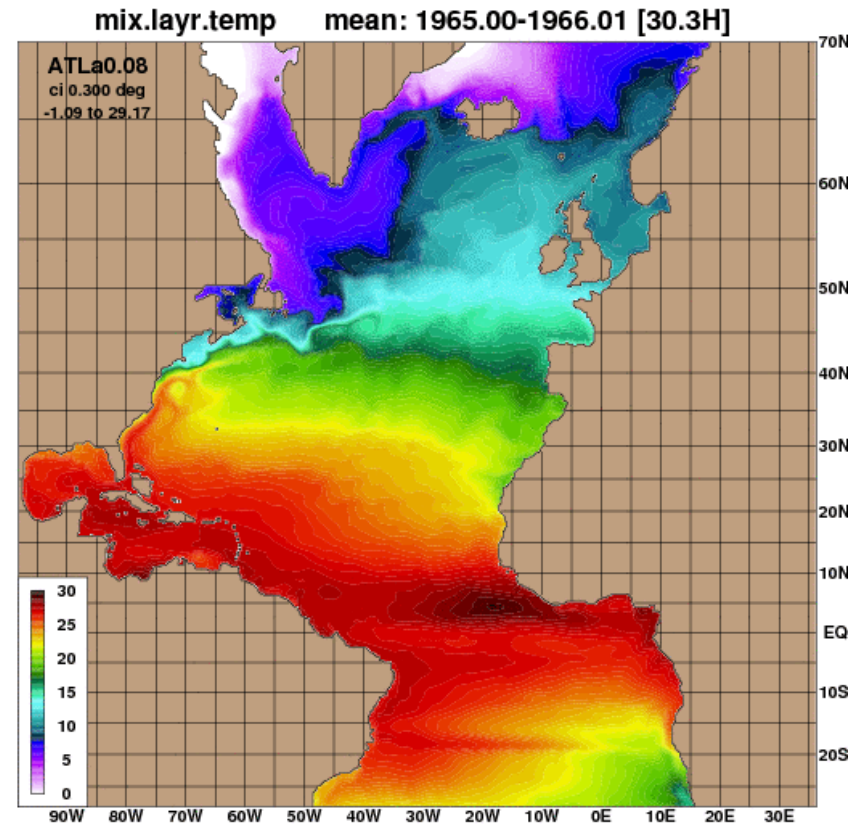# Multi-decadal simulation of Atlantic Ocean climate variability driven by realistic high-frequency atmospheric reanalysis

Z. Garraffo, G.Halliwell, L. Smith, G. Peng, E. Chassignet

North and Tropical Atlantic simulation with The Hybrid Coordinates Ocean Model (HYCOM)

Resolution 1/3 degree, period 1948-2003.

Mediterranean Sea as marginal Sea boundary condition

Specified P-Y Model Parameters:

Bathymetry

Gibraltar Width: 20km
Gibraltar Sill depth: 280m
Shelf-slope break depth: 625m
Slope of continental slope: 0.012

Specified Atlantic Ocean Water Properties

model • T, S of Gibraltar inflow water
model • T, S of entrained interior water a[t] shelf-slope break

P-Y Model Output

Gibraltar inflow transport (Mi)
Gibraltar outflow T, S, transport (Ms)
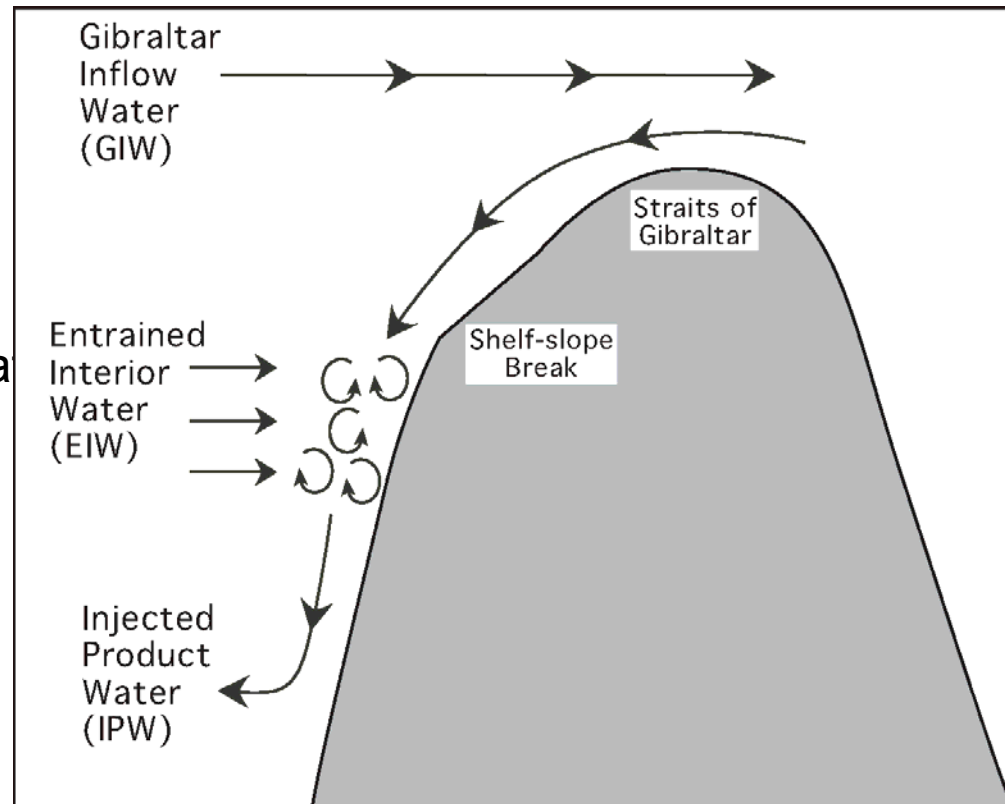Med. Surf. Fluxes
E-P over Mediterranean (.55m/y)
Net Q over Mediterranean (-13 W/m^2)
Entrained interior water transport (Me)
Mp – final product water T

Mediterranean sea parameterized as marginal sea boundary condition, Price-Yang-(Baringer)-Model

• E-P, Q over Med kept constant

Forcing (NCEP)
NCEP/NCAR 1948-1978
NCEP/AMIPII 1979-2003

wind stress anomalies,
wind speed, air temp.,
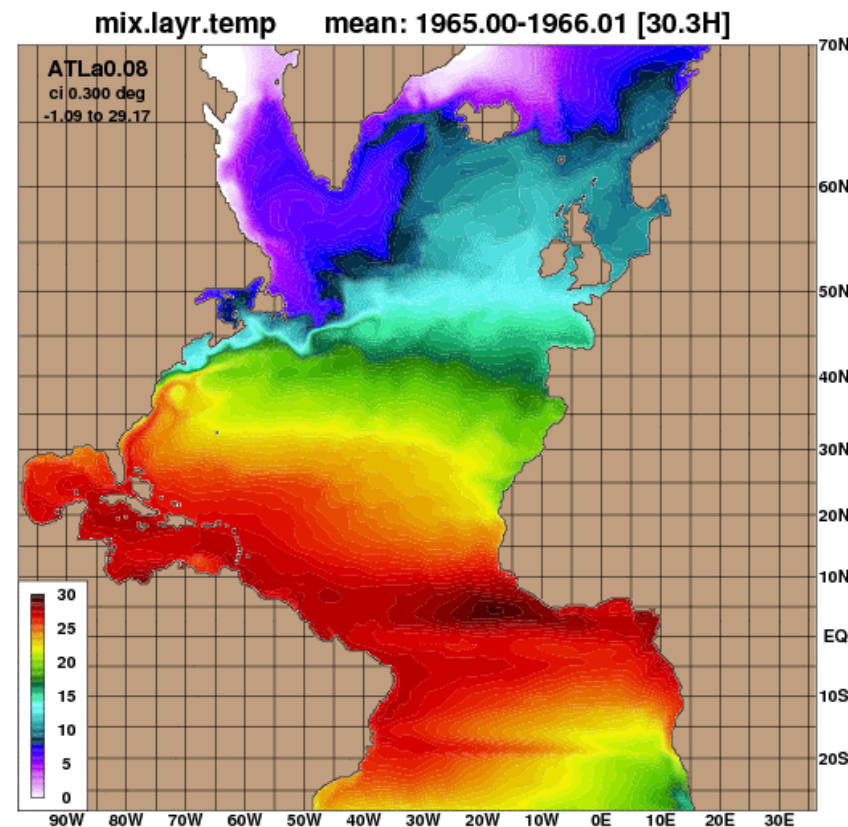radiation, water vapor
Rivers
Other details:
Wind stress mean ERA15m
   (for consistency with a spin up)
Ocean land mask for wind anomalies
SSS relaxation, no E-P, no extra SST relaxation

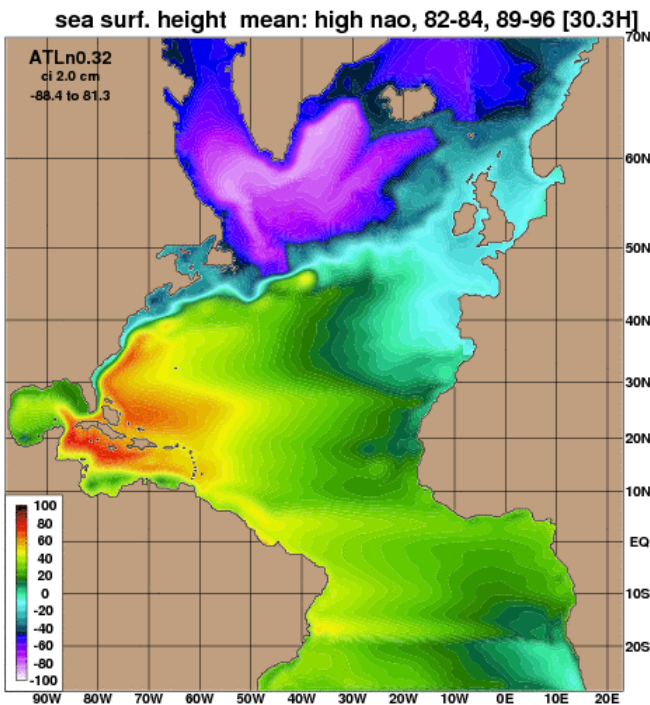mix.layr.temp   mean: 1965.00-1966.01 [30.3H]

ATLa0.08
ci 0.300 deg
-1.09 to 29.17

Start with:

