NEW YORK STATE
WATER RESOURCES INSTITUTE
Department of Earth and Atmospheric Sciences

1123 Bradfield Hall, Cornell University
Ithaca, NY 14853-1901
http://wri.eas.cornell.edu

Tel: (607) 255-3034
Fax: (607) 255-2016
Email: nyswri@cornell.edu

Assessing Flood Risk in a Changing Climate in the Mohawk and Hudson River Basins

Stephen Shaw (sbshaw@esf.edu)
SUNY College of Environmental Science and Forestry
Syracuse, NY

Abstract
Work completed in 2014 finalized a portion of the larger project completed in 2013. In particular, 2014 work focused on investigating the connection between extreme precipitation events and extreme discharge events on rivers. There is a common misconception that very high discharge events on rivers result solely from very high intensity precipitation events. This often leads people to look at information on changes in intense precipitation as a proxy for information on changes in very high discharges. Using data from 300 rivers across the U.S., we show that very high intensity precipitation is often not the only driver of very high river discharges and that people need to be cautious in presuming that trends in very heavy rainfall are representative of trends in very high discharge.

Three Summary Points of Interest

- **There is a common misconception that very high intensity precipitation is directly linked to very high river discharge**
- **While there is a partial relationship, very high intensity precipitation more only sometimes leads to very high river discharge**
- **People should use caution in presuming that trends in changes in precipitation are indicative of trends in changes in river discharge**

Keywords: flood causation, intense precipitation

Introduction

Figure 2.18 in the Third National Climate Assessment (http://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing) presents the percentage increase in precipitation falling in very heavy events across eight geographic regions in the United States from 1958 to 2012 (Walsh et al. 2014, p. 37). "Very heavy" events are defined as the 99th percentile of daily precipitation events. The figure shows a 71% increase in precipitation falling in heavy events in the Northeast from 1958 to 2012, a 27% increase in the Southeast, a 34% increase in the Midwest, and lesser changes across the rest of the contiguous U.S. These findings were corroborated by Groisman et al. [2012] and Karl et al. [1998].

We – the authors – have been at several recent regional workshops in the Northeastern U.S. focused on climate change impact assessment where Figure 2.18 from the National Climate Assessment Report has been presented to provide background context on changes in recent climate. These workshops have had audiences comprised of academics, staff from local and regional governmental agencies, and citizen groups. The figure has been shown at these workshops as evidence of not only an intensification of precipitation, but also as justification for likely increases in flooding, with little distinction whether this may be localized flooding or large scale riverine flooding. While we admittedly have a small observational sample of how people interpret National Climate Assessment Figure 2.18, we have found that – of those we have observed - many non-hydrologists have been inclined to see changes in heavy precipitation and flooding (of all kinds) as closely linked.

Indeed, in small and steep or urban catchments, heavy precipitation and flooding are most likely closely linked. However, the linkage between precipitation and flooding is more nuanced at larger scales and in non-urban areas. Notably, the water resources section of the Third National Climate Assessment explicitly says "River floods are basin specific and dependent not only on precipitation but on soil moisture, topography, and other factors" (Georgakakos et al. 2014, p. 75,). In addition, the hydrology literature itself has numerous studies investigating controls on flooding, with most indicating that a primary control besides precipitation is antecedent watershed. Furthermore, nearly all rainfall-runoff models in hydrology are constructed to track antecedent watershed wetness such that the fraction of rainfall converted to runoff increases as stored water increases Needless to say, the role of antecedent moisture conditions in controlling watershed outflow is well-established.

Therefore, this work is as much one of science communication as the investigation of fundamental scientific principles. In short, despite the well-established fact that riverine flooding is dependent on watershed wetness nearly as much as precipitation intensity, this concept appears to often be overlooked by non-hydrologists when interpreting precipitation data. Because hydrologic studies often focus on simulating variations in moisture condition, these studies rarely see a need to make explicit the fact that discharge is not always directly related to precipitation intensity.

This study is intended to make explicit a simple message: "Very heavy precipitation does not always lead to very high discharge". The primary substance of this work is to evaluate the probability that a high precipitation event causes a high discharge event. We provide additional analysis by separating precipitation events by season and by antecedent moisture conditions. We also evaluate trends in time of very heavy precipitation and very high discharge.

Results & Discussion

By calculating regional trends, we found that the Northeast (NE), Southeast (SE), and Midwest (MW) United States show significant increases ($p<.05$) in the number of very heavy precipitation events per year. In contrast, regional trend analysis showed neutral to negative insignificant trends in extreme discharge events in all regions where precipitation trends were

This report was prepared for the New York State Water Resources Institute (WRI) and the Hudson River Estuary program of the New York State Department of Environmental Conservation, with support from the NYS Environmental Protection Fund.

increasing. This lack of concordance in trends suggests a lack of consistent causation between very heavy precipitation and very high discharge.

