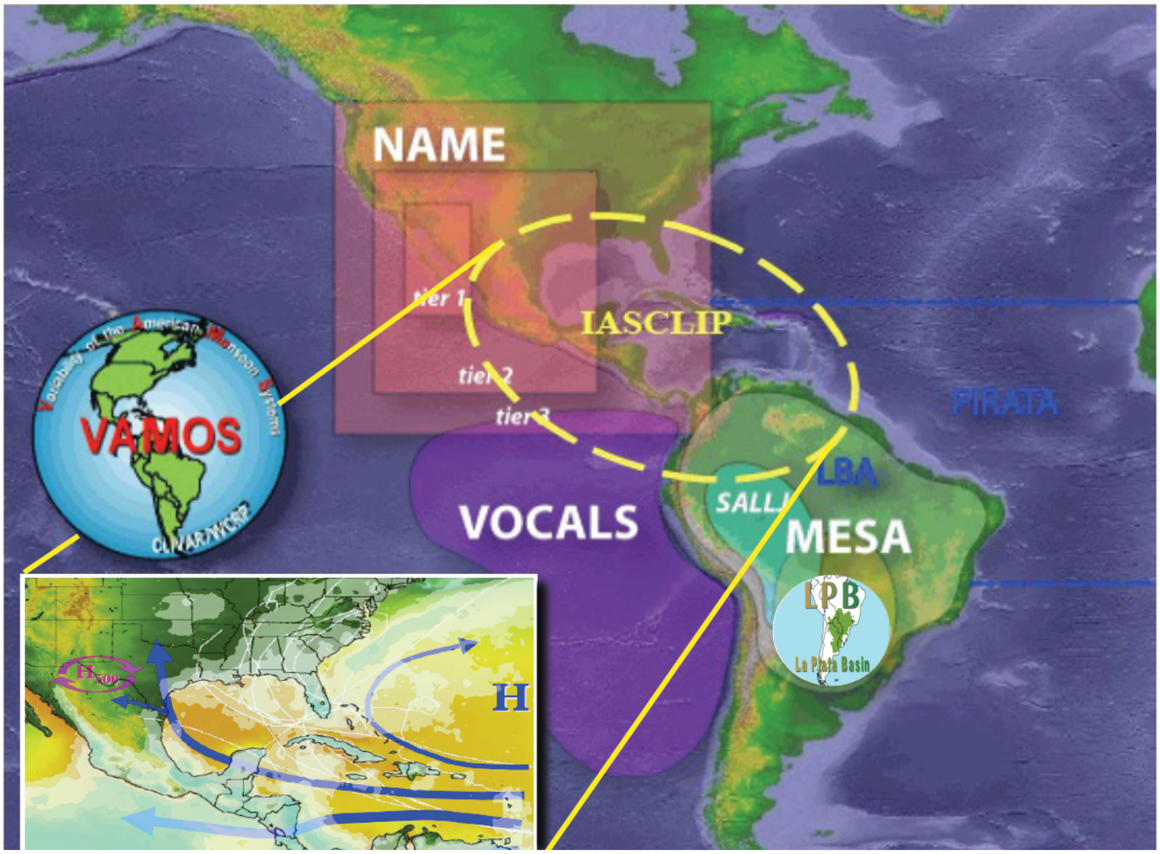
IASCLiP Implementation Strategy*

June 01 2014



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* This is a live document, which will be edited until all working groups and the scientific steering group members have been selected and have had a chance to deliberate on this document

Executive Summary:

The Intra-Americas Seas Study of Climate Processes (IASCLiP) has made significant progress since its inception in CLIVAR in 2005. There are close to 100 publications (http://www.eol.ucar.edu/projects/iasclip/publications/publication_refs.html) and more on the anvil from the program. Several projects in IASCLiP have been funded by NOAA Climate Program Office over the years. Our leadership team and working group members are changing as we embark in to the future.

The Intra-Americas Seas (IAS) is now well recognized for its warmest body of surface ocean temperatures in the western hemisphere that appears in the boreal summer and fall seasons, which is often referred as the Atlantic Warm Pool (AWP). There is considerable evidence to suggest from observational and modeling studies the influence of AWP on seasonal rainfall anomalies in the boreal summer and fall seasons in the continental US, Central America and in the Caribbean region. The association of the AWP variability with the Atlantic tropical cyclone activity is also well documented in the literature. However the role of IAS providing moisture for extratropical storms in the central and eastern US during winter and spring cannot be understated while the recent discovery of its role in the frequency modulation of intense tornado outbreaks in the US is illuminating. The Caribbean Sea, which is part of the IAS comprises the pathway of much of the upper limb of the global thermohaline circulation in the North Atlantic and therefore has an important role in regulating climate variations in low frequency time scales. Some modeling studies suggest that AWP variations have a negative feedback on the AMOC variability. Similarly the remote teleconnections of AWP with the North and the South American monsoons makes IASCLiP well poised to bridge them as a unified system, which was a vision of the VAMOS program.

The pathological and grave model bias in the climate models over the IAS region that transcend generations of climate model development, the diminishing insitu observational coverage of the oceans and land areas around IAS, and the continuing vulnerability of several countries including the US to climate extremes (e.g. droughts, floods, landfalling tropical cyclones) pose overwhelming challenges to IASCLiP. These challenges however, offer opportunities for IASCLiP to improve our understanding of the regulation of the climate extremes influenced by IAS variations to be able to better anticipate them. At the same time this program also encourages us to develop a closer cooperation with all the affected countries to bolster our observational networks for improved climate monitoring while also building capacity in many of the IAS rim nations to cope with climate related vulnerabilities. Over the years IASCLiP has built a rich community of investigators who have the ability to work across CLIVAR to meet its grand challenges of changes in water availability, climate extremes, and providing regional climate information with the best available practices.

This implementation strategy (is a live document) of IASCLiP, which lays out the challenges founded on prior work, spans the time scales of weather to secular change. In the months to come, the newly organized IASCLiP governance structure will prioritize the goals that most effectively would deliver in meeting the challenge of ameliorating the model bias, improving observational network and capacity building that faciliates climate application.

Vision statement: The goal of IASCLiP is to serve the needs of improving our understanding and prediction of climate extremes and anomalies in the Americas.

1. Introduction

The Intra-Americas Seas Climate Processes (IASCliP) was established as a program within the Variability of the American Monsoon System (VAMOS) in 2005. An important consideration for establishing an international program like IASCLiP was that the Intra-Americas Seas (IAS; consisting of the Caribbean Sea, the Gulf of Mexico, and the tropical North Atlantic Ocean) which hosts the warmest pool of warm water (>28.5^{0}C) in the western hemisphere (Wang and Enfield 2001, 2003) was shown to be an important regulator of summer climate in North America. Over the years the influence and manifestation of IAS variability on climate extremes and anomalies spanning from intra-seasonal to secular changes has been amply demonstrated (e.g., Maloney and Hartmann 2000; Higgins and Shi 2001; Wang et al. 2006, 2008a,b, 2011; Karnauskas and Busalacchi 2009). However even winter weather extremes in eastern US have their antecedents in the IAS (Bozart and Lin 1994; Orlanski and Sheldon 1995). The corn belt in the United States derives much of its moisture advected from the IAS region and broad teleconnections emanating from the IAS have major influences on Midwest rainfall variability.

IASCLiP is poised to bridge our understanding of the interaction between the monsoon systems of North and South America. Our knowledge of each monsoon has undergone rapid development and progress under the aegis of the now completed programs of the North American Monsoon Experiment (NAME; Gochis et al. 2004) and Monsoon Experiment South America (MESA; Marendgo et al. 2012). Studies in the IASCLiP have revealed the existence of complex teleconnections that intimately relate variability of the IAS to variations in the monsoon systems across the Americas (Wang et al. 2006; Karnauskas et al. 2013; Misra and DiNapoli 2013). Convection in the IAS region also appears to modulate the intensity and location of subsidence over the southeastern subtropical Pacific Ocean (Wang et al. 2010; Lee et al. 2013) and ENSO teleconnections (Xie et al. 2008; Ham et al., 2013).

The challenges of the IASCLiP are to: 1). develop and sustain denser observational network in the region beyond the current distribution of observations, 2). highlight and ameliorate modeling deficiencies, and 3). facilitate knowledge transfer and capacity building in the region. For instance the ocean observations in the IAS are poorly covered compared to other regions of the planet. Similarly, the global climate models exhibit a significant cold SST and dry atmosphere bias in the IAS region, which is pathological across generations of climate modeling (e.g., Liu et al. 2012, 2013; Kozar and Misra 2013; Wang et al. 2014). Many of the island nations and surrounding countries of the IAS are vulnerable to climate extremes from droughts and landfalling tropical cyclones, which continue to be a challenge to forecast with sufficient lead time to mobilize resources to mitigate their impacts on human fatalities and infrastructural damages. An enhanced and sustained observational network combined with model improvements focused on the IAS warm pool are key features to improving forecasting in this region.

These challenges however, foster opportunities for IASCLiP. For example, some of the new WCRP grand challenges relate very closely to the program objectives and roadmap of IASCLiP. Furthermore, IASCLiP provides a perfect medium for building a good synergy between the US and several other neighboring countries to adapt and mitigate impacts of IAS influenced climate anomalies that cross-cuts the economic stature of the affected nations. From its conception in 2005, the IASCLiP community has developed a significant repertoire of scientific understanding of the IAS associated climate variations and change (http://www.eol.ucar.edu/projects/iasclip/publications/publication_refs.html) while also identifying important gaps (http://www.eol.ucar.edu/projects/iasclip/documentation/IASCLIP.Modelplan_latest.pdf; http://www.eol.ucar.edu/projects/iasclip/documentation/IASCLIP_monitoring_plan.pdf), which provide a good foundation to surge forward in IASCLiP.

