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Taming the Mighty Mississippi: Integrating paleo-flood data and modeling to understand the patterns and causes of extreme floods on a major river system

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The Mississippi River is an economic artery of the United States that is heavily managed to provide flood control and maintain a navigable shipping channel. The current system of levees and spillway structures was conceived in the early 20^{th} century, but the ability of this system to withstand the altered hydroclimatic conditions projected for the next century is poorly understood. Here, we present initial results from a project that integrates new sedimentary records from floodplain lakes with analyses of sediment geochemistry and climate model simulations to better understand the causes of extreme floods on the lower Mississippi River.

In our sedimentary paleoflood records, flood event beds are characterized by an upward fining sequence from deposition of the bedload and suspended load during overbank floods, identified here using high-resolution laser particle-size analysis and elemental composition (XRF), and dated using radioisotopes (^{137}Cs, ^{210}Pb, ^{14}C) and optically-stimulated luminescence (OSL) on quartz. Grain-size descriptors and elemental ratios of Zr/Fe and Fe/Rb are highly correlated, and are used alongside historical discharge records to develop a statistical model for reconstructing flood magnitude in prehistoric contexts. Geochemical analyses of sediments from the floodplains of major tributaries of the Mississippi are used to assess the systematics of ^{87}Sr/^{86}Sr, ^{143}Nd/^{144}Nd, ^{206}Pb/^{204}Pb, and ^{208}Pb/^{204}Pb across the basin, enabling identification of the synoptic patterns of individual paleo-flood events.

We investigate the dynamical drivers of past floods on the lower Mississippi using both reanalysis data and the last millennium simulation from NCAR model CESM1 to find that increased likelihoods of extreme floods on the lower Mississippi River are associated with enhanced moisture flux over midcontinental North America that is controlled by the interaction of seasonally variable soil moisture over major tributaries with inter-annual (e.g., ENSO) and decadal (e.g., NAO, PDO) ocean-atmosphere variations. We also find preliminary evidence for increased frequencies of large floods following major human modifications to the Mississippi River and its watershed after the mid-19^{th} century. The insights gained through integrated paleoflood data-model comparison will improve seasonal to decadal forecasts of flood risk for the largest river system in the United States.