Shallow firn saturation: implications for Greenland surface mass balance

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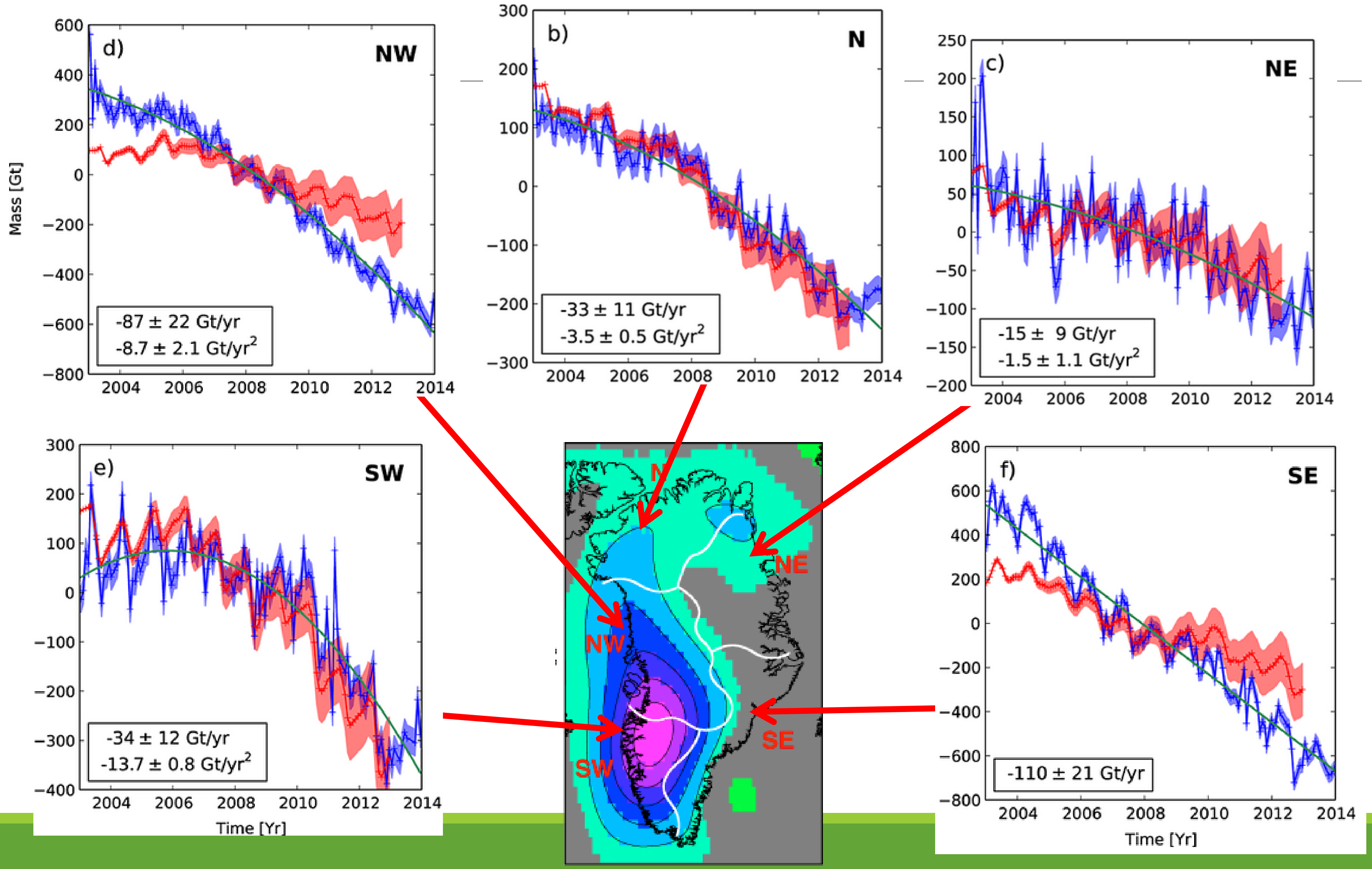
Greenland Mass Balance, 2002-2014

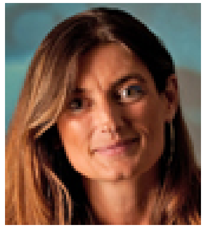


70% of **total mass loss** from the SE (40%) and the NW (30%)

88% of **total acceleration** from SW (54%) and NW (34%)

