Surface Melt Changes and Climate Forcing in the Western Greenland Percolation Zone

C43E-1842

Julianne DeAngelo[1], Erich Osterberg[1], Gabriel Lewis[1], David Ferris[1], Zayta Thundercloud[1], Robert Hawley[1], H. P. Marshall[2], Sean Birkel[3], Karina Graeter[1]

Julianne.T.DeAngelo.19@dartmouth.edu [1]Dartmouth College Department of Earth Sciences, Hanover, NH, [2]Boise State University, Boise, ID, [3]University of Maine, Orono, ME

1. Introduction

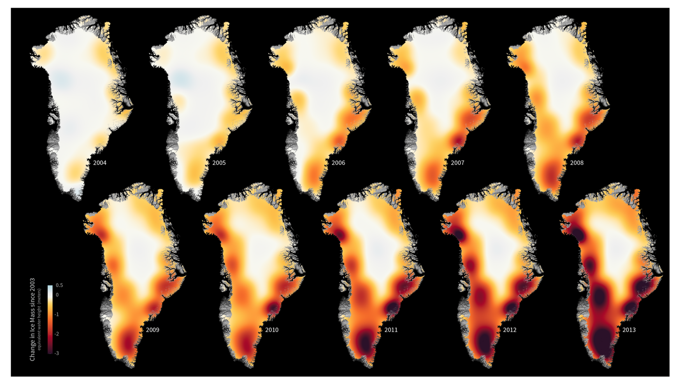


Figure 1: Mass loss of the Greenland Ice Sheet 2003-2013. Image credit: NSIDC, NASA

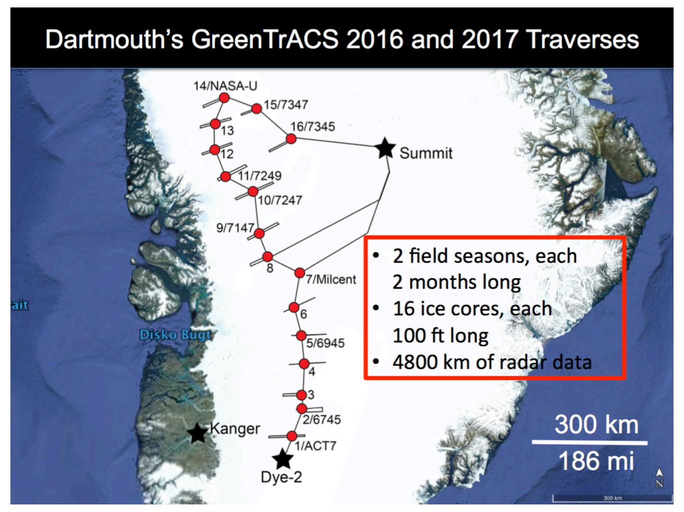


Figure 2: GreenTrACS Traverse

The Greenland Ice Sheet (GrIS) contains 7 meters of potential sea level rise in meltwater equivalent[1]. Surface melting of the GrIS is accelerating in response to anthropogenic warming, but exactly how the GrIS percolation zone is changing remains uncertain.

The Greenland Traverse for Accumulation and Climate Studies (**GreenTrACS**) measures the evolution of the GrIS percolation zone and refrozen melt layer content over the past 30-55 years (Figure 2). Here we present the preliminary results from the 2017 GreenTrACS traverse, to address:

1. *How has melt layer content and distribution changed in the Western GrIS percolation zone over the past 30-55 years?*
2. *What climate forcings affect GrIS surface melt, and how are these forcings reflected in the firn core record?*

2. Methods

1. **Density Measurements**
- In the Dartmouth Ice Core Lab freezer, each piece of firn core was measured (length determined by breaks in the drilling process) and weighed before being cut in half for melt layer stratigraphy and chemical analysis.

2. **Melt Layer Stratigraphy**
- Each half-core was placed on a backlit table and melt features were documented and measured (Figure 3). Of several firn feature categories, only ice layers that spanned the entire diameter of the core were used in calculations.

3. **Continuous Melting and Chemical Analyses**
- Slabbed cores were discretely sampled for chemistry by a continuous melter in the Dartmouth Ice Core Lab. We analyzed meltwater samples for major ion concentrations (by ion chromatography) and δO^{18} by cavity ringdown spectroscopy.

3. **Annual Accumulation and Depth-Age Scales**
- Seasonal oscillations in snow chemistry data were used to determine annual accumulation at each core site. We used the resulting depth-age scales to calculate melt layer thickness by year.

