Connections between AMOC, meridional heat transport and heat content in the North Atlantic from satellite altimetry

LuAnne Thompson, Kathryn A. Kelly

University of Washington

Eleanor Frajka-Williams, Southampton University, U. K.

Maude Gibbons

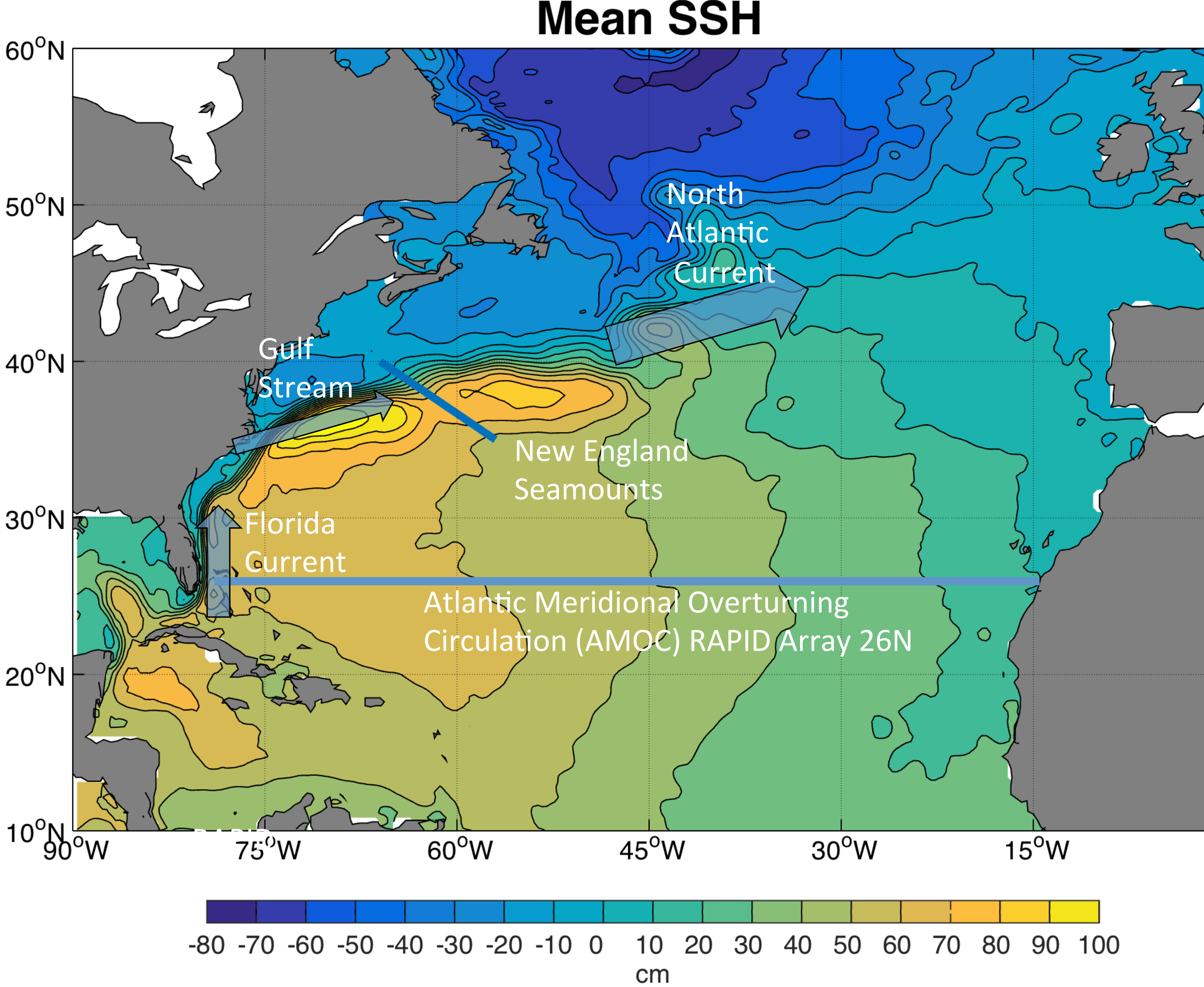
Cambridge Univeristy, U.K.

NASA Ocean Surface Topography Science Team

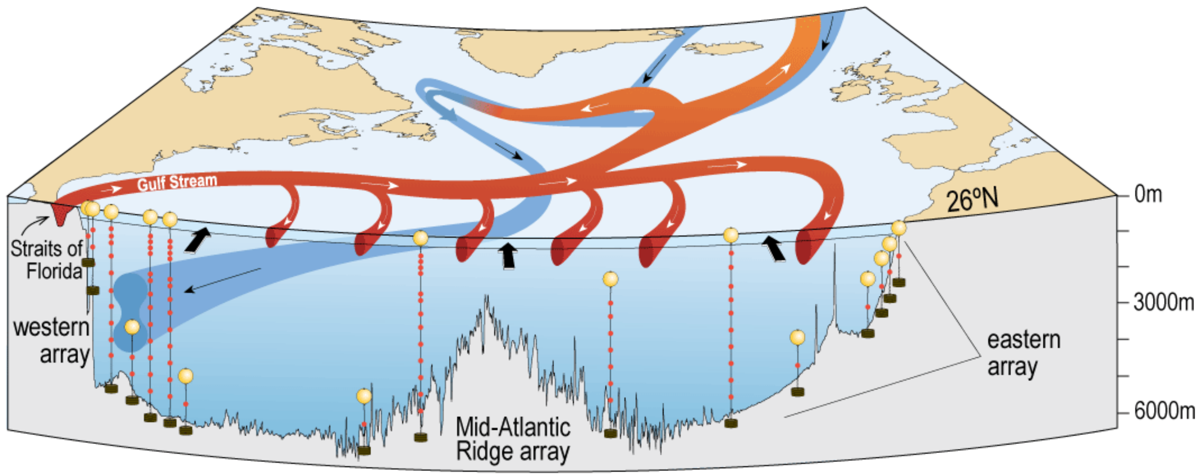
Question: How are the different components of North Atlantic Upper Ocean Circulation connected to the winds, to each other and to heat content changes?

