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Ad hoc estimation of glacier contributions to sea-level rise from the latest glaciological observations

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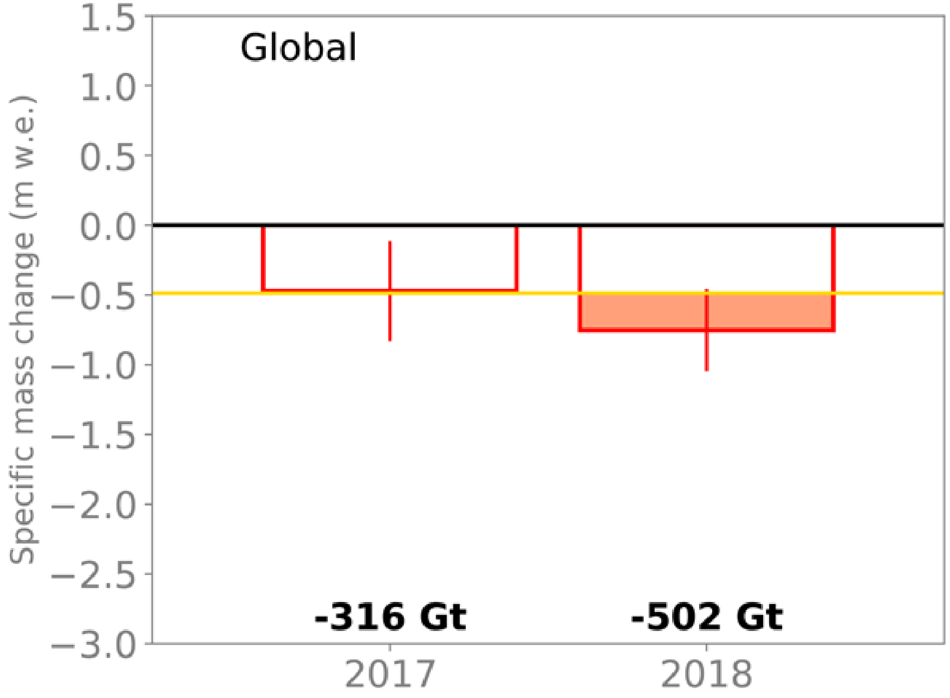
Comprehensive assessments of global glacier mass changes based on a variety of observations and prevailing methodologies have been published at multi-annual intervals. For the years in between, the glaciological method provides annual observations of specific mass changes but is suspected to not be representative at the regional to global scales due to uneven glacier distribution with respect to the full sample.

Here, we present the results of a simple approach to estimate and correct for this bias in the glaciological sample and, hence, to provide an ad hoc estimate of global glacier mass changes and corresponding sea-level equivalents for the latest years.



