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Multi-year landscape-scale assessment of lakewater balances in the Slave River Delta, NWT, using water isotope tracers

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SUMMARY

We apply a coupled-isotope tracer model to quantify end-of-thaw-season (fall) lakewater balances in the Slave River Delta (SRD), Canada, during 2003–2005, which effectively differentiates the relative importance of hydrological processes across this complex northern freshwater landscape. The model incorporates Great Slave Lake evaporated vapour to the ambient atmospheric vapour pool and is thus tailored to the hydroclimatic setting of the delta, which experiences onshore winds. Results, expressed as evaporation-to-inflow ratios (E/I) for 41 delta lakes, reflect the role of spring break-up flooding and local hydrological setting. Fall E/I ratios for lakes where water balances are dominated by exchange with the Slave River or Great Slave Lake are low (0.06–0.53) and do not vary substantially during the three-year monitoring period. E/I ratios for flood-dominated lakes in the active delta are moderate (0.26–0.98) and have low inter-annual variability, even in the absence of spring flooding. This suggests that annual flooding during the spring break-up period is not necessary to maintain positive ($E/I < 1$) water balances in flood-dominated lakes, but multiple years without flooding would clearly lead to greater cumulative evaporation. Fall E/I ratios are generally higher and more variable in evaporation-dominated lakes in the relict delta (0.42 to >1), although greater snowmelt runoff tends to occur in sub-sectors with mature spruce forest and offsets open-water vapour loss. Our results indicate that spring inputs (river flooding and snowmelt runoff) are key components of the hydrological evolution of SRD lakes during the open-water season, and distinguish regions of the delta where expected declines in river discharge and climate warming will likely cause lake-level drawdown. Such findings have particular relevance for informed ecosystem management in the Peace-Athabasca-Slave watershed, where unprecedented industrial development is imposing substantial additional pressure on freshwater resources.

Introduction

Lakes, wetlands and other riparian freshwater ecosystems are ubiquitous in Canada's north. Freshwaters cover $\sim$350,000 km^2 in arctic and subarctic North America (Rouse et al., 1997), while wetlands are estimated to cover $\sim$3.5 million km^2 in the circumpolar Arctic (Huntington and Weller, 2005). These ecosystems provide a rich diversity of habitats, which support biota that have developed a wide range of adaptations for survival in sometimes-severe northern environments (Wrona et al., 2005). Northern freshwater ecosystems provide important permanent and migratory habitats for fish and wildlife populations, notably for migrating waterfowl (Townsend, 1984; Prowse and Conly, 2000; Huntington and Weller, 2005; Wrona et al., 2005). These populations are in turn of vital importance to northern indigenous populations (Rouse et al., 1997; Huntington and Weller, 2005; Wrona et al., 2005), who have been using these resources to support traditional lifestyles for millennia.

Recent studies have highlighted the potential consequences of climate change on lake levels in northern Canadian freshwater ecosystems. Smol and Douglas (2007) documented the disappearance of high Arctic ponds on Ellesmere Island that had existed for thousands of years, as a result of climate change. Emmerton et al. (2007) concluded that water storage in Mackenzie Delta lakes and channels is likely to decline, resulting in lower lake levels, as reductions in spring break-up flood stage and increases in open-water evaporation continue. In the Peace-Athabasca Delta, the combined effects of declining headwater snowpacks and glacial storage, decreased river discharge and changes in local climate are leading to drying in delta lakes (Wolfe et al., 2008a). These and other studies (e.g., Smith et al., 2005) provide compelling evidence that profound changes are occurring in the hydrology of northern freshwater ecosystems.

The Slave River Delta (SRD) is a key hydrological node at the terminus of the Peace-Athabasca-Slave river corridor, and is

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subject to multiple stressors, including flow regulation and water extraction, in addition to climate change. Hundreds of shallow lakes in the SRD are part of an important ecosystem that provides significant migratory, breeding and year-round habitats for birds and mammals (Townsend, 1984), upon which the residents of nearby Fort Resolution depend for both recreation and income (Wesche, 2007). Since the mid-1970s, declining snowpacks have been observed in key tributaries of the Peace River (Romolo et al., 2006), which provides ~66% of annual flow to the Slave River (English et al., 1997). Because melting of the winter snowpack is an important factor influencing spring river discharge, declining snowpacks will alter the hydrograph of both the Peace and Slave rivers during the spring break-up period (Prowse and Conly, 1998; see also Fig. 3 in Wolfe et al., 2008a). Flow regulation in the northern headwaters of the Peace River system by the WAC Bennett Dam, established in 1968, may also have affected the geomorphological and botanical evolution of the SRD (English et al., 1997), although paleolimnological studies do not indicate that flood frequency has declined over the past ~40 years (Brock et al., in review). Continued water diversion and extraction from the upstream Athabasca River to support the Alberta oil sands industry may threaten the ecological integrity of the SRD, as may potential hydroelectric development along the Slave River near Fort Smith, NWT (Fig. 1). Incomplete knowledge of the conse-

