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A Bayesian mixing model framework for quantifying temporal and spatial variation in source of sediment to lakes across hydrological gradients of floodplains

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Episodic flood events are critical for recharging water balance of floodplain lakes and maintaining their ecological integrity, yet are subject to alteration in frequency and magnitude by natural and anthropogenic processes that operate over a range of spatial and temporal scales. To evaluate roles of potential stressors, paleolimnological reconstructions are used to obtain insights into hydrological variability of dynamic floodplain lakes. However, spatial and temporal integration is often underdeveloped because different paleolimnological measurements must be applied across lakes due to the wide range of energy conditions that impart marked differences in sediment composition. Here, we use a linear discriminant analysis to identify 10 significant elemental concentrations in surveyed sediment from multiple sampling campaigns that distinguish the geochemical fingerprints of three end-member sources in lakes at the Peace-Athabasca Delta (PAD; Canada): the Athabasca River, the Peace River and local catchment runoff. Over 90% of the sediment samples were correctly classified into the original groups after cross-validation due to the distinctiveness of the three end members, which permits development of a robust Bayesian mixing model to discern the relative contributions of sediment from the three sources. We evaluate the mixing model at two adjacent lakes in the Athabasca sector of the PAD and demonstrate its effectiveness to discriminate three known hydrological phases during the past 300 years. Notably, the model infers ~60% of the sediment originated from the Peace River during the largest ice-jam flood event on record (1974), which was unrecognized by other methods. We then applied our model to sediment records from 18 lakes spanning the hydrological gradients across the 6000 km^2 PAD to further probe the hydrological evolution during the past ~150 years. Results demonstrate decline in frequency of flooding from both the Athabasca and Peace rivers and lake-level drawdown since the early 20th century and align remarkably well with prior interpretation of conventional paleohydrological records of individual lakes. We advocate our approach provides a universal method that can be applied across the full range of sediment composition to quantify change in source, frequency and magnitude of river floodwaters to lakes and is transferable to other dynamic floodplain landscapes where variation of sediment composition challenges efficacy of other approaches.