Constrained Ice Stream Flow in Northeast Greenland

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Constrained Ice Stream Flow in Northeast Greenland

OUTLINE

- Typical ice stream dynamics
- NEGIS and uniqueness
- 2012 NEGIS field survey
  - Active-source seismic
  - Ice-penetrating radar
- Stability concerns
- Future inquiry?
Ice Stream Dynamics
Why does ice flow fast?

Topographic focusing:

Reduced basal friction:
- deformable sediments
- smoother bed
- subglacial water

High geothermal flux:

Ocean forcing:

(Winsborrow et al., 2010)
NEGIS vs. Antarctica

NEGIS is Greenland’s only interior-reaching ice stream
- 700km from start near divide to Greenland Sea
- Drains ~20% of Greenland Ice Sheet
NEGIS vs. other ice streams

Pine Island Glacier, Antarctica
- Deep basal trough to constrain flow

Northeast Greenland Ice Stream
- Lack of topographic focusing
- Fast flow over highlands
Origin of Fast flow - basal melt

(Fahnestock et al., 2001)

(Joughin et al., 2001)
Origin of Fast flow - geothermal flux

- Basal melt likely due to high geothermal flux
- Thin lithosphere may contribute

Radar data remapped as isochrons using age-depth relationship

(Fahnestock et al., 2001)

(Petrunin et al., 2013)
NEGIS 2012 Field Survey
Integrating Radar and Seismics
Active-source Seismics: Amplitude vs. Offset

- Amplitude of reflected P-wave depends on angle of incidence
- Moveout experiment - Analogous to CMP survey
Active-source Seismics: Amplitude vs. Offset

Seismic Reflectivities
- Modeled
- Calculated
  - Water
  - Dilatant Till Range
  - Stiff/Dewatered Sediment Range
  - Consolidated Sediment Range
  - Lithified Sediment to Crystalline Basement Range

Basal Reflectivity
- 0.8
- 0.6
- 0.4
- 0.2
- 0
- -0.2
- -0.4
- -0.6
- -0.8

Angle of Incidence (degrees)
- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90

Ice Speed (m/a)
- Radar lines
- Shear margins
- AVO sites
- Velocity contours (m/a)
Radio Echo Sounding
Flow into page
Radio Echo Sounding: Stratigraphy

Layers traced from NGRIP and airborne radar surveys
Surface Topography
Subglacial Topography

Bed Elevation (m)

Bed elevation contours (m)
Surface ice speed contours (m/a)
Particle flowpaths

6KHDUïPDUJLQV
AVO sites

NP NP

0 km
5 km
Radio Echo Sounding: Basal reflectivity

Basal Reflectivity (dB)

- Basal reflectivity (dB)
- Surface ice speed contours (m/a)
- Radar profiles
- Particle flowpaths
- Shear margins
- Shear margin profile
- Constant attenuation profiles
- AVO sites

Ice Flow Direction

0 km 5 km

A

B

C

D

E

Ice Flow Direction

75°30'N

75°40'N

35°30'W

35°30'W
Subglacial Hydrologic Potential

Flow direction

Hydropotential

Relative Basal Reflectivity
Putting it all together

Geothermal flux

Initial fast flow

Ice stretches and thins

Steep hydropotential gradient at margins

Water routed to hydropotential troughs

Dry marginal bed

Friction limits ingress of surrounding ice

Stable boundary

Wet central bed sediments

Fast flow
Future Stability

- Broad seismic array for receiver function analysis
- Detailed map of surrounding subglacial environments

Future Inquiry

- Surface melt → drainage
- Could NEGIS jump its hydropotential barriers?
Conclusions

Mechanics of NEGIS are unique:
- no confining trough
- geothermal flux
- underlain by sediment

Integrated radar and seismic survey:
- both indicate saturated till under streaming flow
- stiff, dewatered margins
- some spatial inconsistencies

Proposed feedback mechanism to constrain flow
- but NEGIS could potentially tap a larger area
- future studies could expand understanding of regional system - and past behavior
NEGIS vs. other ice streams

Pine Island Glacier, Antarctica
- Over-deepened outlet

NEGIS Outlet
- Three over-deepened outlet glaciers
- Subject to marine-ice-sheet-instability and oceanic forcing
Subglacial Hydrological Potential