Supplementary Material to

Global and Hemispherical temperature reconstruction from glacier length reconstructions

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P. W. Leclercq and J. Oerlemans

Contents

1 Overview glacier length records

Table S1: Metadata of the glacier length change data set used in this study. Given are the name of the glacier, its position in latitude-longitude, the year of the first and the last data point of the record, the total number of data points in the record, the climatological precipitation, the glacier length in 1950 and references to the sources of the data.

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		ma^{-1}	km	
211	42.01	77.96	1860	2006	7	0.60	4.85	Kutuzov and Shahgedanova [2009]
324	42.04	78.18	1860	2006	6	0.60	5.89	Kutuzov and Shahgedanova [2009]
392	42.00	77.97	1860	2006	7	0.60	3.88	Kutuzov and Shahgedanova [2009]
393	41.99	77.97	1860	2006	6	0.60	4.97	Kutuzov and Shahgedanova [2009]
394	41.98	77.96	1860	2006	6	0.60	2.64	Kutuzov and Shahgedanova [2009]
Abano	42.70	44.52	1860	1990	34	1.50	4.30	WGMS, ID 767 Panov and Pisareva [1973]
Aksu-Vostochniy	42.85	77.10	1921	1990	25	1.00	4.99	WGMS, ID 784 G.B. Osipova, pers. com.

Table S1: (continued)

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		ma^{-1}	km	
Aldegonda	77.97	14.08	1900	2006	7	0.40	4.30	Glazovsky et al. [????]
								I. Solovjanova - pers. com. 2006
								Lavrentiev [2008]
Alibekskiy	43.28	41.53	1875	1990	38	1.50	4.67	Panov [1993]
								WGI
Allalin	46.05	7.93	1881	2005	113	2.00	6.70	WGMS, ID 394
Alpeiner	47.05	11.13	1881	2001	72	2.00	4.90	WGMS, ID 497
Amalia	-50.92	-73.53	1945	2005	5	2.00	29.47	WGMS, ID 1633
								López et al. [2010]
Ape	52.08	-126.22	1900	1984	7	2.50	7.10	Williams Jr. and Ferrigno [2002]
Argentière	45.97	6.93	1600	2005	51	2.50	9.40	WGMS, ID 354
								Huybrechts et al. [1989]
								Bouverot [1958]
								Vivian [1975]
Arolla	45.98	7.50	1856	2007	116	2.00	5.10	WGMS, ID 377
								Swiss glacier monitoring network [1881-2009]
Artesonraju	-8.92	-77.60	1932	1994	5	2.00	3.40	Kaser and Osmaston [2002]
Ashu-Tor south (326)	42.04	78.16	1860	2006	6	0.60	6.04	Kutuzov and Shahgedanova [2009]
Athabasca	52.20	-117.25	1730	1995	31	1.20	7.00	WGMS, ID 7
								Luckman [1988]
Azha	29.13	96.82	1933	1998	5	2.50	21.25	Rai and K [2005]
								Liu et al. [2006]
								Yuanqing et al. [2003]
Azufre	-35.29	-70.55	1894	2005	7	1.50	3.31	Espizúa and Pitte [2009]
								Leiva et al. [2008]
Bachfall	47.08	11.08	1892	1996	56	2.00	3.10	WGMS, ID 500
Baishui No. 1	27.40	100.15	1900	2002	5	2.50	3.00	Yuanqing et al. [????]
Bara Shigri	32.15	77.69	1863	1995	6	0.80	28.18	Raina and Srivastava [2008]
								Kumar et al. [2007]
Basòdino	46.42	8.47	1899	2009	85	1.50	2.42	WGMS, ID 463
								Swiss glacier monitoring network [1881-2009]
Benito	-47.05	-73.69	1945	2005	5	2.00	32.73	WGMS, ID 1040
								López et al. [2010]
Berglas	47.07	11.12	1891	2007	76	2.00	2.60	WGMS, ID 496
								Gletscherberichte
Bergset	61.65	7.03	1743	2006	72	3.00	4.66	WGMS, ID 2290
								Nussbaumer et al. [2011]
Bernardo	-48.68	-73.57	1945	2005	5	2.00	54.87	WGMS, ID 1634
								López et al. [2010]
Bezengi	43.05	43.07	1888	1998	40	1.50	18.00	WGMS, ID 703
								Panov [1993]
Birdzhalychiran	43.37	42.53	1887	2007	5	1.50	7.48	WGMS,ID 756
								D. Petrakov, pers. com.
Bituktube	43.37	42.40	1887	2007	7	1.50	3.13	WGMS,ID 764
								D. Petrakov, pers. com.
Blanc	44.95	6.22	1921	2005	55	2.00	6.30	WGMS, ID 351
Blue	47.83	-123.67	1815	1999	60	4.00	4.20	WGMS, ID 210
								Koutnik [2009]
Bluemlisalp	46.50	7.77	1893	2007	102	2.00	3.20	WGMS, ID 436
								Swiss glacier monitoring network [1881-2009]
Bolshoy Azau	43.28	42.43	1849	2007	42	1.50	9.20	WGMS, ID 701
								Laverov [2004]
								Panov [1993]
								Zolotarev [2009]

Table S1: (continued)

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		ma^{-1}	km	
Bolshoy Chontor	41.97	77.90	1860	2006	6	0.60	4.38	Kutuzov and Shahgedanova [2009]
Bolshoy M	50.12	87.58	1924	1990	17	1.50	9.00	WGMS, ID 792
Bondhus	60.03	6.33	1801	2009	101	3.00	7.80	WGMS, ID 318 NVE reports Bogen et al. [1989] Nussbaumer et al. [2011]
Bossons	45.87	6.78	1580	2005	166	2.50	7.20	WGMS, ID 355 Bouverot [1958] Nussbaumer [2010] Nussbaumer and Zumbühl [in review]
Briksdal	61.65	6.92	1869	2009	119	3.00	5.70	WGMS, ID 314 NVE-reports Bogen et al. [1989] Nussbaumer et al. [2011]
Brunni	46.73	8.78	1882	2003	117	2.00	3.20	WGMS, ID 427 Swiss glacier monitoring network [1881-2009]
Buer	60.03	6.43	1822	2009	87	4.50	7.50	H. Elvehoy (NVE), pers. com. Nussbaumer et al. [2011]
Bøya	61.30	6.46	1867	2009	67	3.00	5.05	WGMS, ID 2297 Nussbaumer et al. [2011] Østrem et al. [1988]
Cachet	-47.10	-73.20	1945	2005	5	2.00	10.00	WGMS, ID 1026 Aniya [2001] López et al. [2010]
Carstensz	-4.10	137.17	1825	1990	7	1.20	1.80	WGMS, ID 1051 Williams Jr. and Ferrigno [2002] Williams Jr. and Ferrigno [1989]
Casa pangue	-41.13	-71.87	1911	2000	7	3.00	6.89	WGMS, ID 2010
Castano overo	-41.18	-71.83	1944	1983	6	3.00	5.40	WGMS, ID 918
Cesar	-0.13	37.30	1899	2004	7	1.20	0.40	WGMS, ID 694 Hastenrath [1983]
Chalaat	43.13	42.70	1890	1988	25	1.50	7.56	WGMS, ID 1110 Panov [1993] WGI
Chamberlin	69.32	-53.53	1848	2005	10	0.94	3.85	Yde and Knudsen [2007]
Charquini Norte	-16.36	-68.12	1663	1997	16	0.90	0.60	Rabatel et al. [2006] Rabatel et al. [2008]
Charquini Oeste	-16.28	-68.19	1663	1997	16	0.90	0.51	Rabatel et al. [2006] Rabatel et al. [2008]
Charquini Sur	-16.18	-68.14	1686	1997	15	0.90	1.36	Rabatel et al. [2006] Rabatel et al. [2008]
Charquini Sureste	-16.30	-68.15	1664	1997	13	0.90	1.60	Rabatel et al. [2006] Rabatel et al. [2008]
Chogo Lumgma	36.00	75.00	1902	1989	6	1.20	46.00	WGMS, ID 972
Chungurchatchiran	43.37	42.55	1887	2007	5	1.50	9.39	WGMS,ID 857 D. Petrakov, pers. com.
Cipreses	-34.55	-70.37	1842	2007	12	1.50	11.88	WGMS, ID 2008 Araneda et al. [2009] Quesne et al. [2009]
Clendenning	50.87	-123.90	1883	1979	7	2.00	11.10	Williams Jr. and Ferrigno [2002] WGMS, ID 17
Colonia	-47.17	-73.43	1945	2005	5	2.00	39.80	WGMS, ID 1027 López et al. [2010]