SSH and NAO index

Transport index
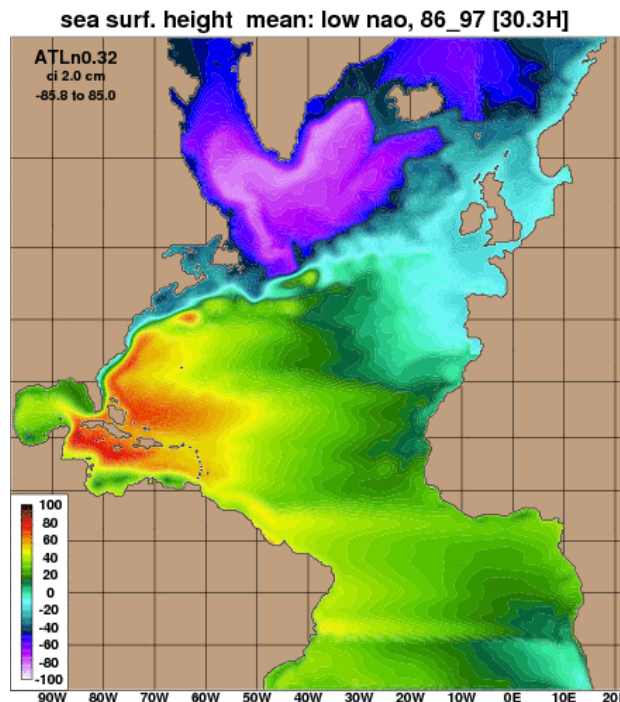
Florida Current transport
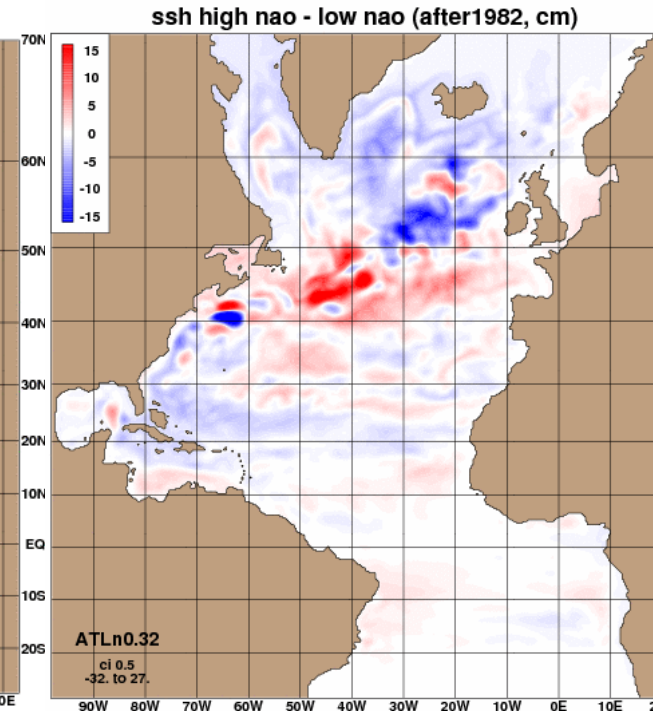
Sea Surface Height

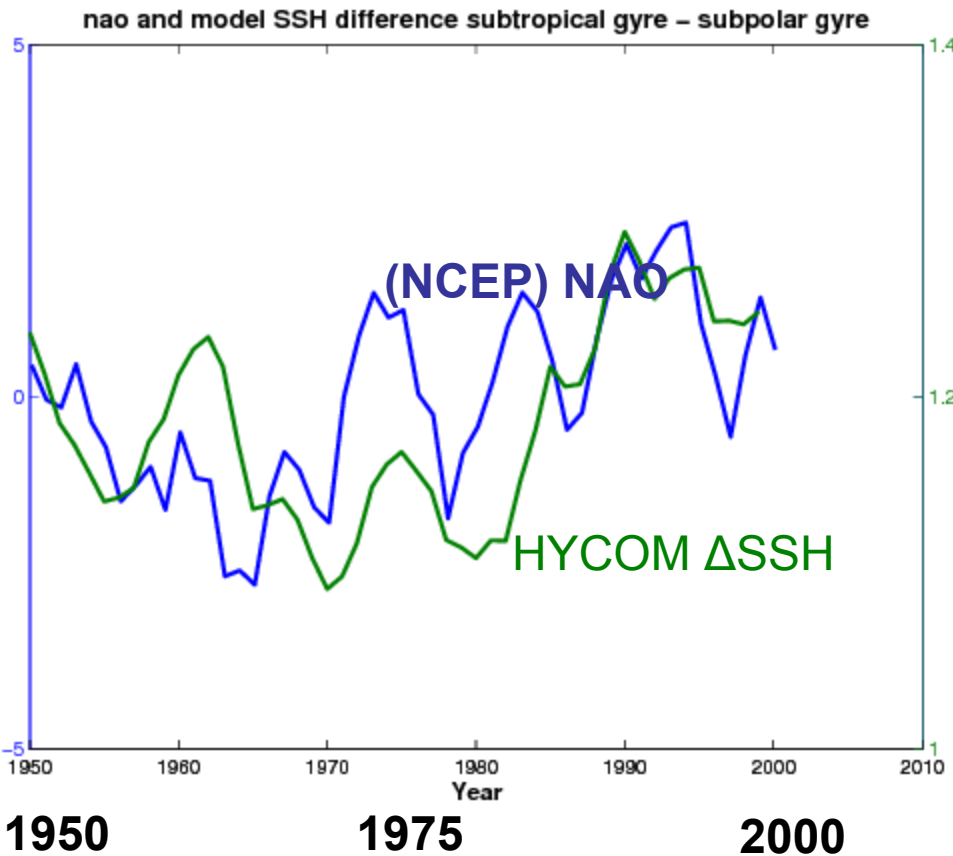**NAO+(strong westerlies and trades)   NAO⁻ (weak westerlies)   NAO⁺-NAO⁻**

1982-1984,1989-1996   1986,1997
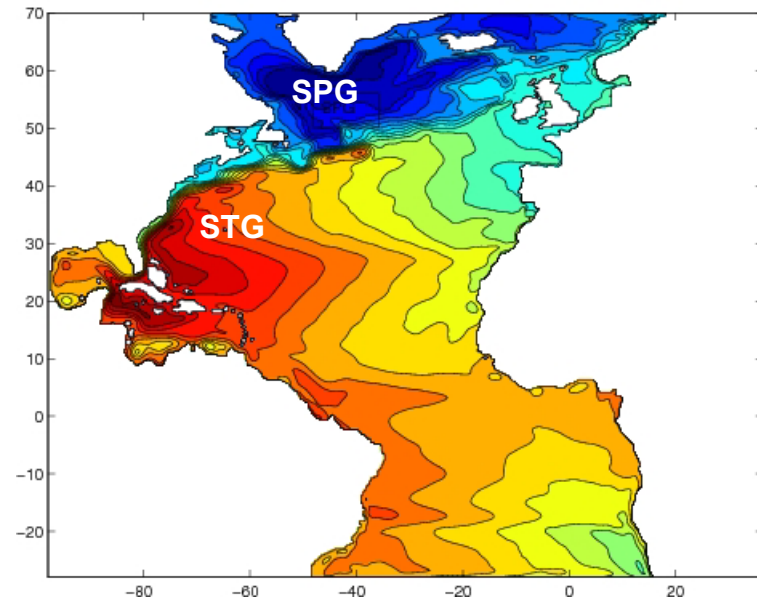
Expt 30.3, SSH vs NAO (3yr running mean)

Following Curry-McCartney baroclinic transport index

(SPG:47W 57N STG:62W 32N)

30.3: Mean SSH

nao and model SSH difference subtropical gyre – subpolar gyre

(NCEP) NAO

HYCOM ΔSSH

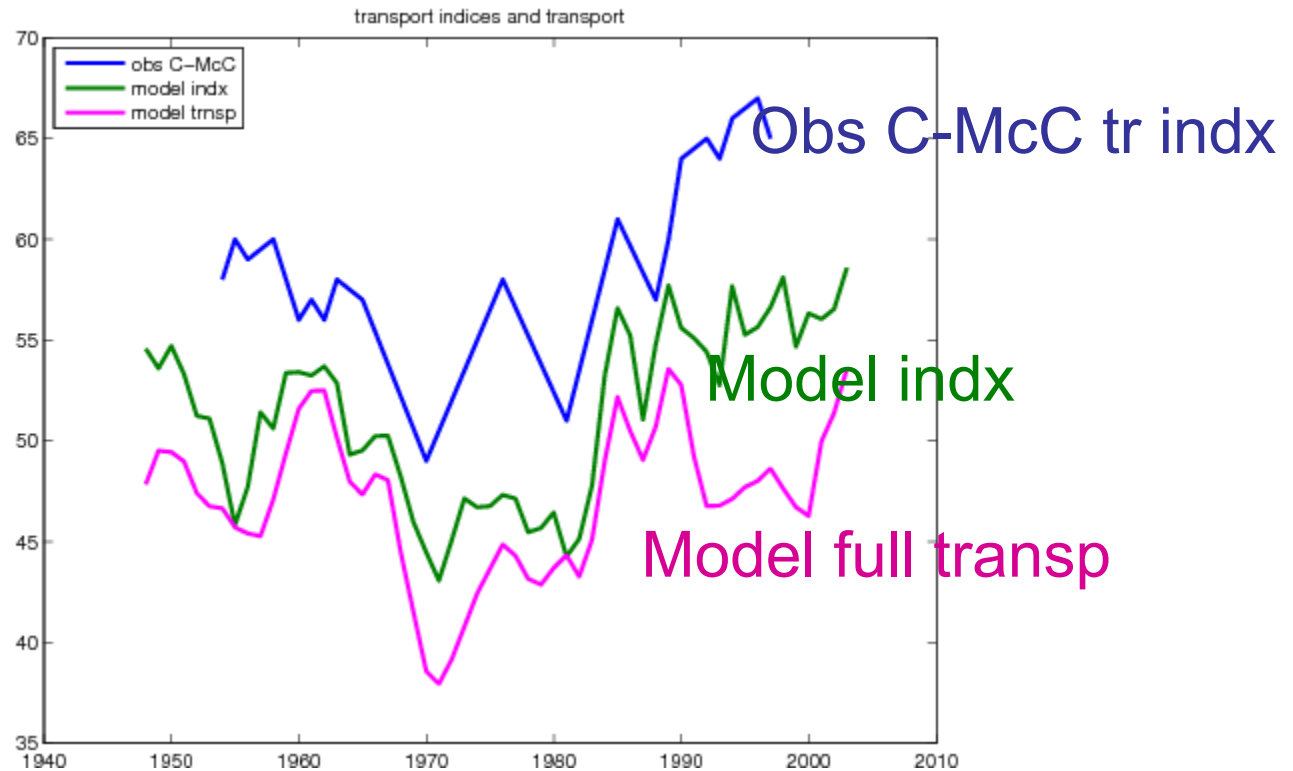**1950**   **1975**   **2000**

Generally model lags NAO, as in Curry-McCartney

After 1960, minima in agreement with Curry-McCartney transport index minima in 1970, 1981,1989.

