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## Climate-relevant imprints and observational implications of the oceanic intrinsic variability: lessons from the OCCIPUT Large Ensemble

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

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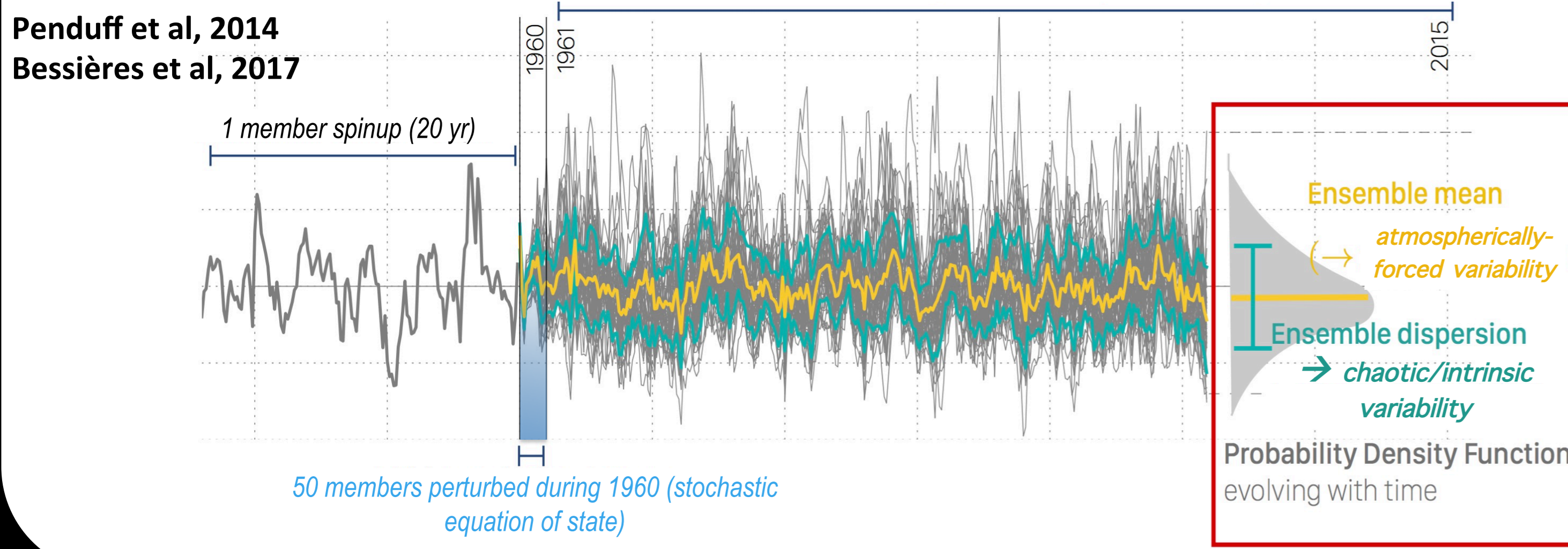
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## The OCCIPUT Ensemble: 50 turbulent ocean hindcasts

- NEMO global ocean model
- Resolution 1/4° — 1960-2015
- 50 members with:
  - Same ERA-Interim atm. forcing
  - Slight initial perturbations

