A SYNOPTIC VIEW OF IONIC CONSTITUTION ABOVE THE F-LAYER MAXIMUM*

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The UK–US satellite Ariel carried an ion mass spectrometer operating on the principle of analysis of arrival energy of the ions. A very large amount of data has been gathered and it is now possible to obtain a picture of the variation of the ionic composition above 400 km with latitude and longitude.

A strong diurnal effect is evident together with marked geomagnetic control. There is evidence also for a seasonal variation.

INTRODUCTION

The international satellite Ariel I (1962 –) provided an opportunity for a synoptic study of the composition of the topside ionosphere over a prolonged period.[1] Data on ionic constitution was received at stations of the Minitrack network from 26 April, 1962 until 26 September, 1962—a period of 151 days during summer in the northern hemisphere. The relative concentration of oxygen in the topside ionosphere is found to increase with latitude during the day. A marked diurnal variation in composition is also evident. This paper presents some of these data and draws special attention to the evidence for a geomagnetic control of the composition from a set of satellite passes with apogee over the equator and another set with apogee at northern apex.

The apparatus consisted of a gridded probe 10 cm. in diameter. The probe was mounted on the axis of the satellite and being spherically symmetrical was insensitive to the spin of the vehicle.

An ion retarding (positive sawtooth) voltage enabled a Dryvesteyn analysis of the energy distribution of the ions arriving to be obtained, the necessary double differentiation of the current-voltage characteristic being carried out electronically.

The energy of arrival of an ion depends principally on its mass so that the energy spectrum consists of a number of peaks corresponding to ions of mass 16 (oxygen), 4 (helium) or 1 (hydrogen) a.m.u. The integration of these peaks leads to the concentration of each type of ion. Since the first derivative of the current voltage curve which corresponds to this integral of the energy distribution was one of the telemetered quantities, typical raw data of the kind shown in figure 1 was obtained. The sizes of the steps in these

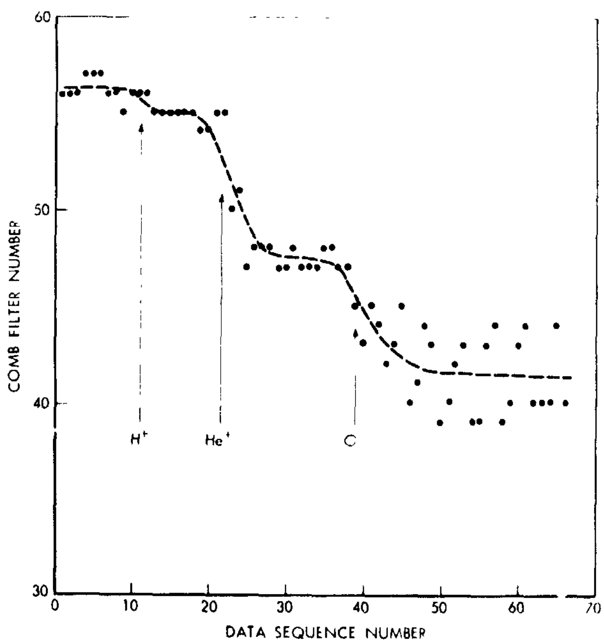

FIGURE 1.—Example of raw telemetered data showing presence of 3 ion types.

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curves lead directly to the concentrations of the various ion species.

THE DAILY VARIATION OF IONIC CONSTITUTION

A number of satellite passes over the equatorial region 10°S. to 10°N. and over the latitude band 35°N. to 45°S. covering a period of 125 days in the northern summer have been analysed, to obtain the diurnal variation in the ion transition altitudes (i.e. where O^+ and He^+ concentrations are equal and where He^+ and H^+ concentrations are equal). Inevitably some seasonal and secular variations are also involved. To reduce the former the altitudes are plotted as a function of solar zenith angle before and after mid-day. In addition, since the basic data gives composition at the actual altitude and local solar time given by the orbital parameters some processing of the data is necessary in order to obtain a single parameter (such as transition altitude) to characterise the state of ionic composition. For this purpose it has been assumed that ion temperature is equal to gas temperature and that the composition at one height may be obtained from that at another height from the hydrostatic equation. The gas temperature function employed was based on the data of Harris and Priester[2] corrected to the mean solar 10 cm. emission for the period covered by the data.

It is certain that this operation introduces some error in scale but it cannot seriously affect the general form of the results.

The diurnal variation of transition altitudes is plotted for the two latitude ranges in figure 2. (The latitude variation will be considered in more detail in the next section). It shows a flat maximum at solar zenith angles corresponding to about 17.00 hours.