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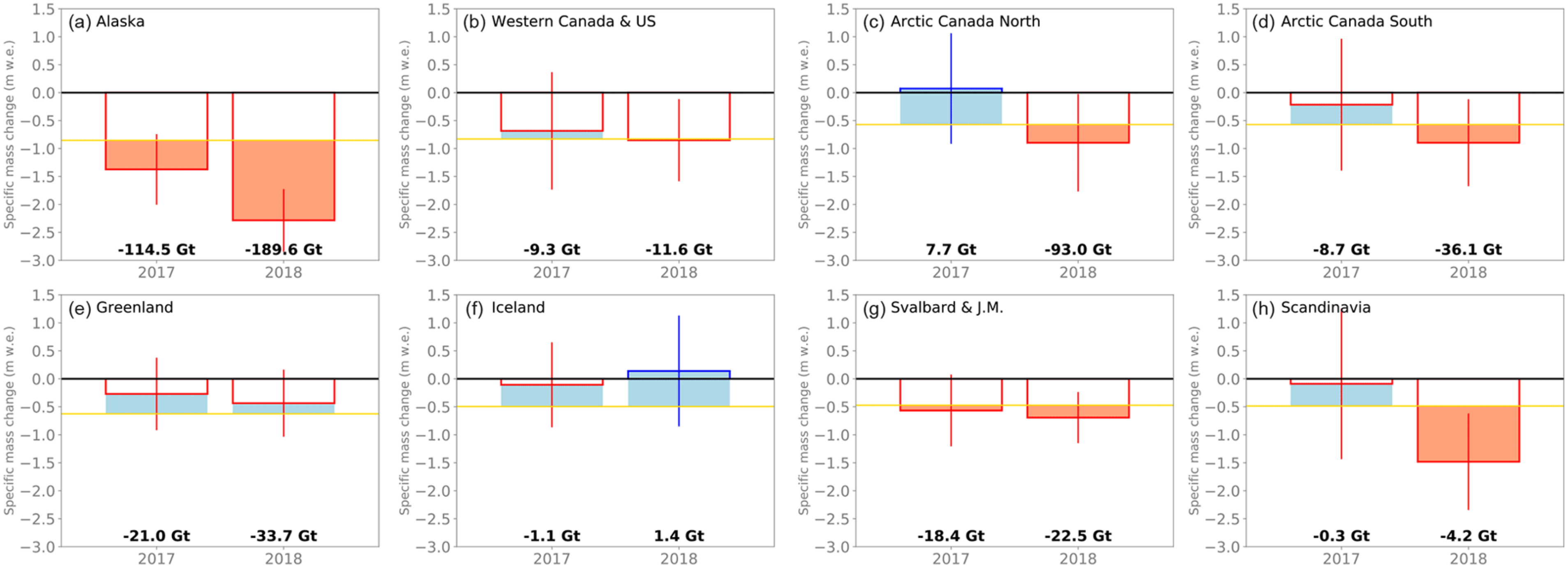

Fig. 1. Ad hoc estimates of regional mass changes in 2016/17 and 2017/18. The regional (a–s) and global (t) bar plots show the annual specific mass changes (in m w.e.) with related error bars (indicating 95 % confidence intervals), with positive and negative values in blue and red, respectively. The golden line indicates the annual mass-change rate of the reference data (in m w.e. yr^{-1}; Zemp et al., 2019, Nature) over the calibration period (2006/07–2015/16). Positive and negative annual mass-change anomalies (with respect to reference data and calibration period) are indicated in pale blue and pale red, respectively. The black values (bottom) indicate annual mass changes in gigatonnes.

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about · **results** · questions

