Supporting Information for

Evaluating snow depth from ICESat-2 laser altimetry using airborne laser-scanning data

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Table S1. Statistics of the co-registration statistics between the external DEMs and the ICESat-2 snow-off DEM.

Digital Elevation Model (DEM)	Horizontal vector		Elevation residual				
	Easting	Northing	Mean	Median	Mode	NMAD before	NMAD after
Airborne lidar (ASO) – 3 m	1.35	-1.04	1.29	0.79	0.25	1.53	1.37
Sat. Photogrammetry (Pléiades) – 3 m	-2.28	-4.37	4.05	4.05	3.95	1.94	1.25
Copernicus DEM – 30 m	20.92	-16.61	-25.71	-25.35	-24.93	9.50	4.12

Table S2. Statistics of the snow depth residuals for different snow-off Digital Elevation Models (DEMs) on 12 March 2019. The *ICESat-2-ASO 3 m* is shown in detail on Figure 1. All residuals are shown in Figure 2.

Snow depth product name	Snow-off DEM source	ASO snow depth	NMAD (m)	RMSE (m)	Mean (m)	Median (m)	Number of points
IS2-ASO 3 m	Airborne lidar (ASO) – 3 m	3 m	1.19	1.88	0.28	0.04	5450
IS2-Pléiades 3 m	Sat. Photogrammetry (Pléiades) – 3 m	3 m	1.11	2.15	-0.38	-0.17	1295
IS2-IS2 15 m	ICESat-2 – 15 m	3 m	3.63	4.17	-1.04	-1.03	127
IS2-Copernicus 30 m	Copernicus DEM – 30 m	3 m	10.92	11.49	-0.16	-1.09	5450
IS2-ASO 15 m	Airborne lidar (ASO) – 15 m	15 m	1.03	1.64	0.31	0.06	5449
IS2-Pléiades 15 m	Sat. Photogrammetry (Pléiades) – 15 m	15 m	1.12	2.06	-0.38	-0.20	1294
IS2-IS2 15 m	ICESat-2 – 15 m	15 m	3.52	4.12	-1.01	-1.09	127
IS2-Copernicus 30 m	Copernicus DEM – 30 m	15 m	10.95	11.46	-0.16	-1.12	5449

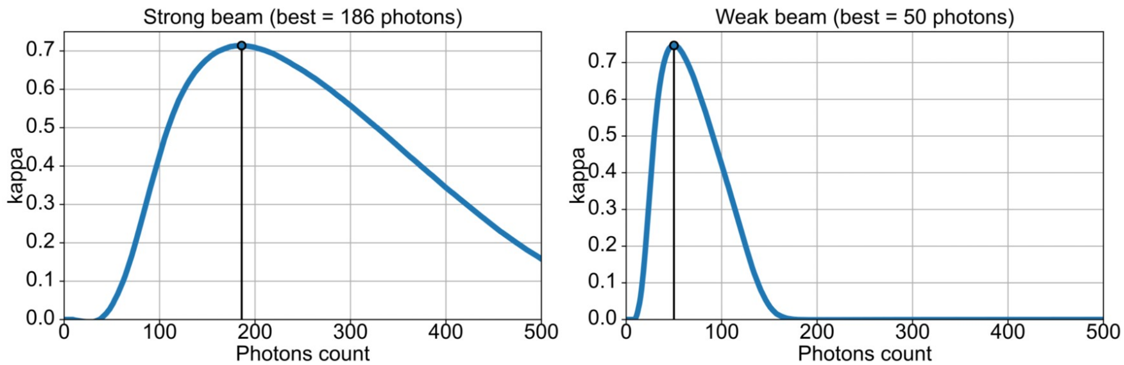

Figure S1. Optimization of the kappa index to determine the photon count threshold defining snow-on and snow-off points based on MODIS snow cover area data.

