Amazon river discharge contribution to tropical Atlantic sea level

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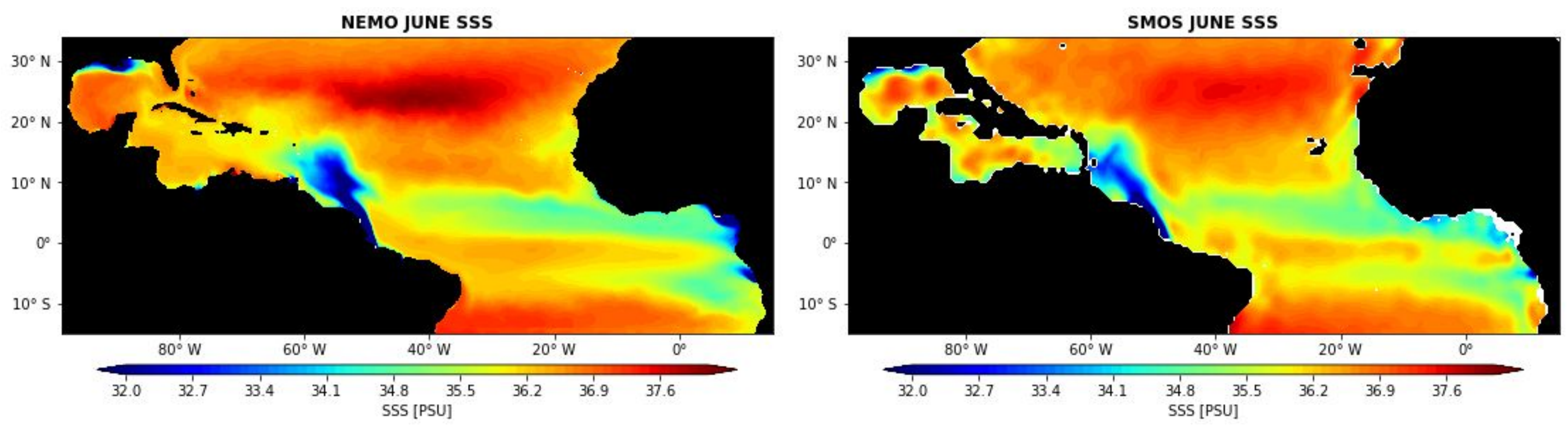
Global mean sea level rise is one of the most important consequences of the on-going global warming. Satellite altimetry has revealed a linear increase of 3.1 mm/yr since 1993 that is explained by both global ocean warming and freshwater incomes from continental ice melt (mountain glaciers melting and ice sheets mass loss; WCRP Global Sea Level Budget Group, 2018). At regional scale, sea level trends present large variation around its global average (Church et al. 2013). Other physical processes are at play such as changes in salinity, ocean circulation and dynamics, heat, freshwater and wind stress fluxes from the atmosphere. If the ocean heat content change has been largely investigated for years, changes in salinity has been neglected because of the lack of in situ salinity data. Since the 2000s and with the Argo program, we have now accessed to an unprecedented amount of salinity measurements revealing the importance of salinity to regional sea level changes.

The Amazon River discharges a very large volume of freshwater into the Tropical Atlantic ocean (~17% of the total world river discharge, Dai et al. 2002). Durand et al. (2019) suggest that its impact on sea level is potentially important at global and regional scales. They convert the Amazon discharge into units of equivalent GMSL and show that the standard deviation of its interannual variability is 0.4 mm, which is significant compared to the standard deviation of 1.0 mm of the GMSL.

However, its impact on the regional sea level is largely unknown. We focus here on the mean-state of sea level over 1993-2015 and used a set of regional simulations of the Tropical Atlantic at 1/4° horizontal resolution based on NEMO model. The model is forced with DFS5.2 atmospheric forcing, GLORYS2V4 lateral boundary conditions, and interannual daily runoffs obtained from ISBA-CTRIP land surface model (Decharme et al. 2019). The difference between a reference simulation and a simulation without Amazon discharge (both initialized in 1979) allows us to isolate its contribution.

