Englacial layers across the Ross and Amundsen Sea ice-flow divide (WAIS Divide), West Antarctica, deduced from SOAR radar data

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This project (NSF # OPP- 0338151) used radar data collected by Support Office of Aerogeophysical Research (SOAR) at University of Texas to estimate englacial radar attenuation (Matsuoka et al., 2010).

The specific radar data were gathered by SOAR and University of Washington (PIs: David Morse and Ed Waddington with NSF support # OPP -9726113 and OPP-9726500) in the 2000 austral summer on traverses both across and parallel to the topographic crest that separates ice flow towards the Ross and Amundsen Seas (Figure 1). Blankenship et al. (2001) describes specifications of the radar system used for this survey. For regional surface and bed topography as well as recent accumulation rates, please see Morse et al. (2002), which also analyzed SOAR radar data collected along orthogonal grids.

As part of the analysis of these data to estimate radar attenuation, we digitized depths to reflecting layers and related properties. Patterns of englacial radar layers along ice flow are an established natural marker to constrain ice flow models.

Explanation of data

Profile names

Names of radar profiles in the data submitted here are identical with profile names originally used by SOAR. However, names used in Matsuoka et al. (2010) and in Figure 1 of this report differ from them. Correspondences are
[SOAR original (i.e. used for this data report), Matsuoka et al. (2010)] =
[SE_X01, Sx1], [SE_X02, Sx2], [SE_X03, Sx3], [SE_X04, Sx4], [CC_X01, not reported], [CC_X02, Cx1], [CC_X03, Cx2], [CC_X04, Cx3], [CC_X05, Cx4], [NW_X01, Nx1], [NW_X02, Nx2], [NW_X03, Nx3], [NW_X04, Nx4], [NW_Y06, Ny1], [NW_Y07, Ny2], [NW_Y08, Ny3], and [NW_Y09, Ny4].

Organization of data files

We provide three kinds of Matlab files; one file for profile locations (profilelocations.mat), one file for ice thickness (beds.mat) provided by David Morse, and 17 files each of which include digitized data of internal layers for each radar profile. The file names (e.g. CC_X04a.mat) are identical with the names of original SOAR profiles. The first two letters show a region (CC: central, NW: northwest, and SE: southeast). The following three characters (e.g. X04 and Y01) show the radar track in each region (Fig. 1). The last lower case shows a profile ID; SOAR collected multiple profiles for most radar tracks with different pulse widths. We analyzed the data collected with the 250-nsec pulse width, which gives a vertical resolution of approximately 20 m. If multiple data sets were collected with the 250-nsec pulse width, we used the data that show internal layers most clearly.

