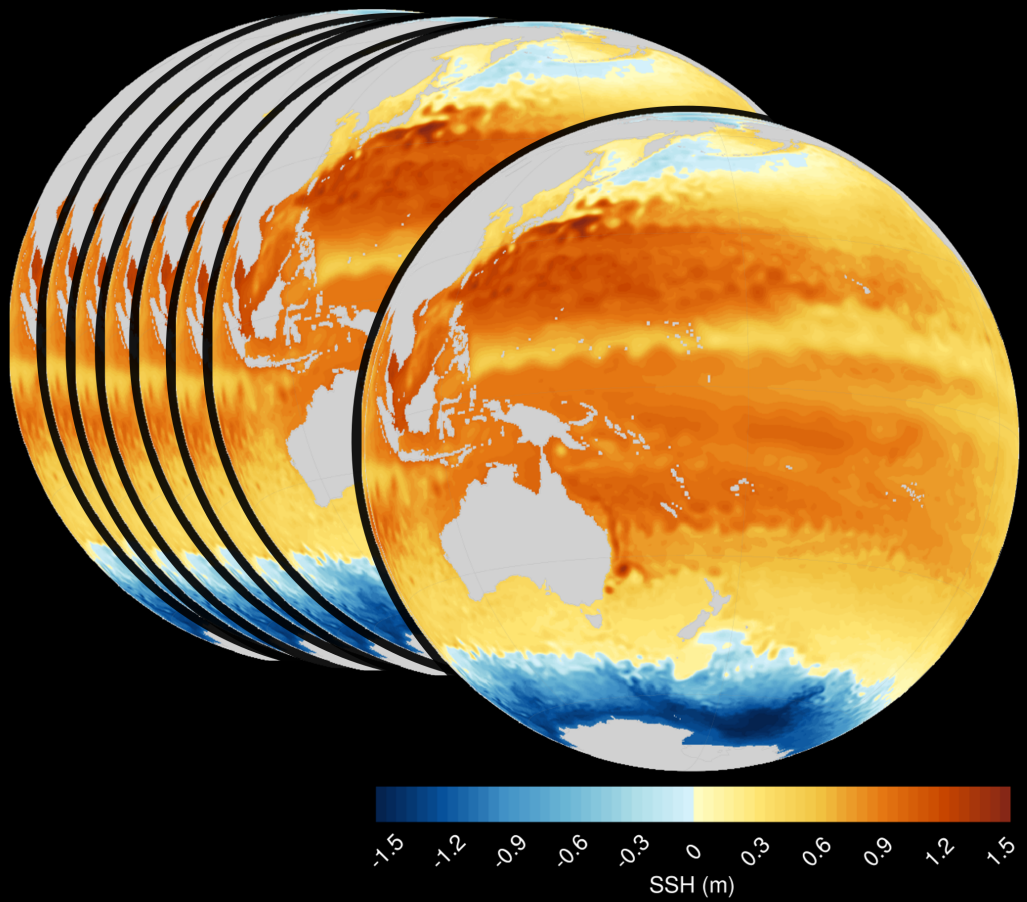
Ocean variability: intrinsic/chaotic vs atmospherically-driven

What can we learn from ocean ensemble-simulations?



5-day mean SSH (1–5 jan. 2015) from the OCCIPUT 50 × ensemble simulation (1/4deg)

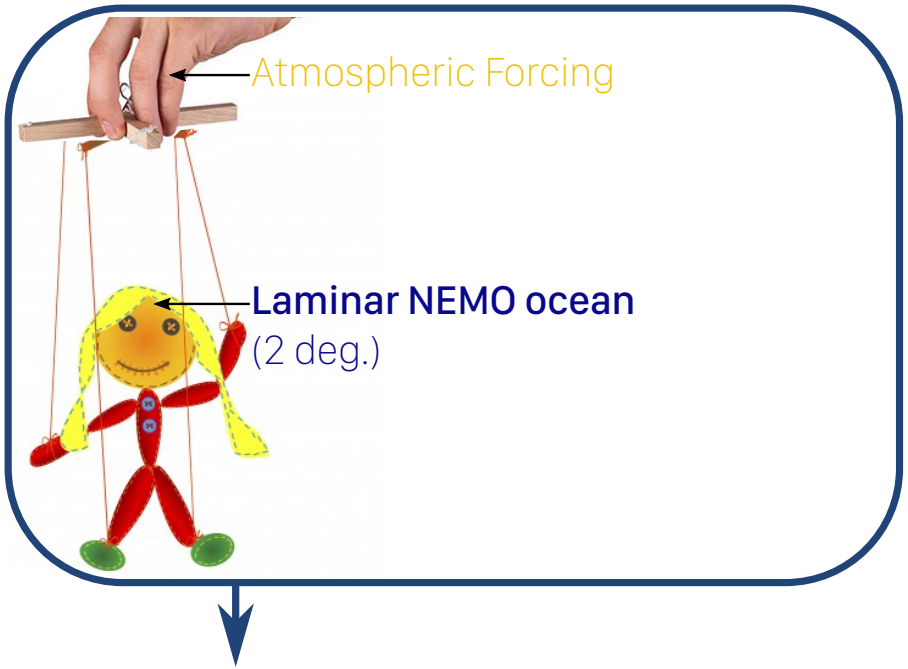
Stephanie Leroux

and the **OCCIPUT** team:

T. Penduff (PI), L. Bessières, B. Barnier, J-M. Brankart, PV. Huot, A. Jaymond, J-M. Molines, G. Sérazin, L. Terray, ET AL.

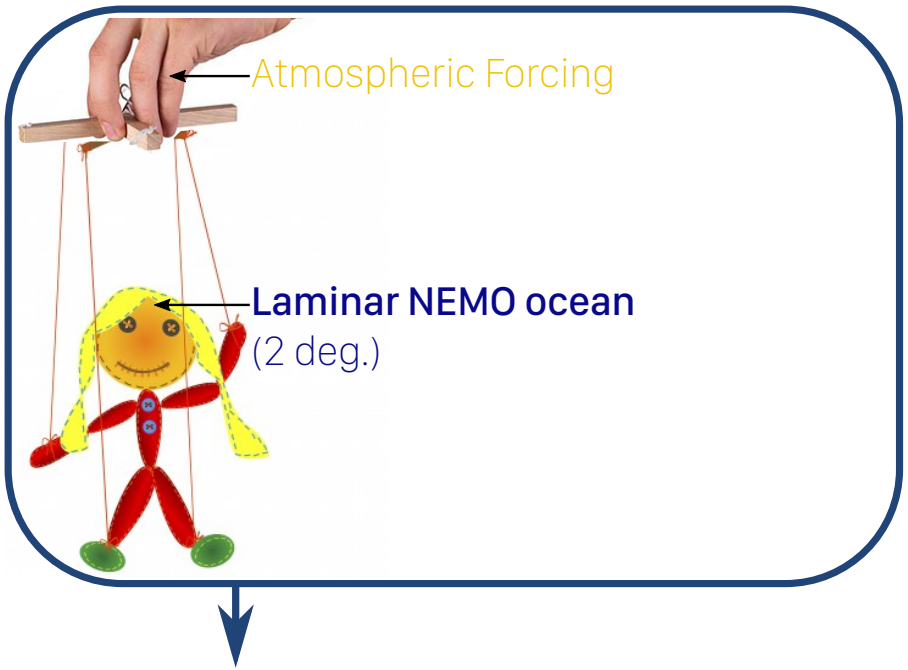
Motivation | Why ocean ensemble simulations?

