Sources of Regional Predictability Across Timescales:

Northern US East Coast

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NOAA/Physical Sciences Laboratory

Simple model for generating SST variability
"stochastic model"

Heat fluxes associated with weather events, "random forcing"

Ocean response to flux back heat which slowly damps SST anomalies

SST anomalies form

Air-sea interface

$$dT_m/dt = \frac{Q_{net}}{\rho c h}$$

$$dT_m/dt = \frac{F - \lambda T_m}{\rho c h}$$

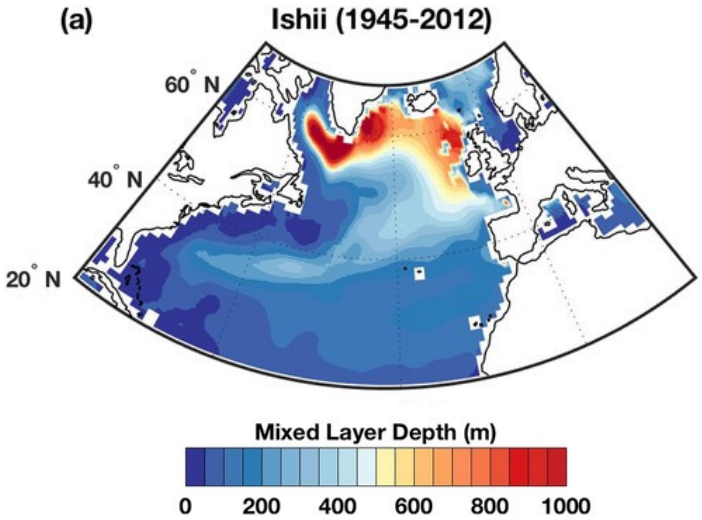
Fixed depth ocean
No currents

Bottom

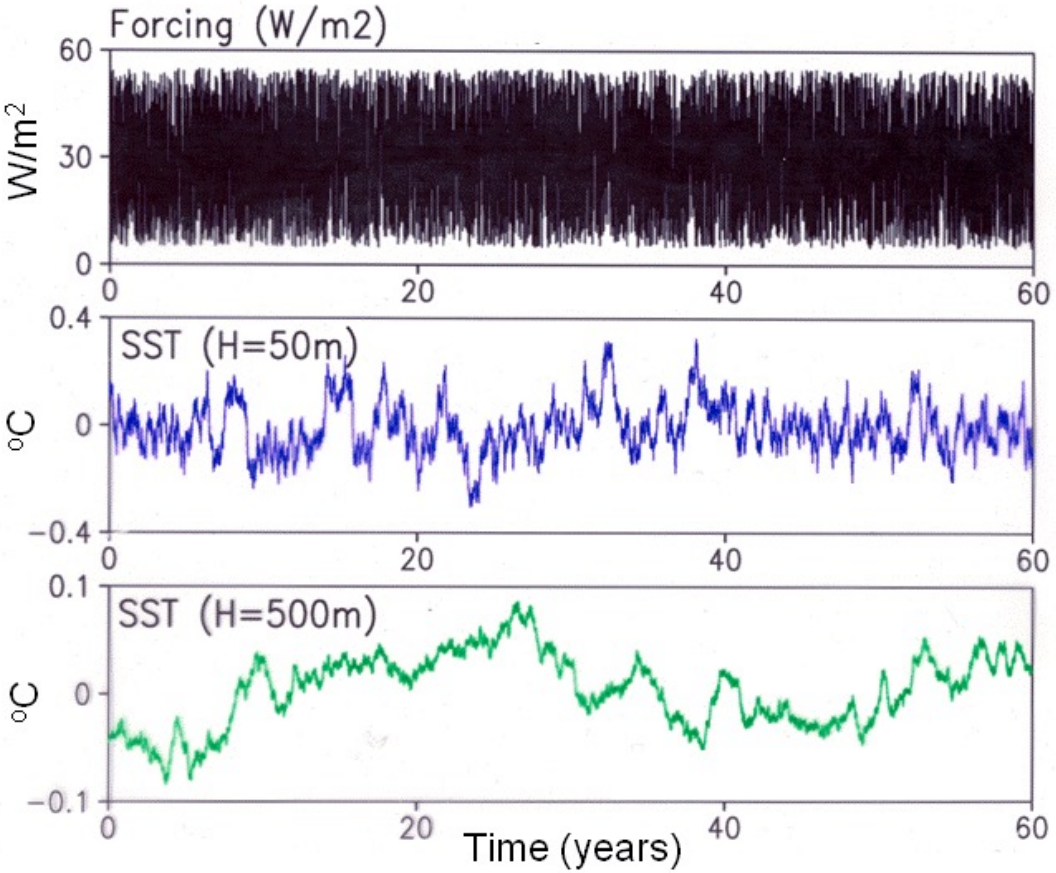
The density & specific heat of sea water is large compared to the atmosphere
Leads to the persistence of temperature anomalies

Stochastic SST Anomaly model: idealized forcing and time series

Winter MLD (m)

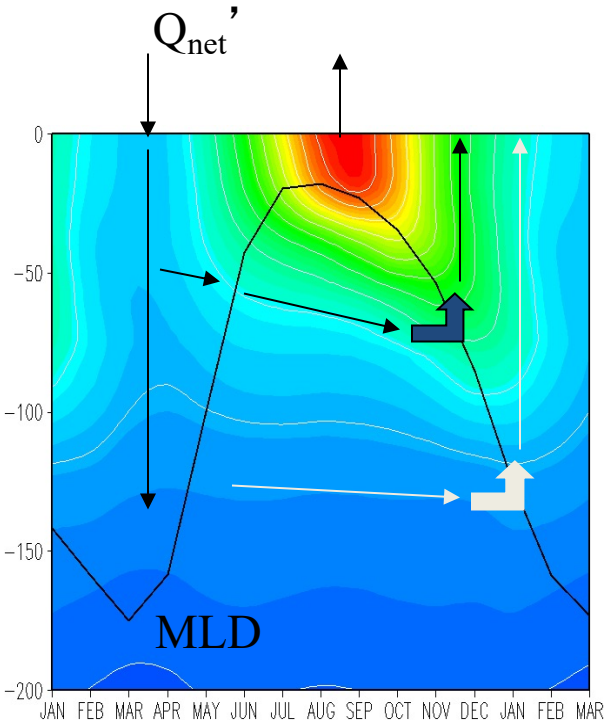


Buckley et al. 2019 J Climate



SSTs can be very persistent if MLD (h) is deep
Although not exceptional deep along NEUS coast

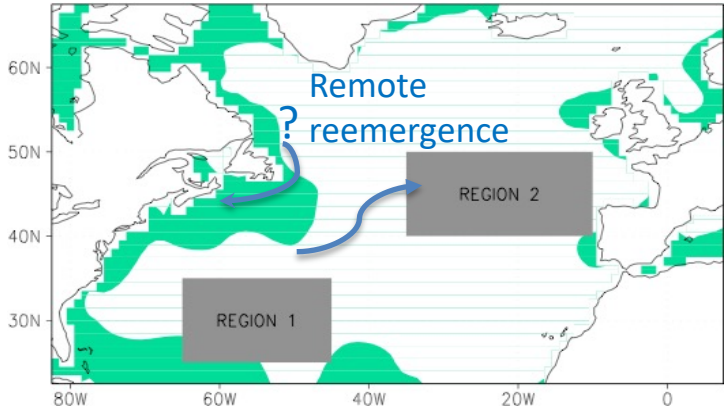
The Reemergence Mechanism



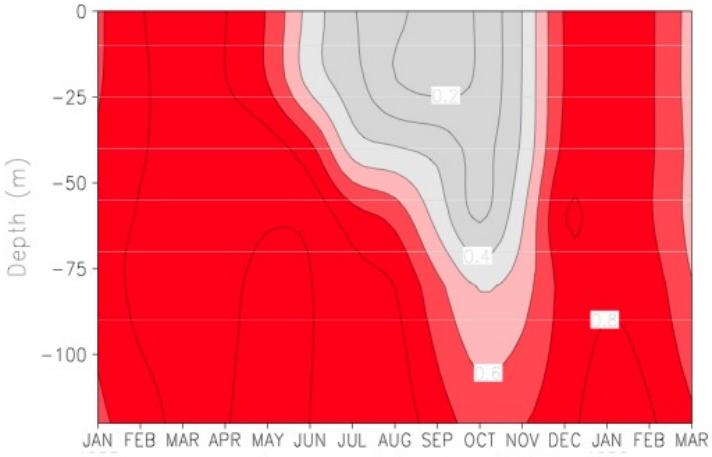
- Winter Surface flux anomalies
- Create SST anomalies which spread over ML
- ML reforms close to surface in spring
- Summer SST anomalies strongly damped by air-sea interaction
- Temperature anomalies persist in summer thermocline
- Re-entrained into the ML in the following fall and winter

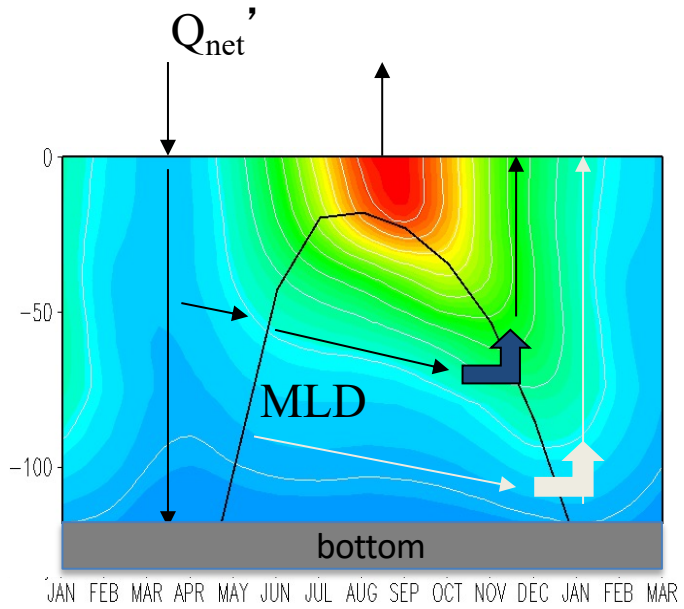
Namias and Born 1970, 1974;
Alexander and Deser (1995, JPO); Alexander et al. 1999
+

