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Characteristics of local circulation in the glacier area in the West Kunlun Mountains, 1987

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Abstract

Local circulation in the West Kunlun Mountains is affected by the local relief of large glaciers and snow fields. During the expedition in 1987, it was discovered that the nocturnal wind blows from glacier to nonglacier area at night, while daytime wind blows from the nonglacier area to the glaciers. The maximum nocturnal wind appears at midnight, and the minimum before sunrise. Its variation is large. The wind system was different from the regular diurnal mountain-valley winds and also from the typical glacier wind occurring in valley glacier areas which blows downhill all day. The nocturnal wind in this region occurs over a wide area; it reaches about 20km far from the glacier. This is attributed to the local circulation between the large glacier area of the West Kunlun Mountains and the dry area of the Tibetan Plateau.

1. Introduction

In alpine areas, the remarkable relief and large area of ice and snow have significant effects on local weather and climate, especially in forming local circulations such as mountain and valley winds and glacier winds (Shen and Gao, 1975; Tang, 1963). However, due to the severe environment in alpine areas, meteorological observations are difficult to continue for a long time. Therefore, study of the glacier wind in alpine area is still scarce in China, especially around ice caps. During the expedition to the West Kunlun Mountains in 1987, the nocturnal wind was observed and researched. The details are as follows.

2. Geographical condition and observation sites

The area of the Gozha Lake region is 224km², of which the area of glacier is 105km², and the area of the Chongce Ice Cap is 16.4km² (Fig. 1). The Chongce Glacier goes down from the east side of the ice cap, and the Gozha Glacier from the west side. The terminus of the ice cap is at about 5800m in altitude.

Winds measurement sites are shown in Fig. 1. There were six stations built along the slope and the ice cap. Among them, two sites were long-term stations (BC and B12 point) and the others were temporary (G1 and G2 on the ice cap, M1 and M2 in the moraine range). The wind speed and direction were observed at BC station (in the nonglacier area) from July 14 to August 30 and at B12 station (on the ice cap) from July 23 to August 24. At points G2 and M1, the wind speed and direction were observed during 6 days. Points G1 and M2 were only occupied for 3 days. Hourly observations were made at all sites.

Chinese Standard Time (CST) (GMT plus 8 hours) is used in this report. The solar noon is at about 14h 40m (CST) at the longitude in this area (about 80°E).

3. Analysis of wind systems

3.1. Daily variation of the wind speed and direction

We divide the wind direction into four quadrants (0 – 90°, 91 – 180°, 181 – 270°, 271 – 360°).

Table 1 shows the diurnal variation of wind frequency and mean wind speed at BC from July 14 to August 30. The north wind prevails at night and the south wind in the daytime. The maximum frequency of the north wind occur at midnight, and of south wind at 14 or 15h (around noon) (Fig. 2).

In this area, the south wind means the valley wind, and the north wind means the mountain wind (the nocturnal wind). Though the diurnal variation of the wind direction in this area is similar to the mountain and valley wind system, the diurnal variation of wind speed is quite different from that of a typical mountain and valley wind system. The maximum velocity of typical mountain and valley winds, in contrast, occurs in the morning and in the evening respectively.

The hours of mountain and valley winds in a day depend on the hours of daytime and nighttime. Therefore, in the summer season (daytime is longer than nighttime), the valley wind should occur more frequently than the mountain wind. However, in our case, the probability of the north wind (mountain wind) is 56%, and that of the south wind (valley wind) is 44%. Obviously, the probability of the north wind is 12% larger than that of the valley wind. Thus the north wind is more prevalent in this area.

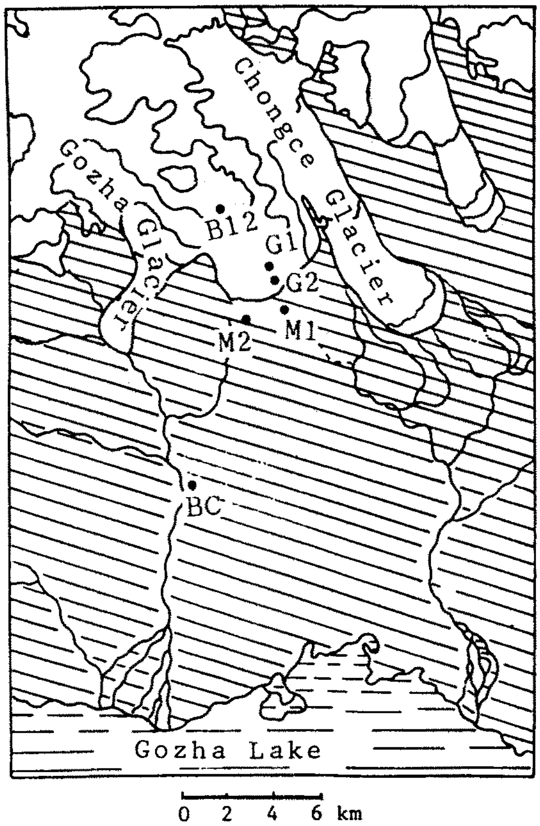

Fig. 1. Position of observation points in the West Kunlun Mountains.

