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Final Report for OGO-6

Experiment F-03

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Introduction

OGO-6 was retired in June, 1971, principally because of system electronic problems that made data acquisition sporadic and unpredictable. The Retarding Potential Analyzer (RPA) of U.T. Dallas, designated experiment F03, was still working perfectly at retirement, two years after launch. A large body of data has been acquired and analyzed.

The retarding potential analyzer on OGO-6 turned out to be a remarkably successful experiment. To date, 13 papers utilizing data from this device have been published or accepted for publication (excluding abstracts for papers presented at meetings). Many of these papers relate to new phenomena that were discovered in the data from this instrument.

These excellent and unique data deserve to be fully reduced and analyzed. This process is about 75% complete and will be finished by the end of 1973. Summaries of the data, plotted orbit by orbit on microfilm, are now being made available to interested OGO-6 experimenters, and some other aeronomers, as they become available. Several cooperative efforts involving data from several OGO-6 instruments are now being planned and will be implemented in the reasonably near future.

It is expected that the entire set of RPA data in all forms that it exists after processing will be placed in the World Data Center within a year from this report date.

RPA Science Contributions

A first look at OGO-6 RPA output shows that the quality of the data is very good. The instrument appears capable of measuring ion temperature to an accuracy of better than five percent in a quiet ionosphere. Fluxes of electrons with energy greater than 10 ev of 10^6 cm^{-2} sec^{-1} $ster^{-1}$ can be detected, and this capability permits the observation of both photoelectrons and soft auroral electrons. During the daytime fluxes of the order of 10^8 cm^{-2} sec^{-1} are observed that change rather smoothly within the plasmasphere but show rapid and large variations at higher latitudes. The device also operates in a mode that examines the horizontal changes in ion concentration (fractional changes as small as 10^{-3} can be observed) with a spatial resolution from 350 meters to as small as 40 meters, depending on the telemetry rate.

In the dawn-dusk plane the ion temperature is observed to vary from 1000°K to 4000°K; the higher temperatures being associated with higher altitudes in the winter hemisphere. Molecular ion (∿30 AMU) concentrations from 25 cm^{-3} to 2500 cm^{-3} are detected near perigee. These ions constitute only a small fraction, from 2% to less than 0.1% of the oxygen ion concentration. Fractional abundance of H^+ and He^+ as low as a few percent of the O^+ concentration can be readily detected, but the determination of the ratio of the concentrations of these ions (H^+/He^+) becomes reliable only when the light ion fraction exceeds approximately 25% (see Sanatani and Hanson, 1969; Hanson et al., 1970). At mid-latitudes and higher altitudes (>700 km) the lighter ions, H^+ and He^+ are both present at approximately the O^+ concentration but their relative importance decreases near and in the polar regions, presumably due to polar winds. Both polar regions display large spatial fluctuations in ion concentration and this behavior extends somewhat into the plasmasphere.

Two papers and a report based on the OGO-6 RPA results were presented at the 1971 spring meeting of AGU-URSI. The first of these dealt with the latitudinal variations of ion temperature on nighttime equatorial passes of OGO-6 during the month of November 1969 (see Sanatani, Hanson, and McClure, 1971).

The second paper dealt with heating in the nighttime ionosphere by conjugate photoelectrons. It utilized the data from both the RPA and the Langmuir probe aboard the OGO-6 satellite (see Sanatani, Hanson, and Nagy, 1971).

The report was presented at the special OGO Session in the 1971 Spring Meeting of the American Geophysical Union. It provided a more general view of the observed thermal behavior of the ionosphere over a wide latitude range, including seasonal and solar activity effects. Special emphasis was given to the equatorial upper F region.

Another paper dealt with the longitudinal variation in equatorial ion temperature at low altitude (400 to 600 km). It is found that the mean equatorial ion-temperature has a maximum over the longitudinal range +10° to -70°. It is found that the longitudinal variation disappears on disturbed days (Sanatani and Hanson, 1971).

