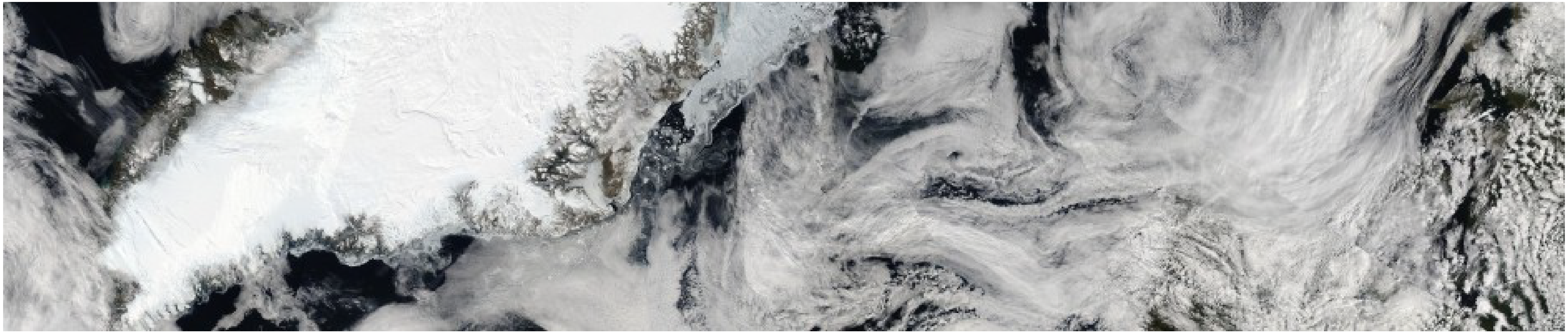


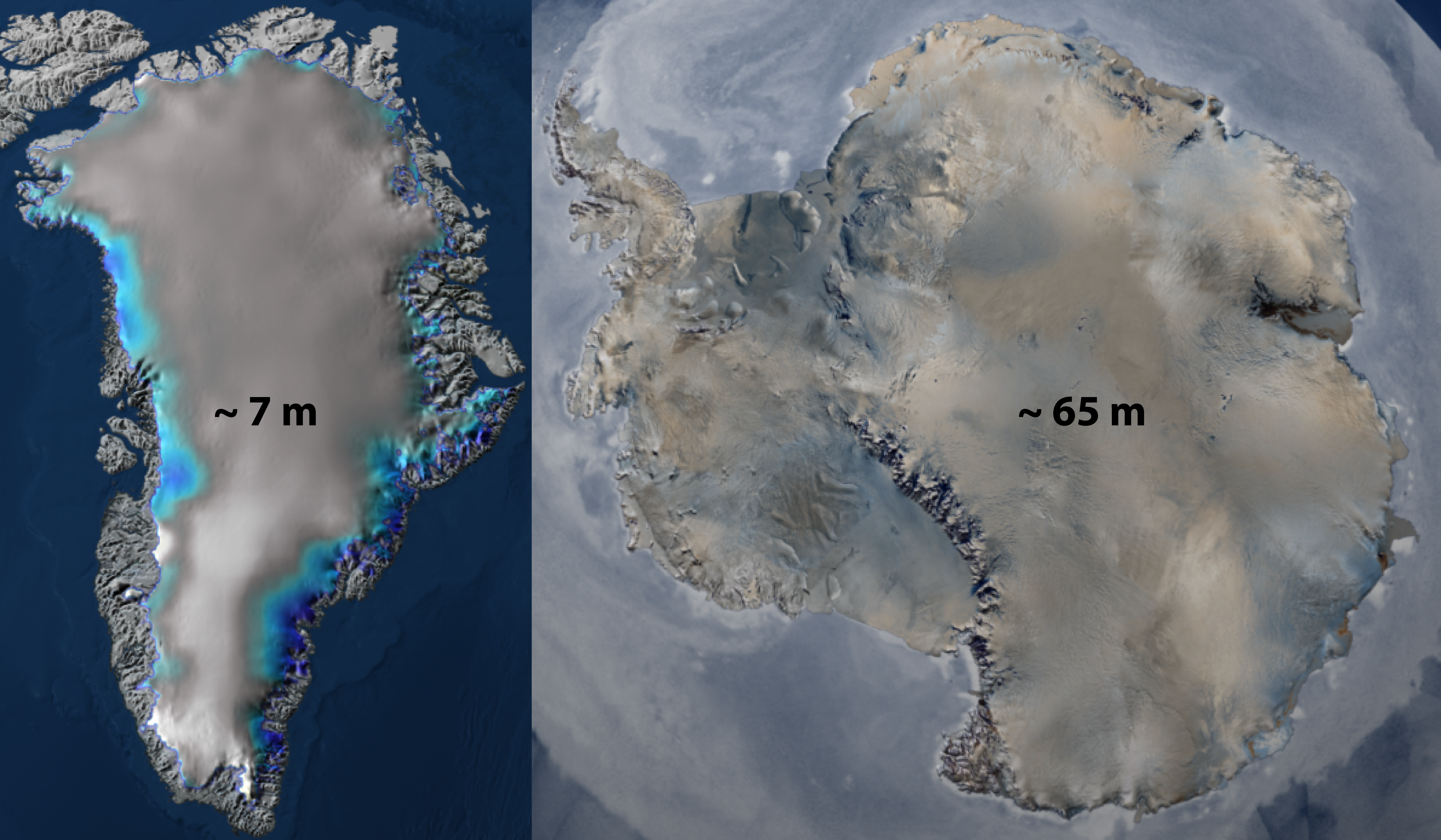
US CLIVAR Working Group

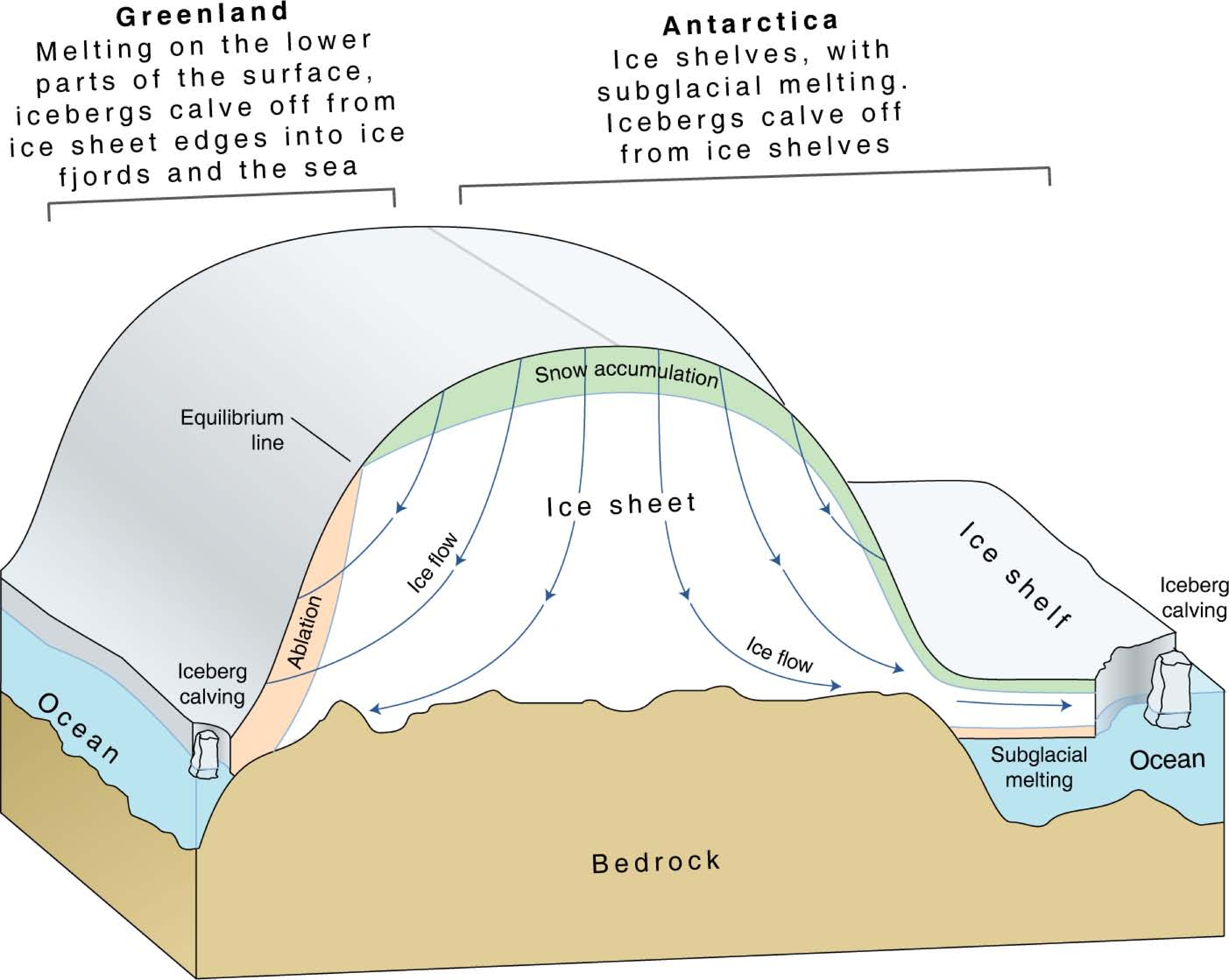
GReenland Ice Sheet-Ocean interactions (GRISO)

