Basal Physics of Ice Motion from Flow Variability of Whillans Ice Plain: the WISSARD GPS Experiment

(in a Shadow of a Borehole)

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Lots of people have to work for many years before a grad student can have a 'hero shot' (Ken Mankoff, UCSC, in Discovery Magazine)

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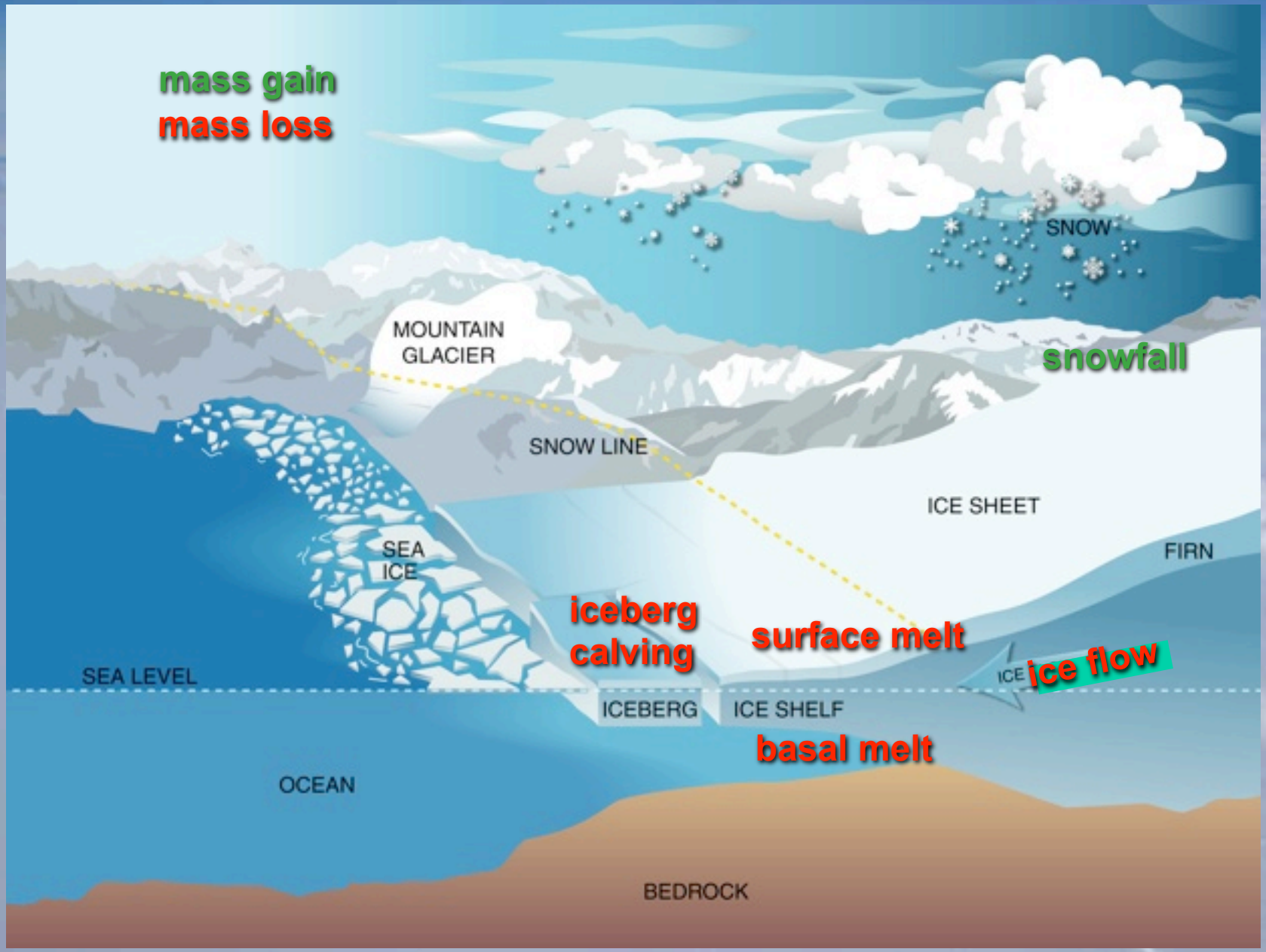
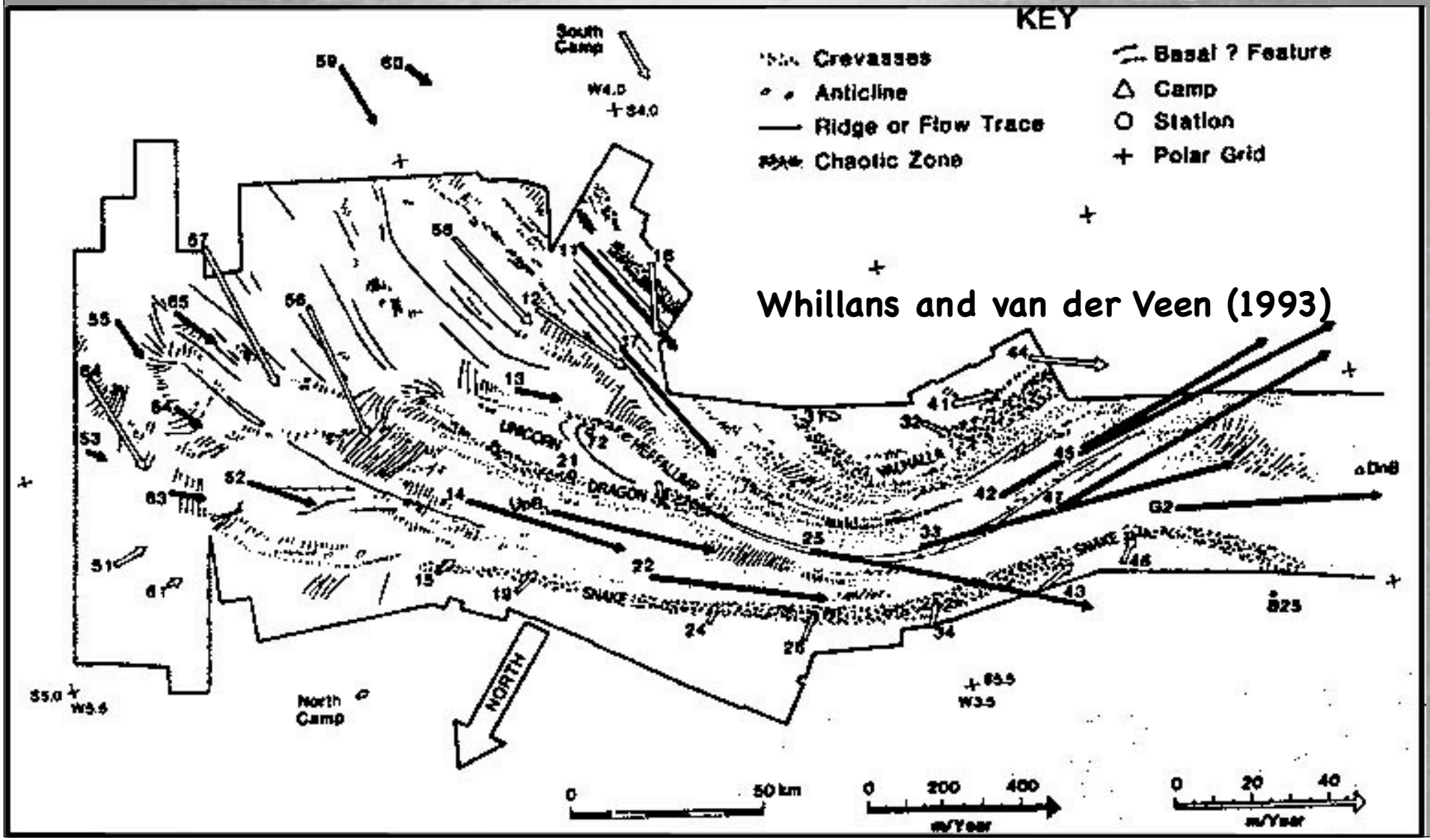
ANTARCTICA
THE LONG TRAVERSE
12 DAYS | 1013 KM
DAY
McMURDO
KM
DRILL SITE
1013
12 TRACTORS
20 CONTAINERS
230 TONS PAYLOAD
50 SCIENTISTS
WISSARD DRILL SITE
2 Empire State Buildings Deep
100m
200m
300m
400m
500m
600m
700m
800m
800 METERS DOWN
To reach the lake waters, scientists used a hot-water drill technology in which hot water is forced under pressure through a nozzle and blasts the ice. The filtration and sterilization of the meltwater produced by drilling reduces the risk of chemical or biological contamination.
ICE SHELF
LIQUID WATER
SEDIMENT
Drill Site Camp
Water Drill Bore Hole
Pneumatic Drill
Microorganism found in Lake Whillans