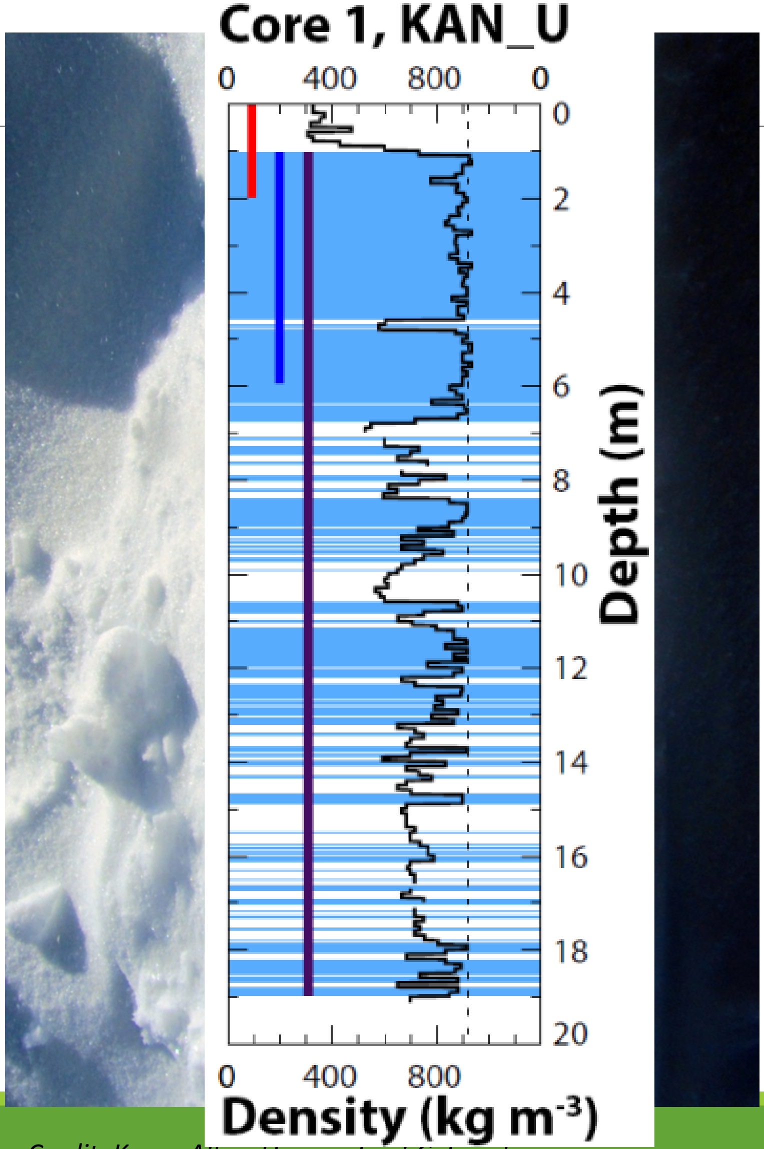
Surface Mass Balance (SMB) accounts for **68% of mass loss** and **79% of acceleration** in Greenland, 2002-2014

Velicogna I., T.C. Sutterley, M. van den Broeke. 'Spatially varying ice mass acceleration of the polar ice sheets from GRACE'. *Geophys. Res. Lett.*, 41 (22), 8130-8137

