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PRELIMINARY RESULTS FROM THE AURORAL ZONE IONOSPHERE OBSERVATIONS DURING THE AZCO BALLOON CAMPAIGN IN 1985

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Abstract: In July 1985 a joint Japanese-Danish-Norwegian balloon campaign for auroral zone conjugate observations (AZCO) was carried out. The campaign was complementing measurements at Japanese geophysical stations in Iceland and in Antarctica. The instrumentation on the ground included magnetometers, riometers, and VLF detectors in both conjugate areas and also back-scatter radar and auroral monitors in the South. The balloons were equipped with detectors for X rays, electric fields, and VLF electromagnetic emissions. This report is preliminary as the data have not been reduced thoroughly yet. Information has been obtained about particle injection during substorms and the connection between ionospheric electric and magnetic fields.

1. Introduction

The auroral zone is a region of special interest for ground based research of the ionosphere and the magnetosphere. Magnetic field lines originating in the remote magnetosphere in close contact with the interplanetary space as well as field lines connecting to the conjugate areas in the opposite hemisphere have their foot prints in this area. A substantial amount of energy (originating in the solar wind) is guided along these field lines and many physical processes (the aurora, etc.) due to the interaction with the upper atmosphere, are observed.

During recent years the NIPR has established a net of scientific stations in Iceland and in Antarctica and good results from these observations have already been obtained (SATO *et al.*, 1985). Not everything can, however, be observed from the ground. When, for example, the objective is to study precipitating particles, fields and waves and the interrelations between them, the ground based measurements are not sufficient. Measurements with balloons, rockets, or satellites are needed for non-propagating phenomena within or above the ionosphere or in cases where a ground based instrument would be screened by the lower atmosphere as is the case for *e.g.* UV emission, X rays and electric fields. It has also in recent years (TREILHOU, personal communication, 1985) become clear that magnetometer measurements benefit from being carried out elevated above the Earth's surface (*e.g.* on a balloon flight). The measurements show more high-frequency details; probably ground based measurements can be modified by induced currents in the ground.

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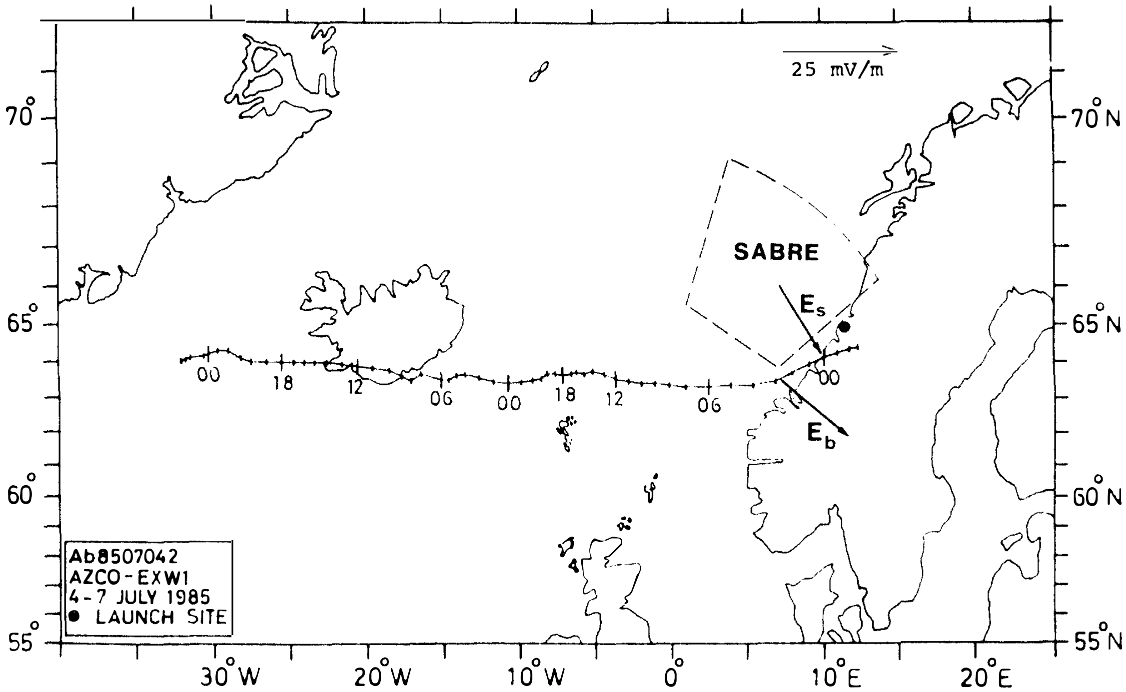

