GLACIERS AND THE CHANGING EARTH SYSTEM: A 2004 SNAPSHOT

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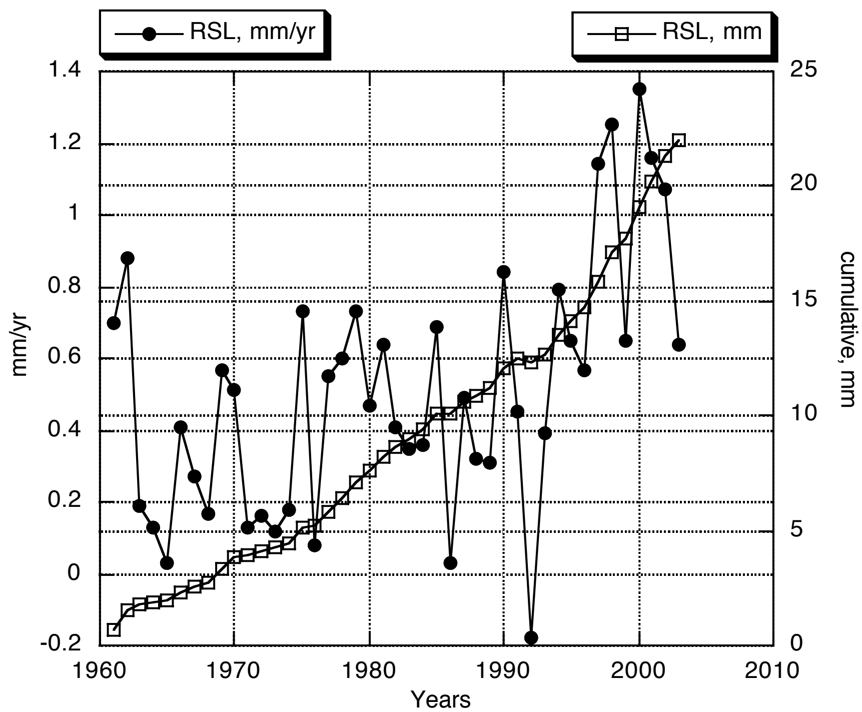

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ABSTRACT

Glacier changes are having impacts on processes of global importance such as sea-level rise, hydrology of mountain-fed rivers, freshwater balance of oceans, and even the shape and rotation of the Earth. Here we discuss the effects of “small glaciers” — all perennial ice masses other than the Greenland and Antarctic ice sheets. We now estimate that the total area of these glaciers and ice caps to be about 785 ± 100 × 10^3 km^2, somewhat larger than earlier estimates because of improved information on isolated glaciers and ice caps around the periphery of the large ice sheets. We estimate the total volume of this ice to be about 260 ± 65 × 10^3 km^3, equivalent to 0.65 ± 0.16 m of sea-level rise.

Glacier mass balance data (both annual and seasonal) can be used to infer current climatic change in precipitation and temperature, and the spatial distribution of these can assist in the analysis and modeling of climate change. This is especially important in high-mountain and high-latitude areas, where precipitation data are few and biased. Air temperature increase is the major forcing of glacier change. Glacier response to recent climate warming shows a steepening mass balance gradient with altitude due to increasing ice ablation below the equilibrium line altitude, and, to a lesser extent, increasing snow accumulation above that altitude. Observational results also show increasing glacier mass turnover and mass balance sensitivity to air temperature; these changes are not predicted by existing climate/glacier models. Sensitivity and turnover have also decreased in variability starting at the end of the 1980s.

Glacier wastage caused sea level to rise at a rate of 0.51 mm yr^{-1} for the period 1961–2003, but glaciers are now (1994–2003) causing sea level to rise 0.93 mm yr^{-1}. This freshwater addition to the oceans may be affecting ocean circulation and ocean ecosystems, and causing socio-economic impacts due to sea-level change. This contribution from glaciers is likely to continue to increase in the future. Acceleration of glacier wastage also affects other global processes, including spatial and temporal changes in the Earth’s gravitational field, Earth oblateness and rotation rate, and regional uplift.

Global acceleration of glacier volume losses has affected the freshwater cycle at many scales, from global to local. The glacier contribution to the freshwater inflow to the Arctic Ocean has been increasing, and this increase will affect many aspects of the arctic climate system. Increasing summer runoff to large Asian rivers and high-elevation glacierized watersheds in both

Americas is important for agriculture and human needs, but this release of water from ice storage may diminish in the future as the relatively small high-mountain glaciers begin to disappear.

ACKNOWLEDGMENTS

We are deeply grateful to colleagues from many countries who made mass balance measurements in the field and provided results for the scientific community and for this publication. We are particularly grateful to Dr. R. Koerner and Professor N. Caine for sending us directly the results of their measurements, and to Professor W. Haeberli, Dr. R. Frauenfelder, and Dr. M. Hoeltzle for providing an unpublished collection of mass balance results through the World Glacier Monitoring Service over the 1996–2000 period. We also thank Professor Graham Cogley from Trent University, Peterborough, Canada, for support with mass balance data and many helpful comments.

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INTRODUCTION

Global warming and other ongoing changes in the Earth system are beginning to have significant impacts, not only on the physical environment, but also on the biosphere and society. Thus, it is important to be able to project future trends, and this means that we must understand the present forcings and effects on the system — including the wastage of glaciers — in order to plan for the future. Glacier variations are sensitive indicators of changes in climate and may have direct impacts on processes of global importance such as sea-level rise, the hydrology of mountain-fed rivers, the freshwater balance of the oceans, natural disasters, and even the shape and rotation of the Earth. In recent years the rate of loss of glacier ice to the oceans has accelerated, and this trend is expected to continue as a result of the rise of "greenhouse" gases in the atmosphere. At the same time, we are becoming increasingly able to measure subtle changes in the Earth system using satellites and other new technology. Thus, it is appropriate to examine the current role of glaciers in global processes.

Here we discuss the effect of the "small" glaciers of the world: all perennial ice masses other than the Greenland and Antarctic ice sheets. We include mountain glaciers, ice fields, ice caps, and all kinds of glaciers, as well as those that are temperate or polar, or polythermal; we do not include outlet termini of the two ice sheets, but we do include those glaciers and ice caps that are peripheral to, and independent of, the ice sheets.

AREAS AND VOLUMES

Total Area

The World Glacier Inventory Program (WGI) was an ambitious attempt to measure and classify all of the perennial ice masses of the world (Haeberli et al., 1989). However, an inventory of glaciers and ice caps could only be completed in certain areas, such as Europe, and many of the more important regions could not be measured. Therefore, the WGI is inherently biased and has to be extended by more approximate techniques, e.g., as suggested by the Global Land Ice Measurements from Space program **(**Kieffer et al., 2000).

Some recent estimates of the total area and volume of glaciers and ice caps are given in Table 1. Our estimates of the total area of this ice is about $785 \pm 100 \times 10^3$ km^2; its volume is about $260 \pm 65 \times 10^3$ km^3, equivalent to about 0.65 ± 0.16 m of sea-level change. It is interesting

TABLE 1. Total areas and volumes of glaciers around Greenland and Antarctic and elsewhere, as reported by several recent sources.

Source	**Area** in 10^3 km^2		**Volume**, in 10^3 km^3		**Total**	
	Excluding Antarct., Greenl.	Antarctica, Greenland[a]	Excluding Antarct., Greenl.	Antarctica, Greenland[a]	**Area**	**Volume**
Meier and Bahr (1996)	540	140	–	–	680	180
Raper and Braithwaite (2005)	522	–	87	–	522	87
Ohmura (2005)	521	–	51	–	521	51
Dyurgerov (2005)	540	245	–	–	785	–
This paper	540±30	245±100	133[b]±20	125[b]±60	785±100	260±65

Uncertainties are estimated based on possible errors in area, the area/size relation, and the scatter in the power-law relation of area and volume.
[a]Not including the Antarctic and Greenland ice sheets.
[b]Obtained by separating out the Antarctic and Greenland glacier area/size distribution as calculated by Meier and Bahr (1996), and increasing it by using the newer (larger) area and the same mean thickness determined for polar and subpolar glaciers as given in Meier and Bahr (1996).

that almost half of this estimated volume occurs around the periphery of the Antarctic and Greenland ice sheets. These area estimates are tabulated by individual regions in Appendix 1.

Large differences exist between the volumes estimated by different authors depending on the assumptions used and the method of calculation. Even larger differences between the various estimates shown in Table 1 are due to whether or not the peripheral glaciers around the two ice sheets are included. Some authors assume that these peripheral glaciers will be analyzed as part of the ice sheets, but we note that these small glaciers are at lower altitudes, in more maritime climates, and are too small to be included realistically in the coarse grids used to model the big ice sheets. As pointed out by Vaughn (2006), "[the glaciers of the Antarctic Peninsula have] greater similarity to sub-polar glacial systems (such as coastal Greenland, Svalbard, Patagonia and Alaska) which are known to be more sensitive to atmospheric warming, than to the cold ice sheets covering the rest of the Antarctic continent…"

Area Distribution

The distribution of individual glaciers by size is important to know in order to calculate their thickness and thus how rapidly their contribution to runoff to the sea will change as they are reduced in size. The existing WGI results need to be extended, not only to Antarctica and Greenland, but also elsewhere, using some kind of realistic model, especially in regions of large glaciers such as those in the Arctic islands and around the Gulf of Alaska. Meier and Bahr (1996) and Bahr and Meier (2000) suggested that the number of glaciers in a region as a function of their size could be approximated by an exponential/power-law function, derived from percolation theory and tested against inventory results. As mentioned by Meier and Bahr (1996), glaciers larger than 2^{13} (8192) km^2 make up a significant portion of the total area; if more glaciers around the Antarctic ice sheet were included, the area of large "small glaciers" would increase. More analysis, modeling, and testing are vitally needed.

Ice Thicknesses and Volumes

Once the distribution of glaciers as a function of their individual areas has been defined, using glacier inventories and a scaling analysis, the distribution of glacier thicknesses and volumes can be calculated. These are important for projecting the glacier contribution to sea-level rise in future years; the areas of thin glaciers will decrease rapidly with wastage, but thick glaciers will continue to produce meltwater long into the future. We use a volume/area scaling algorithm (Bahr et al., 1997; Macheret et al., 1999) with bins 2^n in area to estimate glacier-volume and thickness distributions and thus their likely area changes with further melting. This value for total glacier volume (Table 1) is considerably higher than the values reported by some other authors.

Traditionally, attention has been paid to variations in the length of glaciers — their advance and retreat (e.g., Forell, 1895; Oerlemans, 1994, 2005; Haeberli, 1995). Although useful for demonstrating changes, these data give only crude measures of the glacier's overall changes unless detailed knowledge is available for modeling their dynamic response to mass balance change. This knowledge is available for only a few glaciers, and therefore these advance/retreat histories are of limited use for large-scale syntheses of year-to-year climate change or sea-level rise. Here we direct our attention to the annual (or net) balance of glaciers; this is a direct measure of the exchange of ice mass between the atmosphere and the land/ocean.

MASS BALANCE

Glacier mass balances can be measured several ways. The most common are (1) repeated measurement of the ice surface altitude; these data on thickness changes, combined with glacier area and an appropriate density, yield changes in mass; and (2) mass balance observations made directly on the surface which are summed over the glacier and over a year to get the glacier-wide mass changes, the net or annual balance. The surface-altitude method has recently become especially productive because of the development of laser altimeters that can be flown in aircraft using global positioning systems (GPS) for spatial orientation (e.g., Echelmeyer et al., 1996; Arendt et al., 2002; Abdalati et al., 2001).

Most mass balance data from the world's glaciers have been obtained by traditional surface measurements; however, these are limited because they are very labor intensive. An extensive literature exists on mass balance methods (e.g., Østrem and Brugmann, 1991; Bamber and Paine, 2004), and results have been compiled by the World Glacier Monitoring Service (WGMS) in Zürich, Switzerland, and the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado; see also the data sets by Cogley (2002, http://www.trentu.ca/geography/glaciology.htm), Dyurgerov (2002, http://instaar.colorado.edu/other/occ_papers.html), and Dyurgerov (2005, http://www.nsidc.org). In addition, numerous attempts have been made to model mass balance time series using climate data (e.g., Oerlemans, 1993), but here we emphasize observational data to avoid circularity in studies of the relation of glacier changes to climate. The locations of glaciers with mass balance observations listed here are shown in Figure 1.

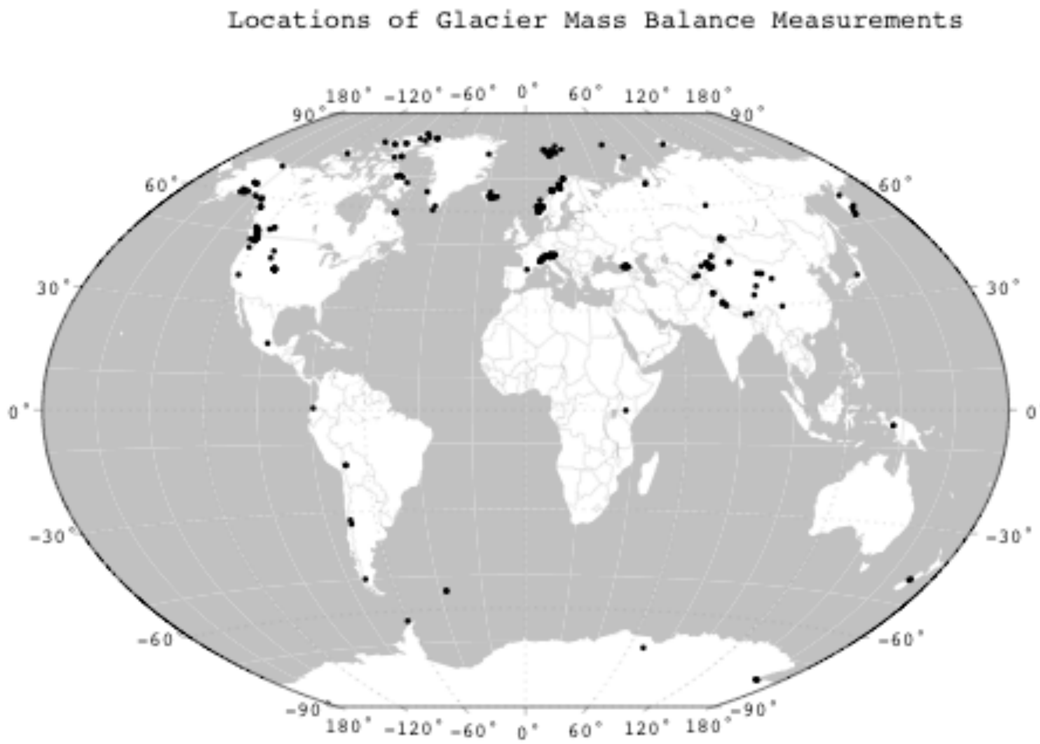

FIGURE 1. Map showing locations of glaciers with mass balance records.

Global Compilation of Mass Balances

The area of glaciers considered here includes areas of individual ice caps in Antarctica, i.e., those that have no direct connection with the ice sheet and were not included in previous evaluations. There is evidence that these glaciers may have a negative mass balance and may now be contributing meltwater to sea-level rise (Morris, 1999; Schneider, 1999; Skvarca et al., 2005; Morris and Mulvaney, 2004; Rignot et al., 2005; Cook et al., 2005). Appendix 1 presents our recent estimates of regional areas. In order to assess the global effects of glacier wastage, we need to compile glacier volume changes for large regions. Difficulties exist for data averaging because the data are unevenly distributed (for some regions we have only one, or no, time series of glacier volume change), and there are unresolved problems with spatial

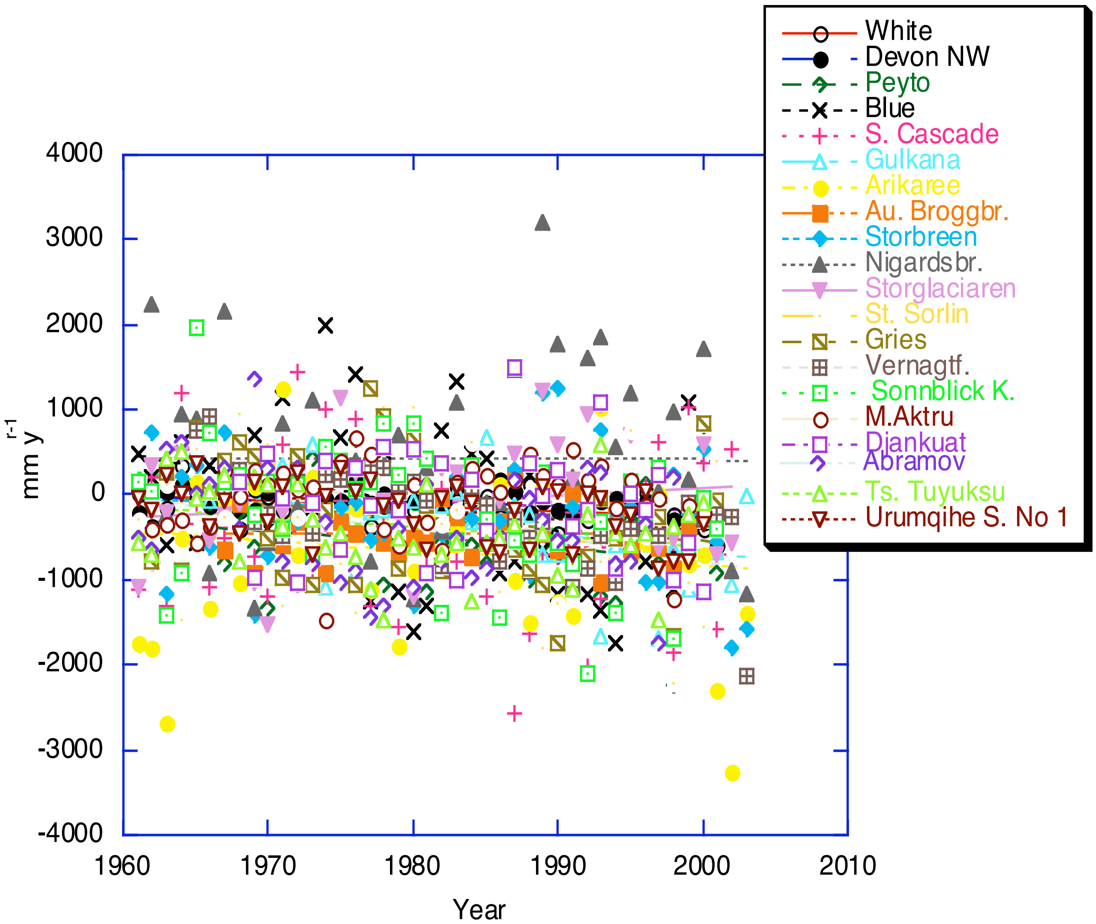

FIGURE 2. Annual mass balances of 20 selected glaciers with long observational records showing large variability.

extrapolation of glaciological data. Glacier mass balance data are extremely variable with respect to many local, regional, and global parameters such as longitude, latitude, elevation, aspect ratio, and distance from sources of moisture (Dyurgerov, 2002). These factors are responsible for much of the variability of glacier mass balance.

We have combined individual volume-change time series, such as those illustrated in Figure 2, into larger, climatically homogeneous regions, placing the data into three different samples/systems: (1) 49 mountain and sub-polar systems where sufficient mass balance observational data exists from individual glaciers, (Dyurgerov, 2005, Appendices 2, 4); (2) 13 larger-scale regional systems combined in regard to geographical and/or climatic similarity (Dyurgerov, 2005, Appendix 5); (3) 7 large composite systems for the world, in order to estimate global glacier-volume changes and their contributions to the planetary water cycle and to sea-level change (Dyurgerov, 2005, Appendix 6).

To calculate these volume changes by systems and regions, we applied a scheme introduced by Dyurgerov and Meier (1997a, 1997b, 2000, 2004). This includes weighting individual specific mass balance values by surface area, because the sample of observed glaciers is biased toward small glaciers in many areas of the globe. We avoid modeling mass balances using data from meteorological observations because precipitation data are poorly known in sub-polar and high mountain regions and are of limited use for independent climate impact analyses.

The main disadvantage of using observational time series, on the other hand, is the necessity for data extrapolation from individual sites to larger areas. This deficiency still exists as no completely reliable approach to mass balance data extrapolation has yet been found. Cogley (2005) has suggested a methodology to estimate the globally averaged mass balance of small glaciers by applying a spatial interpolation algorithm to the single-glacier observations. This approach offers a natural means of incorporating spatial and temporal sampling uncertainties explicitly. He suggests that "…spatial bias due to the uneven distribution of measurements, while not negligible, is of only moderate significance. The correction amounts to +38 mm yr^{-1} in water equivalent for the reference period 1969–98" (Cogley, private communication).

We do not report "reference-surface balances" (Elsberg et al., 2001). These integrate mass balance observations over an unchanging "reference surface," instead of over the area of a glacier that changes with time "conventional balances." Most of the conventional balances that we use here are computed over changing areas, although the areas are not necessarily measured annually. A comparison of the two methods using our data suggests that the effect is real, but small; over the years 1968–1999 it amounts to about 2%. Applying this to the total glacier area on Earth, the difference is about 3.6 km^3 yr^{-1}, equivalent to about 0.01 mm yr^{-1} of sea-level rise, a small correction. We recognize that our result, using conventional methods, may slightly understate the amount of glacier mass exchange with the climate.

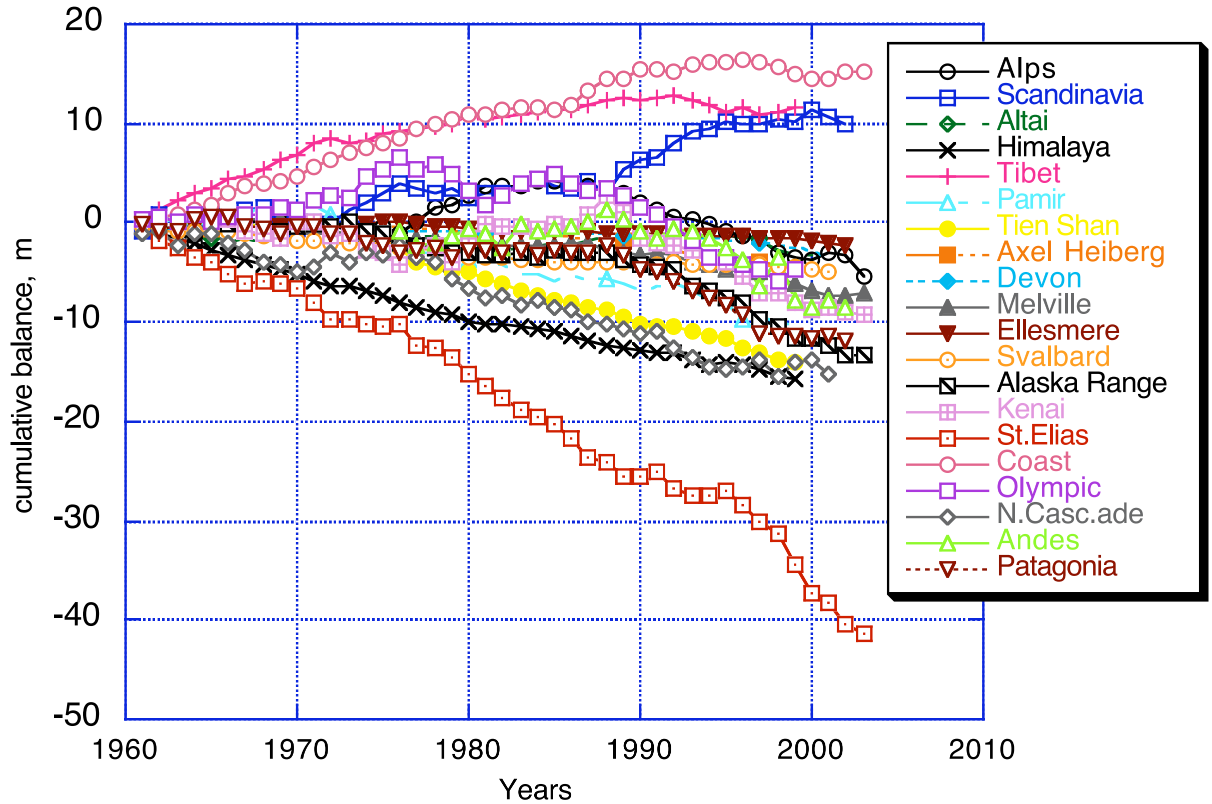

FIGURE 3. Cumulative mass balances of selected glacier systems compiled from individual time series showing differing changes in time up to the last decade of twentieth century.

Mass Balance Results

New compilations of mass balance time series are presented in Figures 3, 4, and 5 for glacier systems, large regions, and the world, respectively. The details of how these were compiled are given in Dyurgerov (2005). There are several interesting aspects of these sequences:

● First, the general trends in volume change and variability are close to those previously calculated and published (Dyurgerov and Meier, 1997a, 1997b; Church and Gregory, 2001; Dyurgerov, 2002).

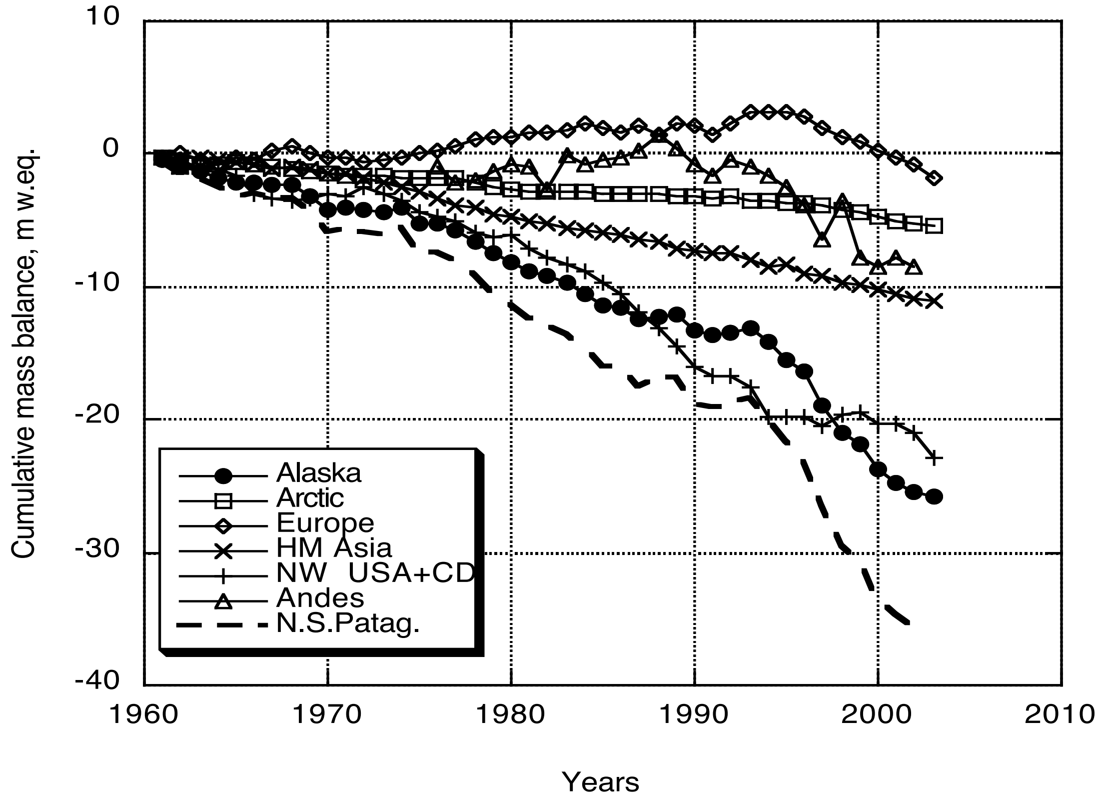

FIGURE 4. Cumulative mass balances calculated for large regions. For these calculations mass balance time series of all glaciers (more than 300 from time to time, and from 30 to 100 with multi-year records) were used (see http://www.nsidc.org). Annual mass balance data were weighted by the surface area of individual glaciers, then by the aggregate surface area of 49 primary glacier systems (20 of them are shown in Figure 3). Cumulative curves for large regions show a clear shift toward acceleration in mass loss by the end of the 1980s or in the 1990s.

● Second, very pronounced peaks in the globally-averaged annual mass balance time series are found in connection with the strongest explosive volcanic eruptions, in particular Mount Agung in 1963, Mount St. Helens in 1980, El Chichon in 1982, and Mount Pinatubo in 1991 (Fig. 5a), with cooling and positive mass balance found for the following 1–3 years, regionally and globally (Abdalati and Steffen, 1997; Dyurgerov and Meier, 2000).

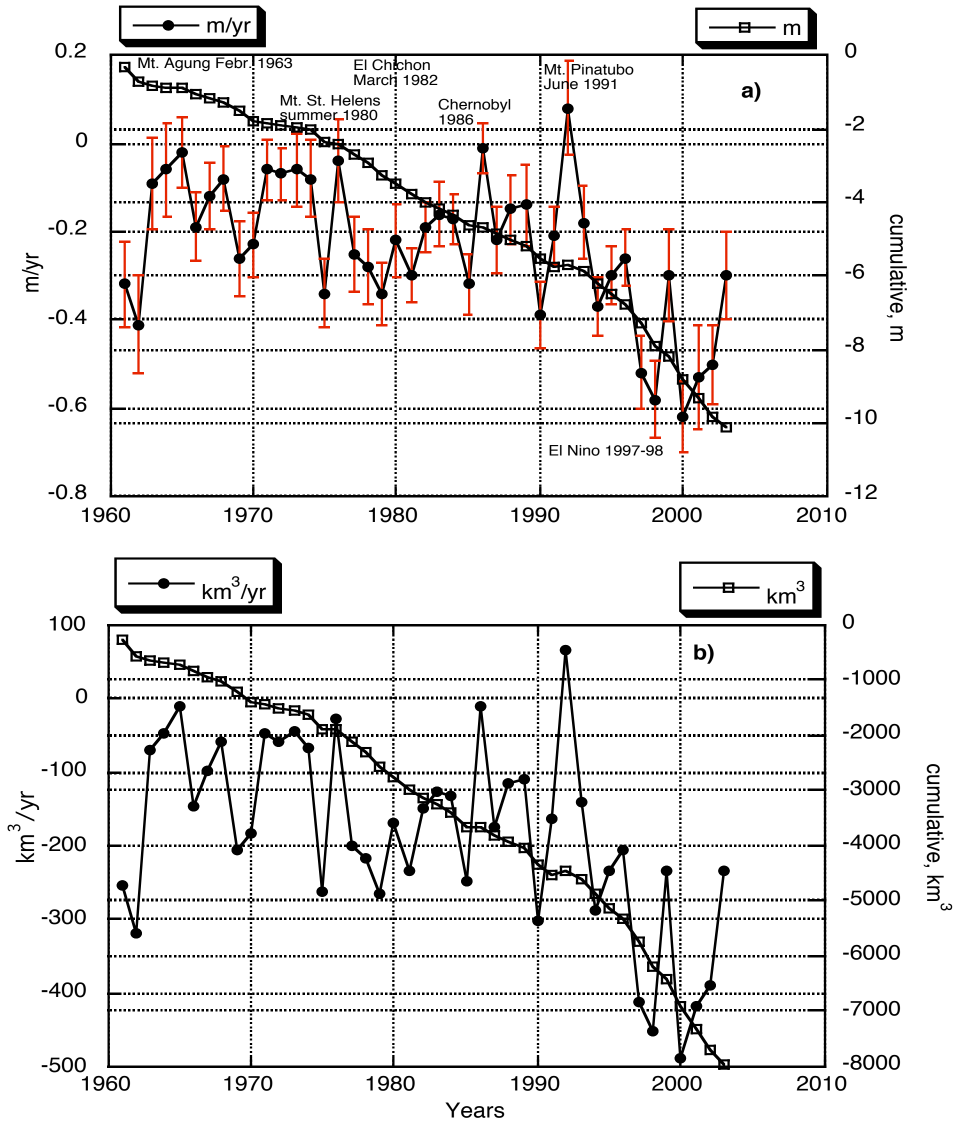

FIGURE 5. Glacier mass balance annual variability and cumulative values (a) in meters of water equivalent, and (b) in km^3, computed for the entire system of glaciers and ice caps with an aggregate area of 785 × 10^3 km^2. The results of direct mass balance observations on 300 glaciers worldwide are averaged by size of individual glaciers, 49 primary systems, 12 larger regions, 6 continental-size regions, and globally to get the one "global curve" (all in water equivalent). Vertical bars are estimated standard errors and represent the uncertainty range due to spatial mass balance distribution patterns.

● Third, the markedly negative mass balances and acceleration of glacier volume losses in the late 1980s and 1990s correspond to the unusually high mean temperatures during these years.

● Fourth, the acceleration of glacier volume change presented here shows consistency with other evidence of warming in the earth system, including reduction of sea-ice area and thickness (Laxon et al., 2004), decreasing areal extent of snow cover for about 0.2% yr^{-1} in the Northern Hemisphere (Armstrong and Brodzik, 2001), increasing temperature and thawing in permafrost (ACIA, 2004)**,** and acceleration of movement and disintegration of outlet glaciers and ice shelves in Greenland and Antarctica (Scambos et al., 2000; Zwally et al., 2002; Rau et al., 2005; Thomas et al., 2004).

One of the reasons for our larger values of glacier mass loss is because we use a somewhat larger total glacier area. Another is the incorporation of new or not previously available data, including the results of new measurements in the most recent years with more negative mass balances, in particular: (1) new mass balance and volume change results from the Patagonia ice fields (Rignot et al., 2003); (2) updated mass balance results for Alaskan glaciers (Arendt et al., 2002); (3) recalculation of mass balance of individual ice caps around the Greenland ice sheet; and (4) new mass balance data for glaciers in South America that have not been available before.

