

# Tropical Atlantic Meeting Report

## (Miami, March 2-4, 2010)

### Introduction

For more than a decade, international Tropical Atlantic meetings have been held on a quasi-annual basis to discuss progress on tropical Atlantic research. The goal of these meeting is to establish more exchanges and collaborations between observational and numerical modeling communities, and maintain links between ongoing research, process study efforts, and sustained observational programs in the region. Recent Tropical Atlantic meetings, encompassing interests of the TACE/CLIVAR, PIRATA, and AMMA projects and communities, have been held in Karlsruhe, Germany (November 27-30, 2007) and in Toulouse, France (February 2-6, 2009). Reports from previous meetings can be found at <http://www.clivar.org/organization/atlantic/TACE/tace.php>.

The 2010 Tropical Atlantic Science meeting, held jointly with the PIRATA-15 annual meeting, was held on March 2-5 in Miami, Florida, co-organized by Rick Lumpkin (NOAA/AOML) and Bill Johns (University of Miami/RSMAS). Scientific presentations from the meeting can be found online at: <http://www.aoml.noaa.gov/phod/pne/meeting2010.html>. Financial support for the meeting was provided by the U.S. CLIVAR Office and NOAA, and facilities support was provided by the Rosenstiel School of Marine and Atmospheric Science, University of Miami.

The 2011 meeting is scheduled for March, to be held in Brazil.

### Meeting Report

The meeting began with individual research presentations organized into scientific sessions. The meeting agenda is included in Appendix 1. Prior to the meeting, the organizing committee suggested several topical areas that the meeting should focus on, as well as soliciting any other presentations relevant to tropical Atlantic climate and variability. These suggested topical areas were:

1. Climate events, trends, and anomalies in the Tropical Atlantic (progress in characterizing Tropical Atlantic variability and climate linkages; attribution)
2. Results from recent/ongoing Tropical Atlantic observational programs (e.g. cold tongue variability, ocean processes)
3. Ocean and coupled model simulations (progress in understanding ocean processes, air-sea interaction processes; resolution and model bias issues)
4. Dynamics and impacts of intraseasonal variability (e.g., TIWs, MJO).
5. Validation and use of data synthesis (assimilation) models
6. Progress on Tropical Atlantic predictability/prediction
7. Tropical Atlantic teleconnections (Pacific and higher latitude Atlantic atmospheric and oceanic (e.g. AMOC) connections; tropical S. Atlantic connections and monsoon interactions (between S. American, S. Africa, W. Africa)
8. Physical-Biogeochemical interactions in the Tropical Atlantic

The final agenda was organized into four half-day sessions:

**Session 1: Climate events and anomalies in the Tropical Atlantic**

**Session 2: a. Tropical Atlantic teleconnections**

**b. Dynamics and impacts of intraseasonal variability**

**c. Physical-Biogeochemical interactions**

**Session 3. Results from recent/ongoing observational programs**

**Session 4. Ocean, atmosphere, and coupled model simulations**

Abstracts of all scientific presentations are included in Appendix 2.

Following the science sessions, discussion sessions were held on two primary topics: (1) Coupled Model Biases, and (2) Observational Initiatives. Summary reports on the main findings of these discussion sessions are included below.

The meeting was attended by approximately 60 people. The registrant list is included in Appendix 3.

## Discussion Group Summaries

### 1. Coupled Model Biases (chair: Ping Chang, rapporteur: Regina Rodrigues)

#### CURRENT STATE OF THE PROBLEM

Considerable recent progress has been made in identifying the source of the tropical Pacific biases in the current generation of coupled models. For example, modeling studies at NCAR and GFDL suggest that uncertainties in convection parameterizations in AGCM are a key source of climate biases in the Pacific. In the newly released NCAR CCSM4, substantial efforts have been put into improving the deep convection parameterization to enhance the role of free-troposphere humidity and reduce the role of boundary layer forcing (Neale et al. 2008), as well as the stratus cloud parameterization. As a result, the model now has a much-improved simulation of the trade winds, leading to an improved simulation of the EUC, the sloping thermocline and the cold tongue SST.

In spite of these improvements in the tropical Pacific, the bias problem in the tropical Atlantic persists. In many IPCC AR4 models, the problem is still so severe that some of the most basic features of the equatorial Atlantic Ocean – the west-to-east SST gradient along the equator and eastward shoaling thermocline – cannot be reproduced (Richter and Xie 2008). Biases in the mean state and variability are present in both seasonal hindcast and climate simulations. In many models, the warm SST bias along Benguela coast is in excess of 5°C and the warm pool in the western basin is severely underestimated. Experiments with AGCMs forced with observed SST show that there is a common precipitation error over the Amazon, which causes a trade wind bias in the AGCMs. In the coupled models, the trade wind bias causes the equatorial SST bias and these biases are further amplified by air-sea feedbacks. Richter and Xie (2008) show that the cold tongue bias in JJA is due to the AGCM failure in simulating MAM convection over the Amazon and ITCZ region.

However, the Benguela SST bias may be caused by different physical mechanisms. The Benguela bias is collocated with the so-called Angola-Benguela Front, where a sharp SST gradient exists. East of the front, a shallow thermocline structure known as the Angola Dome is located at approximately 10S. These unique oceanic features set the southeastern tropical

Atlantic apart from its Pacific counterpart. It is possible that the Benguela SST bias may be attributed to ocean models' inability to resolve these fine scale oceanic features. Feedbacks between stratus-cloud and SST can then amplify the bias.

#### QUESTIONS RAISED:

1) Are the cold tongue and Benguela biases independent? Is the mechanism of the Benguela bias primarily due to the forcing field (winds, radiative forcing) or to improperly represented ocean dynamical processes? Is there too much solar radiation and not enough clouds, or not enough upwelling and offshore transport?

2) Where to focus, and how to proceed? AMIP analysis? OMIP analysis? Coordinated coupled model experiments? New observational programs?

#### RECOMMENDED ACTIONS

1. TACE/PIRATA data (including ancillary data) needs to be gridded/organized in useable format for the modeling community to use to evaluate/improve models.

2. An intercomparison/validation study of available reanalysis products such as SODA, MERCATOR, GODAE should be done with TACE/PIRATA in-situ data to establish these as useful baselines for validation of the ocean components of coupled models.

3. Further AMIP and OMIP experiments should be conducted to better isolate the sources/mechanisms of the biases. Suggested approaches include forcing AGCMs with prescribed SST anomalies, evaluating the resulting biases in atmospheric circulation and consistency among AGCMs, then forcing OGCMs with the obtained atmospheric circulation to determine how much of the bias can be explained by the biased atmospheric circulation (Richter suggests that it may account for 80% of the bias). Sensitivity to ocean dynamics should be tested with differing resolutions of OGCMs.

Specific scientific points related to the Benguela bias to be pursued in an attempt to answer the aforementioned questions:

- 1) Investigate the structure of the wind stress field. Compare different wind products and determine if the winds near the coast are properly represented and consistent with observations.
- 2) Investigate the low clouds off the African coast and over the Gulf of Guinea.
- 3) Determine through sensitivity studies the impact of the SST bias on the ITCZ meridional excursion and precipitation.