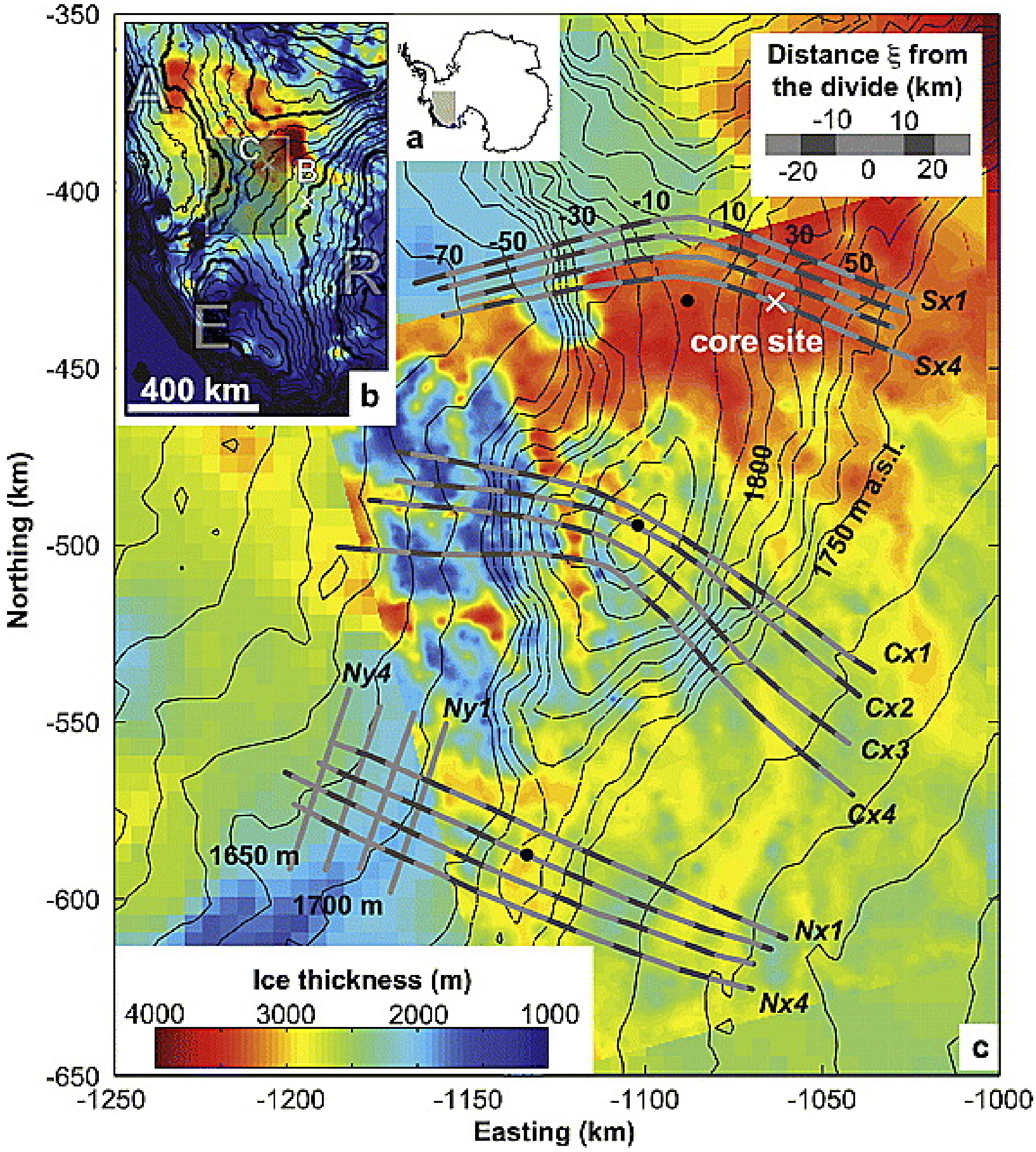

Figure 1: (a) Map of the Antarctic Ice Sheet. (b) Regional and (c) local regional surface topography (contours) and ice thickness (background color) in the WAIS divide area. Gray rectangles in Figure 1a and 1b show the coverage of Figures 1b and 1c, respectively. In Figure 1b, the WAIS divide area is a saddle between ice domes over Executive Committee Range (E) and at the boundary between Ross (R)/Amundsen (A) and Weddell Sea catchments. Byrd ice core site (B) and WAIS divide core site (C) are also shown. Thick contours are drawn at 500 m intervals, and thin contours are drawn at 100 m. In Figure 1c, in the vicinity of the divide area, 10 m interval contours are drawn only between 1750 and 1900 m asl. Surface topography is from Liu et al. (1999), and ice thickness is a composite of a continental BEDMAP model (Lythe et al., 2001) and a regional model by SOAR (Morse et al., 2002). Gray curves show locations of four longitudinal profiles, each in south (Sx), central (Cx), and north (Nx) series and the other four cross-flow profiles (Ny). Dark and light gray scales are assigned to show approximate distances ξ from the divide location along each longitudinal profile. Candidates for ice core drilling sites A, B, and C are shown with solid circles; see Morse et al. (2002) for coordinates of these sites. After Matsuoka et al. (2010).

SOAR collected radar data at every ~14 m along each radar profile. For our study, we analyzed one radar waveform every 10 waveforms in the SOAR's original radar data so that separations between two data locations reported here is approximately 140 m.

Our semi-automatic procedure to track layers follows: First, radargrams are visually inspected so that approximate locations of individual layers are specified by an operator. Second, these individual hand-given locations of the layers are interpolated so an initial guess of layer depths are obtained along the profile (more correctly, they are two-way travel time of the layer, not depth). Third, the routine looks for local maxima of the returned power within a given range of the depths from this initial guess. Finally, the operator inspects how the picks follow radar layers visually. If this trial does not work well, then the operator gives more number of approximate locations and/or tunes the window width. Reflection from the ice sheet surface is usually saturated in the data sets so the procedure above does not work well for surface identification. We differentiated the radargrams so that the ice-sheet surface is identified at a two-way travel time which gives the most rapidt change in the radar returned power associated with the surface reflection.

Individual data files include two-way travel time (unit: second) from the platform to the ice-sheet surface (TWT_surface) and two-way travel time from the platform to layers (e.g., TWT_12_3456). To calculate depths of individual layers from travel time in the ice, TWT_surface (for traveling in the air) should be subtracted from two-way travel time to individual layers.

(depth of layers) = (two-way travel time <u>in the ice</u>) x (propagation speed) / 2

A propagation speed (m/s) in the ice is $300x10^6$/sqrt(ε), where ε is permittivity of ice. We used uniform ε (= 3.2) for our study (Matsuoka et al., 2010). We also report returned power from individual layers (e.g. Echo_12_3456) in the unit of dBm but not from the ice-sheet surface. This is because returned power from the surface reflection is nearly always saturated. The mean noise floor is at -106.9 dBm (see Figure 2 in Matsuoka et al., 2010). All vectors in a data file have the same length. "NaN" indicates that the internal layer was not picked at that location (the layer is not observed continuously). The name of vectors indicate two-way travel time of the layer at the first non-NaN site; the first component of TWT_12_3456(find(isnan(TWT_12_3456))) is 12.3456e6. "dc" show the deepest continuous layer that could be tracked over nearly the entire profile.

"Beds.mat" file reports only two-way travel time, not retuned power. Because echoes from the bed are very weak, depth-differentiated radargrams were used to pick the bed echo. This is done by SOAR (David Morse) and we report it here too for user's convenience. Ice thickness can be derived as

(ice thickness) = (two way travel time to bed) * (propagation speed) / 2

Note that the two-way travel time to the bed provided here is the two-way travel time in the ice. Therefore, two-way travel time in the air is already accounted for. This is different from the two-way travel time for internal layers (which is two-way travel time both in the air and ice).

"profilelocations.mat" file reports x and y coordinates of radar profiles in polar stereographic projection. These coordinate values are in the unit of meters. Coordinates for the WAIS Divide ice core site are also included in this file.

Acknowledgements

We acknowledge Don Blankenship and other participants of SOAR and Ed Waddington at University of Washington for radar data collection. Katie Liu digitized the internal layers as a part of University of Washington's Summer Undergraduate Research Program (SURP). Matt Peters at SOAR provided calibration data to calculate the returned power. Robert Bauer and James Fitzgerald at NSIDC helped to submit these data to NSIDC. These submitted data are made with support from NSF Office of Polar Programs under projects # ANT-0338151, OPP-9726113, and OPP-9726500, and from NASA Space Grant at University of Washington.

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