Fig. 1. Map of the North Atlantic area. The trajectory of the balloon AZCO-EXW1 is shown with 1-hour marks. Also shown in the figure is the observation area for the SABRE and the two electric field measurements E_{SABRE} *and* $E_{BALLOON}$.

Remote sensing of the ionosphere and lower magnetosphere with modern radar instruments (based on coherent or incoherent reflection) is also used for many investigations.

Having the above-mentioned problems in mind, a balloon campaign was planned by Japanese, Danish, and Norwegian groups and it was carried out in July 1985 (for a detailed description see MIYAOKA *et al.*, 1986). When the data are fully analyzed, they can contribute to the solution of questions like the non-symmetry of certain observations at conjugate locations and other problems. This short report shows data from one balloon flight and is intended to give a preview only. The trajectory of the balloon which was launched on July 4, is shown in Fig. 1.

2. A Substorm Observation

A few small substorms were observed during the balloon flights. Although a large number of magnetospheric substorms have been studied in recent years (and extensive descriptions can be found in the literature, see *e.g.* AKASOFU, 1968 and AKASOFU, 1977), a general and complete model has not yet been established. Much is still to be done and results from the AZCO campaign will hopefully also contribute to further progress. A major (and controversial) question is still the significance of a loading phase observed prior to the onset proper of the expansion phase (MCPHERRON, 1970). The onset is a prominent feature of the substorm and is observed as a sudden intensification of the westward auroral electrojet or (in winter time) a sudden auroral arc brightening.

