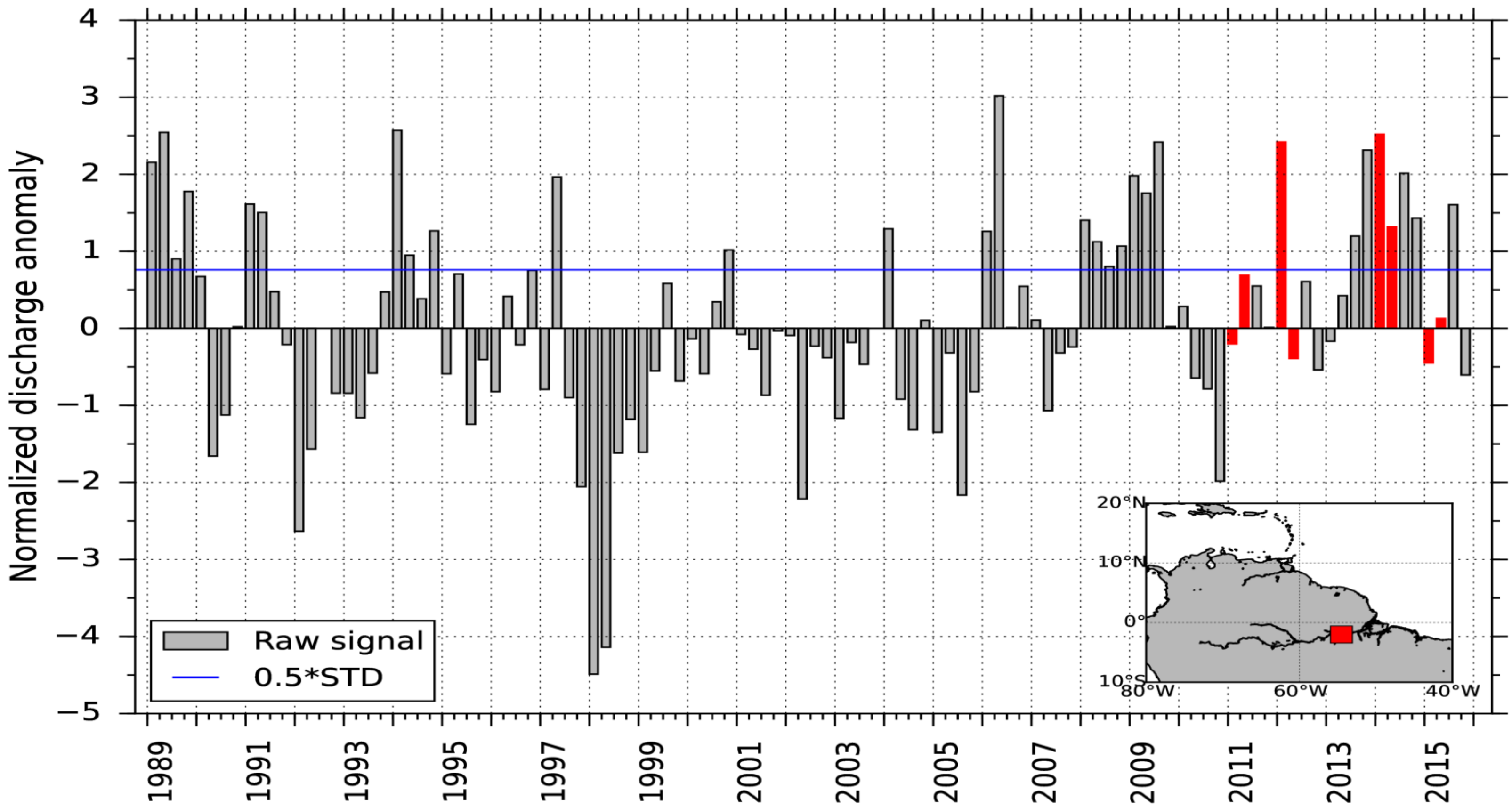
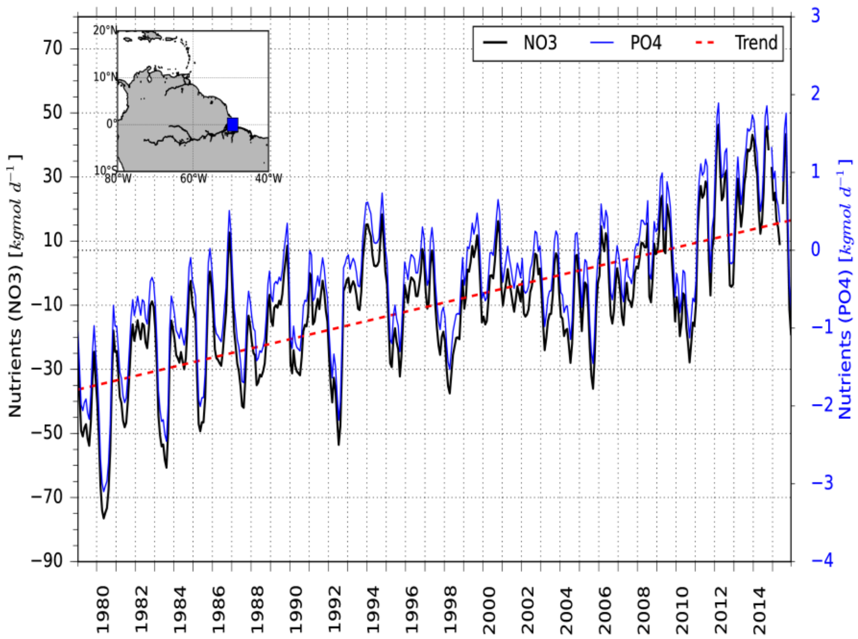


