U.S. CLIVAR Working Group on Ice Sheet/Ocean Interactions in Greenland: Making progress by building bridges across communities

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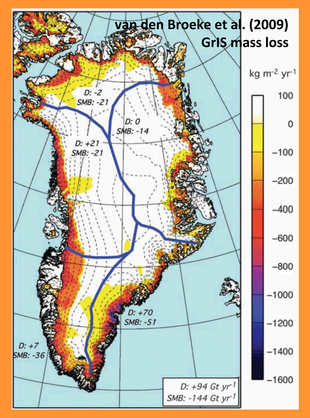
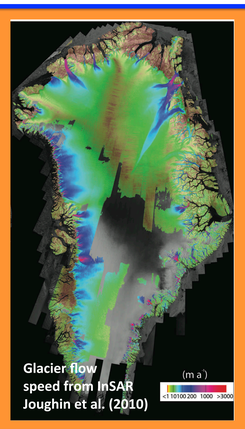
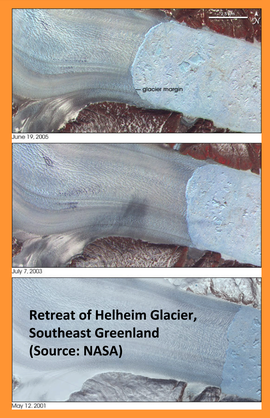
Why Greenland Ice Sheet/Ocean Interactions (GrIO)?

Recent, rapid mass loss from both polar ice sheets has been attributed to changes at the marine margins of Greenland and West Antarctica. Evidence points at ice sheet/ocean interactions as a key player in the ice sheets' mass balance and likely trigger for the changes. Yet the relevant ocean and glacier dynamics are poorly understood and constitute a fundamental barrier to the correct representation of ice sheets in climate/earth system models and to our ability to accurately predict sea level change. This situation is exacerbated in Greenland, where ice/ocean interactions have received less attention than in Antarctica and whose characteristics require special consideration.

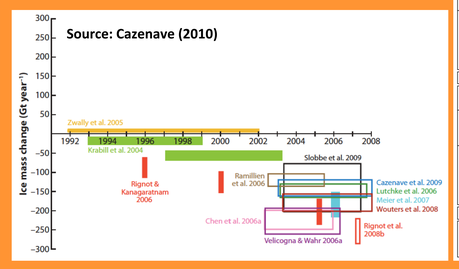






An intrinsically cross-disciplinary problem:

Progress on this complex problem is hindered by the inherent separation of the communities involved, including glaciologists, oceanographers, sea-ice experts, atmospheric and climate scientists.



A. Impact of the ocean on the GrIS	
A.1	mass loss through ocean melting and calving
A.1.i	enhanced calving due to changes in stress balance
A.1.ii	inland migration of longitudinal stress perturbations
A.1.iii	changes in stress balance due to grounding line migration
A.2	mechanical forces exerted by icy melange
A.2.i	enhanced buttressing during winter months
A.2.ii	modulation by waves and tides
A.2.iii	tidal and sea-level impacts on floatation conditions
A.3	regional and large-scale atmospheric ocean circulation variability
A.3.i	atmospheric variability (e.g., NAO)
A.3.ii	oceanic variability (e.g., AMOC)
A.3.iii	variability at the shelf break
A.3.iv	variability at the fjord mouth
A.3.v	SST impacts on atmospheric circulation and sea ice
B. Impact of the GrIS on the ocean	
B.1	freshwater input to the fjord/shelf/ocean interior
B.1.i	barotropic & baroclinic adjustment to freshwater perturbations
B.1.ii	change in dense water formation, convection and overturning
B.1.iii	heat flux to the ocean from glacial freshwater & icebergs
B.2	impact on fjord circulation
B.2.i	buoyancy changes through deep freshwater plume injection
B.2.ii	enhanced mixing due to tipping icebergs
B.3	local and global (relative) sea level response
B.3.i	gravitational self-attraction and loading (SAL)
B.3.ii	elastic glacial isostatic adjustment (GIA)
B.3.iii	viscous post-glacial rebound (PGR)
B.3.iv	global mass redistribution and Earth rotation changes
C. Interactions with the atmosphere	
C.1	orographic controls on the atmospheric circulation
C.1.i	special phenomena, e.g., tip jets, katabatic winds
C.2	surface melting due to turbulent and radiative fluxes
C.2.i	surface meltwater induced basal lubrication and enhanced glacier flow
C.2.ii	enhanced calving due to meltwater-induced hydro-fracturing
C.3	changes in surface albedo
C.3.i	low-level cloud formation
C.3.ii	meltwater ponds
C.3.iii	seasonal snowfall and melt
C.3.iv	changes in sea-ice coverage
D. Intrinsic variability of the coupled system	
D.1	the coupled glacier/ocean/sea-ice/atmosphere as a stochastic system
D.2	dominant time scales of natural fluctuations (coupled and un-coupled)
D.3	intrinsic feedback mechanisms and time scales

Why a U.S. CLIVAR Working Group?

