Nonstationarity in Precipitation Frequency-Duration Estimates?

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Introduction. There is a popular perception driven by statements in authoritative literature that heavy rainfalls have become more frequent, and that this trend will increase with climate change. Most of the scientific literature examines this question from the point of view of climatology using definitions of “heavy”, “very heavy”, or “extreme” rainfall different from those commonly used by civil engineers and municipal, state and Federal planners. The difference in semantics has led to a gap in the understanding of the impacts of climate change on precipitation frequency estimates.

This paper identifies the differences in semantics used by the climate and civil engineering communities and examines trends in the observed record with respect to precipitation frequency estimates. We place the effect of trends in the context of uncertainty associated with the estimates themselves.

Climatology Semantics and Statements. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), in its Climate Change 2007: Synthesis Report states: “It is likely that the frequency of heavy precipitation events … has increased over most areas.” These and similar statements in the literature define terms such as “heavy”, “very heavy”, or “extreme” precipitation. For example, Groisman et al. state: “… we define a daily precipitation event as heavy when it falls into the upper 10% and/or 5% of all precipitation events; as very heavy when it falls into the upper 1% and/or 0.3% of precipitation events; and extreme when it falls into the upper 0.1% of all precipitation events.” They continue: “The return period for such events … varies, for example, from 3 to 5 yr for annual … very heavy precipitation events.” We note that these terms generally apply to events of daily durations. Some authors note: “… there is no single method of analysis that can comprehensively cover all the important aspects of how precipitation changes over the course of time ...”.

Civil Engineering and Civil Infrastructure Planning Semantics. Civil Engineers and municipal, state and Federal planners rely on precipitation frequency estimates defined in terms of average annual exceedance probabilities or average recurrence intervals (ARI). The terms “heavy”, “very heavy”, and “extreme” rainfall are generally subjective in civil engineering literature but their meaning can be construed by considering the frequencies the civil engineering community uses. Historically the community has been interested in ARIs ranging from 25 to 100 and 500 years but in recent decades, ARIs down to 1 year and lower have become relevant. Designs for storm water drains are typically based on ARIs around 25-100 years and flood plain management is typically based on ARIs from 100 to 500 years. Large dams are typically designed for the probable maximum precipitation, which has been variously assigned ARIs from 10,000 to 1,000,000 years.

The different semantics between the climate and civil engineering communities leads to misinterpretation of statements from authorities such as the IPCC by the civil engineering community and conversely a misunderstanding of the information needed for determining the potential impact of climate change on civil infrastructure by the climate community.
Analysis. We attempt to bridge the semantic gap by extending the analyses of the climate community into the range of less frequent events of interest to the civil engineering community. We have used the specific precipitation frequency estimates provided in NOAA Atlas 14 Volumes 1 and 2 as thresholds. We have counted and analyzed the number of exceedances of these thresholds in the historical record. Volume 1 provides estimates for the semiarid southwest U.S. and Volume 2 provides estimates for the Ohio River Basin and surrounding states.

For the semiarid southwest, the frequency of daily duration events over the period 1896-2008, is found to be decreasing at about 0.13% per century for 1 year ARI events to about 1.0% per century for 100 year ARI events. For 6 hour events over the period 1949-2008, they increase at about 0.4% per century for 1 year ARI events to about 0.15% per century for 50 year ARI events. For 100 year ARI events, the trend is decreasing at 0.1% per century; however in this case the data are relatively few and this result needs further investigation.

For the Ohio River basin and surrounding states, the frequency of daily duration events over the period 1904-2008 is found to be increasing at about 0.2% per century for 1 year ARI events to about 1% per century for 100 year ARI events. For 6 hour events over the period 1948-2008, the frequency increases at a rate of about 0.02% per century at 1 year ARI, rises to about 0.15% per century for 5 year ARI events and then reduces to a relatively stationary mode for events of 25 through 100 years ARI.

These trends are small with respect to the uncertainty associated with estimating precipitation frequency. The 90% confidence intervals provided in NOAA Atlas 14 range from the order of +/- 30% in sparsely instrumented areas with shorter periods of record to +/- 10% in areas with more dense instrumentation and longer periods of record. Because the rates of change in frequency of precipitation of primary relevance to civil engineers are small with respect to our ability to accurately define those estimates, civil engineers and planners should therefore be considering such uncertainty in addition to considering any potential future changes in the estimates.

Conclusion. The literature in the climate community examining potential impacts of climate change on rainfall frequencies uses terms, which on face value, appear to address the frequencies required by those who plan and account for those impacts on the Nation’s civil infrastructure. However, because of differences in semantics, this literature does not properly address precipitation frequencies of importance to the Nation’s civil infrastructure. It further appears that at least in the historical record, the uncertainty associated with the estimates is of much greater importance than changes in the estimates over time. As we examine the potential impacts of climate change we should use terminology, and frequencies and durations, specifically used in the design and planning of the Nation’s civil infrastructure.