To more directly evaluate causation of very high discharge by very heavy precipitation, we directly related the probability of occurrence of very heavy precipitation to very high discharge. We found that 99th percentile precipitation only results in 99th percentile discharge 35% of the time when considered across all sites (Figure 1). However - not unexpectedly - when conditioned on soil moisture, 99th percentile precipitation results in 99th percentage discharge 62% of the time during wet periods and 12% of the time during dry periods.

Policy Implications

As noted above, this work is intended to help clarify the intuition of non-hydrologists. Namely, it helps illustrate that changes in precipitation alone cannot only be used to predict changes in high discharge events on river systems. Instead, it is critical to consider changes in precipitation in conjunction with changes in watershed wetness.

There can be a tendency to oversimplify controls on flooding. Especially in terms of trying to assess possible changes in future flooding, it is important to recognize the numerous factors that control flooding and the uncertainty in making future predictions of flooding given the complexity of the factors.

Methods

In this work, we use a set of 300 watersheds spread across the contiguous U.S. We first evaluate the trend in very heavy precipitation (99th percentile) at these 300 watersheds, basically reproducing the analysis in Figure 2.18, albeit for a smaller set of sites. Then, we evaluate the trend in very high flow events (99th percentile) at these same sites and, more critically, directly assess how many high flow events at each site are caused by very heavy precipitation. Additionally, we evaluate how the strength of the linkage between precipitation and discharge changes as antecedent watershed wetness increases. Antecedent wetness is determined from simulations of the Variable Infiltration Capacity (VIC) Hydrological Model retrospective run for 1950-2000.

Outreach

Portions of this work were presented at four different conferences:

1. Sept 2014, Cornell Community Development Institute Conference, Ellenville, NY
2. June 2014, UCOWR/ NIWR/ CUASHI Conference, Tufts University, MA.
3. March 2014, NYS Stormwater and Flood Plain Managers Association Annual Meeting, Poughkeepsie, NY.
4. March 2014, Mohawk Watershed Symposium, Union College, NY.

Additionally, the work presented here is being prepared for submission to the academic journal Climatic Change Letters. The manuscript should be submitted by March 2015.

Student Training

For 2014, this work partially supported a graduate student.

References

Georgakakos, A., et al. (2014), Ch. 3: Water Resources. Climate Change Impacts in the United States: The Third National Climate Assessment, U.S. Global Change Research Program, 69-112.

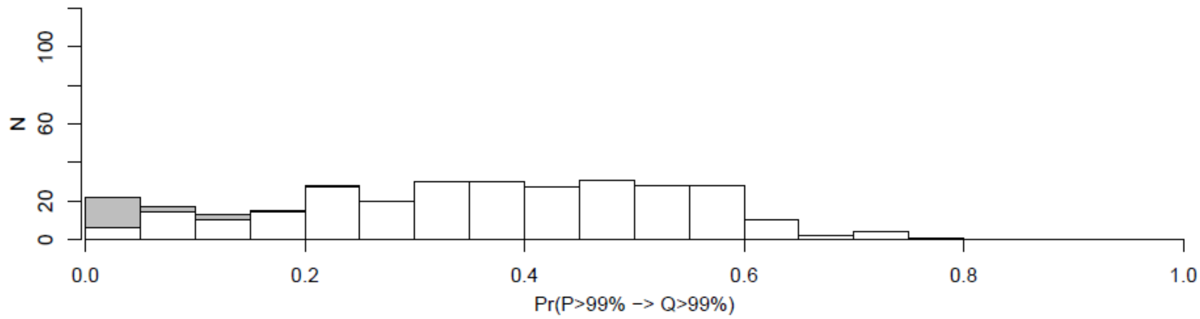
Groisman, P. Y., R. W. Knight, and T. R. Karl (2012) Changes in Intense Precipitation over the Central United States. J. Hydrometeor, 13, 47–66.

Karl, T. R. and R. W. Knight (1998), Secular Trends of Precipitation Amount, Frequency, and Intensity in the United States. Bull. Amer. Meteor. Soc., 79, 231–241,.

Walsh, J., et al. (2014), Ch. 2: Our Changing Climate. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 19-67.

This report was prepared for the New York State Water Resources Institute (WRI) and the Hudson River Estuary program of the New York State Department of Environmental Conservation, with support from the NYS Environmental Protection Fund.

Figure 1. Number of sites (*N*) with given probability that very heavy precipitation (P>99%) leads to very high discharge (Q>99%). For instance, we see that at approximately 150 sites 40% or less of very heavy precipitation events cause very high discharge. Additionally, we see that at virtually all sites, there is a 65% or less chance of very heavy precipitation events cause very high discharge.



This report was prepared for the New York State Water Resources Institute (WRI) and the Hudson River Estuary program of the New York State Department of Environmental Conservation, with support from the NYS Environmental Protection Fund.