Table 2 shows the wind frequency and mean wind speed of four directions at site B12 from July 23 to August 24. The results from Table 2 indicate that the diurnal variation of the wind direction is similar to that at BC. The difference is that the probability of the north wind is larger than that at BC station. The north wind is 59%, the south wind is 41%, the difference between them is 18%. Mean wind speed is also a little larger than that at BC, as shown in Figs. 3 and 4. Another difference is that the probability of the west wind (71%) is much larger than that at BC (50%), which means that the winds at B12 (near the top of the ice cap) is more affected by the westerly wind than at BC.

In general, in an ice-and snow-covered area, the temperature is always lower than that of the free atmosphere at the same altitude. Thus, a local circulation similar to mountain wind or glacier wind is usually observed. This katabatic wind prevails during most of the day and night. From the statistics above, the local circulation in this area has a diurnal variation, although the variation is different from that of a typical mountain and valley wind; the appearance time of the maximum and minimum wind speed is different from the typical one and the percentage of

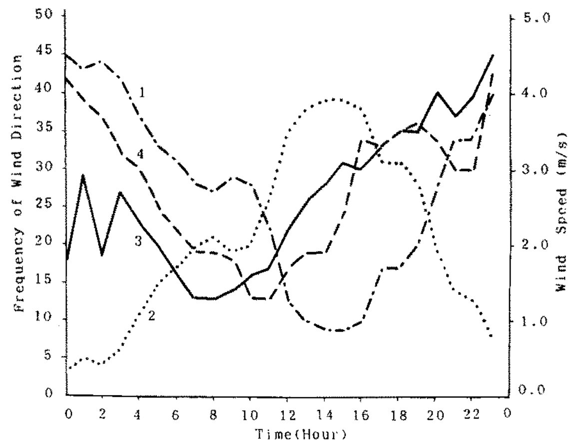

Fig. 2. Diurnal variation of wind direction frequency and speed at Base Camp (5260m) in the West Kunlun Mountains during July 14 – August 30. 1: North wind frequency, 2: South wind frequency, 3: North wind speed, 4: South wind speed.

Table 1. Frequency distribution of wind direction, n, and mean wind speed, V (m/s) at Base Camp (5260m) in the West Kunlun Mountains, during 48 days from July 14 to August 30, 1987.

Hour (CST)	N−E n	N−E V (m/s)	E−S n	E−S V (m/s)	S−W n	S−W V (m/s)	W−N n	W−N V (m/s)
0	22	(4.0)	2	(2.7)	1	(0.9)	23	(4.3)
1	22	(4.0)	4	(3.5)	1	(2.3)	21	(3.8)
2	28	(3.9)	2	(2.5)	2	(1.1)	16	(3.4)
3	26	(3.4)	3	(3.5)	3	(1.8)	16	(3.0)
4	26	(3.1)	5	(2.2)	6	(2.3)	11	(2.8)
5	18	(3.0)	10	(2.3)	5	(1.7)	15	(1.9)
6	15	(2.0)	12	(2.0)	5	(1.2)	16	(2.4)
7	12	(1.9)	13	(1.3)	7	(1.3)	16	(1.9)
8	10	(1.8)	14	(1.4)	7	(1.2)	17	(1.9)
9	11	(1.6)	13	(1.5)	6	(1.3)	18	(2.0)
10	6	(0.7)	16	(1.5)	4	(1.6)	22	(1.8)
11	6	(1.3)	21	(1.8)	5	(1.5)	16	(1.2)
12	4	(1.5)	25	(2.3)	10	(2.0)	9	(1.9)
13	7	(1.4)	26	(2.7)	12	(2.5)	3	(2.4)
14	5	(1.9)	26	(2.7)	13	(2.8)	4	(1.9)
15	3	(2.3)	20	(3.2)	19	(3.0)	6	(2.5)
16	6	(2.1)	14	(2.7)	24	(3.3)	4	(4.7)
17	7	(2.7)	14	(3.2)	17	(3.3)	10	(3.8)
18	7	(3.1)	16	(3.2)	15	(3.7)	10	(3.8)
19	3	(3.8)	17	(3.0)	11	(3.7)	17	(3.1)
20	5	(4.1)	5	(3.1)	14	(3.6)	23	(3.9)
21	7	(3.3)	5	(2.5)	9	(3.5)	27	(4.1)
22	13	(3.8)	2	(2.0)	11	(4.0)	21	(4.2)
23	18	(4.2)	3	(3.0)	5	(5.4)	22	(4.8)
Total(mean)	287	(3.0)	288	(2.4)	212	(2.9)	363	(3.1)
[Percentage]	[25%]		[25%]		[18%]		[32%]	