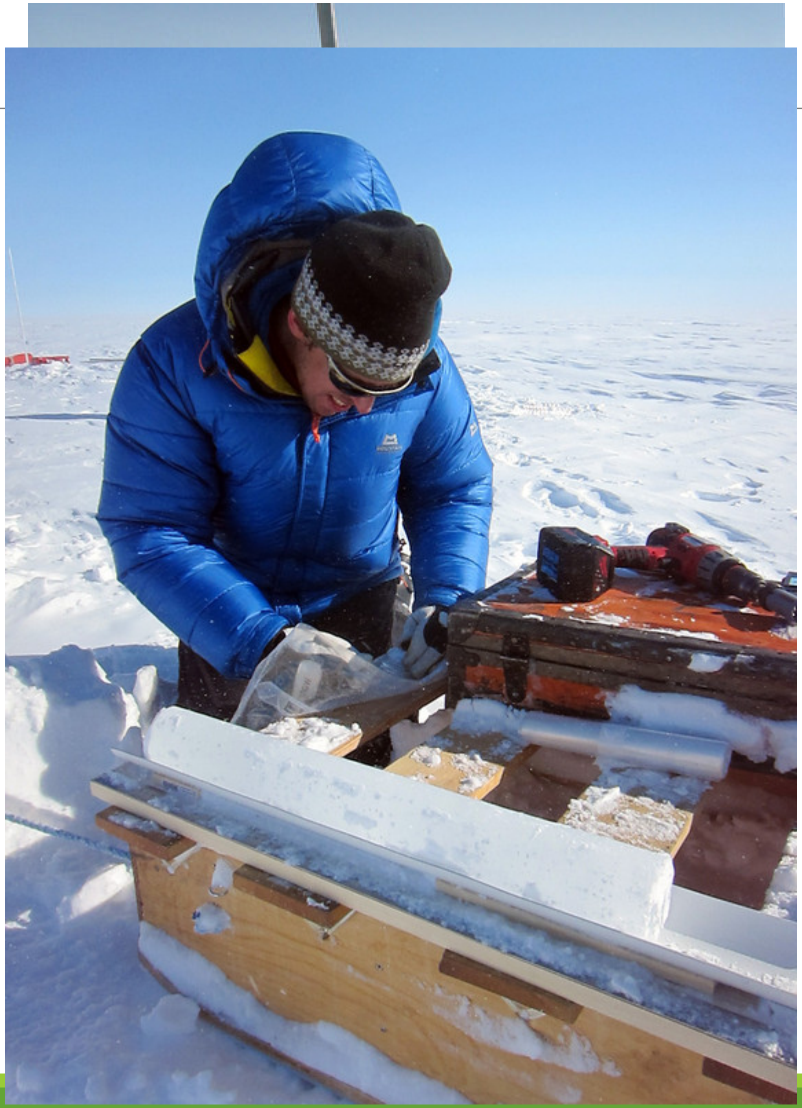


Ice Lenses at KAN-U, SW Greenland, 2012

67.0 N, 47.0 W
1860 m a.s.l.



Credit: Karen Alley, University of Colorado



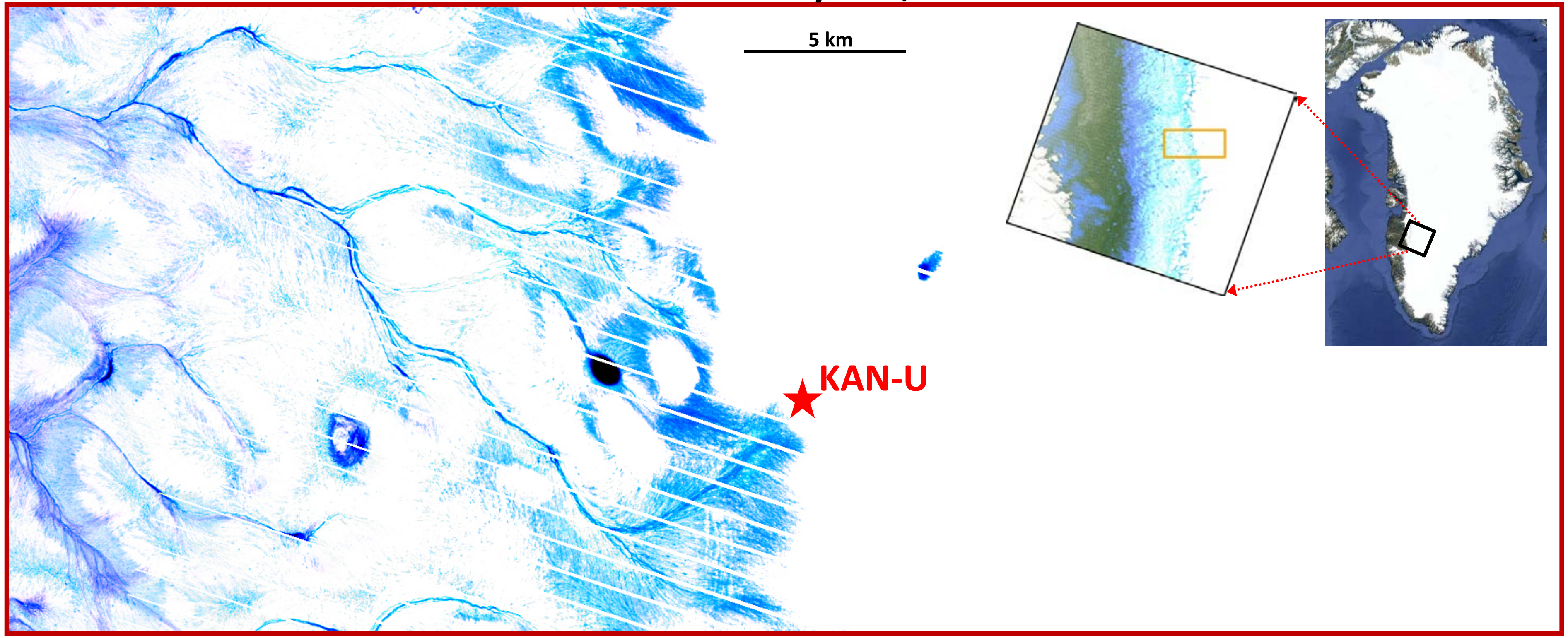
Credit: Babis Charalampidis, GEUS

KAN-U, Spring 2012

Credit: Horst Machguth, DTU

Summer 2012 Runoff Reaches KAN-U

LandSat-7: July 16th, 2012



Runoff had not previously been witnessed this high in southwest Greenland (up to 1900+ m a.s.l.)

