SWEDISH POLAR RESEARCH SECRETARIAT
POLARFORSKNINGSSEKRETARIATET

Research Theme resulting from the Polar Research Process:

North Greenland Earth-Ocean-Ecosystem Observatory

GEOEO

Builds on the legacy of Petermann 2015 and Ryder 2019 expeditions

Presented by
Martin Jakobsson
Nina Kirchner

GEOEO GoNorth

North of Greenland Expedition 2024

Naturhistoriska riksmuseet

Bolin Centre for Climate Research

Stockholm University

University of Gothenburg

KTH Vetenskap och Konst

University of New Hampshire

USGS science for a changing world

Geological Survey of Denmark and Greenland

GEUS

UiO : University of Oslo

UCI University of California, Irvine

AARHUS UNIVERSITY

UiT THE ARCTIC UNIVERSITY OF NORWAY

UNIVERSITY OF BERGEN

UNIS The University Centre in Svalbard

Love Dalén, Centre for Palaeogenetics & the Swedish Museum of Natural History

Anders Götherström, Centre for Palaeogenetics & Stockholm University

Volker Brüchert/Helen Coxall/Agatha De Boer/Martin Jakobsson/Magnus Mörth/ Matt O'Regan/Christian Stranne, Geological Sciences, Stockholm University

Örjan Gustafsson, Department Environmental Sciences, Stockholm University

Christoph Humborg, The Baltic Sea Centre, Stockholm University

Johan Nilsson, Department of Meteorology, Stockholm University

Nina Kirchner/Björn Gunnarsson, Depart of Physical Geography, Stockholm University

Hans Linderholm, Department of Earth Sciences, University of Gothenburg

Adam Ulsbo, Department of Marine Sciences, University of Gothenburg

Jakob Kuttenkeuler, Centre of Naval architecture, KTH Royal Institute of Technology

Larry Mayer, Center for Coastal and Ocean Mapping, University of New Hampshire

Tom Cronin, US Geological Survey

John Hopper/Thomas Funck/Paul Knutz, Geological Survey of Denmark and Greenland

Clinton Conrad/Carmen Gaina, Department of Geosciences, University of Oslo

Mathieu Morlighem, Department of Earth System Science, University of California Irvine

Christof Pearce, Aarhus University, Denmark

Peter Heintzman/Matthias Forwick, Department of Geosciences, UiT The Arctic University of Norway.

Riko Noormets, The University Centre in Svalbard (UNIS), Svalbard

GoNorth representatives: Jan Inge Faleide, Department of Geosciences, Univ. of Oslo; Hanne Sagen, Nansen Env. and Remote Sensing Center, Bergen; Jan Sverre Laberg, Department of Geosciences, UiT The Arctic University of Norway

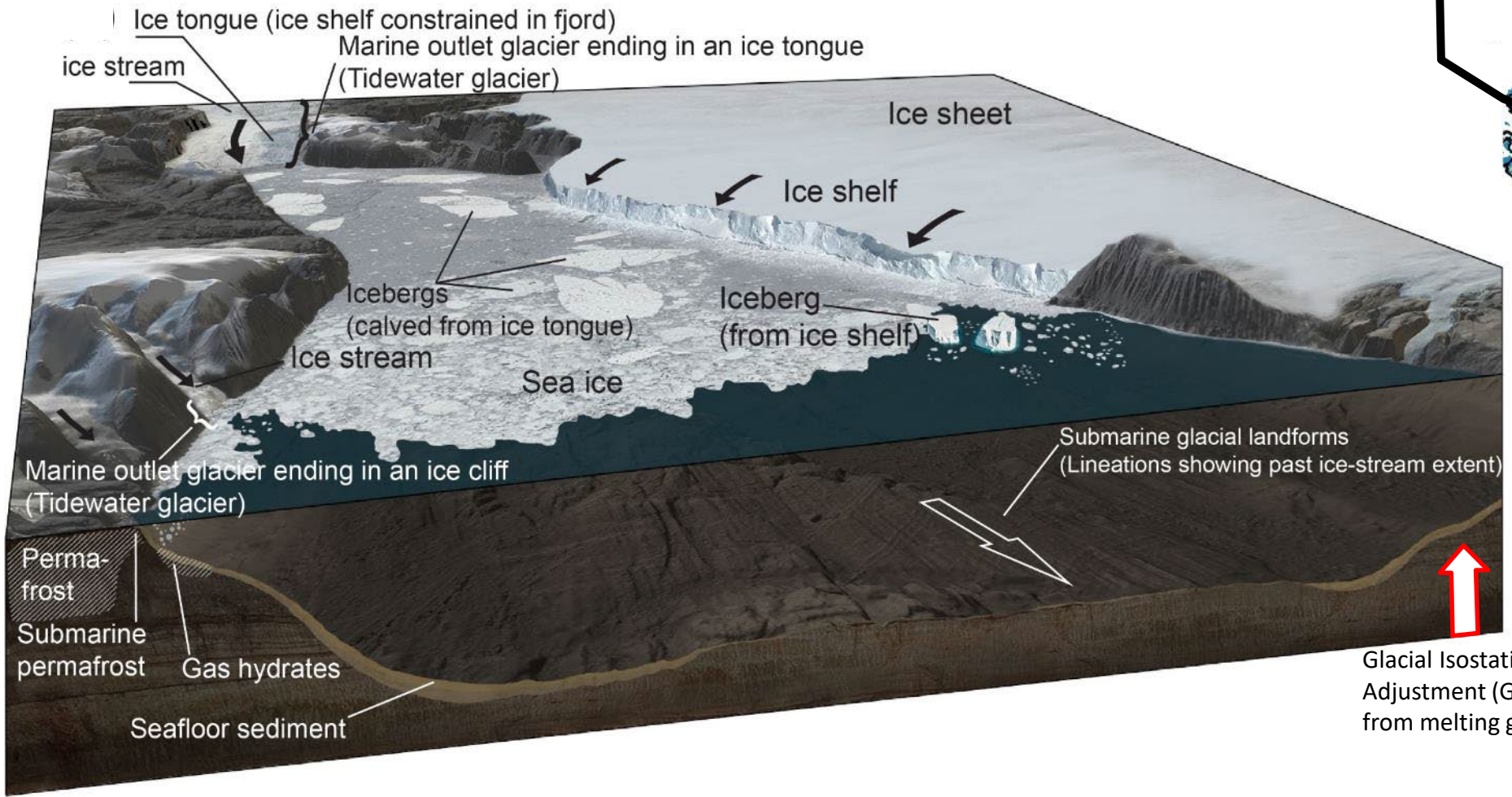
Addition interests expressed in North Greenland from theme proposals:

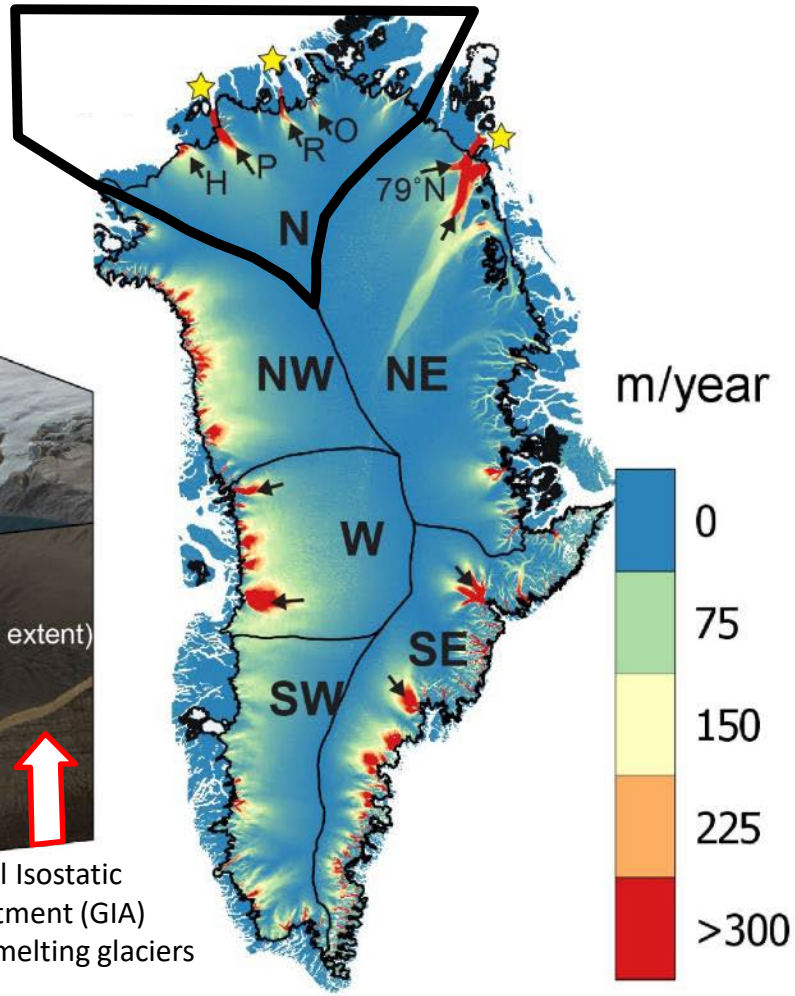
Resilience of terrestrial biodiversity under arctic change. Fredrik Dalerum et al., University of Oviedo, Stockholm University, University of Gothenburg, Swedish Museum of Natural History

Geodiversity of North Greenland
Jaroslaw Majka et al., Uppsala University, Stockholm University, Luleå Technical University, SLU, SGU

The red thread: *GEOEO addresses scientific questions focused on providing new knowledge on the marine cryosphere's dynamic history and response to future climate change, including implications for marine and terrestrial ecosystems in North Greenland and the adjacent Arctic Ocean and the North Greenland Ice Sheet's contribution to global sea-level rise*

The marine cryosphere defined

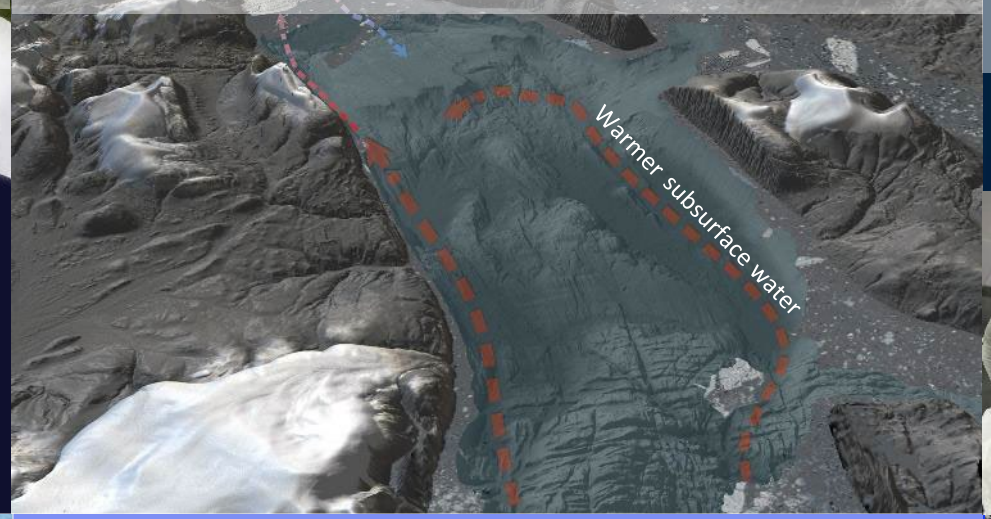




Glacial Isostatic Adjustment (GIA) from melting glaciers

Goal I: Unravelling the Late Glacial to Holocene history and dynamics of the North Greenland Ice Sheet

Goal II: Providing new insights into the variability of the marine cryosphere of North Greenland and the adjacent Arctic Ocean



Goal III: Investigating the interaction between ecosystem community composition, anthropogenic dynamics and climate fluctuations

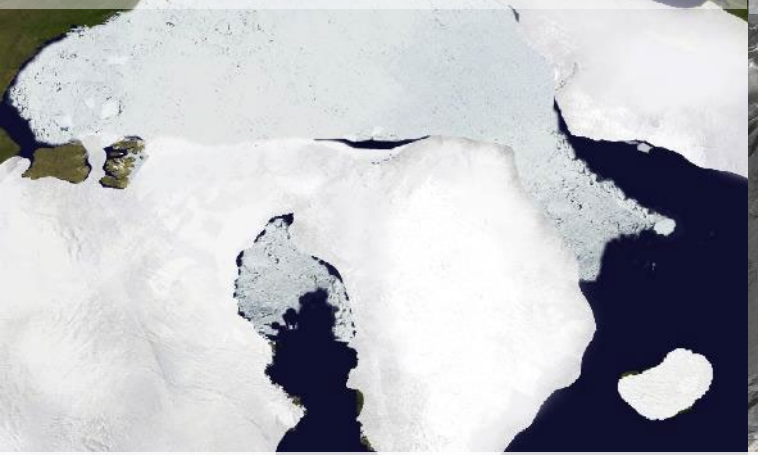
Goal IV: Quantifying ecosystem production and nutrient state in changing marine ecosystems north of Greenland

Goal V: Mapping of the remote ocean frontiers

Goal VI: Mapping the presence of gas hydrates in marine sediments and gas in water column and atmosphere

Goal VII: Numerical modelling of the ice-ocean-atmosphere-geodynamic system

Goal I: Unravelling the Late Glacial to Holocene history and dynamics of the North Greenland Ice Sheet



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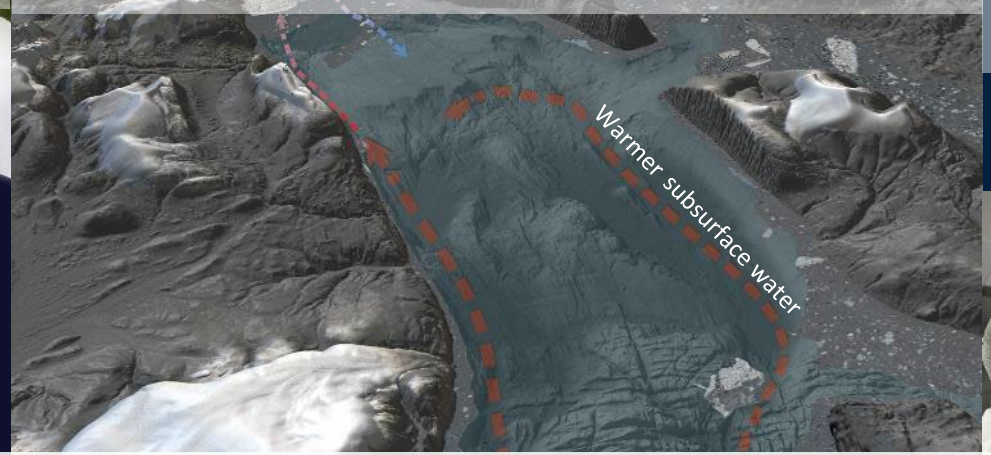