The solar array problems that arose two weeks after launch and caused the vehicle to assume a high (> -20 volt) negative potential when sunlit abated somewhat from late October, 1969, to the middle of February, 1970. During this period the vehicle potential when sunlit was only -13 to -14 volts, and we are able to analyze the data for ion temperature. Perhaps surprisingly, this T_i data joins smoothly onto the satellite eclipsed T_i data, in whose validity we have high confidence.

The T_i data comparisons with the radar backscatter stations has been completed (McClure et al., 1973) and the results are extremely encouraging. The temperature comparisons always agreed within the error bars and usually within a few percent.

Heavy ions were discovered in the upper F region on the basis of the RPA data; they were identified as Fe^+ ions by Hanson and Sanatani (1970). A much larger body of data has since been examined which consistently supports the Fe^+ hypothesis both experimentally and theoretically (Hanson et al., 1972).

The very striking relationship between ionospheric irregularities and Fe^+ ions near the equator discovered in this OGO-6 ion trap data led to the suggestion that the two phenomena are causally related (Hanson and Sanatani, 1971). The nature of this causal relationship has since been described by Hanson et al., 1973.

On some occasions, but always near the magnetic equator, the ion temperature measured along the orbit shows deep depressions above 600 km. The measured temperature goes well below the expected neutral gas temperature. These temperature depressions have been explained in terms of expansion cooling brought about by the flow of plasma from the summer to the winter hemisphere (Hanson, Nagy, and Moffett, 1973; Bailey, Moffett, Hanson, and Sanatani, 1973).

The OGO-6 RPA showed that on some occasions the bottomside of the F layer was drastically depleted of ion content at the magnetic equator, with N_i decreasing by 3 orders of magnitude in only a few vertical kilometers. This behavior was attributed to transport resulting from turbulent electrostatic fields (Hanson and Sanatani, 1973).

The OGO-6 RPA, in conjunction with other OGO-6 instruments, observed the behavior of the ionosphere while passing through several midlatitude red arcs (SAR arcs). The data show unambiguously that the arc energy is derived from thermal conduction from the magnetosphere, not from any local excitation mechanism. This interpretation is consistent with recent suggestions that the energy is ultimately derived from energetic protons just inside the plasmasphere where ion cyclotron wave interactions heat electrons at the expense of the energetic protons. This work has been published (Nagy et al., 1972).

Anticorrelations in molecular ion and oxygen ion concentrations are frequently observed in the OGO-6 RPA data. Since the molecular ions were thought to be formed by charge exchange with O^+, and removed by recombination with electrons, one would expect no such anticorrelations since the O^+ and electron concentrations are essentially equal in the topside F layer. The explanation of this paradox seems to require that the source of the molecular ions be independent of the O^+ concentration. In a recent publication (Rishbeth, Bauer and Hanson, 1972) we have suggested that N^+ could provide this mysterious source of molecular ions, even though a minor ($\sim$ 10%) ion constituent, since it reacts much more rapidly with O_2 and N_2 than does O^+.

The "duct detector" data from the RPA has revealed a spectacular view of the small scale (as well as small amplitude) irregularities in the F region. The general nature of these irregularities, and they have many different characteristic forms, has been described by McClure and Hanson (1973), together with their geographic occurrence. The most common irregularities are stochastic, and the power distribution with frequency, $f = (V_{sat}/\lambda)$, varies as $(1/f)^2$, quite independent of the amplitude of the irregularities in a given disturbed region. A detailed examination of these stochastic properties is given by Dyson, et al. (1973), as a guideline for theorists who are attempting to explain the origin of the irregularities.

Conclusions

This experiment has received very good financial and logistic support from both the OGO-6 project personnel and from NASA headquarters. While I believe the science output has justified this treatment I am nevertheless grateful for it. I anticipate that several papers per year will be generated from the RPA data bank for at least the next five years.

Publications and Papers Presented on OGO-6 Retarding Potential Analyzer Data

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