**Estimate the oceanic:**

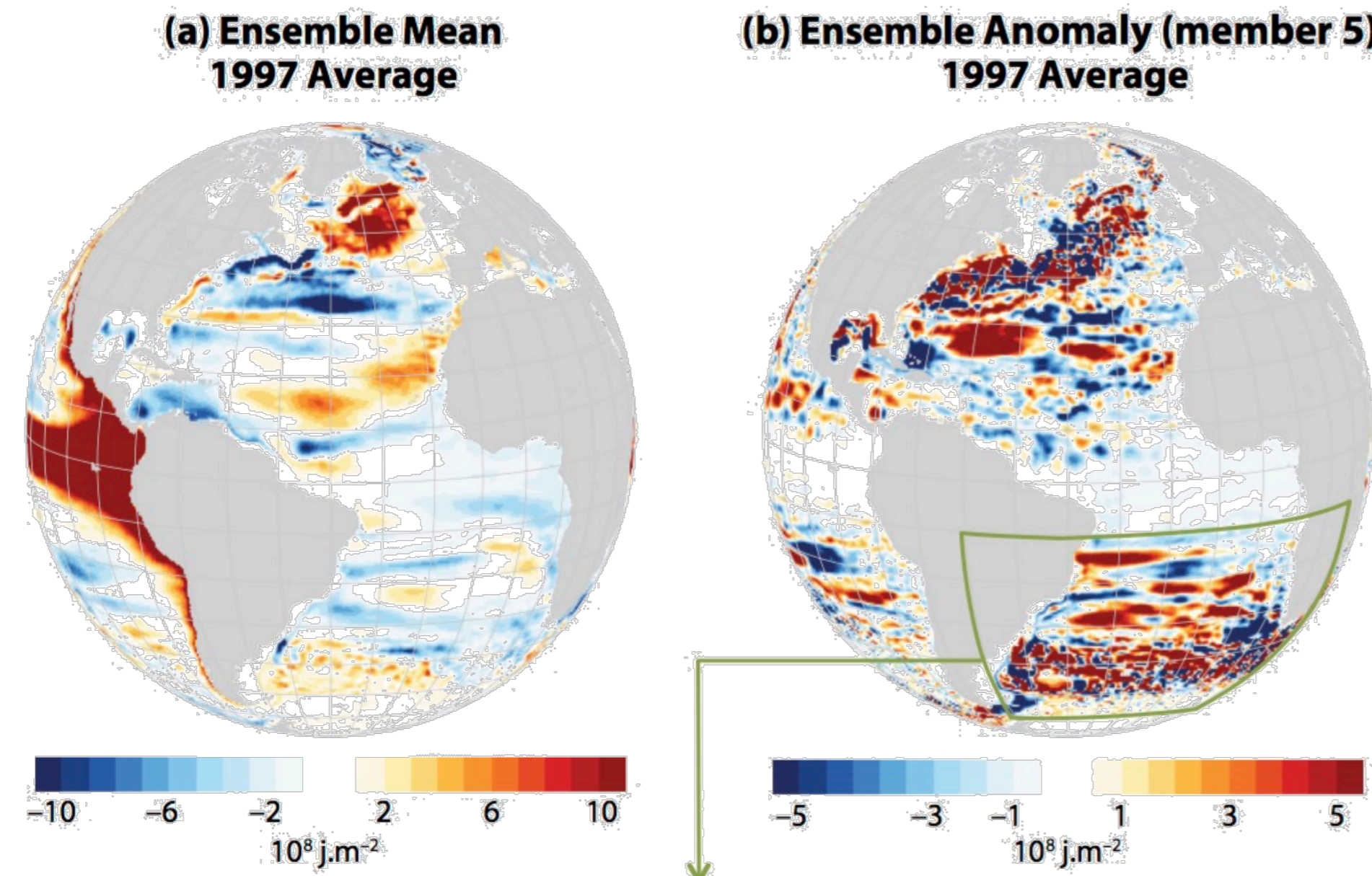
- **Atmospherically-forced variability** ( $\sigma_F = \text{STD of ensemble mean}$ )
- **Chaotic/intrinsic variability** ( $\sigma_C = \text{mean of ensemble STD}$ )



