What is the global glacier ice volume outside the ice sheets?

Regine Hock, Fabien Maussion, Ben Marzeion, Sophie Nowicki

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Supplementary Material

The regional ice volumes given by Millan and other (2022, henceworth referred to as M22) refer to the glacier area for which ice velocity maps could be generated. Therefore, the areal coverage is incomplete in some regions varying between 63 and 100 % coverage (Table 1 in M22). Here we update the regional ice volumes provided by M22 (their Table 1) for all RGI regions outside Antarctica accounting for the missing area (i.e., the area which is glacierized according to the RGI but for which M22 provides no ice thickness values). We apply two methods: volume-area scaling (Bahr and others, 1997), and a scaling method relying on the estimates from Farinotti and others (2019, henceworth referred to as F19) to estimate the missing ice volume over the glacier area not covered by M22. Since values in M22´s Table 1 are given with relatively low resolution (e.g., area in 1000 km^2), we recalculate glacier area, areal coverage and ice volume using their original gridded data (downloaded from https://doi.org/10.6096/1007 on 2022-07-20), which include regional ice volume data on a 50 m x 50 m grid. For each region, we adopt the following procedure:

1) We recompute the area covered by M22´s thickness estimates. To do so, we first remove any erroneous data and then sum the area of all grid cells with valid ice thickness data. We note that:
    a. M22´s column ´Glacierized area´ in their Table 1 refers to the total regional area according to RGI 6.0), i.e., not necessarily to the area their volume estimates refer to.
    b. M22´s column ´Coverage´ in their Table 1 refers to the coverage of their velocity product, which is slightly different from the coverage of their ice thickness product due to their quality check and gap filling methods.
2) We recalculate the relative areal coverage for each region using our results from step 1 and the glacier areas in RGI 6.0 which were also used by F19.
3) We sum the volume of all grid cells with valid ice thickness data.
4) We then upscale the glacier volume for the regions with incomplete areal coverage using two independent methods: Method 1 uses volume-area scaling (Bahr et al., 1997) defined by

$$V = cA^{\gamma} \qquad \text{Equation (S1),}$$

where V is ice volume (km^3), and A glacier area (km^2), and c (km$^{3-2\gamma}$) and γ (-) are scaling coefficients. First, we reproject the gridded M22 dataset onto each RGI glacier outline and generate a subset of RGI glaciers where the M22 dataset includes ice thickness data for at least 95% of each glacier´s area. We then determine c and γ by regressing the glacier volumes computed in step 3 of each region´s subset to their corresponding area.

Method 2 assumes that the fraction of volume contained in M22´s missing area relative to the RGI area is identical to the corresponding fraction in the F19 dataset. Thus, the upscaled regional ice volume $V_{\mathrm{M22,RGI}}$ is computed by

$$V_{M22,RGI} = \frac{V_{F19RGI}}{V_{F19\subset}V_{M22\subset}} \qquad \text{Equation (S2),}$$

where V_{F19RGI} is the total regional F19 volume, and $V_{F19\subset}$ is the subset of glaciers identified above.

Both methods must be considered rough approximations, and uncertainties in our upscaled volumes are expected to increase with increasing missing area. Thus, the results, in particular in regions with large fractions of missing area, must be treated with caution. However, we note that both methods provide overall very similar upscaled regional volumes. Results from both methods and their averages are provided in Table S1.

More detailed information including values of the coefficients c and γ in Equation S1 and the volumes of the regional subsets in Equation 2, as well as all code to reproduce our results and figures are available at https://zenodo.org/record/7492152. Data tables including the glacier volumes recalculated for each individual RGI glacier from the ice thickness data set by M22 are also available.

Table S1. Regional volumes computed in this study from the M22 data set, and volume differences relative to F19 for all RGI regions outside Antarctica. Volumes by M22 are recalculated and upscaled to all glacier area in the RGI 6.0 according to method 1 (Equation 1) and method 2 (Equation 2). M22 refers to the original values in M22´s Table 1.

Region (number)	Area	Glacier volume			Volume difference rel. to F19		
	RGI6.0	Method 1	Method 2	Average of method 1 and 2	Method 1	Method 2	M22
	km²	km³	km³	km³	%	%	%
Alaska and W Canada (1+2)	101249.3	19265.3	19055.1	19160.2	-3.8	-4.8	-4
Arctic Canada N (3)	105110.6	25423.0	25378.4	25400.7	-10.3	-10.4	-10
Arctic Canada S (4)	40888.2	7028.0	7036.0	7032.0	-18.4	-18.3	-19
Greenland (5)	89717.1	12529.8	12557.8	12543.8	-20.2	-20.0	-25
Iceland (6)	11059.7	3727.7	3727.0	3727.4	-1.1	-1.1	-1
Svalbard (7)	33958.9	6876.8	6849.4	6863.1	-8.0	-8.3	-6
Scandinavia (8)	2949.1	330.5	305.0	317.8	10.7	2.2	-4
Russian Arctic (9)	51591.6	15604.3	15527.7	15566.0	6.6	6.1	6
North Asia (10)	2410.1	136.3	134.6	135.5	0.4	-0.9	-22
Central Europe (11)	2092.1	116.5	116.7	116.6	-8.9	-8.8	-11
Caucasus (12)	1307.0	68.4	66.8	67.6	8.4	5.9	-8
High Mountain Asia (13-15)	97605.9	9485.7	9473.5	9479.6	35.3	35.1	34
Low Latitudes (16)	2341.0	84.0	84.0	84.0	-14.6	-14.7	-27
Southern Andes (17)	29429.1	6032.6	6033.5	6033.1	13.0	13.0	10
New Zealand (18)	1161.8	71.4	71.8	71.6	-3.1	-2.6	2