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Supporting Information for

Seismic noise interferometry and Distributed Acoustic Sensing (DAS): measuring the firn layer S-velocity structure on Rutford Ice Stream, Antarctica

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Contents of this file

Introduction

A comparison of noise interferometry and frequency-wavenumber (f-k) domain stacking is provided in Text S1 and Figure S1. DAS noise from 0.01 to 1 Hz is shown in Figure S2. f-k transform of cross-correlations and an active shot are shown in Figure S3. Variations of dispersions curves in Figure S4. Located shear margin seismic events using the geophone array in Figure S5.

Text S1. Locating surface wave events with the geophone array

To get an idea of where the surface wave events originated. We use the geophone array to locate them very roughly. Firstly, a 1 to 10 Hz bandpass filter is applied. Secondly, we detect the surface wave events based on signal peak amplitude from a beamforming analysis. Thirdly, for each detected event, we calculate frequency-dependent arrival time. Lastly, taking the Vs model obtained in the main text, theoretical travel time can be calculated for a given location, thus, we apply an inversion to get the event location. Events which are located with low residuals are plotted in Figure S6.

We admit that this process is very rough, and the uncertainties of the locations are in the order of a few km, due to the small aperture of the array and also that the velocity is only validated in the centre of the ice stream, while most events are originated from the mountain areas (Ellsworth Mountain in the West and Fletcher Promontory in the East). Additional uncertainty might arise from the topography that is not included in the velocity model.