Other actions:

1) Encourage researchers from the TAV community to participate in the Pacific bias meeting and/or invite researchers from the Pacific bias problem to the TAV meetings to share their progress and learn from their experiences.

2) Organize a specific meeting on the Atlantic Bias in Coupled Models, similar to the Pacific counterpart.

3) Develop a new observational program in for the Benguela region in collaboration with VOCAL/VAMOS group.

## 2. Observational Initiatives (chair: Peter Brandt, rapporteur: Renellys Perez)

The following items were discussed as priorities for new research and collaborative study:

### 1. EUC Structure and Termination in the Gulf of Guinea

At the meeting new results regarding the upper layer circulation were presented by different groups. These results that were obtained within the framework of the TACE/PIRATA program cover the whole tropical Atlantic from its western portion (observations are mainly part of Brazil PIRATA) to its central and eastern part including results from the German/US/PIRATA mooring programs. Besides mean and seasonal variations of the current field, enhanced observations during recent years more and more allow addressing interannual fluctuations of the different current branches and their link to SST variations and climate variability. Zonal velocity variability at the equator is particularly linked to the presence of equatorial Kelvin waves. Such waves that are forced by wind anomalies in the western tropical Atlantic are found to be crucial for the preconditioning of the thermocline slope prior to cold/warm events in the cold tongue region. In the eastern equatorial Atlantic, the supply of the westward current bands north and south of the equator out of the EUC could be identified; a possible transport of EUC waters toward the Benguela upwelling region has still to be shown from observations. The current meter mooring arrays at 23°W and 10°W will finally be recovered in both real spring/summer 2011; mooring activities will continue with single equatorial moorings at 23°W and 10°W within the PIRATA program.

### 2. Atlantic and Benguela Nino's

While the advective pathway of EUC waters toward the eastern Atlantic coastal upwelling regions is not yet established from observations, recent studies revealed a link between the western equatorial Atlantic and the Atlantic and Benguela Nino regions via equatorial/coastal Kelvin waves. The forcing of this climate variability was found to be strongly associated with the variability of the St. Helena subtropical high. Although recent publications show a connection between SST pattern and rainfall variability over Africa (region of the West African Monsoon and Southern Africa), seasonal predictions using climate models suffer from strong SST biases in the tropical Atlantic. In fact, the Benguela upwelling region is one of the regions with strongest bias in the global SST distribution simulated by climate models. The source of the bias is still unclear; however it could at least partly be related to local ocean processes, which could be a topic of future ocean observing programs.

### 3. Mixed Layer Heat Budget

Extremely shallow ML depths characterize the central and eastern equatorial Atlantic. Thus, even moderate ML heat fluxes of  $O(10) \text{ Wm}^{-2}$  may significantly impact ML temperature. ML heat content in the central and eastern tropical Atlantic regions is assumed to be mainly controlled by air-sea heat exchange, vertical processes at the base of the ML (i.e. upwelling, diapycnal mixing), and lateral advection of heat due to TIWs. The comparison of atmospheric heat fluxes obtained from observations and operational weather prediction models showed, however, large differences among the different models and systematic model-data biases. These uncertainties make calculations of the seasonal and, even more, the interannual heat budget of the ML questionable. Recent very-high-resolution model simulations yield a better understanding of the processes that affect vertical velocity. However, up to now, there are no adequate observations of vertical velocity available that could be used to validate such model simulations. Observations of different tracers like e.g. Helium and/or Beryllium were used to estimate upwelling transports during active upwelling. The error bars associated with these transport

estimates are still large. Moored and shipboard velocity observations from the equatorial Atlantic were not yet analyzed with respect to divergent flow fields. Much progress was obtained in the observation of diapycnal turbulent heat fluxes. New measurements yield an improved seasonal mixed layer heat budget showing that the diapycnal turbulent heat flux is among the largest contributions to the mixed layer heat budget during the onset of equatorial upwelling. Observations in the eastern equatorial Atlantic region during the Atlantic cold tongue preconditioning phase in boreal spring are particularly underrepresented in the observational data base.

The role of intraseasonal waves, particularly TIWs, in the heat budget, remains an unresolved question and a source of significant disagreement among modeling studies. Although the observational database available for studying the effect of intraseasonal waves in the heat budget is much improved (the analysis of the data has to be carried out), a dedicated observational study testing the different hypotheses from modelling studies is lacking.

The role of mixed layer salinity for the development of the mixed layer (including possible occurrence of barrier layers) is also not well understood. The upcoming SMOS satellite program could help addressing the seasonal to interannual variability of SSS. High quality data are needed to validate these satellite data, i.e. Argo float and PIRATA data (high resolution salinity measurements in the near surface layer are required), surface drifter and glider data. Problems with drifter data are that due to biofouling salinity measurements are only valid for a few months of operation. There are only 10-20 drifters per month in the central and eastern tropical Atlantic and, because of the equatorial divergence, surface drifters in general stay in the equatorial region for a short period only.

#### **4. Formation and Fate of the Equatorial Thermostat**

There is still not much progress answering the question, how the equatorial thermostat in the Atlantic does form and what its fate is. It is not as much of a problem in the Pacific. In that case there is a consensus that waters originate in the Coral Sea with double contribution from southern hemisphere compared to the northern hemisphere. The Equatorial Atlantic thermostat is believed to be formed through convergence processes in the central and eastern Atlantic. Some model improvements were obtained with changes to model mixing parameterizations. High-resolution simulations with low vertical mixing below the EUC also show that the mean current system below the EUC is improved with a more realistic downward propagation of intraseasonal wave energy. Assimilation models could be used to analyse model tendencies to analyze how the thermostat is being corrected due to assimilated data.

#### **5. Comparison of Model Output with Observations**

Mean sections were defined already during the last meeting (see below). These sections still need to be extracted from simulations and compared with observed fields.

Regions and sections defined during the last meeting:

The Tropical Atlantic Region is defined between 20°N and 20°S; transport sections should be implemented online. We suggest to calculate the EUC transport at 23°W between 2.5°N and 2.5°S in the density ranges  $\sigma_{\theta} = 24.5-26.8 \text{ kg/m}^3$  as well as above  $\sigma_{\theta} = 24.5 \text{ kg/m}^3$ . Other important meridional sections, for which transport data should be separately saved are 35°W, 23°W, 10°W, 0°W, 6°E.

To test the correct working of the dynamic Bjerkness feedback, we suggest to store besides the transport time series of the EUC at the equator, time series of the warm water volume in the whole tropical Atlantic (3°S-3°N above the 20°C isotherm), wind in the western tropical Atlantic (WAtl; 3°S-3°N, 40°-20°W) and SST in the eastern tropical Atlantic (Atl3; 3°S-3°N, 20°W-0°).

