Science Results from the NOAA/AOML Physical Oceanography Division using an Ocean Monitoring system for climate and weather studies

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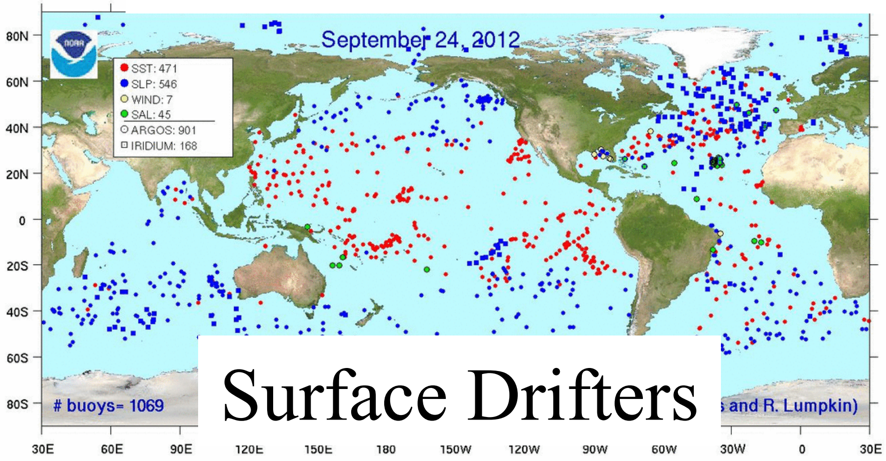
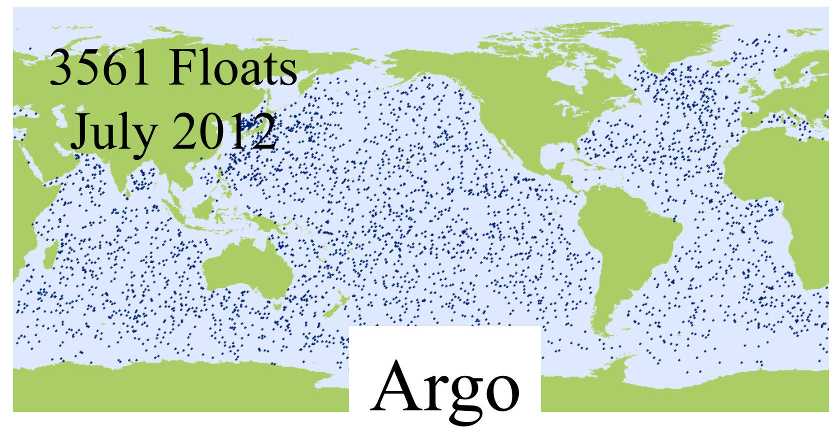
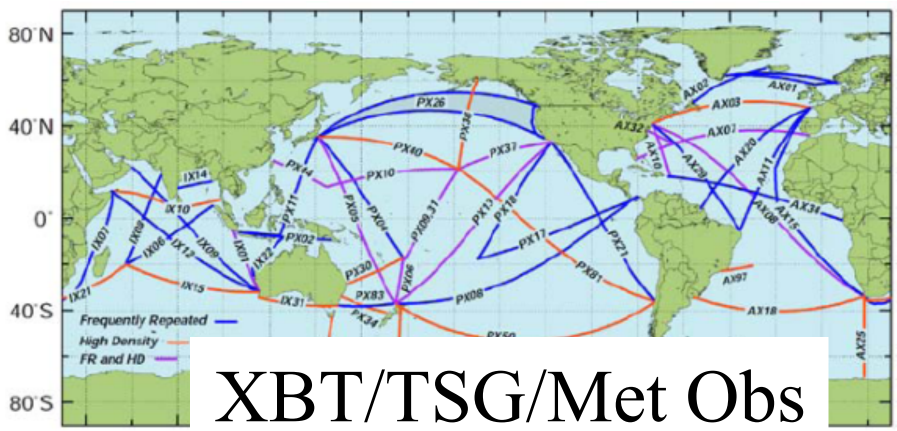
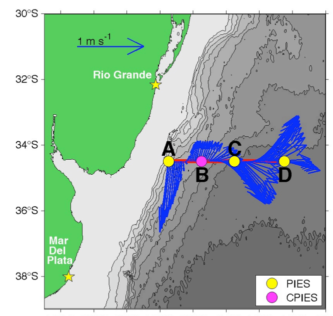
- Physical Oceanography Division Observational Assets
- Meridional Overturning Circulation (MOC) review
- South Atlantic Research
- Tropical Atlantic Research
- North Atlantic Research
    - Ocean’s influence on hurricanes (genesis, track, intensity and prediction)
    - Climate and hurricanes, rainfall and tornadoes
    - MOC observations
- Product Development

PHOD maintains numerous observational systems

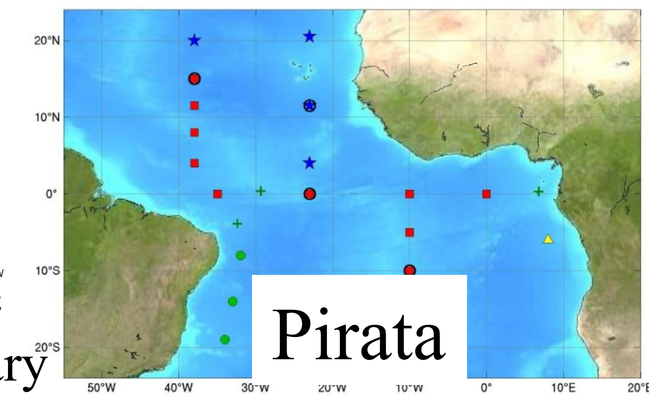


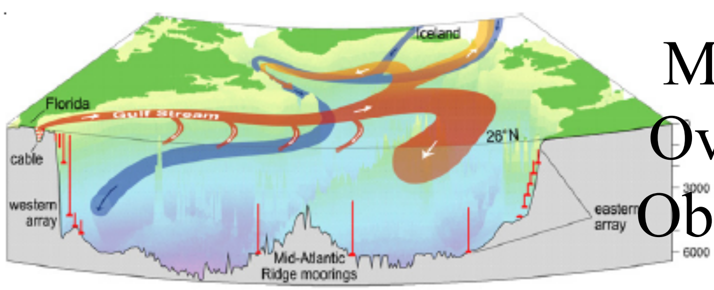




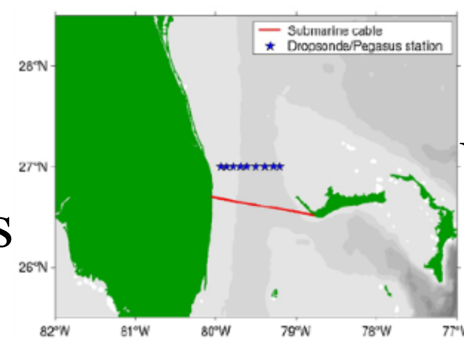


South Atlantic
Western Boundary
Current





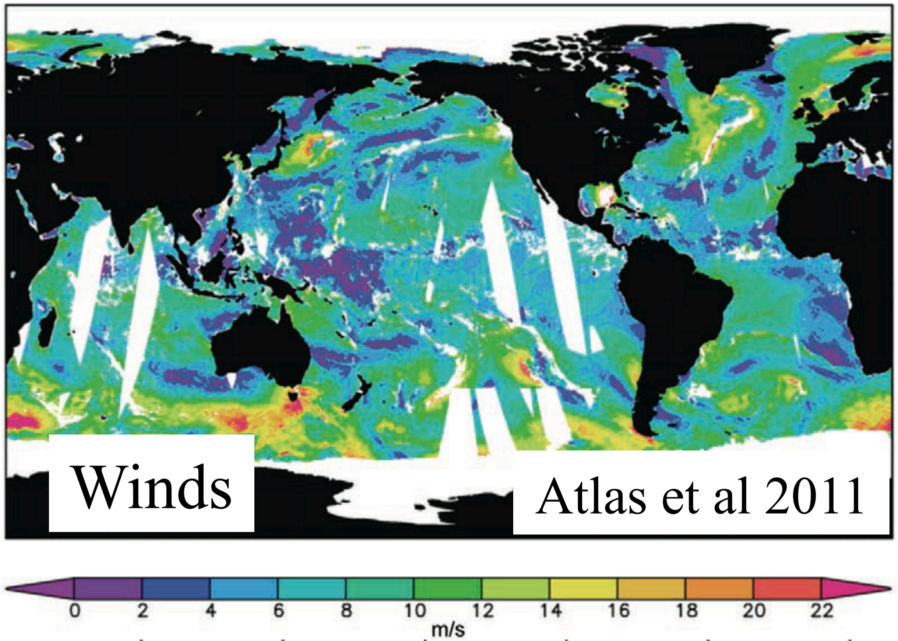
Meridional
Overturning
Observations

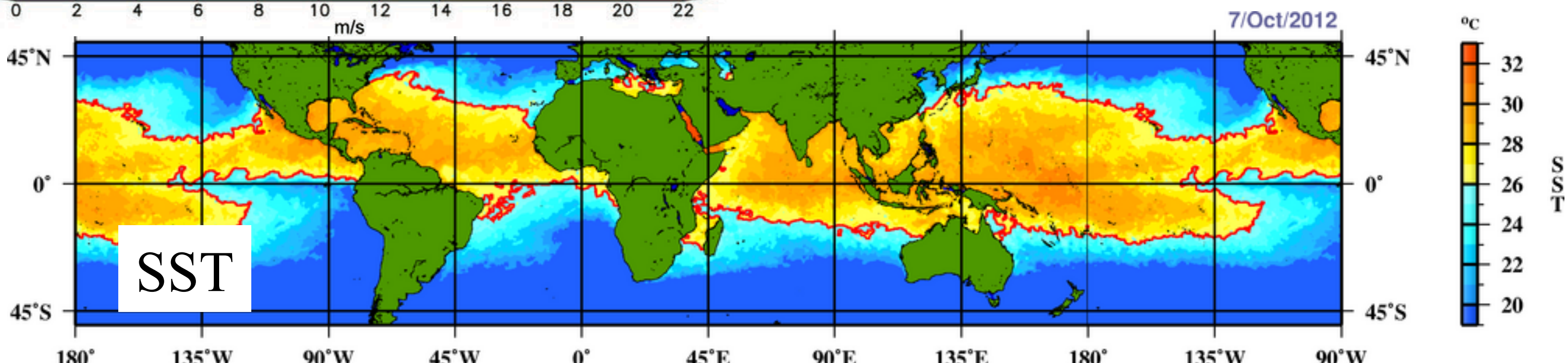


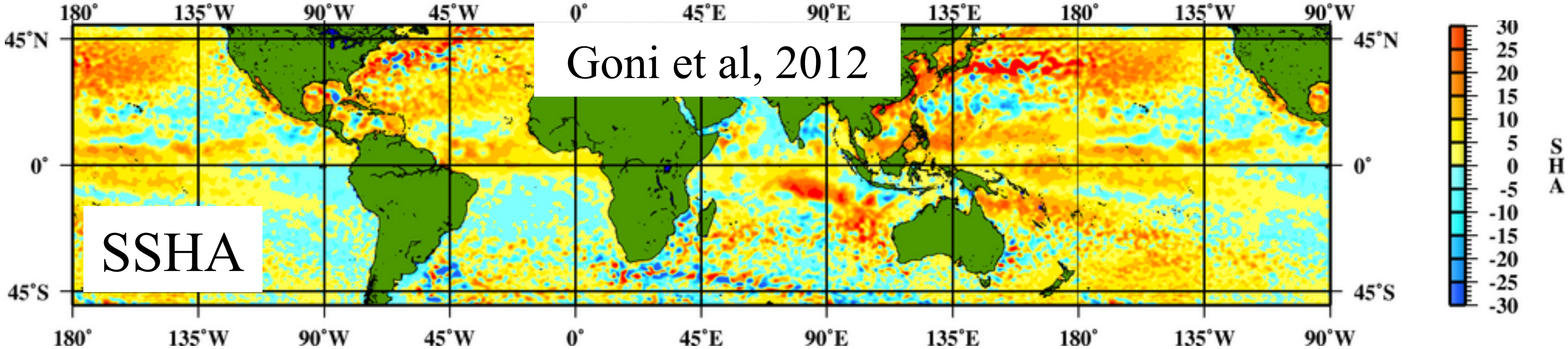
North Atlantic
Western Boundary
Currents

Satellite products

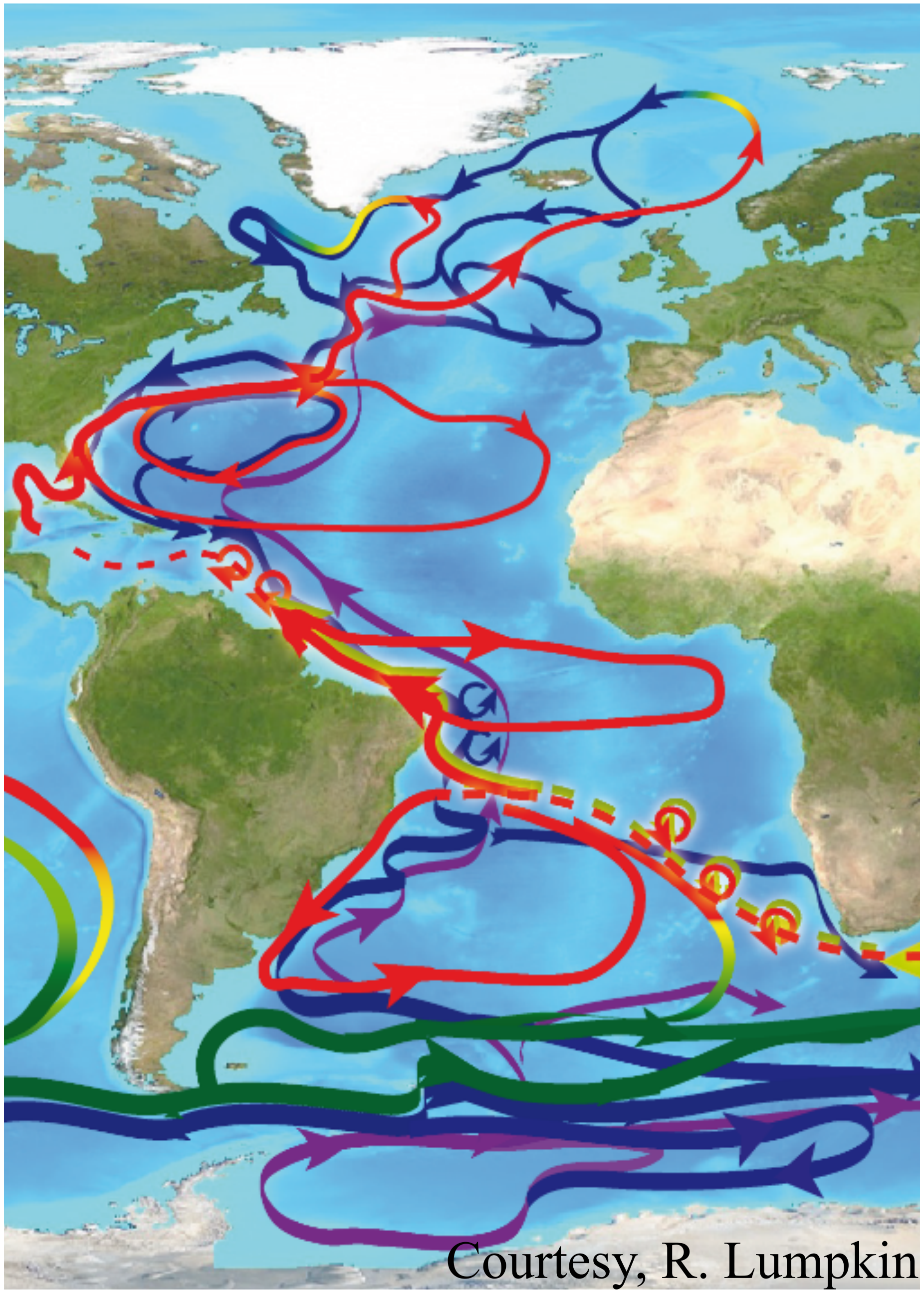
Surface Winds
Surface Currents
Hurricane Heat potential
Current transports

