Atmospherically-forced and ocean-driven interannual variability of the AMOC

(upper cell, $AMOC_{\sigma_2}$)

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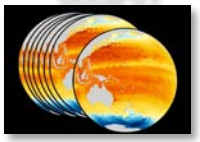
Guillaume SERAZIN

Based on:

Leroux, S., T. Penduff, L. Bessières, J.M. Molines, J.M. Brankart, G. Sérazin, B. Barnier, and L. Terray, **2018** : Intrinsic and Atmospherically Forced Variability of the AMOC : Insights from a Large-Ensemble Ocean Hindcast. *J. Climate*, 31, 1183–1203. https://doi.org/10.1175/JCLI-D-17-0168.1

OCCIPUT

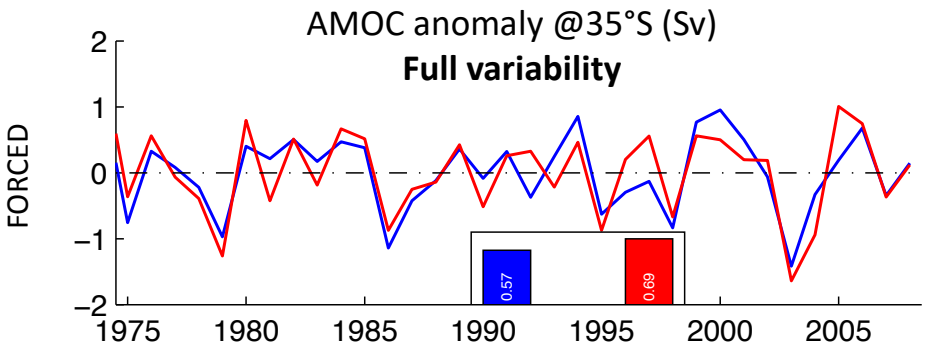


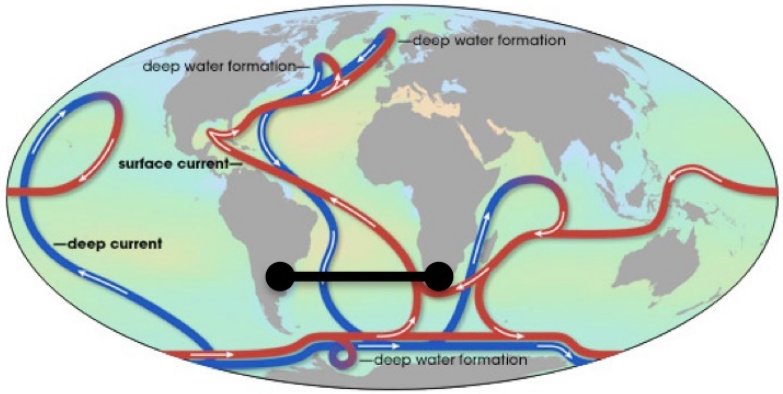
Grégorio et al (JPO 2015)

Full AMOC variability (T > 1yr) at 35°S

Atmosphere | **Global ocean model** | **Ocean variability**

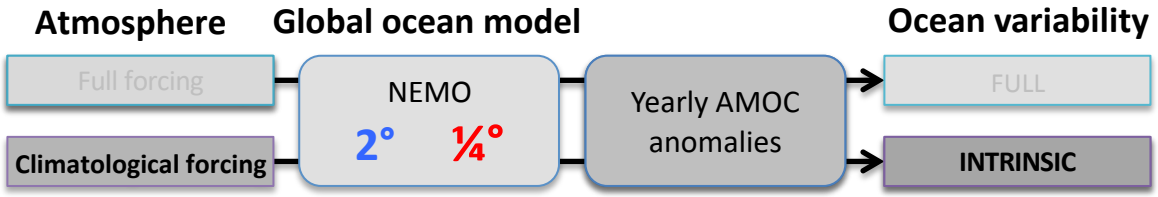
Full forcing → NEMO 2° ¼° → Yearly AMOC anomalies → FULL

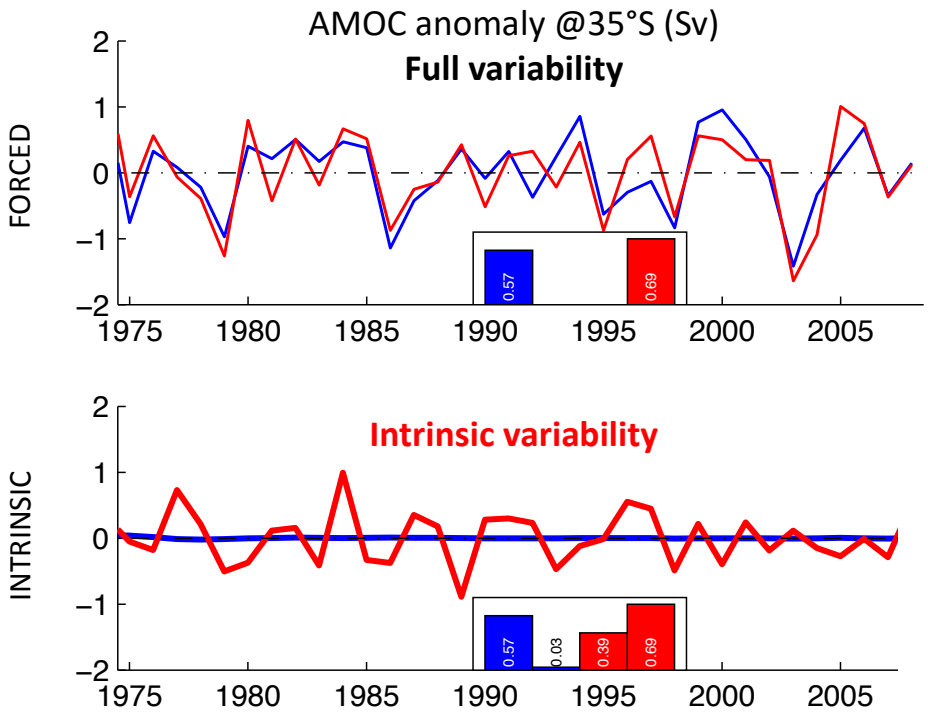


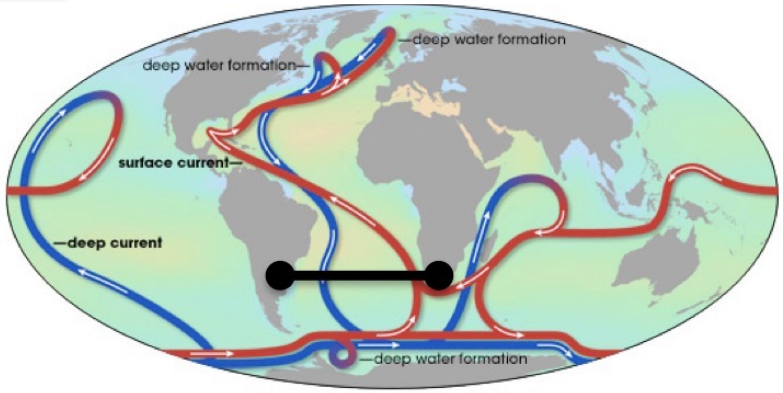


Intrinsic AMOC variability (T > 1yr) at 35°S

Grégorio et al (JPO 2015)





