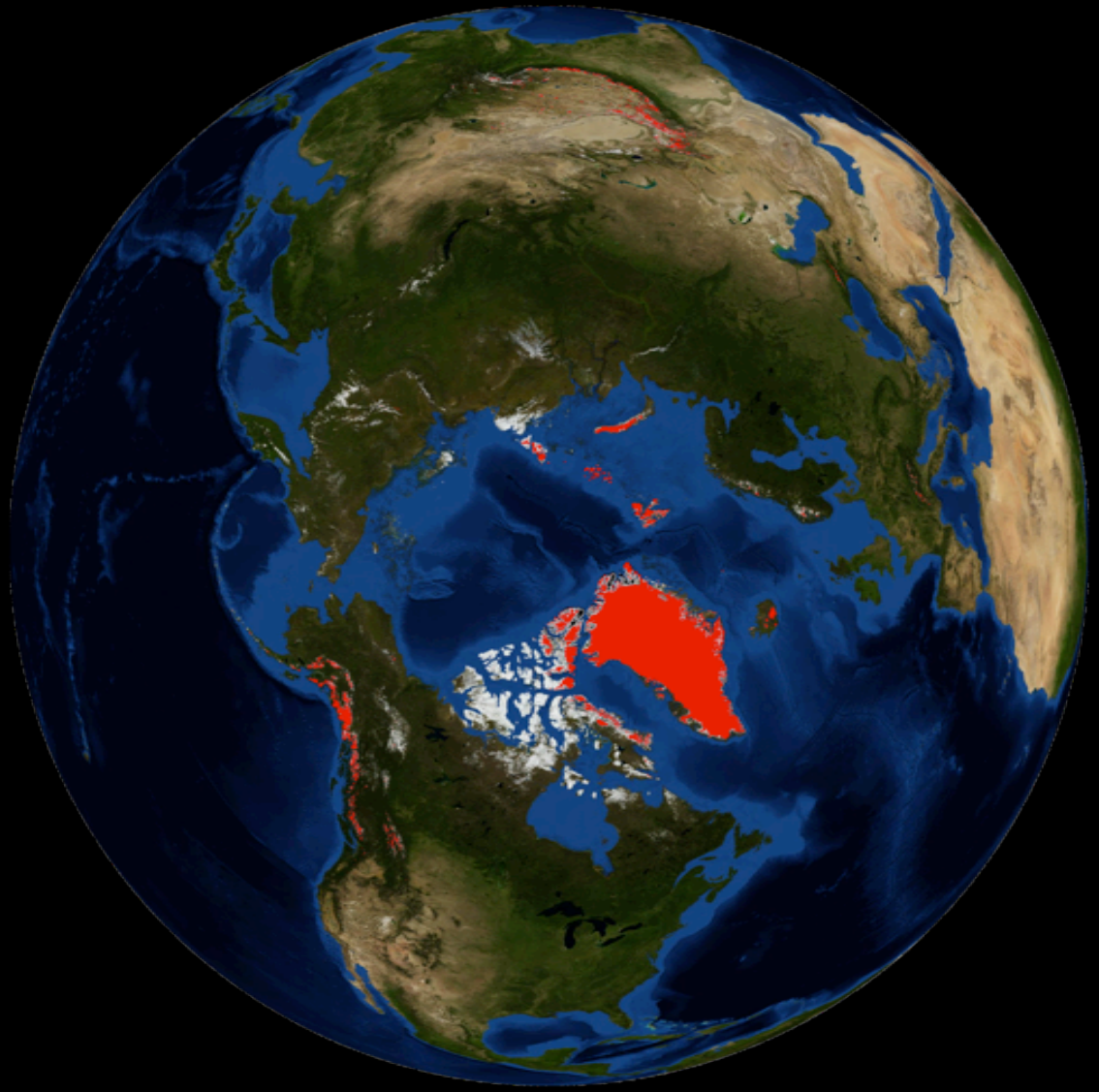
The need for improving the glacier surface energy and mass budgets within CESM



Alex S. Gardner and Mark G. Flanner
University of Michigan

Why improve the glacier surface process within CESM (CLM)?

- land ice = primary driver of sea level change
  - surface mass budget
  - iceberg calving
- Observed recent accelerated mass loss from glaciers
- ~half of acceleration can be directly attributed to more negative surface mass budget
- Indirect influences on glacier flow?

