



Mountain glacier fluctuations in Norway: evidence for a climatically unstable early Holocene, contracted mid-Holocene glaciers and multiple Neoglacial events

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During the early Holocene, abrupt decadal to centennial-scale climate variations caused significant glacier variations in Norway. The studied Norwegian glaciers melted away at least once during the early-/mid-Holocene. The period with the most contracted glaciers was between 6500 and 6000 cal. yr BP. Subsequent to ~6000 cal. yr BP the glaciers started to advance and the periods with the most extensive glaciers were at ~5600, 4500, 3300, 2300, 1600 cal. yr BP, and during the 'Little Ice Age'. Periods with overall less glacier activity were apparently around 5000, 4000, 3000, 2000, and 1300 cal. yr BP. Most Norwegian glaciers attained their maximum 'Little Ice Age' extent during the mid 18th century. Cumulative glacier length variations in southern Norway, based on marginal moraines dated by lichenometry and historic evidence, show an overall retreat from the mid-18th century until the 1930s-40s. Maritime outlet glaciers with short response time (<10-15 years) started to advance in the mid-1950s, whereas long outlet glaciers with longer frontal time lag (>15-20 years) continued their retreat to the 1970s and 1980s. However, in the 1990s maritime glaciers started to advance as a response to higher winter accumulation. After 2000 several of the observed glaciers have retreated remarkably fast (annual frontal retreat >100 m) mainly as a response to high summer temperatures. The general glacier retreat during the early Holocene and the Neoglacial advances after 6000 cal. yr BP are in line with orbital

forcing, due to decrease of Northern Hemisphere summer solar insolation and increase in winter insolation. In addition, regional weather modes, such as the North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO), play a significant role with respect to decadal and multi-decadal climate variability.