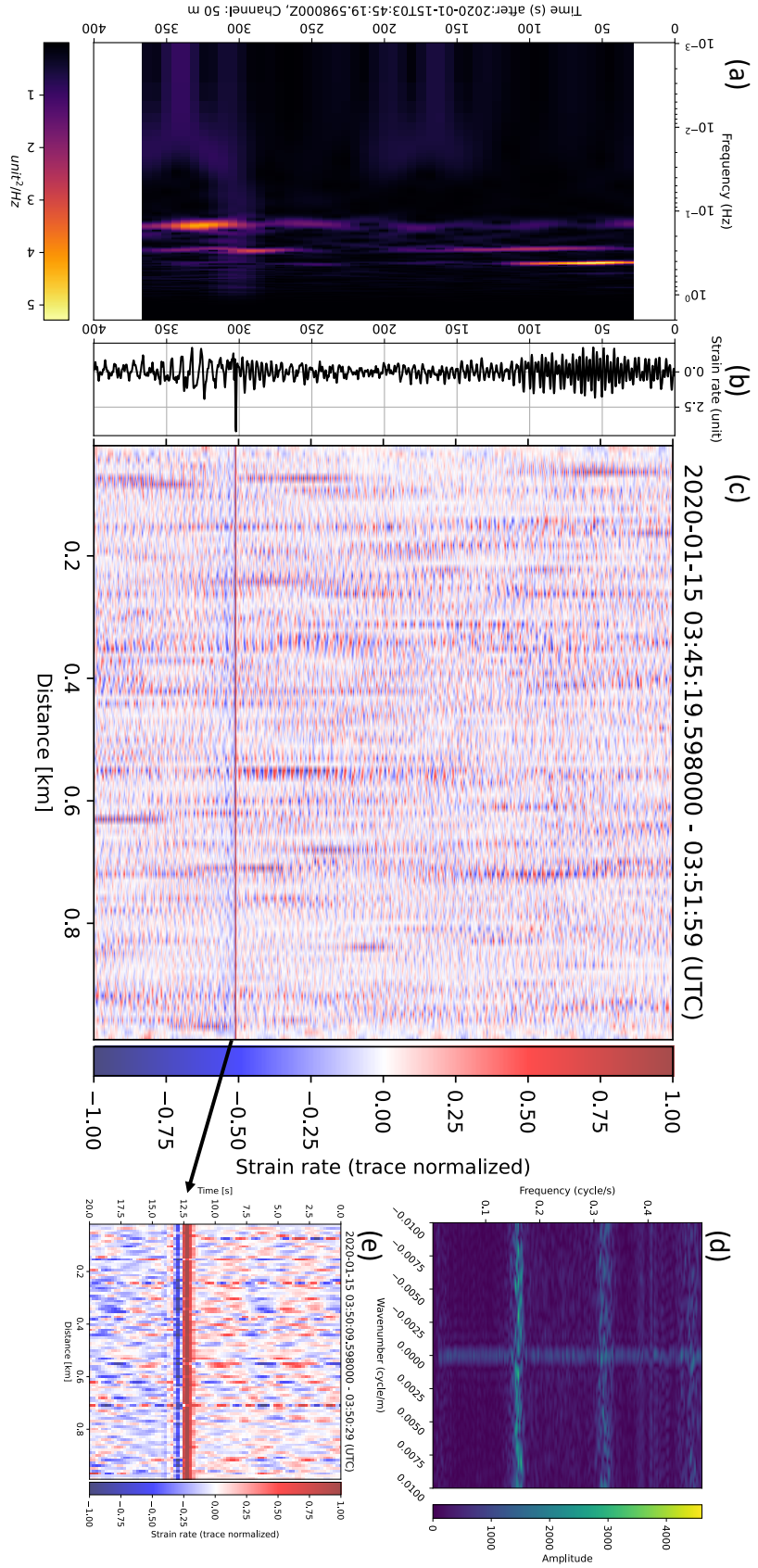

Figure S1. (c) a 400-second example of noises between 0.01 to 1 Hz. (a) spectrogram of the channel at distance of 50 m. Time series is plotted in panel (b). (d) f-k transform of (c). (e) zoom in of (c) as indicated by the arrow.

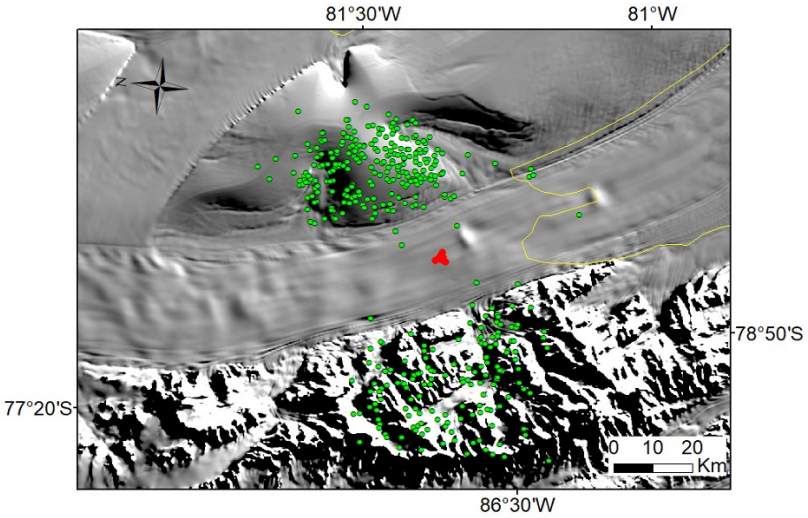

Figure S2. Localized surface wave events using the geophone array (red triangles), using travel time difference obtained from waveform cross-correlation.