## Take-home messages

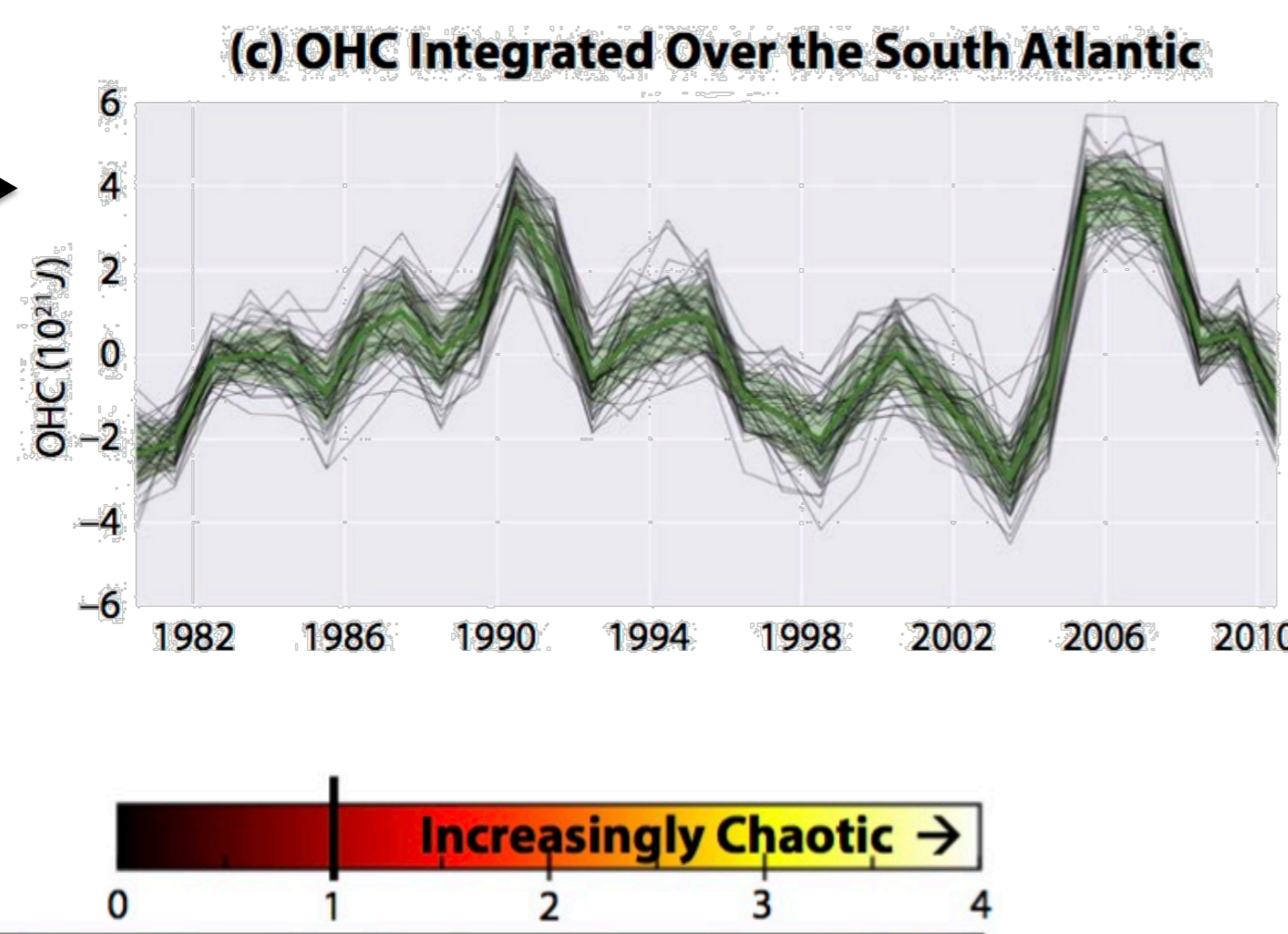
- In the presence of mesoscale, the ocean spontaneously generates a strong **low-frequency chaotic/intrinsic variability (LFCIV)**. It locally competes with the **atmospheric forcing** in driving the interannual-to-multidecadal variability of key ocean climate indices (OHC<sub>0-700m</sub>, AMOC, MHT, 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)