Model Validation

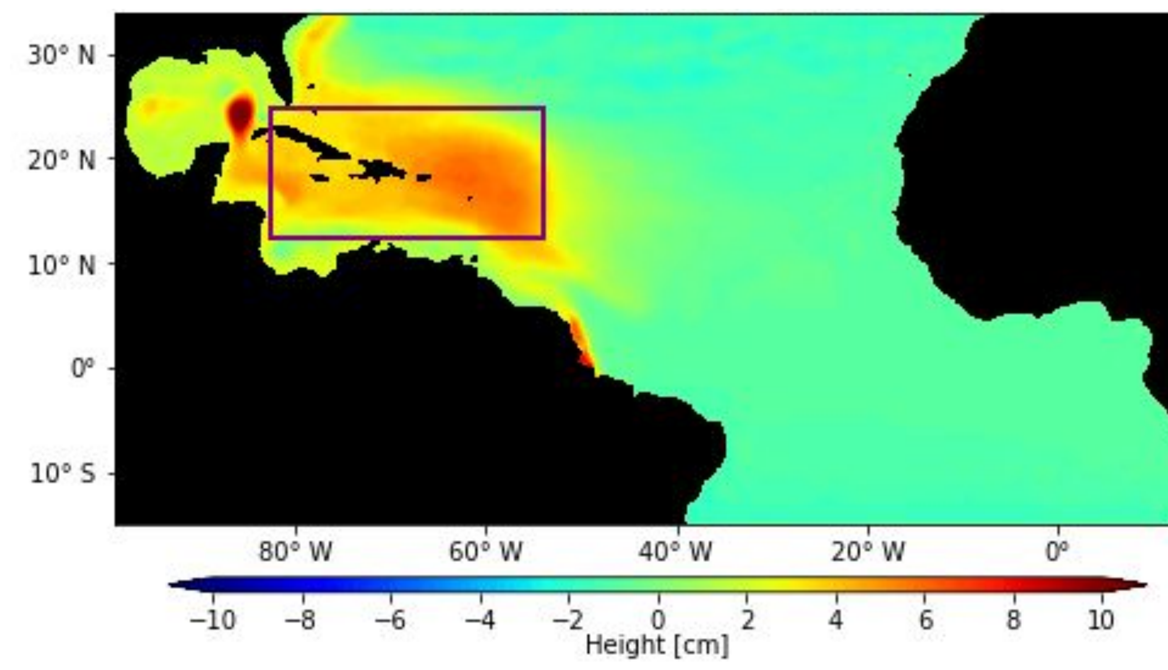
SSS comparison between model (left) and SMOS satellite observations (right) for month of June averaged over the period May 2010 - February 2017.



The Amazon plume is transported by the North Brazil Current toward the Caribbean Archipelago during boreal winter and spring (coherent with Foltz et al. 2015).

Mean-state of sea level over 1993-2015

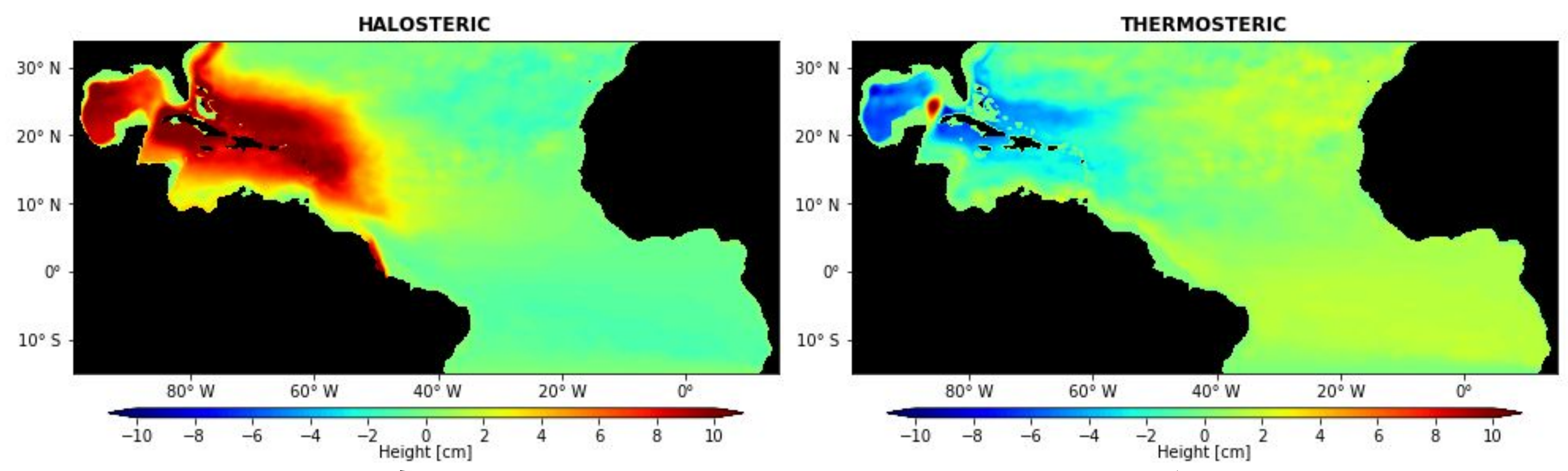
SLA differences between simulations with and without Amazon discharge over 1993-2015.



