Role of ocean-atmosphere coupling for the AMOC decadal variability

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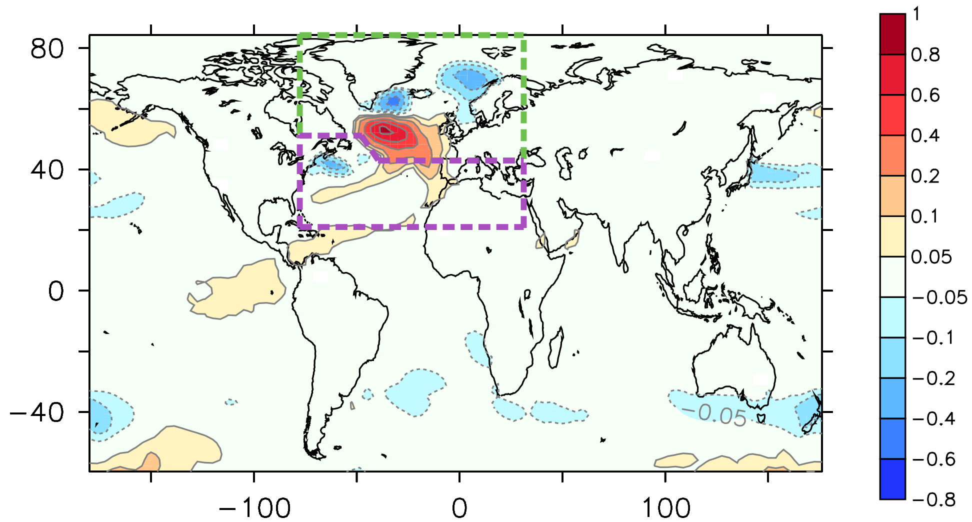
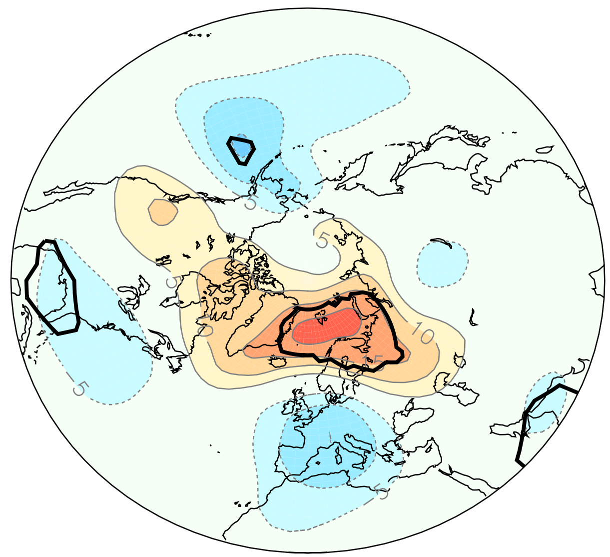
Introduction

- AMOC lead to surface warming into the Atlantic ocean, through an intensification of the Northward oceanic heat transport.
- The surface signature of the AMOC (SST, but also sea ice) can lead to a large scale atmospheric response (Gastineau and Frankignoul, 2012;).

SST (K) Regression onto AMOC-PC1, the AMOC leading by 9-yr in winter (ONDJFM) in IPSL-CM5A-LR



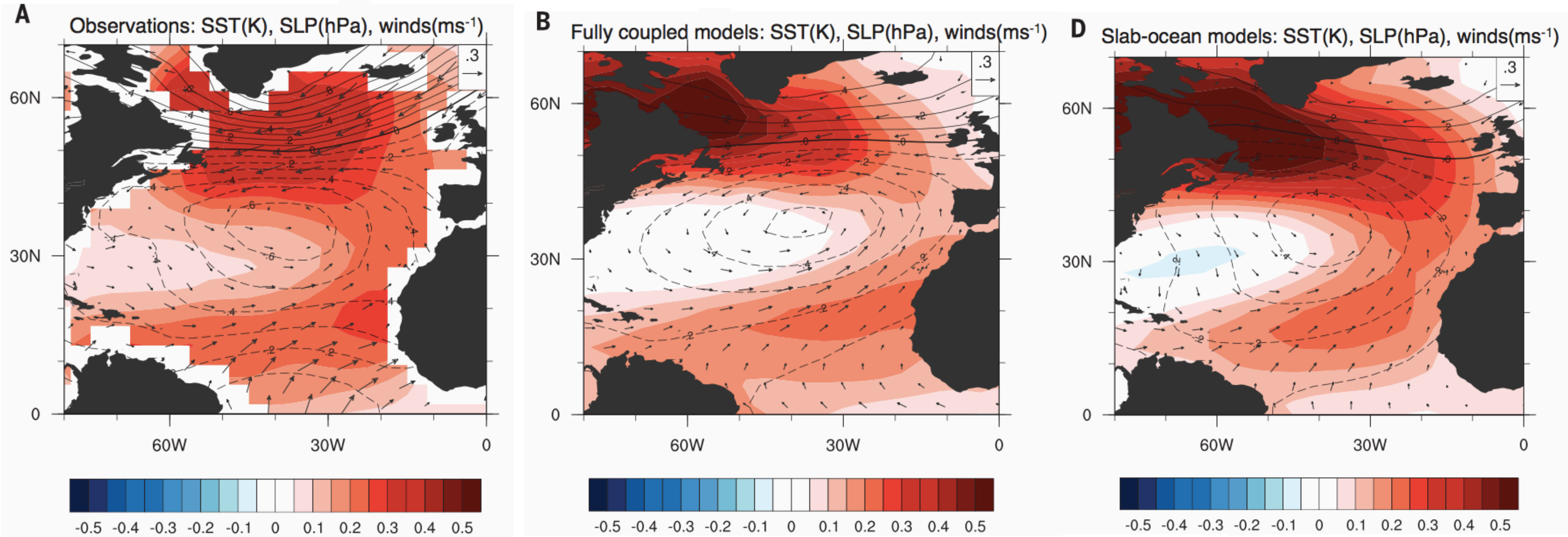
Z500 (m) response in (FM) in atmosphere only sensitivity experiments



A partir de Gastineau et al. 2016

- The decadal variability of the SST in the Atlantic ocean (AMO or AMV) is related to the AMOC and the atmospheric variability. The relative importance of each process is uncertain.

