N73 18367
N73 18367

GEOPHYSICAL INSTITUTE

OF THE

UNIVERSITY OF ALASKA

ANALYSIS OF PHOTOMETRIC DATA OBTAINED ON THE 1969 NASA AIRBORNE AURORAL EXPEDITION

Final Report

Grant NGR-02-001-082

May 1, 1971 - December 31, 1972

Prepared For

National Aeronautics and Space Administration

CASE FILE COPY

G. J. Romick
Principal Investigator

Approved by:

Keith B. Mather
Director
Geophysical Institute

ABSTRACT

The analysis of the 1969 airborne expedition data obtained by the Geophysical Institute has centered around two main topics: dayside auroral characteristics and hydroxyl airglow variations. Many of the data from the expedition have still to be analyzed and are under study; however, some of the conclusions from the present analysis are noteworthy, i.e.,

a) The midday sector of the auroral oval is bound on the equatorward side by a region of $\geq$ 3 kev electrons. This boundary coincides with the > 40 kev trapping boundary which presumably defines the region of last closed field lines on the dayside but only that of the last dipole-like field line on the nightside.

b) The dayside oval is associated with the cusp region in the magnetosphere which has particle energies usually $\leq$ 1 kev and λ 6300 [OI]/λ 4278 N_2^+ ratios > 10.

c) Discrete earth-sun aligned auroras appear in the polar cap just poleward of the oval superimposed on a < 1 kev particle energy background.

d) The discrete earth-sun aligned auroras seen in the open field line region on the dayside have a similar appearance to some rayed auroras seen on the nightside both in terms of characteristic particle energy spectra as well as visual appearance.

e) Airglow OH measurements show no appreciable change with latitude or longitude but do show diurnal changes. Two types of enhancements are observed: one associated with visible aurora, and the other uncorrelated with visible aurora. The explanations for both of these observations are still under study.

The usefulness of these results in understanding the aurora and magnetospheric coupling helps support the overall concept of the airborne expeditions and point towards areas for consideration in the future analyses of the existing data.

INTRODUCTION

The Geophysical Institute of the University of Alaska operated a multi-filter scanning photometer on board the 1969 NASA auroral airborne expedition. The details of the operation and some analyses have been reported in the final reports under grants NGR-02-001-048, NGR-02-001-058 and NGR-02-001-060. The operation of the instrument was directed towards the acquisition of auroral and airglow data. The analysis of these data has been the subject of this grant and has centered on two particular topics. Observations of midday aurora are of special interest due to the paucity of information available regarding their special characteristics and relative emission height variation and general height range. Similarily, the geographical distribution and dynamical behavior of the hydroxyl airglow emissions are poorly known and can be expanded upon by using the data from many of the expedition flights. The results of these studies have been reported in the literature (Romick and Brown, 1971) and in the M.S. thesis by R. Henderson (1972). Consequently, only a brief review of these results will be presented here. The possibilities and important studies for the continuation of the analysis of the 1969 airborne data will also be discussed.

DISCUSSION OF THE ANALYSES

Auroral Studies

The main emphasis in the analyses of the auroral data has been concerned with the two flights (#13 and #14) which covered the noon sector of the auroral oval. Two interesting features which were observed on these flights were (1) the high λ 6300 [OI] to λ 4278 N_2^+ ratios which indicate the presence of very soft incident particles and (2) the occurrence of discrete stable auroral arcs which are aligned almost in the direction of the sun (Romick and Brown, 1971; Romick, 1970a, b). Of specific concern here is the importance and usefulness of the latitude variation of the λ 6300 [OI] to λ 4278 N_2^+ ratio as an indicator of the different boundaries which exist in the magnetosphere. On the dayside, these data are interpreted as showing a relatively hard ($\geq$ 3 kev) uniform particle flux precitating equatorward of and into the position of the statistical auroral oval, producing a relatively uniform glow or weak broad arcs. On the poleward side a soft particle flux ($\leq$ 1 kev) appears, which increases in total energy flux as one proceeds at least partially towards the polar cap. In addition, discrete auroral forms which appear to have typical characteristic energies (2 kev) appear within the more uniform soft particle precipitation. This description matches very well the particle data obtained in the same region by Hoffman and Berko (1970) and Heikkila and Winningham (1971) and recent satellite data of Sharp and Johnson (1972). Winningham (1970) and Heikkila and Winningham (1971) have discussed the penetration of the magnetosheath plasma to low altitudes during the daytime from data from the ISIS-1 satellite. The region where the λ 6300 emission begins to become enhanced coincides with the latitude limit of closed

geomagnetic field lines in the dayside magnetosphere. As stated by Winningham (1970), "this boundary can be identified through a sharp decrease in the flux of electrons of somewhat higher energy $\sim$ 10 kev". He further goes on to show that, above this latitude, fluxes of low energy (< 1 kev) electrons are observed. His description fits our observations and the present concept that this is the trapping boundary for > 40 kev electrons discussed in the literature in general. Thus the polar cap discrete arcs which were observed on these flights must originate from field lines well above the limit of the last closed field lines and come directly from the tail region of the magnetosphere.

