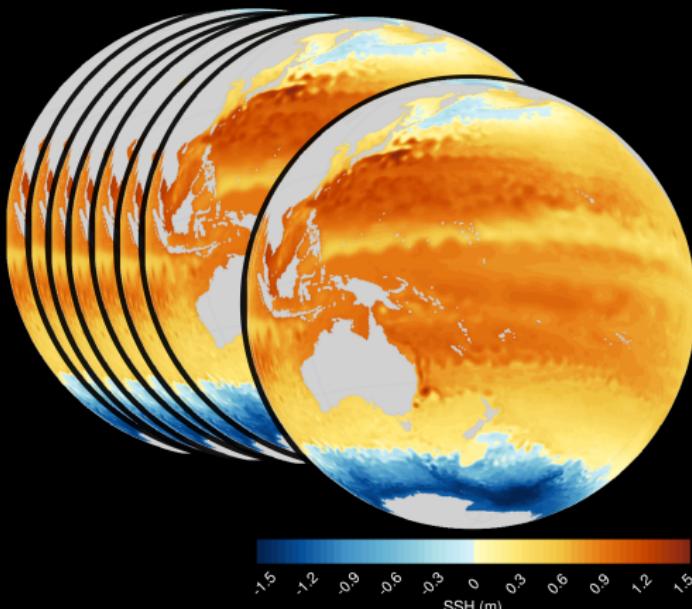


Ocean variability: intrinsic/chaotic vs atmospherically-driven

What can we learn from ocean ensemble-simulations?

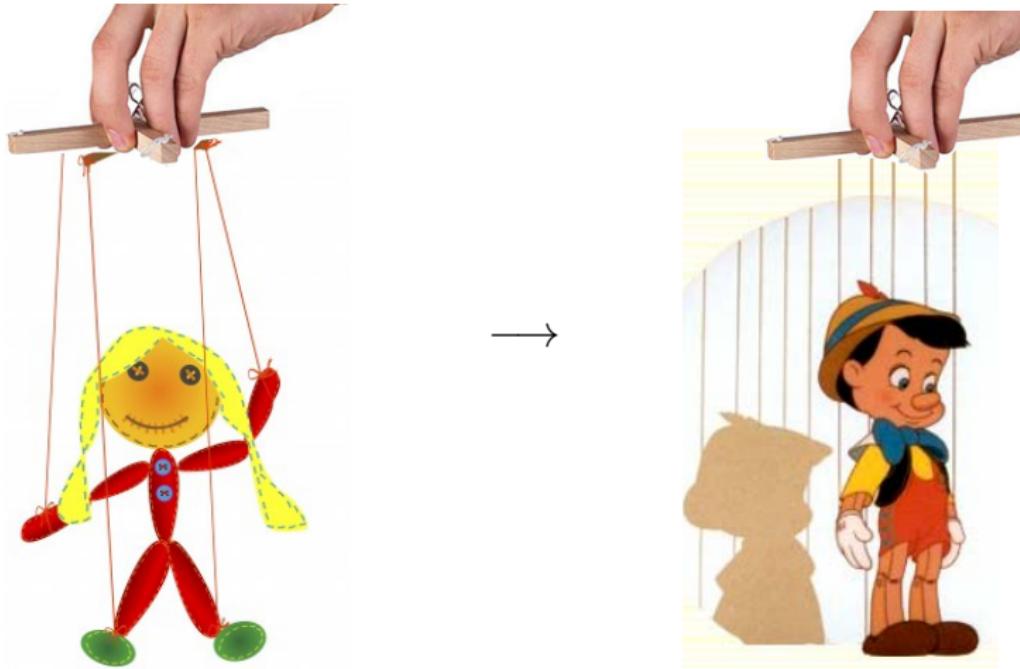


Stephanie Leroux

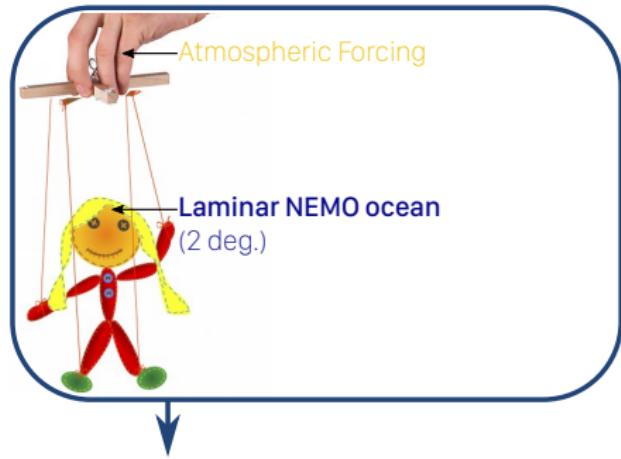
and the **OCCIPUT** team:
T. Penduff (PI), L. Bessières,
B. Barnier, J-M. Brankart, PV.
Huot, A. Jaymond, J-M. Mo-
lines, G. Sérazin, L. Terray, ET AL.



