National Oceanic and Atmospheric Administration
Atlantic Oceanographic and Meteorological Laboratory
Physical Oceanography Division
2011 Science Retreat

Miami, FL
15-16 February 2011

National Oceanic and Atmospheric Administration
Physical Oceanography Division
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Executive Summary

The Physical Oceanography Division (PHOD) of NOAA/AOML gathered together on March 15 and 16 to discuss the status of science for PHOD's main research areas:

- Atlantic Meridional Overturning Circulation
- Tropical Atlantic Variability
- Oceans and Ecosystems
- Oceans and Weather
- General Physical Oceanography

Scientists with AOML's Hurricane Research and Ocean Chemistry divisions also attended the retreat, as well as invitees from external institutions. A total of 26 presentations were made.

An overview prepared by the presenter of each talk follows this summary. Presentations and discussions emphasized the interdisciplinary, multiplatform, and multi-institutional nature of all projects carried out at the divisional level within these five areas of research. In addition, the contribution of research studies to operational oceanography was presented and emphasized.

This two-day workshop only partially covered the research conducted by PHOD. Several current research topics, e.g., advances in engineering, support of the Deepwater Horizon incident, and global trends in environmental parameters, were omitted because of having been recently presented at other workshops. PHOD's refereed publications and research as presented on the division's web pages provide a complete record of the science carried out by the division.

The advancement of knowledge requires constant interaction between scientists and science support personnel within the organization and with extramural members of the division. To this end, PHOD researchers and science support personnel shared their knowledge and expertise through numerous presentations. Invited guests from AOML's two other science divisions and from external institutions also made presentations and actively participated in discussions.

The first section of the retreat was dedicated to assessing how heat is redistributed throughout the world ocean and, in particular, the role of the Atlantic Ocean in this mechanism. Presentations included results and analysis obtained from observational arrays in the Atlantic Ocean, sustained observations, and model outputs. These studies, which are supported by a strong international effort, have AOML as a lead or key participant, such as the South Atlantic Meridional Overturning Circulation (SAMOC), RAPID/MOCHA/WBTS, and Ship Of Opportunity Program. Preliminary results from Observing System Simulation Experiments were also presented to explore the design and enhancement of the SAMOC observing system.

The second and fifth sections focused on the study of interannual to decadal variations in the tropical Atlantic, with special emphasis on the variability of current systems, the role of equatorial waves in mediating interannual variability, the role of Saharan dust in the Atlantic Meridional Mode, the role of the tropical Atlantic heat budget in sea level variations, and the contribution of real-time satellite data to supplement in situ observations. Critical areas for future work include the assessment of vertical temperature and salinity biases in models by using all available observational resources and, in particular, observations from moorings, Argo floats, and expendable bathythermographs.

The interdisciplinary aspects of PHOD's research were highlighted during sections three and four, with the majority of the presentations and discussions focused on the ocean's link to ecosystems and extreme weather events. The importance of observations was recognized as the foundation for creating a baseline or mean field to better assess the impact of extreme events, such as tropical cyclones, oil spills, and harmful algal blooms upon coastal ecosystems. Interdisciplinary ecosystem research and physical oceanography work conducted by PHOD has been enhanced over the past few years, particularly after a joint workshop was held in June 2009 with NOAA's Southeast Fisheries Science Center. New research related to the use of satellite observations and climate model outputs linking environmental parameters to fish catch and larval transports from short to long scales was presented. Novel studies on the role of the Atlantic Warm Pool on hurricane genesis indicate the need to further quantify the upper ocean thermal structure, which has been shown to play a key role in tropical cyclone intensification. The lack of an ocean-observing network in key regions, such as the Caribbean Sea and Gulf of Mexico, was also discussed.

This two-day workshop helped researchers identify new areas of common interest and establish a vision for the work ahead. Consequently, the success of this first-of-its-kind retreat has prompted PDOD to consider holding similar retreats annually during the winter months with the participation of invited scientists.

Gustavo Jorge Goni
Director
Physical Oceanography Division
Atlantic Oceanographic and Meteorological Laboratory
National Oceanic and Atmospheric Administration
4301 Rickenbacker Causeway
Miami, FL 33149
Email: Gustavo.Goni@noaa.gov
Tel: 305-361-4339

AGENDA

Day 1

8:45 – 9:00	Opening remarks/logistics/goals	G. Goni

Atlantic Meridional Overturning Circulation (AMOC)
Moderator = S.-K. Lee

9:00 – 9:20	Meridional overturning circulation variability	M. Baringer
9:20 – 9:40	Deep Western Boundary Current variability	C. Meinen
9:40 – 10:00	Deep Western Boundary Current variability and attribution in the North Atlantic	S. Garzoli
10:00 – 10:20	Errors in the volume transport estimate of the Florida Current at 27 N	R. Garcia
10:20 – 10:40	Break	
10:40 – 11:00	Variability of the meridional heat transport and overturning circulation in the South Atlantic	G. Goni
11:00 – 11:20	Differences in the meridional overturning circulation / meridional heat transport at 35S between observations and model simulations and their possible causes	S. Dong
11:20 – 11:40	Upward trend of the Atlantic meridional overturning circulation in the 20th century	S.-K. Lee
11:40 - 12:00	A study of the Atlantic meridional overturning circulation using HYCOM-based Atlantic OSSEs	H. Yang
12:00 – 13:10	Lunch	
13:10 – 14:00	AMOC Discussion	

Tropical Atlantic Variability (TAV)
Moderator = R. Perez

14:00 – 14:20	On the interannual NECC variability	V. Hormann
14:20 – 14:40	African dust and the Atlantic Meridional Mode	G. Foltz
14:40 – 15:00	Interannual variations of tropical instability waves	R. Perez
15:00 – 15:20	Break	
15:20 – 15:40	What can XBT and altimetry data tell us about the variability of the equatorial current system	M. Goes
15:40 – 16:00	Sea level anomaly trends in the South Atlantic around 10N	E. Campos
16:00 – 16:50	TAV Discussion	

Day 2

Oceans and Ecosystems
Moderator = L. Johns

9:00 – 9:20	Sea surface temperature, salinity, and chlorophyll variability in the Florida Keys and surrounding coastal waters	L. Johns
9:20 – 9:40	Florida Bay sea level response to local wind forcing	N. Melo
9:40 – 10:00	Volume transport across the USVI coastal shelf	R. Smith
10:00 – 10:20	Break	
10:20 – 10:40	Future impact of weakening AMOC on the Loop Current in the Gulf of Mexico	Y. Liu
10:40 – 11:00	Long-term ocean variability in ecosystems in the Gulf of Mexico: mesoscale circulation and physical-biological coupling from altimetry satellite derived observations	D. Lindo
11:00 – 11:50	Discussion	
11:50 – 13:00	Lunch	

Oceans and Weather
Moderator = G. Goni

13:00 – 13:20	Progress in climate research for the Intra-Americas Sea region	D. Enfield
13:20 – 13:40	Relationships of the Atlantic Warm Pool with hurricanes and the AMOC	C. Wang
13:40 – 14:00	Idealized model analysis of the impact of ocean coupling on hurricane intensity forecasts	G. Halliwell
14:00 – 14:20	IPCC simulations of the Atlantic Warm Pool and associated climate impacts	H. Liu
14:20 – 14:40	Break	

General Physical Oceanography
Moderator = R. Lumpkin

14:40 – 15:00	Forecasting the distribution of floating debris using surface drifter observations	R. Lumpkin
15:00 – 15:20	Three-dimensional circulation from Argo data	C. Schmid
15:20 – 15:40	Mechanisms of Pacific climate variability inferred from 55 years of sea level station data	P. Di Nezio
15:40 – 16:00	An improved method for estimating oceanic uptake of anthropogenic CO_2	C. Thacker
16:00 – 16:50	Discussion	
16:50 – 17:00	Closing remarks	G. Goni

List of Participants:

Robert Atlas (OD)
Sim Aberson (HRD)
Diana Aranda
Francis Bringas
Molly Baringer*
Edmo Campos* (University of Sao Paulo, Brazil)
Pedro Di Nezio*
Shenfu Dong*
David Enfield*
Rana Fine (University of Miami)
Gregory Foltz*
Elizabeth Forteza
Rigoberto Garcia*
Silvia Garzoli*
Marlos Goes*
Gustavo Goni*
George Halliwell*
Jay Harris
Verena Hormann*
Elizabeth Johns*
John Lamkin (NMFS)
Sang-Ki Lee*
Alan Leonardi (OD)
David Lindo*
Hailong Liu*
Yanyun Liu*
Rick Lumpkin*
Roberta Lusic
Frank Marks (HRD)
Chris Meinen*
Nelson Melo*
Mayra Pazos
Renellys Perez*
Claudia Schmid*
Ryan Smith*
Carlisle Thacker*
Chunzai Wang*
Rik Wanninkhof (OCD)
Haoping Yang*

* = Oral presentation
HRD= NOAA AOML Hurricane Research Division
NMFS = NOAA National Marine Fisheries Service, Southeast Fisheries Science Center
OCD = NOAA AOML Ocean Chemistry Division
OD= NOAA AOML Office of the Director

Atlantic Meridional Overturning Circulation (AMOC)

Atlantic Meridional Overturning Circulation
Presented by Molly Baringer

This talk described ongoing work to describe, understand and predict the meridional overturning circulation as led by the interagency science advisory group sponsored by NSF, NOAA and NASA. The meridional overturning circulation (MOC) is the warm and salty water that spreads in the North Atlantic that is cooled primarily by evaporation, sinks to the deep ocean and forms the North Atlantic Deep Water (NADW). The closed loop of circulation completed by NADW flowing southward along the Americas, and around the world, globally upwelling, until finally entering the South Atlantic at the intermediate water level south of Africa and returning to the deep water formation regions is coined the Atlantic MOC or AMOC. Recent increases in funding sparked in part by the JSOST declaration that the AMOC is a near-term priority for increased research has led to the creation of this interagency group geared towards three central questions: 1) The design and implementation of an AMOC monitoring system, 2) An assessment of AMOC's role in the global climate, and 3) An assessment of AMOC predictability. Progress has been made on the design of future observing systems not yet implemented and has substantially increased visibility and research into understanding AMOC variability, predictability and impacts; this talk summarized the results from the only in situ observations of the AMOC to date: the MOC/Rapid/Mocha/WBTS program at 26°N, the Argo/Altimetry analysis at 41°N, and the NADW array that measures the lowest limb of the AMOC at 16°N. This talk highlighted some of the differences among these data sets (seasonal cycles that are out of phase) and similarities (e.g. the lack of a significant trend in AMOC transport at 26°N and 41°N due to the opposite trends in interior transport and Ekman transport).

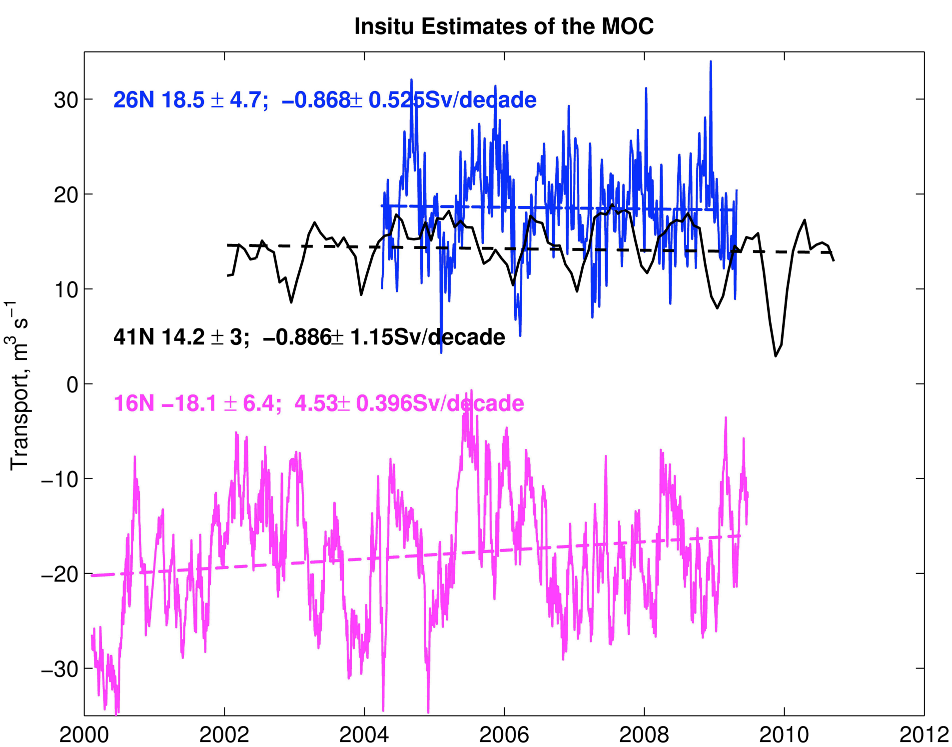


Figure. Updated results from the in situ observations of the AMOC: the MOC/Rapid/ Mocha/ WBTS program at 26°N (blue), the Argo/Altimetry analysis at 41°N (black), and the NADW array that measures the lowest limb of the AMOC at 16°N (pink).

