Predicting decadal changes in the North Atlantic from the GFDL model forecasts: preliminary results and challenges

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NOAA/GFDL

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NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

GFDL Decadal predictions: Experimental design

NON INITIALIZED HINDCASTS

Boundary value problem

600 yrs preindustrial control run (after 900 yrs spin up)

Initial values taken at 60-yr interval from the control run

Historical climate change simulations (10 members)
all forcings (AR5)

1860 2010

Historical climate change simulations (10 members)
No volcano

1860 2010

INITIALIZED HINDCASTS

Initial-boundary value problem

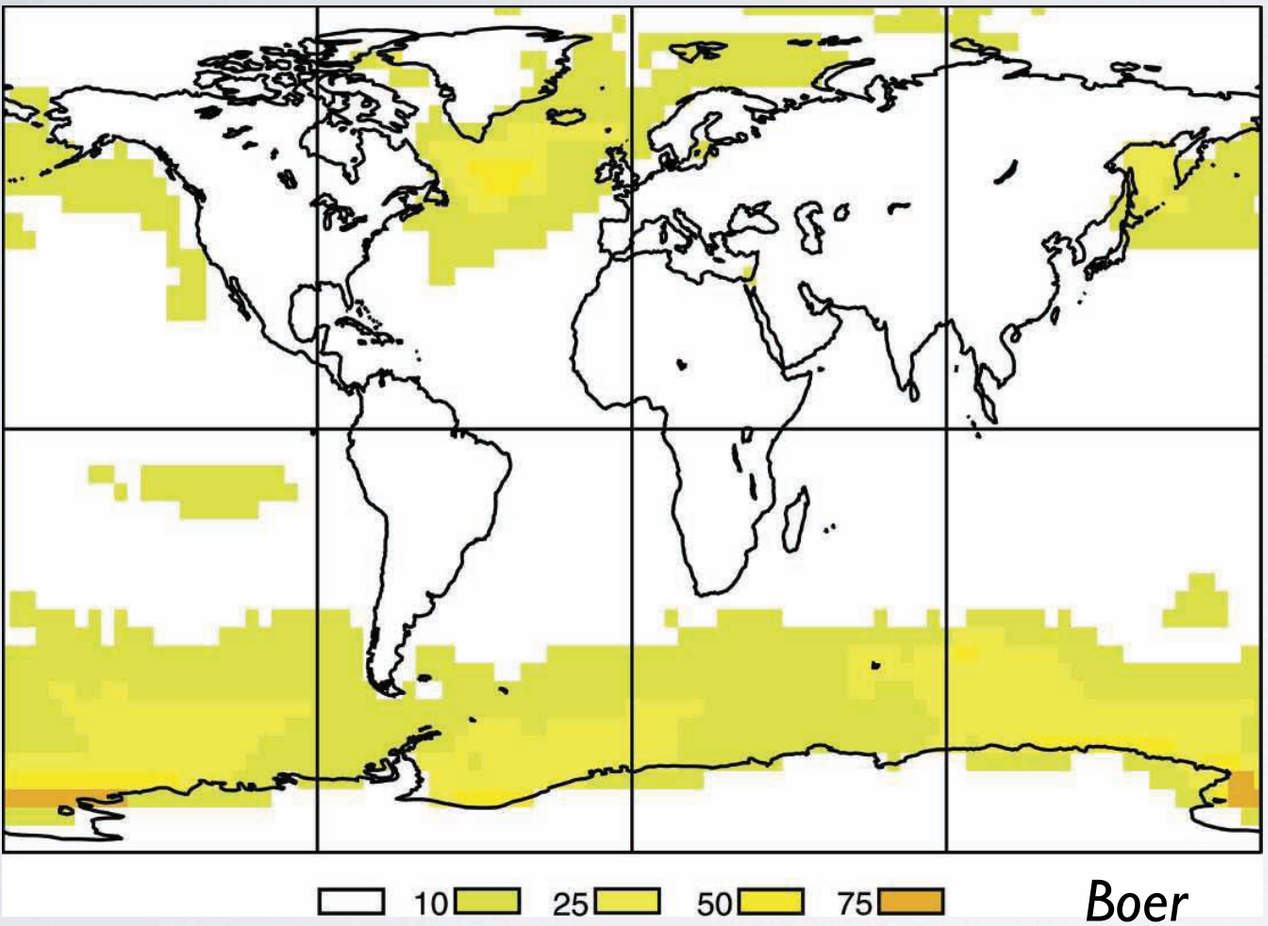
GFDL reanalysis ECDA- coupled assimilation
1970-2009

10-yr long hindcasts/forecasts
Initialized every year
10 members-40 ensembles

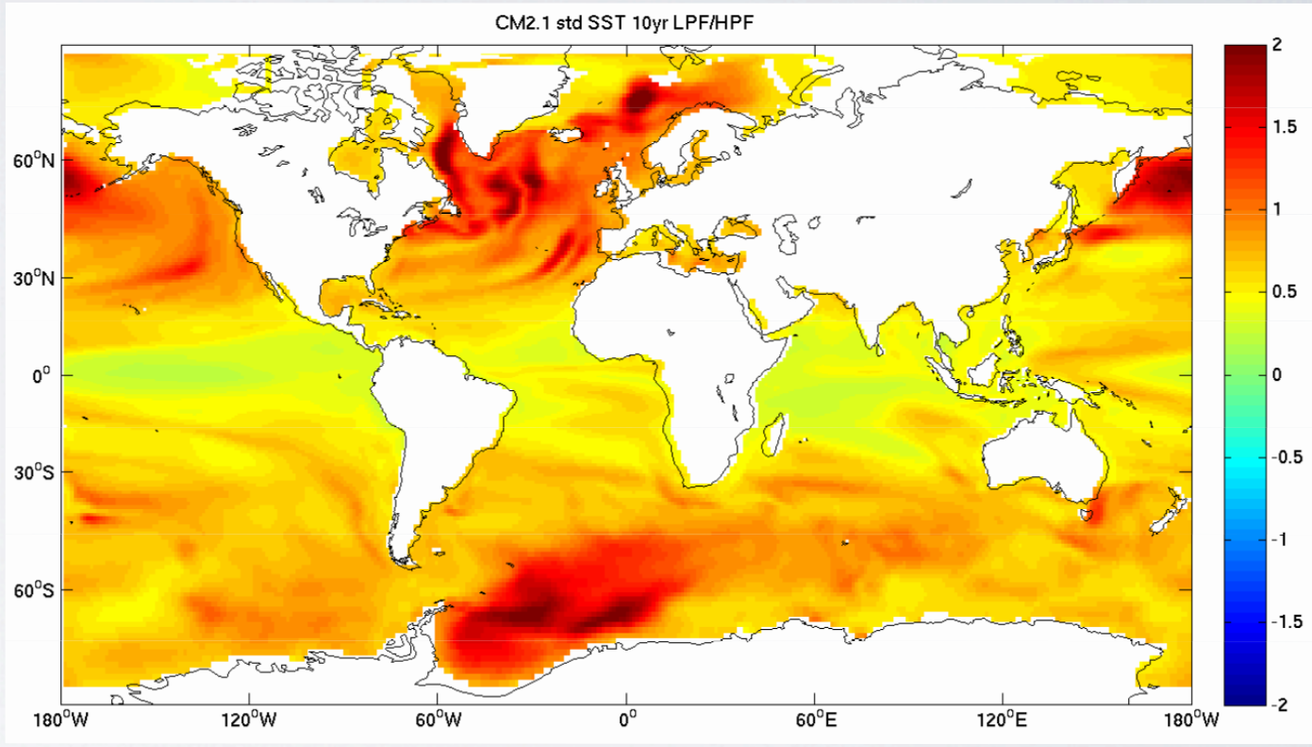
1971-1981 1973-1983 ... 2007-2017 2009-2019

Predictability: where should we look?

Air temperature 11 climate models ratio of the decadal variance over total variance



Ratio decadal variance/high frequency variance for SST in CM2.1

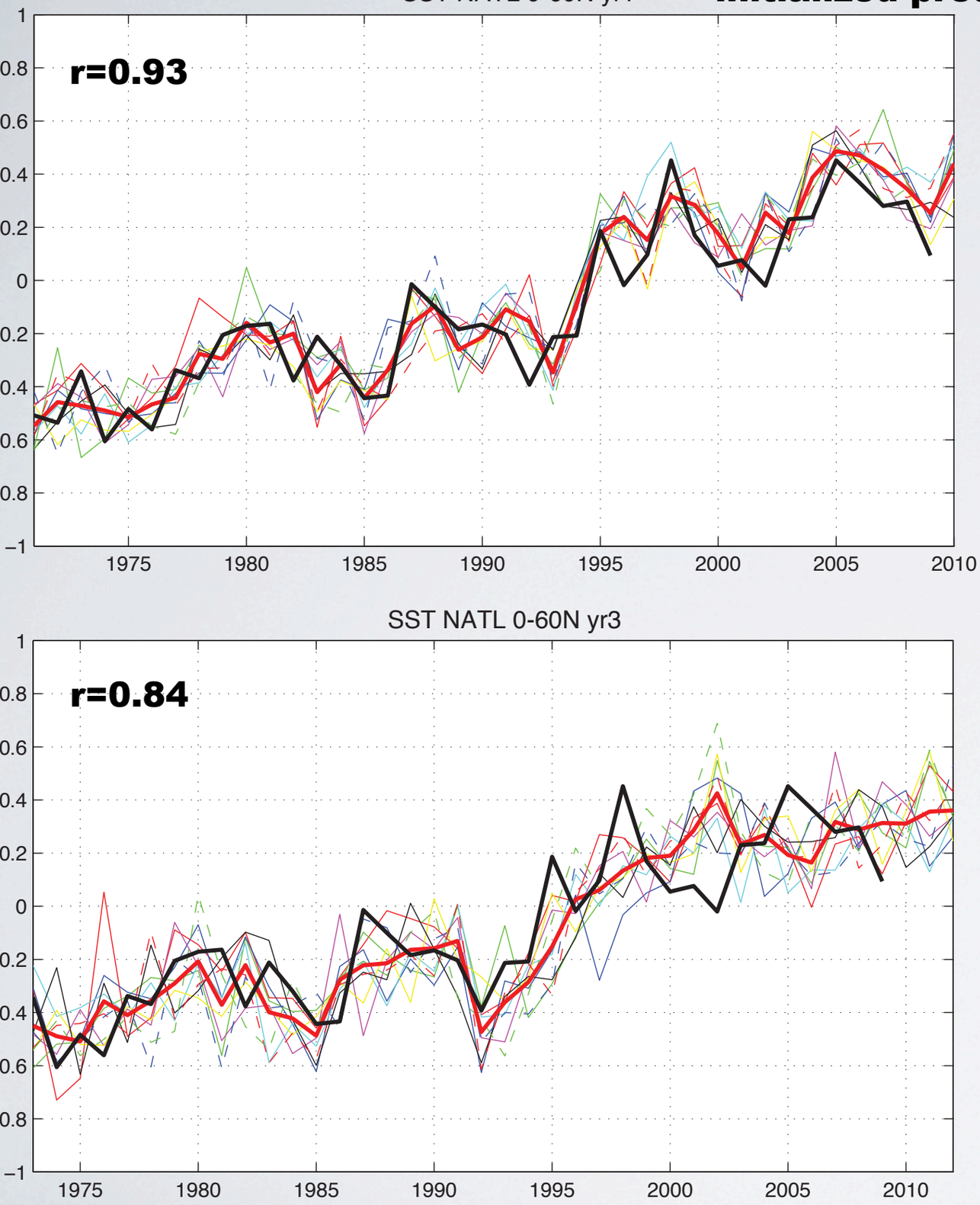


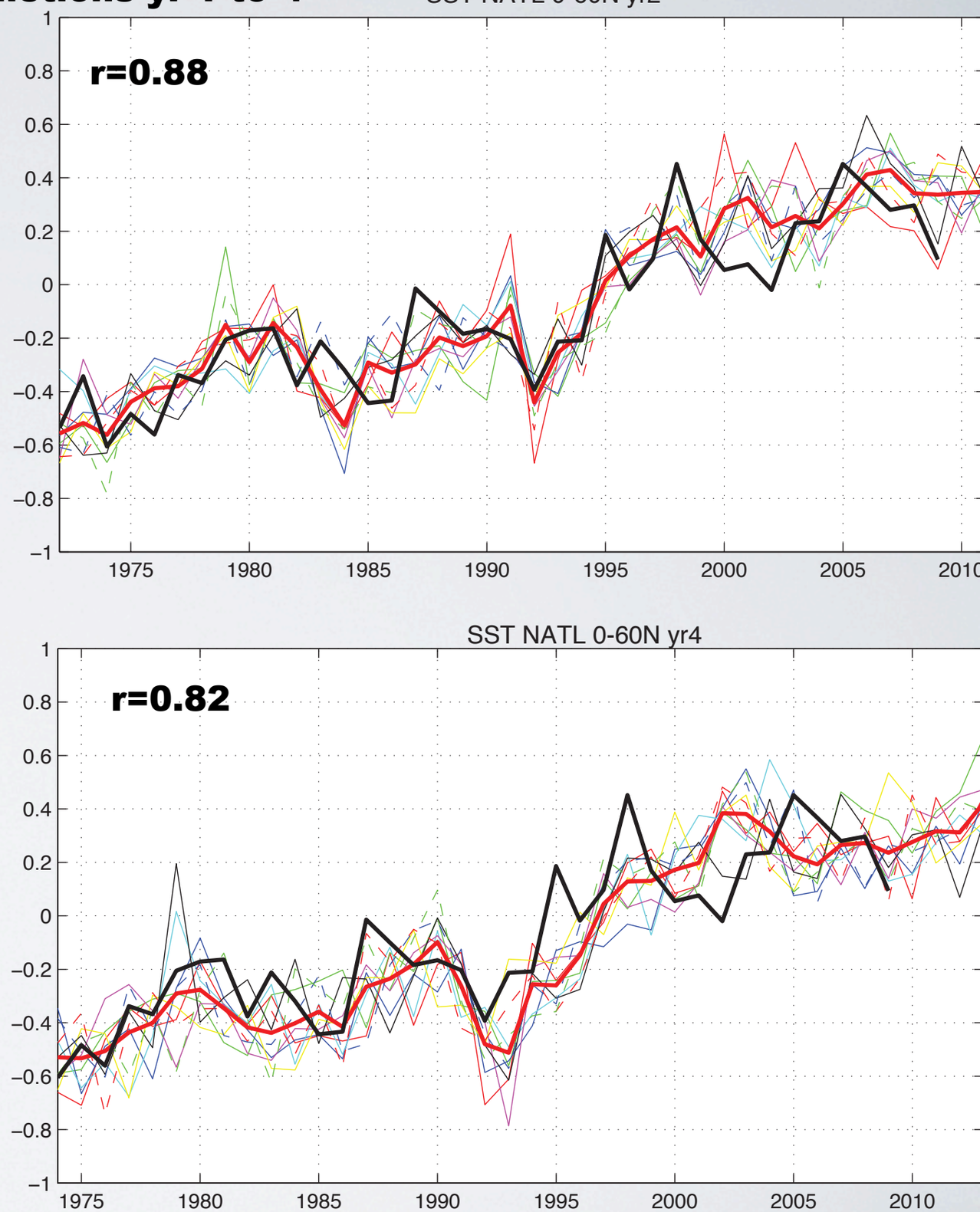
This model showed decadal predictability in the North Atlantic in a perfect model framework (Msadek et al. GRL, 2010)

Does the North Atlantic show any skill in the initialized predictions?

SST NATL 0-60N

initialized predictions yr 1 to 4



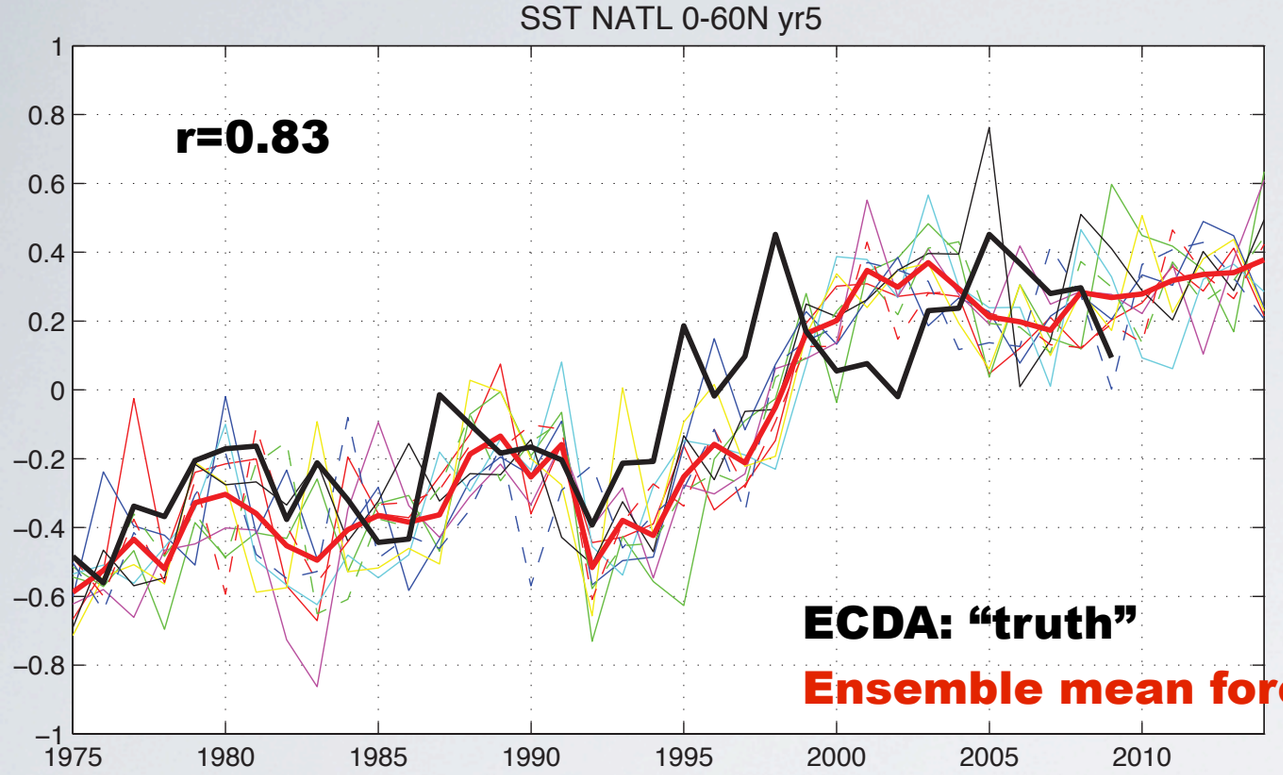


ECDA: “truth”

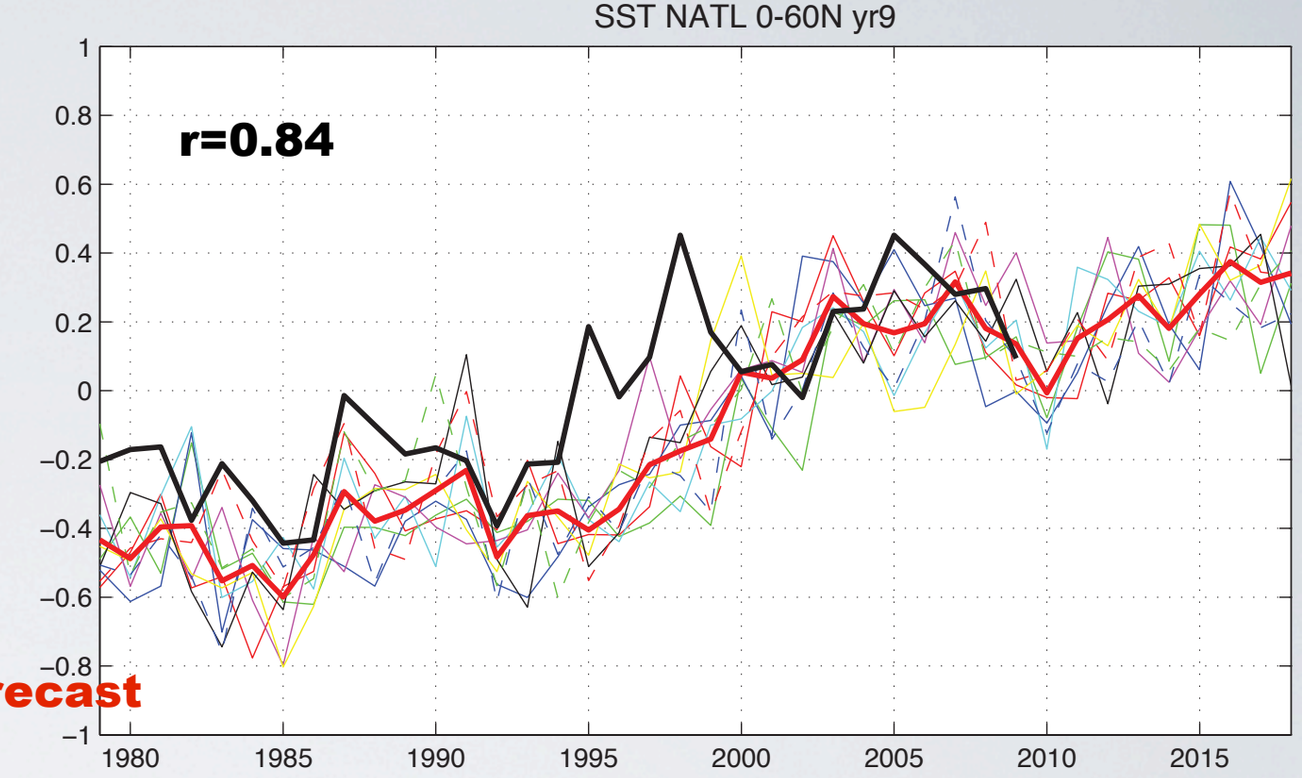
Ensemble mean forecast

SST NATL 0-60N

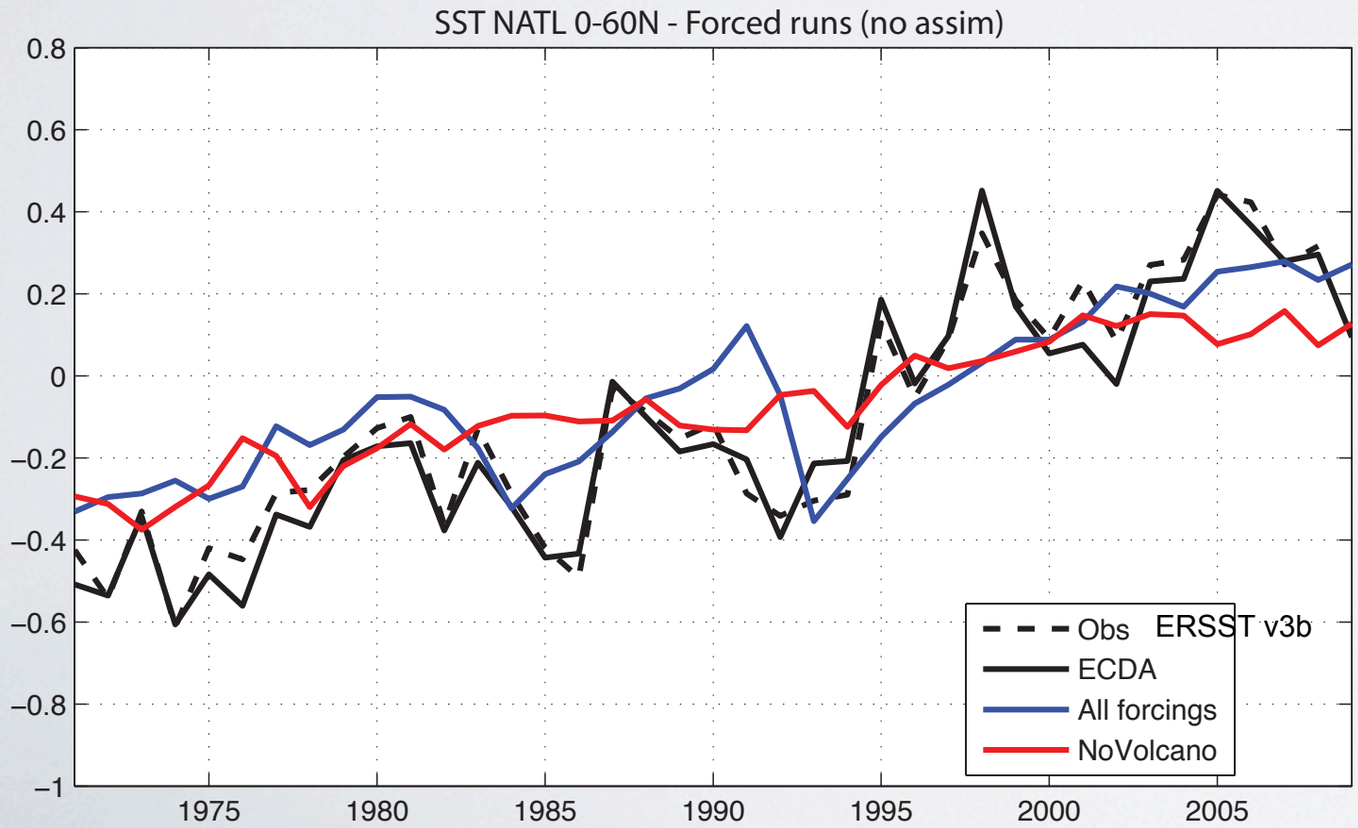
initialized predictions yr 5



initialized predictions yr 9



Projections: No Assim



Correlations:

