Preface

This book mainly concerns the present-day glaciers of the Karakoram Himalaya: the conditions that sustain them, the landscapes they have helped to shape and broader environmental, water resources and hazards issues associated with them. The core region involves about 16,500 km^2 of perennial snow and ice in the headwaters of the Indus and about 4,000 km^2 in the Yarkand drainage. In an otherwise extreme continental, arid region, the glaciers comprise large stores of freshwater. Meltwaters from glacier basins make up between 30 % and 40 % of the average annual flows of these rivers where they leave the Karakoram and dominate their discharges for 2–3 months of summer. Seasonal snowmelt makes up most of the balance. Yields from snowmelt seem, on an average, to be somewhat greater than those from glaciers but may be less in some years. By contrast, glaciers are relatively minor contributors and snowmelt much more important for tributaries of the indus draining the southern flank of the Greater Himalaya. Rainfall is the largest contributor, as it is in most years for the Indus basin as a whole. The upper Indus and Yarkand are among the few large river basins in South Asia where rainfall is not the dominant source of stream flows. It would be difficult to overemphasise the unique ecological and human significance of the glaciers and snowfields in the two basins. They will become more critical with anticipated climate change and economic developments.

Water demands and shortages in surrounding, populous lowlands are placing ever-greater pressures on mountain resources or the desire to exploit them. A sense of urgency arises from national and trans-boundary development plans for water and power. There are existing conflicts in the high mountain areas that could be aggravated, and new ones may arise. More hopefully, rational approaches based on mutual benefits could bring improved relations and greater security in the high mountains.

At the time of writing, a commonly expressed concern is how climate change may greatly reduce the glaciers and water supplies from them. The concern is justified, although some misleading or exaggerated accounts and the talk of ‘disappearing glaciers’ have confused the issue. In many parts of High Asia, glaciers have undergone large retreats and loss of mass in recent decades. However, changes turn out to have been less rapid than widely suggested, quite variable in different regions and,

to date, substantially different in the Karakoram (Hewitt 2005; Raina 2009; Scherler et al. 2011). There were appreciable losses of glacier mass through much of the twentieth century. Since the 1960s, they have been relatively small and inconsistent. In some cases, glacier advances are causing problems. The most likely explanation is that increased warming is being compensated in these high mountains by increased snowfall and summer cloudiness. As global warming intensifies, that may, or may not, continue. For the moment, the more worrying responses concern the timing or greater unpredictability of river flows, and environmental extremes.

From a scientific perspective, a balanced assessment of snow, ice and glacial environments in the region, and just how changes have occurred, is constrained by patchy and limited research (Kaul 1999; Hagg et al. 2009; Raina 2009; Armstrong 2010; Shroder and Bishop 2010). Although it is widely stated that the Karakoram glaciers are vital for water supply and at great risk from climate change, there is almost no continuous or widespread monitoring of them. Indeed, no adequate account is available of what is already known about them. It is over 75 years since the last book-length treatment was published. Moreover, this last major study has never been translated into English (Visser and Visser-Hooft 1935–38). The most extensive overview from a decade earlier is still only available in Italian (Dainelli 1924–35); the exceptional study of High Asian snow and ice by von Wissmann (1959) is available only in German. There have certainly been some valuable, more narrowly focused papers and overview chapters in more recent publications (Mercer 1975; Goudie et al. 1984; Haserodt 1984; Kuhle 2004; Hewitt 2006, 2011; Smiraglia et al. 2008; Shroder and Bishop 2010; Shroder 2011). Constraints of space, interests and language limit their coverage.

The Karakoram has a fairly long history of modern investigations, more so perhaps than newcomers to the topic might imagine. Scientific studies go back almost 200 years (LIGC 1984; Allen 1995). A number of large expeditions and scientists from several countries brought great advances in knowledge (see Chap. 1). Their work is an essential resource, although its limitations must be noted. As a whole, coverage is patchy – discontinuous in time and space. Much of the work pre-dates the development of some basic glaciological concepts and, as noted, may not be available in English or any other but the original language. Rugged terrain and harsh climates have limited scientific work in much of the region, and security issues often prevent it. Few investigations have gone beyond the lower parts of the glaciers and rarely above 4,000 m.[1] Yet, 80 % of glacier basin areas and all the sources of glacier ice occur above this elevation. It makes the few studies at higher elevations that much more important, although these too are biased towards a few valleys and their larger glaciers. Most of the region has received little or no attention, including some of the largest glaciers, but especially the lesser ranges where smaller glaciers prevail. ‘Small’ in this context is taken to mean less than 15 km in length. Collectively,

[1] Measurements of elevations above sea level will be written with a comma separating 100s from 1000s (e.g. 3,000 rather than 3000). This will distinguish elevations, from elevation spans, length or relative height measurements which, unless over 10,000 units, will not include commas.

however, these glaciers alone comprise a greater area than, say, the 2,896 km^2 of glaciers in the European Alps (Haeberli 1998).