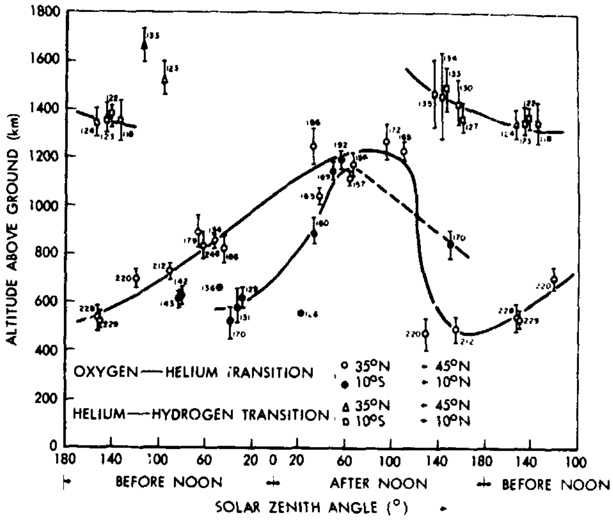

FIGURE 2.—Diurnal variation of transition altitudes.

LATITUDE VARIATION OF IONIC CONSTITUTION

In seeking to establish the variation of composition with latitude it is difficult to eliminate the effects of changing altitude and local solar time. By selecting a short period (four days) during which apogee was nearly over the equator and the descending equatorial passage occurred at about 1500 hours local solar time it is possible to study the region between 45°N. and 45°S. during the period 12.00 to 18.00 hours over which as the previous section shows, the diurnal variation is slowest. At the same time, the altitude range does not change by more than 200 Km. Figure 3 shows contours of percentage oxygen ion concentration betweeen days 189 to 193 in 1962.

There is evidence for a pronounced latitude variation in composition showing higher concentrations of oxygen ions at high latitudes. (The change of composition from 10 percent

$$O^+\left(\frac{[O^+]}{[He^+]}=\frac{1}{9}\right) \text{ to 80 percent } O^+\left(\frac{[O^+]}{[He^+]}=4\right)$$

exceeds the composition change that might be attributed to the 100 Km change in altitude by a factor of 10). The altitude and local solar time are plotted at the side of the figure.

In addition to the evident geomagnetic control of the composition there seems also to be a displacement of the centre of symmetry towards the winter (southern) hemisphere.

LONGITUDE VARIATION OF IONIC CONSTITUTION

A variation of composition with longitude is likely to be due to the asymmetry of the geomagnetic field. This fact is confirmed by the way the contours on figure 3 follow the geomagnetic equator.

Figure 4 shows similar data obtained over the period from day 150 to day 155 in 1962. In this

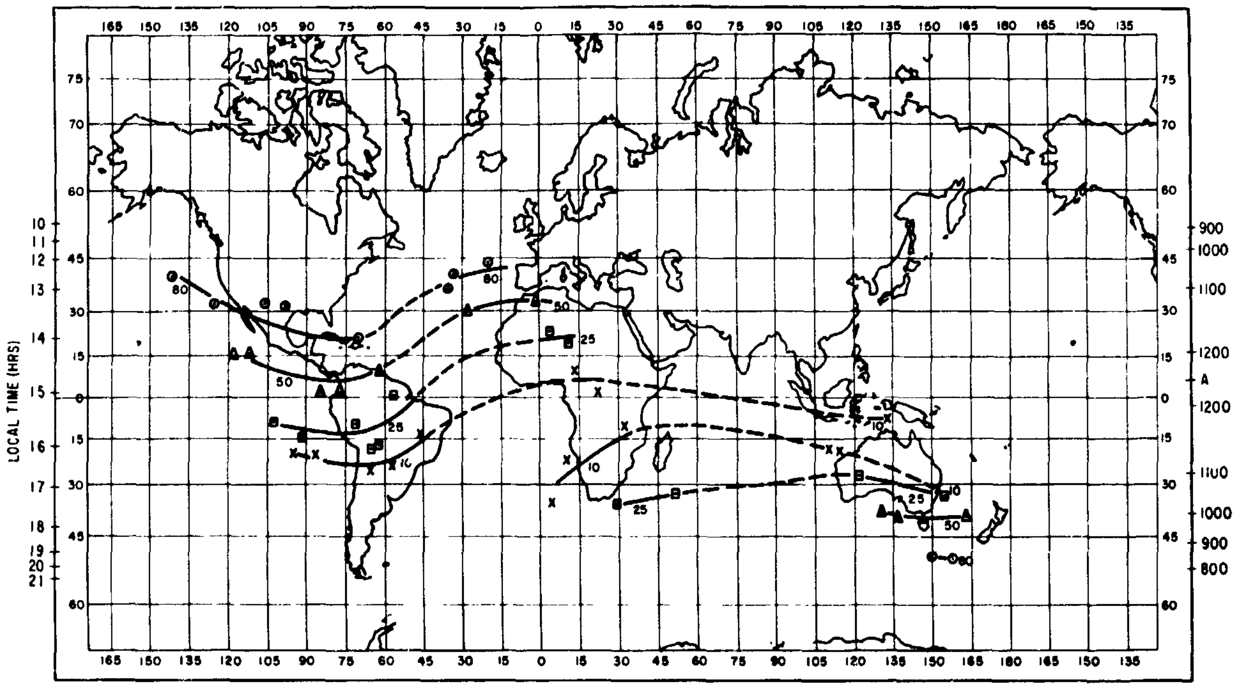

FIGURE 3.—Ion composition contours days 189–193, 1962.

