Indian Journal of Radio & Space Physics
No. 5, March 1976, pp. 66-74

Atmospheric Structure : Exploration over Antarctica & Equatorial Comparison*

PARMJIT SINGH SEHRA†
Physical Research Laboratory, Ahmedabad 380 009

Received 5 *April* 1975; *revised received* 3 *October* 1975

Vertical profiles of zonal and meridional components of winds, and of temperatures as obtained from M-100 meteorological rocket soundings simultaneously conducted at Molodezhnaya, Antarctica and Thumba, equatorial India in 1972, particularly during the months of January (southern summer) and July (southern winter) are discussed and an intercomparison is made. Typical summer and winter profiles of atmospheric temperatures over Antarctica are compared with the corresponding Groves atmospheric model profiles. [G. V. Groves, AFCRL-71-0410 Bedford, Mass., 1971, 147.]. It is found that the polar tropopause and stratopause in summer were about 30 and 20°C warmer than the corresponding winter tropopause and stratopause, while the mesopause was not well-defined. In the southern summer the zonal winds in the stratosphere were predominantly easterly with speed less than 50 msec^{-1} both over Antarctica and the equator, while in the winter the Antarctic zonal winds were strong westerlies with speed less than 100 msec^{-1} and equatorial winds were predominantly easterly with speed less than 40 msec^{-1}. The meridional winds were found to be variable. The temperature departures from the Groves model were found to be less than 40°C.

1. Introduction

Until 1960 synoptic investigations of the terrestrial atmosphere were confined to only balloon altitudes of about 30 km. With the advent of the Meteorological Rocket Network (MRN) such analysis was extended to higher altitudes of about 80 km. Such data are available for a large number of stations in the northern hemisphere. However, in the southern hemisphere there is a sparseness of rocket sounding stations due to which it is relatively less explored. The study of the atmospheric circulation around the South Pole is important since the weather and climate over the globe are strongly influenced by that circulation.

Under a joint Indo-Soviet agreement the author was the first Indian scientist to winter in Antarctica during the 17th Soviet Antarctica Expedition, 1971-73. In particular, the author carried out meteorological rocket soundings of the upper atmosphere at the station Molodezhnaya, located at 67°40′S, 45° 51′E at an altitude of 42 m above mean sea level in East Antarctica (Fig. 1). Some other stations visited by the author during his Antarctic odyssey in 1971-73 are also shown in Fig. 1. Antarctica is the coldest and the windiest continent in the world. The lowest temperature ever recorded on the earth is −88·3°C which is found at Vostok, the pole of cold in Antarctica. Strong winds of speed more than 200 km hr^{-1} are very frequent in Antarctica. Particularly, East Antarctica is the home of blizzards and tempests where gusty winds of speed 300 km hr^{-1} or even more are very common. The Antarctic mainland nurtures no trees and shelters no native mammals other than some seals. It supports only a few species of birds such as penguins (flightless), snow petrels and polar skuas. To our present knowledge Antarctica has never had a native human population.

A view of the station Molodezhnaya where the author wintered over is shown in Fig. 2. At the

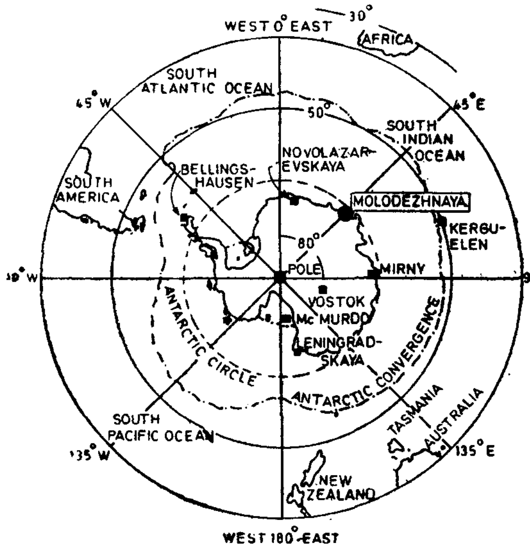

Fig. 1—Map of Antarctica showing the location of the station Molodezhnaya

* Paper presented at the Symposium on Earth's Near Space Environment, 18-21 February 1975, held at the National Physical Laboratory, New Delhi 110 012.

† Also at : Indian Space Research Organization, Space Applications Centre, Remote Sensing & Meteorology Applications Division, Ahmedabad.

Fig. 2—A view of the station Molodezhnaya, Antarctica, where the author wintered during 1971-73

station there is a series of east-west ridges made up of some exposed bed rocks where the ridges are separated by ice-filled valleys with elevations ranging from about 20 to 200 m along the coast. In a narrow zone about 10 km wide parallel to the coast, exposed rock and soil are found in abundance which are, however, very rare inland. Although the station bed itself is confined to erratic and frost-churned mixed materials, yet nearly there are two outlet glaciers, Campbell and Hays, which form active moraines. In 1972 the mean annual temperature observed at the station was −10·5°C varying from a lowest minimum of −35·8°C to a highest maximum of 7·0°C. Southeast winds prevailed over the surface with frequent gusts of 21 to 41 $msec^{-1}$ speed. Annual mean relative humidity was 65% and the annual mean precipitation observed was 0·14 cm.

