Earth's Low-Latitude Boundary Layer

Geophysical Monograph Series Volume 133

EARTH'S LOW-LATITUDE BOUNDARY LAYER
Edited by Patrick T. Newell and Terry Onsager

382 pages, 2003

LLBL and Wave Effects

Viacheslav A. Pilipenko, Valeriy A. Martines-Bedenko, Mark J. Engebretson, Vladimir O. Papitashvilli, and Patrick T. Newell

High-Latitude Mapping of ULF Activity, Field-Aligned Currents, and DMSP-Based Dayside Magnetospheric Domains

DOI: 10.1029/133GM23, Pages 231-240
High-Latitude Mapping of ULF Activity, Field-Aligned Currents, and DMSP-Based Dayside Magnetospheric Domains

Viacheslav A. Pilipenko, and Valeriy A. Martines-Bedenko

Institute of the Physics of the Earth, Moscow, Russia

Mark J. Engebretson

Augsburg College, Minneapolis

Vladimir O. Papitashvili

Space Physics Research Laboratory, University of Michigan, Ann Arbor

Patrick T. Newell

Applied Physics Laboratory, Johns Hopkins University, Laurel

We have developed a technique for simultaneous comparison of the ULF (ultra-low-frequency) activity in the Pc5 frequency band, global patterns of field-aligned currents (FAC), derived from the IZMIRAN Electrodynamics Model (IZMEM) driven by the interplanetary magnetic field, and the ionospheric projections of the dayside magnetospheric domains derived from DMSP satellite particle data. This technique produces a sequence of two-dimensional “snapshots” of the FAC distributions with overlapped DMSP tracks, and the ULF spectral power based on data from a worldwide array of geomagnetic stations. Several events have been analysed as examples. In the cases considered we have found that in the morning sector the IZMEM-predicted region of downward FAC maps together with the low-latitude boundary layer (LLBL) projection to the polar ionosphere, whereas the upward FAC region coincides with the central plasma sheet (CPS) projection. The simultaneous occurrence of two sources of ULF activity in the nominal Pc5 frequency band has been identified: one source is located in the dawn sector at geomagnetic latitudes 65° – 70°, and another source is located near noon at magnetic latitudes 75° – 79°. The peak of Pc5 in the morning sector is situated equatorward of the Region 1 FAC system, in the region of the Region 2 system or between them. The latitude of the near-noon Pc5 pulsations peak power coincides with the equatorward boundary of the low
latitude boundary layer, whereas the resonant maximum of Pc5 pulsations in morning hours corresponds to the CPS region.

1. INTRODUCTION

The energy transfer from the solar wind plasma into the magnetosphere and ionosphere has a turbulent character. Thus, it might be expected that in key regions of the solar wind-magnetosphere interaction, wideband electromagnetic noise can be generated. The occurrence of natural magnetospheric MHD waveguides and resonators may result in the noise's partial filtering producing band-limited pulsations. Indeed, at high latitudes, intense ULF (ultra-low-frequency) pulsations of the geomagnetic field in the nominal Pc5 range (1-10 mHz) are commonly observed, but the exact physical mechanism for these ULF disturbances has not yet been established. The common view is that the main source of the dawn and dusk side Pc5 waves is the solar plasma flow shear at the flanks of the magnetosphere. The broad-band ULF activity near noon at high latitudes is commonly assumed to be related to the cusp — the region of direct magnetosheath plasma penetration into the magnetosphere/ionosphere, particle precipitation and intense field-aligned currents (FACs). Velocity shears may exist at interfaces between other magnetospheric boundary domains, thus being the probable source of the flow instabilities.

