Initial Value Predictability of Upper Layer Temperature and AMOC

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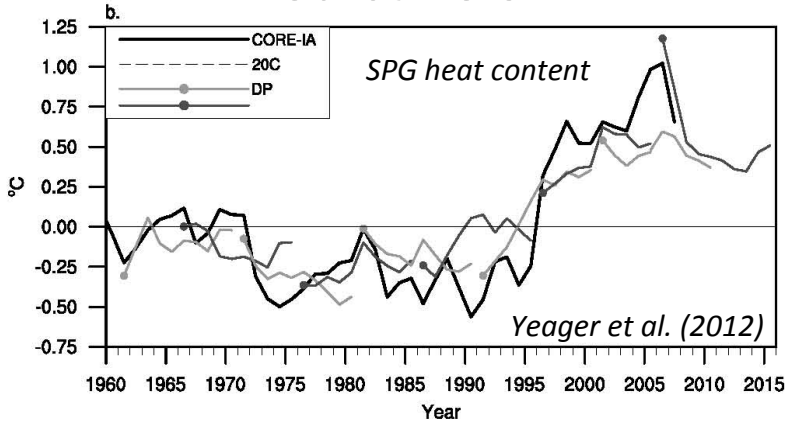
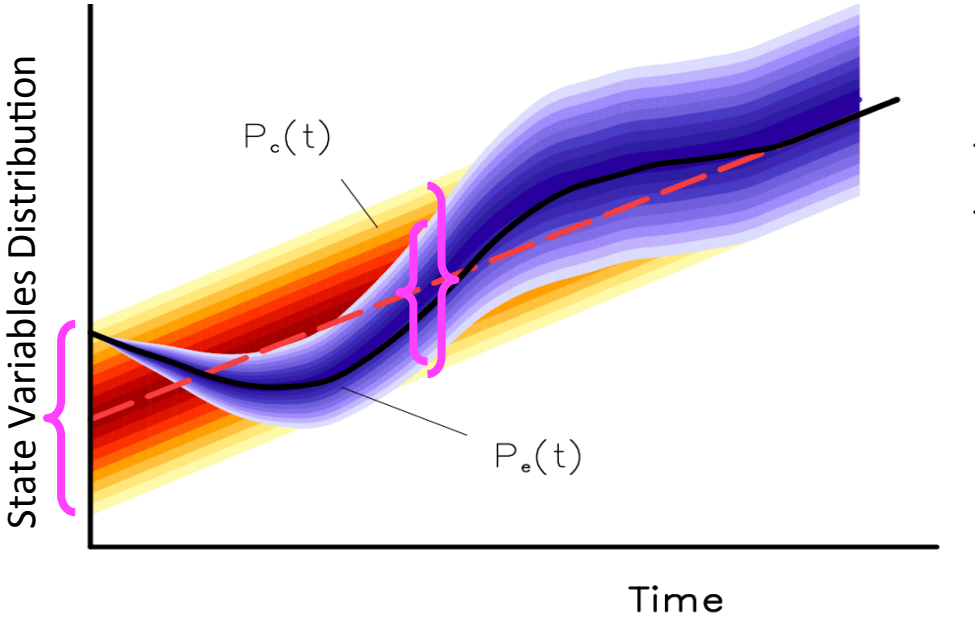
Predictability basics

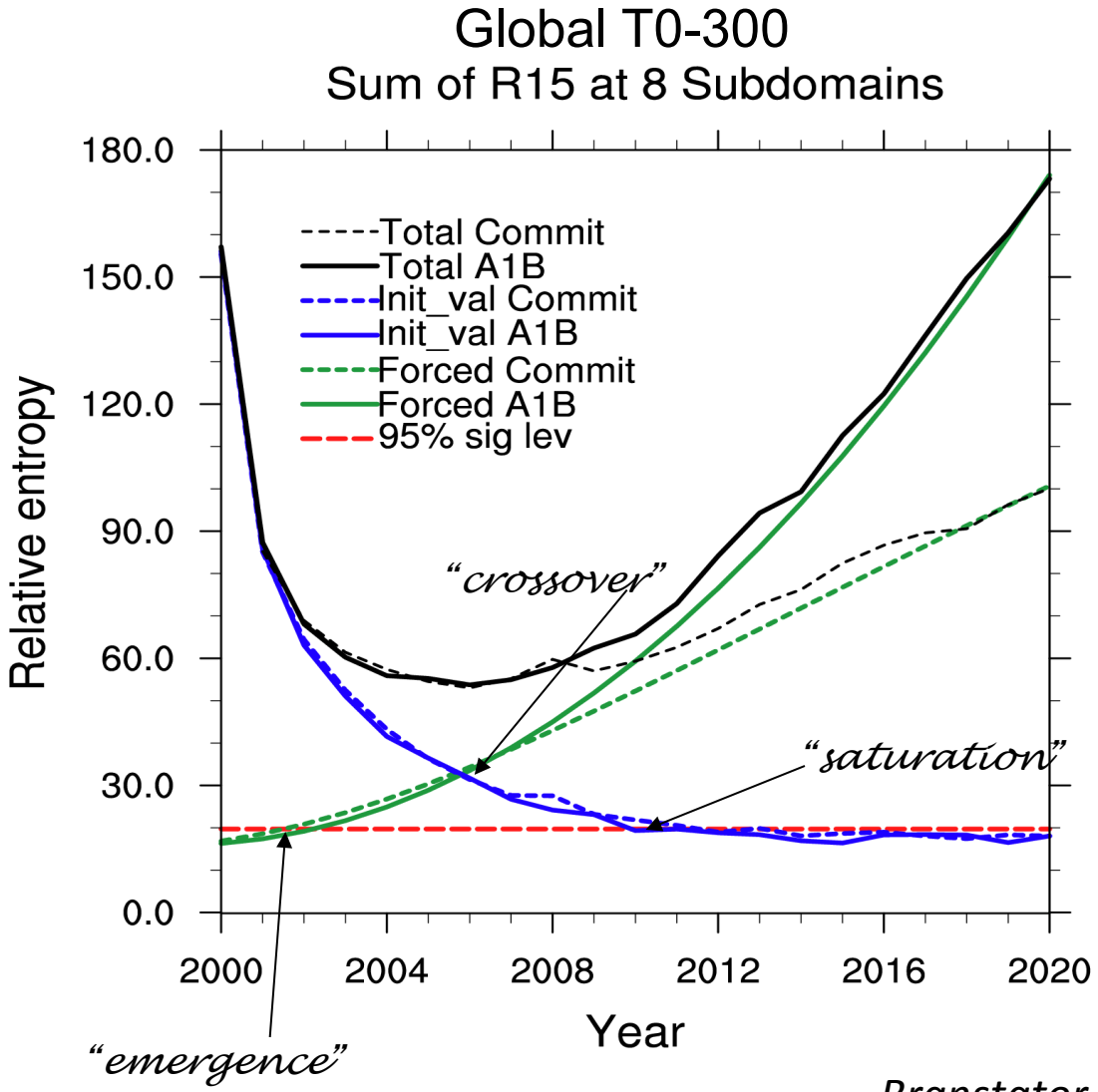
Predictive Skill



Predictability



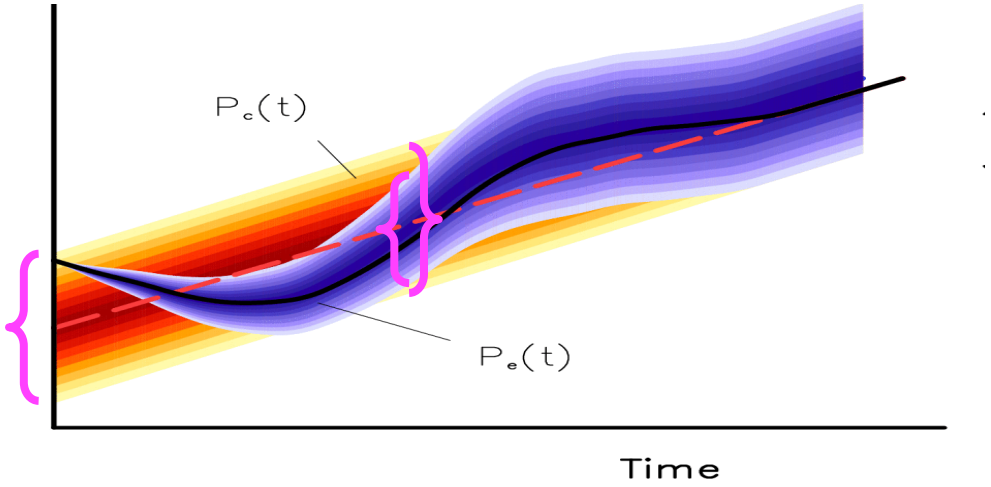
CCSM3



Branstator & Teng (2010)

$$R = \int_S p_x \log_2(p_x / p_c) dS$$

Attractor averages



Predictability from Controls

Method I: Analogs

Method II: Regression dynamics

$$x(t+\tau) = \mathbf{C}(\tau)\mathbf{C}^{-1}(0)x(t) \qquad \text{for } \mathbf{C}(\tau) = \text{lag cov matrix}$$

