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Supplement of

Modelling rock glacier ice content based on InSAR-derived velocity, Khumbu and Lhotse valleys, Nepal

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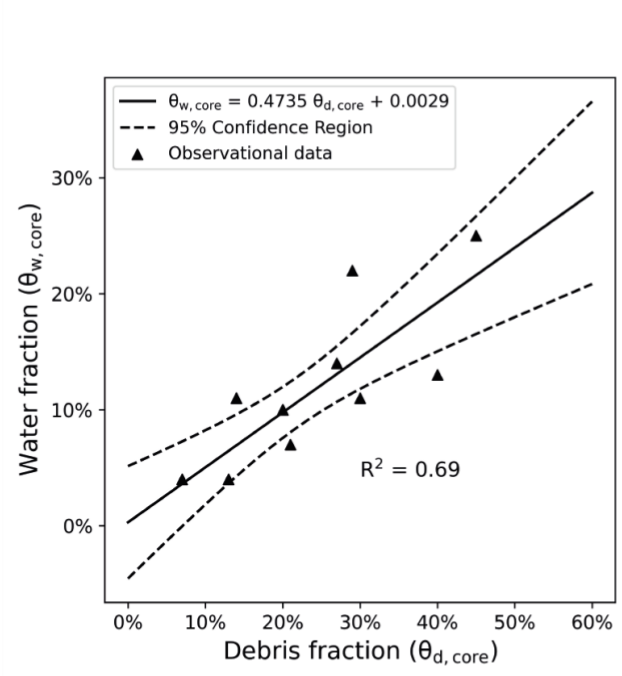

Figure S1: Relationship between debris fraction ($\theta_{d,core}$) and water fraction ($\theta_{w,core}$). The observational data are derived from the GPR and DGPS measurements in Monnier and Kinnard (2015b & 2016).

Table S1. Parameters of the sensitivity experiments. Scn-1.0 (in italic) is the reference scenario that adopts the parameters of Murtèl rock glacier. The other scenarios are designed by multiplying the reference value of each variable with the corresponding factor in their scenario labels.

Scenario	A_{rg} (km^2)	W (m)	α (°)	h_{al} (m)	ρ_d (kg/m^3)	$\theta_{d,al}$ (%)	$\theta_{a,core}$ (%)
Scn-0.2	0.013	40	3.2	0.6	1450	13	1.5
Scn-0.4	0.026	80	6.4	1.2	1700	26	3.0
Scn-0.6	0.039	120	9.6	1.8	1950	39	4.5
Scn-0.8	0.052	160	12.8	2.4	2200	52	6.0
Scn-1.0	*0.065*	*200*	*16*	*3.0*	*2450*	*65*	*7.5*
Scn-1.2	0.078	240	19.2	3.6	2700	72	9.0
Scn-1.4	0.091	280	22.4	4.2	2950	79	10.5
Scn-1.6	0.104	320	25.6	4.8	3200	86	12.0
Scn-1.8	0.117	360	28.8	5.4	3450	93	13.5

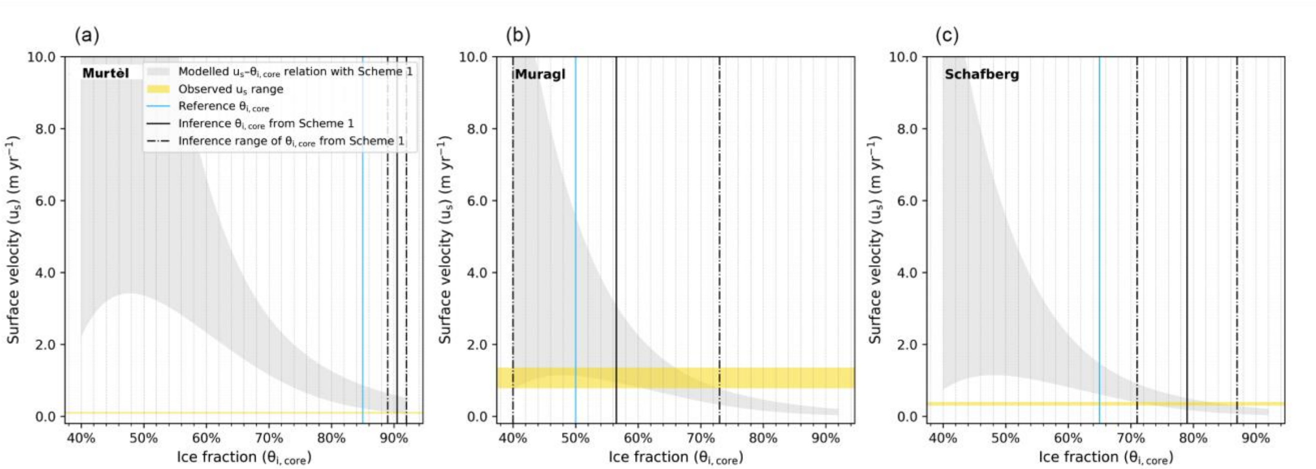

Figure S2: Modelled relationships (grey shaded areas) between the ice fraction ($\theta_{i,core}$) and the surface velocity (u_s) of 95% confidence intervals for the three RGs monitored in the PERMOS network with model parameterisation Scheme 1. The ranges of the observed velocities (yellow bands) are used as velocity constraints for inferring ice content from the modelled relationships. Also shown are the reference ice content obtained from previous field-based surveys (blue lines). The inference ice contents are the mean values (solid black lines) with the estimated ranges (dash-dotted black lines).

