Supporting Information for "Brine extent at McMurdo Ice Shelf, Antarctica, controlled by snow accumulation"

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Introduction The supplementary materials include detailed explanations for the Radar Statistical Reconnaissance principles and applications with the HiCARS2 data set from the 2011-2012 austral summer survey over McMurdo Ice Shelf (MIS). Figures illustrating the RSR results are also provided.

Text S1. Radar Statistical Reconnaissance over McMurdo Ice Shelf

We have used the Radar Statistical Reconnaissance (RSR) in the same manner as *Grima et al.* [2014b, a] to derive the root-mean-square heights (σ_h) and surface snow density (d) over Thwaites glacier, West Antarctica, with HiCARS data. In the MIS case, the along-track data are divided into 1-km sampled spaces ($\sim$1000 surface echoes) repeated every 250 m. The RSR is applied on every sampled space to derive their own set of signal components pair and surface properties. The echo amplitude distributions are fitted with Homodyned K-statistics (HK) that allows the scatterers' amount to be few (non-fully developed speckle) or many (fully-developed speckle) and to be clustered within a footprint (non-stationary) [*Jakeman*, 1980; *Jakeman and Tough*, 1987]. Signal reflectance (Fig. S3.top) and scattering (Fig. S3.bottom) are parameters of the HK envelope and are obtained from the best fit. The correlation coefficient (ρ, Fig. S4) of the fit is a qualitative condence factor to estimate the terrain level-of-compliance with the statistical assumptions.

σ_h (Fig. S5) and ϵ (Fig. S6) are then inverted from the Small Perturbation Model (SPM) [e.g. *Ulaby et al.*, 1981; *Ogilvy*, 1991] with the additional assumption of a footprint-size or higher correlation length for the roughness. The SPM is valid only when $\sigma_h = 0.05\lambda$ (error < 1 dB; λ is radar wavelength) [*Thorsos and Jackson*, 1989], i.e. $\sigma_h = 0.25$ m for HiCARS2 over a horizontal scale of few wavelengths [Grima et al., 2014a]. These assumptions have been tested and validated over Thwaites Glacier, West Antarctica, using laser altimetry measurements.

ϵ is then translated into dry-snow density (d) from an empirical relationship [*Kovacs et al.*, 1995; *Frolov and Macheret*, 1999]. In a steady-state accumulation model, the obtained radar-derived density can be considered as a value for the very top surface (depth ≈ 0 m) [*Grima et al.*, 2014a]. The radar signal has been calibrated over the known ablation area, West of Pegasus airfield, by adjusting the RSR-derived density there to that of solid ice (917 kg.m^{-3}) [*Frolov and Macheret*, 1999]. The exact calibration location (E309009, N-1276517) (red diamond on Fig. S2-S6) corresponds to a high reflectivity spot combined with $\rho = 99.0$ %.

