Supplement of

Penetration of Interferometric Radar Signals in Antarctic Snow

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Tables

Table S1. Elevation difference ∆h of ICESat footprints (IC) and TanDEM-X global DEM (TDMgl) cells (mean values of 5 x 5 pixels), respectively REMA cells (mean values of 5 x 5 pixels). Columns (left to right): ICESat acquisition date, number of ICESat points, mean elevation difference and standard deviation for ∆h (ICESat minus TDMgl), mean elevation difference and standard deviation for ∆h (ICESat minus REMA). Locations: ice-free slope and blue ice area on Union Glacier.

Date	*Nr. points*	*∆h IC - TDMgl [m]*	*St.dev. [m]*	*∆h IC -REMA [m]*	*St.dev. [m]*
Ice-free slope					
05/2005-11/2009	21	-6.91	0.84	0.16	1.27
Blue ice area (BIA)					
2004-05-28	19	-6.79	0.50	-0.37	0.53
2005-01-03	19	-6.81	0.31	-0.40	0.33
2005-05-31	19	-6.86	0.31	-0.41	0.30
2006-04-03	18	-6.63	0.58	-0.17	0.49
2006-06-03	15	-6.76	0.45	-0.34	0.24
2008-02-28	19	-6.84	0.46	-0.40	0.30
2009-11-10	17	-6.61	0.33	-0.19	0.33
All data	***126***	***-6.76***	***0.43***	***-0.33***	***0.38***

Table S2. Elevation difference ∆h of ICESat footprints minus TanDEM-X global DEM (TDMgl) cells (mean values of 5 x 5 pixels), mean value and standard deviation of co-located cells for ICESat tracks across the Union Glacier near snow pit P4. The values are based on 25 ICESat points for each date.

Date ICESat	*∆h*	*St.dev.*
2003-04-11	0.10	0.53
2004-05-06	0.07	0.52
2005-09-03	-0.03	0.60
2006-11-06	0.15	0.52
2006-12-11	0.19	0.49
2007-03-30	0.03	0.47
2007-10-21	0.01	0.66
2008-02-12	0.21	0.46
All data	*0.09*	*0.40*

Table S3. Backscatter coefficient in dB, total normalized coherence and volumetric coherence at the snow pit sites derived from data of the TDM scenes.

	T2013A	T2013B	T2014A	T2014B	T2016HH	T2016VV	T2018HH	T2018VV
Backscatter coefficient, σ° [dB]								
Pit 1	-4.85	-4.98	-3.73	-5.16	-4.41	-4.05	-3.39	-3.33
Pit 2	-7.94	-8.67	-7.01	-7.21	-3.99	-3.61	-3.71	-3.66
Pit 3	-11.86	-12.23	-10.80	-11.71	-5.58	-5.51	-5.94	-5.43
Pit 4	-12.27	-13.27	-11.50	-11.09	-2.83	-2.99	-2.87	-2.14
Pit 5	-16.34	-17.05	-15.86	-15.90	-11.06	-10.65	-11.71	-11.28
Total normalized coherence, γ_{tot}								
Pit 1	0.902	0.917	0.855	0.873	0.891	0.902	0.937	0.937
Pit 2	0.838	0.821	0.776	0.844	0.895	0.907	0.932	0.931
Pit 3	0.682	0.652	0.625	0.663	0.779	0.794	0.864	0.879
Pit 4	0.586	0.513	0.461	0.660	0.805	0.843	0.914	0.893
Pit 5	0.512	0.485	0.467	0.548	0.701	0.746	0.792	0.759
Volumetric coherence, γ_{vol}								
Pit 1	0.954	0.970	0.901	0.924	0.929	0.939	0.974	0.974
Pit 2	0.900	0.887	0.829	0.902	0.932	0.944	0.970	0.969
Pit 3	0.765	0.736	0.690	0.742	0.815	0.830	0.905	0.919
Pit 4	0.662	0.591	0.514	0.732	0.836	0.876	0.950	0.927
Pit 5	0.648	0.634	0.580	0.682	0.777	0.822	0.886	0.843

Table S4. Elevation difference dh [m] between TDM DEMs and REMA (vertically co-registered on the BIA) and computed elevation bias h_{blnv} [m] by inversion of γ_{vol}, for the snow pit sites.

