Vision of a Polar Observing System
Glaciological Perspective

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UCSC Committee on Research

Outline:

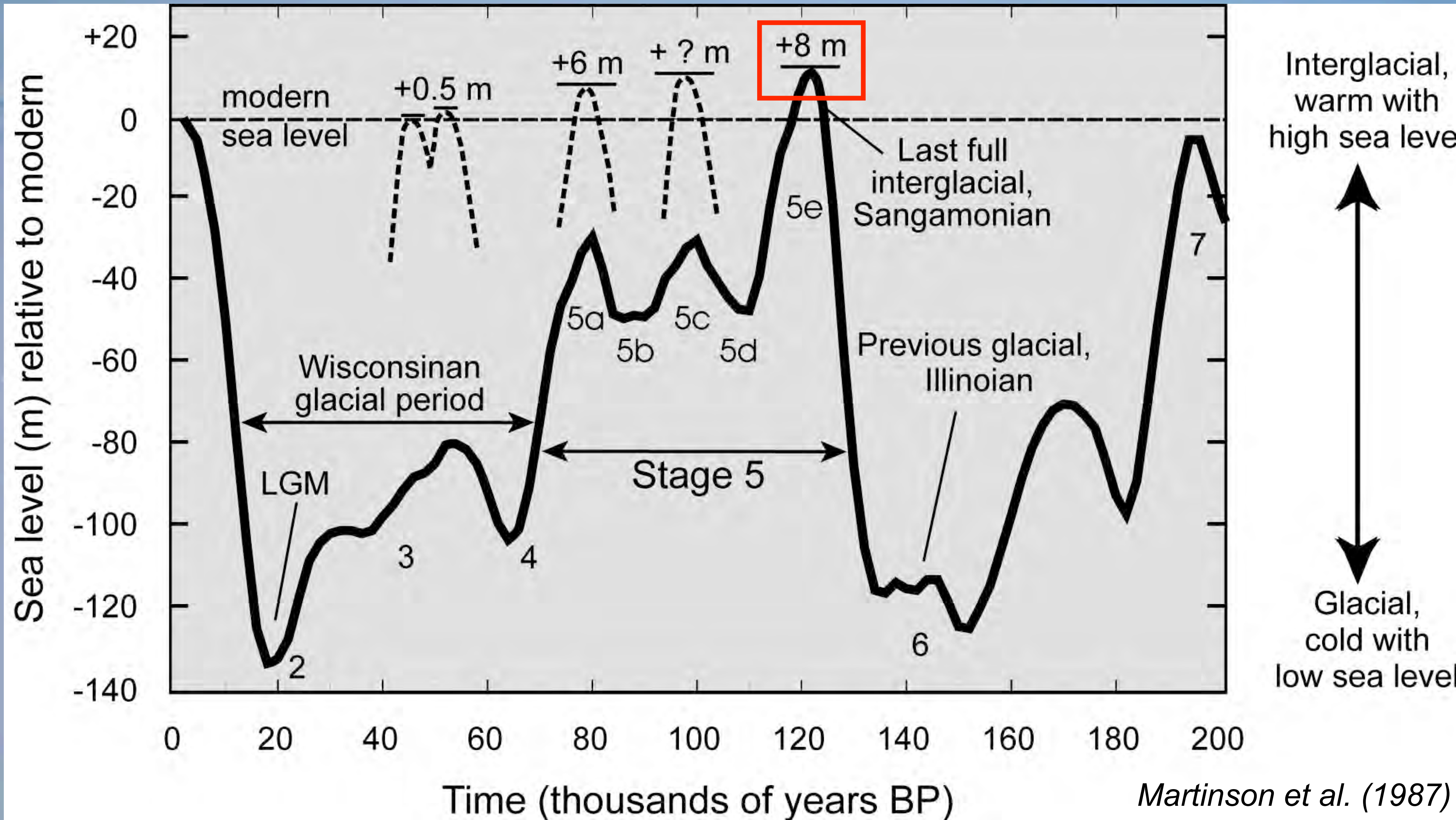
(1) Why we must do polar glaciology?

(2) Brief overview of ice sheet and glacier mass balance

(3) Personal experience in deploying instrumentation (Iceland, Antarctica)

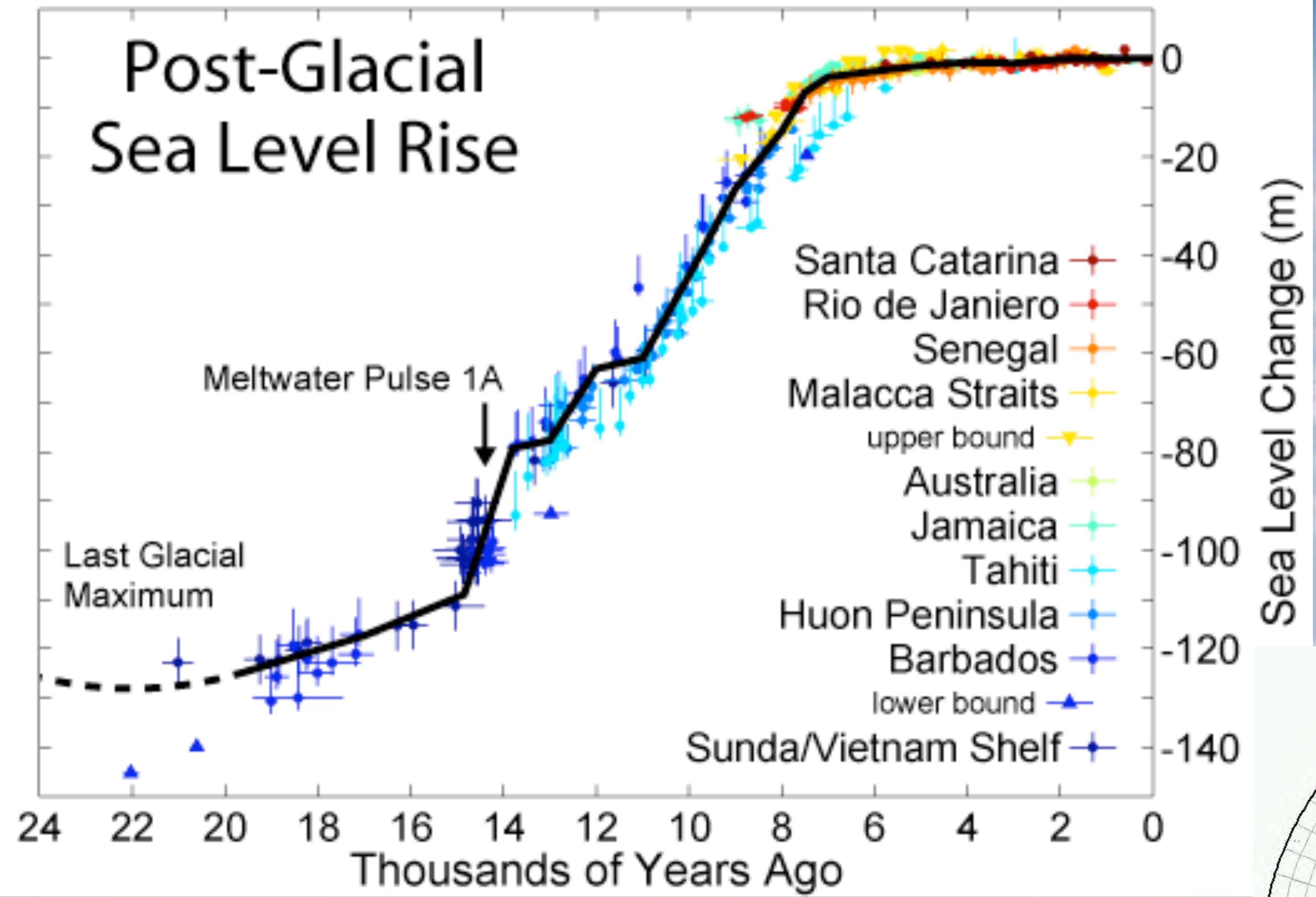
(4) Vision

Last time when global climate was a bit warmer than now …

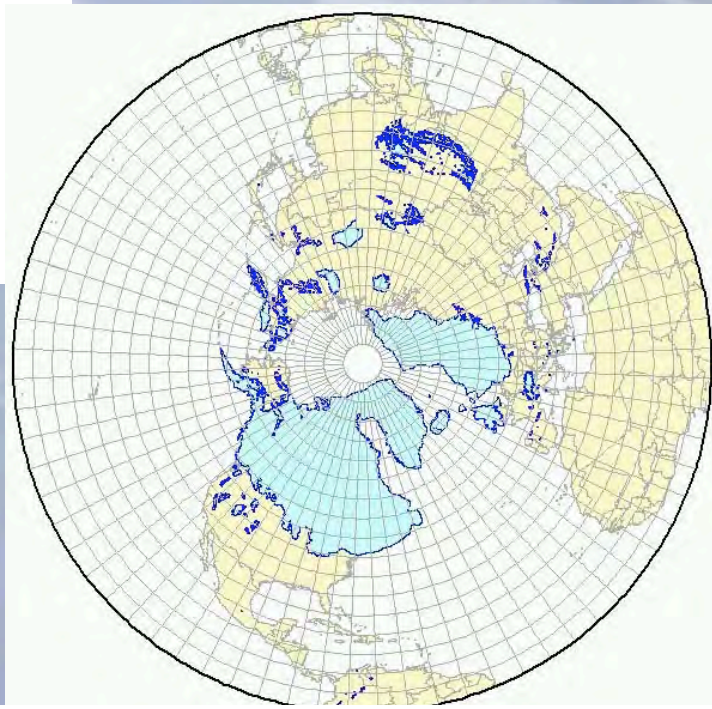


It would take collapse of the West Antarctic ice sheet and a good portion of Greenland (or vice versa)

