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ATS-5 AND ATS-6 POTENTIALS DURING ECLIPSE

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SUMMARY

ATS-5 and ATS-6 data for spacecraft charging during eclipse conditions is analyzed. ATS-5 and ATS-6 charged to voltages greater than 100 volts for about 55% of the eclipse periods examined. The mean spacecraft potential during eclipse was 2 keV for ATS-5, and the highest potential measured was 10 kilovolts. For ATS-6, the mean potential during eclipse was 4 keV, the highest potential measured being 20 keV. The average measured spacecraft potentials for both ATS-5 and 6 depend approximately linearly upon K_p. This relationship is due mainly to the dependence of electron current density on K_p near midnight. Spacecraft potentials at geosynchronous orbit may, to a rough approximation, thus be inferred from ground-based measurements of K_p, the planetary 3-hour index.

INTRODUCTION

As the ATS-5 and ATS-6 spacecraft have been monitoring the plasma environment at synchronous orbit since 1969, the data provided by these satellites comprises the most extensive data base available of low-energy plasma conditions at geosynchronous orbit.

The present paper is a study of the statistics of charging events based on data from 157 eclipses from ATS-5 and 40 eclipses from ATS-6.

THE DISTRIBUTION OF CHARGING POTENTIALS

For these eclipse charging events, ten minute averages of the charging potentials were obtained. Figure 1 shows the distribution of charging potentials plotted separately for ATS-5 and ATS-6.

For ATS-5, 55% exhibit charging to negative potentials greater than 110 volts and 54% of the ATS-6 charging intervals are greater than 100 volts. This means that both ATS-5 and ATS-6 charge to substantial negative voltages in more than half of the eclipse intervals. The mean charging voltage of ATS-5 is 2 kilovolts for ATS-5 and 4 kilovolts for ATS-6. The highest observed potential is 10 kilovolts for ATS-5 and 20 kilovolts for ATS-6.

Figure 2 shows the distribution of K_p and the 3-hour planetary index

for the ATS-5 and ATS-6 data time periods. ATS-6 data was taken during a more active geomagnetic period than ATS-5, so that the mean value of K_p for the ATS-6 time period is considerably higher than that for the ATS-5 time period. The higher mean charging potential for ATS-6 is no doubt due to hotter injected plasmas for the ATS-6 time period.

CHARGING POTENTIALS VERSUS K_p

Eclipse potentials versus K_p are shown in Figure 3 for eclipse events on ATS-5 and ATS-6 for K_p values up to 6. The error bars shown are the standard deviations ($\pm 1\ \sigma$) of the data. The spacecraft potential rises linearly with K_p within the error.

Shown on this figure as well is a theoretical curve based on a current balance calculation in which secondary emission properties of ATS-5 and 6 materials have been accounted for in an approximate manner, using an average secondary emission coefficient. This theoretical curve is given by

$$qV_o = T_e \ln \left(\frac{J_e}{10\ J_i} \right)$$

where the factor 10 takes account of secondary emission properties (Garrett and Rubin, 1978).

R.M.S. electron temperature as a function of K_p is shown in Figure 4 for the time period 2100-300. The electron mean temperature varies from 2 to 4 keV. The variation of the ratio of electron to ion current densities with K_p is much greater, as shown in Figure 5. The theoretical prediction of spacecraft potential, as the product of T_e and $\ln (J_e/10\ J_i)$, shows that it is the dependence of the ratio of electron to ion current densities on the magnetic activity index, K_p, which is responsible for the strong dependence of charging potential on K_p. The mean R.M.S. electron temperature at a given K_p for the 2100-0300 time period, for the entire ATS-5 and ATS-6 data base, was employed for this calculation. The theoretical curve corresponds very well to observed potentials for K_p values up to 4, but is somewhat higher at larger K_p values.

The spacecraft potential is shown to be proportional to K_p for the 6-hour period around midnight. K_p is an easily accessible quantity, having long been used as an indicator of geomagnetic activity. Since K_p is calculated from ground-based magnetometer systems, it will be useful, to the accuracy of the error bars, as an indicator of the maximum potentials to be expected on a shadowed spacecraft surface at geosynchronous orbit. As ATS-5 and ATS-6 have radically different shapes, this result could be applicable for a variety of satellites (see Purvis et al., 1977, for a comparison between ATS-5 and ATS-6 potentials in eclipse).