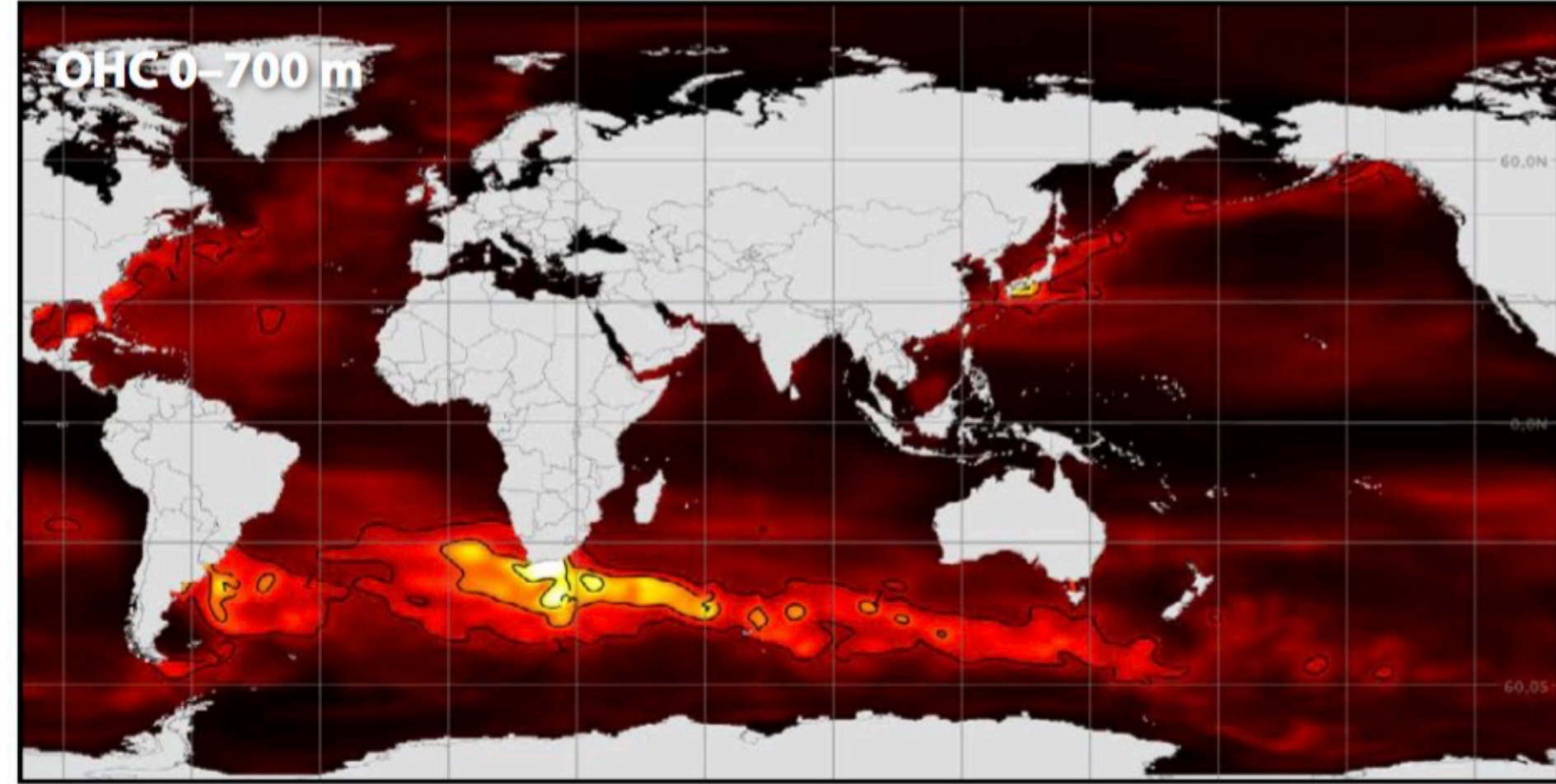


### LFCIV imprint on OHC<sub>0-700</sub>:

- up to basin scales (and multiple decades)
- dominates **Forced variability** in regions within contours



