Project Title: **Variability and Predictability of the Atlantic Warm Pool and Its Impacts on Extreme Events in North America**

PIs: Sang-Ki Lee (Lead-PI)
Institutions: NOAA/AOML
Report Year: FY2016 (Progress Report)

1. Changes in PIs:

1) Chunzai Wang, the lead PI, left NOAA/AOML in 2016. He is no longer serves as a PI. Sang-Ki Lee (NOAA/AOML) will serve as the lead PI during the remaining period of the project.
2) A co-PI, David Enfield retired in 2016. He is no longer serve as a co-PI.

2. Results and Accomplishments

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 PIs of the project have engaged in the following five major areas of research and activity in FY2016:

1) **A virtual workshop on "Observing & Modeling Climate Variability in the Intra-Americas Seas & Impacts on the Continental Americas & the Caribbean"**
2) **Special iussue of CLIVAR Variations (winter 2016) "The Intra-Americas Seas: Vital to regional climate & extreme events"**
3) **The Intra-Americas Sea: Challenges and opportunities to understand North American climate variability and predictability (White paper)**
4) **Past and future climate variability in the Intra-Americas Sea and its impact on the marine ecosystem and fisheries**
5) **Contributions of the atmosphere–land and ocean–sea ice model components to the tropical Atlantic SST bias in CESM1**

Here, we briefly describe results on these five tasks.

2.1. A virtual workshop on "Observing & Modeling Climate Variability in the Intra-Americas Seas & Impacts on the Continental Americas & the Caribbean"

Summary

Chunzai Wang (the former Lead-PI), Vasu Misra (FSU), German Poveda (National University of Colombia), Erick Rivera Fernandez (University of Costa Rica) and Yolande Serra (University of Washington) co-hosted a virtual workshop on "Observing & Modeling Climate Variability in the Intra-Americas Seas & Impacts on the Continental Americas & the Caribbean", which was held during September 9-11, 2016 (https://usclivar.org/meetings/2015-iasclip-virtual-workshop). Both oral and poster presentations were solicited in this unique online format, which allowed participants from different regions to join remotely and interact in meaningful ways. The purpose of the virtual workshop is to provide a platform to facilitate discussions to understand local and

remote atmospheric and oceanic processes that lead to variations in the warm pool in the Intra-Americas Seas (IAS), the dynamics and physics of the teleconnections of the IAS with the continental monsoons of the Americas and weather extremes spanning across time scales, and the opportunities for translating understanding to improved monitoring and prediction of the variations and change in the IAS and their associated impacts. The virtual workshop also address model biases in the region and identify new technology or platforms to improve the rapidly deteriorating observational network of the atmosphere, to bolster ocean observations, and to enhance capacity building in the region.

The virtual workshop was organized around six sessions that cover observational and modeling studies of the IAS spanning intra-seasonal to secular time scales including extremes. The aim of these sessions is to assess the current limitations of both the observational networks and model performance for the region, report on the current state of our understanding of the important physical processes in both the atmosphere and ocean across weather and climate time scales, and promote new ideas for a regional observing system and modeling studies aimed at improving understanding and predictive skill on intra-seasonal to secular time scales. During the three-day meeting, 20 talks and 23 posters were presented, followed by four pannel discusisons.

The IASCLiP virtual workshop agenda, the titles and abstracts of the presentations can be found in the link below. Each poster presentation (located below the agenda) has an abstract and PDF of the poster. Please view the posters and comments (or questions) for the author in the comment box:
https://usclivar.org/meetings/2015-iasclip-virtual-workshop-agenda-page

2.2. Special iussue of CLIVAR Variations (winter 2016) "The Intra-Americas Seas: Vital to regional climate & extreme events"

Summary
Chunzai Wang (former lead PI) and Vasu Misra (FSU) served as the Guest editor of the special issue of CLIVAR Variations (winter 2016 issue). Five articles from the IASLip virtual workship were included in this issue, which clearly attest to the vital role of the Intra-Americas Sea (IAS) in climate variations of the surrounding North American continental region stretching from the Caribbean to the Mesoamerica and across the Midwest Plains to the northeast US.