Deep Western Boundary Current Variability
Presented by Christopher Meinen

The Deep Western Boundary Current (DWBC) in the Atlantic Ocean is believed to carry the bulk of the cold lower limb of the Meridional Overturning Circulation (MOC). Variability of the DWBC has been studied nearly continuously at 26.5°N since 1984 – in 2004 the confluence of three programs has resulted in what is most likely the most highly resolved observing system for measuring the DWBC ever deployed. This presentation highlighted the results to date of an ongoing analysis of five years of data from these combined programs. The key results so far are: 1) the variability of the DWBC transport near the continental slope is quite high (std > 15 Sv), with variations occurring on time scales ranging from a few days to a few months; 2) the variability of the transport in the DWBC layer significantly exceeds that of the MOC as a whole, even if the transport is calculated in this layer all the way out to the western side of the Mid-Atlantic Ridge; and 3) there is no significant correlation between the transport in the deep (800-4800 dbar) layer in the western sub-basin of the Atlantic and the basin-wide MOC transport integrated in the upper layer, suggesting some communication between the deep layers on either side of the Mid-Atlantic Ridge despite the topographic blocking. Future work on this project will focus on further analysis of the observed deep signals with the aims of attribution and understanding. The study will also to continue to evaluate the strengths and weaknesses of the different observing systems being used in order to provide information for the design of a long-term observing system for the MOC at this location.

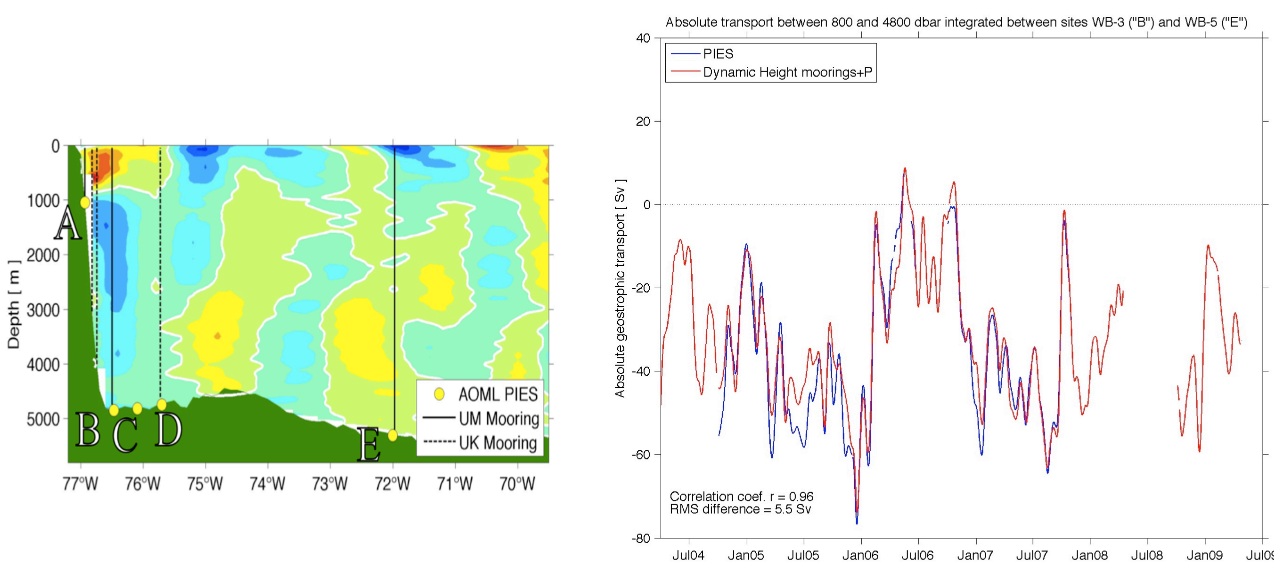


Figure. Left – Schematic illustrating a vertical section of meridional velocity along the WBTS-Abaco line with the locations of the WBTS pressure-equipped inverted echo sounders (PIES) and the tall, taut-line, dynamic height moorings deployed as part of the US MOCHA and UK RAPID-MOC programs. Right – Time series of absolute volume transport determined geostrophically between either the PIES (blue line) or the tall moorings (red line) at the B and E sites. Time series have been smoothed with a 30-day low-pass filter. Correlation coefficient and root-mean-square difference are noted on the figure.

Deep Western Boundary Current Variability and Attribution in the North Atlantic
Presented by Silvia Garzoli

The displacement of the core of the deep western boundary current (DWBC) at 26°N in the North Atlantic has been the subject of discussion and interpretation since the observations started in the early 90's. The observed "reversal" or offshore shifts of the DWBC core near the western boundary has been attributed to meandering of the core or pulsations of the current. To further analyze the causes of this variability three inverted echo sounders (IES) were deployed between the core array sites D and E (see Meinen, previous presentation) for a period of two years (September 2006 to September 2008). The available data from the whole array during that period of time is being analyzed in conjunction wit the product of the Ocean General Circulation Model for the Earth Simulator (OFES) model to further interpret the results. The main results from the height frequency analysis of the records can be summarized as follows: The empirical orthogonal function analysis of the series indicates a decoupling of the volume transport variability west of 75.5°W (mode 1, 48% of the total variance) with the one observed east of that site. The spectral and cross-spectral anaysis of the series show oscillations at all sites at periods in the bands 15-18 and 25-30 days coherent with the local winds indicating forced oscilation. Strong peaks in the energy are also observed at all sites centered in the 70 to 90 day period band and between 180-220 days (semiannual period). Westward propagation is observed for periods centered at 70 days at 5 to 7 cm/sec that could be attributed to propagating eddies or barotropic Rossby waves. The pressure records and dynamic height records are uncorrelated at periods larger than 50 days, confirming previous results that indicated that barotropic and baroclinic fields are not correlated. The results of the joint analysis of data and model products does not confirm meandering of the DWBC nor pulsation. The variability of the core of the DWBC can be attributed to an eastward displacement due to a westward propagation of eddies or baroclinic waves. The displacement of the core is observed both in the upper layer (0 to 800m) and in the deeper ocean at the DWBC core level (800 to 4800 m), indicating that it is barotropic.

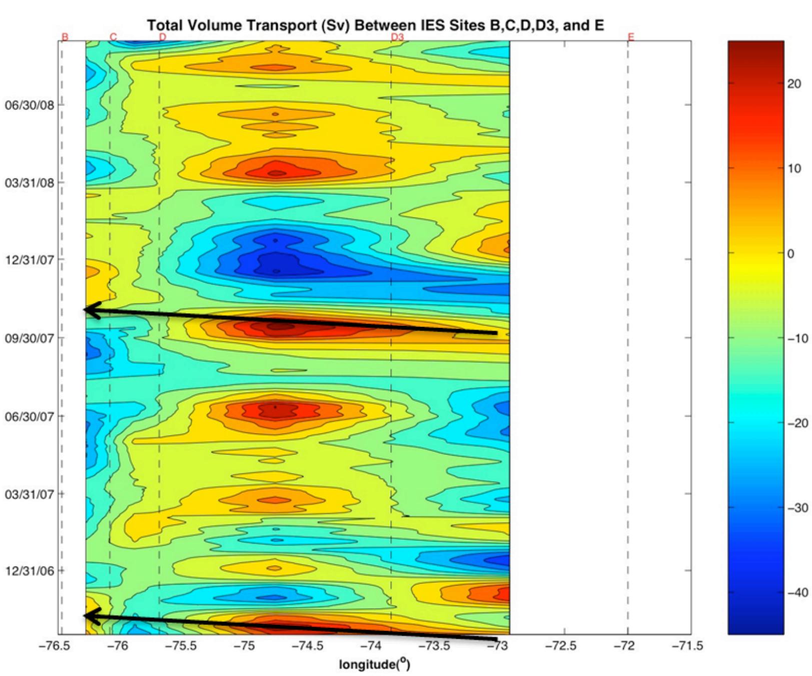


Figure. Time series of volume transport between the sites estimated from the IES . The arrows indicate observed westward propagation from the interior of the basin.

Errors in the Volume Transport Estimate of the Florida Current at 27° N
Presented by Rigoberto Garcia

The Florida Current represents both the western boundary current for the subtropical wind-driven gyre as well as a return pathway for the Atlantic Meridional Overturning Circulation (MOC). The Florida Current program is part of the Western Boundary Time Series (WBTS) project, to monitor the transport variations of the current using a submarine cable and snapshot estimates made by shipboard instruments. Calibration of the cable voltages into volume transport is done via comparison with ship section data collected using a dropsonde float, which is a free-falling float that carries a GPS receiver. The methods of processing and tide correction for the dropsonde float observations, and the error of the transport estimates inherent to the dropsonde system were presented. Future work on this project will focus on the evaluation of the accuracy of the transport estimate associated with the tidal correction.

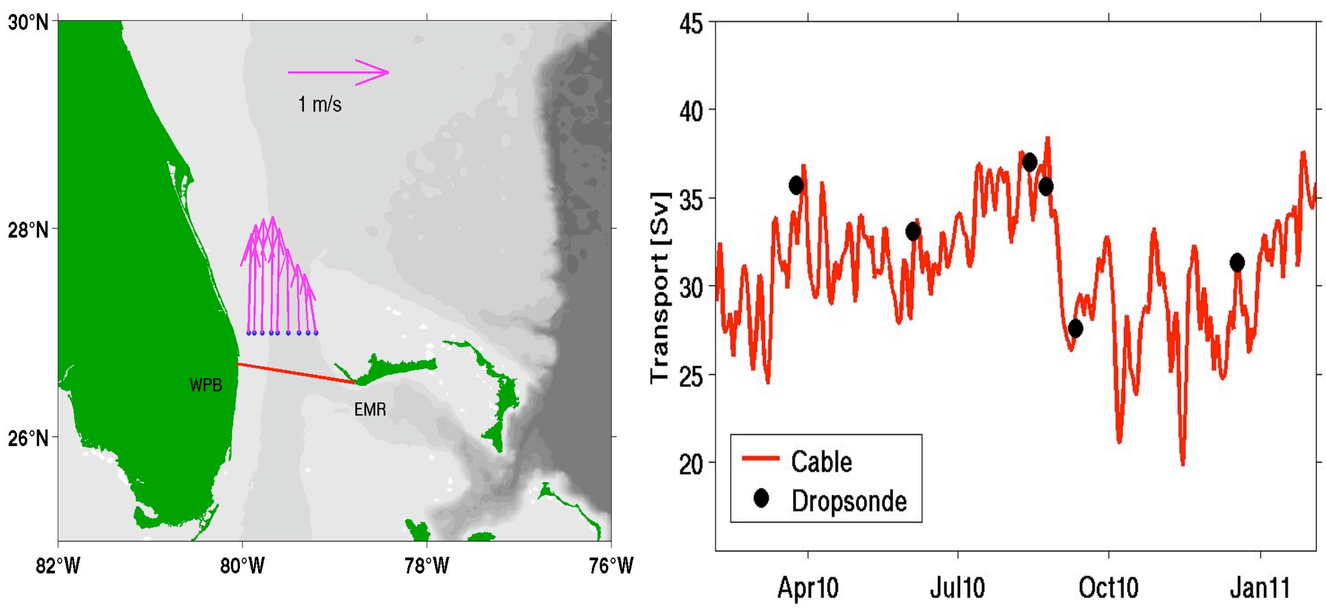


Figure. Map of the Straits of Florida study area (left). Red line indicates approximate cable location between West Palm Beach, Florida (WPB) and Eight Mile Rock, Bahamas (EMR). Blue circles denote locations of the long-term dropsonde and Pegasus stations. Magenta vectors indicate average vertical-mean horizontal velocities from all dropsondes collected since 1991. Most recent year of Florida Current transports from cable and dropsondes (right).

Variability of the Meridional Heat Transport and Overturning Circulation in the South Atlantic
Presented by Gustavo Goni

Studies using eXpendable BathyThermographs (XBTs) deployed along a zonal transect at nominally 35°S since 2002 have shown that the geostrophic component of the circulation dominates the net meridional heat transport (MHT) and that, at the seasonal time scale, the geostrophic and Ekman components of the circulation are out of phase. Further analysis of these data has shown that the variability of the Meridional Overturning Circulation (MOC) is similarly very weak on seasonal time scales. Both in situ observations and numerical model simulation have also shown that the MOC in the South Atlantic has important contributions not only from the boundaries (Agulhas and Brazil-Malvinas Confluence regions) but also in the ocean interior. This presentation showed the use of blended satellite altimetry observations together with XBT and Argo profiling float data to investigate the year-to-year variability of the MHT and MOC along 35°S since 1993. The barotropic and baroclinic components are extracted from the altimetric and hydrographic records using a methodology demonstrated previously in the Brazil-Malvinas Confluence region (Goni et al., 1996). The barotropic contribution to the MHT and MOC are validated using a short record of three bottom pressure sensors (PIES) deployed in the South Atlantic at 35°S in 2009-2010, while the baroclinic component will be validated by the XBT-derived MHT and MOC estimates. Results obtained from this study demonstrate the importance of satellite altimetry observations for MOC studies in the South Atlantic Ocean and in particular to extend the in situ observational record for the longer time scales needed for understanding climate dynamics.

