Thoughts on connecting geophysical observations and dynamic ice sheet models — surface elevation, bed topography, roughness and turbulence

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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)

  (8) CryoSat (since Feb 2010)
- Satellites with laser altimeters

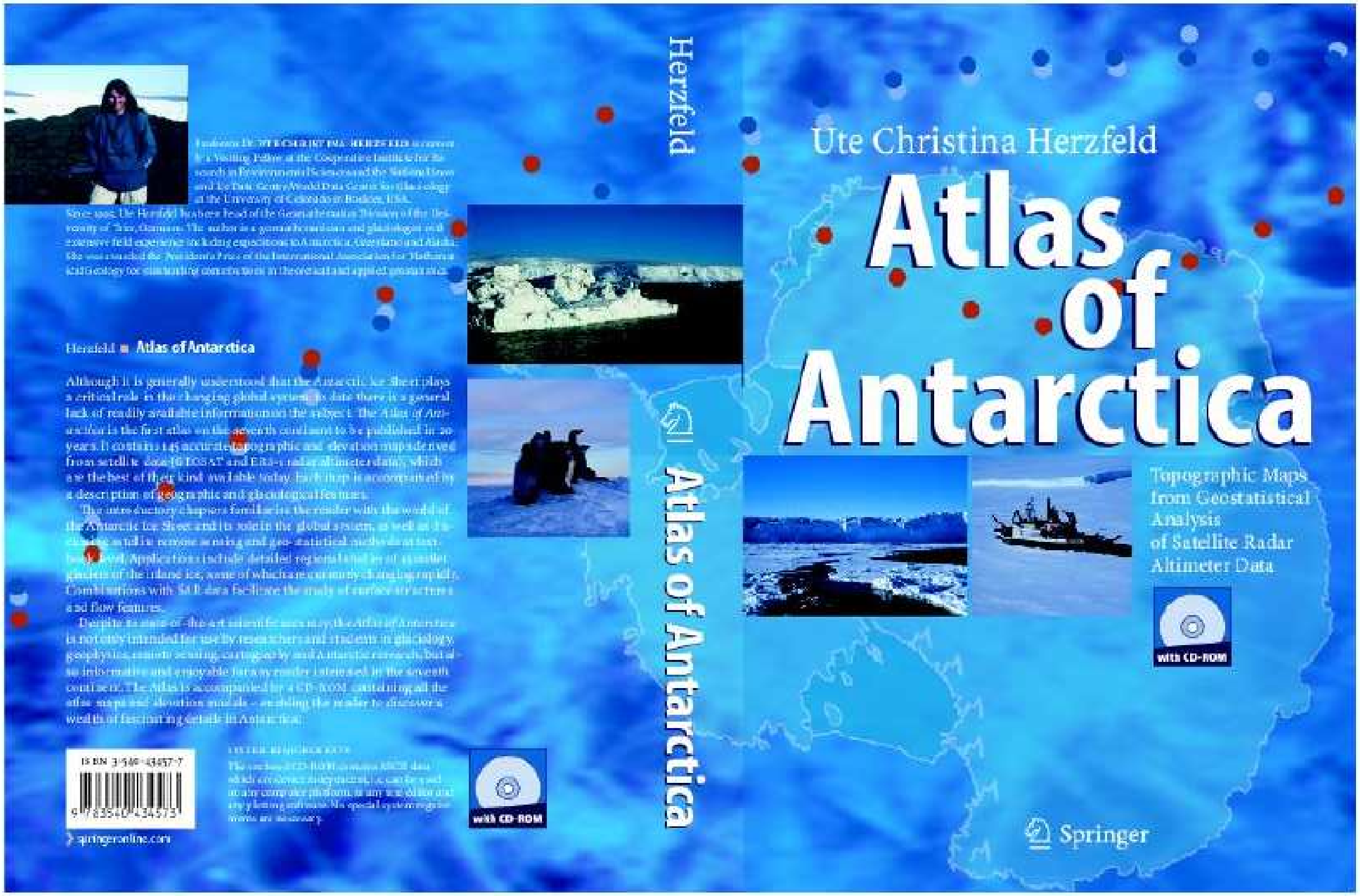
  (1) ICESat: GLAS (2003-2009)

  (2) ICESat-2 (launch 2015)

Survey campaigns and satellite missions

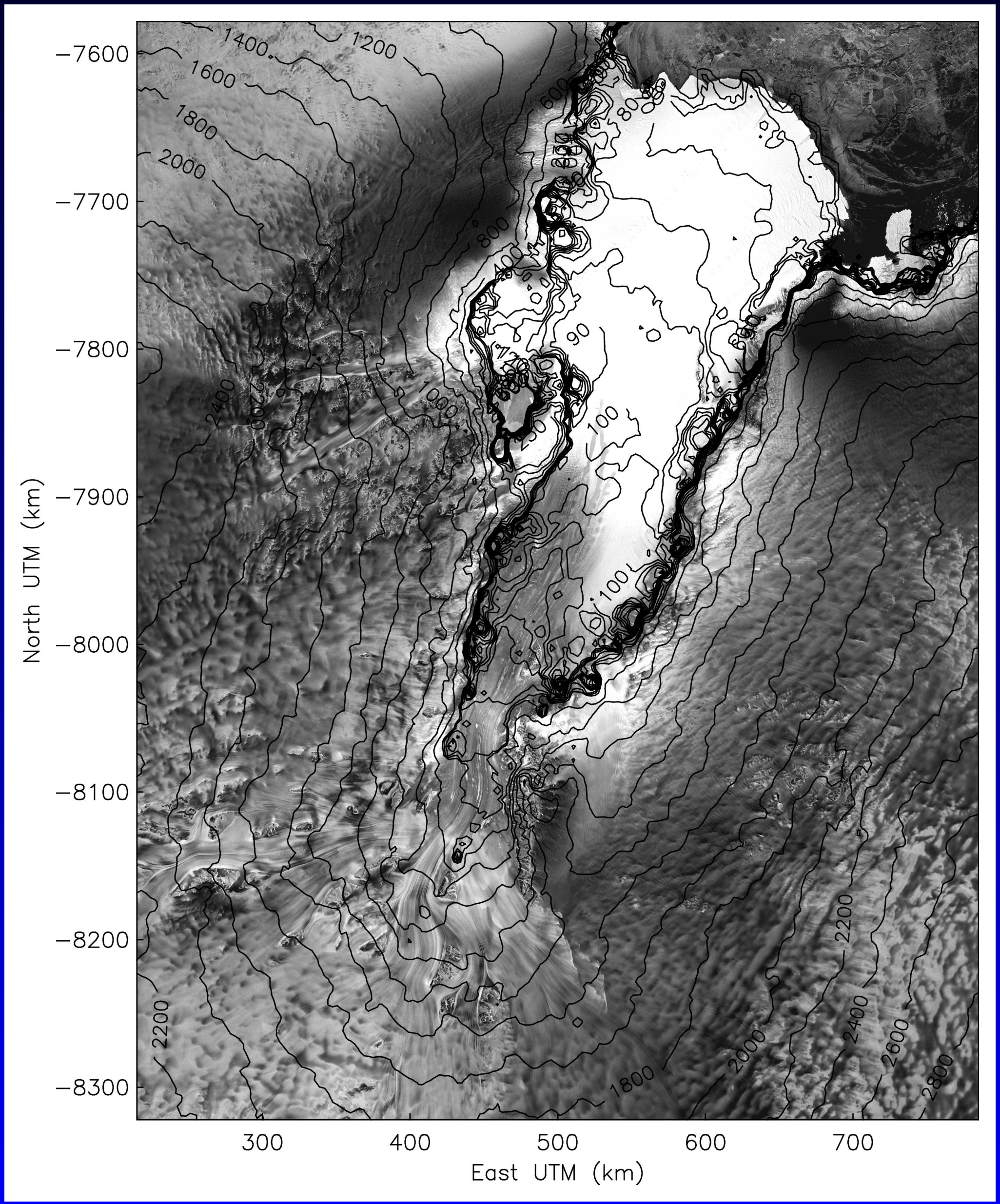
$\longrightarrow$ tiers of observations

SCALE



Ute Christina Herzfeld
Atlas of Antarctica
Topographic Maps from Geostatistical Analysis of Satellite Radar Altimeter Data
with CD-ROM
Springer
Herzfeld
Atlas of Antarctica
Herzfeld ■ Atlas of Antarctica
ISBN 3-540-43457-7
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