Curry-McCartney (2001) transport index, subjective reading
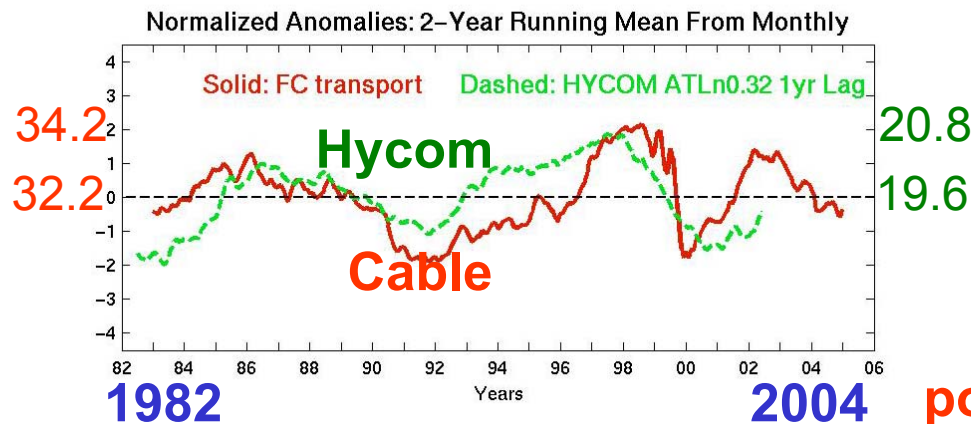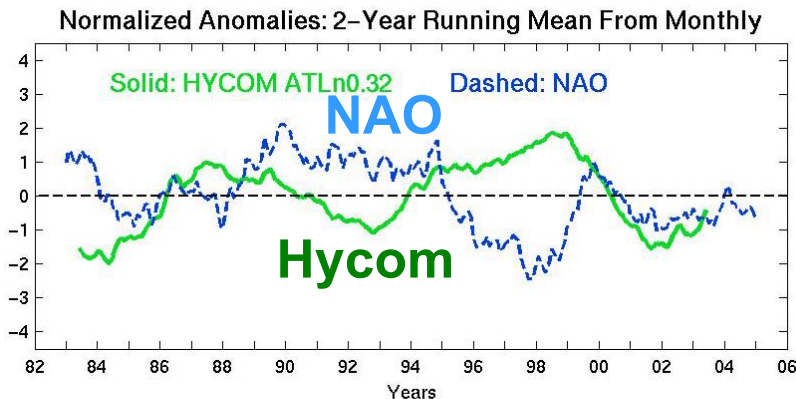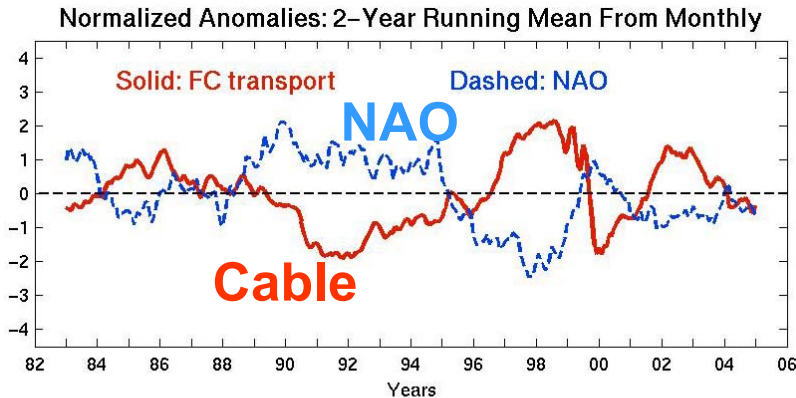**Model transport index**
Model transport (upper 2000m, same end points)

transport indices and transport

Obs C-McC tr indx

Model indx

Model full transp

Good agreement
Model indicates decadal and maybe ~30 year oscillation

Following Baringer and Larsen, 2001

Florida current transport anomalies, (de-meaned values divided by standard deviation), for cable data vs NAO, hycom vs NAO, hycom vs cable data
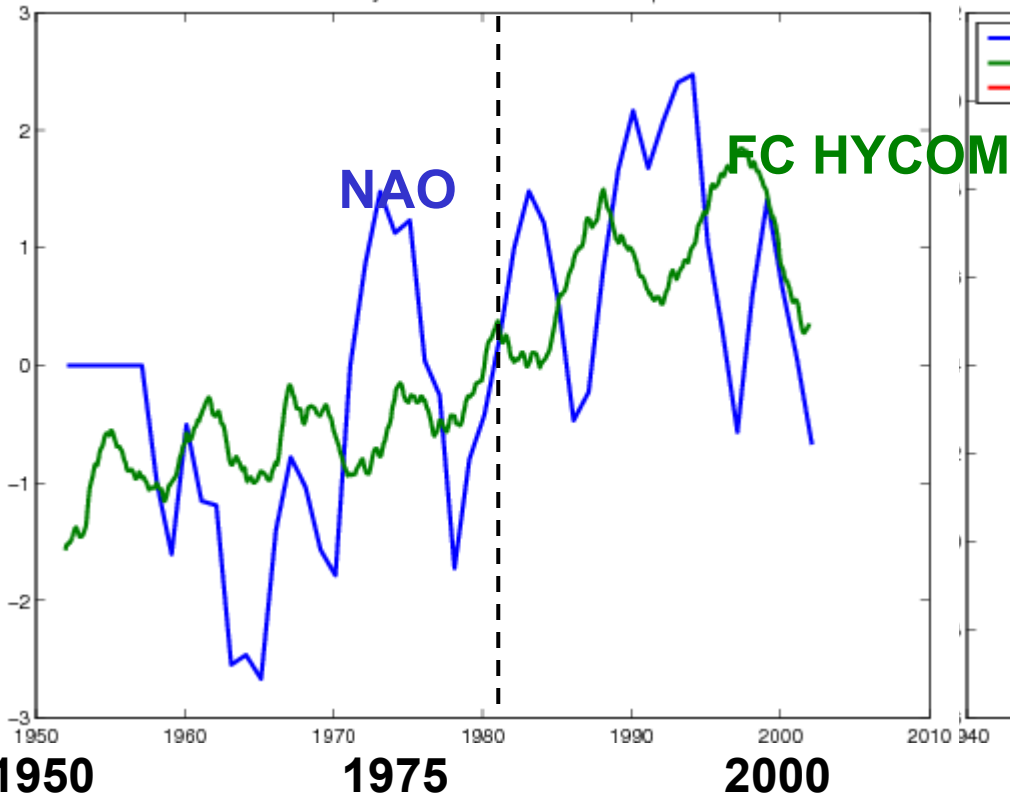
Good agreement in the phase of the observed and simulated transport anomalies
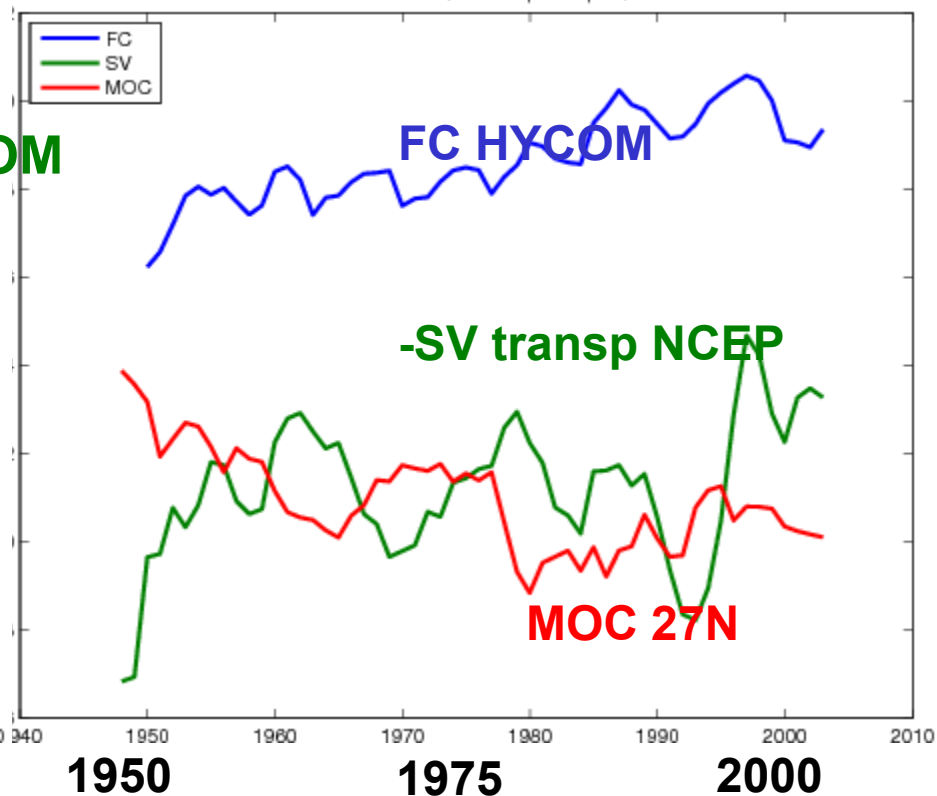
(Sv)	Cable	hycom
mean	32.2	19.6
std	1	0.65

1982   **2004**

poor resol. Fl St, (alsoMOC too weak)