Simultaneous M-100 meteorological rocket soundings were conducted weekly on all Wednesdays from Molodezhnaya, Antarctica, and from Thumba (8° 32′N; 76°52′E) in 1972. This investigation is confined to the months of January (southern summer) and July (southern winter). Vertical profiles of zonal and meridional components of winds, and of temperatures are studied and an inter-comparison is made. Typical summer (5 Jan.) and winter (5 July) profiles of atmospheric temperatures over Antarctica are compared with the corresponding Groves[1] atmospheric model profiles.

2. Data Acquisition

For acquiring meteorological data of the upper atmosphere, high altitude balloons and rockets are employed which incorporate a network of ground-borne and rocket-borne equipments. The objectives of the M-100 rocket system are to measure the meteorological parameters of the upper atmosphere upto an altitude of about 80 km. It is a two-stage rocket lifted by a solid propellant made of nitrocellulose up to about 95 km. As the head part with the payload is separated on the ascending trajectory, a parachute with a surface area of 35 m^2 is opened. The instruments start measurement when the shielding device is thrown away after 60 sec from the take-off.

Head part consists of the steeple with the temperature sensors and an instrument bay for telemetry transmitter, commutator, responder, power supply, and control unit. The telemetry transmitter on board the vehicle works at a frequency of 22150 ± 100 kHz. The mechanical commutator provides scanning of 60 channels per cycle. A special super regenerative radio transponder working at a frequency of 1770-1795 MHz is used. The payload incorporates 4 variable resistance thermometers made of 40 micron tungsten rhenium wire connected in one arm of a balanced wheatstone bridge. The radar data on the drift of the trajectory of the parachute, which gets completely filled around 60 km on the descending trajectory of the rocket, is used for measurement of the wind speed and direction. The ground telemetry consists of FM receiver with an input sensitivity of 2 μV. The transmitter signals are amplified in the receiver and are fed to the screen of a panoramic oscilloscope. The signals are photographed on a 35 mm film with the help of a cine-camera. During the complete flight, the station radar automatically tracks the rocket which is fitted with the transponder. The computers Minsk-2/IBM-360 finally process the data and apply all the necessary temperature and wind corrections using a standard programme written for this purpose.