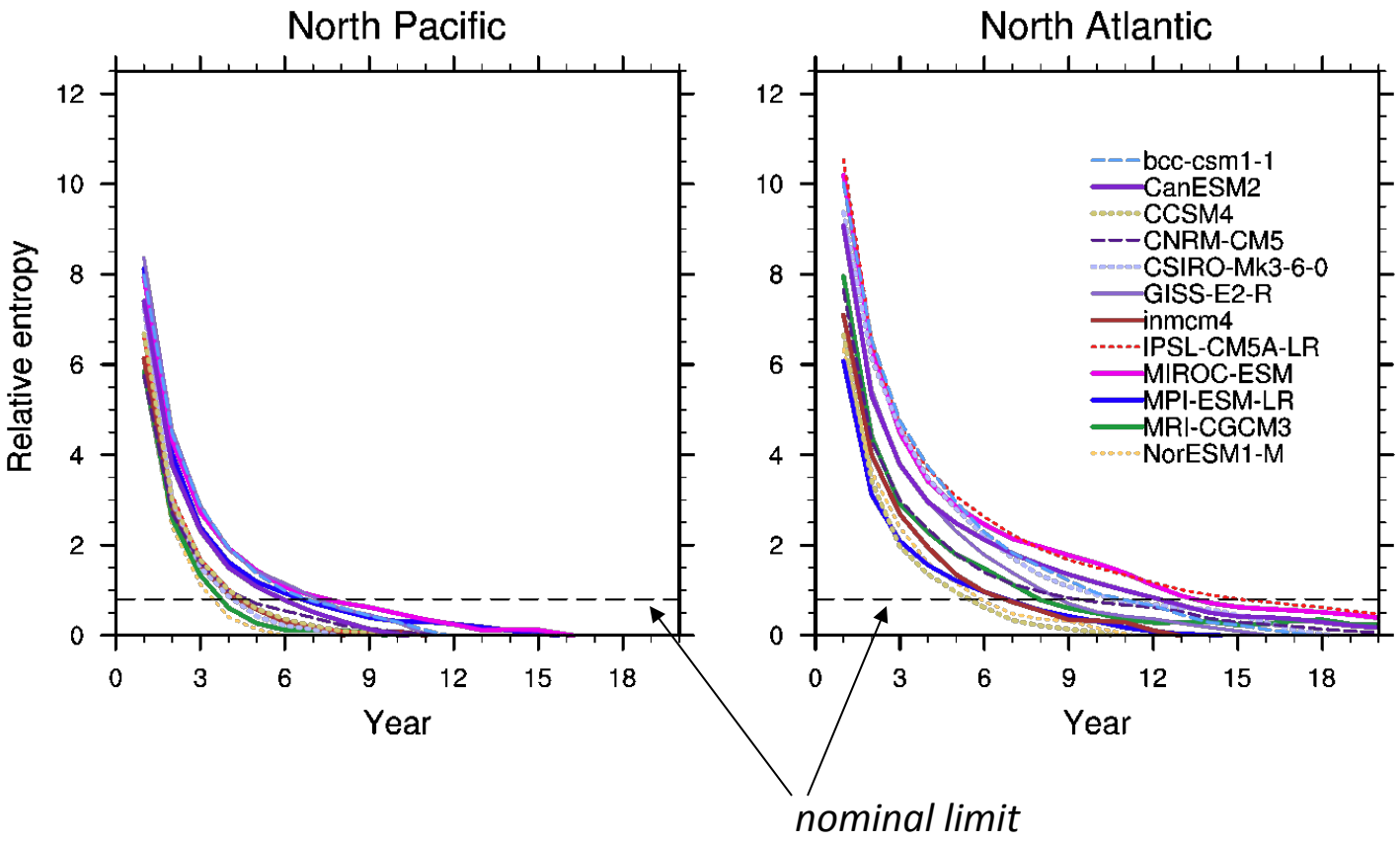
- DelSole & Tippet (2009)
- Lorenz (1969)

Subsurface temperature predictability in CMIP5 models

CMIP5

Initial Value Predictability

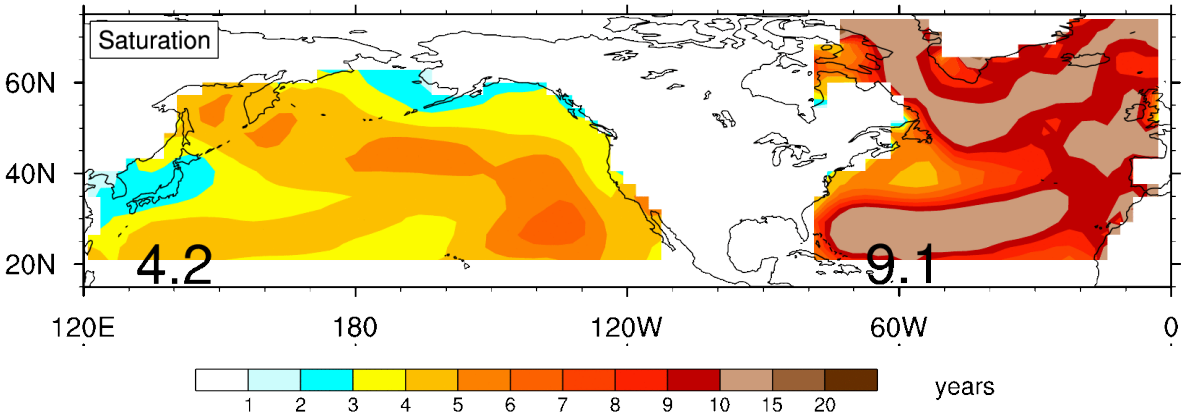
T0-300 10 PCs



(minimum of 500 years in each control)