AMO pattern (K) ; SLP (hPa) and wind (m s^{-1}) regression onto AMO



From Clement et al. 2015, Science.

Questions :

- What is the role of the atmospheric stochastic forcing for the AMO and AMOC?
- Is the atmospheric response to the SST related to the AMOC have an important feedback of the AMOC variability?

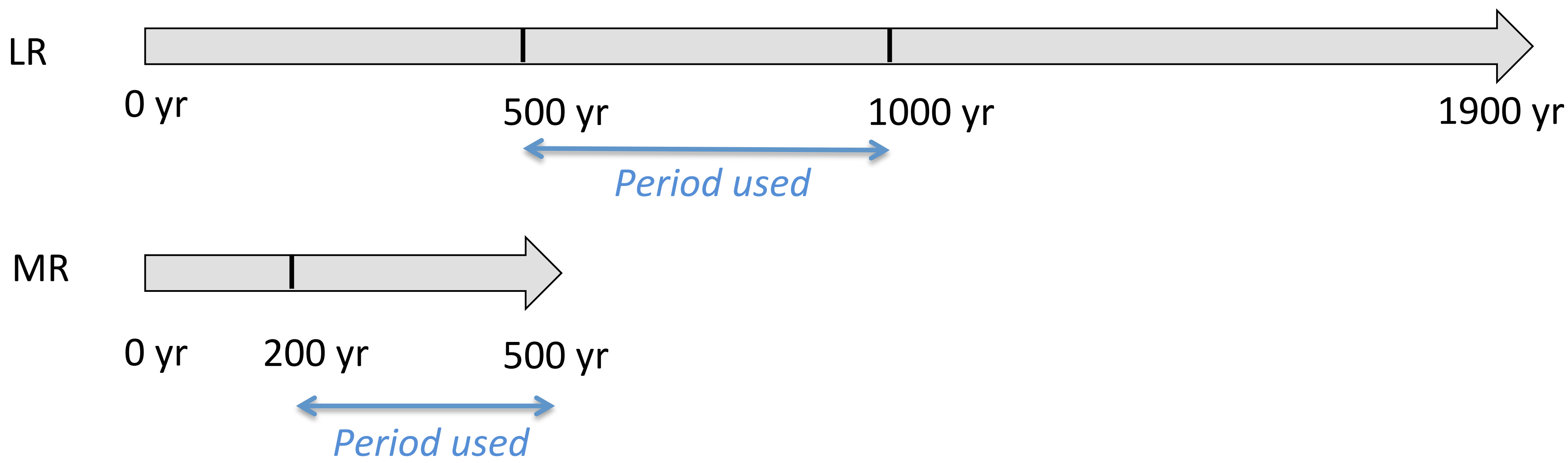
Experimental protocol

- We use the results of two *ocean-atmosphere* or *coupled* models IPSL-CM5A (CMIP5 version) :

  Atmospheric Low Resolution **LR** : ORCA2 / 3.75°x1.9° LMDZ-A
  Atmospheric Medium Resolution **MR** : ORCA2 / 2.5°x1.25° LMDZ-A

Preindustrial control runs, without any external forcing.

- We performed *ocean-only* simulations of at least 300-yr using the daily buoyancy and momentum fluxes from each of these two runs.



Experimental protocol

Ocean-only simulations use:

- NEMO (version 3.6) ORCA2 with the same parameter than IPSL-CM5A,
- Flux formulation for surface,
- Weak SST (-10 W/m2/K) and SSS (-50 mm/day) restoring to coupled model IPSL-CM5A climatology
- prescibed sea ice (*ice-if*), using coupled model IPSL-CM5A climatology.

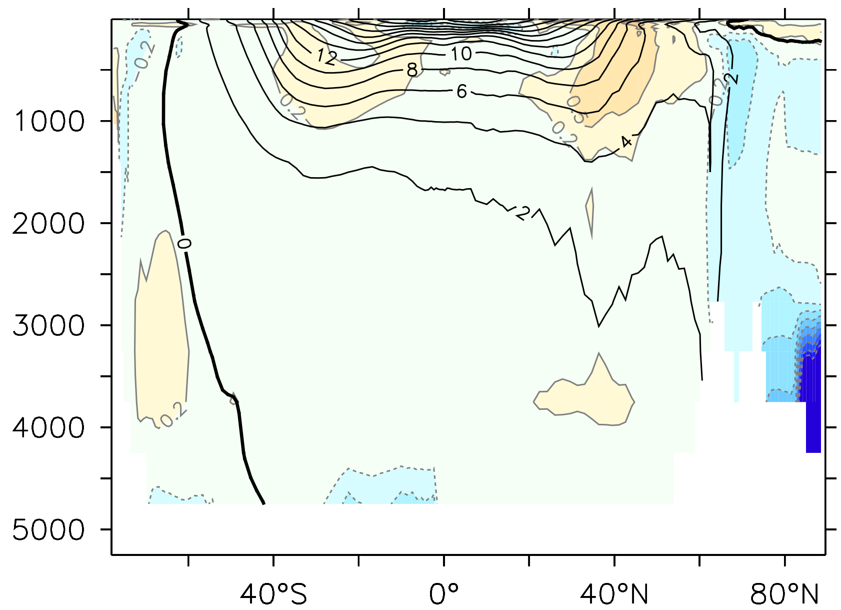
Name	Type	Coupling/forcing
COUPLED	AOGCM	Fully coupled
CLIM	OGCM	Heat + Freshwater + Momentum flux using climatology from preindustrial coupled run LR. Length = 500 yr
TOTAL	OGCM	Same as CLIM but daily fluxes are provided by COUPLED. Length = same as COUPLED
RANDOM	OGCM	Same as TOTAL, but random shuffling of fluxes using 3-yr blocks. All low frequency in fluxes is randomized. Length > 1500 yr

