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The climate background and synoptic situation of fog at Great Wall Station, Antarctica

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Abstract Based on the observed and NCEP reanalysis data from 1985 to 2006, the climate background and synoptic situation of fog at Great Wall Station were analyzed. It is shown that the seasonal variation of fog is controlled by the change of general circulation and local pressure field. Three favorable typical synoptic situations for fog development are found, the Front-of-A-Depression type, the Saddle-Shaped-Field type and the Passing-Weak-Cyclone type. The first one is the most important situation. Advection cooling fog is dominant at Great Wall Station, but there are other kinds of fog as well. As a result, some helpful principles for local fog forecasting are given.
Key words sea fog, synoptic situation, Great Wall Station, Antarctic.
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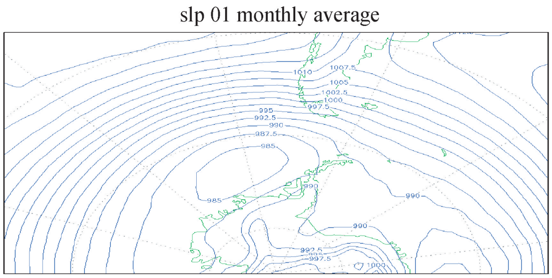
1 Introduction

Great Wall Station (GWS; 62°13′S, 58°58′W) is located at King George Island of the South Shetland Islands in West Antarctica, with typical sub-polar marine climate of low temperature and high humility. The Drake Passage which is the main corridors of circumpolar cyclones is nearby, and averagely one cyclone passes every three to four days in summer. King George Island is surrounded by cold ocean currents of Antarctic Circumpolar Current and Weddell Gyre, warm and cold air masses are often mixed here[1], and fog is easily formed. Fog damage is serious and there have been more than ten casualties in accidents of aviation, sailing and field operation under dense fogs in the region since 1985. Peng analyzed fog in Maxwell Bay in the summer of 1985, and pointed out that the air temperature and humility are beneficial to the generation of fog throughout that summer, the NW wind is an important factor[2]. Yang *et al*. discussed the meteorological elements of GWS and found that more fogs were recorded in summer than in winter, and most fogs were developed by advection cooling[3]. However, the data used by former study were only surface observation and synoptic charts, and the climatic features were not studied yet. In this paper, based on the observed and NCEP reanalysis data from 1985 to 2006, the climate background and typical synoptic situations for fog development are given.

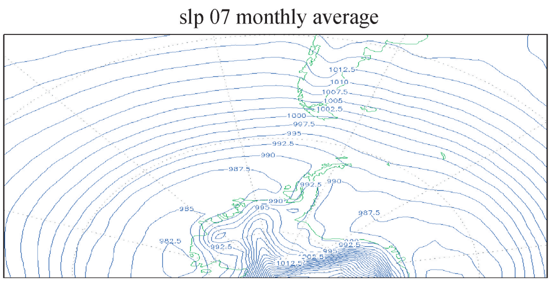
2 The climate background of seasonal variation

There were 136 annual mean fog days at GWS, which was 37.3% of a year according to weather records during 1985-2006. The statistics also showed that there were more fogs in summer (from Nov. to Mar.) than in winter (from June to Aug.), with 13 and 9 monthly mean fog days, respectively[3].

Figure 1 and Figure 2 are mean sea level pressure and surface wind field of January and July, respectively, which were made from NCEP reanalysis data from 1985 to 2006. In summer, low pressure area is located in West Antarctica and a deep low center is at 65 °E, 90 °W west of Antarctic Peninsula, where cyclones are active. A weak subtropical high ridge covers the Weddell Sea and a dense isobars region is between the low and the subtropical high (Fig. 1a). NW wind prevails from Drake Passage to the northern part of Antarctic Peninsula and it is clear that warm and moist ocean air is easy to reach GWS (Fig. 2a).