dh	TDMgl	T2013A	T2013B	T2014A	2014B	2016H	2016V	2018H	2018V
Pit 1	-2.50	-2.41	-2.29	-2.18	-2.56	-2.95	-3.02	-3.39	-3.88
Pit 2	-4.58	-4.97	-4.28	-4.49	-4.19	-3.52	-3.22	-3.82	-3.26
Pit 3	-6.69	-7.02	-7.29	-6.18	-5.65	-6.06	-5.34	-5.31	-4.37
Pit 4	-6.15	-8.25	-7.57	-7.24	-5.03	-5.33	-4.84	-5.64	-5.85
Pit 5	-5.86	-6.99	-7.07	-5.07	-6.04	-4.53	-4.73	-4.65	-5.68
h_{blnv}									
Pit 1		-2.76	-2.04	-2.59	-3.06	-3.16	-2.93	-3.18	-3.18
Pit 2		-4.09	-3.98	-3.42	-3.49	-3.10	-2.81	-3.42	-3.47
Pit 3		-6.34	-6.17	-4.67	-5.74	-5.16	-4.94	-6.11	-5.64
Pit 4		-7.68	-7.78	-5.94	-5.85	-4.85	-4.20	-4.42	-5.35
Pit 5		-7.84	-7.33	-5.49	-6.41	-5.93	-5.28	-6.37	-7.50

Figures

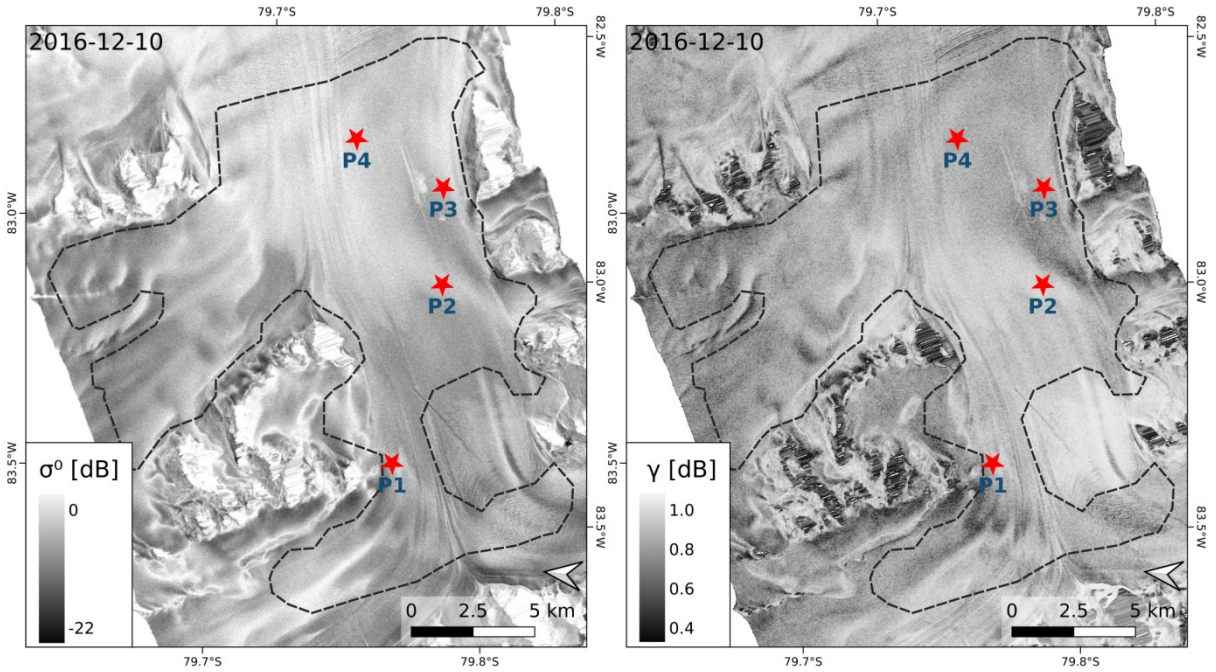

Figure S1. Section of TDM images over Union Glacier, 10 December 2016. Left: Backscatter coefficient (σ°) HH polarizations. Right: Total normalized coherence. The outline encloses the level area of the glacier excluding the BIA (LGA).