There is as yet no agreement on the existence of specific ULF signatures of boundary phenomena. In some studies, the broadband disturbances in the period range of 3-15 min (named as "Irregular Pulsations at Cusp Latitudes", IPCL by Troitskaya [1985] or broad-band Pc5 pulsations by Engebretson et al. [1995]) were claimed to be a typical feature of the dayside boundary. In early studies [Rostoker et al., 1972; Troitskaya and Bol'shakova, 1977, 1988; Olson, 1986], it was believed that a probable source of the dayside high-latitude long-period pulsations was related to the cusp. In other studies [McHarg et al., 1995; Lanzerotti et al., 1999] it was assumed that quasi-monochromatic Pc5 pulsations on the dayside are a signature of a near-cusp closed field line and can be used as a cusp discriminator. Statistical characteristics of ground-based pulsations have been suggested for monitoring of the dynamics of the cusp/cleft region [Kleimenova et al., 1985; Bol'shakova, 1988; McHenry et al., 1990]. However, later experimental observations at the MACCS cusp-oriented array questioned this hypothesis [Engebretson et al., 1995]. Various hypotheses have been suggested for interpretation of the cusp-related ULF disturbances, including a fluctuating component of FACs or precipitating electrons [Posch et al., 1999]; fluctuations of the cusp-related current system [Olson, 1986], and the Kelvin-Helmholtz (KH) instability in the region of the convection reversal boundary, geomagnetically conjugate with the inner part of the low latitude boundary layer (LBL) [Clauser et al., 1997]. Inside the magnetosphere, these disturbances are transformed into more regular, quasi-monochromatic Pc5 pulsations under the influence of magnetospheric resonance effects]. The position of the resonance is determined by the match between the local Alfvén frequency and the frequency of an external source, regardless of any particular source mechanism. According to this notion, the latitude of maximal ULF intensity is determined by the features of the magnetospheric plasma distribution.

Elucidation of physical mechanisms for different types of ULF waves will be possible only when their place in the global context of the electrodynamics of the solar wind-magnetosphere-ionosphere system can be identified.

The transfer of energy and momentum from the solar wind through the magnetosheath into the magnetosphere occurs in the dayside magnetospheric boundary region. Mapping of the boundary layer regions to low altitudes is not quite certain because of the still uncertain topology of the entire magnetosphere, although it is clear that these spatially vast regions map into a very limited area around the low altitude cusps. This mapping can be studied either by using advanced magnetic field models, or by low-altitude measurements of charged-particle precipitation, visible auroral emissions, radar observations, etc. Charged-particle precipitation characteristics seem to be the best low-altitude means to categorize the boundary layers [Newell and Meng, 1988].

The global magnetosphere-ionosphere current system can be decomposed into several sub-systems, driven by the IMF changes through the quasi-steady viscous interaction and magnetic reconnection at the dayside magnetopause. In the dawn/dusk sectors, the ionospheric DP1/2, or field-aligned Region 1 (R1) and Region 2 (R2), current system dominates. This current system consists of two longitudinally elongated current sheets, the polar Region 1 sheet with downward (upward) FAC and the wider equatorward Region 2 sheet with upward (downward) FAC at dawn (dusk). This system is intensified for southward IMF (Bz < 0). In the dayside cusp/cleft region, the DPY current system dominates [Troshichev et al., 1997], which is mainly controlled by the azimuthal IMF component By. In its simplest form, the DPY current system comprises two sheets of FACs coupled via the ionosphere, which drive the east-west Hall current. Poleward of the cusp, the NBZ current system remains, most evident during periods of northward IMF, when Bz > 0. The NBZ current system is located near noon at geomagnetic latitudes higher than 80°, with upward pre-noon FACs and downward post-noon FACs.

For the most part, studies of global electrodynamics and ULF physics have been isolated from each other. To put ULF studies in a more global magnetosphere/ionosphere context, we have developed an approach to study simultaneously the ULF global pattern together with some proxies of
2. COMPONENTS OF THE METHOD