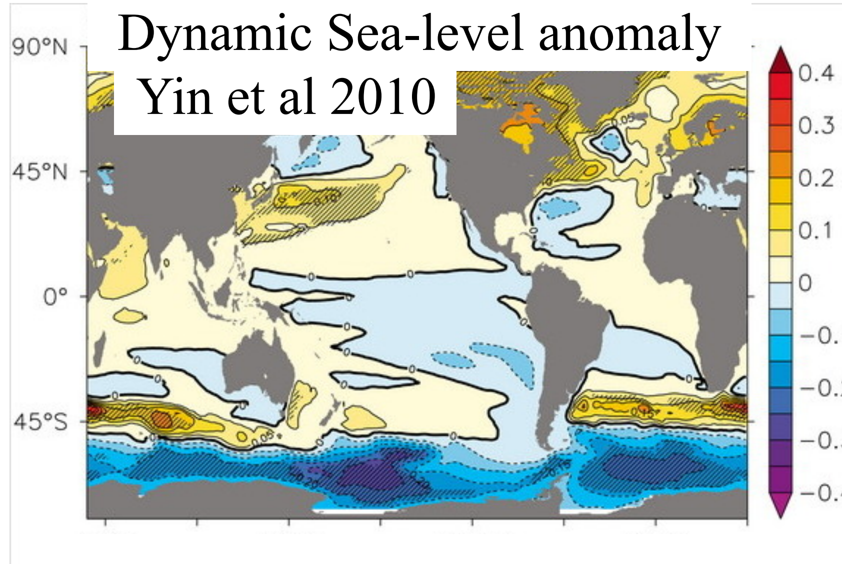


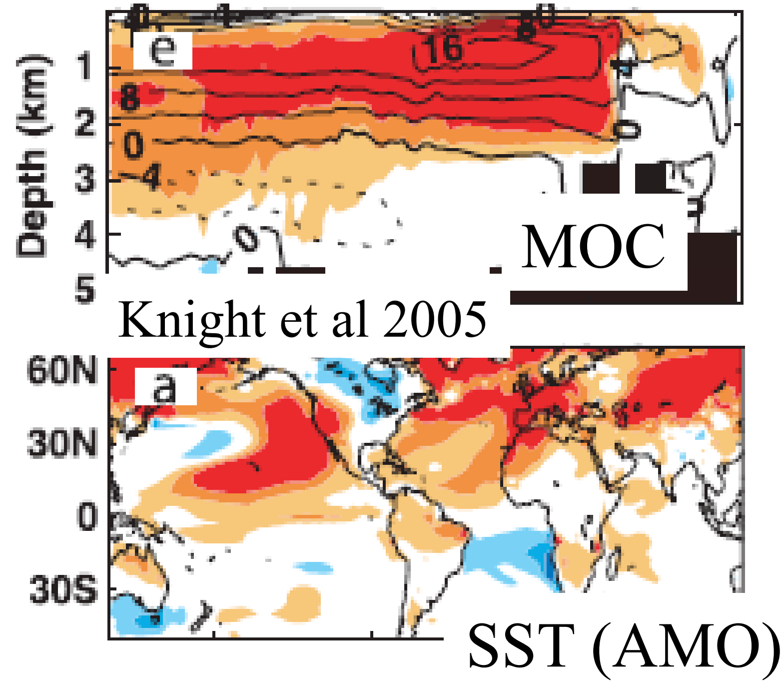




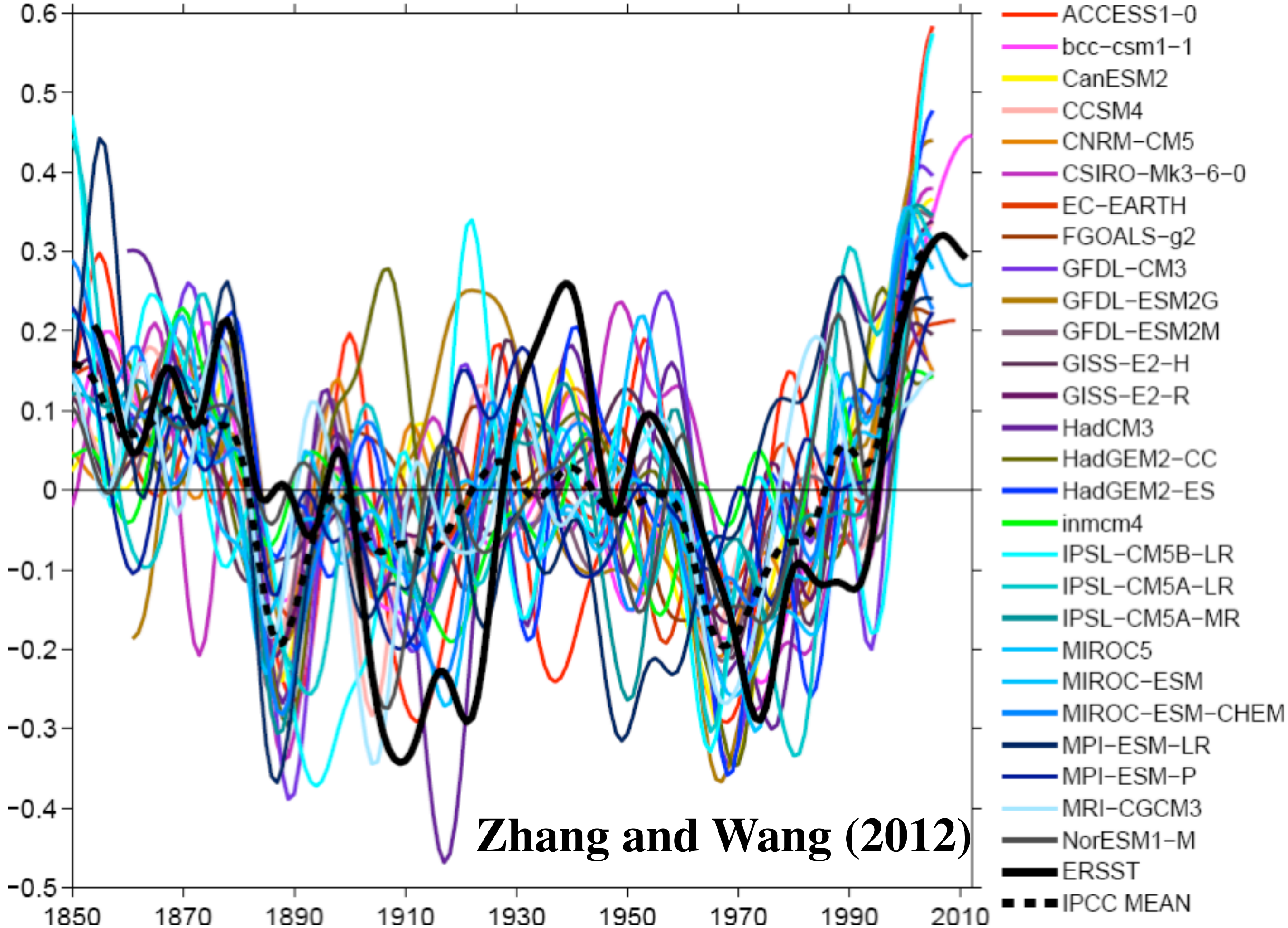
Meridional Overturning Circulation(MOC)







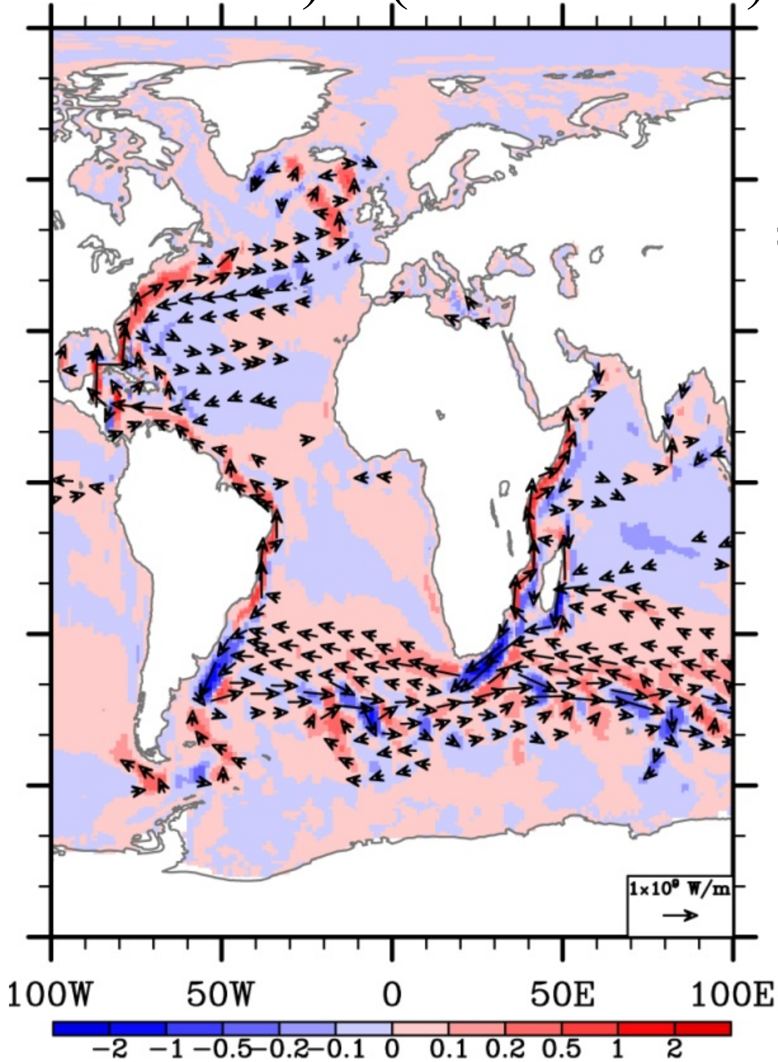
The Atlantic Multidecadal Oscillation (AMO) Simulated from 27 IPCC-AR5 Models



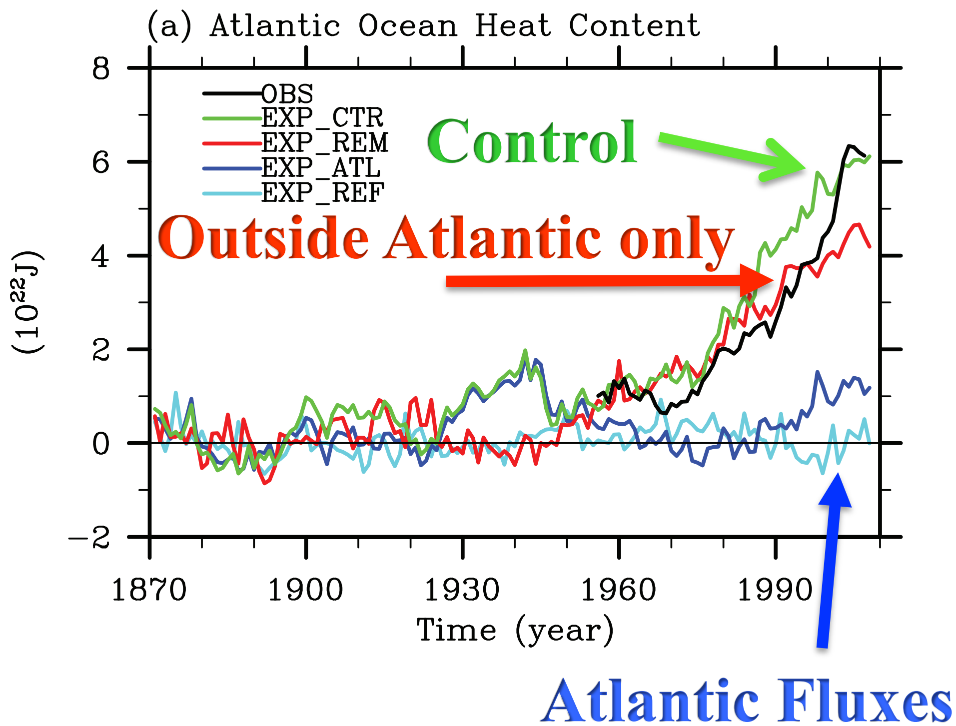
- Models show a large spread of uncertainty, but better than IPCC-AR4 simulations.
- All models display a warming in the last two decades.
- Models underestimate the cooling (1900-25) and the subsequent warming (1926-65).

Why has the Atlantic Ocean warmed substantially more than any other ocean basin since the 1950s?

(1979 to 2008) – (1871 to 1900)



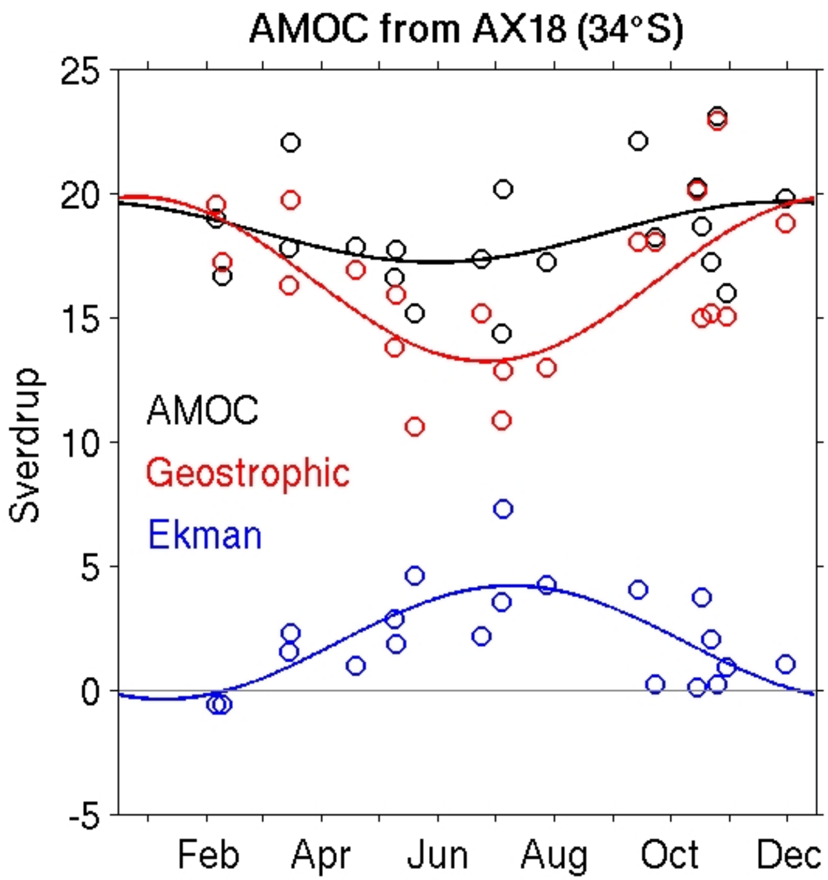
Heat transport and vectors

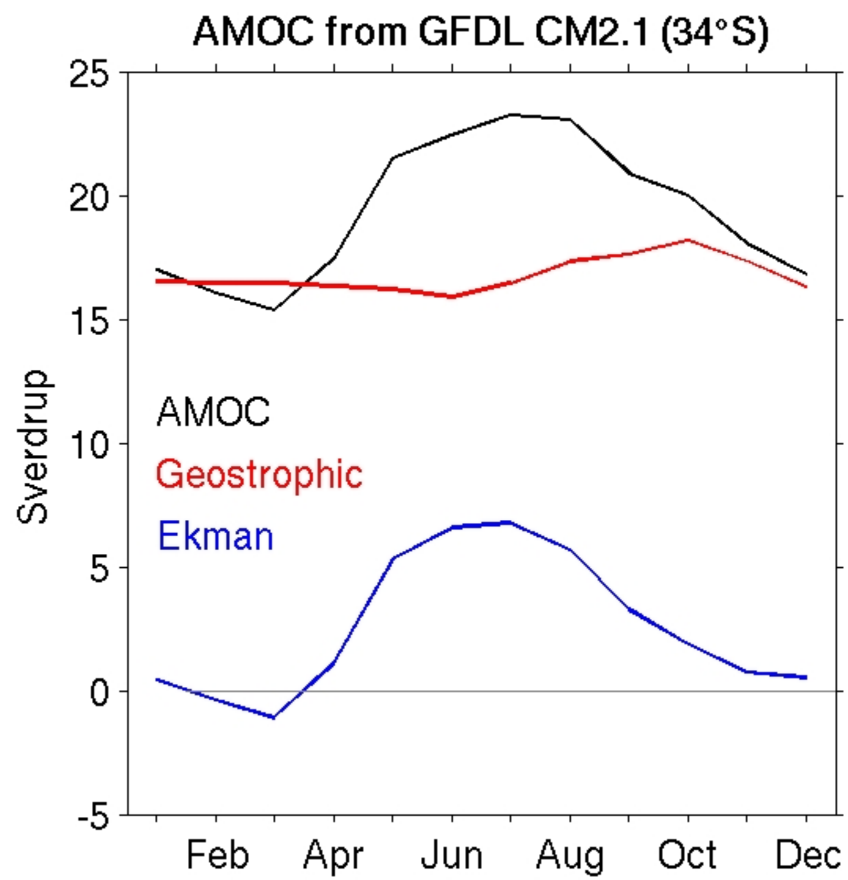


South Atlantic MOC and associated heat transport can explain observed warming in the North Atlantic since 1950's (black curve).

