SEASONAL AND LATITUDINAL TEMPERATURE CHANGES IN THE OZONOSPHERE

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ABSTRACT

A calculation is made of seasonal and latitudinal temperature changes in the ozonosphere which would be caused solely by the absorption by ozone of solar radiation in the Huggins, Hartley and Chappius regions. A constant density of the atmosphere with season and latitude is assumed. Strong seasonal and latitudinal temperature changes are noted, with maximum increases over the poles during their respective summers.

1. Introduction

A systematic and reasonably realistic computation of seasonal and latitudinal 24-hr temperature changes in the ozonosphere would be of intrinsic interest and of value to theories of wind systems and other phenomena in this region. The writer [1], in an investigation of the absorption of solar energy by ozone, has computed the variation of ozone solar absorption with season and latitude. In this computation, use was made of the calculation by Craig [2] of $E_z{}^N/n$, which is the solar energy absorbed by ozone per unit volume per second (after the solar radiation has passed through N cm of O_3 NTP) divided by the ozone concentration, n. The vertical ozone distribution varied proportionately to the Craig number 1 distribution [3], with the total amount being proportional to the distribution of total ozone amount with season and latitude as given by Götz [4]. Allowance was made for absorption during twilight.

2. Computations

The absorption calculations form the basis of the following computations on temperature increases. These temperature increases are made on a daily basis. It is assumed that all the energy absorbed in a day goes into temperature increase. Underlying this assumption is the physical hypothesis that the ozone concentration is in equilibrium, so that the absorbed energy which is lost by dissociation of the ozone molecule is regained by an equivalent recombination. In addition, it is assumed that the energy absorbed by the ozone molecules is transferred to the other gases in the unit volume in the form of heat, resulting in a uniform increase in temperature. We have

$$T_D{}^z = E_z{}^N/(\rho c_p),$$

where $T_D{}^z$ is the temperature increase per day in degrees Celsius at height z for a specified latitude and day of year due to ozone solar absorption, ρ is the density in c.g.s. units, and $c_p = 0.239$ cal g^{-1} deg^{-1} (specific heat of dry air at constant pressure).

The seasonal and latitudinal variations of density have not been measured in a systematic manner in the region in question (20 to 60 km). Some methodical measurements have been made of seasonal and latitudinal changes in temperature by radiosondes at pressures up to 10 mb (30.9 km in the National Advisory Committee for Aeronautics standard atmosphere) and occasionally up to 7 to 4 mb [5]. In the latter study it was concluded that, on the average, the 10-mb temperatures range between −38 and −52C; on daily 10-mb synoptic maps, covering an area from Central America to Canada (9 to 79°N), the range of temperature was 15C. However, there is a definite seasonal and latitudinal trend in the temperature at this altitude within the above-mentioned limits. These temperature variations at a constant pressure were not sufficient to cause density changes of 10 percent, except in the few extreme instances which fell outside these limits. At pressures of 50 mb (NACA height of 20.6 km), the seasonal and latitudinal variations are on the average included between the limits of −40 to −65C. Again this temperature variation would cause for this constant pressure, as an upper limit, a 10 percent variation in density. This variation in temperature with latitude and season for a constant pressure decreases from 50 mb to around 14 mb, where there is practically no change with season and latitude. This indicates that the density from about 20 to 30 km is, in general, a fairly conservative atmospheric property. Measurements of density [6] at the ground, under more extreme temperature conditions, have not indicated large variations in density. Densities at 90 km [7], as computed by meteor measurements, have indicated larger variations in density; but these values are presently undergoing revision.

Consequently, in view of the apparently small

TABLE 1. Assumed densities.

Height (km)	Density (g/cm³)
20.0	8.99×10^{-5}
30.0	1.93×10^{-5}
42.5	2.62×10^{-6}
57.5	5.08×10^{-7}

variations and for lack of any measurements, it was assumed that for a specific height the density was constant with latitude and season. The densities used were those given by the Rand Corporation [8] for 45°N and do not differ from its values for the equator by more than 10 percent. The assumed values are given in table 1.

3. Results

The results of the computation are given in figs. 1 to 6, meridional cross-sections of 24-hr temperature-increment isopleths for alternate months. These graphs apply to the 15th of the month. From these graphs, and the data for the intervening months not presented here because of lack of space, we may make the following observations as to the seasonal trend of the increments. On 15 January, the maximum of 10C is located at 45 km over the South Pole. There is a smooth falling off of this maximum with height, so that at 20 km this temperature increase is insignificant (less than half a degree); but even at 57.5 km, the temperature increase is 4C. The latitudinal decrease is more gradual, and it is not until 70°N that a zero is reached in the earth's shadow region. By 15 February, the maximum has shifted to about 40°S and has diminished in intensity to 7C, with the shadow region at 84°N. By 15 March, there is an almost symmetrical distribution centered at 5°S of maximum value 6C. The distribution of energy absorbed has three maxima at 30 km at this time of the year, caused by the double maxima in the latitudinal distribution of ozone and the variation of length of day with latitude. However, these three maxima become only slight undulations at 30 km in the temperature-increment curves. Because of the rapid decrease of air density

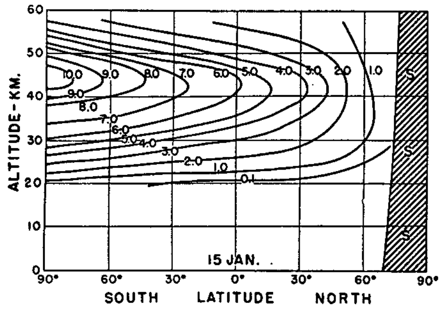

FIG. 1. Meridional cross-section of 24-hr temperature-increment isopleths (deg C) for 15 January.

