Flow variability and propagation behavior in the Ross Ice Shelf

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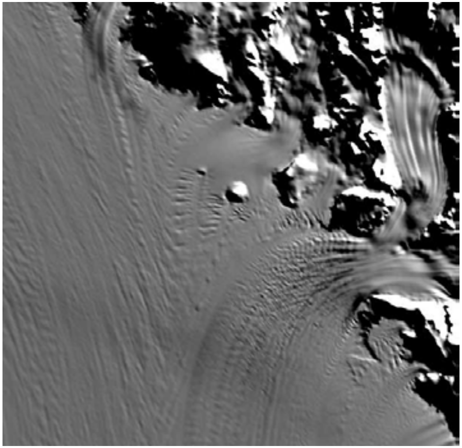
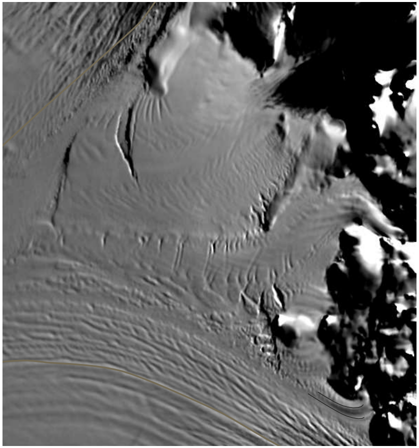
Funding from NASA Cryosphere and NSF-OPP.





MOA (Haran and others, 2005)

Portland State UNIVERSITY

WAIS 2011

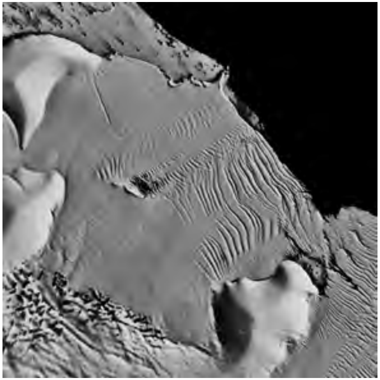
overview

Physical Processes and Structural Map
Derivation of Datasets
Examples
Fracture Model Results

fracture mechanics

simple geometries of young fractures

- transverse, shear, lateral corner (shear + compression)
- 'sharp slit' geometry
- similar fracture lengths
- active tips aligned with the present-day stress field



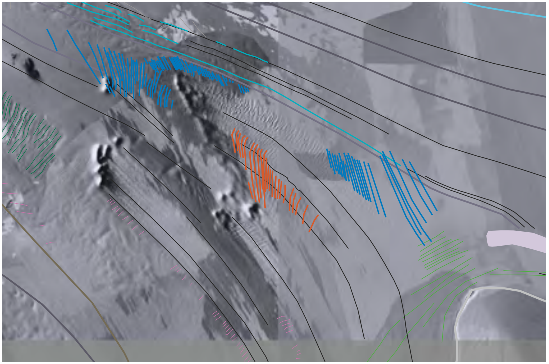
Example from MOA

Propagate in direction of least extensive principal stress when stress intensity factor at tip exceeds fracture toughness of the ice.

LIMA

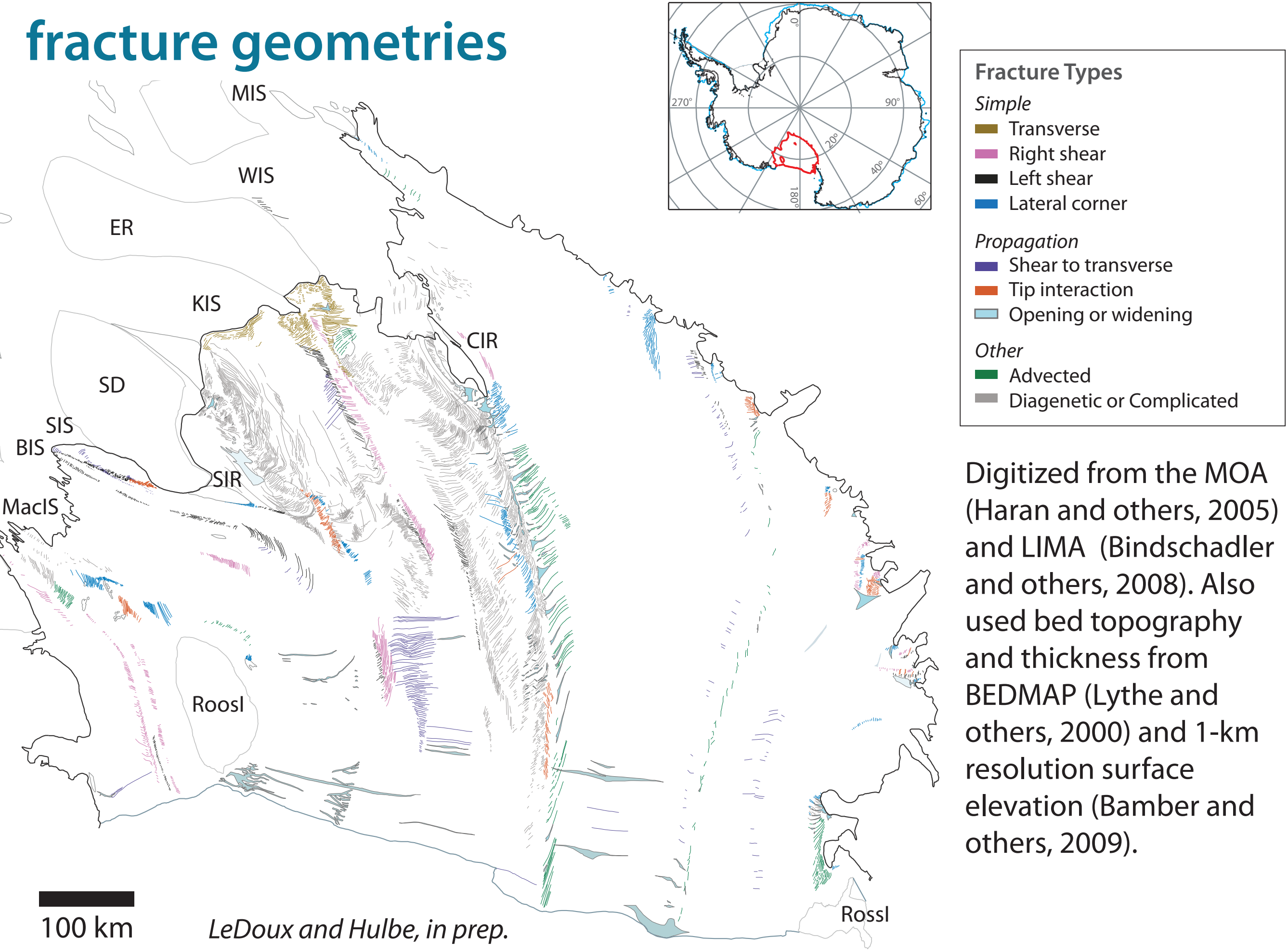
propagation geometries

- shear to traverse
- opening or widening
- mechanical interaction of fracture tips
- episodic growth
- secondary growth (e.g. "horse feathers")