Table S1: (continued)

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		ma^{-1}	km	
Cook	-54.48	-36.20	1882	2003	5	2.30	8.62	WGMS, ID 2870 Gordon et al. [2008] Hogg et al. [1982]
Coronas	43.63	0.65	1825	2005	11	1.50	0.40	Chueca et al. [2003]
Daunkogel	47.00	11.10	1891	2007	89	2.00	3.20	WGMS, ID 604 Gletscherberichte
Davidova	41.83	78.18	1932	2003	6	0.70	6.56	Aizen et al. [2006] Aizen et al. [2007]
Dich-Su	42.98	43.18	1850	2000	11	1.50	14.35	Panov and Pisareva [1973] I. Bushueva, pers. com.
Dickson	-50.77	-73.22	1897	2003	9	2.00	14.80	WGMS, ID 1660 López et al. [2010] Rivera and Casassa [2004]
Diem	46.82	10.95	1893	2007	99	2.00	3.60	WGMS, ID 513 Gletscherberichte
Djankuat	43.20	42.77	1887	2005	23	2.80	4.40	WGMS, ID 726 Panov and Pisareva [1973]
Dolonata	42.83	77.05	1927	1990	24	1.00	4.06	WGMS, ID 798 G.B. Osipova, pers. com.
Dorfer	47.10	12.33	1896	1997	64	2.00	4.20	WGMS, ID 577
Drummond	51.60	-116.10	1884	1965	7	1.00	1.20	Williams Jr. and Ferrigno [2002] WGMS, ID 1398
E. Gruebl	46.98	11.23	1897	1994	53	2.00	3.40	WGMS, ID 597
Ebbabreen	78.73	16.95	1900	2005	7	0.50	8.41	Rachlewicz et al. [2007] Hagen et al. [1993]
Eel	48.22	-123.55	1920	1976	12	2.00	2.00	WGMS, ID 188
Elena	0.38	29.70	1906	2005	6	2.00	0.75	Kaser and Osmaston [2002] Taylor et al. [2006]
Engabreen	66.65	13.85	1600	2007	77	3.00	12.00	WGMS, ID 298 NVE reports Bogen et al. [1989]
Fåbergstølsbreen	61.43	7.14	1899	2007	103	3.00	7.00	H. Elvehoy (NVE), pers. com.
Fedchenko	38.71	72.33	1928	1990	11	1.00	77.27	Barbat et al. [1977] G.B. Osipova, pers. com.
Fee	46.08	7.88	1883	2007	99	2.00	5.70	WGMS, ID 392 Swiss glacier monitoring network [1881-2009]
Fernau	46.98	11.13	1902	2007	82	2.00	2.70	WGMS, ID 601 Gletscherberichte
Ferpècle	46.02	7.58	1891	2005	113	2.00	6.50	WGMS, ID 379 Swiss glacier monitoring network [1881-2009]
Fiescher	46.05	8.15	1891	2007	113	2.00	16.40	WGMS, ID 471 Swiss glacier monitoring network [1881-2009]
Fisht	43.95	43.18	1905	1990	15	1.50	1.29	Barbat et al. [1977] Panov [1993] I. Bushueva, pers. com.
Fleur de Neige	49.83	-122.60	1895	1978	9	1.50	1.30	WGMS, ID 20 Williams Jr. and Ferrigno [2002]
Forni	46.40	10.57	1833	2005	72	1.50	5.40	WGMS, ID 670
Forno	46.30	9.70	1857	2007	98	1.50	5.70	WGMS, ID 396 Swiss glacier monitoring network [1881-2009]
Fox	-43.53	170.15	1894	2002	41	2.50	13.20	WGMS, ID 1536 B. Fitzharris, pers. com. 1993 Williams Jr. and Ferrigno [1989]

Table S1: (continued)

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		ma^{-1}	km	
Franz Josef	-43.50	170.22	1600	2005	113	5.00	10.25	McKinzey et al. [2004] B. Fitzharris, pers. com. 1993 Williams Jr. and Ferrigno [1989] WGMS WGMS_ID 899
Freya	74.38	-20.83	1939	2008	5	0.58	6.70	Hynek et al. [2009] Ahlmann [1953] Ettema et al. [2009]
Frías	-41.15	-71.83	1639	2009	27	2.50	6.59	Villalba et al. [1990] Leiva et al. [2008] Masiokas et al. [2009b]
Fyles	52.10	-126.23	1900	1985	6	2.50	9.20	WGMS, ID 27 Williams Jr. and Ferrigno [2002]
Güssfeldt	-32.61	-70.03	1896	2005	11	1.50	8.39	Espizúa and Pitte [2009] Leiva et al. [2008]
Gaissberg	46.83	11.07	1891	2007	111	2.00	3.50	WGMS, ID 508 Gletscherberichte
Gangotri	30.80	79.20	1780	2007	15	3.00	31.20	Naithani et al. [2001] Intute [2009] Raina and Srivastava [2008]
Garabashi	43.30	42.47	1887	2007	7	1.50	3.90	WGMS, ID 761 D. Petrakov, pers. com.
Geblera	50.13	87.58	1835	1989	22	1.50	5.20	WGMS, ID 1083 Galakhov and Mukhamedov [1999]
Gebroulaz	45.28	6.63	1907	2001	54	2.00	4.00	WGMS, ID 352
Gepatsch	46.85	10.77	1763	2007	91	2.00	9.00	WGMS, ID 522 Gletscherberichte Nicolussi and Patzelt [2000]
Gergeti	42.65	44.57	1860	1990	43	1.50	8.50	WGMS, ID 768 Panov and Pisareva [1973] Panov [1993]
Golubina	42.45	74.48	1861	2003	10	1.00	5.48	Aizen et al. [2006] Aizen et al. [2007]
Gorner	45.97	7.80	1882	2007	111	2.00	14.70	WGMS, ID 391 Swiss glacier monitoring network [1881-2009]
Gr Aletsch	46.50	8.03	1870	2007	117	2.00	25.40	WGMS, ID 360 Swiss glacier monitoring network [1881-2009]
Gr Gosau	47.48	13.60	1905	2007	68	2.00	2.60	WGMS, ID 536 Gletscherberichte
Gregoriev	41.96	77.92	1860	2006	5	0.60	3.76	Kutuzov and Shahgedanova [2009]
Gregory	-0.15	37.32	1893	2004	11	1.20	0.60	WGMS, ID 693 Hastenrath [1983]
Greve	-48.89	-73.91	1945	2005	7	2.00	45.86	WGMS, ID 1637 López et al. [2010]
Grey	-50.86	-73.34	1936	2005	7	2.00	34.22	WGMS, ID 1659 López et al. [2010] Rivera and Casassa [2004]
Gries	46.43	8.33	1847	2006	49	1.50	6.80	WGMS, ID 359 Swiss glacier monitoring network [1881-2009]
Griffin	49.85	-122.63	1795	2004	13	1.50	2.60	WGMS, ID 21 Koch et al. [2009]
Grosselend	47.03	13.32	1898	2006	89	2.00	2.70	WGMS, ID 542 Gletscherberichte

Table S1: (continued)

