LETTERS TO THE EDITOR

GEOPHYSICS

Semi-annual Variation in Upper-atmosphere Density

A SEMI-ANNUAL variation in upper-atmosphere density, with maxima in April and October, and minima in January and July, was discovered in 1960 and has been generally accepted as a feature of the upper atmosphere at heights of 250–600 km. In a recent article, Anderson¹ suggested that the variation is a disguised effect of latitude. Anderson's hypothesis can be tested by analysing the orbit of a satellite of a near-circular polar orbit which samples all latitudes in a nearly equal degree. If the semi-annual variation is recognizable in the orbit of such a satellite, it cannot be due to changes in latitude.

Samos 2 (1961 α 1) is a suitable satellite, having an orbital inclination of 97°, a mean height near 500 km and a mean eccentricity of about 0.005. The motion of *Samos 2* during 1961 and 1962 has been analysed using orbital data given in *Spacetrack Bulletins* and orbits recently determined at the Royal Aircraft Establishment².

Fig. 1 shows the monthly change Δa in the semi-major axis of the *Samos 2* orbit, expressed as a fraction of the Earth's equatorial radius R . Small corrections have been made to allow for the effects of an oblate atmosphere with day-to-night variation in air density^{3,4}, the small variation in eccentricity due to the odd harmonics in the Earth's gravitational potential, and the decline in solar activity between 1961 and 1962. The change in semi-major axis is an indication of the average (over all latitudes) of the air density at heights near 500 km. The last four points in 1962 are likely to be the least accurate, because the orbital data are not so complete at these times. Satisfactory values are not available for February in either year.

The mean of the values for 1961 and 1962, shown by the solid line, reveals a semi-annual variation, the maximum values of $10^6 \Delta a/R$ being 73 in April and 89 in October, and the minimum values being 44 in July and January. Thus at 500 km height in 1961–62, there is a clear semi-annual variation, independent of latitude,

with the maximum density exceeding the minimum by a factor of 2.0.

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¹ Anderson, A. D., *Nature*, **209**, 656 (1966).

² Merson, R. H., and Neville, E. R., *Orbital Parameters of Samos 2*, R.A.E. Tech. Rep. 66042 (1966).

³ King-Hele, D. G., *Theory of Satellite Orbits in an Atmosphere*, chapt. 5 (Butterworths, London, 1964).

⁴ Cook, G. E., and King-Hele, D. G., *Phil. Trans.*, **259**, 33 (1965).

Ionospheric Storms and Small Pressure Fluctuations at Ground Level

In the past a number of attempts have been made to establish relationships between events occurring in the troposphere and in the ionosphere^{1–3}. However, none of them has as yet been decisive. Recent work^{4,5} has shown that it may be possible to link the two regions by the passage of gravity waves from one region to the other. Infrasonic waves, recorded at ground level near polar regions⁶, indicate a possible relationship between aurora and these infrasonic waves. Earlier⁷, infrasonic waves had been recorded at Washington, D.C., at times of magnetic activity travelling at speeds somewhat higher than the local speed of sound. Maeda and Watanabe⁸ and, more recently, Iyengar⁹ have discussed the possibility of pressure waves being generated at auroral heights. Also, Maeda and Young¹⁰ have discussed the periods of pressure waves from aurorae. Bowman¹¹ has suggested that pressure waves generated near polar regions may be responsible for ionospheric storms at the times of magnetic storms. This report gives some results of possible troposphere-ionosphere relations from the analysis of microbarograph records, which have been made at Brisbane since July 1963. The type of microbarograph used is described by Jones and Forbes¹².

At about 0310 h on August 19, 1963, the microbarograph record at Brisbane begins a period of increased intensity, for the short-period oscillations (period less than 1 min),

Fig. 1. Monthly change Δa in the semi-major axis of the *Samos 2* satellite during 1961–1962, after correction for solar activity, etc.