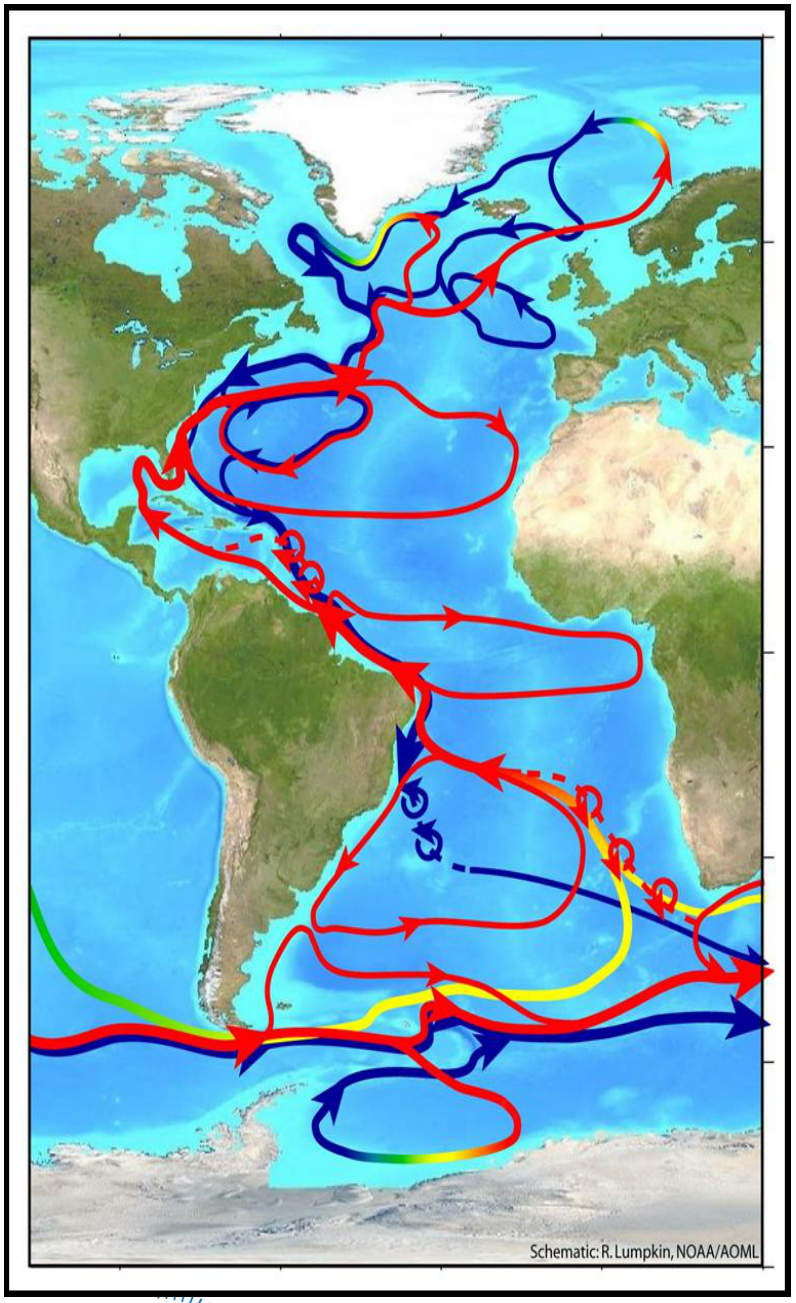

Interannual-to-multidecadal AMOC variability: the intrinsic component

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DRAKKAR ocean modelling consortium

Constant/seasonal forcing + eddying model ($\overline{u'\nabla u'}$) ➔
➔ intrinsic, chaotic 1-10yr variability (u,v,SSH)

Idealized models

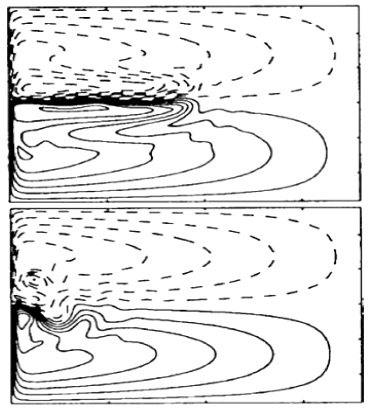
- Surface/deep WBCs
- Recirculation gyres
- Mode waters PV, Rossby modes

Dijkstra & Ghil 2005 ; Sushama et al 2007

Spall 1996

Dewar 2003

Hazeleger & Drijfhout 2000



OGCMs

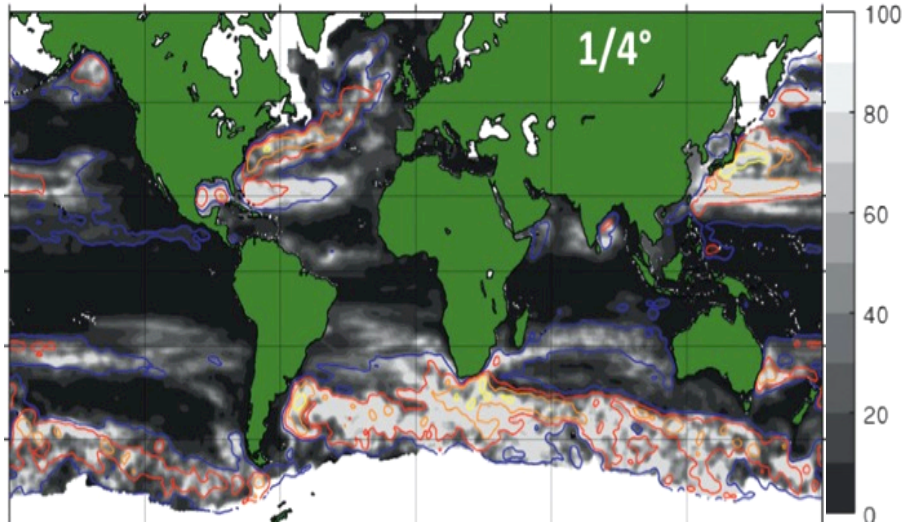
- High resolution ➔ Eddies ➔

Observed 1-10yr SSH variance is largely intrinsic.

Consistency with idealized results

- Low-resolution ➔ no intrinsic low-freq SSH

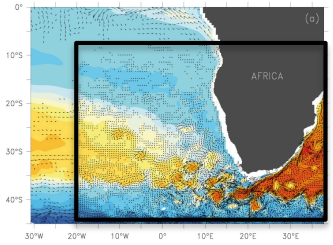
Penduff et al 2011

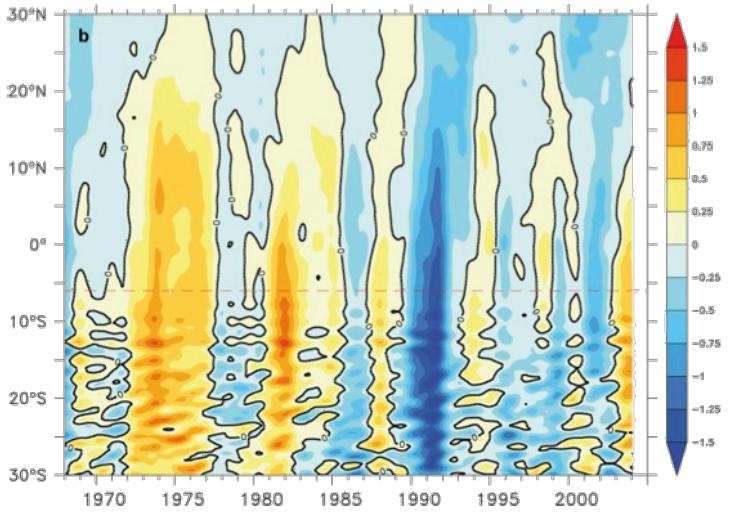


Reanalyzed (realistic) forcing + eddying model ($\overline{u'\nabla u'}$) ➔ ➔ chaotic 1-10yr variability (AMOC)

- Local eddies (Agulhas) modulate the decadal AMOC phase up to 30°N

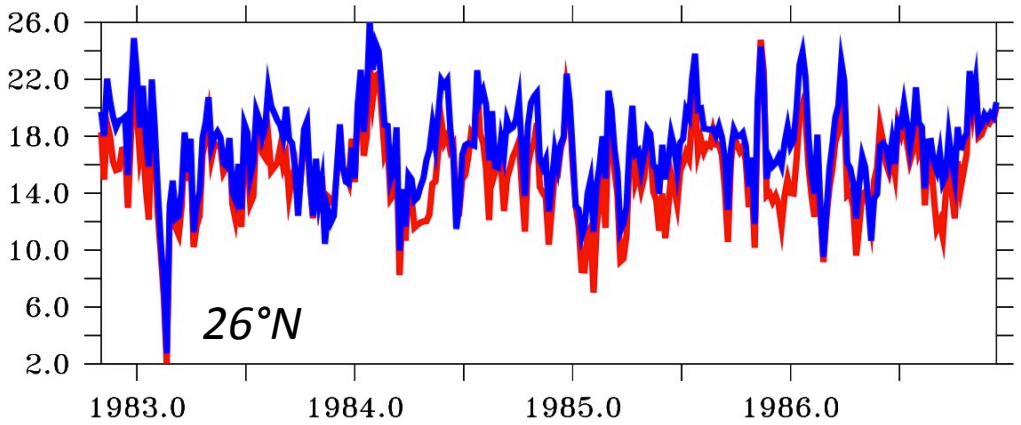
  Biastoch et al 2008





- Eddies throughout the basin : AMOC phase sensitive to initial conditions

  Hirschi et al 2013



- Longer timescales (whole Atlantic) ?
- Meridional coherence?

This study : Time-frequency-latitude analysis of low-frequency intrinsic AMOC variability

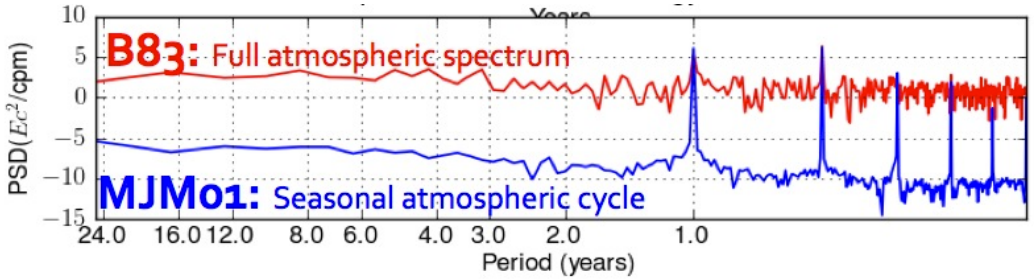
Outline

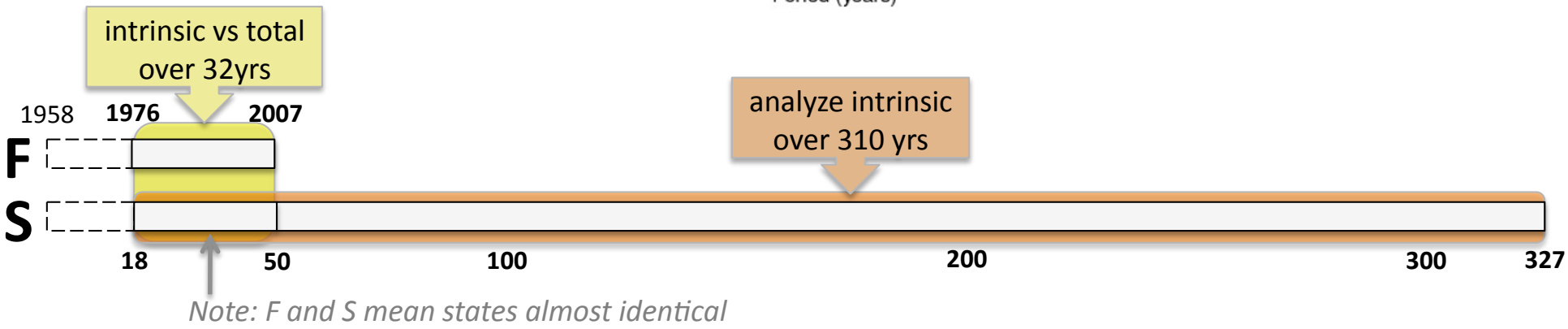
- Methodology
- Intrinsic AMOC analysis
  - intrinsic contribution to the actual AMOC variance (1-10yr)
  - temporal structure — longer timescales
  - meridional coherence work in progress
- Summary

Methodology

Two 1/4° global ocean/sea-ice simulations (NEMO code, DRAKKAR configuration)

- **F run** (50 yrs) : « full » forcing (all timescales) ➔ **Total variability**
- **S run** (327 yrs) : repeated seasonal cycle ➔ **Intrinsic variability**





From monthly model outputs

- compute yearly MOC_z and $MOC_{\sigma 2}$ (each latitude, both runs).

