# Summer acceleration in west Greenland: Review and recent insights

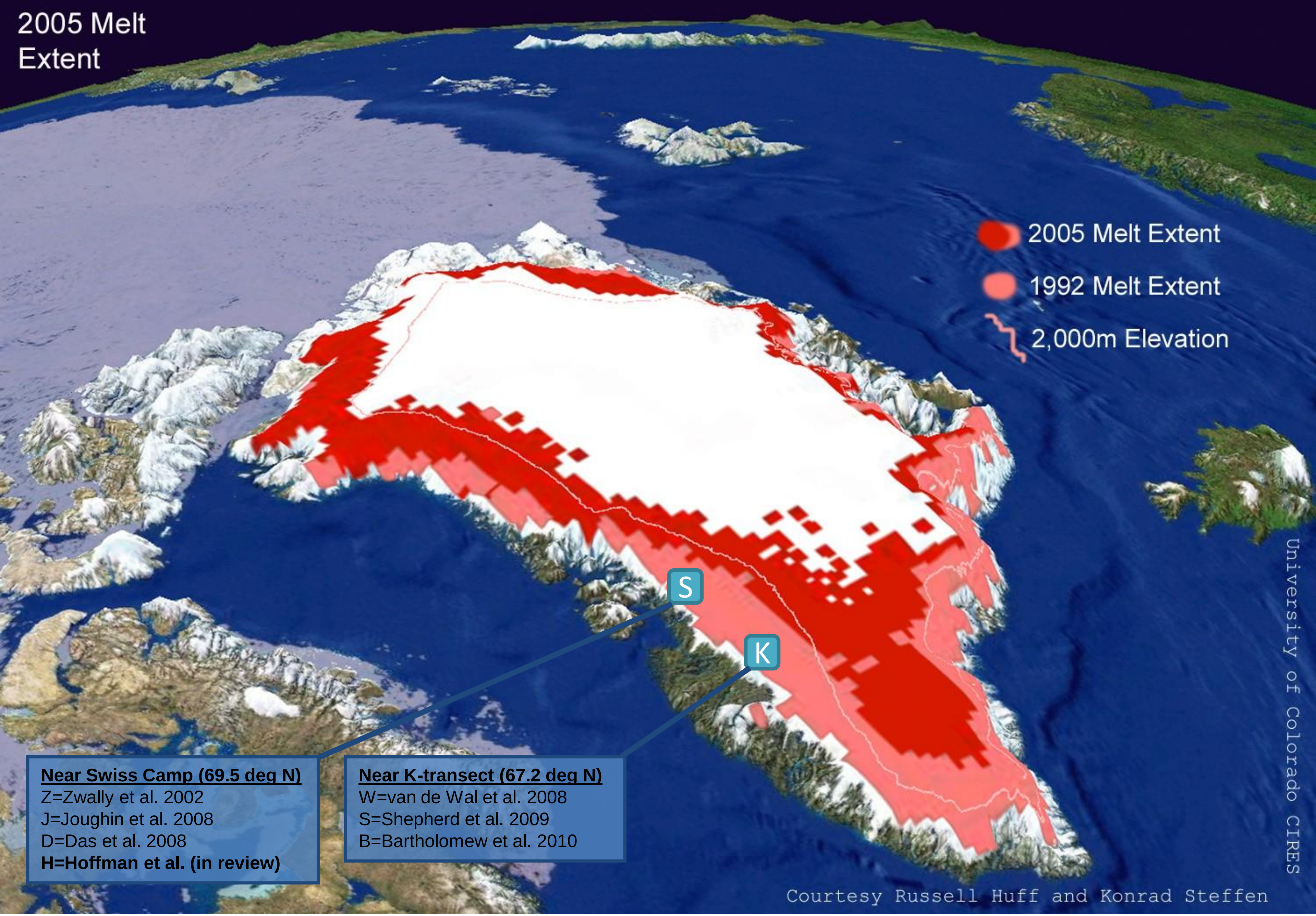
Matt Hoffman
University of Maryland, Baltimore County
Cryospheric Sciences Branch
NASA Goddard Spaceflight Center

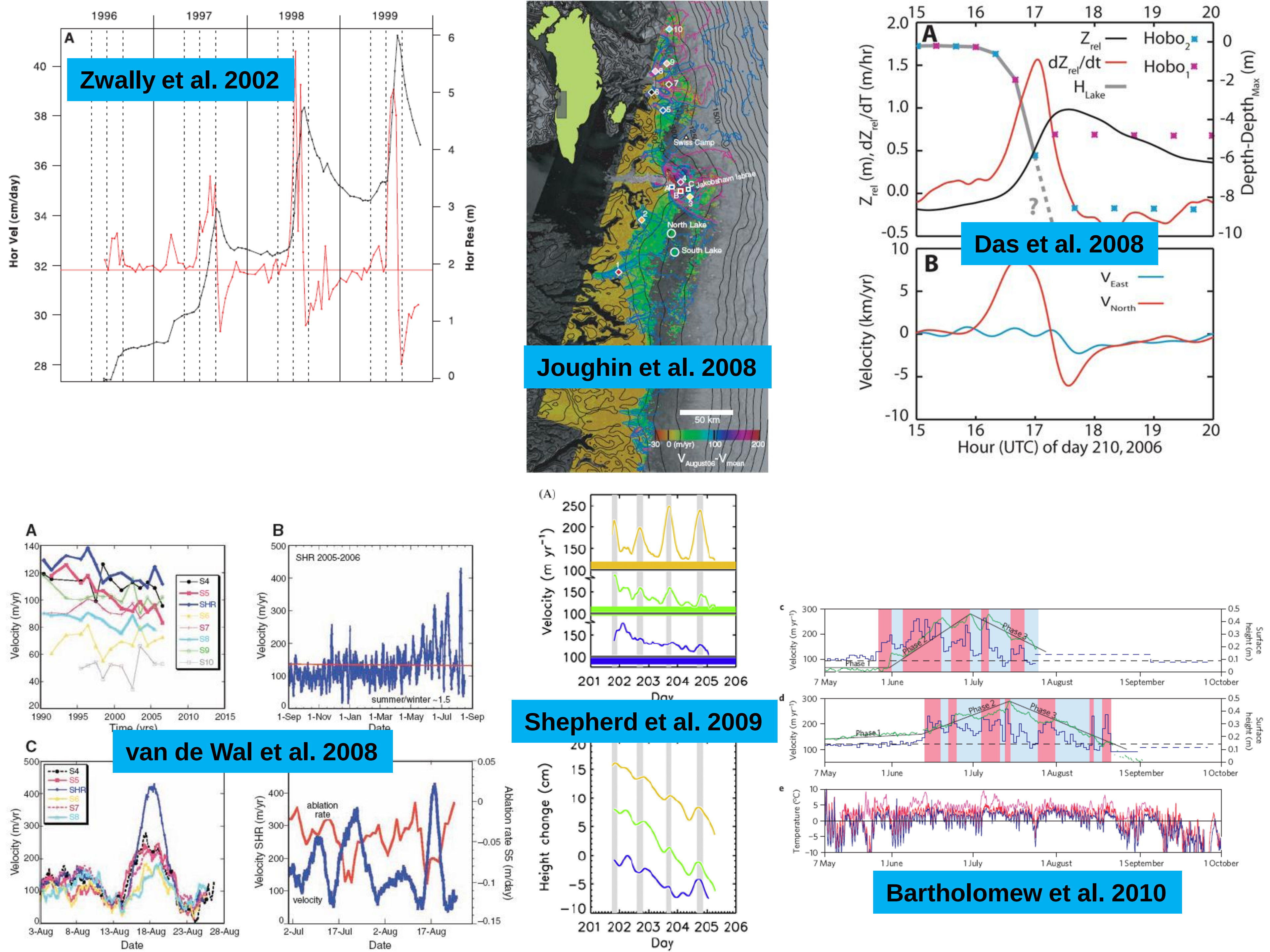
Tom Neumann (NASA Goddard)
Ginny Catania (University of Texas)
Lauren Andrews (University of Texas)

