Spatial distribution of frictional ice-bed interactions beneath the Whillans Ice Plain, West Antarctica

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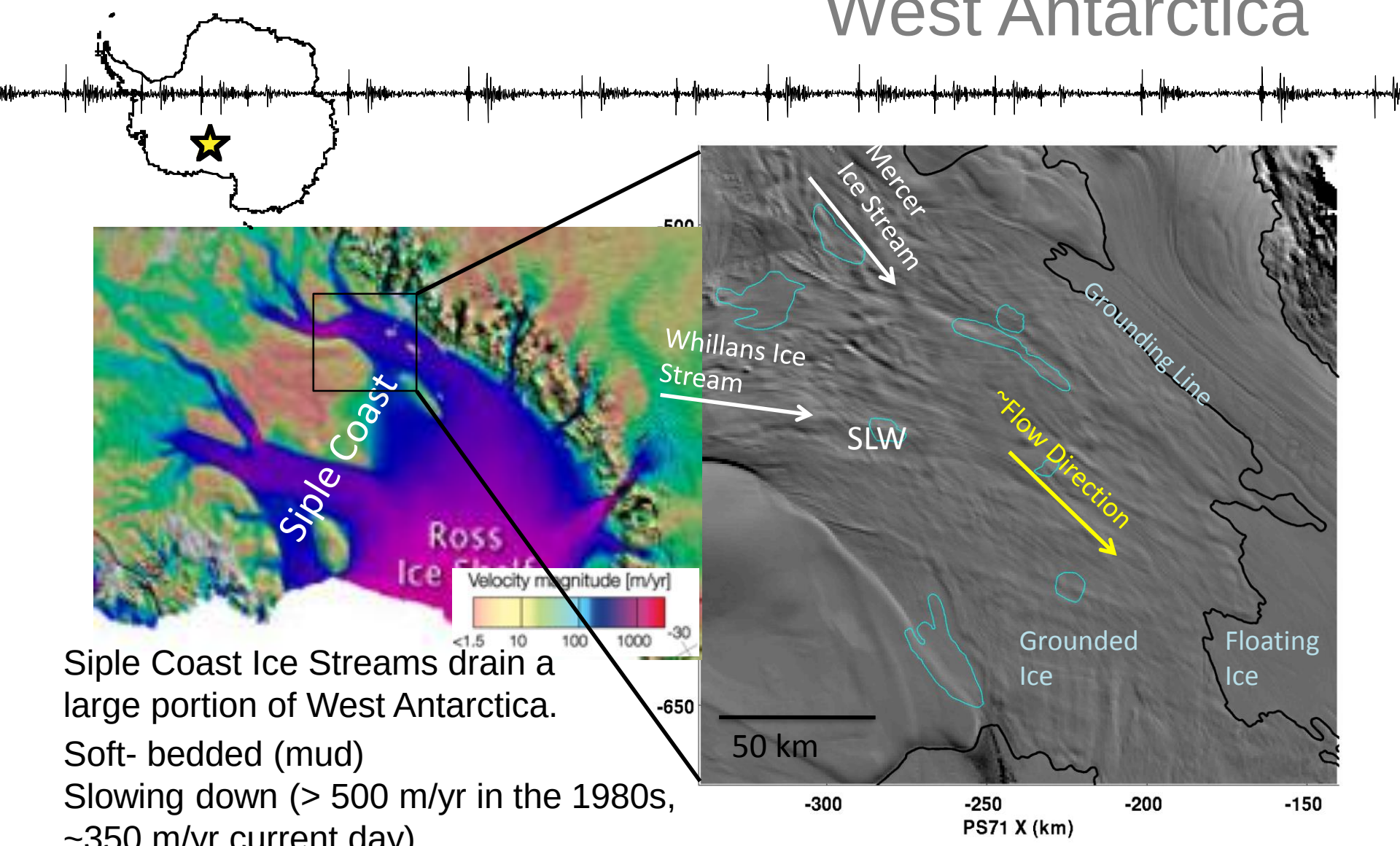
Whillans Ice Plain, West Antarctica