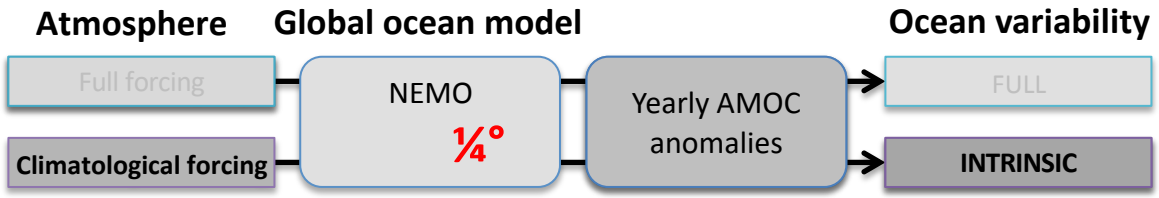


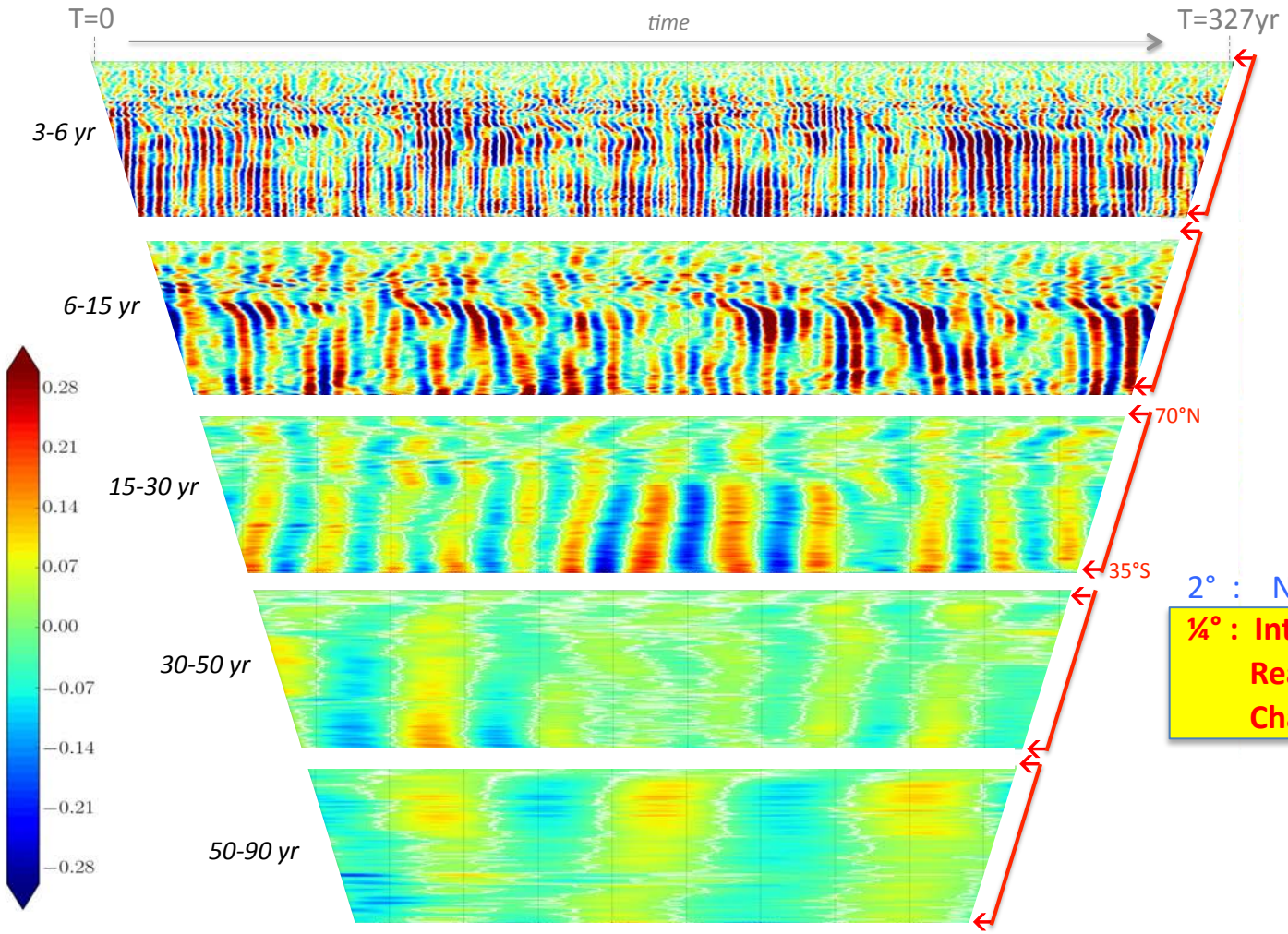
2° : NO Intrinsic variability

¼° : Intrinsic variability

Intrinsic AMOC variability (3 < T < 90 yr)

Grégorio et al (JPO 2015)





327 year Climatological NEMO simulation

2° : NO Intrinsic variability

¼° : Intrinsic variability
Reaches multi-decadal timescales
Chaotic behavior

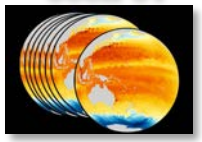
Disentangling forced and chaotic/intrinsic variability

Global ocean ensemble simulation

NEMO ocean/sea-ice model. $\Delta = 1/4°$

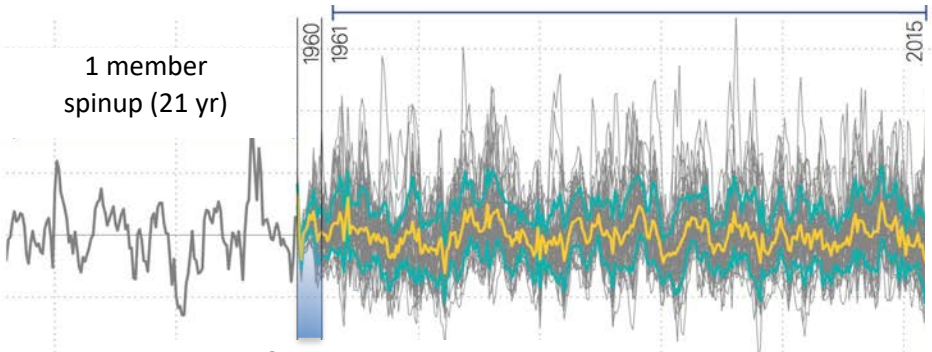
50 members - **56** years (1960-2015)

OCCIPUT



https://meom-group.github.io/projects/occiput/

same full forcing (based on the ERA-interim reanalysis)



1-year Stochastic Perturbations

Penduff et al (2014)
Bessières et al (2017)
Leroux et al (2018)

Disentangling forced and chaotic/intrinsic variability

Global ocean ensemble simulation

NEMO ocean/sea-ice model. $\Delta = 1/4°$

50 members - **56** years (1960-2015)

https://meom-group.github.io/projects/occiput/

same full forcing (based on the ERA-interim reanalysis)

1 member spinup (21 yr)

1960 1961 2015

1-year Stochastic Perturbations

Non-linear detrending, AMOC

Time-dependent E-PDFs

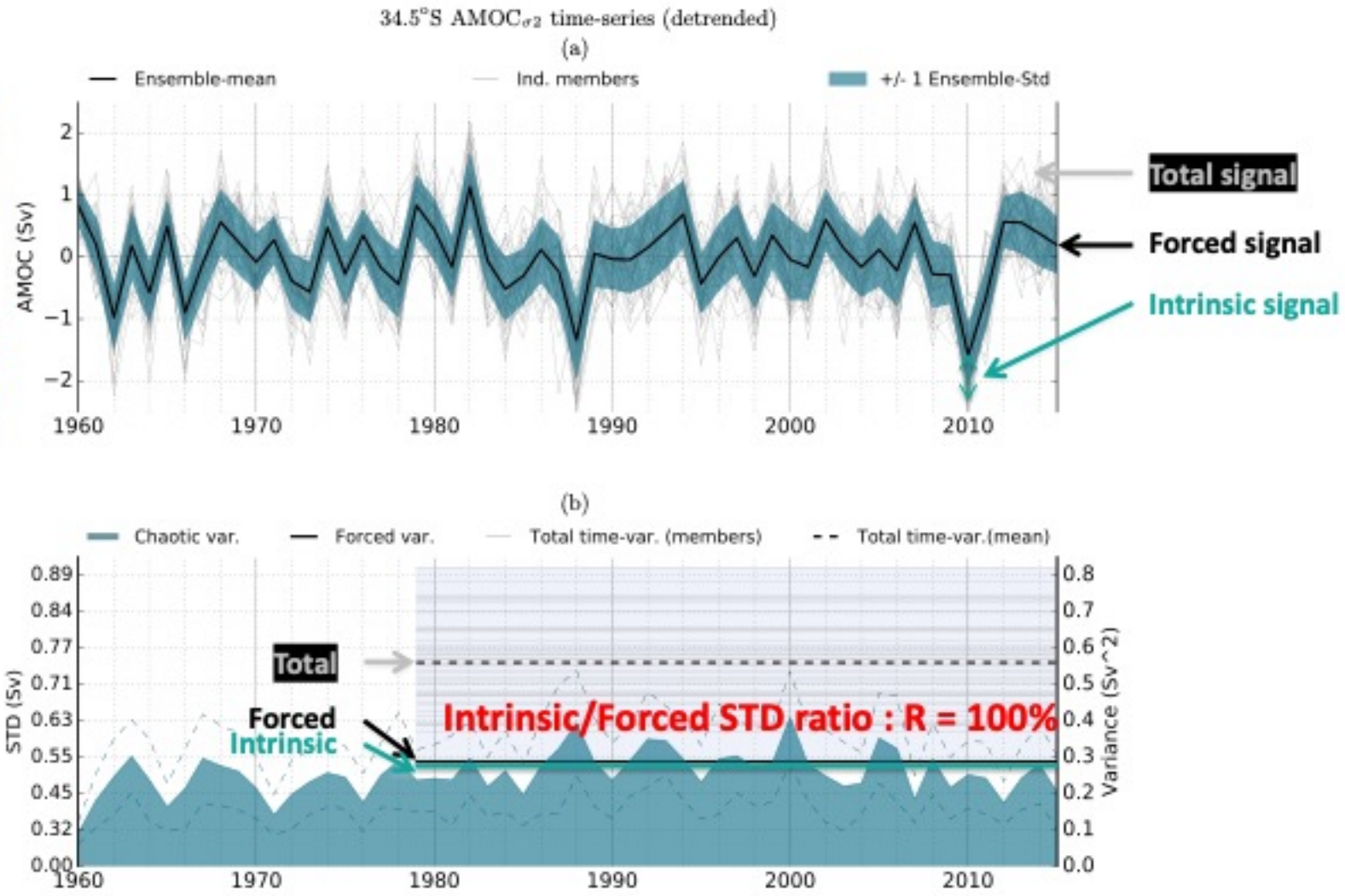
Ensemble mean (forced variability) → $\sigma_F{}^2$ *deterministic*

Ensemble dispersion (Chaotic Intrinsic Variability) → $\sigma_C{}^2$ *random*

Ensemble mean of temporal variance —> Total variance : $\sigma_T{}^2 = \sigma_F{}^2 + \sigma_C{}^2$

