The AMOC interdecadal mode related to westward propagation of density anomalies in CMIP5

Les Muir

Alexey Fedorov

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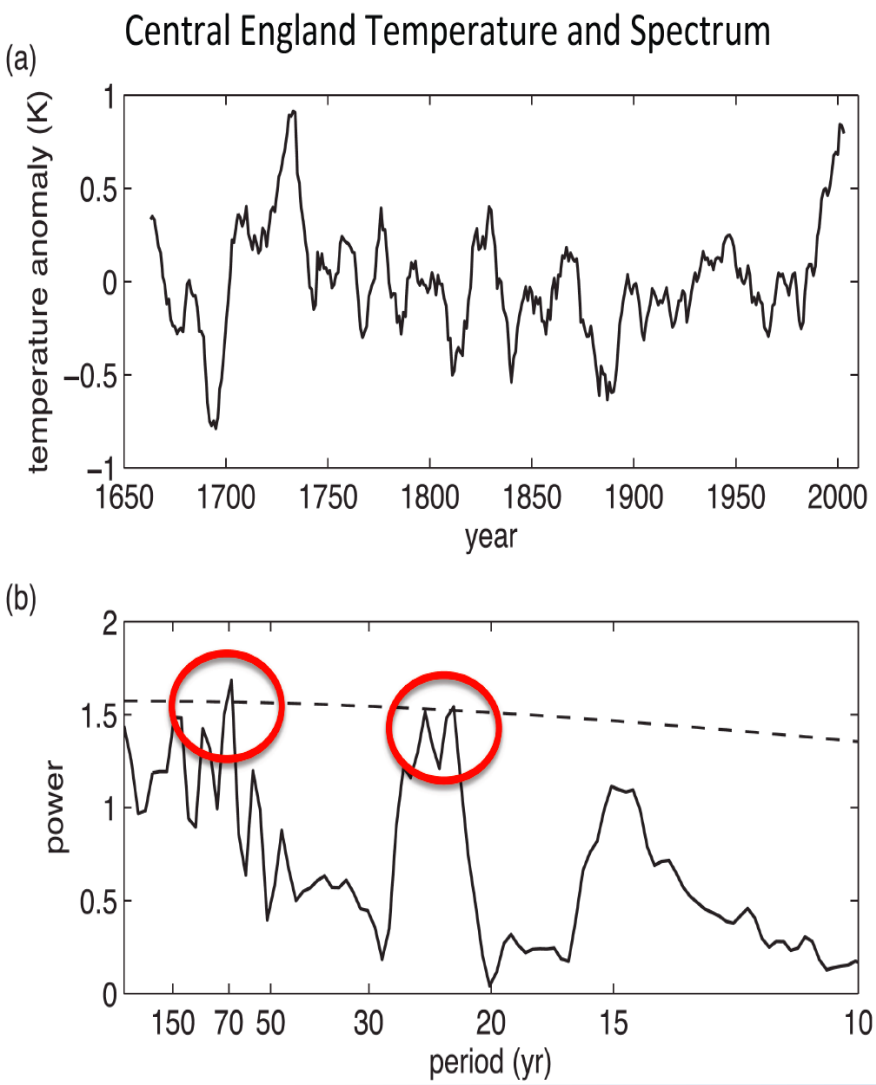
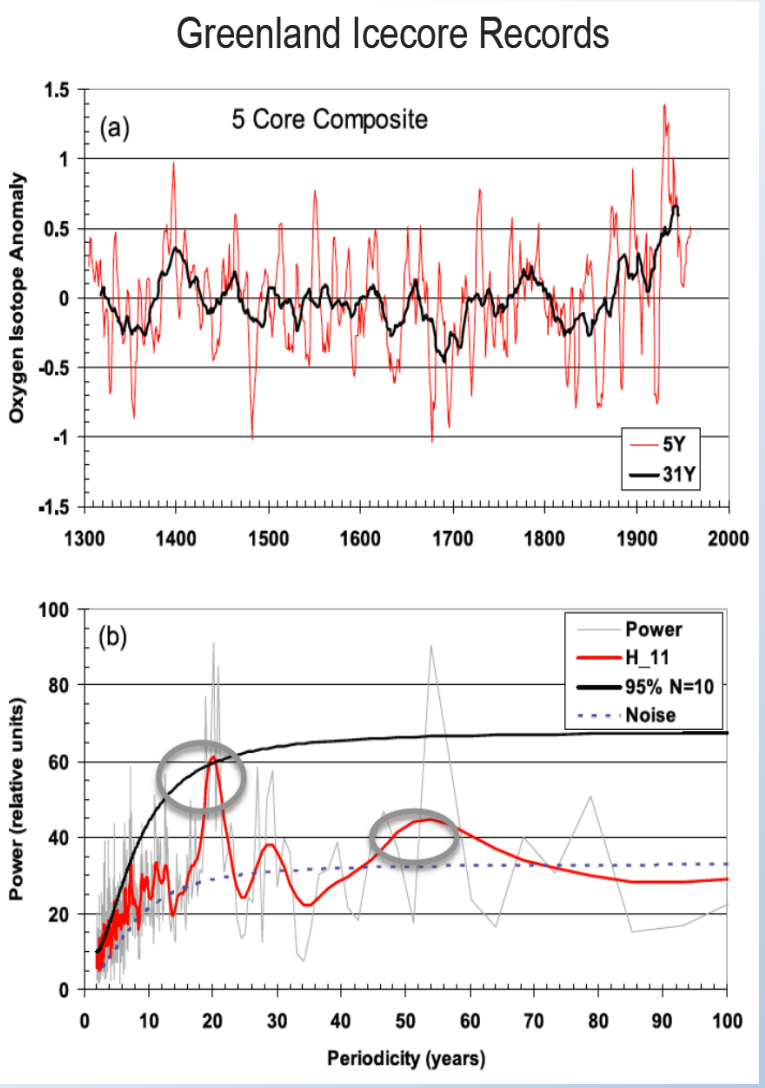
AMOC 20yr cycle observations.



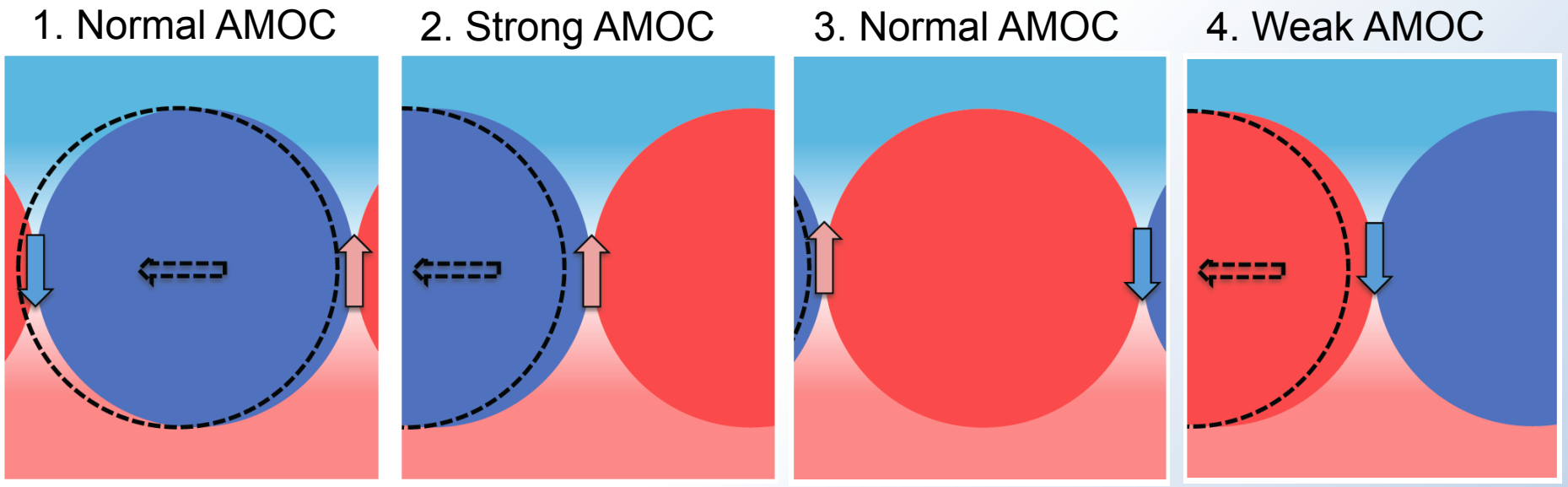
(Frankcombe and Dijkstra 2010)

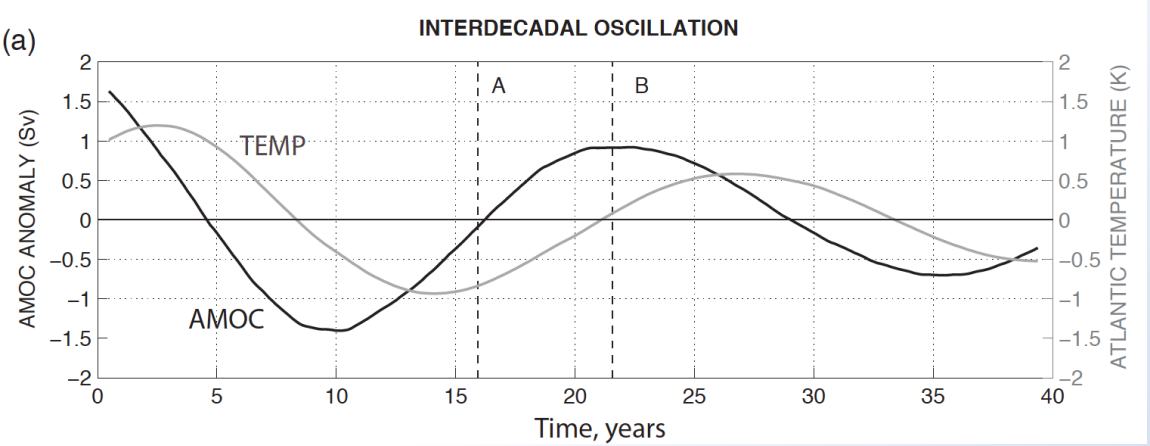


(Chylek et al. 2012)

