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# Rivers as archives of paleo-precipitation patterns and extreme precipitation

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Fluvial systems commonly experience hysteresis and complex signal buffering effects that complicate tracking of allogenic forcing factors and autogenic processes. This paper presents a study of 52 modern and ancient fluvial datasets where river dynamics are dominated by highly seasonal precipitation pattern, such as in monsoonal domain and the bordering subtropical arid to sub-humid climate zones.

Rivers that receive significant amounts of their surface water supply from monsoon precipitation characteristically experience seasonal floods, and display seasonally highly variable discharge, controlled by the monsoon trough passage and its related cyclones. The intense summer rainfall causes high-magnitude floods, whereas rivers only transmit a low base flow during the dry winters. Also for many rivers in the sub-humid to arid subtropics, bordering the monsoon domain, the monsoon rain is the main source of surface water recharge. However, such rivers may receive monsoon rain and transmit discharge only during abnormal or strengthened monsoon seasons. This annual discharge variability or range, as compared to the mean annual discharge, distinguishes the monsoonal and subtropical rivers from the rivers in equatorial tropics and temperate perennial precipitation zones, where the annual range is relatively small compared to the annual mean discharge.

The positive deviation is clearly demonstrated by comparing the Q90 values to the mean discharge values, indicating flood discharge or magnitude values of >200-400% as compared to the annual mean discharge. Moreover, Q50 values of rivers that receive their surface water supply from monsoon precipitation are less than 10% of the annual mean discharge in some such rivers, and range from 20-50% in most. In comparison, in perennial precipitation zone rivers the Q90 values are within110-160% as compared to the annual mean, and the Q50 values are very close to the annual mean discharge, within 90-98%. Even Q30 values for the perennial precipitation zone rivers are within 72-96% of the mean annual discharge. This implies that the perennial precipitation zone rivers transmit discharge that is very close to the annual mean discharge for most of the year, whereas rivers with high seasonal variability transmit discharge that may be as low as 10% of the annual mean for most of the year. This implies that although the perennial precipitation zone rivers experience floods, including floods of catastrophic proportions (e.g. on the Mississippi), the difference between their flood discharge and annual mean discharge is small, as compared to the monsoonal zone and subtropical rivers.

This highly peaked discharge pattern results in river morphodynamics that are distinct from perennial precipitation zone rivers. Sediment transport and deposition in such rivers occurs during transient seasonal events that exhibit high water discharge and Froude supercritical flow, resulting in dominant suspension transport mode even for sandy and gravely sediments. These morphodynamic processes produce distinct small and large scale bedforms, depositional lithologies and geometries, as well as minimize hysteresis and buffering effects due the increased advection lengths. Recognition of rivers with highly seasonal discharge thus provide new dependable proxies for interpreting paleo-precipitation regimes.