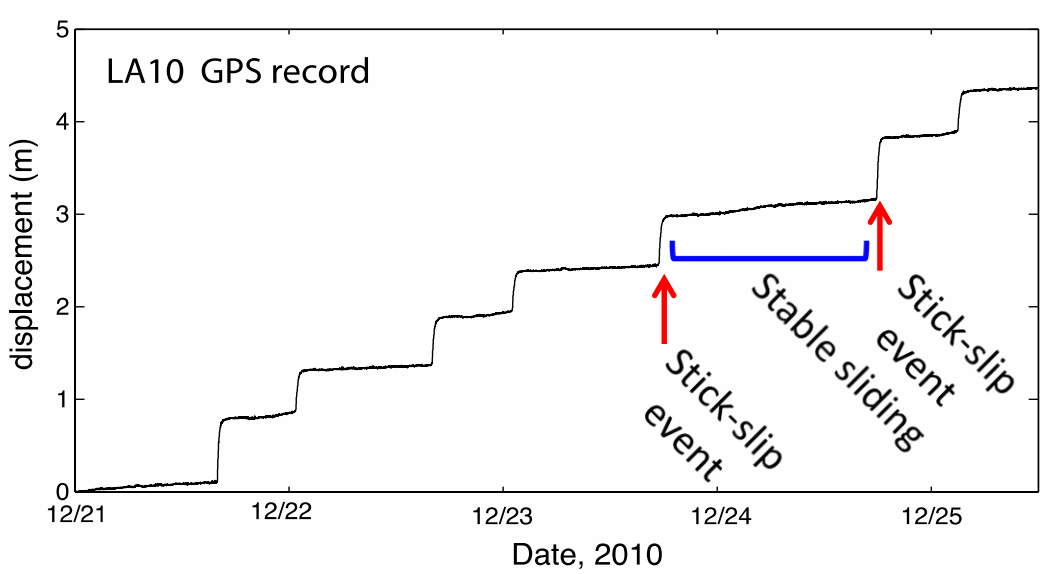


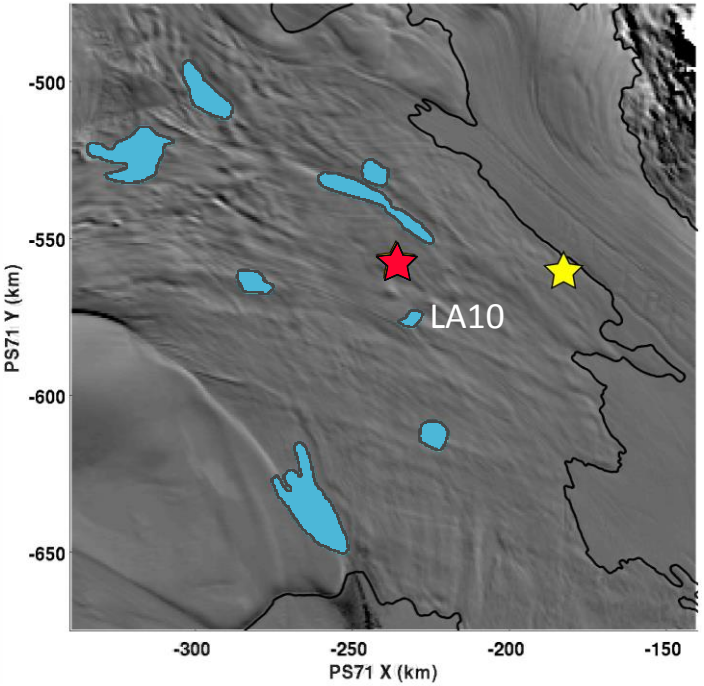
Siple Coast Ice Streams drain a large portion of West Antarctica.

Soft- bedded (mud)

Slowing down (> 500 m/yr in the 1980s, ~350 m/yr current day)

WIP stick-slip cycle





- Like the earthquake cycle: *un*stable sliding during stick-slip events
- Stars='epicenters' (Pratt et al., 2014)
  - Red star: high tide slip initiation ('central'))
  - Yellow star: low tide slip initiation ('grounding zone')
- Small basal earthquakes occur in a few locations during the stick-slip cycle (Winberry et al., 2013)

Motivation:

1. What basal mechanism causes this ice stream to move by stick-slip?
2. Is this important anywhere else in the ice sheet?
3. What can we learn about fault mechanics?

