Influence of the Amazon discharge interannual variability on the western tropical Atlantic salinity and temperature

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Intensification of the hydrological cycle in the recent decades

[Gloor et al., 2015; Barichivich et al., 2018]

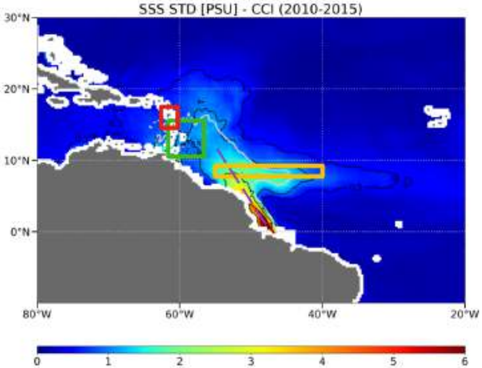
- 7 of the 10 biggest Amazon floods occured in the last 13 years

Flooding in Brazilian Amazon in June 2021. Photo by Alexandre Noronha

- How does this affect the tropical Atlantic Ocean salinity and temperature ?

Discrepancies between previous studies on SSS

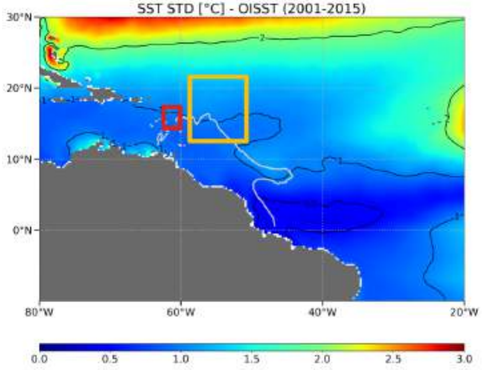
- Correlation between interannual variability of Amazon runoff and SSS in several regions:
  - Barbados (Hellweger and Gordon, 2002)
  - Lesser Antilles (Jury, 2019)
  - North Equatorial Countercurrent (Gouveia et al., 2019)
  - along the Amazon plume trajectory (Salisbury et al., 2011)



- Other studies suggest that SSS variability is not impacted by runoff variability, but by currents and wind variability (Grodsky et al., 2014, 2015; Fournier et al., 2017)

Few studies on SST

- Correlation between interannual variability of Amazon runoff and SST in the Lesser Antilles (Jury, 2019)
- Correlation between interannual variability of SSS and SST in the northern extension of the plume (Fournier et al., 2017)



- Most studies are conducted with satellite or in-situ observations
  - Use of a model to disentangle the different mechanisms (currents, winds, rivers)
  - A coupled ocean-atmosphere model is necessary to study SST (Gévaudan et al., 2021)

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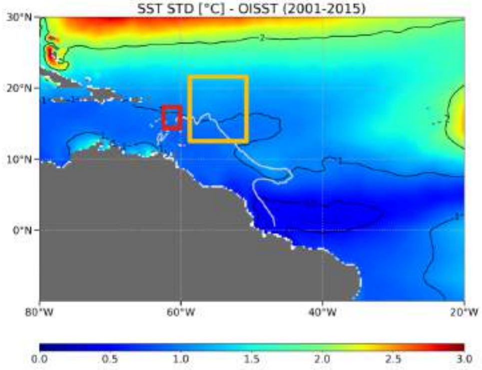

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  - Use of a model to disentangle the different mechanisms (currents, winds, rivers)
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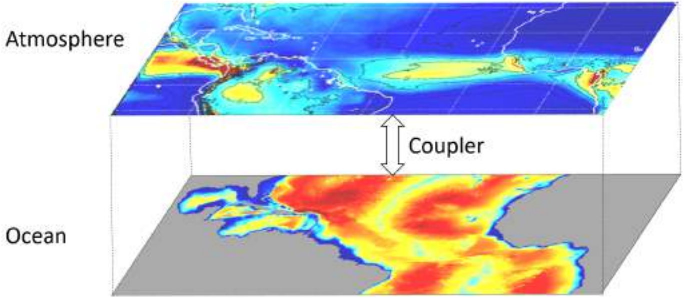
Description of the coupled model

