Forced and chaotic variability of the Gulf of Mexico and surrounding regions

I. García Gómez [1], T. Penduff[1], B. Barnier[1], J. Sheinbaum[2],JM. Molines[1], JM. Brankart[1]

(1)Institut des Géosciences de l'Environnement, CNRS/UGA; (2) CICESE, Ensenada,Mexico

Contact: `ixetl.garcia-gomez@univ-grenoble-alpes.fr`

Objectives

- **Propose ensemble-based metrics to study the chaotic ocean variability (sensitive to initial conditions uncertainties) and its modulation by the atmosphere.**
- **Quantify the imprints of chaotic variability and atmospheric forcing on various variables, regions, and temporal scales.**

Context

The OCCIPUT (oceanic chaos impacts, structure, predictability) project has the objective to study, the contribution of the intrinsic and forced variabilities, at different time and space scales.

- A 50-member ensemble simulation is performed: $1/4°$ (1993-2012). Stochastic initial perturbations, same atmospheric forcing on each member.

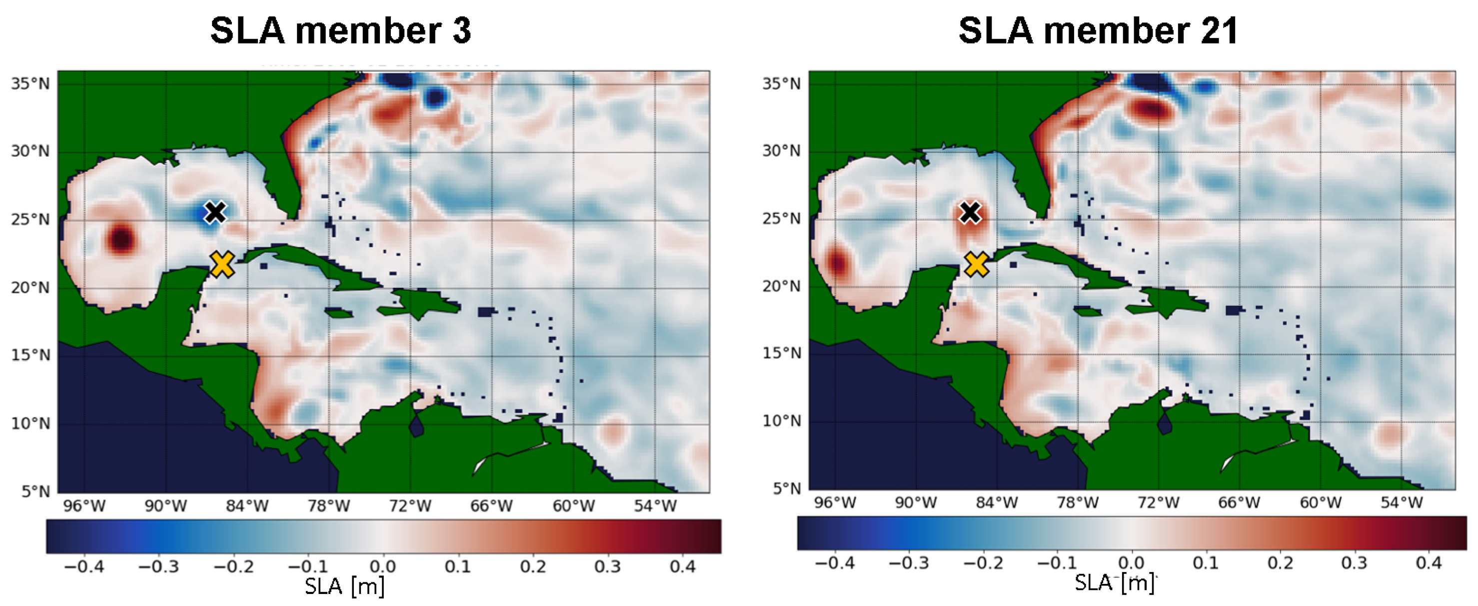


Figure 1: Snapshot (18/01/2005) of SLA in different members. Cross represent the locations of the time series in fig 2.

