"Advancing predictive understanding of North American Drought: The role of the North Atlantic SST" **Final Report**

1. General Information

Project Title:
Advancing predictive understanding of North American Drought: The role of the North Atlantic SST

PI/co-PI names and institutions:
Mingfang Ting, Yochanan Kushnir, Dong Eun Lee, and Richard Seager
Lamont-Doherty Earth Observatory of Columbia University
Anthony Barnston
International Research Institute for Climate and Society, Columbia University

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2. Main goals of the project, as outlined in the funded proposal

- Investigate mechanisms of North Atlantic SST impact on U.S. drought
- Understand the dynamical linkages between SST and U.S. hydroclimate
- Understand predictability of U.S. precipitation given the phases of the Atlantic Multidecadal Variability (AMV)

3. Results and accomplishments

Mechanisms of North Atlantic SST impact on winter U.S. hydroclimate

We have conducted several atmospheric general circulation model experiments to explore the role of North Atlantic sea surface temperature on the continental U.S. hydroclimate, both in terms of seasonal mean changes and sub-seasonal variability. In the first type of experiments, we used NCAR CAM5 with prescribed historical observed SST to try reproducing the observed changes in hydroclimate during this period. We found that not only is the seasonal mean precipitation over the continental U.S. decreased as a result of a warm phase of AMV, but the monthly variance also substantially reduced. This led to the detailed exploration of the mechanisms of the change in mean and variance of precipitation during the warm phase of AMV relative to the cold phase. The dominant mechanism is through the warming of the atmosphere and the suppressed vertical motion due to increased stability coupled with a circulation pattern that is La Niña like and favors dryer condition in the Southwest U.S. in the winter. A paper summarizing the results have been published in the Journal of Climate (Lee et al., 2018).

North Atlantic SST modulation of U.S. summer maximum temperature

We use weather types (WTs), one type of cluster analysis, to identify summer daily maximum temperature regimes and their circulation characteristics in this study. By using ECHAM5 model with prescribed historical SST for the period 1930-2013, we were able to identify six weather types that contribute to the frequent maximum summer temperature days that occur coherently throughout the

continental U.S. Positive (negative) AMV anomalies not only translates to more (less) warming over the US across all regimes, but also alter the frequency of WTs conducive to broad continental warming through modulations of associated ridging anomalies in the North American-European sector, hence indicating AMV controls on heat wave prone conditions over North America since the last decades. This study is published in the Journal of Climate (Vigaud et al., 2018). Another study looked at the United States warming hole and the role of natural variability versus anthropogenic forcing in contributing to the warming hole (Mascioli et al., 2017). We found an important contribution from the Atlantic multidecadal variability to the lack of warming in some regions of the United States.

Understand the dynamic link between SST and US hydroclimate and heat waves

In addition to the North Atlantic SST – drought relationship, we also explored the role of different ENSO SST and the Pacific zonal SST gradient on the US drought and heat waves. In Jong et al., (2016, 2018), we explored the link between California precipitation and EL Niño in terms of seasonality and strength of the event in later winter, when the ENSO influence is the largest. Jong et al. (2016) found that those El Niño events that can maintain a moderate strength through late winter (Feb, Mar, Apr) are the ones that can bring excessive precipitation to California, thus the hope of alleviating persistent drought conditions in the region. The El Niño teleconnection is found to strengthen from early to late winter even though the SST anomalies are decreasing from early to late winter. This is partially due to the background SST condition being warmer in late winter, facilitating stronger convective anomalies in the eastern Pacific in late winter than early winter. Jong et al. (2018) further explored the 2015/16 EL Niño and the reason for its relatively weak impact on California in both early and late winter. The sharp decline in late winter SSTA and the westward shifted SSTA center is found to be partially responsible for the lack of impact in California.

In Guo et al. (2017), the distinct patterns of tropical Pacific SST were examined using the Self-Organizing Map technique and the atmospheric teleconnection to the different patter of SST is examined. We found that there are two distinct EL Niño patterns that can induce distinct teleconnection patterns in North America that further impacts the surface climate anomalies. With the canonical and stronger eastern Pacific El Niño primarily responsible for a north-south pattern, versus a weaker and more westward shifted SSTA patterns associated with east-west pattern of surface temperature and precipitation. This is potentially important for accurate seasonal climate prediction based on ENSO SST.

