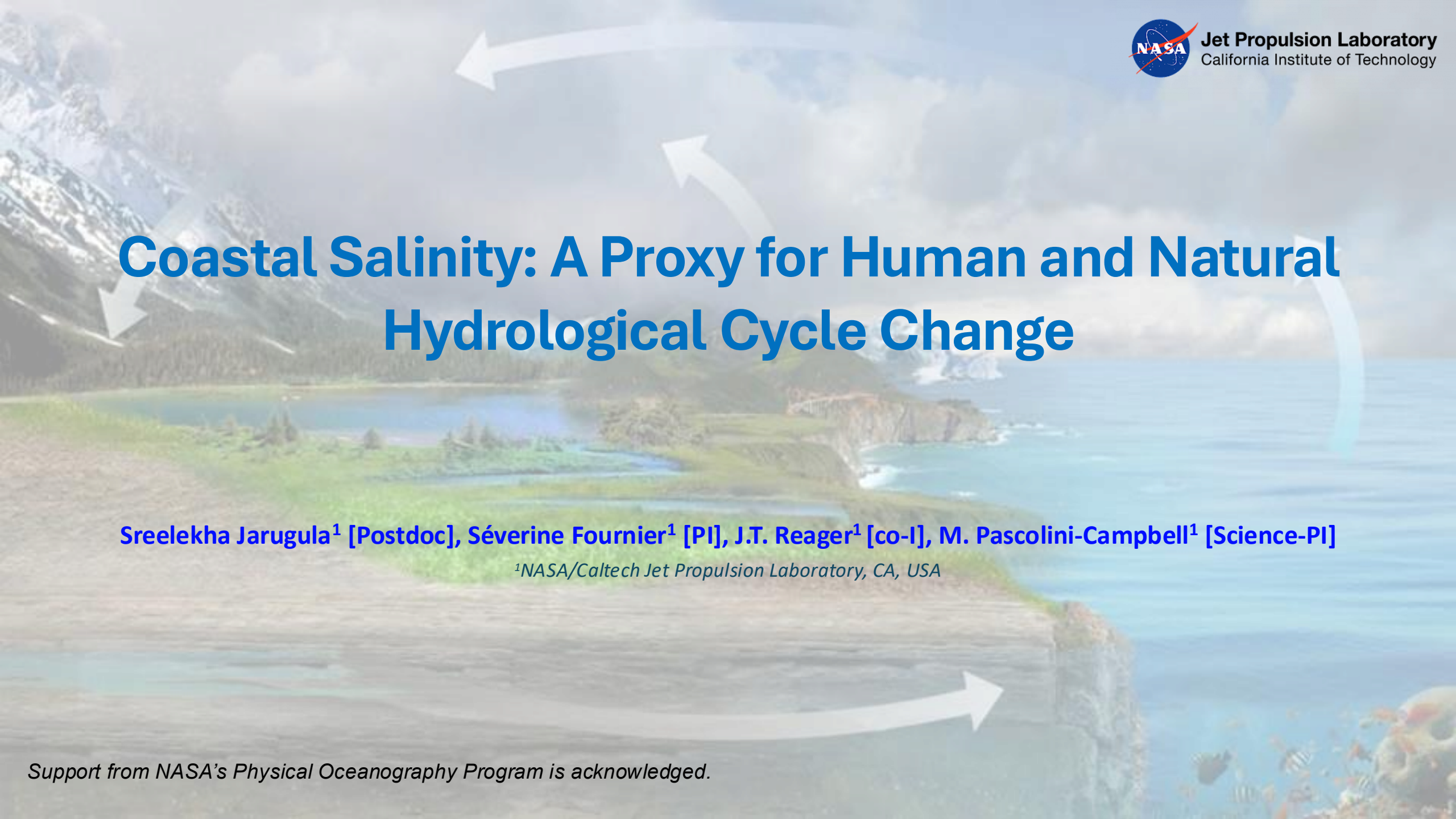

Jet Propulsion Laboratory
California Institute of Technology

Coastal Salinity: A Proxy for Human and Natural Hydrological Cycle Change

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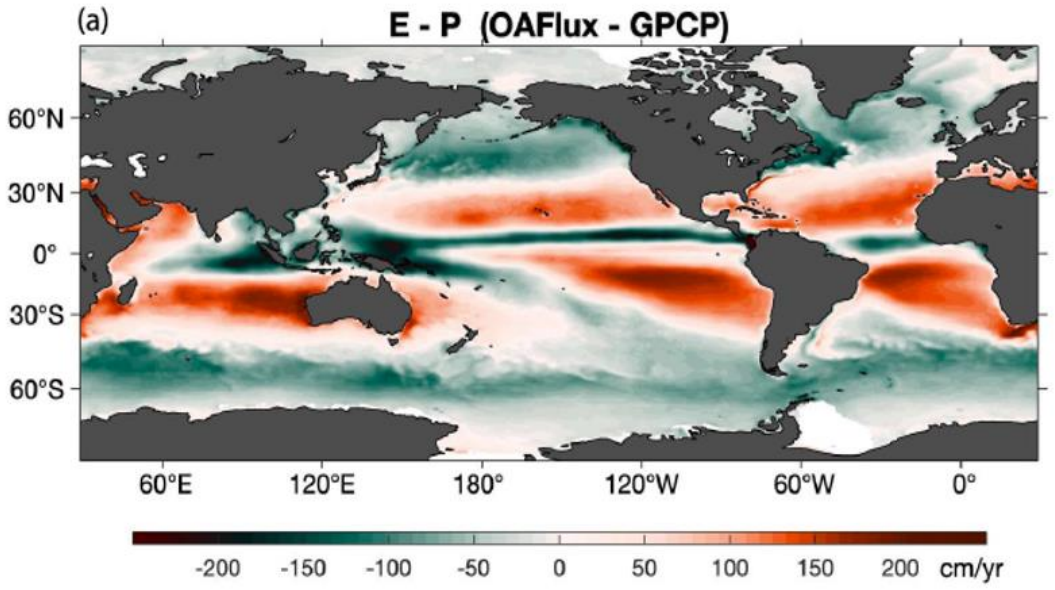
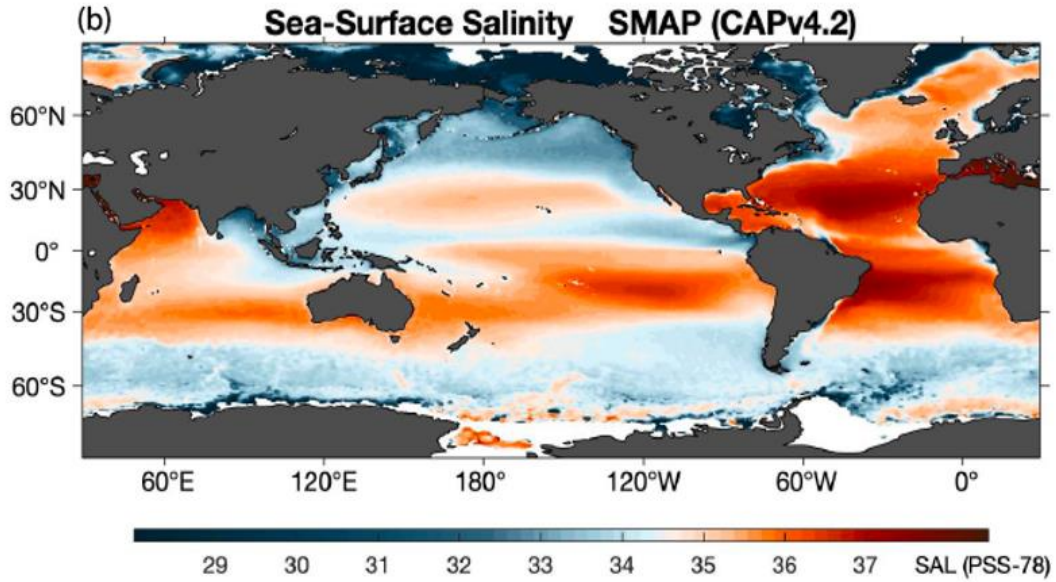
[1]NASA/Caltech Jet Propulsion Laboratory, CA, USA

Support from NASA's Physical Oceanography Program is acknowledged.



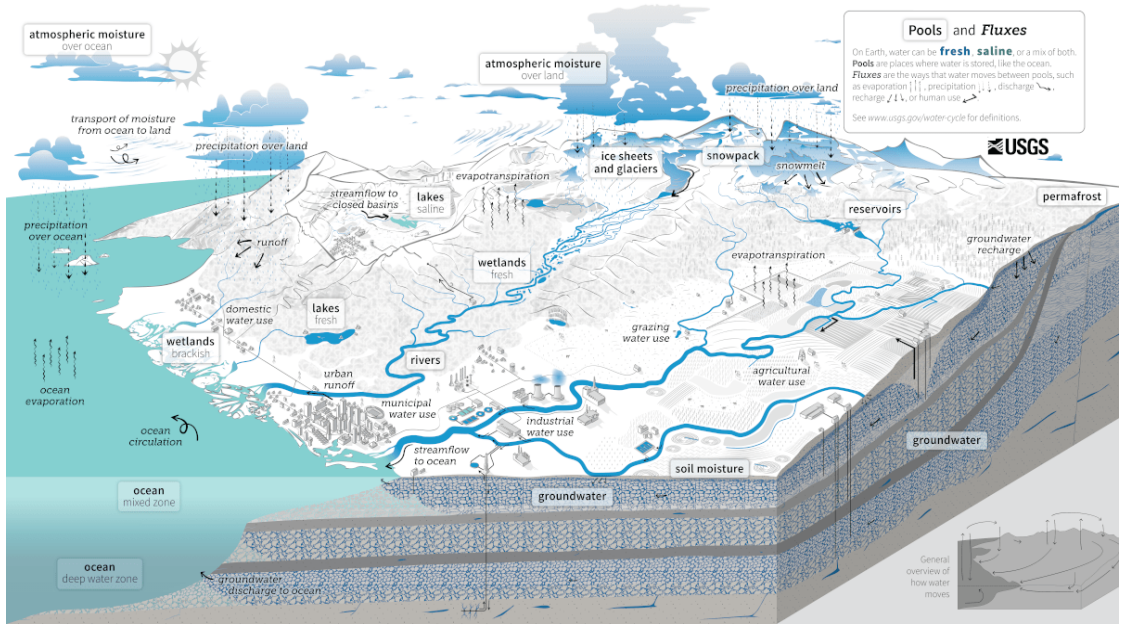


Yu et al. 2020

Ocean Salinity and Water Cycle

- Ocean salinity is a key indicator for changes in the global water cycle [*Zika et al., 2018, Yu et al., 2020]*
- Long-term trends in salinity are linked to changes in the surface freshwater flux over open ocean [*Durack et al. 2012, 2015, Vinogradova et al. 2017]*
- Salinity is a useful tool to monitor signatures of water cycle intensification as increasing ocean *E - P* is an anticipated consequence of global warming *[Trenberth et al., 2007, Held and Soden 2006]*

