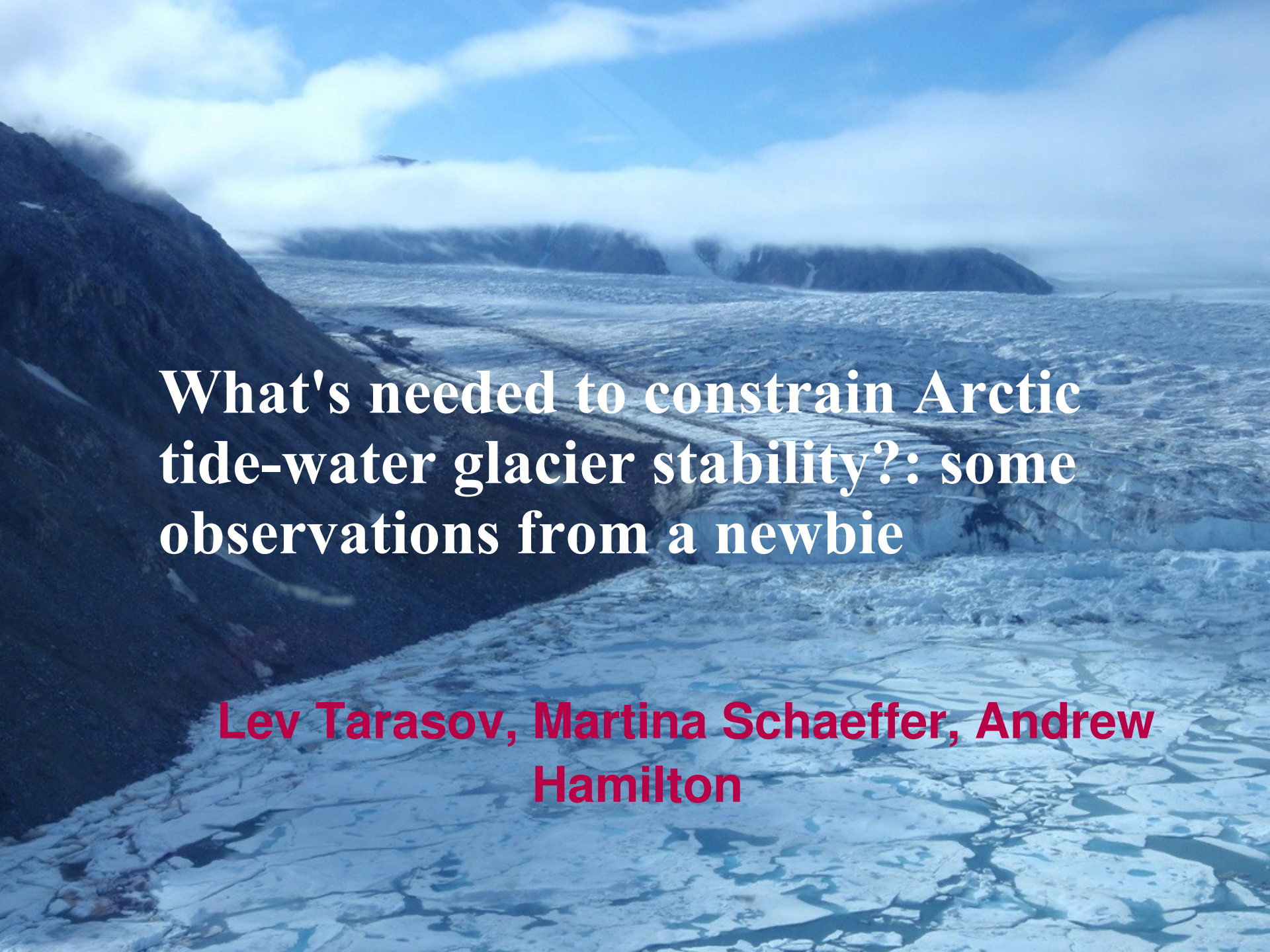
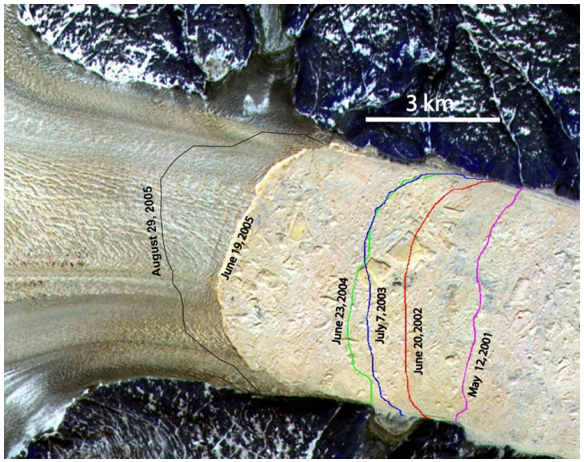


What's needed to constrain Arctic tide-water glacier stability?: some observations from a newbie

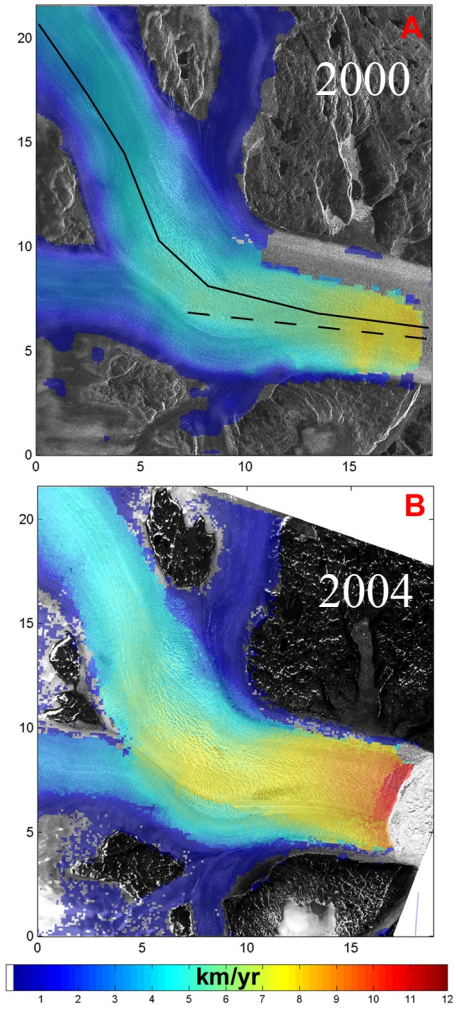
Lev Tarasov, Martina Schaeffer, Andrew Hamilton