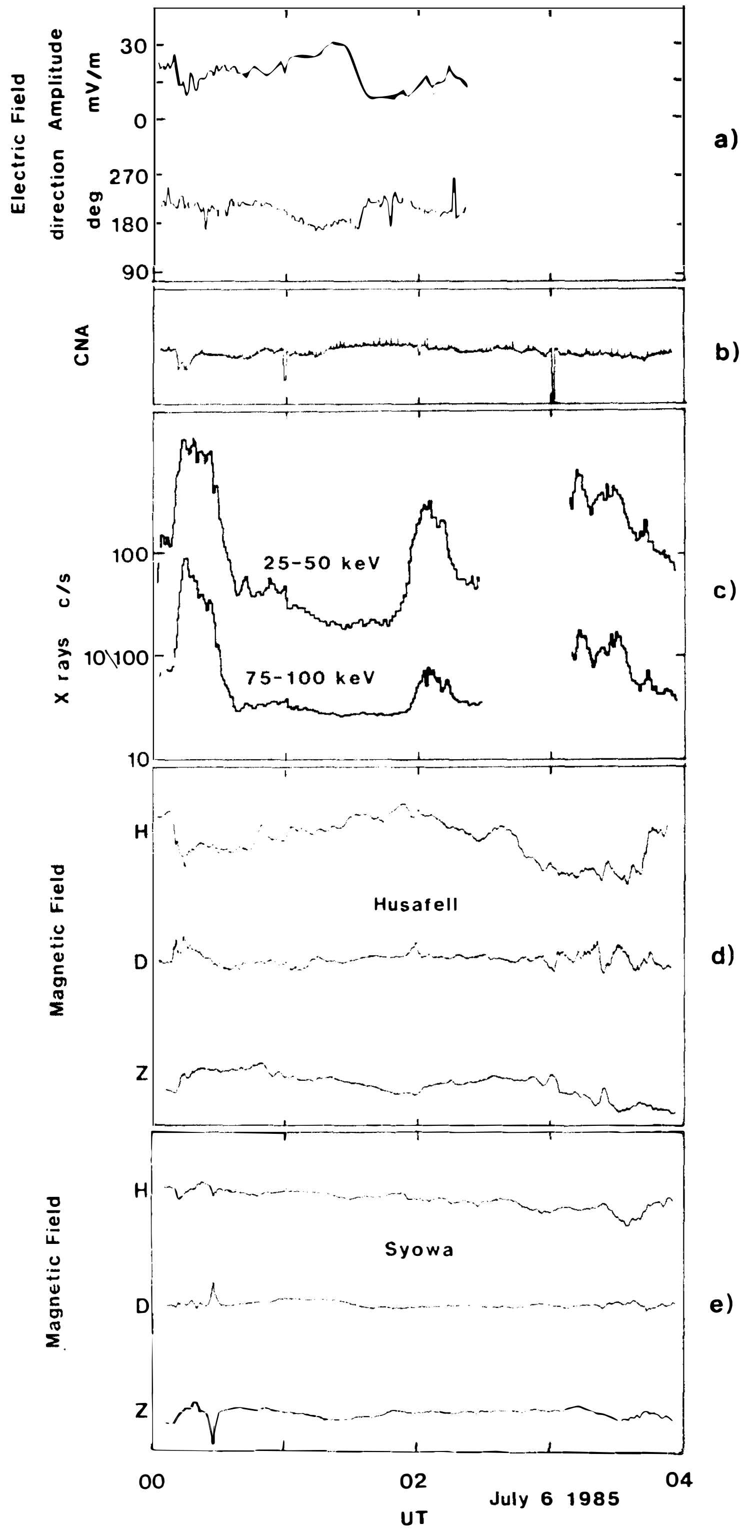

Fig. 2. Sample of measurements when a substorm onset is observed. At the time of the onset the balloon was located at about local magnetic midnight and 64° inv. latitude. The panels are: a) The balloon electric field amplitude and direction. b) The cosmic radio noise measured at Husafell with a riometer. c) The X ray emission measured from the balloon in two energy bands. d) The magnetogram from Husafell. e) the magnetogram from Syowa.

During the AZCO EXW1 flight a few small substorm like events were observed, one of them can be seen in Fig. 2. It occurred on July 6 at 0009 UT at which time the balloon was positioned in the middle of the auroral oval. The geographic position can be seen in Fig. 1. The data shows a typical case of a sudden intensification of the X ray intensity and riometer absorption (both due to an increased particle precipitation), a negative bay in the magnetogram and an abrupt change of the electric field.

No sign of loading is found in these data but other features can be seen as described in the following.

2.1. *Precipitation of energetic electrons*

X rays generated by energetic electrons interacting with the upper atmosphere (see *e.g.* Brown, 1966) are usually observed during substorms. The observations give a complicated picture which is a result of many phenomena like particle injection in the midnight sector, magnetic field re-configuration, wave particle interactions, azimuthal particle drift, and others (Kremser *et al.*, 1982). In Fig. 2 can be seen a clear softening of the X ray spectrum immediately after the onset. At least two different explanations can be given for this observation. One is that the spectrum softening is due to energy dispersion of the injected electrons when grad B drifting, in this case the injection point must be somewhat west of the balloon position. The other is that the energy spectrum for the electrons before the injection (onset) is softening in a radially outward direction so that the hard spectrum will be observed first, in this case the balloon can be close to the longitude of injection. The latter explanation is probably the most likely one because we are close to local midnight and a drift dispersion would be too small.

Particle precipitation is also causing increased CNA (cosmic noise absorption) which is measured by riometers on the ground. In Fig. 2 is shown the record from Husafell, and the precipitation onset is clearly seen which is also the case for the other stations on Iceland (not shown). The balloon is at that time positioned about 400 km east-southeast of Husafell so the onset is a widely extended phenomenon.

2.2. *The electrojet*

The magnetometers in Iceland recorded a sudden intensification of the westward electrojet. This is seen as a negative bay in the *H* component. The position of the electrojet can qualitatively be estimated. A comparison of the sign and the strength of the various components of the magnetic intensifications at the three Iceland stations indicates a rather broad current distribution centered somewhere south of Husafell. This observation is relevant for the electric field observation as described in the next section.