Approach: use altimetry to enhance direct observations of those components

1. Interannual variability using lagged regressions
2. 10 year trend

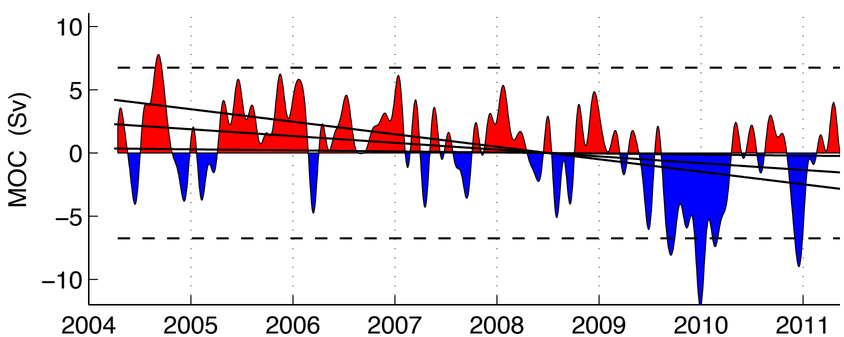

Mean SSH
60°N
50°N
40°N
30°N
20°N
10°N
90°W
75°W
60°W
45°W
30°W
15°W
North Atlantic Current
Gulf Stream
New England Seamounts
Florida Current
Atlantic Meridional Overturning Circulation (AMOC) RAPID Array 26N
-80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100
cm

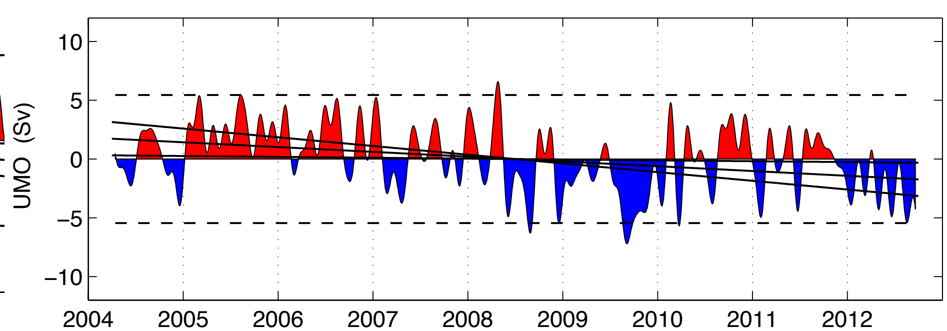
AMOC trend in observed AMOC: mostly owing to Upper Mid-Ocean transport Smeed et al 2014



