

A satellite image of an ice sheet, likely Antarctica, showing a complex network of meltwater channels and lakes. The channels are dark blue and brown, winding through the white and light blue ice. The background is a vast, textured expanse of ice. The text is overlaid on the right side of the image.

# Ice Sheet Surface and Basal Melting

Kenneth Jezek

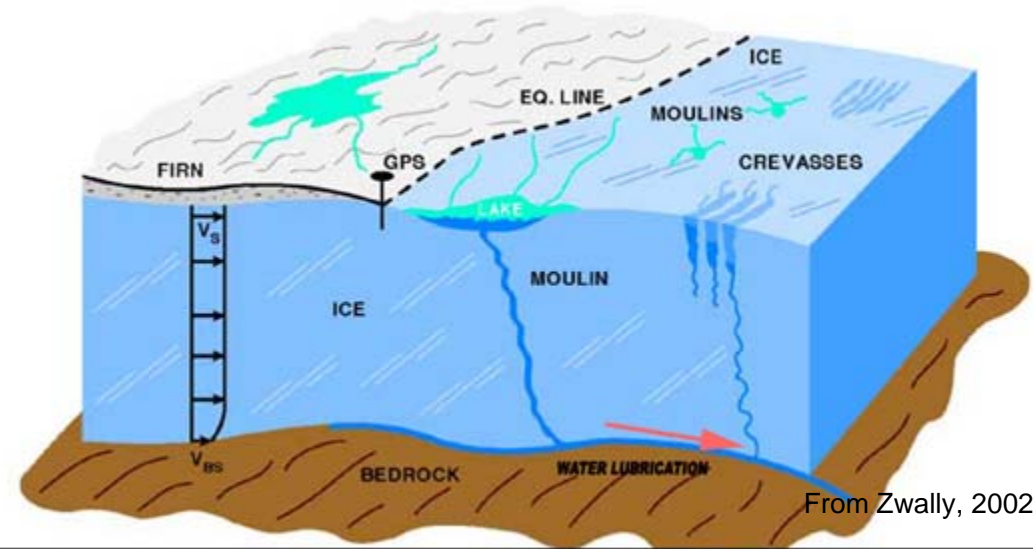
Byrd Polar Research Center  
The Ohio State University

# The Role of Surface Melt

- Changes Surface Albedo
- Proxy climate record
- • Lubricates flow over the bed
- Component of mass balance ←



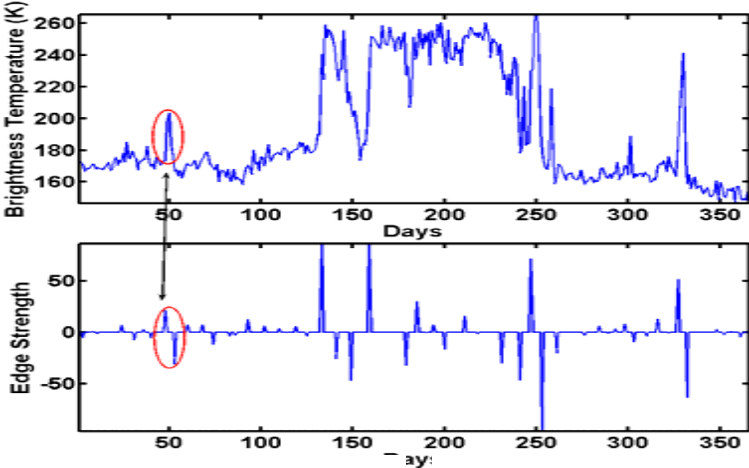
$$\frac{\partial h}{\partial t} = -\nabla \cdot H \bar{V} + \dot{a} + \dot{b}$$