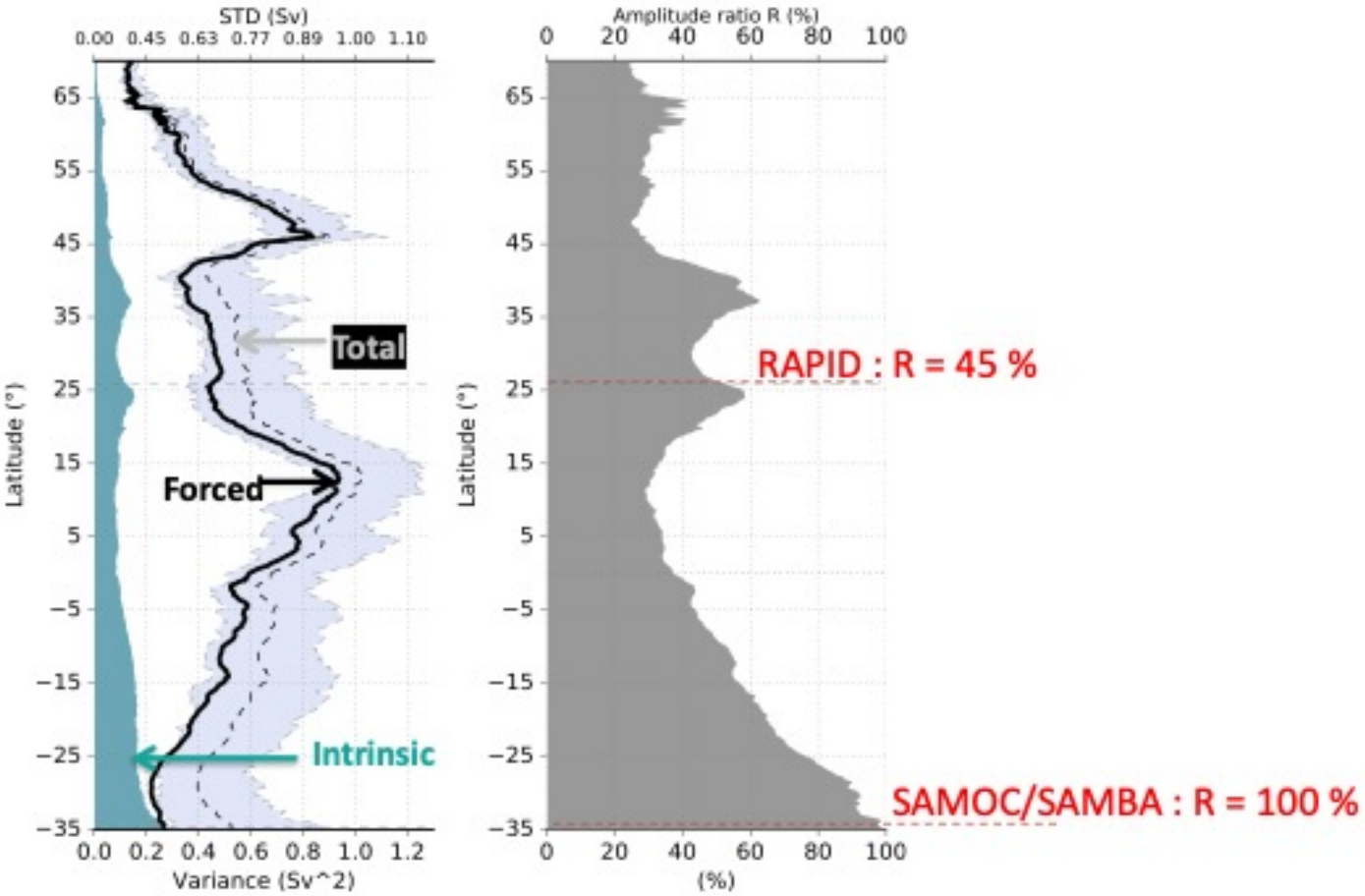
Penduff et al (2014)
Bessières et al (2017)
Leroux et al (2018)

AMOC LF variability : 35°S (SAMBA)



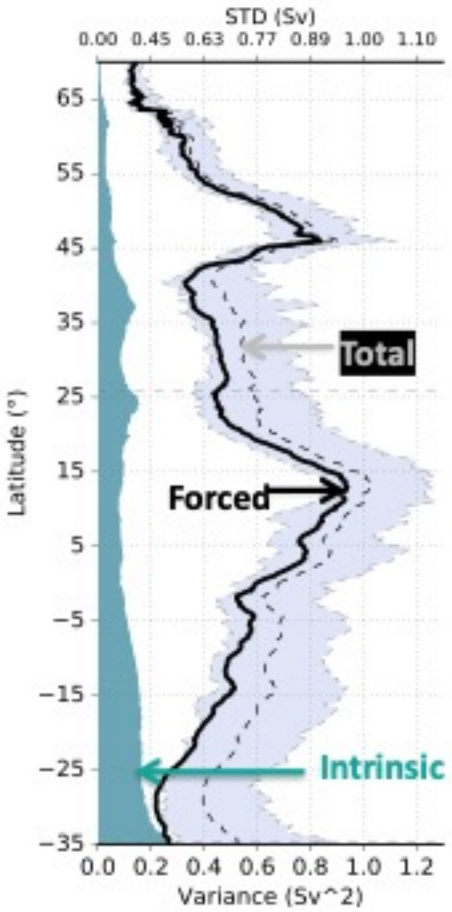
Leroux et al (2018)

AMOC LF variability : R = intrinsic-to-forced STD ratio

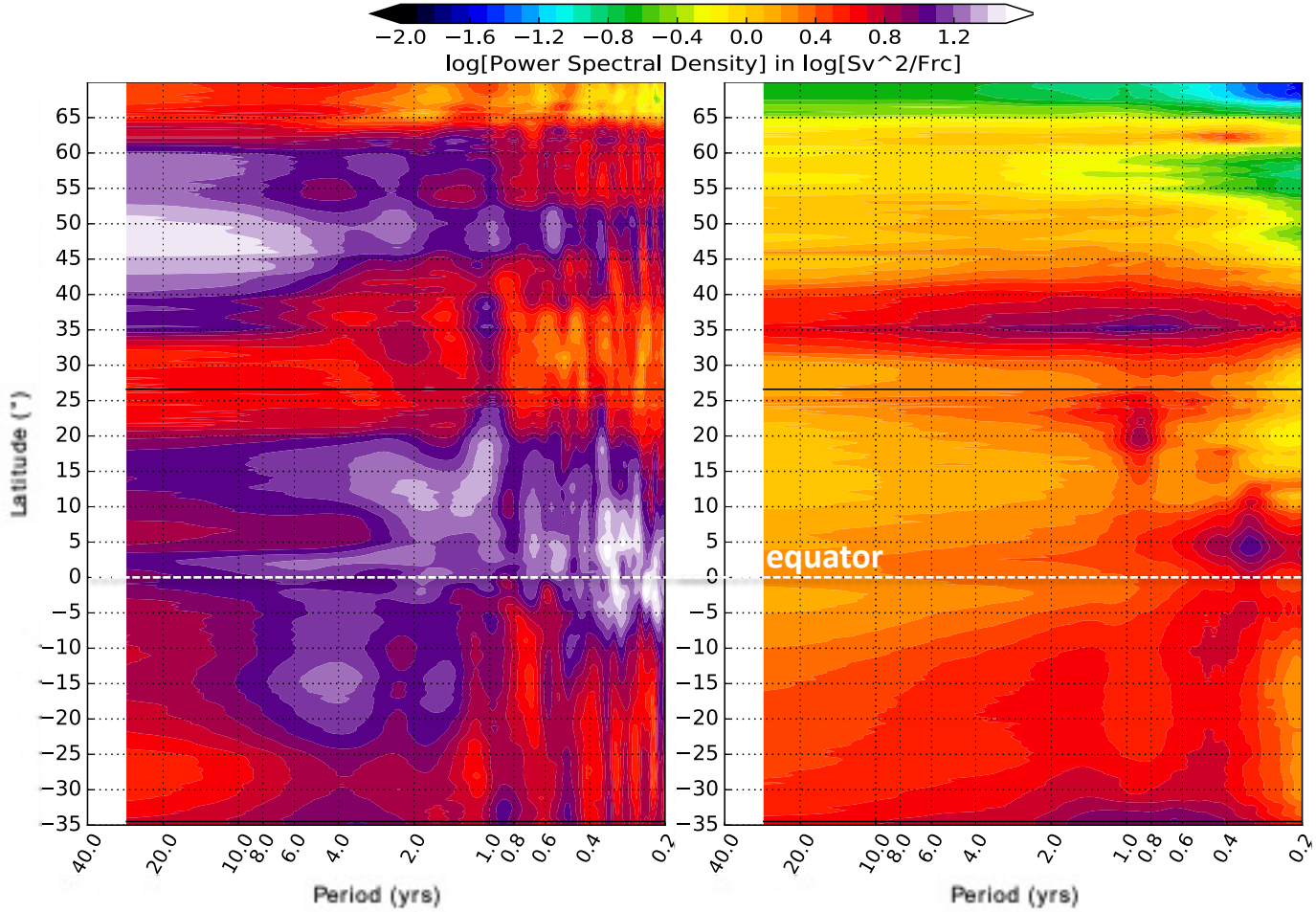


Leroux et al (2018)

