Surface Roughness as Indicator of Geophysical Change in Greenland Glaciers and Ice Streams — Conclusions from ICESat and IceBridge Data Analysis (- and Model Implications?)

Ute C. Herzfeld, Bruce Wallin

Cooperative Institute for Research in Environmental Sciences
and
Department of Applied Mathematics
University of Colorado at Boulder
herzfeld@tryfan.colorado.edu

Thanks to my collaborators and students ...

William Krabill, Serdar Manizade (both NASA Goddard Space Flight Center), Koni Steffen, Roger Barry (CIRES), Jay Zwally, John DiMarzio (both NASA Goddard Space Flight Center), Robert Schutz (Univ Texas Austin), David Korn (NSIDC), Bruce Wallin, Steve Sucht, Danielle Lirette, Patrick McBride, Scott Williams, Chris Higginson, Michael Matassa (all CU Boulder and CIRES), Oliver Zahner, Matthias Mimler, Tim Erbrecht, Christoph Overbeck, Helmut Mayer, Sandra Boehm, Benno Rothstein, Ralf Stosius (all Geomathematik, Univ Trier), Wolfgang Feller (Techn Abt, Univ Trier), Nel Caine (Geography, CU Boulder), Michael Kuhn (Inst f Meteorologie und Geophysik, Univ Innsbruck), Jason Box (Byrd Polar Research Center, OSU)

... and for support through

- NASA Cryospheric Sciences
- NSF Hydrological Sciences
- Deutsche Forschungsgemeinschaft (DFG), Antarctic and Arctic Research Program
- University of Colorado UROP Program

Satellite Altimetry

- Geophysical measurement of surface elevation from satellite, using active microwave radar technology or laser technology
- Satellites with radar altimeters

(1) SEASAT (1978)

(2) GEOSAT (1985–1989)

(3) ERS-1 (1991-1996)

(4) ERS-2 (since 1995)