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0094-8276/16/$5.00

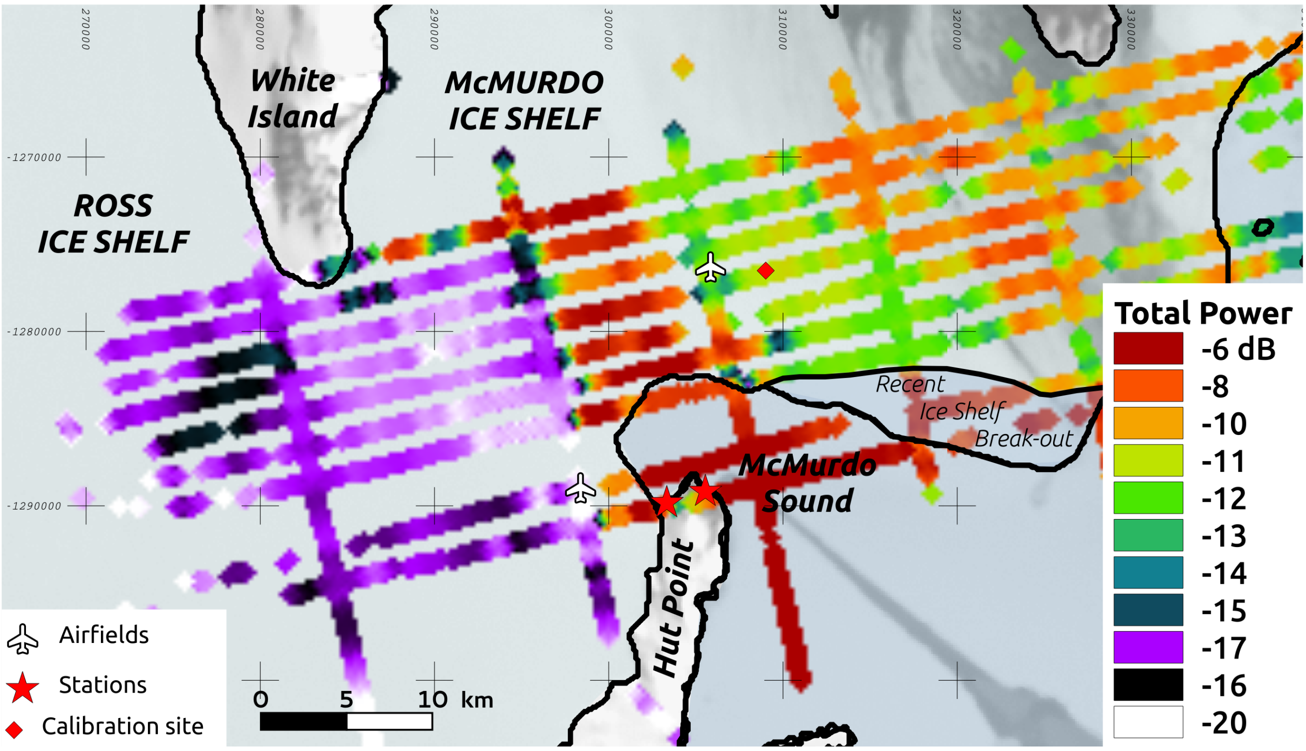

Figure S2. Total signal power of the HiCARS2 surface echo. The signal is adjusted so that a reflection over a perfect mirror would be 0 dB (no loss). This is the surface signal used by the RSR to derive surface properties.