OUTLET GLACIER RETREAT, THINNING AND ICEBERG CALVING

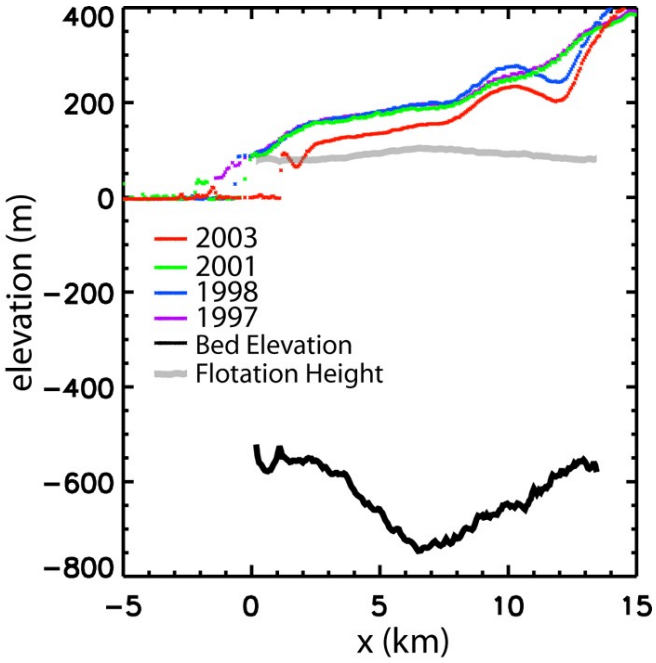
Helheim Glacier



Frontal Retreat



Velocity

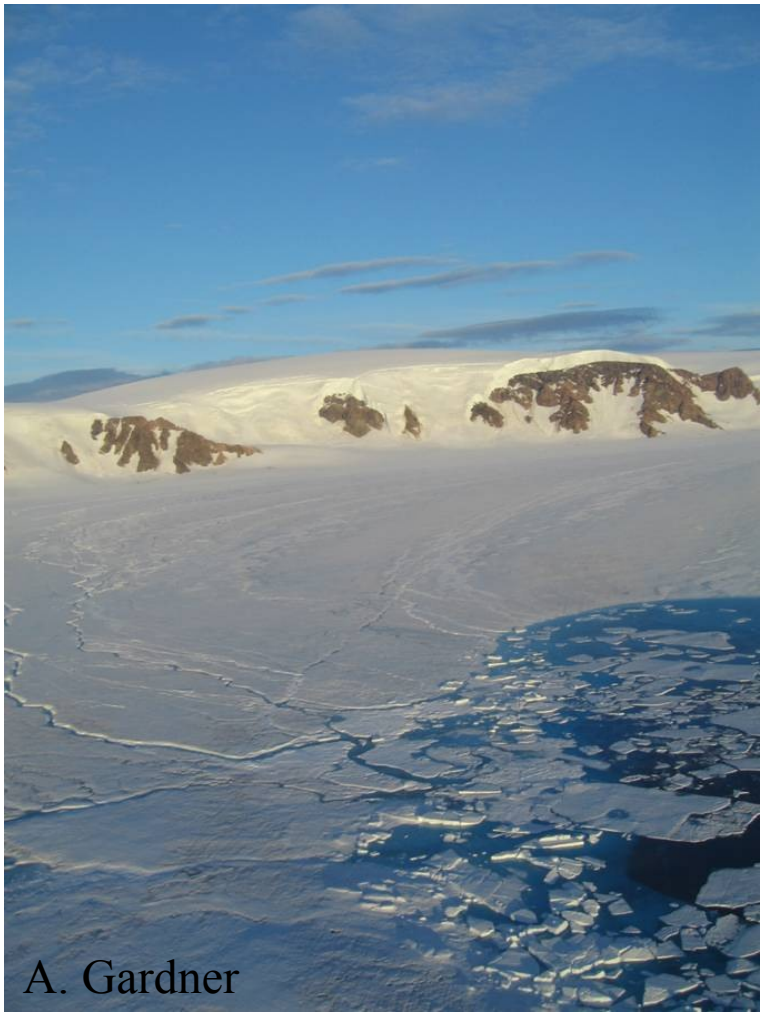


Thickness Change

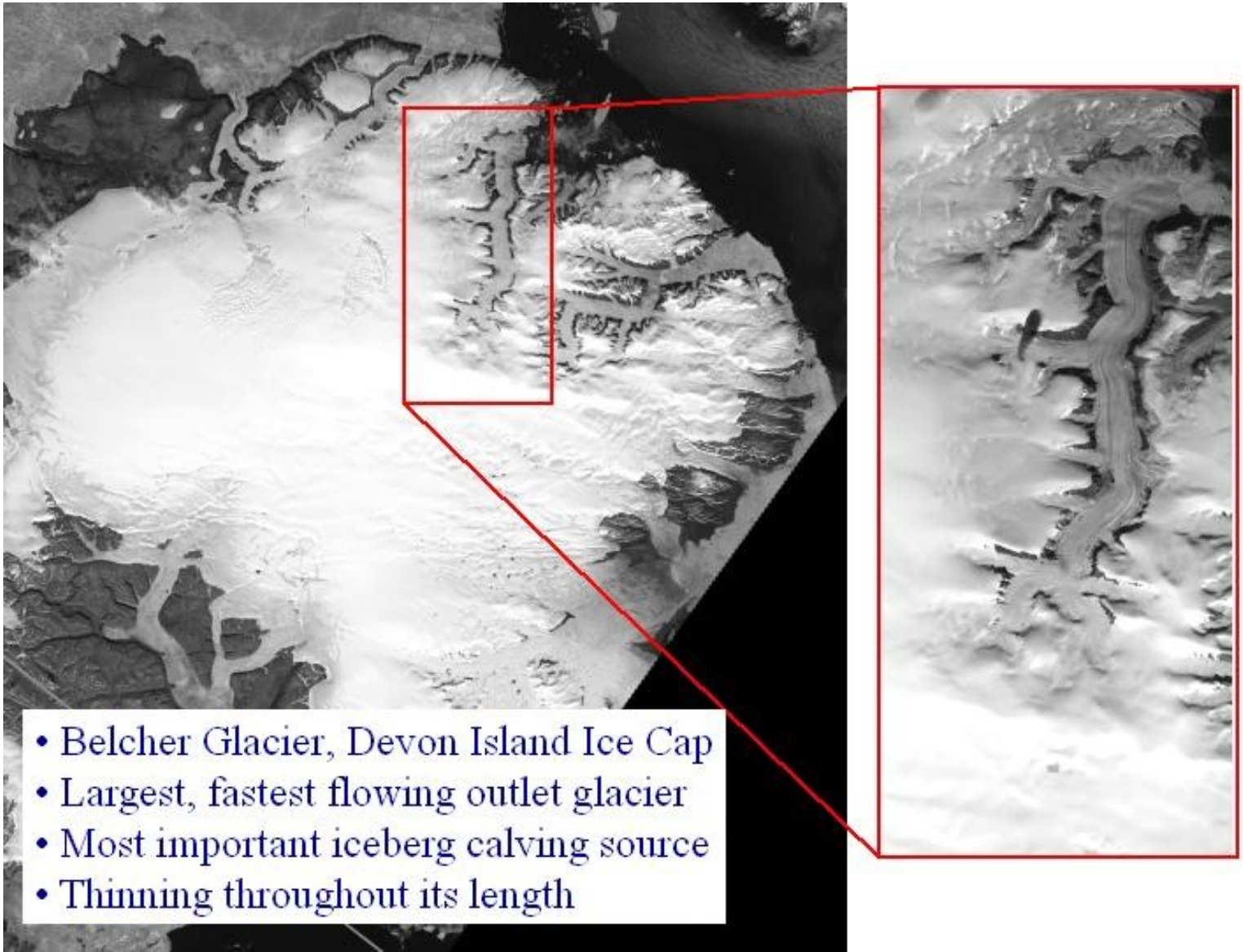
I. Howat et al., *GRL*, 2005

WHAT'S DRIVING THESE CHANGES?