Watson River in early May

Credit: Karen Alley, Univ. Colorado

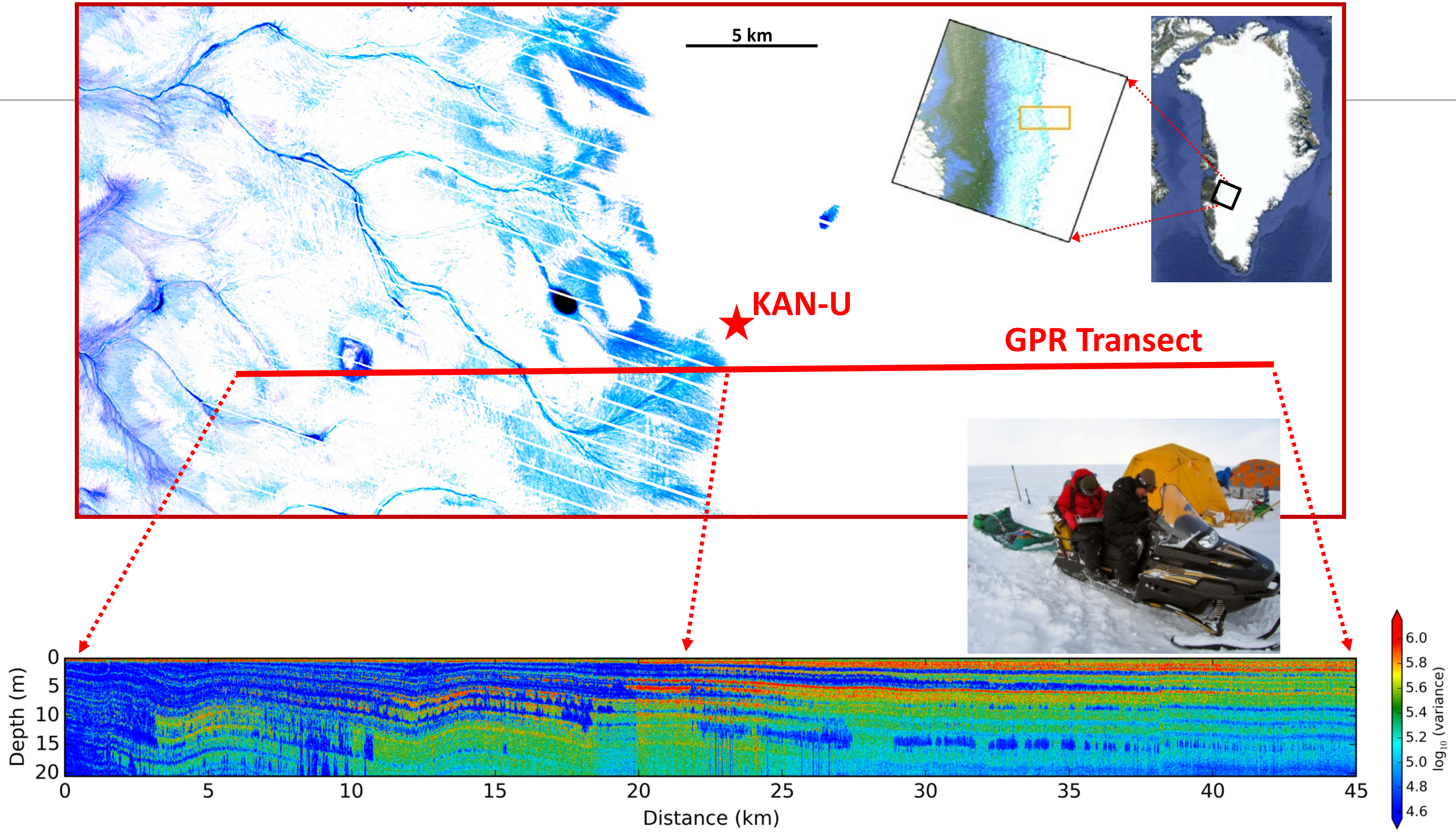
Watson River in July 2012

9±3% of 2012 Watson River area runoff came from “perched layer” zones

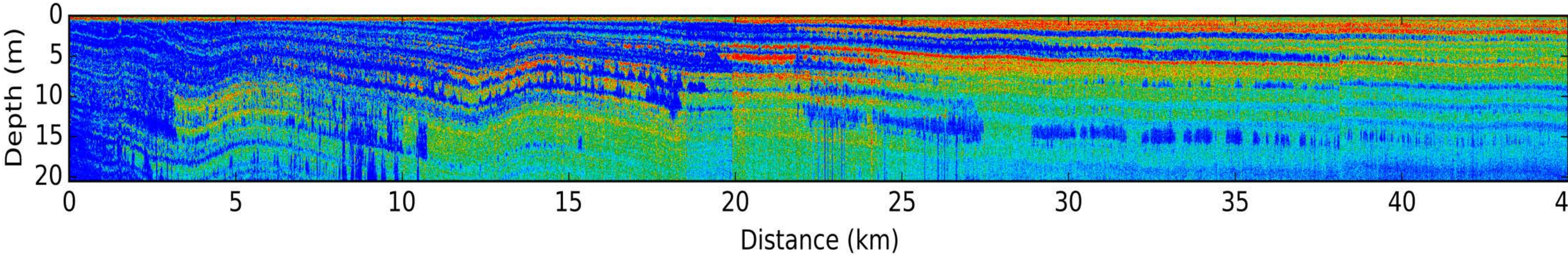
Machguth H., M. MacFerrin, D. van As, J. Box, C. Charalampidis, W. Colgan, R. Fausto. “Succession of melt events is key to abrupt Greenland ice sheet surface mass loss”. *Nature (in review)*. 2015

