WINDS AND TEMPERATURES IN THE LOWER STRATOSPHERE

By *C. J. Brasefield*

Signal Corps Engineering Laboratories, Fort Monmouth, New Jersey[1]

(Manuscript received 21 May 1949)

ABSTRACT

About twenty radiosonde flights to altitudes above 100,000 ft have been made from Belmar, New Jersey (latitude 40.2°N) during the period July 1948 to April 1949, using a balloon whose nominal weight was 10,000 grams. The radiosonde and associated equipment were specially designed to accurately measure pressure, temperature and winds to an altitude of 150,000 ft. It was found that the mean daytime temperature of the stratosphere is about −60C from 50,000 ft to 60,000 ft, above which the mean temperature rises at a rate of about 0.5C per 1000 ft to a temperature of about −30C at 120,000 ft. No abnormally high temperatures at high altitudes resulting, for example, from a solar flare, were detected in any of these flights.

It was found that the winds below 60,000 ft were predominantly westerly, with maximum speed at an altitude of about 40,000 ft. Between 60,000 ft and 120,000 ft, the winds were easterly during the summer and westerly during the winter. The pronounced easterly flow commenced about three weeks after the vernal equinox and ceased about three weeks before the autumnal equinox. Usually the wind speed was still increasing at the bursting altitude of the balloon. These results are consistent with the existence of a stratospheric circumpolar vortex which is cyclonic in winter, anticyclonic in summer. The fragmentary wind data obtained from these flights at high altitudes suggest the possible existence of a stratospheric jet stream in middle latitudes. The significance of such a jet stream, if confirmed, is discussed.

1. Introduction

A knowledge of the winds in the stratosphere will undoubtedly be a prerequisite to an understanding of the general circulation of the atmosphere. As a matter of fact, the winds in the lower stratosphere may play an important role in the large-scale fluctuations of the general circulation. Furthermore, a knowledge of the temperature fluctuations in the ozonosphere is important in solving the problem of radiation exchange in the atmosphere and in determining the effect of solar activity on surface weather. It is probable that most of the desired data on the temperature and wind structure of the atmosphere will be found at altitudes not exceeding 150,000 ft. The most suitable vehicle for daily soundings to this altitude, perhaps from several stations along a meridian, is a balloon. It was therefore decided to develop balloon-borne radiosonde equipment capable of accurately measuring temperature, pressure and winds to 150,000 ft. In order to attain this objective, it was necessary to develop an unusually large expandable balloon. It was also necessary to make certain improvements in the conventional radiosonde in order to accurately measure pressure and temperature at pressures as low as one millibar. Although the development of the large balloon is still incomplete, a number of radiosonde flights have been made to altitudes above 100,000 ft. Temperature and wind data from these flights are presented here for the benefit of those who may find these data of immediate interest.

2. Equipment

The balloon used for these flights, whose development has been described elsewhere [2], was made of neoprene and had a nominal weight of 10,000 grams. This balloon, which is only partially inflated when it leaves the ground, first becomes spherical at an altitude of approximately 35,000 ft, at which time its diameter is about 20 ft.

The baroswitch of the conventional radiosonde was improved in several respects. The sensitivity in the range 50 mb to 1 mb was increased by using a 3-inch aneroid capsule in series with the conventional 2-inch capsule. Friction between contact arm and commutator was eliminated by allowing the contact arm to float; periodically the contact arm is pressed against the commutator by a tapper bar actuated by a motor-driven cam. The temperature of the capsules is measured throughout the flight by a ceramic resistor, so that the calibration of the capsules can be corrected for temperature effects. In the range 10 mb to 1 mb, it is believed that this baroswitch is accurate to about 0.2 mb.

Air temperature was measured with a white ceramic resistor [1] whose diameter was 30 to 35 mils. The resistor had 5-mil lead wires of low thermal conductivity designed to minimize heat transfer between the element and the supporting rods. The temperature indicated by the element was corrected for radiation effects by measuring the temperature of a similarly exposed black ceramic resistor [1]. Residual errors, including that due to lag, should not exceed 1C at 100,000 ft and 2C at 150,000 ft.

The one-rpm motor used to actuate the cam of the baroswitch also operates a 6-point rotary selector switch in the grid circuit of the audio oscillator, thus permitting the measurement of six resistances every minute. Two of these were reference resistances in series with the commutator of the baroswitch. The

---

[1] Presented at the Washington meeting of the American Meteorological Society on 19 April 1949.

remaining four points of the selector switch were connected to temperature sensitive resistors. The temperatures ordinarily measured were (*1*) that of the capsules, (*2*) the black temperature element, and (*3*) the white temperature element, two readings of the latter being obtained every minute. On a few flights, a fourth temperature was measured, namely, that of boiling CS_2 contained in a small hypsometer. None of these flights went much above 100,000 ft but in the pressure range 14 mb to 8 mb, the discrepancy between pressures as measured with the baroswitch and those measured with the hypsometer ranged from 0.0 mb to 1.4 mb with a mean discrepancy of 0.7 mb, the hypsometer indicating the lower pressure in every case.

