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STATISTICAL INVESTIGATIONS ON SOME ATMOSPHERIC PROPERTIES ABOVE THE TROPICAL ATLANTIC OCEAN

PART I. CALCULATIONS OF AVERAGE LAPSE RATES

by

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Abstract

Some statistics on the lapse rate of temperature over the tropical Atlantic Ocean is presented. Deviations between the mean tropospheric lapse rate adopted by the ICAO standard atmosphere and the observed one have been pointed out.

1. *Introduction*

During the International Geophysical Year 1957—58, by the initiative and sponsorship of the Department of Meteorology, the University of Helsinki, an aerological ship station was established and operated on board of M/S Angra of the Finland South-America Line. The ship performed four voyages between Finnish and Argentinian harbours during the IGY. Radiosoundings were carried out on board ship 2—3 times per day, except in harbours. Upper wind measurements were made by the aid of a cardanically adopted optical theodolite which made the results dependent on the conditions of cloudiness. Unfortunately they were not too favorable and the wind data collected showed to be less representative than expected.

The first voyage covered the period of August 14—October 30, 1957. On the outbound voyage (14. 8.—1. 10) the sounding series was inter-

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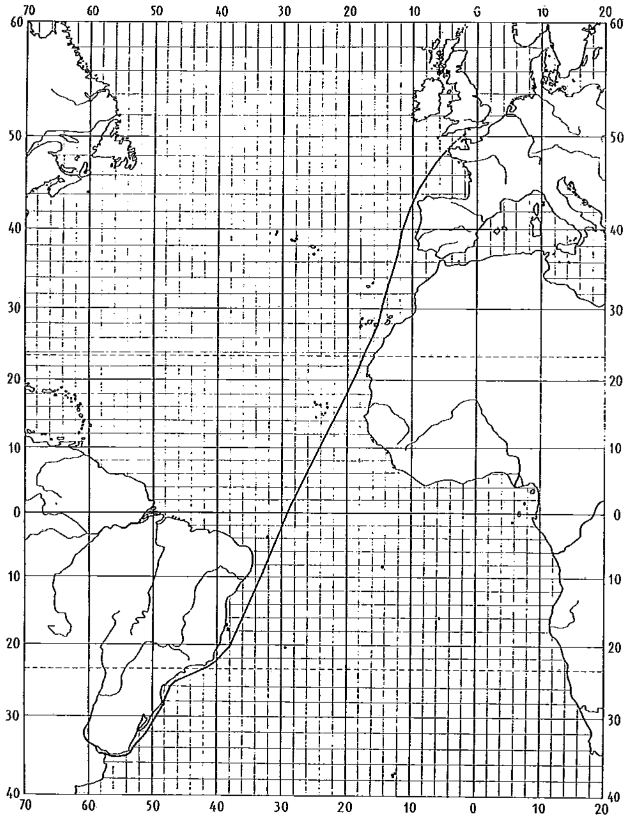


Fig. 1. The average route of the ship station,

rupted between 29. 8.—11. 9. and 14. 9.—1. 10. On the homebound voyage (1. 10.—30. 10) there was an interruption from 8. 10 to 16. 10.

The second voyage covered the interval of December 11. 1957—February 15. 1958. The interruptions on the outbound voyage (11. 12. 1957—5. 1. 1958) took place between 22. 12.—28. 12. and 28. 12. 1957—3. 1. 1958. The sounding series of the homebound voyage (28. 1.—15. 2. 1958) was continuous.

The third voyage took place between March 20—June 17, 1958. During the outbound voyage there was a sounding stop of thirteen days, from 2. 4. to 15. 4. The voyage terminated on 17. 4. and the homebound voyage was started on 14. 5., including a sounding pause between 17. 5.—27.5.

The fourth and last voyage covered the period of July 10—September 12, 1958. There were interruptions in the sounding activity between 22. 7.—2. 8. on the outbound portion (10. 7.—5. 8.) and between 13.—24. 8. and 26.—30. 8. on the homebound part (12. 8.—12. 9.) of the voyage. The route of the ship was practically the same on all of the voyages (Fig. 1.).