Limitation of methodology

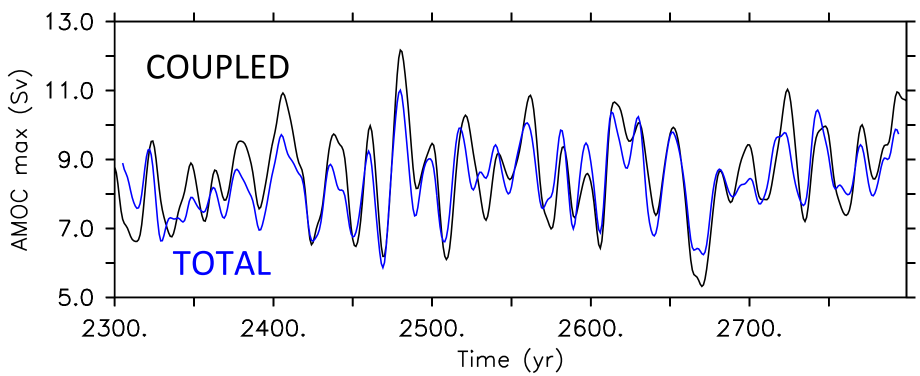
- Sea-ice imposed in NEMO-ORCA2,
- SST and SSS restoring,
- Important drift if SSS restoring too large.

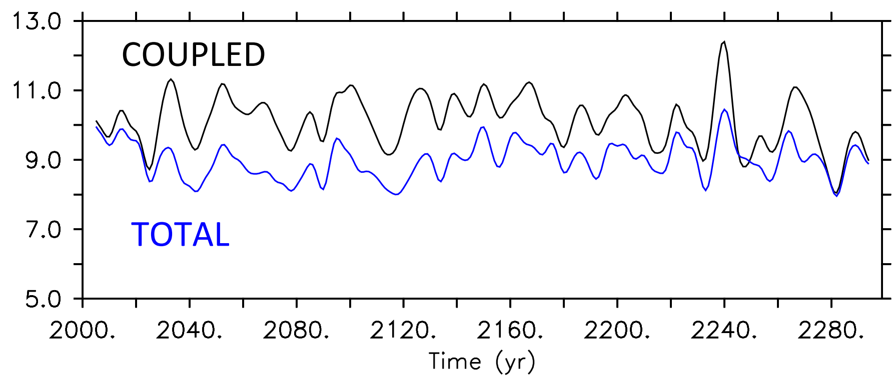
Difference CLIM-COUPLED (LR)

Zonal mean T pot (°C)



AMOC index = max AMOC in (40N-55N; 500m-2000m) smoothed (10 year)

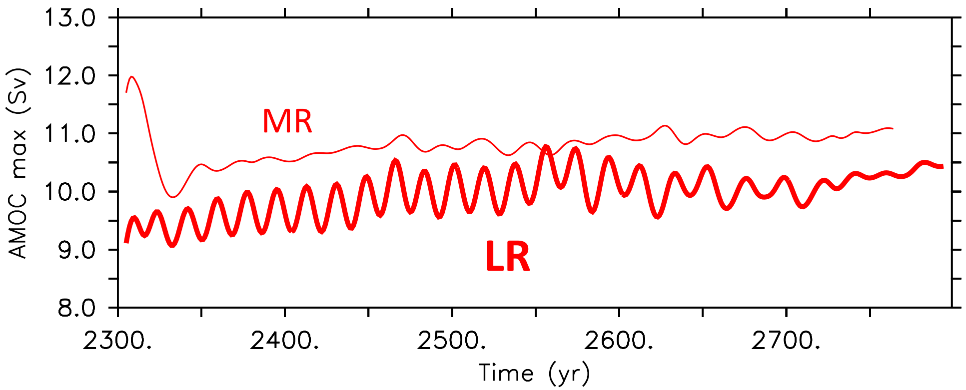




Atlantic Ocean variability

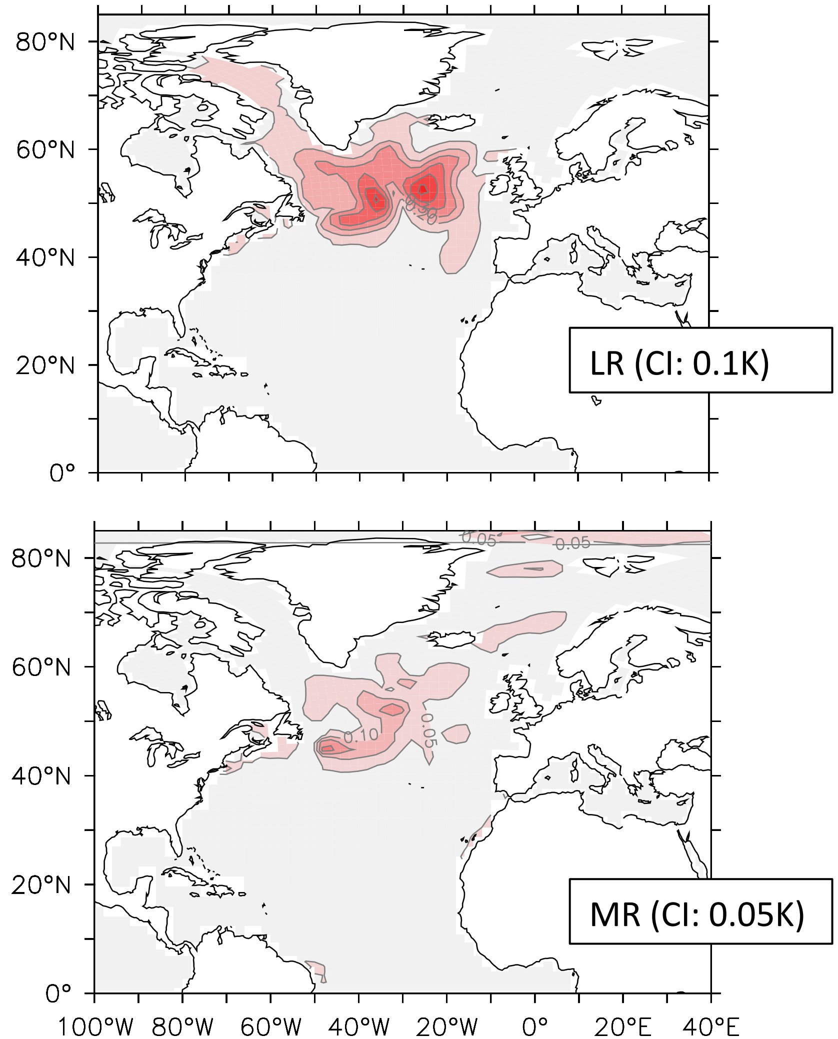
- Presence of decadal variability originating in subpolar region in CLIM
  std dev approx. 0.5 that of COUPLED

