Acceleration of Inland Ice via Longitudinal Coupling to Marginal Ice

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NATURAL ENVIRONMENT RESEARCH COUNCIL

Outline

- brief background on Greenland ice sheet (GIS)
- background on seasonal flow acceleration along the western flank of the GIS (the “Zwally effect”)
- a more general hypothesis for explaining the ZE
- testing this hypothesis using:
    - flow modeling
    - recent observations
- summary and conclusions

Ilulisat, Western Greenland

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Greenland Ice Sheet

- 6-7 meters of sea level equivalent
- mass loss through both calving and surface melting
- surface mass balance is likely to become negative with continued climate warming[1]
- ice sheet models[2,3] suggest that sustained warming of 3°C could “melt” the ice sheet
- If removed, GIS would likely NOT re-grow under current climate conditions[4]
- recent changes[5] suggest that the GIS may be more sensitive to climate change than previously thought, in particular w.r.t. ice dynamics

[1]IPCC (2007), [2]Greve (2000), [3]Huybrechts & DeWold (1999), [4]Toniazzo et. al (2004), [5]Alley et. al (2005)

Greenland Ice Sheet – recent changes

- acceleration, thinning, and retreat of numerous large outlet glaciers[1] on eastern and western flanks
- responsible for “mass loss” signal in gravity data at low elevations[2] and in near-coastal regions[3]?

[1]Rignot & Kanagaratnam (2006), [2]Luthcke et. al (2006), [3]Velicogna & Wahr (2006),

Greenland Ice Sheet – recent changes

For large, polar ice sheets, this process is generally thought to take many thousands of years (depending on advective vs. diffusive timescales for heatflow)

Atmospheric Forcing?

(2) change in basal boundary condition?
- increase in basal lubrication leads to faster sliding

Cause for changes in basal lubrication could include:

(1) increase in basal melting (through friction or geothermal)

(2) increase in **amount** of surface meltwater reaching the bed

(3) increase in the **access** of surface meltwater to the bed

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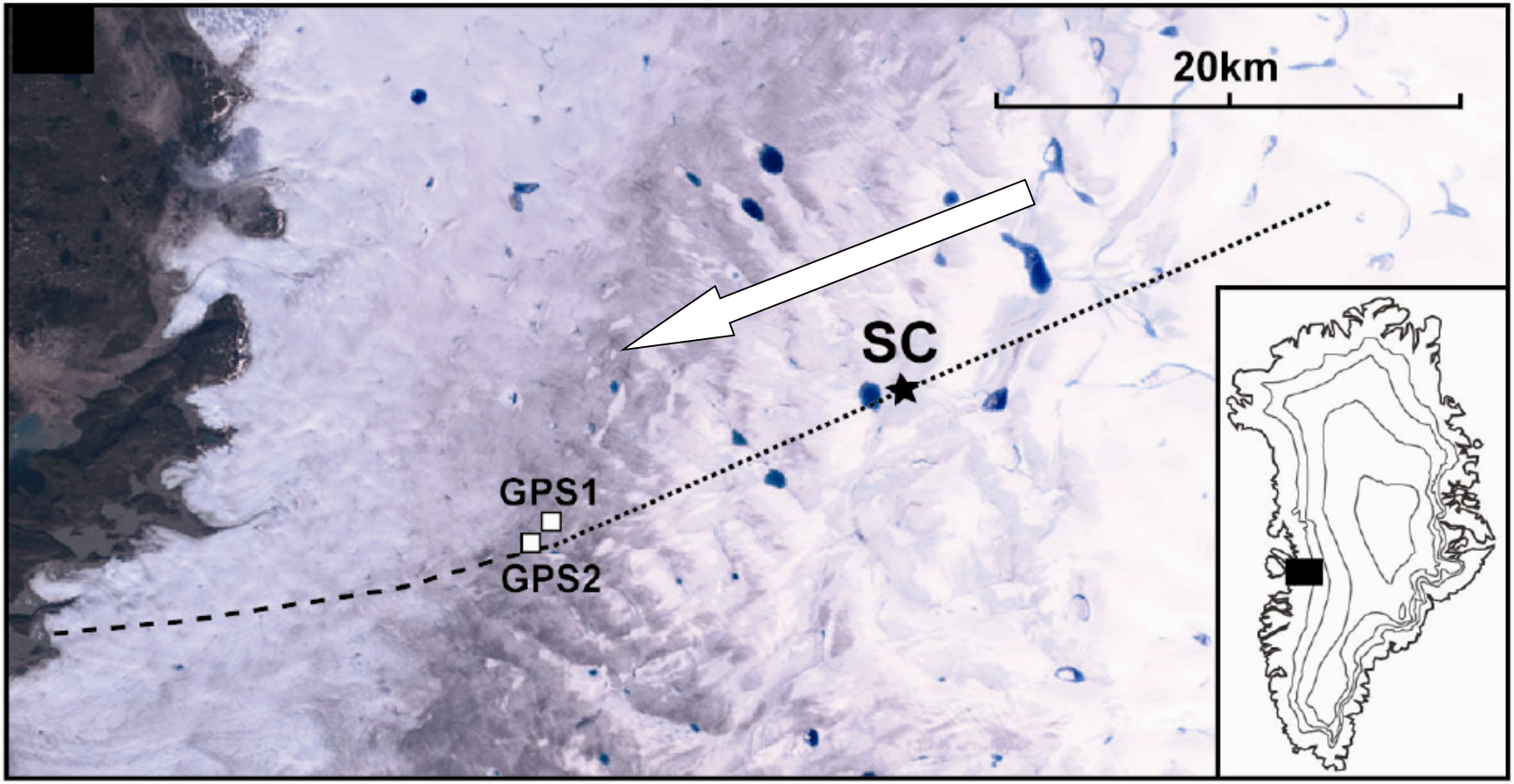
field camp, Southern Greenland