THE UNIVERSITY OF TEXAS AT AUSTIN

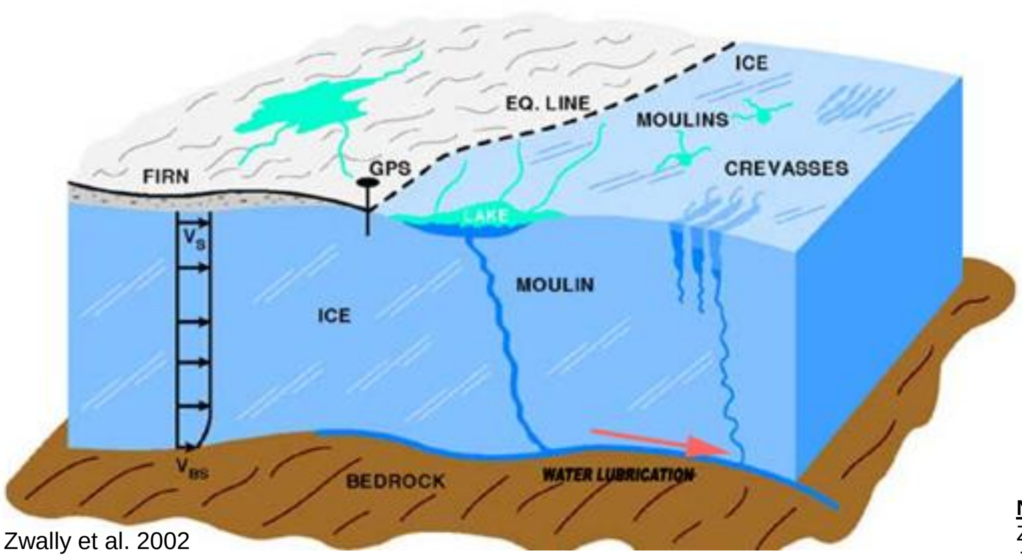
UMBC AN HONORS UNIVERSITY IN MARYLAND

NASA


2005 Melt Extent
2005 Melt Extent
1992 Melt Extent
2,000m Elevation
S
K
Near Swiss Camp (69.5 deg N)
Z=Zwally et al. 2002
J=Joughin et al. 2008
D=Das et al. 2008
H=Hoffman et al. (in review)
Near K-transect (67.2 deg N)
W=van de Wal et al. 2008
S=Shepherd et al. 2009
B=Bartholomew et al. 2010
University of Colorado CIRES
Courtesy Russell Huff and Konrad Steffen


Zwally et al. 2002
Joughin et al. 2008
Das et al. 2008
van de Wal et al. 2008
Shepherd et al. 2009
Bartholomew et al. 2010

In summer, surface melt water drains to the bottom of the Greenland Ice Sheet and lubricates the bed, increasing sliding.




Zwally et al. 2002

Summer velocity is faster than winter by:

- Z: 10-20%
- J: 50-100%
- W: 50%
- S: 50%
- B: 15-40%
- H: 0-40%

(Depends on location, year, and how you define summer.)

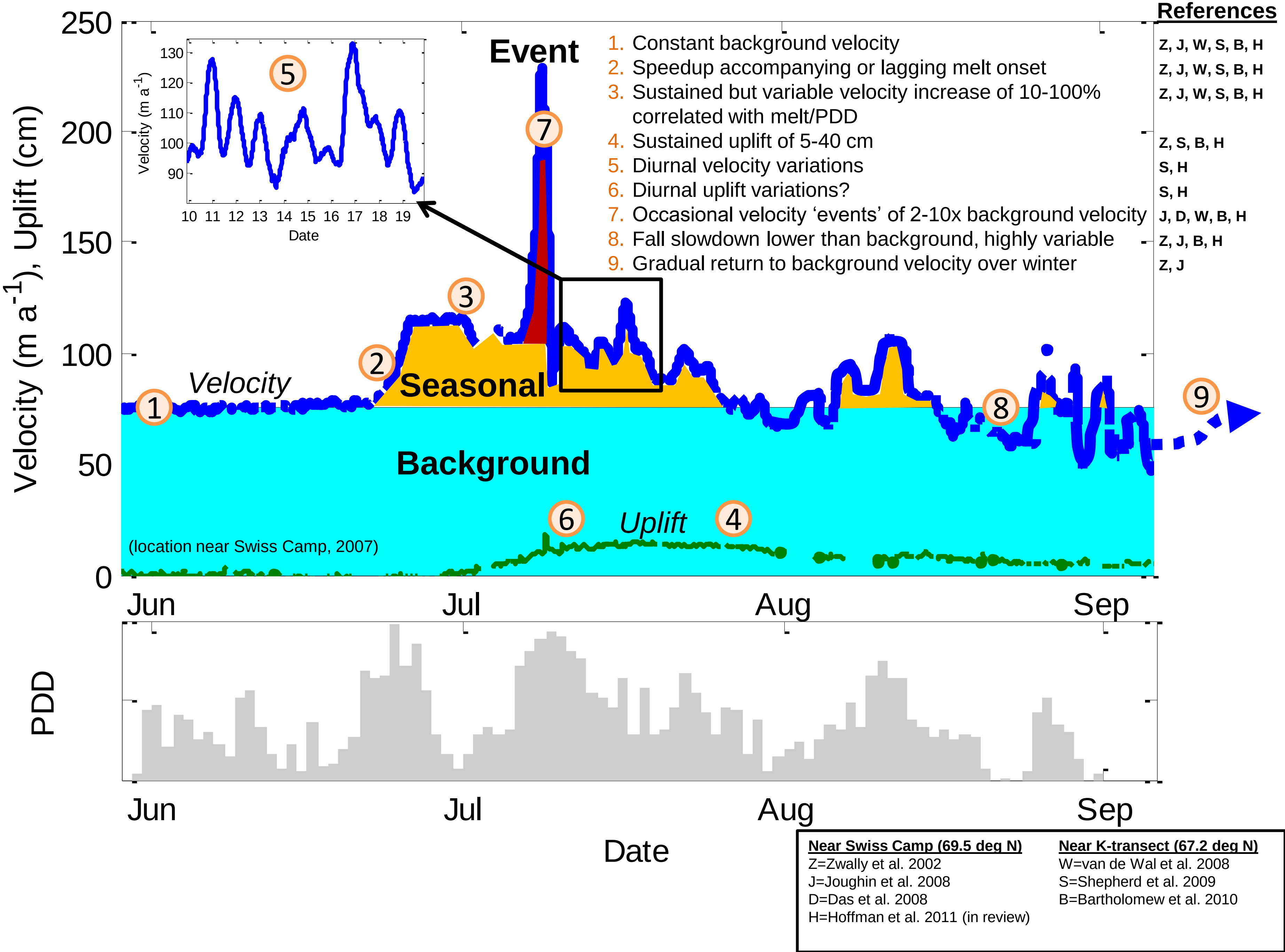
**<u>Near Swiss Camp (69.5 deg N)</u>**
Z=Zwally et al. 2002
J=Joughin et al. 2008
D=Das et al. 2008
H=Hoffman et al. 2011 (in review)