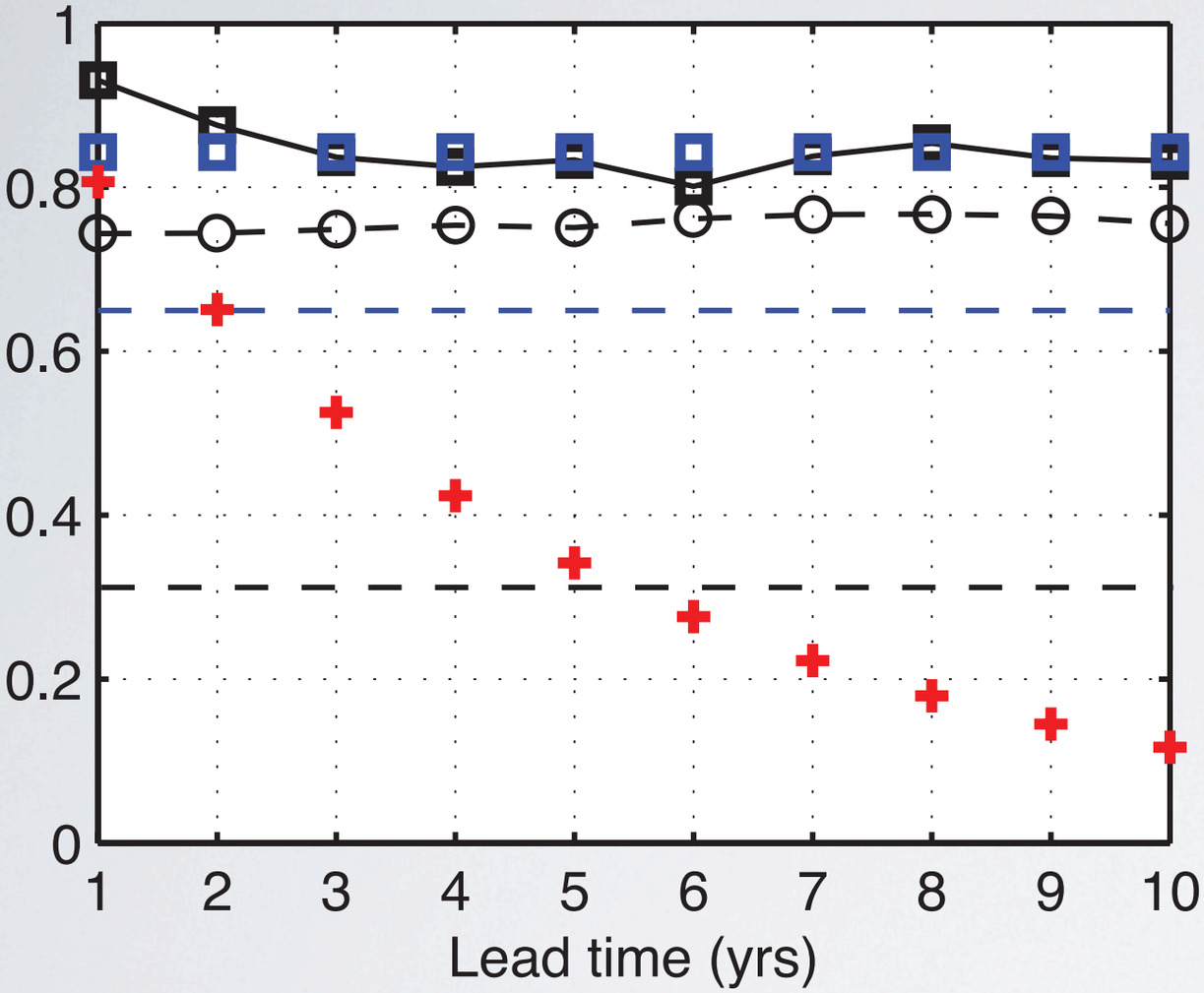
Obs/NoAssim r=0.84

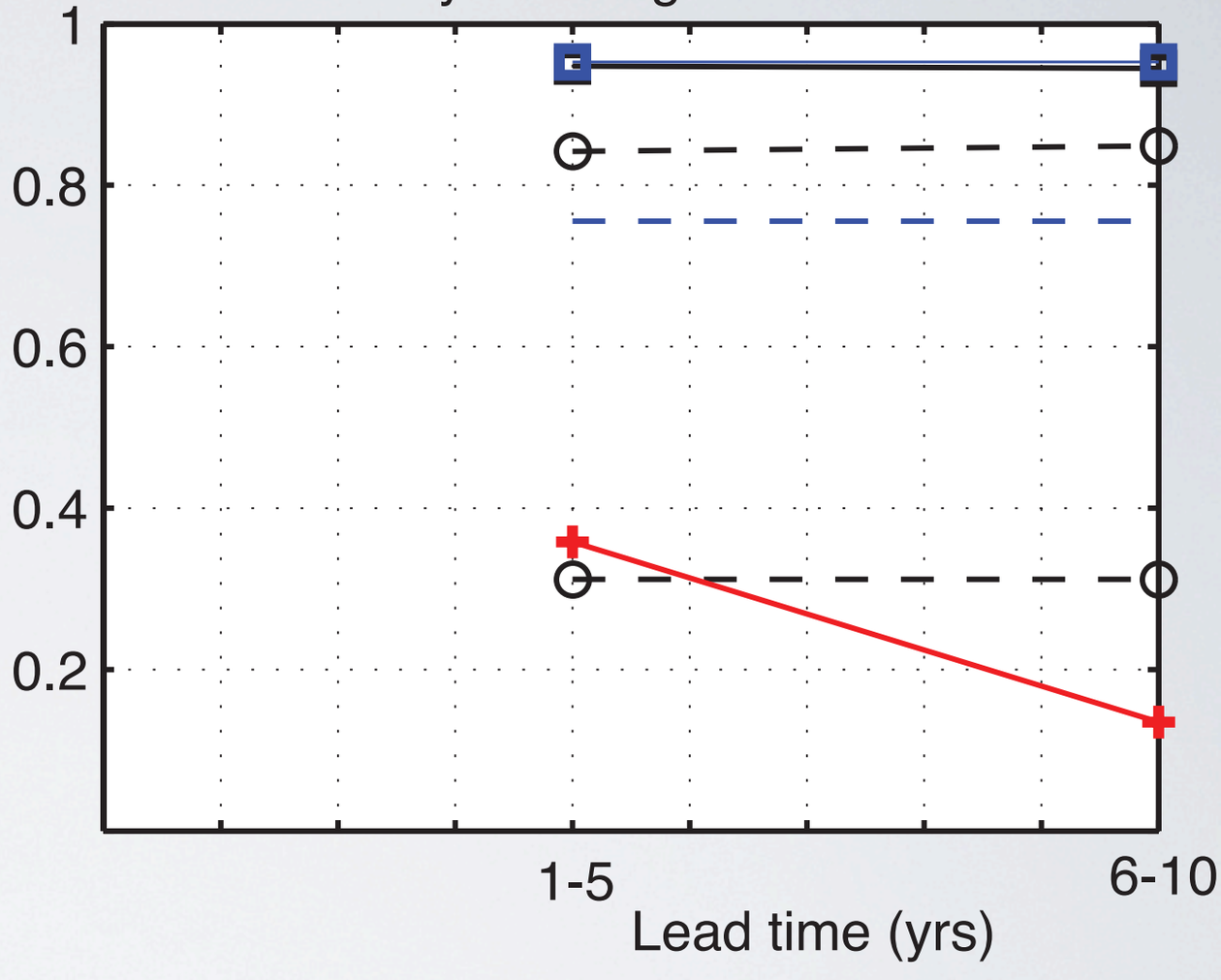
ECDA/NoAssim r=0.80

Obs/Novolcano r=0.83

ECDA/Novolcano r=0.82

Correlation SST NATL 0N–60N





Hindcasts

Forced (no assim)

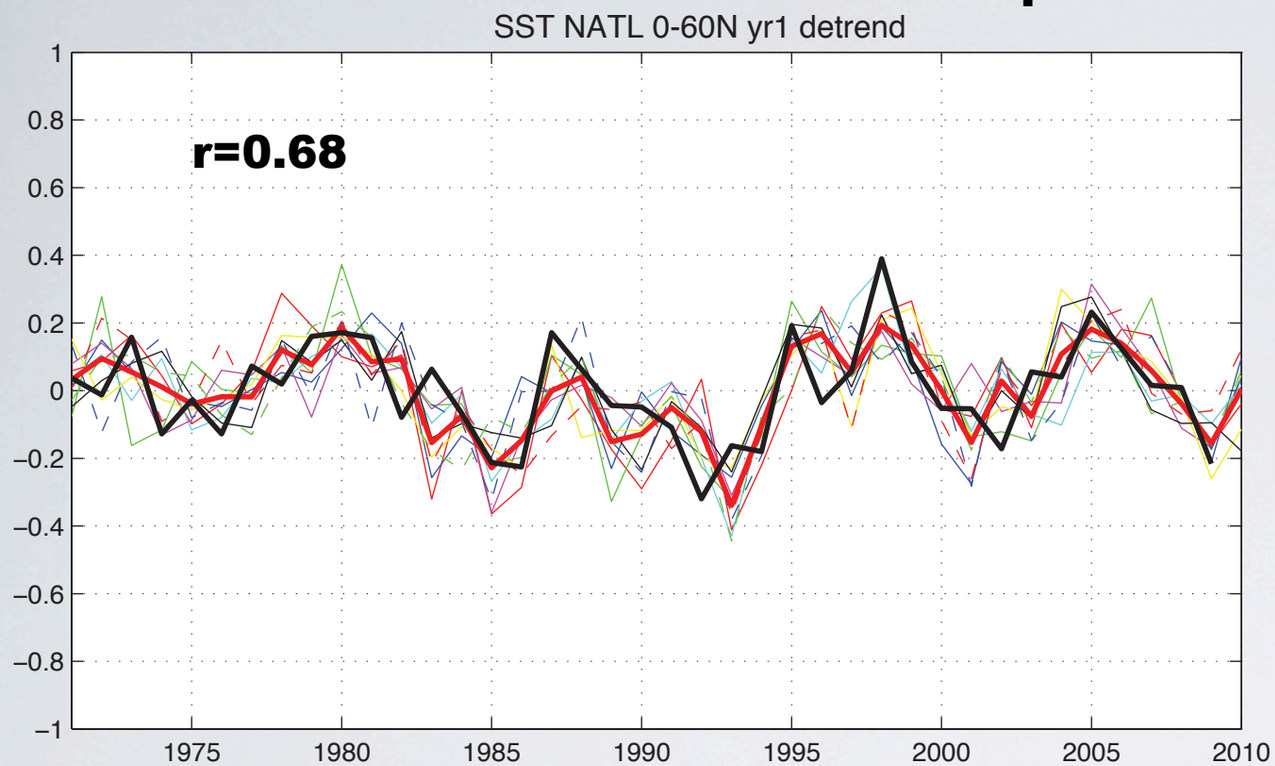
Persistence

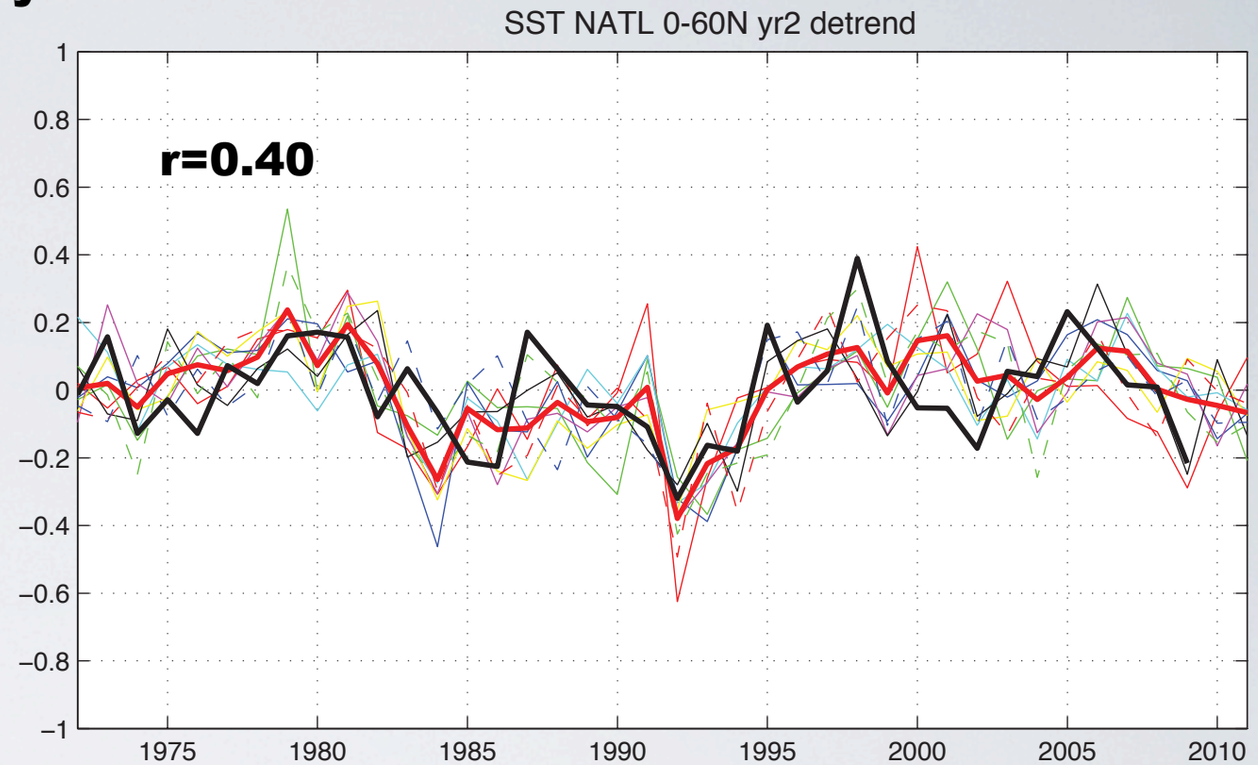
– – – – – **significance level**

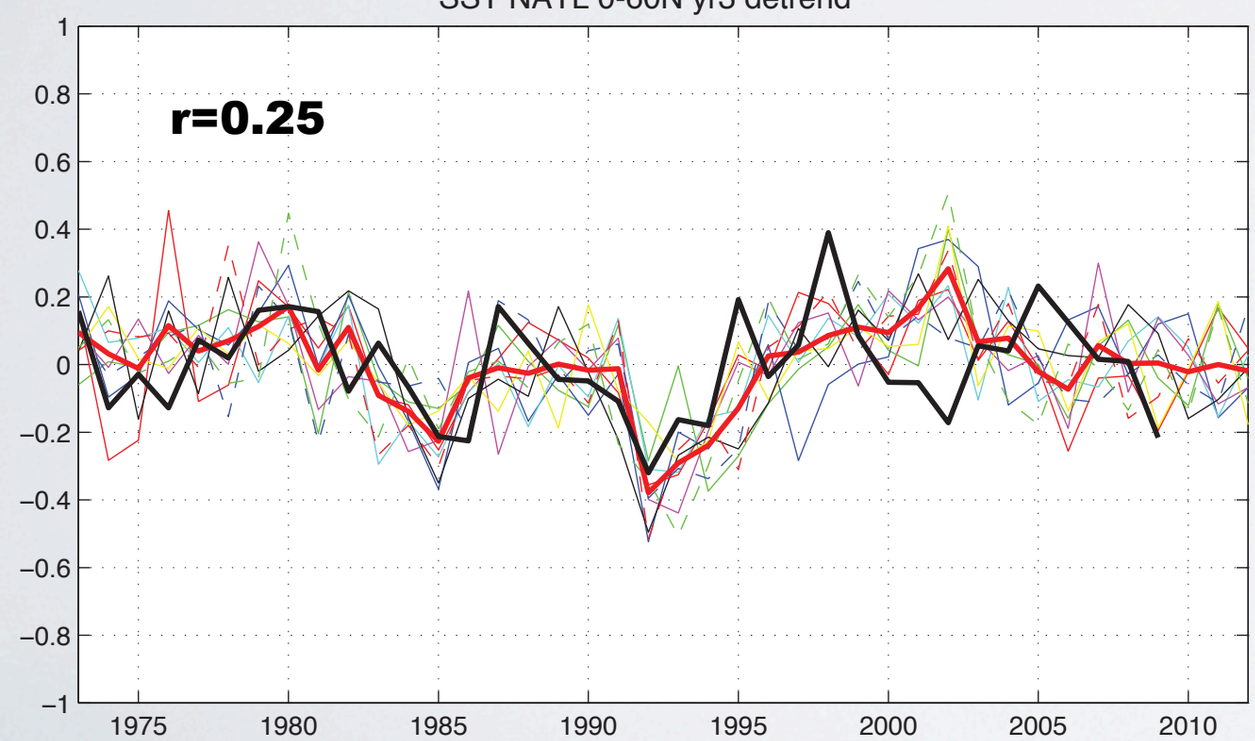
Predictions better than projections for the first 2 yrs

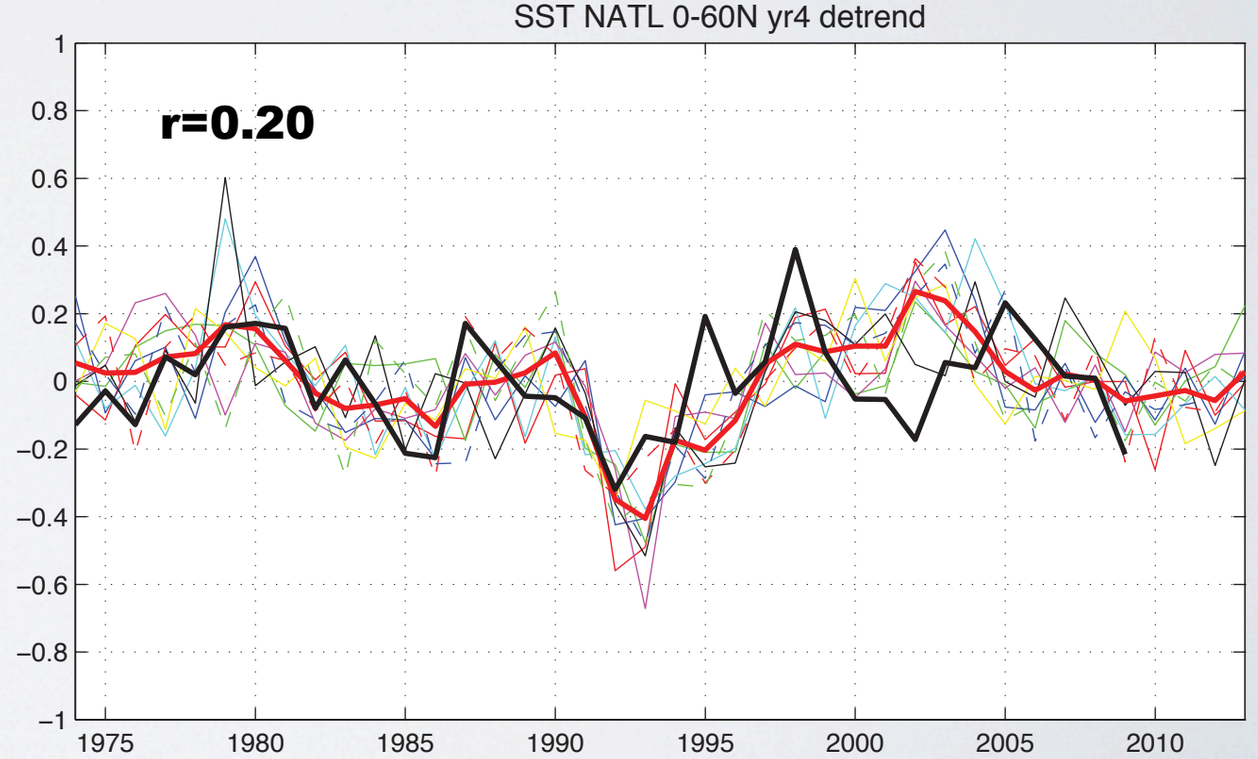
SST NATL 0-60N

initialized predictions yr 1 to 4: detrended







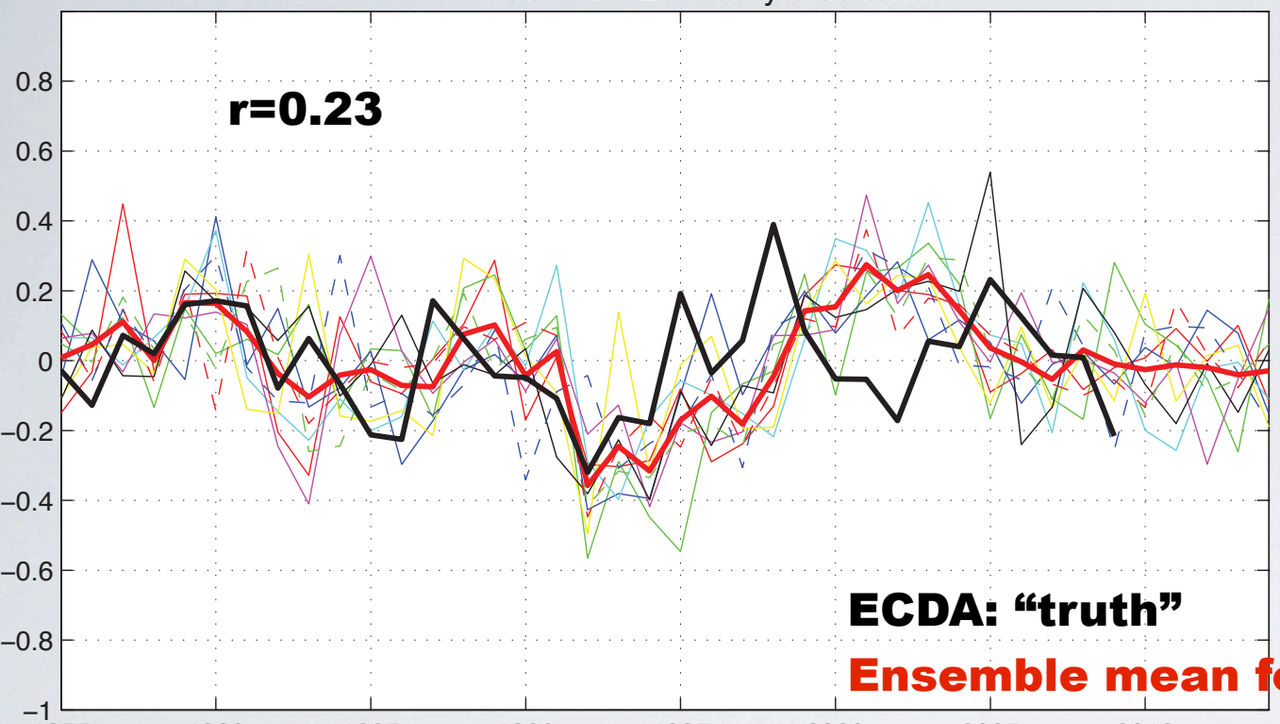


ECDA: “truth”