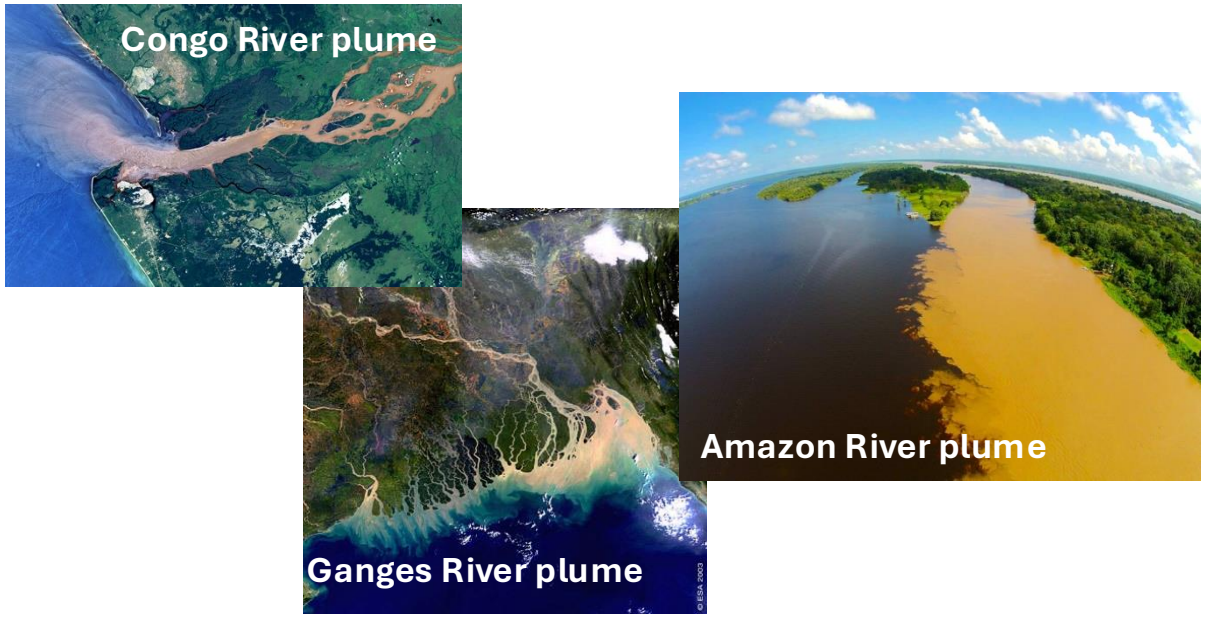
Salinity in the Coastal Ocean



Credit: Hayley Corson-Dosch/USGS VizLab

- Coastal ocean SSS is highly sensitive to subtle changes in the terrestrial water cycle occurring at river basin scales

- Hydrological cycle expected to intensify *[Held and Soden, 2006]*
  - Runoff projected to increase by ~7% *[Huntington, 2006]*
  - Impacts on the coastal ocean: marine ecology *[Muller-Karger et al., 1988]* and physical processes *[Pailler et al., 1999]*

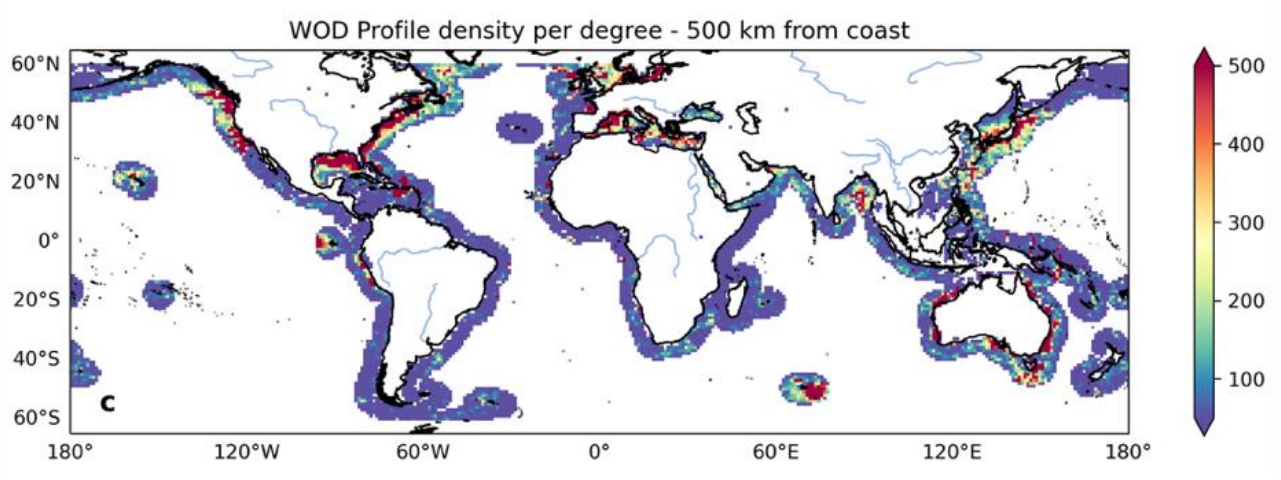


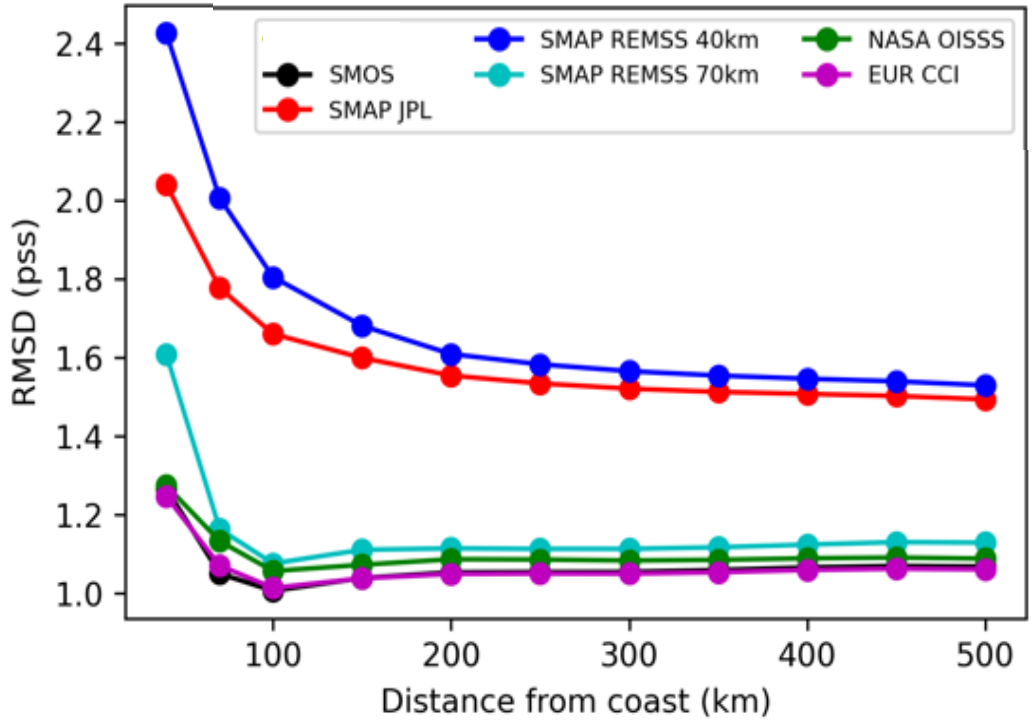
Objectives of this project:

- **Identify hotspots and examine the relationship of the global terrestrial hydrological cycle with global coastal *SSS*.**

- **Disentangle the contribution of natural and human drivers to land hydrology and coastal *SSS* variability and trends.**

Evaluation of satellite SSS products in the global coastal ocean



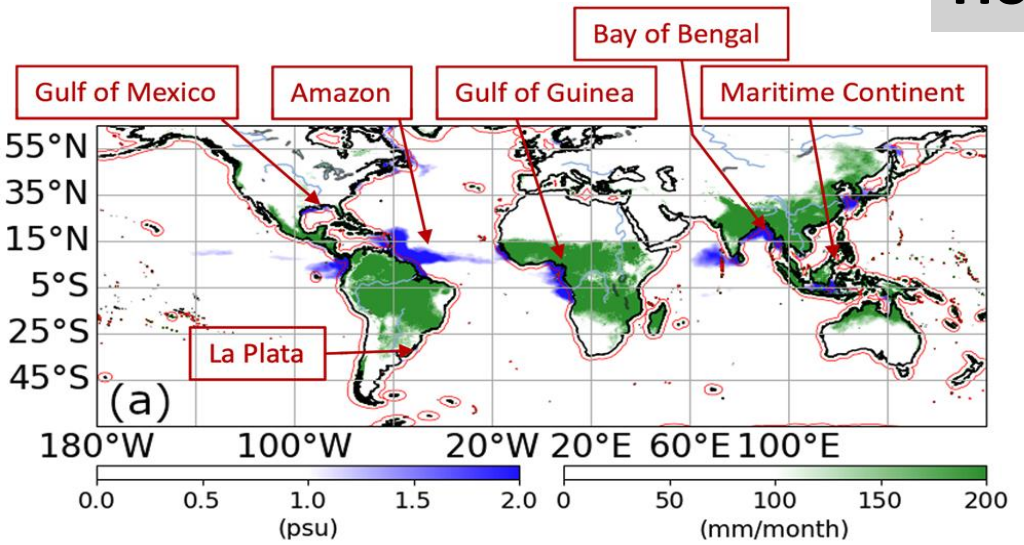


- High RMSD values in satellite SSS close to the coastline are mainly attributed to issues such as radio frequency interference, land contamination in the retrieved signals, sampling differences between the satellite and *in situ* platforms and few *in situ* data collocations available closer to the coastline.