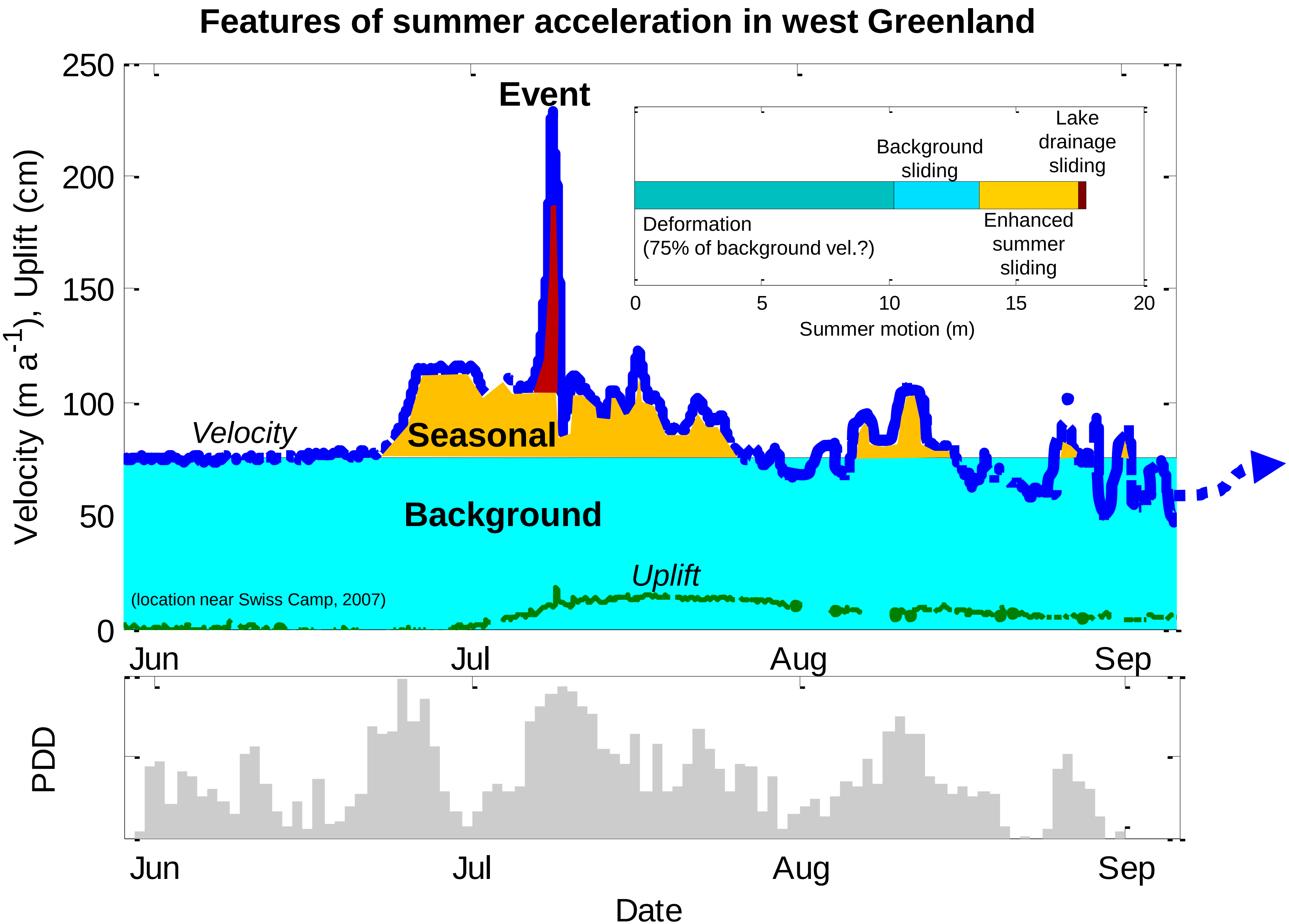
**<u>Near K-transect (67.2 deg N)</u>**
W=van de Wal et al. 2008
S=Shepherd et al. 2009
B=Bartholomew et al. 2010

Questions:

- Q1: How does the ice sheet hydrology differ from that of a temperate glacier?
- Q2: What is relative role of locally generated sliding versus flow coupling?
- Q3: What is role of supraglacial lakes?