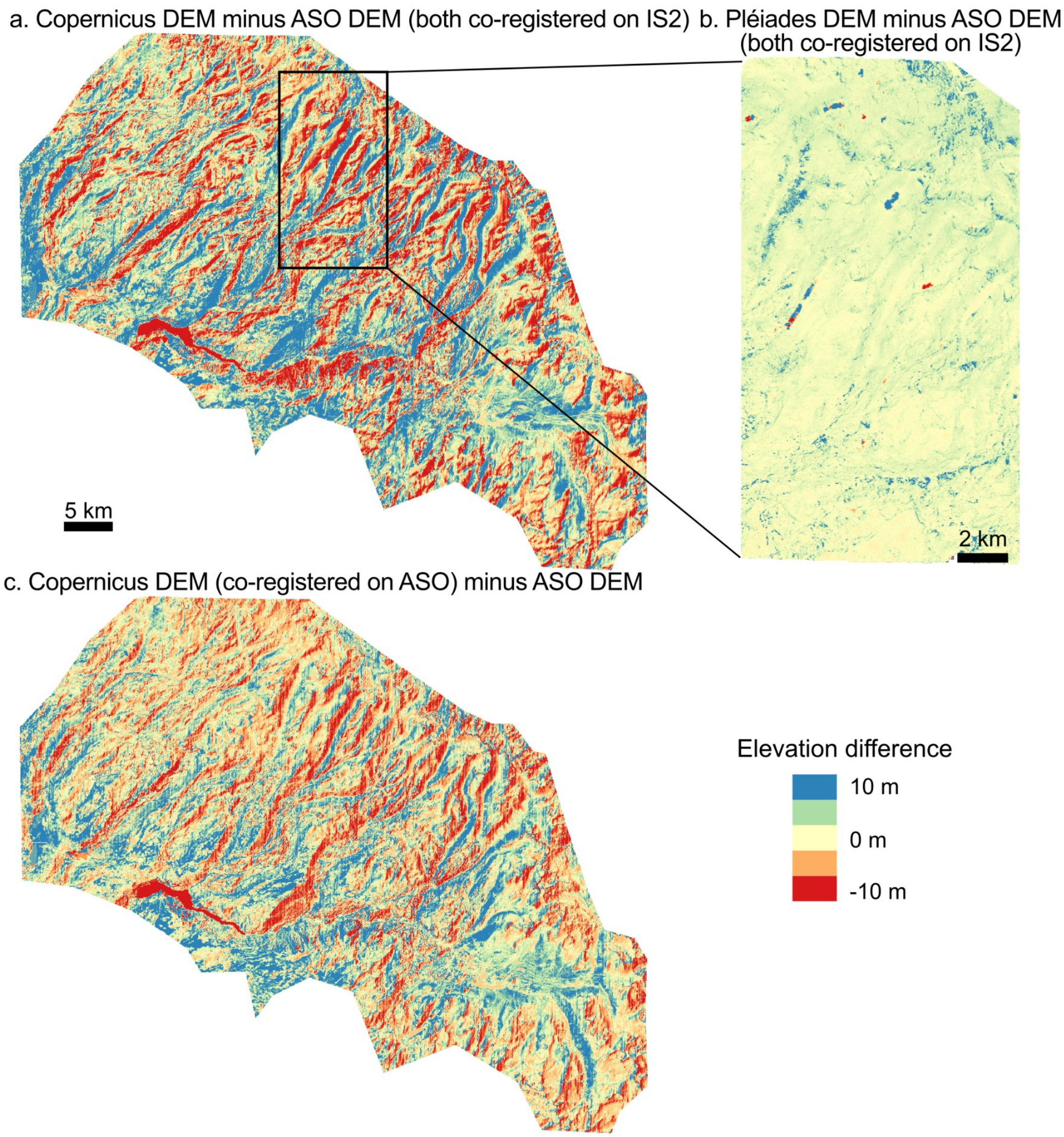

Figure S2. Elevation difference of the snow-off DEMs. The top panel shows the difference between the Copernicus 30 DEM and the ASO DEM (a) and the Pléiades DEM and the ASO DEM (b). All DEMs of (a) and (b) were co-registered on the ICESat-2 snow-off points. The Copernicus 30 DEM was co-registered on the ASO DEM (c).