CURRENT IMPACTS OF GLACIER WASTAGE ON SEA LEVEL

The trend of rising sea levels is one of the most troublesome aspects of global climate change. More than 100 million people live within 1 m of mean sea level (Douglas and Peltier, 2002), and the problem is especially urgent for the low-lying small island nations. Sea-level changes are caused by several different processes, including ocean-water warming and freshening, changes in surface and groundwater storage, and the loss of glacier ice mass. Our new glacier volume change time series has been expressed in terms of sea level (Fig. 6) and shows that the glacier contribution in 1961–2003 is somewhat larger than that estimated in our previous calculations (Dyurgerov and Meier, 1997a; Dyurgerov, 2001, 2002), and those presented in Church and Gregory (2001). This glacier contribution of 0.51 mm yr^{-1} is a

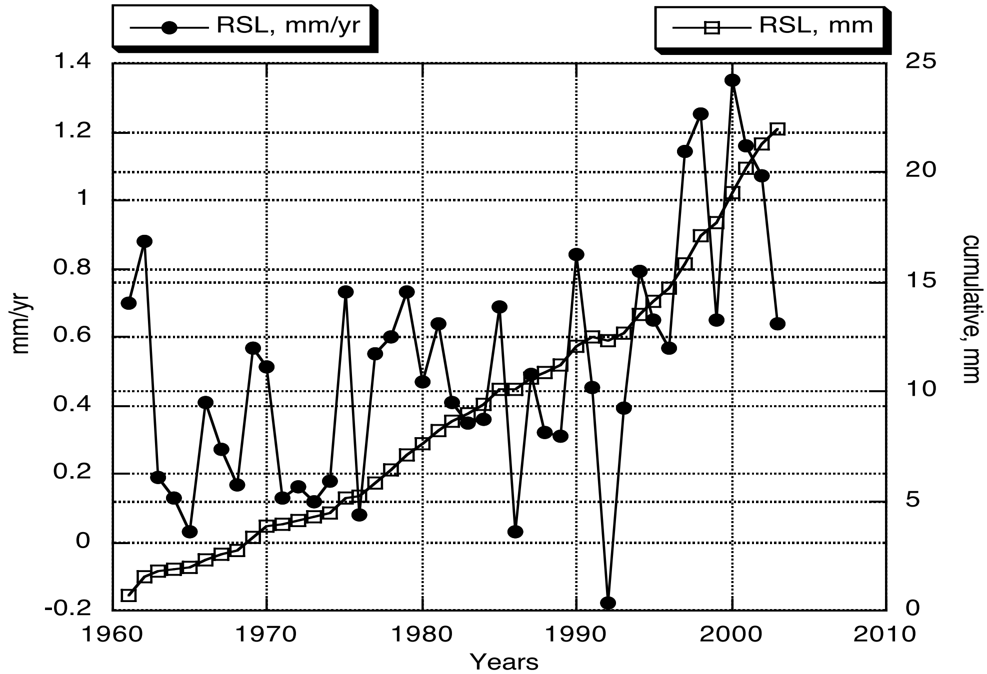

FIGURE 6. Glacier contribution to rise in sea level from glaciers and ice caps with an aggregate area of 785 × 10^3 km^2. Observational data from Figure 5 have been used to express glacier volume change in terms of contribution to sea level by dividing the volume change, or mass balance, in km^3 of water, by 362 × 10^6 km^2, which is the surface area of the world ocean.

significant fraction of the total twentieth century sea-level rise rate, listed in the last IPCC assessment (Church and Gregory, 2001) as 1.5 ± 0.5 mm yr^{-1}, and raises the question of the relative roles of the addition of water mass from land to ocean (eustatic rise) versus warming and thermal expansion or freshening of ocean water (steric changes). New analyses of the tide gage and satellite observations by Miller and Douglas (2004) and Lombard et al (2004) suggest that, of the twentieth century average sea-level rise of 1.5–2.0 mm yr^{-1}, only 0.5–0.8 mm yr^{-1} is due to steric rise, leaving a significant fraction attributed to eustatic inputs of about 1.3 ± 0.5 mm yr^{-1}. This contribution is likely to be mostly from glacier and ice-sheet melt, as the only appreciable other sources are changes in land hydrology which appear to contain both positive and negative effects in roughly equal portions.

Our recent estimates of the average contribution to sea-level rise from glaciers (1961–2003) is 0.51 mm yr^{-1}, rising to 0.93 mm yr^{-1} in the decade 1994–2003 (Fig. 6). This addition of freshwater to the ocean is probably beginning to have significant effects on ocean circulation, ocean ecosystems, and sea-level change. Glacier ice melt is accelerating in recent years, and is likely to continue at a high rate into the future. Although many small glaciers will disappear, much of the current meltwater runoff is from large glaciers (e.g., Bering and Malaspina Glaciers in Alaska, each about 5×10^3 km^2 in area), which will be slow to decrease in size, and additional glacier ice area will add to the hydrological cycle as cold glaciers warm and begin producing runoff.

GLACIER - CLIMATE INTERACTIONS

Glaciers as Indicators of Climatic Change

We discuss here the use of glacier mass balance data (both annual and seasonal) to infer climate variables such as precipitation and air temperature, and to use the spatial distribution of these data to assist in the analysis of climate and of climate modeling. Seasonal glacier-balance data, including winter balance, ***bw***, and summer balance, ***bs***, provide estimates of precipitation and summer temperature distributions in high-mountain and high-latitude areas where observational climatic data are both rare and biased. Very few long-term climatic stations exist above 3000 m in altitude, and those that do grossly underestimate the actual precipitation as compared to observed glacier winter balances. Winter balance and precipitation also obey rather different spatial statistics. The autocorrelation with distance for point measurements of precipitation is not high even at short distances of separation, decreasing to zero at a distance of 2000 km (Fig. 7). Winter balance, on the other hand, shows a higher autocorrelation at these distances, and drops to only about 0.5 at 2000 km. This suggests that accumulation values are well correlated spatially, and are less influenced by local variations.

Another important measure of glacier-climate interactions is the vertical gradient in mass balance, $d\mathbf{b}/dz$ (Shumskiy, 1947; Meier and Post, 1962; Kuhn, 1980, 1984; Dyurgerov and Dwyer, 2001). Observational results show that $d\mathbf{b}/dz$ is changing; $d\mathbf{b}/dz$ is steeper in recent years with warmer climate conditions (Fig. 8), because glaciers are losing mass at low altitudes due to higher temperatures, and gaining mass at high altitudes due to increasing snow accumulation

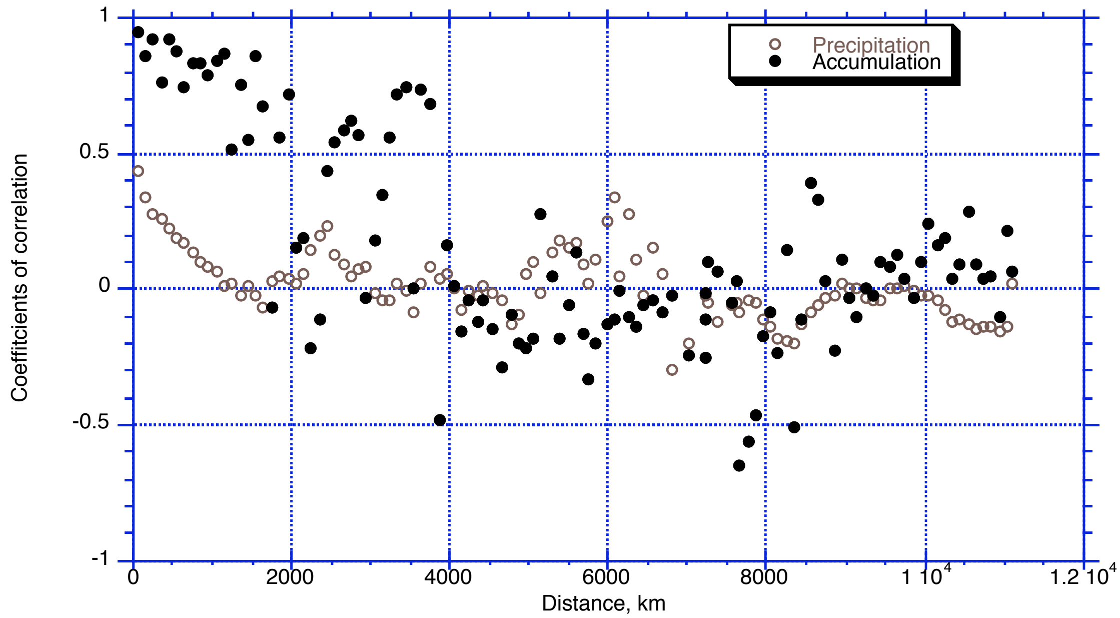

FIGURE 7. Relationship between spatially distributed patterns of autocorrelations computed for annual snow accumulation on glaciers, and annual precipitation (from meteorological stations, GDCN data base); both in the Northern Hemisphere. Precipitation at 1000–1500 m elevation; *bw* is the maximum snow accumulation amount measured at the glacier surface at the end of accumulation season (these *bw* are usually 20%–30% less than annual snow accumulation amount).

(Dyurgerov and Dwyer, 2001). This indicates an increase in the intensity of the hydrological cycle during these times of global warming.

Along with this change in the mass balance gradient, the equilibrium-line altitude (***ELA***) has been increasing, and the ratio of glacier area above the ***ELA*** to the total glacier area (the accumulation-area ratio, ***AAR***) has been decreasing. One interesting indication of recent shifts in glacier mass balances is seen in the averaged ***AAR*** data plotted as standard departures (Fig. 9); this shows an accelerated decrease in the ***AAR*** in about 1977 and again in the early 1990s, in common with other evidence of increased glacier wastage. Measurements of ***AAR*** can be made from satellite images, so this is an especially useful metric.

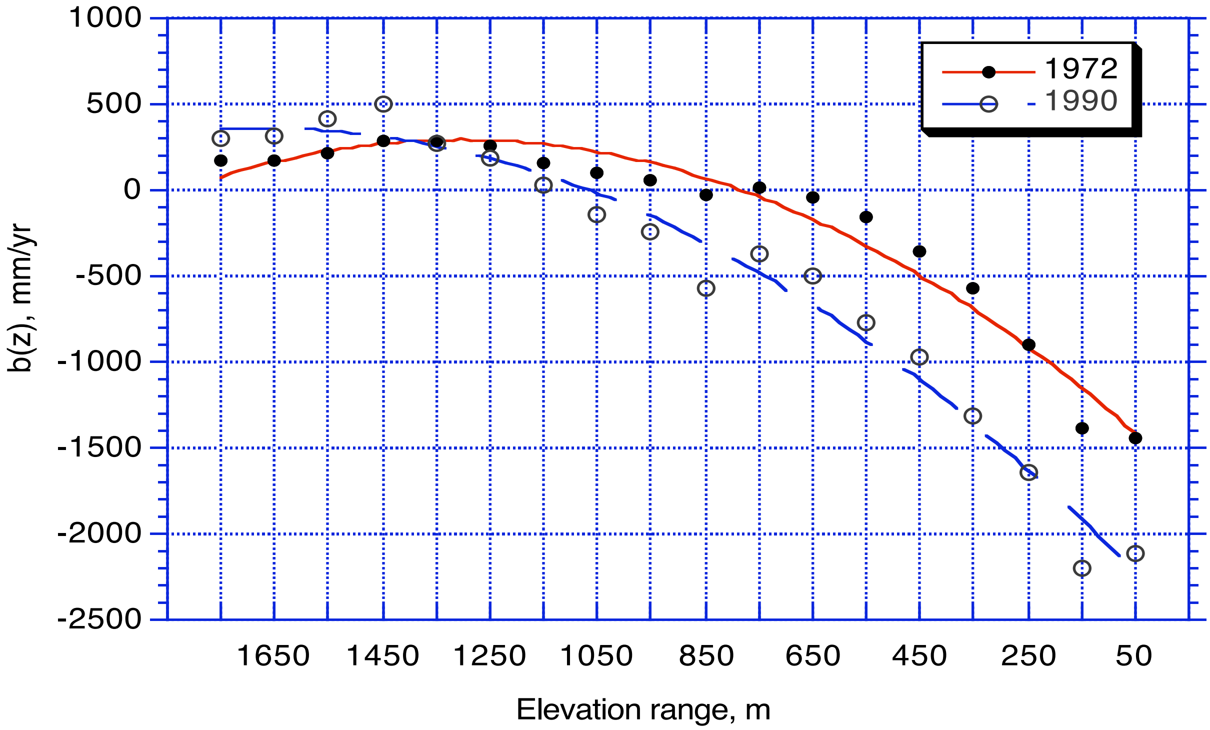

FIGURE 8. Change in mass balance gradient between cold and warm years; mass balance data have been averaged for 21 Northern Hemisphere glaciers and adjusted to the same elevation.

The current increases in winter balances at high elevations have been especially rapid in the last decade, and have not been paralleled by appreciable increases in precipitation as measured at (lower altitude) climate stations (Fig. 10). This also suggests a significant increase in the intensity of the hydrologic cycle at high elevations. The increase in ***bw*** is even more remarkable considering the simultaneous decrease in glacier accumulation areas.

An appropriate measure of this change in both major components of glacier mass balance is the glacier mass turnover, the average of the absolute values of ***bw*** plus ***bs*** (Meier, 1984) (Fig. 11a). Another important measure is the sensitivity of mass balance to air temperature, ***db/dT*** (Fig. 11b). These observations show that both demonstrate changes in the recent warm decades of the twentieth century; these have not been predicted by, or used in, glacier-climate models. An

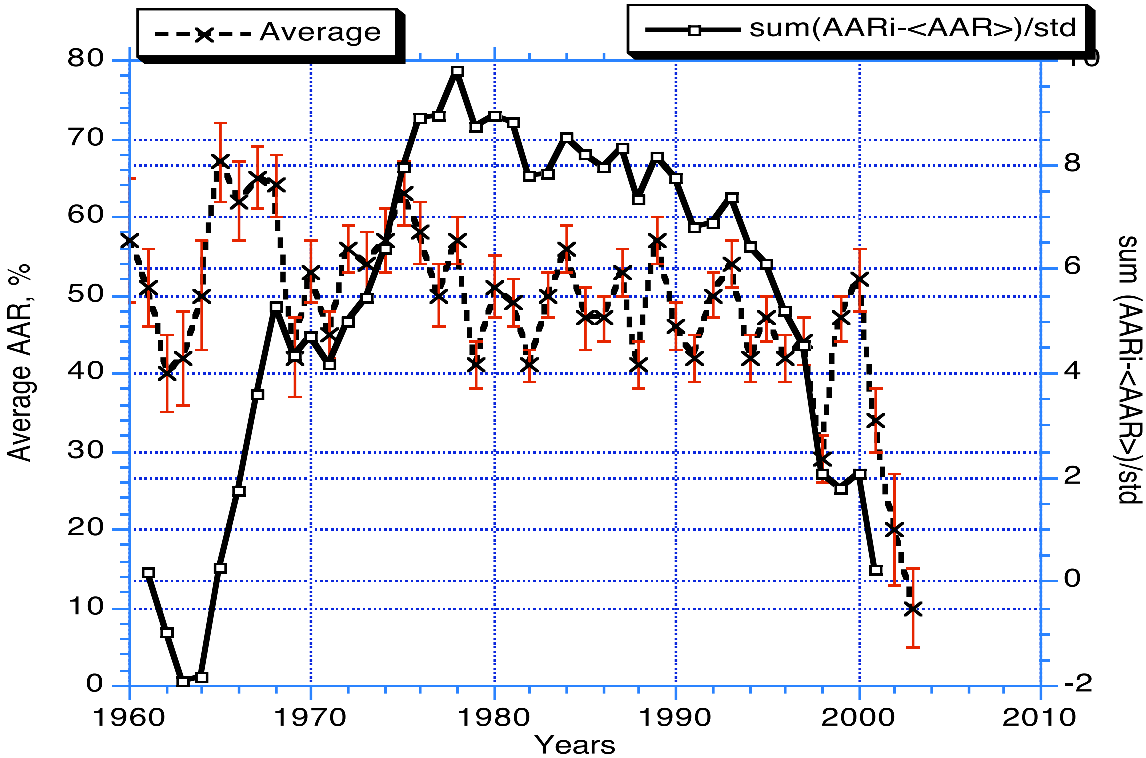

FIGURE 9. Annual variability and the change with time of the accumulation-area ratio <*AAR*> in terms of standardized cumulative departure. The data are averaged for all time series longer than 5 years; bars are standard errors. The time of <*AAR*> shifts to a decrease at the end of 1970s and again the early 1990s; data after 2001 are incomplete.

interesting result of these observations is that the variability of both mass turnover and sensitivity show a sharp change at the end of the 1980s, followed by decreasing variability. This is temporal variability, but at the same time the calculation is based on dozens of time series in different geographical locations, so it represents spatial variability as well.

The spatial-temporal changes in glacier mass balances appear to be forced by changes in air temperature, which has increased globally. Figure 12 presents mass balance standardized departures calculated for large glacier regions. This shows that an acceleration in volume wastage started in some regions as early as the 1970s (e.g., in Central Asia) and was completed by the end of the twentieth century in other regions (e.g., Arctic).

The large differences between observations of snow accumulation and measured precipitation indicate that one must use extreme caution and make necessary adjustments in any

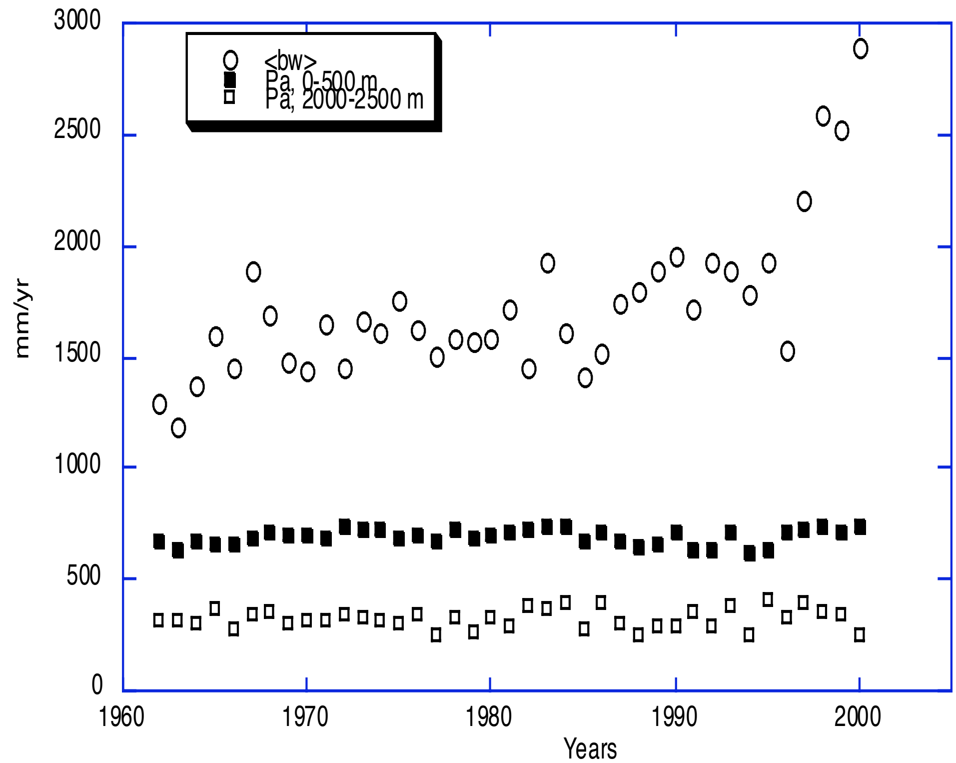

FIGURE 10. Apparent trend in winter snow accumulation <*bw*> **from bench mark glaciers, (averaged for all available observations, see data base); and annual precipitation,** <*Pa*>**, averaged for 40–60°**N **latitude from Global Historical Network Climatology database at two altitudinal ranges, 0–500 m and 2000–2500 m.**

use of precipitation data for glacier mass balance modeling and the projection of glacier-melt contributions to sea-level change. These glacier data give realistic information on the fundamental processes of climate-glacier interrelations, many of which are not realized or predicted by existing models. Glaciers are major contributors to global and regional water cycles, and observations on them deserve more attention and better monitoring as part of the evolving Earth system.

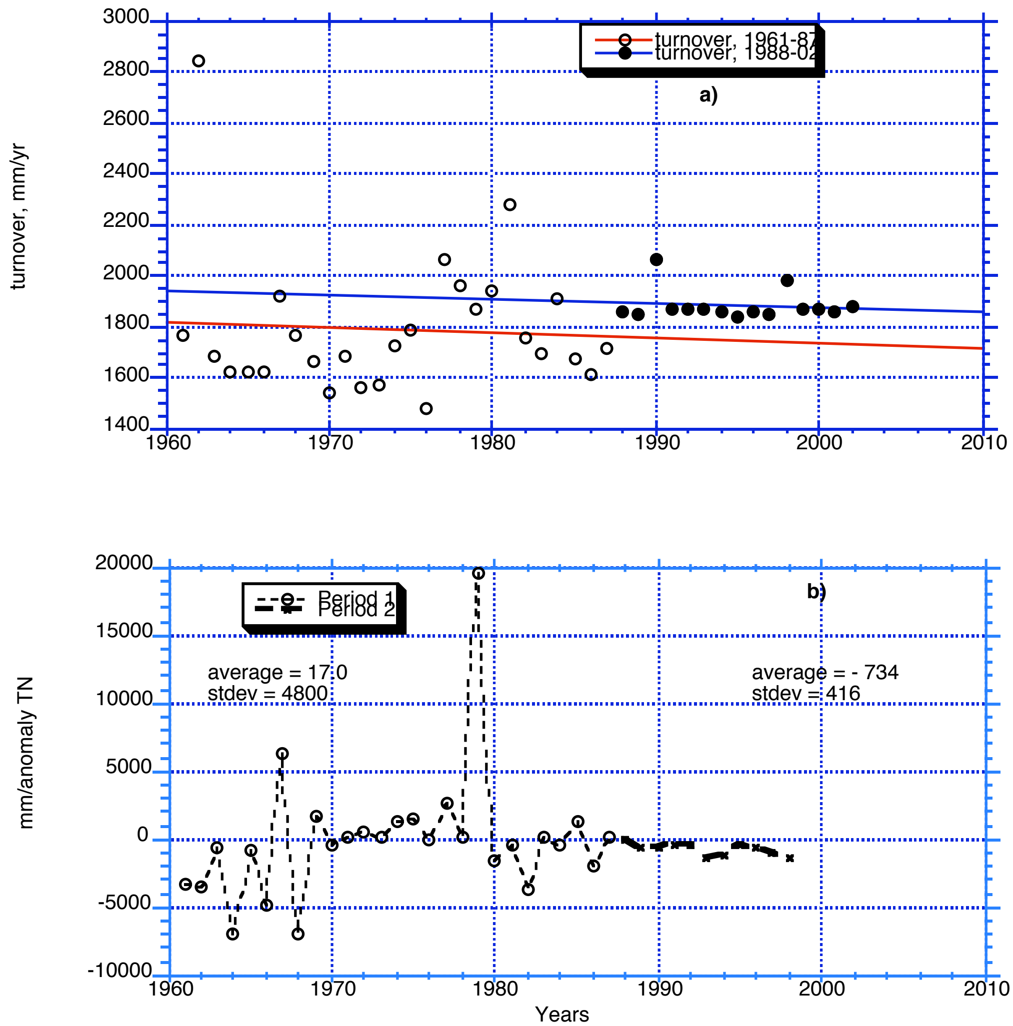

FIGURE 11. (a) Glacier mass balance turnover has dramatically increased after 1987 with a decrease in annual variability at the same time. (b) The mass balance sensitivity to the Northern Hemisphere air temperature anomaly (°C) has also increased. Northern Hemisphere glacier mass balances are used to calculate sensitivity to annual air temperature. Long-term annual mass balance time series averaged for about the same 40 bench mark glaciers have been used to calculate averages (Dyurgerov, 2001). Note, this is a different measure of sensitivity than that used by the IPCC (Church and Gregory, 2001), which involves a change between two steady states.

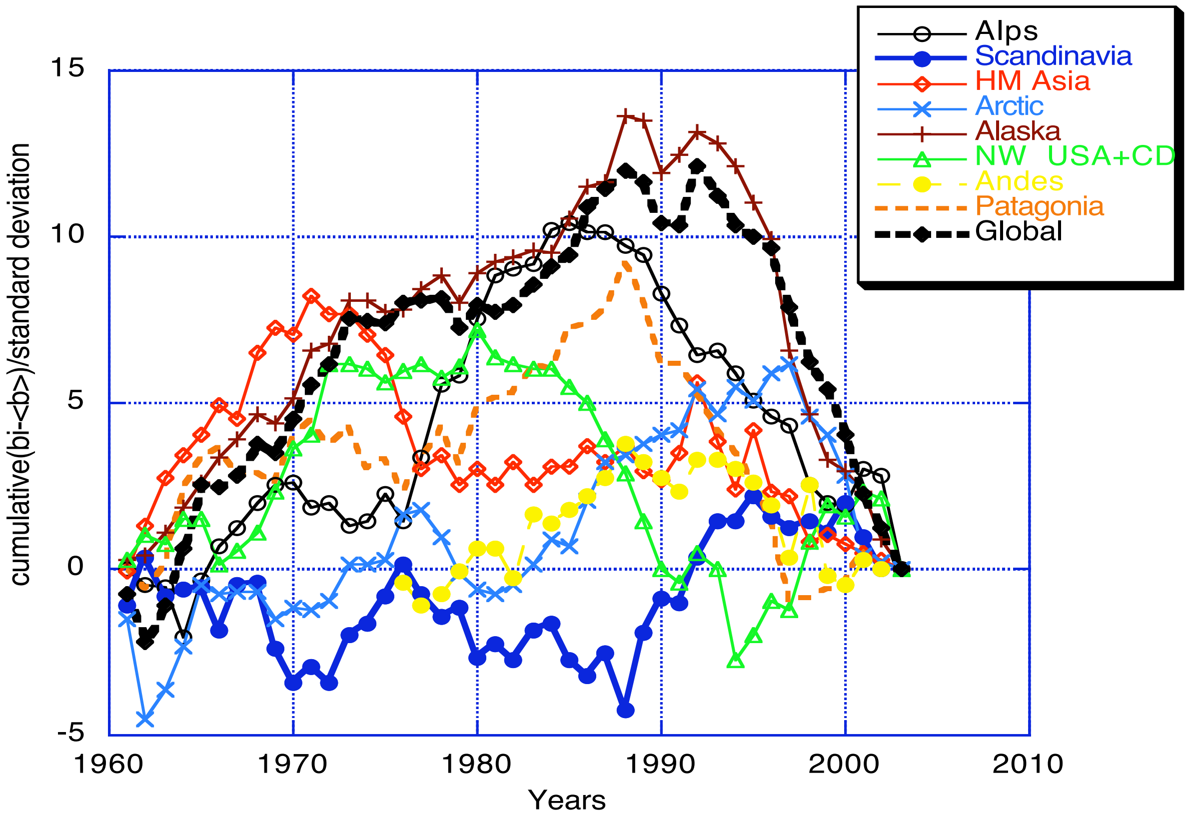

FIGURE 12. Timing of glacier volume shifts toward acceleration in wastage expressed in standardized cumulative departures. These show that different glacier systems have responded to large-scale changes in climate with differences in timing, from the early 1970s until the end of the 1990s. This process of glacier volume change in response to climate has taken about three decades.

IMPACT ON THE EARTH'S GRAVITATIONAL FIELD

Changes in the Earth's shape are influenced by the transfer of mass between land and ocean, so this subject is related to the variations in ice mass and sea level discussed above. The Earth's obliquity (the main component is known as J_2) varies at many time scales, and this influences its rotation rate (length of day, *lod*), as well as movement of the rotational axis (polar wander). Using modern geodetic satellites such as TOPEX and GRACE, we can measure the temporal and spatial changes in the gravity field, J_2, and *lod* with remarkable precision. This permits us to examine the role of glaciers on this system, or alternatively, the geodetic data can be used as a check, both regionally and globally, on our estimates of ice wastage. However, some questions remain (Munk, 2002).

J_2, averaged over a long time, is decreasing, due to tidal friction, post-glacial rebound, mass transfers, and other effects (Munk, 2002; Cox and Chao, 2002). This causes the Earth's rotation rate to speed up in order to preserve angular momentum. In 1998, however, J_2 began to increase. Dickey et al (2002) suggested that this increase might be caused, at least in part, by the accelerated wastage of mountain glaciers. The global long-term trend in J_2 is -2.7×10^{-11} yr^{-1}. Ivins and Dyurgerov (2004) suggest that glacier wastage during recent years with very negative mass balances could cause an addition of $+1.8 \times 10^{-11}$ yr^{-1} to this trend due to Northern Hemisphere glaciers and the Greenland Ice Sheet, not quite enough to reproduce the observed jump but demonstrating that glacier wastage at high latitudes is important in understanding changes in the Earth's geophysical system. These changes in gravity may be significant on a regional basis as well. Regional uplift in southeastern Alaskan has been attributed to recent glacier wastage (Larsen et al., 2005).

GLACIER HYDROLOGY AND ITS IMPACT ON OCEAN SALINITY

Freshwater runoff from glaciers has distinctive characteristics. These include a natural regulation that buffers the effect of warm/dry years or cool/wet years, seasonal water storage and release in summer when it is generally most needed, a high sediment discharge and marked daily variation in flow that renders stream channels unstable, and the possibility of temporarily storing bodies of water adjacent to or under the ice, causing damaging floods on release in certain regions (Meier, 1969). In addition, this runoff is a component of the exchange of freshwater with the ocean, affecting ocean circulation. Thus, glacier runoff affects water resources, agriculture, hydroelectric power, the environment, the economy, and even ocean circulation.

Glacier Impact on the World Ocean

Observational results of ***bw*** in the Northern Hemisphere, plus summer precipitation (estimated to be about 1/3 of ***bw***) suggest an average precipitation on glaciers of about 912 mm yr^{-1} for the 1961–2003 period, assuming that the glaciers are in a steady state. Another estimate of steady-state annual precipitation/accumulation using glacier mass turnover suggests an average value of 970 mm yr^{-1}. Average precipitation on Northern Hemisphere land is about 690 mm (Gleick, 1993). The ratio of the two values is 1.36; i.e., precipitation over glaciers is, on the average, about 36 % higher than that over non-glacier land, assuming steady-state conditions.

In reality, glaciers were not in a steady state during the last 30–40 years, and mass losses are accelerating. These negative mass balances represent the loss of perennial ice/water storage, augmenting runoff. To estimate the current annual glacier runoff to the world ocean (excluding iceberg calving), the annual mass balance rate multiplied by 1.36 is shown in Figure 13. The total glacier meltwater runoff (excluding the Greenland and Antarctic ice sheets) is small relative to the global river runoff (about 40×10^3 km^3 yr^{-1}) (Gleick, 1993). Regionally, it is substantial and can dominate other sources of fresh water, not only during the summer melt period, but also over long periods of time.

Glacier Meltwater Flux to the Arctic Ocean

The Arctic ocean basin is unique in the Northern Hemisphere in that most glaciers, especially those on arctic archipelagos, contribute water directly to the ocean rather than to the large rivers feeding the ocean.

The nine major river basins in Siberia and North America that are regularly gaged, excluding the contribution from western Europe, have a glacier area of less than 4% of the pan-Arctic total glacier area, so river-discharge data cannot provide an integrative measure of water balance for the entire land area of the pan-Arctic. This is a region where the two major components of freshwater inflow (from rivers and glaciers) to the ocean must be studied separately. Estimated glacier runoff compared with river runoff in the Arctic is shown in Figure 14. River runoff data show little trend; during the reference period, 1961–1990, no increase in river runoff was evident and only after 1995 did an increase appear.

The glacier contribution of freshwater to the Arctic Ocean, on the other hand, has been steadily increasing (Fig. 15). This comes primarily from glaciers in the Canadian, Russian, and Svalbard archipelagos, and individual ice caps and glaciers around the Greenland Ice Sheet. The increase in the glacier contribution, combined with a small increase in river runoff (Fig. 14), since the end of twentieth century support the conclusion derived from modern hydrographic records on freshening of North Atlantic waters (e.g., Bard, 2002), which suggests that deep

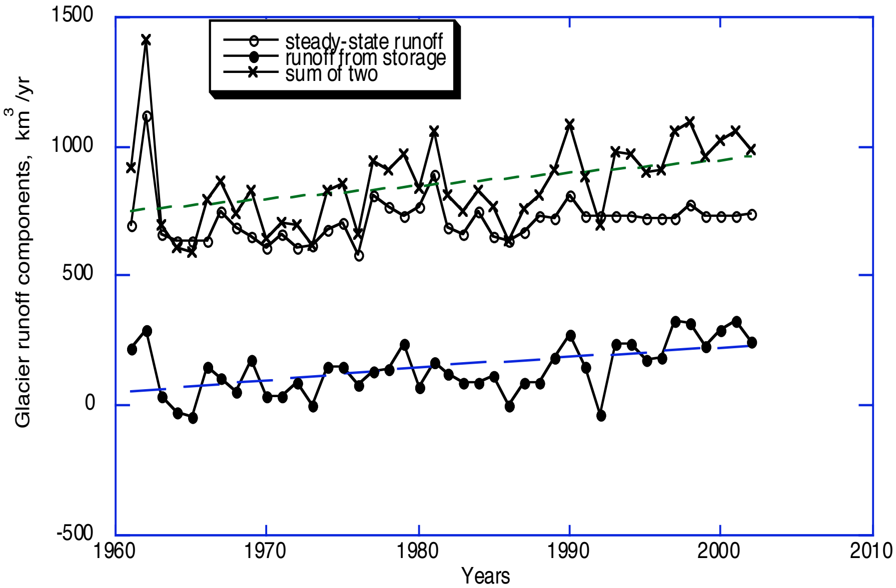

FIGURE 13. The components of meltwater runoff from glaciers. Winter mass balance observational results have been used to calculate the steady-state runoff for 40 glaciers worldwide over the 1961–2003 period, and increased by 1/3 (to account for accumulation in four summer months) to approximate the annual value. These annual values of mass gain were multiplied by the glacier area of 785 × 10^3 km^2 to get the annual rate of total freshwater volume flux from glaciers to the world ocean excluding the Greenland and Antarctic ice sheets (steady-state component in the figure). Runoff from the storage equals glacier mass balance.

arctic ventilation has steadily changed over the past 40 years (Dickson et al., 2002). This freshening and ventilation must be known to model future climate, changes in sea-ice extension, bioproductivity, and other environmental changes in the Arctic.

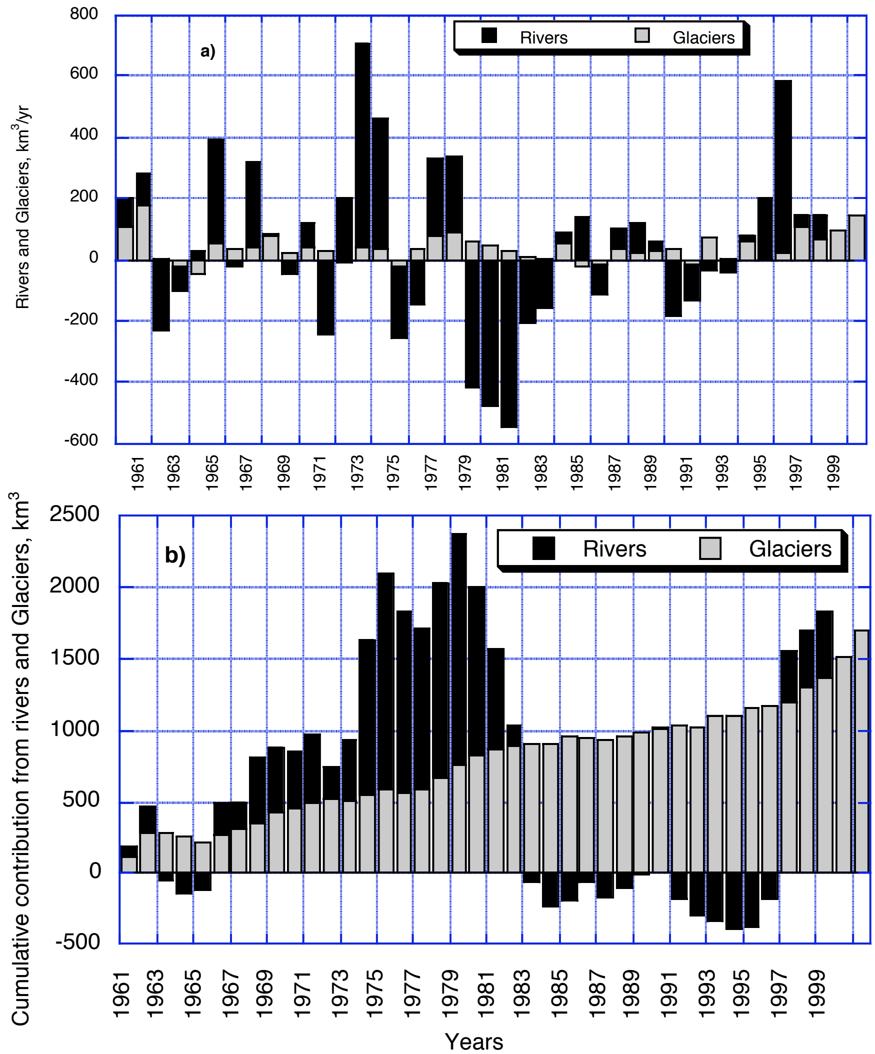

FIGURE 14. (a) Annual net inflow from pan-Arctic rivers and glaciers, not including Greenland Ice Sheet, to the Arctic Ocean. (b) Cumulative contribution from rivers, glaciers and both components combined.

