POLISH POLAR RESEARCH	8	1	75—83	1987

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Vertical wind profile under small velocity conditions over the Admiralty Bay, King George Island, West Antarctica

ABSTRACT: The analysis of speed and direction distribution of upper wind in the layer up to 3500 m was carried out on the basis of pibal ascents performed over the Admiralty Bay (King George Island, South Shetland Islands).

Key words: Antarctica, upper wind.

General conditions

Surface winds in the area of the Antarctic Arctowski Station are strongly modified by topographic conditions as on many other stations situated on the islands of subantarctic archipelagoes. Mountainous, glacier--covered slopes forming indented coast are an obstacle to the air-flow. As an effect a sideward or upward deflection of the air-stream occurs. The stream undergoes a dynamic deformation resulting, among others, in a very strong gustiness, especially well marked on the leeward slopes (Kowalski 1985). In some cases, however, when the direction of wind is favorable, there might be calm weather on the leeside of the obstacle. The vertical effect of the obstacle is extending to a considerable height. The latter depends on the height of the obstacle itself, on the force and direction of the wind and, of course, on the distance of the measuring point from the obstacle. It is very useful to know, for many purposes among others for the sake of aviation, how great the described dependence is. There are some means to reveal it, one of them being the measurements of upper winds by pilot-balloon (pibal) method. On the Arctowski Station the pibal measurements were performed during several expeditions. In this paper the results of only the first series of them are elaborated.

The South Shetland Islands are lying on the southern edge of the strong circumpolar air flow what determines the predominance of strong westerly winds there, of course if undisturbed by any kind of obstacle as islands, mountain slopes and so on. This could be confirmed by upper wind data, among others from the USSR Bellingshausen Station (Skrzypczak 1980 *unpubl.*). The surface wind in the surroundings of the Arctowski Station deviates to some extent from this rule and shows a rather great nonuniformity in directions and force, even when measured at points not very far from one another (Kowalewski and Wielbińska 1983).

In the period in which the first series of upper wind measurements were taken (Dec. 1978 to March 1980) the surface wind at the Arctowski Station had mainly south westerly directions with a considerable share of northerly winds (Nowosielski 1980). A predominance of easterly winds in summer 1979/80 was the other characteristic feature (Cygan 1981). The aim of the analysis of the pibal ascents was to prove the close connection between the described distribution of surface wind in the area of the Arctowski Station and the upper wind over the Admiralty Bay and, if possible, to find the influence of the surroundings of the station on the vertical profile of the wind.

Characteristics of observation material

The measurements were carried out by the optical method with a use of a theodolite. The ascent rate was secured to 200 m min^{-1}, and in some cases to 100 m min^{-1}. The readings of the position of the balloon were taken at one minute intervals. Calculations were made using the Molchanov circle.

The applied technique enabled to perform observations only under conditions ensuring good visibility of the balloon, *i.e.* a relatively high transparency of the atmosphere and a rather high base of clouds or a lack of the latter. At the Arctowski Station, due to predominance of great cloud amount and its low ceiling in the time considered (Nowosielski 1980, Cygan 1981), the conditions favourable for the pibal ascents were rare. Thus the number of ascents did not exceed 60. Fair weather is determined by mainly two types of atmospheric pressure pattern and winds of different character are connected with them. The high pressure system with light variable winds, appearing within considerable thick layer of the atmosphere, is the one and the pressure field after the passage of a cold front, accompanied by stronger winds within the whole vertical profile, mainly from southwesterly directions, is the other. Both these pressure systems were frequent among the 60 pibal ascents analyzed. All the ascents were elaborated jointly (because of their small number), disregarding the differences resulting from the different air flow character.

Somewhat more than 50% of the ascents exceeded the height of 2300 m, several of them reached 6000 m, the highest one reached 11,400 m. Over 45% of measured wind profiles were characterized by south westerly and westerly wind directions, variable directions at small speeds were represented by 25% of ascents, north westerly directions by 15% and the north easterly ones by 10%. Remaining directions in the wind profiles were represented by only 5% of ascents and there was no ascent of easterly wind.