This study : Time-frequency-latitude analysis of low-frequency intrinsic AMOC variability

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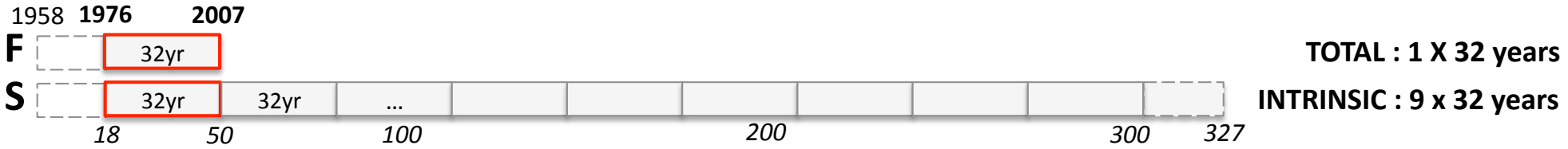
- Summary

TOTAL and INSTRINSIC $AMOC_{\sigma 2}$ 2-10yr **std** analysis



At each latitude : Each 32-yr timeseries is **high-passed** (*loess,* cutoff 11 years)

➔ 1+9 estimates of the **1-10 yr AMOC std**

Compare low-freq AMOC std driven by: realistic forcing

: repeated seasonal cycle (ensemble mean)

TOTAL and INSTRINSIC AMOC$_{\sigma 2}$ 2-10yr **std** analysis

TOTAL : 1 X 32 years

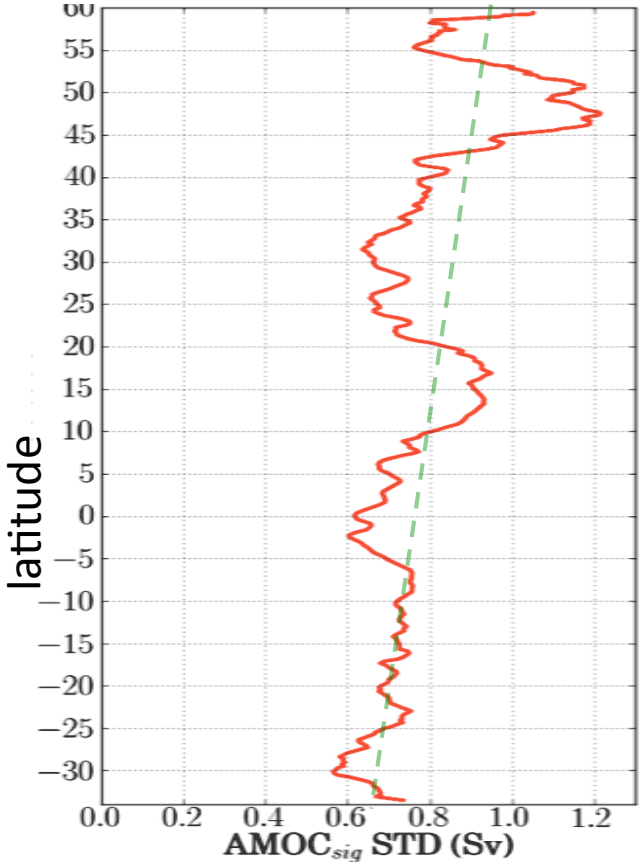
INTRINSIC : 9 x 32 years

At each latitude :

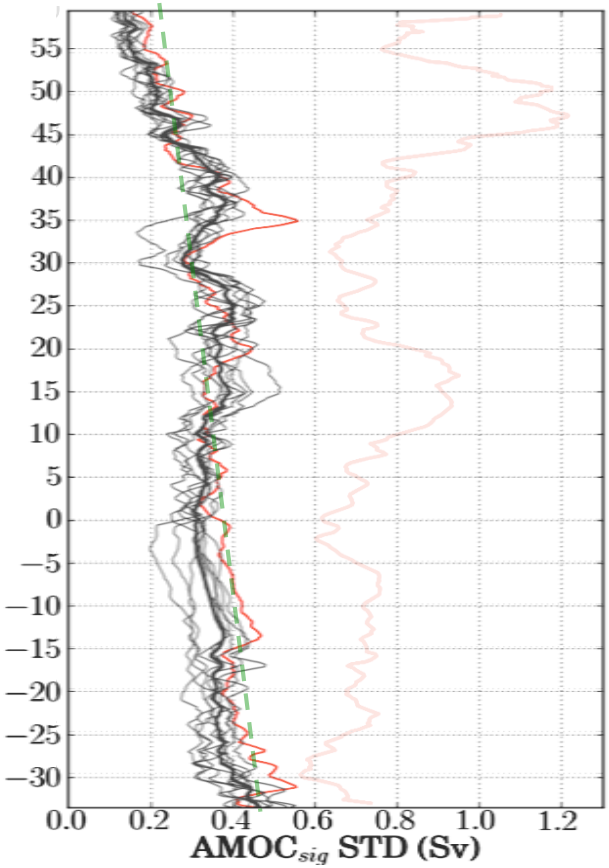
Each 32-yr timeseries is **high-passed** (*loess,* cutoff 11 years)

➔ 1+9 estimates of the **1-10 yr AMOC std**

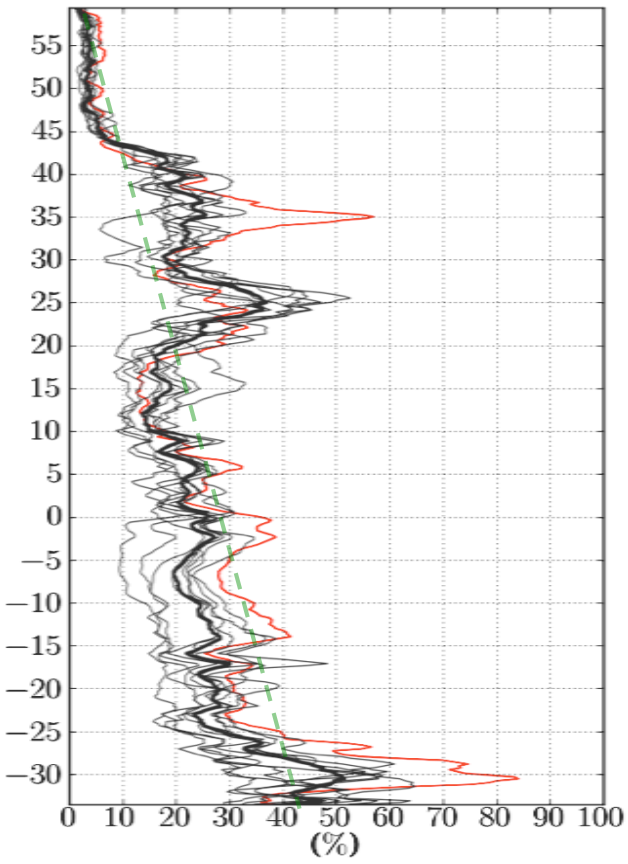
TOTAL std



INTRINSIC std



100%.var(I)/var(T)



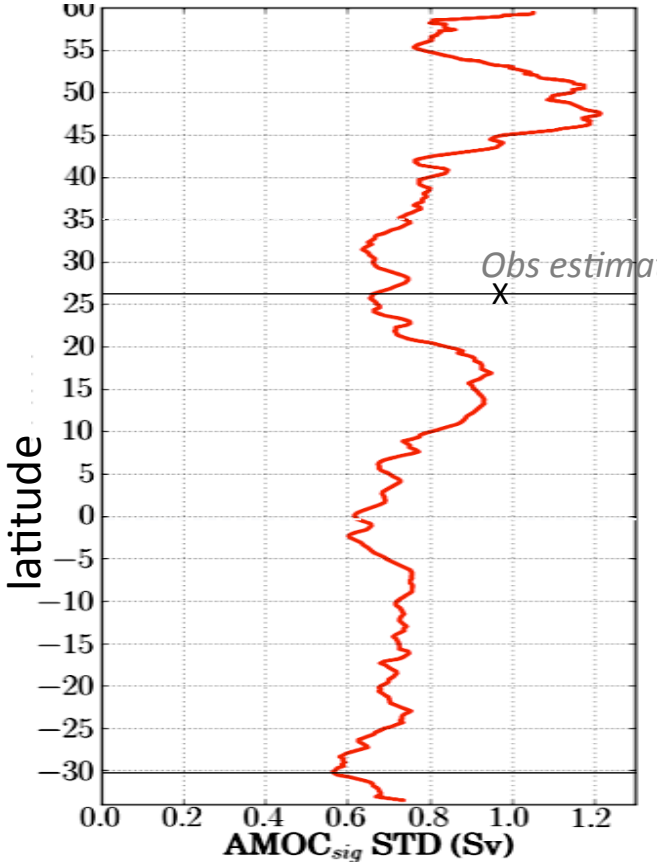
TOTAL and INSTRINSIC $AMOC_{\sigma 2}$ 1-10yr **std** analysis

TOTAL : 1 X 32 years

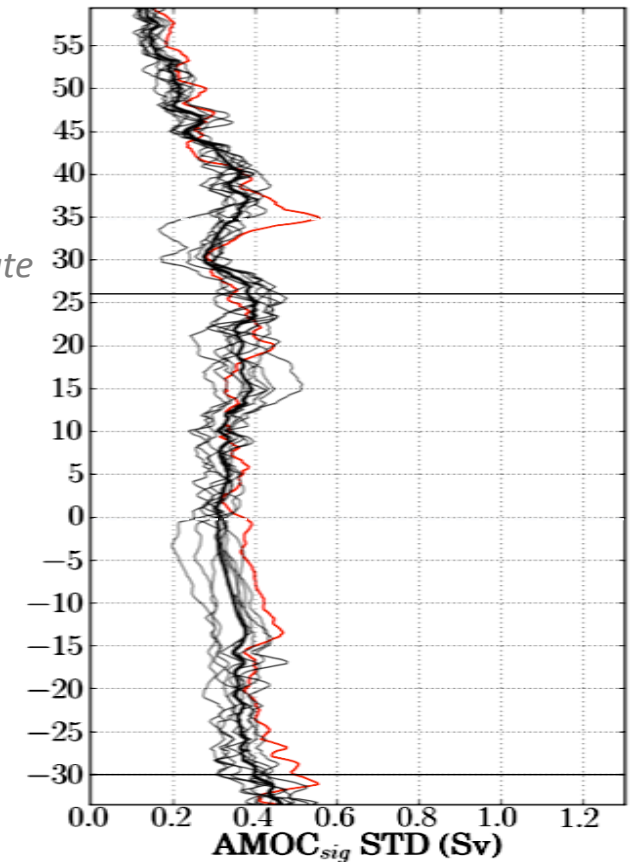
INTRINSIC : 9 x 32 years

At each latitude : Each 32-yr timeseries is **high-passed** (*loess,* cutoff 11 years)
➔ 1+9 estimates of the **1-10 yr AMOC std**

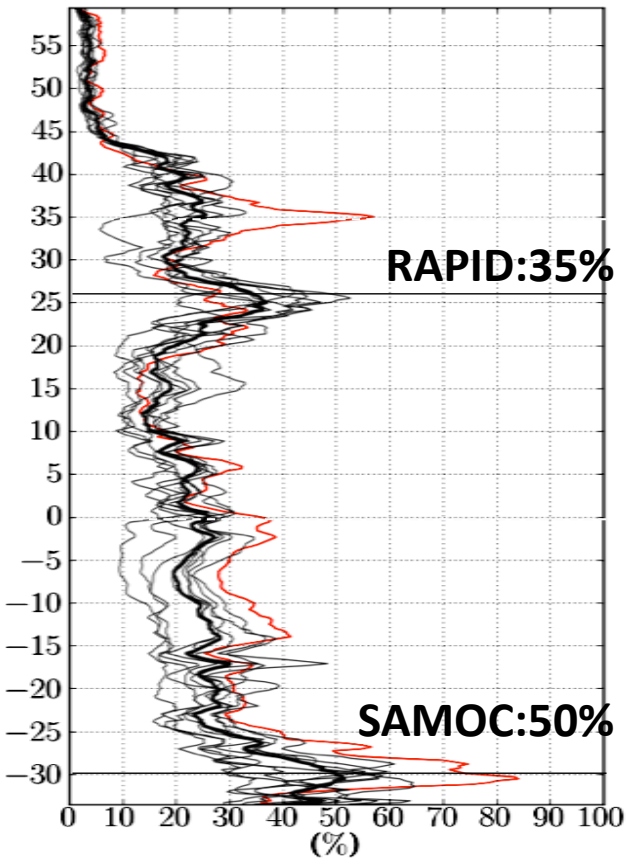
TOTAL std



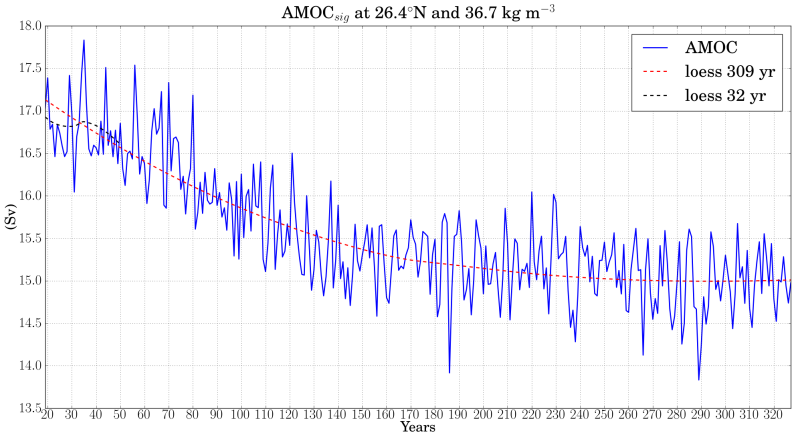
INTRINSIC std



100%.var(I)/var(T)

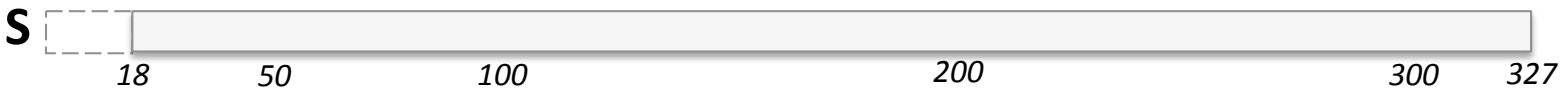


This study : Time-frequency-latitude analysis of low-frequency intrinsic AMOC variability



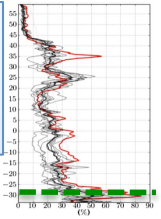
Outline

- Methodology
- Intrinsic AMOC analysis
  - intrinsic contribution to the actual AMOC variance (1-10yr)
  - temporal structure — longer timescales (RAPID, SAMOC, 55°N)



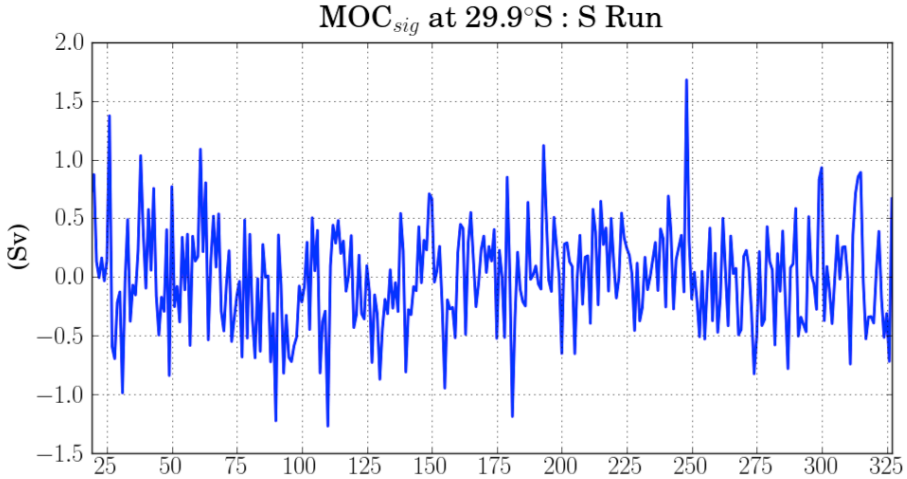
At each latitude : The 310-yr timeseries are **high-passed** (*loess,* cutoff 100 years)
➔ **wavelet power spectra**

