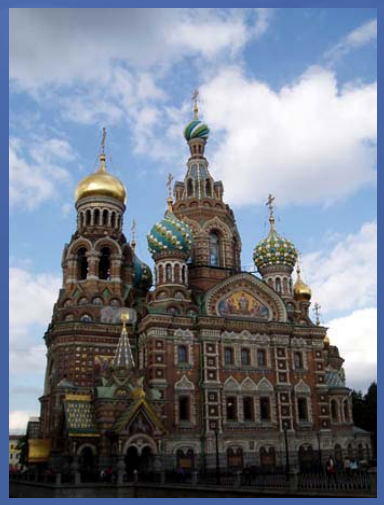
St. Petersburg and beyond



Kees van der Veen

University of Kansas

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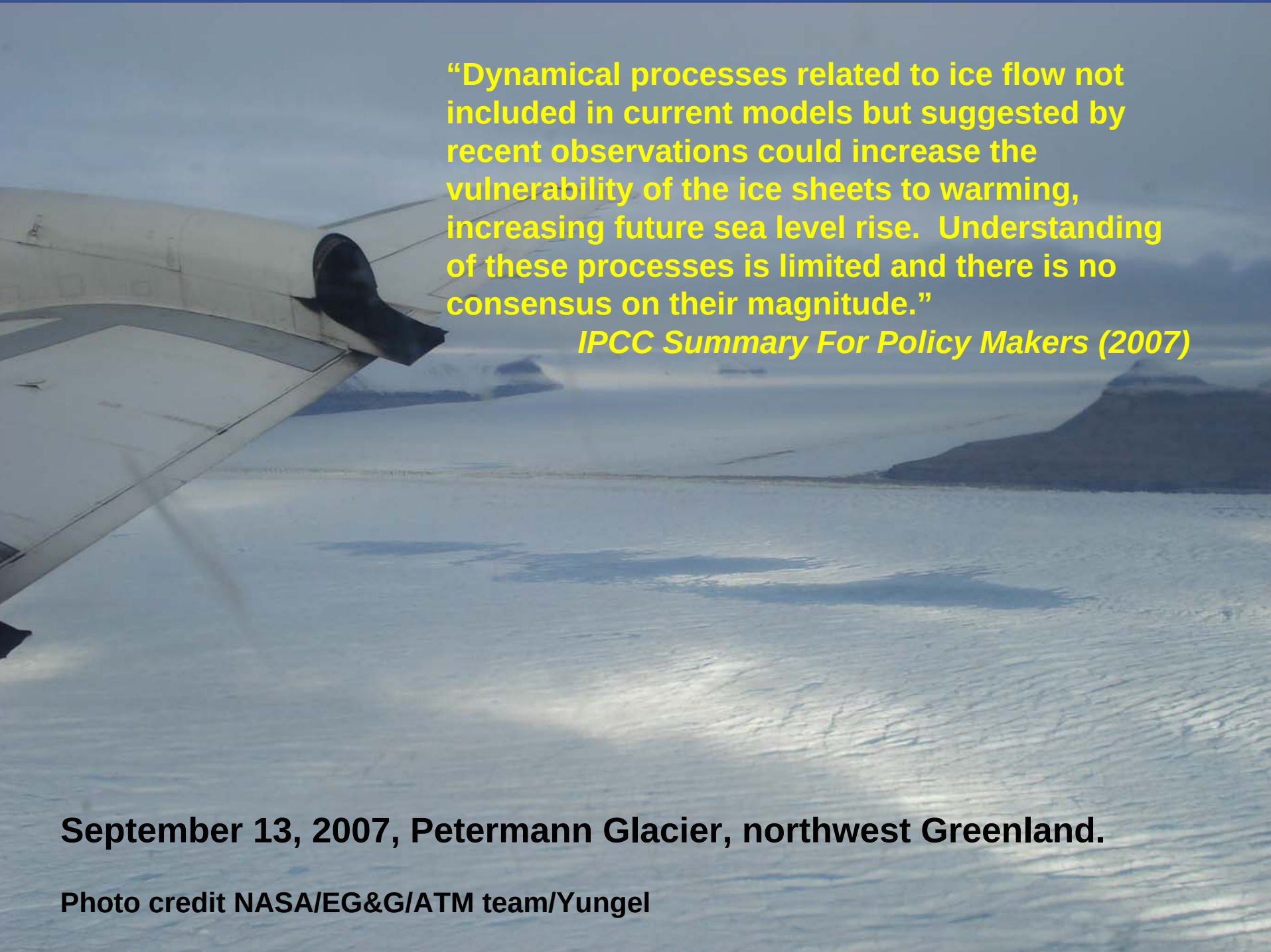


"Dynamical processes related to ice flow not included in current models but suggested by recent observations could increase the vulnerability of the ice sheets to warming, increasing future sea level rise. Understanding of these processes is limited and there is no consensus on their magnitude."

IPCC Summary For Policy Makers (2007)