AMOC=Florida Current+Ekman+Upper Mid Ocean

Mean 17.5 = 31.5 +3.5 - 17.5 Sverdrups





MOC

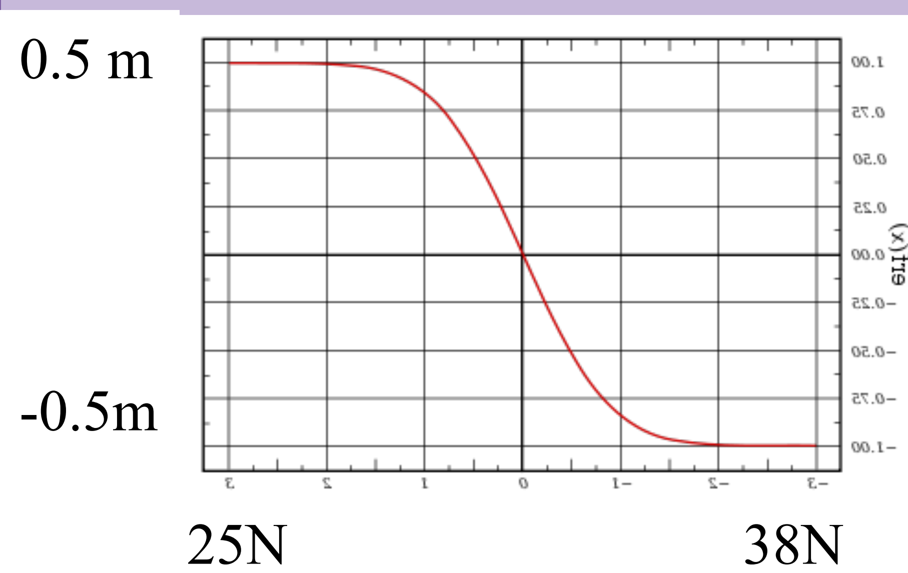
Upper Mid-Ocean

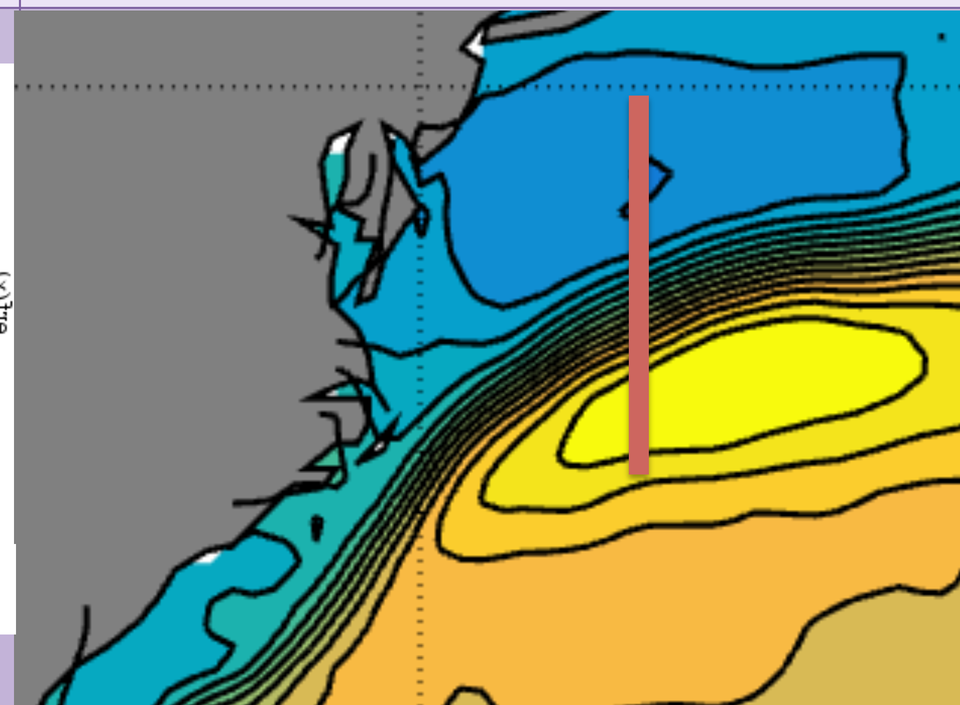
Circulation and heat content variability enhanced by SSH:

Quantity	**Method**
SSH	Monthly AVISO fields spatially smoothed with 400 km Gaussian smoother to removed eddies. Use SSH as a proxy for upper ocean heat content (Lyman and Johnson, 2014)
AMOC at 26N	Atlantic Meridional Overturning Circulation: Extend RAPID AMOC time series back to 1993 using altimetry Frajka-Williams (2015) for Upper Mid Ocean transport
Florida Current	Fill 1.5 year gap of cable measurements using SSH difference across Florida Strait
Gulf Stream path and strength	Fit the across path structure of the SSH to an error function (Kelly and Gille, 1990)

Location and strength of the Gulf Stream from SSH difference

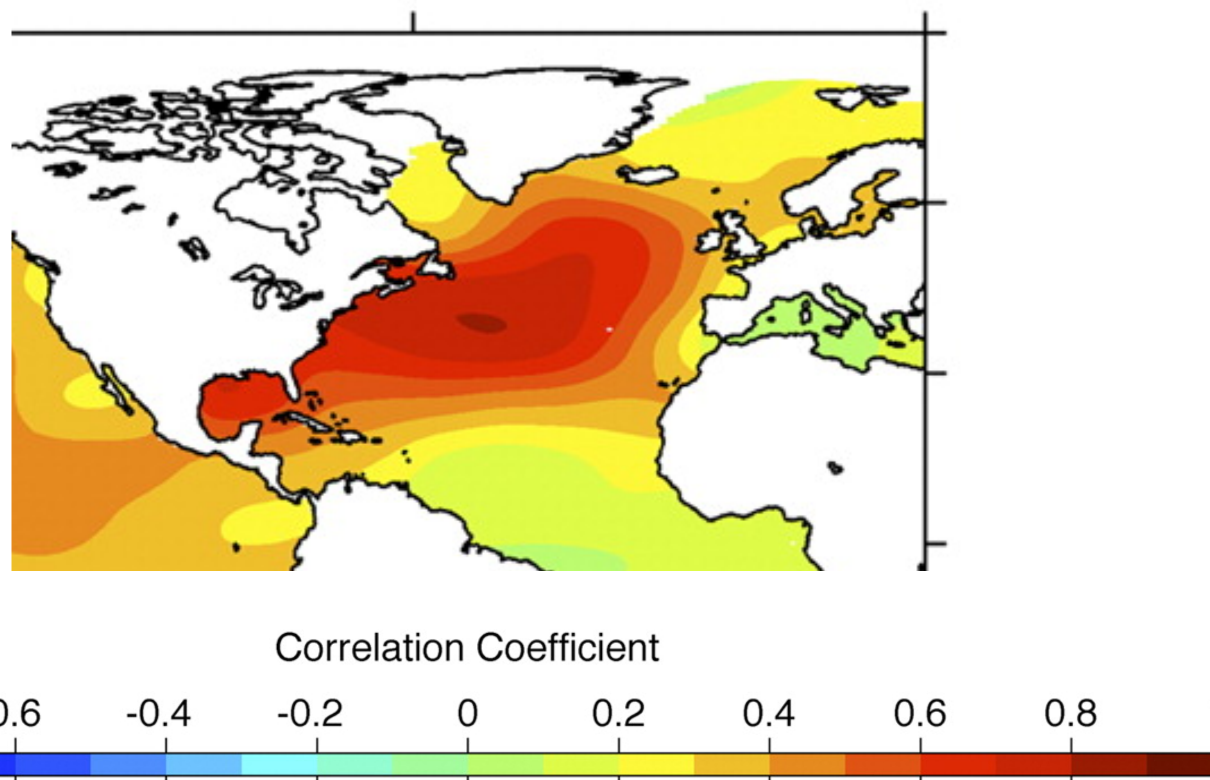
Quantity	Method
Gulf Stream path and strength	Fit the across path structure of the SSH to an error function (Kelly and Gille, 1990)