Spatial surface roughness

- a derivative of (micro)topography
- morphology at large scale
- interaction with bed topography
- ice flow and turbulence

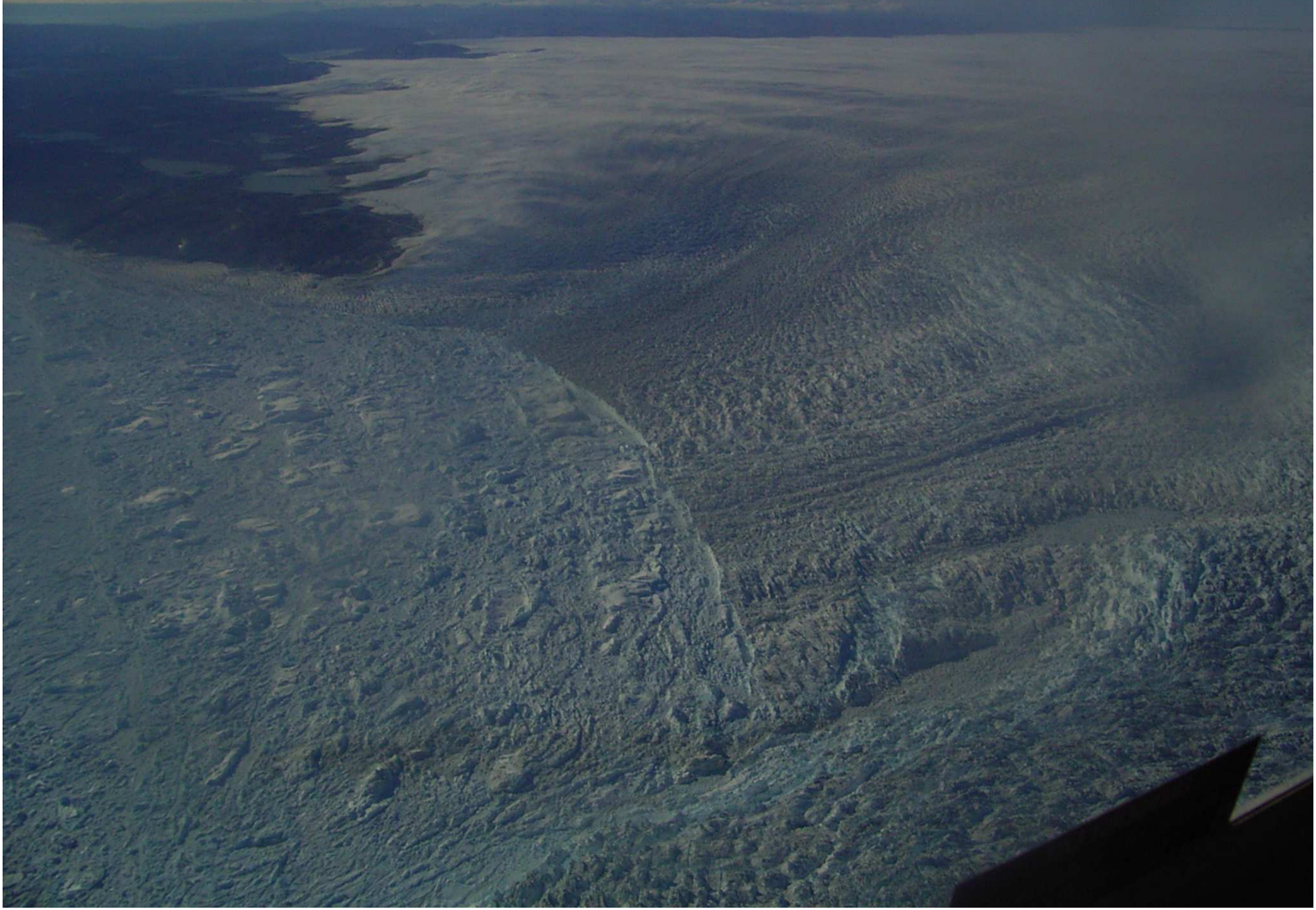
$\longrightarrow$ effects on sea-level rise?

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

Jakobshavn Isbræ Drainage Basin – Spring Ice Surface

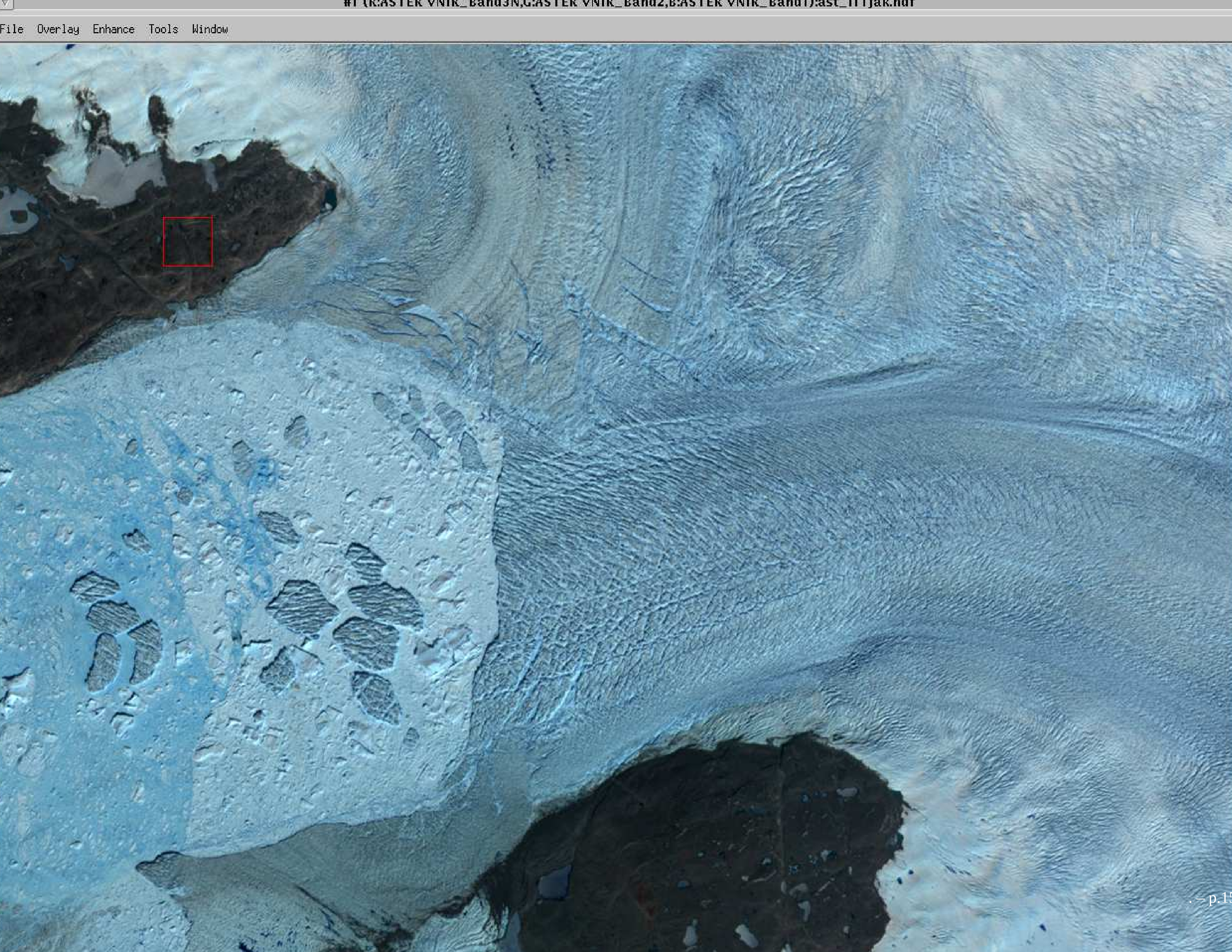
Jakobshavn Isbræ Drainage Basin – Summer Ice Surface