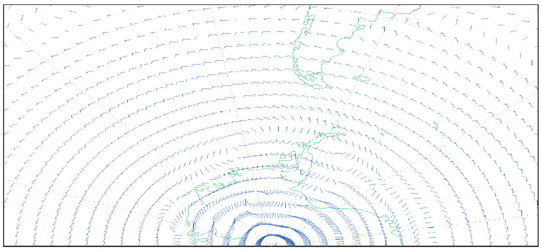
(a)



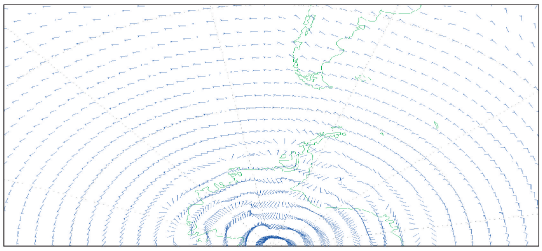
(b)

Fig. 1 Mean sea level pressure in the west Antarctic sector. (a) January, (b) July.

In winter, the closed low center locating at the sea west of Antarctic Peninsula disappears and the low pressure region moves back to the west (Fig. 1b), which means less cyclone activities at GWS. The Antarctic continent high extends northward and SE winds become strong. NW winds are still blowing on Drake Passage and the north part of Antarctic Peninsula but the north wind element is weaker than in summer (Fig. 2b). It is shown that the seasonal variation of fog at GWS is controlled by general circulation and synoptic situation, and it is more favorable to generate fog in summer than in winter.



(a)



(b)

Fig. 2 Mean surface wind in the west Antarctic sector. (a) January, (b) July.

3 Synoptic situation for fog development

Based on the NCEP reanalysis data from 1985 to 2006, the synoptic situations of fog at GWS were classified and three favorable typical synoptic situations were found. The composite charts of 500 hPa height, 850 hPa height, sea level pressure and surface relative humidity of each situation are given as follows.

3.1 Synoptic situation I (Front-of-a-deep-depression type)

Figure 3 is the composite synoptic charts of heights 500 hPa and 850 hPa, sea level pressure and surface relative humidity of situation I. The chart of 500 hPa shows that the area west of Antarctic Peninsula is controlled by a deep trough with a closed center at 65°S, 90°W. The temperature trough and the height trough are coincided fairly. The Atlantic subtropical high is strong and extends southwards to the northeast of Antarctic Peninsula. A ridge is along 40°W. A dense pressure gradient region is formed between the deep trough and the subtropical high, and covers most of the Antarctic Peninsula. On the 850 hPa height, a dense pressure gradient region is between 50°S and 60°S, where northwest wind prevails. A warm advection steam flows from low latitude ocean towards King George Island. On sea level pressure chart, the Antarctic continent high is weak and the whole west Antarctica is a low pressure area. A strong depression moves to the west of Antarctic Peninsula. Most cyclones are matured or weakened as they get to the west of the Antarctic Peninsula, because Bellinsgauzen Sea is one of "graveyards" of circumpolar cyclones[4]. The Antarctic Peninsula is ahead of the front of the cyclone, the warm and moist air gets there from low-latitude ocean by NW wind, which is very important for fog forming. It can be seen from the surface humidity distribution that a high humidity tongue is in the NW wind region ahead of the cold front (Fig. 3d). If the subtropical high is strong and the cyclone is blocked, fog will last longer time at GWS. Most fog recorded at GWS is controlled by this synoptic situation.