Fig 8 : Seasonal anomalies of Amazon River discharge, related to 1993-2015.
JFM and AMM of Sargassum events 2011, 2012, 2014, 2015 are represented in red.

⇒ **No apparent direct link between Amazon River discharge and Sargassum bloom (2011, 2015)**

BUT: possible links with terrestrial discharge from the Amazon?

AMAZON RIVER NUTRIENTS FLUX



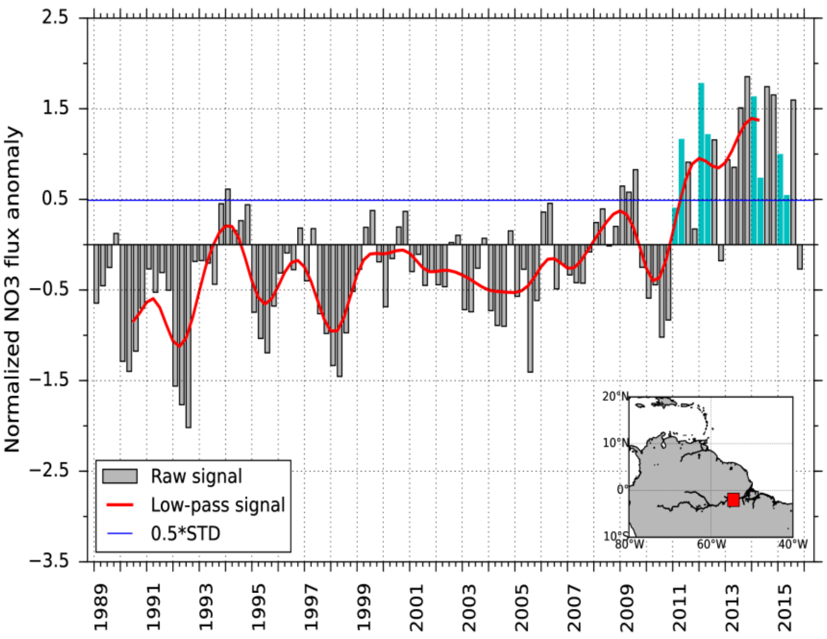


Fig 9 : Nutrients flux anomalies, related to 1993-2015. JFM and AMM of Sargassum events 2011, 2012, 2014, 2015 are represented in cyan (right).