AMOC LF variability : Spectral power

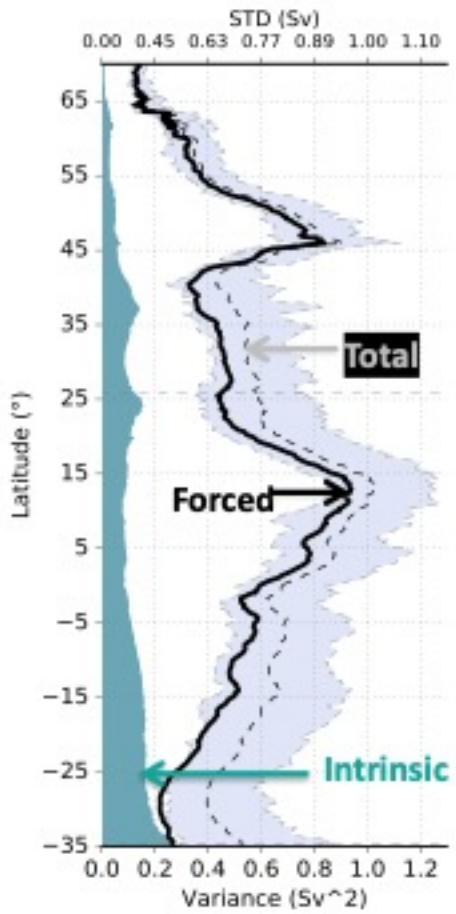


FORCED (σ_F^2) **INTRINSIC (σ_C^2)**

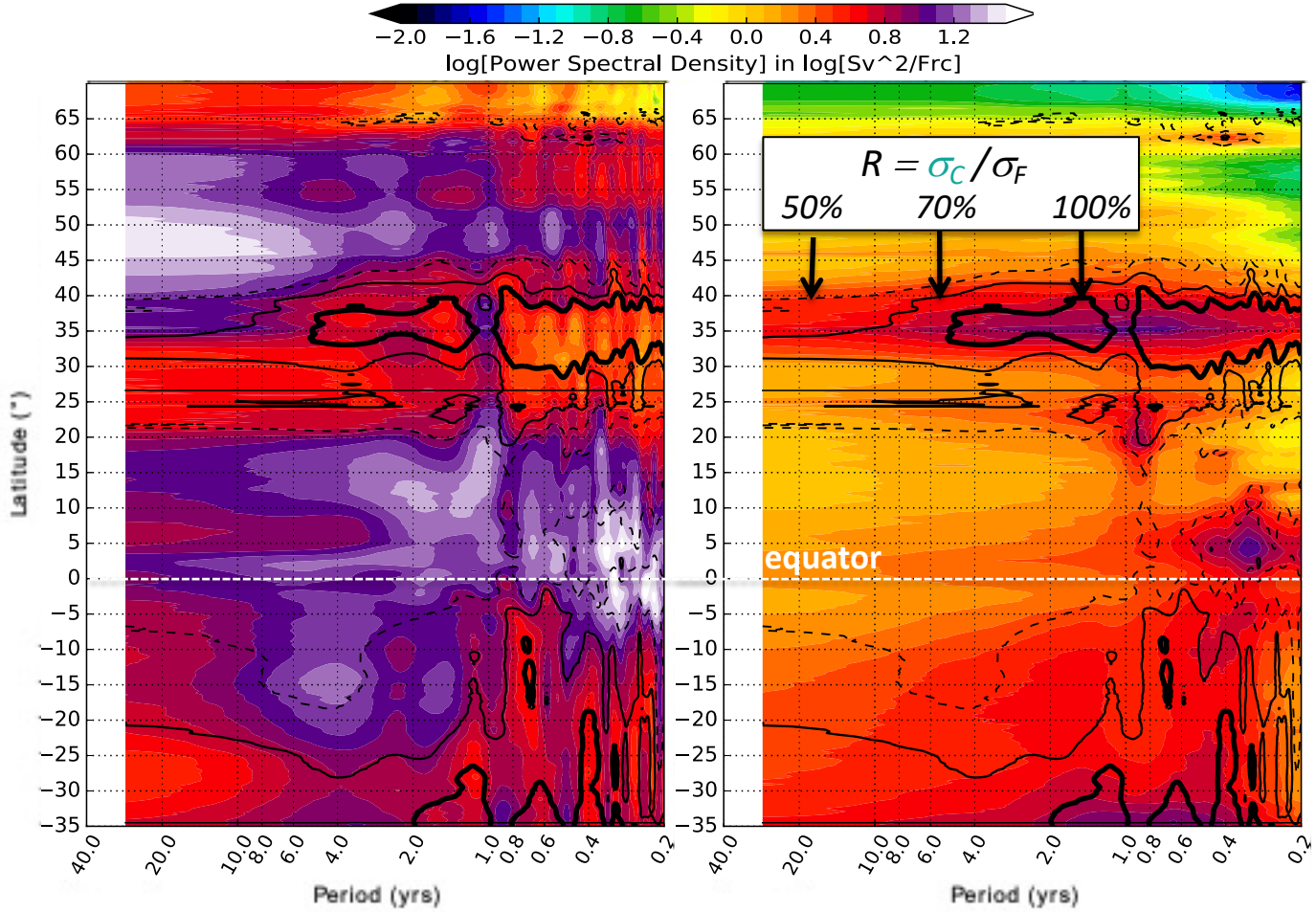


Leroux et al (2018)

AMOC LF variability : Spectral power. STD ratio R

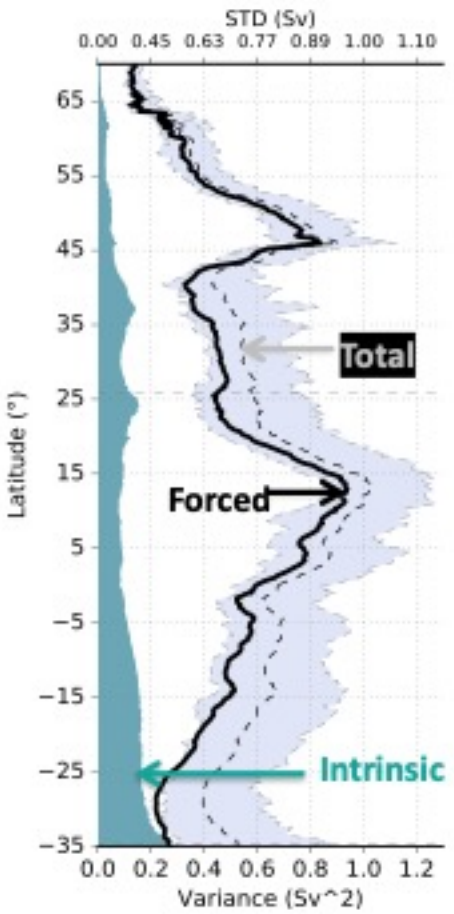


FORCED (σ_F^2) **INTRINSIC (σ_C^2)**



Leroux et al (2018)

AMOC LF variability : Latitude-time hovmoellers



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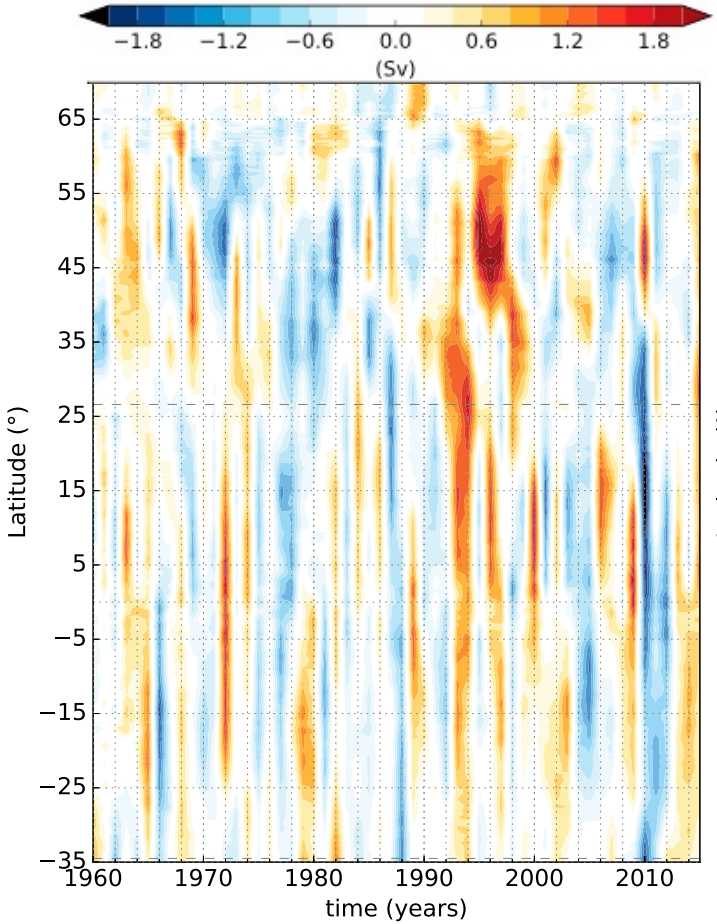
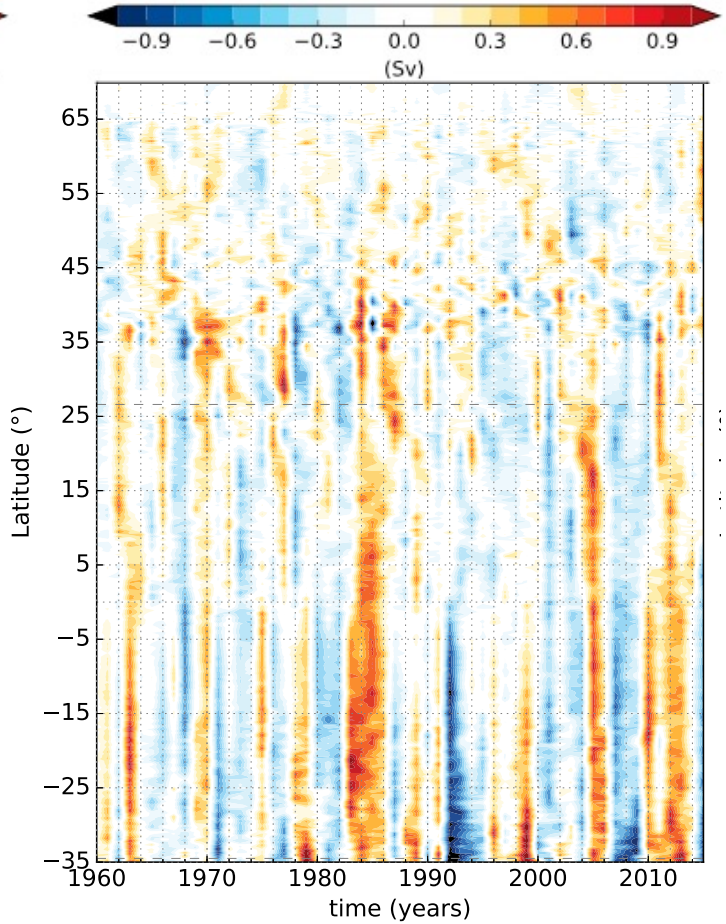
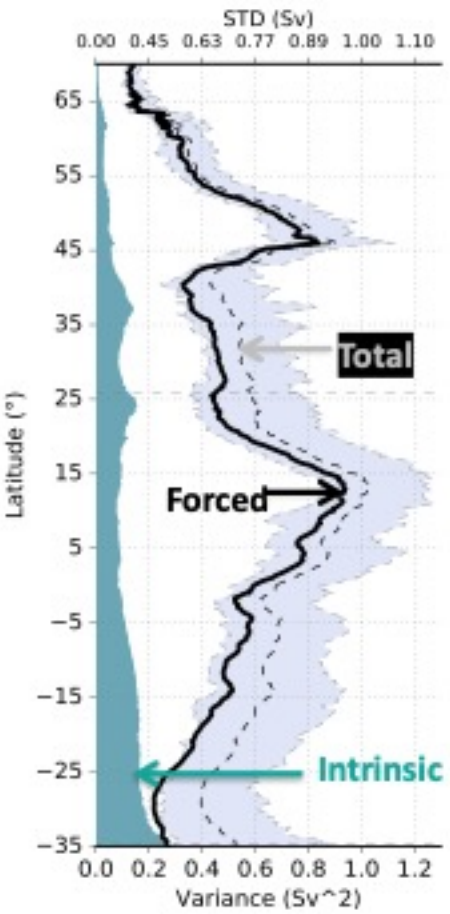


