SSH as a predictor of Air-Sea Interaction in the North Atlantic

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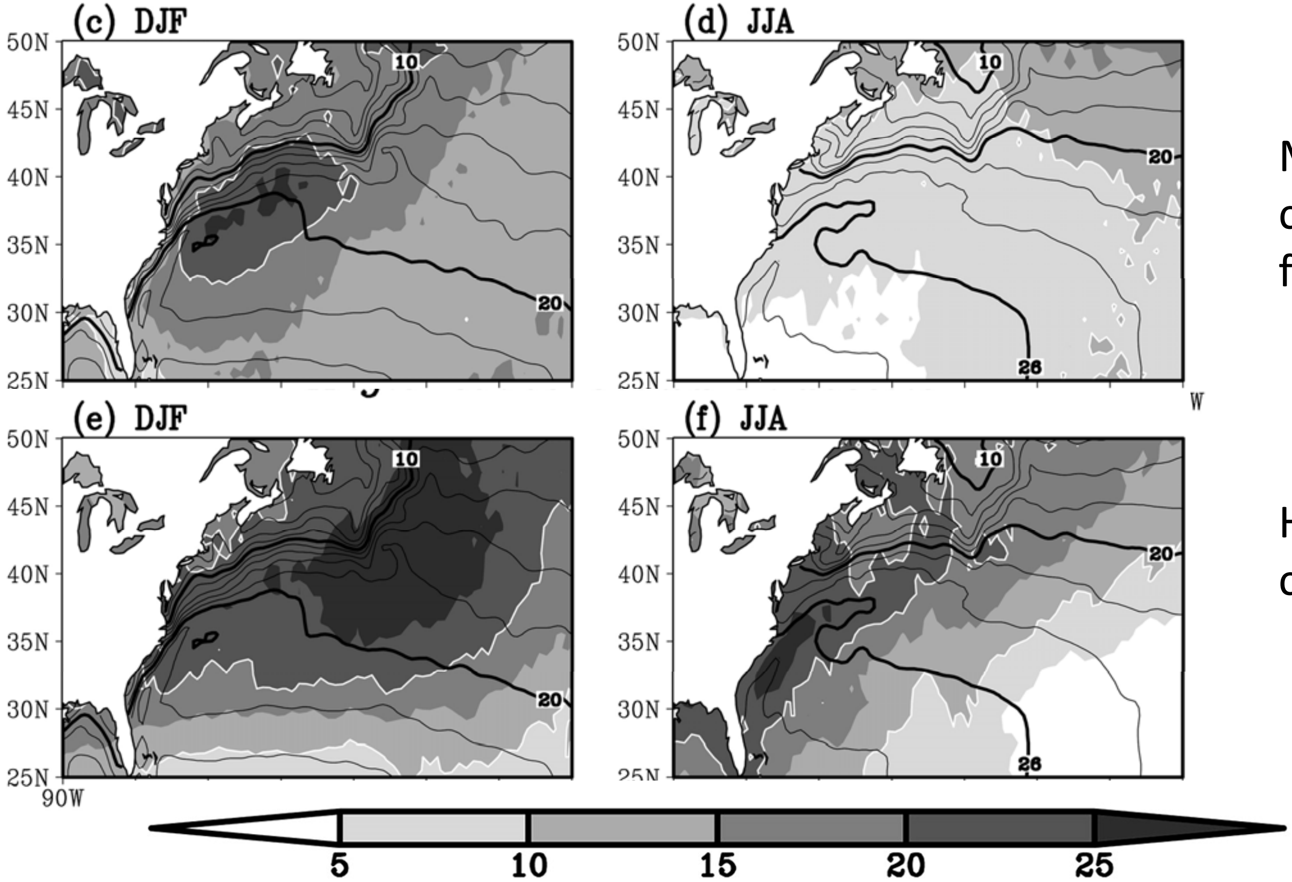
Questions:

1. Where in the North Atlantic does upper ocean heat content anomalies that result from ocean heat transport convergence control air-sea heat flux?

