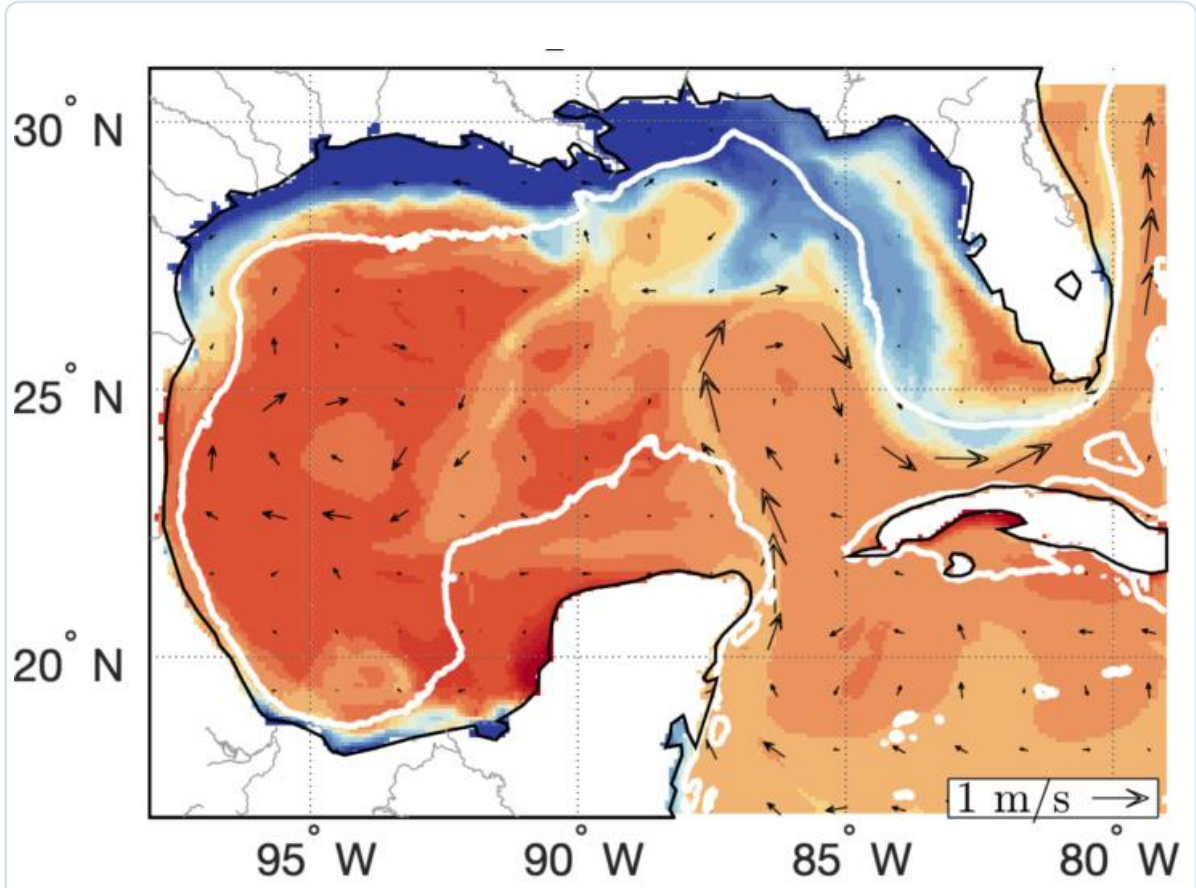
# Characterization of surface salinity variability in Gulf of Mexico

## using a regional ocean model ensemble

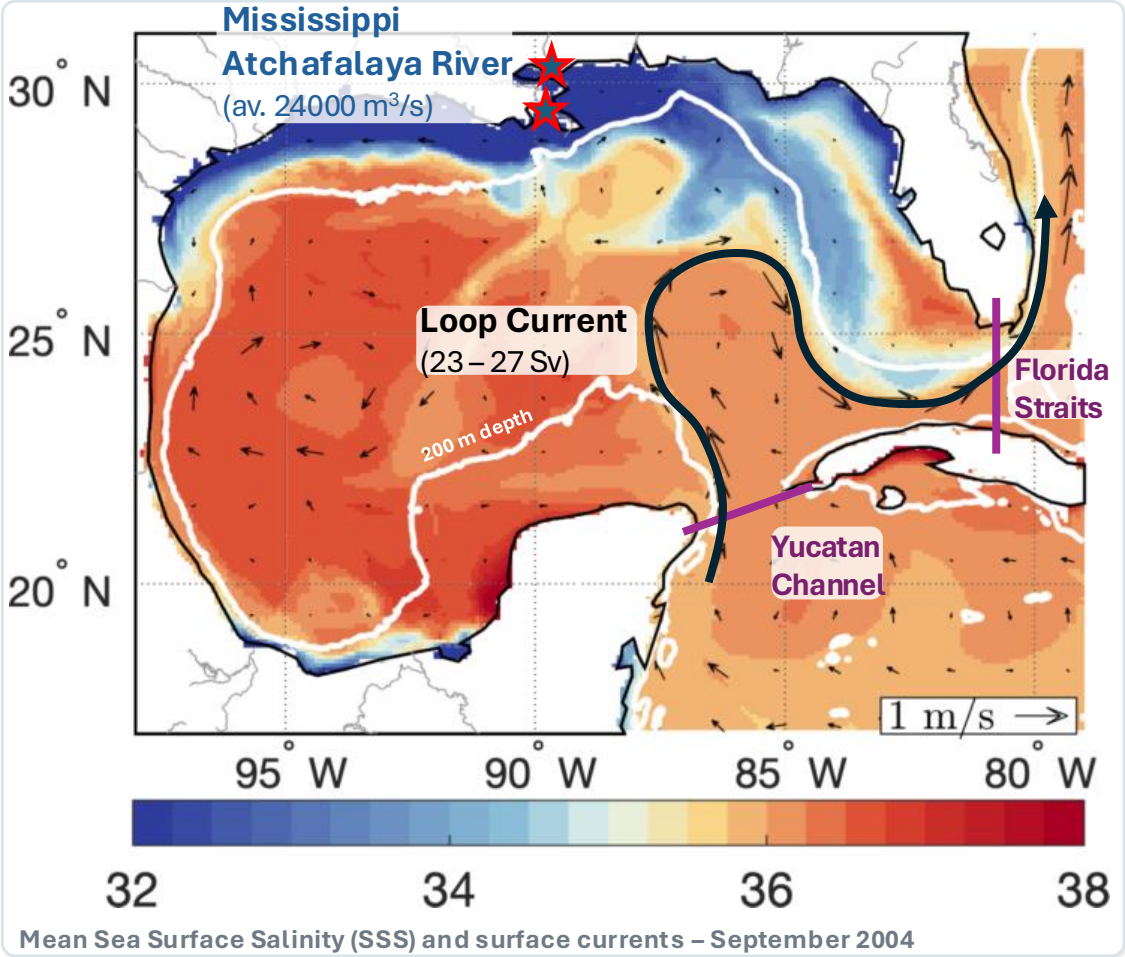
Clovis Thouvenin-Masson,[1,2] Julien Jouanno[1,3]

