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Research papers

A 100-year record of changes in water renewal rate in Sermilik fjord and its influence on calving of Helheim glacier, southeast Greenland

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ABSTRACT

Here we present a 100 year long proxy record for the renewal rate of the subsurface ocean waters in Sermilik Fjord at the edge of Helheim Glacier, based on investigations of two sediment cores (ER11-24 and ER11-25) obtained from the head of the fjord. By calculating the mean sortable silt ($\overline{SS}$) in current-sorted melt water plume sediments we find that episodes of increased water renewal rates lasting 3–5 years coincide with a positive North Atlantic Oscillation (NAO) index. This is not surprising as low pressure systems and northeasterly storms are observed more frequently along the east coast of Greenland during positive NAO years as a result of the northward shift in the North Atlantic storm track. Previous studies of sediment cores obtained from the mid-region of the fjord showed that Helheim Glacier destabilization coincides with a negative NAO index. Therefore we conclude that inter-annual variability in storm-induced flushing of Sermilik Fjord and thus the water renewal rate towards the glacier margin is not the controlling factor for inter-annual variability in Helheim Glacier destabilization. Such knowledge may have implications on predictive model studies of ice-ocean interactions and glacier behavior.

1. Introduction

In the early part of the 21st century, the Greenland Ice Sheet (GrIS) experienced a marked increase in net mass loss (Rignot and Kanagaratnam, 2006; Van den Broeke et al., (2009)), intensifying the debate concerning the extent to which future glacier retreat will affect global sea level rise. Outlet glaciers have thinned, accelerated and retreated in both southeast Greenland (Howat et al., 2007; Moon and Joughin, 2008; Stearns and Hamilton, 2007; Luckman et al., 2006, Rignot and Kanagaratnam, 2006) and west Greenland (Thomas et al., 2003). Holland et al. (2008) suggested that thinning, retreat and the doubling of flow velocities of the Jakobshavn Isbræ in West Greenland was linked to a pulse of warm waters in the West Greenland Current (WGC) entering Disko Bay in 1997 (Fig. 1). Similarly, it was hypothesized that the extensive glacier retreat in Southeast Greenland was linked to warming of Atlantic subsurface waters here (Straneo et al., 2010, Nick et al., 2009). This warming was associated with an increase in the volume of Atlantic Waters in the subpolar gyre of the North Atlantic and on the nearby Greenland continental shelves (see review by Straneo and Heimbach, 2013). Once on the shelves, these warm waters flow towards the fjords, and glaciers that terminate at their heads, through deep troughs. A warming and/or thickening of these Atlantic waters can give rise to increased submarine melting of the glacier fronts and/or their buttressing melanges and thereby increase iceberg calving rates and mass loss (Rignot et al., 2010; Vieli and Nick 2011). The exact mechanisms involved in ocean-forced destabilization of outlet glaciers are still not well understood. The heat content of the water masses coming into contact with the glacier margins likely plays an important role, as well as the replenishment of this water, i.e. the renewal

