

Intrinsic and atmospherically-forced variability of the AMOC : insights from a large ensemble ocean hindcast

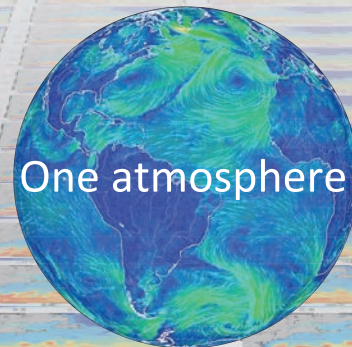
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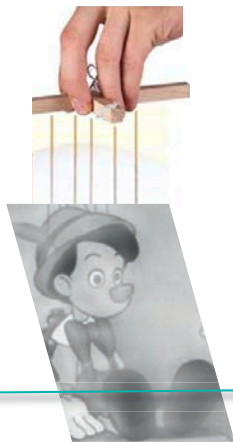
²CERFACS, Toulouse



N oceans

Oceanic variability in the laminar and **turbulent** regime

Atmospheric
Reanalysis



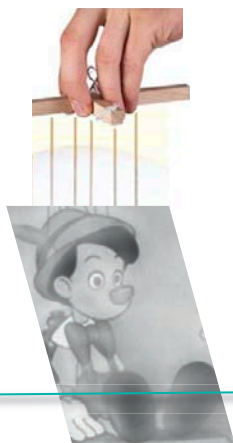
Laminar
regime

(NEMO 2°)
Atmosphere
drives **ALL** the
oceanic variability



Oceanic variability in the laminar and **turbulent** regime

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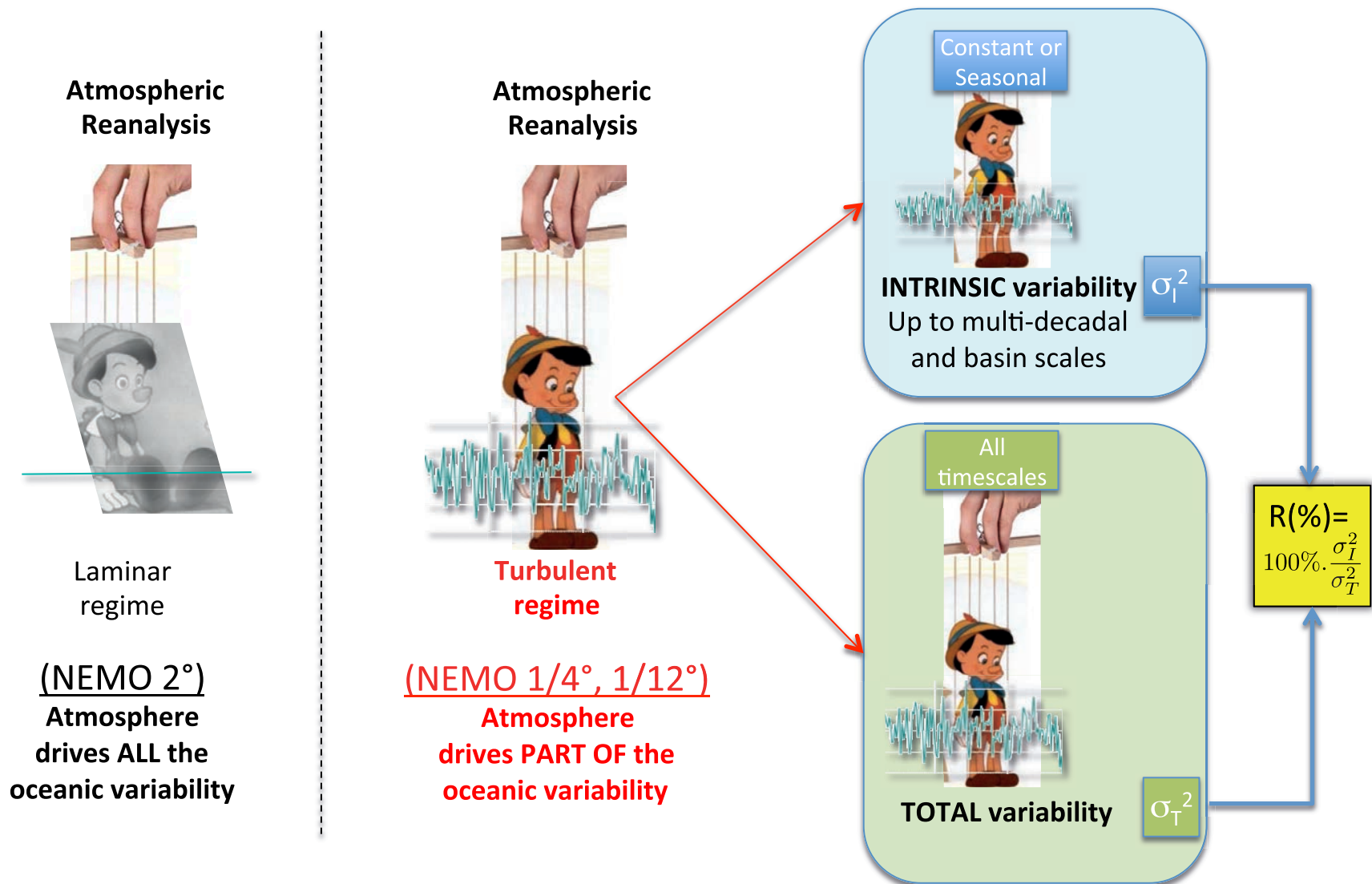
Atmospheric
Reanalysis



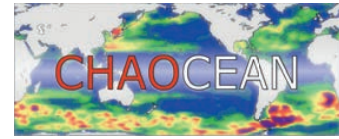
**Turbulent
regime**

(NEMO 1/4°, 1/12°)
**Atmosphere
drives PART OF the
oceanic variability**

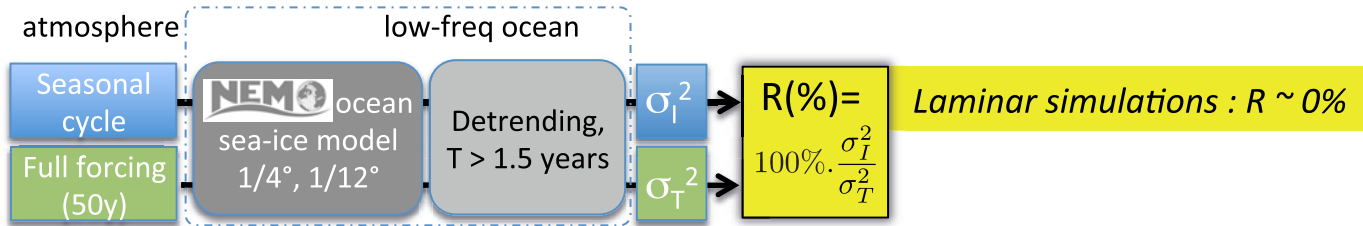
Oceanic variability in the laminar and **turbulent** regime



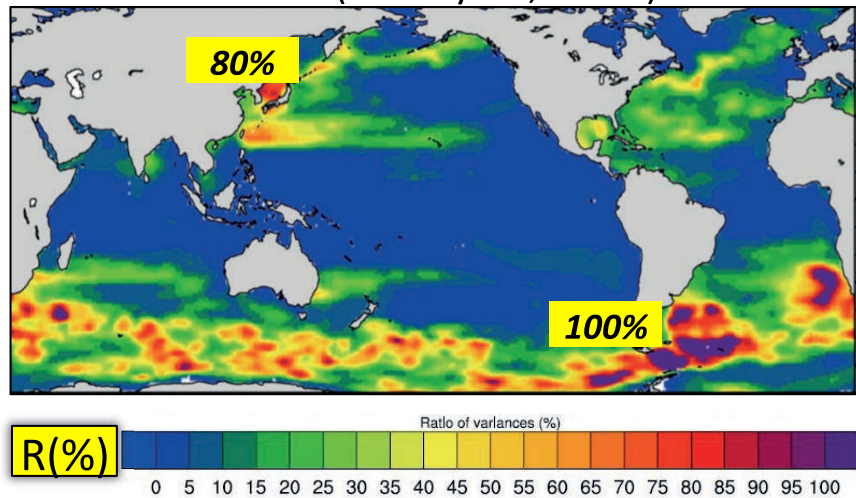
Chaotic large-scale low-frequency variance