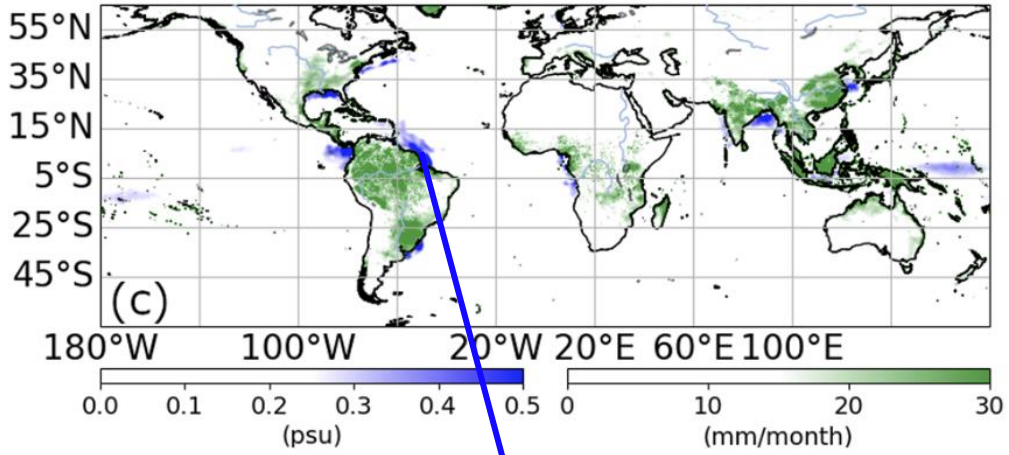
- Good agreement between the satellite and *in situ* coastal SSS in resolving the seasonal variability but there are notable differences on non-seasonal timescales, specially in NASA OISSS.

Jarugula et al. (2024)

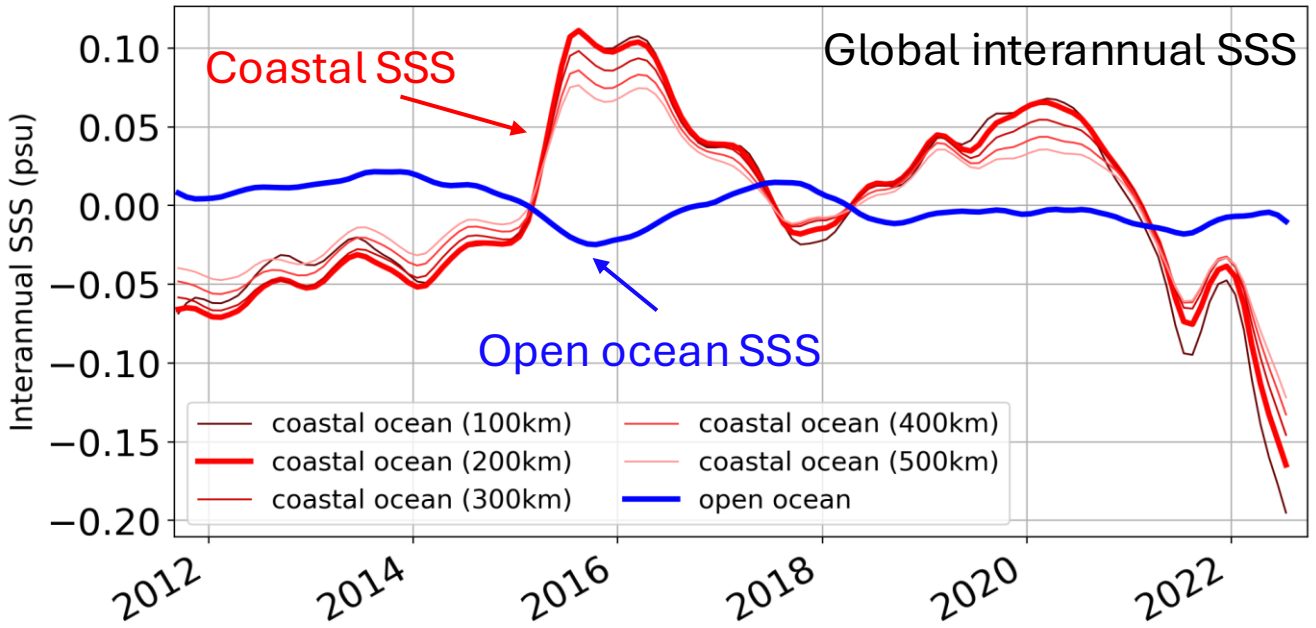
Hotspots for terrestrial hydrology-coastal SSS linkages



STD of interannual SSS anomalies



Most of the SSS variability happens at the coast (30 times higher)



- Higher amplitude of variability in the coastal SSS signals
- Phases of variability are different -> different nature of SSS variability

-> Important SSS signals at the coast

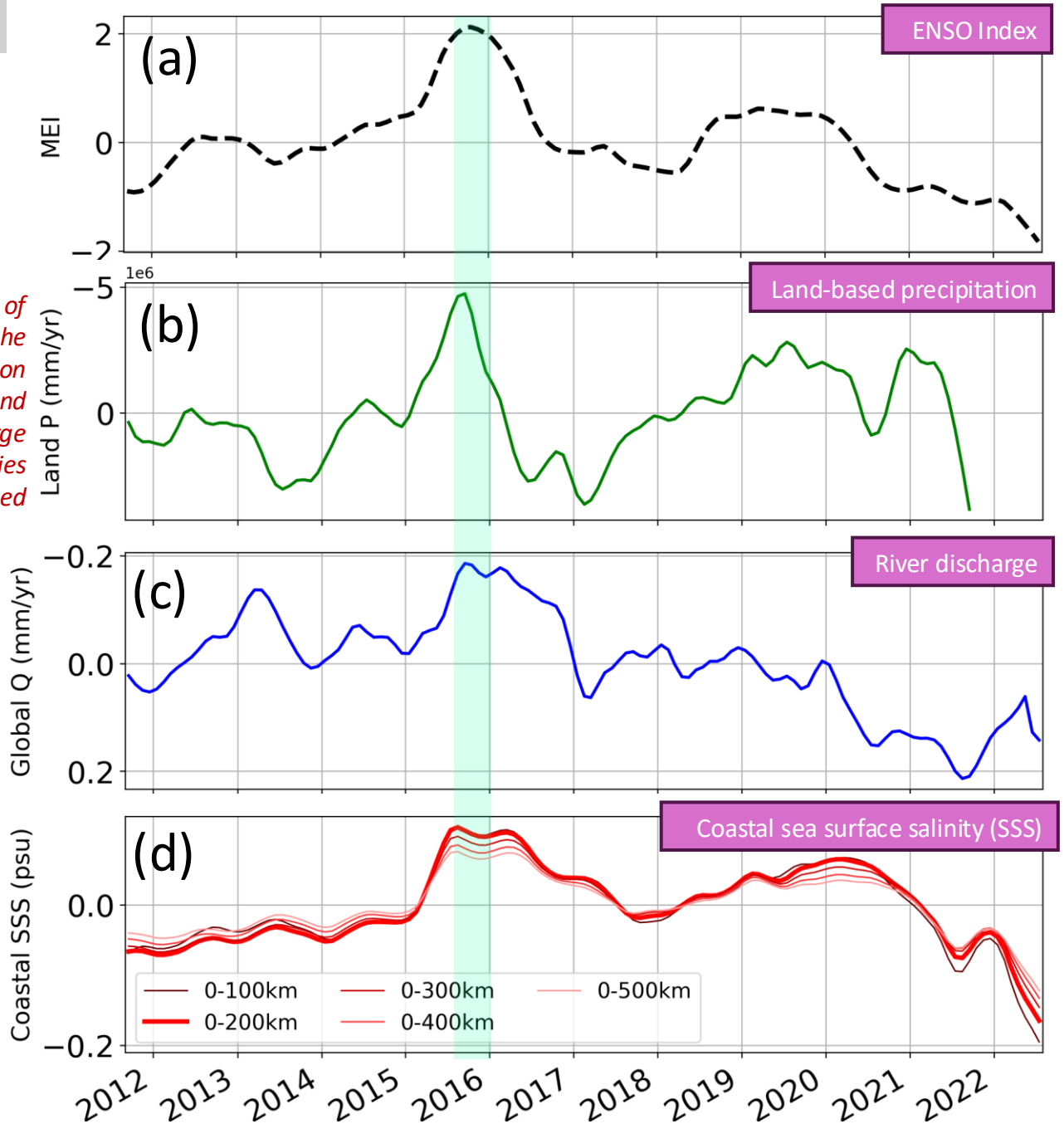
Fournier et al., 2023

Coastal SSS: An indicator of water cycle changes

High significant correlations between interannual variability of the MEI and:

- Global land precipitation
- Global discharge - *consistent with Syed et al. (2010)*
- Global coastal SSS