Lee et al, 2011

South Atlantic: Disagreements between models and observations:



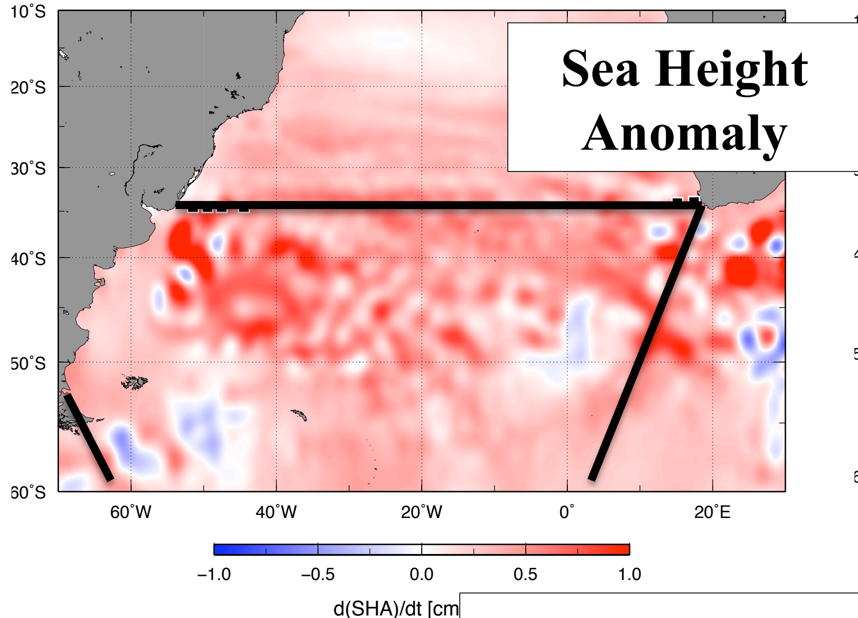


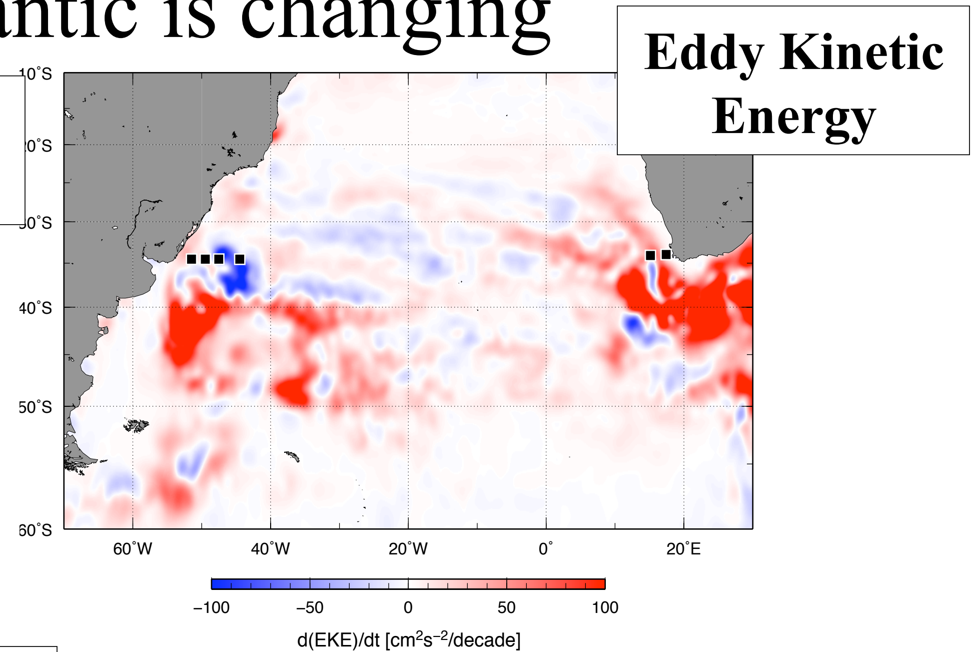
Also for Fresh Water transport
Observations: Flux < 0
Models: Flux > 0

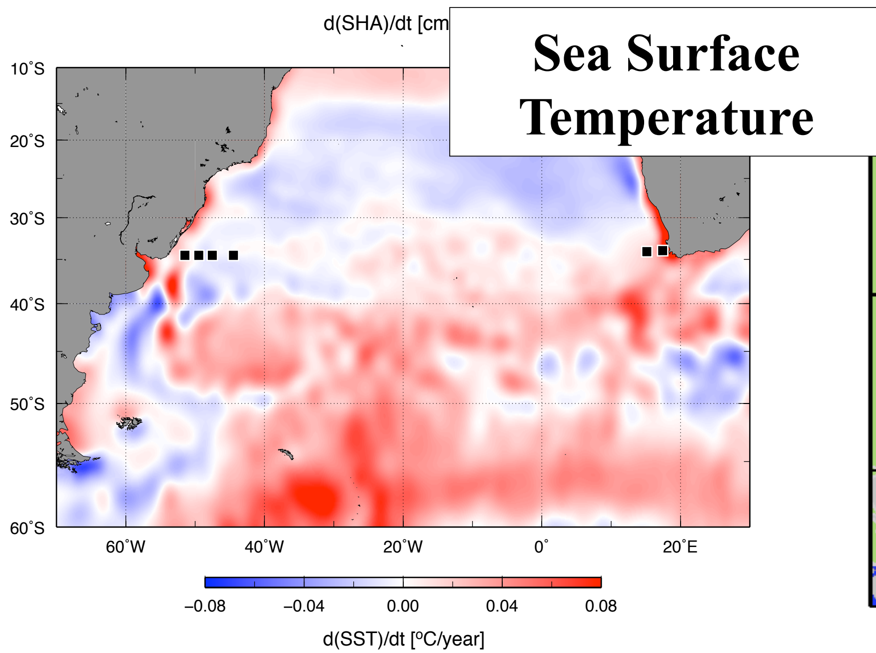
$$\text{AMOC} = max \int_0^z \int_0^L \vec{v}(x,z)\ dx\ dz$$

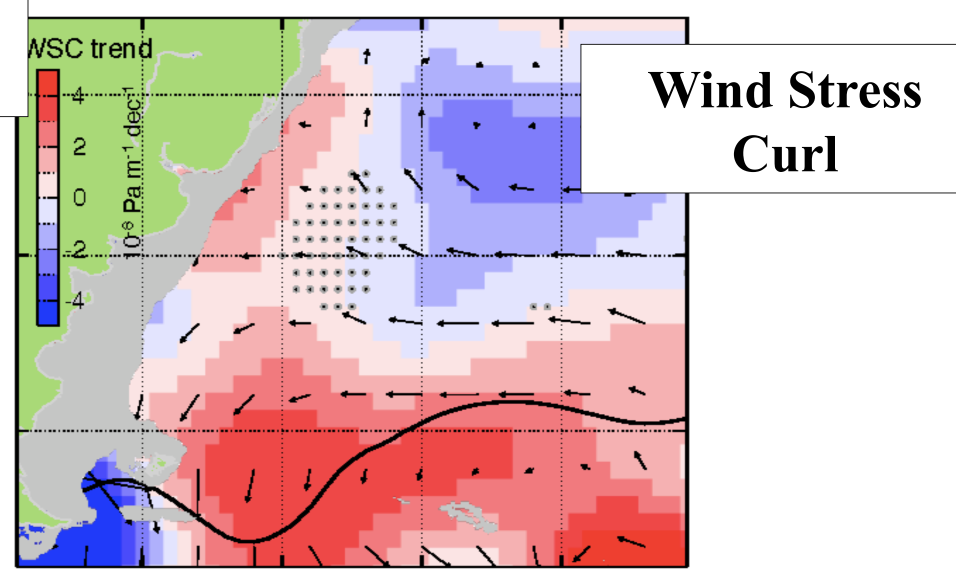
Garzoli et al., 2012; ; Dong et al., 2011; Dong et al., 2009; Baringer and Garzoli, 2007; Garzoli and Baringer, 2007

The South Atlantic is changing



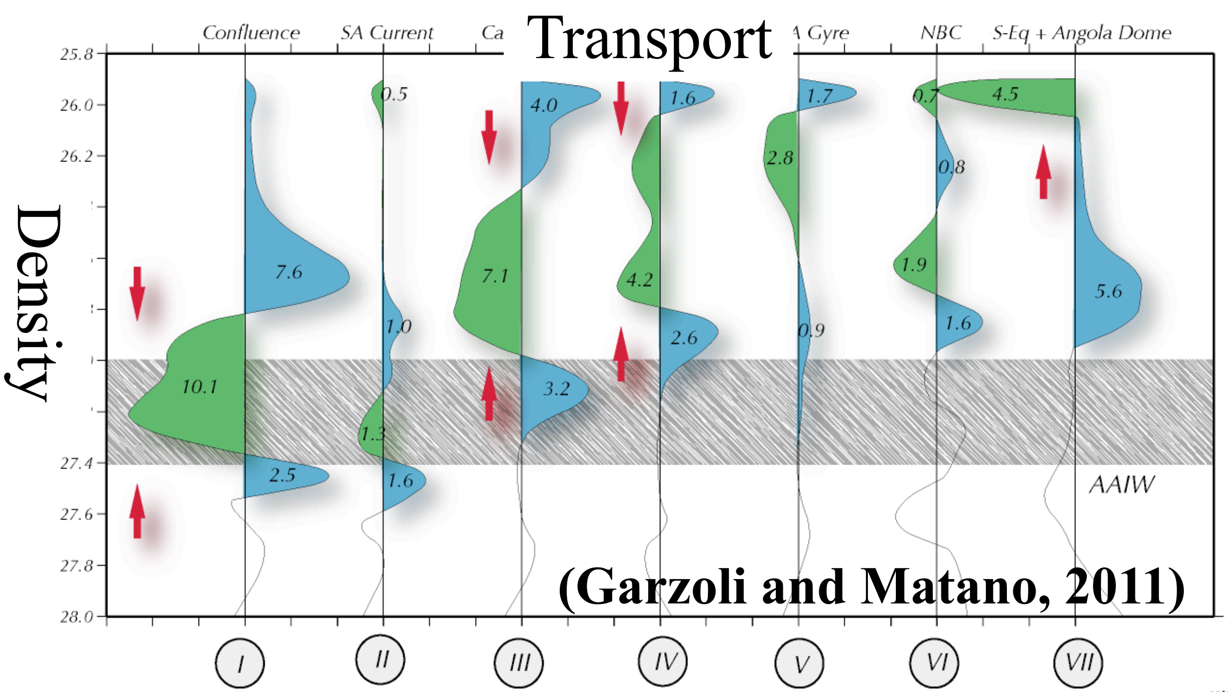


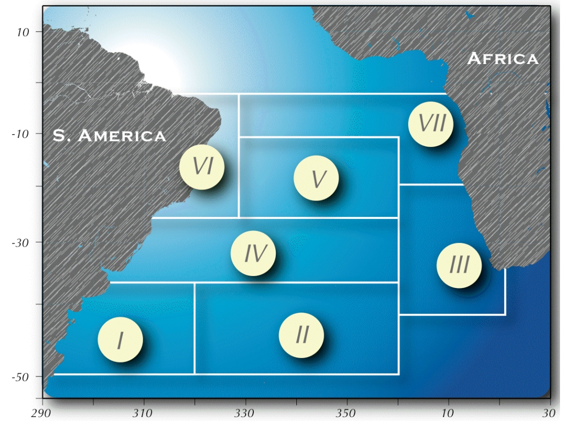


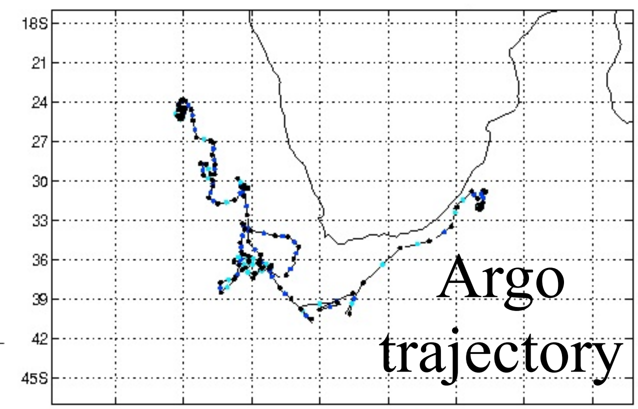


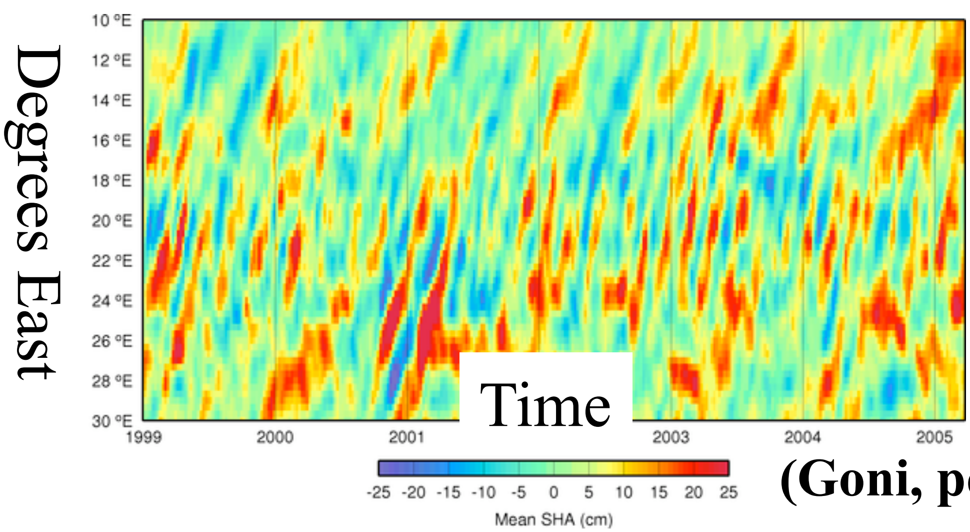
Goni et al, 2012

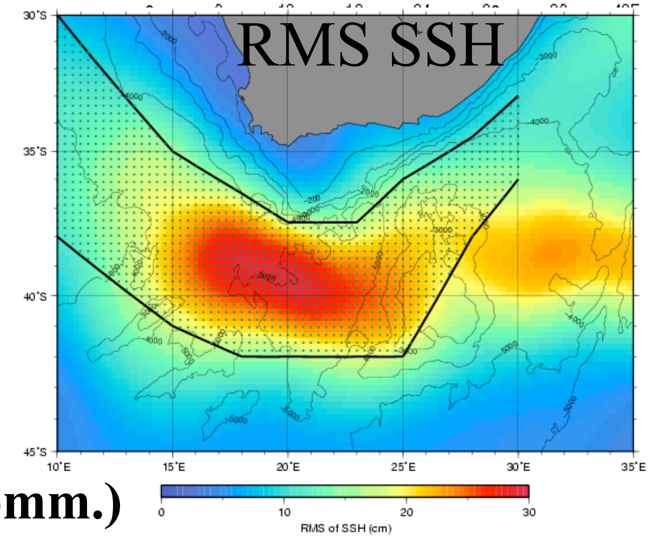
South Atlantic Upper Ocean Water Mass Transformations and Pathways