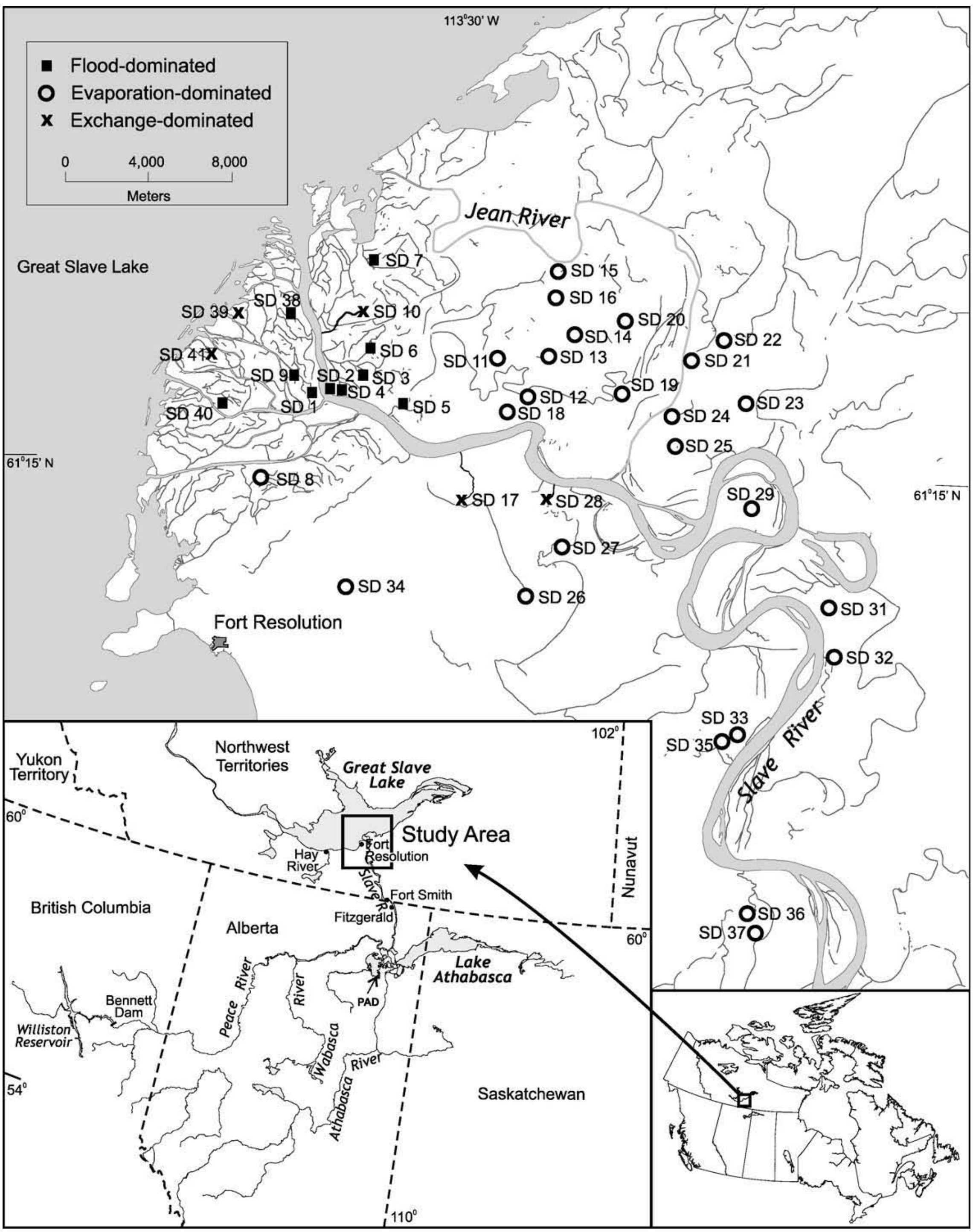

Fig. 1. Location of the Slave River Delta, NWT, including lake and river sampling sites.