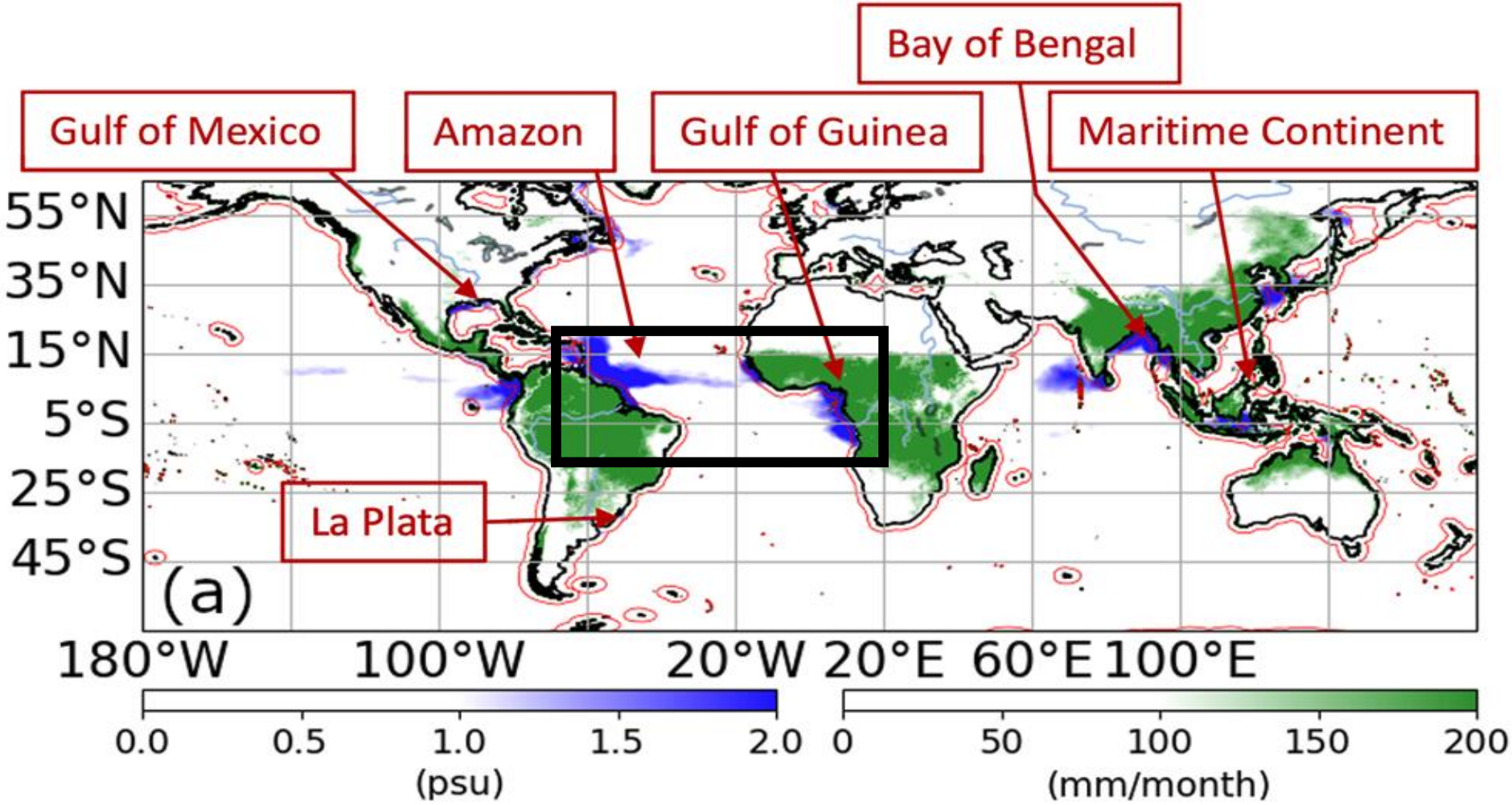
the y-axis of the precipitation and discharge times series are flipped



Year to year variations of coastal SSS are strongly correlated with ENSO via modulation of precipitation on land and subsequent river runoff

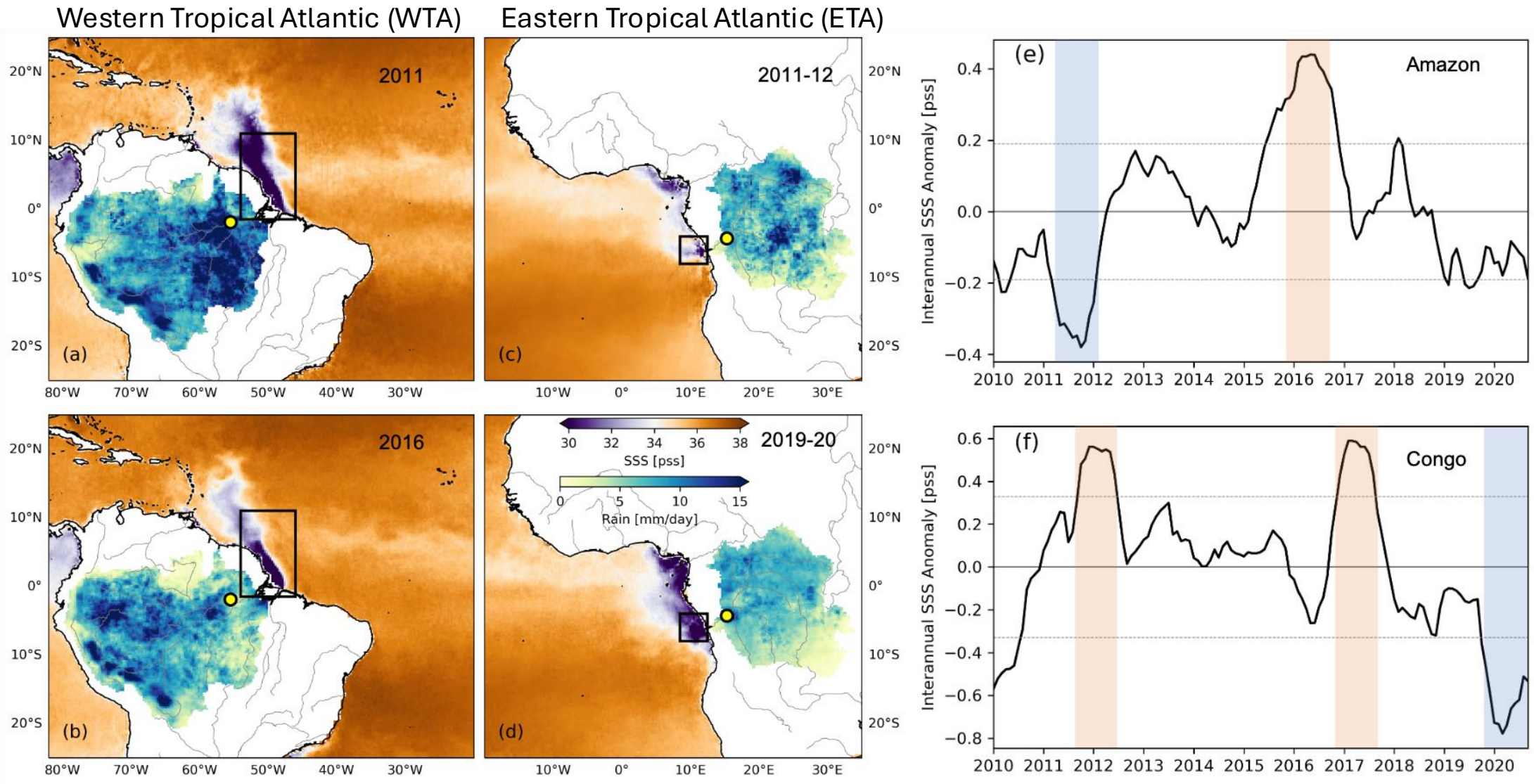
-> Coastal SSS could be used as a proxy for detection of changes that are expected in the cycling of water between the oceans and continents

Fournier et al., 2023



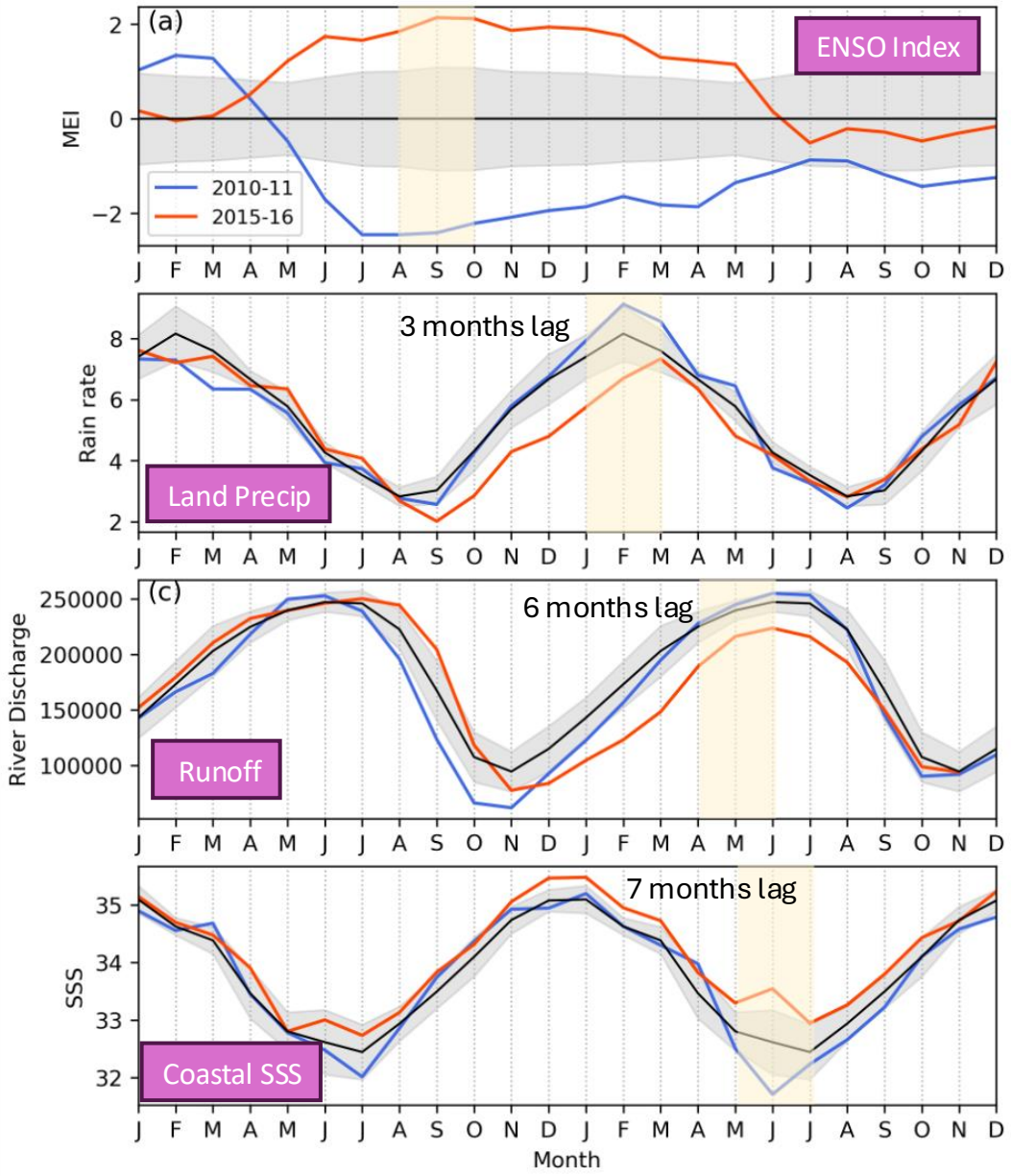
Is ENSO the only major natural driver of terrestrial water cycle and coastal SSS?