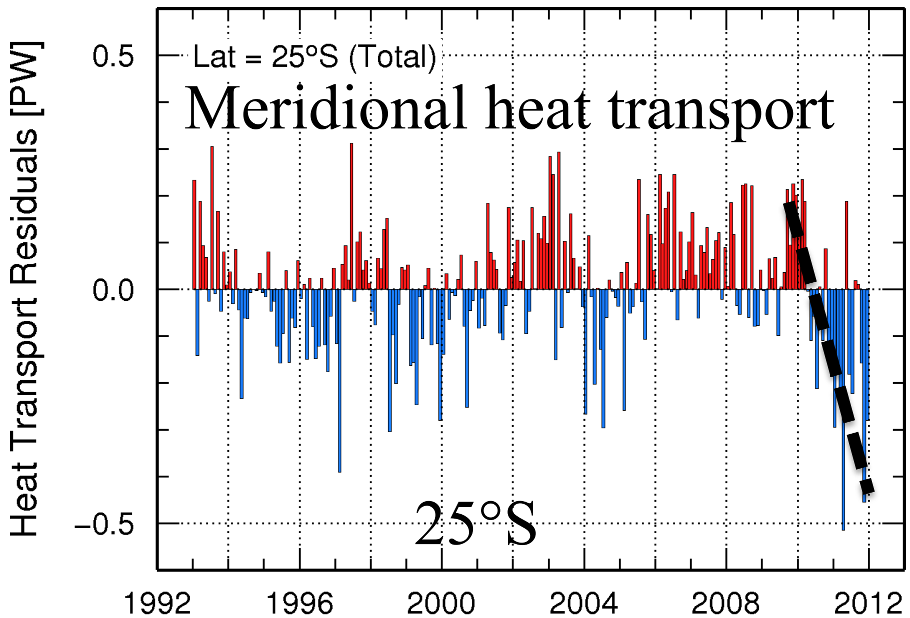


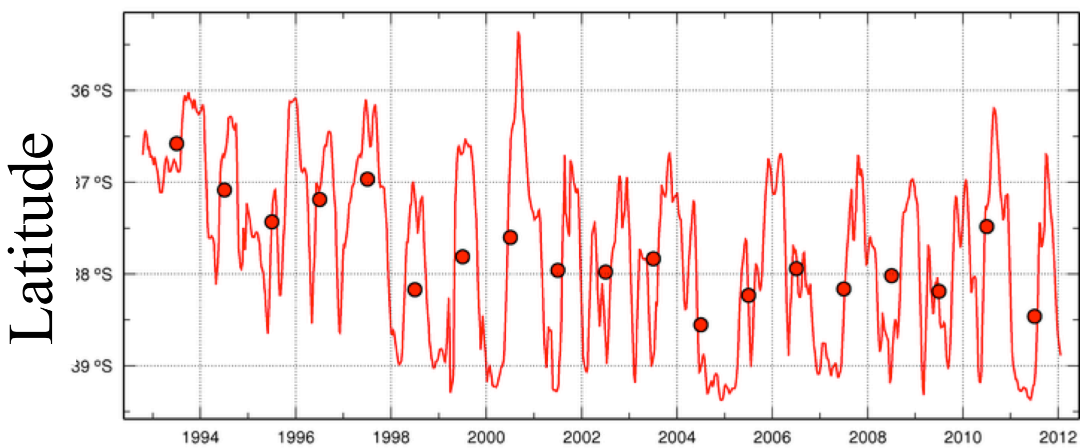




(Goni, pers. comm.)

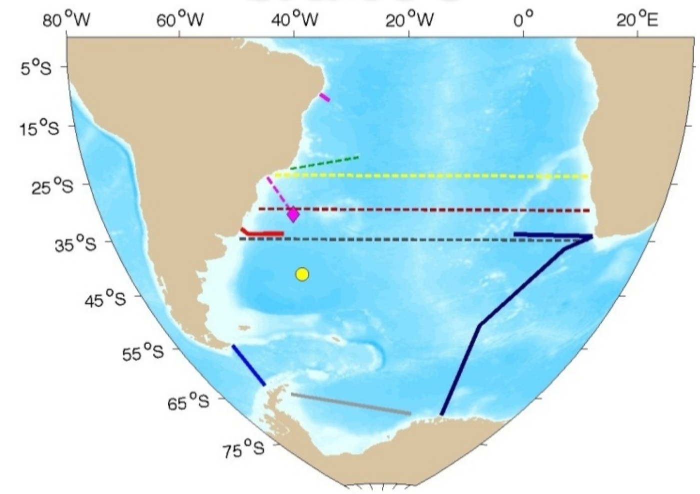
South Atlantic: Future Plans



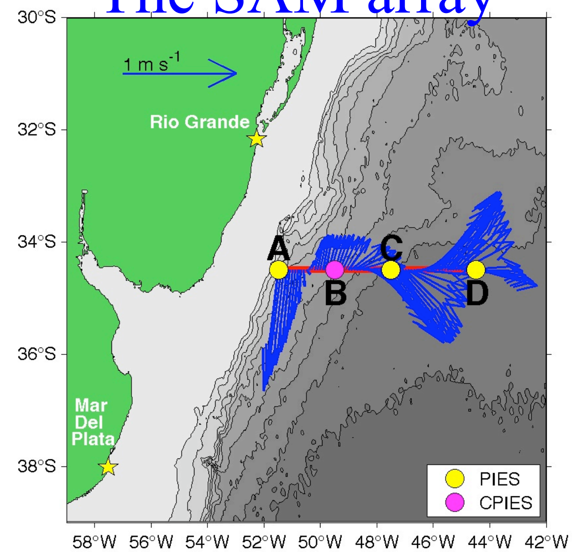


Brazil Current Shifts Southward

The international effort started and lead at AOML: SAMOC



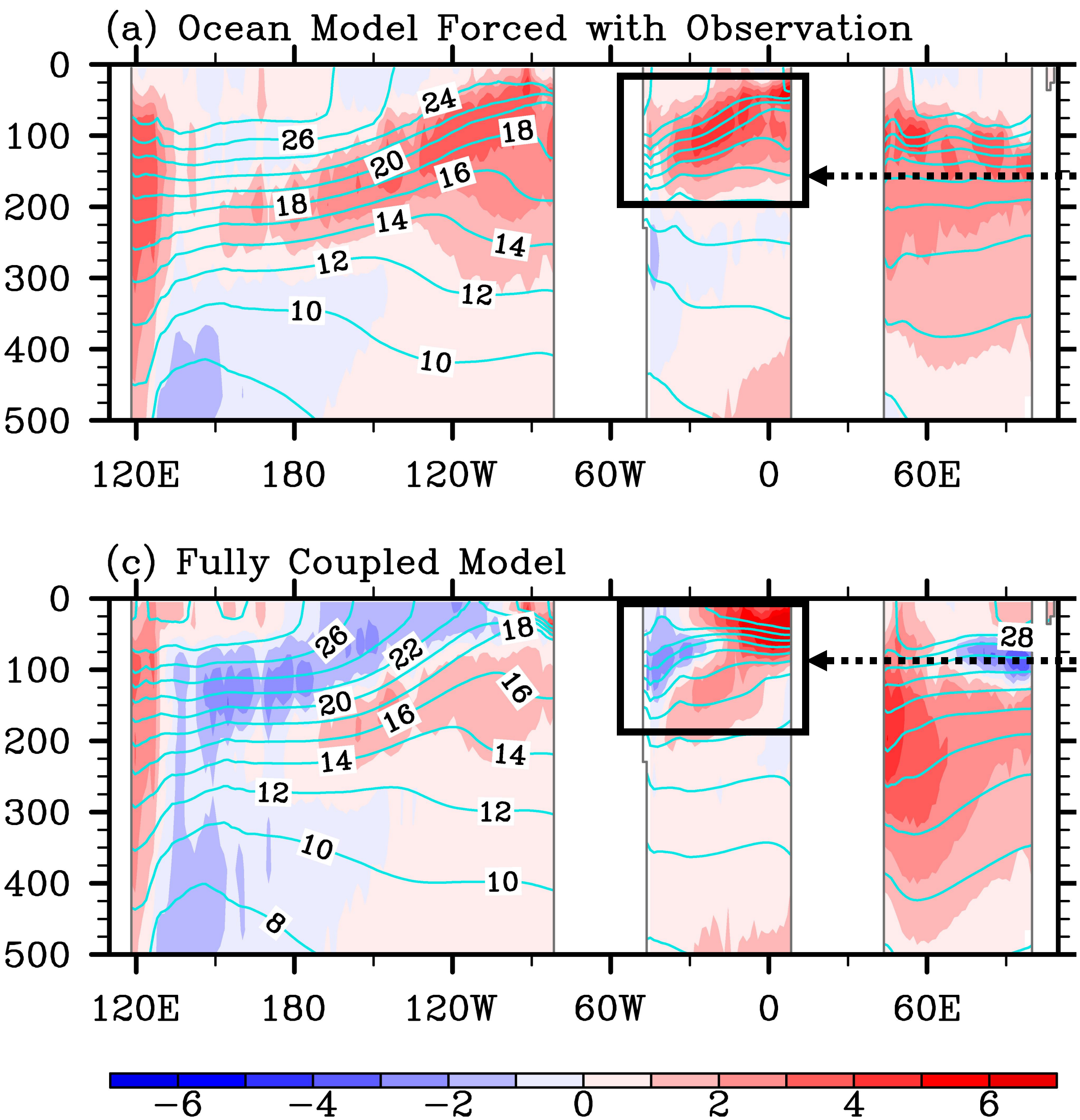
The SAM array



Meinen et al, 2012, Perez et al, 2012

Tropical Atlantic warm bias in climate models

NCAR Coupled Model (CCSM3) – Obs for JJA



Thermocline layer is too diffusive and thus too warm in the ocean model component.

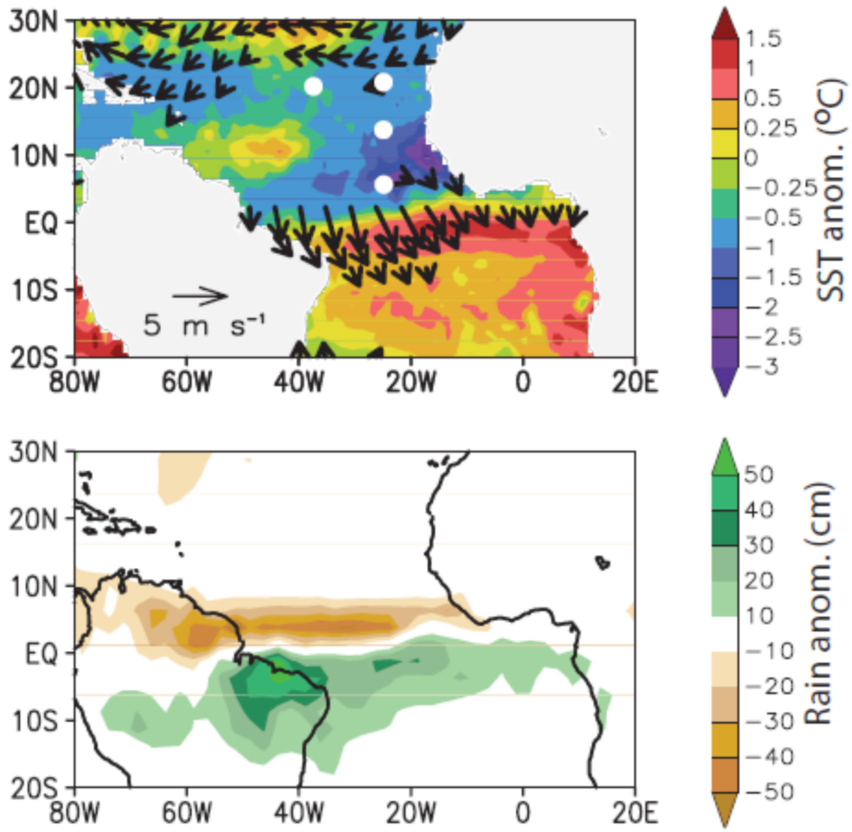
Seasonal upwelling of the thermocline water warms the surface water.

Air-sea coupling further amplify the surface warm bias.

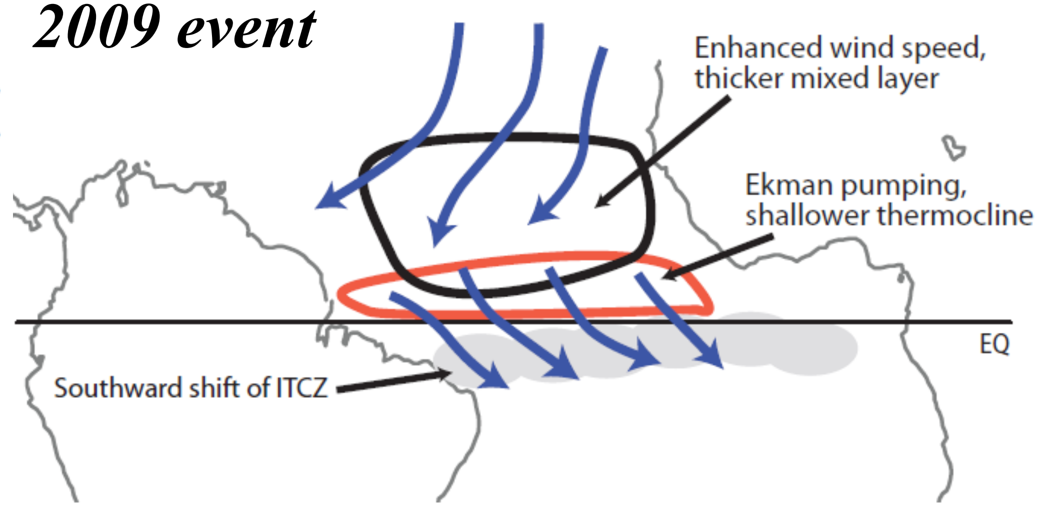
Lee et al, in prep.

Tropical Atlantic variability

Anomalous conditions during Apr-May 2009



Data from PIRATA and Argo reveal the mechanisms responsible for the 2009 event

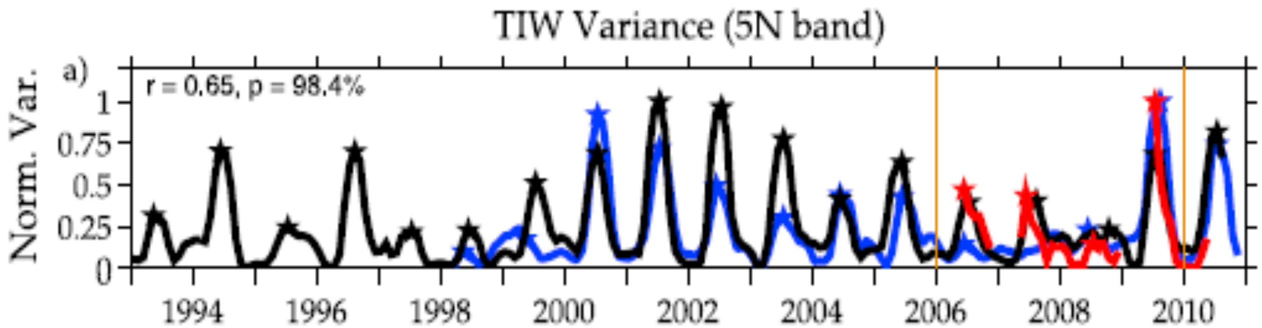


Mixed-layer heat budget

$$\rho c_p h \frac{\partial T}{\partial t} = Q_0 - \rho c_p h \vec{\mathbf{v}} \cdot \nabla T + Q_{-h}$$

Foltz et al 2012, Foltz et al in prep.