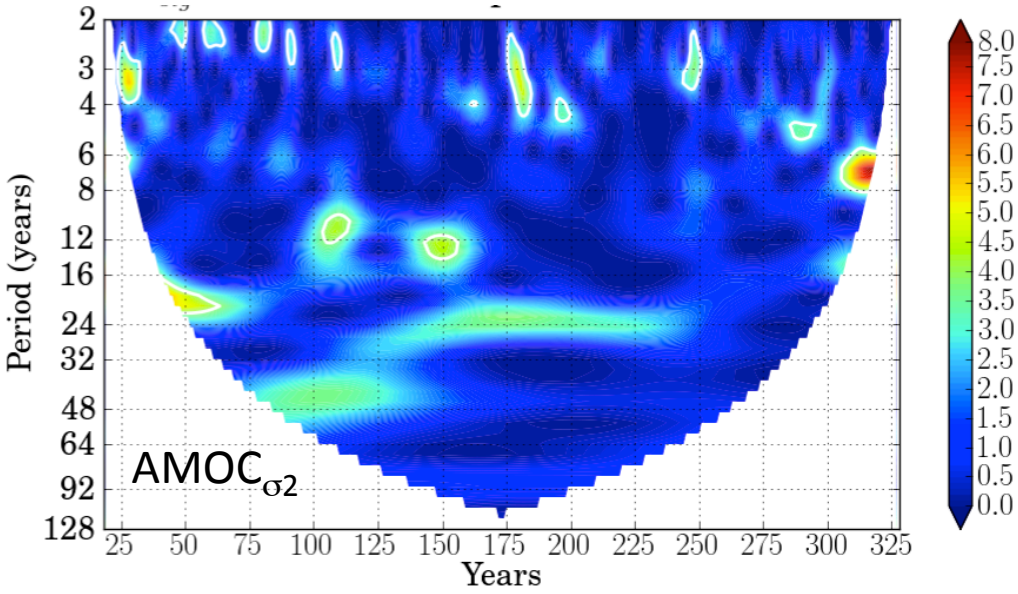
30°S (yr 19-327) : Intrinsic $AMOC_{\sigma 2}$ *(50% intrinsic)*



- Intermittent
- Broad range of timescales
- Most energy at 2-6, ~10/12 years

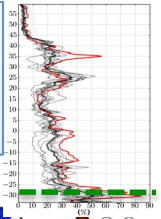
Consistent with
Biastoch et al 2008





Normalized wavelet power spectrum

30°S (yr 19-327) : Intrinsic $AMOC_z$ *(50% intrinsic)*

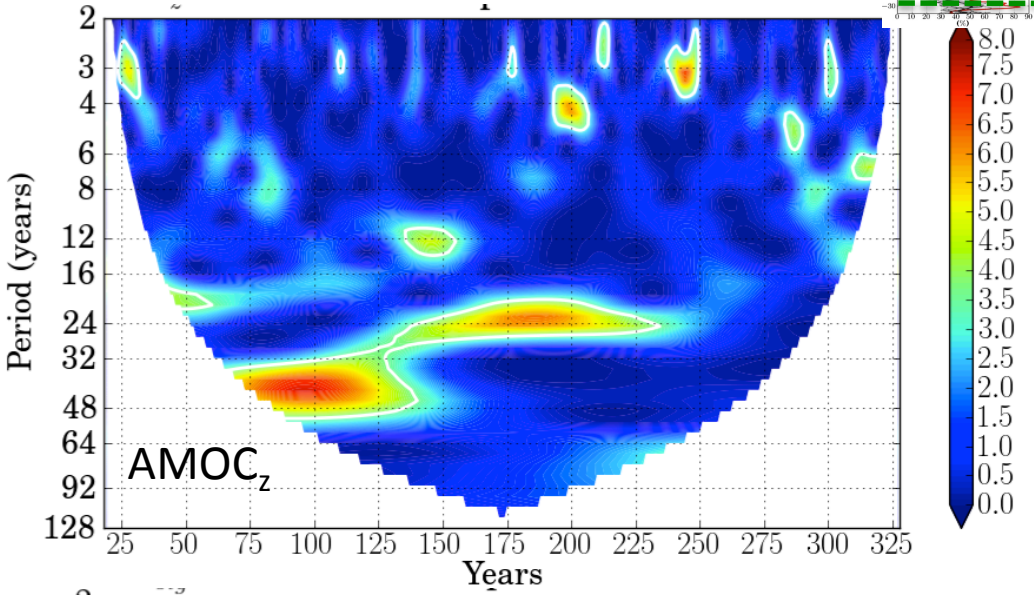


- Intermittent

- Broad range of timescales

- Most energy at 2-6, ~10/12 years

Consistent with
Biastoch et al 2008

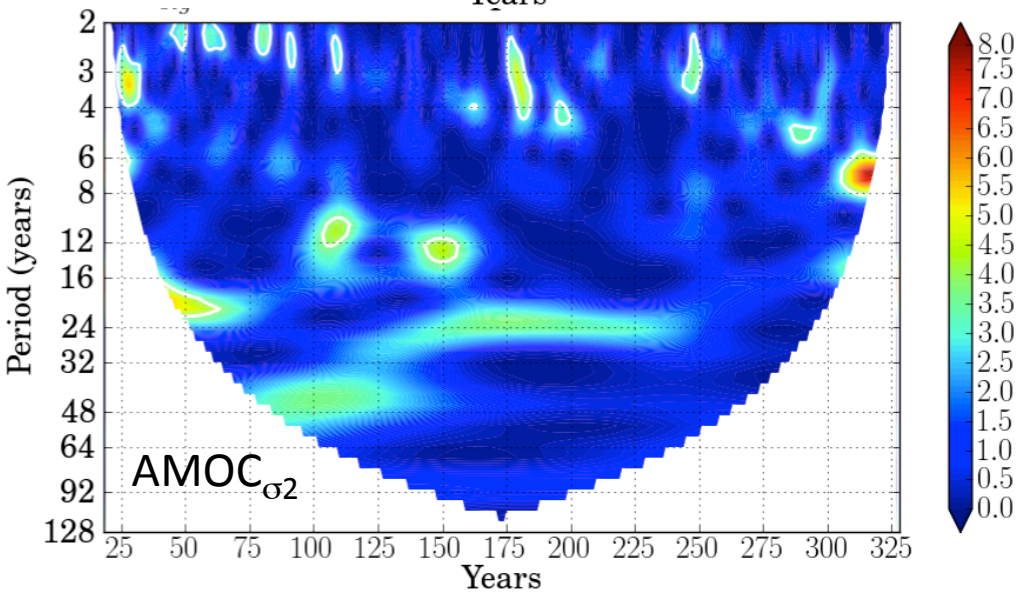


$AMOC_z$:

+ Multidecadal variability (20-50 years)

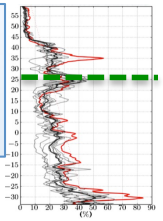
Slow modulation of
isopycnal immersions?

(Matt Menary's talk)



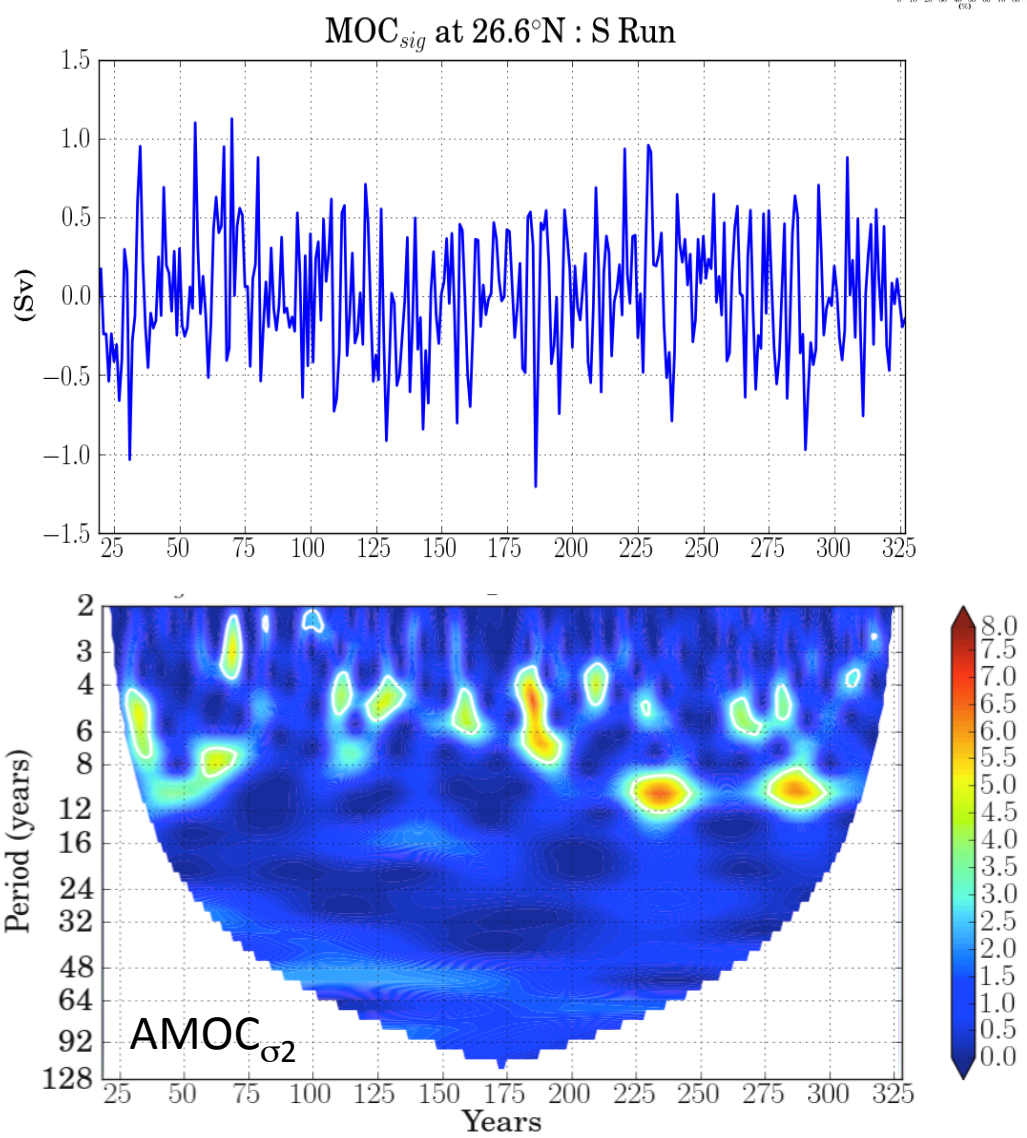
Normalized wavelet power spectrum

26°N (yr 19-327) : Intrinsic $AMOC_{\sigma 2}$ *(35% intrinsic)*



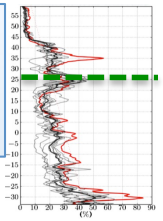
- Intermittent
- Interannual to decadal
- Most energy at 4-8 , 10 years

As in SSH, GS position, STMW PV, etc.
Resembles 'gyre mode' (*Hazeleger & Drijfhout 2000, Dijkstra & Ghil 2005)*



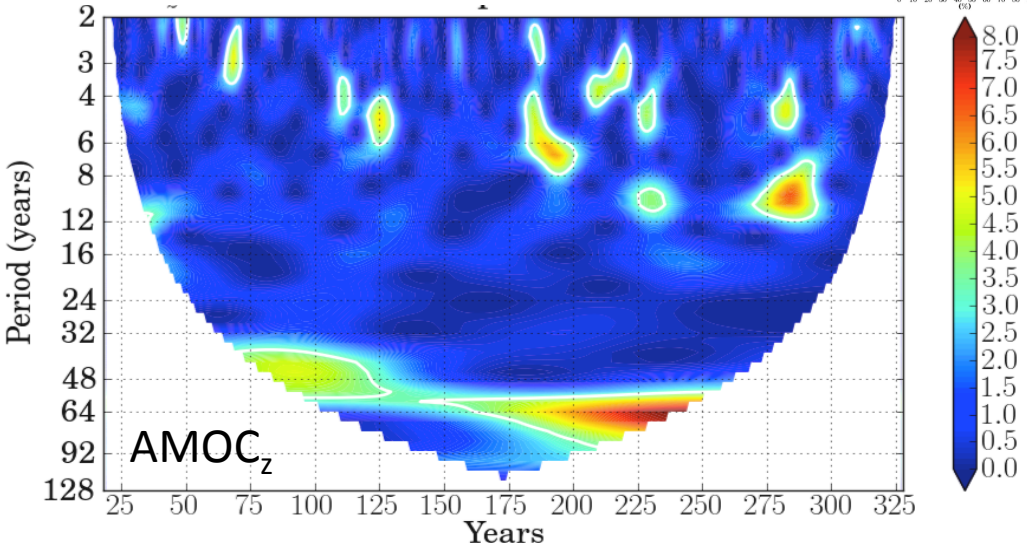
Normalized wavelet power spectrum

26°N (yr 19-327) : Intrinsic $AMOC_z$ *(35% intrinsic)*



- Intermittent
- Interannual to decadal
- Most energy at 4-8 , 10 years

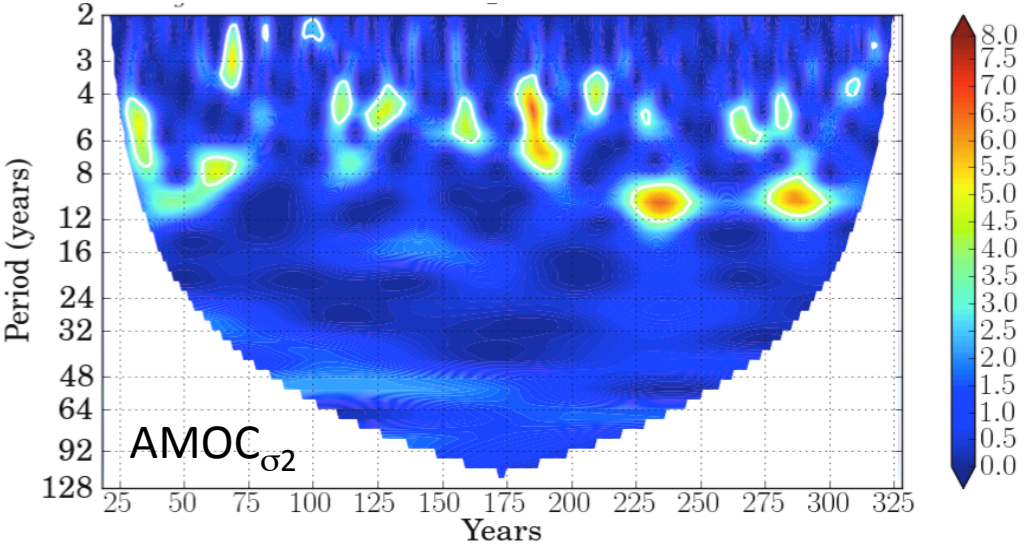
As in SSH, GS position, STMW PV, etc.
Resembles 'gyre mode' (*Hazeleger & Drijfhout 2000, Dijkstra & Ghil 2005)*



$AMOC_z$:

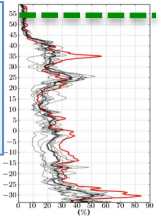
+ Multidecadal variability (40-92 years)

Slow modulation of isopycnal immersions?