REFERENCES

1. Garrett, H.B. and A.G. Rubin (1978): Spacecraft Charging at Geosynchronous Orbit-Generalized Solution for Eclipse Passage, Geophysical Res. Lett. (to be published).

2. Purvis, C.K., R.O. Bartlett, and S.E. DeForest: Active Control of Spacecraft Charging on ATS-5 and ATS-6, Proceedings of the Spacecraft Charging Technology Conference, edited by C.P. Pike and R.H. Lovell, AFGL-TR-770051/NASA TM 7350, p. 107-120 (1977).

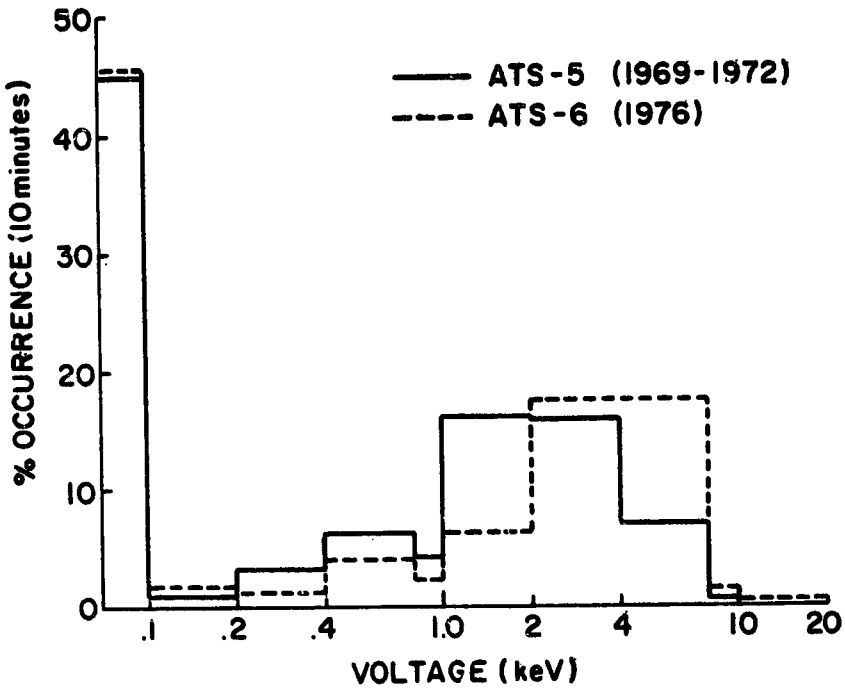

Figure 1. - Occurrence frequency of charging potentials on ATS-5 and ATS-6.

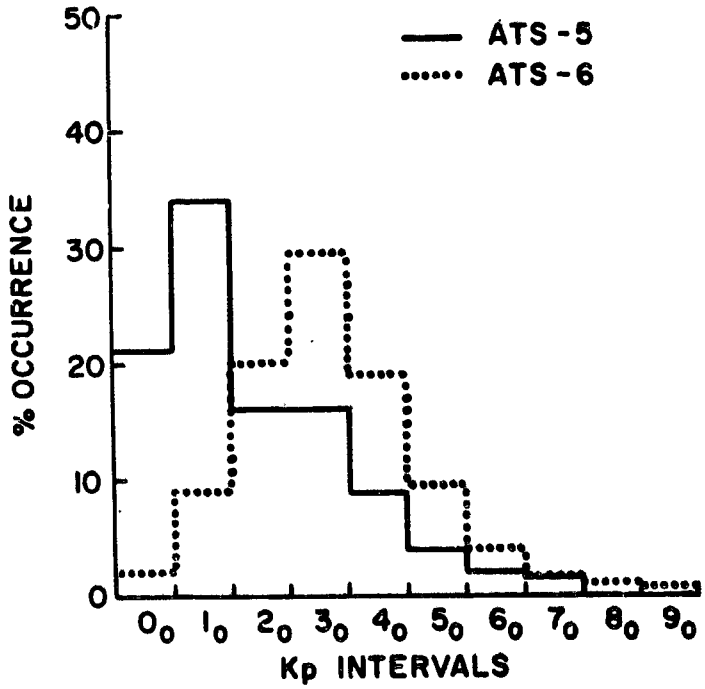

Figure 2. - Occurrence frequency of K_p for ATS-5 and ATS-6 time periods.