Models:

- Ocean: NEMO 4.0
- Atmosphere: WRF 3.7.1
- Coupler: OASIS3-MCT 3.0



Resolution: 1/4° ($\sim$ 27 km)

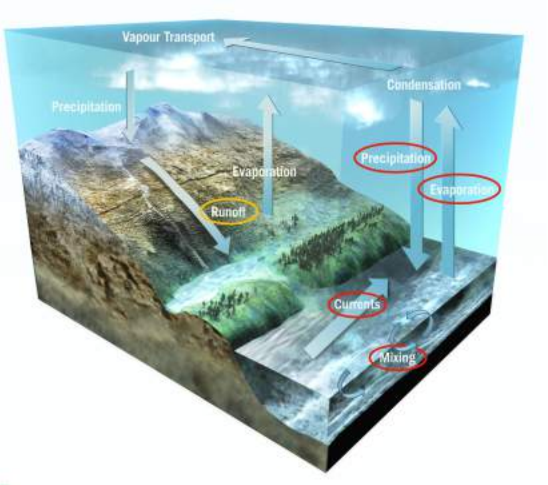
Grid: 15°S to 35°N – 100°W to 20°E — Mercator projection

Period: 2001-2015 (+ 1 year of coupled spin-up +30 years of forced ocean spin-up)

See Gévaudan et al. (2021) for validation

Isolating the sources of interannual variability

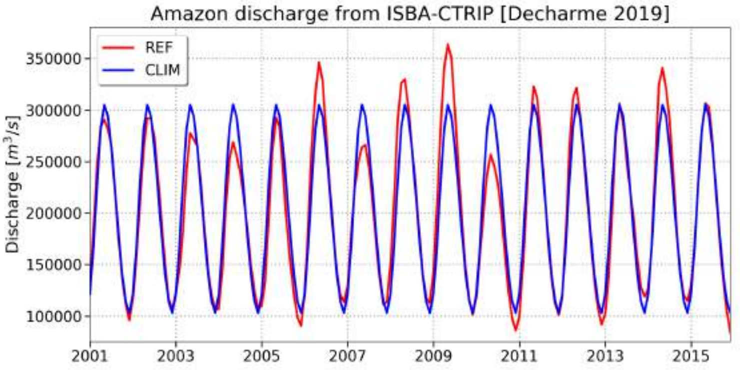
- Main sources of interannual variability:
  - River discharge (floods & droughts)
  - Ocean (currents, mixing) + Air-sea fluxes (precipitation, evaporation)
- Development of a methodology to separate variability due to river discharge from the variability due to ocean processes and air-sea fluxes



Sensitivity experiments

2 simulations:

- REF run
  - Interannual discharge
- CLIM run:
  - Climatological discharge

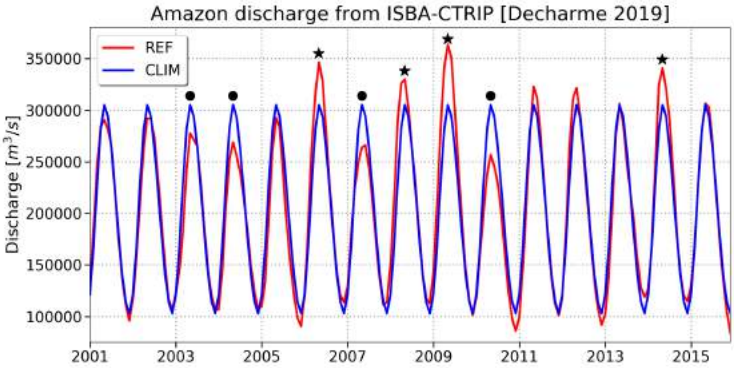


Composites

2 composites of 4 years:

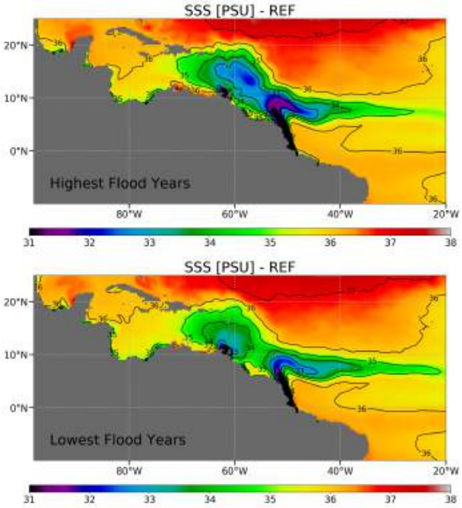
- Highest floods (HF): 2006, 2008, 2009, 2014
- Lowest floods (LF): 2003, 2004, 2007, 2010

Applied to both simulations: REF_{HF}, $CLIM_{HF}$, REF_{LF}, $CLIM_{LF}$

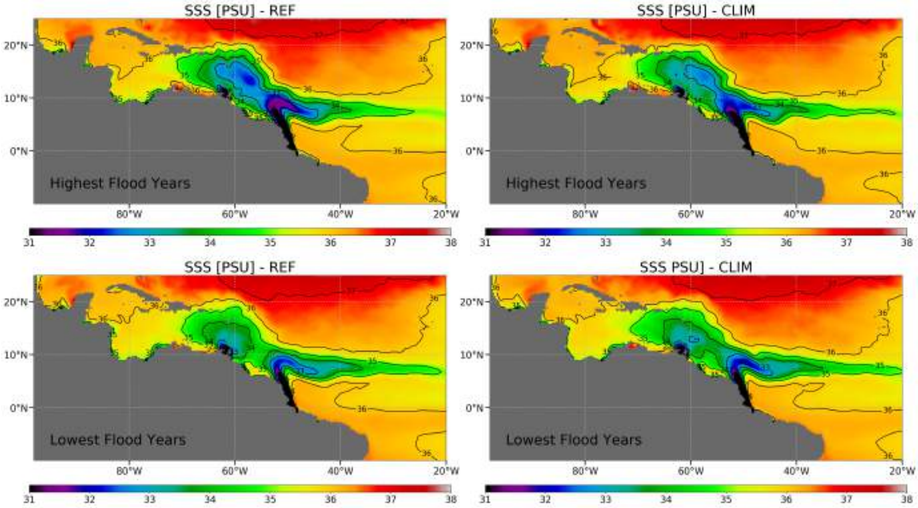


Dots: years with lowest floods (LF)
Stars: years with highest floods (HF)

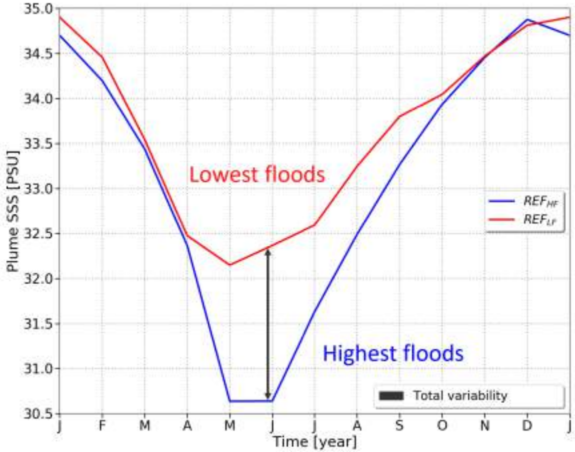
Composite maps



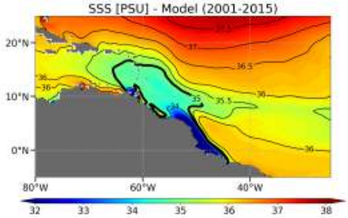
Composite maps



SSS sensitivity to Amazon floods



Seasonal cycle of SSS in the Amazon plume



- Strong SSS anomaly in spring
- SSS anomaly fading rapidly: disappeared by October