Frozen till

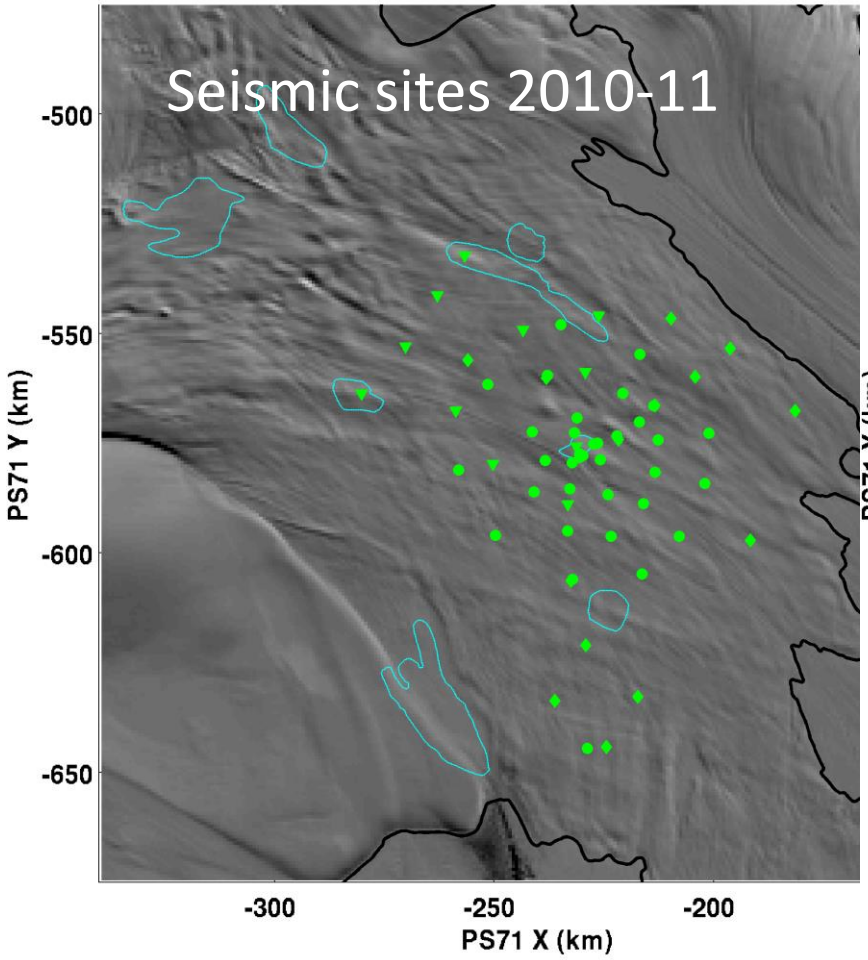
Bedrock outcrop

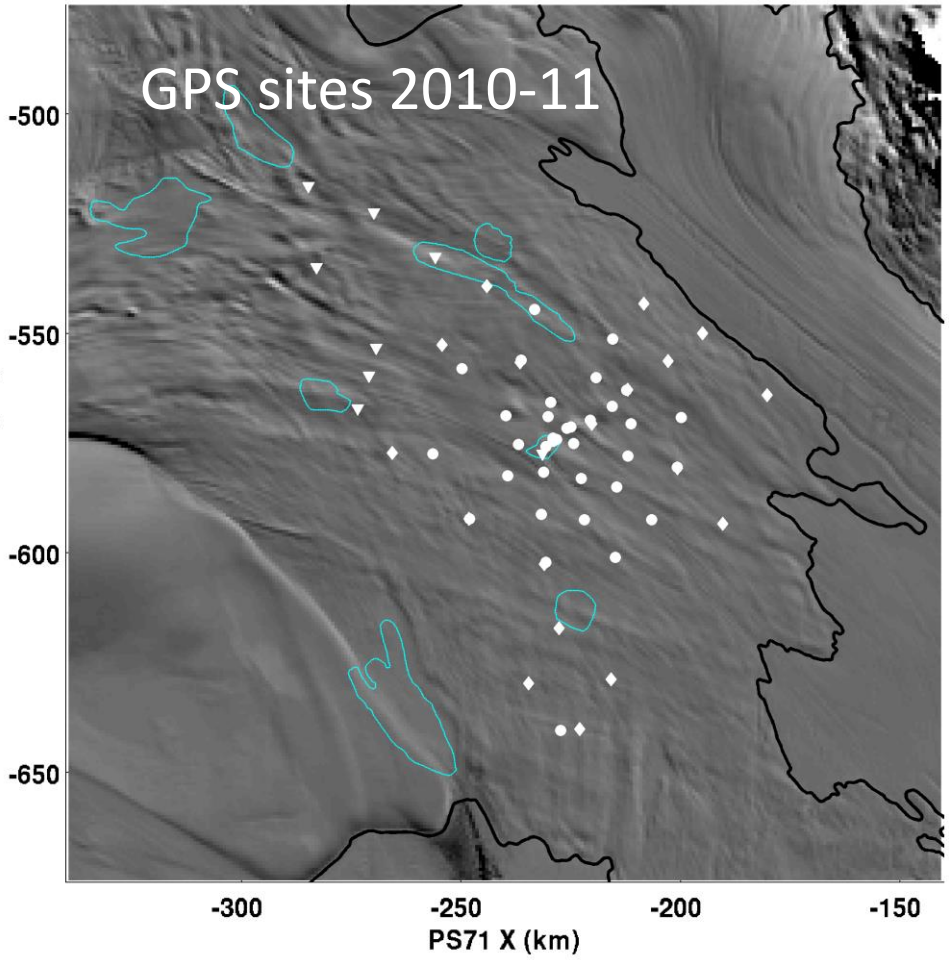
Highly consolidated till

Question: What is the spatial extent of frictional ice-bed interactions beneath the Whillans Ice Plain?