2.1. Empirical-Analytical Model of High-Latitude Global Electrodynamics (IZMEM)

Long-term magnetic observations at high latitudes established a reliable connection between the IMF and ionospheric current systems, which resulted in several empirical-analytical models. One of the approaches, developed at the Institute of Terrestrial Magnetism, Ionosphere, and Radio Wave Propagation (IZMIRAN) [Feldstein and Levitin, 1986; Papatashvili et al., 1994], is utilized in this study. The IZMIRAN Electrodynamics Model (IZMEM) utilizes a linear regression relationship between the IMF and ground-based geomagnetic disturbances, and provides a parameterization of geomagnetic variations by the IMF components' strength and direction. The ionospheric electrodynamics parameters are calculated from ground magnetic data and mapped over the polar regions using a statistical model of ionospheric conductivity [Wallis and Budzinski, 1981; Robinson and Vondrak, 1984]. The IZMEM does not require collection of in situ ground-based geomagnetic data for the event under investigation or selection of a magnetically quiet period to calculate geomagnetic disturbances. The IZMEM has recently been recalibrated utilizing the DMSP electrostatic potentials [Papatashvili et al., 1999]; the Web-based interface to this model has been made available at http://www.spr.umd.edu/MIST/LiMie.html. IZMEM was used as an empirical model, however physical mechanisms of predicted current systems and identification of the basic current elements within the magnetospheric domains have not been considered so far.

The virtue of the IZMEM is the simplicity of its usage, so this model should be considered as the first step in the study of an instantaneous distributions of ionospheric electric potentials and FACs for a given IMF during the season under investigation. For more detailed case studies this model is to be augmented by more sophisticated algorithms such as the KRM method [Kamide et al., 1981], and the AMIE technique [Richmond and Kamide, 1988].

2.2. Ground-Based Experimental Facilities

The experimental basis of our research is the data from four global networks of magnetic stations at high latitudes, shown in Figure 1:

CANOPUS (http://www.dan.sp-agency.ca/www/canopus-home.html), a network of 13 automatic stations deployed over West-Central Canada with a time sampling period of 5 s;
MACCS (http://space.augsburg.edu/space/MaccesHome.html), a network with 12 fluxgate magnetometers with 0.5-s or 1.0-s sampling deployed in the Canadian Arctic. Together with CANOPUS, these two arrays form 3 meridian profiles: -15°, -335°, and -315° in corrected geomagnetic (CGM) coordinates;

Greenland Coastal Array (http://www.dmi.dk/projects/chain/), two latitudinal arrays of 21 magnetic stations with 20-s sampling deployed along the West (-40°) and East (-95°) coasts of Greenland. This network is augmented by MAGIC (http://www.sprl.umich.edu/MIST/) consisting of an array on the Greenland ice cap (-60°); and

IMAGE (http://www.geo.fmi.fi/image/), an auroral and subauroral network of 24 magnetometers with 10-s sampling at stations along the Scandinavian meridian (-105°).

2.3. Automated Identification of Ionospheric Projections of Magnetospheric Domains From DMSP Data

In this study we use the results of the automated dayside region identification program based on fine features of energetic particle spectra in the 30-eV – 30-KeV range detected by the Defence Meteorological Satellite Program (DMSP) satellites F10–F12. This algorithm explicitly separates the basic magnetospheric signatures at the altitude of the DMSP satellites (~800 km) [Newell et al. 1991]. Classification of the boundary regions is described on the Web site http://sd-www.jmapl.edu/Aurora/index.html. The key regions are identified as mantle (further marked by dark blue color in figures) – de-energized magnetosheath ions observable poleward of the dayside oval; cusp (yellow) – projection of the magnetospheric exterior cusp, a region with full intensity magnetosheath ions and electrons; LLBL (red) – transitional boundary layer consisting of tailward flowing plasma having properties intermediate between those of magnetosheath and magnetosphere, PS (plasma sheet, Central PS is marked as light blue, and Boundary PS is marked as green) - the zone of hard precipitation on the dayside, which consists of ~1 keV electrons, which have been injected into the near-Earth region on the nightside and subsequently drift around the Earth. The DMSP region identification database is given as a set of files with the labelling of equatorward and poleward crossings of each boundary by universal time (UT), geomagnetic latitude, and magnetic local time.

2.4. Visualization and Mapping Technique

We develop a technique for simultaneous mapping (as a sequence of 2D “snap-shots”) of the ionospheric electrodynamical pattern, predicted by the IZMEM model, and of the ULF spectral power. The program reduces the original geomagnetic data to a common sampling period of 20 sec. Then, a fast Fourier transform technique is used to estimate the spectral power in a selected frequency band within a moving window for each station. These data are used to construct the 2D spatial distribution of ULF power for a particular time interval.