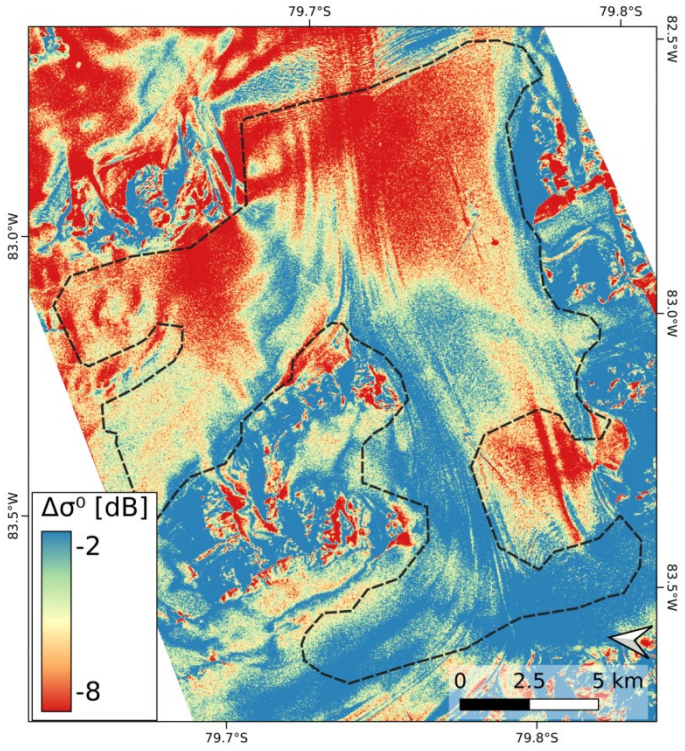

Figure S2. Angular difference of the HH-polarized backscatter coefficients between the TDM images from 6 May 2013 (θ_i = 40.9°) and 10 December 2016 (θ_i = 21.6°), $\sigma°_{HH\ 2013}$ minus $\sigma°_{HH\ 2016}$.

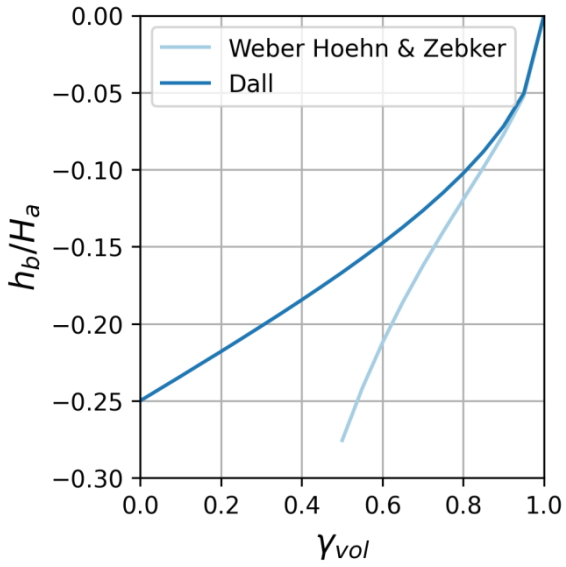

Figure S3. Relation of the relative elevation bias (h_b/H_a) vs. volumetric coherence (γ_{vol}) according to the models of Weber Hoehn & Zebker (2000) and Dall (2007).

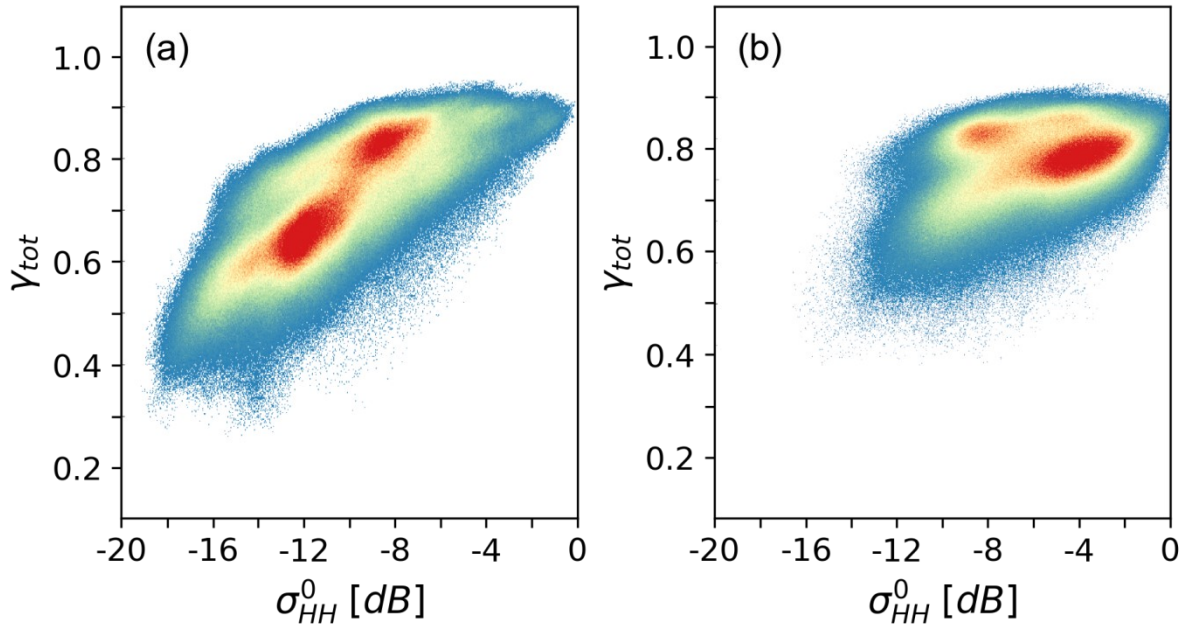

Figure S4. Scatterplot of the backscatter coefficient $\sigma°_{HH}$ [dB] vs. the total normalized coherence, γ_{tot}, for the level glacier area (LGA). (a) 6 May 2013; (b) 10 December 2016. The colour epresents the 2D data density increasing from blue to red.