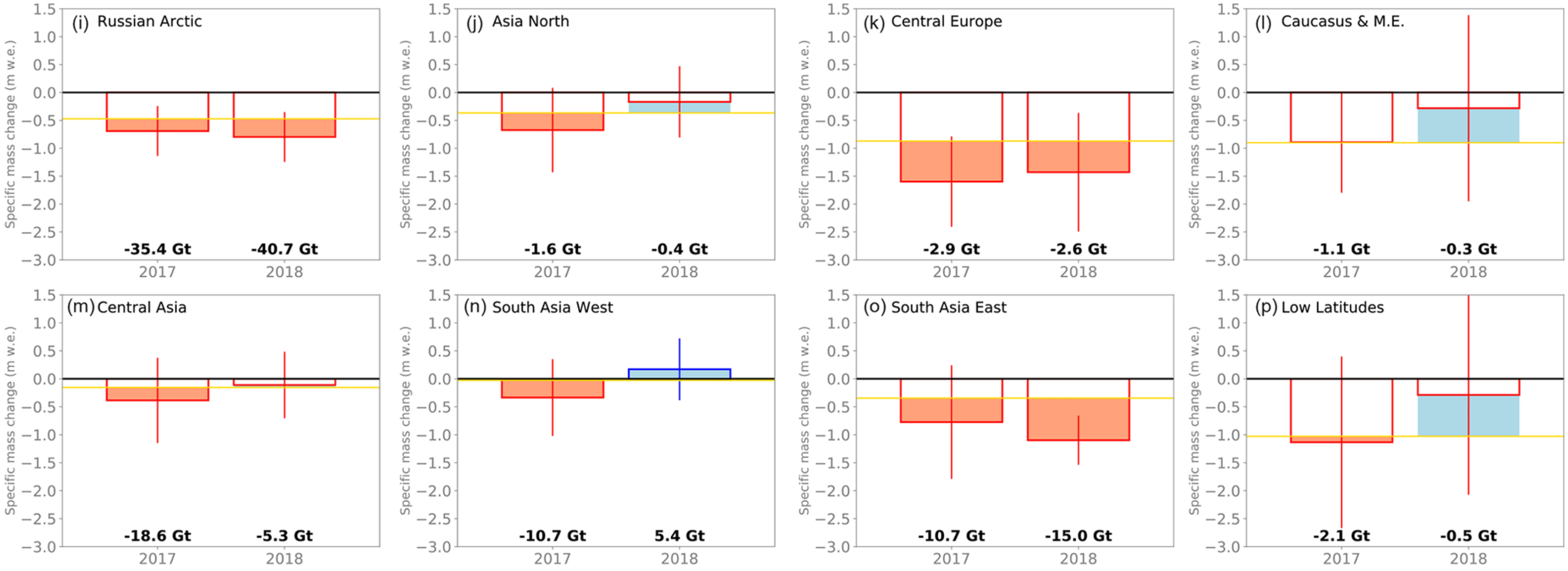

Fig. 1 continued. Ad hoc estimates of regional mass changes in 2016/17 and 2017/18. The regional (a–s) and global (t) bar plots show the annual specific mass changes (in m w.e.) with related error bars (indicating 95 % confidence intervals), with positive and negative values in blue and red, respectively. The golden line indicates the annual mass-change rate of the reference data (in m w.e. yr^{-1}; Zemp et al., 2019, Nature) over the calibration period (2006/07–2015/16). Positive and negative annual mass-change anomalies (with respect to reference data and calibration period) are indicated in pale blue and pale red, respectively. The black values (bottom) indicate annual mass changes in gigatonnes.

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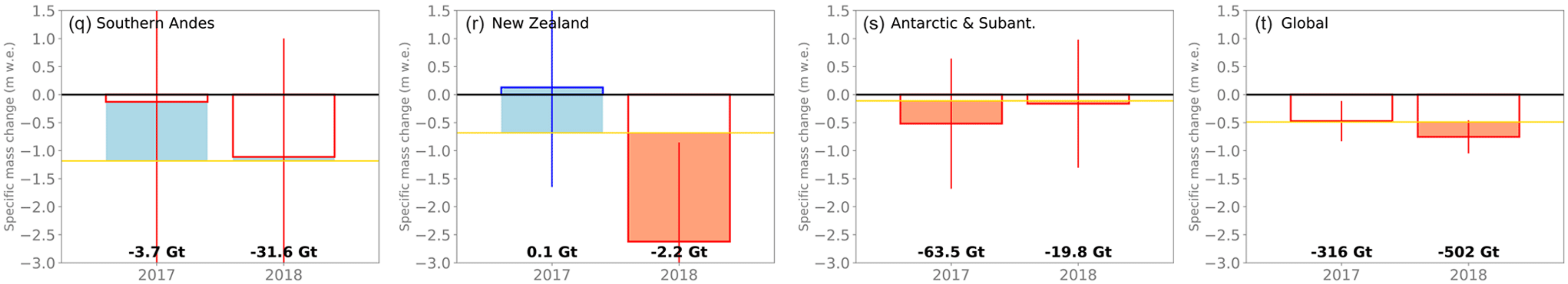

Fig. 1 continued. Ad hoc estimates of regional mass changes in 2016/17 and 2017/18. The regional (a–s) and global (t) bar plots show the annual specific mass changes (in m w.e.) with related error bars (indicating 95 % confidence intervals), with positive and negative values in blue and red, respectively. The golden line indicates the annual mass-change rate of the reference data (in m w.e. yr^{-1}; Zemp et al., 2019, Nature) over the calibration period (2006/07–2015/16). Positive and negative annual mass-change anomalies (with respect to reference data and calibration period) are indicated in pale blue and pale red, respectively. The black values (bottom) indicate annual mass changes in gigatonnes.