Fiammetta Straneo (WHOI) Patrick Heimbach (MIT)
Olga Sergienko (Princeton/GFDL)

Cecilia Bitz (U. Washington), David Bromwich (Ohio State University),
Ginny Catania (U. Texas), Robert Hallberg (GFDL), Gordon Hamilton (U. Maine)
Adrian Jenkins (British Antarctic Survey), Ian Joughin (APL/UW),
Stephen Price(LANL), Eric Rignot (UC Irvine/JPL), Michael Spall (WHOI)

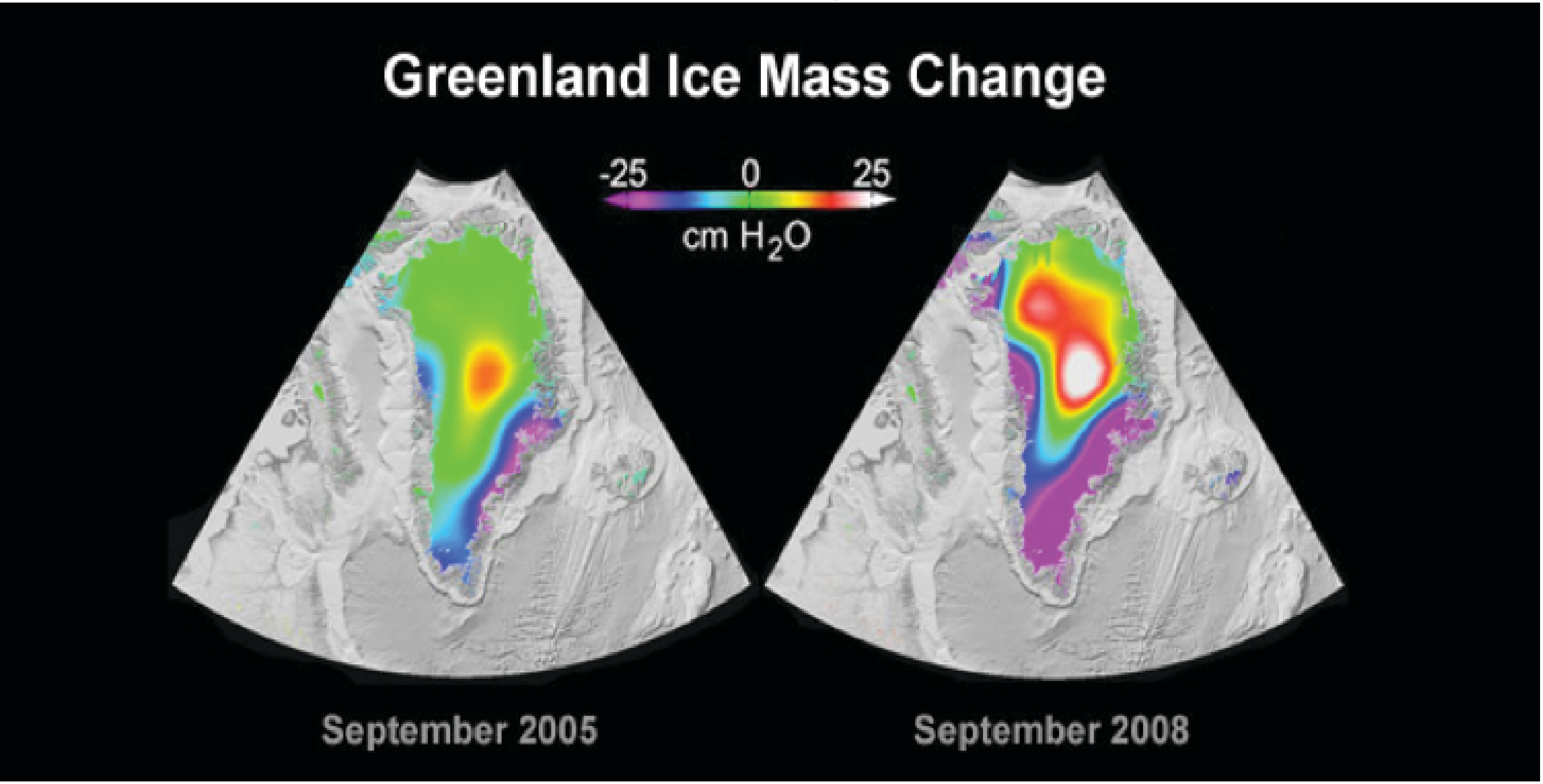
www.griso-wg.org


~ 7 m
~ 65 m


Greenland
Melting on the lower parts of the surface, icebergs calve off from ice sheet edges into ice fjords and the sea
Antarctica
Ice shelves, with subglacial melting. Icebergs calve off from ice shelves
Snow accumulation
Equilibrium line
Ice sheet
Ice flow
Ice flow
Ablation
Ice shelf
Iceberg calving
Iceberg calving
Ocean
Ocean
Subglacial melting
Bedrock

