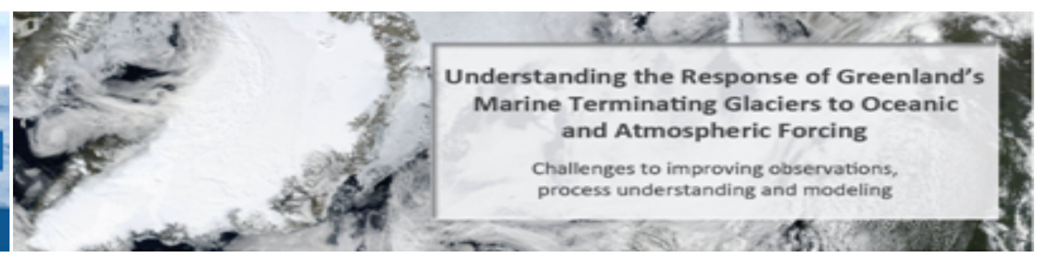
Staying Ahead of the Greenland Ice Sheet

Robert Bindschadler

CLIVAR-GRISO Workshop
June 4-7, 2013
Wylie Inn and Conference Center, Beverly MA



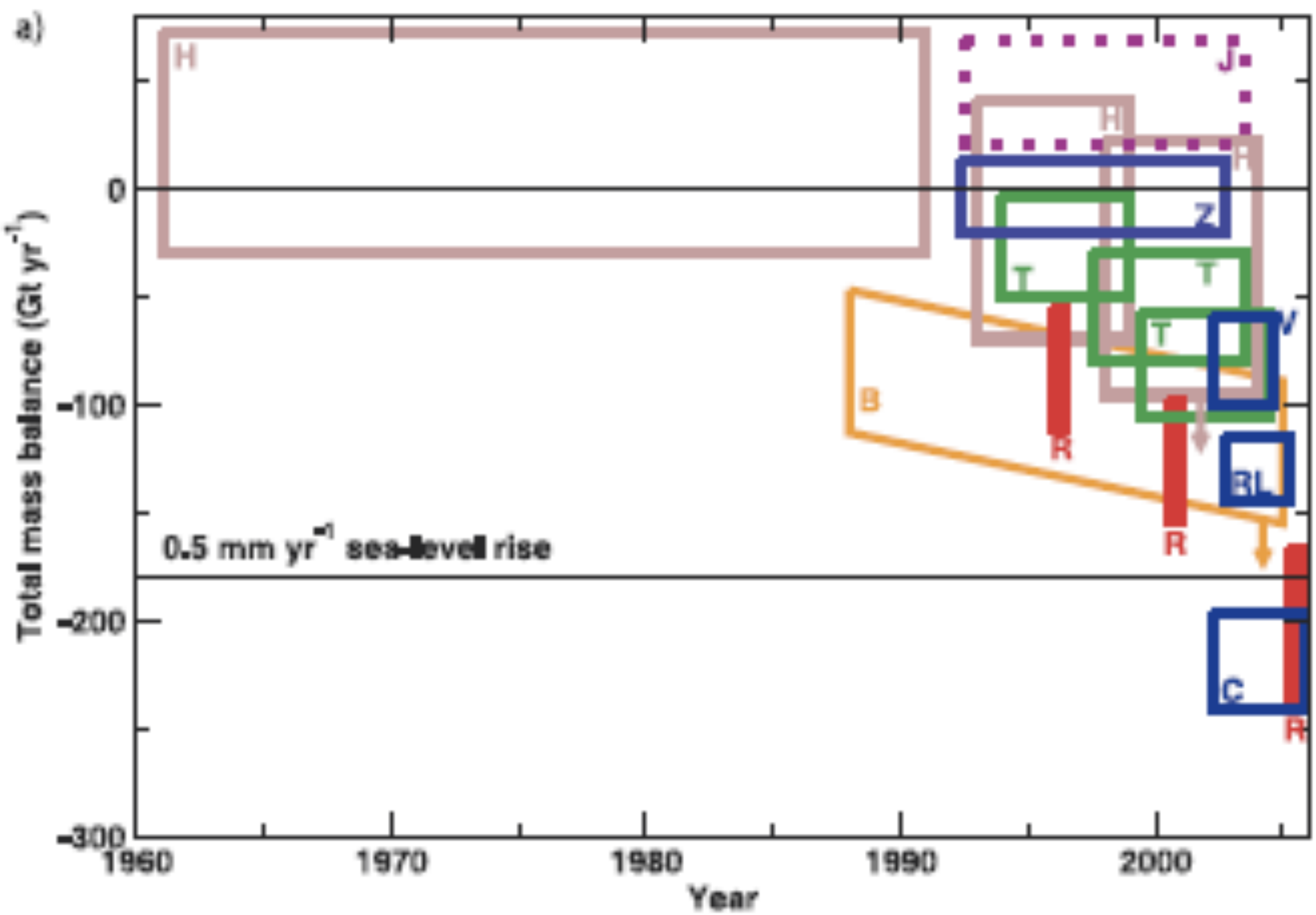
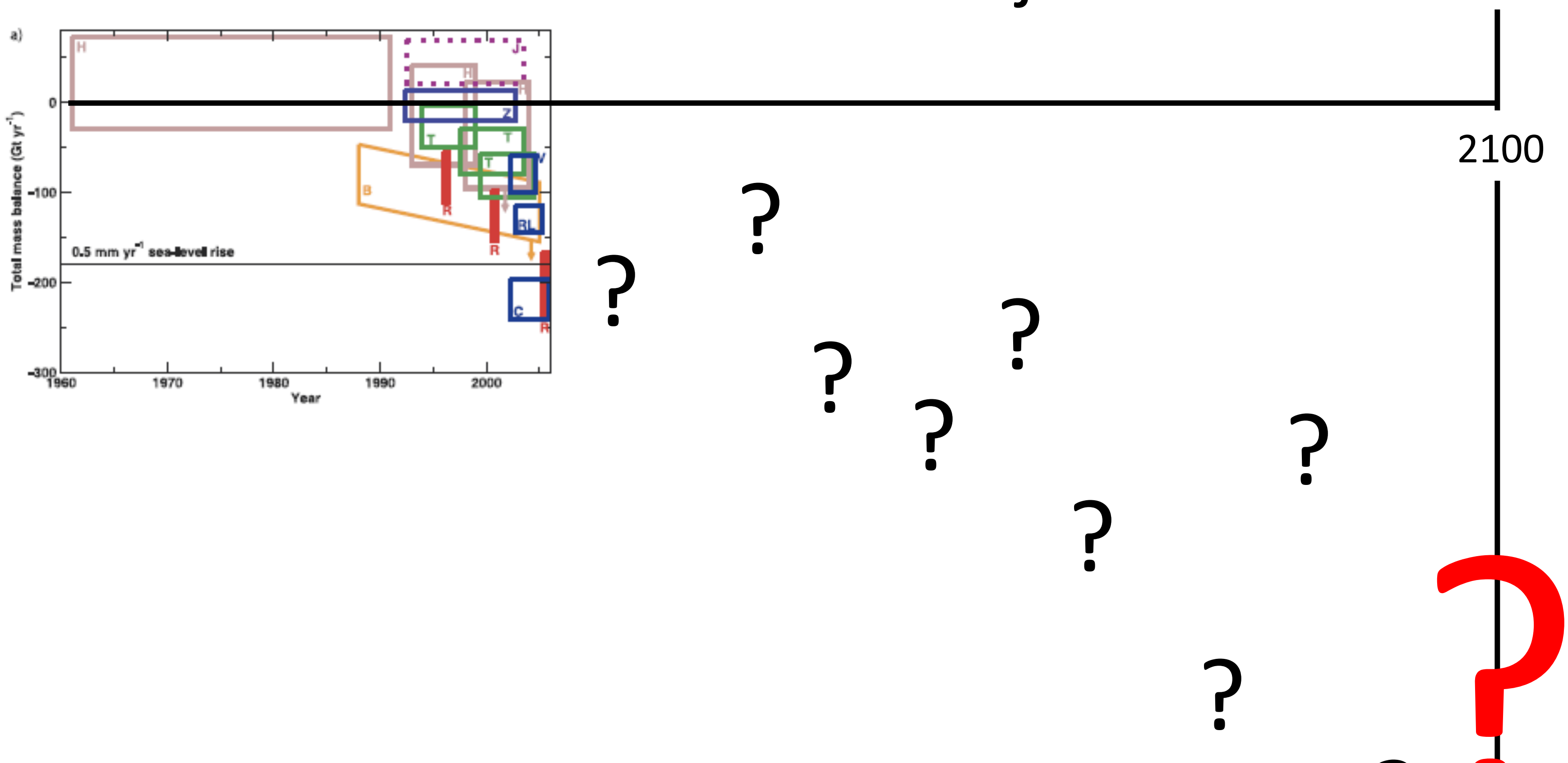


