STATISTICAL ANALYSIS OF CYCLONE TRACKS IN WESTERN ANTARCTIC REGION

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ABSTRACT

The paper shows the statistical analysis of cyclone tracks that have influence on the western Antarctic region. Based on the conditions of cyclone movement and its impact upon the weather, cyclone tracks are classified into three categories, i. e., the track moving towards the northern tip of the Antarctic Peninsula, southern track, and northern track.

Moreover, in this paper, the frequency distributions of cyclone tracks, the major tracks with higher frequencies, the original region of Antarctic cyclones and the seasonal features of Antarctic cyclones have been analyzed. The results show that there are higher cyclogeneses in summer, whereas relatively fewer cyclogeneses in winter, and cyclone numbers in transitional seasons are close to the climatological average. The analysis also shows that the moving velocity of Antarctic cyclone is about the same in winter and summer. It obviously speed up during the transitional season.

I. INTRODUCTION

Antarctic cyclones are one of the main weather systems that influence weather in the Antarctic region. The meteorological information about the Antarctic region has gradually increased with the continuous development of Antarctic scientific survey. The features of movement of cyclones in the Southern Hemisphere and Antarctic region are more or less studied both at home and abroad, (Kep, 1984; Taljaard, 1967; Harry, 1972). Using the climatological data about cyclogenesis, cyclolysis and cyclone path in the Southern Hemisphere during 1972—1981 compiled by Kep (1984), Melbourne University, Australia, Chen et al. (1987) have processed and analyzed the climatic features of cyclone movement in the Southern Hemisphere, and published a volume of atlas. The atlas has a larger grid of 10° latitude/10° longitude, thus a rough analysis for cyclone movement in the Antarctic region is obtained. After the founding of the Great Wall Antarctic Station of China in 1985 in King George Island, Chen et al. (1989) provided the monthly Antarctic cyclone paths influencing the Antarctic Peninsula and adjacent areas, and analyzed the features of their movement in accordance with a series of 1985 data including ground surface observations, facisimile weather maps, satellite photographs and ground surface maps of the Southern Hemisphere made by NMC (National Meteorological Center) of China. In this paper the Antarctic cyclone paths, original region, moving speed and seasonal variation features influencing the Antarctic region according to the information gained from the Great Wall Station between 1985—1987, and surface maps of the Southern Hemisphere made by NMC have further been analyzed.

II. DATA AND STATISTICAL METHOD

Using the weather map of the Southern Hemisphere from 1985 to 1987 drawn by NMC, and the meteorological data collected since the establishment of the Great Wall Antarctic Station, the essential features of cyclone tracks affecting the weather in western Antarctic region (40—80°S, 0—160° W) have been analyzed. The criteria for selecting Antarctic cyclones are that the cyclones should be generated within a certain region under consideration, and the cyclones coming from the other regions should be excluded; and that the cyclones must be the depression cyclone systems with, at least, one closed isobar at intervals of 5 hPa on the surface weather map, and they have direct influence on the Antarctic Peninsula area during the moving period. The statistical method is to symbolize the cyclone locations from the daily surface weather map, and draw the tracks of every cyclone process, and then to classify these tracks using the grid of 5° latitude /5° longitude, so that the cyclone numbers within each grid are obtained, and the frequency distributions of various cyclones are drawn. In addition, the statistics for the distribution of cyclone source is also performed.

III. THE CYCLONE TRACK CLASSIFICATION AND SOURCE

One hundred and sixty-nine Antarctic cyclones in 1985—1987 influencing western Antarctic region have been analyzed. Based on the characteristics of weather influence and the features of moving tracks, these tracks are classified into three categories: tracks moving towards the northern tip of the Antarctic Peninsula; southern tracks; and northern tracks. In terms of the frequency distributions of cyclone tracks, the features of moving tracks have been discussed.