MODE MECHANISM:

Westward propagation of large-scale depth-integrated temperature (density) anomalies



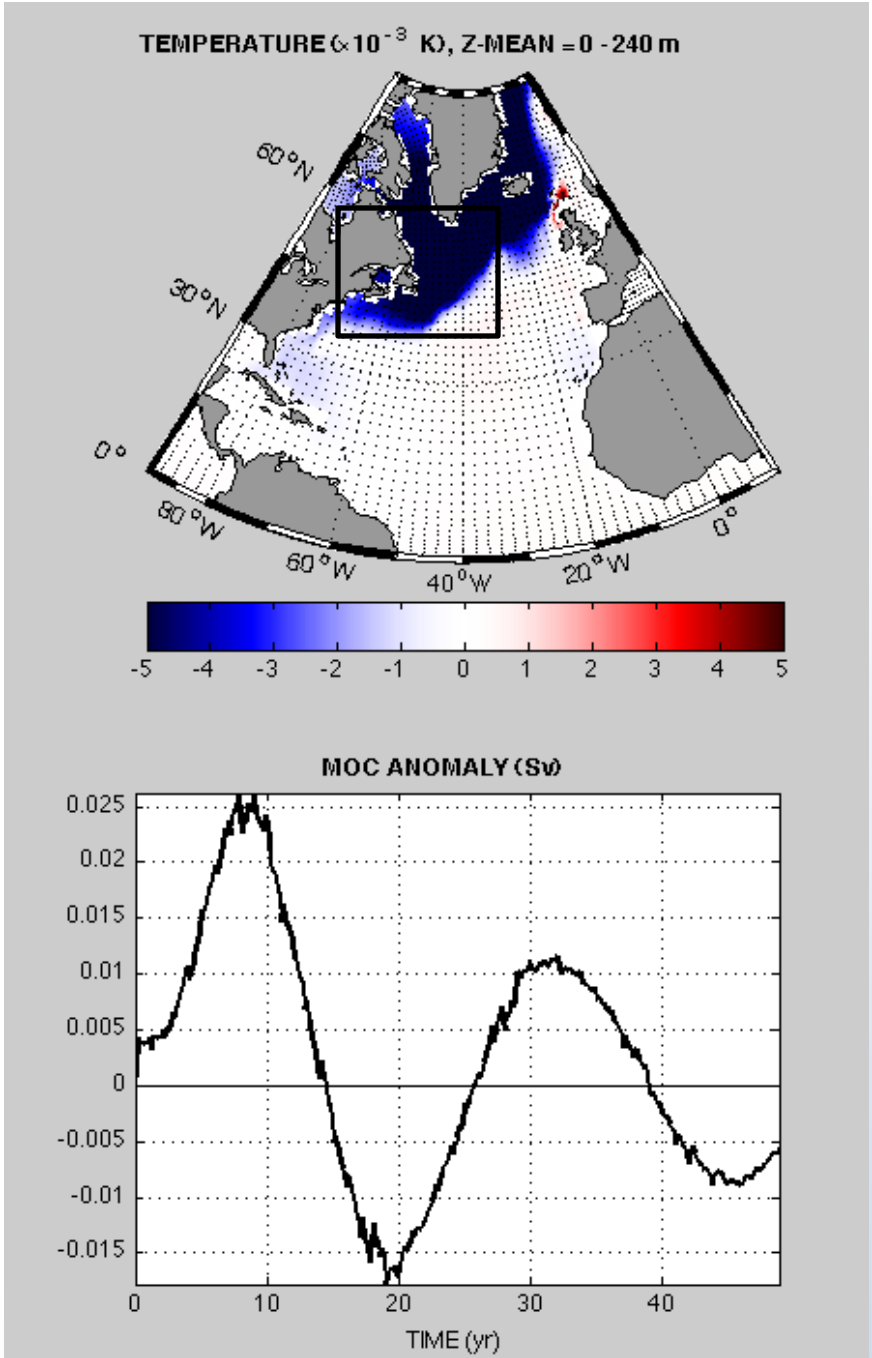


Propagation is the sum of 3 things:

- mean flow.
- geostrophic self advection
- β-effect.

Sevellec and Fedorov 2013a,b

OGCM OPA 8.2



Sevellec and Fedorov 2013b

Robust Mode Properties

- 1) The mode's dominant period falls within 15-35 years.
- 2) Westward propagation of density/temperature anomalies in the northern Atlantic Ocean (40-60^{o}N) controls the mode period:

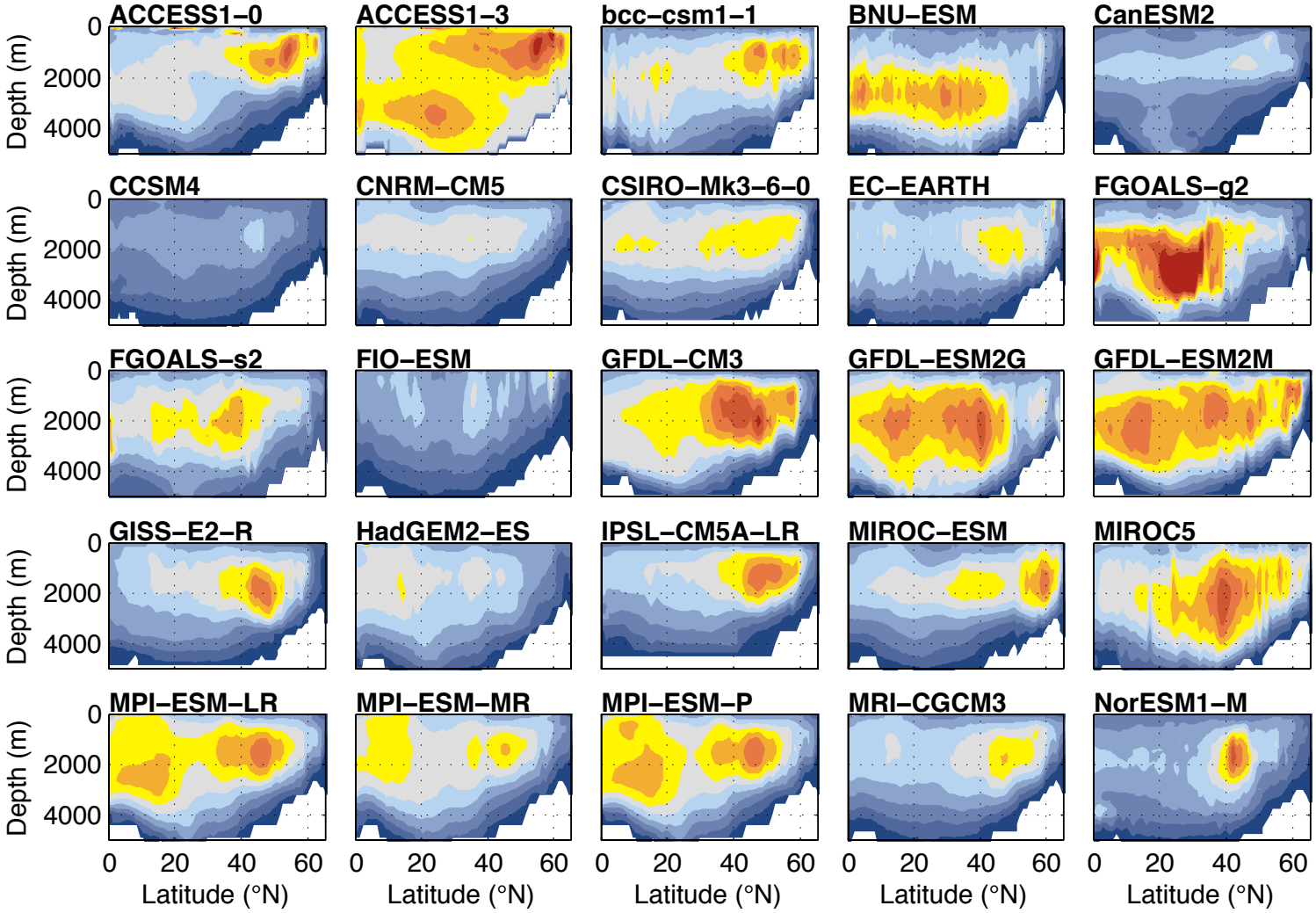
  1⁄2 period ≈ the basin crossing time for the anomalies

- 3) AMOC variations are correlated with the east-west density gradient across the upper northern Atlantic ocean (40-60^{o}N, 200-500m)
- 4) Temperature anomalies averaged over the upper northern Atlantic and the AMOC are in quadrature:

  cold temperature anomalies lead positive AMOC anomalies by ~ 1⁄4 of the mode period

- 5) Density anomalies are controlled by temperature with slight compensation by salinity