## **6. Enhanced Observing Period in Boreal Spring/Summer 2011**

From April to July 2011 there will be an enhanced observational program in the central and eastern equatorial Atlantic including research cruises with the French R/V Suroit the German R/V Maria S. Merian. The planned observations that are part of TACE/PIRATA cover the onset and height of equatorial upwelling. The physical program consists of hydrographic, current and microstructure measurements as well as of a glider swarm experiment in the cold tongue region. Together with enhanced current measurements that are planned at the PIRATA buoy at 10°W at the equator, these observations are aimed at studying the mixed layer heat budget including the role played by intraseasonal waves.

## **7. Suggestions for TACE II**

The overarching goal of TACE is to advance the understanding of coupled ocean-atmosphere processes and improve climate prediction for the Tropical Atlantic region. While TACE significantly contributed to the understanding of different processes at play, climate predictions still suffer from a strong SST bias in the eastern tropical Atlantic. The SST bias in state-of-the-art climate models is strongest in the Benguela upwelling region. As a source of the SST bias atmospheric and oceanic processes that are not well represented in those models are discussed. Among these processes are atmospheric convection over the Amazon region and coastal upwelling in the Benguela region. Further open questions regard the role of the St. Helena subtropical high variability in forcing Atlantic and Benguela Nino's or the strength of solar radiation in the Benguela region. During the meeting it became evident that there is need for an Atlantic VOCALS program. To discuss such a program a 2-day Workshop on Southeast Atlantic Coupled Ocean-Atmosphere-Land Processes was proposed by Laurent Terray (AIP, co-chair), C. Roberto Mechoso (VOCALS chair), Robert Wood (VOCALS PI), and Paquita Zuidema (VAMOS/VOCALS; RSMAS). The workshop is planned to be held in Miami on March 23-25, 2011, appended to the next dedicated VOCALS meeting. Paolo Nobre agreed to host the next TACE/PIRATA meeting in Brazil on March 14-18, 2011. These two meeting should be used to further discuss requirements for a new observational program as well as for dedicated simulations with ocean, atmosphere and coupled models.

## **Appendices**

### **Appendix 1. Meeting Agenda**

#### **CLIVAR Tropical Atlantic Meeting 2-4 March 2010**

*Rosenstiel School of Marine and Atmospheric Science, University of Miami  
Seminar Room, Science/Administration Building*

#### **Agenda**

##### **Tuesday, March 2**

1:30pm: Welcome and Opening Remarks

*Welcome*

Roni Avissar

Dean, Rosenstiel School of Marine and Atmospheric Science, University of Miami

*Meeting Organization and Focus*  
Bill Johns

**Science Session 1: Climate events and anomalies in the Tropical Atlantic**

Moderator: *Y. Kushnir*

2:00PM Abderrahim Bentamy  
*Seasonal and Interannual Variability of Turbulent Fluxes over the Atlantic Tropical Ocean*

2:20PM Greg Foltz  
*Interaction between the Atlantic meridional and Nino modes during 2009*

2:40PM Semyon Grodsky  
*Interannual near-surface salinity variability from PIRATA and Argo observations*

3:00PM Coffee Break

3:20PM Julien Jouanno  
*The equatorial cold tongue in November-December in the Tropical Atlantic -- mechanisms and variability*

3:40PM Ingo Richter  
*On the triggering of Benguela Ninos - equatorial vs. local forcing*

4:00PM Fabrice Hernandez  
*Tropical Atlantic Analysis Using Mercator Reanalysis*

4:20PM Ben Kirtman  
*Impact of Ocean Model Resolution of CCSM4 Climate Variability*

**5:30-7:00PM Meeting Reception, RSMAS Commons**

**Wednesday, March 3**

**Science Session 2a. Tropical Atlantic Teleconnections**

Moderator: *M. Rouault*

9:00AM Chunzai Wang *Teleconnected Influence of the Tropical Atlantic on the Tropical Indian and Pacific*

9:20AM Regina Rodrigues *The impacts of inter-El Nino event on the Tropical Atlantic variability and the Northeast Brazil climate*

9:40AM Yochanan Kushnir *The role of tropical Atlantic SST anomalies in forcing global circulation anomalies*

10:00AM Coffee Break

**Science Session 2b. Dynamics and impacts of intraseasonal variability**

10:20AM Anne Marie Treguier *Biweekly oscillations in the Gulf of Guinea - a case of strong currents on an eastern boundary*

10:40AM Renellys Perez *Interannual variations of Tropical Instability Waves and their influence on the equatorial Atlantic cold tongue*

### **Science Session 2c. Physical-Biogeochemical Interactions**

11:00AM Ajit Subramaniam *Spatial variability in optical and biogeochemical properties of the Equatorial Atlantic*

11:20AM Moacyr Araujo *Coral bleaching analysis in the western tropical Atlantic*

### **12:00PM-1:30PM Lunch**

### **Science Session 3. Results from recent/ongoing observational programs**

Moderator: *R. Lumpkin*

1:30PM Peter Brandt *Variability of the Equatorial Undercurrent in the central Atlantic*

1:50PM Bernard Bourles *Analysis of the Equatorial Undercurrent in the Gulf of Guinea*

2:10PM Bill Johns *TACE observations of the Equatorial Undercurrent in the Gulf of Guinea*

2:30PM Roberto de Almeida *Seasonal variability of the upper circulation of the southwestern Tropical Atlantic*

2:50PM Coffee Break

3:20PM Frederic Marin *Does the intraseasonal variability in the Gulf of Guinea impact the cold tongue development?*

3:40PM Claudia Schmid *Analysis of the variability of the Salinity in the eastern tropical Atlantic*

4:00PM Monika Rhein *Upwelling and associated heat flux in the Equatorial Atlantic inferred from helium isotope disequilibrium*

4:20PM Marcus Dengler *On the parameterization of mixing processes at the equator*

4:40PM Domingos Urbano *Upper ocean circulation in the southwestern tropical Atlantic*

### **Thursday, March 4**

### **Science Session 4. Ocean, atmosphere, and coupled model simulations**

Moderator: *P. Chang*

9:00AM Paulo Nobre *Uncoupled Variations of the Tropical Atlantic EUC in a fully coupled ocean-atmosphere model*



9:20AM Herve Giordani *Diagnosing Vertical Motion in the Equatorial Atlantic*

9:40AM Karthik Balaguru *Barrier layers in the Atlantic warmpool - Formation and influence on climate at various time-scales*

10:00AM Mathieu Rouault  
*Intrusion of tropical water in the Benguela upwelling, a numerical study*

10:20AM Coffee Break

10:40AM Kerstin Kirchner *An analysis of the formation, propagation and decay of North Brazil Current rings in the FLAME model*

11:00AM Ramalingam Saravanan *Hurricanes and Air-Sea Interaction in the Tropical Atlantic*

11:20AM Chidong Zhang *A possible root cause of the surface westerly bias over the equatorial Atlantic in climate models*

11:40PM Brian Mapes *Trying not to rain over the IAS in summer - largest analysis tendencies (model struggles) in the MERRA reanalysis*