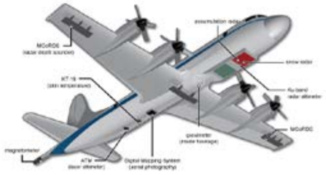
youtube.com/watch?v=WrIX-WzWA8k

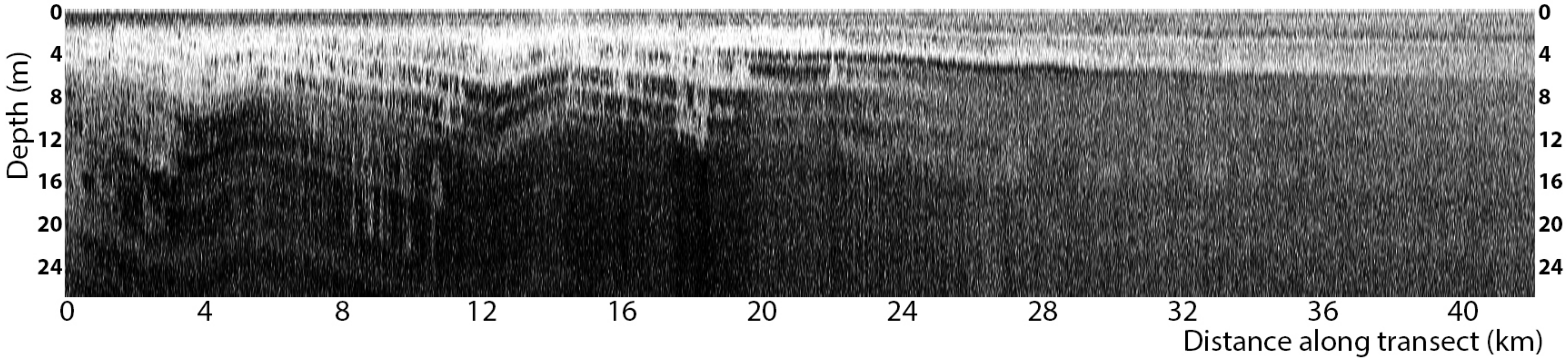
Mapping thick ice lenses with radar



Ground radar → IceBridge radar



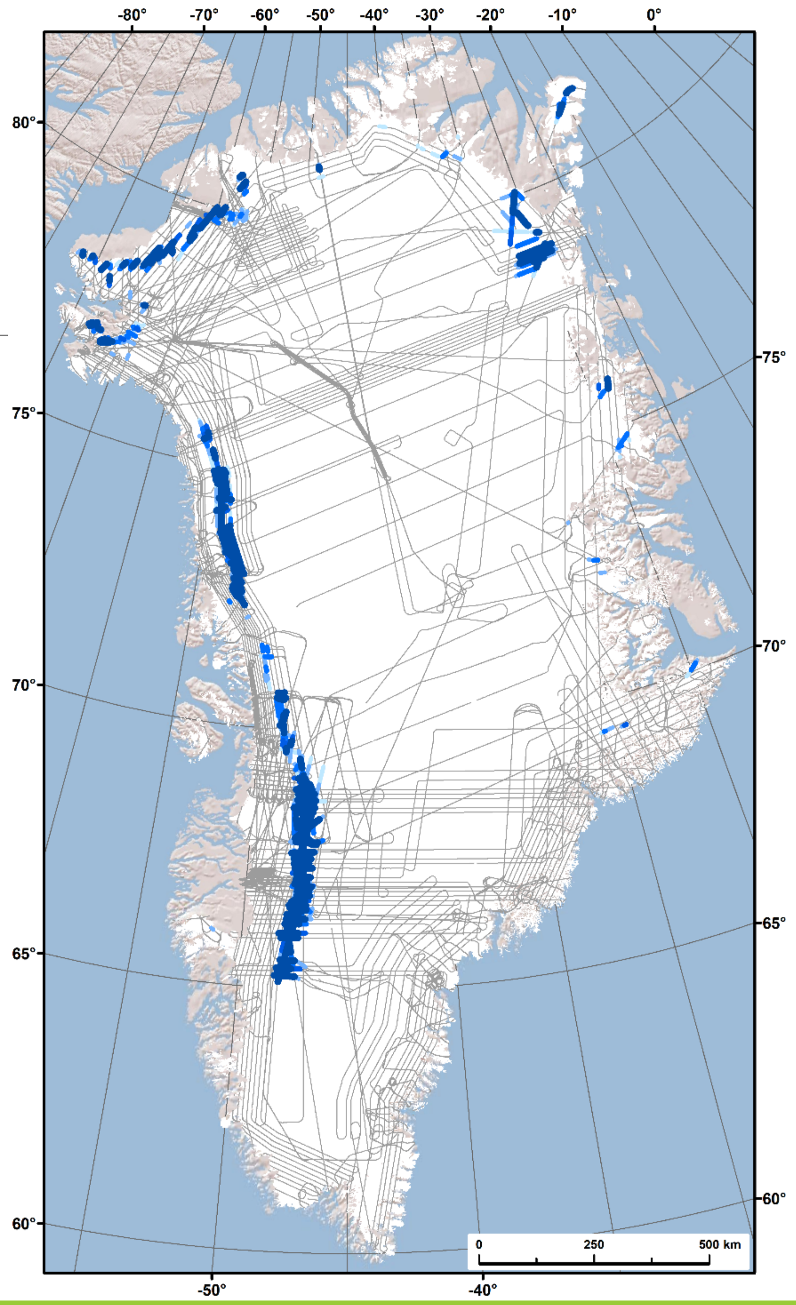




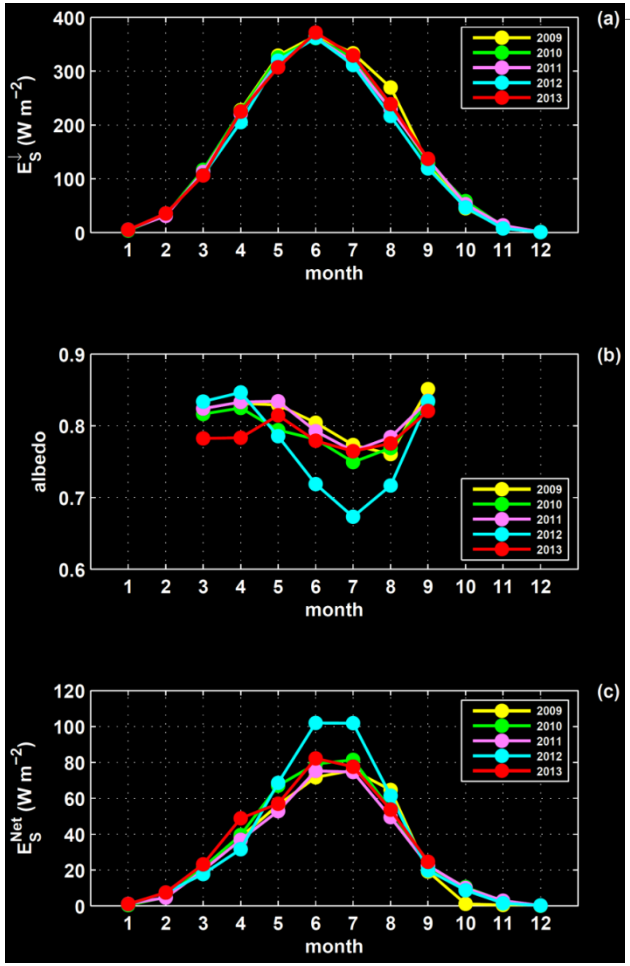
Perched Ice Layers across Greenland

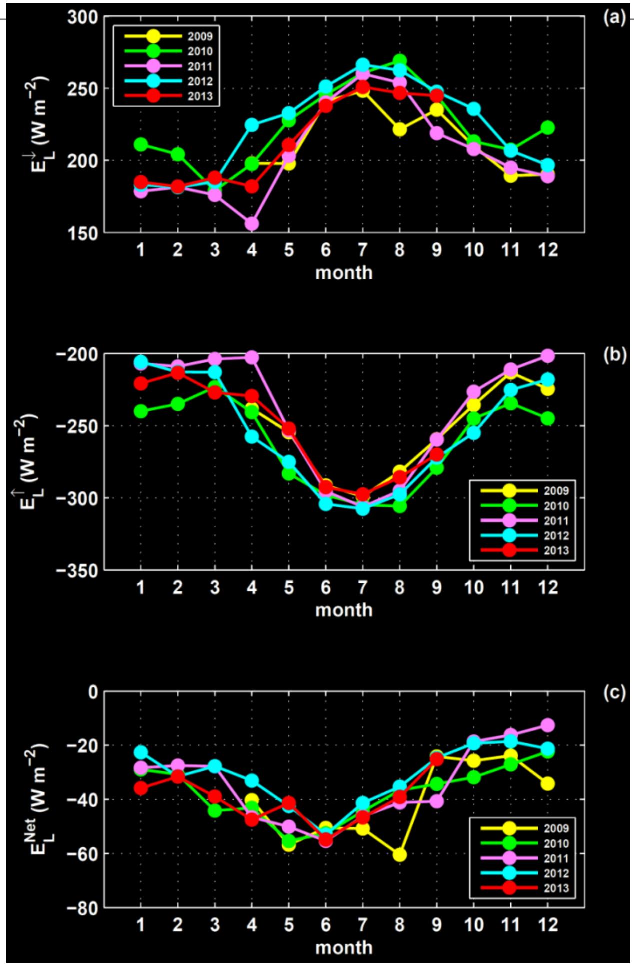