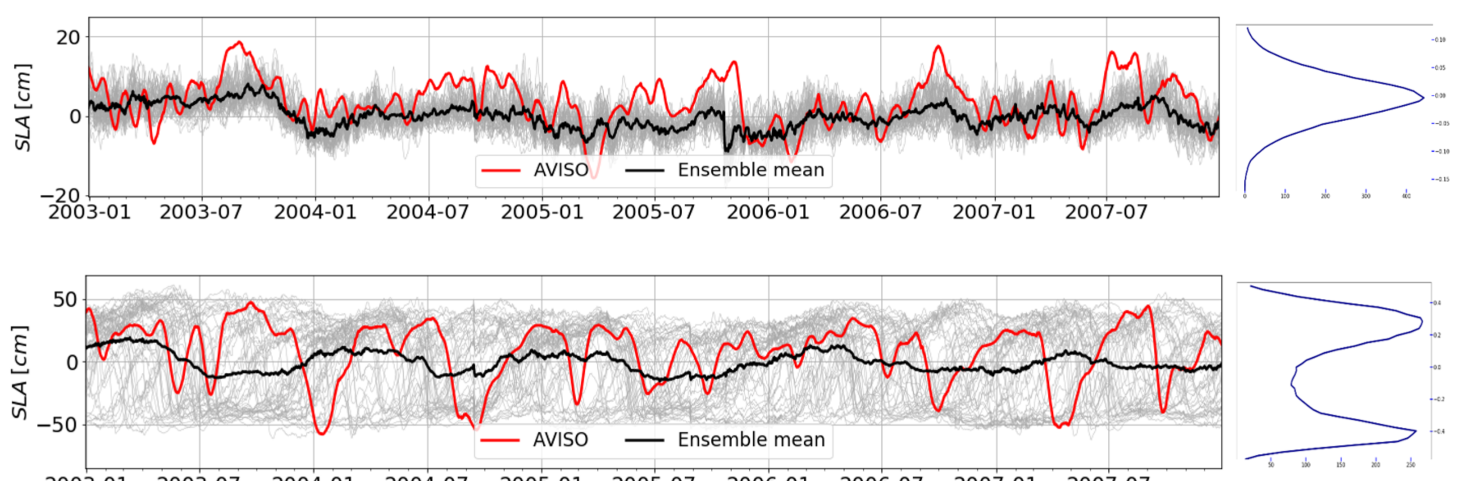


Figure 2: SLA in the Yucatan channel (upper) and Loop Current(lower) over 2003-2008. AVISO observations (red), ensemble-mean (black) and individual members (grey thin) SLA. Right panels corresponds to the climatological PDFs at each location. Locations in fig 1

- We found regions in the north Atlantic where the distribution of the SLA is not Gaussian. Use ensemble mean and ensemble std will not provide accurate information of the variability.

Data and Methods

- **50-member** 20-yr daily **SSH** time series → nonlinear detrending → LP filter.
- **50-member** 20-yr 5-d **volume transport** in the Yucatan Channel (YC) and the Florida Straits (FS).

Entropy: New methods for non-Gaussian variables

1. Compute the climatological PDF at each location (all members, all time steps).
2. Calculate the deciles from the climatological PDF
3. Construct daily ensemble PDFs (p_i) based on the latter deciles.
4. Compute normalized entropy (daily-to-climatological):

