Climate-relevant imprints and observational implications of the chaotic/intrinsic ocean variability: lessons from the OCCIPUT oceanic Ensemble.

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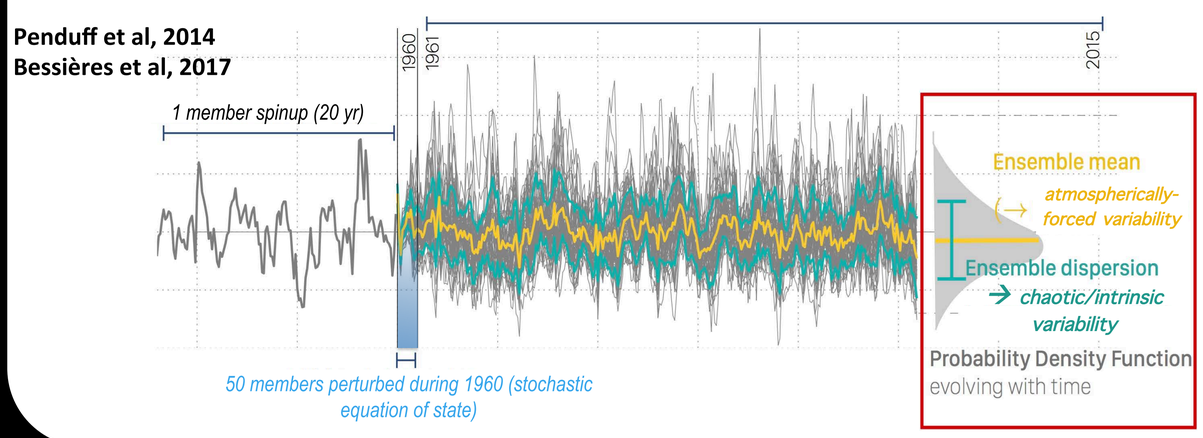
The OCCIPUT Ensemble: 50 turbulent ocean hindcasts

- NEMO global ocean model
- Resolution ¼° — 1960-2015
- 50 members with :
  - Same *ERA-Interim* atm. forcing
  - Slight initial perturbations

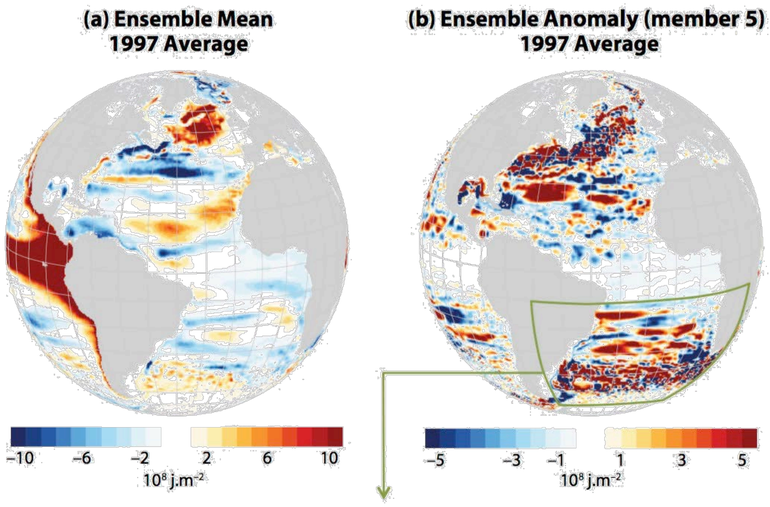
Estimate the oceanic :
- Atmospherically-forced variability
(σ_F = STD of ensemble mean)
- Chaotic/intrinsic variability
(σ_C = mean of ensemble STD)