AMOC index = max AMOC in (40N-55N; 500m-2000m)



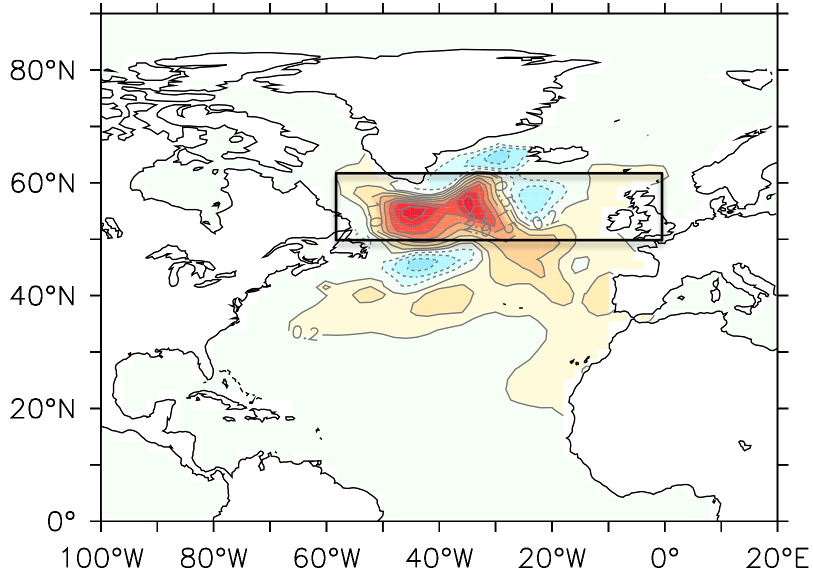
SST restoring (W/m2/K)	SSS restoring (mm/day)	Std. Dev. AMOC (10yr<T<100yr), Sv
10	50	0.305
2.3	50	0.301
10	216	0.031

Std. dev. yearly ocean mean pot. temperature (K) between 0m and 700m

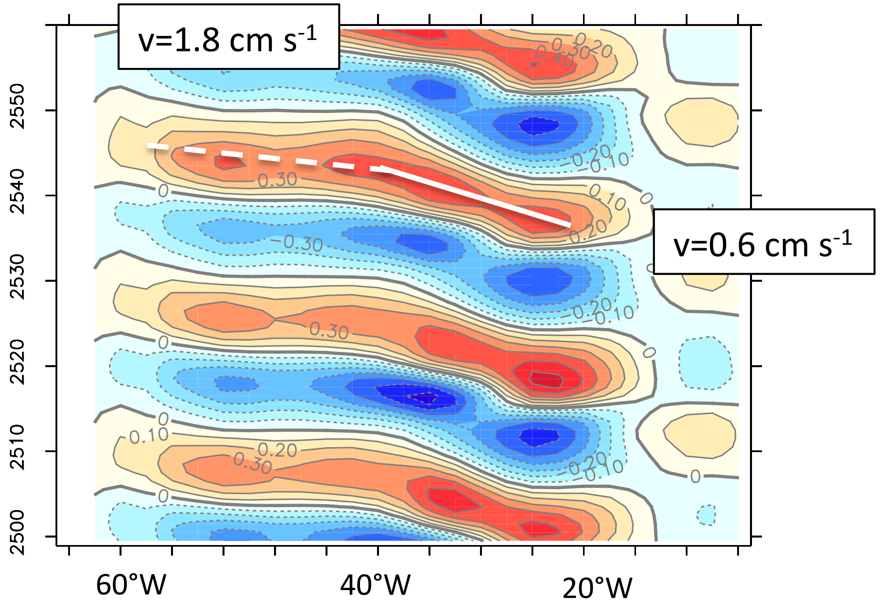


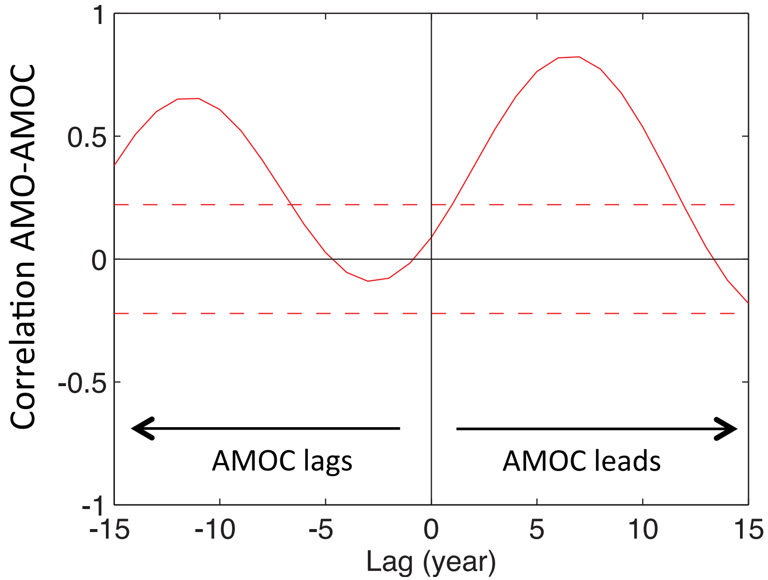
Process of ocean variability in LR

AMO pattern (in 10^{-1} K) in CLIM-LR



Mean T (°C) 300m-1000m over Subpolar Atl.