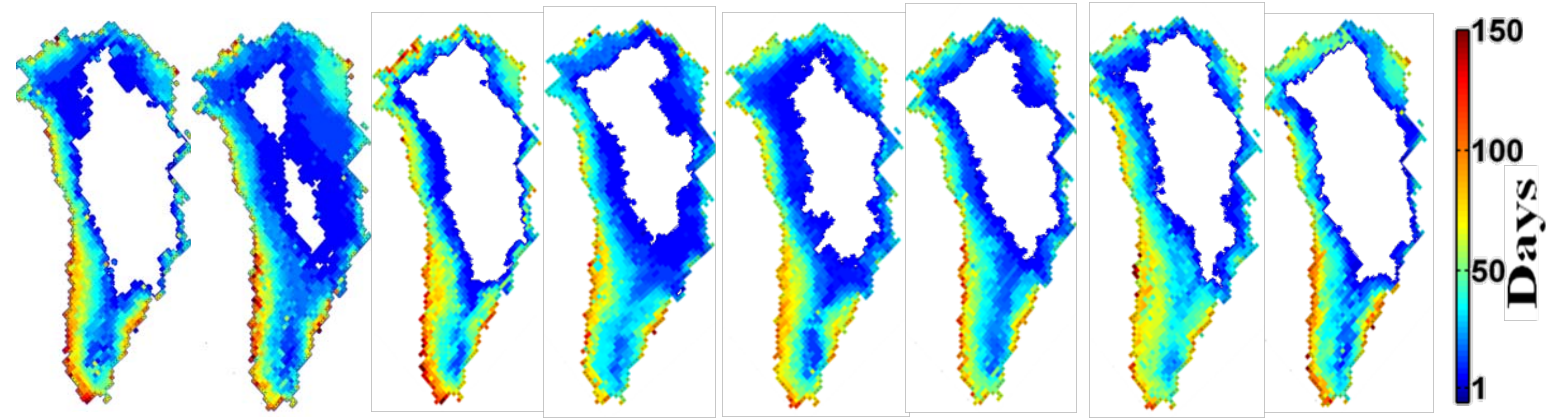
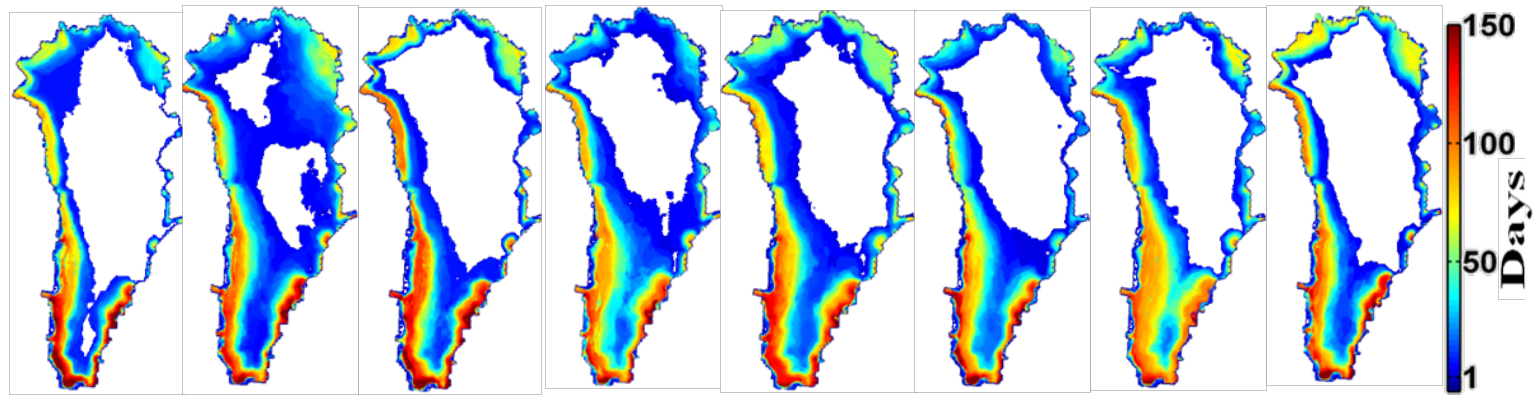
From Zwally, 2002

# Greenland melt from SSMI and Quickscat

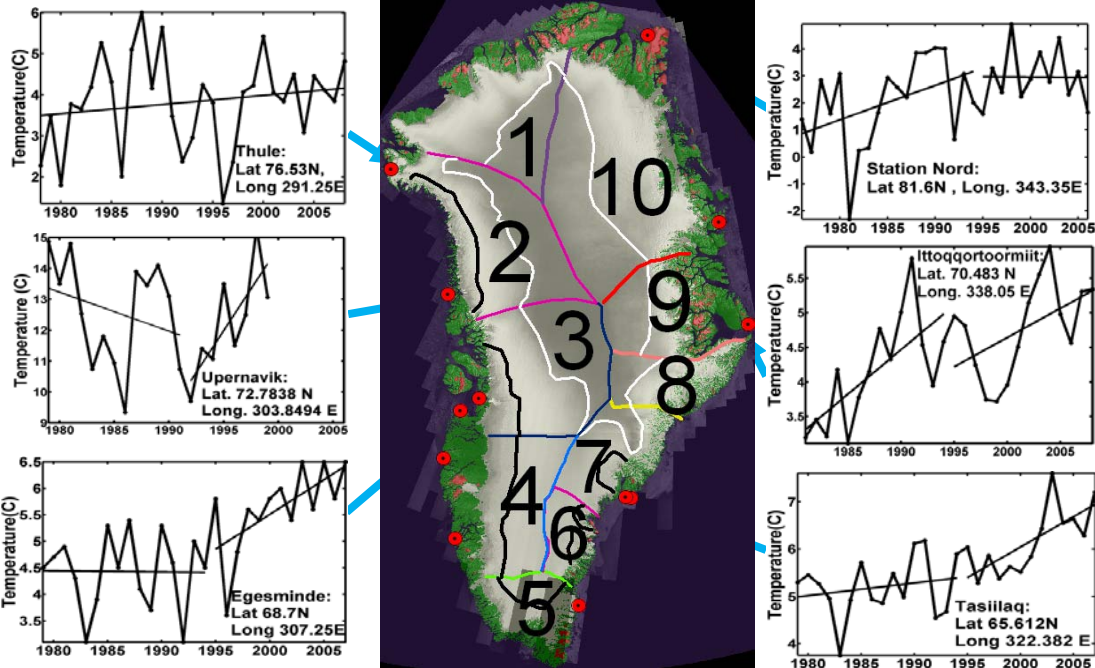
from Bhattacharya, Jezek, Liu, Wang, 2009