The most recent global warming = high rates of sea level rise



Webster et al. (2005)



Meltwater Pulse 1A (SLR >4 cm/year)

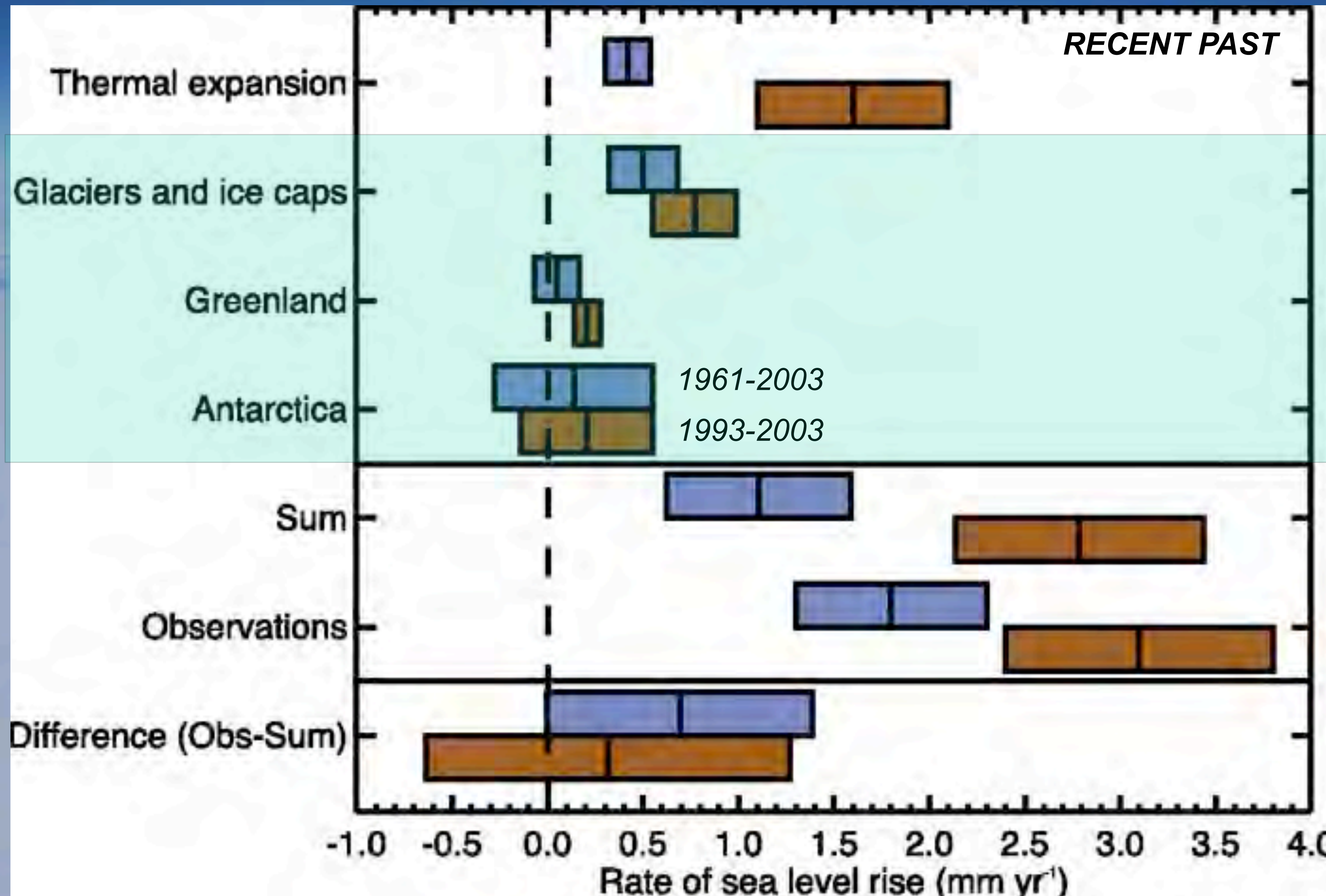
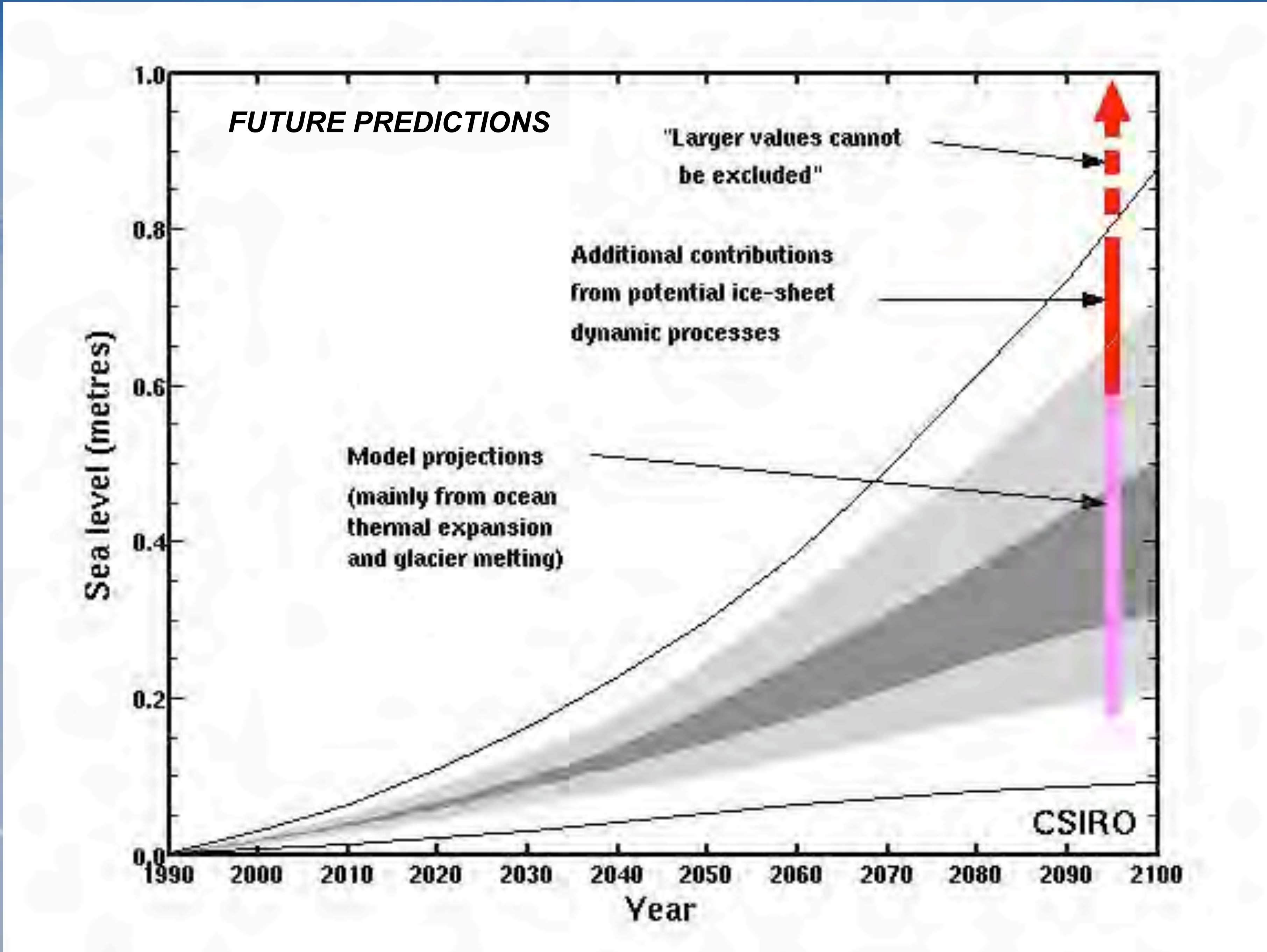


Figure 5.21. Estimates of the various contributions to the budget of the global mean sea level change (upper four entries), the sum of these contributions and the observed rate of rise (middle two), and the observed rate minus the sum of contributions (lower), all for 1961 to 2003 (blue) and 1993 to 2003 (brown). The bars represent the 90% error range. For the sum, the error has been calculated as the square root of the sum of squared errors of the contributions. Likewise the errors of the sum and the observed rate have been combined to obtain the error for the difference. (IPCC AR4, 2007)



after Church et al. (2008), IPCC (2001, 2007)