2. Is there evidence for changes in the atmosphere from these heat fluxes? ***Investigate using lagged correlations between SST/SSH and turbulent heat exchange with the atmosphere, and cloud fraction***

AIRS mid-level cloud fraction: Minobe et al 2010 suggested a role for Gulf Stream in atmospheric state

Climatological Cloud Fraction from AIRS in winter

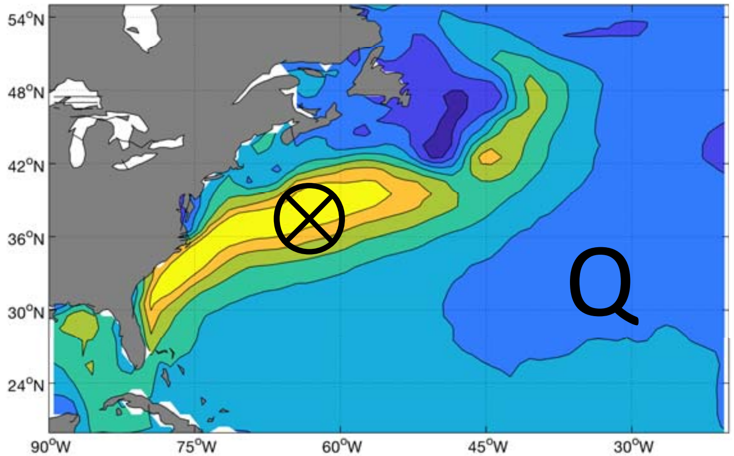


Mid level cloud fraction

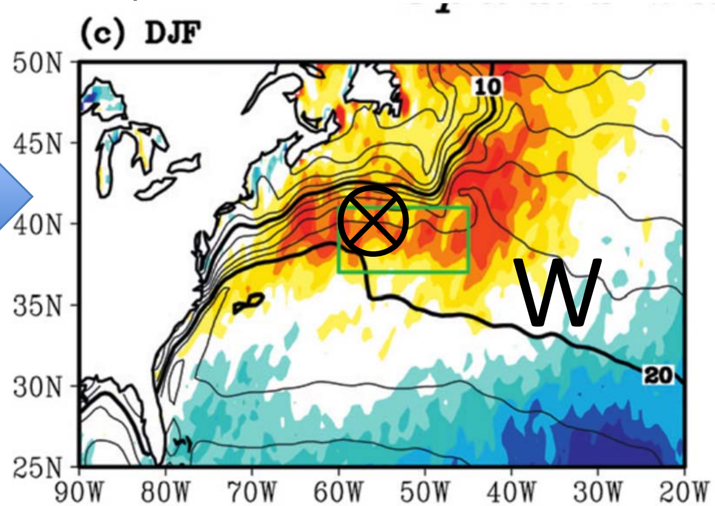
High level cloud fraction

The impact of the Gulf Stream/North Atlantic Current on clouds is maximum in winter.

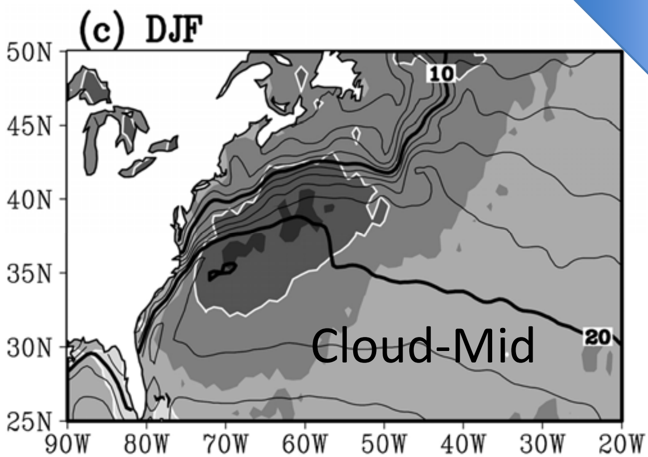
Heat flux out of the ocean driven by ocean heat transport convergence in Gulf Stream/NAC leads to

