Ocean and Climate Change Institute
2011 Funded Project
Final Report

Project Title: Northeast US rainfall: Variability versus long-term change

PIs: Ummenhofer CC, Schmitt RW, Joyce TM

What were the primary questions you were trying to address with this research? (Or, if more appropriate, was there a hypothesis or theory that you were trying to prove or disprove?)
Key research questions this research was trying to address were:

- What are the dominant patterns of rainfall variability in the Northeast US and how do they change over time?
- What role do low-frequency variations in the ocean-atmosphere system of the North Atlantic region play for decadal variations in Northeast US rainfall?
- Do recent Northeast US rainfall trends lie within the low-frequency variability exhibited over the region over the past 120 years?

What have you discovered or learned that you didn't know before you started this work?
From high-resolution precipitation data over the past century, it appears that the Northeast US has sustained considerable trends towards wetter conditions, predominantly due to higher rainfall during the warm-season, while winter precipitation has actually decreased. The seasonality in precipitation trends also exhibits distinct decadal to multi-decadal signals. Year-to-year variability in winter precipitation is especially high for the coastal regions of New England, which frequently experience the brunt of extreme precipitation events.

What is the significance of your findings for others working in this field of inquiry and for the broader scientific community?
We identified recurring New England precipitation 'regimes' and related these to large-scale atmospheric circulation and sea surface temperature patterns. Variations over time in these dominant precipitation patterns and the associated circulation features provide dynamically-based explanations of decadal to multi-decadal rainfall variability and long-term trends in the Northeast US. This has implications for seasonal to decadal rainfall predictions. The approach can also be used to help understand long-term projections of regional climate for the Northeast US in the 21st Century.

What is the significance of this research for society?
Our results show that winters with extreme wet conditions in coastal New England are dynamically linked to localized atmospheric blocking patterns associated with anomalously warm sea surface temperatures near Newfoundland. There are indications that these unusual warm oceanic temperatures are preceded by anomalous conditions on the Northeast US shelf. This could have implications for seasonal predictions of unusual wet New England winters.

What were the most unusual or unexpected results and opportunities in this investigation?
We related dominant and recurring New England precipitation patterns to large-scale atmospheric circulation and sea surface temperature patterns across the broader North Atlantic region. Links between rainfall patterns and oceanic temperature patterns were explored both simultaneously and with oceanic temperatures preceding rainfall anomalies by a season. It appears that unusual rainfall conditions in some seasons are preceded by distinct temperature signals in the North Atlantic. Such oceanic precursors could help towards improving seasonal and decadal predictions of rainfall on land in the Northeast US.

What were the greatest challenges and difficulties?

When assessing trends and decadal to multi-decadal signals in Northeast US precipitation over the past century, the results were very sensitive to the specific analysis period and season. Obtaining broadly consistent signals across seasons and analysis periods proved to be challenging. This also applied to potential lead-lag relationships, where oceanic temperature signals might act as precursors for atmospheric anomalies related to the dominant precipitation patterns.

When and where was this investigation conducted? (For instance, did you conduct new field research, or was this a new analysis of existing data?)

Research was conducted at WHOI. An undergraduate student from Williams College was entrained into the project and co-advised by PI Ummenhofer: Samuel Amdur conducted an independent study project on coastal New England cool season precipitation variability and links to regional sea surface temperatures and geopotential height anomalies off Labrador. He presented his results as a poster at the 19th Conference on Air-Sea Interaction at the Annual Meeting of the American Meteorological Society (Amdur *et al.* 2015).

What were the key tools or instruments you used to conduct this research?

A series of state-of-the-art atmospheric reanalysis products and sea surface temperature datasets were used for this research. In addition, a new high-resolution gridded precipitation dataset for the continental US (PRISM) was obtained to better assess regional New England precipitation variability and trends. Cluster analysis techniques were employed to classify seasonal New England precipitation into dominant 'regimes'. These recurring precipitation regimes were related to large-scale atmospheric circulation and sea surface temperature patterns across the region.

Is this research part of a larger project or program?

The project provided the starting point to build up a more comprehensive research program in this area for PI Ummenhofer. Funding from the NSF Climate and Large-scale Dynamics and Physical Oceanography programs was secured for a 3-year project on "Decadal variability in the North Atlantic extratropics: The role of coupling between atmospheric blocking and the Atlantic Multidecadal Oscillation" by PIs Ummenhofer, Seo, Kwon, and Joyce. In addition, undergraduate research students were entrained into this research, working on coastal New England cool season precipitation and links to regional sea surface temperature anomalies off Labrador (Amdur *et al.* 2015), as well as on links between North Atlantic atmospheric blocking and the Atlantic Multidecadal Oscillation.

What are your next steps?

Completion of the *Journal of Climate* paper currently in preparation that summarizes the project's results (Ummenhofer *et al.* 2015a). We are also in the process of applying the techniques used for Northeast US rainfall more broadly to understand European precipitation trends (Ummenhofer *et al.* 2015b,c).

Have you published findings or web pages related to this research? Please provide a citation, reprint, and web link (when available).

