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Structure of Jetlike Winds in the Lower Atmosphere, King George Island, Antarctica

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Abstract : The structure of the jetlike winds in the lower atmosphere in King George Island, Antarctica, was investigated for the period of 13 through 15 April, 1987. The formation of coastal low-level jetlike wind is primarily associated with the upper tropospheric jet stream due to the downward momentum transport from the upper level to the height of the jetlike wind, and secondly, coupled with the frontal or subsidence inversion in the lower atmosphere. In addition, isallobaric high or low in the surface boundary layer which induces the divergence or the convergence near the surface also influences the formation of low-level jet, resulting in the subsidence or the upward motion in the coastal region.

Key words : jetlike winds, lower atmosphere, King George Island, Antarctica

Introduction

The coastal low-level jetlike winds which should be greater than 12 m s^{-1} are often detected at an altitude of 2 km or less, while the surface wind speeds are weak within the Antarctica. Bromwich et al. (1988), Parish and Pickett (1988) indicated that the intensity of katabatic wind in the Antarctic coastal rim is influenced by confluence zones where drainage currents converge and become focused on a restricted stretch of coastline. Katabatic winds are also controlled by the slop-induced baroclinicity, turbulent mixing, and synoptic forcing (Sorbjan et al., 1986) and accelerated by the blowing snow entrained into the atmospheric boundary layer (Kodama et al., 1985). The past studies have been restricted on katabatic winds in the surface layer, not the elevated high wind speed regime.

In this study the documentation is presented for the relationship between the coastal low-level jetlike wind and upper tropospheric jet stream. This research also gives attention to the frontal and subsidence inversion layers associated with the low-level jetlike wind, and to the role of strong isallobaric winds, which blow into King George Island during the occurrence of low-level jetlike winds.

Measurement

The first data is upper air data obtained by the radiosonde at President Frei Station (Chile -62.2°S; 58.9°W) and Bellingshausen Station (U.S.S.R.-62.2°S; 59.0°W) on King George Island, Antarctica, from 00Z April 13 through 12Z April 15, 1987. Wind and temperature soundings were taken every twelve hours at 00Z by Bellingshausen and at 12Z by President Frei except for one missing of sounding observation at Bellingshausen Station due to the bad weather. These data were decoded from the weather teletype transmission and plotted on a skew T-log P diagram. This allowed the determination of the height, speed, and direction of the coastal low-level jetlike wind on King George Island.

The second set is surface wind data obtained by President Frei Station during the period of investigation. The automatic wind recording instrument was mounted on the top of a 10 m tower which was about 0.1 km inland from the coastline. The tower was set up on the sand beach changing to low dunes less than 6 meters above mean sea level. The surface weather maps provided by President Frei every tweleve hours a day were used for analyzing the frontal passage, and convergence or divergence into or out of the isallobaric center in the surface boundary layer from reforming the isallobaric charts.

Results and Discussion

1. Relationship of the coastal low-level jetlike wind to the upper tropospheric jet stream

In order to investigate the relationship of the upper tropospheric jet stream to the coastal low-level jetlike wind on the King George Island, upper air data for President Frei and Bellingshausen Stations were used. In this study the occurrences of coastal low-level jetlike winds were counted when the maximum wind speed was greater than 12 m s^{-1} at an altitude of 2 km or less (Duric, 1981). In the same way the speed of upper tropospheric jet stream should be greater than 25 m s^{-1}. Table 1 shows the simultaneous occurrence of a coastal low-level jetlike wind on King George Island with the occurrence of upper tropospheric jet stream. The average occurrence of low-level jetlike winds with upper jet stream was 60 %. From this analysis one can see that the occurrence of a low-level jetlike wind is closely associated with an upper tropospheric jet stream. However, these results showed that when a low-level jetlike wind is present, an upper tropospheric jet stream can be expected to exist, but when a jet stream is present a low-level jetlike wind does not always occur.

Table 1. Relationship of the upper tropospheric jet stream to the coastal low-level jetlike wind during the period of April 13−15, 1987.

Data	Upper Tropospheric Jet Stream (m s^{-1})	Coastal jetlike Wind (m s^{-1})
4/13 00Z	No (15)	No (08)
12Z	Yes (50)	Yes (20)
4/14 00Z	Yes (43)	Yes (35)
12Z	Yes (53)	Yes (13)
4/15 12Z	Yes(43)	No (10)

2. Characteristics of temperature and wind profile

Figure 1 makes illustrations on the vertical distribution of the temperature and wind speed from 00Z April 13 through 12Z April 15. At 00Z April 13 neither upper tropospheric jet stream nor low-level jetlike wind was observed. On this occasion the upper tropospheric maximum wind speed was 18 m s^{-1} at the 7.5 km height and that of low-level was 8 m s^{-1} at the 1.5 km, respectively. At 12Z April 13 both upper tropospheric jet of 50 m s^{-1} and low-level jet of 20 m s^{-1} were detected at 11 km and 1.5 km height. On this sounding a subsidence inversion layer from 810 mb to 780 mb was stronger than the frontal inversion layer from 730 mb to 710 mb. The low dew point temperatures of the 810 mb and 780 mb layer identify this layer as a subsidence layer. Since a cold front producing a wide spread band of weather is associated with subsidence and divergence (Tieman, 1969), the downward motion of air mass from the frontal and lower subsidence inversion layers reaches the height of low-level jetlike wind, enhancing the formation of jetlike wind in the lower atmosphere.