Motivation | Why ocean ensemble simulations?

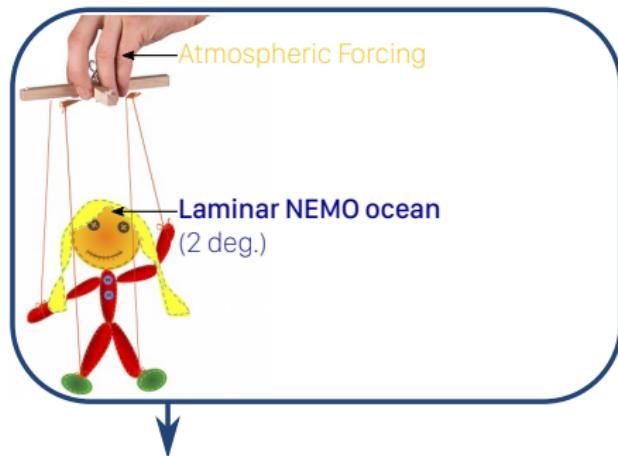


Motivation | From laminar to eddy-permitting Ocean-GCMs

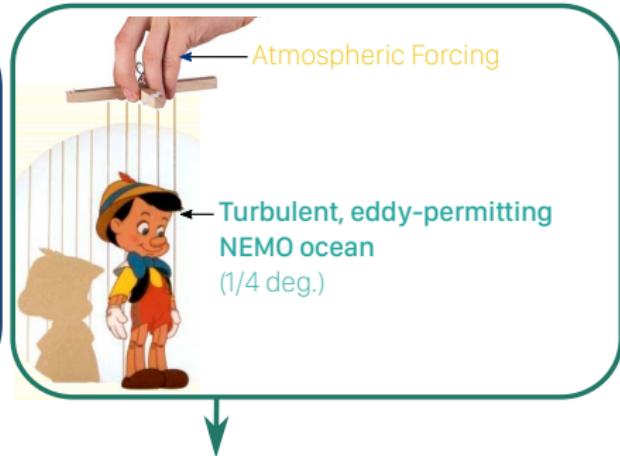


- ▶ The atmosphere modulates a passive ocean.

Motivation | From laminar to eddy-permitting Ocean-GCMs



- ▶ The atmosphere modulates a passive ocean.

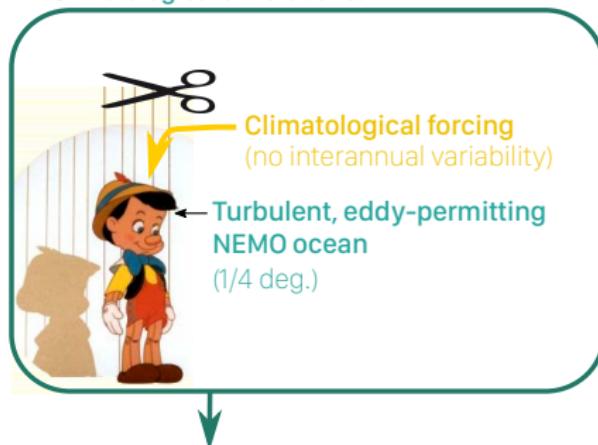


- ▶ The atmosphere modulates a turbulent, chaotic ocean.
- ▶ How can we disentangle the intrinsic and the atmospherically-forced contributions of the variability?

Motivation | Intrinsic chaotic variability in eddy-permitting NEMO

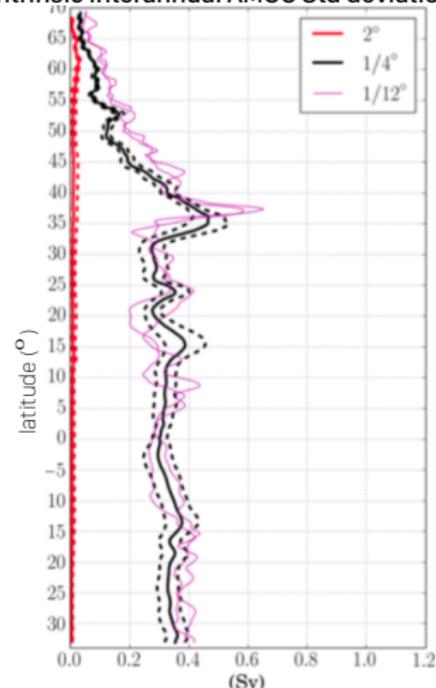
Penduff et al (2011), Sérazin et al (2015), Gregorio et al (2015) :

Climatological simulations:



- ▶ "Pure", isolated intrinsic variability:
 - mesoscale turbulence,
 - cascading to interannual timescales and larger spatial scales,
 - potential impact on climate variability.