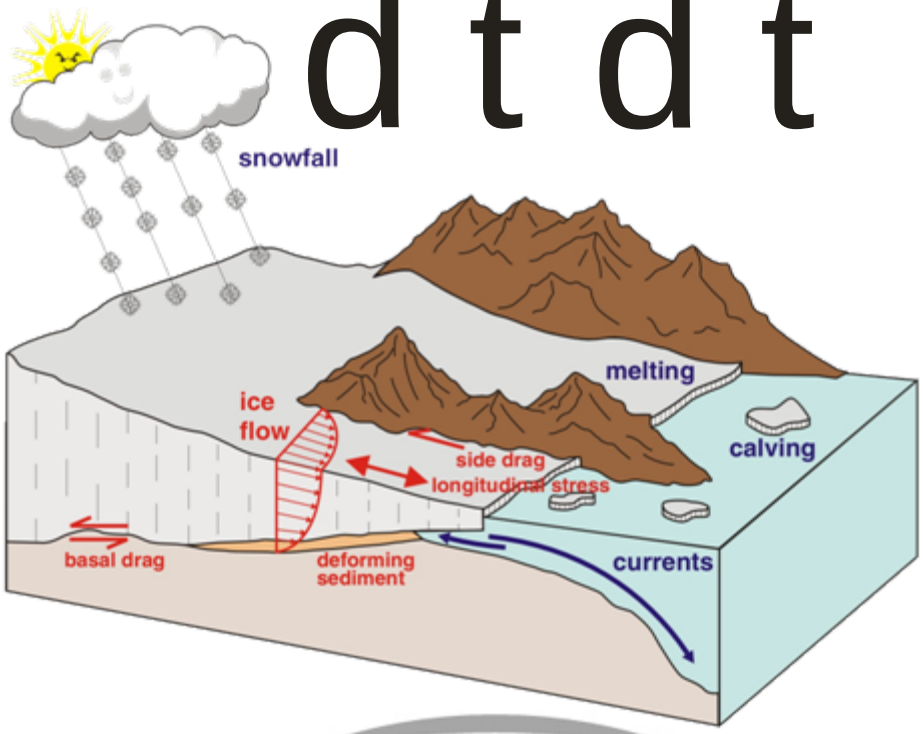
September 13, 2007, Petermann Glacier, northwest Greenland.

Photo credit NASA/EG&G/ATM team/Yungel

Challenges for Glaciologists

- Improve understanding of processes
- Develop quantitative prognostic models
- Incorporate small-scale processes into whole ice-sheet models

$$\frac{d}{dt}\ \frac{d}{dt}$$



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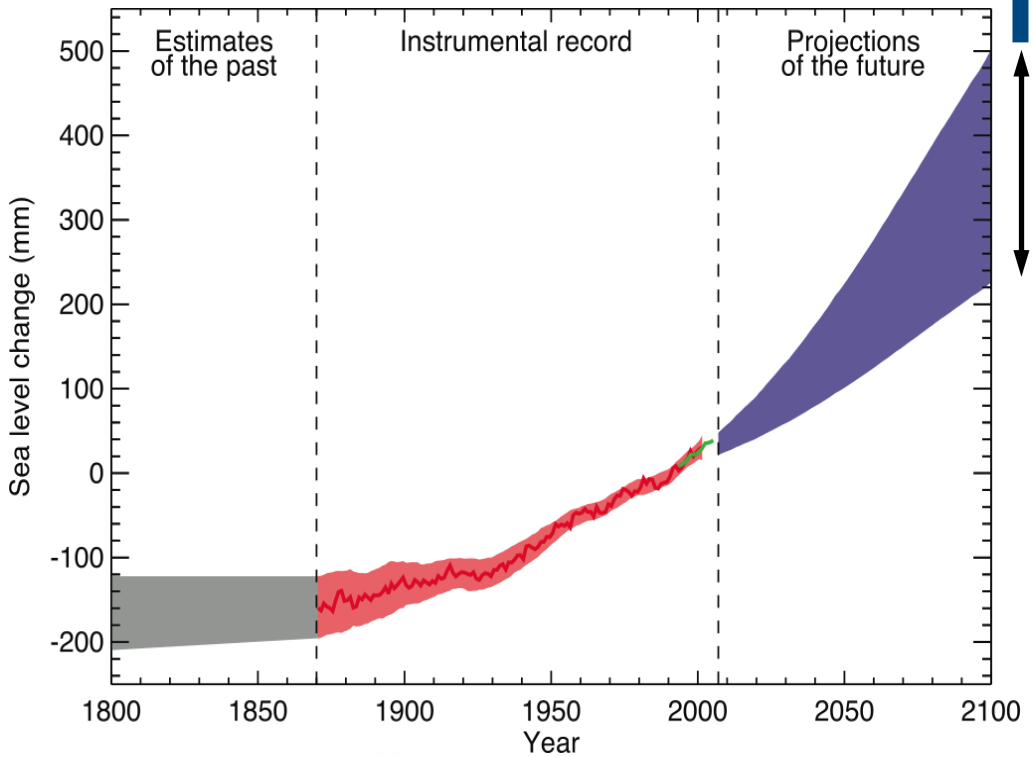
Focus on the important question!



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18-59 cm

CReSIS

Addressing the IPCC AR4

International Council for Science

SCAR report No 30 November 2007

Contents

A Need For More Realistic Ice-Sheet Models

SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH

at the Scott Polar Research Institute, Cambridge, United Kingdom

This report is co-sponsored by

SCAR Report 30 November 2007

A NEED FOR MORE REALISTIC ICE-SHEET MODELS

C.J. van der Veen
Center for Remote Sensing of Ice Sheets and Department of Geography,
University of Kansas, Lawrence KS 66045