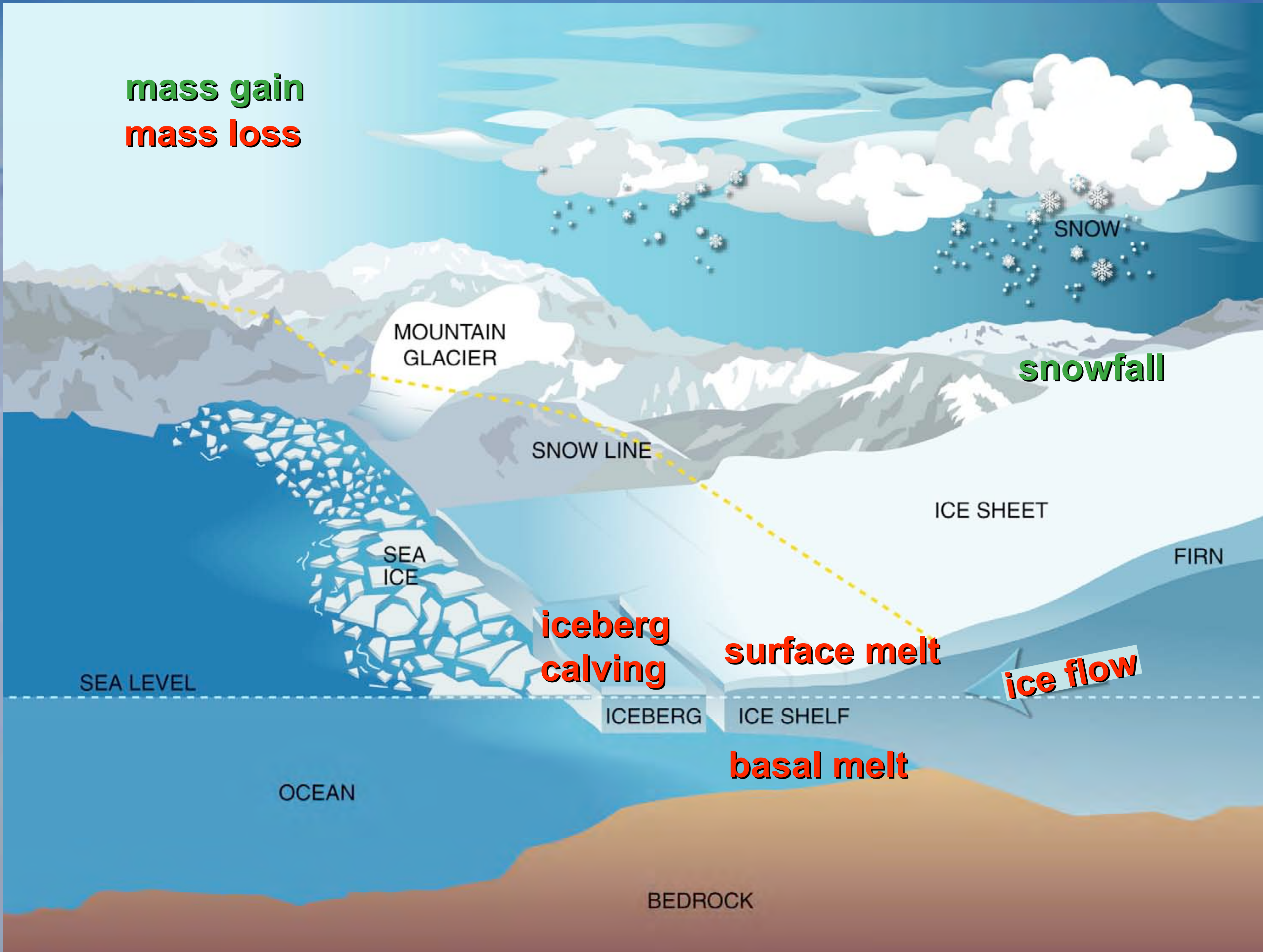
Ice covers about 10% of continental area