- Two main hypotheses:
  - **From the top** – increased or more widespread penetration of surface meltwater to the glacier bed enhances sliding
  - **From the bottom** – terminus destabilisation by flotation (due to rising sea level or thinning caused by increased surface or marine melt) reduces flow resistance
- But which is it ? Hard to measure in Greenland



Study site: Belcher Glacier

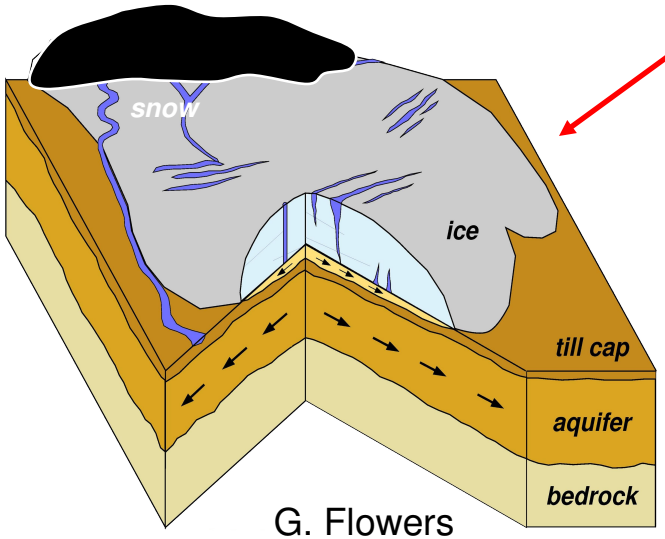


Glaciodyn Canada Modelling Goals

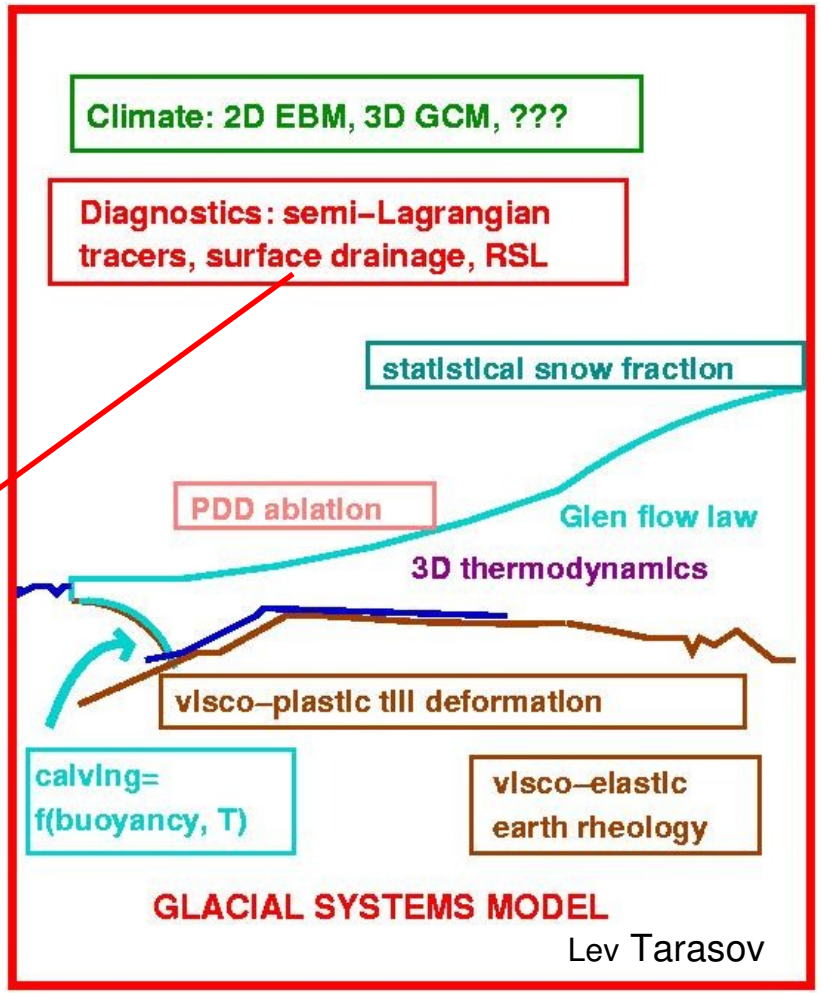
1. Develop high order coupled model of outlet glacier dynamics
   - incorporate surface mass balance, glacier hydrology, ice flow and iceberg calving
2. Collect detailed field and remotely sensed data
   - Design, initialize, drive, and validate model
3. Run model
   - Explore Belcher Glacier response to climate change
     - atmospheric and oceanic climate
     - amount and distribution of surface water inputs to glacier bed
     - Ice dynamics, terminus stability and iceberg calving
     - What are the important processes?

Methods: *Modelling*

- Surface mass balance model
- Whole ice cap flow model
- Coupled hydrology/ thermomechanical outlet glacier flow model
- Iceberg calving mechanics



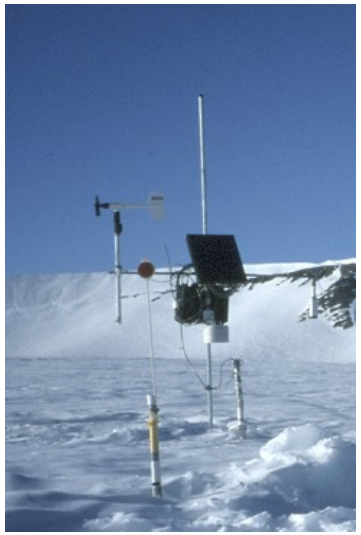
G. Flowers

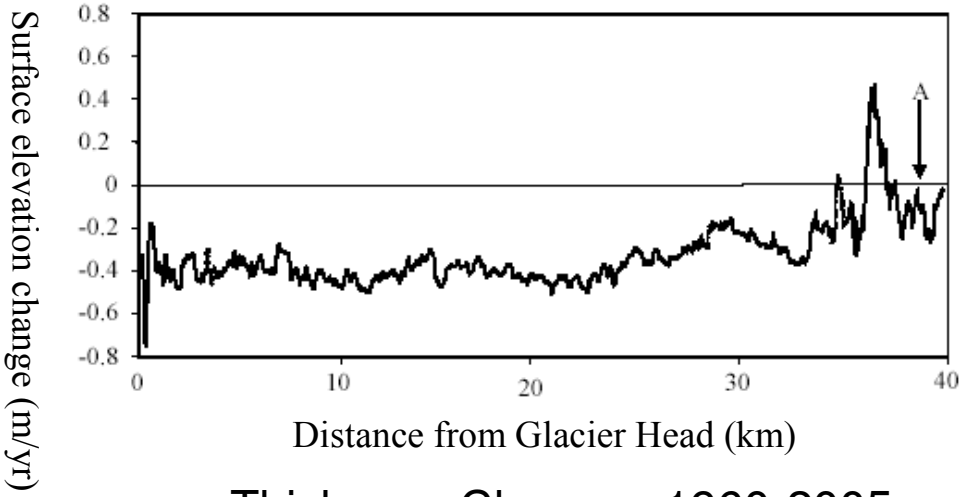


Lev Tarasov

Methods: *Surface Processes & Properties*

- Mass balance
  - *radar, ice cores, AWS, stakes, remote sensing of summer melt*
- Hydrology & Drainage
  - *remote sensing, time lapse photography, hydrometric measurements,*
- Topography
  - *Kinematic GPS, Airborne laser altimetry, Photogrammetry*