- Regressar linear model based on surface run-off and density population *[Araujo et al., 2014].*
- NO3 : limiting nutrient, high anomalies since 2011 (weak relative minima in 2013).

=> Link between NO3, PO4 inputs and Sargassum bloom.

CONGO RIVER NO3 FLUX

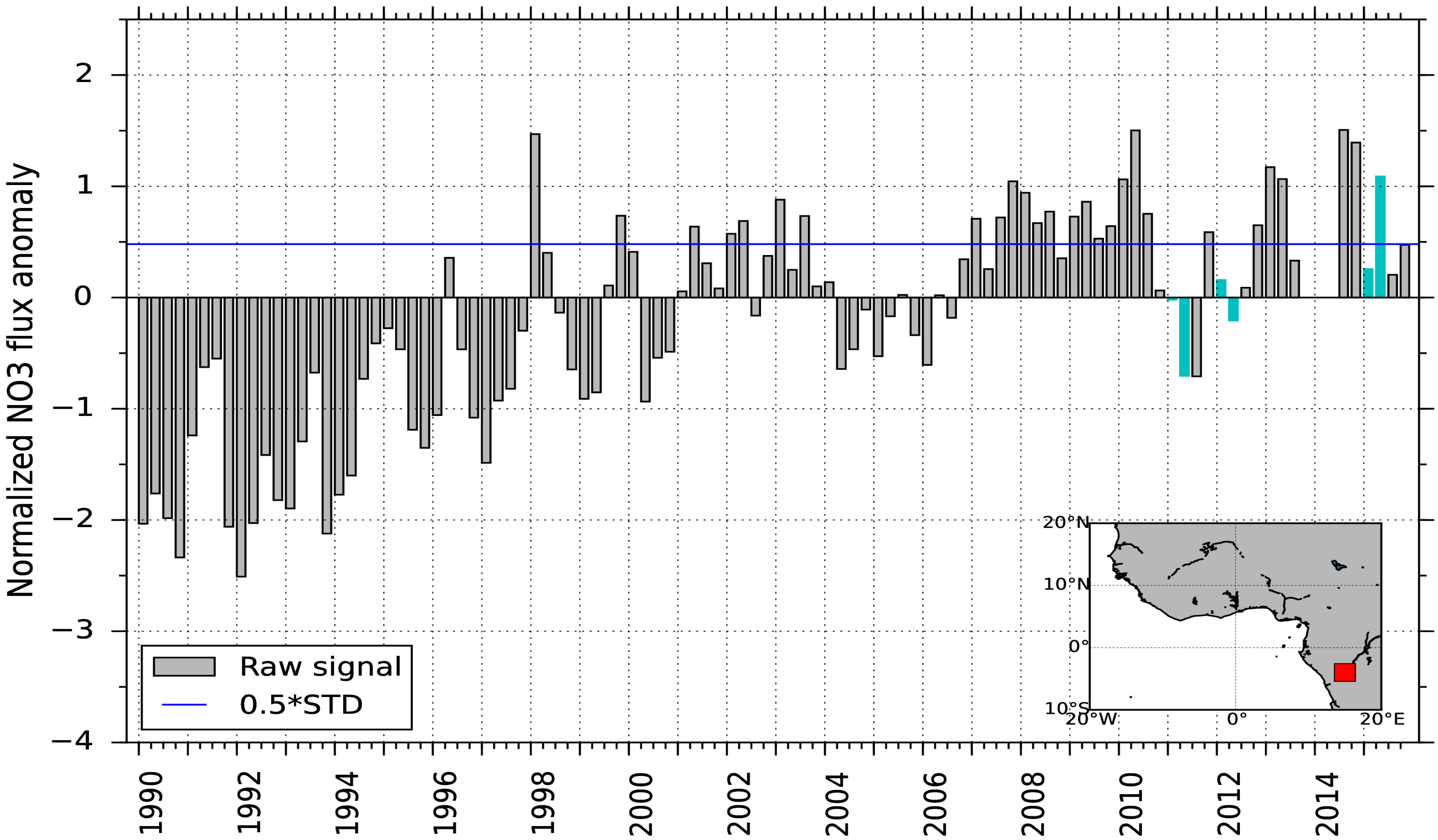


Fig 10 : Nutrients flux anomalies, related to 1993-2015. JFM and AMM of Sargassum events 2011, 2012, 2014, 2015 are represented in cyan.

=> No apparent direct link between NO3 inputs from Congo river and Sargassum bloom.