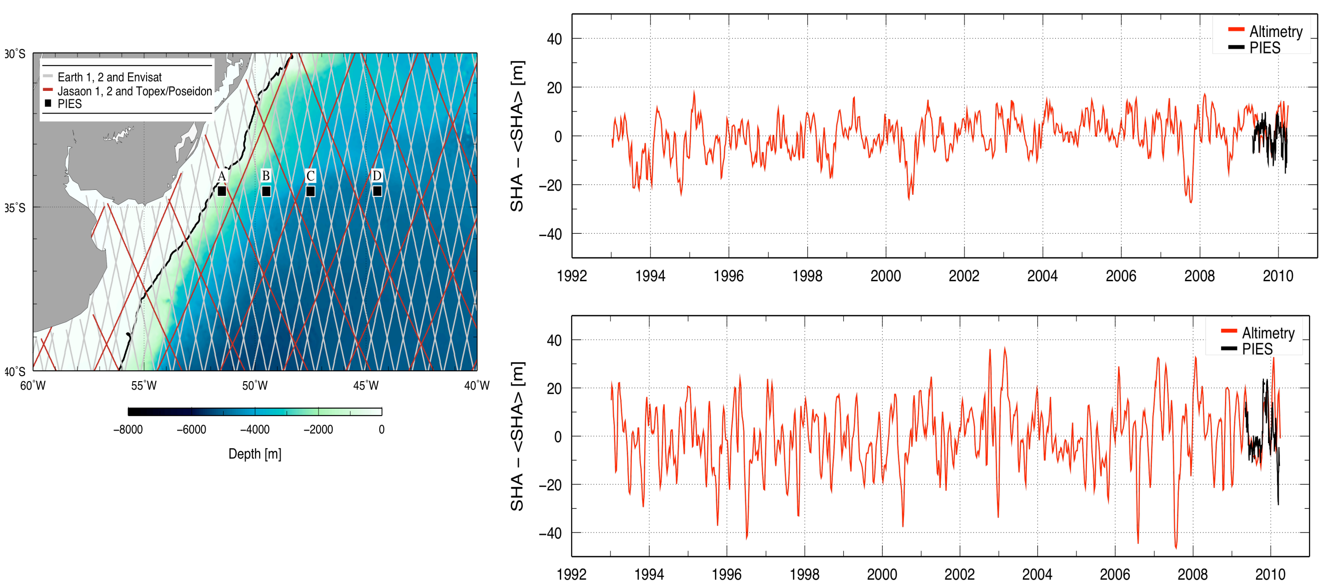


Figure. (left) Location of four PIES sites (circles) and altimeter groundtracks (white and red lines) with bathymetry as the color background and 1000 m isobath (black line). Time series of altimetry-derived sea height anomalies (red lines) and inverted echo sounder-derived dynamic height for sites A (top right) and B (bottom right).

Importance of the Argo Float Measurements in Assimilating Meridional Overturning Circulation in the South Atlantic
Presented by Shenfu Dong

The meridional overturning circulation (MOC) and meridional heat transport (MHT) from the GFDL coupled models with and without data assimilation (GFDL CM2.1, GFDL-CDA) are examined and compared with observations at 34°S in the South Atlantic. Both models show similar correspondence between MHT and MOC changes as estimated from observations: one Sverdrup increase in MOC would give a 0.05 PW increase in MHT. The MOC and MHT, as well as regional contributions from the GFDL couple data assimilation (CDA) before Argo float profiles assimilated are similar to those from GFDL CM2.1 IPCC simulation, both give weak boundary currents and strong interior overturning transports compared to observations. However, the performance of the data assimilation model is greatly improved in terms of representing the observed MOC and MHT zonal structure at 34°S after Argo profiles were assimilated. The transports of boundary currents and interior region are comparable to observations, with much stronger and deep-reaching boundary currents and reduced interior overturning flow (Figure). The strong interior transports in GFDL CM2.1 and GFDL-CDA before Argo era is possibly related to the bias in the salinity fields.

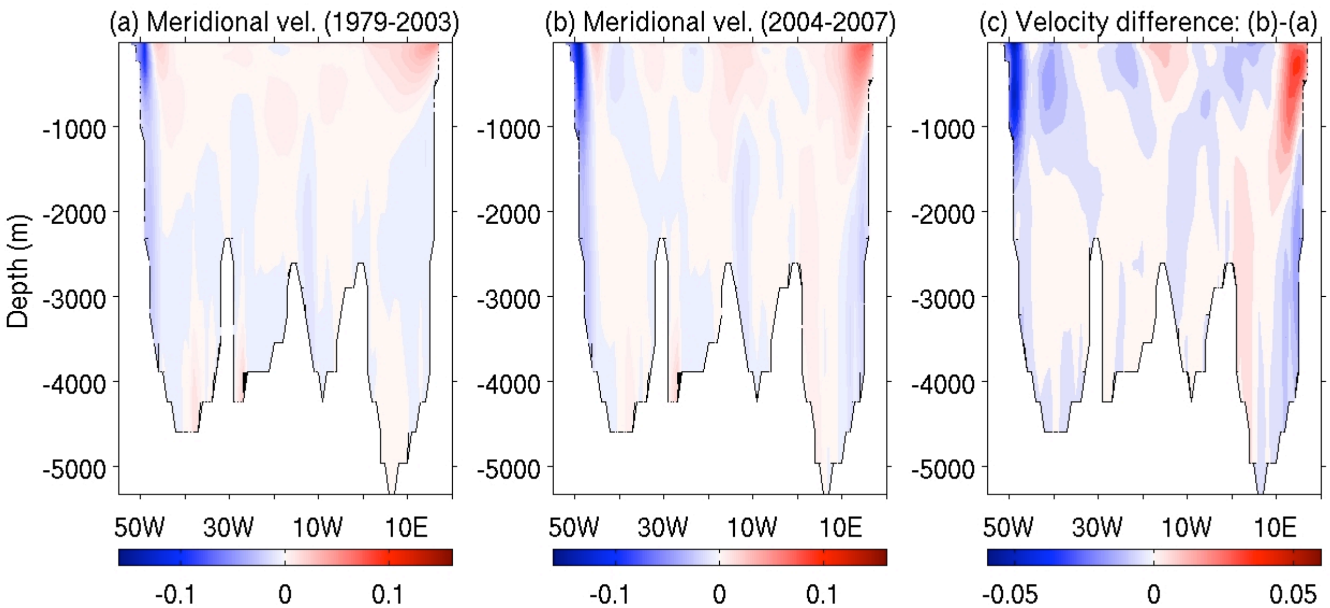


Figure. Meridional velocity at 34°S from GFDL coupled data assimilation (CDA) averaged between (a) 1979-2003 and (b) 2004-2007. (c) Differences of the meridional velocity, (b) minus (a). Units are m s^{-1}.

Atlantic Meridional Overturning Circulation Variability in the 20th Century Simulated by CCSM3 POP
Presented by Sang-Ki Lee

Instrumental records indicate that the heat content of the Atlantic Ocean in the upper 3000m has been increased during the later half of the 20th century at a rate almost matching that of the Pacific and Indian Oceans combined (Levitus 2000). This is quite surprising because the Atlantic Ocean covers less than 20% of the global ocean in surface area. Climate model experiments with and without anthropogenic greenhouse forcing have shown that the observed warming of the Atlantic Ocean since the mid-20th century could be largely attributed to the anthropogenic greenhouse effect (Levitus 2001; Reichert et al. 2002). However, since there is no apparent reason to expect that the sea surface warming associated with the anthropogenic greenhouse effect is particularly larger over the Atlantic Ocean, a question still remains as to why the warming trend of the Atlantic Ocean is substantially larger than that in other ocean basins. Perhaps, the answer to this conundrum can be found in the Atlantic Meridional Overturning Circulation (AMOC), which is a unique thermohaline circulation feature in the Atlantic basin and an important component of the great ocean conveyor (Broecker 1987). Since the AMOC carries oceanic heat northward from the Southern Ocean to the Artic Ocean and thus maintains the warmth of the Atlantic Ocean, it is hypothesized here that the AMOC and the associated northward oceanic heat transport may have been increased in recent decades. The global ocean-ice coupled model of the NCAR Community Climate System Model version 3 (CCSM3 POP) is forced with the 20th century reanalysis (20CR) for the period of 1871-2008. Preliminary analysis of the 138-year model run suggests that the simulated AMOC is steadily increased during 1960s-2000s, due to the increased Ekman transport from the Southern Ocean associated with the much increased Southern Annular Mode (SAM) since the mid-20th century. Further model experiments are required to explore and quantify the role of eddy-induced mass and heat transport from the Southern Ocean because the version of CCSM3 POP used in this study is non eddy-resolving.

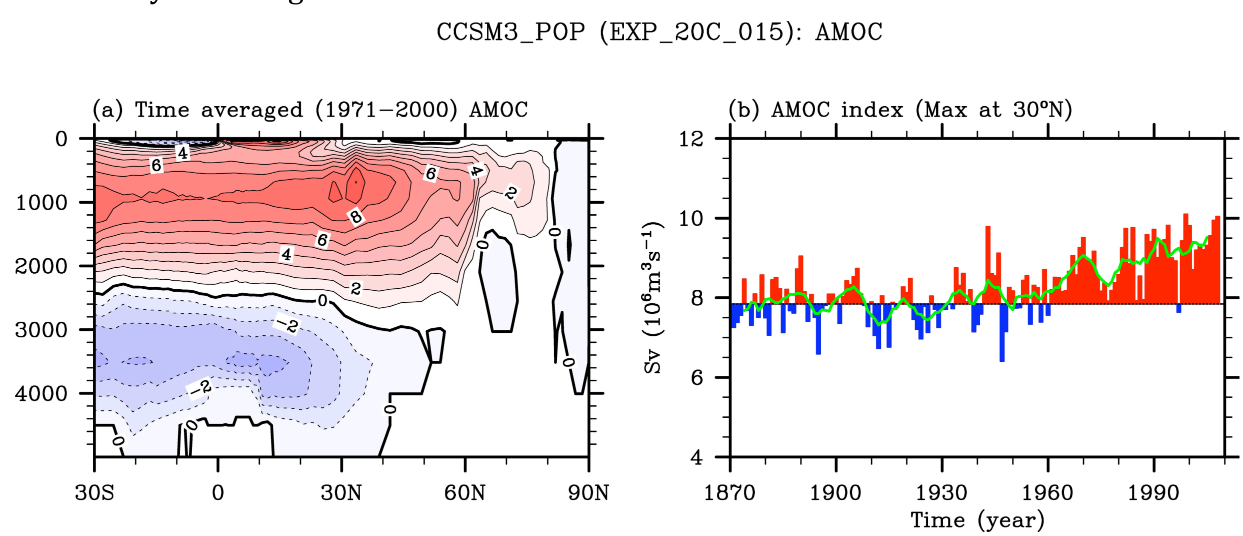
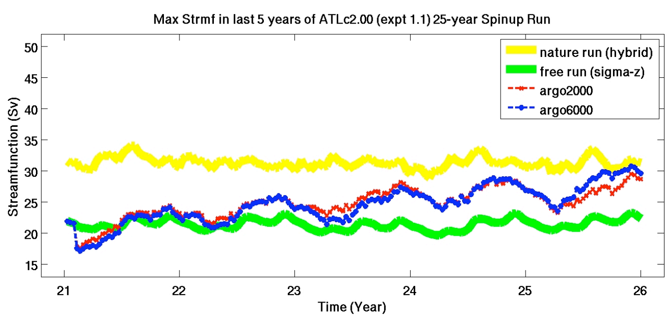


Figure. CCSM3 POP-simulated AMOC: (left) time-averaged AMOC for 1971-2000; (right) time series of maximum stream function at 30N.

A Study of AMOC using HYCOM-based Atlantic OSSEs
Presented by Haoping Yang

Due to the large uncertainties existing in the present-day ocean models on the representations of meridional transport and heat flux, suitable nature runs are difficult to produce to perform the classical Observing System Simulation Experiments (OSSEs). As an early effort towards the long-term goal of designing optimal observing strategies to monitor changes in AMOC, a series of HYCOM-based fraternal twin "demonstration" OSSEs are performed in a low-resolution Atlantic Ocean domain to validate the performance of our new data assimilation and OSSE software toolboxes. Two HYCOM models, with different configurations, serve as the nature-run and the operational models, respectively. In these demonstration OSSEs, HYCOM is bundled with SESAM (an integrated SystEm of Sequential Assimilation Modules) where the SEEK (Singular Evolutive Extended Kalman) filter is used for data assimilation. Synthetic observations sampled from the nature run are assimilated into operational model runs with a 10-day update cycle. To verify software performance, different choices for the nature-run and operational models are tested. Performance is systematically examined for various model configurations and a wide range of observing systems including Jason-2, MCSST, ARGO-2000 and ARGO-6000 (ARGO-6000 samples synthetic data from sea surface to the bottom of ocean) profiles, volunteer ships, etc. Many important features associated with the AMOC are calculated and evaluated from these OSSE tests. Also, the evolution of RMS errors is analyzed for the user-defined state vector. Results obtained from our OSSEs have demonstrated error reductions in the assimilative operational model runs with respect to the "truth" (nature-run simulation), with two examples for ARGO float assimilation shown in the figures below. This study is one part of a comprehensive effort to develop and validate a full ocean OSSE capability at AOML.



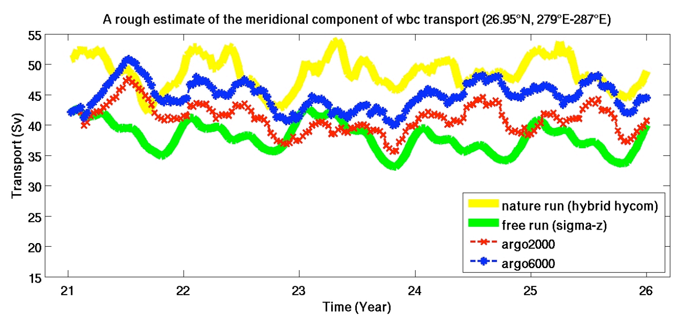


Figure: Evolution of the maximum overturning stream function (left) and the meridional component of the western boundary current evaluated at 27°N (right) in the last five years of a spinup run, where the nature-run model (yellow) uses the standard HYCOM hybrid coordinates and the operational model (green, blue, red) uses sigma-z coordinates. Curves in yellow and green are from non-assimilative runs. The operational model run assimilated with argo6000 (blue) performs better than the one assimilated with argo2000 (red) on the representation of the nature run.