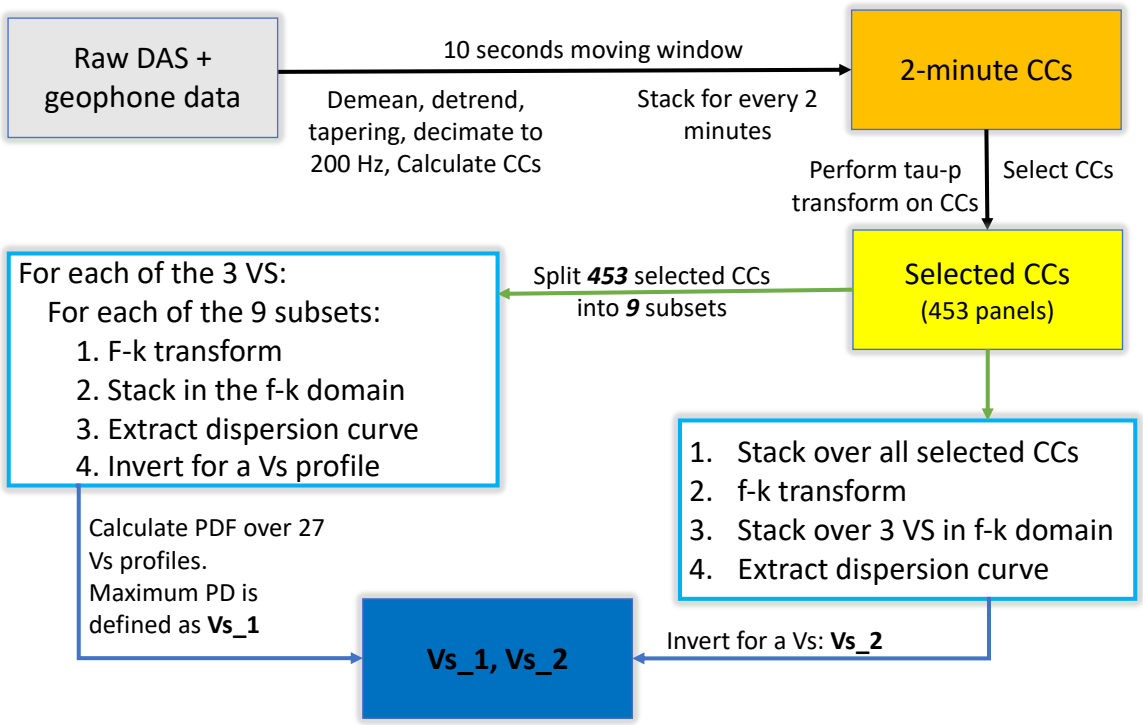

Figure S3. Workflow for DAS noise interferometry and surface wave inversion implemented in this study.

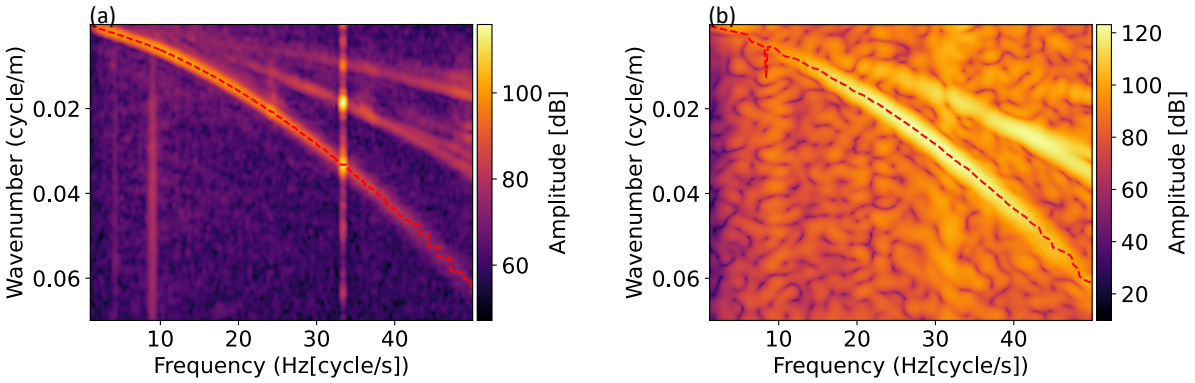

Figure S4. Plots of the f-k domain amplitude spectrum. (a) f-k for selective stacked cross-correlations (CCs), with picks of fundamental mode surface wave shown by a dashed line. (b) The same as (a) but for one active shot gather.

