Disruption of the sedimentary environment in Greenland fjords due to enhanced cryosphere melting caused by > 2°C climate warming

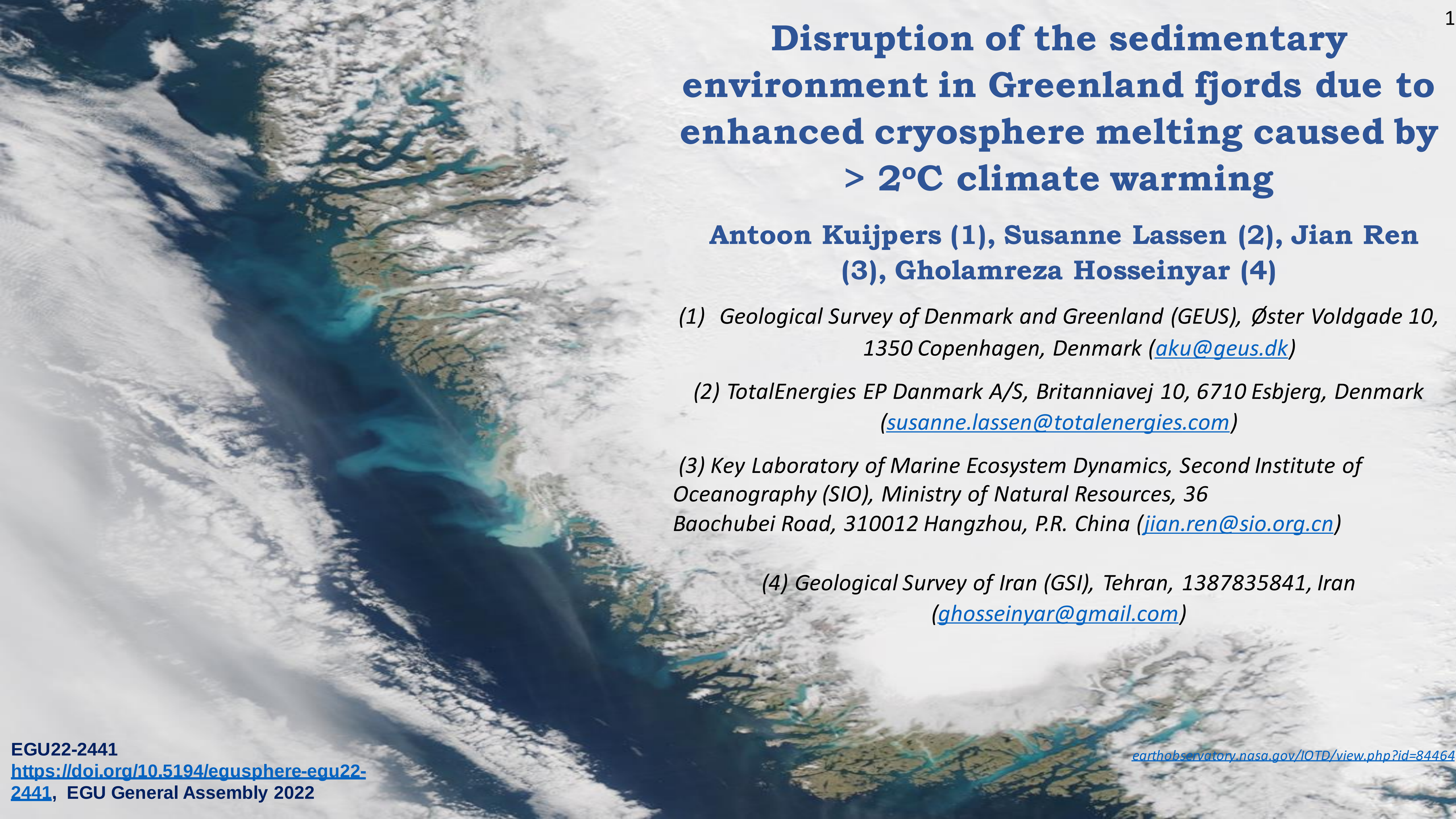
Antoon Kuijpers (1), Susanne Lassen (2), Jian Ren (3), Gholamreza Hosseinyar (4)

(1) Geological Survey of Denmark and Greenland (GEUS), Øster Voldgade 10, 1350 Copenhagen, Denmark (aku@geus.dk)

(2) TotalEnergies EP Danmark A/S, Britanniavej 10, 6710 Esbjerg, Denmark (susanne.lassen@totalenergies.com)

(3) Key Laboratory of Marine Ecosystem Dynamics, Second Institute of Oceanography (SIO), Ministry of Natural Resources, 36 Baochubei Road, 310012 Hangzhou, P.R. China (jian.ren@sio.org.cn)

(4) Geological Survey of Iran (GSI), Tehran, 1387835841, Iran (ghosseinyar@gmail.com)