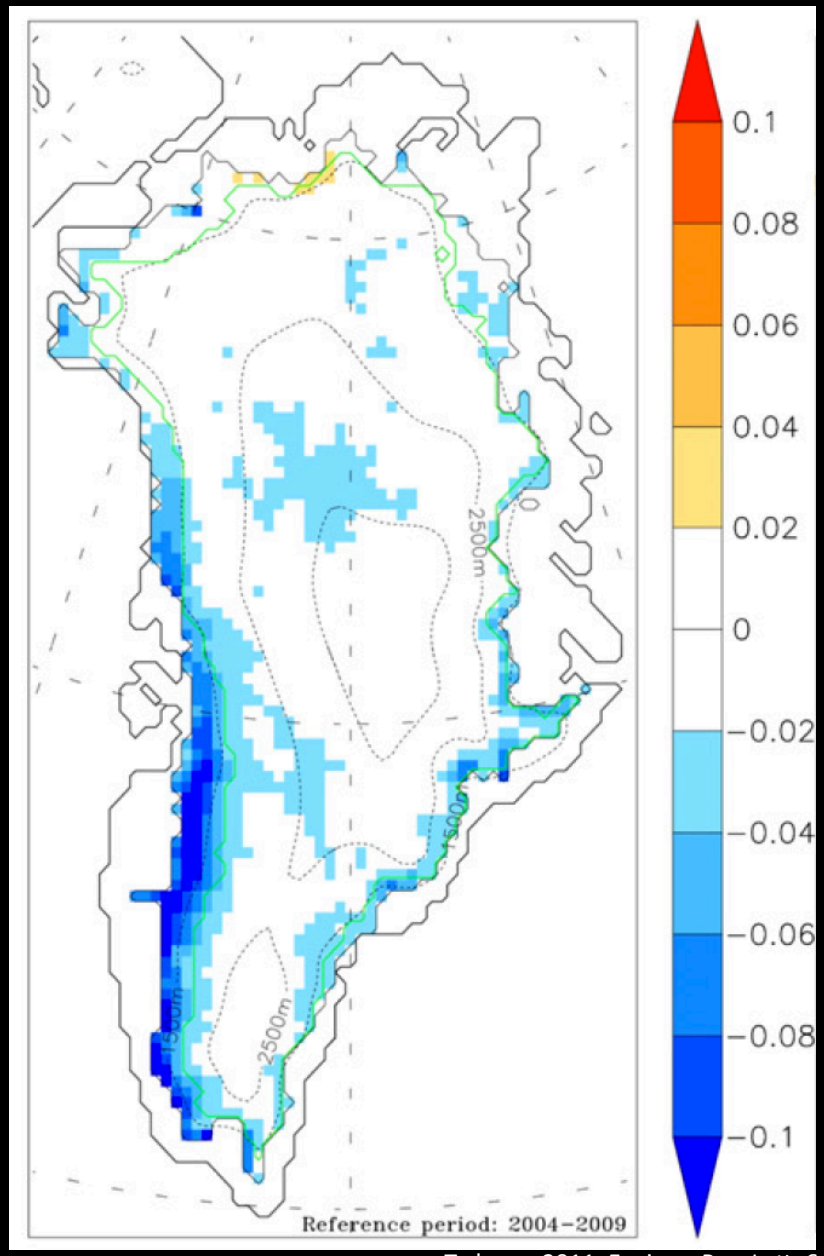
What needs improving

- RT scheme for glacier ice
- Supraglaciel lakes
- Impurity (tracer) transport within CISM
- Surface roughness evolution
- Firn formation & meltwater routing
- Improved atmospheric downscaling for glacier M.E.C. units