# Features of summer acceleration in west Greenland

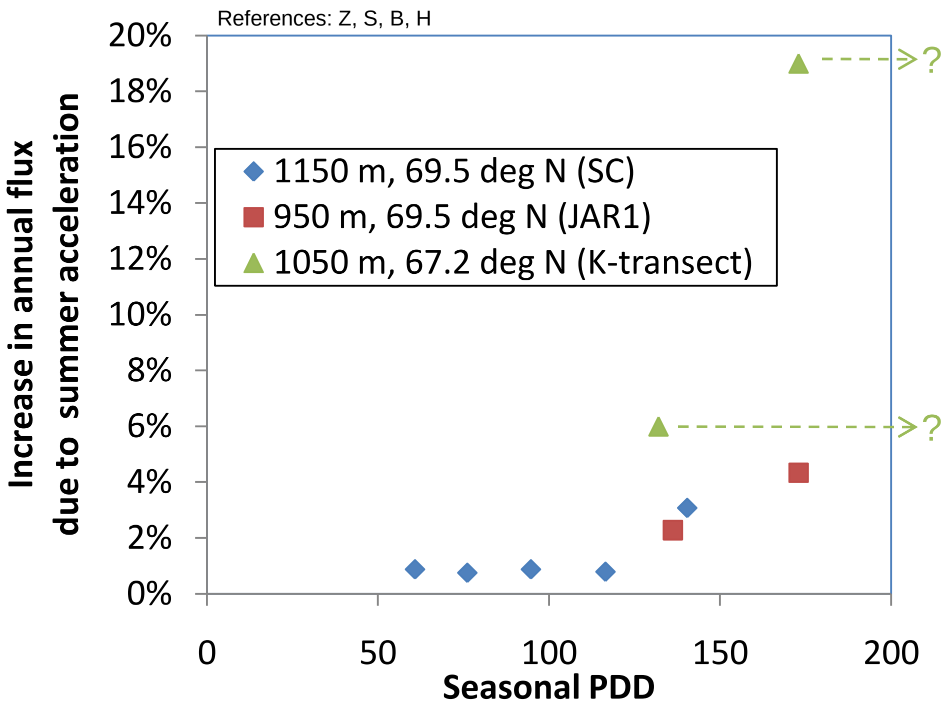


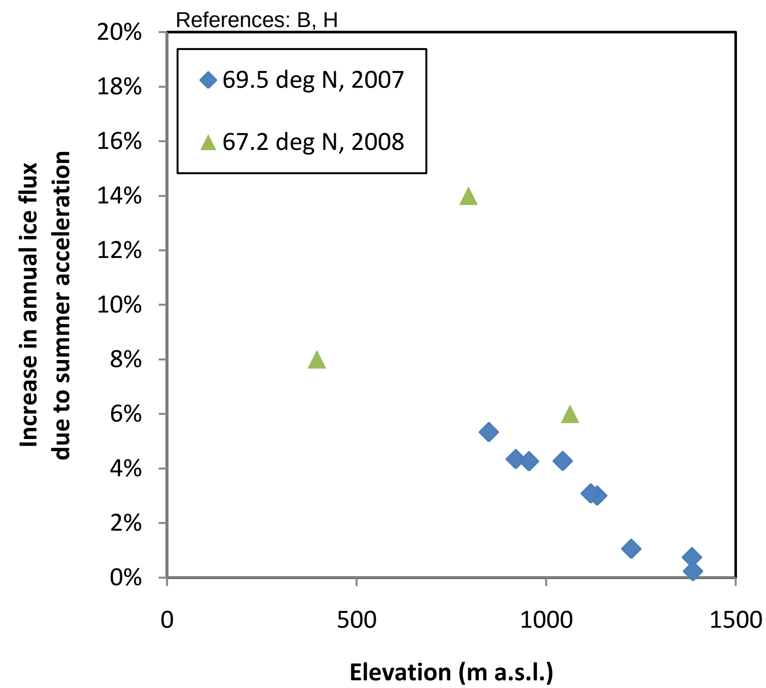


Features of summer acceleration in west Greenland
Event
Velocity
Seasonal
Background
Uplift
(location near Swiss Camp, 2007)
Velocity (m a-1), Uplift (cm)
250
200
150
100
50
0
Jun
Jul
Aug
Sep
Background sliding
Lake drainage sliding
Deformation (75% of background vel.?)
Enhanced summer sliding
0
5
10
15
20
Summer motion (m)
PDD
Jun
Jul
Aug
Sep
Date