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Goal IV: Quantifying ecosystem production and nutrient state in changing marine ecosystems north of Greenland

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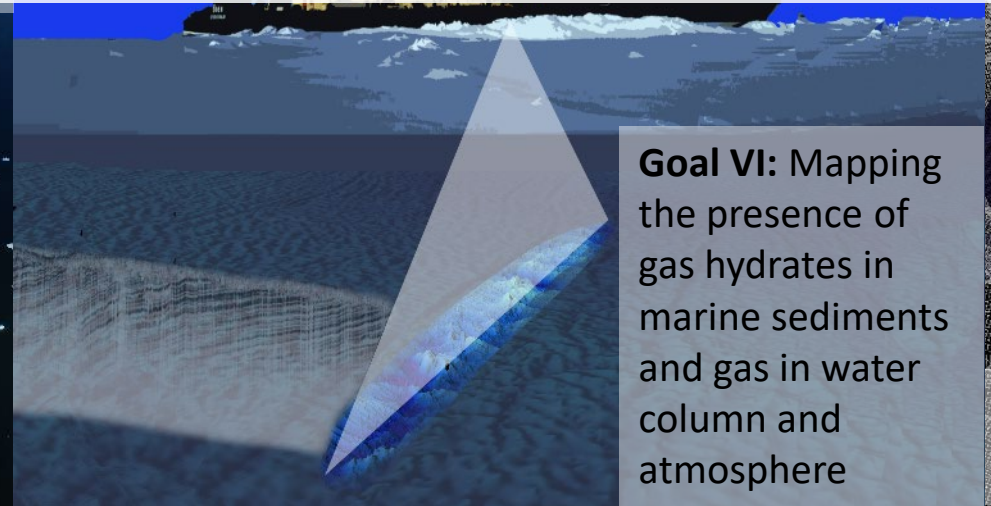

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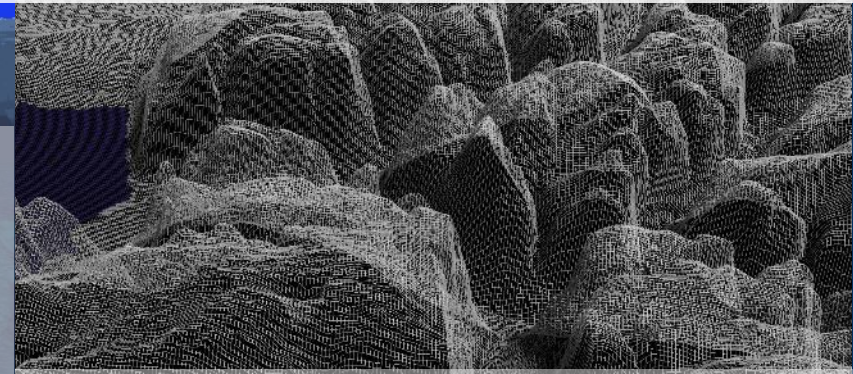

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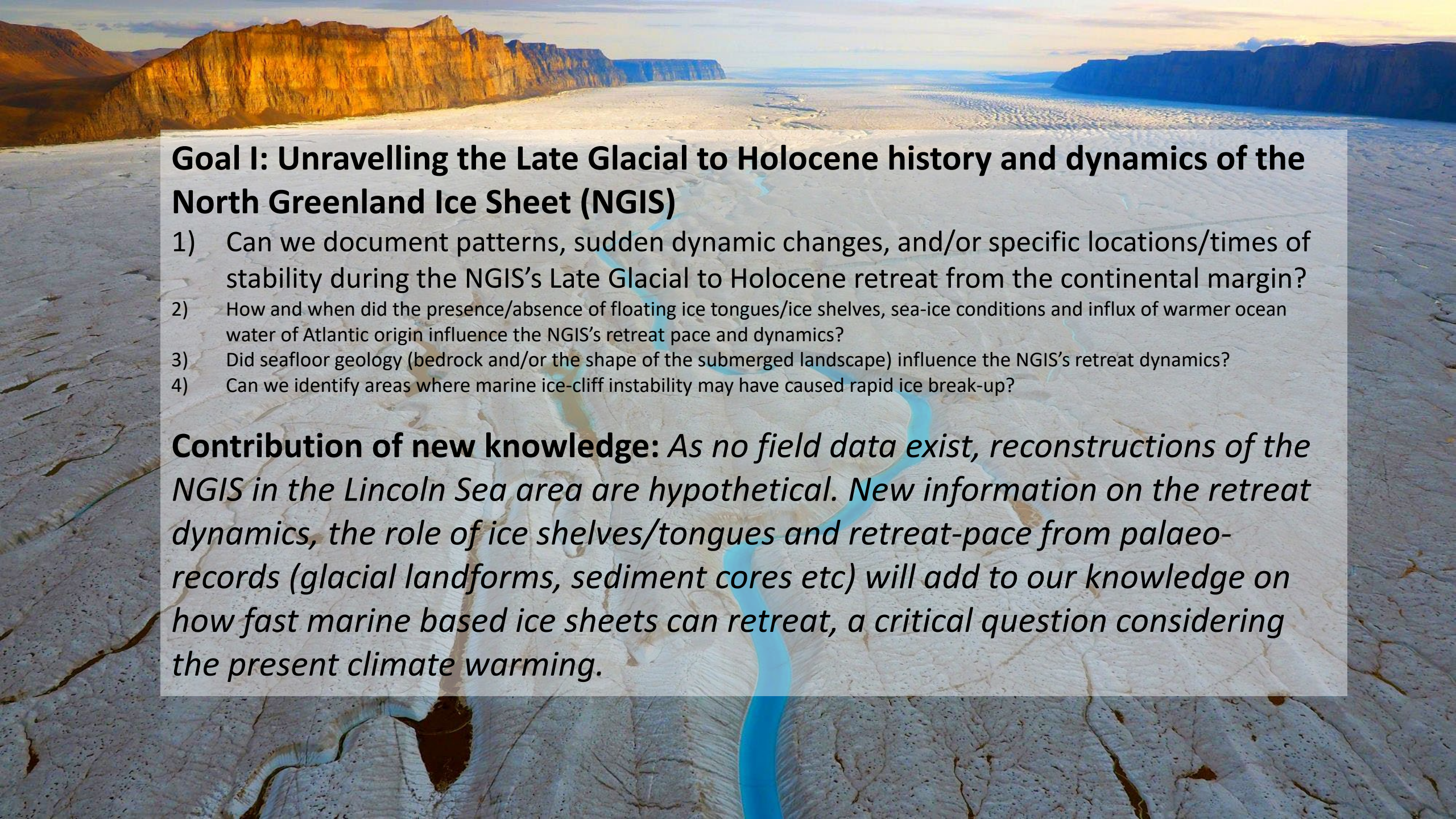


Goal I: Unravelling the Late Glacial to Holocene history and dynamics of the North Greenland Ice Sheet (NGIS)

1) Can we document patterns, sudden dynamic changes, and/or specific locations/times of stability during the NGIS's Late Glacial to Holocene retreat from the continental margin?
2) How and when did the presence/absence of floating ice tongues/ice shelves, sea-ice conditions and influx of warmer ocean water of Atlantic origin influence the NGIS's retreat pace and dynamics?
3) Did seafloor geology (bedrock and/or the shape of the submerged landscape) influence the NGIS's retreat dynamics?
4) Can we identify areas where marine ice-cliff instability may have caused rapid ice break-up?