3. Analysis of Data

Winds up to an altitude of about 60 km are deter-

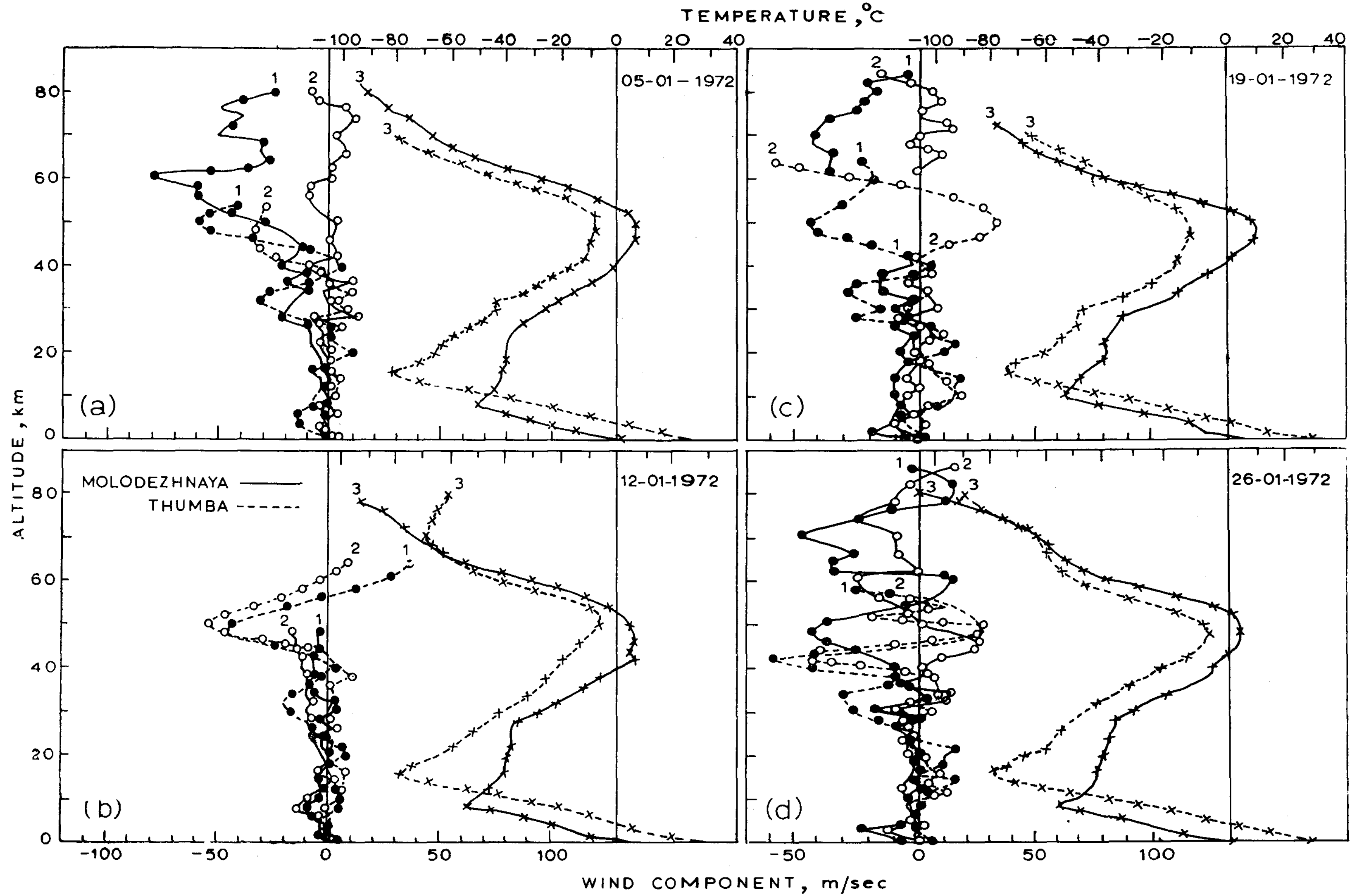

Fig. 3—Vertical profiles of zonal winds (curves 1), meridional winds (curves 2) and temperatures (curves 3) over Molodezhnaya, Antarctica (solid curves 1, 2, 3) and Thumba, equatorial India (dashed curves 1, 2, 3) in January 1972 (southern summer) on (a) 5 Jan., (b) 12 Jan., (c) 19 Jan. and (d) 26 Jan., respectively

mined by measuring the drift of the parachute from the position data of the ground radar and above 60 km by using an additional wind sensor "chaff". In 1972, sixteen chaff-borne rocket flights were conducted from Molodezhnaya and none from Thumba. Upper mesospheric wind results derived from the chaff flights have been discussed by the author in an earlier paper.[2]

The temperature data are obtained from the variation in the resistance of the sensor coil using the relation

$$R_t = R_0\,(1 + \alpha t + \beta t^2)$$

where R_t and R_0 are the resistances of the thermometer wire at temperatures t°C and 0°C, and α and β are the thermal factors of wire resistance. Temperature corrections for conductivity between the sensor wire and the insulating blocks, aerodynamic heating, thermal inertia of the thermometers, ohmic heating of the sensor wire and radiation from it, and heating due to long wave radiation are applied. In these measurements the accidental r. m. s. error in the determination of temperature over an altitude region 60-80 km does not exceed 7 to 10°C, at 50 km it is 5°C, and below 40 km the error is less than 3°C. In 1972, more than sixty M-100 meteorological rockets were launched from Molodezhnaya, Antarctica. The stratospheric and mesospheric temperatures obtained from such flights are discussed by the author in another paper.[3]

Data from the various flights conducted are used and the vertical profiles of atmospheric winds and temperatures over Molodezhnaya and Thumba for the months of January (southern summer) and July (southern winter) are drawn in Figs. 3 (a to d) and 4 (a to d), respectively. Radiosonde data are used for completing the profiles in the lower atmosphere as each rocket flight was preceded by a standard radiosonde release. Table 1 gives the monthly average values of zonal and meridional components of winds,