Tropical Atlantic variability



Normalized variance along 5°N associated with Tropical Instability Waves (TIWs), calculated from TMI SST (blue), AVISO SLA (black), and the current meter on the PNE mooring 4ºN 23ºW (red).

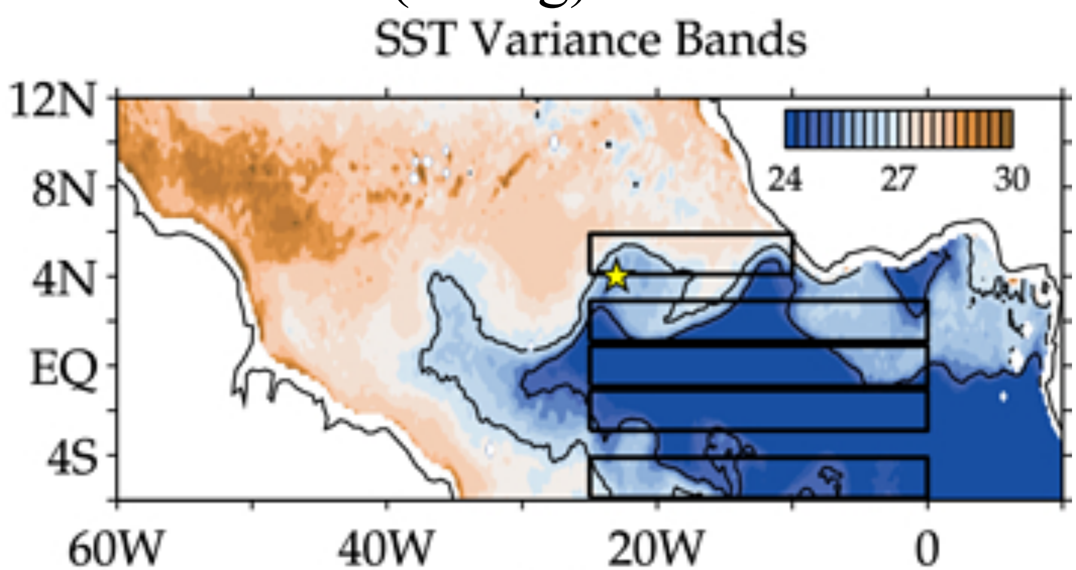
Low (high) TIW associated with

≈ warm (cold) SSTs in the cold tongue region

≈ weak (strong) wind stress divergence

≈ (strong) zonal current shear in the nSEC-NECC region (2N-5N)

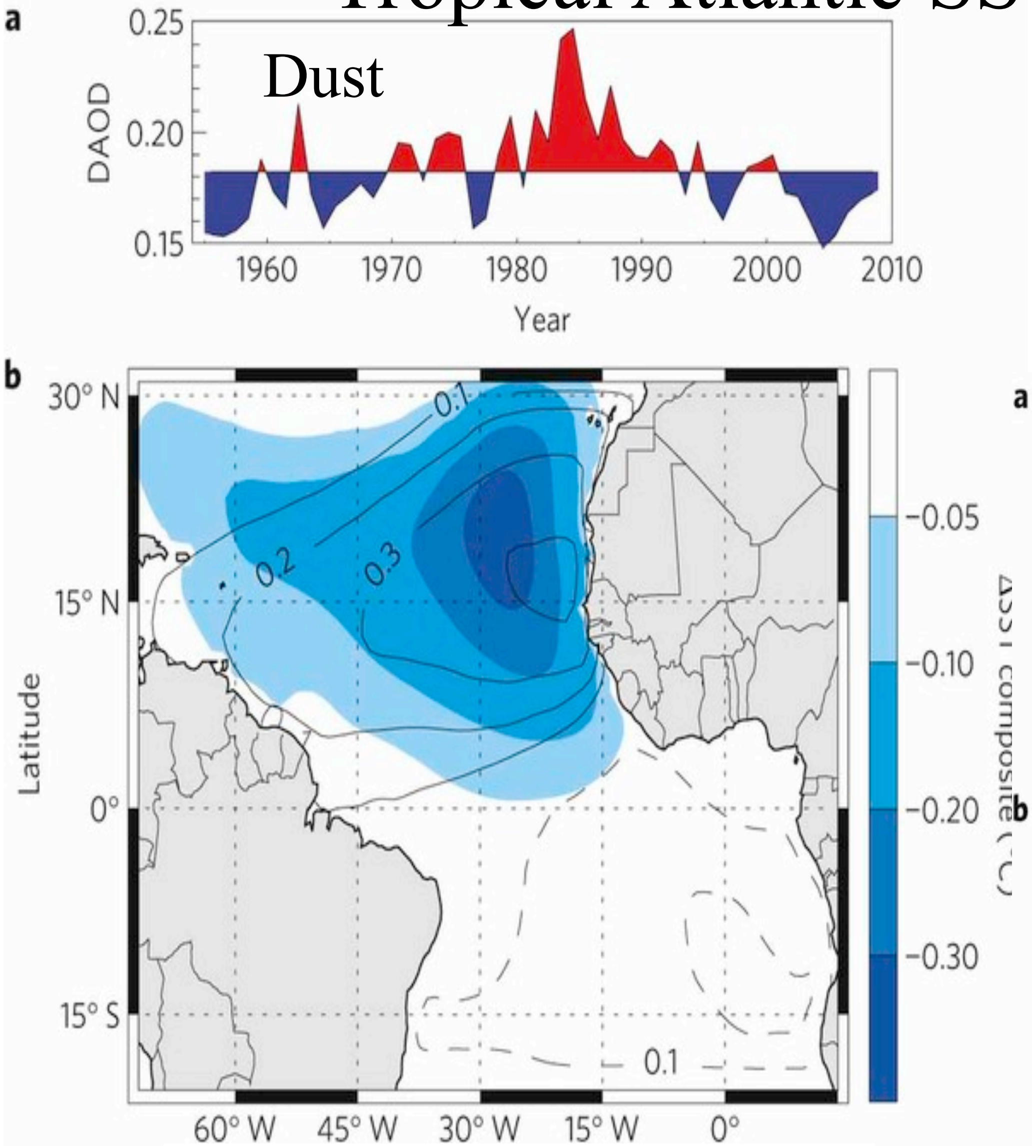
≈ weak (strong) curl in the EUC-nSEC region (2S-2N)



$$\frac{\partial U_\tau}{\partial y} \approx -\frac{r_s curl(\tau_x, \tau_y)}{\rho_0 (f^2 + r_s^2)}$$

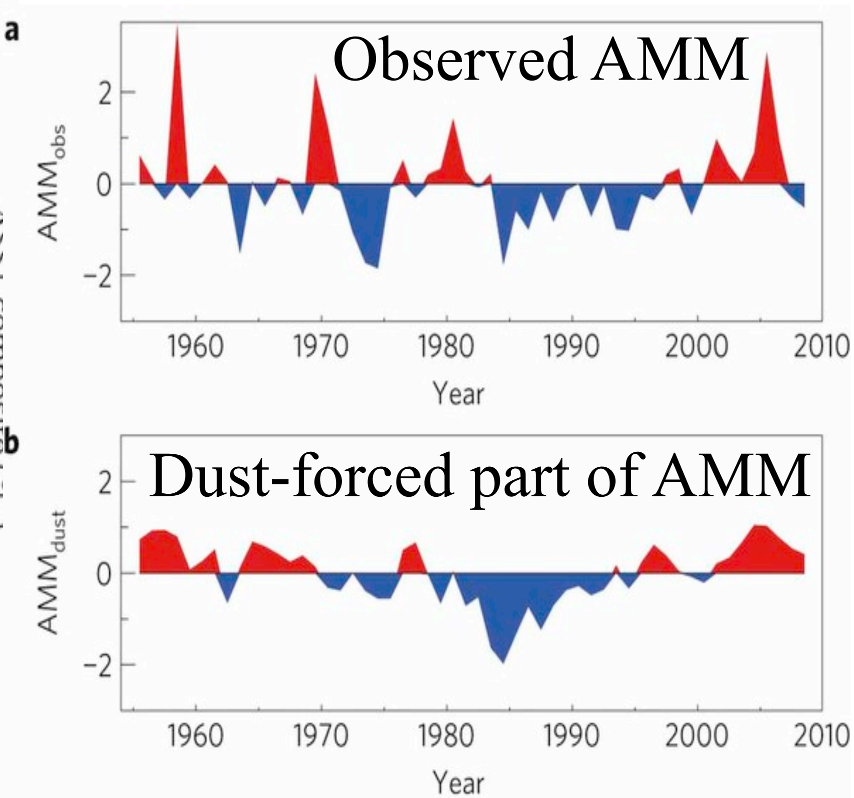
Perez, et al (2012).

Tropical Atlantic SST forced by Dust



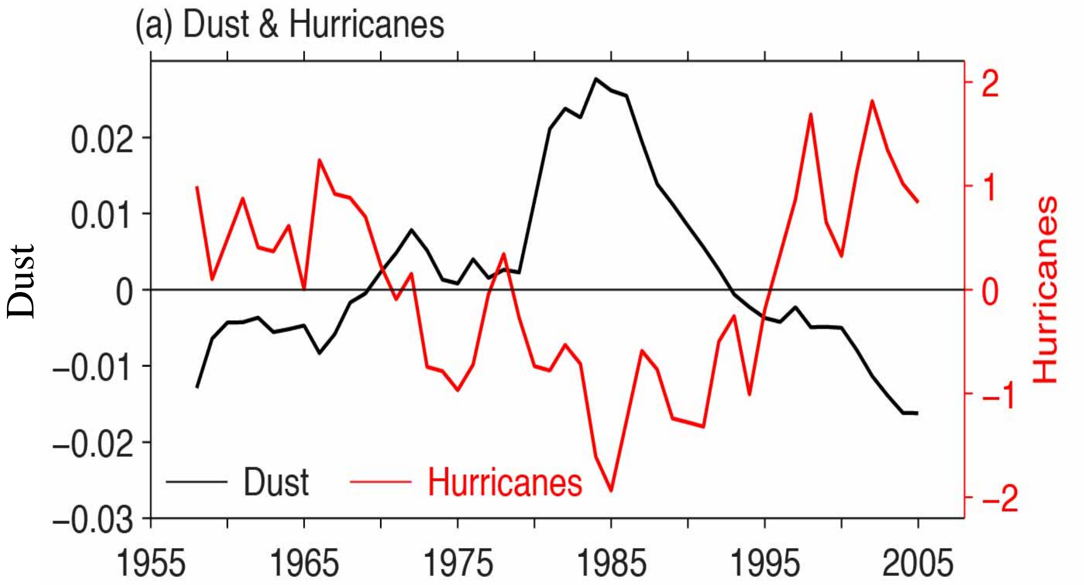
SST induced dust shading
AMM contours

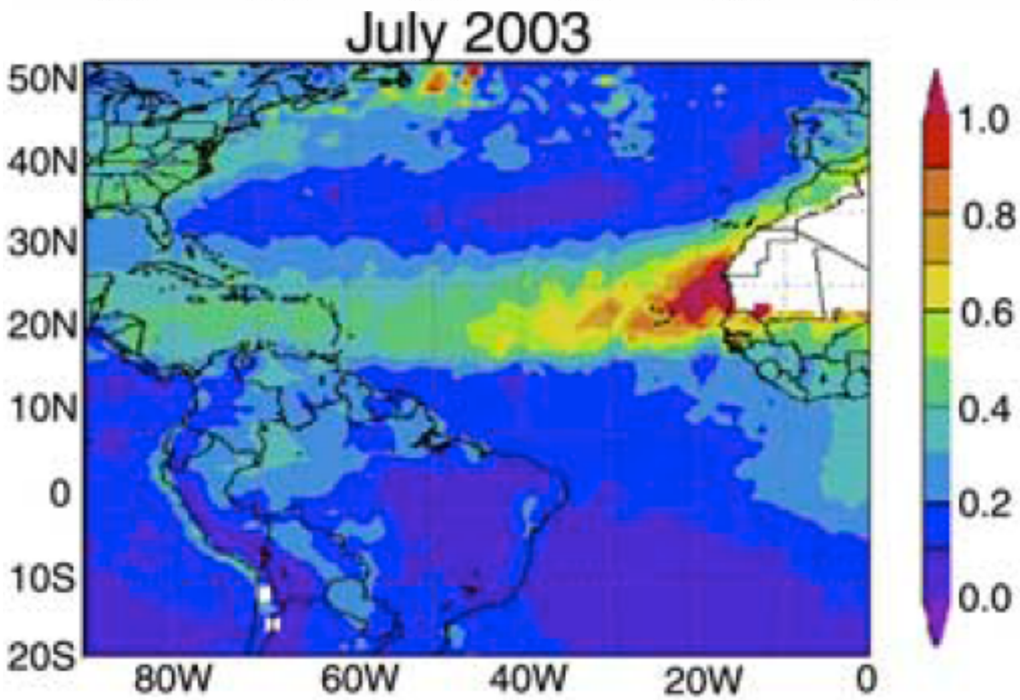
AMM=Atlantic Meridional
Mode of SST variability



Evan et al, 2011

Dust and Atlantic Hurricanes



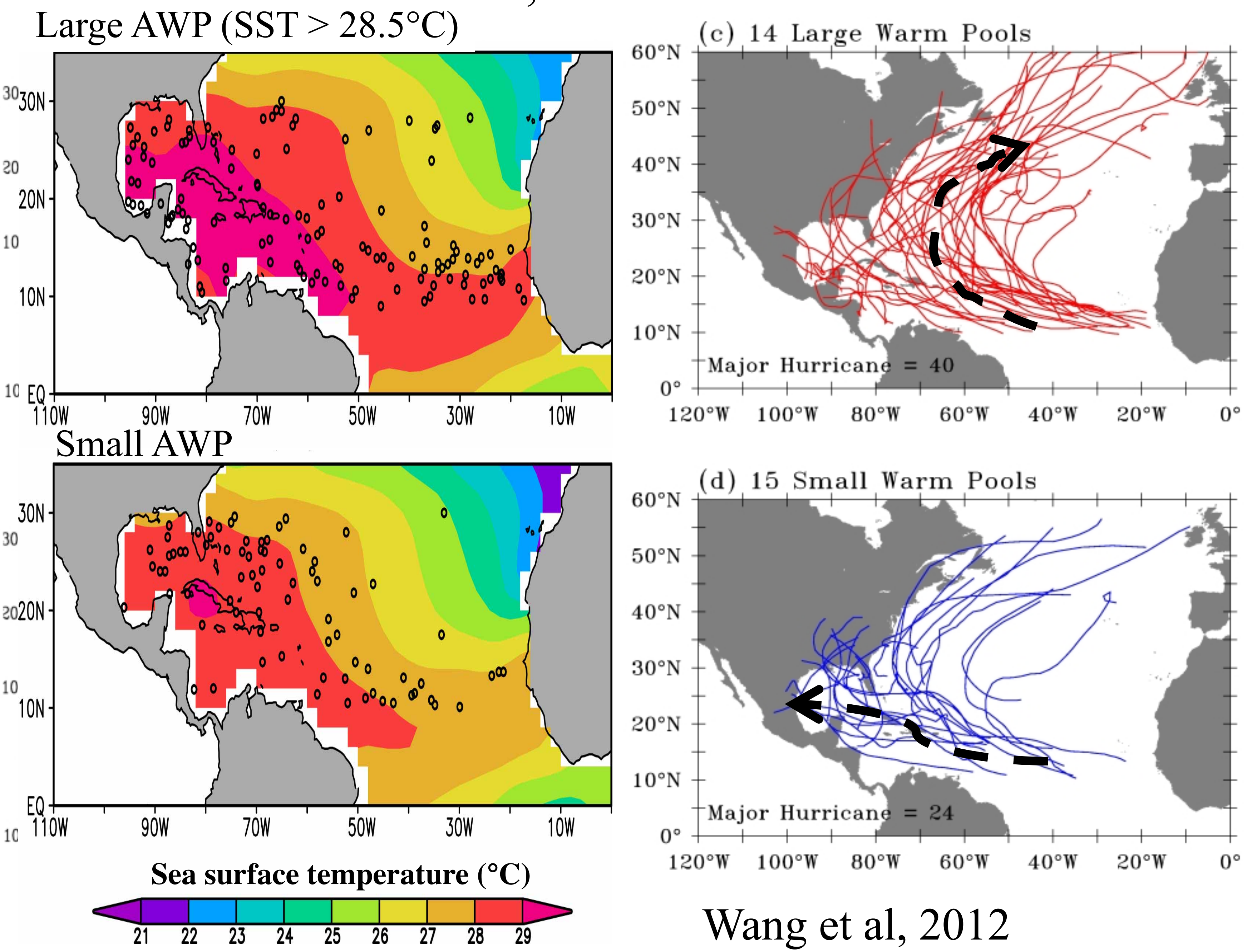


When dust concentration in the tropical North Atlantic is low (high), the number of Atlantic hurricanes is large (small).