Reemergence in the North Atlantic



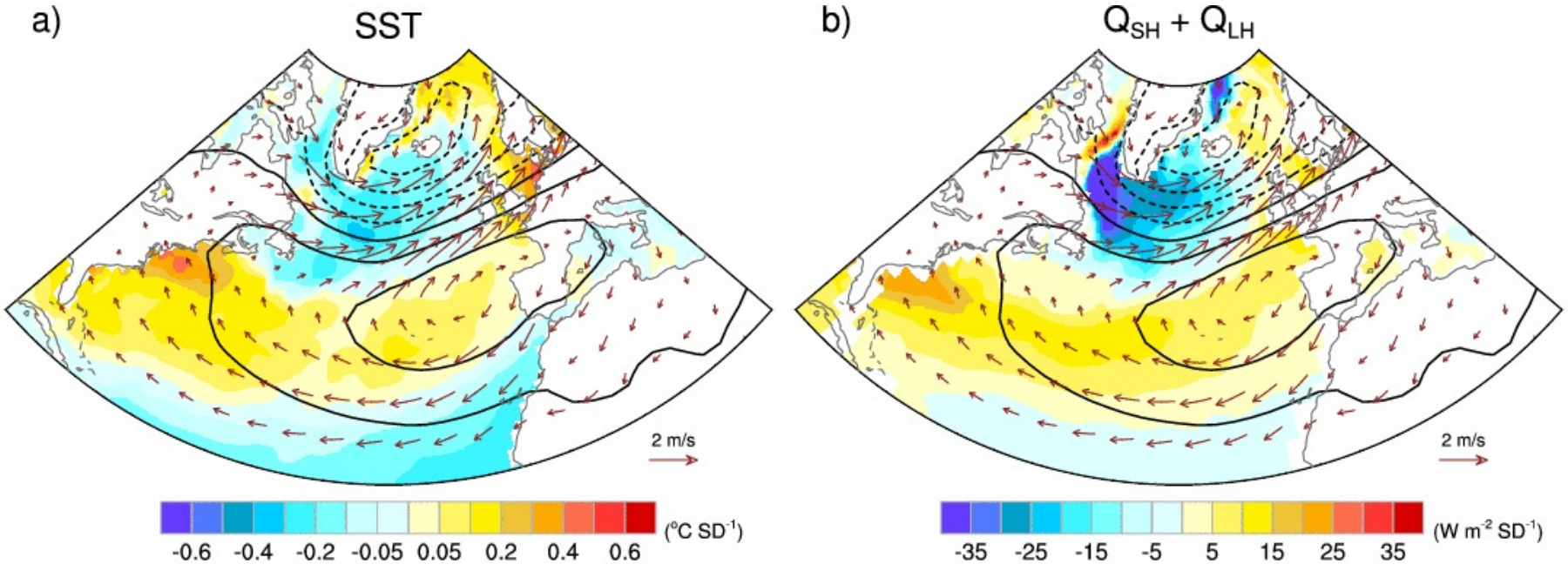
Reg 1 - Subtropical Atlantic (48%)





Timlin, Alexander, Deser, 2002, J. Climate

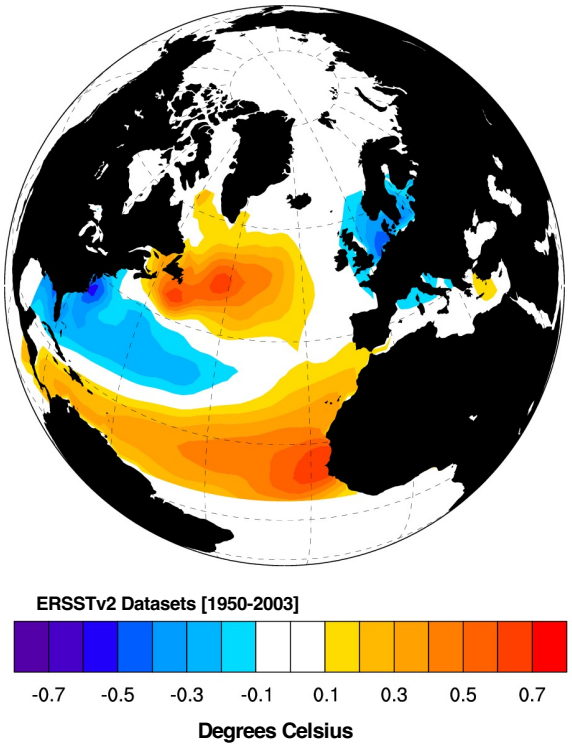
Patterns of Surface Fluxes and SSTs associated with the North Atlantic Oscillation (NAO)



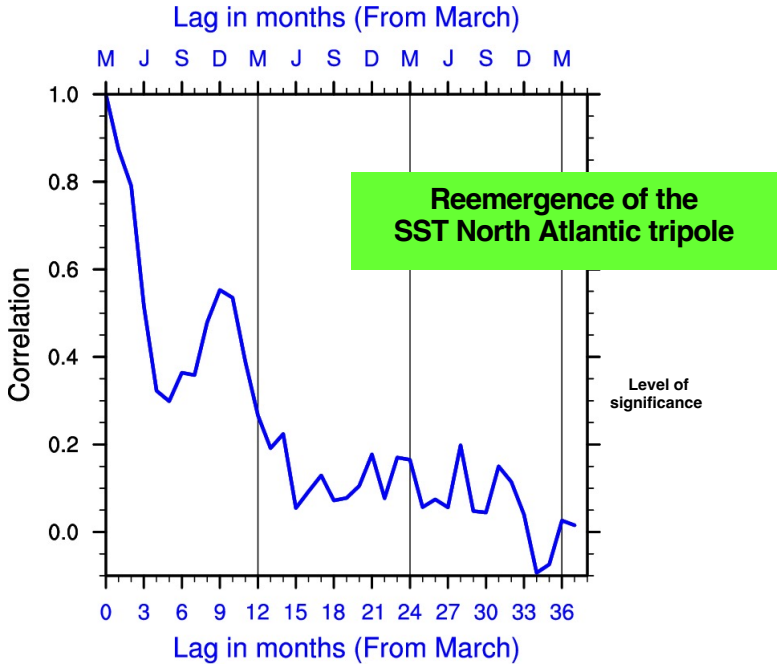
Contours are sea level pressure (SLP); vectors - winds
Shading left is SST anomalies, on right is the Flux anomalies

Reemergence of SST Tripole pattern

Leading EOF of March SST



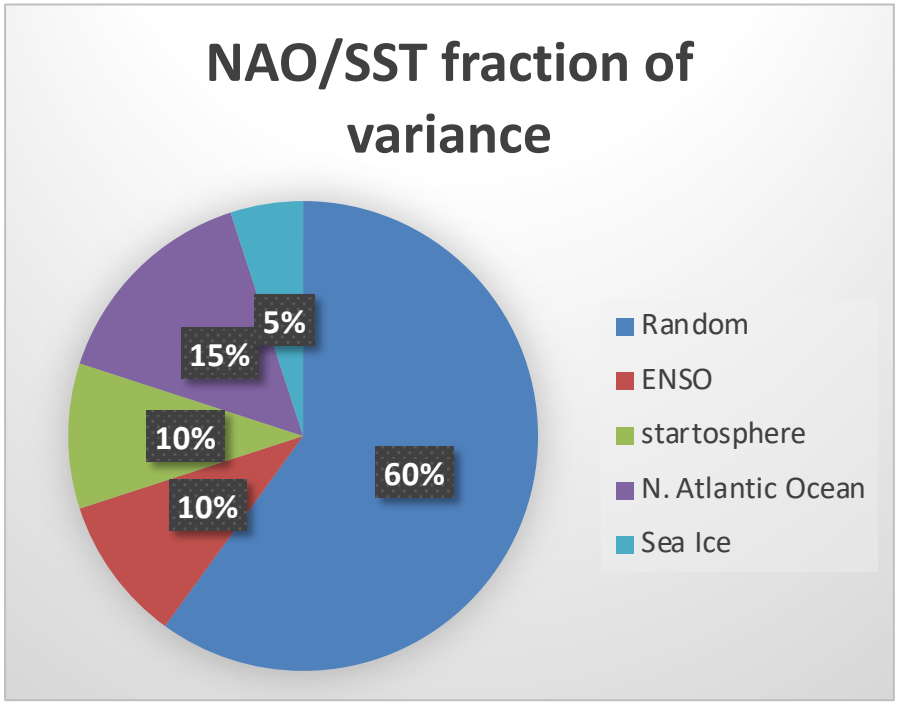
Auto-correlation of EOF PC time series



Reemergence of the SST North Atlantic tripole

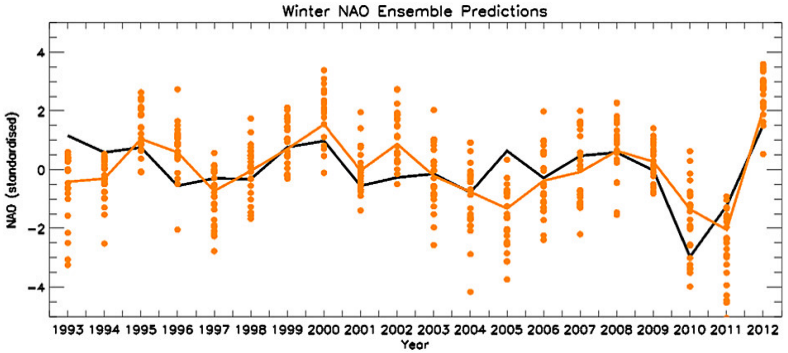
Watanabe and Kimoto (2000); Timlin et al. 2002, Deser et al 2003, De Coetlogon and Frankignoul 2003 : all in J. Climate

Predictability of the NAO/N. Atlantic SST Variability



- (Made up) example of predictability of NAO and regional SSTs in general
- True predictability is still open to question and likely depends on time scale and averaging period
- NAO can be generated by internal atmospheric dynamics (predictable to ~2 weeks)
- Recent results are encouraging for longer time scale predictability

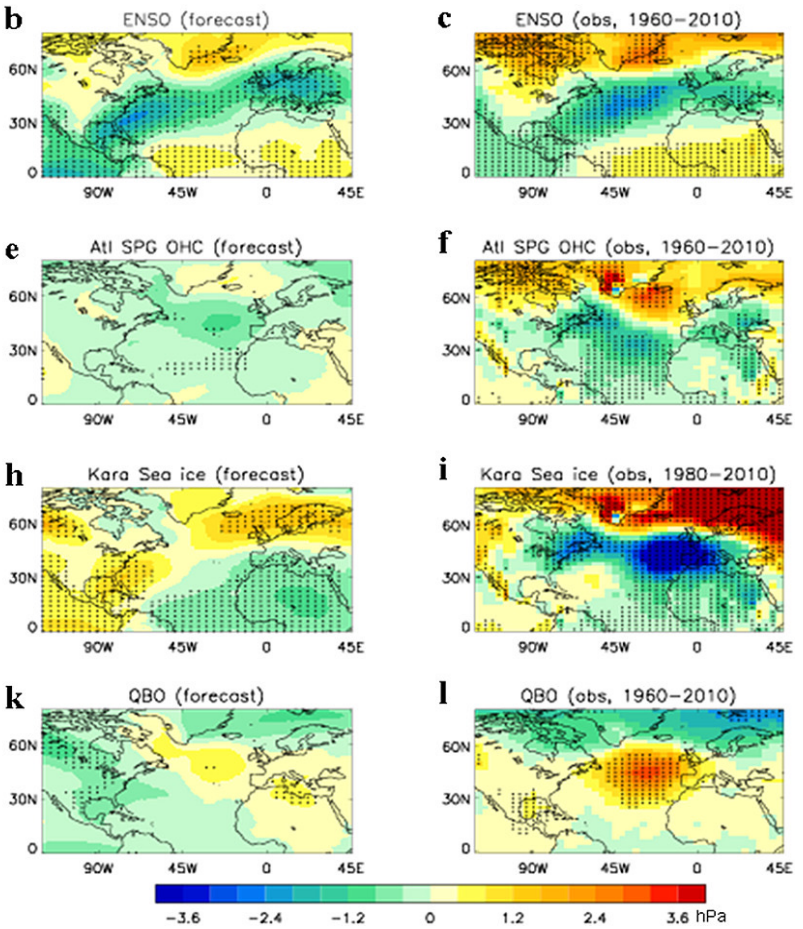
Prediction of the NAO



24-member ensemble of forecasts for each winter 1993 to 2012 centered on 1 November