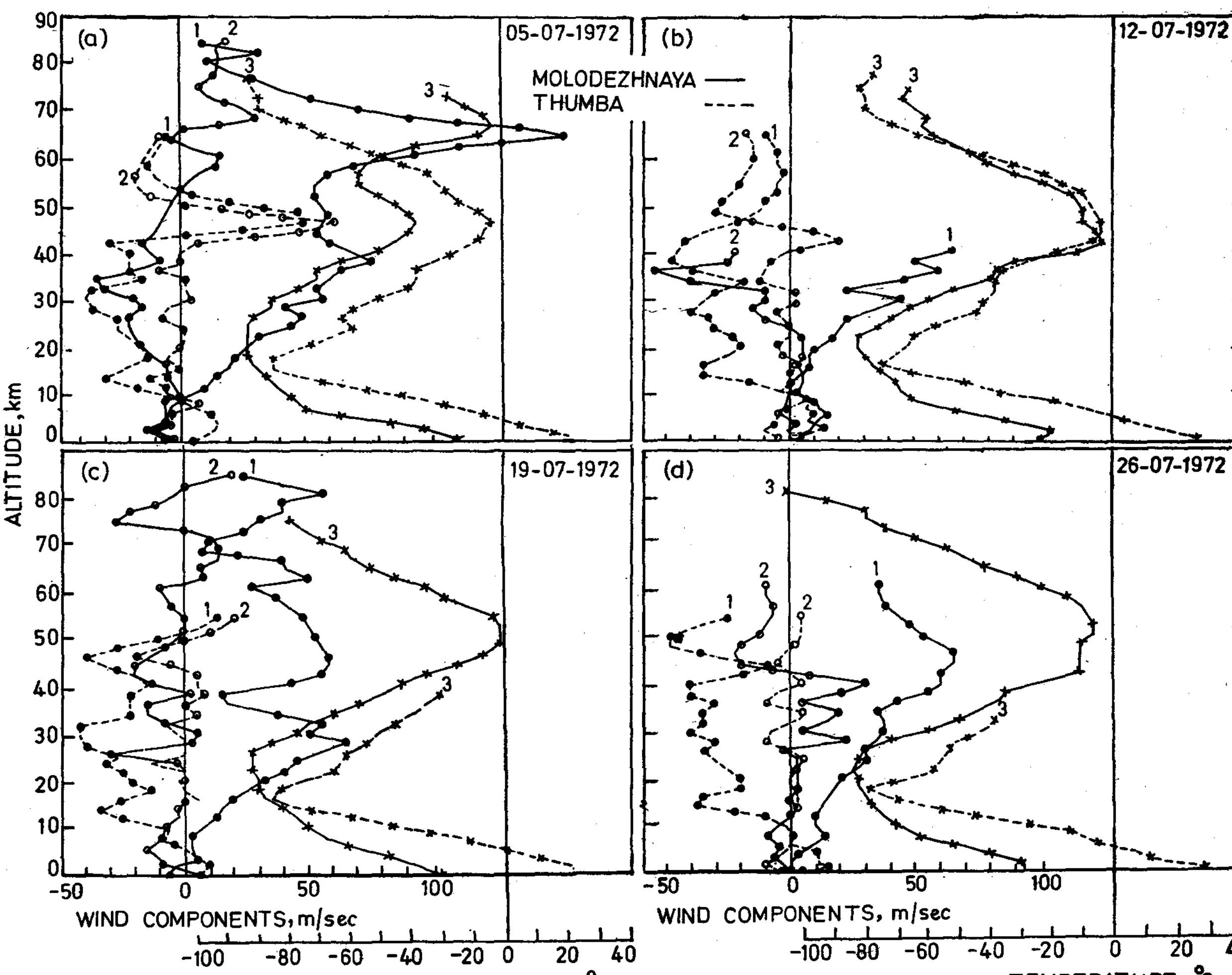

Fig. 4—Vertical profiles of zonal winds (curves 1), meridional winds (curves 2) and temperatures (curves 3) over Molodezhnaya, Antarctica (solid curves 1, 2, 3) and Thumba, equatorial India (dashed curves 1, 2, 3) in July 1972 (southern winter) on (a) 5 July, (b) 12 July, (c) 19 July and (d) 26 July, respectively

Table 1—Monthly Average Values of Zonal and Meridional Components of Winds, and of Temperature at Molodezhnaya (M) and Thumba (T) in January (southern summer) and July (southern winter) 1972

	January (southern summer)						July (southern winter)					
Altitude km	Zonal winds msec^{-1}		Meridional winds msec^{-1}		Temperature °C		Zonal winds msec^{-1}		Meridional winds msec^{-1}		Temperature °C	
	M	T	M	T	M	T	M	T	M	T	M	T
0	−2·8	2·3	1·0	1·8	3·0	31·6	−3·0	2·8	2·2	−1·3	−19·7	27·8
5	−5·0	−7·0	−6·3	0·0	−26·0	−1·2	4·5	9·0	−5·6	−2·5	−42·3	0·0
9	−6·5	1·8	−8·0	1·0	−51·8	−27·6	6·8	1·5	−5·0	−0·8	−66·5	−23·3
10	−5·5	3·2	−4·8	6·6	−51·0	−35·8	7·2	−3·0	−2·8	−1·8	−68·5	−34·3
15	−1·8	7·4	−3·0	5·5	−43·8	−74·3	15·0	−35·8	−1·1	0·3	−76·8	−72·3
17	−3·5	−4·5	−0·3	0·8	−41·5	−78·8	19·6	−21·5	−1·3	1·5	−79·5	−77·3
20	−3·5	9·5	−2·5	0·6	−40·0	−64·9	25·8	−19·5	−3·8	−1·3	−82·5	−64·8
25	−6·8	−2·3	−2·5	4·8	−38·0	−55·5	36·3	−29·0	−7·5	−0·5	−80·3	−53·0
30	−13·5	−20·3	1·0	1·8	−28·5	−44·8	46·0	−38·5	−5·6	−0·5	−67·4	−40·8
35	−10·5	−19·5	−2·5	4·5	−15·0	−31·5	48·2	−23·8	−19·2	−5·0	−48·4	−32·3
40	−11·3	−7·8	−5·8	−2·0	−2·8	−20·0	58·6	−29·8	−6·1	3·0	−27·2	−17·0
45	−17·0	−16·3	3·5	−12·8	5·3	−12·3	52·2	−12·0	−12·4	10·5	−14·8	−5·0
46	−19·3	−19·5	3·0	−9·5	6·3	−11·5	53·6	−10·0	−12·0	6·0	−13·6	−4·5
47	−21·3	−24·0	1·3	−7·0	6·5	−10·5	54·8	−9·5	−11·4	1·3	−12·8	−5·0
48	−23·0	−27·8	−0·3	−6·0	6·3	−9·3	55·6	−9·8	−10·4	−1·8	−12·4	−7·0
49	−33·5	−29·8	5.0	−5·8	6·0	−9·0	56·0	−9·8	−9·8	−3·0	−12·6	−9·5
50	−34·0	−30·5	1·5	−6·3	5·3	−8·8	56·6	−9·8	−8·8	−3·5	−13·2	−11·0
55	−29·0	−16·5	−12·0	−8·8	−10·3	−19·5	58·4	−3·5	−3·2	−3·0	−24·2	−21·5
60	−33·5	2·5	−12·0	−11·0	−35·5	−42·8	35·7	−7·5	4·7	−13·0	−35·4	−41·5
65	−31·0	N.A.	0·7	N.A.	−57·5	−58·8	93·0	−9·5	4·5	−13.0	−42·4	−64·0
70	−46·7	N.A.	−3·0	N.A.	−70·0	−70·8	40·0	N.A.	19·0	N.A.	−52·8	−79·5
75	−31·0	N.A.	−4·0	N.A.	−82·0	−73·5	36·5	N.A.	−7·5	N.A.	−66·0	−82.0
80	−10·0	N.A.	−4·0	N.A.	−99·0	−76·5	31·0	N.A.	6·5	N.A.	−87·5	N.A.

Note : N.A. means "Not available"

and of temperatures for the southern summer month January and the winter month July, respectively.