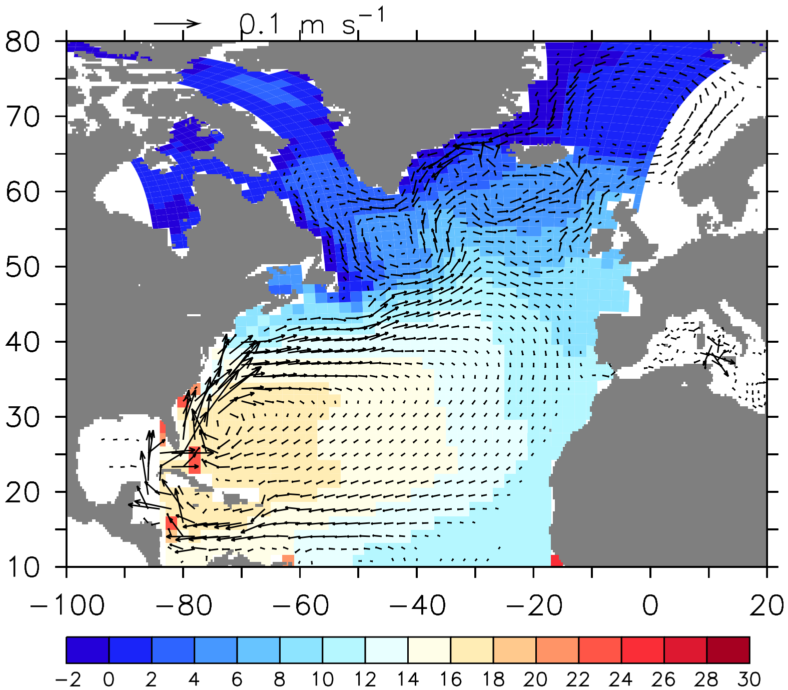
- Many studies found westward propagating subsurface anomalies linked to the AMOC variability :

  - in similar models (Sévellec and Fedorov, 2013; Ortega et al. 2015)
  - in more idealized models (Colin de Verdière and Huck 1999; Jamet et al. 2016)

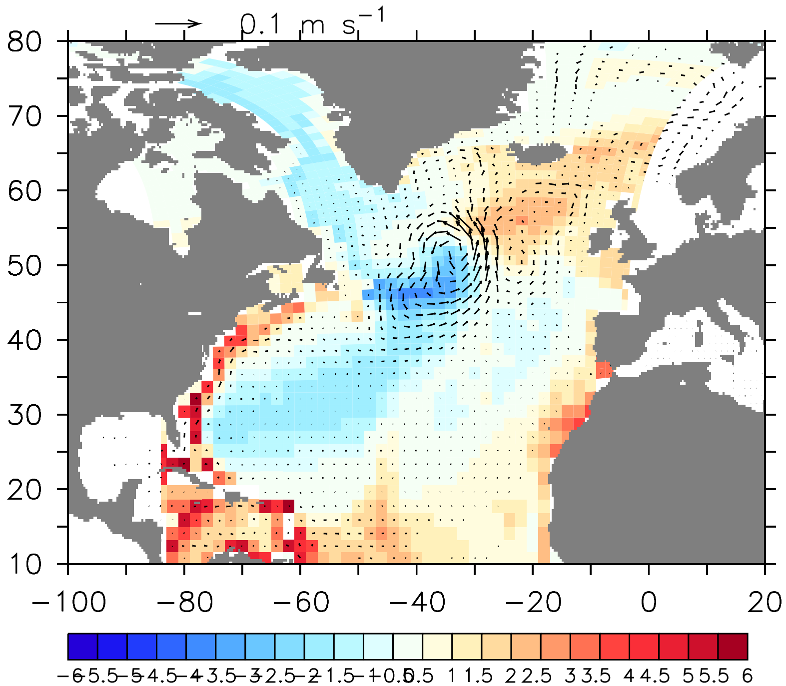
Process of ocean variability in MR

- Similar process compared in LR, but in this case, almost no variability east of Reykjanes ridge.

Mean pot. Temperature (K) and current (m s^{-1}) in 0-700m ; CLIM – LR



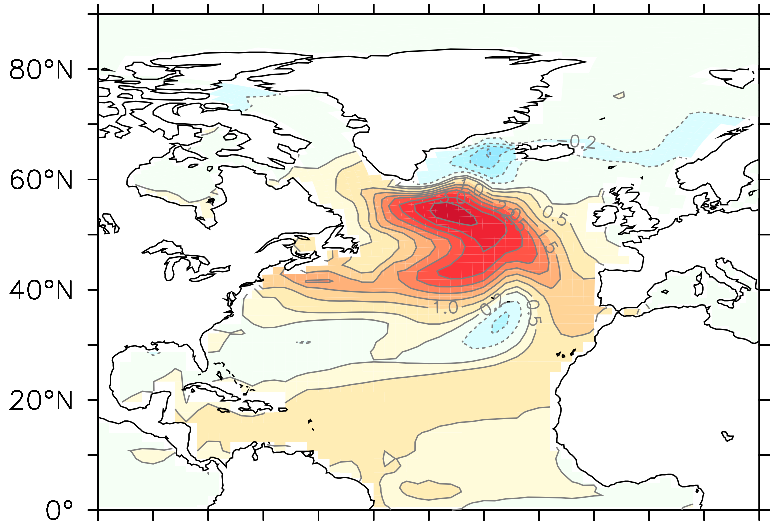
Same, but for the difference MR minus LR