# Net seasonal effect

**What is the increase in annual ice flux?**



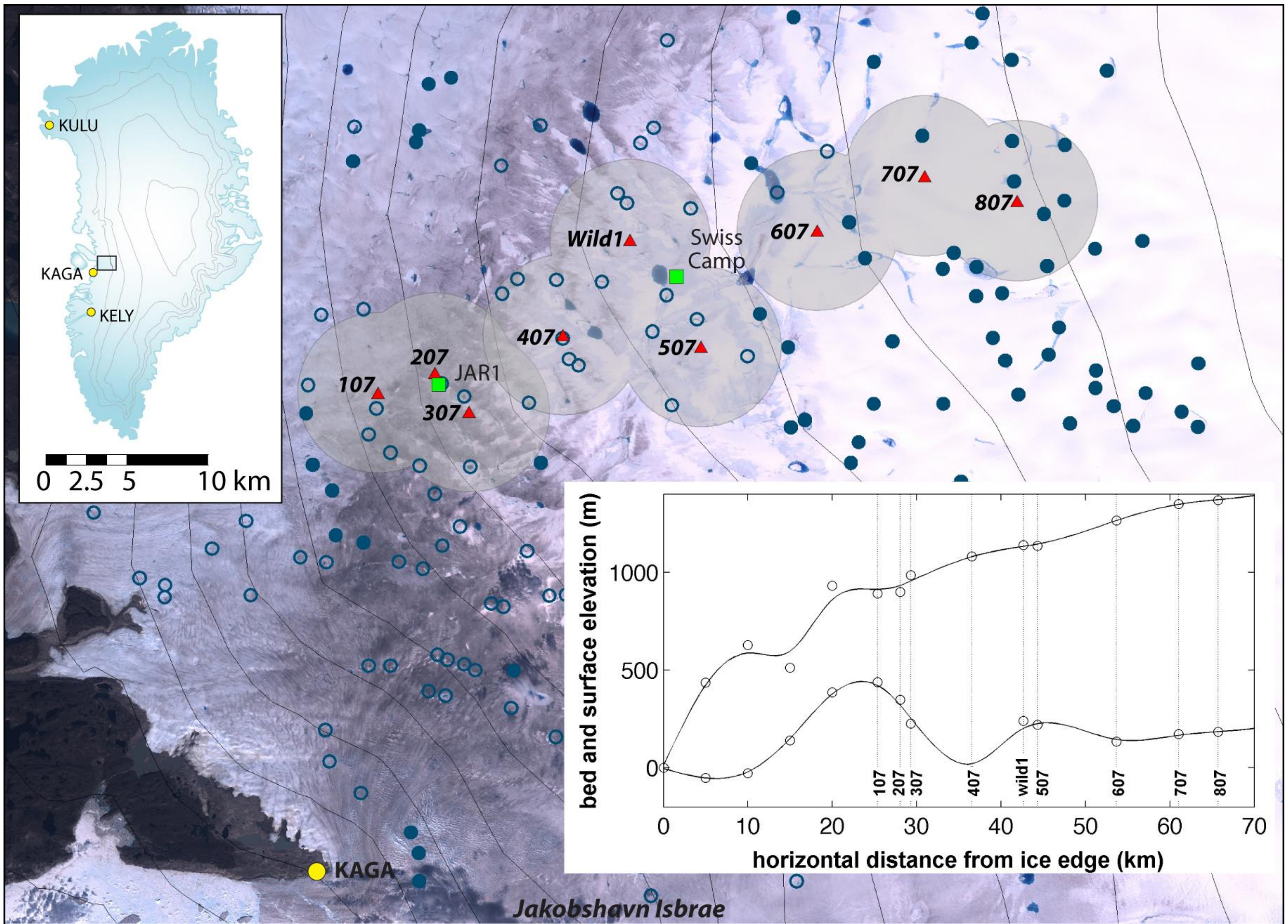
# Summer 2007 GPS Campaign

Tom Neumann, Ginny Catania

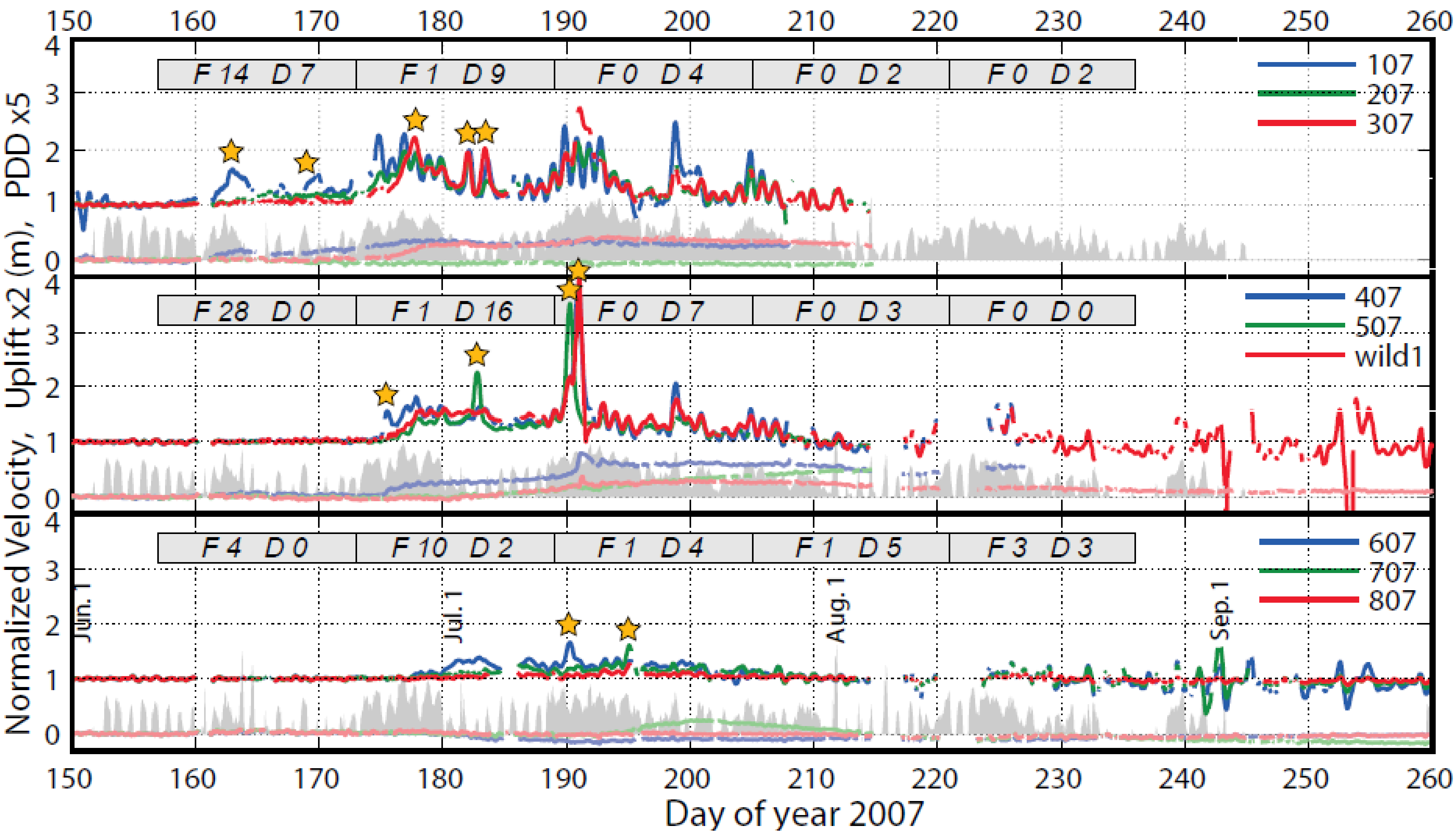
Large spatial coverage: 40 km transect
Moderate spatial resolution: stations spaced 5-10 km

Long temporal coverage: entire summer
High temporal resolution: subdaily positions