1. Seismic coupling (creeping vs locked, GPS)
2. Spatial distribution of basal seismicity

Seismic and GPS sites

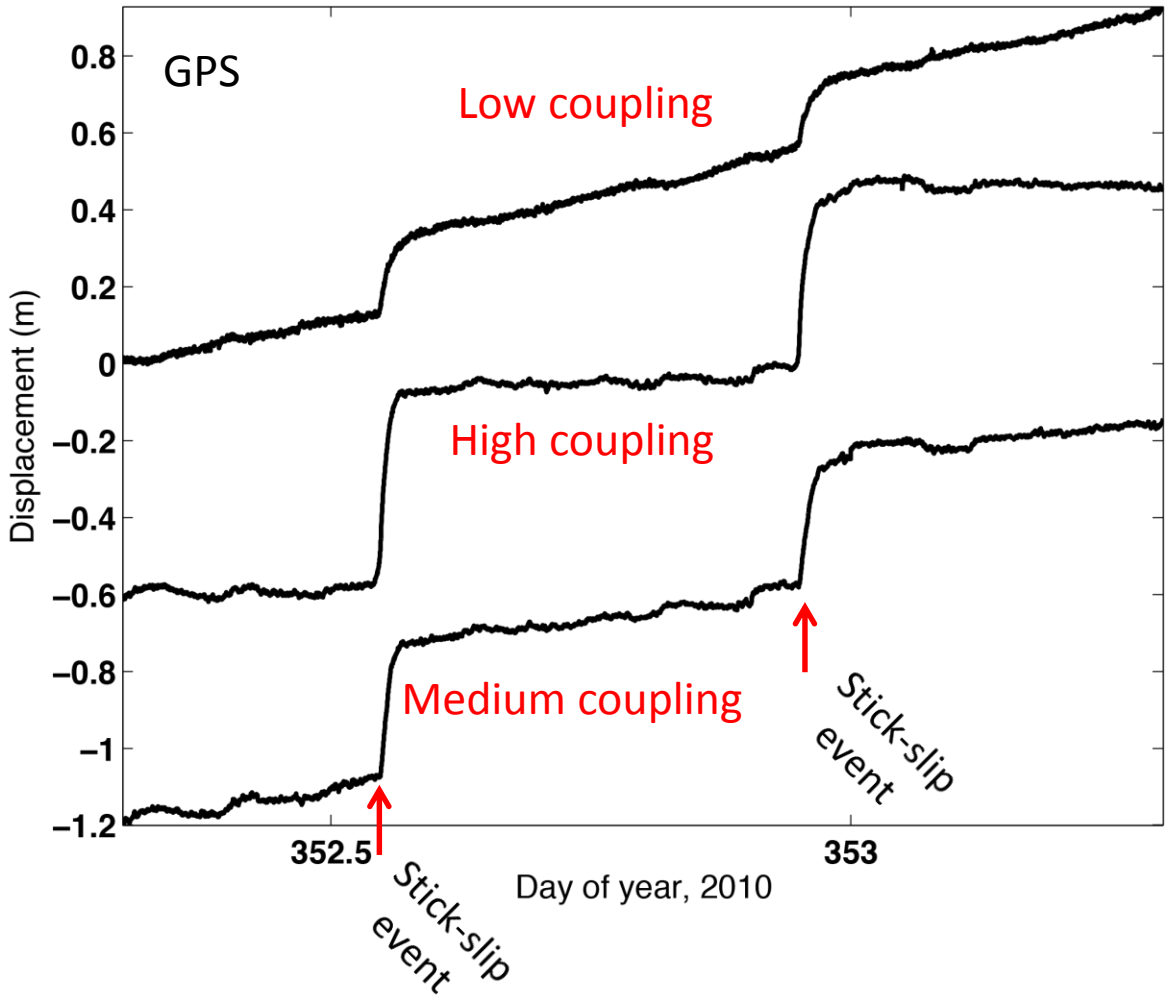




Seismic Coupling:

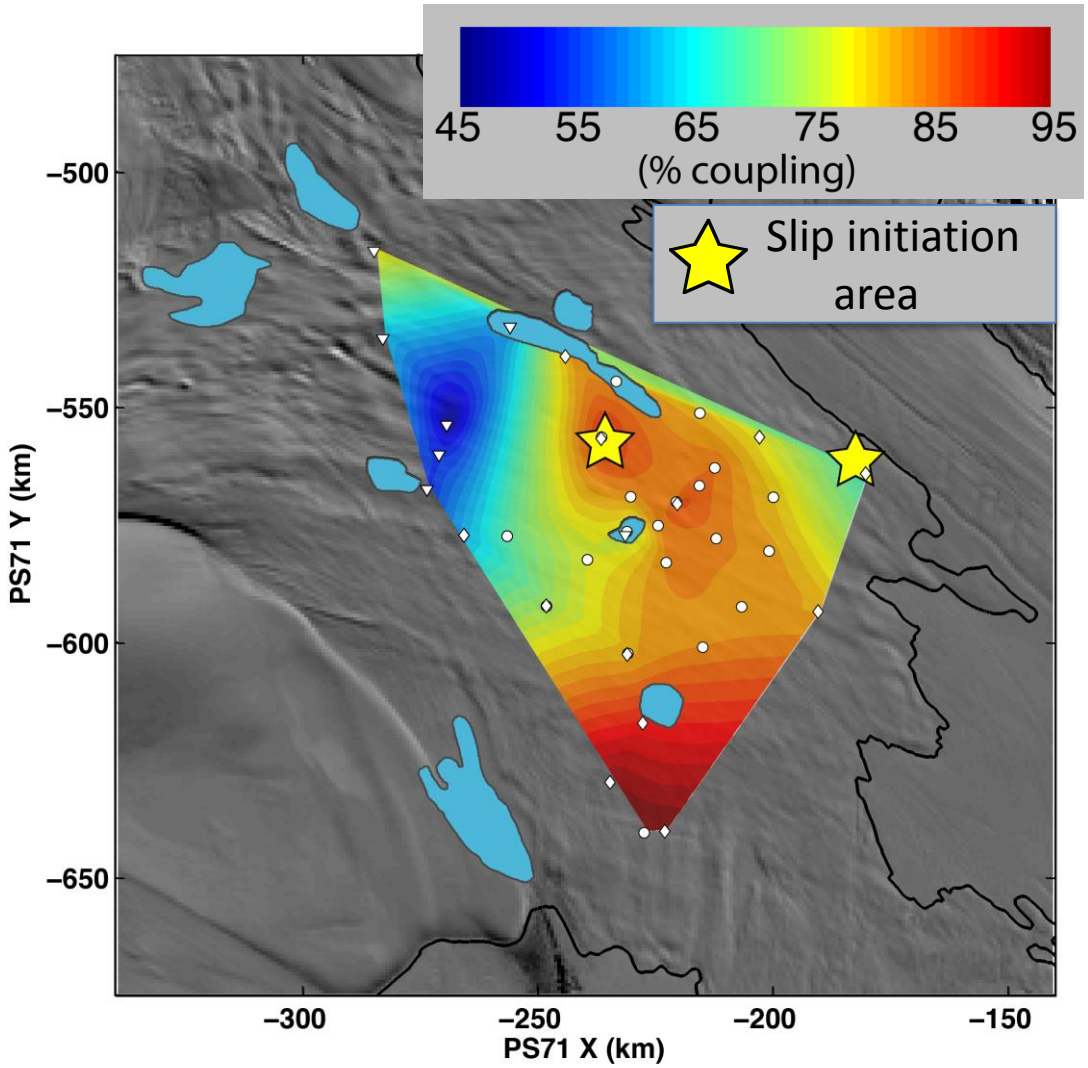
(or How sticky is the bed?)