Typical summer (5 Jan.) and winter (5 July) profiles of atmospheric temperatures over Molodezhnaya, Antarctica in the altitude region of 25 to 85 km at 5 km interval are compared with the corresponding Groves[1] atmospheric model profiles in Fig. 5. Since in the model no data are available for 70°S station, actual temperatures over Molodezhnaya (67° 40′S) for January are compared with the 70°N data for July of the Groves[1] model and similarly, the July actuals of the station with those for January of the model.

4. Results and Discussion

4.1 Zonal Winds

In the southern summer month of January, the solid curves (1) in Fig. 3 (a to d) show that the summer zonal winds over the Antarctic station Molodezhnaya were predominantly easterly with speeds less than 80 msec^{-1} up to an altitude of about 80 km. The easterlies were weaker with speeds less than 30 msec^{-1} in the troposphere and up to about 45 km in the stratosphere. The easterly winds became stronger in the mesosphere and attained a maximum speed of 79 msec^{-1} at 60 km on 5 Jan. [solid curve (1) in Fig. 3 (a)] with a secondary maximum of 47 msec^{-1} at 70 km on 26 Jan. [Fig. 3 (d)]. In January end, a core of weak westerly winds with speeds less than 13 msec^{-1} was detected in an altitude region 55-60 km and again from 78 to 85 km [solid curves (1) in Fig. 3 (d)]. The average values of zonal winds at Molodezhnaya, Antarctica in January given in Table 1 show that the winds were easterly throughout the atmosphere up to about 84 km with weaker easterlies of speed less than 10 msec^{-1} in the

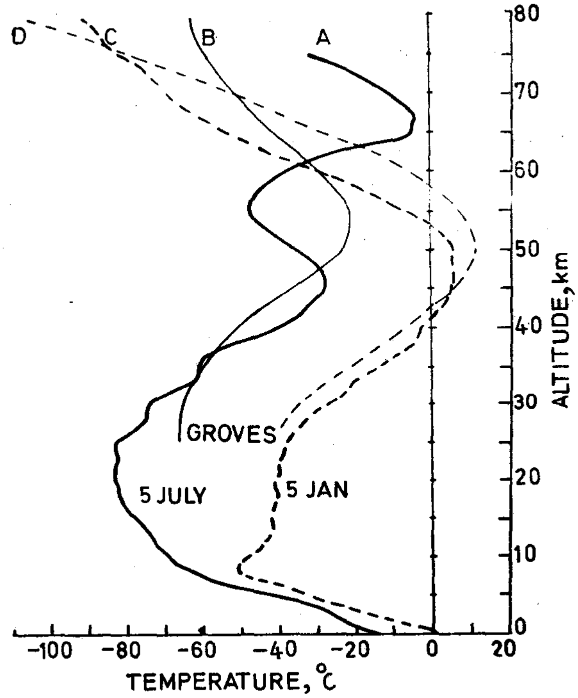

Fig. 5 – Comparison of the typical southern summer (5 Jan.) and southern winter (5 July) vertical temperature profiles (curves C and A) at Molodezhnaya (67° 40′S), Antarctica in 1972 with the corresponding Groves[1] atmospheric model profiles (curves D and B) at 70°N on 1 July and 1 Jan., respectively (The southern winter temperature profiles are shown by the solid curves A, B and the southern summer profiles by the dashed curves C, D)

troposphere and stronger easterlies aloft. The zonal wind maximum was found in the mesosphere at 70 km, which had a speed of 47 msec^{-1}. Above 70 km, the easterly winds decreased with height with a wind shear of about 0·004 sec^{-1}.

The corresponding zonal winds over the equatorial station Thumba in January shown by the dashed curves (1) [Figs. 3 (a to d)] were found to be variable having speeds less than 30 msec^{-1} in the lower atmosphere up to an altitude of about 30 km, which had predominantly westerly winds in an altitude region from about 10 to 25 km. In the upper stratosphere the winds were predominantly easterly having a maximum speed of 61 msec^{-1} at 50 km on 5 Jan. and again 61 msec^{-1} at 42 km on 26 Jan. with secondary maxima of 47 msec^{-1} at 49 km and 42 msec^{-1} at 50 km on Jan. 12 and January 19, respectively, indicating that the zonal wind maximum in January over equatorial India lies around the stratopause. During January, the zonal winds over Thumba in an altitude region from about 50 to 60 km showed wind reversal from easterlies to westerlies and vice versa as is obvious from the dashed curves (1) in Figs. 3 (a to d). Similarly, for January for the equatorial station Thumba, Table 1 shows that up to about 7 km the winds were weak easterlies having speeds less than 7 msec^{-1}. Around 7 km the zonal winds changed to weak westerlies with speeds less than 11 msec^{-1} with the maximum at 21 km. From 25 to 60 km, the zonal winds were easterlies *in toto*, with speeds ranging from about 5 to 31 msec^{-1} having the maximum at 50 km around the stratopause. However, above 60 km the zonal winds showed a westerly trend.