Contribution of new knowledge: *As no field data exist, reconstructions of the NGIS in the Lincoln Sea area are hypothetical. New information on the retreat dynamics, the role of ice shelves/tongues and retreat-pace from palaeo-records (glacial landforms, sediment cores etc) will add to our knowledge on how fast marine based ice sheets can retreat, a critical question considering the present climate warming.*

Goal II: Providing new insights into the variability of the marine cryosphere of North Greenland and the adjacent Arctic Ocean

1) When did the Arctic Ocean north of Greenland last experience sea-ice free summers?
2) Have past occurrences with sea-ice free summers in the northern Greenland realm been linked to a complete loss of Arctic Ocean's summer sea-ice cover?
3) Are sea-ice variations in northern Greenland during the Holocene linked to known climate forcings, e.g. solar insolation and atmospheric greenhouse gases?
4) To what extent do variations of Atlantic water inflow to northern Greenland affect sea-ice conditions and the stability of ice tongues?
5) How fast could the summer sea ice and collapsed ice tongues recover if the climate is cooled?
6) Are there climatic thresholds beyond which the cryospheric retreat becomes irreversible?
7) What are the water mass structures and distributions of dissolved constituents (gases, nutrients, carbonate system, transient tracers) in this key gateway area for export of Arctic-derived water of both Atlantic, Pacific and riverine origin to the North Atlantic?

Contribution of new knowledge: *There are neither in-situ observations nor paleo-records from the Lincoln Sea area north of 82°30' to-date. Answering the questions above, will provide new critical knowledge for assessments of the future development of the marine cryosphere, not only in North Greenland, but in some aspects for the entire Arctic Ocean as the region north of Greenland is hypothesized to be a sea-ice indicator for the entire Arctic Ocean.*

Goal III: Investigating the interaction between ecosystem community composition, anthropogenic dynamics and climate fluctuations

1) How is genomic biodiversity distributed throughout the marine water column?
2) To what extent are past changes in Holocene biodiversity correlated with inferred changes in temperature, sea-ice cover and ice shelf dynamics?
3) Do we find invasive subpolar species? Does presence-absence of DNA from organisms that depend on sea ice lend support to inferences of earlier periods of an ice-free Arctic Ocean?
4) To what extent is the arrival and disappearance of human cultures on Greenland, as inferred from sedimentary ancient DNA, correlated with past climate change, coastal sea ice changes, and/or prey species population dynamics? In addition, dendrochronological data from north Greenland shrubs will be assembled to reconstruct past climate and investigate vegetation dynamics.

Contribution of new knowledge: *The plankton/benthos surveys will document the current state of Arctic marine biology in unexplored regions North of Greenland. Genomic analyses will contribute completely novel insights into temporal dynamics in marine biodiversity and how these are related to past changes in climate and sea-ice cover. On the terrestrial side, the analyses will enhance our knowledge of the extent to which pioneering human populations were affected by changes in terrestrial and marine biotic communities, especially prey population demography, in the context of Holocene climate fluctuations.*

Goal IV: Quantifying ecosystem production and nutrient state in changing marine ecosystems north of Greenland

1) What is the coupling between meltwater plumes, Arctic Ocean circulation, warm water pools and biological productivity, export, and remineralization?
2) Who are the primary producers in these ecosystems?
3) What sustains the biological productivity in fjords and near shore areas– nutrient inflow of Arctic Ocean water or subglacial runoff from land?
4) What were the biogeochemical changes over the past decades and what can they tell us about future ecosystem changes?

Contribution of new knowledge: *Through on-board continuous CO_2 and stable isotope water monitoring systems, CTD Rosette profiling for nutrients, microscopic and primary productivity measurements, and chemical and biological profiling of sediments and porewaters we can provide new data for both local and regional synoptic insights of the present and future Arctic marine carbon and nutrient cycles.*

Goal V: Mapping of the remote ocean frontiers:
There has been growing recognition that our limited knowledge of the seafloor shape and depth has a severe impact on our ability to model ocean circulation and global heat transport, understand sediment dynamics and glacial history, assess sea-level rise, predict tsunamis and storm surges, and manage critical benthic habitats. The Decade of Ocean Science in Support of Sustainable Development has identified the complete mapping of the seafloor as a priority research area, necessary for meeting several of the U.N. Sustainable Development Goals (SDGs). The seafloor around Northern Greenland is virtually unmapped.

Contribution of new knowledge: *We will provide all mapping data from the **North of Greenland 2024 Expedition** directly to the International Bathymetric Chart of the Arctic Ocean (IBCAO)/Seabed 2030 project, which assembles these data to freely available data compilations provided to the community through the General Bathymetric Chart of the Oceans (GEBCO).*

Goal VI: Mapping the presence of gas hydrates in marine sediments and gas in water column and atmosphere