Motivation

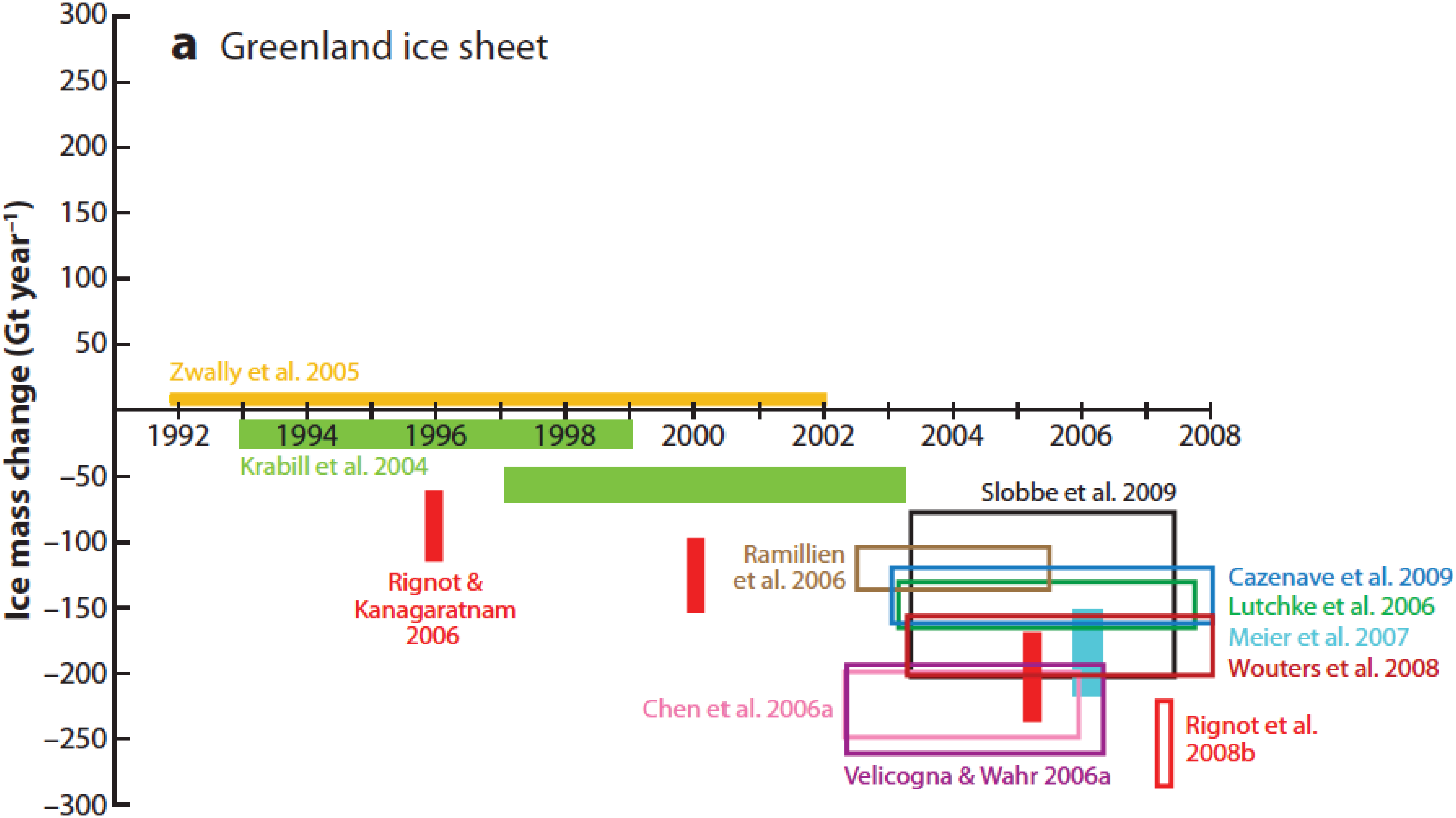
Greenland has been losing mass for a while...



GRACE observations (Khan et al, 2010)

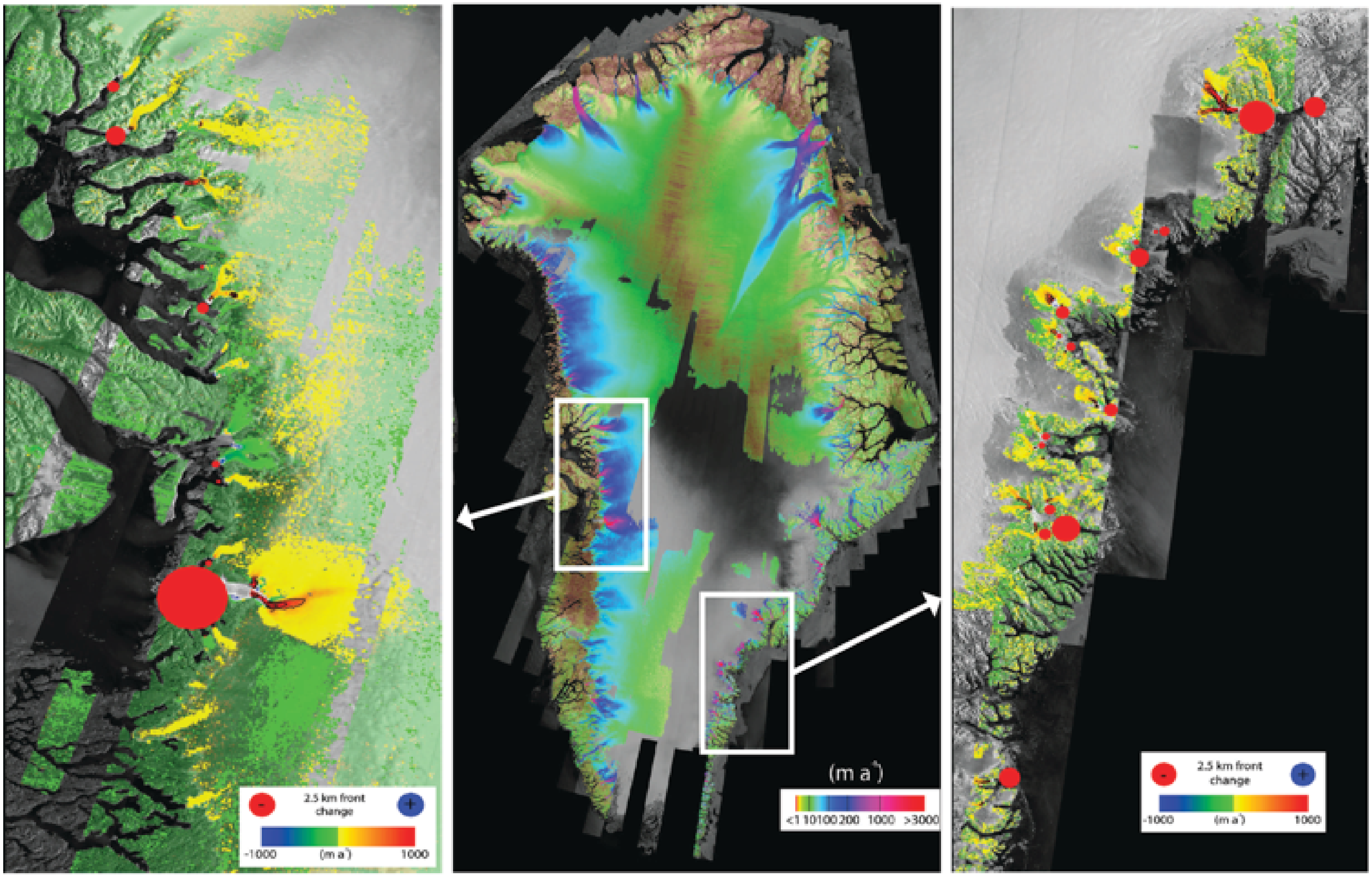
... and recently with accelerated rate

it presently accounts for 25 % of global sea level rise



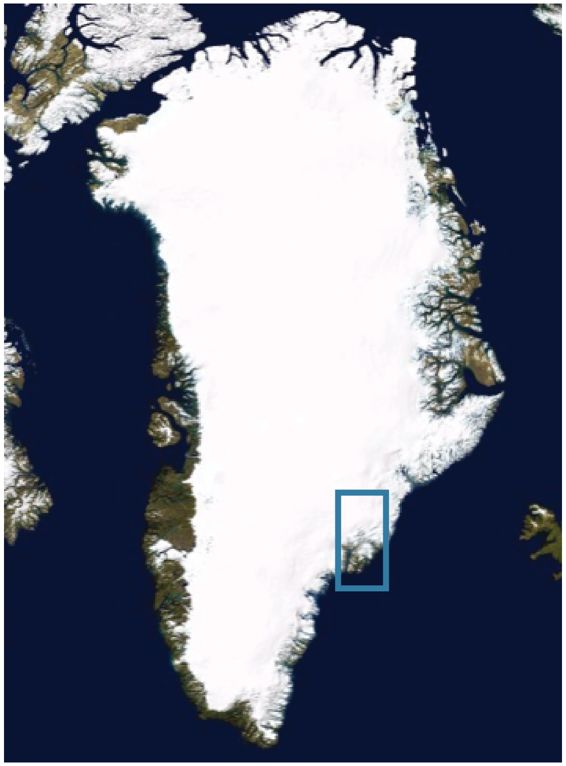
Cazenave (2010)

