Geophysical Research Abstracts
Vol. 20, EGU2018-375, 2018
EGU General Assembly 2018

Reconstructing the evolution and environmental legacy of the last Eurasian ice sheet complex

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The Eurasian ice sheet complex (EISC) was the third largest ice mass during the Last Glacial Maximum, spanning >4,500 km from southwest Britain to northern Siberia and locking up around 20 m of eustatic sea-level equivalent. Recent empirical data and insights have significantly advanced our understanding of the chronology, pattern, and rates of retreat in most sectors of this vast ice complex, yet model-based reconstructions have remained conspicuously absent. Through use of a first-order, thermomechanical ice sheet model, validated using independent glacio-isostatic modelling and a diverse suite of empirical constraints, we demonstrate the 3-D asynchronous evolution of the EISC during the last 37,000 years, reflecting contrasting regional sensitivities to climate forcing, oceanic influence, and internal dynamics.

Most rapid retreat of the EISC was experienced across the Barents Sea sector after 17.8 ka BP when this marine-based ice sheet disintegrated at a rate of ∼670 gigatonnes per year (Gt a^{-1}) through enhanced calving and interior dynamic thinning, driven by oceanic/atmospheric warming and exacerbated by eustatic sea-level rise. From 14.9 to 12.9 ka BP the EISC lost on average 750 Gt a^{-1}, peaking at rates >3000 Gt a^{-1}, roughly partitioned equally between surface melt and dynamic losses, and potentially contributing up to 2.5 m of global sea-level rise during Meltwater Pulse 1A (14.65 - 14.31 ka BP).

The complex environmental legacy of the EISC can be examined effectively with respect to a range of geosystems using model outputs that account for the evolving relative sea level, patterns of climate forcing, and ice sheet properties. Here, we focus on the impact the evolving EISC had on the subglacial and proglacial hydrological networks. Simulation of the hydrological landscape across the Eurasian domain reveals potential for up to 4,000 subglacial lake locations during the Last Glacial Maximum, with >70% having a surface area of <10 km2. Observed drainage switching and water piracy in response to subtle changes in ice surface configurations – activity that is similarly detected in Antarctica today - holds potential implications for the stability of palaeo-ice stream flow, particularly in the Baltic and Barents seas.

Changes in the subglacial hydrological environment were overshadowed by the amalgamation of mega proglacial river catchments across the Eurasian continent, which consolidated freshwater and sediment discharge through relatively narrow gateways into the Atlantic and Arctic oceans. The growth of large glacial lakes dammed by ice margins in the North, Baltic, White, Pechora and Kara seas further contributed to large-scale modifications of the palaeo landscape, and potentially even ocean circulation patterns during their abrupt drainage when ice retreated.