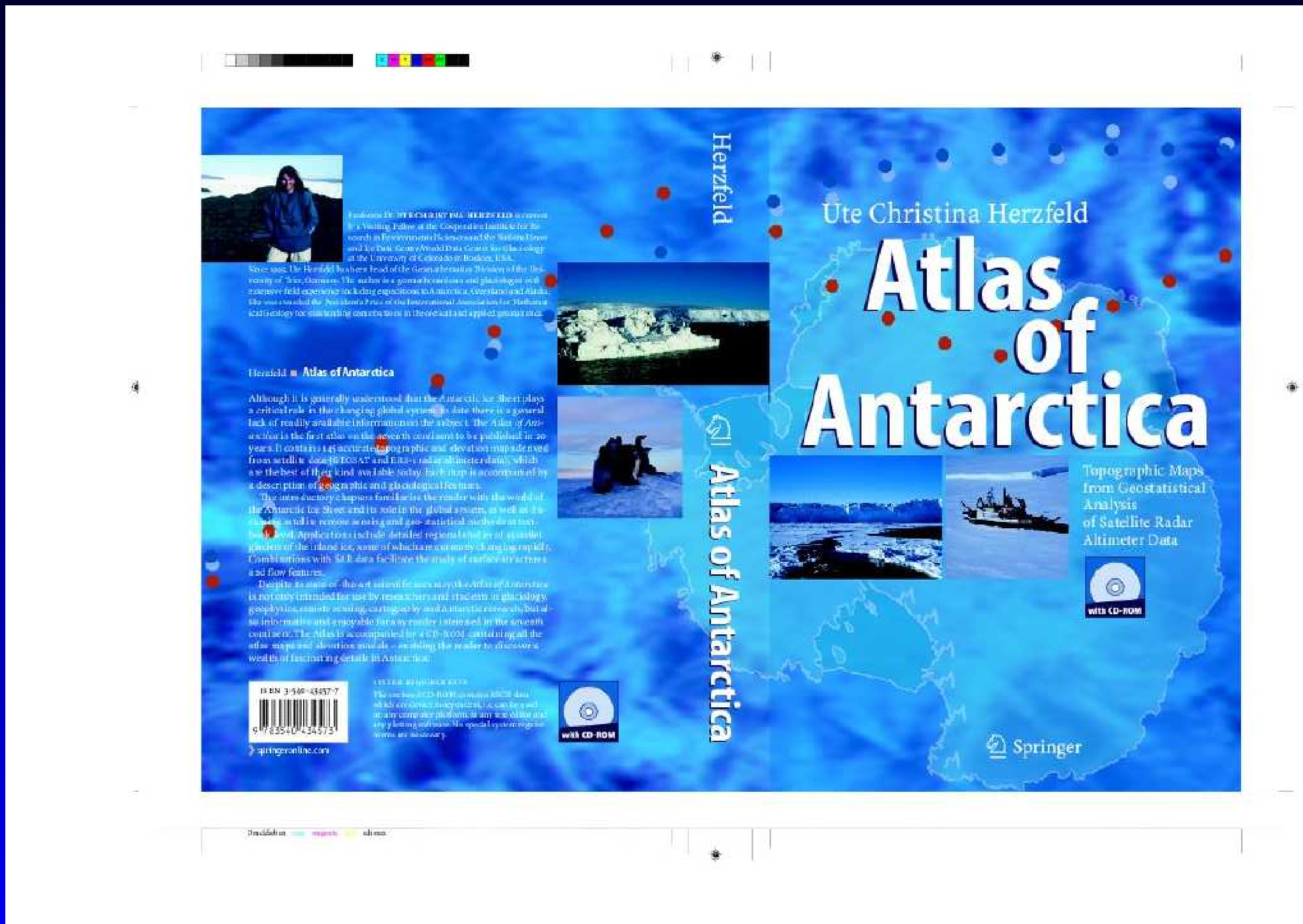
(5) TOPEX/POSEIDON

(6) JASON-1/2

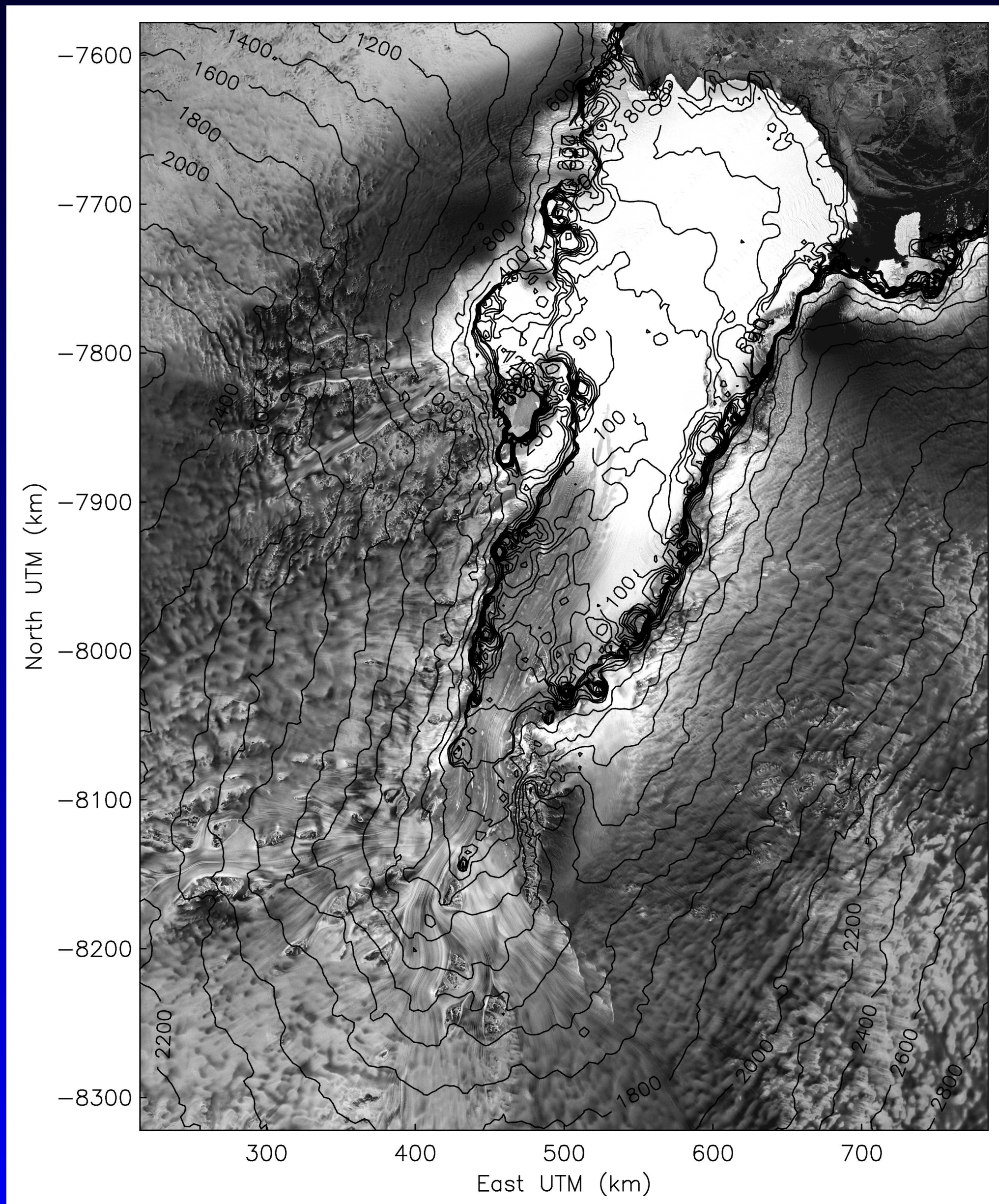
(7) ENVISAT (since 2002)

- Satellite with laser altimeters

ICESat: GLAS (since 2003)


Herzfeld
Ute Christina Herzfeld
Atlas of Antarctica
Topographic Maps from Geostatistical Analysis of Satellite Radar Altimeter Data
with CD-ROM
Springer
Herzfeld ■ Atlas of Antarctica
Atlas of Antarctica
with CD-ROM
springeronline.com

Topography and Flowlines of Lambert Glacier/Amery Ice Shelf System



Elevation:

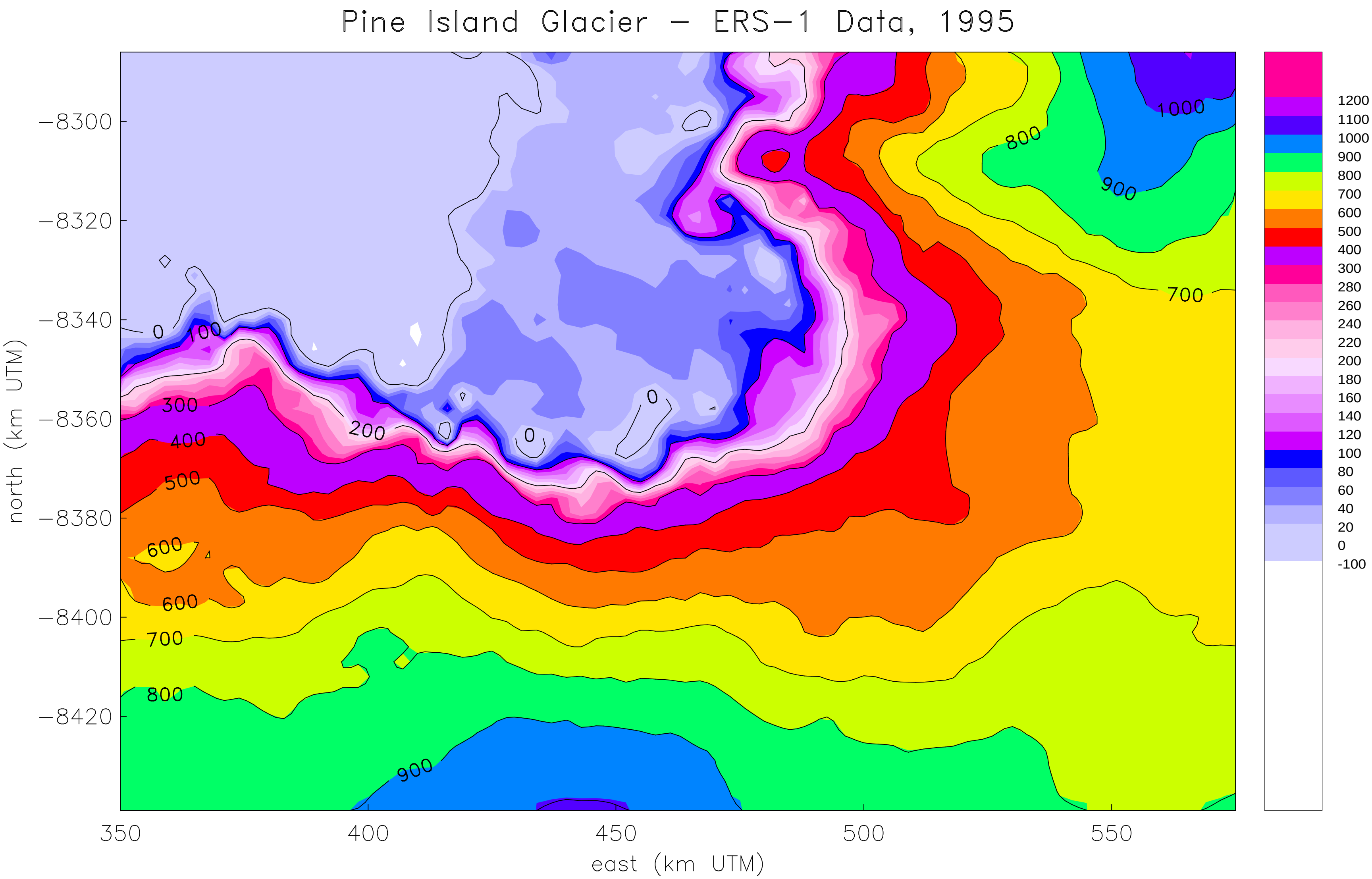
1997 ERS-2 data (1 Aug–31 Oct 1997), geostatistical analysis (Herzfeld et al.)

