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Climate-driven trends in the occurrence of major floods across North America and Europe

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Every year river floods cause enormous damage around the world. Recent major floods in North America and Europe, for example, have received much press, with some concluding that these floods are more frequent in recent years as a result of anthropogenic warming. There has been considerable scientific effort invested in establishing whether observed flood records show evidence of trends or variability in flood frequency, and to determine whether these patterns can be linked to climatic changes. However, the river catchments used in many published studies are influenced by direct human alteration such as reservoir regulation and urbanisation, which can confound the interpretation of climate-driven variability. Furthermore, a majority of previous studies have analysed changes in low magnitude floods, such as the annual peak flow, at a national scale. Few studies are known that have analysed changes in large floods (greater than 25-year floods) on a continental scale. To fill this research gap, we present a study analysing flood flows from reference hydrologic networks (RHNs) or RHN-like gauges across a large study domain embracing North America and much of Europe. RHNs comprise gauging stations with minimally disturbed catchment conditions, which have a near-natural flow regime and provide good quality data; RHN analyses thus allow hydro-climatic variability to be distinguished from direct artificial disturbances or data inhomogeneities. One of the key innovations in this study is the definition of an RHN-like network consisting of 1204 catchments on a continental scale. The network incorporates existing, well-established RHNs in Canada, the US, the UK, Ireland and Norway, alongside RHN-like catchments from Europe (France, Switzerland, Iceland, Denmark, Sweden, Finland, Spain), which have been incorporated in the network following a major effort to ensure RHN-like status of candidate gauges through consultation with local experts. As the aim of the study is to examine long-term variability in the number of major floods, annual exceedances of 25-, 50-, and 100-year floods during the last 50 - 80 years are estimated for all study gauges across North America and Europe, and for smaller groups of gauges defined by catchment size, location, climate, flood threshold, and period of record. Trends are computed using logistic regression techniques, supported by a suite of methods used to test the assumptions used in the analysis. We also analyse relationships between major flood occurrence and atmosphere/ocean indices (the AMO, NAO, PDO and SOI). Our analysis finds no compelling evidence for consistent changes over time in major-flood occurrence across North America and Europe, indicating that generalizations about major-flood occurrence trends across large domains or a diversity of catchment types are ungrounded. There are in fact more significant relationships between major-flood occurrence and the AMO than between flood occurrence and time. Flood occurrence overall (based on data from all 1204 gauges in our study) increased from 1961 to 2010 but not significantly, driven primarily by European increases. Non-significant increases were also found overall from 1931 to 2010 (322 gauges) but driven primarily by North American increases. Flood occurrence increased and decreased (including some significant changes) for the various sub-groups of gauges. Overall this study demonstrates that past changes in major-flood occurrence are highly complex and future changes will be likewise. International hydrologic networks containing minimally altered catchments will play a key role in understanding these complexities.