LeDoux and Hulbe, in prep.

fracture geometries

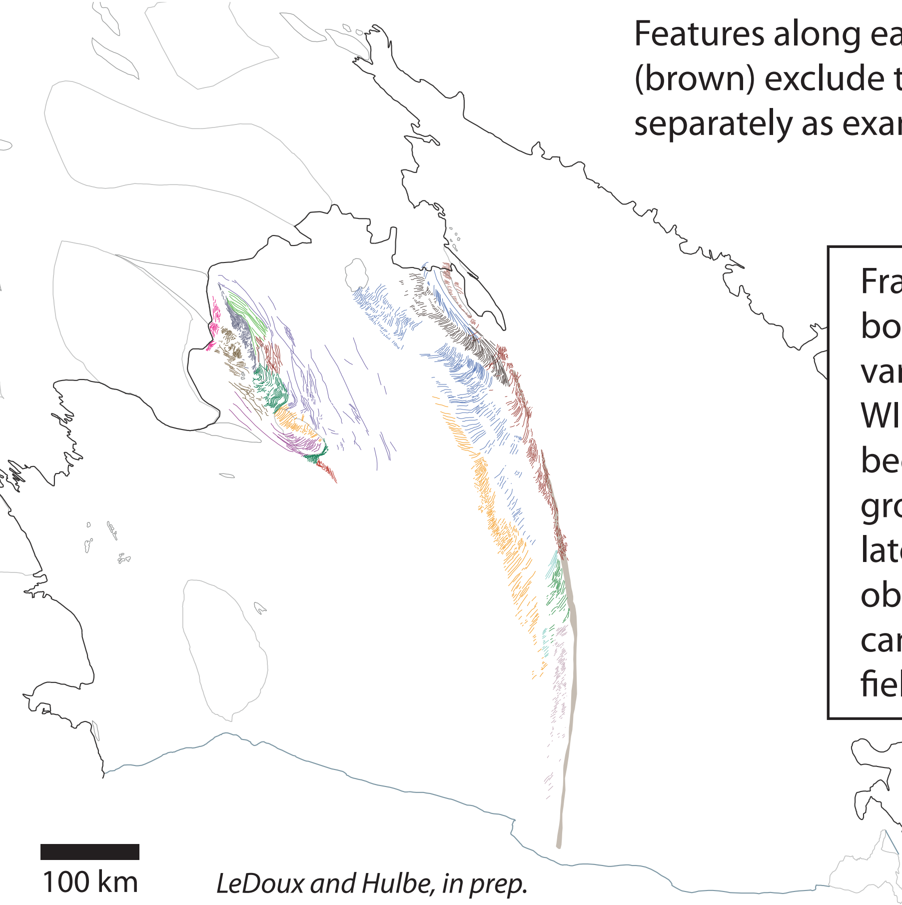


LeDoux and Hulbe, in prep.

Digitized from the MOA (Haran and others, 2005) and LIMA (Bindschadler and others, 2008). Also used bed topography and thickness from BEDMAP (Lythe and others, 2000) and 1-km resolution surface elevation (Bamber and others, 2009).

diagenetic geometries (similar origin)

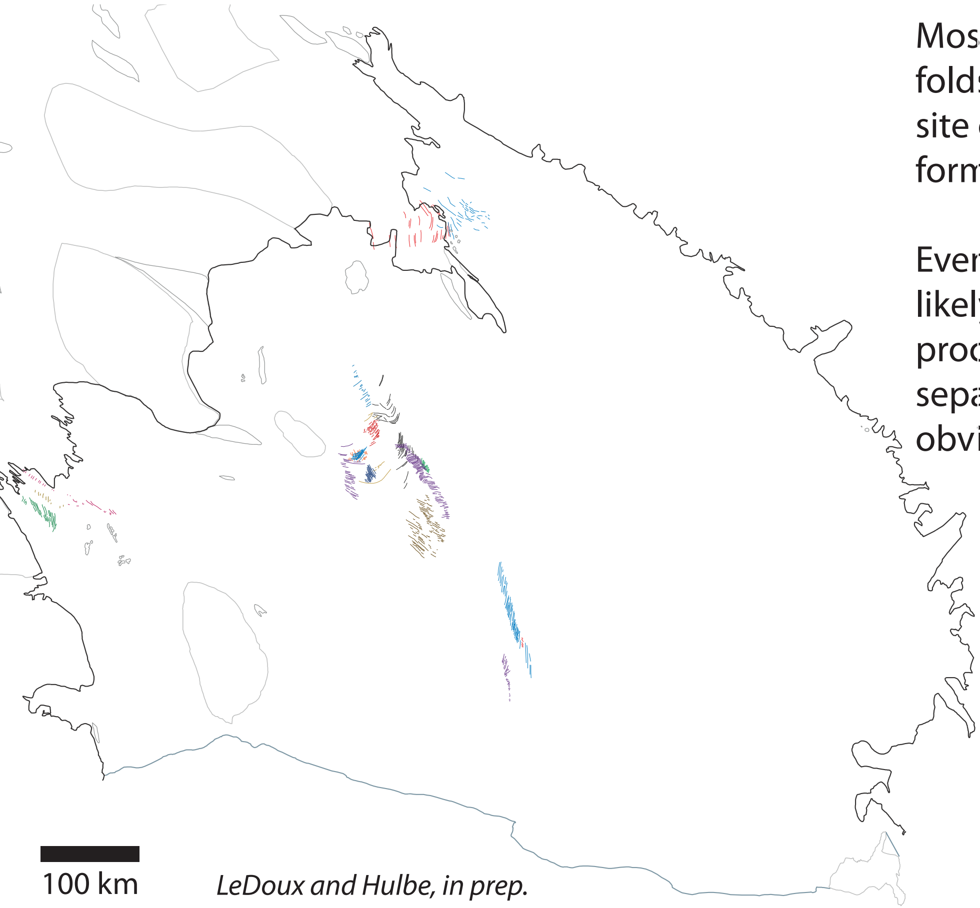
Features along eastern Crary suture zone (brown) exclude those categorized separately as examples of simple geometries.



