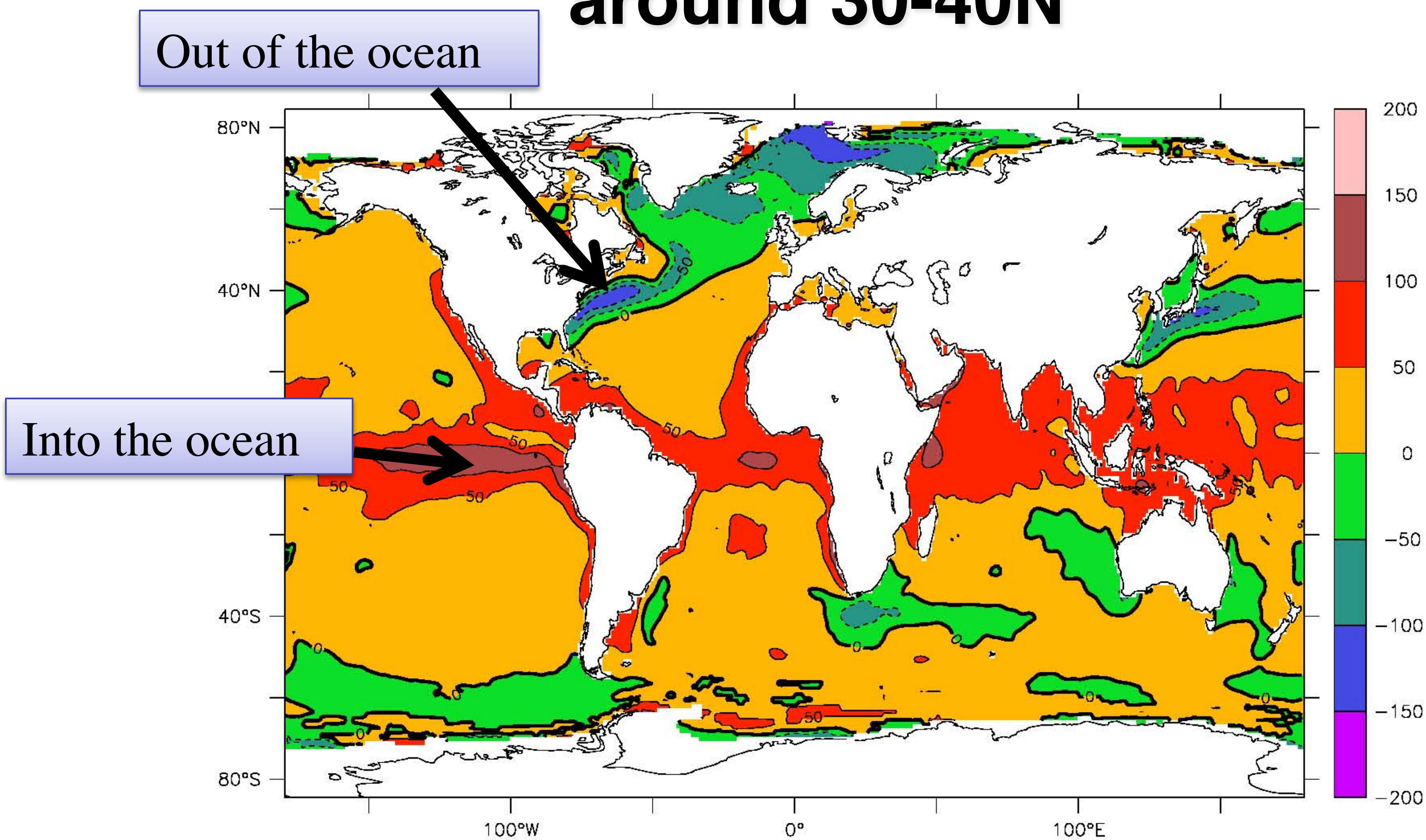
An observational analysis of coupling between the ocean and the Atmosphere in the subtropical North Atlantic

LuAnne Thompson
School of Oceanography
University of Washington

Kathryn Kelly (UW/APL), James Booth (NASA/GISS)
Thanks also to Frank Bryan

NASA Ocean Surface Topography Science Team

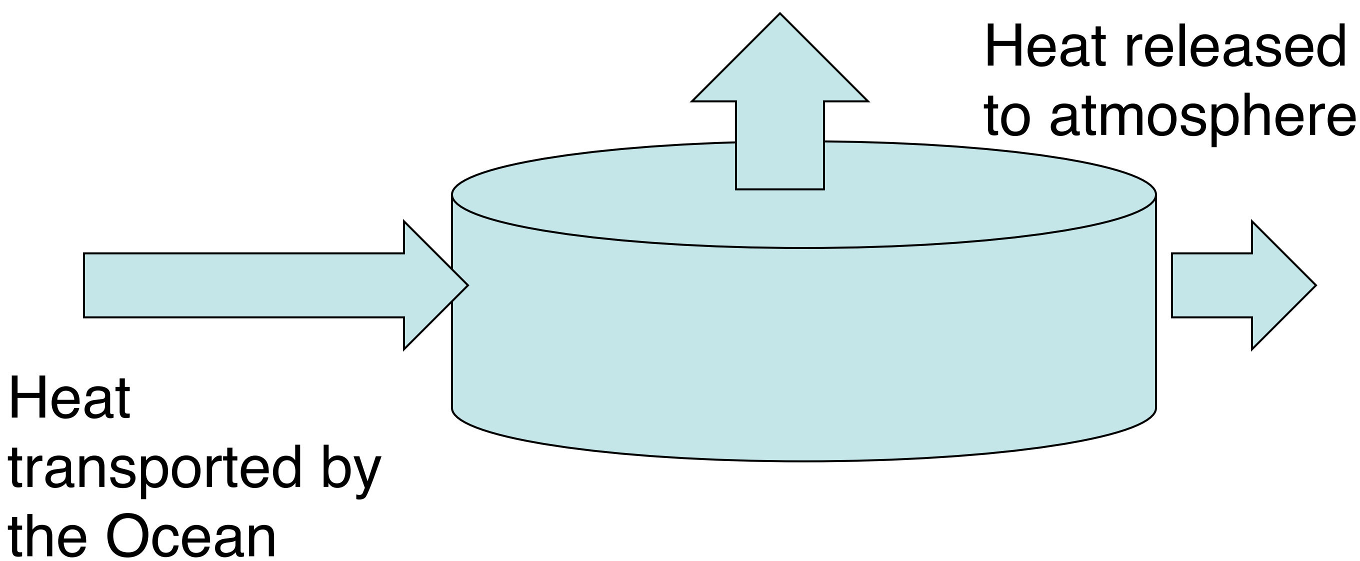
Net surface flux from the atmosphere to the oceans Watt/m^2: implied ocean heat transport convergence, maximum around 30-40N