In the analysis of conjugate nighttime auroral data, Belon et al. (1969) found that detailed conjugacy depends upon the latitude of the aurora and the level of geomagnetic activity. It is suggested in these analyses that in auroral arcs poleward of major activity there appears to be poor conjugacy possibly as low as dp latitudes near 69°.

Whether this lower variable latitude is the latitude of the limit of closed field lines or last dipole-like field lines on the nightside is still uncertain, but regardless, it too may be characterized by a change in the characteristics of particle flux which may be determined by the change in the background λ 6300/λ 4278 ratio similar to that observed on the dayside. Indeed, the statistical results of Eather (1969) from results of the 1968 NASA Airborne Expedition indicate a rapid change near 72° invariant latitude (approximate latitude 73°) for the λ 6300/λ 4278 ratio which implies that averaged over the 22 flights the latitude limit of this steep gradient is near 72°. This latitude may shift with activity since Eather's plot was obtained only when all data were combined. Thus it represents an average latitude for the average of the activity which occurred over these flights. Sharp and Johnson (1970), from satellite data, show

a displacement of the peaks in the hard and soft zones on the dayside; although the separation was not pronounced on the nightside, they seemed to be able to detect a softening of the electron spectrum towards the pole. It appears that the boundary between these hard and soft zones is the region of the last closed field lines on the dayside. The region of sharp change in λ 6300/λ 4278 does change in latitude as observed by Eather and Mende (1971) using statistical results of the 1969 NASA Airborne Expedition. Here, the region on the nightside moved poleward from that indicated in the 1968 data. This movement fits with the change in average activity between the two expeditions. In addition, the access of the solar wind particles into the dayside is easier than on the nightside (causing a hardening of the nighttime spectra due to gradient drift), thus explaining the larger observed λ 6300 OI enhancement on the dayside than on the nightside, the softer flux in the dayside soft region compared to the nighttime soft region and the difficulty in separating the two zones on the nightside. This concept may also, at least in part, explain the poleward limit of pulsating auroral displays.

Perhaps, although somewhat premature at this stage in the analysis, the fact that the discrete arcs observed in the dayside have the same appearance and precipitating energy spectra as other similar arcs seen on the nightside implies that they all have the same acceleration mechanism regardless of the origin of the particles, i.e., the acceleration of the particles is carried out close to the earth rather than in the tail region. Thus one expects similar aurora even on the nightside both above and below the limiting closed field lines, but only those below need be close to conjugate in the Southern Hemisphere. Obviously,

further work needs to be done to substantiate these ideas, but if they are true, the λ 6300/λ 4278 ratio and other characteristics of the auroral emission spectrum as a function of latitude may allow the determination of the position of the boundary between the open, extended, and closed field lines at any time and at any degree of activity. These ideas are basic to the context of the future studies of the airborne data.

Airglow Data

The analysis of the airglow data has been primarily concerned with the intensities and the latitude and longitude variations of the hydroxyl emissions observed on many of the flights. A preliminary description of these data were given by Brown (1970). The complete discussion is presented in the Master's degree thesis of R. Henderson (1972).

The most salient points can be discussed in terms of the anticipated dynamics.

Latitude Variations

The plot of average intensities as a function of geographic latitude appeared at first to show a slight latitude change. The average times for the observations at the various latitudes were 0500 LT, 0041 LT and 1845 LT for 48.6°N, 58.5°N and 71.6°N, respectively. The diurnal investigations of Bertheir (1955) at low latitudes and the current investigation at high latitudes suggest that the same type of temporal behavior occurs in both regions. Since the average latitudinal intensity values covered a rather large diurnal period, the average diurnal variations were compared with the observed deviations in latitude. The observed latitudinal changes

easily fit into the intensity ranges found for the diurnal variation. Therefore, the existence of a significant latitude effect is doubted for the range of latitude from 48.6°N to 71.6°N during December.

Longitude Variations

Almost no prior data are available on longitudinal variations. However, we have two flights of interest, #11 and #15. A portion of Flight #11 is entirely within the polar cap region within a latitudinal range of 0.58°. Despite the 33° change in longitude, the average OH and O_2 levels remained uniform. Again, on Flight #15 no particular pattern was established over an 18° change in longitude.