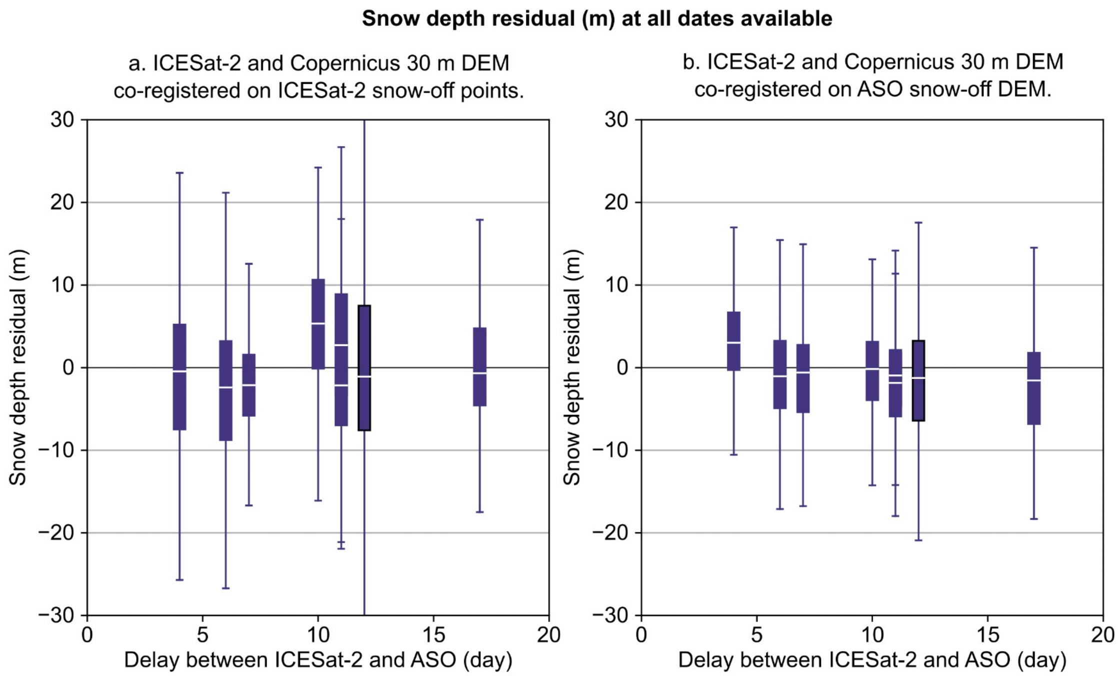

Figure S3. Snow depth residuals for snow depth derived from ICESat-2 and Copernicus 30 m DEM. The Copernicus 30 m was co-registered to the ICESat-2 snow-off point (a), i.e. similar processing as for airborne lidar and satellite photogrammetry DEM, or co-registered to the airborne lidar DEM itself co-registered to the ICESat-2 snow-off point (b). The latter snow depth have a better accuracy and precision showing the contribution of the co-registration error to the ICESat-2 – Copernicus 30 m snow depth.