Role of heat transport: mean balance

Heat is lost from the Gulf Stream to the atmosphere (about 0.2 PWatts)

Dong and Kelly (2004) show that heat transport convergence forces heat storage which in turn controls the net surface heat flux that damps the heat anomalies.
holds on interannual time scales



Barsugli and Battisti (1998) ocean-atmosphere interaction
Ocean-noise added Wu et al (2006)

$$\gamma_a \frac{dT_a}{dt} = -\lambda\left(T_o - T_a\right) - \lambda_a T_a + N_a$$

⇐ Atmosphere noise

$$\gamma_o \frac{dT_o}{dt} = \lambda\left(T_o - T_a\right) - \lambda_o T_a + N_o$$

⇐ Ocean noise

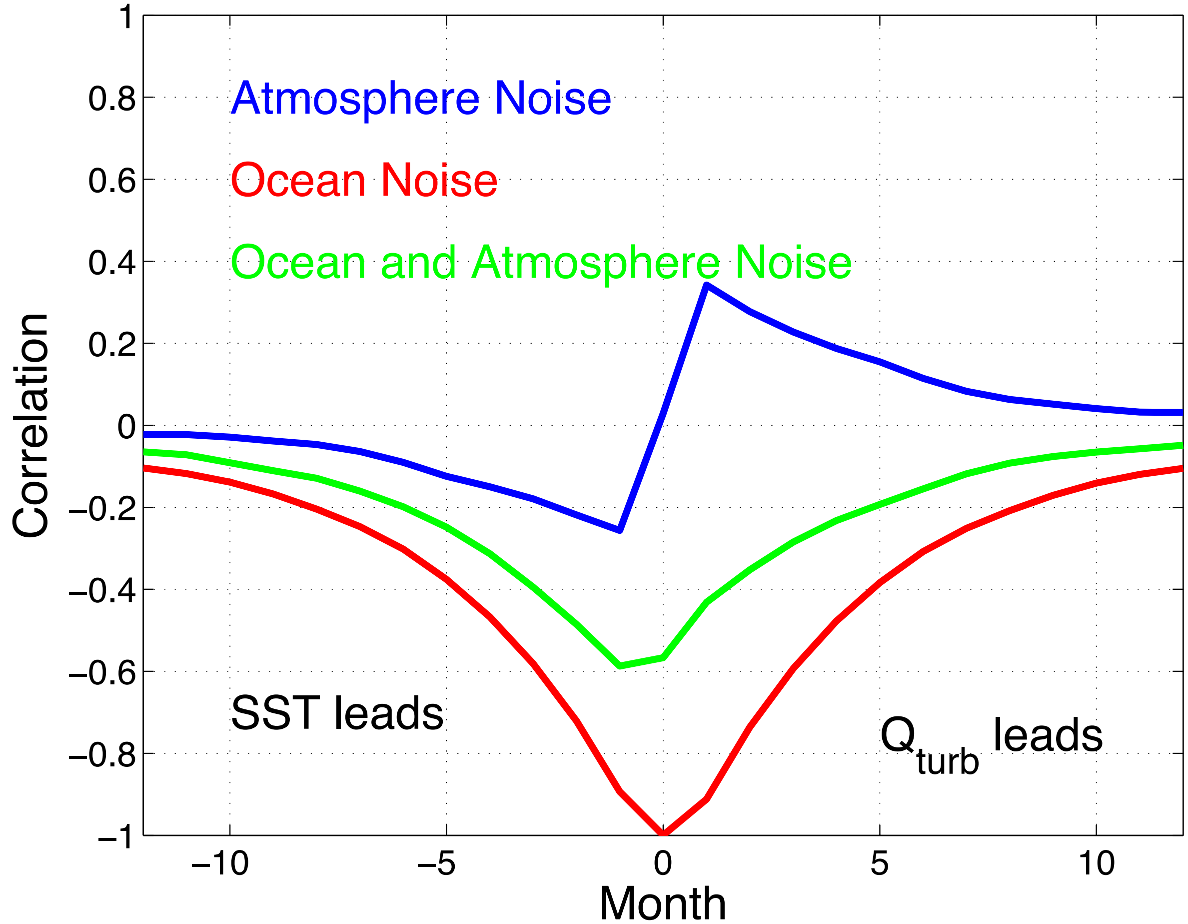
= Ocean heat transport convergence anomalies