- Extensive "perched" ice layers ≥1.5 meters (~5 feet) atop porous firn
- Perched layer zone spans

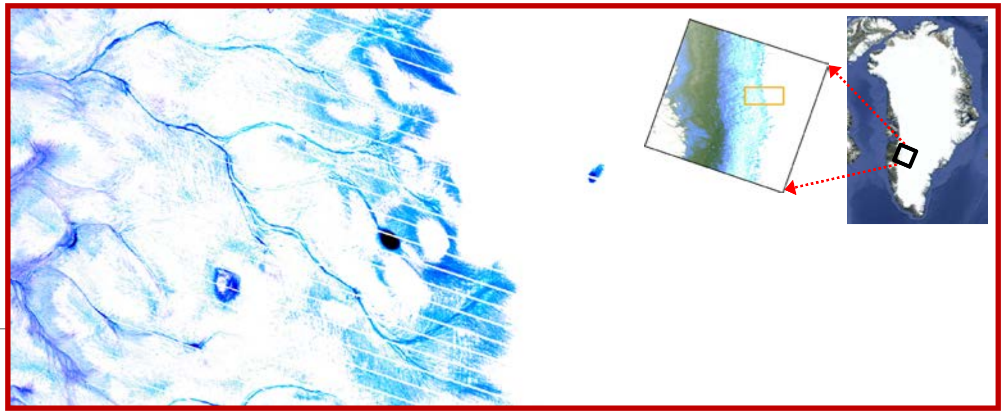
  ~60,000 km^2
- Some of these layers already block percolation and enhance runoff, some don't yet
- Firn can saturate **rapidly**
  - (*Harper, et. al. [2012]* isn't holding true)