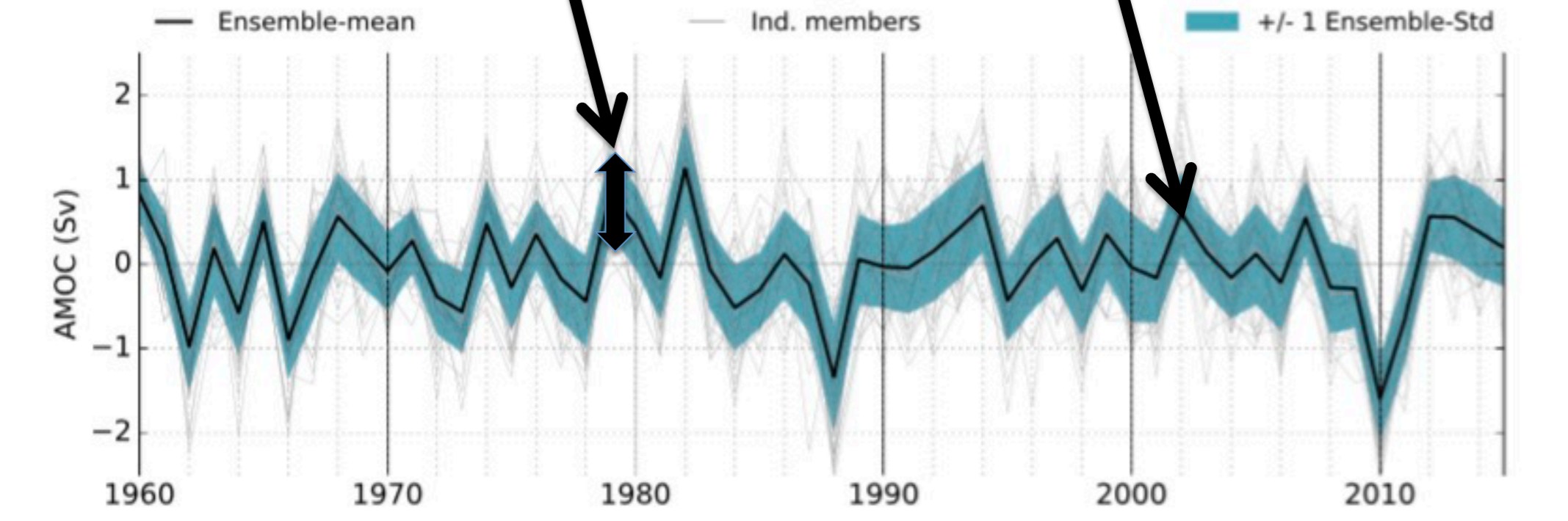
**This strong 1-30yr chaotic variability of OHC & AMOC** (almost absent without eddies) is expected to impact the atmosphere in coupled models with eddying oceans



Sérazin et al, 2017  
Penduff et al, 2018

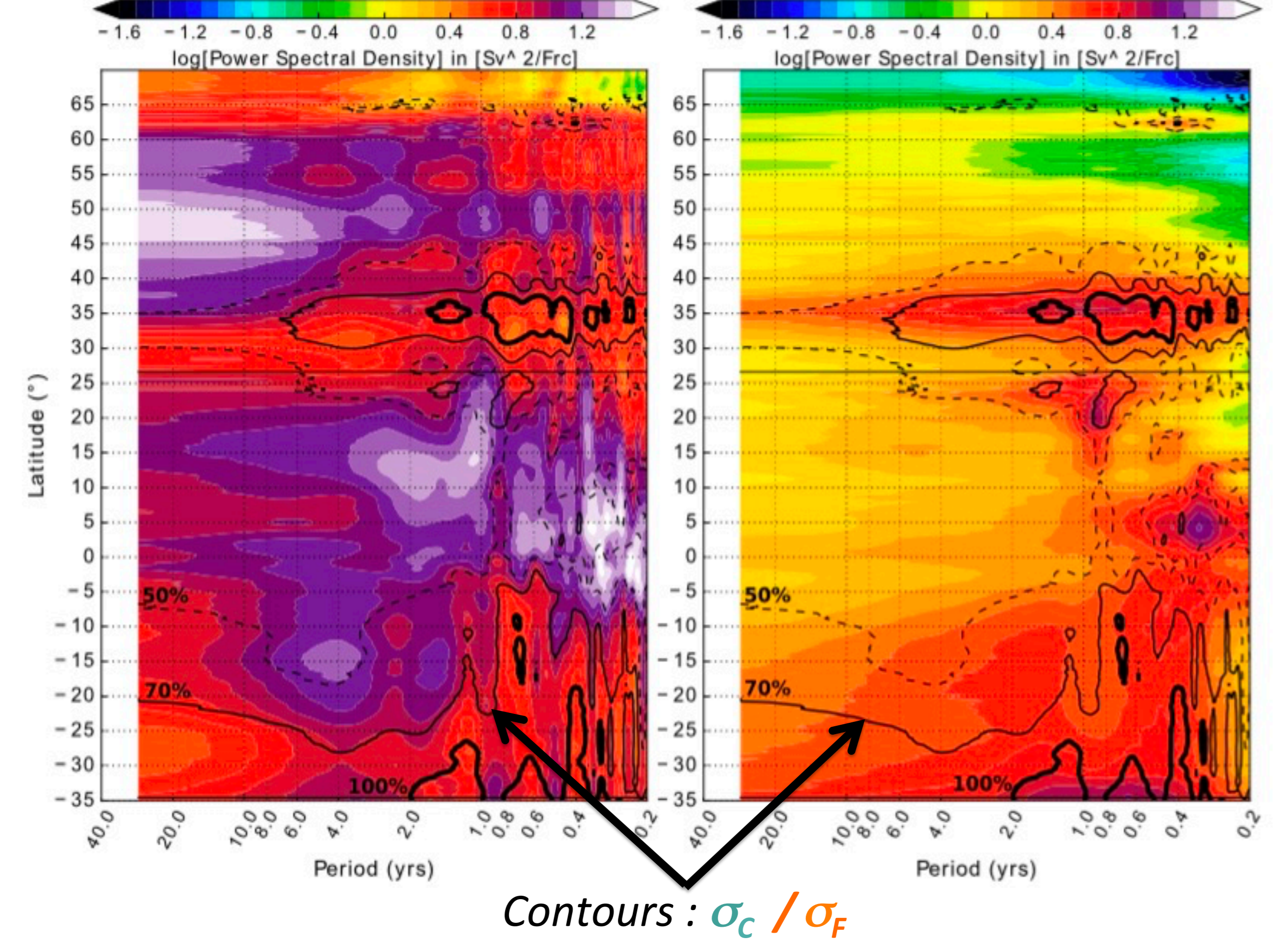
## Interannual variability of the Atlantic Meridional Overturning Circulation