The radiosonde transmitter generally used in these flights operated on a frequency of 1680 megacycles per second and was tracked by automatic direction-finding equipment [7]. A few flights were made with a transmitter operating at 400 megacycles per second, which was tracked with a manually operated direction finder. In clear weather, the balloon was also tracked with a theodolite.

3. Results

Radiosonde flights using the 10,000-gram balloon have been made from Evans Signal Laboratory, Belmar, New Jersey (latitude 40.2°N) since July 1948. The height of the balloon at all points in its trajectory could be computed from radiosonde data. Then, by using the values of elevation angle and azimuth angle obtained from the direction-finding equipment, it was possible to determine wind velocities at all altitudes up to the bursting height of the balloon. Wind data from those flights which went above 100,000 ft during the period July 1948 to March 1949 are shown in fig. 1. It appears that below 60,000 ft the winds are predominantly westerly and have maximum speed at approximately 40,000 ft; these results confirm observations of others [3; 5]. Above 60,000 ft the winds were predominantly easterly during the summer until 1 September (three weeks before the autumnal equinox). During early September the winds were light and variable at high altitudes, but after the autumnal equinox the winds were predominantly westerly above 60,000 ft throughout the winter and at least until 1 April. Usually the wind speed at high altitudes was still increasing at the bursting altitude of the balloon.

Temperature data were obtained for most of the flights shown in fig. 1. Fig. 2 shows the temperature structure to 120,000 ft, averaged over about 20 flights. It should be noted that, in the mean, the stratosphere is isothermal only from 50,000 ft to 60,000 ft, above which the temperature rises at a rate of about 0.5C per 1000 ft. The mean temperature structure shown in fig. 2 agrees reasonably well with similar data reported by Gutenberg [5], except that the mean temperature at 100,000 ft is somewhat lower than the mean temperature observed by Gutenberg at the same altitude.

In none of the flights reported here was there observed any pronounced rise in temperature at high altitudes. It may be concluded either that fluctuations

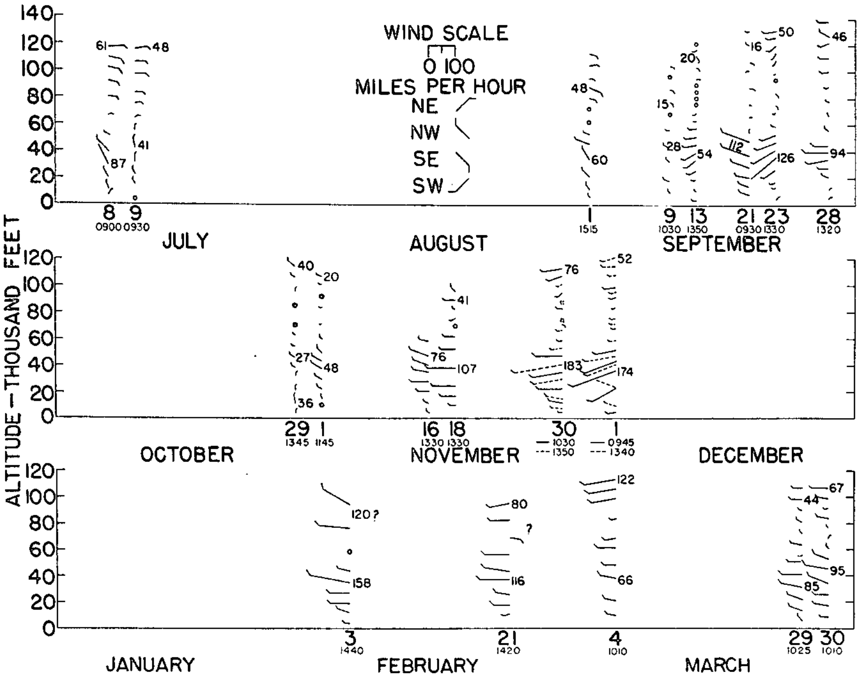

FIG. 1. Wind data obtained from flights of the 10,000-gram balloon during the period July 1948 to March 1949. The number appearing below the day of the month is the local time of release from Belmar, New Jersey. Winds aloft are indicated by vectors whose lengths are proportional to the wind speed. Numbers adjacent to wind vectors indicate the magnitude (mi hr^{-1}) of the maximum wind speed. Circles indicate winds less than 5 mi hr^{-1}. During February 1949, the 400-mc direction finder was used; wind data at high altitudes were computed from elevation angles of doubtful accuracy (10° to 15°).