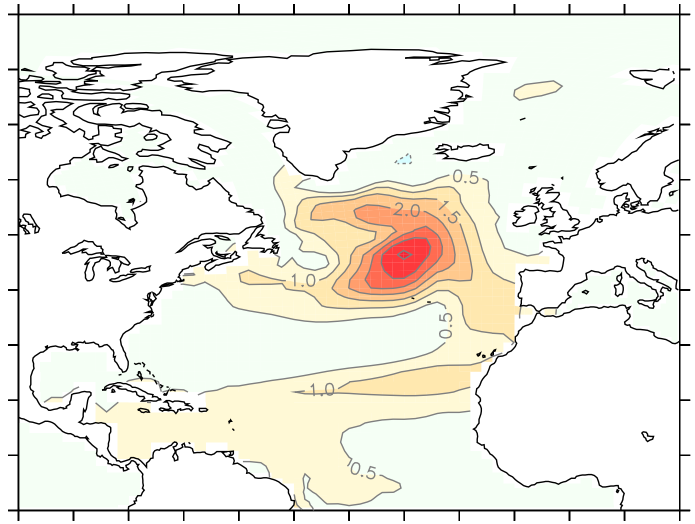
- Role of the warmer surface water making the water column more stable south of Iceland (similar feature in COUPLED).

