Discussion of “Frequency of ice-jam flooding of Peace-Athabasca Delta”

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We present an alternative analysis of the observational record of historical ice-jam floods in the lower Peace River presented in Beltaos (2018) and illustrate the need to examine the history of hydrological change in lakes of the Peace-Athabasca Delta (PAD) to identify causes of recently observed drying.

Beltaos (2018) uses an observational record of historical ice-jam floods in the lower Peace River, as compiled by Timoney (2009), to suggest that flood frequency changed in 1968, coincident with the start of hydroelectric regulation of the Peace River by the WAC Bennett Dam (British Columbia), and that this has contributed to drying of perched lakes in the Peace-Athabasca Delta (northern Alberta). On a graph that shows the cumulative frequency of occurrence of large ice-jam floods, Beltaos (2018) forces a quadratic equation through the ‘baseline interval’ (i.e., 1880–1967) before regulation and then develops a separate linear regression to characterize the post-dam interval (1971–2017; see figure 3 in Beltaos 2018). Beltaos (2018) postulates that the decrease in slope identifies that regulation of the Peace River is a contributing factor to drying of perched lakes in the delta.

We contend that Beltaos’ use of regression analysis on a time series of episodic ice-jam floods is problematic on many accounts. For example, assumptions of the statistical tests presented are violated because residuals are not independent (as shown in Beltaos (2018), figure 3, which demonstrates that non-flood years tend to follow non-flood years). But even if we excuse this, the use of quadratic regression as shown in figure 3 of Beltaos (2018) is flawed because it implicitly predicts that flood frequency increases over time, for which there is no physical basis nor does it align with independent, paleolimnological reconstructions of flood frequency and magnitude from oxbow lake sediment records in the delta that are proximal to the Peace River (Wolfe et al. 2006). Thus, it is misleading to construe an expectation of accelerating flood frequency during the post-regulation era. Furthermore, inflation of the effective sample size by counting every year as an observation for the purposes of regression analysis, as performed by Beltaos (2018) (i.e., cumulative floods for 1920 = 4, 1921 = 4, 1922 = 4, ..., 1931 = 4 are part of his regression so n = 88), results in excessive confidence in the estimated frequency of floods (and slope of the relation) between 12 major pre-regulation flood events over 88 years. We have attempted to account for some of these shortcomings by applying a more conservative linear regression model, which only includes observed floods as data points to characterize the baseline (i.e., 1880–1967) interval (Fig. 1a). This pre-regulation linear regression model also captures the post-1971 observational ice-jam flood frequency data, indicating that there is no significant decrease in flood frequency within the 95% prediction intervals.
is no statistical change in occurrence of large ice-jam floods after regulation of the Peace River by the WAC Bennett Dam (Fig. 1b).

Clearly, this dataset of historical ice-jam flood events on the lower Peace River does not explain the drying of lakes that is evident in the Peace-Athabasca Delta. We suspect that this is because the observational record of ice-jam flood frequency for the lower Peace River and its treatment is too simplistic. For example, the dataset assumes each flood possesses the same magnitude and each flood is inferred to have the same substantial effect on the water balance of perched lakes in the delta. In contrast, we have demonstrated from paleolimnological reconstructions that Peace River flood magnitude (and frequency) has been highly variable over time, extending in the past to several centuries (Wolfe et al. 2006, 2008). Based on long-term monitoring of lake water balance, water chemistry and paleohydrological records, we have also shown that the effects of a recent high-magnitude ice-jam flood event in 2014 were short-lived and largely inconsequential to the water balance of lakes in the delta beyond the flood year (Remmer et al. 2018).

To understand the drying of lakes that is occurring in the delta, one needs to examine the lakes in the delta, as we have done for nearly 20 years, and in particular their sediment records which integrate over time the complexity and interplay of hydrological processes that influence the delta. Ice-jam flood frequency on the lower Peace River is but one of several hydrological processes that regulate water balance of lakes in the delta (e.g., Prowse and Conly 2002; Wolfe et al. 2007). Of note, our paleolimnological investigations have not been dependent on “calibrations relating current conditions to current lake sediments (0.5 to 1 cm thick bed layer)” (Beltaos 2018, p. 73). Rather, interpretations of these informative records have been based on robust and mechanistic relations between well-established paleolimnological methods and measurement of hydrological and limnological conditions. In contrast to comments of Beltaos (2018), these records show remarkable agreement with observational records, including the aforementioned observational ice-jam flood frequency record for the lower Peace River (see figure 9 in Wolfe et al. 2006) despite recognized uncertainties in both sources of information (Prowse and Conly 2002; Wolfe et al. 2006).

Beltaos (2018) also counters conclusions that we have drawn from our studies that lake drying began several decades before the construction of the WAC Bennett Dam. Instead, he argues in favour of the apparent quadratic-inferred pre-1968 (i.e., pre-dam) increase in the observational ice-jam flood frequency record for the lower Peace River (see figure 9 in Wolfe et al. 2006) despite recognized uncertainties in both sources of information (Prowse and Conly 2002; Wolfe et al. 2006).

Beltaos (2018) also counters conclusions that we have drawn from our studies that lake drying began several decades before the construction of the WAC Bennett Dam. Instead, he argues in favour of the apparent quadratic-inferred pre-1968 (i.e., pre-dam) increase in the observational ice-jam flood frequency record for the lower Peace River. In contrast, we have presented abundant evidence to show that one must consider longer timescales to capture the extended period of drying that is occurring in the delta, and these data are not limited to paleolimnological evidence (reviewed in Wolfe et al. 2012). For example, historical maps of the central interior of the delta show a trend of long-term drying that began in the early 20th century as higher water levels of Lake Athabasca receded following the Little Ice Age (~1600-1900 CE) when the lake was as much as 2 m higher than present day (Fig. 2; Johnston et al. 2010; Sinnatamby et al. 2010). We have formerly shown that the paleolimnological record from lake PAD 9 aligns exceptionally well with this independent observational...
evidence of water-level change in the delta, as illustrated by the diatom stratigraphy which clearly captures the transition from open-drainage to closed-drainage hydrological conditions in the 1920s (Fig. 2). Lake-level drawdown has now resulted in near desiccation of PAD 9 (Fig. 2; also see Remmer et al. 2018), a culmination of nearly a century of emergence from the last extended high stand of Lake Athabasca (Wolfe et al. 2011). Notably, no inflection is coincident with the beginning of the post-1968 Peace River regulation era indicating, as in most other parts of the Peace-Athabasca Delta that we have investigated, that drying is overwhelmingly driven by local climate and long-term decline in discharge of eastward-flowing rivers draining the hydrographic apex of western North America (Wolfe et al. 2008, 2012).

These differing perspectives of hydrological change and its causes in the Peace-Athabasca Delta come at a critical juncture of stakeholder discourse. Already, the flawed analysis of figure 3 in Beltaos (2018) has been used in a widely publicized strategic environmental assessment report for Wood Buffalo National Park (IEC 2018) and, thus, has potential to mislead water resource managers and decision-makers who are currently developing an Action Plan for the Peace-Athabasca Delta to mitigate supposed effects of the WAC Bennett Dam. Rather, we urge water resource managers and decision-makers to recognize the need for sufficient temporal and spatial perspectives to fully appreciate and understand the drying that is currently enveloping much of the delta, as an informed foundation for the Action Plan.

References