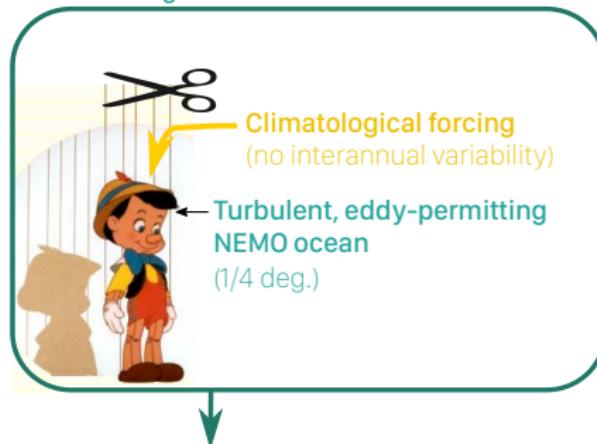
Intrinsic interannual AMOC Std deviation:



Motivation | Intrinsic chaotic variability in eddy-permitting NEMO

Penduff et al (2011), Gregorio et al (2015), Sérazin et al (2015) :

Climatological simulations:



- ▶ "Pure", isolated intrinsic variability:
 - mesoscale turbulence,
 - cascading to interannual timescales and larger spatial scales,
 - potential impact on climate variability.
- ▶ Consistent with idealized studies
E.g. Sevillec & Huc 2015, Dijkstra & Ghil 2005

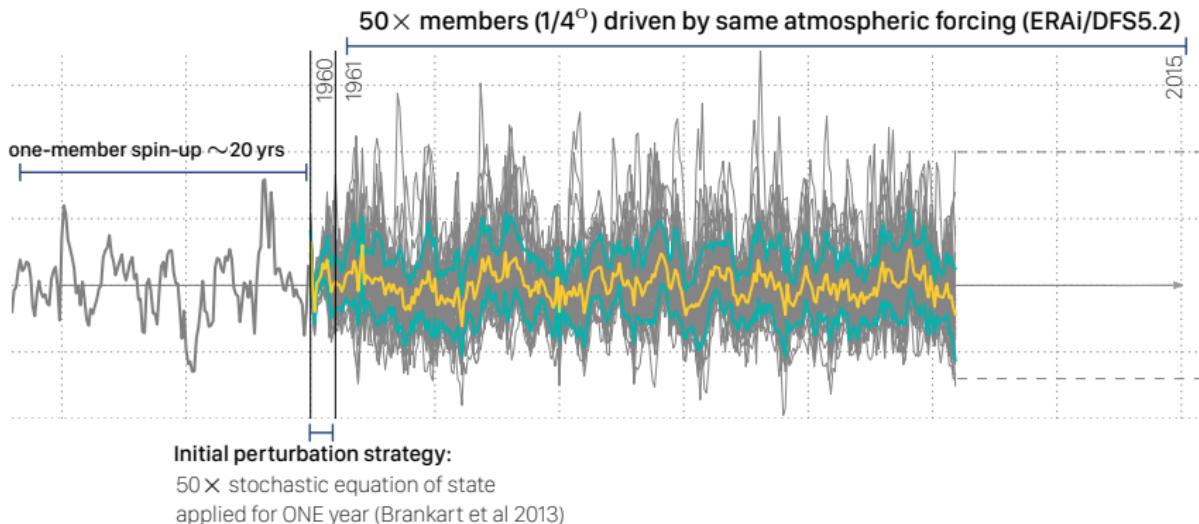
- ▶ How does this intrinsic variability look like when simulated under realistic atmospheric forcing?
- ▶ How do magnitudes compare (forced/intrinsic)?

- ▶ **Ensemble simulations:** provide a way to disentangle the forced and intrinsic contributions.