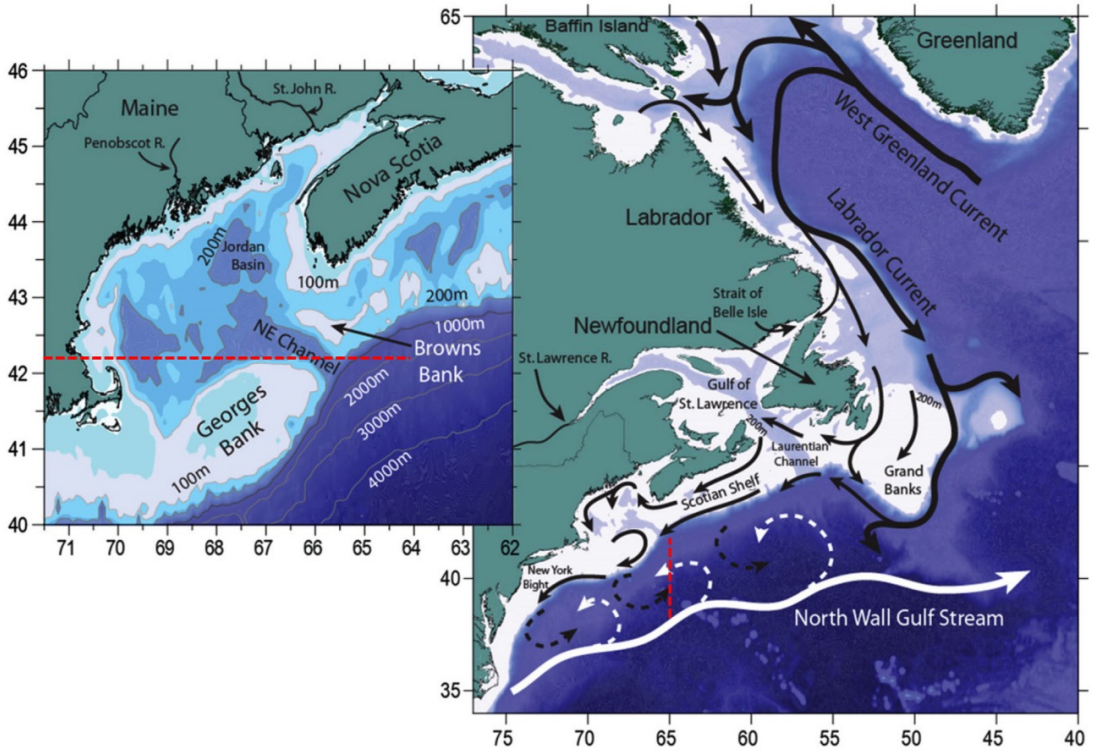
Large ensemble needed due to low signal-to-noise ratio. Termed “Signal to noise paradox”: model (ensemble mean) predicts observations better than it predicts any one simulation (“perfect prog”)

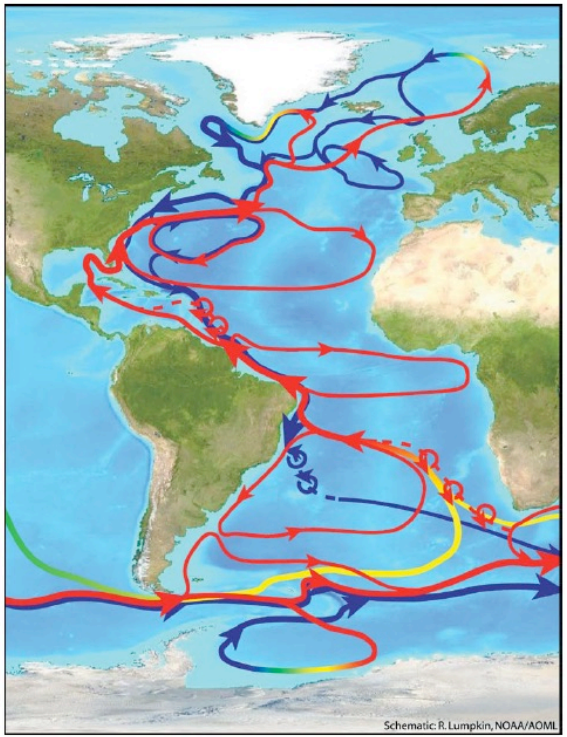
Also skillful multiyear prediction of the NAO using NCAR DPLE system: Athanasiadis, et al. 2021 Climate and Atmospheric Science

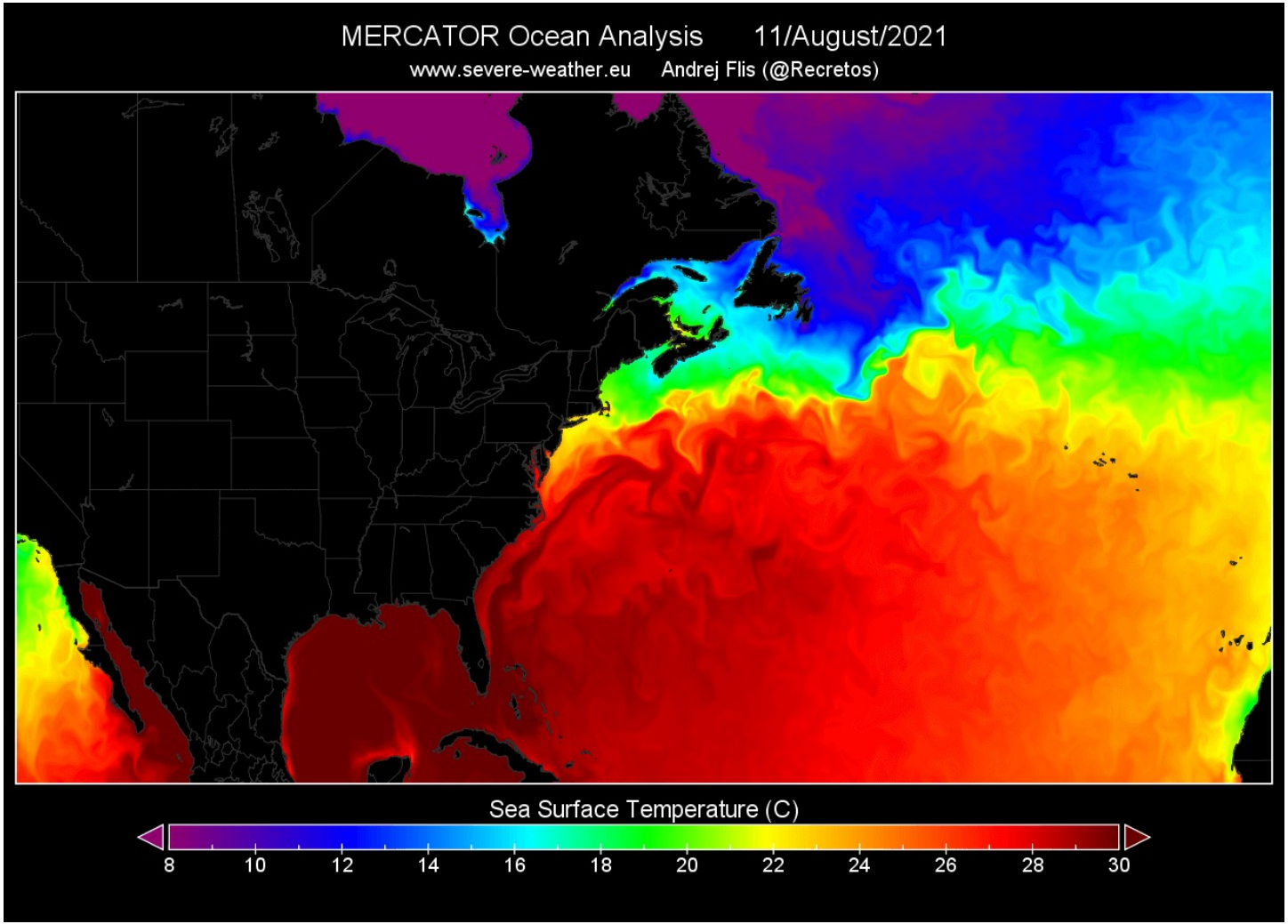


Scaife et al. 2014, GRL

Ocean Circulation of the North Atlantic






MERCATOR Ocean Analysis 11/August/2021
www.severe-weather.eu Andrej Flis (@Recretos)
Sea Surface Temperature (C)
8
10
12
14
16
18
20
22
24
26
28
30

North Atlantic Rossby Waves (SSH)

