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The Editor,
Journal of Glaciology

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Abrupt decrease in recent snow accumulation at Mount Qomolangma (Everest), Himalaya

The glacier mass-balance history constructed from ice-core records can be used to quantify the future response of glaciers to climate change, and to predict possible variations of glacier mass balance and water resources. This kind of work is particularly important on the Tibetan Plateau where direct observations are relatively scarce. In 1997, a 41 m ice core was recovered from a site 6500 m a.s.l. on Far East Rongbuk Glacier, approximately 13 km north of the peak of Mount Qomolangma (Everest), Himalaya. Here, we present a discussion of the net accumulation record since 1955 as deduced from the top 10 m of the core.

We use the β-activity peaks correlated to known nuclear-fallout events as reference layers, and the annual signals in the $\delta^{18}O$ series to date the ice core (Fig. 1). When the $\delta^{18}O$ data do not provide a clear seasonal cycle, seasonal variations in profiles of major ions (Ca^{2+} and Na^{+}) are utilized. Thus we can calculate the chronological series of annual net accumulation (Fig. 2a) accurately, based on dating and the density–depth profile. Five-point smoothing is adopted to eliminate the stochastic effect of dating on the annual net accumulation.

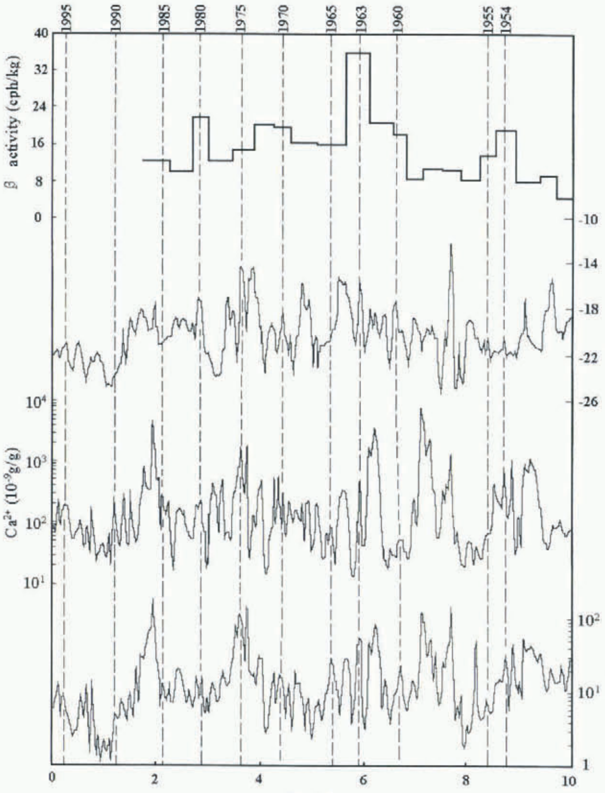

Fig. 1. β-activity, $\delta^{18}O$ and major-ion time series for the ice core from Far East Rongbuk Glacier. The double β-activity peaks correspond to the 1954 and 1963 annual reference layers, respectively.

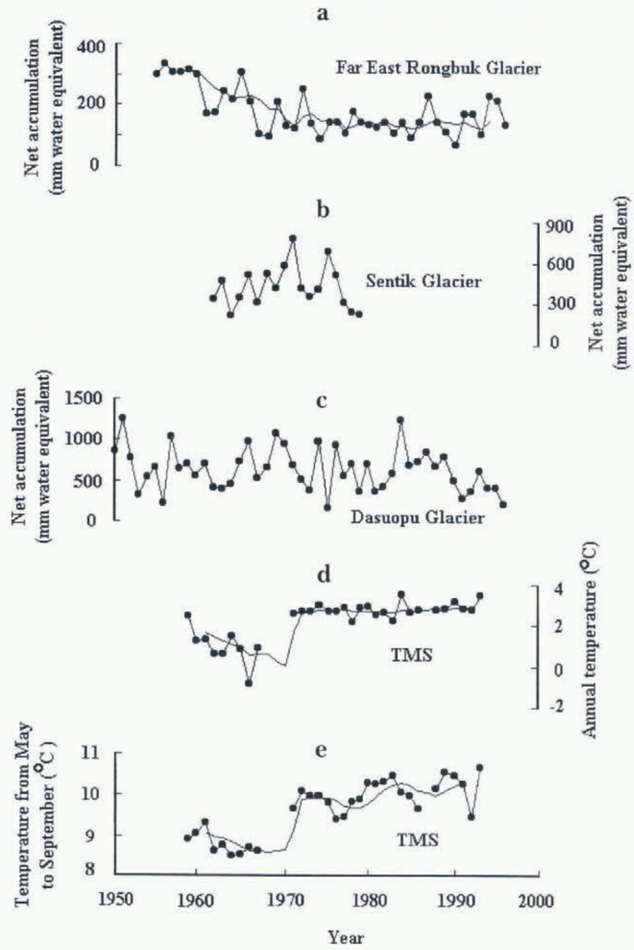

Fig. 2. The net accumulation profiles of the ice cores collected at (a) Far East Rongbuk, (b) Sentik and (c) Dasuopu Glaciers, together with the (d) annual and (e) summer (May–September) temperature records from the nearby Tingri meteorological station (TMS). The coarse lines stand for the five-point smoothing results.