KAN-U Albedo, 2012



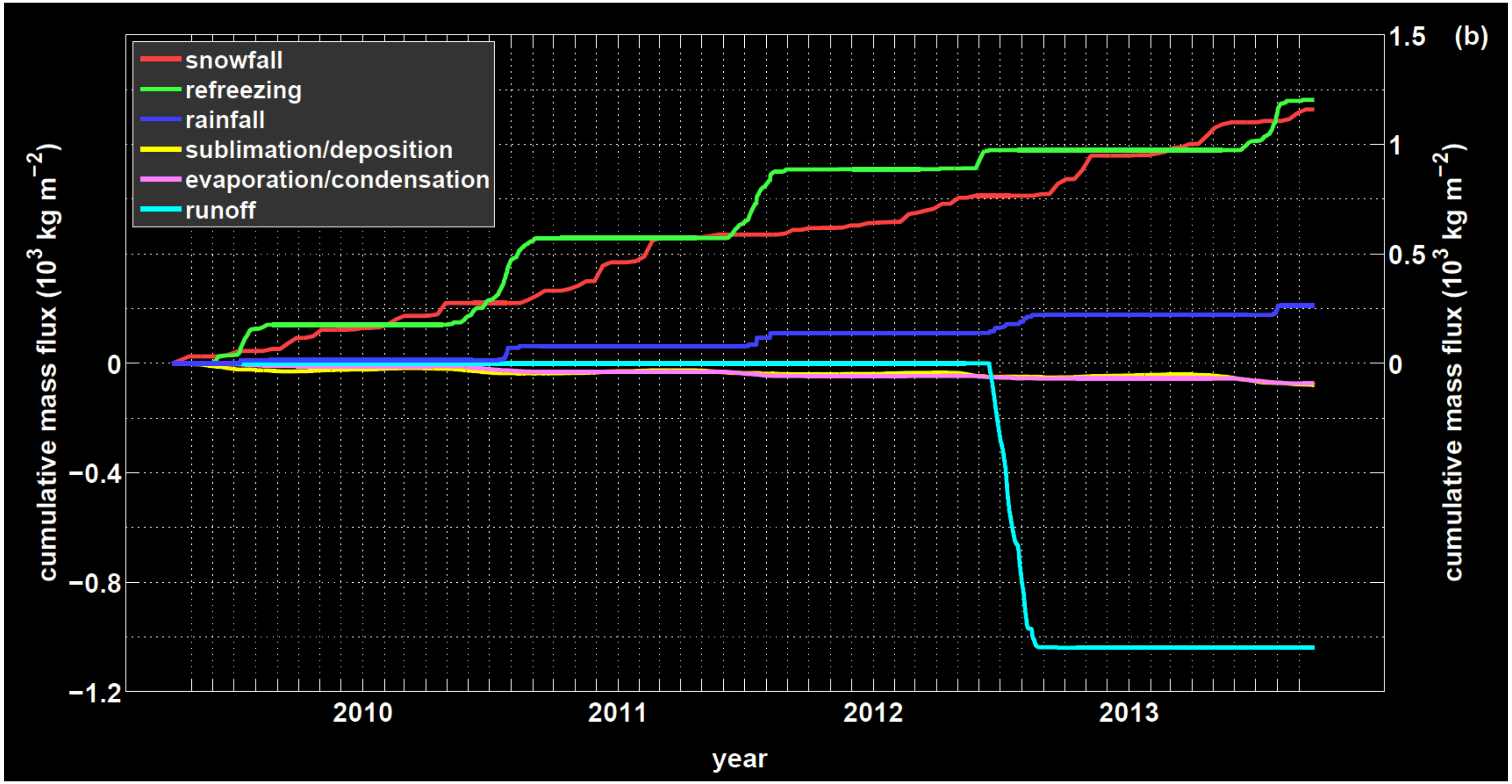




- July 2012 albedo at KAN-U reduced from 0.78 → 0.68
- 30% more solar radiation absorbed in 2012 (213 MJ m^{-2})

Charalampidis C., D. van As, H. Machguth, M. MacFerrin, C. Smeets, M van den Broeke, J. Box. “Changing surface-atmosphere-energy exchange and refreezing capacity of the lower accumulation zone”. *AGU Fall Meeting, 2014.*

KAN-U Runoff, 2012



- 97% of all 2009-2011 accumulation was lost to runoff in 2012 (1039 kg m^{-2})