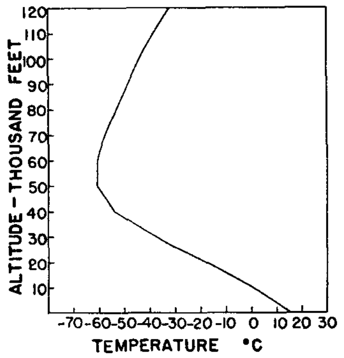

FIG. 2. Mean daytime temperature structure at Belmar, New Jersey (latitude 40.2°N).

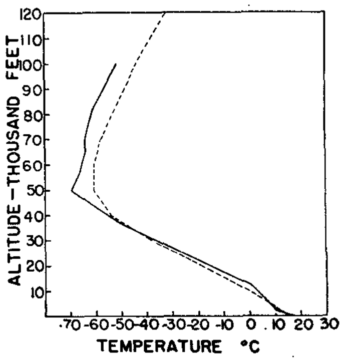

FIG. 4. A typical autumn temperature structure; dashed curve is mean temperature structure. Balloon released 1330 (local time) 18 November 1948.

in solar radiation at the time of these flights were too small to appreciably affect the temperature of the ozonosphere, or that temperature changes resulting from the fluctuations occurred at higher altitudes. Since no marked deviations from the mean temperature structure were observed in any of the flights, only a few typical cases will be presented. Fig. 3 shows a typical summer temperature structure. Temperatures above the tropopause are higher than the mean. Fig. 4 shows a typical autumn temperature structure, with stratospheric temperatures lower than the mean. As a matter of fact, judging from the results of the few flights here reported, minimum temperatures in the lower stratosphere occur during the months October to December. This may be due to the low concentration of ozone in the atmosphere during autumn [4]. Gutenberg [5] on the other hand reports minimum temperatures in this region during the period January to March. Fig. 5 shows a typical winter temperature structure, with temperatures near the mean in the vicinity of 100,000 ft. The inversion at 40,000 ft, followed by the isothermal region extending to 75,000 ft, seems to be typical of this season.

Fig. 6 shows results obtained from a flight on 12 April 1949. There is nothing remarkable about the temperature data, stratospheric temperatures being near the mean. The wind data, however, indicate that the pronounced easterly flow in the lower stratosphere, which ceased about three weeks before the autumnal equinox, was resumed about three weeks after the vernal equinox.

4. Discussion

The seasonal behavior of the winds above 60,000 ft illustrated in fig. 1 is consistent with the existence of a stratospheric circumpolar vortex which is cyclonic in winter, anticyclonic in summer. The existence of such a vortex is suggested by Scherhag's [9] charts of the northern-hemisphere circulation at the 41-mb level, and is supported by observations on winds in this region reported by Gutenberg [5] and others. (In the flights here reported, no evidence was found of occasional easterly winds in the lower stratosphere during the winter, as reported by Gutenberg [5], nor was his observation that the westerly winds in the lower stratosphere decreased with altitude confirmed.) The data presented here are insufficient to determine whether or not the stratospheric circumpolar vortex is characterized by a jet stream in middle latitudes, as is the tropospheric circumpolar vortex. To confirm the existence of such a stratospheric jet stream, it would be necessary to make daily flights to altitudes well above 120,000 ft from a number of stations located

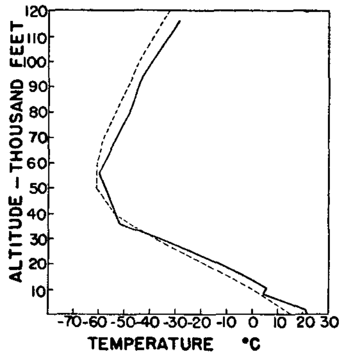

FIG. 3. A typical summer temperature structure; dashed curve is mean temperature structure. Balloon released 0930 (local time) 9 July 1948.

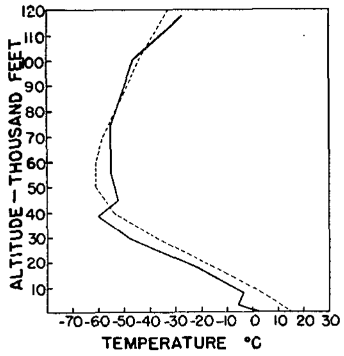

FIG. 5. A typical winter temperature structure; dashed curve is mean temperature structure. Balloon released 1010 (local time) 4 March 1949.