2. Roadmap for IASCLiP

IASCLiP like CLIVAR is undergoing through organizational changes as new leadership is taking charge. Therefore this roadmap of IASCLiP will be a live document until we get reorganize and repopulate the three critical working groups (modeling, observational and capacity building) working groups that will be tasked to accomplish the following goals:

i) Addressing the systematic biases in our global climate models in the IAS region
ii) Diagnosing large-scale control of IAS variation on climate anomalies and weather extremes with intent of providing better handle on their outlooks from existing or novel prediction techniques that span from the intraseasonal to projections of the secular change
iii) Building a persuasive case for engaging multiple nations to leverage existing and new resources for enhancing the observational network of one the most poorly observed oceans of the world.
iv) Capacity building in climate services and applications across the Americas including US, Caribbean, Central and Latin American countries that are exposed to climate extremes that have their antecedents in the IAS

In order for IASCLiP to accomplish these tasks we require CLIVAR's support and cooperation in:

a) Facilitating periodic meetings (both live and remote) of the working group members who would ideally be from several countries in the Americas
b) Developing synergy and networks with existing and future CLIVAR groups
c) Help in capacity building efforts of IASCLiP

I) Goals of the Modeling Working Group

Although not explicitly stated, all of the goals outlined below do have an implication on the projection of changing climate or in the understanding of the phenomenology under a changing climate.

i. Diagnosing and reducing model biases in IAS and IAS impacted regions

(1). Cold SST bias

Almost of all state-of-the-art models exhibit significant biases in the AWP (or IAS) region (e.g., Liu et al. 2012, 2013; Kozar and Misra 2013), yet the mechanisms are likely to be quite different than those leading to the well known cold bias in the eastern equatorial Pacific Ocean. Many of these studies indicate a pervasive cold bias displayed by the global cooupled ocean-atmosphere models over the IAS region. When an atmospheric GCM is forced by observed SST, there is an excessive precipitation over the AWP region during the summer contrary to observations (Fig. 1d). However, when the atmosphere and ocean models are fully coupled, there is a dry and cold SST bias in the AWP region (Figs. 1b and c and Figs. 1e and f). Using more CMIP3/CMIP5 models obtains similar results to those in Fig. 1. The cause of these model biases in the AWP region is a challenging problem although it has been suggested that the largest impact on the rainfall bias may come from the negative SST biases since the same CMIP3 models that have the least SST bias also have the most realistic rainfall (Liu et al. 2012).

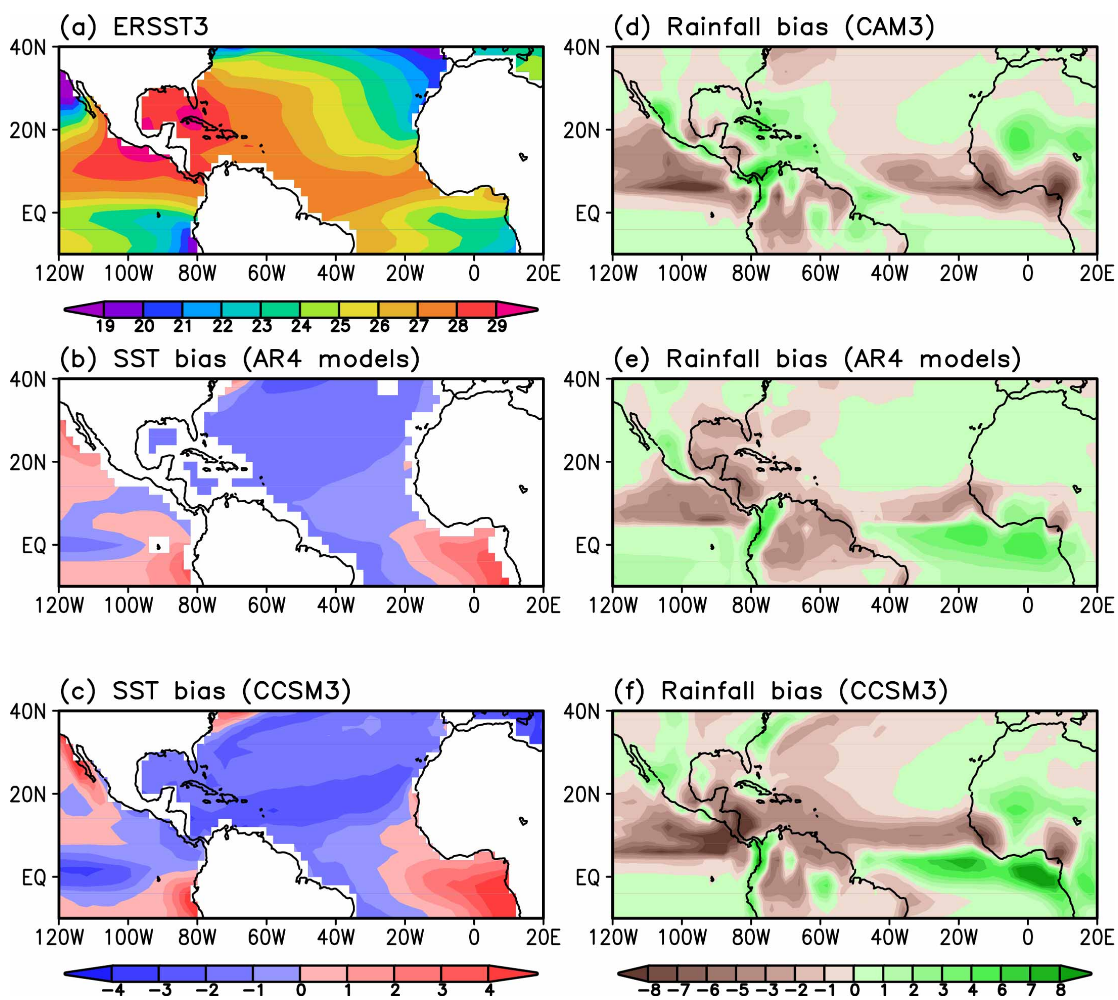

Figure 1. *The observed SST and long-term averaged model biases in the summer months of June-August (JJA; Wang et al.; unpublished). Shown are (a) the ERSST, (b) the model SST bias of the 22 CMIP3 coupled model ensemble, (c) the model SST bias of CCSM3, (d) the model rainfall bias of the atmospheric GCM (CAM3), (e) the model rainfall bias of the 22 IPCC-AR4 coupled model ensemble, and (f) the model rainfall bias of CCSM3.*

The coupled general circulation models in both CMIP3 and CMIP5 suffer from cold SST bias in the AWP region, and show very weak AWP variability (Liu et al. 2012, 2013; Misra et al. 2009; Kozar and Misra 2013). In CMIP3 climate models, the cold SST bias in the AWP region is due to excessive amounts of simulated low level cloud, which blocks shortwave radiation from reaching the sea surface (Liu et al. 2012). However, the AWP SST cold bias in CMIP5 climate models is more modulated by an erroneous radiation balance due to misrepresentation of high-level clouds rather than misrepresentation of low-level clouds as in CMIP3 (Liu et al. 2013). *An improvement of model simulated clouds is important for reducing the climate model biases in the AWP region and thus a better prediction for rainfall in the United States. Given these previous analyses, it is necessary to perform some further diagnostic experimental modeling studies to understand and design strategies for ameliorating these model biases.*

(2). Summer seasonal predictability

The summer season prediction skill in the Americas is still a huge challenge (Stefanova et al. 2011; Kim et al. 2012; Misra et al. 2013) with very little useful skill available for climate applications. However given that a major fraction of the rain events in the surrounding land region of the IAS derive their moisture from IAS (Chan and Misra 2010; Wang 2007; Wang and Lee 2007) *it is important to understand the manifestation of this low skill in the summer and fall seasons that coincides with the AWP*. Fig. 3 clearly shows that the AWP variations have a much larger influence than ENSO variations in the boreal summer season rainfall over the US. Similarly, the variability of the onset date of the AWP has a significant influence on the onset, demise and length of the rainy season in Central America (Misra et al. 2014; Fig. 4). Fig. 4 suggests that early (late) onset of AWP is associated with early (late) onset and early (late) demise of the rainy season, which leads to increased (shortened) length of the rainy season in Central America. More recently Misra et al. (2014) show that some of the current coupled general circulation models exhibit significant improvement in their AWP seasonal prediction skill compared to the earlier generation of the models.

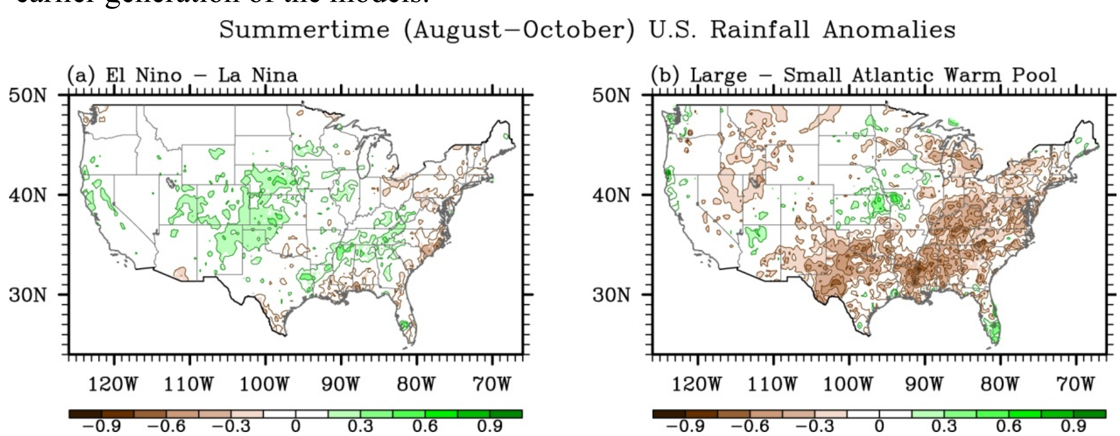

Figure 3. *Composite mean differences of summertime U.S. rainfall anomalies between 21 El Niño and 22 La Niña events (left panel), and between 10 large and 10 small AWP events (right panel) during 1948-2010 derived from the CPC unified gauge-based analysis of the U.S. daily precipitation. Negative and positive contours are in brown and green, respectively. Significant values at 90% or above based on a Student's t test (two-tailed) are shaded. The unit is in mm day^{-1}.*

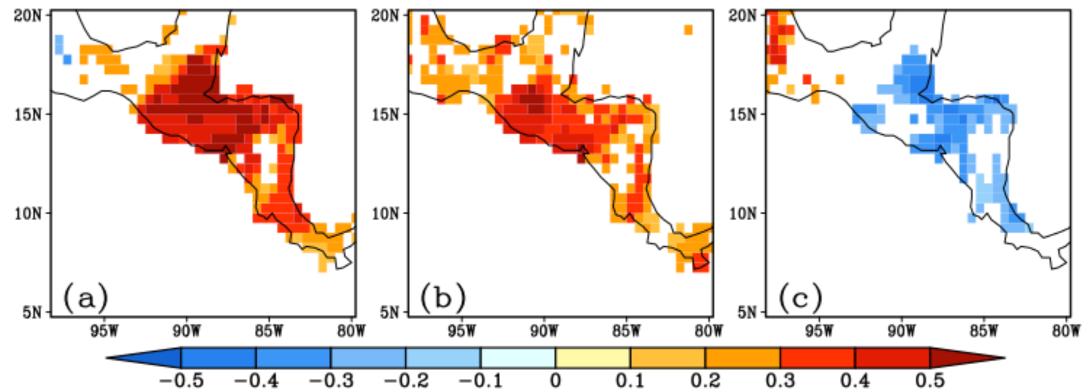

Figure 4: *Correlation of the variability of the onset date of the AWP season with the (a) onset of the rainy season, (b) demise of the rainy season, and (c) length of the rainy season. Only significant values at 90% confidence interval are shown. From Misra et al. (2014).*

ii. Understanding phenomenology in the IAS region that has both local and remote impacts