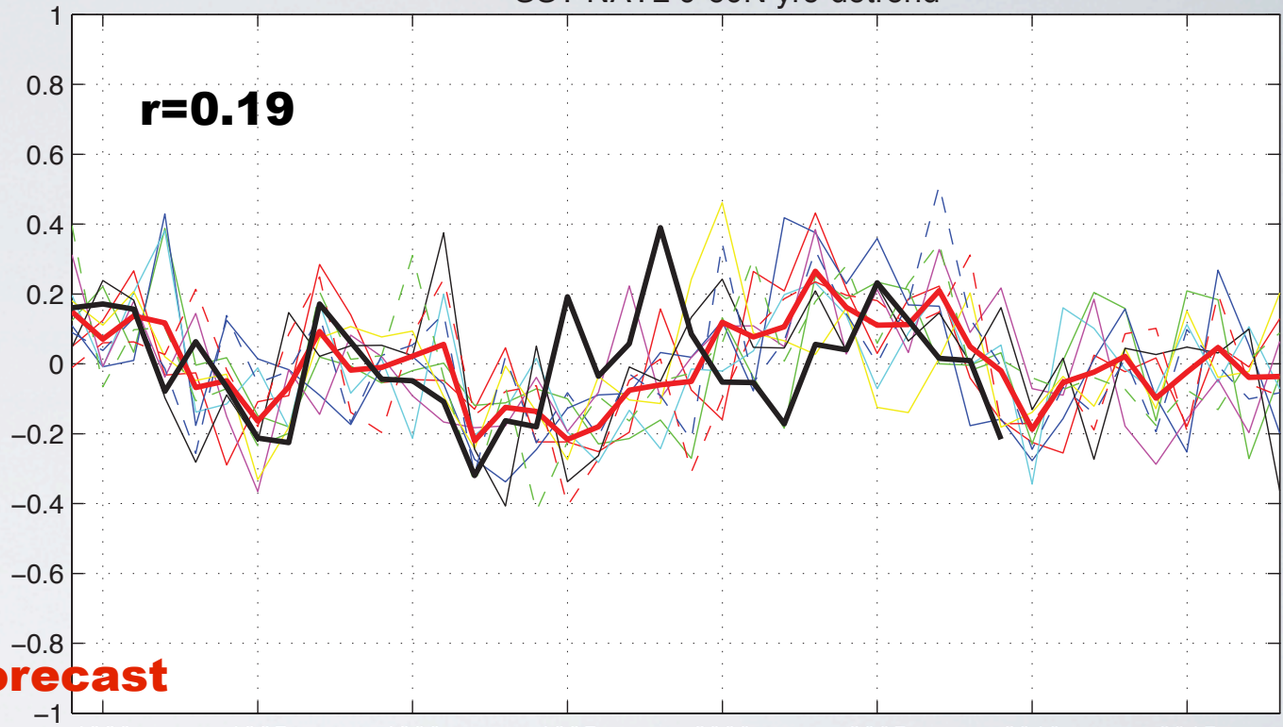
Ensemble mean forecast

SST NATL 0-60N

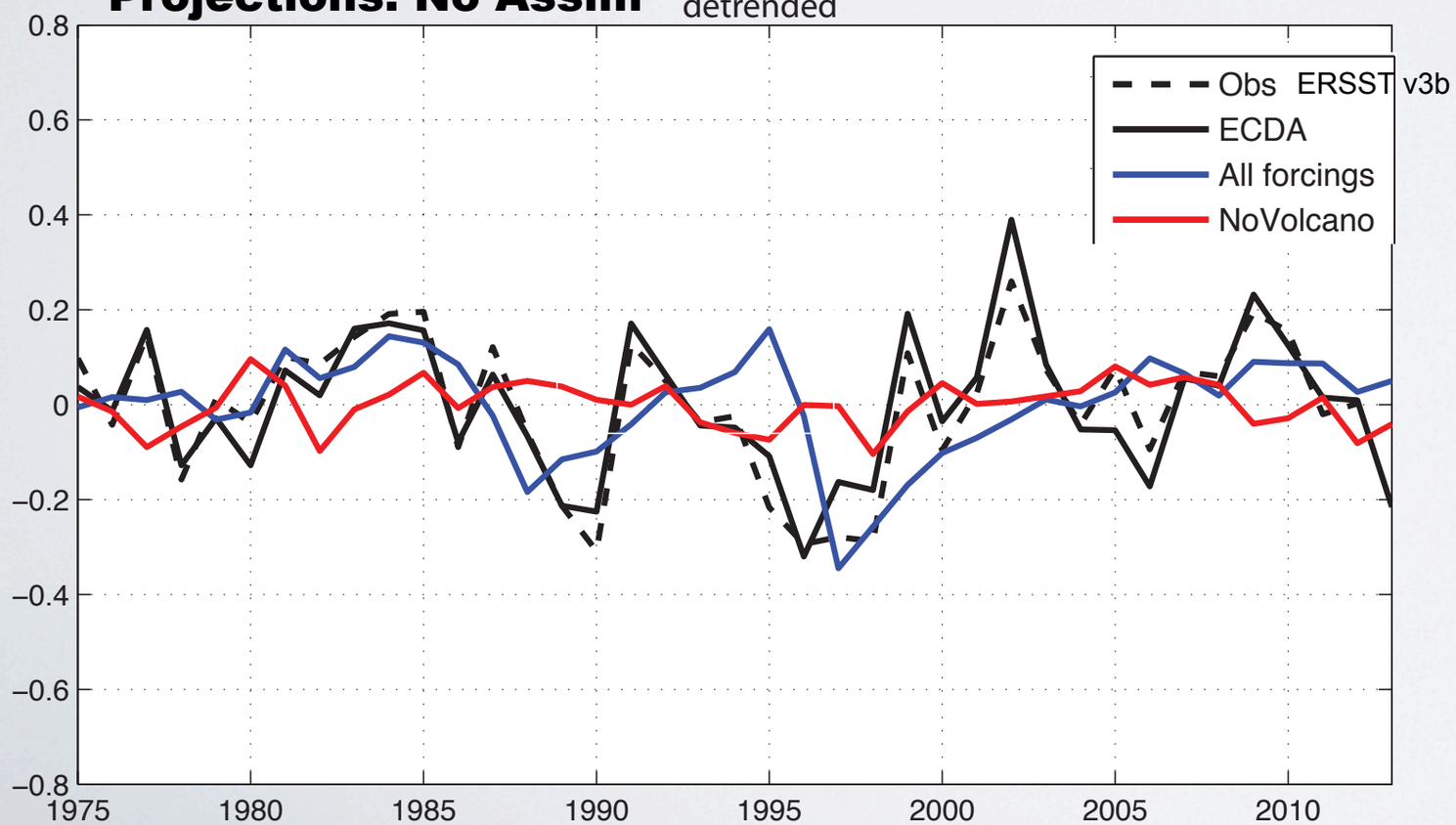
initialized predictions yr 5 detrended



initialized predictions yr 9 detrended



Projections: No Assim detrended

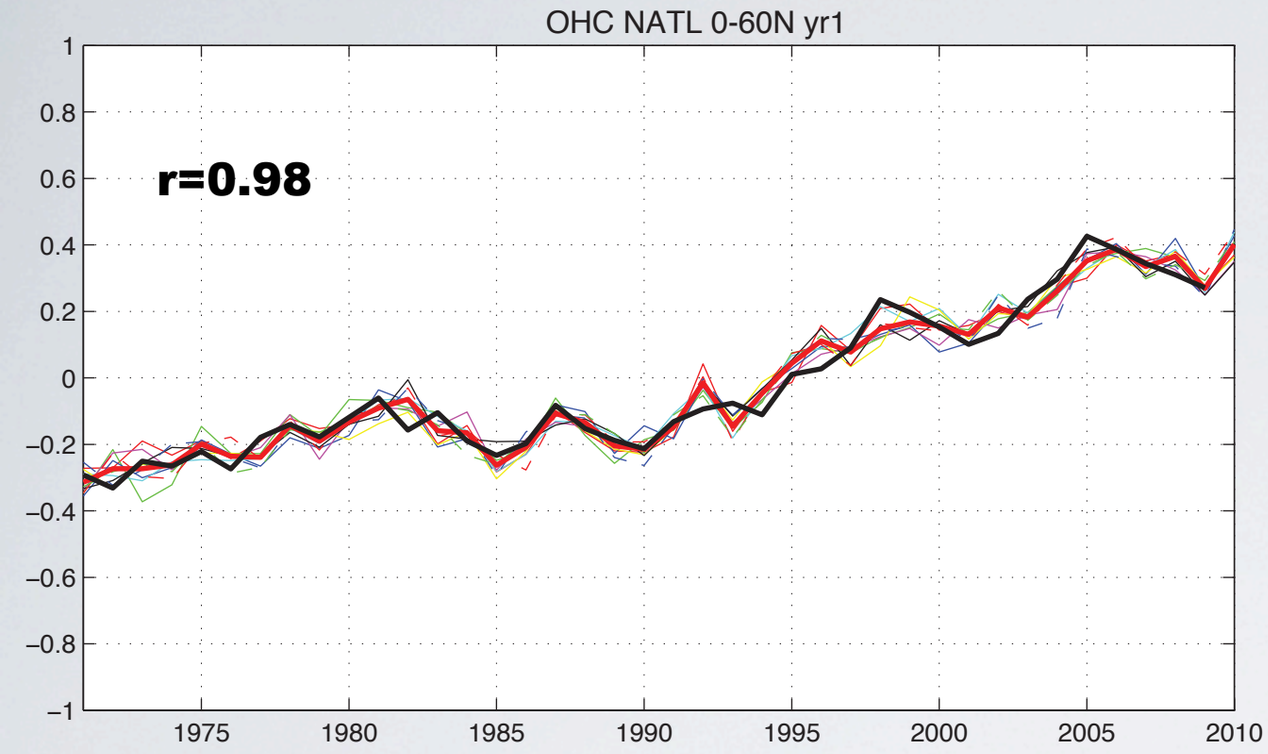


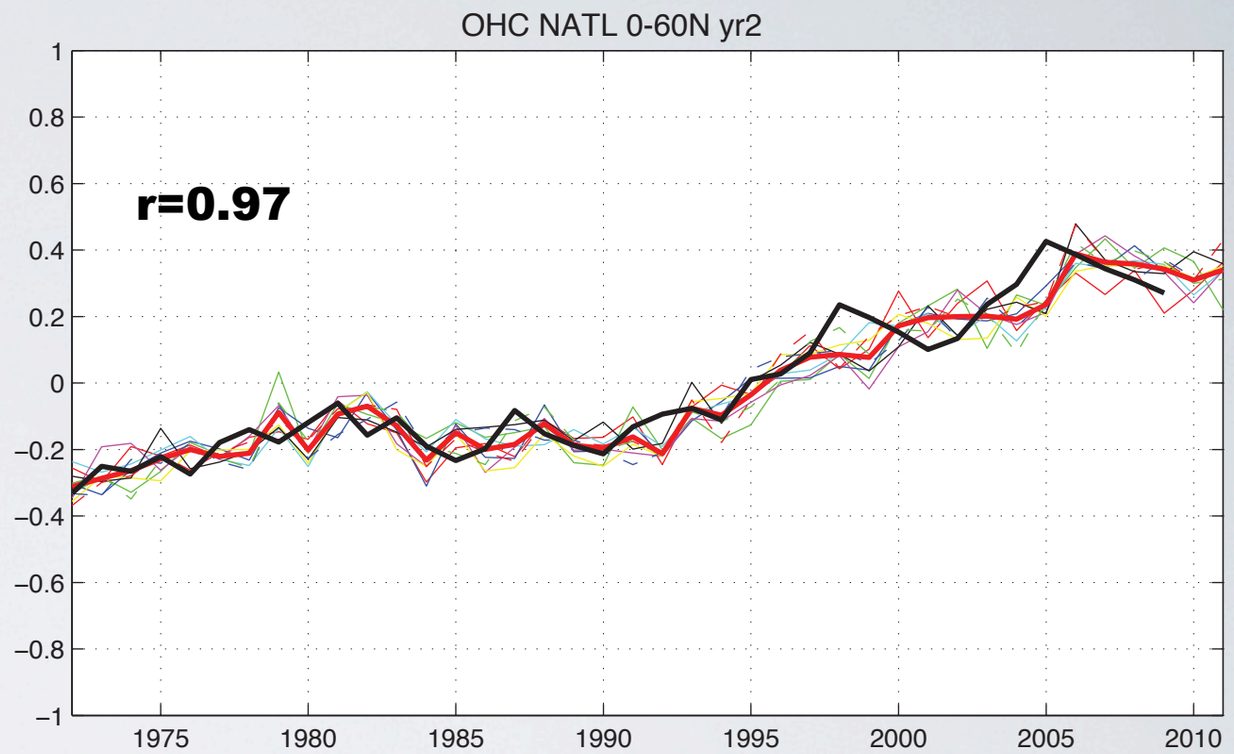
Correlations:

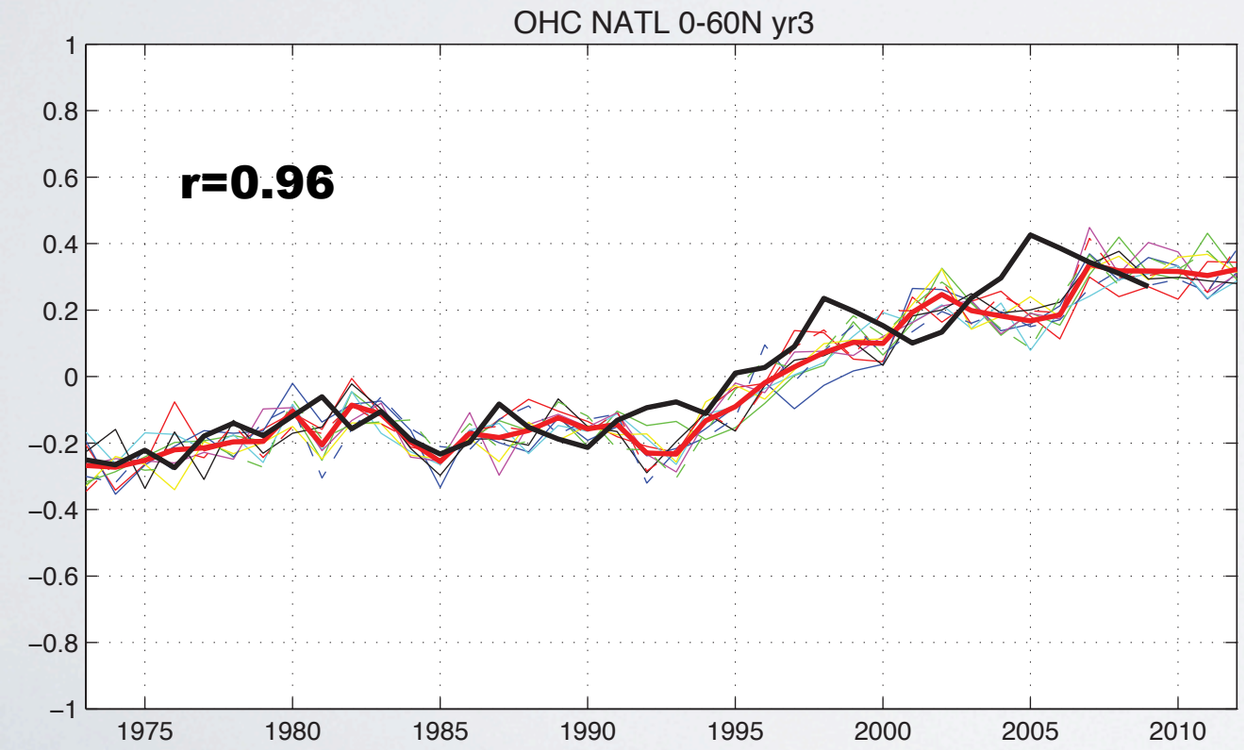
Obs/NoAssim r=0.46
ECDA/NoAssim r=0.28
Obs/Novolcano r=0.14
ECDA/Novolcano r=0.02

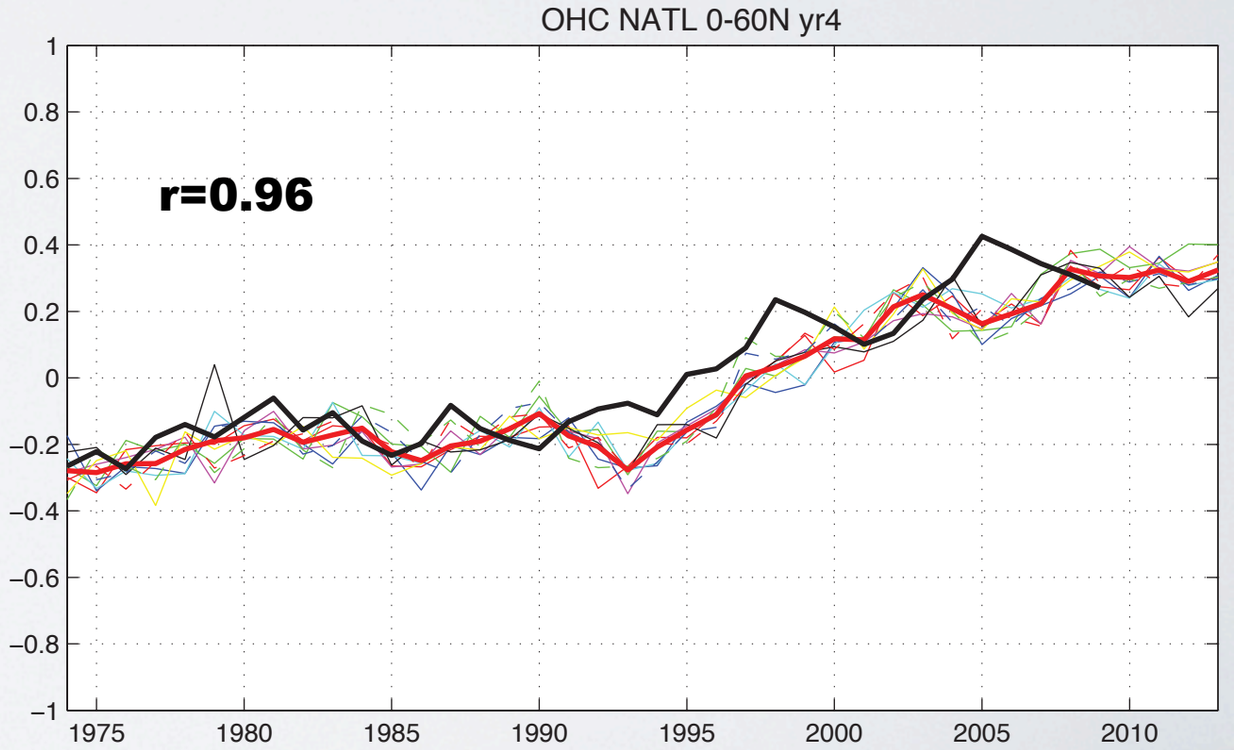
OHC NATL 0-60N

initialized predictions yr 1 to 4







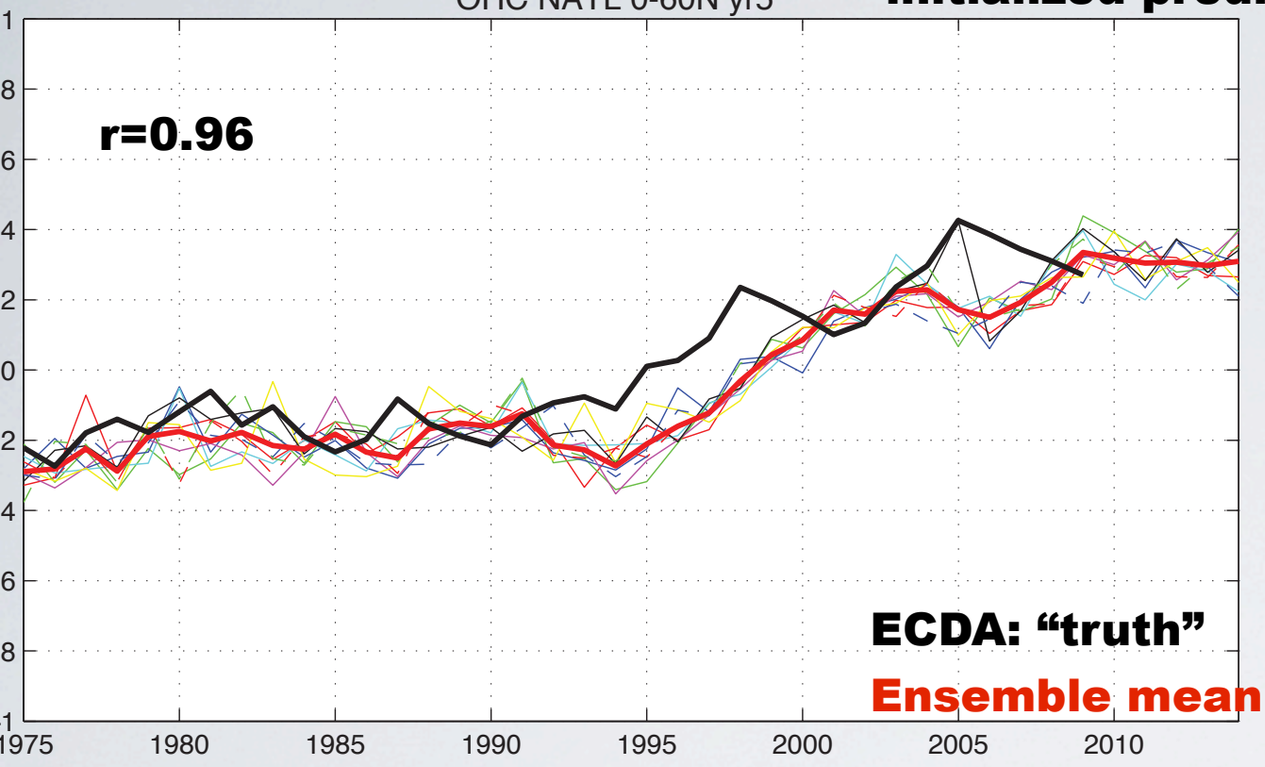


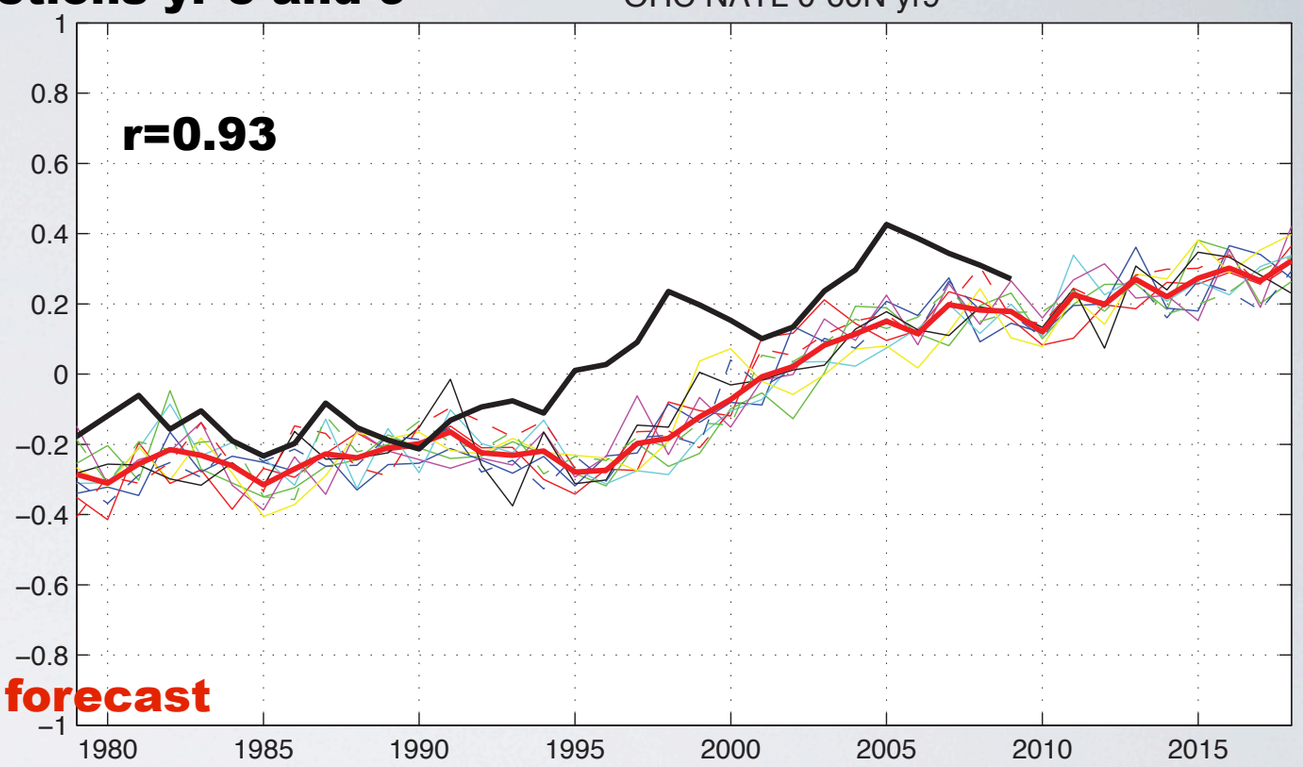
ECDA: “truth”