Fracture geometries from both recent discharge variation events (Kamb, WIS-MIS) support ice becoming increasingly grounded from "inside" of a lateral corner flow obstruction. Propagation can show changes in stress field of advective path.

LeDoux and Hulbe, in prep.

fracture sets lacking obvious explanation



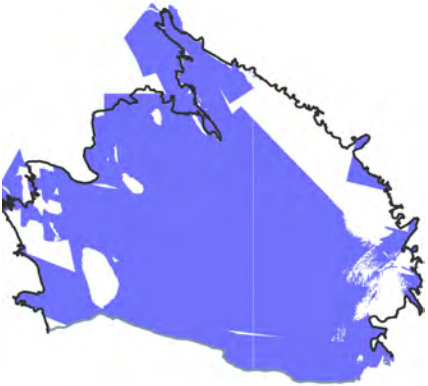
Most fractures and rifts (or folds) can be tracked to a site or physical process of formation.

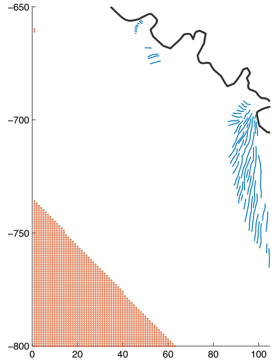
Even many of these have a likely source or physical process, but categorize separately because not obvious.

derived velocity using statistical methods

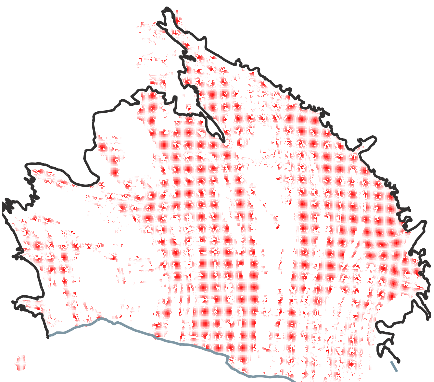
showing midshelf interpolation

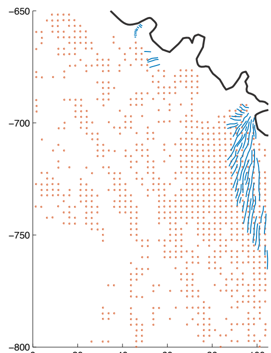
Spatial coverage of input datasets, showing grid locations





Surface velocities from InSAR (Ian Joughin, personal communication, 2011) with midshelf natural neighbor interpolations

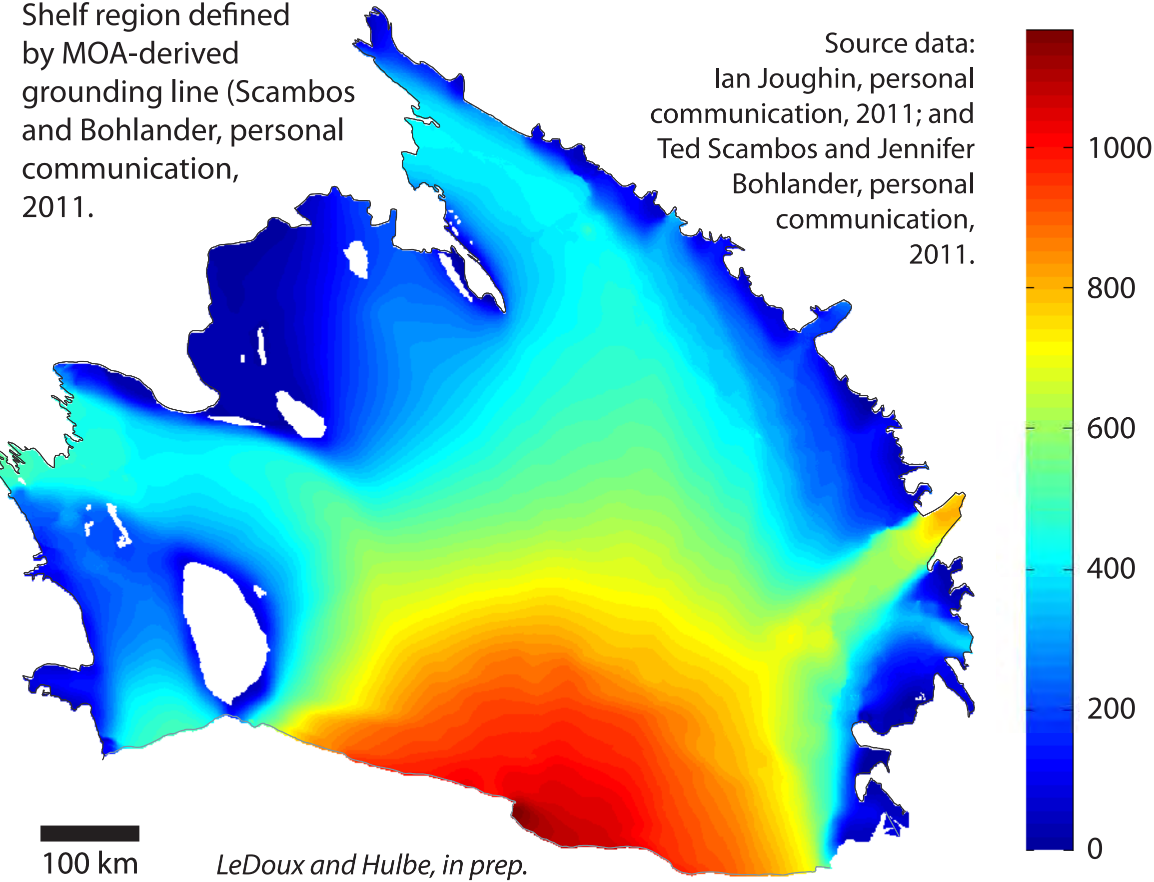




Survace velocities derived using image cross-correlation (Scambos, 1992) between the 2004 and 2009 versions of the MODIS MOA on a 125-m scattered grid (Ted Scambos and Jennifer Bohlander, personal communication, 2011).