T_a	Air Temperature
T_o	Sea surface Temperature
γ_a	Atmosphere heat capacity
γ_o	Ocean heat capacity
N_a	Atmospheric Noise
N_o	Ocean Noise
λ_a	Atmosphere radiational cooling
λ_o	Ocean radiational cooling
λ	Coefficient for air-sea turbulent flux of heat

Barsugli and Battisti (1998) ocean-atmosphere interaction Ocean-noise added Wu et al (2006)

Lagged correlations of SST/Q_{turb} with normally distributed noise

Q_{turb} is the sum of latent and sensible heat flux. negative when it cools the ocean



Ocean-atmosphere interaction can be examined via SST/heat flux lagged correlations

Here we also examine sea surface height (SSH, upper ocean heat content)

SSH/heat flux gives information about how heat stored below the seasonal mixed layer interacts with the atmosphere.

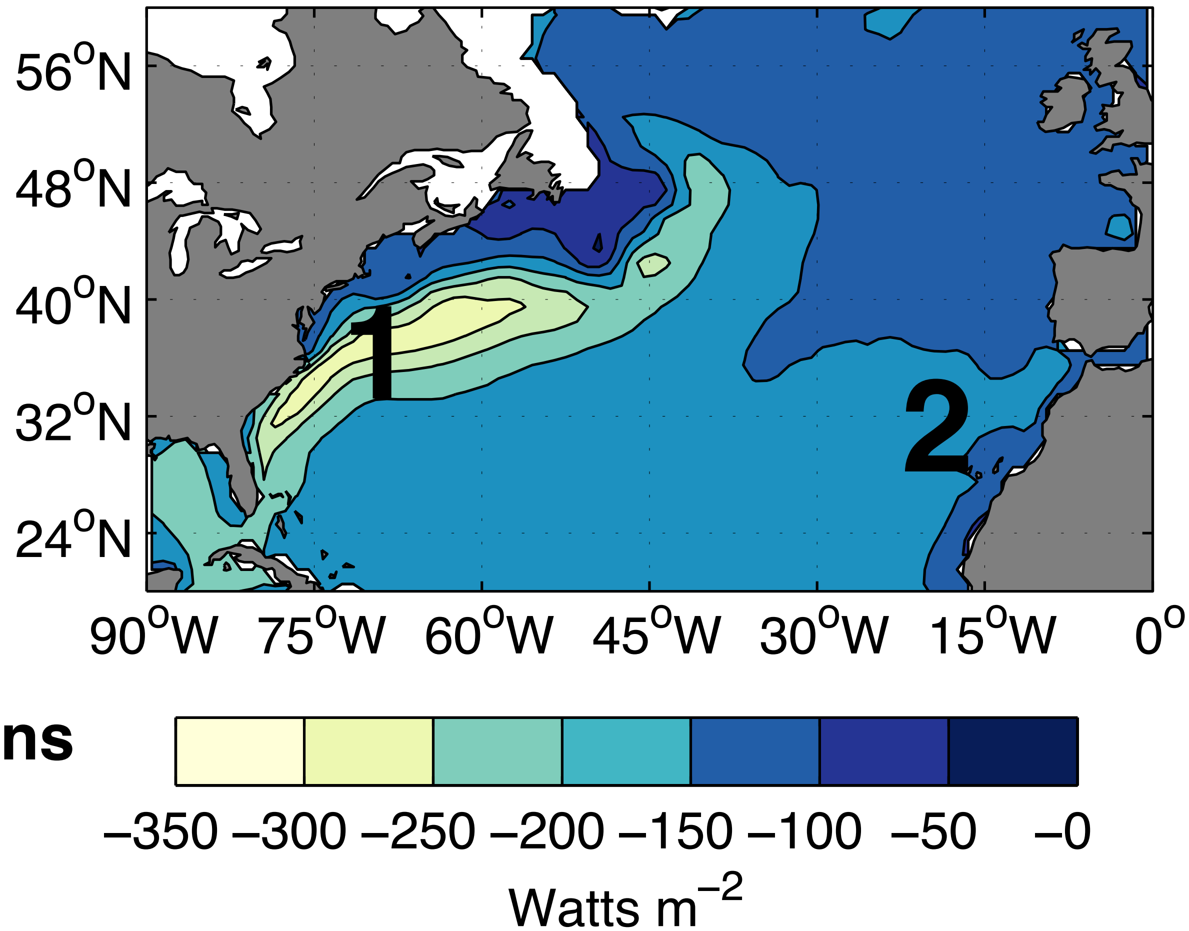
Using observations to look at the relationship between the heat content and surface flux

Smooth both with 400 km full width at half max Gaussian smoother

Removing seasonal cycle and lowpass

Observational Analysis variables	Source	Comment
Sea surface height (SSH)	Monthly maps of sea level anomaly from Ssalto/Duacs 1/3° x 1/3°, Mercator grid, Aviso	Used as proxy for upper ocean heat content
Turbulent heat flux Q_{turb} And net suface heat flux Q_{net} And SST on the same grid	OAflux: Objectively Analyzed air-sea fluxes for the Global Oceans (Yu and Weller, 2007)	Fluxes are positive for warming the ocean.

Mean turbulent heat flux out of the ocean.