Table 2. Frequecy distribution of wind direction, n, and mean wind speed, V (m/s) at B12 (6320m) during 33 days from July 23 to August 24, 1987.

Hour (CST)	N−E n	N−E V (m/s)	E−S n	E−S V (m/s)	S−W n	S−W V (m/s)	W−N n	W−N V (m/s)
0	6	(3.4)	0	(−)	1	(6.2)	26	(6.1)
1	9	(3.6)	0	(−)	3	(4.1)	21	(6.2)
2	6	(3.2)	1	(1.3)	3	(6.0)	23	(5.4)
3	3	(3.3)	4	(2.0)	8	(4.0)	18	(5.1)
4	5	(4.0)	5	(1.5)	9	(3.1)	16	(4.0)
5	5	(4.0)	5	(2.0)	12	(2.7)	11	(2.9)
6	7	(3.4)	6	(1.5)	7	(2.1)	13	(1.7)
7	9	(2.1)	4	(2.5)	9	(2.2)	11	(2.1)
8	7	(2.7)	6	(1.8)	7	(2.6)	13	(2.2)
9	7	(2.6)	7	(1.8)	9	(3.1)	10	(1.9)
10	8	(2.3)	5	(1.5)	8	(3.5)	12	(1.7)
11	2	(1.2)	12	(2.2)	6	(4.5)	13	(1.5)
12	5	(1.4)	11	(2.0)	10	(3.8)	7	(1.9)
13	5	(1.7)	12	(2.5)	14	(3.7)	2	(2.7)
14	2	(2.3)	10	(2.6)	18	(3.7)	3	(2.9)
15	1	(0.1)	7	(3.2)	21	(3.9)	4	(3.4)
16	2	(2.4)	6	(3.3)	14	(5.6)	11	(5.2)
17	4	(3.8)	0	(−)	14	(5.9)	15	(5.1)
18	4	(3.8)	2	(1.8)	10	(6.7)	17	(5.3)
19	5	(4.4)	1	(4.0)	9	(8.5)	18	(5.2)
20	5	(4.0)	1	(1.0)	8	(6.9)	19	(5.8)
21	6	(2.9)	0	(−)	7	(8.6)	20	(5.3)
22	8	(4.0)	0	(−)	9	(9.2)	16	(5.9)
23	7	(4.7)	1	(0.4)	5	(9.9)	20	(6.7)
Total(mean)	126	(3.1)	106	(2.2)	221	(4.8)	339	(4.5)
[Percentage]	[16%]		[13%]		[28%]		[43%]	

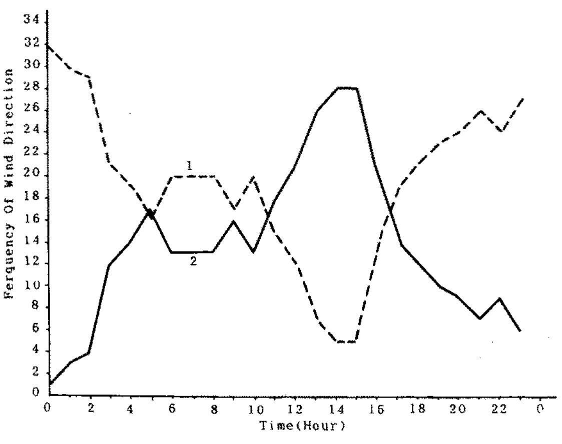

Fig. 3. Diurnal variation of wind direction frequency at B12 (6320 m), July 23 – August 24, 1987. 1: North wind, 2: South wind.