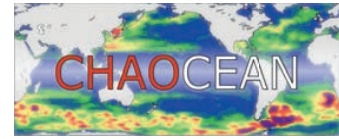
2013-2016 OST-ST Project



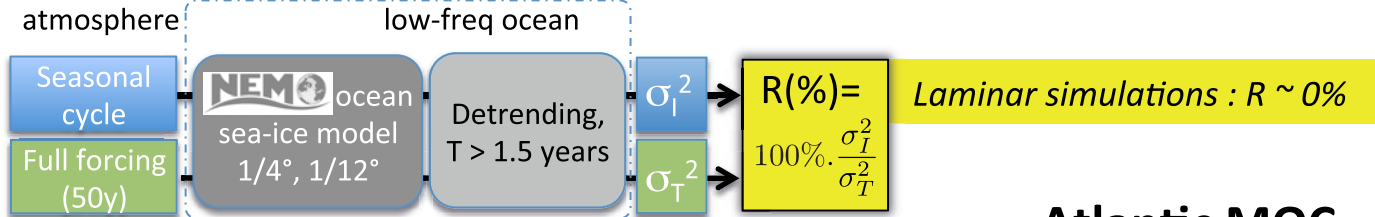
SLA (T > 1.5 year, L > 12°)



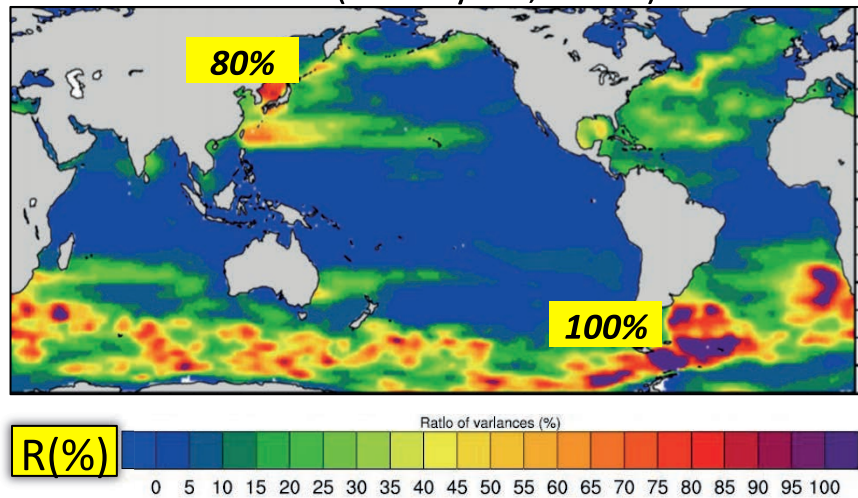
Chaotic large-scale low-frequency variance



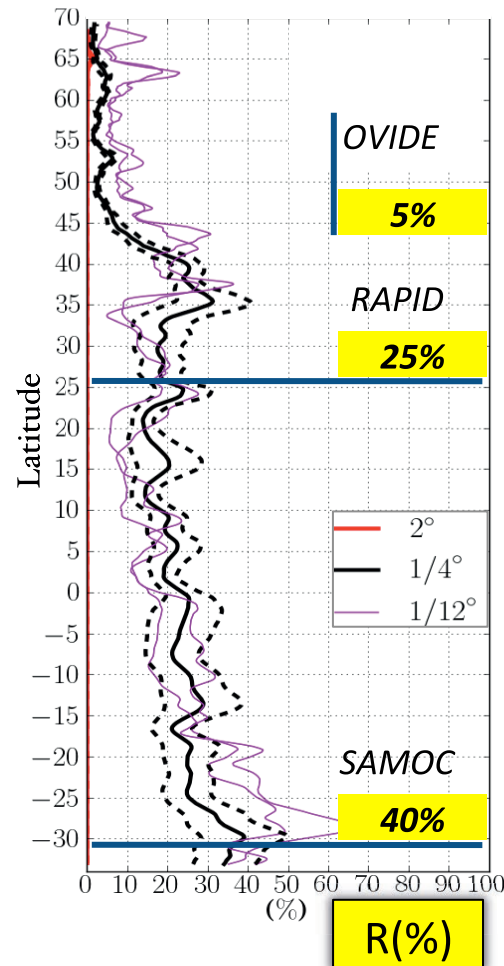
2013-2016 OST-ST Project



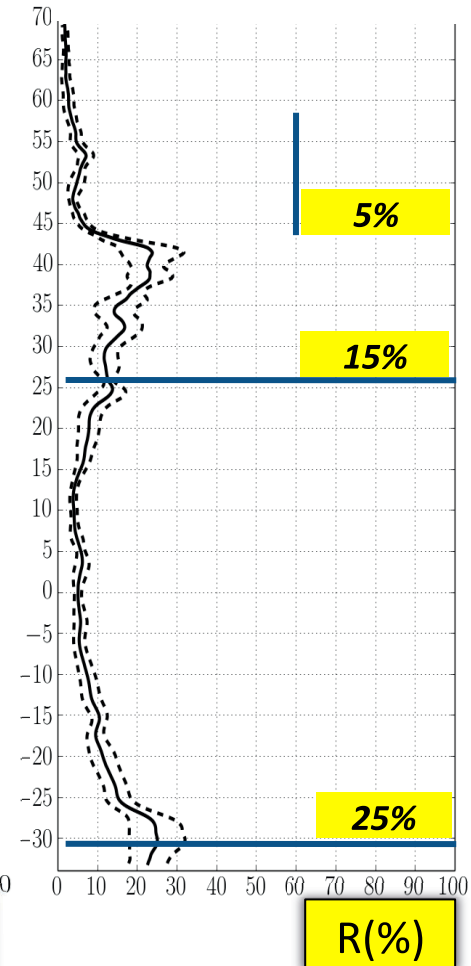
SLA (T > 1.5 year, L > 12°)