CMIP5 AMOC variability

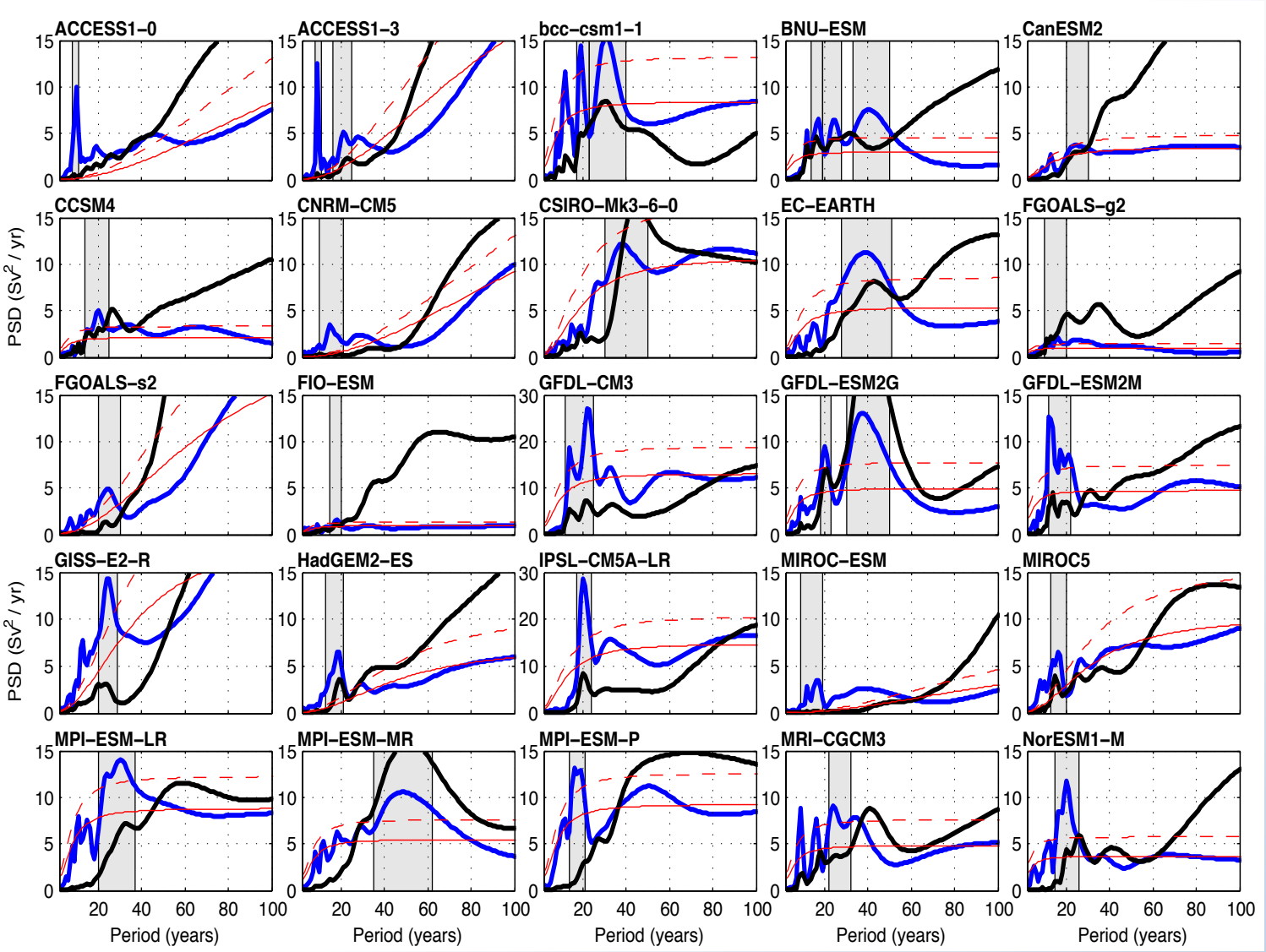


25 Models: Between 450 and 1200 years.

Variability peaks 40°N-60°N in most of the models.

Different magnitudes and locations across all models even from the same modeling group.

AMOC Spectra

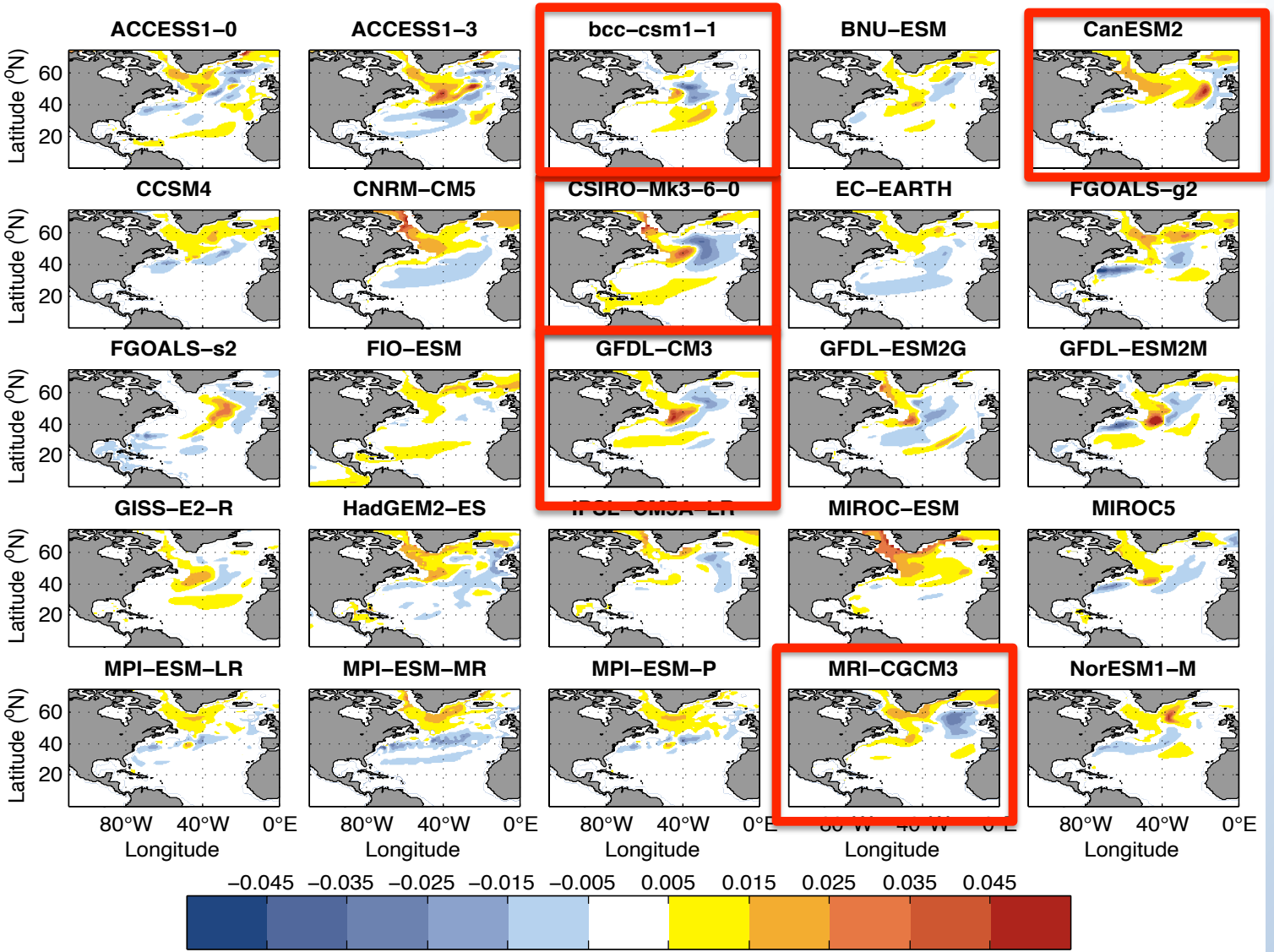


North Atlantic Density

AMOC 45°N

Multidecadal peaks are prominent across the models. In both density and AMOC.

Density Anomalies at an AMOC Peak



Regression of AMOC onto mean density 200-500m.

East-West gradient in Density (and temp).

Most models are temperature dominant with some salinity compensation.