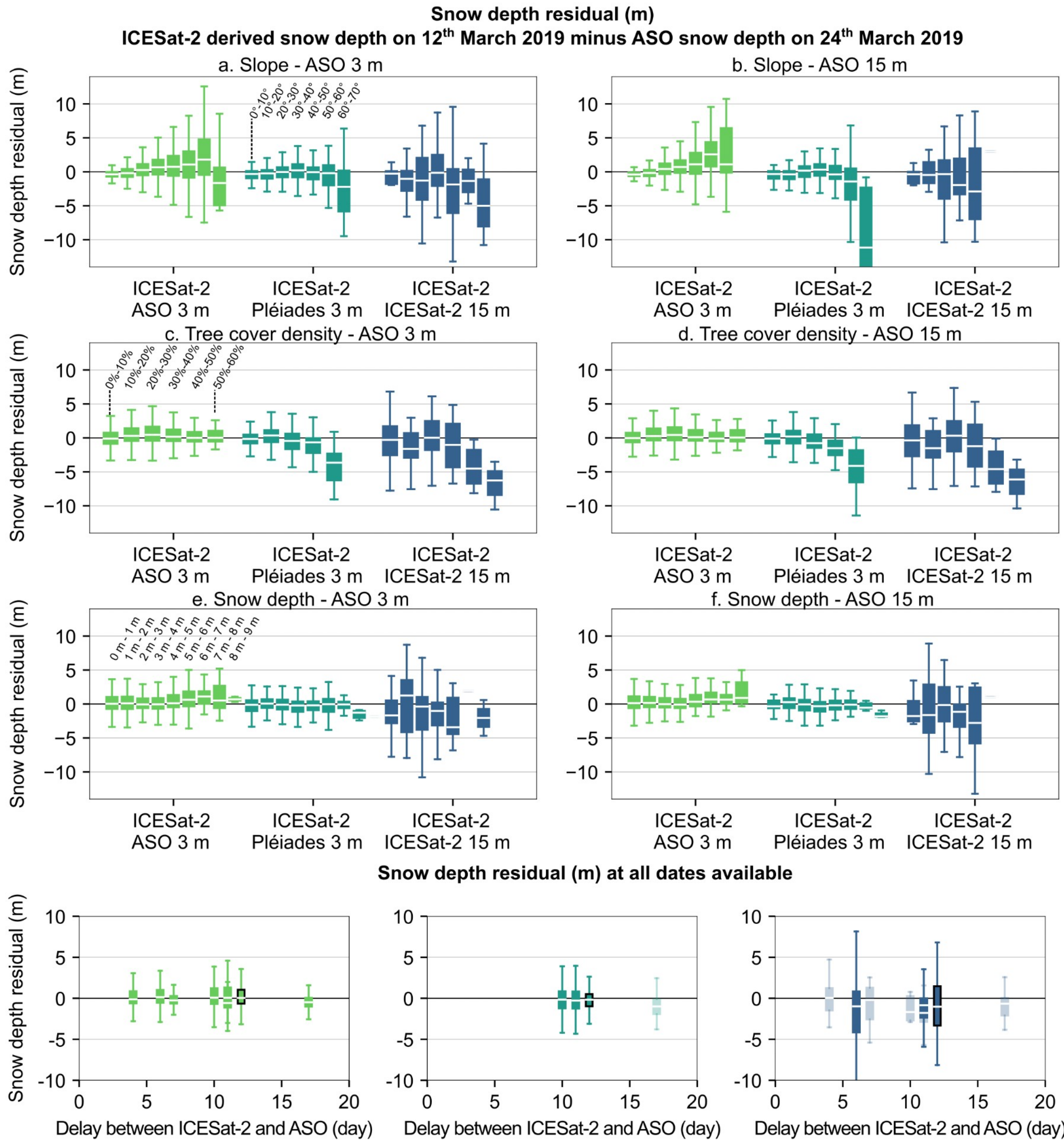

Figure S4. Same as Figure 4 but with snow-on ATL06 from *h_li* instead of *h_mean*. The former is calculated from the latter by including a first-photon bias correction and a pulse shape correction. Little difference is found between the snow depths derived from these two products.