(1) (2) (3)



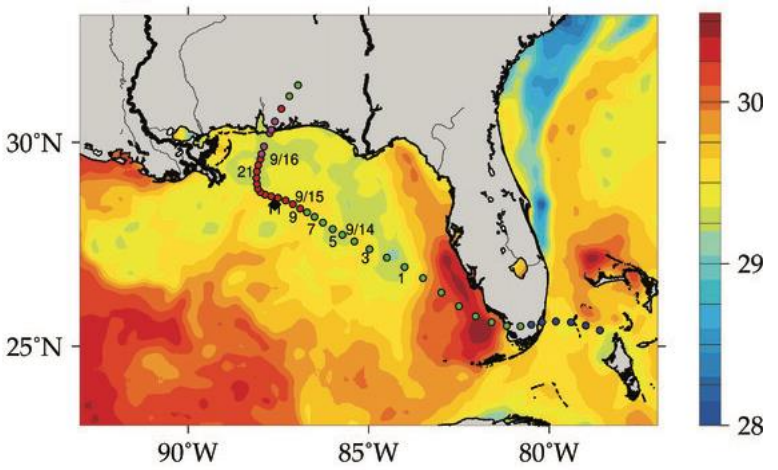

Mean surface salinity and surface currents – September 2004

# Gulf of Mexico main dynamics - Why study salinity?

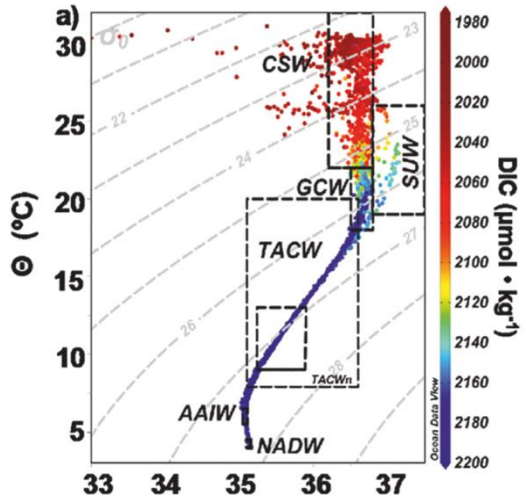



Mean Sea Surface Salinity (SSS) and surface currents – September 2004

- **High stress due to salinity on ecosystems** along Florida coast (*Bachman 2008*)
- Modifies **upper-ocean stratification** → influences tropical cyclones *(John 2023)*.
- Formation of **Gulf Common Water (GCW)**

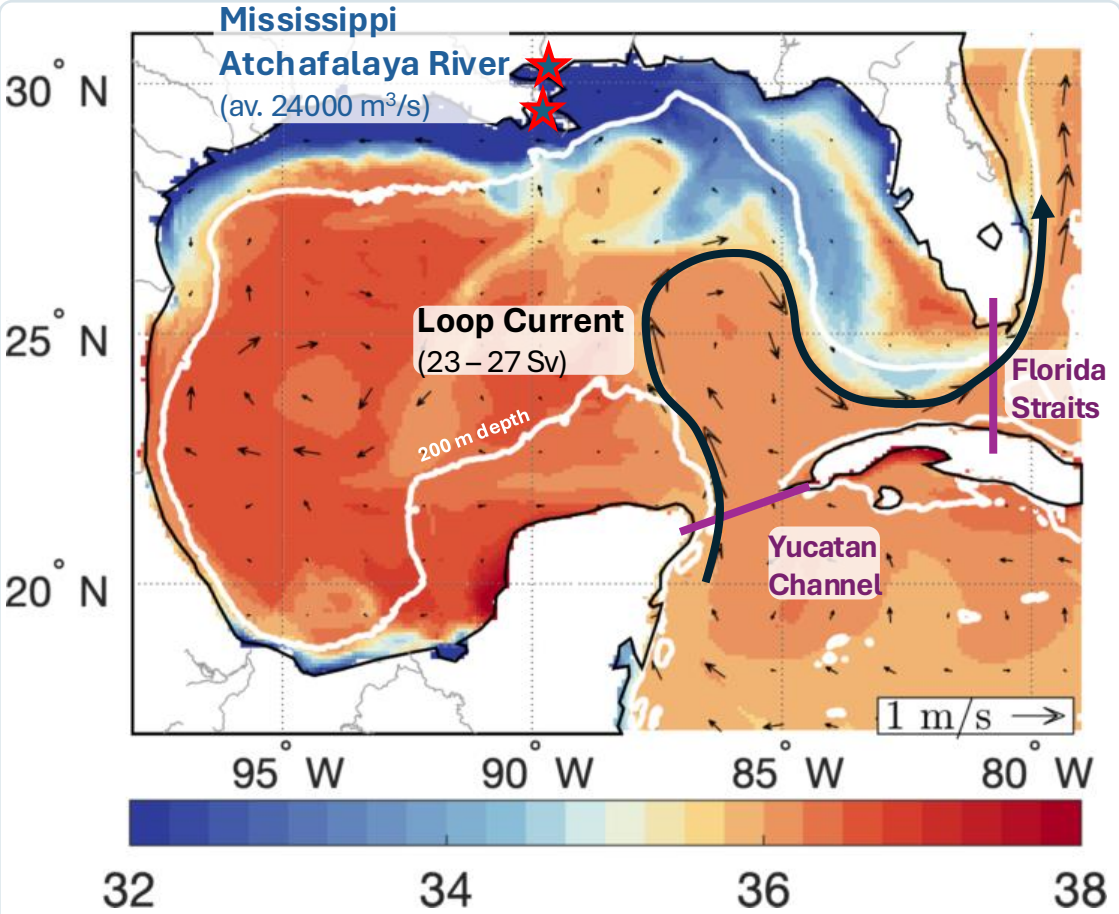



Hurricane Sally (2020) - *John 2023*




T-S diagram - *Cervantes-Díaz 2022*

# Prior work on Gulf salinity and freshwater export




Mean Sea Surface Salinity (SSS) and surface currents – September 2004

Previous studies showed that SSS variability in the North-East Gulf is mainly driven by:

- river discharge (1,5)
- Loop Current interactions (3,4,6)
- wind forcing (1,2,4)

Mississippi waters can reach the West Florida Shelf and Florida Straits (4,7)

They identified **key mechanisms** from **satellite observations** or from **case studies** of specific Loop Current–plume configurations.