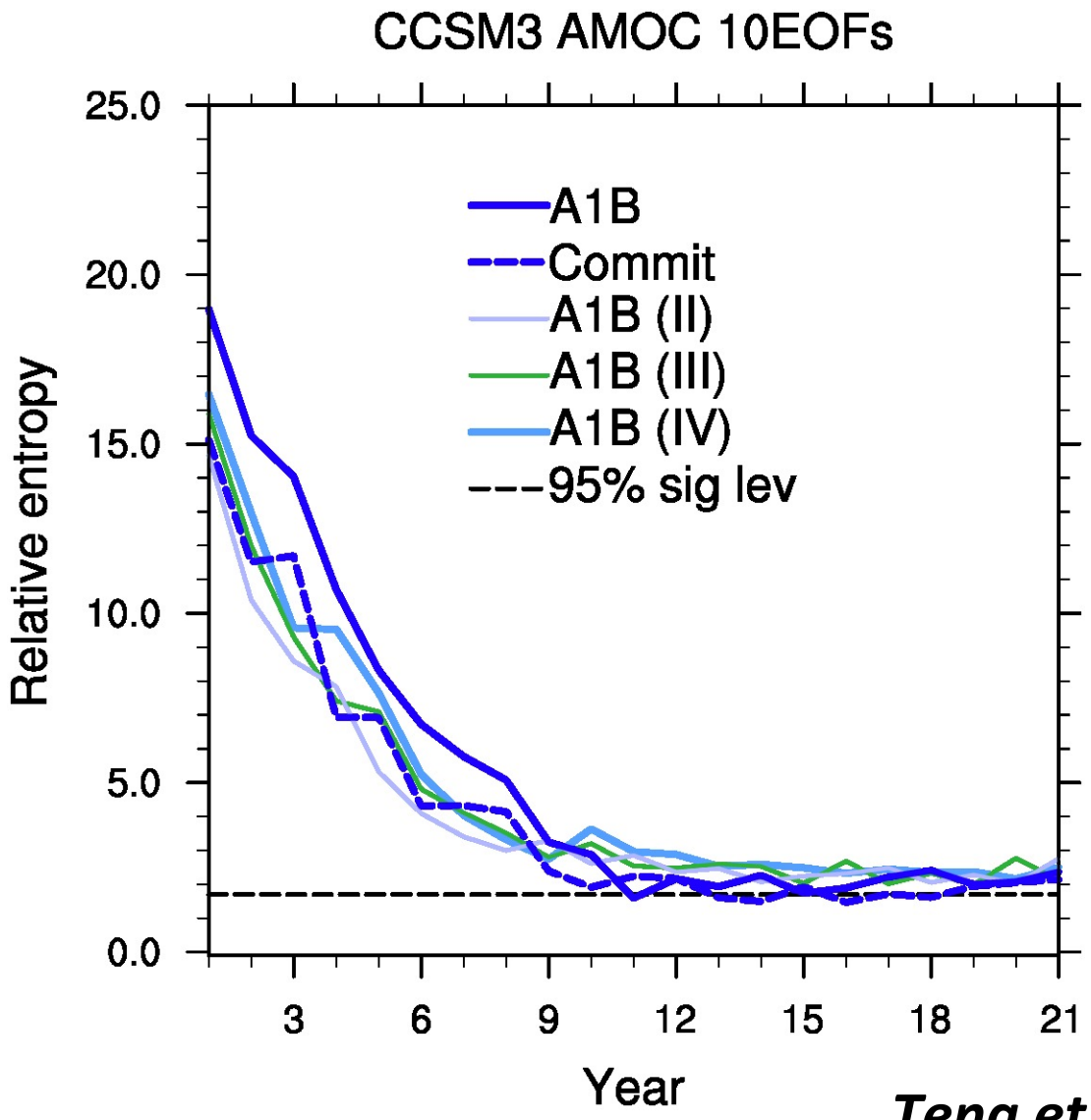
CMIP5

Predictability Limits Averaged Across Models



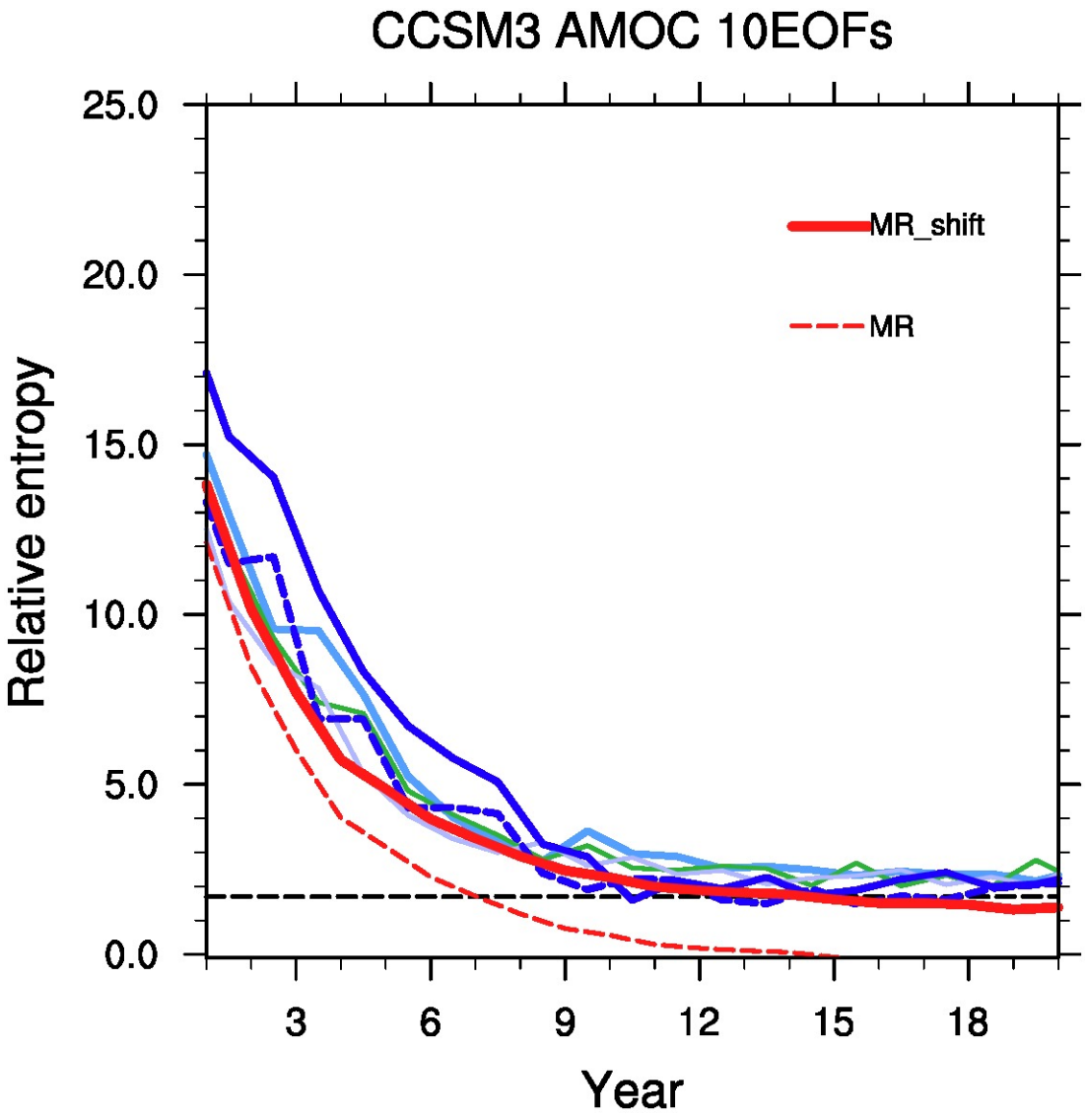
AMOC predictability

Predictability of AMOC from 40 member ensembles



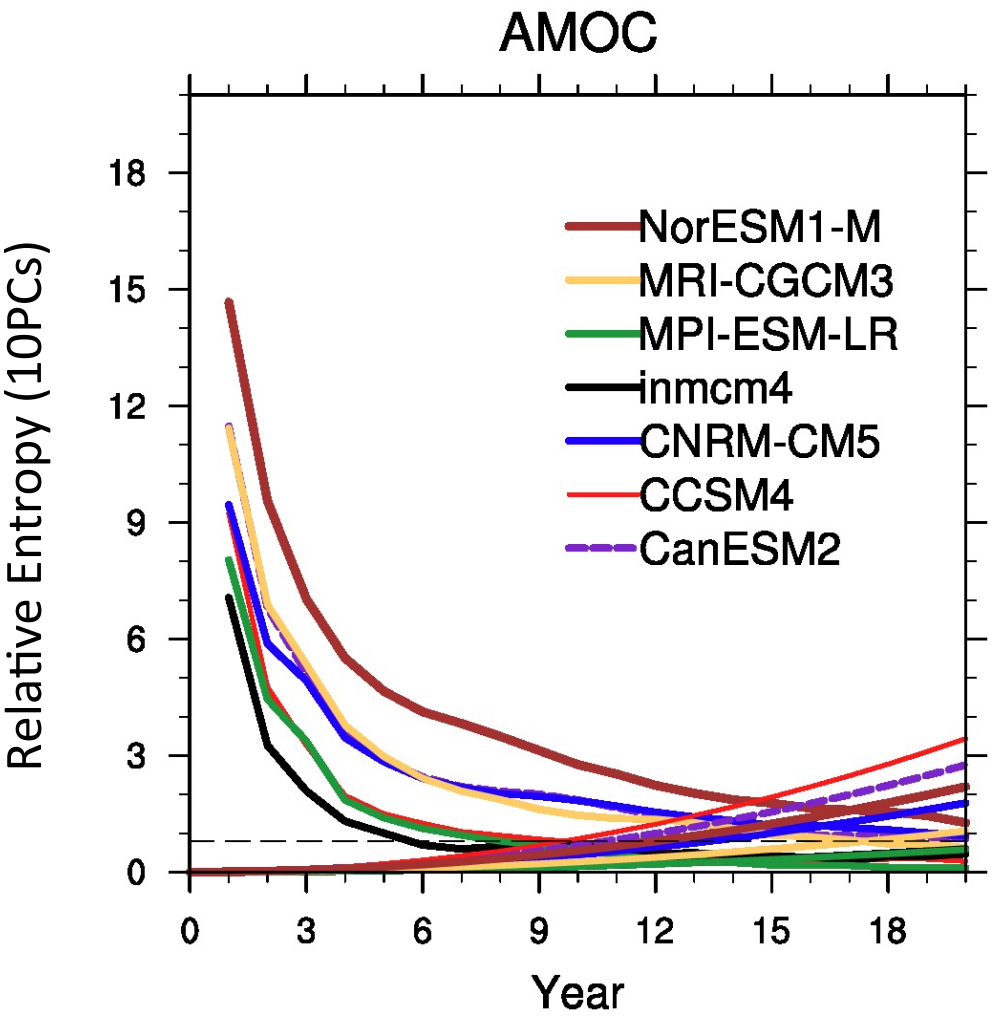
Teng et al. (2011)

Estimating AMOC Predictability from Control



CMIP5

Initial Value & Forced Predictability

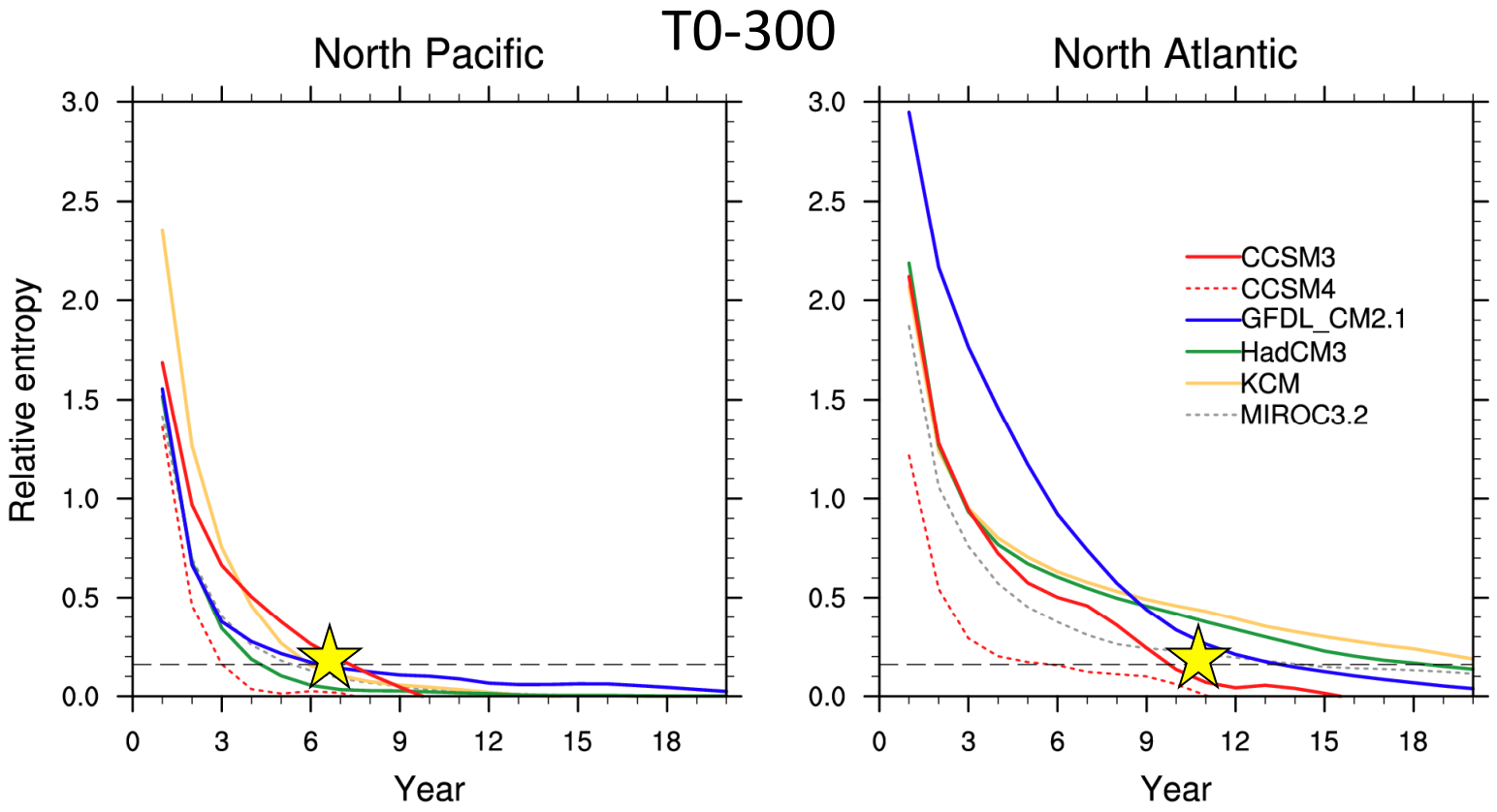


(minimum of 500 years in each control)

Do prominent modes have high predictability?