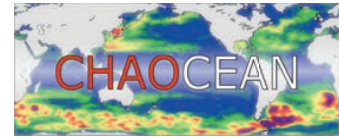
Atlantic MOC



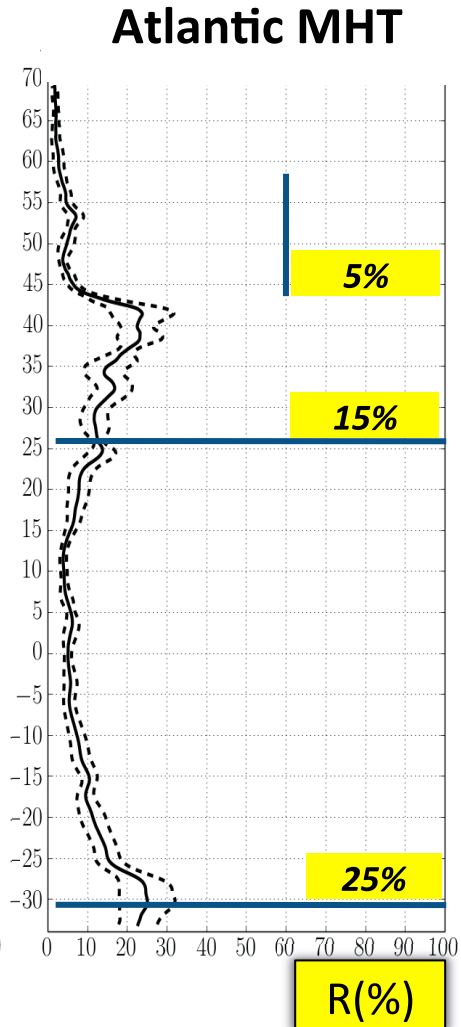
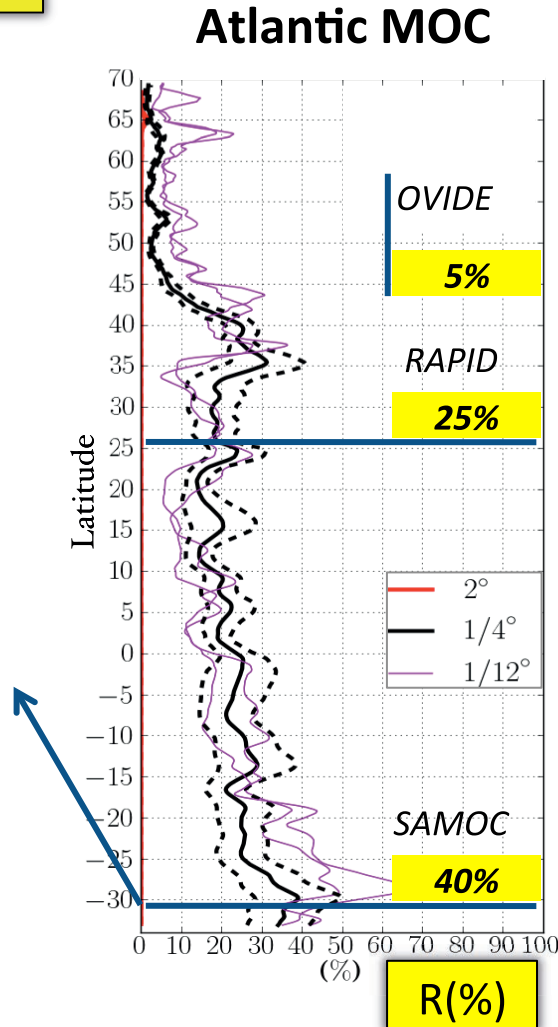
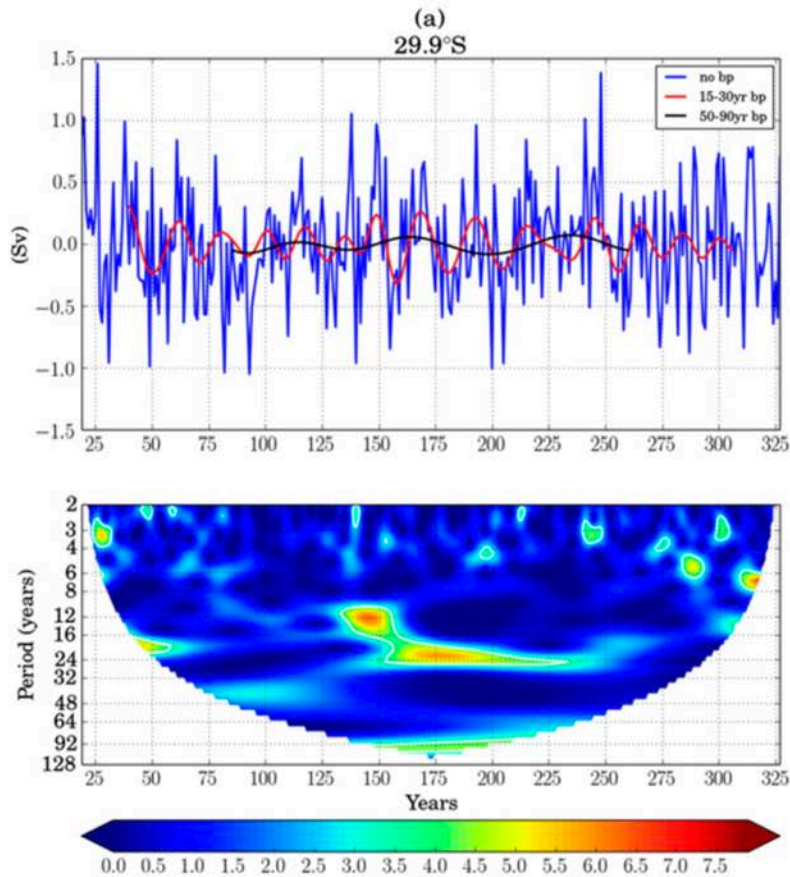
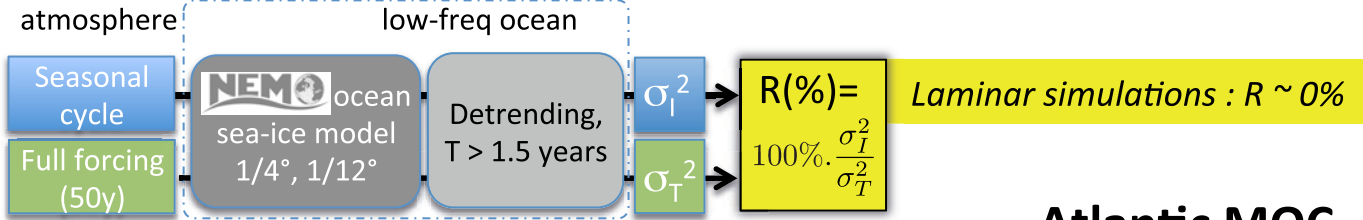
Atlantic MHT



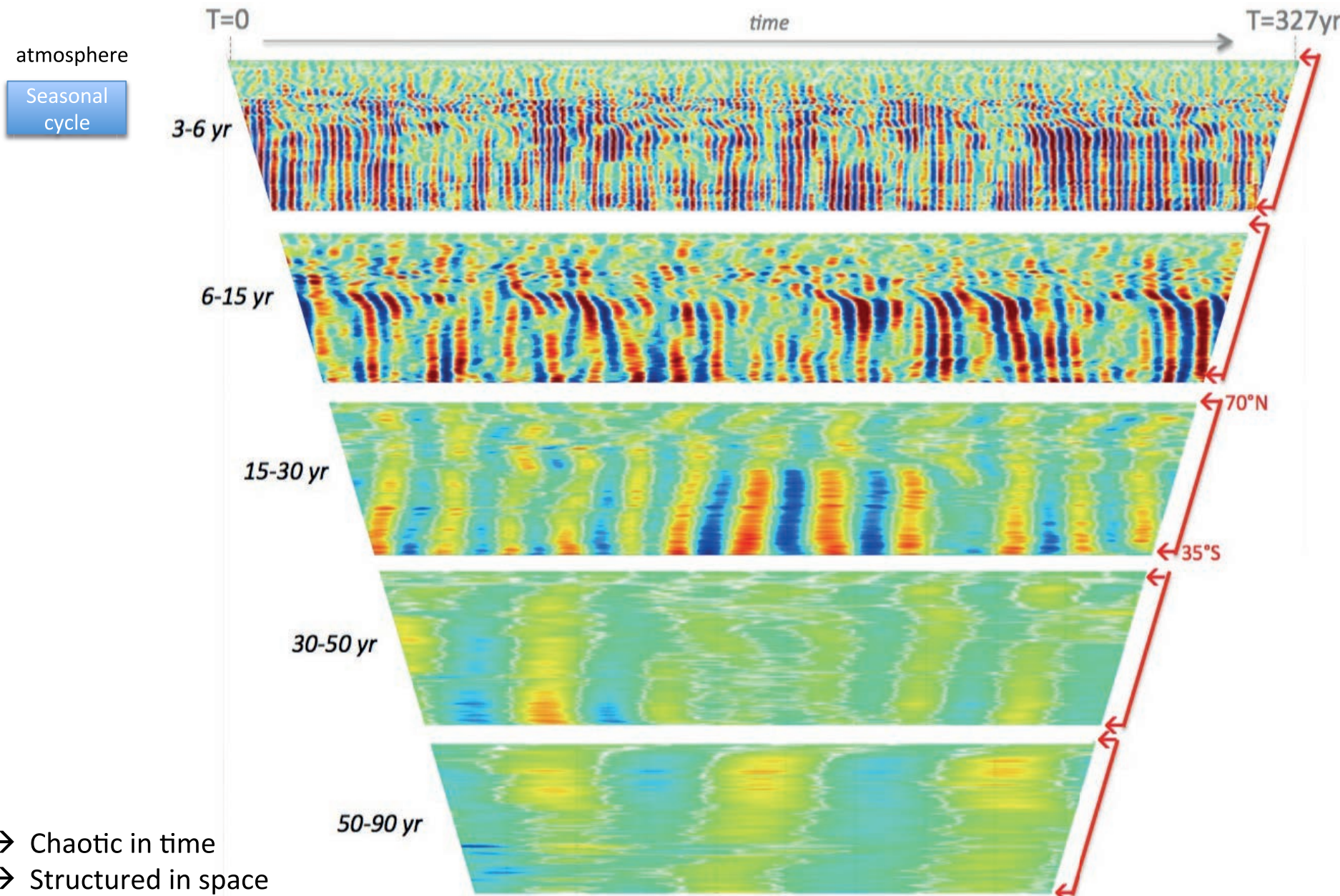
Chaotic large-scale low-frequency variance



2013-2016 OST-ST Project

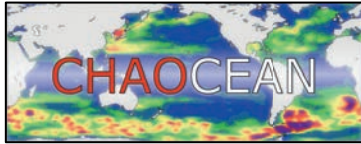


AMOC : Chaotic variability at 1/4° (bandpassed time-lat diagrams)



- Chaotic in time
- Structured in space
- Up to T~100yrs / basin-scale

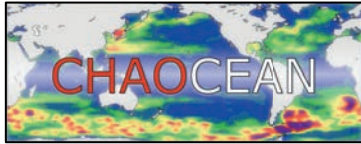
Chaotic Intrinsic variability



CIV isolated under seasonal forcing

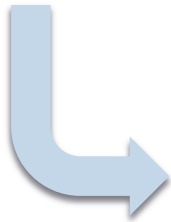
- Strong
- Broad range of scales
- Multiple observable imprints

Chaotic Intrinsic variability



CIV isolated under seasonal forcing

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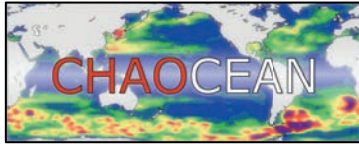


CIV under full forcing ?

CIV \leftrightarrow Forced variability ?

Atmospheric constraint on oceanic variability ?