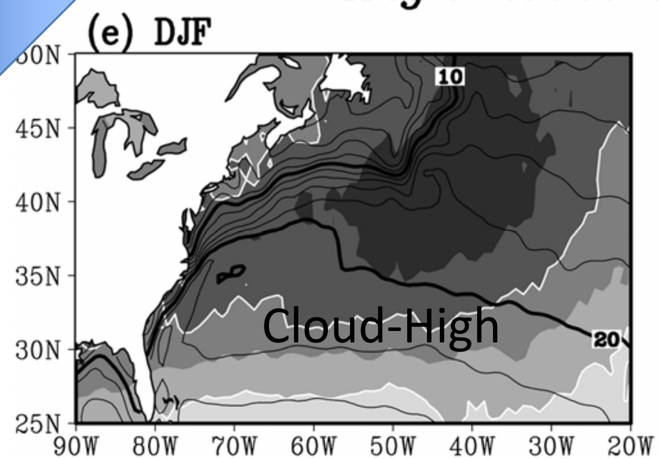


Upward winds that lead to



Increased Cloud Cover





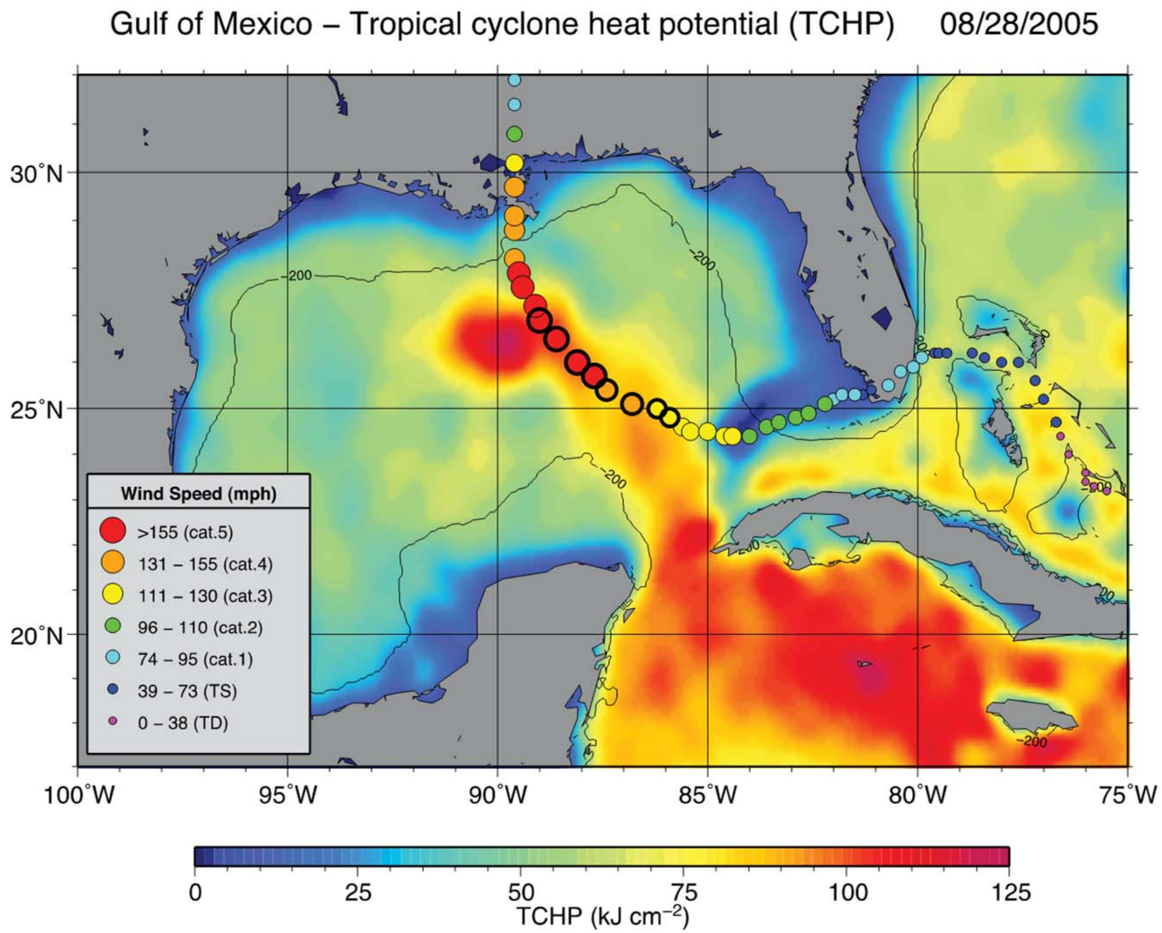
Observations	**Source: all fields smoothed with 400 km Gaussian smoother**
Sea surface height (SSH) 1993-	Monthly maps from Ssalto/Duacs, AVISO 1/4° x 1/4°, Mercator grid, non-seasonal anomalies, 1993-
Turbulent heat flux Q_{turb} latent plus sensible Sea surface temperature (SST) 1958-	OAflux: Objectively Analyzed air-sea fluxes for the Global Oceans (Yu and Weller, 2007). Monthly maps of non-seasonal anomalies
ISCCP Cloud Fraction, mid (680-440 hPa) tropospheric clouds	ISCCP:1 degree monthly from 1985-2009
MODIS Terra/Aqua 2002	1 degree monthly from 2002 (not shown here)