Figure 4.18a (IPCC AR4)

Observations Projections



This is applied
This is focused
This IS HARD!

Austin Post (1922-2012)

- Glaciological visionary
- First to identify “drastic retreat” mode of tidewater glaciers

Humility

- You are bright but…
- Our ideas are not always the most important
- You may not do the research laid out here

- Can we be sure of the “knowns”?
- Can we be as sure of the “need to knows”?

- The “new” is not always the “important”
- Balance ambition with feasibility

My message has been “ice sheets hate water”

- Albedo darkening
- Cryo-warming (ice softening)
- Basal lubrication
- Basal melting/ice-shelf thinning
- Hydro-fracturing/ice-shelf disintegrating

Must consider Spatial and Temporal Response Scales

- Surface Mass Balance Change
  - Driven by change in accumulation or surface melting
  - Local mass change is immediate
  - Regional mass change is gradual
- Rheological Change
  - Driven by change in ice strength
  - Local and regional mass changes are gradual
- Stress Field Change
  - Driven by change in calving, basal melt or lubrication
  - Local mass change is quick
  - Propagation is rapid on thick, fast-moving, low slope ice (i.e., outlet glaciers)
  - Regional mass change for slower ice is gradual

It's all about future sea-level (1)

- IPCC reports
  - 1990: Time scale of ice sheet response too long for ice sheets to matter
  - 1995: West Antarctic collapse mentioned as high-risk/low-probability event
  - 2001: Report ignored feedback emphasizing importance of rapid ice sheet dynamic response
  - 2007: Observed ice sheet dynamic response clearly identified as a major limitation to prediction of future sea level