% of total motion on a fault that occurs during unstable sliding



- Proxy for bed strength
- Variable across the Ice Plain

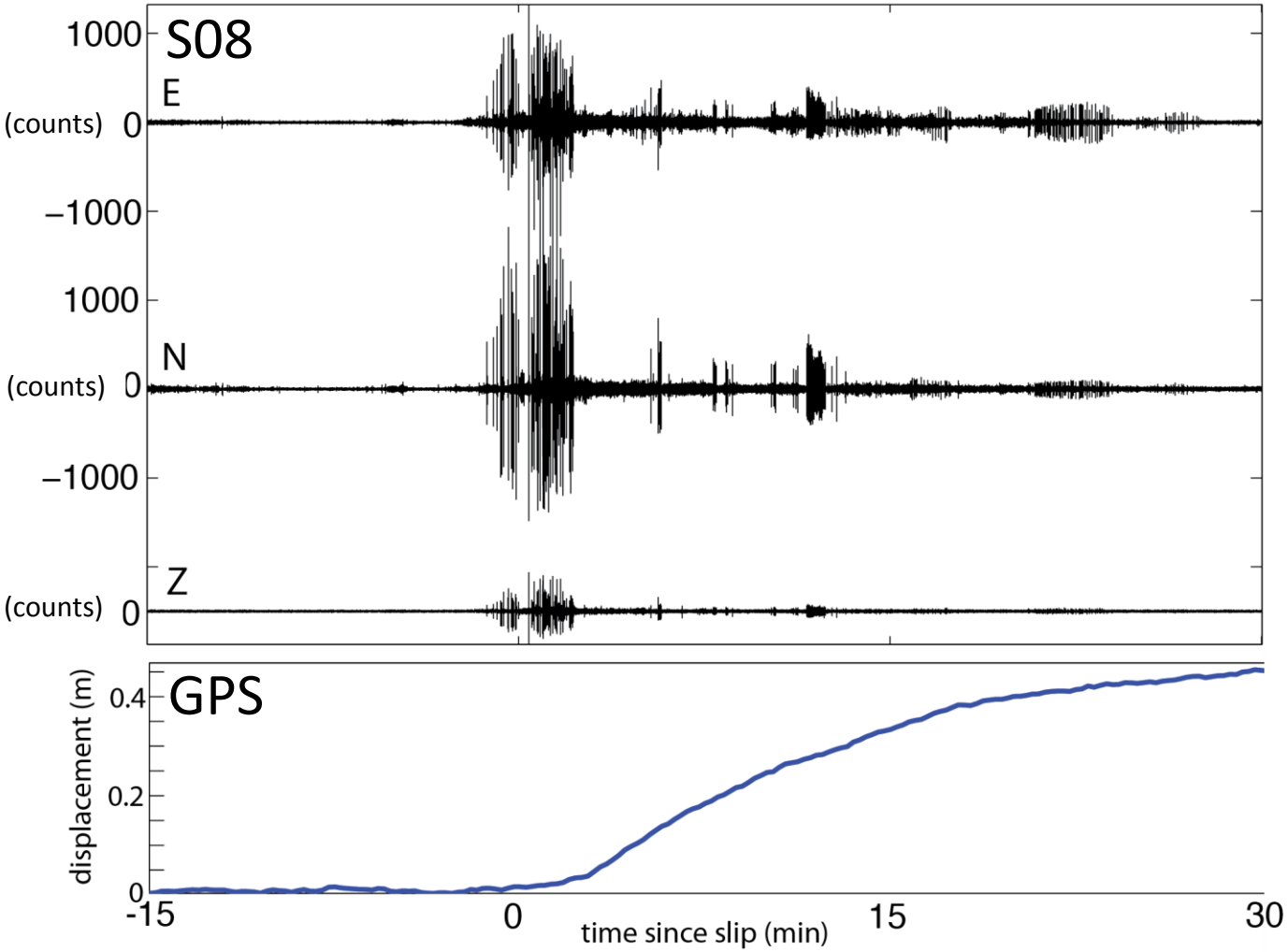
Spatially variable seismic coupling



- The bed is stickier near the central initiation area
- Responds to hydrology
- Patchy