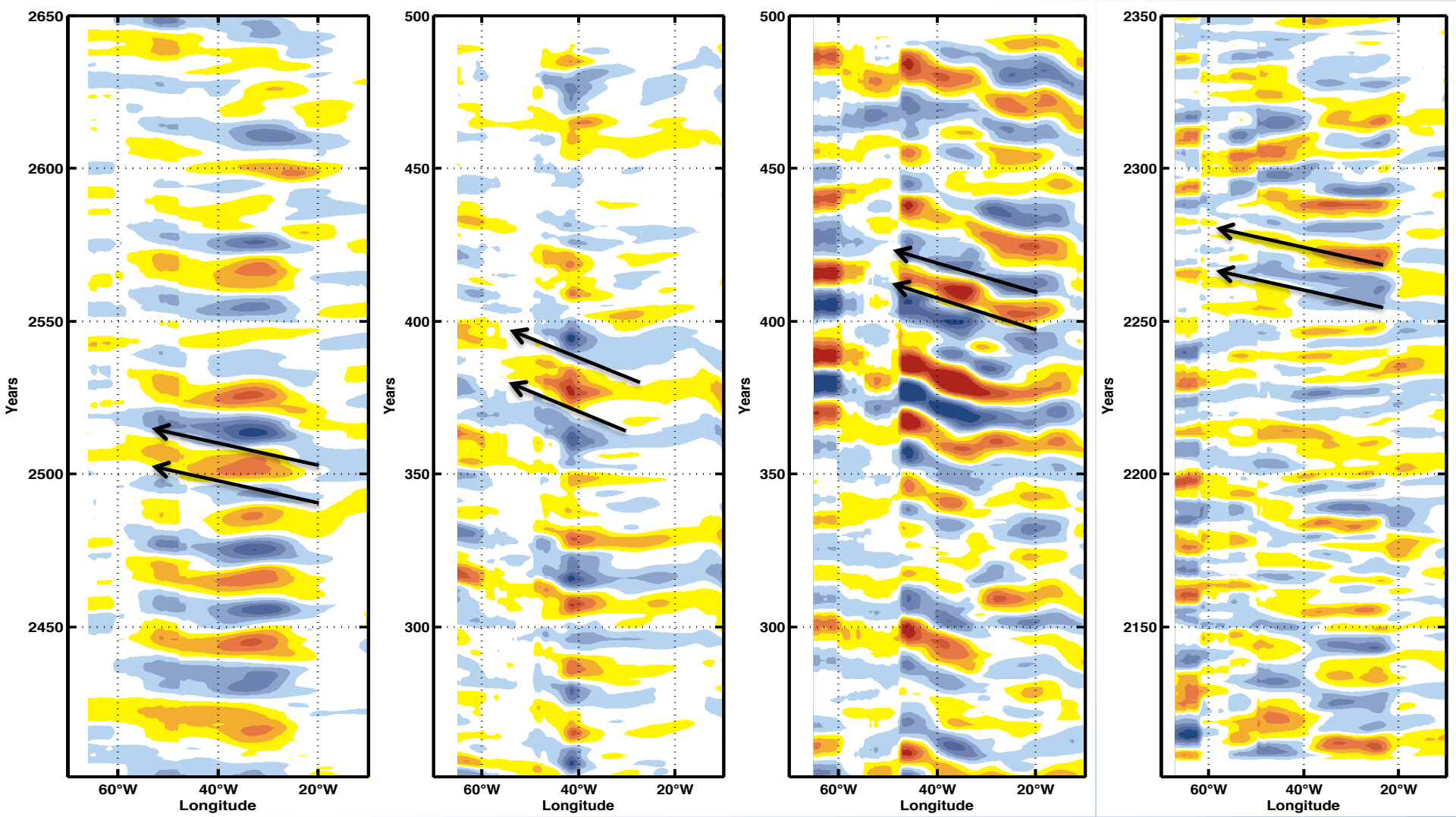
Westward propagation of temperature anomalies (200-500m,40-60ºN)

IPSL−CM5A−LR

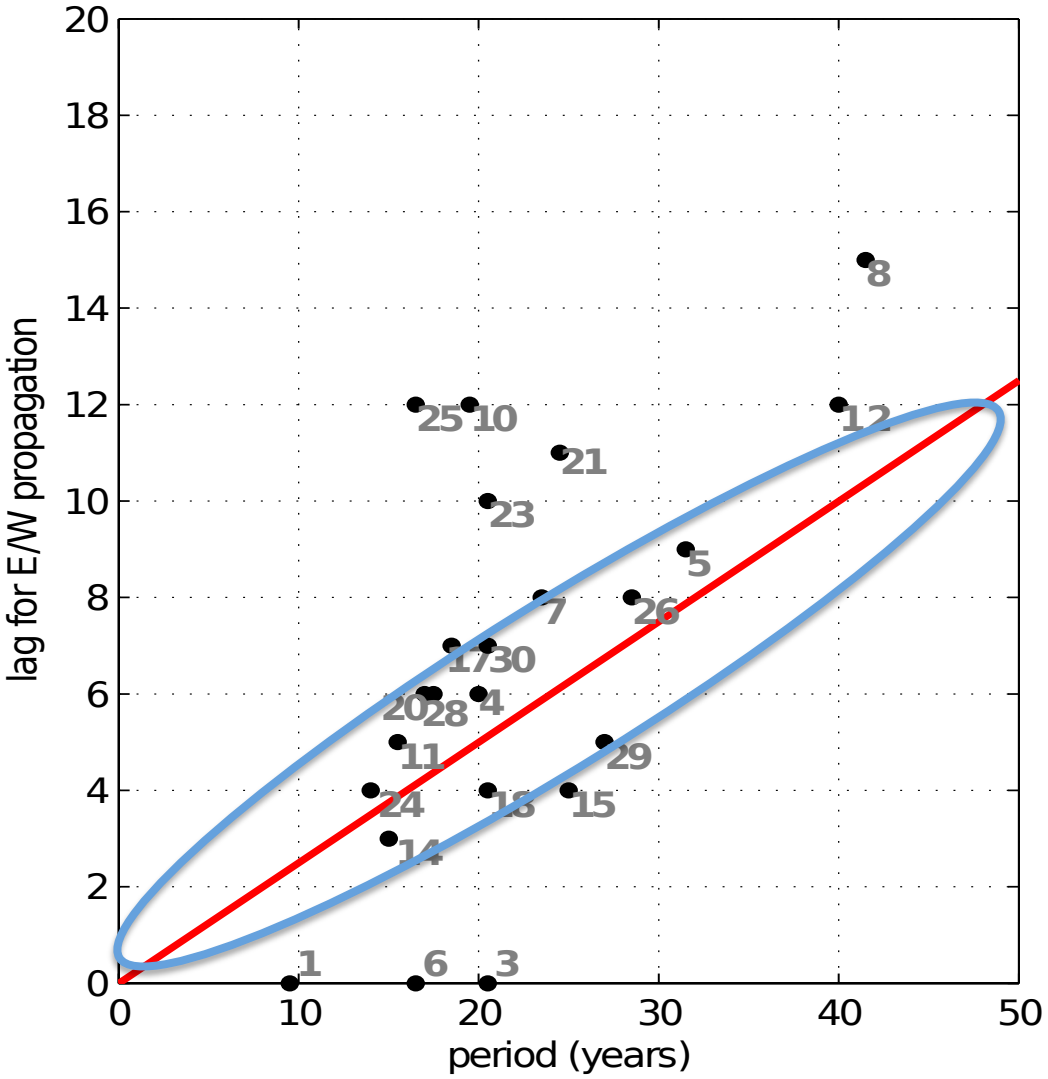
GFDL−ESM2G

GFDL−CM3

MIROC5



Westward Propagation



1	ACCESS1-0
2	ACCESS1-3
3	ACCESS1-3
4	bcc-csm1-1
5	bcc-csm1-1
6	BNU-ESM
7	BNU-ESM
8	BNU-ESM
9	CanESM2
10	CCSM4
11	CNRM-CM5
12	CSIRO-Mk3-6-0
13	EC-EARTH
14	FGOALS-g2
15	FGOALS-s2
16	FIO-ESM
17	GFDL-CM3
18	GFDL-ESM2G
19	GFDL-ESM2G
20	GFDL-ESM2M
21	GISS-E2-R
22	HadGEM2-ES
23	IPSL-CM5A-LR
24	MIROC5
25	MIROC-ESM
26	MPI-ESM-LR
27	MPI-ESM-MR
28	MPI-ESM-P
29	MRI-CGCM3
30	NorESM1-M

MODE MECHANISM:

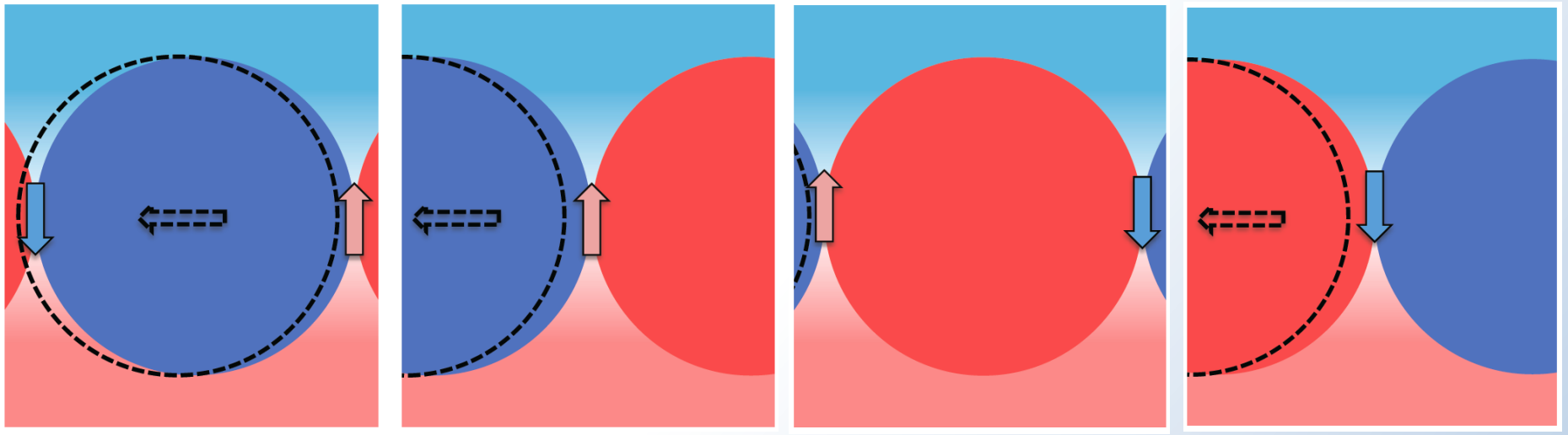
Westward propagation of large-scale depth-integrated temperature (density) anomalies