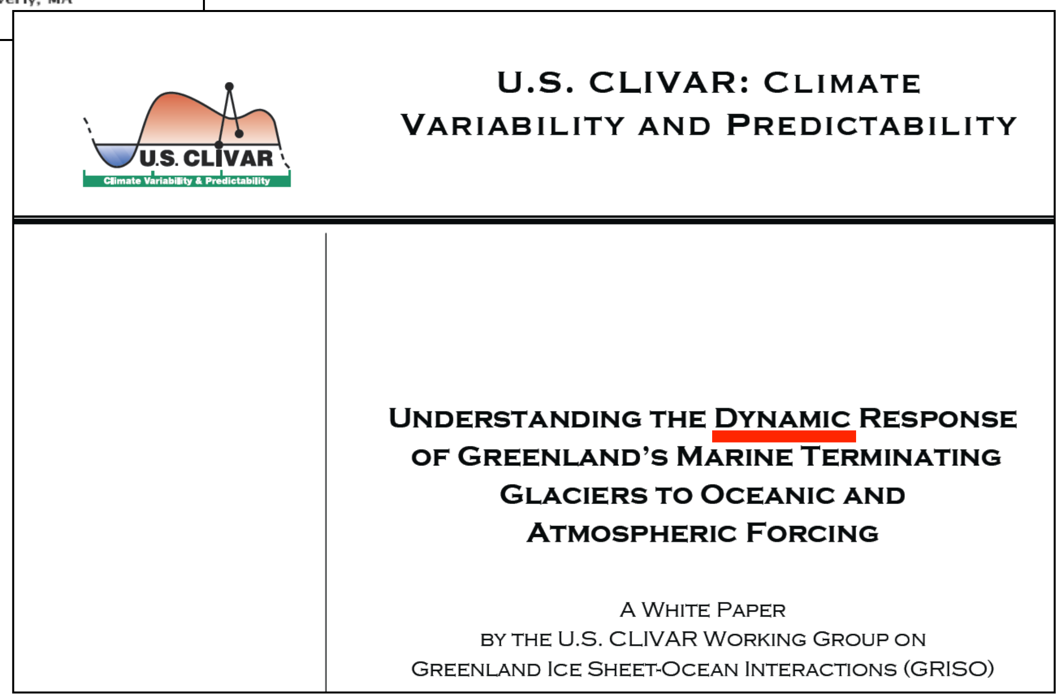
It's all about future sea-level (2)

- Greenland Surface Mass Balance (SMB) contribution
  - ~50% of mass loss from 2000-2008 (van den Broeke et al., 2009)
  - modeled "acceptably well"
- Dynamics contribution
  - not well modeled
  - Potential to vastly exceed SMB component
  - Is the largest unknown in future sea level contribution in a warming world

Are the most significant ice mass losses driven by dynamic response to intrusion of warm ocean water in tidewater glacier outlets?

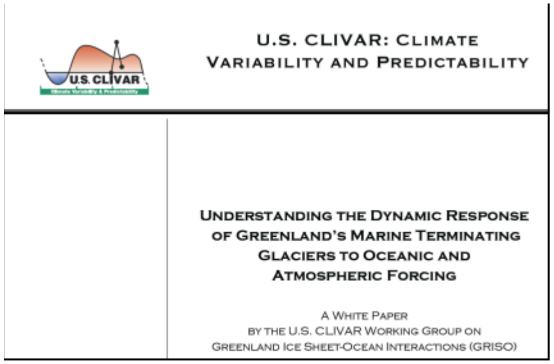
This workshop

Built on this white paper


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)



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Proposed Mechanisms and Forcings

i. Structural weakening of a floating ice tongue by thinning from excessive submarine melt [Motyka et al., 2011]

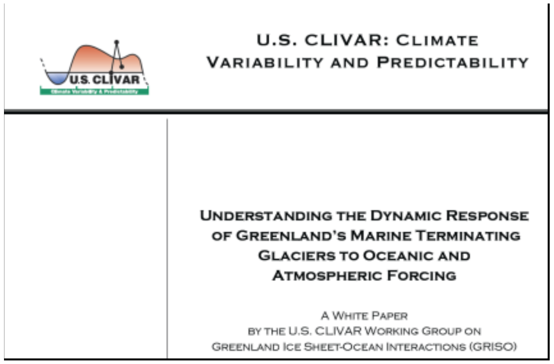
ii. Decrease in backpressure exerted by a thinning, decreasing ice mélange leading to increased calving [Joughin et al., 2008; Amundson et al., 2010; MacAyeal et al., 2012]

iii. Effects of the increased surface melting on the ice flow [Zwally et al., 2002; Joughin et al., 2008; see also Bell, 2008; Andersen et al., 2010; Hoffman et al., 2011]

iv. Effects of the subglacial hydrological systems on ice flow [Pfeffer, 2007; Schoof, 2010; Sundal et al., 2011]

v. Weakening of lateral shear margins due to cryo-hydrologic warming of subsurface ice [Phillips et al., 2010; van der Veen et al., 2011]

vi. Hydro-fracturing and calving of the floating tongues leading to reduced buttressing [Sohn et al., 1998; Post et al., 2011]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Three Triggering Mechanisms

1. Increased submarine melting a the ice/ocean interface (#i, #vi)
2. A reduction or weakening of the ice mélange in front of the glacier (#i, #ii)
3. Increased crevassing and reduced structural coherence and strength due to surface warming and increased surface melt (#iii, #iv, #v)

i. Structural weakening of a floating ice tongue by thinning from excessive submarine melt [Motyka et al., 2011]