Using sea level as a proxy for heat content. Lyman and Johnson 2014

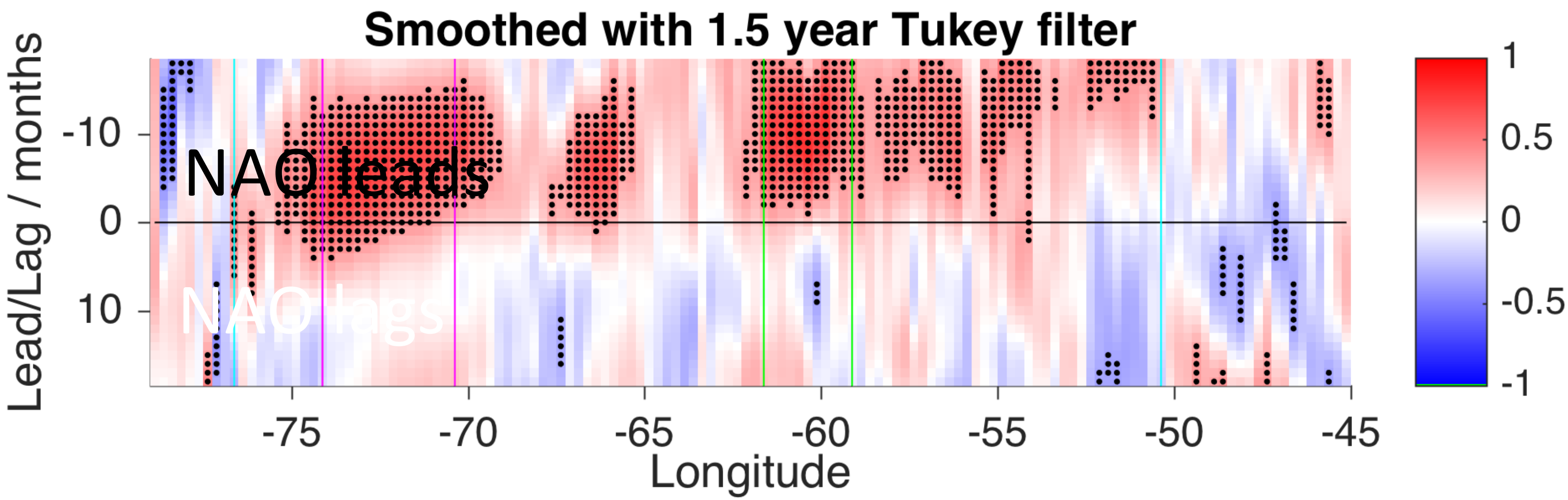
Local sea level determined by thermosteric (thermal expansion), and halosteric (haline contraction).
Thermosteric dominates in tropics and subtropics
Correlation coefficent seasonal heat content with SSH 300-700 m



Example:

Influence of North Atlantic Oscillation (the dominant mode of atmospheric variability) on Gulf Stream Path on interannual times scales

NAO leads location of Gulf Stream by 1-18 months at almost all longitudes (Frankignoul et al, 2001)

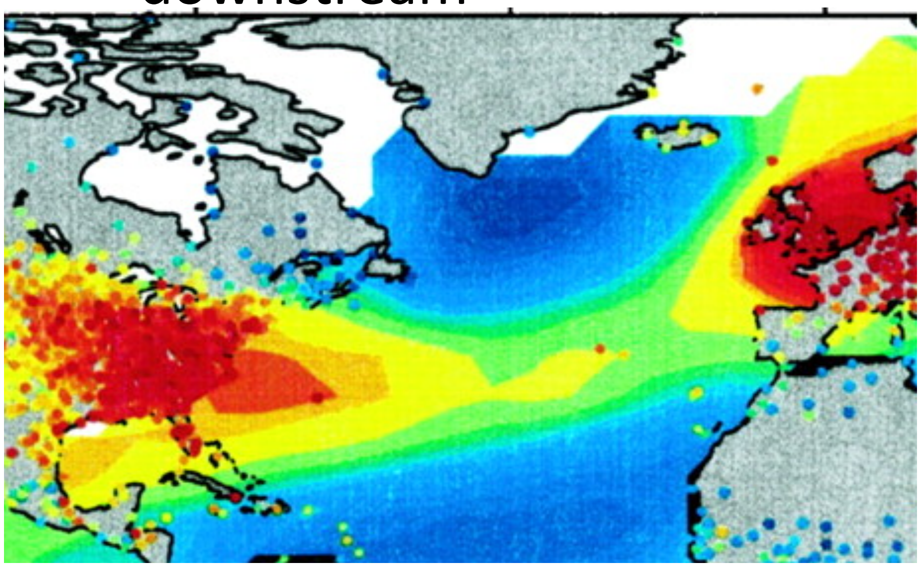


Results: Gulf Stream moves north and gets stronger about a year after changes in transport or winds

