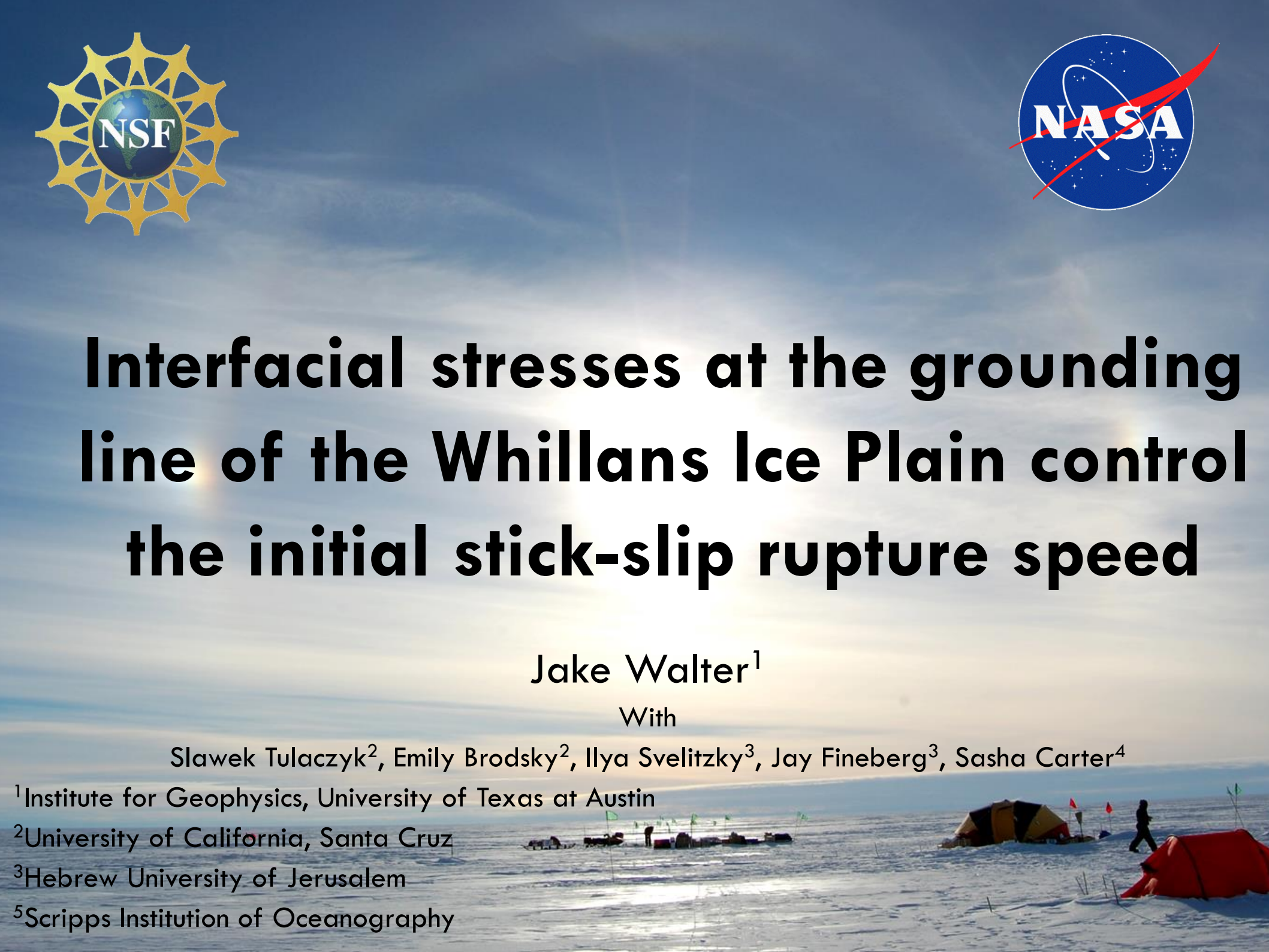

Interfacial stresses at the grounding line of the Whillans Ice Plain control the initial stick-slip rupture speed

Jake Walter[1]

With

Slawek Tulaczyk[2], Emily Brodsky[2], Ilya Svelitzky[3], Jay Fineberg[3], Sasha Carter[4]

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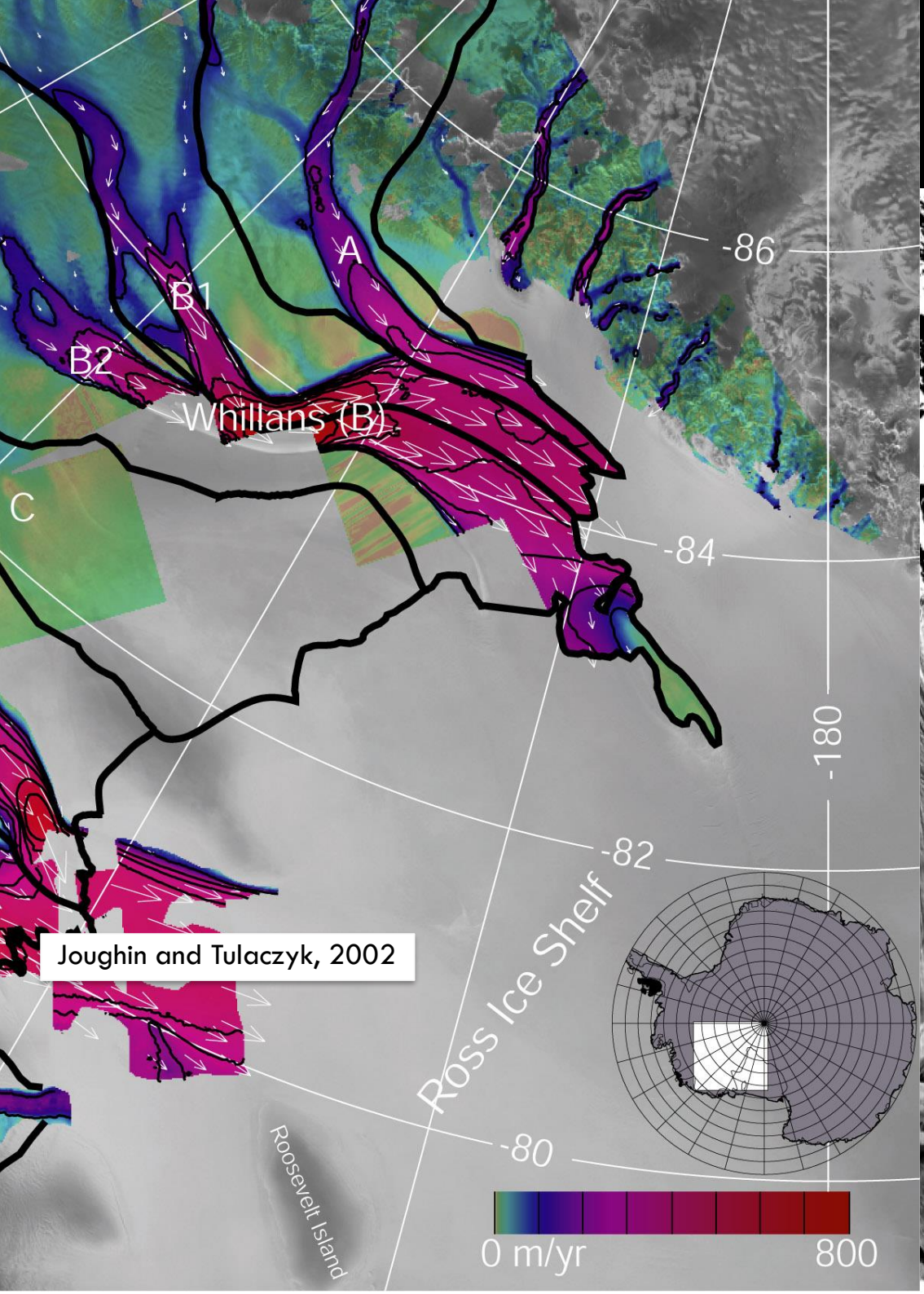
[3]Hebrew University of Jerusalem

[5]Scripps Institution of Oceanography

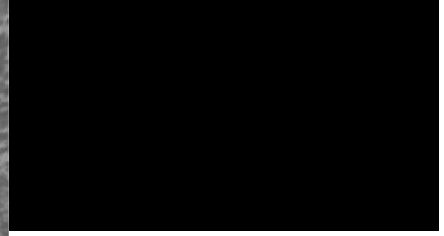
Outline

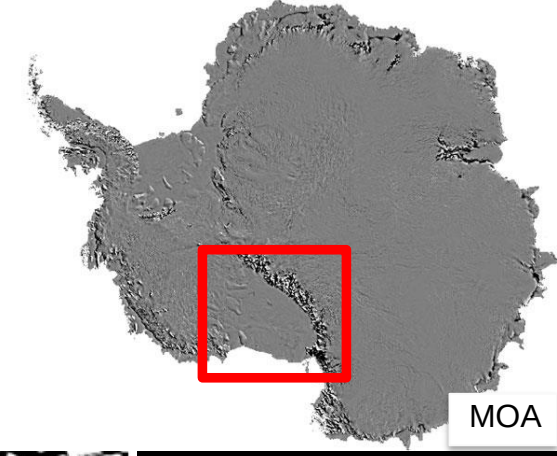
Whillans Ice Plain, West Antarctica

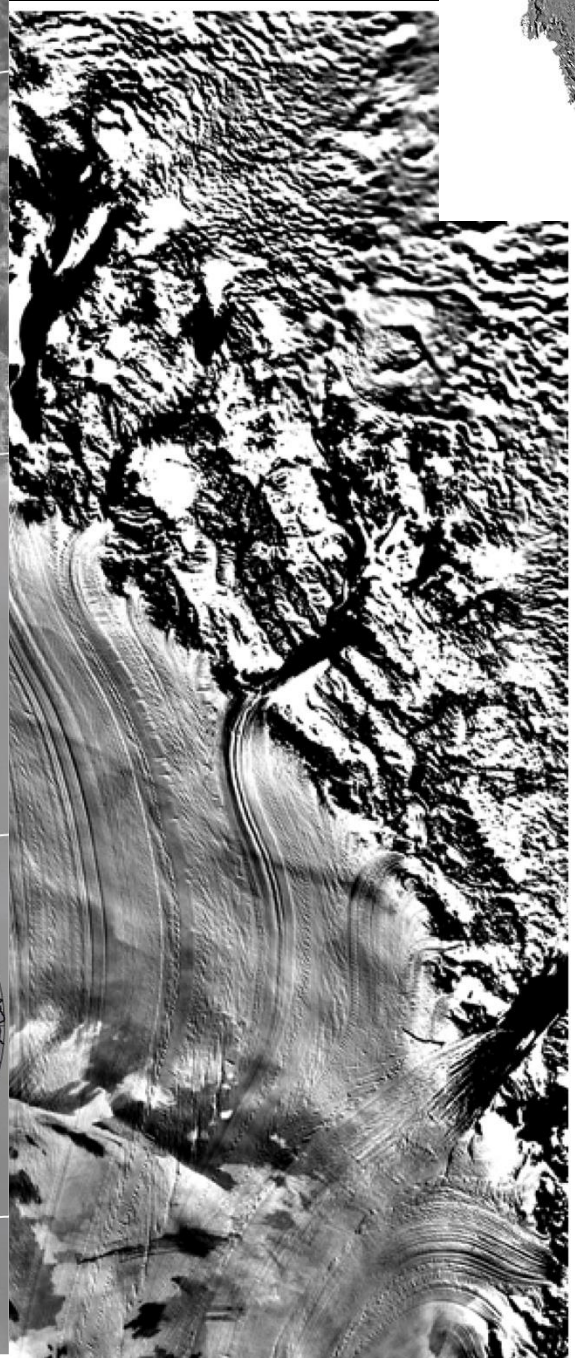
- stick-slip events
- Interesting behavior when they start near the grounding line
- Small-scale friction experiments