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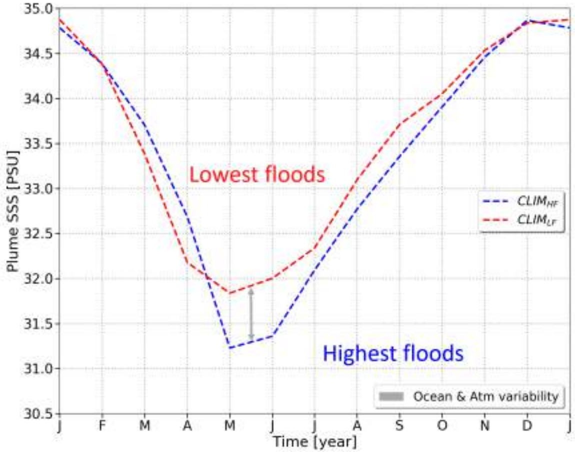

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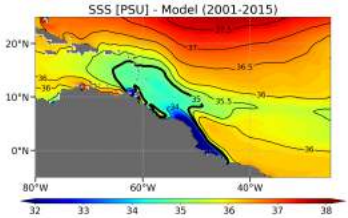
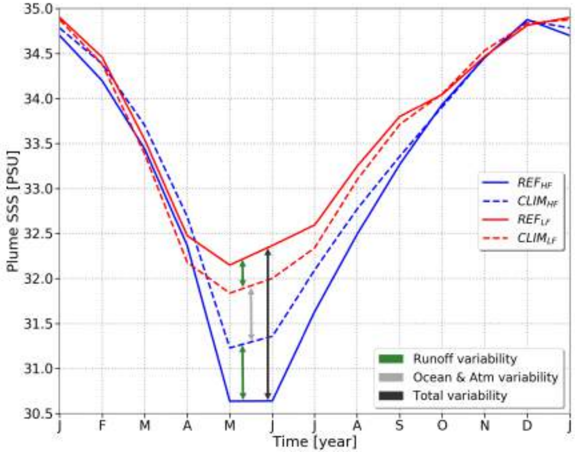


- Strong SSS anomaly in spring
- SSS anomaly fading rapidly: disappeared by October
- Ocean and atmospheric variability also play an important role

SSS sensitivity to Amazon floods



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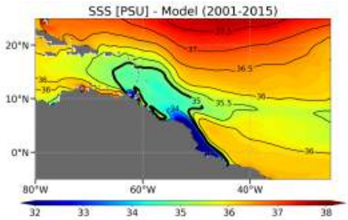
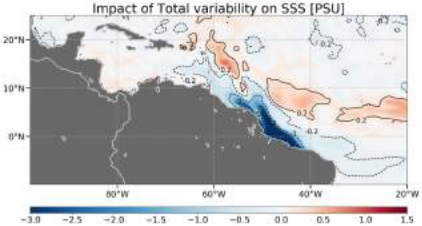


- Strong SSS anomaly in spring
- SSS anomaly fading rapidly: disappeared by October
- Ocean and atmospheric variability explain 1/3 of the variability

SSS spatial sensitivity to Amazon floods in spring



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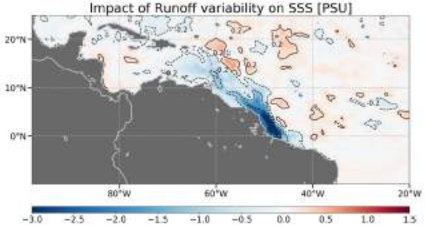