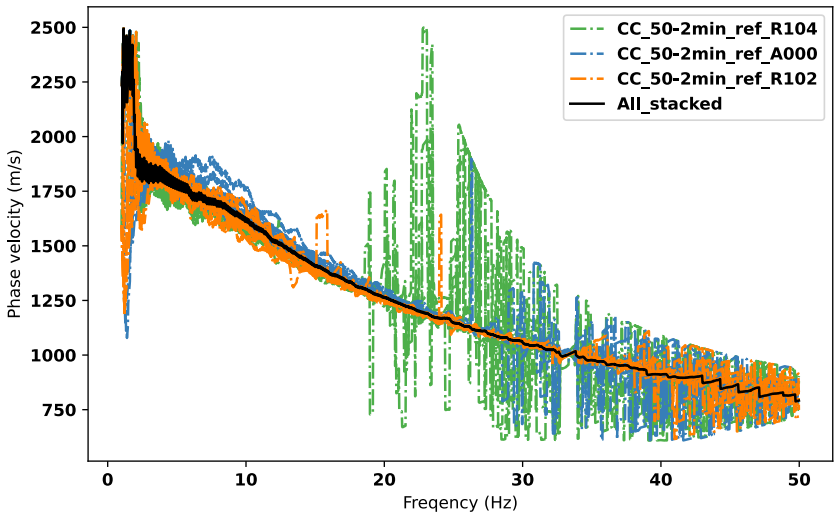

Figure S5. Variation of dispersions from all 50-2min-CC stacks, compared with the stack over all selected 2-min CCs.

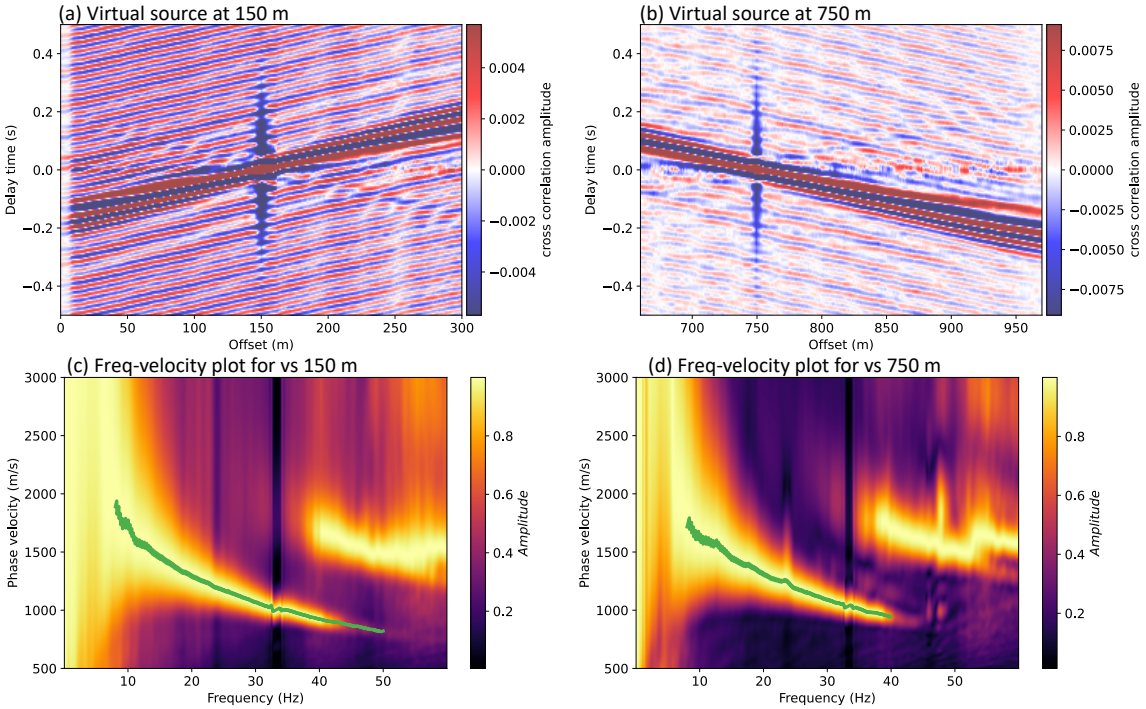

Figure S6. Stacked CCs and Phase velocity plots from two segments of the triangular array. (a) segment 0 to 330 m, with a virtual source at 150 m. (b) segment 660 to 960 m, with a virtual source at 750 m. (c) Phase velocity plot for virtual source at 150 m and dispersion extraction from 8 to 50 Hz. (d) Phase velocity plot for virtual source at 750 m and dispersion extraction from 8 to 40 Hz.