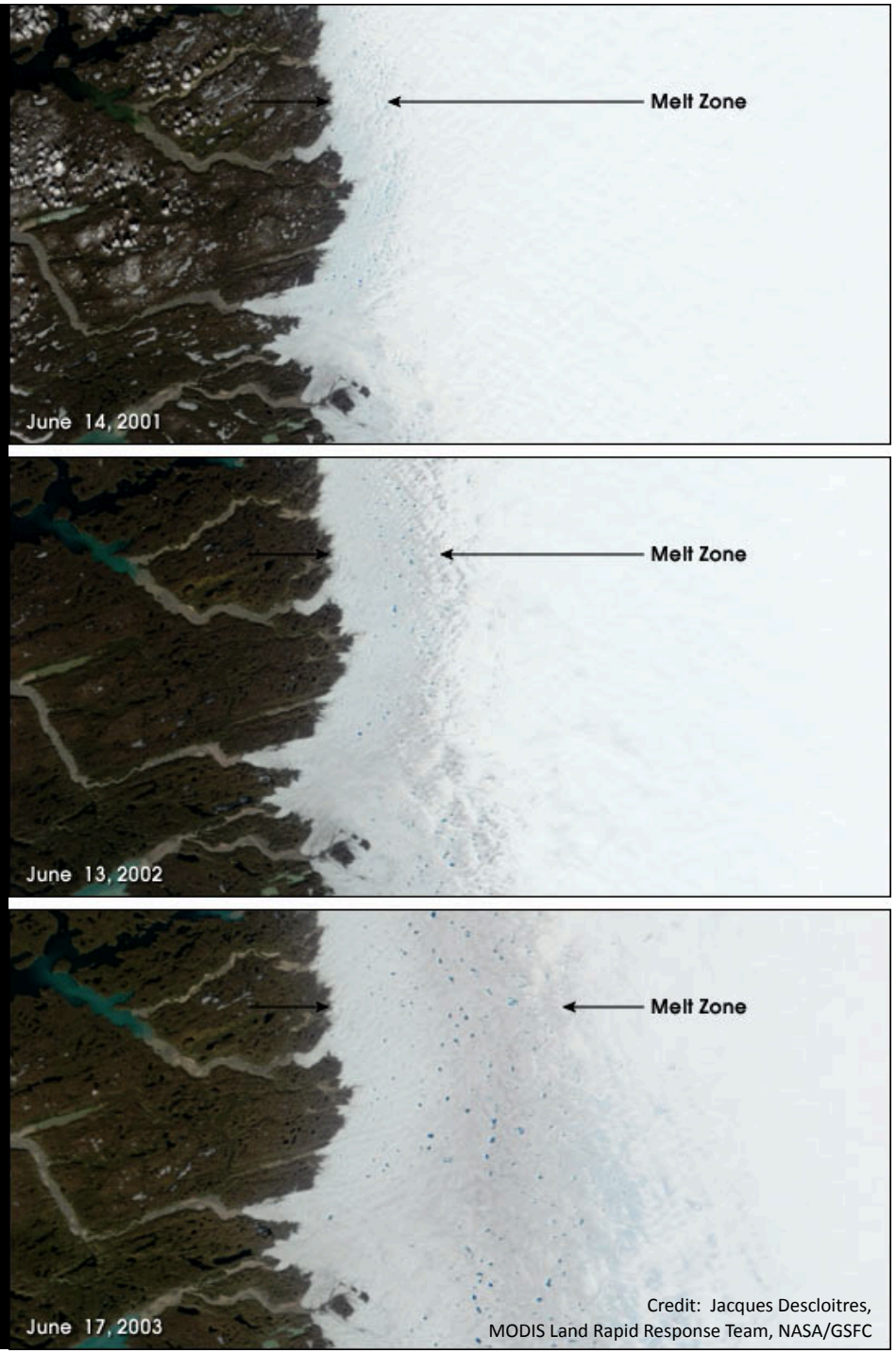
Current focus

Glacier RT scheme

May–August 2010 MODIS albedo anomaly relative to 2004-2009 mean



Tedesco, 2011. Environ. Res. Lett. 6

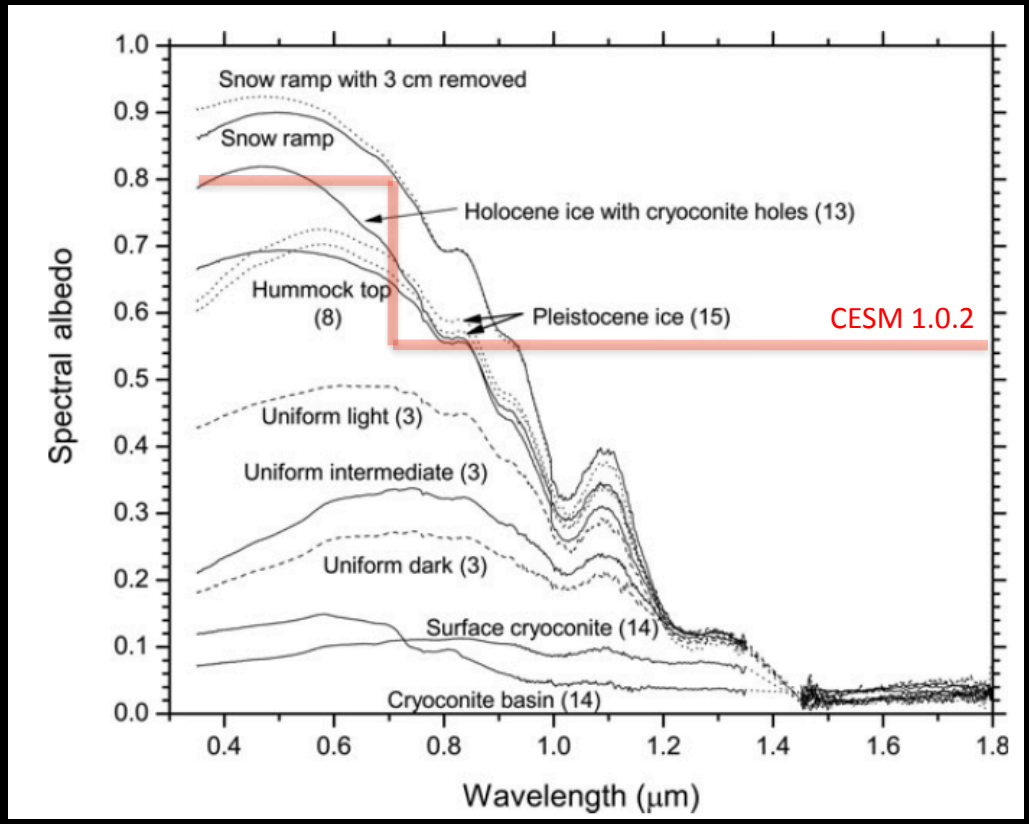


Credit: Jacques Descloitres,
MODIS Land Rapid Response Team, NASA/GSFC

An RT scheme for glacier ice

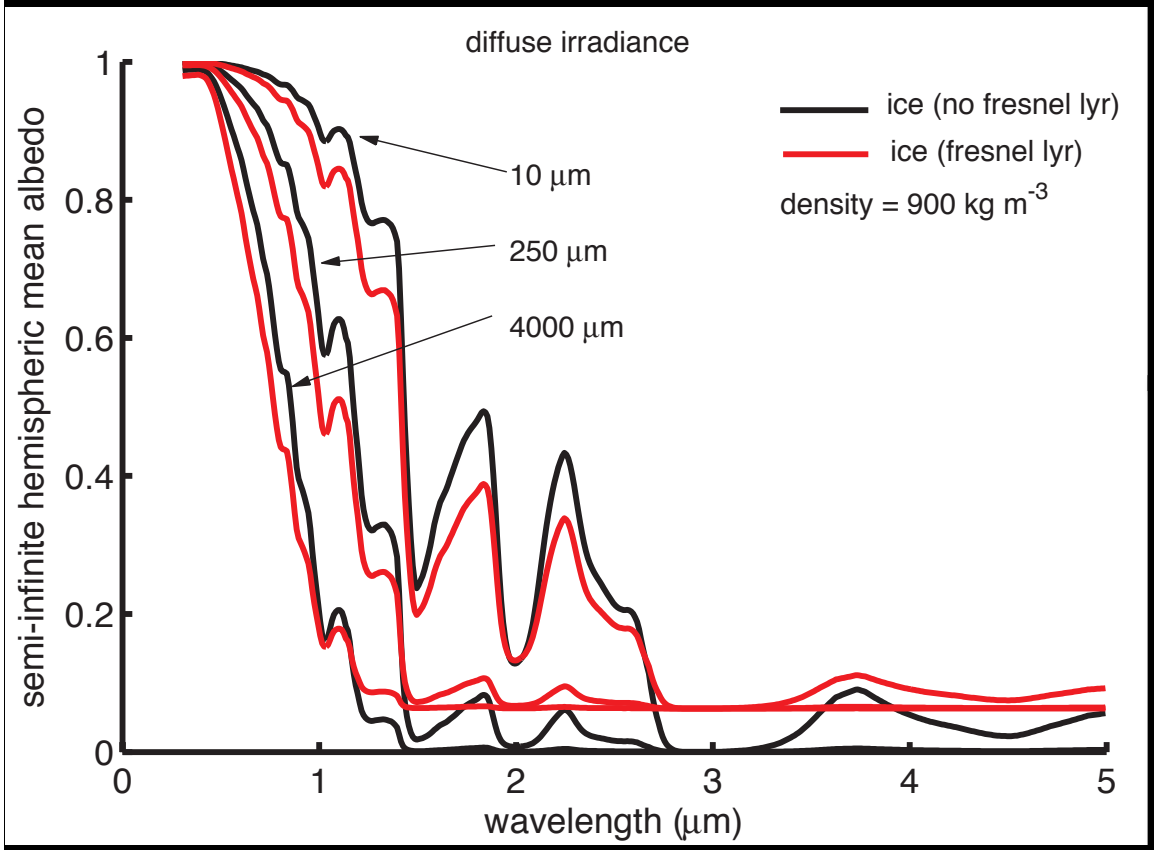
Requirements:

- Multiple scattering within snow, bubbly ice and water
- Able to handle "Fresnel" boundaries between layers with different refractive indices
- Impurities
- Surface roughness