Vertical profile of wind velocity

A detailed analysis of the observation data allows to distinguish several characteristic features of air flow over the station.

Two types of velocity distribution in the vertical cross-section were most common among the wind profiles measured. First of them, connected with pressure field of considerable gradient was characterized by wind velocities which increased more or less regularly with height; the other was connected with high pressure area and maintained low wind velocities

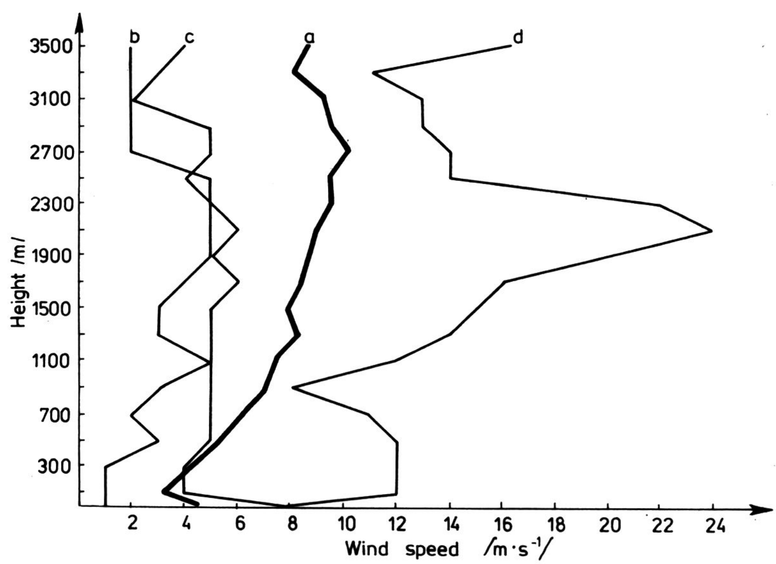

Fig. 1. Vertical wind profiles prepared on the basis of pibal ascents from over the Admiralty Bay

a — mean wind profile, *b* and *c* — wind velocity profiles on January 11 and February 16, 1979, characteristic for extremely small velocities, *d* — wind velocity profile on January 26, 1979: an example of exremely great velocities among the measured ones to considerable height of the atmosphere. Both of them had a common feature: the surface wind was very often stronger than the upper wind at 100 — 400 m, and only higher it showed again an uniform increase or steady light velocities. A second reduction of wind velocity occurred

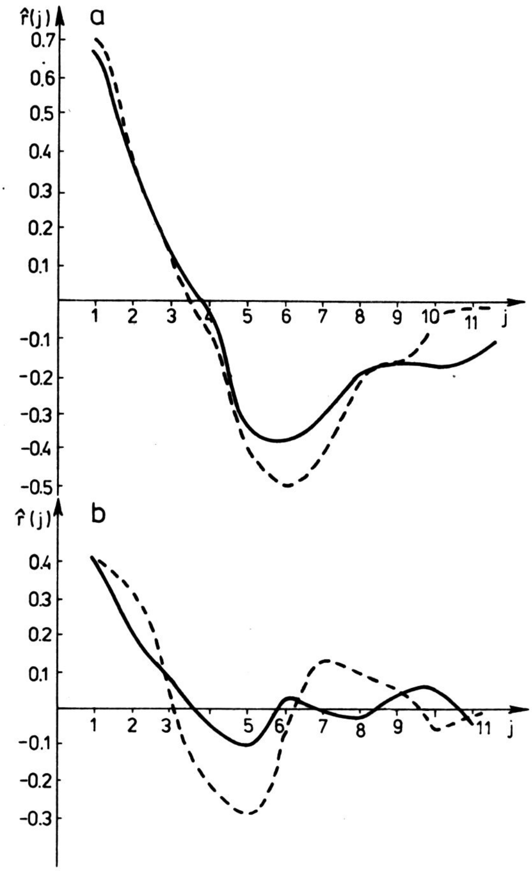

Fig. 2. Autocorrelation of wind velocities at particular levels at Δj set for 200 m
a — for the vertical wind profile on January 26, 1979, *b* — for the vertical wind profile on January 11, 1979