EQUATORIAL DIVERGENCE

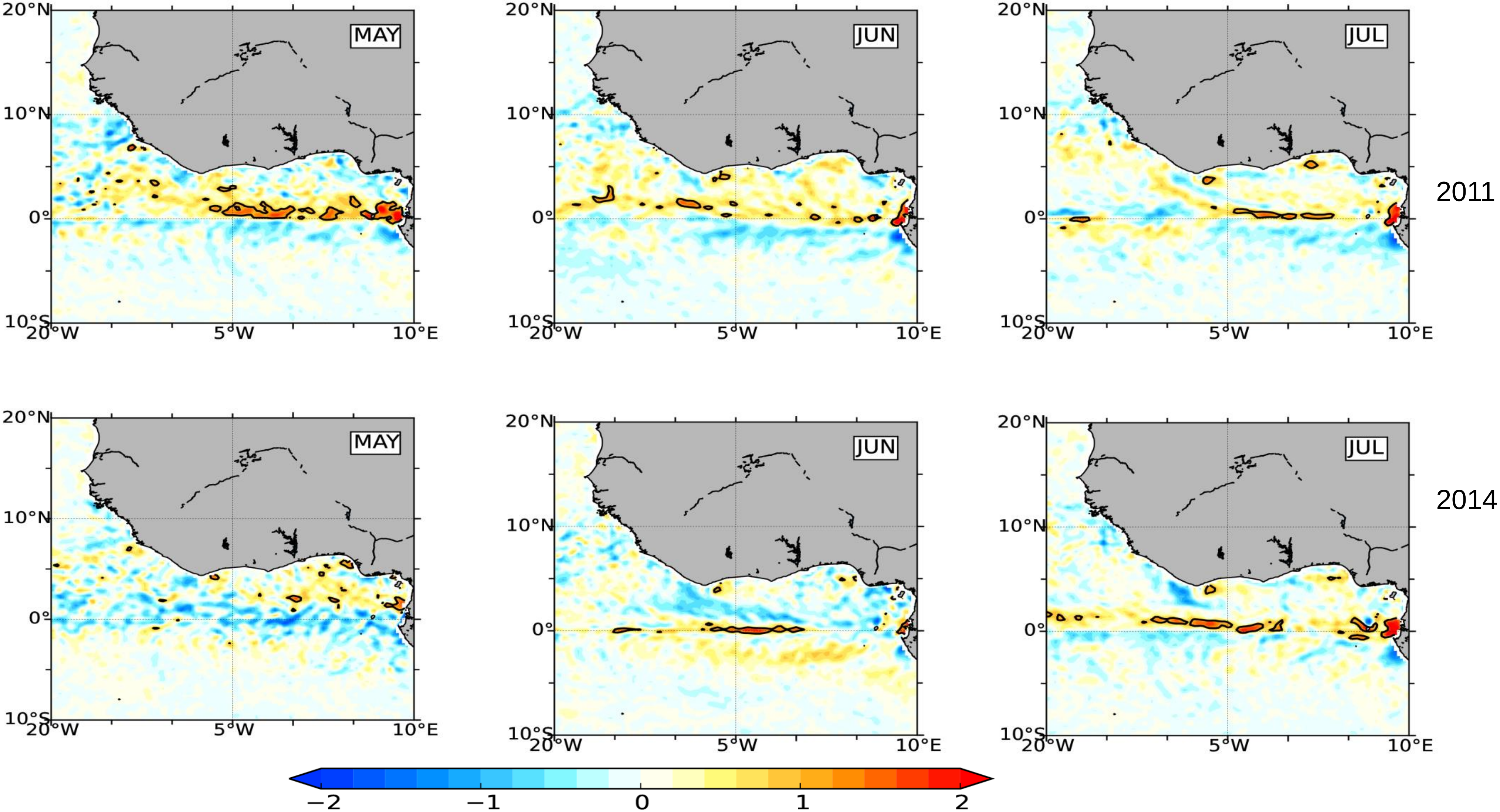


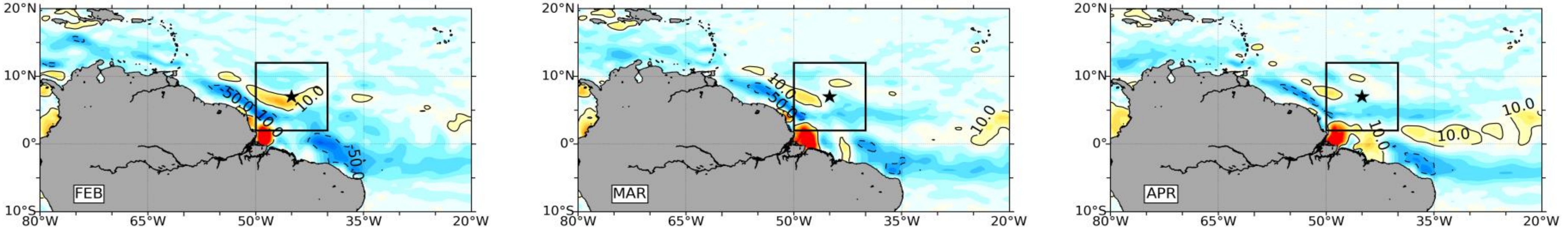
Fig 11: Equatorial divergence anomalies [m/d] from May to July: (top) 2011 and (bottom) 2014. Isolines 1m/d are represented by the black solid lines. Vertical vel. calculated from the GEKCO Ekman currents (Sudre et al., 2013)