(1). Influences on TC activity

The AWP plays an important role in shaping TC genesis and tracks (Wang et al. 2006, 2008, 2011). The AWP in August-October expands toward the east during large AWP years, whereas it is greatly contracted during small AWP years. TC activity increases with an eastward shift of warm water and associated reduction in vertical wind shear. More TCs are formed east of 40°W in large AWP years due to the increased SST and atmospheric convective instability. The eastward shift in TC genesis increases the possibility that TC's moving northward without making landfall in the southeastern United States. The North Atlantic subtropical high retreats northeastward with a large AWP and this favors more frequent recurvature of TCs to the northeast; while the subtropical high moves further southwestward with a small AWP, which makes the environment more favorable for the TCs to make landfall in the southeastern United States (Fig. 2). *This needs to be more closely examined and exploited for operational predication.*

Improvement on hurricane intensity prediction is challenging because of the complex physical processes controlling TC intensity (Elsberry 2014). The hurricane Potential Intensity (PI) index, proposed by Emanuel (1988), is a fundamental concept and a widely used guide to estimate the upper bounds of hurricane intensity given atmospheric and oceanic surface conditions. However, the PI index uses SST only to characterize the ocean contribution to hurricane intensity and does not consider the contribution from the subsurface ocean. It is shown that cooling of the upper ocean by TC-induced mixing is an important process that impacts TC intensity (Lin et al. 2013). In addition to the upper ocean thermal structure, the upper ocean salinity also affects the stratification and stability which in turn change the vertical mixing and upwelling of the upper layer ocean (Balaguru et al. 2012). *Thus, understanding and studying of subsurface ocean temperature and salinity impacts on TC intensity in the IAS region are important issues for IASCLiP.*

Global climate model simulations forced by future greenhouse warming project that the AWP warms at a slower rate than the tropical Indo-Pacific in the twenty-first century. Several recent studies have shown that the suppressed warming of the AWP increases the vertical wind shear and static stability aloft in the main development region (MDR) for Atlantic hurricanes, and thus decreases overall Atlantic hurricane activity in the twenty-first century (Lee et al. 2011; Vecchi and Soden 2007; Latif et al. 2007). *Therefore, in order to improve the future projection of Atlantic hurricane activity, it is important to undertand the role of AWP in a warming climate.*

(2). Impacts on rainfall and tornado activity in U.S. and central America

A large (small) AWP is associated with reduced (enhanced) rainfall in the U.S. during summer and fall (Wang et al. 2006; Liu et al. 2014). The mechanism is that a large (small) AWP decreases (increases) the moisture transport to the U.S. from the Gulf of Mexico (Fig. 5). A decreased rainfall can cause drought in the Mississippi valley in U.S. when the large AWP persists for a long time. In additional to U.S. rainfall, a recent study explored a potential relationship between several climate indices and U.S. tornado activity (Lee et al. 2013). It is shown that for active (inactive) U.S. tornado years in the spring during 1950-2010, moisture transport from the IAS to the United States is enhanced (decreased) (Fig. 3). Similarly extreme events in the winter over eastern US gain substantial moisture from the Gulf of Mexico (Bozart and Lin 1994; Sheldon and Orlanski 1995). Likewise there is substantial interest in understanding the role of IAS variability on Central American and Caribbean rainfall variations (Fig. 4). Thus, *quantifying the IAS variability on U.S., Caribbean and Central American rainfall in all seasons of the year (particularly summer) and gleaning any predictability for any seasonal U.S. tornado activity and other extremes would be of immediate interest to IASCLiP.*

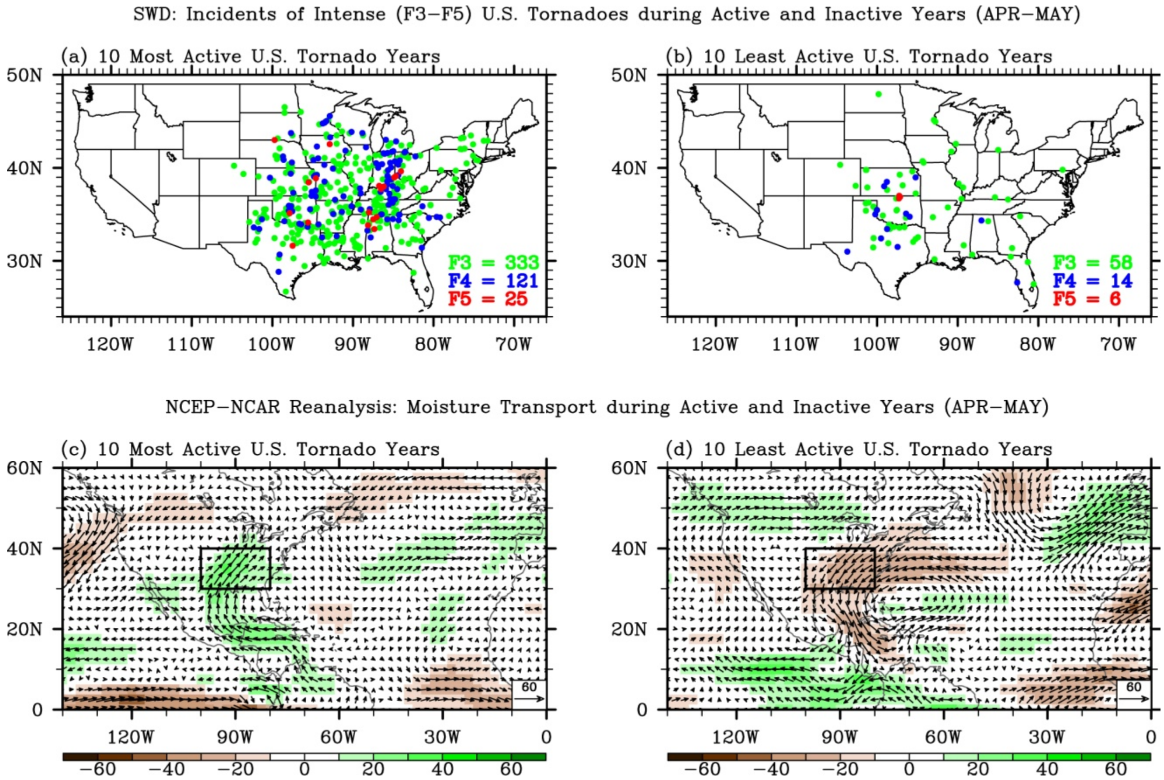

Figure 5. *Incidents of intense (F3-F5) U.S. tornadoes in April-May for (a) the ten most active U.S. tornado years and (b) the ten least active U.S. tornado years (Lee et al. 2013). Green color is for F3, blue color for F4 and red color for F5 tornadoes. Anomalous moisture transport for (c) the ten most active U.S. tornado years and (d) ten least active U.S. tornado years in April-May during 1950-2010 obtained from NCEP-NCAR reanalysis. The unit is kg* $m^{-1}sec^{-1}$ *for moisture transport. The small box in (c) and (d) indicates the central and eastern U.S. region frequently affected by intense tornadoes (30°N-40°N and 100°W-80°W).*

(3). Links of the AWP with the AMOC and the tropical southeastern Pacific

Wang et al. (2013) suggest that variability of freshwater and ocean salinity associated with the AWP may have the potential to affect the Atlantic meridional overturning circulation (AMOC). On one hand, as the AMOC weakens, its northward heat transport is reduced and thus the North Atlantic cools and the AWP weakens and becomes smaller. On the other hand, a small AWP decreases rainfall in the tropical North Atlantic and increases the cross-Central American moisture export 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 positive salinity anomalies are believed to increase the upper-ocean density in the deep-water formation regions and thus strengthen the AMOC. Therefore, the AWP plays a negative feedback role that acts to restore the AMOC after it is weakened or shut down. This hypothesis has been tested and confirmed by ocean-only model experiments (Zhang et al. 2014). *The role of the AWP variations in AMOC needs to be further studied uisng fully coupled climate models.*

The AWP shows a remote interhemispheric link to the tropical southeastern Pacific (Wang et al. 2010). In the Western Hemisphere during the summer season, there is strong diabatic heating and ascent over the AWP. On seasonal and longer timescales, anomalies of the warm pool extend eastward and modulate the regional ascent and associated remote descent above the tropical southeastern Pacific in a Hadley-type, interhemispheric atmospheric circulation. This regional Hadley circulation is stronger during the boreal summer and fall seasons. It is shown that the cold model SST biases in the tropical North Atlantic can be linked to the warm model SST bias in the tropical southeastern Pacific (Wang et al. 2014; Fig. 6). As the AMOC weakens, the SST bias in the tropical North Atlantic is cold, which is associated with the warm SST bias in the tropical southeastern Pacific. The successful simulation of the tropical southeastern Pacific climate with numerical models is a very challenging problem. Almost all state-of-the-art coupled ocean-atmosphere models exhibit significant errors in the form of a severe warm bias in