1. *Tracks Moving towards the Northern Tip of the Antarctic Peninsula*

The center of the Antarctic cyclones which move towards the northern tip of the Antarctic Peninsula (see Fig. 1) passes through the area within 60—65°S. During the period

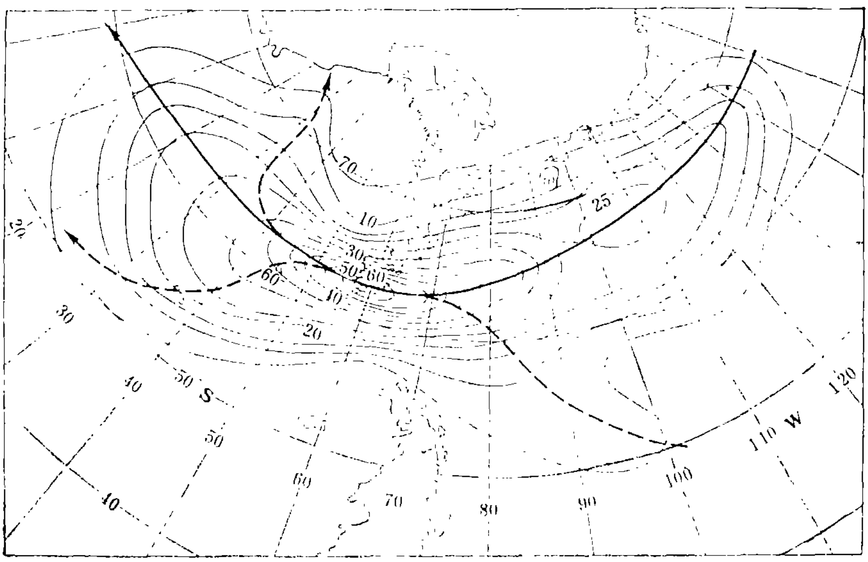

Fig. 1. The frequency distribution of Antarctic cyclones influencing the weather in the northern tip of the Antarctic Peninsula.

of movement from west to east, the center of the cyclones moves towards the Great Wall Antarctic Station of China. The major tracks of high frequency cyclones are along the parallel moving eastwards by north and through the area between 68°S and 60°S. The minor tracks of cyclones are as below. Before passing through the Antarctic Peninsula, the cyclones from Southeast Pacific near 50°S, 100°W advance southwards to northern tip of the Antarctic Peninsula. After passing, some of the cyclones continue to move southwards, travelling over Weddel Sea and influencing the weather in the coast area of the Antarctic continent, and some move northwards.

2. *Southern Tracks*

The center of the Antarctic cyclones with southern tracks passes through the Antarctic Peninsula in the area south of 65°S. The warm air in this kind of cyclone is much stronger, and the Great Wall Antarctic Station is situated in the warm sector of the northern side of the cyclone. The major tracks of cyclones with high frequency move eastwards along 70°S, and gradually deflect ot the north. The minor tracks, when they are located of the west of Bellingshausen Sea, move southeastwards from 62°S and merge with the major tracks at about 100°W. After passing through Antarctic Peninsula, the cyclones continue to move eastwards, and turn to north at about 30°W.