Normalized wavelet power spectrum

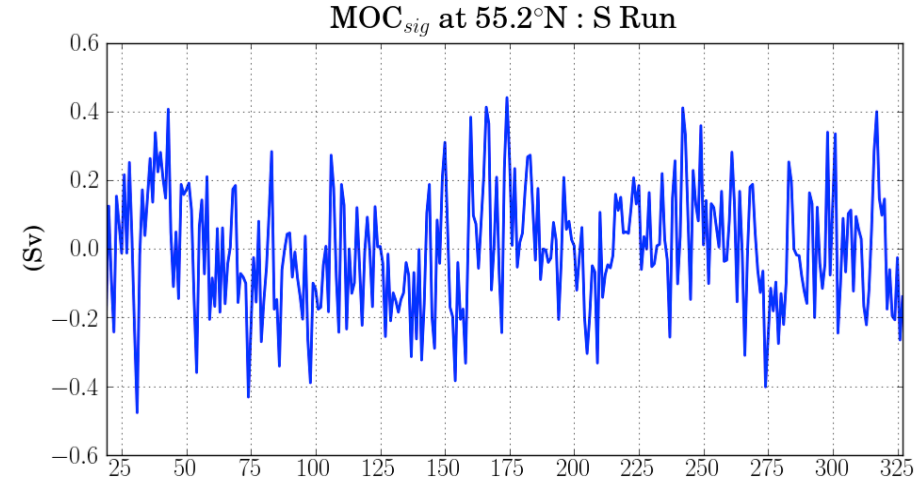
55°N (yr 19-327) : Intrinsic $AMOC_{\sigma 2}$ *(5% intrinsic)*

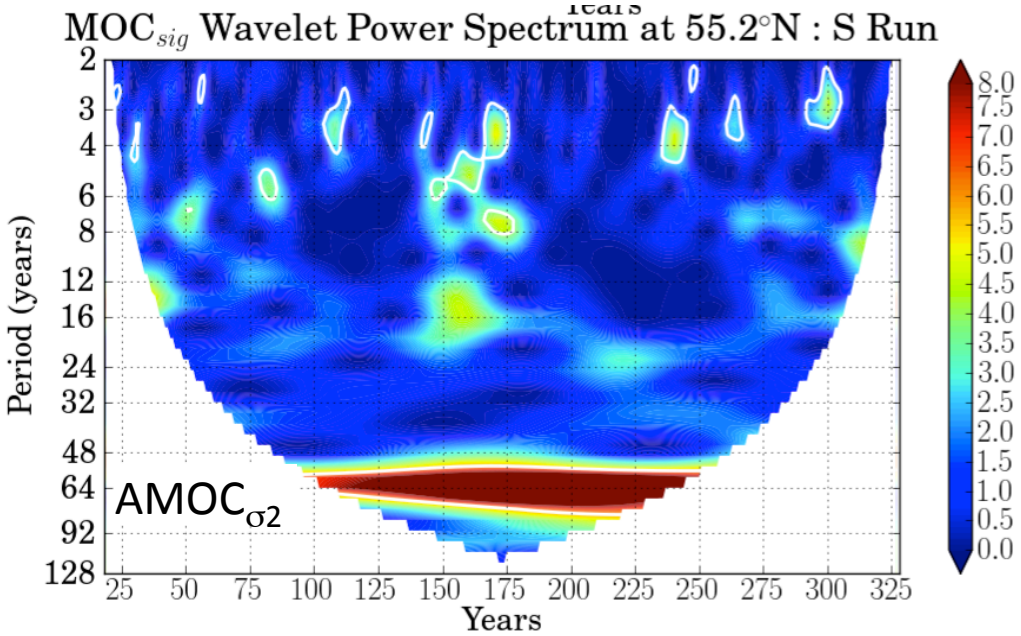


- Intermittent
- Interannual to multidecadal
- Most energy at 3-8, ~64 years
- Some energy at 16-24 years

Consistent with Sevellec & *Fedorov 2013 ?*

$AMOC_z$: comparable



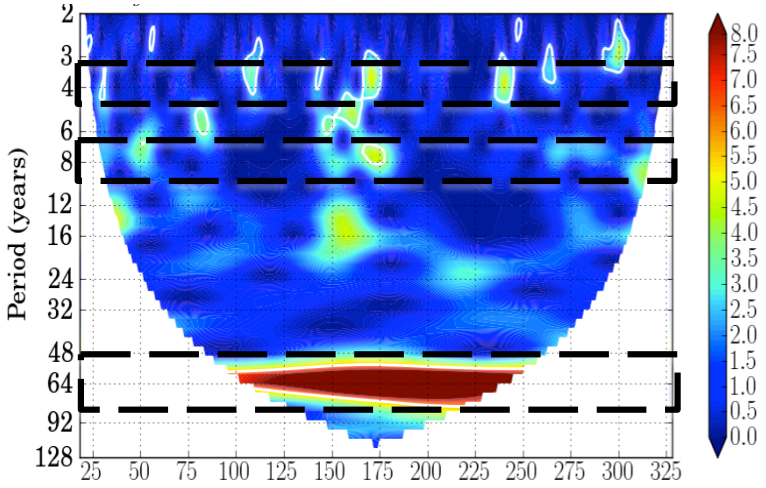


Normalized wavelet power spectrum

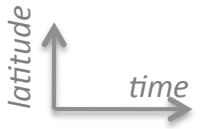
This study : Time-frequency-latitude analysis of low-frequency intrinsic AMOC variability

Outline

- Methodology
- Intrinsic AMOC analysis
  - intrinsic contribution to the actual AMOC variance (1-10yr)
  - temporal structure — longer timescales
  - meridional coherence : MOC(t,lat)
- Summary

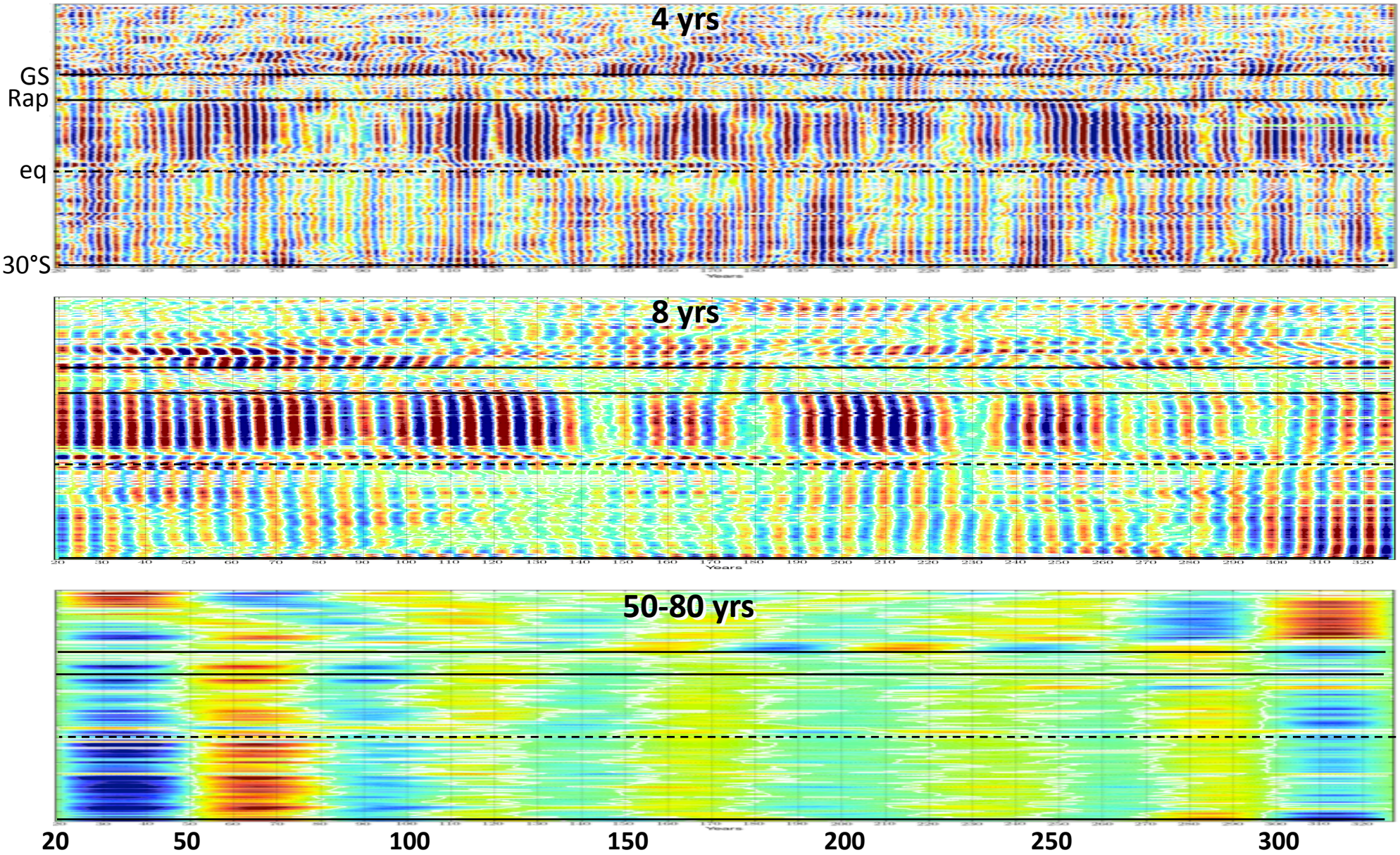


Intrinsic $AMOC_{\sigma 2}$: meridional coherence



min -0.3Sv
max +0.3Sv

bandpassed Hovmoellers



Summary

1/4° model + seasonal forcing ➔ intrinsic low-frequency AMOC variance

55°N **(subploar)**	about **5%**	**3-8**, 16-24, 64 **years**
26.5°N **(RAPID)**	about **35%**	**4**, **8,** 10 years
30°S **(SAMOC)**	about **50%**	**2-6**, 10-12, 20-50 years

- Forcing not white : nonlin. prod. of low-freq more likely than lin. reddening
- Substantial intrinsic low-freq — remains chaotic with full forcing *(Hirschi et al 2013)*
- Interannual to multidecadal (high latitudes or MOCz)
- Temporal intermittence / meridional coherence (30°S-30°N)

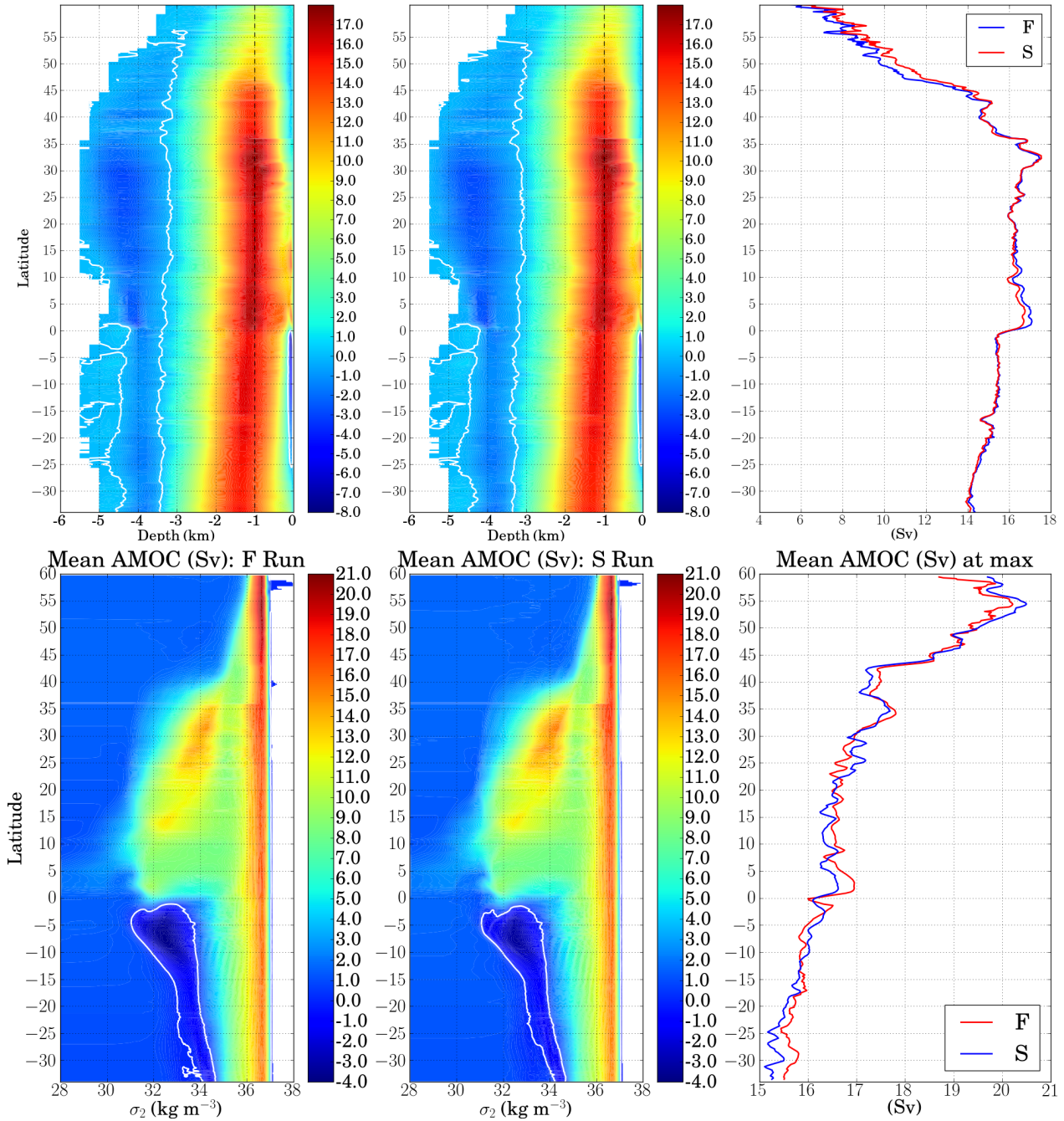
1/12° model with seasonal forcing ➔

- MOC_z intrinsic variance is similar 30°S-40°N (enhanced further north)
- Significant 24-year subpolar AMOC variability *(Sevellec & Fedorov 2013 ?)*