Anomalously high value of vertical velocities in 2011 and 2014 that may suggest more nutrients inputs from the subsurface in addition to nutrients from Amazon rivers.

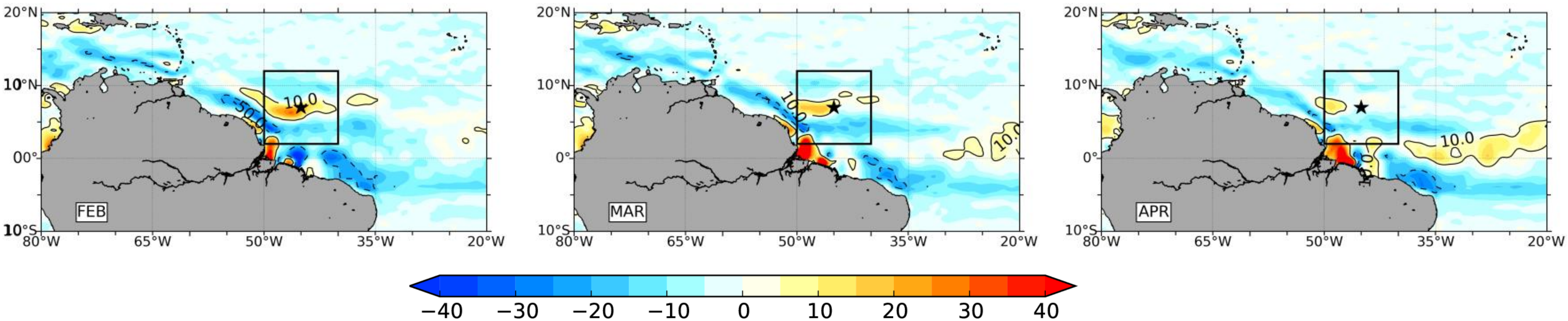
(to be confirmed with other numerical experiments with nutrients)