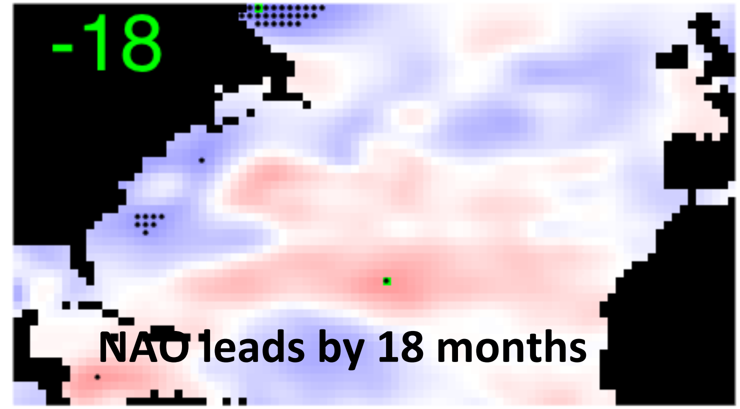
Index	Gulf Stream Path	Gulf Stream Strength
NAO-North Atlantic Oscillation	35 km/unit NAO Over Entire Path (See Frankignoul et al, 2001)	9 cm/unit NAO Near New England Seamounts
AMOC at 26N	7.7 km per Sverdrup Upstream of New England Seamounts *Opposite to what is found in climate models (Joyce and Zhang, 2010)*	4 cm per Sverdrup Downstream of New England Seamounts
Florida Current	-	1.6 cm per Sverdrup Over entire path
UMO/ Thermocline Transport at 26N	5 km per Sverdrup Over entire path	-

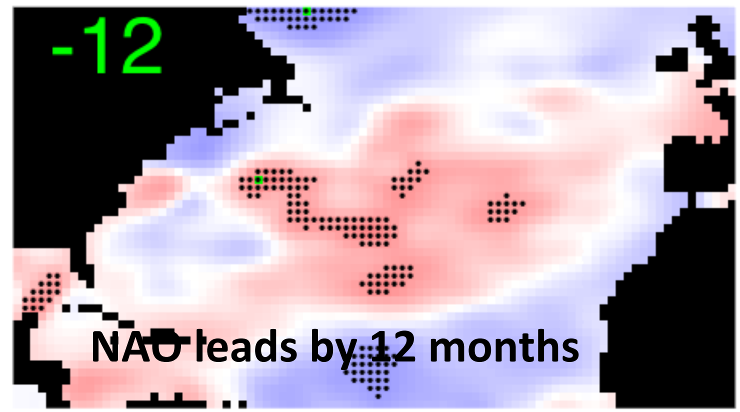
SSH pattern Forced by the NAO (interannual, spatially smoothed)

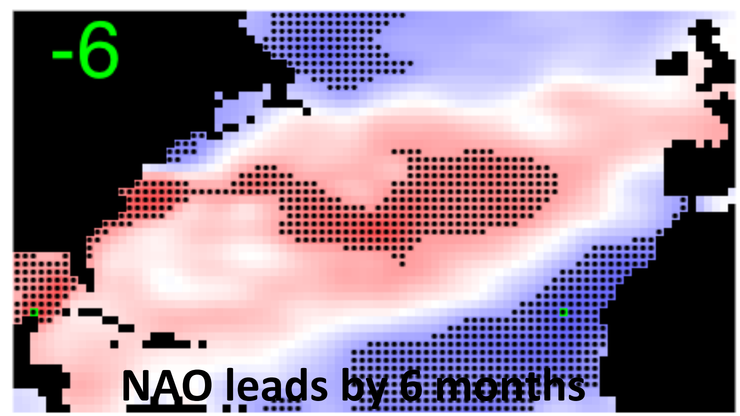
- SSH increases in the central tropical gyre and decreases in the subpolar and SE Subtropical gyre.
- GS path shifts North and increases in strength downstream



SST pattern associated with NAO (Vizbeck et al. 2001)



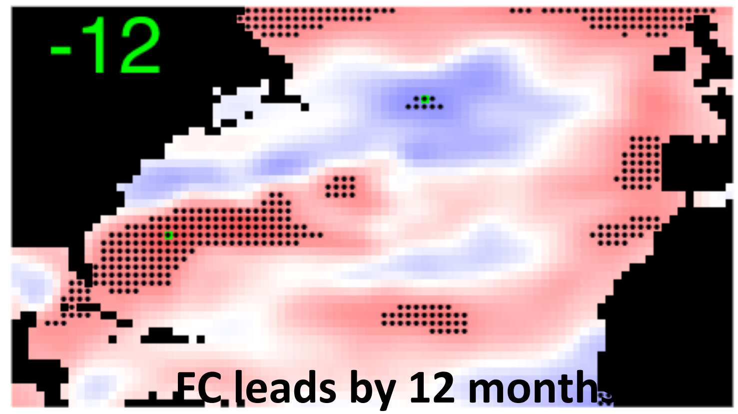


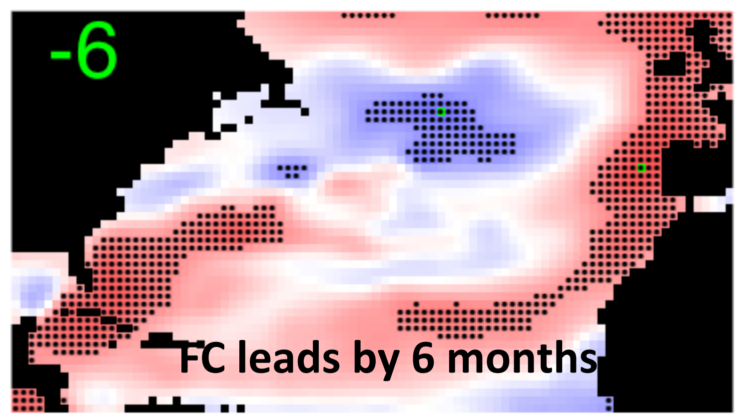


SSH pattern forced by changes in the Florida Current (interannual, spatially smoothed)

