Glacier mass balance data for 1961-2010

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Roger J. Braithwaite[1], Sarah C. B. Raper[2]

1. *School of Environment and Development (SED), University of Manchester, Manchester M13 9PL, UK*
2. *Centre for Air Transport and the Environment (CATE), Manchester Metropolitan University, Manchester M1 5GD, UK*

For further information please contact r.braithwaite@manchester.ac.uk

WORLD GLACIER MASS BALANCE

We have compiled observed glacier mass balance data from all over the world for the period 1946-2010 together with relevant metadata. The data refer to measurements of winter, summer and annual balance using stakes and snowpits, i.e. by the so-called direct or glaciological method (Cogley and others, 2011). Balance is measured at a number of points at different altitudes on the glacier and the data are then area-averaged over the whole glacier to give mean specific balances. Braithwaite (2002) outlines the early development of glacier monitoring, and Dyurgerov (2002) and Dyurgerov and Meier (2005) have been assiduous in finding early data, which were often scattered through obscure expedition reports. However, modern data collection is now well integrated within a global monitoring system where data are collected by various agencies, or even individuals, and are transmitted to the World Glacier Monitoring Service (WGMS) in Zürich, formerly known as the Permanent Service on Fluctuations of Glaciers (PSFG). The WGMS then re-distribute the data to potential users through regular publications (electronic and hardcopy): *Fluctuations of Glaciers* and *Mass Balance Bulletin*.

The longest mass balance series in the whole world are shown in Table 1 where mean and standard deviation refer to the annual balances for the period for which data are available. The data are extracted from *Fluctuations of Glaciers* (PSFG, 1967, 1973 1977 and 1985: WGMS, 1988, 1993, 1998, 2005 and 2008) and *Mass Balance Bulletin* (WGMS, 2009 and 2011) and we currently have annual balance data up to 2010 for most glaciers. Other data, e.g. glacier areas and winter and summer balances, are only available up to 2005 (WGMS, 2008), and we must wait for Volume X of *Fluctuations of Glaciers* for the latest 2006-2010 values. This illustrates the fact that the global glacier monitoring is still far from operating in real time: you must wait 2 years for annual balance data and up to 6 years for winter and summer balances. No doubt, better performance could be achieved if WGMS were better funded.

The regions in Table 1 are broadly defined and should not be taken as objectively defined to contain glaciers with the same, or similar, pattern of mass balance variations. It is notable that many glacierized regions of the world are not even represented in this list of glaciers with long records.

ALPINE GLACIER MASS BALANCE

The locations and periods of all known mass-balance measurements in the Alps (36 glaciers) are listed in Table 2. The periods of record are widely divergent. Measurements were started on eight glaciers before 1961, either for scientific curiosity or as background data for planning/operating hydropower stations, but two of these were terminated in 1989 (Limmerngletscher and Plattalvagletscher, both in Switzerland). The large number of presently measured

glaciers (24 glaciers in 2010) probably indicates increasing concern about the potential effects of global warming.

The mean balances vary between negative and positive values, partly reflecting the varying periods of measurement. The standard deviations (given for series longer than seven years) express the inherent variability of mass balance at the various locations. At the bottom of the table, we calculate statistics for mass balance for the three periods 1948-1960, 1961-1990 and 1991-2010. The mean balance for 1961-1990 is relatively close to zero (-0.15 m w.e. a^{-1}) while balances in 1948-1960 were more negative (-0.41 m w.e. a^{-1}) and are even more negative (-0.93 m w.e. a^{-1}) for the most recent period 1991-2010.

The figures at the bottom of the table refer to statistics for a varying number of glaciers. We know that systematic differences in mean mass balance can arise between neighbouring glaciers. It is therefore better to base statistics on the same glaciers for all years as statistics might otherwise be affected by the presence or absence of data from a particular glacier for a particular year. Records for six glaciers start before 1961 and continue to 2010 (Glacier de Saint Sorlin, Glacier de Sarennes, Silvrettagletscher, Hintereisferner, Kesselwandferner and Sonnblickkees). Measurements on a further two glaciers (Griesgletscher and Vernagtferner) start in the early 1960's, i.e. they only miss one or four years of the thirty years 1961-1990, and we include them in our 8-glacier dataset for the Alps for the 50-years 1961-2010.

