RESPONSE OF CRYOSPHERE TO CLIMATIC WARMING SINCE THE 1980s OVER THE NORTHERN HEMISPHERE

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The paper is mainly concerned with changes in glaciers, permafrost, and snow cover since the 1980s, over the northern hemisphere.

VARIATION OF GLACIERS

Table 1 shows the glacier mass balance (B) average for 10 years, and relative variance of air temperature (ΔT) estimated by the linear relationship between mass balance and equilibrium line altitude (ELA) and difference between average ELA and ELAo as B=O (Ding 1995). It is found that, except for glaciers in Scandinavia, glacier mass balance is obviously decreasing in the 1980s compared to the 1960s and 1970s. Loss of mass balance is obviously decreasing in the 1980s, corresponding to the rise of 1.0-1.5°C in air temperature compared to the temperature of 10-20 years before. However, there is an increase of mass balance in Scandinavia even with a rise of about 0.7-1.0°C in air temperature. In the hemispherical range, loss of mass balance during the 1980s increased sharply by 1.3 times compared to the 1960s and 1970s, with a resultant rise of 0.38°C in air temperature.

Based on the sensitivity of change of small glaciers to climatic warming (Ding and Haeberli 1995), variations of front position of glaciers for lengths shorter than 2km are compared between the 1980s and the 1970s in the main glacier areas of the hemisphere (Table 2). It may be found that small retreating glaciers increased by 15-20% in the 1980s compared to the 1970s.

CHANGE OF PERMAFROST

The change in permafrost since the 1980s is also remarkable. The change in permafrost temperature in the Alps has been continuously measured during the past several years (Haeberli et al. 1993). The results show that permafrost temperature at 10m depth is rising by 0.5-1.0°C per ten years, which resulted in twice the increase in thaw of underground ice in the 1980s than in the 1970s. The descending rate of surface height of the Gruben rockglacier in the Swiss Alps in the 1980s is two to three times more than in the 1970s. Surface depression of the rockglacier is caused by melting of the buried ice in the frozen layer (Vonder Muhll and Schmid 1993).

In the north of China, comparison of the 1970s with the beginning of the 1990s demonstrates that seasonal thaw depth has increased at least 30cm in the Amur area of Mehe county (Gu et al. 1993), and permafrost temperature at 20cm depth rose by about 0.8°C. The southern limit of perennial permafrost has degenerated 500-3,000m along both sides of the Daling River in the Lingzhong and Fuke areas in the 1980s compared to the 1970s, so that the range of thaw area has expanded remarkably and the island thaw area has appeared in the perennial frozen region (Yuan 1989). In the upper reach of Hilongjiang River, Hilongjiang Province, investigations have shown that, compared to the 1950s, the southern limit of permaforst in the 1980s has extended up to 50-100km along the valley and permafrost temperature at a depth of 10m has risen by 0.6°C (Yu et al. 1993).

In the Tian shan Mountains, northwest China, there is an obvious change in permafrost (Table 3). Comparison of permafrost temperature, frozen thickness, and table between the 1970s and the 1980s, in two quite close positions, shows that these permafrost characteristics vary with climatic warming.

CHANGE OF SNOW COVER

The average area of snow cover in spring and within a year has been reduced by 1.4 million km^2 (4.5%) and 1.0 million km^2 (4.0%) in the 1970s and 1980s respectively, in the northern hemisphere.

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Table 1. Change of Air Temperature Relative to Zero Balance in Various Regions. ΔT is Estimated by Difference between ELA and ELAo with Lapse Rate of 0.65°C/100m

Durations		Alps	Scandinavia	Rocky Mts	Tianshan Mts	Mean
1961-1970	B (mm/yr)	-60	-118	-427	-84	-184
	ΔT (°C)	0.2	0.5	1.0	0.2	0.5
1971-1980	B (mm/yr)	-24	-45	-343	-354	-192
	ΔT (°C)	0.1	0.2	0.7	1.0	0.5
1981-1990	B (mm/yr)	-590	267	-912	-418	-413
	ΔT (°C)	1.7	-1.2	1.9	1.2	0.9
Average	B (mm/yr)	-255	35	-567	-285	-216
(1961-1990)	ΔT (°C)	0.7	-0.2	1.2	0.8	0.6

Table 2. Ratio of Advance and Retreat of Glaciers for Length Shorter than 2km between 1970s and 1980s

Glacier areas	Durations	Ad. Glaciers %	St. Glaciers %	Re. Glaciers %	Mass balance (mm)
Alps	1971-1980	48.0	12.4	39.6	-24
	1981-1990	33.6	3.9	62.5	-590
North America	1971-1980	53.9	18.2	27.9	-117
	1981-1990	31.8	26.8	41.4	-386
High Asia	1971-1980	26.3	12.4	61.3	-265
	1981-1990	7.1	15.4	77.5	-380
Mean	1971-1980	42.8	14.3	42.9	-142
	1981-1990	24.4	15.3	60.5	-315

Table 3. Comparison of Some Permafrost Parameters between the Kuixian Pass and Source of Urumuqi River in the Tian Shan Mountains, China

Position	Date	Altitude (masl)	Active Layer Temperature	Frozen Table (m)	Depth of Permafrost	Source
Kuixian pass	1973-1975	3271	-2.0	2.0	100	Qiu et.al,1983
Source of Urumuqi river	1991-1992	3300	-0.7	3.0	50	Jin et.al, 1993
		3450	-1.0	3.5	60	
		3500	-1.6	2.0	95	
		3540	-1.8	2.3	100	