Chaotic Intrinsic variability



CIV isolated under seasonal forcing

- Strong
- Broad range of scales
- Multiple observable imprints

CIV under full (reanalyzed) forcing

- Ensemble run
- Perturbed initial conditions
- Same forcing on all members



CIV under full forcing ?
CIV \leftrightarrow Forced variability ?

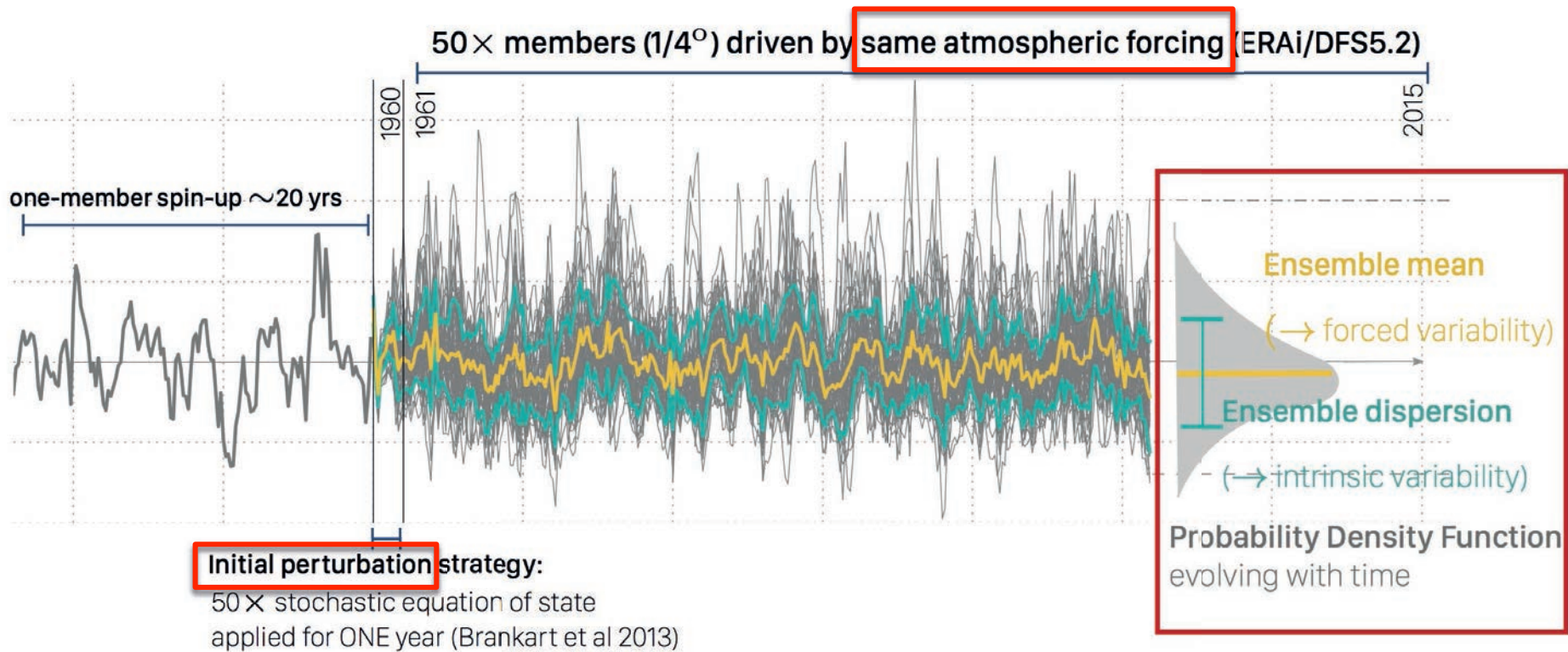


Atmospheric constraint on oceanic variability ?

OCCIPUT ensemble simulations

50-member $\frac{1}{4}^\circ$ ensemble hindcasts :

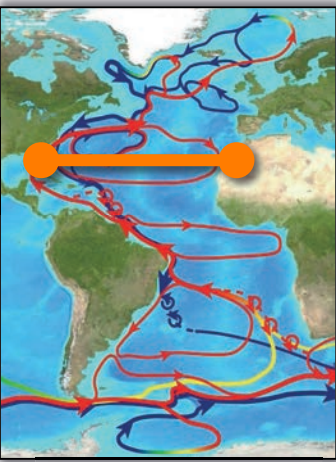
- Global ocean (56 years)
- North Atlantic (20 years)



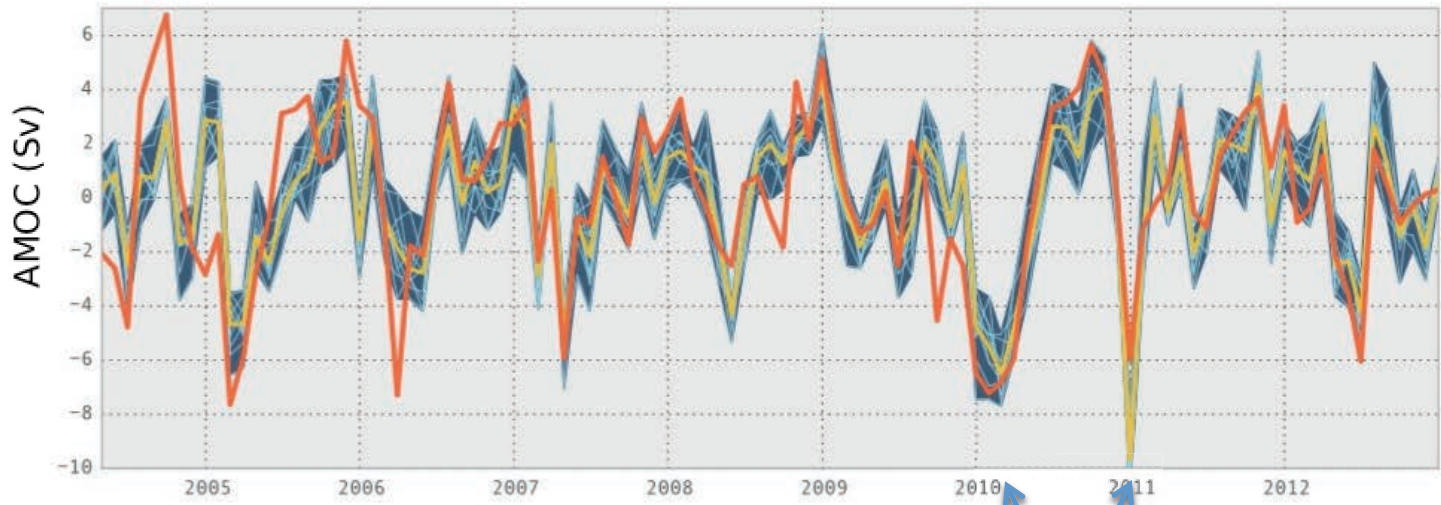
Forced & Intrinsic AMOC monthly variability : 26.5°N

non-linearly detrended timeseries

Corr(RAPID,Members) ~ 0.65
Corr(RAPID,ENSmean) = 0.70



RAPID
26.5°N

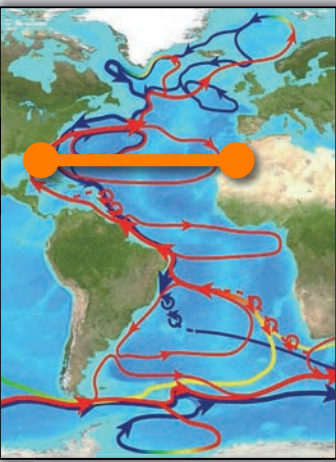


Atmospherically-forced AMOC minima

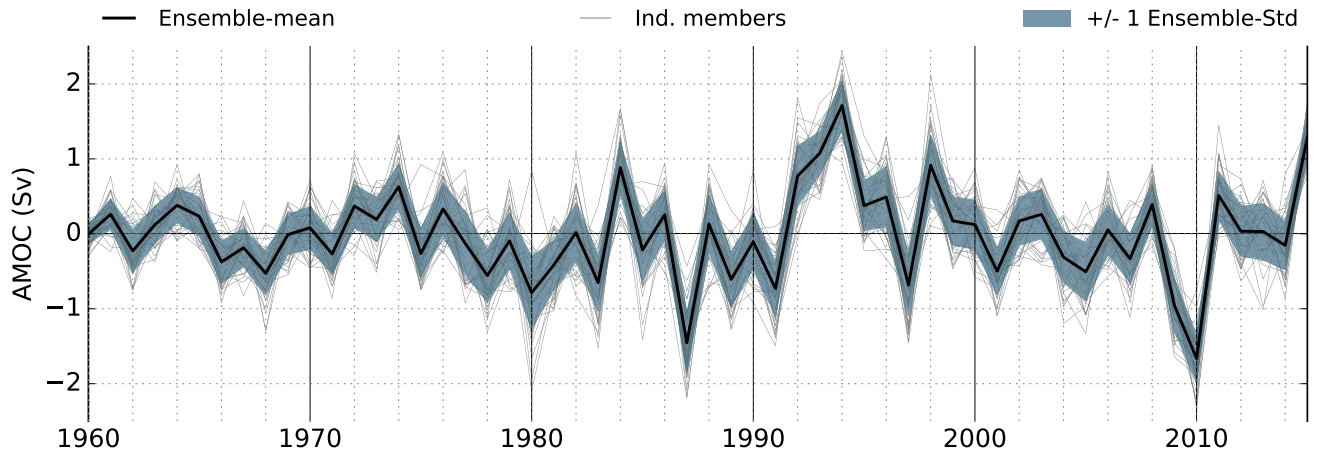
Forced & Intrinsic AMOC interannual variability : 26.5°N