Result: Captured most of the features of previous studies in a single dataset

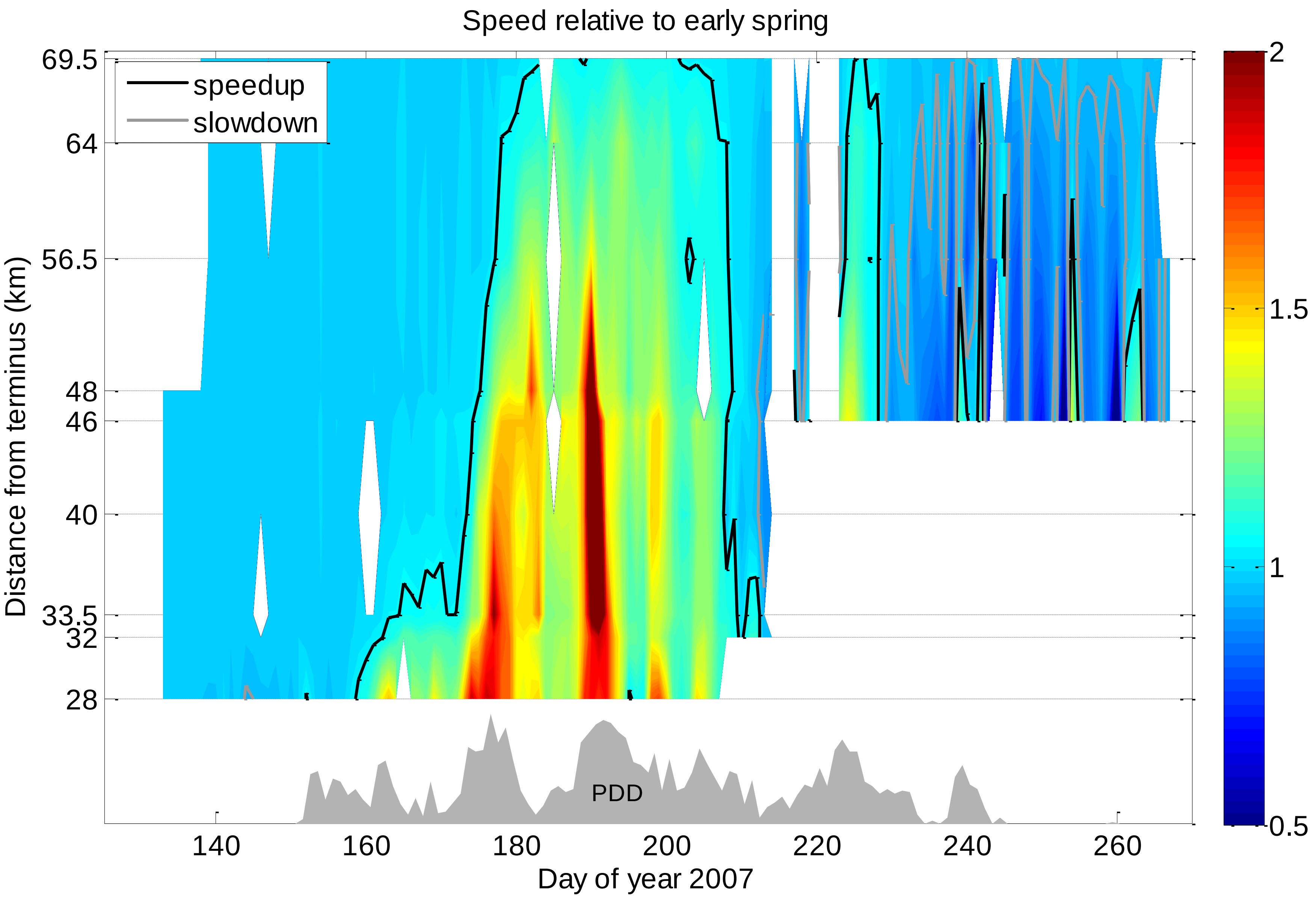


# Summer speed directly related to surface melt.
# Catastrophic lake drainage events (★) are rare and short.



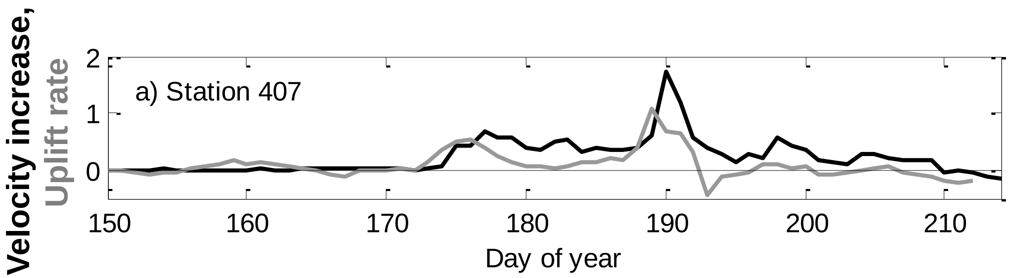
No acceleration occurs:

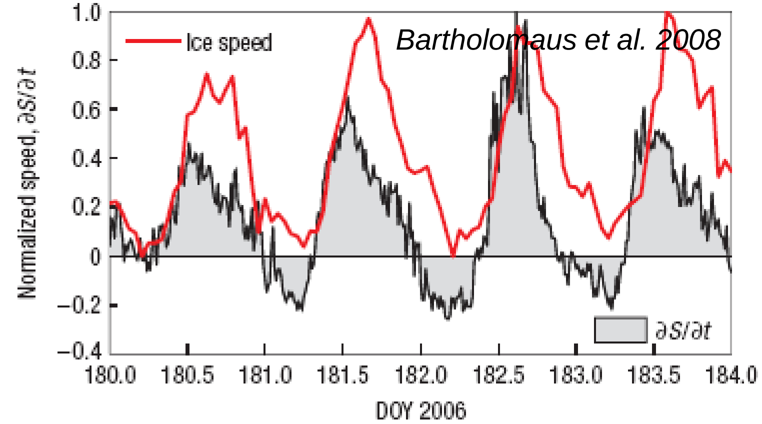
1) Early in the summer before connections to the bed have opened.
2) Near/above the ELA where connections to the bed are absent.



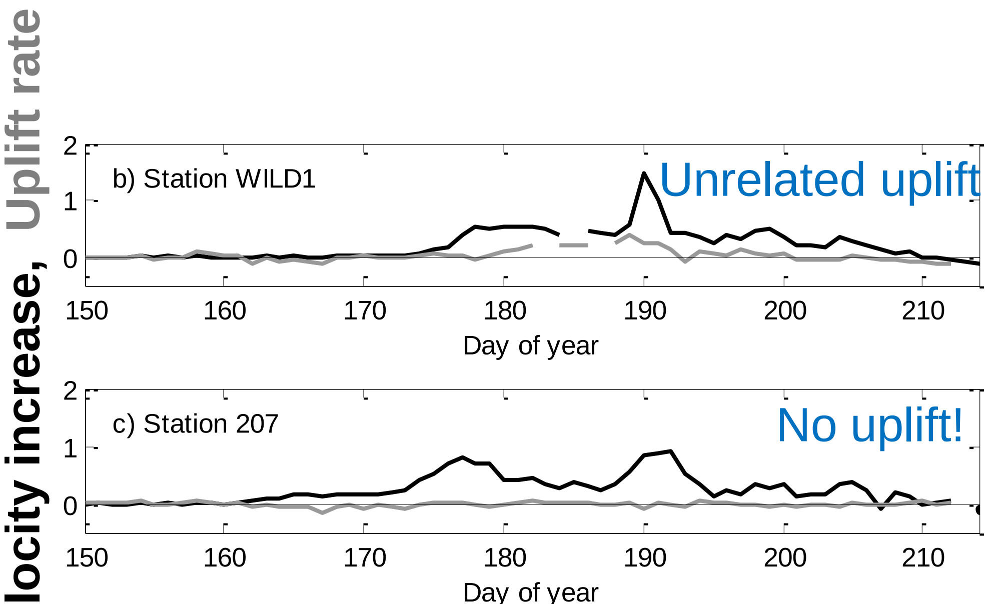
# Q1: Differences from temperate glacier

Evidence that like a temperate glacier, sliding is generated by increases in water storage.