The mechanism is that high (low) concentration of dust enhances (reduces) vertical wind shear in the hurricane main development region.

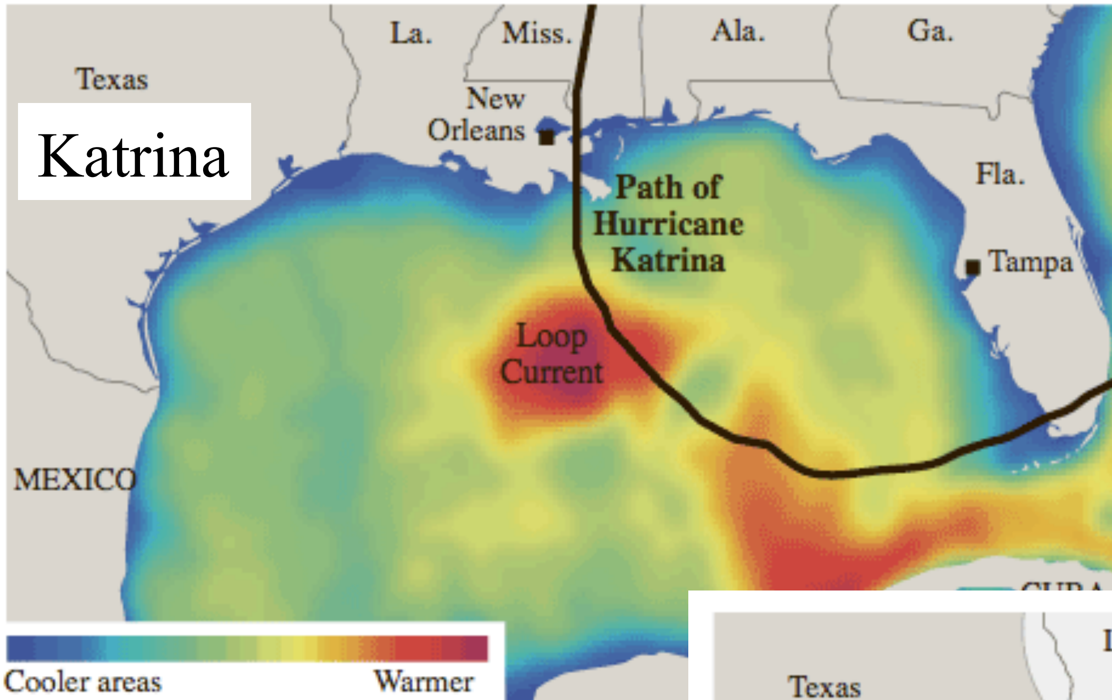
Wang, Dong, Evan, Foltz, and Lee (2012)

Atlantic Warm Pool, Hurricane Genesis and Track



Wang et al, 2012

Tropical Cyclone Heat Potential

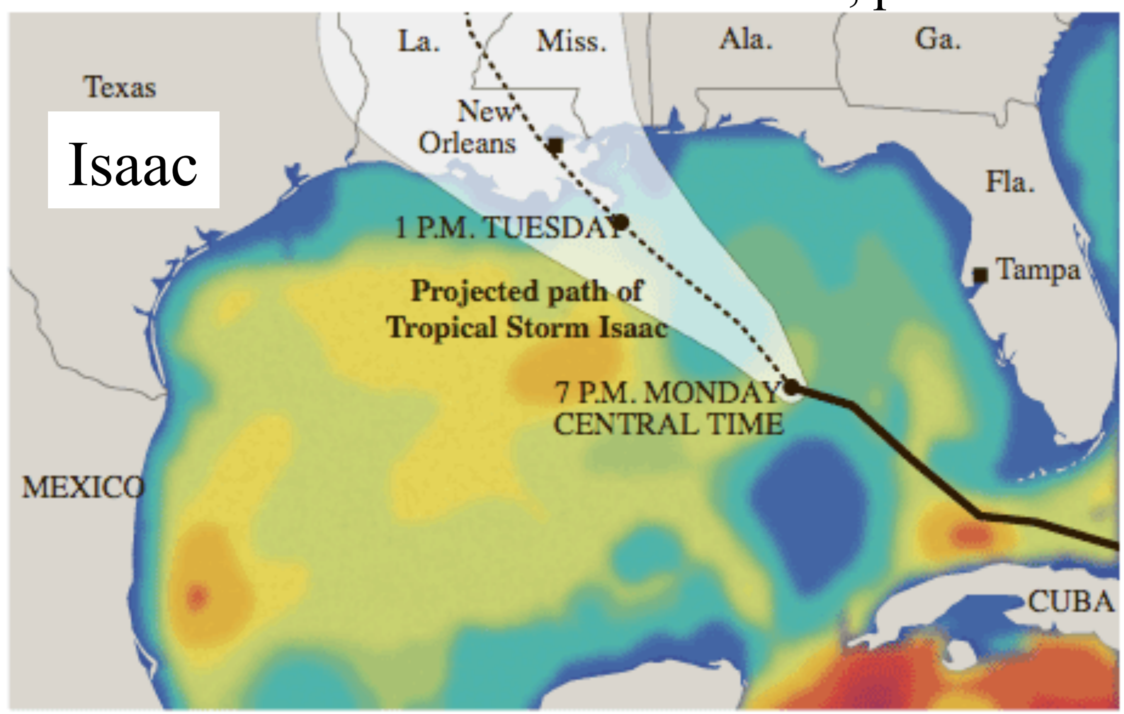


Developed at AOML, now is one of the predictors used in the SHIPS and STIPS hurricane intensity forecast tools.

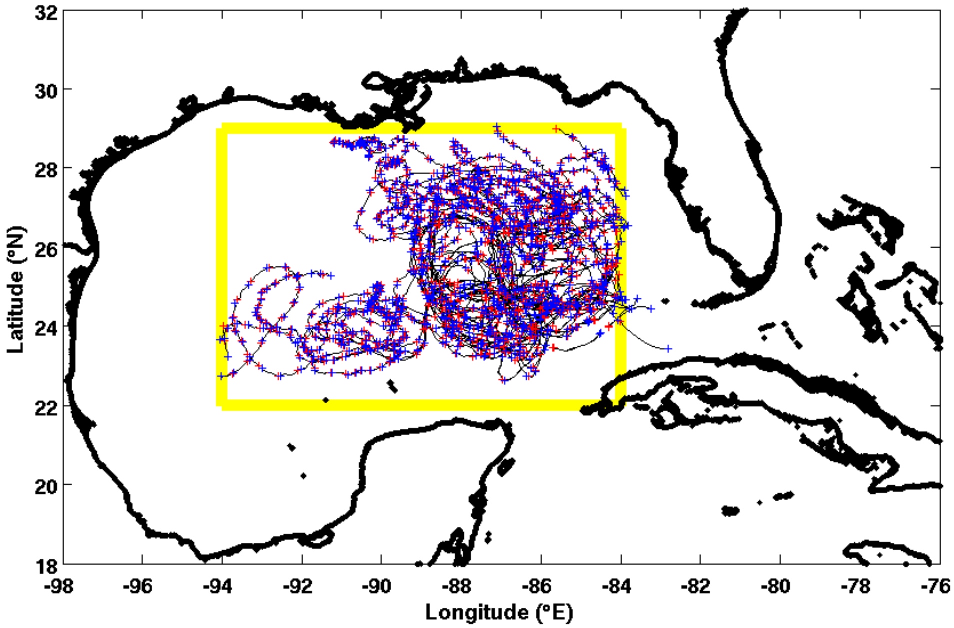
Goni, pers. comm.

Upper ocean heat content can provide one source of energy to intensify hurricanes.

One difference between Isaac and Katrina was the ocean conditions.



Using observations to improve models



Ocean Model	U RMS error (m/s)	V RMS error (m/s)
Operational global HYCOM	0.19	0.17
Operational Gulf of Mexico HYCOM	0.18	0.17
IASROMS (ROMS ocean model)	0.19	0.18
IASNFS (NCOM ocean model	0.22	0.20
No data assimilation	0.42	0.39

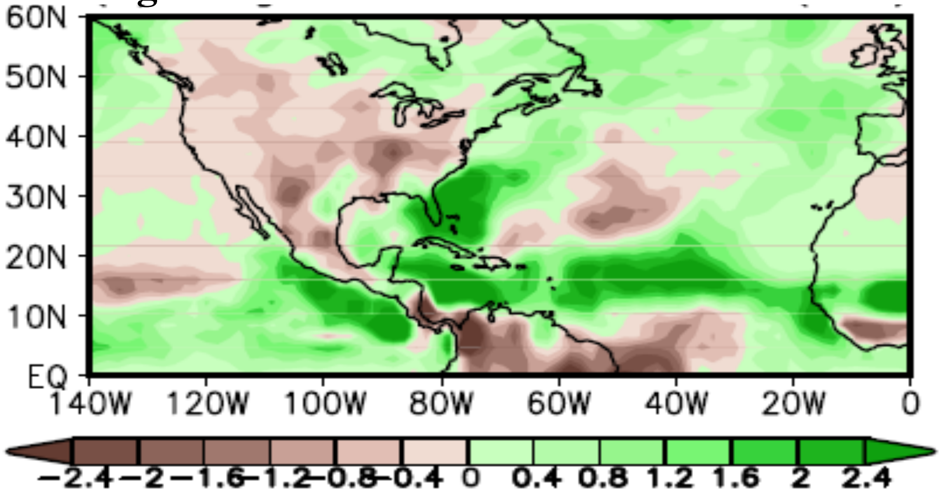
Evaluation of ocean model velocity fields, June-December 2010 (DWH oil spill)

1. Synthetic drifters released every 2 days at actual *in-situ* drifter locations
2. Velocity difference calculated between 1104 synthetic and real drifter pairs
3. RMS differences calculated for *u* and *v* shown in above table
   - Data assimilation can reduce errors by >50%
   - Relative performance of different models can be compared

Halliwell et al. (in prep.)

Impact of Ocean Temperature on North American Rainfall

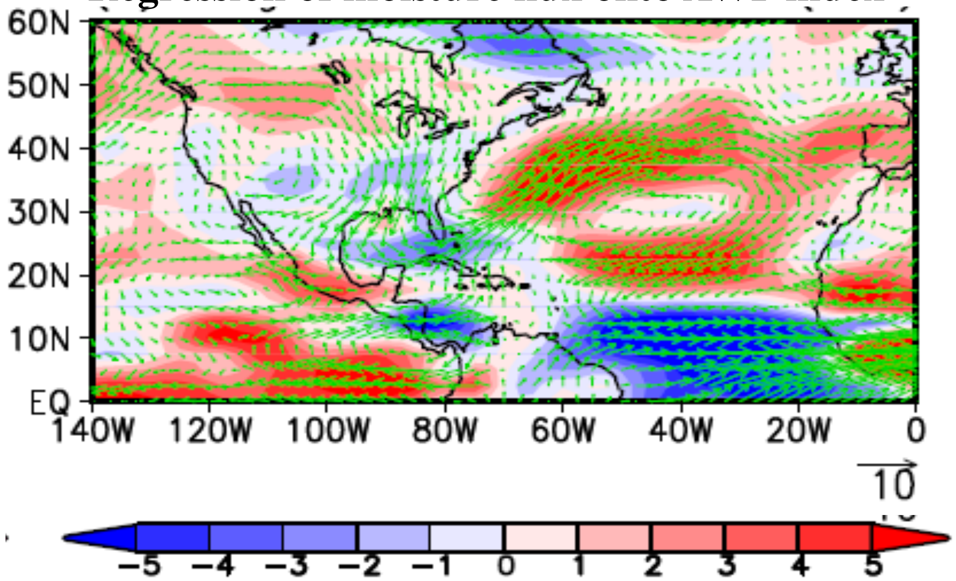
Regression of rainfall onto AWP index



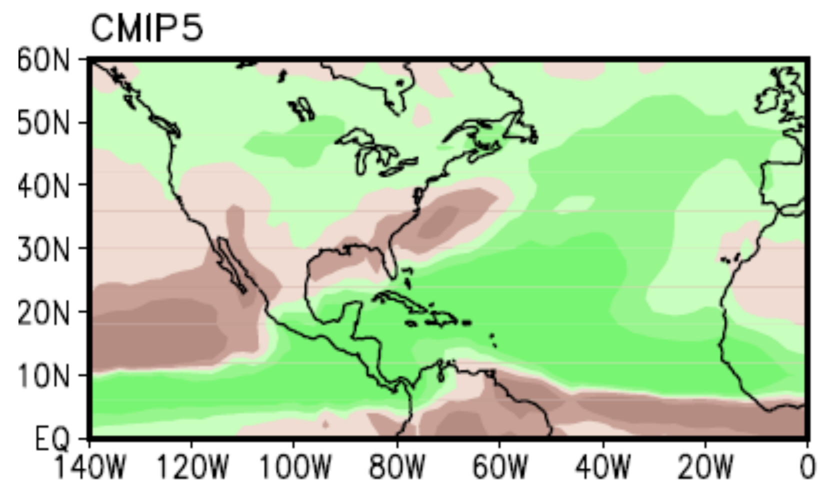
A large Atlantic warm pool is associated with reduced rainfall in the United States during summer and fall.

Why: high ocean temperatures decrease the moisture transport to the United States from the Gulf of Mexico. The opposite occurs when temps are cool.