non-linearly detrended timeseries: $T \sim 2-28$ yrs

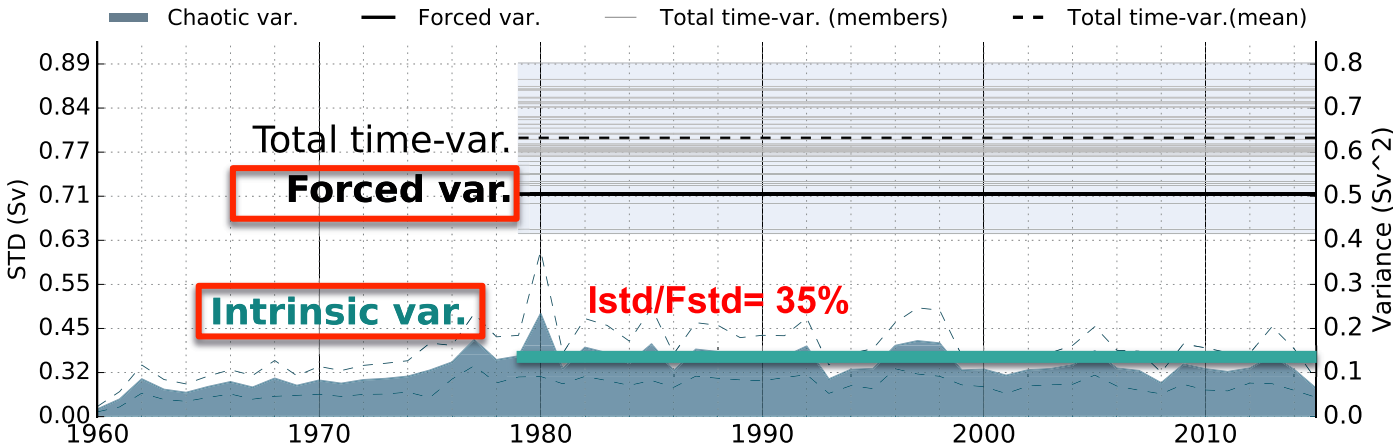
Intrinsic std/Forced std



RAPID
26.5°N



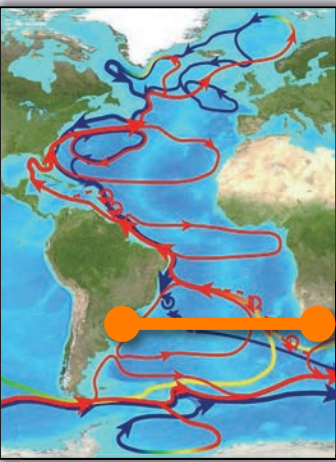
(b)



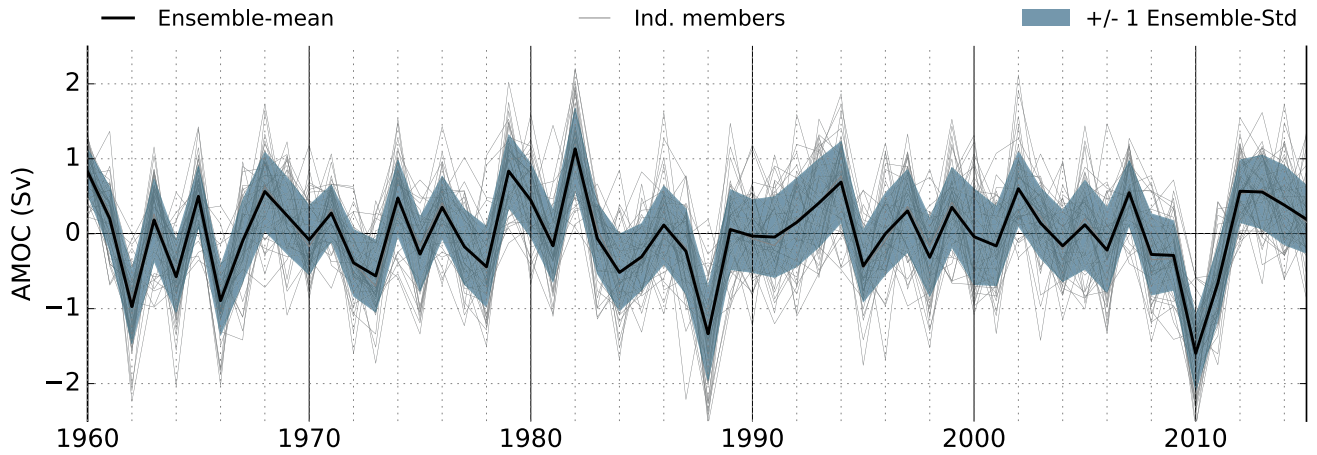
Forced & Intrinsic AMOC interannual variability : 34.5°S