Major Natural Drivers of Tropical Atlantic Coastal SSS Variability



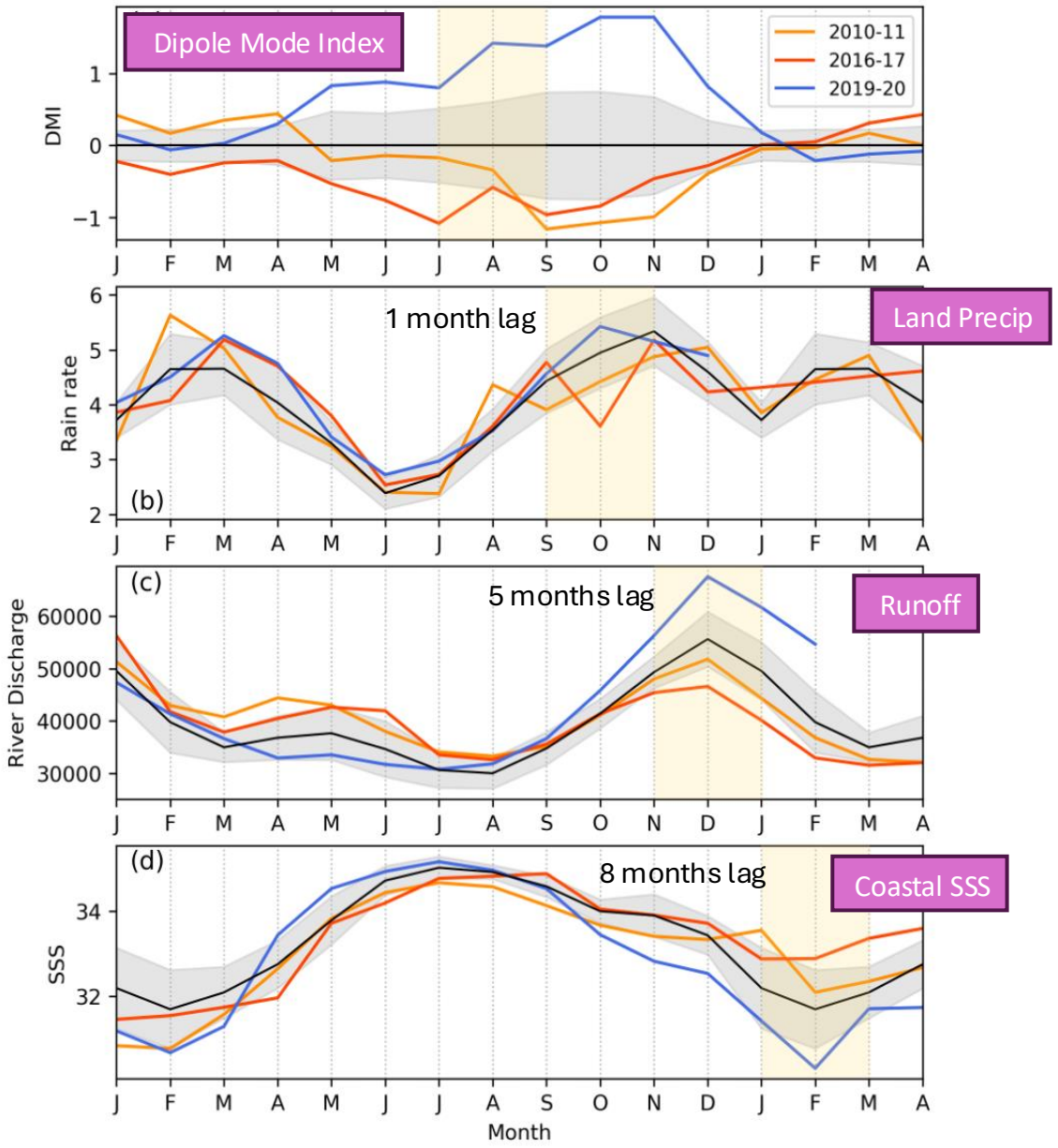
Jarugula et al. 2026

Amazon basin hydrology and WTA SSS



ENSO explains ~44% of WTA SSS variability

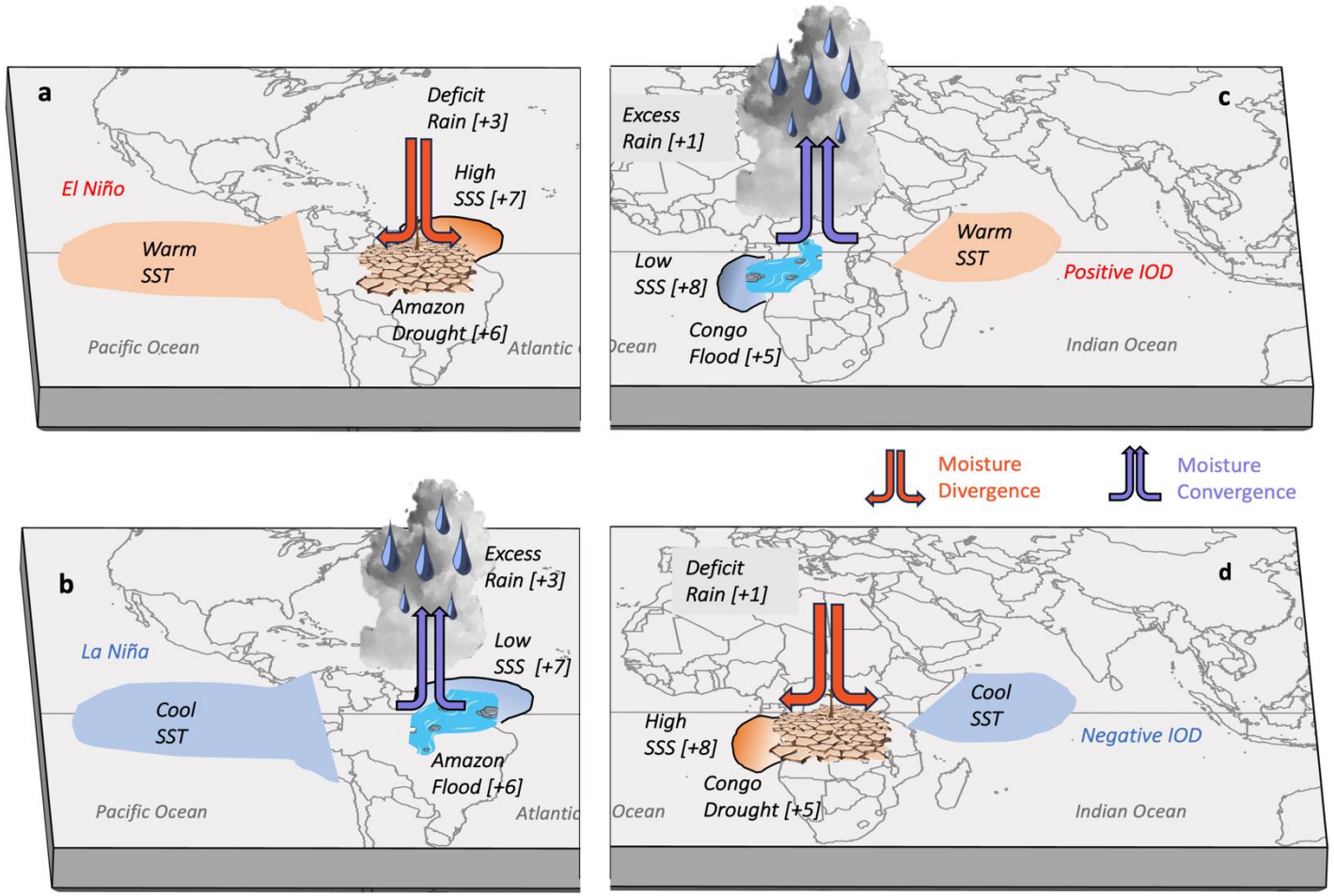
Congo basin hydrology and ETA SSS



IOD explains ~43% of ETA SSS variability

Jarugula et al. 2023, 2026

Western and Eastern Tropical Atlantic coastal SSS are independently forced by ENSO and IOD, respectively.



Jarugula et al. 2026

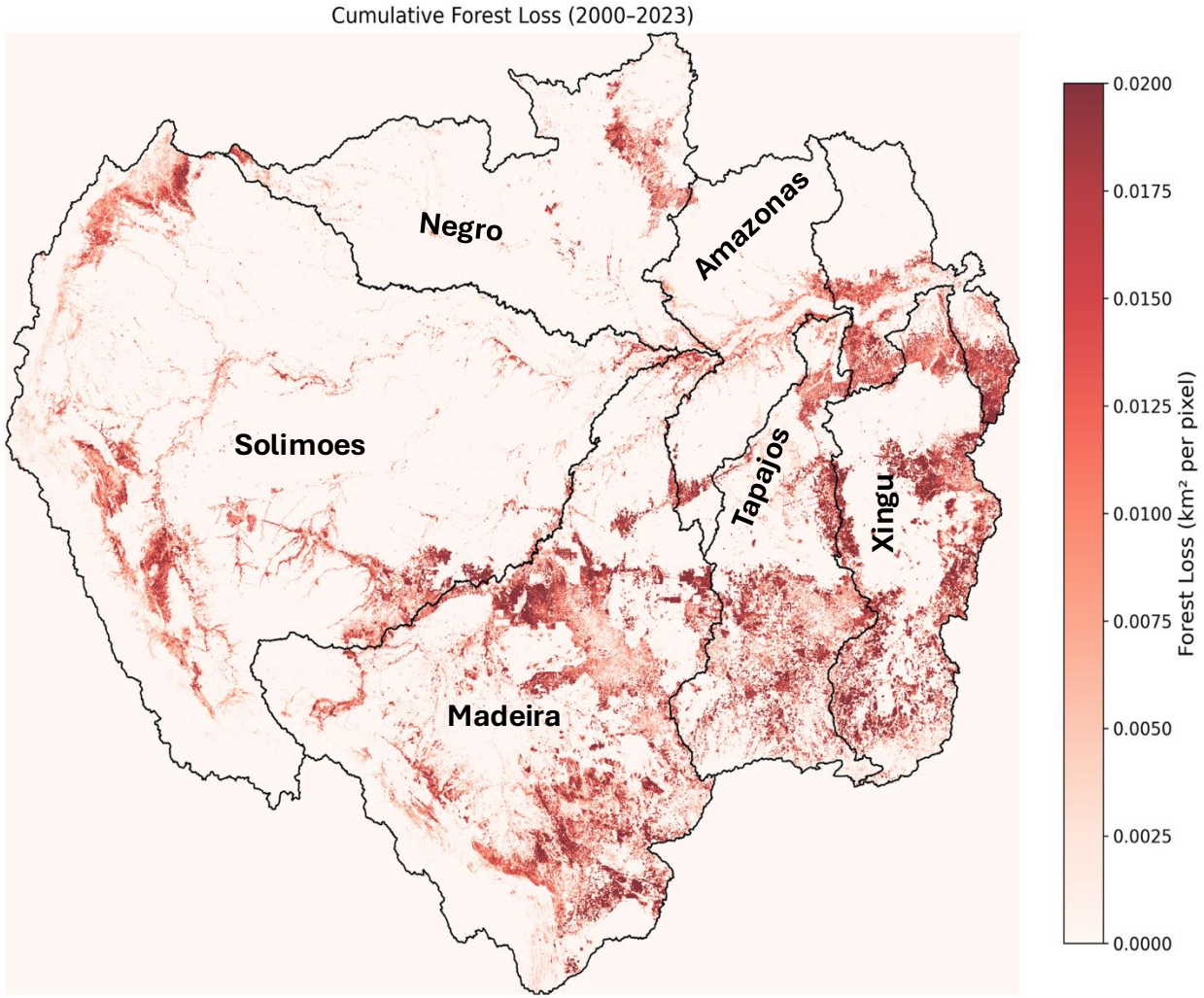
"Super teleconnection" linking the Pacific, Indian, and Atlantic Oceans through coupled atmosphere–land–ocean processes.