INTRINSIC

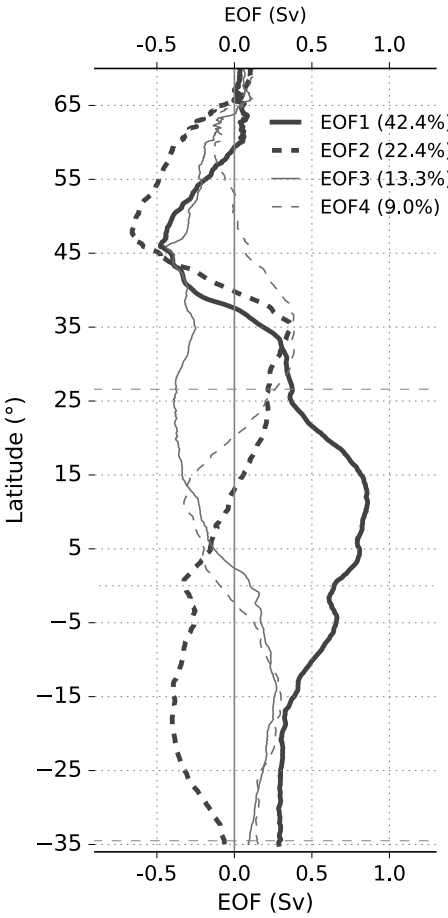


Leroux et al (2018)

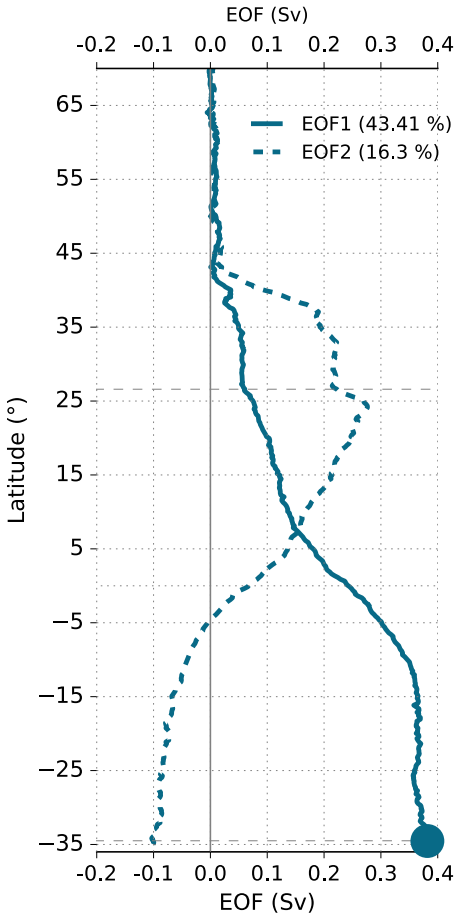
AMOC LF variability : Meridional EOFs



FORCED

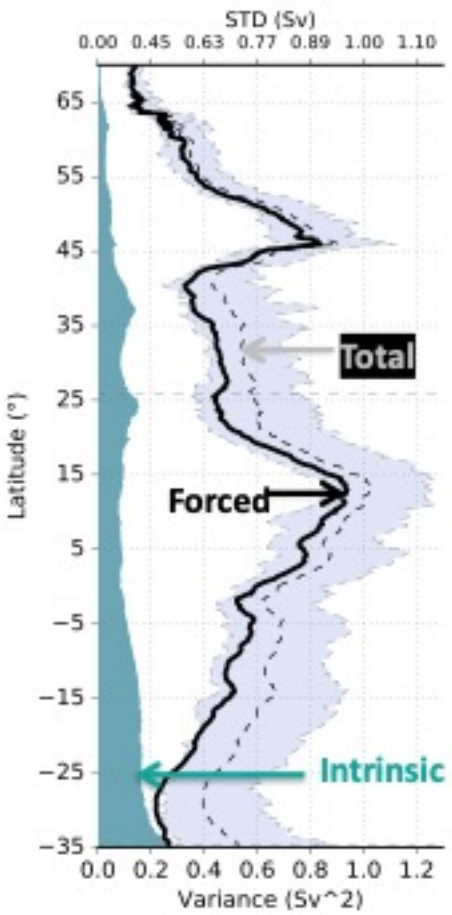


INTRINSIC



Leroux et al (2018)

AMOC intrinsic var. : Global vs North Atl. ensembles



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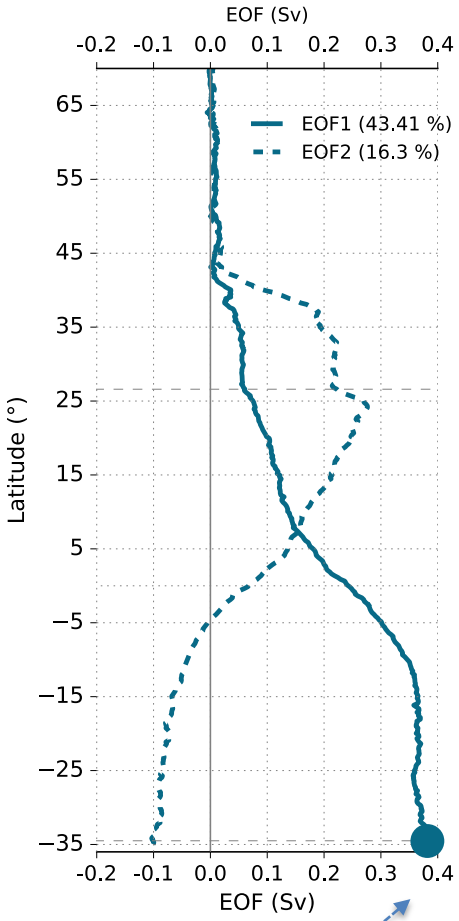
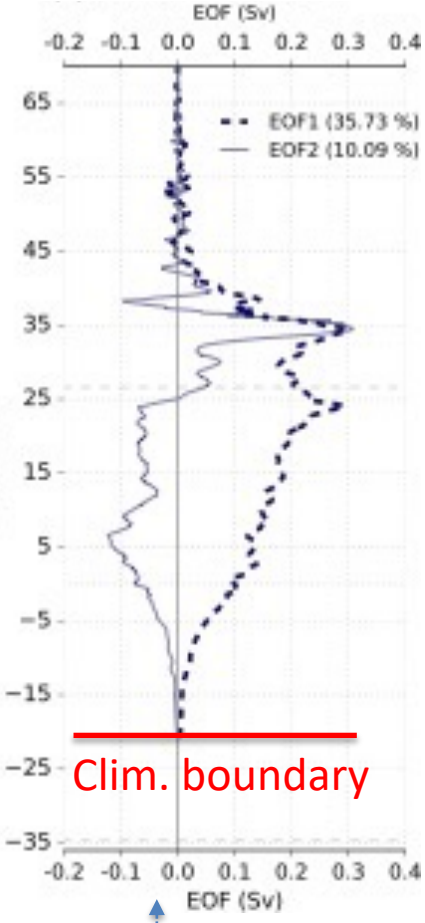


INTRINSIC



Leading EOFs is absent in regional ensemble: The main AMOC intrinsic variability source lies south of 20°S