non-linearly detrended timeseries: $T \sim 2-28$ yrs

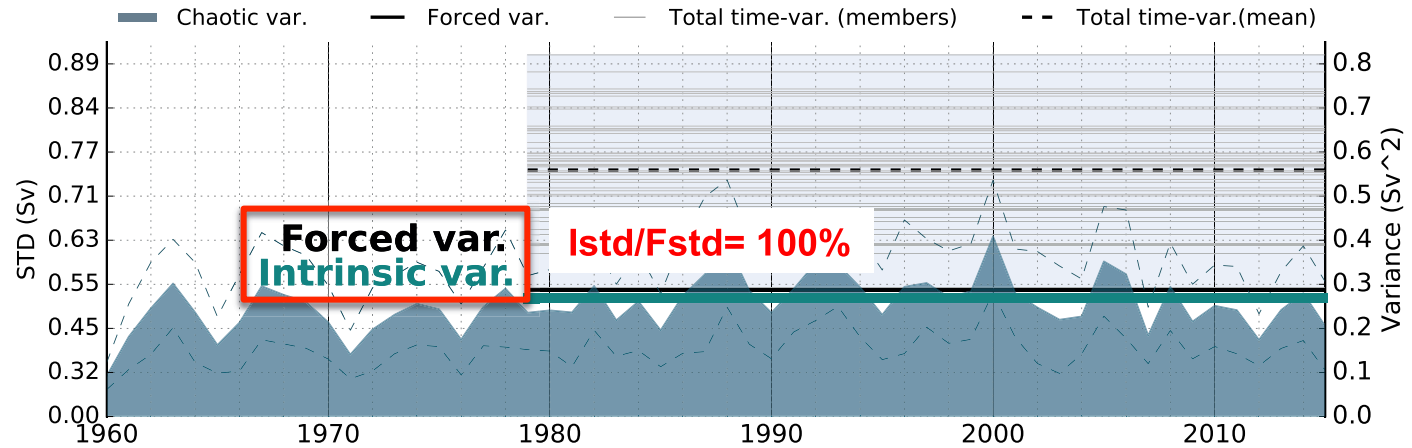
Intrinsic std/Forced std



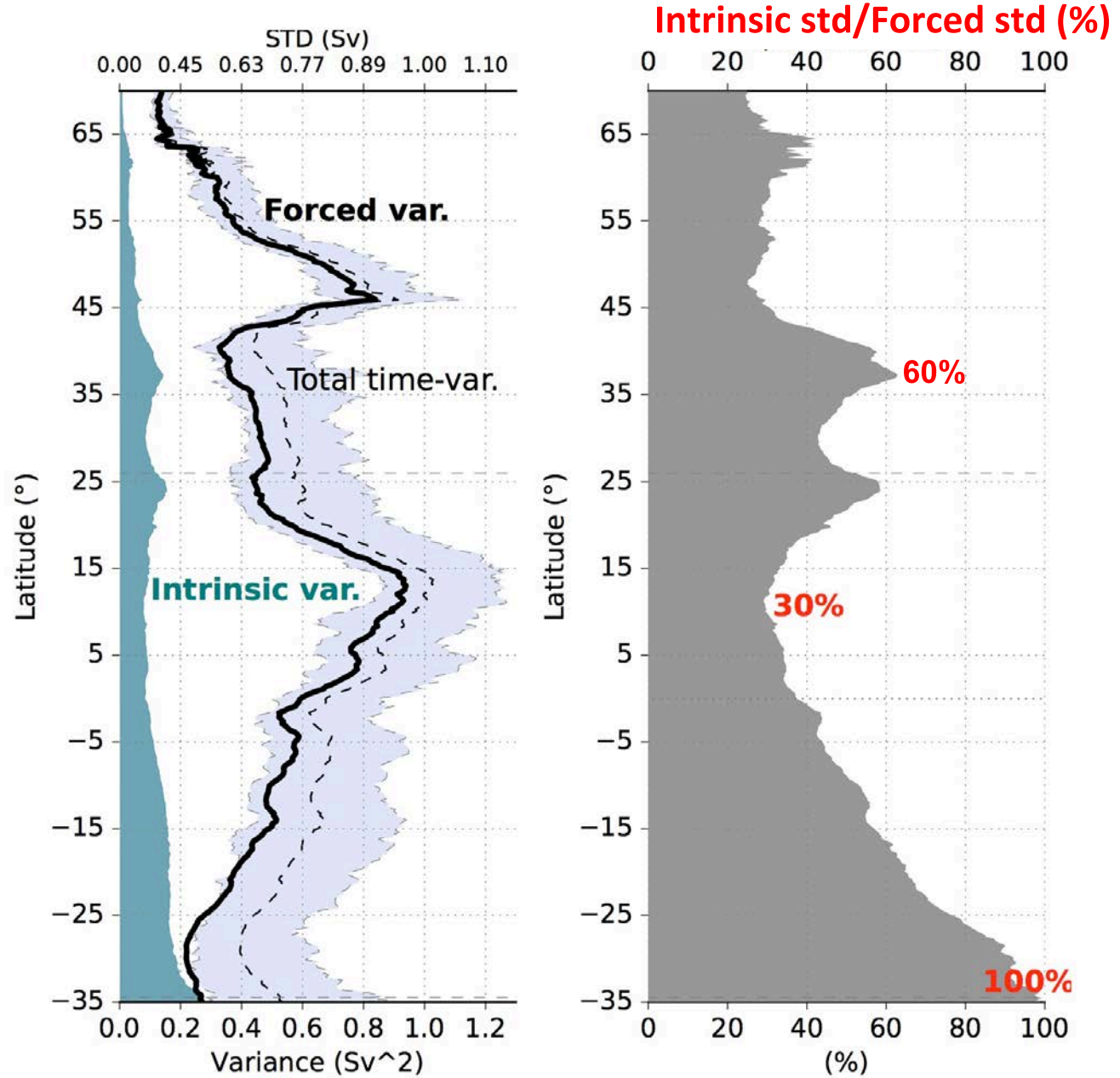
SAMOC
34.5°S



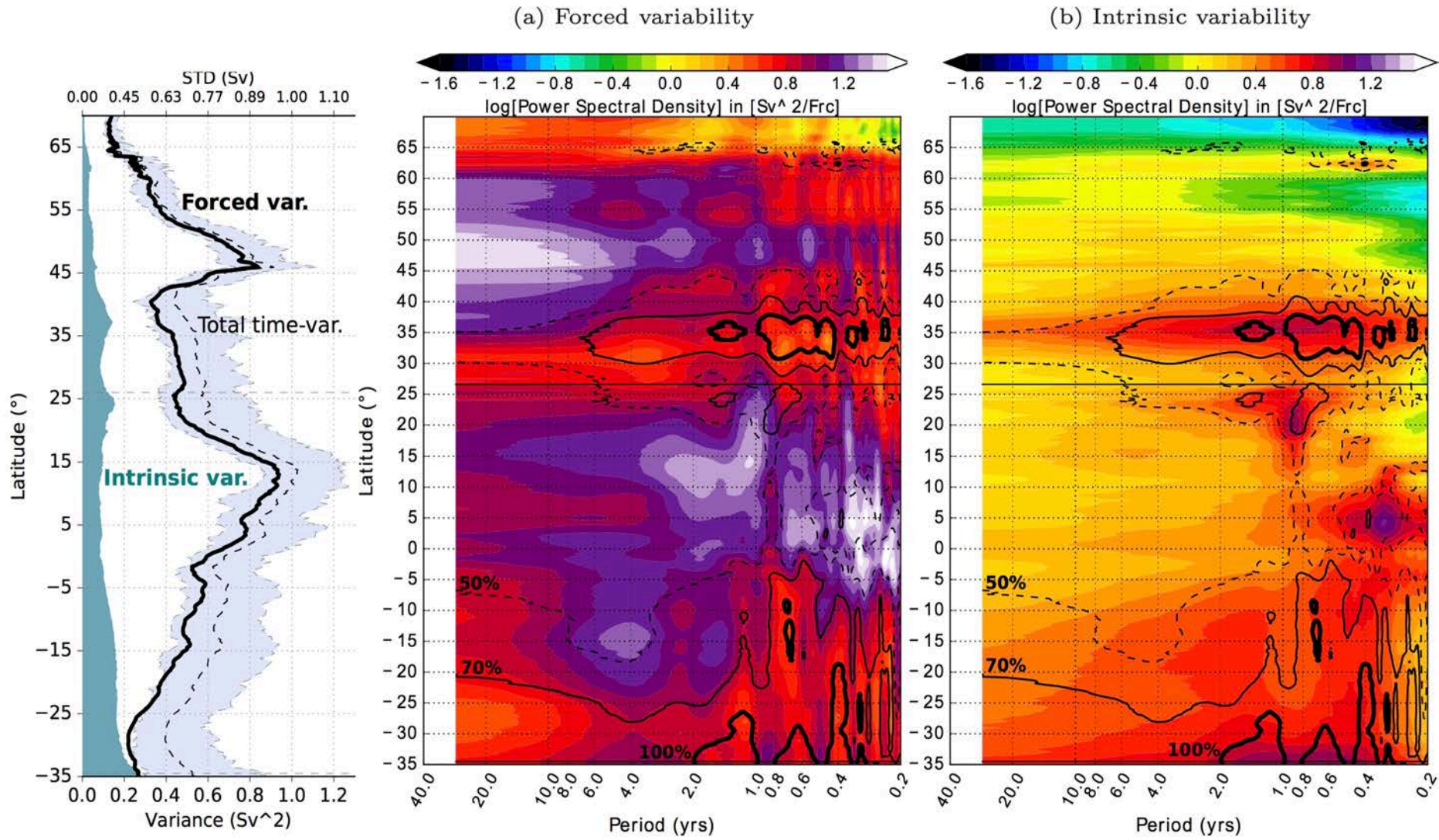
(b)