preCMIP5

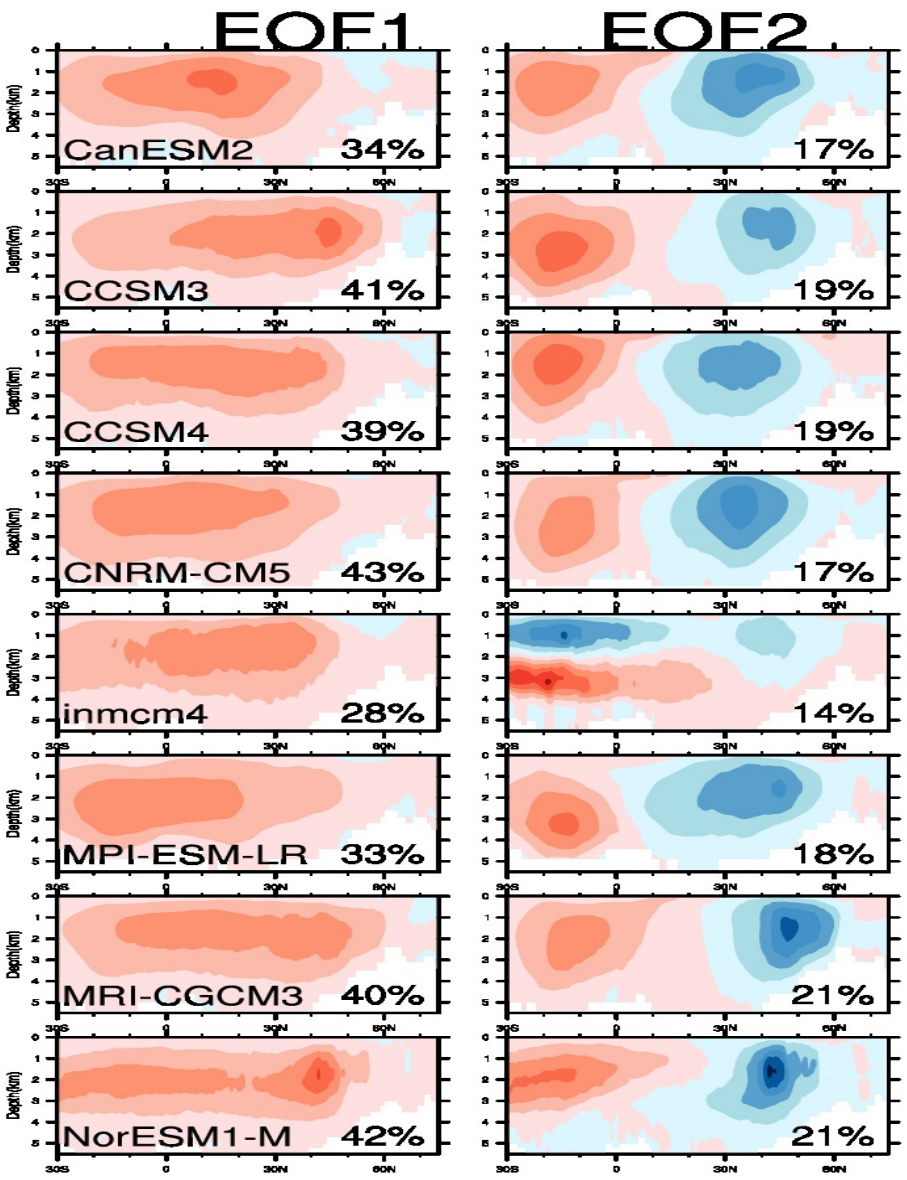
Relative Entropy for CEOF1

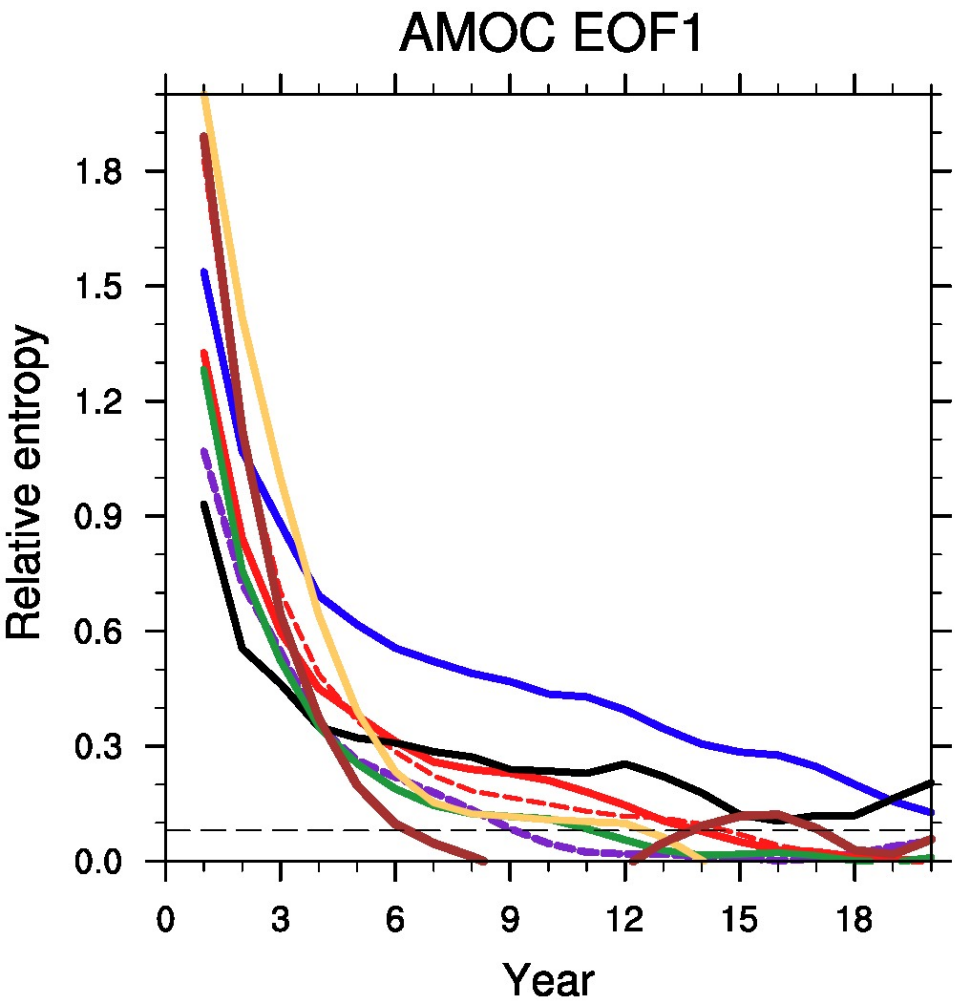


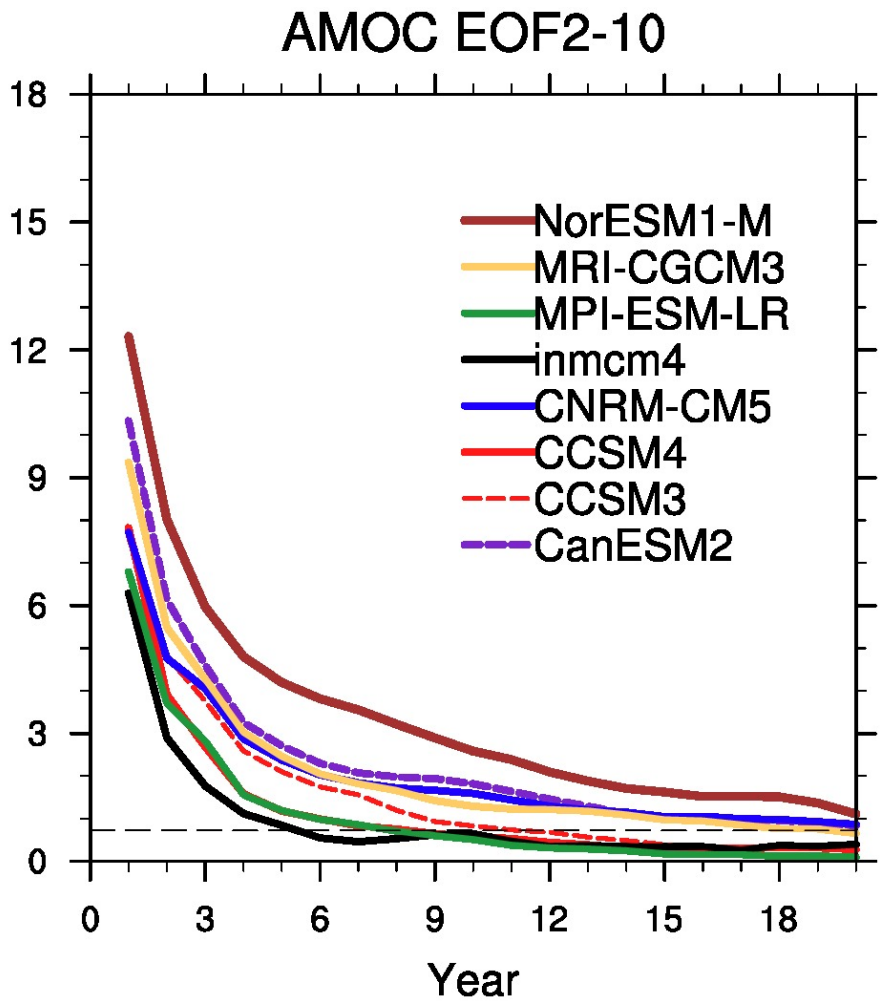
PDO

Counterclockwise propagating SPG dipole

AMOC EOFs


EOF1
EOF2
CanESM2
34%
17%
CCSM3
41%
19%
CCSM4
39%
19%
CNRM-CM5
43%
17%
inmcm4
28%
14%
MPI-ESM-LR
33%
18%
MRI-CGCM3
40%
21%
NorESM1-M
42%
21%
Depth(km)
30S
0
30N
60N


AMOC EOF1
Relative entropy
1.8
1.5
1.2
0.9
0.6
0.3
0.0
0
3
6
9
12
15
18
Year


AMOC EOF2-10
18
15
12
9
6
3
0
0
3
6
9
12
15
18
Year
NorESM1-M
MRI-CGCM3
MPI-ESM-LR
inmcm4
CNRM-CM5
CCSM4
CCSM3
CanESM2

Might there be highly predictable AMOC events?