**12:00PM-1:30PM Lunch**

**1:30 Plenary Discussion: Planned Research Activities (~5 min. summaries)**

3:00 Coffee Break

**3:30 Plenary Discussion: Research Priorities and Progress**

Review of recommendations from last TA meeting (Toulouse, 2009)

*Coupled Model Biases (Ping Chang)*

*Observational Initiatives (Peter Brandt)*

Further Discussion and Next Meeting

**5:00 Meeting Adjourns**

## **Appendix 2. Presentation Abstracts**

### **CLIVAR Tropical Atlantic Meeting 2-4 March, 2010**

#### **Session 1. Climate events and anomalies in the Tropical Atlantic**

*Abderrahim Bentamy*

*Affiliation: IFREMER*

*Seasonal and Interannual Variability of Turbulent Fluxes over the Atlantic Tropical Ocean*

Abstract: This study aims to assess the consistencies and discrepancies of the seasonal and interannual variability of the ocean surface turbulent fluxes, including wind stress, latent and heat fluxes during the period 1993 -- 2008, over the Atlantic tropical basin. Data are derived from remotely sensed data and from

the new ECMWF re-analysis ERA-Interim. Even though some discrepancies are found, the results provide encouraging agreement on the spatial/temporal variations of the three turbulent flux components.

*Greg Foltz*

*Affiliation: University of Washington JISAO*

*Interaction between the Atlantic meridional and Nino modes during 2009*

Abstract: During the first half of 2009 sea surface temperatures (SSTs) were anomalously cold in the northeastern tropical Atlantic and anomalously warm in the central and eastern equatorial Atlantic. Associated with this anomalous meridional dipole in SST was a southward displacement of the ITCZ and extreme flooding in Northeast Brazil. In this study a combination of observations and a linear equatorial wave model is used to investigate the mechanisms responsible for the evolution of anomalous conditions in the equatorial Atlantic during 2009. It is found that anomalous cooling in the northeastern tropical Atlantic began in January, driven by stronger than normal wind-induced latent heat loss. The atmospheric response to anomalously cold SSTs included anomalous northwesterly surface winds along the equator and Ekman pumping to the north (3N-5N). The Ekman pumping in turn led to further anomalous cooling in the 3N-5N band and further strengthening of the meridional SST dipole during boreal spring. Along the equator, weaker than normal westward winds led to an anomalously deep thermocline and surface warming during boreal spring and early summer. The transient response to the anomalous equatorial wind forcing was a downwelling equatorial Kelvin wave and an upwelling equatorial Rossby wave. The Rossby wave reflected off the western boundary and propagated eastward along the equator as a Kelvin wave in June-July, raising the thermocline and putting an abrupt end to the developing equatorial warm event. These results highlight the role of ocean dynamics and air-sea coupling in the development of SST anomalies in the eastern ITCZ region and identify the equatorial Rossby wave as a potential link between the boreal spring meridional mode and the boreal summer Nino.

*Semyon Grodsky*

*Affiliation: University of Maryland*

*Interannual near-surface salinity variability from PIRATA and Argo observations*

Abstract: We focus on 8S30W PIRATA location where both PIRATA and Argo have consistent time series indicating gradual salinification during 2000-2007 and rapid freshening in the two recent years. We compare these changes in salinity with the surface freshwater forcing.

*Julien Jouanno*

*Affiliation: LEGOS*

*The equatorial cold tongue in November-December in the Tropical Atlantic -- mechanisms and variability*

Abstract: The equatorial Atlantic is characterized by a seasonal cooling of surface temperatures from April to August. This cooling generally extends from 35°W to the African coast. Three months later, during November-December (ND), a secondary cooling occurs in the central equatorial Atlantic. The extent and intensity of this cold tongue shows a significant interannual variability. In comparison with its summer counterpart, it does not necessarily extend into the Gulf of Guinea. In this preliminary study, observations from PIRATA moorings, satellites and numerical simulations at 1/4° resolution based on global OGCM NEMO, are used to describe the characteristics and the variability of this cooling during the period 2001 to 2007. Interannual variability of the ND cold tongue in the model is in good agreement with observations and allows to explore the processes which drive its occurrence and characteristics. A special attention is given to the respective roles of thermocline shoaling, windstress and intraseasonal variability.

*Ingo Richter*

*Affiliation: RIGC JAMSTEC Japan*

*On the triggering of Benguela Ninos - equatorial vs. local forcing*

Abstract: Several studies have highlighted the importance of equatorial wind forcing on the development of Benguela Ninos, suggesting that downwelling Kelvin waves propagate the signal along the equator and southwest African coast in a time span of about 1-2 months. The influence of local along shore winds, on the other hand, has received less attention. The present study compares the relative importance of remote and local effects in the development of Benguela Ninos using a 120-year simulation of the coupled GCM for the Earth Simulator (CFES). Compared to many current GCMs, CFES achieves a rather realistic simulation of the tropical Atlantic. In addition to capturing the mean seasonal cycle the model also

simulates Atlantic and Benguela Ninos with realistic amplitude and phase locking. Analysis of CFES output suggests that anomalous along shore winds in the Angola Benguela Area (ABA) are an important component in the development of Benguela Ninos. These wind variations induce SST anomalies through both increased latent heat flux and reduced upwelling and form part of a large-scale weakening of the South Atlantic subtropical anticyclone that appears to originate from the midlatitudes. Forcing by anomalous winds in the equatorial region also plays a role by preconditioning the ABA, but it is found that the local forcing is dominant. The large spatial extent of the wind anomalies may explain the high correlation between Benguela and Atlantic Ninos, which exists in both CFES and observations. The possible influence of Benguela Ninos on the formation of Atlantic Ninos will also be discussed.

*Mathieu Rouault*

*Affiliation: University of Cape Town*

*Intrusion of tropical water in the Benguela upwelling, a numerical study*

Abstract: Benguela Ninos are warmer than normal events in the Benguela upwelling system that have a negative impact on the ecosystem of region. They are also linked to above average rainfall at the coast. We are using a numerical model that reproduces quite well the observed sea surface temperature of the last 25 years to infer various properties such as poleward transport of Angolan water into the Benguela upwelling. This model indicates that Benguela Ninos are an exaggeration of the seasonal cycle at the Angola Benguela front leading to above normal poleward transport of warm, low salinity Angolan water into the Benguela upwelling.

*Fabrice Hernandez*

*Affiliation: IRD Mercator Ocean*

*Tropical Atlantic Analysis Using Mercator Reanalysis*

Abstract: A global 20-year reanalysis based on ORCA2 configuration is analysed together with the GLORYS1V1 2002-2009 reanalysis. The interannual variability of the Gulf of Guinea cold tongue is examined and discussed.