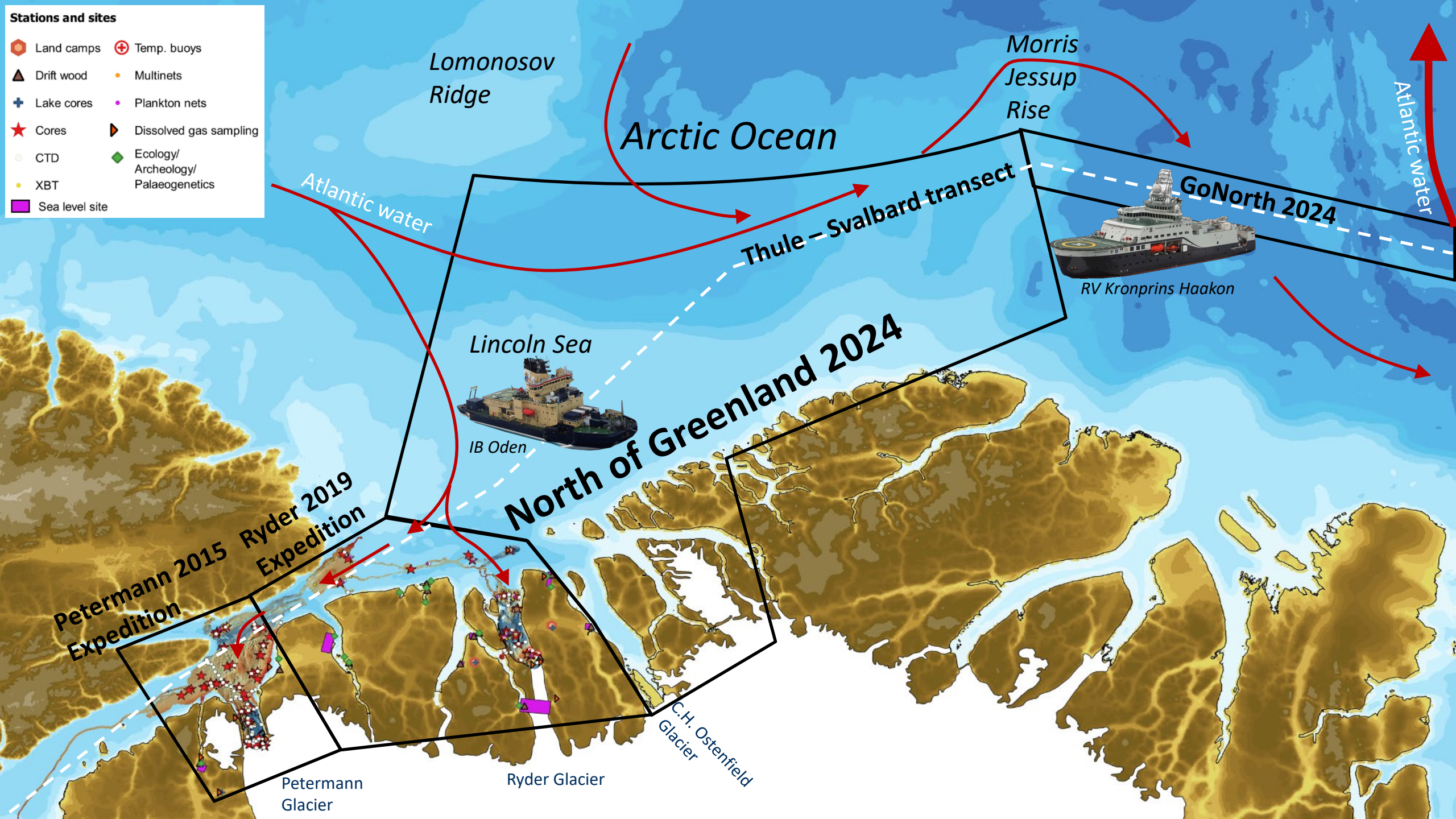
1) Are there gas hydrates in the sediments?
2) Do we see signs of hydrate dissociation and seafloor methane release?
3) How sensitive are the hydrate deposits (if present) to climate warming?

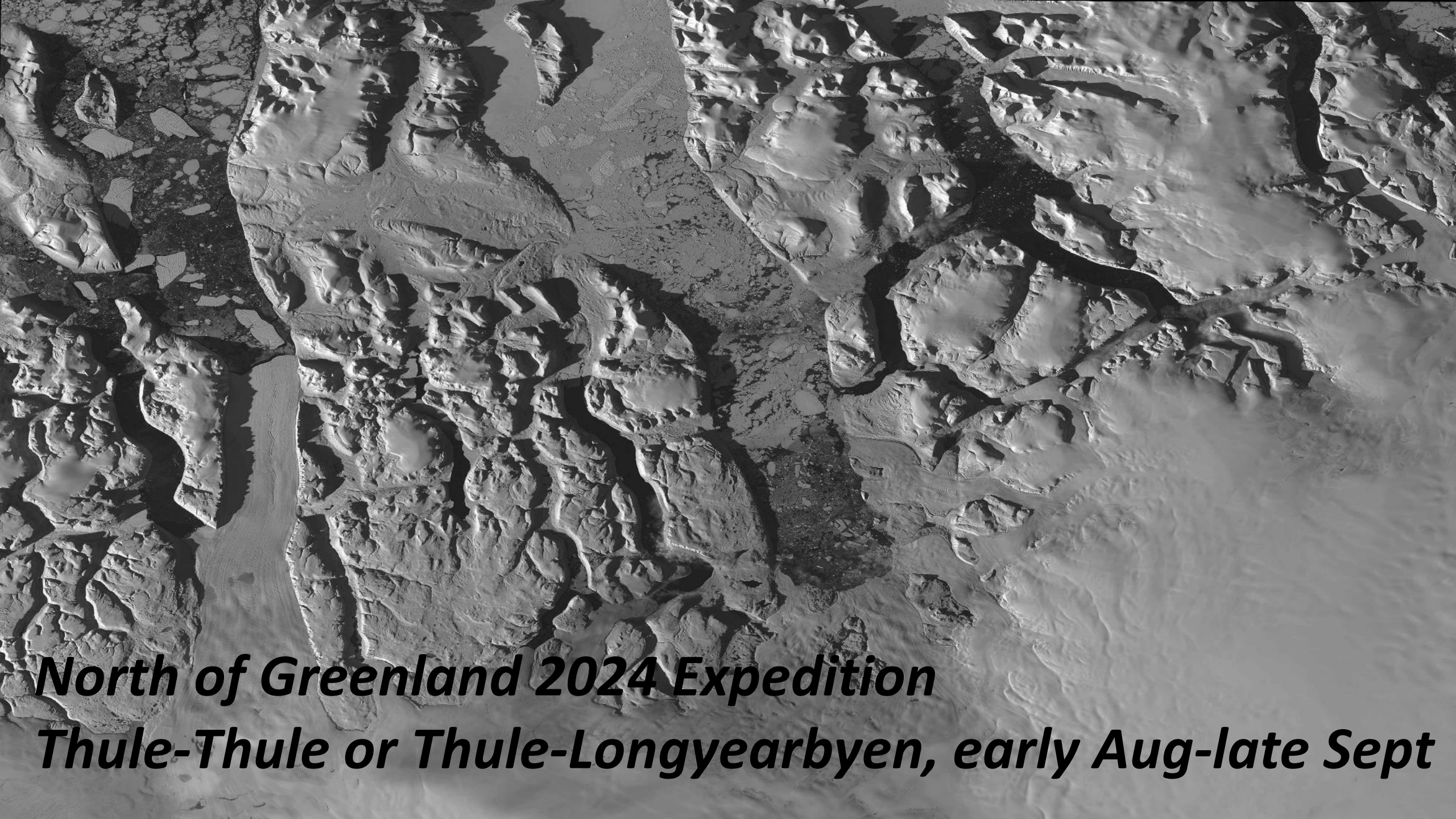
Contribution of new knowledge: *In regional and global assessments of future warming-induced seafloor methane release, it is assumed that hydrates are ever-present along the continental shelf slope off northern Greenland, but this is purely based on assumption. If we reach this area to acquire new data, it will provide the first insights from a region that to-date has no geological base information on gas hydrates in previous assessments.*

Goal VII: Numerical modelling of the ice-ocean-atmosphere-geodynamic system:

1) What is the potential contribution to global sea-level rise from the NGIS under IPCCs RCPs/SSPs?
2) How sensitive is Glacial Isostatic Adjustment (GIA) to geophysical inferred variations in deeper crustal and upper mantle rheologies and how do these geodynamics affect ice dynamics and contribution to sea-level rise?
3) Which are the most critical feedback processes and environmental parameters (influx of warmer water, etc.) controlling the NGIS's future behaviour under the different climate scenarios RCP?

