**Project Title:** Atmospheric Mechanisms Associated with Temperature Extremes over North America in Observations and Climate Models (DE- SC0005467)

**Reporting Period:** September 15, 2010-September 14, 2014

**Funding Period:** September 15, 2010-September 14, 2014 (including no-cost extension)

**Principal Investigator:** Dr. Anthony J. Broccoli, Department of Environmental Sciences, Rutgers University

**Project Synopsis:** The goal of this work was to gain a comprehensive understanding of the key atmospheric mechanisms and physical processes associated with temperature extremes in order to better interpret and constrain uncertainty in climate model simulations of future extreme temperatures.

**Primary Research and Development Activities:** This work consisted of two overarching phases. The first phase focused on understanding the key mechanisms associated with extreme temperatures over North America in the recent climate using observations and reanalysis. The second phase focused on evaluating how realistically a suite of state of the art general circulation models (from the CMIP5 archive) simulate the mechanisms identified in the first phase.

To begin the first phase, we used climate observations and a reanalysis product to identify the large-scale meteorological patterns associated with extreme temperature days over North America during the late twentieth century. We found that temperature extremes were associated with distinctive signatures in near-surface and mid-tropospheric circulation. The orientations and spatial scales of these circulation anomalies vary with latitude, season, and proximity to important geographic features such as mountains and coastlines. This work was published in the *Journal of Climate* in October 2012 (publication details listed below). Motivated by the similarity of some of these circulation patterns with large-scale, recurrent modes of climate variability, we next examined the associations between daily and monthly temperature extremes and large-scale, recurrent modes of climate variability, including the Pacific-North American (PNA) pattern, the northern annular mode (NAM), and the El Niño-Southern Oscillation (ENSO). The strength of the associations are strongest with the PNA and NAM and weaker for ENSO, and also depend upon season, time scale, and location. The associations are stronger in winter than summer, stronger for monthly than daily extremes, and stronger in the vicinity of the centers of action of the PNA and NAM patterns. Our study of the associations between temperature extremes and large-scale, recurrent modes of climate variability was published in the *Journal of Climate* in February 2014 (publication details listed below).

The second phase of this project focused on quantifying how well the climate models that participated in the Coupled Model Intercomparison Project Phase 5 (CMIP5) capture the patterns identified in the first phase. Using a variety of metrics and self-organizing maps, we found the multi-model ensemble and the majority of individual CMIP5 models generally capture the observed patterns well, including their strength and as well as variations with latitude and season. The results from this project indicate that current models are capable of simulating the large-scale meteorological patterns associated with daily temperature extremes and they suggest that such models can be used to evaluate the extent to which changes in atmospheric circulation will influence future changes in temperature extremes. Results from the second phase of the project are in press at the *Journal of Climate* (publication details listed below).

The project provided primary support for the training of Dr. Paul C. Loikith, who received his Ph.D. in Atmospheric Science from Rutgers University in 2012. Upon the completion of his degree, Dr. Loikith went on to a position as a postdoctoral scholar at the California Institute of Technology/NASA Jet Propulsion Laboratory.

**Project Participants:** Anthony J. Broccoli (PI), Paul C. Loikith (Graduate Assistant, now postdoctoral scholar at the California Institute of Technology/NASA Jet Propulsion Laboratory), Bryan Raney (Scientific Programmer)

**Publications:**

[1] Loikith, P. C., and A. J. Broccoli, 2014: Comparison between observed and model simulated atmospheric circulation patterns associated with extreme temperature days over North America using CMIP5 historical simulations, *J. Climate*, in press.

[2] Loikith, P. C., and A. J. Broccoli, 2014: The role of recurrent modes of climate variability in the occurrence of extreme temperatures over North America. *J. Climate*, **27**, 1600-1618, doi: 10.1175/JCLI-D-13-00068.1.

[3] Loikith, P. C., and A. J. Broccoli, 2012: Characteristics of observed atmospheric circulation patterns associated with temperature extremes over North America, *J. Climate*, **25**, 7266–7281, doi:10.1175/JCLI-D-11-00709.1.

**Presentations/Meetings Attended:**

[1] "Simulated and Observed Atmospheric Circulation Patterns Associated with Extreme Temperature Days over North America" U.S. Dept. of Energy Climate Modeling PI Meeting, Potomac, MD, May 2014 **(oral presentation given by Anthony J. Broccoli)**

[2] “Observed and Simulated Atmospheric Circulation Patterns Associated with Extreme Temperature Days over North America” Invited presentation at CLIVAR workshop entitled “Analyses, Dynamics, and Modeling of Large-Scale Meteorological Patterns Associated With Extreme Temperature and Precipitation Events,” Berkeley, CA, August 2013 **(oral presentation given by Anthony J. Broccoli)**

[3] "The Influence of Recurrent Modes of Climate Variability on the Occurrence of Extreme Temperatures over North America" 93rd American Meteorological Society Annual Meeting, Austin, TX, January 2013 **(oral presentation given by Anthony J. Broccoli)**

[4]“The Influence of Recurrent Modes of Climate Variability on the Occurrence of Extreme Temperatures over North America” AGU Fall Meeting, San Francisco, CA, December 2012 **(poster presented by Paul C. Loikith)**

[5] “Atmospheric Circulation Patterns and Physical Processes Associated with Temperature Extremes over North America,” American Meteorological Society Annual Meeting, New Orleans, LA, January 2012 **(oral presentation given by Anthony J. Broccoli)**.

[6] “Key Atmospheric Circulation Patterns and Physical Processes Associated with Temperature Extremes over North America,” American Geophysical Union Fall Meeting, San Francisco, CA, December 2011 **(poster presented by Paul C. Loikith)**.

[7] “Atmospheric Circulation Patterns Associated with Temperature Extremes Over North America in Observations and Models,” Princeton Geosciences Graduate Research Symposium, Princeton, NJ, November 2011 **(poster presented by Paul C. Loikith)**.

[8] “Atmospheric Circulation Patterns Associated with Temperature Extremes over North American in Observations and Models,” World Climate Research Programme Open Science Conference, Denver, CO, October 2011 **(poster presented by Paul C. Loikith)**.

[9] “Atmospheric Circulation Patterns and Physical Processes Associated with North American Temperature Extremes,” Climate and Earth System Modeling PI Meeting, U.S. Department of Energy, Washington, DC, September 2011 **(oral presentation given by Anthony J. Broccoli)**.

[10] “Identification of Atmospheric Circulation Patterns Associated with Observed Temperature Extremes over North America,” American Geophysical Union Fall Meeting, San Francisco, CA, December 2010 **(poster presented by Paul C. Loikith**).

[11] “Atmospheric Circulation Patterns Associated with Temperature Extremes over North America,” 4th Graduate Climate Conference, Pack Forest Conference Center, WA, October 2010 **(oral presentation given by Paul C. Loikith)**.

**Travel:** DOE support was used for only travel to conferences.

**References:** None.