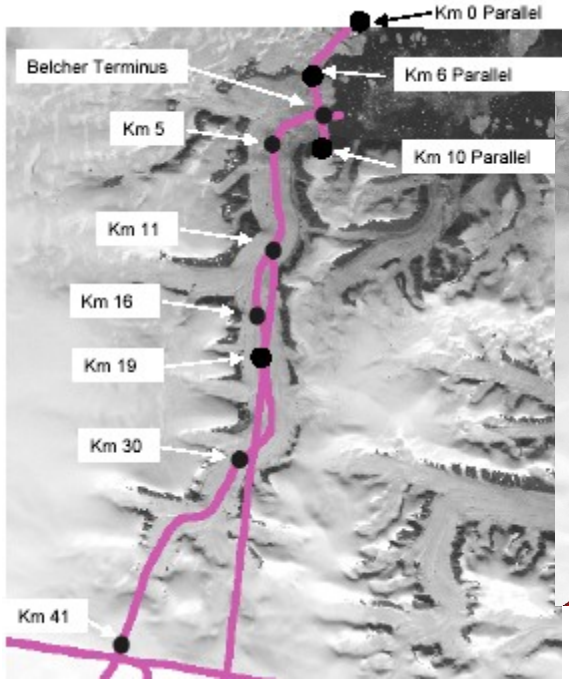


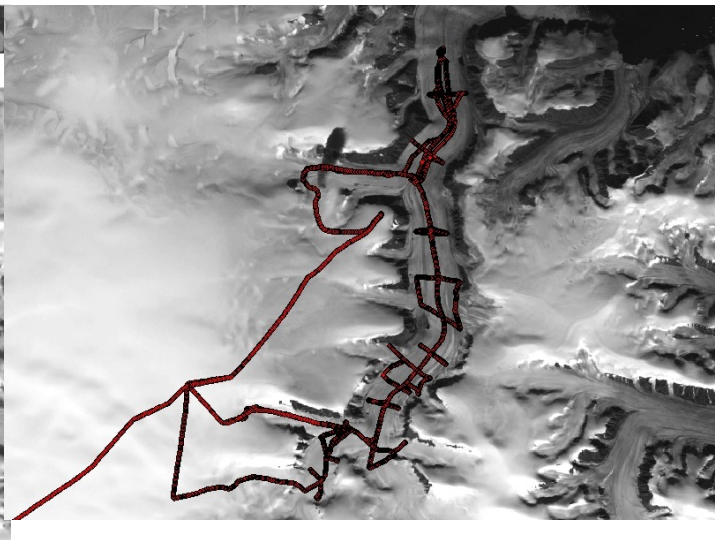


Thickness Changes 1960-2005

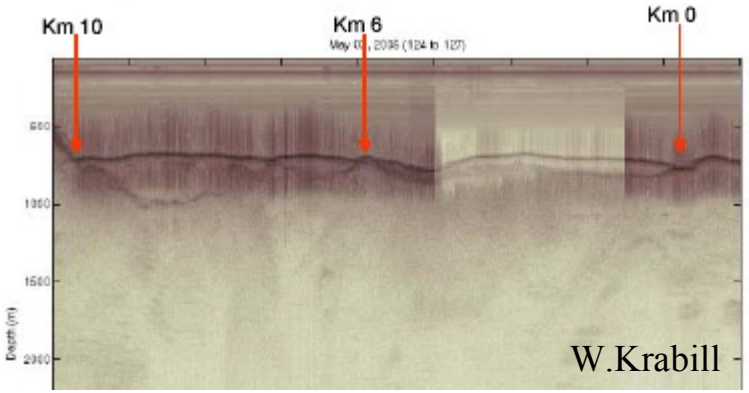
Methods: *Sub-surface characteristics*

- Subglacial topography
  - *RES, GPS*
- Bed properties and their temporal variability
  - *seismic reflection and monitoring*