Diurnal Variations

The diurnal variations that were observed fell into four types. They were: (1) a minimum at or before local midnight, (2) a maximum during the night, (3) constant from local midnight to about 0400 LT, followed by a sharp decrease and (4) constant through the night. Types (1) and (2) were observed most often with each being seen as often as the other. Type (3) was observed once as was type (4). These are consistent with those data reported in the literature. The results of 103 observations made throughout the year by Bertheir (1955) also showed type (1) (minimum near midnight) as the predominant type. Bertheir, observing at a latitude of 44°N, observed some of the same types of diurnal changes as we find at high latitudes. Therefore, since there seems to be no general latitude effect on the intensity of either OH or O_2 in December, the data indicate that OH and O_2 both at high and at low latitudes during this month are very similar both in form and intensity.

OH-Enhancements

Two different types of enhancements were observed in the course of

the current investigation. The first type occurs at or near the time of an intense aurora and is characterized by a quick rise and fall of intensity with the corresponding auroral changes. The second is a general increase in OH intensity over a three- or four-hour interval. During this interval there were no intense auroras at the zenith, and the general intensity level of the auroral background remained unchanged. The exact cause of these enhancements is still under investigation and will be considered in the future studies of these data.

FUTURE STUDIES

One of the fundamental purposes of the 1968 and 1969 airborne expeditions was the gathering of numerous groups and their sophisticated instruments together to study aurora and airglow problems.

Methodical compilation and reduction of all of these data for specific problems is presently being considered under NASA Grant NGR-03-001-099. Some of the primary interests in these studies are as follows:

1) Spectral characteristics and absolute intensities of auroral optical emissions in various auroral regions which can be used to define the particular regions of the magnetosphere.

2) Intensity ratios of different auroral emissions and the energy distribution of precipitating auroral particles implied by some of these ratios and in turn the relation of these energies to the source regions in the magnetosphere.

3) Comparison of the auroral luminosity measurements with satellite particle and optical data with regards to overall fluorescent efficiencies and energy balance.

4) Confirmation of the results discussed on the OH intensity

variations with latitude, longitude and local time.

Obviously close association of the investigators who participated in the two airborne expeditions will be necessary. Such a combination of all experimenters' measurements should yield unique and valuable scientific data on aurora and airglow phenomena since, for the first time, absolute intensities of the auroral emissions covering the spectral range from the UV to the IR were made with simultaneous photographic observations in different phases of the auroral substorm.

REFERENCES

Belon, A. E., J. E. Maggs, T. N. Davis, K. B. Mather, N. W. Glass and G. F. Hughes, Conjugacy of visual auroras during magnetically quiet periods, J. Geophys. Res., 74, 1-28, 1969.

Bertheir, P., Variations d'intensite post-crepusculaires et nocturne des bandes de OH et O_2 du proche inforarauge, Compt. Rend., 240, 1919-1921, 1955.

Brown, N. B., High latitude airborne observations of some airglow and auroral emission features, Trans. ACT, AGU 51, 370, April 1970.

Eather, R. H., Latitudinal distribution of auroral and airglow emissions: The soft auroral zone, J. Geophys. Res., 74, 153-158, 1969.

Eather, R. H. and S. B. Mende, Airborne observations of auroral precipitation patterns, J. Geophys. Res., 76, 1746-1755, 1971.

Heikkila, W. J. and J. D. Winningham, Penetration of magnetosheath plasma to low altitudes through the dayside magnetospheric cusps, J. Geophys. Res., 76, 883-891, 1971.

Henderson, R. B., High latitude airglow, Masters Degree Thesis, University of Alaska, College, Alaska, Fall 1972.

Hoffman, R. A. and F. W. Berko, Primary electron influx to the dayside aurora oval, NASA Goddard Space Flight Center, Rept. X-646-70-351, Sept. 1970.

Romick, G. J., Photometric measurements across the noon sector of the auroral oval, Trans. ACT, AGU 51, No. 3, 1970a.

Romick, G. J., Photometric and photographic analyses of polar cap rayed aurora, Trans. ACT, AGU 51, No. 11, 1970b.

Romick, G. J. and N. B. Brown, Midday auroral observations in the oval, cusp region and polar cap, J. Geophys. Res., 76, 8420-8423, 1971.

Sharp, R. D. and R. G. Johnson, Low-energy auroral particle measurements from polar satellites, Adv. Study Institute on Aurora and Airglow, Queens University, Kingston, Ontario, Canada, 12 Aug. 1970.

Sharp, R. D. and R. G. Johnson, Private communication, 1972.

Winningham, J. D., Penetration of magnetosheath plasma to low altitudes through the dayside magnetospheric cusps, Dissertation, Texas A & M University, December 1970.