**Following Baringer-Larsen,
NAO and Florida Current transport (27N)**

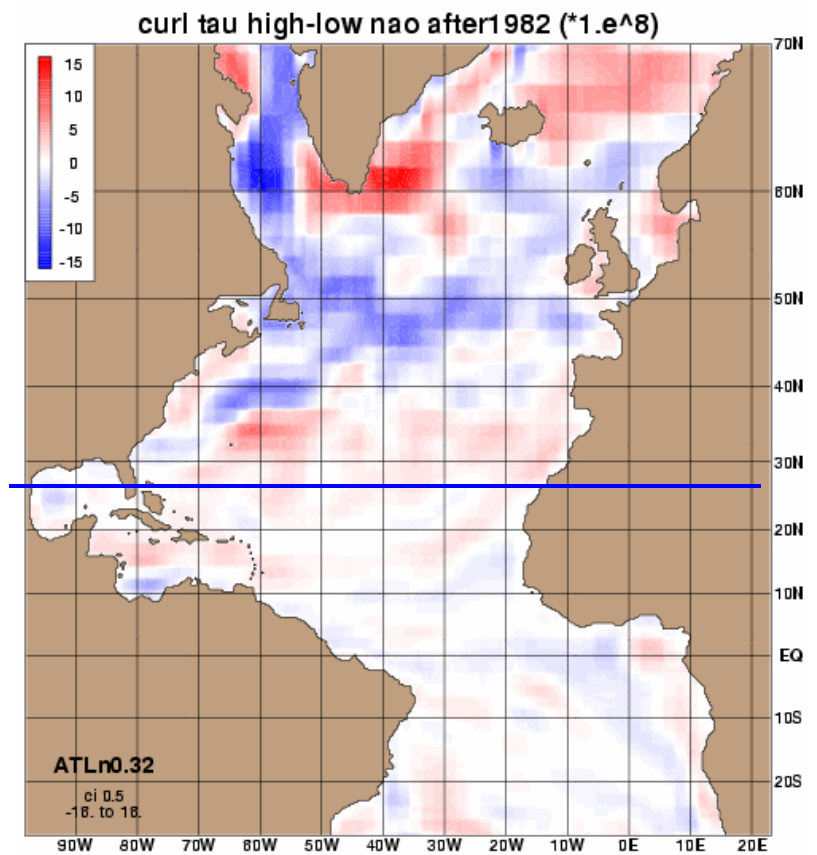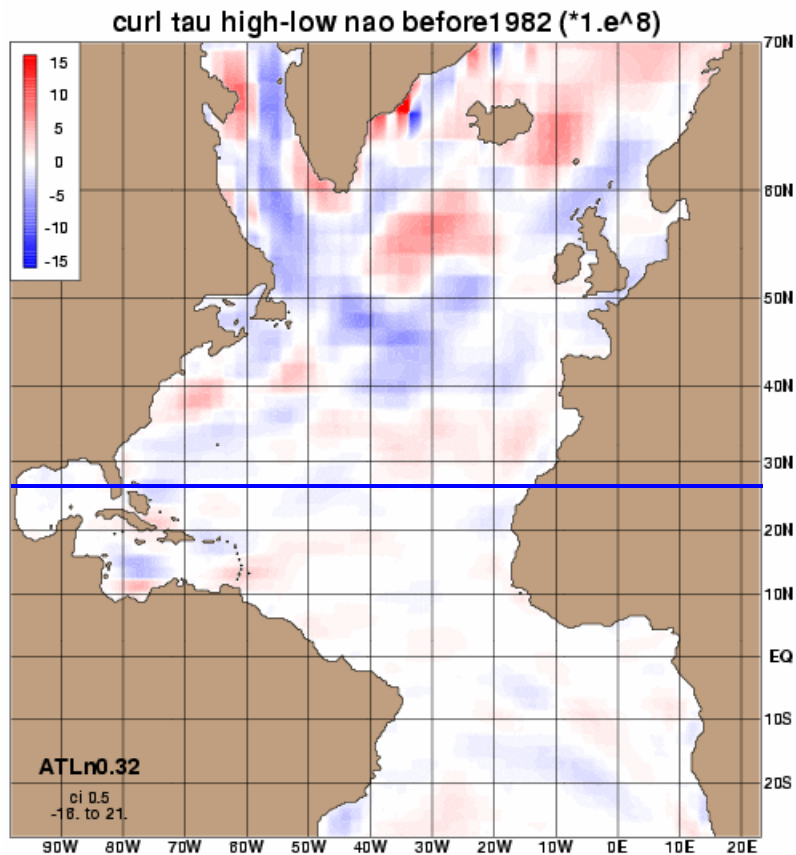After 1980, FC transport in opposite phase to NAO, but not before 1980.
FC variations do not completely follow Sv transport,
or Sv+MOC at that latitude, but more complex
Studied by de Coetlogon et al, 2006 from several OGCMs.
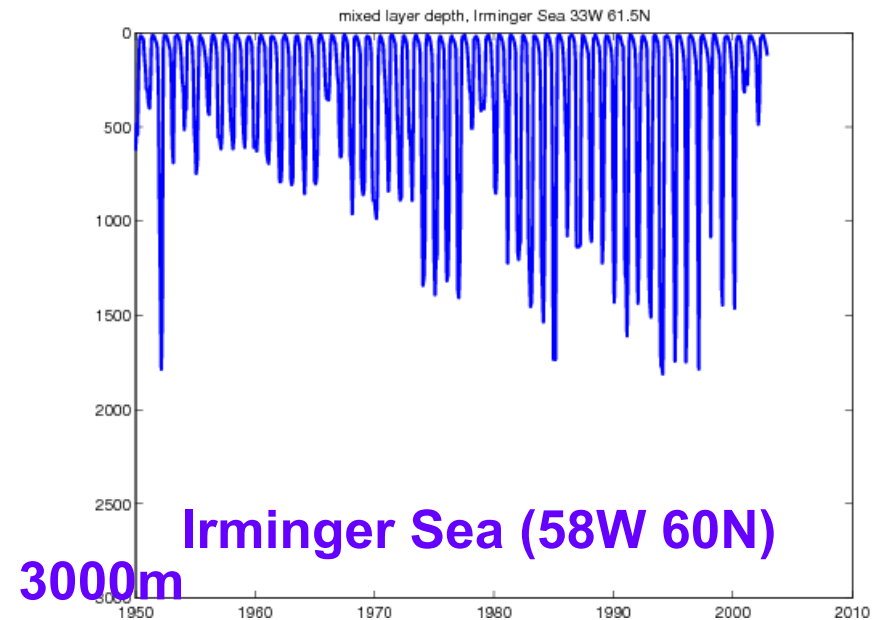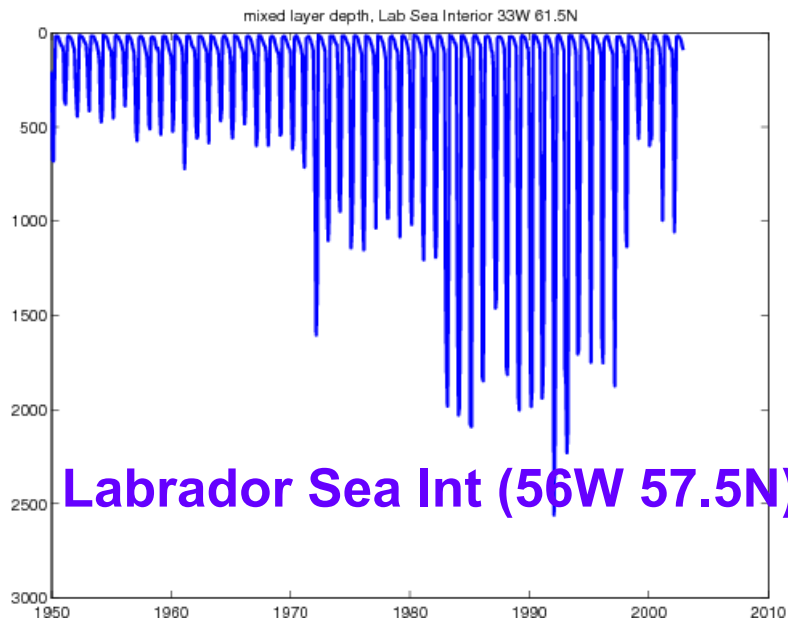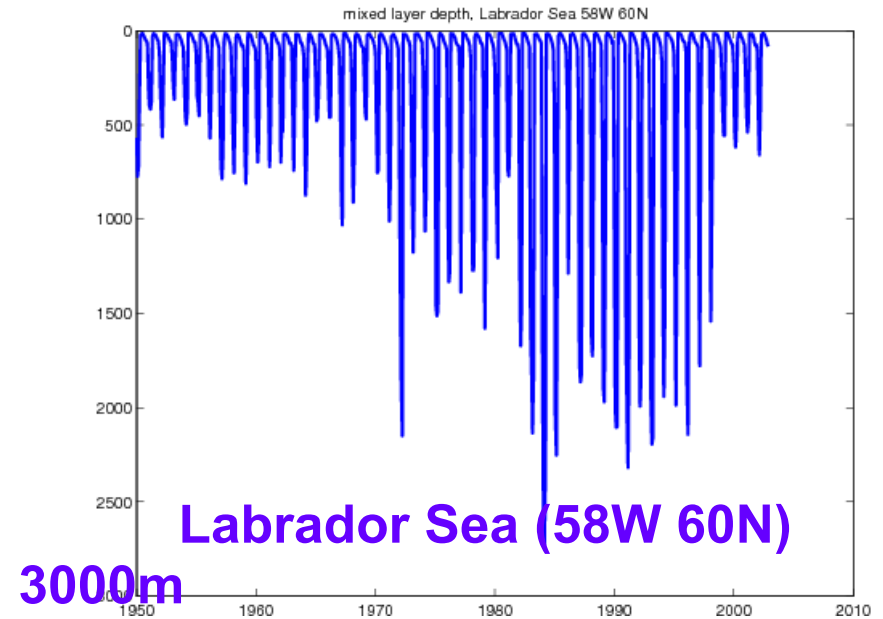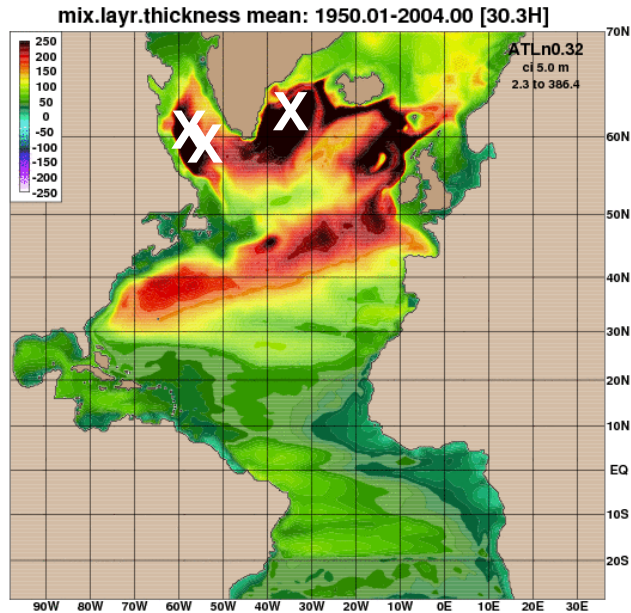
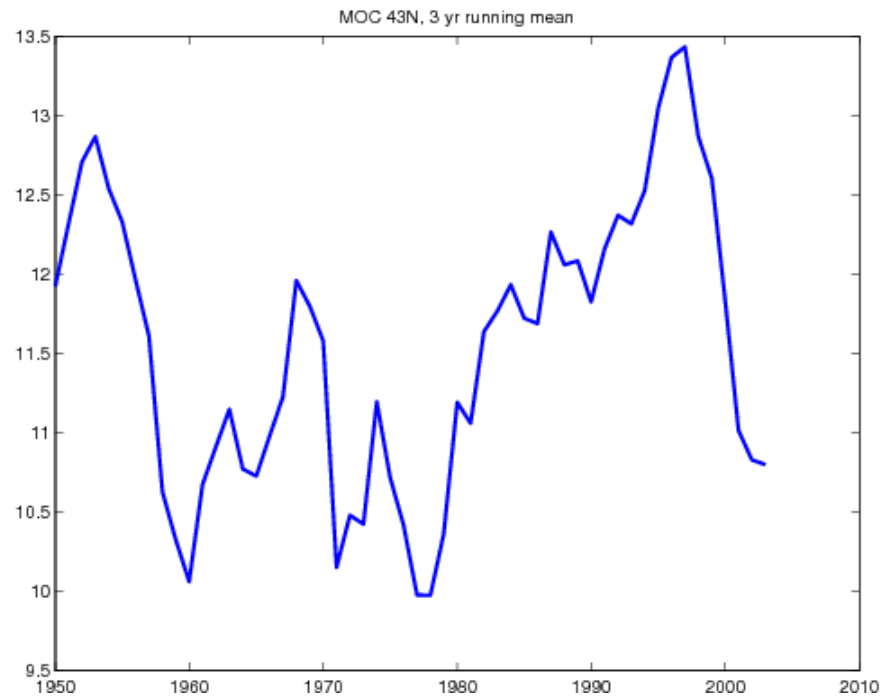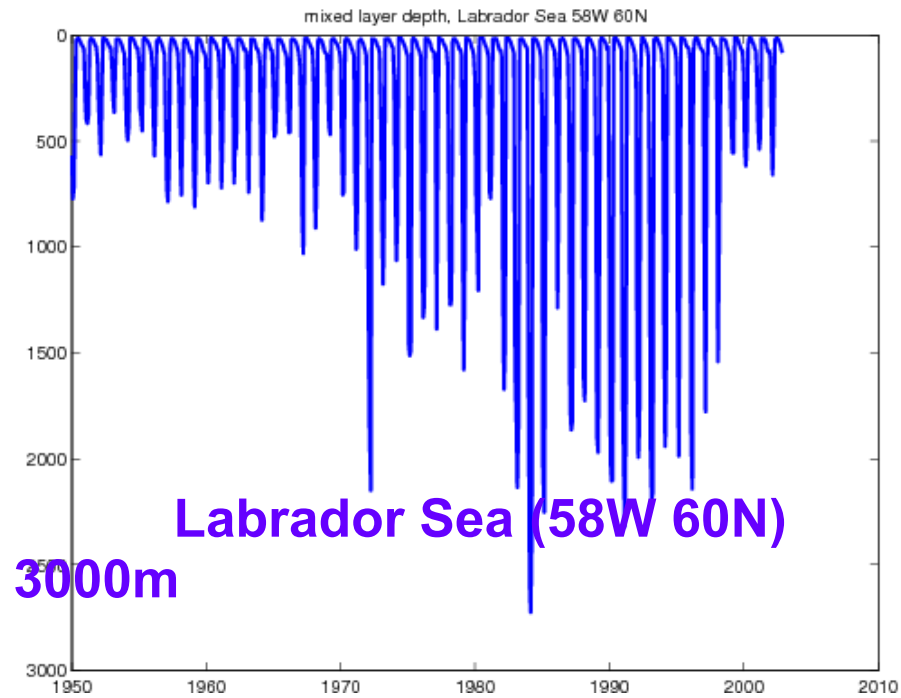# Curl Tau anomaly, NAO+-NAO-
Before 1982
After 1982