Contribution of new knowledge: *As there are no observation data from the Lincoln Sea north of 82°30' N or from the fjords north of Sherard Osborn Fjord where Ryder Glacier drains, there are no assessments based on numerical modelling using observational data as boundary and/or initial conditions. Hence the contribution to new knowledge will be profound.*


Stations and sites
Land camps
Temp. buoys
Drift wood
Multinets
Lake cores
Plankton nets
Cores
Dissolved gas sampling
CTD
Ecology/ Archeology/ Palaeogenetics
XBT
Sea level site
Lomonosov Ridge
Arctic Ocean
Morris Jessup Rise
Atlantic water
Atlantic water
Thule – Svalbard transect
GoNorth 2024
RV Kronprins Haakon
Lincoln Sea
IB Oden
North of Greenland 2024
Ryder 2019 Expedition
Petermann 2015 Expedition
C.H. Ostenfield Glacier
Ryder Glacier
Petermann Glacier

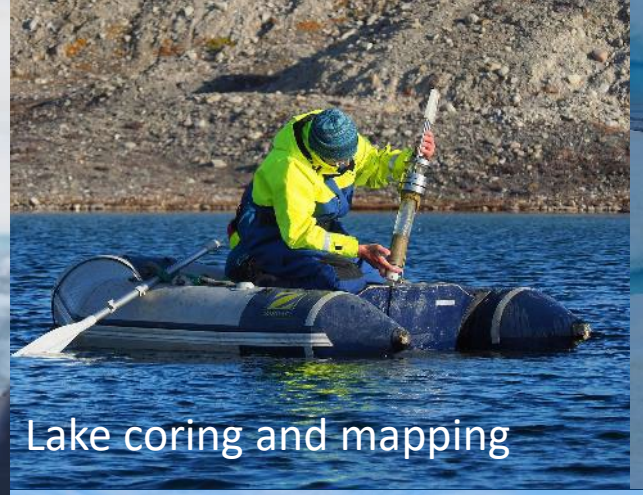


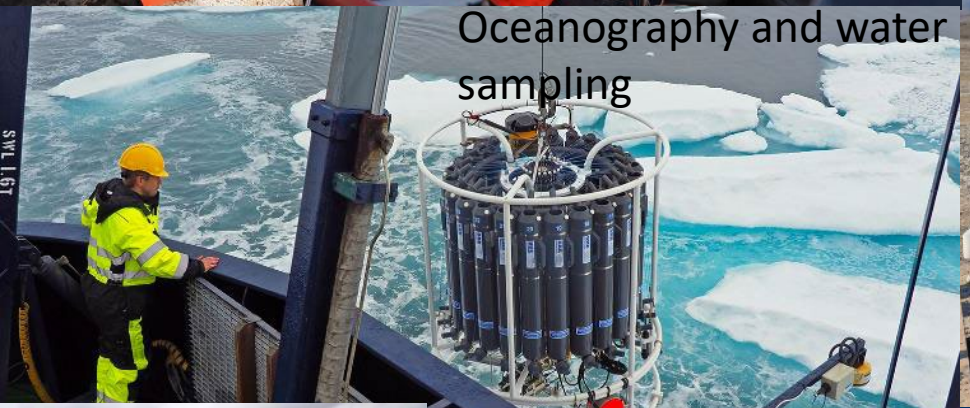
North of Greenland 2024 Expedition

Thule-Thule or Thule-Longyearbyen, early Aug-late Sept

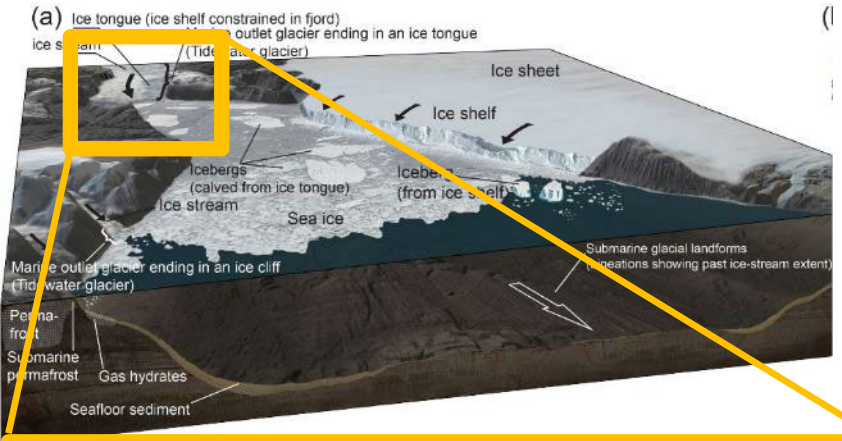

ODEN
ODEN

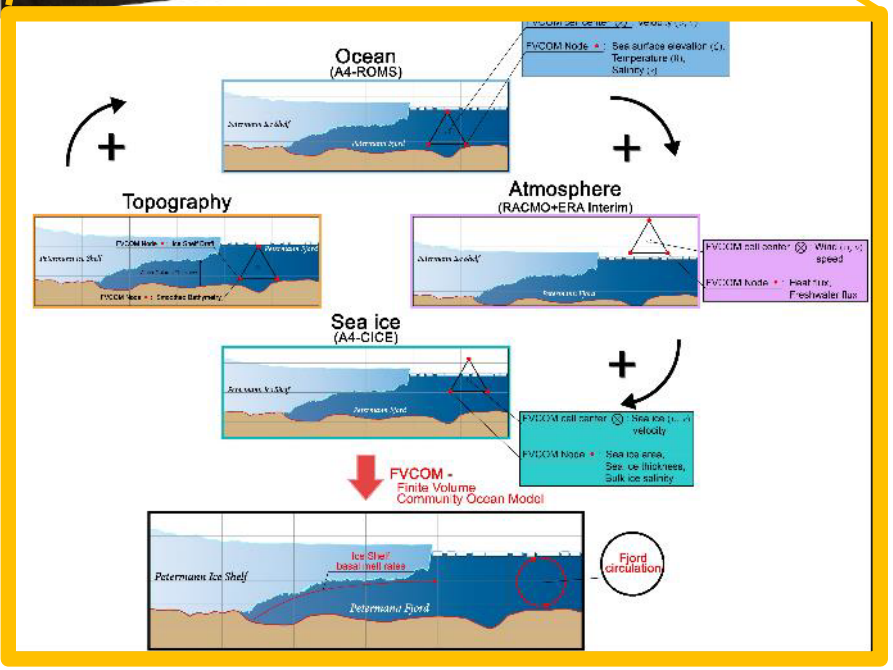

SE-HMM
www.sjofartsverket.se





Previous experiences by Larry Mayer will give more insight into what can be done





Prakash, A,….,Kirchner, N., A nested high-resolution unstructured grid 3-D ocean-sea ice-ice shelf setup for numerical investigations of the Petermann ice shelf and fjord. *Under review, Methods X*

On-shore components and contributions:

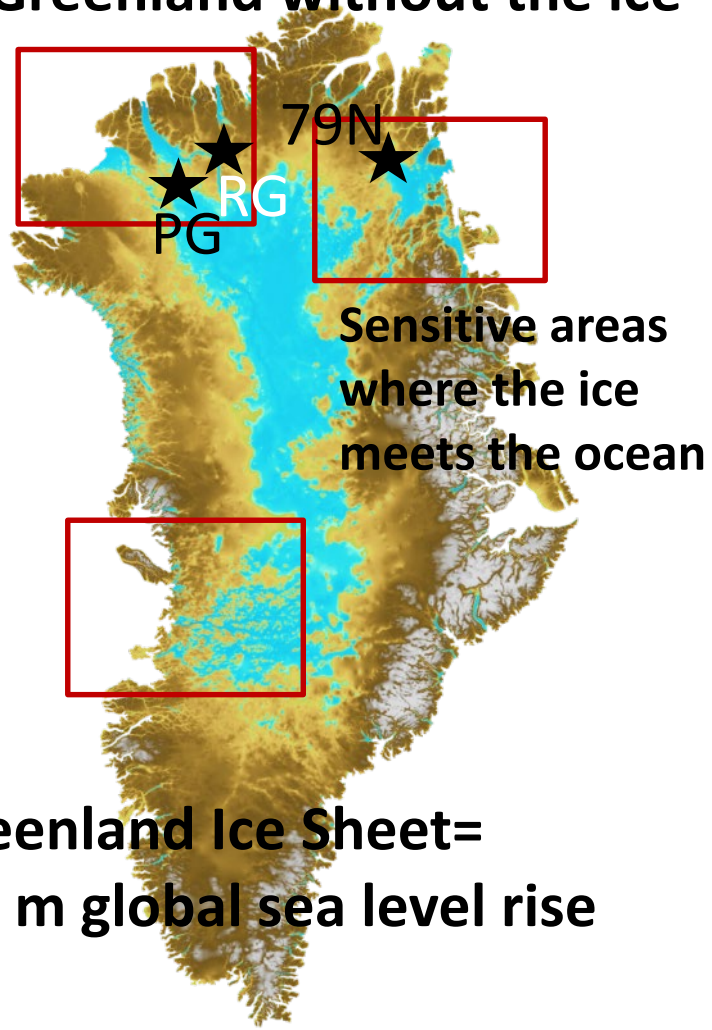
Inaccessible domains (such as the sub ice shelf cavity) become accessible through e.g. modeling

Ice models, e.g ISSM, Elmer/Ice: Calving front dynamics, under variable atmospheric forcing, and parameterized ocean and sea ice impact (ice mélange buttressing, submarine melt,…).

Ocean models, eg. FVCOM: Ocean circulation and induced ice shelf basal melt rates in ice shelf cavity, impact of bathymetry on circulation, … .

Towards fully coupled models, e.g FISOC: ocean-calving front interaction (dynamics and role of undercuts, impact of melt (=fresh) water plumes, implications of frontal ice loss for upstream ice dynamics) .

Greenland without the ice

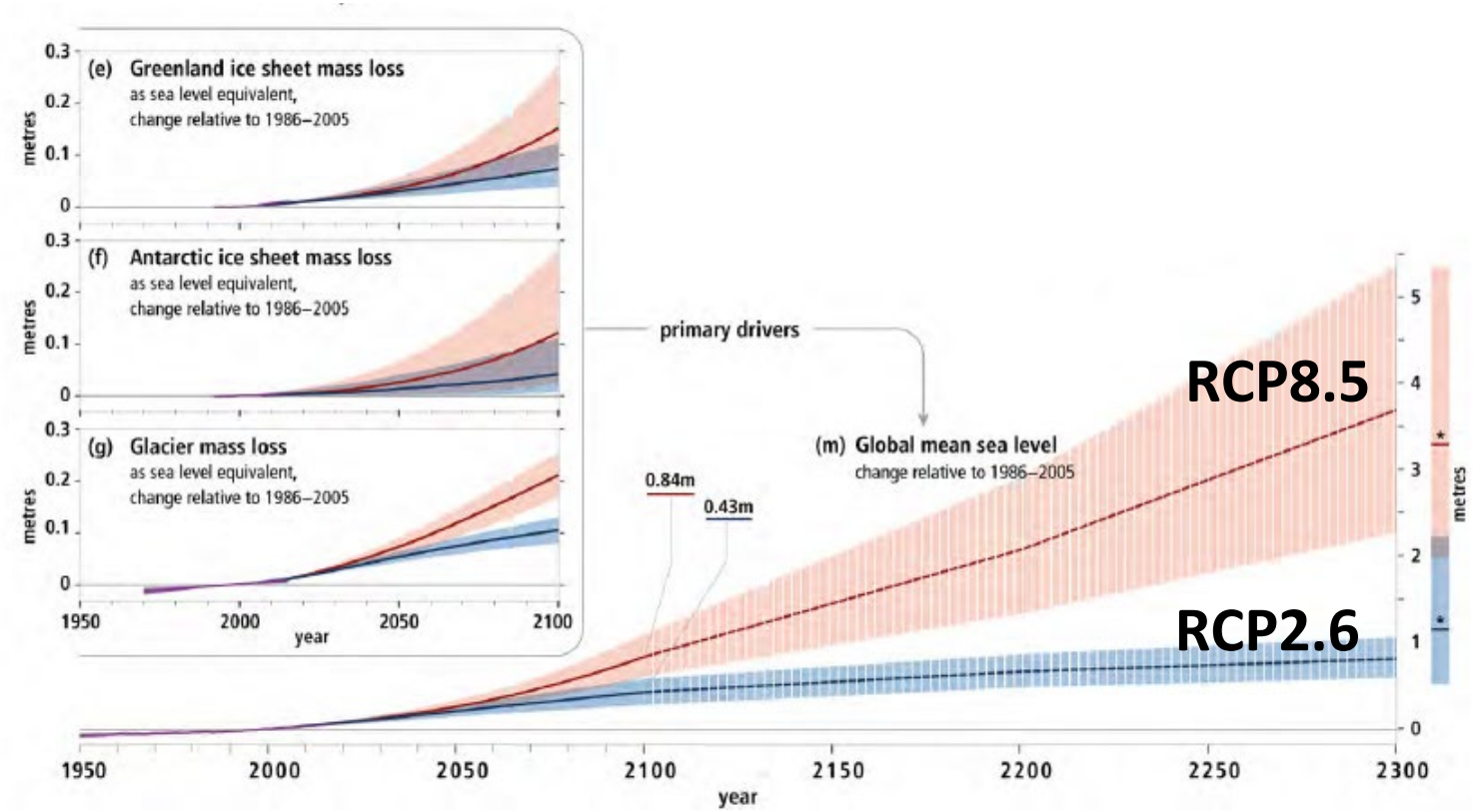


Sensitive areas where the ice meets the ocean

Greenland Ice Sheet=
7.4 m global sea level rise

Predicted global mean sea level rise by 2300

600 million people live within 10 m above sea level



IPCC Special Report 2019: "The Ocean and Cryosphere in a Changing Climate"

Greenland was contributing on average
0.47 ±0.23 mm/year (1991-2015) (Mottram et al., 2019)

North Greenland 2024 Expedition

Why are more field data and improved models needed for improved predictions of sea-level rise?