For the calculation of 2D spatial distributions of FACs over the high-latitude ionosphere as predicted by the IZMEM, the hourly IMF/solar wind parameters are taken automatically from the NSSDC’s OMNI Web system. The IZMEM driven by the IMF parameters produces snap-shots of 2D polar plots with the spatial structure of FACs throughout the dayside high-latitude ionosphere. The upward (negative, denoted by green color in figures) FACs are assumed to be transported by precipitating electrons, whereas the downward (positive, denoted with red) FACs are carried by the upward flow of ionospheric electrons.

To establish a correspondence between the spatial distribution of ULF wave intensities, FACs, and magnetospheric boundaries, we overlay on the plots available DMSP satellite tracks with the results of automated identification of magnetospheric boundaries. The ground track of each orbit is plotted in CGM coordinates where parts of the track are colored according to the color scheme adopted for the DMSP-detected domains. Thus, a track clearly indicates in different colors the position of the ionospheric projection of each magnetospheric region.

3. EXAMPLES

This technique is used to analyze the correspondence between the large-scale current systems, the probable sources of low-frequency ULF waves, and the dayside magnetospheric boundaries. Special attention is paid to the noon and morning MLT sector, as this is the region of the most intense ULF activity in the Pc5 band. Three days have been selected to demonstrate the capabilities of this new mapping technique:

a) February 18, 1995 (day of year 049). The IMF Bz was slightly northward and By varied from +5 nT to -4 nT at ~3-4 UT; then remained near zero.

b) December 26, 1995 (day of year 360). The IMF Bz is slightly negative (~ -2 nT) during this day, stimulating weak substorms at ~0400 UT, and at ~1800 UT.

c) November 24, 1995 (day of year 328). The IMF data indicate distinct periods with By < 0 (up to ~5 nT) for different Bz conditions. Southward deviations of Bz cause substorms at ~1545 UT and ~1900 UT.

The IMF By changes during the latter two days should produce variations of the DPY current system, thus a possible coupling of dayside Pc5 activity and current intensification in the cusp/cleft region could be examined. So far, we do not have extensive statistics, but we present below regularities that have been observed in the majority of time intervals studied.
3.1. Comparison of FAC Regions as Derived From the IZMEM With Magnetospheric Boundaries

Plates 1a and 1b, for 16 UT February 18, 1995 and 23 UT December 26, 1995 respectively, present typical patterns of FAC as derived from the IZMEM. In this and subsequent analysis, a 1-hour window is used. The time interval is indicated by its onset, that is, "16 UT" denotes "1600-1700 UT". As expected, below 80° a typical R1 structure with downward current on the dawn side and upward current on the dusk side can be seen, whereas the occurrence of the NBZ current system is evident near noon at latitudes higher than 80° CGM latitude, with the upward pre-noon and downward post-noon FACs. The mapping of DMSP tracks shows that, in the pre-noon hours (~1000 MLT), the upward R2 current coincides with the central PS projection, whereas the most intense part of the R1 downward FAC is mainly in the LLBL, with some admixture of the boundary PS projections. The NBZ system is clearly seen because of IMF Bz > 0, and DMSP tracks indicate that the upward NBZ current is located in the mantle.

3.2. Identification of Source Regions of ULF Activity

Simultaneous mapping of the ULF power distribution snapshots with the DMSP tracks makes it possible to identify the probable source region of ULF activity. In subsequent analysis, a 1.5-8.0 mHz frequency band is used. In Plates 2 and 3, the normalized ULF power is indicated, which may be used as an indicator of relative ULF intensity in each snapshot.

At 1800 UT on December 26, 1995 (Plate 2a,b) the maximum of monochromatic Pc5 power in the early morning hours at ~72° is equatorward of the R1 current zone. Simultaneous occurrence of near-noon and morning maxima of ULF power is observed. This observation shows that at least two sources in the Pc5 band may operate simultaneously. The overlying of FAC patterns (Plate 2a) shows that the first Pc5 source is located in the morning sector, equatorward of the Region 1 FACs. As the examination of magnetograms (not shown) indicates, this source generates quasi-monochromatic Pc5 pulsations. The other source is located near noon. The magnetograms show that this ULF activity is more long-period and irregular than typical morning Pc5 waves. This second source of broadband Pc5, possibly IPCL, has often been attributed to the cusp ionospheric projection.