2001      2002      2003      2004      2005      2006      2007      2008

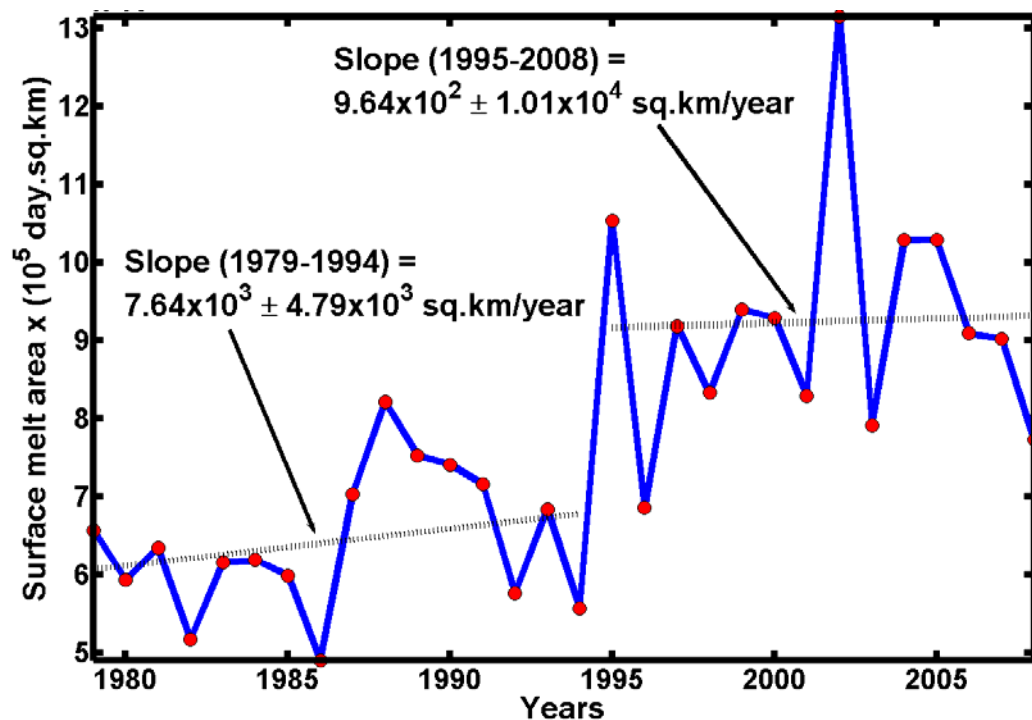


# 29 Year Melt Record

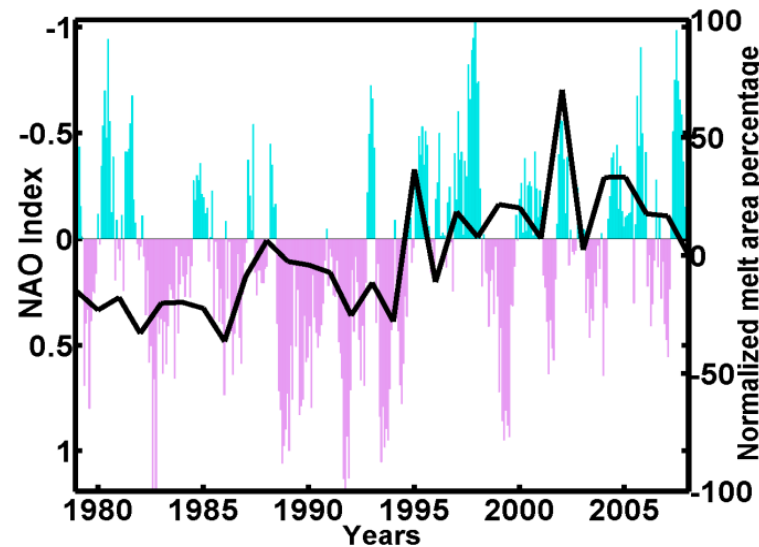
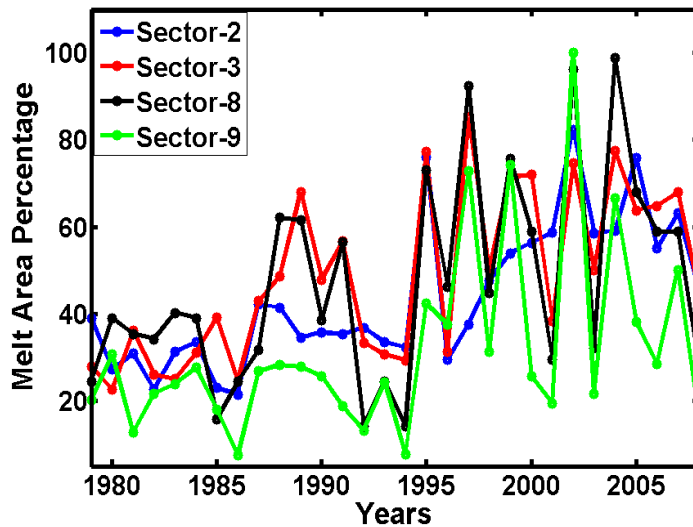