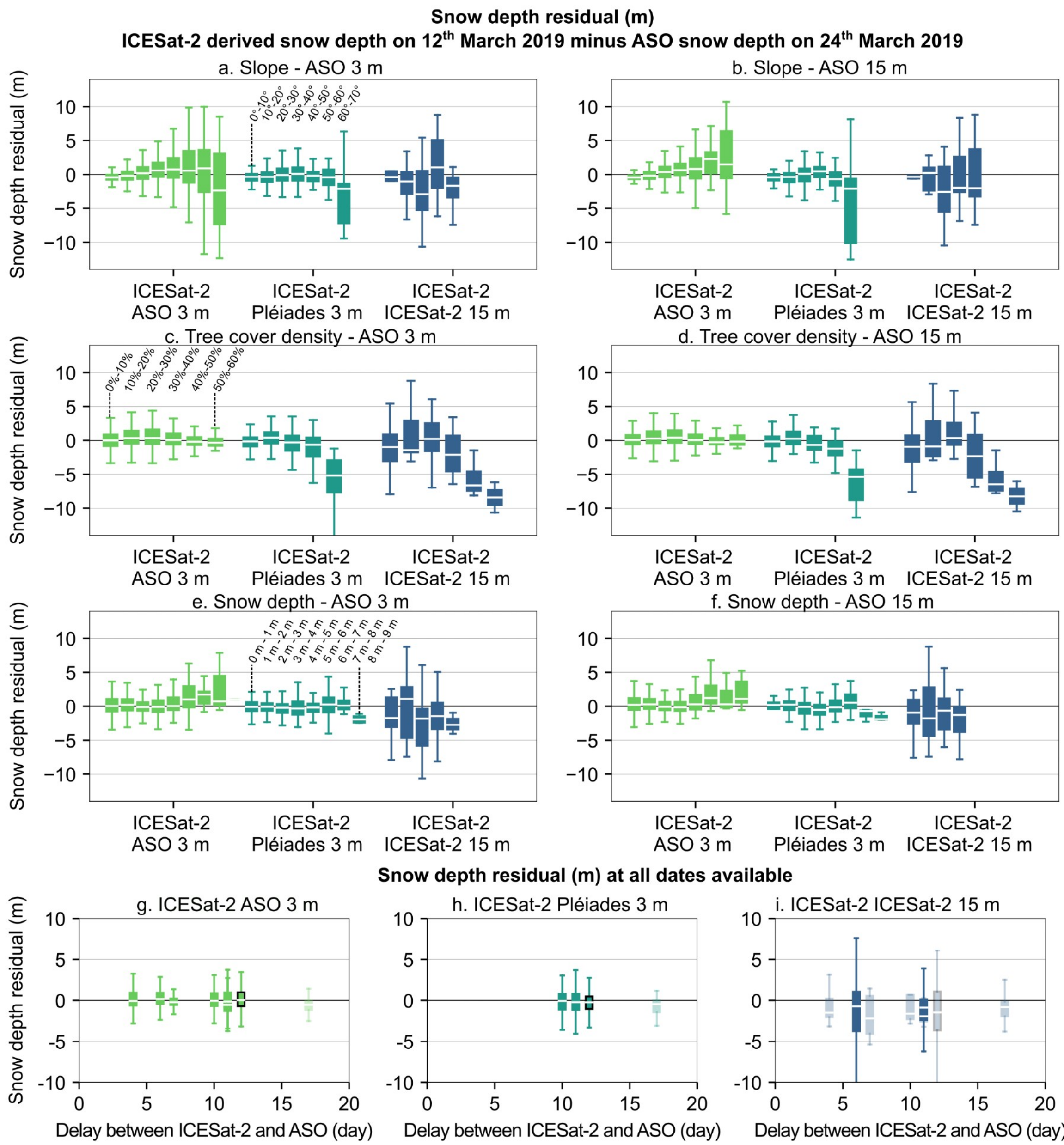

Figure S5. Same as Figure 4 but selecting ICESat-2 ATL06 snow-on points of the strong beams only.