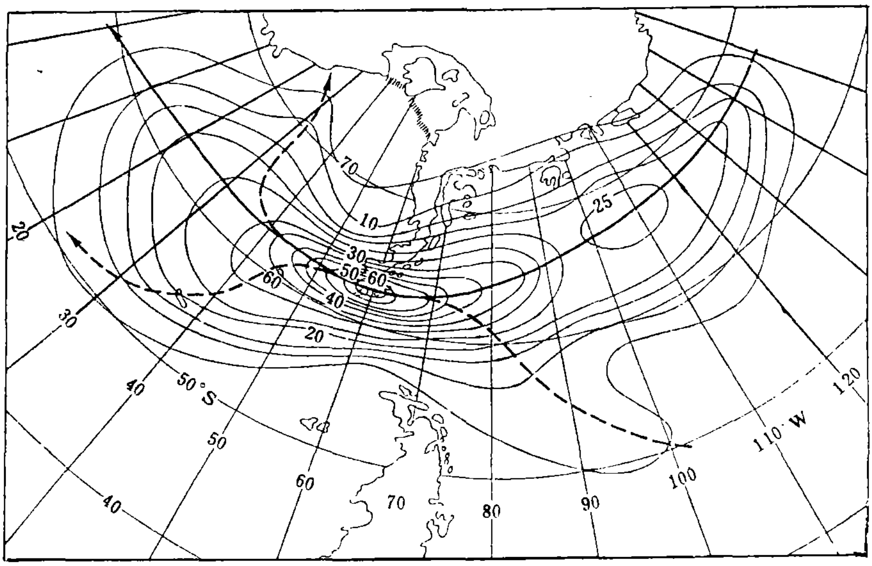

Fig. 2. The frequency distribution of Antarctic cyclones of southern tracks.

3. *Northern Tracks*

The center of the Antarctic cyclones with northern tracks passes through the Drake Passage or the southern tip of South America in the area north of 60°S. The cold air in this kind of cyclone process is stronger, and the Great Wall Antarctic Station is in the cold sector of its south side. The major tracks of cyclones with high frequency move northeastwards from about 68°S, in the west of Bellingshausen Sea; after passing through Drake Passage, they move eastwards by south. The minor tracks, when they are located in the southeast Pacific, move eastwards along 60°S, and after passing through Drake Passage, they approach the coast area of Antarctic continent in southeast direction.

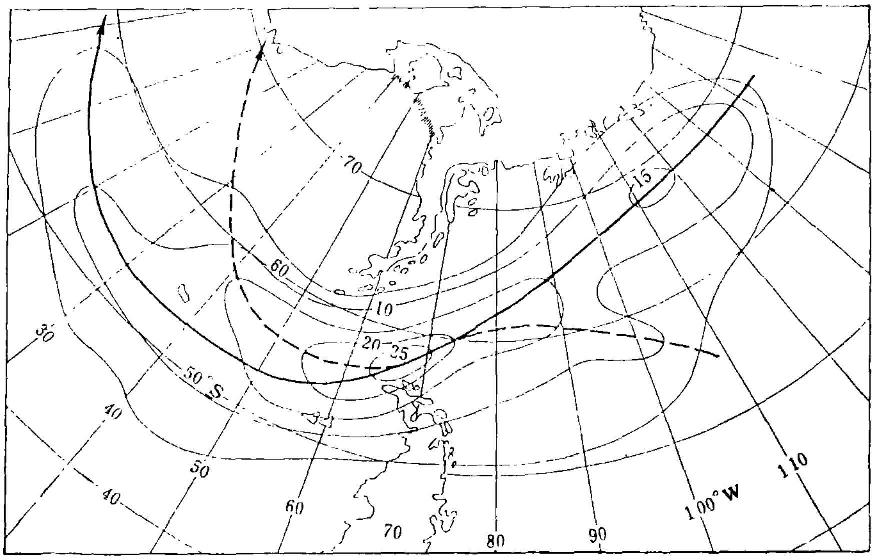

Fig. 3. The frequency distribution of Antarctic cyclones of northern tracks.

The statistic results show that the Antarctic cyclones of southern tracks which account for 43.2% of the total are much more than those of northern tracks which are 20.1% in western Antarctic region. This fact shows that the cold air activity is not strong in the region, in contrast, the warm air is more active there. It is related to the features of atmospheric circulation of Antarctic region and the cold high of Antarctic continent which deflects to the east Antarctic. Under the influence of environmental fields and the underlying surface radiation, Antarctic Peninsula region is warmer than the east Antarctic continental region at the same latitude.

The original region of Antarctic cyclones influencing this region is more concentrated (figure omitted). Most of Antarctic cyclones are generated over the sea surface in the west of Bellingshausen Sea, to be specific, 76.3% of the cyclones are generated within 60—75°S, 120°—150°W, 50% within 65°—75°S, 125°—145°W. Besides, some cyclones are generated over Bellingshausen Sea and southeast Pacific.