and

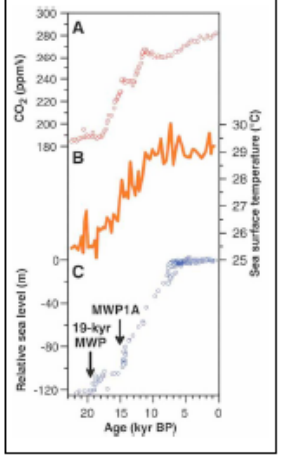
ISMASS Members

1. BACKGROUND

Over the past two decades or so, evidence for active ice sheets – both present-day and in the past – has mounted and the traditional view of ice masses responding sluggishly to external forcings has been replaced by the understanding that large ice sheets can undergo rapid changes. For example, analysis of deep-sea sediment cores has revealed major oscillations in the volume of the Laurentide Ice Sheet, believed to be associated with surges of the Hudson Bay lobe (e.g. Broecker, 1994). On a smaller scale, at the height of the Last Glacial Maximum (~17,000 years B.P.) the margin in the Great Lakes region of North America advanced and retreated over several hundreds of km within a short time span (Karrow and others, 2000). During meltwater pulse 1A, *ca.* 14,000 years B.P., sea level rose approximately 20 m over a period of some 400 years, at an average rate of 5 cm/yr (Klenast and others, 2003), compared to the rate of sea-level rise of 1-2 mm/yr during the 20th century (Church and Gregory, 2001). Such rapid changes cannot be explained by "conventional" models that have been used so far to simulate ice-sheet evolution. The majority of these models is based on the shallow-ice approximation in which the driving force is balanced by friction at the glacier bed. Allowance has been made for basal sliding where the bed is lubricated, or for deformation of a soft sediment layer. However, these models may

Box 1. Time series of key variables encompassing the last interval of significant global warming (last deglaciation). (A) Atmospheric CO_2 from Antarctic ice cores. (B) Sea surface temperature in the western equatorial Pacific based on Mg/Ca measured in planktonic foraminifera. (C) Relative sea level as derived from several sites far removed from the influence of former ice-sheet loading. MWP, meltwater pulse.

From: Alley and others (2005).



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November 2007

Workshop on

Improving Ice Sheet Models

St Petersburg, Russia
5-7 July, 2008

Conveners

- Andrey Glazovsky (IASC/WAG)
- Victoria Lytle (CReSIS)
- Konrad Steffen (WCRP/CliC)
- Cornelis van der Veen (SCAR/ISMASS)

Rationale

Recognising the importance of ice sheets in controlling global sea level, and the inadequacies in current efforts to model the disintegration of ice sheets in response to a warming climate, a Workshop is considered timely to **develop a community strategy** on how best to (i) **improve the physical understanding** of ice sheet processes responsible for rapid change; (ii) **incorporate** improved physical understanding **into numerical models**; (iii) assimilate appropriate **data** into the models **for calibration and validation**; and (iv) **develop prognostic whole ice-sheet models** that better incorporate non-linear ice-sheet response to environmental forcings (such as change in surface mass balance, loss of buttressing from floating ice shelves and ice tongues, and rising sea level).

Workshop objectives

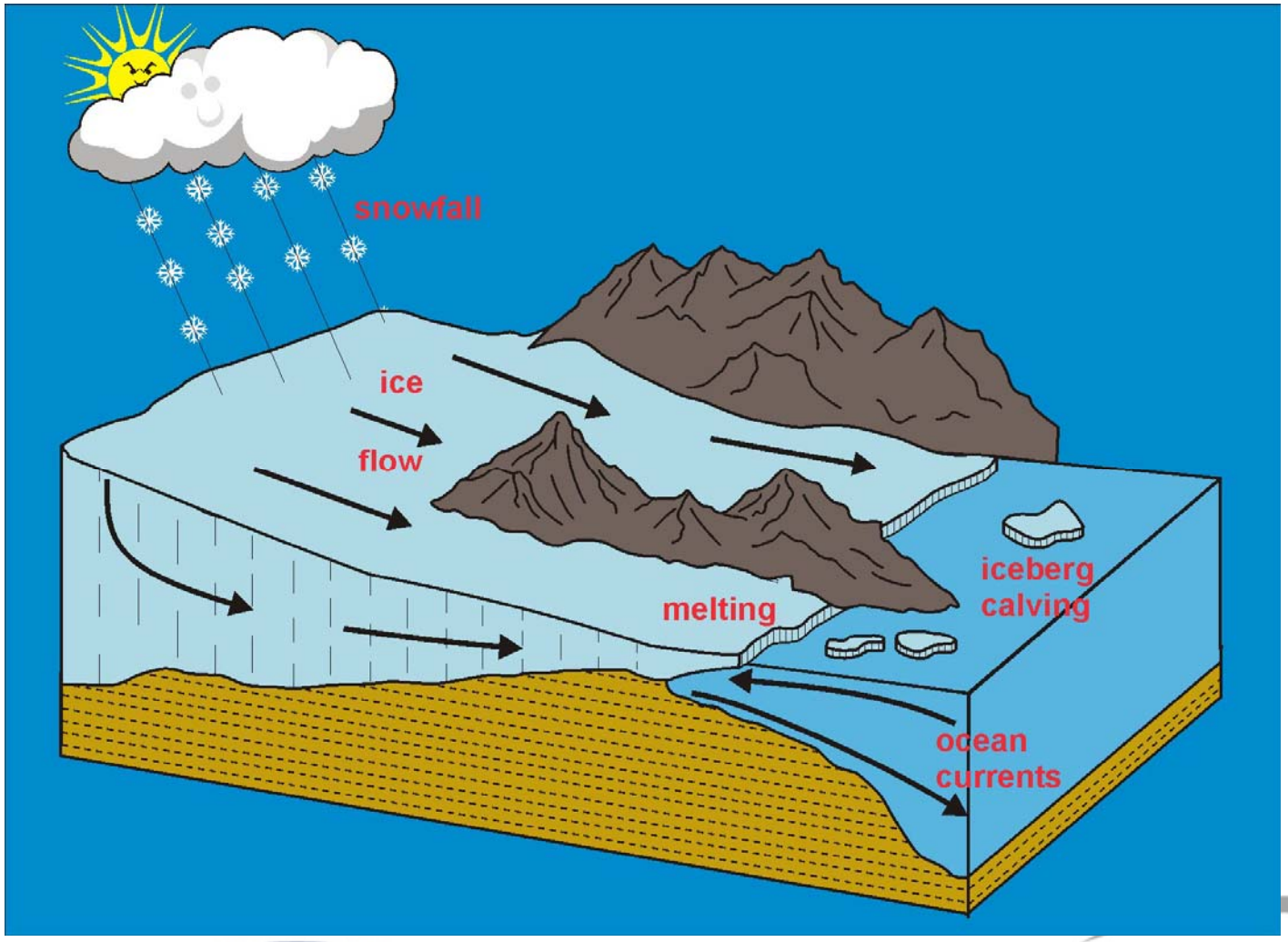
- Community Science Plan (5-10 yr)
  - Centuries time frame
  - Define overarching problems
  - Requirements
  - Timeline for solving stated problems

Not open ended: what can we achieve in 5-10 years?