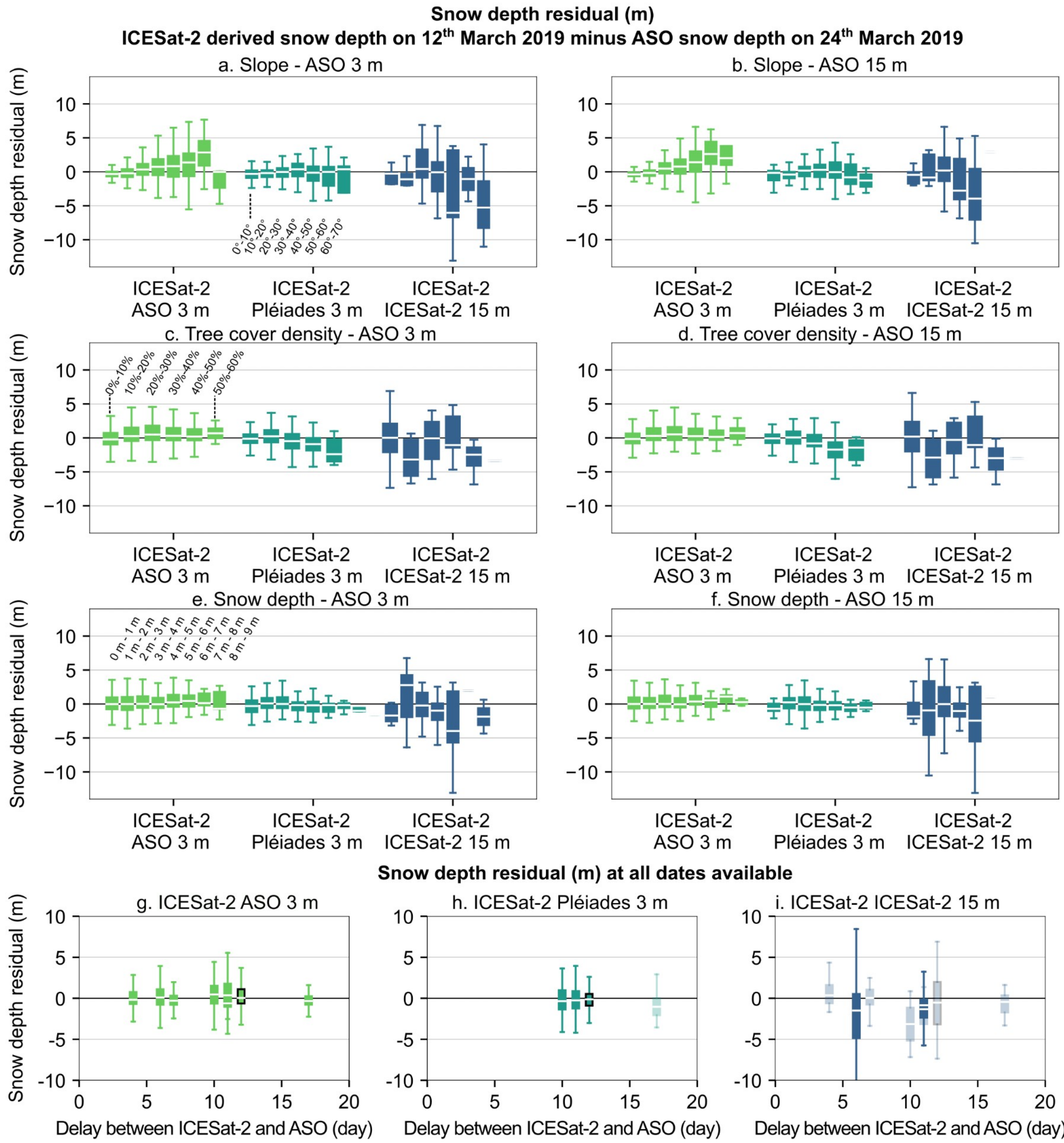

Figure S6. Same as Figure 4 but selecting ICESat-2 ATL06 snow-on points of the weak beams only.