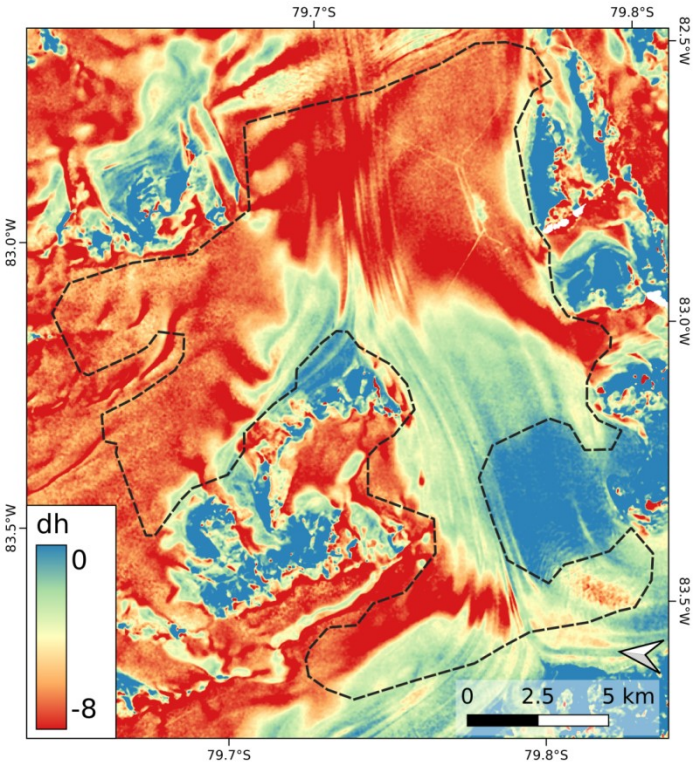

Figure S5. Elevation difference (dh) TDM global DEM minus REMA, vertically co-registered on the BIA.

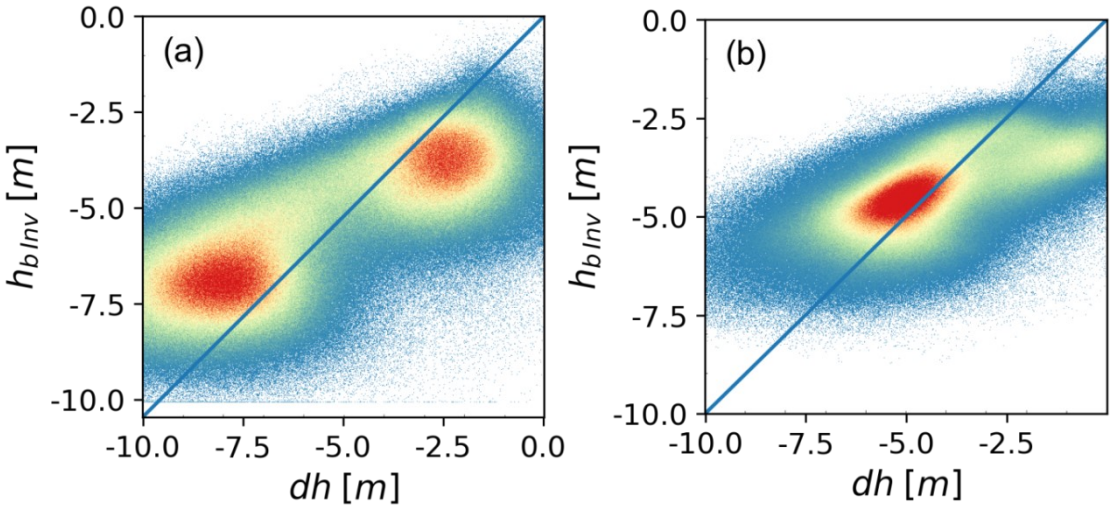

Figure S6. Scatterplot of the elevation difference TDM DEM minus REMA (dh) vs. the computed elevation by inversion of γ_{vol} (h_{blnv}) on Union Glacier LGA. (a) TDM scene 22 May 2013; (b) 10 October 2016, mean values of VV and HH channels. The line shows the 1:1 correspondence. The colour code represents the 2D data density.

References:

Dall, J.: Elevation bias caused by penetration into uniform volumes, IEEE Trans. Geosc. Rem. Sens., 45(7), 2319–2324, 2007.

Weber Hoen, E., and Zebker, H. A.: Penetration depths inferred from interferometric volume decorrelation observed over the Greenland Ice Sheet, IEEE Trans. Geosc. Rem. Sens., 38(6), 2571-2583, 2000.