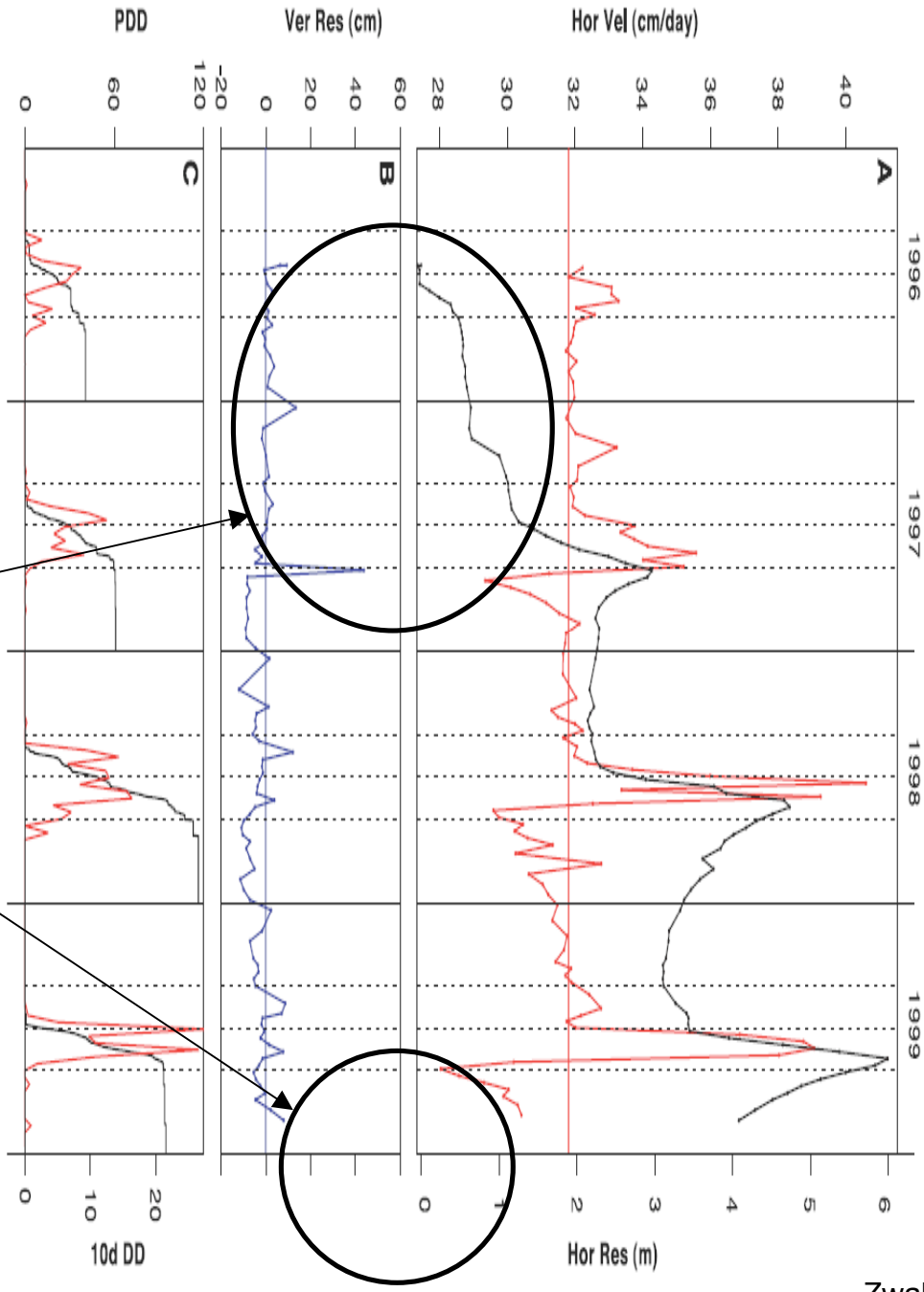
Seasonal acceleration on the western flank of the GIS