Hovmoller Diagram

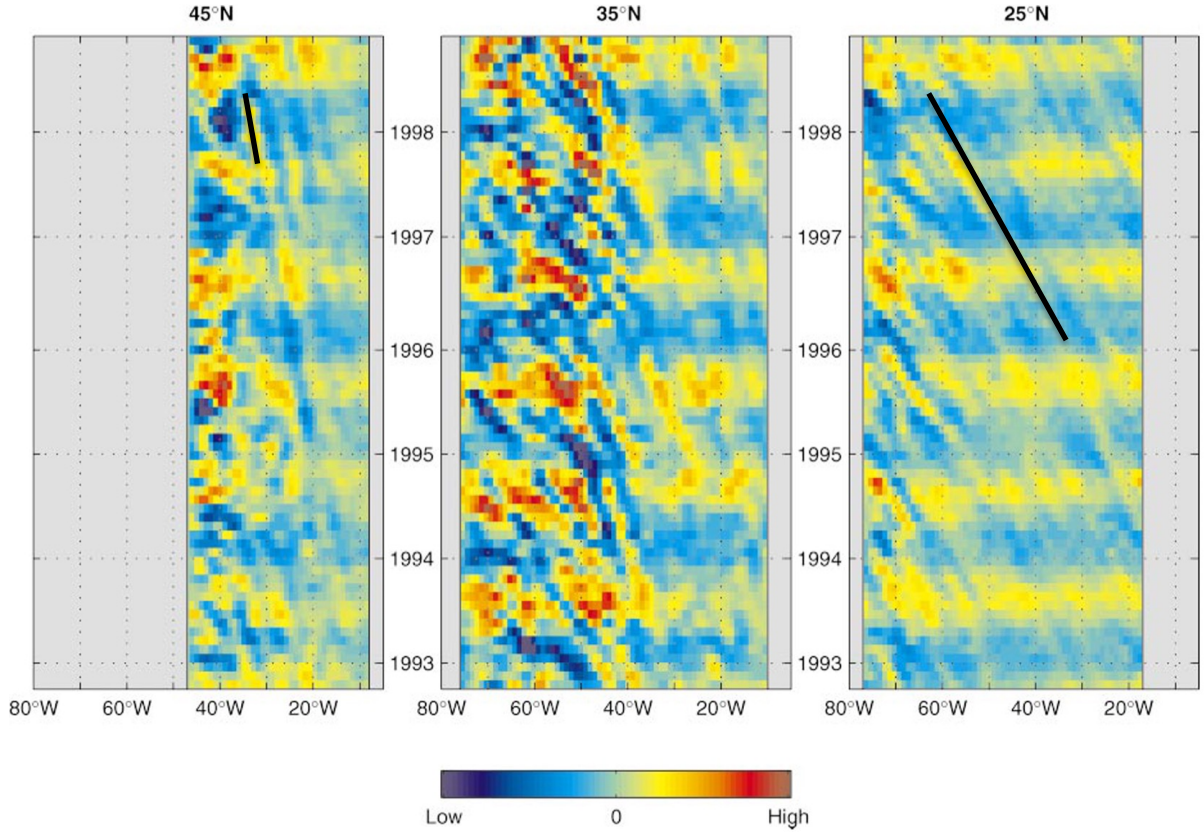


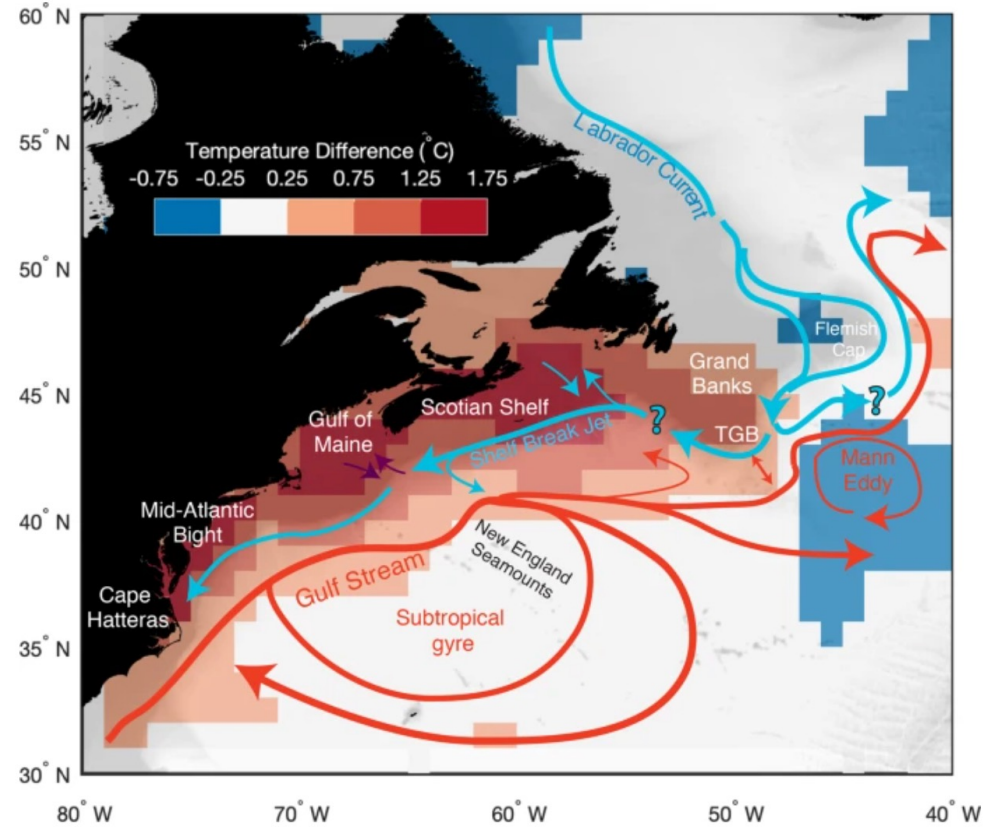
FIG. 1. Time–longitude diagrams of the SSH anomalies. Color scale is the same for all plots in the figure.

- Generated by:
  - wind stress curl,
  - buoyance forcing
  - flow over topography
- Move westward
  - 1-3 year across Atlantic
- Adjustment process
  - Influence Gulf Stream
  - May influence species habitat in frontal & eddy regions
  - May be blocked from reaching the coast

Osychny and Cornillon, 2004, JPO

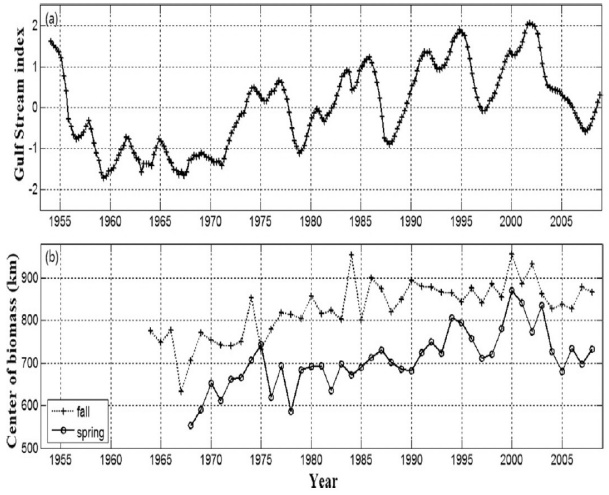
Shifts in the Position of the Gulf Stream

Fig. 1: Schematic of the circulation in the Northwest Atlantic Ocean and the water column average temperature difference between the period 2009–2018 and 2001–2007.

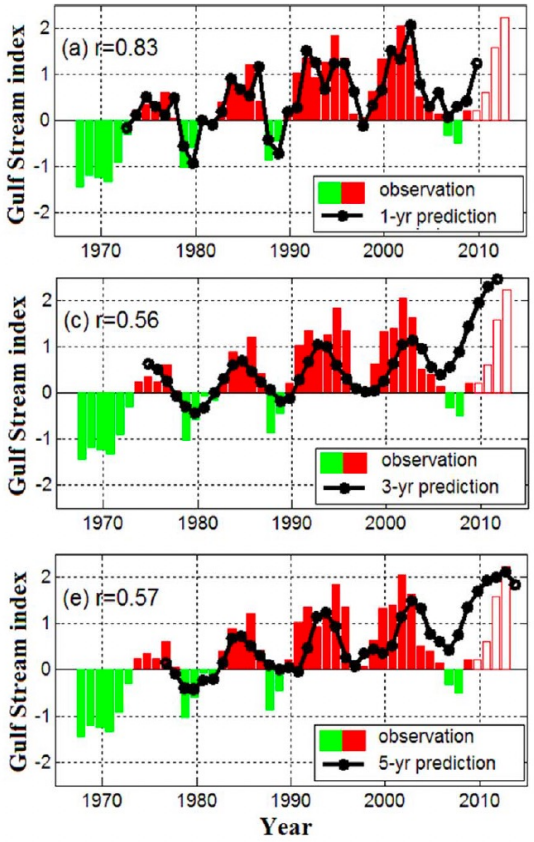


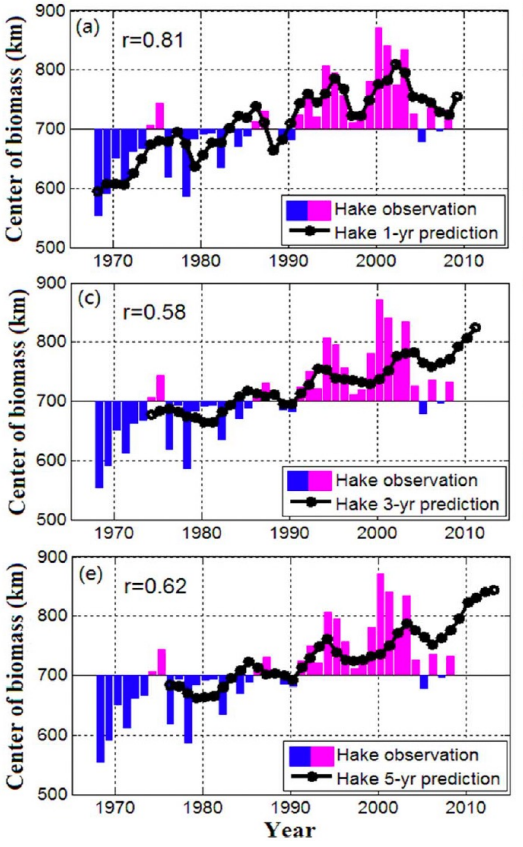
Neto et al. 2021
Communications Earth & Environment

Gulf Stream (Meridional) Position and Silver Hake

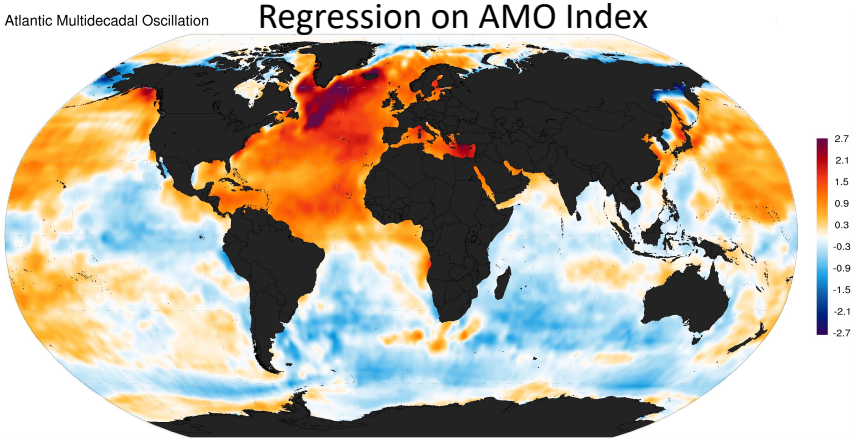


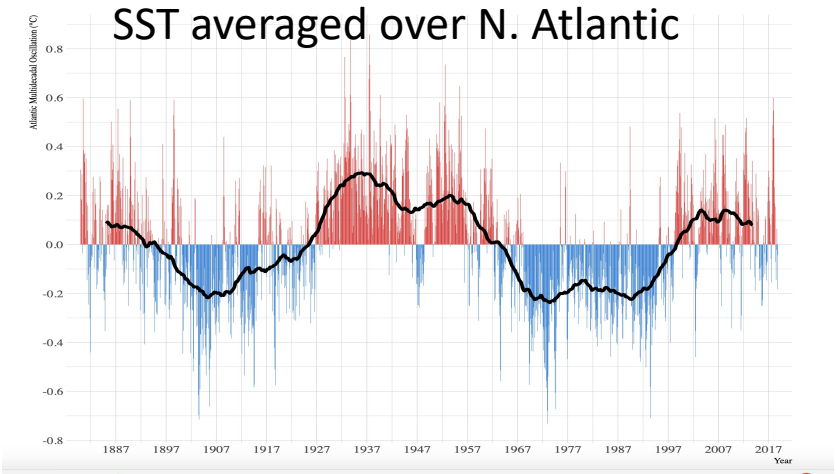
Davis et al. 2017 Continental Shelf Res.