often at approximately 1300 — 1700 m. All this could be explained by the influence of the station area. When the wind comes from the western sector (SW, W, NW) the observation point of the pibal ascents lies in the aerodynamic shadow of the glacier dome. Thence the reduction of velocity at 100 — 400 m occurred as the westerly winds are the most common at the station. Another smaller reduction of velocity at 2000 — 2200 m is probably due to an orographic wave forming over the island in favorable conditions and influencing the air flow over it. Its occurrence is to be proved by many more pibal or radiosonde ascents, performed at different sites of the island (Skrzypczak 1980, *unpubl.*). Stronger surface winds are caused by the commonly great gustiness of turbulent air flow at the ground. All these peculiarities are well reflected in the wind mean velocity profile calculated with a use of all 60 ascents (Fig. 1a). The same illustration presents also some other characteristic profiles. Figure 1b and c shows vertical cross-section of extremely small velocities and Fig. 1d — of the extremely great velocities. The case presented in Fig. 1d seems also interesting, for it illustrates a rapid (in a particular layer) increase of velocity with height, known as jet stream. This phenomenon cannot be assumed not to be the common one in the Subantarctic.

To check whether a closer relationship occurs between the winds on particular levels, the autocorrelation of velocities in a vertical cross-section was calculated, despite the nonuniformity of anemobaric conditions of the ascents and despite of their scantiness. Two versions of calculations were made. One of them took both the upper and the surface winds into consideration and the other was limited only to the upper winds on all levels available.

The results did not reveal much news. First of all, they did not confirm the expected periodicity of velocities in a vertical section which would have been revealed in cases of occurrence of wave motion. Lack of this periodicity was probably due to the averaging of the velocities within too thick layers (200 m). The function of autocorrelation tended relatively quickly towards zero, such decrease being quicker for ascents performed at low velocities, both when the surface winds were and were not considered (Fig. 2a, 2b). The autocorrelation values for adjoining layers amounted to about 0.75, reaching zero already for the layers at the distance of about 1000 m. Proving by means of the autocorrelation method if the orographic wave motion exists in the air flow over the King George Island, should require the application of results gained by smaller ascent rates of the balloon and more frequent readings of its position. Without this, only the orographic clouds (*Altocumulus lenticularis*) that are very common over the island ridges, bear a witness on the occurrence of this deformation of air flow.

Wind direction

Pibal ascents were performed as already mentioned, in relatively fair weather conditions which occurred after a passage of the cold front. The latter is usually followed by winds with a significant westerly component. Another type of clear weather, favorable to trace a pibal occurs during persisting high pressure systems when variable winds of small velocities prevail up to high levels in the atmosphere. Thus the majority of ascents represent these two types of wind directions in a vertical section.

Changes of wind directions with increasing height can be traced when analyzing the horizontal projection of a balloon path. With this method one can find that the greatest changes of wind directions occur between the surface winds and the winds in the low layer of the air (from 100 to 300 m). If we accept as positive the clockwise deviation of winds, we can say that up to 300 m the negative deviations prevailed, exceeding in several cases 150° (in summer 1980). Positive deviations were encountered only twice. From the point of view of the applied method the deviation sign at such wide angles was found to be of no significant importance. In the layer above 300 m a negative deviation also appeared, increasing with the height. In the profiles of the westerly wind the greater velocities and a smaller direction variability were typical (Fig. 3a). Profiles with the predominant easterly and northerly components showed smaller velocities in the whole height and marked changes in directions (Fig. 3b).