Role of atmospheric stochastic forcing

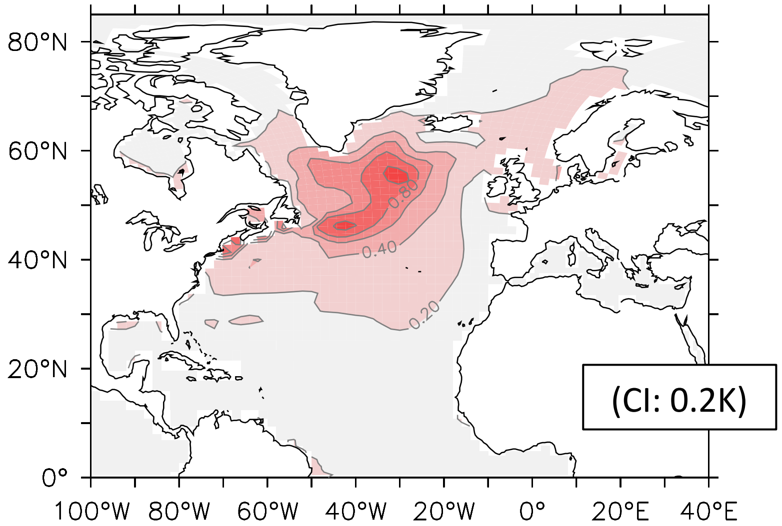
AMO pattern (in 10^{-1} K) in RANDOM-LR



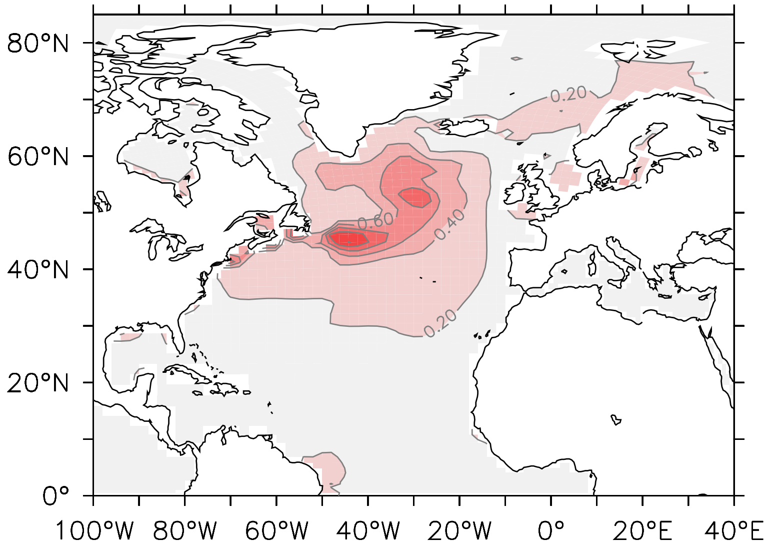
AMO pattern (in 10^{-1} K) in RANDOM-MR



Std. dev. yearly ocean mean pot. temperature (K) 0-700m, in RANDOM- LR

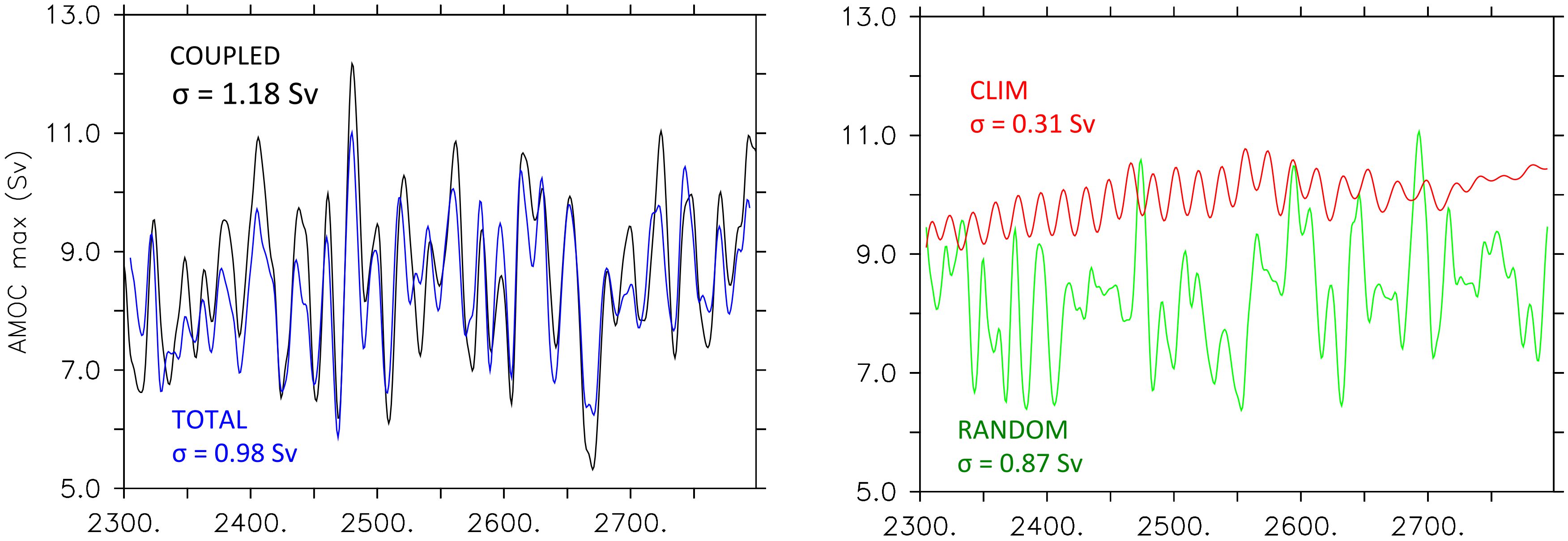


Same, but in MR



AMOC time series - LR

AMOC index = max AMOC in (40N-55N; 500m-2000m) smoothed (10 year)

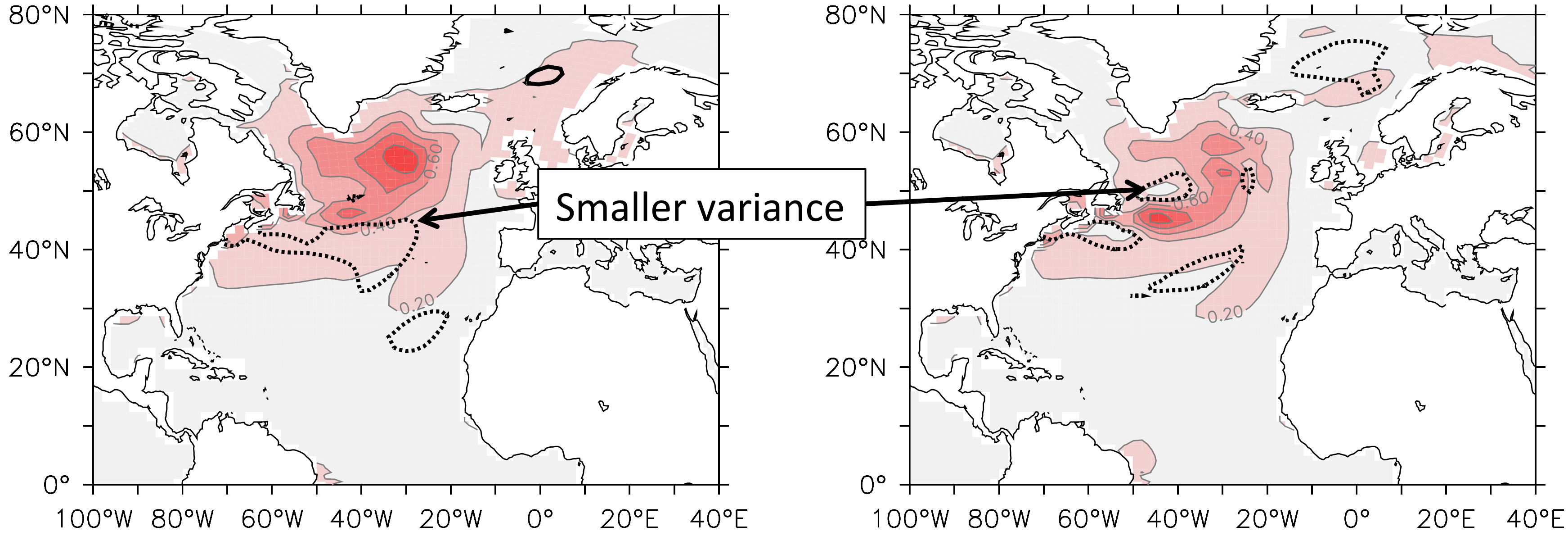


- Level of AMOC variability much better reproduce by adding stochastic forcing.
- Difference between TOTAL and RANDOM not obvious.