Surface Structure:

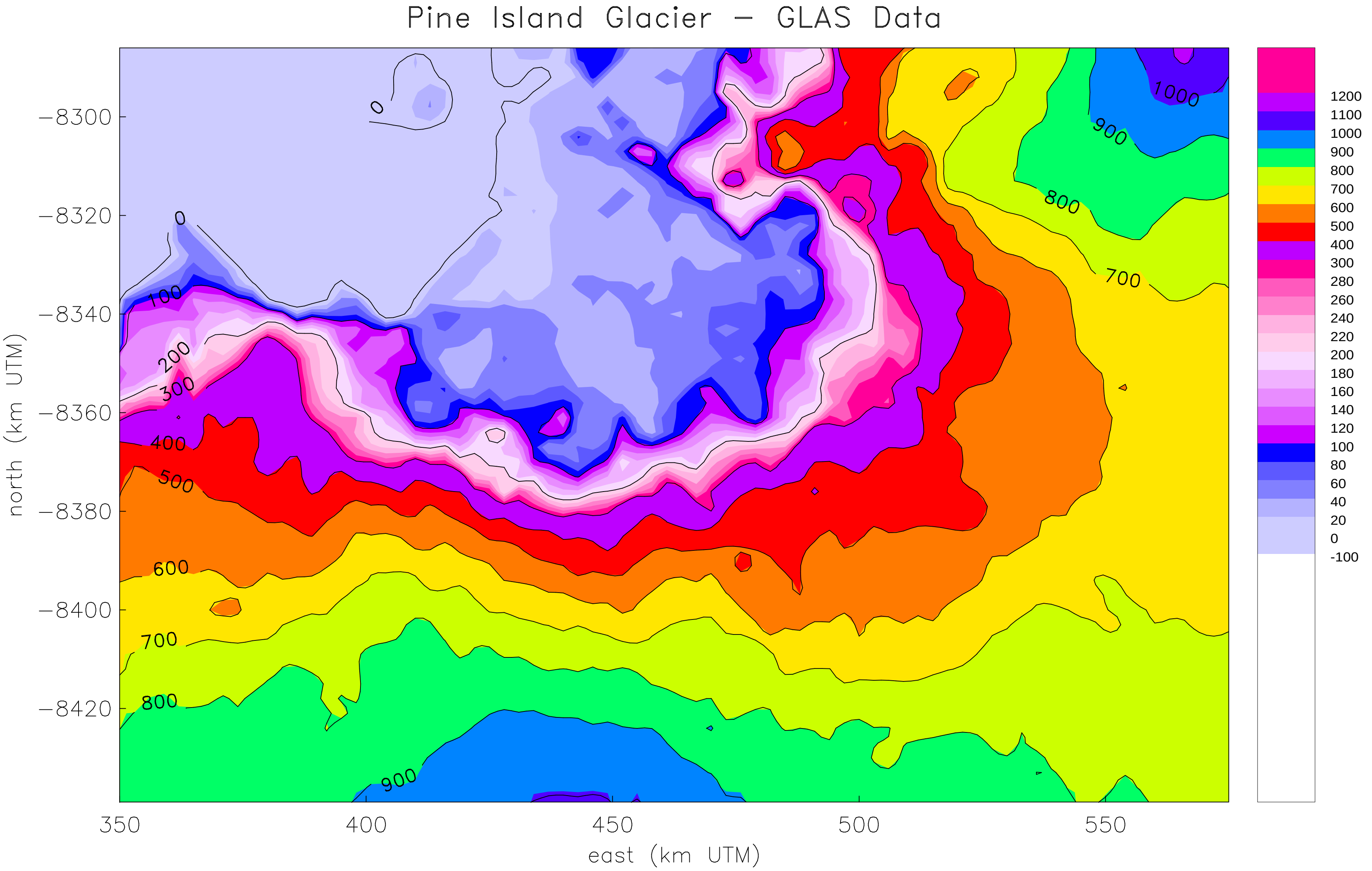
1997 RADARSAT data (RADARMAP 1st Antarctic mission, 2 Sept- 20 Oct 1997; Mosaic Jezek et al., 125m pixels)

Data integration and geo-referencing:

Stosius and Herzfeld



1:2000000, m261e243–279n71–77.e.smallpine2.v2.col8



GLA06 Data, (Laser 2A, gain–crit, rel18), Oct/Nov 2003, vario(350,3450,6000m), search–rg 30km, 1:2000000, gla06.1.gain.smallpine2.v2.col8

higher-resolution properties and processes — same tendency in modeling

What is spatial surface roughness?

- a derivative of (micro)topography

$\rightarrow$ characterization of spatial behavior

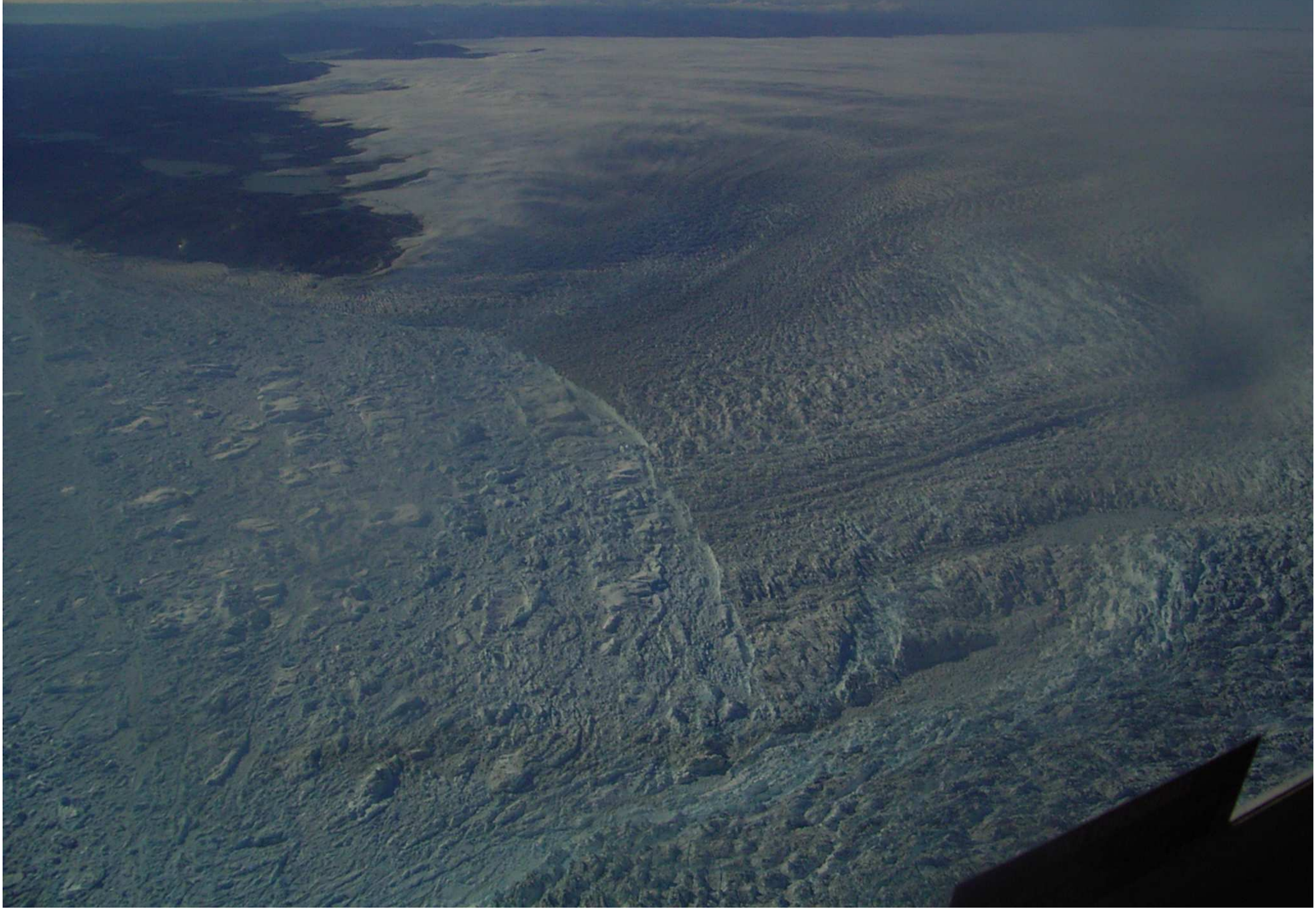
Niwot Ridge Snow Surface: Winter ———————— Summer