Until recently, information about the glaciers was almost entirely a product of expeditions coming from outside the region and, usually, a secondary concern compared to mountaineering or military and commercial intelligence. Most were more or less short term, logistically and spatially limited, usually for a few weeks or months of summer. Those making observations in winter can be counted on the fingers of one hand and for most of the region are non-existent. Members have tended to be new to the region and visited only once, rarely more than two or three times, with some important exceptions (Dainelli 1959; Hewitt 1989, 2007). A few major expeditions by Italian, German, Austrian and Japanese teams were extensive in space and time and made detailed investigations of the glaciers. Many of their results, however, are only available in brief summaries and short papers in English. The more numerous and oft-quoted English sources are mainly from before 1947, when the region was part of the British Empire.

Nevertheless, there are some great advantages of writing this study today: the richness of the literature on glacial environments and processes worldwide and ever-improving coverage of the Karakoram region by satellite imagery. Invaluable background is provided by a number of substantial texts and works of reference on glaciers (Drewry 1986; Hambrey 1994; Paterson 1994; Menzies 1995; Benn and Evans 1998; Singh et al. 2011). The present work benefits hugely from these sources. It should be added, however, that Karakoram glaciers have only rare and minor appearances in any of them, usually in terms of certain exceptional or hazardous phenomena such as glacial lake outburst floods and surge-type glaciers.

In the past decade or so, more frequent and higher-definition satellite imagery has transformed spatial and temporal coverage of the region (Williams and Ferrigno 2010; Bishop and Colby 2011). New monitoring and analytical possibilities are opening up all the time. They offer opportunities for more representative, region-wide and all-season characterisations. An attempt is made here to take advantage of this, especially in relation to the higher, more rugged parts of glacier basins and the least-visited areas. Nevertheless, the dangers of limited or no ground control, or lack of experience in areas of interest, are constant problems. Not only has most information about Karakoram glaciers themselves come from ground-based observation and phenomena, so too has the development of the basic concepts of mountain environments and glaciology. Fully effective translation between them and remotely sensed information and analyses is a work in progress.

Problems can also arise because the most intensively studied mountain glaciers occur in other, very different environments – typically, midlatitude and subpolar regions. They tend to be relatively small ice masses, generally at lower elevations and of much less elevation range than Karakoram glaciers. This applies to most reference or ‘benchmark’ glaciers so fundamental for tracking and comparing mountain ice globally (Oerlemanns 2001; Haeberli et al. 1998; Bolch 2011). The Karakoram is in an extreme continental, subtropical location. More than half of all its glacier ice occurs in 15 basins, in glaciers more than 40 km long and with the highest areas well over 7,000 m. Many glaciers have elevation ranges of more than 4,000 m, some over

5,000 m. As a result, sets of distinctive conditions must be addressed that are of minor significance elsewhere and absent from most of the glaciers literature and research. It is important to have some of these in mind from the beginning.

In the Karakoram, it will be shown that the greater fraction of all glacier ice is input to the glaciers by avalanches rather than direct snowfall. Yet, while there has been a great deal of research into avalanches, it has largely ignored avalanche-fed glaciers, let alone valley glaciers that can be more than 50 km in length. Rock walls too steep to support seasonal or perennial snow build-up account for over 60 % of most glacier basins, more than 80 % in many. These are the main source areas of Karakoram glaciers. In addition, wind action and redistribution of snow have major influences. They probably affected the larger part of all the snow mass that is eventually incorporated into glaciers. The greater part of the vertical descent of most of the glacier ice itself is in icefalls. Much or all of the ice in the most widely observed and studied main and lower ice streams has passed through one or more icefalls. This will be shown to open up a range of situations that can affect or modify the properties and behaviour of the ice. Such uniquely 'Himalayan' conditions are frequently remarked upon but only rarely investigated, even in research on Himalayan glaciers (Yafeng and Wenying 1980; Benn et al. 2003; Cogley 2011; Hewitt 2011). They have to be addressed here, despite the lack of well-developed empirical and conceptual work.

This book can hardly escape the constraints of past work, whether in the studies on which discussion must be based or the author's experience and limitations. The strategy adopted is, however, partly chosen so as to deal with this: a regional approach paying particular attention to the terrain and environmental conditions in and around glacier basins and, to the extent possible, types, forms and features of the ice masses. Although essentially descriptive, terrain classification and distributions offer a more representative sense of the region's glacierised areas and environments and a balanced way to explore where further research is most needed.

The approach is described in more detail at the end of Chap. 1. Chapters 2, 3, 4, 5, 6 and 7 focus on present-day glacier basins, ice masses and their maintenance. Glacial landforms and earth surface processes related to them are considered in Chap. 8. In Chaps. 9 and 10, some more extreme, short-lived glacial phenomena and hazards to human inhabitants are looked at, in particular surge-type glaciers, glacial impoundments and outburst floods. Chapter 11 draws attention to the huge numbers and great diversity of rock glaciers in the region, a part of the Karakoram cryosphere largely neglected in the past. Questions of recent glacier change are elaborated in Chap. 12. A concluding chapter looks at issues relating to people, glaciers and, especially, regional water supply.

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