S1. Physical Evidence for Subsurface Fractures

There are no open crevasses exposed to the ice surface at the 33-km field site. However, through extensive hot-water drilling at this field location in 2014 and 2015 (Hills et al., 2017) there is substantial anecdotal evidence for subsurface fractures within the uppermost 15 m of ice (Figure S1). One form of evidence for these voids comes during the drilling process when water in the borehole rapidly drains. Drainage happened only in the first ~15 m of drilling (Figure S2a), and the drained water volumes are on the order of several cubic meters (Figure S2b). In total we drilled eleven hot-water boreholes at field site 33-km for full-thickness instrumentation, seven for shallow temperature instrumentation, and an additional nine for video observation. Of the 27 holes, 25 separate drainage events were observed, with some holes draining more than once.

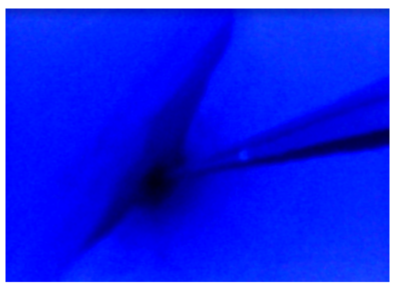

Figure S1: Photo of subsurface crevasse intersected during borehole drilling.

With near-surface borehole drainage as motivation for more subsurface investigation, a borehole video camera was used to directly observe ice below the surface. Camera observations span two different field seasons. In July of 2015, hot-water boreholes drained during drilling and dry holes (drilled with a hand-held Kovacs auger) drained if water was added. Video observations in 2015 reveal what look like subsurface fractures (Figure S1). Unfortunately the confirming images for subsurface fractures were taken after hot water drilling, so the identified features may be somewhat melted out. During a second field season in August of 2016, no hot-water holes were drilled, but many dry holes were drilled to inspect for subsurface fractures. During this season, no video observations show open features below the surface and no holes drained when water was added.

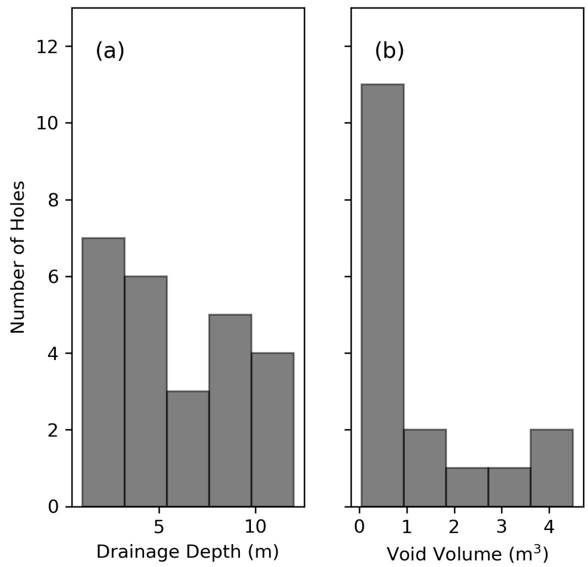

Figure S2: Drilling evidence for subsurface crevasses. Histograms show the drainage depth (a) and total volume filled (b) for each of the 25 instances of drainage during drilling.

Finally, a ground-penetrating radar (GPR) survey was done to inspect ice just below the surface. This study was done with a 200 MHz shielded antenna on an SIR 3000, both from Geophysical Survey Systems Incorporated (GSSI). The GPR survey consisted of 10 transects over a total of 9,000 square meters (Figure S3). Each transect is 100 m in length and separated from its neighboring transects at a common offset of 10 m. GPR data were processed with 1) a high pass filter, 2) an exponential amplitude gain of power 1.2, 3) a 50-100-200-400 frequency bandpass filter, and 4) a horizontal demeaning filter. Among the huge amount of noise caused by water and ice hummocks at the surface, the GPR data do have recognizable features which could be interpreted as fractures that extend 10-20 m deep. For example, one transect has a feature at 20 m horizontal distance which extends from the surface to ~13 m depth (Figure S4).

We now have ample evidence for subsurface fracture in the cold ice of the Greenland Ice Sheet ablation zone. In total, this evidence consists of borehole drainage in 25 separate events, video documentation after hot-water drilling, GPR, and refreezing events under ~10 m of cold ice. On the other hand, results from one season to another were not consistent. These may be transient features that open during the spring and close later in the melt season.