Jakobshavns Isbræ: August 1996

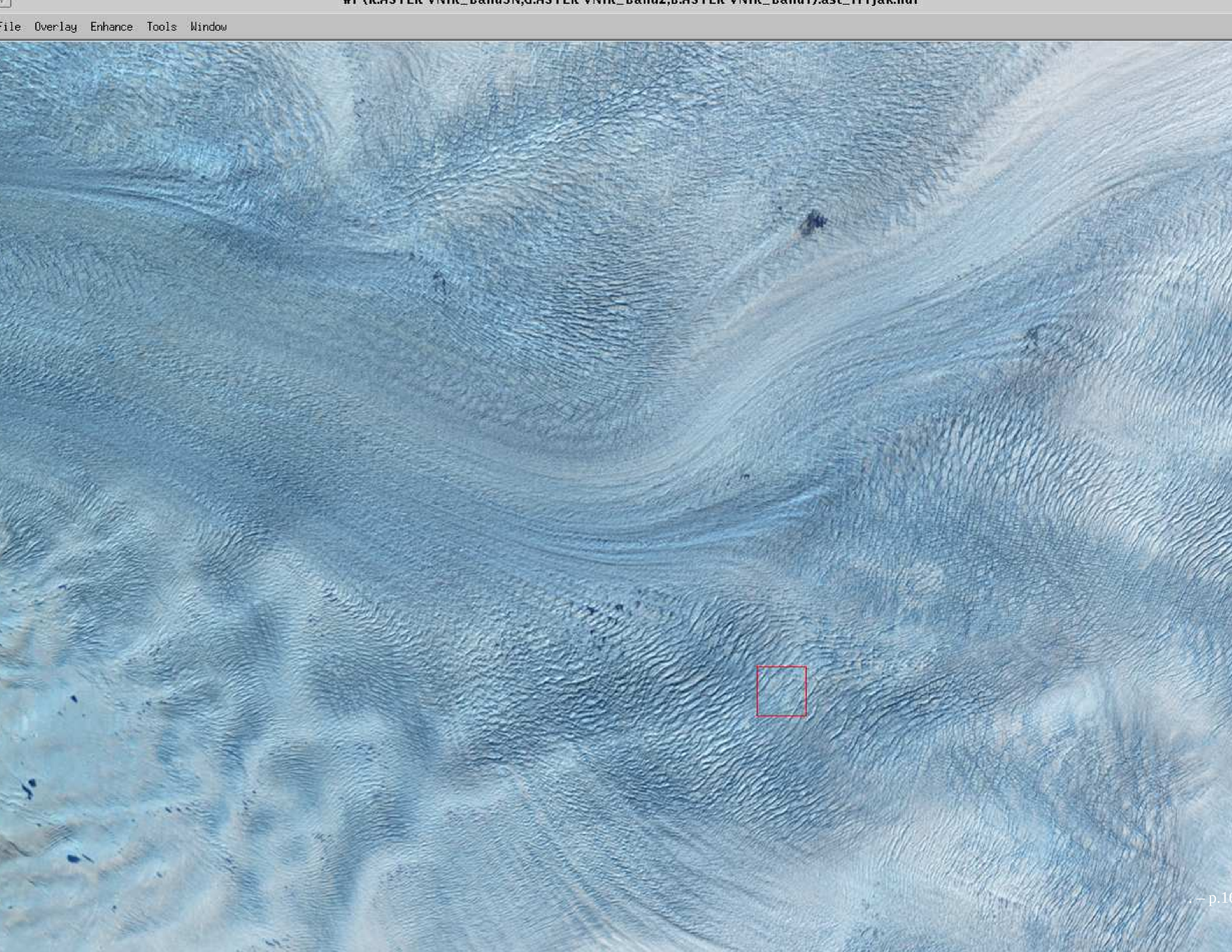


Calving Front of Jakobshavns Isbræ on 16 July 2005

How do we measure surface roughness? — The GRS !



#1 (R:ASTER VNIR_Band3N,G:ASTER VNIR_Band2,B:ASTER VNIR_Band1):ast_l1jak.hdf
File
Overlay
Enhance
Tools
Window