$$\mathbf{S(x,y,t) = \sum p_i(x,y,t) log p_i(x,y,t))/log(1/10)}$$

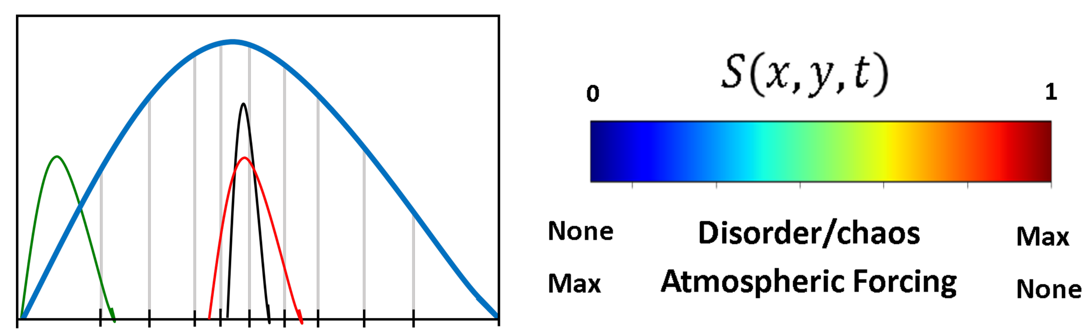
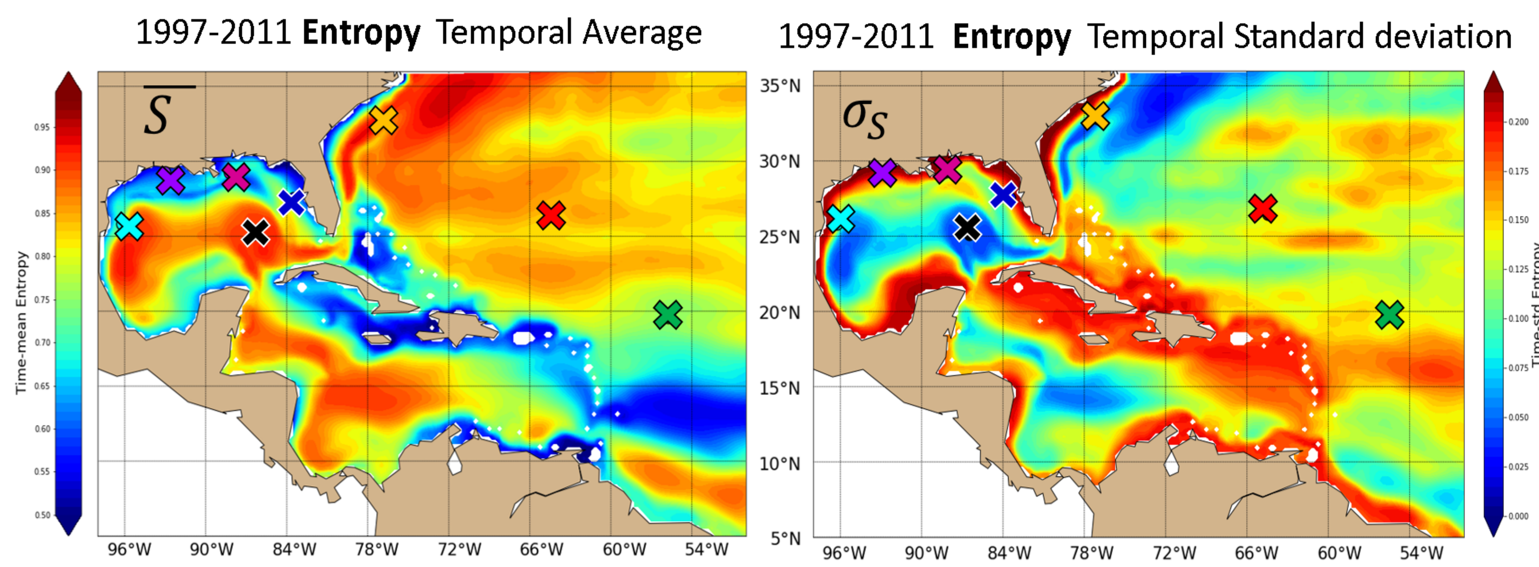


Figure 3: Graphic representation of different relative entropies. Climatological PDF (blue) represented by climatological deciles (black edges). 1) $\sigma = \sigma; \mu \neq \mu \rightarrow (S > S)$. 2) $\sigma \neq \sigma; \mu = \mu \rightarrow (S > S)$.

Results: Surface variability



- Loop Current and Gulf Stream constantly chaotic (large $\overline{S}$ and low σ_S) .