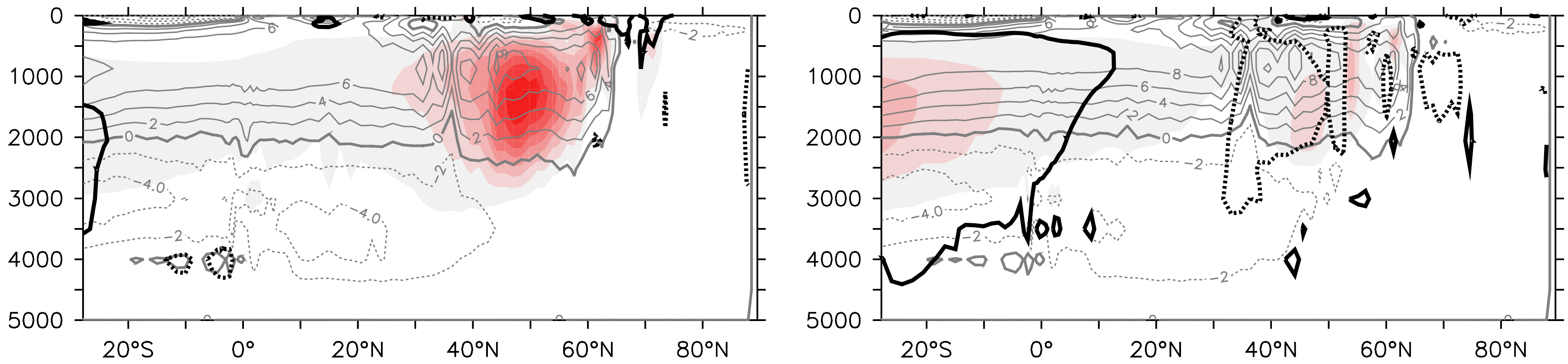
Role of coupling

Std. dev. yearly ocean mean pot. temperature (K) 0-700m, in TOTAL-LR

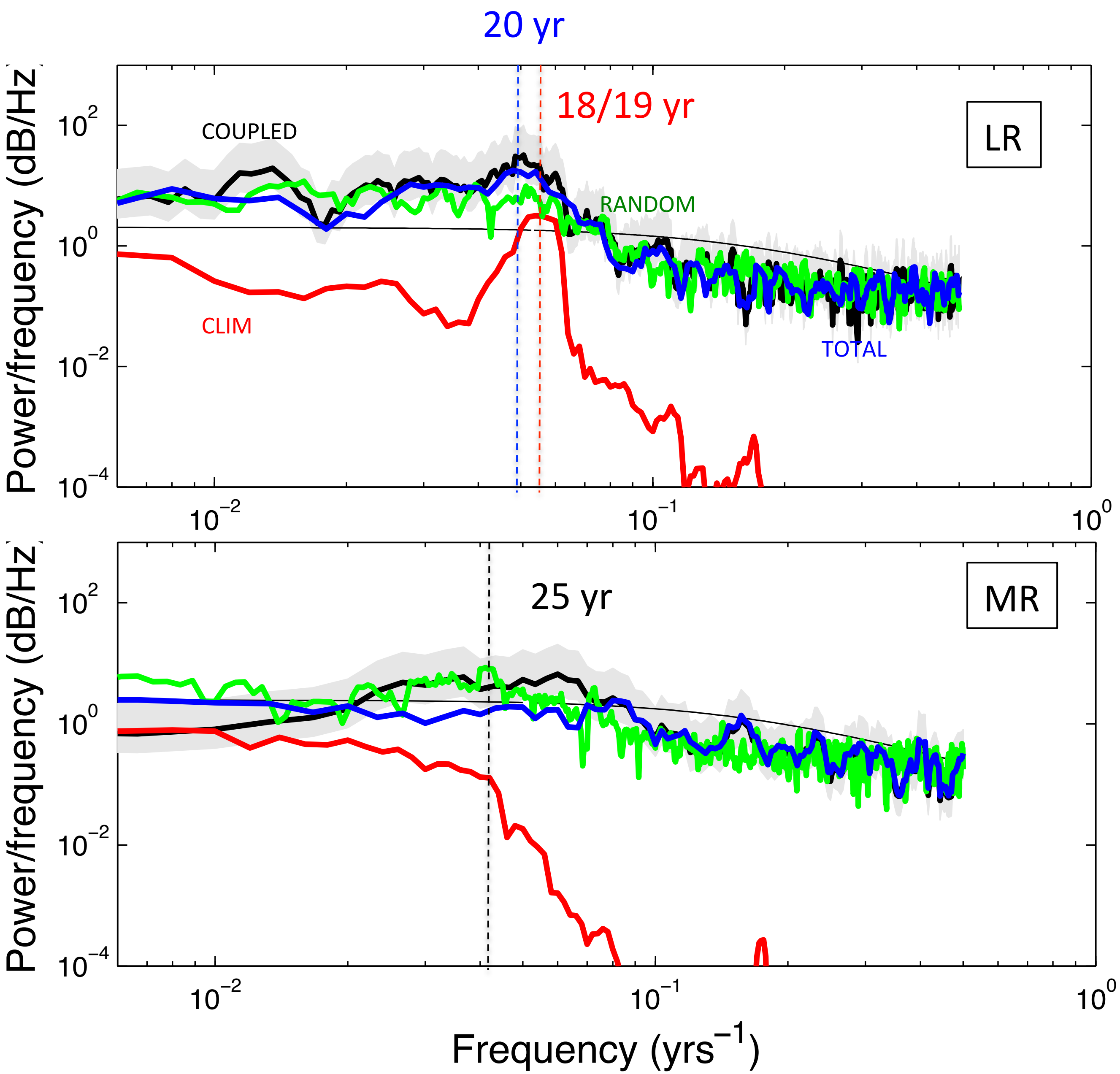
Same in MR



Std. dev. yearly ocean mean pot. temperature (K) 0-700m, in TOTAL-LR



Spectrum



Summary : coupling *enhances* the 20-yr periodicity and *increases* the period.

Simulation	**Std. Dev. (Sv)**
COUPLED	1.178
TOTAL	0.986
CLIM	0.305
RANDOM	0.867

25-yr cycle in MR -> oceanic mode less significant

Simulation	**Std. Dev. (Sv)**
COUPLED	0.753
TOTAL	0.502
CLIM	0.183
RANDOM	0.686

Conclusion

- The NEMO ORCA2 configuration present a large self-sustained oceanic mode in the subpolar Atlantic ocean when forced by IPSL-CM5A-LR fluxes.
- When increasing the atmospheric resolution : warming of the subpolar Atlantic East of Reykjanes ridge which inhibits the self sustained mode.
- The stochastic forcing enhances the AMOC variability. It also act to redistribute and increase the subsurface temperature variance into most of the subpolar Atlantic.
- The coupling has different effect in LR (not significant increase of AMOC) and MR (significant weakening).

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Thank you for your attention