Regression of moisture flux onto AWP index

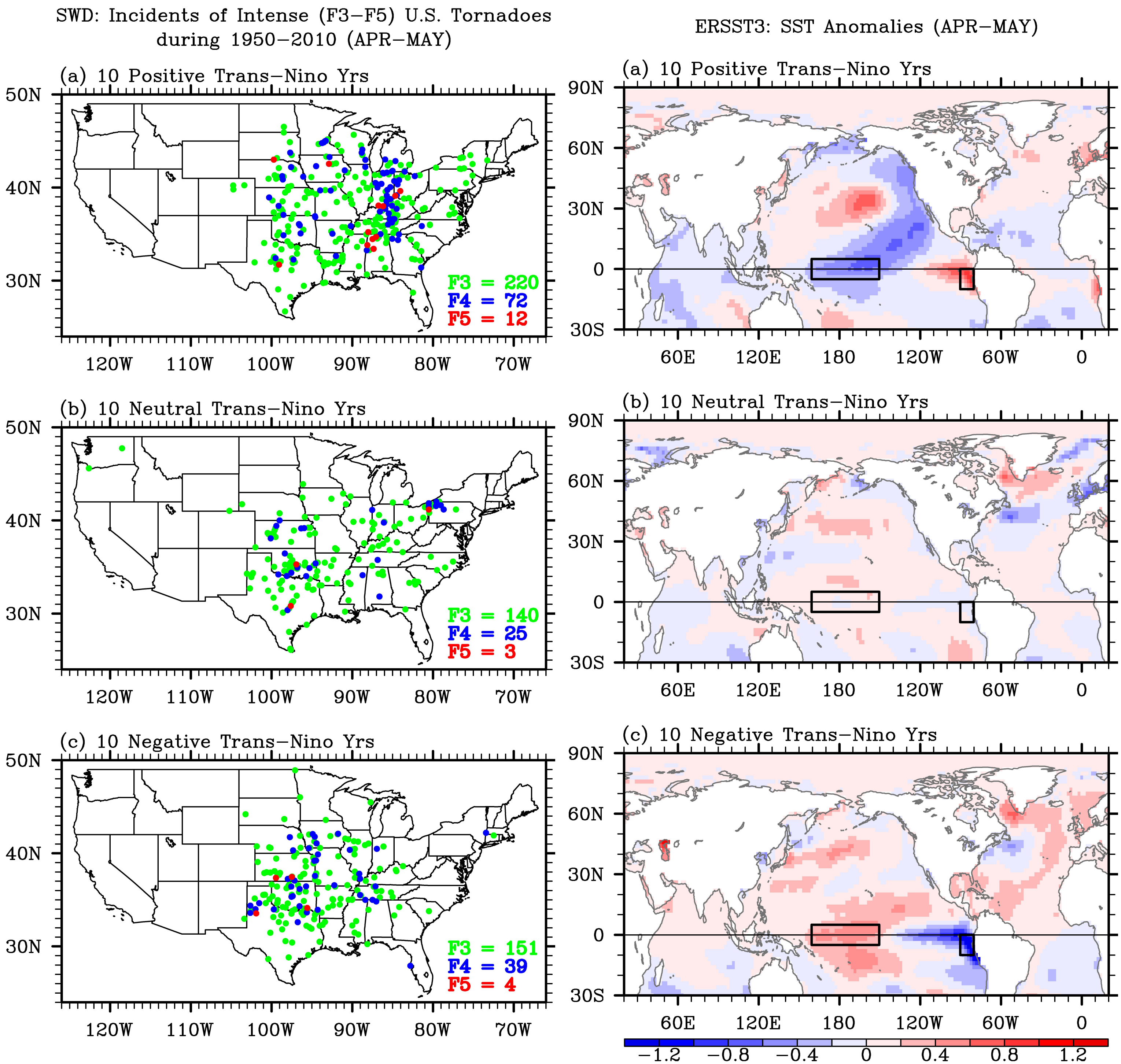


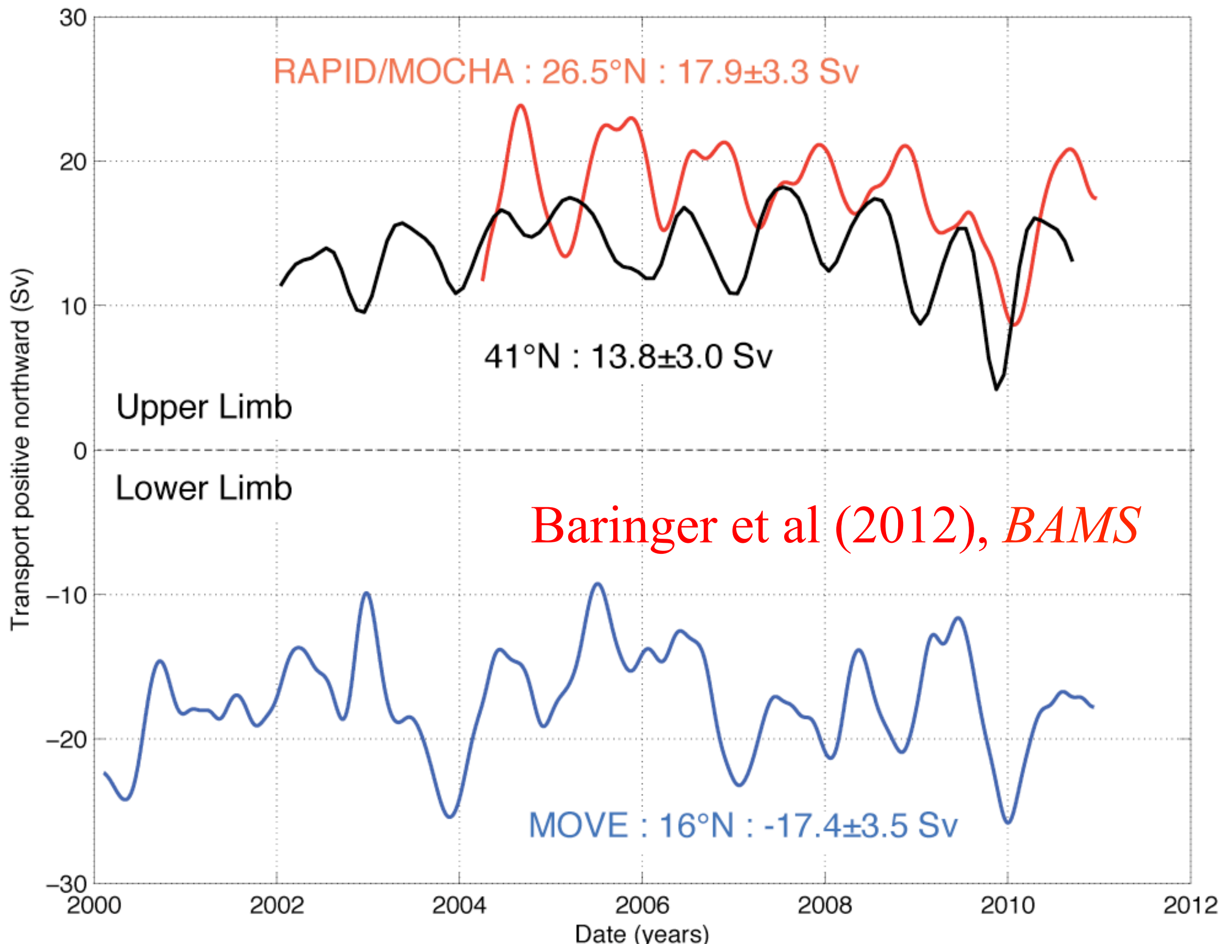
19 IPCC-AR5 climate models fail to simulate the decreased rainfall in U.S.



Liu, Wang, Lee, and Enfield (2012, *J. Climate*)

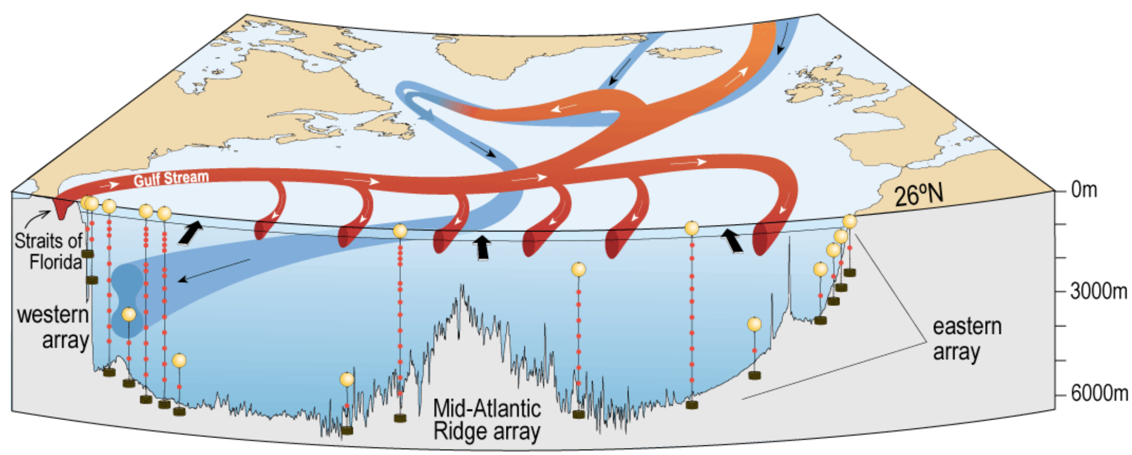
Trans-Niño and U.S. Tornado Outbreak



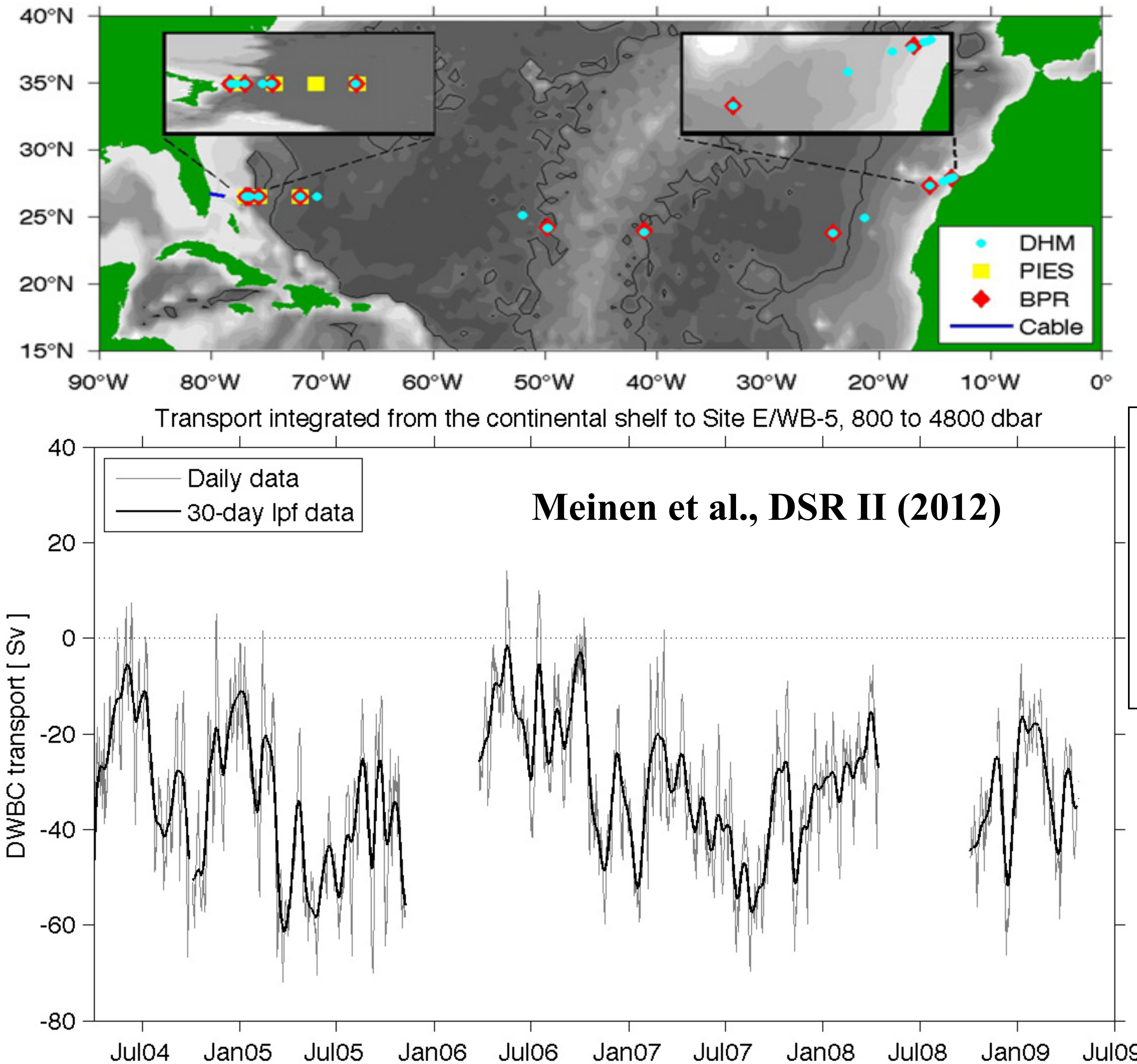


Meridional Overturning Observations in the North Atlantic

Florida Current and Deep Western Boundary Current observations funded by NOAA since 1982



North Atlantic Deep Western Boundary Current Transport



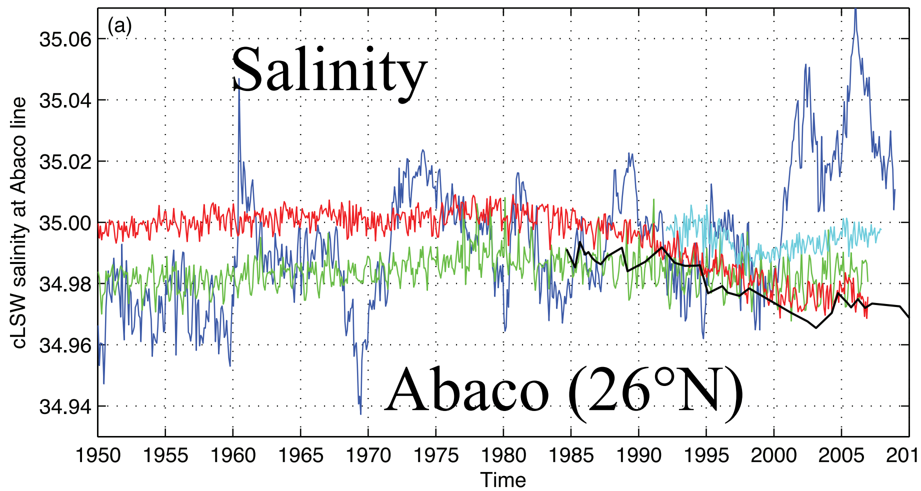
Mean transport
32 ±16 Sv

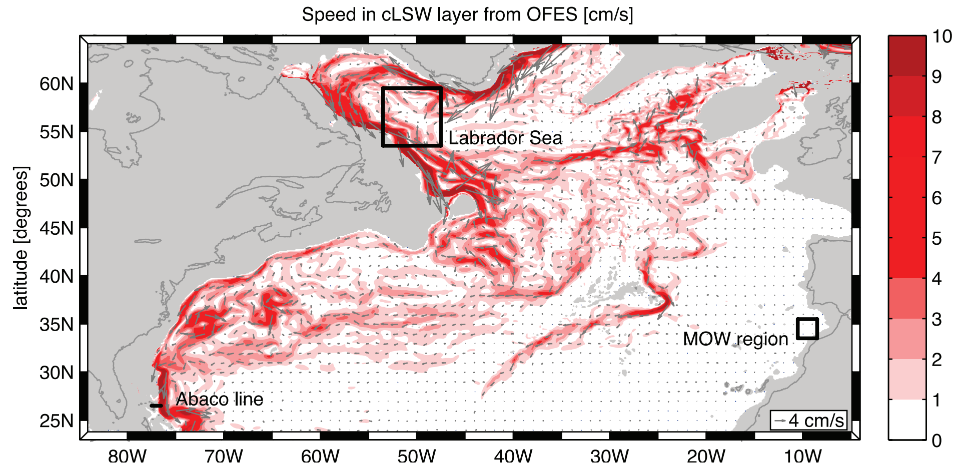
Vs. Mean MOC
18 ± 5 Sv

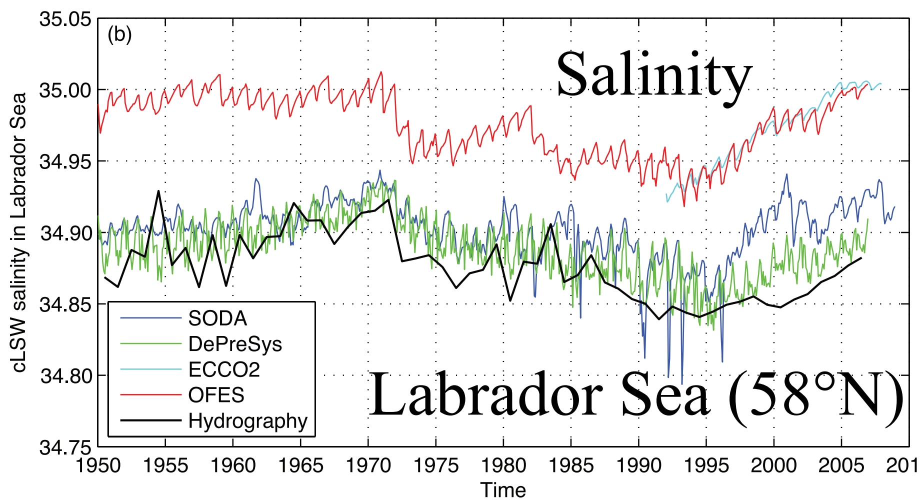
% Variance	
37%	T<2mos
36%	2<T<11 mos
1%	11<T<13 mos
26%	T>13 mos