Direction and velocity distributions observed on January 24, 1980 were especially interesting as the ascent reached 11,400 m, so that the highest

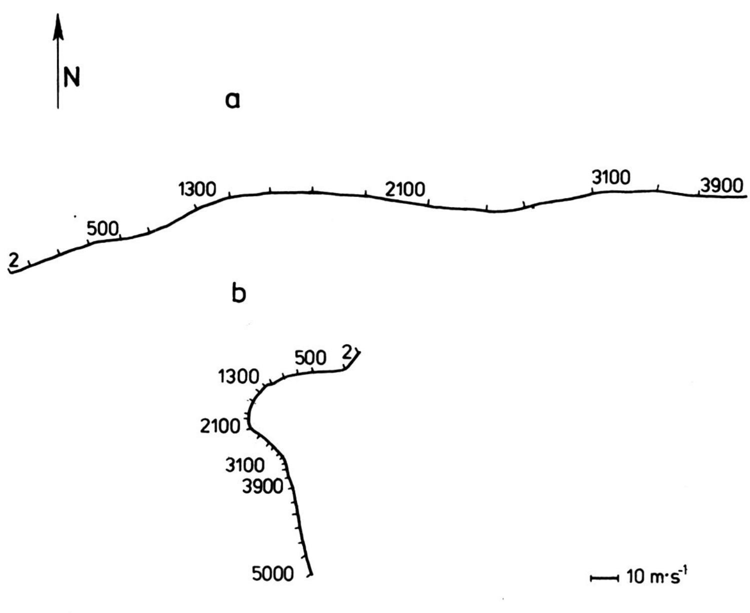

Fig. 3. Horizontal projections of the balloon path in cases of great and small upper wind velocities

a — ascent on January 26, 1979, wind speeds from 8 to 29 m/s, *b* — ascent on January 26, 1979, wind speeds from 2 to 5 m/s. The figures along the balloon track give the height in meters part of the balloon path ran already in the stratosphere (Fig. 4). In the whole cross-section the north-easterly winds prevailed with two thick layers of an inversed air movement. The first inversion was seen between 1200 and 2200 m at the heights of diminishing velocities. The second inversion

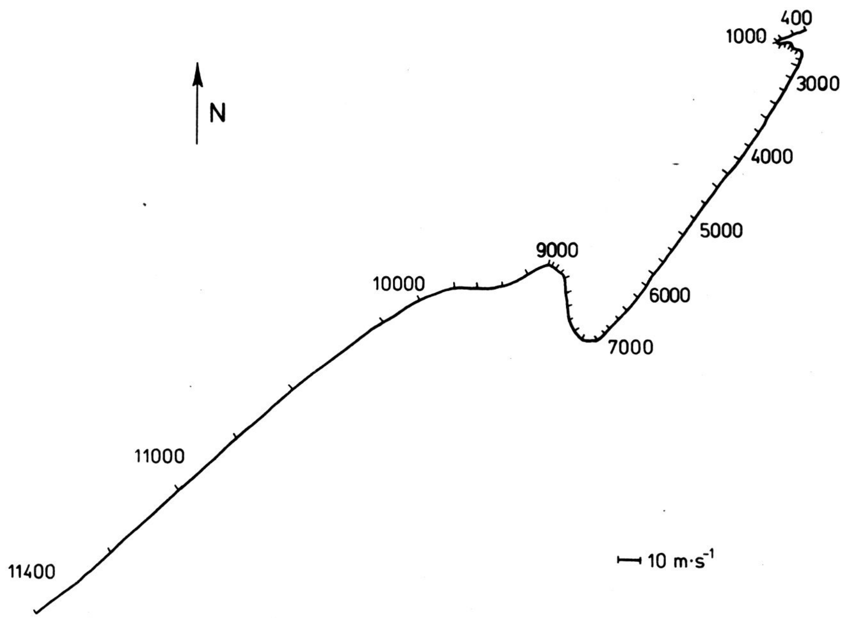

Fig. 4. Horizontal projection of the balloon path of the ascent reaching the stratosphere (on Jan. 24. 1980). Between 7000 and 9000 m the changes of wind direction and velocity are due to the tropopause and above 9000 m already to the stratospheric conditions

of air flow during this ascent was observed between 7000 and 9000 m, where the balloon ran through the nearly motionless tropopause. Above 9000 m the stratosphere was reached: the wind has backed again, the velocities increased and retained steady north easterly directions. The pressure pattern which resulted in the described distribution of winds in the vertical cross-section, maintained over the Antarctic Peninsula for several days.