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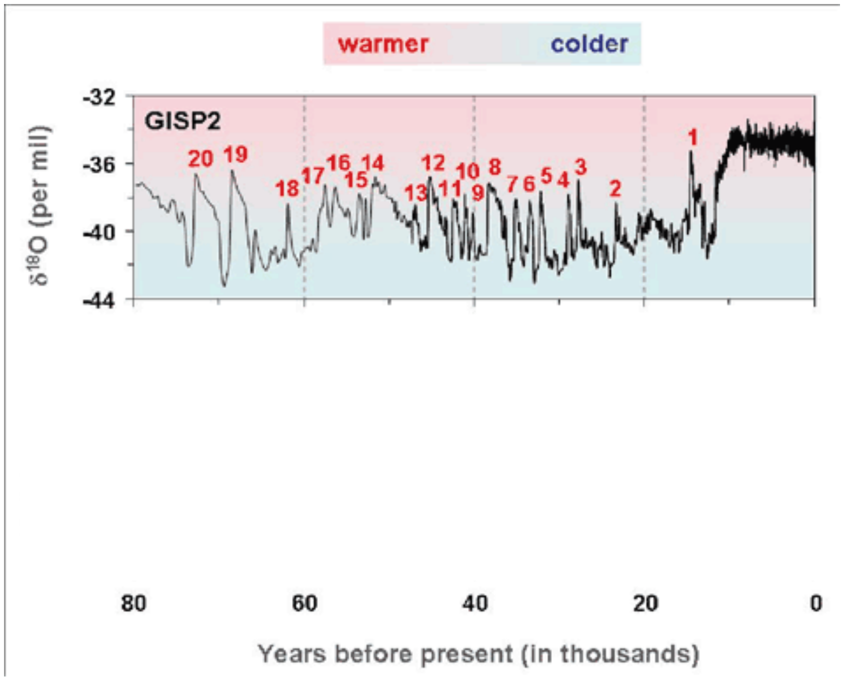
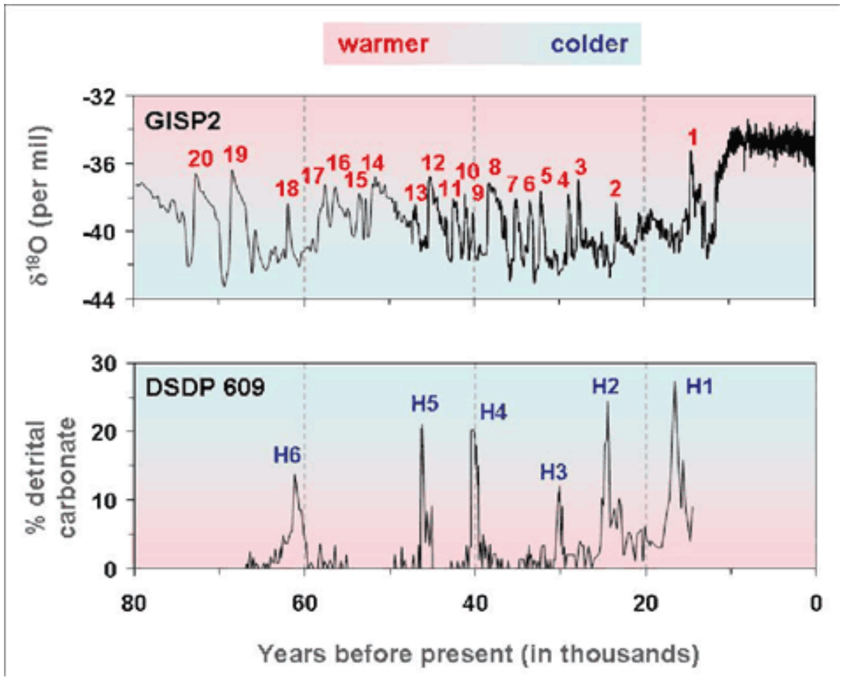
The Past



Dansgaard-Oeschger events:
Possibly caused by state change of thermohaline circulation

The Past



Dansgaard-Oeschger events:
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Heinrich events:
Cause uncertain but directly tied to a large mass loss of Greenland ice sheet

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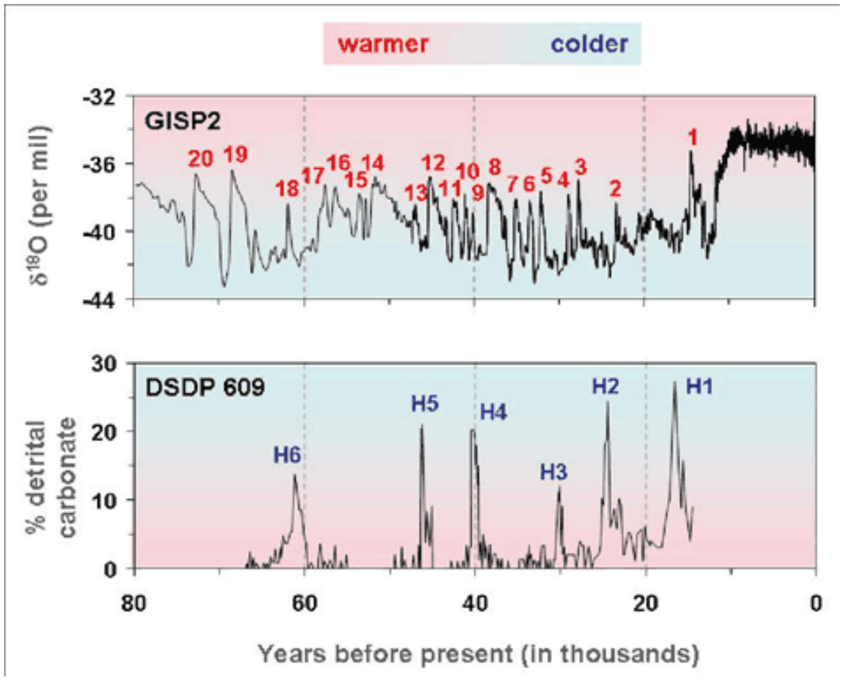