In the southern winter month July, the zonal winds over Molodezhnaya, Antarctica, as shown by the solid curves (1) in Figs. 4 (a to d) were predominantly westerly throughout the terrestrial atmosphere up to an altitude of about 80 km with weak easterlies near the surface. The westerlies built up in the troposphere and the stratosphere and attained jet speed in the lower mesosphere. In the stratosphere the maximum wind speed was 82 msec^{-1} at 39 km on 5 July with secondary maxima of 66 msec^{-1} at 28 km and 58 msec^{-1} at 45 km on July 19 [solid curves (1) in Figs. 4 (a, c)]. In the mesosphere strong easterly winds having large wind shears were detected. Maximum wind speed was 157 msec^{-1} at 64 km on 5 July which indicated a sudden disruption in the atmosphere over Antarctica during the winter regime. Table 1 which gives average values of zonal winds at Molodezhnaya in July 1972 shows that the zonal flow over Antarctica was totally westerly in winter with weaker winds in the lower atmosphere and stronger winds in the upper atmosphere. In the troposphere the westerly winds were of speeds less than 30 msec^{-1}, whereas in the stratosphere the westerlies had a maximum wind speed of 59 msec^{-1} at 40 km and in the mesosphere the maximum speed was 99 msec^{-1} at 64 km. Strong westerly winds decreased with height in the mesosphere and attained a speed of 15 msec^{-1} at 84 km.

The corresponding zonal winds over Thumba, equatorial India, in July 1972 (dashed curves (1) in Figs. 4 (a to d)] were predominantly easterly with speeds ranging from about 10 to 50 msec^{-1} up to about 45 km. At altitudes of about 10 km westerly winds of speeds less than 17 msec^{-1} prevailed. The stratospheric easterly winds had a maximum speed of 49 msec^{-1} at 49 km around the stratopause on 26 July [Fig. 4 (d)], with a secondary maximum of 47 msec^{-1} at 39 km on 12 July [dashed curve (1) in Fig. 4 (b)]. A core of strong westerly winds with a maximum speed of 53 msec^{-1} at 47 km was detected in altitude region 44-52 km on 5 July. The average values of zonal winds at Thumba in July given in Table 1 show that the winds were weak westerlies of speeds less than 13 msec^{-1} up to an altitude of about 10 km. Above 10 km, the zonal winds were totally easterly up to an altitude of 65 km in the lower mesosphere. The easterlies were stronger in the stratosphere with a maximum speed of 39 $msec^{-1}$ at 31 km and weaker in the mesosphere with speeds less than 10 $msec^{-1}$.

4.2 Meridional Winds

For the southern summer (Jan. 1972) [solid curves (2) in Figs. 3 (a to d)], the meridional winds over Antarctica were observed to be variable with speeds less than 26 $msec^{-1}$. On 12 Jan. the winds were predominantly northerly with speed less than 17 $msec^{-1}$, while on 19 Jan. the winds were predominantly weak northerly with speeds less than 6 $msec^{-1}$ up to an alti tude of about 25 km and predominantly southerly with speed less than 13 $msec^{-1}$ in an altitude region 60-80 km in the mesosphere. On 26 Jan. the meridional winds were weak northerlies up to about 30 km with speed less than 10 $msec^{-1}$. In the upper stratosphere, (40-50 km in altitude) strong southerly winds were found which had a maximum speed of 26 $msec^{-1}$ at 45 km. The stratospheric southerlies changed to mesospheric northerlies around the stratopause. In the mesosphere the northerly winds persisted upto about 80 km and attained a maximum speed of 25 $msec^{-1}$ at 74 km with a secondary maximum of 24 $msec^{-1}$ at 60 km. Table 1 shows that the average meridional winds over Molodezhnaya, Antarctica in January were predominantly weak northerly in the lower atmosphere up to about 30 km with speeds less than 10 $msec^{-1}$. From about 30 to 50 km the winds were weak and variable having speeds less than 6 $msec^{-1}$, while in the mesosphere the winds were again predominantly northerly with a maximum speed of 16 $msec^{-1}$ at 58 km. Thus, in the troposphere, lower stratosphere and the mesosphere, the meridional winds were predominantly weak northerly of speed less than 16 $msec^{-1}$, while in the upper stratosphere the winds were weak and variable.

The corresponding meridional winds over Equatorial India [dashed curve (2) in Fig. 3 (a)] were weak and variable with speeds less than 10 $msec^{-1}$ up to an altitude of about 40 km and strong northerly aloft with wind speed ranging from about 15 to 35 $msec^{-1}$ up to 55 km on 5 Jan., while on 12 Jan. the meridional winds were predominantly weak southerlies with speed less than 11 $msec^{-1}$ up to an altitude of 43 km and again strong northerly aloft which attained a maximum speed of 55 $msec^{-1}$ at 50 km around the stratopause [Fig. 3 (b)]. During 12 and 19 Jan., a wind reversal occurred in an altitude range of 45-60 km due to which the northerlies changed to strong southerlies on 19 Jan. having a maximum wind speed of 35 $msec^{-1}$ at 49 km around the stratopause. However, the southerlies again changed to strong northerlies around 59 km and attained a speed of 58 $msec^{-1}$ at 64 km. On 26 Jan. the meridional winds were variable with weaker winds of speeds less than 13 $msec^{-1}$ upto 40 km and stronger winds aloft. The northerlies had a maximum speed of 47 $msec^{-1}$ at 43 km and the southerlies had a maximum speed of 28 $msec^{-1}$ at 49 km. Thus, the upper stratosphere and the lower mesosphere were in a turbulent state having large wind shears with meridional winds rapidly changing from northerlies to southerlies and vice versa. Average values of the meridional winds over the equatorial station Thumba for Jan. 1972 given in Table 1 show that the winds were weak and variable up to about 40 km with speeds less than 10 $msec^{-1}$. Above 40 km, the meridional winds were found to be predominantly northerly with speeds ranging from 5 to 25 $msec^{-1}$.