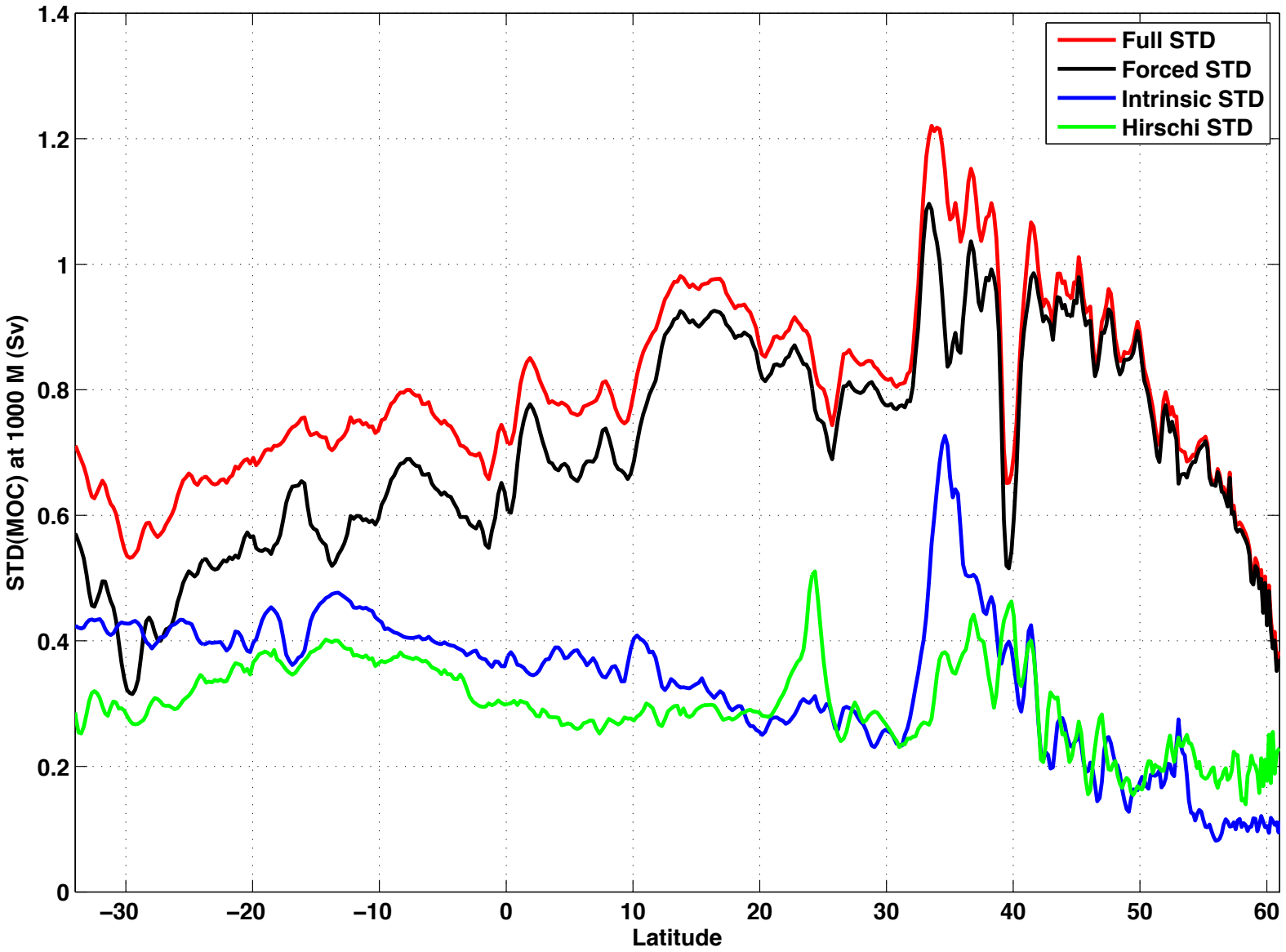
Perspectives

- Associated patterns ? (T, SSH, etc)
- Predictability in the eddying regime (forced/coupled)

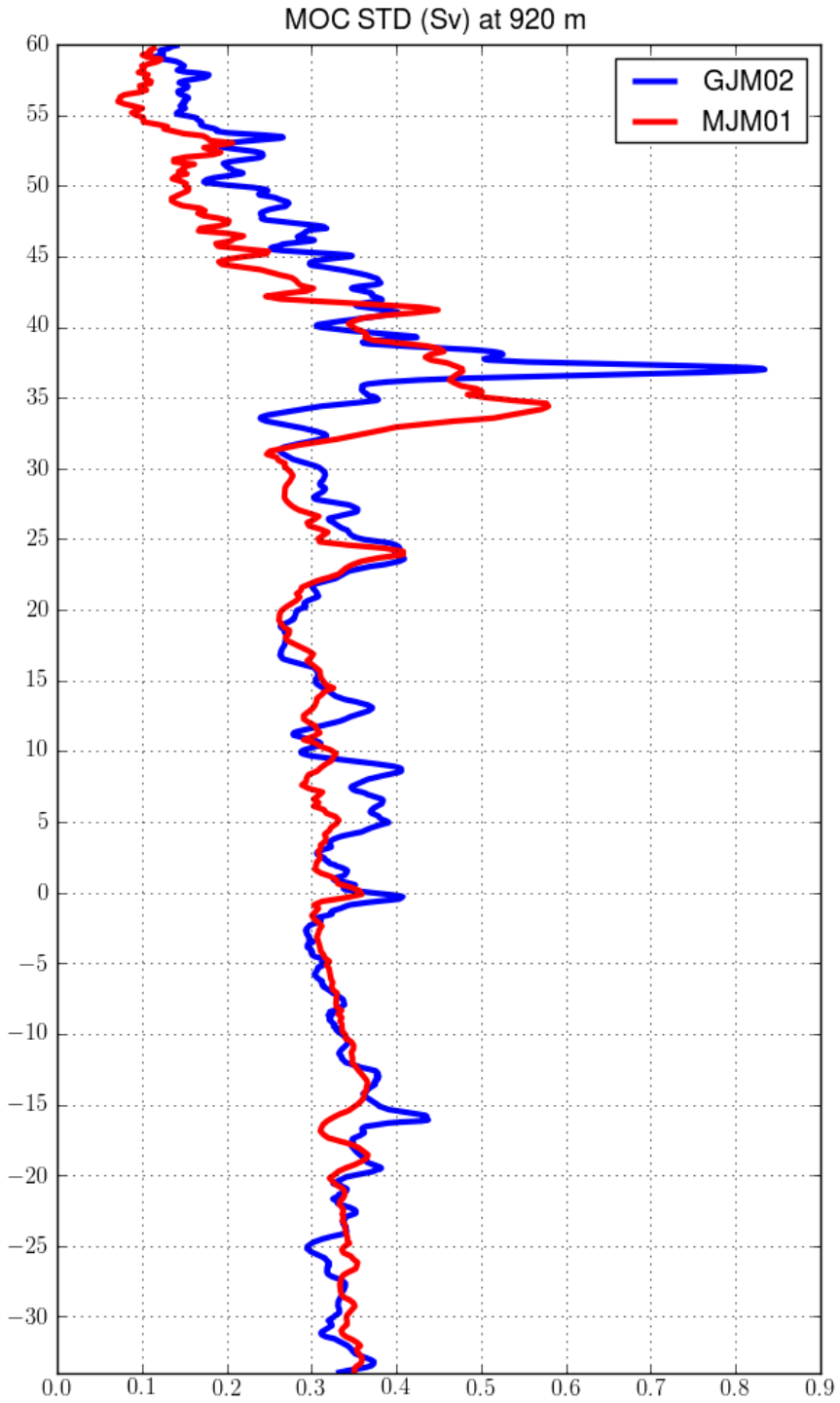
Mean AMOC in F and S runs (years 19-50)



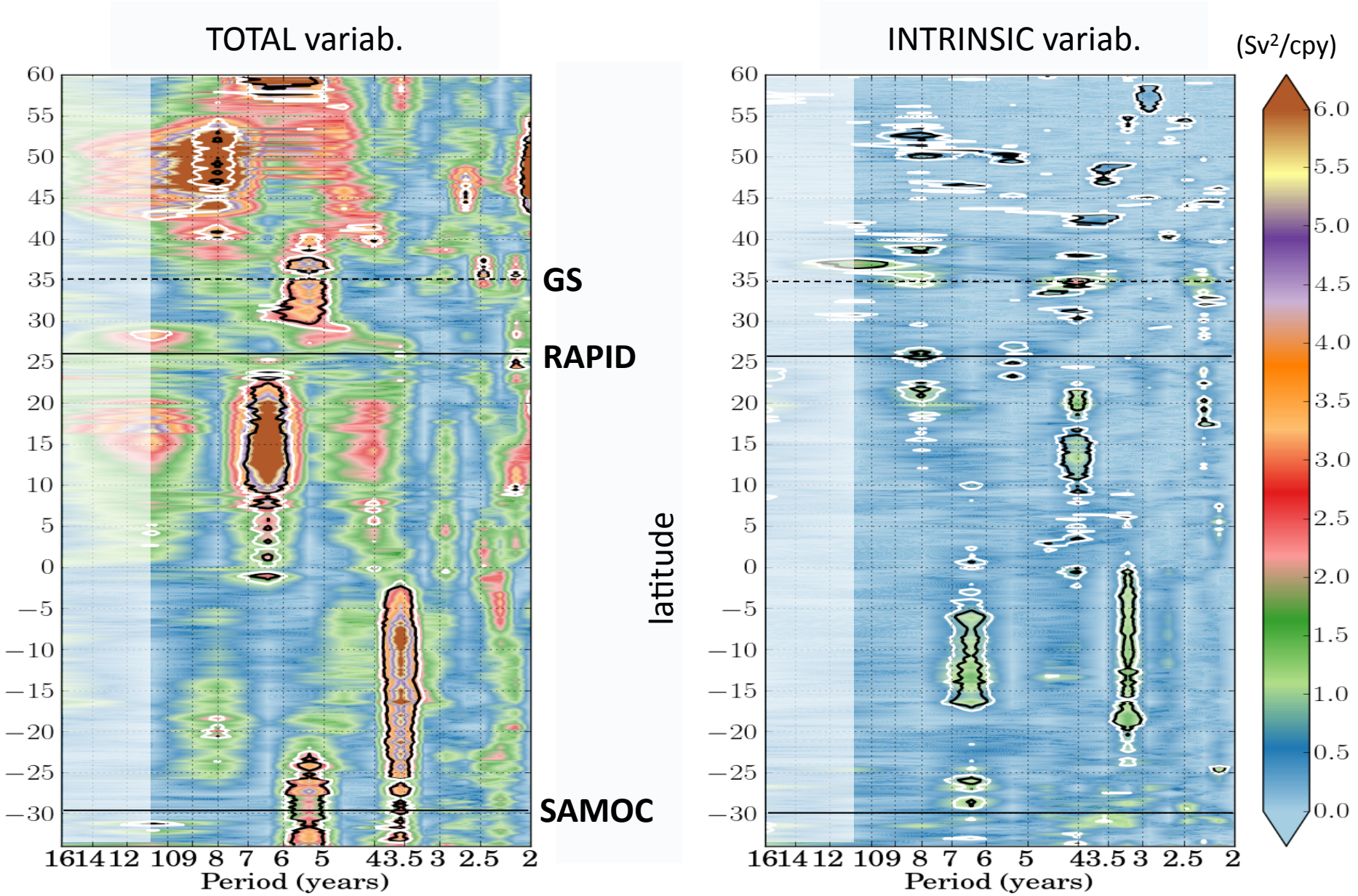
Intrinsic $AMOC_z$ variance similar to Hirschi's chaotic variance