LeDoux and Hulbe, in prep.

derived velocity map using statistical methods



Shelf region defined by MOA-derived grounding line (Scambos and Bohlander, personal communication, 2011.

Source data: Ian Joughin, personal communication, 2011; and Ted Scambos and Jennifer Bohlander, personal communication, 2011.

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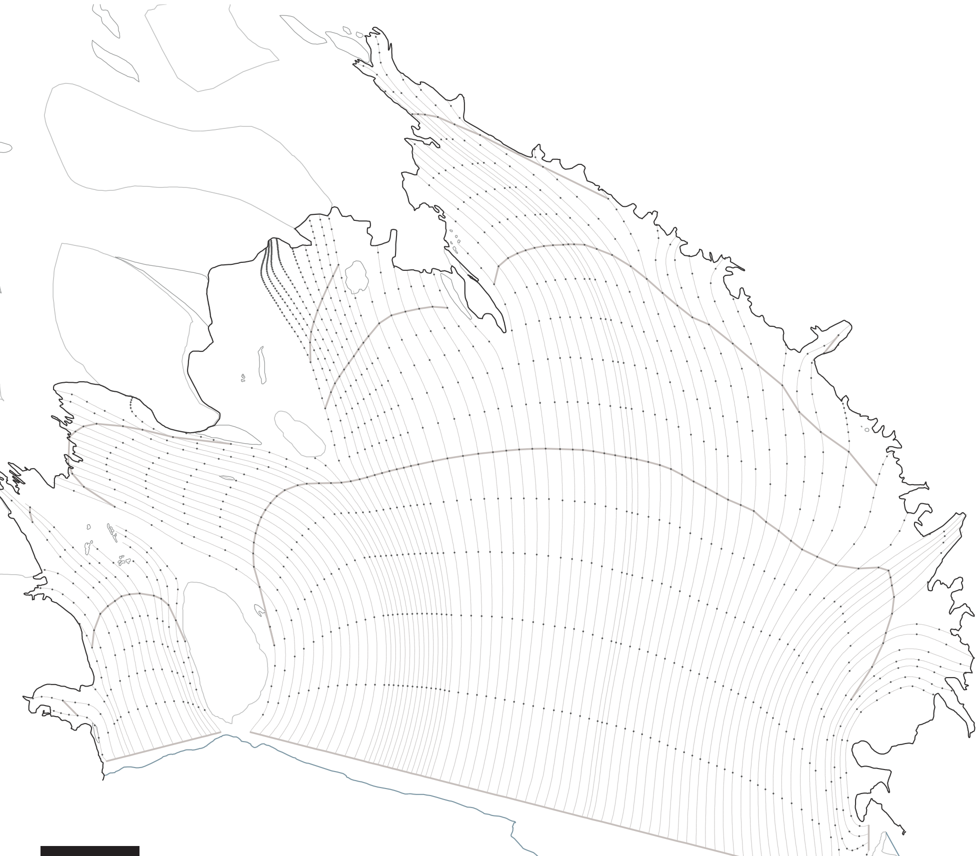
updated flow line map



Previous:
Fahnestock and others (2000) using RIGGS velocities

Starting points at c. 10-km intervals (higher density at transitions)

Dots represent 100-year intervals, gray lines 500-year.

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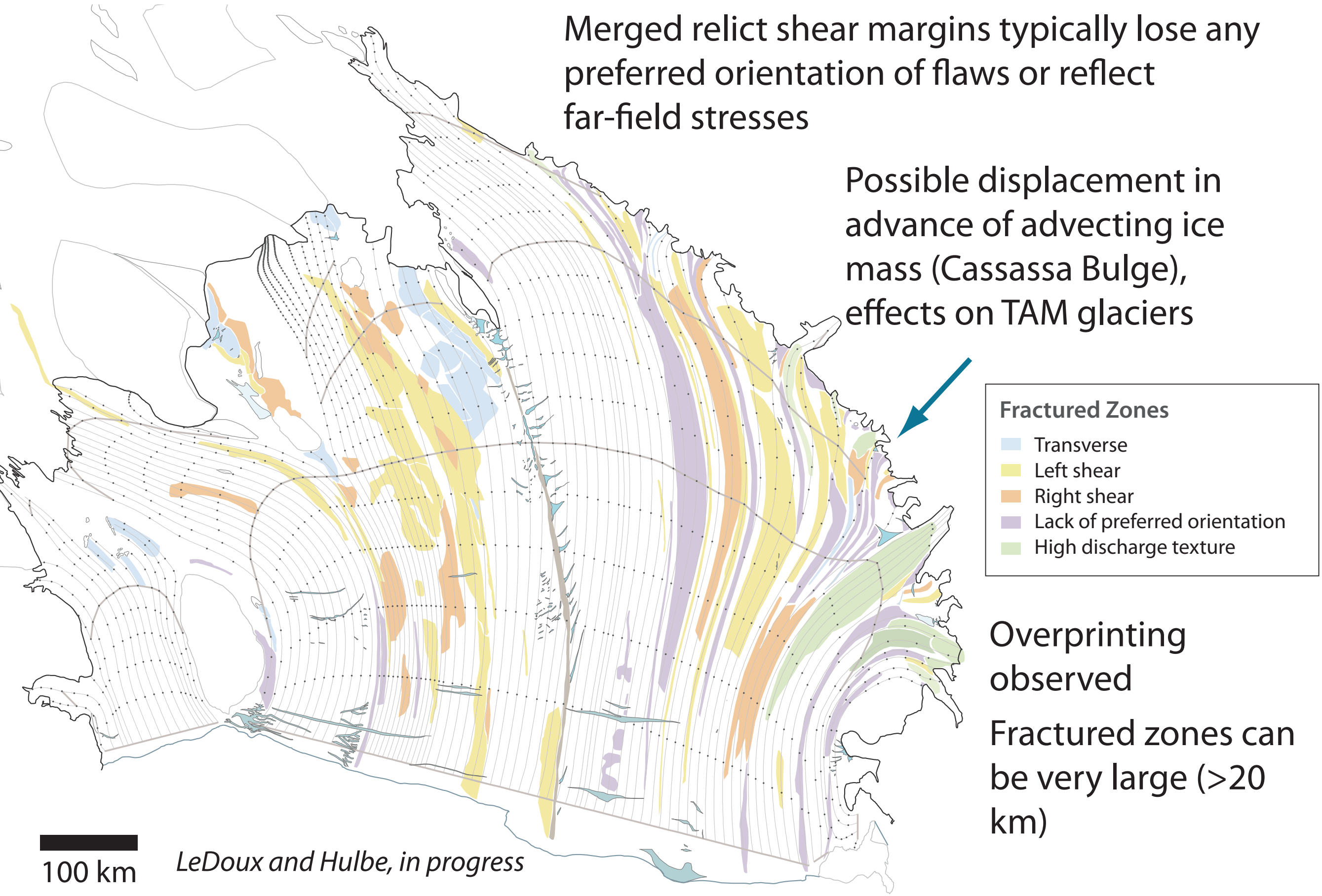
fractured zones