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Region	Area (km^2)		Specific mass change (m w.e.)				Mass change (Gt)	
	S 2017	S 2018	B_{glac} 2017	B_{adhoc} 2017	B_{glac} 2018	B_{adhoc} 2018	ΔM 2017	ΔM 2018
01 Alaska	83 395	82 978	−1.18	−1.37 ± 0.63	−1.85	−2.29 ± 0.56	−115 ± 53	−190 ± 47
02 Western Canada & USA	13 661	13 583	−0.54	−0.68 ± 1.05	−0.65	−0.85 ± 0.74	−9 ± 14	−12 ± 10
03 Arctic Canada North	103 860	103 787	0.03	0.07 ± 0.99	−0.82	−0.90 ± 0.87	8 ± 103	−93 ± 91
04 Arctic Canada South	40 332	40 299	−0.22	−0.22 ± 1.18	−0.82	−0.90 ± 0.78	−9 ± 48	−36 ± 31
05 Greenland	77 946	77 210	−0.41	−0.27 ± 0.65	−0.33	−0.44 ± 0.60	−21 ± 50	−34 ± 46
06 Iceland	10 383	10 343	−0.29	−0.11 ± 0.76	−0.05	0.14 ± 0.99	−1 ± 8	1 ± 10
07 Svalbard & Jan Mayen	32 546	32 458	−0.59	−0.57 ± 0.64	−0.62	−0.69 ± 0.46	−18 ± 21	−23 ± 15
08 Scandinavia	2830	2822	−0.03	−0.09 ± 1.35	−1.44	−1.48 ± 0.86	0 ± 4	−4 ± 2
09 Russian Arctic	51 138	51 097	−0.72	−0.69 ± 0.45	−0.82	−0.80 ± 0.45	−35 ± 23	−41 ± 23
10 North Asia	2348	2337	−0.90	−0.67 ± 0.76	−0.39	−0.17 ± 0.64	−2 ± 2	0 ± 2
11 Central Europe	1820	1800	−1.64	−1.60 ± 0.81	−1.44	−1.43 ± 1.06	−3 ± 2	−3 ± 2
12 Caucasus & Middle East	1196	1189	−0.84	−0.89 ± 0.90	−0.22	−0.28 ± 1.67	−1 ± 1	0 ± 2
13 Central Asia	48 061	47 972	−0.77	−0.39 ± 0.76	−0.51	−0.11 ± 0.59	−19 ± 37	−5 ± 29
14 South Asia West	31 876	31 755	−0.90	−0.34 ± 0.69	−0.39	0.17 ± 0.55	−11 ± 22	5 ± 18
15 South Asia East	13 765	13 695	−1.07	−0.77 ± 1.02	−1.37	−1.10 ± 0.44	−11 ± 14	−15 ± 6
16 Low latitudes	1867	1840	−1.06	−1.13 ± 1.53	−0.37	−0.29 ± 1.78	−2 ± 3	−1 ± 3
17 Southern Andes	28 528	28 476	0.37	−0.13 ± 4.43	−0.64	−1.11 ± 2.11	−4 ± 126	−32 ± 60
18 New Zealand	849	841	0.41	0.13 ± 1.78	−2.34	−2.62 ± 1.77	0 ± 2	−2 ± 2
19 Antarctic & Subantarctic	122 822	122 464	−0.28	−0.52 ± 1.16	−0.13	−0.16 ± 1.14	−64 ± 143	−20 ± 140
Global total, excluding 05 & 19	468 455	467 272	−0.53	−0.49 ± 0.40	−0.91	−0.96 ± 0.28	−231 ± 186	−449 ± 131
Global total	669 223	666 946	−0.47	−0.47 ± 0.36	−0.70	−0.75 ± 0.29	−316 ± 240	−502 ± 197

Table 1. Ad hoc estimates of glacier mass changes in 2016/17 and 2017/18. For both years, the table shows glacier areas (S) based on RGI 6.0 and corrected for annual area change rates from Zemp et al. (2019, Nature), specific mass changes calculated as arithmetic mean of the glaciological sample (B_{glac}) and based on the ad hoc estimation (B_{adhoc}), as well as anomaly-corrected mass change (ΔM) for all regions and global totals. The annual global mass changes in 2016/17 and 2017/18 correspond to 0.9±0.6 and1.4±0.5 mm SLE, respectively. Glaciological input data are from WGMS (2019).