## **Session 2a. Tropical Atlantic Teleconnections**

*Chunzai Wang*

*Affiliation: NOAA AOML*

*Teleconnected Influence of the Tropical Atlantic on the Tropical Indian and Pacific Oceans*

Abstract: Recent studies found that tropical Atlantic variability may affect the climate in both the tropical Pacific and Indian Ocean basins, possibly modulating the Indian summer monsoon and Pacific ENSO events. A warm tropical Atlantic Ocean forces a Gill-Matsuno-type quadrupole response with a low-level anticyclone located over India that weakens the Indian monsoon circulation, and vice versa for a cold tropical Atlantic Ocean. The tropical Atlantic Ocean can also induce changes in the Indian Ocean sea surface temperatures (SSTs), especially along the coast of Africa and in the western side of the Indian basin. Additionally, tropical Atlantic variability can influence the tropical Pacific Ocean via an atmospheric teleconnection that is associated with the Atlantic Walker circulation. Although the Pacific El Nino does not contemporaneously correlate with the Atlantic Nino, anomalous warming or cooling of the two equatorial oceans can form an inter-basin SST gradient!

nt that induces surface zonal wind

anomalies over equatorial South America and other regions in both ocean basins. The zonal wind anomalies act as a bridge linking the two ocean basins, and in turn reinforce the inter-basin SST gradient through the atmospheric Walker circulation and oceanic processes. Thus, a positive feedback seems to exist for climate variability of the tropical Pacific-Atlantic Oceans and atmospheric system, in which the inter-basin SST gradient is coupled to the overlying atmospheric wind.

*Regina Rodrigues*

*Affiliation: Oceanographic Institute - University of Sao Paulo*

*The impacts of inter-El Nino event on the Tropical Atlantic variability and the Northeast Brazil climate*

Abstract: In this study, observations are used to investigate how differences in El Nino events affect the Brazilian Northeast (NE) precipitation and how this relates to the development of SST anomalies in the

Atlantic. Our results show that El Niño telecommunication occurs not only in the tropical North Atlantic as previously thought, but also in the South Atlantic. This is due to the fact that different types of El Niño have different impacts on the SST anomalies over the equatorial and tropical South Atlantic but similar SST responses in the tropical North Atlantic. Strong and long (weak and short) El Niño events are followed by dry (wet) conditions in NE and cold (warm) anomalies in the equatorial Atlantic and Benguela Current region from December to May. Our results suggest that the SST anomalies over the equatorial and tropical South Atlantic are preconditioned by the characteristics of the El Niño event via an indirect extra-tropical route. Preliminary results from an atmosphere-ocean coupled model will also be presented.

*Yochanan Kushnir*

*Affiliation: Lamont-Doherty Earth Observatory*

*The role of tropical Atlantic SST anomalies in forcing global circulation anomalies*

Abstract: The tropical Atlantic exhibits rather small amplitude SST anomalies in comparison to its Pacific counterpart. However, these SST anomalies force important teleconnections that affect global circulation patterns with impact on hydrological cycle variability worldwide. These impacts are felt in North and South America, in Africa, Europe, and Asia. We propose that it is through the tropical Atlantic that the much-discussed Tropical Atlantic Multidecadal Variability (a.k.a., Atlantic Multidecadal Oscillation) can influence global climate variability. In this work we review the patterns and time scales of climate fluctuations associated with tropical Atlantic SST variability and some of the mechanisms by which they operate. We also address the ability of general circulation models to correctly simulate these impacts.

## **Session 2b. Dynamics and impacts of intraseasonal variability**

*Anne Marie Treguier*

*Affiliation: CNRS/ LPO*

*Biweekly oscillations in the Gulf of Guinea-- a case of strong currents on an eastern boundary*

Abstract: Current data on the continental slope off Angola show very energetic biweekly oscillations at 1300 m depth (peak-to-peak amplitude reaching 20-30 cm/s at 30 meters above the bottom). Here we present a synthesis of recent modelling work and observations aimed at understanding the dynamics of these currents. A high resolution primitive equation model demonstrates that this deep variability is forced by equatorial winds, through the generation of equatorial Yanai waves that propagate eastward and at depth, and then poleward as coastal-trapped waves upon reaching the coast of Africa. We have used both the three-dimensional, nonlinear model and a linear model to investigate the kinetic energy at intraseasonal frequencies in the Gulf of Guinea, and the role of equatorial and coastal-trapped waves in its spatial distribution and temporal intermittency. Additional current meter data on the continental slope north of the equator display an energy profile in the 10-20 day period band that is strikingly different from our previous observations, with surface intensification rather than bottom intensification and a secondary maximum near 800 m. The model reproduces these features and explains them-- the surface intensification in the north is due to the regional wind forcing, and the north-south dissymetry of the deep signal is due to shape of the African coast.

*Renellys C. Perez*

*Affiliation: UM CIMAS*

*Interannual variations of Tropical Instability Waves and their influence on the equatorial Atlantic cold tongue*

Abstract: The equatorial Atlantic cold tongue can be dramatically modified by westward propagating tropical instability waves (TIWs). TIWs have strong interannual variations, and we explore whether anomalous sea surface temperatures or anomalous wind forcing have a greater influence on TIW activity using a combination of satellite measurements-- TMI SST, AVISO SLA, QuikSCAT wind stress. These waves were relatively weak in the central and eastern equatorial Atlantic for three successive years beginning in 2006. The intensification of TIWs in mid 2009 and their impact on the cold tongue during the relaxation of the warming event will be described using daily averaged fields from the high-resolution MERCATOR Ocean global ocean analysis products (PSY3V1 and PSY3V2).

## Session 2c. Physical-Biogeochemical Interactions

*Ajit Subramaniam*

*Affiliation: LDEO Columbia University*

*Spatial variability in optical and biogeochemical properties of the Equatorial Atlantic*

*Moacyr Araujo*

*Affiliation: DOCEAN UFPE*

*Coral bleaching analysis in the western tropical Atlantic*

## Session 3. Results from recent/ongoing observational programs

*Peter Brandt*

*Affiliation: IFM-GEOMAR*

*Variability of the Equatorial Undercurrent in the central Atlantic*

Abstract: Easterly/westerly wind anomalies in the western equatorial Atlantic during boreal spring and early summer precondition boreal summer cold/warm events in the eastern equatorial Atlantic (EEA) that manifest in a strong interannual Atlantic cold tongue (ACT) variability. The onset of the ACT is closely linked to the onset of the West African monsoon and particularly to the rainfall in the countries surrounding the Gulf of Guinea. Model simulations suggest a negative correlation between boreal summer ACT sea surface temperature (SST) and the strength of the Equatorial Undercurrent (EUC) supplying the equatorial upwelling. Here we present results from current meter moorings deployed between 2002 and 2008 and from 16 meridional ship sections along 23°W in the central equatorial Atlantic that allow quantifying the mean and the intraseasonal to interannual EUC variability. From shipboard ADCP measurements, the leading modes of zonal velocity variability along 23°W are calculated. A linear regression of the moored ADCP time series onto the leading modes allows reconstructing a time series of meridional sections of zonal velocity in the latitudinal and depth range 1.2°S to 1.2°N and 30 to 300m, respectively. EUC transport variability on seasonal to interannual time scales is discussed with respect to the variability of wind and sea surface temperature in the tropical Atlantic.