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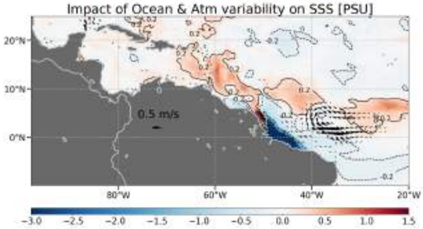
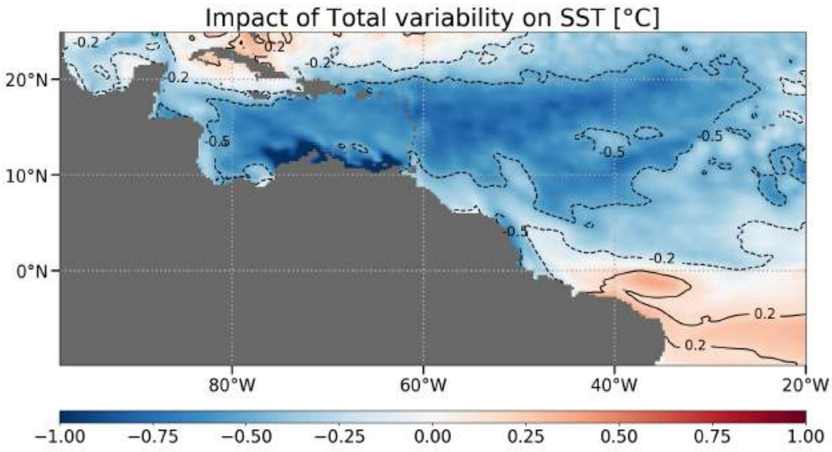
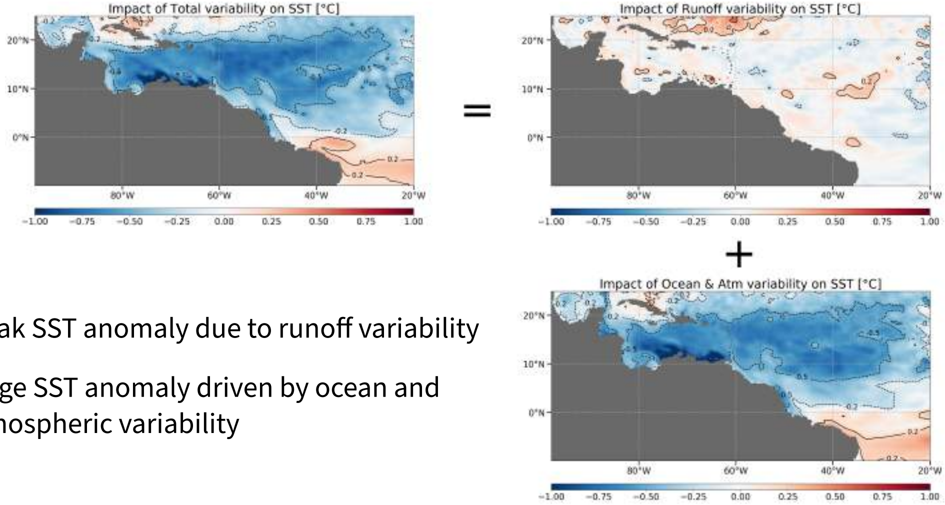


- Strong SSS anomaly near the Amazon mouth
- Rivers explain around half of the negative anomaly
- Anomaly dipole due to ocean and atmospheric variability

SST sensitivity to Amazon floods

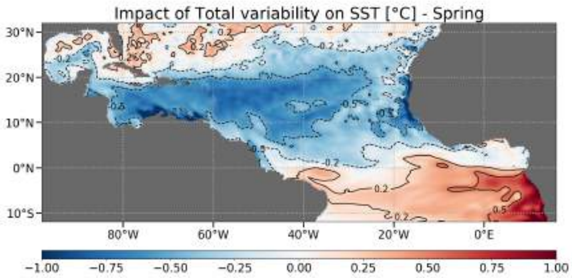


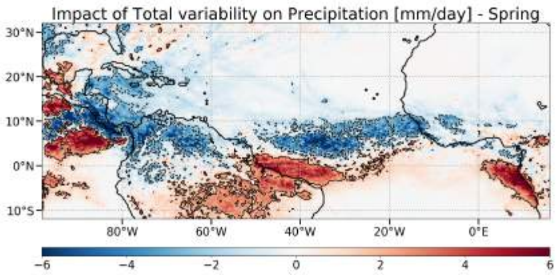
SST sensitivity to Amazon floods



- Weak SST anomaly due to runoff variability
- Large SST anomaly driven by ocean and atmospheric variability