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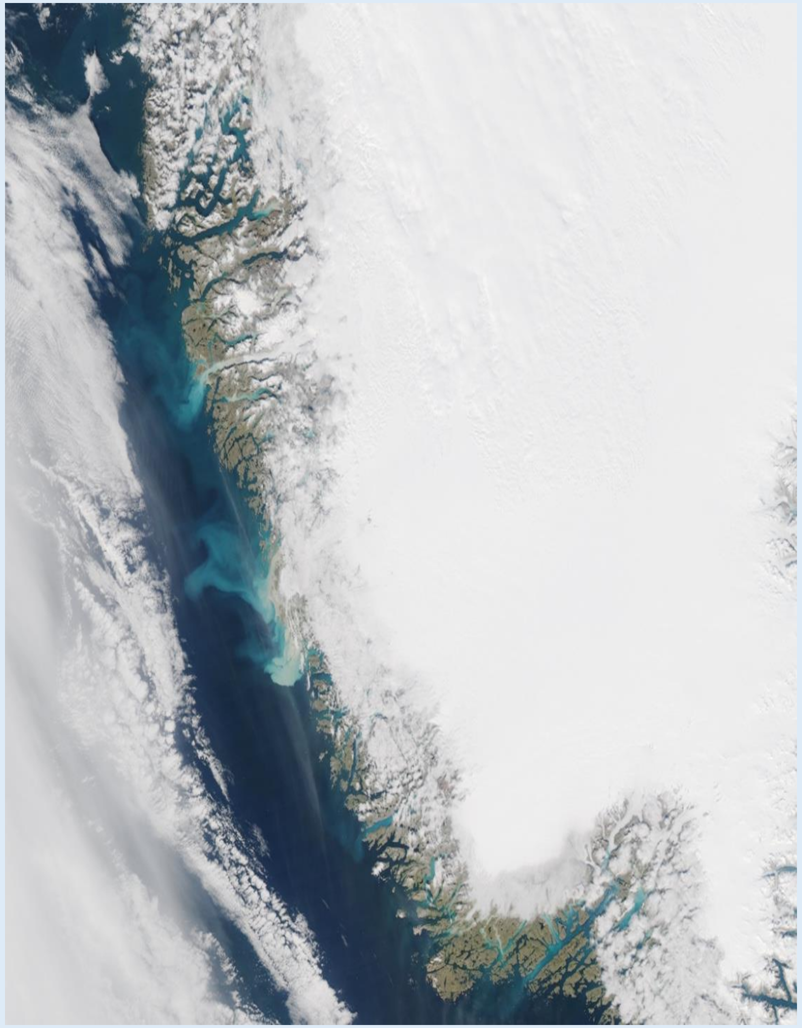
Suspended Sediment in Melt Water – Hyperpycnal Flow



Satellite view of large melt water plumes exiting from the western Greenland Ice Sheet, September 2012

