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Latitudinal Variation of Tropospheric Temperature Lapse Rate.

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Summary. The latitudinal variation of tropospheric temperature lapse rate is examined on the basis of recently published data for the northern hemisphere. In January, the lapse rate systematically decreases from 6.4° C/km. for the equator to 3.6° C/km. for 70° N; in July, the lapse rate is nearly constant in respect of latitude between the equator and 50° N, but decreases from the latter poleward. The average January—July lapse rate decreases systematically from 6.3° C/km. for the equator to 4.7° C/km. for 70° N. This variation is closely described by the equation $\beta\varphi = 6.25 - 2 \sin^4\varphi$, where $\beta\varphi$ is the lapse rate, in °C/km, for latitude φ. For the north pole, the equation gives a lapse rate of 4.25° C/km.

Zusammenfassung. Die Änderung des vertikalen Gradienten der Troposphärentemperatur mit der geographischen Breite wird auf Grund neuen Zahlenmaterials für die Nordhemisphäre untersucht. Im Januar nimmt der Temperaturgradient allmählich von 6.4° C/km am Äquator bis zu 3.6° C/km in 70° N Breite ab; im Juli ist der Temperaturgradient in den Breiten zwischen dem Äquator und 50° N Breite fast gleich und nimmt von hier aus polwärts ab. Der mittlere Temperaturgradient für Januar—Juli nimmt allmählich von 6.3° C/km am Äquator bis auf 4.7° C/km in 70° N Breite ab. Die Breitenabhängigkeit läßt sich gut durch die Gleichung $\beta\varphi = 6.25 - 2 \sin^4\varphi$ darstellen, in der $\beta\varphi$ der Temperaturgradient in °C/km in der Breite φ ist. Für den Nordpol ergibt die Gleichung einen Temperaturgradienten von 4.25° C/km.

Résumé. La variation latitudinale du gradient thermique vertical de la température troposphérique est examinée en se basant sur des données publiées récemment pour l'hémisphère nord. En janvier, le gradient diminue systématiquement d'une valeur de 6.4° C/km pour l'équateur à 3.6° C/km pour 70° N; en juillet le gradient est presque constant pour les latitudes situées entre l'équateur et 50° N, mais il diminue d'ici vers le pôle. Le gradient moyen janvier/juillet diminue systématiquement de 6.3° C/km pour l'équateur à 4.7° C/km pour 70° N. Cette variation peut être représentée par l'équation $\beta\varphi = 6.25 - 2 \sin^4\varphi$ où $\beta\varphi$ est le gradient en °C/km pour la latitude φ. Pour le pôle nord, l'équation donne un gradient de 4.25° C/km.

It is usually stated in meteorological texts as well as in various papers that in the troposphere the average lapse rate of temperature is almost constant with respect to latitude. However, a consideration of the latitudinal distribution of heat balance and of some recent theoretical investigations in hydrodynamics (e. g., CHANDRASEKHAR 1953) has suggested that there might be a systematic latitudinal variation in the value of tropospheric lapse rate. Table I has been prepared to examine this point.

In Table I, the lapse rate values have been computed from WEXLER's (1951) cross-sections of the temperature field in the troposphere and the lower stratosphere between 5° and 75°N for January and July, respectively. These cross-sections appear to be the most recent and complete summaries of the relevant data. In these charts, the surface-temperature data were taken from HANN-SÜRING (1943), the free-air temperature data were assembled and processed at the U. S. Weather Bureau from all figures available at the time and the latitudinal averages of tropopause height are from FLOHN (1947). In our Table, the data for the equator which do not appear in WEXLER's paper, have been obtained by taking (a) the surface temperature value directly from HANN-SÜRING (1943, p. 180), (b) the tropopause height directly from FLOHN (1947), and (c) the temperature at the tropopause as — 80°C. The latter figure is based on various longitudinal atmospheric cross-sections published in the recent literature and on the fact that in WEXLER's charts, which terminate at 5°N, the equatorial tropopause appears to be within the —75°C isotherm with the temperature values decreasing inward.

Table I. *Tropospheric temperature lapse rates.*

T_s and T_t surface and tropopause temperatures, respectively, in °C,
H height of tropopause, in km.
β lapse rate, in °C/km.

Latitude, °N	January				July				Annual	
	T_s	T_t	H	β	T_s	T_t	H	β	β $\left[\frac{(D)+(H)}{2}\right]$	β [From(2)]
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
0	26	— 80	16.6	6.4	26	— 80	16.9	6.3	6.3	6.3
10	26	— 76	16.4	6.2	27	— 77	16.8	6.2	6.2	6.2
20	22	— 72	15.6	6.0	28	— 75	16.3	6.3	6.2	6.2
30	15	— 63	13.4	5.8	27	— 68	14.9	6.4	6.1	6.1
40	5	— 57	11.2	5.5	24	— 58	13.1	6.2	5.9	5.8
50	— 7	— 56	9.8	5.0	18	— 53	11.5	6.2	5.6	5.6
60	— 16	— 56	9.2	4.3	14	— 49	10.4	6.0	5.2	5.1
70	— 26	— 57	8.6	3.6	7	— 46	9.5	5.7	4.7	4.7
80										4.4
90										3.6

It is seen from Table I that (a) in winter, the tropospheric lapse rate systematically decreases from its value for the equator to its value for the high latitudes, (b) in summer, the lapse rate is practically constant for the zone between the equator and the middle latitudes but decreases poleward from the latter, and (c) the annual (January—July) averages, which are dominated by the winter values, show also a systematic decrease from the equator toward the pole.

The lapse rate figures in Table I, depend of course on the figures adopted for the height of the tropopause. Generally, different writers give different figures for this. For instance, the tropopause heights adopted by GOODY (1949), which are due to SAWYER and DEWAR, are for the extra-tropical latitudes substantially lower than those presented by FLOHN. But as both sets of figures give the average height of the tropopause as decreasing poleward, the resulting lapse rate figures would indicate the same trend provided that WEXLER's temperature data are retained. The lapse rate figures for the middle latitudes are probably subject to a greater uncertainty than those for the other latitudes because of the difficulty of defining an average height for the mid-latitude tropopause which is usually of a leaf-like structure.

Let β_φ stand for the average annual tropospheric lapse rate, in ^{0}C/km., for latitude φ. Fitting, by least squares, to the data in column (I) of Table I, a function of the form

$$\beta_\varphi = a + b \sin^2 \varphi + c \sin^4 \varphi, \tag{1}$$

gives a = 6.24, b = 0.02 and c = —1.99, so that, after some slight rounding off,

$$\beta_\varphi = 6.25 - 2 \sin^4 \varphi. \tag{2}$$

The reason for taking in (1) only even powers of sin φ is in that, barring differences in the land-sea distribution, the value of the lapse rate should not depend on the sign of φ (northern or southern hemisphere).

The hemispherical average of the lapse rate is obtained from the integral

$$\int_0^{\pi/2} \beta_\varphi \cos \varphi \, d\varphi. \tag{3}$$

Inserting (2) in (3) yields that the hemispherical average of β_φ is 5.85^{0}C/km. which is slightly less than the figures most often cited in literature.

References.

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