How ice moves (and changes its motion)?

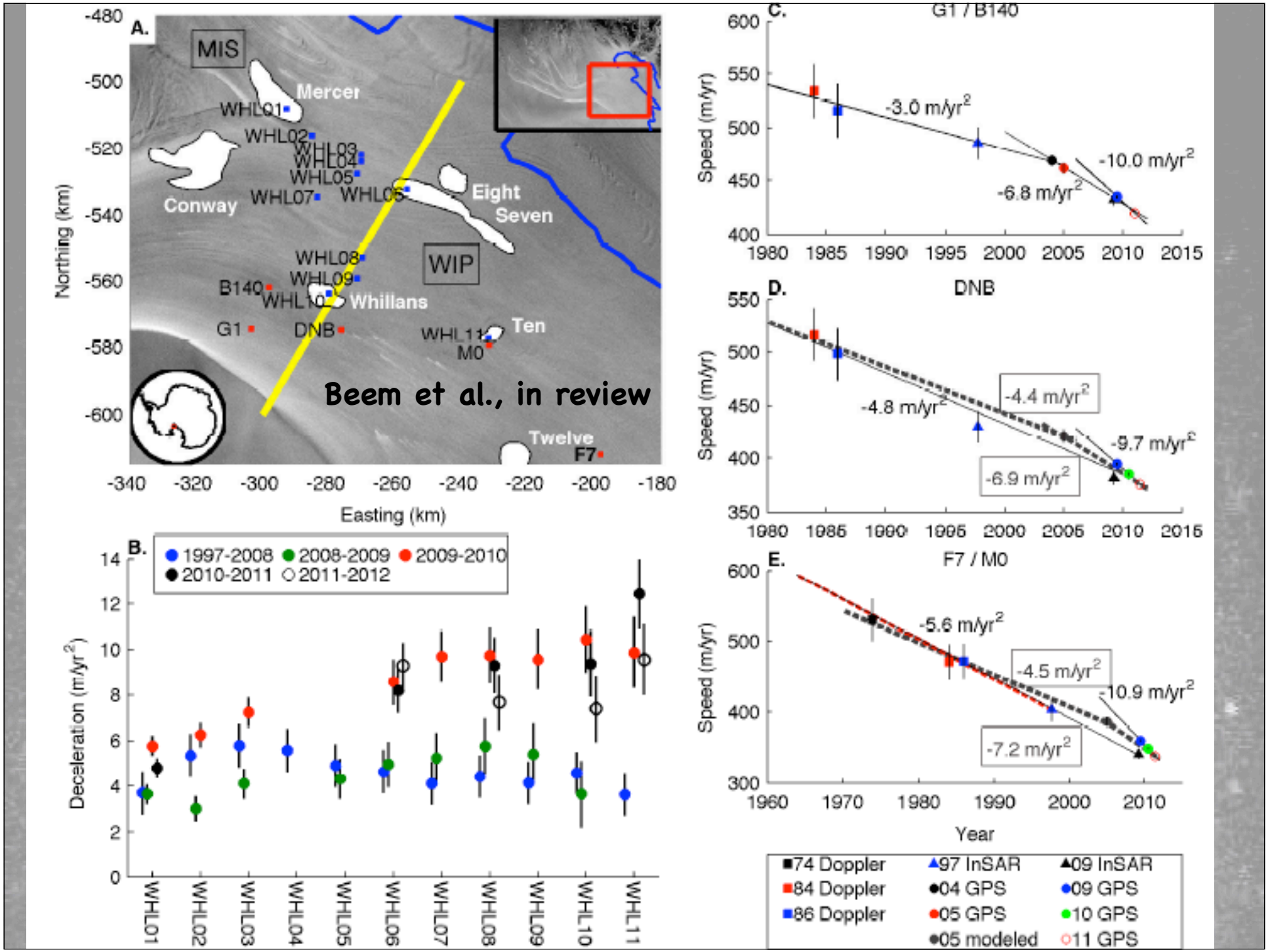


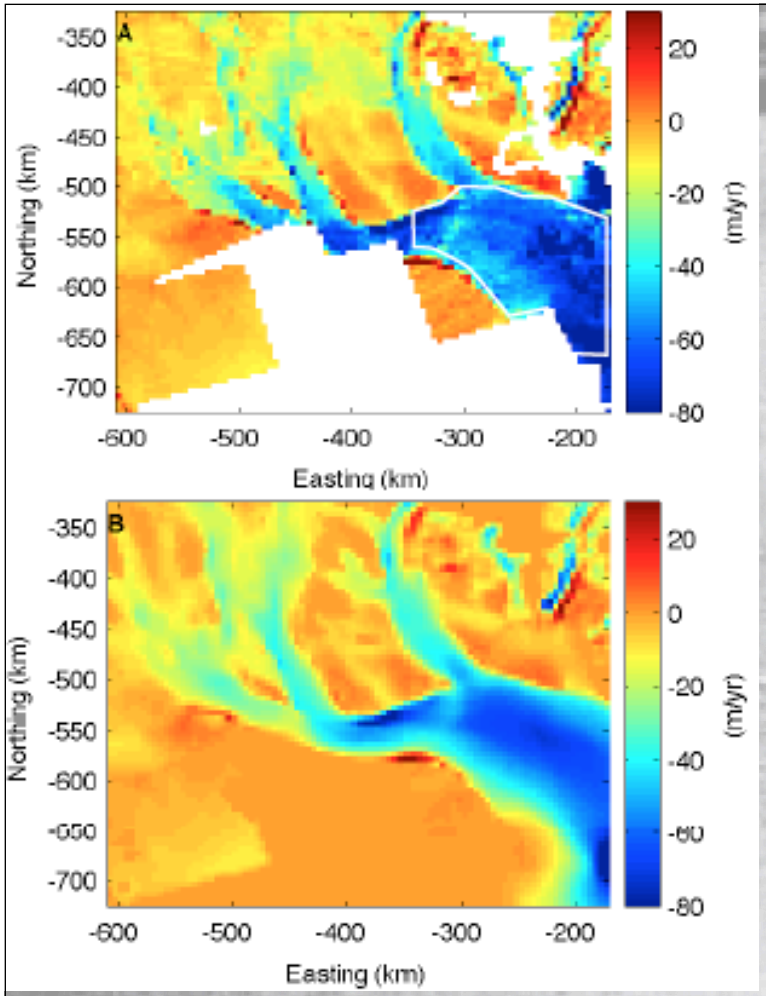
Whillans Ice Plain is a great place to study ice dynamics:

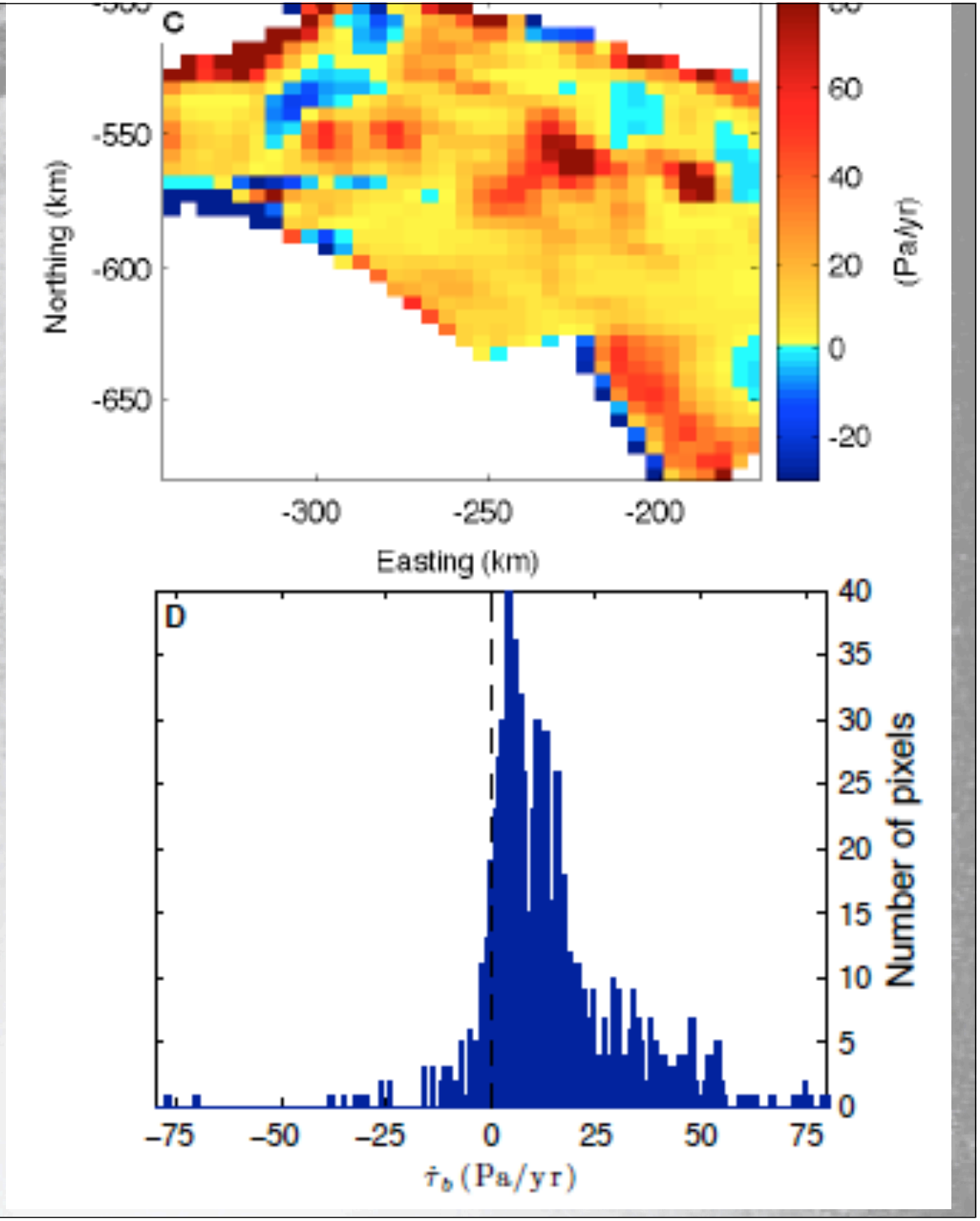
- erratic behavior on timescales ranging from tidal to multi-decadal
- one of the longest records of velocity measurements
- cool system of active subglacial lakes (Fricker et al., 2007)