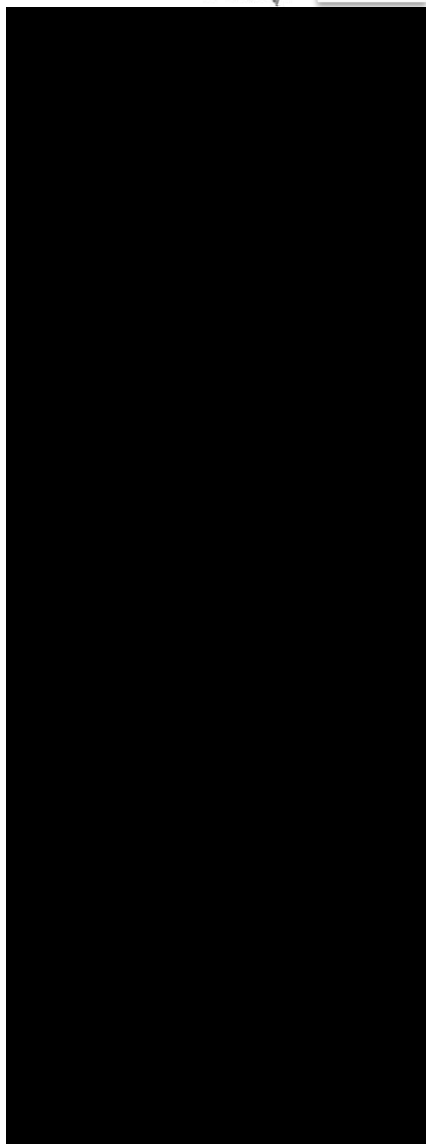


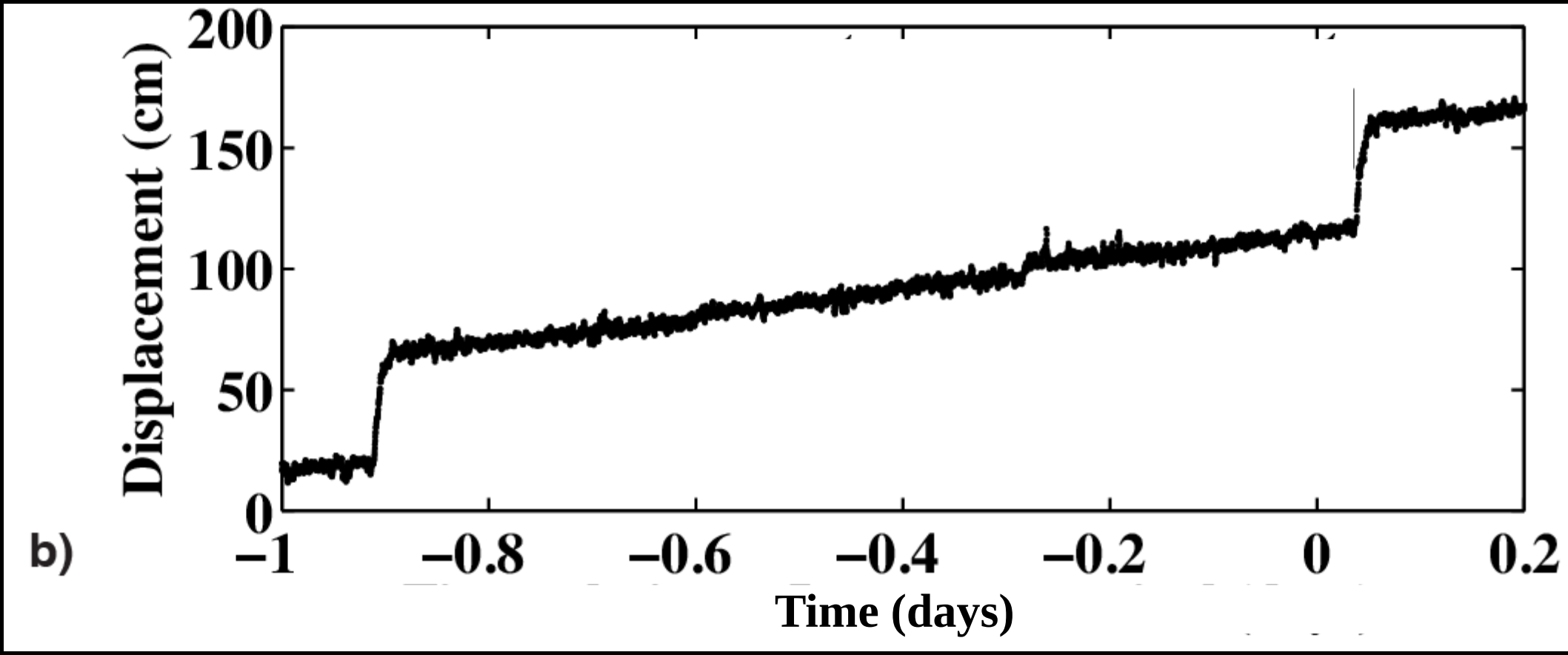
Joughin and Tulaczyk, 2002

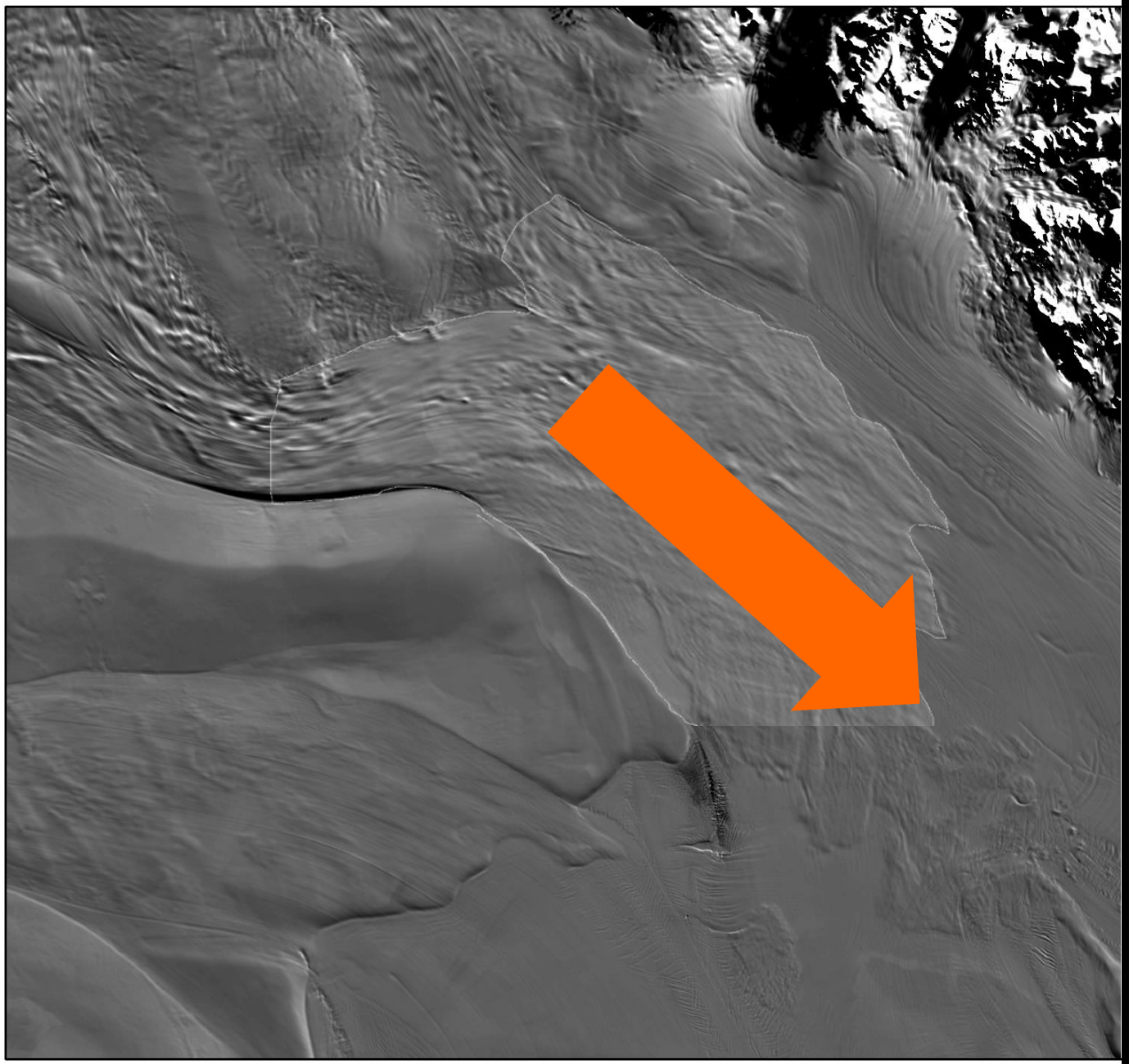




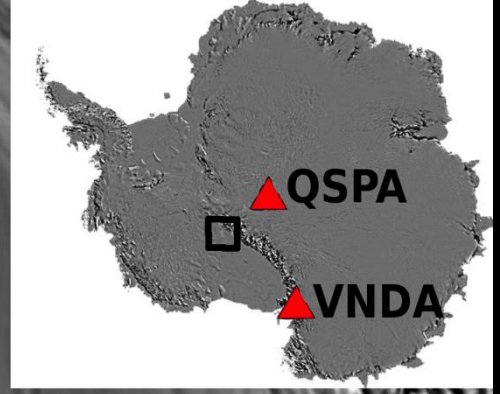





b)
Displacement (cm)
200
150
100
50
0
−1
−0.8
−0.6
−0.4
−0.2
0
0.2
Time (days)


0
50
100
200 Kilometers
0.7 Kilometers
© 2014 Google
Google Earth

Slip Event in the Near-field



Subglacial Lake Conw

Whillans Ice Stream

M17
M9
M8
M6
L7
Crevasse
Tigg
Cookie
A702
SUTURE ZONE
Grounding Line
Ice Raft A
Ice Flow Direct

N
50 km

Bindschadler et al., 2003
Wiens et al., 2008
Winberry et al., 2009
Walter et al., 2011
Winberry et al., 2011
Pratt et al., 2014
Walter et al., in revision
Barcheck et al., in prep.