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		ma^{-1}	km	
Gruenau	46.98	11.20	1891	2007	89	2.00	2.50	WGMS, ID 599 Gletscherberichte
Gualas	-46.59	-73.52	1945	2005	5	2.00	31.94	WGMS, ID 1019 López et al. [2010]
Gurgler	46.80	10.98	1850	2006	62	2.00	8.80	WGMS, ID 511
HPN-1	-47.15	-73.73	1945	2005	5	2.00	26.16	WGMS, ID 1039 López et al. [2010]
HPN-3	-47.24	-73.69	1945	2005	5	2.00	44.47	WGMS, ID 1037 López et al. [2010]
Hüfi	46.82	8.85	1882	2007	115	2.00	7.30	WGMS, ID 426 Swiss glacier monitoring network [1881-2009]
Hailuogou	29.57	101.92	1900	2007	13	3.20	13.19	WGMS, ID 849 Lui et al. [2010] Rai and K [2005]
Hallstaetter	47.48	13.62	1883	2007	76	2.50	2.40	WGMS, ID 535 Gletscherberichte
Hans	77.08	15.67	1900	2009	28	1.20	17.00	WGMS, ID 306 J. Jania - pers. com. 2005 J. Jania and L. Kolondra - pers. com. 2010
Havoc	50.52	-123.88	1750	1979	8	2.00	7.00	WGMS, ID 12 Williams Jr. and Ferrigno [2002]
Heaney	-54.45	-36.27	1928	2003	5	2.30	10.42	WGMS, ID 2871 Gordon et al. [2008] Hogg et al. [1982]
Hellstugubreen	61.34	8.26	1901	2007	68	1.30	3.40	H. Elvehoy (NVE), pers. com.
Helm	49.97	-123.00	1865	2003	20	2.50	2.50	WGMS, ID 45 Canadian Ministry of Water, Land and Air Protection Koch et al. [2009]
Hintereis	46.80	10.77	1770	2007	102	2.00	8.00	WGMS, ID 491 Gletscherberichte
Hochjoch	46.78	10.82	1937	2007	70	2.00	4.50	WGMS, ID 492 Gletscherberichte
Hodges	-54.27	-36.54	1930	2003	5	2.30	1.21	WGMS, ID 28 Gordon et al. [2008] Hogg et al. [1982]
Horn	47.00	11.82	1895	2007	100	2.00	3.40	WGMS,WGMS_ID 589 Gletscherberichte
Humo	-34.55	-70.13	1787	2007	12	2.00	7.00	Cobos [1998] Quesne et al. [2009]
Hyrningsjökull	64.80	-23.77	1931	2007	65	2.20	2.05	WGMS, ID 3092 O. Sigurdsson, pers. com.
Ice river	47.82	-123.67	1924	1976	7	4.00	1.08	WGMS, ID 209
Illecillewaet	51.23	-117.47	1887	1995	34	1.20	3.00	WGMS, ID 1400 Canadian Ministry of Water, Land and Air Protection
Irik	43.33	42.50	1887	2007	5	1.50	9.06	WGMS, 759 D. Petrakov, pers. com.
Irikchat	43.33	42.53	1887	2007	5	1.50	3.47	WGMS, ID 758 D. Petrakov, pers. com.
Isfalls	67.92	18.57	1897	2005	55	1.50	2.20	WGMS, ID 333
Jamtal	46.87	10.17	1902	2007	83	2.00	3.60	WGMS, ID 480 Gletscherberichte
Jankhu Uyu	-16.05	-68.32	1658	1997	10	0.90	0.86	Rabatel et al. [2008]
Karachaul	43.38	42.45	1887	2007	5	1.50	6.35	WGMS, ID 3022 D. Petrakov, pers. com.

Table S1: (continued)

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		$m a^{-1}$	km	
Karlinger	47.13	12.70	1896	1994	58	2.00	3.80	WGMS, ID 568
Kehlen	46.68	8.42	1893	2007	107	2.00	3.40	WGMS, ID 431 Swiss glacier monitoring network [1881-2009]
Kesselwand	46.83	10.80	1914	2007	54	2.00	4.25	WGMS, ID 507 Gletscherberichte
Khakel	43.23	41.85	1888	1994	39	1.50	3.98	WGMS, ID 700 Panov [1993] WGI
Kirtisho	42.50	43.50	1890	1988	22	1.50	5.31	WGMS, ID 1112 Panov [1993]
Kleinelend	47.07	13.25	1898	2007	82	2.00	2.70	WGMS, ID 541 Gletscherberichte
Klujev	39.25	70.45	1936	1990	34	1.50	4.20	WGMS, ID 739 G.B. Osipova, pers. com.
Kolpakovsky	42.08	78.28	1860	2006	6	0.60	13.04	Kutuzov and Shahgedanova [2009]
Korumdu	50.13	87.68	1936	2005	39	1.50	4.00	WGMS, ID 793
Koryto	54.78	161.80	1604	2000	17	4.00	6.40	Y. Muravyev, pers. com. Sawaguchi et al. [1999]
Kozitsiti	42.63	43.72	1888	2000	27	1.50	3.02	WGMS, ID 706 Panov [1993] WGI
Krapf	-0.13	37.32	1893	2004	8	2.00	0.40	Williams Jr. and Ferrigno [1991] Hastenrath [1983]
Krimmler	47.08	12.25	1896	2006	74	1.50	3.60	WGMS, ID 584 Gletscherberichte
Kukurtly	43.35	42.38	1887	2007	6	1.50	7.30	WGMS, ID 763 D. Petrakov, pers. com.
La Mare	46.43	10.60	1895	2005	64	2.00	3.50	WGMS, ID 636
Langfjordjøkulen	70.14	21.75	1900	2005	10	1.50	4.60	NVE Reports
Langgletscher	46.47	7.93	1888	2005	118	2.00	8.00	WGMS, ID 386 Swiss glacier monitoring network [1881-2009]
Langtaler	46.80	11.02	1850	2007	110	1.50	5.50	WGMS, ID 510 Gletscherberichte addition from unknown source
Lazg-Tsiti	42.55	44.37	1850	1987	23	1.50	2.29	Panov [1993]
Leirbreen	61.34	8.06	1909	2007	49	1.50	3.80	H. Elvehoy (NVE), pers. com.
Lengua	-52.80	-72.98	1628	2007	8	10.00	6.83	Koch and Kilian [2005] Schneider et al. [2007] Dickmann [2008] C. Schneider, pers. com.
Leones	-46.80	-73.26	1945	2005	5	2.00	12.86	WGMS, ID 1022 López et al. [2010]
Leviy Karagemsk	50.23	88.17	1850	2005	28	1.50	3.50	WGMS, ID 1084
Lewis	-0.15	37.26	1893	2004	16	1.20	1.00	Williams Jr. and Ferrigno [1991] Hastenrath [1983]
Lodal	61.78	7.24	1750	2005	76	3.00	8.82	Nussbaumer et al. [2011]
Lyngmarksbræ	69.28	-53.55	1812	2005	12	0.94	2.19	Yde and Knudsen [2007]
Lys	45.90	7.83	1904	2005	92	2.00	5.60	WGMS, ID 620
Maliy Aktru	50.08	87.75	1911	2005	53	1.20	4.50	WGMS, ID 795 additions from unknown source
Malyi Azau	43.28	42.45	1887	2007	7	1.50	7.04	WGMS, ID 762 D. Petrakov, pers. com.
Mandrone	46.17	10.53	1942	2005	47	2.00	5.50	WGMS, ID 664
Martial	-54.78	-68.42	1898	2003	6	2.00	0.86	WGMS, ID 917

Table S1: (continued)

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		ma^{-1}	km	
Marukhshkiy	43.33	41.17	1888	2000	35	1.40	4.10	WGMS, ID 727 Panov [1993]
Marzell	46.78	10.88	1891	2006	104	2.00	4.40	WGMS, ID 515 Gletscherberichte
McCall	69.28	-143.83	1895	2005	12	0.80	8.20	WGMS, ID 1388 Rabus and Echelmeyer [1998] M. Nolan, pers. com. Delcourt et al. [2008]
Melang	28.45	99.73	1932	2002	6	2.50	10.85	Rai and K [2005] Yuanqing et al. [2003]
Mer de Glace	45.88	6.93	1570	2005	153	2.50	12.00	WGMS, ID 353 Nussbaumer et al. [2007]
Meren	-4.08	137.17	1825	1990	8	1.50	2.10	WGMS, ID 1050 Williams Jr. and Ferrigno [1989]
Mikelchiran	43.37	42.50	1887	2007	5	1.50	5.08	WGMS, ID 755 D. Petrakov, pers. com.
Mikkajekna	67.40	17.70	1897	2002	44	1.00	4.70	WGMS, ID 338 additions from unknown source
Minapin	36.18	74.58	1889	1987	8	1.50	19.50	WGMS, ID 994
Mizhirgichiran	43.05	43.17	1888	1998	20	1.50	8.81	WGMS, ID 1509 Panov and Pisareva [1973]
Moiry	46.08	7.60	1924	2007	82	1.50	5.80	WGMS, ID 380 Swiss glacier monitoring network [1881-2009]
Morsárjökull	64.12	-16.88	1932	2006	70	4.00	10.54	WGMS, ID 3104 O. Sigurdsson, personal communnication
Morteratsch	46.40	9.93	1878	2007	130	1.50	7.60	WGMS, ID 1673 Swiss glacier monitoring network [1881-2009]
Narssaq	60.25	-45.92	1900	1980	8	1.50	2.05	Weidick [1968] Weidick et al. [1992] Weidick [1988] Ettema et al. [2009]
Nef	-46.98	-73.32	1945	2005	5	2.00	32.76	WGMS, ID 1024 López et al. [2010]
New Moon	53.92	-127.77	1875	2003	83	1.50	1.60	WGMS, ID 5 Williams Jr. and Ferrigno [2002]
Niederjoch	46.78	10.87	1891	2007	112	2.00	3.40	WGMS, ID 516 Gletscherberichte
Nigardsbreen	61.72	7.13	1675	2009	116	3.00	9.60	WGMS, ID 290 NVE reports Østrem et al. [1977] Nesje et al. [2008] Nussbaumer et al. [2011]
Nisqually	46.78	-121.75	1840	2001	75	2.50	7.60	WGMS WGMS_ID 201 Heliker et al. [1984] Granshaw and Fountain [????]
Nordenskiöldbreen	78.70	17.18	1880	2004	10	0.50	29.23	Rachlewicz et al. [2007] Hagen et al. [1993] Kuipers Munneke [2005]
Noroeste	-52.73	-73.12	1942	2007	6	10.00	13.90	Schneider et al. [2007] C. Schneider, pers. com. Dickmann [2008]
Ob Grindelwald	46.62	8.10	1593	2000	129	2.50	5.50	WGMS, ID 444 Swiss glacier monitoring network [1881-2009] Zumbühl [1980]

