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Deciphering the anthropogenic Holocene floodplain sedimentation rate increases from natural bias

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Erosion and sedimentation processes are episodic in nature and the rates of these processes are subject to biases resulting from differing time scales over which they are measured [e.g. Sadler, 1981]. In order to ascribe observed rate changes to specific causes like human activities or climate change, one must first understand the natural, inherent time scale bias introduced when comparing long-term 'background' rates to modern rates. Although some processes producing these biases are well-known, they are considered mere noise superimposed on a larger signal and are often unappreciated. However, the effects of these biases on erosion and sedimentation rate measurements can be extreme such that recently observed rates appear to be $\sim$10 times higher than background rates even in a purely random experimental scenario of erosion and deposition.

Probabilistic models of sedimentation treat the thickness of a stratigraphic section such as those in floodplain cores as random sediment accumulations. In these models and in natural settings, thickness changes through time by the accumulation of independent increments of sedimentation or erosion separated by periods of inactivity. Such random models can be used to understand inherent time scale biases of sedimentation that occur even without any prescribed forcing factors. Here, we show that the standard method of determining floodplain sedimentation rates (i.e. radiocarbon dating material at a given depth below the surface) produce characteristic patterns of observed sedimentation rate over a given time period without any change in real sedimentation rate. In one case, randomly positioned sediment sources diffusing through a floodplain produce increased observed sedimentation rates in recent time [Pelletier and Turcotte, 1997]. The burial and re-exposure of stratigraphic horizons that decay with a characteristic half-life also produces increasing observed sedimentation rates toward recent time. This scenario may be analogous to woody organic material decomposing as it moves through a floodplain.

We compare the predictions from these models with empirical data from various large floodplains that are thought to be severely impacted by anthropogenic erosion. The compiled Holocene to modern floodplain sediment accumulation rates in four large river basins in the Central USA, China, Middle Europe and Eastern USA show the same increases in sedimentation toward the present despite great differences in settlement history and population densities through time. This similar behavior across a variety of geographic settings throughout the world is consistent with a common time scale bias specific to floodplain sedimentation processes. Although we can not rule out an entirely anthropogenic cause for the increase in recent sedimentation rates, various models that include random sedimentation with relatively small perturbations due to human land use explain this dataset equally well.

Pelletier, J.D., and Turcotte, D.L. 1997. Synthetic stratigraphy with a stochastic diffusion model of sedimentation. Journal of Sedimentary Research 67: 1060-1067.

Sadler, P.M. 1981. Sediment accumulation rates and the completeness of stratigraphic sections. Journal of Geology 89: 569-584.