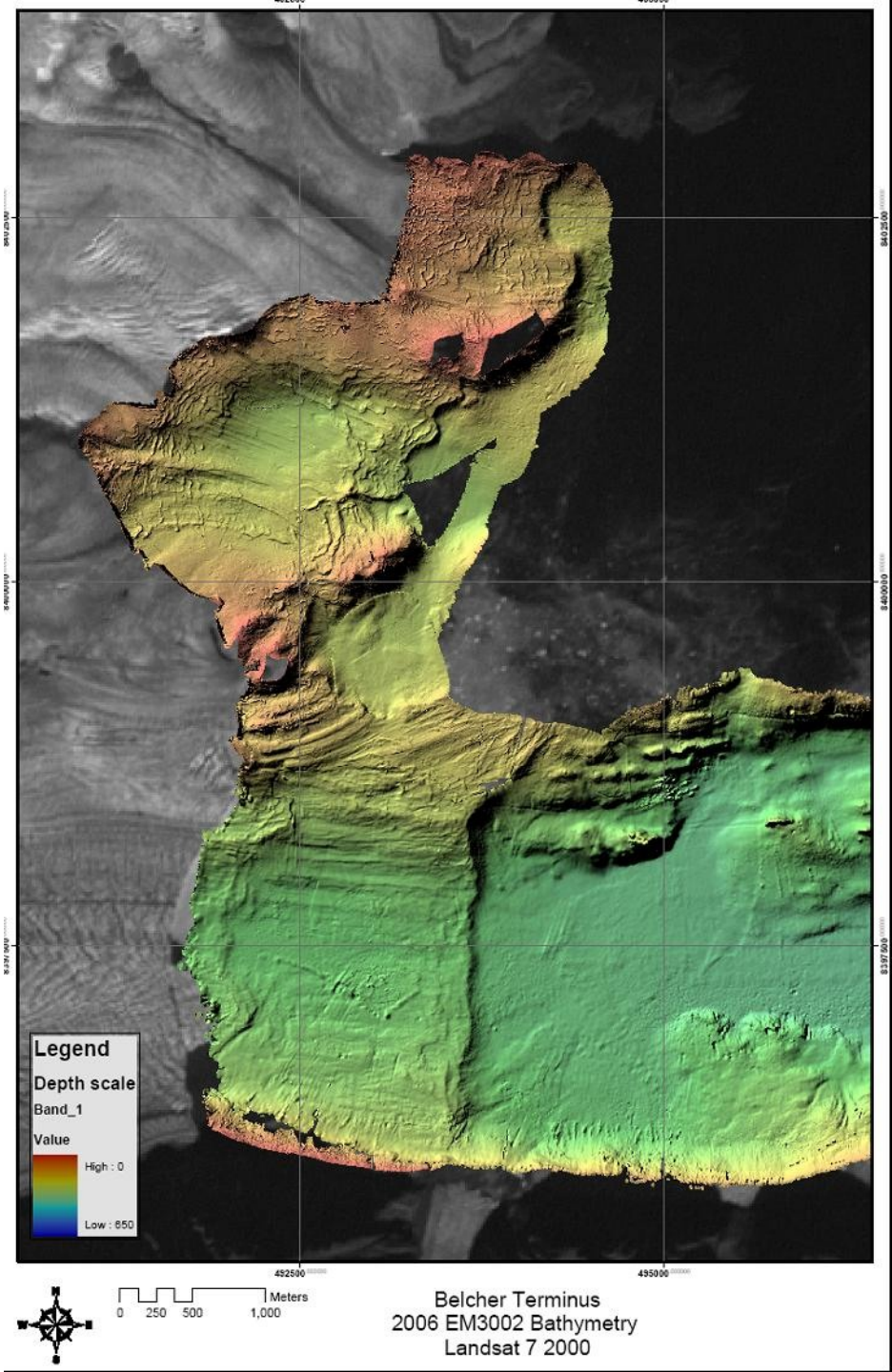


RES Profile Parallel to Belcher Terminus



Methods: *Offshore bathymetry and water column properties*

- RCGS Amundsen

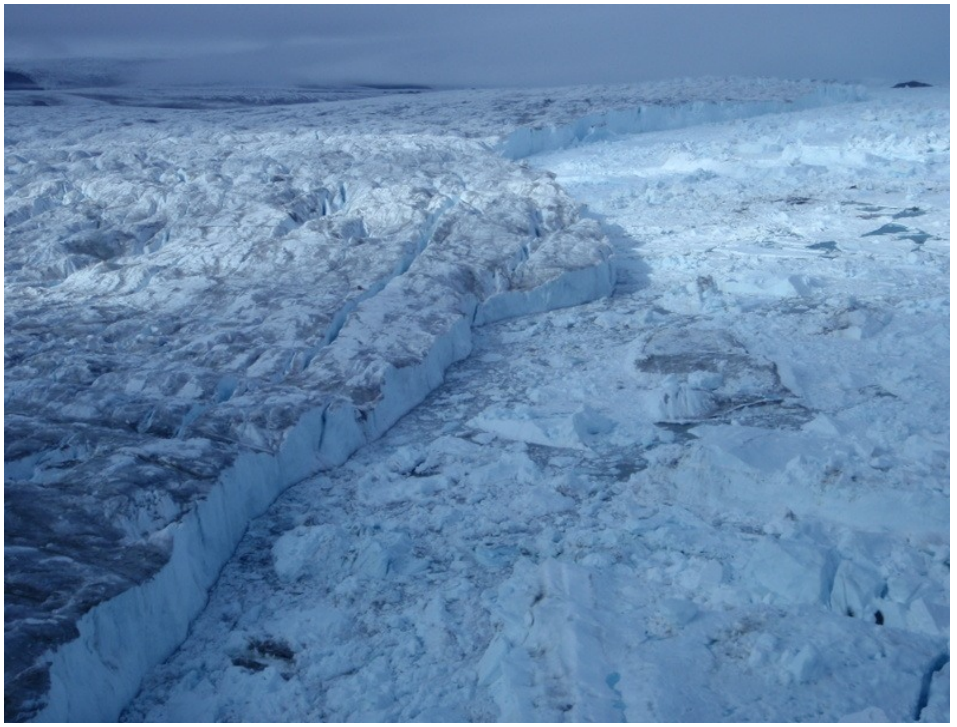


Key questions (1)

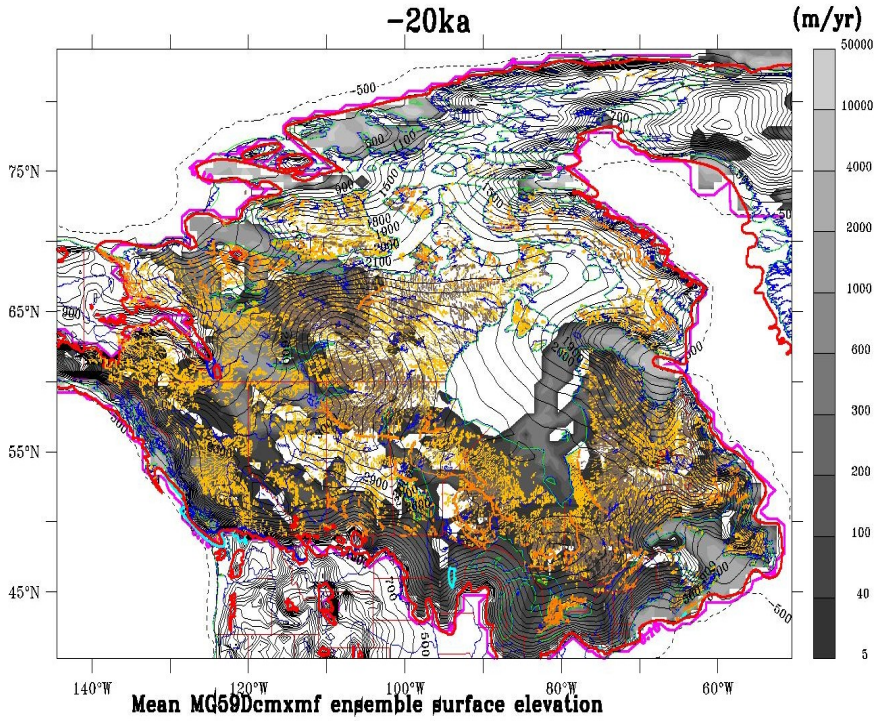
- On what timescale does Belcher Glacier respond to climate warming?
- How is glacier response regulated by changes in the rate and mechanism of ice flow? If so, what causes these changes?
- How do these changes amplify those caused by surface mass balance alone?

Key questions (2)

- Are changes in flow dynamics and iceberg calving related, and how?
- What controls the calving rate and its variation over time – is ocean climate important?



What scale do we work at?



- Large space/time scale, crude parameterizations?
- Or local scale, high data requirements, and detailed physics/ modelling?

What data is needed?

- Calving events: when, where, and magnitude
- Tide level, sea-ice cover
- Sub-glacial water pressure
- Crevasses(time): depth, water depth, width
- Strain rate field near terminus
- Ice thickness, topography and bathymetry at terminus
- Ocean temperature
- Submarine melt

Fieldwork

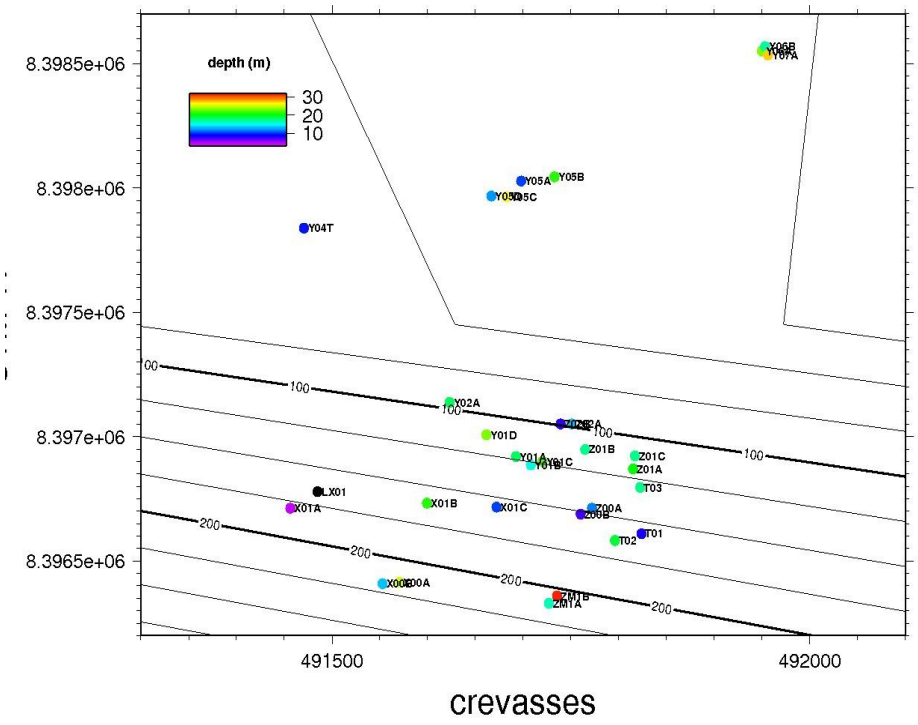
- Timelapse cameras:
  - Size and timing of calving events
  - Sea-ice cover
  - Sub-glacial sediment discharge
  - snow-cover
- Tides: model validated by observations
- Strain field: 1 continuous logger and repeat measurements at 26 sites
- Crevasses: depth and width measurements
- Subglacial discharge:
  - CTD off terminus and from water

Timelapse on a budget

- Pentax Optio W30
- New Model (W60) rated to -10C
- @ 300 shots/battery charge
- Problem: moraine was not stable

That looks like a calving event at the northern border of the picture. The ice-particles in the southern parts are not new.

