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Geodetic reanalysis of annual glaciological mass balances (2001–2011) of Hintereisferner, Austria

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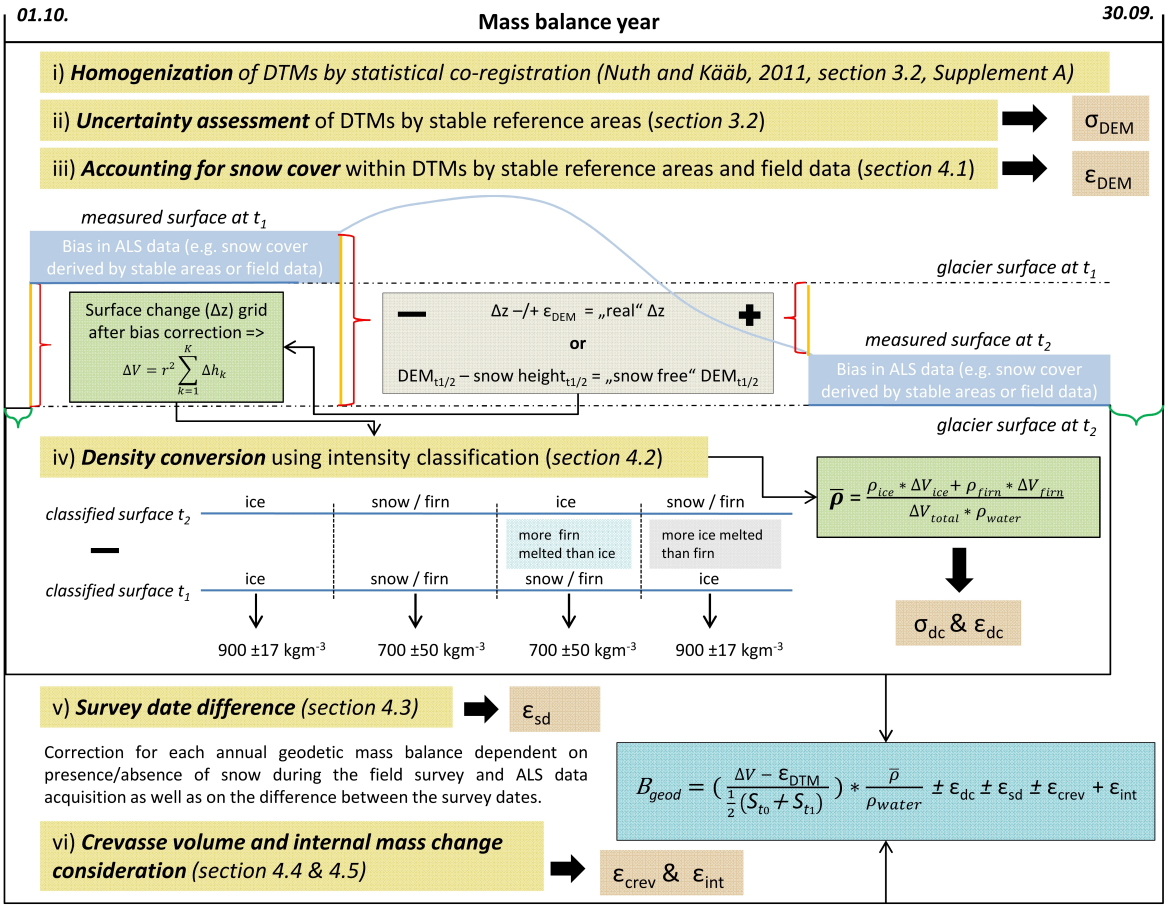

Figure S1: Flow-chart illustrating the pixel-based calculation process for the conversion density $\overline{\rho}$.