X

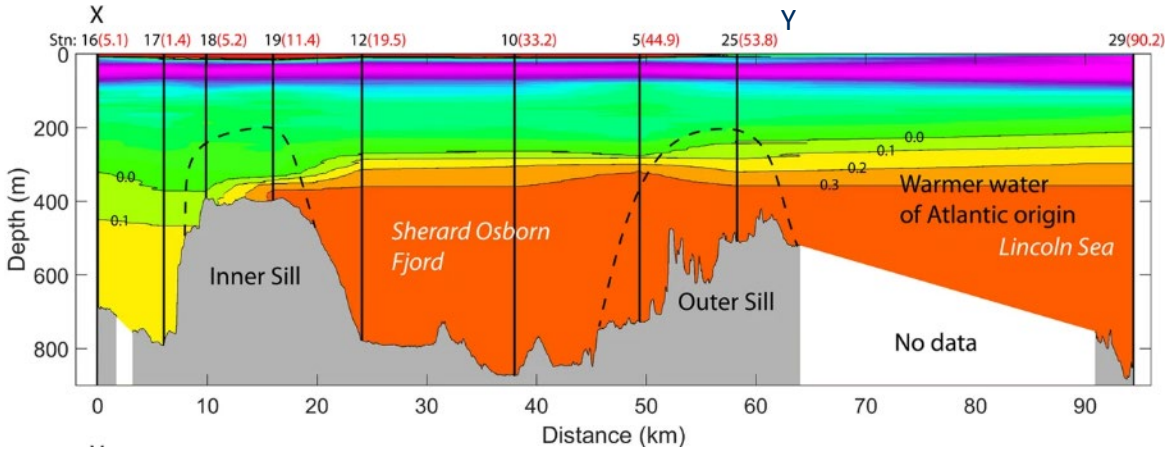
Inner sill

Outer sill

Warm Atlantic water

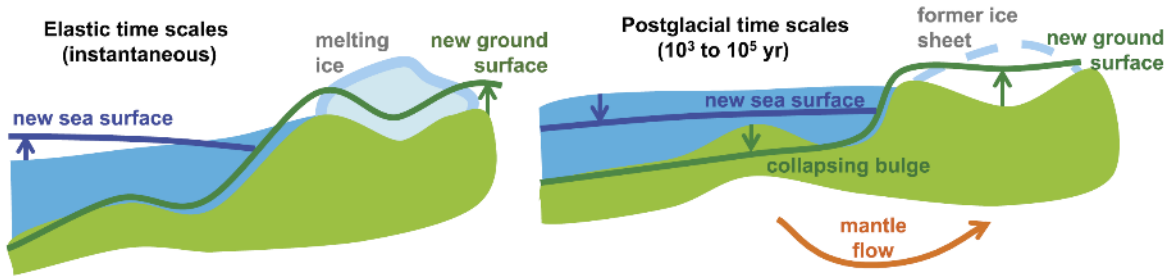
Y

Warm Atlantic water inflow towards Ryder Glacier



Jakobsson, M., Mayer, L. A., Nilsson, J., Stranne, C., Calder, B., O'Regan, M., et al. (2020). Ryder Glacier in northwest Greenland is shielded from warm Atlantic water by a bathymetric sill. *Communications Earth & Environment, 1(1), 45. https://doi.org/10.1038/s43247-020-00043-0*

Solid Earth effects on sea level

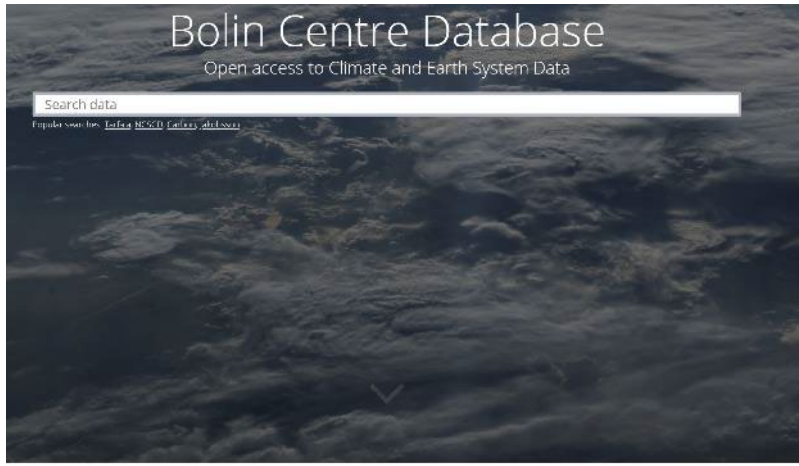


Conrad, C. P. (2013). The solid Earth's influence on sea level. *GSA Bulletin*, 125(7-8), 1027-1052. https://doi.org/10.1130/B30764.1

Synthesis Report:
The North Greenland Marine Cryosphere in a Changing Climate

Possible content:

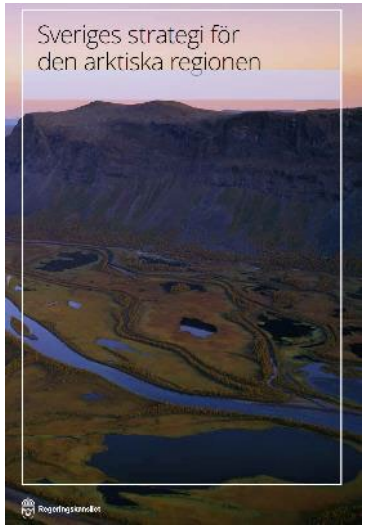
1. Past, present and future of North Greenland's marine cryosphere
2. Potential sea-level rise contribution from the North sector of the Greenland Ice Sheet under the different IPCC Representative Concentration Pathways (RCPs; 2.5, 4.5 and 8.5, or SSPs)
3. The present state and future change of North Greenland's marine and terrestrial ecosystems: A case study providing insights into polar ecosystem changes in response to climate change



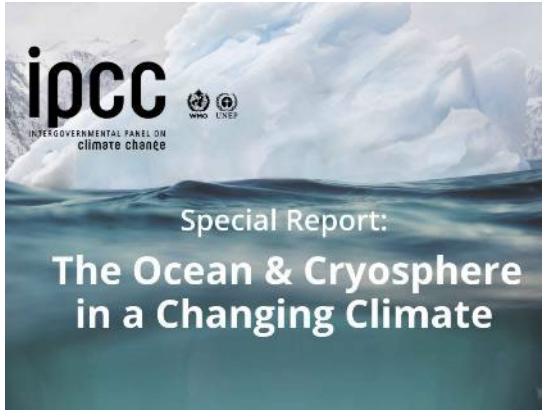
Open Access and rapid distribution of data:
GEOEO will work towards rapid distribution of observations and research data

Contributions to stakeholders and a sustainable development

- Improved Earth system understanding and characterization of one of the least known geographic areas in the Arctic. This directly supports the recently published Swedish Arctic Strategy.



- Contribution to the next generation of IPCC assessment reports beyond 2022 (e.g. state and development of the cryosphere, sea-level rise, ecosystem change). The Antarctic and Greenland ice sheets are pointed out as the potentially largest contributors to global sea-level rise, and also the largest uncertainties.



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2021 2030 United Nations Decade of Ocean Science for Sustainable Development