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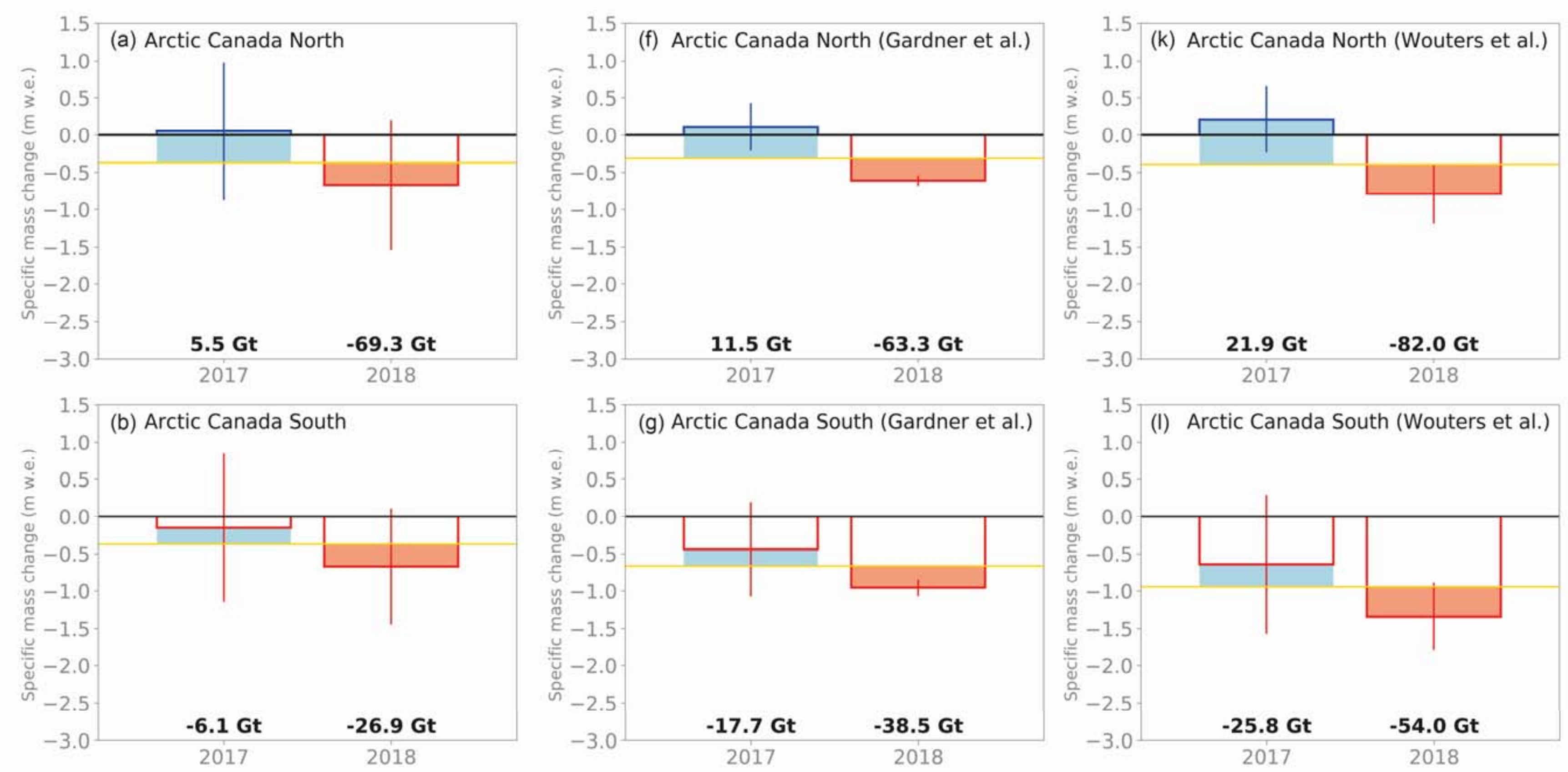