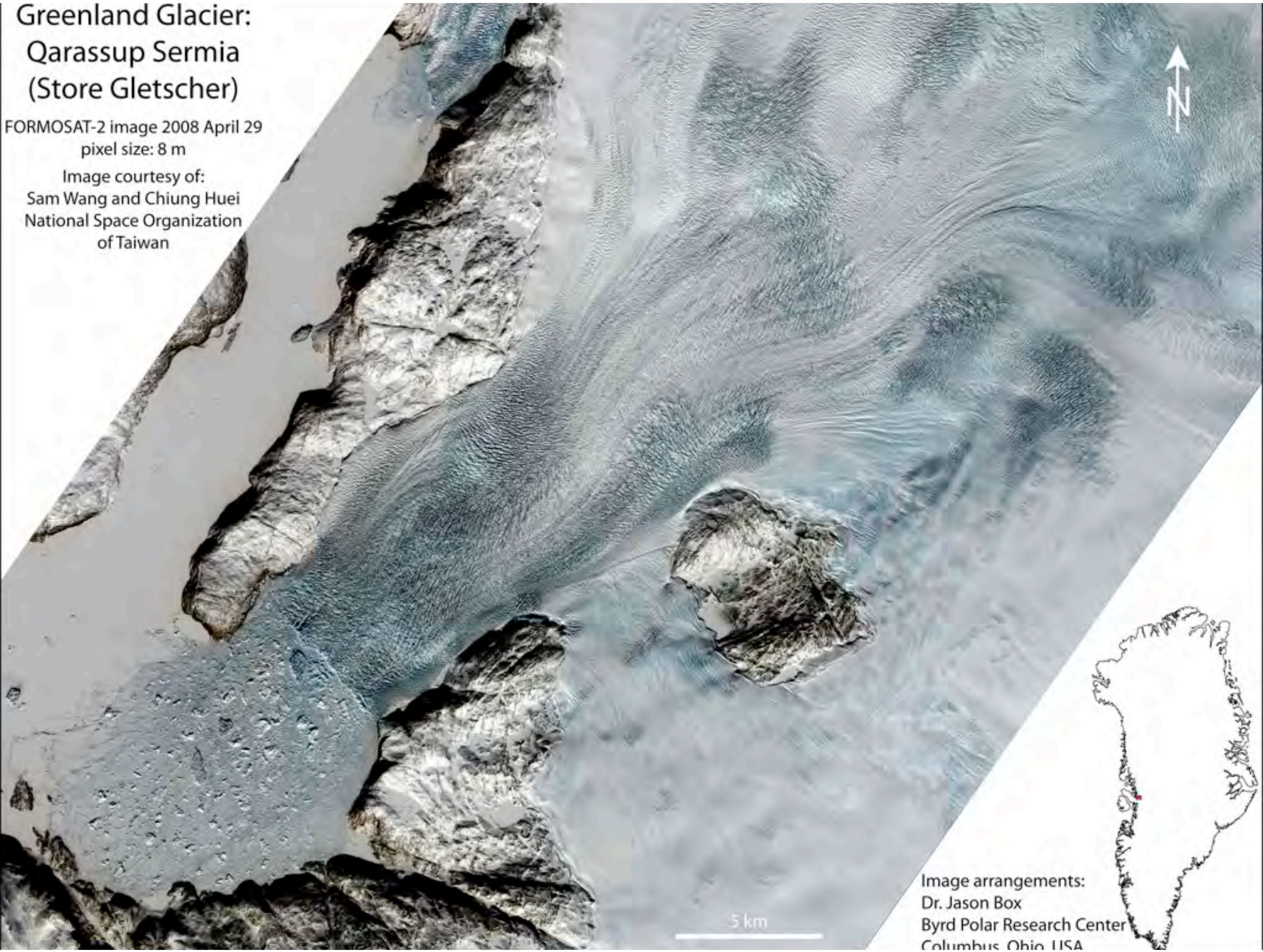
WGMS = World Glacier Monitoring Service

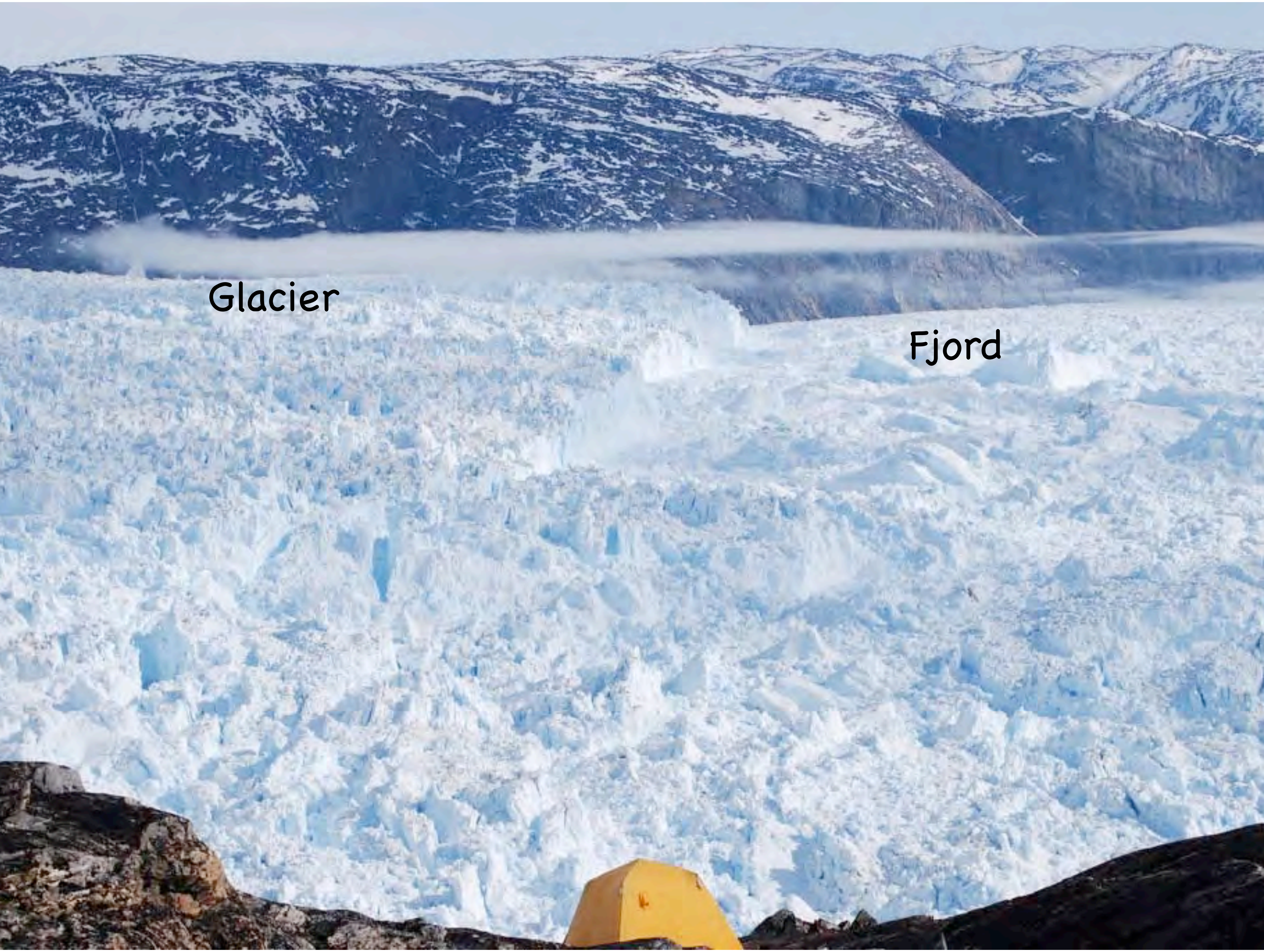
Fig. 6.1 The selected eleven glacierised macroregions.
The selected macroregions are presented in detail in the chapters 6.1 – 6.11. Source: ESRI Digital Chart of the World (DCW), WGMS.

This is down from about 20% 20,000 years ago

Overview of ice mass balance



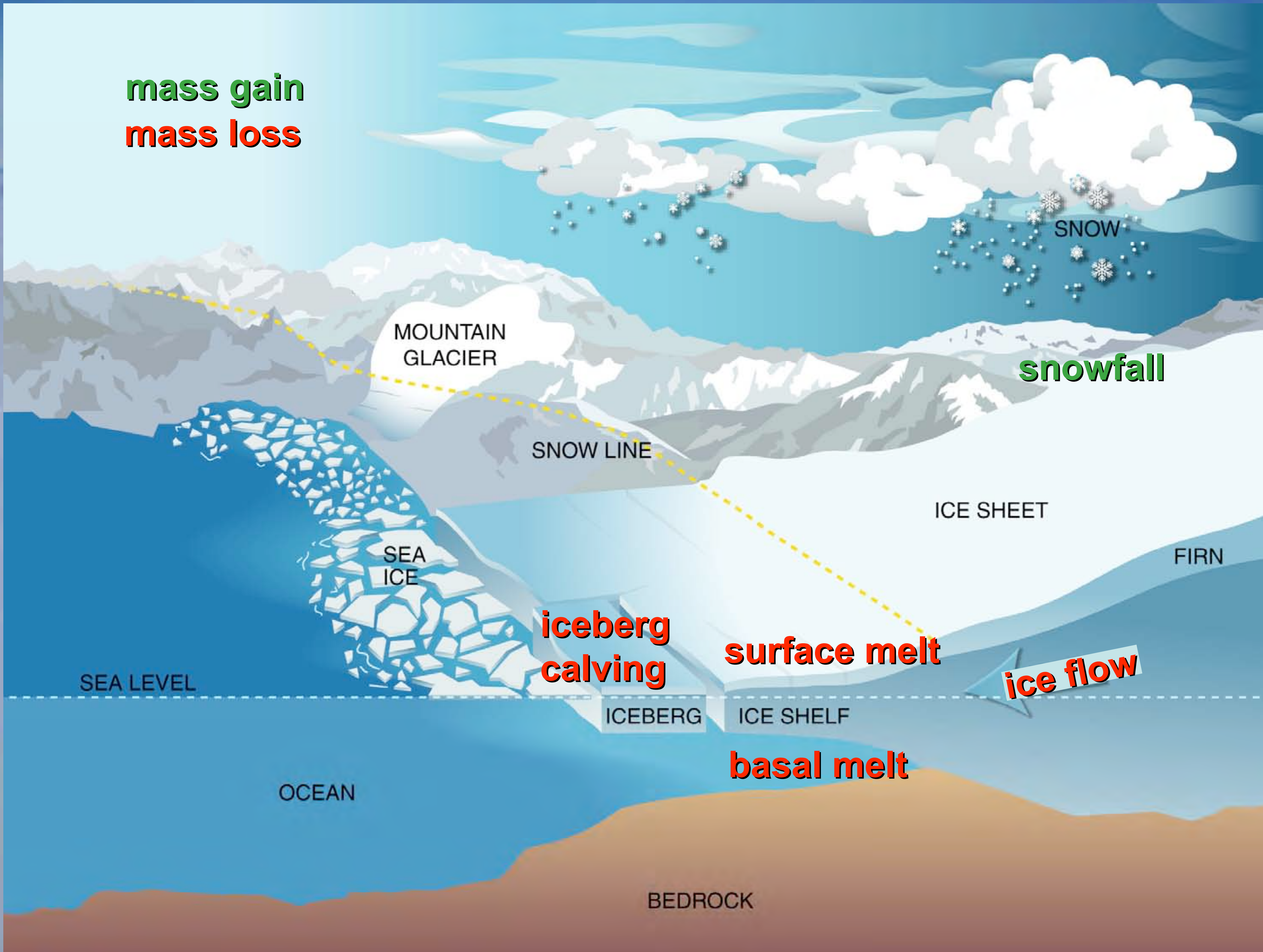

Greenland Glacier:
Qarassup Sermia
(Store Gletscher)
FORMOSAT-2 image 2008 April 29
pixel size: 8 m
Image courtesy of:
Sam Wang and Chiung Huei
National Space Organization
of Taiwan
N
5 km
Image arrangements:
Dr. Jason Box
Byrd Polar Research Center
Columbus, Ohio, USA