Motivation | From laminar to eddy-permitting Ocean-GCMs

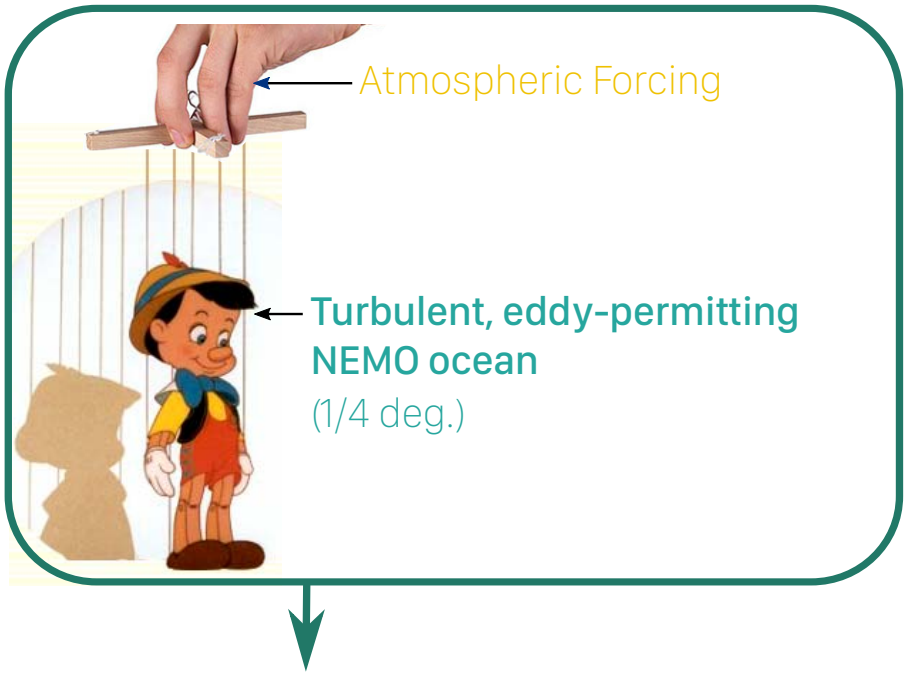


- The atmosphere modulates a passive ocean.

Motivation | From laminar to eddy-permitting Ocean-GCMs



- The atmosphere modulates a passive ocean.

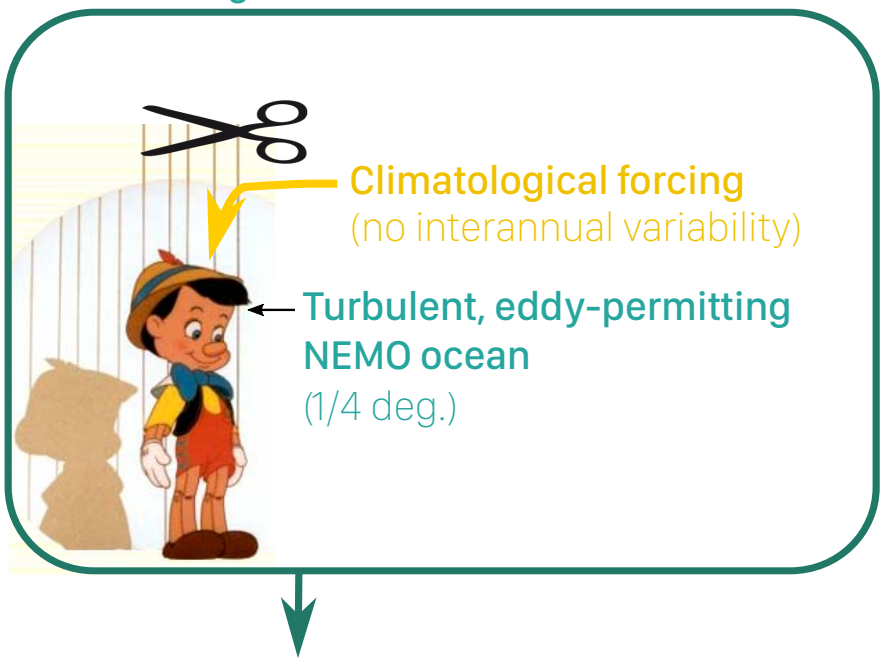


- The atmosphere modulates a turbulent, chaotic ocean.
- How can we disentangle the intrinsic and the atmospherically-forced contributions of the variability?

Motivation | Intrinsic chaotic variability in eddy-permitting NEMO

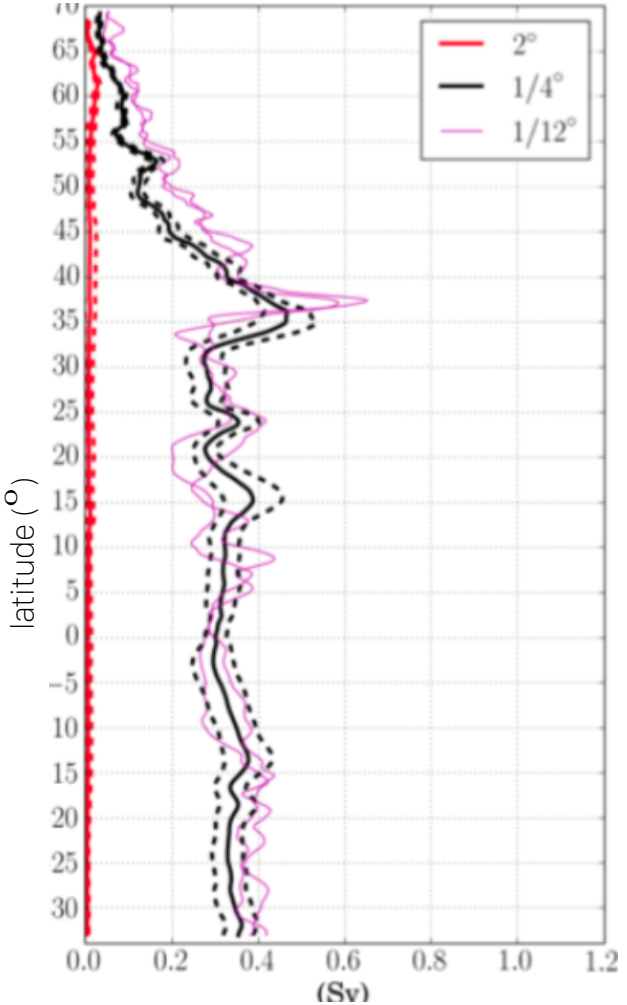
Penduff et al (2011), Sérazin et al (2015),**Gregorio et al (2015)** :