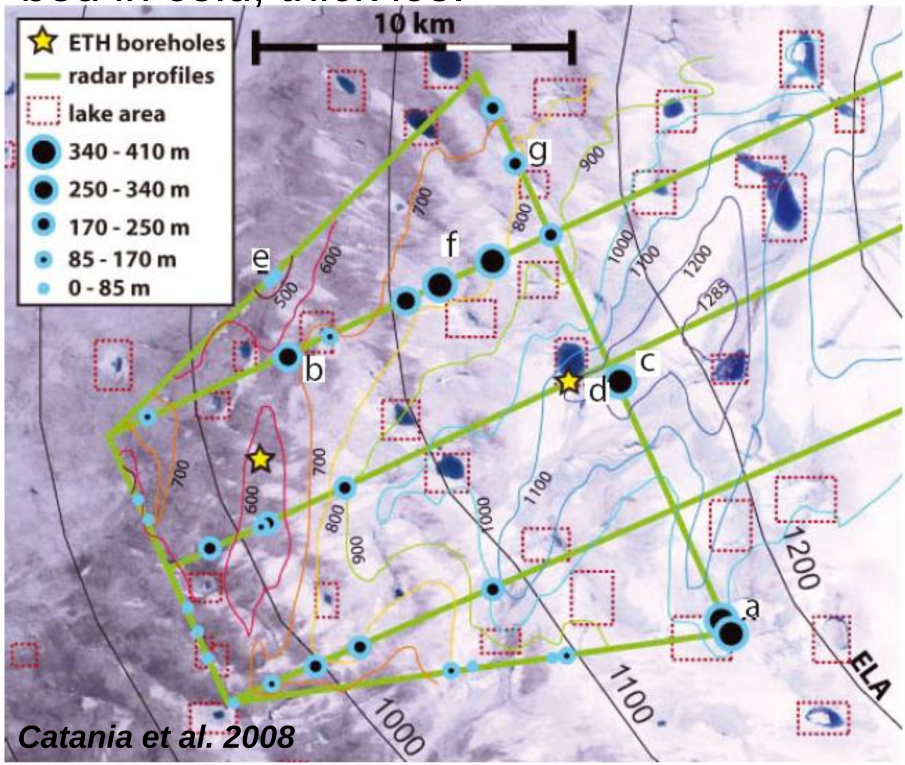



But we see high spatial variability in storage.

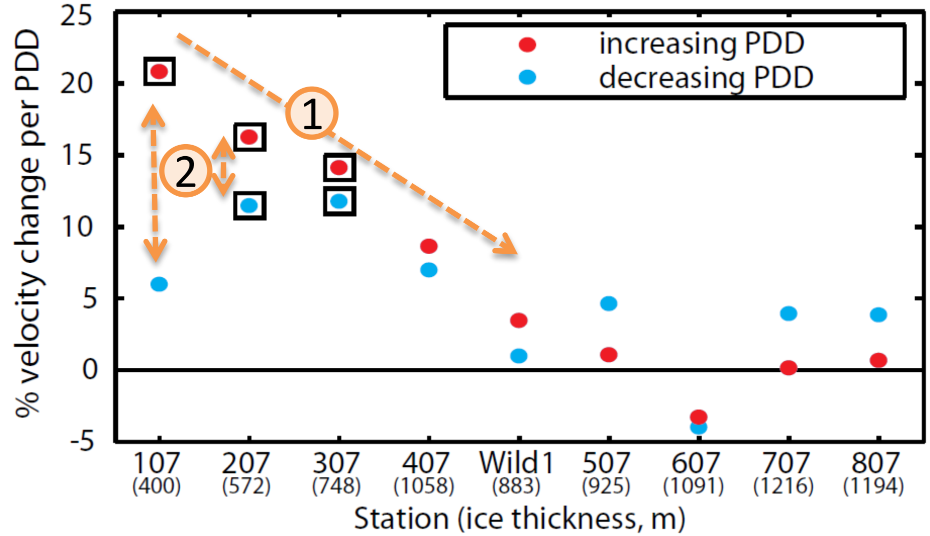



Lower spatial density of connections to bed in cold, thick ice.




Q2: Flow coupling smoothes local variations in sliding

# Q1: Differences from temperate glacier




← **days** —— **hours** ————→

*Creep closure time scale (at low water pressure)*

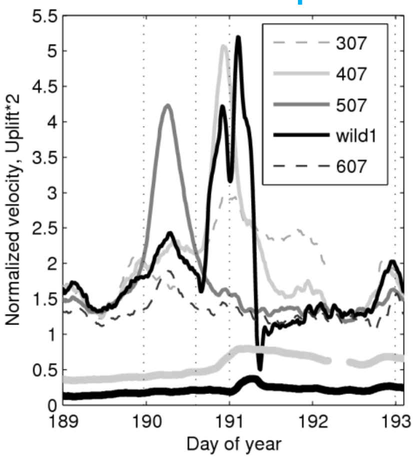
① Dynamic response decreases upglacier.
- less melt
- fewer connections to the bed

② Dynamic response of thicker ice is less variable.
- Meltwater pulse frequency (1 day) is less than channel creep closure rate (few hours).
- Renewed sliding each day.

# Q3: Role of Supraglacial Lakes

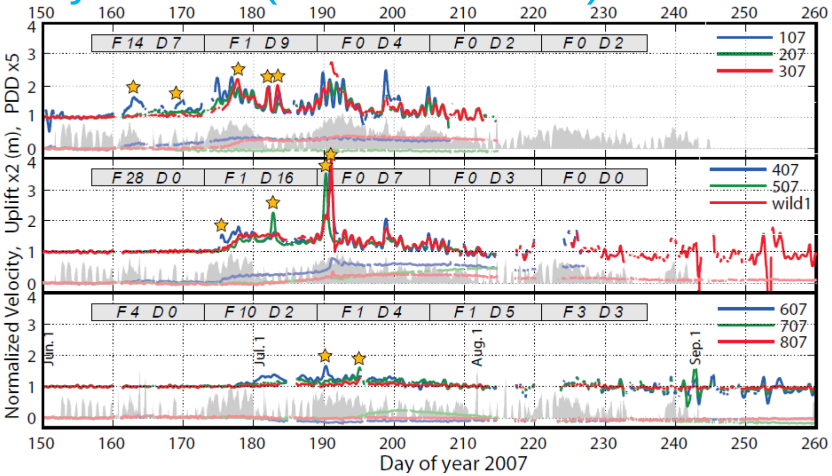
Lakes have 3 effects:

1. Open moulins in early summer by storing large quantities of water.
   Makes sense, but little direct evidence.
2. Catastrophic drainages cause dramatic velocity events (Das et al 2008).

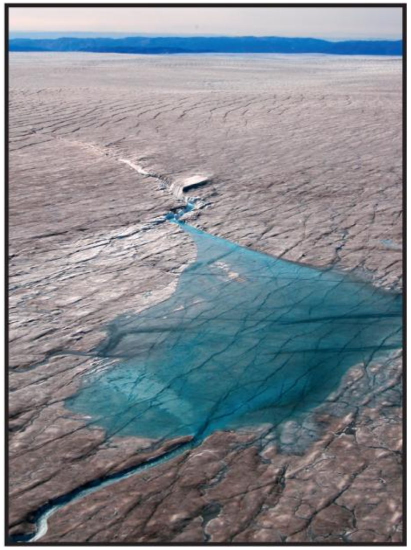


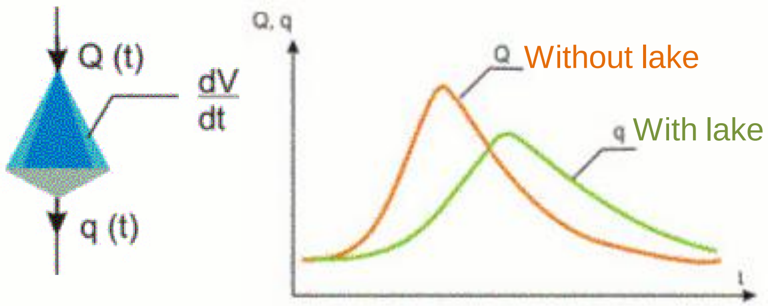

Up to 5-10x background velocity BUT
- •Short-lived (~24 hrs)
- •Local (few ice thicknesses)
- •Infrequent (1-2 per year)
- →Negligible effect on annual flux

•More or less net motion from same water volume delivered in many small daily pulses?