Glacier
Fjord

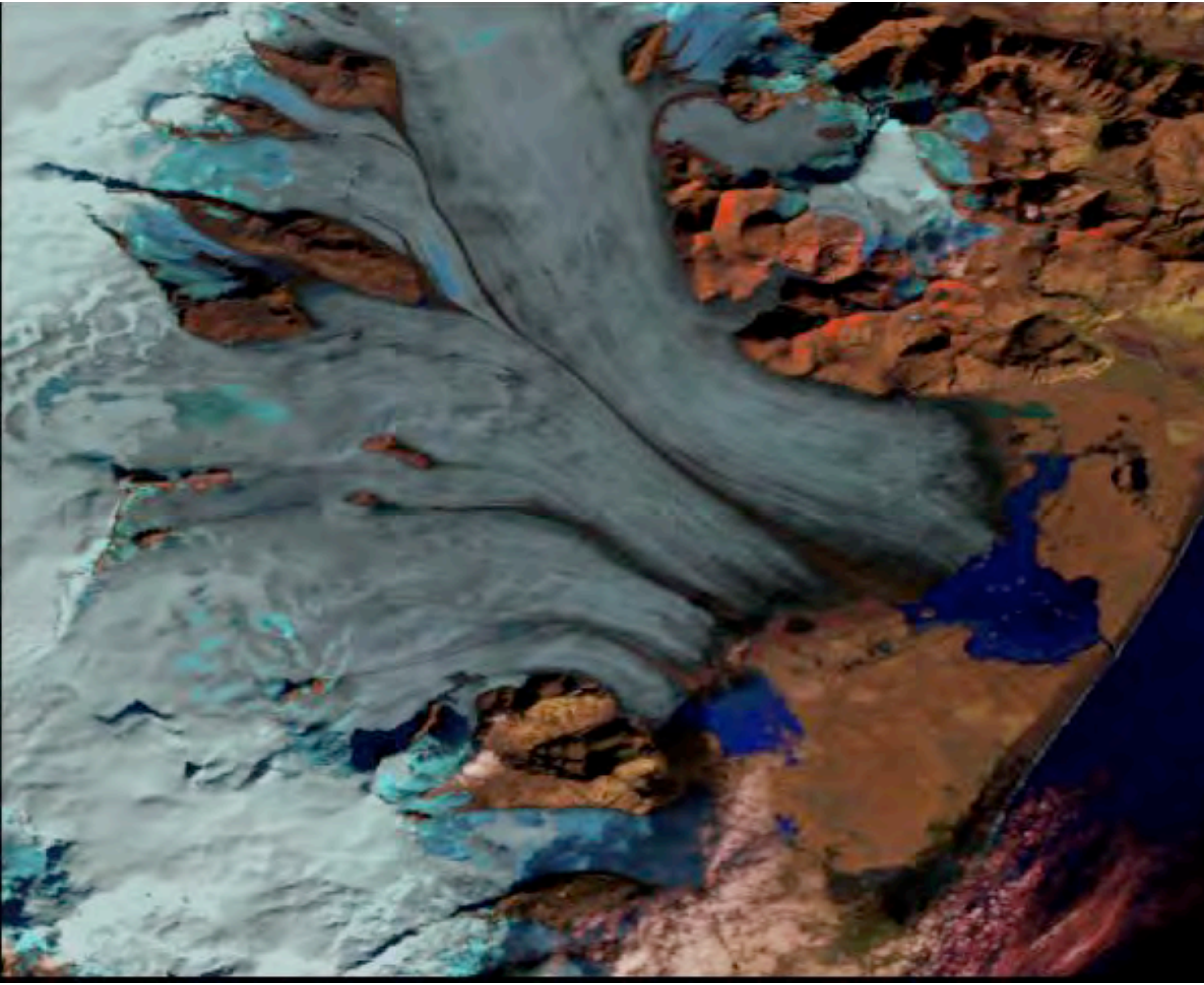

Dynamic surface - horizontal and vertical motion, fracturing, melting and/or snow deposition, formation of ponds, lakes, and surface streams


Ice-ocean interactions control basal melting and calving

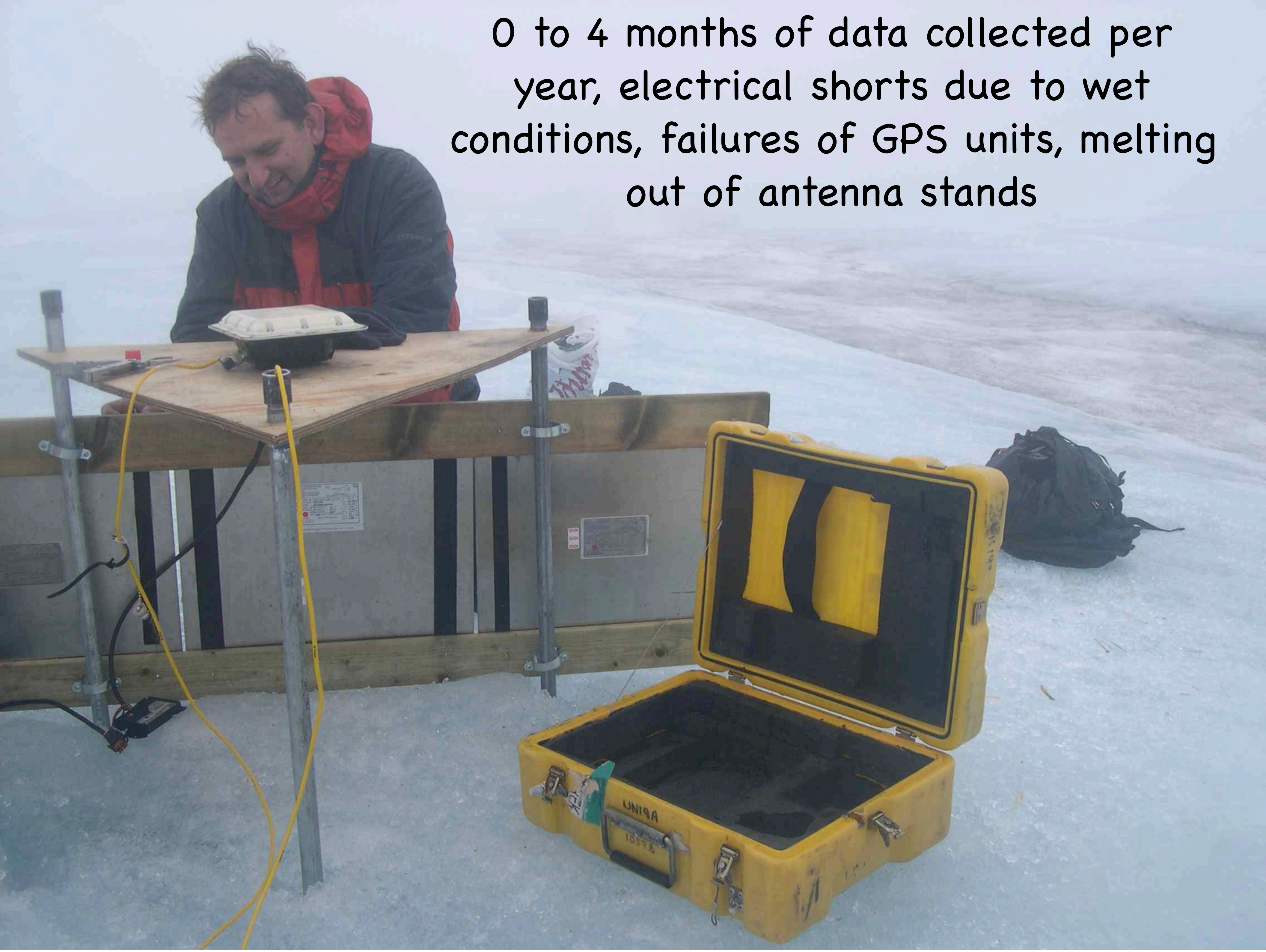
Overview of ice mass balance



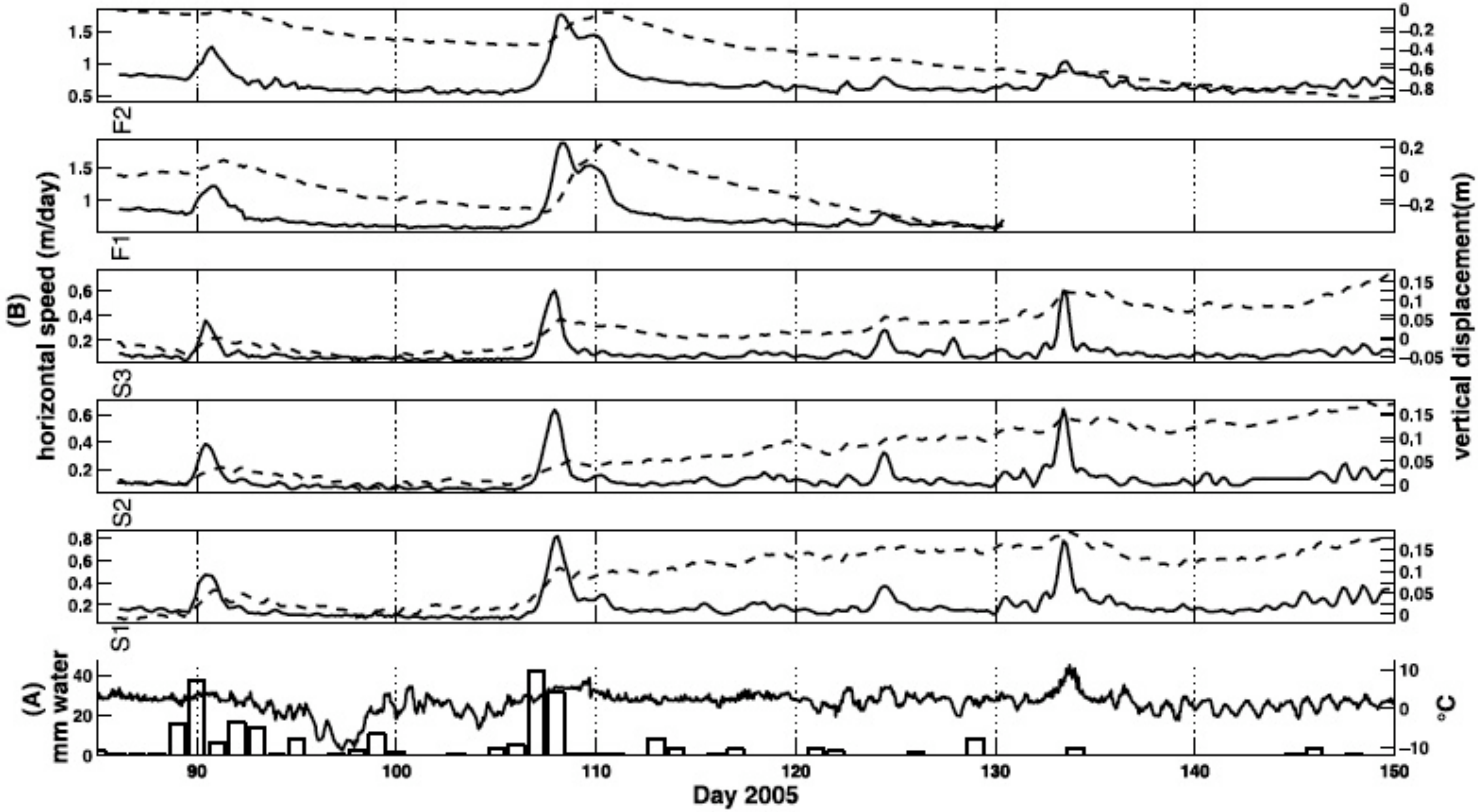

Experience with GPS in Iceland - early 2000s (NSF-OPP-ANS)