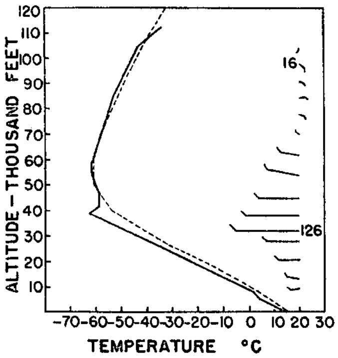

Fig. 6. Temperature and wind data from flight of 12 April 1949; balloon released 1010 (local time).

along a meridian. Such a program is contemplated when the development of the 10,000-gram balloon is complete.

If a stratospheric jet stream exists, it may be a key to the large-scale fluctuations of the general circulation. Rossby and Willett [8], in an excellent review of the characteristics of the tropospheric circumpolar cyclonic (west-wind) vortex, point out that "it remains to be proved just to what extent the westerlies of the middle latitudes are driven from the polar or from the equatorial side. . . ." It is suggested that the effect of a stratospheric jet stream on the tropospheric jet stream should also be considered. The data shown in fig. 1 are too meager to confirm this effect, but it is perhaps more than a coincidence that tropospheric winds are lightest during the summer when stratospheric winds are easterly, and that the tropospheric jet stream is most strongly developed during the winter when there are also strong westerly winds in the stratosphere.

Rossby and Willett [8] have also pointed out that irregular solar activity may be a controlling factor not only in long-period fluctuations of the general circulation, but also in the short-period changes. And Haurwitz [6] has suggested that the ozonosphere represents the missing link between solar activity and tropospheric phenomena. On the basis of these suggestions, and assuming the existence of a stratospheric jet stream, one can conceive of the following chain of events connecting solar activity and surface weather. Localized heating of the ozonosphere by a solar flare could cause a marked change in the poleward temperature gradient in the ozonosphere. This could result in an acceleration (positive or negative) of the stratospheric jet stream, which in turn could accelerate the underlying tropospheric jet stream and thus presumably cause a change in surface weather.

5. Conclusions

The mean daytime temperature of the stratosphere over Belmar, New Jersey (latitude 40.2°N) is about −60C from 50,000 ft to 60,000 ft, above which the mean temperature rises at a rate about 0.5C per 1000 ft to a temperature of about −30C at 120,000 ft. No marked departure from the mean temperature structure has been observed. However, after the development of the 10,000-gram balloon is complete, daily soundings will be made to altitudes of at least 140,000 ft in an attempt to detect abnormally high temperatures resulting from solar flares. Night flights to these altitudes are also contemplated, in order that the diurnal temperature variation of the ozonosphere may be studied.

Below 60,000 ft, the winds were predominantly westerly, with maximum speed at an altitude of about 40,000 ft. Between 60,000 ft and 120,000 ft, the winds were easterly during the summer and westerly during the winter. The pronounced easterly flow commenced about three weeks after the vernal equinox and ceased about three weeks before the autumnal equinox. Usually the wind speed was still increasing at the bursting altitude of the balloon. These results are consistent with the existence of a stratospheric circumpolar vortex which is cyclonic in winter, anticyclonic in summer. After the development of the 10,000-gram balloon is complete, it is planned to make daily flights to altitudes well above 120,000 ft from a number of stations located along a meridian, to determine whether or not the stratospheric circumpolar vortex is characterized by a jet stream in middle latitudes.

Acknowledgments.—This investigation has required the cooperative effort of several Sections of the Meteorological Branch of Evans Signal Laboratory. Thanks are due especially to Dr. Michael Ference, Jr. for his interest and advice, and to Messrs. A. Arnold and W. C. Conover for assistance in preparing for the flights and in evaluating flight records.

REFERENCES

1. Brasefield, C. J., 1948: Measurement of air temperature in the presence of solar radiation. *J. Meteor.*, **5**, 147–151.
2. ——, 1949: Exploring the ozonosphere. *Sci. Mon.*, **68**, 395–399.
3. Dobson, G. M. B., 1920: Winds and temperature gradients in the stratosphere. *Quart. J. R. meteor. Soc.*, **46**, 54–62.
4. ——, 1935: The upper atmosphere. *Annual Report Smithsonian Institute, 1935*, 183–196.
5. Gutenberg, B., 1949: New data on the lower stratosphere. *Bull. Amer. meteor. Soc.*, **30**, 62–64.
6. Haurwitz, B., 1946: Relations between solar activity and the lower atmosphere. *Trans. Amer. geophys. Union*, **27**, 161–163.
7. Kirkman, R. A., and J. M. LeBedda, 1948: Meteorological radio direction finding for measurement of upper winds. *J. Meteor.*, **5**, 28–37.
8. Rossby, C. G., and H. C. Willett, 1948: The circulation of the upper troposphere and lower stratosphere. *Science*, **108**, 643–652.
9. Scherhag, R., 1948: *Neue Methoden der Wetteranalyze und Wetterprognose.* Berlin, Springer Verlag, 424 pp. (see pp. 76–77).