Checking the potential zonal currents (SEC & NECC) shear amplitude :

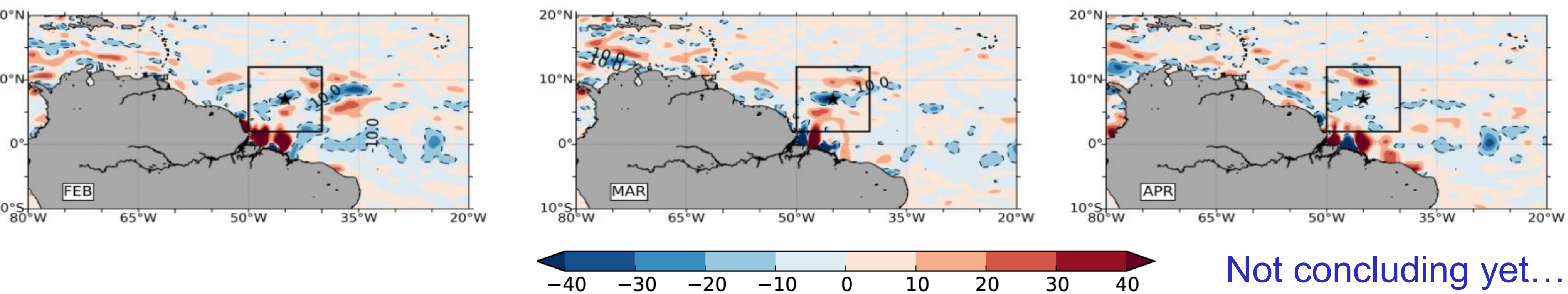
Anomaly of zonal velocity [cm s^{-1}] –NO SARGASSUM BLOOM EVENT (2006-2008-2009-2013)



Anomaly of zonal velocity [cm s^{-1}] – SARGASSUM BLOOM EVENT (2011-2012-2014-2015)



Anomaly of zonal velocity difference [cm s^{-1}] – NO SARGASSUM minus SARGASSUM BLOOM