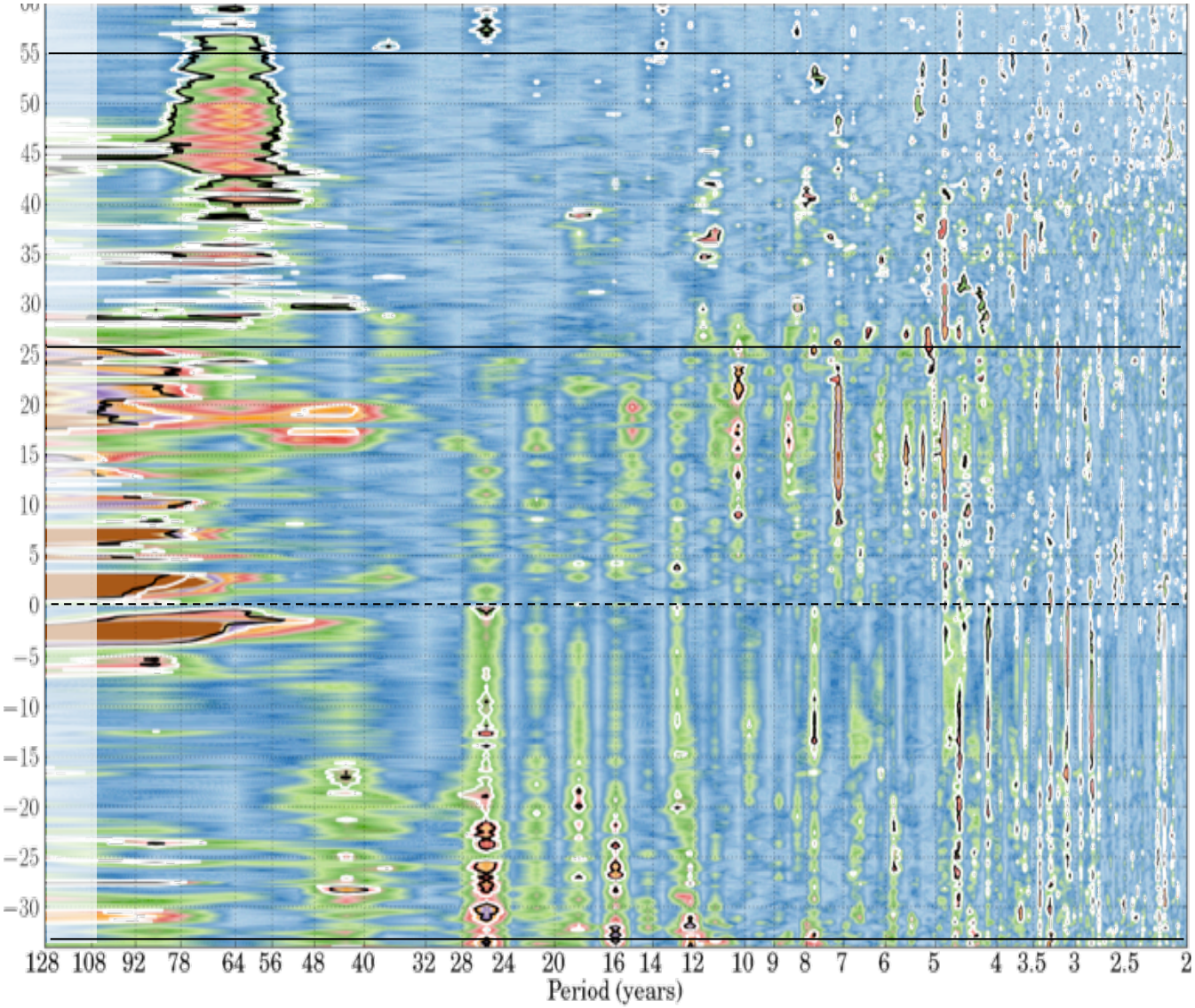
Intrinsic $AMOC_z$ std
at 1/4° and 1/12°

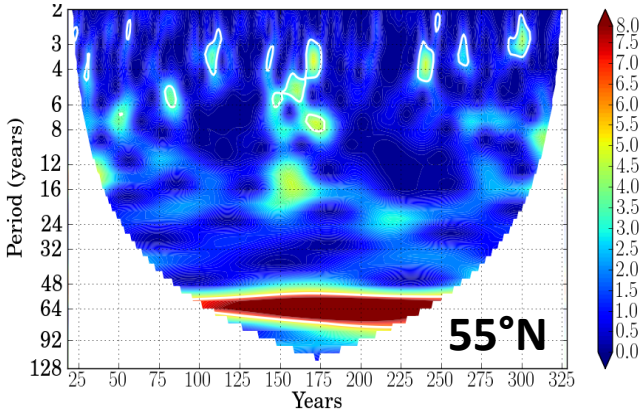


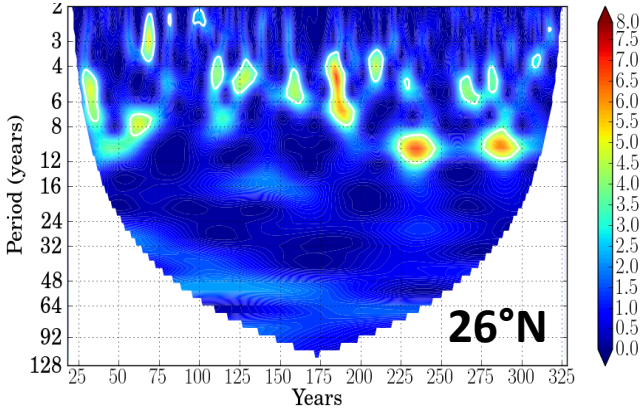
TOTAL and INSTRINSIC AMOC$_{\sigma 2}$: 19-50yr **spectra**