Bering Glacier, 1994, mature surge stage, Khittrov Hills in background

Jakobshavn Isbræ Drainage Basin – Spring Ice Surface

Jakobshavn Isbræ Drainage Basin – Summer Ice Surface

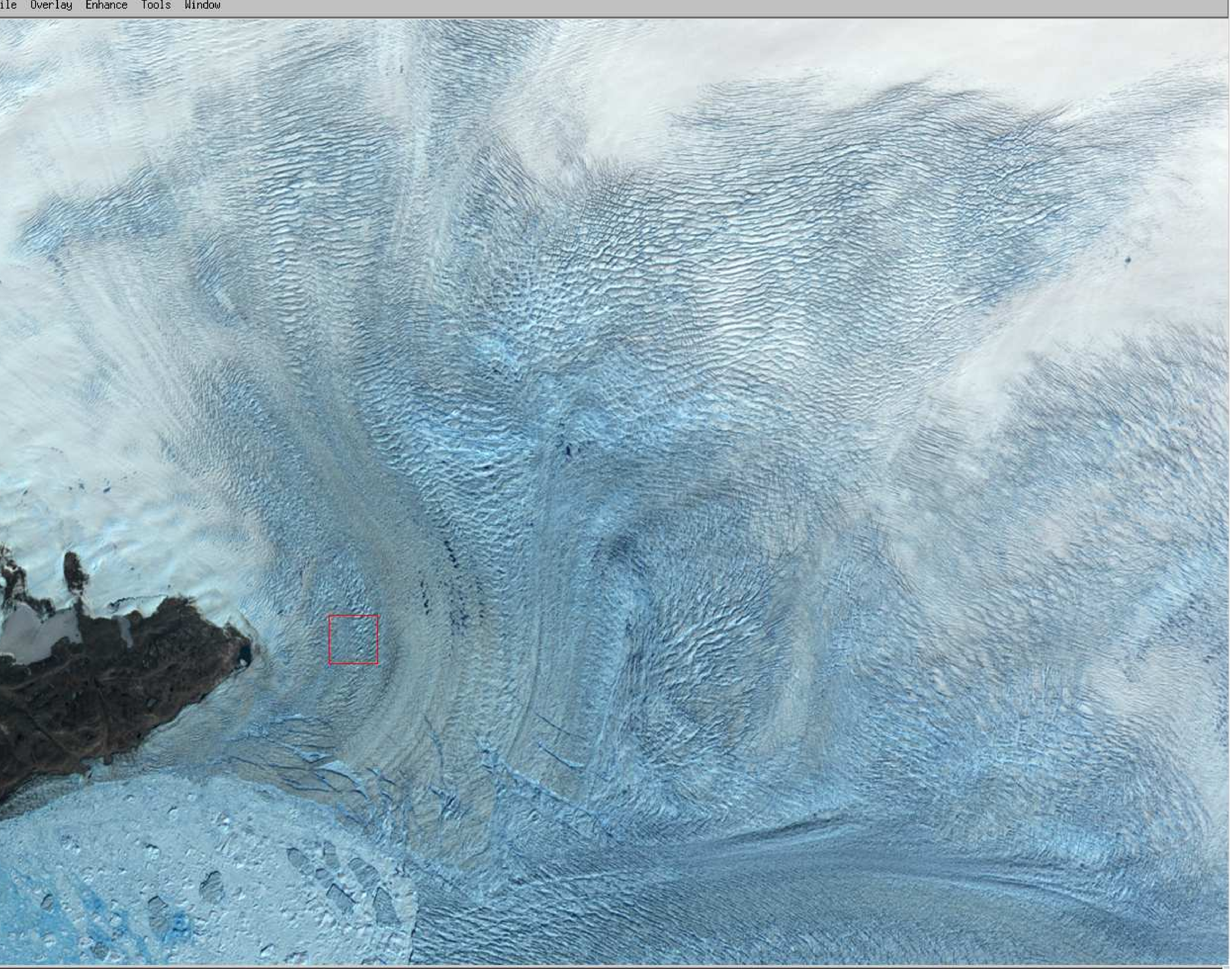
Jakobshavns Isbræ: August 1996



Calving Front of Jakobshavns Isbræ on 16 July 2005

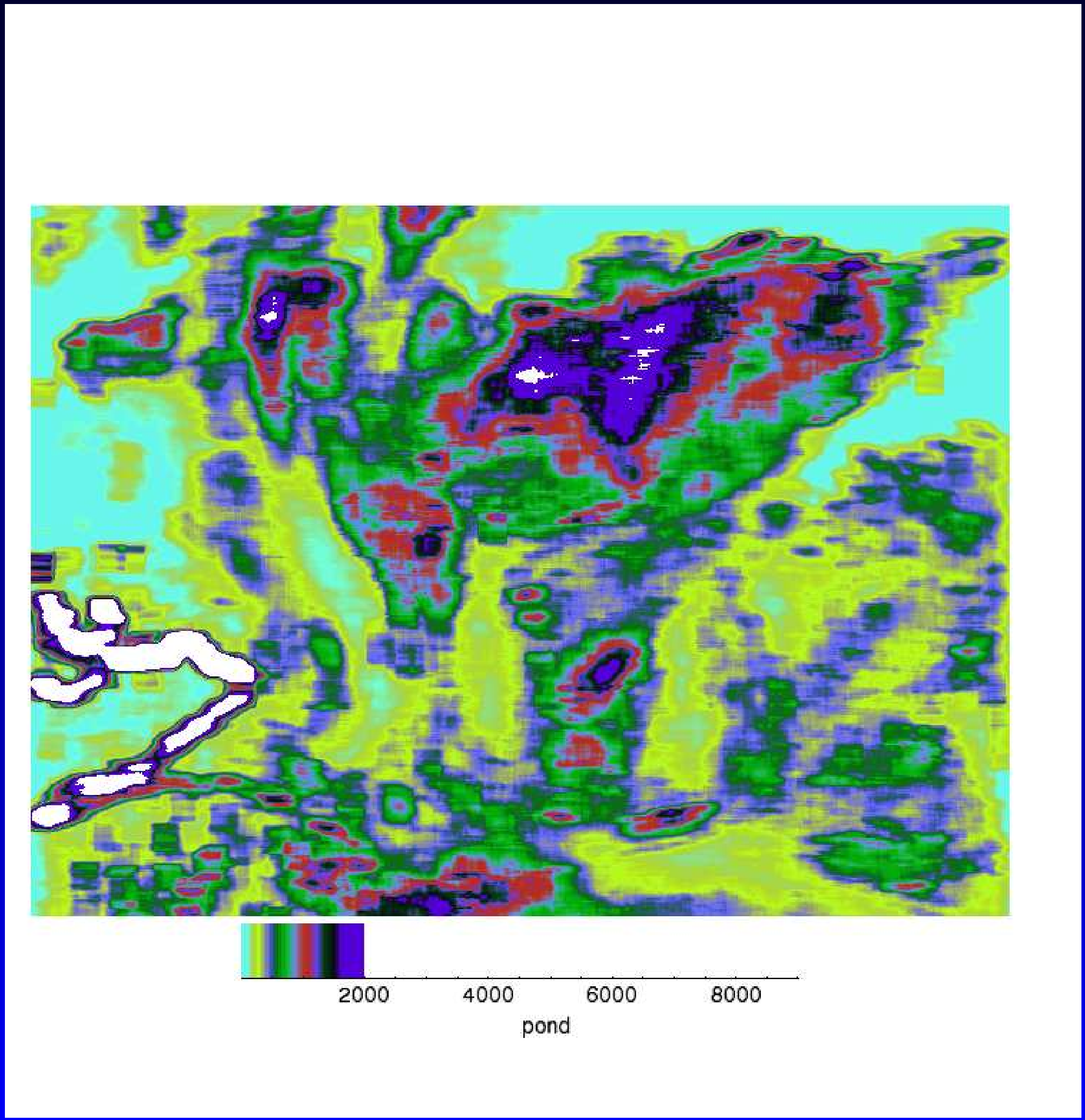
How do we measure surface roughness? — The GRS !