- short-term seasonal accelerations of 10-20% observed at Swiss Camp (SC), a site located ~40km inland from the western margin of the GIS[1]

[1]Zwally and others (2002)


20km
SC
GPS1
GPS2

accelerations of 10-20%, coincident with periods of increased surface melting



Zwally et. al (2002)

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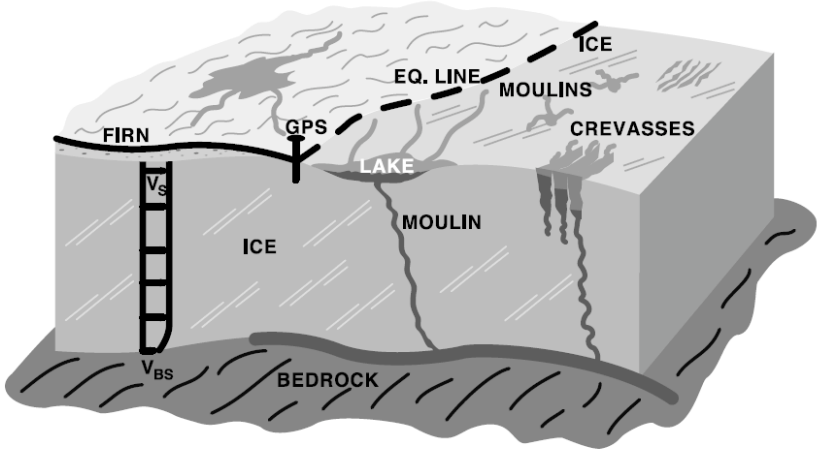
cover: Meltwater stream flowing into a moulin in the ablation zone of the Greenland ice sheet. Accelerations of ice flow in summer are closely related to variations in air temperature and surface melting, and indicate that meltwater quickly travels through 1000 m of ice and enhances basal sliding. These observations reveal a mechanism for dynamic response of ice sheets to climate change.

[Photo: R. J. Braithwaite]



Zwally and others (2002)