No annual cycle

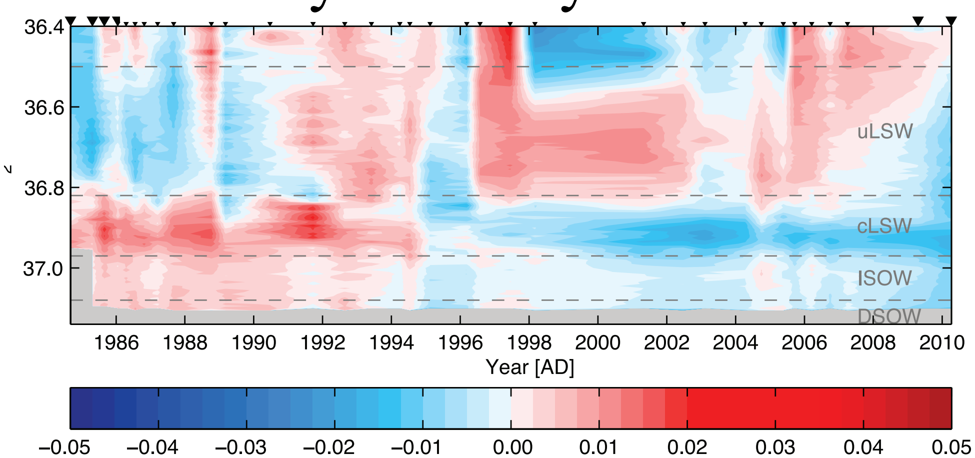
Deep Ocean Water Mass Transformations and Pathways







Salinity Anomaly at Abaco



Anomalies in the Labrador Sea decrease 50% and appear at Abaco 9 years later

Van Sebille et al 2011

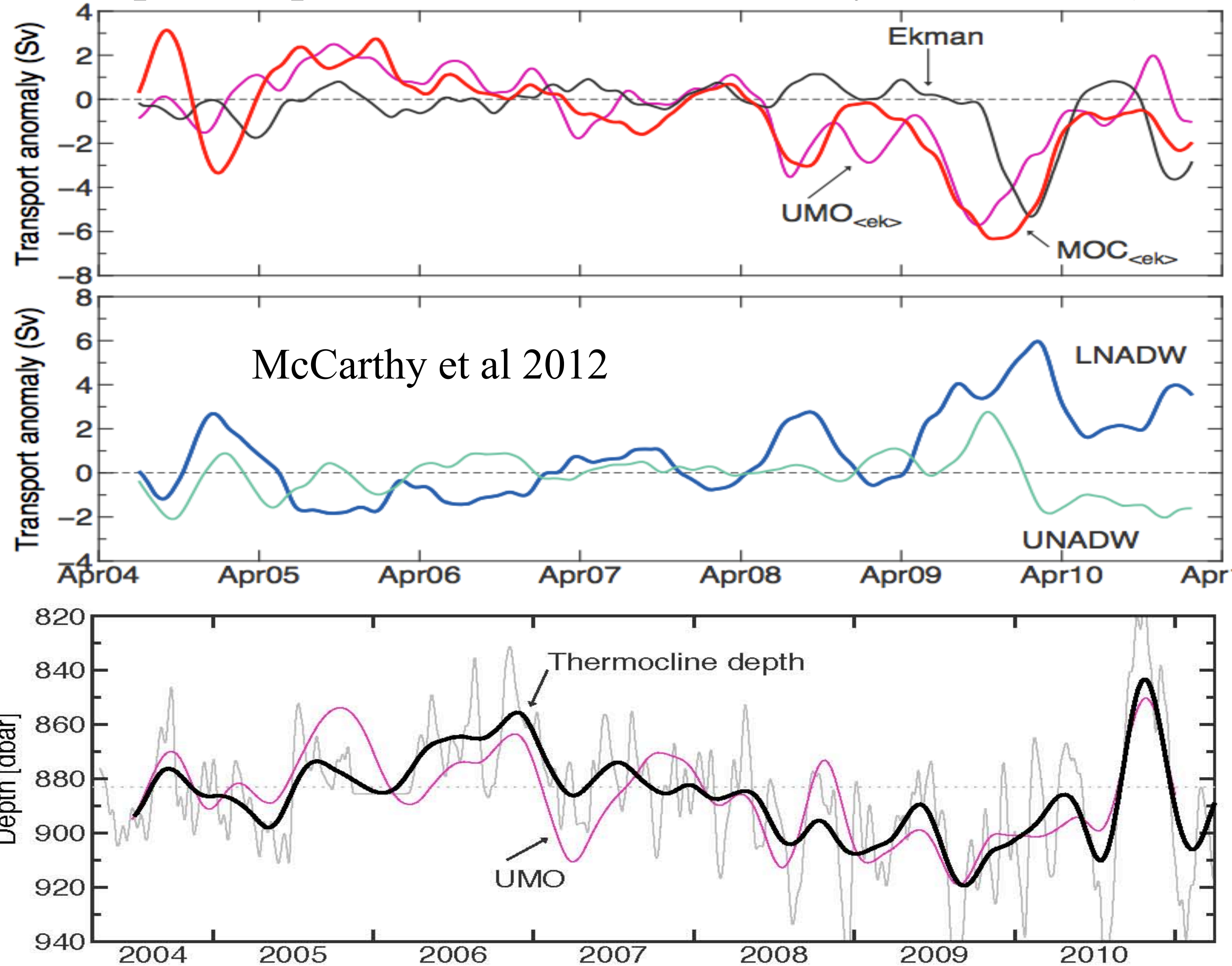
Interannual "Geostrophic" MOC variability

(Ekman transport response and mean seasonal cycle removed)

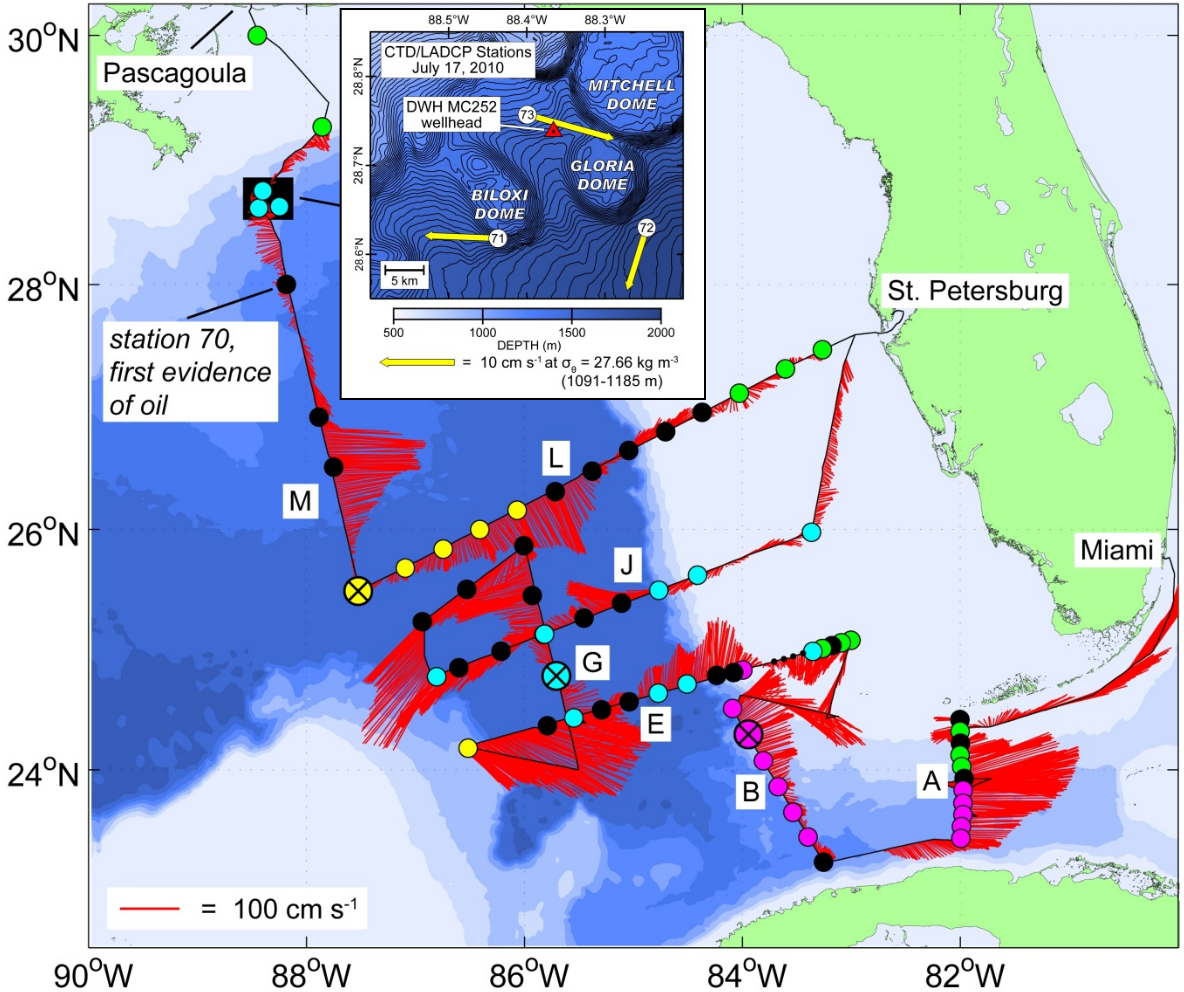
Upper Limb

Lower Limb

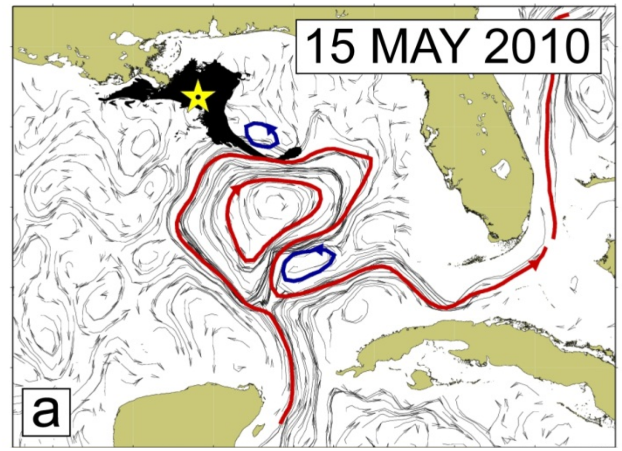
Thermocline depth in west drives interannual variability



Oceanographic Conditions in the Gulf of Mexico in July 2010, during the Deepwater Horizon Oil Spill



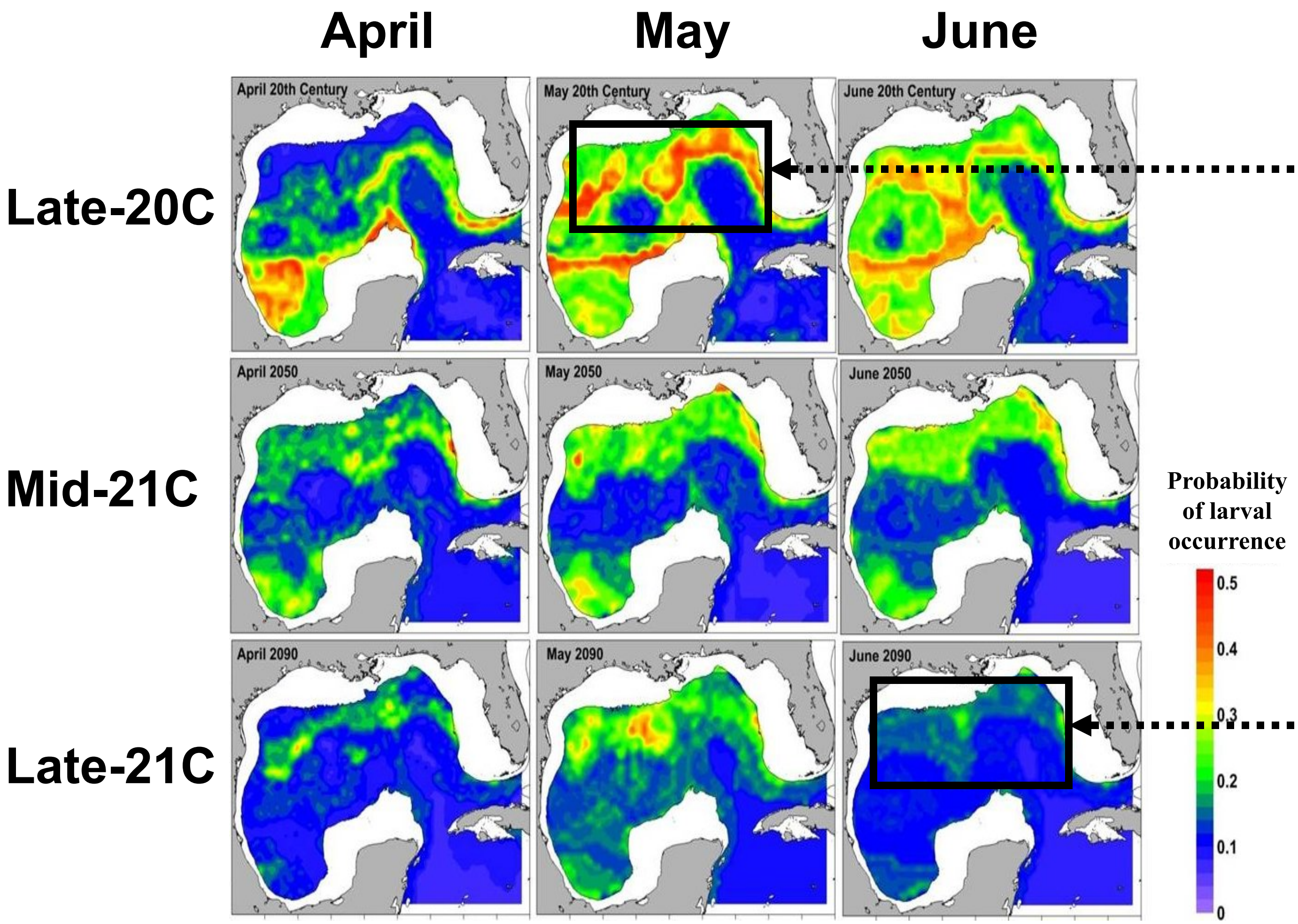
Smith et al., in preparation



No major oil pathway found in Loop Current

Led to collaboration with OR&R for daily maps of surface currents from altimetry

Predicting the effects of climate change on bluefin tuna spawning habitat in the Gulf of Mexico



The spawning of Atlantic bluefin tuna is predominantly in the northern Gulf of Mexico from April to June with the optimal temperature of 24 - 27°C.

Due to the projected warming, the areas with high larval occurrence will decrease by more than 90% toward the end of the 21st century.

- This is a collaborative project between SEFSC and AOML.
- Dynamic downscaling of IPCC-AR4 simulations is performed by AOML scientists and is applied to bluefin tuna spawning habitat model developed by SEFSC scientists [Muhling et al. 2011 ICES_JMS & Liu et al. 2012 JGR].

AOML Key Findings:

PHOD houses a great number of critical observational platforms that are being used to evaluate models and determine physical processes of climate variability.

Analysis done using these observations shows that models don't reproduce the observations particularly well (e.g. seasonal cycle in heat transport, fresh water transport in the SA, changes in deep water properties, phasing of AMO and the tropical thermocline).

Our studies show that large-scale climate phenomena can provide favorable conditions for extreme weather events and changes to ecosystems (tornadoes, hurricanes, rainfall, dust, stock assessments, etc).

The Future:

Improving Observations: Deep Argo, climate quality XBTs, data retrieval systems from moorings, South Atlantic MOC

Testing Models: Confronting models with available observations

Evaluating observing systems to make more cost effective (OSE, OSSE, etc)

Model improvements/evaluations for different time scales (seasonal to decadal and longer)

Hierarchy of models to test hypotheses of physical processes

PHOD will continue to show critical value of the observing system