SSH increases in the western subtropical gyre (heat content increase)
Decreases in NAC (heat content decrease)

GS increases in strength downstream of seamounts





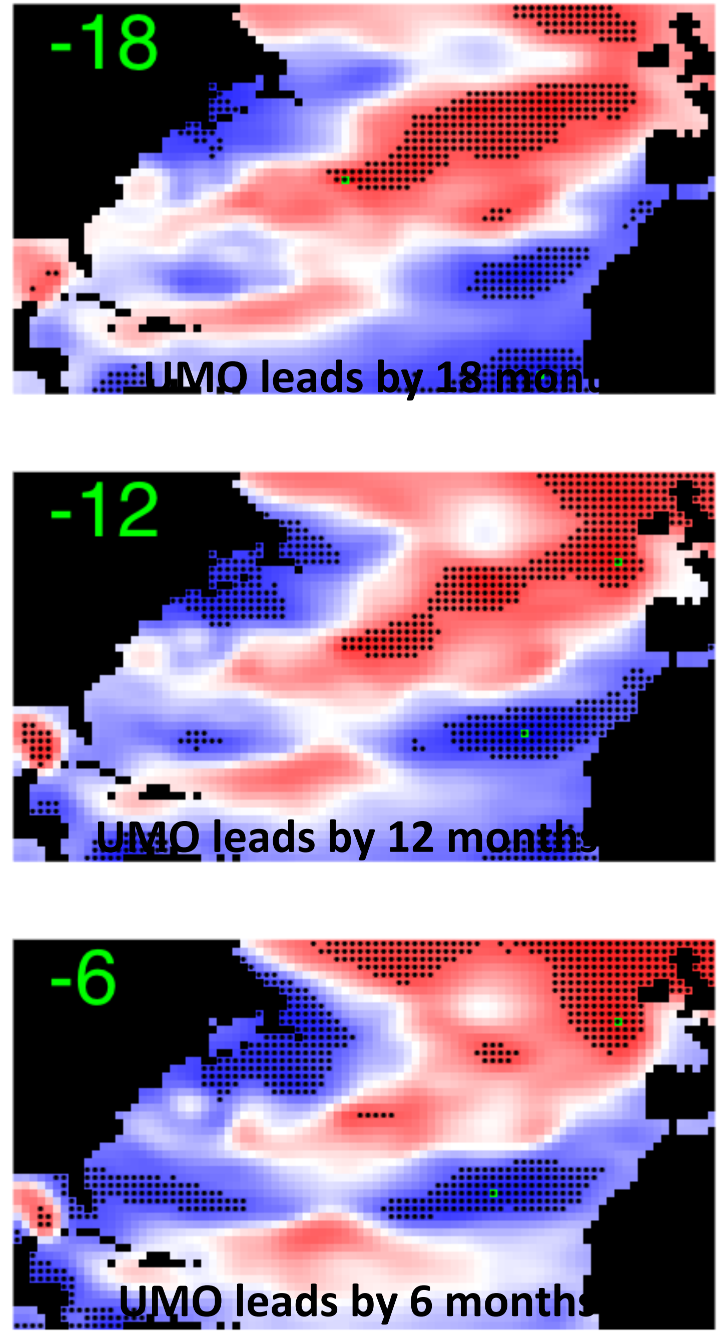
SSH pattern forced by increases in UMO

SSH/heat content increases in North Atlantic Current

Decreases northeast of North America

Decreases across the basin at 26N

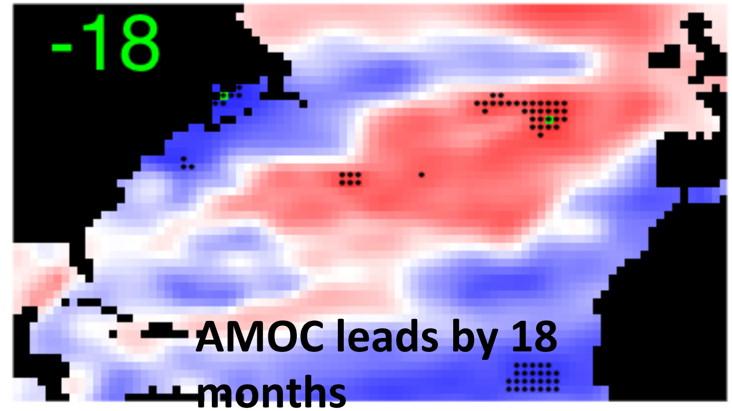
Northward shift of GS path upstream of seamounts