Not concluding yet…

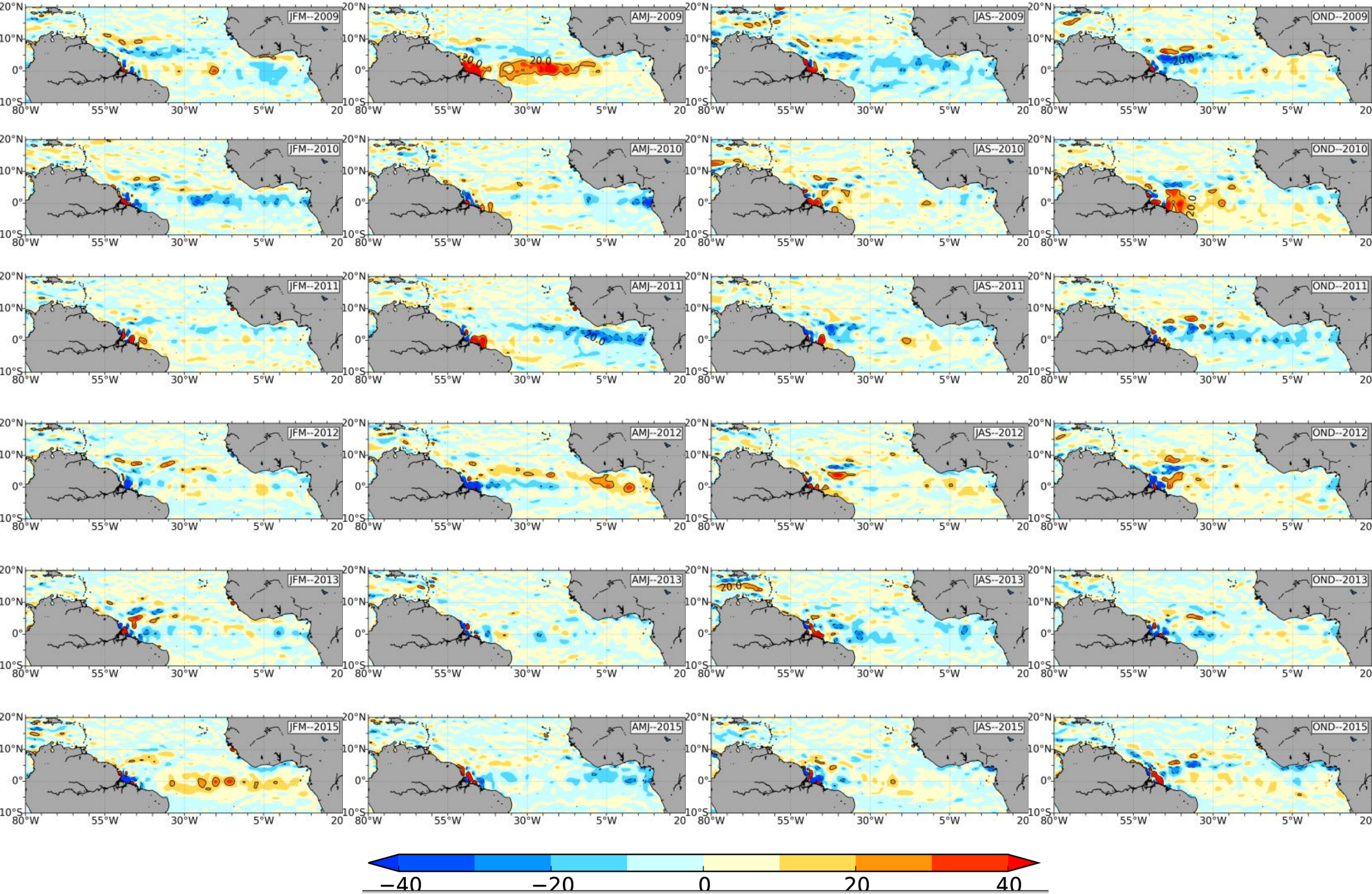


Fig 12 : Spatial distributions of seasonal zonal velocity anomalies [cm/s] related to 1993-2015. Isolines 20 cm/s (resp. -20 cm/s) are represented in solid lines (resp. dashed lines).

Not concluding yet…

SUMMARY OF FIRST RESULTS

- **Amazon River's discharge doesn't control the changes** in the Sargassum ecosystem.
- Good **agreement between nutrient flux inputs** and Sargassum **bloom events** of the years 2011, 2012, 2014 and 2015.
- Results of vertical velocity anomalies suggest more **subsurface nutrients input** in 2011, 2014, 2015.
- **High anomaly of SST in 2010 and decrease since 2011** in the western basin (optimum temperature for maximum growing since 2011) and **increase of zonal velocity** have been also favorable for Sargassum bloom.
- **AMO negative phase and NAO positive phase (2014, 2015**): strongs trade winds favorable to more subsurface nutrients.

PERSPECTIVES

- Using modeling outputs to investigate **subsurface nutrient variability**
- Analysis of **CO_2 and African atmospheric dust variability**
- Analysis of **NECC and SEC transport**
- Analysis of **forward/backward model** outputs

THANK YOU FOR YOUR ATTENTION