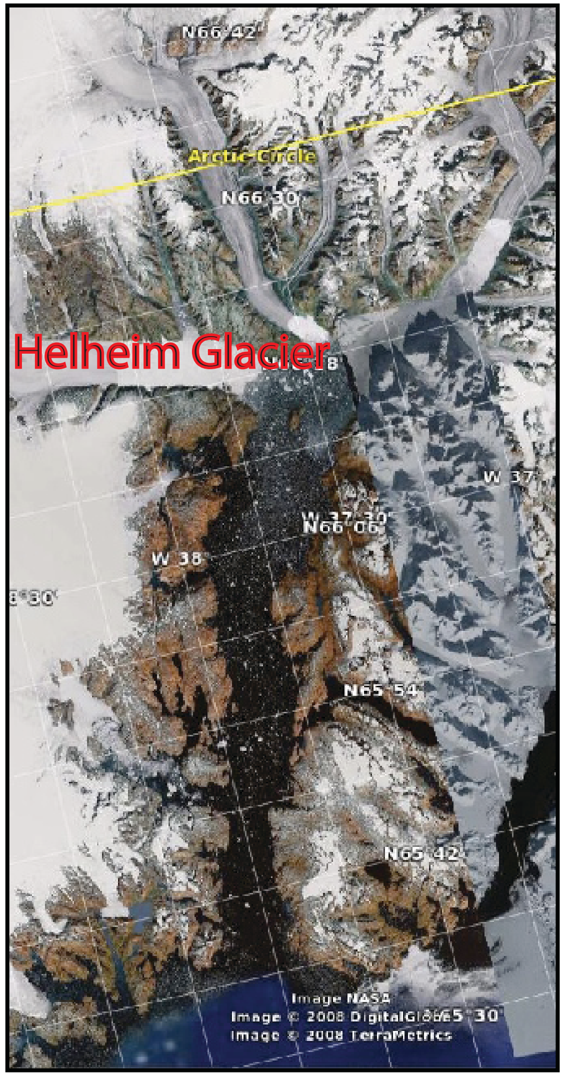
Half of the loss is due to the retreat and acceleration of marine terminating glaciers

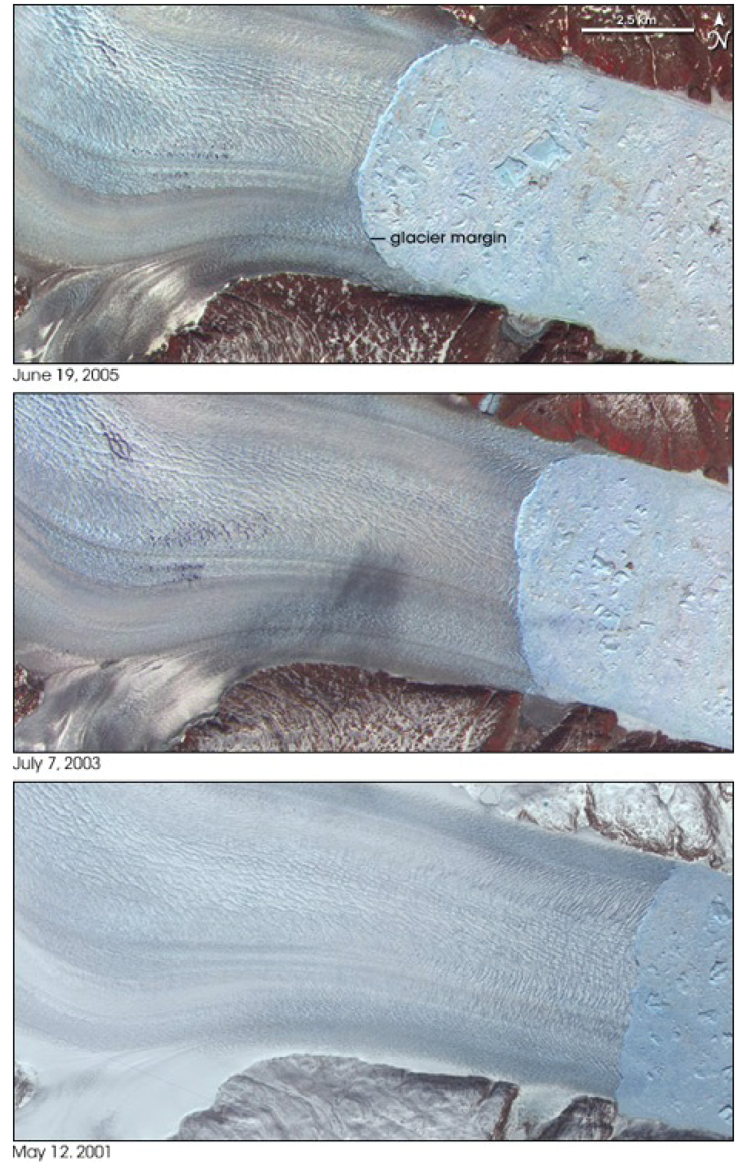


Acceleration of outlet glaciers between 2000/2001 and 2005/2006 in western and southeast Greenland (Joughin et al., 2010).

Half of the loss is due to the retreat and acceleration of marine terminating glaciers





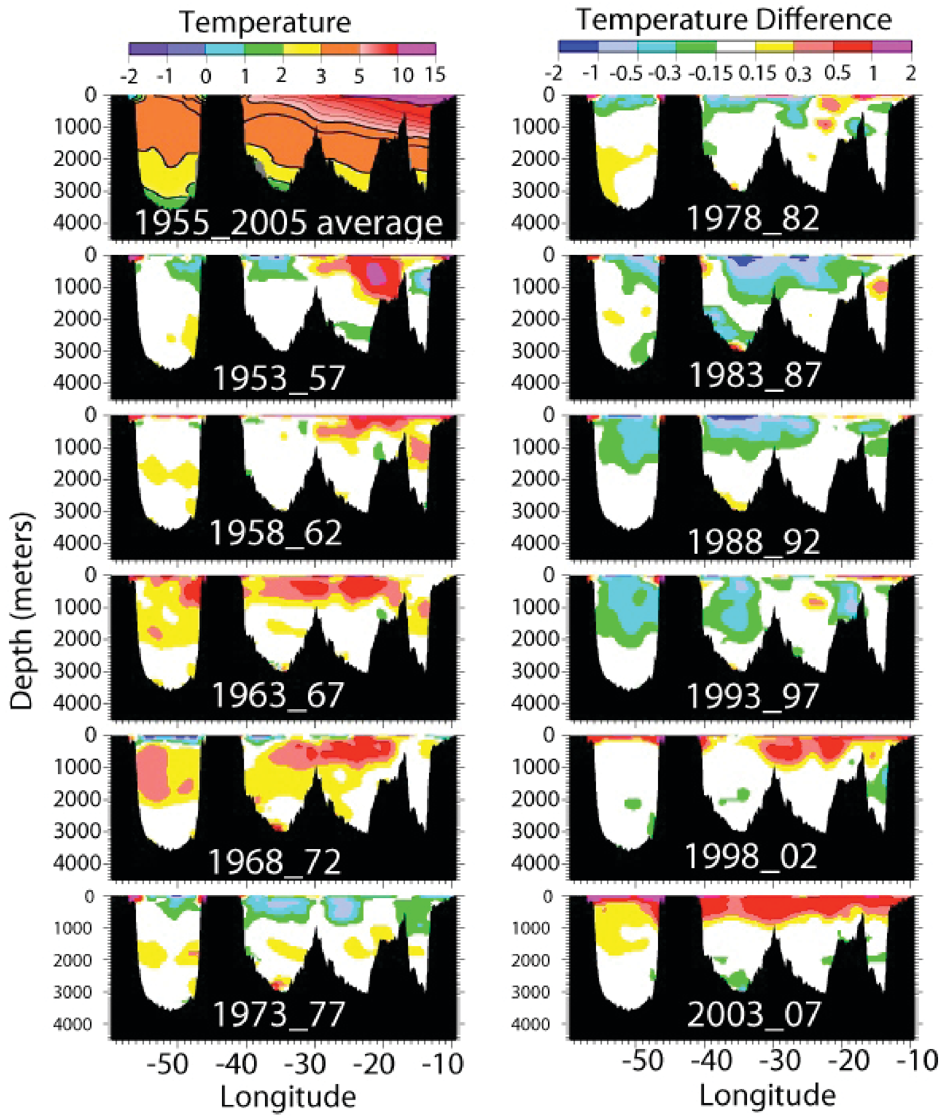


Thinned 200 m
Doubled its speed
Retreated 7.5 km

Stearns and Hamilton 2007; van den Broeke et al. 2009

Outlet glacier acceleration coincided with a period of oceanic and atmospheric warming