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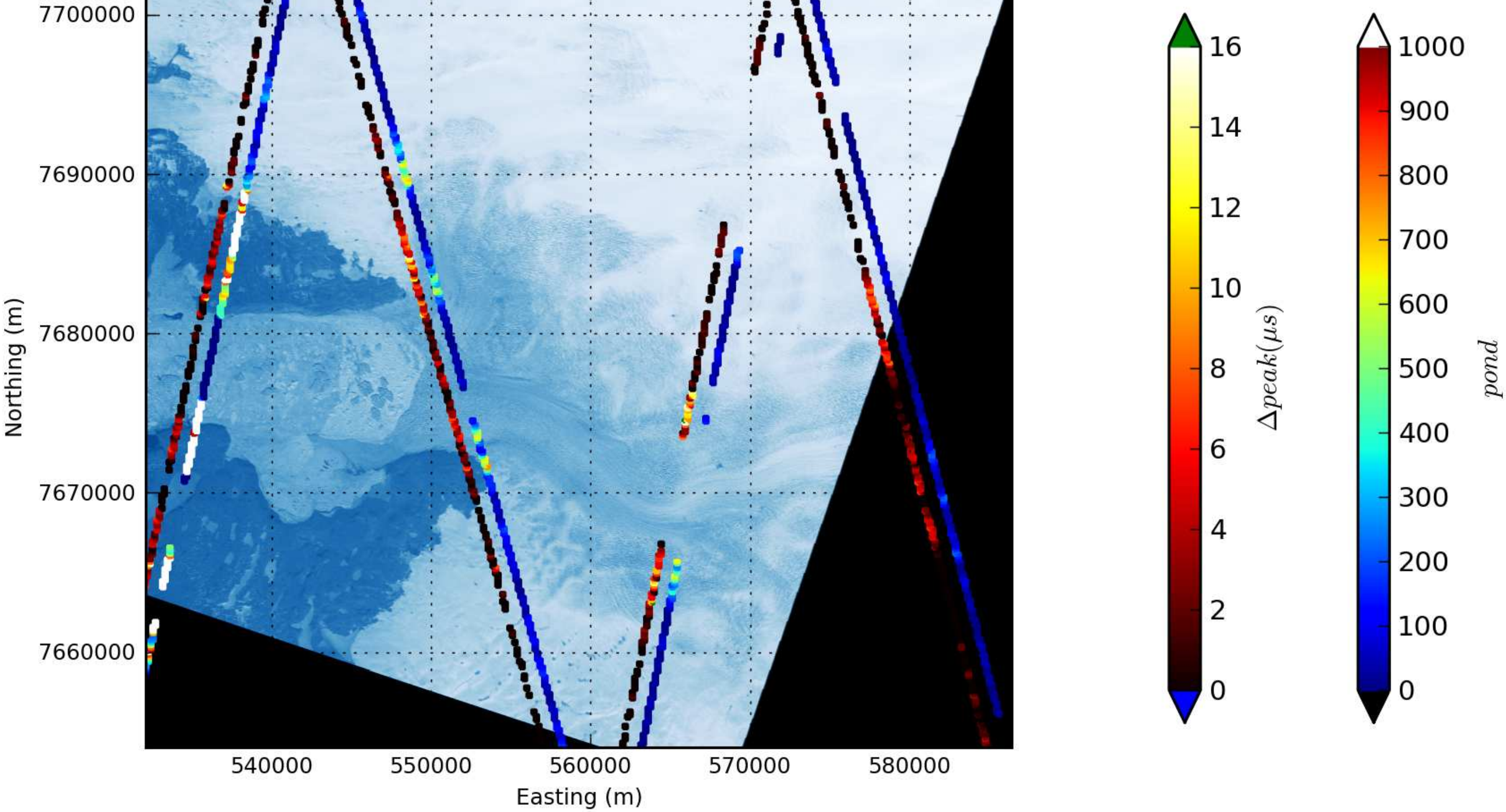
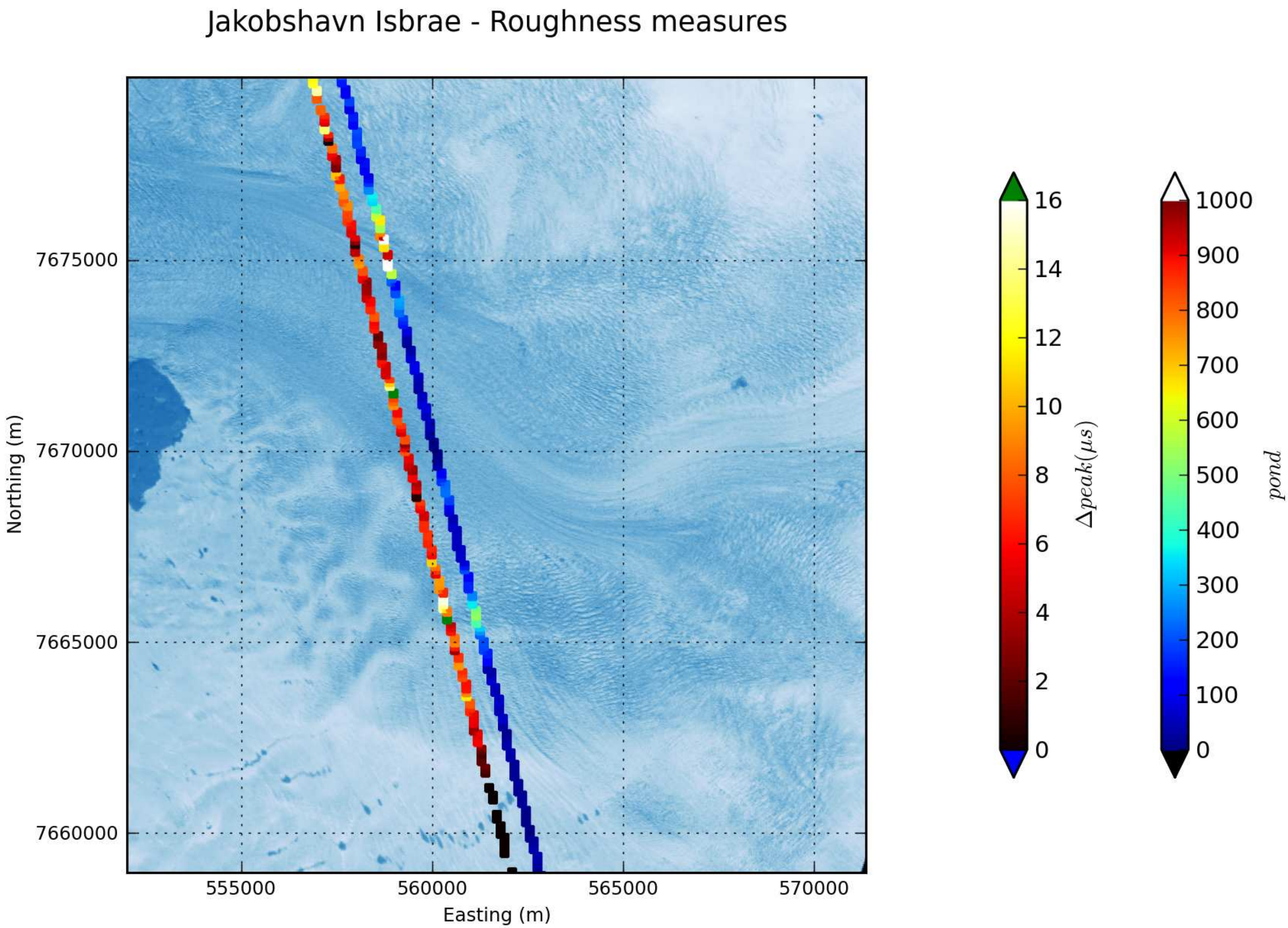
Dynamic Provinces in Jakobshavns Isbræ from ICESat (GLAS, 2003-2009) and IceBridge (ATM, 2009) Data

Jakobshavn Isbrae - Roughness measures

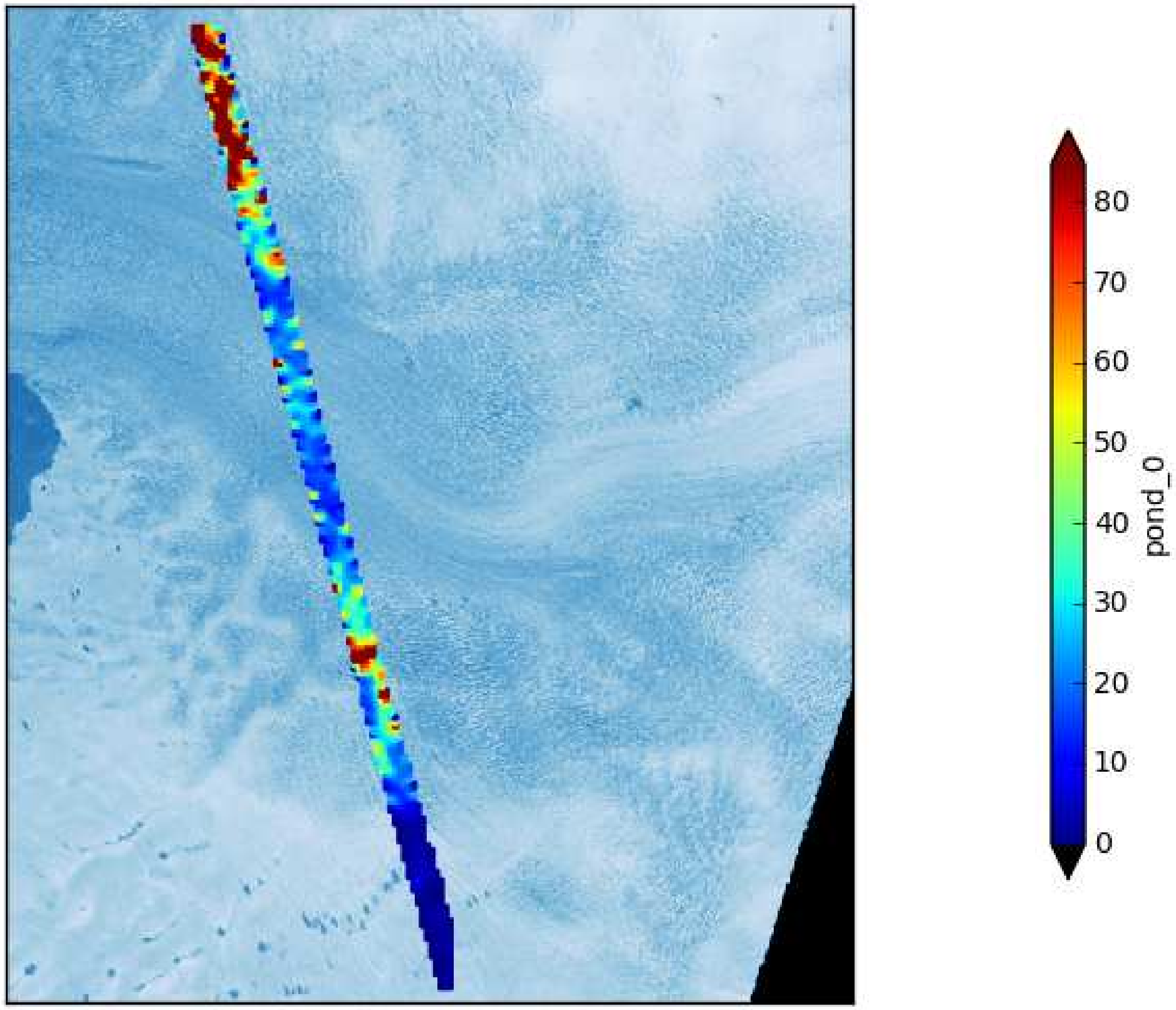


GLAS L3C 05/2005 left to right: $\Delta peak(\mu s)$, $pond$
ASTER 3B 05-2003 Background