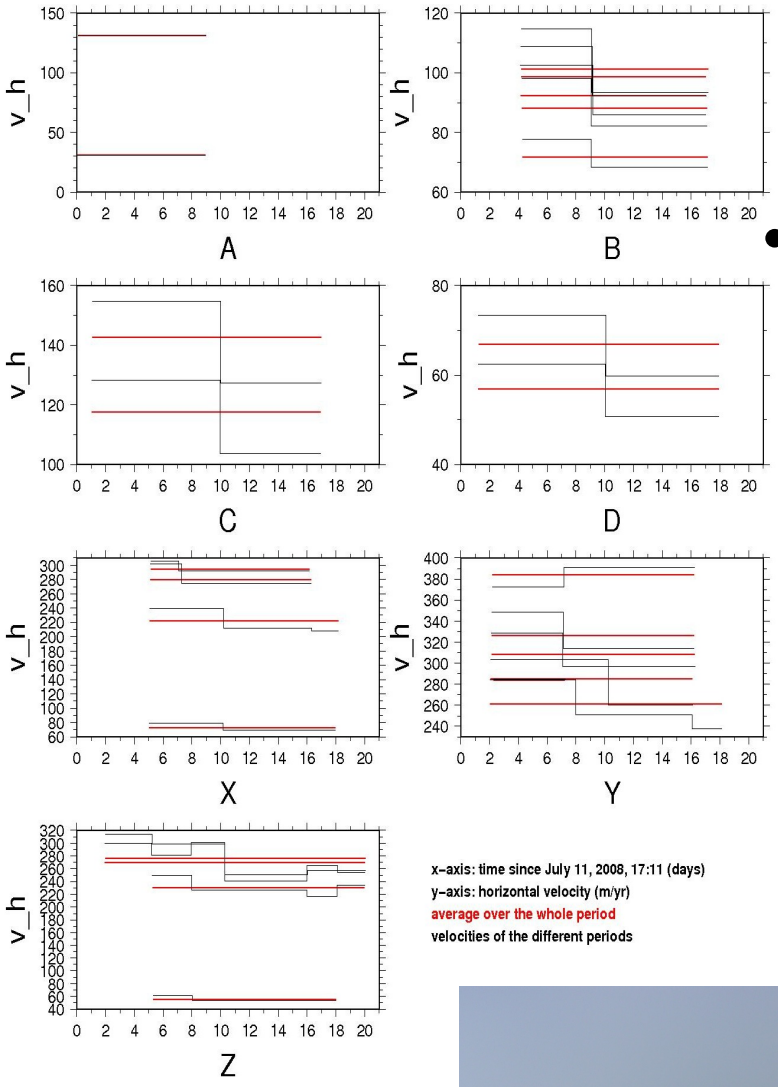
- Often not easy to discern calving events
- High and low cameras help



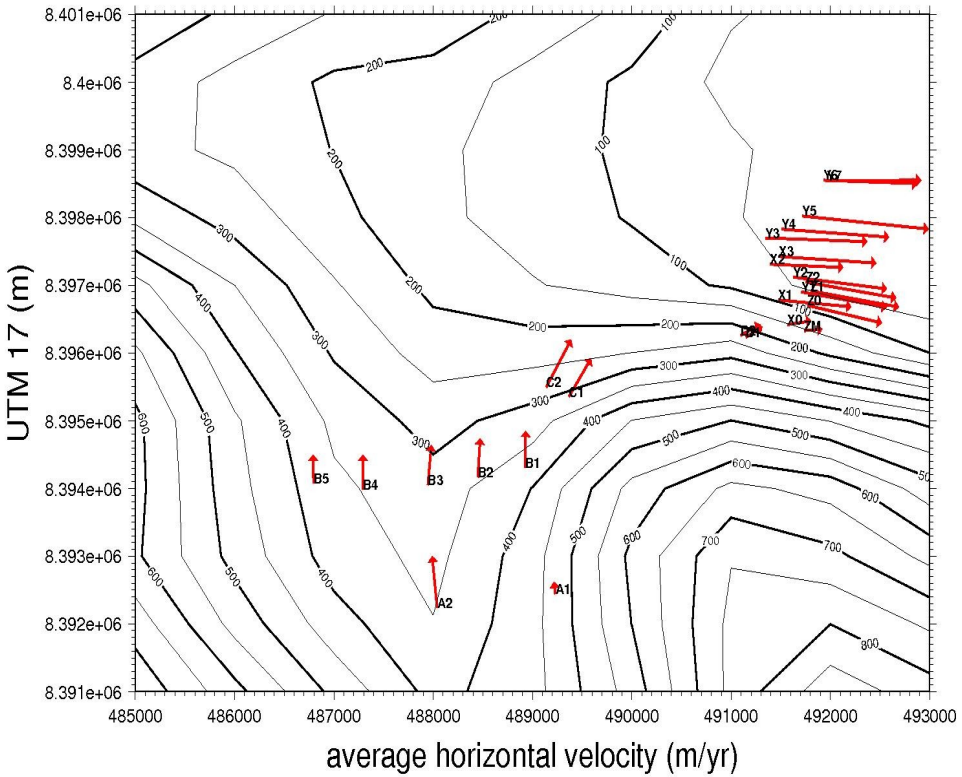
Crevasses

- No clear pattern wrt crevasse depth given limited measurements
- Need more efficient and accurate method than drop lines and old laser range finder
- Key issue is water depth
- Large deep crevasses were dry

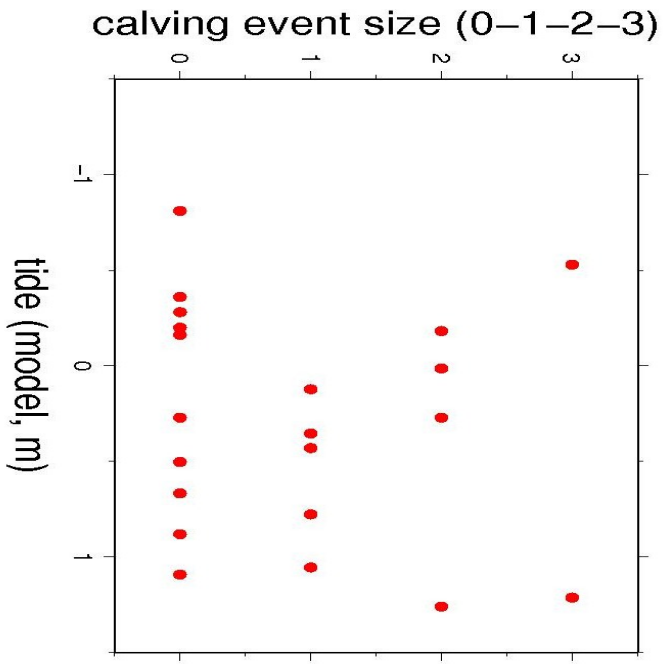
Velocity field



- Need semi-continuous longer term logging, with enough coverage to extract strain field and compare to hydrology

