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Multi-decadal retreat of Novaya Zemlya outlet glaciers, in response to climatic forcing

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Arctic ice masses have rapidly lost ice from the mid-1990s, through a combination of negative surface mass balance and accelerated ice discharge from marine-terminating outlet glaciers. In the past decade, substantial mass deficits have been identified on Novaya Zemlya (NVZ), Russian High Arctic, and its outlet glaciers have retreated dramatically, likely due to declining sea ice concentrations. However, little is known about longer-term glacier behaviour on NVZ, and its potential impact on overall mass balance. Here we greatly extend the available record of retreat and assess multi-decadal glacier response to forcing between 1976 and 2014 using remotely sensed data. Following at least 25 years of gradual recession, retreat rates accelerated substantially from circa. 2000 and again from 2011 onwards. The rate and temporal pattern of retreat were strongly dependant on terminus type: marine-terminating outlets receded an order of magnitude faster than land- or lagoon-terminating glaciers and land-based termini showed limited change in retreat rate over time. Furthermore, retreat was markedly higher on the Barents Sea coast than the Kara Sea. Comparison with forcing data shows that accelerated retreat from 2011 onwards coincided with exceptionally low sea ice concentration and duration between 2011 and 2013. This suggests that sea ice is an important controlling factor, which agrees with shorter-term studies on NVZ. Although air temperature information is more limited on NVZ, data from both meteorological stations and reanalysis highlight 2011 and 2012 as two of the warmest years during the period 1950 to 2014. The limited response of land-terminating outlets suggests that air temperatures do not cause retreat directly, via melting or enhanced basal lubrication, but may have an indirect influence through melting of sea ice or hydro fracture.