Walter et al., 2011

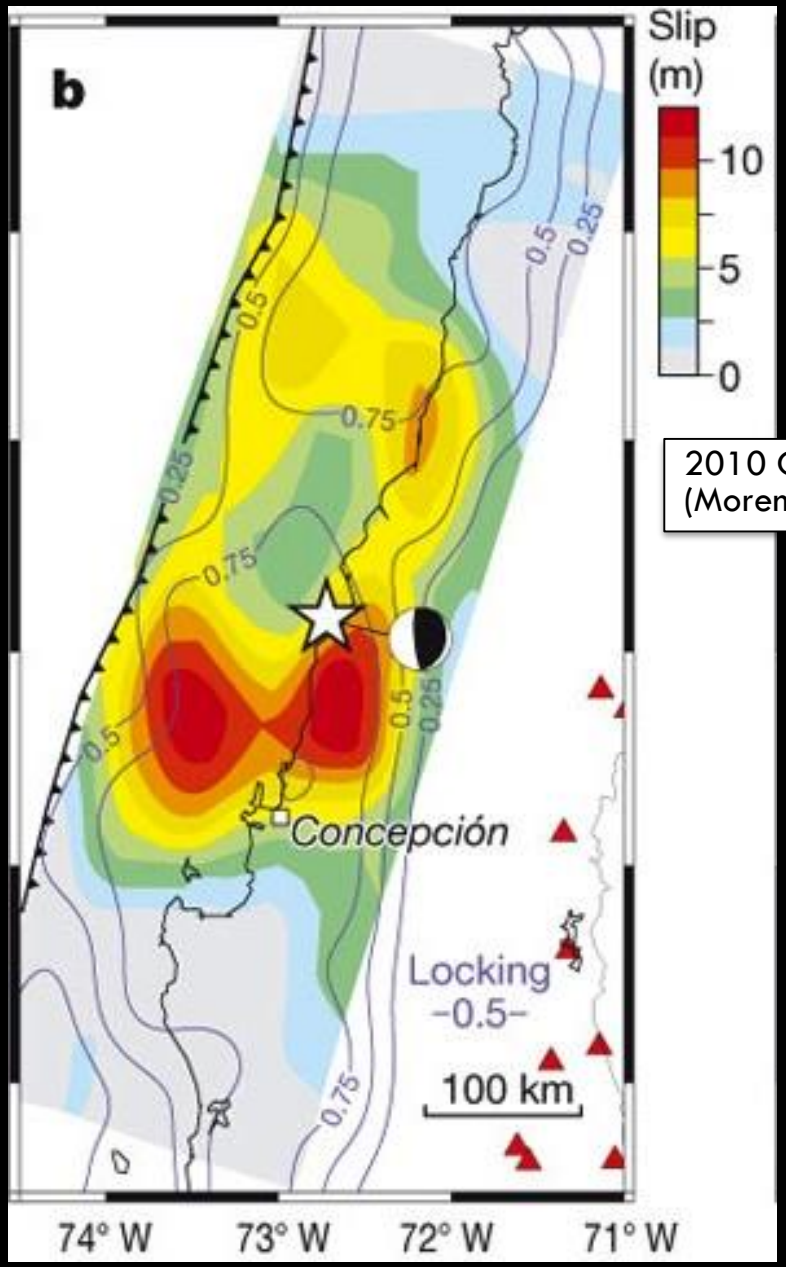
Legend

IceSAT Elevation Range (m)
0 4.5 9

Broadband Seismic Stations

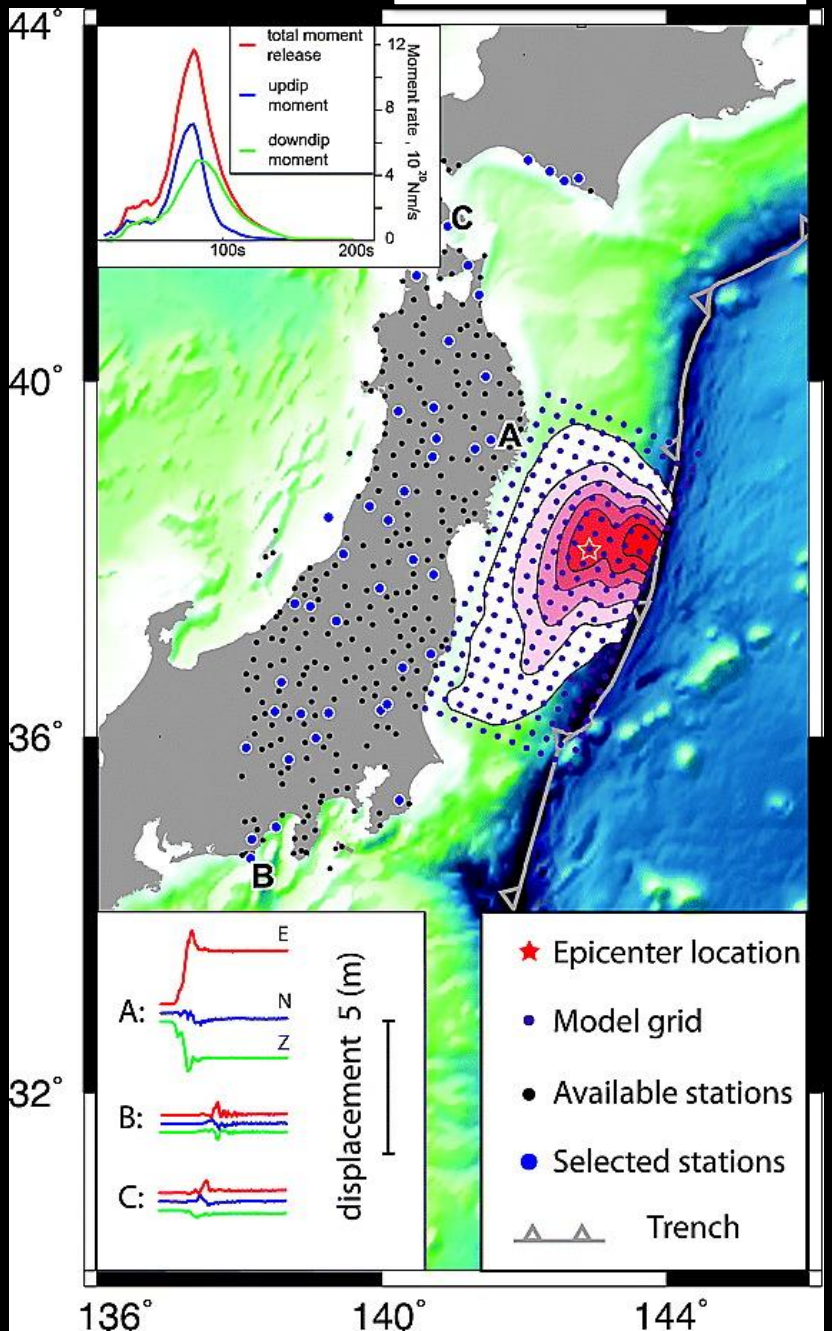
GPS Stations

Analogous to Large Earthquakes

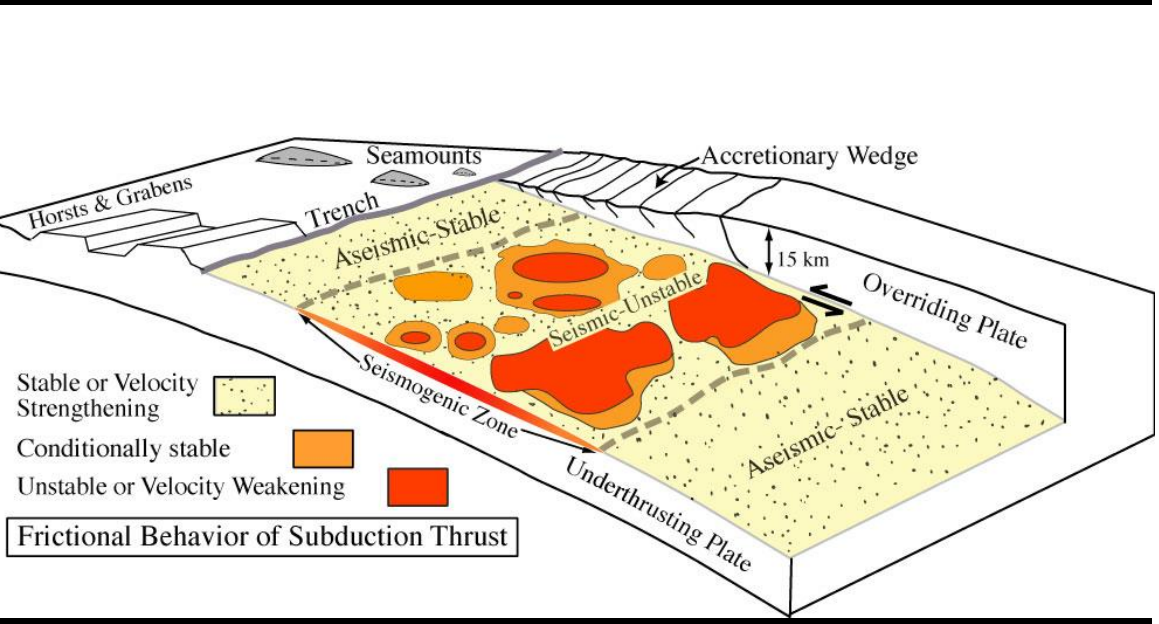


2010 Chile Earthquake
(Moreno et al., 2010)

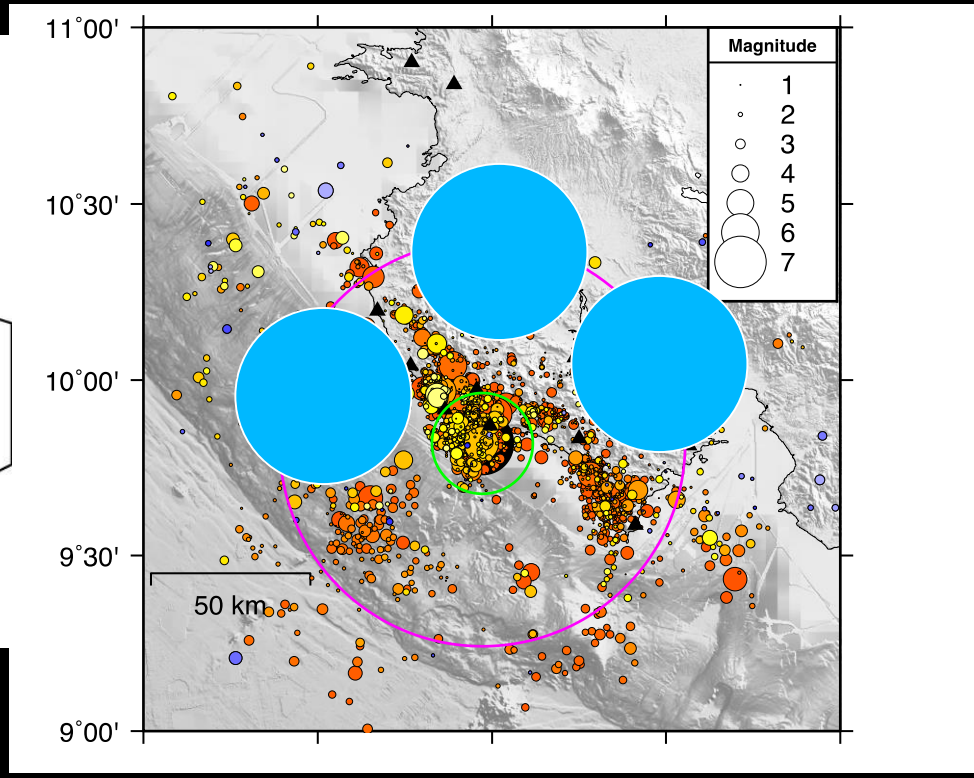
2011 Tohoku Earthquake
(Yue and Lay, 2011)