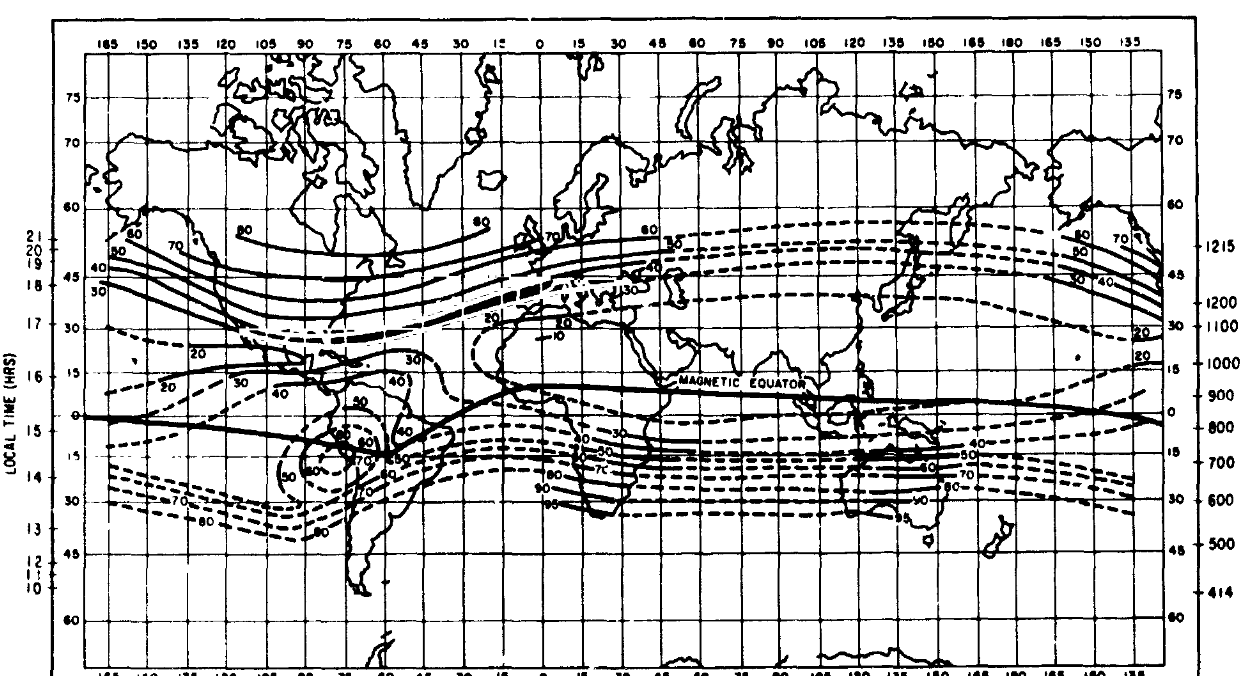

FIGURE 4.—Ion composition contours days 151–155, 1962.

case, the effects of altitude and local solar time on the latitude variation are too great to enable useful conclusions about latitude variation to be drawn. However, variation along any single line of latitude does not suffer from this source of uncertainty and it is again evident that there is a strong geomagnetic control with an extremely complex situation over the South American anomaly. This area of increased oxygen was not detected on the earlier results (days 189–193) possibly because less data was analysed then and also the altitude and local time is this region were such that the percentage oxygen was only of the order of 10 percent which is near the limit of detection of the probe. On the other hand, there may be a real seasonal or secular difference.

It seems likely that many of the features may be attributed to the dependence of ion temperature on electron concentration[3] while near the equator the horizontal magnetic field (and possibly electric fields) probably make the hydrostatic equation inapplicable. It is worth noting that where the ionic composition ratio is determined by the hydrostatic equation it is the ion temperatures, not the electron temperatures that are relevant. Effects of the magnitude of those illustrated could be produced by an ion temperature change of about 20 percent.

REFERENCES

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2. I. Harris and W. Priester. NASA Tech. Note D-1444 (1962).
3. R. L. F. Boyd and W. J. Raitt. Space Research V.