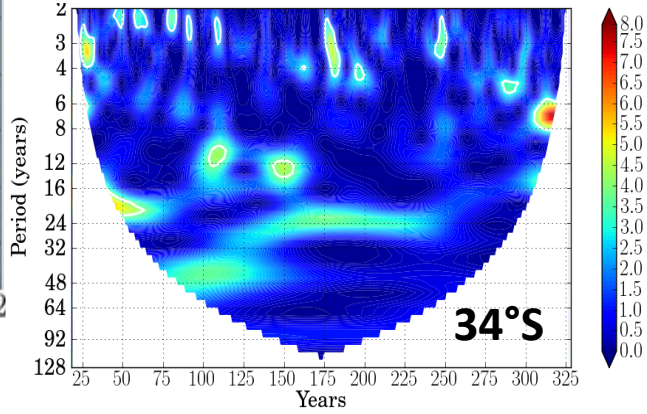


INSTRINSIC AMOC : **19-327yr** wavelets

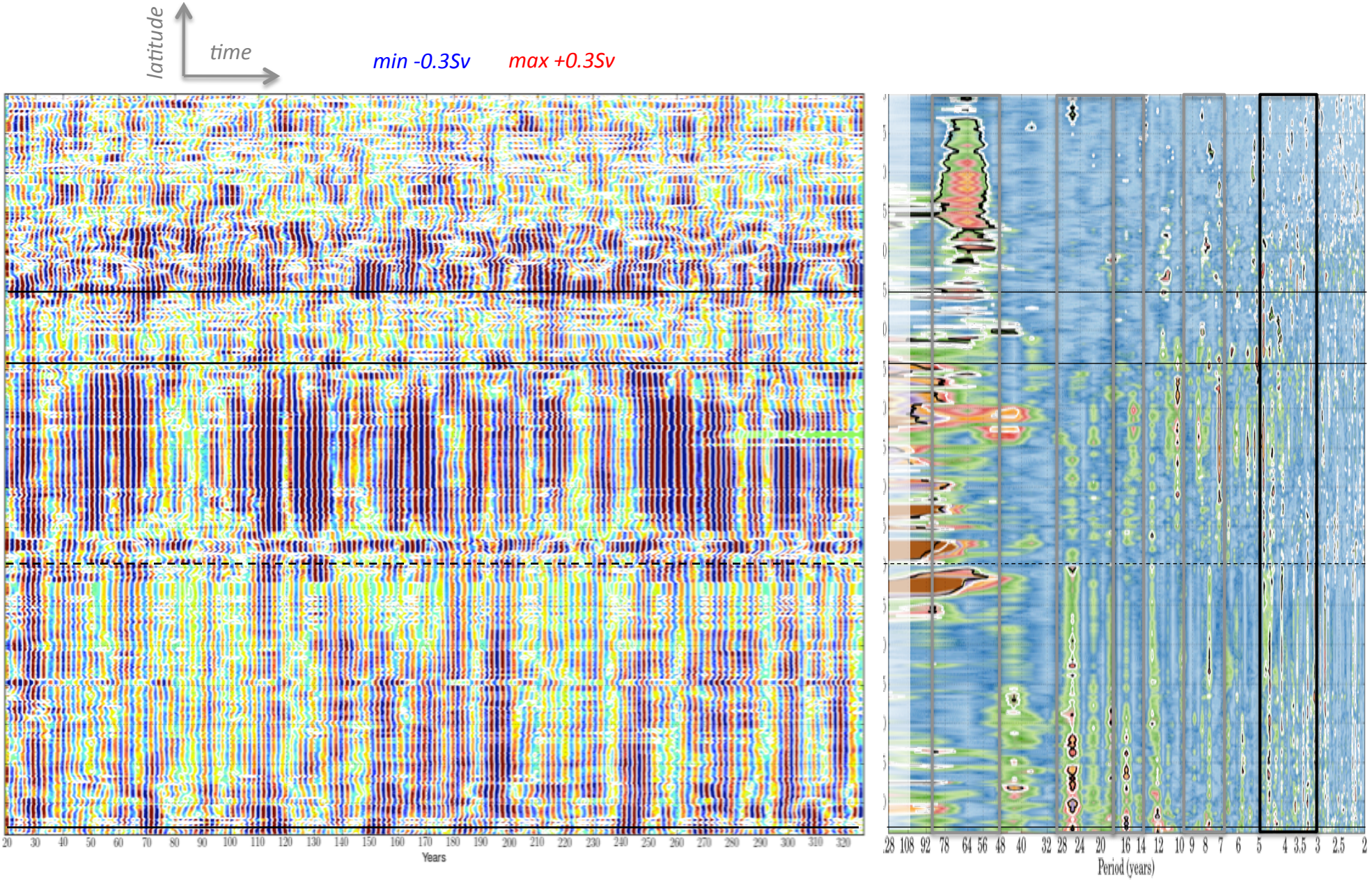




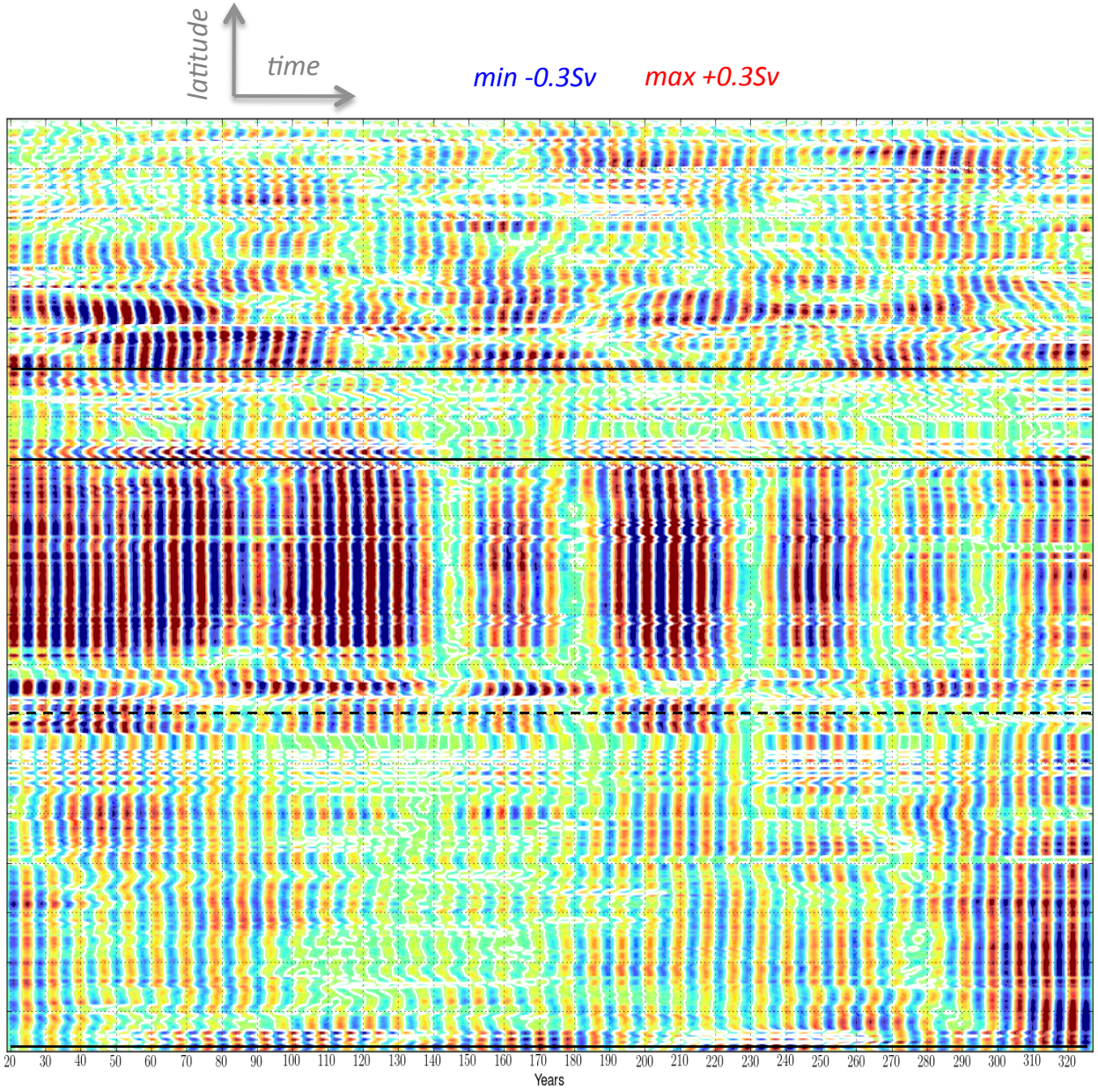


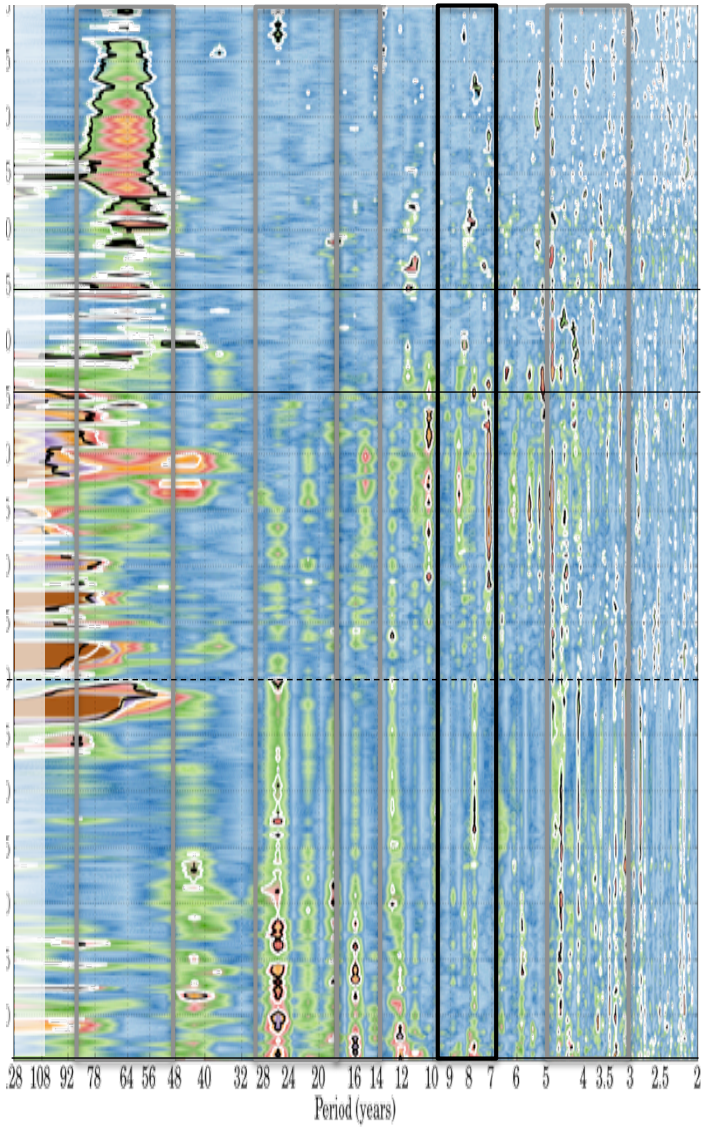


INSTRINSIC AMOC : **~4yr** bandpass Hovmoeller

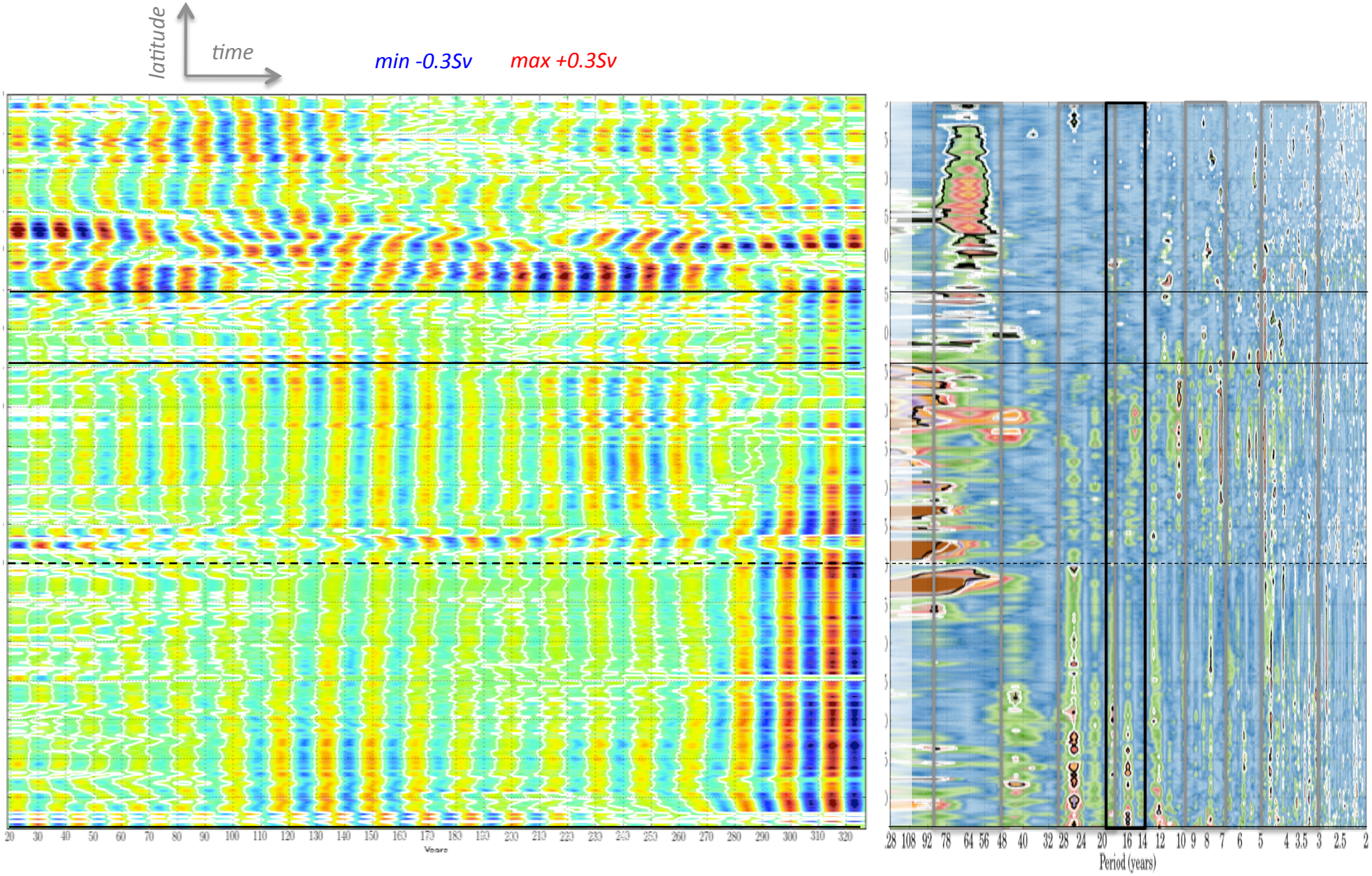


INSTRINSIC AMOC : **~8yr** bandpass Hovmoeller



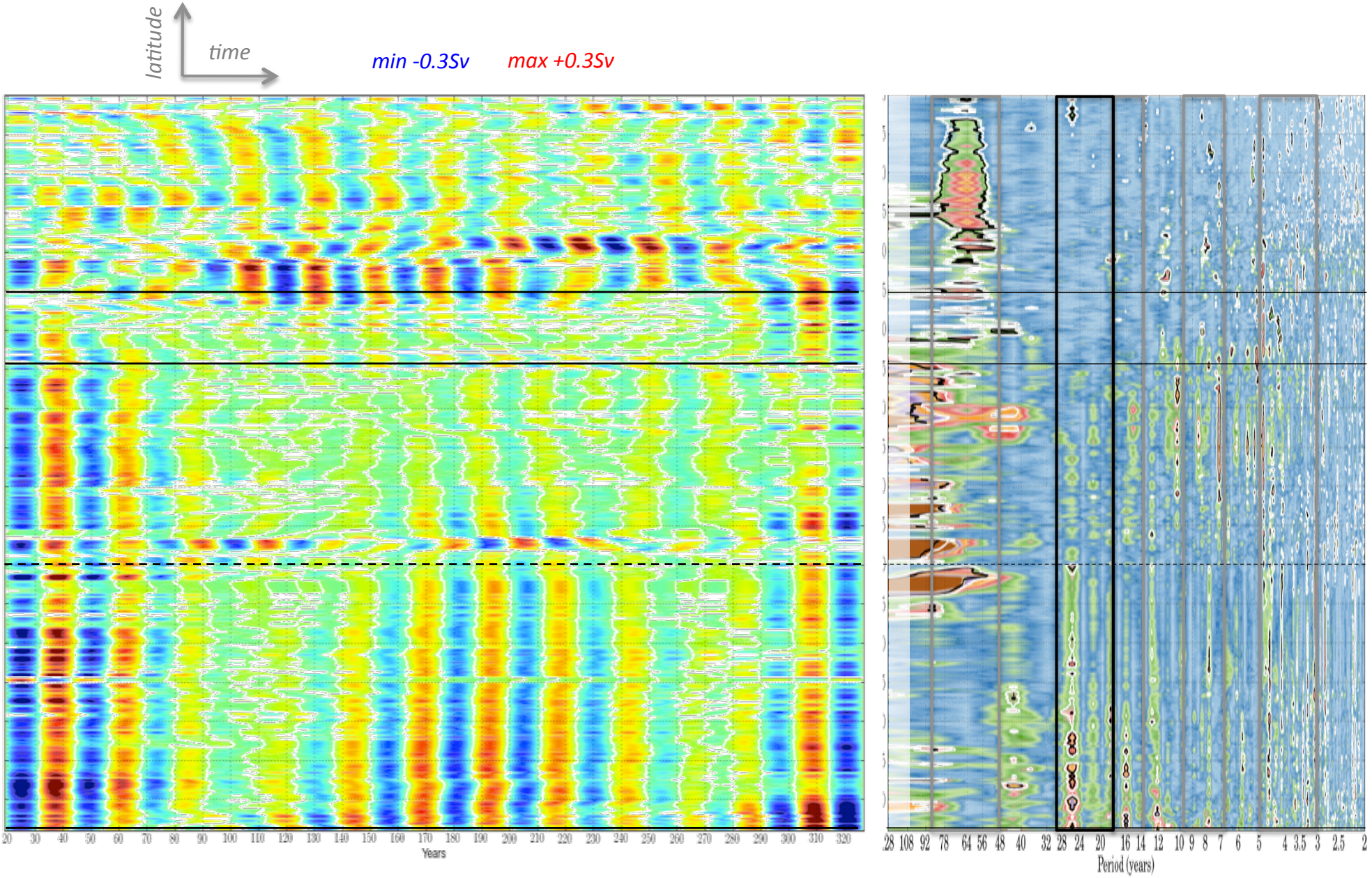


INSTRINSIC AMOC : **~16yr** bandpass Hovmoeller

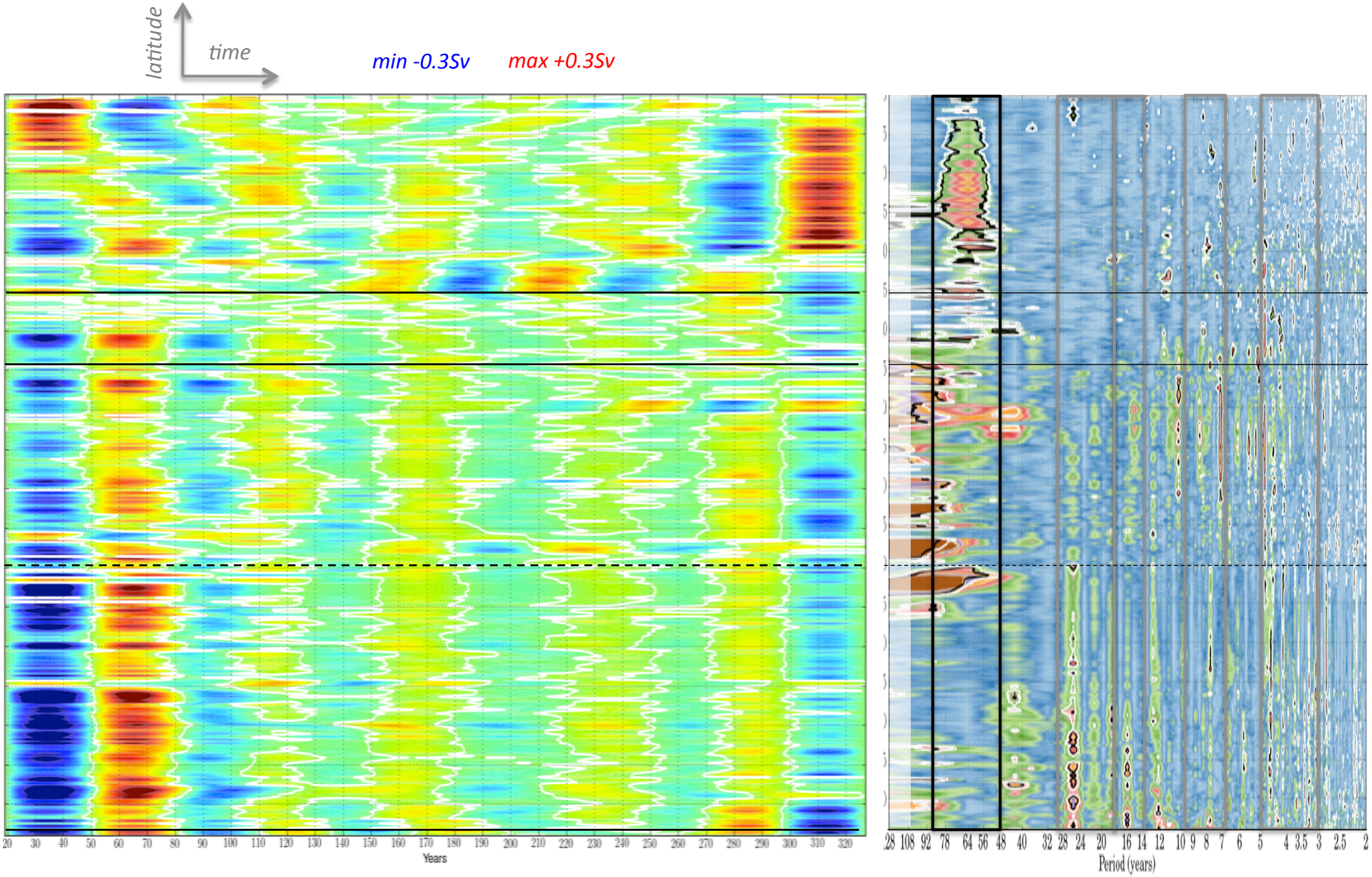


mann eddy (42°N) : 18 year AMOC oscillation (Tulloch & Marshall 2011)