*Bernard Bourles (Coauthors: N. Kolodziejczyk, Y. Gouriou and F. Marin)*

*Affiliation: IRD/ LEGOS & CRHOB*

*Analysis of the Equatorial Undercurrent in the Gulf of Guinea*

Abstract: The Atlantic Equatorial Undercurrent (EUC) remains still very poorly documented in the Gulf of Guinea. At 10°W, the EUC experiences a strong seasonal cycle, with two maxima of EUC transport, one weakest in boreal winter and one strongest in boreal summer when strong upward excursion of the equatorial thermocline is observed (Kolodziejczyk et al., 2009). Here, the EUC is described east of 10°W from both currents and hydrographic measurements carried out from late spring to fall between 2000 and 2007. The fate of saline enriched water coming from tropics and subtropics during the boreal summer is discussed.

*Bill Johns*

*Affiliation: RSMAS/ Univ. of Miami*

*TACE observations of the Equatorial Undercurrent in the Gulf of Guinea*

Abstract: Recent observations conducted as part of TACE include a basinwide survey of the EUC at the onset of the 2009 summer cold tongue season, and moored ADCP observations of the EUC at 10°W and 0°E in the Gulf of Guinea. The May-June 2009 shipboard survey showed that the intensity of the EUC decreased eastward across the basin, from a transport of 16.0 Sv at 23°W to 3.9 Sv at 5°E. The survey also revealed westward flow bands on either side of the equator between 10°W and 5°E extending from the surface to the level of the EUC core. In the thermocline layer these flows contained high salinity cores, indicating that EUC waters are being actively detrained into these westward flows and recirculated back toward the central basin. Near 10°W, a second, deeper, core of eastward flow was found on the equator between about 200-350 m, separated from the EUC by a thin layer of westward flow. Evidence from ADCP records suggests that this two-core structure precedes a summertime maximum in the EUC transport at

10°W, when these two cores merge into a thicker and stronger EUC extending through the thermocline layer. Vestiges of this deep eastward core are seen all across the basin, but in the eastern basin it trends south of the equator to about 2°S and is no longer located below the upper EUC core. At 0°E the EUC appears to have a semiannual cycle, with the weakest transport occurring in late summer and fall, different from the behaviour at 10°W and 23°W.

*Roberto De Almeida*

*Affiliation: CST INPE*

*Seasonal variability of the upper circulation of the southwestern Tropical Atlantic*

In this work we present an analysis of the seasonal variability of the upper circulation of the southwestern Tropical Atlantic, investigated using high-resolution near-surface (drifters + satellite altimeter) velocity measurements.

*Yves du Penhoat*

*Affiliation: LEGOS IRD*

*Mixed layer heat budget in the eastern equatorial Atlantic derived from Argo floats during the AMMA/EGEE program*

Abstract: The mixed layer heat balance in the Eastern Equatorial Atlantic is examined in order to assess the contribution of the main processes, i.e. air-sea exchange, advection and entrainment, inside the oceanic upper layers from January 2005 to December 2007. This period coincides with the period of the AMMA-EGEE program during which the number of observations considerably increased in the basin. This study combines a set of in situ observations including Argo profiling floats, drifting MARISONDE buoys, CTD and XBT and profiles from PIRATA moorings, as well as remotely sensed retrievals --TMI AMSR-E SSTs and upper current analyses. Sea surface heat fluxes are derived from NWP models --ECMWF, ARPEGE and NCEP. Temperature and salinity profiles from in situ measurements are used to compute some terms of the mixed layer heat budget over the basin. We first diagnose the mixed-layer heat budget along the trajectory of some float trajectories. Results show that the tendency of the mixed layer temperature undergoes a strong seasonal cycle with contrasted inter-annual differences. This variability reflects the contribution of the seasonal cycle of sea surface heat fluxes. Oceanic advection and entrainment also experience a seasonal cycle, but less well marked than the surface fluxes. Advection and entrainment are seen to play an important role in the heat budget and can reach values as large as 100 W.m<sup>-2</sup> in absolute value. In order to represent the spatial variability of the heat budget, some boxes are considered over which an average budget is computed. The domain-averaged terms of advection, entrainment, vertical diffusion, air sea flux and mixed layer temperature tendency are largely contrasted according to the considered box.

*Claudia Schmid*

*Affiliation: NOAA/AOML/PHOD*

*Analysis of the variability of the Salinity in the eastern tropical Atlantic*

Abstract: Changes of the salinity in the tropical Atlantic are forced by a combination of atmosphere-ocean exchanges and oceanic fluxes. Data collected with profiling floats, CTDs and PIRATA moorings in conjunction with surface flux products are analyzed in an effort to improve our understanding of the seasonal variability and interannual changes. Rapid changes of the surface and subsurface salinity were observed along a hydrographic section at 23W (two realizations of this section were obtained within 2 weeks of each other). Data collected by the moorings help to analyze the causes of such rapid changes. Preliminary results will be presented in comparison with results from earlier studies.

*Monika Rhein*

*Affiliation: University Bremen*

*Upwelling and associated heat flux in the Equatorial Atlantic inferred from helium isotope disequilibrium*

Abstract: Upwelling velocities  $w$  in the equatorial band are too small to be directly observed. Here we apply a recently proposed indirect method, using the observed helium isotope (<sup>3</sup>He, <sup>4</sup>He) disequilibria in the mixed layer. The helium data were sampled on three cruises in the eastern tropical Atlantic in September 2005 and June/July 2006. A one - dimensional two box model was applied, where the helium air-sea gas exchange is balanced by upwelling from <sup>3</sup>He-rich water below the mixed layer and by vertical mixing. The mixing coefficients  $K_v$  were estimated from microstructure measurements, and on two of the cruises,  $K_v$  exceeded  $1 \times 10^{-4} \text{m}^2 \text{s}^{-1}$ , making the vertical mixing term of the same order of magnitude as the

gas exchange and the upwelling term. In total, Helium disequilibrium was observed on 54 stations. 48% of the calculated upwelling velocities, were smaller than  $1.0 \times 10^{-5}$  m/s, 19% were between  $1.0$  and  $2.0 \times 10^{-5}$  m/s, 22% between  $2.0$  and  $4.0 \times 10^{-5}$  m/s, and only 11% upwelling velocities exceeded this limit. The highest upwelling velocities were found in late June 2006. Meridional upwelling distribution indicated an equatorial asymmetry with higher vertical velocities between the equator and  $1^{\circ}$ - $2^{\circ}$  south compared to north of the equator, particularly at  $10^{\circ}$ W. Associated heat flux into the mixed layer could be as high as  $138$  W/m<sup>2</sup>, but depends strongly on the chosen depths where the upwelled water comes from. By combining upwelling velocities with SST and productivity distributions, a mean monthly equatorial upwelling rate of  $19$  Sv was estimated for June 2006, and a biweekly mean of  $24$  Sv for September 2005.