2. *Average lapse rates*

The mean values of vertical temperature gradients were computed for the layers 1000—800 mb, 800—600 mb, 600—300 mb and 300—100 mb. The soundings used were corrected for the radiation error with the method applied by the s.c. Vaisala sounding system. The temperature change in vertical within the layers listed above was obtained from values of temperature soundings at the pressure surfaces forming the boundaries of the layer in question. As far as the temperature at a boundary was not observed it was obtained by interpolation between the nearest observed values on both sides. The computed values represent mean gradients within the layers considered without any smoothing in horizontal or vertical direction. The results are presented in tabulated form below, separately for each voyage.

First voyage, outbound part (14. 8.—1. 10. 1957).

1000—800 mb:	0°.5 7°C/km,	3°.3C/km	(mean)
800—600 »	3°.5—9°C/km,	6°.3C/km	
600—300 »	6°.5—8°C/km,	7°.3C/km	
300—100 »	1° —7°.5C/km,	4°.3C/km	

First voyage, homebound part (1. 10—30. 10. 1957).

1000—800 mb:	—0°.5—7°C/km,	3°.3C/km
800—600 »	3° —7°.5C/km,	5°.3C/km
600—300 »	6°.5—8°.5C/km,	7°.5C/km
300—100 »	3°.5—7°.5C/km,	5°.5C/km

Second voyage, outbound part (11. 12. 1957—5. 1. 1958).

1000—800 mb:	2° —9°C/km,	5°.5C/km
800—600 »	1° —7°.5C/km,	4°.3C/km
600—300 »	5° —7°.5C/km,	6°.4C/km
300—100 »	2° —7°.5C/km,	4°.8C/km

Second voyage, homebound part (28. 1—15. 2. 1958).

1000—800 mb:	1°.5—8°C/km,	4°.8C/km
800—600 »	3°.5—8°C/km,	5°.8C/km
600—300 »	6°.5—8°C/km,	7°.3C/km
300—100 »	2° —7°.5C/km,	4°.8C/km

Third voyage, outbound part (20. 3—17. 4. 1958).

1000—800 mb:	0°	—7°C/km,	3°.5C/km (mean)
800—600 »	3°	—8°.5C/km,	5°.8C/km
600—300 »	6°	—9°C/km,	7°.5C/km
300—100 »	2°	—8°C/km,	5°/km

Third voyage, homebound part (14. 5—17. 6. 1958).

1000—800 mb:	—1°	—7°C/km,	3°C/km
800—600 »	4°	—8°.5C/km,	6°.3C/km
600—300 »	6°	—7°.5C/km,	6°.8C/km
300—100 »	2°	—8°.5C/km,	5°.3C/km

Fourth voyage, outbound part (10. 7—5. 8. 1958).

1000—800 mb:	1°	—7°.5C/km,	4°.3C/km
800—600 »	3°.5	—7°C/km,	5°.3C/km
600—300 »	6°	—8°C/km,	7°C/km,
300—100 »	2°	—7°.5C/km,	4°.8C/km