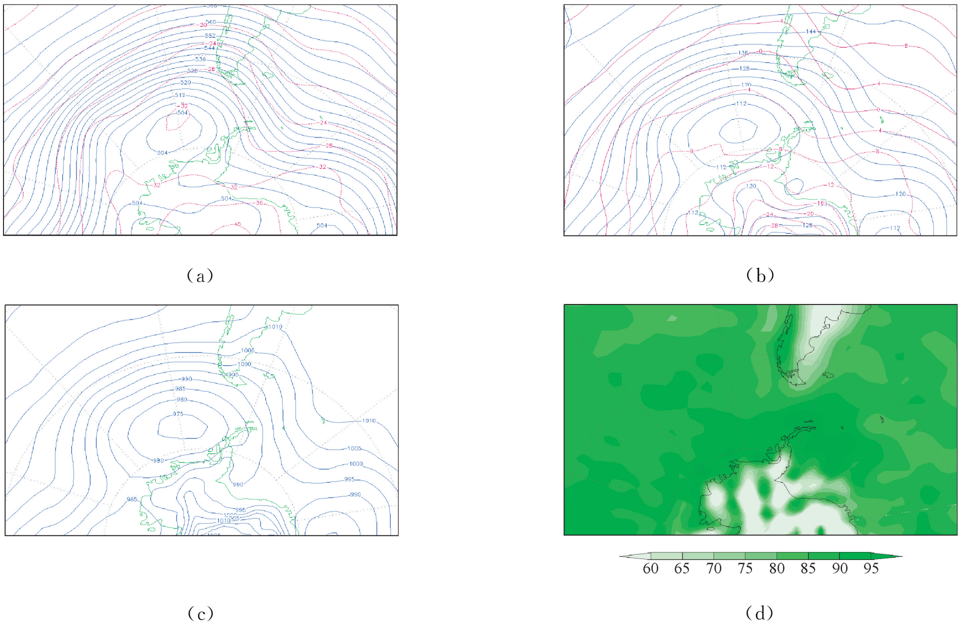


Fig. 3 Composite charts of synoptic situation. (a) 500 hPa , (b) 850 hPa, (c) Sea level pressure and (d) Surface relative humidity.

3.2 Synoptic situation II (Saddle-shaped-field type)

Fog may occur at GWS in a saddle shaped surface pressure field. The important character of this kind of synoptic situation is that two-troughs with one ridge are shown on the 500 hPa height chart. In Figure 4a, one deep trough is at about 110°W, the west of the Antarctic Peninsula and another tough is at 30°W, the east of the Peninsula. The ridge of a high covers the peninsula between two lows. On the chart of

850 hPa, a dense height gradients region is on the west side of the ridge with a strong warm advection (Fig. 4b). Compared with the situation at the 500 hPa, the pressure field on sea level is not so strong, with two weak depressions on the east and west sides of the Antarctic Peninsula respectively. Usually the depression is weakened when it passes the peninsula. Wind direction turns from NW to W near the ridge line. Northern part of Antarctic Peninsula is inside the saddle shaped pressure field with WNW air flow (Fig. 4c). A wet tongue is on the west side of the Antarctic Peninsula (Fig. 4d).

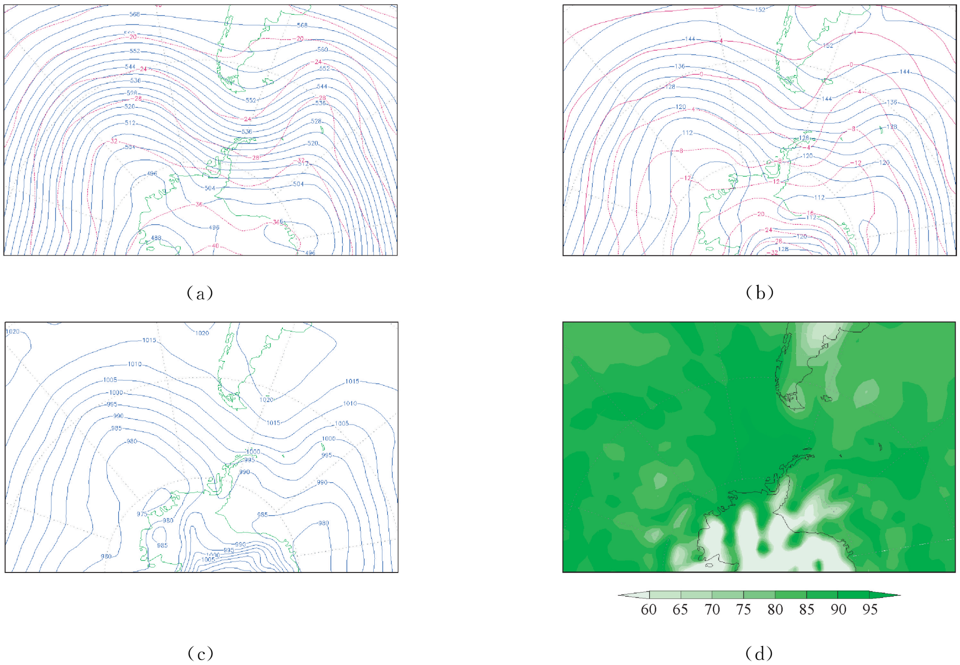
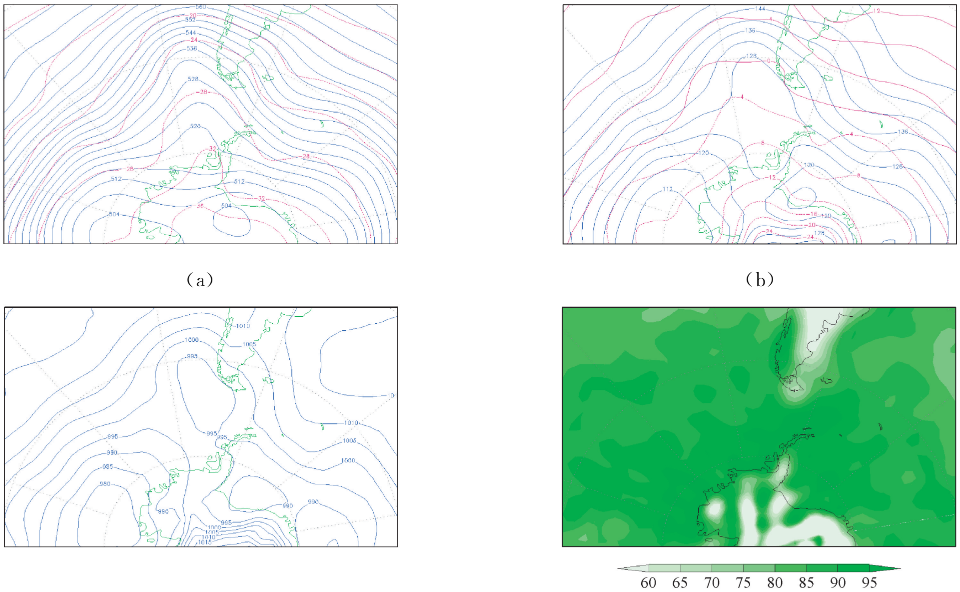