Figure S3 Ad hoc estimates of selected regional mass changes in 2016/17 and 2017/18 based on different reference datasets. The plots (a–b) in the left column correspond to plots in Fig. 1 using Zemp et al. (2019) as reference dataset but for the reference period 2003/04–2008/09. The plots in the middle column (f–g) use Gardner et al. (2013, 2003/04–2008/09) as reference dataset. The plots in the right column (k–l) are using Wouters et al. (2019, 2005/06–2014/15 as reference dataset. Note that within a region, the annual anomalies (pale blue and pale red) are similar but absolute mass changes (in Gt) vary strongly in case of different mass-change rates in the reference datasets.

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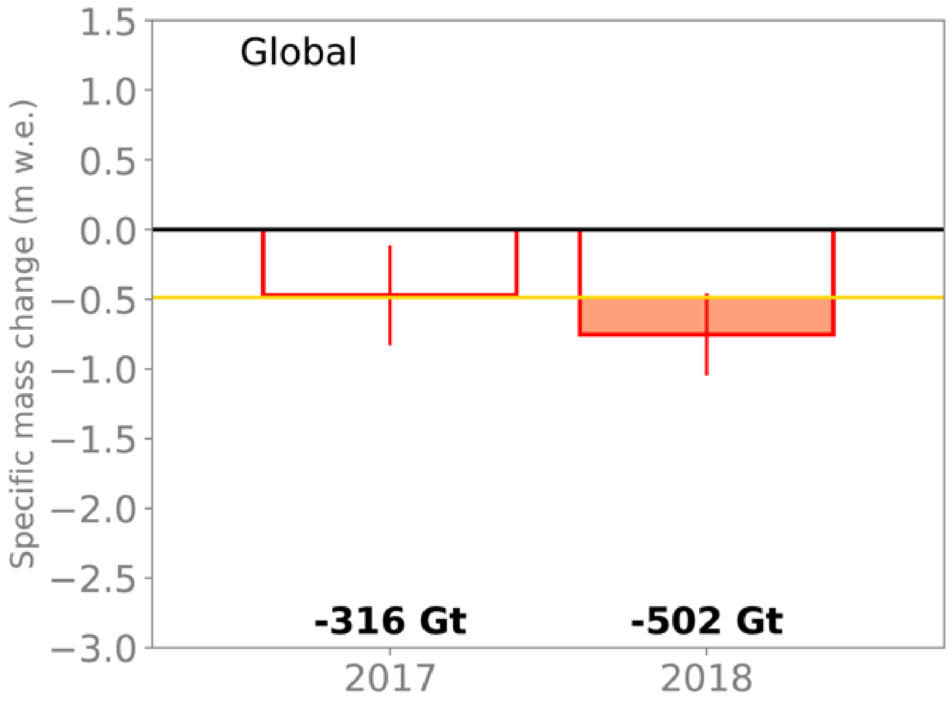
Questions for future work

- How to extend the glaciological network of in situ observations in still underrepresented regions, e.g. Canadian Arctic, Russian Arctic, Asia, peripheral Greenland & Antarctica?
- How fast can we reach global coverage with geodetic surveys from space borne sensors?
- How best to deal with regions and time periods with limited (or no) data?
- How best to combine different reference datasets from geodetic methods?