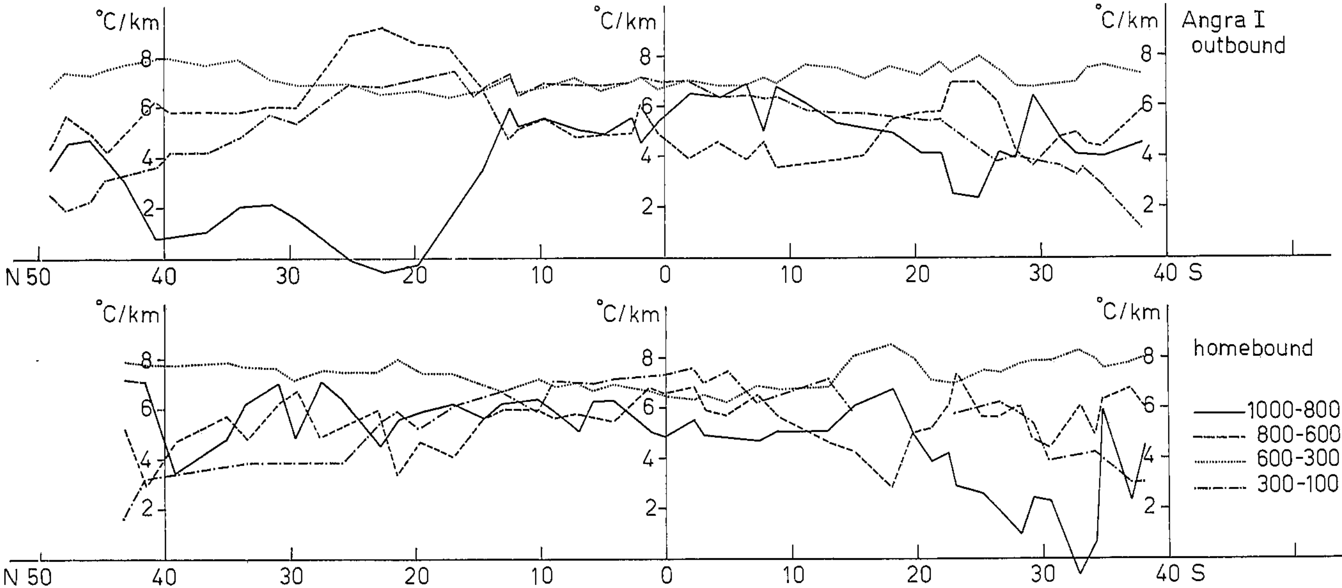
Fourth voyage, homebound part (12. 8—12. 9. 1958).

1000—800 mb:	0°.5	—8°C/km,	4°.3C/km
800—600 »	3°	—9°C/km,	6°C/km
600—300 »	6°	—9°C/km,	7°.5C/km
300—100 »	2°	—7°.5C/km,	4°.8C/km

A characteristic feature, common for all of the sections is, that the mean lapse rate values increase on the average from the surface upwards until the layer of 600—300 mb and then decrease again. In some of the sections the lapse rate within the last mentioned layer approaches the dry adiabatic rate. The change of the gradient does not take place continuously or evenly, more stable or unstable layers merely alternate, particularly in the lower troposphere. A graphical presentation of the lapse rate distribution as a function of latitude (Figs. 2—5) shows this clearly. Regions of large lapse rate ($\gamma \geqq 8°C/km$) in the upper troposphere (600—300 mb) appear occasionally, mainly in lower middle latitudes of the southern hemisphere. In the lower troposphere (800—600 mb) correspondingly large values occur sporadically, roughly within the latitudinal belt 15°—25°N.

The values of the lapse rates, averaged over all of the voyages, are given below:

The layer from	1000—800 mb:	4°.0C/km
» » »	800—600 »	5°.6C/km
» » »	600—300 »	7°.2C/km
» » »	300—100 »	4°.9C/km



Figs. 2—5. A graphical precentation of the lapse rate distribution as a function of latitude during the separate voyages.