Fluctuation Dissipation Theorem

(Leith, 1975; Deker&Haake, 1975; Risken, 1984)

Suppose have a discretized dynamical system with weak anomalous forcing f, such that there is noise in the system, the statistics are quasi-Gaussian and it has a unique F-P eqn, then

the operator that gives the mean response at time *t* to a pulse forcing at t_0 is

$$\delta U(t,t_0) = C(t-t_0)C^{-1}(0),$$

$$\text{for } C(\tau) = \text{lag cov matrix}$$

$$\Rightarrow$$

$$R(t) = \int_{t_0}^{t} C(t-\tau)C^{-1}(0)\,f(\tau)\,d\tau$$

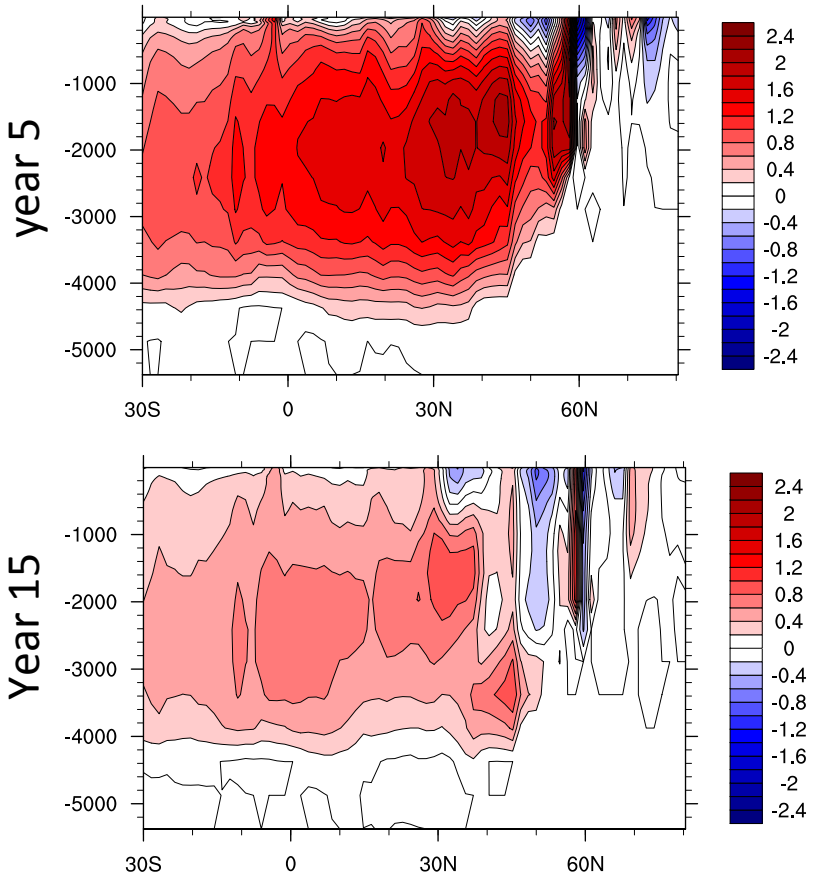
Gritsun & Branstator (2007)

CCSM4 T31x3

Maximized AMOC Response to Surface Heat Flux

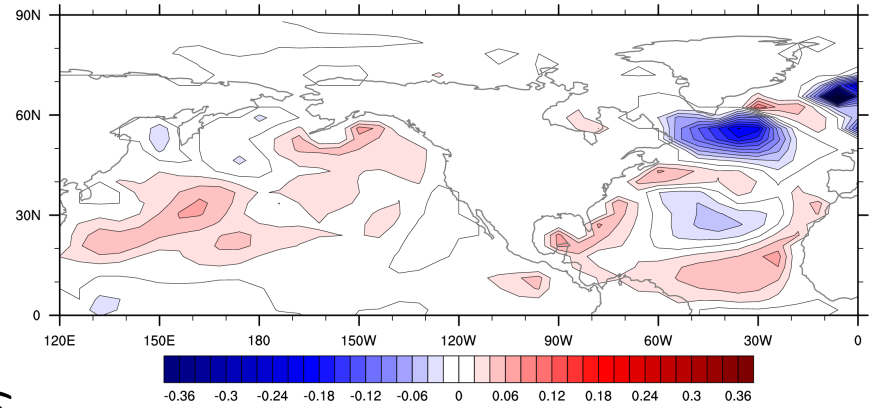
maximize year 5

AMOC Response



Optimal Heat Flux Forcing

(imposed for 5 years)



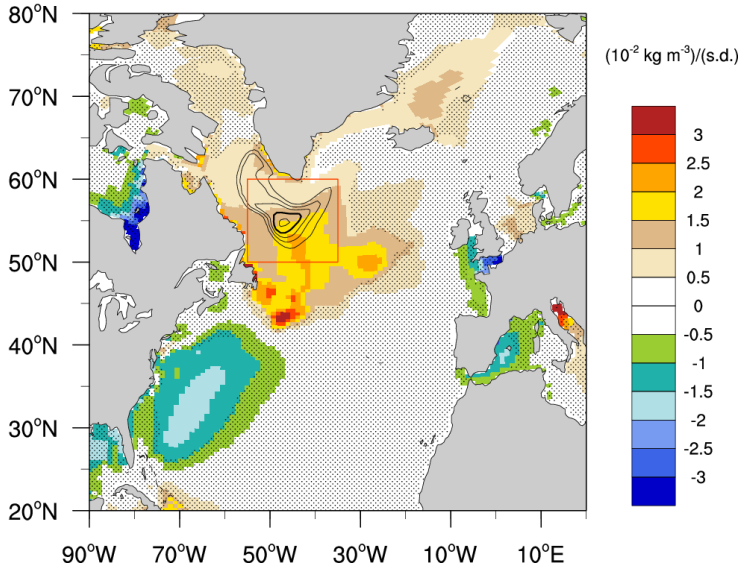
(K/month)

CCSM4 T31x3

Maximized AMOC Response to Surface Heat Flux

maximize year 5

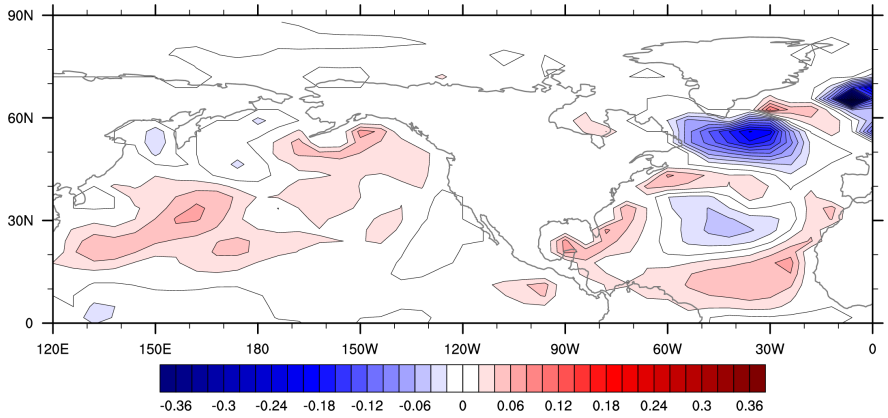
Density0-203 & BL depth Leading AMOC PC1 by 2 years



Danabasoglu et al. (2012)

Optimal Heat Flux Forcing

(imposed for 5 years)



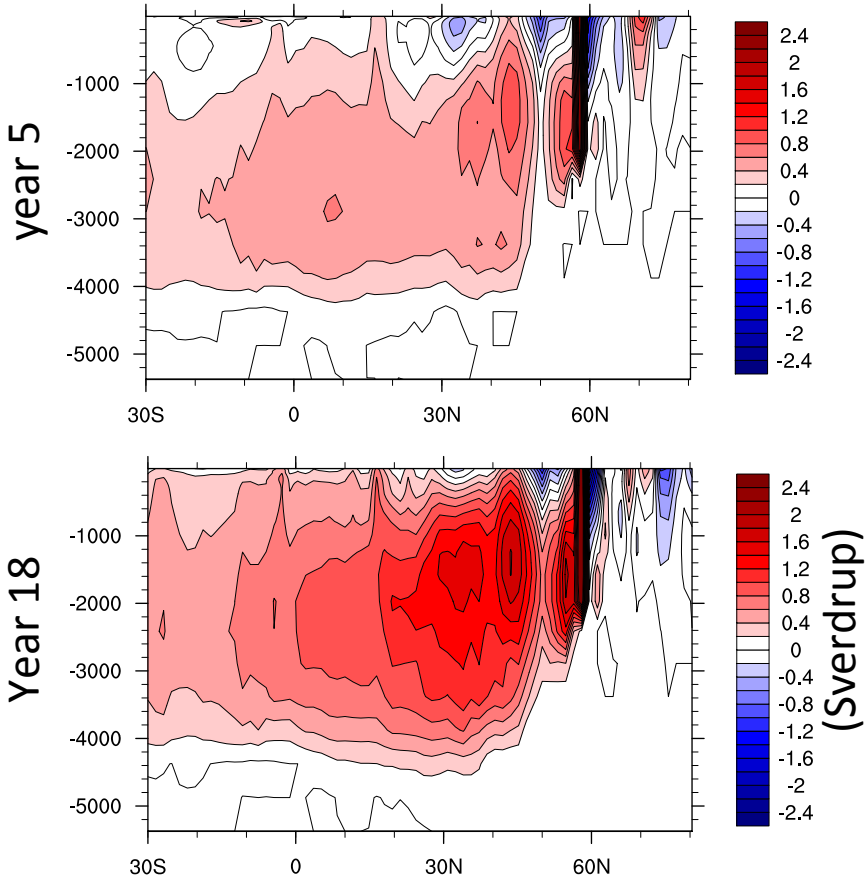
(K/month)