Take-home messages

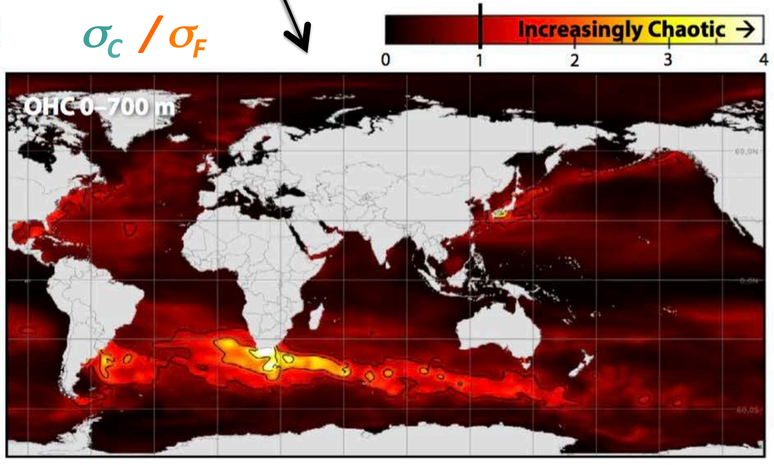
- **In the presence of mesoscale**, the ocean spontaneously generates a strong **low-frequency chaotic/intrinsic variability (LFCIV).** It locally competes with the **atmospheric forcing** in driving the **interannual-to-multidecadal variability of key ocean climate indices ($OHC_{0\text{-}700m}$, AMOC, MHT, etc).**
- Much weaker or absent in coarse-resolution ocean models used in most IPCC-class climate simulators, **this strong LFCIV, might impact the atmosphere in coupled models with turbulent oceans**.
- Over large regions, the **LFCIV** adds a **random component** to local **20/30-year trends of OHC and sea level**, hindering their unambiguous attribution to **[atmospheric+anthropogenic] drivers**.
- Ensemble model statistics can be used to **attenuate the signature of LFCIV in observational datasets** (via filters or Machine Learning), and **unveil the deterministic response of the real ocean to the atmosphere.**

Interannual variability of ***Ocean Heat Content (0-700m)***



LFCIV imprint on $OHC_{0\text{-}700}$:
- up to basin scales (and multiple decades)
- dominates **Forced variability** in regions within contours

σ_C / σ_F

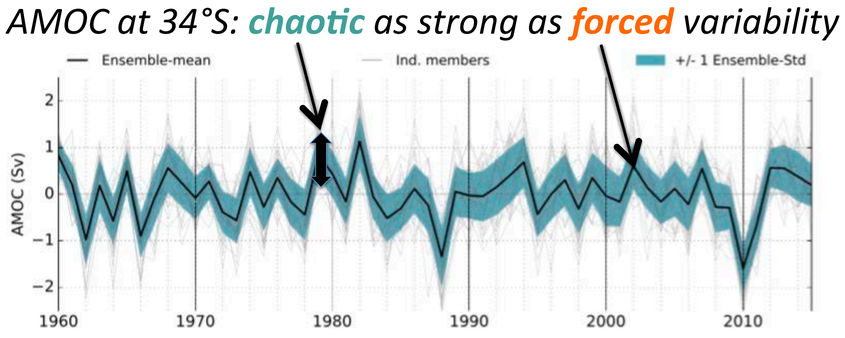


This strong 1-30yr chaotic variability of OHC & AMOC (almost absent without eddies) **is expected to impact the atmosphere in coupled models with eddying oceans**