Merged relict shear margins typically lose any preferred orientation of flaws or reflect far-field stresses

Possible displacement in advance of advecting ice mass (Cassassa Bulge), effects on TAM glaciers



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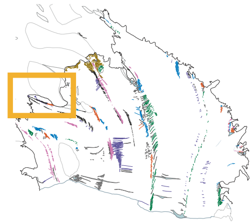
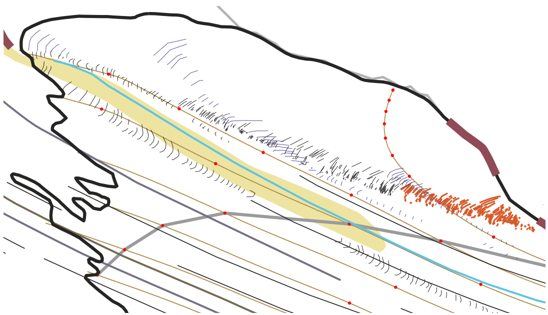
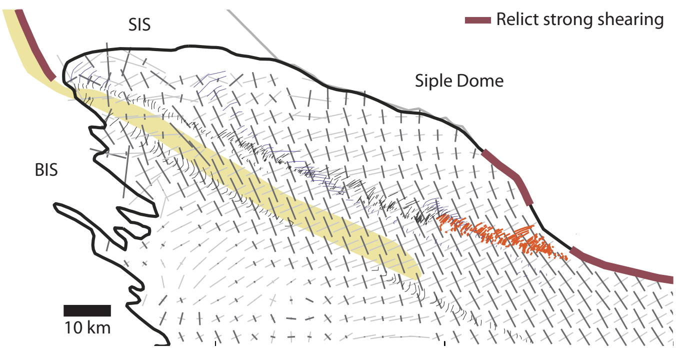
Overprinting observed

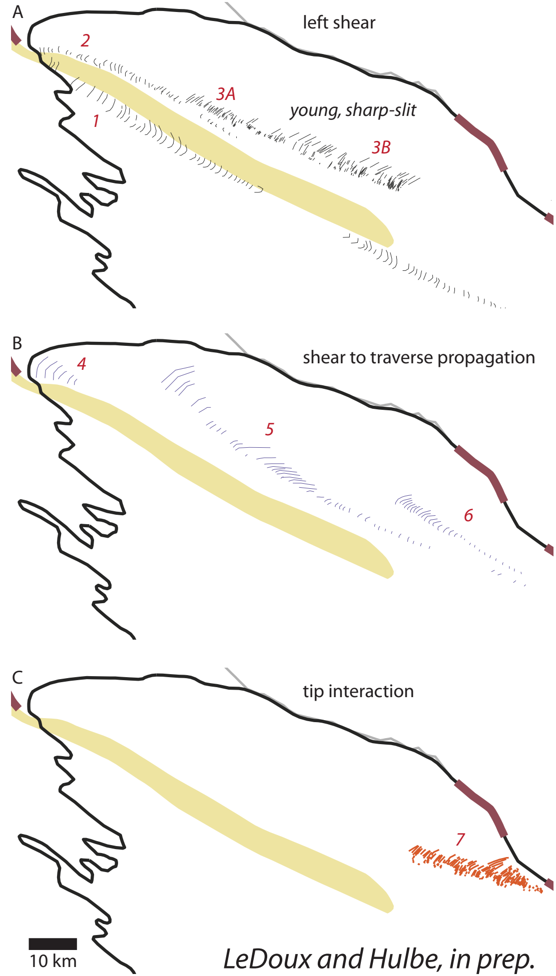
Fractured zones can be very large (>20 km)