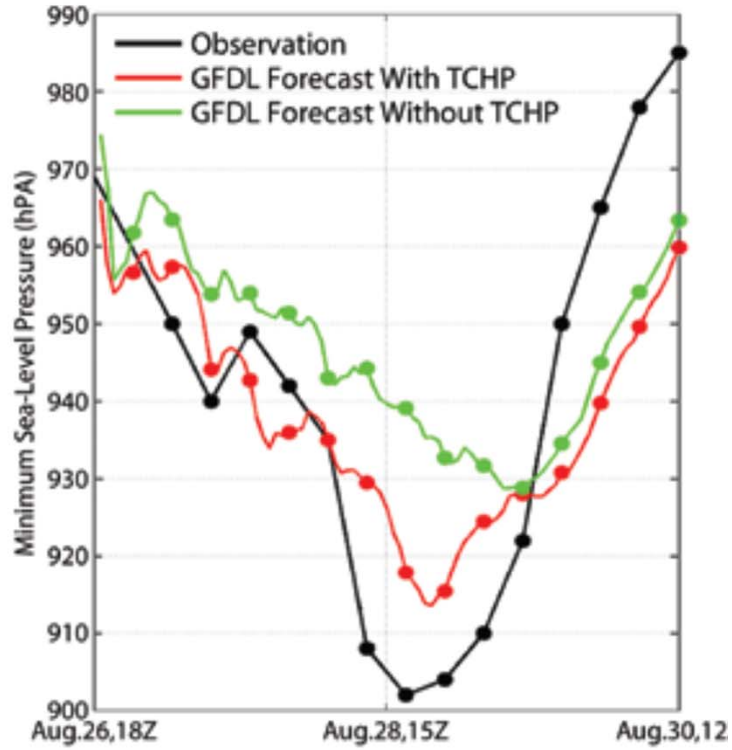
Question: What time of year does ocean the force changes in the atmosphere?
Approach:
Use SSH, SST, Q and Cloud Fraction

Focus on December when the mixed-layers are still deepening and the atmosphere has not yet reset the SSTs

Correlate December Q to previous November SSH, October SSH etc.

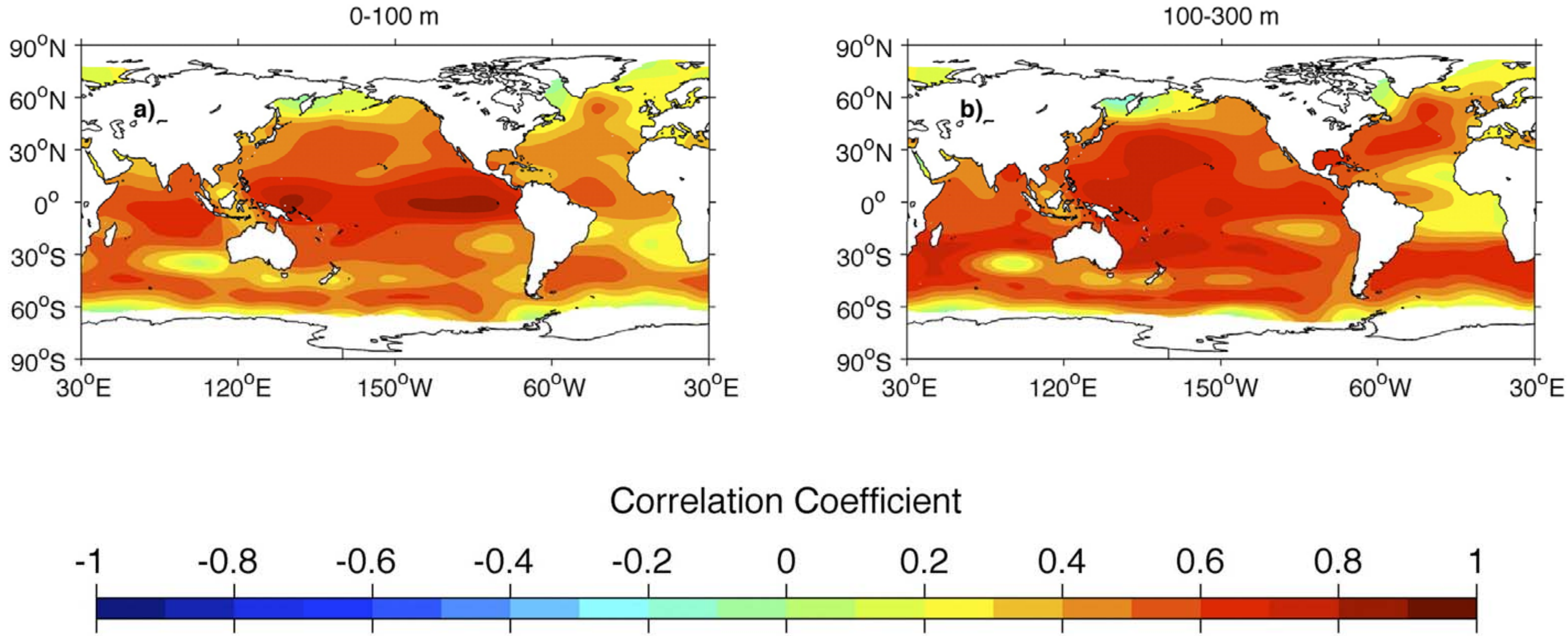
Use of SSH in prediction: Tropical Cyclone Heat Potential using SSH Goni et al, 2009