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

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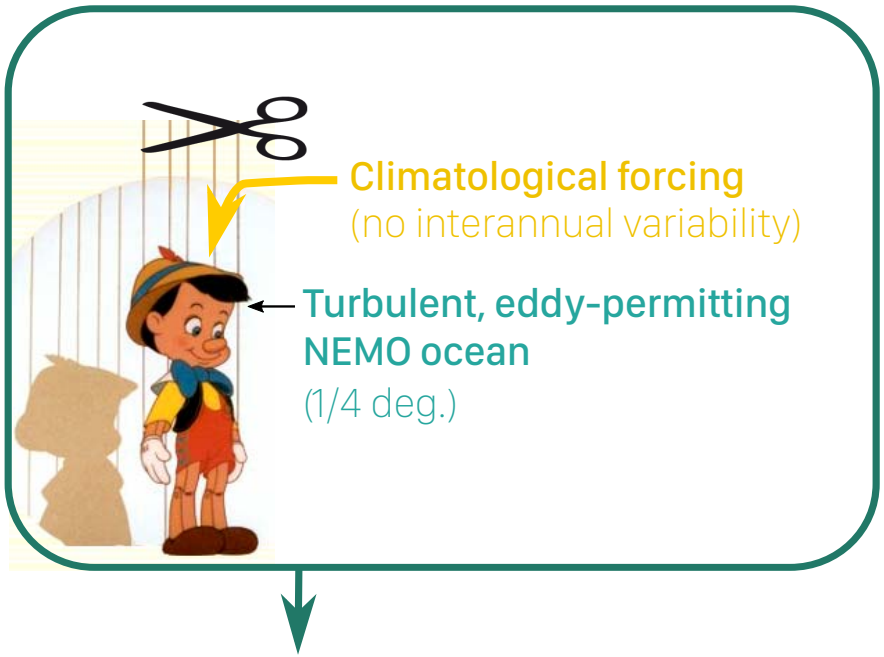

- "Pure", isolated intrinsic variability:
  - mesoscale turbulence,
  - cascading to interannual timescales and larger spatial scales,
  - potential impact on climate variability.
- Consistent with idealized studies

  E.g. Sevellec & 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

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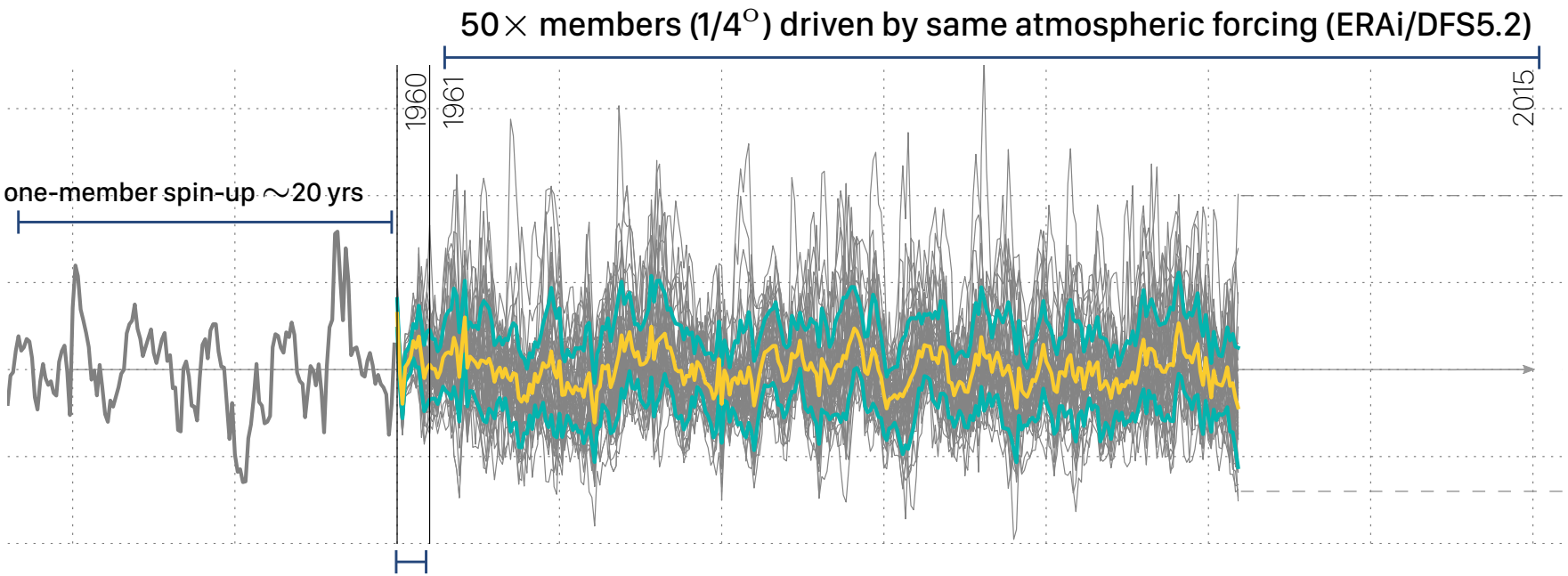
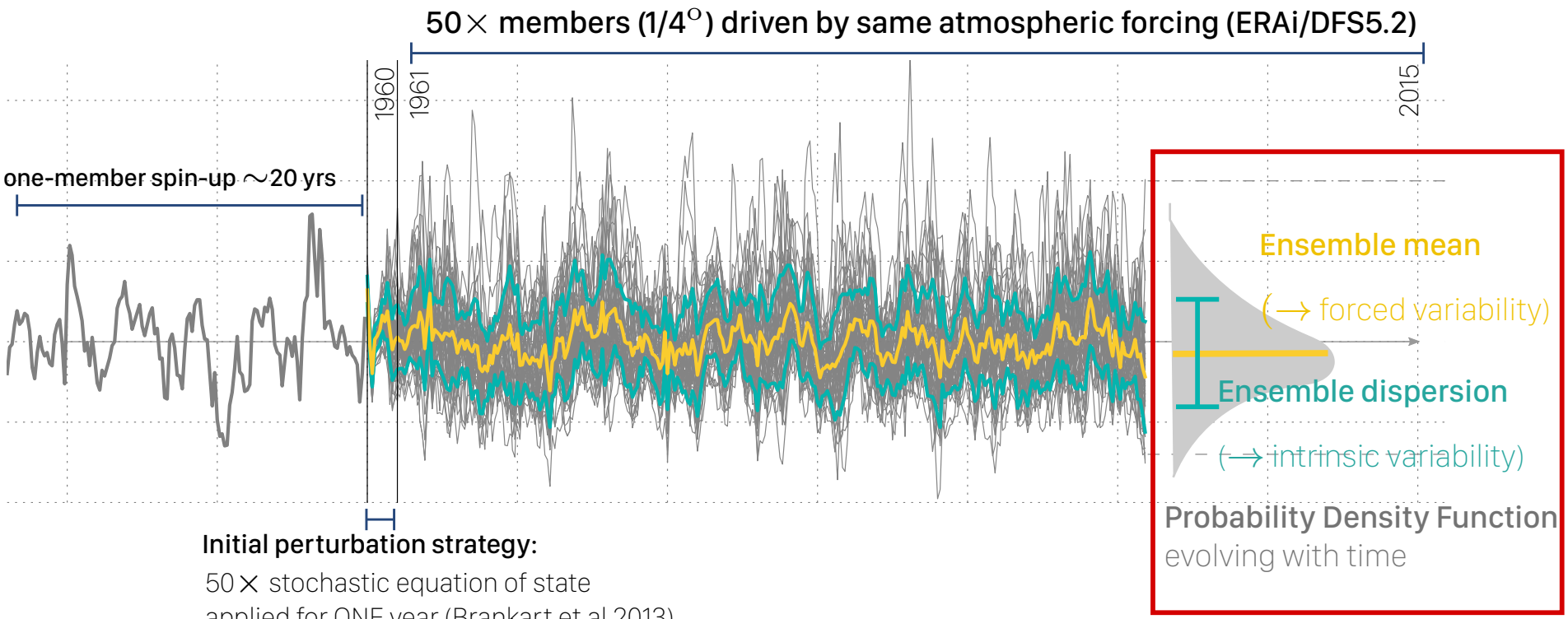