Oceanic



R. Curry (WHOI) from HydroBase II

Atmospheric

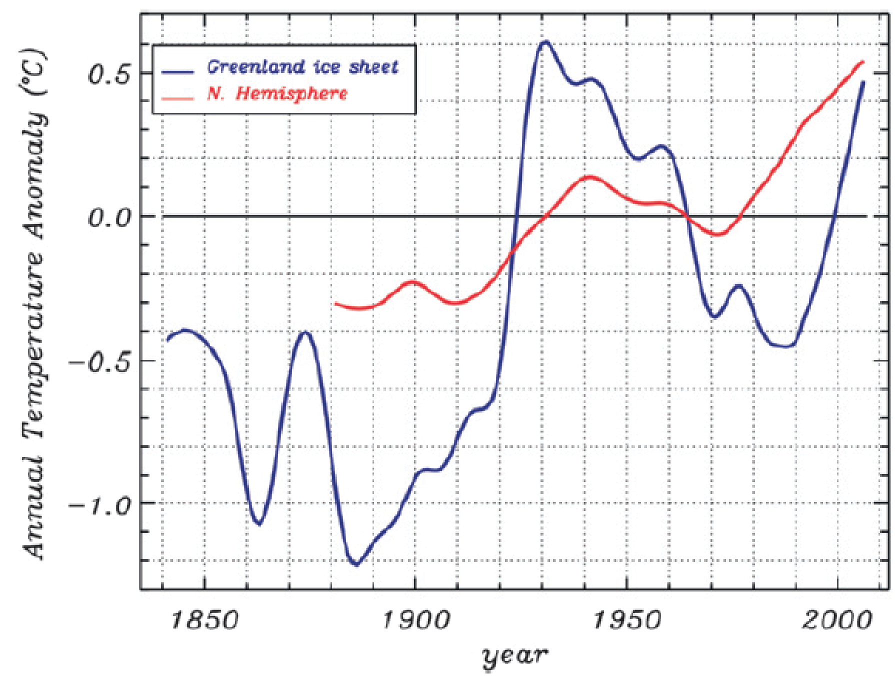


FIG. 14. Time series of low-pass-filtered Greenland inland ice and Northern Hemisphere near-surface air temperature anomalies with respect to the 1951–80 base period.

Box et al (2009)

Ice Sheet Dynamics and the IPCC

1990

no mention of ice sheet dynamics (time scales thought too long)

1995

West Antarctic collapse mentioned high risk / low probability event

2001

Feedback emphasizing importance of ice dynamics all but ignored

2007

"dramatic" ice dynamics clearly identified as major uncertainty

Projections of SLR from Greenland by 2100 range from 0.006-0.5 m

GRISO WG
Overarching Goals

- to foster interaction between the diverse communities

  (oceanographic, glaciological, atmospheric and climate),

  interested in glacier/ocean interactions around Greenland,

  including modelers, field and data scientists within each community

- promote exchange of data and model products

- coordinate field programs

- advance our understanding of the dominant process and improve their representation and/or parameterization in Eath system and climate models

GRISO WG
Specific Goals

- Summarize the present state of knowledge, the ongoing efforts, identify the big questions within each community and from the perspective of ice-sheet, ocean, and climate science;

- Develop strategies to address these questions, whilst identifying the short-term and long-term needs of each community;

- Make specific recommendations on how to move forward and make progress in obtaining the required information and products;

U.S. CLIVAR: Climate Variability and Predictability

Understanding the Dynamic Response of Greenland's Marine Terminating Glaciers to Oceanic and Atmospheric Forcing

A White Paper
by the U.S. CLIVAR Working Group on
Greenland Ice Sheet-Ocean Interactions (GRISO)