SST sensitivity due to Atlantic Meridional Mode (AMM)





- SST and precipitation patterns during flood years are characteristic of a negative AMM event (Foltz et al., 2012; Rugg et al., 2016)

Conclusion

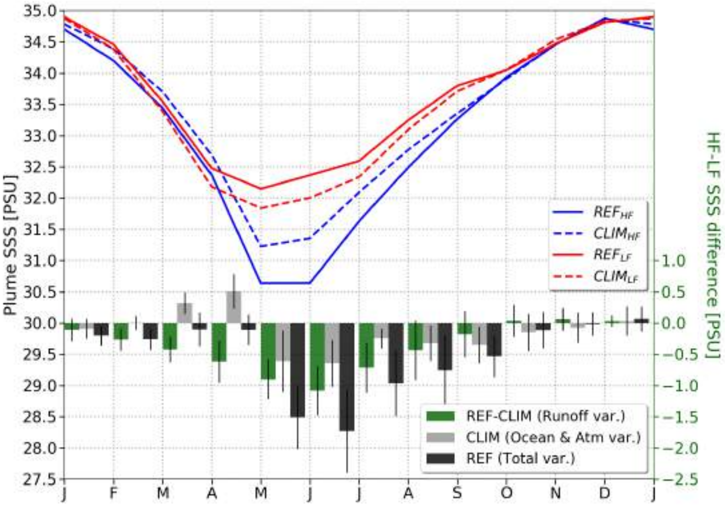
What did we learn?

- Extreme floods of the Amazon affect the sea surface salinity, but the anomalies fade rapidly
- Variability due to ocean and air-sea fluxes also affects SSS significantly
- Sea surface temperature is not impacted by the extreme floods
- Years of extreme floods seem to coincide with negative Atlantic Meridional Mode events, and thus negative SST anomalies

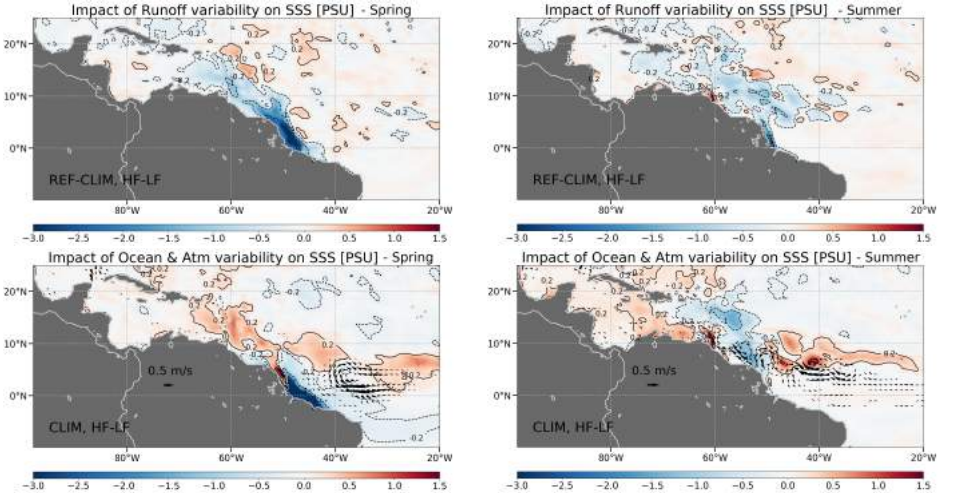
Published in JGR: Oceans (Gévaudan et al., 2022)