Initial perturbation strategy:

50× stochastic equation of state
applied for ONE year (Brankart et al 2013)

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



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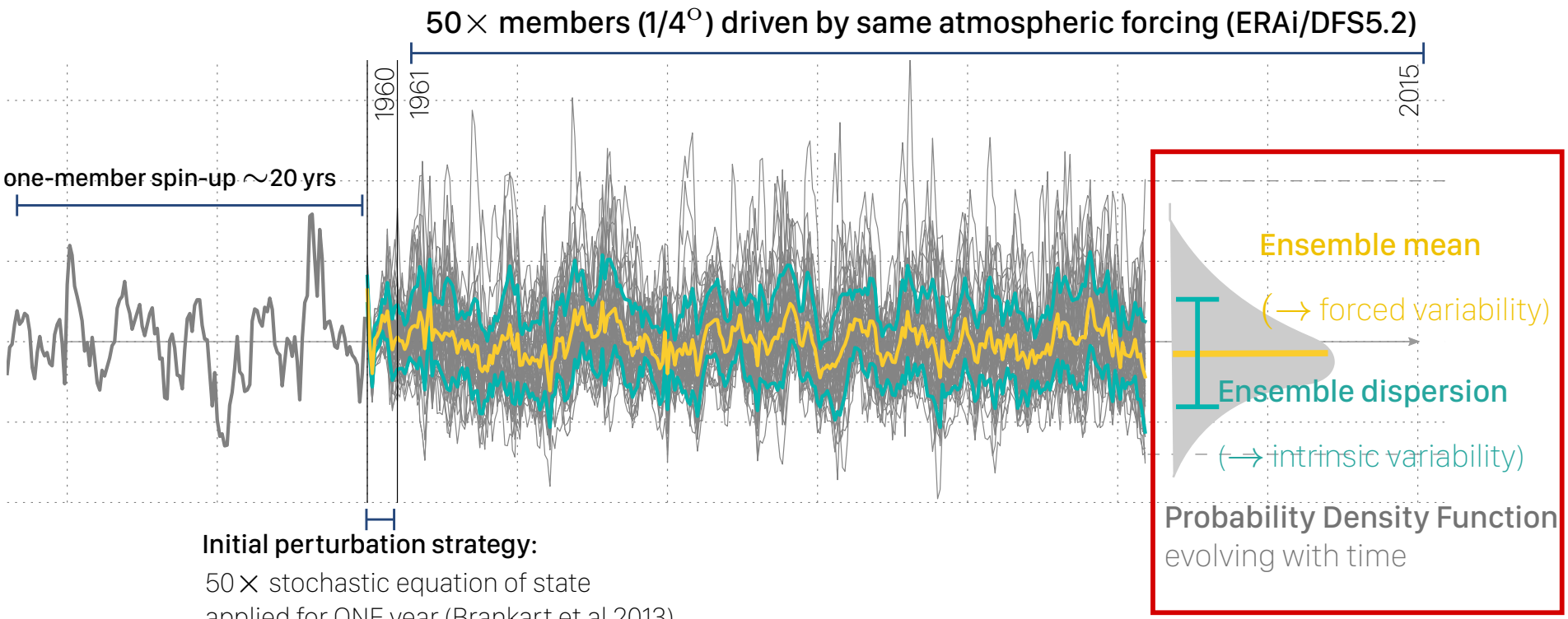
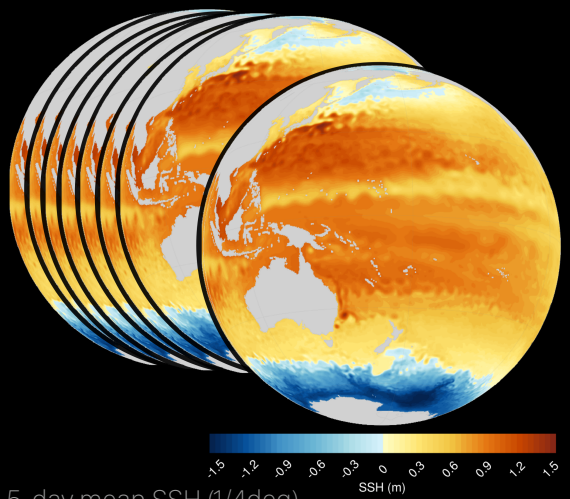


- Ensemble-NEMO: **N members run simultaneously in one single executable**,
- **On-line ensemble statistics** (could be re-injected directly in the on-going integration),
- **50×Synthetic obs datasets** (e.g. Enact/Ensemble in-situ data, Jason2)
- ∼19 million CPU h. Full-time Occiput engineer L. Bessières,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



5-day mean SSH (1/4deg)

A probabilistic description of the simulated ocean

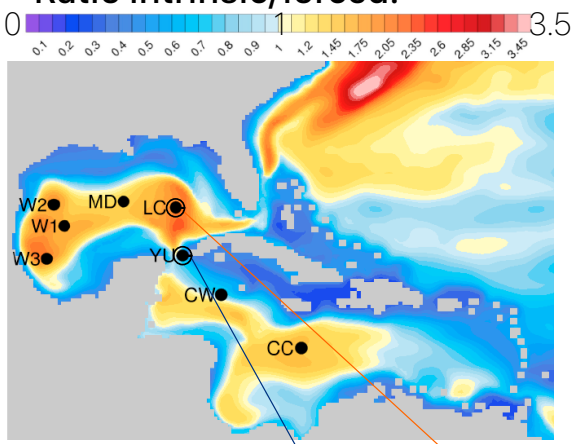
→ Ex: SSH mesoscale variability and AVISO.

OCCIPUT | A probabilistic description of the simulated ocean

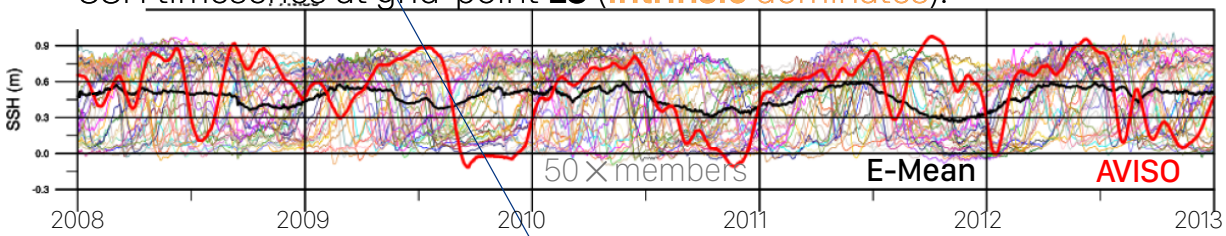
Ex: Daily SSH variability in the Gulf of Mexico:

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

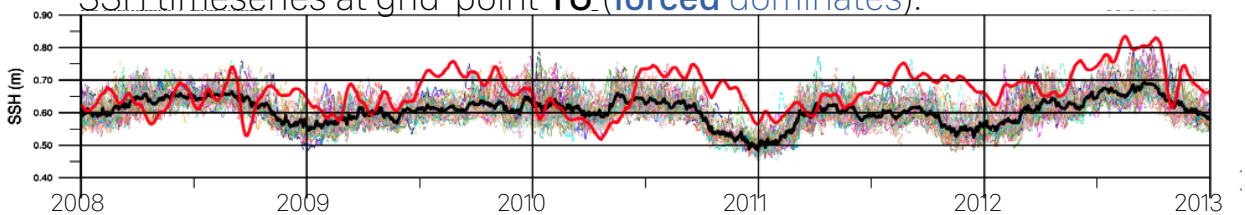
Ratio intrinsic/forced:



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]

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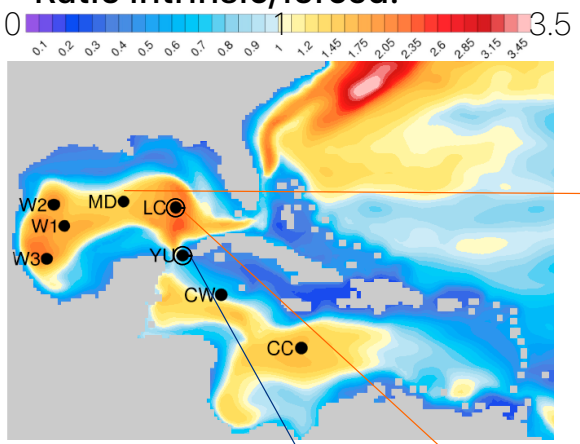

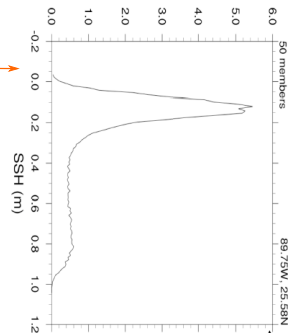

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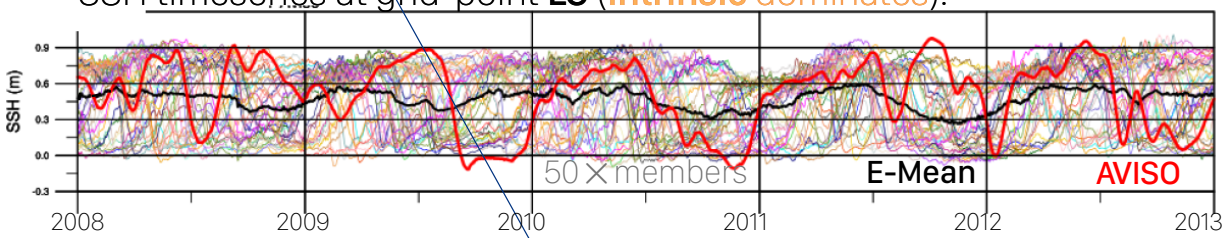

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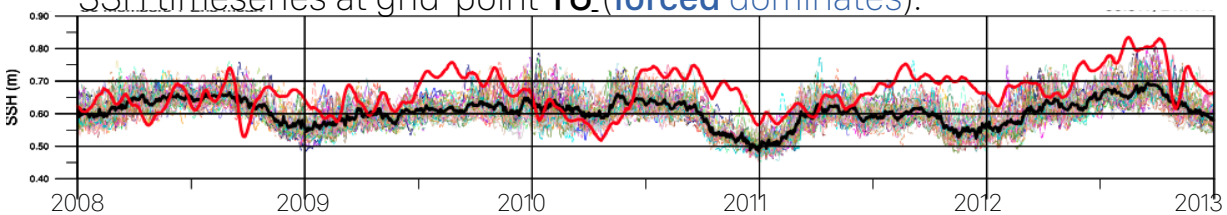
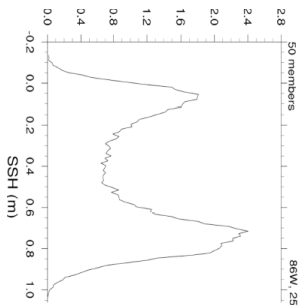
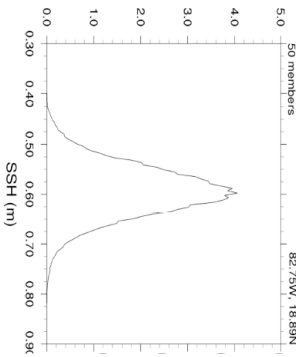
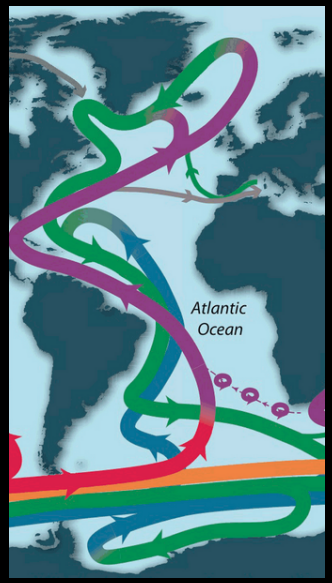


PDFs (all mbs, all timesteps) :





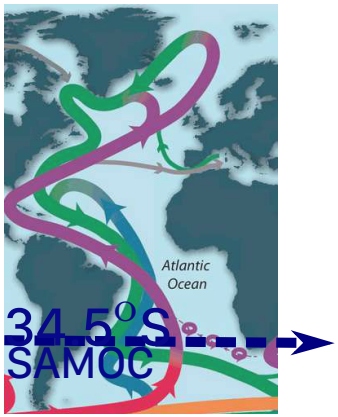


**How much does
this intrinsic variability matter
on longer timescales
and larger spatial domains ?**

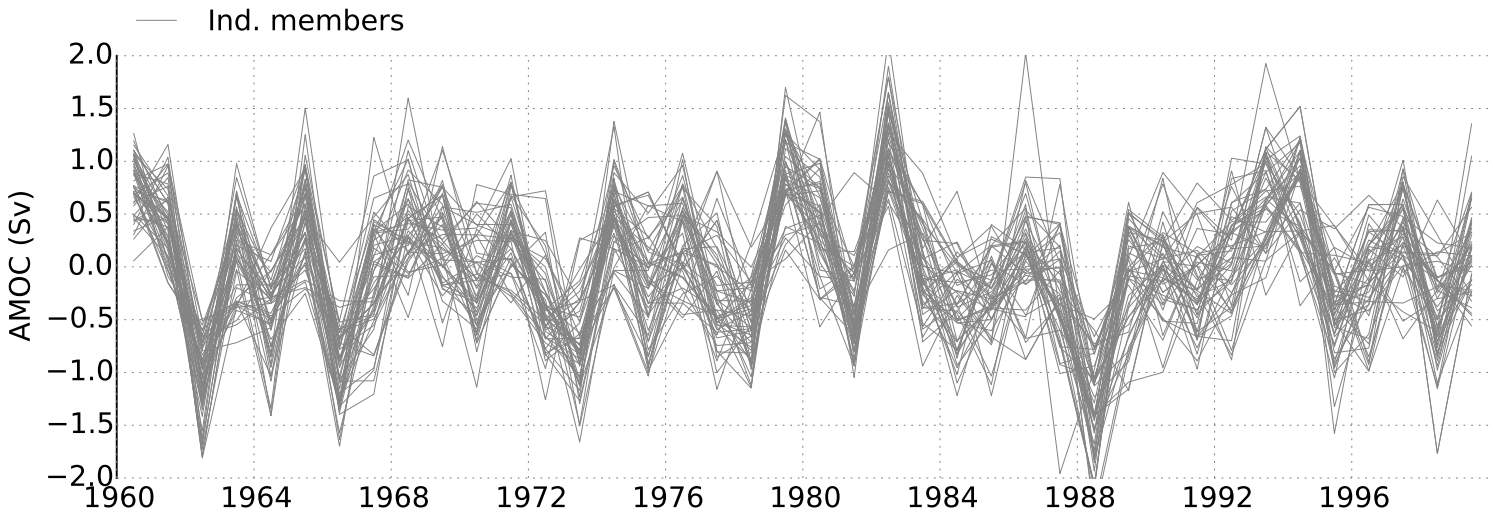
→ Focus on the interannual variability of a basin-integrated quantity: the Atlantic Meridional Overturning Circulation (AMOC).