Discrete zones of varying frictional properties

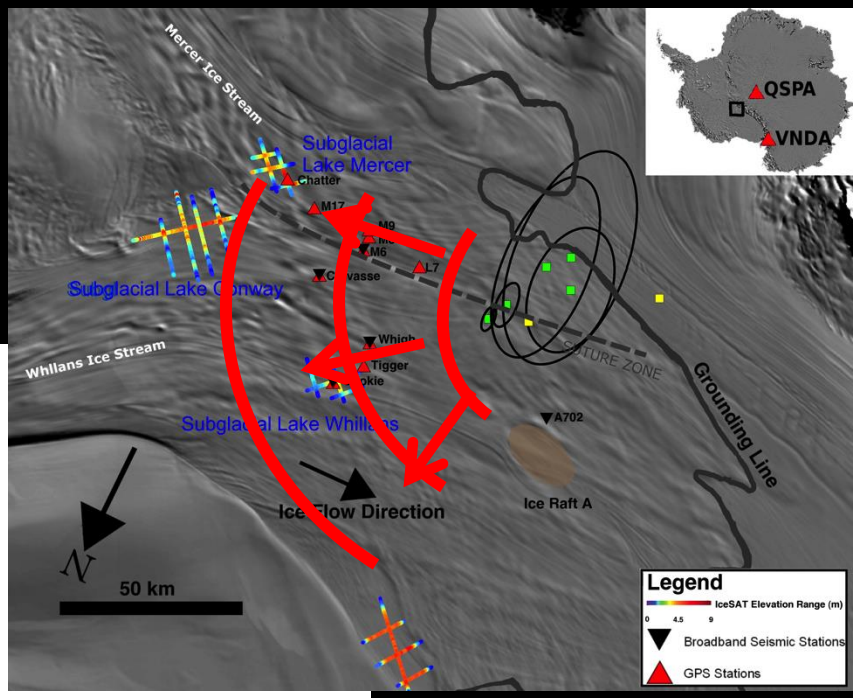


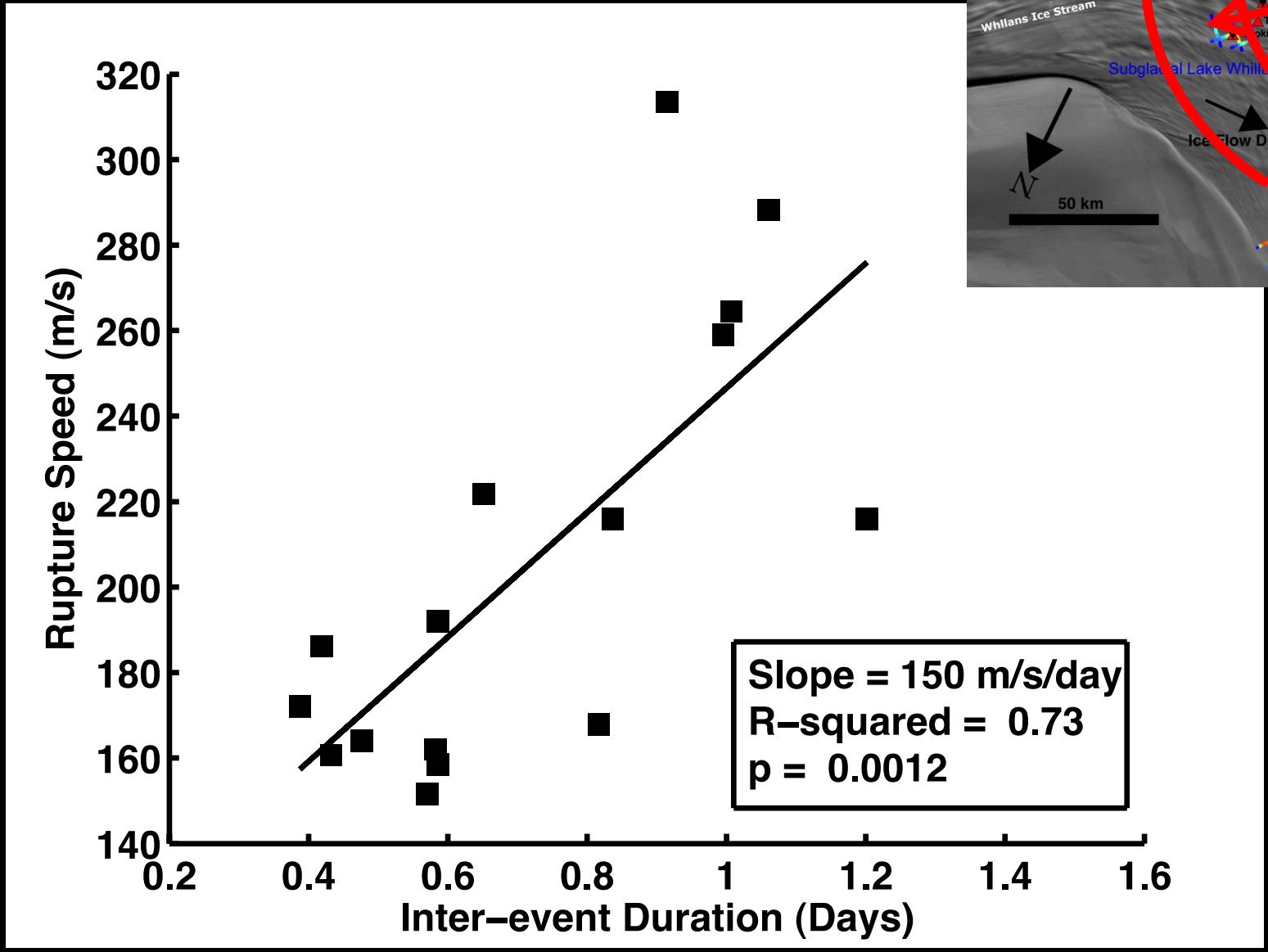
(Bilek and Lay, 2002)



Walter et al., in prep.

Rupture Speed





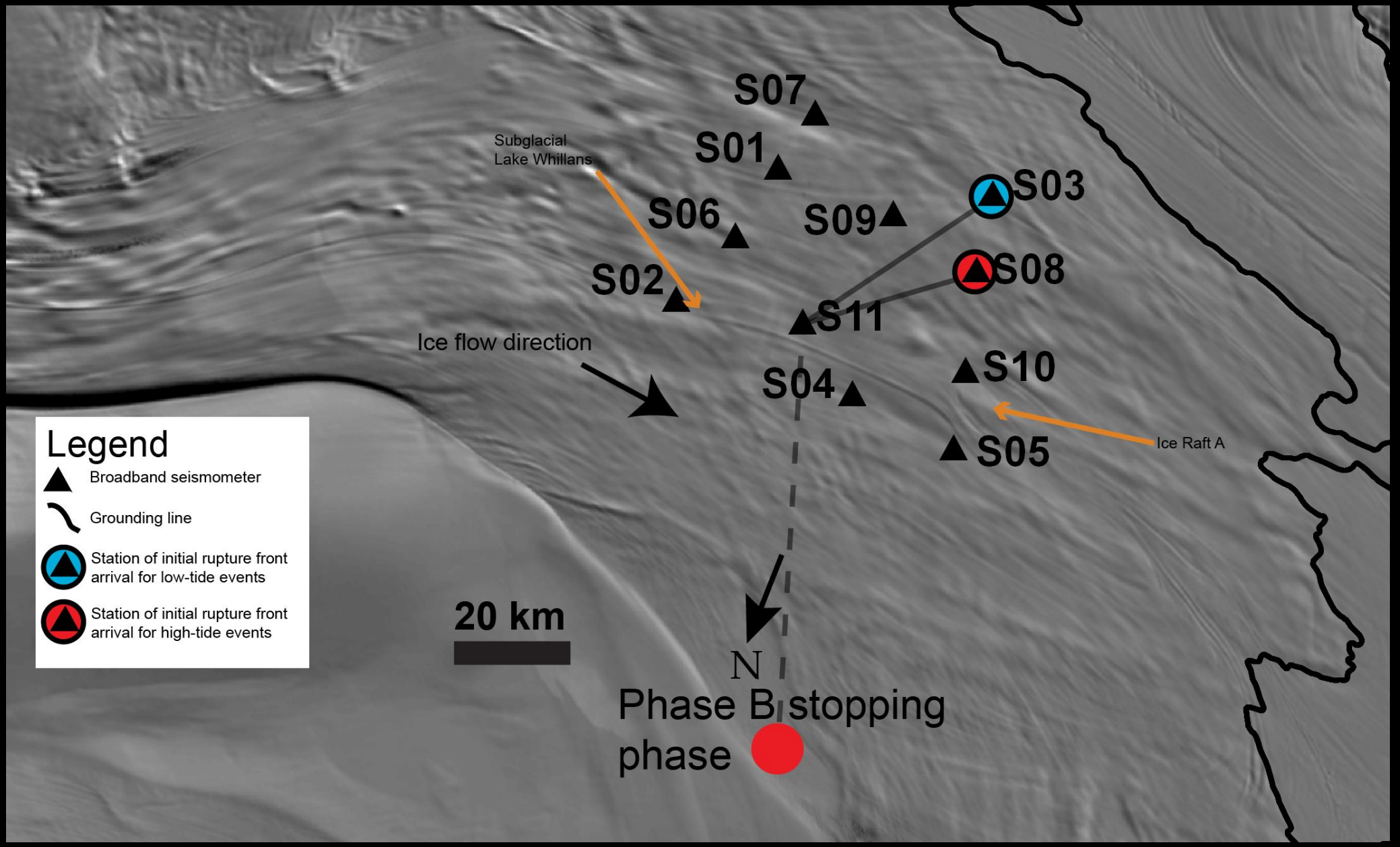
$$V_r \approx 0.9\beta$$

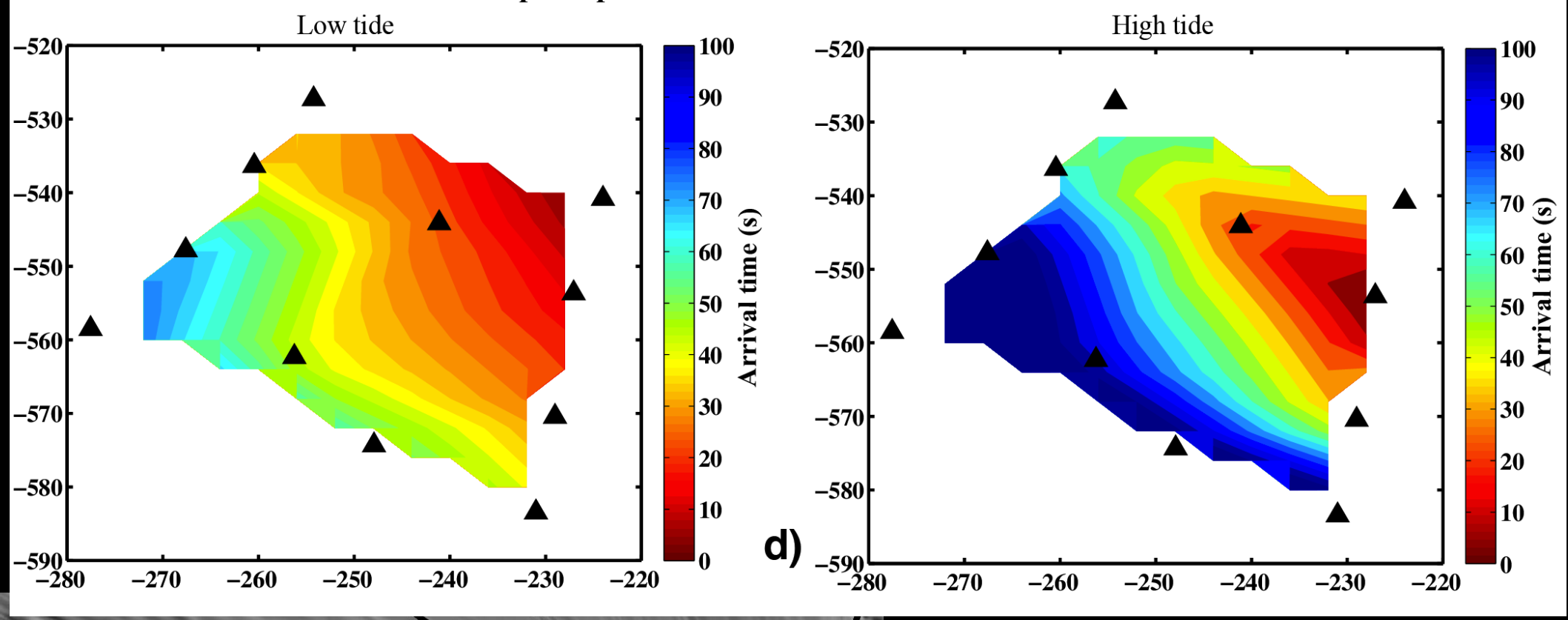
V_r = rupture speed
β = shear wave speed