*Marcus Dengler (Coauthors: J. Schafstall, J. Toole, D. Banyte, B. Bourles)*

*Affiliation: Leibniz Institute for Marine Science (IFM-GEOMAR)*

*On the parameterization of mixing processes at the equator*

Abstract: This contribution explores the skill of mixing parameterization in the upper and intermediate water column at the equatorial. Due to reduced wave-wave interaction, mixing in the deeper water column ( $>200$ m) of the tropical oceans is considered to be very low. Full depth microstructure profiles show that average eddy diffusivities rarely exceed  $3 \times 10^{-6} \text{m}^2 \text{s}^{-1}$  throughout the deeper water column. However, dissipation rates calculated from internal wave-wave interaction parameterization underestimate observed dissipation rates by a factor of 5 within about  $2^{\circ}$  of the equator. In this region, the equatorial deep jets are pronounced and elevated dissipation rates are found in the high shear zones of the jets. A turbulence parameterization evaluated in unstable events overestimates dissipation rates directly on the equator but agrees well with observations away ( $>1^{\circ}$ ) from the equator.

*Domingos Urbano*

*Affiliation: INPE*

*Upper ocean circulation in the southwestern tropical Atlantic*

Abstract: Most of the knowledge on the surface circulation in the southwestern tropical Atlantic off South America is based on geostrophic maps built on from sparse salinity/temperature profiles collected throughout the decades. Schematic pictures provided by previous researches have been important to elucidate the large scale circulation pattern, however uncertainties remains about the linkage in some regions. Almost none observation was collected between  $10$ S and  $15$ S in the eastern Atlantic. Recent direct velocity data collected by shipboard acoustic Doppler current profiler (S-ADCP) during the Brazilian PIRATA cruises, together with atmospheric data provided by radiosondes, reveal the existence of an eastward flow between  $11$ S and  $14$ S, probably generated by a feature in the wind field. Sverdrup transport computed from wind data also present eastward flow in the region. This recent feature can not be identified as the South Equatorial Countercurrent since it was described to be located between  $7$ S and  $9$ S (Molinari, 1982; 1983). How this eastward flow interacts with the sluggish South Equatorial Current system flowing eastward is of major curiosity due to the bifurcation process. High resolution ocean numeric models also present this eastward flow and need to be used to better understand its variability. Coupled ocean-atmospheric models are needed to better understand possible feedbacks that might be related with climate over South America.

#### **Session 4. Ocean, atmosphere, and coupled model simulations**

*Paulo Nobre*

*Affiliation: INPE*

*Uncoupled Variations of the Tropical Atlantic EUC in a fully coupled ocean-atmosphere model*

Abstract: A fully coupled ocean-atmosphere general circulation model (CGCM) is used to investigate the temporal variations of the Equatorial Undercurrent (EUC), which is compared to the EUC variability simulated by the ocean-component of the CGCM forced by prescribed winds. It is shown that the EUC depth variations on the CGCM simulations are seasonally dependent and linked to atmospheric climatological seasonal cycle.

*Herve Giordani*

*Affiliation: CNRM*

### *Diagnosing Vertical Motion in the Equatorial Atlantic*

Abstract: Estimating vertical velocity in the oceanic upper-layers is a key issue for understanding the equatorial upwelling and thus the cold tongue development in the Eastern equatorial Atlantic. This paper aims to identify the physical sources of vertical velocity from a generalized  $w$ -equation valid at the equator. This  $w$ -equation is developed from the divergence equation of the primitive equation system and takes into account the turbulent buoyancy and momentum fluxes. An application of this diagnostic method is provided from a realistic ocean simulation of the Equatorial Atlantic. It is shown that the equatorial upwelling works to continuously adjust the density/pressure fields to the strongly sheared zonal current system formed by the superposition of the South Equatorial Current and the underlying Equatorial Under Current. This result supports the existence of an equatorial balance between the mass and the current fields which depends on the parameter  $b$ . As a consequence of this study, the upwelling along the equator appears to be an indirect response of the ocean to the Southeast surface wind-stress where the mass adjusts to the zonal circulation while the Angola upwelling results from dynamical forcings dominated by the stress-curl.

*Karthik Balaguru*

*Affiliation: Texas A & M University*

### *Barrier layers in the Atlantic warmpool-- Formation and influence on climate at various time-scales*

Abstract: The region to the east of the Caribbean and to the north of Latin America, is known as the Atlantic warm pool as the SSTs in this region are considerably higher than the rest of the basin. Barrier layer (BL) is an important feature of the Atlantic warm pool and may play a role in the maintenance of the warm SSTs, as the BL acts as a barrier to vertical mixing. We explored the formation mechanism of BLs in the Atlantic warm pool using the NCAR climate model CCSM 3.0 through a set of numerical sensitivity experiments. We find that the BL is maintained by not just advection of fresh-water from the Amazon but also through the remote mechanism of subduction. Formation of temperature inversions during boreal winter enhances the role of the BL in maintaining the warm SST. We also find that the BL-SST-ITCZ feedback, albeit weak, does appear to operate, at least in the model simulations. At shorter time scales, the BL can affect oceanic response to hurricane forcing. Using a high-resolution regional coupled climate model (ROMS-WRF) and satellite observations, we find that the BL causes less cooling at the ocean surface in the wake of hurricanes due to reduced vertical mixing. In the simulation, we even observe surface warming when a hurricane passes through a BL with a temperature inversion. This could act as a potential positive feedback for the hurricane intensity.

*Hailong Liu*

*Affiliation:*

### *Diagnosing Atlantic warm pool and its climate impacts in IPCC-AR4 models*

Abstract: Earlier studies using models and observations have demonstrated the importance of the Atlantic warm pool (AWP) for summer climate and hurricanes. In specific, a large AWP weakens the southerly Great Plains low-level jet, which results in reduced northward moisture transport from the Gulf of Mexico to the U.S. east of the Rocky Mountains and thus decreases the summer rainfall over the central U.S. Decreased rainfall, if it persists, can cause drought in North America. A large AWP also reduces the tropospheric vertical wind shear in the hurricane main development region and increases the moist static instability of the troposphere, both of which help the intensification of tropical storms into major hurricanes. Despite these important findings from the earlier works, currently we do not have a clear understanding of AWP predictability. The main objective of this work is to evaluate the performance of IPCC-AR4 models under 20C3M scenario in simulating AWP and associated atmosphere-ocean processes in the light of previous observational and diagnostic modeling studies. This work will provide a valuable guidance to understand and improve seasonal predictability of AWP.