Overarching questions

- Will climate change lead to irreversible (non-linear, rapid) ice sheet response?
- Do rapid changes lead to large mass changes?
- Are observed rapid ice-sheet changes “natural variability”, response to recent warming (ice shelf break up), basal switch?

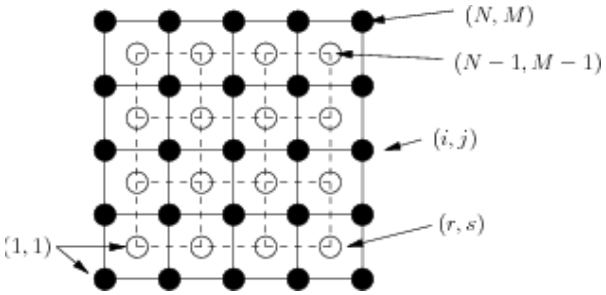
Integrated Approach

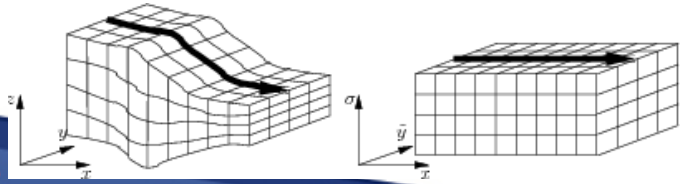


- **Englacial processes**
- **Surface forcing**
- **Basal conditions**
- **Marine margin**
- **Numerical issues**

High-resolution Full Stokes is not enough…..

- Yes, we can, and should (long-term objective)
- Remain aware of limitations
- Processes necessarily excluded
  - Shear margins
  - Subglacial valleys
  - Weak basal layers
  - …..
- Boundary conditions

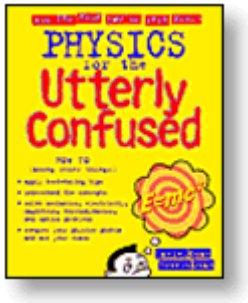




What ice-sheet models need (1)

Better understanding of physics

- What processes are important?
- On what scales should ice sheets be modeled?
- Acceptable parameterizations of physics
- …..