Some results on convection And MOC

Convection: Mixed layer depth
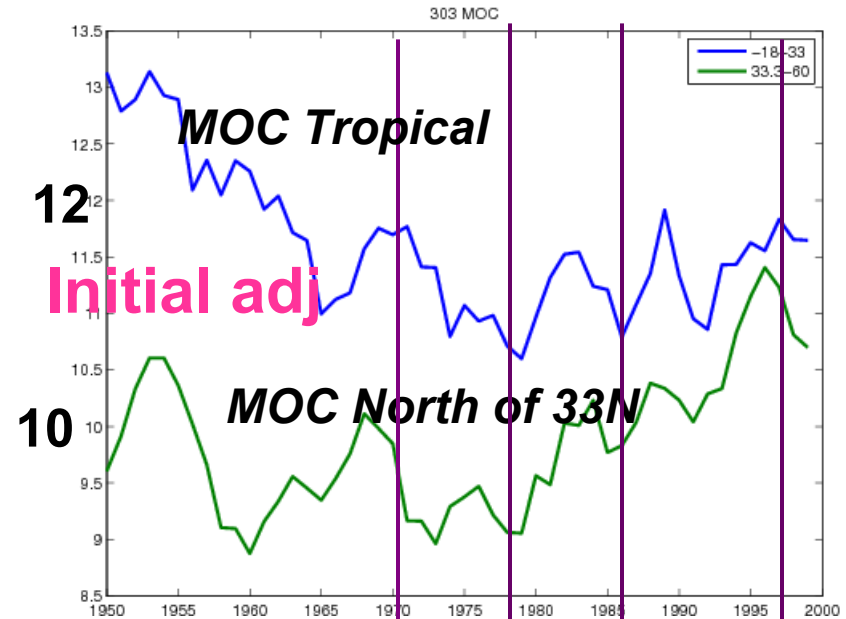

mix.layr.thickness mean: 1950.01-2004.00 [30.3H]

ATLn0.32
ci 5.0 m
2.3 to 386.4

mixed layer depth, Labrador Sea 58W 60N

Labrador Sea (58W 60N)

3000m

mixed layer depth, Lab Sea Interior 33W 61.5N

Labrador Sea Int (56W 57.5N)

mixed layer depth, Irminger Sea 33W 61.5N

Irminger Sea (58W 60N)

3000m

mixed layer depth, Labrador Sea 58W 60N

Labrador Sea (58W 60N)

3000m

MOC 43N, 3 yr running mean

MOC 43N

From Fritz Schott

Layer Thickness Variability of ULSW/LSW, 1948–2003

Big pulse of LSW in 1992-4, then decline of deep convection and **shallow upper LSW** formed

• warming of Labr. Sea!

E: Entrainment   C: Convection   CGFZ: Charlie Gibbs Fracture Zone   MAR: Middle Atlantic Ridge

DWBC: Deep Western Boundary Current   NAC: North Atlantic Current

LSW: Labrador Sea Water   ISOW: Iceland Scotland Overflow Water   DSOW: Denmark Strait Overflow Water

Expt 30.3 overturning (z coord)