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



### Forced variability spectrum

### Chaotic variability spectrum

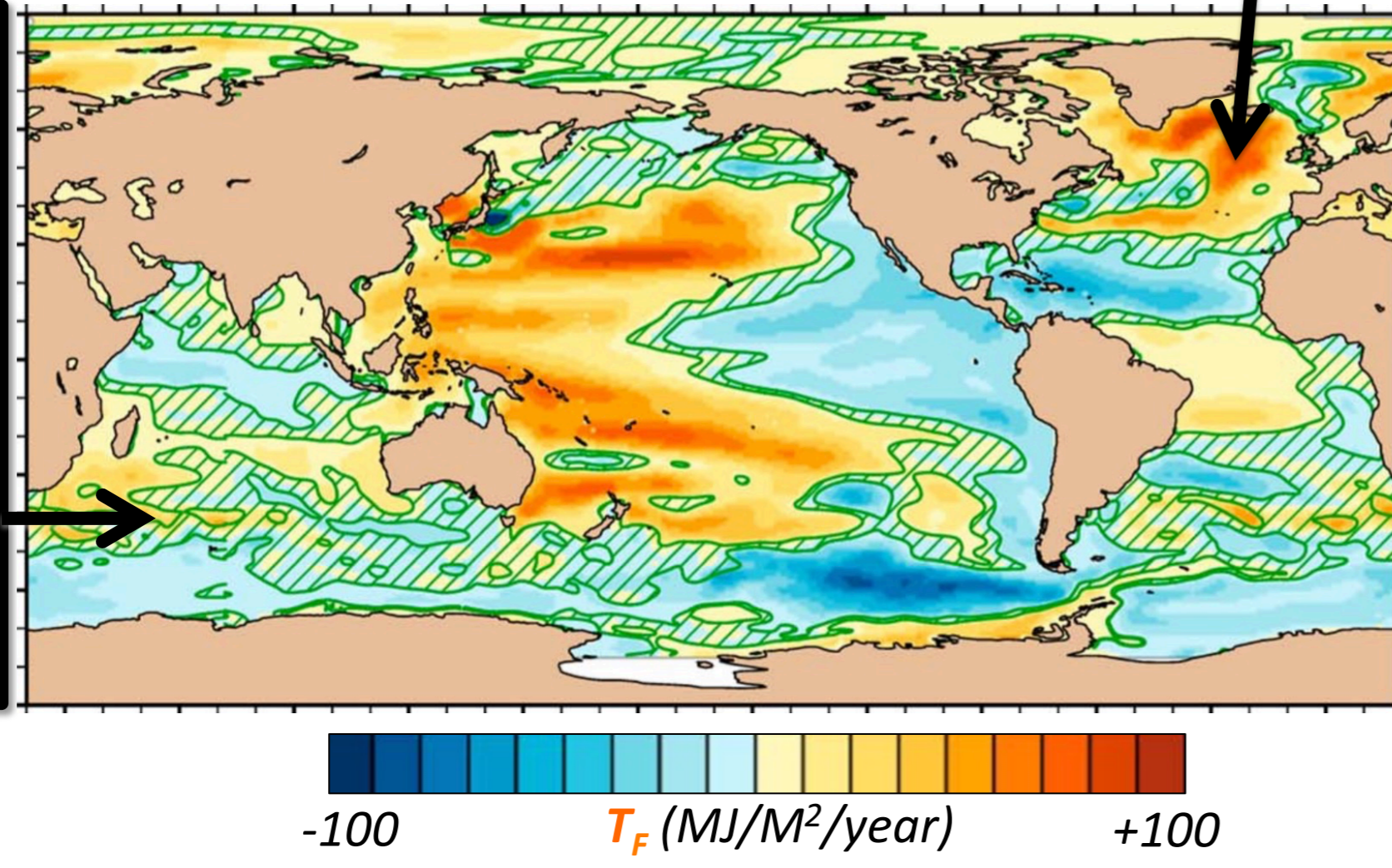


Leroux et al, 2018

## 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  $|T_F| < 2 \cdot T_R$  (green shading) OHC trends can NOT be surely attributed (95% confidence) to **[atmospheric + anthropogenic drivers]**



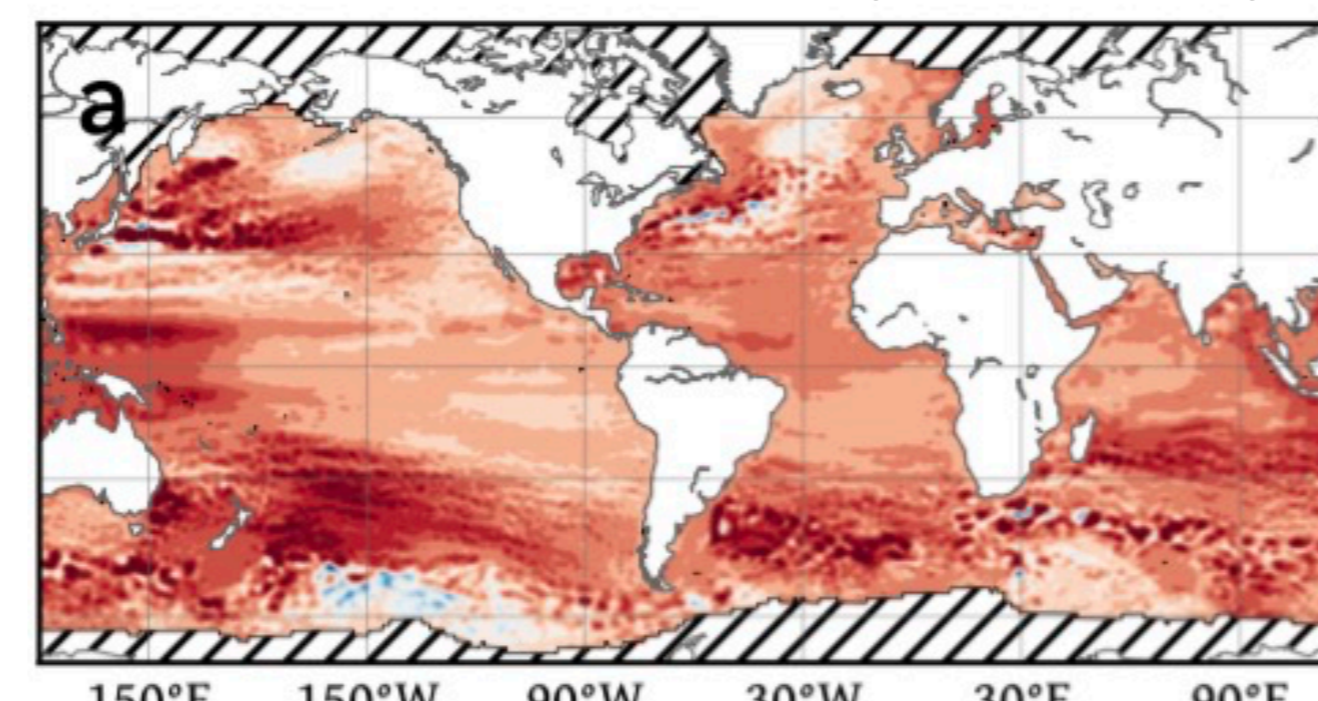
(\* corrected for model drift & global mean trend removed)