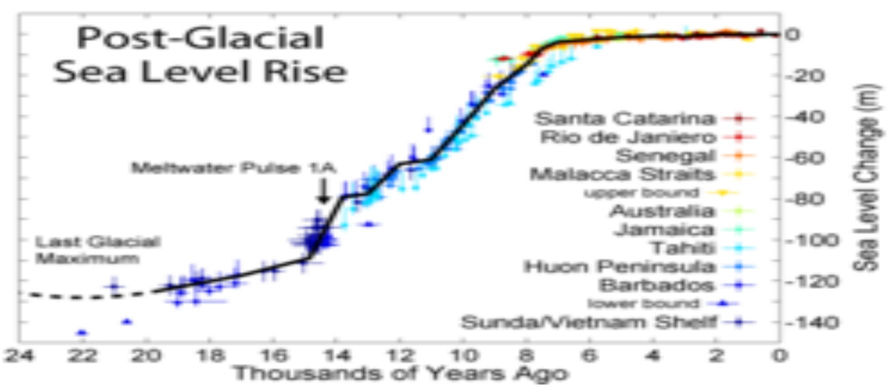

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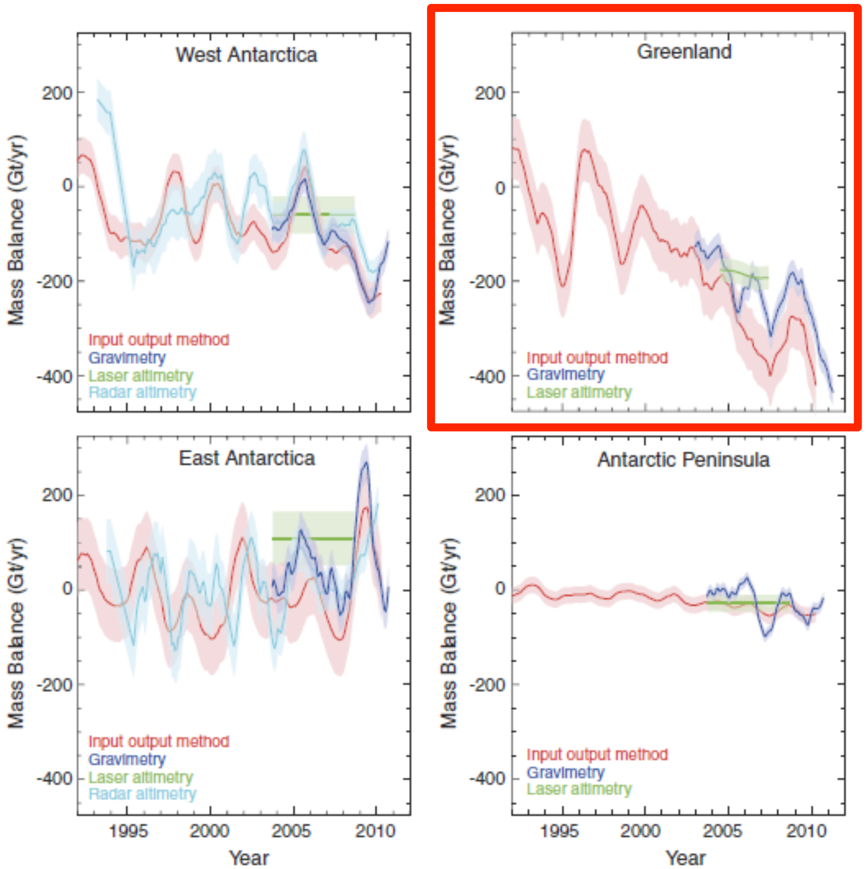
Meltwater Pulses:
Only large loss of land ice can explain sudden, large rise in sea level

The Present (observational period)



(Shepherd et al., *Science*, 2012)

Rate of Greenland ice mass loss:

1. Increasing
2. Variable in time

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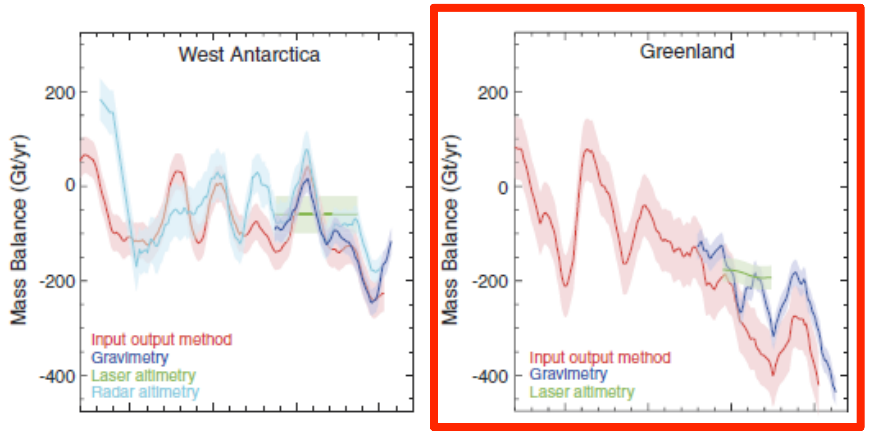

