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# METEOROLOGICAL ASPECTS OF THE INTERNATIONAL GEOPHYSICAL YEAR IN ANTARCTICA

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Scientific observation and exploration in Antarctica were undoubtedly some of the most outstanding achievements of the International Geophysical Year, which was in operation from July 1957 to December 1958. This was especially so in meteorology, as prior to the IGY, occasional expeditions, uncoordinated one with the other, had provided some valuable information regarding the Antarctic but there had been no comprehensive study of the properties and circulation of the atmosphere over the Antarctic continent and surrounding seas. The Antarctic is no longer a large blank region on meteorological charts - now it is the oceans of the southern hemisphere which are the last remaining areas from which meteorological data are lacking.

The meteorological data resulting from the IGY are so numerous that full treatment cannot be expected for a considerable time, but a preliminary examination has already revealed the general nature of the properties and circulation of the Antarctic atmosphere. Many of these tentative conclusions were discussed at the Symposium on Antarctic Meteorology held in Melbourne in February, 1959, and the following remarks are largely based on papers presented at that Symposium.

In examining the meteorology of Antarctica it is desirable to consider first the ice of the continent, because this has an important role in the behaviour of the atmosphere above it. Antarctica is largely a continent of ice - ice constitutes more than half of its volume above sea level. The upper surface of the continent is composed almost exclusively of ice with only occasional rock outcrops. A question which is of interest to both the meteorologist and the glaciologist is that of the ice budget. How much ice or snow is deposited each year from the atmosphere? If the amount of ice in Antarctica is relatively constant, how is a balance preserved?

Loewe (1959), considering available evidence and the investigations of other workers, has estimated the accumulation of ice to vary from a minimum of 5 - 8 cm water equivalent in the central region to 25 cm or more in coastal areas. This is equivalent to

$133 \times 10^{10}$ tons of ice. He estimates that evaporation and rime formation are small and probably balance each other and also considers that the loss of snow drift from the continent by katabatic winds to be of the order of $2 \times 10^{10}$ tons. However, recent work by Mellor and Radok (1959), using a device for measuring snow drift designed by the former, has indicated that the amount lost in this fashion may be considerably higher (up to $50 \times 10^{10}$ tons). Mellor and Radok have also investigated the mechanism of snow drift and have drawn an interesting comparison between drifting snow and blowing snow. Loss of ice by either calving of glaciers or ice shelves has been estimated by Loewe to be from $36 \times 10^{10}$ to $65 \times 10^{10}$ tons, leaving an excess of $30 \times 10^{10}$ to $90 \times 10^{10}$ tons which would be either nett accumulation or may be accounted for by melting at the bottom of the ice cap.

The temperature of the surface of the ice cap depends on the nett radiation at the surface, heat exchange between the atmosphere and ice and heat flux within the ice. For the major part of the year the effect of radiation causes a considerable heat loss from the ice surface and this is offset to some extent by transfer of heat from the atmosphere to the ice. As a result, the temperature of the air near the ice surface becomes very low, indeed the lowest recorded temperatures on the earth's surface have been measured on the Antarctic continent, where temperatures colder than -124°F (86.7°C) have been recorded at Sovietskaya (78°S, 88°E). Prior to the IGY, the record minimum temperature had been recorded in Siberia. These low temperatures are confined to a comparatively thin skin of air over the continent, generally less than 3,000 ft deep. Figure 1 (after Flowers, 1959) shows the intensity and depth of the inversion at Amundsen-Scott (90°S) throughout the year and it seems likely that similar conditions apply elsewhere over the interior of the continent.

As would be expected, where the surface of the continent slopes, the force of gravity causes this skin of air to move downhill and Ball (1959) has pointed out that if the slope is greater than $2 \times 10^{-3}$ the katabatic forces are likely to exceed forces due to the pressure gradient. It follows that any discernible slope is likely to produce strong ageostrophic winds. However, as has been pointed out by Ball, if the wind exceeds a certain critical value, depending on slope and the amount of the temperature inversion, a pressure jump will occur as shown in Figure 2.

