DAYSIDES AURORAL ACTIVITY DEPENDENCE FROM SOLAR WIND PARAMETERS

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ABSTRACT

We report preliminary results from a statistical analysis on the relationship between the dayside (cusp) auroral activity and key parameters of the solar wind at Earth (velocity, pressure, magnetic field, etc.). The present study covers the 2003-2004 and 2004-2005 winter seasons, consisting of about three months each. Data collected by the ITACA² auroral monitor (IFSI/INAF), located at the Italian Arctic base (Dirigibile Italia, Ny-Ålesund, Svalbard), were used in this study. Our statistical approach is based on the analysis of the 630.0 nm keograms (magnetic latitude vs. time plots) between 04:00-13:00 UT, that is, a window of eight-hours centered on the local magnetic noon (~ 09:00 UT), where the probability to observe the transit of the geomagnetic cusp is the highest. The solar wind conditions were derived from the ACE, WIND and GEOTAIL satellite data. It was also studied how the dayside auroral activity is directly influenced by the impact of interplanetary perturbations, linked to solar transient phenomena, such as coronal mass ejections (CME), on the dayside magnetosphere. Halo or partial halo CME events were selected from the on-line catalogue (NASA/GSFC, http://cdaw.gsfc.nasa.gov/CME_list/) derived by the LASCO coronoagraph dataset. The cosmic ray data recorded by the SVIRCO station (IFSI - UniRoma3) was used to help in identifying the interplanetary perturbation at the Earth’s orbit (Forbush decrease).

Key words: Dayside Aurora; CME; Solar Wind.

1. INTRODUCTION

ITACA² is a twin monitors system devoted to the imaging of the high latitude auroral activity, operated and maintained by the Istituto di Fisica dello Spazio Interplanetario (IFSI/INAF). ITACA² is constituted by ITACA-NAL and ITACA-DNB, located in Ny-Ålesund (Spitzbergen, Svalbard) and Daneborg (North-East Greenland) respectively. ITACA² stations are equipped with digital all-sky cameras (ASC), recording the aurora emission at 427.8, 557.7 and 630.0 nm (blue, green and red lines). The field-of-view of the two stations covers a wide zone (130° MLON x 20° MLAT, at 400 km height), along about 76° magnetic latitude, in order to observe the high-altitude red-dominated dayside auroras (Fig. 1). The wide area monitored by ITACA² extends the ground-based observations of the geomagnetic cusp/LLBL regions, and enhances the capability of conjugate studies of ionospheric radar (SuperDARN), magnetometer chains (Greenland, Svalbard) and satellite (e.g. DMSP, IMAGE, Cluster) data.

2. AURORAL DATA

At present, the ITACA² monitors record up to six all-sky images each minute: three with the green filter (557.7 nm), two with the red filter (630.0 nm) and one with the blue filter (427.8 nm), every 20s, 30s and 60s, respectively. An image in white light is taken at the beginning of each hour to check the seeing of the sky. To have a summary of the daily auroral activity, the so-called keograms are created. They are built by taking the central (i.e.: along the local geomagnetic meridian) strip of pixels from 1-min green or red images (Fig. 2 (a)) and then putting them together, side by side, as a function of time. From a keogram (Fig. 2 (b)), the auroral events occurring during the day can be easily identified.
3. DAYSIDE AURORAS AND CUSPS

The dayside auroras are produced by the direct penetration of the shocked solar wind plasma through the geomagnetic cusps, two funnel-like structures present on the frontside magnetosphere. The dayside auroras can be visible only at the ionospheric footprint of each cusp, which lies at about 76° magnetic latitude (e.g.: Newell et al. (1992)). Moreover, since the dayside auroras occur on the sunward side of the Earth, and are characterized by dim red emission, they can be detected only at high geographic latitudes, during the darkness of the polar night (that is, close to the winter solstice, in the northern hemisphere). Due to the low energy (100-200 eV) of the electrons producing the cusp auroras, they generally take place at high altitudes (about 300-500 km), in the F2 ionospheric layer. These auroras provide direct information on the solar wind and the interplanetary magnetic field interaction with the frontside magnetosphere, and can be viewed as a proxy of the magnetic reconnection events ongoing at the dayside magnetopause (e.g.: Sandholt et al. (2004), Massetti et al. (2005)).