Large scale asperity

Basal earthquakes during slip events

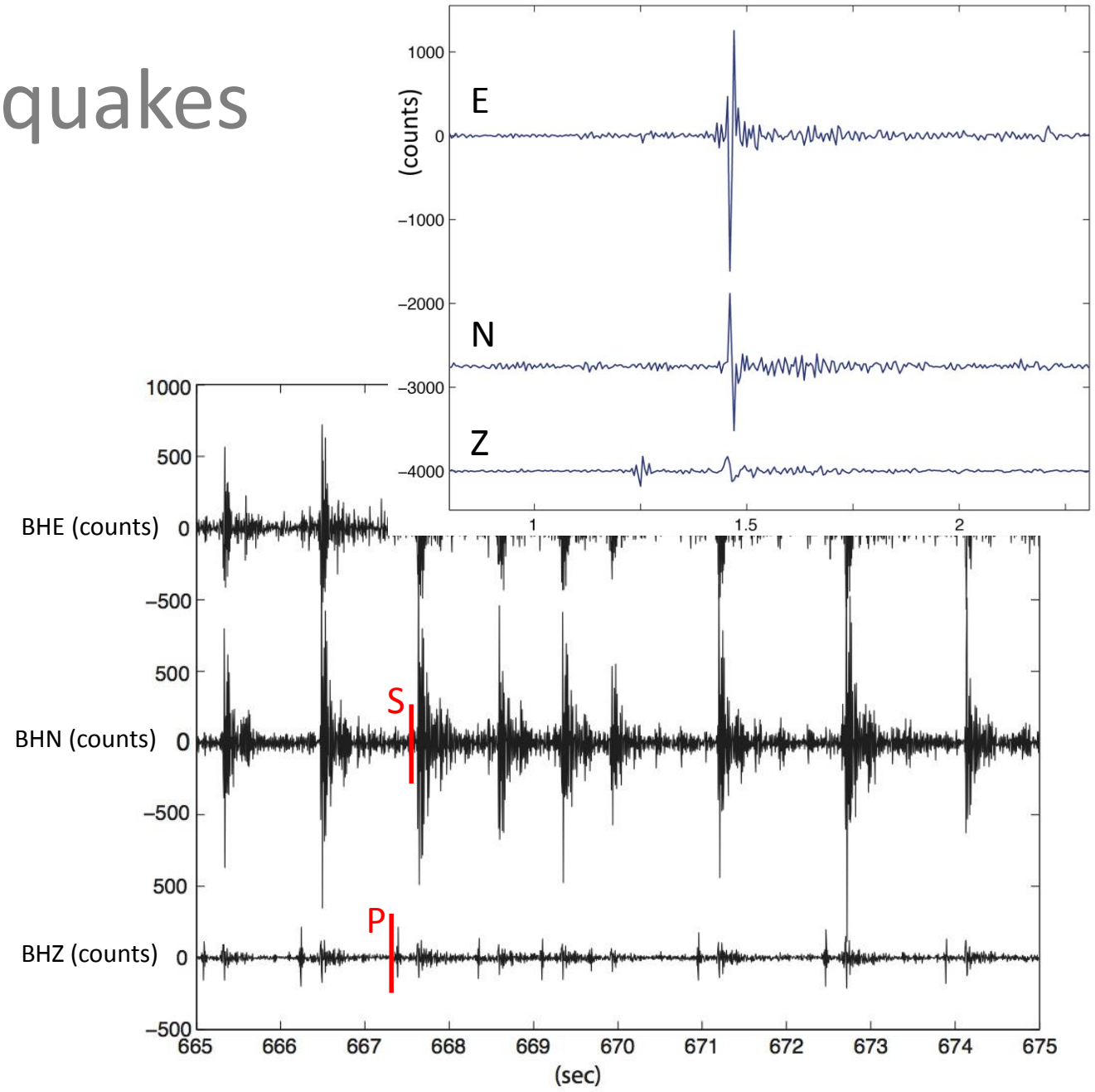


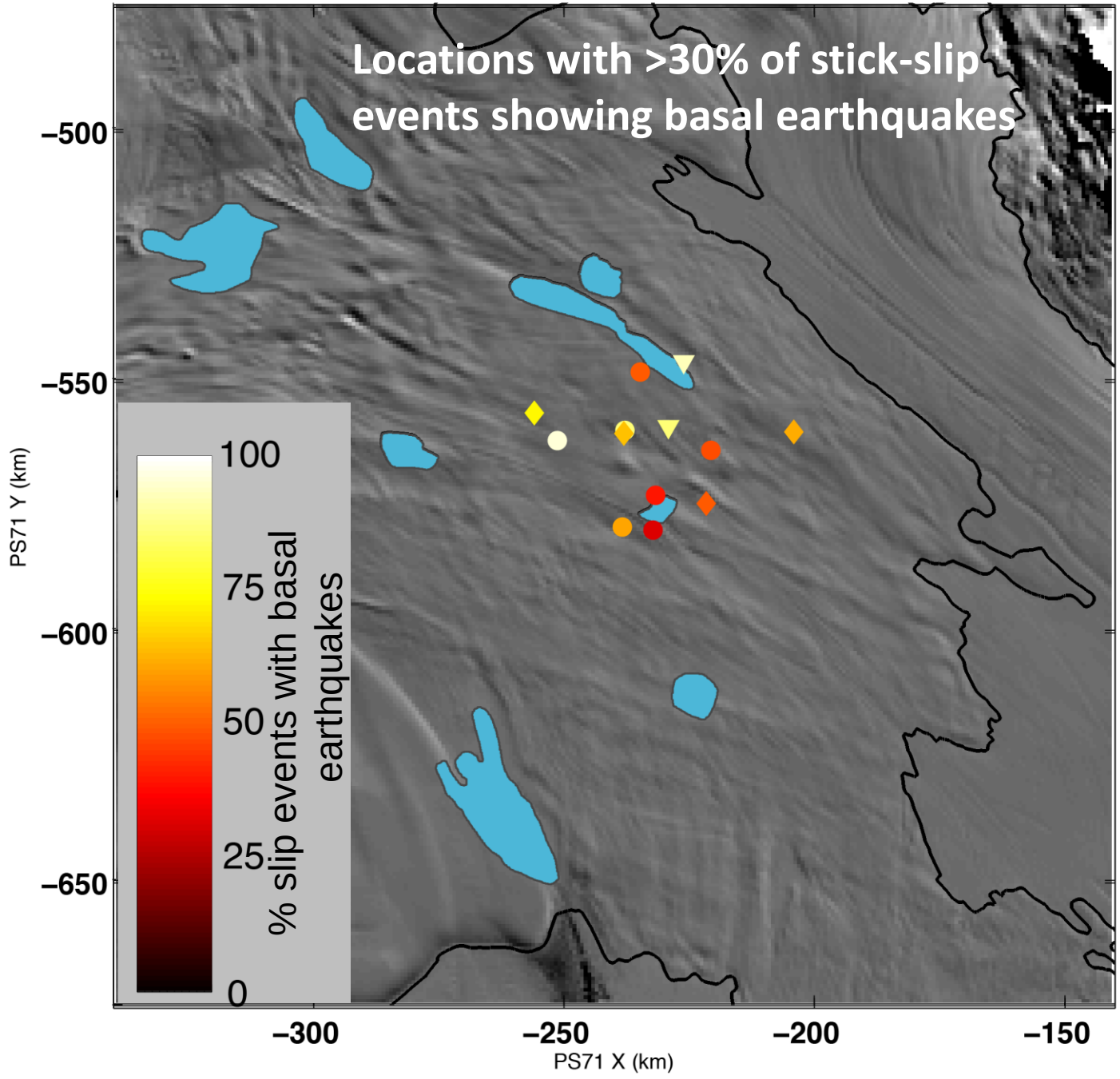
1HZ high pass filtered data

•Occur during stick-slip events

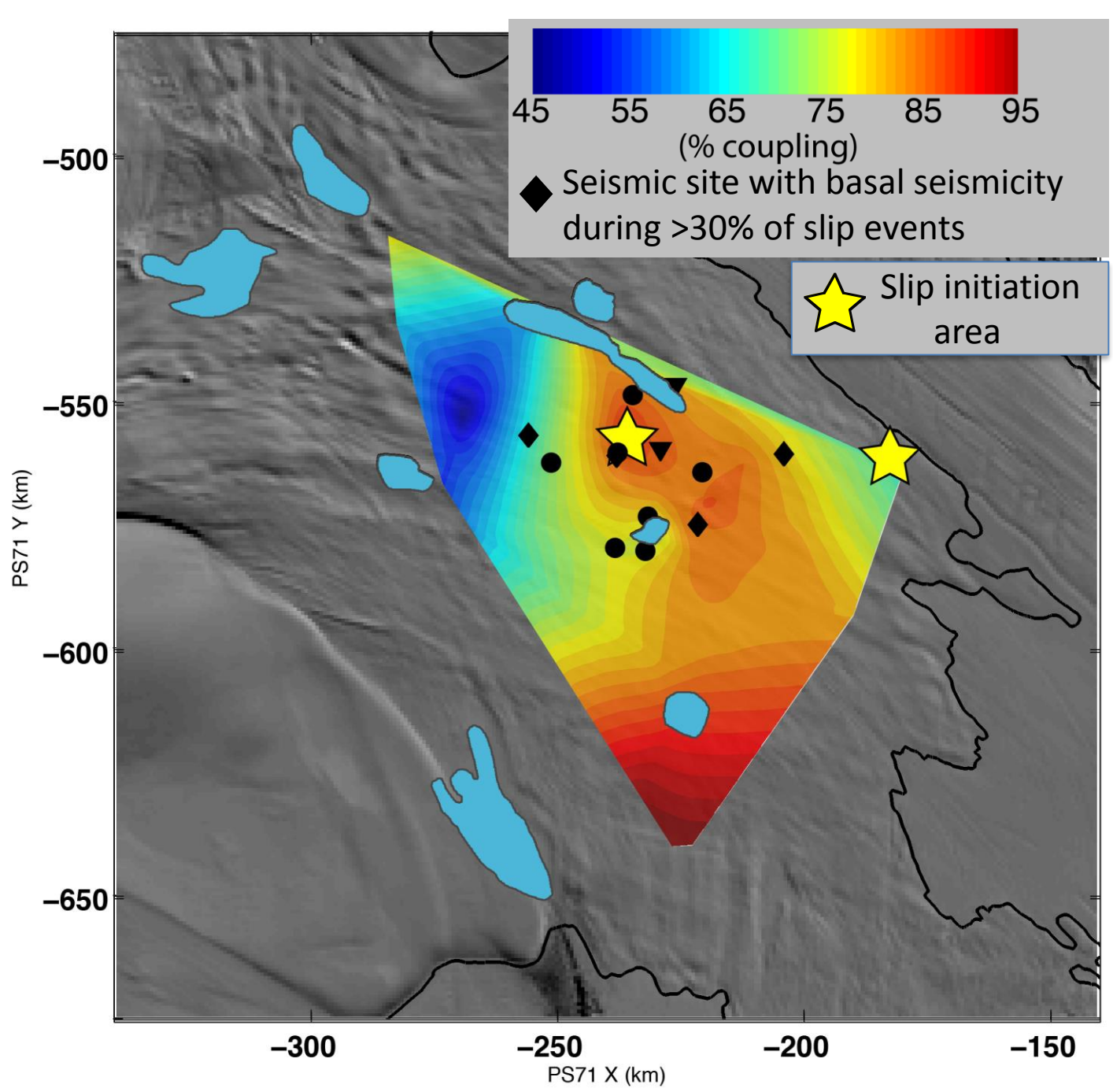
Basal Earthquakes

- Very small, very close (underneath seismometer)
- 750-1600m away
  - Ice-bed interface
- Only visible on a single seismometer





- Frictional ice-bed interactions seem to be focused in a limited area
- Variable seismicity at neighboring sites indicates high spatial variability in bed conditions



- Central slip initiation area of high coupling strongly associated with basal earthquakes

- These earthquakes are an important clue to the mechanism of stick-slip

Possible sources for basal earthquakes:

- Brittle failure of:
  - ice (ex. basal crevassing or thrusting)
  - frozen ice-bed interface
  - brittlely deforming till (highly consolidated or low water-content)
  - bedrock
- Scraping of ice-entrained rocks over bedrock or large clasts in the till

Implications for:

- Importance of stick-slip in ice stream/glacier motion
- Importance of sub-ice geology in controlling motion
- Subglacial erosion
- Frictional ice-bed interactions and dynamic instability

Conclusions

- High seismic coupling (stronger bed) in the central initiation area
- Basal seismicity is clustered near the central initiation area, and in the area of high seismic coupling
  - Variable seismicity at neighboring sites indicates high spatial variability in bed conditions
  - Basal earthquakes do indicate locations of sticky spots!
- This large scale ‘sticky spot’ is characterized by small basal earthquakes, although not everywhere and not all of the time
- FRICTION! A significant potion of the WIP has frictional ice-bed interactions
  - Not viscous, not plastic…

Future Work: Borehole seismic deployment in the WIP to study these basal earthquakes