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Table 1. Glaciers from all over the world with long mass balance records for 1946-2010: data from PSFG (1967, 19731977 and 1985), WGMS (1988, 1993, 1998, 2005, 2008, 2009 and 2011). Mean and standard deviation (S.D) of annual balance refer to the whole period for which data are available. Mass balance units are m w.e. a^{-1}.

Glacier	Region	Lat (N)	Lon (E)	From	To	Mean	S.D.	Years
Meighen ice cap	Canadian Arctic	79.9	-99.1	1960	2010	-0.17	0.29	49
White Glaciers	Canadian Arctic	79.5	-90.7	1960	2010	-0.18	0.28	48
Devon ice cap	Canadian Arctic	75.4	-83.3	1961	2010	-0.11	0.17	48
Melville south ice cap	Canadian Arctic	75.4	-115.0	1963	2010	-0.22	0.31	35
Gulkana	West N. America	63.3	-145.4	1966	2010	-0.45	0.63	45
Wolverine	West N. America	60.4	-148.9	1966	2010	-0.39	1.15	44
Lemon Creek	West N. America	58.4	-134.4	1953	2010	-0.44	0.64	58
Peyto	West N. America	51.7	-116.5	1966	2009	-0.60	0.65	42
Place	West N. America	50.4	-122.6	1965	2010	-0.86	0.82	45
South Cascade	West N. America	48.4	-121.1	1953	2009	-0.60	1.01	56
Austre Broeggerbreen	Svalbard	78.9	11.8	1967	2010	-0.47	0.32	44
Midtre Lovenbreen	Svalbard	78.9	12.1	1968	2010	-0.37	0.30	43
Storglaciaeren	Scandinavia	67.9	18.6	1946	2010	-0.27	0.72	65
Engabreen	Scandinavia	66.7	13.9	1970	2010	0.55	1.11	41
Aalfotbreen	Scandinavia	61.8	5.7	1963	2010	0.13	1.43	48
Nigardsbreen	Scandinavia	61.7	7.1	1962	2010	0.38	1.03	49
Graasubreen	Scandinavia	61.7	8.6	1962	2010	-0.36	0.63	49
Hellstugubreen	Scandinavia	61.6	8.4	1962	2010	-0.39	0.64	49
Storbreen	Scandinavia	61.6	8.1	1949	2010	-0.31	0.69	62
Rembesdalsskaaka	Scandinavia	60.5	7.4	1963	2010	0.07	1.05	48
Saint Sorlin	Alps	45.2	6.2	1957	2010	-0.62	1.02	54
Sarennes	Alps	45.1	6.1	1949	2010	-0.96	1.13	62
Griesgletscher	Alps	46.4	8.3	1962	2010	-0.68	0.81	49
Silvretta	Alps	46.9	10.1	1960	2010	-0.24	0.78	51
Hintereisferner	Alps	46.8	10.8	1953	2010	-0.57	0.59	58
Kesselwandferner	Alps	46.8	10.8	1958	2010	-0.12	0.47	53
Vernagtferner	Alps	46.9	10.8	1965	2010	-0.35	0.52	46
Sonnblickkees	Alps	47.1	12.6	1959	2010	-0.35	0.84	52
Maliy Aktru	Altai	50.1	87.8	1962	2010	-0.09	0.40	48
Djankuat	Caucasus	43.2	42.8	1968	2010	-0.17	0.68	43
Tsent. Tuyuksuyskiy	Tianshan	43.1	77.1	1957	2010	-0.39	0.50	54
Urumqihe S. No. 1	Tianshan	43.1	86.8	1959	2010	-0.29	0.39	52

Table 2. Glaciers in the European Alps with mass-balance data for 1948-2010: data from PSFG (1967, 1973 1977 and 1985), WGMS (1988, 1993, 1998, 2005, 2008, 2009 and 2011). Mean and standard deviation (S.D) of annual balance refer to the period for which data are available. Mass balance units are m w.e. a^{-1}.