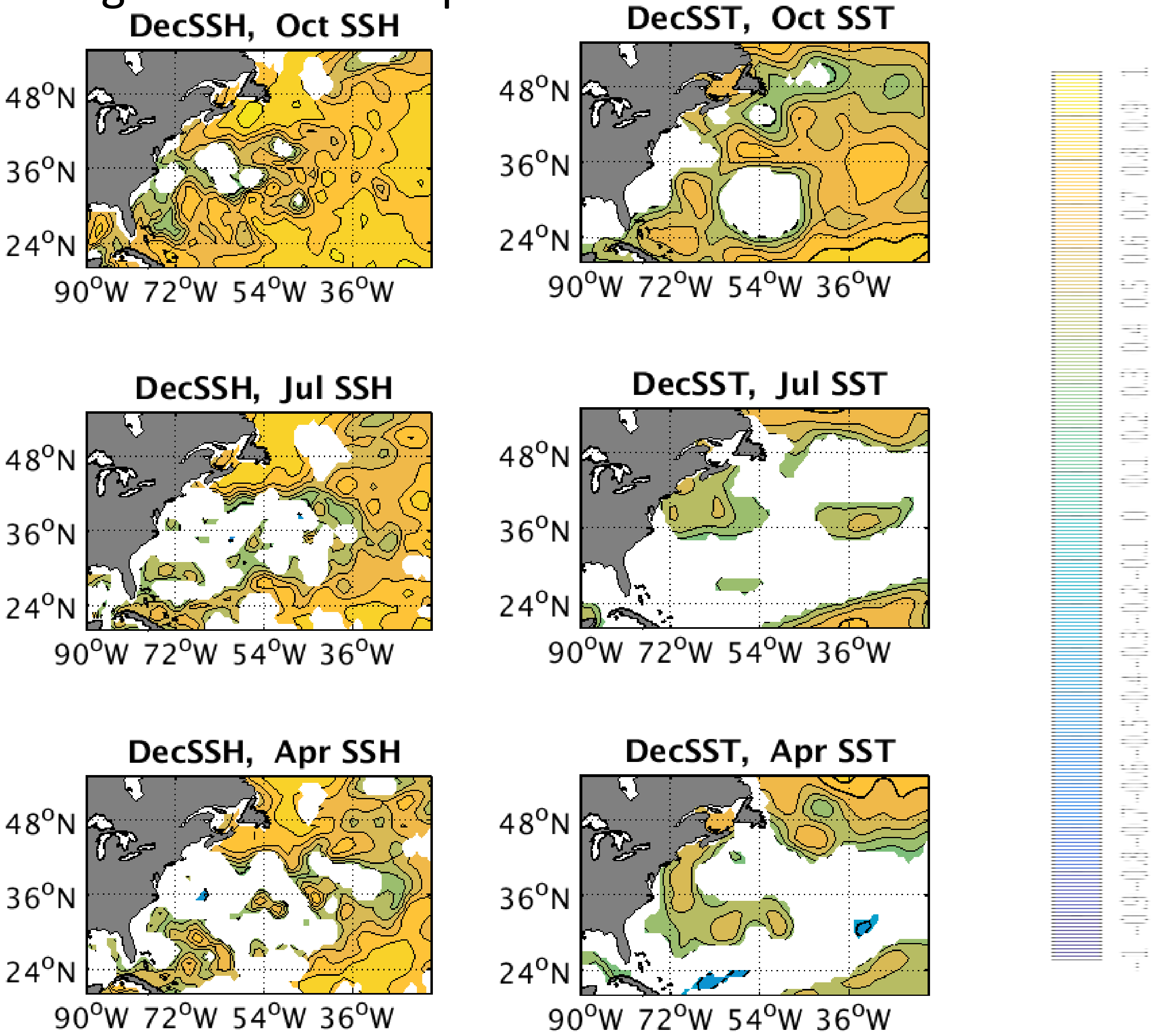


Using sea level as a proxy for heat content. 1993-1999 (Lyman and Johnson, 2014, 1993-2011)