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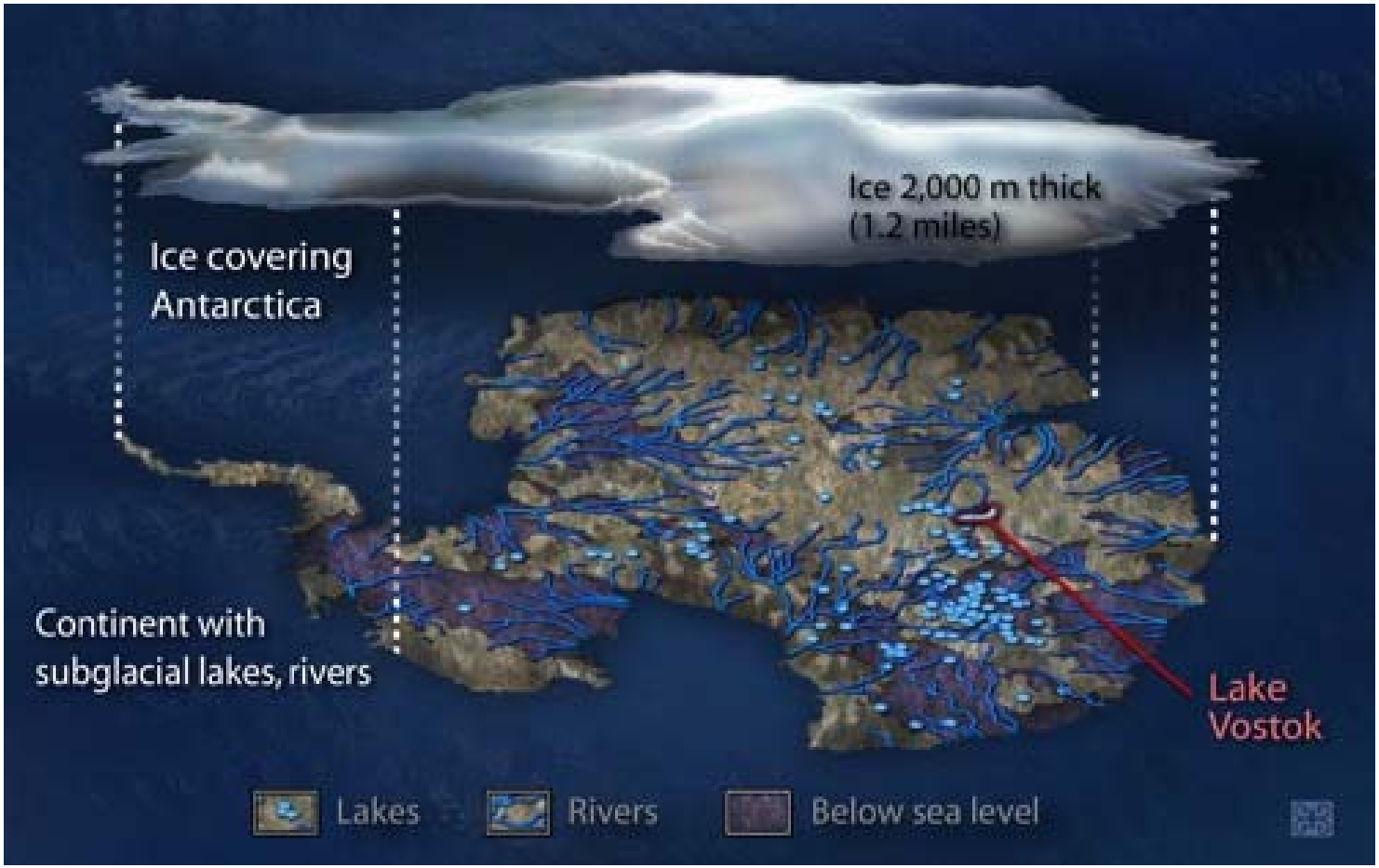
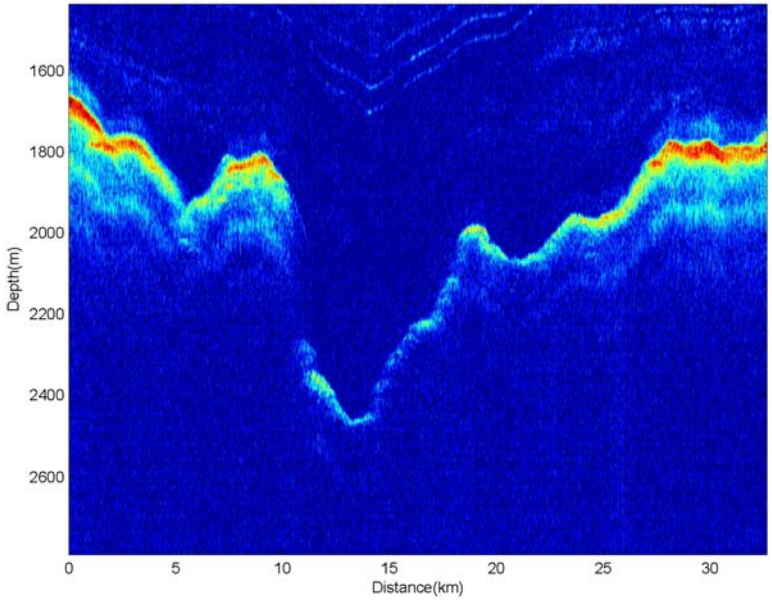
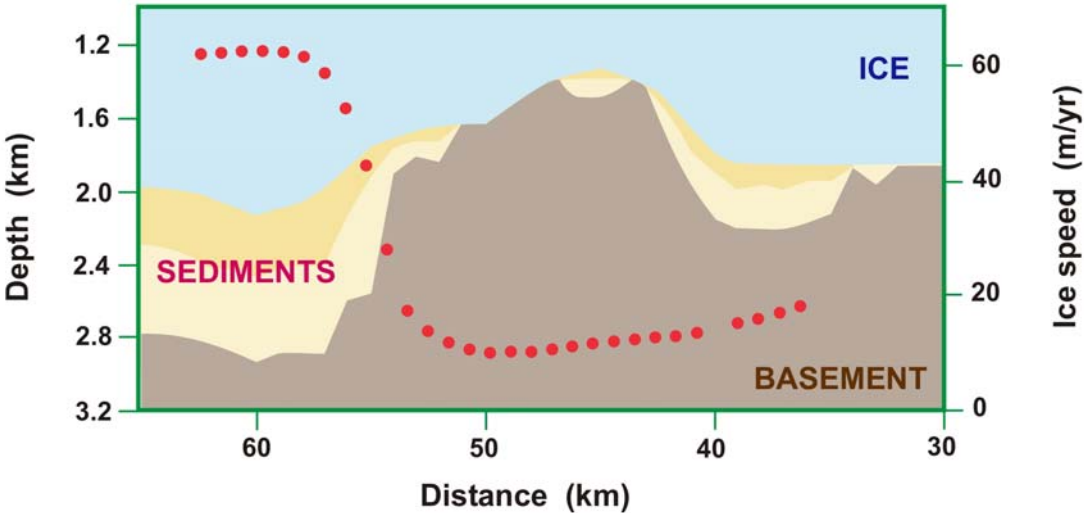
What happens under the ice?



Subglacial morphology

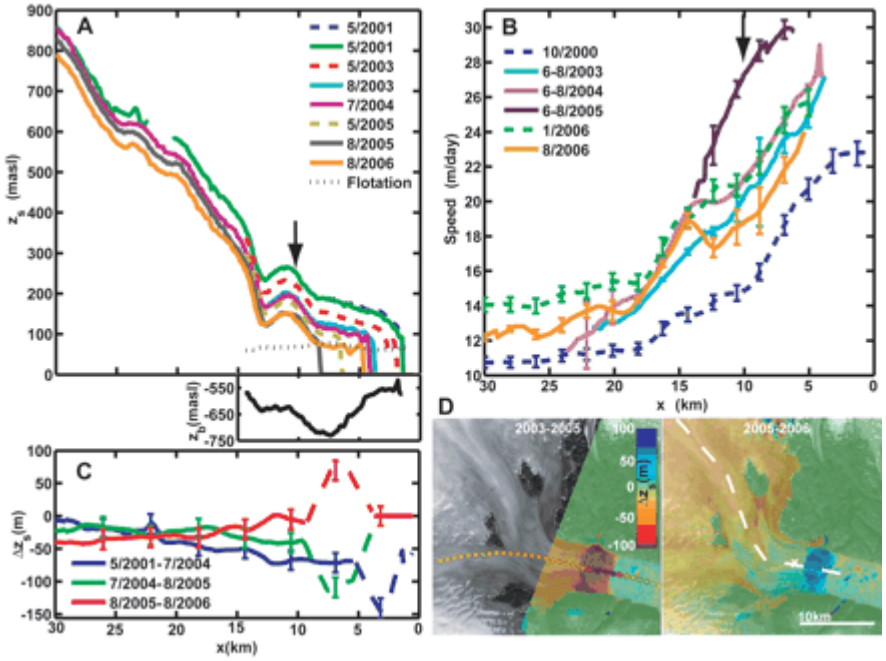
- Channels and trenches
- Sediment versus hard beds
- Geothermal heat flux
- Bed topography at grounding line