The special issue of CLIVAR Variations can be found here:
https://usclivar.org/sites/default/files/documents/2016/Variations2016Winter_0.pdf

2.3 Intra-Americas Sea: Challenges and opportunities to understand North American climate variability and predictability (White paper)

Chunzai Wang (former lead-PI) and Sang-Ki Lee (lead-PI) participated in a whitepaper "Intra-Americas Sea: Challenges and opportunities to understand North American climate variability and predictability"

Misra, V, C. Wang , Y. Serra, K. Karnauskas , E. M. Ellinor, J. Sheinbaum, P. Chang, S.-K. Lee, B. Rosenheim, B. Kirtman, D. Enfield, E. D. Maloney, A. Kumar, G. Poveda, R. Fu, J.

Jouanno, S. Berthet, A. Mishra, M. Bourassa, J. Candela, and J. Ochoa, 2016 The Intra-Americas Sea: Challenges and Opportunities to Understand North American Climate Variability and Predictability.
ftp.aoml.noaa.gov/phod/pub/sklee/projects/cpo_awp/bams_ias_final.pdf

2.4 Past and future climate variability in the Intra-Americas Sea and its impact on the marine ecosystem and fisheries

Summary
This study examines the potential impact of anthropogenic greenhouse warming on the Intra-Americas Sea (IAS, Caribbean Sea and Gulf of Mexico) by downscaling the Coupled Model Intercomparison Project phase-5 (CMIP5) model simulations under historical and two future emission scenarios using an eddy-resolving resolution regional ocean model. The simulated volume transport by the western boundary current system in the IAS, including the Caribbean Current, Yucatan Current and Loop Current (LC), is reduced by 20-25% during the 21st century, consistent with a similar rate of reduction in the Atlantic Meridional Overturning Circulation (AMOC). The effect of the LC in the present climate is to warm the Gulf of Mexico (GoM). Therefore, the reduced LC and the associated weakening of the warm transient LC eddies have a cooling impact in the GoM, particularly during boreal spring in the northern deep basin, in agreement with an earlier dynamic downscaling study. In contrast to the reduced warming in the northern deep GoM, the downscaled model predicts an intense warming in the shallow ($\leq$ 200 m) northeastern shelf of the GoM especially during boreal summer since there is no effective mechanism to dissipate the increased surface heating. Potential implications of the regionally distinctive warming trend pattern in the GoM on the marine ecosystems and hurricane intensifications during landfall are discussed. This study also explores the effects of 20th century warming and climate variability in the IAS using the regional ocean model forced with observed surface flux fields. The main modes of sea surface temperature variability in the IAS are linked to the Atlantic Multidecadal Oscillation and a meridional dipole pattern between the GoM and Caribbean Sea. It is also shown that variability of the IAS western boundary current system in the 20th century is largely driven by wind stress curl in the Sverdrup interior and the AMOC.

This work was published in the Journal of Marine Systems in August 2015 and the winter 2016 issue of CLIVAR Variations, and also presented as a poster during the 2015 IASLip virtual workshop:

Liu, Y., S.-K. Lee, D. B. Enfield, B. A. Muhling, J. T. Lamkin, F. Muller-Karger and M. A. Roffer, 2015: Potential impact of climate change on the Intra-Americas Seas: Part-1. A dynamic downscaling of the CMIP5 model projections. J. Marine Syst., 148, 56-69, doi:10.1016/j.jmarsys.2015.01.007.
http://www.aoml.noaa.gov/phod/Liu_et_al_2015_JMS.pdf

Liu, Y., S.-K. Lee, D. B. Enfield, B. A. Muhling, J. T. Lamkin, F. E. Muller-Karger, and M. A. Roffer, 2016: Past and future climate variability in the Intra-Americas Sea and its impact on the marine ecosystem and fisheries, US CLIVAR Variations, Vol. 14, No. 1, 27-32.