MOC 43N

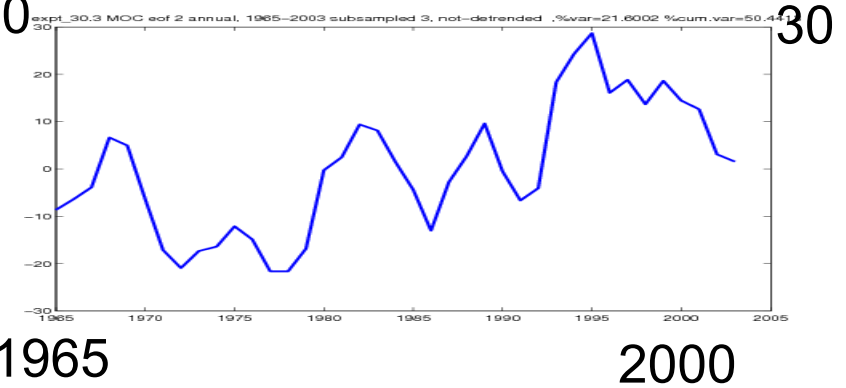1950 1975 2000

MOC Tropical

12

Initial adj

MOC North of 33N

10
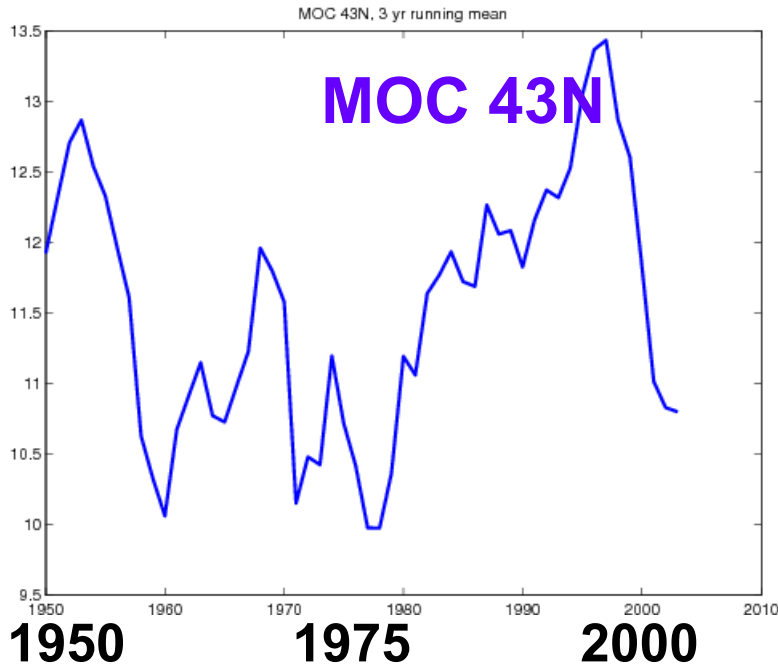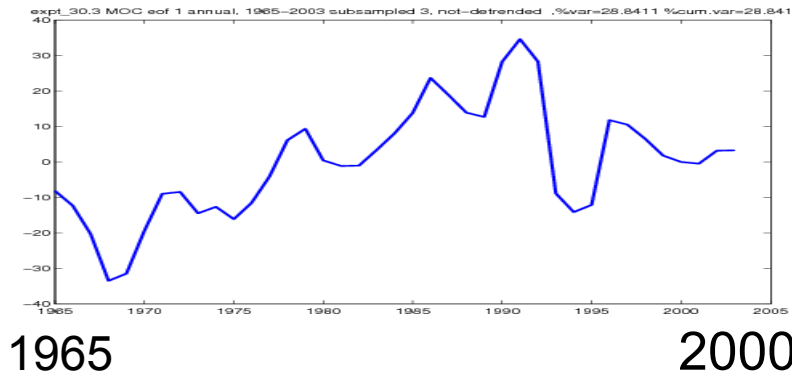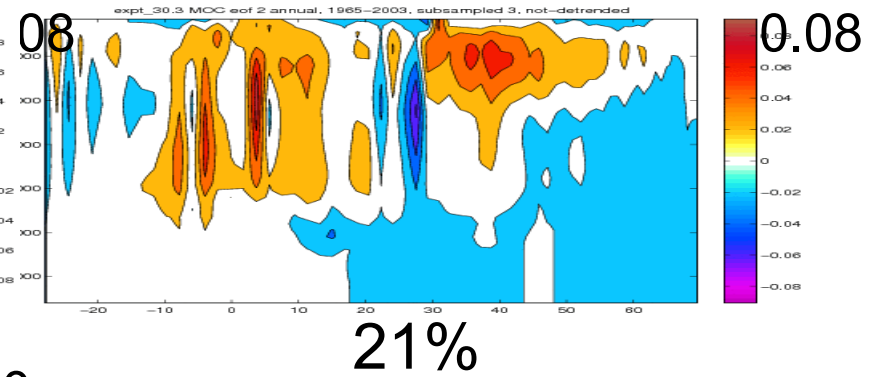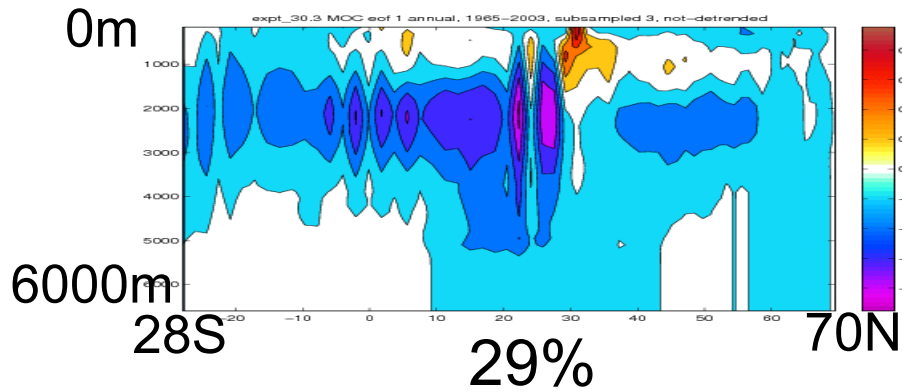
After 1960, increase of MOC
Decrease after 1995, in obs
Compensated by upper LSW
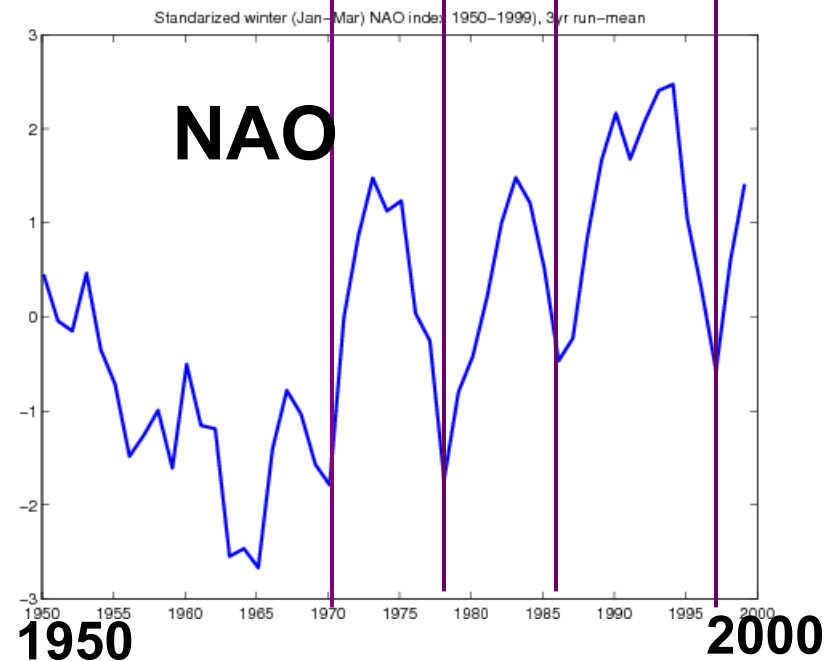
NAO
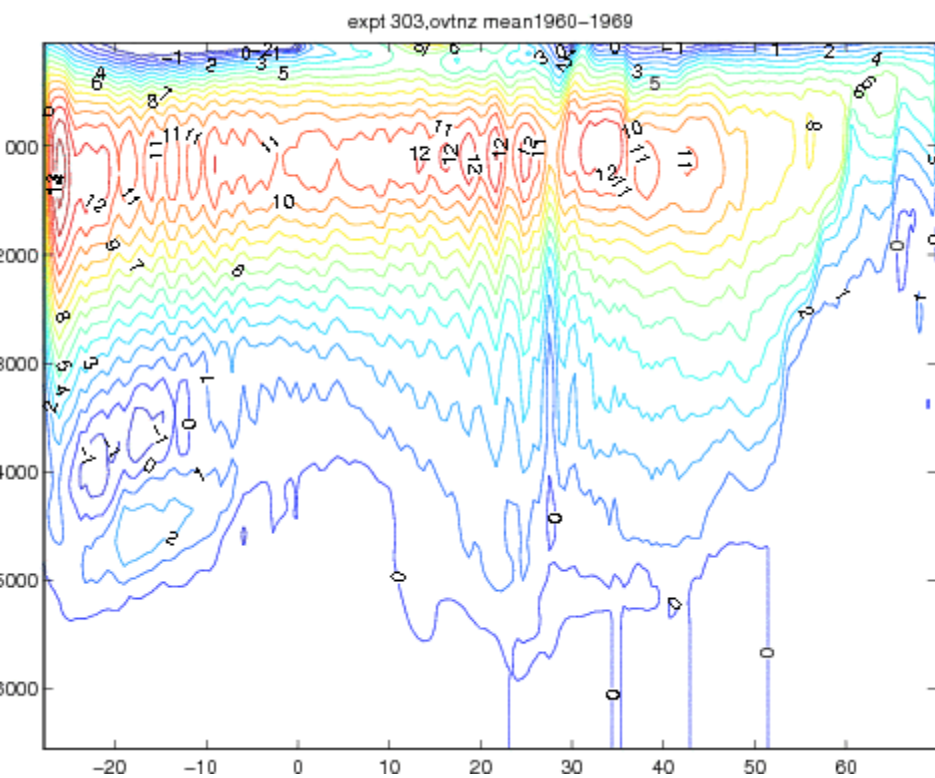
1950 2000
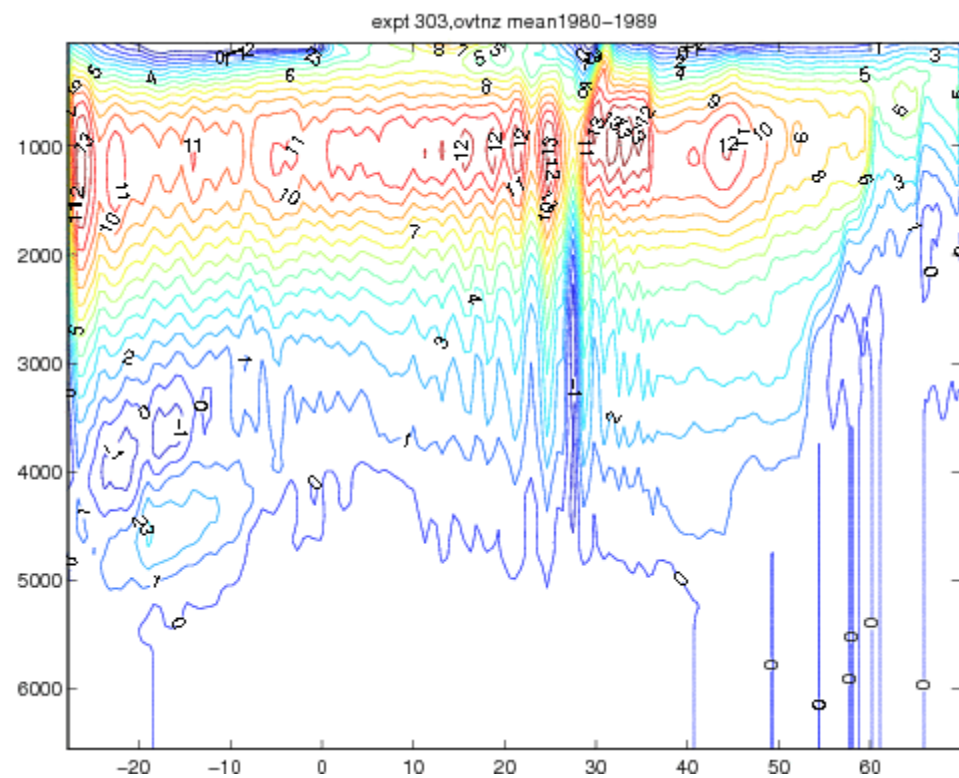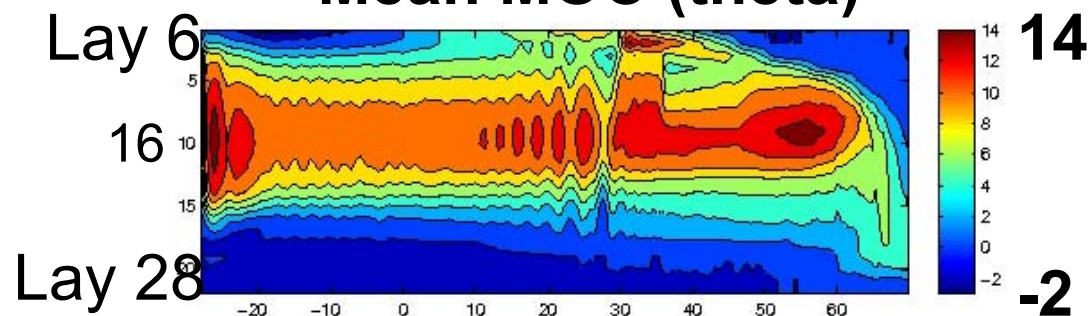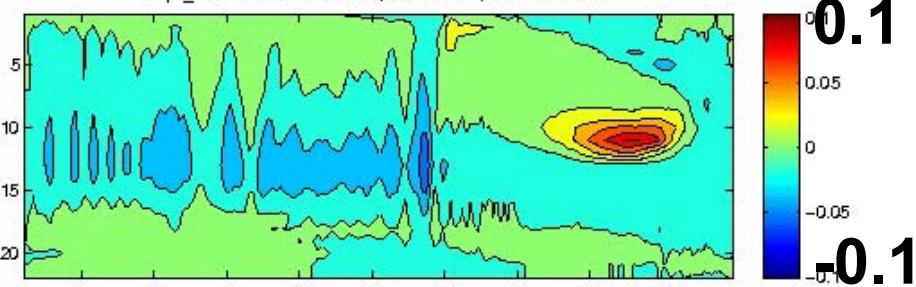
Eof1

0m

6000m

28S

29%

1965   2000

Eof2

08   0.08

21%

10   30

1965   2000

1960-69

1980-89

expt 303,ovtnz mean1960-1969

expt 303,ovtnz mean1980-1989

Mean MOC (theta)

Lay 6

16

Lay 28

14

-2

expt_30.3 MOC eof 1 annual, 1950–2003, not-detrended
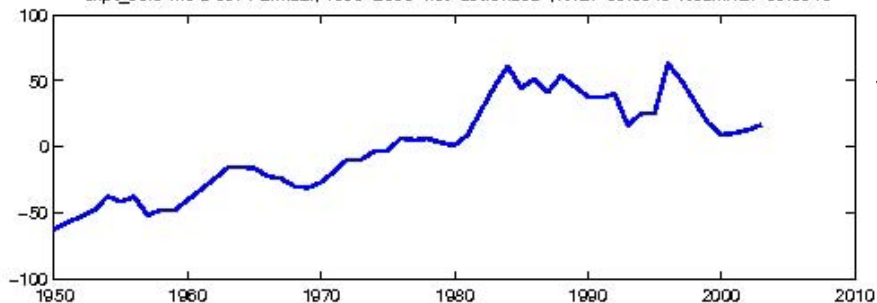
0.1