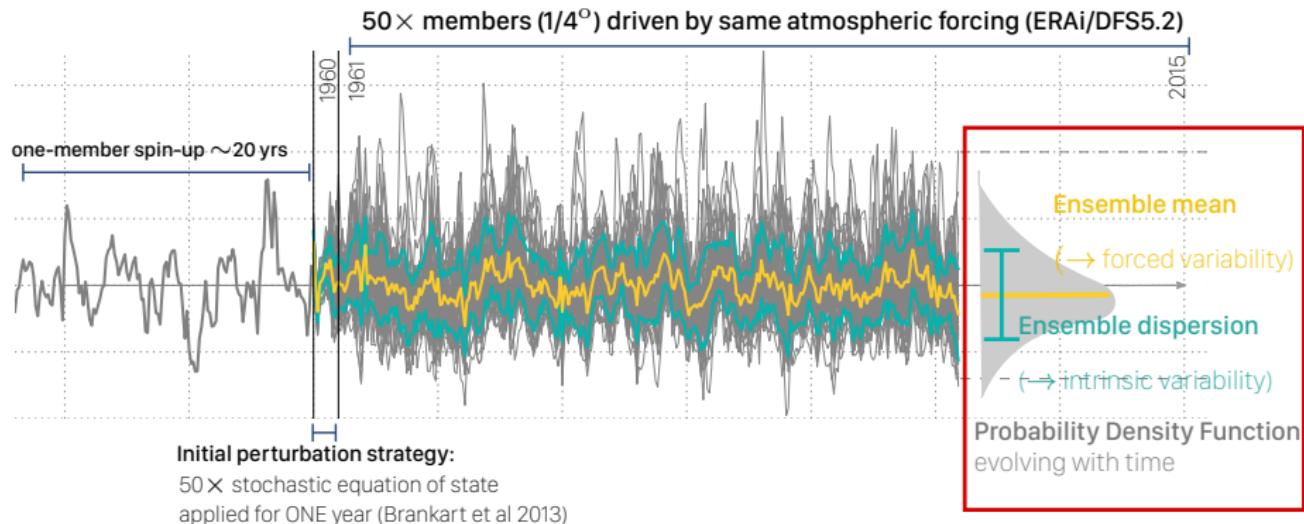
OCCIPUT | 50 × global 1/4° ocean/sea-ice hindcasts 1960–2015



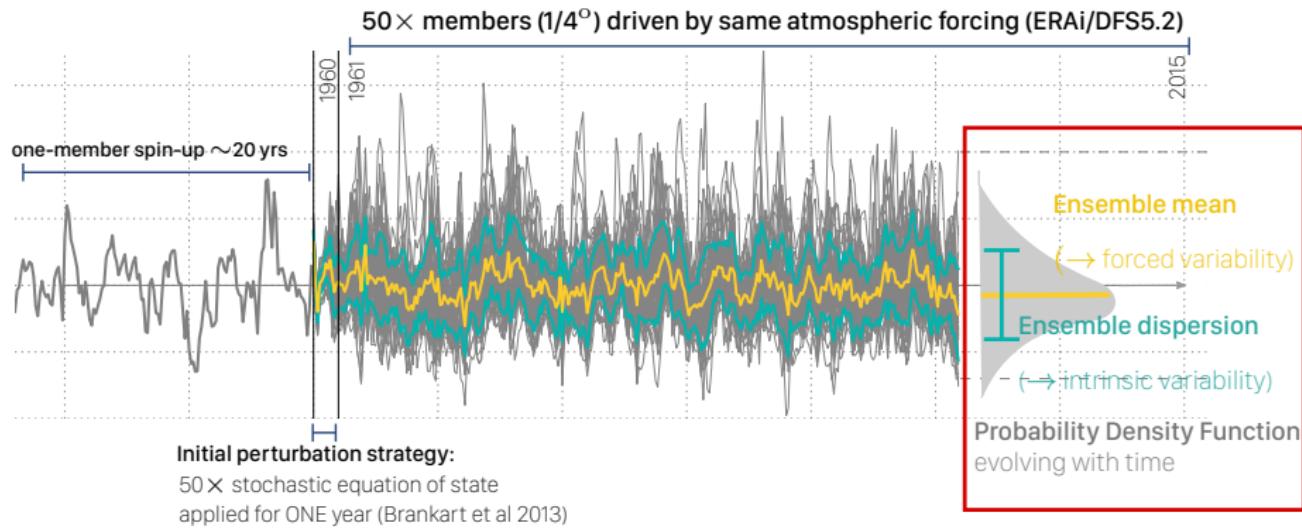
OCCIPUT | 50 × global $1/4^{\circ}$ ocean/sea-ice hindcasts 1960–2015