It is clear that a sharp decline in net accumulation occurred from 1955 to the end of the 1960s. The annual net accumulation values for 1955–63 and 1964–96, as identified by the double β-activity peaks, are 271 and 151 mm w.e., respectively.

To help determine whether net accumulation dropped abruptly in the late 1960s, or accumulation was unusually high in the early 1960s, Figure 2b shows the net annual accumulation of an ice core retrieved in 1980 from Sentik Glacier, Ladakh Himalaya (Mayewski and others, 1984), which indicates low values in the early 1960s. Preliminary results from an ice core recovered in 1997 from Dasuopu Glacier, Xixibangma Himalaya (about 120 km from our drilling site), confirm the evidence from the Sentik ice core (Fig. 2c). Thus we eliminate intuitively the possibility that accumulation was high in the late 1950s and early 1960s, regardless of the fact that these ice cores were retrieved from different geographical and climatic units.

In Figure 2d and e we also show the annual and summer (May–September) temperature records from the nearby Tingri meteorological station (TMS, about 50 km from our drilling site). Note that no temperature measurements are

https://doi.org/10.3189/S0022143000001465 Published online by Cambridge University Press

available for 1968–70 and 1987. According to Tang and others (1998), the direction of the 500 hPa geostrophic wind on the Tibetan Plateau changed from northwest to southwest at the end of the 1960s, which intensified the föhn effect on the north slope of Himalaya and increased the air temperature. Therefore, the abrupt shift in the TMS temperature in 1970 reflects a change in the geostrophic wind, rather than a change caused by instrumentation or changes in the TMS. Since this is the closest station to our ice-core drilling site, and both are located in the rain shadow of the north slope of the Himalaya, we believe that the TMS observations reflect the temperature variations at the drilling site. As shown in Figure 2, a strong relationship between our net accumulation and temperature is apparent. The correlation coefficients (r) are −0.61 between the net accumulation and high summer temperature and −0.50 between the net accumulation and the annual temperature. Both are significant at $p = 0.001$. Thus we speculate that the recent high temperature intensified glacier ablation, resulting in decreased net accumulation. This initial interpretation does not rule out other factors that might also contribute to the net-accumulation decrease.

The decreased net accumulation since the 1950s at our study site is consistent with observed recent glacier retreat. By comparing the maps surveyed in 1959 and 1966, Zheng and Shi (1975) concluded that during the period 1959–66 the terminus of East Rongbuk Glacier had retreated 550 m, at 78 m a^{-1}. In 1997, the termini of the Rongbuk glaciers and their seracs were resurveyed using a global positioning system (Ren and others, 1998). The survey indicated that during the period 1966–97 Far East Rongbuk Glacier had retreated about 230 m, at 7.4 m a^{-1}, and the lower boundaries of the seracs for the nearby Middle Rongbuk Glacier and East Rongbuk Glacier had retreated 170 and 270 m, at 5.5 and 8.7 m a^{-1}, respectively. In the Khumbu Himalaya, the glaciers had also retreated considerably since the 1960s (Mayewski and Jeschke, 1979; Higuchi and others, 1980). One glacier there had retreated about 60 m, at 4.6 m a^{-1}, from September 1976 to November 1989 (Yamada and others, 1992).

Mountain glaciers are considered to be especially sensitive to climate warming. For instance, the replenishment of glacier accumulation due to a precipitation increase of 20% is still less than the excess ablation caused by a temperature rise of 1°C. We speculate that glaciers in the Himalaya will continue to thin and retreat due to negative mass balance, because the effect of warming will counteract and overwhelm any increase in winter precipitation.

ACKNOWLEDGEMENTS

We thank Yao Tandong and Duan Keqin for the Dasuopu Glacier ice-core data. This research was supported by grants from the National Natural Science Foundation of China (49871022), the Chinese Academy of Sciences (KZ-951-A1-402, 204 and 205), the State Committee of Science and Technology of China (95-YU-40), and Atmospheric Science, U.S. National Science Foundation, and was part of a cooperative project between the Lanzhou Institute of Glaciology and Geocryology and the Climate Change Research Center, University of New Hampshire.

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25 May 1999

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