-0.1

Eof 1 (33%)

expt_30.3 MOC eof 2 annual, 1950–2003, not-detrended
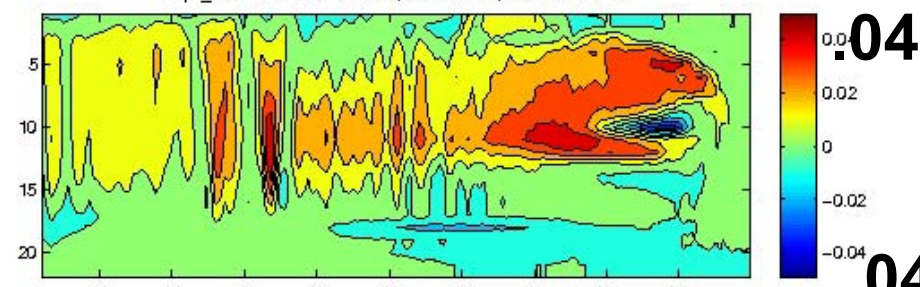
.04

.04

Eof 2 (19%)

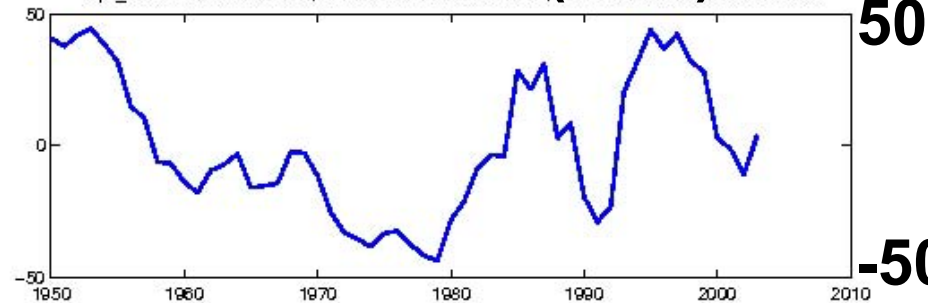expt_30.3 MOC eof 1 annual, 1950–2003 not-detrended ,%var=33.3819 %cum.var=33.3819

50

-50

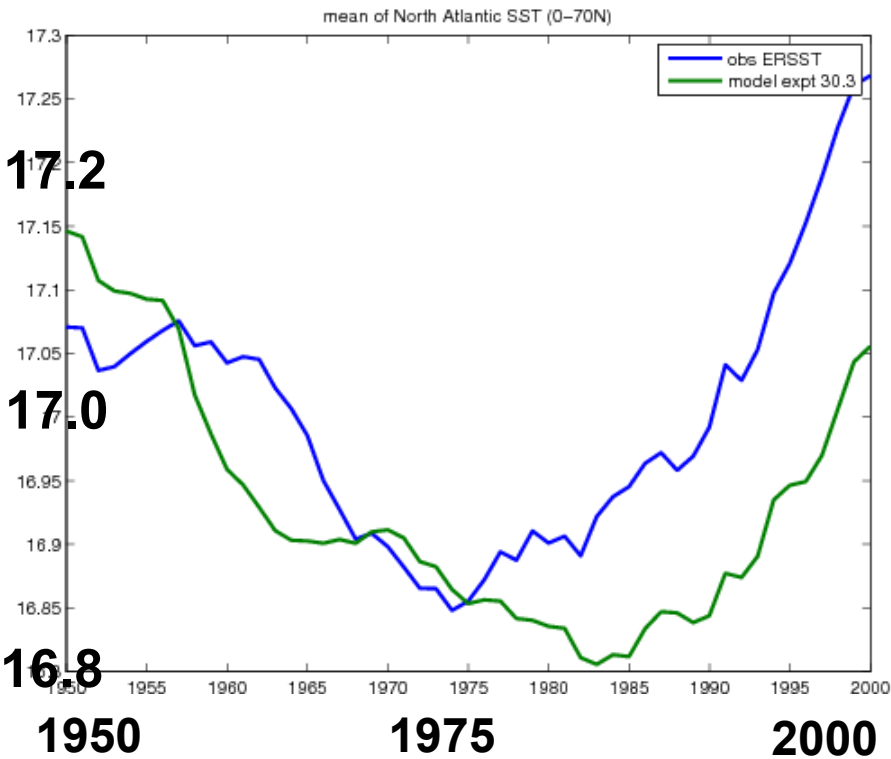expt_30.3 MOC eof 2 annual, 1950–2003 not-detrended ,%var=18.8757 %cum.var=52.2607
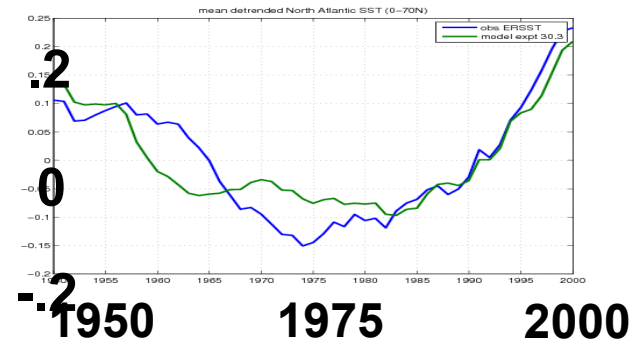
50

-50

Model SST variability vs observations
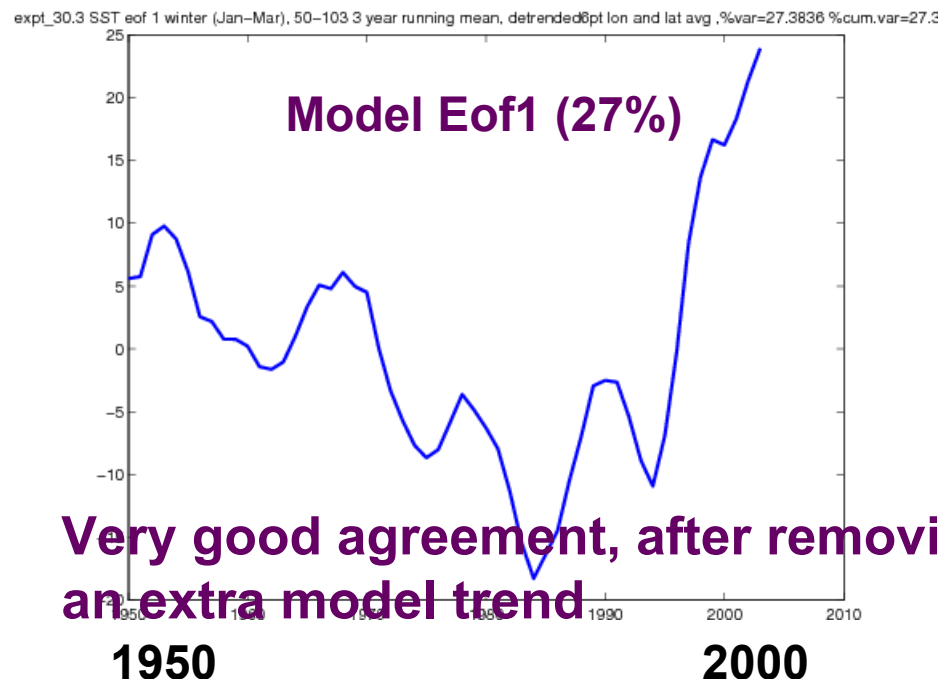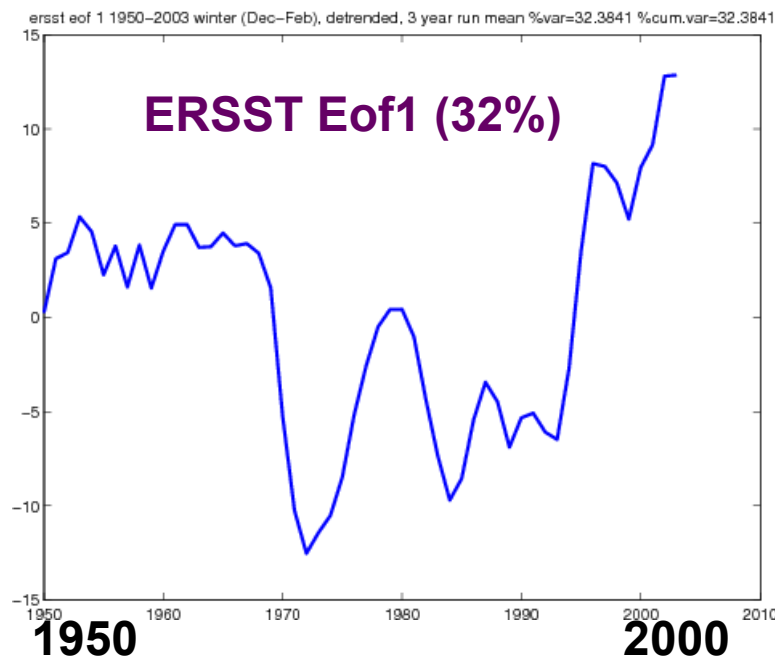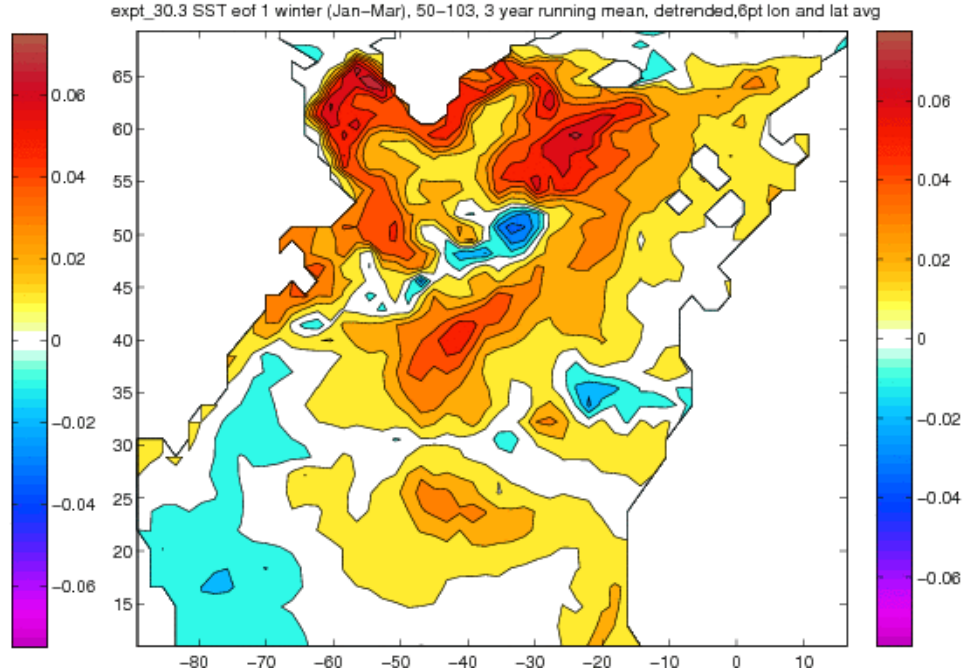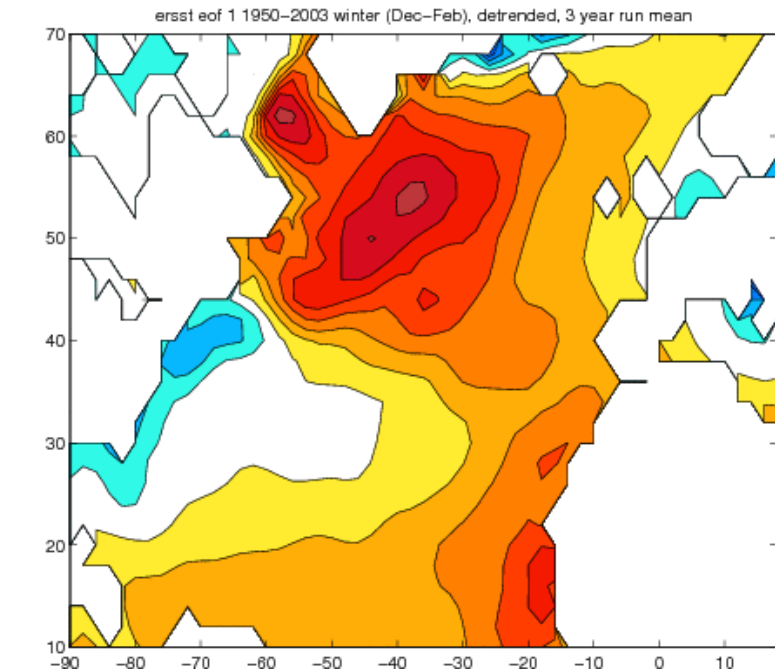
Mean N.Atlantic SST