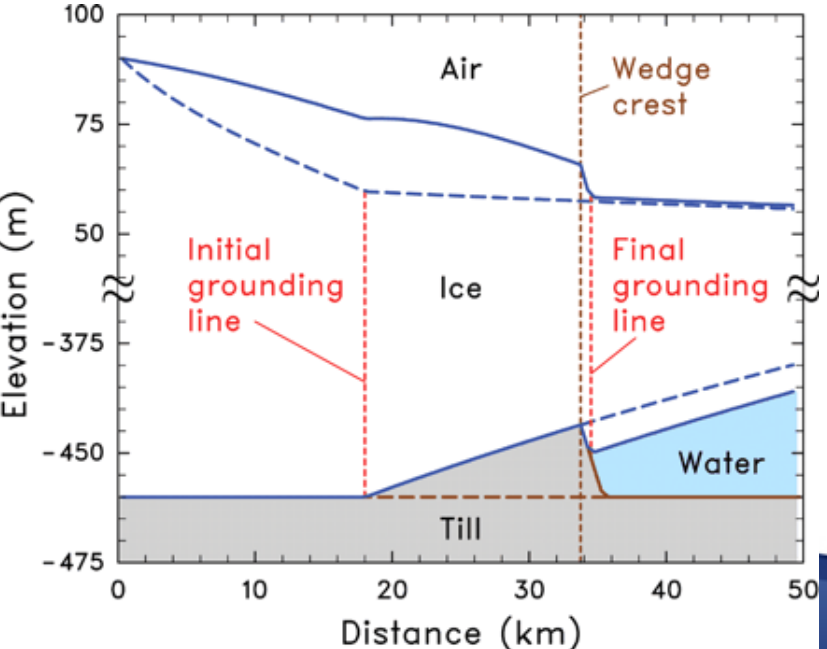


Grounding-line stability

- Topography of the bed
- Sediment deposition
- May be more important to include than Schoof's transition zone



(Howat et al., 2007)



(Alley et al., 2007)

What ice-sheet models need (2)

Bed topography

- Resolve small-scale topography

Geothermal heat flux

- Spatial variations

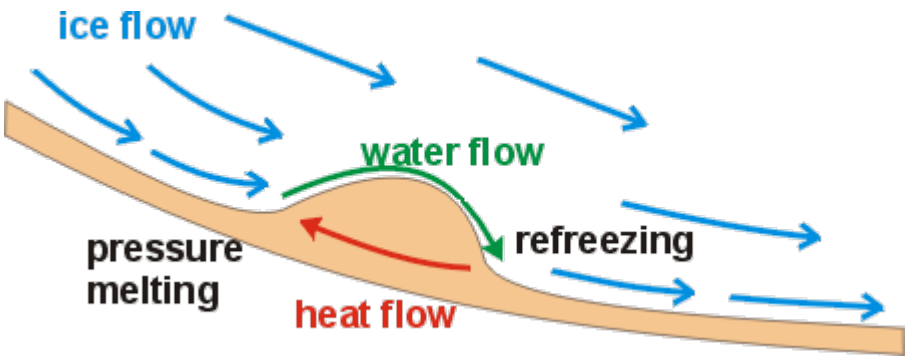
Subglacial hydrology

- Subglacial lakes
  - Water storage
  - Importance of drainage events
- Interaction of till and subglacial water
- Addition of supraglacial meltwater
- Subglacial water budget of different hydrologic systems
- Coupling to ice-flow model
  - Water transport and storage
  - Sediment production and transport

What ice-sheet models need (3)

Sliding relation

- Basal pressure
- Water storage
- Sediment strength
- …..



Ice shelves and other (near) floating peripherals

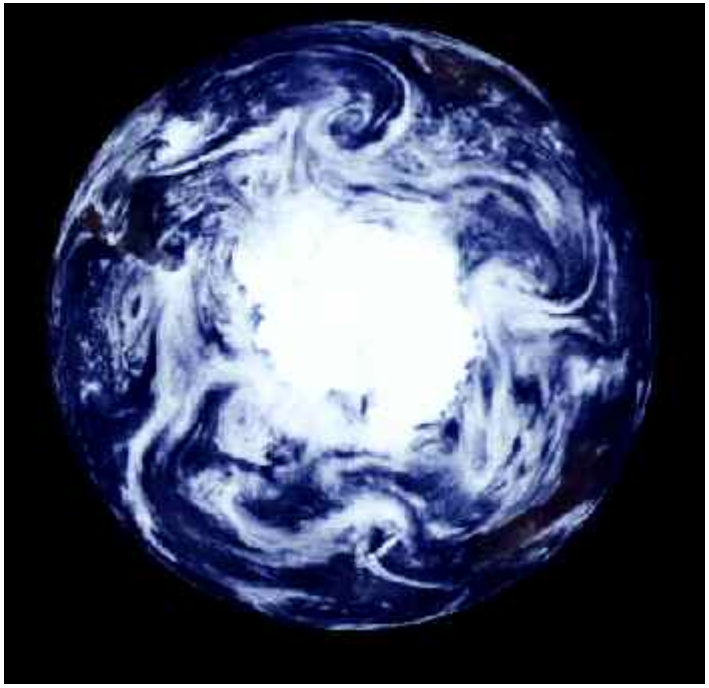
- Mechanisms for break up
- Role of sea ice
- Sub-shelf circulation and melting
- Restraints on interior ice?