**We use a regional ensemble simulation to:**

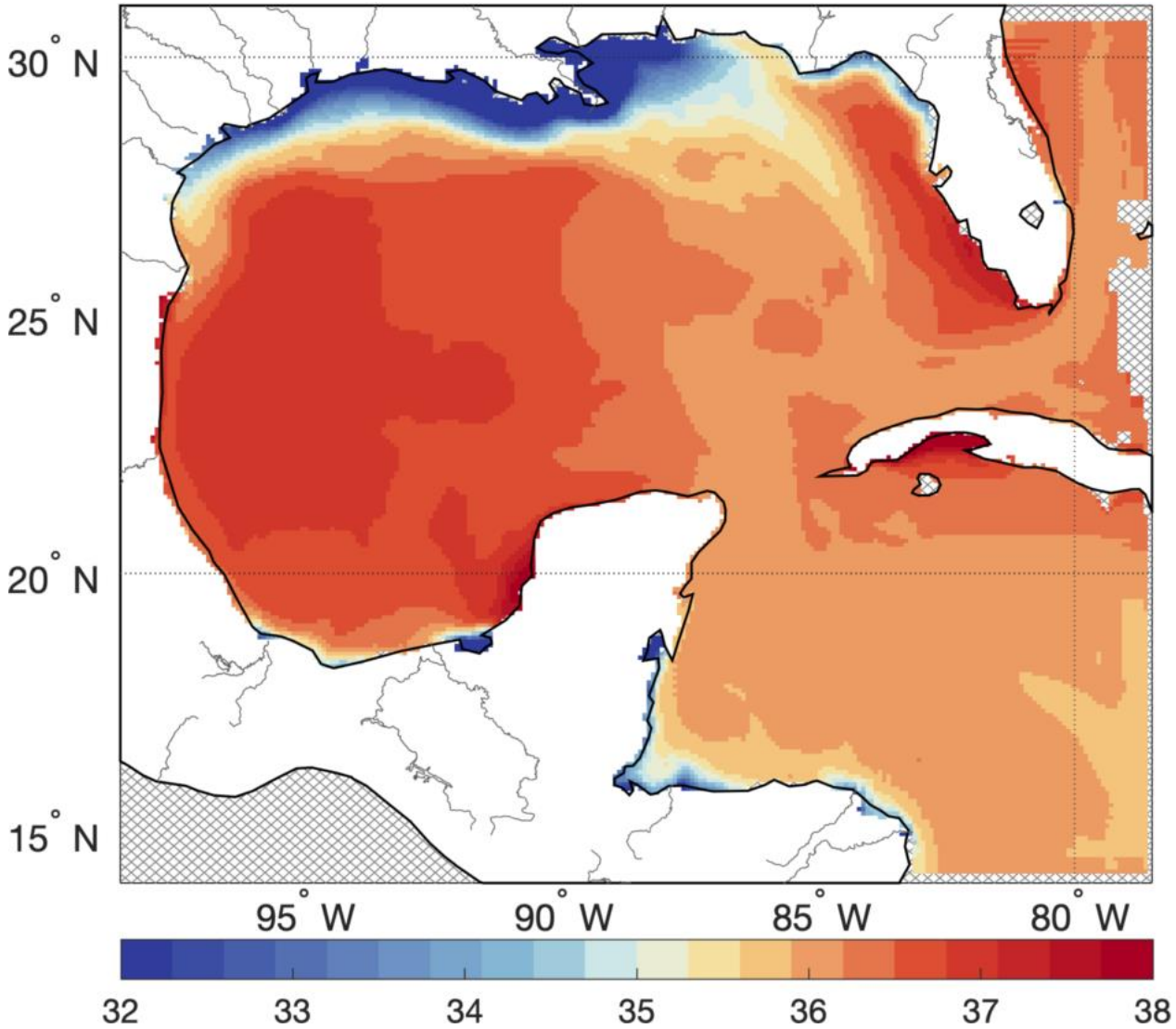
- **assess the robustness** of these mechanisms on a more comprehensive time serie.
- **Quantify the relative importance of forcing and circulation on SSS variability**.

**References**

*(1) Morey et al., 2003*
*(2) Schiller et al., 2011*
*(3) Schiller and Kourafalou, 2014*
*(4) Le Hénaff and Kourafalou, 2016*
*(5) Fournier et al., 2016*
*(6) Brokaw et al., 2019*
*(7) Hu et al., 2005*