It is likely that freshwater inflow to the Arctic Ocean from glaciers will continue to rise as a result of climate warming. Larger areas of ice caps will produce more runoff. These need to

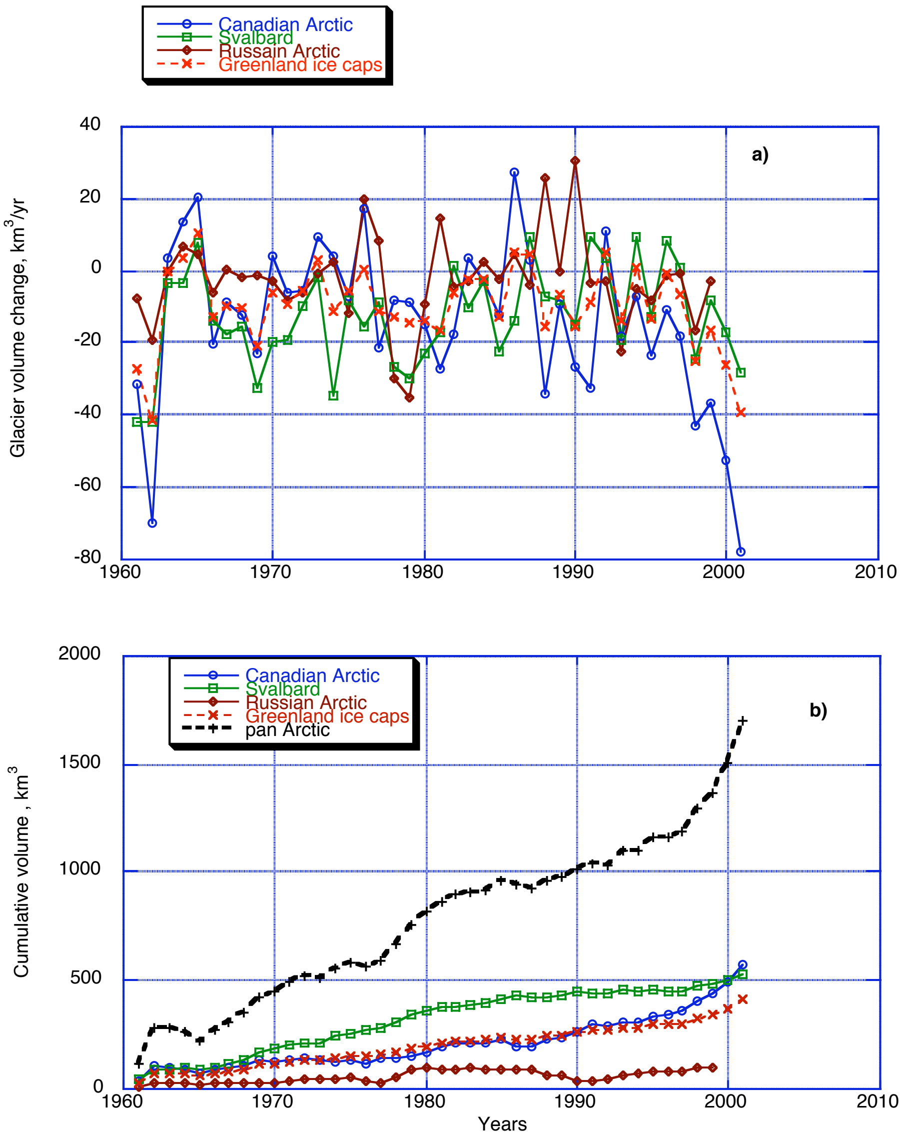

FIGURE 15. (a) Yearly glacier volume change calculated for large arctic archipelagoes, and (b) cumulative values over the study period for the same glacier areas

be monitored in order to develop a long-term environmental strategy. The continuing decline in observational networks on glaciers and ice caps, and their ensuing runoff, ignores the need for monitoring and forecasting of the water cycle in the Arctic.

Glaciers in High-mountain Regions

High-population areas in and near the mountains in Asia and the Americas derive much of their usable water from snow and ice melt. Glacier contribution to annual runoff of important rivers Amu Darya, Syr Darya, and Ily in the former Soviet Union part of Central Asia on the plains is from 5% to 40%, and up to 70% in the upper basins (Kemmerikh, 1972). The glacier contribution to annual runoff increases, on average, in this region from 15.6% to 40% in the ablation season (Kemmerikh, 1972; Krenke, 1982). Yellow (Huang He), The Yangtze, Brahmaputra, and other rivers of eastern and southern Asia head in glacier-clad mountains; the contributions of glacier runoff to these rivers is, however, poorly known. In Las Cuevas river basin (Mendoza, Argentina) glacier runoff may reach 73%–90% of the total flow and 75% for San Juan River basin, in the driest years. Glacier meltwater runoff contribution has increased in the last 40 years due to a decrease in precipitation (Leiva et al., 2005; Milana and Maturano, 1997).

The glacier area in the tropics is relatively small, and the hydrological significance of glaciers here may only be local, except perhaps in Peru. The glacier area defined for tropical South America in 1950–1980 was 2700–2800 km^2, decreasing to less than 2500 km^2 by the end of twentieth century (Kaser and Ostmaston, 2002). More than 70% of this area is in the Cordillera Blanca (Kaser and Ostmaston, 2002) and provide significant river runoff. Small glaciers also occur in the tropics in East Africa and Irian Jaya (Kaser and Ostmaston, 2002). A specific feature of glacier runoff in the tropics is that there is no substantial seasonality in glacier melt (due to very small seasonality in air temperature), as well as little annual variation in precipitation.

OTHER EFFECTS OF GLACIERS ON THE ENVIRONMENT

Large-scale Glacier-induced Events

A series of extremely warm years with a marked increase in glacier melting and iceberg calving, increasing the freshwater contribution to the ocean, may affect ocean thermohaline circulation, water salinity, sea-ice extent unpredictably, and may even alter the trajectory of oceanic currents (Bigg, 2003).We cannot entirely rule out the possibility of large-scale glacier-related events in connection with changes in climate. “Once dramatic change has occurred, returning to a previous state may not be merely a matter of reversing the freshwater forcing, as once the ocean circulation has entered a particular state it may be resistant to change. The ocean state can show bifurcation." (Bigg, 2003, p. 183).

A different combination of extreme climatic events, e.g., that induced by several explosive volcanic eruptions closely spaced in time, may trigger glaciers to gain mass and start to advance with poorly predicted regional effects. Our twentieth/twenty-first century civilization has never dealt with such events, thus we have no recent experience with large-scale glacier advances (Nesje and Dahl, 2000).

Iceberg Calving

Another component of glacier mass balance, which is not measured or reported in most conventional glaciological studies, is iceberg calving. This process is important for many glaciers in coastal Alaska, southern South America, and the sub-Arctic and sub-Antarctic islands. Many other glaciers end in lakes (lacustrine calving) or discharge ice by breakoffs onto land; these are generally smaller components of the overall mass balance. Such "mechanical ablation" needs to be considered in order to obtain a more accurate representation of the climate/mass balance relationship and to estimate the effect of calving on sea-level rise. The calving of floating glaciers, of course, has no immediate effect on sea level but may cause the rate of ice discharge to increase, causing an effect. Also, most small glaciers have grounded termini. Iceberg calving in high latitudes of both hemispheres is of interest and affects human activities such as shipping, coastal and offshore installations, and fisheries; icebergs can be used for freshwater supply in regions with a shortage of freshwater (Camirand et al., 1981).

Glazovskiy (1996) estimated the rate of calving for glaciers in the Russian Arctic. Brown et al (1982) compiled calving rates for the Alaskan coast. Iceberg calving into the lake below the Mendenhall Glacier (Juneau Ice Field, Alaska) amounted to 5.7% of the surface ablation in 1999–2000 (Motyka et al., 2001). Unpublished estimates of total calving for Patagonia and Tierra del Fuego have been communicated by P. Holmlund, and for Svalbard by J.-O. Hagen. Meier (unpublished) has made crude estimates of calving discharge for the Canadian Arctic and for small glaciers around Greenland and Antarctica by estimating the width of calving fronts and individual calving rates based on analogous climatic regions. Cogley in his database (2002) has included the characteristic of potential calving glaciers, both tidewater and lacustrine, from World Glacier Monitoring Service sources. A number of other measurements of individual glacier calving, of all types, have been made. IPCC-1995 (Warrick et al., 1996) combined the estimates of Glazovskiy, Brown, Holmlund, Hagen, and Meier to suggest that iceberg discharge into the sea from small glaciers at the present time totals between 22 and 80 $km^3\ yr^{-1}$, but this is an untested and uncertain result. Probably mass loss by calving is larger considering that Columbia Glacier, Alaska, alone discharges more than 7 $km^3\ yr^{-1}$ (O'Neel et al., 2005).

Ice Recession

Glacier recession has produced a wave of interest to study newly exposed archeological evidence (Dixon et al., 2005) in the ice. This interest accelerated with the discovery in 1991 of a Neolithic "Ice Man" in the Tirolean Alps. Since that time the field of glacial archeology has expanded and many new discoveries have been achieved, especially with the new use of space images and GIS (Dixon et al., 2005).

The opening up of new terrain due to disappearing ice has mixed socio-economic impacts. More than 700 km^2 of land has become freed from glaciers in the eastern Arctic, and perhaps even more in the Canadian Arctic archipelago (Burgess and Sharp, 2004). This may represent practical interest because it may facilitate plant and animal migration, and it may expose new mineral resources. Gold mining has been developed in the Internal Tien Shan, Akshirak Range, by artificial glacier-ice removal (Khromova et al., 2003).

The loss of ice climbs due to glacier recession have affected the Alps, Himalaya, and other mountain regions (e.g., Bowen, 2002). The degradation of scenic impact due to disappearing glaciers may be beginning to damage real estate and tourism in alpine countries (e.g., http://www.newswales.co.uk/?section=Environment&F=1&id=6872) and has certainly decreased the attractiveness of some important tourist designations, such as Glacier National Park, Montana.

Glacier Hazards

Regional and local-scale glacier hazards are pervasive. These are common in most glacierized high-mountain areas in the world. Their impact on society depends on the density of human structures and settlements in those regions.

Lahars are mudflows or debris flows originating on a volcano. Some, but not all, lahars originate with glaciers or are lubricated by melted ice, such as the lahar initiated by the explosive eruption of Mount St. Helens, Washington, in 1980, destroying or damaging bridges, homes, highways, railways, and wildlife and fisheries (Lipman and Mullineaux, 1981). This was lubricated in part by the disintegration of glaciers on the mountain (Brugman and Meier, 1981).

Debris and glacier-ice avalanches are especially dangerous in local scales, because they can occur spontaneously, without any warning. For instance, on September 20, 2002, a collapse of a hanging glacier onto the Kolka Glacier, North Ossetia, triggered an avalanche of ice and debris that went over the Maili Glacier terminus, burying villages and killing dozens of people (Desinov et al., 2002).

Jökulhlaups (glacier outburst floods) are the abrupt release of water stored within or adjacent to glaciers sometimes due to volcanic heating from below (Björnsson, 1998; Johannesson, 2002), but also applied to glacier outburst floods in general. Jökulhlaups can even be produced on steep volcanoes with highly-crevassed glaciers, such as Mount Rainier, Washington (Driedger and Fountain, 1989).

Ice-dammed lakes can form where a glacier blocks a valley, damming streamflow, that may later break out resulting in a glacial outburst flood. Glacier-dammed lakes are common in Alaska (Post and Mayo, 1971). An inventory of glacial lakes has recently been compiled for Nepal and Bhutan (Mool et al., 2001a, 2001b). The number of glacier lakes in high mountain Asia may exceed 100,000. Their possible impact on irrigation, as well as source of hazards, has not yet been estimated properly.

CONCLUSIONS AND RECOMMENDATIONS

As the amount of glacier ice in the world varies with time, it affects many other components of the Earth system. We believe that it is important to continually synthesize results from all glaciers and ice caps including the “small glaciers” peripheral to the ice sheets in Greenland and Antarctica. Although this area is small compared to that of the ice sheets, the glaciers and ice caps cycle mass through their system rapidly, and have significant effects on earth processes. Annual mass balances of these glaciers have been predominately negative since sufficient observations began. However, the rate of wastage in the recent decade has almost doubled. This freshwater addition to the ocean also affects its circulation, especially in the Arctic Ocean, as well as the gravity field of Earth. Seasonal mass balance observations are especially useful, and show a slight increase in the winter balance at high elevations and a more negative summer balance at lower elevations. These seasonal balances give insight into precipitation and other climate variables in the high mountains and high latitudes, where direct climate observations are lacking. Increased runoff from glaciers has affected water supplies, agriculture, and natural hazards such as floods and debris flows in high mountain regions, but as the small glaciers have disappeared, the ice reservoirs have become depleted and vital summer runoff reduced.

Global effects on the environment are now better known and many of them are now quantified due to the application of new technologies. Human society has also became more sensitive to these global changes due to growing populations, especially in regions not previously populated. Changes in glacier regime link to changes in climate and the water cycle through energy and water balances, but glaciers transform the resultant balances through their surface changes, usually in complex and not necessarily predictable ways. Thus, after half a century of observations, we conclude that no alternatives yet exist to direct observations on glaciers.

PART II. MASS BALANCE RESULTS — 2005 UPDATE

Here we present the results of recent updates of glacier mass balance, and glacier volume change as the supplement to previously published results (Dyurgerov, 2002, http://instaar.colorado.edu/other/occ_papers.html).

The original mass balance data are based on observations. Time series of these observations have been compiled and presented for every individual glacier in Appendix 2. The time series in Appendix 2 were quality checked and error analysis has been performed as has been done before (Dyurgerov, 2002, http://instaar.colorado.edu/other/occ_papers.html). The main sources of information for updated time series came from two databases (Cogley, 2002, http://www.trentu.ca/geography/glaciology.htm; Dyurgerov, 2002, http://instaar.colorado.edu/other/occ_papers.html).

Both databases include complete lists of references to original sources of information. Some new and historical data have also been added to the previous data sets. The new mass balance and related data over the period 1996–2000 are from the World Glacier Monitoring Service, Zürich (WGMS; provided by W. Haberli and R. Frauenfelder and by several other colleagues). Separate from Appendix 2, a more complete data set is presented on the Internet (Dyurgerov, 2005, http://www.nsidc.org, Appendix 3), which includes glacier surface area by years, seasonal mass balance components (winter, ***bw***, and summer, ***bs***), equilibrium line altitude, ***ELA***, and accumulation area ratio, ***AAR*** (see also http://instaar.colorado.edu/other/occ_papers.html for the details).

To these directly observed time series we have added a calculated mass balance result for Bering Glacier (Appendices 2 and 3) in Alaska (explained below).

As stated above, there are two main purposes for the update; the first is to enhance all previously published time series by incorporating new data, and the second is to compile glacier volume changes for larger regions. Mass balance data for individual glaciers have been combined by primary systems, larger regions, and continental-size regions (all are in Appendix 3).

Combining individual time series into larger, climatically homogeneous regions may help to represent better the temporal variability and estimate average values for mountain ranges and other glacier systems. In accordance with this, glacier volume-change data have been combined into three different samples/systems: (1) mountain and sub-polar systems where sufficient mass balance observational data exists from individual glaciers — 49 primary systems have been recognized (Appendix 3) — with the individual glaciers assigned to each system listed by number in Appendix 2; (2) these primary systems combined to form 12 larger-scale regional systems (R1-R12), based on geographical and/or climatic similarity (Appendix 3); and (3) in order to estimate possible global glacier-volume changes and their contributions to the global water cycle and sea level change, data calculated for the six largest, continental-size systems as well as the global scale, in terms of sea-level change (Appendix 3).

GLACIER AREA

The entire area of small glaciers (all outside the Greenland and Antarctic ice sheets) is considered here as 785×10^3 km^2 (Appendix 1). This is the new estimate of the area of small glaciers, which had previously been taken as 680×10^3 km^2 (Meier and Bahr, 1996; Dyurgerov and Meier, 1997a). The new area estimate includes areas of individual ice caps in the West Antarctic, i.e., those that have no direct connection with the major ice sheet (note that glaciers on the Antarctic Peninsula are not included in this category). The area of these ice caps was calculated by Shumskiy (1969) as 169×10^3 km^2. These glaciers were omitted from previous evaluations. There is some evidence that these glaciers might have a negative mass balance and may have started to contribute meltwater to sea-level rise (Morris, 1999; Schneider, 1999; Skvarca et al., 2005).

CALCULATION OF GLACIER MASS BALANCE BY SYSTEMS

To calculate glacier volume change by systems and regions we have applied the same scheme we have previously introduced (Dyurgerov and Meier, 1997a, 1997b, 2000, 2004). This includes weighting individual specific mass balance values by the surface area. Averaging by area of individual glaciers and by systems may help to avoid one well-known deficiency in simple averaging, as has been noted by Bamber and Payne (2004): “Unfortunately, the sample (mass balance time series) is not only small but is also very biased, in particular toward small glaciers in certain areas of the globe.” In the original data set (Appendix 2) there are several large glaciers with areas greater than 1×10^2 to 1×10^3 km^2, also representing the largest regions in the dry and cold environments, e.g., the Canadian Arctic and the entire Arctic, which constitute about 40% of all “small” glacier areas on Earth. We do not know yet the size of “average” glaciers in the global population of “small” glaciers (although some regional estimates have been made; e.g., 0.6 km^2 in the Caucasus, and about 1.0 km^2 in the Tien Shan) because the Glacier Inventory has not been completed yet (Haeberli, 1989). In reality, the size of the average glacier in the sample we have in Appendix 2 is larger than the average size in the existing Glacier Inventory, thus data may be biased in the direction of larger and colder glaciers with smaller annual specific balances.

Updating the Observational Results

Data in Appendix 3 have been compiled from Appendix 2 in order to produce time series for larger scales: primary systems, larger regions, sub-continental size, and global scale (all are in Appendix 3). These three larger scale data sets are designed to estimate the global glacier volume change and to express this in terms of sea-level equivalent.

In doing this up-scaling we have, in several cases, filled the gaps in existing time series by applying correlations between observational results (e.g., all time series in High Mountain Asia systems, the Front Range of the Rocky Mountains, and many others). In order to make glacier-system data cover longer time periods and represent all regions more or less equally, similar relationships (linear regressions) between time series have been used. For example, such an extension has been applied to enhance time series for Severnaya Zemlya and the Russian Arctic. For several glacier systems we have applied reconstructions of annual glacier-volume change using different approaches (see next section).

Individual Glaciers in Appendix 2 include all available time series from 1945/1946 (the beginning year of the glacier mass balance study). For larger scale systems the period starting in 1961 has been chosen in order to have enough time series for simple statistical averaging and the application of results for regional analysis (Dyurgerov and Meier, 1997a).

For some systems time series cover the entire period, from 1961 until 2003. For other systems we have filled the gaps in time series using linear correlations between observations available for longer and shorter periods (e.g., glacier systems in High Mountain Asia, [HM Asia]). For a few systems we have used volume change determined over longer periods of time and have interpolated between cumulative values using annual observational results from neighboring glaciers, or where climatic conditions have been found to be similar (e.g., SW Alaska and Patagonia Ice Fields; see below).

Glacier Systems in Appendix 3 are listed with the names of systems in column titles, their numbers (1 to 49), glacier area in km^2, and latitude/longitude, followed by annual values of change in glacier volume ($km^3\ yr^{-1}$). At the bottom is the duration in years, and the average, standard deviation, and standard error values are given as well. The numbers of the primary systems to which they belong have been assigned to the individual glaciers in Appendix 2.

Data from primary systems have been grouped by the larger size regions in Appendix 3:

Europe: All observational time series in the Alps, Scandinavia, Iceland, Pyrenees, and the Western Caucasus (Black Sea basin) have been used, weighted by the areas of individual glaciers and primary systems and summed up.

Western USA and Canada (continental part): Included here are area-weighted mass balance time series for the North Cascades, Sierra Nevada, Olympic Mountains, and Southern Rockies (including all small sub-systems) and data for the Coastal Ranges and Rocky Mountains in Canada (Krimmel, 2002; Ommanney, 2002).

Canadian Arctic: Observational mass balance time series used here include in particular the largest from the entire sample, Devon ice cap (Devon Island), also the relatively large South ice cap on Melville Island, Barnes ice cap (Baffin Island), White glacier on Axel Heiberg Island, and other, smaller glaciers with shorter time series (Appendices 2 and 3). Glacier areas for individual and for sub-regions have been used to calculate volume for the entire Canadian Arctic. Several of these are among the longest continuous mass balance observations in the world. This makes them especially important to introduce into the calculation of larger scale systems in order to make these data not biased by small and maritime glaciers (see above).

Russian Arctic: A restricted number of short-term observational time series are available for Franz Josef Land, Severnaya Zemlya, Novaya Zemlya, and Polar Ural. Rather weak linear correlation has been found between these time series and those in the Canadian Arctic, Svalbard, and NW Scandinavia. These linear regressions have been applied to fill the gaps and partly enhance the time series for the Severnaya Zemlya benchmark ice cap (Vavilov’s Cupol) and for the entire Russian Archipelago time series. There have been no proxy data found to estimate uncertainty in the final result.

Greenland individual ice caps: On Greenland there are limited number of sporadic observations of mass balance for individual ice caps and mountain glaciers in the southwestern and southeastern coastal regions that have been compiled during the last three decades (e.g., Braithwaite, 1989; Hasholt, 1988; Knudsen and Hasholt, 2003; time series in Appendix 3). Mass balance data are significantly correlated with mass balances in western Svalbard and the Canadian Arctic archipelago. These correlations with Svalbard and the Canadian Arctic archipelago ($r = 0.72$) have been used to reconstruct mass balances for the Greenland ice caps back to 1961.

Svalbard: Observational data may be applied for the western part of the Svalbard archipelago (Spitzbergen), where all mass balance observations were carried out (Appendix 3). The eastern, drier, and colder part of the archipelago (Austfonna ice cap) might have been closer to the steady-state regime as has been shown recently (Bamber et al., 2004). For lack of other information, we have applied observational mass balance results from the Spitzbergen part to the entire Svalbard archipelago.

Entire Arctic: From the Canadian Arctic, Russian Arctic, Svalbard, and Greenland ice caps, the glacier volume change has been calculated as the area-weighted sum for the aggregate area of the entire Arctic region (see Appendix 3).

Alaska: Several long-term mass balance time series are available in the Alaska Range, Kenai and Coast Mountains, and several short-term time series in a few other ranges (Appendix 3). There are also mass balance results for two periods: earlier, 1950 to mid-1990s, and recent, mid-1990s to 2000 (2001). These results of mass balance (volume change) have been achieved by repeated laser-altimetry in comparisons with U.S. Geological Survey topographic maps and volume changes. The changes were determined for about 60 glaciers in all major mountain ranges in Alaska (Arendt et al., 2002). We have found relatively good agreement with observational results made by the standard mass balance glaciological method, which has been applied for dozens of years for benchmark glaciers in Alaska (Meier and Dyurgerov, 2002). To these observational results we have added mass balance data for Bering Glacier (St. Elias Mountains, Alaska). This is the largest mountain-piedmont glacier in the world. Mass balance for this was calculated by the PT-HyMet model for the period 1950–1999 (Tangborn, 1999). we have verified the calculated mass balance result with the result determined by repeated laser altimetry (Arendt et al., 2002) for this glacier. For two periods, first, from mid-1950 until the mid-1990s, and second, from mid-1990s until 2000, there is relatively close agreement between the results. For the first period the difference is 12% (PT-HyMet model is more negative). For the second period the difference is about 40% (PT-HyMet model is more positive). The laser altimetry method is better able to account for iceberg calving part (important component in periods of glacier surges, typical for Bering Glacier). At the same time, the laser altimetry may have a systematic 12% error giving more negative mass balance (Arendt et al., 2002). The main discrepancy is probably due to the fact that two different estimates of glacier area have been used. It was important to include mass balance result of Bering Glacier into the regional calculations in order to make this regional estimate more realistic. It has been shown in Arendt et al. (2002) that these few large piedmont glaciers (also the surging and tidewater glaciers Columbia, Malaspina, Bering, LeConte, and Kaskawulsh) represent about 75% of the ice mass loss in Alaska**.**

High Mountain Asia: This is a vast region with more than 10 glacier-mountain systems.
Data availability and reconstructed time series:

(1) Dzhungaria (total glacier area is about 1000 km^2). Observational time series over 1967–1991 for Shumskiy Glacier represents this mountain range.

(2) Himalaya (glacier area is 33,050 km^2). Originally, observed data are available for several glaciers for 1977–1987, plus 1999. To these original data additional series of mass balances have been added using substantial correlation found with Dzhungaria glacier time series. Note that part of the Dzhungaria mass balance data was, in turn, reconstructed using the Tien-Shan time series.

(3) Kun Lun (12,260 km^2). Observed data have been available for the years 1987–1995 and 1997–1998. Gaps in observations were filled and time series have been enhanced using statistically significant linear regression with the Tien-Shan and Dzhungaria time series (1957–1966, 1967–1986; 1996, and 1999–2000).

(4) Tibet (1802 km^2). Observations available for 1957–1988, 1988–1998, 1999, and 2000 for a few glaciers. Gaps in observations were filled and time series have been enhanced using observations in Kun Lun (nine consecutive years, 1988–1998, with r = 0.97).

(5) Pamirs (12,260 km^2): Original data (mostly long-term studies of Abramov Glacier and a few other shorter time series) have been used for 1967 until 1998. Gaps have been filled and time series expanded using significant correlation with observations on Tuyuksu basin (NW Tien Shan).

(6) Quilanshan (1930 km^2). Observed time series are 1963, 1975–1979, and 1984–1985. Between these and the Pamir time series moderate linear regression has been found ($r = 0.68$), which has been used to fill the gaps and enhance the time series for 1957–1962, 1964–1974, 1980–1983, and 1986–2000.

(7) Gongga (Hengduan, 1580 km^2): Measured data are available for only five years, 1989–1993. Linear regression ($r = 0.77$) with the Tien-Shan has been applied to fill the gaps and enhance time series for the Gongga Shan glaciers (1957–1988 and 1995–2000).

(8) Tien Shan (15,417 km^2): Original, observational data for more than 10 glaciers have been used for further calculation.

The aggregate area of these eight mountain glacier systems is 79.3×10^3 km^2 out of about 116×10^3 km^2 of the entire glacier area in HM Asia (Dyurgerov, 2001). No observational volume change or mass balance data are available for Karakoram (glacier area is about 16×10^3 km^2), Nyainqetanglha (7.5×10^3 km^2), Altun (266 km^2), Tanggulla (2.2×10^3 km^2), Gindukush (3.2×10^3 km^2), Hinduradsh (2.7×10^3 km^2), and Tarbagatay (17 km^2). The observational data and enhanced time series may be applicable for about 70% of the entire HM Asia region. At the same time the substantial correlation between observational results over all HM Asia reveals that the entire region belongs to similar climatic regimes, which is important for enhancing results over the entire HM Asia region (Appendix 3).

There are very limited observational data for the last three years, 2001–2003, in HM Asia. Due to this, averaged mass balance values for the period from 1988 to 2000, after the last shift in climate, have been applied for these three years. Similar scaling techniques have been applied to estimate other large system mass balances in Appendix 3, using the smaller aggregate data-sampled area.

Siberia: On the vast territory of Siberia there are many mountain ranges, some of them covered by glaciers. These glaciers are relatively small. The largest well-studied glacier system is Altai (1.75×10^3 km^2) with several benchmark glaciers where mass balance monitoring was carried out for about 45 years. Relatively long observations were carried out in Kamchatka

(0.905×10^3 km^2) on several glaciers, and the Polar Urals (very close to the Arctic Circle). Short-term observational results are available on one glacier in the Suntar Khayata Range (0.202×10^3 km^2) in NE Siberia. These observations have been used to represent the entire Siberia region. According to the Glacier Inventory there are 3.5×10^3 km^2 of glacier area in about 20 separate regions and ranges. The largest glacier-systems where observational results are available (Altai and Suntar Khayata) represent more than 60% of the entire glacier area in Siberia.

North and South Patagonia Ice Fields (NPIF and SPIF): Direct mass balance observational data are only available for one small glacier nearby the NPIF and SPIF, and it cannot be applied to these vast ice fields with enormous mass-turnover values with annual precipitation possibly exceeding 17 m (!) in water equivalent (Schiraiwa et al., 2002). This makes this region unique in terms of snow-accumulation-ablation processes and amount. It is also very important to include this region in the global analysis due to its substantial contribution to the global water cycle (Rignot et al., 2003).

For the Patagonia ice fields we have used recent surveys (i.e., 1995 and 2000) made by the Shuttle Radar Topography Mission (SRTM). These measurements have been compared with digital-elevation-model derived topographic maps developed in 1975. Surface changes for 63 glaciers have been determined (Rignot et al., 2003). We have found that glaciers in maritime parts of Alaska are more or less similar in terms of their climatic conditions to NPIF and SPIF (but mass turnover is much smaller!). We have applied observational data from Alaska as the region analogues, to calculate annual volume change in NPIF and SPIF. Mass balance data from Alaska have been compared with data of the latter over the period between consecutive SRTM-surveys. Specific cumulative mass balance for NPIF and SPIF have exceeded by about 50% those from Alaska. These differences have been further applied to annual mass balance values for Alaska to get an annual mass balance reconstruction for the NPIF and SPIF. We have scaled these calculations to include the glacier area in Terra del Fuego, where no mass balance data exists. (Note: only cumulative volume changes for this region can be considered accurate. Annual data are very questionable; Appendix 3)

South America outside the N. and S. Patagonia Ice Fields: A few mass balance time series exist, two relatively long, spread along longitudinal high mountain ranges in the Cordillera. We have used these observational results to make area-weighted mass balances and volume change. The average volume change over the 1976–1987 period (before the major warming shift in climate) has been about 0.4 $km^3\ yr^{-1}$. These have been applied to the period 1961–1976 where no data were available.

Sub-Antarctic Islands (SAI): Sub-Antarctic islands include those far from the northern borders of the Antarctic continental ice sheet. These SAI include S. Georgia, Kerguelen, Heard, Macquarie, and South Shetland and maybe a few smaller islands with an approximate area of about $7 \times 10^3\ km^2$ (Haeberli, 1989; Appendix 1). Mass balance time series are very short and available for two glaciers in S. Georgia (one year of observations), several years for G1, Deception Island, Vega Island (Skvarca et al., 2005), and one year for Anvers Island (Appendix 2). We have failed to find any reasonable approach to fill the gaps and enhance time series of mass balance observations for this region. Only those results available from observations have been presented here (Appendix 2).

Ice caps around the Antarctic continental ice sheet: Observational data for this region are available for a few glaciers in extreme dry and cold regions in the Antarctic continent and for two ice caps in close vicinity to the major ice sheet (Appendix 2). The latter glacier mass balance observations show that over the last decade or so these ice caps have experienced substantial warming and the melt-rate has accelerated (Morris, 1999; Schneider, 1999), most likely resulting from climate warming in the vicinity of Antarctic Peninsula). As the first guess we have proposed to estimate mass balance for these glaciers using observational results for the coldest and driest glaciers in the high Arctic, i.e. the Canadian archipelago time series, considering these glaciers to be the climatic-analogues of Antarctic ice caps.

Note that Kamchatka and New Zealand glaciers are separate and relatively small systems and do not belong to any larger region. New Zealand mass balance observational data are very scarce. Reconstructed mass balance data are available for Franz Josef Glacier over the 1913–1989 period (Ming-ko Woo and Fitzharris, 1992). Over 74 years, the reconstructed mass balance has shown large positive values, with the only exception being the negative balance in 1936 (Ming-ko Woo and Fitzharris, 1992, page 287, Fig. 6). This long-term mass gain does not agree with strong glacier recession before and over the same period of time (Ming-ko Woo and Fitzharris, 1992, page 283, Fig. 2).

Glaciers in Africa, New Guinea, and Mexico are too small to affect the regional and global water cycle (Appendix 3). Long-term time series are relatively long for East Africa (Kenya, Lewis Glacier), but the area is too small to be included in global analysis of the water cycle.

Global Glacier Volume Change

The last columns in Appendix 3 summarize all other data and results from individual time series and primary systems and larger regions in order to make the global estimate of glacier volume change. Global glacier area also includes the glacier area in Kamchatka, New Zealand, and the equatorial zone; the aggregate area of all “small” glaciers is considered as large as 785×10^3 km^2. The results of updates presented here show that the glacier contribution to sea-level rise appeared to be much larger compared to our previous computations and IPCC-2001 estimates (Dyurgerov and Meier, 1997a; Meier et al., 2003; Church and Gregory, 2001 [IPCC-2001]).

How Realistic Is This Update?

The main drawbacks are the scarcity of observations and the difficulty associated with expanding the data from individual glaciers and primary regions to a larger scale. In order to counter this evidence, we refer to one appropriate observation that “there are about 2500 km^2 of ice per measured glacier, to be compared with about 30 000 km^2 of land per station for temperature climatologies” (Cogley, 2005).

Several independent observations can be applied to confirm the reliability of global glacier volume changes.

First, the general trend in volume change and variability are close to those of previously calculated and published results (Dyurgerov and Meier, 1997a, 1997b; Warrick et al., 1996; Dyurgerov, 2002).

Second, very pronounced peaks in the globally averaged annual mass balance time series curve are found in connection with the strongest explosive volcanic eruptions, in particular Mount Agung in 1963, El Chichon in 1982, and Mount Pinatubo in 1991 (see Fig. 5), with cooling and positive mass balance found regionally and globally for the following 1–3 years (Abdalati and Steffen, 1997; Dyurgerov and Meier, 2000).

Third, the warmest years in the late 1980s and 1990s correspond to the most negative mass balances and acceleration of glacier volume losses (Fig. 5).

Fourth, the acceleration of glacier volume change presented here shows a consistency with other global changes in the Cryosphere, reduction of sea-ice area and thickness (Laxon et al., 2004), increasing temperature in permafrost and permafrost thawing, acceleration of movement and disintegration of polar ice caps, and outlet and tidewater glaciers in Greenland and Antarctic (Scambos et al., 2000; Zwally et al., 2002; Rau et al., 2004; Rignot et al., 2003; Thomas, 2004).

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APPENDIX 1. Area of Mountain and Subpolar Glaciers

Appendix 1 includes area of glacier systems outside the Greenland and Antarctic ice sheets. It includes general information on mountain and subpolar glaciers with mass balance records and also reference on sources of information, including published and private communications with colleagues.

The total area of mountain and subpolar glaciers outside the two major ice sheets is not certain. Adding the numbers in Appendix, which give areal extent of glaciers in different regions around the globe, the total glacierized area is about 785×10^3 km^2, which is much larger than the estimate of Meier and Bahr (1996) and our recent estimates (Dyurgerov and Meier, 1997a, 1997b, 2004; Dyurgerov, 2001, 2002). Ice caps around Antarctica and Greenland, with a surface area of about 169×10^3 km^2 (Shumskiy, 1969) and 70×10^3 km^2 (Weidick and Morris, 1998), respectively, occur in marginal climatic environments and have time constants of response to climate change different from those of the main ice sheet. Thus, they belong to the global population of small glaciers. However, the boundaries between these smaller glaciers and the ice sheet proper are sometimes difficult to determine. In many cases, these ice masses are joined to ice shelves or connected to the main ice sheet by ice shelves (for more details, see Dyurgerov, 2001).