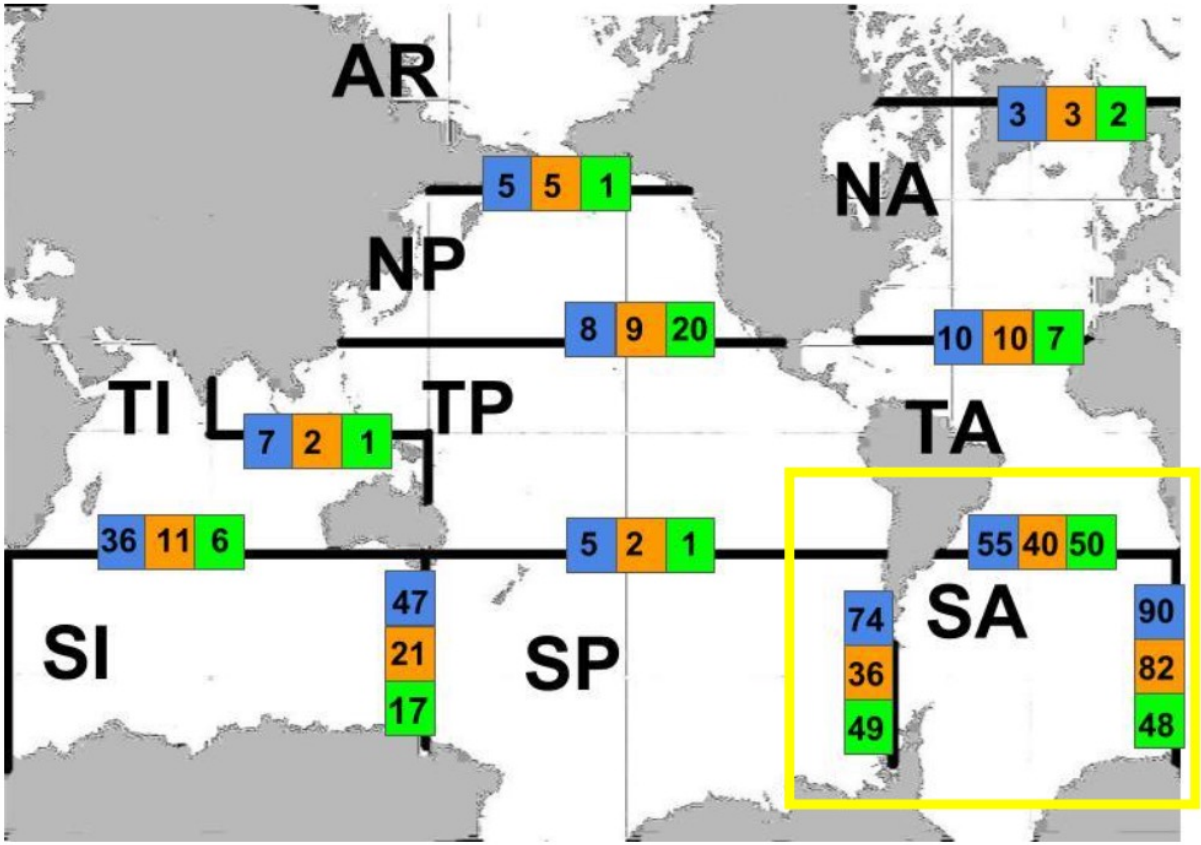
Leroux et al (2018)

AMOC intrinsic var. : Southern source

Advective heat transport

Chaotic part of the total variance σ_C^2 / σ_T^2

2mth 1.5yr 10 yr 20 yr



Yan (2020)

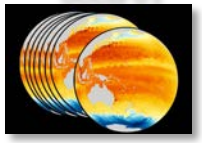
Take-home messages

and certain long-term trends

also of large-scale OHT, OHC, SST, SSH, transports, ...

- ~1-28 year variability of AMOC: | partly paced by the atmosphere (**Signal**)
  partly chaotic/intrinsic (« **Noise** » → limits PP)
- Interannual **Noise**-to-**Signal** STD ratio : **R = 45% at RAPID. R = 100% at SAMBA**
- The atmospheric variability does not drive all observed AMOC anomalies
- Main source of AMOC low-freq **Noise** : presumably Agulhas system
- These results are consistent with (and complement) other studies using different models (Biastoch et al 2008; Hirschi et al 2013; Jamet et al 2020)

OCCIPUT



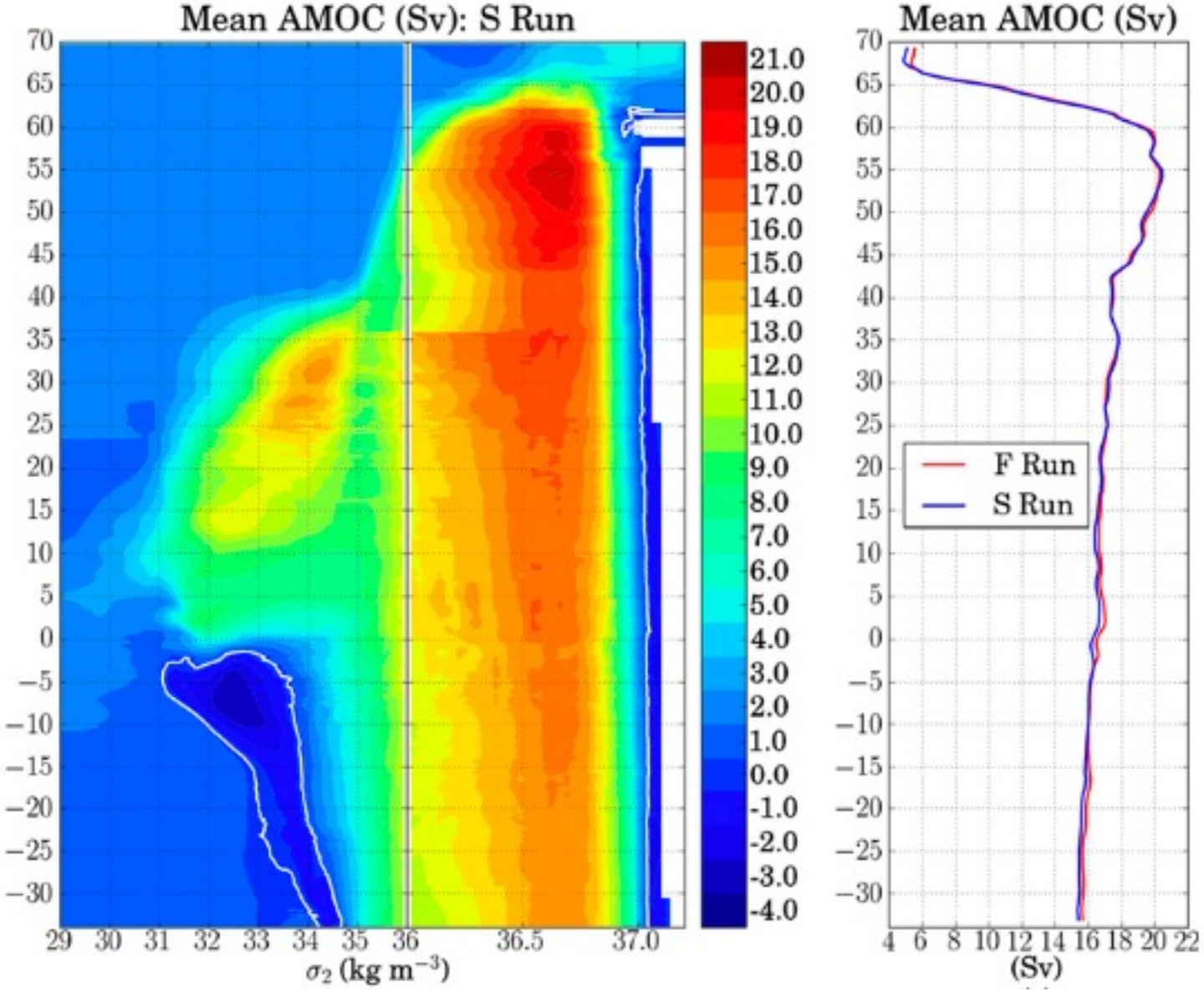
https://meom-group.github.io/projects/occiput/

OCCIPUT ensemble outputs available

Contact: Thierry.Penduff@cnrs.fr

More in :

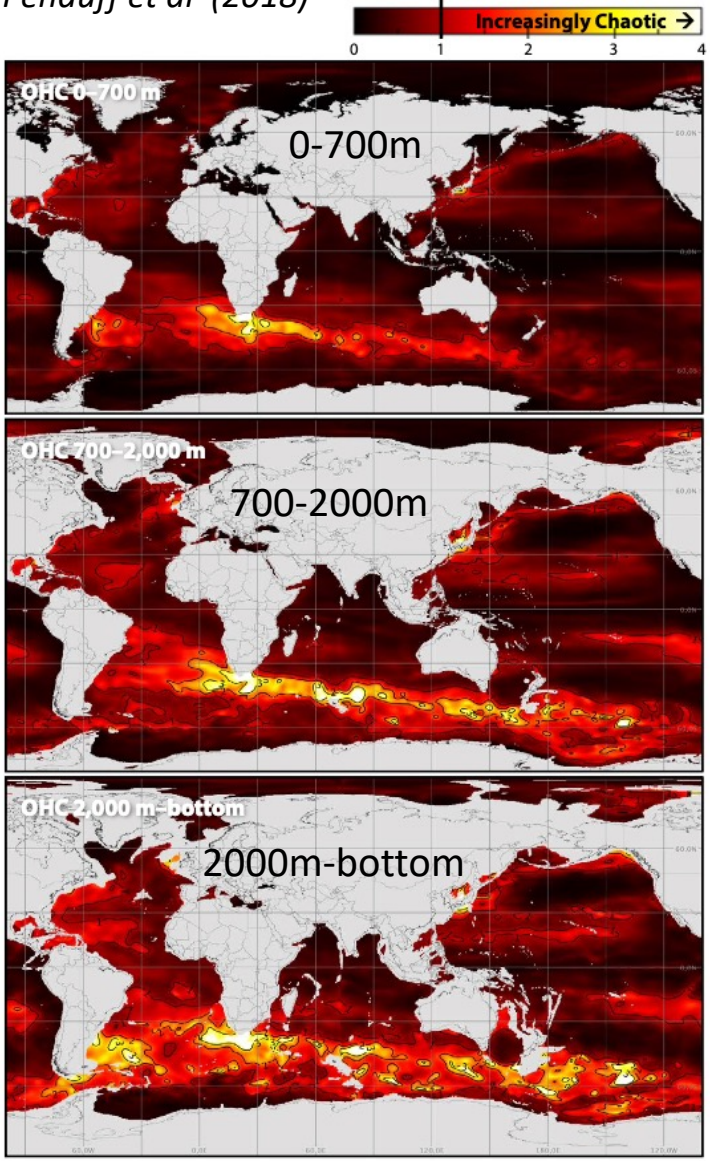
Leroux, S., T. Penduff, L. Bessières, J. Molines, J. Brankart, G. Sérazin, B. Barnier, and L. Terray, **2018** : Intrinsic and Atmospherically Forced Variability of the AMOC : Insights from a Large-Ensemble Ocean Hindcast. *J. Climate*, 31, 1183–1203. https://doi.org/10.1175/JCLI-D-17-0168.1


