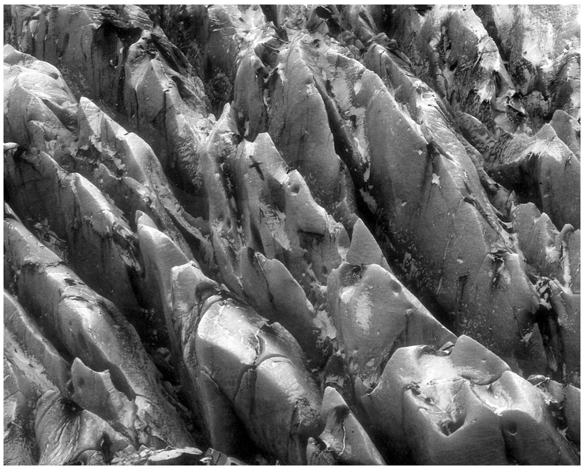
FORTY-SEVEN

Glacier mass-balance data for southern South America (30°S–56°S)



G. Casassa*, A. Rivera† and M. Schwikowski‡

**Centro de Estudios Científicos, Valdivia, Chile*
†Department of Geography, University of Chile, Santiago, Chile
‡Paul Scherrer Institut, Labor für Radio- und Umweltchemie, Switzerland

Southern South America (SSA), i.e. south of 30°S, comprises an estimated glacier area of ca. 27,500 km^2 (Fig. 47.1), which represents ca. 89% of all Andean glaciers. The glaciers in the region show a generalized retreat and thinning (Naruse, this volume, Chapter 46). In spite of their importance in water resources within a region affected by climate changes, glacier mass balance is to a large extent largely unknown. This summary aims at reviewing the few glacier mass-balance studies available for SSA, obtained by means of firn coring and by the traditional stake method.

Data for 15 glacier sites with annual mass-balance observations are presented in Table 47.1. Data obtained from modelling studies, climatological extrapolations or seasonal (and intraseasonal) stake observations are not included in this work. Firn core data include seven sites, covering periods from 1 yr to 68 yr; multistake mass-balance studies which cover complete glacier basins exist for five sites and three sites show mass-balance data from single or multiple stakes covering limited portions of glaciers.

The annual values of accumulation, ablation and net balance have been plotted for the above glacier sites in Fig. 47.2. Data representation is limited due to the restricted spatial coverage of the mass-balance data. In general both accumulation and ablation values increase southward, consistent with the meridional gradient in precipitation driven by the southern position of the storm tracks controlled by the westerlies, as opposed to the location of the stable Pacific anticyclone to the north which results in very dry conditions. This north–south gradient is clearly seen in the data, with net balance data in the upper accumulation areas ranging from 30 cm water equivalent (w. eq.) at Cerro Tapado, largely controlled by sublimation (Ginot *et al*., 2002), to a record value of 1540 cm w. eq. at Glaciar Tyndall in Patagonia (Shiraiwa *et al*., 2002; Kohshima *et al*., accepted for publication).

A clear west–east gradient is observed in the mass balance south of 33°S, particularly in Patagonia, which is affected by an enhanced westerly circulation with precipitation occurring largely on the windward side of the Andes. For example, on the upper accumulation area of the Southern Patagonia Icefield a minimum net balance of 31 cm w. eq. has been recorded at 2300 m a.s.l. on Cerro Gorra Blanca (Schwikowski *et al*., 2003), located on the eastern margin, in contrast to the record value of 1540 cm w. eq. obtained near the ice divide at Glaciar Tyndall.

The low values of net accumulation measured on the leeward-facing glaciers of Patagonia are not regarded as representative for the accumulation area, and are much smaller than expected from hydrological models (e.g. Escobar *et al*., 1992), precipitation estimates from neighbouring meteorological stations (Carrasco *et al*., 2002), *in situ* precipitation observations (Fujiyoshi *et al*., 1987; Casassa *et al*., 2002a), and glacier dynamics models (e.g. Naruse *et al*., 1995), which estimate that an annual accumulation of 5–10 m w. eq. is needed in the upper accumulation areas for maintaining a steady-state at SPI, in order to balance the large annual ablation values that occur at lower elevations, such as those measured at Glaciar Moreno (Stuefer, 1999) and Glaciar Lengua (C. Schneider, personal communication, 2004).