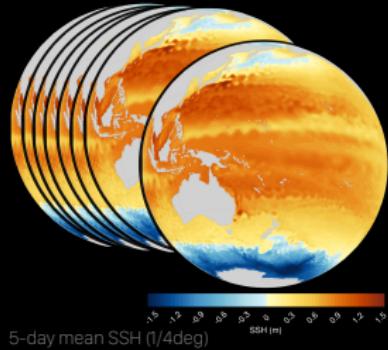
OCCIPUT | 50× Eddy-permitting ocean/sea-ice hindcasts 1960-2015



OCCIPUT | 50× Eddy-permitting ocean/sea-ice hindcasts 1960-2015



- **Ensemble-NEMO**: N members run simultaneously in one single executable,
- **On-line ensemble statistics** (could be re-injected directly in the on-going integration),
- **50× Synthetic obs datasets** (e.g. ENACT/ENSEMBLE in-situ data, Jason2)
- \sim 19 million CPU h. Full-time OCCIPUT engineer L. Bessières, +JM. Molines, JM. Brankart.



A probabilistic description of the simulated ocean

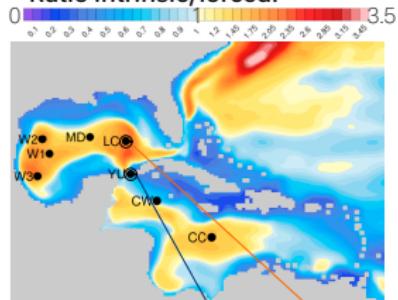
→ Ex: SSH mesoscale variability and AVISO.

OCCIPUT | A probabilistic description of the simulated ocean

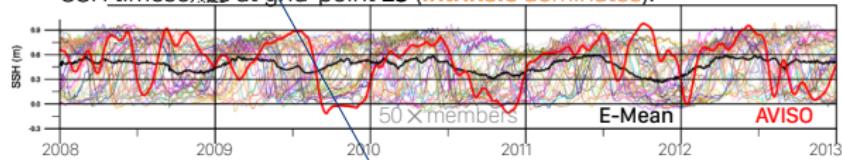
Ex: Daily SSH variability in the Gulf of Mexico:

[On-going work – PV Huot's masters thesis]

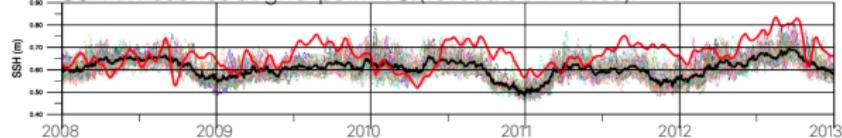
Ratio intrinsic/forced:



SSH timeseries at grid-point LC (intrinsic dominates):



SSH timeseries at grid-point YU (forced dominates):

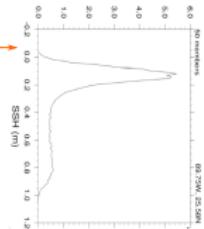
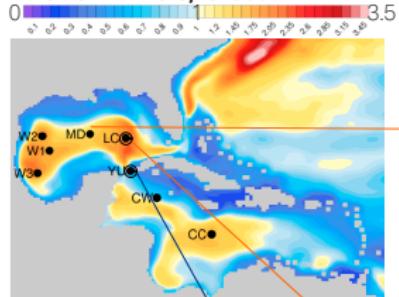


Occiput | A probabilistic description of the simulated ocean

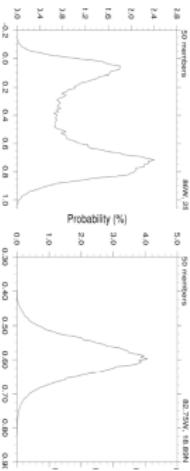
Ex: Daily SSH variability in the Gulf of Mexico:

[On-going work – PV Huot's masters thesis]

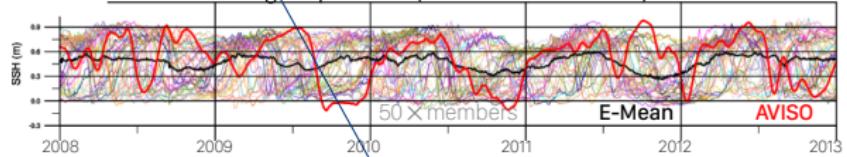
Ratio intrinsic/forced:



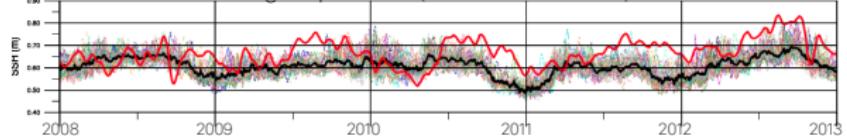
PDFs (all mbs, all timesteps):