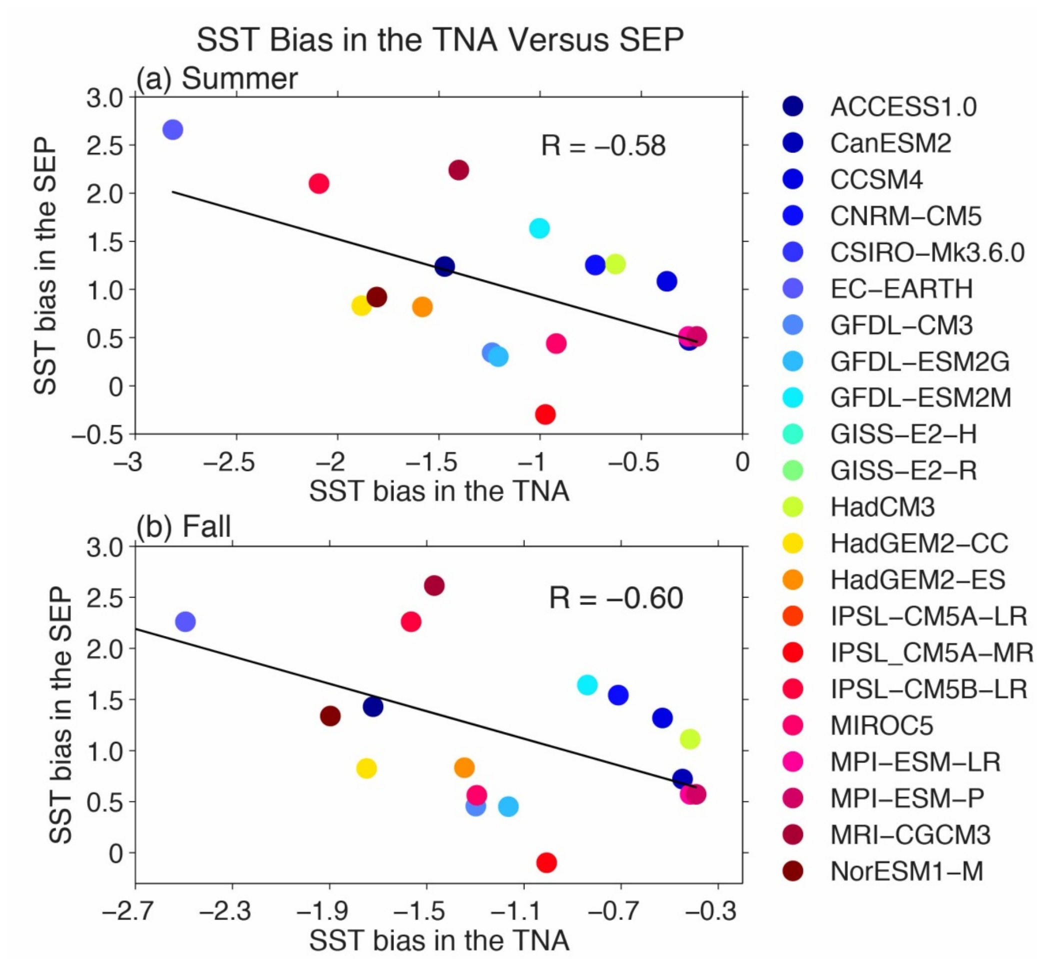

Figure 6*. Interhemispheric link between SST biases in the tropical southeastern Pacific (SEP) and the tropical North Atlantic (TNA) in CMIP5 climate models. Scatterplots of the SST (°C) bias in the SEP versus the SST bias in the TNA during (a) summer (June-August) and (b) fall (September-November). The inter-model correlation R is shown in the right-upper side of each panel. From Wang et al. 2014.*

simulated SSTs over the tropical southeastern Pacific. These studies have shown that the tropical southeastern Pacific can be remotely influenced by the AWP variability. *This indicates that if models cannot succeed in stimulating the AWP variability, they will also fail (at least partially) over the tropical southeastern Pacific. Hence, the improved simulation of the AWP is an important topic in global climate modeling research.*

(4) Links of the Amazon rainfall to IAS variations

Using observations of rainfall and SST analysis, Misra and DiNapoli (2012; Fig. 7) show that there is a robust two season lag relationship between the austral summer (DJF) Equatorial Amazon (EA) rainfall and the following boreal summer season (JJA) IAS SSTA. It is observed that in wetter than normal austral summer seasons over EA, the SSTA in the IAS are cooler than normal in the following JJA season. This teleconnection is also manifested in the ocean heat content of the IAS region. It is indicated that the net surface heat flux into the ocean (particularly the surface longwave and the shortwave radiative fluxes) dictates the strongest influence on the JJA Caribbean SSTA, the core region of the IAS where the observed teleconnection with EA rainfall is strongest. *This teleconnection needs to be more thoroughly understood as it could potentially help in providing a good lead to the evolution of future IAS seasonal SST fluctuations*.

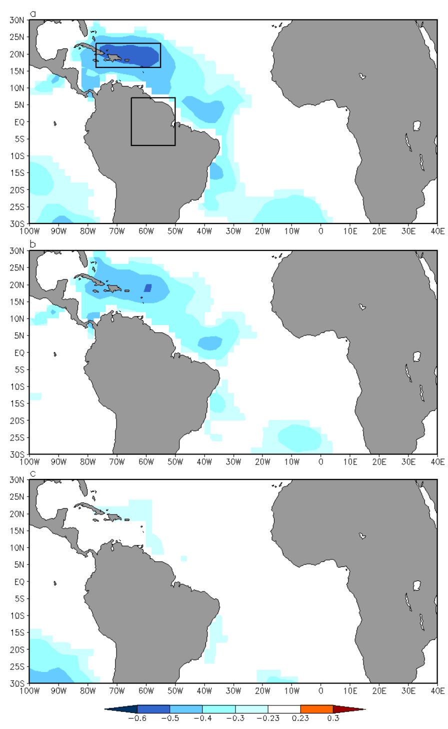

***Figure** 7: The correlation of the mean boreal summer (JJA) seasonal SST anomalies with the a) mean preceding December-January-February (DJF) rainfall, b) the ENSO component of the preceding DJF rainfall and c) the rest of the components of the preceding DJF rainfall besides ENSO from Climate Research Unit (CRU) over Equatorial Amazon (7ºS-7ºN and 65ºW-50ºW). These correlations are computed over the period from 1950-2004. Only significant values at 90% confidence interval according to t-test are shown. The linear trends in rainfall and SST are removed before the correlation is calculated. The reference box over the Caribbean Sea, the core region of the IAS and the EA are outlined in (a). From Misra and DiNapoli (2013).*

II Goals of the Observational Working Group

The observational coverage of both the atmosphere and the ocean in the IAS and surrounding land regions are relatively scarce. *From an IASCLiP perspective, the ideal oceanic and atmospheric monitoring is regular, sustained, upper-ocean profiling and* *surface and deep atmospheric observations respectively. There are several pathways to achieve this objective:*

(1). Leveraging the use of existing observations

The last reporting period year of the radiosonde launches are shown in Fig. 8, which clearly indicates the coverage getting reduced in the Caribbean and Latin and Central American regions.

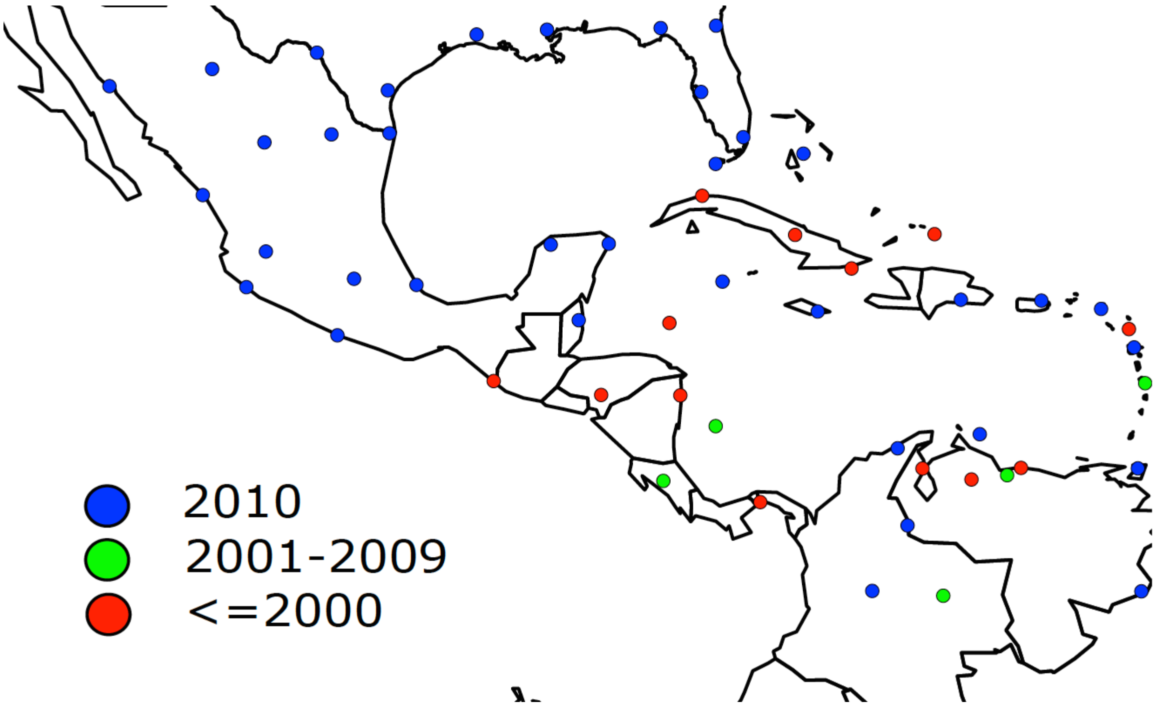

Figure 8. *Last reporting year of radiosonde stations (year 2010 is to be read as current).*

Similarly, the rain gauge station coverage is grim in the IASCLiP region (Fig. 9). In the past decade, however, a network of GPS stations, named COCONet, has been set up around the Caribbean (Braun et al., 2012). While their primary function is for seismic monitoring, they also produce integrated water vapor path datasets. These have not yet been applied for the routine monitoring of moisture nor yet integrated with the remaining radiosonde network, to our knowledge. More recently COCOnet has been augmented by a similar network based in Mexico, named TLACOCNET. *In addition to leveraging this network of GPS stations, IASCLiP in the best interests of climate monitoring and prediction in the region would earnestly explore with the Caribbean, Central and Latin American countries to sustain and improve the current rain gauge and radiosonde network.*

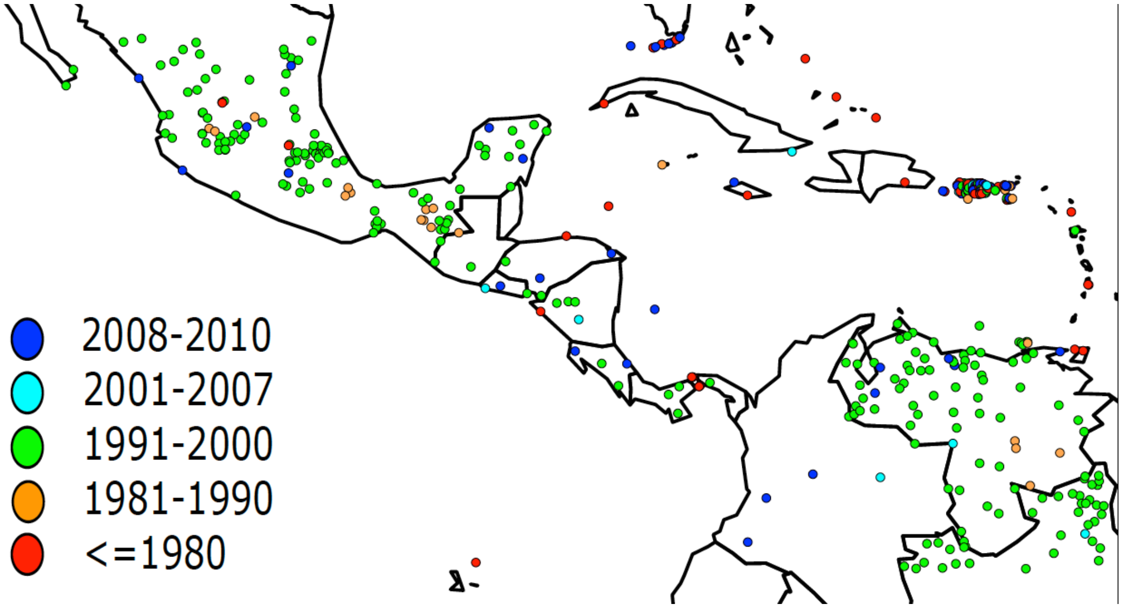

Figure 9. *WMO monthly reporting rainfall stations (year 2008-2010 to be read as current).*

(2). Augmenting the existing observational framework

The in-situ ocean coverage in the IAS region is even more revealing. The observational coverage in the IAS region is as poor as the polar oceans (Fig. 10), which clearly questions our ability to measure and monitor ocean heat content.