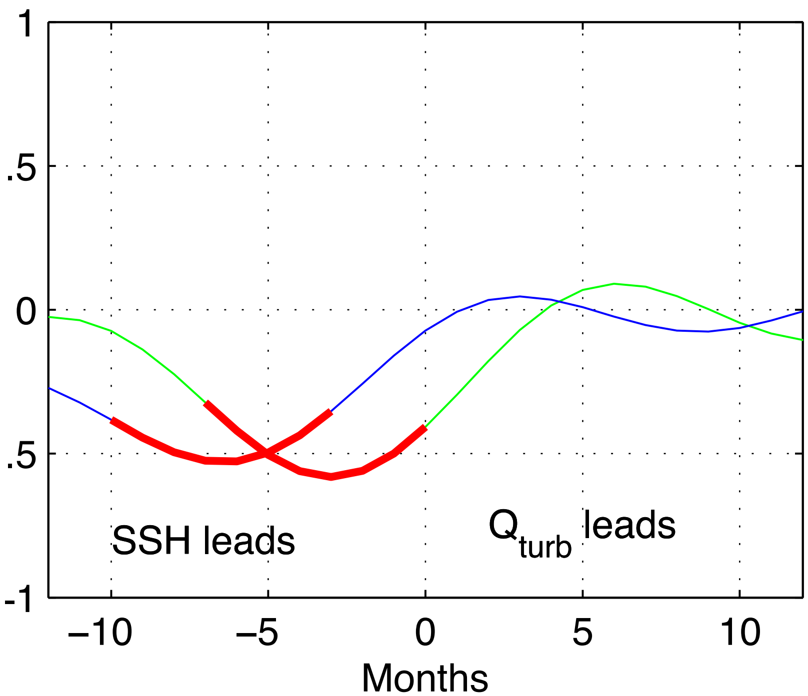
Consider two locations

1. In the Gulf Stream
   Strong Advection
2. In the Eastern Basin
   weak Advection

What can we learn from SST/Q_{turb} and SSH/Q_{turb} lagged correlations?