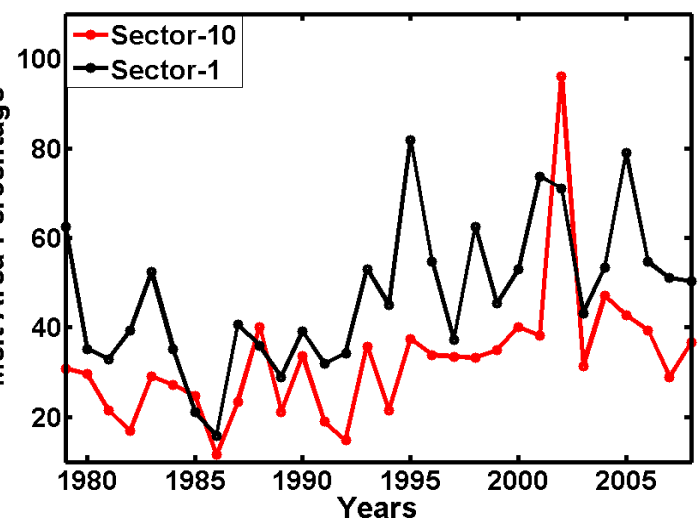
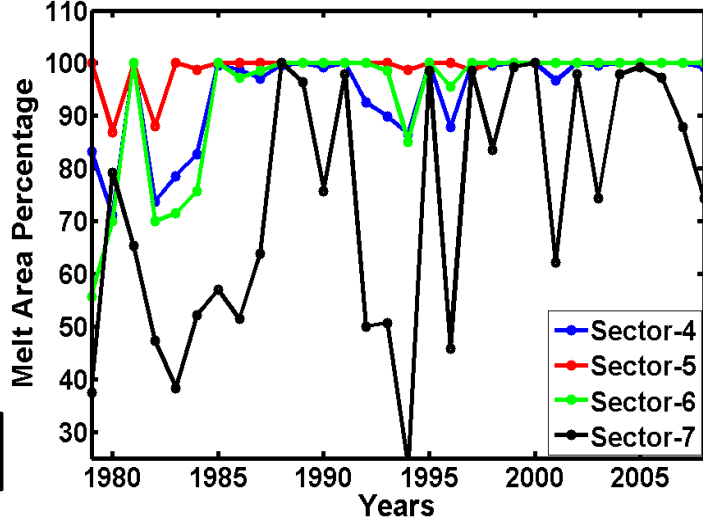


Unlike previous analyses, our results show a step change in surface melt extent. Melt area rate is 8 times lower after 1995