# GOLFO12 regional ensemble simulations

*Configuration provided by Julien Jouanno*




Mean model SSS over year 2023

**Model**
NEMO 1/12°
75 vertical levels (Δz~1m in the upper ocean)

**Forcing**
ERA5 atmospheric forcing
GLORYS12 open boundaries
ISBA-CTRIP river runoff

**Domain**
14 °N – 30.7 °N
98.5 °W – 78.5 °W

**Period**
1980–2023

# GOLFO12 regional ensemble simulations

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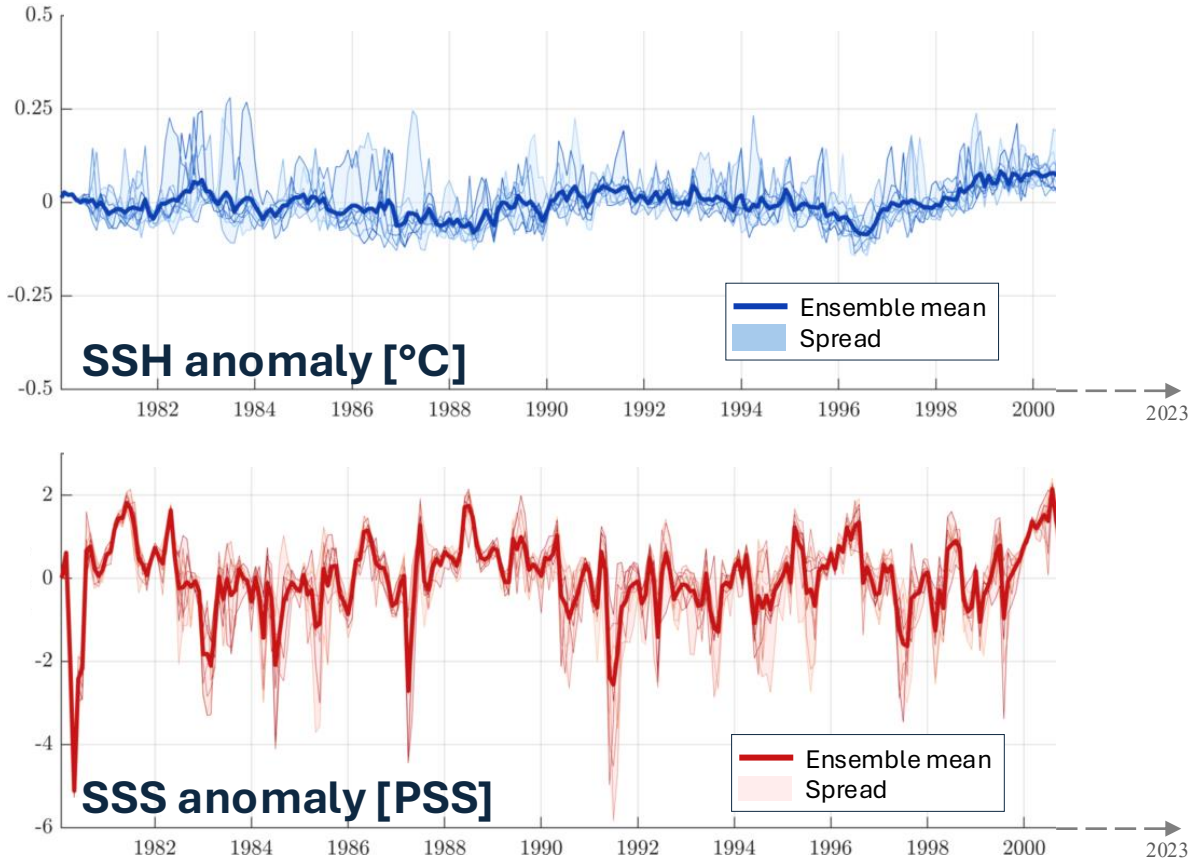