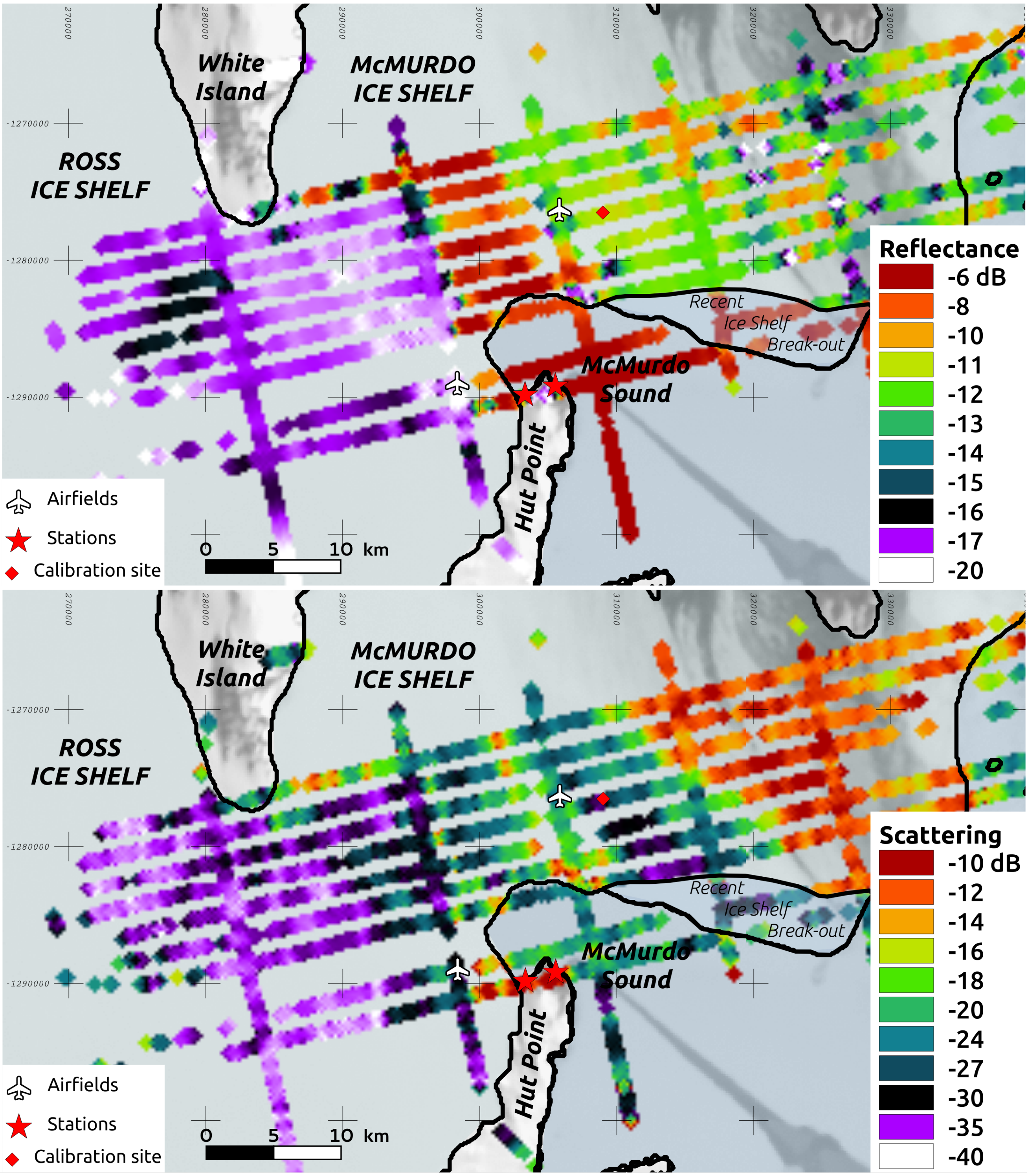

Figure S3. Surface reflectance (top) and scattering (bottom) derived from RSR.