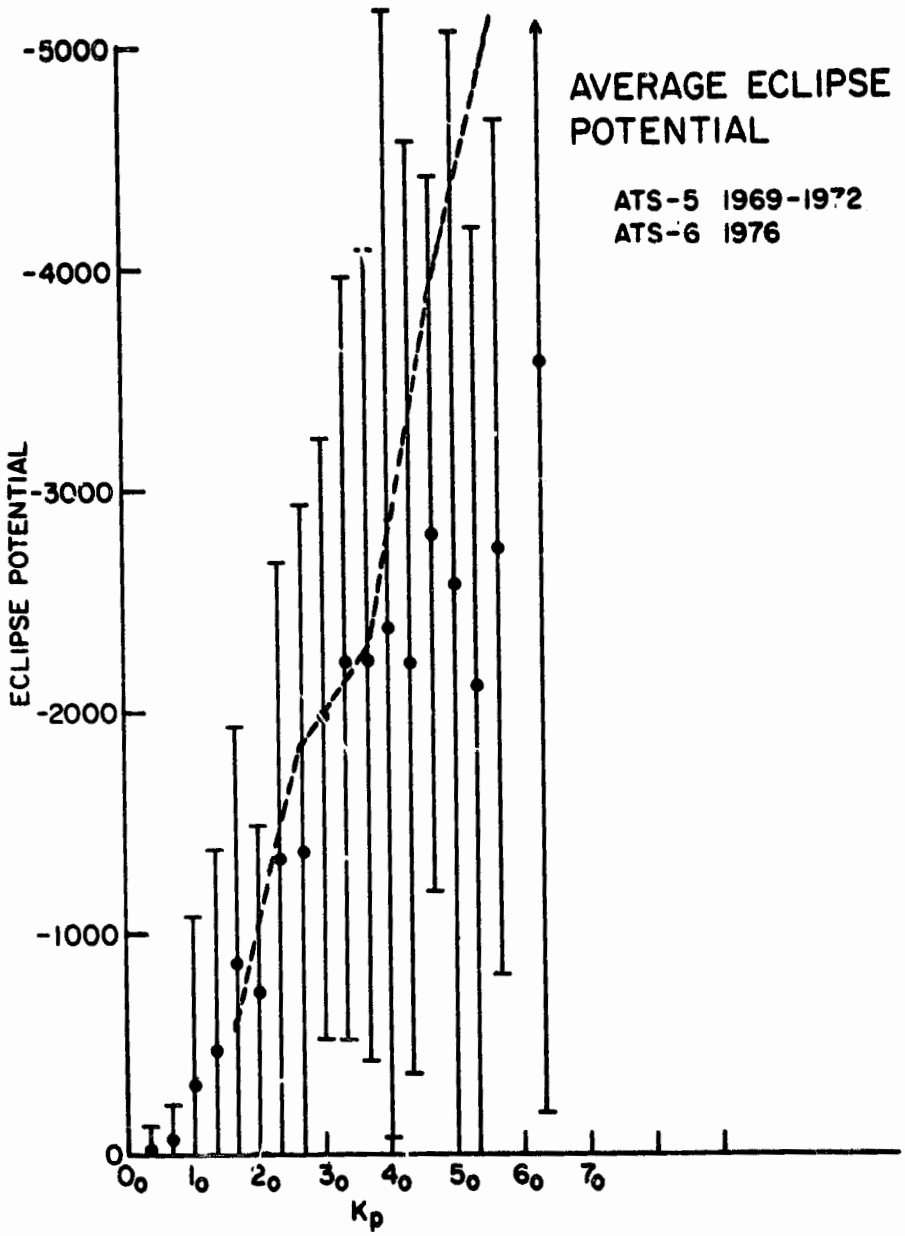

Figure 3. - Average eclipse potentials of ATS-5 and ATS-6 as function of K_p.