siple dome coast



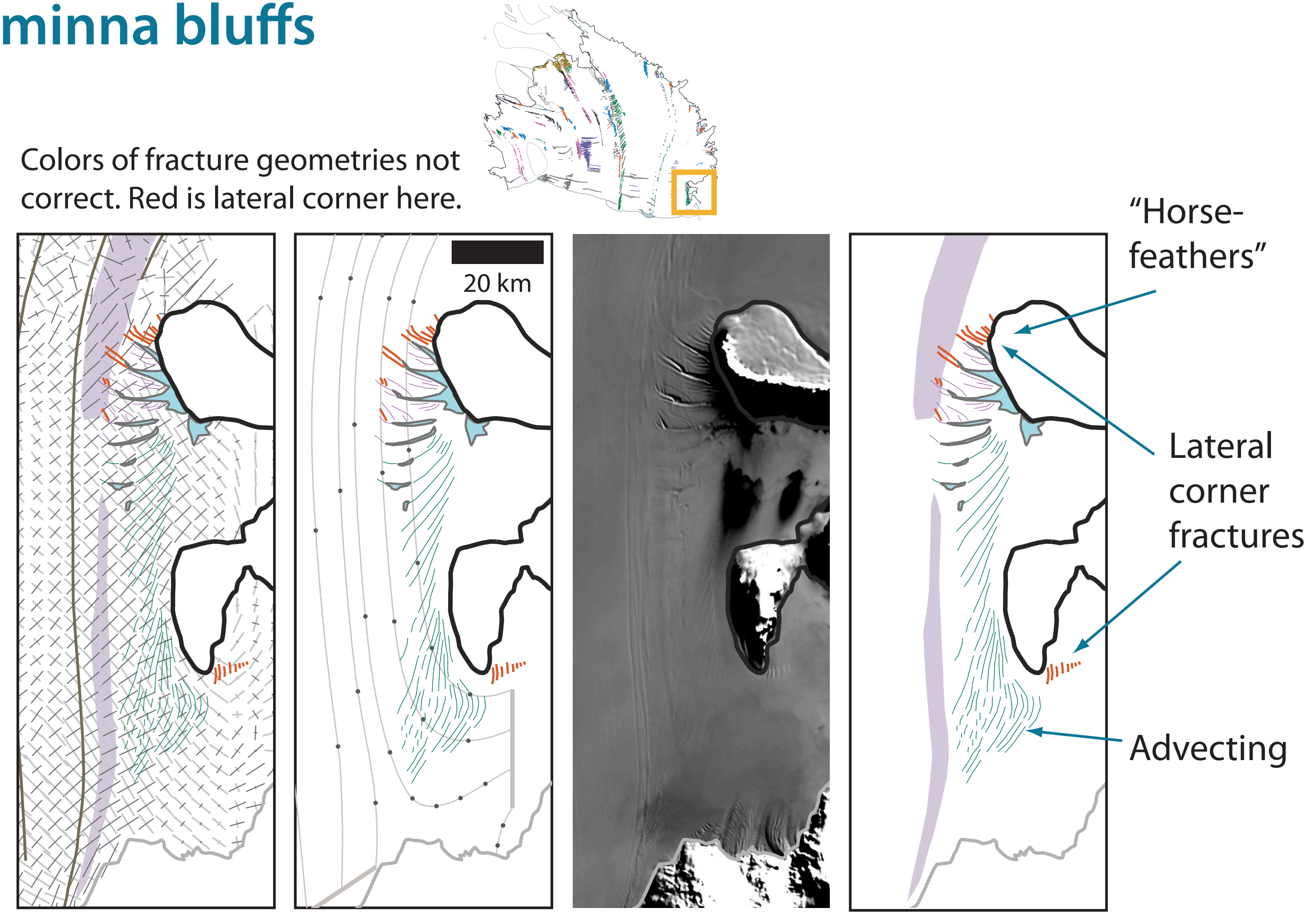






minna bluffs

Colors of fracture geometries not correct. Red is lateral corner here.



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fracture model

Displacement discontinuity boundary element method (Crouch and Starfield, 1983)

Linear elastic fracture mechanics, mixed mode I/II propagation, plane strain assumption

Ice thickness from BEDMAP (Lythe and others, 2000) to compute glaciological stresses using velocity dataset

For model description, see Hulbe et al. (2010):

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Propagation of long fractures in the Ronne Ice Shelf, Antarctica, investigated using a numerical model of fracture propagation

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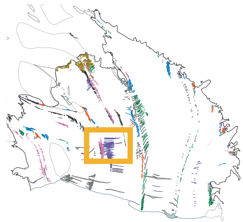
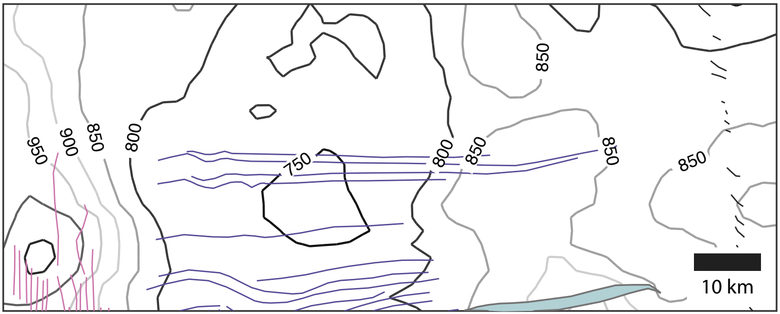
ABSTRACT. Long rifts near the front of the Ronne Ice Shelf, Antarctica, are observed to begin as fractures along the lateral boundaries of outlet streams feeding the shelf. These flaws eventually become the planes along which tabular icebergs calve. The fractures propagate laterally as they advect through the shelf, with orientations that can be explained by the glaciological stress field. Fracture length remains