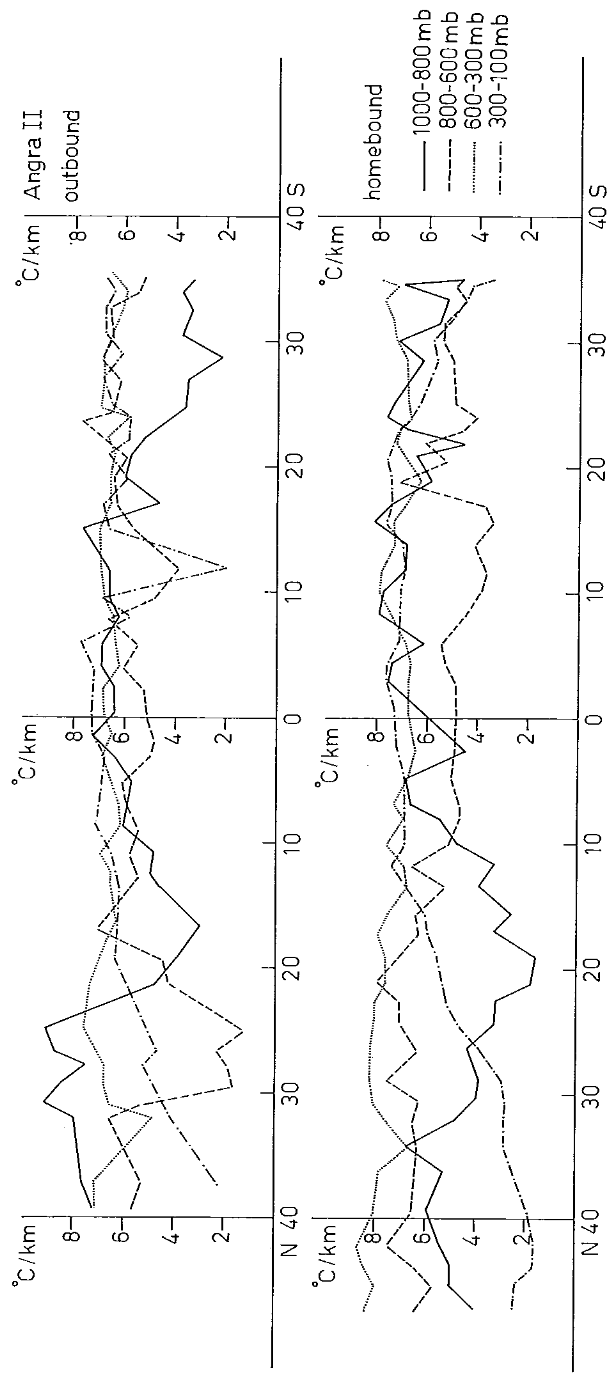

Angra II
outbound
homebound
1000-800 mb
800-600 mb
600-300 mb
300-100 mb
°C/km
N 40
30
20
10
0
10
20
30
40 S
8
6
4
2

Fig. 3.