The substorm is also observed at the Syowa Station conjugate to Husafell. It has already long ago been reported (*e.g.* Nagata and Kokubun, 1960) that a clear similarity (in auroral dynamics as well as in magnetic variations) can be observed at conjugate locations. In the present case we note a similar change both in the *H* and *Z* components.

Similarities are, of course, not surprising. The substorm, as observed from both ends of the field lines, is driven from the equatorial plane and some symmetry can be expected. Observations like those presented here can be used for studying the causes for stronger or weaker deviations from symmetry. Several explanations for such deviations can be imagined:

1) Even if two points are magnetically conjugate at some time it may not be the case at other seasons. Conjugacy may also be lost due to an asymmetric distortion of the Earth's magnetic field (*e.g.* MENG and AKASOFU, 1968). The conjugacy may even break down after the substorm onset for the same reason.

2) The Earth's magnetic field is not symmetric and this may result in different observations at the ends of the field lines. Trapped energetic electrons causing aurora or absorption have mirror points at different levels, which causes the precipitation to be asymmetric, dependent on the actual pitch angle distribution.

3) Both the location and strength of the electrojet is dependent on the ionospheric ionization which is caused both by solar UV influx and by charged particle precipitation. In such cases no sign of conjugacy may be visible.

2.3. The substorm electric field signature

Associated with the intensification of the electrojet an equivalent change in the electric field must be assumed (for a clear example, see IVERSEN, 1980). Actually a clear drop from about 22 mV/m to about 14 mV/m is observed but a closer examination reveals that the direction does not match with the observed electrojet. Assuming either Hall currents or Pedersen currents or something in between requires a current more than 90 degrees out of phase with the one actually observed. The balloon was, apparently, too far away from the given current to be able to detect the associated electric field. The reason for the drop in the electric field actually observed could well be an increased ionospheric conductivity at the balloon position caused by the particle precipitation at the same location. This is supported by the fact that the field direction does not at all change at the time of the onset.

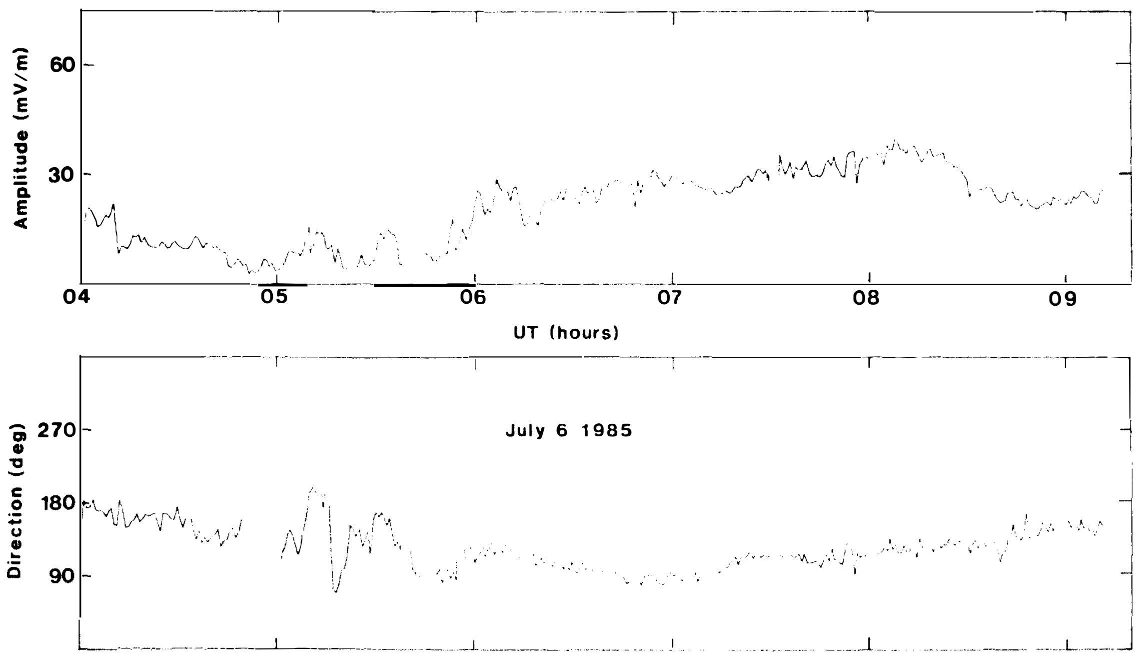

Fig. 3. The amplitude and phase of the electric field measured with the balloon instrument. The field direction is measured from geographic north through east.