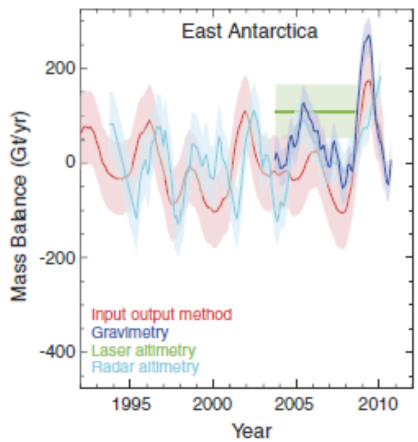

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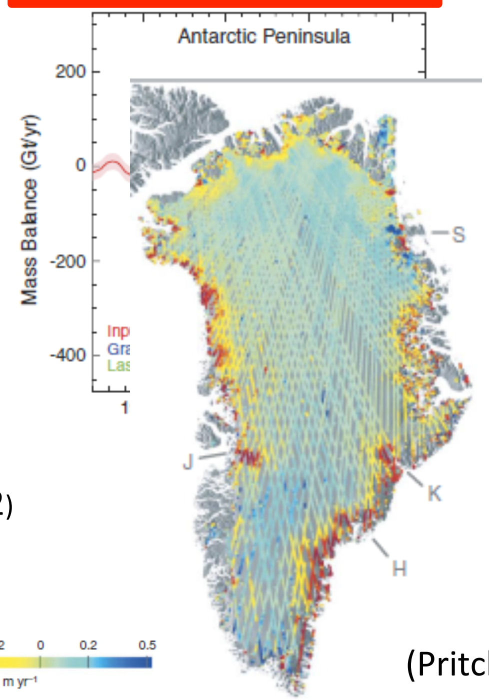
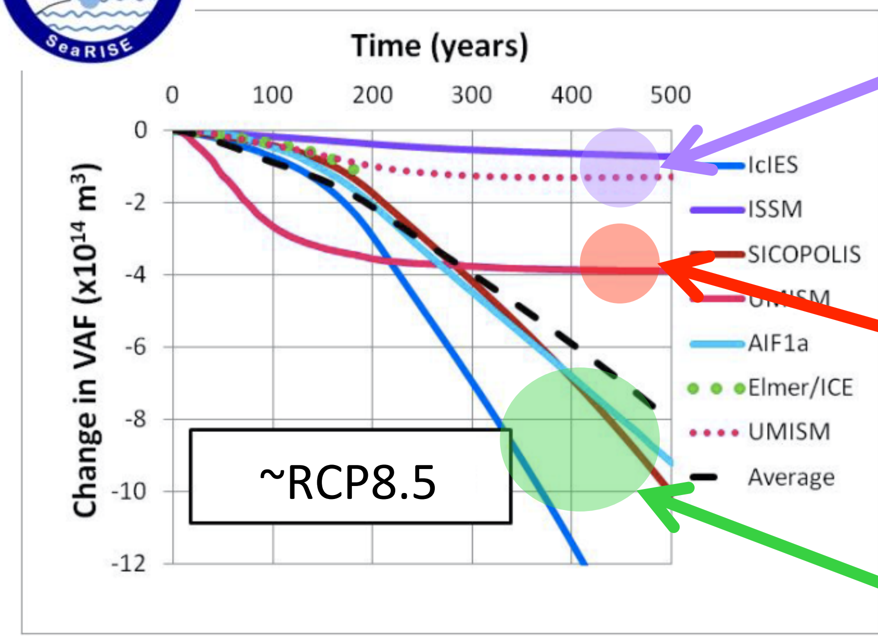


3. Variable in space

(Pritchard et al., Nature, 2009)

Seeking a predictable Future



Not sensitive at ocean-ice interface

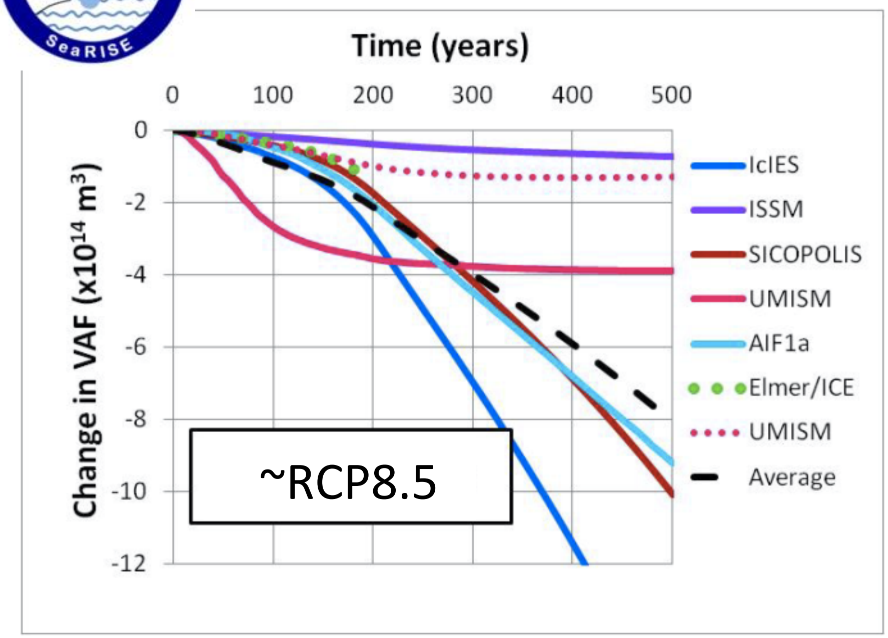
Very sensitive at ocean-ice interface

Modestly sensitive at ocean-ice interface

	2100			
	MIN	MEAN	MAX	
GREENLAND	4.50	22.3	66.3	cm

Volume Above Floatation (VAF)