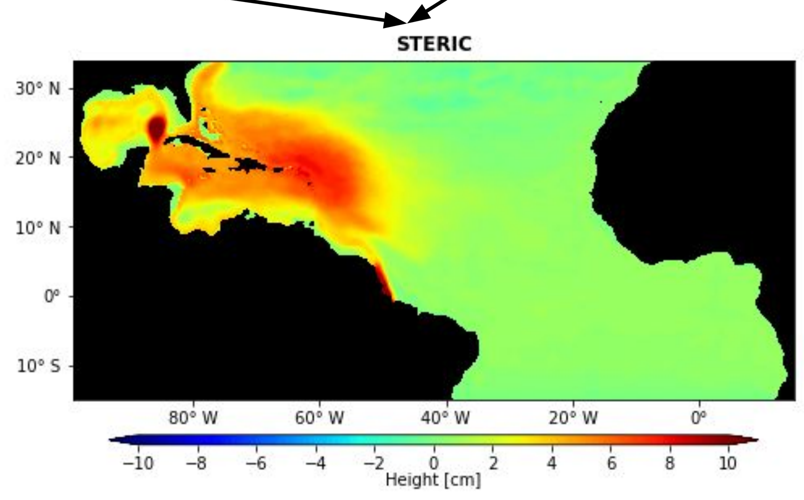
The Amazon discharge contributes to an increase in mean-state sea level of 3.8 cm in the whole Caribbean archipelago (zone delimited by a purple rectangle on the map), reaching up to 6.1 cm near the greater Antilles. This anomaly is stabilized in less than 10 years of model integration.

Thermohaline and mass contributions of the Amazon to the mean sea level

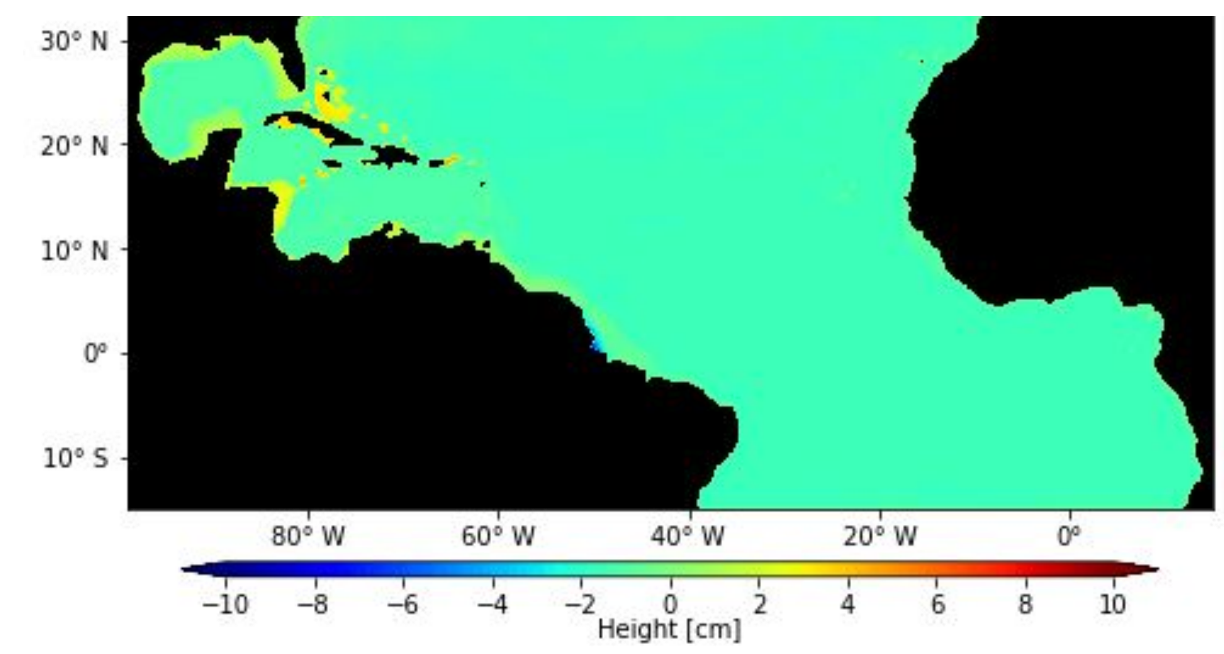
Halosteric, thermosteric and steric sea level contributions averaged over the period 1993-2015.