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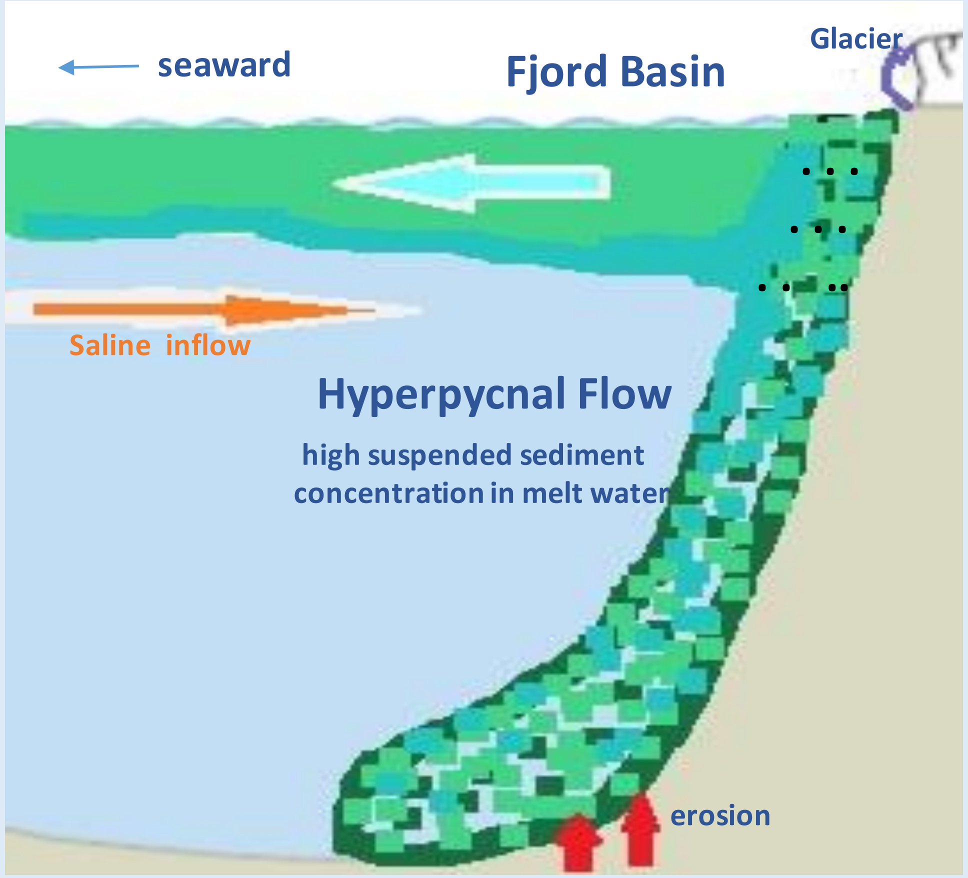