To bring together a diverse group of scientists who are addressing GrIO-related questions from various disciplines. Its goal is to promote interaction between the diverse communities, oceanographic, glaciological, atmospheric and climate, including modelers, field and data scientists within each community, interested in glacier/ocean interactions around Greenland, to advance our understanding of the processes and improve its representation in climate models.

Goals:

- Summarize the present state of knowledge and identify the big questions within each community and for the problem as a whole
- Develop strategies to address the questions/needs (including long-term/ short-term needs of each community)
- Make recommendations on how to move forward

Here, we present an overview of the problem and the overarching questions.

1) What is the impact of the ocean on the Greenland Ice Sheet (GrIS)

Direct – at the ice/ocean boundary in Greenland's glacial fjords

- Submarine melting at the terminus
- Mechanical forcing by ice-melange (or sikkusaq), tides and wave

Indirect – regional/large scale ocean (shelf/gyre scale)

- Shelf properties and circulation influence fjord properties
- Influence of the large-scale ocean on Greenland's atmosphere

2) What is the impact of the Greenland Ice Sheet on the Ocean

Direct:

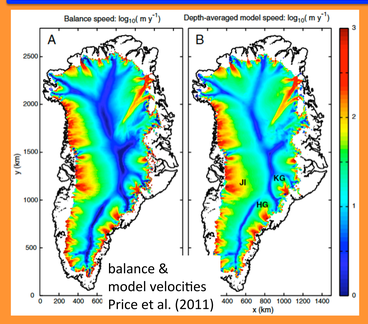
- Sea level rise – the GrIS holds 7 m of sea-level rise and presently accounts for roughly 0.8 mm/yr (i.e. ¼ global sea-level rise)
- Freshwater input – ice melt releases freshwater into the sensitive convective regions of the North Atlantic and Nordic Seas

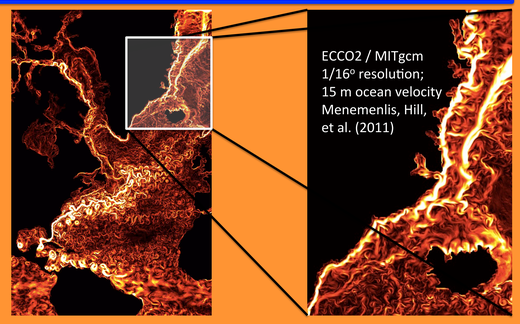
Indirect:

GrIS influences the regional/large scale atmosphere via heat, water vapour exchange which, in turn, feedbacks on the ocean.

3) What is the impact of the atmosphere on ice sheet/ocean interaction?

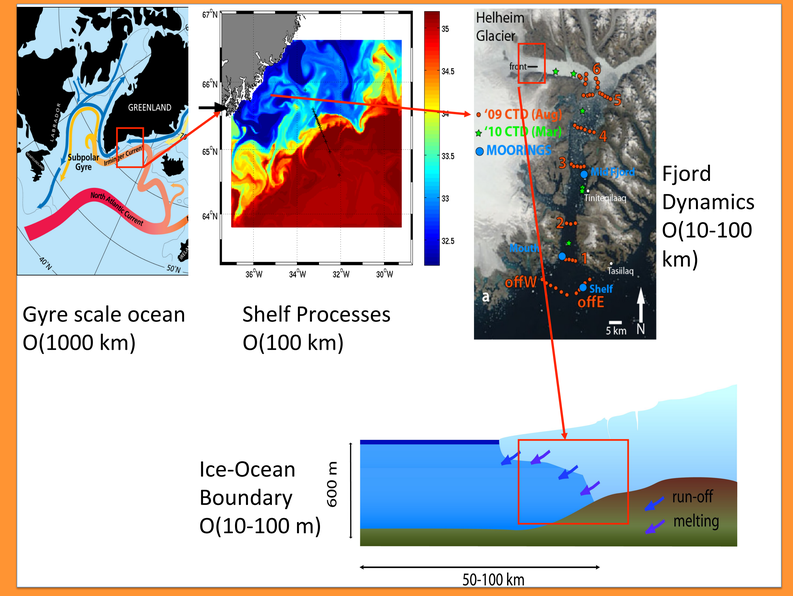
- Tip-jets, barrier winds, katabatic winds which, in turn, have a major impact on the fjord circulation – and fjord shelf exchange.
- Surface melting discharged at the grounding line has a major impact on the submarine melting process.





Case Study – Submarine Melting

- What processes govern the amplitude, spatial and temporal variability of melting at a glacier's terminus?
- What oceanic scales of motion influence melting (and on what time scales)?
- What modeling/field studies are needed to improve our understaning of melting
- How appropriate are Antarctica's parameterizations for Greenland?



For more information, please visit:
http://www.usclivar.org/icesheet.php