Ensemble mean forecast

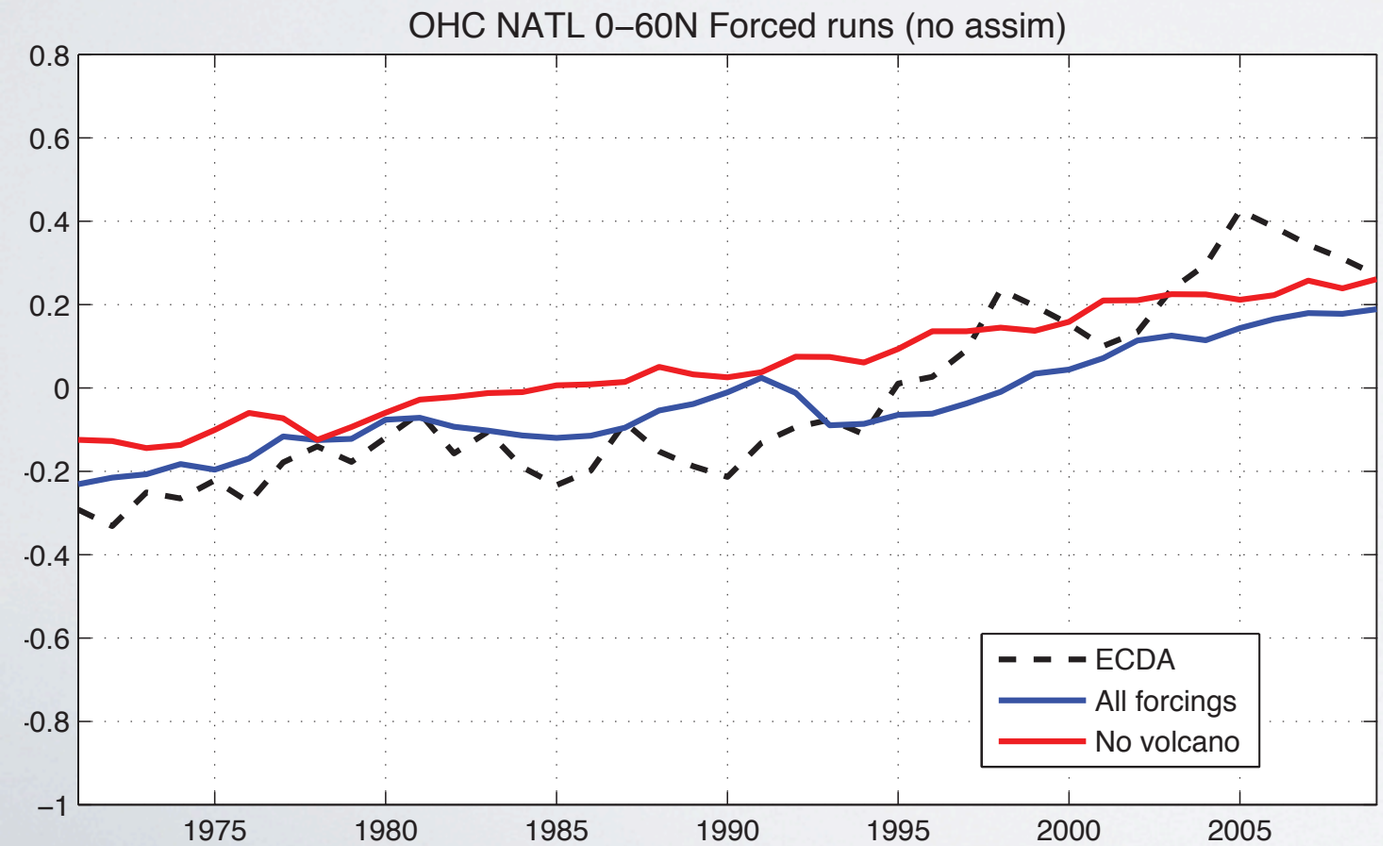
OHC NATL 0-60N

initialized predictions yr 5 and 9





Projections: No Assim



Correlations:

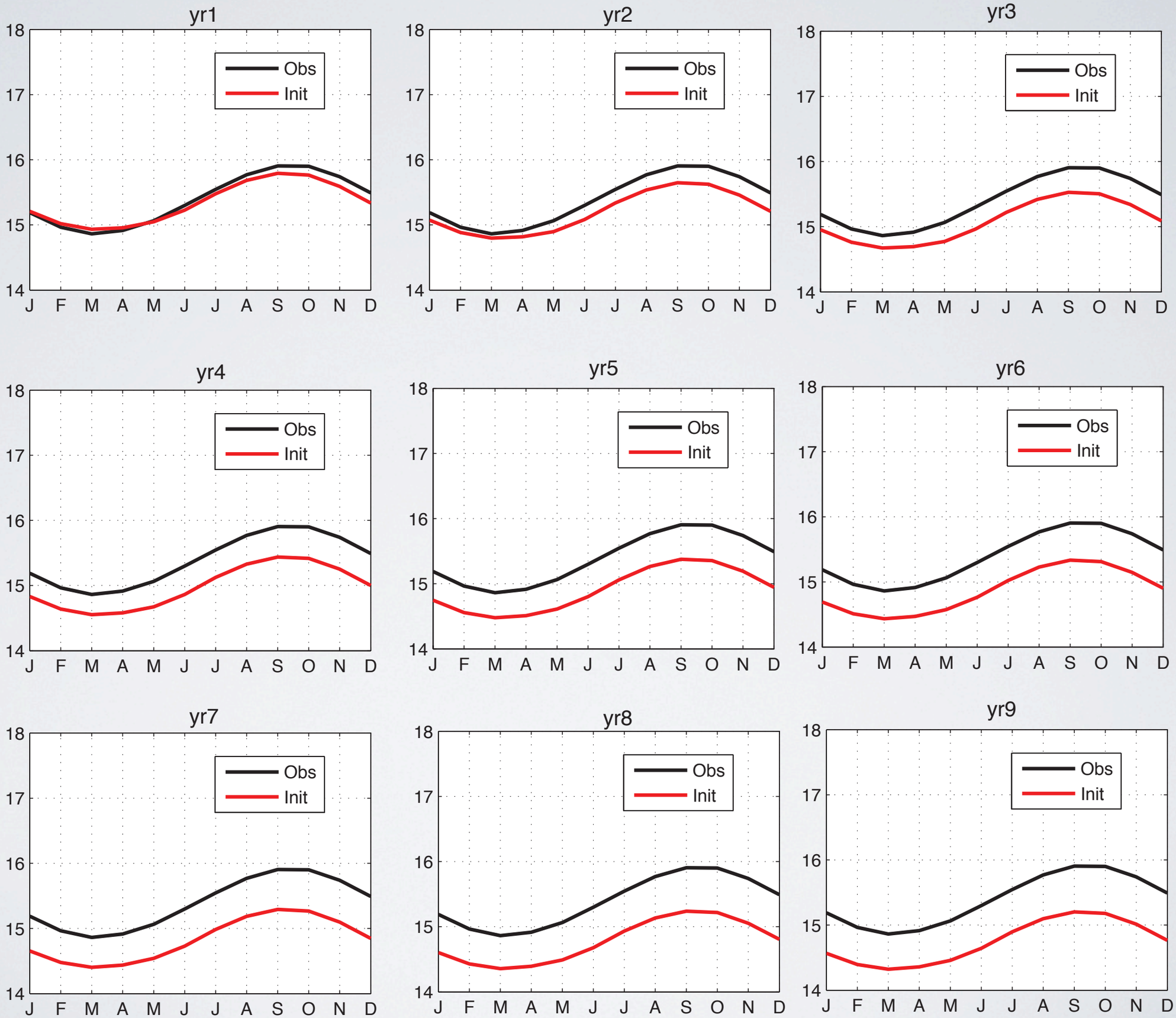
ECDA/NoAssim r=0.91
ECDA/Novolcano r=0.91

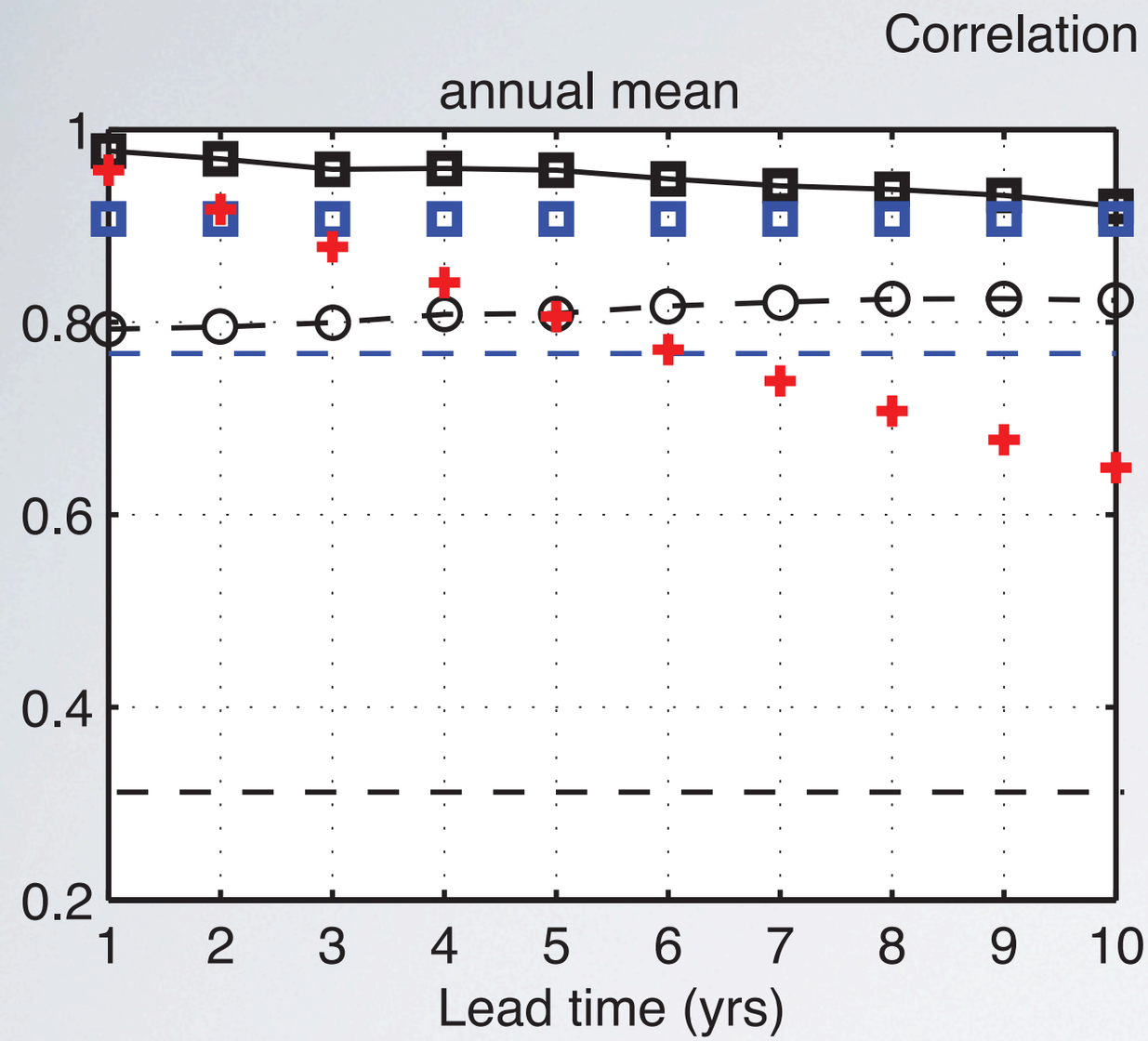
ECDA/NoAssim detrend r=0.38

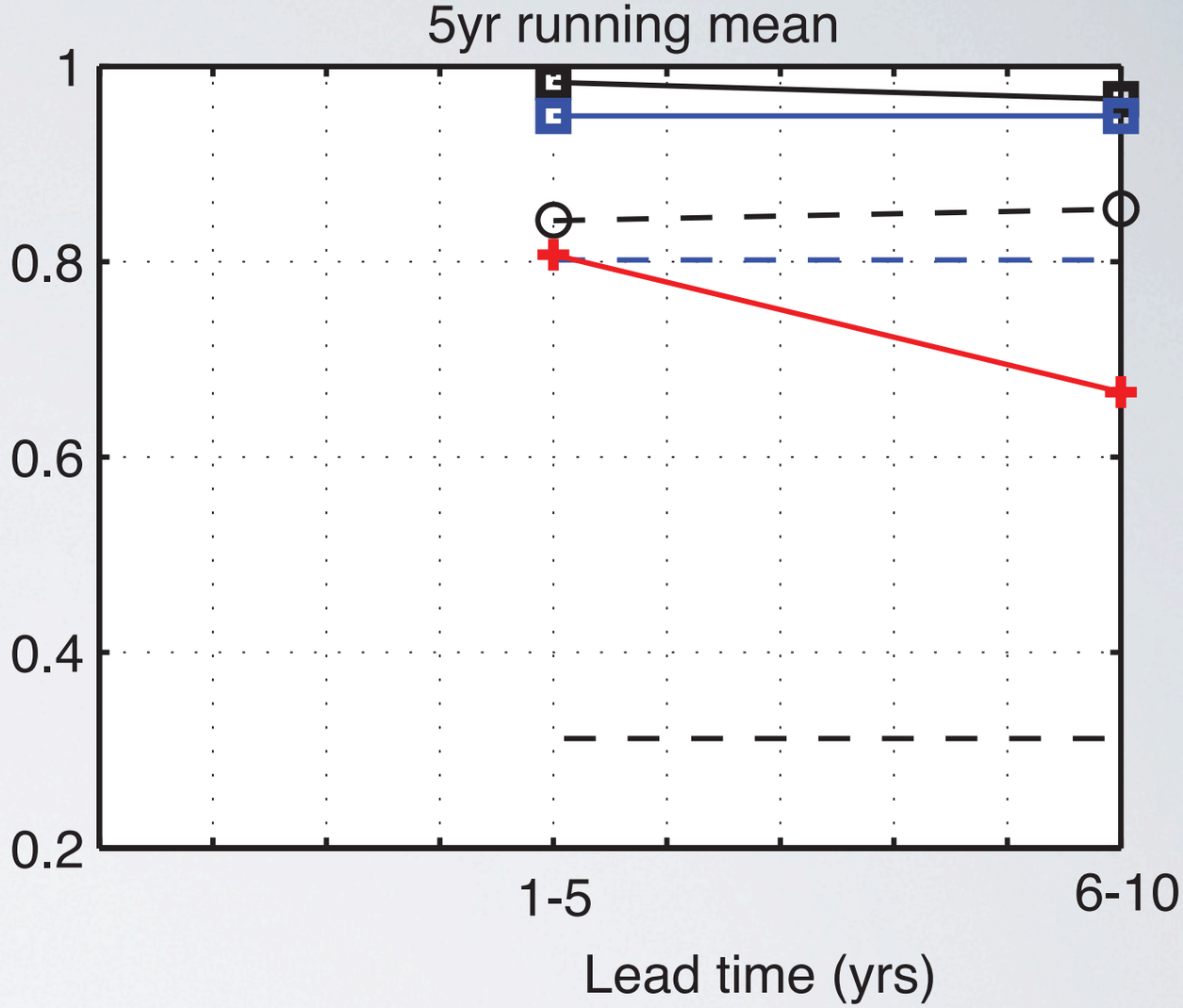
for OHC NATL 30N-60N:
ECDA/NoAssim r=0.80
ECDA/Novolcano r=0.81

OHC NATL 0-60N: Evolution of the bias with lead time

Annual cycle OHC NATL 0-60N (1986–2005)







Hindcasts

Forced (no assim)

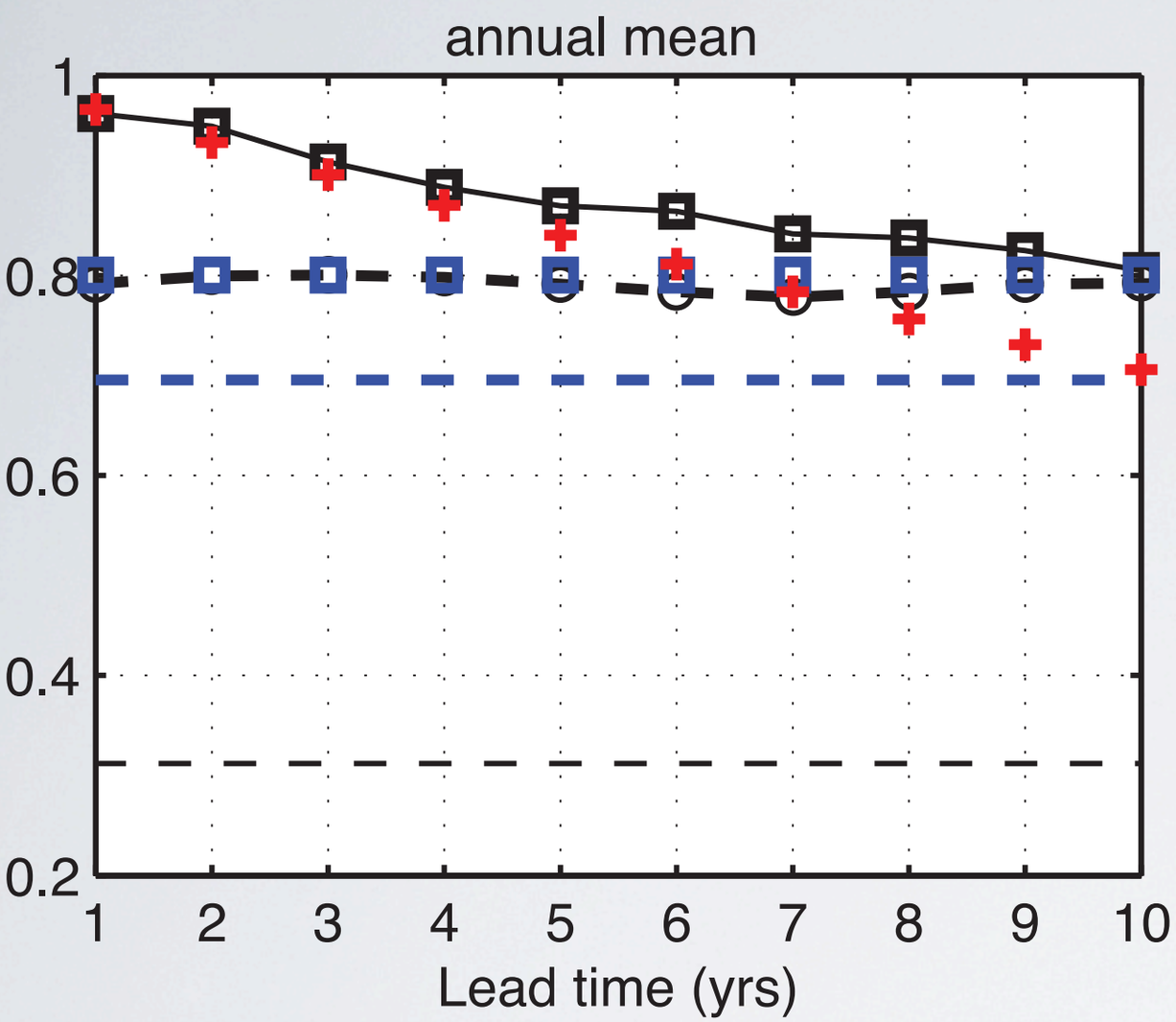
Persistence

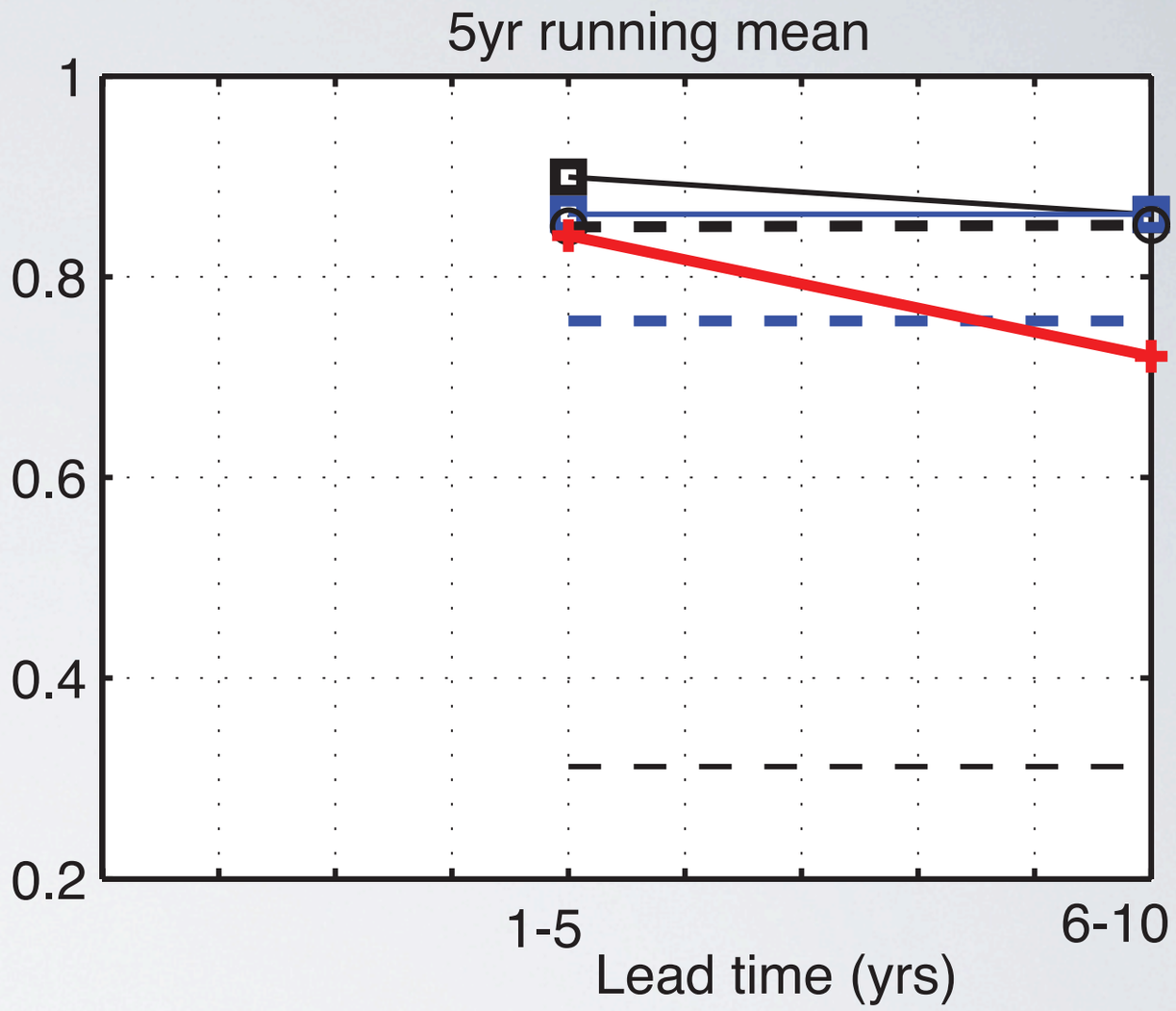
– – – – – significance level

Predictions better than projections for 10 yrs. But comparable with persistence+forcing forecast.

Does it translate into any climatically relevant atmospheric teleconnections (AMO)?