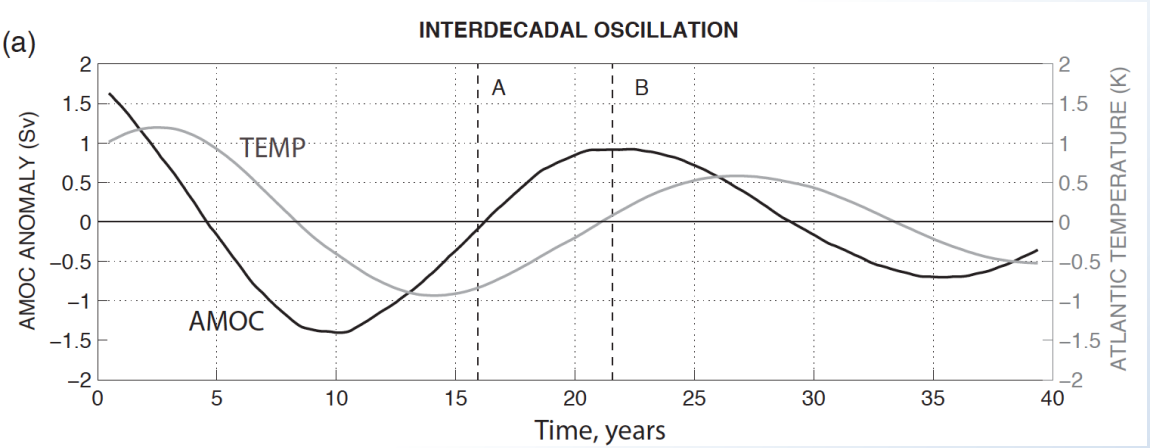
1. Normal AMOC

2. Strong AMOC

3. Normal AMOC

4. Weak AMOC

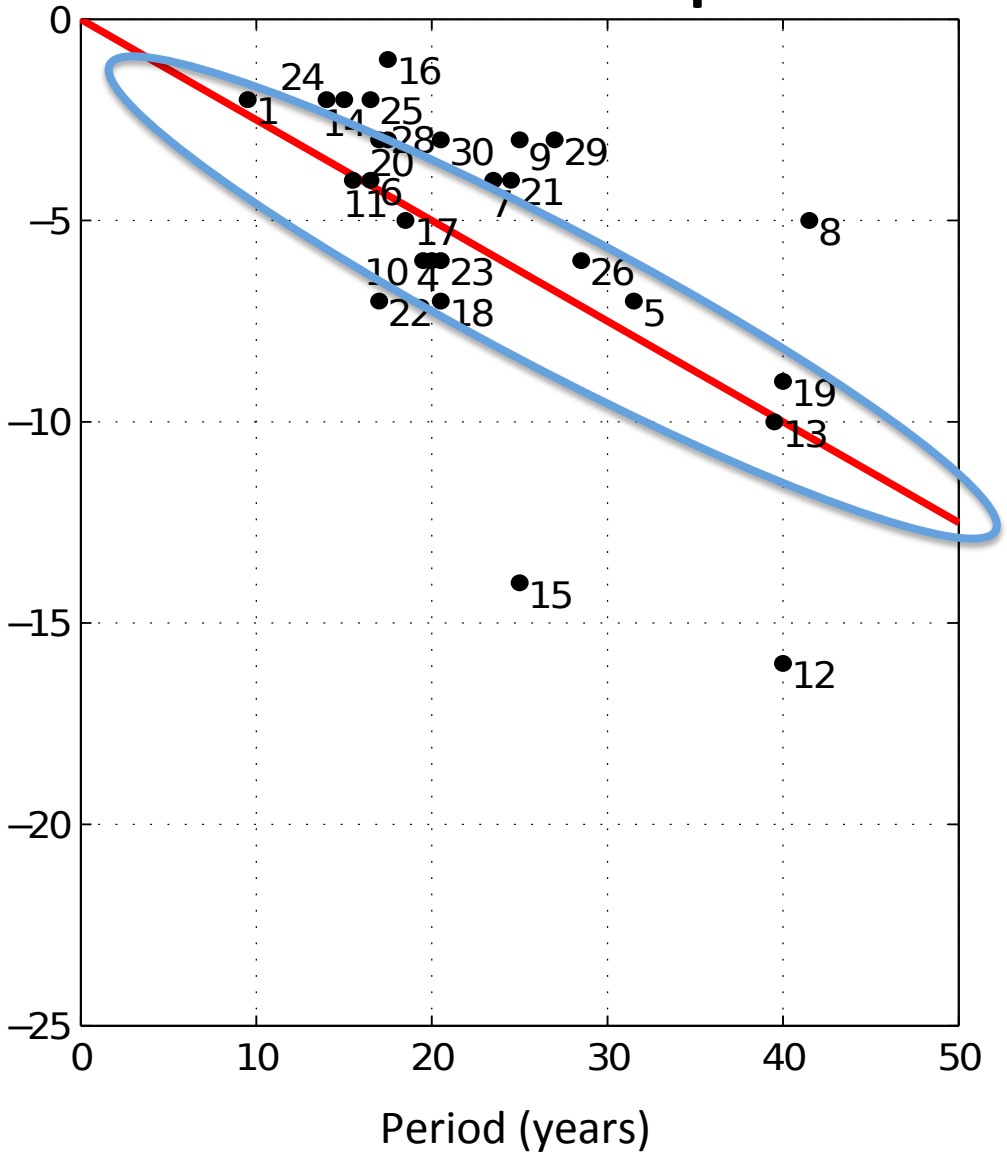




Sevellec and Fedorov 2013a,b

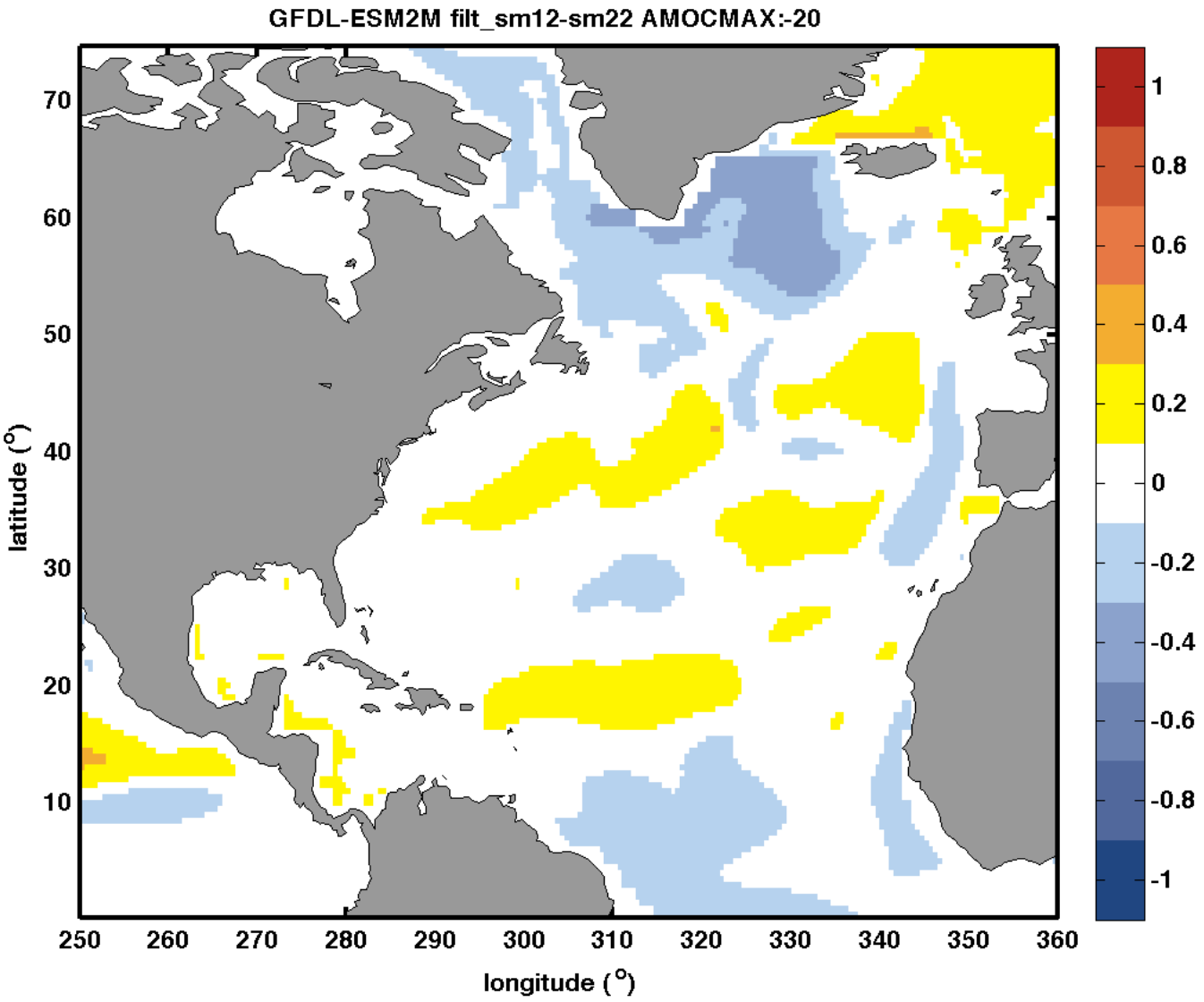
¼ period lag
AMOC and Temp minimum

Lag (years) between AMOC max and Temp min.



1	ACCESS1-0
2	ACCESS1-3
3	ACCESS1-3
4	bcc-csm1-1
5	bcc-csm1-1
6	BNU-ESM
7	BNU-ESM
8	BNU-ESM
9	CanESM2
10	CCSM4
11	CNRM-CM5
12	CSIRO-Mk3-6-0
13	EC-EARTH
14	FGOALS-g2
15	FGOALS-s2
16	FIO-ESM
17	GFDL-CM3
18	GFDL-ESM2G
19	GFDL-ESM2G
20	GFDL-ESM2M
21	GISS-E2-R
22	HadGEM2-ES
23	IPSL-CM5A-LR
24	MIROC5
25	MIROC-ESM
26	MPI-ESM-LR
27	MPI-ESM-MR
28	MPI-ESM-P
29	MRI-CGCM3
30	NorESM1-M

GFDL-ESM2M


GFDL-ESM2M filt_sm12-sm22 AMOCMAX:-20
latitude (°)
70
60
50
40
30
20
10
250
260
270
280
290
300
310
320
330
340
350
360
longitude (°)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

Conclusions.