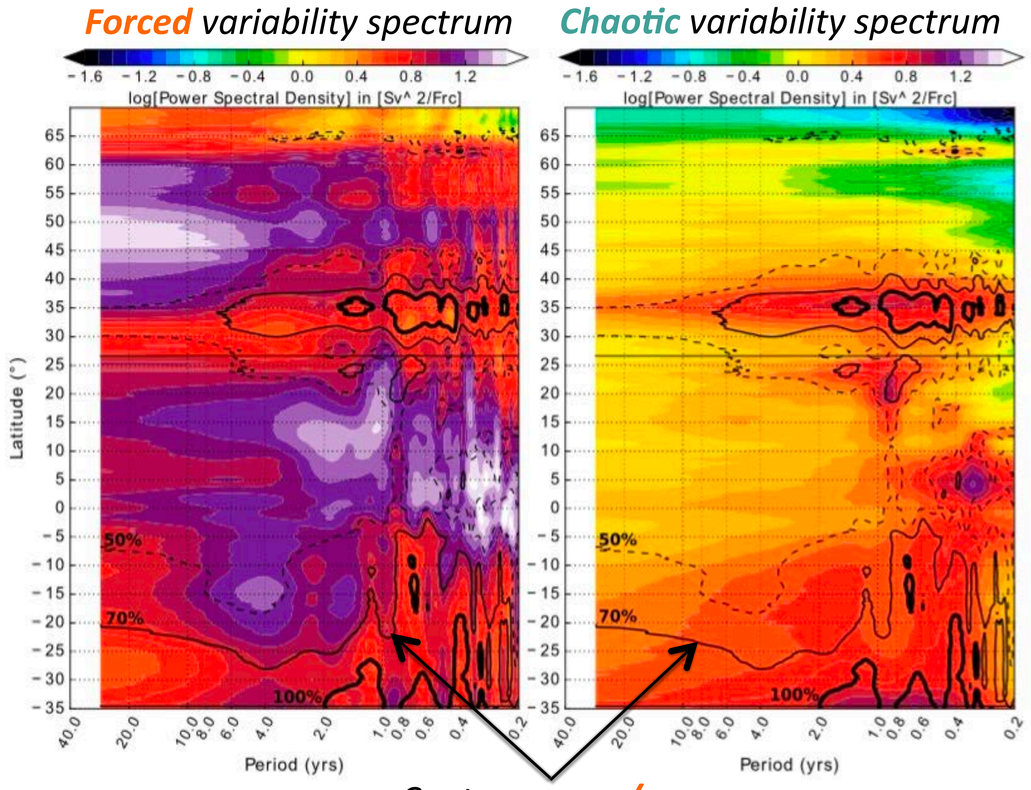
Sérazin et al, 2017
Penduff et al, 2018

Interannual variability of the ***Atlantic Meridional Overturning Circulation***

*AMOC at 34°S: **chaotic** as strong as **forced** variability*



Forced variability spectrum — *Chaotic variability spectrum*



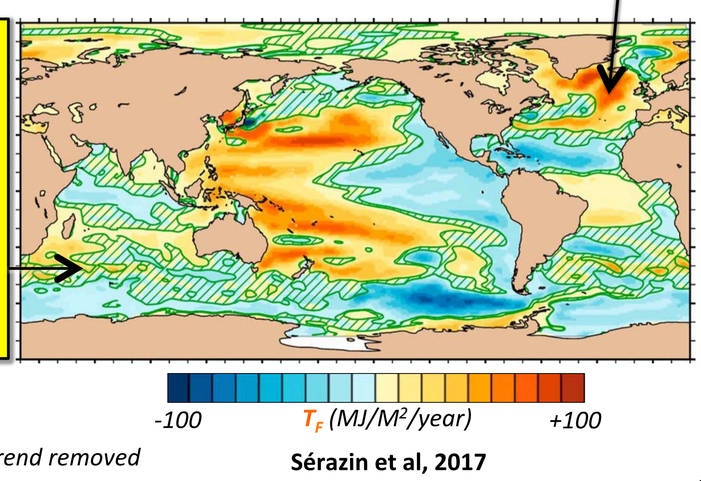
Leroux et al, 2018

21-year trends (1980-2010) of* ***Ocean Heat Content***

- **[atmospheric + anthropogenic drivers]** ➔ **Forced OHC trends T_F** (colors)
- **LFCIV** ➔ **Random OHC trends T_R**

In regions where $|T_F| < 2.T_R$ (green shading)

OHC trends **can NOT be surely attributed** (95% confidence) to **[atmospheric + anthropogenic drivers]**



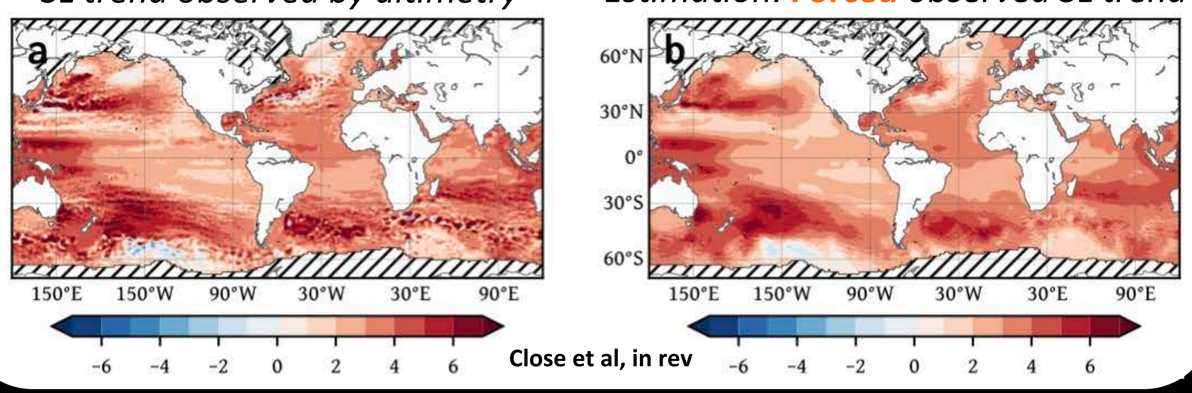
(*) corrected for model drift & global mean trend removed

Sérazin et al, 2017

23-year trends (1993-2015) of ***Observed Sea Level***

- In many regions, $\sigma_C > \sigma_F$ on space scales [110-800km], over *all* time scales
- Filtering out scales [110-800km] ➔ estimation of **Forced** observed trends
- Currently developing an estimator based on Machine Learning (CNN)

SL trend observed by altimetry — *Estimation: **Forced** observed SL trend*



Close et al, in rev

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