Interannual timescale | How chaotic is AMOC variability?

AMOC at 34.5°S (annual mean anomalies)



From 50× global ens.



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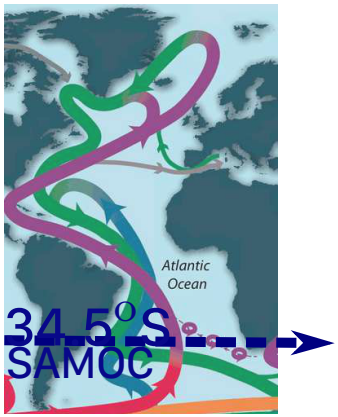

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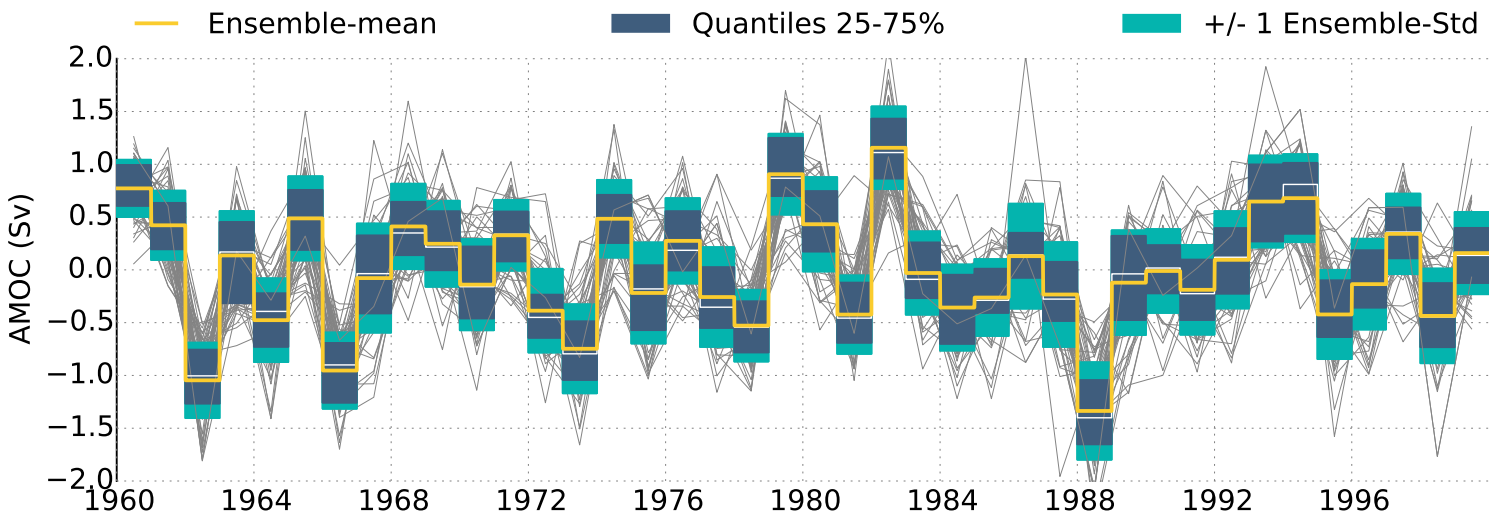

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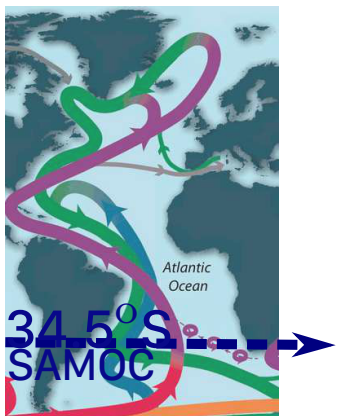