Tauber (1959) has studied the katabatic winds in the vicinity of Mirny and has come to the conclusion that katabatic winds originate near the "pole of inaccessibility" (82°S 55°E). He quotes stations "influenced by the katabatic wind" as having mean wind speed of 11.7 $\text{m.sec}^{-1}$, with stations outside the influence of katabatic winds having speeds of 5.5 $\text{m.sec}^{-1}$. He states that smoke

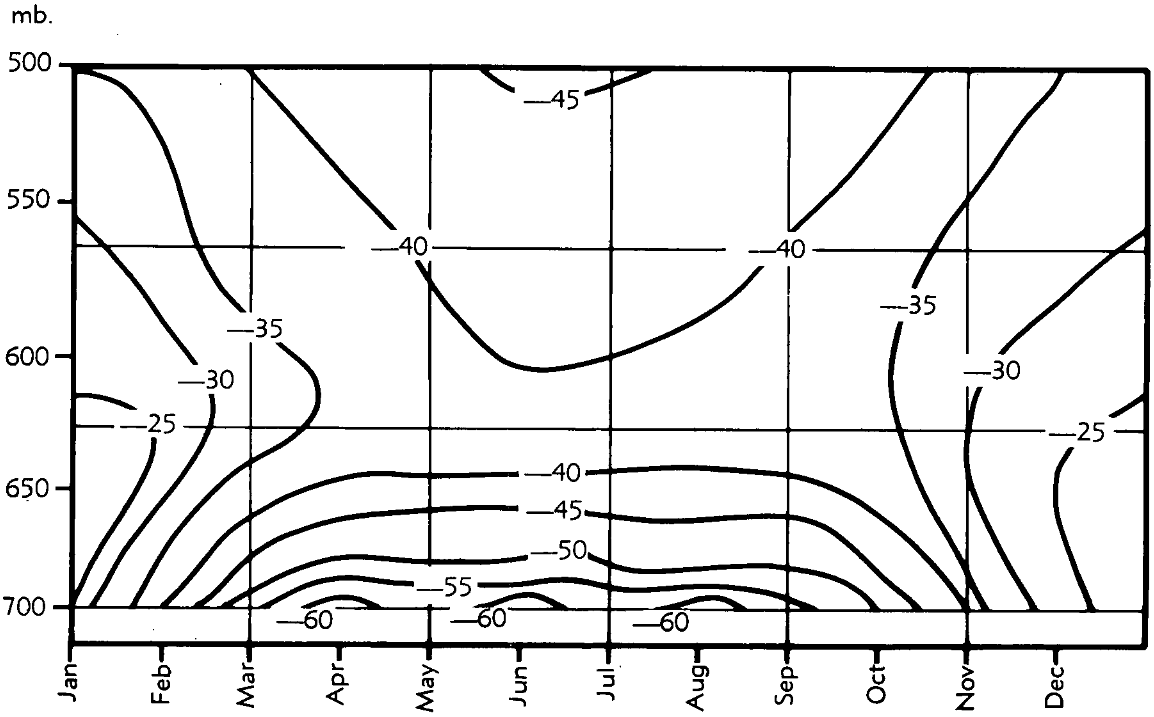

Fig. 1. 30-day Mean Temperatures (degrees C.) over Amundsen Scott throughout the year.

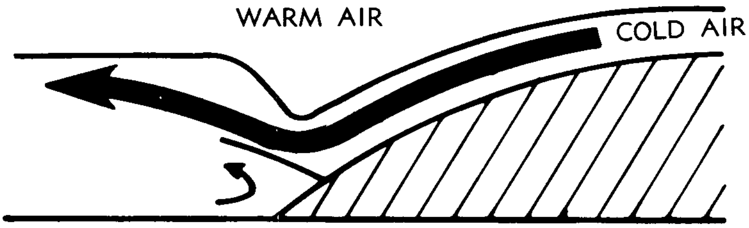

Fig. 2. Illustrating the occurrence of a pressure jump when the wind exceeds a critical value depending on slope and amount of temperature inversion.

trails from rockets showed very little dispersion even under strong katabatic conditions, but under cyclonic conditions marked dispersion occurred. The Russians set up four stations approximately along the meridian of 93°E from which the results shown in Table 1 were obtained.

Table 1 - Results of observations at four stations approximately along the 093°E Meridian

| Station | Distance Inland Km | Mean Wind Speed $m.sec^{-1}$ | Frequency of wind direction (percent) | | | | | Frequency (percent) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | calm | SE | SSE | S | W'ly | Snow Storms | Cloud 0/10-2/10 | Cloud 8/10-10/10 |
| MS-1 | 25 | 9.8 | 0 | 18 | 52 | 4 | - | 86 | 38 | 56 |
| MS-2 | 10 | 10.8 | 0 | 8 | 56 | 25 | - | 82 | 31 | 56 |
| MS-3 | 0 | 11.3 | 0 | 14 | 54 | 6 | - | 77 | - | - |
| MS-4 | -13.6 | 4.4 | 12 | 56 | 11 | 4 | 7 | 42 | 16 | 70 |

Tauber has pointed out that down slope winds must be accompanied by general subsidence, and that the smaller cloud amounts at inland stations compared with coastal stations supports this view.