Supplementary

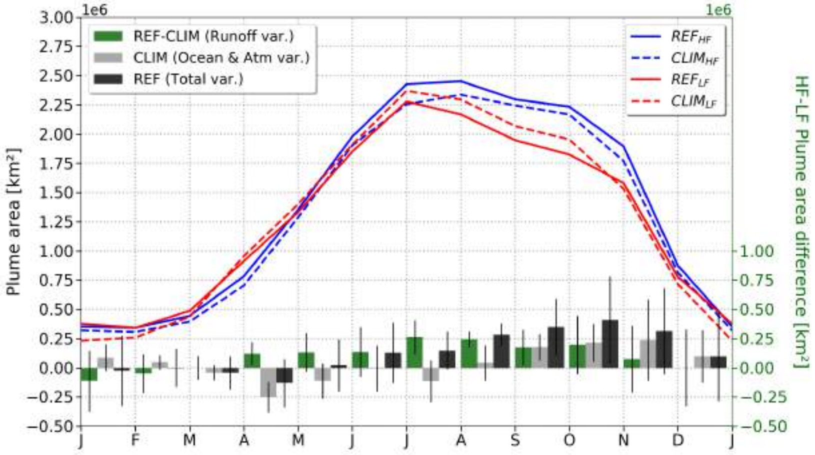
SSS seasonal cycle



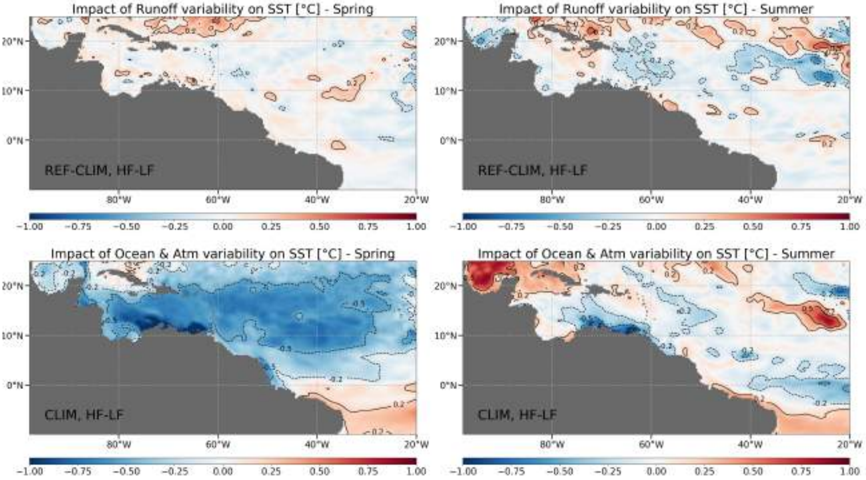
SSS maps


Impact of Runoff variability on SSS [PSU] - Spring
REF-CLIM, HF-LF
Impact of Runoff variability on SSS [PSU] - Summer
REF-CLIM, HF-LF
Impact of Ocean & Atm variability on SSS [PSU] - Spring
CLIM, HF-LF
0.5 m/s
Impact of Ocean & Atm variability on SSS [PSU] - Summer
CLIM, HF-LF
0.5 m/s
20°N
10°N
0°N
80°W
60°W
40°W
20°W
−3.0 −2.5 −2.0 −1.5 −1.0 −0.5 0.0 0.5 1.0 1.5

Plume extent sensitivity to Amazon floods



SST maps


Impact of Runoff variability on SST [°C] - Spring
REF-CLIM, HF-LF
Impact of Runoff variability on SST [°C] - Summer
REF-CLIM, HF-LF
Impact of Ocean & Atm variability on SST [°C] - Spring
CLIM, HF-LF
Impact of Ocean & Atm variability on SST [°C] - Summer
CLIM, HF-LF
20°N
10°N
0°N
80°W
60°W
40°W
20°W
−1.00 −0.75 −0.50 −0.25 0.00 0.25 0.50 0.75 1.00

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