Table S1: (continued)

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		ma^{-1}	km	
Obersulzbach	47.12	12.30	1870	2007	83	2.00	6.30	WGMS, ID 583
								Gletscherberichte
Oedenwinkel	47.12	12.65	1816	2007	52	2.00	4.20	WGMS, ID 559
								Gletscherberichte
								additions from unknown source
Oeste M	-52.82	-73.17	1942	2007	5	10.00	3.01	Schneider et al. [2007]
								Dickmann [2008]
								Schneider et al. [2003]
Oeste N	-52.80	-73.15	1942	2007	5	10.00	11.09	Schneider et al. [2007]
								Dickmann [2008]
								Schneider et al. [2003]
Oeste S L	-52.83	-73.23	1942	2007	5	10.00	9.51	Schneider et al. [2007]
								Dickmann [2008]
								Schneider et al. [2003]
Oeste S R	-52.83	-73.20	1942	2007	5	10.00	8.39	Schneider et al. [2007]
								Dickmann [2008]
								Schneider et al. [2003]
Ofhidro	-48.50	-73.68	1945	2005	5	2.00	26.39	WGMS, ID 1633
								López et al. [2010]
Okpilak	69.15	-144.18	1890	2006	7	0.50	8.76	Evison et al. [1996]
Ossoue	42.78	-0.13	1850	2007	42	3.00	1.70	WGMS, ID 2867
								Réné [2003]
Oulettes	42.78	-0.14	1850	2003	32	3.00	0.80	Réné [2003]
Overlord	50.02	-122.83	1893	2002	17	1.50	2.70	WGMS, ID 43
								Williams Jr. and Ferrigno [2002]
								Koch et al. [2009]
								addition from unknown source
Paierl	77.22	16.25	1900	1984	6	0.80	27.00	WGMS, ID 294
Palü	46.37	9.98	1894	2007	75	2.00	4.30	WGMS, ID 398
								Swiss glacier monitoring network [1881-2009]
Paradies	46.50	9.07	1873	2007	98	2.00	4.10	WGMS, ID 412
								Swiss glacier monitoring network [1881-2009]
Pared Norte	-47.37	-73.35	1945	2005	5	2.00	26.12	WGMS, ID 1030
								López et al. [2010]
Pasterze	47.10	12.70	1620	2007	130	1.60	9.80	WGMS, ID 566
								Lang and Lieb [1993]
								Williams Jr. and Ferrigno [1993]
								Nicolussi and Patzelt [2000]
								Gletscherberichte
Peñon	-35.27	-70.56	1660	2007	10	1.50	2.98	Espizúa and Pitte [2009]
								Leiva et al. [2008]
Petersen	69.30	-53.55	1894	2005	10	0.94	2.11	Yde and Knudsen [2007]
Petrova	41.87	78.27	1869	2003	6	0.70	12.82	Aizen et al. [2006]
								Aizen et al. [2007]
Peyto	51.67	-116.55	1897	2004	19	1.20	5.80	WGMS, ID 57
								S. Munro, pers. com.
Piedras Blancas	-49.27	-72.97	1610	2007	10	2.20	5.72	Masiokas et al. [2009a]
Pizol	46.95	9.38	1893	2009	96	2.00	0.63	WGMS, ID 417
								Swiss glacier monitoring network [1881-2009]
Pjetursson	69.30	-53.42	1894	2005	8	0.94	1.95	Yde and Knudsen [2007]
Popov	41.99	77.93	1860	2006	6	0.60	6.07	Kutuzov and Shahgedanova [2009]
Praviy Aktru	50.05	87.44	1936	1980	15	1.50	5.35	WGMS, ID 831
								G.B. Osipova, pers. com.
Queets	47.77	-123.60	1913	1976	16	4.00	1.44	WGMS, ID 215

Table S1: (continued)

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		ma^{-1}	km	
Rabots	67.90	18.48	1910	2003	26	1.20	4.53	Brugger [2007] Brugger et al. [2005]
Raigorodskiy	39.67	70.75	1908	1990	29	1.50	6.20	WGMS, ID 743
Raikot	35.33	74.59	1934	2007	10	2.30	14.83	Schmidt and Nüsser [2009]
Rama	39.17	70.45	1870	1990	14	1.50	5.64	WGMS, ID 744 G.B. Osipova, pers. com.
Rembesdalsskåka	60.53	7.36	1917	2007	35	2.70	8.10	H. Elvehoy (NVE), pers. com.
Rhone	46.62	8.40	1600	2009	159	2.50	10.50	WGMS, ID 473 Swiss glacier monitoring network [1881-2009] Aellen [1981] Zumbühl and Holzhauser [1988]
Rodzevicha	49.50	87.00	1850	1995	17	1.00	5.30	Galakhov and Mukhamedov [1999] WGMS, ID 1086
Roseg	46.38	9.83	1855	2007	102	2.00	5.80	WGMS, ID 406 Swiss glacier monitoring network [1881-2009]
Rosenlaui	46.65	8.15	1760	1978	62	2.50	5.21	WGMS,ID 445 Zumbühl and Holzhauser [1988] Swiss glacier monitoring network [1881-2009]
Rotmoos	46.82	11.05	1847	2007	113	2.00	3.50	WGMS, ID 509 Gletscherberichte
Sólheima	63.58	-19.28	1705	2007	83	3.00	15.00	WGMS, ID 3122 Sigurðsson [1998] Mackintosh et al. [2002] O. Siggurðsson, pers. com.
Saint Sorlin	45.18	6.17	1893	1996	43	2.50	3.20	WGMS, ID 356
Salajekna	67.12	16.38	1898	2002	24	1.00	9.40	WGMS, ID 341
Saleina	45.98	7.07	1891	2007	113	2.00	6.50	WGMS, ID 458 Swiss glacier monitoring network [1881-2009]
Samarin	76.83	16.42	1900	1985	6	1.50	18.00	WGMS, ID 311
San Quintin	-46.90	-73.62	1945	2005	5	2.00	68.19	WGMS, ID 1041 López et al. [2010]
San Rafael	-46.72	-73.51	1675	2005	9	2.00	57.12	WGMS, ID 1042 López et al. [2010] Araneda et al. [2007]
Sapozhniikova	44.90	79.45	1850	1995	14	1.00	5.40	WGMS, ID 1087 Galakhov and Mukhamedov [1999]
Sari Tor	41.82	78.20	1932	2003	6	0.70	4.50	Aizen et al. [2006] Aizen et al. [2007]
Saskatchewan	52.20	-117.13	1895	1995	28	1.20	14.50	WGMS, ID 8 Williams Jr. and Ferrigno [1989]
Schlaten	47.12	12.38	1912	2007	66	1.80	6.40	WGMS, ID 580 Gletscherberichte
Schwarzenstein	47.02	11.85	1891	2007	99	2.00	2.80	WGMS, ID 588 Gletscherberichte
Sentinel	58.67	-136.58	1935	1985	24	2.50	3.31	WGMS, ID 44
Sherman	60.60	-145.20	1910	1965	5	2.50	13.00	Kienholz [2010]
Shurovskiy	39.62	70.58	1871	1968	14	1.50	11.63	Petrov and Shetinnikov [1977] G.B Osipova, pers. com.
Simony	47.07	12.27	1900	2007	73	1.70	3.80	WGMS, ID 575 Gletscherberichte