3. Gradual drainages buffer delivery of meltwater to englacial/subglacial system.






Smaller diurnal variations of water delivery
→ Less sliding

http://echo2.epfl.ch/VICAIRE/mod_1b/chapt_5/main.htm

# Conclusions

1) Summer speed in the ablation zone is directly related to melt.
2) Obvious lake drainage events in the velocity record are rare and short-lived.
3) Cold, thick ice (~1 km) results in different seasonal behavior than temperate, thin ice:
    a) Rapid creep closure rate of subglacial channels causes re-pressurization overnight and renewed sliding each day of continued melt input. Daily pulses of meltwater generate sliding.
    b) Lower spatial density of connections to the bed reduces the dynamic response of the ice sheet to surface meltwater and increases the spatial variability of that response.

# Subglacial Controls on Greenland Ice Sheet Marginal Acceleration

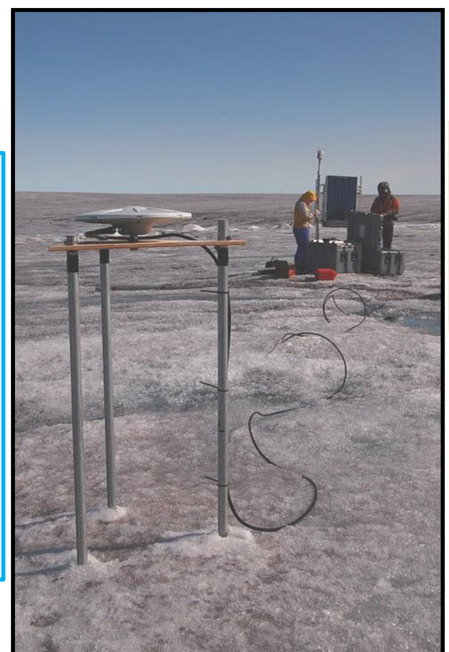
## Borehole Drilling Project, 2010-2012

NEW!

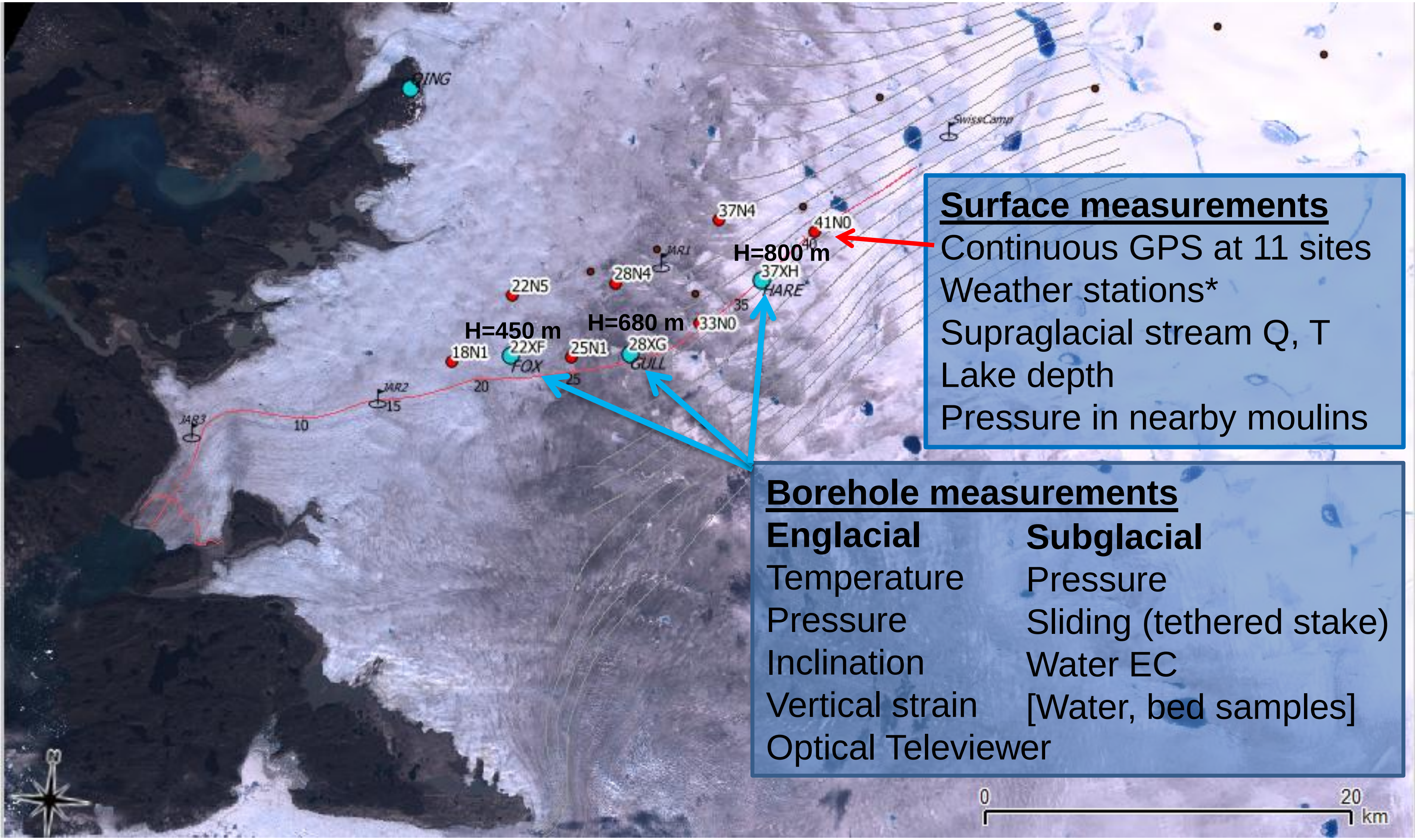

Ginny Catania, U Texas
Bob Hawley, Dartmouth College
Tom Neumann, NASA Goddard
Martin Leuthi, ETH
Martin Funk, ETH


1. Characterize the evolution of the subglacial drainage system over the melt season and into the winter
2. Understand how surface water supply influences ice motion over long term (season) and as impulse (lake drainage)
3. Measure englacial properties (temp., strain) to quantify viscosity

**<u>Field Schedule</u>**
August 2010: GPS install (4)
May 2010: GPS install (8)
June-August 2011: Borehole drilling
(3 sites, 5 holes per site)
Fall 2011: Maintenance, download
Summer 2012: Data download



# Subglacial Controls on Greenland Ice Sheet Marginal Acceleration




*Problems with PDD: snow vs. ice surfaces, subdaily time scales

Options: Diurnally varying DDF

PDD model with solar radiation factor

Energy Balance modeling

# Questions?