Conclusions

The considered vertical profiles of wind velocities and direction at mostly small wind forces allowed to find out a number of regularities in the variation of these elements:

1. When the air flows with a considerable great westerly component (north westerly, westerly and south westerly winds), the velocities increase with the increasing height. Surface wind is somewhat weaker than between 100 and 300 m but is marked by considerable gustiness.

2. When there are weak winds in the whole vertical profile, the varying directions usually prevail. Velocities of the surface wind are often greater than between 100 and 300 m what should be ascribed to the effect of strong turbulence of air motion in the nearest surroundings of the measuring point.

3. In the mean profile three minima of velocity can be distinguished: between 100 and 300 m, 1300 and 1700 m and about 2200 m. First of them is probably the effect of the aerodynamic shadow of the nearest obstacle *i.e.* the nearby hills. Closer to the obstacle the shadow probably extends higher. The both further minima are probably due to the orographic wave forming over the island in favorable conditions of air flow.

4. No distinct relationship between the velocities in particular air layers could be proved.

5. Some of the upper wind measurements proved that a considerable number of days with easterly air flow occurred in the Antarctic Peninsula, even up to relatively great heights.

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Received November 24, 1981
Revised October 31, 1986

Резюме

Анализировали распределение скоростей и направлений верхних ветров в слое до 3500 м в районе станции им. Арцтовского, расположенной на острове Кинг Джордж на базе данных полученных при помощи шаропилотных измерений (по методу одного теодолита).

В среднем профиле ветра обозначалось снижение скорости в слое 100—300 м по отношению к скорости ветра на уровне станции. Затем наблюдался равномерный рост вплоть до очередного сгиба профиля, т.е. повторного уменьшения скорости на высоте около 1500 м.

Исчисленная автокорреляция скорости в вертикали (в двух вариантах, с учетом скорости ветра на уровне станции и без этой величины) не показывала существенной связи между отдельными уровнями.

Величины автокорреляции для смежных слоев составляли 0,75, а для слоев расположенных на расстоянии около 1000 м они уже достигали нуля.

Профили при ветре из западного сектора характеризировались, в общем, более высокими скоростями, а их горизонтальная проекция — малой изменчивостью направления; профили с преобладанием восточного и северного компонентов показывали преимущественно меньшие скорости по всем профиле, а также характерные изменения направления.

Streszczenie

Dokonano analizy rozkładu prędkości i kierunku wiatrów górnych w warstwie do 3500 m, w rejonie Stacji Arctowskiego położonej na Wyspie Króla Jerzego, w oparciu o dane uzyskane podczas III i IV Wyprawy Antarktycznej PAN (fig. 1-4) w ramach MR.II.16B. Pomiary wykonano przy pomocy pilotaży optycznych (metodą jednego teodolitu).

W profilu średnim wiatru zaznacza się zmniejszenie prędkości w warstwie 100—300 m w stosunku do prędkości wiatru na poziomie stacji. Następnie obserwuje się dość równomierny wzrost, aż od kolejnego ugięcia profilu, tj. ponownego zmniejszenia prędkości na wysokości około 1500 m.

Obliczona autokorelacja prędkości w pionie (w dwóch wersjach, z uwzględnieniem prędkości wiatru na poziomie stacji oraz bez tej wartości) nie wykazała wyraźnych związków między poszczególnymi poziomami. Wartości autokorelacji dla warstw sąsiednich wynosiły 0,75, natomiast dla warstw odległych o około 1000 m osiągały już zero.

Profile przy wietrze z sektora zachodniego charakteryzowały się na ogół większymi prędkościami, a ich rzut poziomy — małą zmiennością kierunku; profile z przewagą składowej wschodniej i północnej miały przeważnie w całym przekroju prędkości mniejsze oraz charakterystyczne zmiany kierunku.