- We've identified about half of the cmip5 models investigated that contain evidence of a mode of variability linked to westward propagating temperature anomalies.

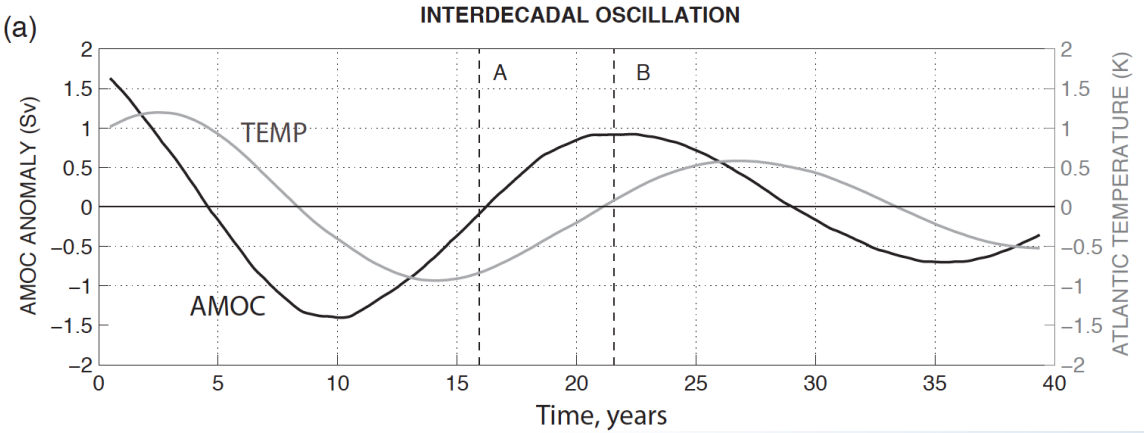
CanESM2	**CNRM-CM5**	**GFDL-CM3**	**GFDL-ESM2G**
GFDL-ESM2M	**GISS-E2-R**	**IPSL-CM5A-LR**	**MIROC5**
MIROC-ESM	**MPI-ESM-LR**	**MPI-ESM-MR**	**MPI-ESM-P**
MRI-CGCM3	**NorESM1-M**		

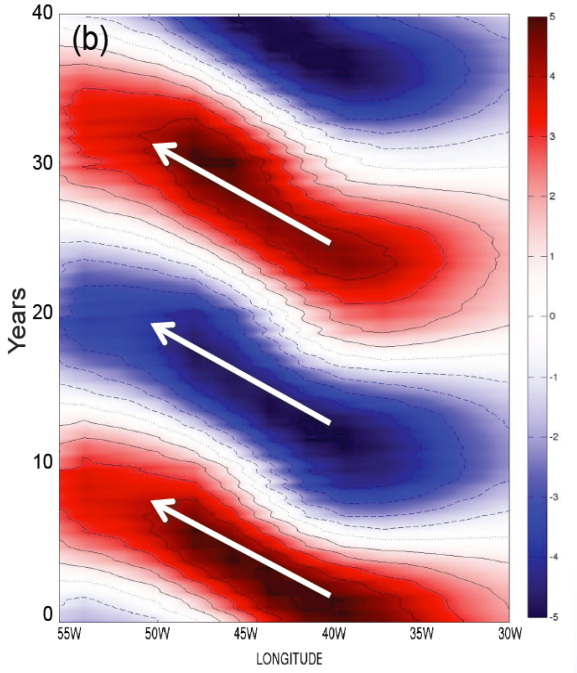
- Once the models that have this behaviour are identified we can start looking at the differences between them.

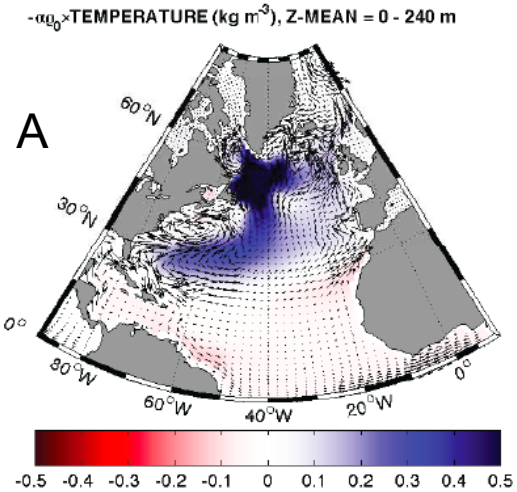
Extra Slides / Content

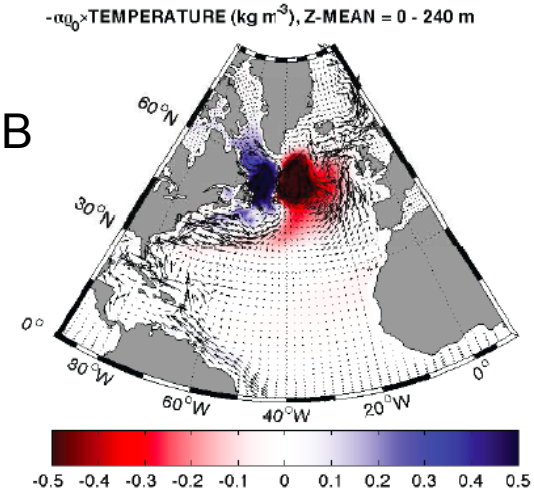
MODE MECHANISM:

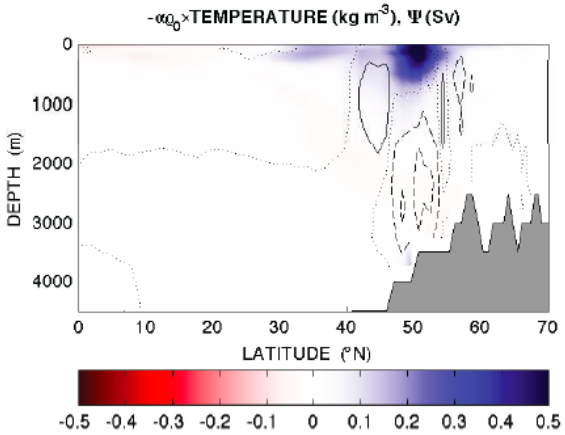
Westward propagation of large-scale depth-integrated temperature (density) anomalies