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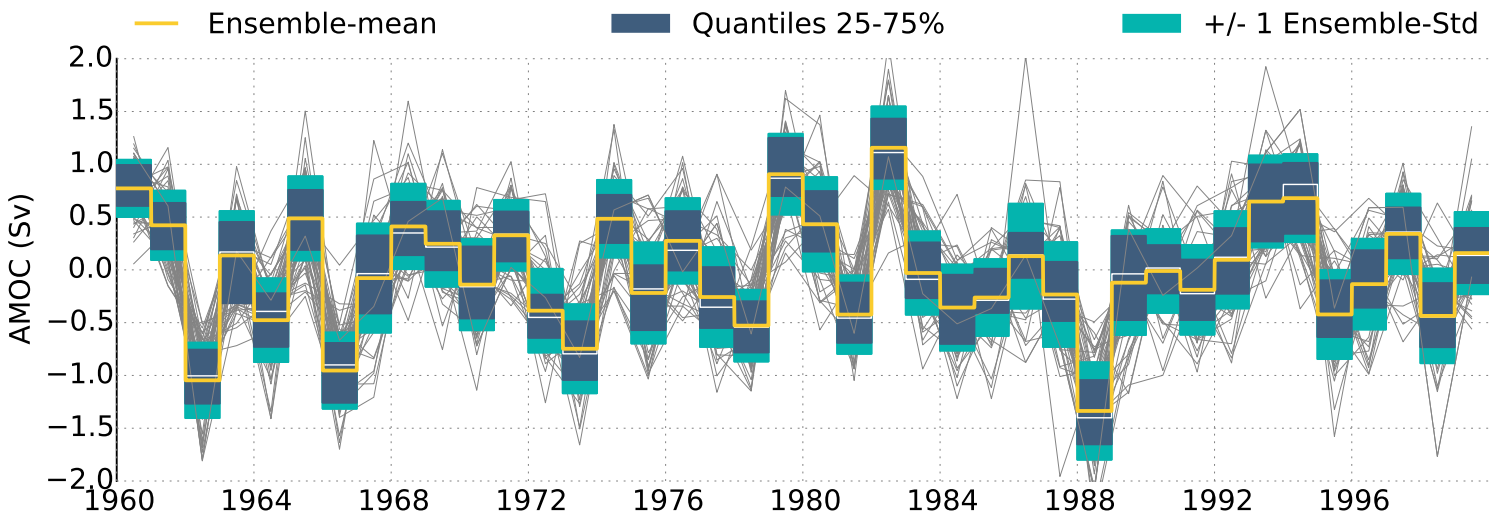
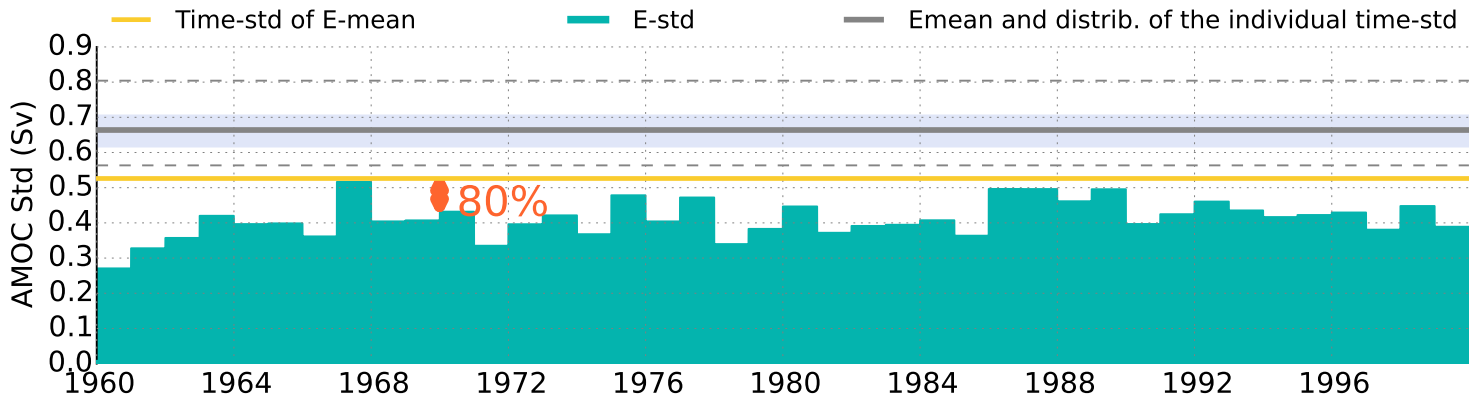
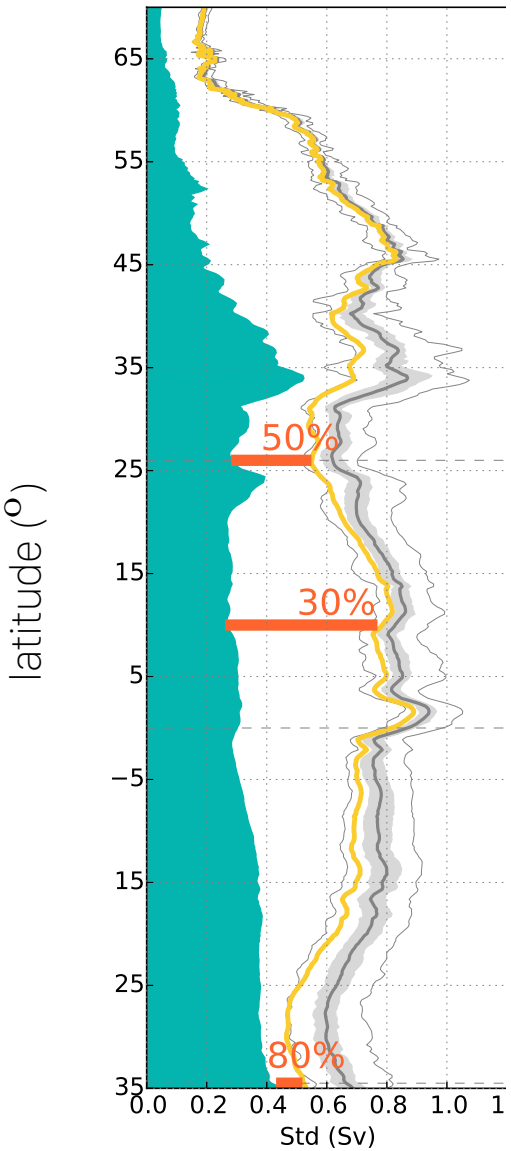




Interannual timescale | How chaotic is AMOC variability?

At all latitudes:



Time-Std of the ensemble-mean: **forced variability**.

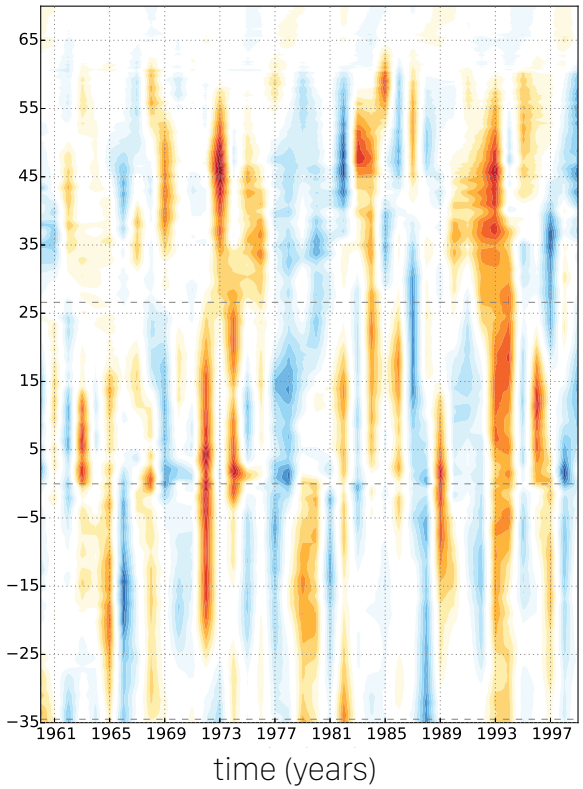
Ensemble-Std (averaged over 1960-1999): **intrinsic variability**

— Distribution of the 50 individual total Time-Std (mean, min, max, q25, q75): **total variability.**

Interannual timescale | AMOC spatio-temporal patterns:

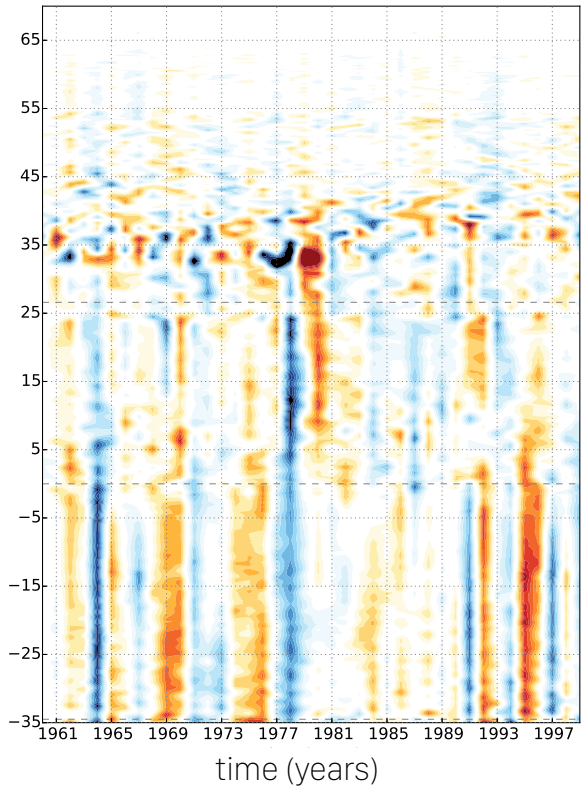
OCCIPUT Ensemble-mean

Forced var.