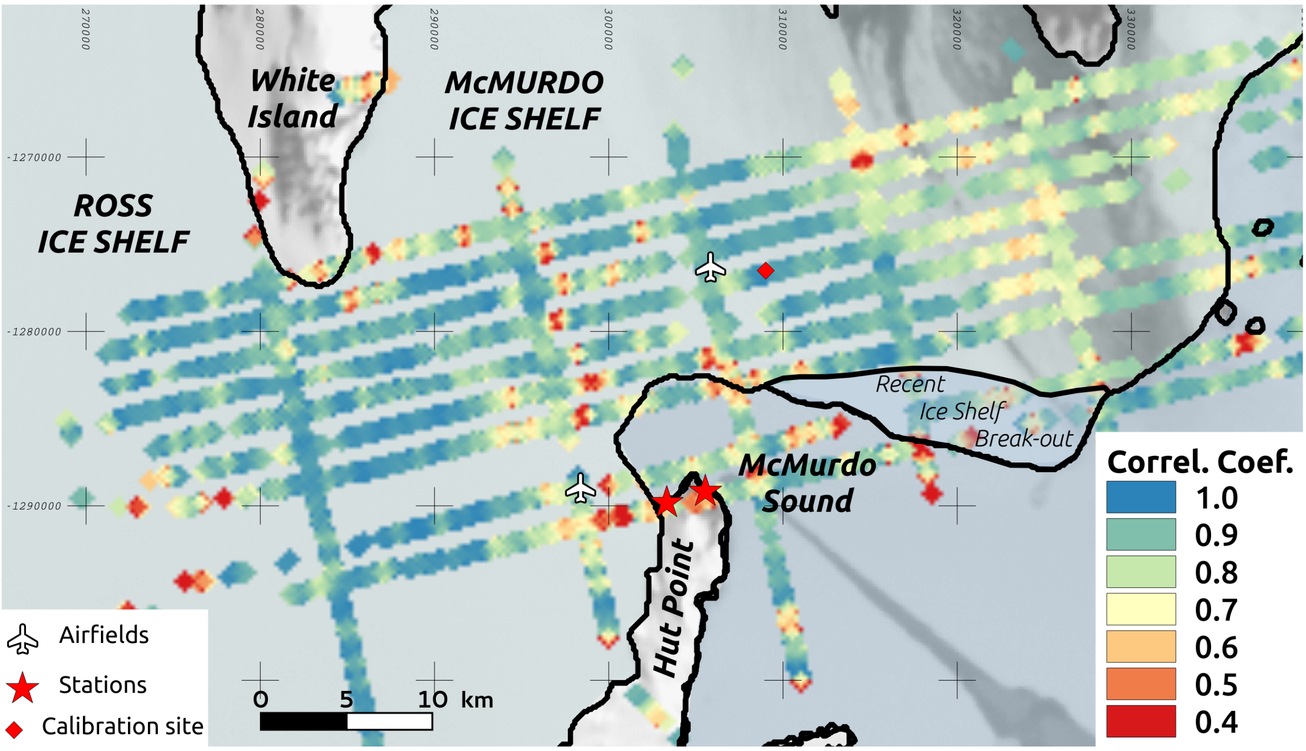

Figure S4. Correlation coefficient (ρ) of the fit between the empirical surface echo amplitudes distribution and the theoretical HK envelope. A low ρ generally means a more heterogenous surface with a higher uncertainty on the RSR-derived parameters.