Mapping Deformation Properties using Geostatistical Classification based on ASTER DATA

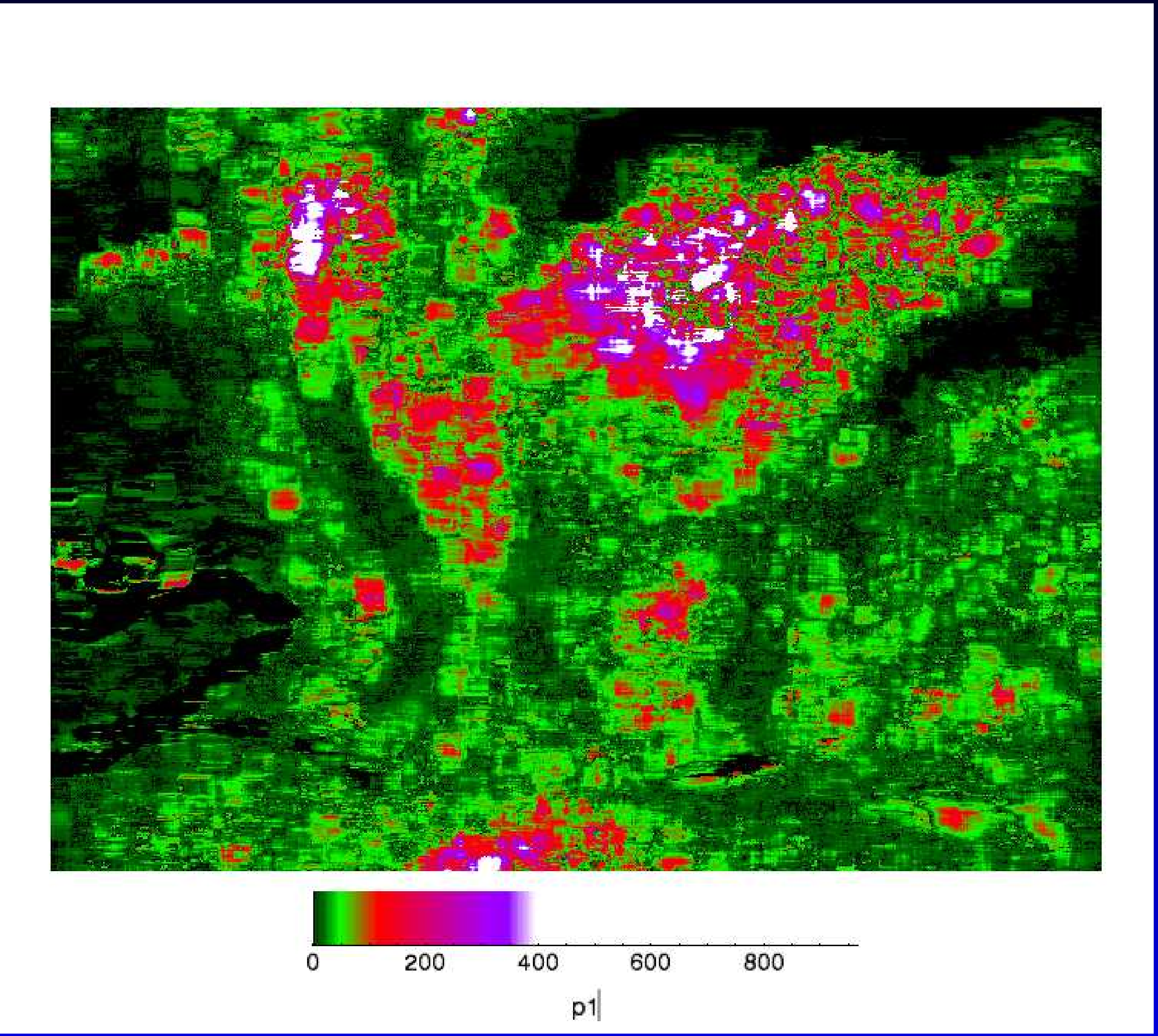


Jakobshavns Isbræ: North Icestream — ASTER Data, May 2003

ASTER Data Classification: Parameter *pond*



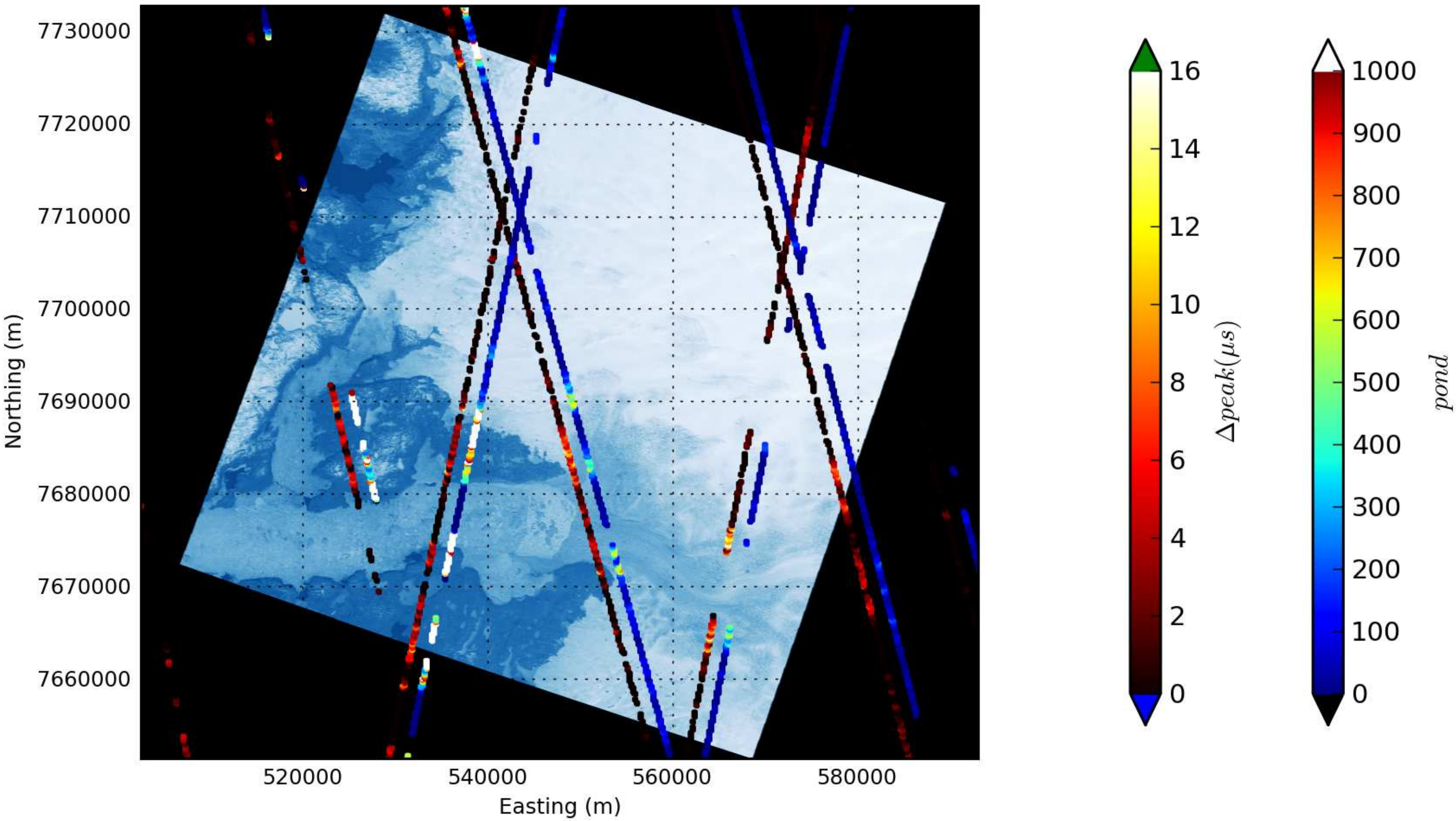
ASTER Data Classification: Parameter $p1$