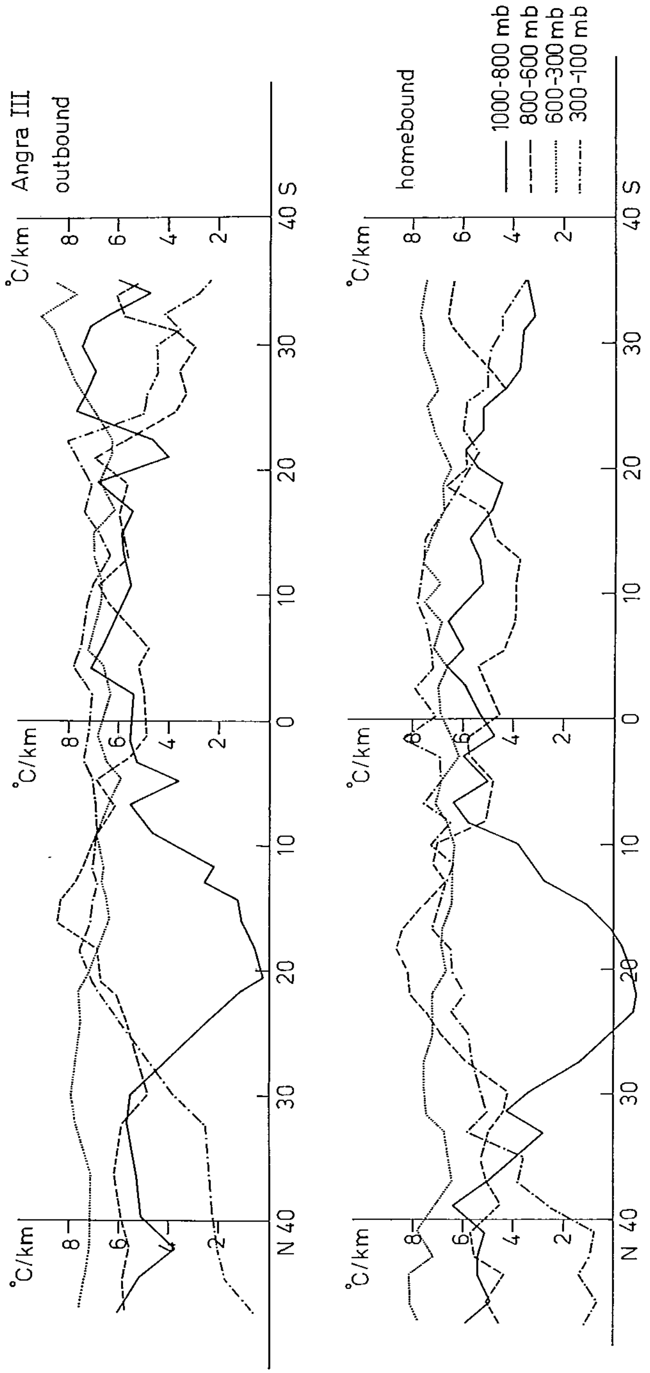

Angra III
outbound
homebound
°C/km
N 40
40 S
1000-800 mb
800-600 mb
600-300 mb
300-100 mb

Fig. 4.

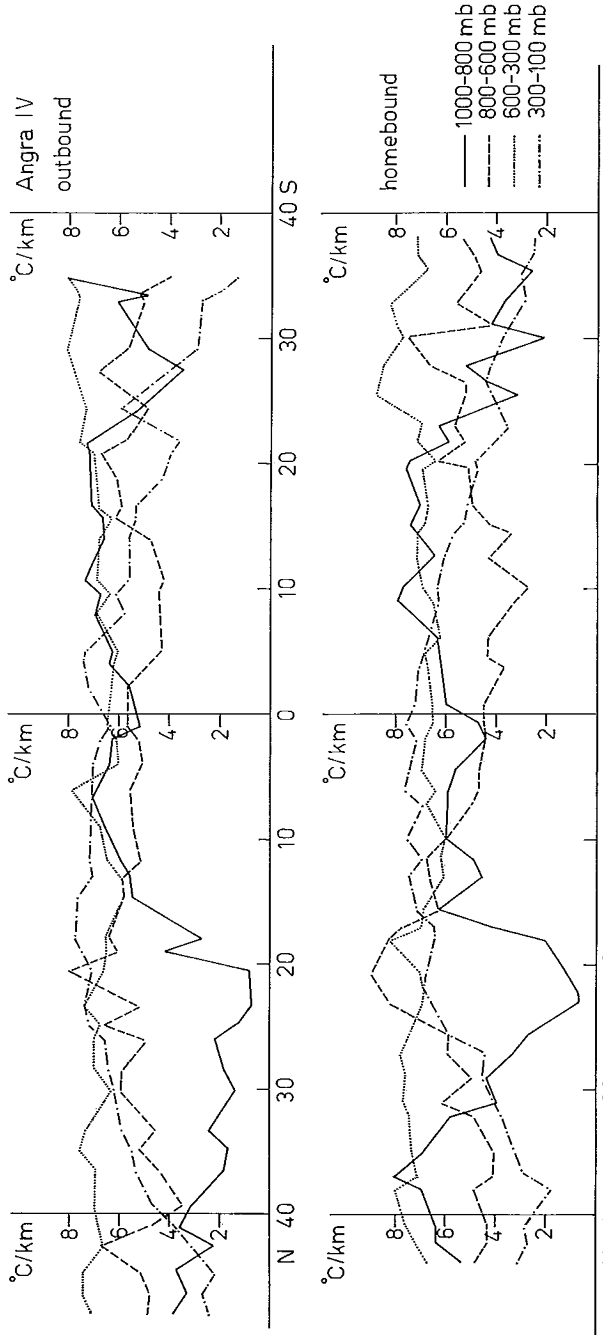

Angra IV
outbound
homebound
1000-800 mb
800-600 mb
600-300 mb
300-100 mb
°C/km
8
6
4
2
N 40
30
20
10
0
10
20
30
40 S

Fig. 5.