Fig. 4 Composite charts of synoptic situation II. (a) 500 hPa, (b) 850 hPa, (c) Sea level pressure and (d) Surface relative humidity.

3.3 Synoptic situation III (Passing-weak-cyclone type)

When a small or weak cyclone passes the Drake Passage from the west, fog is often observed at GWS. On the chart of 500 hPa, the southern tip of South America and the northern part of the Antarctic Peninsula is controlled by a trough; on the chart of 850 hPa (Fig. 5b), a closed low pressure center is in the Drake Passage with north flow blowing over the area between the depression and the Atlantic subtropical high. On the chart of sea level pressure, a usually weak cyclone is passing the Drake Passage with sparse isobars around the Antarctic Peninsula (Fig. 5c). Fog is reported at GWS with N winds when the cyclone is passing the Drake Passage and fog becomes thin soon, as the wind direction turns to E. The humidity distribution shows a high center in the south and the east of the cyclone (Fig. 5d). The fog duration is determined by moving speed of the cyclone. Usually the lasting time of the fog is shorter in synoptic situation III than in situation I and situation II.



(c) (d)

Fig. 5 Composite charts of synoptic situation III. (a) 500 hPa, (b) 850 hPa, (c) Sea level pressure and (d) Surface relative humidity.

An obvious warm advection from low-latitude to the GWS on 850 hPa height chart, and N or NW surface wind prevailing on the northern part of the Antarctic Peninsula are shown in the three synoptic situations above. The statistics from 1985 to 2006 shows that 71%, 15% and 12% of fogs occurred in situation I, situation II and situation III respectively. There was also 2% of fogs in undetermined synoptic situation, meaning that advection cooling fog dominates at GWS, but other kinds of fog appears there too (Fig. 6).

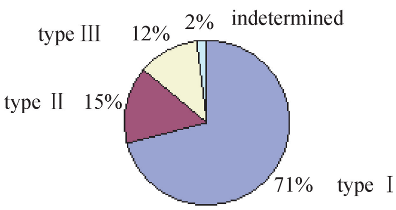


Fig. 6 The occurrence of fog in different synoptic situation.

4 Conclusion

(1) The seasonal variation of fog at GWS is controlled by the change of general circulation and synoptic situation.

(2) Front-of-a-depression type, Saddle-shaped-field type and Passing-weak-cyclone type are favorable synoptic situations for fog development at GWS. The Front-of-a-depression type is the most dominant one.

(3) A significant warm advection from low-latitude to the GWS on the chart of 850 hPa, and N or NW surface wind prevailing on the northern part of the Antarctic Peninsula are shown in all three synoptic situations.

(4) Advection cooling fog dominates at GWS, but other kinds of fog appear there too.

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