Boggild et al., 2010. J. Glaciology. v46

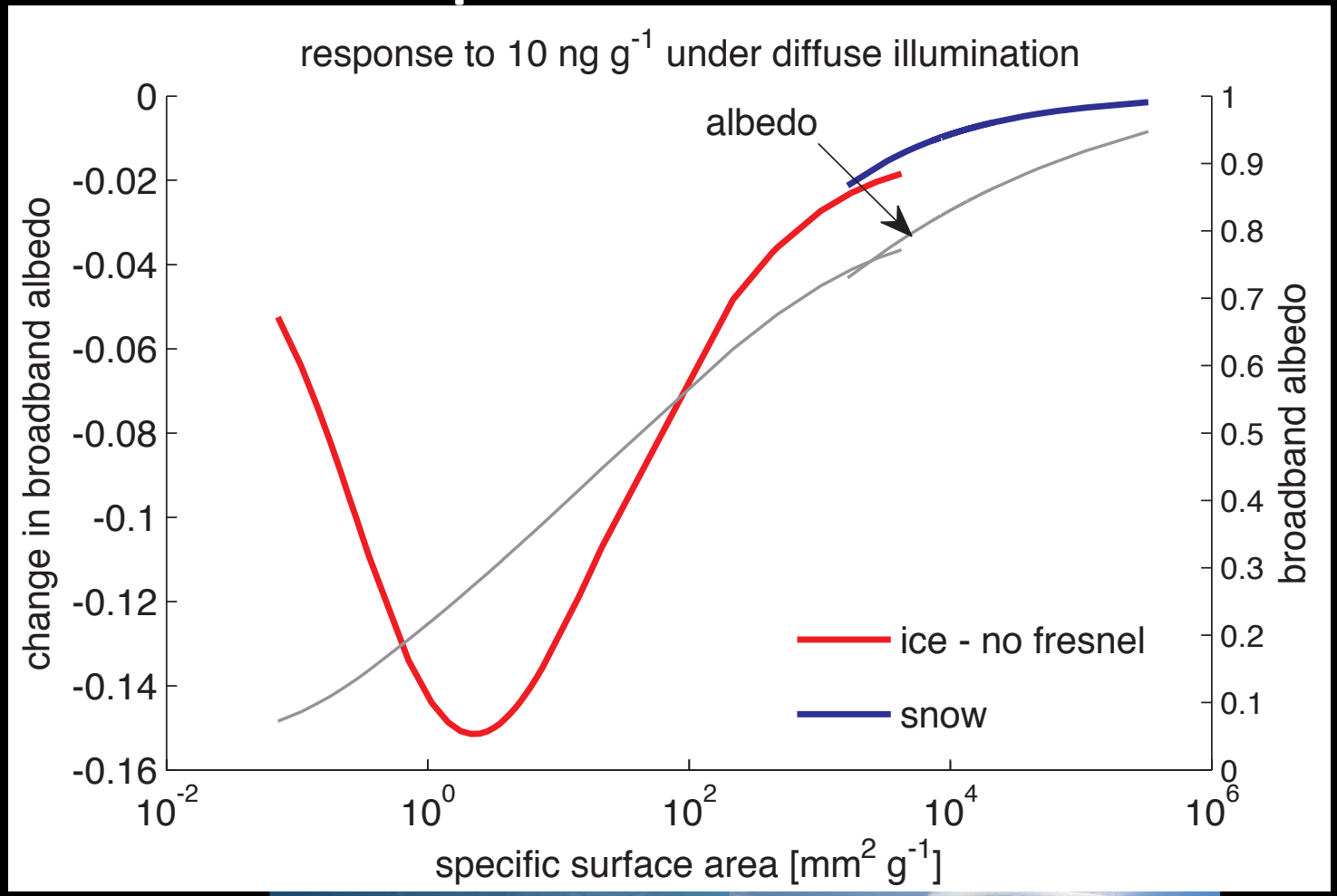
Ice albedo


diffuse irradiance
ice (no fresnel lyr)
ice (fresnel lyr)
density = 900 kg m^{-3}
10 μm
250 μm
4000 μm
semi-infinite hemispheric mean albedo
wavelength (μm)
0
0.2
0.4
0.6
0.8
1
0
1
2
3
4
5