If we compare this distribution with results of similar computations, published by Defant & Taba [1], we find that the agreement is relative good. Their values, converted to correspond with the layer distribution used by us, are shown below:

The	layer	from	1000—800	mb:	4°.3C/km
»	»	»	800—600	»	4°.5C/km
»	»	»	600—300	»	6°.6C/km
»	»	»	300—100	»	4°.9C/km

In the topmost part of the tropical troposphere only the results coincide exactly.

The minimum lapse rates occur according to our sections in the lowest part of the troposphere. Their magnitudes vary from one voyage to another evidently depending on the height and intensity of the trade inversion. A similar variation seems to appear in the results of Defant and Taba. It is also seen that the actual lapse rate in the tropical and subtropical troposphere is generally smaller than 6°.5 C/km, adopted by the ICAO standard atmosphere for the heights below 11 km.

In order to compare our lapse rate values with previous results, published by Kitaoka & Nakamura [2] the distribution of the mean lapse rate in the tropospheric layer 800—300 mb (above the trade wind inversion), as a function of latitude with intervals of 5° latitude is presented in Table I.

The above mentioned Japanese authors have calculated their lapse rate values from temperature difference of two levels, 850 mb and 300 mb using aerological data of the year 1955. They have carried out their calculations along the three meridians 0°, 140°E and 80°W, and the four parallels 60°N, 30°N, 0° and 30°S and for four months, January, April, July and October, 1955. Their mean lapse rate values at the three selected parallels are shown in the last column of Table I. The coincidence of our mean lapse rate values with those of Kitaoka *et al.* is surprisingly complete considering the quite different methodics and collection of data.

According to Table I a quite distinct maximum of the mean lapse rate appears at lat. 20°N (7°.0 C/km) and a some less distinct minimum (5°.6 C/km) at lat. 10°S. However, the vertical extension of the tropical troposphere to the 300 mb-level only does not correspond the reality in conditions where the tropopause height mainly occurs at the level of about 100 mb. In all of our cross sections the tropical tropopause

Table I. Distribution of the average lapse rate in the troposphere (800—300 mb), above the inversion layer, as a function of latitude. Minimum —, maximum -----.

Lat.	Number of voyage, subindex o = outbound, h = homebound									Japanese results
	I_0	I_h	II_0	II_h	III_0	III_h	IV_0	IV_h	Mean	
40°N	7.0	*5.9*	—	7.3	6.5	6.3	5.5	6.1	6.4	
35°N	6.8	6.9	6.0	6.7	6.7	5.7	6.3	5.7	6.4	
30°N	6.5	6.9	4.8	7.3	6.4	5.8	6.2	6.6	6.3(1)	6.32
25°N	7.8	6.5	*4.6*	7.4	6.6	7.0	6.6	6.9	6.7	
20°N	7.6	6.0	5.6	7.5	7.0	7.4	6.9	8.0	7.0	
15°N	6.8	6.1	6.3	6.7	7.3	7.0	5.9	6.5	6.6	
10°N	6.1	6.5	6.1	6.3	6.7	6.6	5.9	6.0	6.3	
5°N	5.8	6.1	6.3	6.0	6.5	5.8	6.1	5.7	6.0	
Eq.	5.8	6.5	6.0	5.8	5.8	5.8	6.1	5.6	5.9(2)	5.97
5°S	5.6	6.0	6.0	6.1	6.0	5.8	*5.1*	5.5	5.8	
10°S	*5.4*	6.0	5.7	5.9	6.3	*5.6*	5.4	*4.8*	*5.6*	
15°S	5.6	6.1	6.4	*5,5*	6.4	5.9	6.0	5.4	5.9	
20°S	6.5	6.4	6.3	6.2	6.4	6.2	5.8	6.1	6.2	
25°S	7.5	6.6	6.7	5.7	*5.4*	6.2	6.3	6.8	6.4	
30°S	*5.4*	6.2	6.5	6.4	5.7	6.8	6.8	7.7	6.4(4)	6.44
35°S	6.0	6.9	5.9	6.2	6.8	6.8	6.0	5.8	6.3	

(around 100 mb) is extended to 30°—35°S. On the side of the northern hemisphere its extension varies between 25°—40°N, but is always combined with a transitional medium tropopause between 200—150 mb. The latitudinal distribution of the mean lapse rate within the layer 800—100 mb, presented in Table II, should hence give a better and more representative picture of the tropospheric lapse rate values at different latitudes of the tropical and subtropical Atlantic as observed by our ship station.