window 20, offset 1, direction N-S

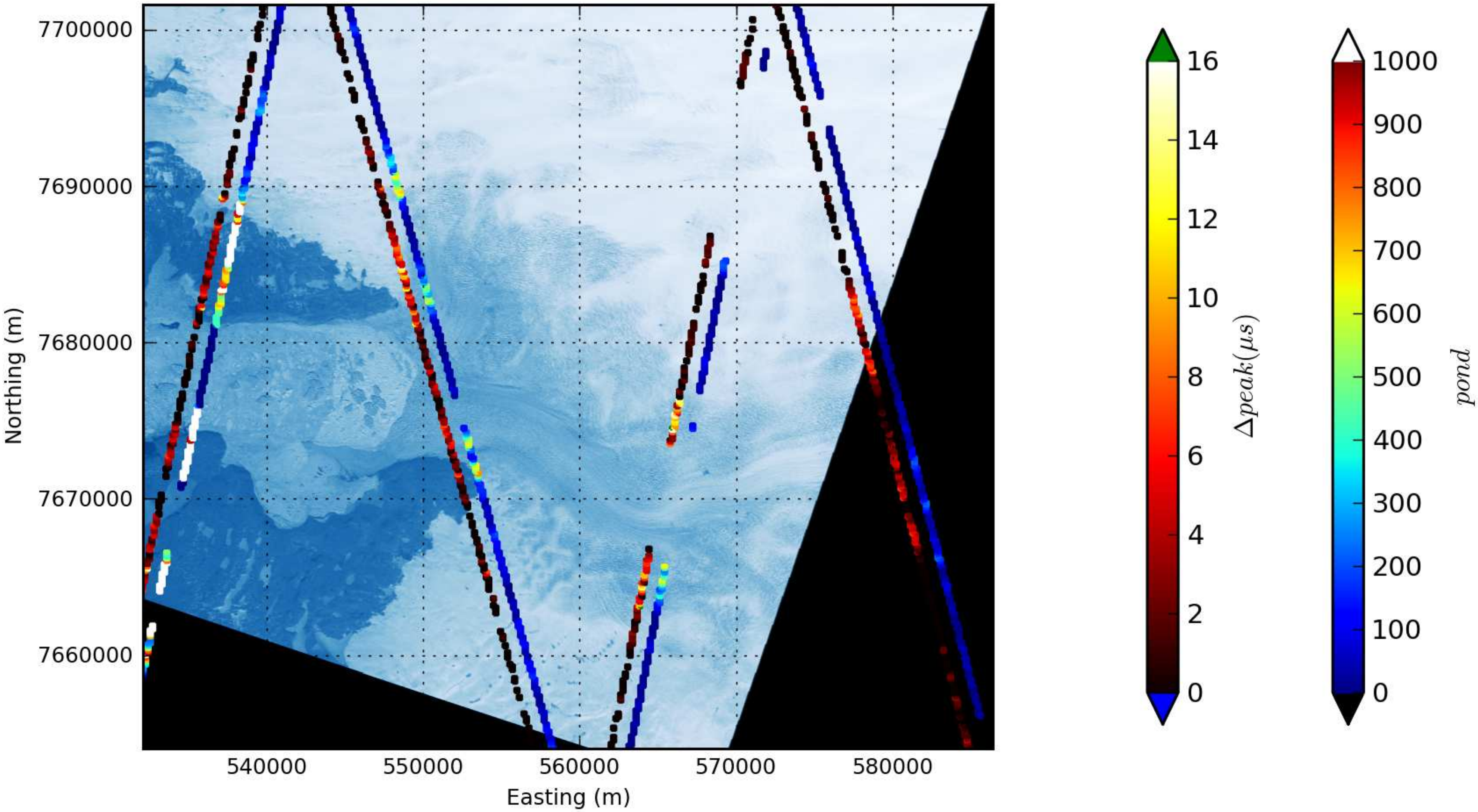
Dynamic Provinces in Jakobshavns Isbræ from ICESat (GLAS, 2003-2009) and IceBridge (ATM, 2009) Data

Jakobshavn Isbrae - Roughness measures



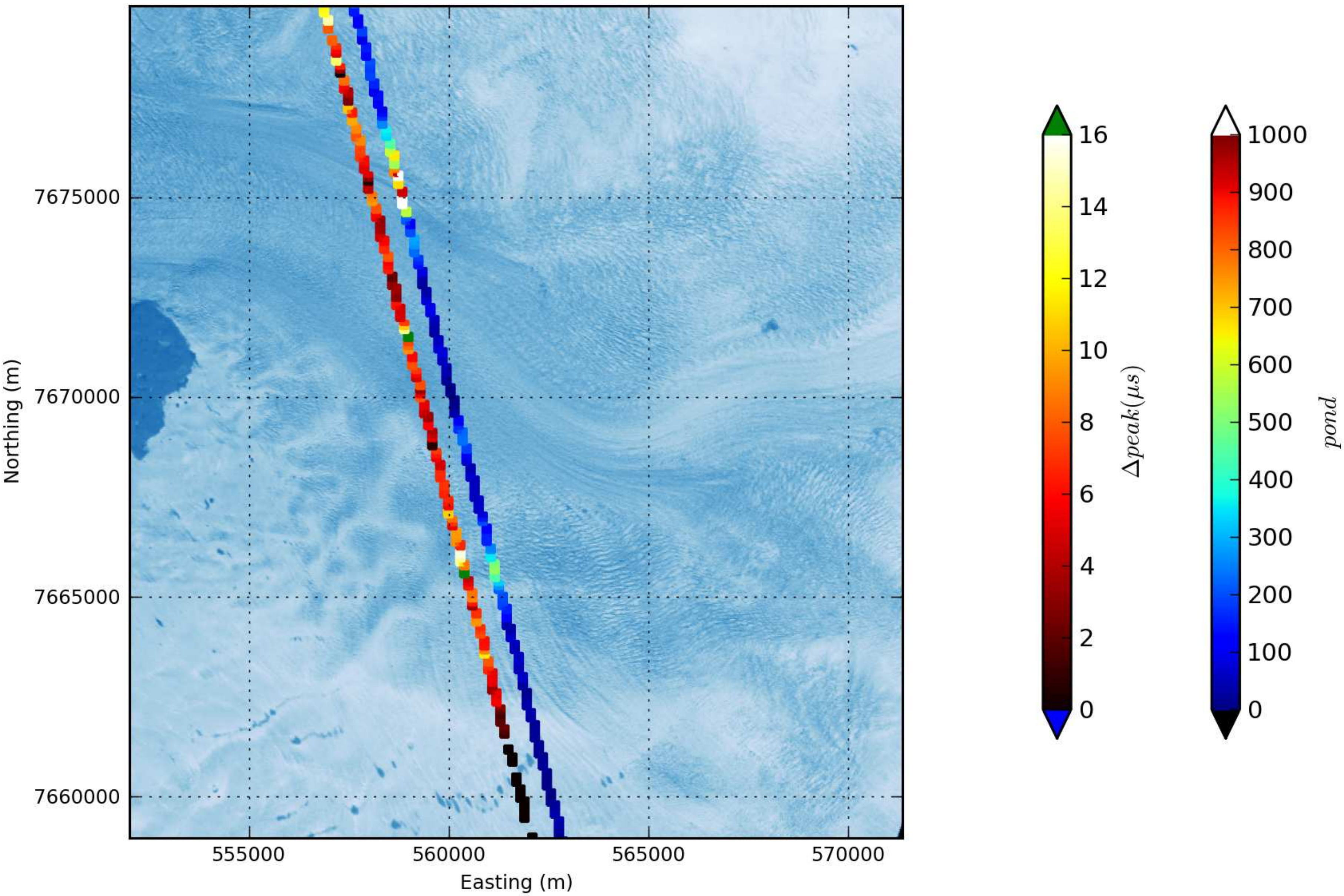
GLAS L3C 05/2005 left to right: $\Delta peak(\mu s)$, $pond$
ASTER 3B 05-2003 Background