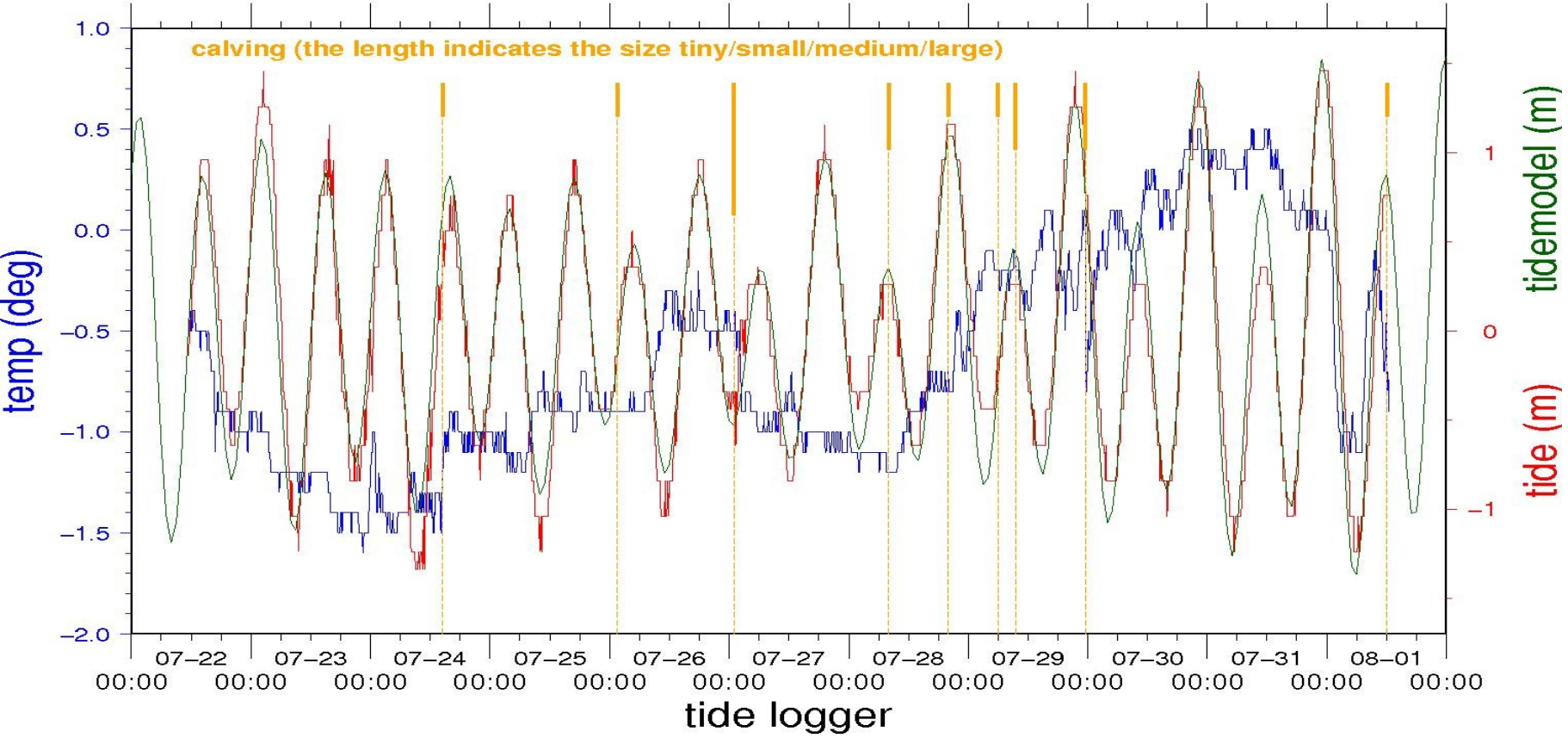


Do Tides affect calving?

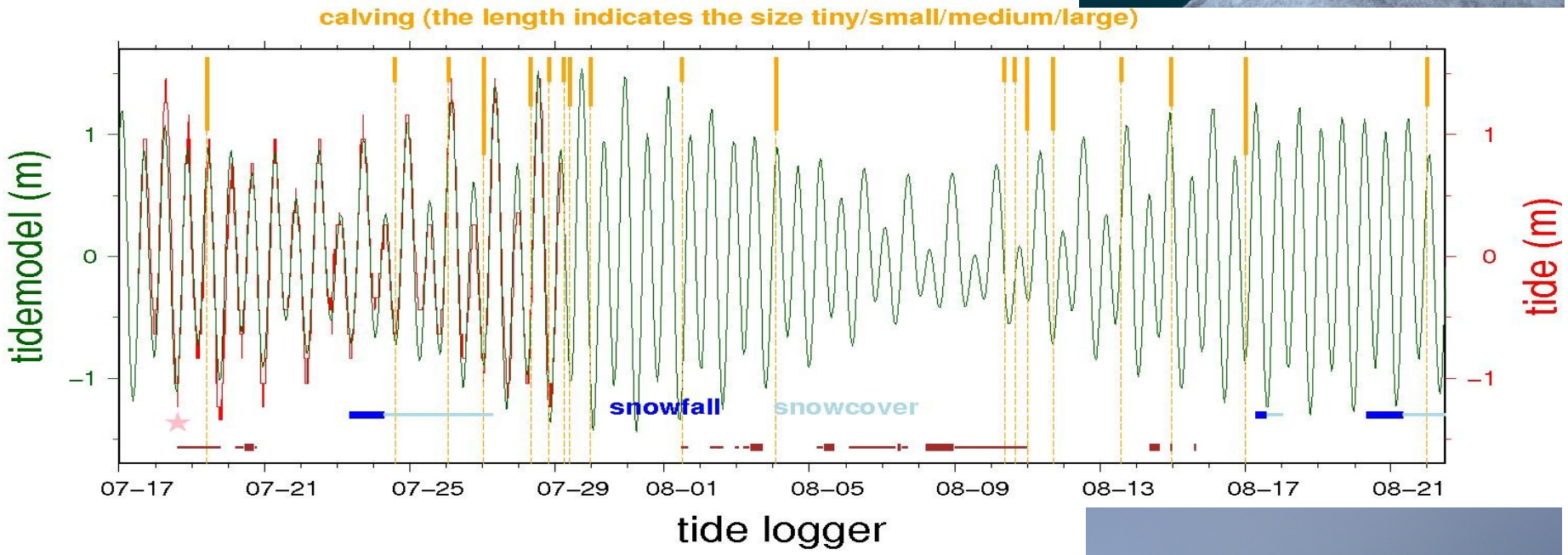


- Need more data
- But stronger events did correlate with higher tide

Tide phasing? (Tidal model matches observations)



Role of Surface Hydrology?



sedimentplume: thickness indicates activity (no activity, small or large)

sea–ice break–up: 90% ice coverage left

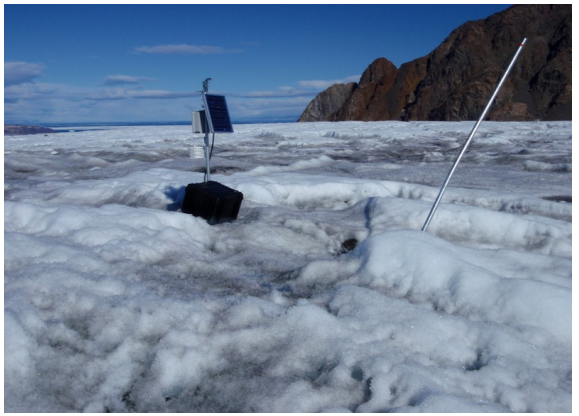
Miscellaneous lessons

- If Belcher is generic, then terminus is not hard to navigate
  - Carpenter's chalk best trail marker aside from drilled in stakes
  - Extendable ladder would have increased accessibility
  - Much more comfortable to have camps on lateral moraines
  - Problem is getting to and from glacier
- Safety
  - Terminus is much safer wrt flooding: crevasses/moulins capture drainage
  - Seals offer protection: Well-fed polar bears may be curious but apparently humans are not a top choice

More miscellaneous lessons

- Equipment Miniaturization:
  - Eg Vemco logger, CTD
  - Should be able to do the same for GPS and GPR
- Kovachs Drill: use WD-40
- Shipping: Canada Post (longer time) or Fed-Ex (3 weeks) is much cheaper than air freight
- Need low and high timelapse cameras as cloud/fog often obscured high camera