Correlation OHC NATL 30N–60N





Hindcasts

Forced (no assim)

Persistence

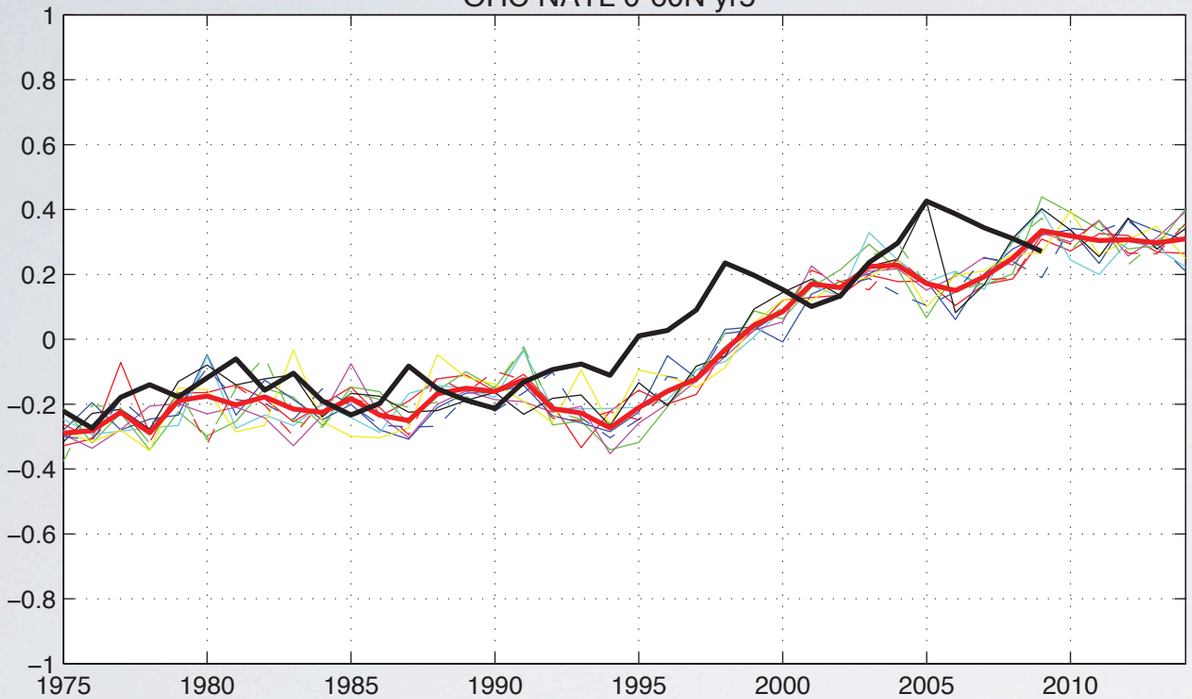
– – – – – significance level

OHC NATL 0-60N

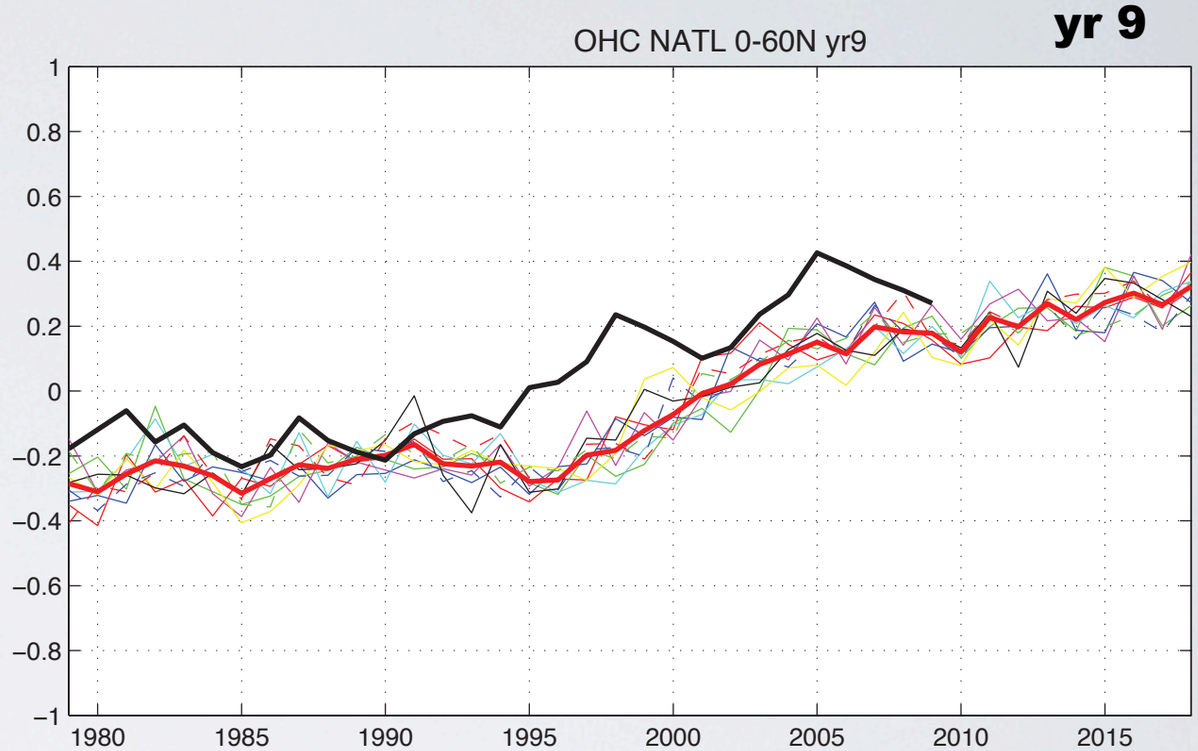
Despite the good correlation, we are not capturing the 1995 signal

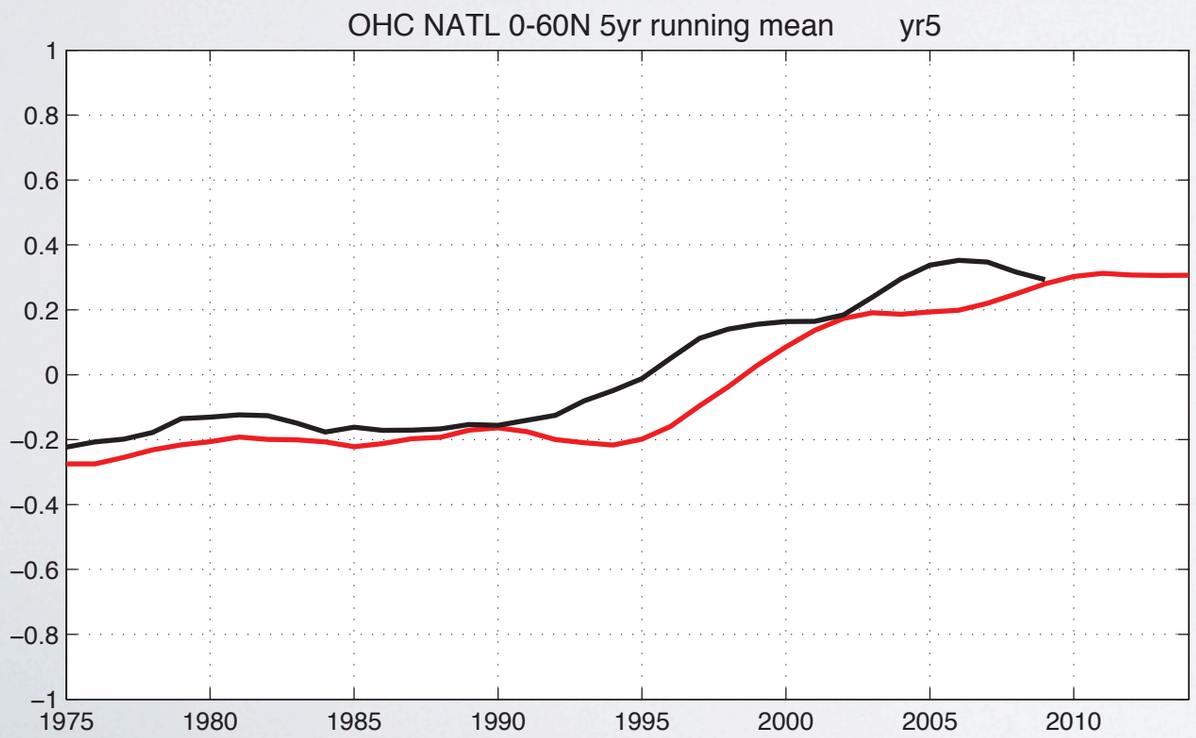
Using a 5yr running mean smoothes the signal of interest

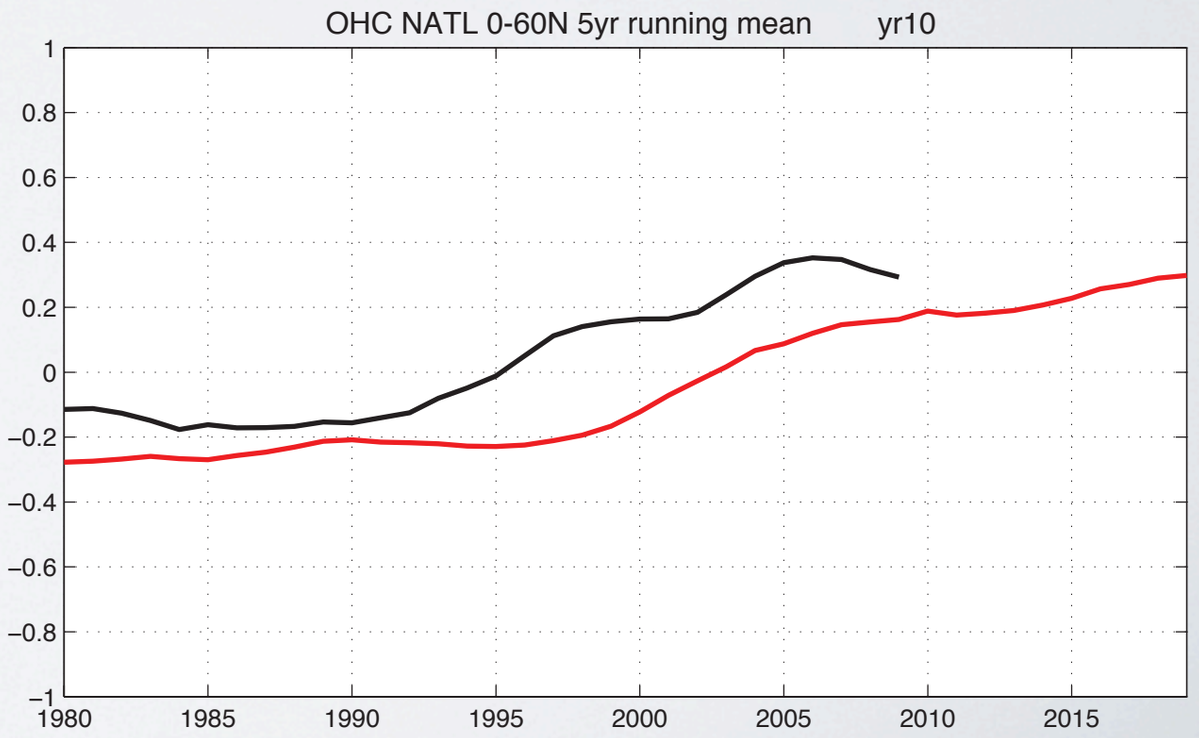
yr 5



yr 9

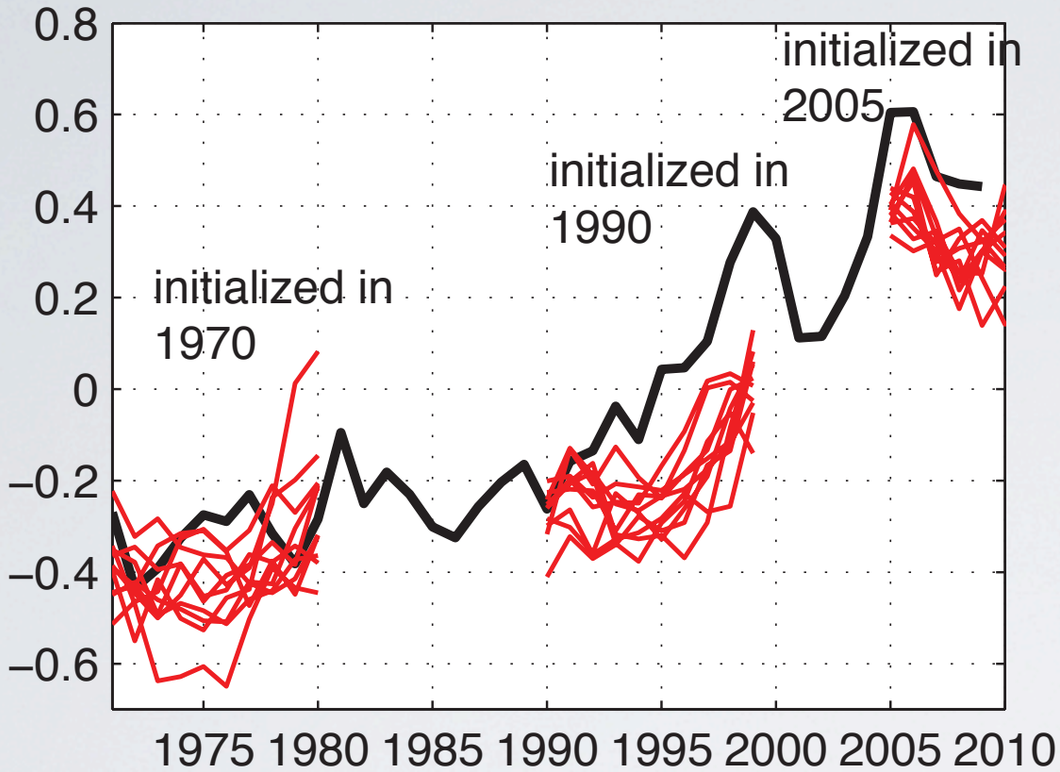


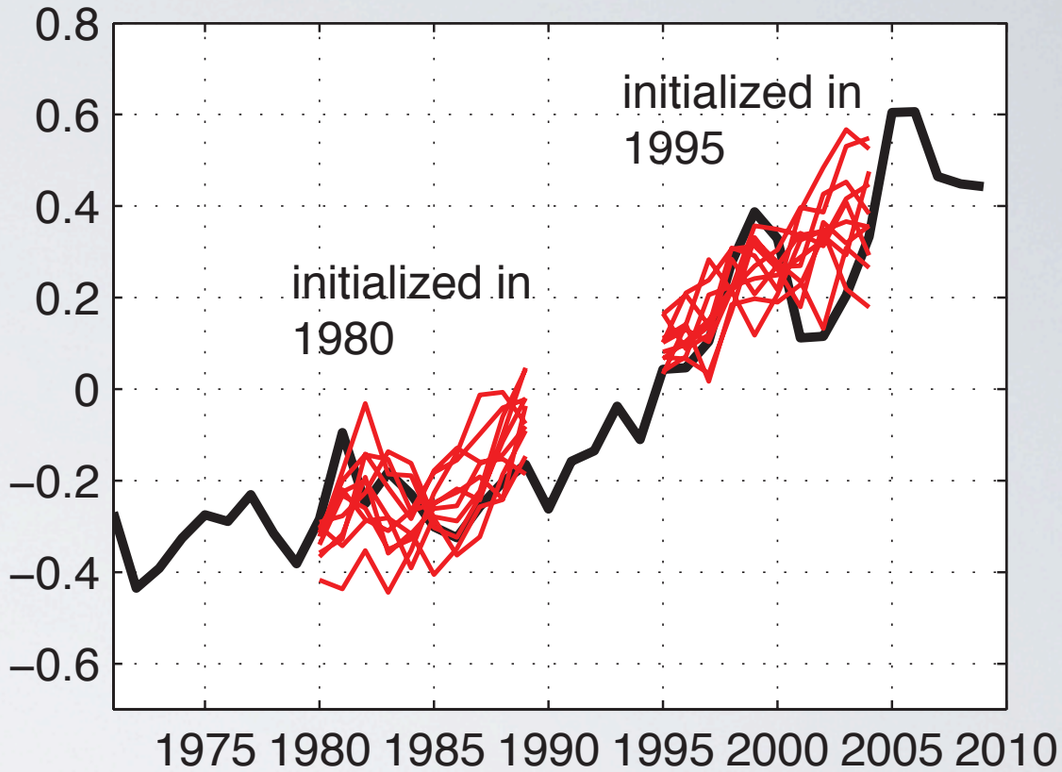


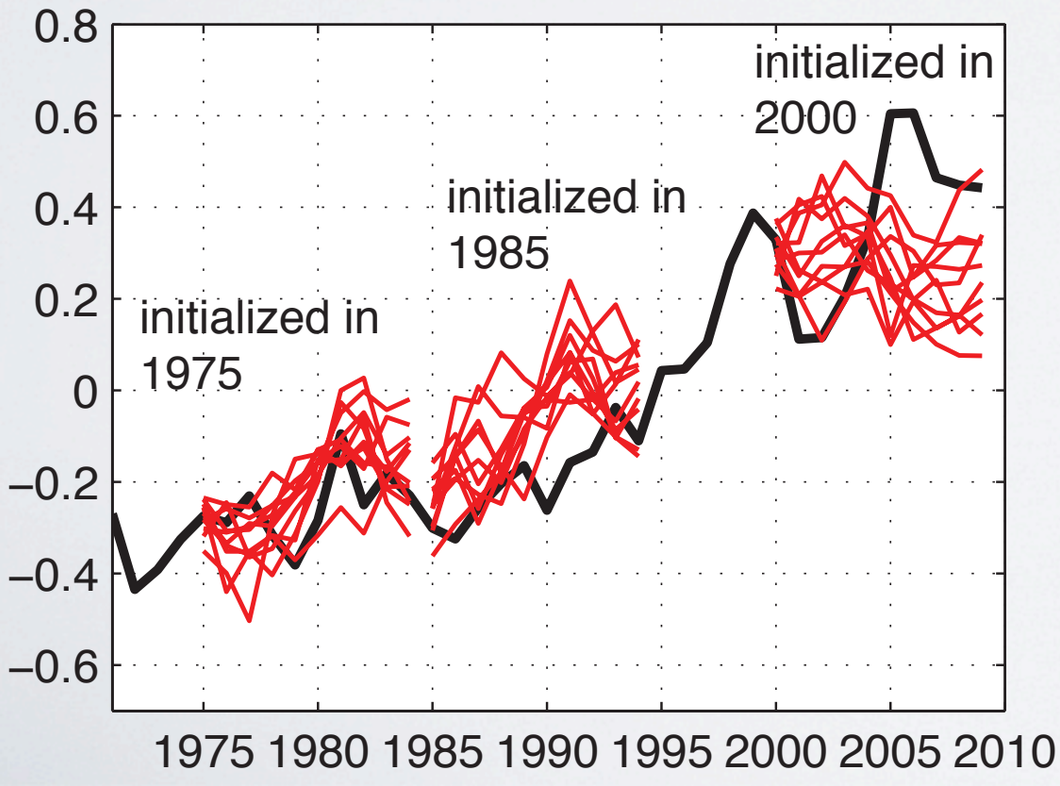


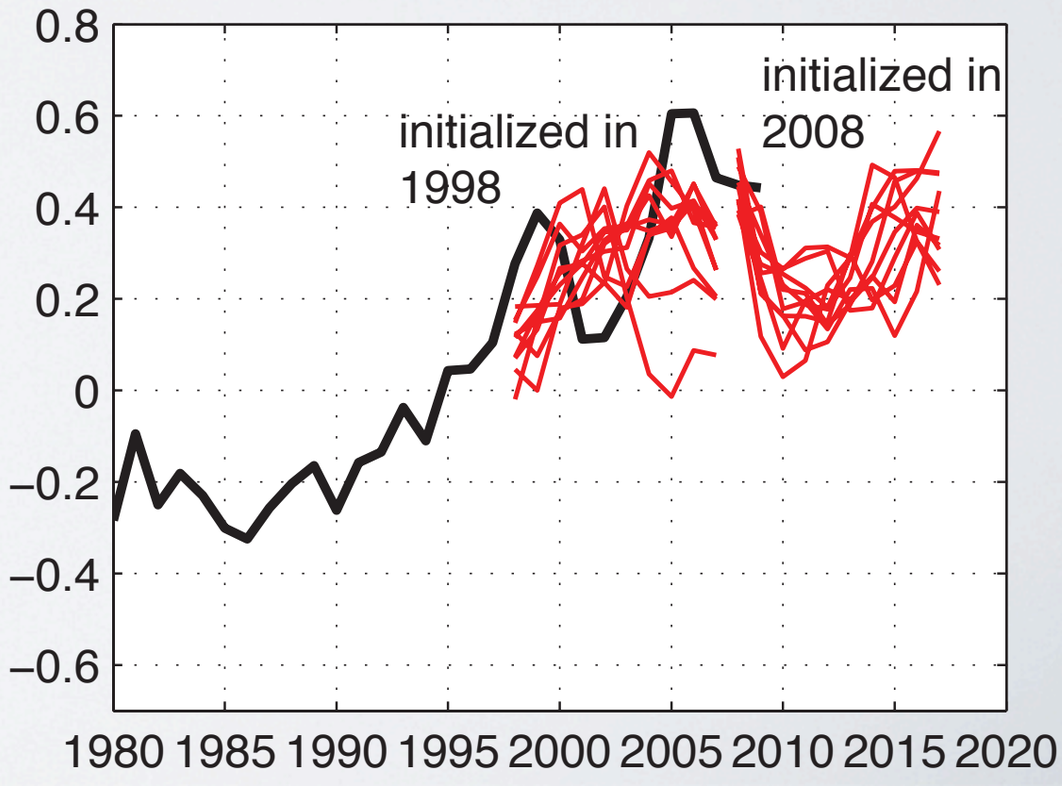
Are there initial states more predictable than others?

OHC NATL 30N60N

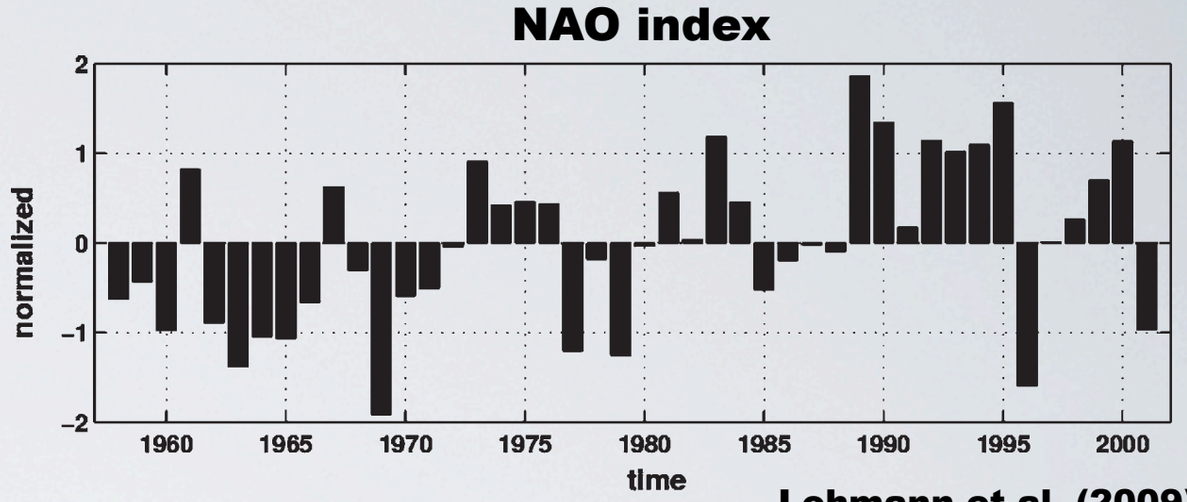








What forced the 1995 warming?