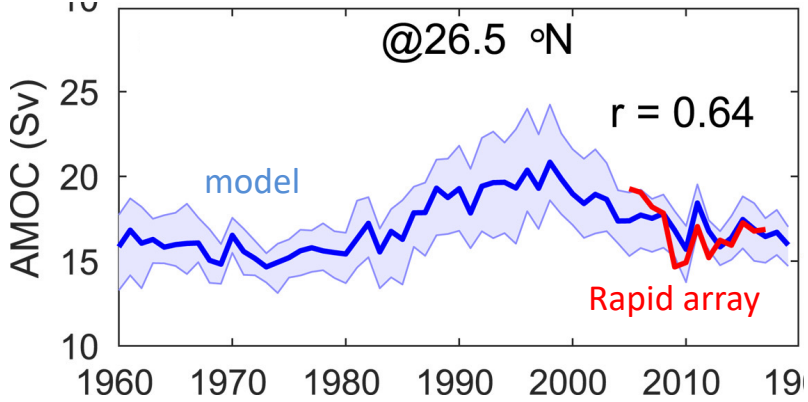
Atlantic Multi-Decadal Oscillation (AMO) or Variability (AMV)





- Important to remove climate change signal
- Temperature fluctuations may be due to:
  - AMOC
  - Thermal forcing
  - Changes in aerosols

SPEAR: GFDL prediction system

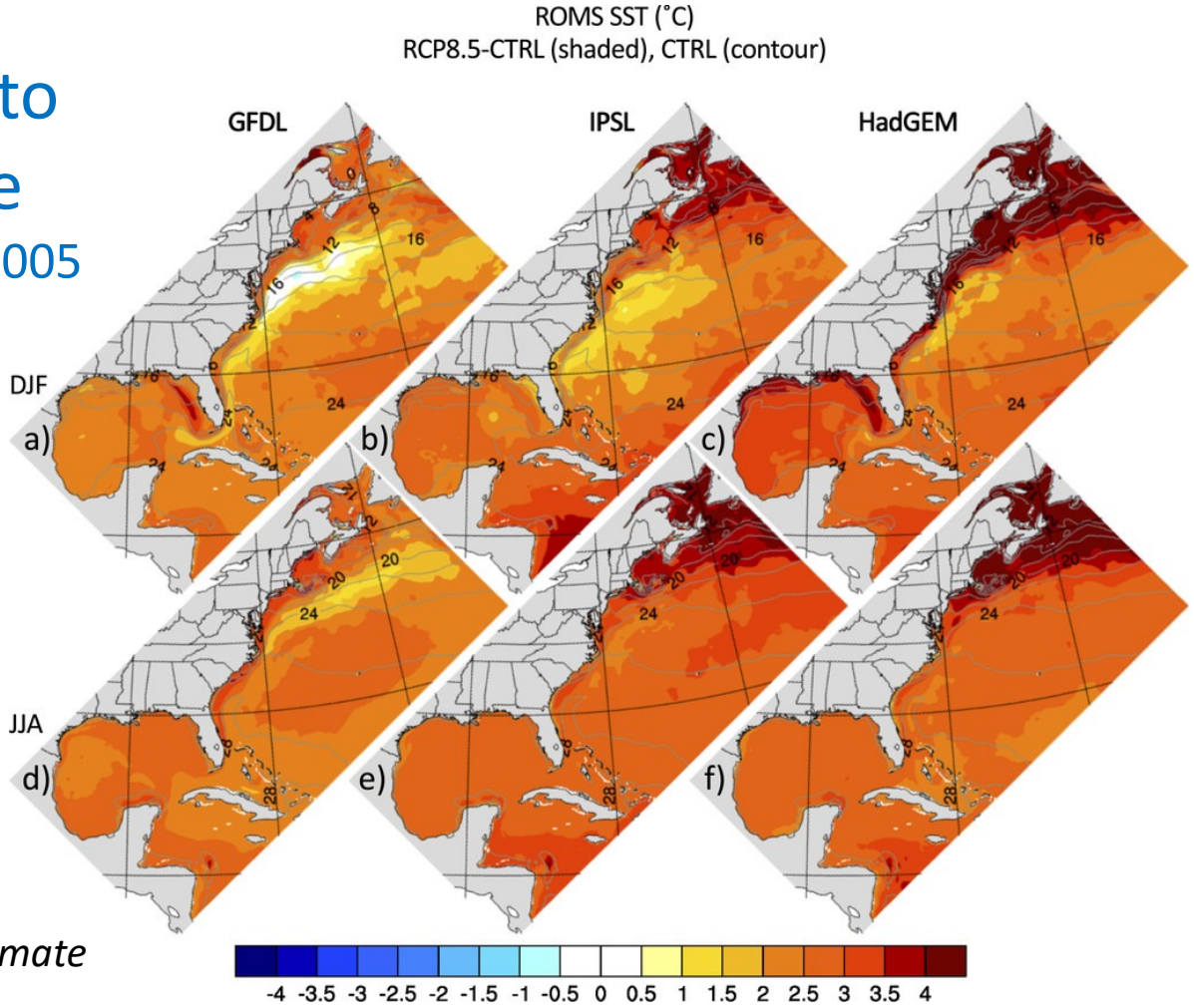


Yang et al. 2021, James

SST Response to climate change

2070-2099 – 1976-2005

ROMS
7 km resolution
Driven by 3 GCMS

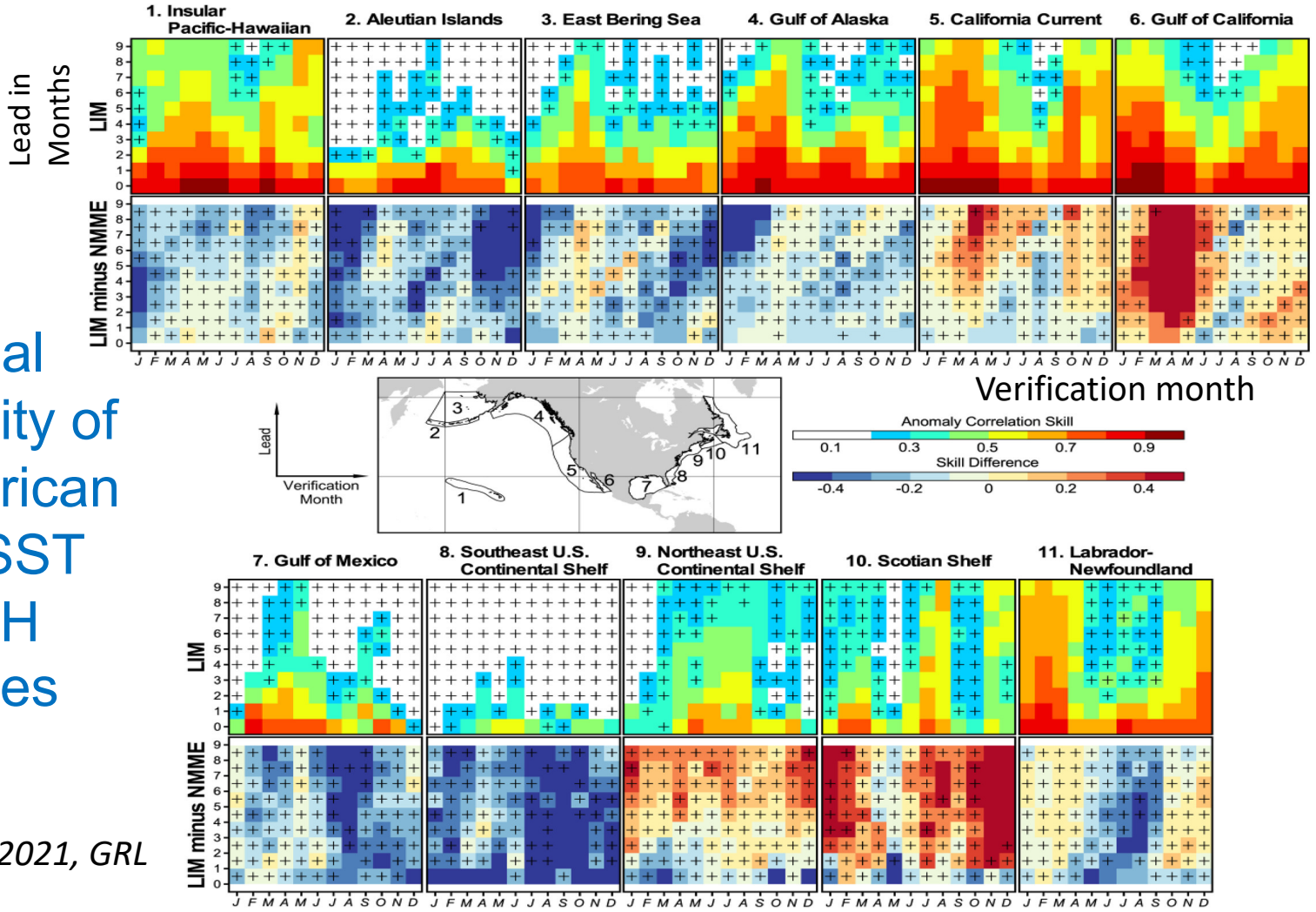


Alexander et al. 2020 J. Climate

Factors influencing Prediction for the NE US shelf

- Several thermodynamic and dynamic processes may lead to prediction of the physics, chemistry and biology along the coast and offshore, But …
  - Nature of the system with strong weather events initiated over N. America can limit predictability at time scales longer than ~2 weeks
  - Region: Complex Bathymetry, Eddies, mixing of two currents, limited ENSO effects, etc.
  - Large-scale open-ocean processes may have limited influence on the shelf
    - Rossby waves are blocked to some degree by the wide shelf
  - Skill of the forecasts mainly determined by Anomaly Correlation, which may obscure some forecast issues
    - e.g., magnitude of the forecasts; actionable?
  - Much of the skill comes from the trend (anthropogenic climate change)
    - Skill greatly decreases when compared with un-initialized climate runs (especially on decadal time scales)
    - Trend may also enhance AC due initializing forecasts with a preset warm or cold state
- NMME models have struggled to make accurate seasonal forecasts for the NEUS shelf region

Seasonal Predictability of North American Coastal SST and SSH Anomalies

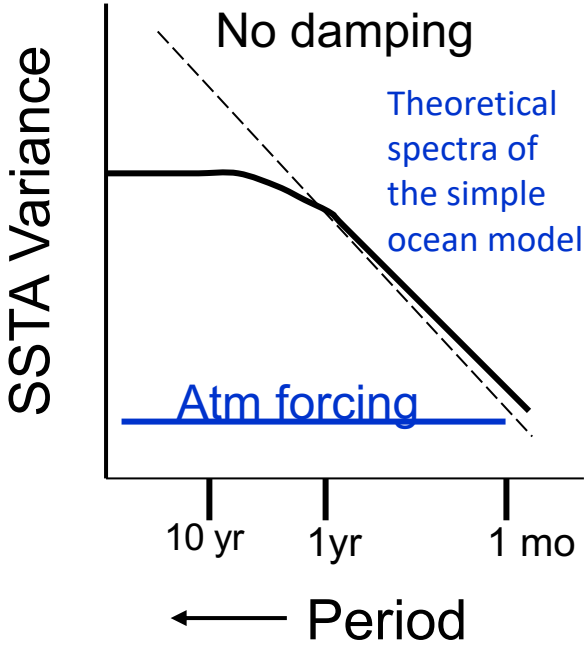


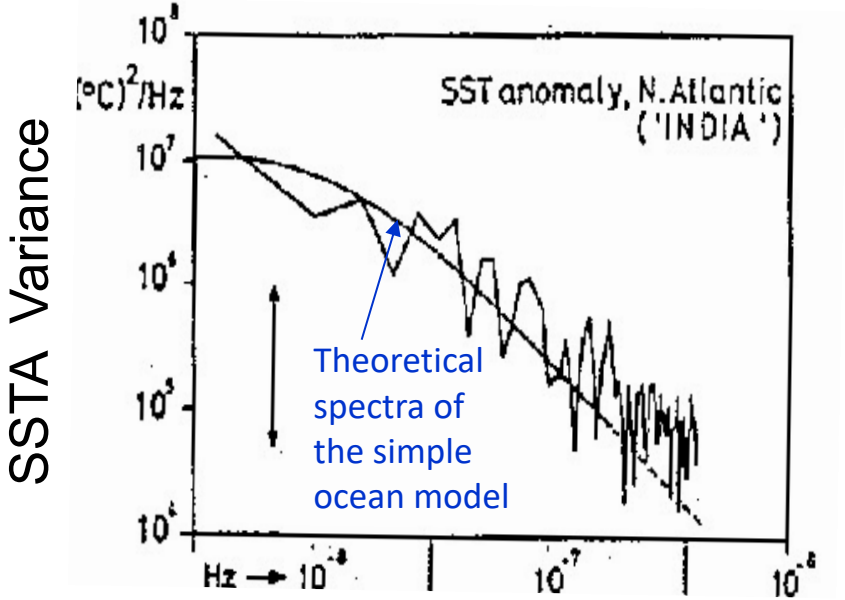
Shin and Newman, 2021, GRL

Additional slides

Stochastic Model: correspondence to the real world?