May 2012

U.S. CLIVAR Report
No. 2012-2

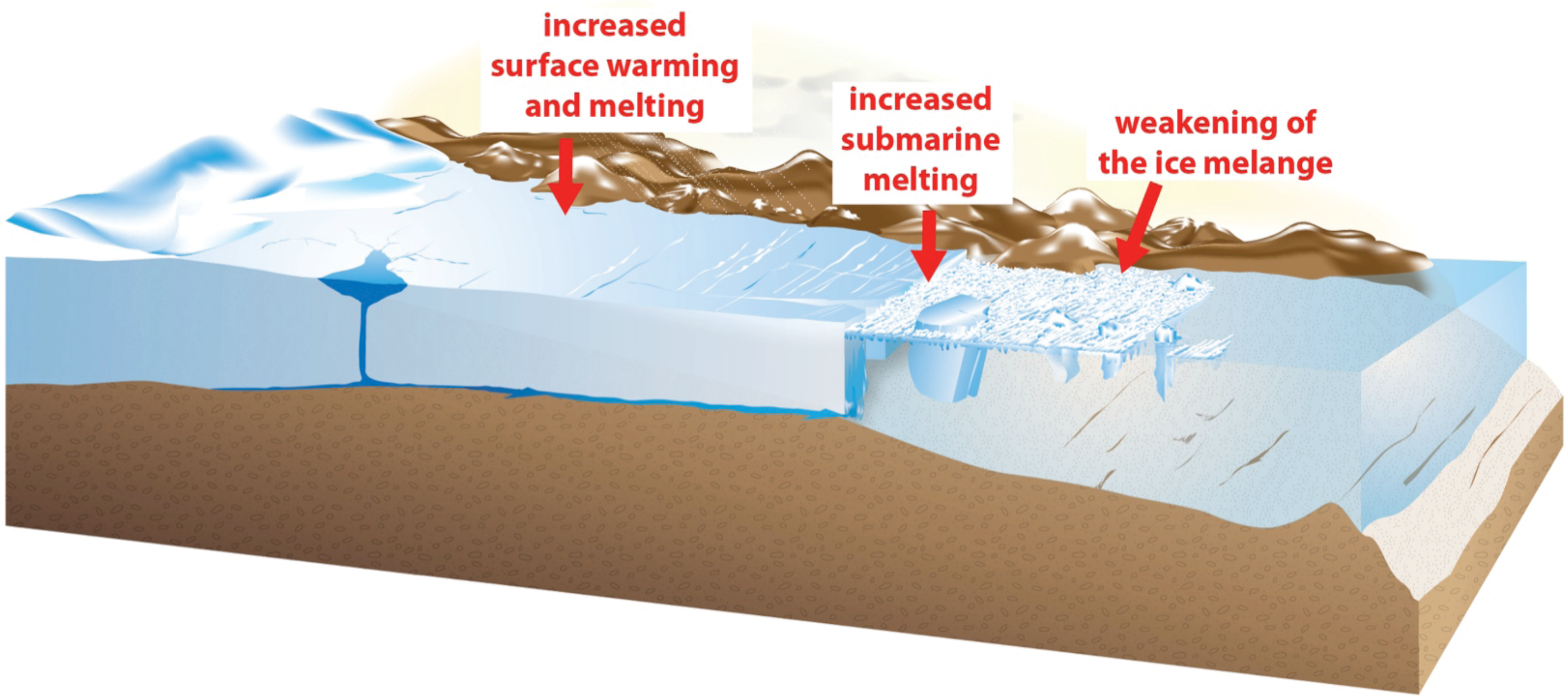
May 2012

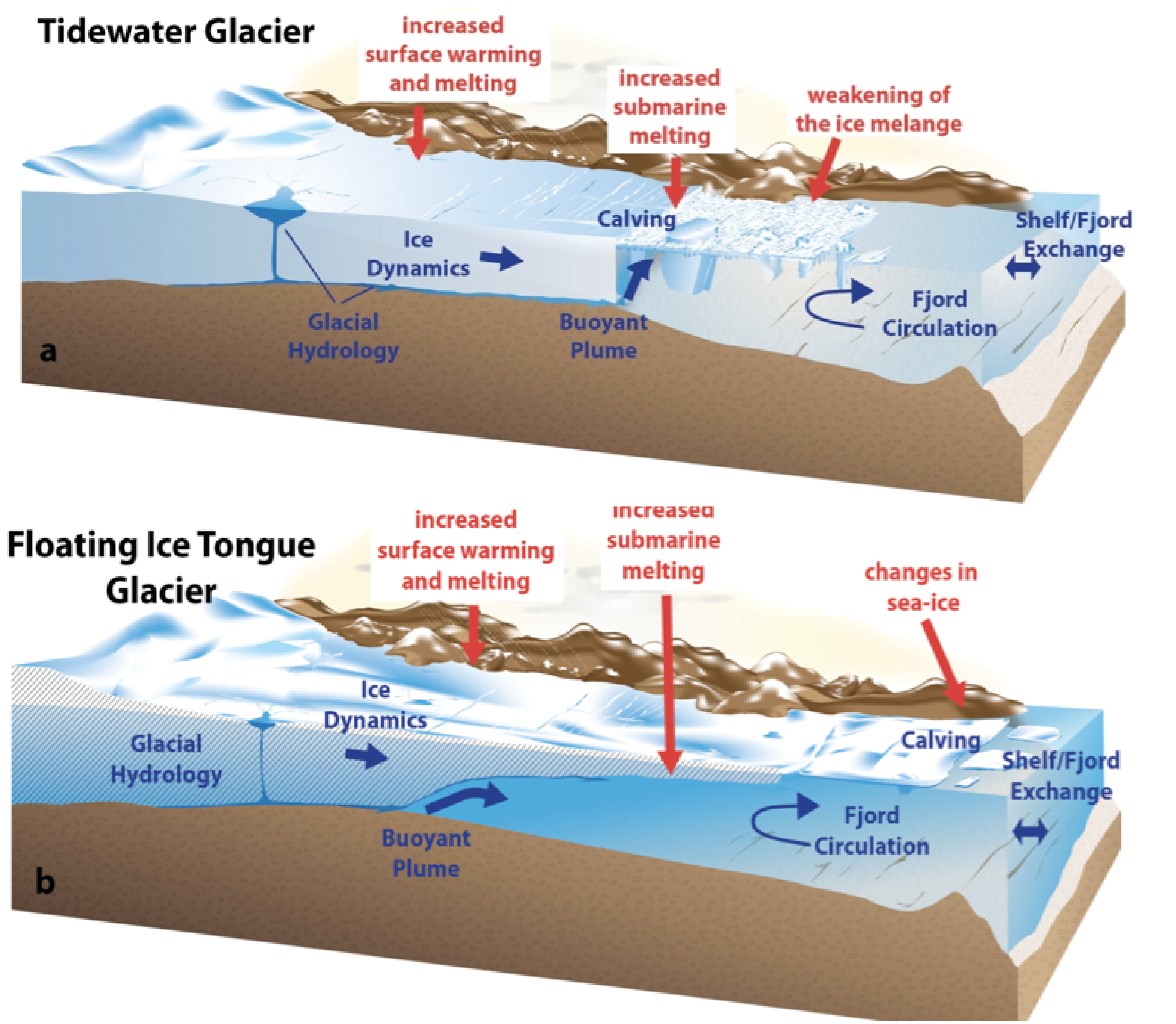
U.S. CLIVAR
Project Office
Washington, DC

Hypothesized causes of glacier acceleration

Acceleration began at the marine termini of the glaciers

i. Structural weakening of a floating ice tongue by thinning from excessive submarine melt
ii. Decrease in backpressure exerted by a thinning, decreasing ice mélange leading to increased calving
iii. Effects of the increased surface melting on the ice flow
iv. Effects of the subglacial hydrological systems on ice flow
v. Weakening of lateral shear margins due to cryo-hydrologic warming of subsurface ice
vi. Hydro-fracturing and calving of the floating tongues leading to reduced buttressing




Tidewater Glacier
increased surface warming and melting
increased submarine melting
weakening of the ice melange
Calving
Shelf/Fjord Exchange
Ice Dynamics
Glacial Hydrology
Buoyant Plume
Fjord Circulation
a
Floating Ice Tongue Glacier
increased surface warming and melting
increased submarine melting
changes in sea-ice
Ice Dynamics
Glacial Hydrology
Calving
Shelf/Fjord Exchange
Buoyant Plume
Fjord Circulation
b

Strategy and Recommendations

I. Process Studies Targeting Specific Dynamic Regimes

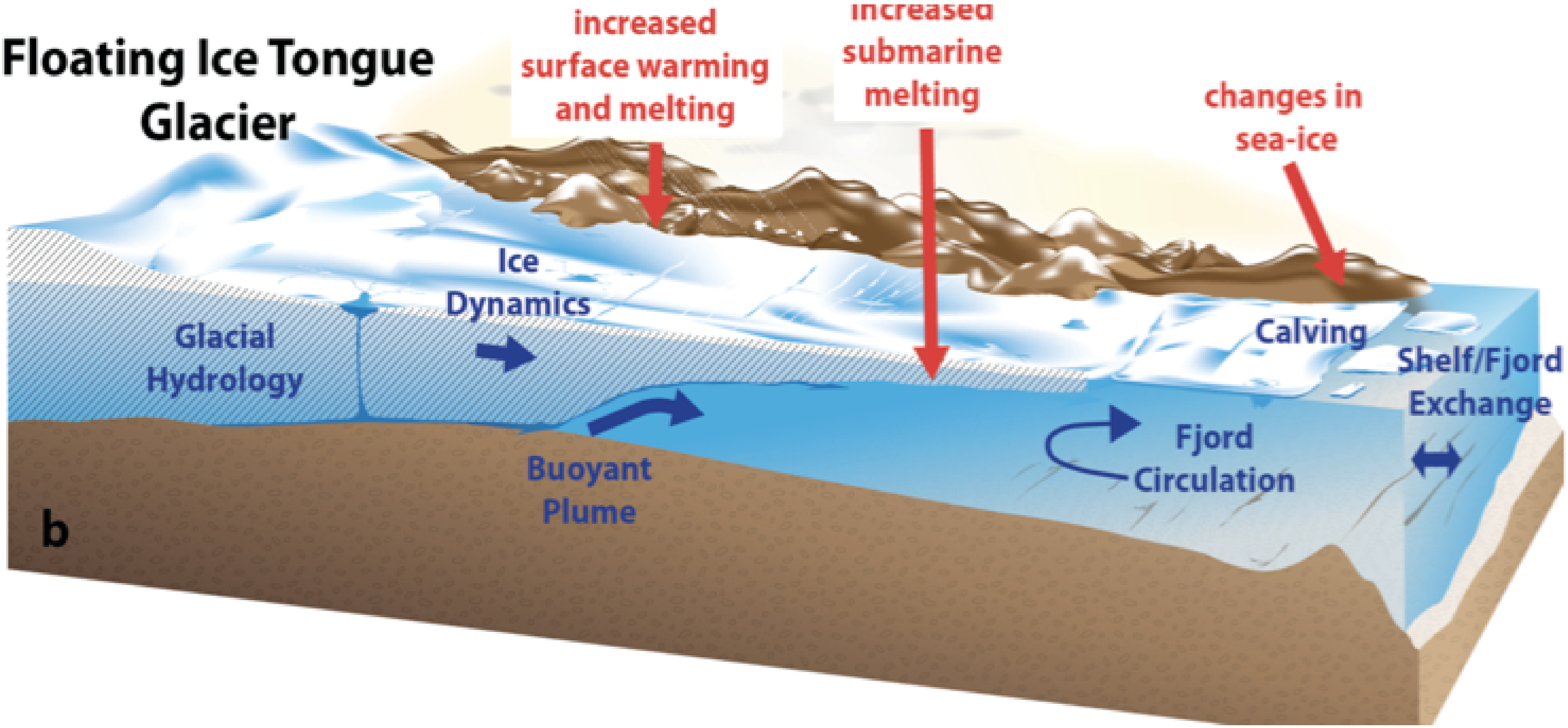
II. Long-term Monitoring of Key Systems in Greenland