Seeking a predictable Future



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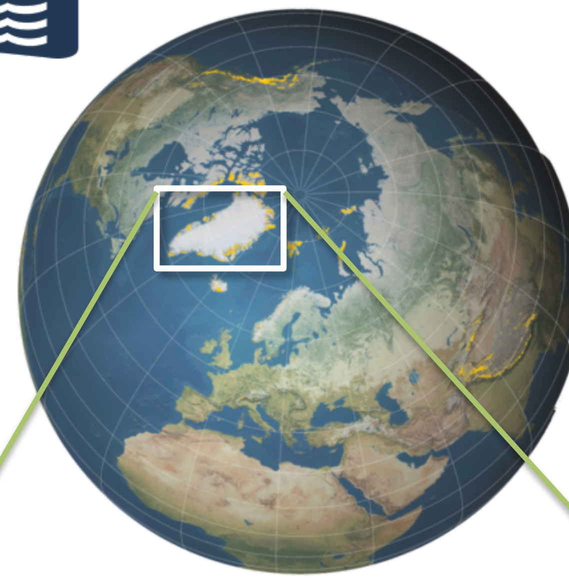
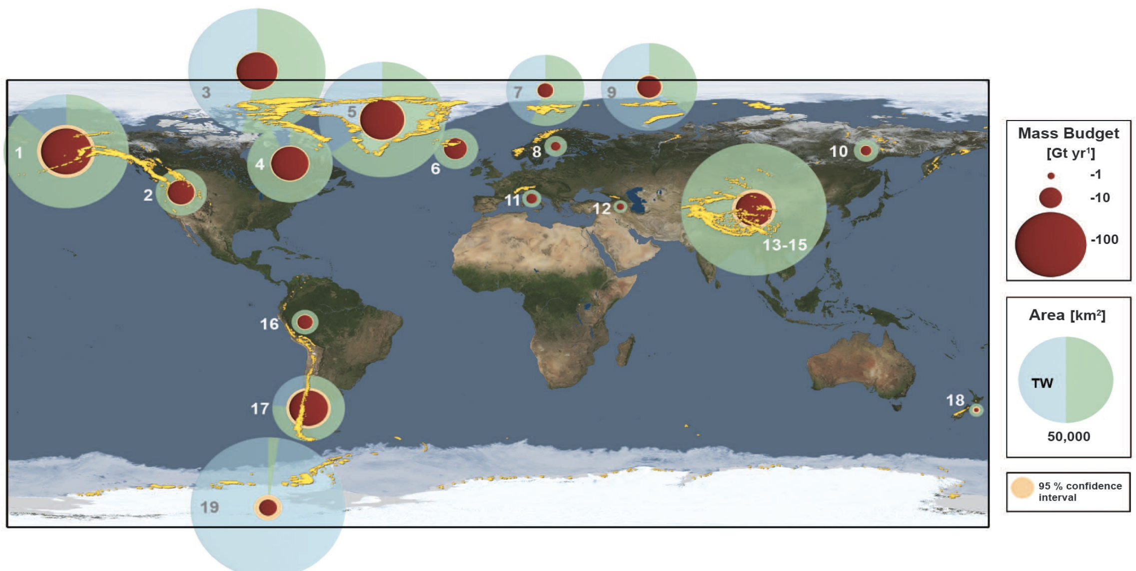
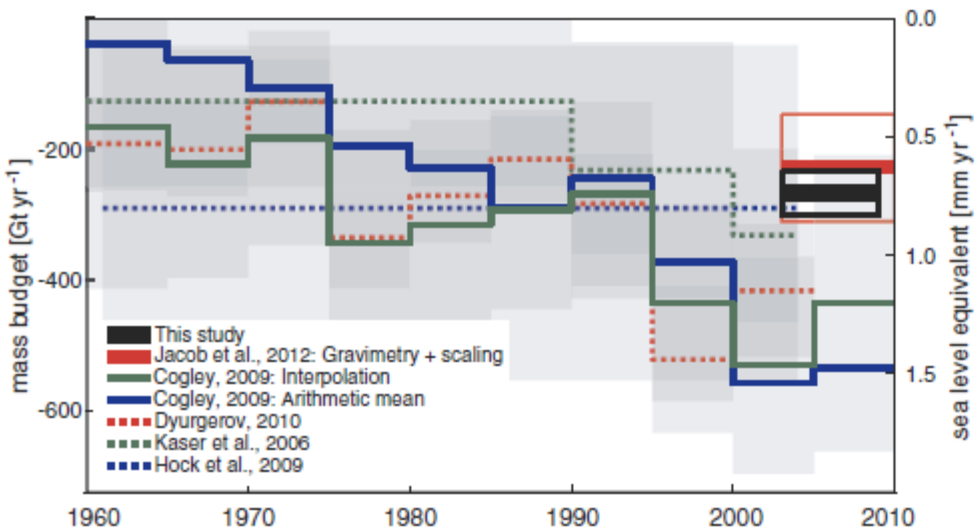


Ice2sea pub no.........Various
Area..........................Greenland ice sheet
Dominant process....Atmospheric and dynamics
Forcing.......................4x RCP Scenarios
SLR by 2100..............0.5 – 18.3 cm
Modelling by............VUB, ULB, CNRS, UL

Broader Relevance



Tidewater glacier discharge (blue portion of circles) responsible for substantial fraction of all land ice loss