**Identical forcing, different realizations:**
**the ensemble spread reflects internal ocean variability.**

**Model**
NEMO 1/12°
75 vertical levels (Δz~1m in the upper ocean)

**Forcing**
ERA5 atmospheric forcing
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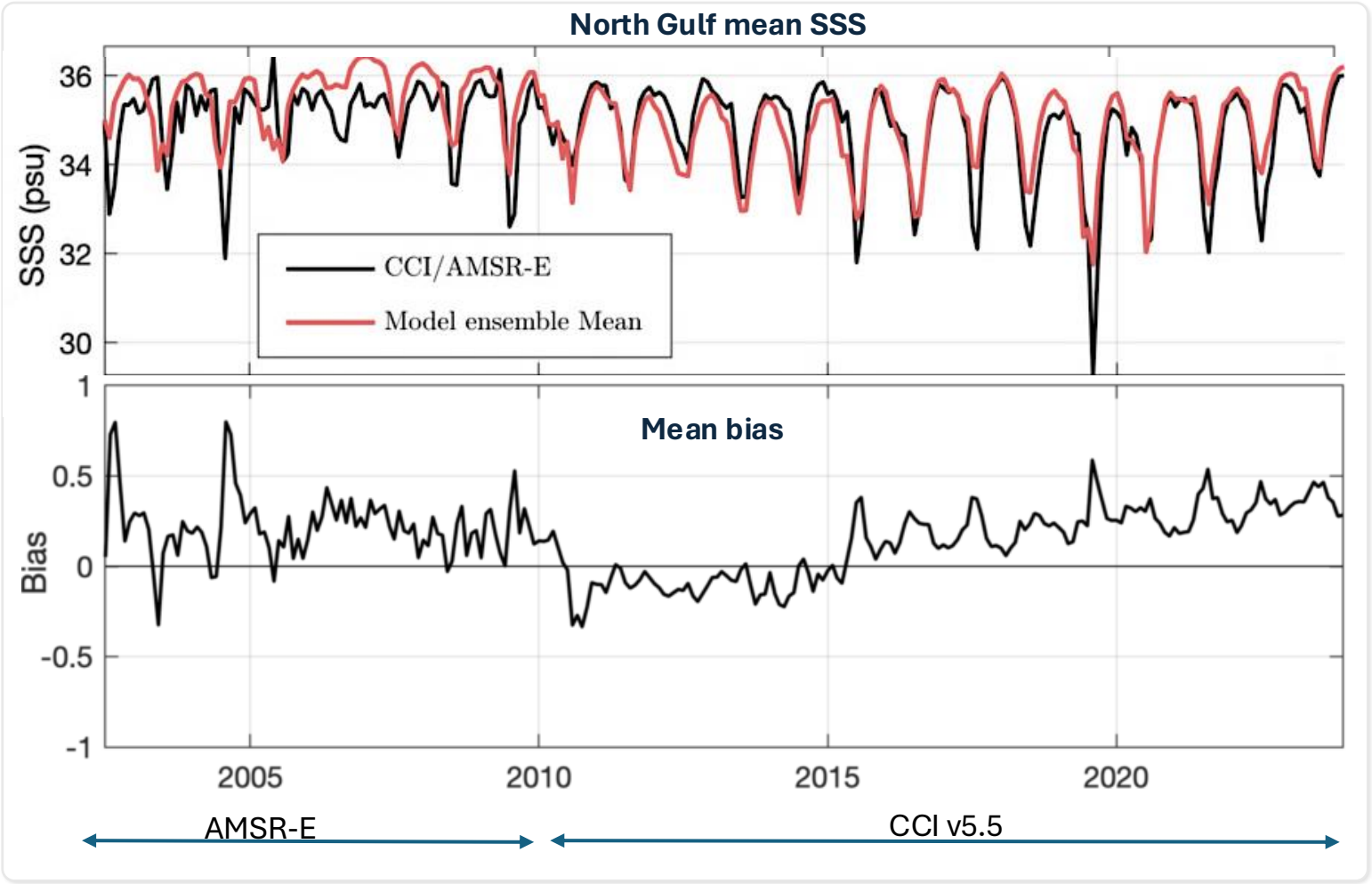
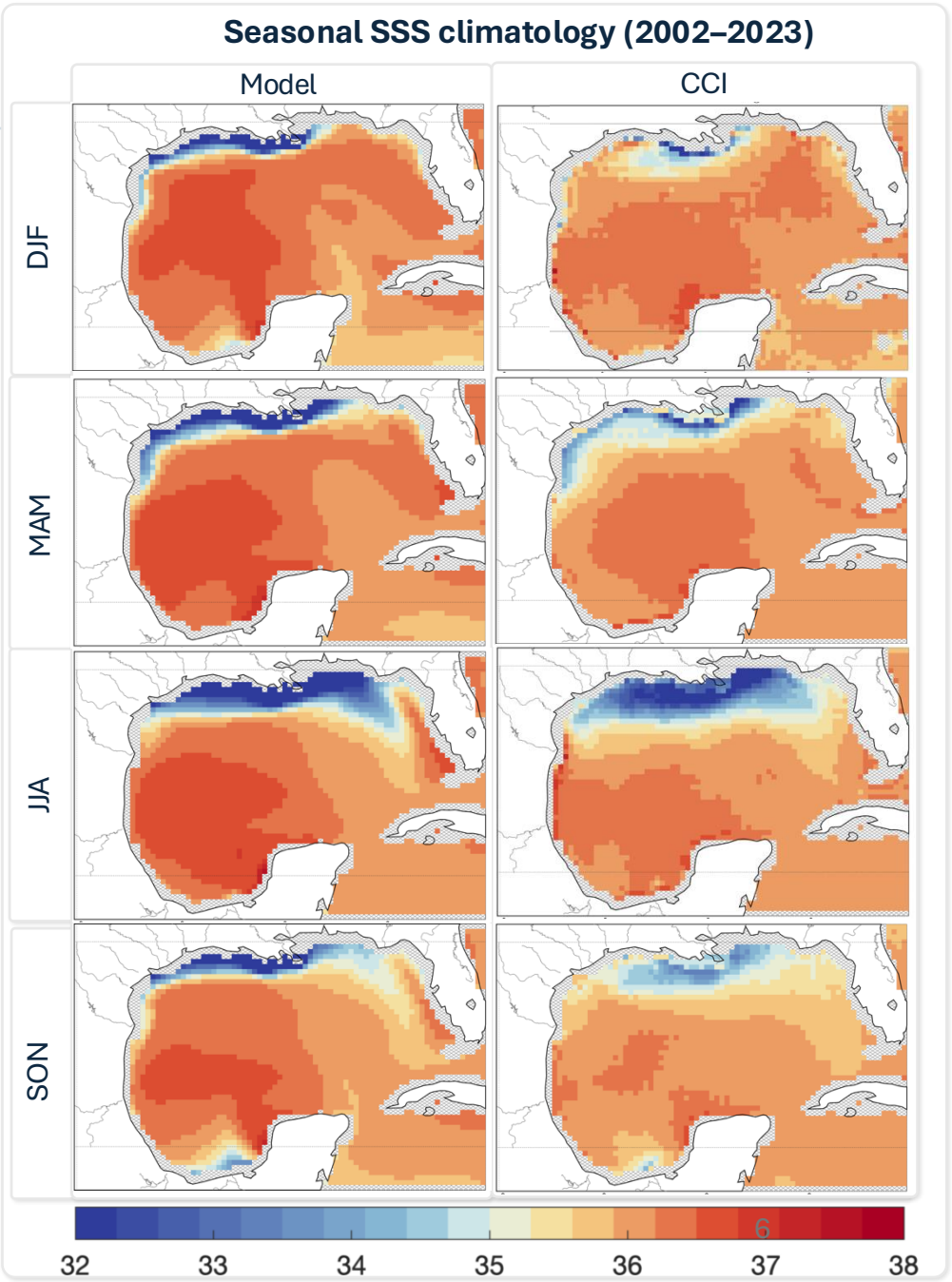
**Domain**
14 °N – 30.7 °N
98.5 °W – 78.5 °W