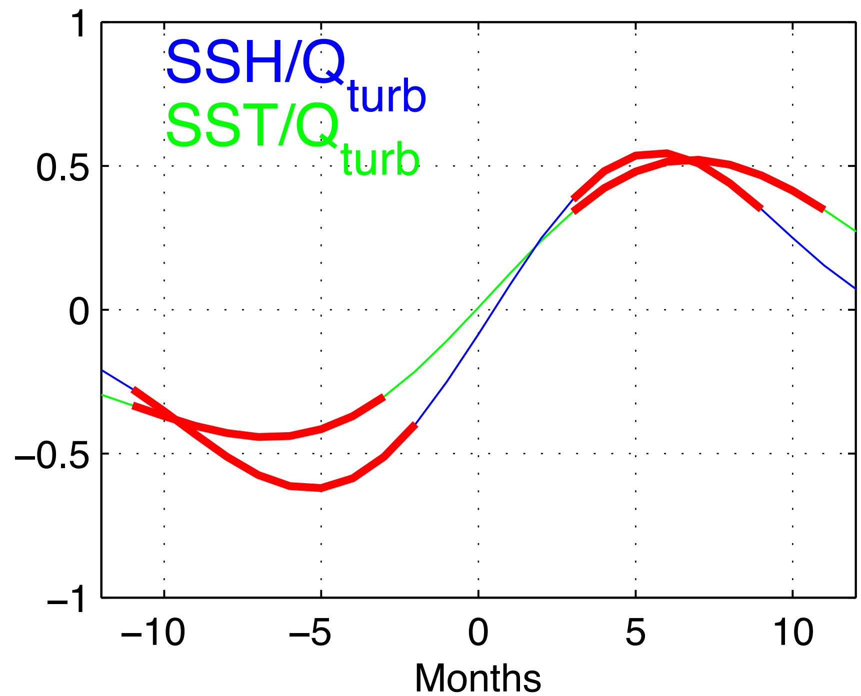
Mixed ocean-atmosphere

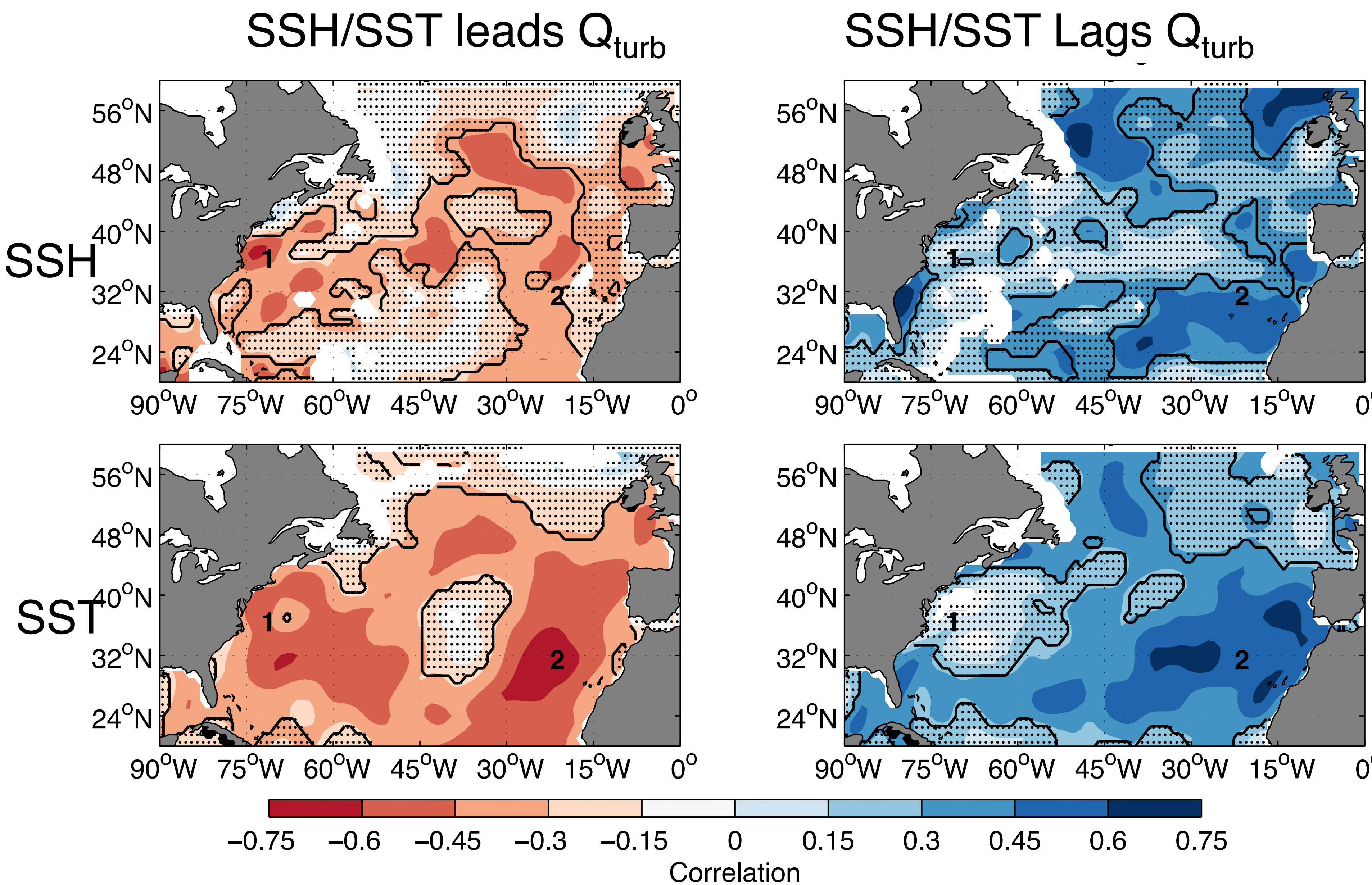
Gulf Stream



Atmosphere forcing

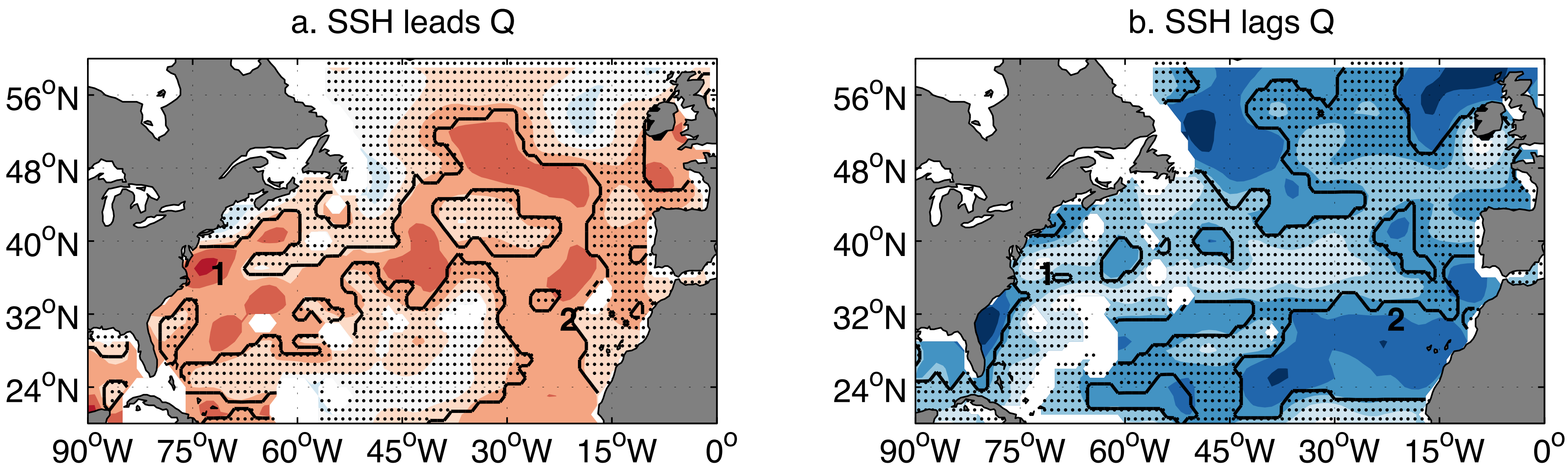
Eastern Basin



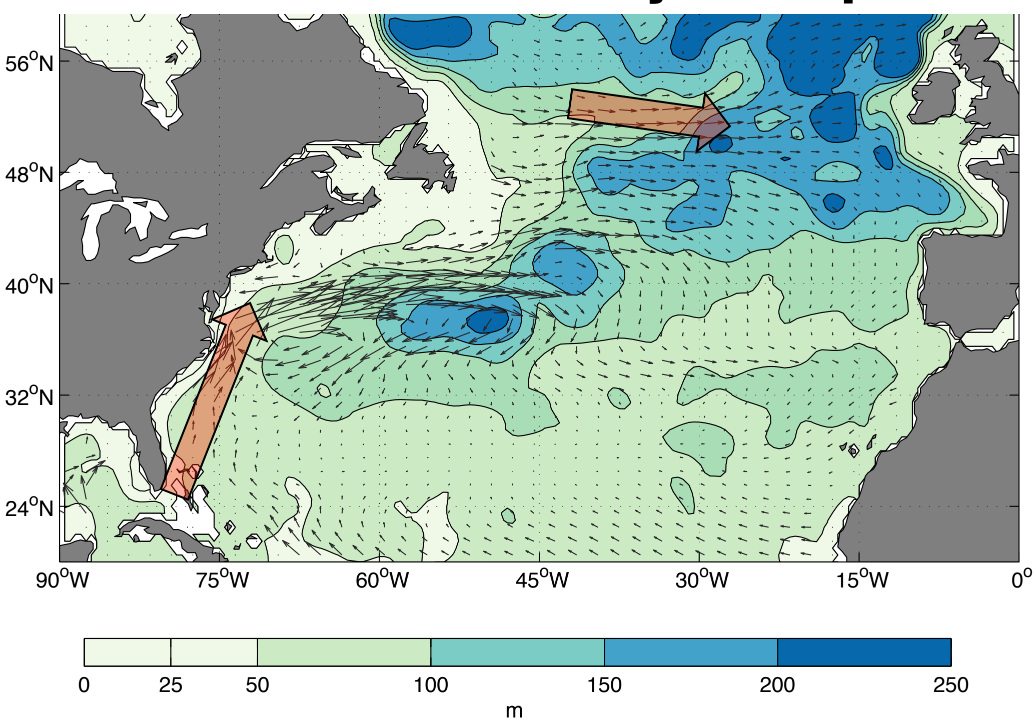