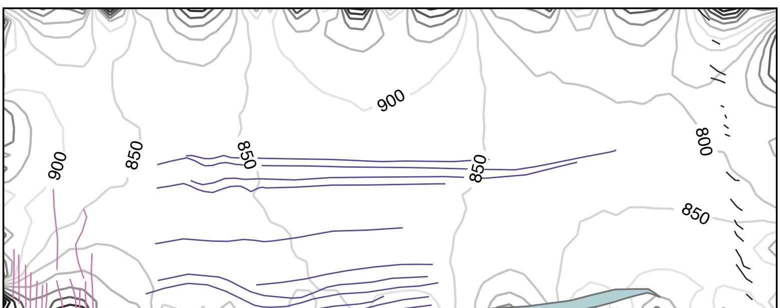
parameter tuning

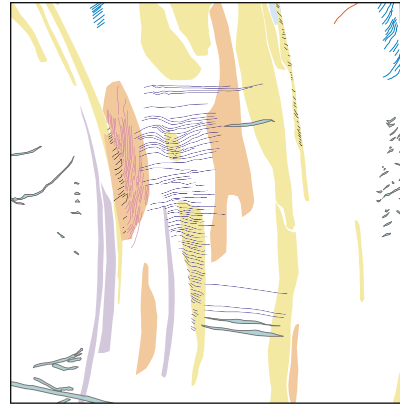


"Observed" mean (glaciological) stresses, kPa



Simulated stress field without fractures

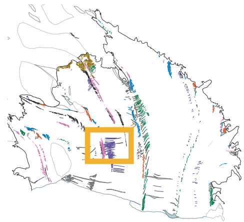




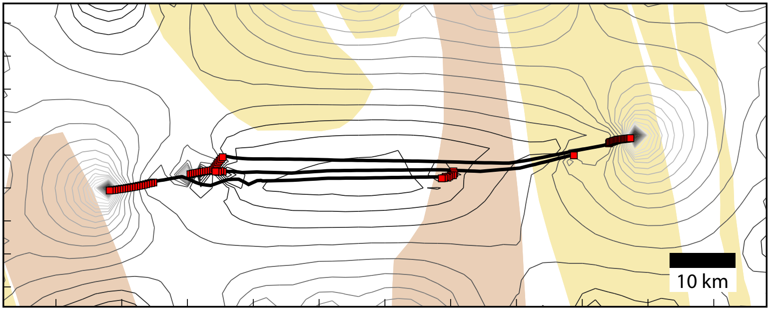
Best-fit parameters:
Modulus of elasticity = 9000 MPa
Poisson's ratio: 0.30
Tuning parameter for principal stresses: 0.65
KIC = 0.3 MPa $m^{1/2}$
RMSE for mean stress = 99 kPa
RMSE for shear stress = 105 kPa

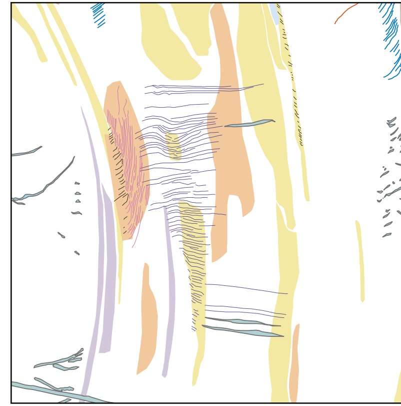
LeDoux and Hulbe, in prep.

preliminary results

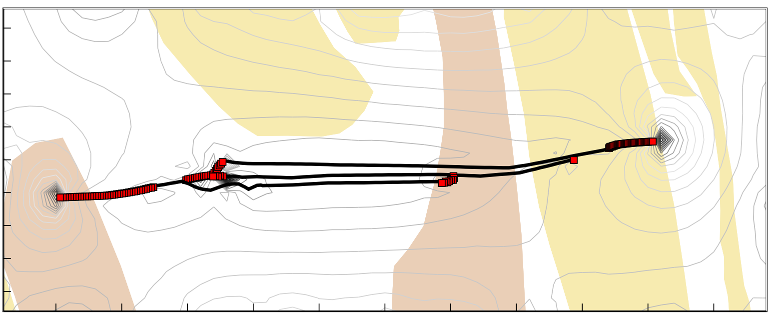


iterative growth, it 20
(glaciological) stresses





iterative growth, it 40



Shortened two upstream fractures at "left" tip

First successful application of fracture model to Ross ice shelf.

$K_{IC} = 0.3$ MPa $m^{1/2}$

Propagates as "single" fracture

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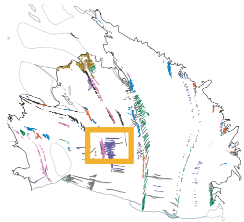
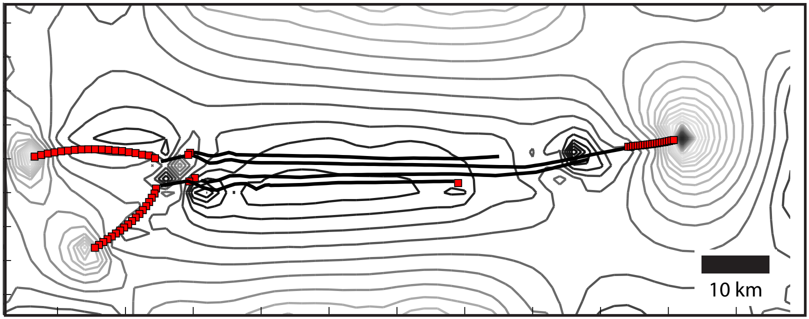
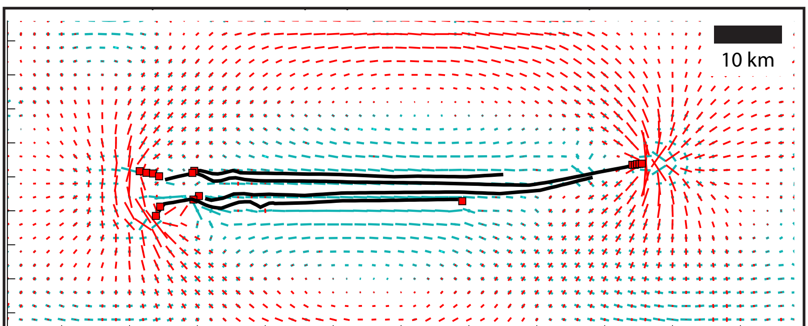
preliminary results

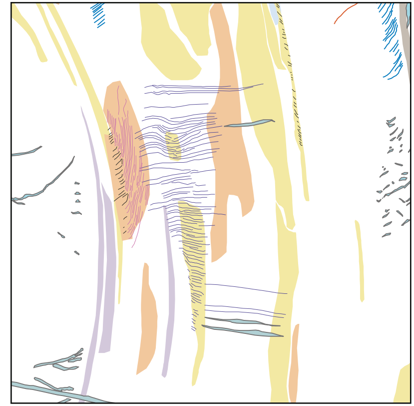


Propagation of current full geometry, iteration 20



Principal stresses it. 5 (red: extensive, blue: compressive)





“Right” tip of most downstream fracture not allowed to grow.

Actual stress field modification would be affected by nearby fractures and fractured zones.