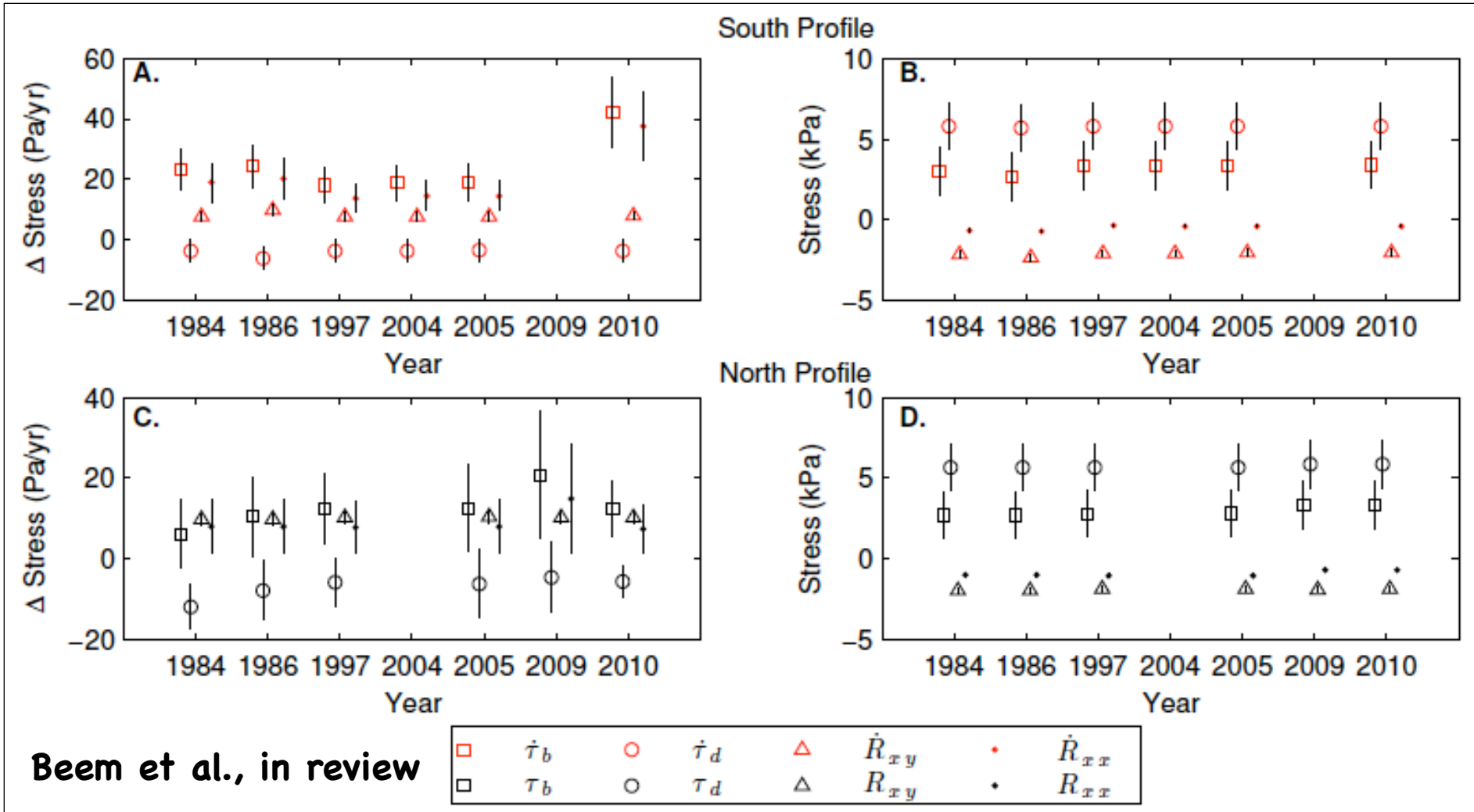
Whillans and van der Veen (1993)


A.
MIS
Mercer
WHL01
WHL02
WHL03
WHL04
WHL05
WHL07
WHL06
Conway
Eight
Seven
WIP
WHL08
WHL09
B140
WHL10
Whillans
G1
DNB
WHL11
Ten
M0
Twelve
F7
Beem et al., in review
Northing (km)
Easting (km)
B.
1997-2008
2008-2009
2009-2010
2010-2011
2011-2012
Deceleration (m/yr²)
C.
G1 / B140
-3.0 m/yr²
-6.8 m/yr²
-10.0 m/yr²
D.
DNB
-4.8 m/yr²
-6.9 m/yr²
-4.4 m/yr²
-9.7 m/yr²
E.
F7 / M0
-5.6 m/yr²
-7.2 m/yr²
-4.5 m/yr²
-10.9 m/yr²
Speed (m/yr)
Year
74 Doppler
84 Doppler
86 Doppler
97 InSAR
04 GPS
05 GPS
05 modeled
09 InSAR
09 GPS
10 GPS
11 GPS