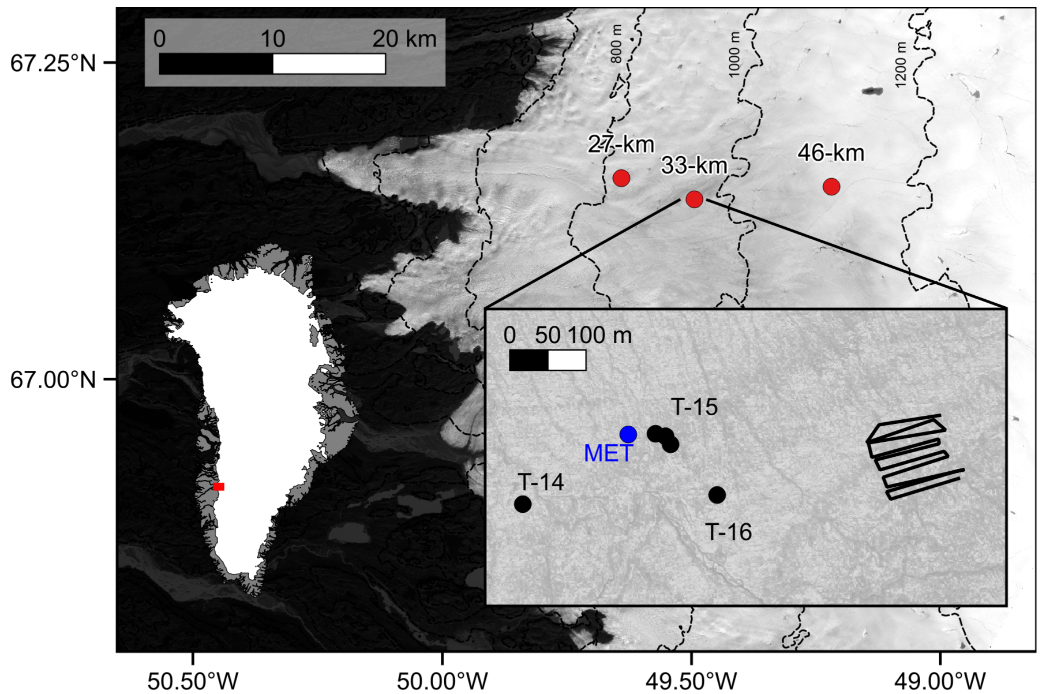

Figure S3: A site map with GPR transects shown by the black line.

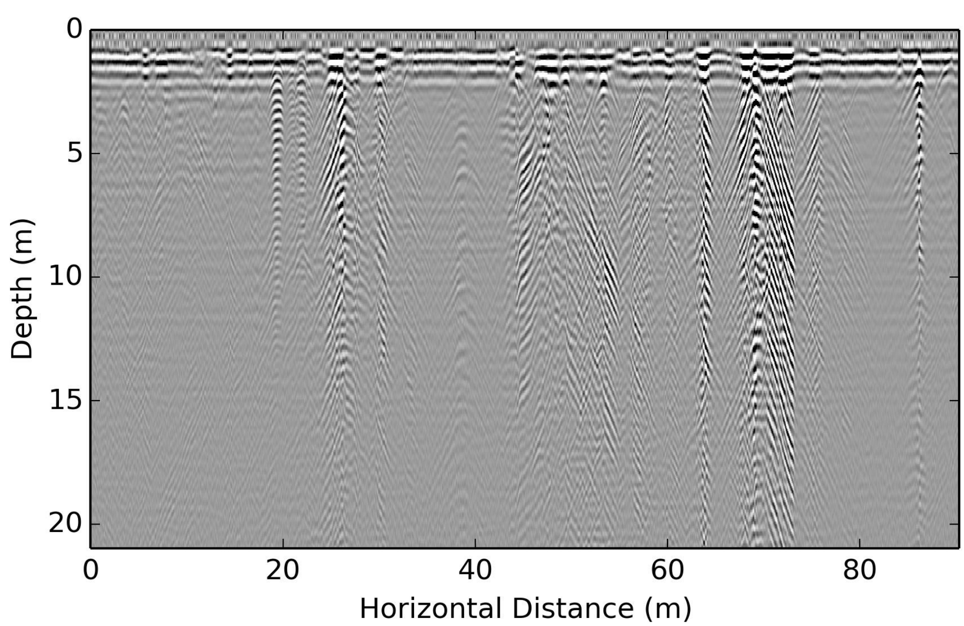

Figure S4: One transect from the ground-penetrating radar survey.