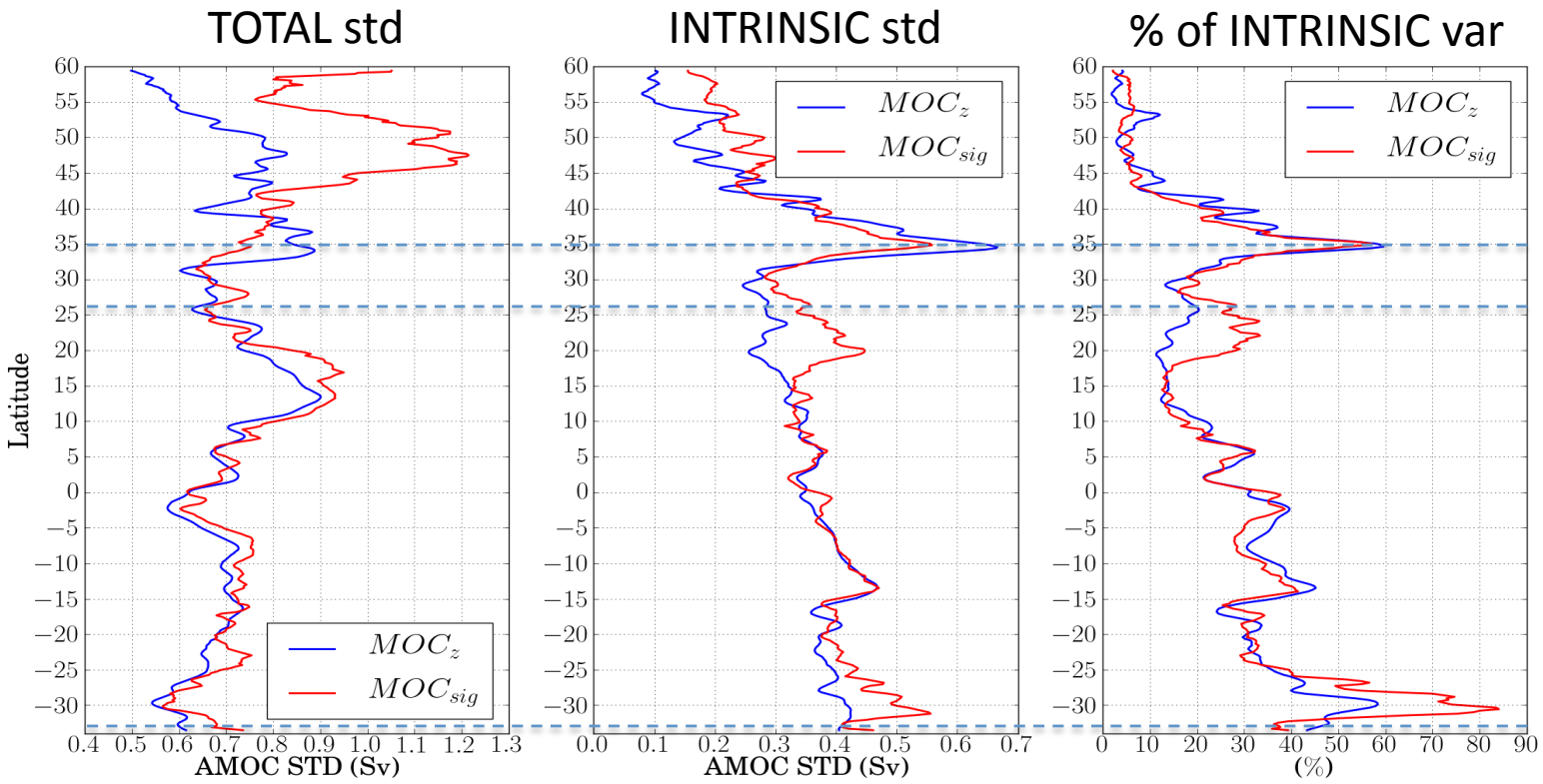
INSTRINSIC AMOC : **18-30yr** bandpass Hovmoeller

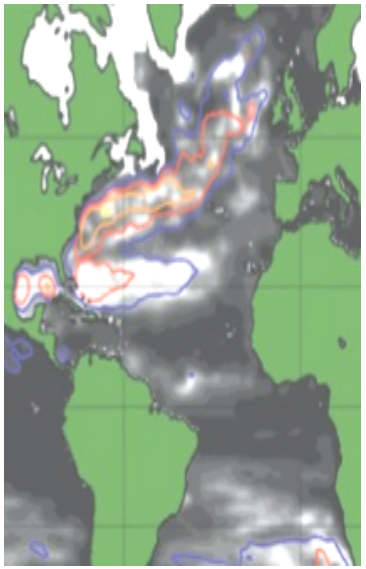


INSTRINSIC AMOC : **50-80yr** bandpass Hovmoeller



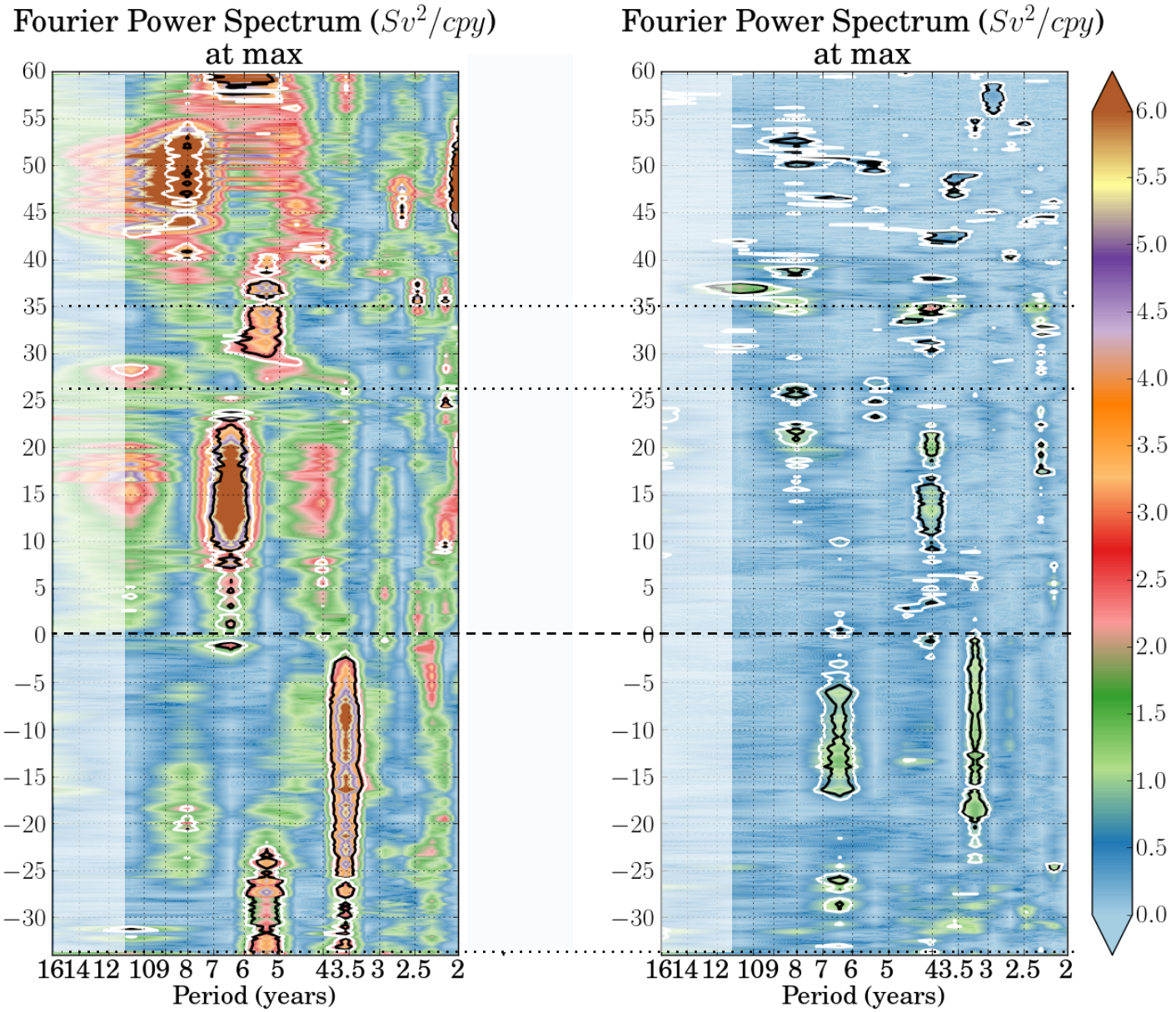
std(AMOC) in F and S runs (years 19-50)



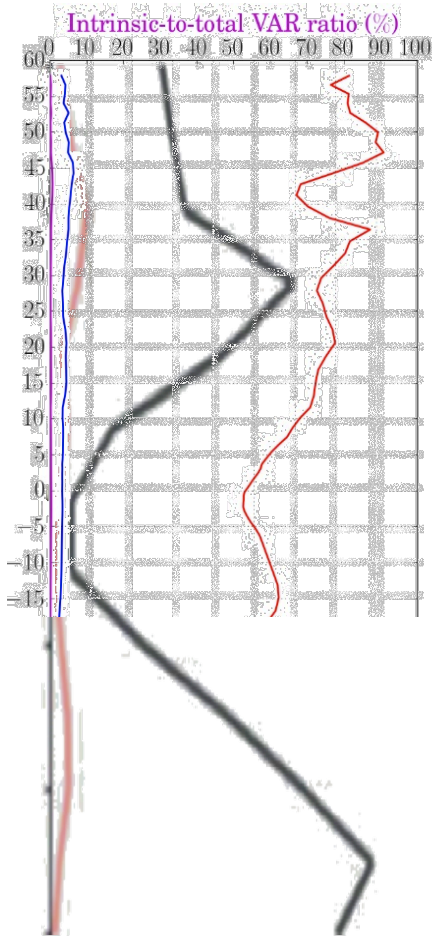


spectrum(AMOC) in F and S runs (years 19-50)

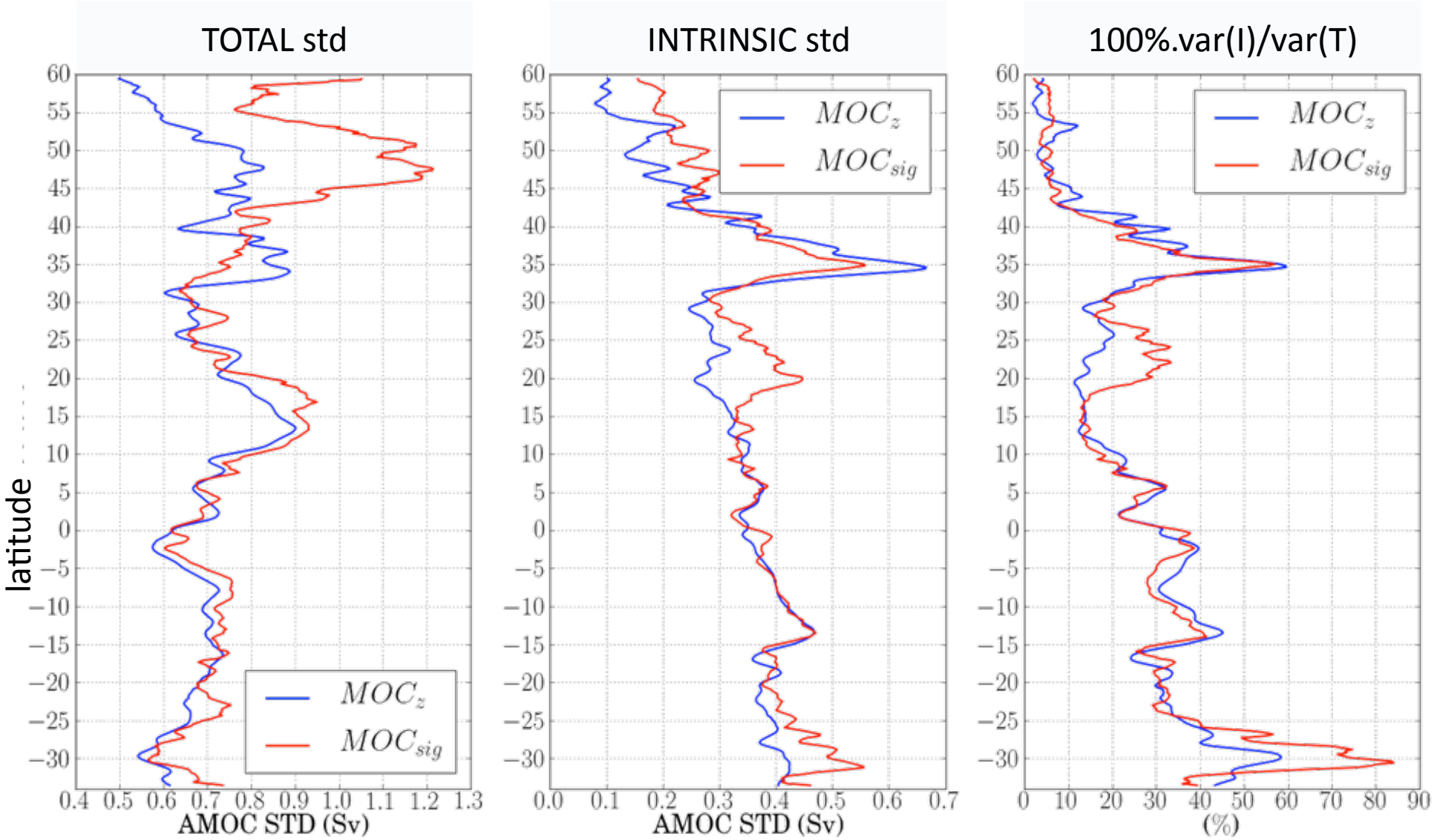
TOTAL



INTRINSIC


Intrinsic-to-total VAR ratio (%)
0 10 20 30 40 50 60 70 80 90 100
60
55
50
45
40
35
30
25
20
15
10
5
0
−5
−10
−15

TOTAL and INSTRINSIC AMOC : 19-50yr **std**



Context

- AMOC: many timescales/processes + predictability issues
- Coarse coupled: atm(NAO) → MLD/DWBC → AMOC → SSTpatterns (atmospherically-involved var)
- What's new with eddying ocean models ? no long coupled eddying runs
- Forced : QG/SW eddying ocean: horiz. circ : chaotic instrinsic variab 1-10yr
- Realistic eddying models:
  - Penduff et al 2011 : strong SSH (and SST variab) if eddies admitted
  - Biastoch, hirschi → identical forcing : 1-10yr AMOC variab
  - eddies generate 1-10yr variab ; sensitivity to IC
- THIS STUDY 2-100yr timescales, MOC frequency analysis.
  - Seasonally-forced eddying ocean : isolate intrinsic ; compare w/ full forcing
  - Questions : contrib intrinsic variance, preferred timescales, temporal regularity
  - Resolution?
- cite griffies & Tzipermann 1995 ?
- issue of meridional coherence vs temporal scatter (f,t)