SLA anomalies are driven at first order by the halosteric effect.
The thermosteric effect tends to counterbalance the SLA increase.

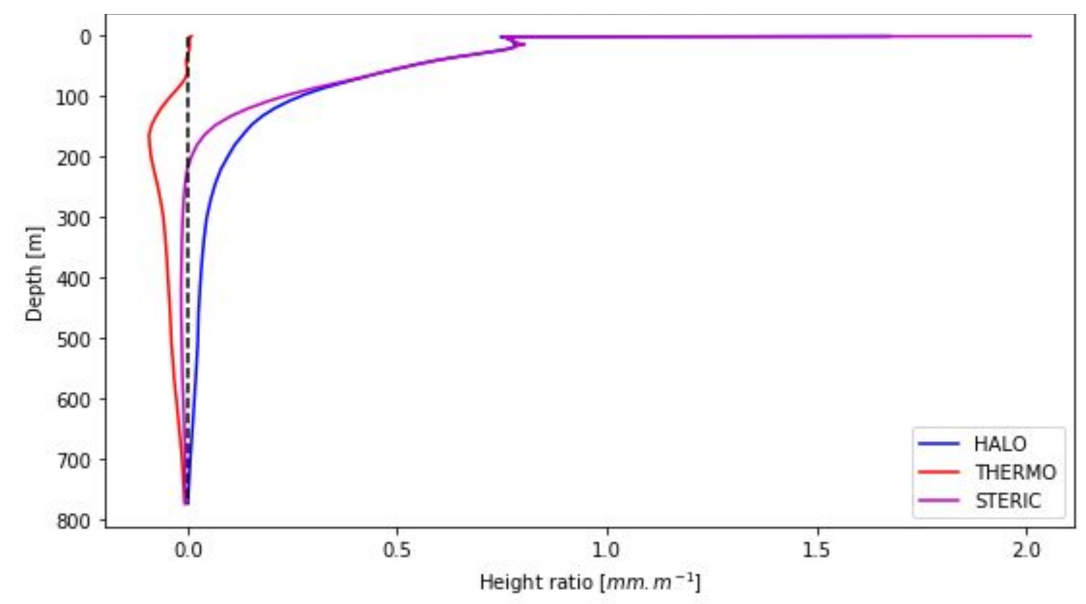


Regional mass redistribution caused by the Amazon river discharge.



The Amazon induce a regional mass redistribution with coastal increases in the Caribbean area and a slight decrease in the open ocean.

Steric anomalies averaged over the period 1993-2015 and over the Caribbean purple box.



The steric height is entirely driven by the halosteric height in the first 100 m, and 95 % of the steric contribution is located in the first 100 m of the ocean. The Amazon steric contribution is negligible deeper that 200 m. Deeper, the thermosteric effect counterbalances the halosteric effect, suggesting large scale adjustment of the regional circulation.

Conclusion

Comparisons of simulations with and without Amazon runoff exhibit a large contribution of sea level locally at the mouth of the river but also remotely and more interestingly around the whole Caribbean archipelago. This increase reaches 6 cm near the greater Antilles. This mean increase is mostly due to the halosteric contribution located in the upper 250 m of the ocean, while thermosteric effects associated with the freshwater input tend to counterbalance this effect. For the mass contribution, the Amazon discharge shows a decrease at the mouth of the river and positive contributions for the shallow coastal areas around the Gulf of Mexico and around the Caribbean archipelago. We show the importance of Amazon discharge to the mean state regional sea level for the tropical Atlantic ocean.

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