As for the southern winter (July), the meridional winds over Antarctica on 5 July [solid curve (2) in Fig. 4 (a)] were predominantly northerly in the troposphere and the stratosphere with a maximum speed of 33 $msec^{-1}$ at 33 km, and were predominantly southerly in the mesosphere with a maximum wind speed of 31 $msec^{-1}$ at 68 km. On 12 July the meridional winds were weak and variable with speed less than 6 $msec^{-1}$ up to an altitude of about 25 km and strong northerly aloft with a maximum speed of 54 $msec^{-1}$ at 36 km [Fig. 4 (b)]. On 19 July the meridional components were predominantly northerly having a maximum wind speed of 30 $msec^{-1}$ at 26 km with a secondary maximum of 28 $msec^{-1}$ at 74 km. However, in an altitude region from about 62 to 72 km, a core of weak southerly winds with speed less than 14 $msec^{-1}$ was detected [Fig. 4 (c)]. On 26 July the winds were variable with southerly components of speed less than 30 $msec^{-1}$ in the middle stratosphere and northerly components of speed less than 23 $msec^{-1}$ above 42 km in the upper stratosphere [Fig. 4 (d)]. Table 1, which gives average values, shows that the meridional winds over Antarctica in winter were predominantly northerly with speed less than 20 $msec^{-1}$ up to 57 km and southerly aloft with a maximum speed of 23 $msec^{-1}$ at 68 km.

The corresponding meridional winds over the equator [dashed curves (2) in Figs. 4 (a to d)] were variable in July. On 5 July, the winds were predominantly southerly in the stratosphere with a maximum speed of 65 $msec^{-1}$ at 45 km and northerly in the lower mesosphere with speed less than 17 $msec^{-1}$ [Fig. 4 (a)]. On 12 July the winds were variable up to 45 km with speed less than 20 $msec^{-1}$ and northerly aloft with a maximum speed of 30 $msec^{-1}$ at 48 km around the stratopause [Fig. 4 (b)]. On 19 July the meridional winds were variable with speed less than

20 $msec^{-1}$ upto 55 km with weaker winds in the troposphere and the lower stratosphere and stronger winds in the upper stratosphere [Fig. 4 (c)], while on 26 July the winds were again weak and variable with speed less than 10 $msec^{-1}$ [curve (2) in Fig. 4 (d)]. The average values of the meridional wind components given in Table 1 also show that the winds over the equator in July were weak and variable of speed less than 12 $msec^{-1}$ in the troposphere and the stratosphere, and northerly in the lower mesosphere having a maximum speed of 17 $msec^{-1}$ at 56 km.

4.3 Temperatures

In January 1972 (southern summer) the vertical temperature profiles over Molodezhnaya, Antarctica [solid curves (3) in Figs. 3 (a to d)] show that the polar tropopause and stratopause were located in an altitude region from 9 to 11 km and 47 to 49 km, respectively, with temperatures varying from −51 to 56°C (tropopause) and from 4 to 10°C (stratopause), respectively. However, the mesopause was not well defined. It is also observed that in an altitude region from about 10 to 30 km the temperature structure was quasi-isothermal with a lapse rate of about +0·5°C km^{-1}. The average temperature (Table 1) over Molodezhnaya, Antarctica shows that in Jan. 1972, the polar tropopause and stratopause were located at altitudes of 9 and 47 km with temperatures of −51·8 and 6·5°C, respectively. The temperature lapse rates in the troposphere, upper stratosphere and the mesosphere were found to be −5·6°C km^{-1}, + 2·0°C km^{-1} and −3·8°C km^{-1}, respectively. However, in an altitude region from 12 to 28 km the lapse rate was very small, viz. +0·5°C km^{-1}, which showed that the temperature structure was quasi-isothermal in that particular layer. From the average January profiles the mesopause was found around 80 km with a temperature of about −99°C.

The corresponding vertical temperature profiles over Thumba [dashed curves (3) in Figs. 3 (a to d)] show that in January the equatorial tropopause was located at 17 km with a temperature varying from −76 to −82°C and the stratopause was in an altitude region from 48 to 51 km with temperature ranging from −5 to −12°C, respectively. The mesopause was again not well-defined. However, on 12 Jan. the mesopause was located at 70 km with a temperature of −71°C [Fig. 3 (b)]. Average temperature profile over Thumba shows that in January the equatorial tropopause and stratopause were at altitudes of 17 and 50 km, respectively with temperatures of −78·8°C and −8·8°C, respectively. The temperature lapse rates in the troposphere and stratosphere were found to be −6·8 and + 2·4 °C km^{-1}, respectively. The mesopause was, however, ill-defined.

In July 1972 (southern winter) the vertical temperature profiles over Molodezhnaya, Antarctica [solid curves (3) in Figs. 4 (a to d)] indicate that the polar tropopause was located in an altitude region from 10 to 25 km with a temperature varying from about −70 to −87°C, while the stratopause was located between 43 and 52 km with a temp rature ranging from −1 to −8°C. The mesopause was again ill defined. However, on 12 July the polar mesopause was located at 73 km with a temperature of −70°C. In the altitude region 15-25 km where the winter polar tropopause was apparently located, the temperature variation was found to be quite small. The average temperature profile over Molodezhnaya, Antarctica shows that in the southern winter month July the polar tropopause was ill-defined due to its multiplicity, while the stratopause was at 48 km with a temperature of −12·4°C. The mesopause was also ill-defined. The temperature lapse rates in the troposphere, stratosphere and mesosphere were found to be about −2·7, +3·1 and −1·9°C km^{-1}, respectively. In an altitude region from 15 to 26 km, where the tropopause was located, the temperature lapse rate was very small, viz. −0.35 °C km^{-1} which showed a quasi-isothermal temperature structure in that layer.