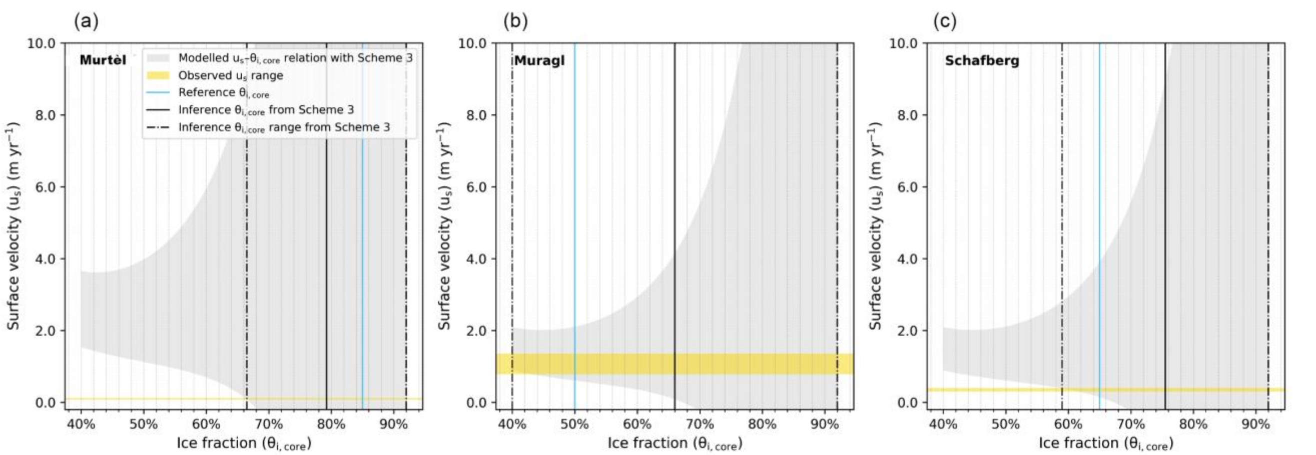

Figure S3: Similar to Fig. S2, but showing results derived from model parameterisation Scheme 3. The grey shaded areas outline the modelled relationships between the ice fraction ($\theta_{i,core}$) and the surface velocity (u_s) with 95% confidence intervals. The yellow bands show the observed surface velocities, and the blue lines denote the reference ice contents. For each rock glacier, the intersection between the simulated $\theta_{i,core}$- u_s relationship (grey shaded area) and the observed velocity (yellow band) gives the estimated range of ice content, as marked by the dash-dotted black lines. The inferred ice content is taken as the average value of the estimated range and indicated by the solid black line.

Table S2: Estimated rock glacier thickness (T_{area}) derived from the thickness–area relationship used in this study, and the corresponding bias relative to in situ measured thickness (T_{ref}) (Barsch et al., 1979; Cicoira et al., 2019a; Arenson et al., 2002; Hoelzle et al., 1998). The rock glacier thickness (T_{slp}) derived from thickness–slope angle relationship proposed by Cicoira et al. (2020), and the associated bias. The last row gives the mean absolute error (MAE) derived from the two methods.

Rock glacier	T_{area} (m)	T_{slp} (m)	T_{ref} (m)
Murtèl	29	26.2	27
Muragl	24	19	20
Schafberg	24	20.8	25
MAE	2.3	2	–