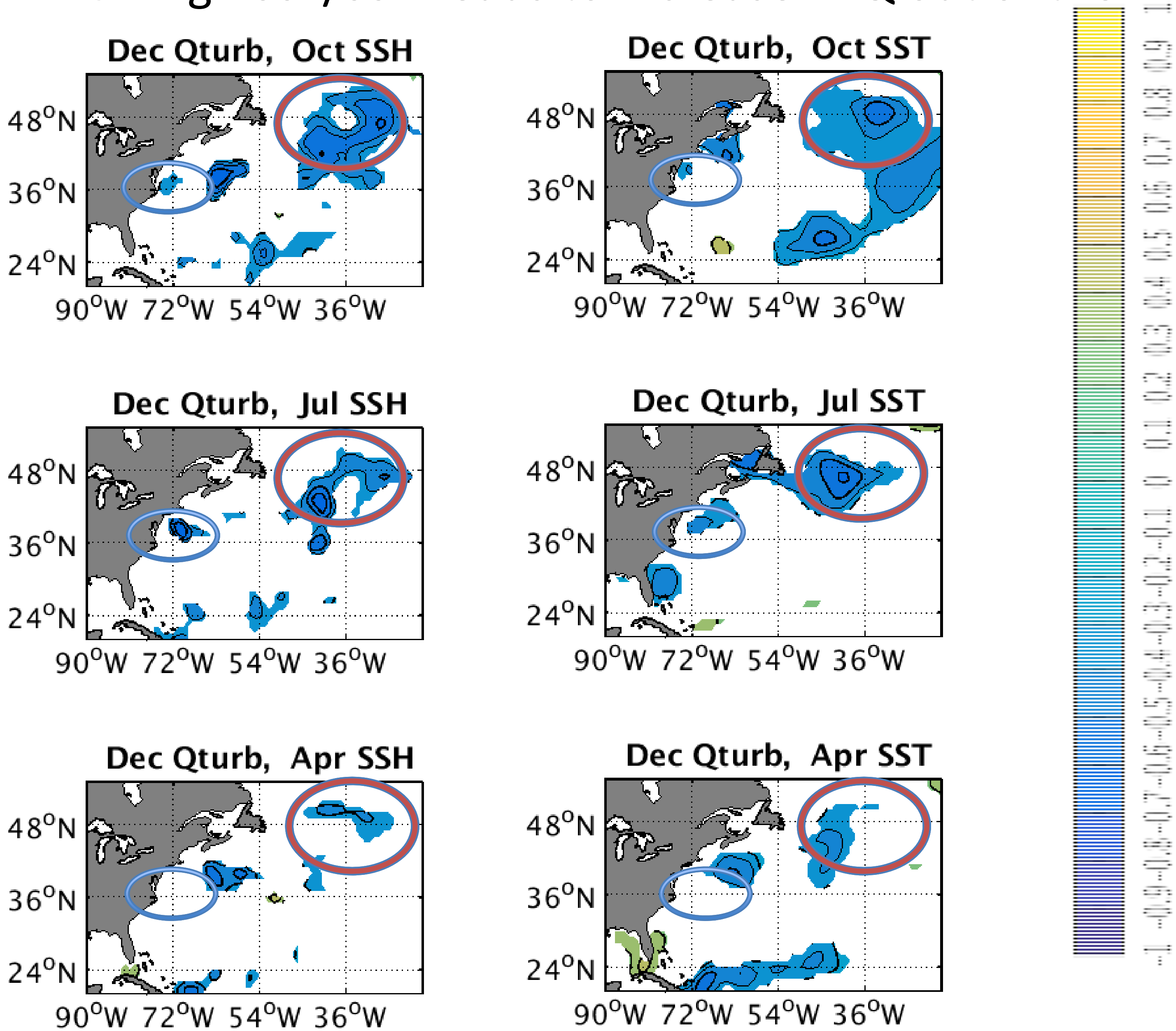
Local sea level determined by thermosteric (thermal expansion), and halosteric (haline contraction). Thermosteric dominates in tropics and subtropics



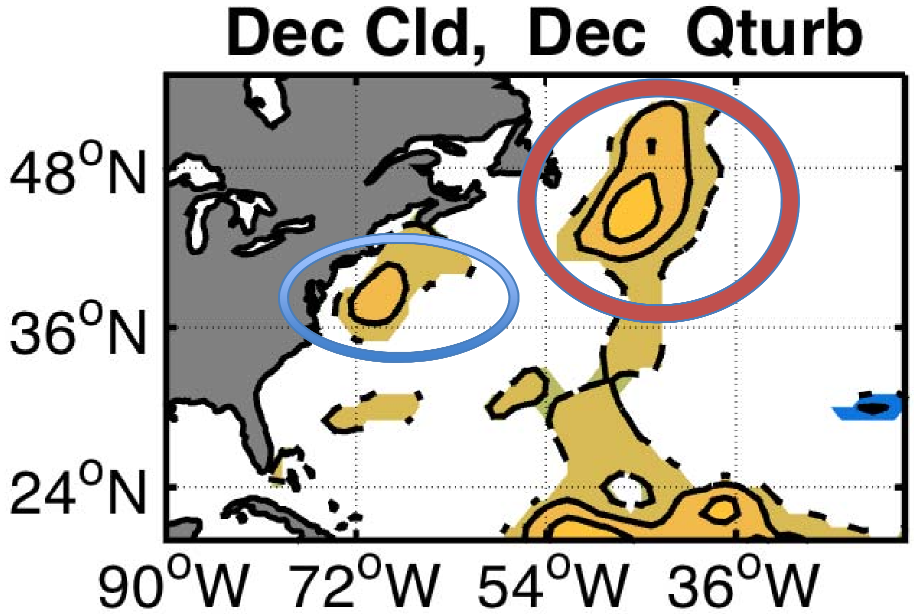
Why use SSH? Auto-Correlation shows persistence in SSH anomaly that reflects storage of heat from previous winter