The dashed curves (3) in Fig. 4 (a to d) give the corresponding vertical temperature profiles over Thumba, in July 1972. It is found that in the southern winter the equatorial tropopause was located at 17 km with a temperature varying from −74 to −80°C while the stratopause was lying around 45 km with a temperature of about −5°C. The mesopause was again found to be ill-defined. However, on 12 July the equatorial mesopause was found at 74 km with a temperature of −82°C. The average temperature profile over Thumba shows that in July, the southern winter the equatorial tropopause and stratopause were located at 17 and 46 km with temperatures of − 77·3°C and −4·5°C, respectively, while the mesopause was not very well defined due to the meagre data available in that particular region. The temperature lapse rates in the troposphere, stratosphere and mesophere were found to be −6·2, + 2·3 and −2·7°C km^{-1}, respectively.

4.4 Comparison with the Groves Atmospheric Model

Typical southern summer (5 Jan.) and southern winter (5 July) vertical temperature profiles obtained from the M-100 meteorological rocket soundings conducted at Molodezhnaya, Antarctica in 1972 are compared with the corresponding Groves[1] atmospheric model profiles at 70°N on 1 July and 1 Jan., respectively, in Fig. 5.

The thick dashed curve (C) in Fig. 5 is the typical southern summer actual temperature profiie, while the curve (D) is the corresponding Groves model profile. These two curves show that the deviation of the actuals from the model ranged from −26 to + 17°C with a maximum of −26°C (absolute value) at 65 and a minimum of −1°C (absolute value) at 45 km. The curves also show that the deviations in the stratosphere were smaller with absolute values less than 10°C, while the deviations in the mesosphere were larger with absolute values less than 26°C. This indicates that the temperatures in summer in the model are given somewhat in excess in the mesosphere, while there is a reasonably good agreement in the stratosphere.

The thick solid curve (A) in Fig. 5 gives the typical southern winter temperature profile, while the curve (B) gives the corresponding Groves atmospheric model profile. The curve (A) shows a sudden disruption in the Antarctic upper atmosphere in the winter regime. The polar stratosphere and the mesosphere were subjected to a significant cooling and warming in the southern winter. A detailed account of this phenomenon has been given by the author in an earlier published paper.[3] Due to this disruption, in winter the departures of the actuals from the model were quite large ranging from −26 to + 39°C [curves (A) and (B) in Fig. 5]. The absolute values of the deviation was minimum 1°C at 35 and maximum 39°C at 70 km. In the stratosphere the departures were smaller with absolute values less than 12°C, while in the mesosphere the departures were larger with values lying in a range of about −10 to + 40°C. The larger departures may be due to the upper atmospheric disruption in the winter regime.

5. Conclusions

(i) In the southern summer the polar tropopause and stratopause were found to be about 27 and 13°C warmer than the corresponding equatorial tropopause and stratopause, while the polar mesopause was about 25°C colder than the corresponding equatorial mesopause. Also, the equatorial tropopause and stratopause were located at about 8 km and 3 km higher than the corresponding polar tropopause and stratopause, while the mesopause was ill-defined.

(ii) In the southern winter the polar tropopause and stratopause were about 5 and 8°C colder than the corresponding equatorial tropopause and startopause. Also, the polar tropopause and stratopause were located at about 3 and 2 km higher than the corresponding equatorial tropopause and stratopause, while the mesopause was again not well-defined.

(iii) It is also found that the south polar tropopause and stratopause in summer were about 30 and 20°C warmer than the correspnding winter tropopause and stratopause, while the equatorial tropopause and stratopause did not show any significant seasonal differences.

(iv) The zonal winds over Antarctica were predominantly easterly in the southern summer and westerly in the southern winter, while over the equator the winds were predominantly easterly in both the seasons with weak westerlies in the troposphere in January, the southern summer. The meridional winds were variable both over the Antarctic and the equator.

(v) During the southern winter a sudden disruption followed by sizeable perturbations in the atmospheric wind and thermal structure is detected over Antarctica, while over the equator the structure was found to be relatively steady.

(vi) Deviations of the actual temperatures from the corresponding Groves model temperatures were found to be quite significant lying in a range of about −30 to + 40°C with smaller departures in the stratosphere and larger departures in the mesosphere.

Acknowledgement

The author acknowledges the collaboration of the members of the 17th Soviet Antarctic Expedition, 1971-73, and thanks the Department of Atomic energy, Government of India, New Delhi, and the Hydrometeorological Service of the USSR for allowing him to take part in the expedition. The author is grateful to Prof. P. R. Pisharoty for stimulating guidance and helpful discussions.

References

1. Groves G V, *Air Force Cambridge Research Laboratories Report No. AFCRL*-71-0410 (L. G. Hanscom Field, Bedford, Massachusetts), 1971, 147.
2. Sehra P S, *Nature, Lond.*, **252** (1974), 683.
3. Sehra P S, *Nature, Lond.*, **254** (1975), 401.