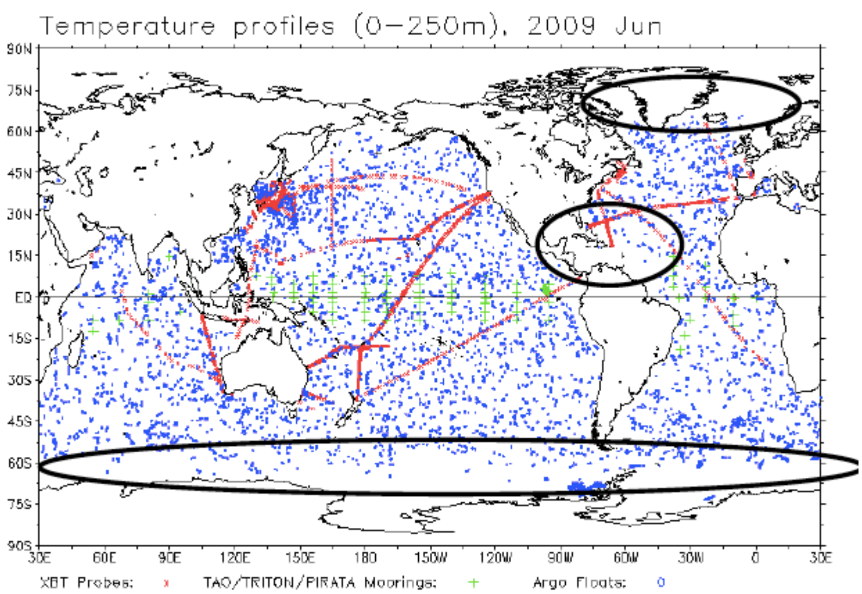

Figure 10. *Snapshot of the observational coverage of in-situ ocean observations that measure temperature profiles in June 2009.*

These observational limitations are also reflected in the global reanalysis products with significant disparity in the rendition of the AWP in them (Misra et al. 2012). Furthermore, a recent study (Li and Misra 2014) suggest that the surface ocean circulation features in the IAS region are also poorly resolved in the Climate Forecast System Reanalysis (CFSR; Saha et al. 2010; Fig. 11). Presently deployed in the central Caribbean are an east-west array of moored meteorological buoys operated and maintained by NDBC <www.ndbc.noaa.gov/maps/West_Caribbean.shtml>, which can be reconfigured to look like the Pacific TAO moorings by adding thermistor chains to the mooring cables. If so modified, these buoys will provide valuable Eulerian time series of the Caribbean thermal structure to complement the lagrangion measurements of Seagliders and Argo floats.

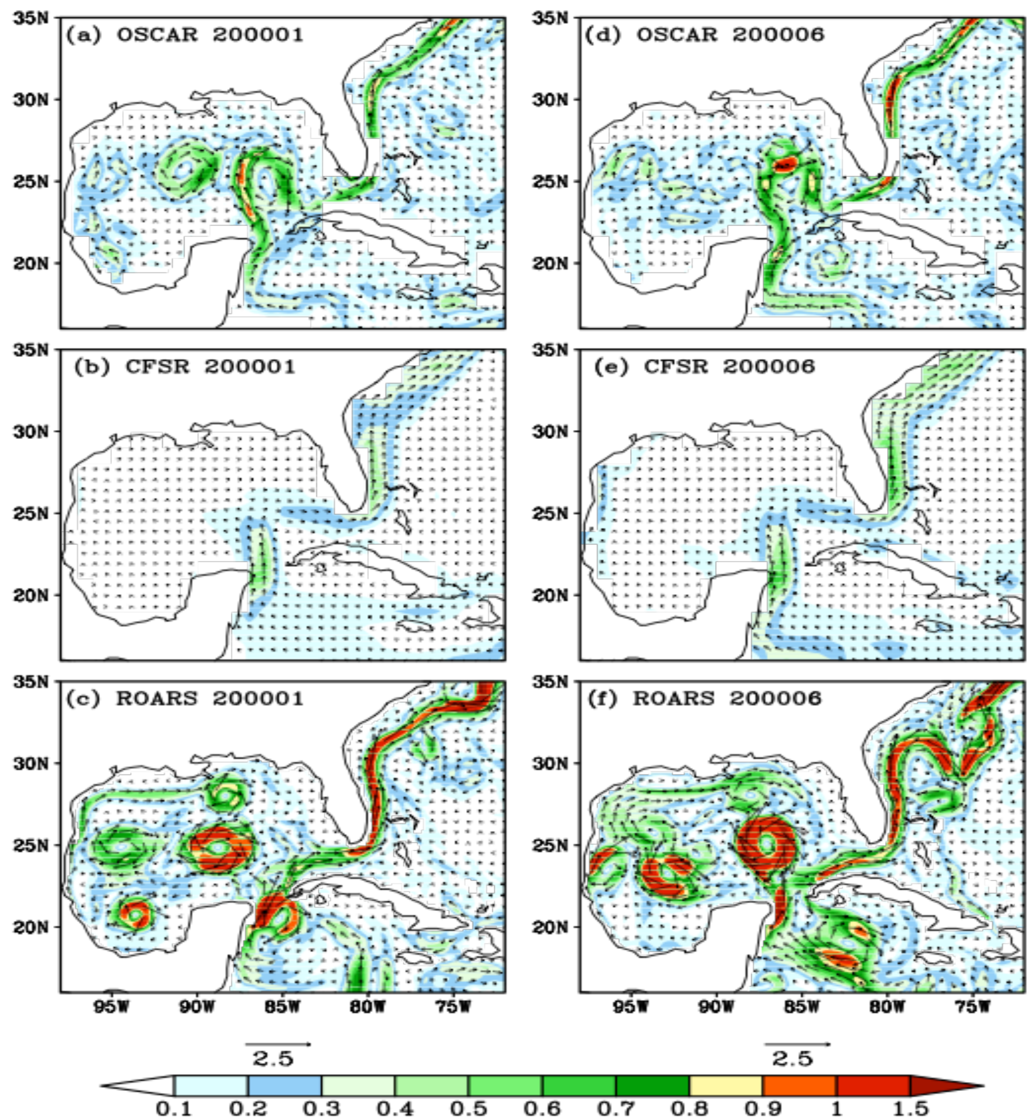

Figure 11. *The ocean surface current (m/s) in January 2000 from (a) OSCAR satellite observation, (b) Regional coupled ocean-atmosphere downscaling of global reanalysis, (c) CFSR, and in July 2000 from (d) OSCAR satellite observation, (e) ROARS simulation, and (f) CFSR. From Li and Misra (2014).*

(3) Networking with other observational groups and programs

Most new oceanic observational work in the region is occurring under the auspices of the Gulf of Mexico Research Initiative motivated by the BP Oil Spill. NASA SPURS2 will investigate the oceanic hydrological cycle near the Gulf of Panama with a focus on salinity. *Although some of these observational works may well be relevant to IASCLIP objectives, this crosscut still needs to be explored.*

(4). Seagliders

Atlantic tropical cyclone intensity forecast lags significantly behind track forecasts (Rappaport et al. 2007) despite some moderate improvements over the recent couple of decades (DeMaria et al. 2014). Although numerous factors contribute to intensification of an individual storm, the upper ocean thermal structure has been shown to play a critical role in determining the maximum intensity it can achieve (e.g., Lin et al. 2013; Shay et al. 2000), and in improving intensity forecasts in statistical and numerical forecast models when warm ocean features with length scales between 20-100km (referred to as mesoscale) could be identified under the path of the cyclones (Mainelli et al. 2008; Goni et al. 2009). These mesoscale warm ocean features are known to have played a critical role in the rapid intensification of tropical cyclones over the AWP (e.g. Katrina in 2005, Wilma in 2005, Sandy in 2012). However, due to the lack of adequate sustained upper ocean thermal monitoring (Fig. 10), ocean and hurricane numerical forecast models are not properly initialized to predict the upper ocean thermal structure. An implementation of targeted observations will help to fill the observational gaps that currently exist in the Caribbean Sea and the western tropical North Atlantic, will aid in the improvement of the intensity forecast and complement targeted atmospheric observations carried out by NOAA. Studies using Observing System Simulation Experiments (OSSEs) will also guide the design of an optimal ocean observing system for Atlantic tropical cyclone forecasts.

We recommend that an array of several Seagliders be implemented to carry out sustained and targeted upper-ocean profiling of temperature (T), salinity (S), and current velocities (u,v) in the IAS region. Seagliders are cost-effective observational underwater vehicles used for targeted and sustained upper-ocean T, S, and (u,v) observations, they operate easily in open waters, even under hurricane strength winds, and can be navigated across moderately strong currents. The Seagliders are durable, autonomous, and have a low-drag and hydrodynamic shape and use battery power to control their buoyancy to move vertically, and use their wings to guide themselves forward along a remotely programmed trajectory (Eriksen et al. 2001). When their batteries run out, the Seagliders can be recovered and then refurbished and redeployed immediately. Their small size (~2m long) and low weight (~50 kg) allow for an easy deployment and recovery by two people from a small vessel. Seagliders transit at approximately 20-25 km/day while executing 8-10 T-S profiles/day to 1,000 meters and of (u,v) to 200m. They can navigate approximately 4,000 km and collect and transmit about 1,600 profiles during a 6-month deployment. While surfaced, they can also download any new instructions for altering the navigation route. Data will be transmitted in real-time into the GTS, and will be used by scientists involved in this and all other projects that utilize GTS profile data. Each Seaglider will provide data of approximately 2,700 profiles per year.