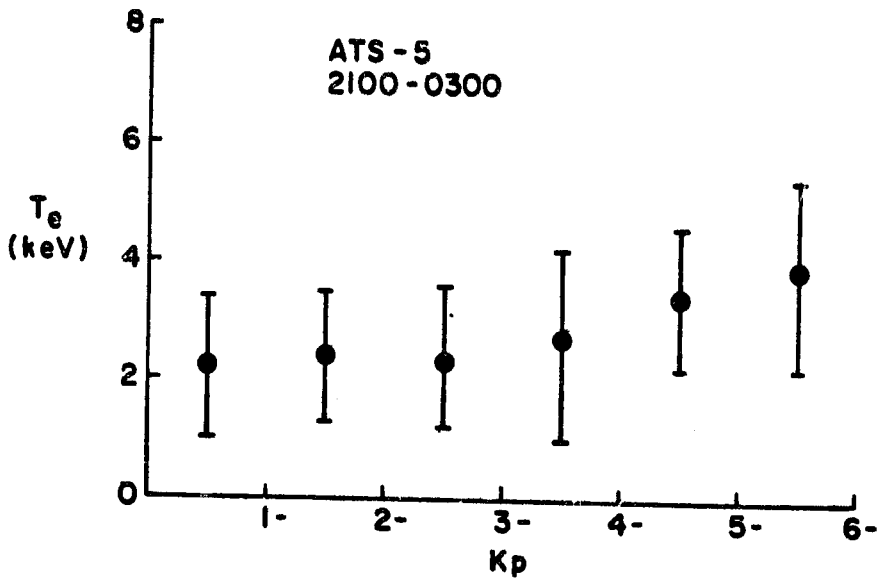

Figure 4. - Mean R. M. S. electron temperature as function of K_p for eclipses.

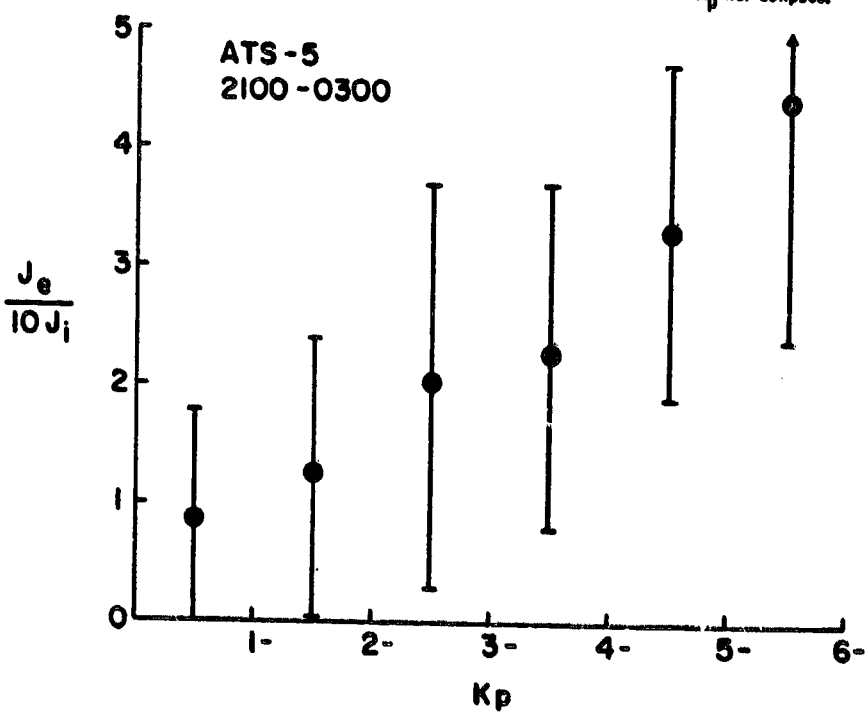

Figure 5. - Ratio of average electron to ion current densities as function of K_p for eclipses.