3. The Convection Electric Field

Electric field measurements with balloons are well suited for exploring the polar cap plasma convection associated with the electric field (see *e.g.* MOZER *et al.*, 1974 or IVERSEN and MADSEN, 1978). Also the data collected during the AZCO campaign can be used for further studies. A preliminary inspection of the data shows that typical features are seen. They are, for example, field amplitudes in the tens of mV/m range and a dominant sunward convection in the dawn and dusk auroral zone sectors the two being separated by the Harang discontinuity as often observed earlier (*e.g.* MADSEN *et al.*, 1976).

One observation in the morning of July 6 attracts special attention. Usually a rather good correlation has been observed between balloon electric field measurements and nearby ground based magnetic measurements as mentioned in the previous section. As far as the morning of July 6 observation is concerned, the situation is different. During several hours (see Fig. 3) a relatively strong (40 mV/m) southward field was observed this being fully consistent with the normal polar cap convection pattern but the nearby magnetometers show no signature of ionospheric currents. No satisfactory explanation has been found yet. The observation could be explained by a very low ionospheric conductivity during the observation which, on the other hand, seems unlikely for the high latitude summer-time ionosphere.

A field of atmospheric origin has also been considered, but it is very unlikely because of the stability and consistency with the normal convection field. Often electric fields of atmospheric origin have been observed during balloon flights (see *e.g.* MADSEN *et al.*, 1983 or BARCUS *et al.*, 1986), but those fields are always strongly fluctuating both in amplitude and direction and they show a strong vertical component which is not found in the present case.

4. Comparison with Radar Data

In recent years many ways of measuring the convection field have been worked out (for a review see *e.g.* STERN, 1977). The experiments are using both ground based instruments, balloons, rockets, and satellites.

One goal is still to obtain a detailed picture of the polar cap convection pattern as a function of time with good resolution. The problem is that one instrument alone cannot monitor the whole system. The only way today is then to combine the simultaneous measurements from many widespread instruments.

Also data from the AZCO campaign can be used for performing a comparison with data from other electric field instruments. In Fig. 1 is shown the area covered by the SABRE (Sweden And Britain Radar Experiment) coherent back-scatter system. This system can, when reflection conditions are favorable, give a two-dimensional picture of the plasma drift in the area.

Preliminary SABRE data do not show a good data coverage during nearby balloon passages, but one example has been found and is presented here in order to show the agreement between the two independent measurements. The electric field vectors calculated from the balloon and SABRE instruments respectively (the quick-look

SABRE data kindly supplied by C.P. STEWART) are shown in Fig. 1. The measurements are obtained on July 5 around 0330 UT (at approximately 05 MLT and 63° inv. latitude) and they agree reasonably well taking in consideration that the data are preliminary and that the two measurements are obtained at some distance. The field direction is essentially south, geomagnetically, consistent with the normal convection field pattern. The balloon measurement has some eastward component, but at this time some magnetic disturbance is present and variations in the field direction can be expected.

5. Concluding Remarks

Already from this study covering a minor part of the AZCO data a few results have been obtained. It seems, *e.g.*, that during disturbed conditions changes in the conductivity play an important role when correlating electric and magnetic fields. Conductivity variations can be due to ionization by precipitating electrons. Another result which, however, is difficult to explain is the existence of a longer period with strong electric field with weak currents only.

This report on the first AZCO results does not present any VLF measurements although such data were recorded from many ground stations, and other data are also omitted. More data reduction is still needed before further interpretation can be carried out and hopefully it will be possible to present, in particular, some pulsation phenomena including data from both conjugate areas.

Acknowledgments

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