Tropical Atlantic Variability (TAV)

On the Interannual North Equatorial Countercurrent (NECC) Variability
presented by Verena Hormann

While the Atlantic NECC, located at about 6°N, is quite well studied on seasonal time scales since the early 80's (e.g. Garzoli and Katz 1983), this is not the case for its interannual variability. On interannual to decadal time scales, tropical Atlantic variability (TAV) is thought to be dominated by two distinct modes of coupled ocean-atmosphere behavior: the thermodynamic meridional mode and the dynamic zonal mode, respectively (e.g. Chang et al. 2006). The first objective here is to investigate interannual NECC fluctuations related to TAV and then (future work) to quantify possible implications of the observed NECC variability. This study is based on a synthesis product of the surface geostrophic circulation (derived from drifter trajectories, NCEP winds, and AVISO sea level anomalies) that reveals a good performance in the NECC region. The NECC shows a large variability on multiple time scales, with a strong annual cycle and evidence of interannual fluctuations. A complex EOF decomposition of the interannual NECC variability and subsequent regression analyses indicate a relation between NECC fluctuations and TAV with involvement of westward propagating Rossby waves.

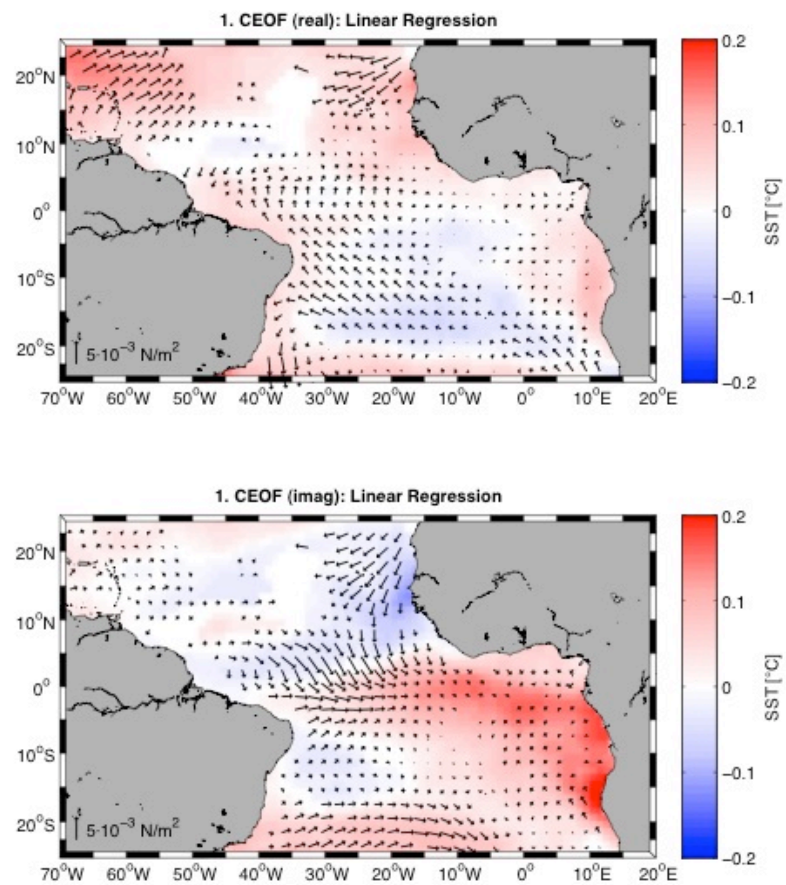


Figure. Linear regression of interannual SST [Reynolds et al. 2002] and wind stress [derived from CCMP ocean surface winds: Atlas et al. 1996] anomalies onto the first complex EOF, describing interannual variations of the NECC (values shown only where significant at 95% level).

African Dust and the Atlantic Meridional Mode
presented by Gregory Foltz

The Atlantic Meridional Mode (AMM) is the dominant source of coupled atmosphere–ocean variability in the tropical Atlantic, characterized by a hemispheric sea surface temperature (SST) gradient and cross equatorial surface winds that reinforce SST anomalies in both hemispheres. Although the wind-evaporation-SST (WES) feedback reinforces the existing meridional SST gradient when either phase of the AMM is excited, the AMM is thermodynamically damped and thus requires external forcing to persist as is observed. However, there is little consensus as to what physical mechanisms may excite the AMM and thus govern regional coupled climate variability. Here we use observations and a physical model to show that the AMM is excited by variability in African dust outbreaks via the dust radiatively-forced SST anomalies on interannual to decadal time scales. Our analysis suggests that SST anomalies resulting from the aerosol direct effect persist in time via the WES feedback that defines the AMM. We conclude that the AMM and the state of the tropical Atlantic are directly tied to land surface processes over West Africa via dust emission. These results suggest that human activity may already be altering regional climate due to land use change and underscore the importance of resolving uncertainty in modeling land surface processes and dust emissions in order to estimate the regional response to future climate change.

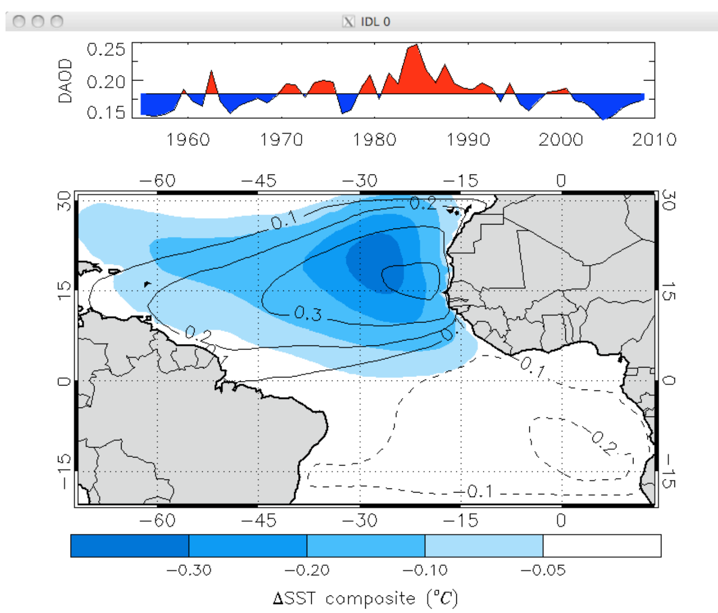


Figure. Time series of dust optical depth (top), and spatial properties of the Atlantic Meridional Mode and high dust minus low dust SST composite difference (bottom). At top: the annual time series of dust optical depth (DAOD) is averaged over the region 10-20°N and 20°-50°W. Dust optical depth is a measure of the extinction of light through the dust layer and is proportional to mass concentration. At bottom: contours are the regression of SST (°C) onto the leading mode of a maximum covariance analysis applied to reanalysis SST and lower-level winds over the domain 19°S–30.5°N and 71°W–13°E. Shading denotes composite differences of SST and demonstrates the similarity between the AMM spatial pattern and the region over which changes in dust cover force SST variability.

Interannual Variations of Tropical Instability Waves
presented by Renellys Perez

The cross-equatorial structure of zonal currents in the central equatorial Atlantic has been described by observations, but much less is known about the meridional and vertical currents. Horizontal advection and entrainment by these currents play an important role in the equatorial Atlantic cold tongue surface mixed layer heat balance. The equatorial circulation is significantly modified by winds and transient phenomena such as westward propagating tropical instability waves (TIWs). The intensity of a TIW season can vary dramatically, and we want to understand the mechanisms that are responsible for modulating its intensity. In this analysis, the variance of TMI sea surface temperature from TMI and AVISO merged sea level anomalies are studied on TIW relevant time scales (10 to 60 days) and length scales (4˚ to 12˚ longitude) from 1998 to 2010 along five different latitudinal bands centered at 5˚S, 2˚S, 0˚, 2˚N, and 5˚N. This variability is related to three indices: the ATL3 SST index derived from TMI SST (as in Wu and Bowman 2007) and wind divergence and curl indices derived from QuikSCAT wind stress. We find that there have been consecutive years of high (early 2000s) and low (2006-2008) TIW intensity. While the ATL3 index continues to explain the variability at 2˚N, wind-based indices perform much better at the equator and 5˚N. SST and SLA measures of TIW variance agree well with one another, but further work is needed to separate the two different types of TIW phenomena that manifest themselves at different latitudes (equatorward of ±2˚ vs. centered at ±5˚ latitude). Model products will be used to explore the role of ocean dynamics in setting the strength of a given TIW season.

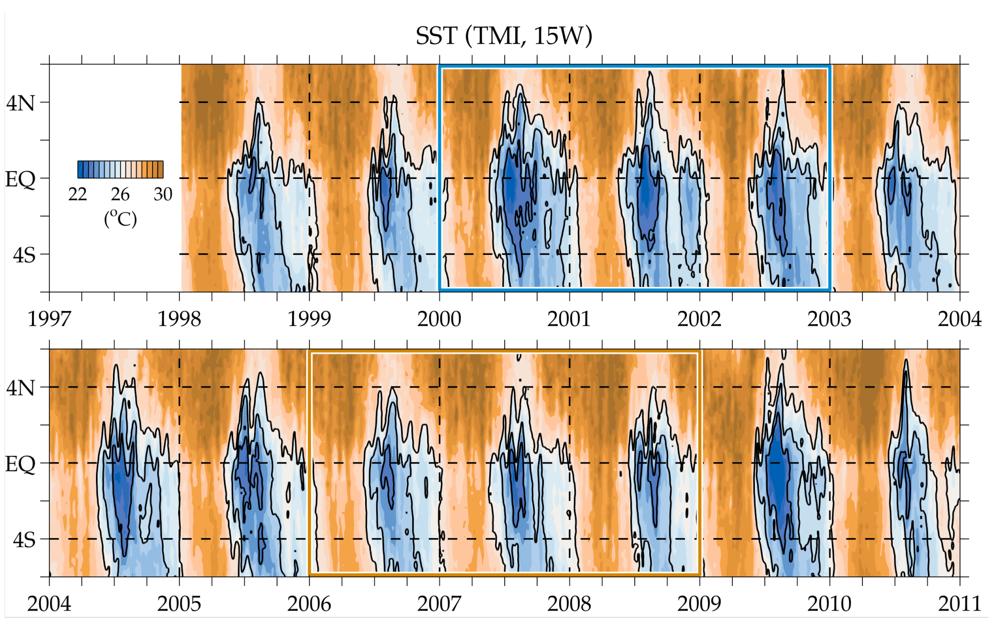


Figure. Latitude-time plot of TMI SST along 15˚W from 1998 to 2010. A two-week low-pass filter was applied to the data. Black contours indicate 23.5˚C, 25˚C, and 26.5˚C isotherms.

What can we learn about the Tropical Atlantic Ocean from XBT's?
Presented by Marlos Goes

The tropical Atlantic Ocean current system is of great importance for both inter-hemispheric and west-to-east exchange of heat and nutrients, and also impacts the climate and weather in the surrounding continental areas. In the present study we use data from the XBT transect AX8, which comprises almost 40 cruises across the equatorial Atlantic between the years 2000-2010, and altimetry to quantify the variability of this system. We determine the skill of these different observations on inferring the properties of the system, such as temperature variability of the location, depth, and strength of these currents. More specifically, we focus on the signature of the NECC and NEUC in these observations. The estimate of the dynamic height generated from the altimetry data is in general highly correlated with the one derived by XBT data, and agrees well over the position and strength of the NECC. However, the altimetry-derived estimate does not clearly present a signature of the NEUC. Therefore, this study emphasizes the need for both altimetry and XBT data on a long-term monitoring system of the region.

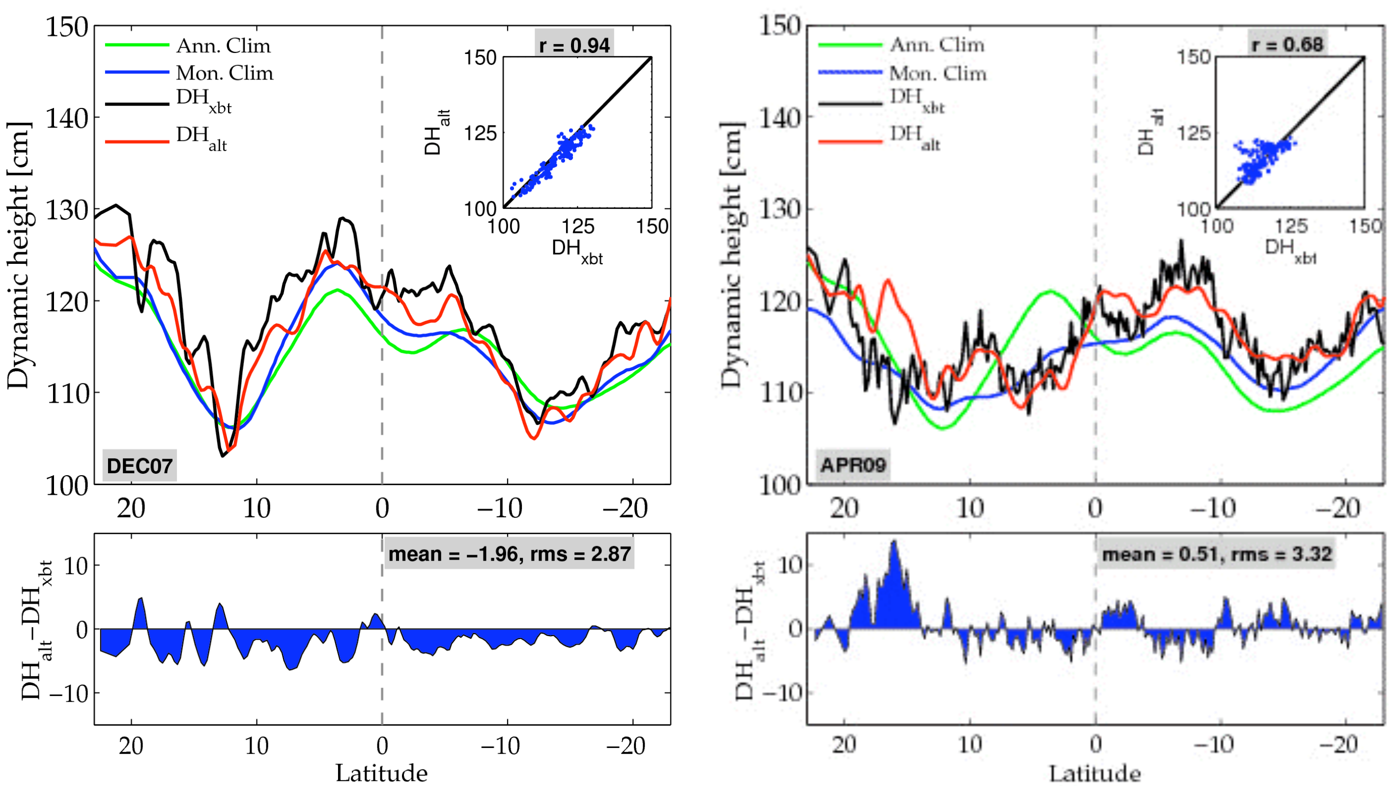


Figure. Left: Dynamic height relative to 800 m for annual climatology (green), monthly climatology (blue), XBT data (black) and altimetry data using annual climatology as mean field (red). The smaller plot on the side is the scatter plot showing the correlation between XBT and altimetry estimates. Right: residuals (altimetry-XBT) of the dynamic height for each latitude.