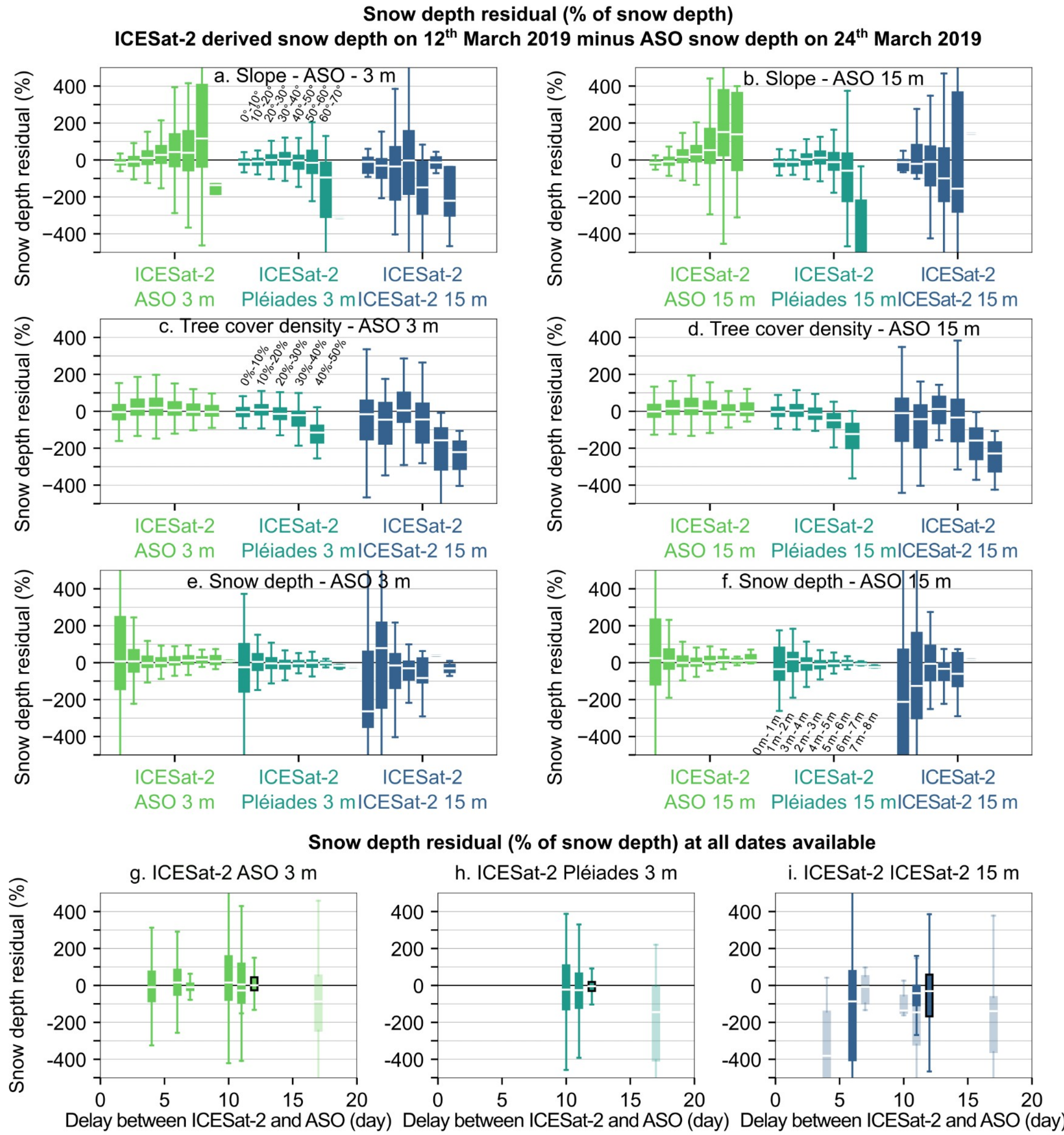

Figure S7. Same as Figure 4 but calculating the relative snow depth error (ICESat-2 derived snow depth minus ASO snow depth divided by ASO snow depth) rather than the absolute snow depth error.