Table S1: (continued)

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		ma^{-1}	km	
Skaftafells	64.08	-16.80	1932	2006	72	4.00	18.38	WGMS, ID 3113
								Sigurðsson [1998]
								O. Sigurdsson, pers. com.
Skazka	42.83	43.67	1890	2000	59	1.00	3.30	WGMS, ID 705
								Panov [1993]
								Panov and Pisareva [1973]
Sofiyskiy	49.78	87.77	1898	2001	5	1.40	7.40	De Smedt and Pattyn [2003]
Soler	-46.90	-73.18	1675	2005	10	1.70	8.30	Aniya [2001]
								López et al. [2010]
Sorbreen	71.03	-8.18	1861	1975	8	1.00	5.80	Anda et al. [1985]
								Aerial photos / Norsk Polarinstitutt
South Cascade	48.37	-121.05	1890	2000	45	2.00	3.70	WGMS, ID 205
								A. Rasmussen, pers. com.
Speke	0.40	29.86	1906	2003	5	1.50	1.00	Kaser and Osmaston [2002]
								Taylor et al. [2006]
Staircase	49.83	-122.61	1895	2004	11	1.50	2.20	WGMS, ID 18
								Koch et al. [2009]
Steffen	-47.33	-73.60	1945	2005	5	2.00	50.22	WGMS, ID 1036
								López et al. [2010]
Stegaholtbreen	61.48	7.19	1903	2007	102	3.00	7.70	H. Elvehoy (NVE), pers. com.
Stein	46.70	8.43	1893	2007	112	2.00	4.70	WGMS, ID 448
								Swiss glacier monitoring network [1881-2009]
Stocking	-43.67	170.07	1865	2001	50	6.30	1.25	Salinger et al. [1983]
								Burrows [2005]
								Chinn [1996]
								WGI
Storbreen	61.57	8.13	1870	2005	59	1.50	3.30	WGMS, ID 302
								NVE Reports
								Matthews [1979]
Storglaciären	67.90	18.57	1891	2002	108	1.20	3.80	WGMS, ID 332
Suatisi Sredniy	42.70	44.42	1882	1990	23	1.20	4.70	WGMS_ID 770
Sulzenau	46.98	11.15	1850	2007	83	1.80	3.70	WGMS, ID 600
								Gletscherberichte
Surf	50.50	-123.97	1893	1979	8	2.00	1.40	WGMS 2008, WGMS_ID 13
								addition from unknown source
Svinafell	64.03	-16.75	1740	2006	77	2.50	12.00	WGMS_ID 3123&3124
								O. Siggurdsson, pers. com.
								additions from unknown source
Taillon	42.70	-0.06	1850	2003	21	2.50	0.70	WGMS, ID 963
								Réné [2003]
Taschach	46.90	10.87	1856	2007	88	1.80	5.80	WGMS, ID 519
								Gletscherberichte
Tavlebreen	77.95	15.05	1936	2006	5	0.50	5.97	Lavrentiev [2008]
Tbilisa	43.13	42.47	1870	1988	18	1.50	3.21	WGMS, ID 724
								Panov [1993]
Tchaikazan	51.02	-123.78	1900	1982	6	1.30	8.90	WGMS, ID 60
Terrific	50.43	-123.43	1883	1979	8	2.00	3.70	WGMS, ID 15
Thunderclap	49.85	-122.65	1886	2004	10	1.40	2.80	WGMS, ID 22
								Koch et al. [2009]
Tikhitsi	41.14	47.47	1850	1988	23	1.50	2.07	WGMS, ID 777
								Panov [1993]
Torre	-49.35	-72.33	1594	2007	10	2.20	6.78	Masiokas et al. [2009a]
Trient	46.00	7.03	1879	2007	127	1.80	5.00	WGMS, ID 457
								Swiss glacier monitoring network [1881-2009]
Ts. Tuyuksuyskiy	43.05	77.08	1923	2005	41	1.50	3.40	WGMS, ID 817

Table S1: (continued)

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		ma^{-1}	km	
Tsanfleuron	46.32	7.23	1892	2005	114	2.00	3.80	WGMS, ID 371 Swiss glacier monitoring network [1881-2009]
Tseya	42.92	43.67	1890	2000	73	1.00	8.80	WGMS, ID 704 Panov [1993] Panov and Borovik [1976]
Tsidjore Nouve	46.00	7.45	1880	2007	118	1.60	4.90	WGMS, ID 376 Swiss glacier monitoring network [1881-2009]
Tsoloss	51.38	-123.87	1720	1982	5	2.00	1.60	WGMS, ID 63 addition from unknown source
Tunorssuaq	69.32	-53.36	1848	2005	9	0.94	2.00	Yde and Knudsen [2007]
Turtmann	46.13	7.68	1885	2005	115	1.60	6.10	WGMS, ID 385
Tyndall	-0.15	37.30	1893	2004	16	1.20	0.60	WGMS, ID 697 Hastenrath [1983]
U Grindelwald	46.58	8.07	1535	1983	128	2.50	9.00	WGMS, ID 443 Swiss glacier monitoring network [1881-2009] Zumbühl [1980]
Uilpata	42.77	43.82	1890	1990	48	1.50	2.30	Panov [1993] Panov and Pisareva [1976]
Ulluchiran	43.38	42.43	1887	2007	5	1.50	6.30	WGMS, ID 836 D. Petrakov, pers. com.
Ullukol	43.38	42.47	1887	2007	5	1.50	5.32	WGMS, ID 834 D. Petrakov, pers. com.
Ullumalienderku	43.38	42.48	1887	2007	5	1.50	5.88	WGMS, ID 833 D. Petrakov, pers. com.
Umbal	47.05	12.25	1896	2007	76	2.00	5.00	WGMS, ID 574 Gletscherberichte
Unteraar	46.57	8.22	1719	2005	128	2.00	14.00	WGMS, ID 450 Swiss glacier monitoring network [1881-2009] Zumbühl and Holzhauser [1988]
Untersulzbach	47.13	12.35	1896	2007	73	1.80	6.40	WGMS, ID 582 Gletscherberichte
Upsala	-49.74	-73.38	1945	2005	10	2.00	62.17	WGMS, ID 921 López et al. [2010]
Vacas	-32.55	-69.99	1896	2005	11	1.50	6.84	Espizúa and Pitte [2009] Leiva et al. [2008]
Valdez	61.30	-146.20	1901	2008	18	2.00	35.20	Millett [1964] Kienholz [2010]
Valsorey	45.90	7.27	1889	2007	112	1.70	4.30	WGMS, ID 365 Swiss glacier monitoring network [1881-2009]
Vatnajökull	64.50	-16.50	1690	1995	23	3.50	20.00	Sigurðsson [1998] Thorarinsson [1943]
Ventina	46.27	9.77	1899	2005	78	2.00	3.80	WGMS, ID 629 Zumbühl and Holzhauser [1988]
Ventorrillo	19.02	-98.62	1921	1999	10	1.25	0.99	WGMS, ID 914
Verstancla	46.84	10.07	1926	2009	72	2.00	2.18	WGMS, ID 409 Swiss glacier monitoring network [1881-2009]
Victoria	51.38	-116.27	1898	1966	15	1.00	4.20	WGMS, ID 1399 Williams Jr. and Ferrigno [1989]
Viltragen	47.13	12.37	1891	2007	72	1.70	4.60	WGMS, ID 581 Gletscherberichte