Strong interannual variations are found within the mass-balance records of Glaciar Piloto Este and Glaciar Echaurren (ca. 33°S), closely related to ENSO events, with dry La Niña years and wet El Niño years. At Glaciar La Ollada, Cerro Mercedario, interannual variations in snow accumulation related to ENSO events are not obvious in the record. After 1988 both mass-balance series of Glaciares Piloto Este and Echaurren Norte show a clear negative trend, consistent with the retreating trend of glaciers in the region, which probably is largely due to a regional warming (Rosenblüth *et al*., 1997). A negative trend is also observed in the short mass-balance record of Glaciar Martial Este.

Table 47.1 Glacier mass-balance data. The mass-balance data represent mean annual values for the indicated period. In the case where mass balance is monitored with a stake array, minimum and maximum represent the altitudinal range of the glacier. For firn core and single stake sites, minimum and maximum represent the altitude of the site. The altitude of the firn core site at Glaciar Moreno is taken from Godoi *et al.* (2001). At Glaciar Tyndall the mass-balance data is an average value from multiproxy analysis based on stable isotope data and microalgae concentrations

Glacier	Latitude (°S)	Longitude (°W)	Location*	Altitude (m a.s.l.)		Ablation (cm w. eq.)	Accumulation (cm w.eq.)	Balance (cm w. eq.)	Period (year)	References
				Minimum	Maximum					
Cerro Tapado†	30.13	69.92	E	5550	5550	24	54	30	1920–1998	Ginot *et al.*, 2002
La Ollada†	31.97	70.12	E	6100	6100			45	1986–2002	Bolius *et al.*, 2004
Piloto Este‡	32.50	70.15	E	4185	4740	110	77	−33	1979/80–1996/97	Leiva, 1999
Echaurren Norte‡	33.55	70.13	W	3650	3880	289	269	−20	1975/76–2003/04	Escobar *et al.*, 1995; F. Escobar, personal communication, 2004
Mocho‡	39.92	72.03	W	1603	2422	346	258	−88	2003/04	Rivera *et al.*, 2005
San Rafael†	46.73	73.53	W	1296	1296			345	1984	Yamada, 1987
Nef†	46.93	73.32	E	1500	1500			220	1996	Matsuoka & Naruse, 1999
Cerro Gorra Blanca†	49.13	73.05	E	2300	2300			31	1995–2001	Schwikowski *et al.*, 2003
Chico§	49.18	73.18	E	1444	1444			57	1994/95–2001/2002	Rivera, 2004
De los Tres‡	49.27	73.00	E	1120	1830	225	232	7	1995/96	Popovnin *et al.*, 1999
Moreno§	50.50	73.00	E	365	365	1025			1998–1999¶	Stuefer, 1999
Moreno†	50.63	73.25	E	2000	2000			120	1980/81–1985/86	Aristarain & Delmas, 1993
Tyndall†	50.98	73.52	W	1756	1756			1540	1998/99	Shiraiwa *et al.*, 2002; Kohshima *et al.*, accepted for publication
Lengua§	52.80	73.00	W	450	450	640			2001–2004**	C. Schneider, personal communication, 2004
Martial Este‡	54.78	68.40	E	1000	1180	86	81	−5	2000–2002	Strelin & Iturraspe, accepted for publication

*Location of the glacier site, E(W) indicates that the glacier is located east(west) of the main Andean range.
†Firn core data.
‡Net mass-balance data from stake array.
§Net balance data from one single stake.
¶20 March 1998 to 7 March 1999, average for three stakes.
**Annual average for three stakes.