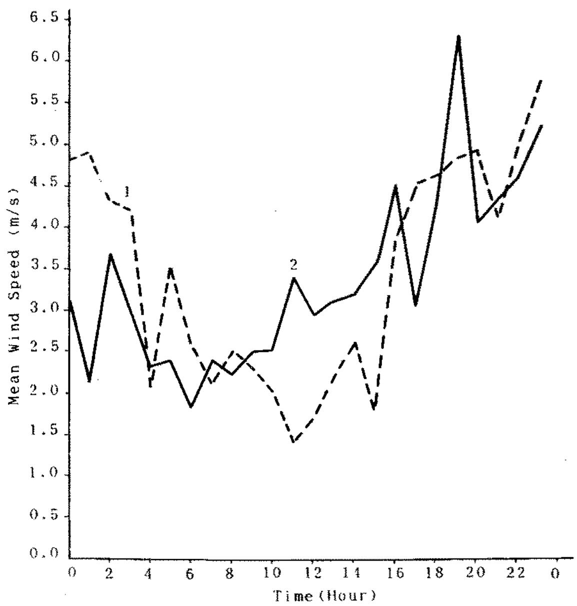

Fig. 4. Diurnal variation of south and north wind speed at B12 (6320m). 1: North wind, 2: South wind.

north wind is larger than that of south wind. We consider that this local circulation are caused by the existence of a "glacier wind", which is different from a typical glacier wind; the wind speed varies diurnally and the diurnal variation occurs even near the top of the ice cap (as seen in the results at B12). This diurnal variation may be related to the circulation between the glacier area in the West Kunlun Mountains and the Tibetan Plateau, similarly to the monsoon climate in the Himalaya Mountains.

3.2. Altitudinal variation of wind direction along mountain slope

The variation of wind direction and wind speed with altitude and time is shown in Fig. 5, based on the observations at B12, G1 and G2 (on the ice cap), M1 and BC (on bare ground) during August 5–7.

The results in Fig. 5 show that the frequency of north wind decreases with increase in altitude from BC to B12. At the three ice cap sites, the mean probability of appearance is 45% for north wind and 42% for south wind, whereas at the two nonglacier area sites, it is 49% for north wind and 44% for south wind. At the ice cap sites, the south wind appeared in daytime and its frequency increases with altitude. When wind direction changes with time or altitude from north to south or in reverse, the direction changes abruptly by an angle of more than 90 degrees. At site M1, the south wind occurs most frequently before sunset. Therefore, between sites M1 and G2 (between the ice cap and nonglacier areas), there are many convergence and divergence zones. The divergence zones occur before sunrise and in the daytime, and the convergence zones occur after sunset and at night.

Fig. 6 shows the variation of wind direction and wind speed with altitude and time at five sites (B12, G2, M2, M1, BC) during August 9–12. In contrast with Fig. 5, there are some differences in Fig. 6. Obviously, the change of wind direction in Fig. 6 is comparatively simple; during most of the time the north wind prevailed. The mean probability of the north wind is 74% at the two sites on the ice cap, and 63% at the three sites in the nonglacier area. Among them, the maximum value of 85% appears at site M1. The dependence of wind speed on altitude is greater than that in

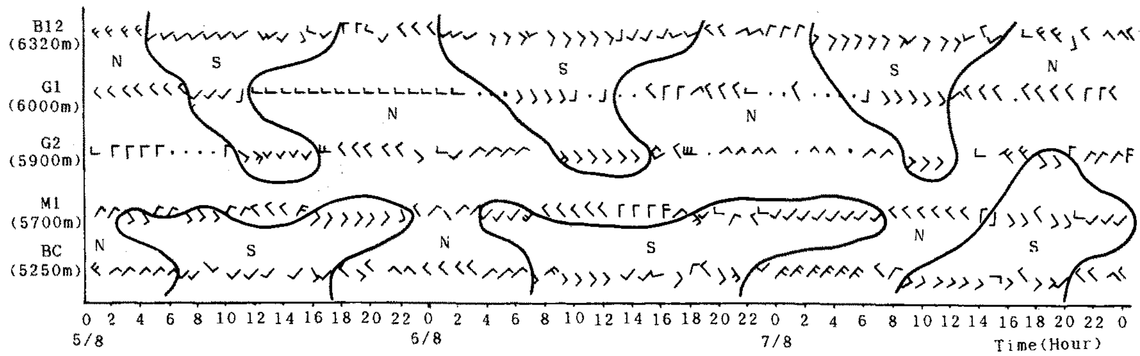

Fig. 5. Variation of wind speed and direction with time and elevation during August 5 – 7, 1987.