Forced & Intrinsic AMOC interannual variability : all latitudes



Forced & Intrinsic AMOC interannual variability : timescales



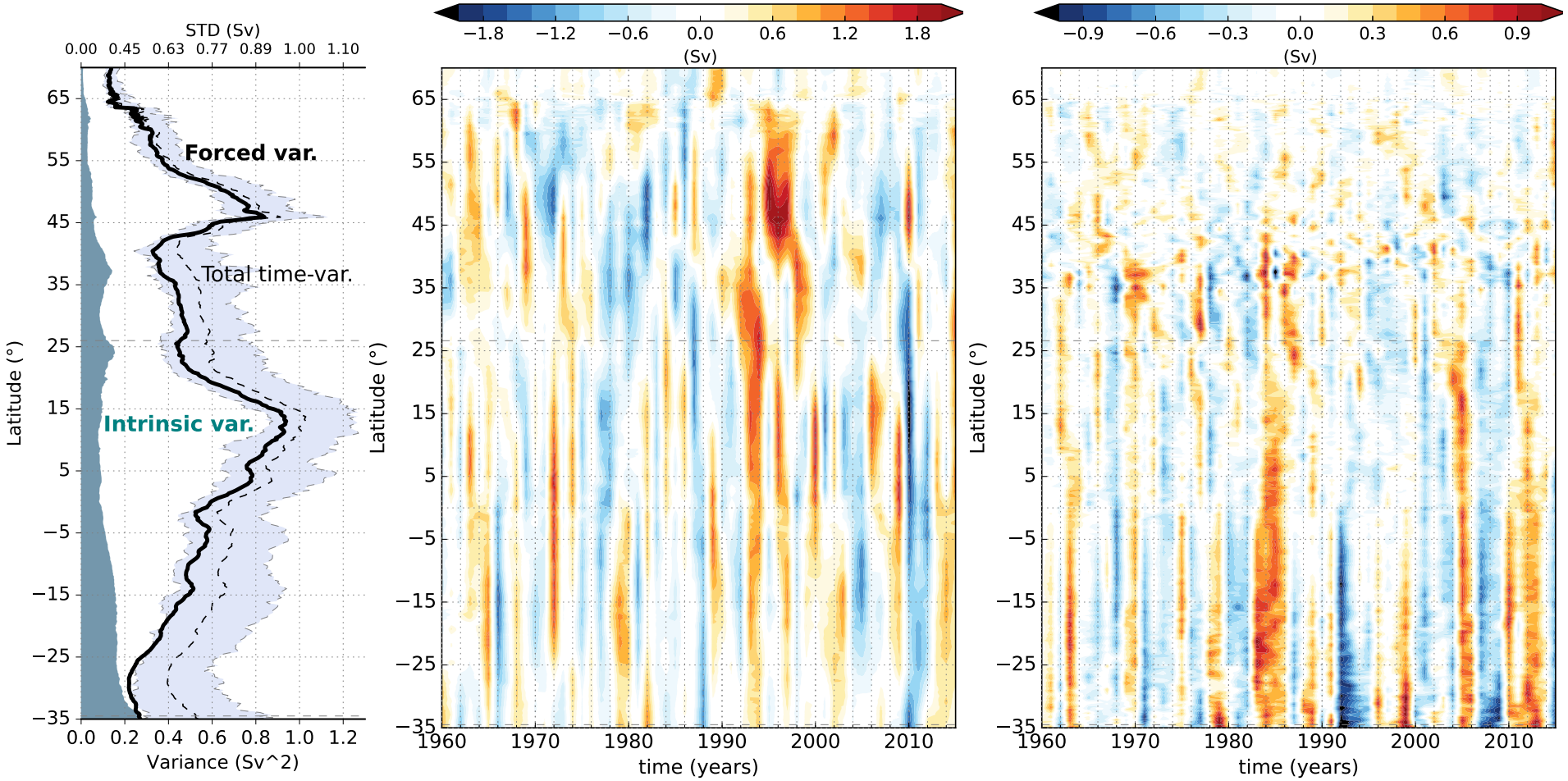
Forced & Intrinsic AMOC interannual variability : latitude-time

(a) Forced variability

(b) Intrinsic variability

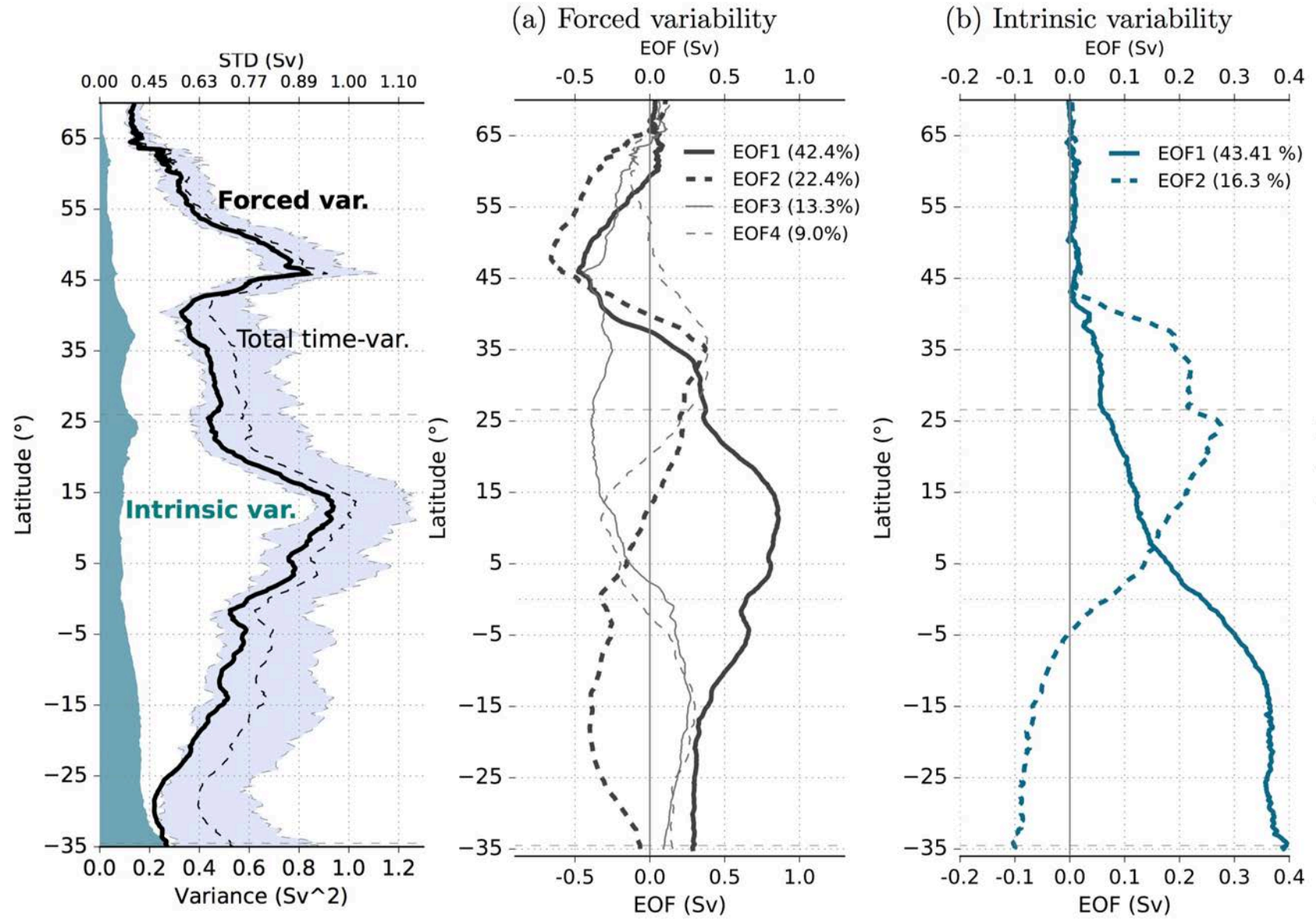
ENSx50-occi025 (Ensemble mean)

ENSx50-occi025 (member #1)



► Intrinsic AMOC variability is organized in large-scale meridionally coherent anomalies in the southern Atlantic.