Amdur S, Kwon Y-O, **Ummenhofer CC**, Cook M. (2015). Regional forcing mechanisms for cool-season precipitation variability in New England. Poster presentation at the AMS Annual Meeting, Jan 4 – 8, 2015, Phoenix, USA.

Ummenhofer CC, Kwon Y-O, Joyce TM, Schmitt RW (2015a). Northeast US precipitation trends and links to North Atlantic regional variability. *Journal of Climate*, in preparation.

Ummenhofer CC, Seo H, Kwon Y-O, Joyce TM. (2015b). Links between North Atlantic atmospheric blocking and recent trends in European winter precipitation. Poster presentation at EGU Meeting, Apr. 12 – 17, 2015, Vienna, Austria.

Ummenhofer CC, Seo H, Kwon Y-O, Joyce TM. (2015c). Links between North Atlantic atmospheric blocking and recent trends in European winter precipitation. *Geophysical Research Letters*, in preparation.

Please provide photographs, illustrations, tables/charts, and web links that can help illustrate your research.

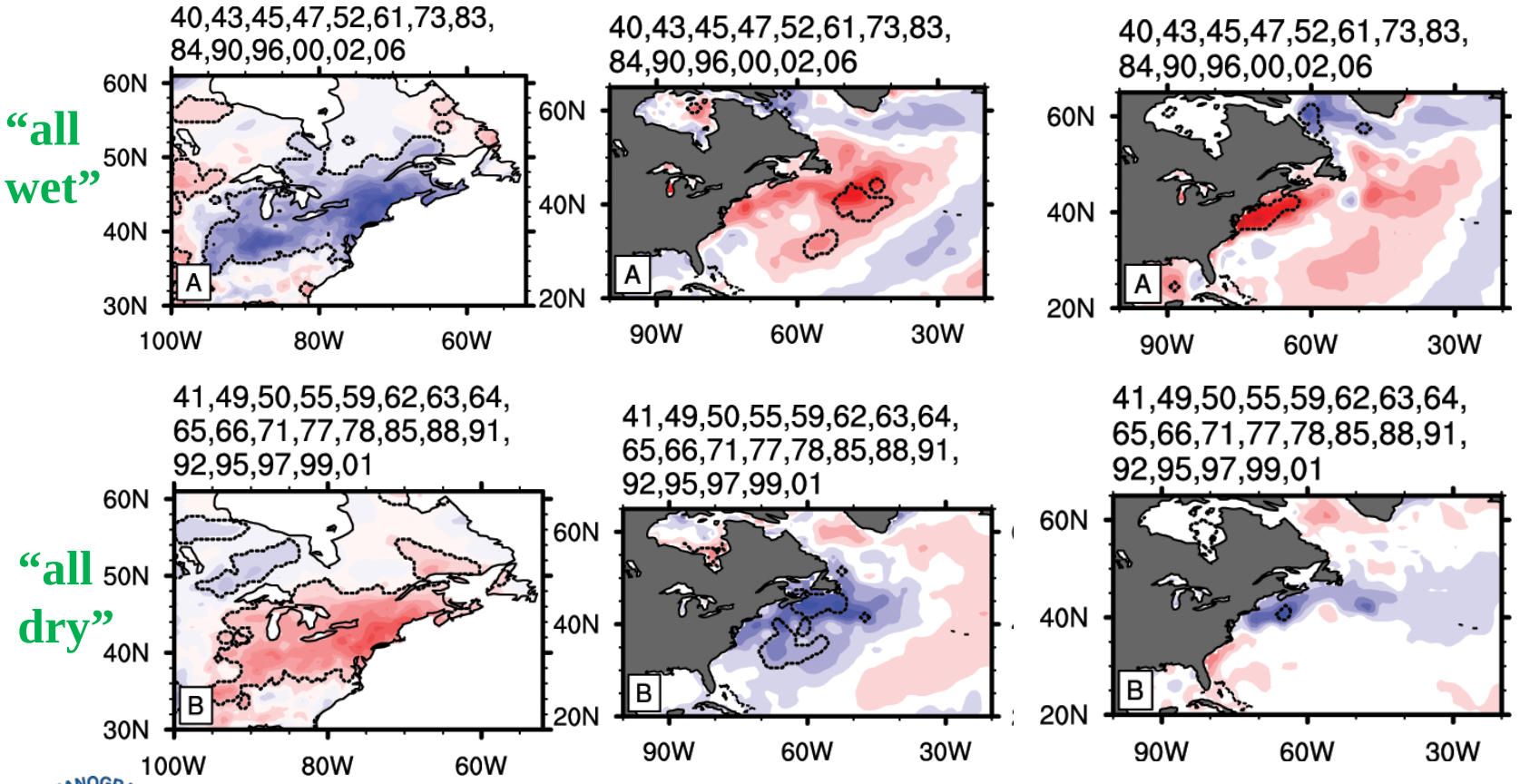
See enclosed figure.

Drivers of Northeast US rainfall patterns

Recurrent rainfall patterns

Concurrent ocean temperatures

Ocean temperatures in **preceding 3 months**



Ummenhofer et al. (in prep)

→ Slower evolution of ocean temperatures → benefit to be drawn for predictions

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