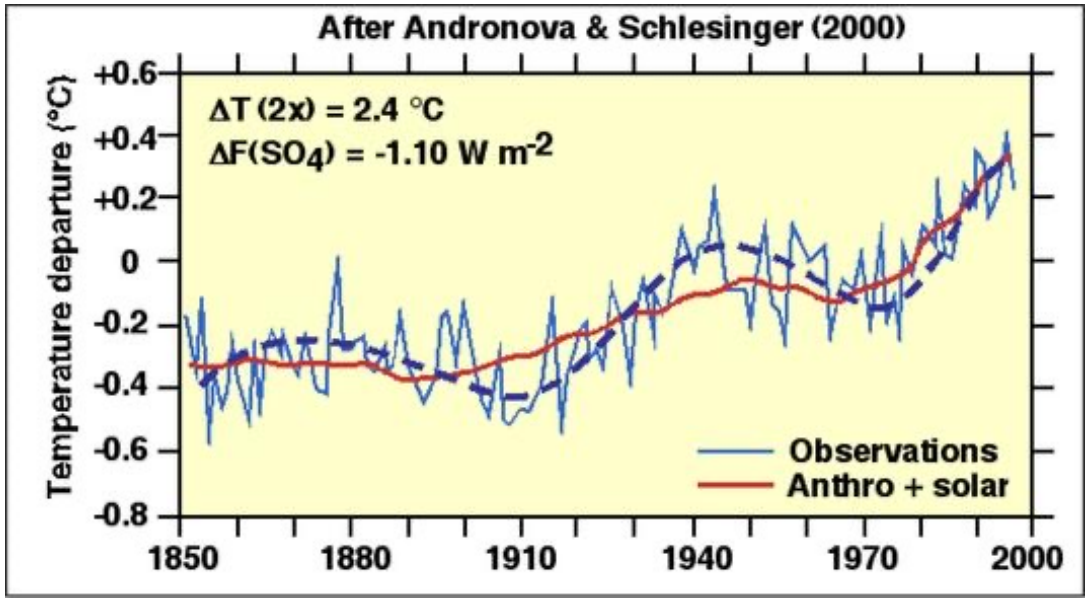
Observed and Theoretical Spectra for SST anomalies (SSTA)
at a location in the North Atlantic Ocean





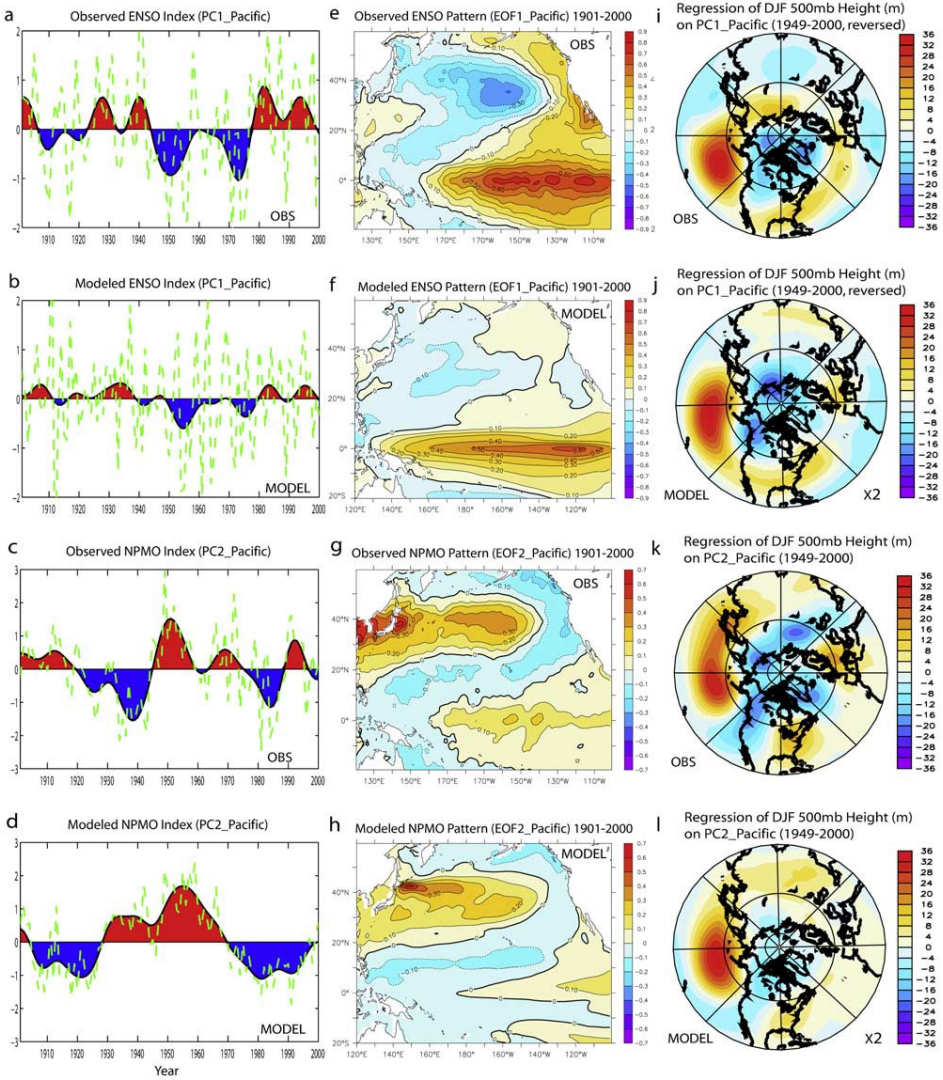
Atmospheric forcing and ocean feedback can be estimated from data.

AMO and Global Warming

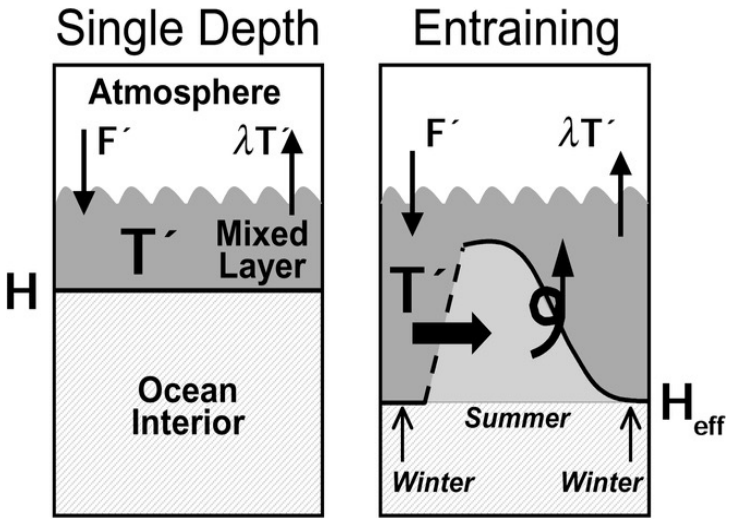


Northern Hemisphere Temperatures

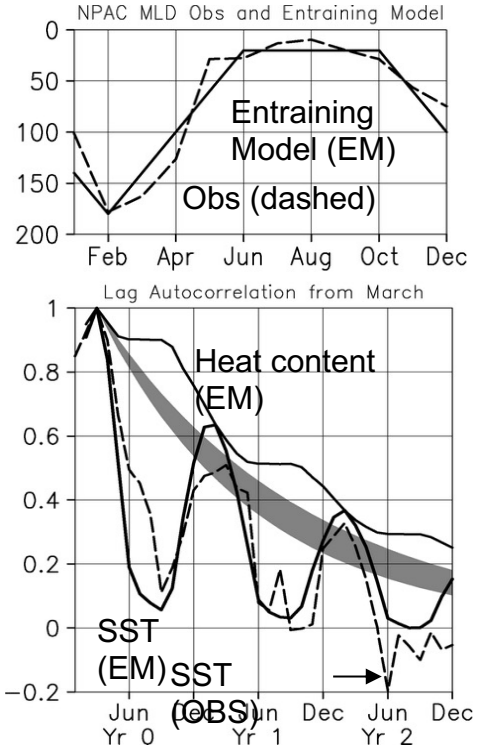
Simple forced climate model no "natural" climate variability


a
Observed ENSO Index (PC1_Pacific)
OBS
b
Modeled ENSO Index (PC1_Pacific)
MODEL
c
Observed NPMO Index (PC2_Pacific)
OBS
d
Modeled NPMO Index (PC2_Pacific)
MODEL
Year
e
Observed ENSO Pattern (EOF1_Pacific) 1901-2000
OBS
f
Modeled ENSO Pattern (EOF1_Pacific) 1901-2000
MODEL
g
Observed NPMO Pattern (EOF2_Pacific) 1901-2000
OBS
h
Modeled NPMO Pattern (EOF2_Pacific) 1901-2000
MODEL
i
Regression of DJF 500mb Height (m)
on PC1_Pacific (1949-2000, reversed)
OBS
j
Regression of DJF 500mb Height (m)
on PC1_Pacific (1949-2000, reversed)
MODEL
X2
k
Regression of DJF 500mb Height (m)
on PC2_Pacific (1949-2000)
OBS
l
Regression of DJF 500mb Height (m)
on PC2_Pacific (1949-2000)
MODEL
X2