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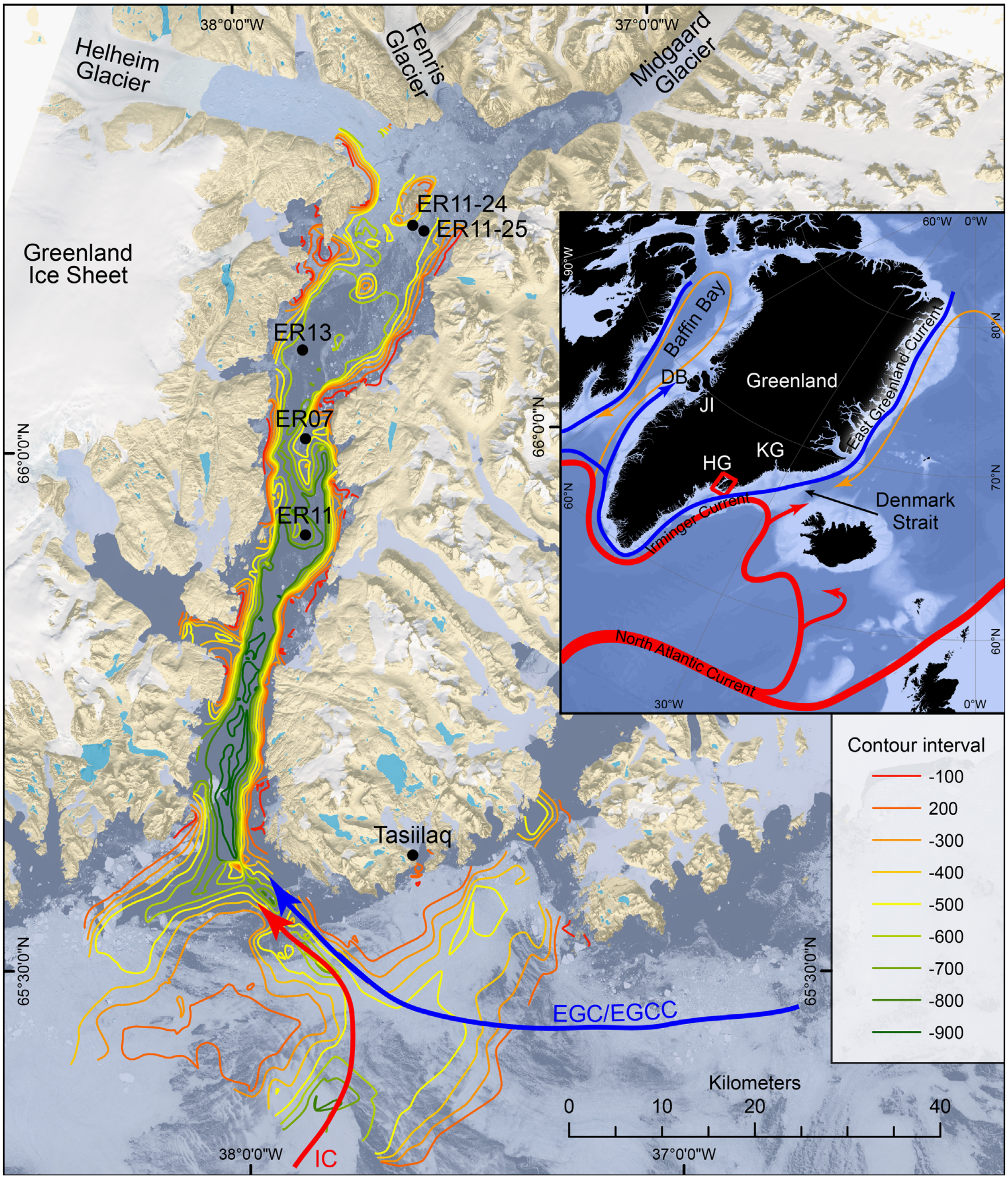

Fig. 1. A. Main currents in the North Atlantic Ocean (Straneo et al., 2012) and location of Helheim Glacier (HG), Kangerdluqssuaq Glacier (KG), Disko Bay (DB), Jakobshavn Isbrae (JI). B. Helheim Glacier and Sermilik Fjord with position of core ER11-24 and ER11-25 presented here as well as ER13, ER07 and ER11 presented in Andresen et al. (2012) (bathymetry from Schjøth et al., 2012). The pathways of the EGC/EGCC system and the IC are also shown (Straneo et al., 2010).

rate of the fjord waters, through shelf/fjord exchange (Straneo and Heimbach 2013). The forces and mechanisms regulating the circulation inside the fjords are not well understood. However one proposed hypothesis is that the renewal is controlled by the buoyancy-driven circulation due to the freshwater discharge by the glacier from submarine melt and subglacial discharge (the release of surface melt at the base of the glacier). This builds on findings from Alaskan fjords (Motyka et al., 2003) which are often associated with shallow sills which strongly constrain the fjord/shelf exchange. For fjords which have deep sills (hundreds of meters) or no sills, however, recent studies have found that the fjord/shelf exchange is more likely due to shelf-driven exchange flows (intermediary flows) as a result of property changes occurring on the shelf (Straneo et al. 2010). Direct evidence that this is the case, during the September to May period when subglacial discharge is at a minimum, has been found in moored records from Sermilik and Kangerdlugssuaq fjords (Jackson et al., 2014). These flows lead to the renewal of fjord waters on sub-seasonal timescales and thus are instrumental in maintaining supply of warm waters at the edge of the glaciers.

Evidence that changes in the renewal rate may have affected the fjords or the glaciers is lacking, however, largely due to the limited number of fjord surveys prior to 2008 (cf. Straneo et al., 2010; Murray et al., 2010). An assessment of this link would require long-term records of both glacier and ocean behavior. Recently, studies on sediment cores collected in Sermilik Fjord, where Helheim Glacier discharges, have extended the glacier and ocean observations 100 years back in time and documented a