Mean AMOC (Sv): S Run
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
−30
29 30 31 32 33 34 35 36 36.5 37.0
σ_2 (kg m^{-3})
21.0
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
Mean AMOC (Sv)
F Run
S Run
4 6 8 10 12 14 16 18 20 22
(Sv)

Heat content variability (T>2yr, L>1000km)

σ_C / σ_F

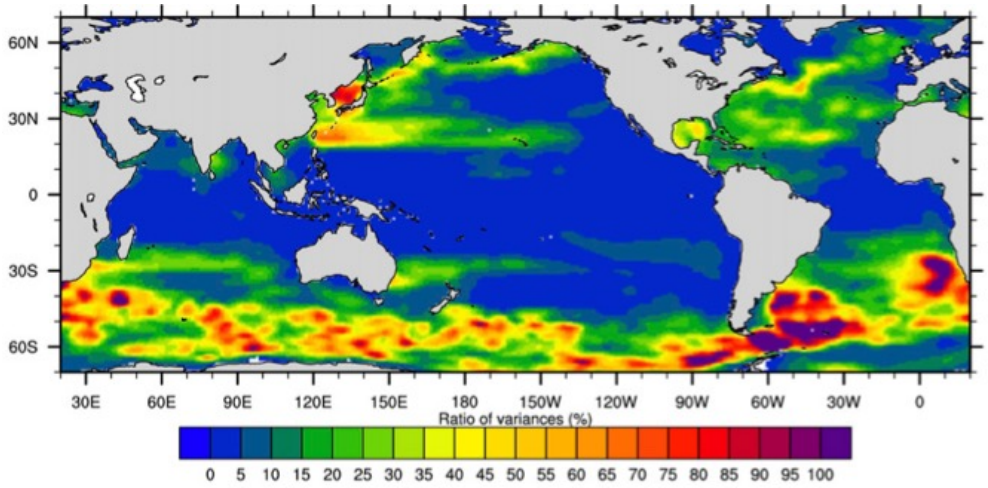
Penduff et al (2018)



Sea level variability (T>2yr, L>1000km)

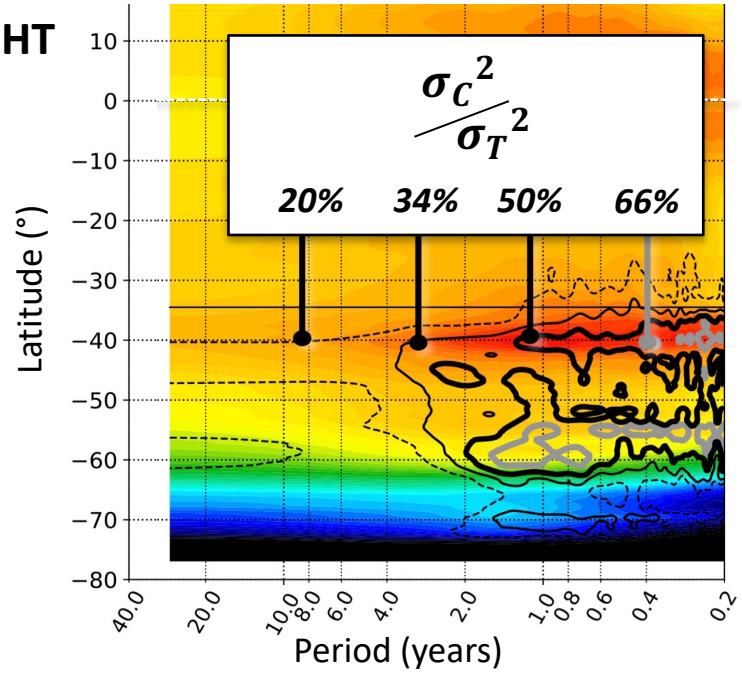
σ_C^2 / σ_T^2

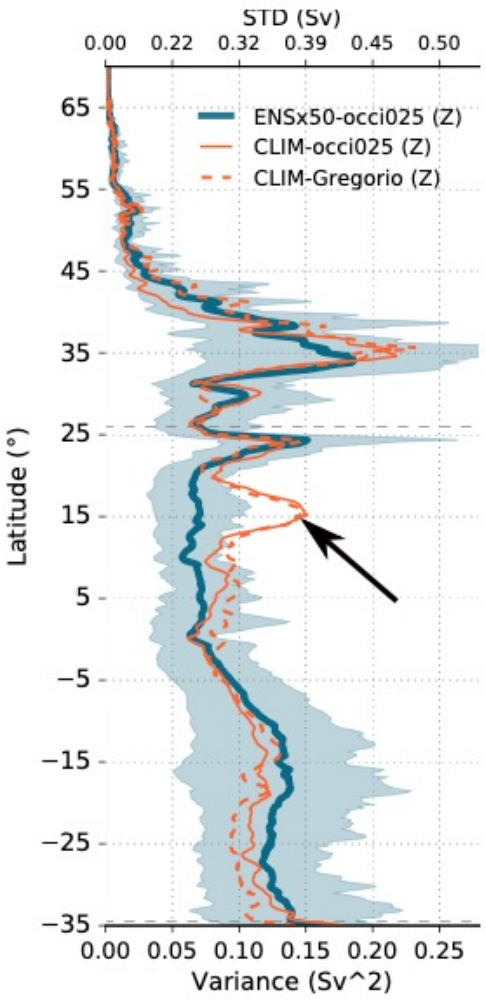
Sérazin et al (2015)



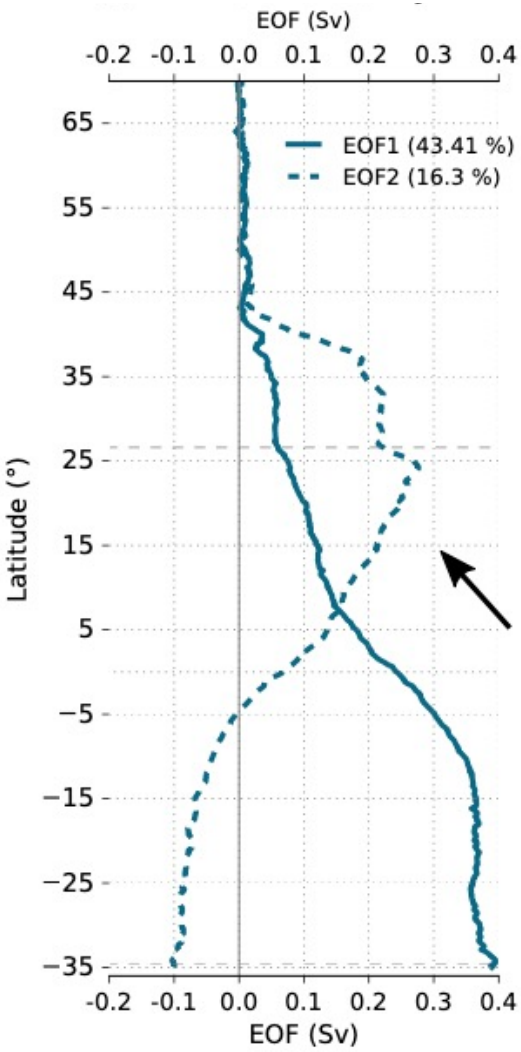
Circumpolar MHT variability

Zanna et al (2020)