SSH timeseries at grid-point **LC** (**intrinsic** dominates):



SSH timeseries at grid-point **YU** (**forced** dominates):



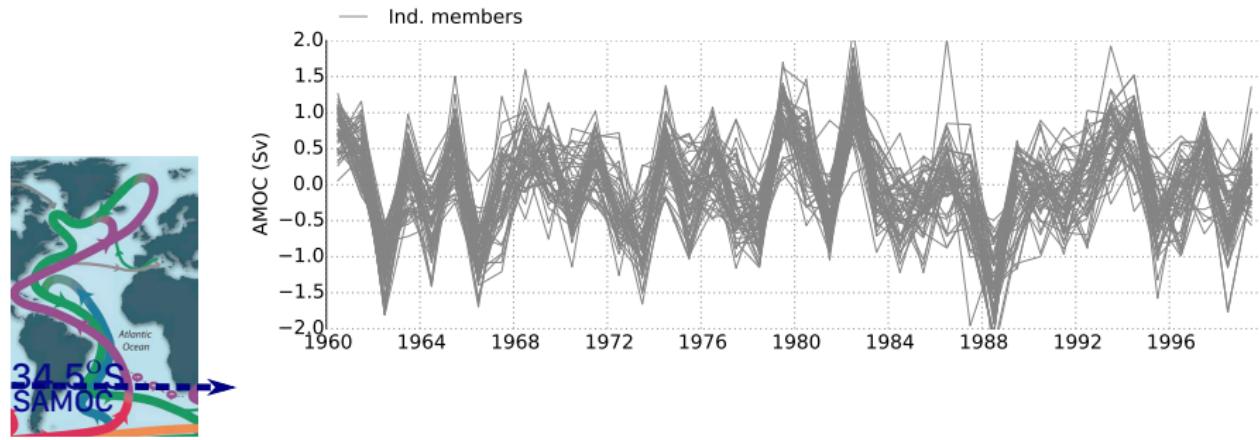


How much does this intrinsic variability matter on longer timescales and larger spatial domains ?

→ Focus on the interannual variability of a basin-integrated quantity:
the Atlantic Meridional Overturning Circulation (AMOC).

Interannual timescale | How chaotic is AMOC variability?

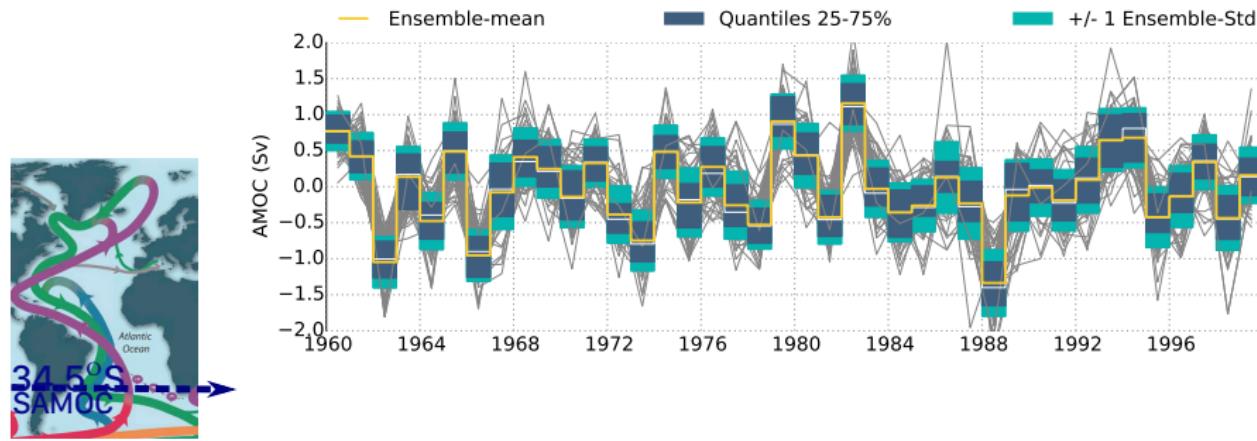
AMOC at 34.5°S (annual mean anomalies)



From 50 ×
global ens.

Interannual timescale | How chaotic is AMOC variability?