Sea Level Anomaly Trends in the South Atlantic around 10N
Presented by Edmo Campos

This presentation is a brief report of an ongoing investigation of regional trends in Sea Level Anomalies (SLA), focusing on the contribution of the steric component. The preliminary results show evidence that for the region around 10°S, in the Atlantic, the steric component cannot explain the altimetric SLA trends. On the western side of the region, the altimetric SLA trend is positive, while the steric SLA has a negative trend. In the eastern side, both SLA trends are positive, but the steric contribution is too small. Furthermore, the difference between altimetric SLA calculated on the western and on the eastern side has a negative trend. Since this quantity is proportional to the upper layer zonal transport, we show evidence that the subtropical gyre northward transport is decreasing at a rate of 0.06 Sv $year^{-1}$ (in the top 200 m). Although steric SLA cannot explain regional trends of altimetric SLA, it is able to explain 45% of the decrease of the subtropical gyre northward transport.

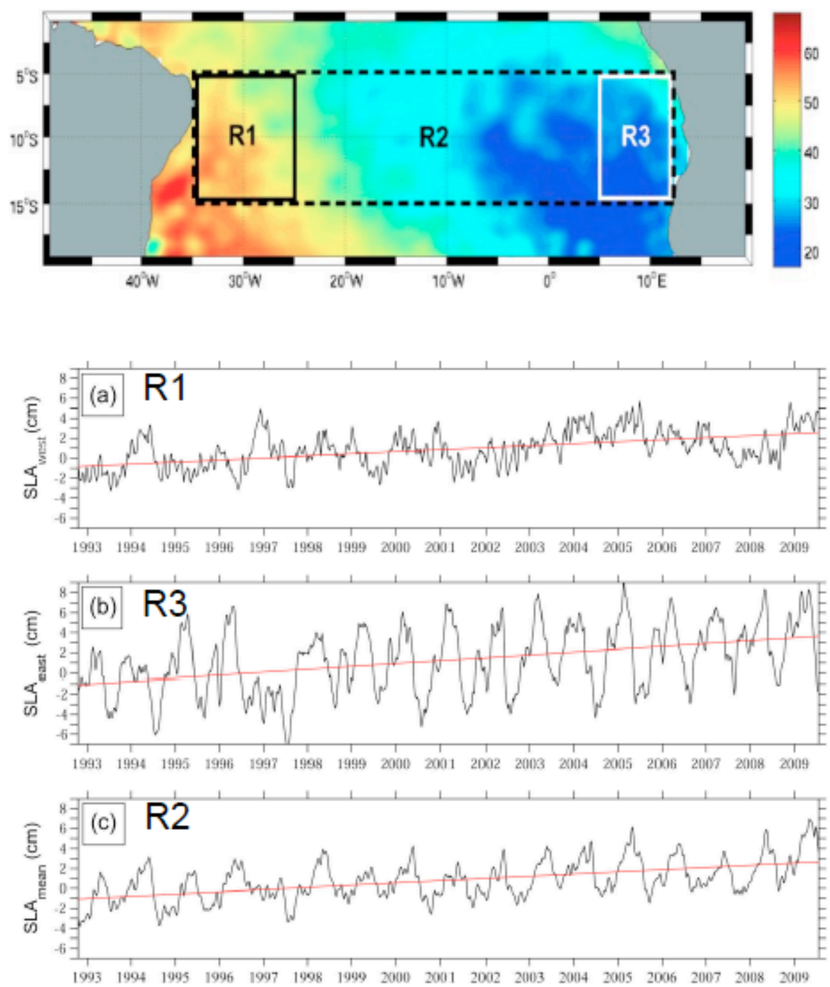


Figure: Sea Level Anomaly (SLA) trends, averaged in each of the three boxes R1, R2 and R3 indicated in the top panel.

Oceans and Ecosystems

Sea Surface Temperature, Salinity, and Chlorophyll Variability in the Florida Keys and Surrounding Coastal Waters
Presented by Elizabeth Johns

South Florida encompasses a broad range of ecosystems including the Everglades, mangrove shorelines, seagrass meadows, and coral reefs. These ecosystems contain a wide variety of wildlife including pelagic fish, benthic vertebrates and invertebrates, turtles, and marine mammals. Water quality affects all of the above, and our research addresses its basic state and variability on all time scales in response to natural and anthropogenic forcing. The surface properties of the Florida Keys coastal waters vary on a wide range of spatial and temporal scales in response to changing meteorological and oceanographic forcing as well as anthropogenic influences. The geographic proximity of the southwest Florida shelf, Florida Bay, Biscayne Bay, the southern estuaries, the Loop Current and the Florida Current all add to the observed variability in the Keys. This presentation uses data from nearly 15 years of interdisciplinary oceanographic cruises covering south Florida coastal waters to examine and quantify the mean and varying sea surface temperature (SST), sea surface salinity (SSS), and sea surface chlorophyll (CHL) in the Keys and adjacent coastal marine and estuarine waters to analyze their mean, seasonal and interannual patterns of variability. Extreme events in the parameter records are identified and put into a larger temporal and spatial context using the data time series within various sub-regions, and compared with regional satellite SST and ocean color imagery. Processes and events most relevant to the resource management of the Florida Keys National Marine Sanctuary (FKNMS) such as extreme high and low SST events over the coral reef, unusual freshwater river or canal outflows into surrounding waters, sudden or prolonged algal blooms, the sporadic arrival of anomalous water from remote sources such as the Mississippi River, and episodic low salinity or high salinity intrusions from Florida Bay through the Keys passages, are highlighted. Results obtained from this study show that south Florida surface temperature, salinity, and chlorophyll vary on a wide range of spatial and temporal scales. Extreme events dominate the time series. The Comprehensive Everglades Restoration and global climate change will likely affect the observed patterns of temperature, salinity and chlorophyll in south Florida coastal regions, bays, and estuaries. Sustained observations are necessary in order to identify and understand both natural and anthropogenic variability on all time scales.

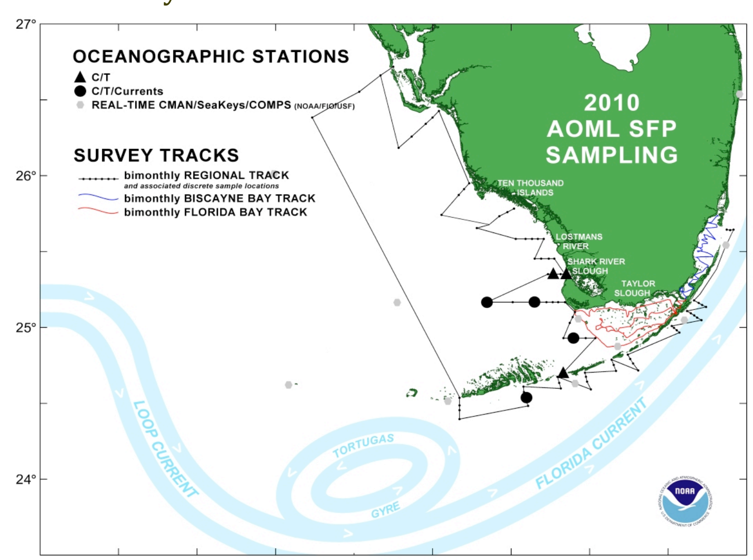


Figure. AOML's South Florida Program sampling configuration as of 2010. Bimonthly Bay-scale surveys are shown in red and blue, and bimonthly large-scale surveys are shown in black. Parameters measured during the surveys include temperature, salinity, chlorophyll, CDOM, nutrients, carbonate chemistry, and light transmission.

Florida Bay Sea Level Response to Local Wind Forcing
Presented by Nelson Melo

The response of sea level in the interior of Florida Bay to wind forcing during dry and wet seasons is shown with a computer-generated movie of subtidal sea level anomaly fields, combined with wind vectors from the Northwest Florida Bay COMPS station. Sea level records from the ENP Marine Monitoring Network, coastal gauge records from the USGS, and bottom pressure data from gauges deployed by RSMAS/AOML were filtered to remove tidal variations and then demeaned over the dry and wet seasons of 2001. The resulting sea level anomaly time series were optimally interpolated to produce sea level anomaly fields for Florida Bay every 12 hours, which were then combined in a continuous movie loop that also displays the subtidal wind vector on each scene. Florida Bay 2001 sea level is shown to be highly coherent and in-phase with local wind forcing. Largest sea level changes occur along the northern boundary where sea level rises (falls) of +/- 30 to 40 cm can occur with northward (southward) winds of 10 m/s. This response occurs as a direct setup (set-down) of sea level across the northern basins. Inter-basin coherency is high and sea level variations tend to be in-phase across the entire Bay. Prevailing winds from the southeast can also cause a setup of sea level along the northern boundary and a north to south sea level slope. Winds from the southwest and west cause sea level to rise to a greater extent in the northeast region of the Bay resulting in a positive sea level anomaly there. An example of the Bay's sea level set-up during northward winds is shown in the figure below. The locations of the sea level stations are shown as +'s. The resolution available from the monitoring network is sufficient to suggest that there can be significant sea level slopes in individual basins associated with strong wind forcing, in addition to a wider-scale subregional response. The movie can also be used to aid in determining the deployment locations of additional sea level stations in order to enhance the spatial resolution of the sea level fields.

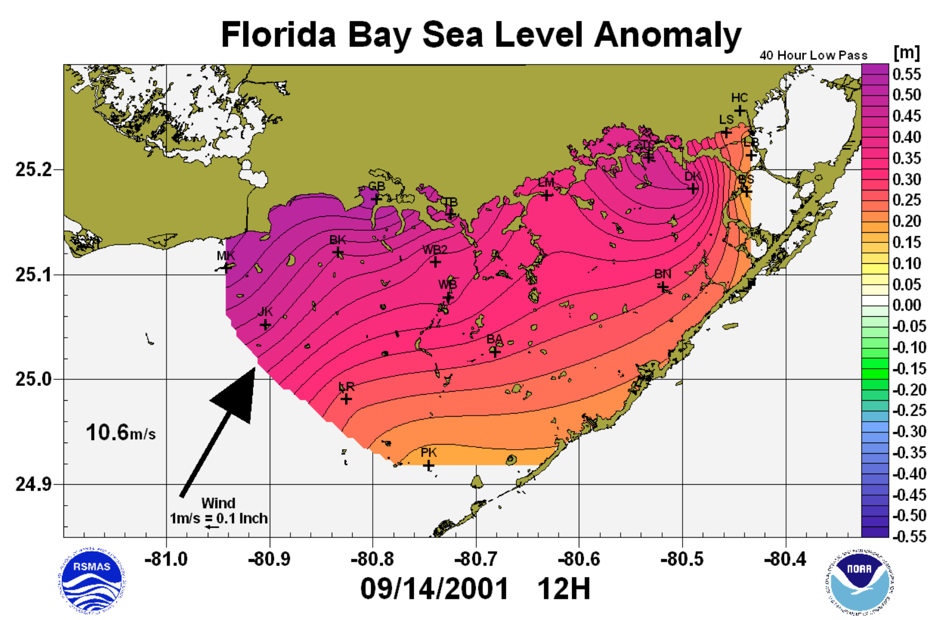


Figure. Scene from movie loop of Florida Bay sea level response to local wind forcing showing sea level rise along the northern coastal boundary due to northward winds.

Volume Transport across the USVI Coastal Shelf
Presented by Ryan Smith

Preliminary results from shipboard acoustic Doppler current profiler (SADCP) surveys and a moored ADCP array were presented. This field research is a component of the Vieques Sound and Virgin Passage Transport Study, funded through NOAA's Coral Reef Conservation Program (CRCP). The study area encompasses a portion of the US Caribbean coastal shelf between Puerto Rico (PR) and St. Thomas, US Virgin Islands (USVI). Regular shipboard surveys and an array of six ADCP moorings were designed to quantify volume transport through Virgin Passage and into and out of Vieques Sound over a 12-month period. Collected data will help scientists to characterize and quantify the poorly understood flow across the region and will be utilized with ichthyoplankton abundance calculations and a nested ROMS model to estimate larval flux between managed and non-managed areas of the USVI and PR coastal shelf.