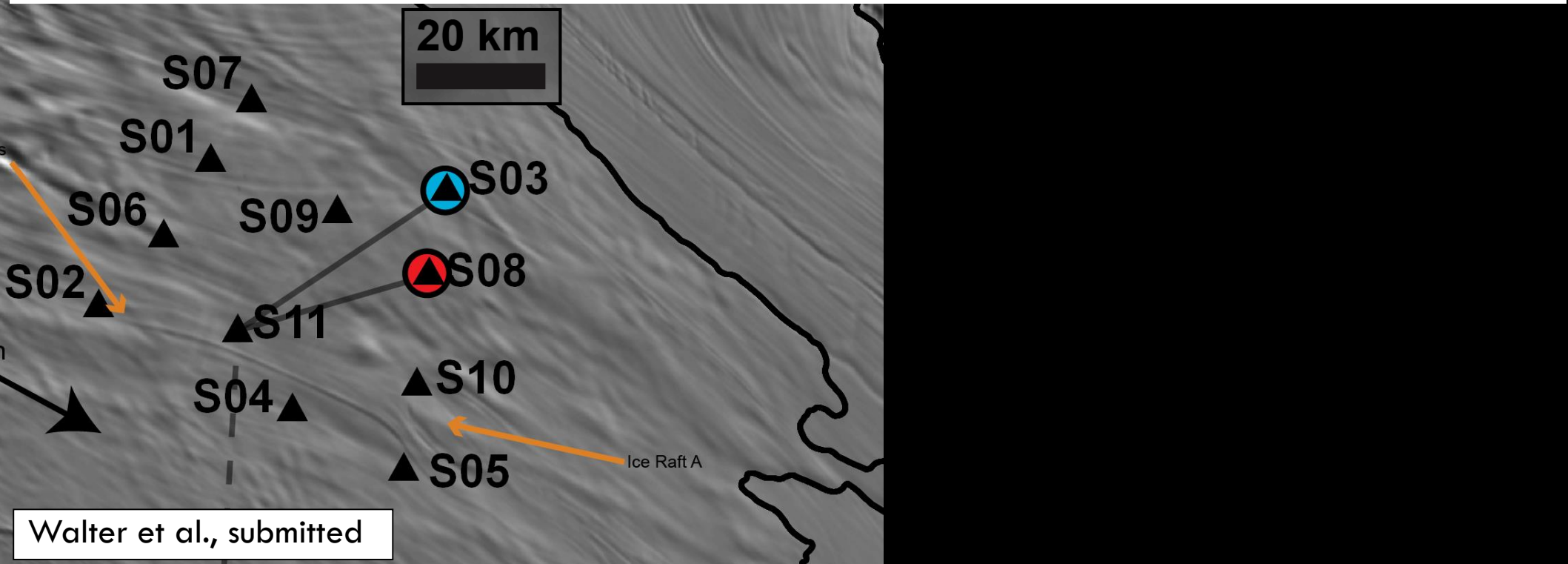
$\beta_{ice} \sim 1800$ m/s
$\beta_{till} \sim 200$ m/s

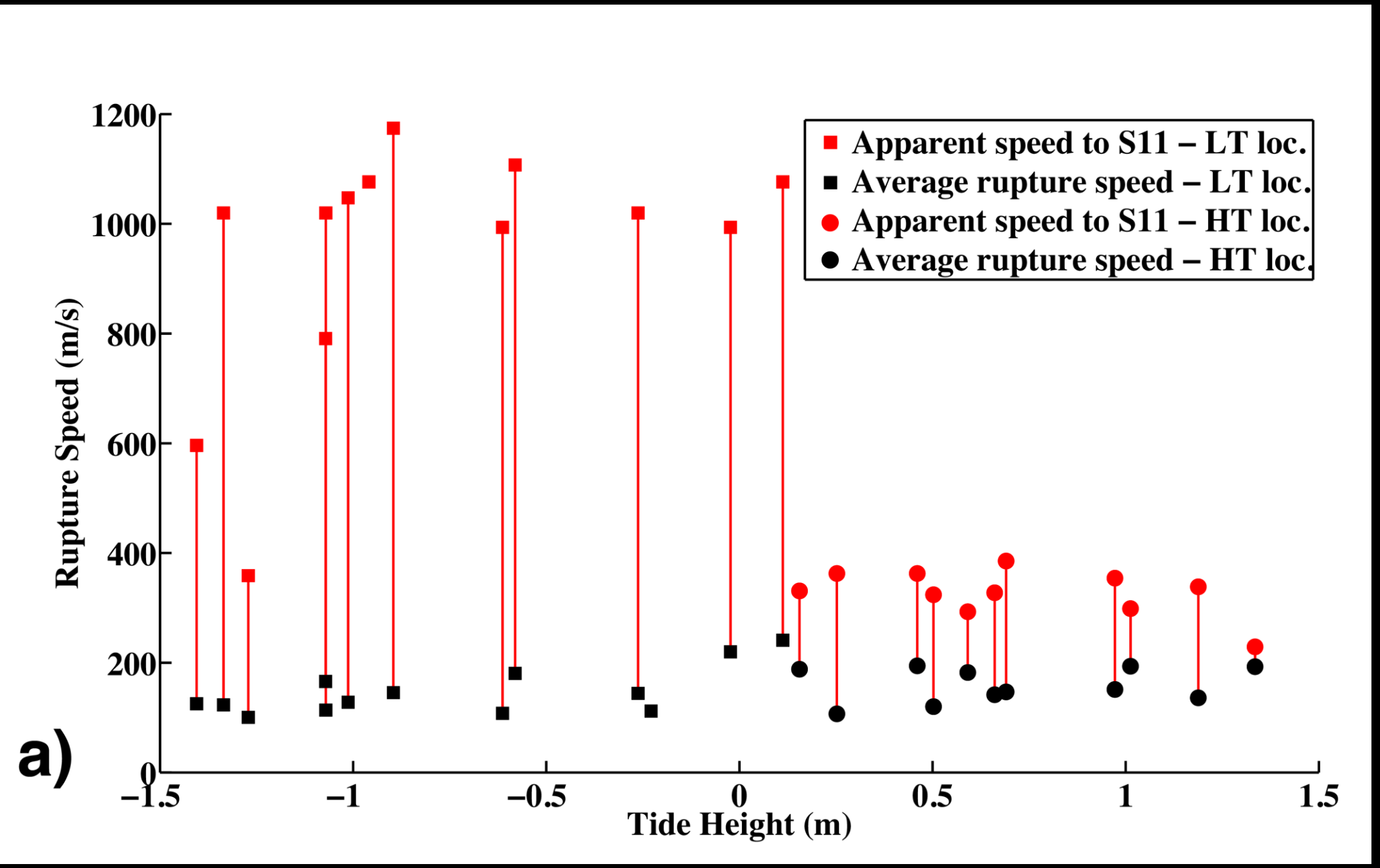
Walter et al., 2011

Chance to collect more data

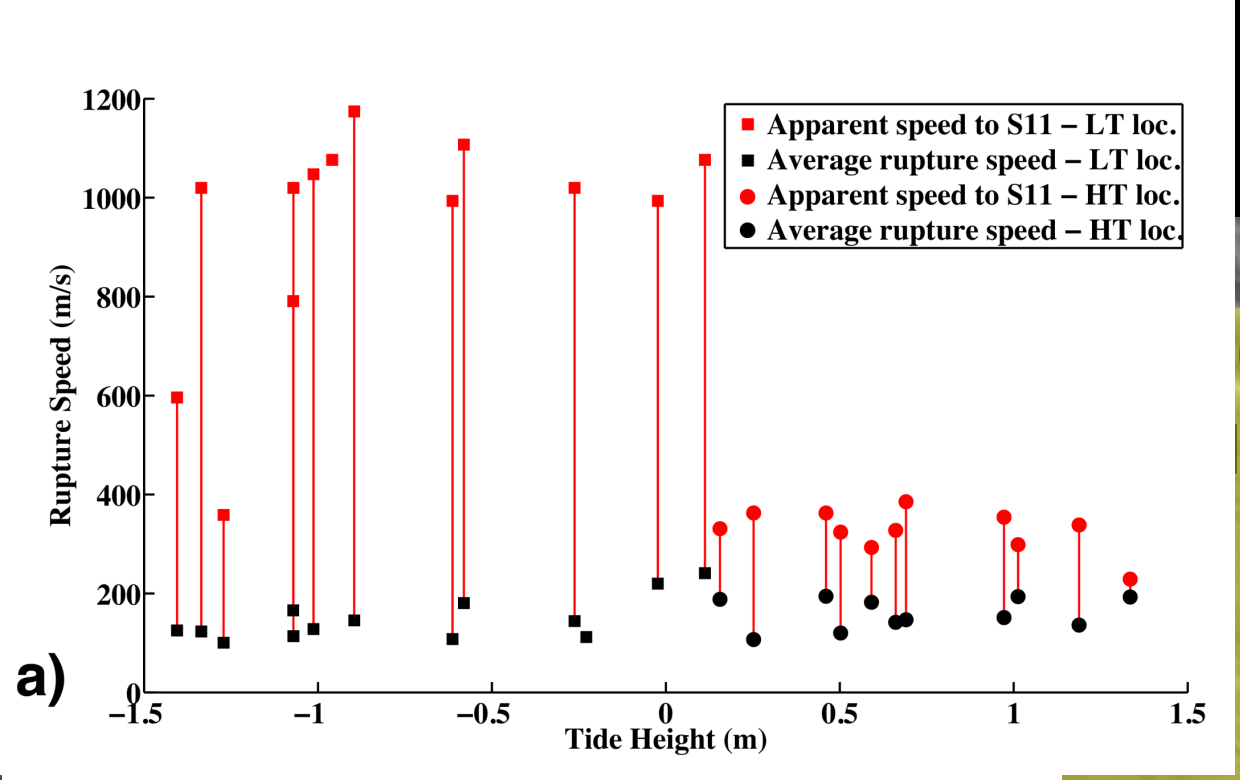


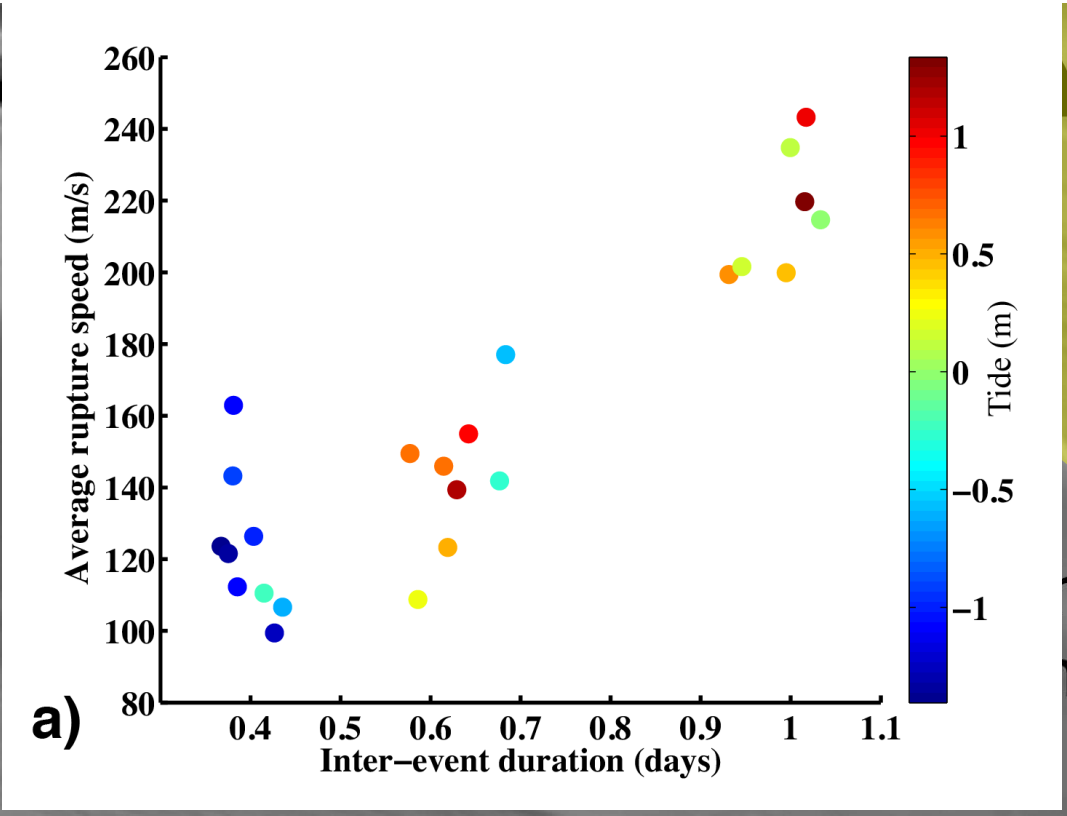

Low tide
High tide
d)
Arrival time (s)
−520
−530
−540
−550
−560
−570
−580
−590
−280
−270
−260
−250
−240
−230
−220
100
90
80
70
60
50
40
30
20
10
0