Lohmann et al. (2009)

Hypothesis

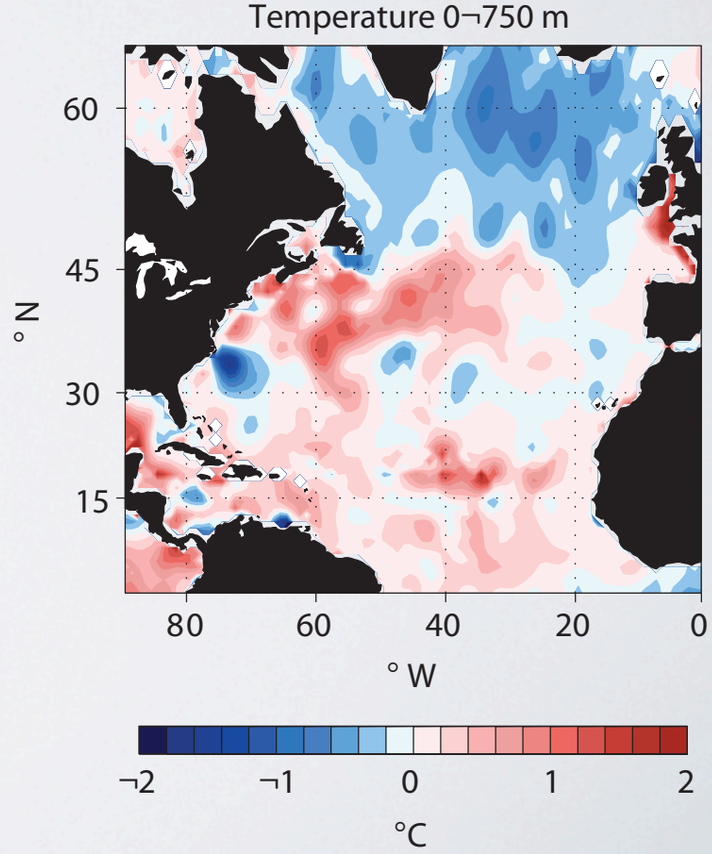
Warming of NATL partly forced by NAO (Lozier et al. 2008, Lohmann et al. 2009)

Persistent + NAO before 1995 => cooling subpolar gyre => spin up and deep water formation => AMOC intensification => increased MHT => warming SPG

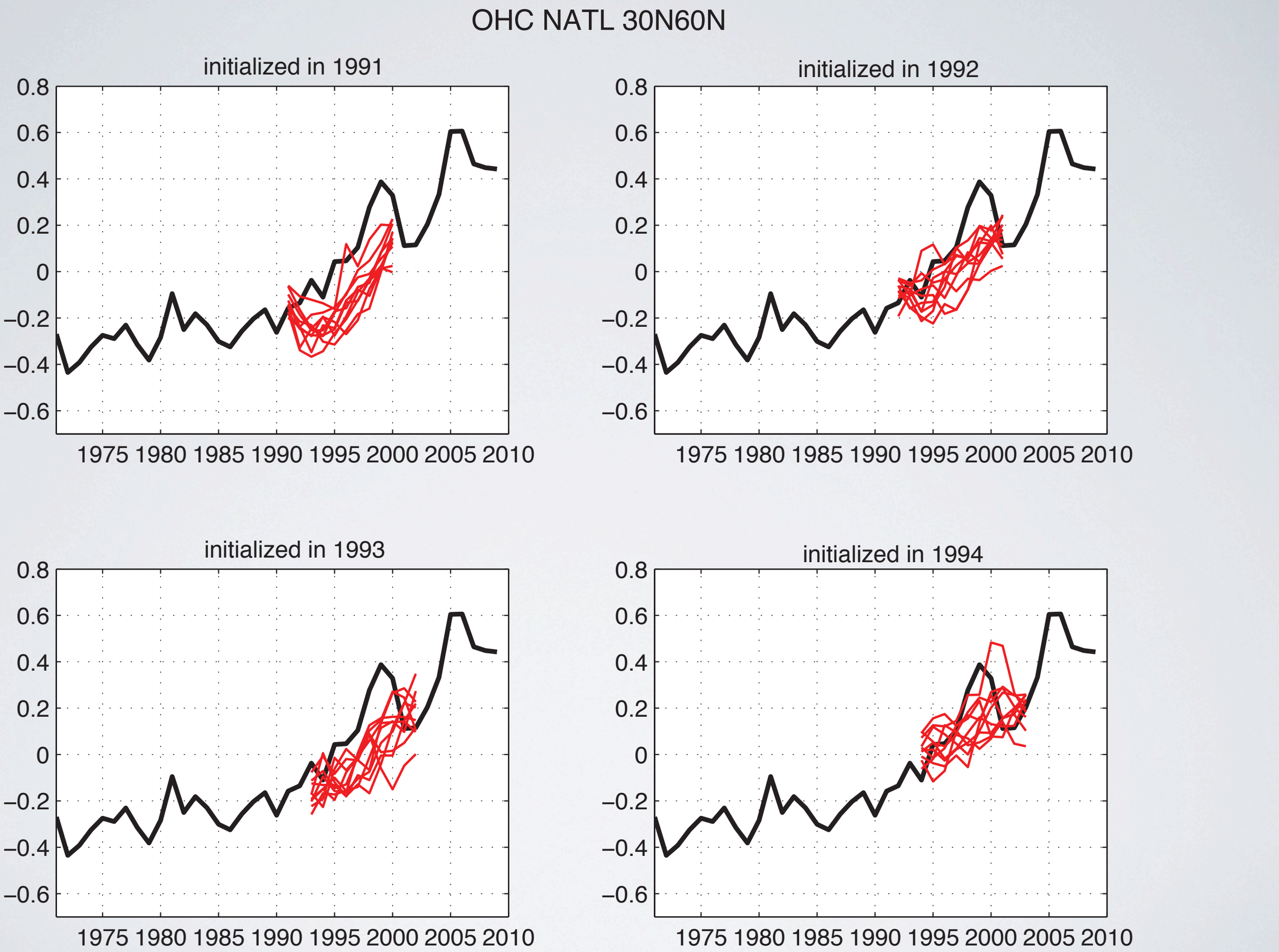
Winter 95/96: switch to NAO -, maximum warming of SPG. Lagged response?

Neutral NAO after 96 and persistent warming suggests other influence than just NAO fluxes: anthropogenic CO2?

Are we able to initialize properly the model to capture these dynamic changes?

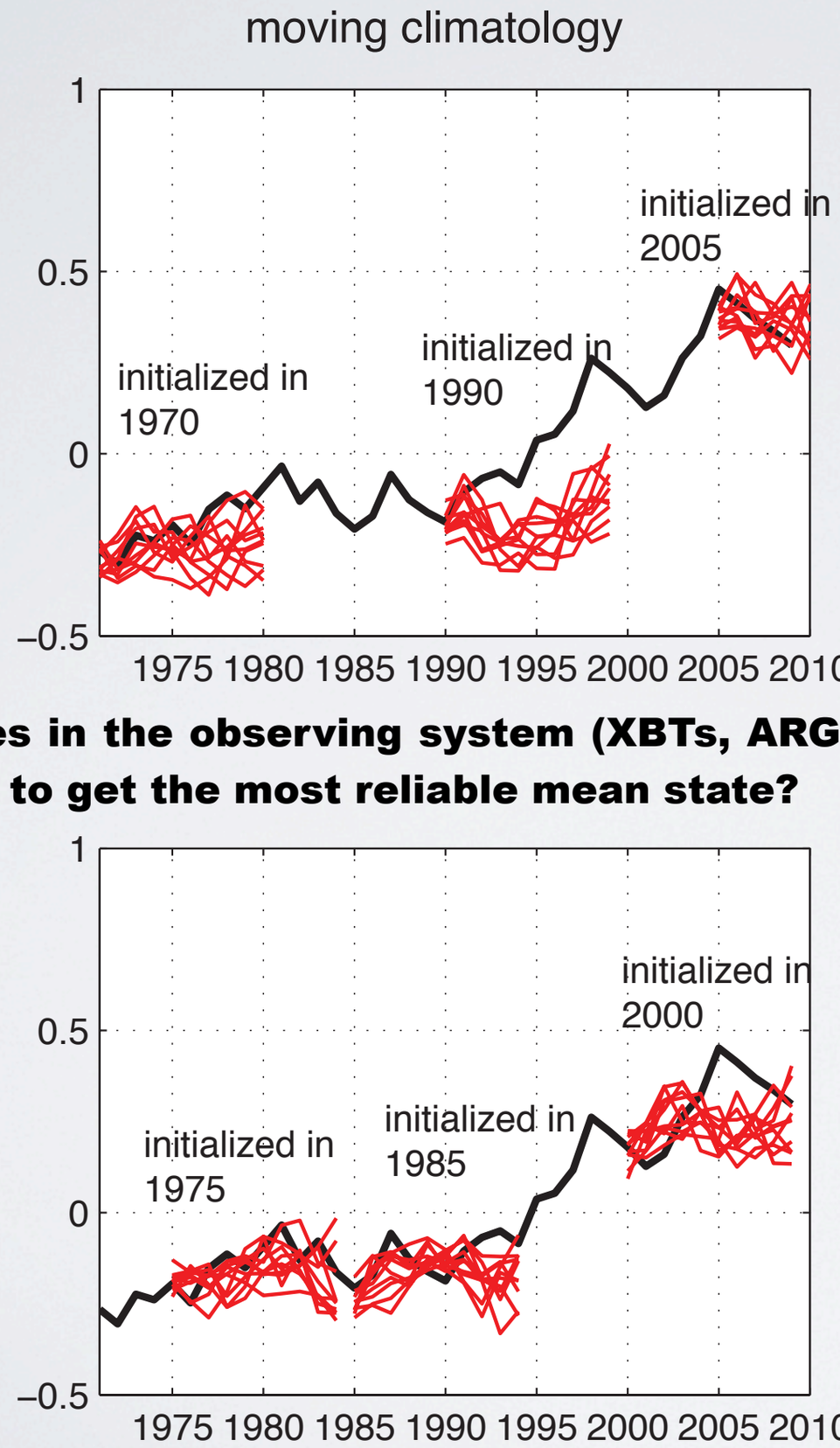


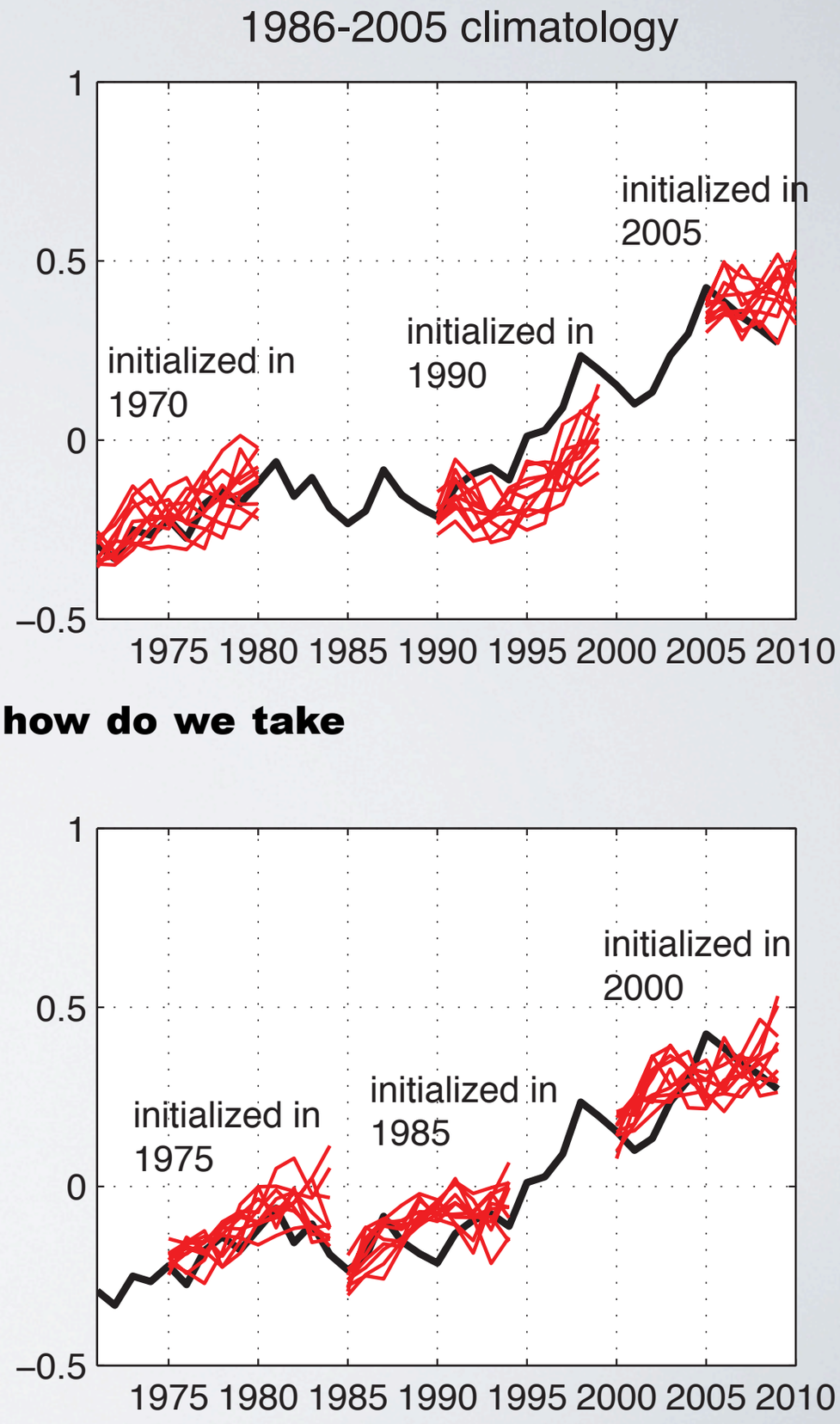
Lozier et al. (2008)


OHC NATL 30N60N
initialized in 1991
initialized in 1992
initialized in 1993
initialized in 1994
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
1975 1980 1985 1990 1995 2000 2005 2010

The choice of the climatology does matter !

(Robson et al. (2011)





Significant changes in the observing system (XBTs, ARGO): how do we take them into account to get the most reliable mean state?

Conclusions

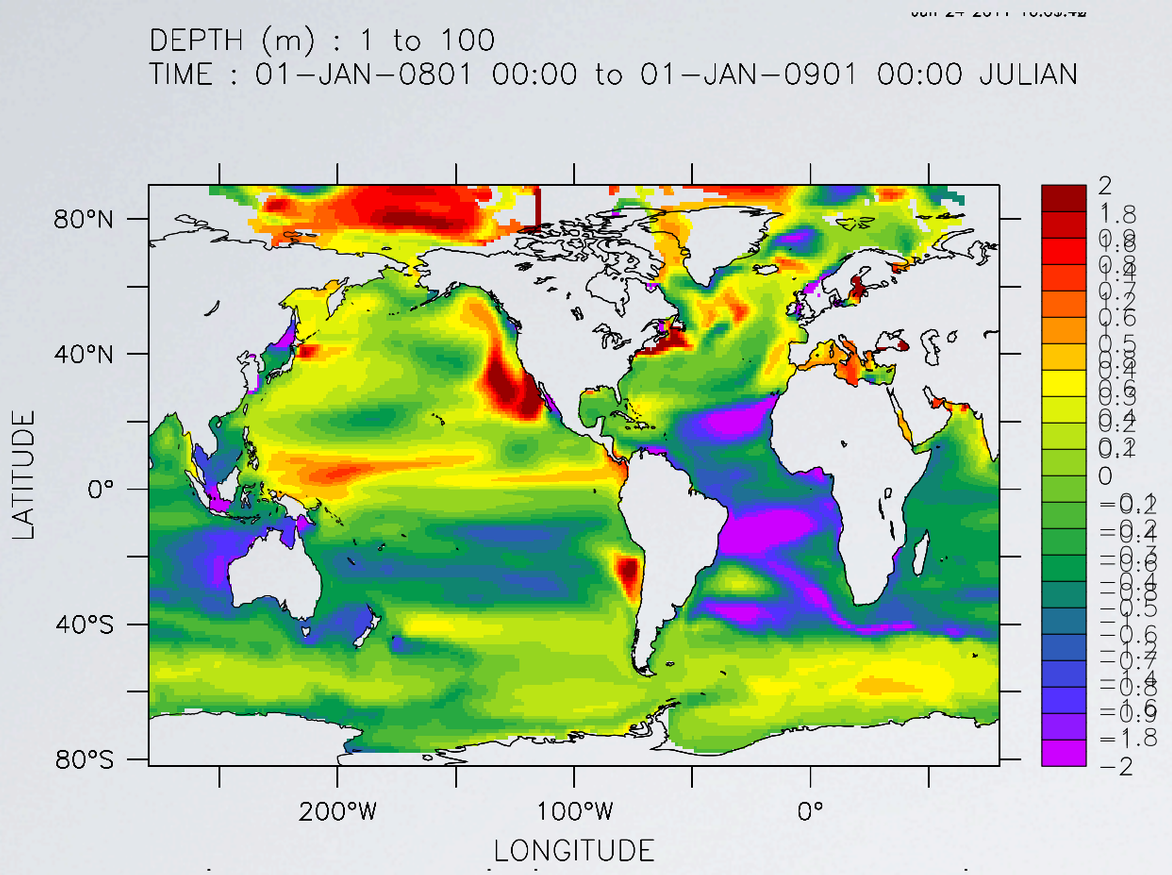
The North Atlantic appears as a region where initialization might bring increased skill compared with non-initialized projections.

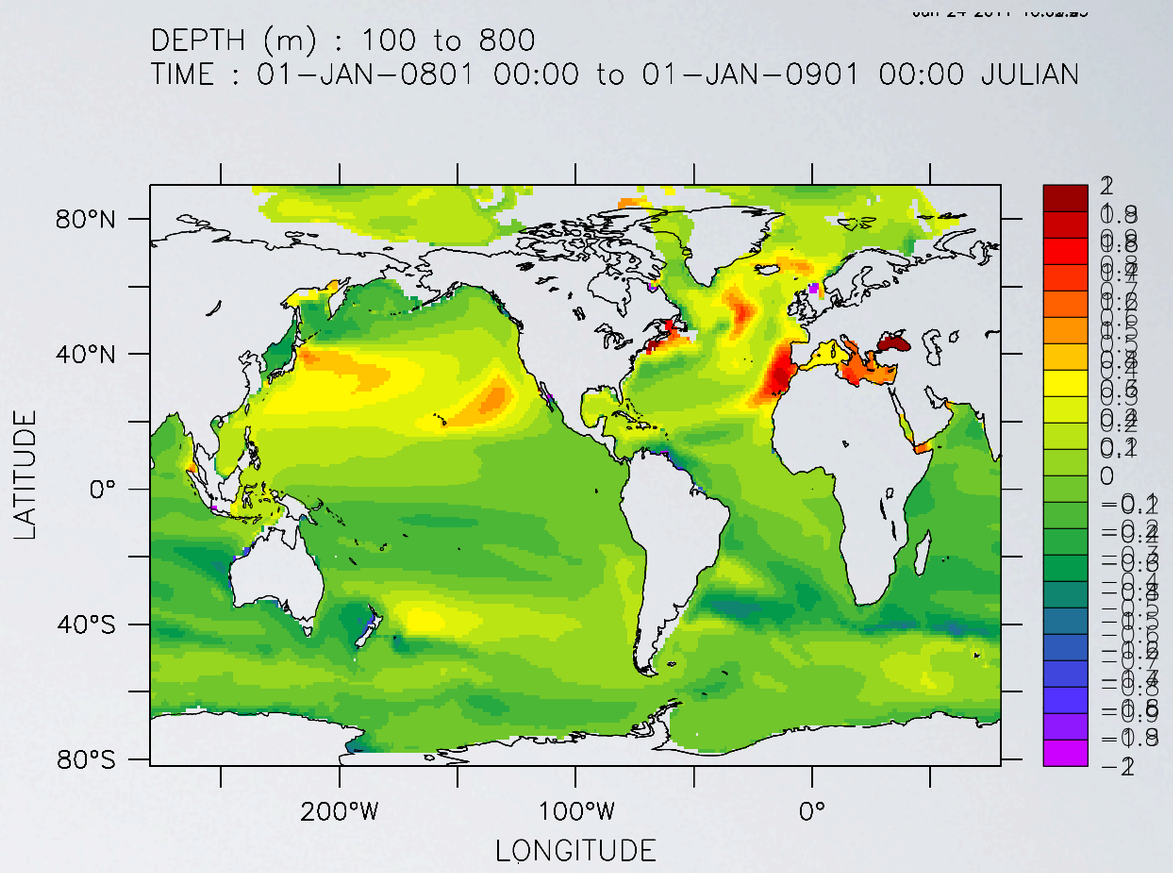
The origin of that possible increased skill and the role of volcanoes (and other noise) needs to be assessed.

Having a very high correlation does not mean that we predict the trend accurately or we capture the signal of interest (the "wiggles" in OHC)

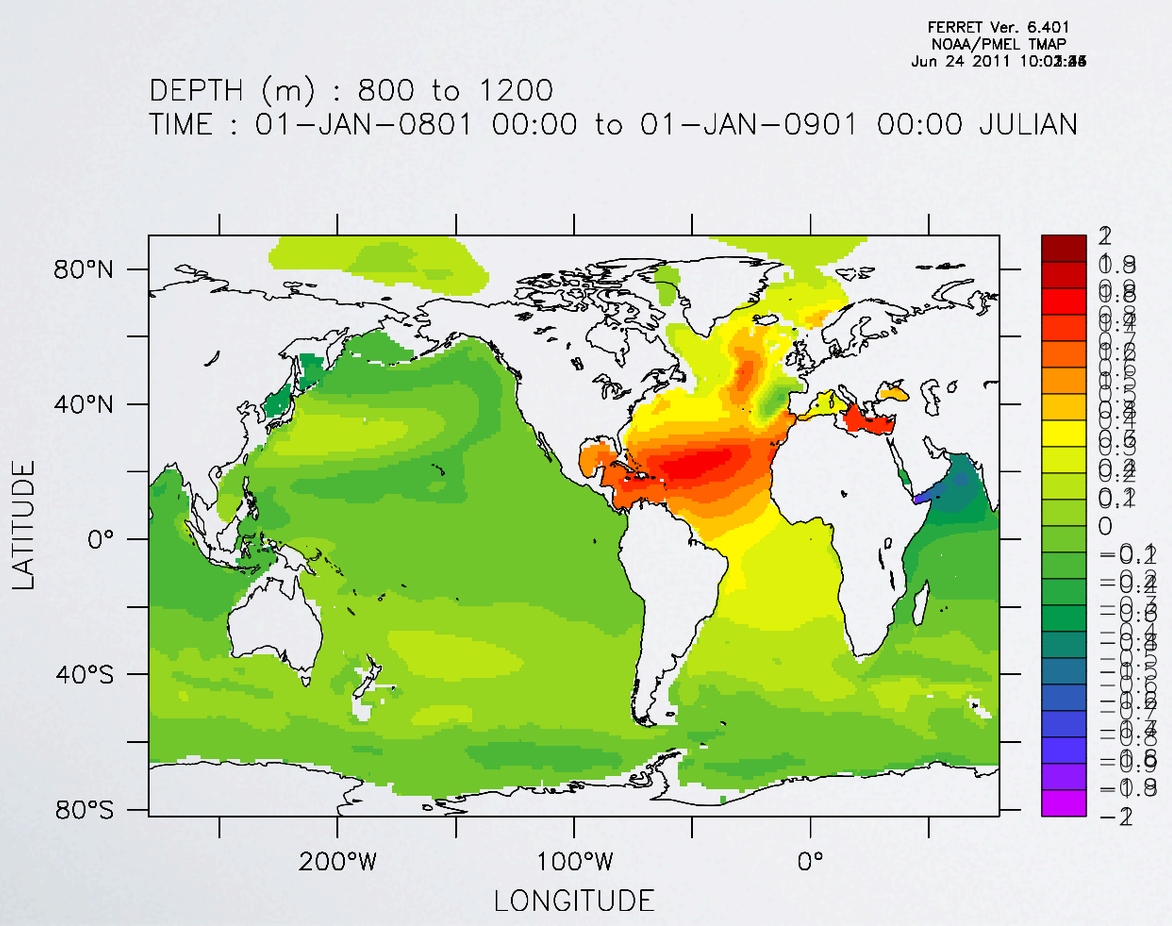
We are looking for signals that are very small: case studies like the 1995 North Atlantic warming should be a case study in single and multi-models

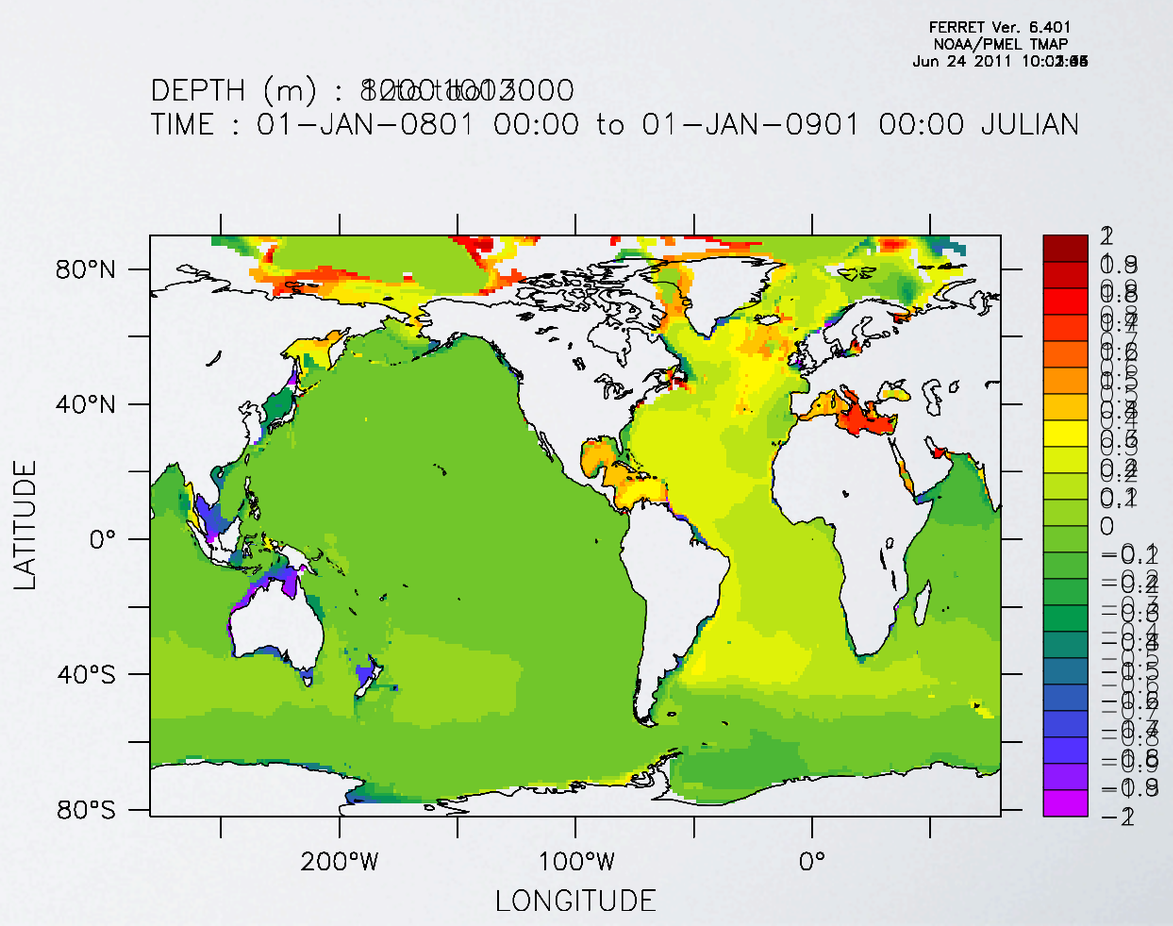
Challenges to overcome model drifts and discontinuities in the observing system.