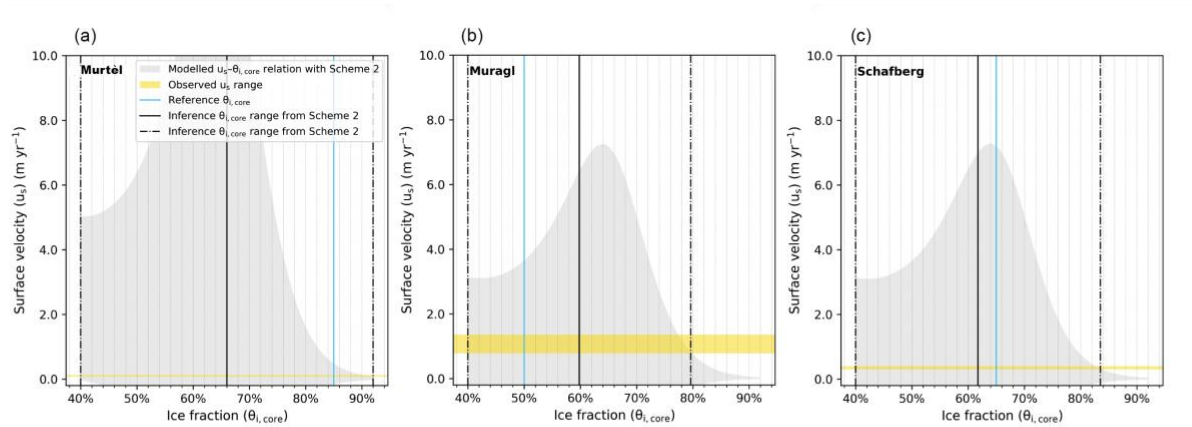

Figure S4: Modelled relationships (grey shaded areas) between the ice fraction ($\theta_{i,core}$) and the surface velocity (u_s) of 95% confidence intervals for the three RGs monitored in the PERMOS network assuming a thickness error of 6 m. The ranges of the observed velocities (yellow bands) are used as velocity constraints for inferring ice content from the modelled relationships. Also shown are the reference ice content obtained from previous field-based surveys (blue lines). The inference ice contents are the mean values (solid black lines) with the estimated ranges (dash-dotted black lines).

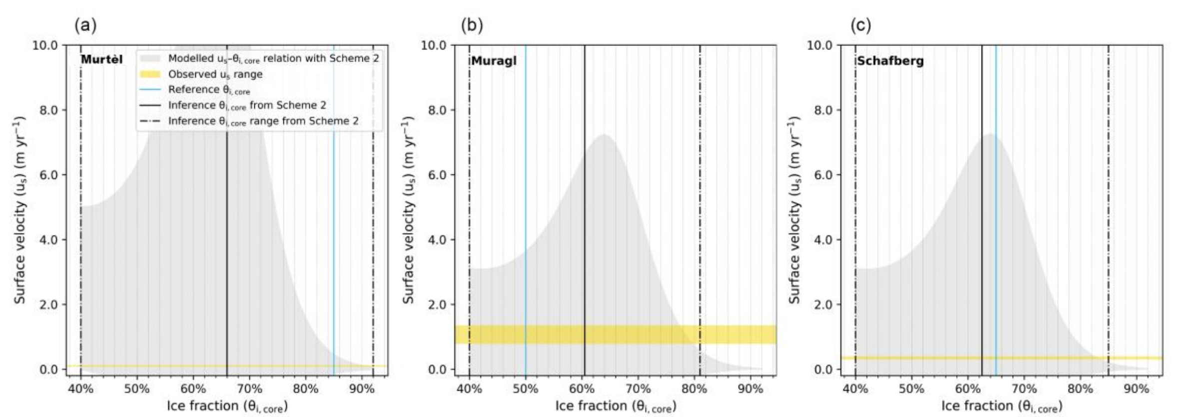

Figure S5: Similar to Fig. S4, but showing results with a thickness error of 10 m.

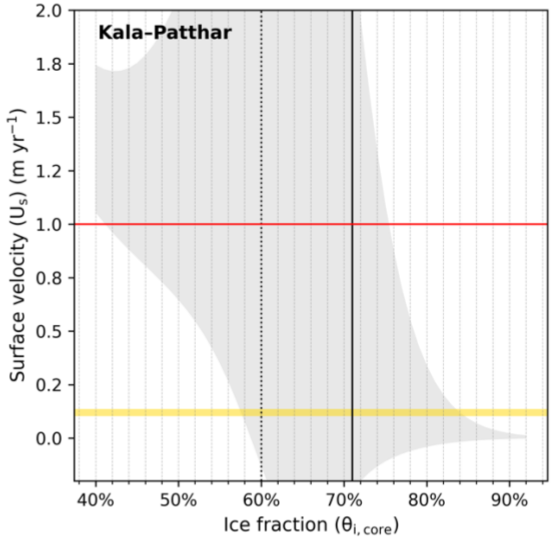

Figure S6: Modified after Fig. 9a in the manuscript. The yellow shading shows the observed surface velocity (~0.1 m yr^{-1}) and the vertical solid black line denotes the modelled ice content (71%). The red shading marks an assumed surface velocity (1 m yr^{-1}) and the estimated ice fraction is shown by the vertical dotted line (60%).

Table S3. Summary of the reference and inference ice contents derived from two scenarios assuming different thickness errors, namely 6 m and 10 m. The values in brackets following the inference ice contents give the corresponding bias from the reference ice contents. The last row presents the root mean square error (RMSE) of the two scenarios.

Rock glacier	Reference (%)	Inference and bias (%)	
		6-m thickness error	10-m thickness error
Murtèl	85	66 (-19)	66 (-19)
Muragl	50	60 (10)	61 (11)
Schafberg	65	62 (-3)	63 (-2)
RMSE	–	12	13