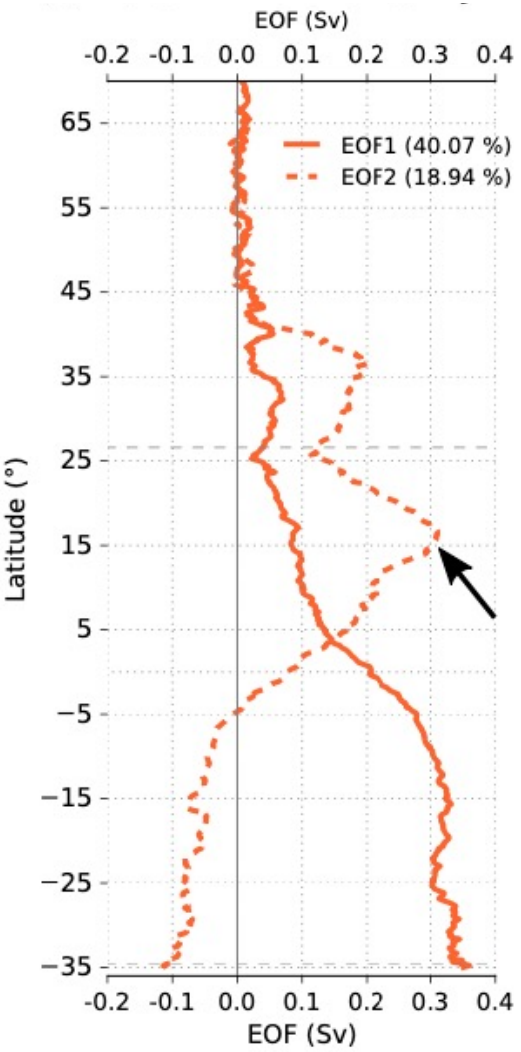




50-member ensemble
Interannual forcing:
INTRINSIC

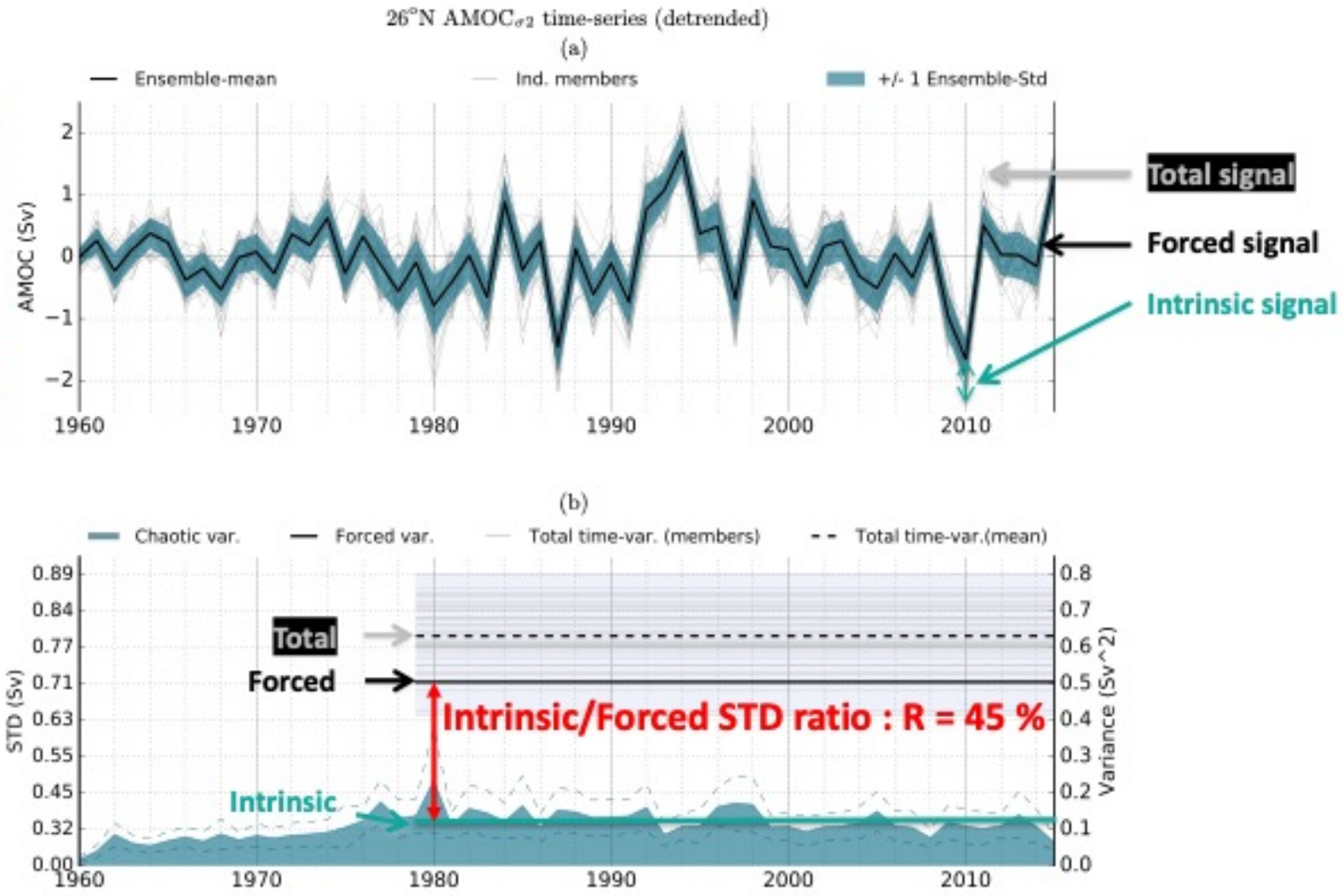


1-member run
Seasonal forcing:
« PURE » INTRINSIC



15°N → Interannual forcing may partly damp or lock the phase of the « pure » intrinsic variability

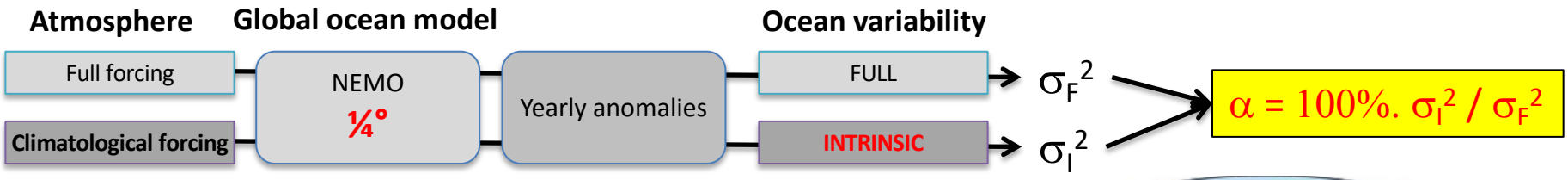
AMOC LF variability : 26°N

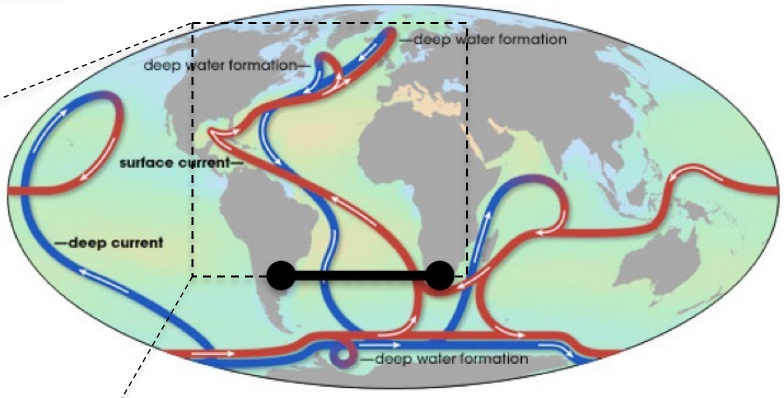


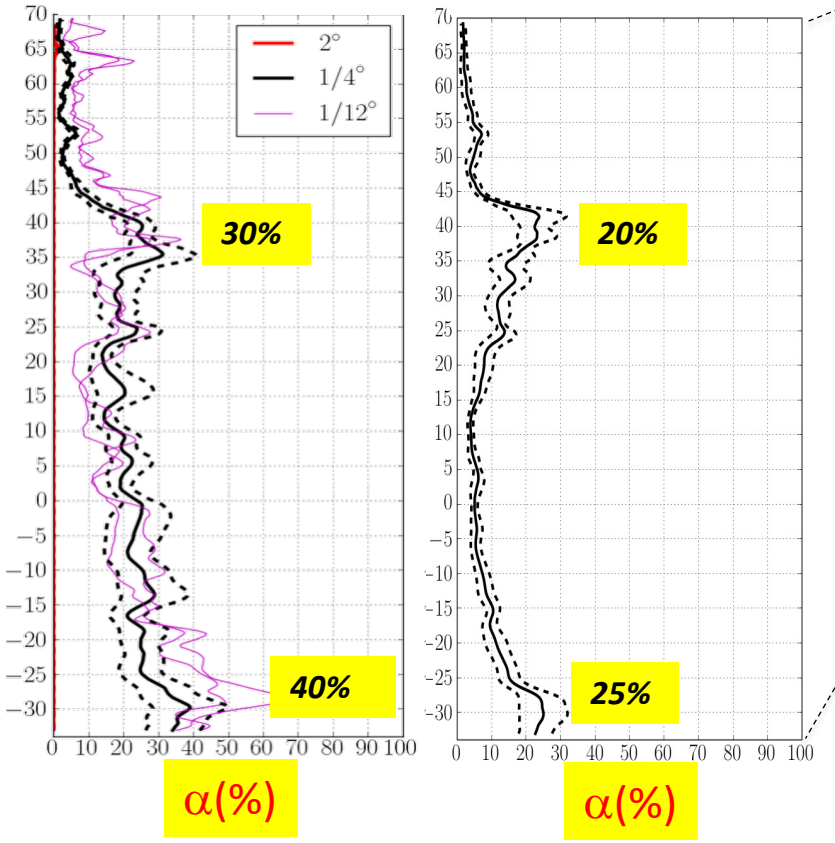
Leroux et al (2018)

Low-freq variability (T>1 year) : AMOC

Penduff et al (J Clim 2011)
Grégorio et al (JPO 2015)
Sérazin et al (J Clim 2015)







2° : NO Intrinsic variability

¼° : LARGE Intrinsic variability
Reaches multi-decadal timescales
Chaotic behavior