III. Synthesis of the Results into Earth System Models

IV. Interagency and International Program Coordination

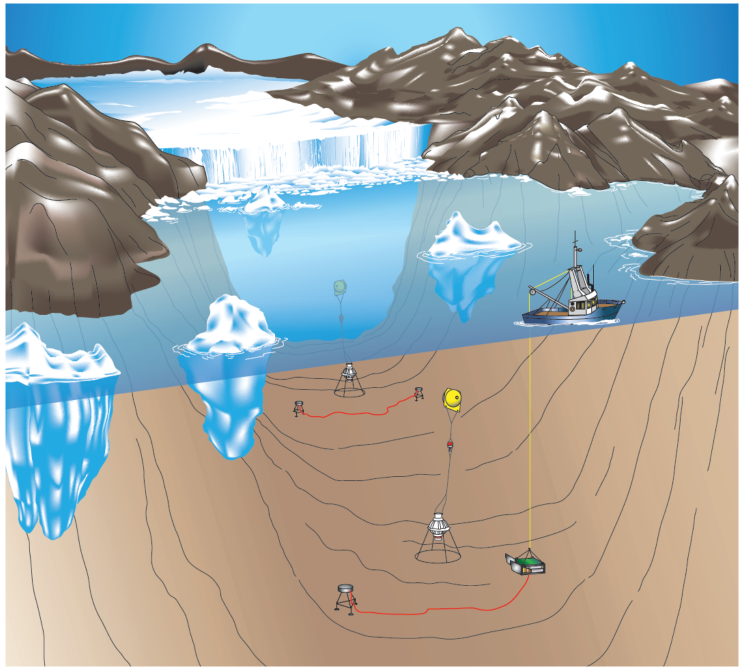
Process Studies Targeting Specific Dynamic Regimes

- Ice/ocean boundary layer and plume dynamics
- Fjord circulation and exchanges with the continental shelf
- Glacial hydrology
- Glacial dynamics
- Calving

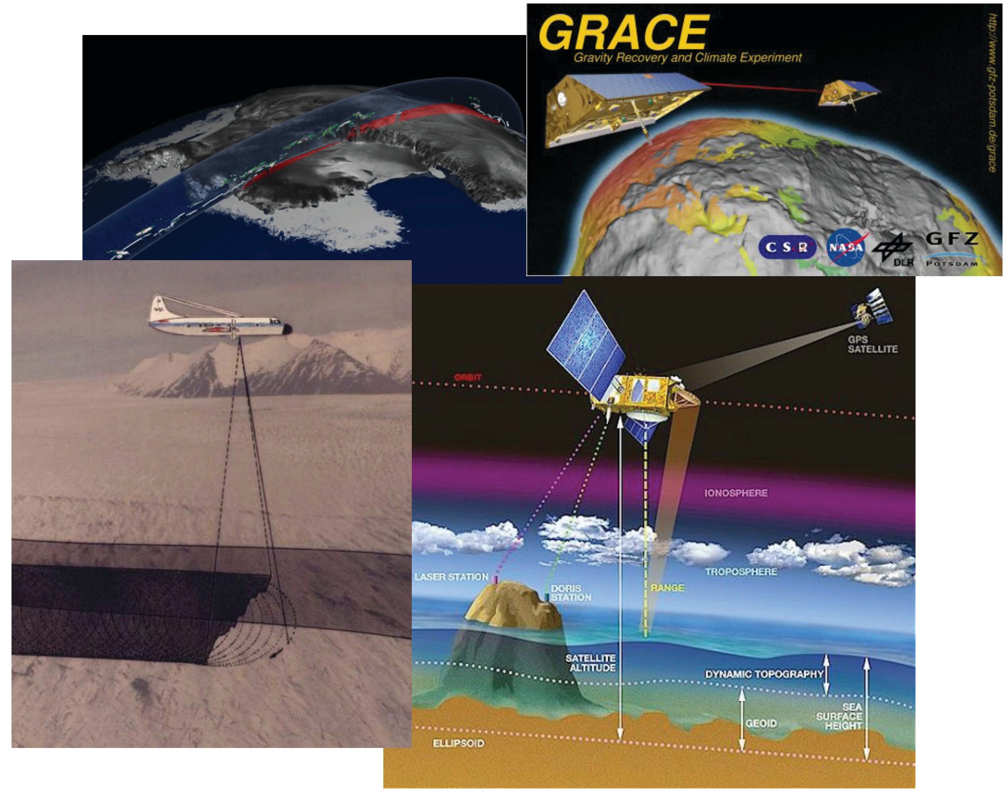


Long-term Monitoring of Key Systems in Greenland

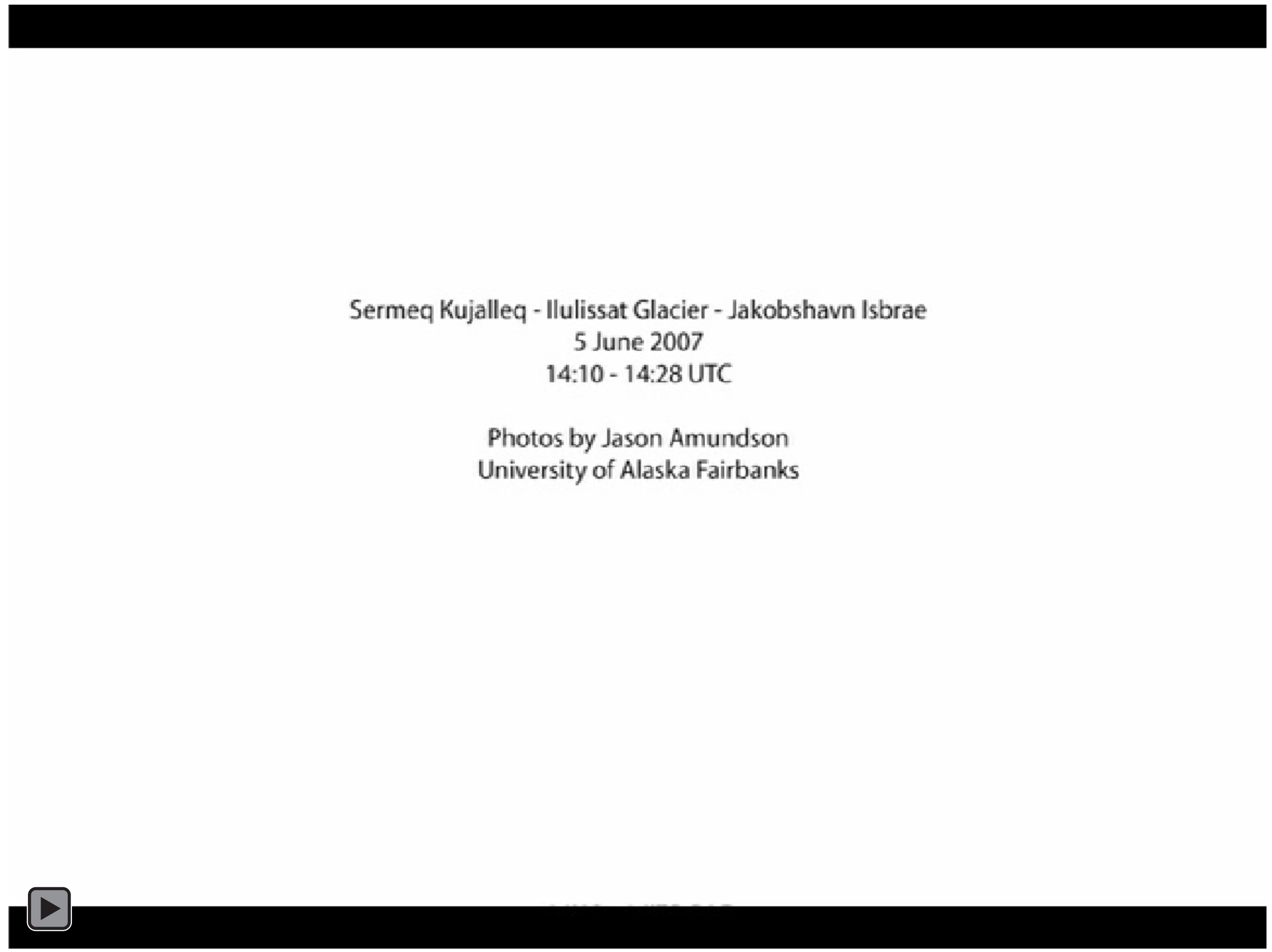
in situ



remote sensing



1. Oceanic basins
2. Range of glacier types
3. Proximity to oceanic monitoring sites
4. Proximity to atmospheric monitoring sites
5. Accessibility
6. Local synergy