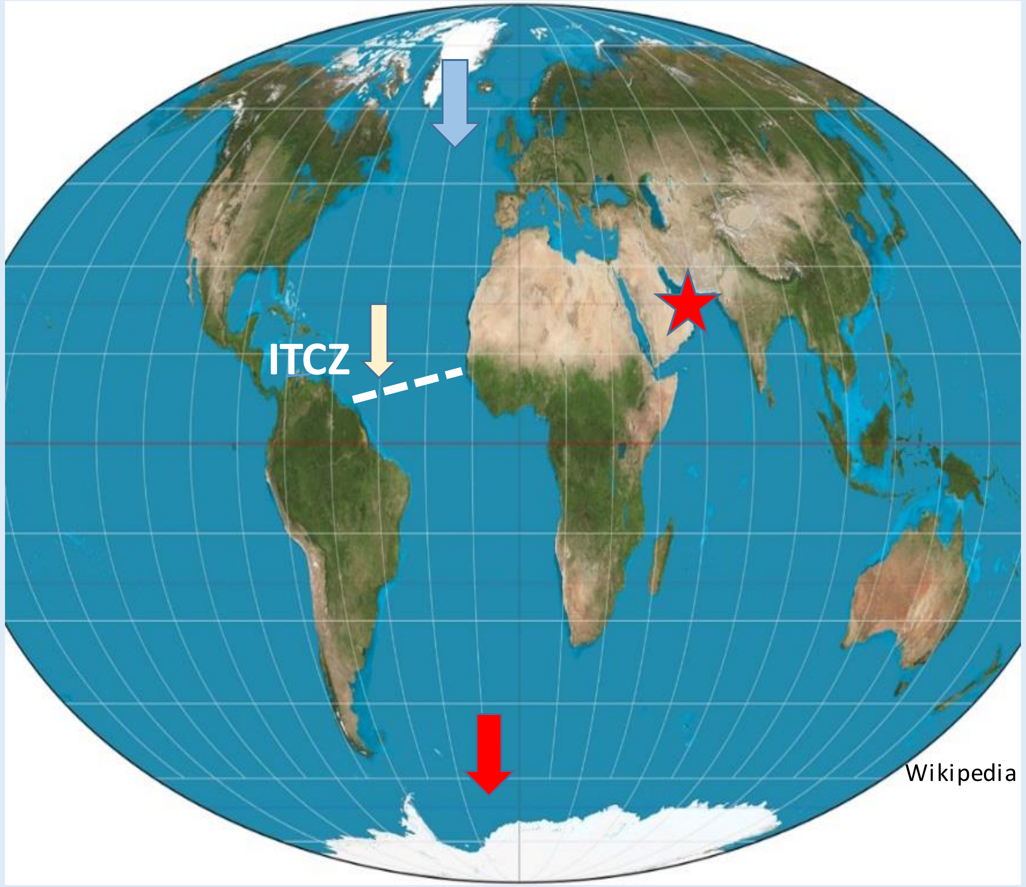
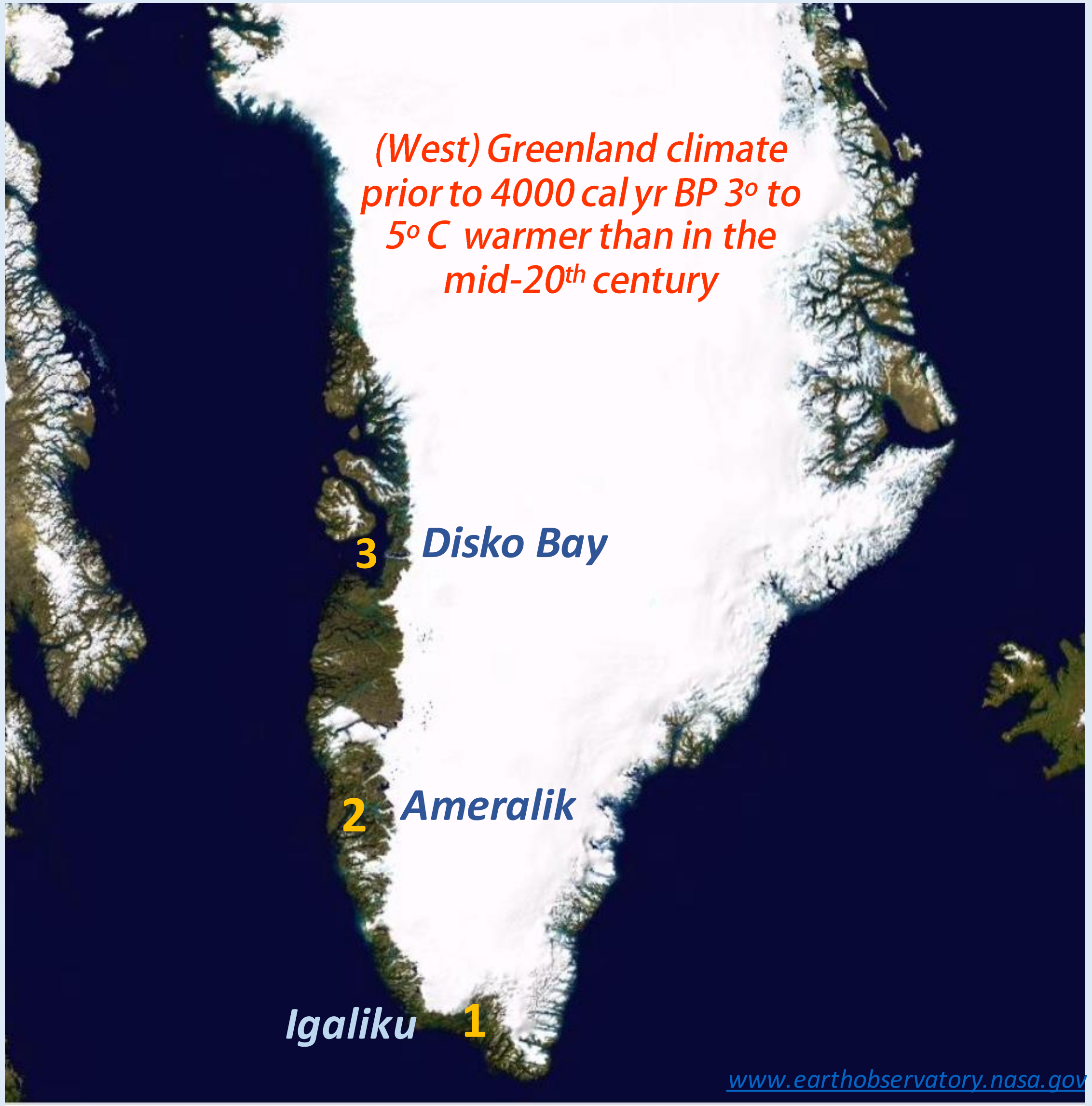