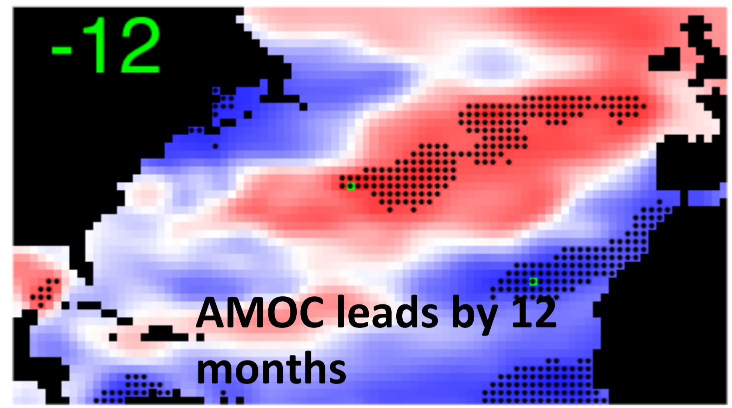


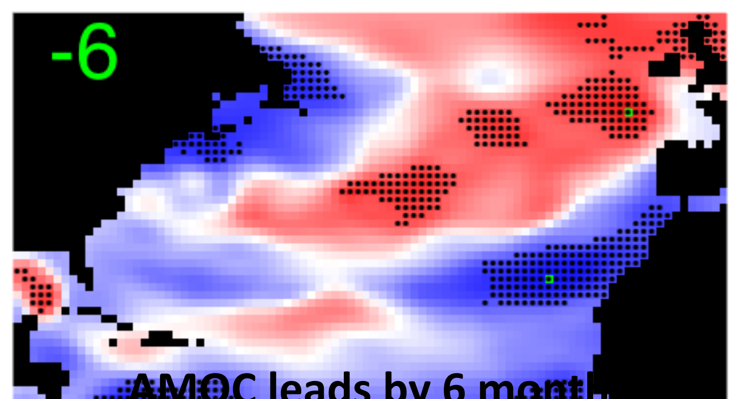
SSH pattern forced by changes in AMOC: Dominated by Upper Mid Ocean response

SSH/heat content increases in "intergyre" and decrease off northeast North America