http://www.gi.alaska.edu/~amundson/5june2007.mov

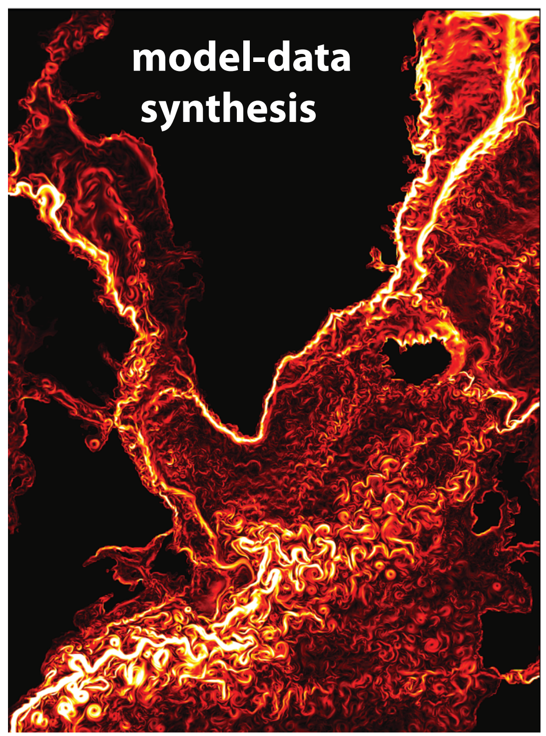
Synthesis of the Results into Earth System Models

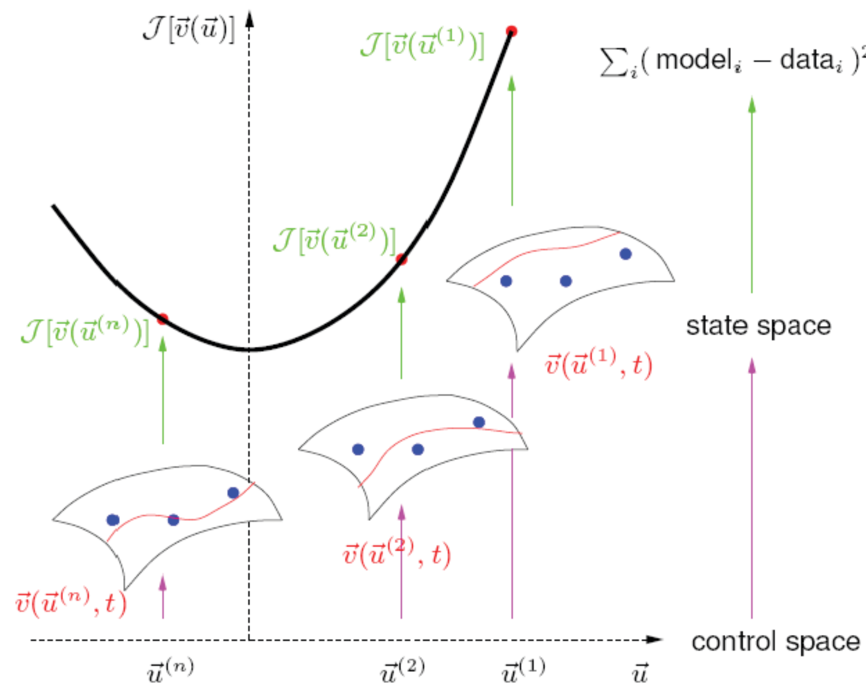
Physically based parameterizations of unresolved processes

Data assimilation and parameter optimization constrained by observations

Coupling of the various components of the Earth System Models

Model testing, analysis and intercomparison





Interagency and International Program Coordination

Creation of an international, community-based platform with specific focus on research in Greenland

Establishing connections with existing programs and committees
CLiC, AMAP/SWIPA, SeaRISE, AON/ADI, ARCUS, U.S. AMOC, SEARCH

Recomendations to the
Interagency Arctic Research Policy Committee (IARPC)

3.4 Understanding the causes of increased Arctic land ice mass loss, their connection to ocean and atmospheric variability, and implications for sea level

Lead Authors: ...

Agency Partners: DoE, NASA, NOAA, NSF, ONR

Mass loss from Antarctica, the Greenland ice sheet (GrIS), and glaciers and ice caps (GICs) have increased rapidly since the mid-1990s. The combined loss from both polar ice sheets now accounts for one-third to one-half of sea level rise, roughly equally partitioned between the two [Cazenave and Llovel, 2010; Church et al., 2011; Rignot et al., 2011]. A further substantial contribution presently comes from Arctic glaciers and ice caps [Jacobs et al., 2012]. Geodetic measurements of continental uplift and Earth rotation support these observations [e.g., Jiang et al., 2010; Nerem and Wahr, 2011; Mitrovica and Wahr, 2011]. In the Arctic, the loss is due to increased surface melting and to the acceleration, retreat and thinning of marine terminating outlet glaciers in Greenland [van den Broeke et al., 2009] and Arctic tidewater glaciers [Arendt, 2011]. Despite the spatio-temporal complexity of the glacier's acceleration [Moon et al., 2012], a pattern of synchronous and widespread glacier retreat is discernible and its coincidence with a period of oceanic and atmospheric warming suggests a common climate driver. Evidence points to the marine margins of these glaciers as the region from which changes have propagated inland but the drivers and mechanisms behind the acceleration are still unclear [Vieli and Nick, 2011]. The significance of this dynamic response has only recently been appreciated and is not represented in current-generation ice sheet models [Little et al., 2007]. In the 2007 IPCC AR4 report, this shortcoming was identified as the largest source of uncertainty in sea level change projections [Lemke et al., 2007]. Current projection estimates vary by more than an order of magnitude [Pfeffer et al., 2008; Price et al., 2011]. In addition, the proximity of Greenland to the North Atlantic's dense water formation regions imply that an increasing discharge of freshwater from Greenland can potentially impact the large-scale overturning circulation of the North Atlantic [Dickson et al., 2008], a major player in the global oceanic heat transport, with far-reaching climatic implications. In summary, the mass drainage of Arctic land ice (from the GrIS and GICs) is a new and poorly understood problem with global implications [Milne et al., 2009].

Several recent reports have highlighted the importance of research into the causes of increased Arctic land ice mass loss. They include:

- the *ACIA - Arctic Climate Impact Assessment 2005* (chapter 6 by Walsh et al.; see http://www.acia.uaf.edu/),
- the 2009 report by the U.S. Climate Change Science Program and Subcommittee on Global Change Research on *Past Climate Variability and Change in the Arctic and at High Latitudes* (chapter 5 by Alley et al.; see http://www.climatescience.gov/Library/sap/sap1-2/final-report/default.htm),
- NOAA's *Arctic Report Card 2011* (chapter by Box et al.; see http://www.arctic.noaa.gov/reportcard),
- the Arctic Monitoring and Assessment Programme (AMAP) report 2011 on *Snow, Water, Ice and Permafrost in the Arctic (SWIPA): Climate Change and the Cryosphere* (chapter 8 by Dahl-Jensen et al.; see http://www.amap.no/swipa),
- the Science and Implementation Plan to NSF edited by Bindschadler, R.A., P.U. Clark, and D. Holland (2011) on *A Research Program for Projecting Future Sea-Level Rise from Land-Ice Loss* (see