Bhattacharya, Jezek, Wang, Liu, 2009



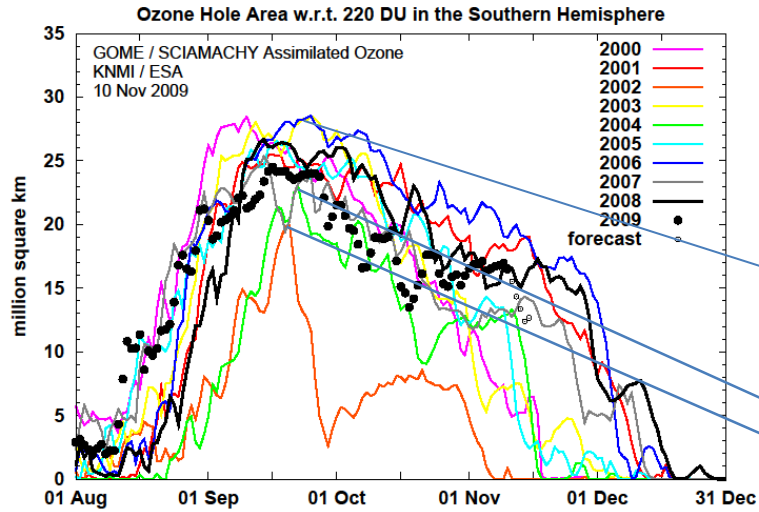
# Melt and Regional Climate



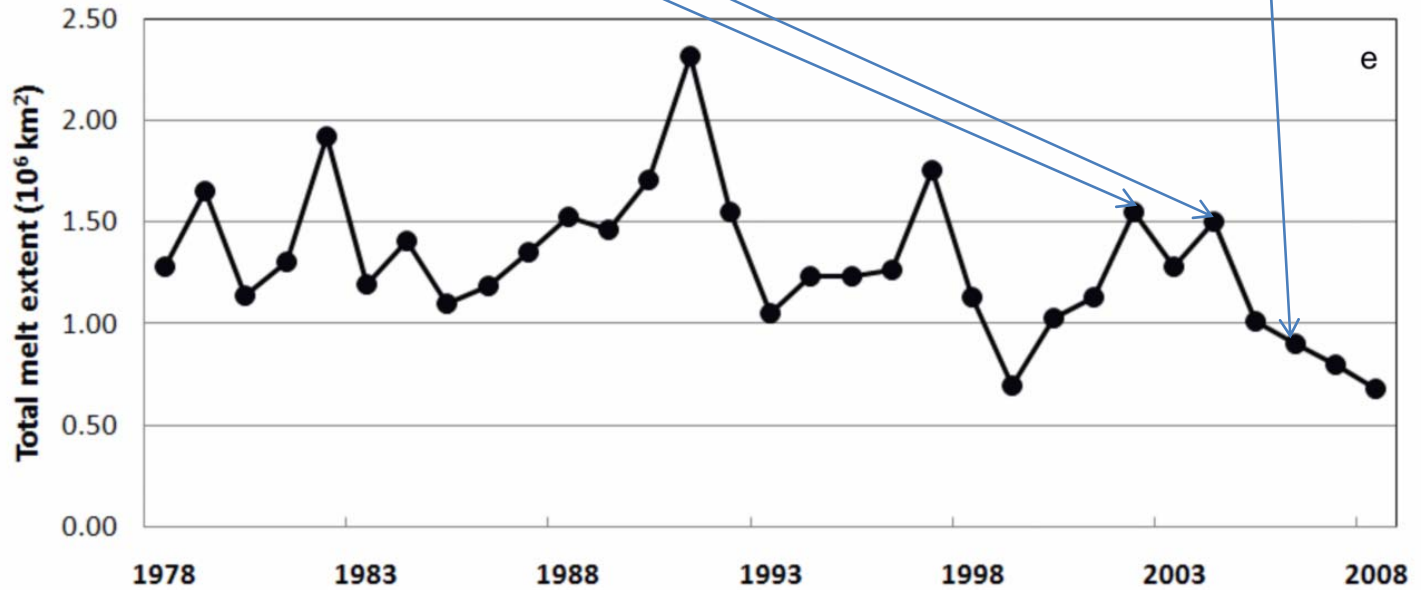
Three out of four southerly sectors (upper left) have been melting completely since early 1990's. The northerly part of the ice sheet (upper right), show large inter-annual variability and a general increase of  $4.74 \times 10^3 \pm 1.37 \times 10^3 \text{ km}^2/\text{year}$  in melt-area from 1979-2008. The mid-section of the ice-sheet (lower left), the melt-area increases by  $3.14 \times 10^3 \pm 2.54 \times 10^3 \text{ km}^2/\text{year}$  till 1994 and from 1995-2008 the trend is statistically not different from zero.

NAO characterizes the broad atmospheric pressure variations between the Arctic and the subtropical Atlantic. Air temperature over Greenland and NAO are inversely correlated (higher NAO seems to cause cooler Greenland temperatures).