Wet, up to 10m/yr of surface melt
Old Trimble 4000 units

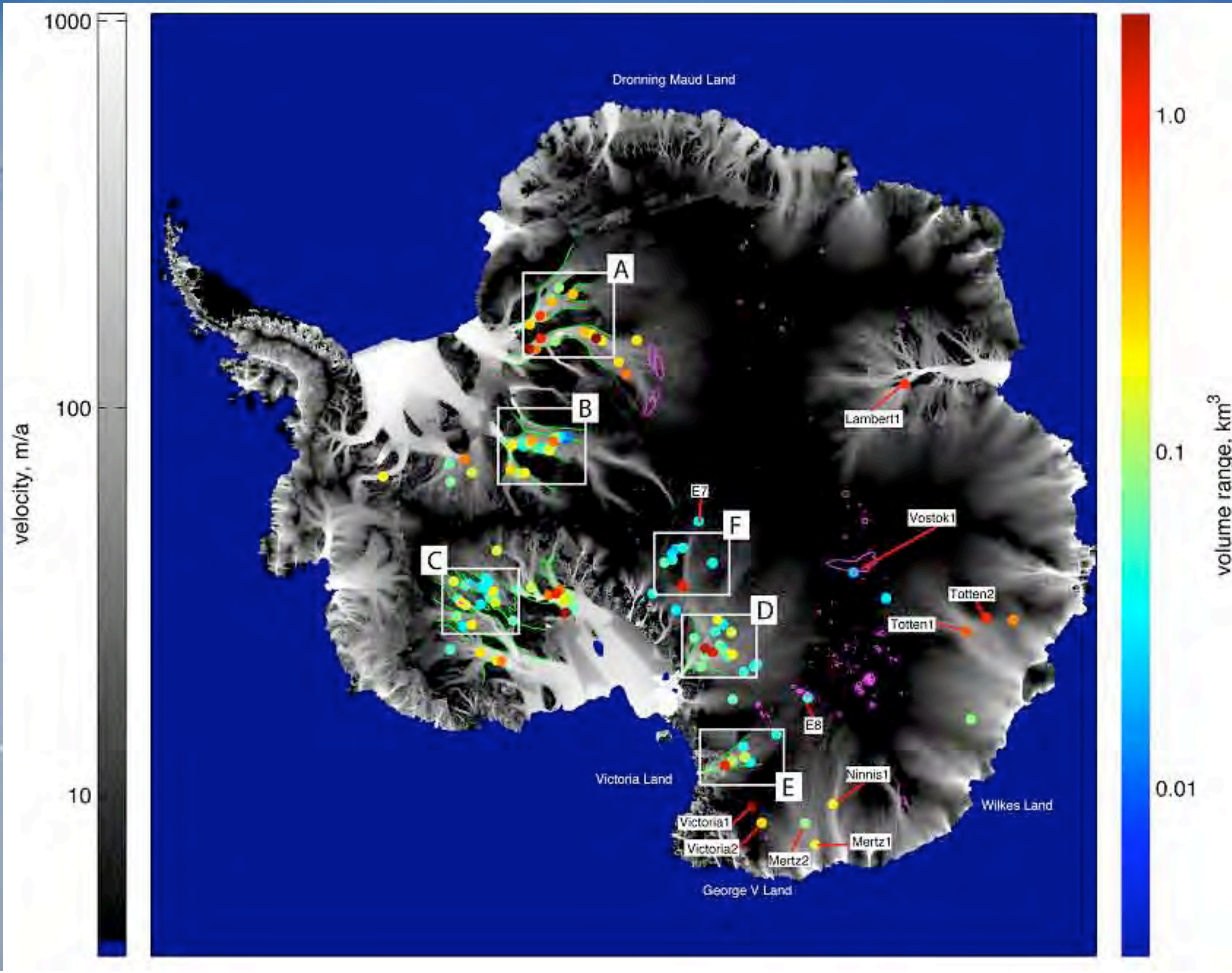

0 to 4 months of data collected per year, electrical shorts due to wet conditions, failures of GPS units, melting out of antenna stands
UNI9A

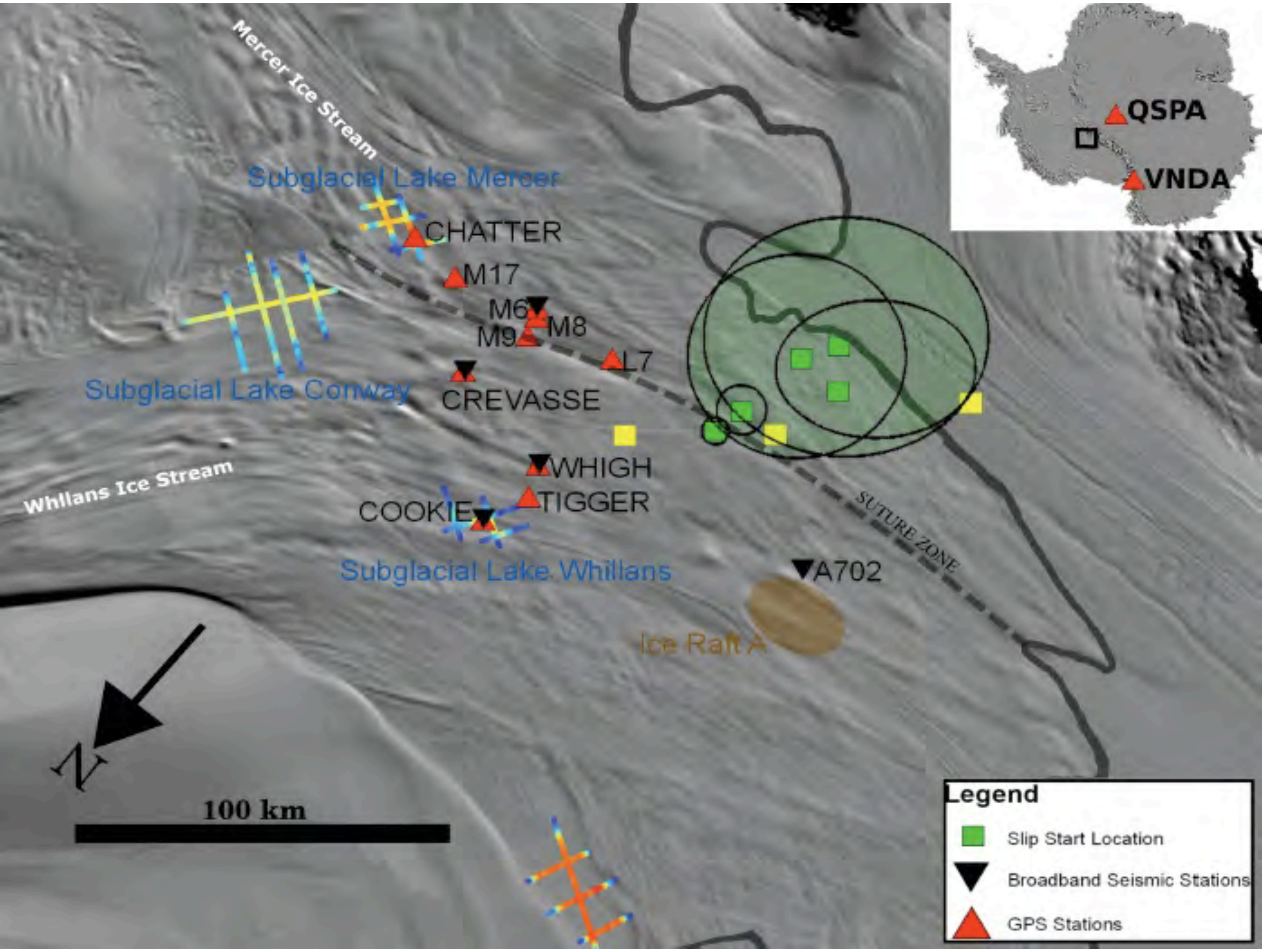
Input of meltwater and rain induces up to 1m of surface uplift associated with horizontal speed up