Rate of basal drag change as map (C) and histogram (D) between 1997 and 2009 from inverse modeling (Beem et al., in review)



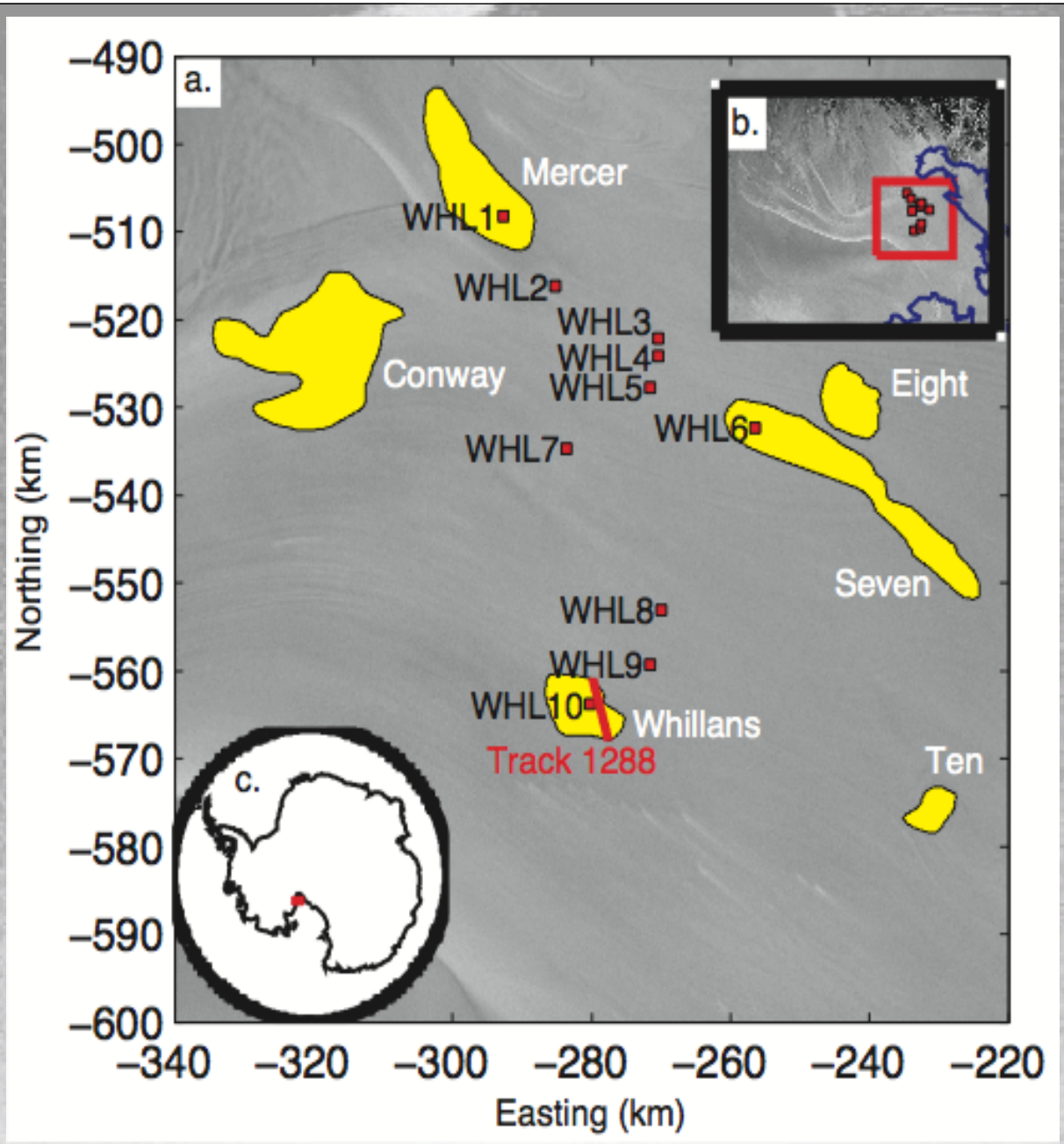
Beem et al., in review

- The rate of basal drag change from force budget calculations = same
- Slowdown occurs due to basal strengthening at the rate of dozens of Pa/yr