Surface area of glaciers outside the major ice sheets

Region	Area, km^2	**Source**
Northern Hemisphere, east latitudes		
Europe		
Alps	2345	Paul et al., 2004
Pyrenees	11.5	WGI, 1989, p. C82
Scandinavia	2941.7	WGI, 1989, p. C80
Iceland	11,260	WGI, 1989, p. C79
W. Caucasus, Black and Azov sea basins	646.3	WGI, 1989, p. C90
Khibiny Mts.	0.1 (?)	WGI, 1989, p. C83
Total in Europe	**17,290**	
Northern Asia and Siberia		
Chukotka Plateau and Pekul'ney	17.07	Sedov, 1997a
Taigonos Peninsula, Far East	2	Sedov, 1997b

Polar Ural	28.7	Dolgushin and Osipova, 1989
Byrranga Mts.	30.5	WGI, 1989, p. C84
Putorana Plateau	2.54	Dolgushin and Osipova, 1989
Orulgan Range	18.38	Sedov, 1997a
Kharaulakh Range	3	Dolgushin and Osipova, 1989
Cherskogo Range	155.3	Dolgushin and Osipova, 1989
Koryak Range	291.7	Dolgushin and Osipova, 1989
Suntar-Khayata Range	201.6	Dolgushin and Osipova, 1989
Kodar Range	18.8	Dolgushin and Osipova, 1989
Sayany	34.1	Dolgushin and Osipova, 1989
Altay (Russian and Mongolian parts)	1750	Dolgushin, 2000
Kamchatka	905	Muravyev, 1999
Kuznetskiy Alatau	6.8	Dolgushin and Osipova, 1989
Khrebet Saur	16.6	WGI, 1989, p. C87
Baykal and Barguzin Ranges	6.2	Dolgushin and Osipova, 1989
Total in Siberia	**3500**	
High Mountain (HM) Asia		
Tien Shan	15,417	Kuzmichenok, 1993
Dzhungaria	1000	Dolgushin and Osipova, 1989
Tarbagatay	17	Wang and Yang, 1992
Pamir	12,260	Dyurgerov and Meier, 1997b
Qilian Shan	1930	Wang and Yang, 1992
Altun	266	Wang and Yang, 1992
Kunlun Shan	12,260	Dyurgerov and Meier, 1997b
Karakoram	16,600	Dyurgerov and Meier, 1997b
Qiantang Plateau	1802	Wang and Yang, 1992
Tanggulla	2206	Wang and Yang, 1992
Gandishi	1615	Dyurgerov and Meier, 1997b
Nyainqentanglha	7536	Wang and Yang, 1992
Hengduan	1618	Wang and Yang, 1992
Himalaya	33,050	Dyurgerov and Meier, 1997b
Gindukush	3200	Dyurgerov and Meier, 1997b
Hinduradsh	2700	Dyurgerov and Meier, 1997b
Total in HM Asia	**116,180**	
Middle East (Near East)		
East Caucasus(Caspian Sea basin)	781.7	Dolgushin and Osipova, 1989
Maliy Caucasus	3.8	Dolgushin and Osipova, 1989
Turkey	24	WGI, 1989, p. C91
Iran	20	WGI, 1989, p. C91
Total in Middle East	**830**	
Total in Asia	**120,680**	
East Arctic Islands		
Victoria	10.7	Dolgushin and Osipova, 1989
Franz Josef Land	13,459	Macheret et al., 1999
Novaya Zemlya	23,600	Dowdeswell and Hambrey, 2002
Severnaya Zemlya	18,300	Dowdeswell and Hambrey, 2002
Ushakova Island	325.4	Dolgushin and Osipova, 1989
De Longa Island	80.6	Dolgushin and Osipova, 1989
Wrangel Island	3.5	Dolgushin and Osipova, 1989
Total in East Arctic Islands	**55,779**	

<u>West Arctic Islands</u>		
Svalbard and parts:	36,591	Dowdeswell and Hambrey, 2002
Nordaustlanded	11,309	Dowdeswell and Hambrey, 2002
Edgeoya	2130	Dowdeswell and Hambrey, 2002
Ice caps on other islands	1385	Dowdeswell and Hambrey, 2002
Jan Mayen	115	Dowdeswell and Hambrey, 2002
Total in W. Arctic Islands	**36,607**	
<u>Canadian Arctic Archipelago</u>		
Ellesmere	80,000	WGI, 1989, p. C74
Ellesmere floating ice-shelves	500	WGI, 1989, p. C74
Axel Heiberg	11,375	Dowdeswell and Hambrey, 2002
Devon	16,200	WGI, 1989, p. C74
Bylot	5000	WGI, 1989, p. C74
Baffin	37,000	WGI, 1989, p. C74
Coburg	225	WGI, 1989, p. C74
Meighen	85	WGI, 1989, p. C74
Melville	160	WGI, 1989, p. C74
North Kent	152	WGI, 1989, p. C74
others	736	WGI, 1989, p. C74
Total in Canadian Arctic Archipelago	**151,433**	
Greenland: small glaciers	**76,200**	Dowdeswell and Hambrey, 2002
Total in Arctic Islands	**320,019**	
<u>Alaska</u>		
Brooks Range	722.4	WGI, 1989, p. C72
Seward Penins. and Kilbuk Mtns.	233	WGI, 1989, p. C72
Aleutian Islands	960	WGI, 1989, p. C72
Alaska Peninsula	1250	WGI, 1989, p. C72
Alaska Range	13,900	WGI, 1989, p. C72
Talkeetna Mtns.	800	WGI, 1989, p. C72
Wrangel Mtns.	8300	WGI, 1989, p. C72
Kenai Mtns.	4600	WGI, 1989, p. C72
Chugach Mtns.	21,600	WGI, 1989, p. C72
St. Elias Mtns.	11,800	WGI, 1989, p. C72
Coast Mtns.	10,500	WGI, 1989, p. C72
Total in Alaska	**74,600**	$\mathbf{90\times10^3}$ in Arendt et al., 2002
<u>Mainland USA, Mexico, Canada (US+ Mx+CD), without Alaska</u>		
Pacific	37,500	WGI, 1989, p. C74
Nelson	320	WGI, 1989, p. C74
Great Slave	620	WGI, 1989, p. C74
Arctic Ocean	84	WGI, 1989, p. C74
Labrador, Torngat Mtns.	24	WGI, 1989, p. C74
Yukon Territory	10,500	WGI, 1989, p. C74
Washington State, includes:	428.5/424.8	Krimmel, 2002
North Cascades	**267.0**	Krimmel, 2002
Olympic Mountains	45.9	Krimmel, 2002
Mount Adams	16.1	Krimmel, 2002
Mount Rainier	92.1	Krimmel, 2002
Goat Rocks area	1.5	Krimmel, 2002

Mount St. Helens	5.92/2.16	Krimmel, 2002
Oregon, includes:	**25.1**	Krimmel, 2002
Mount Hood	13.5	Krimmel, 2002
Mount Jefferson	3.2	Krimmel, 2002
Three Sisters area	8.3	Krimmel, 2002
Wallowa Mountains	0.1	Krimmel, 2002
California, includes:	**57.2/70.2**	Krimmel, 2002
Mount Shasta	6.9	Krimmel, 2002
Salmon-Trinity Mountains	0.3	Krimmel, 2002
Sierra Nevada	50.0/63.0	Krimmel, 2002
Montana, includes:	**42.5**	Krimmel, 2002
Glacier National Park	28.4	Krimmel, 2002
Cabinet Range	0.5	Krimmel, 2002
Flathead-Mission-Swan Ranges	2.3	Krimmel, 2002
Crazy Mountains	0.4	Krimmel, 2002
Beartooth Mountains	10.9	Krimmel, 2002
Wyoming, includes:	**37.5**	Krimmel, 2002
Big Horn Mountains	1.0	Krimmel, 2002
Absaroka Range	0.7	Krimmel, 2002
Teton Range	1.7	Krimmel, 2002
Wind River Range	31.6	Krimmel, 2002
Colorado:	**1.5**	Krimmel, 2002
Rocky Mountain Park-Front Range, others	1.5	Krimmel, 2002
Idaho:	**1.0**	Krimmel, 2002
Sawtooth Mountains	1.0	Krimmel, 2002
Utah:	**0.2**	Krimmel, 2002
Wasatch Mountains	0.2	Krimmel, 2002
Nevada:	**0.2**	Krimmel, 2002
Wheeler Peak	0.2	Krimmel, 2002
Western conterminous United States	**593.7/603**	
Mexico, includes:	**11.259**	
Citlaltepetl (Mexico)	9.5	WGI, 1989, p. C70
Iztaccihuatl (Mexico)	1.2	WGI, 1989, p. C70
Popocatepetl volcano (Mexico)	0.559	Hugo Delgado Granadas, 1997
Total in US+CD and Mexico	**49,660**	
Total in N. Hemisphere	**582×10^3**	
S.Hemisphere		
Africa		
Mount Kenya	0.7	Hastenrath and Chinn, 1996
Kilimanjaro	3.3	Hastenrath and Greischar, 1997
Ruwenzori	1.7	Kaser, 1999
Total in Africa	**6**	
New Guinea, Irian Jaya	**3**	Kaser, 1999
New Zealand	**1160**	Chinn, 1996
South America		
Tierra del Fuego	2700	WGI, 1989, p. C64
South Patagonian Icefield	13,000	Naruse and Aniya, 1992
North Patagonian Icefield	4200	Aniya, 1988
Argentina, includes:		
Rio Negro, part (Argentina)	55.8	WGI, 1989, p. C65
Argentina: Province of Neuquen	156.4	WGI, 1989, p. C65
Argentina: Province of Mendoza and southern part of Province of San Juan	1173.10	WGI, 1989, p. C66

Chile:		
Higgins	743	WGI, 1989, p. C67
Bolivia: Cordillera Oriental	556	WGI, 1989, p. C67
Peru: Southern Cordilleras	649	WGI, 1989, p. C68
Peru: Northern Cordilleras	1131	WGI, 1989, p. C68
Equador	110.8	WGI, 1989, p. C68
Columbia: Sierra Nevada de Santa Marta	19.1	WGI, 1989, p. C69
Columbia: other regions	91.9	WGI, 1989, p. C69
Venezuella: Sierra Nevada de Merida	2.7	WGI, 1989, p. C69
Total in S.America	**25×10^3**	
Subantarcic Islands	**7×10^3**	WGI, 1989
Antarctica: small glaciers	**169×10^3**	Shumskiy, 1969
Total in S. Hemisphere	**202×10^3**	
Global	**785×10^3**	
Note: All numbers are rounded. For some parts of S. America, e.g., Argentina and Chile, information on glacier area is not available.		

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APPENDIX 2. Results of Annual Mass Balance Measurements

The table is arranged as follows:

- Row 1 is the number of the primary glacier system to which the glacier belong.
- Glacier names (row 2) are taken from World Glacier Monitoring Service (WGMS) publications (*Fluctuations of Glaciers* and *Glacier Mass Balance Bulletin*) or, in several cases, from other sources, mostly locally accepted names (sometimes not official, such as Viatau, Koiavgan, Visyachiy, all are small glaciers in the Djankuat basin, Caucasus).
- Countries and geographical regions are given in rows 3 and 4.
- Code (row 5 — three digits giving primary classification, form, and frontal characteristics, respectively, according to that given in WGMS publications, e.g., *Fluctuations of Glaciers*, v. 7, p. 106-108 (1998).
- Latitude and longitude (rows 6 and 7) are taken from WGMS publications (*FoG* volumes), or from other sources if available.
- Elevation, max, med, min (rows 8, 9, and 10) denote maximum, medium and minimum absolute elevation in meters above sea level, defined from topographical maps and published in *FoG* volumes or other referred sources.
- Length (row 11) is the length of glacier along the flow line (horizontal projection) from maximum to minimum elevation in kilometers, and reflects the latest published determination, if such is available.
- Area, km^2 (row 12) is total area of glacier in square kilometers and reflects the latest published determination, if such is available.
- Aspect (row 13) is the orientation of main ice stream in accumulation/ablation areas where available
- Blank cells mean no data were found.
- ND — not determined, mostly due to a sample being too small.

Appendix 2. Glacier mass balance results

System number	1	1	1	1	1	1	1	1	1	1	1	1
Glaciers	Argentiere	Mer de Glace	de Marinet	St. Sorlin	Sarennes	Rhone	Limmern	Plattalva	Limm+Platt	Gries	Silvretta	Gr. Aletsch
Country	France	France	France	France	France	Switzerland	Switzerland	Switzerland	Switzerland	Switzerland	Switzerland	Switzerland
Geogr.area	Fr. Alps	Fr. Alps	Fr. Alps	Fr. Alps	Fr. Alps	Alps	Alps	Alps	Alps	Alps	Alps	Alps
Code	519	519		529	640	514	627	656		534	626	519
Lat	45°58'N	45°53'N	45°N	45°11'N	45°07'N	46°37'N	46°49'N	46°50'N	46°49'N	46°26'N	46°51'N	46°30'N
Long	6°56'E	6°56'E	6°E	6°10'E	6°10'E	8°24'E	8°59'E	8°59'E	8°59'E	8°20'E	10°05'E	8°02'E
Elev. Max	3100	3580	3000	3463	3190	3620	3421	2980	3421	3373	3160	4160
Elev. Med	2600	3000		2900	3000	2940	2760	2740		2920	2780	3140
Elev. Min	1550	1480	2782	2650	2830	2125	2260	2550	2260	2389	2439	1556
Length	9.4	12.0		2.9	1.5	10.2	2.9	1.1		6.2	3.5	24.7
Area	15.60	33.00	0.20	3.00	0.50	17.38	2.52	0.73	3.25	6.19	3.15	126.99
Aspect	NW/NW	N/N		N/N	S/S	S/S	NE/NE	E/E		NE/NE	NW/W	SE/S
1946												–56
1947												–2399
1948							400	472				684
1949					–2990		–1670	–1418				–1810
1950					–1620		–1346	–1357				–1240
1951					200		372	382				200
1952					–1620		–511	–497				–710
1953					–640		–145	–71				–320
1954					–550		484	352				60
1955					660		726	634				620
1956					–600		–265	–171				415
1957				–360	–520		56	50				–10
1958				–220	–670		–836	–950				–650
1959				–1180	–1260		–1035	–1024				–1070
1960				130	120		–27	–308	–55		544	410
1961				–280	–390		202	–107	136		387	–180
1962				–520	–910		–137	–359	–396	–786	–488	–410
1963				110	190		–458	–557	–309	270	–919	–120
1964				–1460	–1830		–1396	–1437	–1833	–882	–1312	–1270
1965				530	30		1102	985	924	770	1388	1180
1966				690	420		874	849	505	46	1284	620
1967				–260	–410		538	505	–363	409	411	300
1968		–400		960	340		780	864	397	619	704	670
1969		430		450	–360		332	383	–140	468	–181	310
1970		530		600	–410		–159	–26	–165	–506	186	–120
1971		–410		–1310	–1100		–1332	–1406	–1340	–981	–833	–710
1972		300		–270	–370		–225	–363	–247	453	–199	–220
1973		–650		–640	–870		–1043	–985	–1013	–1067	–1212	–530
1974		–350		–670	–1600		39	189	85	–185	745	70
1975		360		–810	110		540	659	572	266	792	560
1976	–1580			–1390	–2070		–993	–849		–1060	–509	–688
1977	700			1200	990		788	544		1246	620	1477
1978	800			1020	550		902	1275		928	926	1805
1979	–170			200	–110		–36	–159		–863	–59	162
1980	830			1040	320	888	721	980		665	1030	1534
1981				40	40	87	–111	–181		–123	512	1276
1982				–340	–100	–375	–649	–246		–890	–211	346
1983				–170	–70	–160	–810	–549		–557	–547	149
1984				610	–40		–335	74		–8	280	797
1985				–470	–1210		250	400		–259	509	166
1986				–1150	–1790		–360	–750		–535	–290	–152
1987				–640	–920		190	260		–659	–369	40
1988				10	–690		–220	–310		–878	–604	–345
1989				–1790	–2590		–308	–780		–1063	–251	–190
1990				–1290	–2140					–1743	–576	–1029
1991				–1150	–1200					–1097	–1178	–616
1992				–690	–1310					–724	–826	–674
1993				–780	–1200					–32	–229	92
1994			–860	–340	–630					–494	–668	–449
1995				750	760					158	204	–965
1996				–480	0					–230	–70	
1997				–130	–430					–270	540	
1998				–2200	–2340					–1660	–1530	
1999				–1040	–1060					–580	520	
2000				–1550	–1530					–847	218	
2001				390	390					–55	858	
2002				–1690	–2320					–600	–240	
2003				–2950	–3140					–2630	–1674	
2004												
Years	5	8	1	47	55	4	42	42	16	42	44	50
Average	116	–24	–860	–415	–736	110	–122	–119	–203	–380	–53	–60
Stdev	1034	471		907	973	552	700	714	714	768	754	822
st. error	462	167	ND	122		276	108	110	178	110	112	116

Appendix 2. Glacier mass balance results

System number	1	1	1	1	1	1	1	1	1
Glaciers	Basodino	N.Schneeferner	Hintereisferner	Kesselwandferner	Vernagtferner	Filleck Kees	Sonnblick Kees	Wurten Kees	Jamtalferner
Country	Switzerland	Germany	Austria	Austria	Austria	Austria	Austria	Austria	Austria
Geogr.area	Alps, Ticino	Alps	Otzt. Alps	Otzt. Alps	Otzt. Alps	Sonnblick	Sonnblick	Sonnblick	Alps
Code		648	528	638	626	606	606	628	528
Lat	46°25'N	47°25'N	46°48'N	46°50'N	46°53'N	47°08'N	47°08'N	47°02'N	46°42'N
Long	8°26'E	10°59'E	10°46'E	10°48'E	10°49'E	12°36'E	12°36'E	13°00'E	10°10'E
Elev. Max	3272	2820	3710	3490	3627	2920	3050	3120	3160
Elev. Med		2688	3050	3180	3187	2860	2780	2680	2810
Elev. Min	2540	2556	2426	2720	2748	2780	2500	2380	2408
Length		0.9	7.1	4.2	3.3	0.4	1.5	3.0	2.8
Area	2.40	0.33	8.00	4.16	8.53	0.15	1.50	1.09	3.68
Aspect		E/E	E/NE	SE/E	S/SE	SE/SE	NE/E	SW/S	N/N
1946									
1947									
1948									
1949									
1950									
1951									
1952									
1953			–540						
1954			–286						
1955			76						
1956			–275						
1957			–189						
1958			–981	–382					
1959			–763	–372			–374		
1960			–63	118			249		
1961			–205	271			148		
1962			–696	–416			54		
1963		–1282	–603	–406			–1426		
1964		–1401	–1245	–537		–1260	–928		
1965		1877	925	1040	751	1890	1976		
1966		997	344	590	932	680	736		
1967		576	20	299	83	190	160		
1968		625	338	452	301	350	234		
1969			–431	–154	–313	–430	–246		
1970			–553	5	–225	280	144		
1971			–600	43	–483	–300	–386		
1972			–73	367	138	120	129		
1973			–1230	–418	–460	–860	–721		
1974			55	552	240	690	568		
1975			65	339	170	560	397		
1976			–314	–40	76	280	79		
1977			761	700	352	230	148		
1978			411	420	309	870	833		
1979			–219	70	44	130	224		
1980			–50	160	139	860	834		
1981			–173	161	–55		414		
1982			–1240	–620	–845		–1376		
1983			–581	–182	–535		–535	–1033	
1984			32	178	24		338	14	
1985			–574	–8	–112		–281	–1111	
1986			–731	–496	–796		–1432	–1606	
1987			–717	–242	–289		–525	–870	
1988			–946	–265	–500		–711	–825	
1989			–636	–150	–315		252	–172	–441
1990			–996	–243	–571		–561	–800	–430
1991			–1325	–847	–1079		–818	–1074	–1439
1992	350		–1119	–414	–858		–2092	–1310	–1232
1993	–80		–574	–74	–472		–315	–484	–369
1994	440		–1107	–828	–1028		–1385	–1617	–827
1995	610		–461	144	–398		142	–403	–159
1996	170		–827	–111	–413		–246	–638	–550
1997	–210		–591	11	–487		314	–154	–217
1998	–1070		–1230	–604	–1003		–1695	–1315	–1320
1999	–440		–861	–12	–108		–652	–1135	–257
2000	–782		–633	140	–287		–33	–680	–81
2001	620		–173	524	–224		–399	–300	–62
2002	–356		–647	17	–266		–485	–966	–671
2003	–2043		–1814	–1546	–2133		–2870	–2177	–2229
2004									
Years	12	6	51	46	39	17	45	21	15
Average	–233	232	–475	–60	–274	252	–269	–888	–686
Stdev	784	1306	549	462	549	718	853	546	618
st. error	226	533	77	68	88	174	127	119	160

Appendix 2. Glacier mass balance results

System number	1	1	1	1	1	1	1	1	2	2	2
Glaciers	Vermuntgletscher	Ochsentaler	Langtaler	Careser*	Ciardoney	Sforzellina	Pendente	Fontana B.	Austdalsbreen	Jostefonn	Engabreen
Country	Austria	Austria	Austria	Italy	Italy	Italy	Italy	Italy	Norway	Norway	Norway
Geogr.area	Alps	Alps	Alps	Ortles–Cevedale	Gran Paradiso	Alps	Alps	Alps	Jostefonn	Jostefonn	Svartisen
Code	628	528	538	638	640	648	520	640	424		438
Lat	46°51'N	46°51'N	46°48'N	46°27'N	45°31'N	46°20'N	46.97°N	46°29'N	61°48'N	61°25'N	66°40'N
Long	10°08'E	10°06'E	11°01'E	10°42'E	7°26'E	10°30'E	11.23°E	10°46'E	7°21'E	6°35'E	13°45'E
Elev. Max	3130	3160	3420	3350	3170	3120	3125	3355	1630	1620	1594
Elev. Med	2790	2910	2910	3092	3000	2925	2818	3197	1480		1220
Elev. Min	2430	2290	2450	2857	2900	2760	2620	2880	1160	950	40
Length	2.8	2.8	5.1	2.2	1.9	0.7	1.1	1.1	5.7		11.5
Area	2.16	2.59	3.05	3.86	0.83	0.42	1.07	0.66	11.87	3.81	38.02
Aspect	NW/NW	N/N	N/NW	S/S	N/N	NW/NW	S/S	E/E	SE/SE		N/NW
1946											
1947											
1948											
1949											
1950											
1951											
1952											
1953											
1954											
1955											
1956											
1957											
1958											
1959											
1960											
1961											
1962											
1963			–623								
1964			–1067								
1965			771								
1966			478								
1967			–63	–386							
1968			190	247							
1969			–515	–5							
1970			–706	–631							–990
1971				–650							1017
1972				400							–82
1973				–1276							2718
1974				–319							789
1975				145							1602
1976				–268							2413
1977				988							879
1978				79							–507
1979				–182							404
1980				12							–507
1981				–839							980
1982				–1678							840
1983				–787							1060
1984				–591				395			1050
1985				–758				–600			–950
1986				–1138				–106			252
1987				–1645		–920		–466			941
1988				–1056		–970		–1096	–1280		–1791
1989				–817		–570			1840		3178
1990				–1578		–1160			1200		849
1991	–1491	–695		–1734		–1210			0		689
1992	–1346	–1119		–1199	–970	–770		–1091	540		2339
1993	–570	–188		–303	–410	–286		–556	910		1039
1994	–1447	–979		–1743	–1100	–712		–955	–70		417
1995	–238	32		–1081	–560	–728		–682	620		1734
1996	–720	–270		–1320	–370	–816	–534	–440	–1070	–1530	831
1997	–500	60		–930	–660	–814	–11	–630	–530	–280	1223
1998	–1544	–936		–2240	–3360	–1682	–1210	–1620	190	300	160
1999	–528	–30		–1800	–2430	–1202	–541	–970	–480	380	–30
2000				–1610	–1230	–1440	–1379	–740	1110	1020	1490
2001				–250	160		48	395	–1620		–1530
2002				–1217	–400		–1294	–435	–2010		–590
2003				–3316	–3000		–2074	–2950	–2290		–600
2004									–960		820
Years	9	9	8	37	12	14	8	17	17	5	35
Average	–932	–458	–192	–851	–1194	–949	–874	–738	–229	–22	632
Stdev	516	473	639	839	1128	363	737	763	1195	961	1138
st. error	172	158	226	138	326	97	261	185	290	430	192

Appendix 2. Glacier mass balance results

System number	2	2	2	2	2	2	2	2	2
Glaciers	Svartishiebreen	Trollbergdalsbreen	Austre Okstindbreen	Storglombreen	Hogtuvbreen	Langfjordjokelen	Svartfjelljokelen	Storstainfjellbreen	Cainhavarre
Country	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Norway
Geogr.area	Svartisen	Svartisen	Svartisen	Svartisen	Svartisen	Finnmark	Finnmark	Skjomen	Skjomen
Code		538	438		528	438		528	238
Lat	66°35'N	66°43'N	66°14'N	66°41'N	66°27'N	70°10' N	70°N	68°13'N	68°06'N
Long	13°45'E	14°27'E	14° 22'E	14°00'E	13°39'E	21°45' E	21°E	17°55'E	18°00'E
Elev. Max	1420	1300	1750	1580	1160	1050		1850	1540
Elev. Med	1040	1050	1340		940	850		1380	1410
Elev. Min	770	900	730	520	588	280		930	1210
Length	4.0	2.1	7.3	10.5	2.7	4.0		5.3	1.4
Area	5.48	1.82	14.01	59.16	2.59	3.66	2.70	5.91	0.71
Aspect	SE/SE	SE/SE	N/NE	NE/NE	E/E	reconstructed	E/SE	NE/N	NE/NE
1946									
1947									
1948									
1949									
1950									
1951									
1952									
1953									
1954									
1955									
1956									
1957									
1958									
1959									
1960									
1961									
1962									
1963									
1964								650	
1965								440	201
1966								–809	–954
1967								–403	–165
1968								455	257
1969									
1970		–2470							
1971		–337			–742				
1972		–1236			–963				
1973		755			1088				
1974		–403			–207				
1975		–284			722				
1976					909				
1977					–523				
1978							–100		
1979									
1980									
1981									
1982									
1983									
1984									
1985				–1190					
1986				–420					
1987			700	450					
1988	–1610		–1900	–1820					
1989	2360		1500			–560			
1990	820	–117	300			–320			
1991	173	1	–500			0		–36	
1992	1209	599	1230			190		1043	
1993	918	228	210			200		949	
1994	–29	–1108	–170					205	
1995	900		460					572	
1996	400		–300			20			
1997	700		–260			–690			
1998	5					–1440			
1999	–600					–1580			
2000	700			1110		–610			
2001				–1760		–2280			
2002				–1250		–1540			
2003				–1100		–1070			
2004				120		–1920			
Years	13	11	11	9	7	14	1	10	4
Average	457	–397	115	–651	41	–829	–100	307	–165
Stdev	947	920	922	1025	848	818	ND	583	558
st. error	263	277	278	342	320	219		184	279

Appendix 2. Glacier mass balance results

System number	2	2	2	2	2	2	2	2	2
Glaciers	Blaisen	Alfotbreen	Hansebreen	Hardangerjokulen	Omnsbreen	Austre Memurubre	Vestre Memurubre	Storbreen	Hellstugubreen
Country	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Norway
Geogr.area	Skjomen	Alfotbreen	Aalfotbreen i. c.	SW. Scand.	Hardangerjokulen	Jotunheimen	Jotunheimen	Jotunheimen	Jotunheimen
Code	648	436	322	438		627	638	526	518
Lat	68°20'N	61°45'N	61°45'N	60°32'N	61°N	61°33'N	61°32'N	61°34'N	61°34'N
Long	17°51'E	5°39'E	5°41'E	7°22'E	6°E	8°26'E	8°30'E	8°08'E	8°26'E
Elev. Max	1240	1380	1320	1850	1570	2280	2200	1970	2130
Elev. Med	1040	1230	1160	1740		1940	1880	1440	1900
Elev. Min	860	890	925	1050	1460	1630	1570	1380	1470
Length	2.3	2.9	2.5	8.1		4.0	4.0	2.9	3.4
Area	2.18	4.36	2.91	17.10	1.52	8.71	9.01	5.26	2.97
Aspect	NE/NE	NE/N	W/W			SE/SE	SE/E	NE/NE	N/N
1946									
1947									
1948									
1949								200	
1950								–290	
1951								–540	
1952								310	
1953								–850	
1954								–770	
1955								–490	
1956								–170	
1957								50	
1958								–80	
1959								–1280	
1960								–1090	
1961								–520	
1962								720	780
1963	200	–1100		–1400				–1180	–980
1964	630	280		540				210	–120
1965	539	494		510				340	515
1966	–1276	–1557		–640	–840			–610	–665
1967	–973	1310		1190	490			720	558
1968	259	990		530	–180	13	241	50	–111
1969		–2104		–1900	–2590	–1460	–1060	–1420	–1279
1970		–1278		–600	–1500	–899	–786	–720	–1007
1971		935		702		–189	105	180	–142
1972		115		–70		–392	–261	–310	–496
1973		2182		846				80	–221
1974		1026		410				240	238
1975		1210		150				–150	–369
1976		1524		150				–90	–751
1977		–560		–720				–540	–693
1978		–509		–300				–440	–565
1979		–130		300				100	–34
1980		–610		–1400				–1310	–1240
1981		220		850				–100	–330
1982		–130		–700				–470	–350
1983		1600		1700				200	170
1984		1320		–100				–300	–510
1985		–560		–520				–400	–290
1986		–413	–590	–101				–320	–494
1987		2070	1130	936				300	457
1988		–2480	–2740	–1521				–950	–1034
1989		2242	420	2111				1200	720
1990		1772	320	1924				1249	660
1991		775	260	–96				–145	–459
1992		2092	980	1797				86	139
1993		2101	1080	1910				757	296
1994		782	420	169				–245	65
1995		1109	480	289				–155	–123
1996		–1896	–2020	–1081				–1028	–737
1997		77	–150	–470				–1029	–1654
1998		110	–30	690				220	–20
1999		60	110	50				–240	–420
2000		1990	870	1430				550	190
2001		–2090	–2720	–850				–280	–330
2002		–1530	–1930	–710				–1790	–1410
2003		–2510	–2670	–1360				–1570	–1530
2004		–100	–510	80				–580	–840
Years	6	42	19	42	5	5	5	56	43
Average	–104	210	–384	113	–924	–585	–352	–262	–335
Stdev	813	1376	1346	1011	1190	595	561	649	615
st. error	332	212	309	156	532	266	251	87	94

Appendix 2. Glacier mass balance results

System number	2	2	2	2	2	2	2	2	2
Glaciers	Blabreen	Tverrabreen	Graasubreen	Nigardsbreen	Tunsbergdalsbreen	Vesledalsbreen	Harbardsbreen	Midtre Folgefonna	Braidablikkbrea
Country	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Norway
Geogr.area	Jotunheimen	Jotunheimen	Jotunheimen	Jostedal	Jostedal	Jostedal	Jostedal	Folgefonna	Folgefonna
Code			676	438	428	438		303	303
Lat	60°09'N	60°09'N	61°39'N	61°43'N	61°36'N	61°50'N	61°40'N	60°09'N	60°04'N
Long	6°43'E	6°44'E	8°36'E	7°08'E	7°03'E	7°16'E	7°35'E	6°29'E	6°24'E
Elev. Max	2150	2200	2300	1950	1930	1730	1970	1570	1660
Elev. Med			2060	1618	1530	1450		1460	
Elev. Min	1550	1415	1850	355	540	1130	1250	1190	1250
Length			2.3	9.6	18.5	3.0		2.2	
Area	3.60	5.90	2.36	47.80	50.10	4.19	13.20	8.70	3.60
Aspect			NE/E	SE/SE	SE/SE	N/NW	E/E	NW/NW	NW/NW
1946									
1947									
1948									
1949									
1950									
1951									
1952									
1953									
1954									
1955									
1956									
1957									
1958									
1959									
1960									
1961									
1962	800	750	770	2250					
1963	–860	–1220	–710	–220					–1210
1964			–320	945					240
1965			408	903					–560
1966			–285	–922	–1088				–1650
1967			711	2156	1794	354			1170
1968			–80	221	39	637			870
1969			–1359	–1318	–1692	–2180			
1970			–664	–560	–840	–1140		–620	
1971			–469	827	568	422		370	
1972			–644	–145	–500	–350			
1973			–891	1110					
1974			346	472					
1975			–948	275					
1976			–1002	401					
1977			–389	–777					
1978			–218	–128					
1979			42	712					
1980			–895	–1222					
1981			–190	310					
1982			–510	–420					
1983			–40	1090					
1984			–370	340					
1985			0	–100					
1986			–765	–102					
1987			720	1479					
1988			–585	–896					
1989			446	3196					
1990			726	1763					
1991			–530	203					
1992			–10	1602					
1993			415	1850					
1994			1	569					
1995			–114	1187					
1996			–450	–409					
1997			–1687	40			–542		
1998			110	970	660		60		
1999			–390	170			–340		
2000			–50	1720	1410		780		
2001			20	–350		577	–1110		
2002			–1420	–900	–1160				
2003			–1390	–1160					–2270
2004			–490	–40					–950
Years	2	2	43	43	10	7	5	2	8
Average	–30	–235	–306	397	–81	–240	–230	–125	–545
Stdev	1174	1393	601	1032	1167	1066	705	700	1217
st. error	830	985	92	157	369	403	315	495	430

Appendix 2. Glacier mass balance results

System number	2	2	2	2	2	2	2	2	2
Glaciers	Grafjellsbrea	Bondhusbreen	Blabreen, Ruklebreen	Blomsterskardsbreen	Spoerteggebreen	Grabreen	Midtdalsbreen	Salajekna	Rundvassbreen
Country	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Norway
Geogr.area	Folgefonna	Folgefonna	Folgefonna	Folgefonna	Jostedal	Folgefonna			Blamannsisen
Code		438		438	303				
Lat	60°09'N	60°02'N	60°10'N	59°59'N	61°36'30"N	61°08'N	60.57°N		67°20'N
Long	6°29'E	6°20'E	6°43'E	6°17'E	7°27'E	6°40'E	7.47°E		16°05'E
Elev. Max	1650	1635	1610	1640	1770	1660		1650	1536
Elev. Med		1450			1575	1510			
Elev. Min	1100	450	1065	820	1260	1030		900	
Length		6.0		10.0	6.8	5.0			
Area	8.90	10.67	4.50	45.72	27.94	6.62	7.07	23.81	11.50
Aspect		NW/NW		SW/SW					N/NW
1946									
1947									
1948									
1949									
1950									
1951									
1952									
1953									
1954									
1955									
1956									
1957									
1958									
1959									
1960									
1961									
1962						–1000			
1963			–2100			340			
1964	320		500			40			
1965	–280		50			–1370			
1966	–1350		–1500			1370			
1967	1320		1300			720			
1968	570		370			599			
1969						371			
1970				0					
1971				980					
1972				320					
1973				1570					
1974	580			510					
1975	250			1700					
1976				1400					
1977		–998		–1400					
1978		–513							
1979		336							
1980		–455							
1981		1320							
1982									
1983									
1984									
1985									
1986									
1987									
1988					–1540				
1989					1140				
1990					1020				
1991					30				
1992									
1993									
1994									
1995									
1996									
1997									
1998						133.75		–470	
1999								–370	
2000							1320	620	
2001							–640		
2002									–1050
2003	–2170								–1070
2004	–810								–210
Years	9	5	6	8	4	9	2	3	3
Average	–174	–62	–230	635	163	134	340	–73	–777
Stdev	1093	909	1298	1026	1239	847	1386	603	491
st. error	364	406	530	363	620	282	980	348	283