IV. ZONAL DISTRIBUTION FEATURES OF ANTARCTIC CYCLONES

When the zonal distribution of Antarctic cyclones in western Antarctic region is counted, the actual distribution can not be known if using the latitude-longitude grid to calculate the frequency of cyclones. Because the area in high latitudes is smaller than that in low latitudes even for the same latitude-longitude grid, the area correction must be made. According to the method of Kep (1984), F_i is introduced

$$F_i = \frac{f_i}{n_i \times \cos l_i},$$

where F_i is the frequency density of average Antarctic cyclones in given latitude zone; f_i, the frequency of Antarctic cyclones in the latitude zone; n_i, grid numbers in the latitude zone; and l_i, average latitude of the latitude zone.

According to the above formula, frequency density of the average Antarctic cyclones of all latitude zones in this region is calculated. Fig. 4 shows the longitudinal distribution of Antarctic cyclone frequency. It is not difficult to know that there is only one high frequency latitude zone of cyclones in western Antarctic region, near 67.5°S, which is corresponding to upper westerly jet at high latitudes.

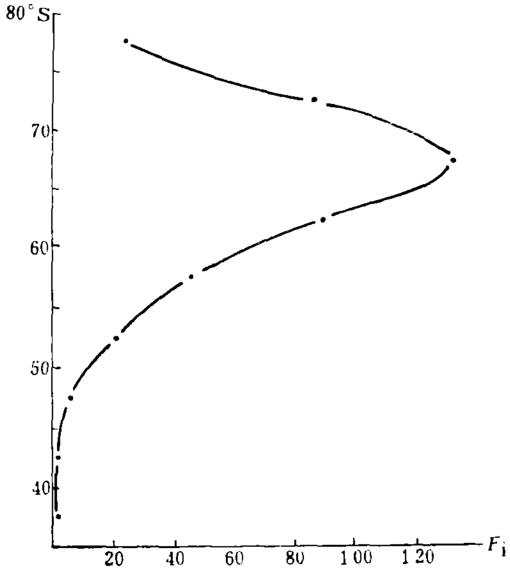

Fig. 4. The longitudinal distribution of frequency density of Antarctic cyclones in western Antarctic region.

V. SEASONAL VARIATION AND MOVING SPEED OF ANTARCTIC CYCLONE TRACKS

1. *Seasonal Variation*

The Antarctic cyclone tracks have obvious seasonal features. There are higher numbers of cyclones in summer, whereas relatively fewer cyclones in winter. The top curve of Fig.5 shows the mean monthly distribution of Antarctic cyclone number during 1985—1987. From the figure we can see that the Antarctic cyclone numbers every month of summer (Dec.—Mar.) are more than or close to the mean monthly 4.7, whereas those in winter (June.—Sept.) are less than or close to 4.7, and in the transitional season (April—May, Oct.—Nov.) they sway about the monthly mean. There occur cyclones frequently in summer, on an average, 5.4 Antarctic cyclone processes for every month, but the active period of winter cyclones is longer. There are 4.1 Antarctic cyclone processes for every month, and 4.5 every month during the transitional seasons. The bottom in Fig. 5 shows the mean monthly distribution of three kinds of Antarctic cyclone numbers. There is greater Antarctic cyclone number moving towards the northern tip of the Antarctic Peninsula in summer, especially the greatest in January 3.0 on an average, whereas less in winter. It is worth noting that in winter, especially in mid-winter July—Sept., the Antarctic cyclone number of southern tracks obviously increases, whereas the number of northern tracks decreases. In the end of August the Antarctic cyclones of northern tracks begin to appear. This fact further shows that even in winter, the cold air in Antarctic Peninsula and surrounding areas is not strong, and the warm air is more active. It can also be seen in Fig. 5 that in May, when it is to enter winter, the Antarctic cyclone number of northern tracks occurs most, 2.7 on an average, whereas 0.3 on an average for southern tracks. In general, before or after winter coming, there are strong cold air outbreaks for several times, which influence the areas close to Antarctic Peninsula, and then severe winter is followed. For example, in May 1985 there were three strong cold air influences and the trend of northern tracks was very obvious in this month (figure omitted). By the analysis of climatic features of Antarctic region, the cold air of the Antarctic continent is very strong in winter but the Antarctic Peninsula is not so cold as the continent. In comparison, the climatic condition in the Antarctic Peninsula and its adjacent areas is much better.