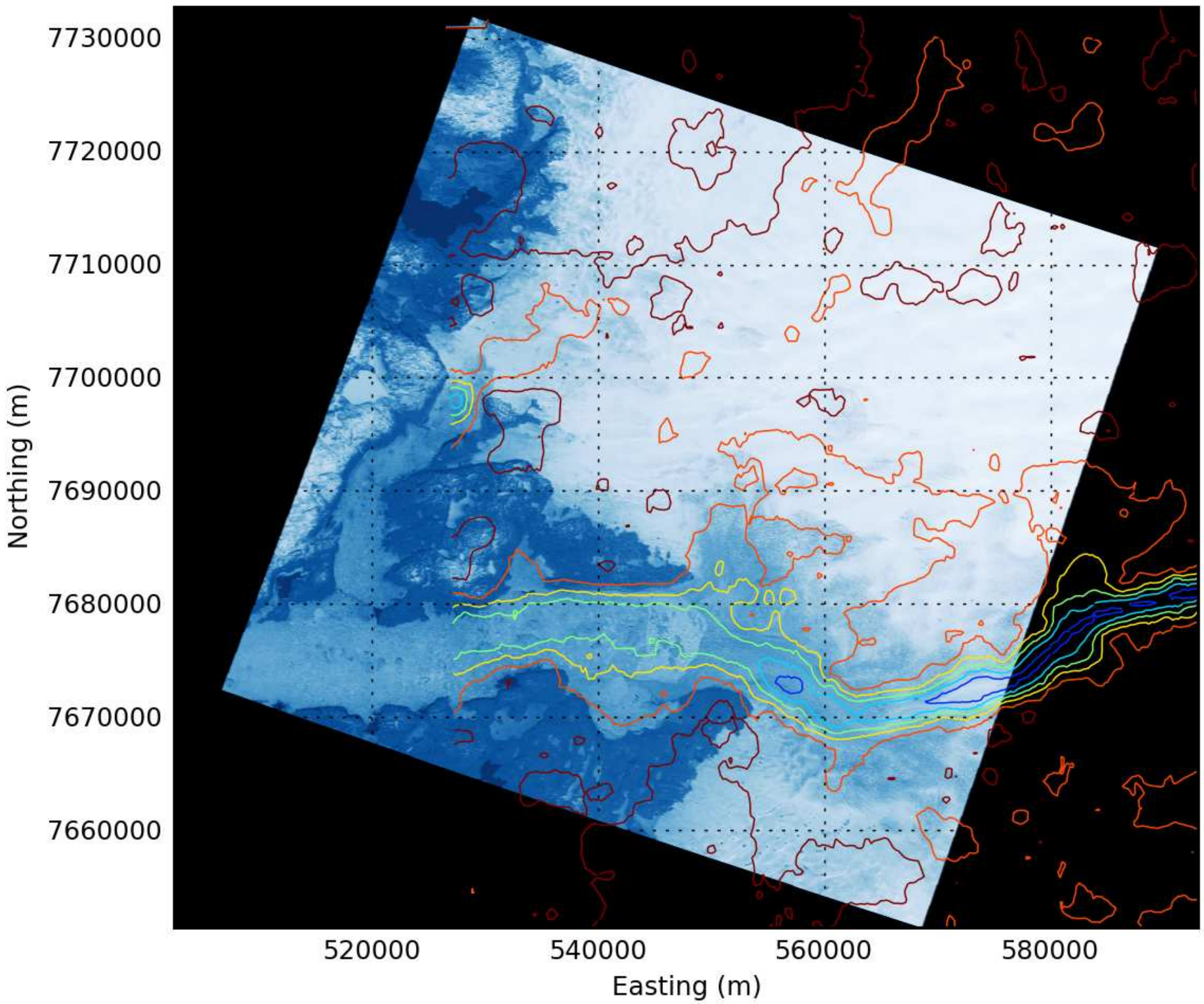


GLAS L3I 11/2007 left to right: $\Delta peak(\mu s)$, $pond$

Jakobshavn Isbrae - Roughness measures



ATM full pond_0 parameter
ASTER 3B 05-2003 Background



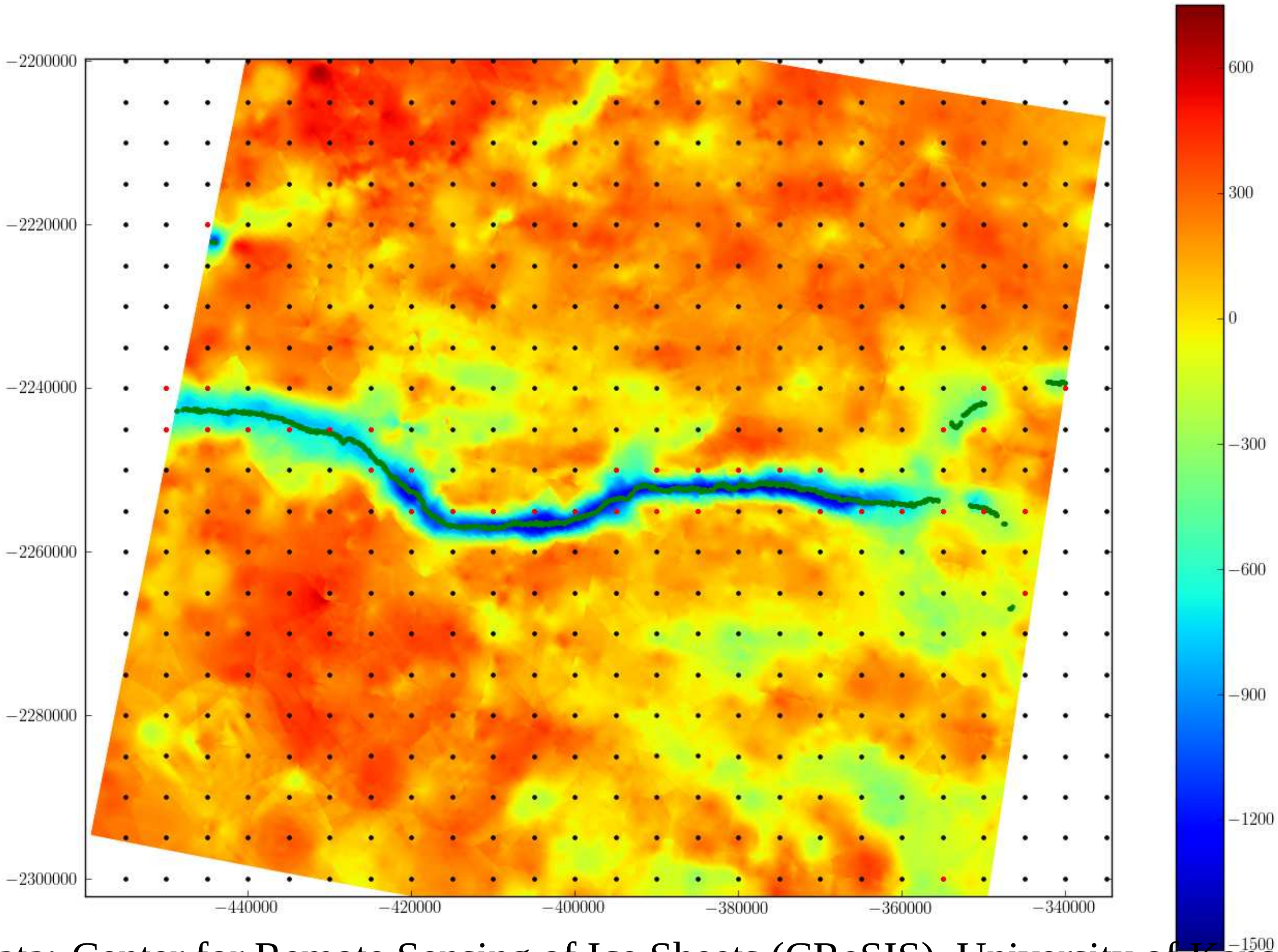
ASTER 3B 05-2003 Background
with CRESIS Bed contours
/data/wallinb/jak/plots/v9/jak_zoom1_b.png 2010-4-28