The Greenland Ice Sheet produces 8% of modern fluvial export of suspended sediment to the global ocean. This contribution may significantly increase under strong climate warming (Overeem et al. 2017). During rapid deglacial warming melt water from the North-American Laurentide Ice Sheet is concluded to have partly been released through hyperpycnal flow (Roche et al.2007; Kuijpers & Van der Klugt 2018). High suspended sediment concentrations in snow melt water have recently been observed to trigger hyperpycnal flow replacing bottom water in an Canadian Arctic lake (Lewis et al. 2018). Muddy hyperpycnal flows can erode basin bottom sediments (Zavala 2020).

Greenland Mid-to-Late Holocene Climate in a Global Perspective

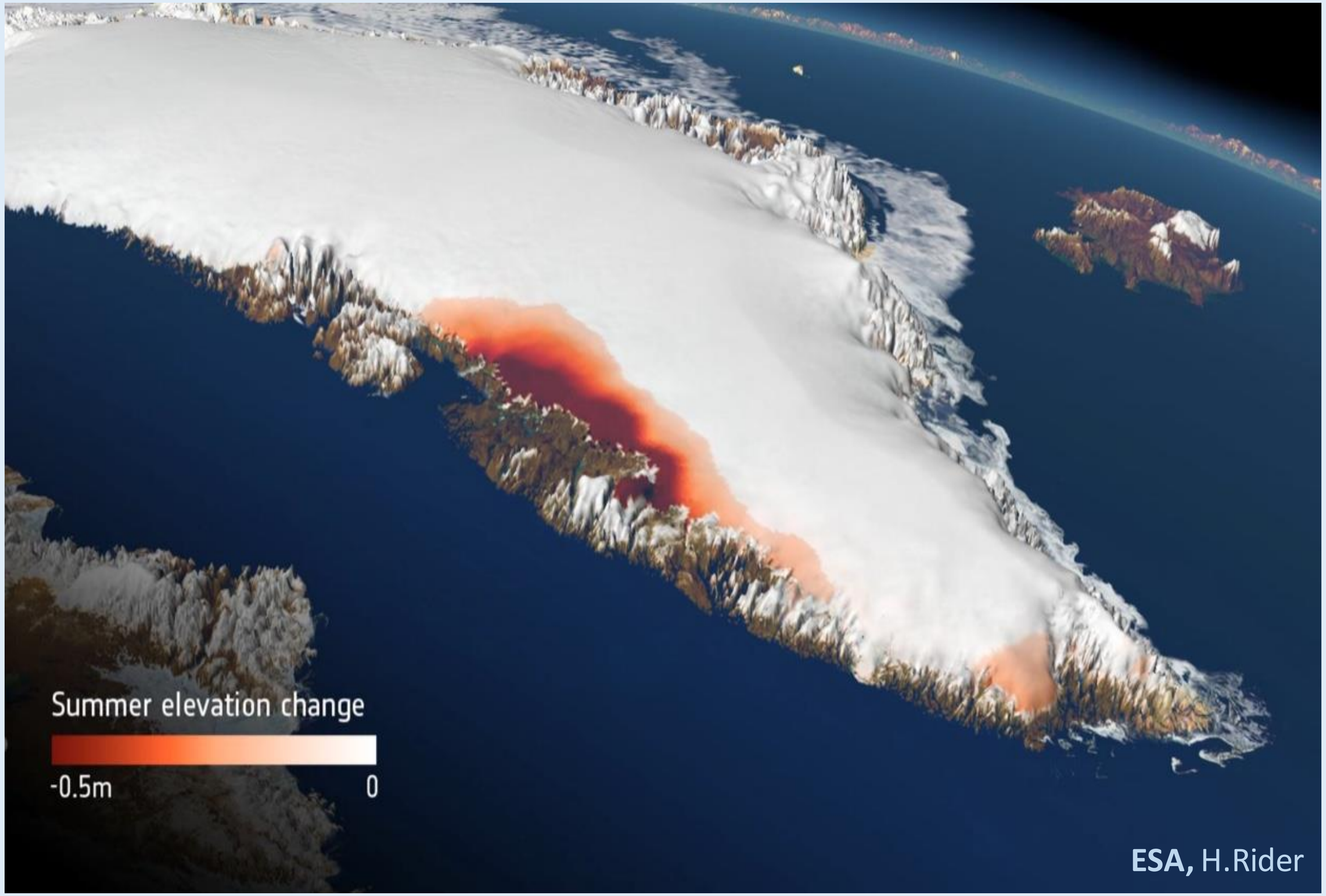


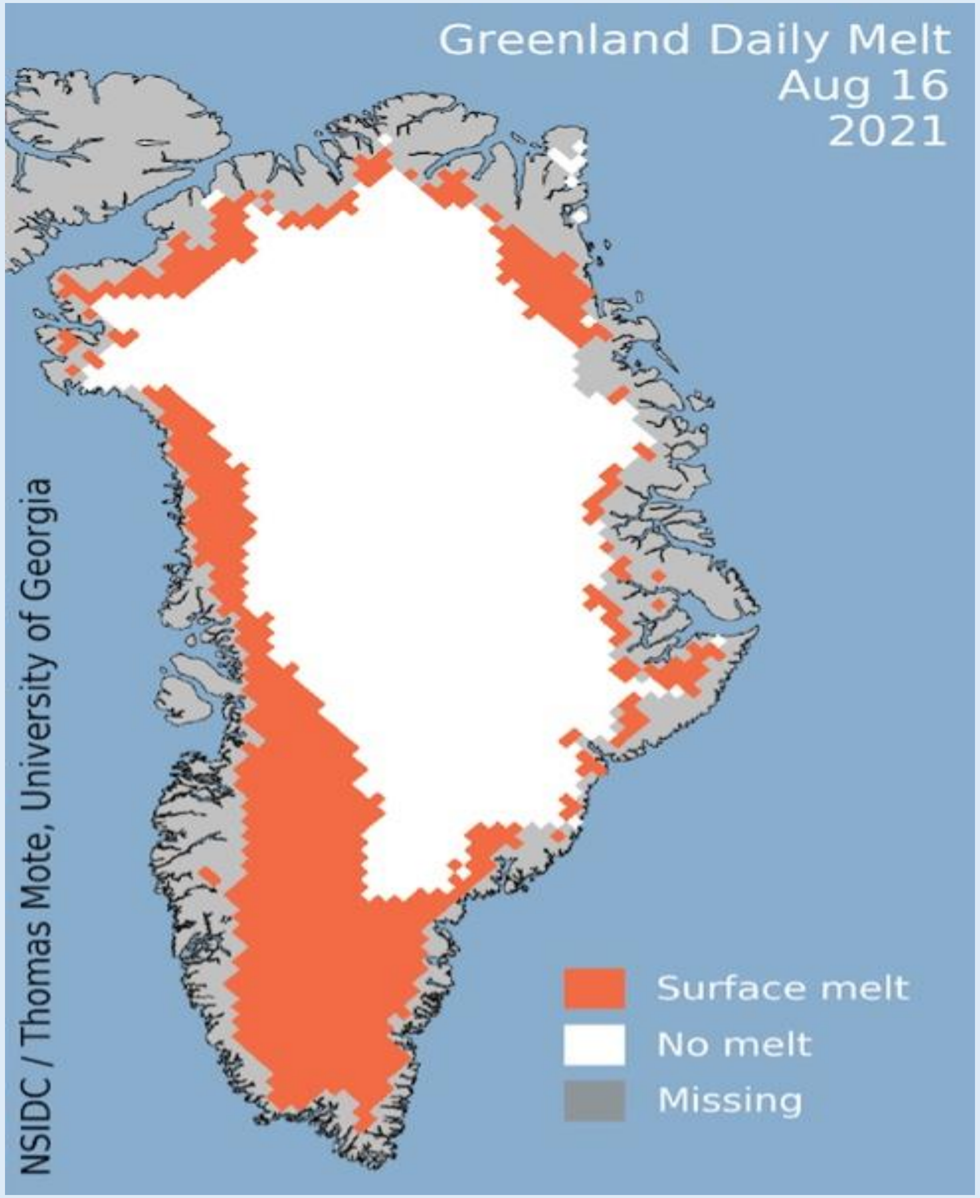
During the late 'Holocene Thermal Maximum' (HTM) prior to ca 4000 cal yr BP climate in Greenland (Axford et al.2020, Levy et al.2018), Canada, and Svalbard was markedly warmer than today. During this period sea level in the far-field region of the Indian Ocean (asterix) reached a maximum highstand at about 6000 and 4300 cal yr BP (Hosseinyar et al. 2021). While after 4000 cal yr BP climate cooling occurred in the North, the Southern Ocean was warming (Nielsen et al.2004, Peck et al. 2015) and the Intertropical Convergence Zone (ITCZ) moved southward (Fischel et al.2017). Broken white line indicates modern, annually averaged mean position of the ITCZ in the Atlantic