NOAA's Atlantic Oceanographic & Meteorological Laboratory (AOML, Miami) is currently funded by NOAA's Sandy Supplement program to deploy two seagliders north and south of Puerto Rico in cooperation with the National Data Buoy Center (NDBC) and entities in Puerto Rico and Dominican Republic during 2014-2015 (Fig. 12). This pilot program is specifically designed to intercept tropical cyclone tracks and explore the effect of observed thermal structure on TC intensification and if successful, may provide the basis for a geographically expanded glider monitoring program operated by AOML and NDBC. The glider project will be coordinated with aircraft-deployed instrumentation planned by NOAA's Hurricane Research Division and with modified surface Argo floats, called ALAMO floats, deployed in the Caribbean and Gulf of Mexico by Woods Hole Oceanographic Institution (WHOI).

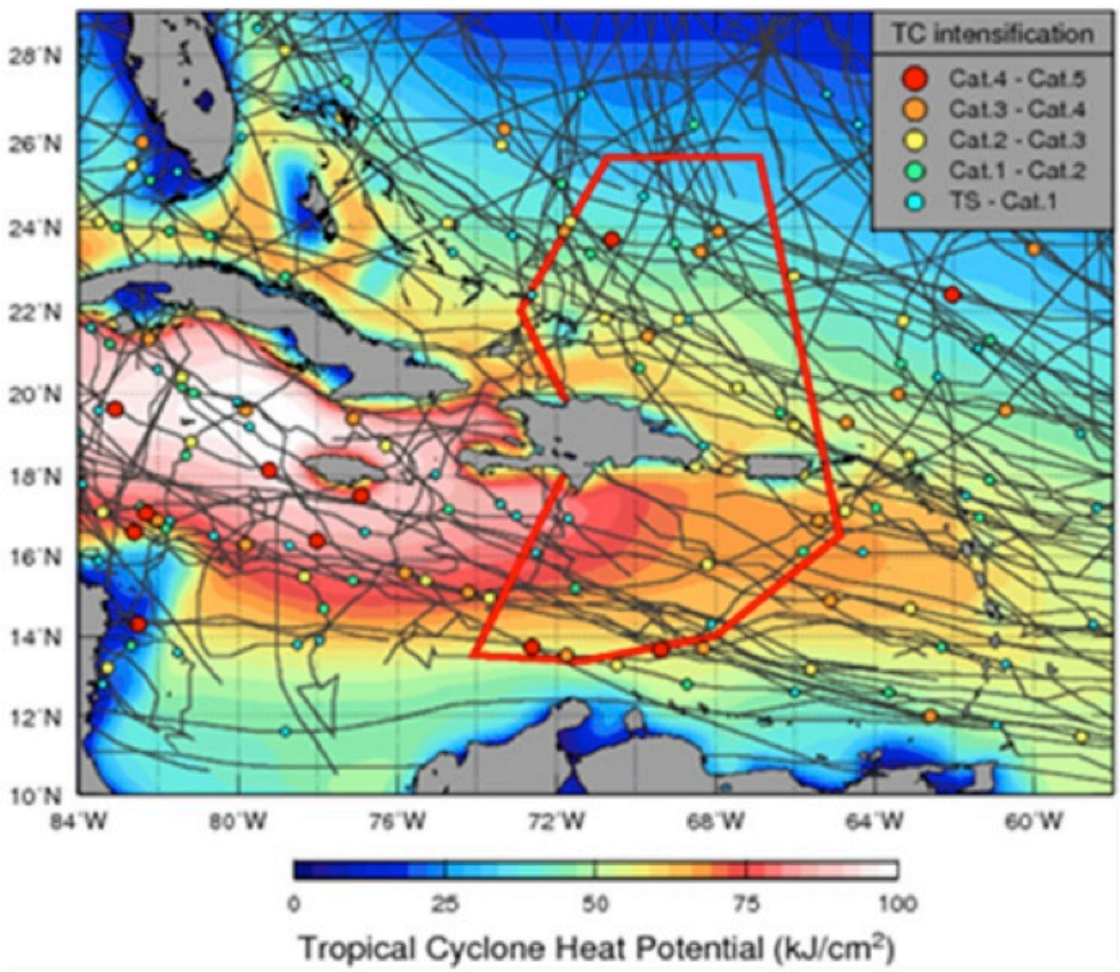

***Figure 12**. The two regions (bounded with red lines) where Seagliders will be deployed under the AOML-led Seaglider pilot project. Shown are tracks of Cat. 1-5 cyclones (in grey) in the AWP during 1993-2011, with circles indicating the location of their intensifications. The background color is the Tropical Cyclone Heat Potential (proportional to the upper ocean heat content).*

NWP models coupled to three-dimensional ocean models are shown to exhibit higher TC intensity forecast skill than non-coupled models or those coupled to mixed-layer ocean models (Bender et al., 2007). Therefore, realistic representation of the upper ocean thermal structure is key for TC intensity forecasting. Sustained upper-ocean T-S and (u,v) observations from Seagliders housing an onboard ADCP will provide more realistic oceanic initial conditions. Gliders were successfully navigated under hurricane strength winds during Irene (2011) and Sandy (2012). Their data helped to better resolve surface oceanographic features linked to hurricane intensification.

(5). Leveraging on existing observational network

We can enhance the current NDBC buoys in the Gulf of Mexico and in the Caribbean by attaching thermistor chains, which will allow for temperature profiling of the upper ocean.

III Goals of the Capacity Building Working Group

(1). Partnerships with prediction centers in US, Caribbean, Central and Latin American Countries

We would like to build partnerships on even footing with the prediction centers around the IAS region to:

- i) Understand their success and failure stories of climate prediction
- ii) Develop and sustain a regular IASCLiP seasonal forecast forum using currently available resources of climate prediction and monitoring
- iii) Develop a short quarterly or biannual newsletter on the ongoing developments in IASCLiP
- iv) Develop the capacity and the understanding to produce regional climate information
- v) Explore and push for effective application of climate prediction on various sectors (e.g. agriculture, human health etc.)

Considerable progress and precedent has been created through earlier attempts at forecast forum (http://www.eol.ucar.edu/projects/iasclip/documentation/IFF.html) that needs to be re-initiated with new resources. Furthermore, IASCLiP members from the US have developed relatively strong networks with their counterparts in North, South and Central America, who have expressed interest in participating in such forums.

(2). Observational network

Earlier interactions of IASCLiP members with university researchers and meteorological and oceanography institutes in several Caribbean and Central American countries indicate a significant enthusiasm and interest in sharing data, updating their networks and data transmission (http://www.eol.ucar.edu/projects/iasclip/documentation/colombia.html). *We need to follow up on this effort as there is siginificant scarcity of observations*.

3. Roadmap to IASCLiP2020

In the near term to year 2020, IASCLiP has to think of priortizing its goals for each of the three working groups of modeling, observational and capacity building teams.

The challenges are many that span from Atlantic TC intensity forecast/simulation issues to AMOC variations and climate change responses in the region. A long hanging fruit for IASCLiP would be to address the issue of the warm season predictability and prediction in North America. There is significant evidence to suggest the infleunce of the IAS variability on the warm season rainfall variations in North America. This however will benefit from the amelioration of the pervasive cold bias in the IAS displayed by our current GCMs or diminish its influence on the local and remote teleconnections. Some suggested approaches are coordinated modeling experiments for conducting sensitivity studies, establishing climate process teams for the IAS bias. Similarly understanding climate extremes in the region and their regulation by IAS is also equally important. Likewise, conducting observed system simulation experiments with synthetic observations to highlight the importance of in-situ observations, developing a network of cooperating agencies around the IAS rim nations that can help in enhancing the observational network, and beginning to simultaneously engage the researchers and prediction centers in regional forecast forums to distil climate data for regional applications would be some of the other perogatives of the incoming IASCLiP team. As outlined in Appendix I the NOAA Climate Program Office has already made significant investment on the Intra-Americas Sea research with 9 funded projects since 2010.

The incoming IASCLiP working group members will be given the task to develop detailed strategies for the broad framework of issues outlined in this report and conform very closely to the grand challenges of the WCRP. This report will be a live document till we repopulate the scientific steering and working groups, which we hope will be achieved in the subsequent months.

Appendix I: Funded projects from the NOAA CPO Modeling, Analysis, Predictions and Projections Program

GC#	Title	PI
GC10-685	The Influence of convective systems on intraseasonal to interannual variability of the Intra-American Monsoon	Liebmann, G
GC10-398	Evaluation of the Tropical Storm Track Across the Intra-Americas Sea in IPCC AR5 Models and the Mechanisms of change in a warmer climate	Serra
GC12-431	Modulation of Tropical Cyclone (TC) Activity over the Intra-Americas Sea by Intraseasonal Variability: Implications for Dynamical TC Prediction on Intraseasonal Time Scales	Jiang/Zhao
GC12-432	Mesoscale variability in the Gulf of Mexico and its importance in climate extremes over North America	Kamenkovich/Halliwell
GC12-433	Intraseasonal to Interannual Variability in the Intra-Americas Sea in Climate Models	Maloney/Xie
GC12-434	Variability and Predictability of the Atlantic Warm Pool and Its Impacts on Extreme Events in North America	Wang
GC12-435	Understanding climate variations in the Intra-Americas Seas and their influence on climate extremes using global high-resolution coupled models	Vecchi
GC12-442	Climate Variability of the Tropical Western Atlantic Storms: Is it hinged to Intra-Americas Seas climate processes	Misra
GC12-454	Predictability of Atlantic Hurricane Activity by the NMME Coupled Models	Barnston/Schemm