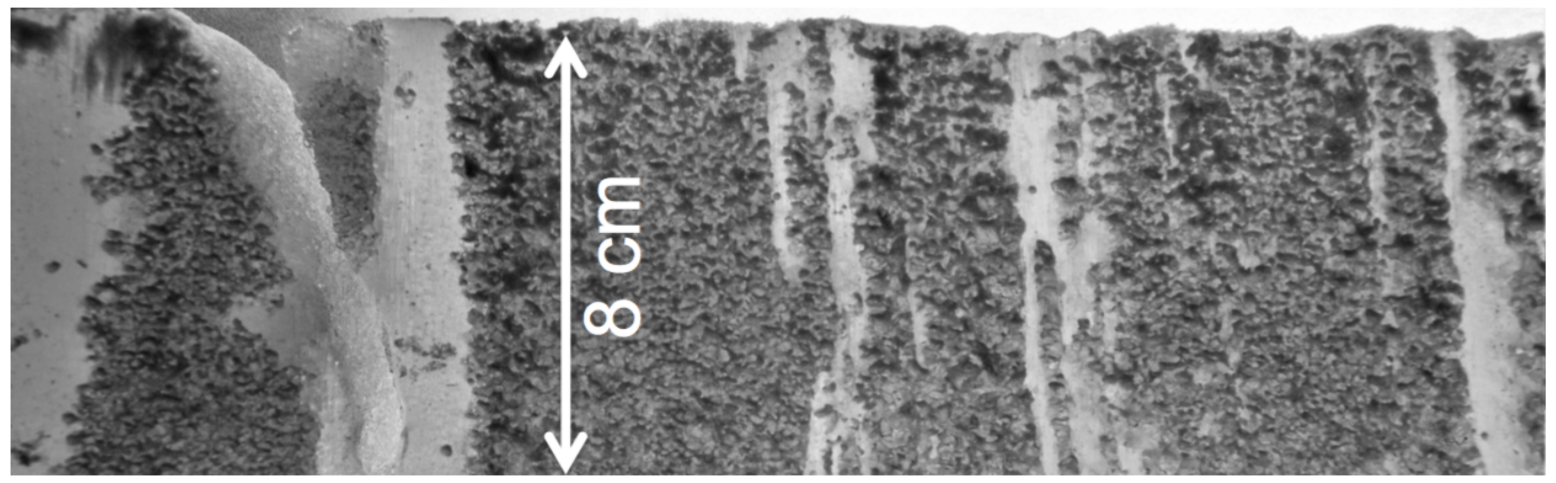
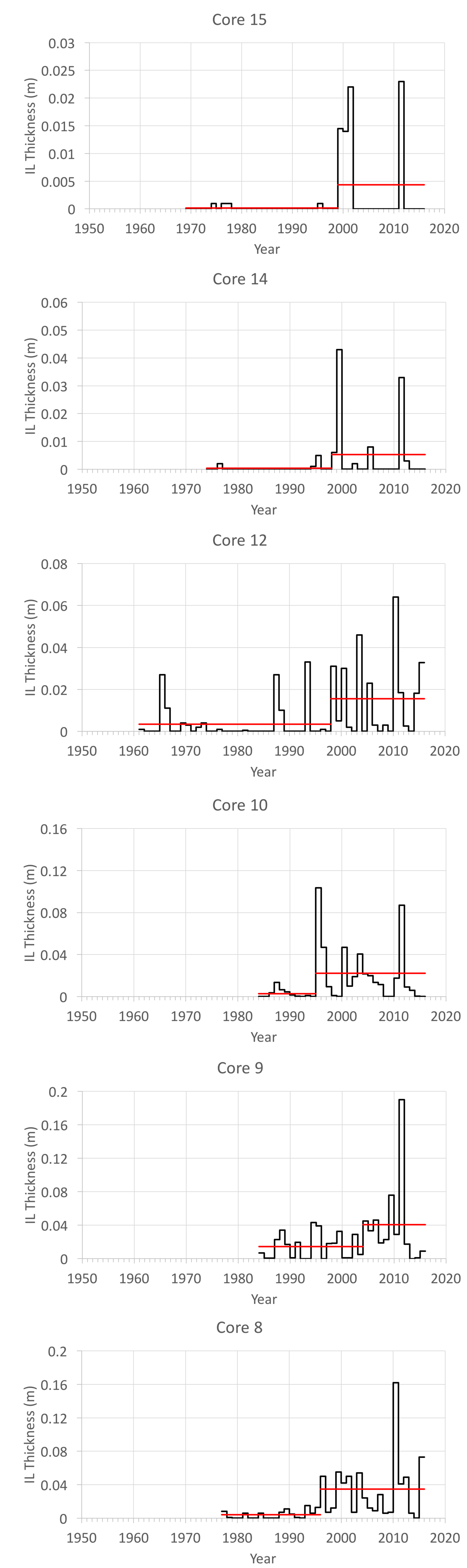


Figure 3: a GreenTrACS core on a backlit table, with visible solid ice layers (light grey stripes) in contrast with the surrounding firn (dark grey sections).

3. Results

Melt Layer Stratigraphy with Pruned Exact Linear Time Changepoint Analysis:



Changepoint Analysis determines the year at which the mean ice layer thickness changes most significantly.

Annual melt layer thickness and changepoint data for six of the nine cores from the 2017 traverse are shown here. Solid black lines represent melt layer thickness by year, and broken red lines represent changepoint averages.

Graphs are arranged based on core site locations, with Core 15 the farthest north and Core 8 the farthest south. The remaining three cores—core 11, core 13, and core 16 were either too short for changepoint analysis, had too few melt layers for analysis, or did not have a significant changepoint.

