Longitudinal Seismic Waves in the Ross Ice Shelf Excited by Whillans Ice Stream Stick-Slip Events

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Rapid variations in the flow rate of upstream glaciers and ice streams may cause significant deformation of ice shelves. The Whillans Ice Stream (WIS) represents an extreme example of rapid variations in velocity, with motions near the grounding line consisting almost entirely of once or twice-daily stick-slip events with a displacement of up to 0.7 m (Winberry et al, 2014). Here we report observations of longitudinal waves from the WIS slip events propagating hundreds of kilometers across the Ross Ice Shelf (RIS) detected by more than 20 broadband seismographs deployed on the ice. The WIS slip events consist of rapid basal slip concentrated at three high friction regions (often termed sticky-spots or asperities) within a period of about 25 minutes (Pratt et al, 2014). Compressional displacement pulses from all three sticky spots are detected across most of the RIS up to about 600 km away from the source. The largest pulse results from the third sticky spot, located along the northwestern grounding line of the WIS. The best fitting propagation velocity, estimated using least squares and assuming the known location of the 2nd sticky spot, is 2.8 km/s. This agrees well with the predicted velocity derived by Press and Ewing (1951) for longitudinal wave propagation in a floating ice shelf. Particle motions are within the horizontal plane and roughly radial with respect to the WIS sticky-spots, but show significant complexity, presumably due to differences in ice velocity, thickness, and the thickness of water and sediment beneath. Strains within the ice shelf during wave passage are on the order of 10^{-6} s^{-1}, which is similar to strains from the surface waves of M_w ~ 9 earthquakes, which are known to trigger icequakes in continental ice sheets (Peng et al., 2014). Study of this phenomenon should lead to greater understanding of how the ice shelf responds to sudden forcing around the periphery.

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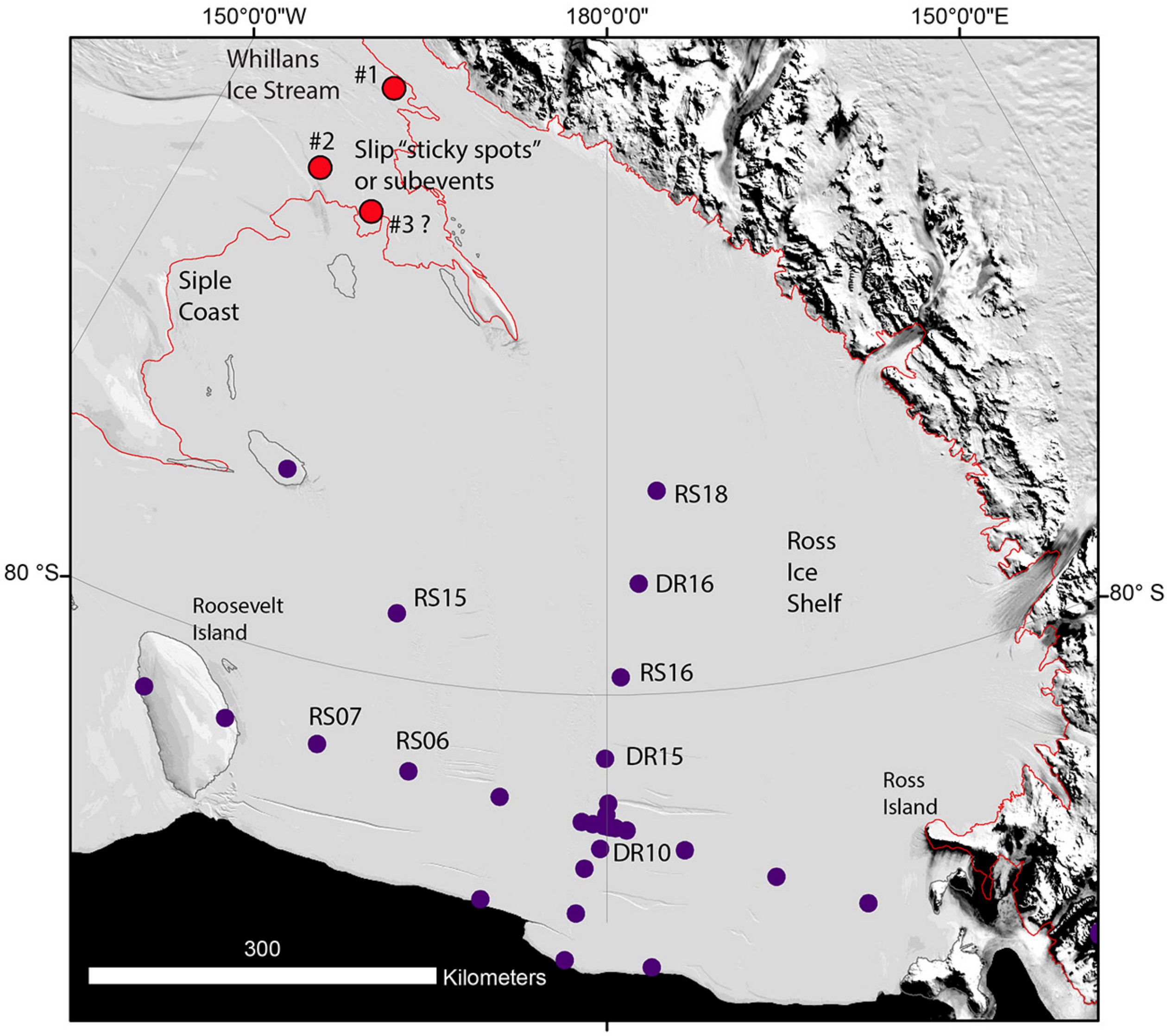
150°0'0"W
180°0'0"
150°0'0"E
Whillans
Ice Stream
#1
#2
Slip "sticky spots"
or subevents
#3 ?
Siple
Coast
RS18
Ross
Ice
Shelf
80 °S
80° S
DR16
RS15
Roosevelt
Island
RS16
RS07
RS06
DR15
Ross
Island
DR10
300
Kilometers