blue ice

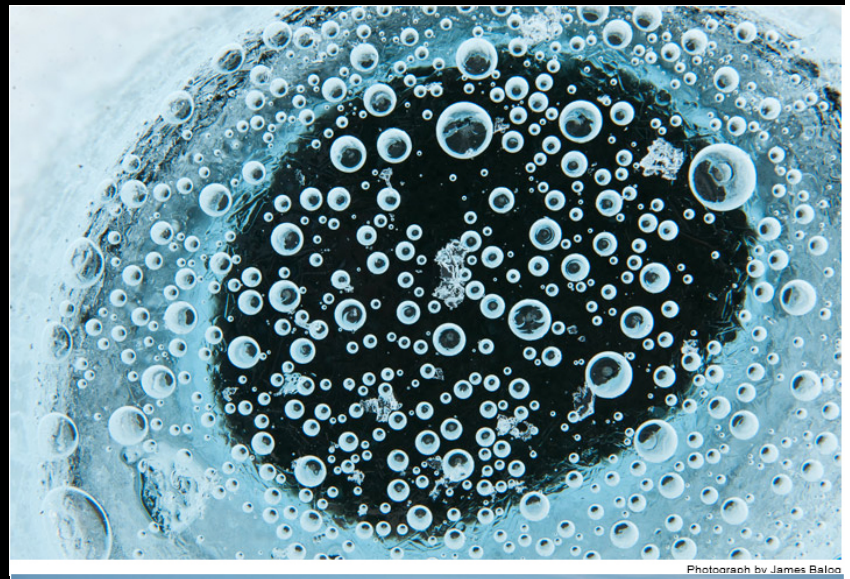

white ice

Albedo response to soot vs SSA

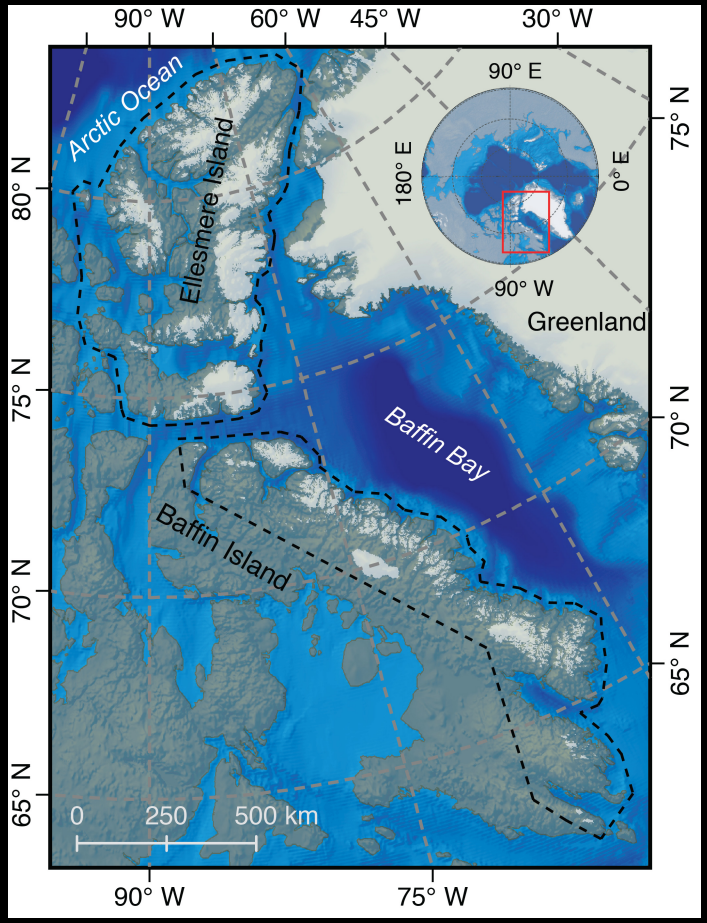


What's next?

- Surface roughness
- Lakes
- Cryoconite
- Implementation in CLM and coupling with CISM



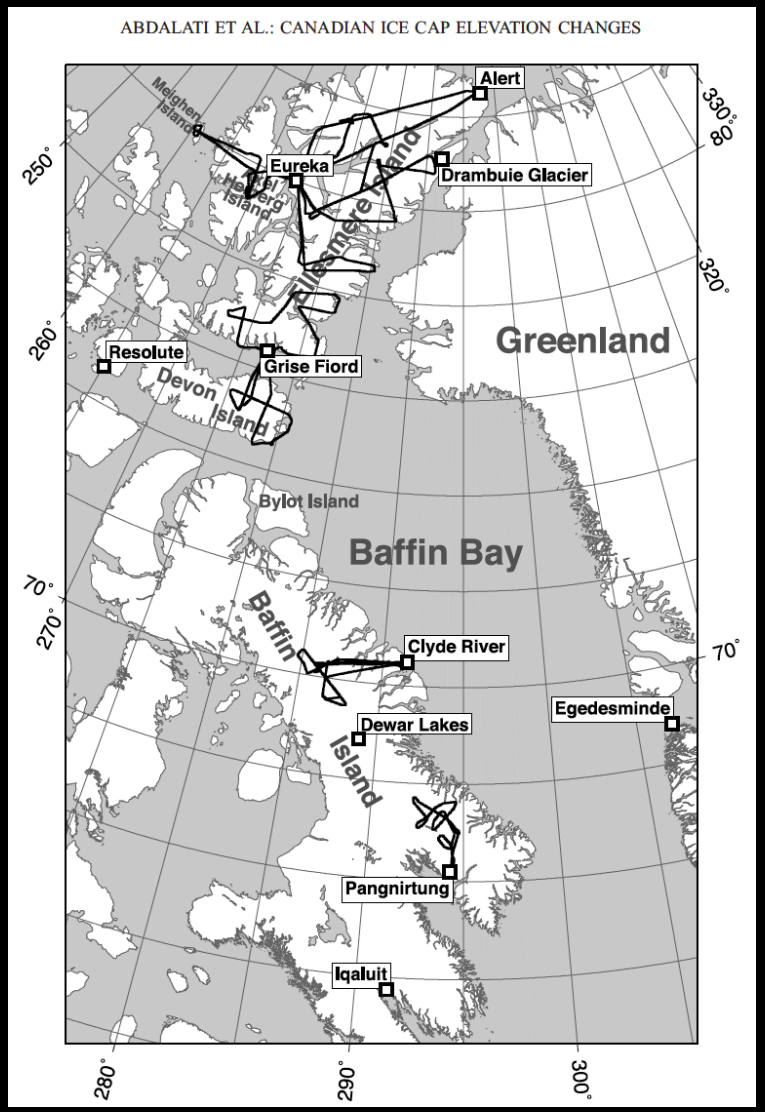
Sharp increase in mass loss from glaciers in the Canadian Arctic Archipelago (CAA)



Gardner et al. 2011

Only one preexisting regional estimate

- NASA Airborne Topographic Mapper
- measured elevation changes using airborne LIDAR
- Estimated mass loss
  - 1995-2000 = 23 Gt yr^{-1}