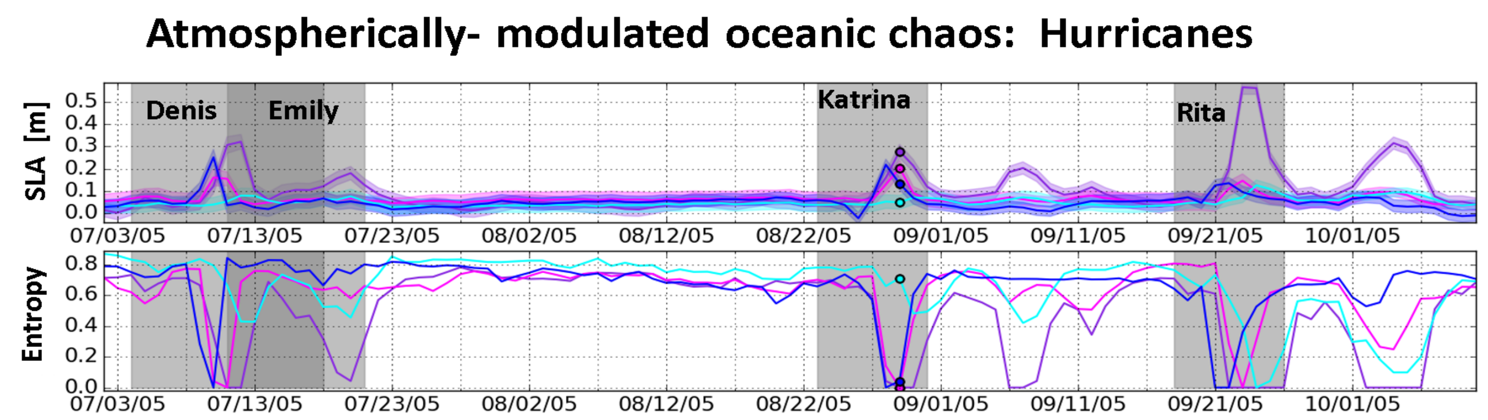


Figure 4: Evolution of daily normalized entropy during hurricane season of 2005. Gray shading represents the period of the passage of major hurricanes. Positions refer to fig.

- Large σ_S: intermittent chaos. Regions where the oceanic chaos is impacted by the atmospheric variability.

Results: Eddy Shedding ⟺ Transports

- Is there a link between LC extension and transport fluctuations through the YC and FS?