**Period**
1980–2023

**Ensemble**
10 members, same forcing
small T/S perturbations in the upper 100 m in 1980

# Validation against CCI data

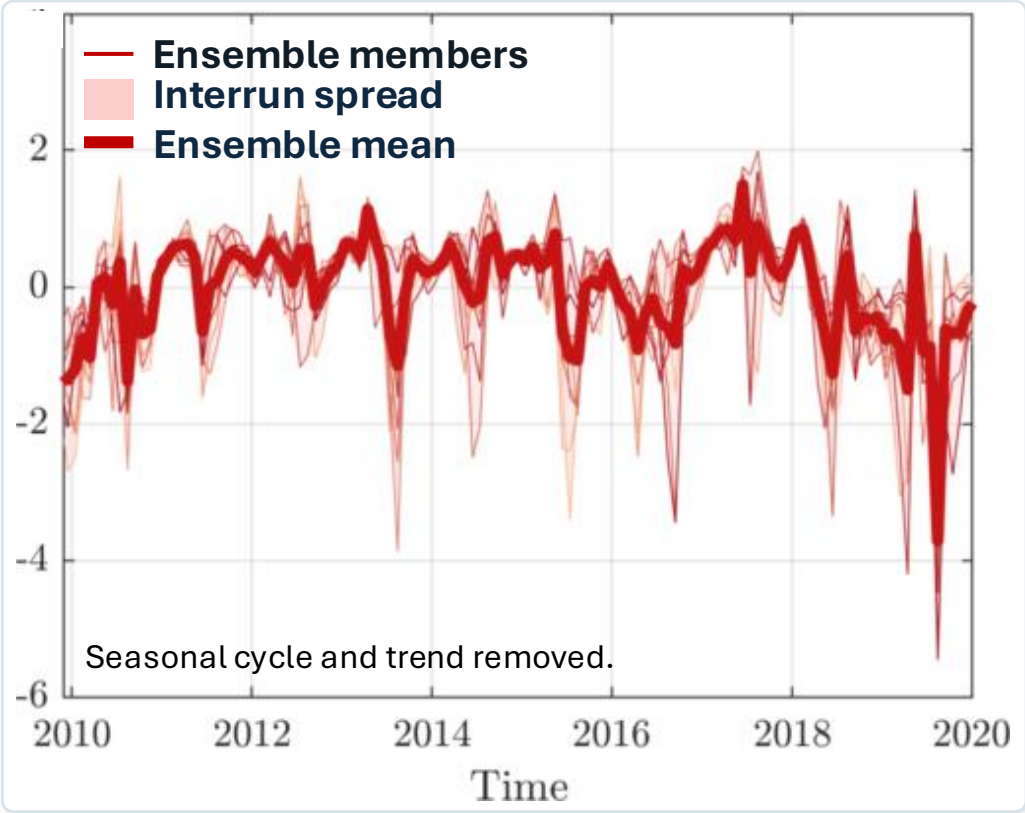


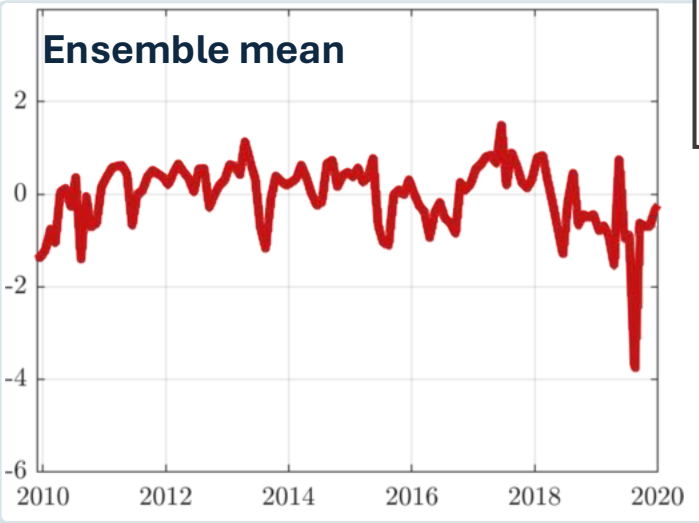




**Seasonal and interannual SSS variability is realistically reproduced**

# Separating forced and intrinsic variability

*Method adapted from Penduff et al. (2018)*

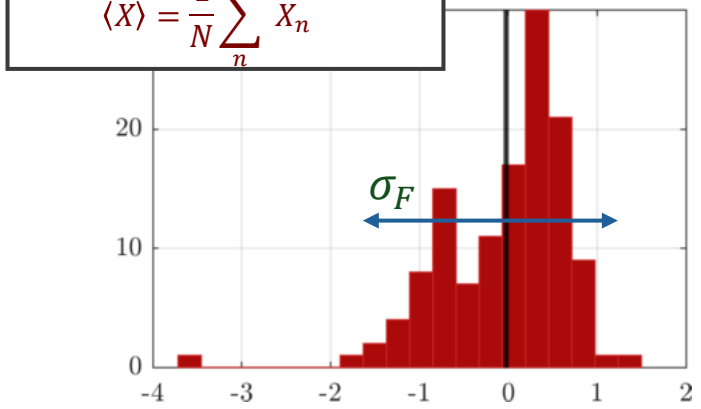


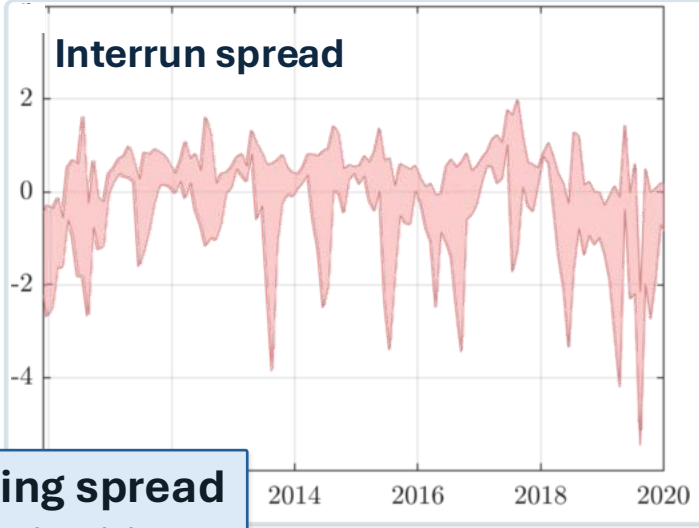




**Variability due to forcing**

$$\sigma_F = \mathrm{std}_t(\langle X \rangle)$$

$$\langle X \rangle = \frac{1}{N}\sum_n X_n$$

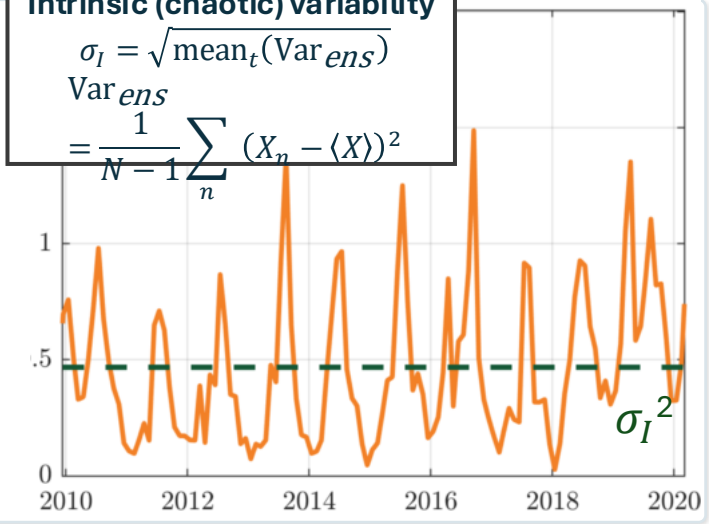



**Intrinsic (chaotic) variability**

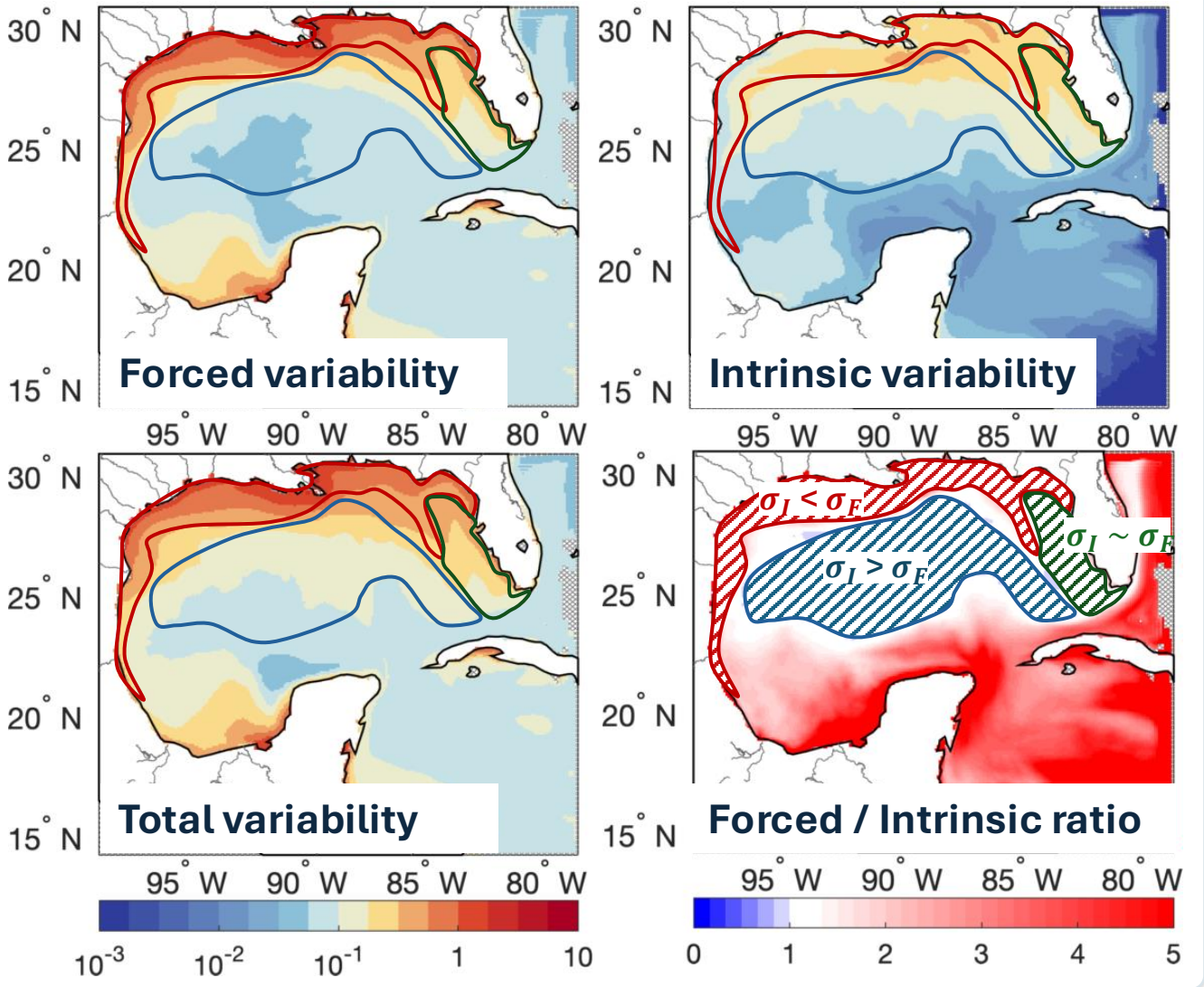