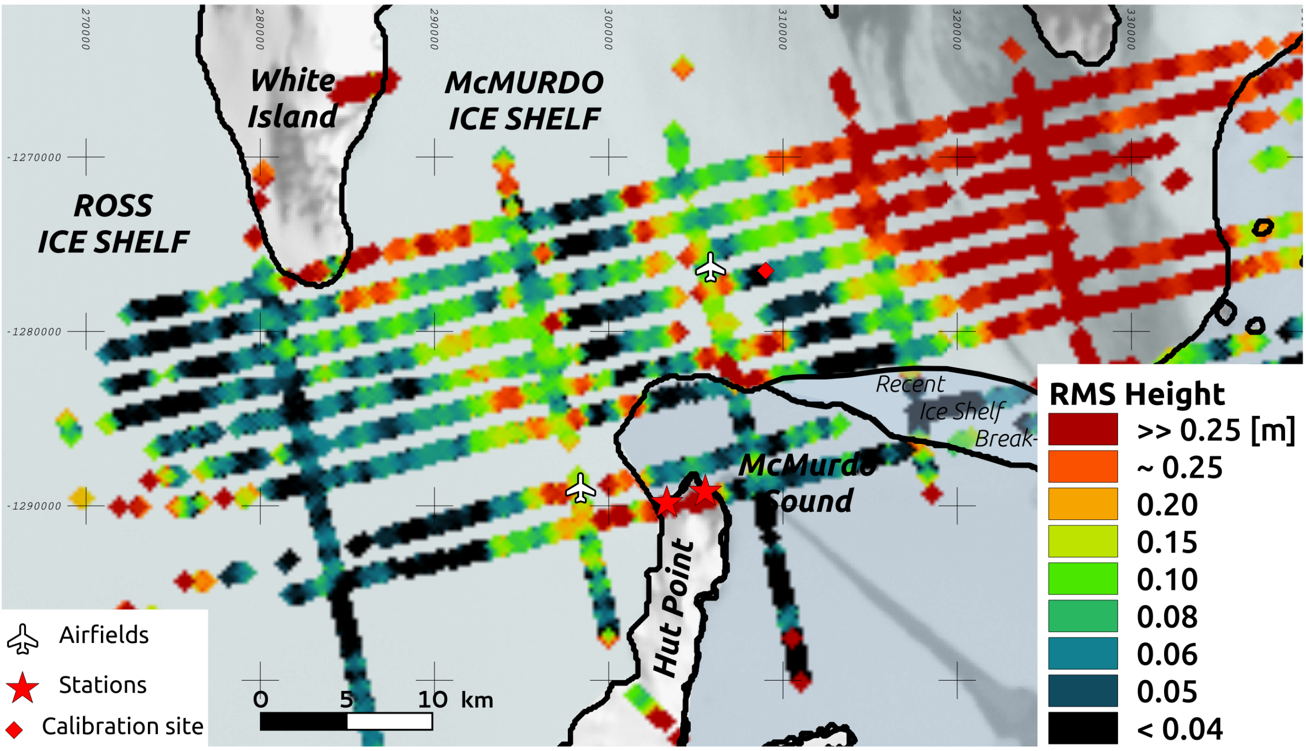

Figure S5. Surface root-mean-square heights (σ_h, roughness) derived from the Small Perturbation Model. Values >0.25 m (5 % of the signal wavelength) are underestimated. Underestimation increases with increasing roughness above this threshold.

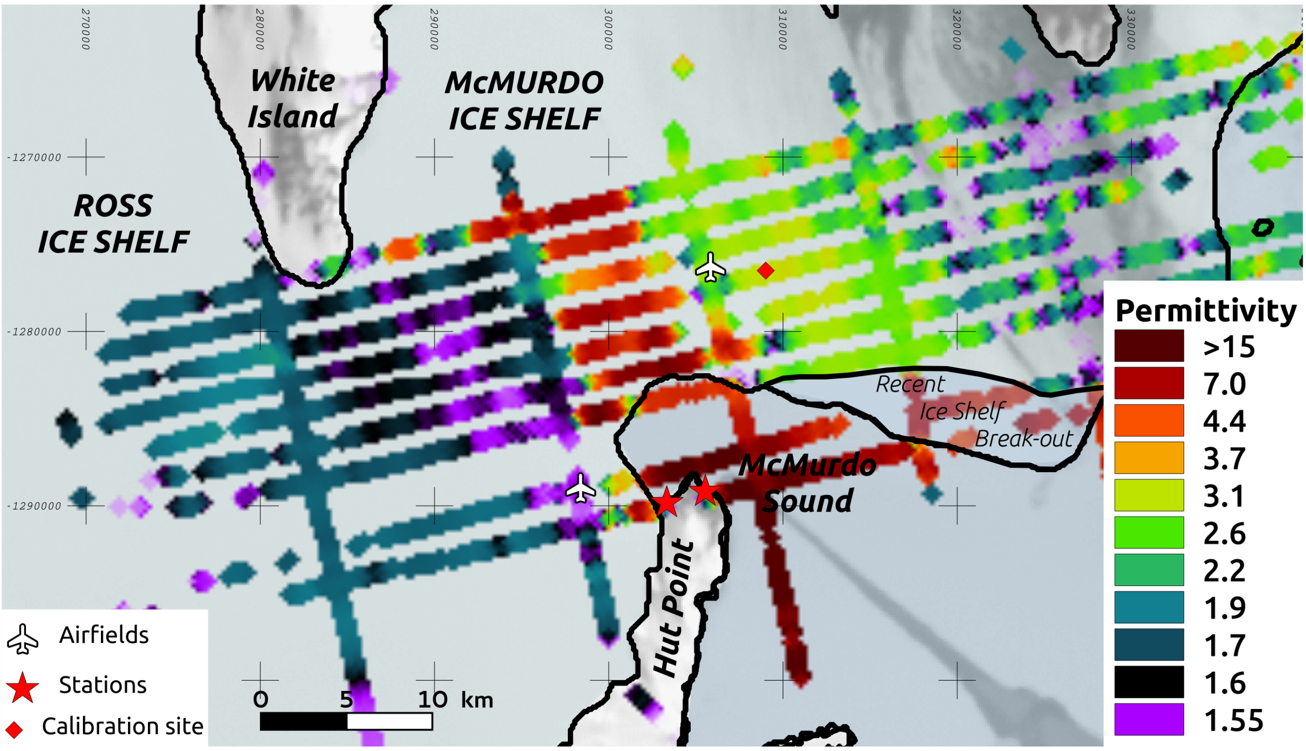

Figure S6. Surface permittivity (ϵ) derived from the small perturbation model. ϵ is uncertain where σ_h >0.25 m.