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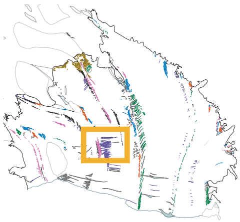
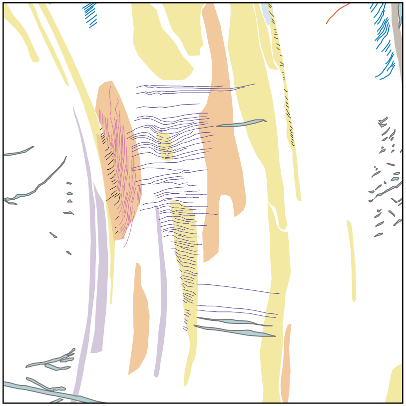
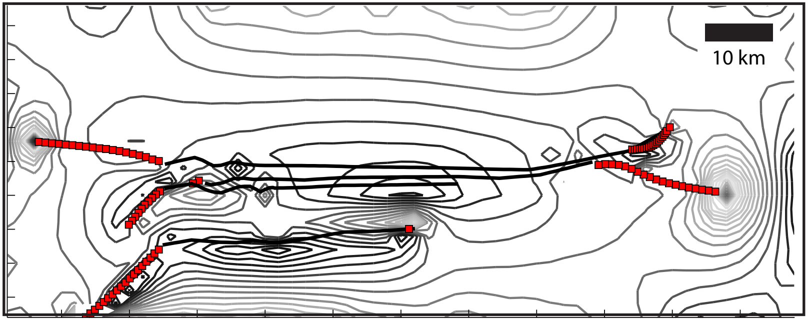
preliminary results





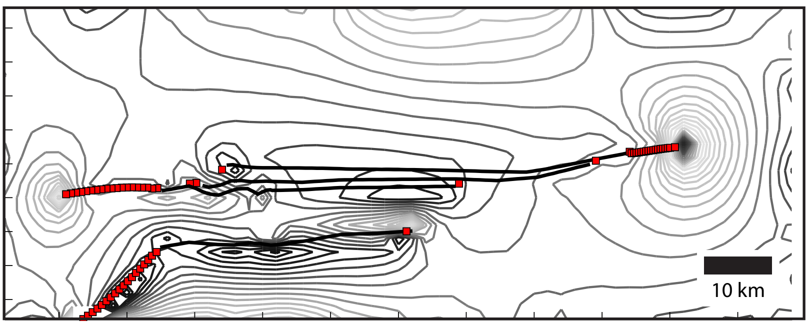


Both are iteration 20

Simulated glaciological stresses

Fractures respond to shear (from BIS) and compressive stress field (from convergence of BIS and WIS)

shortened left tip of upstream fracture



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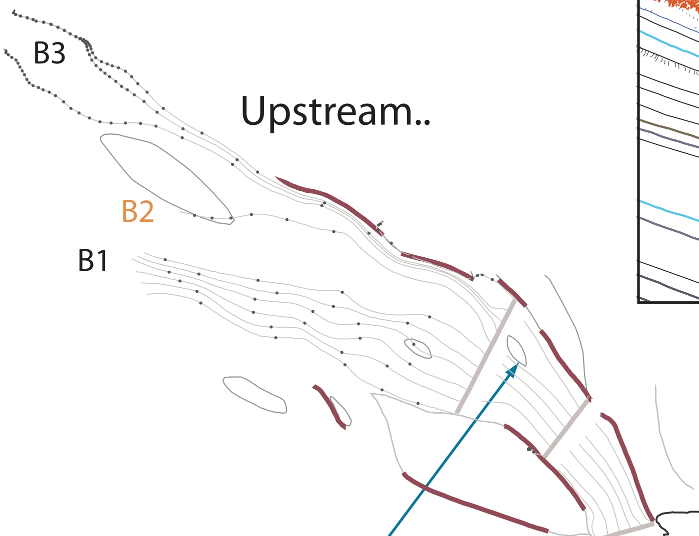
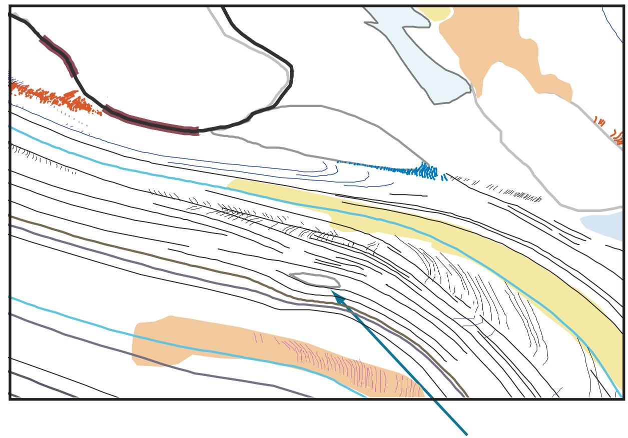
investigation of sticky spots..

Bindschadler ice stream



Downstream..



Present-day sticky spot at bedrock constriction and convergence of tributaries. Past changes observed in surface features (not shown here, see upcoming).

Ice stream flow lines created from InSAR velocities (Ian Joughin, personal communication) at tracers within ice stream (dot interval 500 years).

LeDoux and Hulbe, in prep.

acknowledgements

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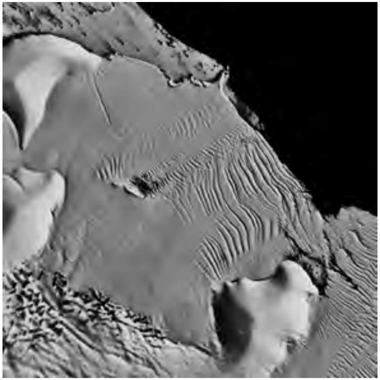
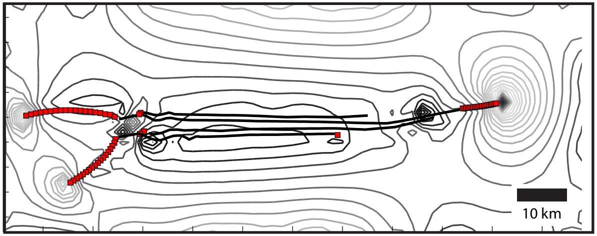
Funding from NASA Cryosphere and NSF-OPP.

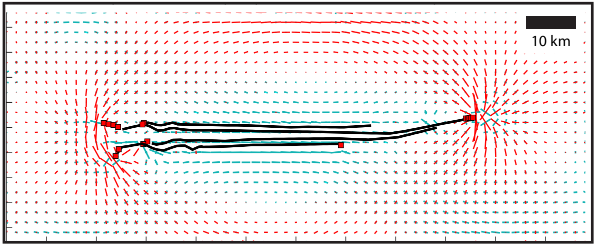
Data will be made available on NSIDC.

Interpretations at AGU poster, and paper in progress.



Example from MOA





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