Appendix 2. Glacier mass balance results

System number	2	2	2	2	2	2	2	2	3	3	3
Glaciers	Charles Rabot	Marmaglaciaren	Partejekna	Riukojietna	Tarfalaglaciaren	Karsojietna	Storglaciaren	Rabots	Baegisarjokull	Bruarjokull	Blagnipujokull
Country	Norway	Sweden	Sweden	Sweden	Sweden	Sweden	Sweden	Sweden	Iceland	Iceland	Iceland
Geogr.area	Kebnekaise	NE Scand.	NE Scand.	Kebnekaise	Kebnekaise	Kebnekaise	NE Scand.	N.Iceland	Vatnajokull	Hofsjok. SW	
Code		521		303	670	538	528	528	530	433	433
Lat		68°05'N	67°10'N	68°05'N	67°56'N	68°21'N	67°54'N	67°54'N	65°59'N	64°40'N	64°43'N
Long		18°41'E	17°40'E	18°05'E	18°39'E	18°19'E	18°34'E	18°33'E	18°38W	16°10'W	19°03'W
Elev. Max		1740	1860	1456	1710	1515	1828	1700	1300	1900	1750
Elev. Med						1100			1120	1255	1205
Elev. Min		1340			1390	940	1125	1071	920	550	750
Length		3.5	5.4	3.0	1.0	1.7	3.7	4.1	1.4	45.0	13.0
Area	1.10	3.96	9.91	4.65	0.86	1.23	3.24	3.88	1.70	1695.00	51.30
Aspect		NE/E	E/E	E/E	E/E	NE/E	E/E	NW/W	N/N	N/N	SW/SW
1946						–400	–1130				
1947							–2070				
1948						–240	0				
1949							910				
1950							–1290				
1951							–640				
1952							–160				
1953							–800				
1954							–970				
1955							–160				
1956							–480				
1957							–330				
1958							–650				
1959							–970				
1960							–1610				
1961							–1090				
1962							330				
1963							–200				
1964							480				
1965							410				
1966							–530				
1967							–230		250		
1968							–100				
1969							–1040				
1970	–1900						–1520				
1971	470						–196				
1972	–1040						–1058				
1973	1440						30				
1974							–350				
1975							1152				
1976							270				
1977							200				
1978							–80				
1979							–220				
1980							–1190				
1981							–180				
1982						330	325	–66			
1983						340	267	–109			
1984							120	–514			
1985							–612	–1275			
1986				–540	17		–79	–158			
1987				–260	884		474	223			
1988				–910	–1290		–865	–1052			
1989				890	1230		1223	615			450
1990		–110		210	130	350	591	–33			–680
1991		–240		70	160	70	168	–200			–1490
1992		90		586	1360	870	947	91			680
1993		270		350			1044	487		1090	130
1994		–340		–300			–368	–106		280	–720
1995		100		253			699	81		–200	–1170
1996		–380		–61			–360	–470		–220	–1230
1997		–190	–870	–984			–630	–140		–1350	–1420
1998		–280	–480	–740			–520	–470		–670	–1590
1999		–320	–390	–780			–180	–400		–300	–1090
2000		130	–100	–310	1190		580	–230	117	–1010	–1750
2001		–410		–1730	790		–700	–760	101	110	–1890
2002		–660		–1830			–830	–880		143	–640
2003	–1420	–1420		–1780			–1040	–1440		–460	–1170
2004							–190			–712	
Years	5	14	4	18	9	7	59	22	3	12	15
Average	–490	–269	–460	–437	497	189	–261	–309	156	–275	–905
Stdev	1397	417	318	802	842	424	714	524	82	645	784
st. error	625	112	159	189	281	160	93	112	47	186	203

Appendix 2. Glacier mass balance results

System number	3	3	3	3	3	3	3	3	3	3	4
Glaciers	Dyngjujokull	Eyjabakka	Koldukvislar	Satujokull	Sidujokull	Thjorsarjokull	Thrandarjokull	Grimsvotn	Tungnaarjokull	Langjokull	Maladeta
Country	Iceland	Iceland	Iceland	Iceland	Iceland	Iceland	Iceland	Iceland	Iceland	Iceland	Pyrenees
Geogr.area	Vatnajokull	Vatnajokull	Vatnajokull	Hofsjok.N.	Vatnajokull	Hofsjok.E.	E. Iceland	Vatnajokull	Vatnajokull		Spain
Code	423	423	433	433	432	433	300		433		648
Lat	64°40'N	64°39N	64°35'N	64°55'N	64°11'N	64°48'N	64°42'N	64°25'N	64°19'N		42°39'N
Long	17°00'W	15°35W	17°40'W	18°50'W	17°53'W	18°35'W	14°53W	17°20'W	18°04'W		0°38'E
Elev. Max	2000	1520	2000	1800	1700	1800	1240	1760	1660		3180
Elev. Med	1475	1095	1410		1050	1185	1080		1210		3025
Elev. Min	700	680	850	860	650	620	820	1380	690		2790
Length		18.0	25.0	20.0	40.0	19.0		15.0	40.0		1.1
Area	1,040.00	109.00	309.00	90.60	380.00	248.80	19.40	160.00	309.00		0.50
Aspect	N/N	N/NE	NW/NW	SW/S	SW/S	E/E		S	SW/W		NE/NE
1946											
1947											
1948											
1949											
1950											
1951											
1952											
1953											
1954											
1955											
1956											
1957											
1958											
1959											
1960											
1961											
1962											
1963											
1964											
1965											
1966											
1967											
1968											
1969											
1970											
1971											
1972											
1973											
1974											
1975											
1976											
1977											
1978											
1979											
1980											
1981											
1982											
1983											
1984											
1985											
1986									30		
1987											
1988				–960							
1989				500		1000					
1990				–600		110					
1991		–900		–1410		–990	–990				
1992	1700	40	980	1060	500	1610	390	3000	240		–327
1993	1270	740		910		1120	720	2840	130		–32
1994	190	460	–30	80		–180	400	1600	–140		351
1995	20	–420	–590	–580		–800	–1130				–643
1996	–390	–850	–390	–780		–1170	–450				207
1997	–1060	–2200	–1170	–1050		–1150			–1880	–1300	512
1998	–490	–1390	–980	–560		–1080			–1480	–1700	–955
1999		–1120	–540	–250		–510			–1020	–770	–912
2000		–2020	–730	–1340		–970			–1280	–750	–1178
2001		80	–970	–580		–1550			–1710	–1270	435
2002		–1090	–280	–1000		–730			–1300	–1656	–811
2003		–1095	–1120	–980		–1310			–1300	–1946	–1102
2004											
Years	7	13	11	16	1	15	6	3	11	7	12
Average	177	–751	–529	–471	500	–440	–177	2480	–883	–1342	–371
Stdev	986	896	617	750	ND	975	788	766	789	461	639
st. error	373	249	186	188		252	322	442	238	174	184

Appendix 2. Glacier mass balance results

System number	5	5	5	5	5	5	5	5	5	5
Glaciers	Djankuat	Koiavgan	Visyachiy	Viatau	Garabashi	Kayarta	Yunom	Kelbashi	Bezengi	Tseya
Country	Russia	Russia	Russia	Russia	Russia	Russia	Russia	Russia	Russia	Russia
Geogr.area	C. Caucasus	N–C. Caucasus	N–C. Caucasus	N–C. Caucasus	C. Caucasus	C.Caucasus	N–C. Caucasus	N–C. Caucasus	N–C. Caucasus	N–C. Caucasus
Code	528	648	640	648	8	622	538		529	529
Lat	43°12'N	43°12'N	43°12'N	43°12'N	43°18'N	43°N	43°N	43°N	43°10'N	42°55'N
Long	42°46'E	42°46'E	42°46'E	42°46'E	42°28'E	43°E	42°E	42°E	43°E	43°40'E
Elev. Max	3798	3600	3700	3600	5000		4342	3980	5050	4460
Elev. Med	3280				3880				–	–
Elev. Min	2700	3300	3200	3300	3316		3100	3340	2080	2200
Length	4.2	0.6	1.0	0.8	5.8		2.8		17.6	8.6
Area	3.10	0.36	0.45	0.21	4.47	1.90	3.34	1.50	36.20	9.70
Aspect	N/NW	NW	NW	NW	SE/S	N	NW/W		NE/NE	NE/NE
1946										
1947										
1948										
1949										
1950										
1951										
1952										
1953										
1954										
1955										
1956										
1957										
1958										
1959										
1960										
1961									470	60
1962									–620	–630
1963									–960	–390
1964						405			250	1150
1965						–830			30	–40
1966						–870		–60	–600	–250
1967						530		930	40	40
1968	154	–190	0	–50		495		70	290	1410
1969	–977	–1180	–1000	–800		–550		290	–910	–200
1970	486	250	840	950		765		740	–530	–500
1971	–40	–570	540	700		215			130	360
1972	–1032	–1380	–1100	–900		–590			–970	
1973	–107	–250	600	420		165			–860	
1974	397	–260	990	850		615			–980	
1975	–652					–390			–820	
1976	327					665				
1977	–129					80	630			
1978	561									
1979	–167									
1980	531									
1981	–914									
1982	372									
1983	–1014									
1984	173				340					
1985	–423				–100					
1986	–545				–640					
1987	1507				410					
1988	369				269					
1989	–8				29					
1990	298				90					
1991	–358				–30					
1992	–171				140					
1993	1077				310					
1994	–867				–430					
1995	10				–10					
1996	–172				–30					
1997	240				190					
1998	–1000				–1470					
1999	–560				–820					
2000	–1140				–1060					
2001	–620				–750					
2002	430				260					
2003	280				160					
2004										
Years	36	7	7	7	20	14	1	5	15	11
Average	–102	–511	124	167	–157	50	630	394	–403	92
Stdev	625	580	860	769	525	581	ND	427	537	652
st. error	104	219	325	291	117	155		191	139	197

Appendix 2. Glacier mass balance results

System number	5	5	5	6	6	6	6	6	6	7	7	7
Glaciers	Khakel	Marukh	Tbilisa	L.Aktru	M.Aktru	Pr.Aktru	No 125	Stager	Sofiyskiy Gl.	Grechishkin	Koryto	Kozelskiy
Country	Russia	Russia	Georgia	Russia	Russia	Russia	Russia	Russia	Russia	Russia	Russia	Russia
Geogr.area	N–C. Caucasus	W.Cucasus	S. Caucasus	Altaiy	Altaiy	Altaiy	Altaiy	Altaiy	Altaiy	Kamchatka	Kamchatka	Kamchatka
Code	5	539	528	536	538	536	303			538	538	539
Lat	43°10'N	43°05'N	43°18'N	50°05'N	50°05'N	50°05'N	50°06'N	50°07'N	50°N	58°00'N	54°41'N	53°14'N
Long	41°40'E	41°10'E	42°28'E	87°44'E	87°45'E	87°44'E	87°42'E	87°41'E	87°E	160°38'E	161°38'E	158°49'E
Elev. Max	3240	3160	4300	4043	3714	3750	3550		3867	1770	1200	2050
Elev. Med		2785		3250	3200	3000	3100			1550	810	1590
Elev. Min	2270	2490	2950	2559	2229	2500	3025		2480	790	320	880
Length	3.9	4.0	3.0	5.9	4.2	5.3	1.4			8.1	7.0	4.6
Area	2.70	3.33	3.75	5.95	2.73	3.88	0.75	0.24	16.81	14.20	7.55	1.79
Aspect		NE/NE	SE/SE	SE/SE	E/N	NE/NE	N/N	N/N		W/W	NW/NW	S/S
1946												
1947												
1948												
1949												
1950												
1951												
1952												
1953												
1954												
1955												
1956												
1957												
1958												
1959												
1960											–90	
1961												
1962					–400							
1963					–340							
1964					–280							
1965					–560							
1966					–380							
1967		–260			290							
1968		60	310		–20							
1969		–740	–353		290							
1970		770	–464		120							
1971		–740	–2		250						580	
1972		–1080	–488		70							
1973		130	115		100							410
1974	–680	–140	–127		–1470							1470
1975	–360	–1170	–932		400							–220
1976	390	670	–186		680							1330
1977	260	–660	–284	240	490		80	760				–1050
1978	–320	190	–137	–370	–410		–190					–1110
1979	441	–160	–137	–630	–580		–780			–140		–370
1980		–1470	–281	–20	110	250	–120					–170
1981		–360		–320	–310	–330	–10					–2125
1982		–180		–410	–660	–310	–310				–284	–110
1983				330	150	330	160					–420
1984				320	310	330	290					–340
1985				150	240	290	210					2020
1986				60	40	150	120					–1660
1987				200	170	230	180					–300
1988				367	470	310	160		250			–1940
1989				25	220	190	100		50			–741
1990				50	130	70	140					–1282
1991				–418	540		–420					470
1992				–168	170		–20					–405
1993				268	340		100					–334
1994				–315	–150		–210					–673
1995				20	180		50					–263
1996				–170	–130		–120				1140	600
1997				–150	–50		–170				2350	940
1998				–1120	–1230		–980		–1150			
1999				–140	–110		–90					
2000				–290	–210		–190					
2001				–240	–190		–140					
2002				–370	–410		–290					
2003				–400	–370		–320					
2004												
Years	6	16	13	27	42	11	27	1	3	1	5	25
Average	–45	–321	–228	–130	–60	137	–103	760	–283	–140	739	–251
Stdev	468	630	306	338	439	240	292	ND	757	ND	1062	1021
st. error	191	157	85	65	68	72	56		437		475	204

Appendix 2. Glacier mass balance results

System number	7	7	7	8	9	10	10	10	10	10
Glaciers	Kropotkina	Mutnovs.SW	Mutnovs.NE	No 31	Shumskiy	Changmekhan.	Dunagiri	Shaune Garang	Gor Garang	Tipra Bank
Country	Russia	Russia	Russia	Russia	Kazakhstan	India	India	India	India	India
Geogr.area	Kamtshatka	Kamtshatka	Kamtshatka	Suntar Khayata, E.Siberia	Dzhungariya	Himalaya	Himalaya	Himalaya	Himal Pradezh	Himalaya
Code	649	660	660	538	536	530	537	527		
Lat	54°20'N	52°23'N	52°25'N	60°N	45°05'N	27°57'N	30°33'N	31°17'N	31°37'N	30°44'N
Long	160°01'E	158°07'E	158°10'E	90°E	80°14'E	88°41'E	79°54'E	78°20'E	78°49'E	79°41'E
Elev. Max	1300	1800	1950	2728	4464	5520	5150	5360		5730
Elev. Med	1180	1710	1700		3660	5300	4560	4600		4400
Elev. Min	1025	1500	1460	2023	3126	4840	4240	4400	4760	3720
Length		1.5	1.7	4.0	3.5	5.6	5.5	5.5		6.0
Area	0.60	1.09	1.38	3.20	2.81	4.50	2.56	4.94	2.00	7.00
Aspect	N/N	NE/NE	NW/NW		N/N	S/S	N/N	W/N		N/NW
1946										
1947										
1948										
1949										
1950										
1951										
1952										
1953										
1954										
1955										
1956										
1957				–140						
1958				180						
1959				–410						
1960				–490						
1961				–740						
1962				110						
1963				–305						
1964				330						
1965				220						
1966				–130						
1967				45	761					
1968				–320	–358					
1969				–120	383					
1970					715					
1971					–62					
1972					1041					
1973					61					
1974					–1157					
1975					–408					
1976					466					
1977					–263				–670	
1978					–483				–520	
1979					–25				–330	
1980		290	280		–418				–470	
1981		–480	–470		590	–392			–970	
1982		1150	680		–1082	–297		–570	200	
1983		–140	–160		–471	–291		–500	510	
1984		230	550		–208	–157		460	–750	
1985	1600				–334	–240		–100		
1986					–438	–72	–945	30		–59
1987					–574		–1038	–790		–65
1988					30		–1289	–630		–605
1989					273		–976	340		
1990					–581		–1235	–270		
1991					–1101					
1992										
1993										
1994										
1995										
1996										
1997										
1998										
1999										
2000										
2001										
2002										
2003										
2004										
Years	1	5	5	13	25	6	5	9	8	3
Average	1600	210	176	–136	–146	–242	–1097	–226	–375	–243
Stdev	ND	610	483	312	583	113	156	440	497	314
st. error		273	216	86	117	46	70	147	176	181

Appendix 2. Glacier mass balance results

System number	10	10	10	10	10	10	11	11	12	13	13	14
Glaciers	Neh Nar	Kolahoi	Shishram	Langtang	Rikxa Samba	AX010	Meikuang	Chongce i.c.	Xiaodongkemadi	Abramov	No.314	Qiyi
Country	India	India	India	Nepal	Nepal	Nepal	China	China	China	Kirghizstan	Kirghizstan	China
Geogr.area	Himalaya	Himalaya	Himalaya	Himalaya	Himalaya	Himalaya	Kunlun	W. Kunlun	Tibet	Pamir	Pamir	Qilanshan
Code				538		636	628		538	528	536	520
Lat	34°16'N	34°20'N	34°20'N	28°30'N		27°42'N	35°40'N	81°07'E	33°10'N	39°40'N	39°21'N	39°14'N
Long	75°52'E	75°47'E	75°43'E	85°30'E		86° 34'E	94°11'E	35°14'N	92°08'E	71°30'E	70°08'E	97°54'E
Elev. Max	4925	5000	4900	7000		5360	5520	6374	5926	4960	4340	5145
Elev. Med						5220				4200	3980	4720
Elev. Min	3920	3690	3740	4500		4952	4805	5750	5380	3620	3660	4310
Length						1.7	1.8		2.8	9.4	2.2	3.8
Area	1.70	11.90	9.90	74.80	1.00	0.57	1.10	16.40	1.77	22.50	1.46	3.04
Aspect						E/SE			S/SW	N/N	NW/NW	NW/NW
1946												
1947												
1948												
1949												
1950												
1951												
1952												
1953												
1954												
1955												
1956												
1957												
1958												
1959												
1960												
1961												
1962												
1963												
1964												
1965												
1966												
1967												
1968										–384		
1969										1349		
1970										312		
1971										–793		
1972										328		
1973										–818		
1974										–311		
1975										–1034		35
1976										–903		384
1977										–1448		351
1978										–1313		
1979										–387		
1980	–450									–1081		
1981	–480									129		
1982	–240									–774		
1983	–10									–507	–125	
1984	–630	–265	–287							–971	–850	221
1985										–855	–385	–30
1986										–575		
1987				240				–14		170		
1988				120						–52		
1989				–400			274		525	–286		
1990				390			–90		49	–539		
1991				–60			–300		–191	–540		
1992				–370			120		376	312		
1993				80			100		211	267		
1994				–700			–400		–540	–803		
1995				–480			–456		–570	–780		
1996				300		–180			–530	–350		
1997				–360		–391	10		370	–1730		
1998						–1328	–420		–670	210		
1999					–732	–502						
2000												
2001												
2002												
2003												
2004												
Years	5	1	1	11	1	4	9	1	10	31	3	5
Average	–362	–265	–287	–113	–732	–600	–129	–14	–97	–457	–453	192
Stdev	241	ND	ND	365	ND	503	272	ND	458	640	367	185
st. error	108			110		252	91		145	115	212	83

Appendix 2. Glacier mass balance results

System number	14	14	14	15	16	16	16	16	16	16
Glaciers	Shuiguan. No 4	Yanglonghe No 5	Laohuguou	Hailogou	Ts. Tuyuksu*	Igly Tuyuksu	Molodezhniy	Mametova	Korzhenevsky	Teu–South
Country	China	China	China	China	Kazakhstan	Kazakhstan	Kazakhstan	Kazakhstan	Kazakhstan	Kazakhstan
Geogr.area	Qilanshan	Qilanshan	Qilanshan	Gongga	Tien Shan	Tien Shan	Tien Shan	Tien Shan	Tien Shan	Tien Shan
Code	640	538	518	518	536	536	736	736		
Lat	37°33'N	39°14'N	39°26'N	29°35'N	43°N	43°N	43°N	43°N	42°37'N	43°N
Long	101°45'E	98°34'E	96°33'E	101°56'E	77°06'E	77°E	77°E	77°E	77°24'E	77° E
Elev. Max	5024	5262	5481	7514	4219	4220	4150	4190	5020	
Elev. Med	4620	4840	4880		3770					
Elev. Min	4200	4420	4260	2980	3414	3450	3450	3610	3300	
Length	2.2	2.5	10.1	13.1	3.1	2.2	1.7	0.6	11.5	
Area	1.36	1.62	21.91	25.71	2.66	1.72	1.43	0.35	38.00	1.88
Aspect	NE/NE		N/NW	SE	N/N	NW/NW	NE/NE	W/W		
1946										
1947										
1948										
1949										
1950										
1951										
1952										
1953										
1954										
1955										
1956										
1957					–150	30	90	100		
1958					330	450	410	380		
1959					–420	–170	–110	–110		
1960					–100	210	160	180		
1961					–560	–230	–60	–110		
1962					–690	–370	–330	–150		
1963	–53				440	400	360	200		580
1964					520	460	460	410	60	680
1965					–50	–190	–230	–310	60	
1966					40	20	–80	190	70	
1967					230	–10	–80	140		
1968					–780	–820	–1010	–630		
1969					210	160	240	260		
1970					110	–230	–390	–60		
1971					–360	–200	–370	–430		
1972					130	190	30	330		
1973					–290	–210	–240	–60		
1974					–620	–500	–670	–540		
1975					–450	–270	–390	–270		
1976	276		331		–720	–460	–700	–250		
1977	74	496			–1100	–750	–1220	–770		
1978		–275			–1480	–1720	–2030	–2350		
1979		35			–520	–440	–391	–486		
1980					–630	–460	–890	–730		
1981					110	–30	–120	80		
1982					–690	–620	–780	–660		
1983					–550	–540	–670	–550		
1984					–1250	–1200	–1420	–149		
1985					–550	–550	–700	–550		
1986					–520	–520	–660	–510		
1987					–340	–340	–450	–270		
1988					–610	–600	–750	–630		
1989				–81	–460	–460	–590	–430		
1990				–115	–960	–940	–1160	–1100		
1991				–155	–1100					
1992				–145	–240					
1993				–659	602					
1994					–443					
1995					–587					
1996					–456					
1997					–1467					
1998					–359					
1999					–230					
2000					–113					
2001					–561					
2002					–300					
2003					360					
2004										
Years	3	3	1	5	47	34	34	34	3	2
Average	99	85	331	–231	–375	–321	–434	–289	63	630
Stdev	166	388	ND	241	487	459	547	523	6	71
st. error	96	224		108	71	79	94	90	3	50

Appendix 2. Glacier mass balance results

System number	16	16	16	16	16	16	16	16	16	16	16
Glaciers	Teu–North	Shokalskiy	No.131	Kayandy	S.Inylchek	Kara–Batkak	Grigor'yev i.c.	Golubina	Davidov	Suyok Zap.	Sary–Tor
Country	Kazakhstan	Kazakhstan	Kirgizstan	Kirgizstan	Kirgizstan	Kirgizstan	Kirgizstan	Kirgizstan	Kirgizstan	Kirgizstan	Kirgizstan
Geogr.area	Tien Shan	Tien Shan	Tien Shan	Tien Shan	Tien Shan	Tien Shan	Tien Shan	Tien Shan	Tien Shan	Tien Shan	Tien Shan
Code		536	538			538		538	526	538	538
Lat	43°N	43°N	41°51'N	42° N	42° N	42°06'N	42° 30' N	42°27'N	41°50'N	41°47'N	41°50'N
Long	77° E	77°18'E	77°46'E	79°E	79° E	78°18'E	78° E	74°30'E	78°12'E	77°47'E	78°11'E
Elev. Max		4540	4433	5520	6870	4829	4609	4437	4980	4496	4800
Elev. Med			4151			3886		3970	4280	4187	4252
Elev. Min		3560	3864	3400	2800	3293	4150	3250	3780	3895	3860
Length		4.7	1.3	29.0	60.5	3.6		5.1	6.1	2.5	4.5
Area	1.90	10.80	0.51	84.10	567.20	4.56	9.35	5.75	11.43	1.25	3.61
Aspect		N/N	NE/NE			N/N		NW/NW	NW/NW	N/N	NE/NE
1946											
1947											
1948											
1949											
1950											
1951											
1952											
1953											
1954											
1955											
1956											
1957						–31					
1958						62					
1959						–344					
1960						–291					
1961						–806					
1962						–86					
1963	630	470				–40					
1964	710	690				144					
1965						–41					
1966						–156					
1967						10					
1968						–652					
1969						0		–130			
1970						–182		150			
1971						148		–90		–461	
1972						53		–109			
1973						–753		–391			
1974						–51		–462			
1975						–475		–236			
1976						–841		–397			
1977						–864		–322			
1978						–1176		–462			
1979						–501		–289			
1980						–364		–500			
1981						–447		128			
1982						–784		–212			
1983						–948		–251			
1984				–335	–35	–1572		–515	–949	–1348	–88
1985				–131	98	–1292		–573	100		–145
1986						–392		–372			–142
1987			–260			–682	–217	151			270
1988			–714			–456	–295	–433			–453
1989			–352			–396		–421		–517	–192
1990			–282			–778		–570		–676	
1991			–502			–398		–573		–527	
1992						–352		–454			
1993						–185		–276			
1994						–505		–501			
1995						–515					
1996						–373					
1997						–648					
1998						–360					
1999											
2000											
2001											
2002											
2003											
2004											
Years	2	2	5	2	2	42	2	26	2	5	6
Average	670	580	–422	–233	32	–436	–256	–312	–425	–706	–125
Stdev	57	156	189	144	94	395	55	218	742	368	232
st. error	40	110	84	102	67	61	39	43	525	164	95

Appendix 2. Glacier mass balance results

System number	16	17	18	18	19	20	21	21	22	22	22
Glaciers	Urumqihe S. No 1	Lewis	White	Baby	Devon i.c.	South i.c.	Laika GL.	Laika GL.+ i.c.	Barnes S. D–1	Barnes S.D–2	Barnes i.c.N.
Country	China	Kenya	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada
Geogr.area	E.Tien Shan	E.Africa	Axel H.Isl.	Axel H.Isl.	Devon Isl.	Melville Isl.	Coburg Isl.	Coburg Isl.	Baffin Isl.	Baffin Isl.	Baffin Isl.
Code	622	533	515	650	303	303	431	230			300
Lat	43°05'N	0°09'S	79°27'N	79°26'N	75°25'N	75°25'N	75°53'N	75°53'N	69°47'N	70°15'N	69°45'N
Long	86°49'E	37°18'E	90°40'W	90°58'W	83°15'W	115°01'W	79°10'W	79°10'W	72°25'W	72°00'W	73°40'W
Elev. Max	4486	4962	1780	1170	1890	715	520	520	951	951	970
Elev. Med	4040	4750	1160	1020	1200	600	360	370			
Elev. Min	3736	4611	80	710	0	490	20	20	365	365	420
Length	2.2	1.0	15.4	1.4	50.0	15.0	3.8	3.8			
Area	1.74	0.20	38.50	0.61	1667.60	66.00	4.25	9.82	266.60	675.00	3,090.00
Aspect	NE/NE	SW/SW	SE/SE	SW/SW	NW/NW	NE/NE		NE	Dome 1		
1946											
1947											
1948											
1949											
1950											
1951											
1952											
1953											
1954											
1955											
1956											
1957											
1958											
1959	87										
1960	–188		–406	–878							
1961	–33		24	106	–197						
1962	–167		–780	–979	–359						–615
1963	235		–153	–150	44	–100					–40
1964	2		350	250	125	290					42
1965	375		–7	150	64	100					
1966	–374		–21	70	–135	–130					
1967	–69		122	210	–27	160					
1968	–457		–406	–506	–175	25					
1969	148		75	140	–175	25					
1970	–313		–2	110	39	–260					
1971	102		–184	–476	–69	–470			96		
1972	262		116	321	102	–390			–206		
1973	–707		192	66	–95	–390			339		
1974	–24		–46	66	–77	–220	–451		–618		
1975	306		257	319	–69	–73	–575	–624		–724	
1976	29		113	149	171	–73			370		
1977	180		–370	–480	–99	–73			–80		
1978	–110		–133		27	–73			380		
1979	–76	–70	–90		39	–73			230		
1980	–337	–1750	0		–57	–73					
1981	–655	–1216	0		–146	–160			–890		
1982	–49	–320	0		–95	–310					
1983	100	–721	–82		105	–50			–380		
1984	–83	–898	–54		–31	50					
1985	–612	–941	–10		–108	–40					
1986	–669	–696	–259		185	230					
1987	–175	–721	–615		44	0					
1988	–644	–2282	131		–216	–570					
1989	105	769	30		–69	–320					
1990	52	–953	–447	–351	–166	–250					
1991	–706	–810	–179	–162	–230	210					
1992	23	–1746	–295	–91	96	–290					
1993	–29	–440	–480	–509	–62	–740					
1994	–378	–2287	–314	–129	–32	–110					
1995	–228	–452	–362	–448	–147	–470					
1996	46	–490	38	242	–80	–210					
1997	–773		–56	–163	–129	10					
1998	–826		–229	–14	–276	–750					
1999	–821		–494	–971	–217	–540					
2000	–379		–401	–560	–320	–850					
2001	–840		–181	–100	–585	–260					
2002	–834		32			16					
2003	–384		–106			20					
2004											
Years	45	18	44	30	41	41	2	1	10	1	3
Average	–220	–890	–129	–159	–83	–175	–513	–624	–76	–724	–204
Stdev	353	762	239	376	151	266	88	ND	443	ND	358
st. error	53	180	36	69	24	42	62		140		207

Appendix 2. Glacier mass balance results

System number	22	22	22	23	23	23	23	23	23	23	23
Glaciers	Boas	Decade	Meighen	Gilman	Nirukittuq	Per Ardua	Quviagivaa	Un–named i.c.	Ward H.I. R.	Ward H.I.Sh.	Murray i.c.
Country	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada
Geogr.area	Baffin Isl.	Baffin Isl.	Baffin Isl.	Ellesmere Isl.	Ellesmere Isl.	Ellesmere Isl.	Ellesmere Isl.	Ellesmere Isl.	Ellesmere Isl.	Ellesmere Isl.	Ellesmere Isl.
Code		408	303			408		300	804	804	
Lat	67°58'N	69°38'N	79°57'N	82°06'N	79°55'N	81°31'N	79°55'N	81°57'N	83°07'N	83°05'N	81°57'N
Long	65°27'W	69°49'W	99°08'W	70°37'W	83°30'W	76°27'W	83°34W	64°12'W	74°10'W	73°30'W	64°50'W
Elev. Max	1350	1470	1267	1850	1100	1710	1250	650	30	10	1100
Elev. Med		1100	600			1150		420	10	10	
Elev. Min	750	400	70	410	800	310	550	200	0	0	
Length		6.1	56.0			5.4			10.0	89.0	
Area	1.40	8.65	85.00	480.00	0.40	4.26	4.70	7.60	602.00	2,000.00	3.05
Aspect		NW/NW			SW/SW				N/N	N/N	
1946											
1947											
1948											
1949											
1950											
1951											
1952											
1953											
1954											
1955											
1956											
1957				–183							
1958				–110							
1959				–42						–110	
1960			–750	–202						–68	
1961			–110	52						–288	
1962			–970							–288	
1963			–200							117	
1964			360							104	
1965			60							202	
1966		–710	–70							–137	
1967		–20	–50							–91	
1968		240	50			–320				–7	
1969		–750	110								
1970	404	80	–10								
1971			–420								
1972	210		30					140	–110	–105	
1973			30					140	150	146	
1974			–30					300	170	168	
1975			80					–80	140	140	
1976			80							39	
1977			–240							–177	
1978			–90							–177	
1979			–5							–177	
1980			–5							–140	
1981			–170						–101	–140	
1982			160						–101	–150	
1983			–250						–10	36	
1984			230						2	–28	
1985			–30						–20		
1986			250								
1987			–180								
1988			–290								
1989			290								
1990			–210								
1991			–220								
1992			10								
1993			–590		–530		–532				
1994			–200								
1995			60								
1996			190								
1997			–60								
1998			–100								
1999			–350								–490
2000			–490								–290
2001			10								–470
2002			80								–290
2003			–530								
2004											
Years	2	5	44	5	1	1	1	4	9	23	4
Average	307	–232	–103	–97	–530	–320	–532	125	13	–49	–385
Stdev	137	464	269	105	ND	ND	ND	156	113	144	110
st. error	97	208	41	47				78	38	30	55

Appendix 2. Glacier mass balance results

System number	23	23	23	24	24	24	24	24	24	24	24
Glaciers	Simmons i.c.	STPBIC–NE	STPBIG–SW	Au. Broeggebreen	Bertil	Longyer	Voering	Nordensheld	Fritjof	Greenfjord	Bogerbreen
Country	Canada	Canada	Canada	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Norway
Geogr.area	Ellesmere Isl.	Ellesmere Isl.	Ellesmere Isl.	Svalbard	Svalbard	Svalbard	Svalbard	Svalbard	Svalbard	Svalbard	Svalbard
Code				529							
Lat	81°56'N	82N	82N	78° 53'N	78°40'N	78°20'N	78°N	78°05'N	78°N	78°N	78°25'N
Long	64°53'W	65W	65W	11°50'E	17°20'E	16°00'E	14°E	17°E	20°E	14°05'E	16°10'E
Elev. Max	1100	900	900	600	600	1030	560	1200		600	945
Elev. Med				260							
Elev. Min				60	240		100	30		5	320
Length				6.0							
Area	3.94	4.61	1.72	6.12	4.80	3.30	2.65	199.50	67.00	17.80	4.20
Aspect				NW/N							
1946											
1947											
1948											
1949											
1950											
1951											
1952											
1953											
1954											
1955											
1956											
1957											
1958											
1959											
1960											
1961											
1962											
1963		40									
1964		40									
1965		40						320			
1966		40								–330	
1967		40		–650			–200			–340	
1968		40		–100							
1969		40		–930							
1970		40		–540							
1971		40		–580							
1972		–140		–310							
1973		–140		–80							
1974		–140		–920			–1160				
1975		–140		–310	–290		–260				0
1976	–80	–140		–450	–720		–1170				–200
1977	–80	–140		–110	–590	–420	–130				–260
1978	–80	–140		–560	–1000	–730	–1160				–810
1979	–80	–140		–710	–850	–1230	–890				–1070
1980	–80	–140		–520	–920	–690	–500				–650
1981	–80	–140		–550	–660	–330	–940				–360
1982	–80	–140		–40	–170	120	–20				250
1983	–80	–140	170	–270	–470		–530				–300
1984	–30	–60	–70	–730	–1030		–1100				–610
1985	–30	–60	–70	–550	–970		–450				–570
1986	–30	–60	–70	–320			–550				–600
1987	–30	–60	–70	220			–320		–170		
1988	–30	–60	–70	–520			–540		–370	–460	
1989	–30	–60	–70	–450			–540		–330	–500	
1990	–30	–60	–70	–660			–870		–410	–490	
1991	–30	–60	–70	24			–420	340	50	–170	
1992	–30	–60	–70	–200							
1993	–30	–60	–70	–1022							
1994	–30	–60	–70	–176							
1995	–30	–60	–70	–641							
1996	–30	–60	–70	–170							
1997	–30	–60	–70	–620							
1998	–30	–60	–70	–860							
1999		–60	–70	–360							
2000	–400	–60	–70	–20							
2001	–520			–480							
2002				–580							
2003				–900							
2004											
Years	25	38	18	37	11	6	19	2	5	6	12
Average	–80	–62	–57	–450	–697	–547	–618	330	–246	–382	–432
Stdev	118	67	57	300	293	454	370	14	189	127	361
st. error	24	11	13	49	88	185	85	10	84	52	104