SSH leads Q_{turb} in Gulf Stream

SST/Q lagged correlation more symmetric

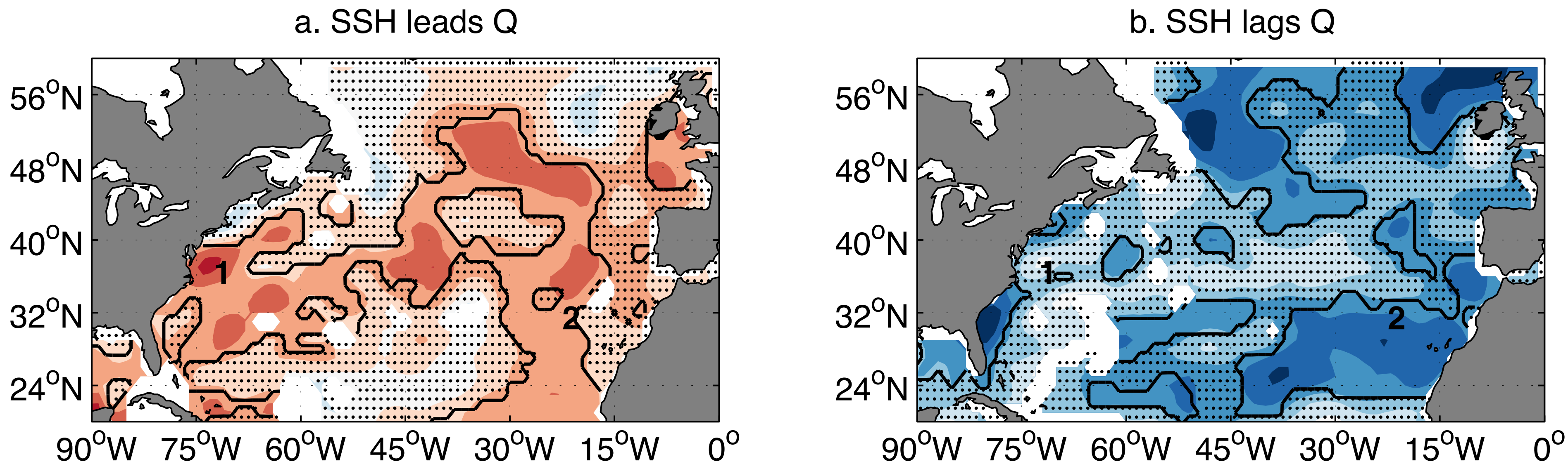


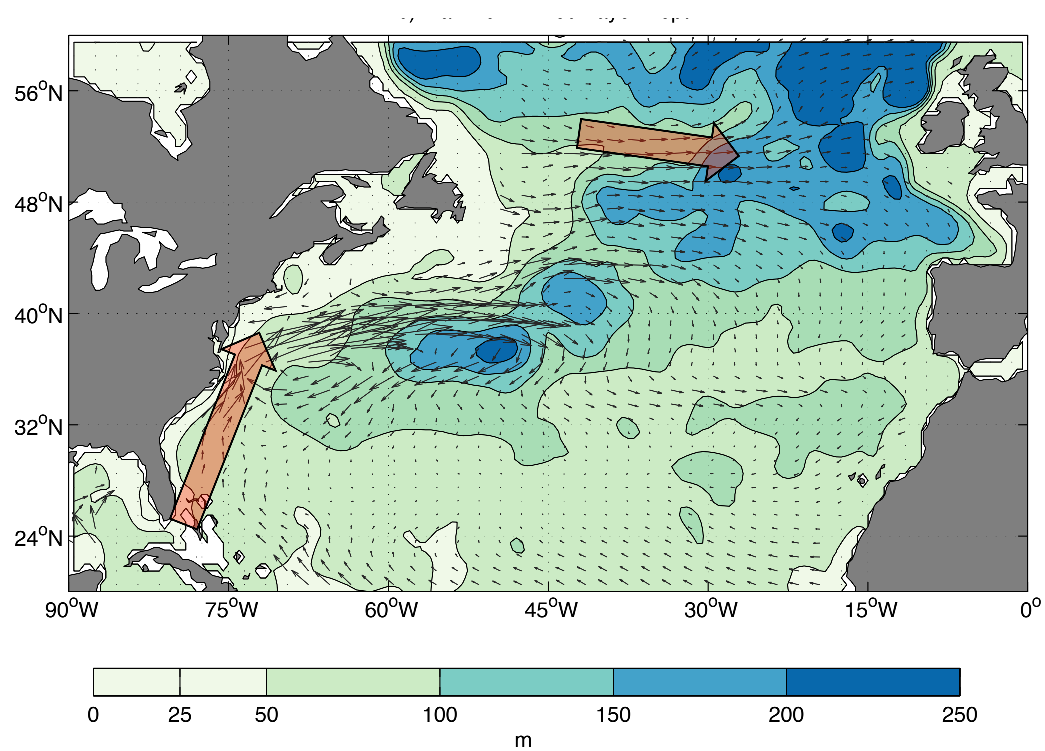
Maximum mixed-layer Depth



Evidence for role of heat stored below mixed-layer

