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Late Holocene expansion of Siberian dwarf pine (*Pinus pumila*) in Kamchatka in response to increased snow cover as inferred from lacustrine oxygen-isotope records

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ABSTRACT

Holocene records of cellulose-inferred lake-water $\delta^{18}O$ were produced from two lake-sediment sequences obtained in central and northern Kamchatka, Russian Far East. The sediment records share similar fluctuations in $\delta^{18}O$ during the interval of ca. 5000–800 cal yr BP that correspond (inversely) with changes in K^+ content of the GISP2 ice-core record from Greenland, a proxy for the relative strength of the Siberian High, suggesting control by climate-related variability in $\delta^{18}O$ of regional precipitation. The dramatic expansion of Siberian dwarf pine (*Pinus pumila*) in northern and central Kamchatka between ca. 5000 and 4000 cal yr BP, as inferred from pollen records from the same and neighbouring sites, appears to have occurred at a time of progressively declining $\delta^{18}O$ of precipitation. This development is interpreted as reflecting a regional cooling trend accompanied by increasing winter snowfall related to gradual intensification of the Siberian High from ca. 5000 to ca. 3000 cal yr BP. A thicker and more long-lasting snow cover can be assumed to have favoured *P. pumila* by providing a competitive advantage over other boreal and subalpine tree and shrub species in the region during the later part of the Holocene. These results, which are the first of their kind from Kamchatka, provide novel insight into the Holocene vegetational and climatic development in easternmost Asia, as well as long-term atmospheric circulation dynamics in Beringia.

1. Introduction

Siberian dwarf pine, *Pinus pumila* (Pallas) Regel, is a very common coniferous shrub in easternmost Asia. On the Kamchatka Peninsula it presently occurs as a dominant species in the subalpine zone of the Sredinny and Eastern Mountain Ranges, covering approximately 80,000 km^2 (Krestov, 2003). In the northern parts of the peninsula and along the coastline further south, particularly in well-drained settings, it occurs down to sea level. Elsewhere, it occurs both as an understory component of birch and larch forests at low elevations, and more importantly, as a continuous shrub belt or scattered thickets at an altitudinal range of 700–1200 m a.s.l. in the slightly more continental climatic setting of the interior region, reaching maximum altitudes of approximately 1400 m a.s.l. (Khomentovsky, 2003). The abundance of *P. pumila* in Kamchatka is assumed to reflect the generally cool and maritime subarctic climate, which typically involves a thick and late-melting snow cover that favours the species by protecting its leaves and branches from desiccation and wind damage during the winter and spring seasons before the onset of photosynthesis (Okitsu and Ito, 1984, 1989). As demonstrated by pollen records from adjacent parts of western Beringia (Anderson et al., 2010; Lozhkin and Anderson, 2011), *P. pumila* is a key species for studies of past climate changes in the region, particularly precipitation amount and seasonality dynamics. Dirksen et al. (2013) recently published a review of Holocene vegetation dynamics in Kamchatka based on pollen data mainly from the Russian literature, and this issue provides several new

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