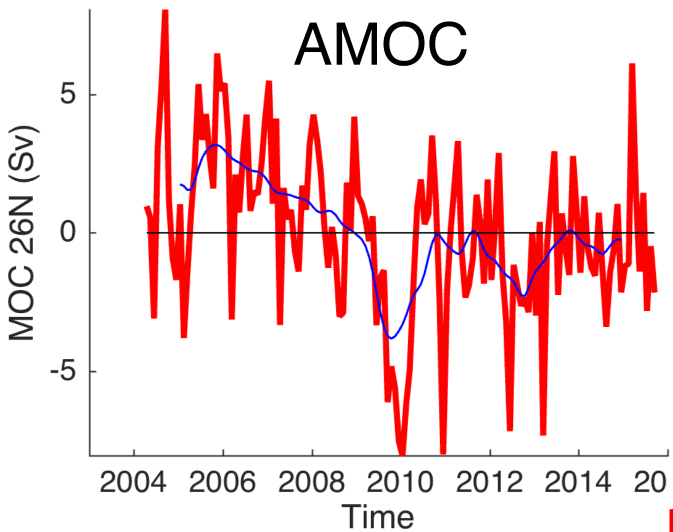
UMO shows similar pattern

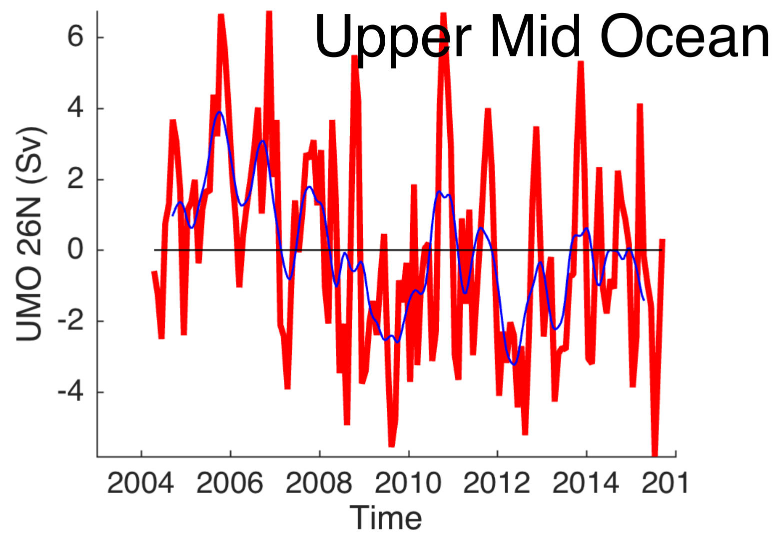


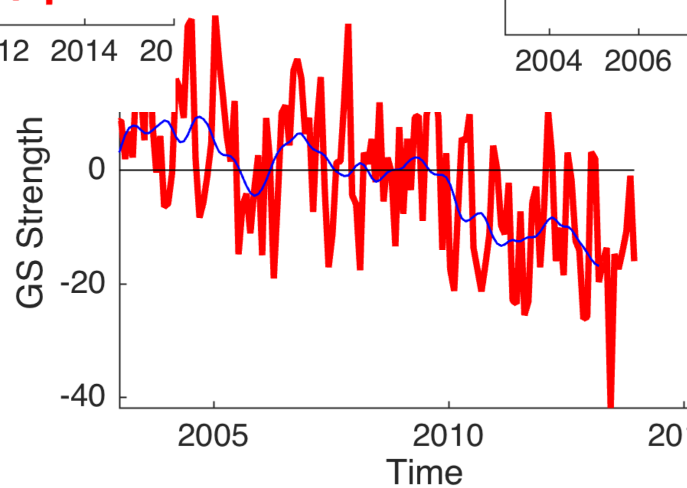




Trend in AMOC 2004-2014: linked to SSH/heat content and GS changes 2004-2014

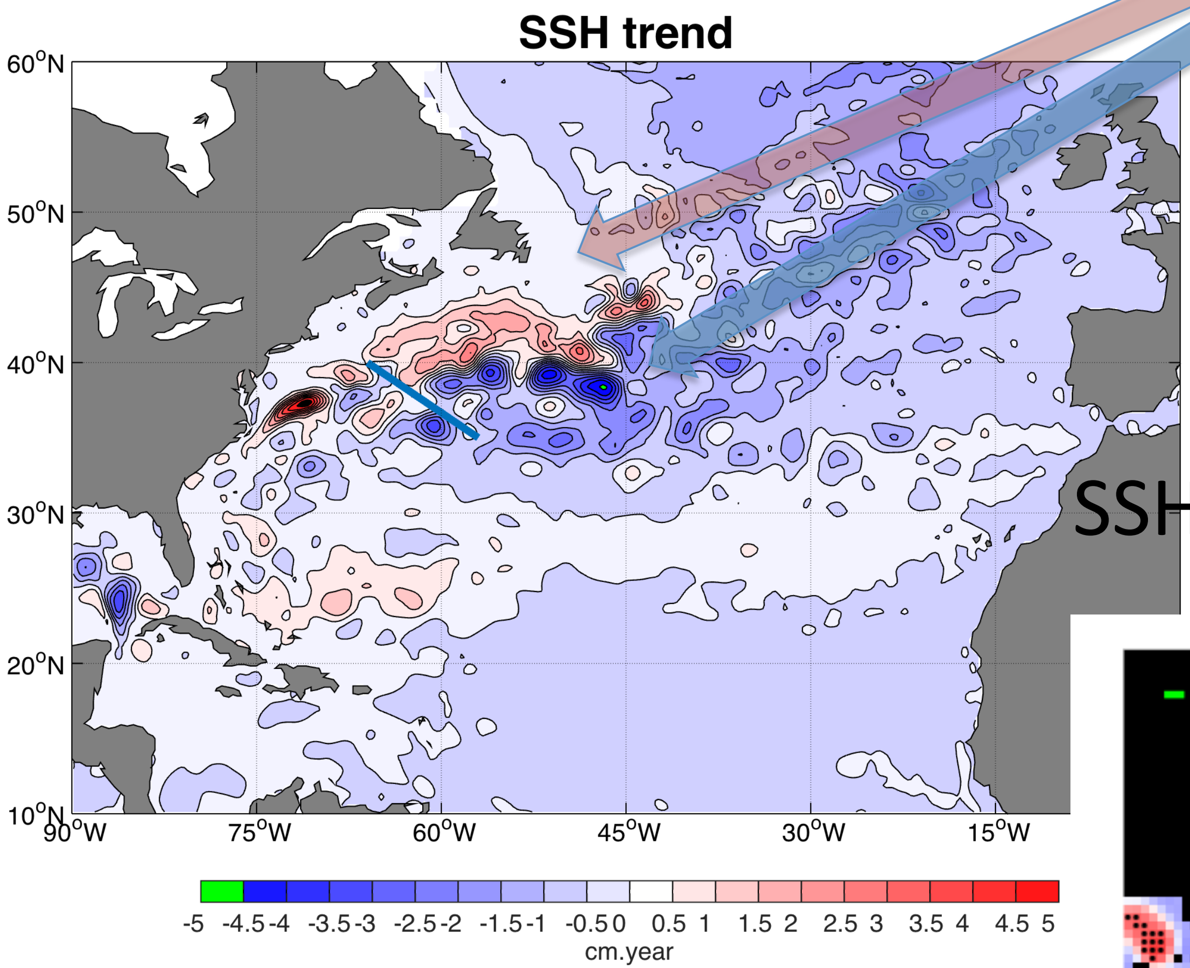






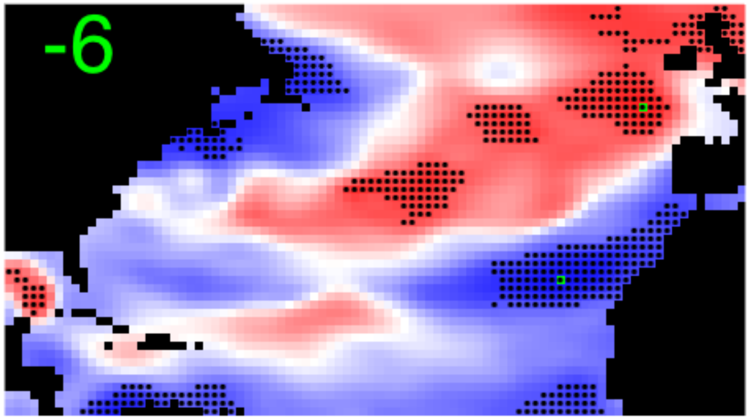
Gulf Stream Strength downstream of NE Seamounts

Trend in SSH 2004-2014



SSH difference decrease

SSH pattern associated with AMOC



- ***Interannual Variability***
  - Response of Gulf Stream different upstream and downstream of New England Seamounts; the location where the mean speed of Gulf Stream decreases.
  - Confirmation of the important role of the NAO in controlling Gulf Stream position, and we also find a relationship with strength
  - Increase UMO linked to northward shift
  - Increase in Florida Current linked to increase in Gulf Stream Strength
  - Increase in AMOC linked to northward shift and increase in strength
- ***Trends***
  - Downward trend in AMOC occurs at the same time as the decrease in Gulf Stream Strength downstream of the New England Seamounts
  - Structure of SSH trend mirrors the response of SSH to AMOC on interannual time scales.