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Liebmann, Brant - **Influence of Convective Systems on Intraseasonal to Interannual Variability of the Intra-American Monsoon** - We propose to examine the contribution from large-scale organized transient disturbances to intraseasonal and seasonal total rainfall of the intra-Americas Sea region (IAS). The focus will be on disturbances with periods of less than 30 days affecting the tropical regions from Mexico to northern South America. Kelvin waves, cold surges and easterly waves are of primary interest. A visual inspection of Hovmoeller diagrams reveals many examples of Kelvin disturbances that form near the dateline and propagate eastward. When they encounter South America, convection - as depicted by outgoing longwave radiation (OLR) - typically increases over tropical regions. These disturbances propagate into the Atlantic, where they substantially affect the intertropical convergence zone there (Wang and Fu 2007). Kelvin waves can also form in-situ over the Amazon basin during southern summer when cold surges originating in the middle latitudes of South America force convection at the Equator (Liebmann et al. 2008). During southern winter, when cold surges are stronger and Amazon convection is weak, they frequently propagate across the Equator and into the Caribbean. Mesoscale convective activity is seen to be significantly modulated by equatorial waves, and this will also be examined in some detail. Our initial analyses indicate that convective activity is enhanced when westward propagating disturbances encounter Kelvin waves and cold surges. It is likely that problems in representation of the climate of the IAS by models suffer from an incorrect representation of subseasonal disturbances. In addition to analyzing the aforementioned disturbances in observations, a similar analysis will be made for the coupled general circulation models that will constitute the basis of the Intergovernmental Panel on Climate Change 5th Assessment Report. The questions we propose to address are the following:

1) What is the seasonal cycle and interannual variability of Kelvin wave activity, and how is Kelvin wave activity related to large-scale, slowly varying phenomena?
2) How do Kelvin and other equatorial waves modulate mesoscale variability and the diurnal cycle?
3) Although transients are prominent in satellite-based observations of cloud top such as OLR, to what extent do they account for seasonal totals in the IAS?
4) Do westward propagating disturbances amplify or diminish when they encounter Kelvin waves or cold surges from either hemisphere?
5) Where are the transients that affect the IAS initiated?
6) Do coupled atmosphere-ocean models represent well the subseasonal transients, and to what extent do errors in their climatology result from problems in representing these disturbances?
7) Can rainfall be predicted with skill for several days in advance from trajectories of disturbances as they approach the IAS?

Serra, Yolande - **Evaluation of the Tropical Storm Track Across the Intra-Americas Sea in IPCC AR5 Models and the Mechanisms of change in a warmer climate** - The Intra-Americas Sea (IAS) includes the Gulf of Mexico, Caribbean Sea and tropical northeast Pacific Ocean, the latter of which is the most prolific hurricane formation region in the world per square meter. Heavy rains arrive over the IAS during boreal summer, when the Inter- Tropical Convergence Zone (ITCZ), or axis of the tropical storm track, migrates north off the equator and SSTs warm throughout the region. Localized moisture convergence over land areas within the IAS is important for hydropower, agriculture and fresh water supplies. IAS moisture transport into northern Mexico and Southwest U.S. is also important for agriculture and populations in these regions.

Several studies point out the critical role that orography plays in present day mid-latitude and tropical storm tracks. Recent work also suggests that the Caribbean low-level jet (CLLJ) influences storm track activity within the IAS. Studies of tropical storm tracks within the projected warmer conditions of the 21st century find reduced storm track activity in the tropical Atlantic and a shift of the tropical northeast Pacific storm track southward. The intensity of tropical storms overall appears to remain unchanged in studies that have accounted for a mean shift in the tropical mean sea surface pressure due to warmer temperatures. However, predicting storm intensity changes remains a difficult task, as this parameter is more dependent on model resolution than storm frequency.
The following questions are raised by these studies: i) Will the roles of orography and the CLLJ change if the storm track in the tropical eastern Pacific shifts southward in the 21st century? ii) How would such a change affect intensity of storms in the tropical eastern Pacific? iii) How would changes in the position of the tropical eastern Pacific storm track affect the precipitation over land areas of the IAS and NAM regions?
This study proposes to investigate these questions through the following set of analyses:

- Obtain 20th century tropical storm track statistics using state-of-the-art reanalyses.
- Assess tropical storm track statistics of all AR5 model 20th century scenario data available at greater than daily resolution against the reanalyses' statistics.
- Use high-resolution regional model simulations to assess physical mechanisms associated with several real cases of developing and non-developing tropical depressions within the IAS using the reanalyses as boundary forcing for these simulations.
- Force the regional model for actual cases of 21st century storms/waves from AR5 models that produce realistic track statistics for the 20th century and compare mechanisms of storm initiation and intensification with the cases from step 3.

This project will make use of a numerical technique in which actual features of the tropical storm track (easterly waves and mature storms) in the AR5 models will be simulated using a high-resolution regional model, rather than using idealized simulations of a mature tropical storm forced with the general conditions of a warmer climate. This approach permits changes in genesis mechanisms to be evaluated.

Jiang, Xianan and Zhao, Ming - **Modulation of Tropical Cyclone (TC) Activity over the Intra-Americas Sea by Intraseasonal Variability: Implications for Dynamical TC Prediction on Intraseasonal Time Scales** - Tropical intraseasonal variability (ISV, e.g. Madden-Julian Oscillation) exerts significant influences on global climate and weather systems including tropical cyclones (TCs). This serves as a critical basis of the "Seamless Prediction" concept by bridging the forecasting gap between medium- to long-range weather forecast and short-term climate prediction. For extended range forecasts of TC activity on an intraseasonal time scale (10~60 days), most of current approaches are based on statistical models or downscaling techniques. Recently, with the development of high-resolution general circulation models (GCMs) with improved model physics, it has become possible for these GCMs to represent both ISV and hurricanes, leading to a new avenue for intraseasonal TC prediction by using dynamical models.
Our recent analyses (Jiang et al. 2011b; Jiang et al. 2011a) of ISV and TC activity over the eastern North Pacific (ENP) based on simulations by the high resolution

NOAA/GFDL HiRAM AGCM illustrate that the observed dominant ISV modes over the ENP are captured well in HiRAM; meanwhile, the observed relationship between ISV and TC activity over the ENP can also be faithfully represented in this model. Motivated by these encouraging results, we propose to use HiRAM, a leading edge model in terms its ISV-TC fidelity, to qualify the predictive skill and estimate the predictability for TCs across the Intra-Americas Sea (IAS) on intraseasonal time scales. The objectives of this proposed study are as follows:

1. Conducting hindcast experiments to fully evaluate the prediction skill of ISV over the IAS by the NOAA/GFDL HiRAM;
2. Analyze the HiRAM hindcast ensembles to estimate the intrinsic predictability of TC activity over the IAS;
3. Evaluate the role of ISV in characterizing the prediction skill of TCs over the IAS on intraseasonal time scales;
4. Explore the physical mechanisms associated with ISV modulation of TC formation over the IAS;
5. Using both HiRAM climate simulations and hindcasts, evaluate how model horizontal resolution and different physical parameterization specifications influence model skill in simulating / predicting ISV and TC activity.

Kamenkovich, Igor and Halliwell, George - **Mesoscale variability in the Gulf of Mexico and its importance in climate extremes over North America** - The motivation for this study is in the need to improve understanding and modeling capabilities of regional air-sea interaction processes within the Intra-Americas Sea (IAS) region and their relationship with climate extremes. Oceanic circulation, which is characterized by strong mesoscale (order of 10-100km) variability, strongly affects air-sea interactions in the region and distribution of heat anomalies, which has important implications for U.S. climate. In particular, distribution of surface temperature anomalies associated with the Atlantic Warm Pool (AWP) influence the rainfall over North America, thus playing a key role in frequency and severity of draughts and rain events. In addition, heat anomalies play the role of a heat reservoir for hurricanes in the IAS, particularly in the Gulf of Mexico (GoM) region, controlling conditions favoring their formation and intensification. In this regard, the mesoscale variability in the GoM – a key region linking the IAS and continental U.S. – is particularly important. The GoM circulation is complex and highly variable, and its rich dynamics, as well as its connection to the North American climate, continue to be poorly understood. Furthermore, key mesoscale processes involved in the dynamics are not captured by the current generation of CMIP5-class climate models, which lack resolution in their ocean component.

The goal of this study is to improve understanding and modeling capabilities of the circulation within the IAS and its mesoscale variability with implications for U.S. climate and extreme events. Our particular focus is on the major conduit of oceanic heat transport in IAS – the Caribbean Current (CC) / Loop Current (LC) system and associated eddies through Yucatan and into the GoM. Specific objectives are to analyze: (i) the dynamics of mesoscale variability in GoM; (ii) the importance of this variability for the heat distribution; (iii) role of these processes and their adequate resolution for climate studies. To achieve these objectives, we propose a comprehensive approach, which will utilize a hierarchy of numerical simulations, both coupled atmosphere-ocean and ocean-only, including the analysis of CMIP5-class climate model existing simulations. Key novel elements of the proposed research include examination of mesoscale dynamics in ocean-only models at very high resolutions not previously available, as well as a comparative analysis of coupled CMIP5-class simulations with low and high resolution in the oceanic component.

Maloney, Eric and Xie, Shang-Ping - **Intraseasonal to Interannual Variability in the Intra-Americas Sea in Climate Models** - This study assesses the ability of CMIP models to produce realistic intraseasonal to interannual variability (IAV to ISV) in the Atlantic warm pool (AWP) region and the implications for hurricanes, the ability of parameterization modifications in the GFDL AM3 to improve the simulation of AWP ISV, and how mean state biases in CMIP models develop and the implications for forecast biases in ISV and IAV. The following questions will be answered:

1. Can IAS-region intraseasonal variability in the GFDL AM3/CM3 be improved through modifications to the treatment of deep convection? The sensitivity of IAS mean state and ISV to modifications in the Donner convection scheme in GFDL AM3/CM3 will be assessed, including different treatments of triggering, rain evaporation, and entrainment. The degree to which IAS- region ISV is coherent with that in the Eastern Hemisphere will be assessed, which has consequences for prediction. Variables that impact hurricane genesis potential will be a focus.
2. How do model errors develop over the Atlantic warm pool? In the AWP, the ensemble mean of CMIP3 models features SST errors of 2oC or larger in the annual mean, with considerable variability in rainfall errors among different atmosphere models forced by observed SSTs. A systematic investigation into errors of SST, rainfall, sea level pressure and wind in the AWP based on the CMIP3/5 database will be conducted, including the similarities and differences among models. Initial emphasis will be GFDL models, especially initialized seasonal forecasts, followed by a diagnosis in the broader suite of CMIP5 models.
3. How well can CMIP5 models simulate the ENSO-Atlantic hurricane teleconnection?
Substantial biases in the ENSO-Atlantic hurricane teleconnection occur in all CMIP3 models (Shaman and Maloney 2011). We will assess the ability of CMIP5 models to capture the ENSO teleconnection to the Atlantic and its manifestation in large-scale variables that affect tropical cyclone (TC) genesis, with specific focus on the GFDL CM3. We will also intercompare CMIP5 model ability to capture other modes of Atlantic IAV including the Atlantic meridional mode and Atlantic Multidecadal Oscillation, and the variables relevant for TCs.
4. How do IAS-region mean state biases affect forecasts of ISV and IAV and extreme events?
The climatology of a coupled prediction model drifts quickly, and the model errors approach the equilibrium in a matter of months. Biases in the mean state, such as those in

SST, precipitation, and winds can have profound implications for Atlantic climate variability and how remote forcing from climate variability in other basins is manifest in the Atlantic. The effect of the climate drift on forecast results within the IAS will be assessed. The regional climate model from U. Hawaii will be used to examine how mean state biases affect biases in ISV and IAV and extreme events over the IAS region. ISV to IAV in boundary conditions will be retained while biasing the mean state to that of the GFDL CM and other CMIP models to determine how changes in the climate state and its statistics affect the simulation of extreme events like TCs.