Calculations from a series of SADCP surveys, conducted across the two section between July 29 and August 1, 2010, reveal a mean outflow from the Caribbean into Vieques Sound (between Vieques and Culebra) of 34,726 $m^3 s^{-1}$, and a mean outflow through Virgin Passage (from the Caribbean into the Atlantic Ocean, between Culebra and St. Thomas) of 138,371 $m^3 s^{-1}$, roughly four times the flow entering the Sound. When compared with wind data measured at a NOAA weather station located on Culebra, current velocity time-series data (recovered from the moored array for March through July 2010) reveal that the largest transports observed across the sections are closely correlated with local wind forcing.

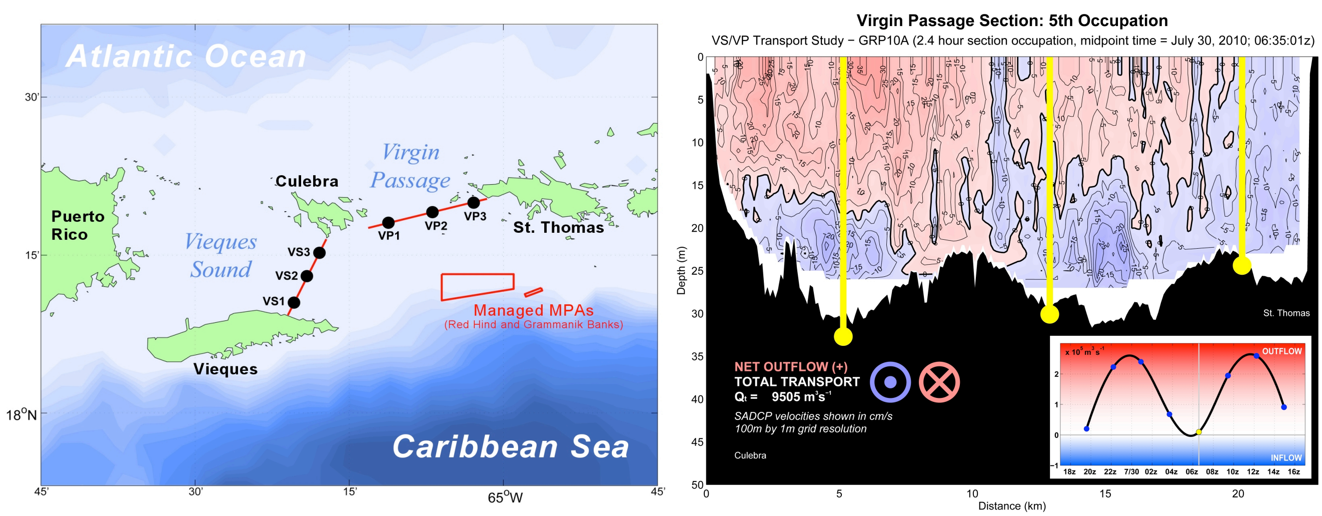


Figure. Project mooring locations, SADCP survey sections, and selected MPA boundaries (left). An SADCP section conducted across Virgin Passage (right). Though mean outflow (red) was observed at the passage, a semidiurnal signal associated with tidal flows is clearly visible over the eight section occupations (lower right).

Future Impact of Weakening Atlantic Thermohaline Circulation on the Loop Current in the Gulf of Mexico
Presented by Yanyun Liu

Although the Atlantic bluefin tuna is widely distributed, spawning in the western Atlantic has been recorded predominantly in the Gulf of Mexico (GoM) from April to June. While bluefin tuna can better tolerate colder waters than other tropical tunas, they are adversely affected by warm water (>28°C) and avoid warm features in the GoM such as the Loop Current. In this study, we study the potential changes in ocean circulation and water mass properties in the GoM under the impact of future anthropogenic global warming (AGW), by using a downscaled high-resolution ocean model (Modular Ocean Model 4). Preliminary model results indicate that SST increases in the entire GoM, but its pattern is quite different with that projected by the IPCC-AR4 models. In particular, the high-resolution model SST increase (Fig. 1b) is much less than the IPCC projected increase (Fig. 1a), especially in the northern GoM. A possible reason for this difference may come from the weakening of the Loop Current (LC) and the reduced Yucatan Current transport, which are not properly simulated in the IPCC-AR4 models. The Yucatan Current transport reduces drastically by as much as 20% by late 21st century (see Fig. 1c). Figure 1d shows clearly the weakening of the main branch of the LC, an anomalous cyclonic ring formed in the central and northern GoM. This means that the warm eddies detached from the LC are weakened, thus shallower and cooler. The reduced LC is likely to be forced remotely by the slowing down of the Atlantic Meridional Overturning Circulation (MOC). In summary, the LC may slow down as much as 20% by the late 21st century, resulting in a mitigation of AGW-induced surface warming, particularly in the northern GoM, a known spawning ground for Atlantic bluefin tuna.

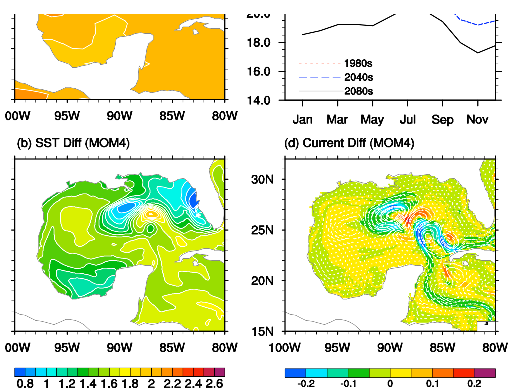


Figure. SST difference between the late 21st century and late 20th century for AMJ season obtained from (a) IPCC-AR4 models (low-resolution) and (b) MOM4 model (high-resolution). (c) Seasonal Yucatan Current transport for the three different periods (late-20th century, mid 21st century and late 21st century) from MOM4. (d) Surface current and current speed difference between the late 21st century and late 20th century for AMJ season from MOM4. Vectors indicate the current difference and contours show the current speed difference.

Long-term Ocean Variability in Ecosystems in the Gulf of Mexico: Mesoscale Circulation and Physical-Biological Coupling from Altimeter Satellite-Derived Observations
Presented by David Lindo-Atichati

Researchers with AOML's Physical Oceanography Division (PhOD) conduct an ongoing collaborative effort with NOAA Southeast Fisheries Science Center (SEFSC), which focuses on the investigation of the link between the ocean and stock assessment of species with relevant commercial importance. New results on the application of altimeter satellite-derived observations to larvae research in the Gulf of Mexico are being reported in this science retreat presentation. Given the strong link between temperature and salinity in habitats, the main mesoscale features are related to larvae distribution of six fish species, bluefin tuna among them. Time series of the northernmost and westernmost locations of the Loop Current (LC) and a ring census were obtained from altimetry fields, and related to spring larvae locations from January 1993 to December 2008. The variability of the LC was reflected in larval fish distributions, with generally higher larval abundances during years of high northward penetration. Analysis made from 23 rings shed by the LC during the study period indicate that warm-core rings shed by the LC are generally less likely to contain larvae. Detailed associations between the inner and outer regions of mesoscale features and larval catches show higher abundances of bluefin tuna, little tunny, Thunnus, Auxis and red snapper in the boundaries and frontal areas of anticyclonic regions. Two peer-reviewed publications are going be submitted from this research in the near future, and collaborative work will continue between AOML and SEFSC to analyze the link between ocean features and stock assessment.

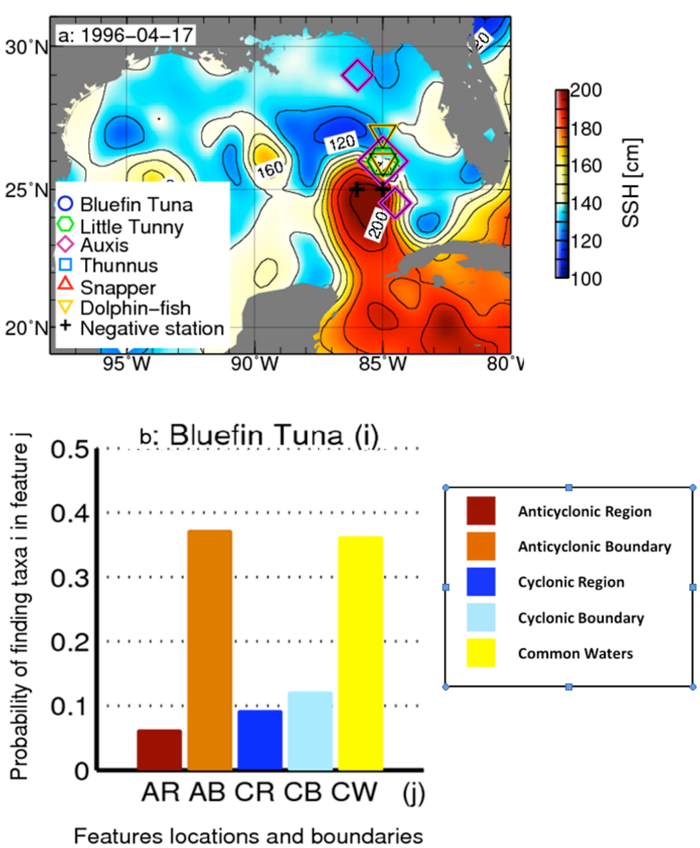


Figure. The top panel (a) shows the spatial distribution and density of larvae of bluefin tuna (dark blue circles), little tunny (green hexagon), Auxis (pink diamond), Thunnus (light blue square), snappers (red triangle) and dolphin-fishes (inverse yellow triangle). Background is the SSH field. Larval fish captures are collected on frontal areas of the LC and negative stations are found in core regions of the LC on April 17, 1996. The bottom panel (b) illustrates the probability of finding larvae of bluefin tuna in anticyclonic regions (AR, red bar), anticyclonic boundaries (AB, orange bar), cyclonic regions (CR, blue bar), cyclonic boundaries (CB, turquoise bar), and common waters (CW, yellow bar).

Oceans and Weather

Progress on Climate Research for the Intra-Americas Sea Region
Presented by David Enfield

Summer climate variability over and around the Caribbean region has much to do with the year-to-year behavior of the tropical Atlantic SST in relation to the global tropics and tropical Pacific. A large body of work by AOML scientists and others has shown that when the tropical Atlantic is relatively warm — interannually or decadally — there are more tropical cyclones in the Atlantic, more Caribbean rainfall in summer, less rainfall over much of the US, and decreased likelihood of Midwest floods and tornado activity in the spring. A new US CLIVAR program for American Monsoon research (VAMOS) is now embarking on a multi-year project, the Intra-Americas Study of Climate Processes (IASCLIP), designed to leverage and improve our understanding of these relationships, assess and improve the ability of models to predict summer conditions, and to improve the ocean and atmospheric observations in the Intra-Americas Sea (IAS) region. A major challenge for modelers is to assess and remedy large biases in most models — SSTs that are 1-2 °C too cool in the tropical Atlantic, and Caribbean precipitation that is too small. An IASCLIP Forecast Forum has been launched to conduct experimental forecasts that complement the model assessment and improvement tasks. Ocean observations in the IAS — which are sorely lacking when compared to global coverage — need to be improved through XBT transects, drifter and Argo deployments, and the addition of subsurface temperature sensors below fixed buoys. Atmospheric observations need to be enhanced through a program of surface meteorological observations and improved soundings on small islands.

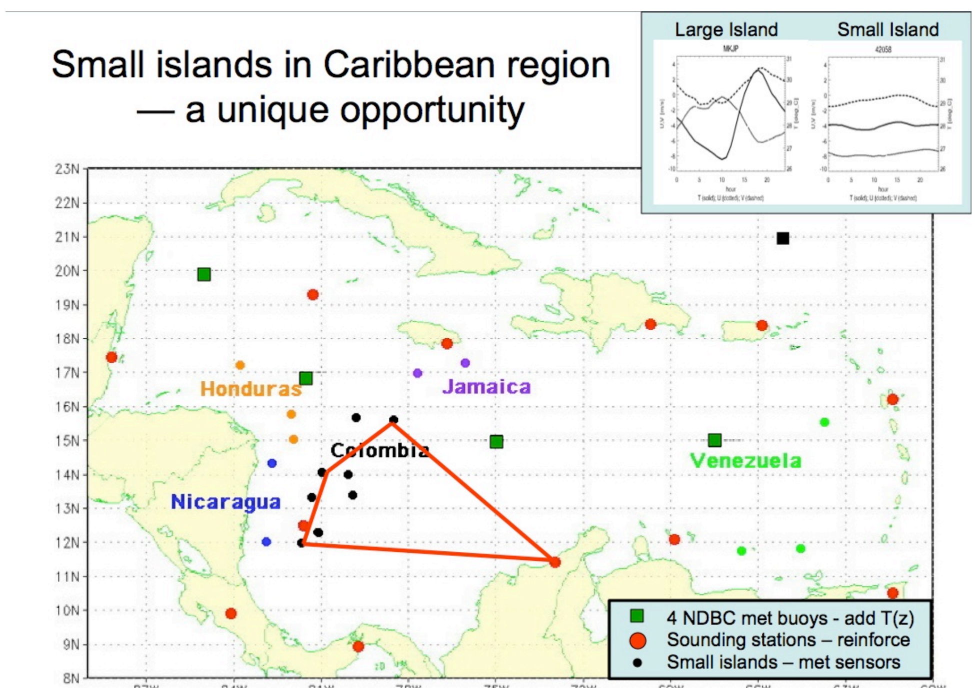


Figure: Illustration showing small islands where diurnal variability looks like open sea conditions. Surface and upper air measurements can be deployed on these islands with logistical support from the Colombian Navy. To get subsurface temperatures, thermistor strings can be added to the mooring cables on NDBC-NWS meteorological buoys now in the Caribbean (green squares).