Table S1: (continued)

name	location		record period		# data	precip	L1950	references
	lat	lon	first	last		ma^{-1}	km	
Vostostochniy Klukhorskiy	43.23	41.87	1890	1990	16	1.50	1.52	Panov [1993]
								Borovik and Kravcova [1977]
Waldemarbreen	78.67	12.00	1909	1995	8	0.38	3.83	WGMS, ID 2307
Waxegg	47.00	11.80	1881	2007	103	2.00	2.40	WGMS, ID 590
								Gletscherberichte
Wedgemount	50.15	-122.78	1900	1995	26	1.50	3.00	WGMS, ID 42
								Williams Jr. and Ferrigno [1989]
White (USA)	47.87	-123.70	1815	2001	14	4.00	3.50	WGMS, ID 212
Wila Lluxita	-16.05	-68.30	1662	1997	11	0.90	0.85	Rabatel et al. [2008]
Yuzhniy	42.17	46.15	1862	2000	43	1.50	2.01	WGMS, ID 779
								Panov [1993]
Zemu	27.71	88.23	1903	2005	6	4.50	28.63	Raina and Srivastava [2008]
								Krishna [2005]
Zeravshanskiy	39.52	70.67	1880	1990	15	1.50	28.50	WGMS, ID 745
Zettalunitz	47.08	12.38	1896	2007	70	1.80	4.90	WGMS, ID 578
								Gletscherberichte
Zinal	46.07	7.63	1891	2007	114	1.60	8.60	WGMS, ID 382
								Swiss glacier monitoring network [1881-2009]
Zongo	-16.30	-68.14	1680	2008	29	0.90	3.22	Rabatel et al. [2008]
Zulumart	39.10	72.83	1943	2001	5	1.50	21.00	WGMS, ID 2100
								Osipova et al. [2005]

WGMS:	World Glacier Monitoring Service, Fluctuations of Glaciers ISSN 1997-910X (print)/ISSN 1997-9118 (online), ID number corresponds with the glacier identification number in the WGMS database
WGI:	National Snow and Ice Data Center. 1999, updated 2009. World glacier inventory. World Glacier Monitoring Service and National Snow and Ice Data Center/World Data Center for Glaciology. Boulder, CO. Digital media
Gletscherberichte:	Glacier monitoring of Austrian glaciers by volunteers of the OEAV, published annually in *Bergauf*
NVE reports:	Annual reports of the Norwegian Water Resources and Energy Directorate
pers. com.	personal communication

2 Calculation of uncertainty

The uncertainty estimates are based on smooth bootstrapping. The temperature reconstruction is calculated several times using samples, drawn randomly with replacement, from the glacier length records. This accounts for the variability in the temperature reconstructions of the available records. In addition to the sampling, the reconstructed temperature of each record is perturbated to account for the uncertainty in the translation of glacier length change to temperature change. These perturbations of the individual records make the bootstrapping used in this article a smooth bootstrapping method [Hesterberg et al., 2005]. The reconstructed temperature of the individual records has an uncertainty due to: i) uncertainties in the measurements of the glacier length change, ii) gaps is the glacier length records, that are interpolated using the Stineman interpolation, iii) uncertainty in the calculated response time τ, and iv) uncertainty in the calculated (inverse) climate sensitivity γ. Below we explain the calculation of these uncertainties in the temperature reconstruction of individual glacier length records.

As an example, we discuss the uncertainties in the global average temperature reconstruction are given for each of the causes seperately (Figure S1). We have calculated ensembles of the global average temperature change with only one of the four pertubations mentioned above (Figure S1a–d). In addition, we have calculated the global average from random samples of all records (Figure S1e). The ensembles are shown along with the best estimate of the global temperature change. The magnitude of the uncertainties is given by the spread of the members in the ensemble calculated from random perturbation of the originally used values. By comparing the Figures S1a–e it becomes clear that the major contributors to the total uncertainty of the global average temperature are the uncertainty in the climate sensitivity and the variability in the individual reconstructions. The smallest contributor is the uncertainty in the response time. In Figure S1f, the ensemble, consisting of 1100 members, of the complete uncertainty estimate is shown along with the ensemble average and the best estimate with its uncertainty (cf. Figure 4a). The ensemble average and the best estimate are almost identical.

2.1 Uncertainty in measurements

The uncertainty of the data points is related to the method of measurement, given by the categories described in section 2.2. The perturbation of a glacier length change data point is a number randomly drawn for a normal distribution times a factor ϵ given by the data accuracy category of that measurement. Hence the perturbed glacier length change L'_{pertb} is given by:

$$L'_{\mathrm{pert}} = L' + r_d * \epsilon \tag{s1}$$

where for each data point of the record a new random number r_d is drawn. The errors of the measurements are with 99% certainty (3 standard deviations) within the limits given in section 2.2. The factors ϵ give the standard deviation of the perturbations, and should thus be one third of the estimated maximum error.

2.2 Uncertainty due to gaps in length record

If a record does not have annual data, as most records do for at least some period, the gaps are filled by interpolation (see section 2.1). If the period without length measurements is in the order of the response time of the glacier or larger, information on climatic variations is lost. As we have shown in Appendix C, the reconstructed temperature from a sparse record is more or less equal to the 50-year moving average of the “real” temperature reconstruction. Autoregressive (AR) noise is added to the parts of the length records that are interpolated for a period longer

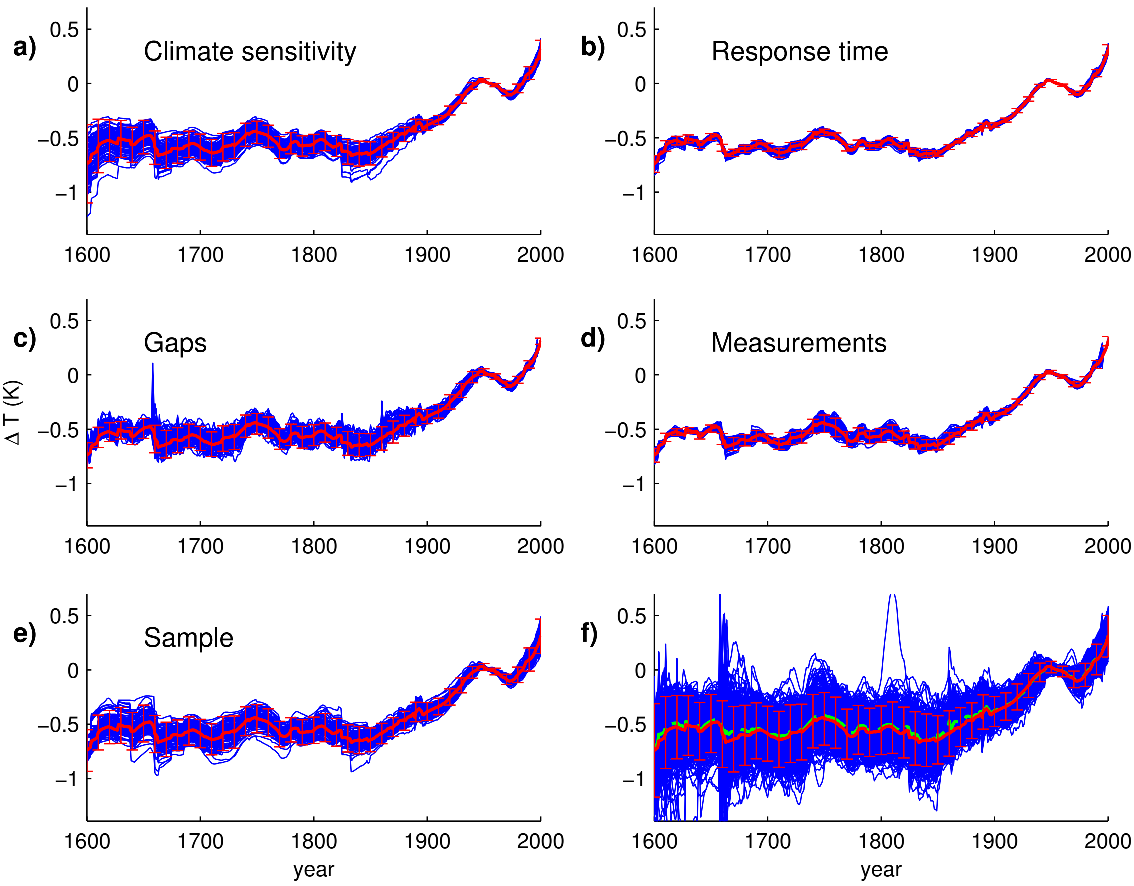

Figure S1: The uncertainty in the global average reconstructed temperature for each of the 5 separate causes, based on the spread of the 100-member ensemble caused by uncertainty in: a) the inverse climate sensitivity γ; b) response time τ; c) gaps in sparse records; d) measured length change; and e) sampling of the 308 available records. In f), the 1100-member ensemble including all uncertainties of the global average is shown (cf. Figure 4a). The ensemble average (dashed green) is very close to the best estimate (red). The uncertainty bars give twice the standard deviation of the ensemble.