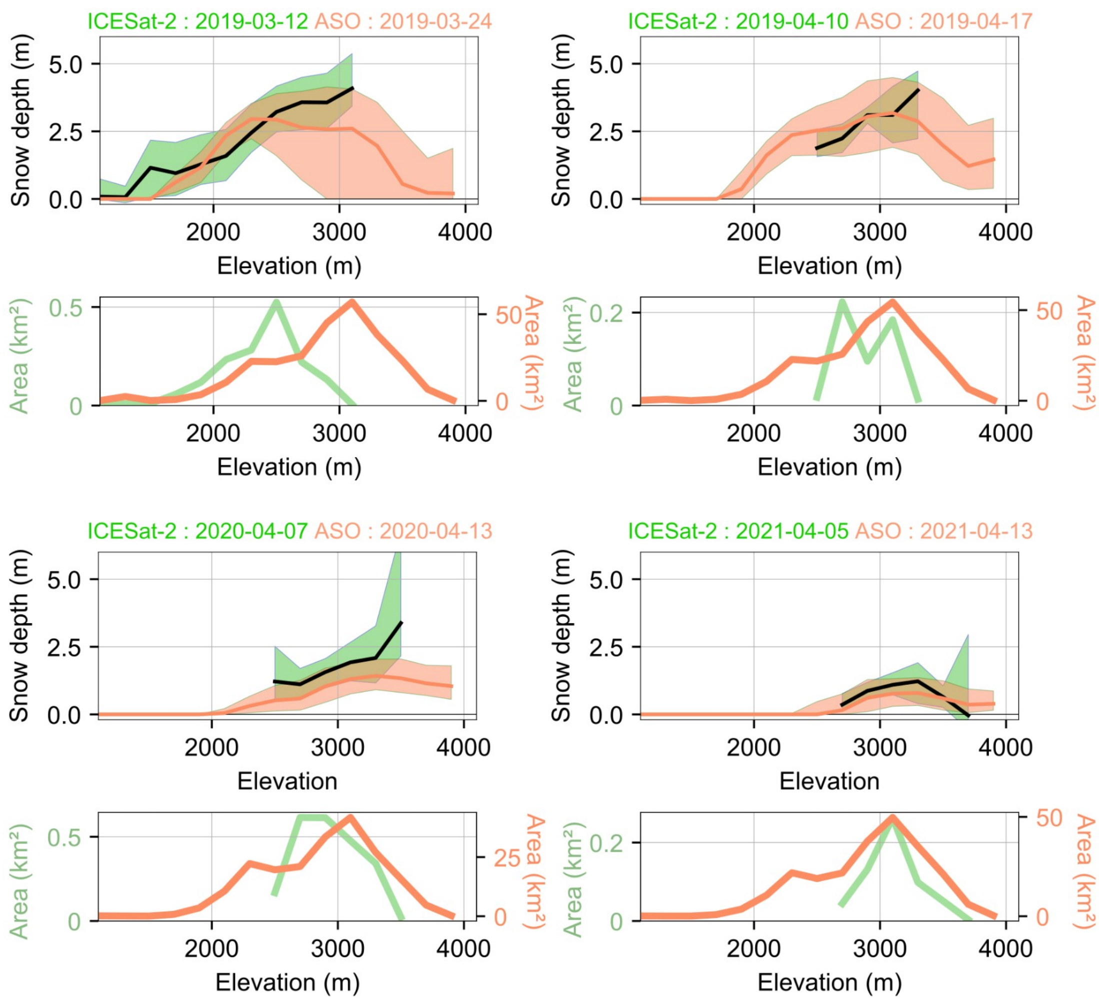

Figure S8. Snow depth gradient with elevation (top) from ICESat-2 and ASO snow-off (green) on four dates over the three winter of the period and from the closest in time ASO snow depth map (orange). Hypsometry of the snow covered areas is shown below. Please note the different y-axis scale to increase the visibility of the smaller surfaces sampled by ICESat-2.