Howat et al., 2008

>100 active subglacial lakes mapped out in 2003-08

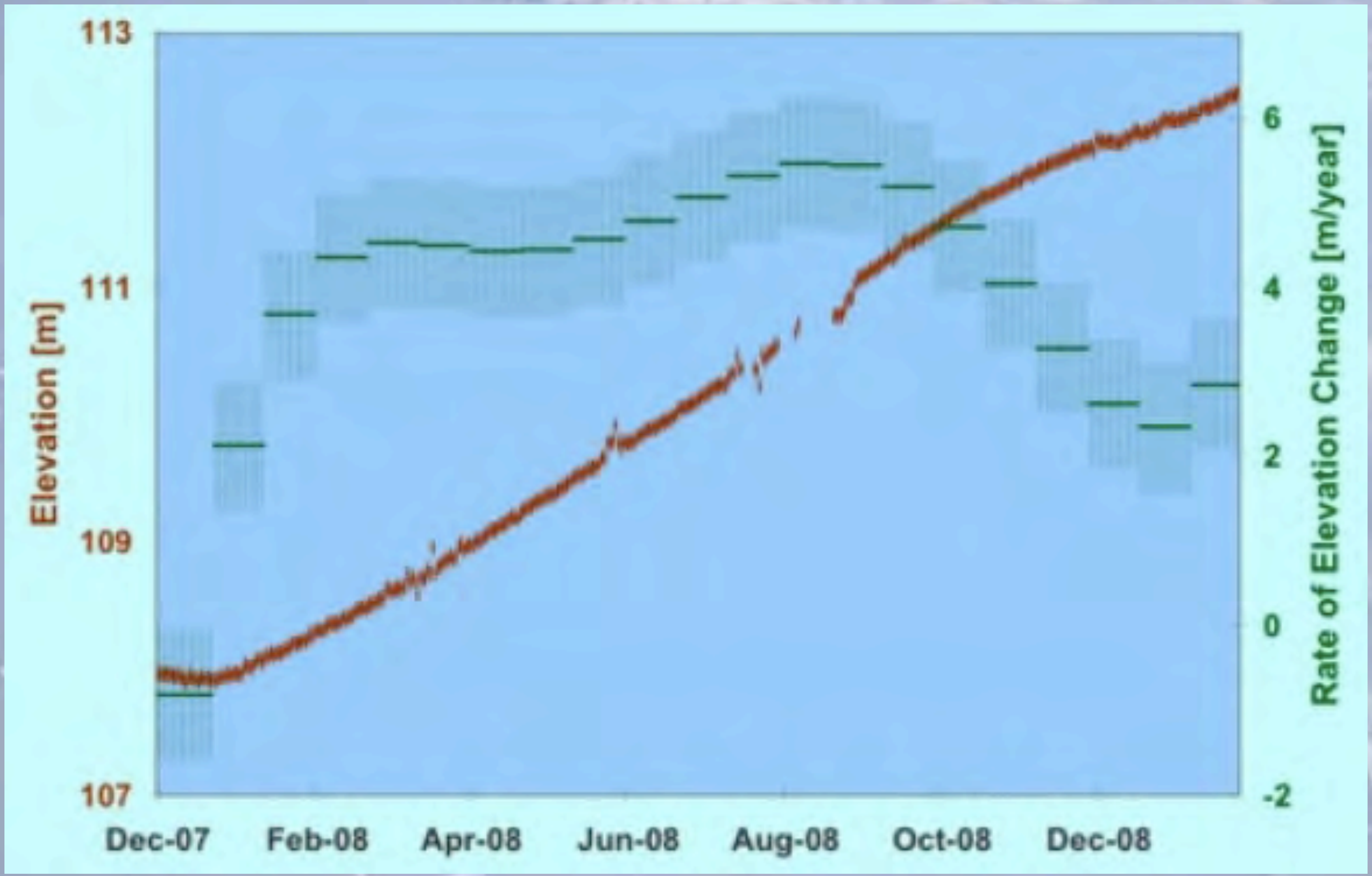




Mercer Ice Stream
Subglacial Lake Mercer
CHATTER
M17
M6
M8
M9
L7
Subglacial Lake Conway
CREVASSE
WHIGH
Whillans Ice Stream
TIGGER
COOKIE
Subglacial Lake Whillans
A702
SUTURE ZONE
Ice Raft A
N
100 km
QSPA
VNDA
Legend
Slip Start Location
Broadband Seismic Stations
GPS Stations


Whillans Ice Stream:
Accumulation zone (~0.2 m/yr SWE)

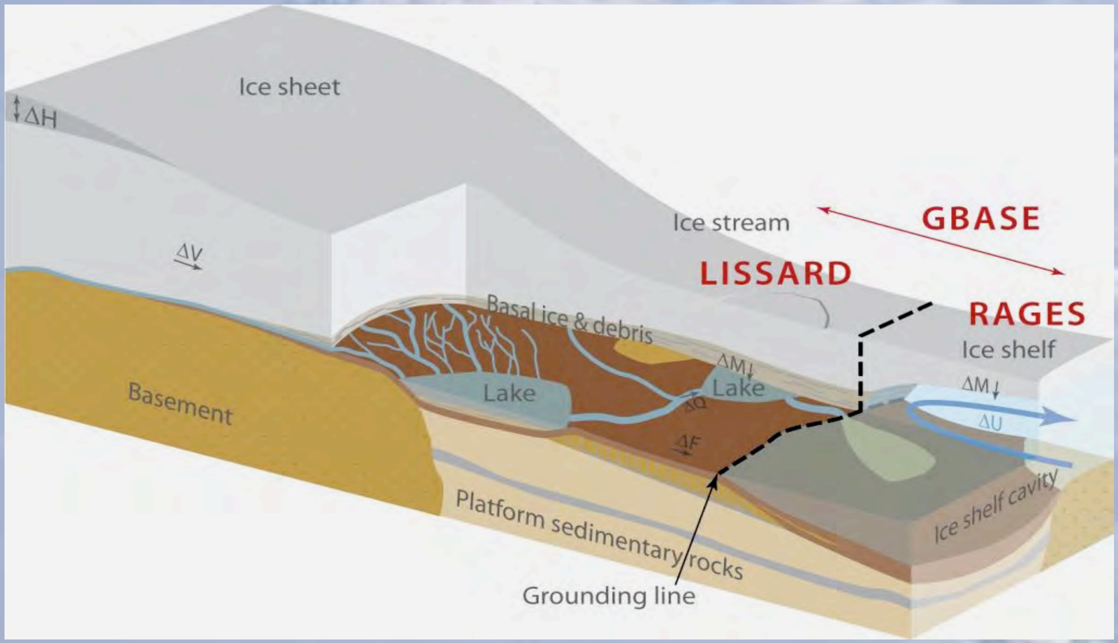
4-11 months of data
power outages in winter
firmware limitations of R7 units
physical setups performed well



WISSARD OVERARCHING GOAL:

... to examine distinct, but hydrologically related, subglacial environments using a combination of physical, chemical, geological and biogeochemical/genomic measurements

... to answer key questions on: (1) marine ice sheet stability; (2) subglacial hydrologic and sedimentological dynamics; (3) metabolic and phylogenetic biodiversity; and (4) the biogeochemical transformation of major nutrients within subglacial environments.



GBASE = GeomicroBiology of Antarctic Subglacial Environments = direct examination of sub-ice life, its structure, adaptations and impact on geochemical fluxes

LISSARD = Lake and Ice Stream Subglacial Access Research Drilling = control of active sub-ice hydrology on rates of changes in ice sheet mass balance (forcing from underneath)

RAGES = Robotic Access to Grounding zones for Exploration and Science = control of ice-ocean interactions on rates of changes in ice sheet mass balance (forcing from marine margins)

WISSARDs in three WISSARD components:

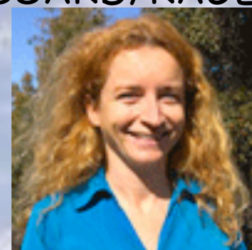
Ross Powell
RAGES Lead PI
LISSARD PI

Sridhar Anandakrishnan
LISSARD/RAGES PI

Brent Christner
GBASE PI

Andrew Fisher
LISSARD/RAGES PI

John Priscu
GBASE Lead PI



Helen Fricker
LISSARD/RAGES PI

David Holland
RAGES PI

Robert Jacobel
RAGES/LISSARD PI

Slawek Tulaczyk
LISSARD Lead PI
RAGES PI

Jill Mikucki
GBASE PI

Andrew Mitchell
GBASE PI

Reed Scherer
LISSARD/RAGES PI

Project Partners:
Raytheon Polar Services Company (Logistics/Traverse)
Deep Ocean Exploration and Research (Sub-Ice Robot etc.)
Subglacial Lake Ellsworth Project (UK initiative)