$\phi(0)$	$\phi(1)$	$\phi(2)$	$\phi(3)$	$\phi(4)$	$\phi(5)$	$\phi(6)$	σ_L
1	-1.2738	0.1549	0.0738	0.0367	-0.0060	0.0391	1706

Table S2: AR coefficients

than 0.3 times the response time, to estimate the magnitude of the error in the temperature reconstruction that is caused by the use of sparse glacier length records. That means that for every year in the gap of the record, we have recalculated $L(t)$:

$$L(t) = L_{\text{interp}}(t) + L^*(t), \tag{s2}$$

where $L(t)$ is the new perturbed length record, L_{interp} is the record obtained from the Stineman interpolation of the data points, and $L^*(t)$ is the red noise perturbation. The perturbation term $L^*(t)$ is calculated with an autoregressive model (AR model) [e.g. Box and Jenkins, 1976; Fisher, 2002]:

$$\sum_{k=0}^{p} \phi(k) L^*(t-k) = \sigma_L \epsilon(t), \tag{s3}$$

where ϵ is zero-mean white noise, $\phi(k)$ are the order-p autoregressive model coefficients, and σ_L is the noise variance. The values of $\phi(k)$ and σ_L are calculated from the eight detrended dense records, long records with gaps much smaller than the response time, using the Yule–Walker method.

The records used for the calculation of the AR model parameters are: Bergsetbreen, Bondhusbreen, Glacier des Bossons Brikdalsbreen, Buerbreen, Mer de Glace, Rosenlauigletscher and Untere Grindelwaldgletscher. As can be seen in Figure S2, all these records span a period of more than 150 years and they are highly detailed, as a result of continuous frontal position measurements [WGMS, 2008 and earlier volumes] and the interpretation of abundant historical material [Nussbaumer et al., 2011, 2007; Nussbaumer and Zumbühl, in review; Zumbühl, 1980; Zumbühl and Holzhauser, 1988]. We could only include detailed records. For records with sparse data, not all variations variations are given by the record. This leads to a poor AR model. In addition, we have only used records that capture the variations before 1900, as most of the record gaps will be before 1900. As a result, the AR model is based on records from Norway and the Alps only. This means that the climatic fluctuations of this relatively small region is applied to all glaciers in the data set. Moreover, only a limited range in glacier response time and climate sensitivity is represented by the eight glaciers. It can be expected that the variance of the glacier length record is larger for glaciers with a short response time or a large climate sensitivity. Thus the variance of the perturbation is likely to be too large for glaciers in regions with a dry continental climate.

The order of the model is estimated from the reflection coefficients. We have found that a AR model of order 6 is satisfying for all 8 records. The averages of the AR coefficients and noise variances of the individual records (Table S2) are used as $\phi(k)$ and σ_L in eq. (s3).

The AR model is run both forward and backward, starting from both sides of the gap. A linear transition from the forward to the backward noise signal is made, such that the perturbed record starts and ends at a data point without abrupt length changes. If end moraines are present (measurements category 3 or 4), the AR model is maximised to the glacier length at these moraines. In Figure S3 examples of perturbed interpolations are shown.

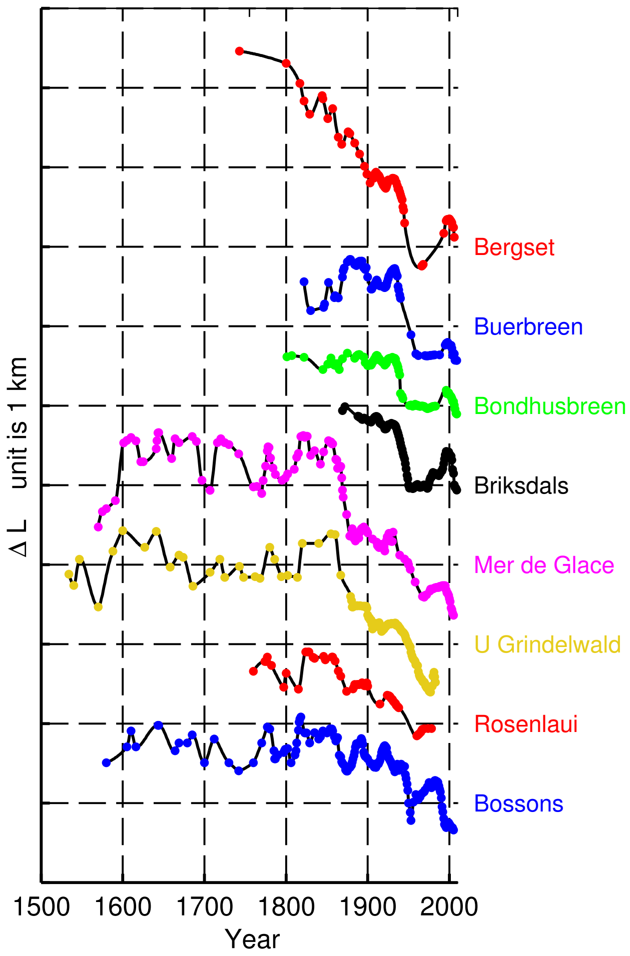

Figure S2: The detailed records used to estimate the AR model parameters

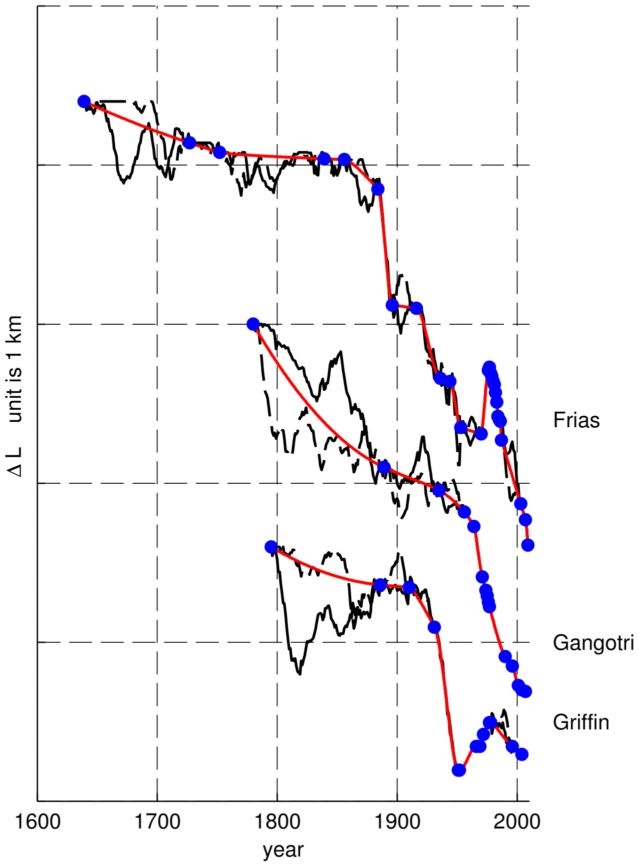

Figure S3: Examples of sparse records (see Table S1 for references) with AR noise added to gaps. The measured length changes are indicated by blue dots; the interpolated record (red) with added AR noise is given in black lines. For each record, two independent perturbations of the record are shown.

2.3 Uncertainty in response time

The uncertainty in the response time τ calculated with the analytical glacier model is derived from the goodness of fit of the calibrated results (eq. 4) to the results of the numerical models (Table 1). We divide the values obtained with the numerical model by those of the corresponding analytical model. We get 15 numbers spread around the ideal value 1. The standard deviation of these numbers is $\sigma_\tau = 0.28$. We perturb τ calculated with the analytical model by multiplying it with a random factor. As τ can not have negative values, we draw the factors from the gamma distribution instead of a normal distribution. The perturbed values τ_{pert} are thus given by:

$$\tau_{\mathrm{pert}} = r_\tau * \tau \tag{s4}$$

where r_τ is a random number drawn from the gamma distribution with mean 1 and standard deviation σ_τ. The random numbers are redrawn for each time a temperature is reconstructed from a glacier length record.

2.4 Uncertainty in climate sensitivity

The uncertainty in the inverse climate sensitivity γ (eq. 3) is treated in the same way as the uncertainty in the response time. For the 14 glaciers, we divide the results from numerical models in Table 1 by the result of the analytical model. The standard deviation σ_γ of these numbers is 0.50. We perturb γ by multiplying it with a random factor. Like τ, γ cannot be negative (that would imply the glacier advances when temperature increases), hence we draw the factors from the gamma distribution as well. The perturbed values γ_{pert} are thus given by:

$$\gamma_{\mathrm{pert}} = r_\gamma * \gamma \tag{s5}$$

where r_γ is a random number drawn from the gamma distribution with mean 1 and standard deviation σ_γ. The random numbers are redrawn for each time a temperature is reconstructed from a glacier length record.