Sérazin et al, 2017

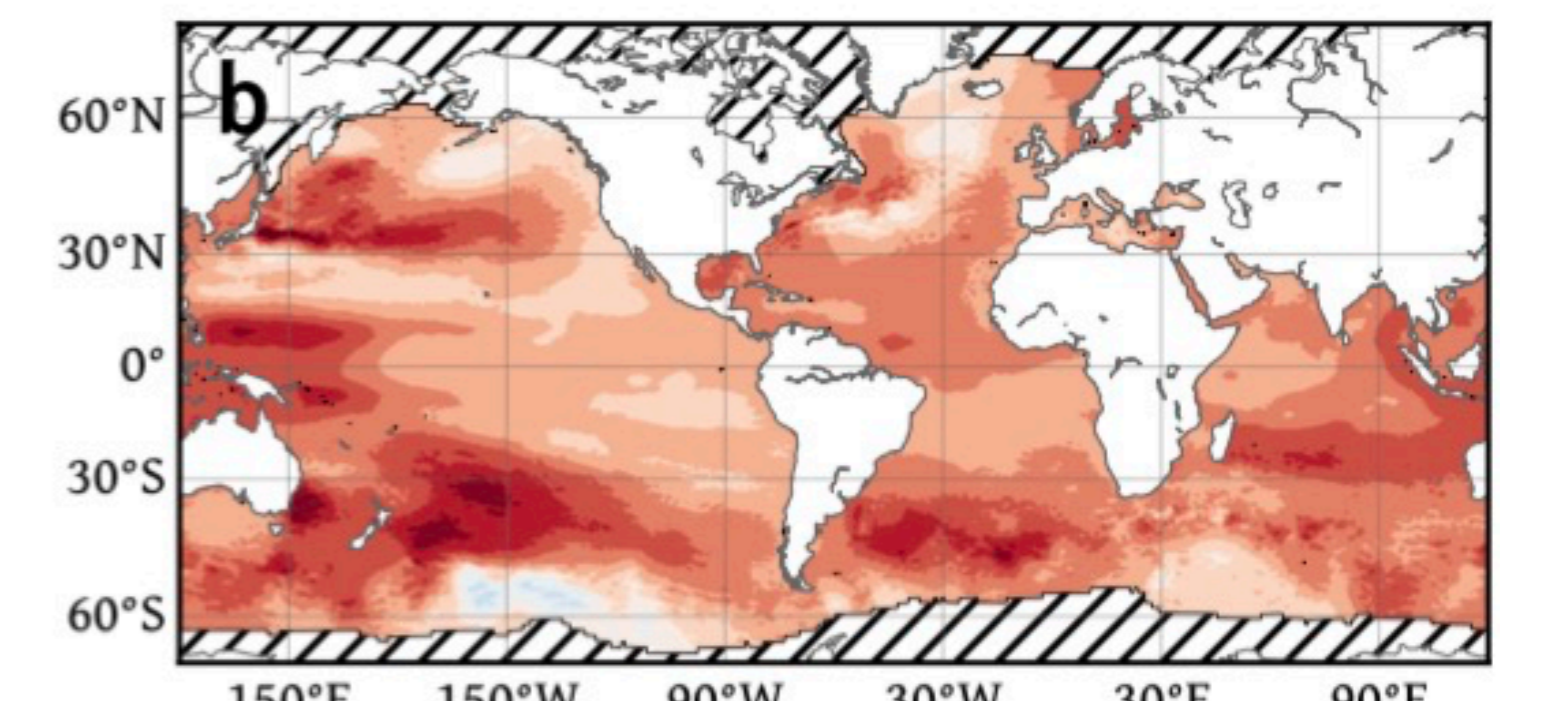
## 23-year trends (1993-2015) of Observed Sea Level

- 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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