Impact of reemergence on SST Persistence:
Augmenting the Stochastic SST model

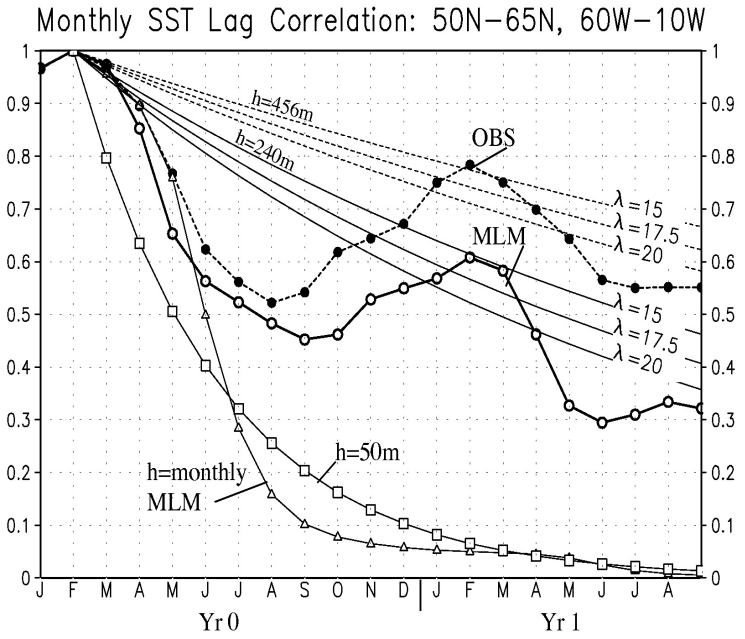


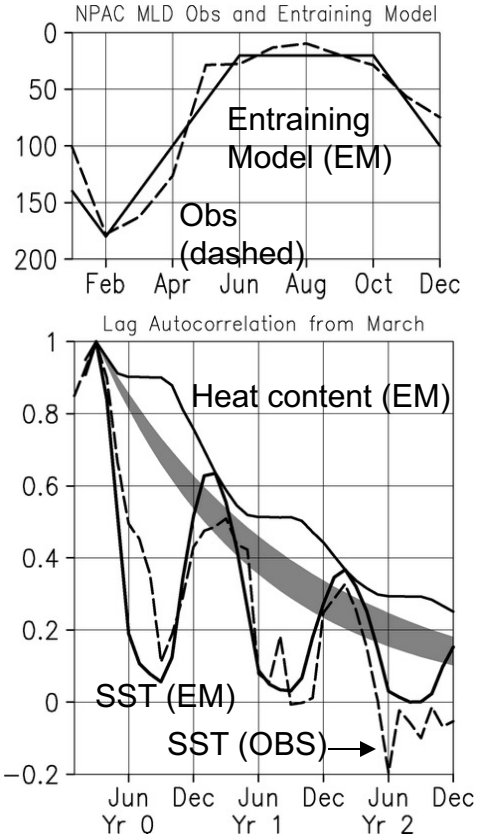
$$r(\tau) = \exp\left[-\lambda\tau/\rho ch\right]$$



Deser et al. 2003

North Atlantic

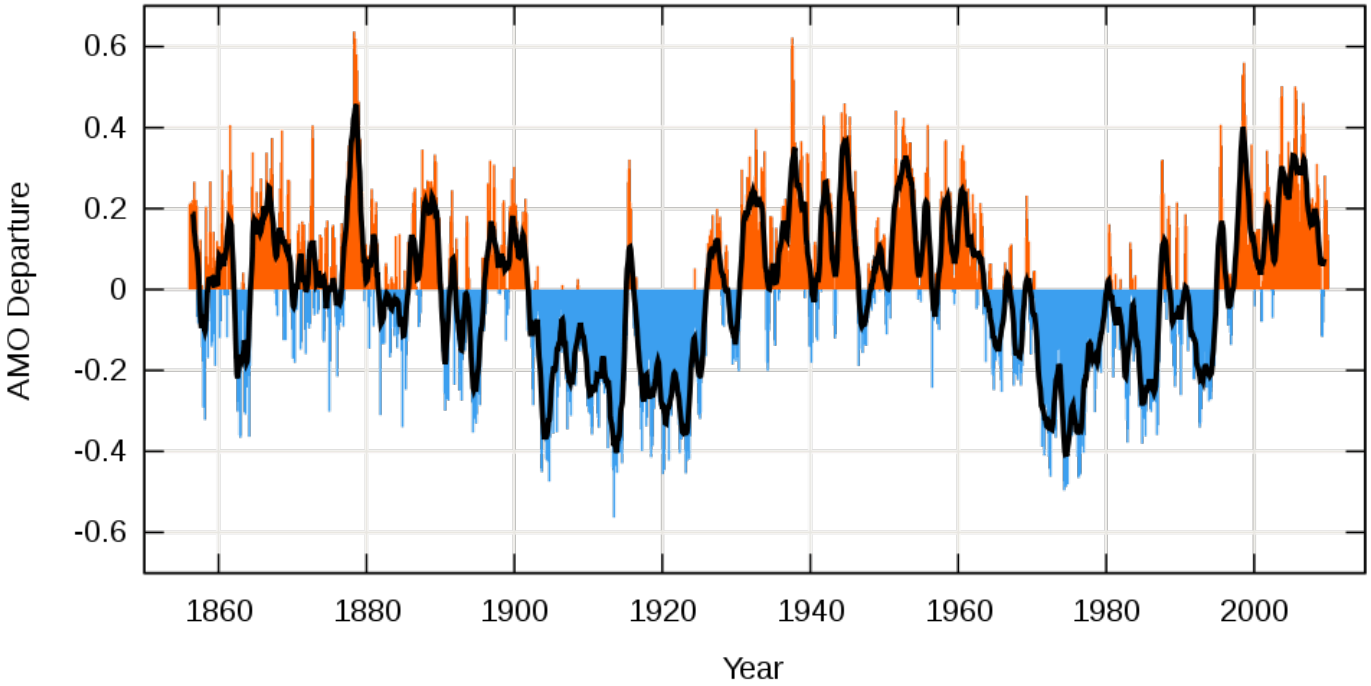




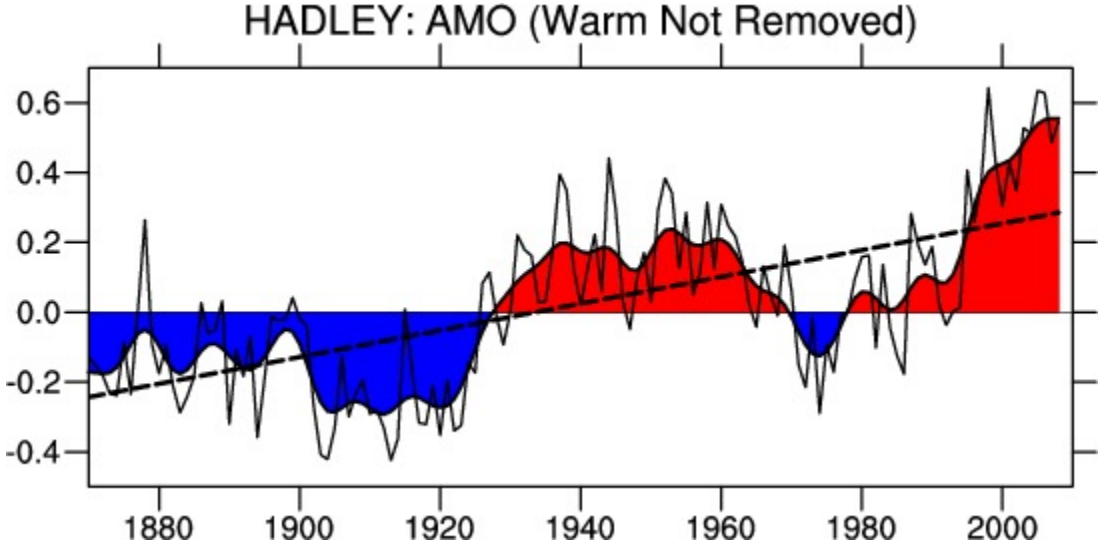
Deser et al. 2003

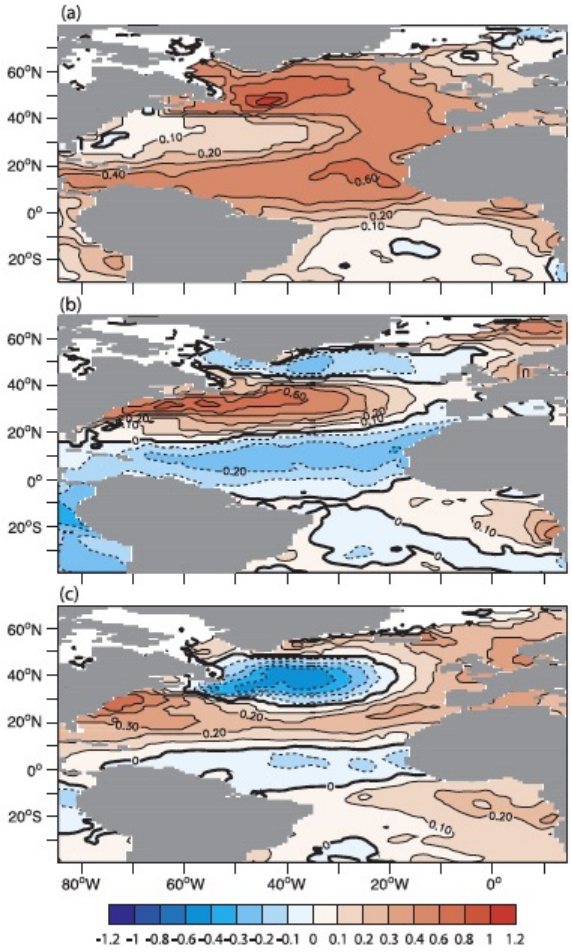
Heff = winter MLD for interannual variability in a stochastic model