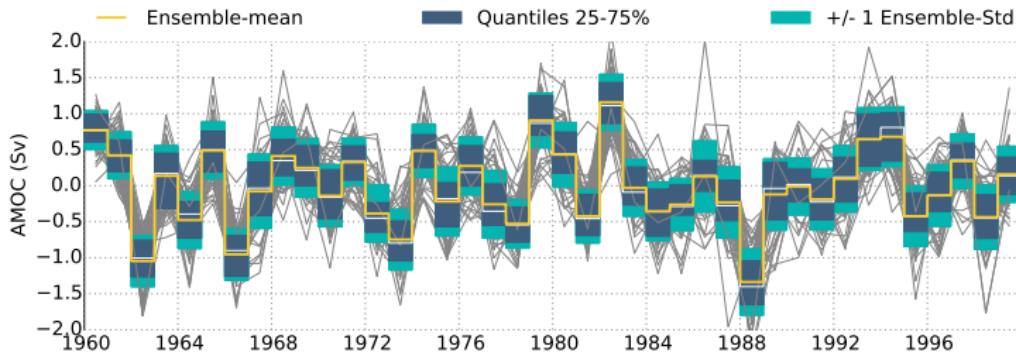
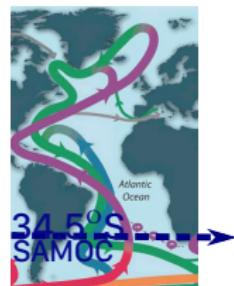
AMOC at 34.5°S (annual mean anomalies)



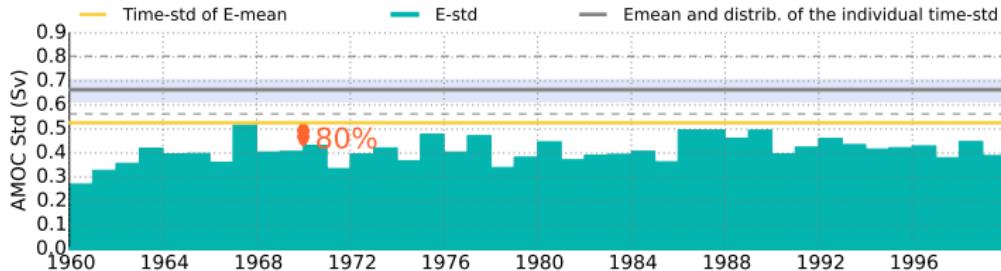
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Interannual timescale | How chaotic is AMOC variability?

AMOC at 34.5°S (annual mean anomalies)