Appendix 2. Glacier mass balance results

System number	24	24	24	24	24	24	24	24	24	25
Glaciers	Daud	East and South Ice	Finsterwalder	Werenskiold	Kongsvegen	Md. Lovenbreen	Hansbreen	Irenebreen	Waldemar	Narssaq Brae
Country	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Poland	Denmark
Geogr.area	Svalbard	Svalbard	Svalbard	Svalbard	Svalbard	Svalbard	Svalbard	Svalbard	Greenland	Greenland
Code				528	424	529	424			620
Lat	78°10'N	79°05'N	77°50'N	77°05'N	78°48'N	78°53'N	77°05'N		78°40'N	60°15'N
Long	18°50'E	24°0'E	15°50'E	15°24'E	12°59'E	12°04'E	15°40'E		12°00'E	45°55'W
Elev. Max	560	750		810	1050	650	600			1300
Elev. Med				400	500	330	350			1110
Elev. Min	100	0		27	0	50	0		140	900
Length				7.0	27.0	4.8	15.8			1.6
Area	4.70	7,895.00	33.80	28.00	101.90	5.45	56.76		2.66	1.43
Aspect				SW/W	NW/NW	NE/N	S/S			W/W
1946										
1947										
1948										
1949										
1950										
1951			–1350							
1952			–1350							
1953			50							
1954			50							
1955			–1200							
1956			–1200							
1957			200							
1958		240	200							
1959			–50							
1960			–50							
1961			–1150							
1962			–1150							
1963			–100							
1964			–100							
1965			–400							
1966			–400							
1967			–550							
1968			–550			–30				
1969						–840				
1970						–530				
1971						–460				
1972						–220				
1973						–20				
1974						–890				
1975						–210				
1976						–350				
1977						–40				
1978	–660					–480				
1979	–580					–660				
1980	–570			–650		–430				
1981	–120					–460				–360
1982	120					20				–320
1983	–100					–170				400
1984						–680				
1985						–480				
1986						–210				
1987					540	240				
1988					0	–490				
1989					–150	–240	–90			
1990					–310	–510	–540			
1991					430	100	130			
1992					320	–140	–270			
1993					–380	–880	–680			
1994				–360	500	–120	200			
1995					–250	–790	–450			
1996					390	20			26	
1997					100	–430			–380	
1998					–710	–590	–600		–785	
1999					–150	–340	–350		–684	
2000					330	–50	–480		–319	
2001					–480	–330	–1070		–767	
2002					–220	–520	–600	–613	–514	
2003					–350	–790	–560	–630	–727	
2004										
Years	6	1	18	2	17	36	13	2	8	3
Average	–318	240	–506	–505	–23	–361	–412	–622	–519	–93
Stdev	325	ND	574	205	383	295	343	12	283	428
st. error	133		135	145	93	49	95	9	100	247

Appendix 2. Glacier mass balance results

System number	25	25	25	25	25	26	26	27	28
Glaciers	Qapiarf. Sermia	Valhaltinde	Nordbogl.	Mittivakkat	Hans Tausen i.c.	IGAN	Obrucheva	Vavilova Cupol	Shokalskiy
Country	Denmark	Denmark	Denmark	Denmark	Denmark	Russia	Russia	Russia	Russia
Geogr.area		Greenland	NE.Greenland	SE Greenland	N.Greenland	Polar Ural	Polar Ural	Severnaya Zemlya	Novaya Zemlya
Code	366	640	124			648	648	3	
Lat	65°36'N	61°26'N	61°25'N	65°41'N	82°30'N	67°40'N	67°43'N	79°22'N	76°N
Long	52°08'W	45°21'W	45°23'W	37°48'W		65°80'E	65°70'E	95°39'E	62°05'E
Elev. Max	1040	1630	2140			1180	650	728	860
Elev. Med		1420				950	520	500	
Elev. Min	517	1080	660			820	400	40	0
Length		2.2				1.4	0.9	55.0	
Area	20.85	1.90	56.90	17.60	3,975.00	0.88	0.30	1,817.00	515.00
Aspect		NW/N	S			E/E	E/E		
1946									
1947									
1948									
1949									
1950									
1951									
1952									
1953									
1954									
1955									
1956									
1957									
1958						–300	–500		10
1959						–350	–555		–290
1960						–680	–500		
1961						–260	–210		
1962						0	–150		
1963						–1270	–730		
1964						–1000	–1300		
1965						–660	–360		
1966						–200	280		
1967						310	200		
1968						2490	1810		
1969						–580	–550		140
1970						10	340		
1971						–140	–210		
1972						380	850		
1973						320	180		
1974						–930	–680	40	
1975						920	170	–210	
1976						–1320	–1350	350	
1977						–1660	–1640	150	
1978						890	1560	–530	
1979		–10				–370	–10	–630	
1980		–220	–1240			1020	1070	–160	
1981	–40	–500				–1110	–940	260	
1982	–50	–270							
1983	870	170							
1984	650								
1985	–630								
1986								80	
1987				–120				–70	
1988								460	
1989									
1990								540	
1991									
1992									
1993									
1994									
1995					–80				
1996				10					
1997				–400					
1998				–1170					
1999				–770					
2000				–830					
2001				–960					
2002				–500					
2003									
2004									
Years	5	5	1	8	1	24	24	12	3
Average	160	–166	–1240	–593	–80	–187	–134	23	–47
Stdev	603	256	ND	412		916	856	366	221
st. error	269	115		146	0	187	175	106	127

Appendix 2. Glacier mass balance results

System number	29	29	30	31	31	31	31	31	31
Glaciers	Jackson i.c.	Sedov	McCall	Eklutna	Fork East	Fork West	Gulkana	West Gulkana	Maclaren
Country	Russia	Russia	USA	USA	USA	USA	USA	USA	USA
Geogr.area	Franz Josef Land	Franz Josef Land	Brooks Range	Alaska Range	Alaska Range	Alaska Range	Alaska Range	Alaska Range	Alaska Range
Code			528	538	518		529	538	518
Lat	80°06'N	80° N	69°17'N	61°15'N	63°26'N	63°31'N	63°14'N	63°16'N	60°21'N
Long	52°48'E	53° E	143°50'W	148°58'W	146°47'W	147°23'W	145°28'W	145°30'W	146°32'W
Elev. Max	580	360	2700	1769	3500	3591	2460	2100	3000
Elev. Med			2010	1373			1840		
Elev. Min	0	0	1350	732	880	845	1165	1325	930
Length			7.6	12.9	17.0	41.0	8.5	4.2	17.0
Area	50.00	5.50	7.40	31.60	46.00	311.00	19.30	2.23	68.00
Aspect			NW/N	N/N	W/SW	SW/S	S/SW	S/SE	S/S
1946									
1947									
1948									
1949									
1950									
1951									
1952									
1953									
1954									
1955									
1956									
1957									
1958	–240	–290							
1959									
1960									
1961									
1962									
1963									
1964									
1965									
1966							–60		
1967							120		
1968							–40		
1969			–450				–920		
1970			–40				460		
1971			–120				350		
1972			–140				–310		
1973							580		
1974							–1090		
1975							–230		
1976							–920		
1977							–210		
1978							–190		
1979							–530		
1980							–70		
1981						–10	30		310
1982					–200	–240	–110		140
1983					90	120	30		370
1984							–320		
1985							680		
1986				–325			60	–450	
1987				–200			–120	–245	
1988				425			–220		
1989							–700		
1990							–690		
1991							–70		
1992							–240		
1993			–500				–1670		
1994			–770				–590		
1995			–550				–700		
1996			30				–530		
1997			–450				–1690		
1998			–860				–640		
1999			–560				–1110		
2000			–310				–50		
2001							–680		
2002							–1060		
2003							–20		
2004									
Years	1	1	12	3	2	3	38	2	3
Average	–240	–290	–393	–33	–55	–43	–354	–348	273
Stdev	ND	ND	283	402	205	182	545	145	119
st. error			82	232	145	105	88	103	69

Appendix 2. Glacier mass balance results

System number	31	32	32	33	34	34	35	35	35	35
Glaciers	Susitna	Wolverine	Sherman	Columbia	Variegated	Bering	Tats	Lemon Creek	Taku	Mendenhall
Country	USA	USA	USA	USA	USA	USA	Canada	USA	USA	USA
Geogr.area	Alaska Range	Kenai Mts.	Kenai Mts.	Chugach Mnt.	St. Elias Mnt.	St. Elias Mnt.	Coast Mts., USA	Coast Mts., USA	Coast Mts., USA	Coast Mts. USA
Code	519	538	528	514	529		519			424
Lat	63°31'N	60°22'N	60°55'N	61°00'N	60°00'N		59°41'N	59°36'N	58°40'N	59°N
Long	146°57'W	148°54'W	145°13'W	147°06'W	139°18'W		137°46'W	134°36'W	134°12'W	134°W
Elev. Max	3600	1700	1590	3353	2492		1980	1512	2160	1600
Elev. Med		1310		800	1000		1450			
Elev. Min	815	400	110	0	53		670	470	20	20
Length	36.0	8.0	13.0	61.0	20.0		16.1	5.6		21.5
Area	323.00	17.62	54.10	1,090.00	28.00		27.89	11.73	671.00	120.00
Aspect	W/SW	S/S	W	SE/S	W/W	reconstructed	NW/SE			
1946									–40	
1947									360	
1948									510	
1949									930	
1950						–1382			–180	
1951						–1122			–340	
1952						–733			160	
1953						–1562		–560	–150	
1954						–1948		–180	–70	
1955						–111		1120	970	
1956						–328		–640	–130	
1957						–2829		0	–40	
1958						–1038		–580	210	
1959						–2163		–900	350	
1960						–851		–820	160	
1961						–876		–240	480	
1962						–593		–690	390	
1963						–1090		170	570	
1964						–919		1040	1130	
1965			400			25		80	790	
1966		–780	200			–205		–490	80	
1967		–2180	–800			–333		–600	250	
1968		–880	0			–1420		–220	460	
1969		–550				–1876		210	1170	
1970		1540				13		–90	760	
1971		140				–272		–400	630	
1972		–1560				–394		–650	420	
1973		260			0	241		–520	520	
1974		–1650			–1000	–2158		–370	580	
1975		–220				–160		290	850	
1976		–1210				–957		–250	660	
1977		1390				–1636		–480	470	
1978		460		360		–1342		–800	310	
1979		–1580				–1152		–630	140	
1980		2320				–1227		–270	540	
1981	–300	1620				–663		–810	120	
1982	–220	–330				–781		–430	150	
1983	400	110				–1376		–1620	–420	
1984		–370				–1847		–250	640	
1985		410				–534		330	1400	
1986		–250				–1388		–510	1200	
1987		1330				19		–840		
1988		2000				349		110		
1989		–1910				–1734	–178	–1240		
1990		–2440				–539		–1110		
1991		–600				28		–380		
1992		–210				471		–660		
1993		–570				–1554		–980		
1994		–690				–1645		–760		
1995		–400				–1225		–1310		
1996		–1510				–3143		–1580		
1997		–1720				–2950		–1810		
1998		100				–852		–1460		–1520
1999		–880				–2093				0
2000		–910				–965				820
2001		450								
2002		–690								
2003		–200								
2004										
Years	3	38	4	1	2	51	1	46	41	3
Average	–40	–320	–50	360	–500	–1036	–178	–495	414	–233
Stdev	383	1152	526	ND	707	841	ND	605	430	1187
st. error	221	187	263		500	118		89	67	686

Appendix 2. Glacier mass balance results

System number	36	36	36	36	36	36	36	36	36
Glaciers	Alexander	Yuri	Andrei	Bench	Bridge	Helm	Place	Sentinel	Sykora
Country	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada
Geogr.area	Rockies+Coast	Rockies+Coast	Rockies+Coast	Rockies+Coast	Rockies+Coast	Rockies+Coast	Rockies+Coast	Rockies+Coast	Rockies+Coast
Code	538	538	428	648	414	626	538	530	418
Lat	57°06'N	57°06'N	56°56'N	51°26'N	50°49'N	49°58'N	50°26'N	49°54'N	50°52'N
Long	130°49'W	130°49'W	130°59'W	124°55'W	123°34'W	123°00'W	122°36'W	122°59'W	123°35'W
Elev. Max	1820	1820	2190	2740	2900	2150	2610	2105	2750
Elev. Med	1670	1670	1280	2000	2100	1900	2089	1850	2050
Elev. Min	1190	1190	610	1480	1400	1770	1860	1660	1520
Length	5.3	5.3	22.5	8.0	18.2	2.5	4.2	1.9	9.2
Area	5.74	5.74	91.89	10.51	88.10	0.92	3.45	1.72	25.35
Aspect	NE/NE	NE/NE		SW/NW	SE/E	NW/NW	NE/NE	N/NW	E/E
1946									
1947									
1948									
1949									
1950									
1951									
1952									
1953									
1954									
1955									
1956									
1957									
1958									
1959									
1960									
1961									
1962									
1963									
1964									
1965							–651		
1966							115	146	
1967							–1212	–191	
1968							–131	376	
1969							–216	118	
1970							–1510	–1297	
1971							–340	566	
1972							–344	204	
1973							–300	785	
1974							–564	2108	
1975							–240	880	
1976						568	877	1470	830
1977						–1464	–1227	–1329	–510
1978			–830			–783	–433	363	–160
1979	–500	–500	–640			–2301	–2212	–1740	–1080
1980	–520	–520	–180			–944	–923	272	–510
1981	–180	–180	75	–614	–404		–1097	168	128
1982	–1181	–1181	–984	–929	–509	–347	–754	868	–115
1983	–1397	–1397	–797	–538	205	–209	–443	1201	647
1984	94	94	132	–194	275	–328	–341	854	750
1985				–878	–1869	–1732	–1887	838	–1340
1986						–1333	–1317	–372	
1987						–789	–903	98	
1988				0		–559	–961	366	
1989	–970	–970	–460	–1060		–1582	–1010	–880	
1990	–1070	–1070	–420	–1070		–1790	–938		
1991						–2239	–990		
1992						–2798	–790		
1993						–2342	–2280		
1994						–1885	–2010		
1995						–1465	–2486		
1996						211	–221		
1997						–1073	–888		
1998						–2850	–2450		
1999						1500	620		
2000						110	130		
2001						–600	–760		
2002						–2544	–123		
2003						–1895	–995		
2004									
Years	8	8	9	8	5	27	39	24	10
Average	–716	–716	–456	–660	–460	–1165	–826	245	–136
Stdev	521	521	399	400	862	1080	785	898	747
st. error	184	184	133	141	386	208	126	183	236

Appendix 2. Glacier mass balance results

System number	36	36	36	36	37	37	37	37	38	39	39
Glaciers	Woolsey	Zavisha	Peyto	Ram River	Abraham	Hidden	Minaret	Superguksoak	Blue	Nisqually	Columbia
Country	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	USA	USA	USA
Geogr.area	Rockies+Coast	Rockies+Coast	Rockies N.	Rockies N.	Labrador P.	Labrador P.	Labrador P.	Labrador P.	Olympic Range	Cascades	Cascades
Code	628	636	538	648	648	648	648	649	528	529	648
Lat	51°07'N	50°48'N	51°40'N	51°51'N	58°56'N	58°56'N	58°53'N	58°57'N	47°49'N	46°48'N	47°58'N
Long	118°03'W	123°25'W	116°32'W	116°11'W	63°32'W	63°33'W	63°41'W	63°47'W	123°41'W	121°44'W	121°21'W
Elev. Max	2670	2500	3185	3020	1150	1090	1505	1080	2320	2430	2080
Elev. Med	2240	2200	2635	2750	900	920	1250	820	2377		1950
Elev. Min	1920	2010	2125	2560	690	790	1020	660	1280	1400	1840
Length	2.9	3.1	5.3	2.1	1.2	1.5	1.9	2.0	4.2	2.9	0.7
Area	3.87	6.49	11.75	1.80	0.97	0.85	0.86	1.40	4.20	4.60	0.90
Aspect	NE/NE		NE/NE	NE/N	NW/NW	NW/NW	NE/NE	N/N	NE/NW	S/S	NE/NE
1946											
1947											
1948											
1949											
1950											
1951											
1952											
1953											
1954											
1955											
1956									1150		
1957									–1340		
1958									–1900		
1959									–300		
1960									–280		
1961									470		
1962									210		
1963									–580		
1964									630		
1965	–60								–560		
1966	–171		–107	–63					340		
1967	143		–804	–1107					340		
1968	23		–201	290					30		
1969	–808		–617	–283					710		
1970	–1908		–1329	–1246					–390		
1971	72		–411	–941					1150		
1972	258		–250	–132					400		
1973			434	–37					–140		
1974	700		238	58					2000		
1975	360		–570	–620					670		
1976		1100	638						1420		
1977		–260	–203						–1240		
1978		390	–1060						510		
1979		–690	–810						–1150		
1980		–670	–576						–1610		
1981		–204	–1127						–1310		
1982		–524	–565		109	–229	25	–64	750		
1983		366	–389		96	–213	263	210	1340		
1984		314	–580		–775	–816	–184	–606	490		210
1985		–1215	–812						420		–310
1986			–472						–920		–200
1987			–621						–790		–630
1988			–992						220		140
1989			–599						–640		–90
1990			–734						–1180		–60
1991									–790		380
1992									–1180		–1850
1993			–1198						–1350		–900
1994			–1268						–1750		–960
1995			–280						–10		–550
1996			129						–790		–620
1997			–818						–490		350
1998			–2210						–1110		–1460
1999			–320						1090		1750
2000			810								400
2001			–920								–1520
2002			–500								600
2003			–1370							–2397	–1170
2004											–1839
Years	10	10	36	10	3	3	3	3	44	1	21
Average	–139	–139	–568	–408	–190	–419	35	–153	–170	–2397	–397
Stdev	734	682	591	535	507	344	224	415	959	ND	900
st. error	232	216	98	169	293	198	129	240	145		196

Appendix 2. Glacier mass balance results

System number	39	39	39	39	39	39	39	39	39	39	39	39	39
Glaciers	Foss	Ice Worm	Lower Curtis	Lynch	Rainbow	Watson	Yawning	Noisy Creek	N.Klawatti	Sandalee	Lyman	Easton	Silver
Country	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA
Geogr.area	Cascades	Cascades	Cascades	Cascades	Cascades	Cascades	Cascades	Cascades	Cascades	Cascades	Cascades	Cascades	Cascades
Code	638	648	648	654	638	636	658	648	55	645	648	648	648
Lat	47°33'N	47°50'N	48°48'N	48°39'N	48°48'N	48°39'N	48°27'N	48°40'N	48°34'N	48°25'N	48°17'N	48°75'N	48°59'N
Long	121°12'W	121°10'W	121°37'W	121°11'W	121°46'W	121°34'W	121°02'W	121°32'W	121°07'W	120°48'W	120°90'W	121°83'W	121°15'W
Elev. Max	2100	2120	1730	2390	2200	1790	2080	1890	2399	2280	2100	2900	2698
Elev. Med		2030	1625	2140	1760	1620	1950	1791		2154			2309
Elev. Min	1840	1900	1500	1780	1240	1475	1840	1683	1729	1965	1850	1700	2088
Length		0.6	0.8	1.1	2.4	0.7	0.7	0.5	2.8	0.8			0.5
Area	0.40	0.10	0.80	0.70	1.60	0.20	0.30	1.14	1.46	0.20	0.50	2.90	1.08
Aspect	NE/NE	E/E	W/W	N/N	E/E	N/N	NE/NE	N/N	SE/SE	N/N			N/NE/SE
1946													
1947													
1948													
1949													
1950													
1951													
1952													
1953													
1954													
1955													
1956													
1957													
1958													
1959													
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1961													
1962													
1963													
1964													
1965													
1966													
1967													
1968													
1969													
1970													
1971													
1972													
1973													
1974													
1975													
1976													
1977													
1978													
1979													
1980													
1981													
1982													
1983													
1984	510	860	390	330	580		90						
1985	–690	–750	–160	–220	40		–230						
1986	120	–450	–220	–70	200		–100				–640		
1987	–380	–1390	–560	–300	–260		–470				–1150		
1988	230	–240	–60	170	430	550	–60				–530		
1989	90	–670	–290	30	–240	–340	–190				–580		
1990	–270	–920	–510	–120	–460	–240	–320				–900	–580	
1991	300	630	40	360	440		230				550	410	
1992	–1920	–2230	–1760	–1380	–1650		–2060					–1670	
1993	–730	–1020	–480	–620	–800		–660	–952	–1090		–980	–1010	–40
1994	–680	–1230	–550	–400	–720		–620	–1160	–1930	–190	–710	–920	–110
1995	310	470	–210	180	–200		–260	–110	–470	370	–480	–310	460
1996	340	570	–180	530	120		340	220	330	810	–410	220	870
1997	500	760	270	620	510		500	100	880	870	430	530	630
1998	–1950	–1640	–1380	–1970	–1490		–2030	–1540	–1490	–1100	–1660	–1870	–70
1999	1560	2150	1550	1450	1840		1630	1450	1570	1450	580	1610	1490
2000	–100	–330	–250	–240	150		–180	340	800	700	–280	–10	1010
2001	–1920	–2150	–1880	–1820	–1710	–250	160					–1930	
2002	100	50	130	–130	120		260	462	224	752		180	–147
2003	–1350	–1400	–1250	–1200	–1080		–1850	–952	–1367	–1155		–980	–1421
2004	–1940	–2000	–1510	–1980	–1670		–1780					–960	
Years	21	21	21	21	21	4	21	10	10	9	14	15	10
Average	–375	–520	–422	–323	–279	–70	–362	–214	–254	279	–483	–486	267
Stdev	971	1144	796	898	899	416	915	917	1184	908	645	992	813
st. error	212	250	174	196	196	208	200	290	374	303	173	256	257

Appendix 2. Glacier mass balance results

System number	39	39	39	39	40	40	40	40	40	40	40	40
Glaciers	Eliot	Emmons	S. Cascade	Vesper	Grasshoper	Dinwoody	Arapaho	Henderson	St.Vrain 3	Arikaree	Navajo	Isabelle
Country	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA
Geogr.area	Cascades	Cascades	Cascades	Cascades	Rockies	Rockies S.	Rockies S., M.	Rockies S.	Rockies S.	Rockies S.	Rockies S.	Rockies S.
Code			538				648	648	648	648	648	648
Lat	45°38' N		48°22'N	48°00'N	45°13'N	43°11'N	40°03'N	40°03'N	40°09'N	40°03'N	40°03'N	40°04'N
Long	121°68'W		121°03'W	121°50'W	109°88'W	109°35'W	105°38'W	105°38'W	105°39'W	105°39'W	105°39'W	105°39'W
Elev. Max	1920		2140	1710	3350	4023	4070		3650	3870	4020	3910
Elev. Med			1920									
Elev. Min			1630	1110	3145	3414	3690		3410	3790	3810	3660
Length			3.1								0.2	0.6
Area	1.80		2.03	0.20	0.41	3.47	0.28	0.10	0.04	0.06	0.02	0.12
Aspect		N/N					reconstructed			reconstructed partly		
1946												
1947												
1948												
1949												
1950						860						
1951												
1952												
1953			–600									
1954			0									
1955			250									
1956			150									
1957			–150									
1958			–3300									
1959			700									
1960			–500				–2753			–2223		
1961			–1100				–2173			–1735		
1962			200				–2257			–1806		
1963			–1300				–3292			–2676		
1964			1200				–705			–500		
1965			–170				76			157		
1966	–500		–1030				–1681			–1321		
1967	–1600		–630		810		–211			–85		
1968	–2600		10		530		–1347			–1040		
1969	700		–731				9			100		120
1970	–300		–1201				250	250	–100	400	–300	300
1971			596				1170			1240		
1972			1430				–600			–700		
1973			–1040				230			200		
1974			1020	–1200			227			284		
1975			–50	–400			213			272		
1976			950				–287			–149		
1977			–1300				–1444			–1122		
1978			–380				–606			–417		
1979			–1560				–2210			–1766		
1980			–1020				–1185			–904		
1981			–840				–422			–262		
1982			80				–1010			–757		
1983			–770				–568			–385		
1984			120				190			253		
1985			–1200				–404			–247		
1986			–610				45			131		
1987			–2060				–1291			–993		
1988			–1340				–1886			–1494		
1989			–910				–7			87		
1990			–110				–1582			–1238		
1991			70				–1802			–1423		
1992			–2010				85			164		
1993			–1230				1101			1019		
1994			–1600				–1243			–953		
1995			–690				–989			–739		
1996			100				–776			–560		
1997			630				–81			25		
1998			–1860				–1255			–963		
1999			1020				–1071			–808		
2000			380				–940			–698		
2001			–1570				–2822			–2281		
2002			550				–3991			–3264		
2003		–2882	–2100				–1900			–1397		
2004										–772		
Years	5	1	51	2	2	1	44	1	1	45	1	2
Average	–860	–2882	–500	–800	670	860	–936	250	–100	–697	–300	210
Stdev	1270	ND	987	566	198	ND	1118	ND	ND	935	ND	127
st. error	568		138	400	140		169			139		90

Appendix 2. Glacier mass balance results

System number	40	40	40	40	40	40	40	40	41	41		43
Glaciers	St.Vrain 1	St.Vrain 2	St.Vrain 4	St.Vrain 5	St.Vrain 6	Andrews	Fair	Fair	Maclure	Maclure	Ventorillo	Chacaltaya
Country	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	Mexico	Bolivia
Geogr.area	Rockies S.	Rockies S.	Rockies S.	Rockies S.	Rockies S.	Rockies S.	Rockies S.	Rockies S.	Sierra Nevada	Sierra Nevada	Popocatepetl	Real Bolivia
Code	648	648	648	648	648	648	648	648	64	64		648
Lat	40°09'N	42°09'N	42°10'N	40°10'N	40°10'N	40°17'N	40°04'N	40°04'N	37°45'N	37°45'N	19°01'N	16°21'S
Long	105°38'W	105°38'W	105°39'W	105°40'W	105°40'W	105°41'W	105°39'W	105°39'W	119°28W	119°28W	98°38'W	68°07'W
Elev. Max	3620	3600	3590	3740	3770	3660	3770	3770	3598	3598	5380	5395
Elev. Med												5320
Elev. Min	3430	3490	3490	3600	3610	3410	3460	3460	3460	3460	4760	5125
Length	0.4	0.2	0.2	0.4	0.4	0.4			0.4	0.4	0.8	0.6
Area	0.07	0.04	0.02	0.04	0.07	0.14	0.15	0.15	0.20	0.20	0.45	0.08
Aspect											NW	S/S
1946												
1947												
1948												
1949												
1950												
1951												
1952												
1953												
1954												
1955												
1956												
1957												
1958												
1959												
1960												
1961												
1962												
1963												
1964												
1965												
1966												
1967									1210	1210		
1968									–760	–760		
1969									700	700		
1970	50	100	150	200	650	200	400	400				
1971												
1972												
1973												
1974												
1975												
1976												
1977												
1978												
1979												
1980												
1981												
1982												
1983												
1984												
1985												
1986												
1987												
1988												
1989												
1990												
1991												
1992												–1160
1993												277
1994												–1080
1995												–1470
1996												–1874
1997												–659
1998											–2871	–3716
1999												–1827
2000												–852
2001												–350
2002												–1827
2003												–507
2004												
Years	1	1	1	1	1	1	1	1	3	3	1	12
Average	50	100	150	200	650	200	400	400	383	383	–2871	–1254
Stdev	ND	ND	ND	ND	ND	ND	ND	ND	1022	1022	ND	1019
st. error									590	590		294

Appendix 2. Glacier mass balance results

System number	43	43	43	44	44	44	45	46	46	47
Glaciers	Charquini sur	Zongo	Antizana	Piloto East	Martial Este	Enchaurren N.	De Los Tres	Meren	Carstenz	Ivory
Country	Bolivia	Bolivia	Equador	Argentina	Argentina	Chile	Argentina	Indonesia	Indonesia	New Zealand
Geogr.area		Real Bolivia	Real Bolivia	Central Andes	Centr. Andes	Centr. Andes	S.Patagonia	Irian Java	Irian Java	S.Island
Code		538	478					536	538	644
Lat		16°15'S	0° 29'S	32° 27'S		33°35'S		4°05'S	4°06'S	43°08'S
Long		68°10'W	79°09'W	70°09'W		70°08'W		137°10'E	137°10'E	170°55'E
Elev. Max		6000	5760	4740		3880	1830	4860	4800	1730
Elev. Med		5450	5200			3650		4610	4600	1510
Elev. Min		4890	4800	4185		3750	1198	4260	4380	1390
Length		3.0	2.0	2.5		1.2		2.1	1.8	1.4
Area		2.18	0.35	0.50		0.40	0.98	1.95	0.89	0.80
Aspect		S/E	NW/NW	SE/S		SW		SW/W	W/NW	S/S
1946										
1947										
1948										
1949										
1950										
1951										
1952										
1953										
1954										
1955										
1956										
1957										
1958										
1959										
1960										
1961										
1962										
1963										
1964										
1965										
1966										
1967										
1968										
1969										
1970										–2110
1971										–1320
1972										–1660
1973								–512	–81	–1730
1974										–3480
1975										–4000
1976						–920				
1977						–1300				
1978						180				
1979						670				
1980				950		300				
1981				–800		360				
1982				–1000		–2420				
1983				1550		3700				
1984				–200		–1240				
1985				200		340				
1986				–750		1510				
1987				100		950				
1988				150		2430				
1989				–850		–1260				
1990				–700		–1530				
1991				–800		–1050				
1992		–1498		650		1740				
1993		163		–450		–290				
1994		–736		250		–1860				
1995		–1276	–1880	–800		–950				
1996		–675	–428	–1500		–1180	70			
1997		797	–612	–2400		–2880	650			
1998		–1962	–845	–1200		2890	–280			
1999		–333	515	–1100		–4260				
2000		116	393	–200	785	–740				
2001		577	515	–390	–691					
2002		0	–598	290	–682	80				
2003	–883	–100	–1362		–202	2060				
2004										
Years	1	12	9	23	4	27	3	1	1	6
Average	–883	–411	–478	–391	–198	–173	147	–512	–81	–2383
Stdev	ND	843	840	858	694	1821	470	ND	ND	1093
st. error		243	280	179	347	350	271			446

Appendix 2. Glacier mass balance results

System number	47	48	48	49	49	49	49	49	49
Glaciers	Tasman	Hodges	Hamberg	Spartan	G1	Little Dome	Anvers Isl. i.c.	Glaciar Bahia del Diablo	Alberich
Country	New Zealand	Gr.Britain	Gr.Britain	Antarctic i.c.	Sub Ant.	Sub Ant.	Ant. Penins	.	Antarctic i.c.
Geogr.area	S.Island	S.Georgia Isl.	S.Georgia Isl.	Alexandra Isl.	Desep. Isl.	King George Isl.	Anvers Isl.	Vega Island	Dry Valley
Code	524								
Lat	43°31'S	54°27'S	54°40'S	71°03'S	63°0'S	59°06'S	63°75'S	63°49'S	77°35'S
Long	170°19'E	36°53'W	36°50'W	68°20'E	60°35'W	62°33'S	64°75'W	57°26'W	161°37'E
Elev. Max	2830	1730	2000	450	400	252	1600	630	1800
Elev. Med									
Elev. Min	730	1390		40	100			75	1400
Length	28.5								
Area	98.34	0.30	11.40	6.30	0.42	14.00	230.00	14.30	1.36
Aspect								NE/E	
1946									
1947									
1948									
1949									
1950									
1951									
1952									
1953									
1954									
1955									
1956									
1957									
1958		–150	–254						
1959	–770								
1960									
1961									
1962									
1963									
1964									
1965									
1966									
1967							87		
1968									
1969					–10				
1970					–300				
1971				–86	–560				
1972				–76					20
1973				–189					30
1974				–62					–20
1975									10
1976									
1977									
1978									
1979									
1980									
1981									
1982									
1983									
1984									
1985									
1986									
1987									
1988									
1989									
1990									
1991									
1992						163			
1993									
1994									
1995									
1996									
1997									
1998									
1999									
2000								–560	
2001								–60	
2002								–510	
2003								–150	
2004									
Years	1	1	1	4	3	1	1	4	4
Average	–770	–150	–254	–103	–290	163	87	–320	10
Stdev	ND	ND	ND	58	275	ND	ND	252	22
st. error				29	159			126	11

Appendix 2. Glacier mass balance results

System number	49	49	49		years	time		standard	standard		
Glaciers	Heimdall	Jeremy Sykes	Meserve			series	average	deviation	error	Minimum	Maximum
Country	Antarctic i.c.	Antarctic i.c.	Antarctic i.c.								
Geogr.area	Dry Valley	Dry Valley	Wright Valley								
Code	538										
Lat	77°35'S	77°36'S	77°52'S								
Long	162°52'E	161°33'E	162°45'E								
Elev. Max	1800	2040	1600								
Elev. Med	1500										
Elev. Min	1200	1170	440								
Length	6.0										
Area	7.96	9.92	9.90								
Aspect	W/NW										
1946					1946	4	–407	510	255	–1130	–40
1947					1947	3	–1370	1507	870	–2399	360
1948					1948	6	304	350	143	–240	684
1949					1949	7	–835	1520	575	–2990	930
1950					1950	9	–872	822	274	–1620	860
1951					1951	9	–315	649	216	–1350	382
1952					1952	9	–568	637	212	–1620	310
1953					1953	12	–516	441	127	–1562	50
1954					1954	12	–319	667	193	–1948	484
1955					1955	12	258	670	193	–1200	1120
1956					1956	13	–196	562	156	–1200	1150
1957					1957	21	–271	670	146	–2829	200
1958					1958	30	–387	763	139	–3300	450
1959					1959	29	–527	581	108	–2163	700
1960					1960	35	–371	700	118	–2753	544
1961					1961	37	–293	589	97	–2173	480
1962					1962	45	–285	740	110	–2257	2250
1963					1963	58	–453	787	103	–3292	630
1964					1964	60	–107	819	106	–1833	1200
1965					1965	62	270	647	82	–1370	1976
1966			–610		1966	73	–188	686	80	–1681	1370
1967					1967	81	119	695	77	–2180	2156
1968					1968	88	54	673	72	–2600	2490
1969					1969	82	–345	764	84	–2590	1349
1970					1970	95	–232	720	74	–2470	1540
1971					1971	82	–120	615	68	–1406	1240
1972	–10	20			1972	84	–188	542	59	–1660	1430
1973	–20	0			1973	81	–67	740	82	–1730	2718
1974	–20	–10			1974	85	–115	827	90	–3480	2108
1975	–10	20			1975	84	–21	707	77	–4000	1700
1976					1976	76	–50	828	95	–2070	2413
1977					1977	83	–229	771	85	–1660	1477
1978					1978	79	–179	768	86	–2350	1805
1979					1979	82	–403	620	69	–2301	712
1980					1980	86	–224	764	82	–1750	2320
1981					1981	90	–211	569	60	–2125	1620
1982					1982	95	–317	537	55	–2420	1150
1983					1983	96	–76	729	74	–1620	3700
1984					1984	103	–123	587	58	–1847	1320
1985					1985	90	–307	658	69	–1887	2020
1986					1986	87	–374	529	57	–1790	1510
1987					1987	92	–131	686	72	–2060	2070
1988					1988	97	–500	810	82	–2740	2430
1989					1989	104	–89	937	92	–2590	3196
1990					1990	104	–372	775	76	–2440	1924
1991					1991	97	–376	631	64	–2239	775
1992					1992	100	–155	1076	108	–2798	3000
1993					1993	104	–88	861	84	–2342	2840
1994					1994	104	–514	671	66	–2287	1600
1995					1995	100	–261	644	64	–2486	1734
1996					1996	103	–344	661	65	–3143	1140
1997					1997	106	–365	855	83	–2950	2350
1998					1998	110	–948	924	88	–3716	2890
1999					1999	100	–260	994	99	–4260	2150
2000					2000	103	–158	815	80	–2020	1990
2001					2001	88	–642	847	90	–2822	858
2002					2002	87	–677	828	89	–3991	752
2003					2003	89	–1287	921	98	–3316	2060
2004					2004	25	–870	788	158	–2000	820
Years	4	4	1								
Average	–15	8	–610								
Stdev	6	15	ND								
st. error	3	8									

APPENDIX 3. Specific Annual or Net Mass Balances

This table includes specific annual or net (no differences made here) mass balances in meters and volume changes (in km^3), both in water equivalent, for 49 primary glacier systems, 12 larger glacier regions, 6 continental-size systems, and global (expressed in terms of sea-level change). Description of methods applied are presented in the text. In the first row there are numbers of primary systems; larger regions (from R1 to R12), and continental-size systems are given at the end of the table. Names of all systems (row 2) and their glacier surface areas (row 3) are also presented. Global values of annual/net glacier specific mass balance, change in volume, and expressed in the equivalent of sea level change are given at the very end of the Appendix 3 table.