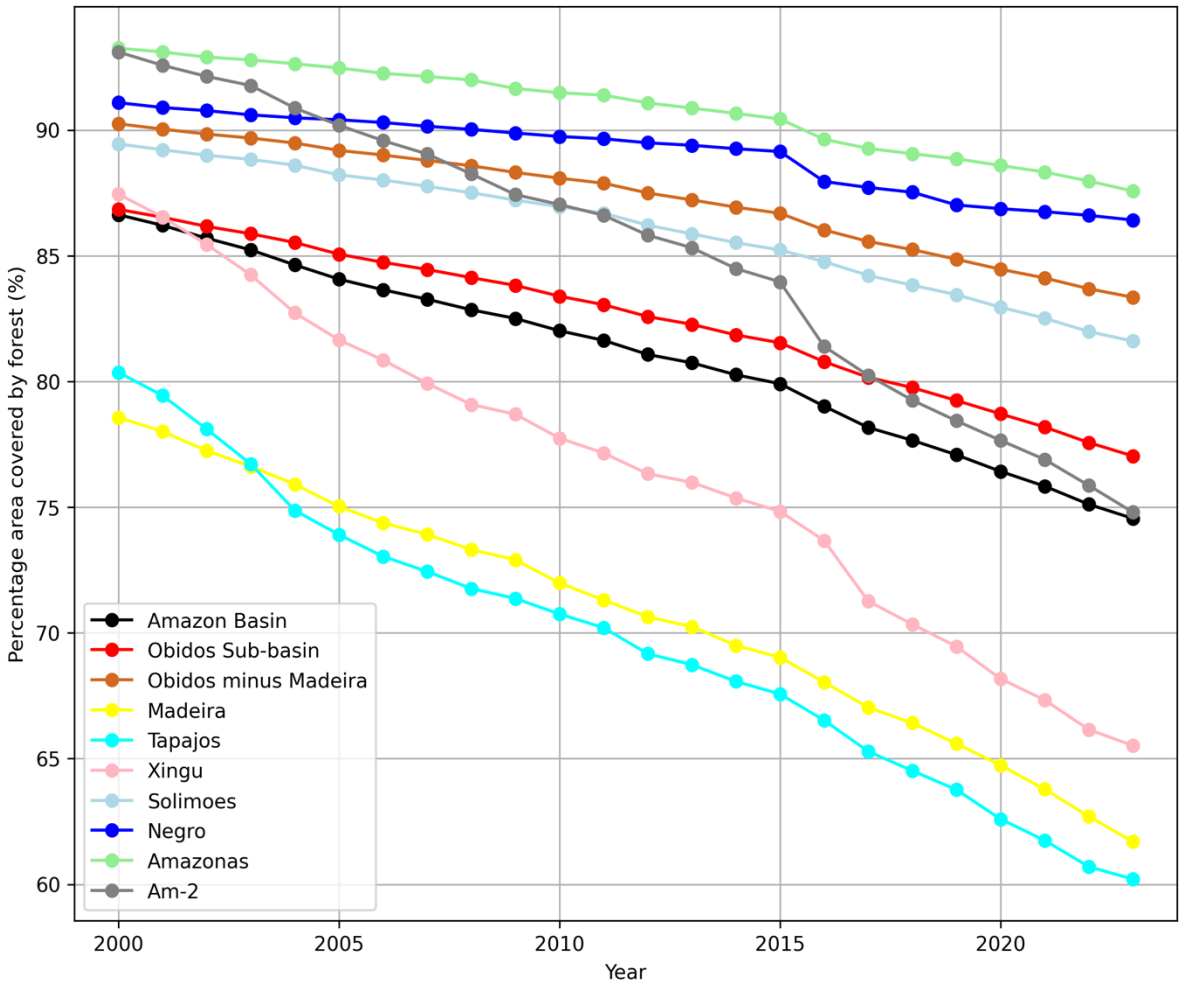
The identified lag structure provides a predictive framework for hydrological extremes and coastal ocean conditions.

Objectives of this project:

- **Identify hotspots and examine the relationship of the global terrestrial hydrological cycle with global coastal *SSS*.** ✅
- **Disentangle the contribution of natural and human drivers to land hydrology and coastal *SSS* variability and trends.**

Human Drivers to hydrological cycle and coastal SSS: A case study on Amazon deforestation