$$\sigma_I = \sqrt{\mathrm{mean}_t(\mathrm{Var}_{ens})}$$

$$\mathrm{Var}_{ens} = \frac{1}{N-1}\sum_n (X_n - \langle X \rangle)^2$$




**Ensemble-mean variability is forced; remaining spread across members reflects intrinsic ocean variability.**

# Separating forced and intrinsic variability

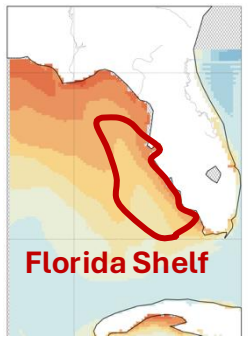


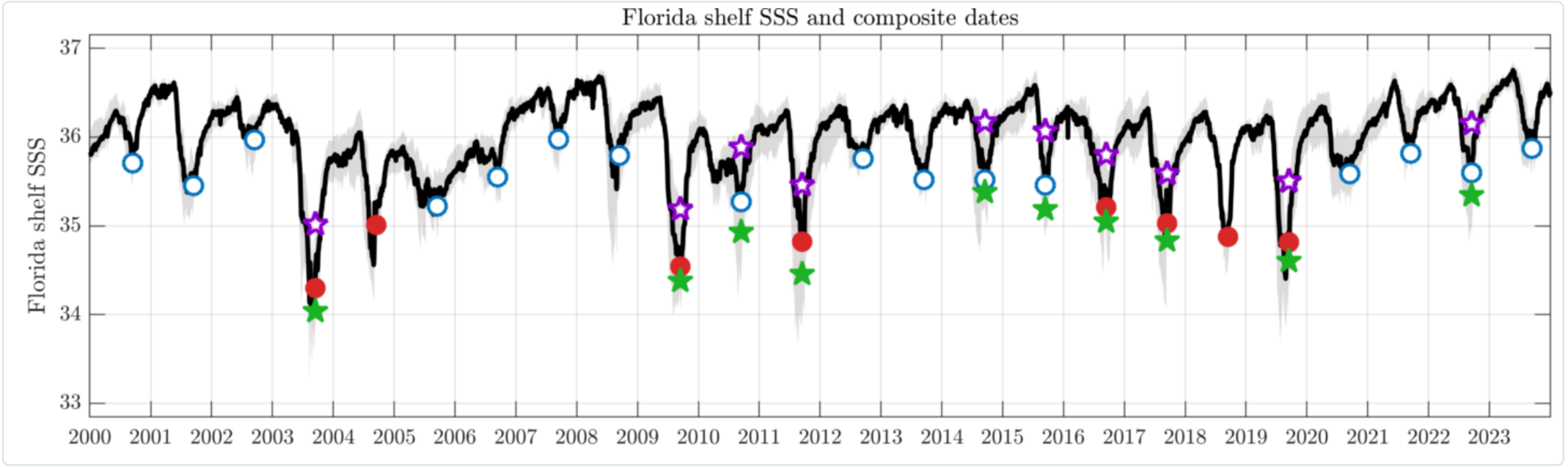

## Regional summary

| Region | σF | σI | σtot | Regime |
|---|---|---|---|---|
| Whole GoM | **0.10** | **0.09** | 0.14 | Mixed |
| Coastal plume | **0.54** | 0.10 | 0.55 | Forced |
| Central Loop Current | 0.07 | **0.09** | 0.11 | Intrinsic |
| Florida shelf & Straits | **0.09** | **0.10** | 0.14 | Mixed |