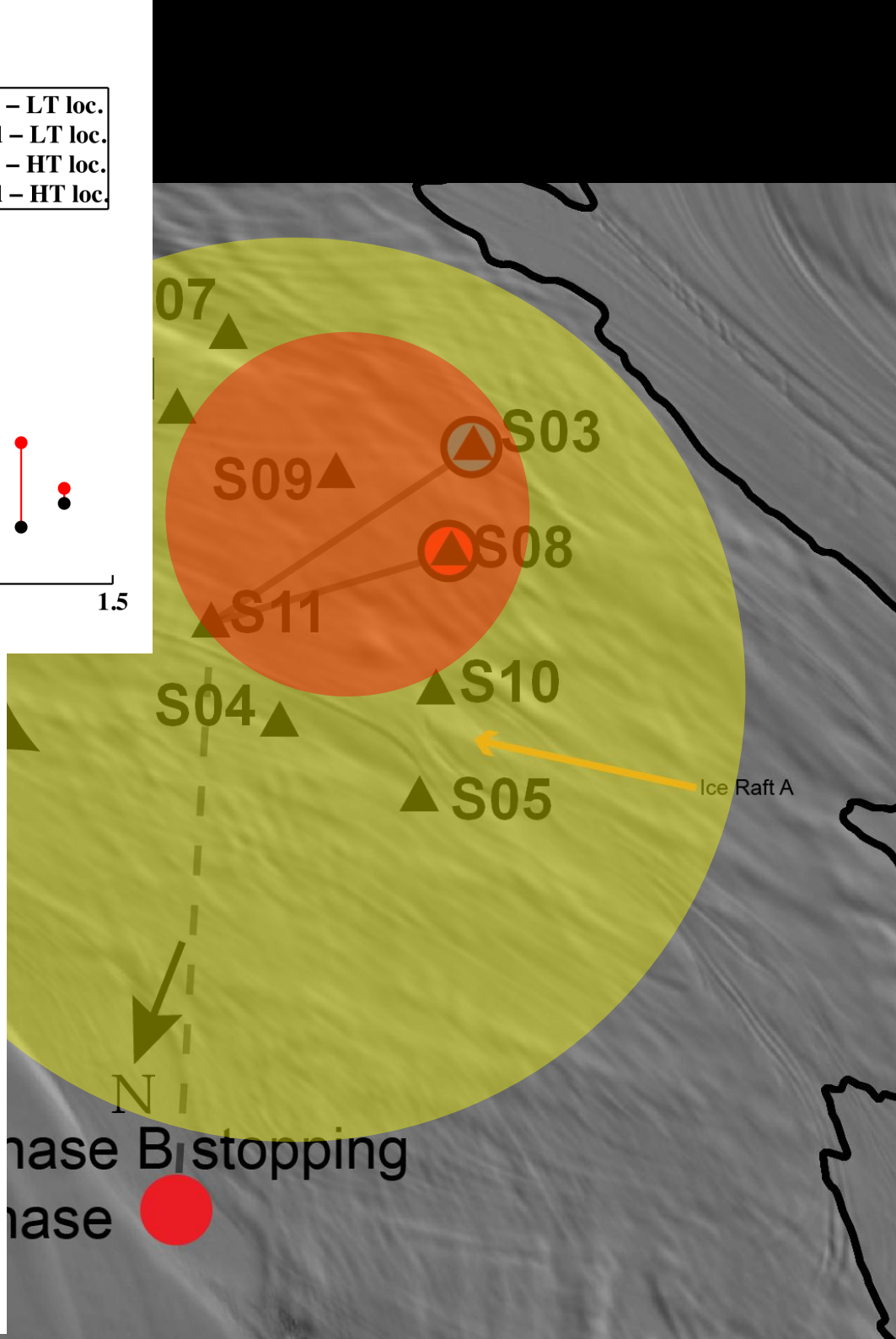

20 km
S07
S01
S03
S06
S09
S08
S02
S11
S10
S04
S05
Ice Raft A
Walter et al., submitted



Walter et al., submitted

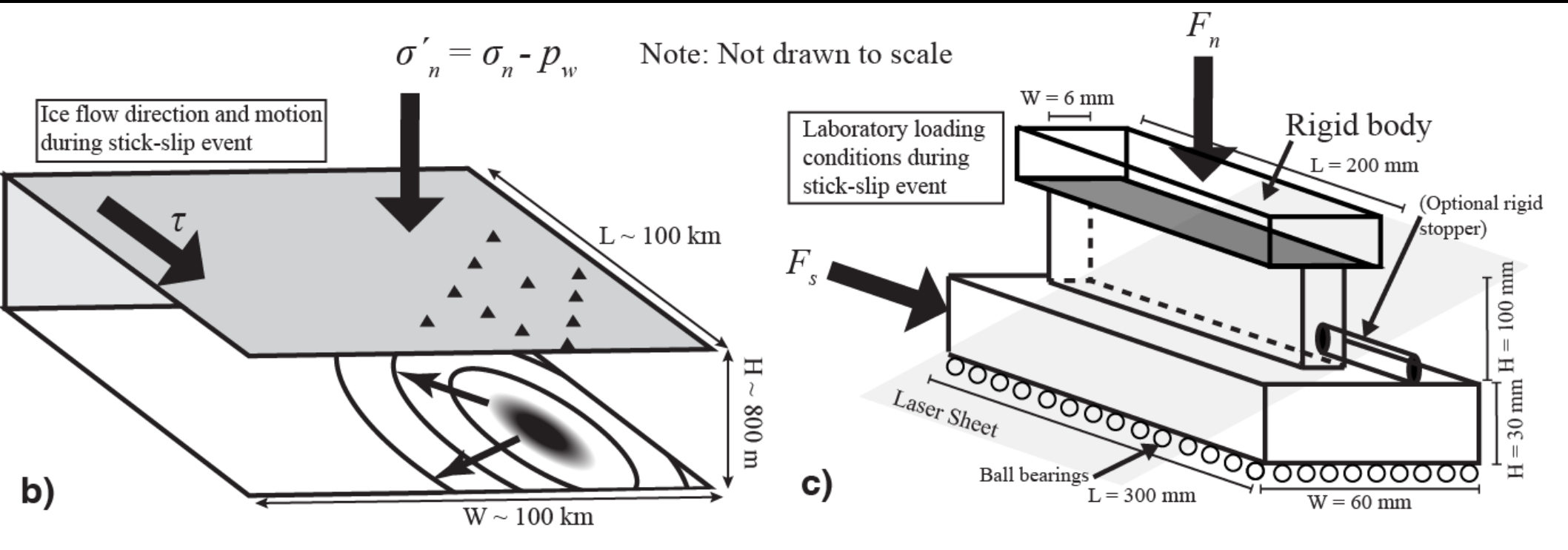

Apparent speed to S11 – LT loc.
Average rupture speed – LT loc.
Apparent speed to S11 – HT loc.
Average rupture speed – HT loc.
Rupture Speed (m/s)
Tide Height (m)
a)


Average rupture speed (m/s)
Inter−event duration (days)
Tide (m)
a)

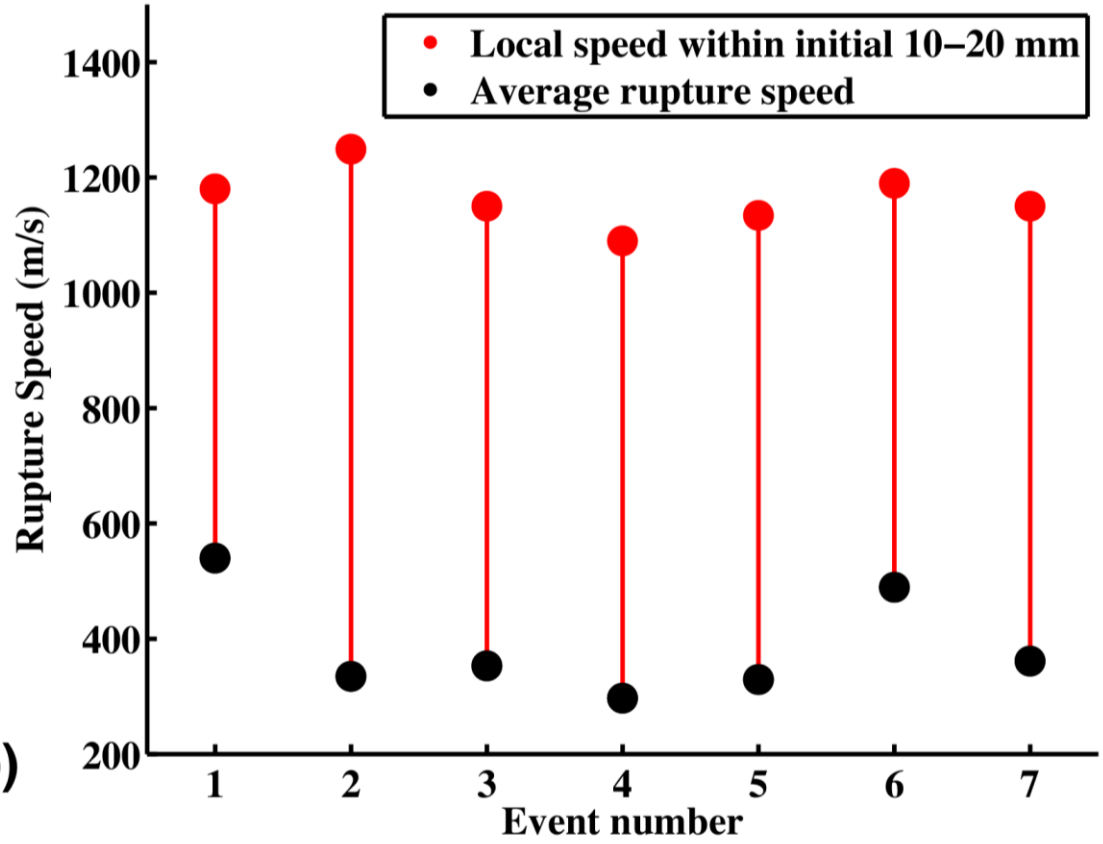

07
S03
S09
S08
S11
S10
S04
S05
Ice Raft A
N
hase B stopping
hase

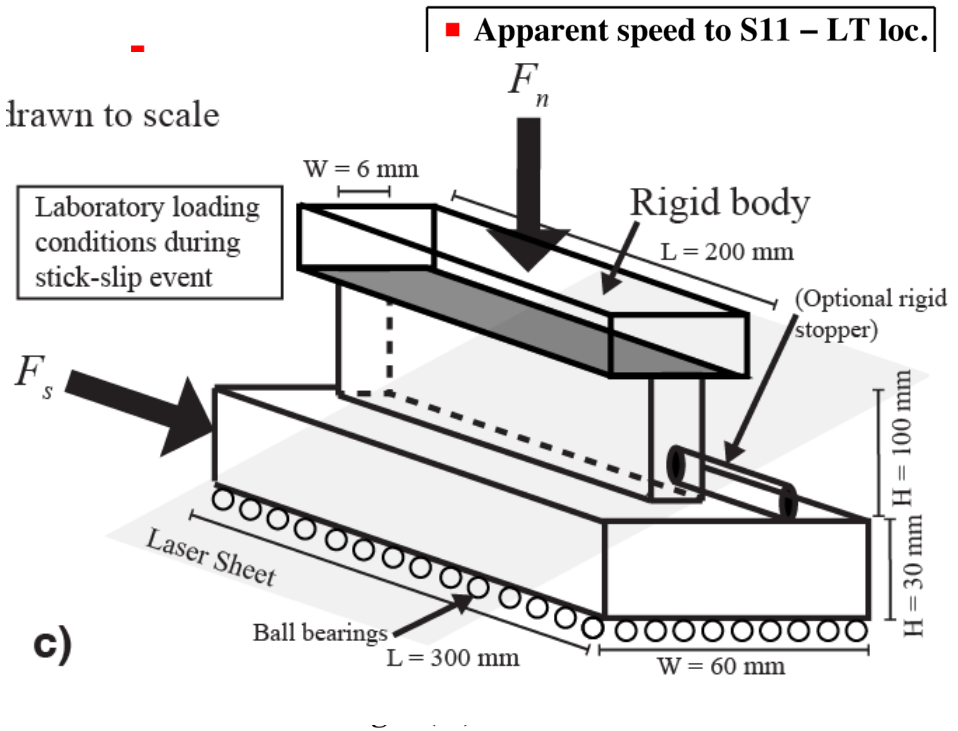
Whillans Ice Plain, West Antarctica observations