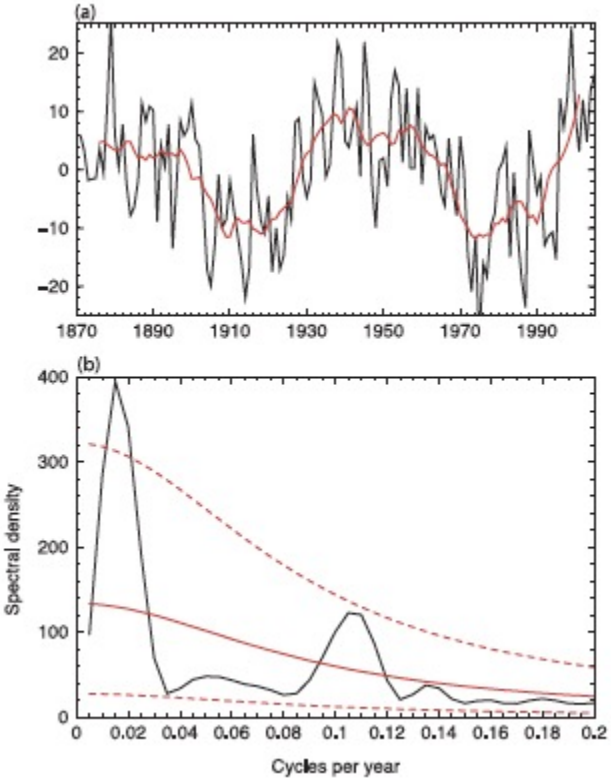
AMO time series and method



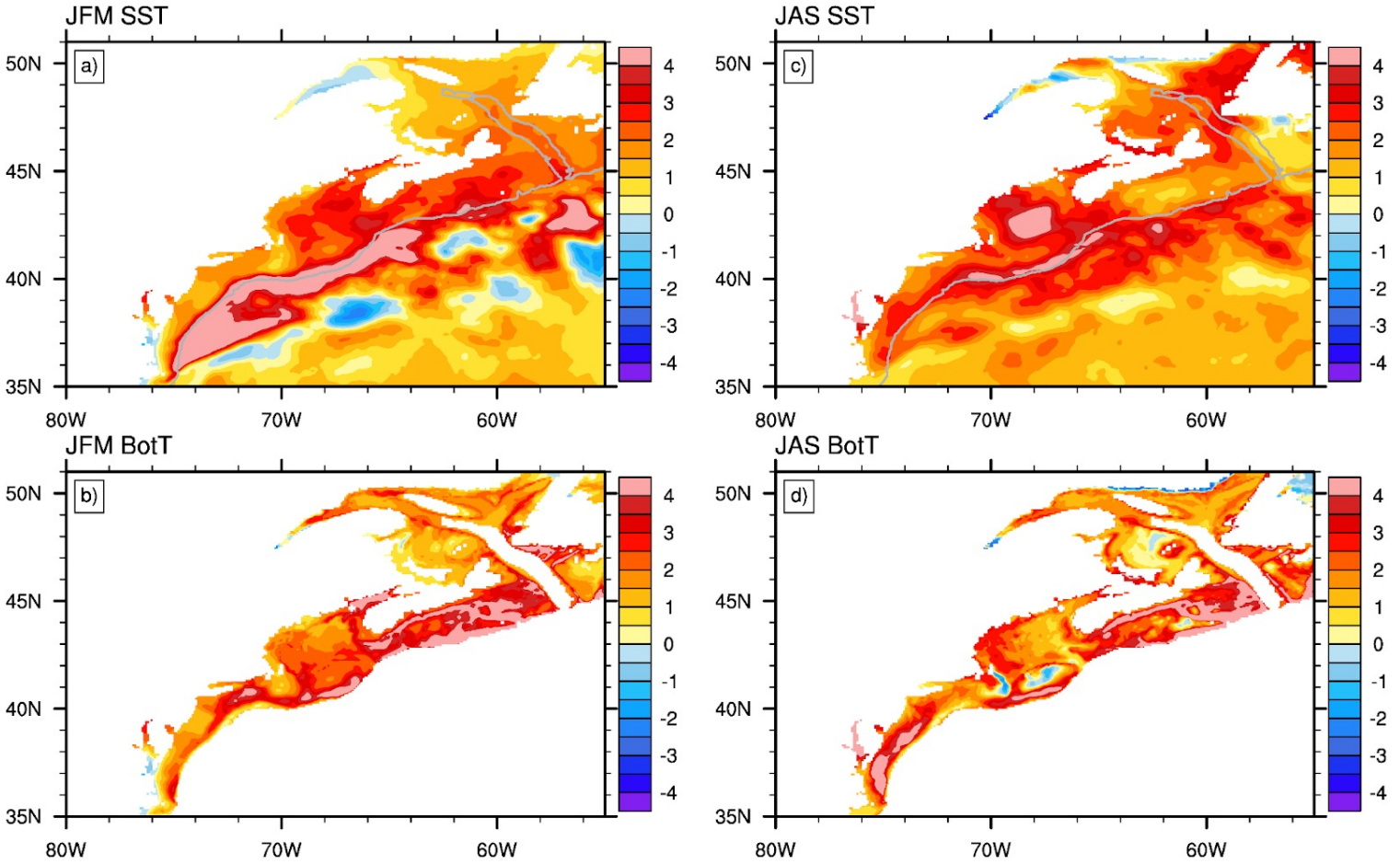
Use the Kaplan SST dataset (5x5).
Compute the area weighted average over the N Atlantic, basically 0 to 70N.
Detrend that time series
Optionally smooth it with a 121 month (10 Yr) smoother.


HADLEY: AMO (Warm Not Removed)
0.6
0.4
0.2
0.0
-0.2
-0.4
1880
1900
1920
1940
1960
1980
2000


(a)
60°N
40°N
20°N
0°
20°S
0.10
0.20
0.40
0.60
0.20
0.10
(b)
60°N
40°N
20°N
0°
20°S
0.60
0.20
0.10
0
0.20
0.10
(c)
60°N
40°N
20°N
0°
20°S
0.30
0.20
0.20
0
0
0.10
0.20
80°W
60°W
40°W
20°W
0°
-1.2 -1 -0.8 -0.6 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.6 0.8 1 1.2

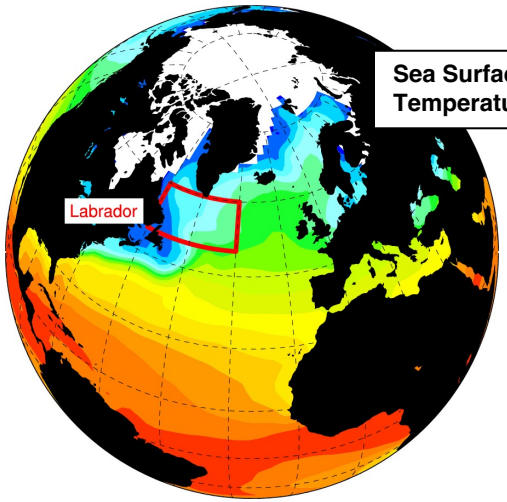

(a)
20
10
0
−10
−20
1870
1890
1910
1930
1950
1970
1990
(b)
400
300
200
100
0
Spectral density
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
Cycles per year

Temperature Trends (°C decade^{-1}) 1993-2018

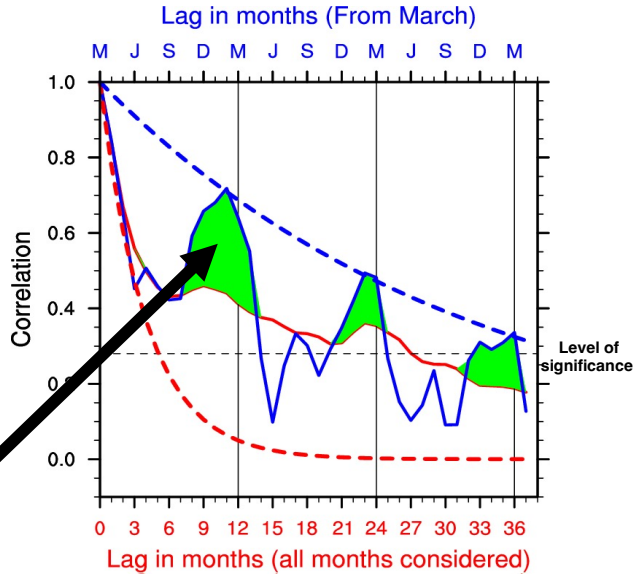


Main Concepts

- Mixed Layers
  - Processes that control its depth
  - Wind stirring buoyancy forcing, density jump at base of ML
  - Processes that control its temperature (SST)
    - Surface heat flux
    - Entrainment heat flux
- Mechanisms for the behavior of SST anomalies
    - Stochastic model
    - Reemergence
    - Large scale patterns of atmospheric forcing organizes fluxes, shapes SST Anomaly and reemergence patterns
- Questions?



Auto-correlation of the Labrador SST time series *(Starting from March),* **e.g. for lag=1, March and April time series are correlated, for lag =2 March and May etc.**



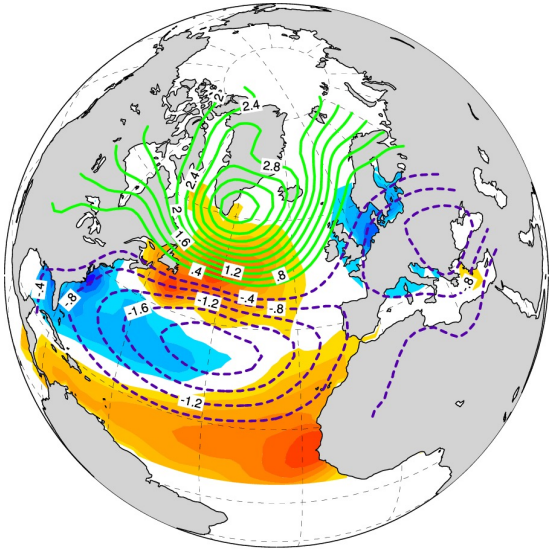
Deser et al. 2003 (J.Clim)

Reemergence of the late winter SST anomalies a year after

Auto-correlation of the Labrador SST time series *(all months considered),* **e.g. for lag=1, Jan50/Feb50/…/Dec00 values are correlated with Feb50/Mar50/…/Jan01 values**

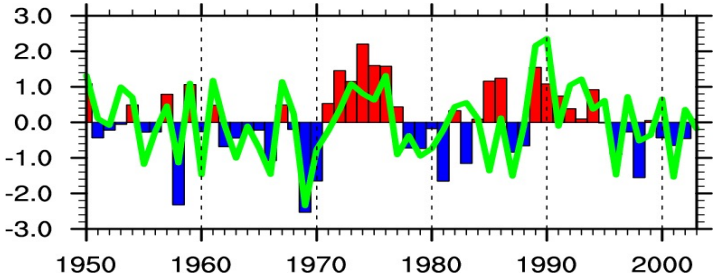
Atmosphere forcing the ocean in winter: NAO & the Atlantic SST tripole

March SST EOF1 (shade)
Regressed JFM SLP (contour)



NCEP MSLP [1950-2003]

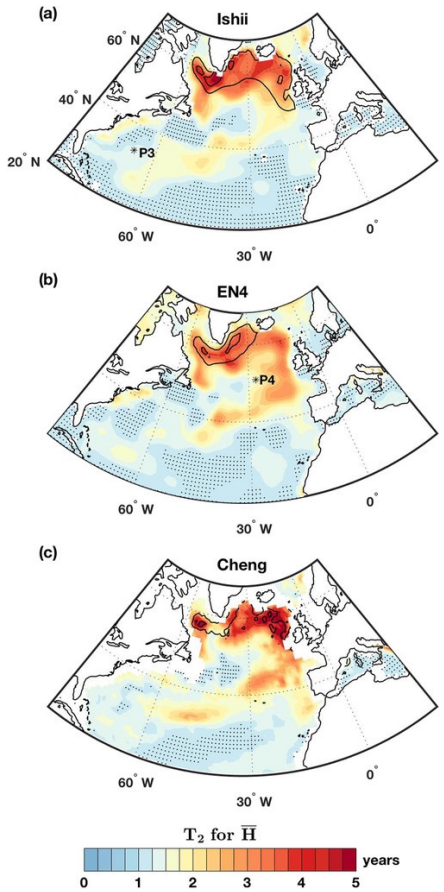
PC time series: March SST (bars),
JFM MSLP (line)



Correlation=0.63

e.g. Deser and Timlin (1997), J.Clim.

Fig. 3.



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The decorrelation time scale T2 (colors) for based on (a) Ishii, (b) EN4, and (c) the Cheng OHC product. The black dots show the points where the decorrelation time scale does not exceed the time scale predicted from white noise on interannual time scales at the 90% confidence level; see the appendix for details. The black contours show the wintertime climatological MLD D at levels of 500 and 1000 m. For Ishii and EN4, D is based on a density criterion applied to the gridded observations. For Cheng, D is based on an Argo MLD climatology (Holte et al. 2017). Starred points P3 in (a) and P4 in (b) correspond to points P3 and P4 shown in Figs. 9a and 9b.

What can we learned about the Atlantic Meridional Overturning Circulation using ocean reanalysis products?

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