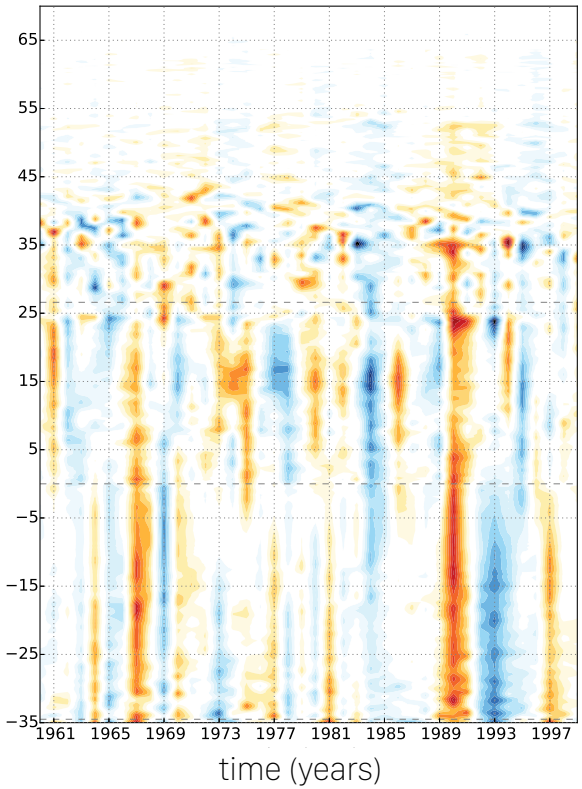
OCCIPUT intrinsic mb#1

Fully-forced intrinsic var.



CLIM run

Pure intrinsic var.



→ "Fully-forced" and "pure" intrinsic variability:

similar space-time organisation.

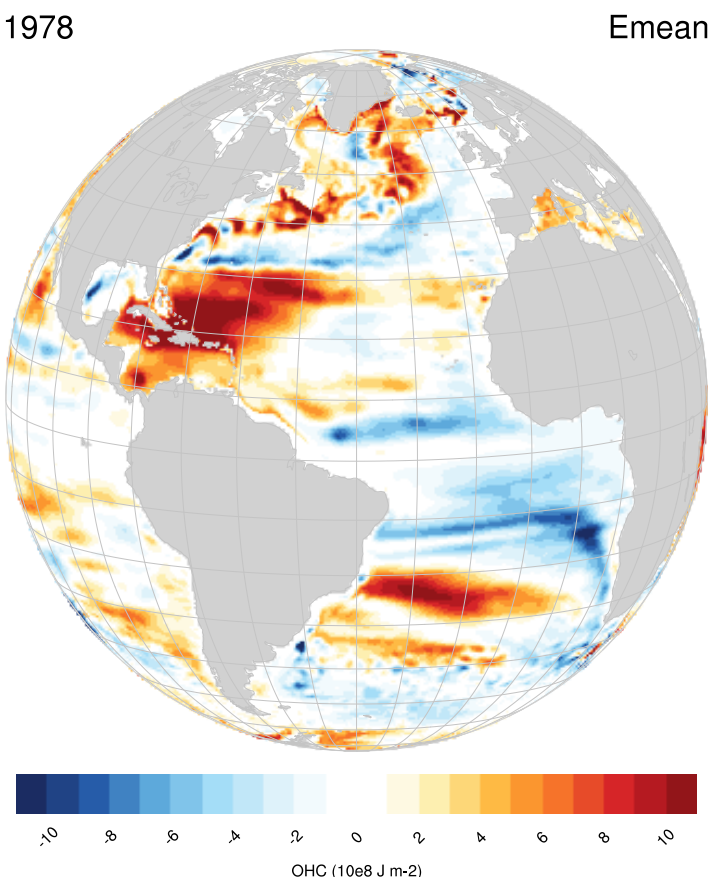
→ Forced and intrinsic variability: similar space-time

organisation south of ∼25N, different to the north.

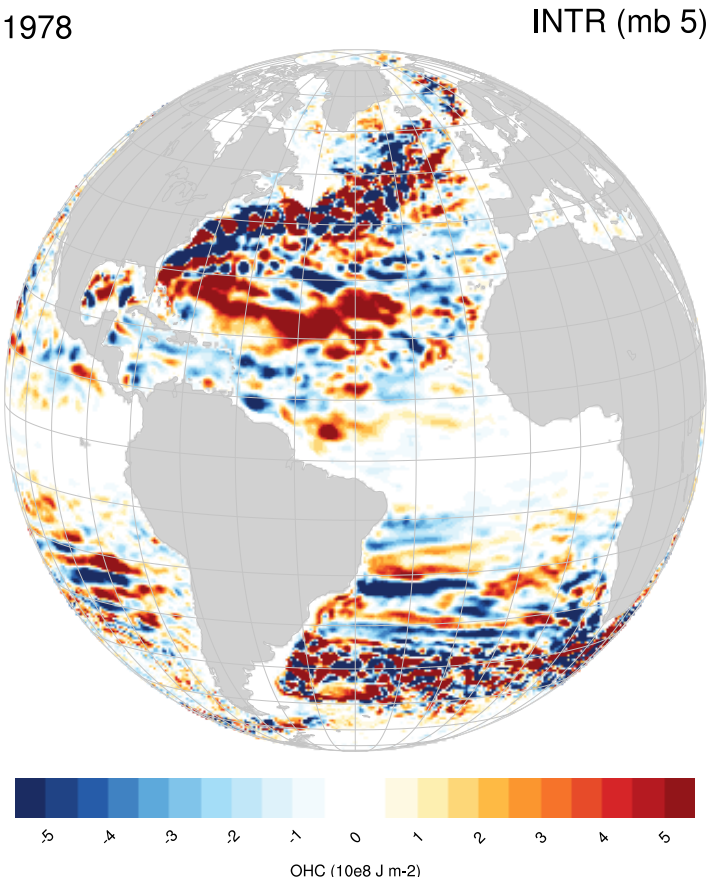
Interannual timescale | Ocean Heat Content variability

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

Forced (E-Mean)

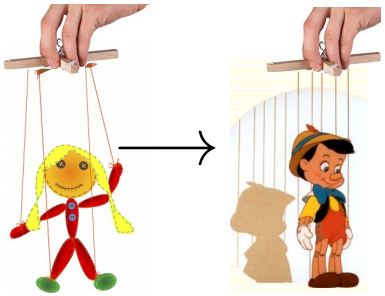


Intrinsic (mb#5)

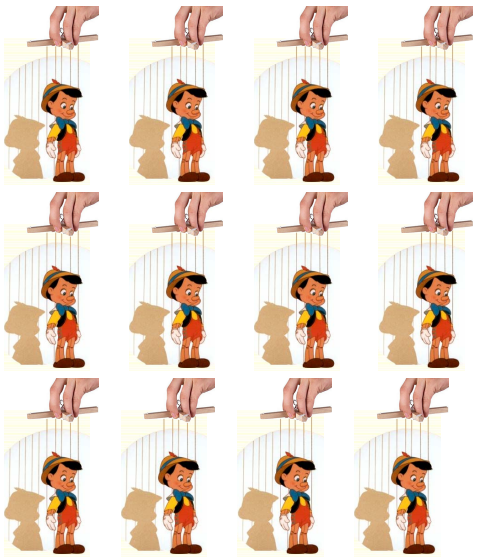


[On-going work – A. Jaymond's masters thesis]

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. $\longrightarrow$comparison with obs),
  - a way to disentangle intrinsic and forced contributions.
- SST, SSH, AMOC, OHC show substantial intrinsic variability on interannual timescales ($\longrightarrow$potential impact on climate variability).

On-going work...