The wind profile at 00Z April 14 showed that a strong low-level jetlike wind of 35 m s^{-1} was observed at the 1 km height when the upper tropospheric jet of 43 m s^{-1} existed over 10.5

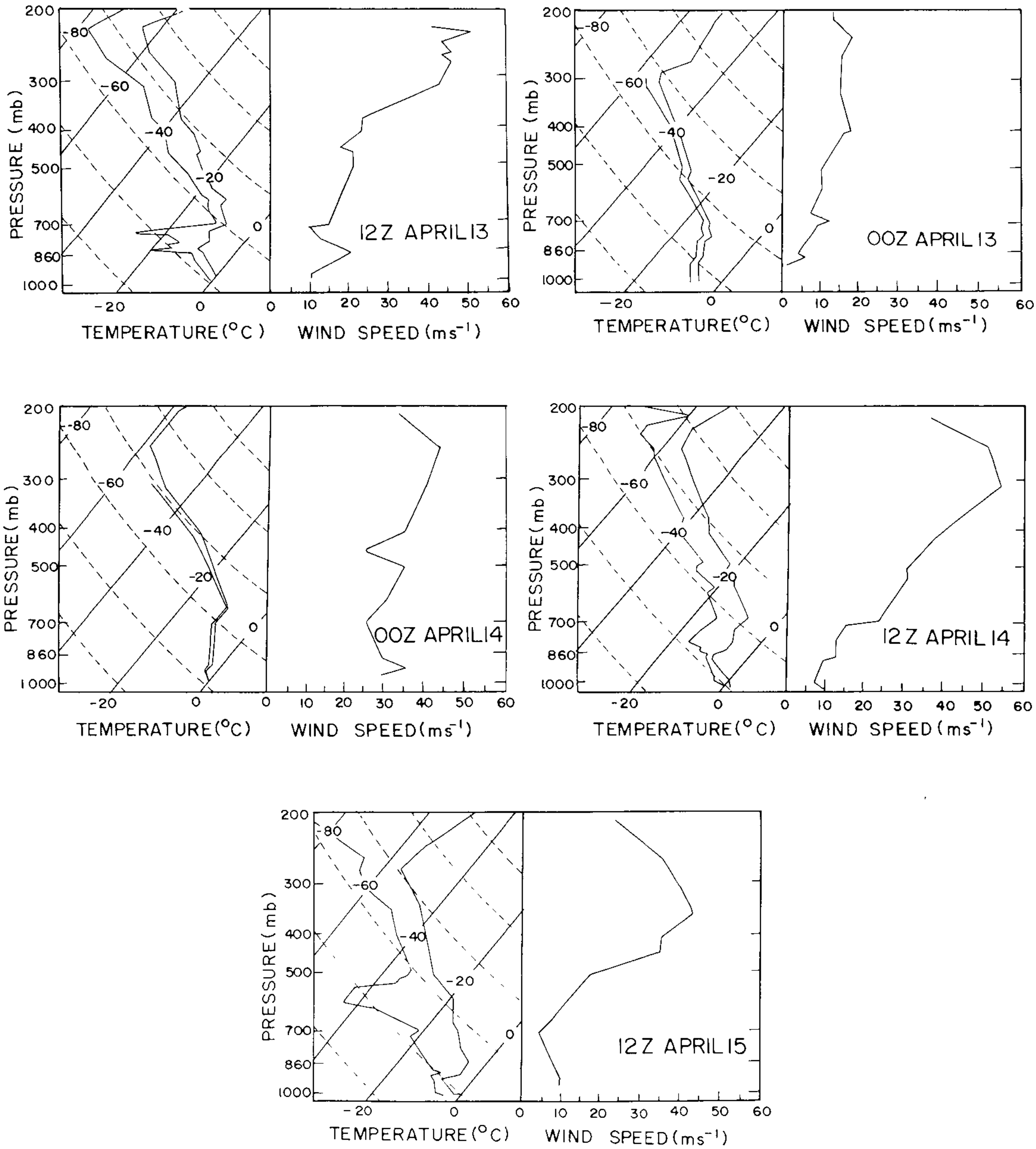

Fig. 1. Vertical profiles of temperature and wind speed from 00Z April 13 through 12Z April 15, 1987 on King George Island, Antarctica. Thick and thin lines indicate air and dew-point temperatures, respectively.

km. At this time the polar front had just passed by King George Island. The whole layer from surface to 300 mb levels was humid as shown in the typical frontal passage and wind speeds from the upper jet decreased gradually to the top of the frontal inversion layer of the 920 mb to 890 mb level. Especially, near the 1 km height where the frontal inversion was formed a cold front characterized by a narrow weather band produced down slope motion in the relative warm air over the heigher ranges of the frontal surface. Thus, the formation of the low-level jetlike wind could be easily expected at the coastal site.