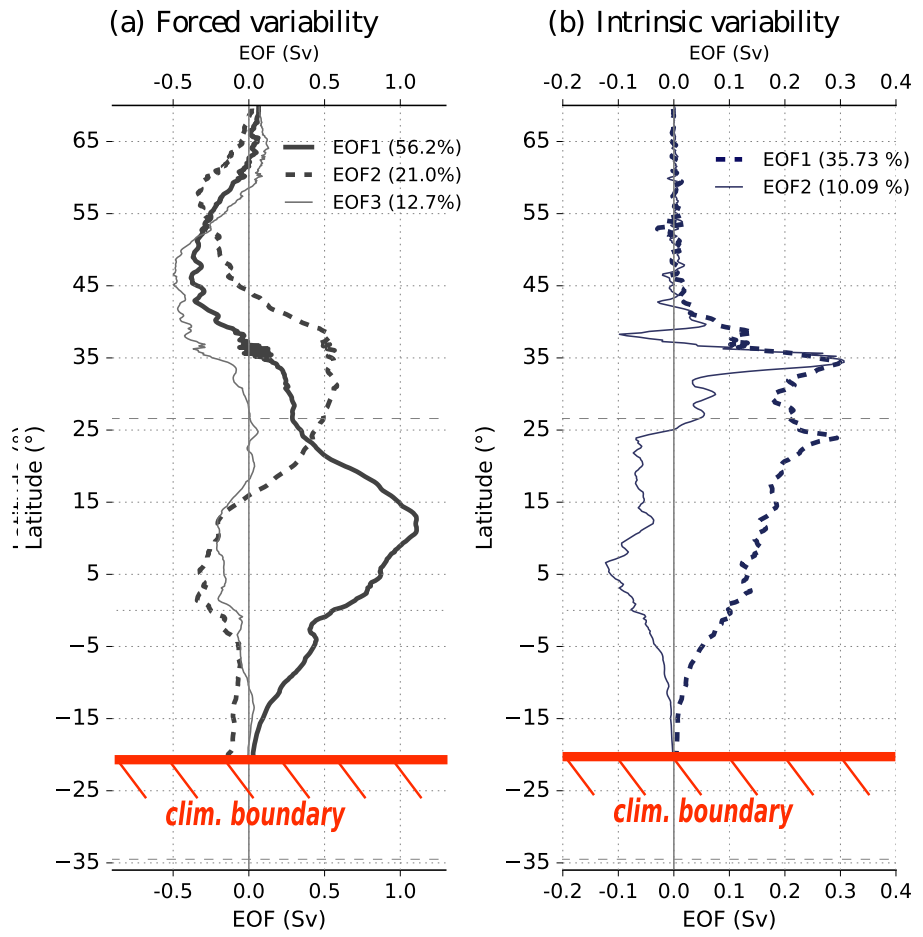
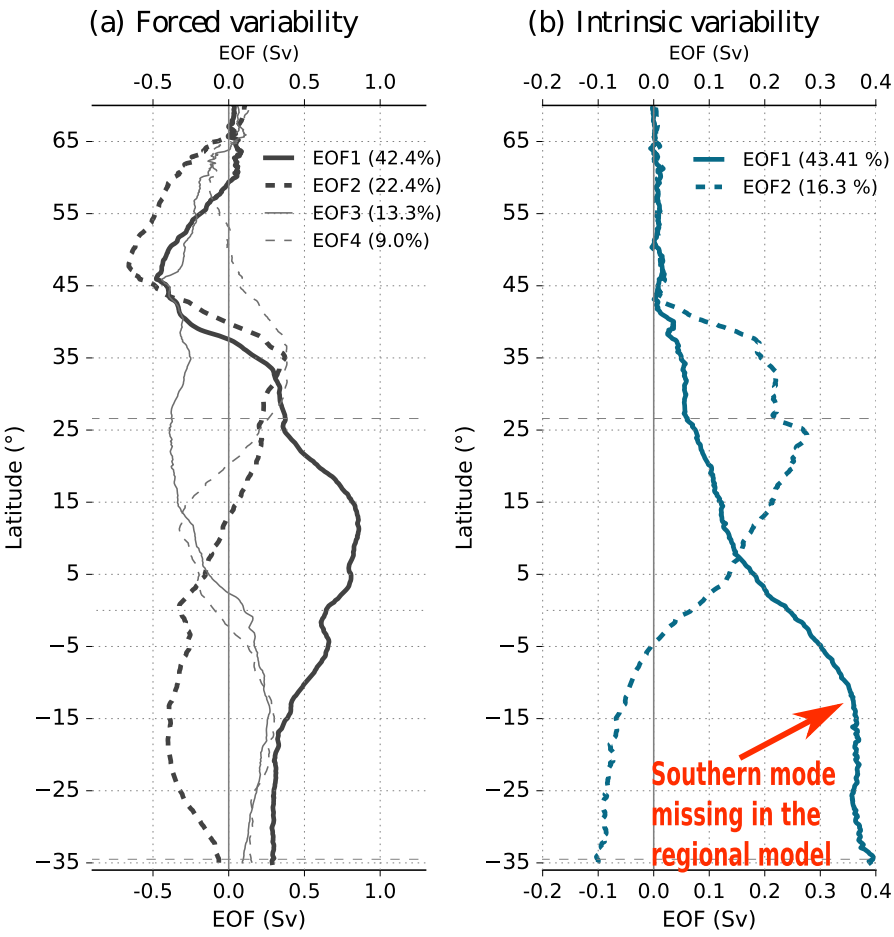
Forced & Intrinsic AMOC interannual variability : spatial EOFs



Forced & Intrinsic AMOC interannual variability : South Atl.

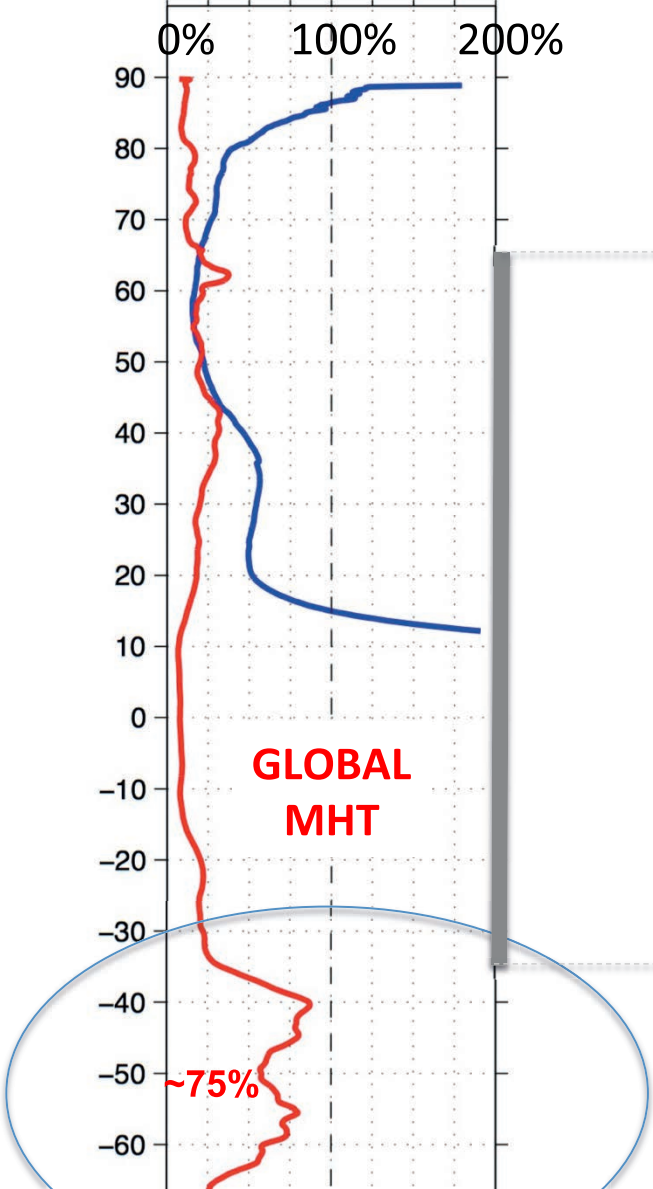
Global NEMO

Regional NEMO (NATL)

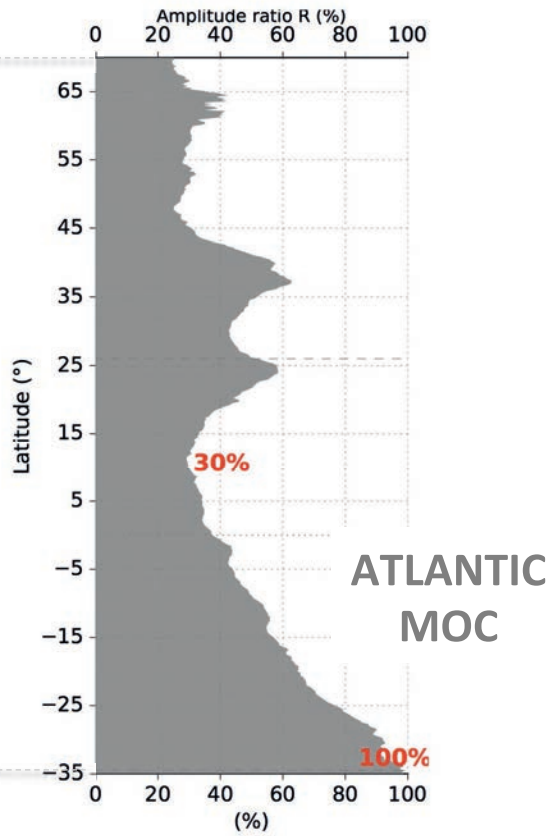


► Suggests that the "southern mode" of intrinsic AMOC variability is generated further south than 20°N. Influence of the Agulhas region? Of the Southern Ocean?

Intrinsic interannual variability : AMOC & global MHT



Intrinsic std/Forced std (%)



Conclusions & Perspectives

◆ Variability in the eddying ocean (AMOC, OHC, SSH, SST, ...)

- Simulations: Atmospherically-modulated **chaos**
Poorly-known, **strong « noise »**
Up to **climatic and basin scales** | ➔ *Ensemble simulations required*
- Observations: One among many possible evolutions
Ensemble runs: Simulate these possible evolutions
Disentangle Forced/Chaotic observed signals | ➔ *Probabilistic oceanography*

◆ Next steps

- Observational and operational implications (OST-ST, CMEMS, GMMC, AtlantOS, ...)
- Other perspectives (climate, biogeochemistry, etc) | ➔ *share OCCIPUT data subsets*

OCCIPUT	: Penduff et al (Clivar Exch. 2014)
Probabilistic NEMO	: Bessières et al (GMD 2017)
SLA	: Penduff et al (J. Clim 2011)
Scales	: Sérazin et al (J. Clim 2015)
SLA (D & A)	: Sérazin et al (GRL 2016)
MOC, MHT	: Gregorio et al (JPO 2015), : <u>Leroux et al (J. Clim in rev)</u>
OHC	: Sérazin et al (GRL in rev)
Temporal inv. casc.	: Sérazin et al (JPO to be subm.)