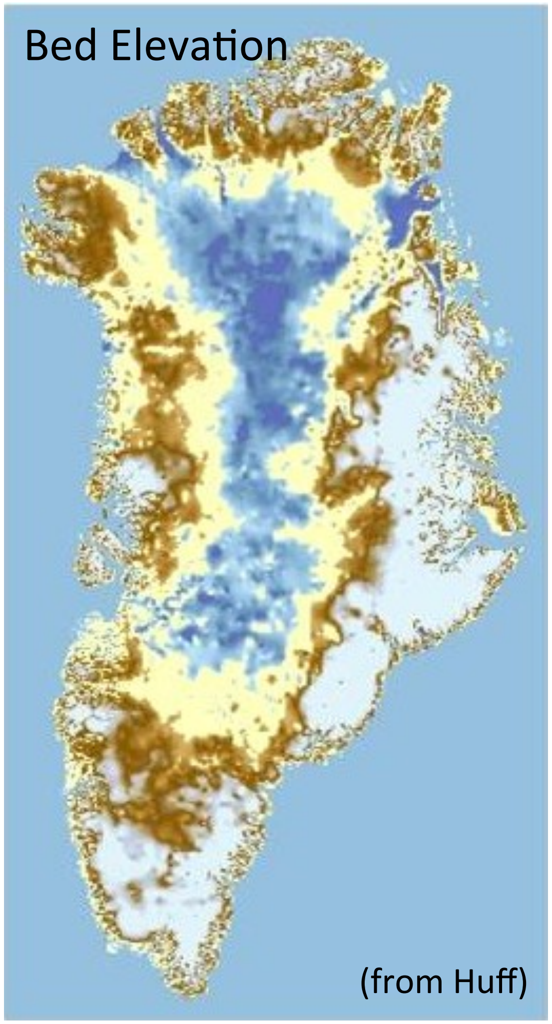


A Reconciled Estimate of Glacier Contributions to Sea Level Rise: 2003 to 2009

Alex S. Gardner,[1,2*] Geir Moholdt,[3] J. Graham Cogley,[4] Bert Wouters,[5,6] Anthony A. Arendt,[7] John Wahr,[5,8] Etienne Berthier,[9] Regine Hock,[7,10] W. Tad Pfeffer,[11] Georg Kaser,[12] Stefan R. M. Ligtenberg,[13] Tobias Bolch,[14,15] Martin J. Sharp,[16] Jon Ove Hagen,[17] Michiel R. van den Broeke,[13] Frank Paul[14]

(*Science*, 2013)

Limits are valuable

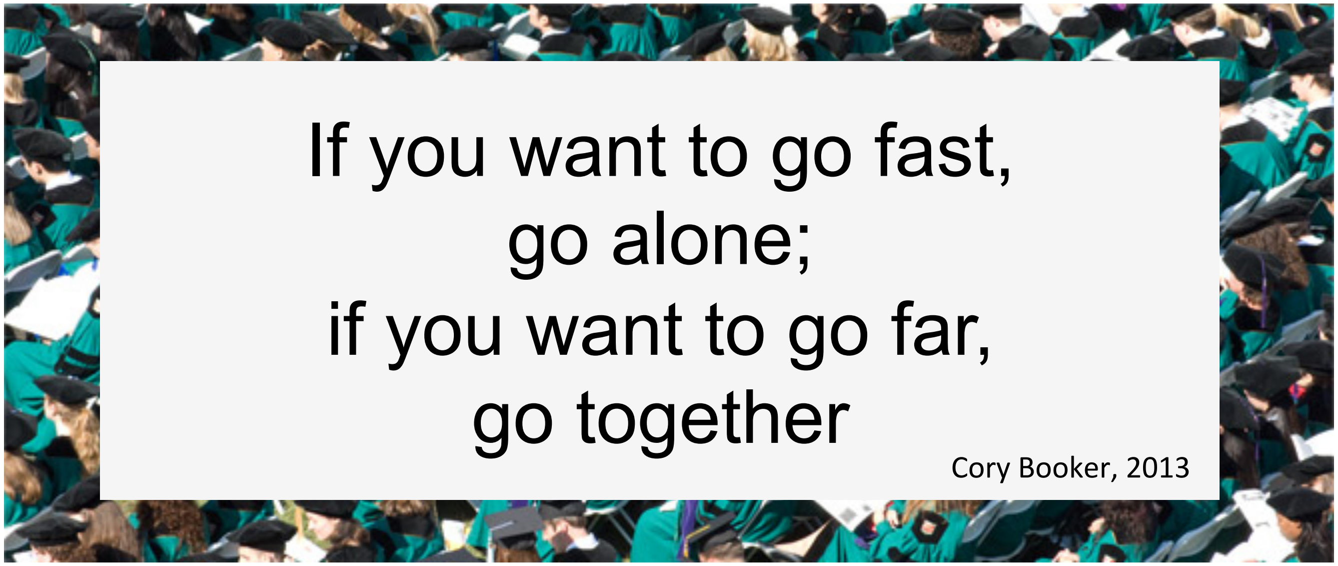


How much of Greenland is “ocean vulnerable?”

How fast can outlet glaciers deliver ice?

Do paleo-analogues work?

Washington University Commencement, May 17, 2013



- The present earth science research environment has become “highly-hyphenated”
- Disciplinary → Multi-disciplinary → Integrated
- Technological innovations have led to scientific discoveries
- Co-existence → Coordination → Cooperation → Collaboration

Other External Groups are listening

- SEARCH (Study of Environmental Change in the Arctic) and IASC
  - Goal #3 (of 4) Land-ice mass changes and future sea level
    - Near-term objectives focused studies of ocean-ice interaction at outlet glaciers
    - Working Group led by F. Straneo and T. Scambos
- IARPC (Interagency Arctic Research Policy Committee)
  - Chaired by OSTP
  - Members are funding agencies
  - 1 of 14 implementation teams focused on land ice (Land-ice and Land-ice observations: chaired by Bill Wiseman)

Humility (again)

- You are bright but…
- You are here to do community work

- Challenge each other to be sure of the "knowns", the "need to knows" and the strongest methods to use

- "New" is not always the same as "important"
- Balance ambition with feasibility

Thank you for your attention