- Forced variability dominates the coastal plume
- intrinsic variability peaks in the central Loop Current region
- Florida shelf and Straits: both sources of variability matter equally

# Origin of forced and intrinsic variability on Florida Shelf - composite analysis




## Composite selection

### Forced variability

**Ensemble mean**

→ **Low-S months** vs **High-S months**
September, all years

### Intrinsic variability

**Run-to-run spread**

→ **Low-S runs** vs **high-S runs**
At high-spread September

## Lagged composite analysis

**Composite target**

September Fl. Shelf SSS

High-S vs Low-S cases

**Monthly lagged predictors**

Spring to summer evolution

- **Plume**
- **Wind forcing**
- **Loop Current**
- **Regional SSS**

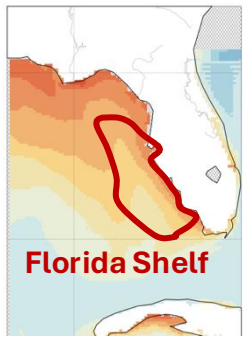
**Mechanism diagnosis**

Correlations

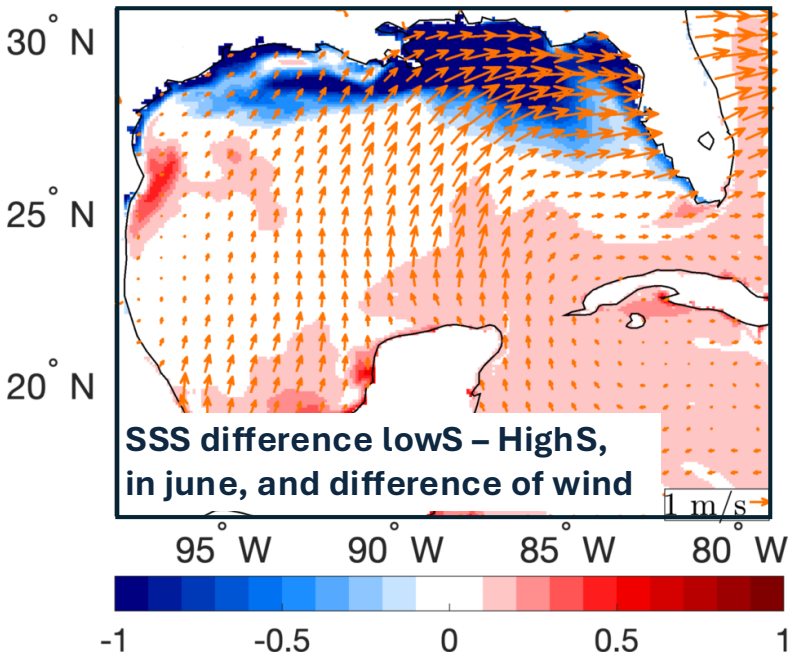
High – Low composite maps

**Objective: link September freshening to earlier plume conditions, wind forcing, and Loop Current state.**

# Origin of forced and intrinsic variability on Florida Shelf




## Forced variability




**April - June wind**
Eastward anomaly
**April Discharge**

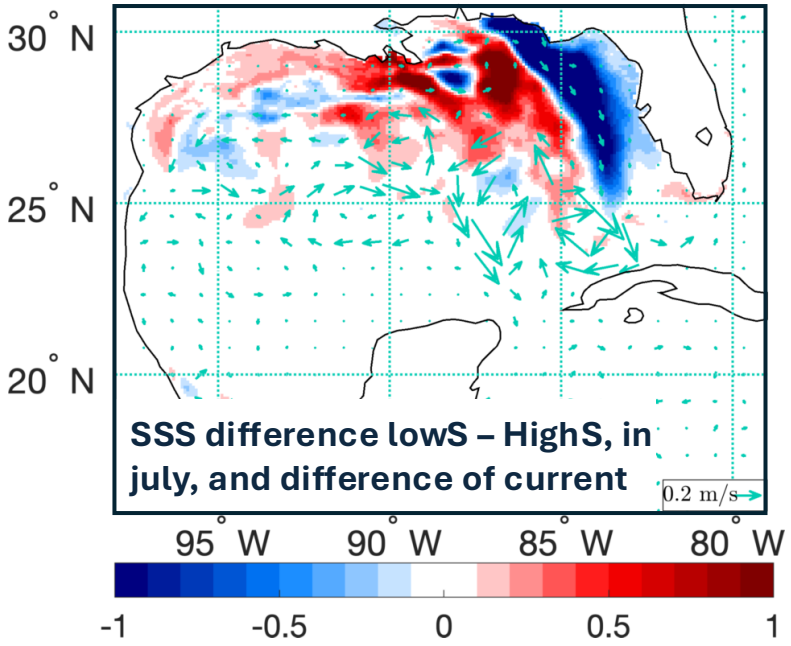
$r^2$=0.68

**June plume**
South extent

$r^2$=0.66

**September Florida shelf**
freshening event

## Intrinsic variability




**Summer LC**
North-East extent

$r^2$=0.60

**Plume centroid Current**
East

$r^2$=0.66

**September Florida shelf**
Low run

**Forced variability depends on spring plume conditions**
**Intrinsic variability depends on summer Loop Current position**

# Conclusions

GOLFO12 realistically reproduces the main Gulf of Mexico SSS patterns and the variability of the Mississippi freshwater plume. CCI and AMSR-E allow long term validation of simulation in the Gulf

Mississippi plume variability is **primarily forced**, driven by river discharge and wind-driven spreading.

In the central Gulf, SSS variability is mainly controlled by **intrinsic eddy dynamics**.

On the Florida Shelf, variability has **comparable forced and intrinsic contributions**: forced freshening depends on **spring plume conditions**, while intrinsic differences are linked to the **summer Loop Current position and circulation**.

# Perspectives

The processes by which the variability of the LC modulates salt transport along the Florida Shelf need to be investigated in more details.

Focus on **Florida Straits** to determine when freshwater can be exported this far downstream.