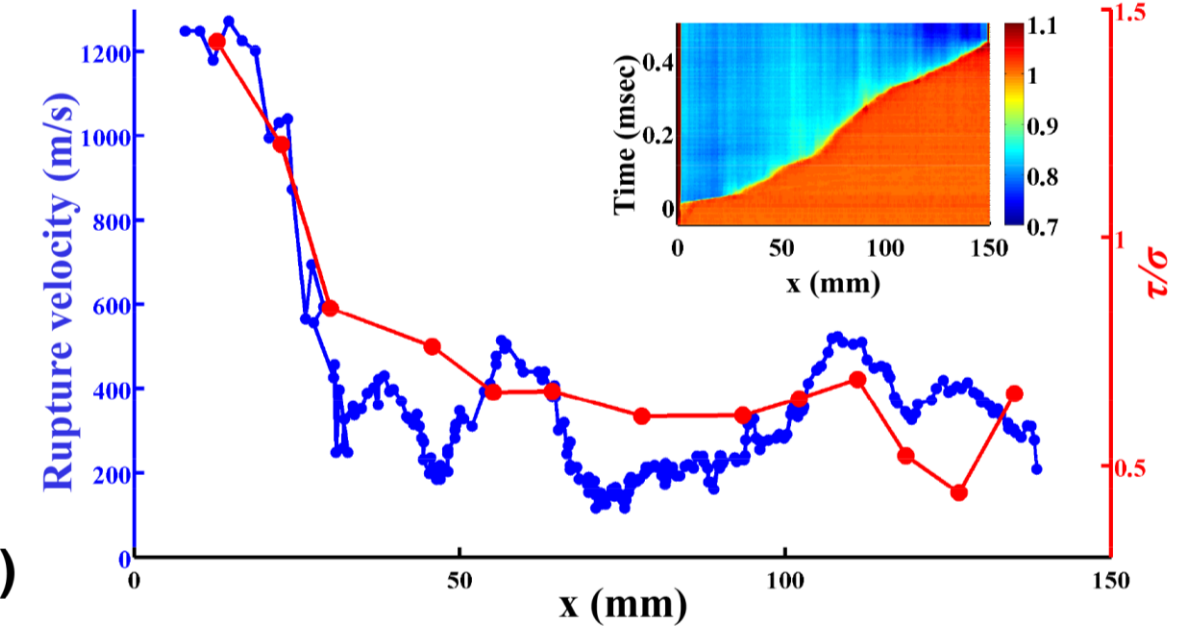
- Variable rupture speeds for different events (~ranging by factor of two)
- Variable rupture speed along rupture path
- Some correspondence between fast rupture and interfacial stresses

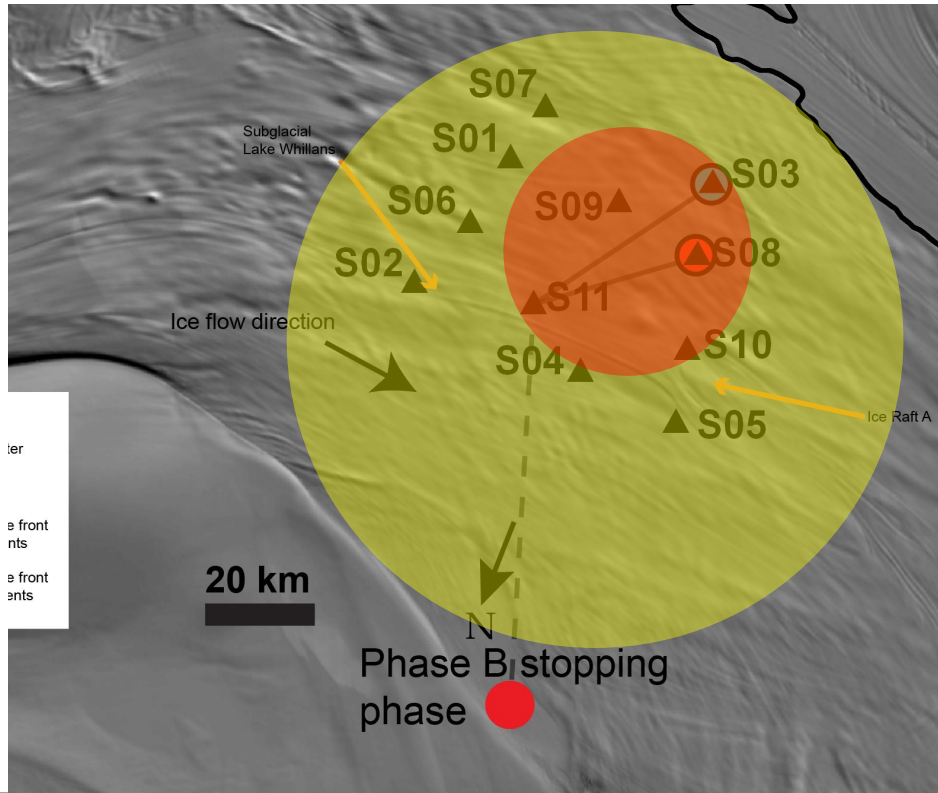


Walter et al., in revision

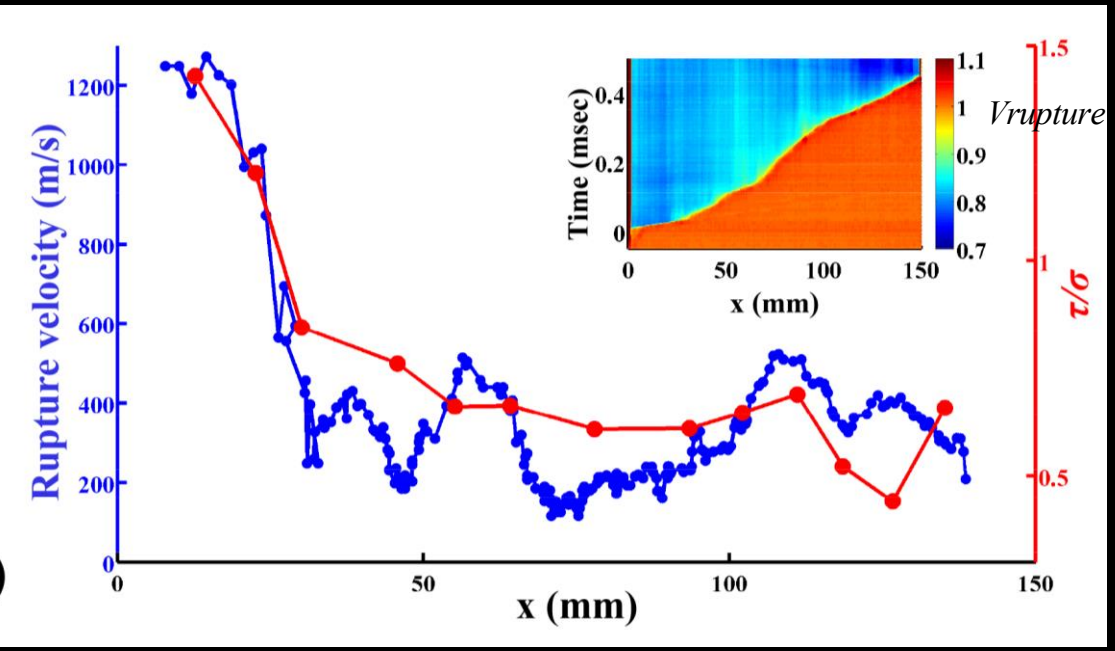

Local speed within initial 10–20 mm
Average rupture speed
Rupture Speed (m/s)
1400
1200
1000
800
600
400
200
1
2
3
4
5
6
7
Event number

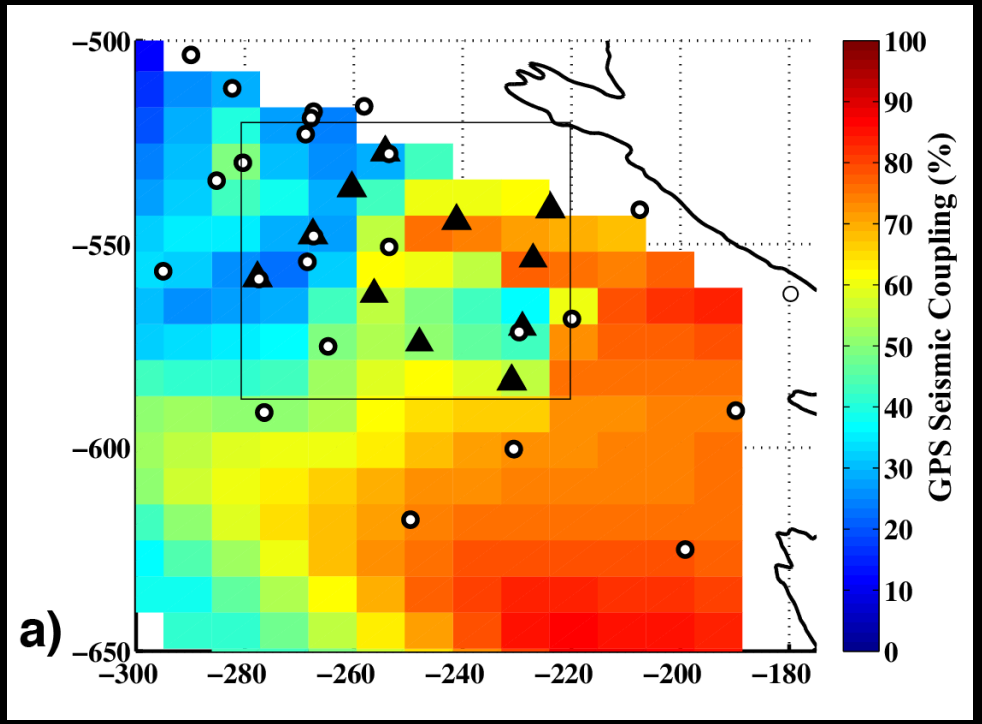

Apparent speed to S11 – LT loc.
drawn to scale
F_n
W = 6 mm
Laboratory loading conditions during stick-slip event
Rigid body
L = 200 mm
(Optional rigid stopper)
F_s
H = 100 mm
H = 30 mm
Laser Sheet
Ball bearings
L = 300 mm
W = 60 mm
c)