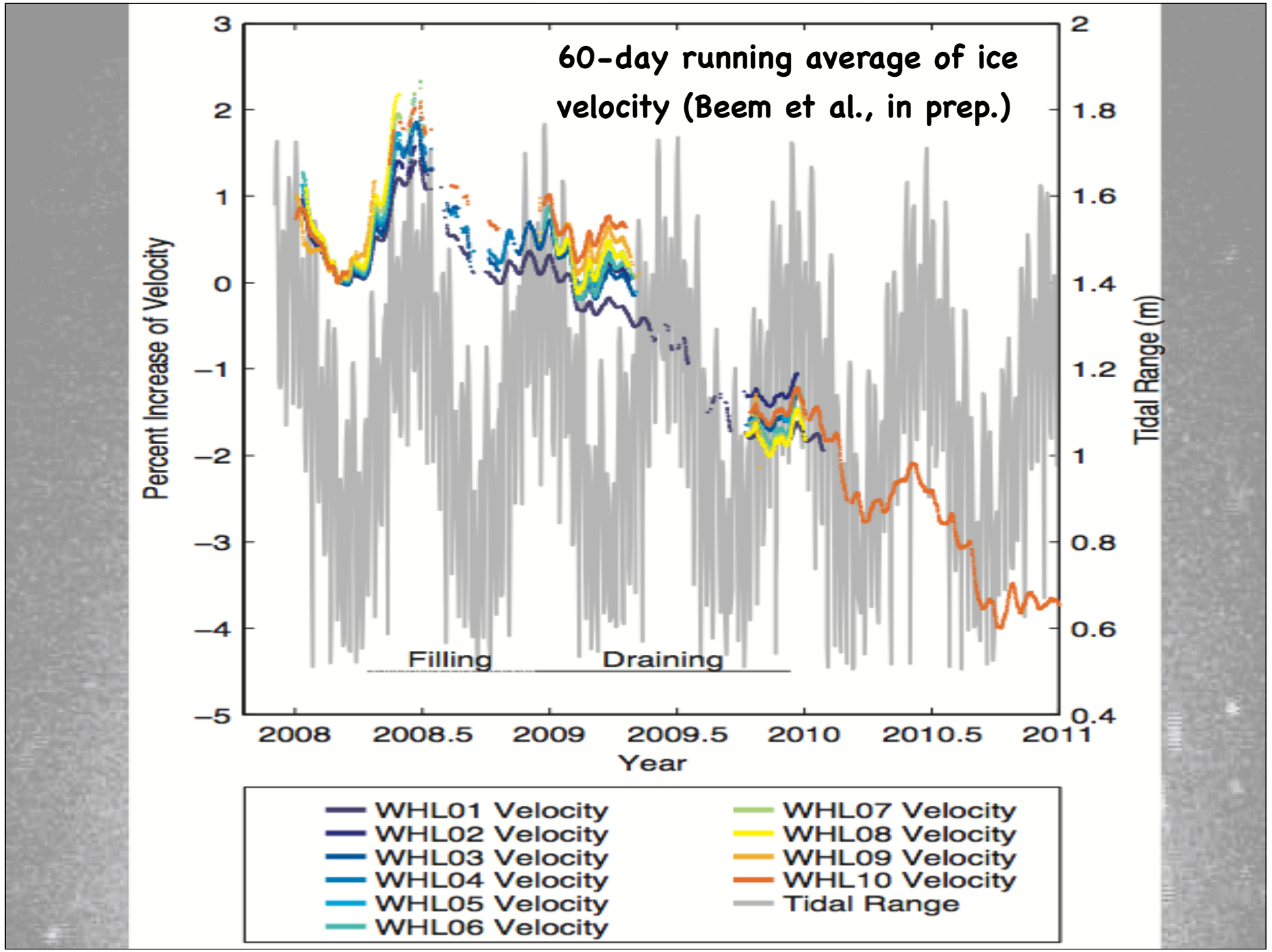
(Mystery 1.0 = when annual slowdown rate changes, does it mean that the rate of basal strengthening changes as well? => suggests a non-boring basal process as the driving factor)

What strengthens the bed?