Jakobshavn Isbrae - Roughness measures



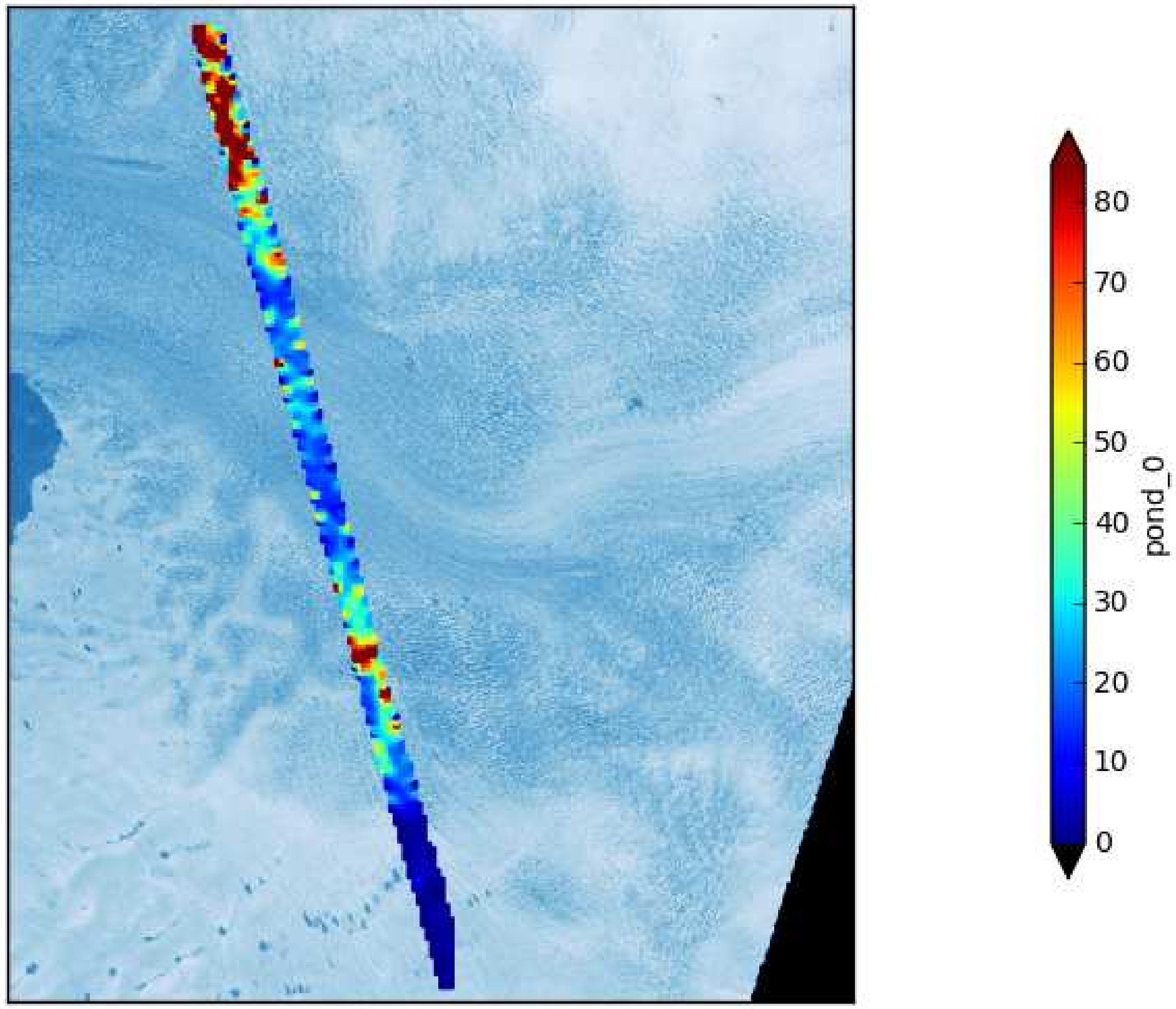
GLAS L3C 05/2005 left to right: $\Delta peak(\mu s)$, $pond$
ASTER 3B 05-2003 Background

Jakobshavn Isbrae - Roughness measures



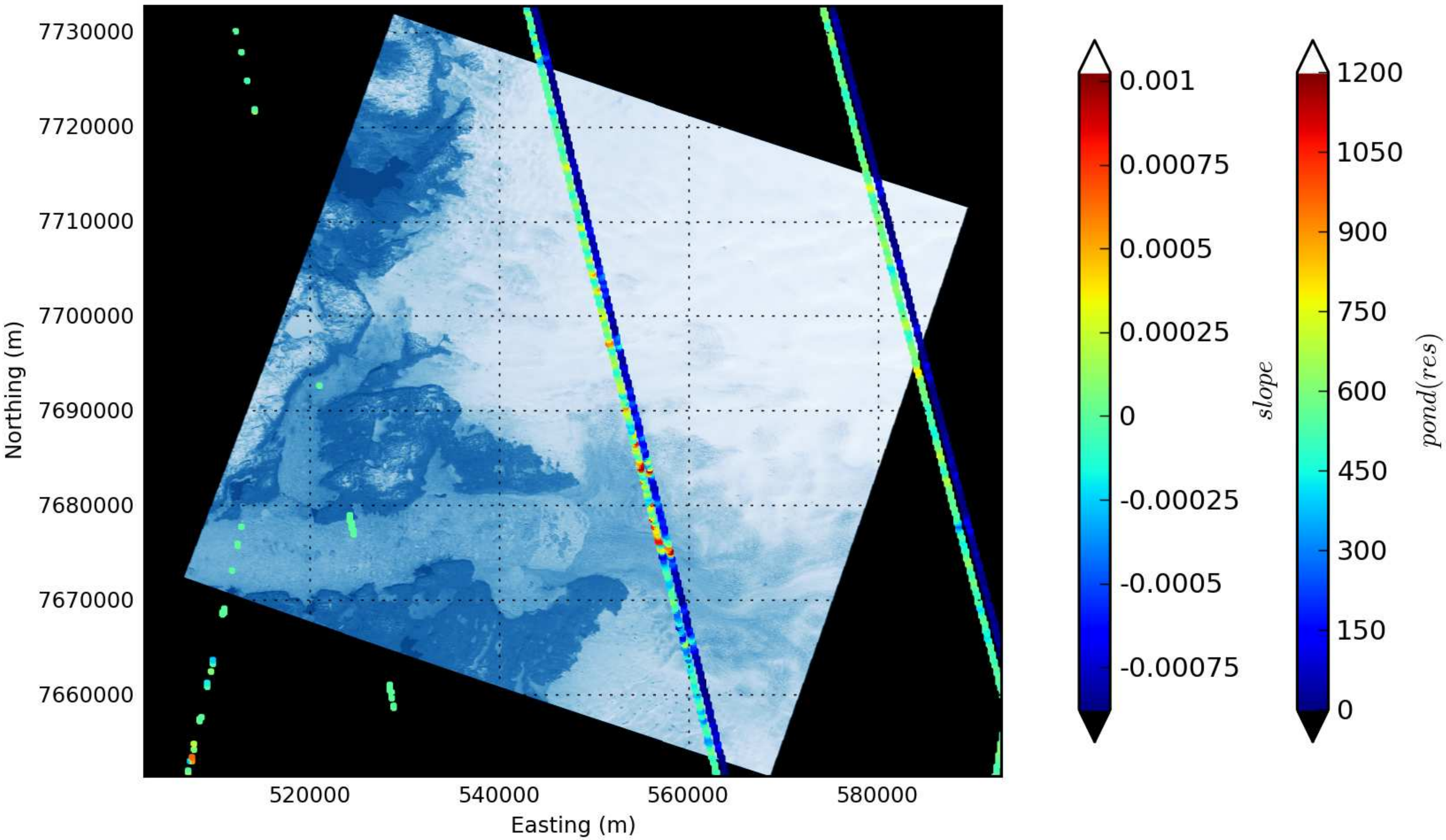
GLAS L3I 11/2007 left to right: $\Delta peak(\mu s)$, $pond$