Charalampidis C., D. van As, H. Machguth, M. MacFerrin, C. Smeets, M van den Broeke, J. Box. “Changing surface-atmosphere-energy exchange and refreezing capacity of the lower accumulation zone”. *AGU Fall Meeting, 2014.*

MAR (Modèle Atmosphérique Régional)

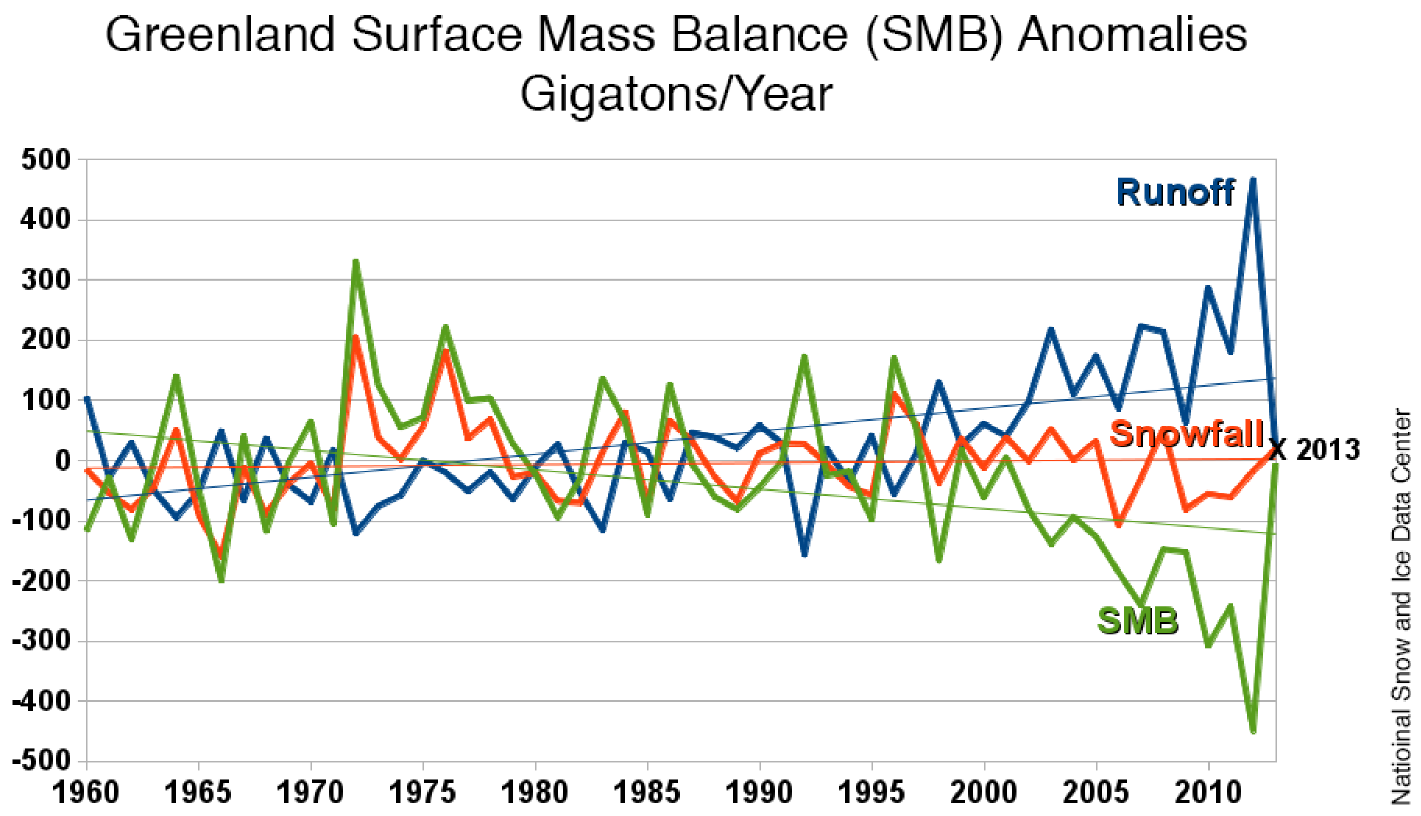


Image from NSIDC.org

- Data (MAR v 3.2+) freely distributed by
  - ✓ MAR Explorer at CCNY (www.cryocity.org/mar-explorer.html)
  - ✓ ACADIS (www.aoncadis.org)
  - ✓ Xavier Fettweis (via ftp)
- Open source code (available at CCNY or Xavier Fettweis)
- Current version (3.5)
- Parallelized and running on NASA and other supercomputers

Tedesco M., X. Fettweis, P. Alexander. “MAR v3.2 regional climate model data for Greenland, 1958-2013”. ACADIS Gateway.

Conclusions

- Surface Mass Balance is a major driver of current and future Greenland mass loss
- SMB feedbacks can rapidly reduce albedo and enhance runoff
- To accurately constrain and predict future Greenland mass loss, SMB feedbacks must be accurately handled
- Current RCMs—specifically geared toward SMB simiulations—are working to constrain these processes in both Greenland and Antarctica, may be useful for GCM simulations

Questions?