1. Atmosphere forcing in shallow mixedlayer
2. Ocean releases heat in deep mixed-layer





Evidence for role of heat stored below mixed-layer

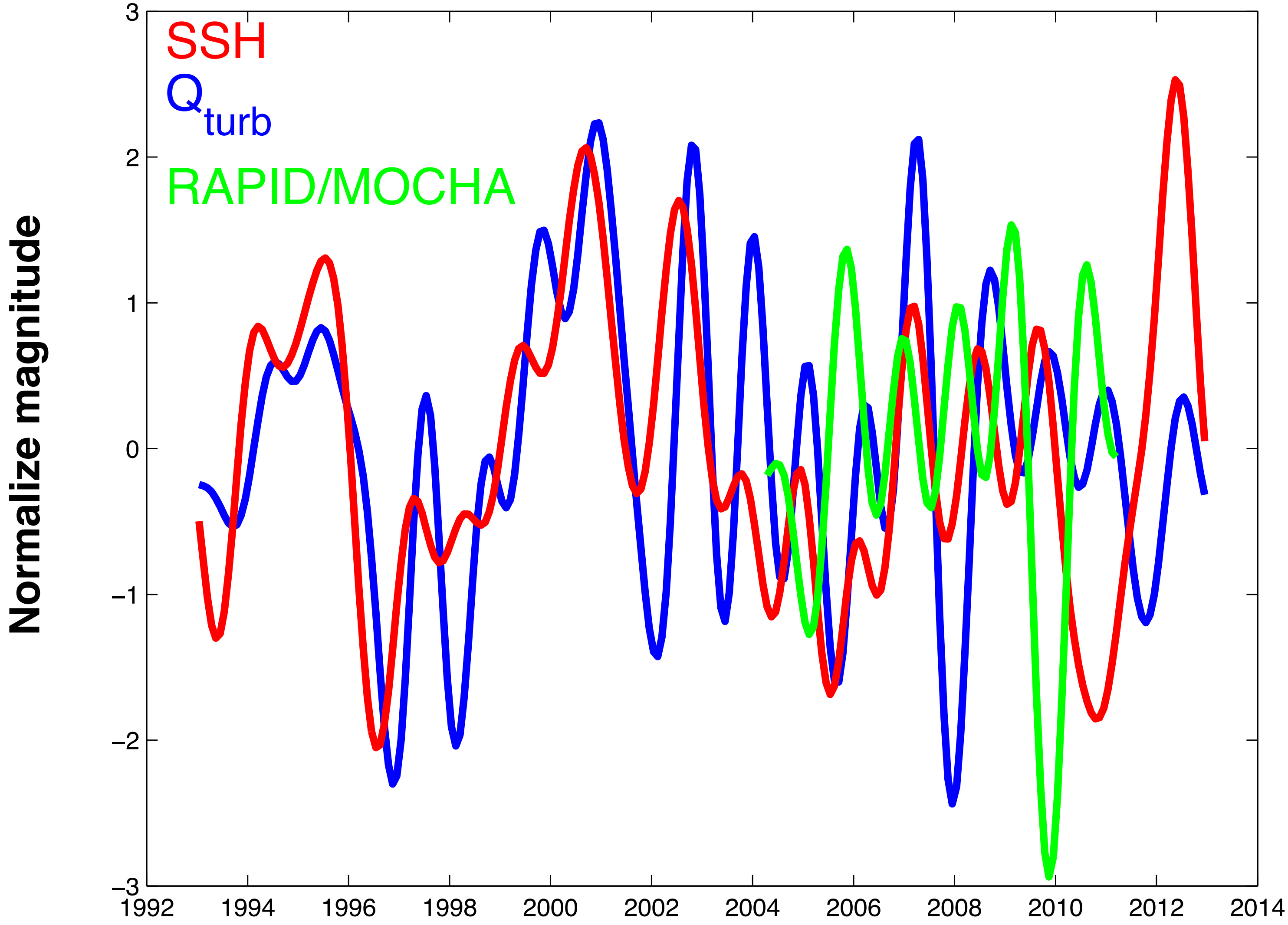
Atmosphere forcing

Ocean forcing downstream

What is the connection to AMOC?