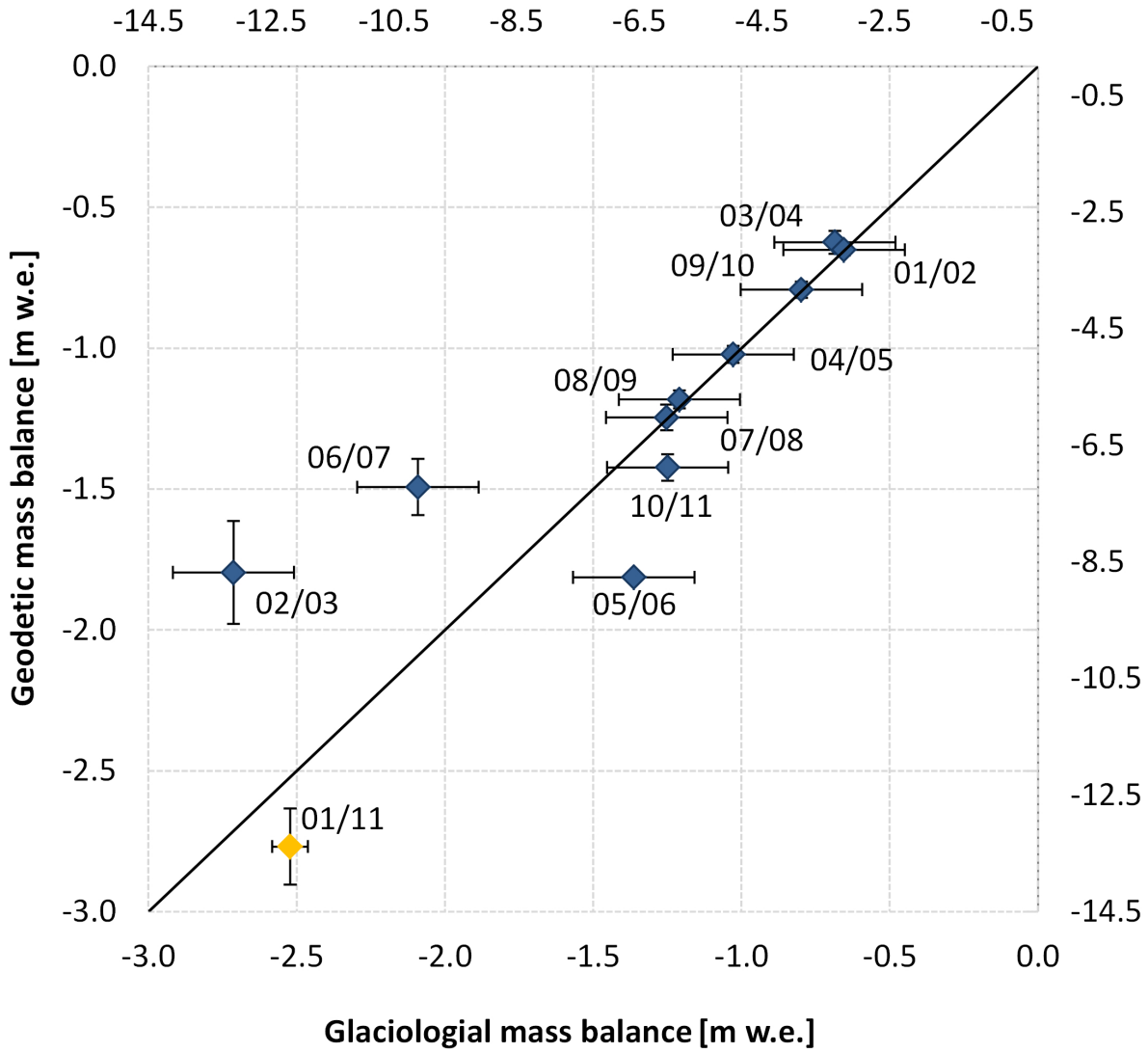

Figure S2: Homogenized glaciological versus corrected geodetic mass balances and corresponding ranges of uncertainties for individual years (x-scale bottom, y-scale left) and the whole study period (01/11, x-scale top and y-scale right).