Wang, Chunzai - **Variability and Predictability of the Atlantic Warm Pool and Its Impacts on Extreme Events in North America** - Our current/previous NOAA/CPO-funded research has pointed out the importance of the Atlantic Warm Pool (AWP) for summer climate and extreme events in the Western Hemisphere. AWP variability occurs on seasonal, interannual, multidecadal, and secular (global warming) timescales, with large AWPs being almost three times larger than small ones. The effect of the AWP is to weaken the North Atlantic subtropical high (NASH) and strengthen the summer continental low over the North American monsoon region. A large AWP also weakens the southerly Great Plains low-level jet, which results in reduced northward moisture transport from the AWP to the central U. S. and thus decreases the summer rainfall over the central United States. A large AWP increases the number of Atlantic hurricanes by reducing vertical wind shear and increasing the moist static instability of the troposphere, and influences the hurricane steering flow changes that become unfavorable for hurricanes to make landfall in the United States. Our research also suggests that the AWP serves as a link between the Atlantic Multidecadal Oscillation (AMO) and climate and hurricane activity. Despite its importance, almost of all state-of-the-art coupled models exhibit serious biases in the AWP region, which limit the seasonal prediction of AWP-related climate and extreme events.

We propose to continue our investigation of the AWP using fully coupled climate models. Two specific areas of proposed work are (1) diagnosing the CMIP5 outputs to assess model biases near the AWP region and to understand their skill in simulating the mechanisms and climate impacts of AWP variability, and (2) performing coupled model experiments using CESM1 (also called CCSM4) and analyzing the Climate Forecast System version 2 (CFSv2) reforecasts to assess and improve predictability of the AWP and its impacts on climate and extreme events such as hurricanes, flood and drought in North America. The diagnostic analyses will mainly focus on variability of the AWP, and its impacts on the NASH, the Caribbean low- level jet and its moisture transport, and the Great Plains low-level jet and its moisture transport. Other areas of the focus in the diagnostic analyses include the relationships of rainfall in the U. S. with the AWP, the external influences (such as ENSO, the AMO, and the NAO) versus local ocean-atmosphere processes on AWP variability, and the relationships among environmental factors contributing to hurricane activity. We will perform CESM1 model simulations with and without realistic initialization of the AWP to explore the impact of AWP initialization on seasonal forecasts. We will also examine the influences of model resolution and deep convective parameterizations in CESM1 on AWP SST and rainfall biases. One of the tasks is to analyze the CFSv2 reforecasts to explore its skill for seasonal predication of the AWP and AWP-related climate and extreme events. The CESM1 experiments and the analysis of CFSv2 reforecasts are designed to identify the sources that contribute to the model biases, thus provide a basis for improving model simulations and predictions. In collaboration with scientists at NOAA/CPC, we will attempt to transition research results to operations at NOAA/CPC.

Vecchi, Gabe - **Understanding climate variations in the Intra-Americas Seas and their influence on climate extremes using global high-resolution coupled models** - We propose to use a hierarchy of GFDL high-resolution climate models to improve our understanding of the climate of the Caribbean Sea and Gulf of Mexico ("Intra-Americas Seas", or "IAS"), including its influence on climate-scale variations and changes in Atlantic hurricane activity and North American drought. Because of the complex, multi-scale oceanographic, atmospheric and coupled air-sea phenomena that characterize the IAS region, we will focus on both atmospheric and oceanic climate, and their interactions. We will explore the sensitivity of the simulation of the mean climate and climate variations in the IAS to changes in resolution and parameterization in the context of the coupled GFDL high-resolution models. The role of remote influences on climate in the IAS will be explored, assessing oceanic and atmospheric teleconnections by performing "data override" and "partial coupling" experiments with the climate models. Analogous perturbations to the coupled model will be used to explore the influence of the IAS on remote climate through atmospheric and oceanic processes. We will focus particularly on the influence of the IAS on North Atlantic hurricanes and on drought over North America. Predictability of the climate variations and teleconnections from the IAS will be explored using initialized prediction experiments using the GFDL high-resolution modeling system.

The principal hypotheses to be tested are i) increased resolution and high-order numerics in global coupled climate models improve simulation of mean climate and variations of the Intra-Americas Seas, ii) remote, large-scale factors (e.g., ENSO and the Atlantic Meridional Overturning Circulation) drive variations and changes in the IAS through atmospheric and oceanic bridges, iii) changes in oceanic circulation and atmospheric convection in the IAS have a detectable influence on remote oceanic and atmospheric conditions, iv) modeled climate variations in the IAS modulate North American drought and North Atlantic tropical cyclone activity in the North Atlantic, v) the improved representation of drivers of IAS variability (e.g., ENSO and AMM) and the mean climate of the IAS in higher resolution models leads to enhanced predictive capacity for regional climate due from initialization and response to radiative forcing. The proposed work should improve our understanding and ability to model a key area of the global climate system, and the model simulations performed in this study and analysis of them will be beneficial to the high-resolution climate model development.

Misra, Vasubahdhu - **Climate Variability of the Tropical Western Atlantic Storms: Is it hinged to Intra-Americas Seas climate processes** - The proposal seeks to understand the low frequency variability of the Tropical Western Atlantic Storms1 (TWAS) and its relationship with Intra-Americas Seas (IAS) climate processes. Traditionally simulations and predictions beyond the NWP range for tropical Atlantic storms have largely been on their frequency of occurrence throughout the basin over the 6-month period from June through November. This type of forecast or simulation has limited application although they have demonstrated admirable skill on seasonal time scales and on longer time scales in their rendition of the 20th century variability. The success of this study could be a harbinger for attempting predictions of a subset of the tropical Atlantic storms that are geographically more limited in the basin (western Atlantic). Furthermore a majority of TWAS make landfall over continental North America. In addition, the TWAS climatologically has a characteristic dominance of genesis in June and November, which could also be potentially exploited if we understand their causality. Thus this proposal is relevant to NOAA's NGSP mission on climate adaptation and mitigation to the threat of potential land falling tropical storms in North America.

The proposed work will employ high-resolution (~10km) coupled ocean-atmosphere model centered over the IAS in an attempt to resolve the TWAS, the Caribbean Low Level Jet (CLLJ), air-sea fluxes in the IAS, the diurnal variations in the region and capture the associated, intricate sub-surface ocean structure. In addition several sensitivity experiments are also proposed to understand the influence on the genesis and lifecycle of TWAS. This framework of regional coupled ocean-atmosphere modeling is deliberately chosen to afford the high resolution for multi-decadal integrations and limit the model drift by forcing the regional system with credible large-scale reanalysis (NCEP CFSR). The coupled GCM's have shown acute climatological bias in the IAS region with poor depiction of the associated variability in the boreal summer season.

The central objective of the proposal is to understand whether (and followed by how) IAS climate processes like the evolution of the IAS SST and sub-surface ocean evolution from the prior seasons, variability of CLLJ, air-sea fluxes in IAS, overlying atmospheric meridional cell can influence TWAS. The basis for this investigation is buttressed by several related observational evidence, a clear working knowledge of the models to be employed with its demonstration of use over another domain, and availability of computing resources to conduct the proposed integrations.

Barnston, Anthony and Schemm, Jae-Kyung - **Predictability of Atlantic Hurricane Activity by the NMME Coupled Models** - We propose to investigate, and then implement into a real-time forecast system, the response of the CFS CGCM to the Madden-Julian Oscillation (MJO) in north Atlantic hurricane activity. The very high resolution (T382) version o f CFS will be used, as it has already been found to reproduce the interannual variations of hurricane activity level and individual hurricane tracks quite effectively over a multidecadal hindcast period.

Seasonal Atlantic hurricane activity level is known to vary in response to environmental variables such as the ENSO state, the sea surface temperature (SST) in the Main Development Region (MDR), and the state of the north Atlantic multidecadal oscillation. Relatively recently, dynamical tools have been used to predict hurricane activity with some success, defining individual cyclones and quantifying their seasonal total energy. The MJO phase and strength is also definable, and some statistical and dynamical predictability for the MJO is discernible out to the first 2-3 weeks. The MJO is also found capable of affecting the genesis and strength of tropical cyclones in both the Pacific and Atlantic oceans, and this MJO-cyclone relationship is reproducible in some dynamical models. We plan to capture these relationships in a real-time hurricane prediction system that can distinguish preferred timings and locations of hurricane activity up to 2-3 weeks.

Four main tasks of the project will be to (1) assess the extent and quality of MJO representation in the T382 CFS model; (2) examine the relationship between the model's MJO and its hurricane activity compared with that found in observations, and statistically correct systematic errors; (3) repeat steps (I) and (2) for the standard (T 126) CFS version 2 model and for the other models in the NMME experiment, and test multimodel ensemble prediction; and (4) assuming favorable results from (l), (2) and/or (3), implement a real-time hurricane forecast system using the T382 CFS and/or other models in the NMME.

Better prediction of the seasonal Atlantic hurricane activity level, and of preferred subregions for hurricane activity in the medium-range timescale (first few weeks) due to the MJO, is relevant to U.S. economic, safety and national security issues--disaster management, water management, health, and protection of life and property. An example of the level of hurricane forecast detail potentially resulting from the proposed work would be: "During week 1, hurricanes are more likely to emerge in the Gulf of Mexico or in the vicinity of Cuba than near or north of the Leeward Islands, whileduringweek2theyaremostlikelyinthesubregionsouthofHaiti, the Dominican Republic, Puerto Rico and Virgin Islands, and relatively unlikely in the western Gulf of Mexico. " Such intraseasonal specificity, still not targeting individual hurricanes, would complement the overall seasonal prediction o f hurricane activity to render the suite o f time scales more seamless.

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