Overview of Greenland showing the location of the Igaliku (1) and Ameralik (2) fjord from where sediment core records are presented. In addition the geographic setting of Disko Bay (3) is indicated, from where a sub-bottom profiler record is shown (Slide 6).

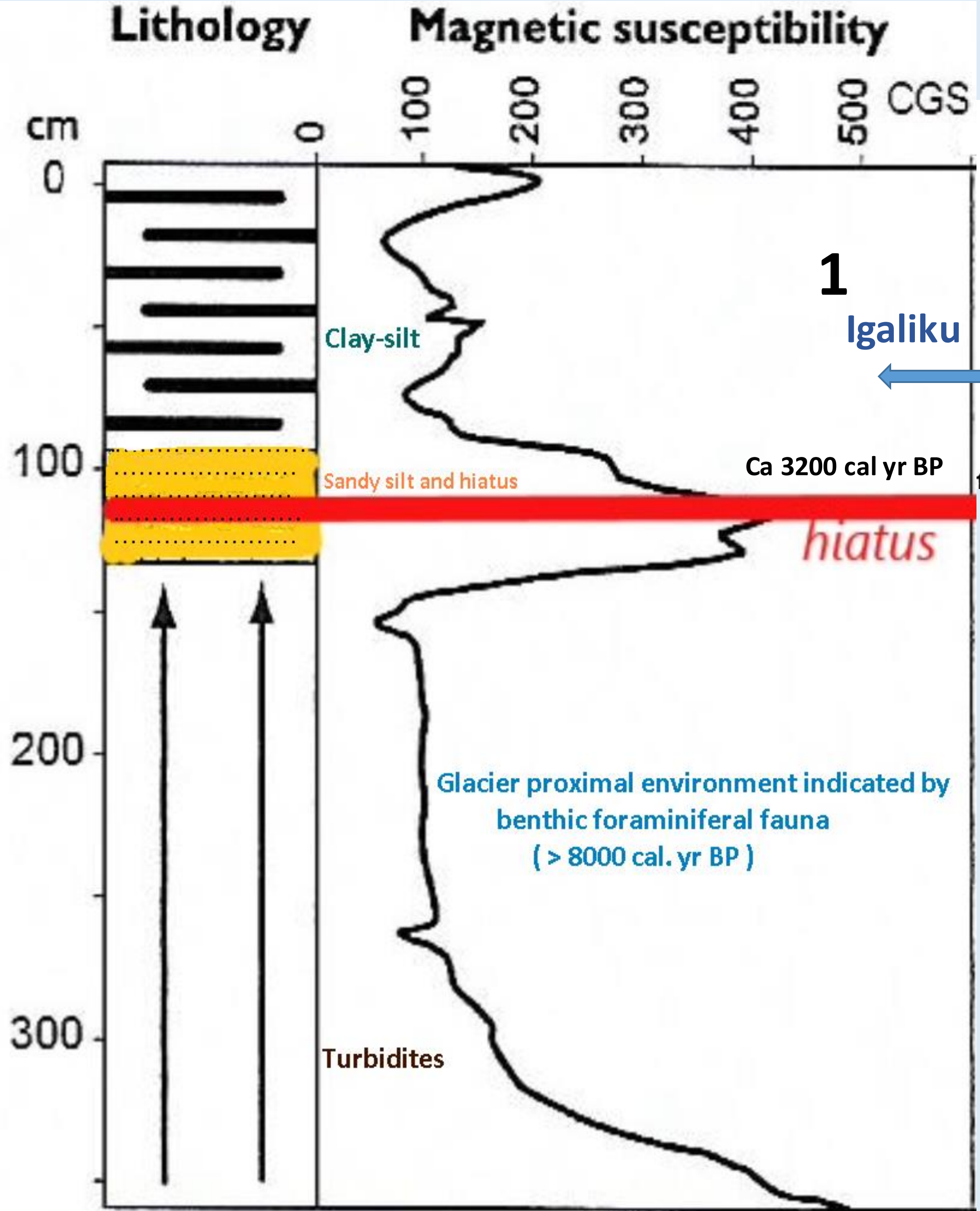
Recent Greenland Ice Sheet Melting, 2020 and 2021