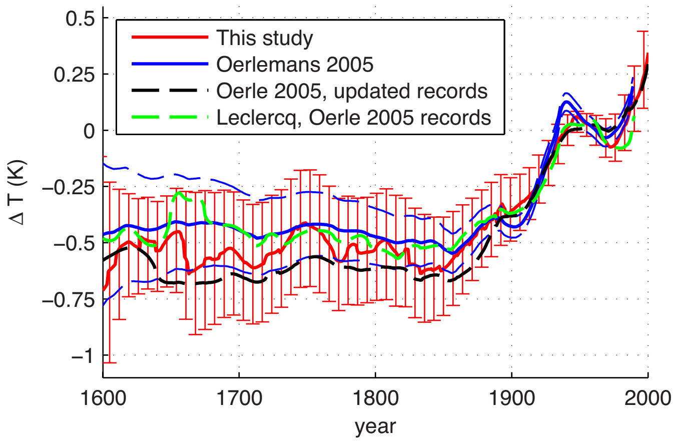

Figure S4: Reconstructed global temperature from: this study (red, with uncertainty bars); the study of Oerlemans [2005] (blue, uncertainty range in dashed blue); the method as used in Oerlemans [2005] on the revised 169 records (dashed black); and calculated from the original 169 records of Oerlemans [2005] with the methods of this study (dashed green).

3 Comparison with results of Oerlemans 2005

In Figure S4, the reconstructed global temperature anomaly for the period 1600–2000 of this study is compared with the earlier results of Oerlemans [2005]. There are several differences between the two reconstructions: the uncertainty in results of this study is larger than that given in Oerlemans [2005]; the present reconstruction continues longer, up to 2000 instead of 1990, showing the continuing warming of the recent decade; the local maximum of the temperature around 1940 is more pronounced in the study of Oerlemans [2005]; and in the present study the middle of the 19th century is colder and the warming from then to 1940 is more continuous than in the results of Oerlemans [2005].

Because the number of glacier length records has increased, one would expect the uncertainty in the reconstruction presented in this study to be smaller than the uncertainty in Oerlemans [2005]. However, the present uncertainty is larger. We have attributed larger uncertainties to the values of the response time and climate sensitivity of each glacier, as calculated with the analytical glacier model. And we have included the uncertainty due to missing data and an estimate of the uncertainty in the data on glacier length change.

To determine if the differences in reconstructed temperature are due to the improved methods of this study or to the extended data set, we recalculated the temperature with the use of our methods from the glacier length data set that was used by Oerlemans [2005] (Figure S4, dashed green). This leads to a lower maximum around 1940, but the temperature anomaly in the 19th century is in agreement with the previous results of Oerlemans [2005]. We have also calculated the global temperature anomaly from the updated version of the 169 records used in Oerlemans [2005], as they are in the present data set (Figure S4, dashed black). Most of the updated records were extended, some were revised, and some were omitted (section 2.1). In the calculation we made use of the weighted average of the five regions as done in Oerlemans [2005] (see Appendix B for the definition of the regions). This gives substantial differences with the other reconstructions. Again the maximum in 1940 is less pronounced as in the results of Oerlemans [2005], and the global temperature before 1900 is lower than in the other reconstructions.

In Figure S5 the regional averages of the three different data sets are shown. For the regions North West America and Alps, the differences between the temperatures reconstructed from the different data sets are reasonably small. For both regions a few records of the data set of Oerlemans [2005] are excluded in the present data set, and a limited amount of records is added. For the North Atlantic, the updated records show a stronger warming in 1940's than the data used by Oerlemans [2005]. With the additional records, this maximum is less pronounced and the second half on the 19th century is much colder. In Asia, the number of available records has increased drastically. This did not lead to a large change in the reconstructed temperature, but the time spanned by the records in this region has strongly improved. To conclude, the reconstruction of the SH temperature based on the revised data, as well as the reconstruction from the complete data set, show significantly lower temperatures before 1900. In addition, the small peak around 1940 that is visible in the reconstruction of Oerlemans [2005] is not shown by the revised data, nor by the extended data set that has 50 additional records. Following the method of Oerlemans [2005] differences on the SH have the highest impact on the global reconstruction, as the weight of the SH region is the same as that of the sum of the other four regions (see Appendix B). The results of Oerlemans [2005] are very sensitive to changes in, or additions to, the data of the SH.

To conclude, for the data set presented in this study, as well as for the data set of Oerlemans [2005], the reconstructed global temperature anomaly calculated with the method of Oerlemans [2005] is in agreement with the temperature anomaly calculated with the glacier length data presented in section 2 and the methods described in section 3 of this study. However, the pronounced local maximum around 1940 in the reconstruction of Oerlemans [2005] is not robust. The other three reconstructions all show a less strong warming in this period.

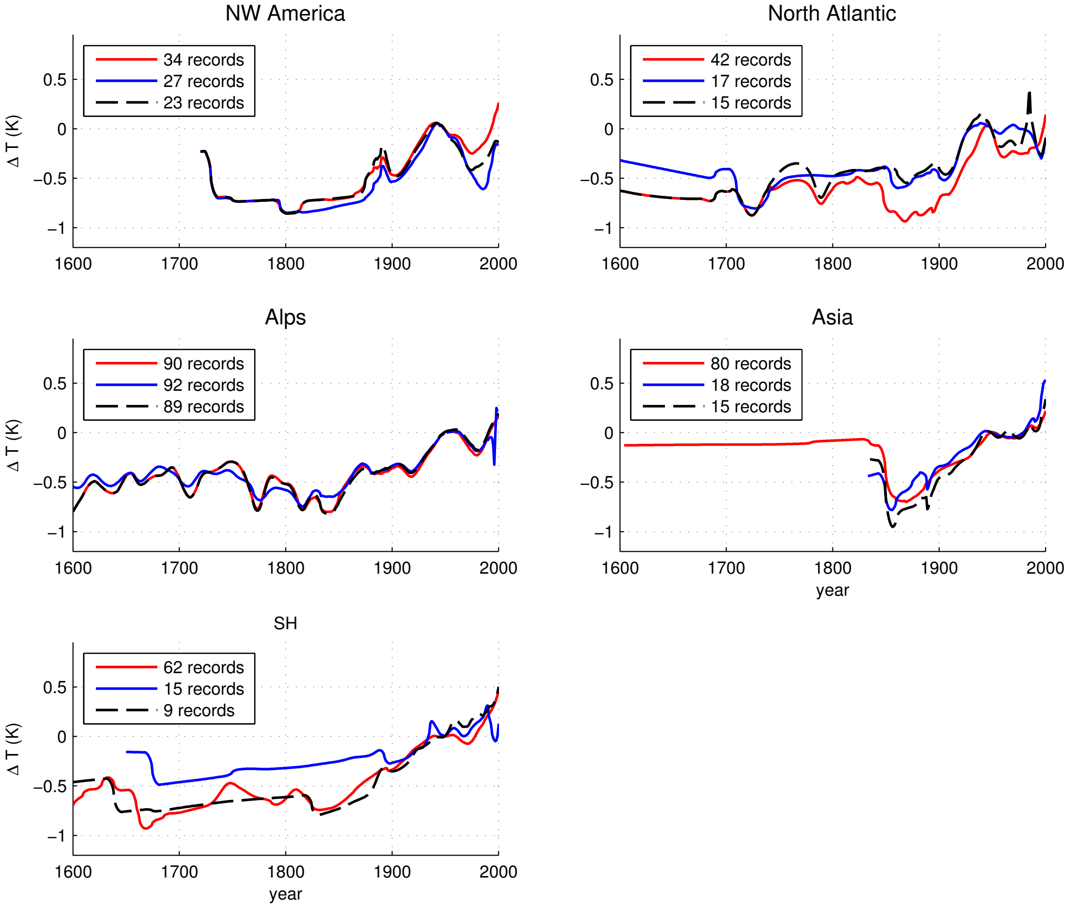

Figure S5: Regional average temperature anomaly of five regions for three data sets: the data set with 308 records used in this study (red), the data set with 169 records of Oerlemans 2005 (blue), and the updated and revised version of the records used in Oerlemans [2005] (dashed black). For each data set, the total number of available records in each of the regions is shown.

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