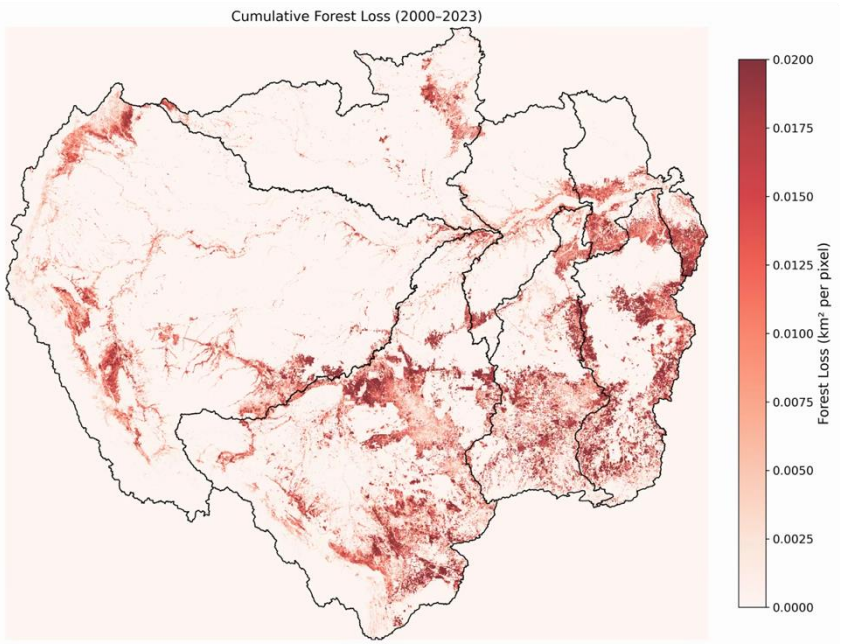




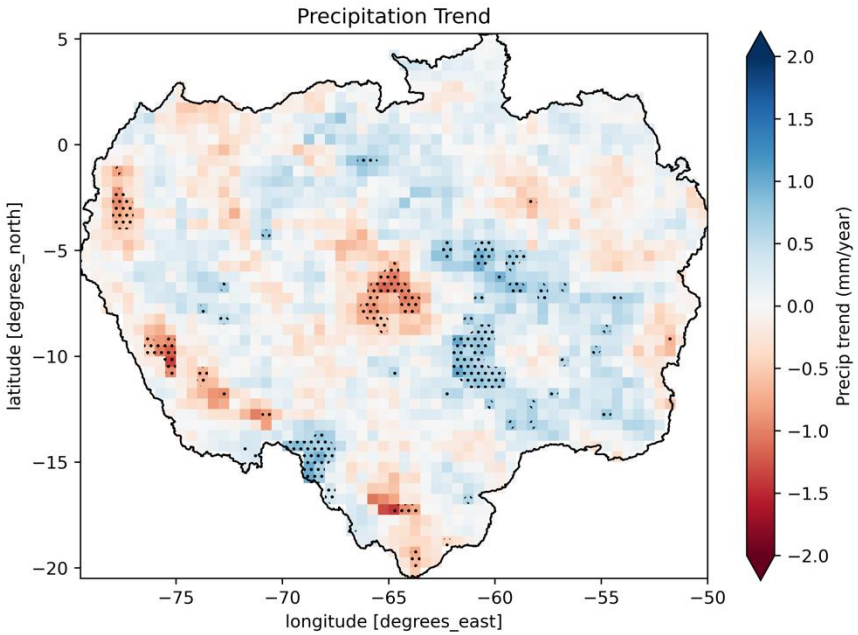
Jarugula et al. in prep

Impacts of Deforestation on Land Hydrology

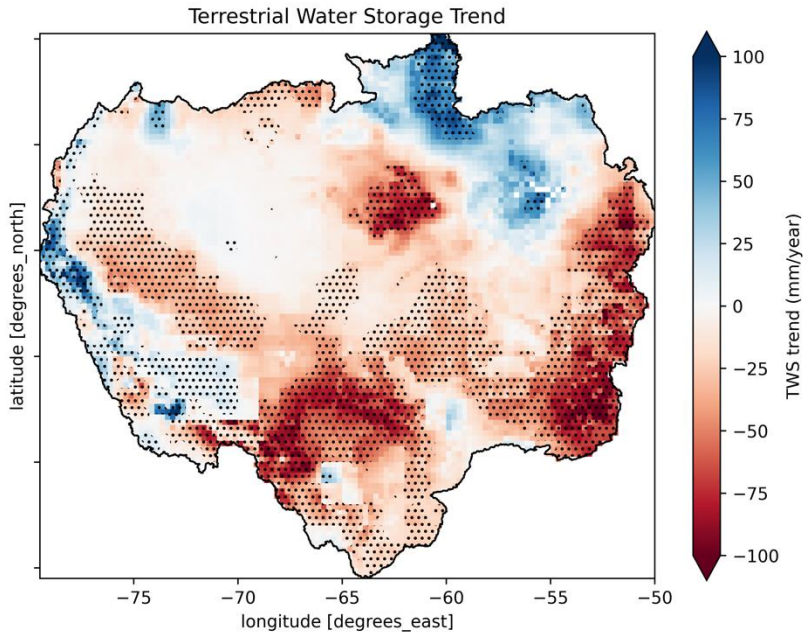
Deforestation Map 2000-2023



Wet Season Precip Trend Map 2000-2023



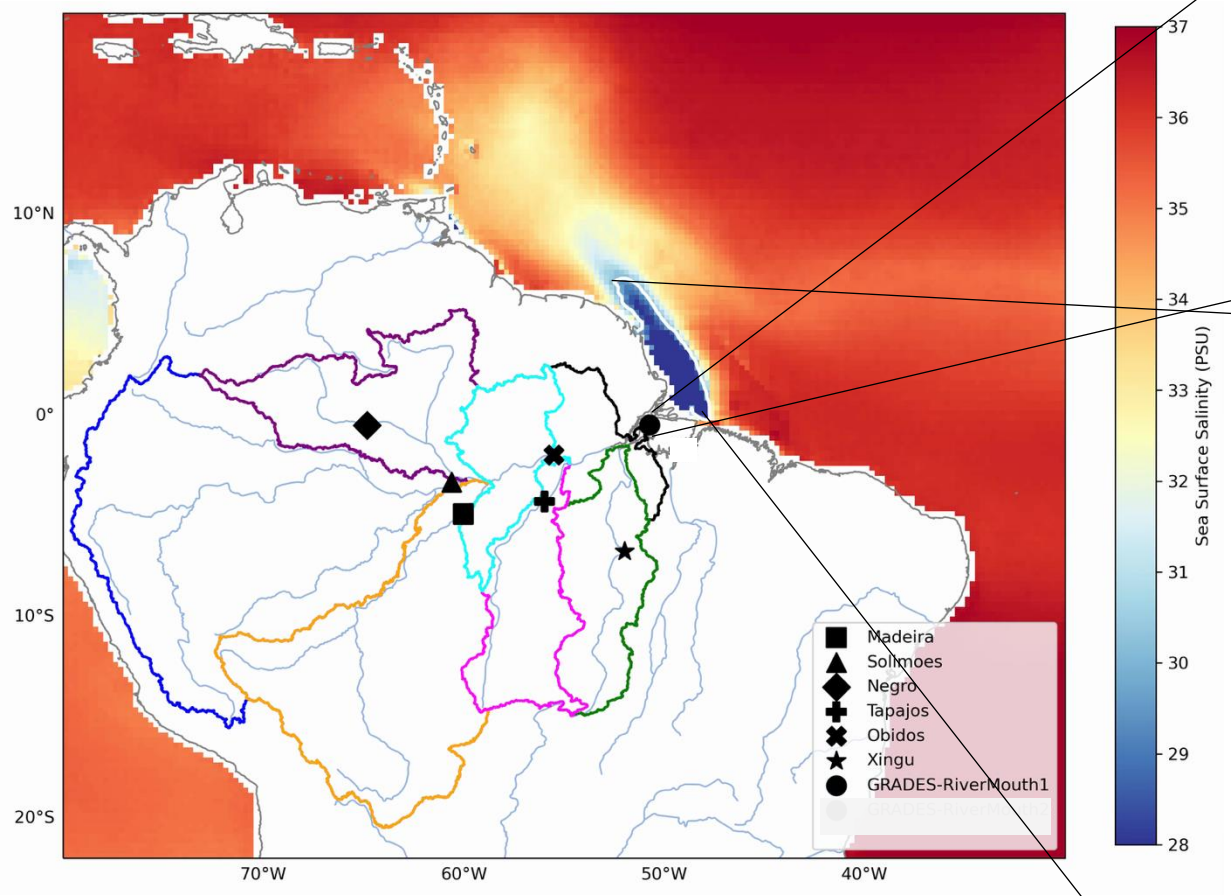
Wet Season TWS Trend Map 2000-2023



Is there an observed increasing trend in the river runoff?

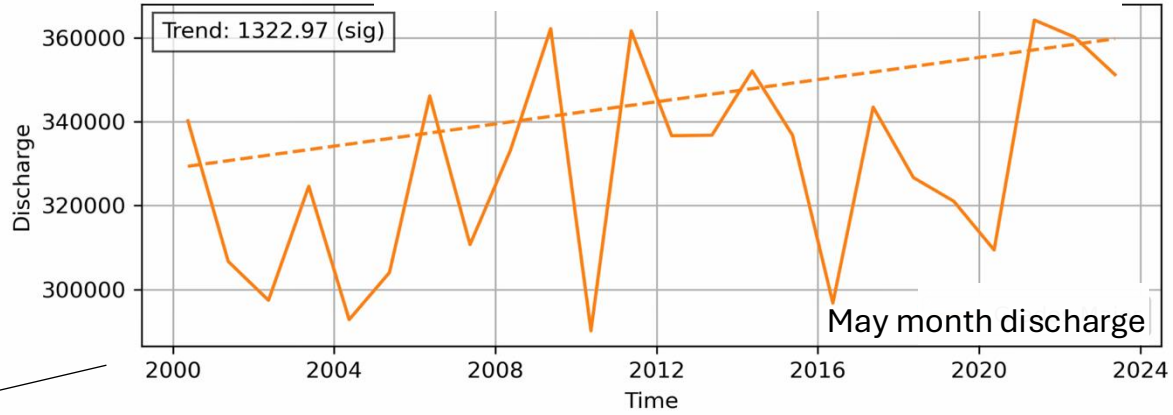
Jarugula et al. in prep

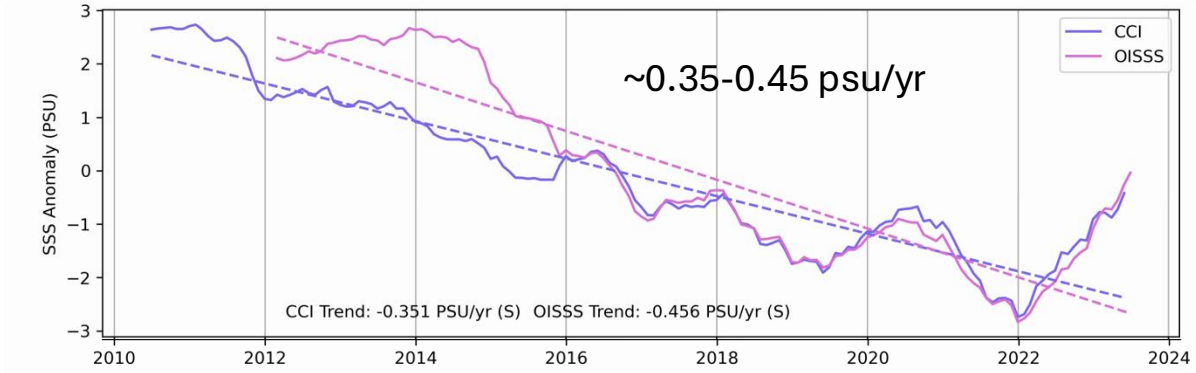
Is Amazon Deforestation Freshening the Coastal Tropical Atlantic Ocean?

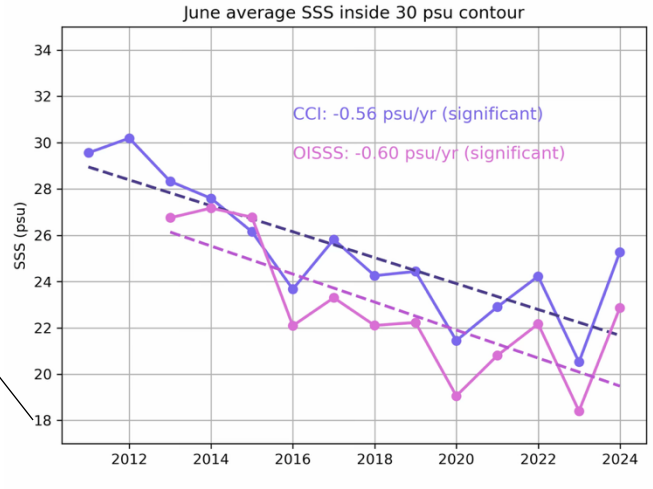


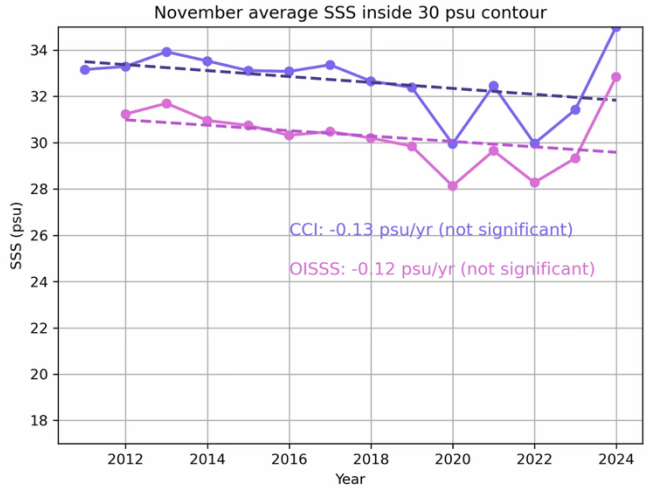
Most likely, yes!!

GRADES Model discharge at river mouth









Jarugula et al. in prep

Summary:

- Coastal ocean is extremely rich in providing signals of change in water cycle. SSS variability in the coastal ocean is 30 times higher than in open ocean.
- Climate modes such as ENSO, IOD are major natural drivers but can independently impact the hydrological cycle over land and coastal SSS depending on the geographical location of river basins.
- Human impacts such as deforestation and land cover changes can have significant impact on the hydrological cycle and thereby coastal SSS.