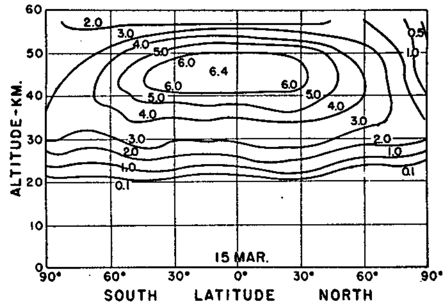

FIG. 2. Same as fig. 1, but for 15 March.

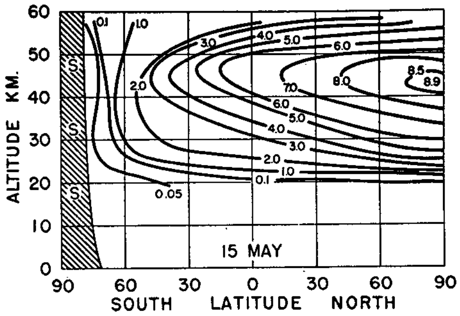

FIG. 3. Same as fig 1, but for 15 May.

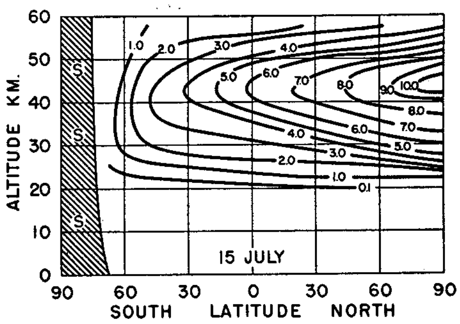

FIG. 4. Same as fig. 1, but for 15 July.

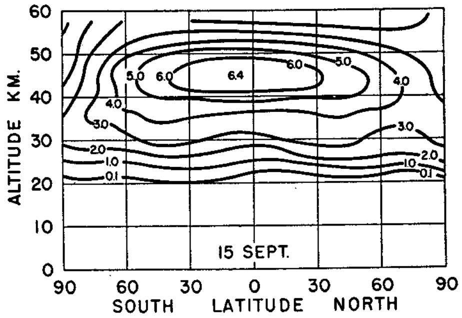

FIG. 5. Same as fig. 1, but for 15 September.

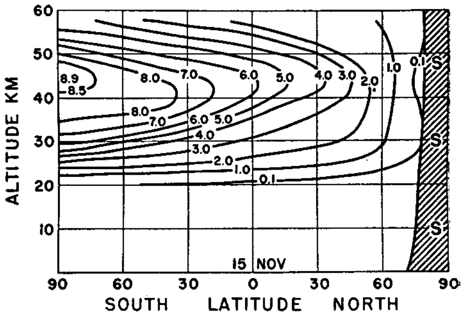

FIG. 6. Same as fig. 1, but for 15 November.

with height, the region of maximum temperature change lies at 45 km, where only one maximum at 5°S is located.

By 15 April, a maximum of 7C occurs at 36°N, and a shadow region occurs as far north as 86°S. The maximum shifts to the North Pole by 15 May, and remains there until at least 15 July and reaches the value of 10.5C. In August, September and October, the region of maximum increase moves southward to 40°N, 5°S and 35°S, and equals in value 7.2, 6.3 and 7.2C, respectively.

By 15 October, the maximum amount of 7.2C is at 35°S. It then moves by 15 November over the South Pole, where it remains for the next few months. By 15 November, it is of magnitude 8.5C; by 15 December, 10.5C; and by 15 January, it is back to 10C.

4. Conclusions

The following facts are indicated by these computations:

1. The height of maximum 24-hr temperature increase is located at approximately 45 km;
2. The region of maximum 24-hr temperature increase (10 to 11C per day) is over the poles during the respective summer seasons, and lasts for about three months;
3. There is a relatively constant (with season) 24-hr increment over the equator;
4. Below 20 km, the 24-hr temperature increment is insignificant, of the order of a few tenths of a degree, while at 57.5 km it is still significant but never above 4C; the actual amount depends on the latitude and solar declination;
5. There is a strong seasonal variation, with marked changes in early spring and fall.

It should be remarked again that these calculations were made for an ozone distribution with a maximum at 30 km, which varied in total amount with season and latitude in accordance with Götz [4], and for a fixed vertical distribution of air density which did not vary with season and latitude.

There is no particular reason to believe that these temperature changes actually occur, since the actual temperature variations depend also on the presence of carbon dioxide, water vapor, and on physical processes, *e.g.*, radiative transfer and convection, which distribute heat in the atmosphere.

It is hoped that these computations may prove helpful in elucidation of the temperature structure of the middle atmosphere and other allied phenomena.

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