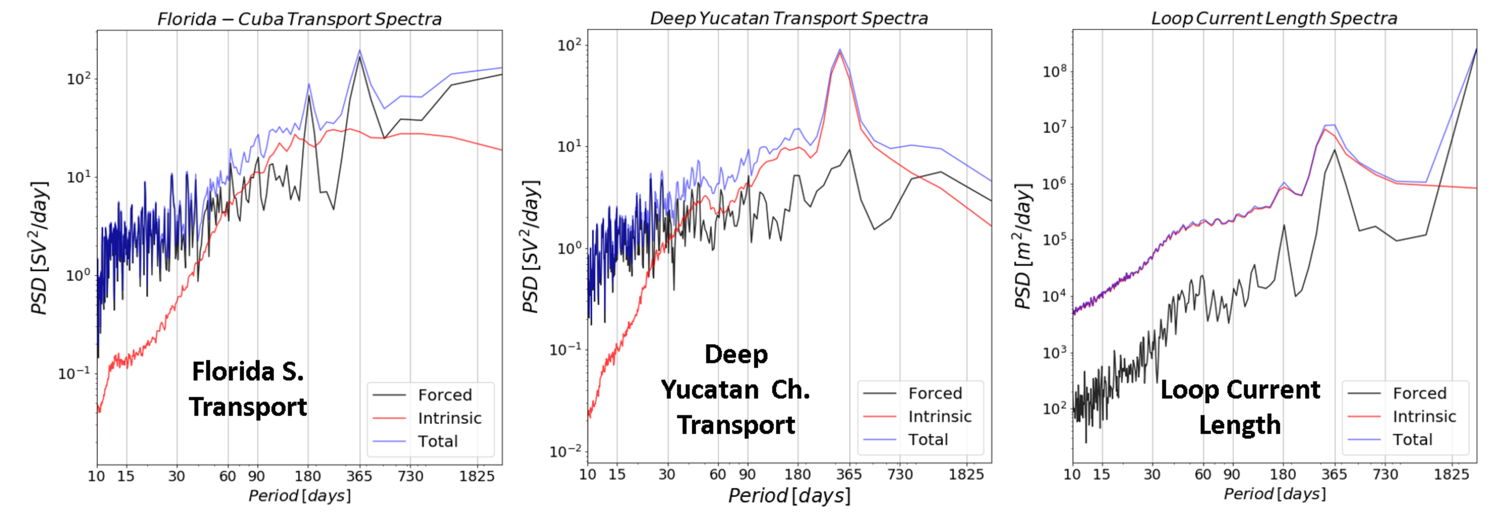


Figure 5: Spectra of the variability of the, Florida strait transport, Deep Yucatan transport and Loop Current length.

- Period 270- 365 days: Very robust coherence between Deep Yucatan transport and the LC length. LC length leads the transport by 30-45 days.

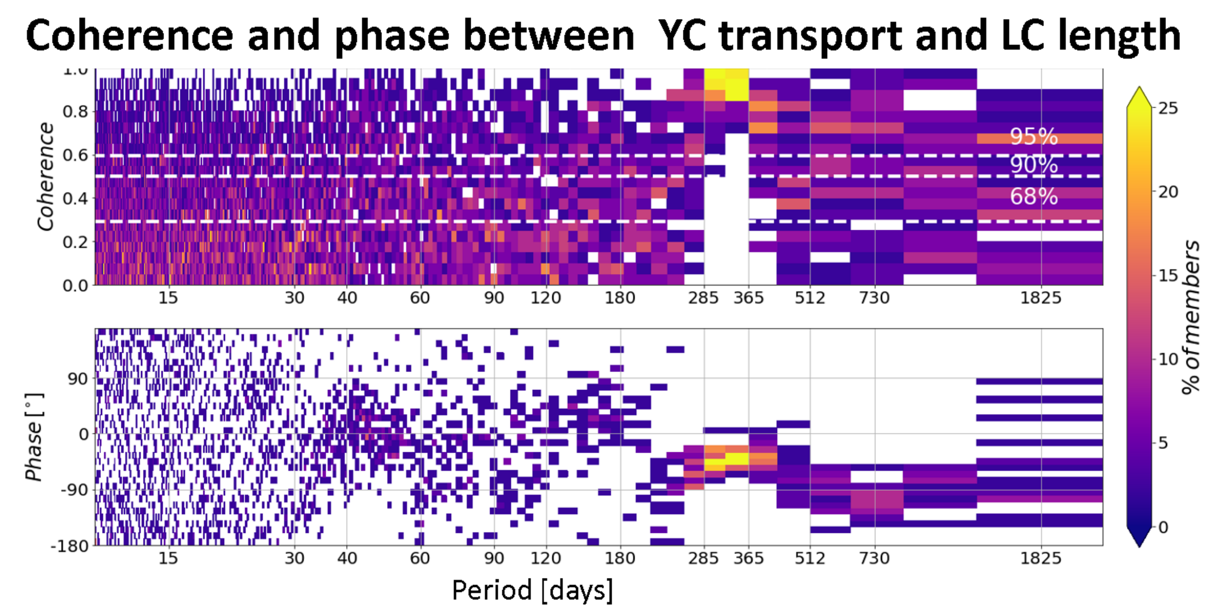


Figure 6: Histogram of the 50-member coherence between Deep Yucatan transport and LC length.

Conclusions

- **Ensemble simulations/diagnostics ⟶ atmospheric modulation of the chaotic ocean variability.**
- **We propose new metrics and methods to describe and interpret the ocean variability.**
- **Propagation of chaos/order?:**
  Caribbean eddies → GoM eddies → GS transport → AMOC?
- **Large areas of non-Gaussian SSH distributions → anamorphosis for data assimilation?**