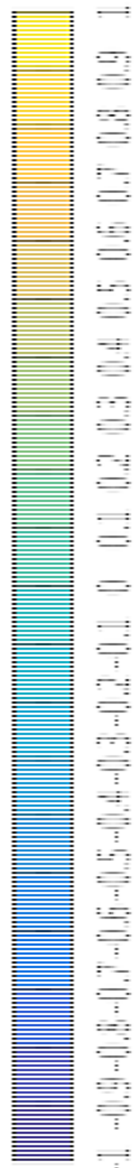


Robust connections between previous summer SST/SSH and surface flux in GS and NAC: high SST/SSH leads to increase in Q out of the ocean

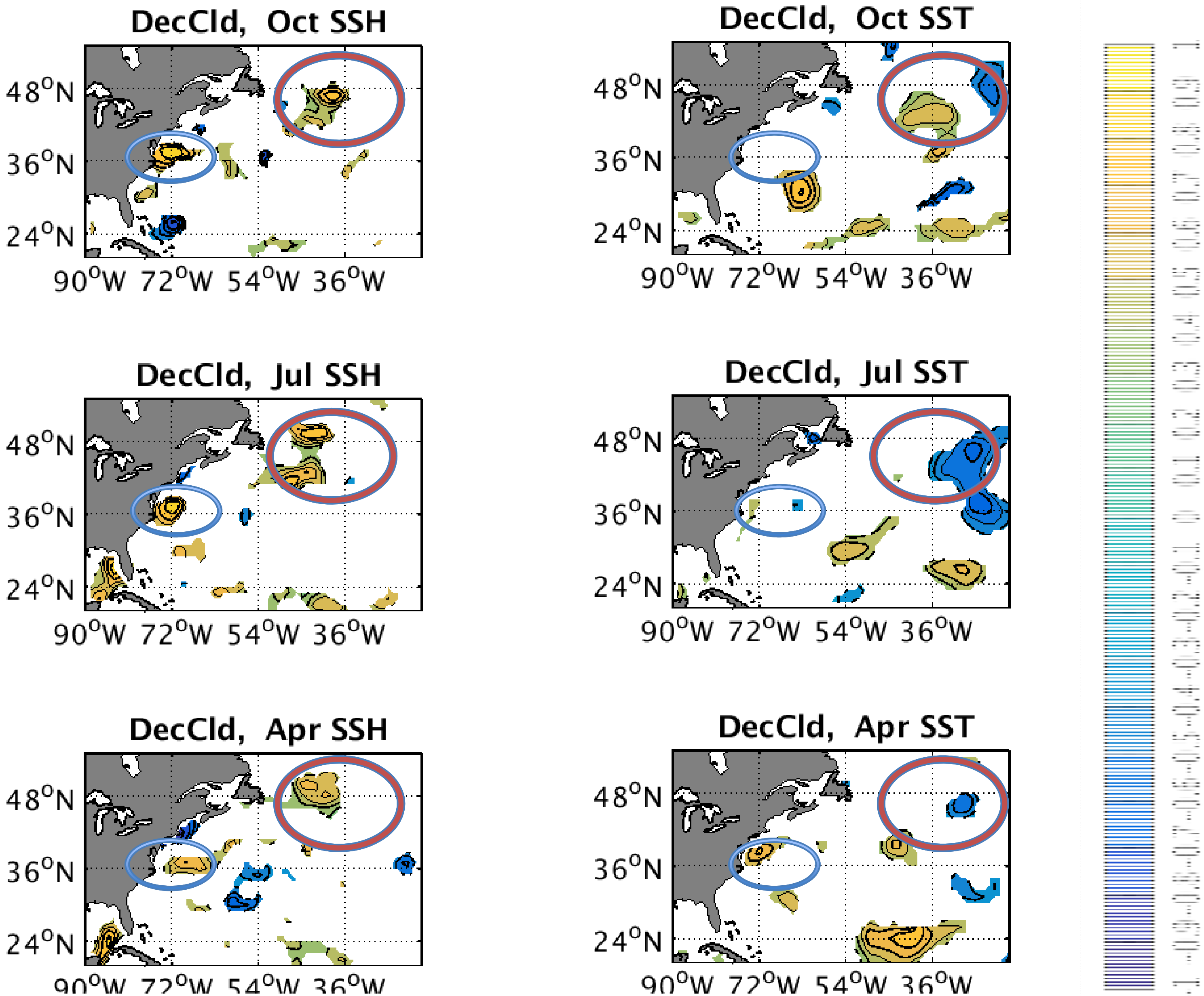


In December, surface flux out of the ocean linked to increased mid-level cloud cover





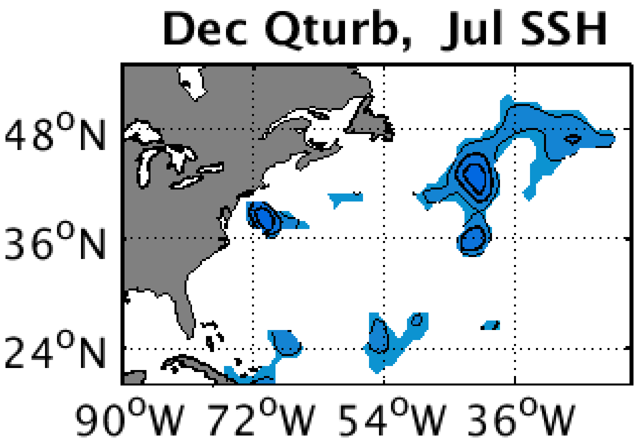
Robust connections between previous spring SST/SSH and clouds over the GS and NAC. SSH/Cloud connection persists over the summer

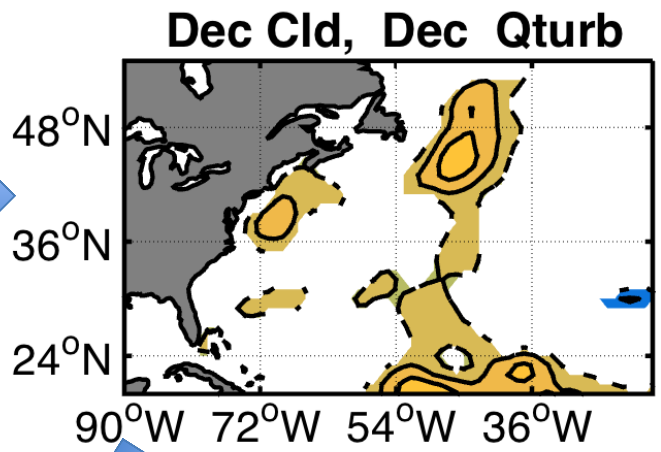


Mean relationships also hold for interannual variations

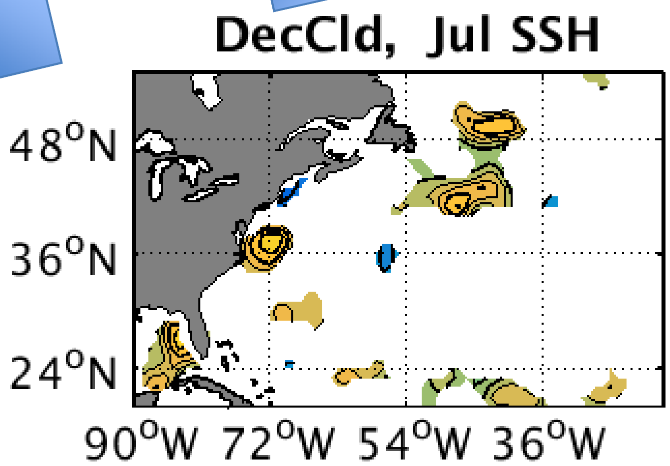
Increase in SSH/SST lead to
Increase in Q

Increase in heat lost to atmosphere
leads to increased cloud cover





Increase in SSH (upper ocean heat
content) in spring/summer leads to an
increase in cloud cover in December



Conclusions: In the Gulf Stream/NAC:

1. Spring/summer SSH anomalies are forced by ocean heat transport convergence (not shown here).
2. Spring/summer SSH predicts air-sea heat exchanges in winter with warmer ocean leading to heat fluxed out of the ocean
3. Increase in heat flux out of the ocean leads to increase in cloud cover in winter
4. SSH in spring/summer can be used locally to predict cloud in Winter
5. Preliminary analysis using MODIS cloud cover shows very similar results: relationships robust from independent and non-overlapping observations of cloud cover