Creating A Glacier Bed DEM for Jakobshavns Trough as Low-Resolution Input for Dynamic Ice Sheet Models

(1) Derivation of an Algorithm for Adjusting Topography to Grids while Preserving Sub-Scale Morphologic Characteristics

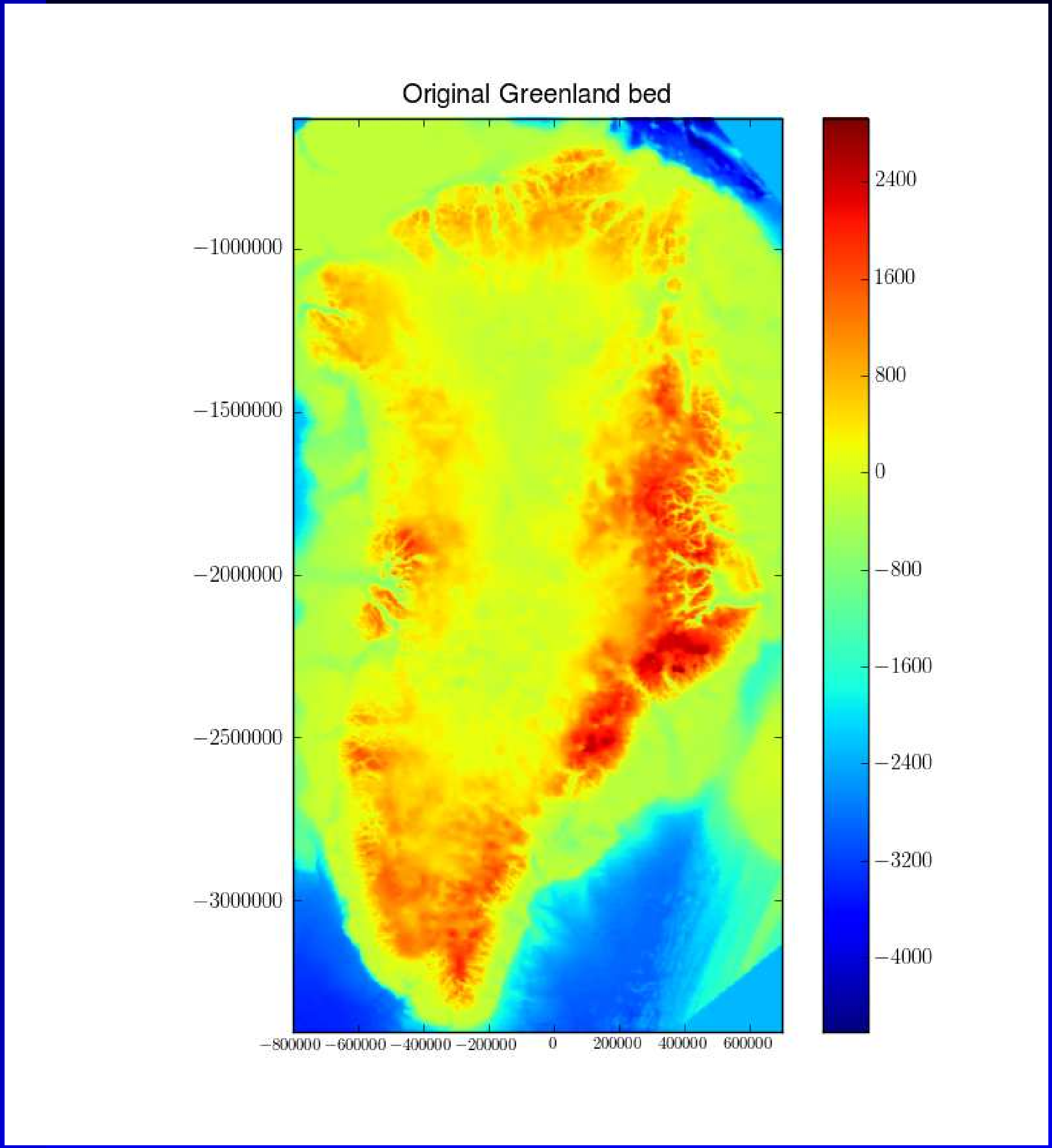
(2) A service to SeaRISE: estimation of maximal ice-sheet contribution to sea-level rise (in 200 years)

Jakobshavn region subglacial topography (CReSIS, prelim)
With AlgoA trough set (red)



radar data: Center for Remote Sensing of Ice Sheets (CReSIS), University of Kansas
cartography and coloring of CReSIS data by Bruce Wallin