Jeff Severinghaus
LISSARD PI

Project Schedule

2009-10
Tool development

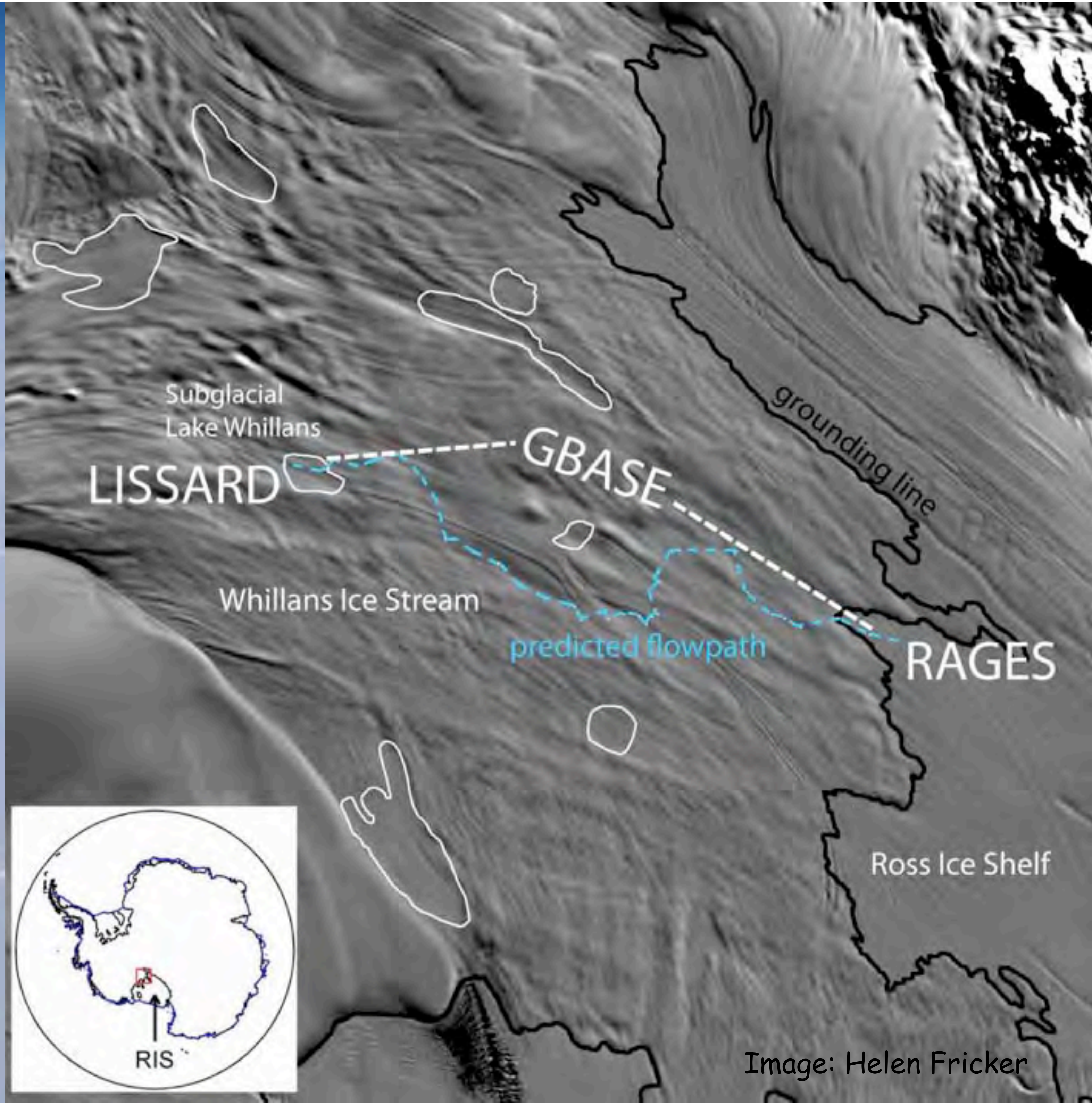
2010-11
Tool development
Surface geophysics

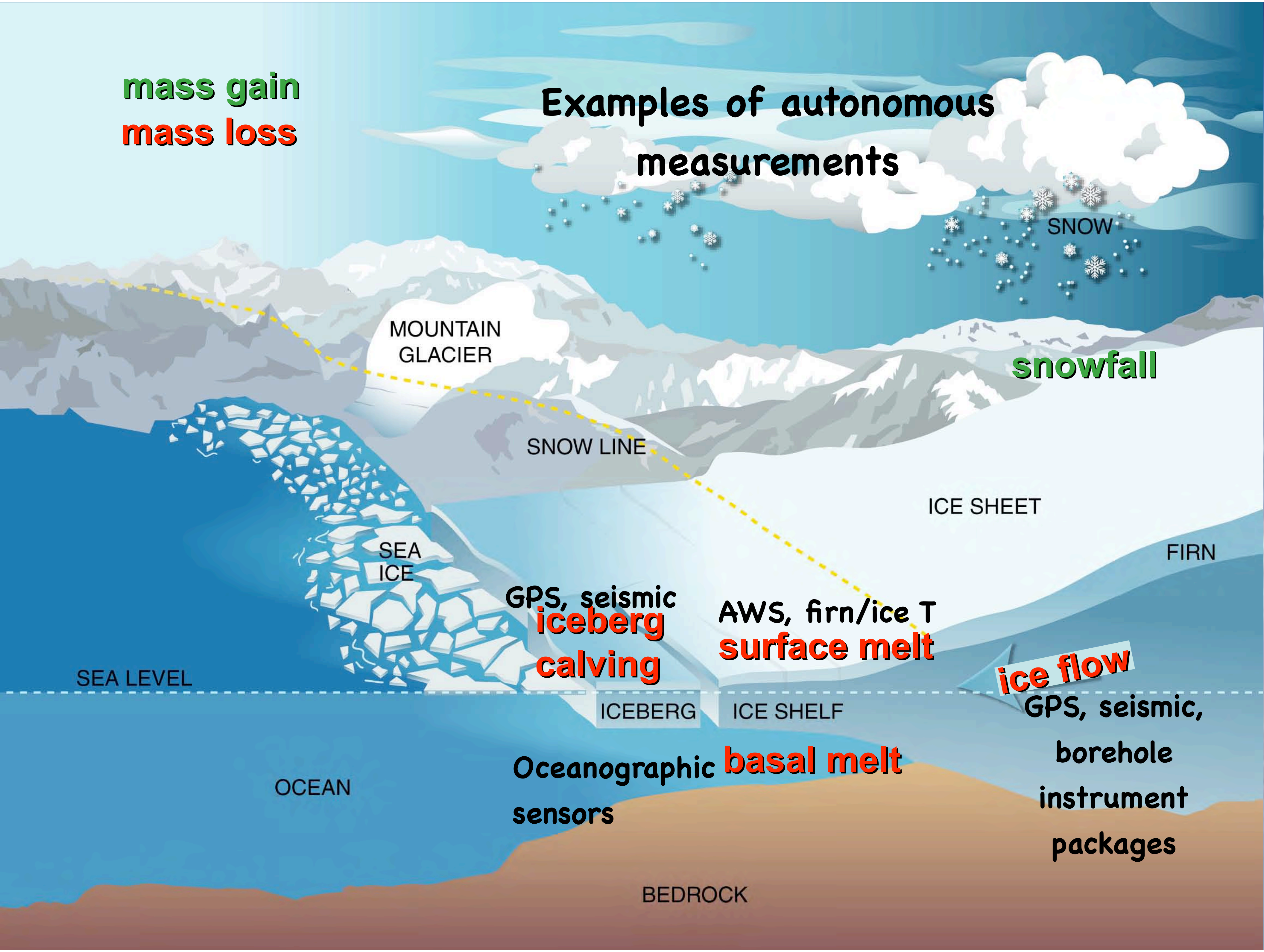
2011-12
Surface geophysics
Test drilling (McM)

2012-13
Lake and ice stream drilling

2013-14
Grounding zone drilling

2014-15
End of project





Examples of autonomous measurements
mass gain
mass loss
MOUNTAIN GLACIER
SNOW
snowfall
SNOW LINE
ICE SHEET
FIRN
SEA ICE
GPS, seismic
iceberg calving
AWS, firn/ice T
surface melt
ice flow
GPS, seismic, borehole instrument packages
SEA LEVEL
ICEBERG
ICE SHELF
Oceanographic sensors
basal melt
OCEAN
BEDROCK

APOS on Ice: Instrument Support Packages

(1) Power generation and storage improved but still problematic

(2) Need for well-engineered and tested, standard, but customizable instrument support packages which will provide sensor power, shelter, and data logging/transmission options

(3) Configuration of such instrument support packages should be flexible to permit various sensors and to customize to local conditions (over-designed worst-case packages are expensive to make and deploy)

(4) Develop strategies for sensor deployments in dangerous localities without 'boots on the ground' (heli deployed, parachuted, transported by remotely controlled vehicles?)

APOS on Ice: Future developments

(1) Need for new sensors to provide additional constraints on glaciological processes (e.g. addition of seismometers to GPS packages or deployment of fiberoptic Distributed Temperature Sensors)

(2) More focus on collecting data on ice-ocean interactions, including coastal oceanographic observations (calving and basal melting)

(3) Increase deployments of deep sensors through drilling and/or ice-penetrating probes (calving, basal melting, ice flow)

(4) Parallel development of data storage, sharing, processing, and interpretation capabilities with data policies that maximize science output (investment in computational and human capital, assuring that each data stream has a motivated community of users that is open to new entrants)