Relationships of the Atlantic Warm Pool with the AMOC and Hurricanes
Presented by Chunzai Wang

The distribution and variation of salinity and temperature are important to determine the meridional overturning circulation. The figure below shows the map of mean annual surface ocean salt content. At any given latitude, Pacific surface waters are 1 to 3 psu lower in salt content than their equivalents in the Atlantic. As a result, even when seawaters are cooled in the North Pacific, they do not come close to being dense enough to sink into the deep sea in the North Pacific. It is this difference that provides the impetus for deep-water formation in the Atlantic Ocean. Surprisingly, the excess in the Atlantic's salt content is the result of the Earth's wind systems including the moisture transport by the Caribbean Low-Level Jet (CLLJ). Our recent research shows that the warm (cool) phases of the AMO are characterized by repeated large (small) summer/fall AWPs and that a large (small) AWP results in increased (decreased) rainfall in the tropical North Atlantic, and a weakening (strengthening) of CLLJ's westward moisture transport from the Atlantic to the Pacific. These results suggest that there is an interaction between the AWP and AMOC. On one hand, as the AMOC weakens, its northward heat transport reduces and thus the North Atlantic cools and the AWP becomes small. On the other hand, a small AWP decreases rainfall in the tropical North Atlantic and increases the cross-Central American moisture transport to the eastern North Pacific. Both of these factors tend to increase salinity in the tropical North Atlantic Ocean. Advected northward by the wind-driven ocean circulation, the increased salinity increases the upper-ocean density in the deep-water formation regions and thus strengthens the AMOC. Therefore, the AWP seems to play a negative feedback role that acts to restore the AMOC after it is weakened or shut down.

The 2010 Atlantic hurricane season was extremely active, with 19 named storms, 12 hurricanes, and 5 major hurricanes, but not a single hurricane made landfall in the U.S. This is because a large AWP shrank the North Atlantic subtropical high eastward and hurricanes were steered away from the eastern coast of the U.S. The large AWP in 2010 also resulted in the out-of-phase relationship between tropical cyclones in the North Atlantic and the eastern North Pacific: An active 2010 Atlantic season with 19 named storms (a long-term mean of 10 storms) and an inactive 2010 eastern Pacific season with 7 named storms (a long-term of 14 storms).

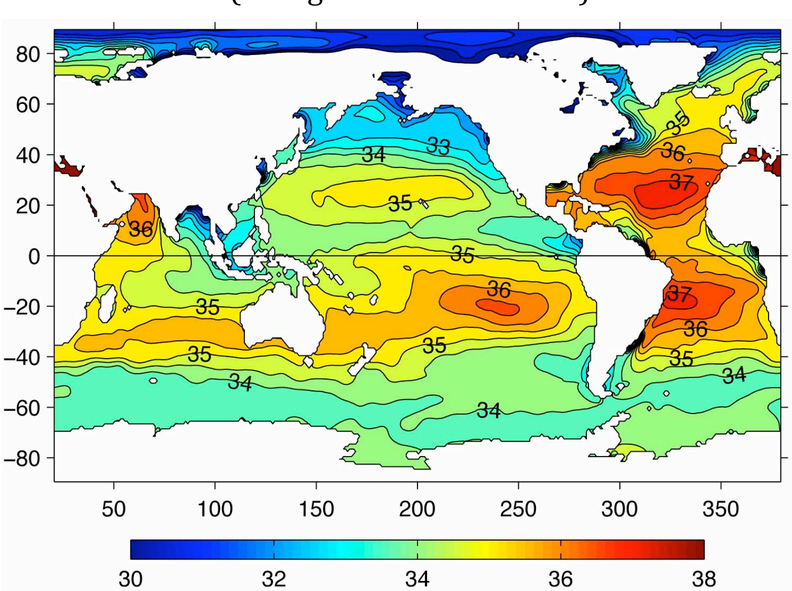


Figure. Map of the distribution of mean annual surface ocean salinity (psu).

Problems and Recommendations Concerning the HWRF Operational Feature-Based Ocean Initialization Procedure
Presented by George Halliwell

This presentation describes a planned idealized experiment to document the impact of ocean coupling on hurricane intensity forecasts using coupled forecast models. These idealized coupled experiments use a highly simplified atmospheric structure of a bogus storm vortex patched into uniform background Trade Winds to minimize the impact of atmospheric processes on intensity evolution. One-dimensional ocean models extracted from HYCOM have been embedded in the experimental HWRF (HWRF-x) model used by NOAA/HRD and will provide idealized ocean coupling that adequately reproduces the local thermodynamical response to storm forcing. Initial ocean fields are horizontally uniform, but different choices of vertical temperature and salinity profiles are used to represent oceanic conditions with widely-varying values of Tropical Cyclone Heat Potential (Figure below). By controlling the strength of the background Trade Winds, the impact of storm propagation speed on SST cooling and storm intensity evolution will be quantified for oceanic conditions with different heat potential. This type of detailed parametric study on the impact of ocean coupling on storm intensity and the time scale of this intensity response has never been conducted for any forecast model. The study will aid forecasters in interpreting the potential influence of oceanic conditions on intensity evolution in forecast runs produced by the HWRF model. Given that this study will be performed using the latest version of HWRF-x with one 27 km parent domain and two moving nests (9 and 3 km) and that this version is not ready at this time, preliminary results are presented using an older version of HWRF-x with one 9 km moving nest but with the one-dimensional ocean models embedded. Three forecast runs were performed for Hurricane Ike using the three different initial ocean states shown in the left panel of the Figure below. The evolution of storm intensity (right panel) demonstrates a significant ocean impact.

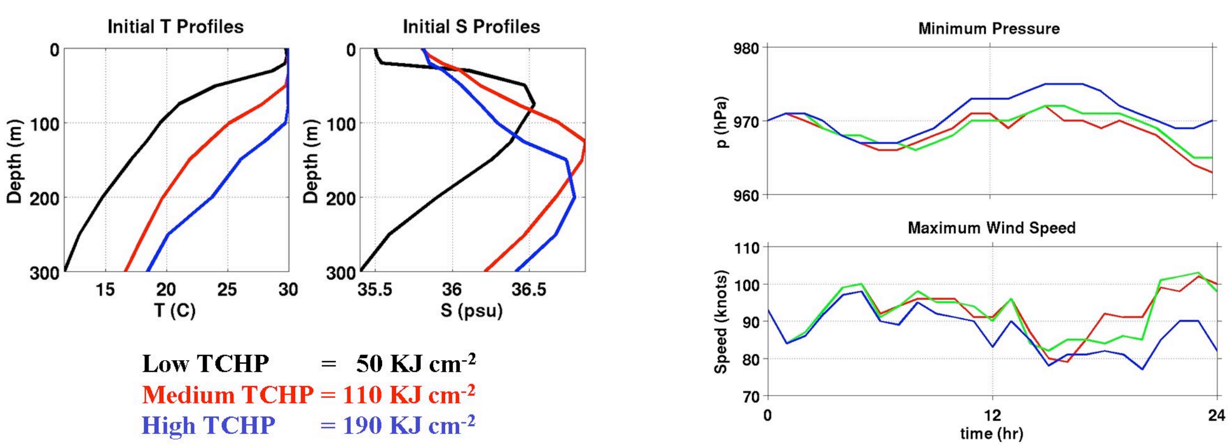


Figure. The horizontally-uniform initial ocean fields provided to the three Ike experiments representing three levels of Tropical Cyclone Heat Potential (left panel). Three 5-day forecasts of Hurricane Ike initialized from the horizontally-uniform ocean profiles (right panel). Minimum atmospheric pressure and maximum wind speed are used to represent intensity.

Summary of Atlantic Warm Pool Variability in the IPCC Twentieth-Century Climate Simulations
Presented by Hailong Liu

This study investigates the Atlantic Warm Pool (AWP) variability in the 20th century climate simulations of 22 coupled general circulation models (CGCMs) submitted to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). Based on AWP area index definition, most coupled models show very weak AWP and variability (Figure below) because of the cold sea surface temperature (SST) bias in the northwest tropical Atlantic. The box-averaged SST in AWP region is defined as AWP index for this study. Only for 4 models the seasonal cycles are in good accordance with observations. Wavelet analysis reveals only multidecadal band variability of AWP is significant in observations. Most models successfully capture this character but a few models show that either interannual or decadal variability is dominant. Time series of AWP SST index further shows that each model demonstrates very different interannual variability. Empirical Orthogonal Function (EOF) analysis on observational SST of July to October in the tropical Atlantic shows zonal mode as the first mode and meridional mode as the second mode. A majority of the coupled models are able to display the second mode (meridional mode) correctly. But some models misrepresent the first mode (zonal mode) due to the southeast tropical Atlantic SST warm bias included in the interannual variability. Regression of global SST onto AWP SST index at multidecadal band shows the AWP multidecadal variability resembles the Atlantic Multidecadal Oscillation (AMO) for most coupled models. Observation analysis indicates both positive ENSO phase and negative NAO phase in winter corresponding to anomalous westerlies in the AWP region. The ENSO (NAO) induced westerlies anomaly leads to local heating and warm SST during March to May (during Febuary to April). This feature is well captured by 4 models.

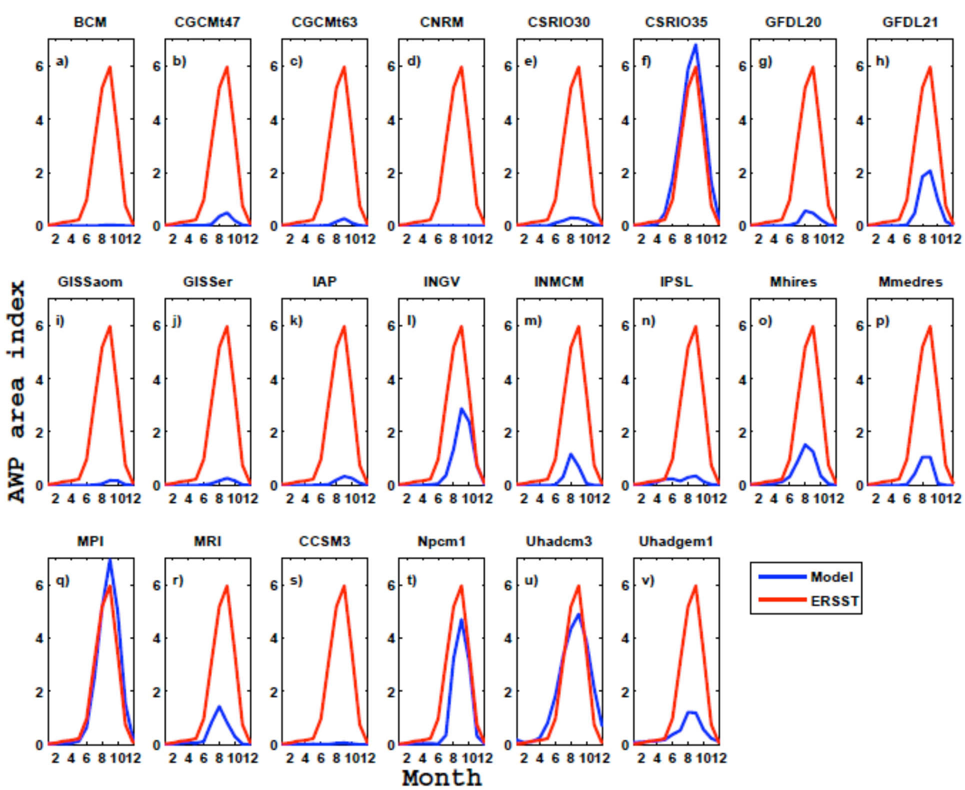


Figure. Seasonal cycles of AWP area index in unit: 106 km2. Blue lines are for each CGCM and red lines are ERSST for comparison.

General Physical Oceanography

Forecasting the distribution of floating debris using drifters
Presented by Rick Lumpkin

The trajectories of surface drifters can be used to estimate Lagrangian near-surface pathways of passive tracers and particles such as water masses, plankton, oil, and floating marine debris. Observations of floating plastic debris in the North Atlantic Ocean (Law et al., 2010) indicate that, although there was a large increase in plastic production and disposal in the period 1986—2008, there has been no observed trend in plastic concentration in the Sargasso Sea region of highest accumulation. In this study, possible pathways of the debris are constructed globally using drifter trajectories. The trajectories of drifters that run aground are used as a proxy for the locations where plastic is removed from the ocean via shore deposition. Preliminary results indicate the sensitivity of the solution to the release locations and to the rate of in-situ removal, which simulates processes such as plastic fragmentation and subsequent ingestion by organisms and/or sediment deposition.

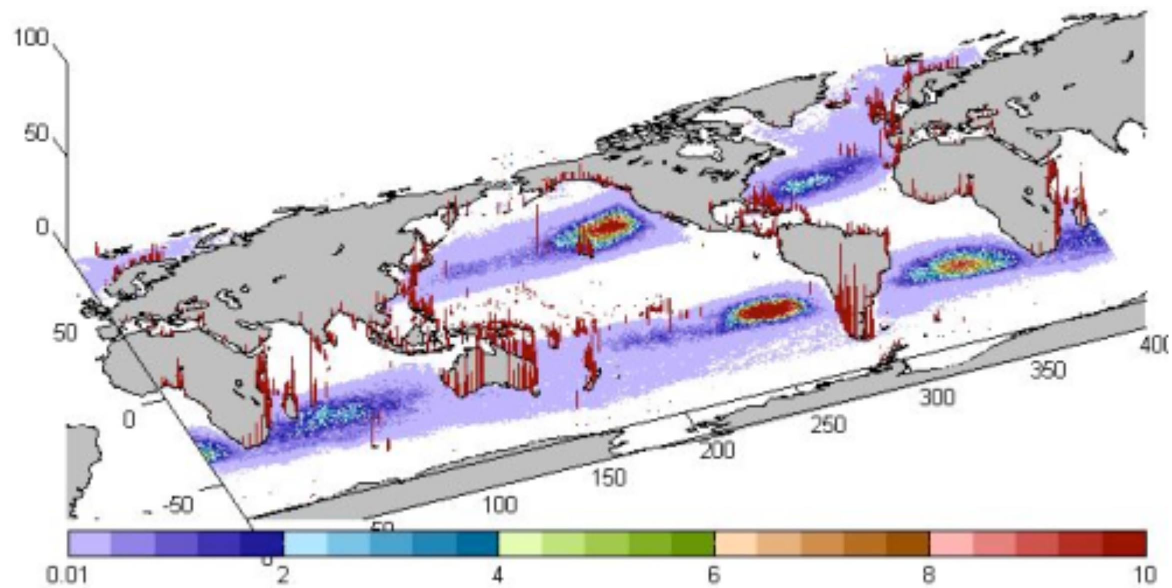


Figure. Simulation of plastic debris using reassessed "quit" drifters, showing the density of debris in the ocean and on shore (vertical bars) after 10 years of integration. The scale for the coastal bars has been multiplied by 10. In this simulation, all debris is initially released homogeneously throughout the global ocean and no additional debris is added or removed except via shoreline deposition.