*Kerstin Kirchner (Coauthors: M. Rhein, S. Hüttl-Kabus and C.W. Böning)*

*Affiliation: University of Bremen, Institute of Environmental Physics*

### *An analysis of the formation, propagation and decay of North Brazil Current rings in the FLAME model*

Abstract: Near the western boundary of the tropical North Atlantic, where the North Brazil Current (NBC) retroflects into the North Equatorial Countercurrent, large anticyclonic rings are shed. After separating from the retroflexion region, the so-called NBC rings travel northwestward along the Brazilian coast, until they reach the island chain of the Lesser Antilles and disintegrate. These rings contribute substantially to the upper limb return flow of the Atlantic Meridional Overturning Circulation (AMOC) by carrying South



Atlantic Water into the northern subtropical gyre. Their relevance for the northward transport of South Atlantic Water depends on the frequency of their generation as well as on their horizontal and vertical structure. Different types of rings are produced: they can be either confined to the surface layers or deep reaching, as well as only subsurface intensified with no surface signature. The ring shedding and propagation and the complex interaction of the rings with the Lesser Antilles are investigated in the 1/12° FLAME model. The ring properties simulated in FLAME reach the upper limit of the observed rings in diameter and agree with recent observations on seasonal variability, which indicates a maximum shedding during the first half of the year. When the rings reach the shallow topography of the Lesser Antilles, they are trapped by the island triangle of St. Lucia, Barbados and Tobago and interact with the island chain. The model provides a resolution which is capable of resolving the complex topographic conditions at the islands and illuminates various possible fates for the water contained in the rings. It also reproduces laboratory experiments, which indicate that both cyclones and anticyclones are formed after a ring passes through a topographic gap. We provide a detailed comparison with results from Garaffo et al. (2003), who used the isopycnic MICOM model with monthly climatological forcing to analyze the ring shedding and discuss the differences between both studies. Trajectories of artificial floats, which were inserted into the modeled velocity field, are used to investigate the pathways of the ring cores and their fate after they encounter the Lesser Antilles. The majority of the floats entered the Caribbean, while the northward, Atlantic pathway was found to be of minor importance. No prominent pathway was found east of Barbados, where a ring could avoid the interaction with the islands and migrate towards the northern Lesser Antilles undisturbed.

Ben Kirtman

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title: Impact of Ocean Model Resolution of CCSM4 Climate Variability

Coauthor:

Abstract: Several recent studies have focused on the importance of atmospheric model resolution in the simulations of climate (e.g., Gent et al. 2009). The results include little or no change in the mean and variable climate (i.e., Hack et al. 2006) to significant differences in the ENSO cycle (Navarra et al. 2008) and in SST biases in the upwelling regions (i.e., Gent et al. 2009). The Gent et al. (2009; hereafter G09) study is of particular relevance here. First, both studies use the same version of the National Center for Atmospheric Research (NCAR) Community Climate System Model (CCSM). The model used by G09 is identical to the control model used here. Third, where G09 focus on atmospheric model resolution (e.g., 2 degrees vs. 0.5 degrees horizontal resolution) our emphasis is on ocean model resolution. We enhance the 1 degree ocean model resolution used by G09 to 0.1 degree. The atmospheric component model resolution is identical (i.e., 0.5 degrees) in all the experiments presented here.

Ramalingam Saravanan

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title: Hurricanes and Air-Sea Interaction in the Tropical Atlantic

Coauthor:

Abstract: The frequency and intensity of hurricanes show considerable variations from year to year. Of particular importance is to distinguish between natural and human influences responsible for these variations. It is difficult to make this attribution using global climate models because they do not currently have sufficient horizontal grid resolution to properly simulate tropical cyclones. Therefore, "time-slice" experiments are used to make this attribution, where a fine-resolution regional atmospheric model is embedded inside a coarser global climate model. In this talk, we focus on two factors affecting hurricane activity, vertical shear and air-sea coupling, in the context of this regional modeling approach. We investigate how well global general circulation models manage to simulate the observed vertical shear in this region, and show that coupling between the atmosphere and the ocean must be properly represented to simulate the large-scale influences on vertical shear. To properly represent the effects of air-sea coupling, it is necessary to develop regional climate models that incorporate ocean-atmosphere interaction. We present some preliminary results from a high-resolution coupled regional climate model (CRCM) that we have developed, consisting of a regional atmospheric model (NCAR WRF) coupled to a regional ocean model

(ROMS). We compare the simulation of hurricanes in coupled and uncoupled integrations of the CRCM, to assess the sensitivity to air-sea interaction.

*Chidong Zhang*

*Affiliation: RSMAS/ University of Miami*

*A possible root cause of the surface westerly bias over the equatorial Atlantic in climate models*

Abstract: The notorious warm SST bias in the tropical Atlantic Ocean in coupled GCM has been a subject of active research. It has been suggested that this bias is at least partially produced by unrealistic surface westerly wind near the equator. The westerly bias itself has been attributed to erroneous zonal gradients in surface pressure and precipitation in the tropical Atlantic and over the adjacent land. In this study, we suggest that even if there was no systematic error in the zonal gradient in precipitation, many atmospheric GCMs (AGCM) may still produce the westerly bias and warm SST bias when coupled with an ocean GCM. This suggestion is based on an analysis of vertical diabatic heating profiles from sounding observations, TRMM observations, and from two AGCMs. In observations of both soundings and TRMM, there is a strong low-level heating maximum over the Amazon basin, which is missing in the AGCMs. A low-level heating maximum is much more effective than a upper-level maximum to generate surface wind responses. A lack of such low-level heating maximum over the Amazon basin in AGCMs can then lead to insufficient easterlies or a westerly bias over the tropical Atlantic. It is argued that the unrealistic heating profile in AGCMs is a consequence of deficient parameterizations of atmospheric convection and precipitation processes.

*Brian Mapes*

*Affiliation: RSMAS*

*Trying not to rain over the IAS in summer-- largest analysis tendencies (model struggles) in the MERRA reanalysis*

Abstract: The new NASA atmospheric reanalysis (MERRA) includes datasets of analysis tendencies. These fields indicate where and how hard the assimilated observations are acting to resist the underlying model's erroneous tendencies or first guess errors. A climatology of analysis tendencies shows global extrema in the NW Atlantic in summer. The sense of these is that the model has a lot of convective heating over this warm pool area that it shouldn't.

#### **Thursday afternoon Plenary Discussion: Planned Research Activities**

*Bernard Bourles*

*Affiliation: IRD/ LEGOS & CRHOB*

*Status of Pirata in France*

Abstract: France is one of the three nations in charge of the PIRATA program, with specific commitments on the field. This presentation is dedicated to the different actions carried out in 2009 in the framework of Pirata by the french scientific community, to the organization and management of PIRATA in France and to new perspectives.

*Edmo Campos*

*Affiliation: University of Sao Paulo*

*Developing an Atlas Buoy Prototype in Brazil*

Abstract: Efforts towards the construction of an Atlas Buoy prototype (ATLAS-B) has been started as part of the Brazilian PIRATA Program. A Pilot Project for monitoring the SW Atlantic has been approved by Brazilian funding agencies, based on the deployment of an ATLAS-B near 28S, 43W. This mooring site will complement the data from the PIRATA SW Extension, providing important information for studying the variability of the atmospheric South Atlantic Convergence Zone (SACZ). The enhancement of the Brazilian capacity of instrument calibration is also part of this project.

### Appendix 3. Meeting Registrants

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