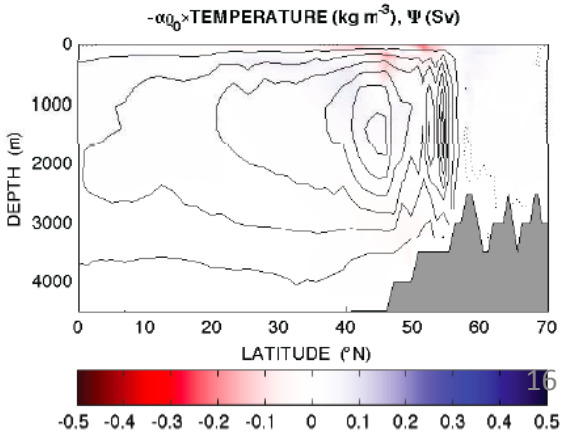




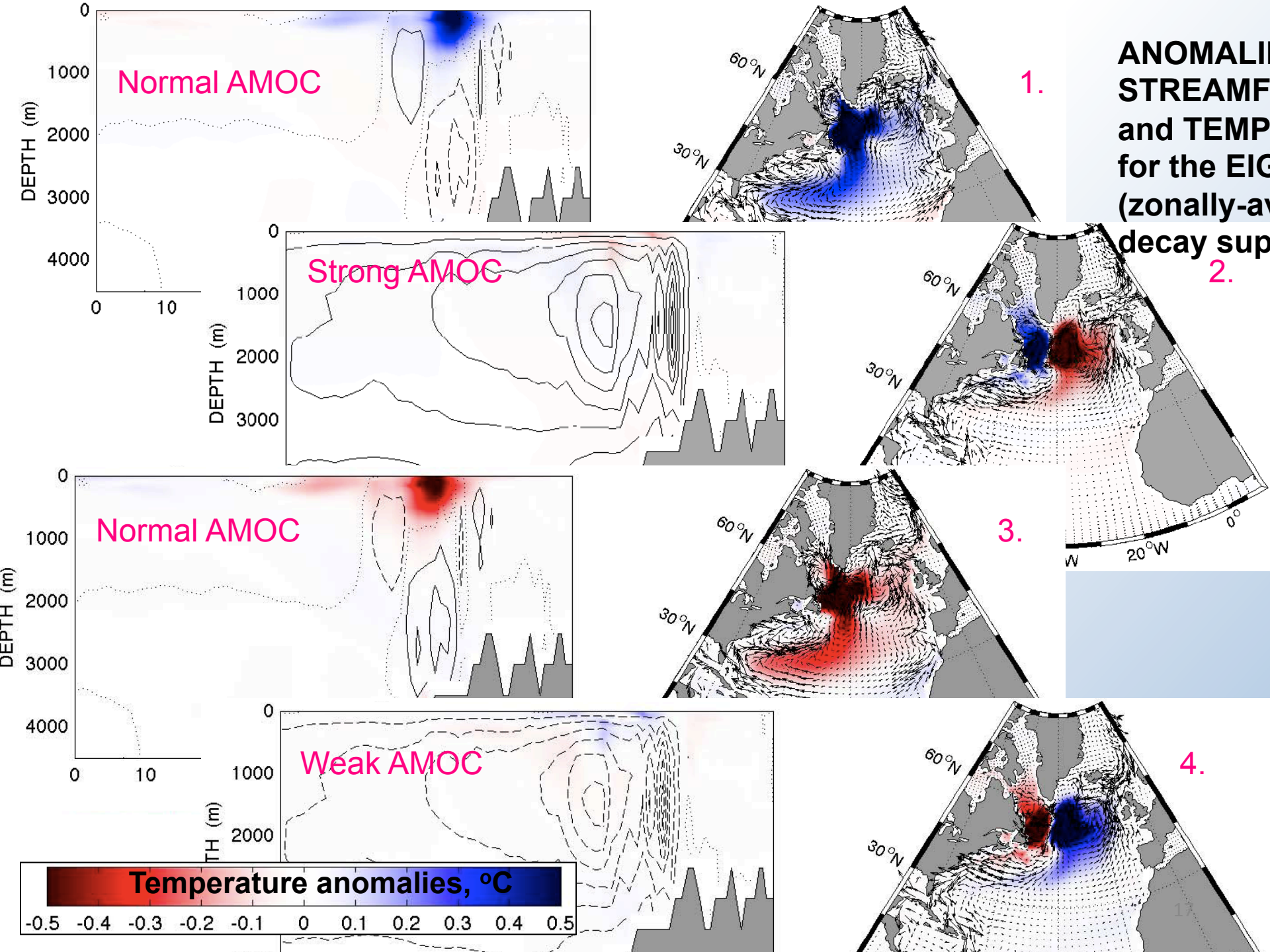




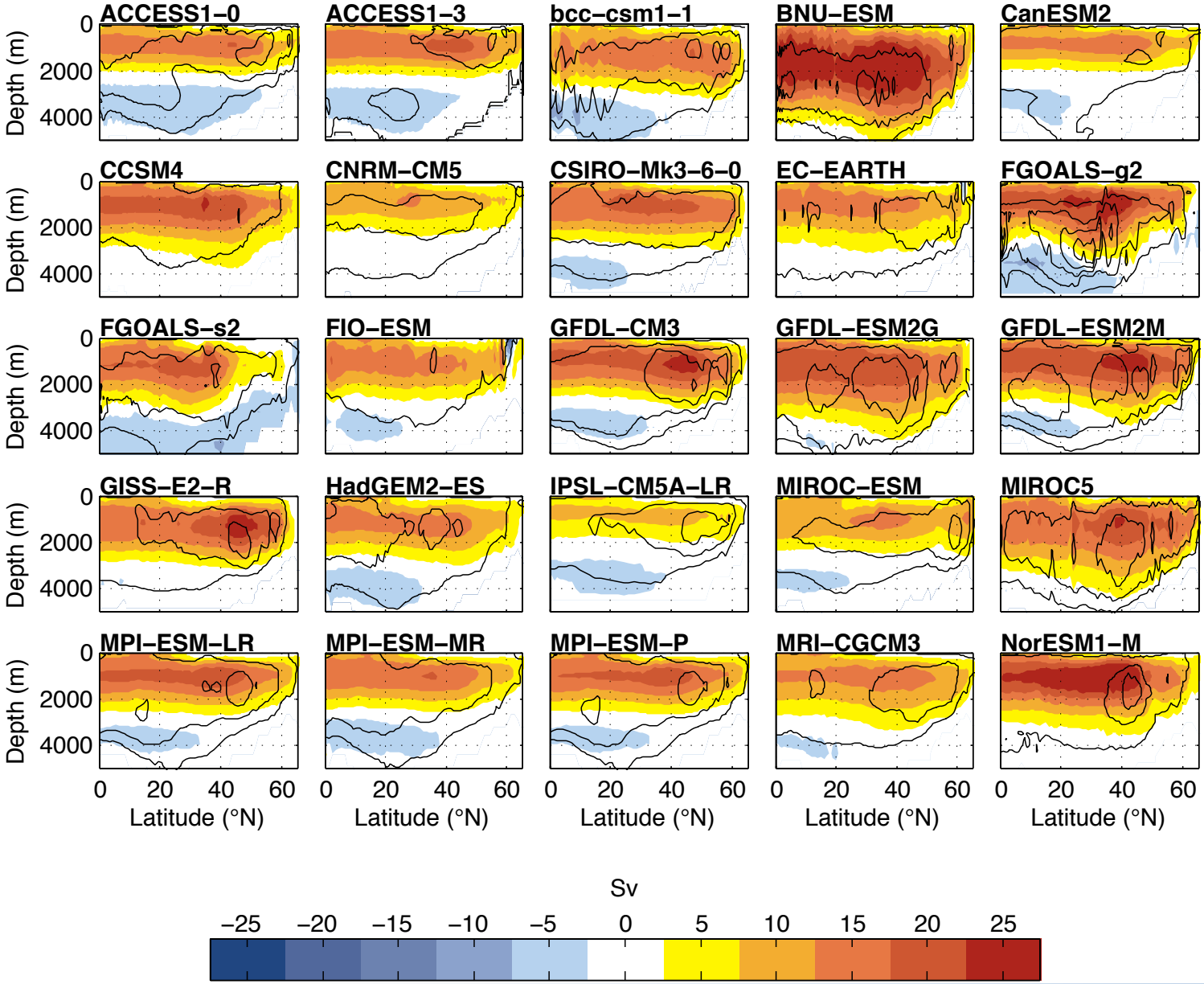




Sevellec and Fedorov 2013a,b


Normal AMOC
DEPTH (m)
0
1000
2000
3000
4000
0
10
1.
60°N
30°N
Strong AMOC
2.
20°W
0°
Normal AMOC
3.
Weak AMOC
4.
Temperature anomalies, °C
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5

CMIP5 AMOC mean state

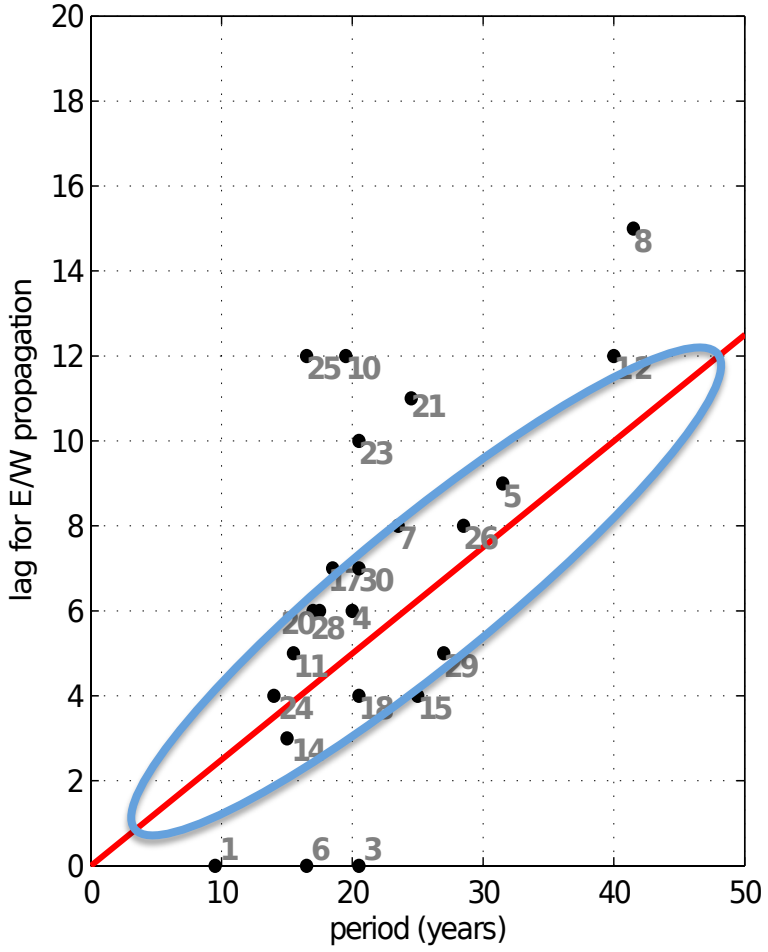


Latitude of max AMOC varies across the models.

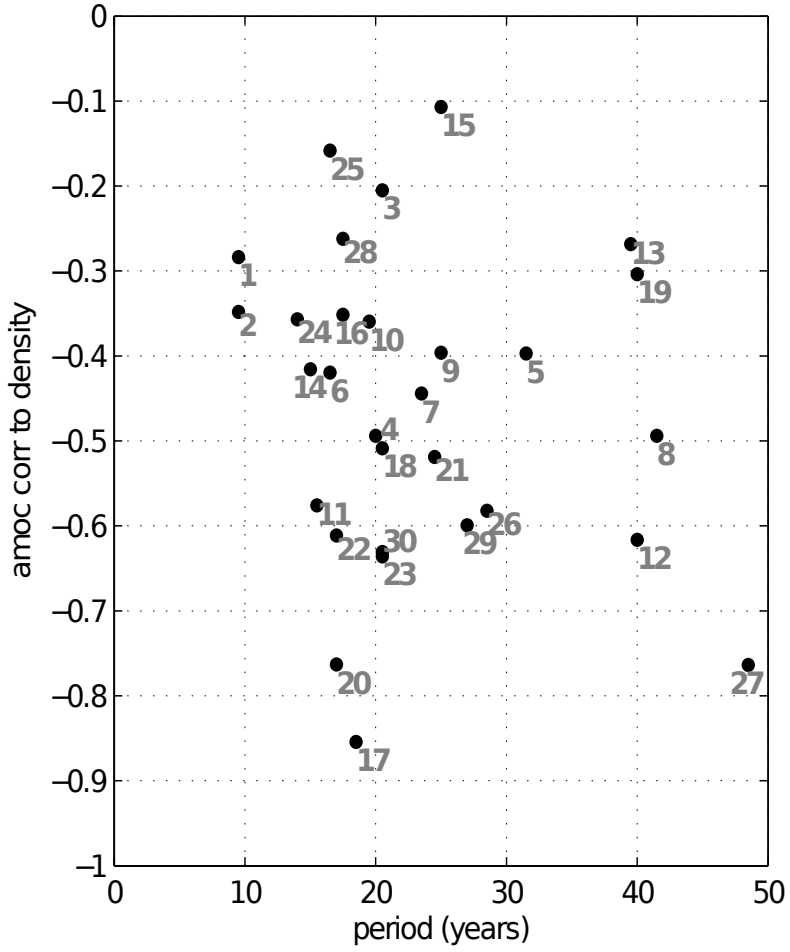
Wide range in magnitude of the mean.