CCSM4 T31x3

Maximized AMOC Response to Surface Heat Flux

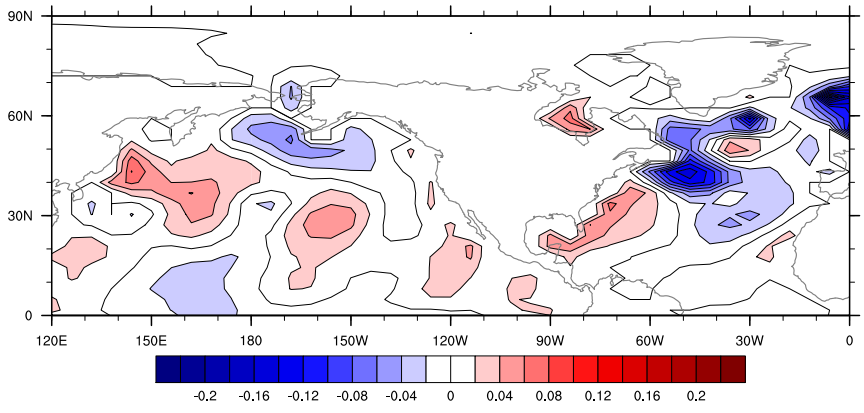
maximize year 18

AMOC Response



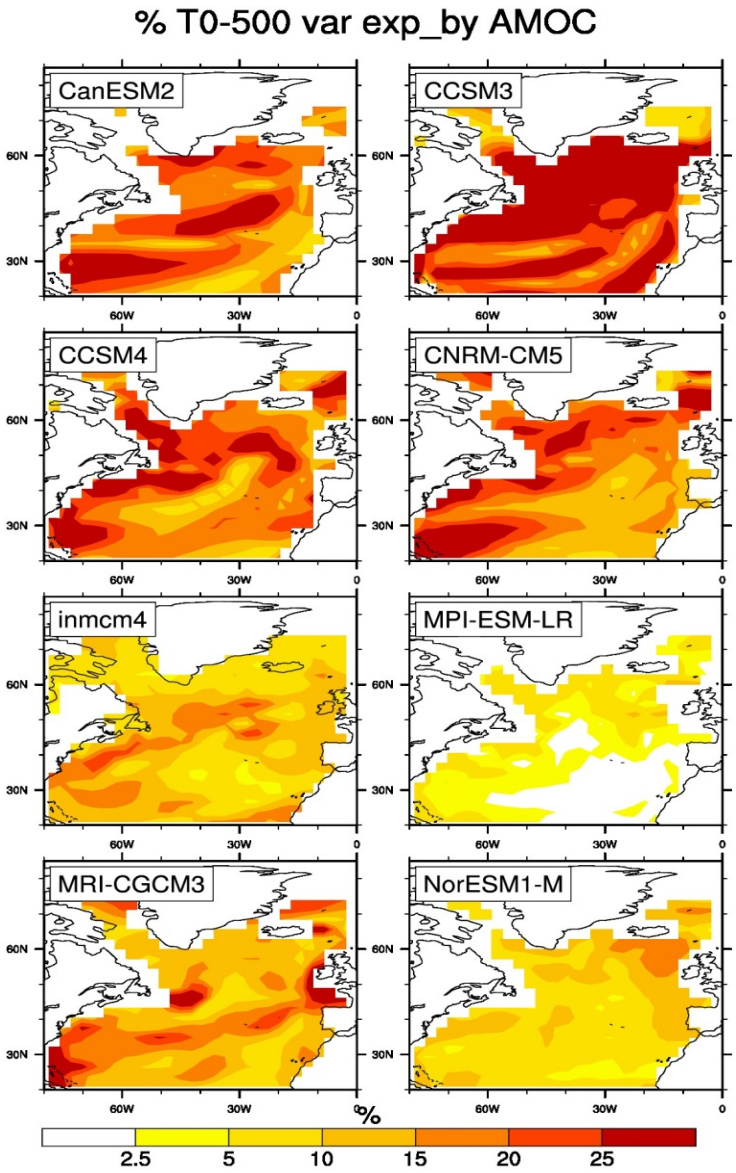
Optimal Heat Flux Forcing

(imposed for 5 years)

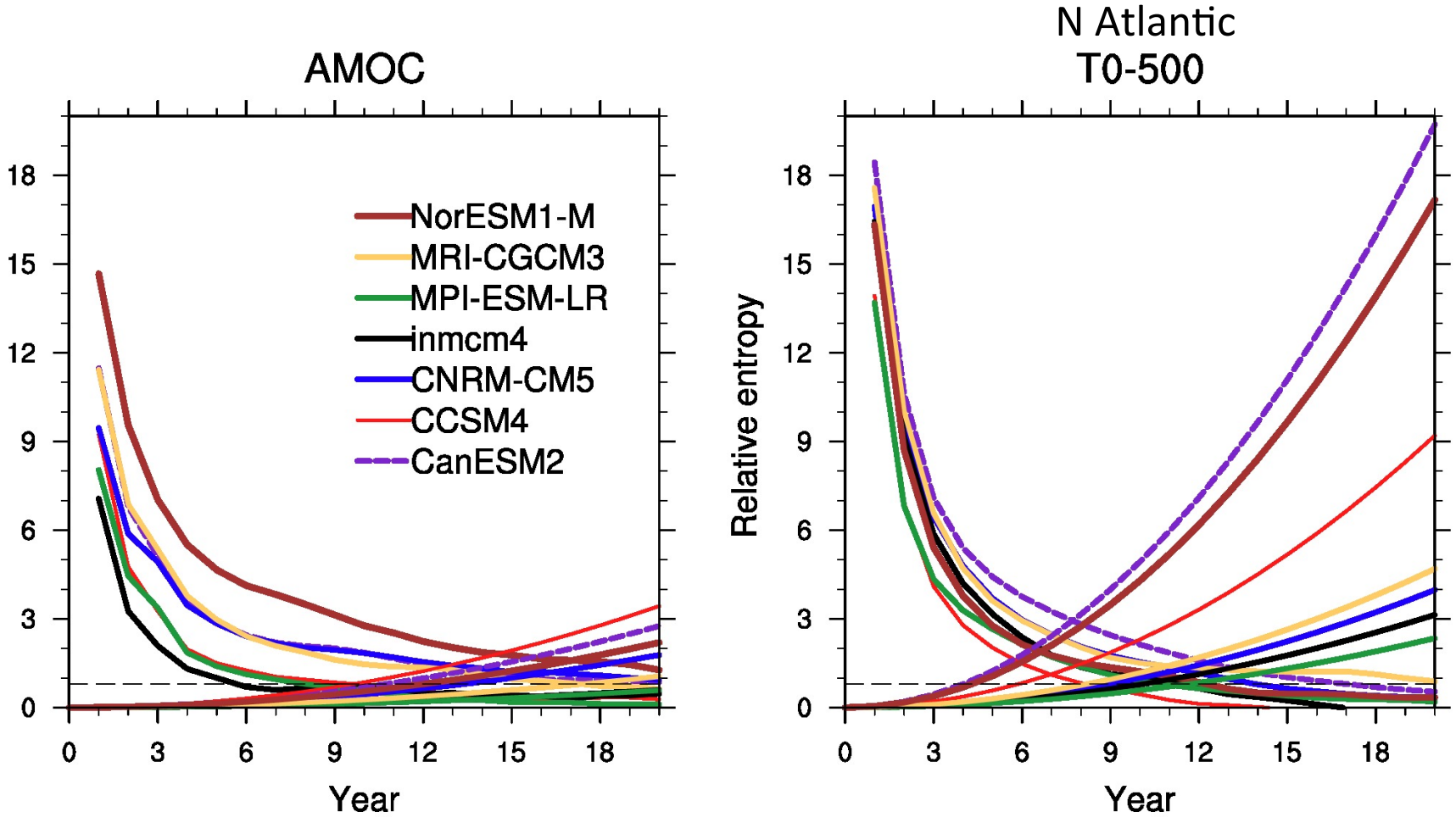


(K/month)

Is AMOC worth worrying about for prediction of T0-500?