Implications:

- Implications for coastal ocean stratification, circulation, extreme events, air-sea interaction and biogeochemical processes.
- For retrieval teams and design of future missions: Reliable satellite SSS observations near river mouths are important.
- For the modelling community:
  - SSS measurements near river mouth provide an effective constraint on discharge estimates for poorly gauged river basins
  - SSS data also provide constraint on ocean state estimation in coastal regions

Open Science Questions:

- How will the linkages between the hydrological cycle and coastal sea surface salinity (SSS) evolve as the global hydrological cycle intensifies?
- How will projected increases in the frequency and intensity of extreme ENSO and IOD events under global warming amplify or dampen the hydrological cycle and its influence on coastal SSS?
- How do human-driven changes — including dam construction, deforestation, and land-use/land-cover change — alter freshwater transport and coastal SSS across major river basins worldwide?

Publications related to this project:

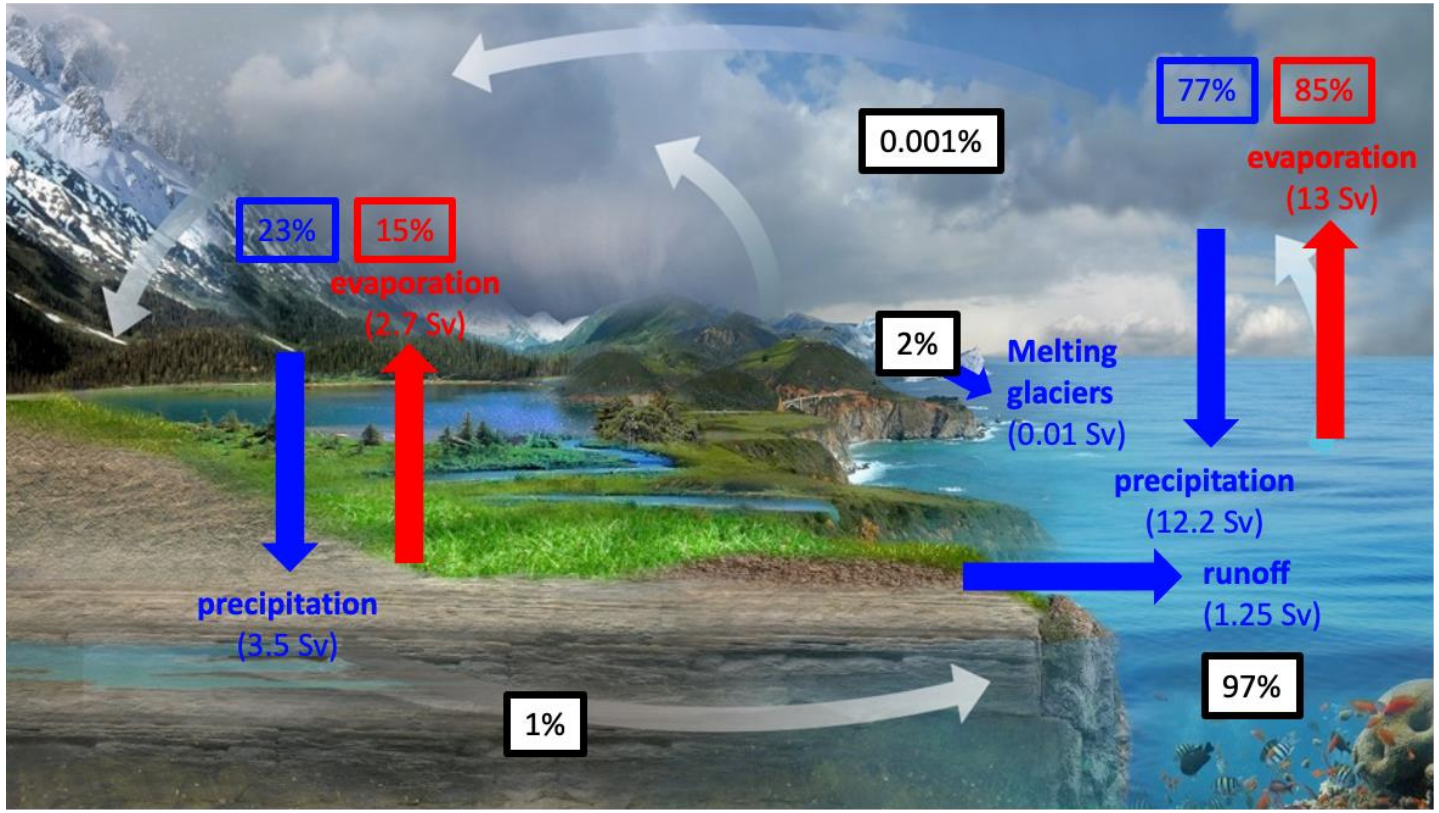
1. Fournier, S., Reager, J. T., Chandanpurkar, H. A., Pascolini-Campbell, M., & Jarugula, S. (2023). The salinity of coastal waters as a bellwether for global water cycle changes. Geophysical Research Letters, 50, e2023GL106684. https://doi.org/10.1029/2023GL106684

2. Jarugula, S., S. Fournier, J. T. Reager, and M. Pascolini-Campbell, 2024: Intercomparison of In Situ and Satellite Sea Surface Salinity Products for Global Coastal Ocean Studies. *J. Atmos. Oceanic Technol.*, **42**, 3–16, https://doi.org/10.1175/JTECH-D-23-0168.1.

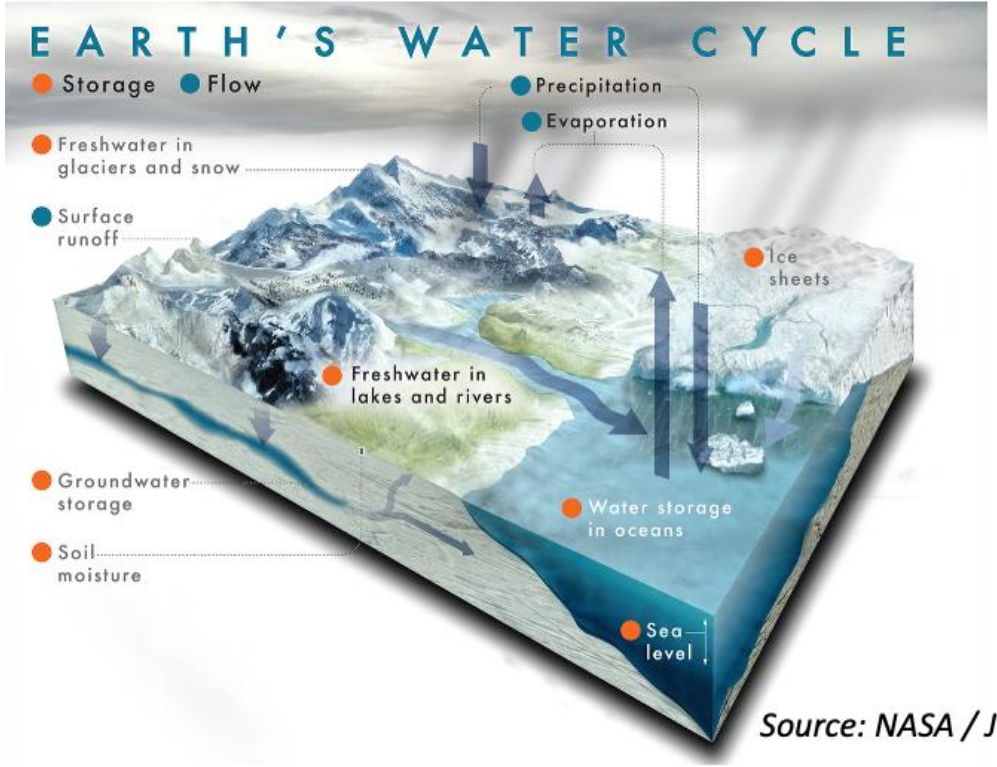
3. Jarugula, S., Fournier, S., Reager, J., & Pascolini-Campbell, M. (2026). Land–ocean pathways linking Indo-Pacific sea surface temperature variability to tropical Atlantic coastal salinity. Journal of Geophysical Research: Oceans, 131, e2025JC023816. https://doi.org/10.1029/2025JC023816

In prep: Jarugula, S., Fournier, S., Reager, J., & Pascolini-Campbell, M. (2026). Is Amazon Deforestation Freshening the Coastal Tropical Atlantic Ocean?

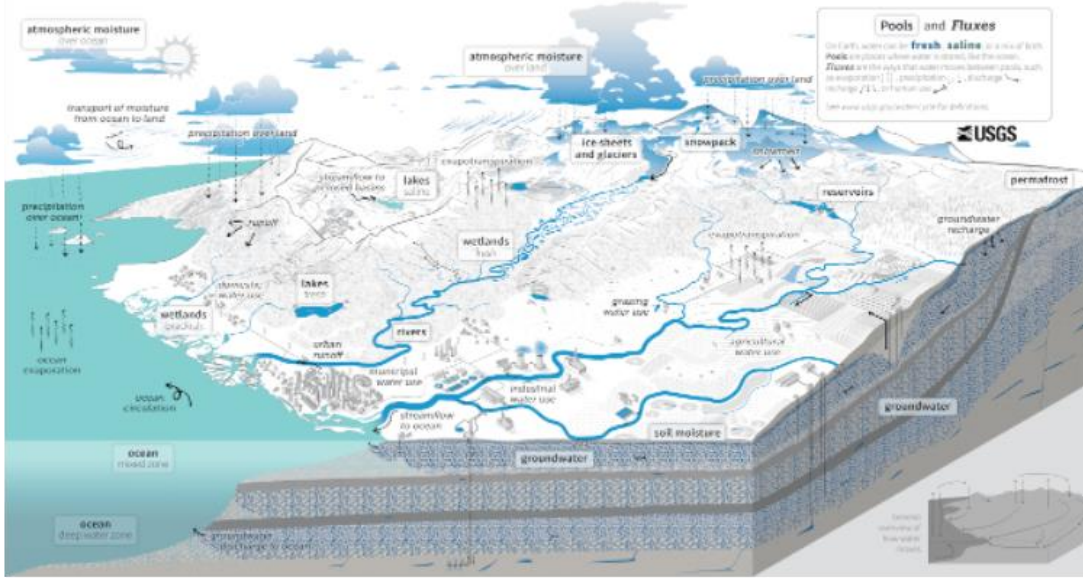
Global water cycle: Movement of water between land, ocean, atmosphere, and cryosphere



Source: Baumgartner and Reichel, 1975; Durack, 2015; Schanze et al., 2010



Source: NASA / JPL



Credit: Hayley Corson-Dosch/USGS VizLab