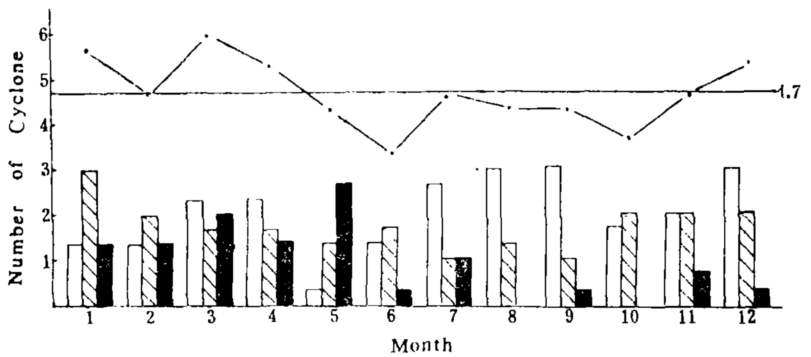

Fig. 5. Mean monthly distribution of cyclone number in western Antarctic region. The top figure shows mean monthly distribution of Antarctic cyclone total number. Thick line depicts the distribution of monthly Antarctic cyclone number; thin line depicts the mean monthly frequency distribution of every kind of Antarctic cyclone: cyclone of southern tracks (block), cyclone influencing the northern tip of the Antarctic Peninsula (hatched) and cyclone of northern tracks (black).

2. *Moving Speed*

According to the crossed longitude spacing of every Antarctic cyclone track, the moving speed of cyclone is calculated at different latitudes. The results show that the average cyclone moving speed is 14.4° longitude/day, and according to the length of every longitude at different latitudes, the average moving speed of Antarctic cyclone is calculated to be 29.9km/h. However, the moving speed of every kind of Antarctic cyclone is different. The statistic results show that the speed of cyclones influencing the northern tip of Antarctic Peninsula is 30.0km/h, close to the cyclone average speed whereas the cyclone speed of southern tracks is 28.7km/h, and that of northern tracks is faster, 32.5km/h. From the distribution of monthly cyclone speed (figure omitted), we have obtained that the difference between summer and winter is not too much, and the cyclone speed in summer is close to the average speed, 29.4km/h, the speed in winter is slightly less than the average, 28.5km/h. And the Antarctic cyclones move evidently fast during the transitional seasons at a speed of 31.8 km/h. The appearance of the extreme is in October, and the cyclone speed is the fastest, 34.2 km/h, on an average.

It is worth noticing that when some cyclones move into both sides of the Antarctic Peninsula, i. e. into Bellingshausen and Weddell Sea waters, the cyclones tend to slow down, and often loop around or even stagnate. The statistic calculation shows that the average speeds of cyclones are 27.4 and 28.5 km/h in these two sea waters respectively, slower than the average speed of Antarctic cyclones 29.9 km/h. It is attributed to the following facts: the high frequency region of the cyclones occurrence in this region, the curved topographic features of Antarctic coast, and the characteristics of the oceanic underlying surface. In addition, when cyclones pass through the Peninsula, they quite often "iump" over it at an average speed of 44.4 km/h. As cyclones pass through the Drake Passage, they appear to travel at even higher speed of 50.5 km/h, on an average, under the influence of topography.

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