Jakobshavn Isbrae - Roughness measures



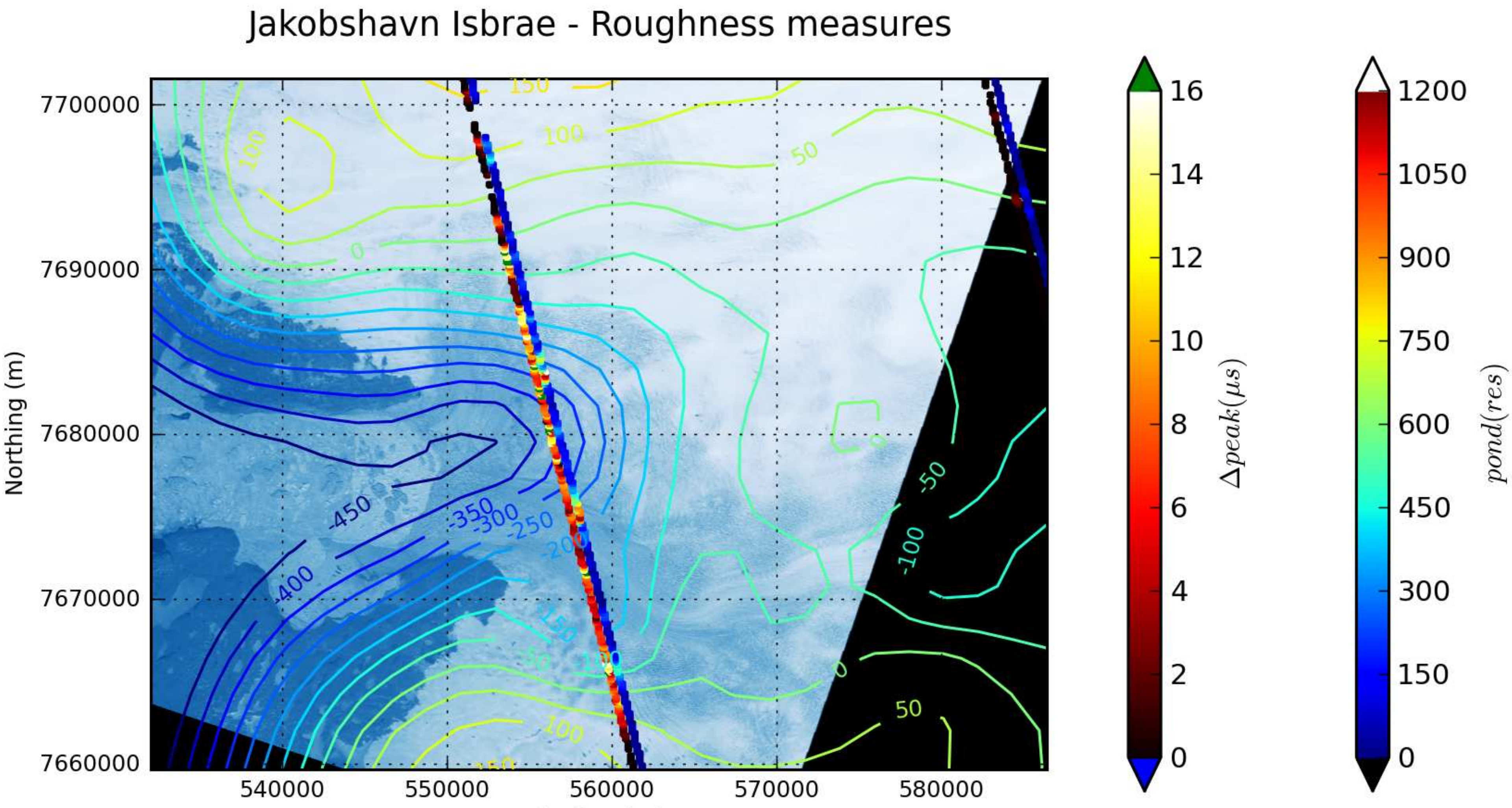
ATM full pond_0 parameter
ASTER 3B 05-2003 Background

Jakobshavn Isbrae - Roughness measures



GLAS L3I 11/2007 left to right: $slope$, $pond(res)$
ASTER 3B 05-2003 Background

/data/wallinb/jak/plots/v5/jak_GLASL3I_slopepondres_zoom1_v4.png 2010-1-21



GLAS L3I 11/2007 left to right: $\Delta peak(\mu s)$, $pond(res)$
ASTER 3B 05-2003 Background
with CRESIS Bed contours

/data/wallinb/jak/plots/v7/jak_GLASL3I_peakdiffpondres_zoom2_b_v7.png 2010-2-12

Possible implications of spatial surface roughness analyses for climate modeling

(1.) Indicator variable for harder-to-observe spatial properties

(2.) Ice dynamics

(3.) Effects on energy fluxes ice-atmosphere

(n.) ......[your idea here]

Snow- and ice-surface-roughness — Climate — Ablation feedback

(1) Derivation of mathematical relationship bt surface roughness and geostatistical characterization

(2) Calculation of surface roughness length from GRS measurements

(3) Utilization of micrometeorological observations (PARCA Network Greenland; Mountain Research Station, Niwot Ridge (NSF CU LTER))

(4) Calculation of energy available for melting (with J. Box, M.Kuhn)

Result: Melt energy varies by a factor of 2.6 dependent on surface roughness !!

HERZFELD, U.C., J.E. BOX, K. STEFFEN, H. MAYER, N. CAINE, and M.V. LOSLEBEN, A case study on the influence of snow and ice surface roughness on melt energy, Zeitschrift Gletscherkunde Glazialgeol., v. 39 (2003/2004, printed 2006), p. 1-42