CM2.1 FWC biases (control minus ECDA)





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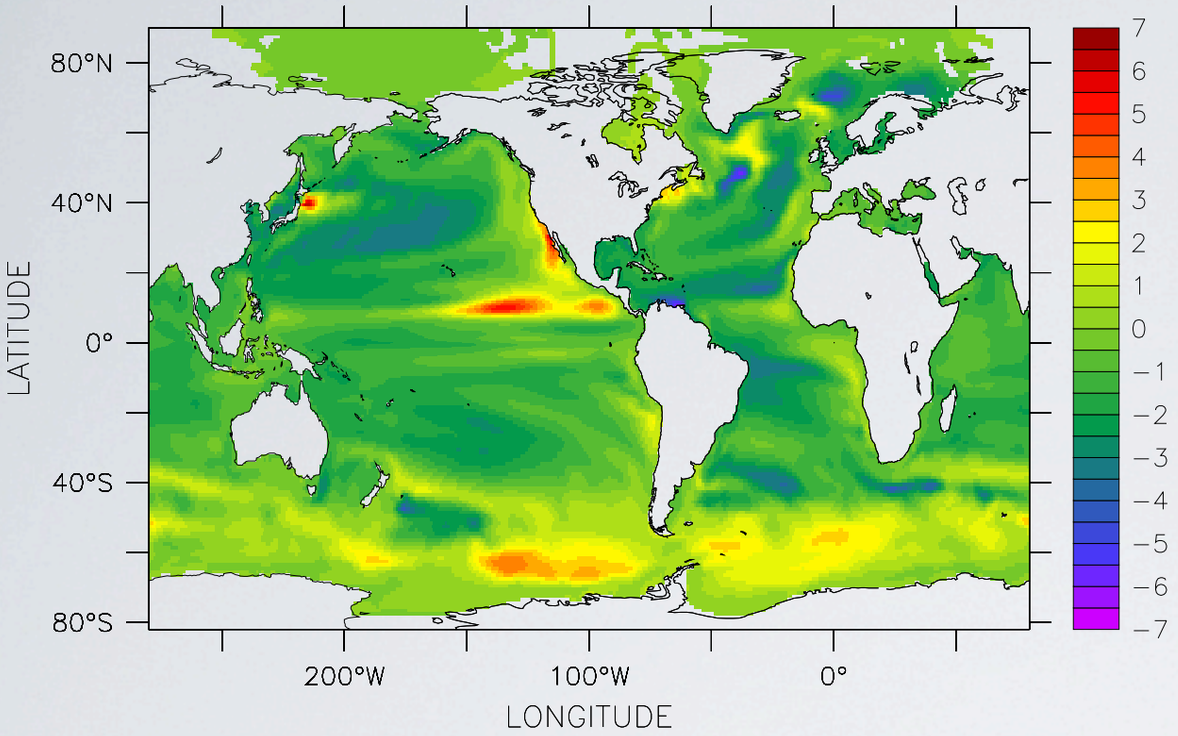

DEPTH (m) : 100 to 800
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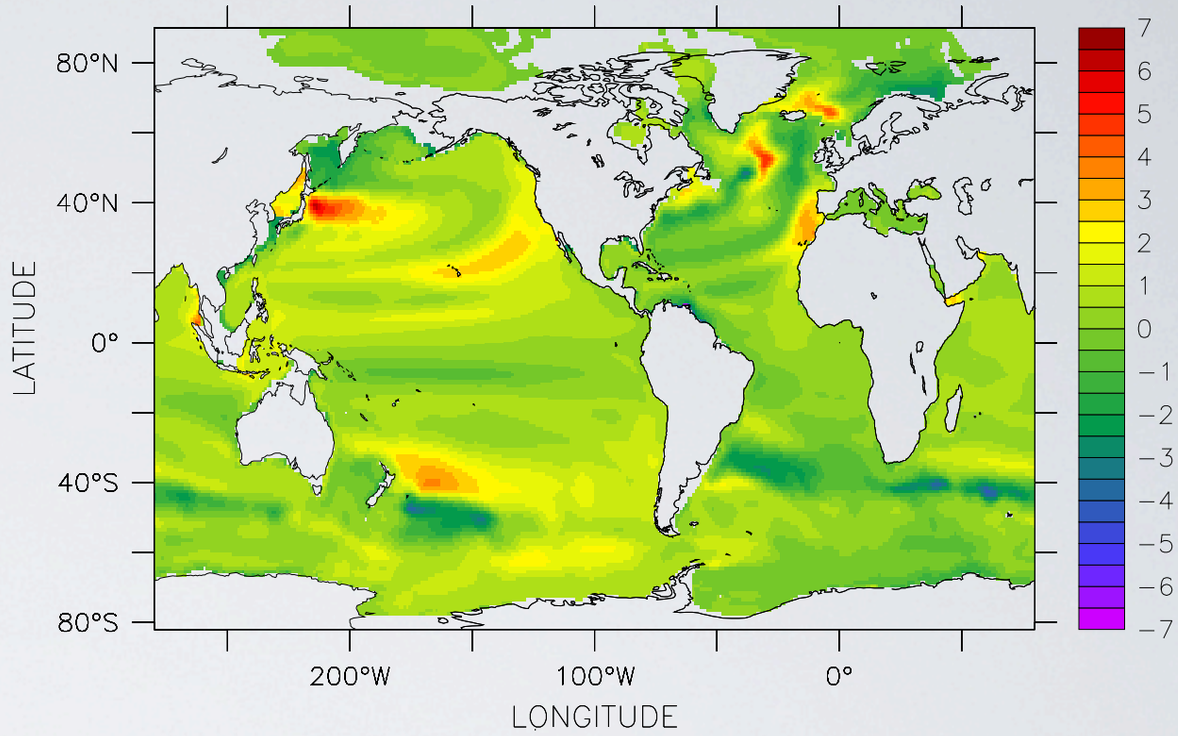

CM2.1 OHC biases (control minus ECDA)

FERRET Ver. 6.401
NOAA/PMEL TMAP
Jun 22 2011 12:04:48

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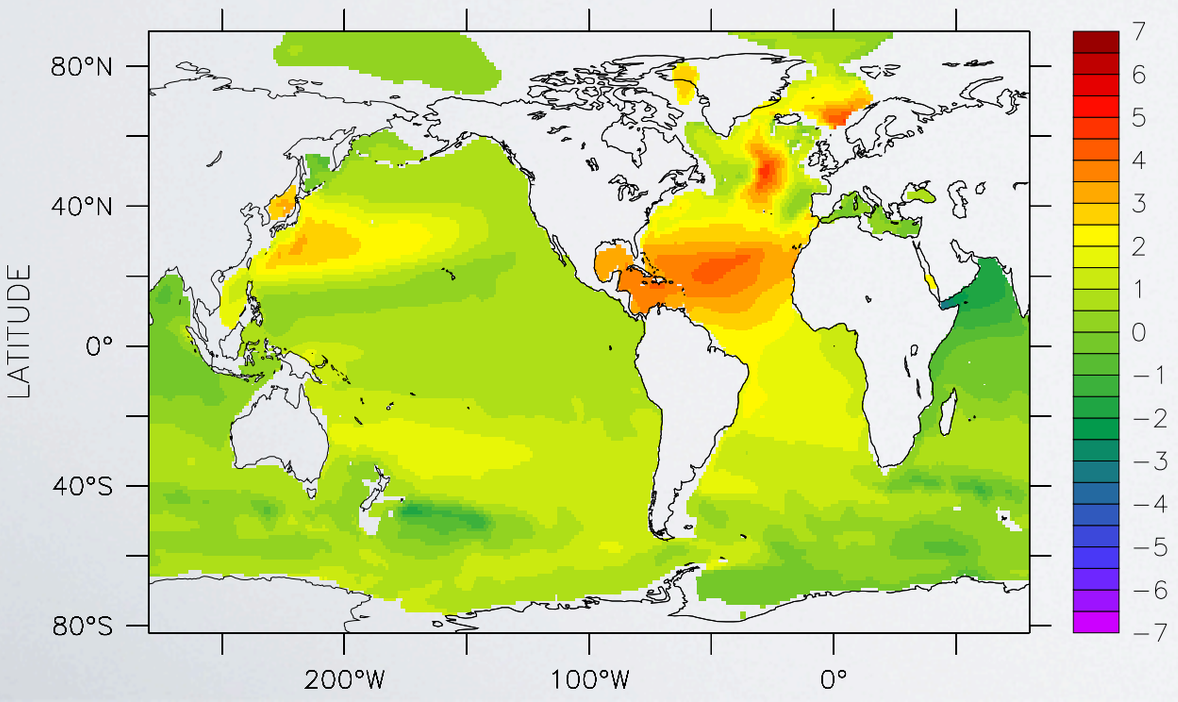

FERRET Ver. 6.401
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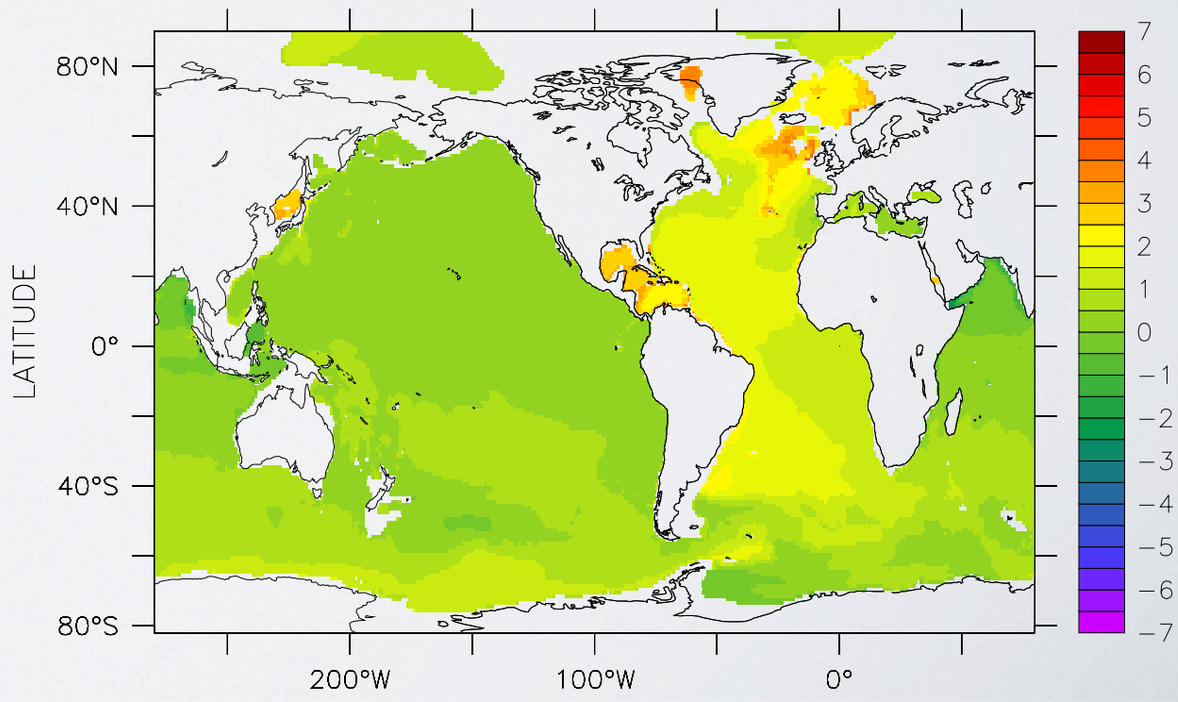
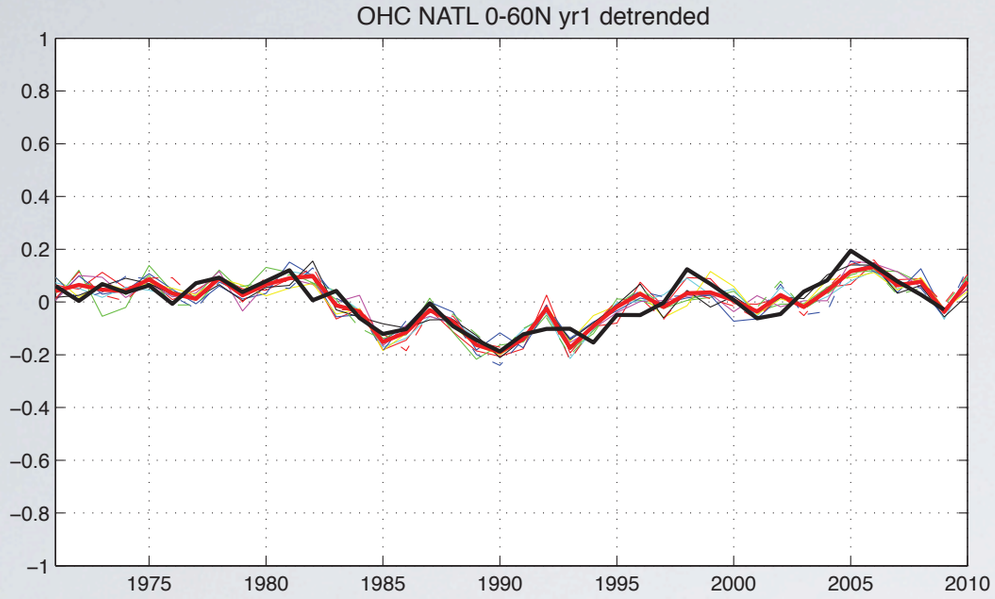
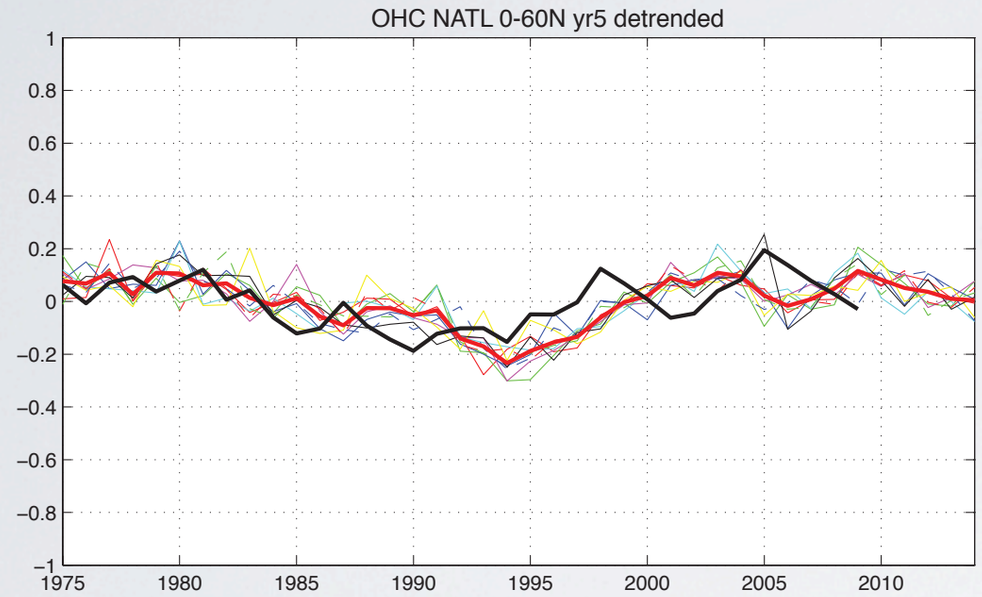
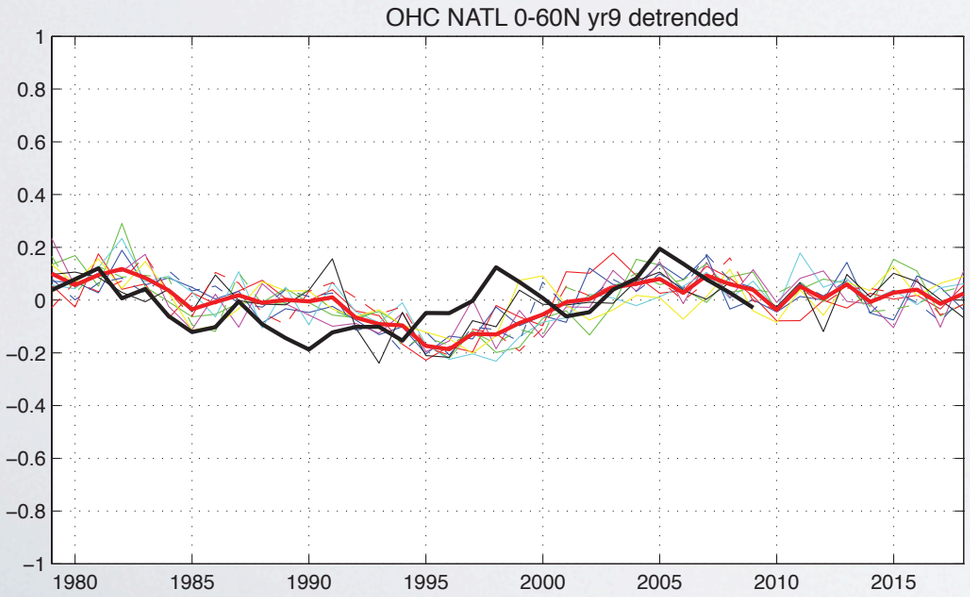
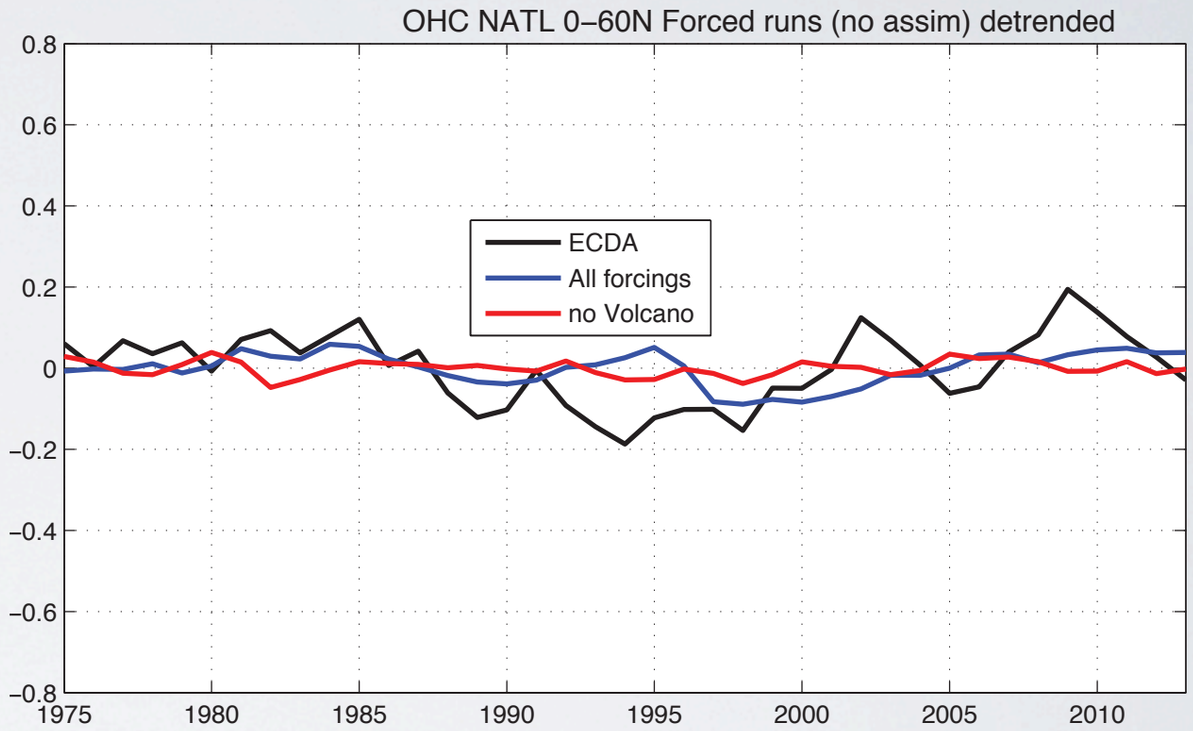
DEPTH (m) : 1200 to 3000
TIME : 01-JAN-0801 00:00 to 01-JAN-0901 00:00 JULIAN