4. DATA ANALYSIS

Our analysis extends over two time periods of about three months each, in the 2003-2004 and 2004-2005 winter season. For this study it was decided to limit the analysis to the ITACA-NAL dataset only, due to its wider and more uniform time coverage. Starting from the all-sky images, the keograms were created in both green and red wavelengths. The keograms were then projected to a reference altitude of 250 km to transform the elevation angles into magnetic latitudes (MLAT). By comparing the keograms with the all-sky white-light images, the cloudy periods were identified and eliminated from the dataset. Then, the average MLAT was estimated on half-hourly basis, within a window of 4 hours centered on local magnetic noon (about 09:00 UT), where the transit of the cusp usually takes place. We used the GEOTAIL, WIND and ACE satellite data, to derive the key parameters of the unperturbed solar wind, that is, upstream the bow-shock. When possible the GEOTAIL data were used, since this satellite was closer to the Earth than WIND and ACE. The plasma and magnetic field data were therefore used to create daily plots of the solar wind key parameters: speed, density, dynamic pressure and the three components of the interplanetary magnetic field (IMF). To draw an accurate comparison, the mean temporal delay between satellite and ground-based measurements was estimated, and taken into account in the data analysis. In the first approximation, the delay is a function of the satellite position and the solar wind speed, and can be expressed as the sum of the delays in the propagation from the satellite to the bow-shock ($t_{sat-bw}$), and then to the magnetopause ($t_{bw-mp}$), as follow (e.g.: Lockwood et al. (1989)):

$$\Delta t = t_{sat-bw} + t_{bw-mp} + t_{mp-io} + t_{io-fov} + t_{630}$$

where the last three terms are the time lags between the magnetopause and the ionosphere ($t_{mp-io}$=2-3 min.), between the ionosphere and the instrument field-of-view ($t_{io-fov}$=2-3 min.), and the 630.0 emission delay (110s). From the keograms the following parameters were derived: i) the average latitude of the red emission (MLAT), ii) its latitudinal width ($\Delta$ LAT), and iii) the red intensity (I630), between 05:00 and 13:00 UT. Then we analysed the dependence of the mean magnetic latitude of the red aurora emission with respect to the three components of the interplanetary magnetic field ($B_x, B_y, B_z$), the solar wind dynamic pressure ($P_{dyn}$), and the IMF clock-angle ($\theta$) (see Figs. 3 and 4).

5. CME INTERPLANETARY PERTURBATION EFFECTS

Some events have been preliminarily chosen in order to analyse the effects linked to the transit of interplanetary perturbations caused by solar transient phenomena, as the coronal mass ejections (CME), on the dayside magnetosphere. Halo or partial halo CME events were selected from the online catalogue.

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Figure 3. Solar wind parameter distributions.

Figure 4. (a) Dependence of the average magnetic latitude of the 630.0 nm emission (MLAT) from IMF $B_z$, for IMF $B_z < 0$ and IMF $B_z > 0$. When the IMF $B_z$ component is positive the MLAT is mostly located above 75° MLAT, while for negative IMF $B_z$ values, MLAT extends at lower latitudes. (b) Dependence between average magnetic latitude of the 630.0 nm emission (MLAT) and IMF $B_z$. Dependence between MLAT and IMF $B_z$ from a statistical analysis based on Polar satellite data (Zhou et al. (1999)). The trend is similar to the one in our plot, but referred to the position of the outer cusp.
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Figure 5. (a) Cosmic ray hourly (black) and 5-min (red) averages, from the Rome neutron monitor; (b) ITACA red-line keogram. The arrows mark the estimated arrival time of the CME associated interplanetary perturbation.

6. CONCLUSIONS

We presented some preliminary results derived from our statistical analysis of ground-based cusp aurora observations. The most interesting are the following (see Figs. 3 and 4):

1) a dependence of the average magnetic latitude of the 630.0 nm emission (red aurora) from IMF $B_z$. In particular, the latitude decreases from the nominal cusp position, i.e. 76° MLAT, to about 70° MLAT, for average IMB $B_z$ ranging between -5 nT to 0 nT; while it is substantially confined between 75°-77° MLAT during periods with IMF $B_z > 0$. To our knowledge, this is the first time that the correlation cusp aurora and IMF $B_z$ has been highlighted through the statistical analysis of ground-based data. Our findings are comparable with the results derived from satellite data (e.g.: Zhou et al. (1999), Newell et al. (1989));

2) a dependence of the average magnetic latitude of the 630.0 nm emission from IMF $B_y$. There seems to be a clear decrease of the MLAT during periods with IMF $B_y > 0$. If confirmed, this result is very interesting, since it is not reported in literature;

3) a dependence of the average magnetic latitude of the 630.0 nm emission from IMF $B_x$. There is a general increase of higher latitude events during positive IMF $B_x$ periods;

4) a dependence of the average magnetic latitude of the 630.0 nm emission from the IMF clock-angle ($\theta$). The distribution of the magnetic latitude is concentrated around 76° MLAT, the nominal cusp position, for $\theta \sim 0°$ (IMF parallel to geomagnetic field), while it extends progressively at low latitudes when is close to 180° (IMF antiparallel to the geomagnetic field, regime of maximum reconnection).

Some events clearly showing the dependence of the dayside cusp aurora from abrupt variations of the solar wind parameters (IMF, pressure, etc.) linked to CMEs, were found. They will be the subject of further studies involving the analysis of complementary parameters as: cosmic ray flux, geomagnetic variations, space-based UV aurora emission.

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REFERENCES


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