What ice-sheet models need (4)

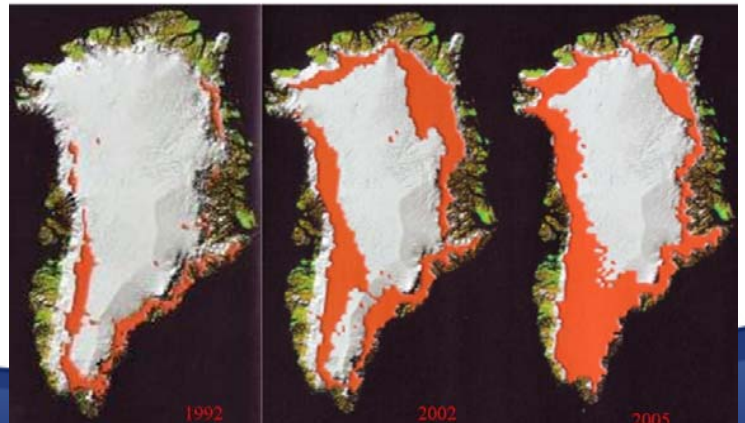
Calving “law” that works for all scales of icebergs and bits

Surface mass balance

- Accumulation
  - Predict changes over time
  - Coastal/slope areas
  - Drifting snow
- Ablation
  - Extent and duration
  - Runoff and percolation



Surface melting on Greenland is expanding

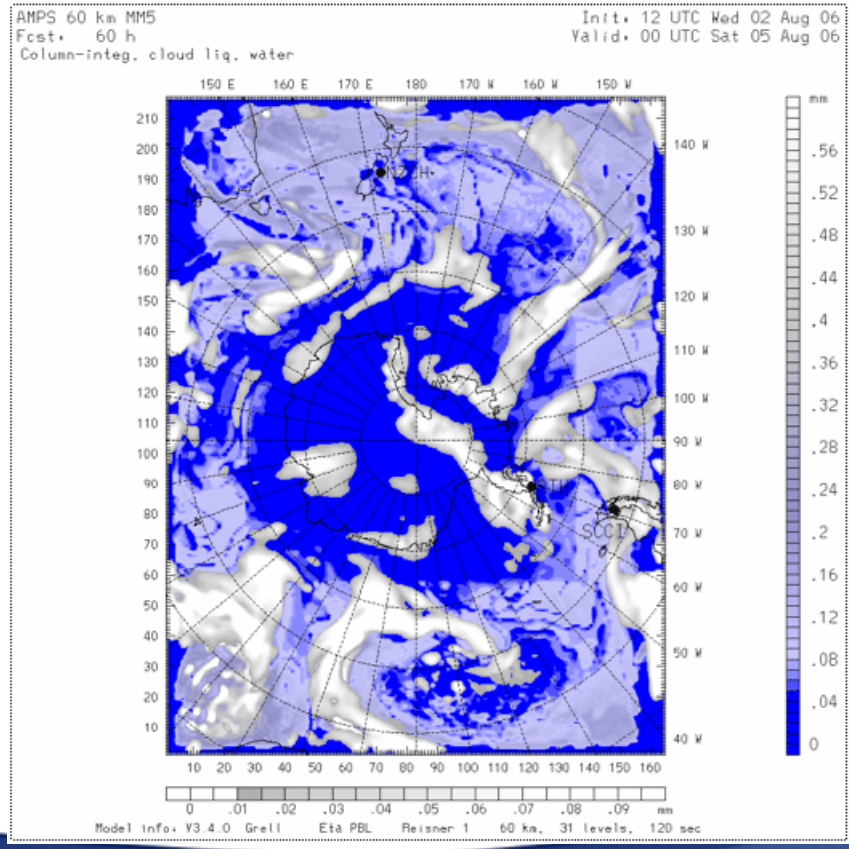


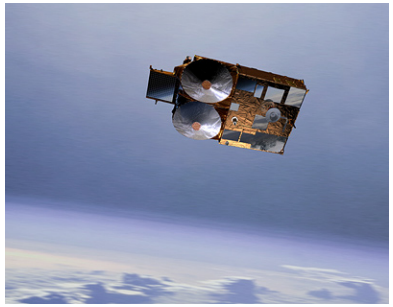
What ice-sheet models need (5)

Better meso-scale models for Greenland and Antarctica

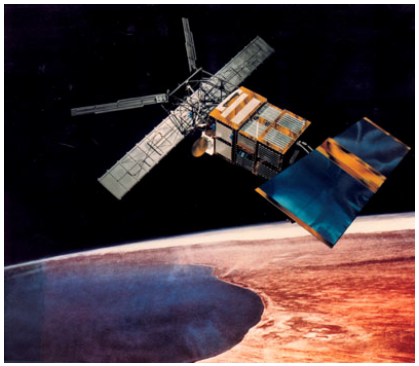
- Accumulation does not depends on temperature only
- Changing circulation patterns
- Effect of changing sea-ice cover
- Slope effects
- …..