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

System's #	1	1	2	2	3	3	4	4	5	5	6	6
System's name	Alps	Alps	Scandinavia	Scandinavia	Iceland	Iceland	Pyrenia	Pyrenia	Caucasus	Caucasus	Altai	Altai
Area, km^2	2345	2345	2942	2942	11260	11260	11	11	1432	1432	1750	1750
Latitude	45–47N	45–47N	61–68N	61–68N	64–65N	64–65N	42.5N	42.5N	42.5–43.5N	42.5–43.5N	51–52N	51–52N
Longitude	6E–11E	6E–11E	7–18E	7–18E	16–20W	16–20W	0–2E	0–2E	43–45E	43–45E	89–91E	89–91E
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961	–0.46	–0.20	–2.14	–0.73					0.55	0.38		
1962	–1.04	–0.44	4.35	1.48					–0.89	–0.62	–0.70	–0.40
1963	–0.42	–0.18	–2.24	–0.76					–1.20	–0.84	–0.60	–0.34
1964	–2.92	–1.24	1.24	0.42					0.63	0.44	–0.49	–0.28
1965	2.62	1.12	0.98	0.33					–0.03	–0.02	–0.98	–0.56
1966	1.45	0.62	–2.65	–0.90					–0.75	–0.53	–0.67	–0.38
1967	0.58	0.25	4.24	1.44					0.09	0.06	0.51	0.29
1968	1.07	0.46	0.77	0.26					0.64	0.45	–0.04	–0.02
1969	0.55	0.24	–4.24	–1.44					–1.03	–0.72	0.51	0.29
1970	–0.13	–0.06	–1.93	–0.66					–0.44	–0.30	0.21	0.12
1971	–1.56	–0.67	1.96	0.67					0.15	0.10	0.44	0.25
1972	–0.16	–0.07	–0.48	–0.16					–1.34	–0.93	0.12	0.07
1973	–1.50	–0.64	4.33	1.47					–0.87	–0.61	0.03	0.01
1974	0.00	0.00	1.58	0.54					–0.97	–0.68	–2.57	–1.47
1975	1.06	0.45	2.76	0.94					–1.15	–0.80	0.70	0.40
1976	–1.70	–0.72	3.14	1.07					0.47	0.33	1.19	0.68
1977	2.99	1.27	–1.63	–0.55					–0.06	–0.04	0.54	0.31
1978	3.42	1.46	–0.95	–0.32					0.11	0.08	–0.64	–0.36
1979	0.14	0.06	1.41	0.48					–0.04	–0.03	–1.10	–0.63
1980	2.63	1.12	–3.12	–1.06					–0.60	–0.42	0.13	0.08
1981	2.00	0.85	1.66	0.57					–0.90	–0.63	–0.53	–0.30
1982	0.03	0.01	–0.53	–0.18					0.12	0.09	–0.75	–0.43
1983	–0.08	–0.03	3.05	1.04					–1.45	–1.01	0.22	0.13
1984	1.41	0.60	1.27	0.43					0.39	0.27	0.56	0.32
1985	0.10	0.04	–2.14	–0.73					–0.33	–0.23	0.37	0.21
1986	–0.77	–0.33	–0.44	–0.15					–0.86	–0.60	0.16	0.09
1987	–0.31	–0.13	2.36	0.80					1.23	0.86	0.35	0.20
1988	–1.03	–0.44	–3.56	–1.21					0.44	0.31	0.52	0.30
1989	–0.74	–0.32	6.59	2.24	9.14	0.81			0.02	0.01	0.14	0.08
1990	–2.41	–1.03	3.22	1.10	–1.78	–0.16			0.25	0.18	0.14	0.08
1991	–1.87	–0.80	0.44	0.15	–12.32	–1.09			–0.24	–0.16	–0.25	–0.14
1992	–1.83	–0.78	4.17	1.42	14.17	1.26	0.00	–0.34	0.02	0.01	–0.10	–0.06
1993	–0.11	–0.05	3.46	1.17	12.48	1.11	0.00	–0.03	0.89	0.62	0.48	0.28
1994	–1.43	–0.61	0.69	0.24	2.63	0.23	0.00	0.37	–0.87	–0.61	–0.45	–0.26
1995	–1.76	–0.75	2.52	0.86	–2.56	–0.23	–0.01	–0.67	0.00	0.00	0.12	0.07
1996	–1.17	–0.50	–0.84	–0.29	–4.50	–0.40	0.00	0.22	–0.13	–0.09	–0.27	–0.15
1997	–0.76	–0.32	–0.11	–0.04	–13.09	–1.16	0.01	0.54	0.30	0.21	–0.21	–0.12
1998	–3.34	–1.42	1.20	0.41	–8.64	–0.77	–0.01	–1.00	–1.83	–1.28	–2.01	–1.15
1999	–1.24	–0.53	–0.21	–0.07	–5.27	–0.47	–0.01	–0.95	–1.02	–0.71	–0.22	–0.13
2000	–1.72	–0.73	3.32	1.13	–12.02	–1.07	–0.01	–1.18	–1.56	–1.09	–0.45	–0.26
2001	0.15	0.07	–3.40	–1.16	–4.78	–0.42	0.00	0.44	–1.00	–0.70	–0.38	–0.22
2002	–1.77	–0.75	–3.22	–1.09	–2.73	–0.24	–0.01	–0.81	0.47	0.33	–0.66	–0.38
2003	–6.57	–2.80	–4.26	–1.45	–8.54	–0.76	–0.01	–1.10	0.30	0.21	–0.67	–0.38
2004			–2.08	–0.71								
Years	43	43	43	43	15	15	12	12	43	43	42	42
Ave. 1961–2003	–0.43	–0.18	0.47	0.16	–2.52	–0.22	0.00	–0.38	–0.29	–0.20	–0.17	–0.10
St. deviation	1.82	0.78	2.69	0.91	8.68	0.77	0.01	0.65	0.73	0.51	0.70	0.40
St.error	0.28	0.12	0.41	0.14	2.24	0.20	0.00	0.19	0.11	0.08	0.11	0.06

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

System's #	7	7	8	8	9	9	10	10	11	11
System's name	Kamchatka	Kamchatka	Suntar–Khayata Range	Suntar–Khayata Range	Dzhungaria	Dzhungaria	Himalaya	Himalaya	Kun–Lun	Kun–Lun
Area, km^2	905	905	202	202	1000	1000	33050	33050	12260	12260
Latitude	53–55N	53–55N	62–62.5N	62–62.5N	43N	43N	28–30N	28–30N	36–37N	36–37N
Longitude	158–160N	158–160N	140–142E	140–142E	80E	80E	78–92E	78–92E	77–87E	77–87E
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961			–0.15	–0.74	–0.01	–0.01	–14.40	–0.44	2.07	0.17
1962			0.02	0.11	0.72	0.72	–19.95	–0.60	5.75	0.47
1963			–0.06	–0.30	0.77	0.77	–20.37	–0.62	6.03	0.49
1964			0.07	0.33	0.26	0.26	–16.44	–0.50	3.43	0.28
1965			0.04	0.22	0.27	0.27	–16.56	–0.50	3.50	0.29
1966			–0.03	–0.13	0.76	0.76	–20.27	–0.61	5.97	0.49
1967			0.01	0.04	–0.36	–0.36	–11.73	–0.35	0.30	0.02
1968			–0.06	–0.32	0.38	0.38	–17.39	–0.53	4.05	0.33
1969			–0.02	–0.12	0.72	0.72	–19.92	–0.60	5.74	0.47
1970					–0.06	–0.06	–13.99	–0.42	1.80	0.15
1971	0.52	0.58			1.04	1.04	–22.41	–0.68	7.39	0.60
1972					0.06	0.06	–14.93	–0.45	2.42	0.20
1973	0.37	0.41			–1.16	–1.16	–5.63	–0.17	–3.75	–0.31
1974	1.33	1.47			–0.41	–0.41	–11.35	–0.34	0.05	0.00
1975	–0.20	–0.22			0.47	0.47	–18.02	–0.55	4.47	0.36
1976	1.20	1.33			–0.26	–0.26	–22.14	–0.67	0.78	0.06
1977	–0.95	–1.05			–0.48	–0.48	–17.19	–0.52	–0.33	–0.03
1978	–1.00	–1.11			–0.03	–0.03	–10.91	–0.33	1.99	0.16
1979	–0.15	–0.17			–0.42	–0.42	–15.20	–0.46	0.00	0.00
1980	0.08	0.09			0.59	0.59	–20.29	–0.61	5.10	0.42
1981	–1.06	–1.17			–1.08	–1.08	–7.50	–0.23	–3.37	–0.27
1982	–0.01	–0.01			–0.47	–0.47	–2.41	–0.07	–0.27	–0.02
1983	–0.24	–0.26			–0.21	–0.21	–8.99	–0.27	1.06	0.09
1984	0.09	0.09			–0.33	–0.33	–5.62	–0.17	0.42	0.03
1985	1.73	1.91			–0.44	–0.44	–8.66	–0.26	–0.11	–0.01
1986	–1.50	–1.66			–0.57	–0.57	–13.65	–0.41	–0.17	–0.01
1987	–0.27	–0.30			0.03	0.03	–19.86	–0.60	2.26	0.18
1988	–1.76	–1.94			0.27	0.27	–11.40	–0.35	3.36	0.27
1989	–0.67	–0.74			–0.58	–0.58	–12.29	–0.37	–1.10	–0.09
1990	–1.16	–1.28			–1.10	–1.10	–1.98	–0.06	–3.68	–0.30
1991	0.43	0.47			0.04	0.04	–12.23	–0.37	1.47	0.12
1992	–0.37	–0.41			0.35	0.35	2.64	0.08	1.23	0.10
1993	–0.30	–0.33			–0.18	–0.18	–23.14	–0.70	–4.90	–0.40
1994	–0.61	–0.67			–0.17	–0.17	–15.86	–0.48	–5.59	–0.46
1995	–0.24	–0.26			0.03	0.03	9.92	0.30	2.28	0.19
1996	0.94	1.04			–0.74	–0.74	–11.90	–0.36	0.12	0.01
1997	1.88	2.08			–0.33	–0.33	–11.93	–0.36	–5.15	–0.42
1998					–0.26	–0.26	–24.19	–0.73	0.81	0.07
1999					0.06	0.06	–14.90	–0.45	2.40	0.20
2000										
2001										
2002										
2003										
2004										
Years	26	26	9	9	39	39	39	39	39	39
Ave. 1961–2003	–0.07	–0.08	–0.02	–0.10	–0.07	–0.07	–13.41	–0.41	1.23	0.10
St. deviation	0.94	1.04	0.07	0.33	0.53	0.53	7.25	0.22	3.22	0.26
St.error	0.18	0.20	0.02	0.11	0.08	0.08	1.16	0.04	0.52	0.04

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

System's #	12	12	13	13	14	14	15	15	16	16	17	17
System's name	Tibet	Tibet	Pamir	Pamir	Quilanshan	Quilanshan	Gongga	Gongga	Tien Shan	Tien Shan	E.Africa	E.Africa
Area, km^2	1802	1802	12260	12260	1930	1930	1580	1580	15417	15417	6	6
Latitude	30–33N	30–33N	37–39N	37–39N	37–39N	37–39N	30N	30N	41–43N	41–43N	0	0
Longitude	80–95E	80–95E	72–75E	72–75E	95–100E	95–100E	97E	97E	76–82E	76–82E	37.2E	37.2E
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961	0.79	0.44	–5.63	–0.46	0.11	0.06	–0.45	–0.29	–4.61	–0.30		
1962	1.67	0.93	5.45	0.44	–0.10	–0.05	–1.10	–0.70	5.61	0.36		
1963	1.74	0.97	6.24	0.51	–0.31	–0.16	–1.15	–0.73	6.38	0.41		
1964	1.11	0.62	0.65	0.05	–0.11	–0.06	–0.69	–0.44	–0.85	–0.06		
1965	1.13	0.63	1.53	0.12	–0.14	–0.07	–0.70	–0.45	–0.63	–0.04		
1966	1.73	0.96	3.39	0.28	–0.21	–0.11	–0.78	–0.49	0.57	0.04		
1967	0.36	0.20	–4.71	–0.38	0.08	0.04	–0.04	–0.02	–11.18	–0.73		
1968	1.27	0.70	16.54	1.35	–0.67	–0.35	–0.87	–0.55	1.96	0.13		
1969	1.67	0.93	3.83	0.31	–0.22	–0.12	–0.62	–0.39	–2.02	–0.13		
1970	0.72	0.40	–9.72	–0.79	0.25	0.13	–0.54	–0.34	–3.21	–0.21		
1971	2.07	1.15	4.02	0.33	–0.23	–0.12	–0.87	–0.55	1.96	0.13		
1972	0.87	0.48	–10.03	–0.82	0.26	0.14	–0.37	–0.24	–5.84	–0.38		
1973	–0.61	–0.34	–3.81	–0.31	0.04	0.02	–0.34	–0.22	–6.32	–0.41		
1974	0.30	0.17	–12.68	–1.03	0.07	0.04	–0.50	–0.31	–3.93	–0.26		
1975	1.37	0.76	–11.07	–0.90	0.68	0.35	–0.28	–0.18	–7.35	–0.48		
1976	0.48	0.27	–17.75	–1.45	0.63	0.33	–0.07	–0.04	–10.67	–0.69		
1977	0.21	0.12	–4.06	–0.33	–0.53	–0.28	0.56	0.35	–20.55	–1.33		
1978	0.77	0.43	0.26	0.02	0.07	0.04	–0.37	–0.23	–5.95	–0.39		
1979	0.29	0.16	–8.71	–0.71	0.22	0.11	–0.20	–0.13	–8.62	–0.56	0.00	–0.07
1980	1.52	0.84	0.91	0.07	–0.12	–0.06	–0.62	–0.39	–2.05	–0.13	–0.01	–1.75
1981	–0.52	–0.29	–4.13	–0.34	0.06	0.03	–0.22	–0.14	–8.36	–0.54	–0.01	–1.22
1982	0.23	0.13	–1.03	–0.08	–0.05	–0.03	–0.27	–0.17	–7.51	–0.49	0.00	–0.32
1983	0.55	0.30	–11.53	–0.94	0.43	0.22	–0.02	–0.01	–11.49	–0.75	0.00	–0.72
1984	0.39	0.22	–2.62	–0.21	–0.06	–0.03	–0.31	–0.20	–6.88	–0.45	–0.01	–0.90
1985	0.27	0.15	–7.33	–0.60	0.17	0.09	–0.28	–0.18	–7.29	–0.47	–0.01	–0.94
1986	0.25	0.14	7.36	0.60	–0.35	–0.18	–0.52	–0.33	–3.56	–0.23	0.00	–0.70
1987	0.84	0.46	–3.57	–0.29	0.04	0.02	–0.20	–0.13	–8.62	–0.56	0.00	–0.72
1988	0.95	0.53	–0.96	–0.08	–0.06	–0.03	–0.13	–0.08	–5.72	–0.37	–0.01	–2.28
1989	0.09	0.05	–6.61	–0.54	0.14	0.07	–0.18	–0.12	–10.99	–0.71	0.00	0.77
1990	–0.34	–0.19	–6.62	–0.54	0.14	0.07	–0.24	–0.16	–9.77	–0.63	–0.01	–0.95
1991	0.68	0.38	3.83	0.31	–0.22	–0.12	–0.23	–0.15	–3.95	–0.26	0.00	–0.81
1992	0.38	0.21	3.27	0.27	–0.20	–0.11	–1.04	–0.66	0.43	0.03	–0.01	–1.75
1993	–0.97	–0.54	–9.84	–0.80	0.26	0.13	–0.30	–0.19	–7.05	–0.46	0.00	–0.44
1994	–1.03	–0.57	–9.56	–0.78	0.25	0.13	–0.31	–0.20	–6.83	–0.44	–0.01	–2.29
1995	–0.96	–0.53	–4.29	–0.35	0.06	0.03	–0.49	–0.31	–4.02	–0.26	0.00	–0.45
1996	0.67	0.37	–21.21	–1.73	0.66	0.34	0.20	0.12	–14.85	–0.96	0.00	–0.49
1997	–1.21	–0.67	2.57	0.21	–0.18	–0.09	–0.17	–0.11	–9.14	–0.59		
1998	0.49	0.27	–5.47	–0.45	0.10	0.05	–0.23	–0.15	–8.11	–0.53		
1999	0.87	0.48	–1.23	–0.10	–0.05	–0.02	–0.51	–0.32	–3.68	–0.24		
2000									–3.07	–0.20		
2001									–10.35	–0.67		
2002									–7.88	–0.51		
2003									1.01	0.07		
2004												
Years	39	39	39	39	39	39	39	39	43	43	18	18
Ave. 1961–2003	0.54	0.30	–3.19	–0.26	0.02	0.01	–0.40	–0.25	–5.46	–0.35	–0.01	–0.89
St. deviation	0.82	0.45	7.31	0.60	0.29	0.15	0.34	0.22	5.20	0.34	0.00	0.76
St.error	0.13	0.07	1.17	0.10	0.05	0.02	0.06	0.03	0.79	0.05	0.00	0.18

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

System's #	18	18	19	19	20	20	21	21	22	22
System's name	Axel Heiberg	Axel Heiberg	Devon i.c.	Devon i.c.	Melville Island	Melville Island	Coburg Island	Coburg Island	Baffin Island	Baffin Island
Area, km^2	11700	11700	16200	16200	160	160	225	225	37000	37000
Latitude	78–80N	78–80N	75–76N	75–76N	75.5N	75.5N	76N	76N	67–74N	67–74N
Longitude	87–93W	87–93W	80–83W	80–83W	115W	115W	79W	79W	65–80W	65–80W
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961	0.30	0.03	–3.19	–0.20					–4.07	–0.11
1962	–9.16	–0.78	–5.82	–0.36					–23.11	–0.62
1963	–1.79	–0.15	0.71	0.04	–0.02	–0.10			–1.64	–0.04
1964	4.08	0.35	2.03	0.13	0.05	0.29			1.87	0.05
1965	–0.05	0.00	1.04	0.06	0.02	0.10			2.22	0.06
1966	–0.23	–0.02	–2.19	–0.14	–0.02	–0.13			–4.78	–0.13
1967	1.44	0.12	–0.44	–0.03	0.03	0.16			–1.75	–0.05
1968	–4.77	–0.41	–2.84	–0.18	0.00	0.03			2.50	0.07
1969	0.89	0.08	–2.84	–0.18	0.00	0.03			1.13	0.03
1970	0.00	0.00	0.63	0.04	–0.04	–0.26			0.16	0.00
1971	–2.21	–0.19	–1.12	–0.07	–0.08	–0.47			–1.06	–0.03
1972	1.40	0.12	1.65	0.10	–0.06	–0.39			–5.46	–0.15
1973	2.26	0.19	–1.54	–0.10	–0.06	–0.39			9.78	0.26
1974	–0.53	–0.05	–1.25	–0.08	–0.04	–0.22	–0.10	–0.45	–17.61	–0.48
1975	3.02	0.26	–1.12	–0.07	–0.01	–0.07	–0.14	–0.61	–23.46	–0.63
1976	1.33	0.11	2.77	0.17	–0.01	–0.07			11.10	0.30
1977	–4.35	–0.37	–1.60	–0.10	–0.01	–0.07			–4.39	–0.12
1978	–1.56	–0.13	0.44	0.03	–0.01	–0.07			9.86	0.27
1979	–1.05	–0.09	0.63	0.04	–0.01	–0.07			6.41	0.17
1980	0.01	0.00	–0.92	–0.06	–0.01	–0.07			–0.19	–0.01
1981	0.01	0.00	–2.37	–0.15	–0.03	–0.16			–26.49	–0.72
1982	0.01	0.00	–1.54	–0.10	–0.05	–0.31			5.92	0.16
1983	–0.96	–0.08	1.70	0.11	–0.01	–0.05			–12.90	–0.35
1984	–0.63	–0.05	–0.50	–0.03	0.01	0.05			8.51	0.23
1985	–0.11	–0.01	–1.75	–0.11	–0.01	–0.04			–1.11	–0.03
1986	–3.04	–0.26	3.00	0.19	0.04	0.23			9.25	0.25
1987	–7.22	–0.62	0.71	0.04	0.00	0.00			–6.66	–0.18
1988	1.55	0.13	–3.50	–0.22	–0.09	–0.57			–10.73	–0.29
1989	0.36	0.03	–1.12	–0.07	–0.05	–0.32			10.73	0.29
1990	–5.21	–0.45	–2.69	–0.17	–0.04	–0.25			–7.77	–0.21
1991	–2.09	–0.18	–3.73	–0.23	0.03	0.21			–8.14	–0.22
1992	–3.41	–0.29	1.56	0.10	–0.05	–0.29			0.37	0.01
1993	–5.62	–0.48	–1.00	–0.06	–0.12	–0.74			–21.83	–0.59
1994	–3.64	–0.31	–0.52	–0.03	–0.02	–0.11			–7.40	–0.20
1995	–4.25	–0.36	–2.38	–0.15	–0.08	–0.47			2.22	0.06
1996	0.48	0.04	–1.30	–0.08	–0.03	–0.21			7.03	0.19
1997	–0.67	–0.06	–2.09	–0.13	0.00	0.01			–2.22	–0.06
1998	–2.64	–0.23	–4.47	–0.28	–0.12	–0.75			–3.70	–0.10
1999	–5.87	–0.50	–3.52	–0.22	–0.09	–0.54			–12.95	–0.35
2000	–4.72	–0.40	–5.18	–0.32	–0.14	–0.85			–18.13	–0.49
2001	–2.10	–0.18	–9.48	–0.59	–0.04	–0.26			0.37	0.01
2002	0.37	0.03			0.00	0.02			2.96	0.08
2003	–1.24	–0.11			0.00	0.02			–19.61	–0.53
2004										
Years	43	43	41	41	41	41	2	2	43	43
Ave. 1961–2003	–1.43	–0.12	–1.34	–0.08	–0.03	–0.18	–0.12	–0.53	–3.60	–0.10
St. deviation	2.80	0.24	2.45	0.15	0.04	0.27	0.03	0.11	10.08	0.27
St.error	0.43	0.04	0.38	0.02	0.01	0.04	0.02	0.08	1.54	0.04

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

System's #	23	23	24	24	25	25	26	26	27	27
System's name	Ellesmere Island	Ellesmere Isl.	Svalbard	Svalbard	Greenl. i.c.	Greenl. i.c.	Polar Ural	Polar Ural	Sev. Zemlya	Sev. Zemlya
Area, km^2	80500	80500	36612		70000	70000	29	29	18326	18326
Latitude	78–83N	78–83N	77–81N		60–85N	60–85N	68N	68N	78–81N	78–81N
Longitude	70–85W	70–85W	11–26E		20–70W	20–70W	65E	65E	95–105E	95–105E
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961	–17.73	–0.22	–14.40	–0.39	–16.17	–0.23	–0.01	–0.24	–2.41	–0.13
1962	–22.93	–0.28	–14.40	–0.39	–37.03	–0.53	0.00	–0.04	–6.25	–0.34
1963	9.33	0.12	–1.25	–0.03	–3.15	–0.05	–0.03	–1.11	0.00	0.00
1964	8.29	0.10	–1.25	–0.03	5.60	0.08	–0.03	–1.07	2.23	0.12
1965	16.10	0.20	2.70	0.07	5.60	0.08	–0.02	–0.57	1.57	0.09
1966	–10.90	–0.14	–4.71	–0.13	–9.31	–0.13	0.00	–0.07	–1.95	–0.11
1967	–7.24	–0.09	–6.05	–0.17	–4.27	–0.06	0.01	0.28	0.04	0.00
1968	–0.60	–0.01	–5.31	–0.14	–9.17	–0.13	0.07	2.28	–0.51	–0.03
1969	1.10	0.01	–11.10	–0.30	–13.30	–0.19	–0.02	–0.57	–0.50	–0.03
1970	1.11	0.01	–6.70	–0.18	–4.62	–0.07	0.00	0.10	–0.99	–0.05
1971	0.01	0.00	–6.53	–0.18	–13.65	–0.20	0.00	–0.16	–2.72	–0.15
1972	–8.45	–0.11	–3.33	–0.09	–3.29	–0.05	0.01	0.50	–1.92	–0.10
1973	11.71	0.15	–0.64	–0.02	0.91	0.01	0.01	0.28	–0.20	–0.01
1974	13.46	0.17	–11.92	–0.33	–14.21	–0.20	–0.02	–0.85	0.73	0.04
1975	11.11	0.14	–2.76	–0.08	–6.58	–0.09	0.02	0.71	–3.85	–0.21
1976	3.05	0.04	–5.39	–0.15	–2.73	–0.04	–0.04	–1.31	6.42	0.35
1977	–14.17	–0.18	–3.06	–0.08	–9.66	–0.14	–0.05	–1.64	2.75	0.15
1978	–14.17	–0.18	–9.12	–0.25	–9.94	–0.14	0.03	1.06	–9.72	–0.53
1979	–14.17	–0.18	–10.27	–0.28	–11.13	–0.16	–0.01	–0.28	–11.55	–0.63
1980	–11.22	–0.14	–7.84	–0.21	–9.94	–0.14	0.03	1.02	–2.93	–0.16
1981	–10.51	–0.13	–5.89	–0.16	–12.74	–0.18	–0.03	–1.06	4.77	0.26
1982	–11.13	–0.14	0.40	0.01	–2.73	–0.04			–1.44	–0.08
1983	2.00	0.02	–3.56	–0.10	–5.81	–0.08			–1.01	–0.06
1984	–1.71	–0.02	–1.05	–0.03	–0.98	–0.01			0.82	0.04
1985	–1.65	–0.02	–7.65	–0.21	–8.89	–0.13			–0.73	–0.04
1986	–3.19	–0.04	–4.77	–0.13	–3.36	–0.05			1.47	0.08
1987	–3.18	–0.04	3.11	0.08	–1.61	–0.02			–1.28	–0.07
1988	–3.18	–0.04	–2.52	–0.07	–7.91	–0.11			8.43	0.46
1989	–3.17	–0.04	–2.76	–0.08	–3.78	–0.05			0.00	0.00
1990	–3.16	–0.04	–5.23	–0.14	–11.90	–0.17			9.90	0.54
1991	–3.16	–0.04	3.26	0.09	–0.14	0.00			–1.19	–0.07
1992	–3.15	–0.04	1.13	0.03	–2.10	–0.03			–0.98	–0.05
1993	–12.98	–0.16	–6.50	–0.18	–18.83	–0.27			–7.26	–0.40
1994	–3.14	–0.04	3.19	0.09	–1.12	–0.02			–1.71	–0.09
1995	–3.13	–0.04	–4.36	–0.12	–10.85	–0.16			–2.72	–0.15
1996	–3.12	–0.04	2.82	0.08	2.80	0.04			–0.44	–0.02
1997	–3.11	–0.04	0.33	0.01	–2.10	–0.03			–0.31	–0.02
1998	–3.10	–0.04	–8.47	–0.23	–14.77	–0.21			–5.40	–0.29
1999	–11.63	–0.14	–2.84	–0.08	–16.66	–0.24			–0.90	–0.05
2000	–21.16	–0.26	1.11	0.03	–58.10	–0.83				
2001	–33.63	–0.42	–24.65	–0.67	–67.20	–0.96				
2002	–37.84	–0.47	–29.59	–0.81	–35.00	–0.50				
2003	–23.35	–0.29	–42.13	–1.15						
2004										
Years	43	43	43	43	42	42	21	21	39	39
Ave. 1961–2003	–5.76	–0.07	–6.05	–0.17	–10.71	–0.15	0.00	–0.13	–0.81	–0.04
St. deviation	11.42	0.14	8.75	0.24	14.62	0.21	0.03	0.93	4.10	0.22
St.error	1.74	0.02	1.33	0.04	2.26	0.03	0.01	0.20	0.66	0.04

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

System's #	28	28	29	30	30	31	31
System's name	Novaya Zemlya	Novaya Zemlya	Franz Josef Land	Brooks & Arctic Ocean	Brooks & Arctic Ocean	Alaska Range	Alaska Range
Area, km^2	23645	23645	13459	1563	1563	13900	13900
Latitude	76°N	76°N	80°06'N	68N	68N	62–63N	62–63N
Longitude	62°05'E	62°05'E	52°48'E	150–160W	150–160W	150–153W	150–153W
Notice		m/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961							
1962							
1963							
1964							
1965							
1966						–0.83	–0.06
1967						1.67	0.12
1968						–0.56	–0.04
1969	3.31	0.14		–0.70	–0.45	–12.79	–0.92
1970				–0.06	–0.04	6.39	0.46
1971				–0.19	–0.12	4.87	0.35
1972				–0.22	–0.14	–4.31	–0.31
1973						8.06	0.58
1974						–15.15	–1.09
1975						–3.20	–0.23
1976						–12.79	–0.92
1977						–2.92	–0.21
1978						–2.64	–0.19
1979						–7.37	–0.53
1980						–0.97	–0.07
1981						–1.51	–0.11
1982						–2.67	–0.19
1983						3.56	0.26
1984						–4.45	–0.32
1985						9.45	0.68
1986						–2.65	–0.19
1987						–2.40	–0.17
1988						2.51	0.18
1989						–9.73	–0.70
1990						–9.59	–0.69
1991						–0.97	–0.07
1992						–3.34	–0.24
1993				–0.36	–0.23	–23.21	–1.67
1994				–0.56	–0.36	–8.20	–0.59
1995				–0.40	–0.25	–9.73	–0.70
1996				0.02	0.01	–7.37	–0.53
1997				–0.33	–0.21	–23.49	–1.69
1998				–0.62	–0.40	–8.90	–0.64
1999				–0.40	–0.26	–15.43	–1.11
2000				–0.48	–0.31	–0.70	–0.05
2001						–9.45	–0.68
2002						–14.73	–1.06
2003						–0.28	–0.02
2004							
Years	1	1	0	12	12	38	38
Ave. 1961–2003	3.31	0.14	–0.07	–0.36	–0.23	–4.89	–0.35
St. deviation			calculated from volume	0.22	0.14	7.64	0.55
St.error			change 1953–93, Macheret	0.06	0.04	1.24	0.09

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

System's #	32	32	33	33	34	34	35	35	36	36
System's name	Kenai Mount.	Kenai Mount.	Chugach	Chugach	St. Elias	St. Elias	Coast	Coast	Rockies+Coast	Rockies+Coast
Area, km^2	4600	4600	21600	21600	11800	11800	10500	10500	38604	38604
Latitude	60–61N	60–61N	61–62N	61–62N	58–61N	58–61N	56–59.5N	56–59.5N	49–60N	49–60N
Longitude	145–148W	145–148W	146–149W	146–149W	134–142W	134–142W	132–135W	132–135W	116–130W	116–130W
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961					5.52	0.47	3.49	0.33	–13.81	–0.36
1962					–25.52	–2.16	1.53	0.15	–2.28	–0.06
1963					–10.04	–0.85	4.93	0.47	–26.83	–0.70
1964					–10.34	–0.88	3.93	0.37	–2.91	–0.08
1965	1.84	0.40			–7.00	–0.59	5.93	0.56	–19.31	–0.50
1966	–0.19	–0.04			–12.86	–1.09	11.85	1.13	–55.23	–1.43
1967	–5.24	–1.14			–10.84	–0.92	8.19	0.78	–11.05	–0.29
1968	–0.99	–0.22			0.30	0.03	0.76	0.07	–5.45	–0.14
1969	–2.53	–0.55			–2.42	–0.21	2.50	0.24	9.32	0.24
1970	7.08	1.54			–3.93	–0.33	4.73	0.45	11.99	0.31
1971	0.64	0.14			–16.76	–1.42	12.14	1.16	–10.30	–0.27
1972	–7.18	–1.56			–22.14	–1.88	7.85	0.75	31.76	0.82
1973	1.20	0.26			0.15	0.01	6.46	0.62	–20.46	–0.53
1974	–7.59	–1.65			–3.21	–0.27	4.25	0.40	–24.59	–0.64
1975	–1.01	–0.22			–4.65	–0.39	5.31	0.51	–30.87	–0.80
1976	–5.57	–1.21			2.84	0.24	5.95	0.57	–13.10	–0.34
1977	6.39	1.39			–25.46	–2.16	8.84	0.84	–15.14	–0.39
1978	2.12	0.46	7.78	0.36	–1.89	–0.16	6.80	0.65	–30.95	–0.80
1979	–7.27	–1.58			–11.29	–0.96	4.79	0.46	–11.19	–0.29
1980	10.67	2.32			–19.30	–1.64	3.09	0.29	7.43	0.19
1981	7.45	1.62			–15.84	–1.34	1.36	0.13	–40.41	–1.05
1982	–1.52	–0.33			–13.59	–1.15	5.55	0.53	–27.15	–0.70
1983	0.51	0.11			–14.48	–1.23	1.12	0.11	–24.06	–0.62
1984	–1.70	–0.37			–7.82	–0.66	1.49	0.14	–20.93	–0.54
1985	1.89	0.41			–9.22	–0.78	–4.59	–0.44	–33.60	–0.87
1986	–1.15	–0.25			–16.24	–1.38	6.59	0.63	–32.79	–0.85
1987	6.12	1.33			–21.79	–1.85	14.54	1.38	–47.92	–1.24
1988	9.20	2.00			–6.30	–0.53	12.35	1.18	–46.36	–1.20
1989	–8.79	–1.91			–16.38	–1.39	1.62	0.15	–57.52	–1.49
1990	–11.22	–2.44			0.22	0.02	9.76	0.93	–56.20	–1.46
1991	–2.76	–0.60			4.12	0.35	–1.80	–0.17	–31.51	–0.82
1992	–0.97	–0.21			–20.46	–1.73	–0.69	–0.07	2.34	0.06
1993	–2.62	–0.57			–6.36	–0.54	5.56	0.53	–32.58	–0.84
1994	–3.17	–0.69			0.33	0.03	3.17	0.30	–88.89	–2.30
1995	–1.84	–0.40			5.56	0.47	0.43	0.04	–0.57	–0.01
1996	–6.95	–1.51			–18.34	–1.55	2.31	0.22	4.84	0.13
1997	–7.91	–1.72			–19.41	–1.65	–2.40	–0.23	–27.92	–0.72
1998	0.46	0.10			–14.46	–1.23	–4.71	–0.45	31.08	0.81
1999	–4.05	–0.88			–37.09	–3.14	–6.68	–0.64	5.02	0.13
2000	–4.14	–0.90			–34.81	–2.95	–5.17	–0.49	24.11	0.62
2001	2.07	0.45			–10.05	–0.85	–1.09	–0.10	–33.49	–0.87
2002	–3.17	–0.69			–24.70	–2.09	8.61	0.82	–20.69	–0.54
2003	–0.92	–0.20			–11.39	–0.97	–1.09	–0.10	–50.95	–1.32
2004										
Years	39	39	1	1	43	43	43	43	43	43
Ave. 1961–2003	–1.10	–0.24	7.78	0.36	–11.33	–0.96	3.71	0.35	–19.51	–0.51
St. deviation	5.07	1.10			10.21	0.87	4.91	0.47	24.87	0.64
St.error	0.81	0.18			1.56	0.13	0.75	0.07	3.79	0.10