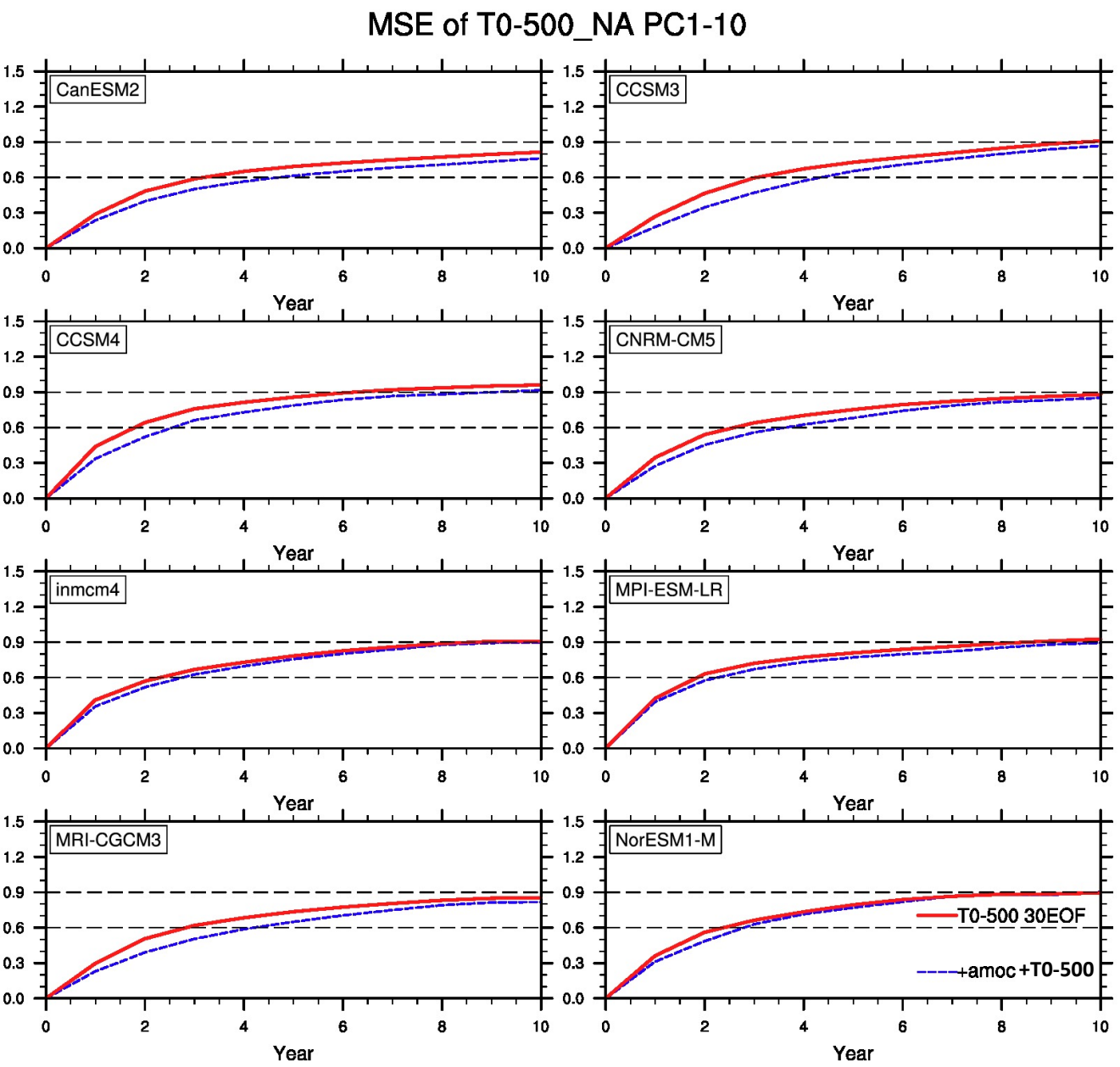


3yr-running-mean (T0-500) explained by 30 AMOC PCs at lag0


AMOC
N Atlantic
T0-500
NorESM1-M
MRI-CGCM3
MPI-ESM-LR
inmcm4
CNRM-CM5
CCSM4
CanESM2
Relative entropy
Year
Year
0
3
6
9
12
15
18

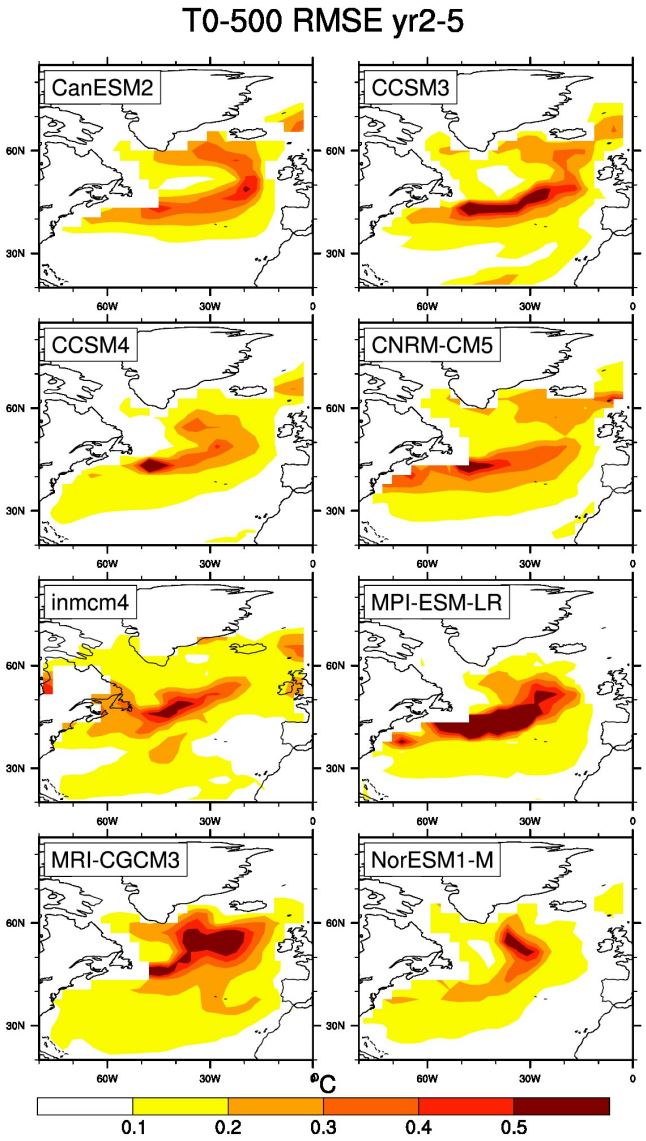
10 PCs

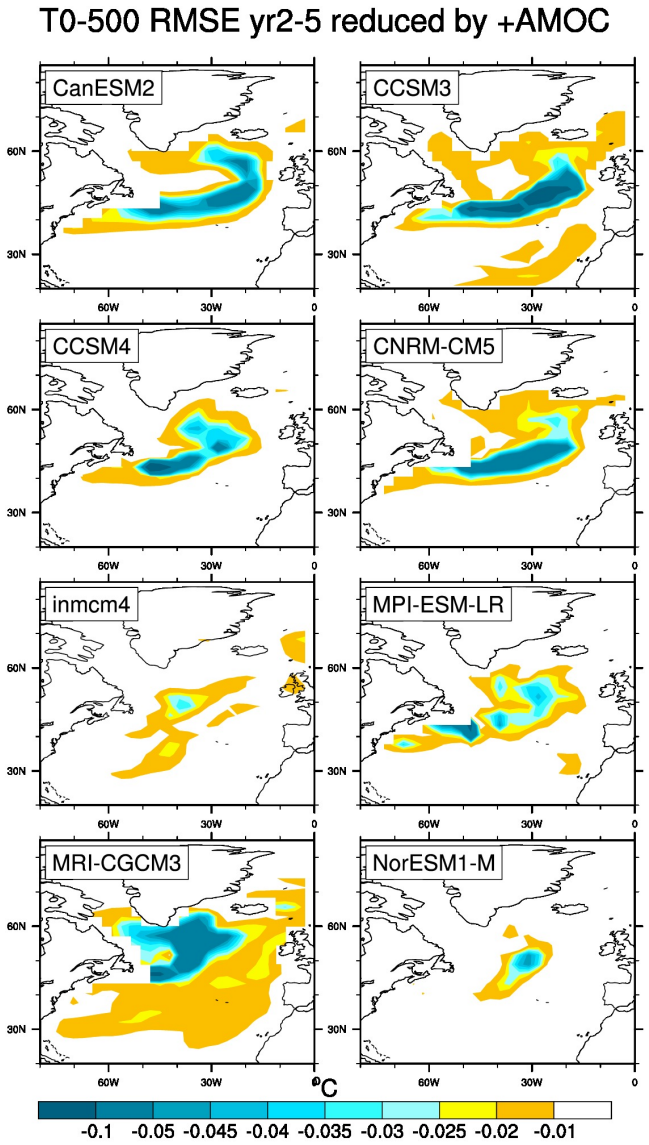
Reduction in T0-500 Uncertainty from Initializing AMOC



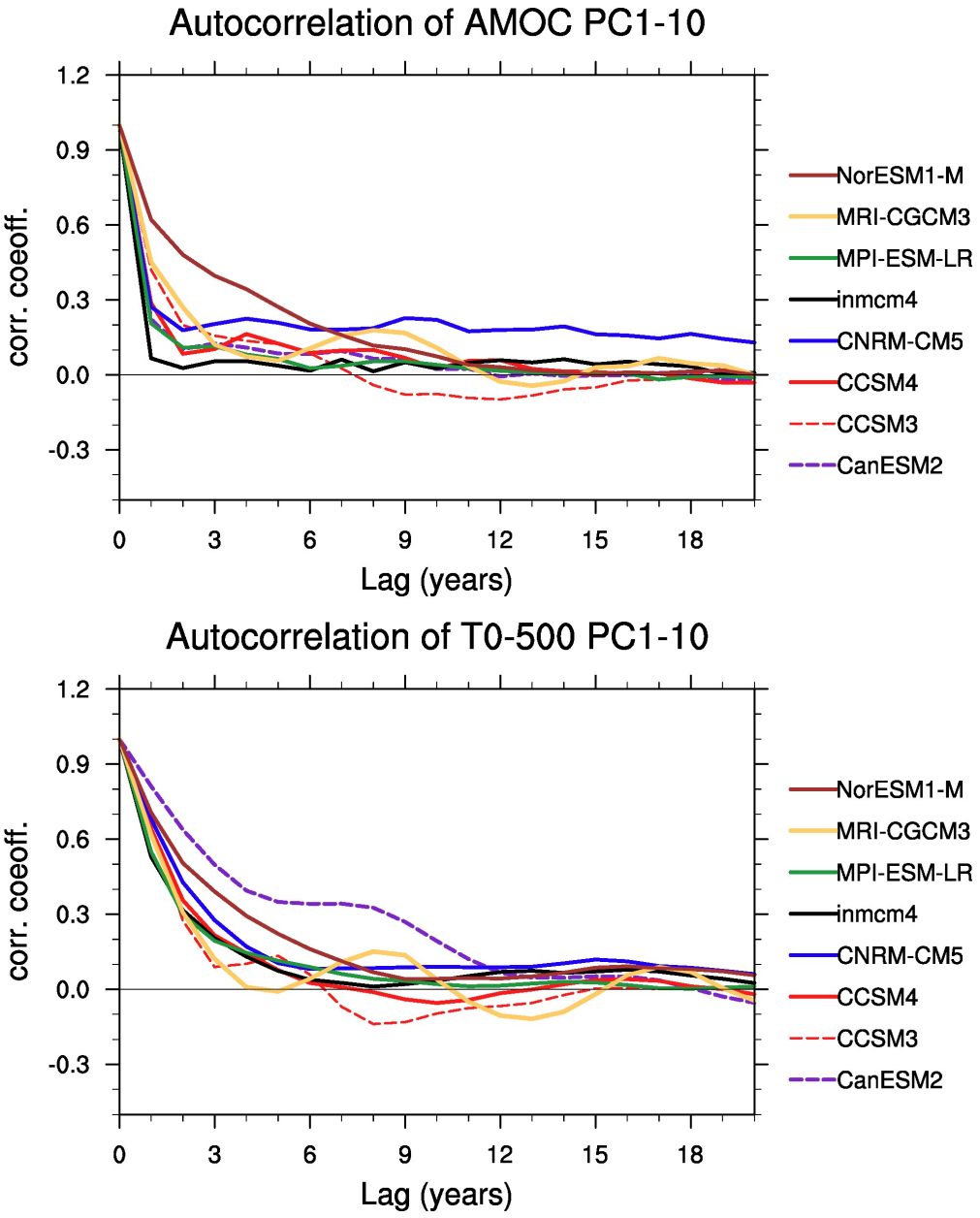
Reduction in T0-500 Uncertainty from Initializing AMOC