Name	Country	Lat	Lon	From	To	Mean	S.D.	Years	Data collection agency
N. Schneef.	D	47.4	11.0	1965	1968	1.02		4	Bavarian Acad. Sc.(D)
Argentiere	F	46.0	7.0	1976	2010	-0.62	0.89	35	LGGE Grenoble (F)
Mer de Glace	F	45.9	6.9	1968	1975	-0.02	0.47	8	LGGE Grenoble (F)
Saint Sorlin	F	45.2	6.2	1957	2010	-0.62	1.02	54	LGGE Grenoble (F)
Sarennes	F	45.1	6.1	1949	2010	-0.96	1.13	62	CEMAGREF (F)
de Marinet	F	45.0	6.0	1994	1994	-0.86		1	LGGE Grenoble (F)
Gebroulaz	F	45.3	6.6	1995	2010	-0.71	0.72	16	LGGE Grenoble (F)
Griesgletscher	CH	46.4	8.3	1962	2010	-0.68	0.82	48	VAW-ETH (CH)
Rhonegl.	CH	46.6	8.4	1980	1983	0.11		4	VAW-ETH (CH)
Basodino	CH	46.4	8.5	1992	2010	-0.50	0.85	19	Giovanni Kappenberger
Limmerngl.	CH	46.8	9.0	1948	1989	-0.12	0.70	42	VAW-ETH (CH)
Plattalvagl.	CH	46.8	9.0	1948	1989	-0.14	0.72	42	VAW-ETH (CH)
Silvrettagl.	CH	46.9	10.1	1960	2010	-0.24	0.78	51	VAW-ETH (CH)
Findelengl.	CH	46.0	7.9	2005	2010	-0.38		6	Uni. Zurich + Uni. Freiberg
Ochsentalerf.	A	46.9	10.1	1991	1999	-0.46	0.48	9	Uni. Innsbruck (A)
Vermuntgl.	A	46.9	10.1	1991	1999	-0.93	0.52	9	Uni. Innsbruck (A)
Jamtalferner	A	46.9	10.2	1989	2010	-0.80	0.58	22	Uni. Innsbruck (A)
Hintereisferner	A	46.8	10.8	1953	2010	-0.57	0.59	58	Uni. Innsbruck (A)
Kesselwand	A	46.8	10.8	1958	2010	-0.12	0.47	53	Uni. Innsbruck (A)
Vernagtferner	A	46.9	10.8	1965	2010	-0.35	0.52	46	Bavarian Acad. Sc.(D)
Langtalerferner	A	46.8	11.0	1963	1970	-0.19	0.64	8	Uni. Innsbruck (A)
Sonnblickkees	A	47.1	12.6	1959	2010	-0.35	0.84	52	Uni. Salzberg (A)
Filleckkees	A	47.1	12.6	1964	1980	0.23	0.72	17	Uni. Salzberg (A)
Pasterzen	A	47.1	12.7	2005	2010	-1.16		6	Zentral. Met. Geodyn. (A)
Wurtenkees	A	47.0	13.0	1983	2010	-0.83	0.50	27	Zentral. Met. Geodyn. (A)
Gr. Goldbergk.	A	47.0	12.5	2001	2010	-0.70	0.57	9	Zentral. Met. Geodyn. (A)
Kl. Fleisskees	A	47.1	13.0	2001	2010	-0.56	0.48	9	Zentral. Met. Geodyn. (A)
Ciardoney	I	45.5	7.4	1992	2010	-1.25	0.97	19	Società Meteorologica (I)
Sforzellina	I	46.2	10.3	1987	2000	-0.95	0.36	14	Com. Glaciolog. Trentino (I)
Careser	I	46.5	10.7	1967	2010	-1.00	0.87	44	Com. Glaciolog. Trentino (I)
Font. Bianca	I	46.5	10.8	1984	2010	-0.85	0.72	24	Ufficio Idrograf. Bolzano (I)
Pendente	I	47.0	11.2	1996	2010	-0.98	0.71	15	Com. Glaciolog. Venezia (I)
Marmolada	I	46.5	11.9	1964	1965	0.54		2	Com. Glaciolog. Trentino (I)
Vedr. Lunga	I	46.5	10.6	2004	2010	-1.29		7	Uni. Innsbruck (A)
Calderone	I	42.5	13.6	2001	2010	-0.24	1.08	10	Italian Mountain, Inst. (I)
Malavalle	I	47.0	11.2	2002	2010	-0.84	0.48	9	Comm. Glaciolog. Venezia (I)
1948-1960						-0.41	0.72	56	
1961-1990						-0.15	0.72	386	
1991-2010						-0.93	0.84	411	
ALL						-0.55	0.72	853	