2.5 Contributions of the atmosphere–land and ocean–sea ice model components to the tropical Atlantic SST bias in CESM1

Summary
In order to identify and quantify intrinsic errors in the atmosphere–land and ocean–sea ice model components of the Community Earth System Model version 1 (CESM1) and their contributions to the tropical Atlantic sea surface temperature (SST) bias in CESM1, we propose a new method of diagnosis and apply it to a set of CESM1 simulations. Our analyses of the model simulations indicate that both the atmosphere–land and ocean–sea ice model components of CESM1 contain large errors in the tropical Atlantic. When the two model components are fully coupled, the intrinsic errors in the two components emerge quickly within a year with strong seasonality in their growth rates. In particular, the ocean–sea ice model contributes significantly in forcing the eastern equatorial Atlantic warm SST bias in early boreal summer. Further analysis shows that the upper thermocline water underneath the eastern equatorial Atlantic surface mixed layer is too warm in a stand-alone ocean–sea ice simulation of CESM1 forced with observed surface flux fields, suggesting that the mixed layer cooling associated with the entrainment of upper thermocline water is too weak in early boreal summer. Therefore, although we acknowledge the potential importance of the westerly wind bias in the western equatorial Atlantic and the low-level stratus cloud bias in the southeastern tropical Atlantic, both of which originate from the atmosphere–land model, we emphasize here that solving those problems in the atmosphere–land model alone does not resolve the equatorial Atlantic warm bias in CESM1.

This work was published in Ocean Modelling in December 2015:

Song, Z. S.-K. Lee, C. Wang, B. Kirtman and F. Qiao, 2015: Contributions of the atmosphere-land and ocean-sea ice model components to the tropical Atlantic SST bias in CESM1. Ocean Modelling, 96, 280-290, doi:10.1016/j.ocemod.2015.09.008.
http://www.aoml.noaa.gov/phod/1-s2.0-S146350031500178X-main.pdf

3. Publications and Presentations

Domingues, R., G. Goni, F. Bringas, **S.-K. Lee**, H.-S. Kim, G. Halliwell, J. Dong, J. Morell and L. Pomales, 2015: Upper-ocean response to Hurricane Gonzalo (2014): salinity effects revealed by sustained and targeted observations from underwater gliders. Geophys. Res. Lett., 42, 7131-7138, doi:10.1002/2015GL065378.

Jo, H.-S., S.-W. Yeh and **S.-K. Lee**, 2015: Changes in the relationship in the SST variability between the tropical Pacific and the North Pacific across the 1998/99 regime shift. Geophys. Res. Lett., 42, 7171-7178, doi:10.1002/2015GL065049.

Lee, S.-K., A. T. Wittenberg, **D. B. Enfield**, S. J. Weaver, **C. Wang** and R. Atlas, 2016: Springtime U.S. regional tornado outbreaks and their links to ENSO flavors and North Atlantic SST variability. Environ. Res. Lett., 11, 044008, doi:10.1088/1748-9326/11/4/044008.

Liang, Y.-C., J.-Y. Yu, M.-H. Lo, and **C. Wang**, 2015: The changing influence of El Niño on the Great Plains low-level jet. Atmo.Sci.Lett., 16(4):512-517, (doi: 10.1002/asl.590).

Liu, Y., S**.-K. Lee**, **D. B. Enfield**, B. A. Muhling, J. T. Lamkin, F. Muller-Karger and M. A. Roffer, 2015: Potential impact of climate change on the Intra-Americas Seas: Part-1. A

dynamic downscaling of the CMIP5 model projections. J. Marine Syst., 148, 56-69, doi:10.1016/j.jmarsys.2015.01.007.
http://www.aoml.noaa.gov/phod/Liu_et_al_2015_JMS.pdf

Liu, Y., **S.-K. Lee**, **D. B. Enfield**, B. A. Muhling, J. T. Lamkin, F. E. Muller-Karger, and M. A. Roffer, 2016: Past and future climate variability in the Intra-Americas Sea and its impact on the marine ecosystem and fisheries, US CLIVAR Variations, Vol. 14, No. 1, 27-32.

Liu, Y., **S.-K. Lee**, **D. B. Enfield**, B. A. Muhling, J. T. Lamkin, F. Muller-Karger and M. A. Roffer, 2015: Potential impact of climate change on the Intra-Americas Seas: Part-1. A dynamic downscaling of the CMIP5 model projections. J. Marine Syst., 148, 56-69, doi:10.1016/j.jmarsys.2015.01.007.

Moon, I.-J., S.-H. Kim, and **C. Wang**, 2015: Reply: El Niño and intense tropical cyclones. Nature, 526(7575):E4-E5 (doi:10.1038/nature15546)

Song, Z. **S.-K. Lee**, **C. Wang**, B. Kirtman and F. Qiao, 2015: Contributions of the atmosphere-land and ocean-sea ice model components to the tropical Atlantic SST bias in CESM1. Ocean Modelling, 96, 280-290, doi:10.1016/j.ocemod.2015.09.008.

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