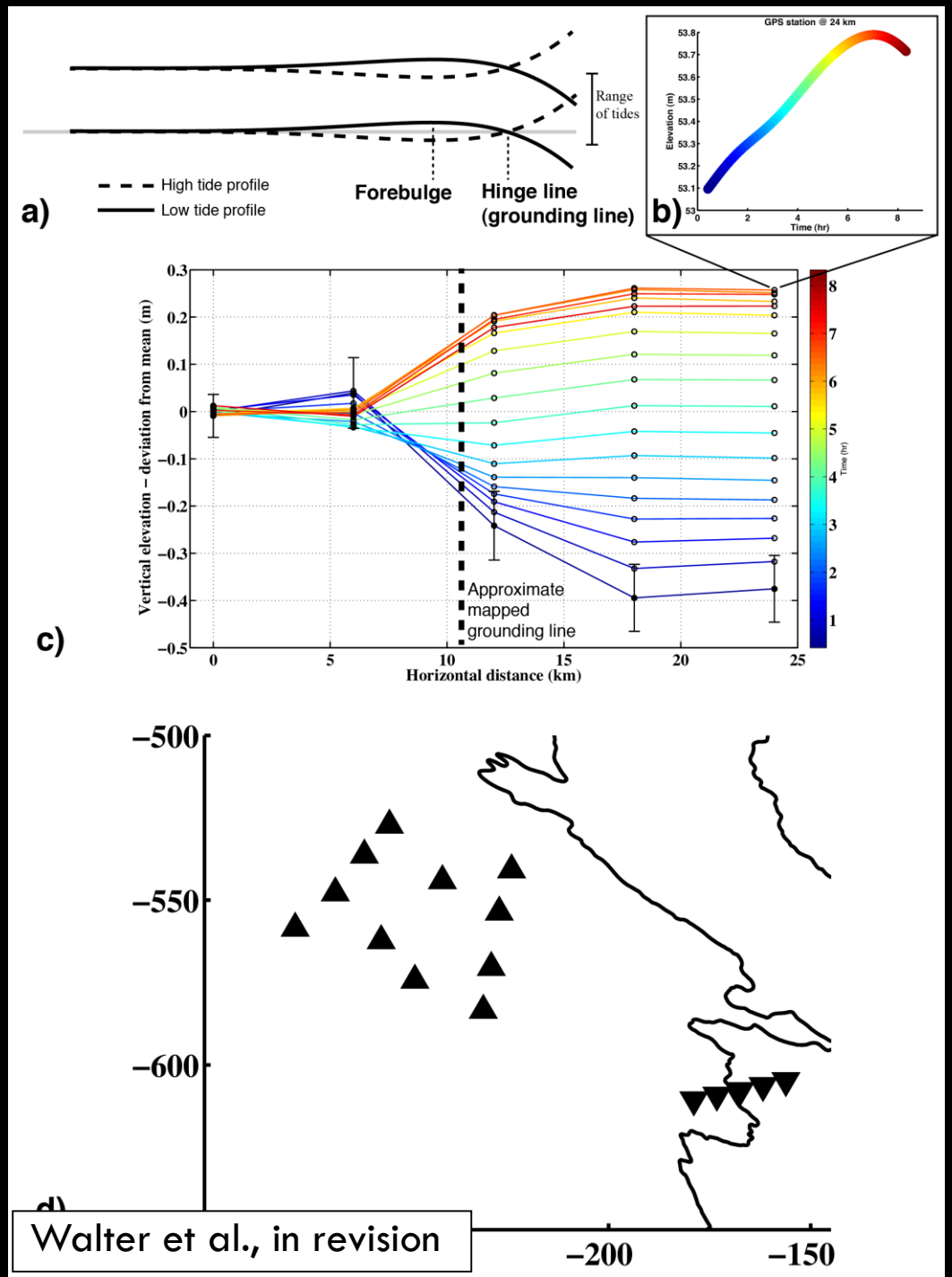

Rupture velocity (m/s)
1200
1000
800
600
400
200
0
50
100
150
x (mm)
Time (msec)
0.4
0.2
0
1.1
1
0.9
0.8
0.7
x (mm)
1.5
1
0.5
τ/σ


S07
S01
Subglacial Lake Whillans
S03
S06
S09
S08
S02
S11
Ice flow direction
S10
S04
S05
Ice Raft A
20 km
N
Phase B stopping phase

$V_{rupture} \sim \tau/\sigma$

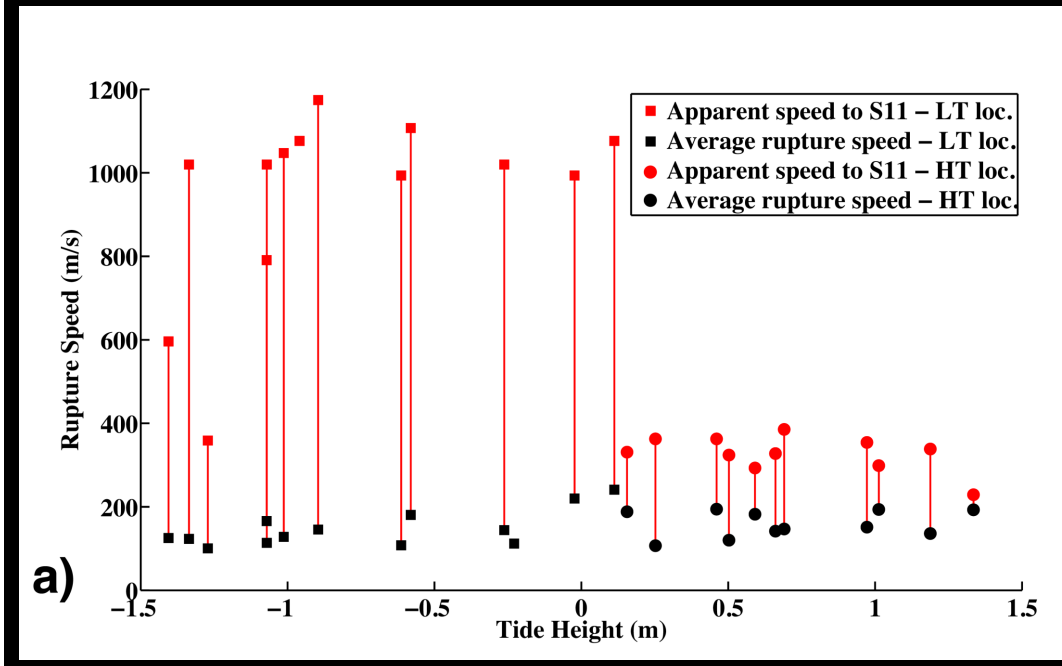






Walter et al., in revision

$$V_{rupture} \sim \tau/\sigma$$



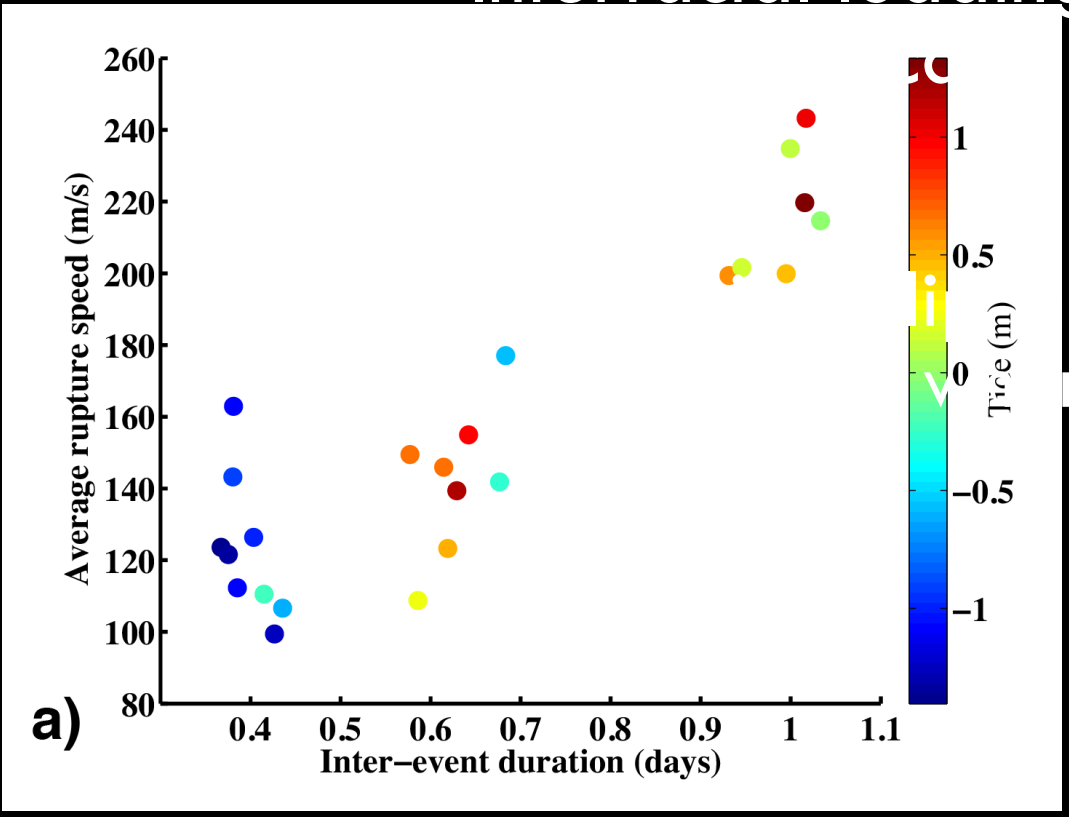
What we learn about frictional stick-slip, *in general*:

- No characteristic failure threshold

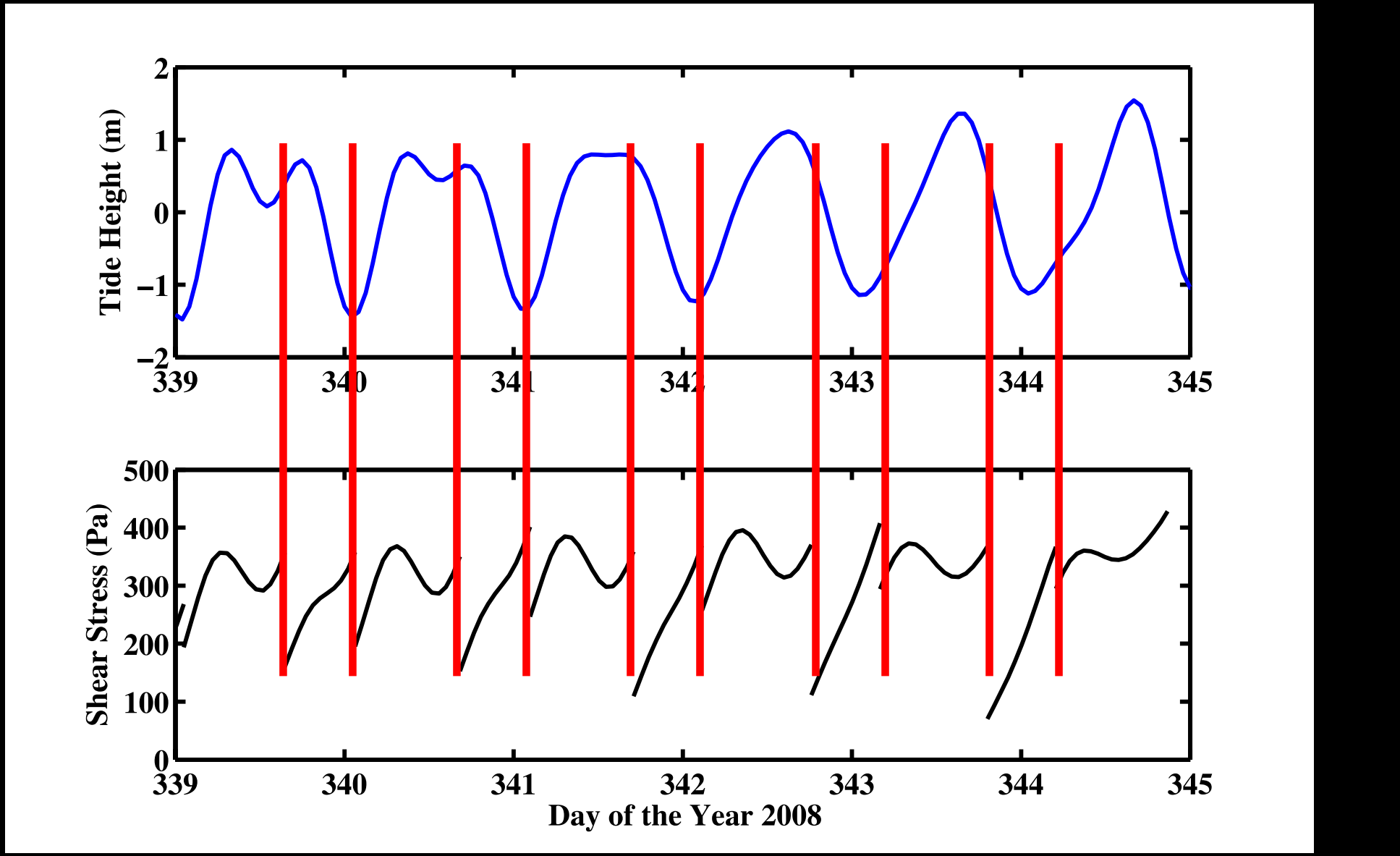
- Interfacial loading "steers" rupture at local

$$V_{rupture} \sim \tau/\sigma$$

itiation) is still a big
n do earthquakes start?)



Questions?


Tide Height (m)
2
1
0
−1
−2
339
340
341
342
343
344
345
Shear Stress (Pa)
500
400
300
200
100
0
339
340
341
342
343
344
345
Day of the Year 2008


QUESTIONS?