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over large regions of the temperate zone ionosphere as well as the auroral zones. Such heat input can modulate[5] the temperature at 150 km. by hundreds of degrees K. For the following calculation put $\delta T_0 = 300°$ K. and $T_0 = 500°$ K. originally. Then n_0 changes by 60 per cent due to change in scale height at the 0 level. The percentage change in n will increase with height until it is more than 200 per cent at 650 km. This compares favourably with the increase by a factor of 2·5 of the density at 656 km. deduced from the orbital acceleration[1] of Satellite 1958 β2 (cf. ref. 3).

It is concluded on the basis of the crude analysis above that joule heating of the lower reaches of the ionosphere (100–250 km.) is a major factor in modulation of thermospheric densities. Other factors would be the absorption of radiation from the Sun giving an additional day–night effect[6] superimposed on the *Sq* variation, and the generation of heat by corpuscular radiation impinging on the ionosphere from the magnetosphere. While the energy for the *Sq* variation is thought to be derived from tidal oscillation of the upper atmosphere, the energy for the magnetic disturbance variation is due to that portion of the radiation of the Sun which takes a day or so to come to the Earth. The magnitude of the density fluctuations dependent on magnetic disturbance should increase with height and with proximity to auroral regions. It is suggested that thermospheric densities as deduced from the orbital acceleration of a satellite should correlate well with the local magnetic *K* index at the latitude and longitude of its perigee.

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A Source of Energy for the Ionosphere

THE heat requirement of the equatorial and temperate zone ionosphere is normally about 2×10^{10} cal. sec.$^{-1}$ (cf. Johnson[1]). This is because of the loss of heat downwards due to a temperature gradient of about 10° K. km.$^{-1}$ between 100 and 200 km. altitude. It is the purpose of this communication to suggest that joule heating by ionospheric electric currents can supply heat in this quantity. Current of density (j) causes joule heating at the rate Q given by j^2/σ_3, where σ_3 is the Cowling conductivity.

Consider first those ionospheric currents causing the quiet solar daily variation (*Sq*) of the geomagnetic field. Their intensity[2] is about 10^4 amp. per degree of latitude. Assuming they flow in a height range of 50 km. in a quiet ionosphere in which $\sigma_{3(\text{average})} \approx 4 \times 10^{-14}$ E.M.U., $Q(Sq)$ is about 10^{-8} erg cm.$^{-3}$ sec.$^{-1}$. Over the whole globe this amounts to about 10^{10} cal. sec.$^{-1}$.

Secondly, there are the currents which contribute to the disturbance daily variation (*Ds*) of the geomagnetic field. Average currents in the auroral zone during the Second International Polar Year[3] taken in conjunction with a ten-fold increase of ionospheric conductivity implies a peak $Q(Ds$, auroral) value of 10^{-5} erg cm.$^{-3}$ sec.$^{-1}$ at 150 km. altitude and averaging about 10^{-6} erg cm.$^{-3}$ sec.$^{-1}$ throughout the 100–200 km. height-range[4,5]. An estimate of $Q(Ds$, low latitude) is difficult to make, for the appropriate ionospheric conductivity during disturbance is not known. However, $Q(Ds$, low latitude) is assumed to be of the same order as $Q(Sq$, low latitude). Assuming the auroral heating region extends 10,000 km. around the two auroral zones at any given instant, the total average flux from them is about 2×10^{10} cal. sec.$^{-1}$.

Thirdly, there is probably a contribution from the storm time (*Dst*) variation of the geomagnetic field supposed here to be due to currents flowing in the ionosphere with an average strength of about 10^4 amp. per degree of latitude (cf. Figs. 23. 24 of Chapman and Bartels[2]). Assuming no great change in average conductivity over the whole globe, $Q(Dst)_{\text{av}} \approx Q(Sq)$.

There will be a flux of heat from auroral regions to other parts of the ionosphere. Johnson[1] has shown that convection is far more important than conduction in this process. Heating of the auroral ionosphere will cause distortion of the constant pressure surfaces so that at 200 km. altitude such a surface can change height by as much as 50 km. (refs. 4 and 5). The horizontal gradient of pressure is balanced by the Lorentz force $j \times H$, where H is the (near vertical) geomagnetic field. This Lorentz force was not taken into account in ref. 1. This pressure gradient can have winds of more than 100 msec.$^{-1}$ associated with it[4]. Such winds could convect heat from the auroral zones to distances of 10,000 km. in times of order 10 hr., and could produce all the heat requirements of the lower latitude ionosphere[1]. Any conduction of heat from the auroral zones would proceed most rapidly at the higher ionospheric levels, to come downwards in other regions of the globe.

Now $Q(Ds)$, and $Q(Dst)$, may range over some orders of magnitude. However, this point is uncertain for it is not known whether an increase in j is accompanied by an increase of σ_3 to leave $Q(Ds)$ substantially unaltered. Since magnetic disturbance (δH) is approximately proportional to j, an increase of a factor 10 of δH above average implies a 100-fold increase of σ_3 (that is, 1,000 times a quiet low latitude value) to keep $Q(Ds)$ constant. The implied electron densities are then 10^8 cm.$^{-3}$, that is, a factor of 50–100 larger than can reasonably be expected over large regions. Thus it is reasonable that $Q(Ds)$ increases at least by a factor 10 above average for the very large magnetic disturbance. Moreover, magnetic disturbance is generally more widespread when it is more intense. Hence at these times the flux available to the global atmosphere is greatly enhanced, perhaps by a factor 100 above normal.

A major source of heat for the ionosphere is joule heating by those electric currents flowing in it to cause geomagnetic variations (separated above into *Sq*, *Ds*, *Dst*). It is suggested that heat from this source is normally sufficient to account for the heat flux in the low-latitude ionosphere. At times of very large magnetic disturbance the available heat, due to *in situ* heating and flux from the auroral zones, can be at least a factor 10 above average.

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