On the other hand, the upper tropospheric jet at 12Z April 14 was present at 9 km and the strong wind in the lowest layer of atmosphere existed with the magnitude of 12 m s^{-1} near 1.5 km height above ground. The atmosphere over 1 km height was very dry and the subsidence inversion layer was found at 840 mb to 780 mb level. The downward momentum transport from the strong upper jet took toward the ground and it created a gradual decrease of wind speed to the height of a jetlike wind. From the isallobaric chart evaluated from the surface weather maps isallobaric high due to the rapid change of pressure fields with time was near King George Island (Fig. 2a). As the mass transport out of the isallobaric high produces the divergence (subsidence) of air in the surface boundary layer, it may play a role in the vertical distribution of wind speed with height.

At April 15 the low-level jetlike wind was not observed, despite the occurrence of upper tropospheric jet at the 8.3 km height. This means that the maximum wind speed near the 2 km height was only 8 m s^{-1} less than the magnitude of low-level jetlike wind. According to the sounding the aspect of temperature profile at this time was not much different from that of 12Z April 14 and non-occurrence of low-level jetlike wind may be explained similarly as in the case of 12Z April 14. As the isallobaric high was still observed in the vicinity of King George Island, it could produce the divergence in the surface layer and drive the subsidence from upper over ground (Fig. 2b). The magnitude of

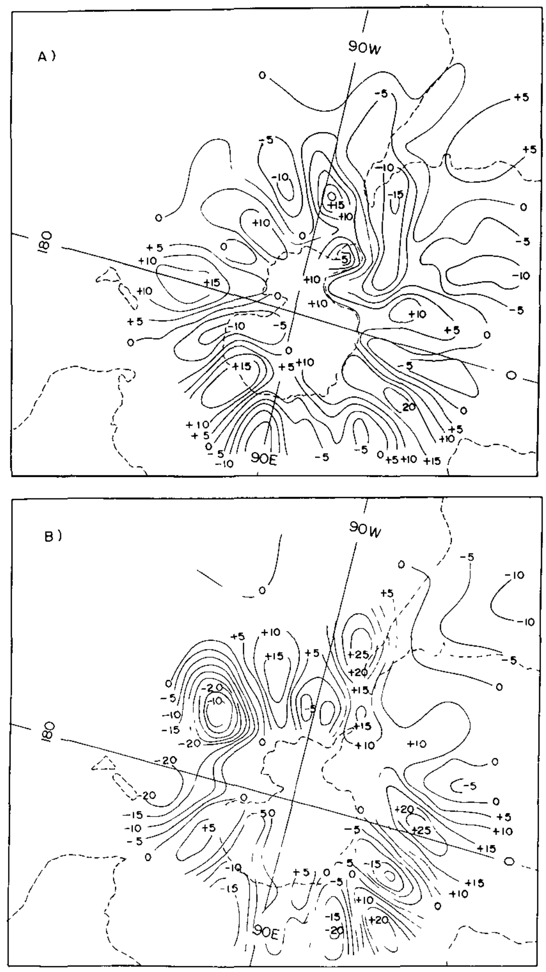

Fig. 2. Distribution of surface isallobar during the periods of a) 12Z April 14 through 00Z April 14 and b) 12Z April 15 through 12Z April 14, 1987 in Antarctica.

isallobar across King George Island reached 12 mb for 24 hours and it might be partly associated with non-occurrence of coastal low-level jetlike wind in the study area.

Conclusion

The occurrence of a coastal jetlike wind might be derived by the very complicated generation mechanisms in the Antarctic. Consequently, the formation of coastal low-level jetlike wind in the study area is primarily associated with the upper tropospheric jet stream due to the downward momentum transport, and secondly, coupled with the frontal or subsidence inversion inducing the increase of horizontal wind speed in the lower atmosphere. Furthermore, isallobaric high or low in the surface layer also influences the formation of low-level jetlike wind, resulting in the subsidence or the uprising of air in the coastal region. A mathematical model in the near future will be suggested to evaluate the exact quantities of momentum transport from the upper tropospheric jet level toward the height of low-level jetlike wind and surface isallobaric winds for generalizing this phenomenon.

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