SST eofs

Observed and model mean winter North Atlantic SST, 0-70N

Detrended (AMO)

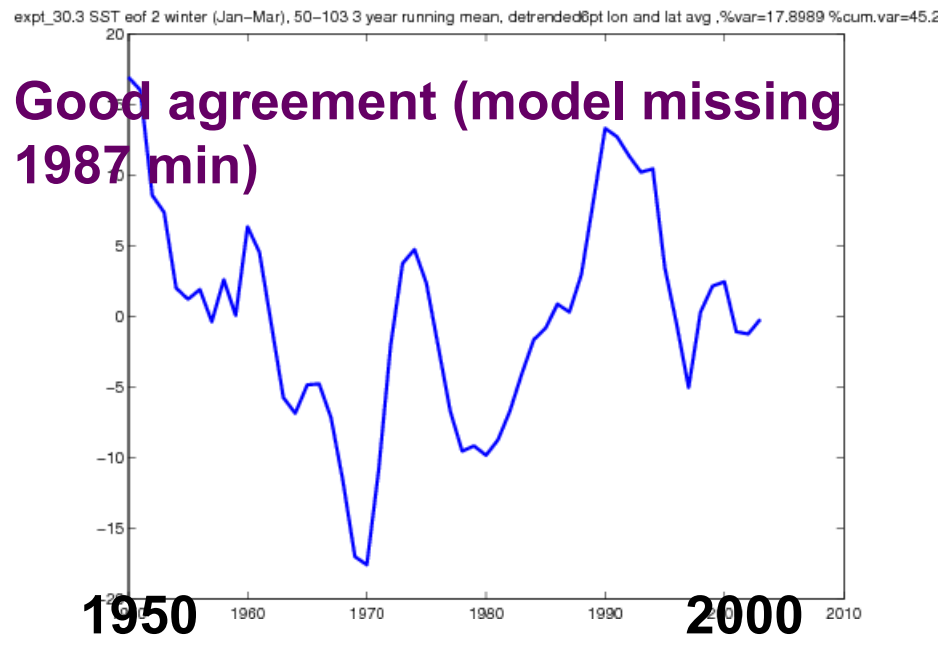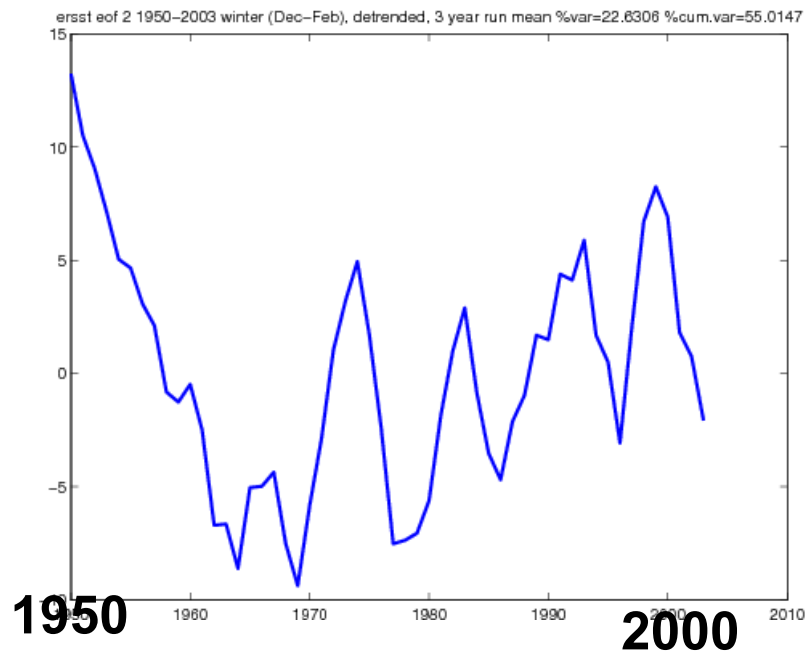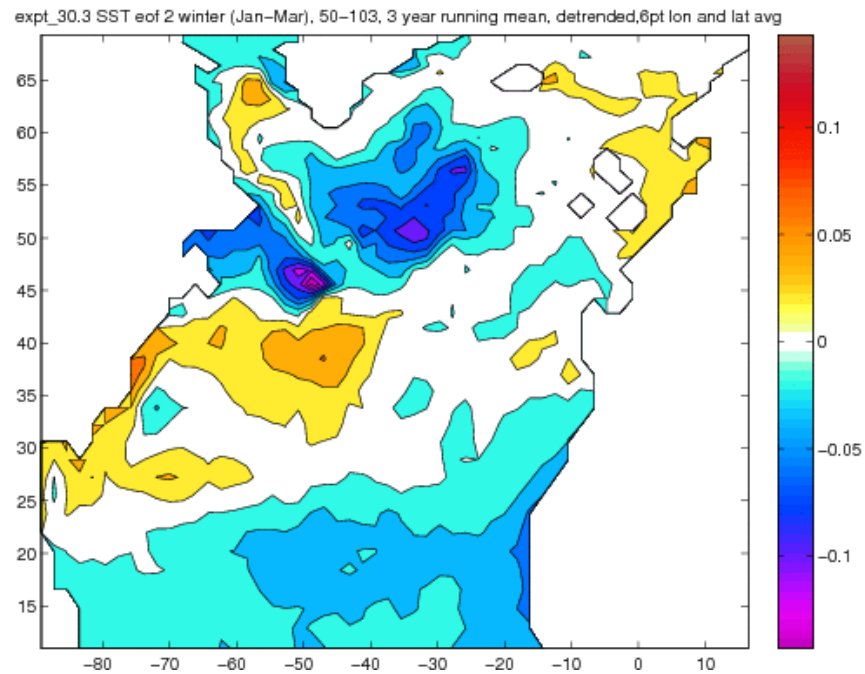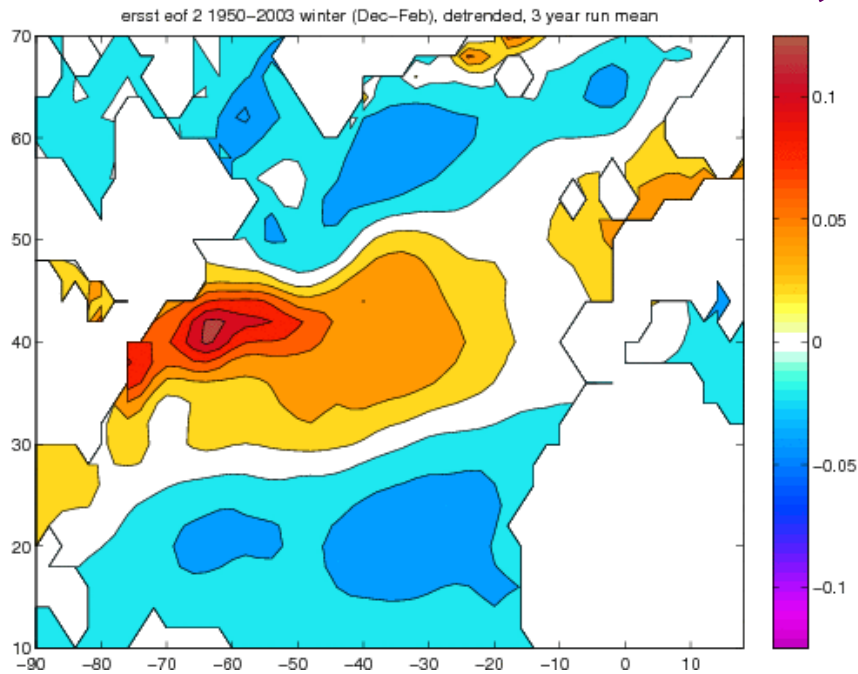# 1st eof of detrended SST, observed ERSST vs model.

ERSST Eof1 (32%)

Model Eof1 (27%)

Very good agreement, after removing an extra model trend

1950   2000   1950   2000

2nd eof of detrended SST, observed ERSST vs model.

ersst eof 2 1950–2003 winter (Dec–Feb), detrended, 3 year run mean

expt_30.3 SST eof 2 winter (Jan–Mar), 50–103, 3 year running mean, detrended,6pt lon and lat avg

ersst eof 2 1950–2003 winter (Dec–Feb), detrended, 3 year run mean %var=22.6306 %cum.var=55.0147

expt_30.3 SST eof 2 winter (Jan–Mar), 50–103 3 year running mean, detrended6pt lon and lat avg ,%var=17.8989 %cum.var=45.2

Good agreement (model missing 1987 min)

1950   **2000**   **1950**   **2000**

In progress/to be started:

Atlantic 1/12 degree ecmwf forcing 1960-present (spinup started)

Probably Global 1/3 interannual

Simulations done at Pittsburgh Supercomputing Center and at ERDC.