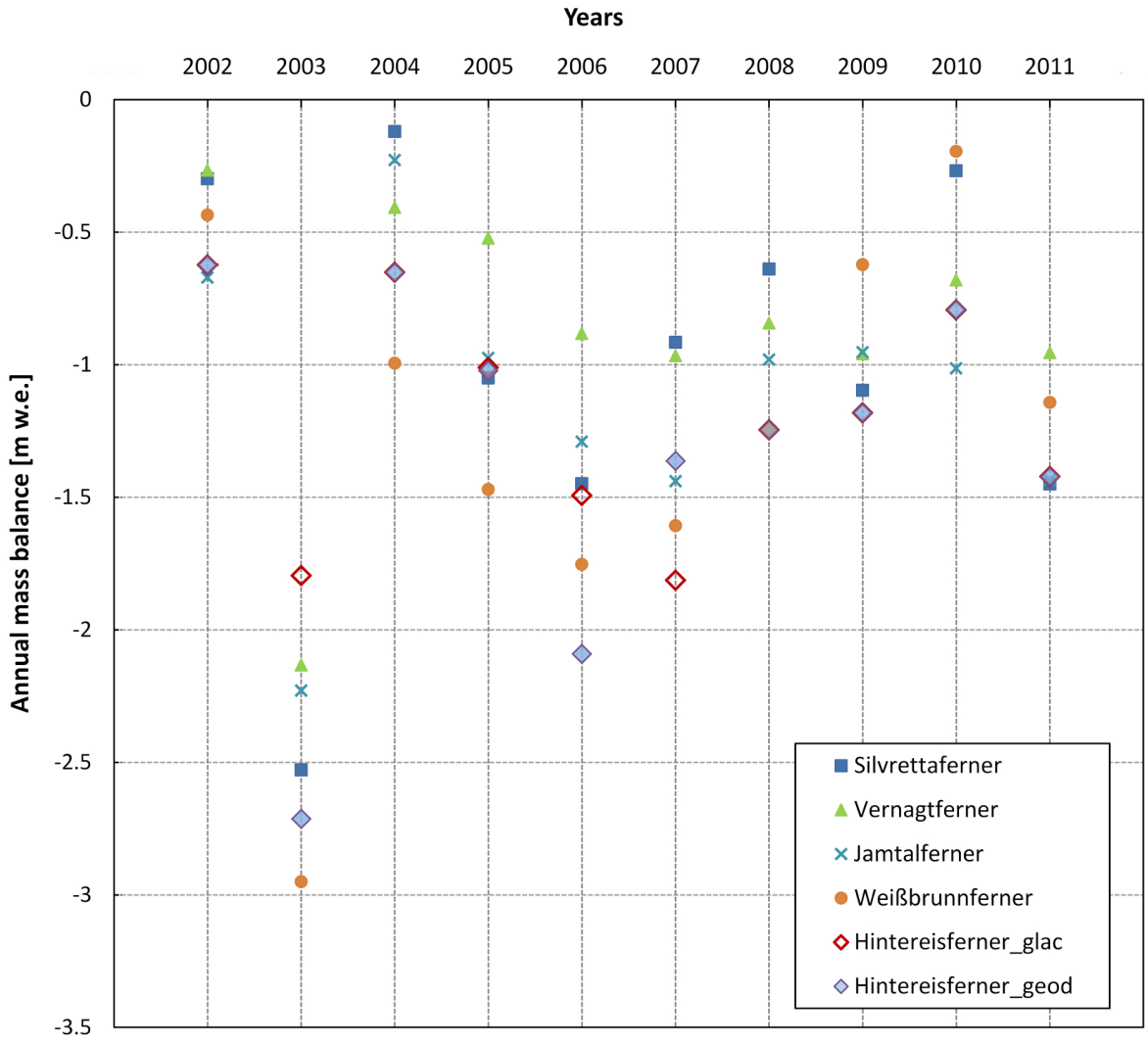

Figure S3: Additional confidence for our assessment comes from comparing the 2002/03, 2005/06 and 2006/07 mass balances of Hintereisferner with those of Silvrettagletscher (2.7 km^2, Switzerland, 52 km away), Jamtalferner (3.7 km^2, Austria, 45 km), Weißbrunnferner (0.5 km^2, Italy, 35 km) and Vernagtferner (7.9 km^2, Austria, 6 km). While in the years 2002/03 and 2006/07 glaciological Hintereisferner values lay outside the spread of mass balances and the geodetic ones are inside, the glaciological balance of 2005/06 is inside and the geodetic value becomes the most negative one. This is of no surprise with Hintereisferner being the lowest reaching glacier of all and its mass balance being among the most negative results in all analysed years. However, a more comprehensive discussion and justification for the different relative positions would require a detailed investigation of local conditions including meteorological patterns for each individual glacier and mass balance year.

Table S1: Area averaged annual altitudinal changes $\overline{\Delta Z}$ [m] and according standard deviation $SD_{\Delta Z}$ [m] of selected stable areas in the surroundings of Hintereisferner. Bold numbers indicate the existence of snow cover.