# Melt Extent across Antarctica

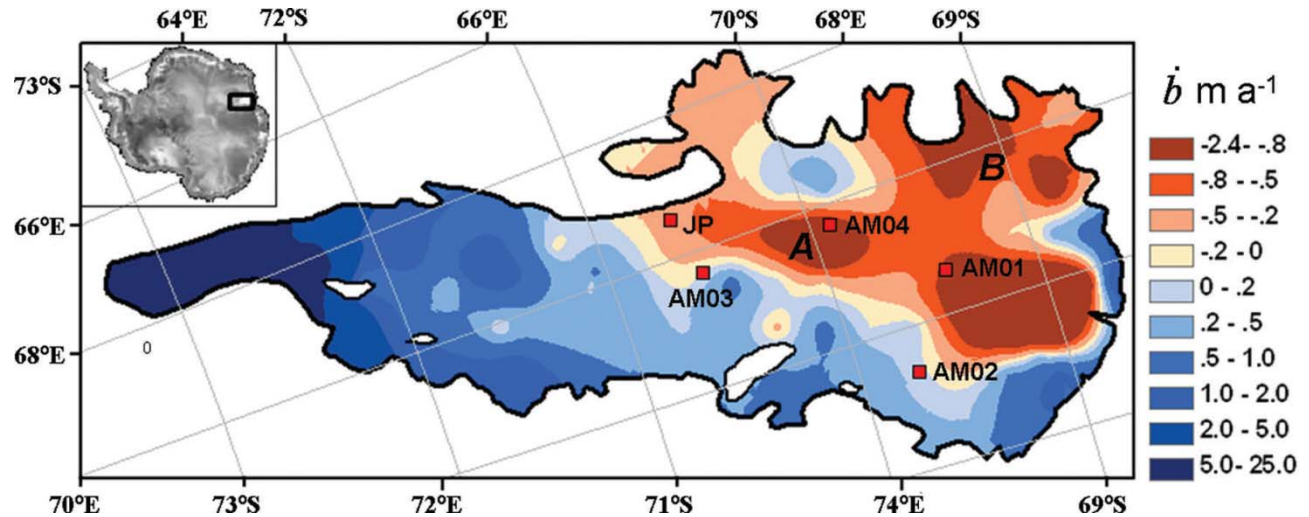


Cooling over Antarctica seems to be controlled by ozone and other greenhouse gases which effect the energetics of circum-polar circulation



# The Role of Basal Melt

Basal melt freeze beneath the Amery Ice Shelf. From Wen, Wang, Wang, Jezek, Liu and Allison, 2010



- Mass balance (particularly for ice shelves)
- Erosional processes sculpt the glacier bed
- Subglacial lake reservoirs
- Lubricates the bed and weakens sediments – basal sliding law and fast glacier flow including ice streams

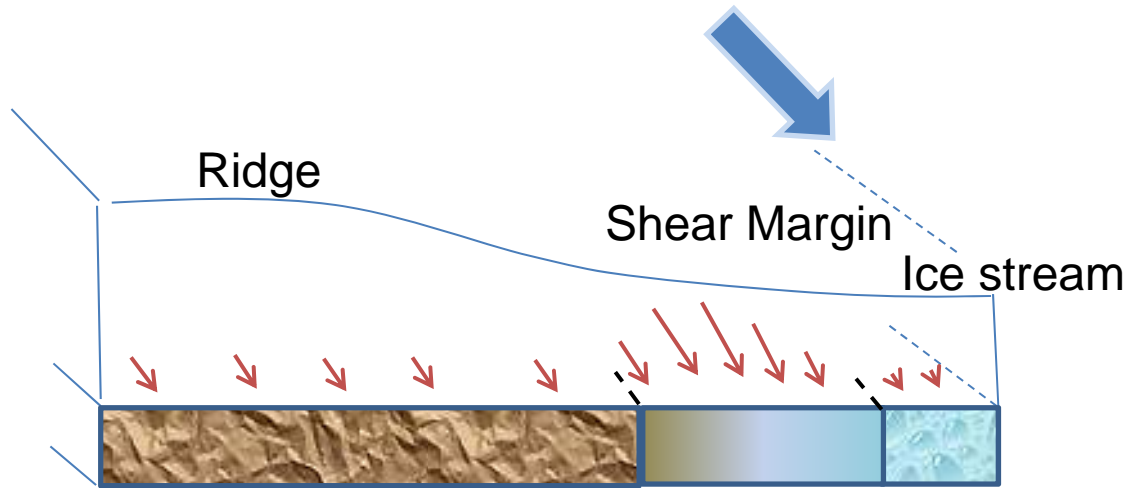
# Modeling Melt Rates Beneath Ice Streams

$$\int_{u(b)}^{u(h)} du = \int_b^h 2 \frac{R_e^{n-1} R_{xz}}{B^n} dz$$

$$\left( \frac{R_e^{n-1} R_{xz}}{B^n} \right)^{1/n} = \left( \frac{h-z}{H} \right)^m \frac{\tau_{bx}}{B_b}$$

$$\tau_{bx} = B_b \left( \frac{mn+1}{2H} U(h)(1-S) \right)^{1/n}$$

$$\dot{M} = \frac{1}{\rho L_i} \left( G - k \frac{\partial T}{\partial z}(b) + \tau_b U(b) \right)$$