Finally, in a recent study (Deng et al., 2018), we have examined the Texas heat wave days and their trend and found that these are linked to the intensified Pacific zonal SST gradient which leads to a wavetrain originating from the western tropical Pacific and a ridge over the Texas area in spring. Along with the La Niña wavetrain that also place a ridge over Texas in spring, this serves to reduce spring rainfall in Texas and trigger soil moisture –temperature feedback that led to increased heat wave days and drought in the region. This has been published in the Journal of Climate (Deng et al., 2018) and a NOAA MAP blog was written about this work in June 2018 (https://research.noaa.gov/article/ArtMID/587/ArticleID/2366/Ready-for-summer-heat-Study-finds-new-primary-driver-of-extreme-Texas-heat-waves).

4. Highlights of Accomplishments

- Positive phase of AMV not only causes reduction in winter precipitation over the southwest United States, but also reduces significantly its shorter-term variability, from daily to monthly time scales
- The main physical mechanisms for the reduction in seasonal mean and subseasonal variability of winter precipitation in SWUS are a La Niña like circulation pattern and the suppression of vertical

motion due to increased atmospheric stability over the US associated with warm North Atlantic
- AMV positive phase contributes to significant increases in mean daily maximum temperature over continental US by increasing the frequency of occurrences of the weather types that are conducive to broad continental warming
- There is a more consistent temperature driven drought associated with positive AMV compared to precipitation driven drought over the US across the CMIP5 models.
- The Texas summer heat waves are driven primarily by an enhanced Pacific SST gradient that is partially La Niña driven and partially due to increasing temperature in the western tropical Pacific

5. Transitions to Applications

The work being performed could lead to improved assessment of model-based forecasts of hydroclimate conditions across North America on seasonal to decadal timescales. For example, the AMV is found to modulate seasonal to subseasonal precipitation variability can lead to more accurate assessment of the ENSO-based seasonal forecast. Furthermore, results on the distinct patterns of tropical Pacific SST and their teleconnection to North America is useful for more accurate regional climate prediction based on subtle but important differences in the SST patterns. The results on weather type occurrences and the Atlantic impact on these events can be very useful for predicting decadal trend in heat wave occurrences in the United States. In a paper published in Current Climate Change Report special issue, Seager and Ting (2017) provided a comprehensive review of the potential predictability of North American drought on decadal time scale. The PI and co-PIs are active participants in the DTF telecons and publications in the hope that this will be a vehicle whereby transitions to applications are made.

6. Publications from the Project

Deng, K., M. Ting, S. Yang, and Y. Tan, 2018: Increased Frequency of Summer Extreme Heat Waves over Texas Areas Tied to the Amplification of Pacific Zonal SST Gradient. J. Climate, https://doi.org/10.1175/JCLI-D-17-0554.1.

Guo, Y.-Y., M. Ting, Z. Wen, and D. Lee, 2017: Distinct Patterns of Tropical Pacific SST Anomaly and Their Impacts on North American Climate. J. Climate, 30, DOI: 10.1175/JCLI-D-16-0488.1.

Lee, D.-E., M. Ting, N. Vigaud, Y. Kushnir, and A. Barnston, 2018: Atlantic Multidecadal Variability as a modulator of the precipitation variability in the continental US. J. Climate, https://doi.org/10.1175/JCLI-D-17-0372.1.

Jong, B.-T., M. Ting, R. Seager, N. Henderson, D. E. Lee, 2018: Role of Equatorial Pacific SST forecast error in the late winter California precipitation forecast for the 2015/16 El Niño. J. Climate, 31, 839-852, doi:10.1175/JCLI-D-17-0145.1.

Jong, B., M. Ting and R. Seager, 2016: El Niño's impact on California precipitation: Seasonality, regionality and El Niño intensity. *Env. Res. Lett.*, **11**, 054021, doi:10.1088/1748-9326/11/5/054021.

Mascioli, N., A. Fiore, M. Previdi, M. Ting, 2017: Timing and seasonality of the United States “warming hole”. Environ. Res. Lett. 12 (2017) 034008, https://doi.org/10.1088/1748-9326/aa5ef4.

Seager, R. and M. Ting, 2017: Decadal drought variability over North America: Mechanisms and predictability, *Curr. Clim. Change Rep*., DOI 10.1007/s40641-017-0062-1.

Vigaud, N., M. Ting, D.-E. Lee, Y. Kushnir, and A. Barnston, 2018: Multi-scale variability in summer maximum temperatures over the US and modulations from the North Atlantic simulated by an AGCM. J. Climate, 31, 2549-2562, doi:10.1175/JCLI-D-17-0392.1.

7. PI Contact Information

Mingfang Ting
ting@ldeo.columbia.edu
845-365-8374