Maximums in mean and variability are no collocated.

Westward Propagation



E-W gradient corr. AMOC



Idealised Model propagation speed.

Propagation speed of temperature anomalies

$c=\bar{U}+U'+c_{rossby}$

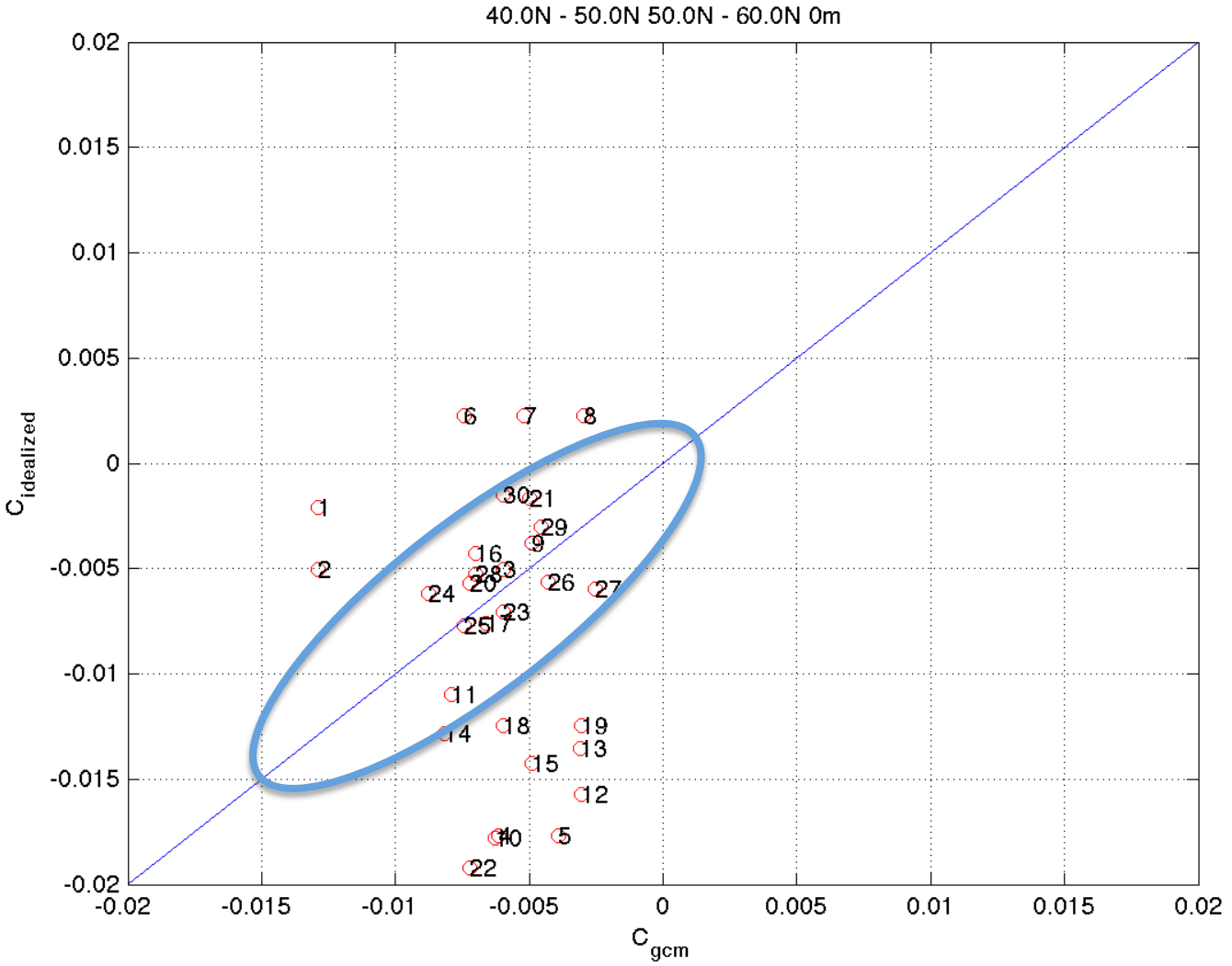
$\bar{U}$- eastward advection by mean flow

$U' \propto \partial_y \bar{T}$ - westward geostrophic self-advection on temp grad

c_{rossby} - baroclinic Rossby wave speed (the β-effect)

Idealised Model propagation speed.

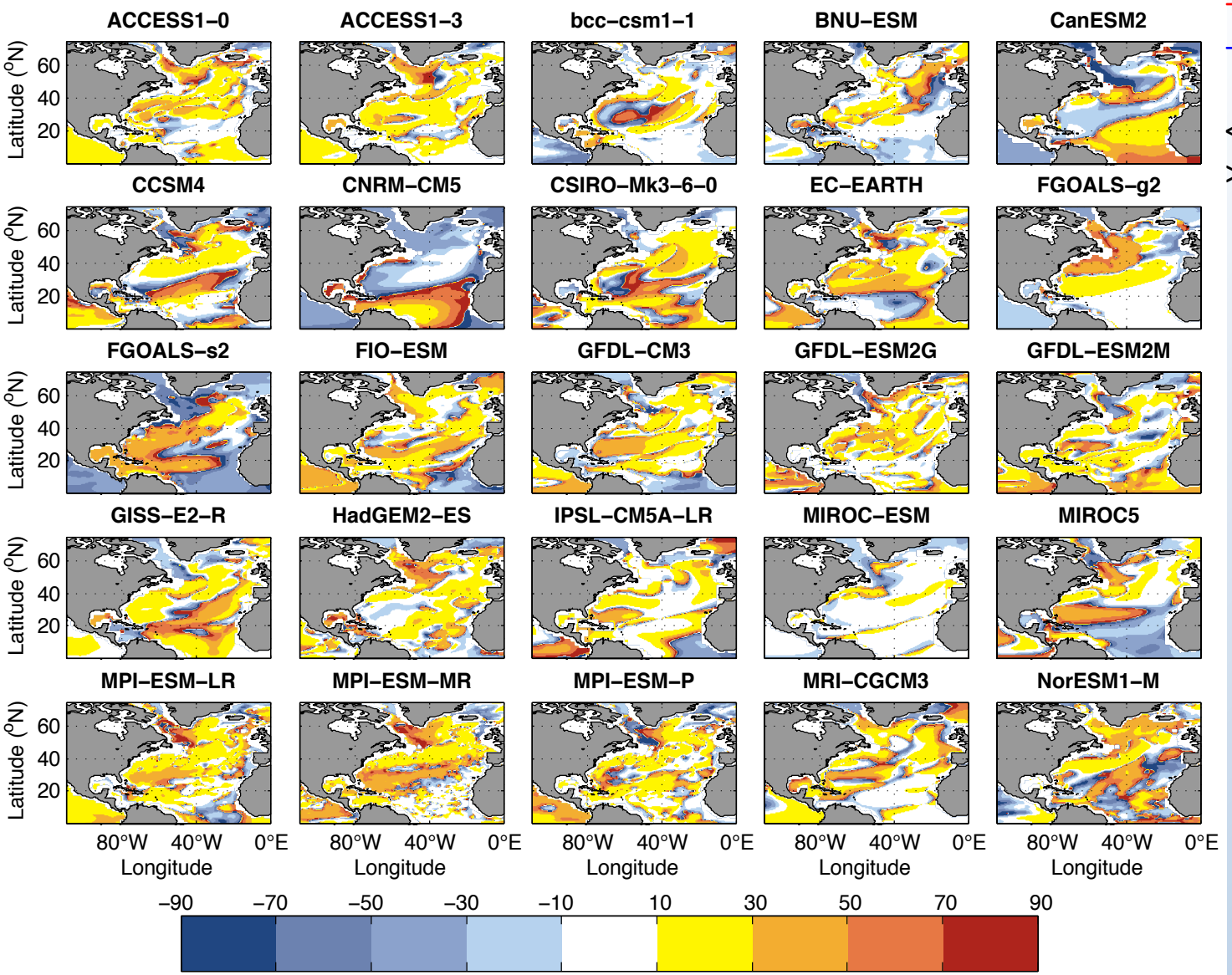
Idealised model (m/s)



GCM (m/s)

‘turner like’ angle

$$\tan^{-1}\left(\frac{\alpha\Delta T - \beta\Delta S}{\alpha\Delta T + \beta\Delta S}\right)$$



+ve : Temp Dominates

-ve: Salinity Dominates

<45° compensation

>45° additive

Most models are temperature dominant with some salinity compensation