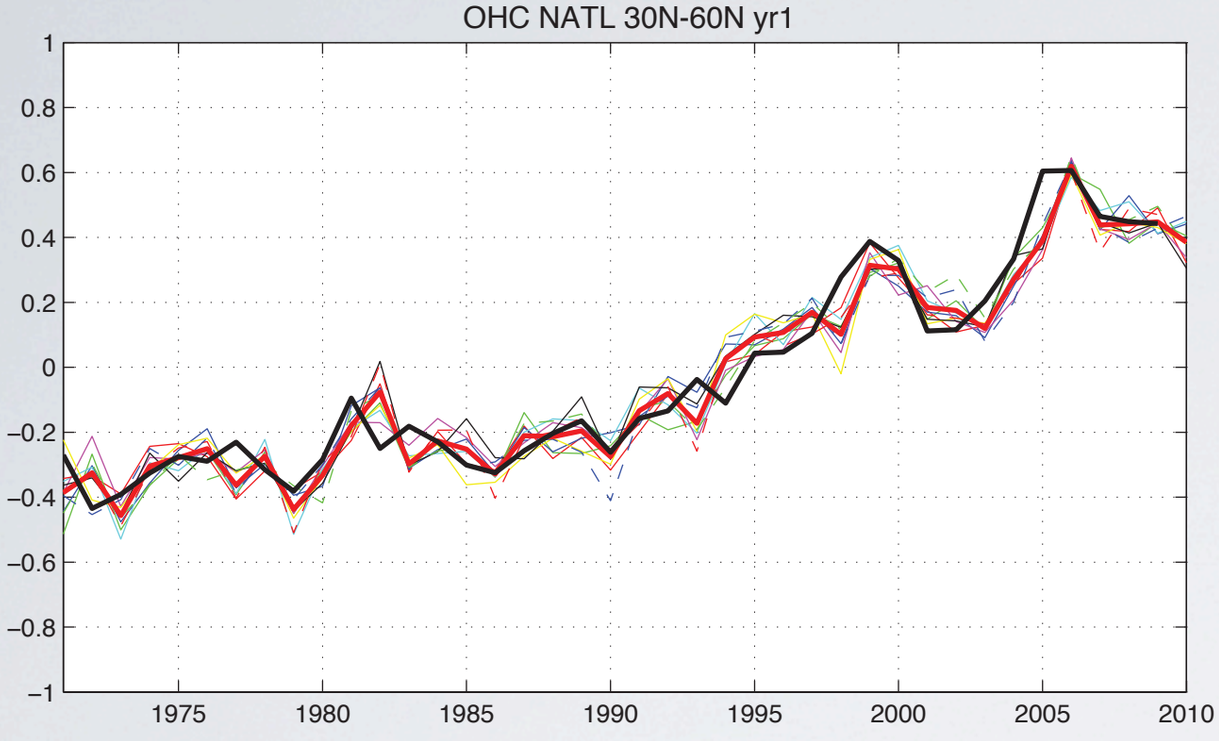


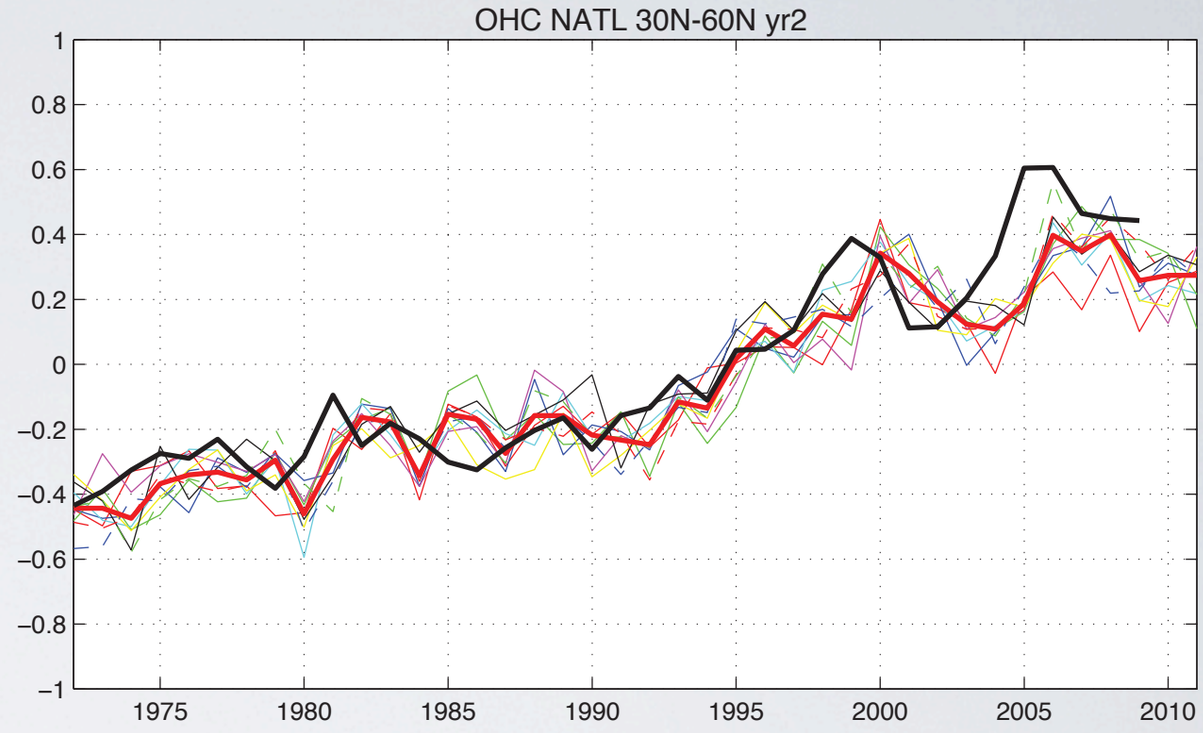

OHC NATL 0-60N yr1 detrended
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
1975
1980
1985
1990
1995
2000
2005
2010

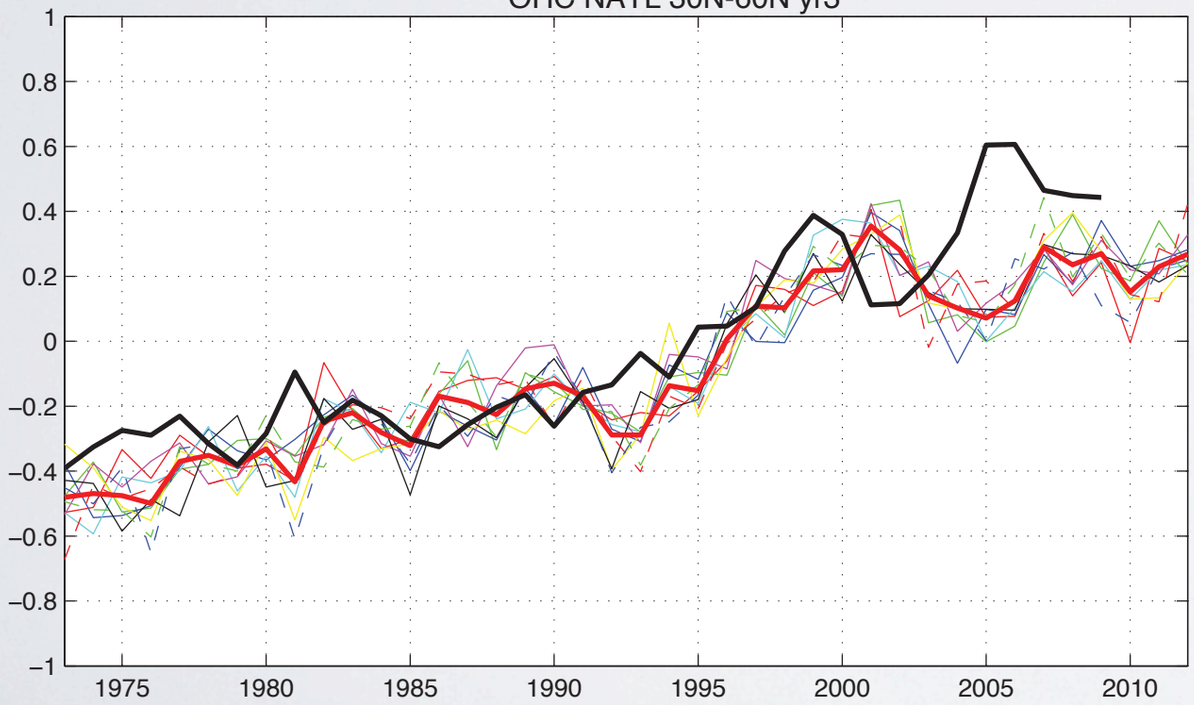

OHC NATL 0-60N yr5 detrended
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
1975
1980
1985
1990
1995
2000
2005
2010

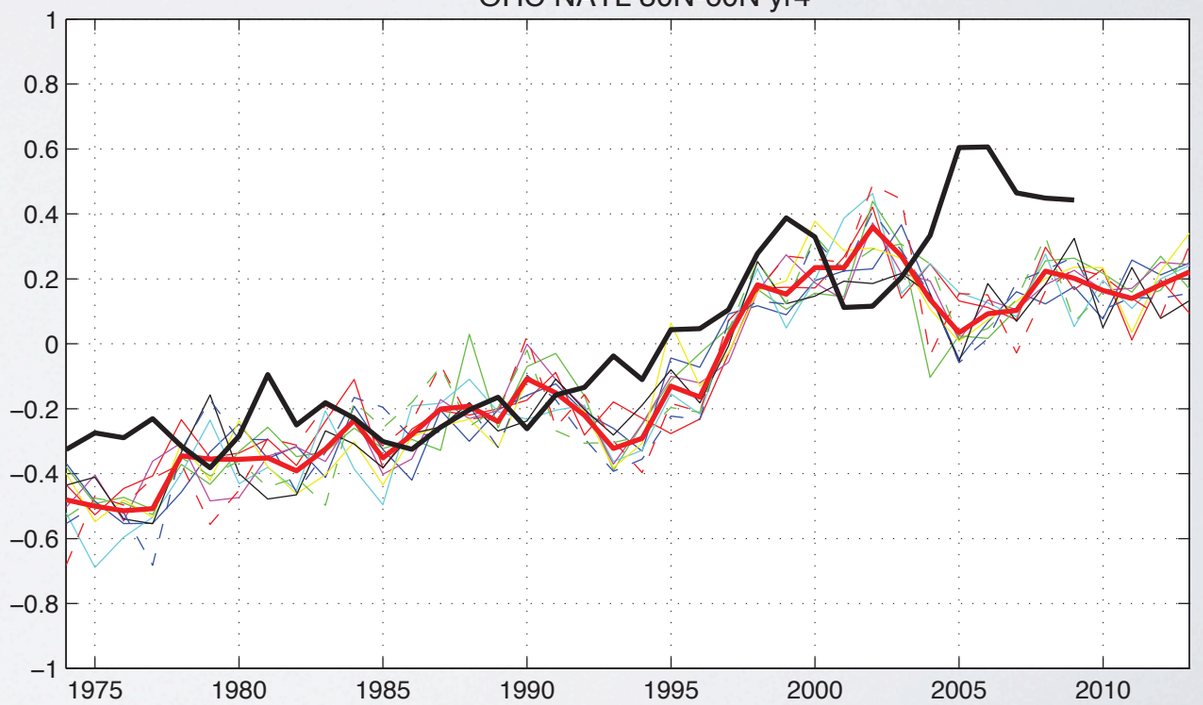

OHC NATL 0-60N yr9 detrended
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
1980
1985
1990
1995
2000
2005
2010
2015


OHC NATL 0–60N Forced runs (no assim) detrended
ECDA
All forcings
no Volcano
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
1975
1980
1985
1990
1995
2000
2005
2010


OHC NATL 30N-60N yr1
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
1975
1980
1985
1990
1995
2000
2005
2010

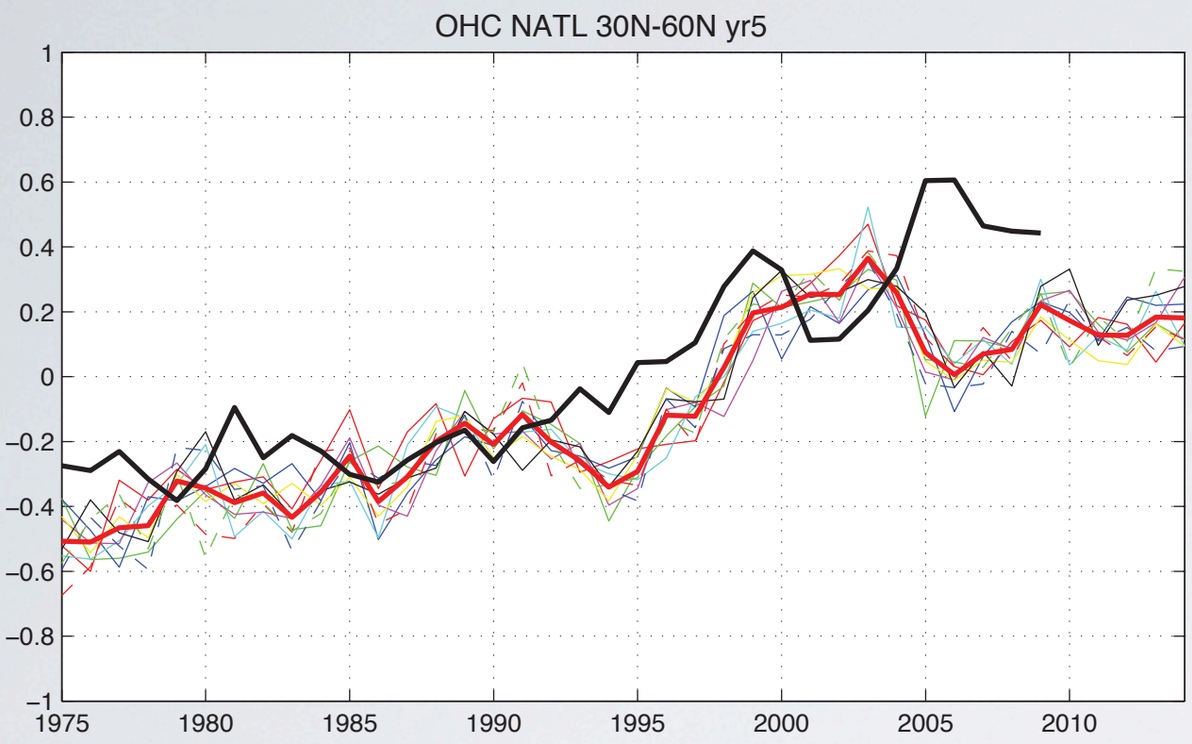

OHC NATL 30N-60N yr2
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
1975
1980
1985
1990
1995
2000
2005
2010


OHC NATL 30N-60N yr3
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
1975
1980
1985
1990
1995
2000
2005
2010

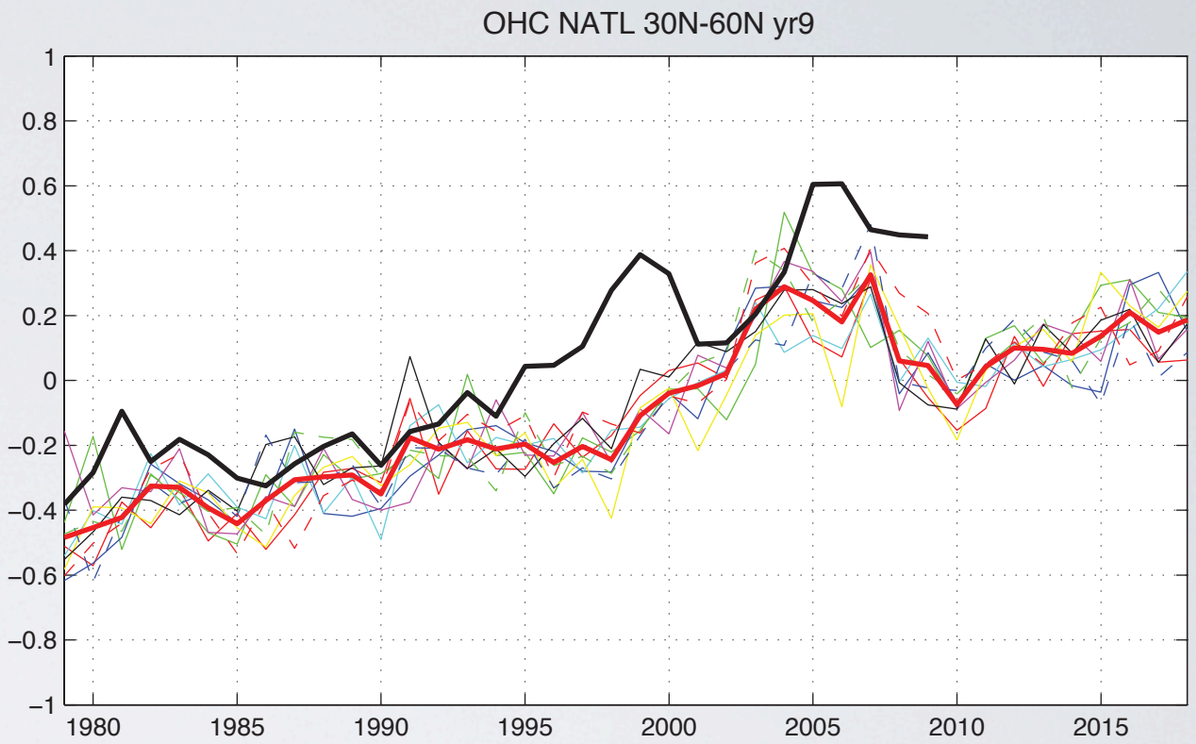

OHC NATL 30N-60N yr4
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
1975
1980
1985
1990
1995
2000
2005
2010

OHC NATL 30-60N

initialized predictions yr 5

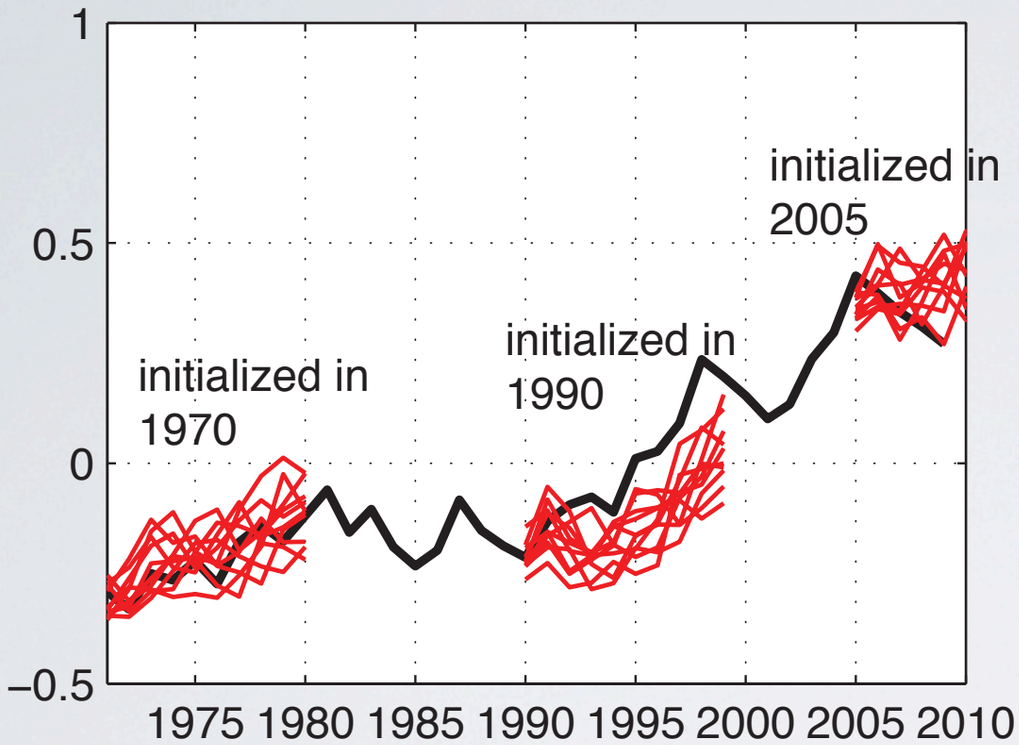


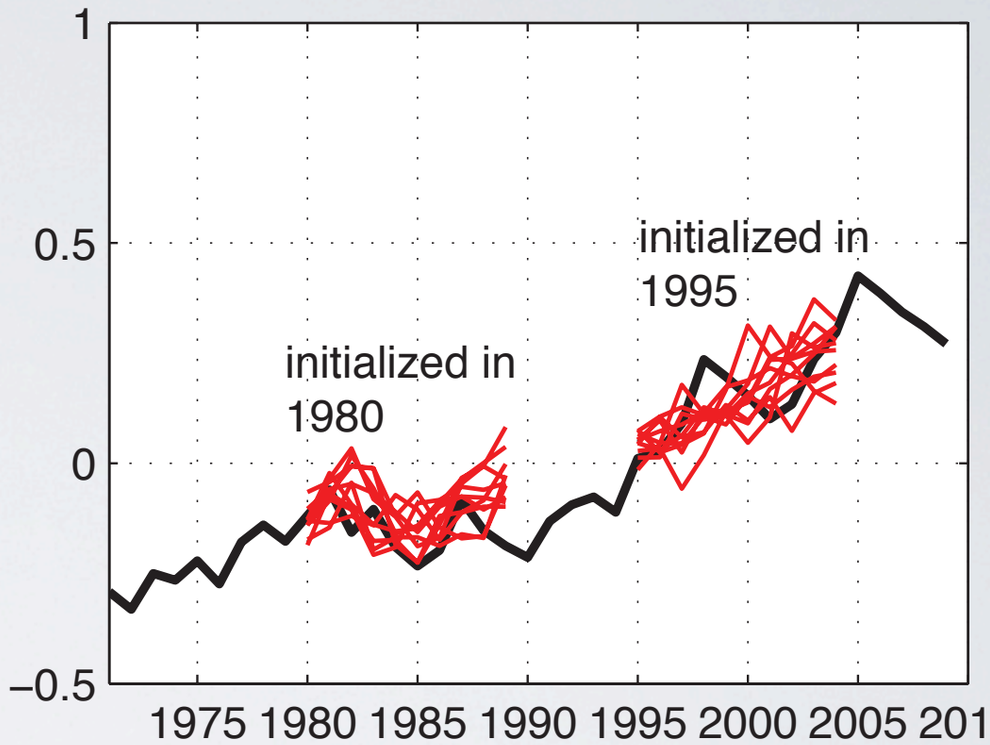
initialized predictions yr 9

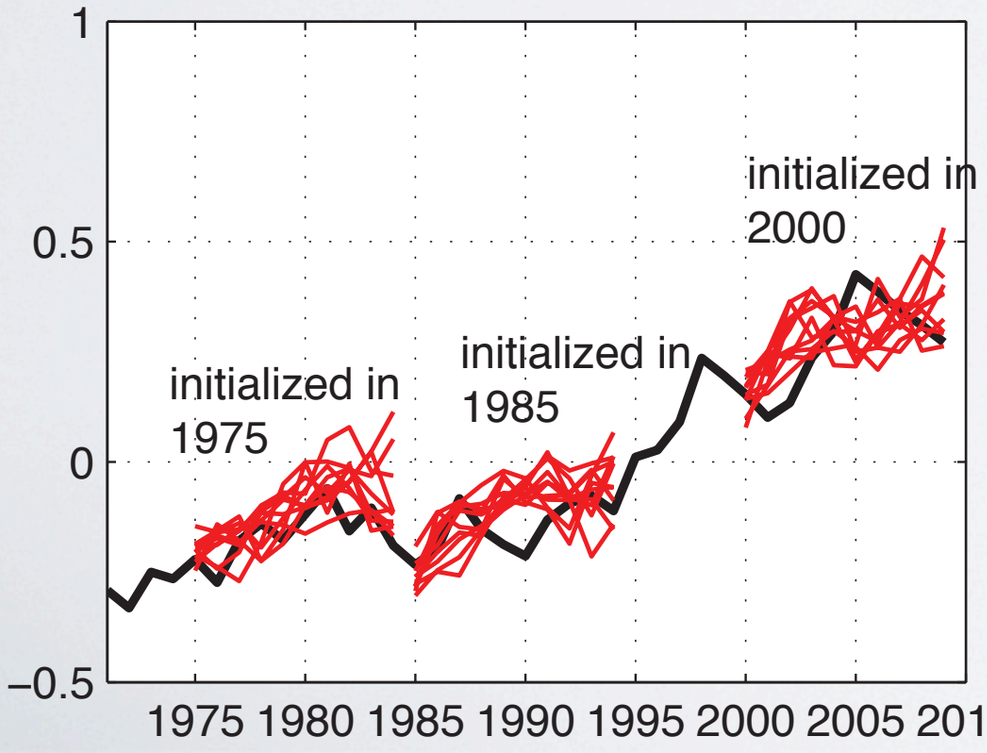


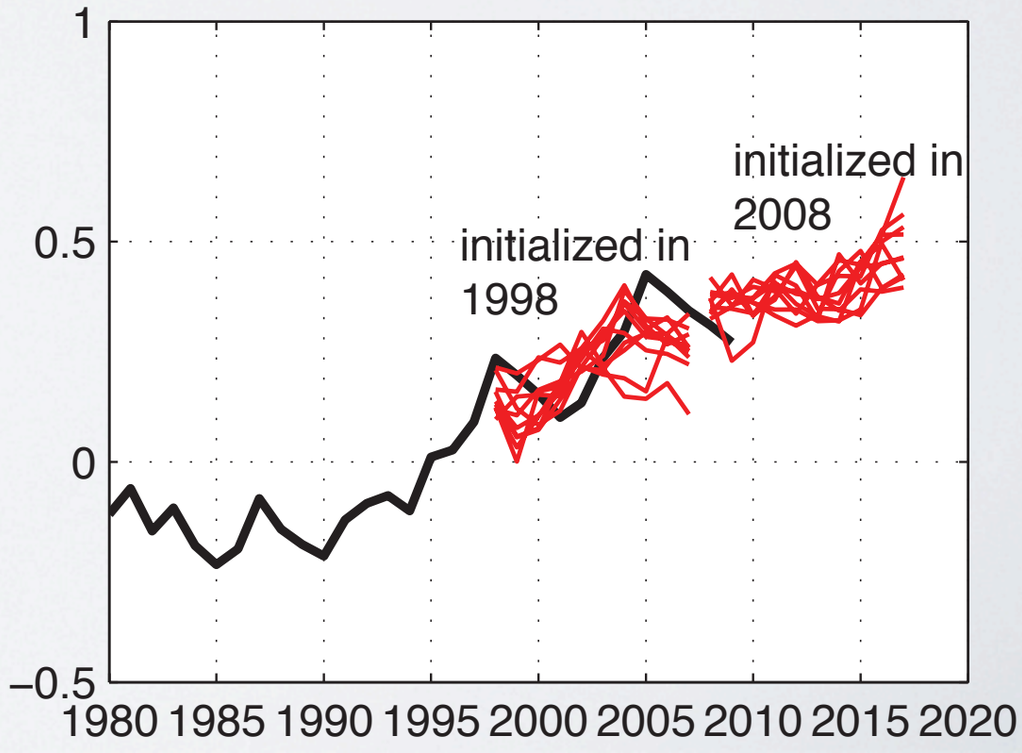
Which initial states are most predictable?
Can we capture the 1995 warming?

OHC NATL 0N60N









OHC NATL 0N60N