Greenland subglacial topography - without Jak trough

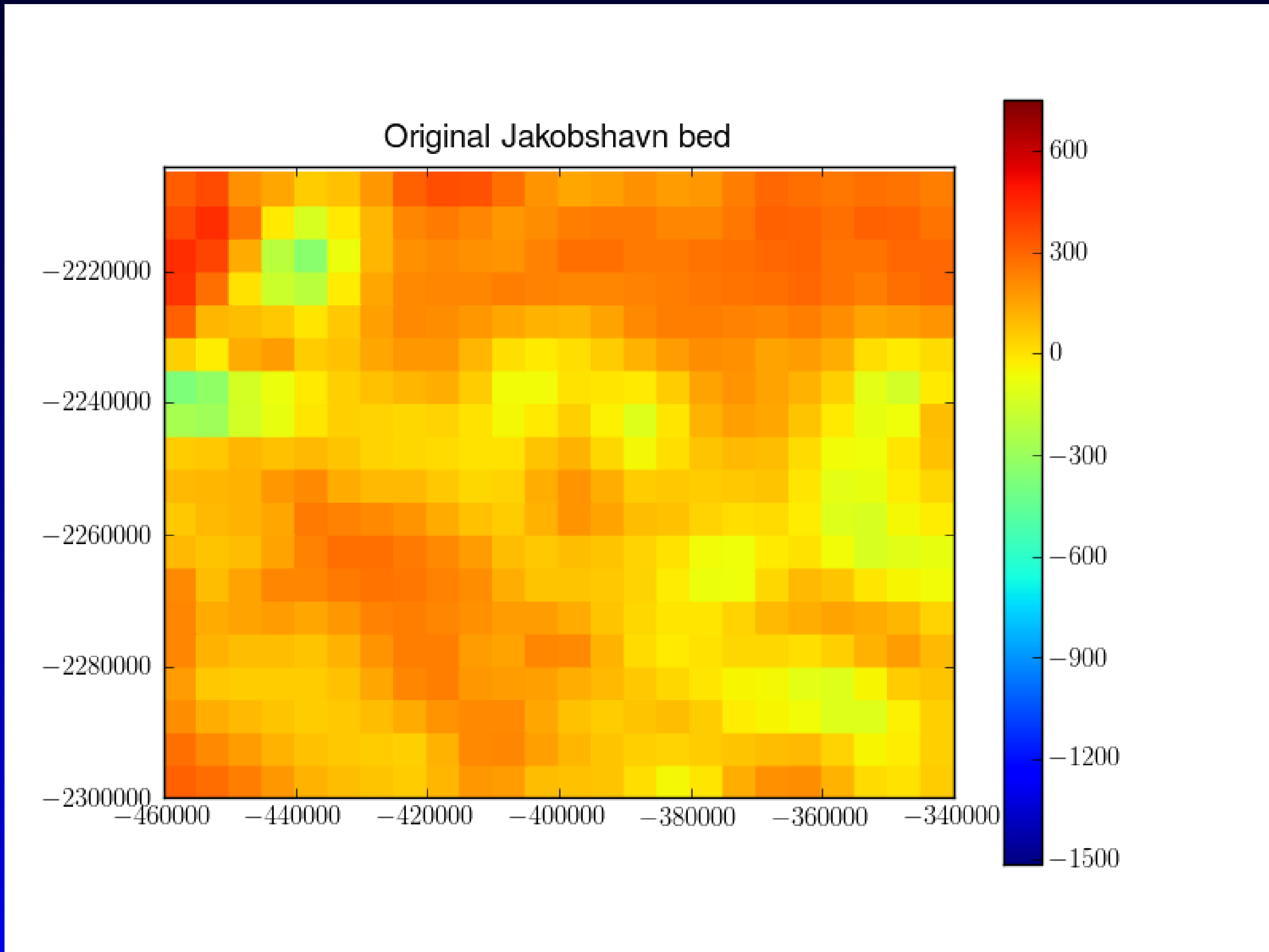


based on

Bamber, Layberry and Gogineni

2001

Jakobshavn region subglacial topography - without Jak trough



based on Bamber, Layberry and Gogineni 2001

Jakbed Algo

(1) identification of trough location

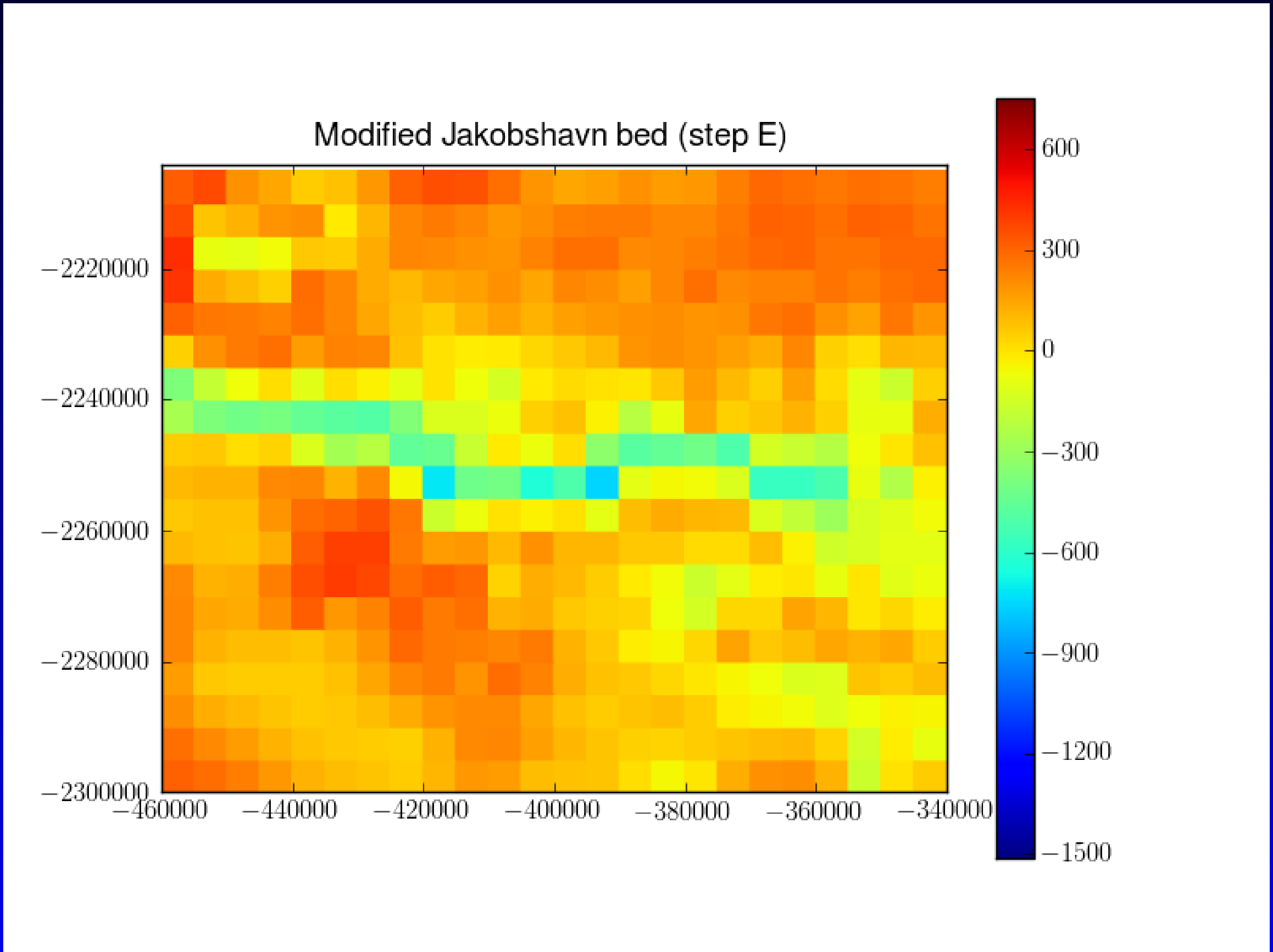
(2) establish edge-connectedness of trough bottom

(3) adjustment of high-resolution grid to trough-location (morph-stretch algorithm for entire Jak region), preserves morphology