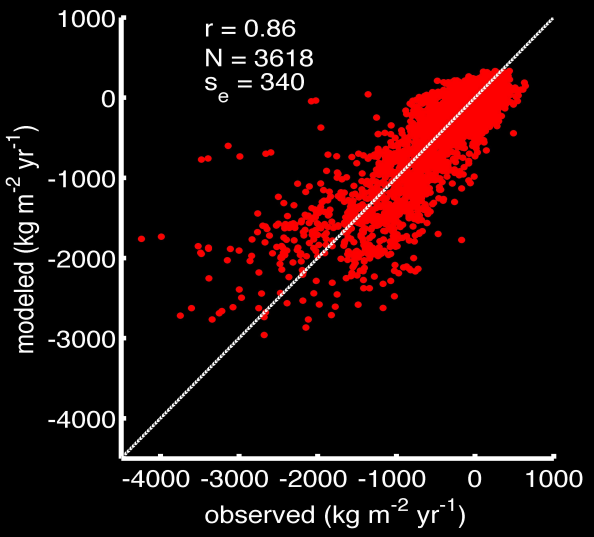


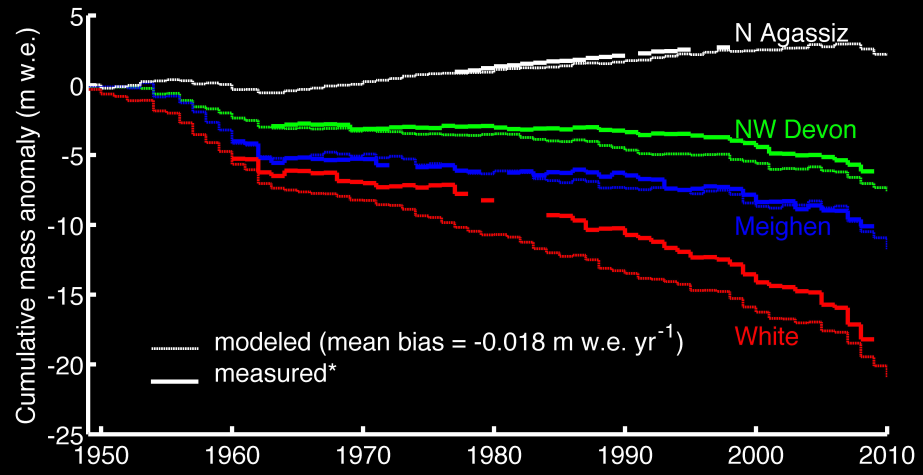
Abdalati et al. 2004

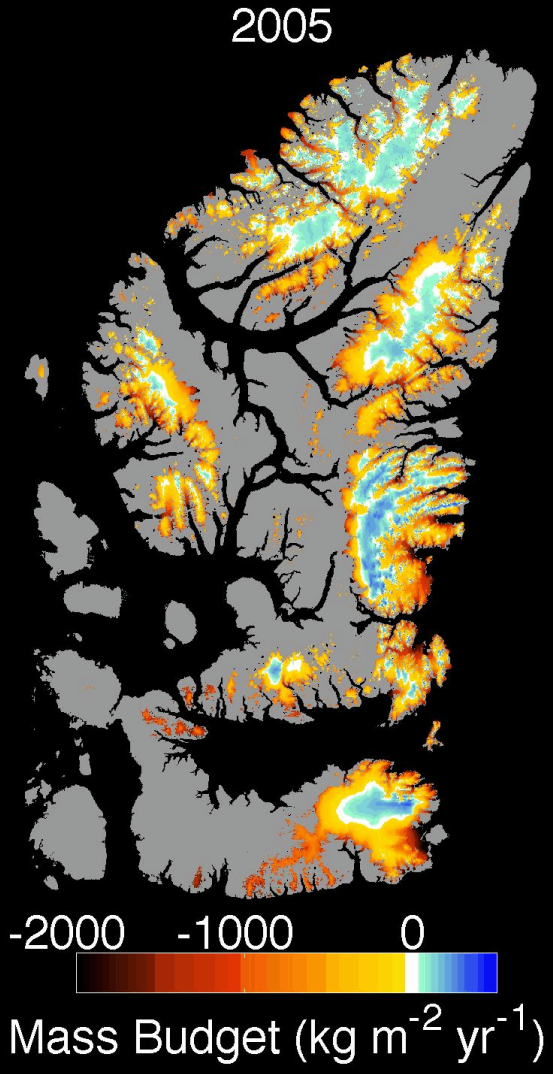
Our Study

- Time period: fall 2003 to fall 2009
- Methods:
  - Modeling (North CAA only)
  - GRACE
  - ICESat

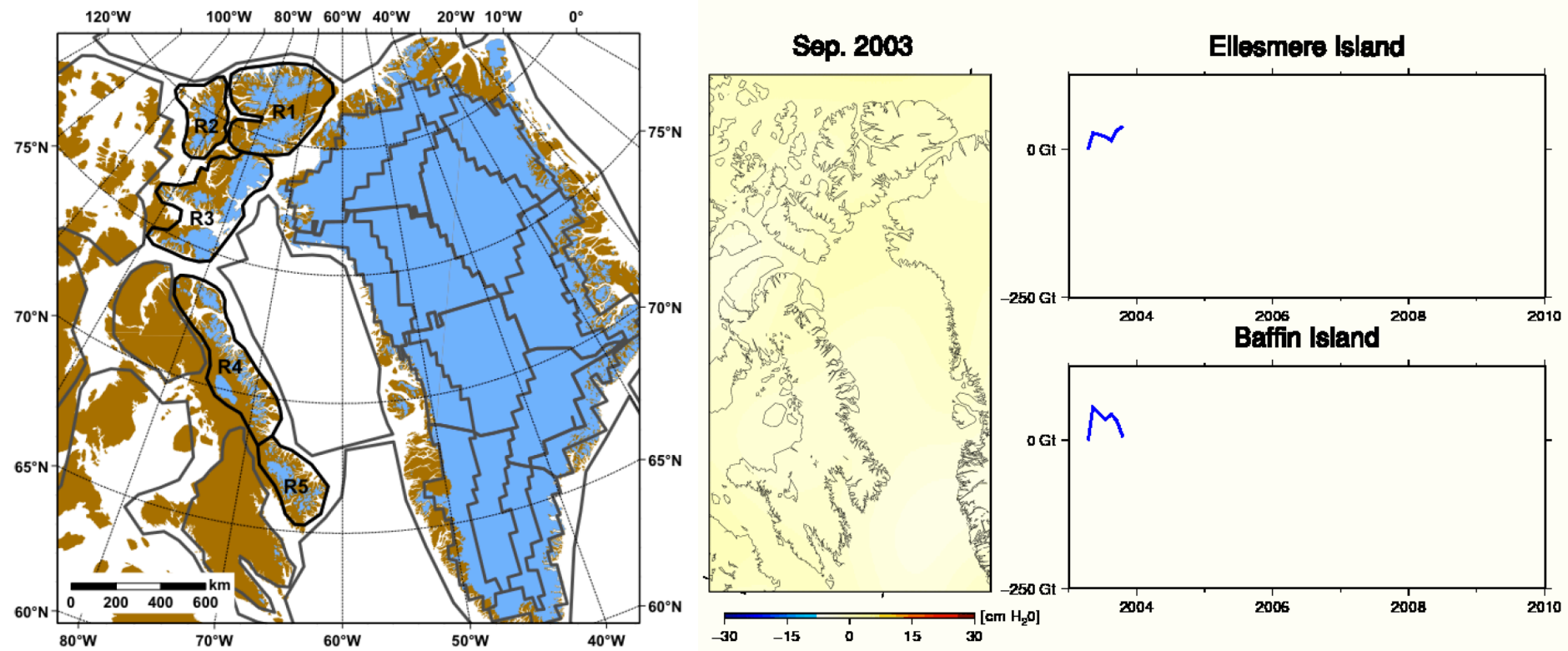
Surface mass budget (2004-2009)