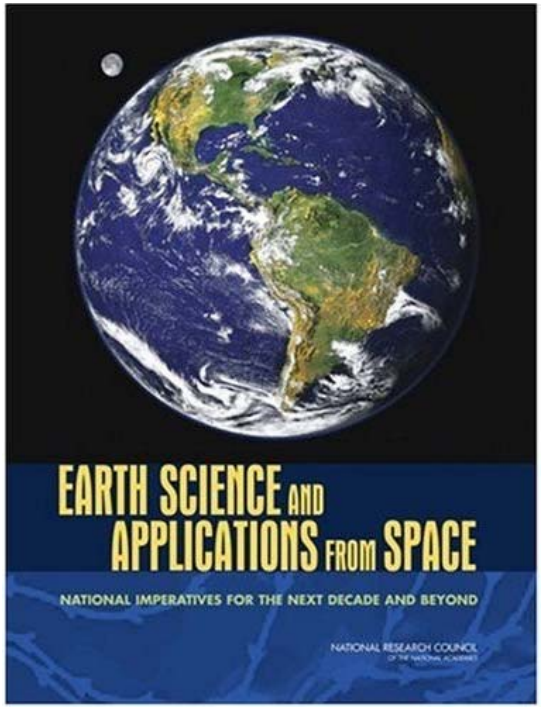
AOGCM can provide the boundary conditions, but are inadequate for applications over the polar ice sheets





Model Validation





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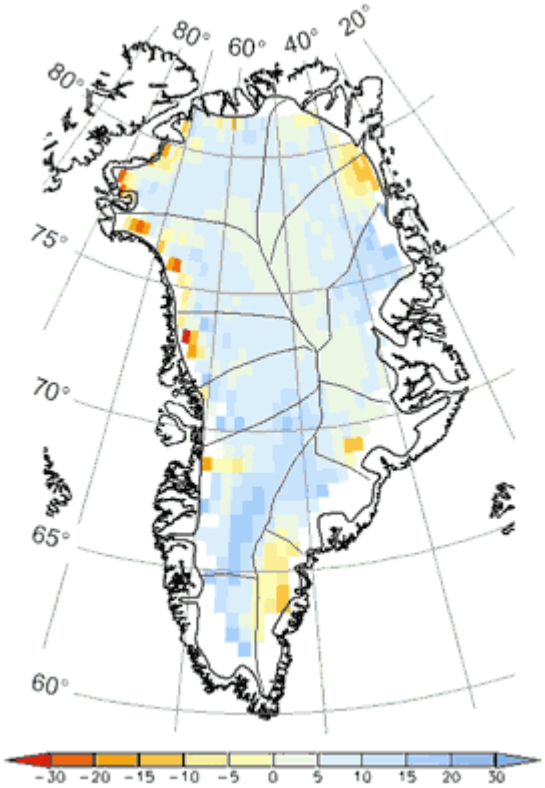
Advisers to the Nation on Science, Engineering, and Medicine

"Evaluation and assessment of model capability will increasingly be the focus of future measurement activities. Demonstrating model capability is likely to be a driver for developing and evolving observation systems and field campaigns."



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NSF NASA KTEC

How well do our models apply to real ice sheets?

- Model inter-comparisons
- Data for validation
- Capability of simulating past and current changes

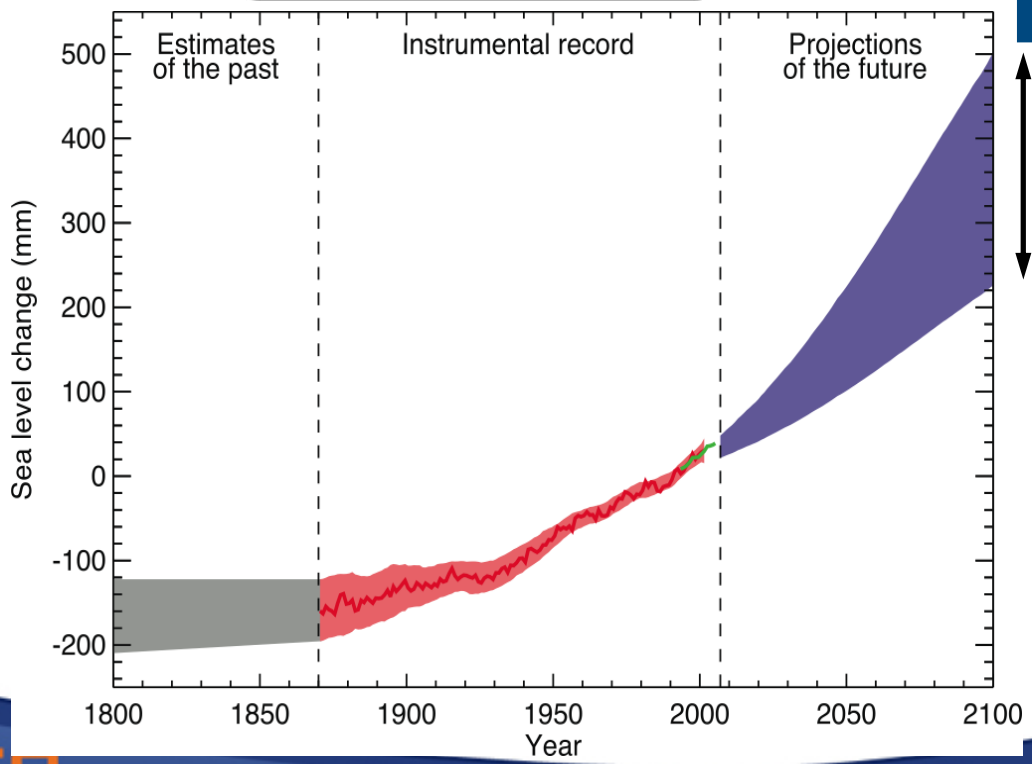
by The M.C.Escher Company B.V.

What ice-sheet models need (6)

Data for calibration and validation

- What data?
- Open data access
- Compatible formats
- “easy to use”

The long road ahead….



18-59 cm

Thanks for you attention
A thin polar bear called Onassis
Moaned "Why can't you get off your asses?
It's clear climate change
Is reducing my range
So you must make big cuts to bad gases!"

National Science Foundation

WHERE DISCOVERIES BEGIN

CReSIS