(4) apply distance-weighted average in morph-stretched topology

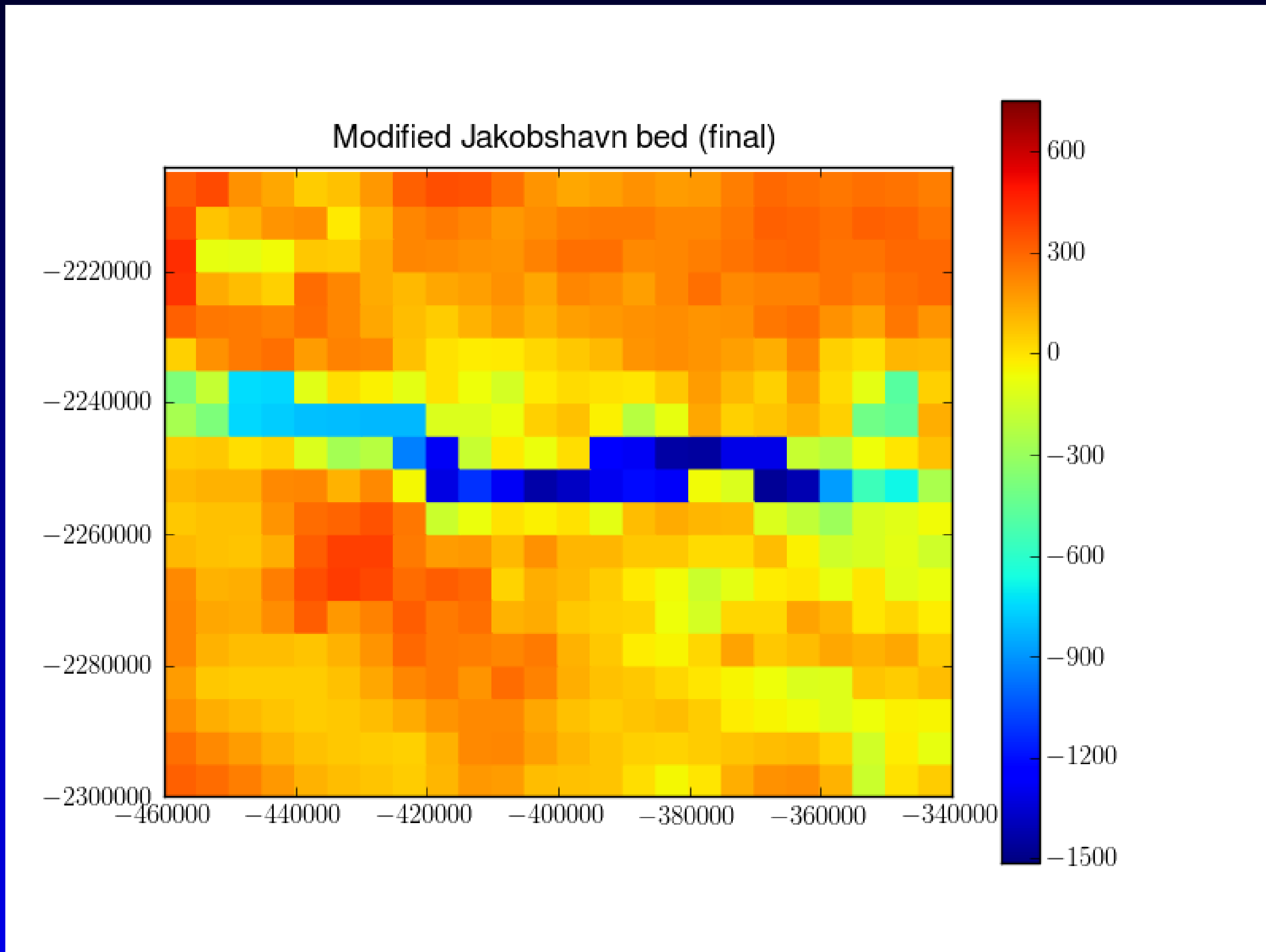
(5) assign local trough minimum to grid nodes in trough set

Intermediate step
after morph-stretch and distance-weighted averaging, v5



(from Herzfeld, Wallin, Leuschen and Plummer 2010)

Jakobshavn region subglacial topography
AlgoA (edge-connected), morph-stretched, v5



(from Herzfeld, Wallin, Leuschen and Plummer 2010)

Integration of Jakbed into Greenland modeling DEMs

(1) trafo CRESIS data onto same coordinate system as used by modeling groups

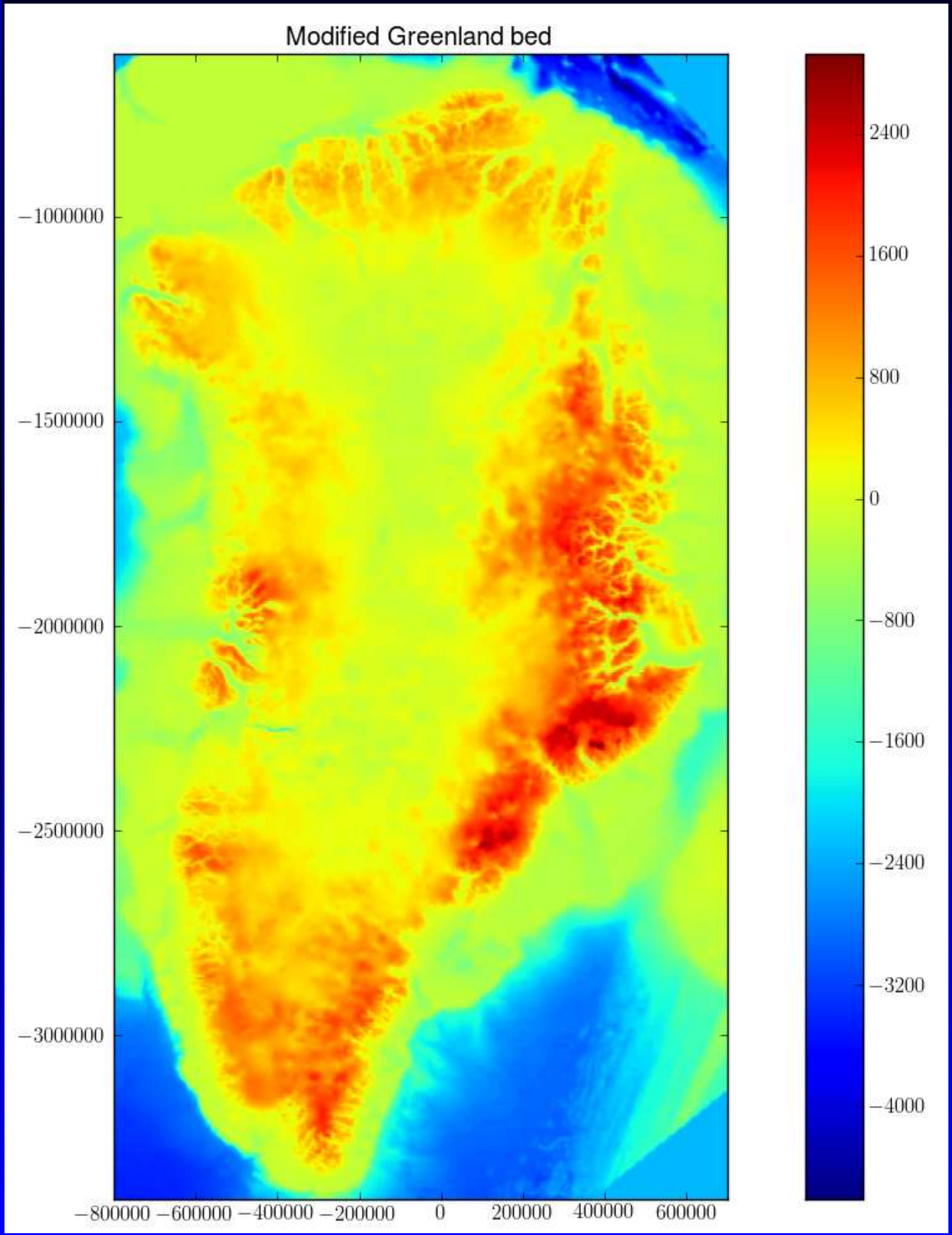
(2) utilize netCDF format preferred by modeling groups

(3) morph-stretch algo facilitates seamless integration

(4) variable package provided for easy use of data in model runs (bed topography, precipitation and other data fields)

see http://websrv.cs.umt.edu/isis/index.php/SeaRISE_Assessment (maintained by Jesse Johnson's group at University of Montana)

Greenland subglacial topography - with Jak trough (v5)



Uploaded to SeaRISE web site (http://websrv.cs.umt.edu/isis/index.php/SeaRISE_Assessment) [Developmental data set 1.2]

(from Herzfeld, Wallin, Leuschen and Plummer 2010)

Does bed topography create turbulence?

(1) *in reality:* creates surface roughness structures (which we understand)

(2) *in models:* does it create artificial turbulence in model runs? (q to modeling community/ searise experiment runs)

Implications of spatial surface roughness and topography for climate modeling

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

(2.) Ice dynamics

(3.) Effects on energy fluxes ice-atmosphere

(4.) Snow- and ice-surface-roughness — climate — ablation feedback

(5.) Influence of subglacial morphology on ice dynamics

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

Questions?

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