Moderate drag to accommodate driving stress but low speed = little melt

Combination of high drag and high speed = more melt

High speed but low drag = less melt

S=0

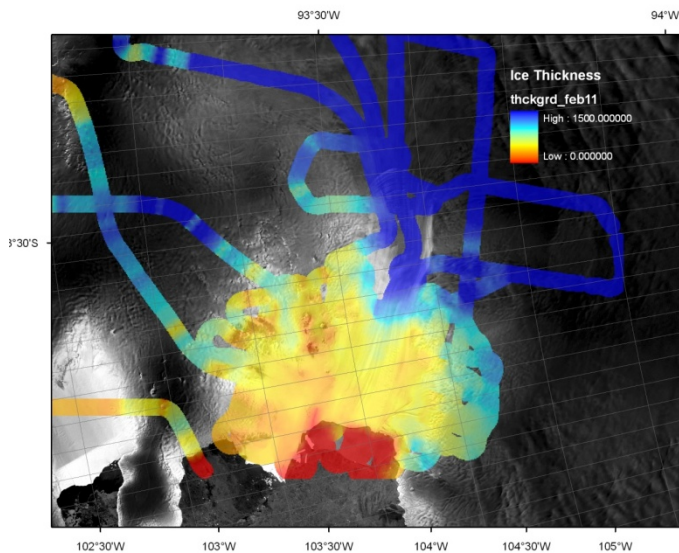
S=1



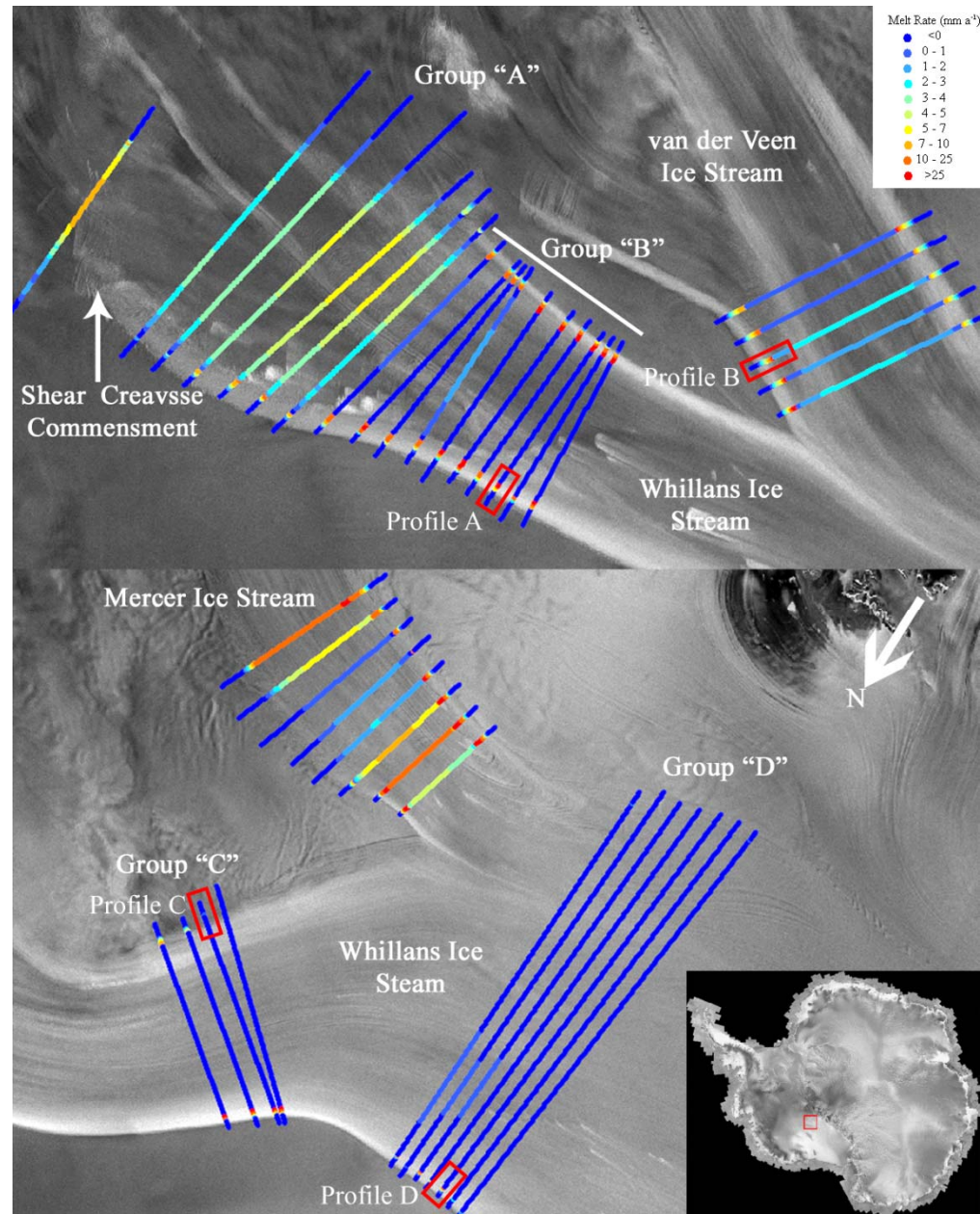
# Melt Regimes Beneath WIS

Because of changing distributions of basal drag, we identify two patterns of basal melt. Downstream of the onset of shear crevasses strong basal melt (20-50 mm a<sup>-1</sup>) is concentrated beneath the relatively narrow shear margins. Farther upstream, melt rates are consistently 3-7 mm a<sup>-1</sup> across the width of the ice stream. The transition in melt patterns is coincident to the onset of shear margin crevassing and streaming flow.

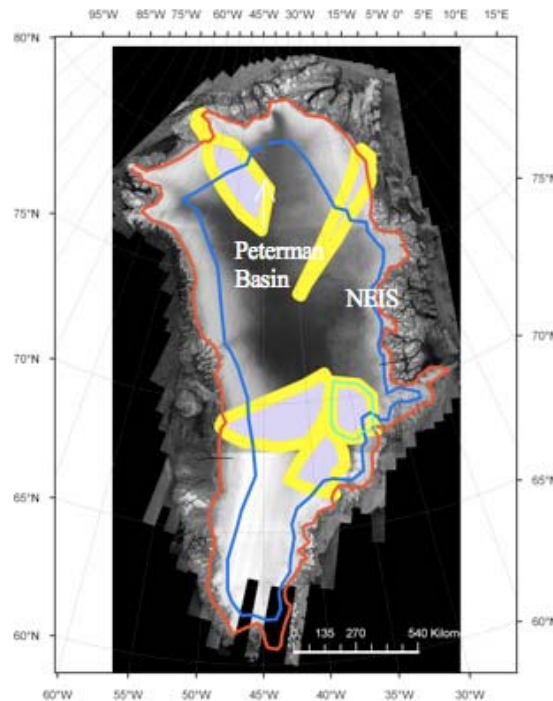
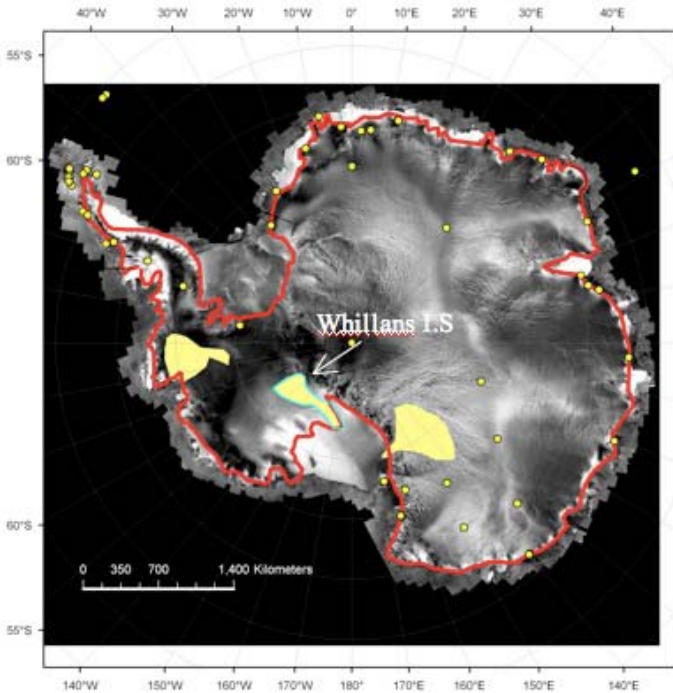
(From Beem, Jezek and van der Veen, submitted)



November 2009 Ice-Bridge ice thickness model for Pine Island Glacier. Preliminary data from 4 of 6 flights covering the region collected by U. Kansas and compiled by OSU.



# The Next Step: Basal Ice Imaging through Radar



BIIR is a proposed OSU and JPL collaboration to image the base of the Greenland and Antarctic Ice Sheets along a 50 km wide ribbon near the grounding line/terminus.

# Data Sets and Plans

- Greenland Surface Melt Data; Greenland velocity data; Antarctic velocity data at:  
[www.bprc.osu.edu/rsl/](http://www.bprc.osu.edu/rsl/)

Greenland tomographic data will be available at this site this summer.

Plan to put the Antarctic surface melt data and the Amery ice shelf basal melt data on the web site soon (pending final agreement with co-authors).