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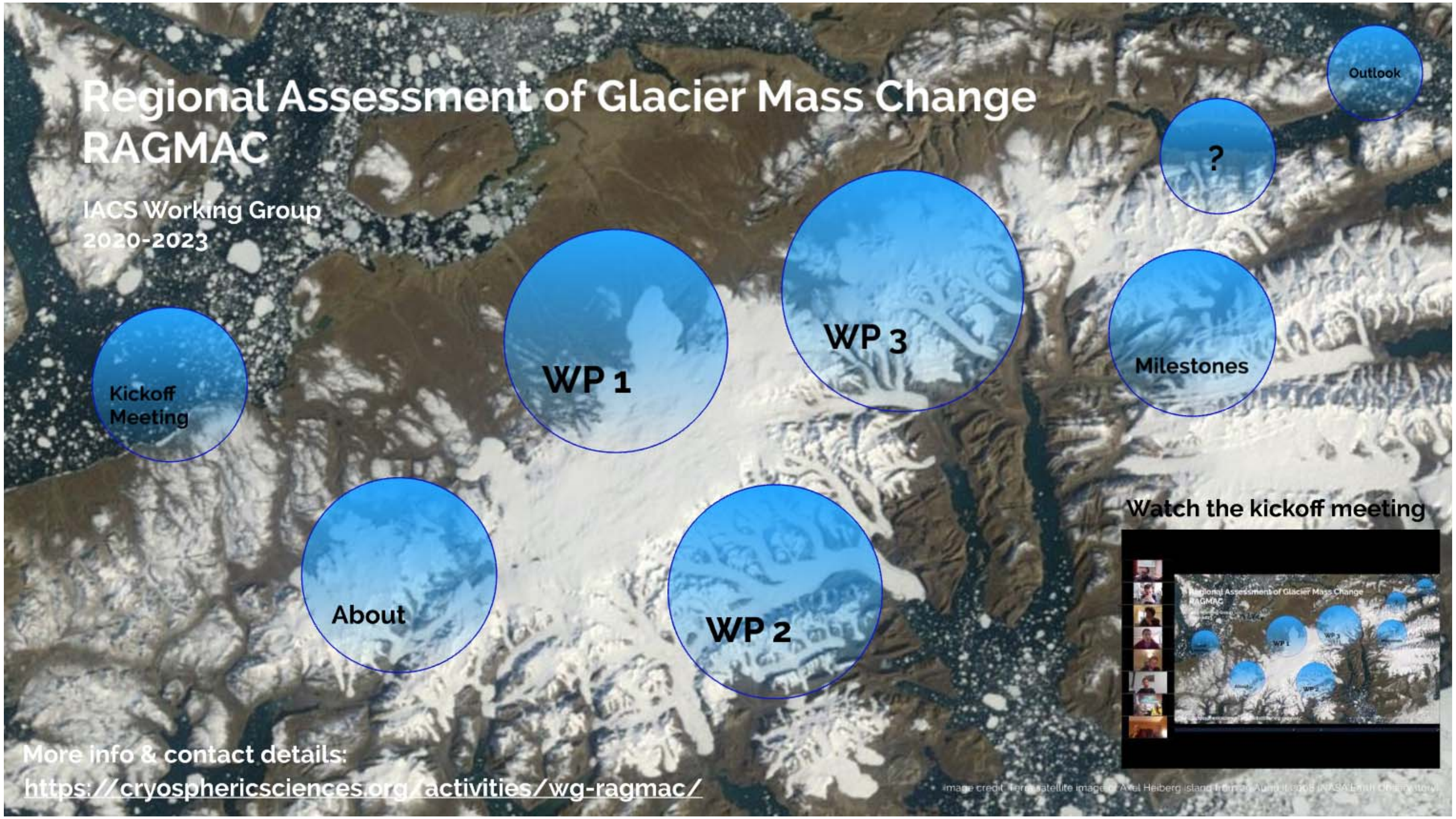
Do you have answers to these questions? Then, you might be interested in joining the new working group of the International Association of Cryospheric Sciences:



Watch our kick-off meeting: https://prezi.com/view/hZHOtiJ6MGsBnCSr8hyO/