(RMSE)

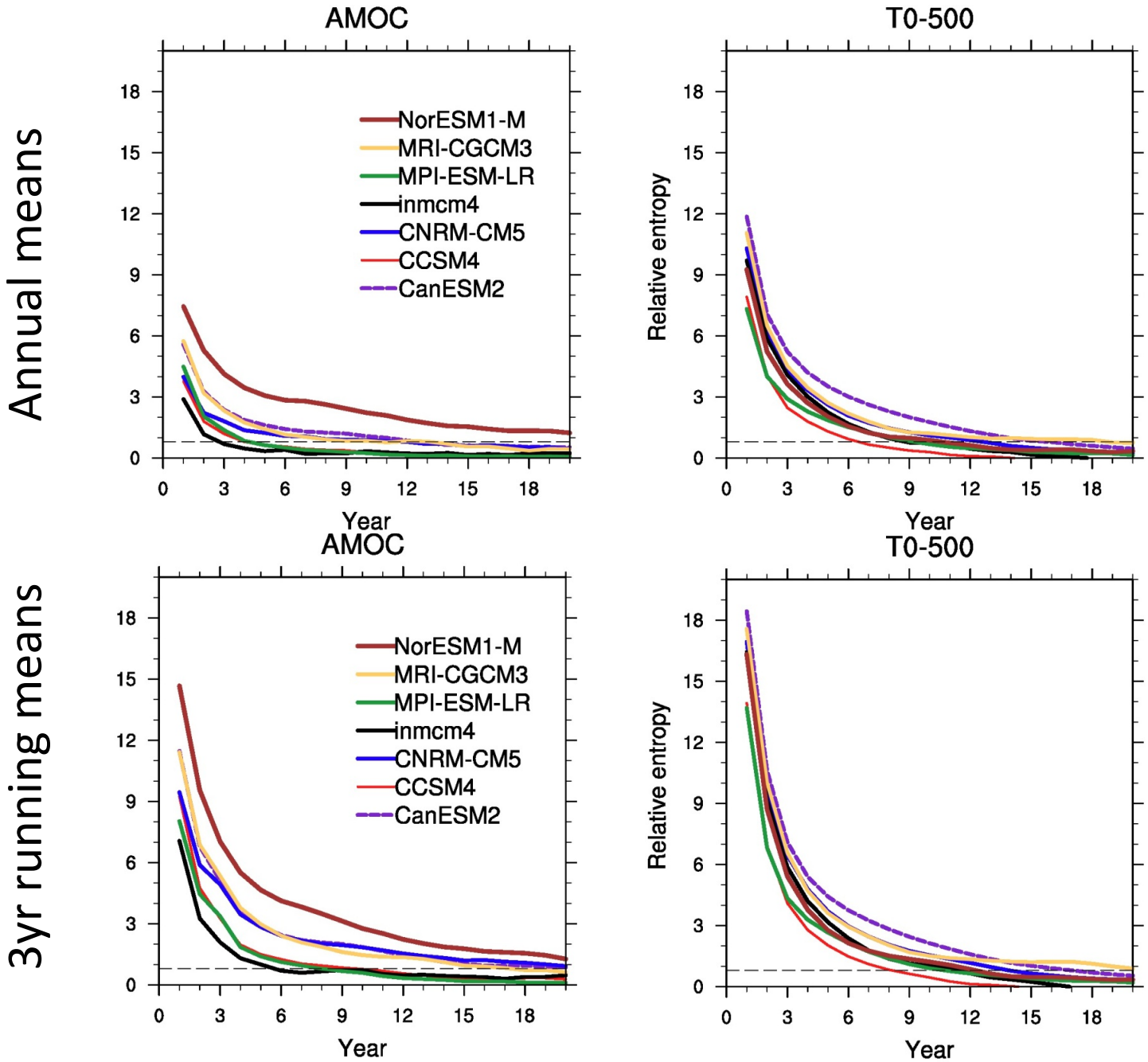




What limits predictability and predictions of AMOC?

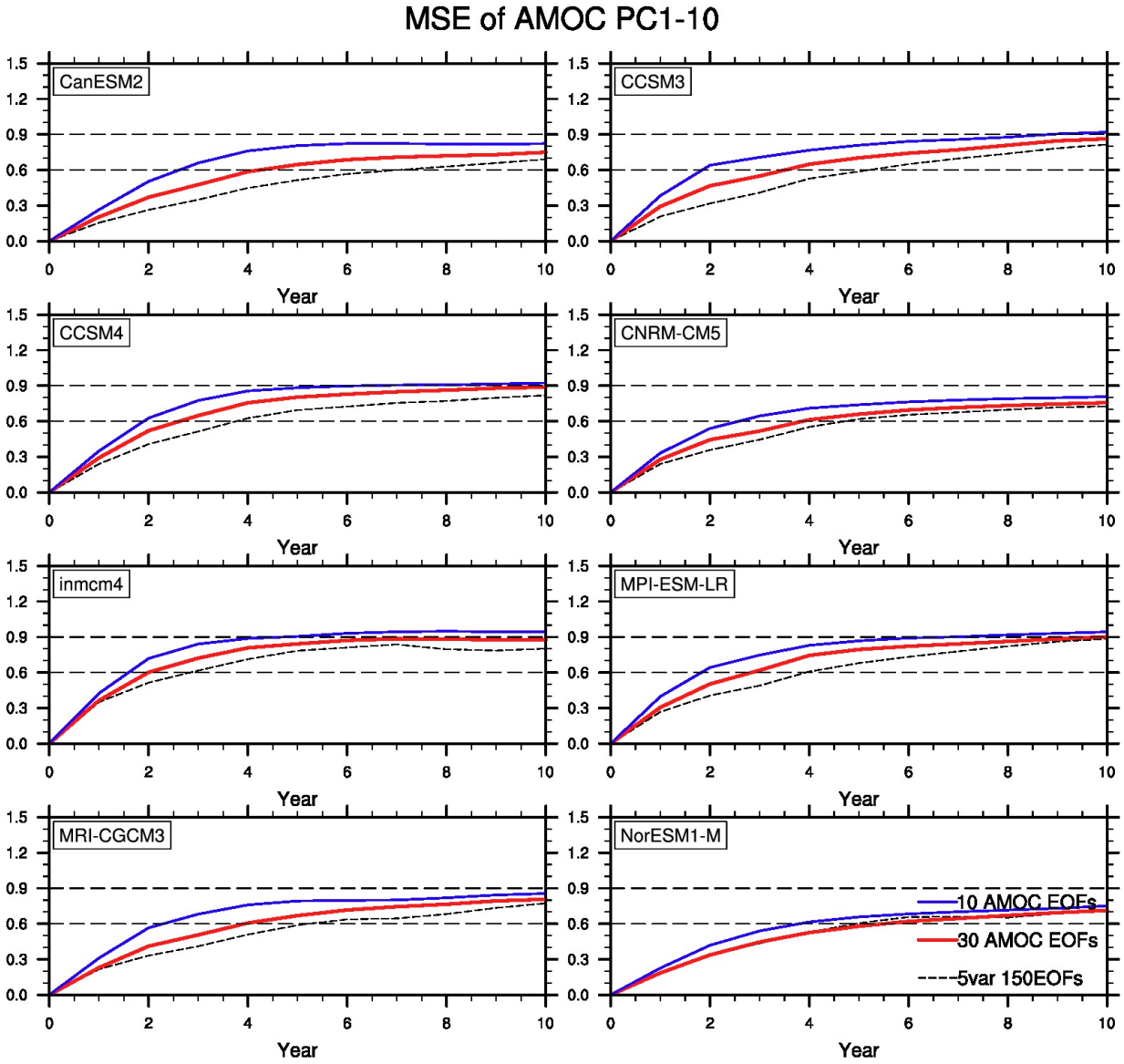

Autocorrelation of AMOC PC1-10
corr. coeoff.
1.2
0.9
0.6
0.3
0.0
-0.3
0
3
6
9
12
15
18
Lag (years)
NorESM1-M
MRI-CGCM3
MPI-ESM-LR
inmcm4
CNRM-CM5
CCSM4
CCSM3
CanESM2
Autocorrelation of T0-500 PC1-10
corr. coeoff.
1.2
0.9
0.6
0.3
0.0
-0.3
0
3
6
9
12
15
18
Lag (years)
NorESM1-M
MRI-CGCM3
MPI-ESM-LR
inmcm4
CNRM-CM5
CCSM4
CCSM3
CanESM2

Effect of temporal smoothing on predictability



What variables affect uncertainty of AMOC forecasts?

30 AMOC, 30 T0-500, 30 T500-1000, 30 T1000-2000, 30 Salt0-500



Summary

In climate models:

- Subsurface North Atlantic temperature has initial value predictability of about a decade and is highly dependent on region
- AMOC predictability is somewhat less than subsurface temperature
- Leading patterns of subsurface temperature are no more predictable than generic patterns
- Leading patterns of AMOC may be predictable for a few more years than generic patterns

Issues

- Should more emphasis be put on pentadal rather than decadal predictions?
- Are there events with unusually high predictability?
- How much can observations of AMOC contribute to predictive skill of near surface fields?
- Which fields must be observed to predict AMOC?
- Does ocean predictability lead to atmospheric predictability over land?
- Is there any hope for estimating nature's predictability?