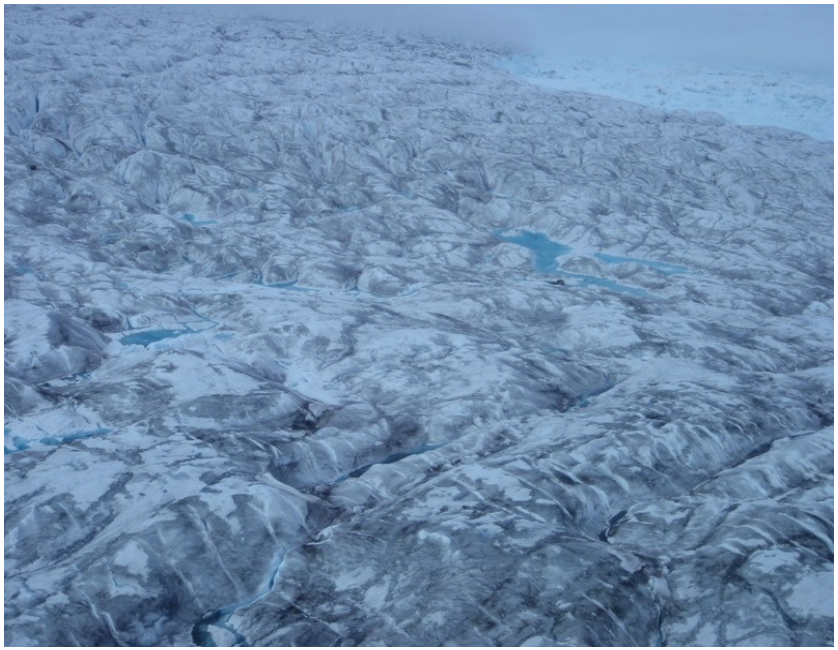
What's needed to constrain stability of Arctic tide-water glaciers?



- Continuous, multi-year data
  - GPS : need strain rate field
  - Timelapse, multiple levels
  - Subglacial input and discharge or pressure:How???
    - CTD, robotic rubber duckies, dye tracing, vertical motion, sediment plumes,
- Multiple sites
  - Need global data-base
- Modelling
  - Need topo/ice thickness data right up to terminus

Personal Learning

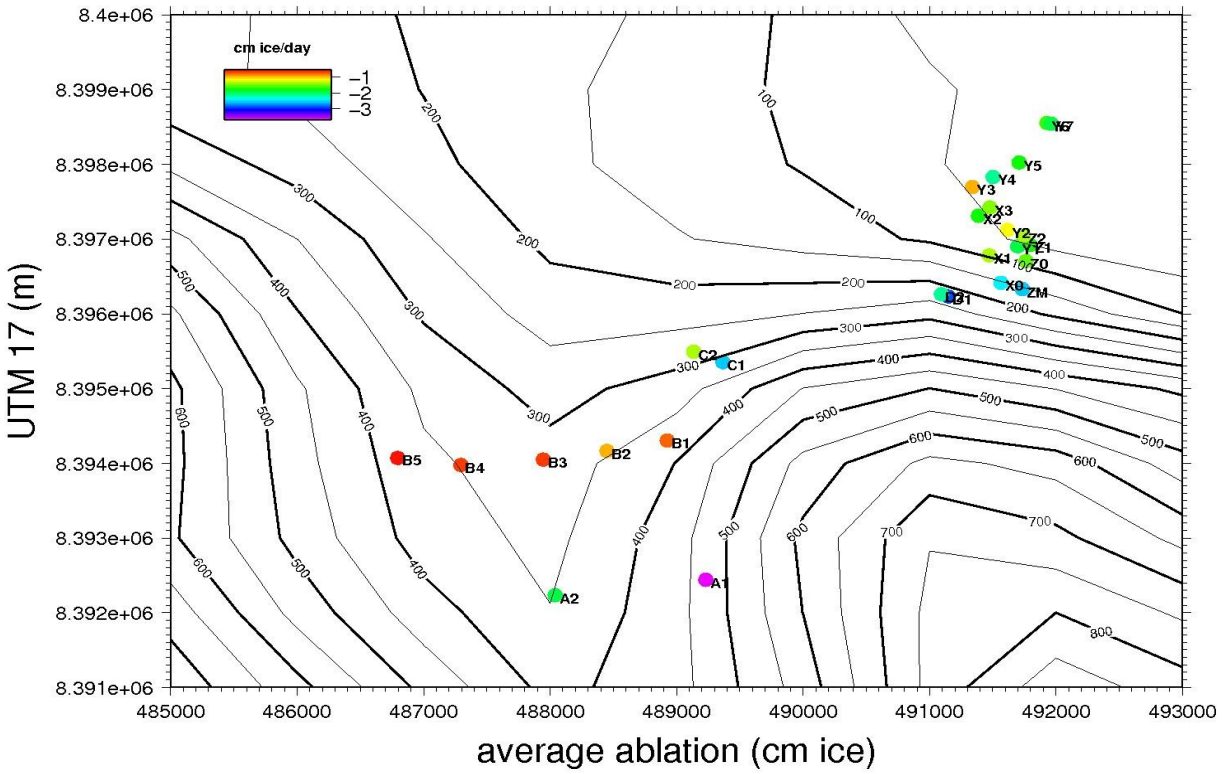
- Hydrology matters

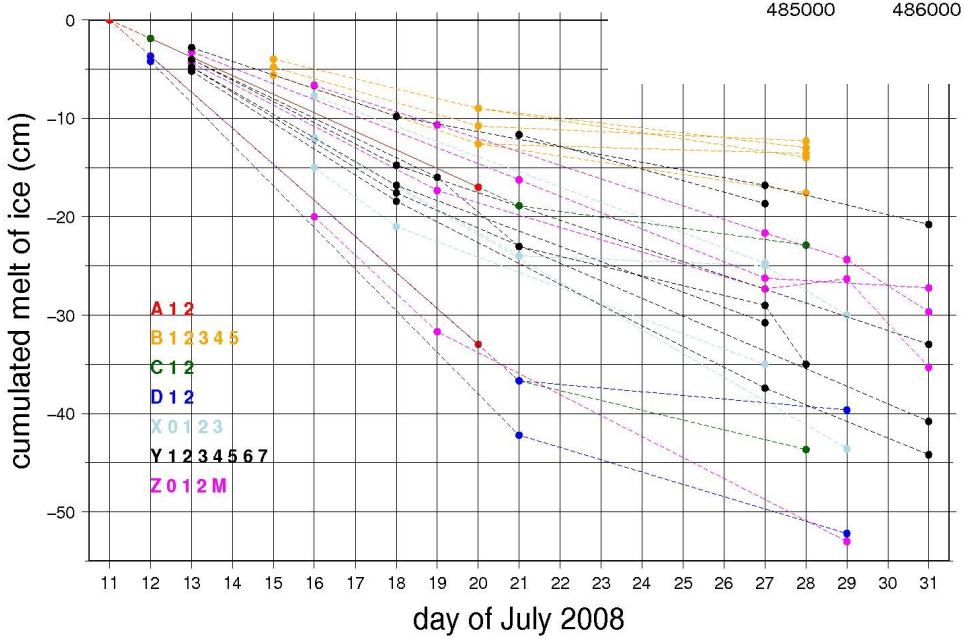


Remaining Questions: Who's is this? And how to keep feet dry?

Thanks to Martin, Luke, and Brad for organizing the proposal, equipment, data and guidance

mass-balance





Funding

- NSERC
  - IPY SRO
  - Discovery Grant
- CFI
- AceNet
- ArcticNet
- PCSP