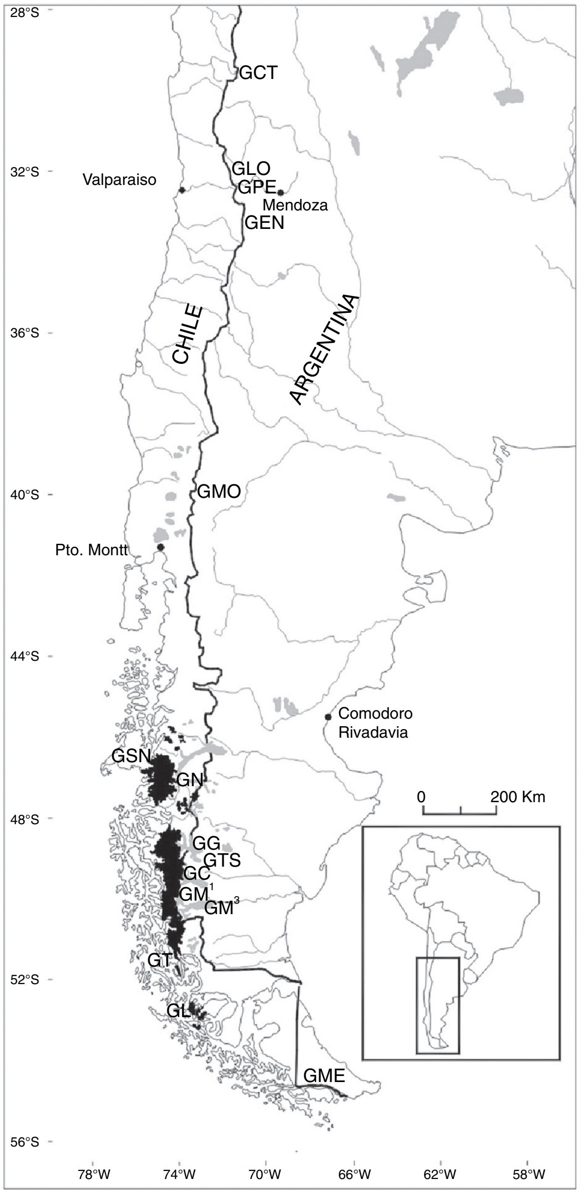


Figure 47.1 Map of southern South America showing the glacier sites mentioned in the text: GCT, Glaciar Cerro Tapado; GLO, Glaciar La Ollada; GPE, Glaciar Piloto Este; GEN, Glaciar Echaurren Norte; GMO, Glaciar Mocho; GSN, Glaciar San Rafael; GN, Glaciar Nef; GG, Glaciar Cerro Gorra Blanca; GC, Glaciar Chico; GTS, Glaciar de los Tres; GM[3], Glaciar Moreno, ablation stakes site; GM[1], Glaciar Moreno, firn core site; GT, Glaciar Tyndall; GL, Glaciar Lengua; GME, Glaciar Martial Este.

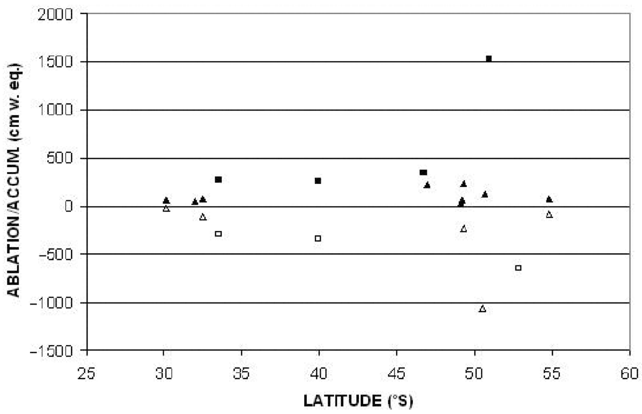


Figure 47.2 North–south transect along the Andes showing annual ablation and accumulation values, as quoted in the text. Solid squares and solid triangles represent accumulation values for western Andean glaciers and eastern Andean glaciers respectively. Hollow squares (triangles) represent ablation values for western (eastern) glaciers. Values increase southward to a maximum at ca. 50–51°S.