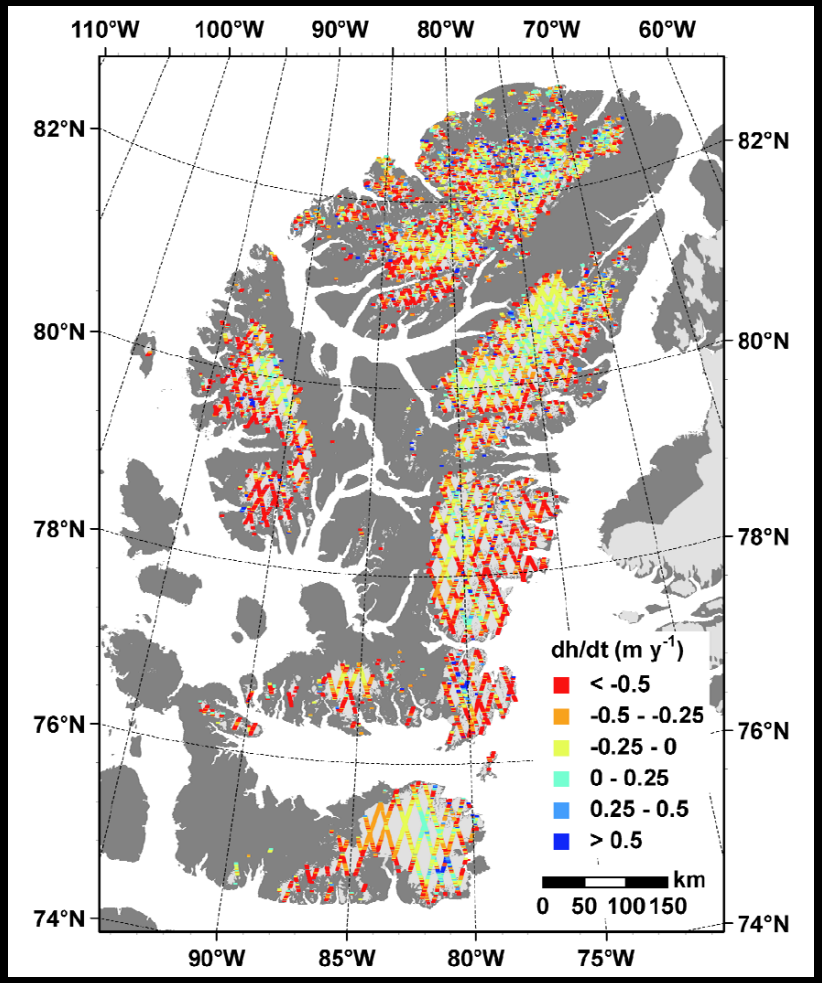


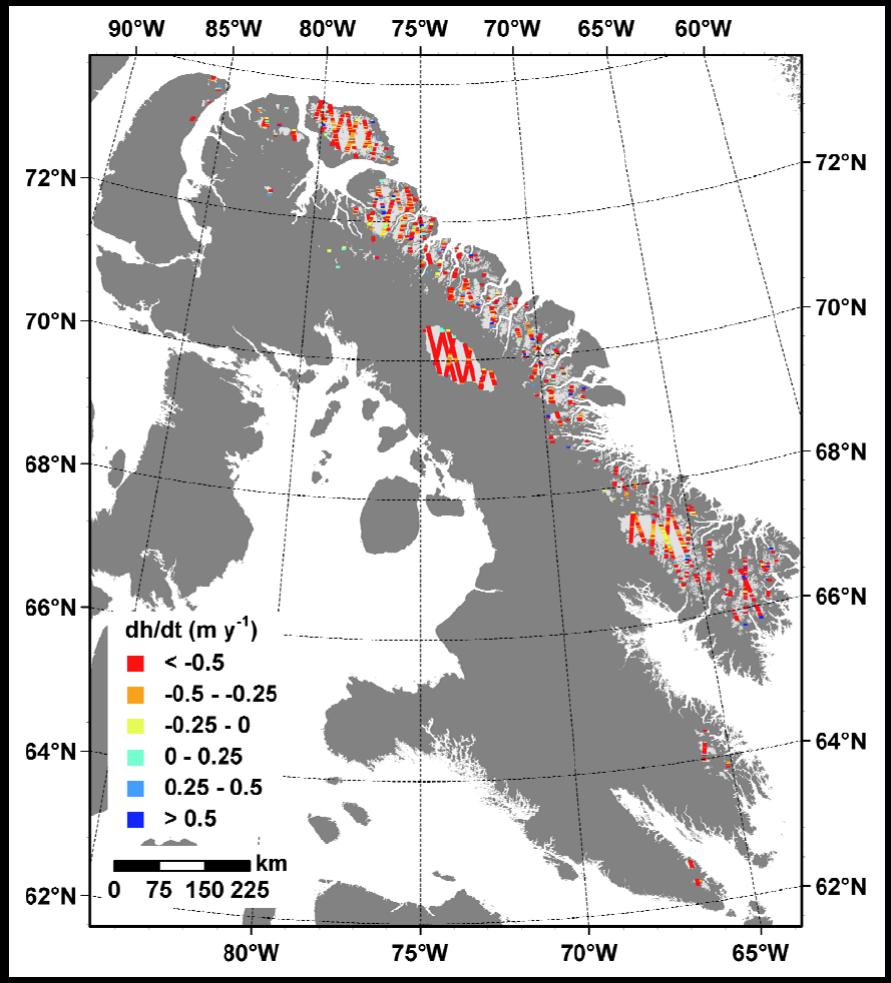
GRACE (2004-2009)



Credit: Bert Wouters, The Royal Netherlands Meteorological Institute

ICESat (2004-2009)