Shaw (1957, 1959) has described similar measurements made at a network of four stations in the vicinity of Mawson. At Mt. Henderson (2,000 ft elevation, 10 miles inland from Mawson) the temperature was generally such that the assumption of adiabatic warming on descent to Mawson would result in temperatures lower than those actually observed. Shaw compared the wind to be expected from the pressure gradient and that normally experienced in the vicinity of Mawson and found that generally the wind was ageostrophic. He has quoted one case in which the pressure gradient indicated wind with a northerly component of 30 kt while the wind had a southerly component of almost 60 kts. Comparison of wind run measured at "satellite" stations with Mawson gave the results which are supported by Tauber's figures. The ratios of wind speed at the station to that observed at Mawson were, Mt. Henderson, 2000 ft 10 mi inland, - 1.89

Ringoya, at sea level 5 miles along the
coast from Mawson, - 1.03
Ytterskjera, 5 miles to seaward, - 0.88

Shaw suggests a pressure jump is present inland from Mawson on most occasions to account for the observed difference in wind speed between Mawson and Henderson.

Other workers who have studied the katabatic wind in recent years are Valtat (1959 a, 1959 b) and other French meteorologists. Valtat has noted the extreme local variation between Port Martin and Cape Denison on the coast and D'Urville slightly to the seaward. The limit of the katabatic winds in this region has often been observed to lie between the coast and D'Urville.

The temperature of the upper air in Antarctica has been measured regularly, during and since the IGY, by a network of Antarctic radiosonde stations. Apart from the surface inversion the most remarkable feature is the position of the tropopause. Taylor (1959) has presented the results of some soundings over Antarctica which show that the tropopause occurs at about 300 mb in summer but during the winter the rapid decrease in temperature of the stratosphere makes this tropopause somewhat indefinite and produces another at about 10 mb. Hanson (1959) has studied temperature variations in the stratosphere over Antarctica, where the temperature cools during the eight months from the January to August from -32°C to -88°C and warms by the same amount during the four months September to December. This sudden stratospheric warming occurs about the time of the return of the sun to the Antarctic, some portion of which is in continuous darkness from March 22nd to September 22nd. Hanson (1959) has described a spectacular warming about October 24th, 1958, which occurred about the same time as a moderate geomagnetic disturbance, significant ionospheric absorption and annual sunspot activity. However, Hanson does not suggest that this relationship is necessarily other than coincidental.

A study of the movement of the atmosphere over Antarctica is made possible by the network of radar and radio wind-finding stations and by pressure measurements derived from radiosonde ascents. Rastorguev and Alvarez (1958) and Alt, Astapenko and Ropar (1959) have established the main features of these circulations. In lower levels over the continent the circulation is characterized by an anticyclone over East Antarctica and cyclones in the vicinity of the Ross and Weddell Seas. At higher levels the circumpolar vortex is in evidence and during winter stratospheric jet streams occur about the latitude of the Antarctic coastline.

The importance of low level circulations in replenishing the Antarctic ice cap has been mentioned by Alvarez and Lieske (1959) who have described the case in May 1957 in which the occurrence of cyclones in the Ross Sea area was associated with a marked invasion of warm air which caused an increase in temperature at Amundsen-Scott from -100.4°F to -30.1°F and gave widespread snowfalls over the interior of the continent. Wexler (1959) and others have suggested that advection plays an important part in temperature and circulation patterns over Antarctica.

An important question which has interested meteorologists for a considerable time is the possible relationship between processes over Antarctica and those over the other continents of the southern hemisphere, and suggestions have been made in the past that a knowledge of meteorological conditions over Antarctica would enable long range forecasts to be made for Australia. Studies of synoptic processes by Hannay (1959) Karelsky (1959) and Langford (1959) have shown the relationship between circulation patterns over Australia, the Southern Ocean and Antarctica and have emphasised the value of Antarctic reports in arriving at a complete meteorological picture. However, there was no evidence to show that meteorological developments over Australia have their origin in the Antarctic. It was generally considered rather that developments must be viewed on a broader scale and it is evident that hemispheric analysis is desirable for purposes of forecasting for periods longer than 24 hours.

## REFERENCES

| | | |
|---|---|---|
| Rastorguev, V.I. and Alvarez, J.A. | 1958 | IGY General Report Series No.1, National Academy of Sciences, Washington, D.C. |
| Shaw, P.J. | 1957 | Aust. Met. Mag. No. 18, September 1957, p.1. |

The other references quoted are to be included in the Report on the Symposium on Antarctic Meteorology, Melbourne, February 1959, to be published by Pergamon Press Limited, London.