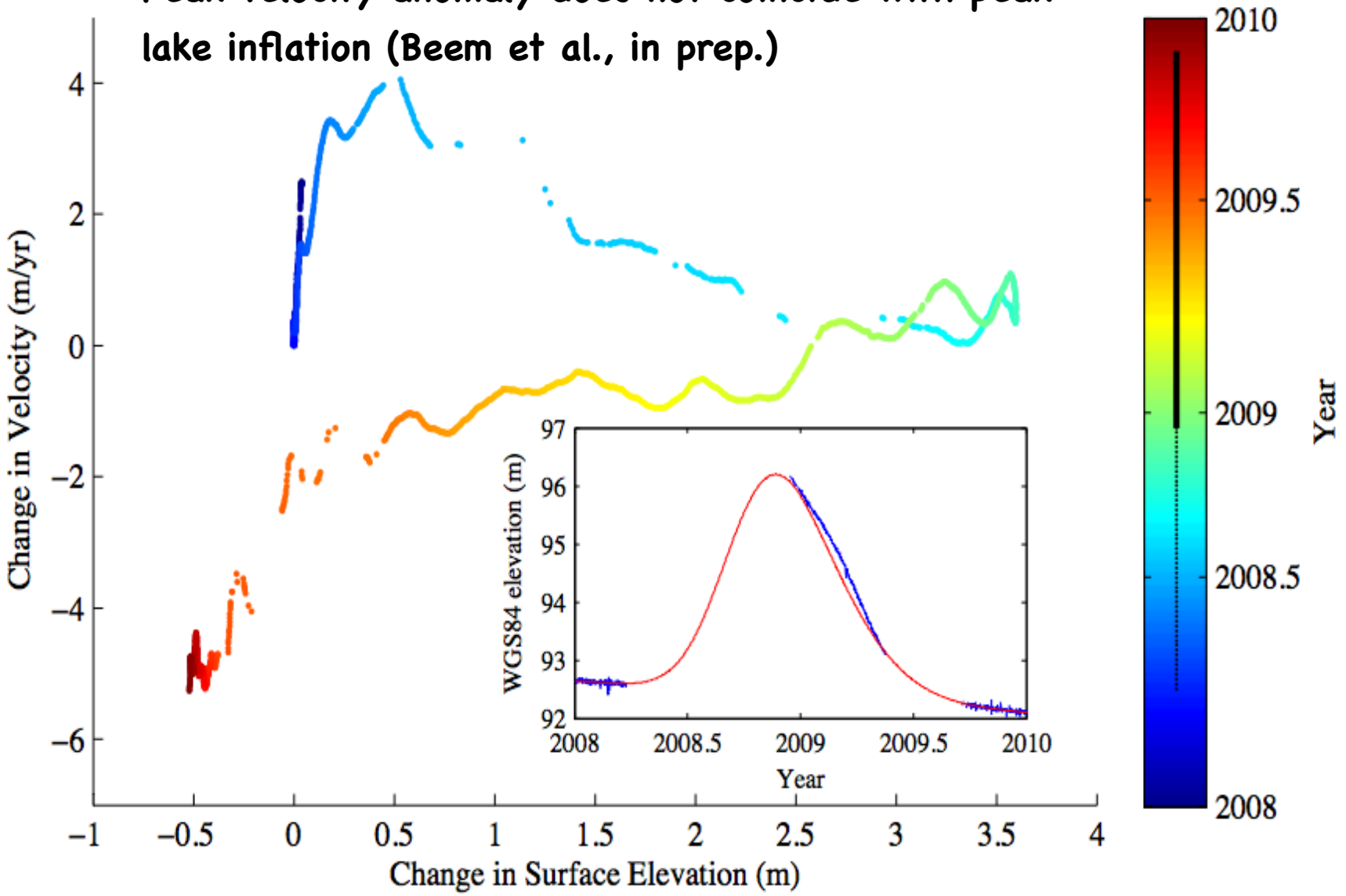
- basal freezing (but it should be boring, i.e. same rate each year)
- differential erosion removes weak bed (e.g. seds) and exposes hard bed?
- less water (and lower water pressure) - I like the fact that this could be variable on inter-annual timescales (remember the lakes!)



Beem et al., in prep.


60-day running average of ice velocity (Beem et al., in prep.)
Percent Increase of Velocity
Tidal Range (m)
Year
Filling
Draining
3
2
1
0
−1
−2
−3
−4
−5
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
2008
2008.5
2009
2009.5
2010
2010.5
2011
WHL01 Velocity
WHL02 Velocity
WHL03 Velocity
WHL04 Velocity
WHL05 Velocity
WHL06 Velocity
WHL07 Velocity
WHL08 Velocity
WHL09 Velocity
WHL10 Velocity
Tidal Range

Peak velocity anomaly does not coincide with peak lake inflation (Beem et al., in prep.)



Hysteresis of ice stream surface velocity and SLW inflation magnitude. The dashed line within the colorbar on the right shows maximum period of filling and solid line shows period of draining. Inset is plot is of GPS vertical position (blue) and fitted hypothetical gaussian curve of surface inflation (red).

Take home:

- Whillans Ice Stream is slowing down at a rate that is variable on inter-annual timescales

- The slowdown is driven by the bed getting stronger by dozens of Pa/yr

- Variability in subglacial hydrology is likely responsible for this inter-annual variability in ice flow (overprinted on top of strengthening due to freezing and/or erosion?)

- Inflation and drainage of Subglacial Lake Whillans had a small impact on ice velocity. Peak velocity anomaly came before significant inflation of the lake (did lake inflation lower regional water pressure?)

How ice moves (and changes its motion)?