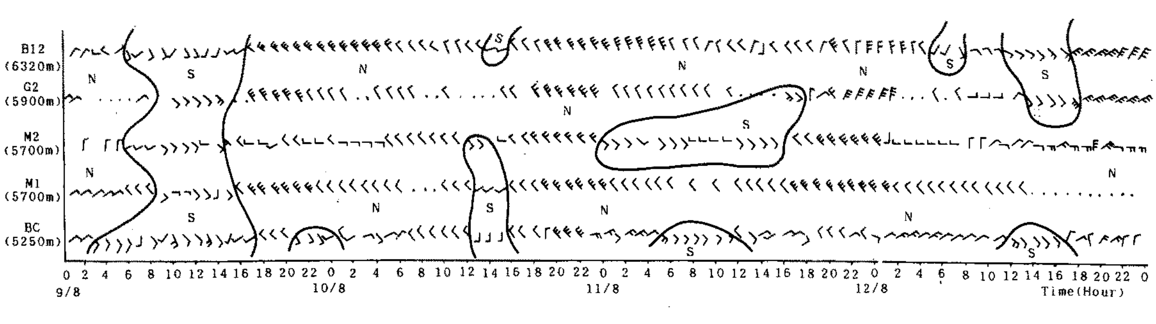

Fig. 6. Variation of wind speed and direction with time and elevation during August 9 – 12, 1987.

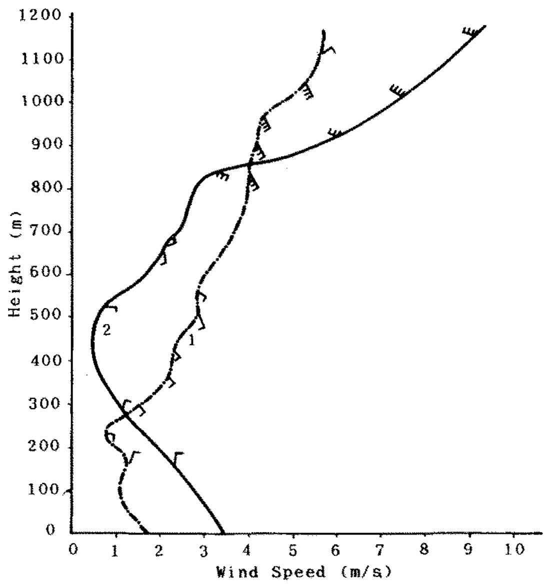

Fig. 7. Vertical profiles of wind speed by sounding observation. 1: on August 5 (cloudy or overcast day), 2: on August 10 (clear day).

Fig. 5. The convergence and divergence in Fig. 6 are smaller than those in Fig. 5. These differences are caused by different weather; it was clear in the morning but cloudy and with intermittent snowfall in the afternoon during August 5 – 9, whereas it was fine during August 10 – 12. Another reason of the difference can be in the synoptic scale change of winds; the westerly wind was strong in the August 9 – 12.

The probability of the north wind from the ice cap area to the nonglacier area decreased with distance. For example, during August 5 – 7, it was 54% at site G2 and 44% at site M1. During August 9 – 12, it was 74% at site B12, 73% at site G2, 57% at sites M2 and M1 as well as at BC; the difference from the highest site to the lowest site was 17%. The distance from B12 to BC is about 20km. The results show that the intensity of the "glacier wind" decreases with distance from the glacier.

3.3. Vertical structure of the wind system

We used two pilot balloon measurements to study the vertical structure of local wind. From Fig. 7, the height of the prevailing north wind reached 200m in the example of August 5 (cloudy or overcast day), but in the example of August 10 (clear day) it was about 450m. From these examples, the depth of the "glacier wind" is different under different weather conditions, high on a clear day and low on a cloudy day.

4. Concluding remarks and discussion

According to the above analysis, the glacier wind in the region of Chongce Ice Cap is quite different from other regions, such as the north slope of the Himalaya and the Qilan Mountains. The former is relatively flat while the latter have narrow deep valleys. Some of the characteristics can be summarized as follows.

1) For both north and south winds, the maximum wind speed appeared at midnight and the minimum appeared in the morning, in contrast to a typical mountain-valley wind system.

2) Wind direction varied abruptly between the ice cap area and nonglacier area.

3) North wind (mountain wind) had a larger probability of appearance than south wind (valley wind).

4) The above characteristics indicate the existence of "glacier wind", but the wind speed varies diurnally and the diurnal variation occurs even near the top of the ice cap; therefore the wind system is different from the typical glacier wind.

5) The intensity of the "glacier wind" decreased with distance from the glacier area. Its depth is large on a clear day and small on an cloudy day.

6) The wind system in this area may be concerned with the meso-scale circulation between the glacier area of West Kunlun Mountains and the dry area of the Tibetan Plateau, similarly to the monsoon climate in the Himalaya.

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