	ΔZ campaign	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	01/11
A	$\overline{\Delta Z}$ stable area (A)	**-0.38**	-0.10	0.00	**0.13**	**-0.58**	**-0.17**	**-0.26**	0.03	0.15	-0.06	-0.46
~3000 m a.s.l.	$SD_{\Delta Z}$ surface lowering A	0.03	0.04	0.03	0.06	0.09	0.12	0.06	0.02	0.04	0.03	0.12
B	$\overline{\Delta Z}$ stable area (B)	**-0.42**	-0.14	-0.02	**0.17**	**-0.52**	**-0.16**	**-0.18**	0.04	0.10	-0.05	-0.38
~3100 m a.s.l.	$SD_{\Delta Z}$ surface lowering B	0.09	0.03	0.07	0.06	0.12	0.08	0.03	0.03	0.09	0.01	0.14
C	$\overline{\Delta Z}$ stable area (C)	**-0.46**	-0.15	-0.06	-0.06	**-0.45**	**-0.19**	-0.07	0.10	0.15	-0.10	-0.42
~3200 m a.s.l.	$SD_{\Delta Z}$ surface lowering C	0.12	0.02	0.05	0.09	0.07	0.11	0.01	0.04	0.04	0.03	0.17
D	$\overline{\Delta Z}$ stable area (D)	-0.14	-0.07	-0.03	0.03	-0.09	-0.01	-0.06	0.05	0.05	-0.11	-0.26
~2500 m a.s.l.	$SD_{\Delta Z}$ surface lowering D	0.06	0.07	0.02	0.02	0.07	0.05	0.07	0.03	0.03	0.04	0.09
E	$\overline{\Delta Z}$ stable area (E)	**-0.19**	-0.04	-0.04	0.05	**-0.39**	-0.06	-0.01	-0.02	0.10	-0.13	-0.24
~2850 m a.s.l.	$SD_{\Delta Z}$ surface lowering E	0.03	0.02	0.03	0.06	0.07	0.05	0.06	0.05	0.03	0.03	0.11

Table S2: Summary of ALS and closest field survey dates of Hintereisferner, mean snow cover in DEM ((SC) ALS) and in field survey ((SC) field) used for DEM correction, values of survey date adjustments (ϵ_{sd}), glacier area (A) and classified firn area (AF). Short comments are taken from field measurement minutes. The mean accumulation area decreased from 3.85 km^2 to 1.98 km^2 for the period 2001-2011.

ALS survey	field survey	$\overline{SC}_{ALS}$ [m]	$\overline{SC}_{field}$ [m]	ϵ_{sd} [m w.e.]	A [km]^2	AF [km]^2	Comments
11 Oct 2001	8 Oct 2001	0.52	0.47	-0.12	8.02	3.85	Continuous snow cover at field survey (10 – 50 cm, probings <3400 m a.s.l.); further snowfall between 8^{th} and 11^{th} of October; snow cover estimation based on ALS data
18 Sept 2002	02 Oct 2002	0.00	0.17	0.08	7.86	3.53	Continuous snow cover at field survey (10 – 35 cm, <3400 m a.s.l.), snow cover estimation based on field survey October; and meteorological data
26 Sept 2003	30 Sept 2003	0.00	0.00	-0.02	7.66	3.12	Strong ablation on stakes between 16^{th} August and 30^{th} <3400 m a.s.l.);September; 1 – 4 cm/d below 3000 m a.s.l. estimated based October;on field survey and meteorological data ; no snow cover at geodetic survey
5 Oct 2004	30 Sept 2004	0.23	0.23	0.05	7.61	3.05	Continuous snow cover at field survey (5 – 40 cm, <3400 m a.s.l.); additional snowfall event between 1^{st} and 12^{th} of October (103 mm on HEF) snow cover estimation based on ALS data
12 Oct 2005	30 Sept 2005	0.46	0.30	-0.07	7.51	2.72	Continuous snow cover at field survey (1 – 30 cm, <3400 m a.s.l.); further snowfall between 8^{th} and 11^{th} of October; snow cover estimation based on ALS data
08 Oct 2006	30 Sept 2006	0.13	0.00	-0.01	7.38	2.43	No snow cover at field survey; snowfall events between 3^{rd} and 8^{th} of October (82 mm on HEF); snow cover estimation data
11 Oct 2007	1 Oct 2007	0.12	—	-0.01	7.28	2.32	No field survey data available; snowfall events between 1^{st} and 12^{th} of October; snow cover estimation based on ALS data
09 Sept 2008	30 Sept 2008	0.00	0.18	-0.05	7.15	2.03	Continuous snow cover at field survey (0 – 32 cm, <3400 m a.s.l.; 4 – 28 cm ablation at stakes between 9^{th} and $30^{th}$of September; snow cover estimation based on field survey and meteorological data
30 Sept 2009	27 Sept 2009	0.00	0.00	0.00	7.05	2.01	No correction necessary; no significant snow cover ¡ <3400 m a.s.l.
08 Oct 2010	27 Sept 2010	0.26	0.26	-0.03	6.88	2.22	Continuous snow cover at field survey (1 – 42 cm, <3400 m a.s.l.; snowfall event between 28^{th} of Sept and 8^{th} of October (12 mm on HEF) but nearly no ablation; snow cover estimation based on field data
04 Oct 2011	04 Oct	0.00	0.00	0.00	6.79	1.98	No correction necessary; no significant snow cover <3400 m a.s.l.