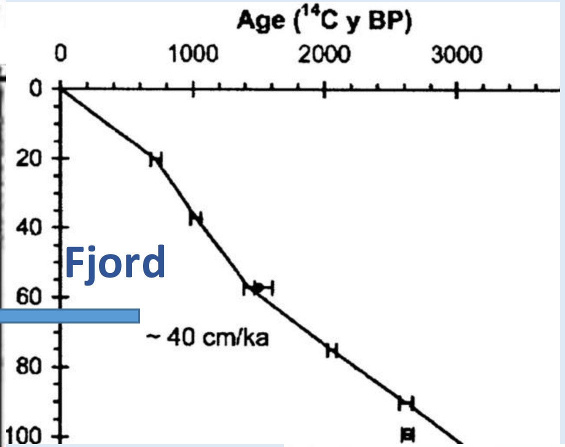




Greenland Ice Sheet melting in 2020 (European Space Agency) and 2021 (NSIDC) was particular prominent in the southern and western region of Greenland where the sites of our fjord sediment records are located

Sediment Hiatus in Greenland Fjords during the late HTM





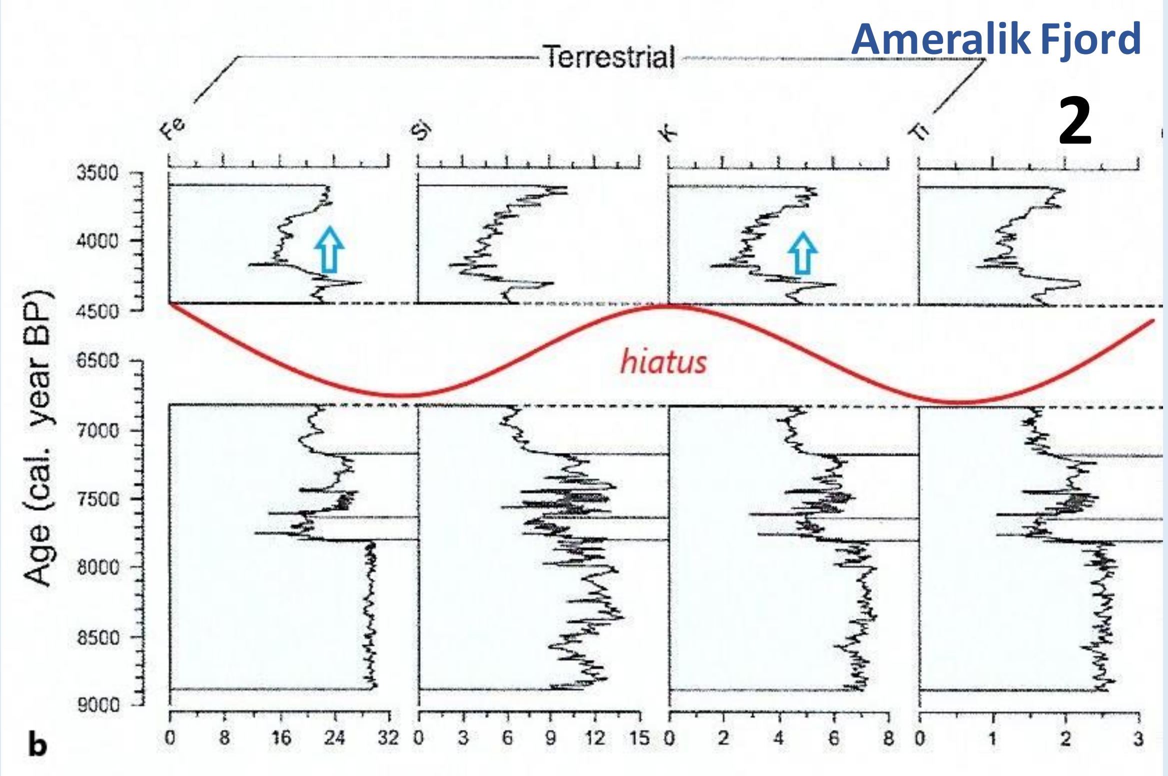
1

Igaliku Fjord

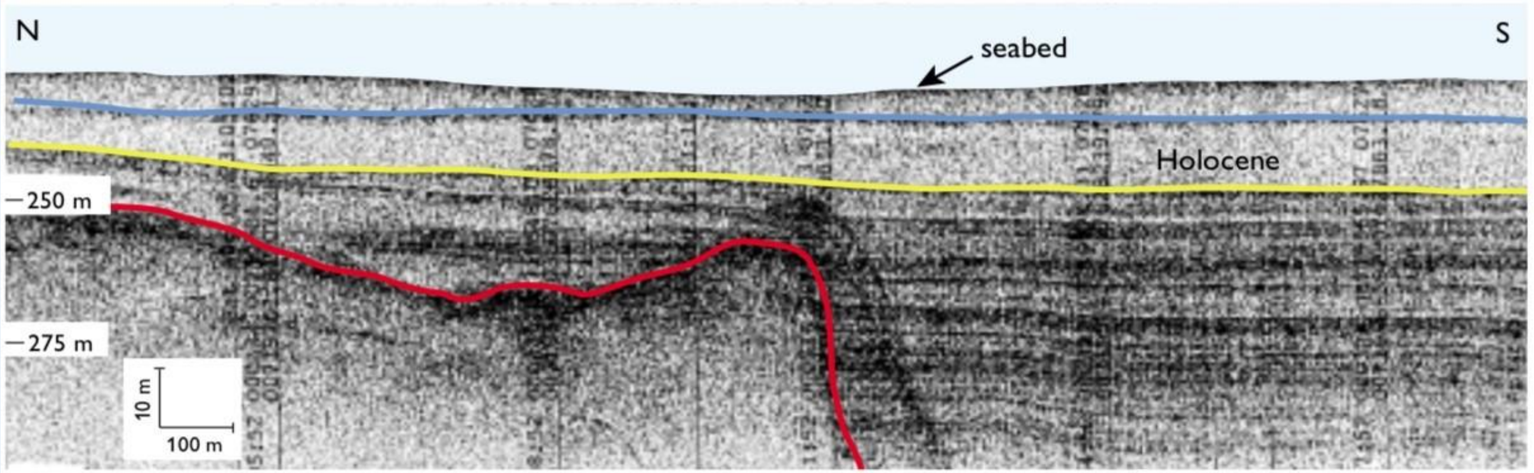
<u>Fig. 1</u>. Lithology (Kuijpers et al.1999), environmental information and chronology (Lassen et al. 2004) of gravity core PO245-451 from Igaliku fjord (water depth 304 m) .
<u>Fig. 2</u>. Multi-element XRF record of piston-core DA04-41P (Ren et al.2009) from Ameralik (water depth 744 m). Both records display a large mid-Holocene hiatus. Another sediment core from shallower depth in Ameralik (Møller et al.2006) shows massive melt water silt deposition, similarly as in Igaliku fjord terminating at ca 3200 cal yr BP .

Ameralik Fjord

2



Late HTM Melt Water Surge in Disko Bay ?



Sub-bottom record from southeastern Disko Bay (Kuijpers et al.2001) showing an upper transparent, holocene unit with one single (blue) reflector. This unit covers the time-span from deglaciation of eastern Disko Bay at ca 9000 cal yr BP until present. Rapid sedimentation from widespread melt water plumes prevailed until 6000 cal yr BP (Perner et al. 2013). The blue reflector is therefore tentatively estimated to have an age between 4000 and 5000 cal yr BP. Although so far its origin has not been resolved by coring, an exceptional , late HTM melt water outburst may have been responsible, which is supported by a prominent IRD sand peak in the adjacent fjord dated close to 4000 cal yr BP (Lloyd et al. 2007).

Conclusions

As coastal deposits lack evidence of mid-holocene earthquake-induced tsunami activity, this potential trigger mechanism may be excluded. Instead, we conclude that widespread glacier melting under a much warmer climate must have led to repeated (sub)glacial meltwater outburst surges producing high-energy, hyperpycnal flow processes in the fjords. Sea level high-stand data from far-field regions around the Indian Ocean suggest a late, prominent melting episode near 4300 cal yr BP. Higher temperatures and increased precipitation presumably also favored widespread onshore permafrost thawing, further contributing to heavy loads of suspended sediment in glacial melt water. The sedimentary record from both fjords indicates a significant decrease of melt water flow after ca 3200 cal yr BP. Hyperpycnal flow processes related to excessive melting during the late HTM led to severe disruption of the fjord sedimentary environment. In support of studies by Overeem et al (2017), these processes may further intensify under ongoing global warming, with major hazardous effects on the benthic environment of glacial fjords.

References

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