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Final Report

# Measurement of the Worldwide Ionospheric Electric Field on Balloons

Contract No.: NAS 9-9502

Principal Investigator: F. S. Mozer





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for

# Measurement of the Worldwide Ionospheric Electric Field on Balloons

(12 May 1969 to 30 November 1970)

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for

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12 November 1970

The purpose of Contract NAS 9-9502 was to provide support for fabrication and flight of 24 balloon payloads to measure ionospheric and atmospheric electric fields from six sites in Canada, and to analyze the data thereby obtained. The 24 balloons were flown in groups of six on August 2, 3, 8 and 9, 1969. A summary of the number of hours of usable data obtained from each flight is given in Table 1. Ninety-two percent of the launches obtained useful data and the total of 371 hours of data collected represented more than 70% of the amount of data that would have been collected if all flights had been perfect.

The launch from Fort McMurray that produced no data did so because of a telemetry transmitter malfunction shortly after launch. This was the only payload failure in the entire program. The only launch incident in the entire program occurred during the fourth launch from Cambridge Bay when the transmitting antenna on the balloon payload scraped the ground and broke at lift-off.

There were five short duration (three or four hours) flights that were terminated by cutdown timer operation prior to the nominal 24-hour flight time. The reason for these short flights was that the balloons malfunctioned (probably leaked) and the payloads sank below 60,000 feet altitude, at which point they were automatically cut down in accordance with safety regulations.

Following the successful collection of nearly 400 hours of electric field data the program effort was directed toward computer programming for automatic data reduction and plotting. The data reduction phase was completed in March, 1970 and the effort since

that time has involved analysis and publication of the results.

An initial interest in the data concerned the question of whether electric fields of ionospheric origin can be separated from fields of atmospheric or weather origin. The conclusion from this study, reported at the IUGG meeting in Madrid in 1969 and being published in Pure and Applied Geophysics, is that fields of ionospheric origin can generally be separated from those of atmospheric origin and that magnetospheric electric fields can therefore be measured on balloons.

Analyses of certain averages of the electric field data obtained from these flights has been completed and are presently in publication in the Journal of Geophysical Research. The long-term averages of this data indicate that magnetospheric electric fields and bulk plasma flow are turbulent with a scale size less than about 100 kilometers in the ionosphere, that the average equatorial electric field strength increases with increasing Kp and is independent of altitude to within about a factor of two from L = 4 to L = 23, and that its direction varies with a typical diurnal pattern. Short term averages of these data show that this diurnal pattern is associated with magnetic bays in that the east-west component of the ionospheric electric field becomes westward about an hour before a bay and remains so throughout the night while the meridional component switches from poleward to equatorward at the onset of the bay near local midnight. A previous model of the magnetospheric electric field variation during a bay is reinforced and extended by the present observations. In this model, bays are triggered deep within the magnetosphere in the equatorial plane by an instability associated

with a radial plasma density gradient. This gradient is established by the convective flow stemming from a westward electric field that exists for about an hour before the onset of the bay. The equatorward component of the ionospheric electric field that develops at the onset of the bay drives Hall currents which are largely responsible for the ground observed magnetic variations. The electric fields implied by this model are in agreement with balloon observations in the auroral zone on a total of 17 nights, during 10 of which negative bays occurred.

The data obtained in the balloon flight program have also been used to study auroral motions and their causes. The electric field measurements have been compared with simultaneous all-sky camera pictures of north-south motions of auroral forms for the purpose of interpreting the large scale motions, real or apparent, of visible auroras. During magnetically quiet times, the drift of auroral forms is largely due to a magnetospheric $\overline{E} \times \overline{B}/B^2$ drift of the "source" of auroral primaries. During the breakup phase of a magnetospheric substorm, however, the explosive poleward expansion is probably not a mass motion due to an electric field drift but may be an apparent motion due to an instability propagating in the magnetospheric plasma.

Several additional analyses have been undertaken but not completed prior to the termination of the contract. They are summarized below:

1. Electric field fluctuations. The power spectra of fluctuations having periods between one second and one day

are being analyzed to determine their local time, latitude and magnetic activity dependencies. These fluctuations contain sufficient power to explain the radial diffusion of radiation belt particles.

2. Large scale magnetospheric electric field patterns. The nearly 400 hours of data are being statistically analyzed in order to obtain typical diurnal patterns of the large scale magnetospheric electric fields.

3. Longitudinal extent of substorm related electric fields. Data from a worldwide network of ground magnetometer stations has been assembled and is being correlated with the electric field data to determine the longitudinal extent and signature of substorm electric fields.

4. Correlation with precipitating particles. About 100 hours of coordinated x-ray and electric field data have been obtained in the auroral zone and the relationships between electric fields and precipitating particles are being studied. It appears that precipitation is preceeded by a westward electric field.

5. Correlation with trapped particles. About 100 hours of electric field data have been obtained near the foot of the magnetic field line on which the ATS-5 satellite moves in synchronous orbit. These data are presently being compared with proton and electron fluxes measured by the principal investigator on the ATS satellite.

6. Long period wave studies. The balloon data is being correlated with simultaneous ground magnetometer data in the study of PC2 through PC5 types of waves, their propagation, origin, etc.

7. Atmospheric electricity. The balloon measurements represent a significant advance in studies of atmospheric electricity such as vertical field diurnal and latitude variations, horizontal fields above electrified clouds, the global atmospheric electric field, etc. Analysis of the data from these points of view are proceeding.

With the termination of the contract it is unclear which, if any, of the above analyses will be brought to successful completion.

Table 1

Hours of Data Collected from Each Balloon Launch

| Site | Flight 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| Cambridge Bay | 24 | 15 | 3 | 0 | 42 |
| Yellowknife | 24 | 24 | 18 | 3 | 69 |
| Uranium City | 21 | 20 | 24 | 22 | 87 |
| Fort McMurray | 0 | 19 | 3 | 4 | 26 |
| Penhold | 3 | 20 | 15 | 24 | 62 |
| Fort Churchill | 20 | 22 | 24 | 19 | 85 |
| Total | 92 | 120 | 87 | 72 | 371 |

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