Three-dimensional circulation from Argo data with application to the Meridional Overturning Circulation
Presented by Claudia Schmid

A three dimensional field of velocity in the South Atlantic is derived from the data collected with Argo profiling floats. Temperature and Salinity profiles are interpolated vertically (10 dbar resolution) and then mapped onto a regular grid. These 3-D fields are used to derive the geostrophic circulation. The absolute velocity is derived by adjustment based on the quasi-Lagrangian observations from the Argo floats.
Dong et al. (2009) demonstrated that the interior region of the South Atlantic has an important contribution to the Meridional Overturning Circulation (MOC) and the associated meridional heat transport at 35°S. The goal is to use Argo data to monitor the MOC at various latitudes. As a proof of concept gridded fields from Argo are used to derive the annual mean MOC transports at 35°S. To minimize the impact of mesoscale variability correlation length scales of 20° and filtering was used. Extension of profiles to the ocean bottom was done with World Ocean Atlas 2005 before the relative and absolute geostrophic velocity is derived. HYCOM plus NCODA global 1/12° analysis was used in the boundary regimes (http://www.hycom.org/dataserver/glb-analysis). The bottom triangle approach for the transport estimates is: velocity=0 at the bottom, with a temperature slope from the longer profile. From here on the method is similar to Baringer and Garzoli (2007). Preliminary transport estimates agree with earlier results. The example indicates that the interior and eastern transports seems to be more sensitive to the adjustment of the geostrophic velocity than the total transports.

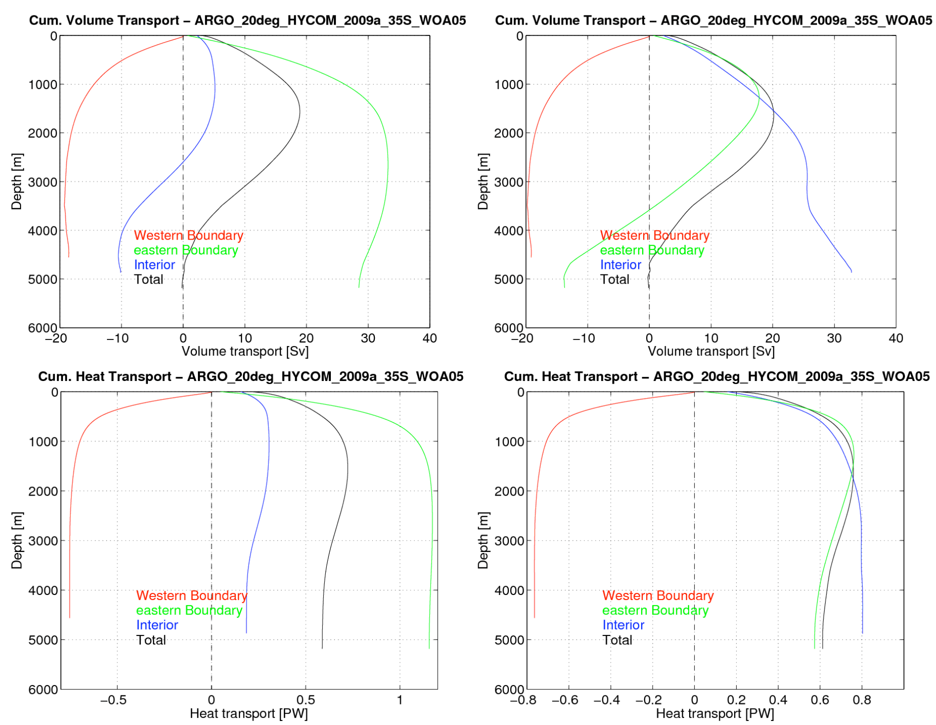


Figure: Cumulative transports across 35S in 2009 based on Argo and HYCOM. Left: level of no motion. Right: level of known motion from Argo floats (using the quasi-Lagrangian velocity). Top: Volume transport. Bottom: Heat transport.

A Surface Bjerknes Mode for Generating Pacific Decadal Variability
Presented by Pedro DiNezio

We identify a Surface Bjerknes mode (SBM) that generates a decadal ENSO-like sea surface temperature (SST) pattern in climate models via surface processes alone. This mode emerges on decadal and longer timescales when the thermocline is closer to equilibrium with the wind changes. The decadal thermocline response to wind changes is consistent with the linear steady-state forced Sverdrup response, which has no signal in the east, and shoaling increasing towards the west. The shoaling of the thermocline in the central Pacific, the region where coupling is strongest, results in ocean dynamical cooling opposing the development of the decadal SSTA. However, the Bjerknes feedback is still positive on decadal timescales thanks to the zonal advection and upwelling feedbacks. The lack of delayed thermocline adjustment does not lead to a self-sustained oscillation. Thus, the SBM requires external forcing to grow. The models and observations indicate that part of the PDV could result from the asymmetry between ENSO events. However, the physics of the SBM mode are present in models with very symmetric ENSO, thus are not the result of rectification.

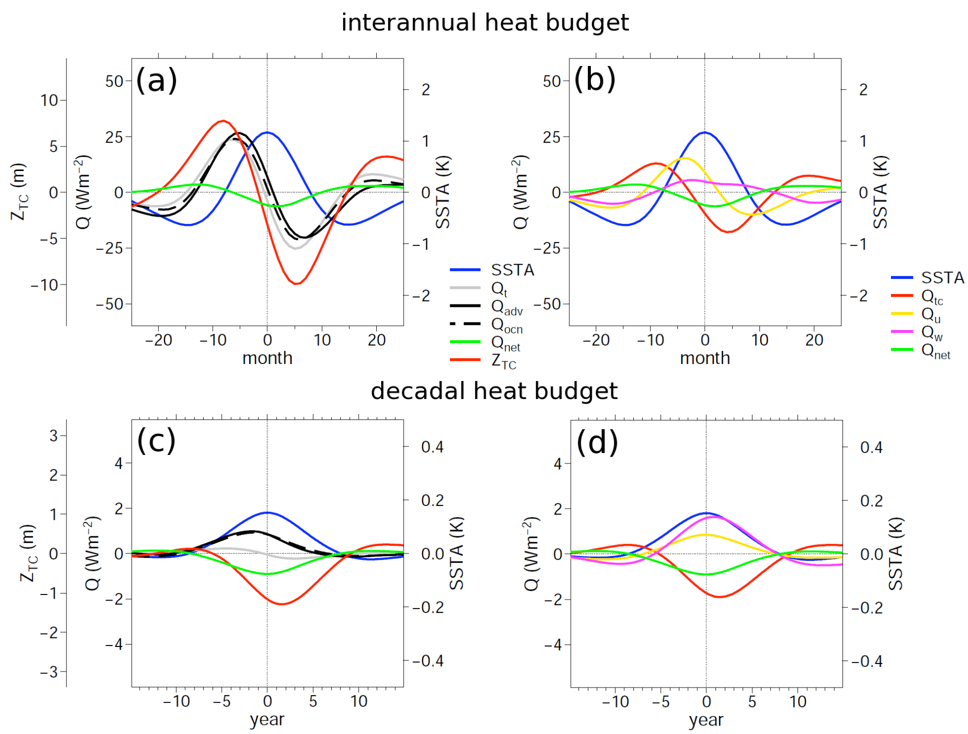


Figure. Multi-model composite heat budget on (a,b) interannual and (c,d) decadal timescales. Left panels (a,c) show the anomalies in sea surface temperature (SST) (blue), heat storage rate (gray), ocean heat convergence (dashed black), ocean heat convergence due to resolved monthly mean currents (black), net atmospheric heat flux (green), and thermocline depth (red). Right panels (b,d) show the decomposition of the ocean heat convergence into contributions from thermocline (red), zonal current (yellow), and upwelling (magenta) anomalies. All variables are averaged over the Nino-3.4 region (180º-110ºW 4ºS-4ºN).

An Improved Method for Estimating Oceanic Uptake of Anthropogenic CO_2
Presented by Carlisle Thacker

Regression-based methods commonly used for estimating the rate of oceanic uptake of anthropogenic CO_2 are shown to suffer from a variety of problems. The causes of these problems are identified and an improved method is presented. This method has four characteristic features. First, the data are treated locally so that the empirical relationships of carbon to other environmental variables can be treated as being linear in order that linear regression is applicable. Second, linear regression is used twice: once to separate natural variability from the uptake signal, which remains in the residuals, and then to extract the uptake rate from the residuals. Third, uptake rates are computed as spatial averages to achieve robustness. Fourth, standard errors of the uptake rate are simple to compute. The method is particularly attractive as it can be used, not just with data from repeated hydrographic surveys, but with data such as might be obtained by a fleet of appropriately instrumented autonomous profiling floats.

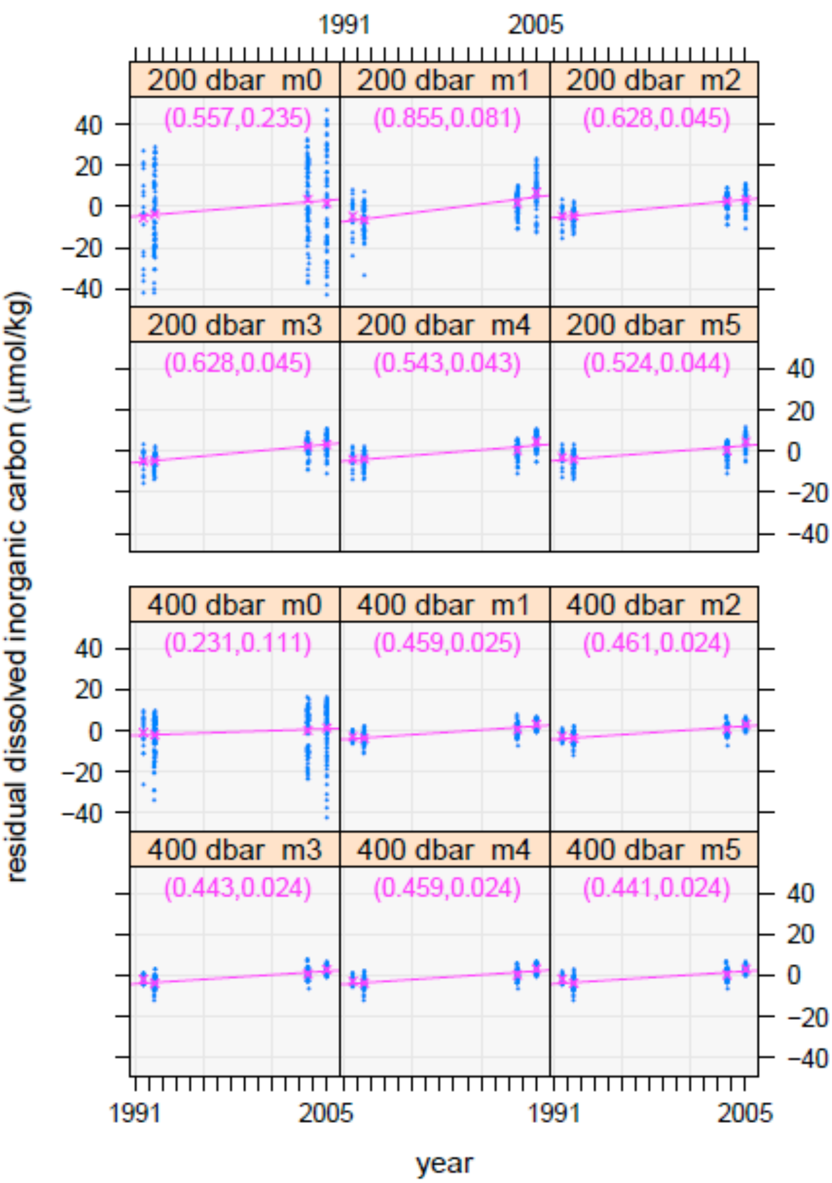


Figure. Six linear regression models were fitted to data from repeated hydrographic cruises along sections P06 and P16 from two layers, one centering on 200 dbar and the other centering on 400 dbar, in order to explore how effectively each might account for the natural variability that can obscure the relatively small anthropogenic-uptake signal. The residuals are plotted vs. year, and those associated with each of the four surveys are easily identified. The slopes of the regression lines provide estimates of the anthropogenic uptake and the standard errors of the slope parameters quantify their uncertainty. Those values are shown within each panel. The default model m0 ignores the possibility of background variation. Within both layers model m2 with density and nitrate concentration serving as proxies of background variability provides the most robust estimates of uptake.

Physical Oceanography Division
Atlantic Oceanographic and Meteorological Laboratory
National Oceanic and Atmospheric Administration
4301 Rickenbacker Causeway
Miami, FL 33149