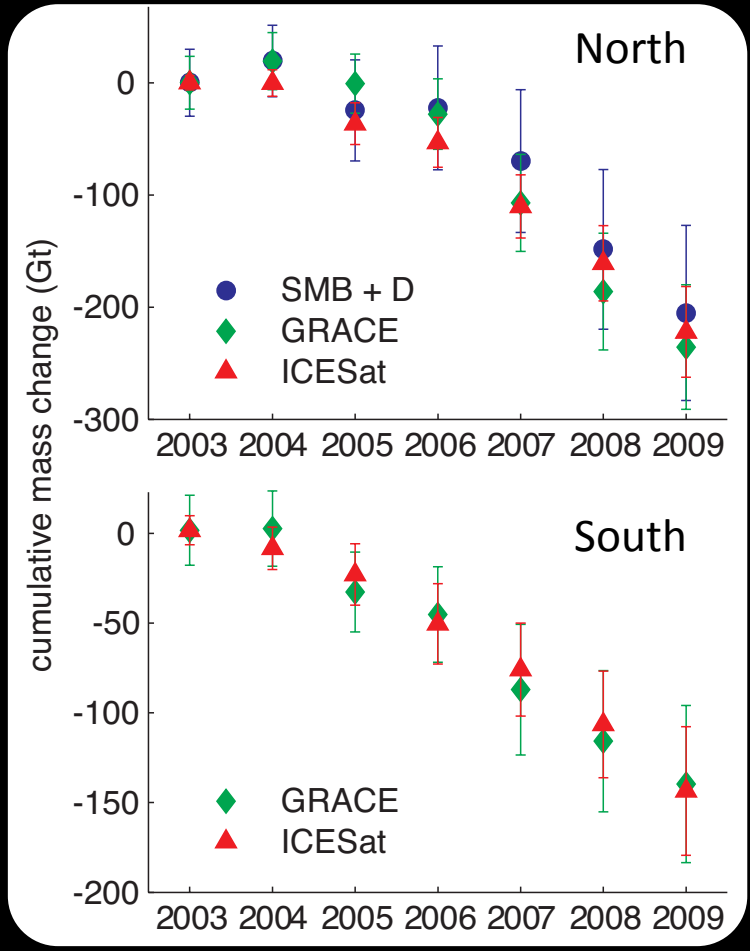


Credit: Geir Moholdt, Scripps Institution of Oceanography

CAA glacier mass loss

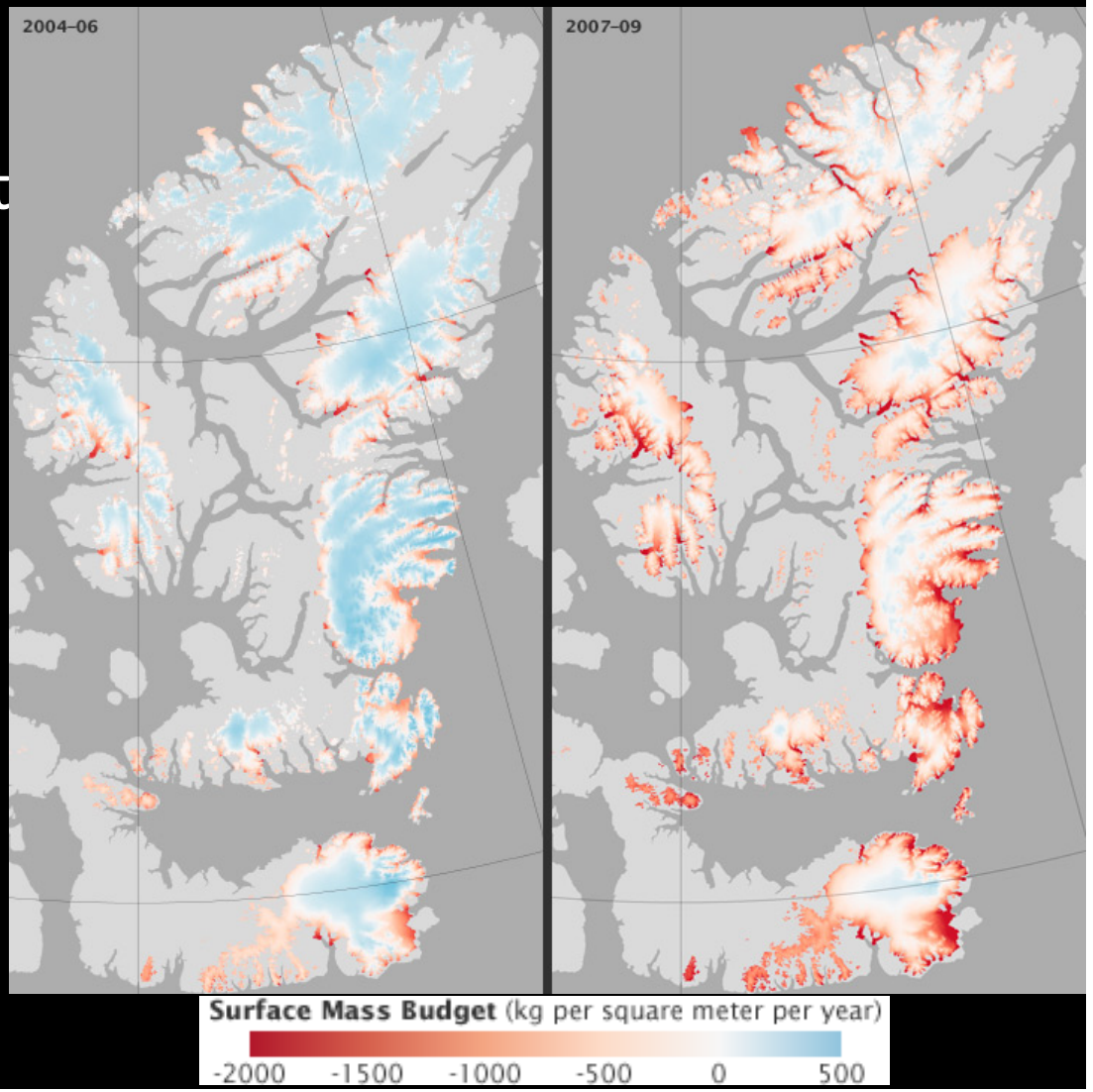
- very good agreement between methods

- 1995-2000 = 23 ± ? Gt yr^{-1}
- 2004-2006 = 31 ± 8 Gt yr^{-1}
- 2007-2009 = 92 ± 12 Gt yr^{-1}



Causes and outlook

- Nearly all of the increased loss was due to increased melt
- Every 1°C increase in surface temperature resulted in a 60 Gt yr^{-1} increase in mass loss
- Even at it's peak loss rate of 92 Gt yr^{-1} the CAA will survive another 800 years



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