The maximum of the mean lapse rate appears in Table II again at 20°N but the minimum values favour the highest latitudes included in the table at the sides of both hemispheres most likely due to the increasing stability of the upper layers in the region of the medium tropopause. Nevertheless, even this latitudinal distribution underlines the discrepancy between the mean tropospheric lapse rate taken in ICAO standard atmosphere and the observed one in the real atmosphere above the subtropical and tropical Atlantic.

Table II. Distribution of the average lapse rate in the troposphere (800—100 mb), above the inversion layer, as a function of latitude. Minimum —, maximum ----.

Lat.	Number of the voyage, subindex o=outbound, h=homebound								Mean
	I_0	I_h	II_0	II_h	III_0	III_h	IV_0	IV_h	
40°N	6.0	*5.0*	—	5.5	5.1	*4.7*	5.1	*4.9*	*5.2*
35°N	6.0	5.8	5.0	*5.3*	5.3	5.1	6.1	*4.9*	5.4
30°N	6.1	5.9	4.7	5.8	5.5	5.6	6.2	5.8	5.7
25°N	7.6	5.7	*4.6*	6.5	6.3	6.6	6.8	6.6	6.3
20°N	7.4	5.8	5.8	6.8	7.0	7.1	7.0	7.5	6.8
15°N	6.7	6.2	6.3	6.5	7.2	7.0	6.5	6.7	6.6
10°N	6.4	6.3	6.3	6.5	6.8	6.8	6.3	6.5	6.5
5°N	6.1	6.4	6.5	6.3	6.6	6.1	6.4	6.3	6.3
Equator	6.2	6.7	6.3	6.3	6.2	6.2	6.2	6.1	6.3
5°S	5.8	6.5	6.5	6.6	6.5	6.3	5.9	5.8	6.2
10°S	5.7	6.2	5.8	6.3	6.7	6.3	5.6	5.3	6.0
15°S	5.7	6.0	6.4	6.2	6.5	6.4	5.8	5.4	6.0
20°S	6.2	6.4	6.3	6.7	6.7	6.0	5.9	5.6	6.2
25°S	6.4	6.4	6.6	6.0	5.2	6.1	6.1	5.9	6.1
30°S	*4.8*	5.6	6.5	6.1	5.2	6.0	5.4	6.3	5.7
35°S	4.9	5.9	6.1	*5.3*	*5.0*	5.7	*4.4*	*4.9*	5.3

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1. DEFANT, FR. and H. TABA, 1957: The threefold structure of the atmosphere and the characteristics of the tropopause. *Tellus*, **9**, 259—274.
2. KITAOKA, T. and S. NAKAMURA, 1958: Some considerations on the standard atmosphere. *Geophys. Mag.*, **28**, 421—430.

CORRIGENDA

The article entitled »Statistical Investigations on some Atmospheric Properties above the Tropical Atlantic Ocean. Part I. Calculations of Average Lapse Rates» by LAURI A. VUORELA and JORMA RIISSANEN (*Geophysica*, **10**, 89—99) contains an error in the table on page 97. The lapse rate value on the third row should read 7°.3 C/km instead of 6°.6 C/km.

In the article entitled »Some Characteristics of Auroral-Zone Precipitations during a Single Long-lived Balloon Flight» by J. KANGAS (*Geophysica*, **10**, 109—119), the reference numbers in the text do not correspond with those in the list of references. This is a mistake of the Editor who arranged the references at the end of the paper alphabetically although the author had given them in his manuscript in order of citation with the appropriate numbers appearing in brackets in the text.