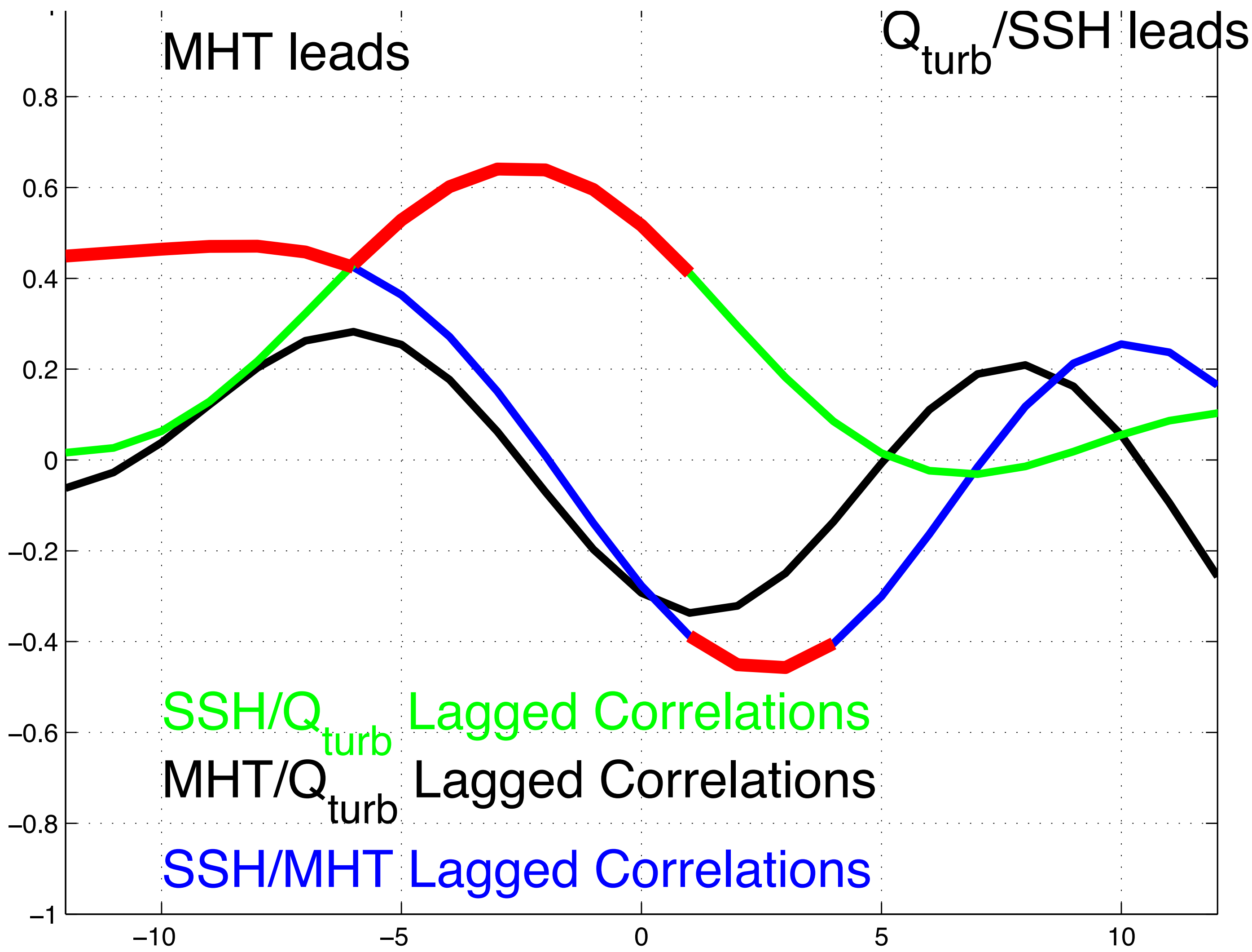
Look for a connection between RAPID/MOCHA Meridional heat transport and heat content (SSH) in Gulf Stream

Standard deviation SSH 4.4 cm, Q_{turb} 18 Watts/m^2



What is the connection to AMOC?

RAPID/MOCHA MHT leads SSH in Gulf Stream (but short times series)



Conclusions

1. The 20 year satellite altimeter record allows investigation of the role of regional upper ocean heat content in ocean-atmosphere interactions.
2. SST follows the model of atmospherically forced anomalies that are then damped by surface fluxes throughout most of the basin
3. SSH is forced regionally by “ocean noise”
4. Gulf Stream: warm upper ocean heat content leads to turbulent surface flux out of the ocean
5. There is evidence for heat content anomalies forced by the atmosphere upstream in the North Atlantic Current and the Gulf Stream
6. Heat content released to the atmosphere where flow enters deeper maximum mixed-layer depth.
7. Some evidence for connection between MHT at 26N and Gulf Stream heat storage.

What does this mean for understanding the influence of AMOC on the atmosphere?

1. Variations in AMOC Meridional Heat Transports may be linked to local heat transport convergence
2. On interannual time scales heat transport convergence drives heat into or out of the ocean in the Gulf Stream
3. On going work: The release of heat to the atmosphere in the Gulf Stream occurs primarily in December/January/February
4. Evidence for mid-level cloud fraction increase when Q_{turb} is out of the ocean and heat content is high (see Koehlinger poster). Consistent with Minobe et al (2008) mid-level cloud fraction large over the Gulf Stream in winter.
5. Ocean only models do not show the correlations found here: coupled model analysis is needed to investigate further (also underway)