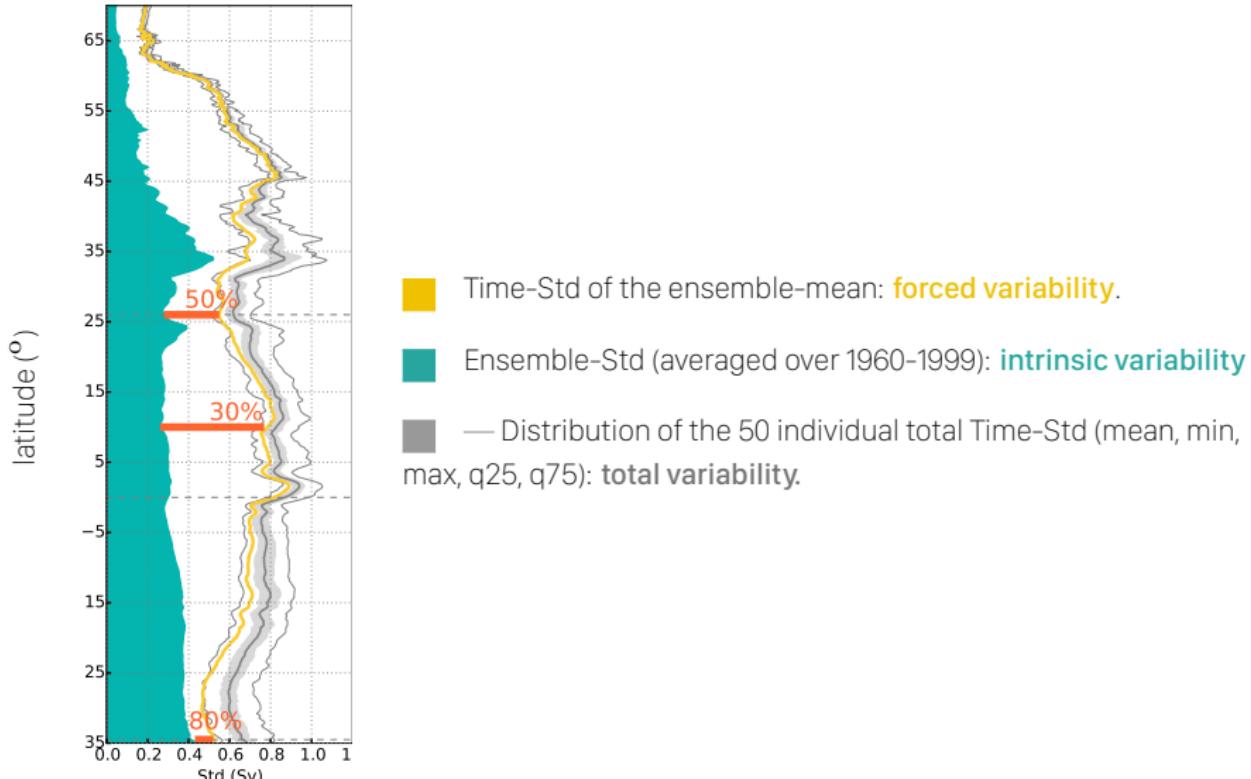


From 50 ×
global ens.

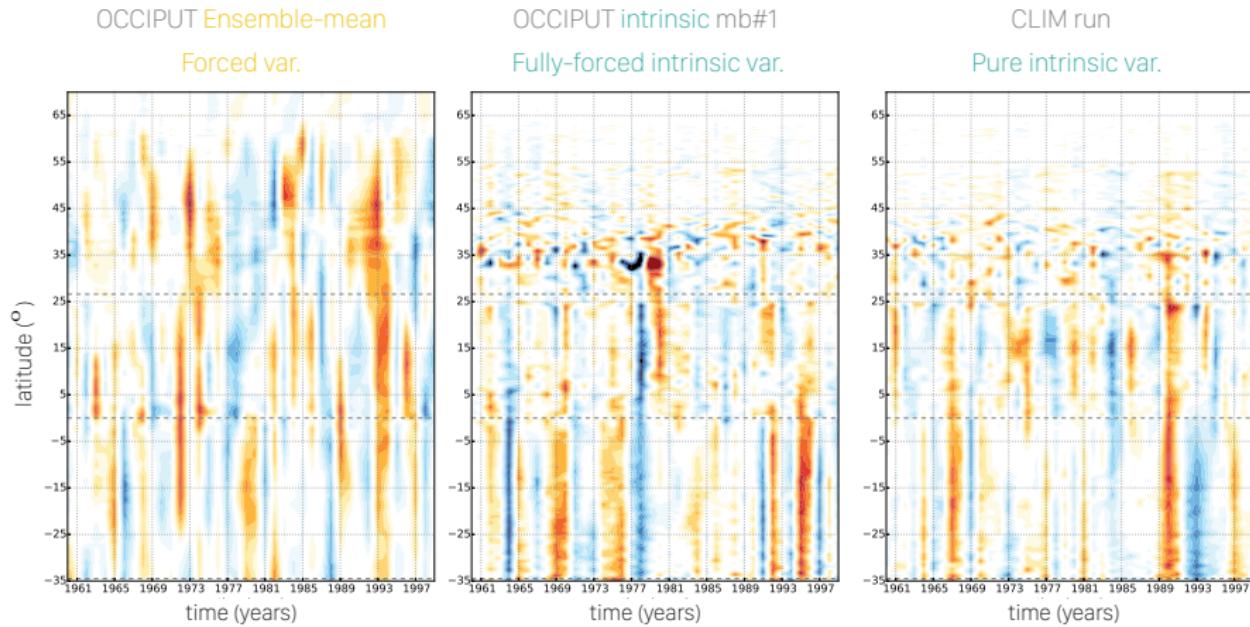


Interannual timescale | How chaotic is AMOC variability?

At all latitudes:



Interannual timescale | AMOC spatio-temporal patterns:



→ "Fully-forced" and "pure" intrinsic variability:
similar space-time organisation.

→ Forced and intrinsic variability: similar space-time

organisation south of $\sim 25N$, different to the north.

Interannual timescale | Ocean Heat Content variability

0–700m OHC anomalies (BP filtered T= 2–22 yrs)

Summary



- ▶ At **eddy-permitting resolution**: ocean variability is NOT fully determined by the atmospheric forcing.
- ▶ A substantial intrinsic and chaotic component adds up, cascading from mesoscale turbulence **to interannual timescales**.



- ▶ **Ensemble simulations** provide:
 - a probabilistic description of the simulated ocean under realistic atmospheric forcing (e.g. →comparison with obs),
 - a way to disentangle intrinsic and forced contributions.
- ▶ SST, SSH, AMOC, OHC show **substantial intrinsic variability on interannual timescales** (→potential impact on climate variability).

On-going work...