Of the six records shown, five have changepoints in the mid-to-late 1990s, while core 9 has a changepoint in the early 2000s:

- **Core 8: 1995**
- **Core 9: 2003**
- **Core 10: 1994**
- Core 11: record too short for robust statistical analysis
- **Core 12: 1998**
- Core 13: no significant changepoint
- **Core 14: 1997**
- **Core 15: 1998**
- Core 16: too few melt layers for analysis (only one full-diameter ice layer, from melt in 2012).

4. Discussion

Comparison with results from 2016 GreenTrACS cores:

- Five of the seven 2016 cores show significant changepoints in the mid-1990s.
- Remaining two show changepoints in the mid-1980s.
- Cores 3 and 5 show similar melt layer patterns to Core 8 (from the 2017 traverse) along with a common changepoint around 1995.
- Why a **common mid-1990s changepoint**? Graeter et al. (2018) propose a combination of climate factors and anthropogenic warming.

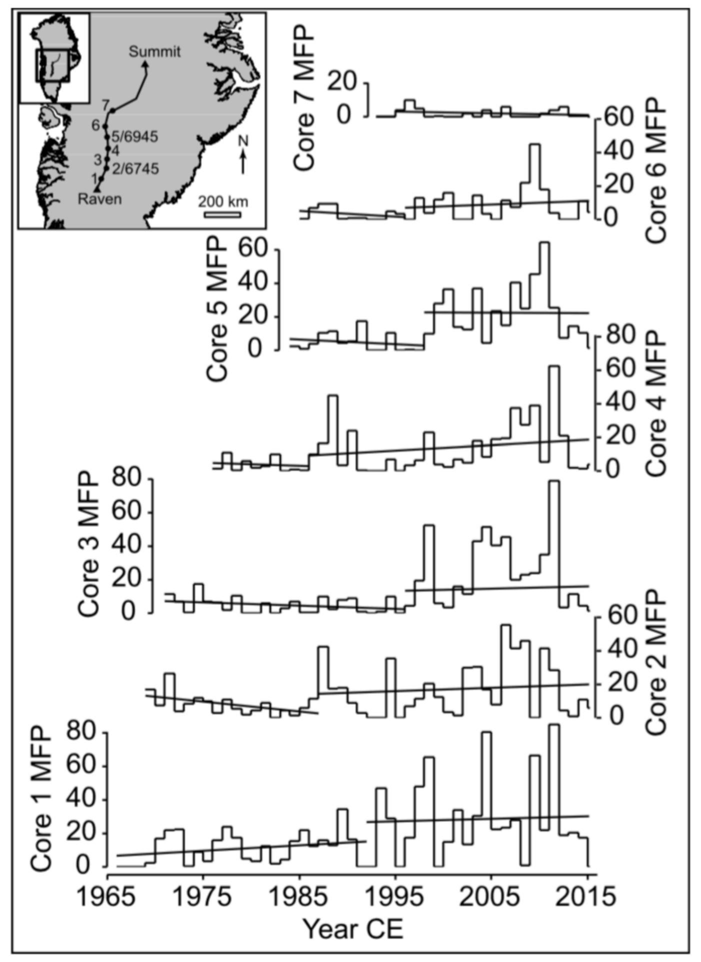


Figure 4: GreenTrACS 2016 melt feature percent with changepoint analysis (Source: Graeter et al. 2018)

5. Future Work

Melt layer record extension and comparison with data from PARCA cores:
- Melt layer stratigraphy records from the Program for Arctic Regional Climate Assessment (PARCA) and other deep cores can be used to extend the GreenTrACS record back several hundred years[2].

Density comparison with PARCA records:
- Density data from GreenTrACS cores compared with PARCA density data will show the evolution of shallow GrIS density since the 1990s.

Climatological Context
- GrIS surface melt is influenced by North Atlantic ocean-atmosphere interactions (Greenland Blocking Index (GBI) and Atlantic Multidecadal Oscillation (AMO)).
- GBI and AMO both turned positive in the mid-1990s [2].
- Quantify the roles of the AMO, GBI, and anthropogenic warming on Greenland melt back through time.

References:

1. Dowdeswell, Julian A. "The Greenland Ice Sheet and Global Sea-Level Rise." *Science*, vol. 311, no. 5763, 17 Feb. 2006, doi:10.1126/science.1124190.
2. K. Graeter, E. Osterberg, D. G. Ferris, R. Hawley, H. P. Marshall. G. Lewis, T. Meehan, F. McCarthy, T. Overly, S. Birkel. "Ice Core Records of West Greenland Melt and Climate Forcing." Geophysical Research Letters, 2018.

Acknowledgements:

This project was supported by the US National Science Foundation under grants ARC-1417678 (to E.O. and R.H.), ARC-1417921 (to H.M.), ARC-1417640 (to S.B.), and DGE-1313911 (to G.L.), and Dartmouth Undergraduate Advising and Research. We thank CH2MHill Polar Services, the National Science Foundation Ice Drilling Program Office, and the US Air National Guard 109th Airlift Wing for logistically supporting the GreenTrACS traverses.