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

System's #	37	37	38	38	39	39	40	40	41	41
System's name	Labrador	Labrador	Olympic	Olympic	N.Cascades	N.Cascades	M and S.Rockies	M and S.Rockies	Sierra Nevada	Sierra Nevada
Area, km^2	56	56	46	46	266	266	76	76	56	56
Latitude	59N	59N	48N		48.5N	48.5N	40–43N	40–43N	38N	38N
Longitude	65W	65W	123W		121W	121W	105–109W	105–109W	119W	119W
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961			0.02	0.47	–0.29	–1.10	–0.13	–1.74		
1962			0.01	0.21	0.05	0.20	–0.14	–1.81		
1963			–0.03	–0.58	–0.35	–1.30	–0.20	–2.68		
1964			0.03	0.63	0.32	1.20	–0.04	–0.50		
1965			–0.03	–0.56	–0.02	–0.09	0.01	0.16		
1966			0.02	0.34	–0.23	–0.85	–0.10	–1.32		
1967			0.02	0.34	–0.25	–0.94	–0.01	–0.09	0.07	1.21
1968			0.00	0.03	–0.28	–1.05	–0.08	–1.04	–0.04	–0.76
1969			0.03	0.71	–0.05	–0.17	0.01	0.10	0.04	0.70
1970			–0.02	–0.39	–0.23	–0.85	0.03	0.40		
1971			0.05	1.15	0.16	0.60	0.09	1.24		
1972			0.02	0.40	0.39	1.45	–0.05	–0.70		
1973			–0.01	–0.14	–0.28	–1.04	0.02	0.20		
1974			0.09	2.00	0.23	0.85	0.02	0.28		
1975			0.03	0.67	–0.02	–0.09	0.02	0.27		
1976			0.07	1.42	0.23	0.88	–0.01	–0.15		
1977			–0.06	–1.24	–0.35	–1.30	–0.09	–1.12		
1978			0.02	0.51	–0.10	–0.38	–0.03	–0.42		
1979			–0.05	–1.15	–0.42	–1.56	–0.13	–1.77		
1980			–0.07	–1.61	–0.29	–1.09	–0.07	–0.90		
1981			–0.06	–1.31	–0.22	–0.84	–0.02	–0.26		
1982	0.00	–0.02	0.03	0.75	0.02	0.08	–0.06	–0.76		
1983	0.00	0.05	0.06	1.34	–0.21	–0.77	–0.03	–0.39		
1984	–0.01	–0.26	0.02	0.49	0.08	0.30	0.02	0.25		
1985			0.02	0.42	–0.14	–0.54	–0.02	–0.25		
1986			–0.04	–0.92	–0.08	–0.29	0.01	0.13		
1987			–0.04	–0.79	–0.31	–1.15	–0.08	–0.99		
1988			0.01	0.22	–0.11	–0.40	–0.11	–1.49		
1989			–0.03	–0.64	–0.10	–0.36	0.01	0.09		
1990			–0.05	–1.18	–0.14	–0.52	–0.09	–1.24		
1991			–0.04	–0.79	0.06	0.24	–0.11	–1.42		
1992			–0.05	–1.18	–0.45	–1.71	0.01	0.16		
1993			–0.06	–1.35	–0.24	–0.91	0.08	1.02		
1994			–0.08	–1.75	–0.25	–0.92	–0.07	–0.95		
1995			0.00	–0.01	–0.07	–0.25	–0.06	–0.74		
1996			–0.04	–0.79	0.05	0.20	–0.04	–0.56		
1997			–0.02	–0.49	0.15	0.56	0.00	0.03		
1998			–0.05	–1.11	–0.43	–1.62	–0.07	–0.96		
1999			0.05	1.09	0.41	1.54	–0.06	–0.81		
2000					0.07	0.25	–0.05	–0.70		
2001					–0.43	–1.60	–0.17	–2.28		
2002					0.06	0.21	–0.25	–3.26		
2003					–0.40	–1.51	–0.11	–1.40		
2004					–0.40	–1.49	–0.06	–0.77		
Years	3	3	39	39	43	43	43	43	3	3
Ave. 1961–2003	0.00	–0.08	–0.01	–0.12	–0.11	–0.41	–0.05	–0.66	0.02	0.38
St. deviation	0.01	0.16	0.04	0.94	0.23	0.86	0.07	0.92	0.06	1.02
St.error	0.01	0.09	0.01	0.15	0.03	0.13	0.01	0.14	0.03	0.59

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

System's #	42	42	43	43	44	44
System's name	Mexico	Mexico	S. Am., 0.0 S–20.0 S	S. Am., 0.0 S–20.0 S	S.Am. 20S to N.Patag.	S.Am. 20S to N.Patag.
Area, km^2	11	11	2560	2560	2128	2128
Latitude	19N	19N	02–20S	02–20S	20–45S	20–45S
Longitude	98W	98W	69–80W	69–80W	73–75W	73–75W
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972						
1973						
1974						
1975						
1976					–1.96	–0.92
1977					–2.77	–1.30
1978					0.38	0.18
1979					1.43	0.67
1980					1.41	0.66
1981					–0.61	–0.29
1982					–3.47	–1.63
1983					5.32	2.50
1984					–1.41	–0.66
1985					0.56	0.26
1986					0.53	0.25
1987					1.01	0.48
1988					2.47	1.16
1989					–2.20	–1.03
1990					–2.27	–1.07
1991					–1.94	–0.91
1992			–3.80	–1.49	2.41	1.13
1993			0.43	0.17	–0.81	–0.38
1994			–1.92	–0.75	–1.45	–0.68
1995			–3.49	–1.36	–1.84	–0.87
1996			–1.71	–0.67	–2.89	–1.36
1997			1.35	0.53	–5.56	–2.61
1998	–0.03	–2.94	–5.14	–2.01	6.15	2.89
1999			–1.15	–0.45	–9.07	–4.26
2000			0.34	0.13	–0.01	0.00
2001			0.29	0.11	–1.15	–0.54
2002			–2.12	–0.83	–0.25	–0.12
2003			–0.72	–0.28	–0.05	–0.02
2004						
Years	1	1	12	12	28	28
Ave. 1961–2003	–0.03	–2.94	–1.47	–0.58	–0.64	–0.30
St. deviation			1.96	0.77	2.99	1.40
St.error			0.57	0.22	0.56	0.27

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

System's #	45	45	46	46	47	47	48	48
System's name	S. and N. Patag.	S. and N. Patag.	Irian Jaya	Irian Jaya	N.Zealand	N.Zealand	Sub–Ant. Islands	Sub–Ant. Islands
Area, km^2	17500	17500	3	3	1160	1160	7000	7000
Latitude	46–54S	46–54S	4S	4S	43–44S	43–44S	54–55S	54–55S
Longitude			137E	137E	170–171E	170–171E	36–37W	36–37W
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961								
1962								
1963								
1964								
1965								
1966								
1967							0.61	0.09
1968								
1969							–0.07	–0.01
1970					–2.45	–2.11	–2.10	–0.30
1971					–1.53	–1.32	–3.92	–0.56
1972					–1.93	–1.66		
1973			0.00	–0.38	–2.01	–1.73		
1974					–4.04	–3.48		
1975					–4.64	–4.00		
1976								
1977								
1978								
1979								
1980								
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990								
1991								
1992								
1993								
1994								
1995								
1996	1.23	0.07						
1997	11.38	0.65						
1998	–4.90	–0.28						
1999								
2000								
2001								
2002								
2003								
2004								
Years	3	3	1	1	6	6	4	4
Ave. 1961–2003	2.57	0.15	–0.0011	–0.38	–2.76	–2.38	–1.37	–0.20
St. deviation	8.22	0.47			1.27	1.09	2.05	0.29
St.error	4.75	0.27			0.52	0.45	1.03	0.15

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

System's #	49	49	49	49
System's name	Antarctic i.c.	Antarctic i.c.	Antarctic i.c.	Antarctic i.c.
Area, km^2	169000	169000	169000	calculated
Latitude			60–150W	from
Longitude			65–72S	NH Arctic
Notice	km^3/yr	m/yr	km^3/yr	m/yr
1961			–35.12	–0.21
1962			–78.22	–0.46
1963			3.77	0.02
1964			14.85	0.09
1965			22.79	0.13
1966	–103.09	–0.61	–22.75	–0.13
1967			–9.41	–0.06
1968			–13.87	–0.08
1969			–25.80	–0.15
1970			4.40	0.03
1971	–14.53	–0.09	–6.74	–0.04
1972	–2.20	–0.01	–6.22	–0.04
1973	–8.66	–0.05	10.54	0.06
1974	–4.47	–0.03	4.42	0.03
1975	1.16	0.01	–7.78	–0.05
1976			19.25	0.11
1977			–23.73	–0.14
1978			–9.14	–0.05
1979			–9.58	–0.06
1980			–16.61	–0.10
1981			–30.24	–0.18
1982			–19.91	–0.12
1983			4.09	0.02
1984			–3.26	–0.02
1985			–13.59	–0.08
1986			30.48	0.18
1987			3.13	0.02
1988			–37.99	–0.22
1989			–10.04	–0.06
1990			–29.89	–0.18
1991			–35.97	–0.21
1992			11.86	0.07
1993			–20.31	–0.12
1994			–8.17	–0.05
1995			–25.95	–0.15
1996			–11.78	–0.07
1997			–20.18	–0.12
1998			–48.13	–0.28
1999			–40.65	–0.24
2000			–98.56	–0.58
2001			–10.56	–0.06
2002			–89.76	–0.53
2003			–26.40	–0.16
2004				
Years	6	6	43	43
Ave. 1961–2003	–21.97	–0.13	–16.67	–0.10
St. deviation	40.11	0.24	26.67	0.16
St.error	16.38	0.10	4.07	0.02

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

REGIONAL SYSTEMS	R1	R1	R2	R2	R3	R3
system #	Europe	include primary systems	W.USA+ Canada	include primary systems	Canadian Arct.	include primary systems
Area, km^2	17286	1,2,3,4, 5 (W. part)	39194	36, 37, 38, 39, 40, 41	151800	18, 19, 20, 21,22, 23
Latitude			105–130W		69–92W	
Longitude			35–60N		70–82N	
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961	–4.78	–0.28	–14.32	–0.37	–31.38	–0.21
1962	5.20	0.30	–2.16	–0.06	–70.04	–0.46
1963	–9.43	–0.55	–27.54	–0.70	3.38	0.02
1964	–4.20	–0.24	–2.25	–0.06	13.31	0.09
1965	9.90	0.57	–19.40	–0.49	20.37	0.13
1966	–3.85	–0.22	–55.62	–1.42	–20.32	–0.13
1967	11.91	0.69	–11.26	–0.29	–8.40	–0.06
1968	6.45	0.37	–5.87	–0.15	–12.38	–0.08
1969	–10.93	–0.63	9.36	0.24	–22.90	–0.15
1970	–6.01	–0.35	11.62	0.30	3.93	0.03
1971	0.39	0.02	–9.96	–0.25	–6.01	–0.04
1972	–4.79	–0.28	32.36	0.83	–5.60	–0.04
1973	3.80	0.22	–20.88	–0.53	9.40	0.06
1974	1.44	0.08	–23.99	–0.61	3.92	0.03
1975	6.92	0.40	–30.86	–0.79	–6.99	–0.05
1976	3.71	0.21	–12.53	–0.32	17.16	0.11
1977	4.56	0.26	–15.91	–0.41	–21.27	–0.14
1978	7.83	0.45	–31.10	–0.79	–8.22	–0.05
1979	3.65	0.21	–12.08	–0.31	–8.62	–0.06
1980	–0.80	–0.05	6.74	0.17	–14.90	–0.10
1981	7.60	0.44	–40.95	–1.04	–27.10	–0.18
1982	–1.10	–0.06	–27.04	–0.69	–17.86	–0.12
1983	3.47	0.20	–24.34	–0.62	3.63	0.02
1984	7.99	0.46	–20.73	–0.53	–2.94	–0.02
1985	–5.56	–0.32	–33.83	–0.86	–12.16	–0.08
1986	–5.29	–0.31	–33.01	–0.84	27.07	0.18
1987	7.63	0.44	–48.56	–1.24	2.73	0.02
1988	–10.36	–0.60	–46.55	–1.19	–33.87	–0.22
1989	13.85	0.80	–57.76	–1.47	–9.00	–0.06
1990	–1.14	–0.07	–56.56	–1.44	–26.67	–0.18
1991	–13.41	–0.78	–31.46	–0.80	–32.08	–0.21
1992	15.07	0.87	1.38	0.04	10.52	0.07
1993	15.54	0.90	–33.15	–0.85	–18.14	–0.12
1994	0.69	0.04	–89.51	–2.28	–7.33	–0.05
1995	–1.99	–0.12	–0.70	–0.02	–23.17	–0.15
1996	–6.34	–0.37	4.87	0.12	–10.55	–0.07
1997	–12.79	–0.74	–27.68	–0.71	–18.03	–0.12
1998	–12.19	–0.71	30.17	0.77	–42.95	–0.28
1999	–7.49	–0.43	5.89	0.15	–36.41	–0.24
2000	–11.99	–0.69	24.28	0.62	–51.45	–0.34
2001	–9.02	–0.52	–34.30	–0.88	–46.81	–0.31
2002	–7.25	–0.42	–21.02	–0.54	–40.48	–0.27
2003	–19.08	–1.10	–51.78	–1.32	–51.86	–0.34
2004			–52.11	–1.33		
Years	43	43	43	43	43	43
Ave. 1961–2003	–0.75	–0.04	–20.46	–0.52	–14.66	–0.10
St. deviation	8.50	0.49	25.18	0.64	20.98	0.14
St.error	1.30	0.08	3.84	0.10	3.20	0.02

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

REGIONAL SYSTEM	R4	R4	R5	R5	R6	R6
system #	Russian Arctic	include primary systems	Svalbard	include primary systems	Greenland ice caps	include primary systems
Area, km^2	56100	26, 27, 28, 29	36612	24	70000	25
Latitude	45–105E		77–81N		20–70W	
Longitude	75–81N		11–26E		60–85N	
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961	–7.37	–0.13	–14.40	–0.39	–16.17	–0.23
1962	–19.14	–0.34	–14.40	–0.39	–37.03	–0.53
1963	–0.01	0.00	–1.25	–0.03	–3.15	–0.05
1964	6.82	0.12	–1.25	–0.03	5.60	0.08
1965	4.80	0.09	2.70	0.07	5.60	0.08
1966	–5.97	–0.11	–4.71	–0.13	–9.31	–0.13
1967	0.11	0.00	–6.05	–0.17	–4.27	–0.06
1968	–1.55	–0.03	–5.31	–0.14	–9.17	–0.13
1969	–1.54	–0.03	–11.10	–0.30	–13.30	–0.19
1970	–3.02	–0.05	–6.70	–0.18	–4.62	–0.07
1971	–8.33	–0.15	–6.53	–0.18	–13.65	–0.20
1972	–5.89	–0.10	–3.33	–0.09	–3.29	–0.05
1973	–0.60	–0.01	–0.64	–0.02	0.91	0.01
1974	2.25	0.04	–11.92	–0.33	–14.21	–0.20
1975	–11.79	–0.21	–2.76	–0.08	–6.58	–0.09
1976	19.64	0.35	–5.39	–0.15	–2.73	–0.04
1977	8.42	0.15	–3.06	–0.08	–9.66	–0.14
1978	–29.75	–0.53	–9.12	–0.25	–9.94	–0.14
1979	–35.36	–0.63	–10.27	–0.28	–11.13	–0.16
1980	–8.98	–0.16	–7.84	–0.21	–9.94	–0.14
1981	14.59	0.26	–5.89	–0.16	–12.74	–0.18
1982	–4.41	–0.08	0.40	0.01	–2.73	–0.04
1983	–3.10	–0.06	–3.56	–0.10	–5.81	–0.08
1984	2.50	0.04	–1.05	–0.03	–0.98	–0.01
1985	–2.23	–0.04	–7.65	–0.21	–8.89	–0.13
1986	4.49	0.08	–4.77	–0.13	–3.36	–0.05
1987	–3.93	–0.07	3.11	0.08	–1.61	–0.02
1988	25.82	0.46	–2.52	–0.07	–7.91	–0.11
1989	0.00	0.00	–2.76	–0.08	–3.78	–0.05
1990	30.31	0.54	–5.23	–0.14	–11.90	–0.17
1991	–3.65	–0.07	3.26	0.09	–0.14	0.00
1992	–3.01	–0.05	1.13	0.03	–2.10	–0.03
1993	–22.22	–0.40	–6.50	–0.18	–18.83	–0.27
1994	–5.24	–0.09	3.19	0.09	–1.12	–0.02
1995	–8.32	–0.15	–4.36	–0.12	–10.85	–0.16
1996	–1.35	–0.02	2.82	0.08	2.80	0.04
1997	–0.96	–0.02	0.33	0.01	–2.10	–0.03
1998	–16.54	–0.29	–8.47	–0.23	–14.77	–0.21
1999	–2.77	–0.05	–2.84	–0.08	–16.66	–0.24
2000			1.11	0.03	–58.10	–0.83
2001			–24.65	–0.67	–67.20	–0.96
2002			–29.59	–0.81	–35.00	–0.50
2003			–42.13	–1.15		
2004						
Years	39	39	43	43	42	42
Ave. 1961–2003	–2.49	–0.04	–6.05	–0.17	–10.71	–0.15
St. deviation	12.55	0.22	8.75	0.24	14.62	0.21
St.error	2.01	0.04	1.33	0.04	2.26	0.03

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

REGIONAL SYSTEM	R7	R7	R8	R8	R9	R9
system #	Alaska and Coast Mtns	include primary systems	HM Asia	include primary systems	Siberia	include primary systems
Area, km^2	90000	31, 32, 33, 34, 35	116180	9,10,11,12,13,14,15,16	3472	6, 8
Latitude	131–152W		67–95E		51–67N	
Longitude	51–64N		37–43N		70–150E	
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961	–43.90	–0.49	–31.14	–0.27	–2.57	–0.74
1962	–47.88	–0.53	–4.50	–0.04	–1.21	–0.35
1963	–24.72	–0.27	–2.91	–0.03	–1.17	–0.34
1964	–43.18	–0.48	–17.98	–0.15	–0.75	–0.22
1965	–39.29	–0.44	–17.73	–0.15	–1.66	–0.48
1966	3.16	0.04	–14.08	–0.12	–1.23	–0.35
1967	–9.64	–0.11	–37.56	–0.32	0.92	0.26
1968	–10.73	–0.12	7.59	0.07	–0.18	–0.05
1969	–63.94	–0.71	–15.44	–0.13	0.86	0.25
1970	–101.55	–1.13	–34.77	–0.30	0.42	0.12
1971	16.02	0.18	–8.38	–0.07	1.26	0.36
1972	–8.60	–0.10	–39.36	–0.34	0.24	0.07
1973	–12.47	–0.14	–30.26	–0.26	0.52	0.15
1974	26.89	0.30	–42.23	–0.36	–1.62	–0.47
1975	–118.36	–1.32	–41.74	–0.36	0.66	0.19
1976	5.32	0.06	–64.78	–0.56	3.13	0.90
1977	–50.07	–0.56	–59.85	–0.52	–0.54	–0.16
1978	–63.54	–0.71	–22.01	–0.19	–2.15	–0.62
1979	–83.96	–0.93	–47.41	–0.41	–1.64	–0.47
1980	–58.80	–0.65	–21.06	–0.18	0.28	0.08
1981	–62.51	–0.69	–38.00	–0.33	–2.07	–0.60
1982	–38.86	–0.43	–17.44	–0.15	–0.99	–0.29
1983	–43.97	–0.49	–43.33	–0.37	–0.02	–0.01
1984	–67.04	–0.74	–19.76	–0.17	0.84	0.24
1985	–87.75	–0.98	–30.39	–0.26	2.75	0.79
1986	–6.29	–0.07	–18.22	–0.16	–1.76	–0.51
1987	–84.33	–0.94	–39.59	–0.34	0.11	0.03
1988	24.72	0.27	–20.51	–0.18	–1.61	–0.46
1989	11.63	0.13	–44.79	–0.39	–0.69	–0.20
1990	–112.99	–1.26	–34.23	–0.29	–1.34	–0.39
1991	–22.16	–0.25	–14.77	–0.13	0.23	0.07
1992	8.12	0.09	9.22	0.08	–0.61	–0.18
1993	29.61	0.33	–63.53	–0.55	0.24	0.07
1994	–95.55	–1.06	–56.80	–0.49	–1.39	–0.40
1995	–112.47	–1.25	3.37	0.03	–0.15	–0.04
1996	–90.62	–1.01	–64.92	–0.56	0.87	0.25
1997	–220.36	–2.45	–33.12	–0.29	2.18	0.63
1998	–192.27	–2.14	–55.95	–0.48	–3.98	–1.15
1999	–72.30	–0.80	–25.23	–0.22	–0.44	–0.13
2000	–176.68	–1.96	–36.12	–0.31	–0.90	–0.26
2001	–85.09	–0.95	–79.39	–0.68	–0.76	–0.22
2002	–58.50	–0.65	–60.45	–0.52	–1.30	–0.38
2003	–27.76	–0.31	7.78	0.07	–1.34	–0.38
2004						
Years	43	43	43	43	43	43
Ave. 1961–2003	–53.78	–0.60	–30.74	–0.26	–0.43	–0.12
St. deviation	56.86	0.63	21.58	0.19	1.39	0.40
St.error	8.67	0.10	3.29	0.03	0.23	0.06

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

REGIONAL SYSTEM	R10	R10	R11	R11	R12	R12
system #	N.&S. Patagonia (calculated)	include primary systems	S.Am., outside Patag.	include primary systems	sub Antarctic i.c.	include primary systems
Area, km^2	19900	44 plus Tierra del Fuego	4688	43, 44	176000	48+49
Latitude	68–70W		70–80W		(observations)	(observations)
Longitude	46–54S		0–45S			
Notice	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961	–13.64	–0.69	0.04	0.01		
1962	–14.88	–0.75	0.04	0.01		
1963	–7.68	–0.39	0.04	0.01		
1964	–13.42	–0.67	0.04	0.01		
1965	–12.21	–0.61	0.04	0.01		
1966	0.98	0.05	0.04	0.01	–107.36	–0.61
1967	–2.99	–0.15	0.04	0.01		
1968	–3.33	–0.17	0.04	0.01		
1969	–19.86	–1.00	0.04	0.01		
1970	–31.55	–1.59	0.04	0.01		
1971	4.98	0.25	0.04	0.01	–15.14	–0.09
1972	–2.67	–0.13	0.04	0.01	–2.29	–0.01
1973	–3.87	–0.19	0.04	0.01	–9.02	–0.05
1974	8.35	0.42	0.04	0.01	–4.66	–0.03
1975	–36.77	–1.85	0.04	0.01	1.21	0.01
1976	1.65	0.08	–1.96	–0.42		
1977	–15.55	–0.78	–2.77	–0.59		
1978	–19.74	–0.99	0.38	0.08		
1979	–26.08	–1.31	1.43	0.30		
1980	–18.27	–0.92	1.41	0.30		
1981	–19.42	–0.98	–0.61	–0.13		
1982	–12.07	–0.61	–3.47	–0.74		
1983	–13.66	–0.69	5.32	1.14		
1984	–20.83	–1.05	–1.41	–0.30		
1985	–27.26	–1.37	0.56	0.12		
1986	–1.95	–0.10	0.53	0.11		
1987	–26.20	–1.32	1.01	0.22		
1988	7.68	0.39	2.47	0.53		
1989	3.61	0.18	–2.20	–0.47		
1990	–35.10	–1.76	–2.27	–0.48		
1991	–6.89	–0.35	–1.94	–0.41		
1992	2.52	0.13	–0.70	–0.15		
1993	9.20	0.46	–0.19	–0.04		
1994	–29.68	–1.49	–1.69	–0.36		
1995	–34.94	–1.76	–2.67	–0.57		
1996	–28.15	–1.41	–2.30	–0.49		
1997	–68.46	–3.44	–2.11	–0.45		
1998	–59.73	–3.00	0.50	0.11		
1999	–22.46	–1.13	–5.11	–1.09		
2000	–54.89	–2.76	0.33	0.07	–98.56	–0.56
2001	–26.43	–1.33	–0.86	–0.18	–10.56	–0.06
2002	–18.17	–0.91	–2.37	–0.51	–89.76	–0.51
2003			–0.77	–0.17	–26.40	–0.15
2004						
Years	42	42.00	43	43	10	10
Ave. 1961–2003	–16.90	–0.85	–0.49	–0.10	–36.25	–0.21
St. deviation	17.83	0.90	1.71	0.37	43.84	0.25
St.error			0.26	0.06	13.86	0.08

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

CONTINENTAL	Europe	Europe	Entire Arctic	Entire Arctic	Entire Asia	Entire Asia
SIZE		include primary systems		include primary systems		include primary systems
SYSTEMS	17286	1,2,3,4, 5 (W. part)	315000	18–30	121575	from 5 (E.part)– 16
and GLOBAL						
		May15.05 update				
	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961	–4.78	–0.28	–108.38	–0.34	–32.35	–0.27
1962	5.20	0.30	–173.25	–0.55	–4.68	–0.04
1963	–9.43	–0.55	–0.42	0.00	–3.03	–0.02
1964	–4.20	–0.24	20.07	0.06	–18.68	–0.15
1965	9.90	0.57	43.70	0.14	–18.41	–0.15
1966	–3.85	–0.22	–52.88	–0.17	–14.63	–0.12
1967	11.91	0.69	–35.71	–0.11	–39.01	–0.32
1968	6.45	0.37	–39.86	–0.13	7.88	0.06
1969	–10.93	–0.63	–78.17	–0.25	–16.04	–0.13
1970	–6.01	–0.35	–24.49	–0.08	–36.12	–0.30
1971	0.39	0.02	–42.90	–0.14	–8.70	–0.07
1972	–4.79	–0.28	–27.00	–0.09	–40.88	–0.34
1973	3.80	0.22	9.84	0.03	–31.43	–0.26
1974	1.44	0.08	–40.13	–0.13	–43.86	–0.36
1975	6.92	0.40	–32.41	–0.10	–43.36	–0.36
1976	3.71	0.21	21.69	0.07	–67.29	–0.55
1977	4.56	0.26	–33.12	–0.11	–62.17	–0.51
1978	7.83	0.45	–77.56	–0.25	–22.86	–0.19
1979	3.65	0.21	–88.35	–0.28	–49.24	–0.41
1980	–0.80	–0.05	–60.86	–0.19	–21.87	–0.18
1981	7.60	0.44	–46.31	–0.15	–39.47	–0.32
1982	–1.10	–0.06	–27.32	–0.09	–18.12	–0.15
1983	3.47	0.20	–12.33	–0.04	–45.01	–0.37
1984	7.99	0.46	–5.76	–0.02	–20.53	–0.17
1985	–5.56	–0.32	–49.65	–0.16	–31.57	–0.26
1986	–5.29	–0.31	22.90	0.07	–18.92	–0.16
1987	7.63	0.44	12.39	0.04	–41.12	–0.34
1988	–10.36	–0.60	–31.07	–0.10	–21.30	–0.18
1989	13.85	0.80	–23.46	–0.07	–46.53	–0.38
1990	–1.14	–0.07	–27.48	–0.09	–35.55	–0.29
1991	–13.41	–0.78	–34.90	–0.11	–15.34	–0.13
1992	15.07	0.87	16.12	0.05	9.58	0.08
1993	15.54	0.90	–73.67	–0.23	–66.00	–0.54
1994	0.69	0.04	–3.07	–0.01	–59.00	–0.49
1995	–1.99	–0.12	–58.17	–0.18	3.50	0.03
1996	–6.34	–0.37	–4.55	–0.01	–67.44	–0.55
1997	–12.79	–0.74	–24.83	–0.08	–34.41	–0.28
1998	–12.19	–0.71	–110.43	–0.35	–58.12	–0.48
1999	–7.49	–0.43	–64.64	–0.21	–26.21	–0.22
2000	–11.99	–0.69	–132.19	–0.42	–37.52	–0.31
2001	–9.02	–0.52	–169.03	–0.54	–82.47	–0.68
2002	–7.25	–0.42	–128.08	–0.41	–62.79	–0.52
2003	–19.08	–1.10	–114.57	–0.36	8.08	0.07
2004						
Years	43	43	43	43	43	43
Ave. 1961–2003	–0.75	–0.04	–44.43	–0.14	–31.93	–0.26
St. deviation	8.50	0.49	50.56	0.16	22.41	0.18
St.error	1.30	0.08	7.71	0.02	3.42	0.03

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

CONTINENTAL	N.America	N.America	S. America	S. America	sub+Ant.i.c.	sub+Ant.i.c.
SIZE	continental part	include primary systems		include primary systems		include primary systems
SYSTEMS	129300	31–42	25000	43–45	176000	systems 48+49
and GLOBAL						
	km^3/yr	m/yr	km^3/yr	m/yr	km^3/yr	m/yr
1961	–58.26	–0.45	–13.60	–0.54	–36.57	–0.21
1962	–50.04	–0.39	–14.84	–0.59	–81.46	–0.46
1963	–52.26	–0.40	–7.64	–0.31	3.92	0.02
1964	–45.43	–0.35	–13.38	–0.54	15.47	0.09
1965	–58.69	–0.45	–12.17	–0.49	23.74	0.13
1966	–52.46	–0.41	1.02	0.04	–23.70	–0.13
1967	–20.90	–0.16	–2.96	–0.12	–9.80	–0.06
1968	–16.60	–0.13	–3.30	–0.13	–14.45	–0.08
1969	–54.59	–0.42	–19.83	–0.79	–26.87	–0.15
1970	–89.93	–0.70	–31.51	–1.26	4.58	0.03
1971	6.06	0.05	5.01	0.20	–7.01	–0.04
1972	23.76	0.18	–2.63	–0.11	–6.48	–0.04
1973	–33.35	–0.26	–3.84	–0.15	10.98	0.06
1974	2.90	0.02	8.39	0.34	4.60	0.03
1975	–149.21	–1.15	–36.73	–1.47	–8.10	–0.05
1976	–7.21	–0.06	–0.30	–0.01	20.05	0.11
1977	–65.98	–0.51	–18.32	–0.73	–24.71	–0.14
1978	–94.64	–0.73	–19.36	–0.77	–9.52	–0.05
1979	–96.04	–0.74	–24.66	–0.99	–9.98	–0.06
1980	–52.06	–0.40	–16.86	–0.67	–17.30	–0.10
1981	–103.45	–0.80	–20.03	–0.80	–31.50	–0.18
1982	–65.91	–0.51	–15.54	–0.62	–20.74	–0.12
1983	–68.30	–0.53	–8.34	–0.33	4.26	0.02
1984	–87.78	–0.68	–22.23	–0.89	–3.40	–0.02
1985	–121.59	–0.94	–26.70	–1.07	–14.15	–0.08
1986	–39.30	–0.30	–1.42	–0.06	31.75	0.18
1987	–132.89	–1.03	–25.19	–1.01	3.26	0.02
1988	–21.83	–0.17	10.14	0.41	–39.56	–0.22
1989	–46.13	–0.36	1.42	0.06	–10.46	–0.06
1990	–169.56	–1.31	–37.37	–1.49	–31.13	–0.18
1991	–53.62	–0.41	–8.82	–0.35	–37.46	–0.21
1992	9.50	0.07	1.83	0.07	12.35	0.07
1993	–3.54	–0.03	9.01	0.36	–21.15	–0.12
1994	–185.06	–1.43	–31.37	–1.25	–8.51	–0.05
1995	–113.17	–0.88	–37.61	–1.50	–27.03	–0.15
1996	–85.75	–0.66	–30.46	–1.22	–12.27	–0.07
1997	–248.04	–1.92	–70.56	–2.82	–21.01	–0.12
1998	–162.10	–1.25	–59.22	–2.37	–50.12	–0.28
1999	–66.41	–0.51	–27.57	–1.10	–42.34	–0.24
2000	–152.41	–1.18	–54.60	–2.18	–98.56	–0.56
2001	–119.39	–0.92	–27.20	–1.09	–10.56	–0.06
2002	–79.52	–0.61	–20.80	–0.83	–89.76	–0.51
2003	–79.54	–0.62	–0.79	–0.03	–26.40	–0.15
2004	–82.06	–0.63				
Years	43	43	43	43	43	43
Ave. 1961–2003	–73.70	–0.57	–17.00	–0.68	–17.14	–0.10
St. deviation	56.69	0.44	18.12	0.72	27.24	0.15
St.error	8.64	0.07	2.76	0.11	4.15	0.02

Appendix 3. Glacier volume change (km^3/yr) and specific mass balance (m/yr) determined for primary glacier systems, larger regional systems, and continental-size systems, based on observational mass balance results (updated May 2005)

CONTINENTAL	Aggregate volume change	Cumulative	area weighted	area weighted	Contribution	Contribution
SIZE	all systems	all systems	all systems	all systems	to sea level	to sea level
SYSTEMS	area=785000	Global	Global	Global		cumulative
and GLOBAL						
		cumulative		cumulative		cumulative
	km^3/yr	km^3	m/yr	m	RSL, mm/yr	RSL, mm
1961	–254	–254	–0.32	–0.32	0.70	0.70
1962	–319	–574	–0.41	–0.73	0.88	1.58
1963	–69	–643	–0.09	–0.82	0.19	1.78
1964	–46	–689	–0.06	–0.88	0.13	1.90
1965	–12	–701	–0.02	–0.89	0.03	1.94
1966	–147	–847	–0.19	–1.08	0.41	2.34
1967	–97	–944	–0.12	–1.20	0.27	2.61
1968	–60	–1004	–0.08	–1.28	0.17	2.77
1969	–207	–1211	–0.26	–1.54	0.57	3.34
1970	–184	–1394	–0.23	–1.78	0.51	3.85
1971	–47	–1441	–0.06	–1.84	0.13	3.98
1972	–58	–1500	–0.07	–1.91	0.16	4.14
1973	–44	–1544	–0.06	–1.97	0.12	4.26
1974	–67	–1610	–0.08	–2.05	0.18	4.45
1975	–263	–1873	–0.34	–2.39	0.73	5.18
1976	–29	–1903	–0.04	–2.42	0.08	5.26
1977	–200	–2103	–0.25	–2.68	0.55	5.81
1978	–216	–2319	–0.28	–2.95	0.60	6.41
1979	–265	–2584	–0.34	–3.29	0.73	7.14
1980	–170	–2754	–0.22	–3.51	0.47	7.61
1981	–233	–2987	–0.30	–3.81	0.64	8.25
1982	–149	–3136	–0.19	–4.00	0.41	8.66
1983	–126	–3263	–0.16	–4.16	0.35	9.01
1984	–132	–3394	–0.17	–4.32	0.36	9.38
1985	–249	–3644	–0.32	–4.64	0.69	10.07
1986	–10	–3654	–0.01	–4.66	0.03	10.09
1987	–176	–3830	–0.22	–4.88	0.49	10.58
1988	–114	–3944	–0.15	–5.02	0.32	10.90
1989	–111	–4056	–0.14	–5.17	0.31	11.20
1990	–303	–4358	–0.39	–5.55	0.84	12.04
1991	–164	–4522	–0.21	–5.76	0.45	12.49
1992	65	–4458	0.08	–5.68	–0.18	12.31
1993	–140	–4598	–0.18	–5.86	0.39	12.70
1994	–287	–4884	–0.37	–6.22	0.79	13.49
1995	–235	–5119	–0.30	–6.52	0.65	14.14
1996	–207	–5326	–0.26	–6.78	0.57	14.71
1997	–412	–5738	–0.52	–7.31	1.14	15.85
1998	–453	–6191	–0.58	–7.89	1.25	17.10
1999	–235	–6426	–0.30	–8.19	0.65	17.75
2000	–488	–6913	–0.62	–8.81	1.35	19.10
2001	–418	–7332	–0.53	–9.34	1.16	20.25
2002	–389	–7720	–0.50	–9.83	1.07	21.33
2003	–233	–7953	–0.30	–10.13	0.64	21.97
2004						
Years	43				43	43
Ave. 1961–2003	–184.95				0.51	
St. deviation	127.28				0.35	
St.error	19.40				0.07	