Plate 2a shows that morning Pc5 are excited equatorward of the Region 1 current. These pulsations may be related to the auroral electrojet flowing between the R1 and R2 current sheets.

For the analyzed days, we found no clear correspondence between the near-noon Pc5 peak and high-latitude current system features (such as DPY or NBZ).

The DMSP magnetospheric domain identification algorithm indicates that the center of the dawn-side Pc5 power is located inside the CPS region (Plate 2b). At the same time, weaker near-noon and evening spatial maxima can be seen. However, there are no DMSP passes over these centers of the ULF activity to identify the magnetospheric region of their source.

During the event of 1800 UT November 24, 1995 (Plate 3), DMSP passes through the near-noon maximum of ULF activity. Examination of the magnetograms (not shown) indicates that this ULF activity is broadband Pc5, commonly named cusp-related Pc5 or IPCL. The latitude of the spatial distribution peak, Φ ~ 78°, is higher than typical latitudes of morning Pc5. As DMSP data indicate, the source region of the near-noon, broadband Pc5 for this event is not located in the cusp, but coincides with the equatorward boundary of the LLBL.

3.3. Discussion of Examples

Our study shows that the IZMEM-predicted location of R1 FACs coincides mostly with the LLBL, which is in accord with the common notion that the LLBL is the driver of the Region 1 current system. A connection between Region 1 currents and the LLBL, that is, FAC that flows at the magnetosphere/LLBL interface, has previously been suggested [e.g., Hones, 1983]. This correspondence gives additional support to the physical background of the IZMEM. Our mapping technique enables one to apply further any other ionospheric model [e.g., Weimer, 2001].

This mapping technique provides a typical 2D spatial scale of the hourly averaged ionospheric projection of the region occupied by Pc5 pulsations. As follows from Fig. 3, the azimuthal scale ΔL/T = 2-3hours, and the latitudinal scale ΔΦ = 5°-7°. These parameters are of key importance for modelling of the relativistic electron acceleration by Pc5 pulsations [Elkington et al., 1999].

In the morning sector, the peak of ULF intensity is commonly situated equatorward of the downward FAC (Region 1). This location may correspond to the typical position of an intense westward auroral electrojet [Lam and Rostoker, 1978], or to the Region 2 with upflowing FACs [Potemra et al., 1988]. The problem of possible correspondence between the global magnetospheric and ionospheric currents and Pc5 activity needs more detailed data than the empirical ionospheric model can provide. So far, the possibility of correspondence between Pc5 pulsations and the auroral electrojet is not taken into account by modern theories of ULF waves, which assume that the position of the morning Pc5 peak is determined only by the magnetospheric plasma distribution. Thus, this comparative study could be significant for augmentation of existing Pc5 models.

Early studies of dayside ULF activity at high latitudes gave hope that long-period irregular variations were suppos-
Plate 1. Identification of the FAC regions as derived from the IZMEM and comparison with the magnetospheric boundary domains during two events: a) 1600-1700 UT February 18, 1995 (day of year 049), and b) 2300-2400 UT December 26, 1995 (day of year 360). Circular lines show magnetic latitude at 5° intervals from 90° down to 60°. Upper right-hand panels show variations of the OMNI IMF Bx, By, and Bz components during the days. The color bar denotes intensity and direction (red – downward, green – upward) of the modelled FACs. Color codes of magnetospheric domains: CPS, BPS, LLBL, Cusp, Mantle, and Polar Rain are shown on right-hand inserts (Void – fluxes too low).
Plate 2. The spatial relationship between the FAC system derived from the IZMEM, ULF wave activity, and dayside magnetospheric domains from 1800 to 1900 UT December 26, 1995 (day of year 360): a) IZMEM model and superposed Pc5 power in the same format as Fig. 2, and b) DMSP domain identifications and superposed Pc5 power. The magnitude of the Pc5 wave power (right-hand inserts) for a given time interval is normalized to the maximum throughout the whole day.

Plate 3. Identification of source regions of the broadband ULF wave power occurring near local noon from 1800 to 1900 UT November 24, 1995 (day of year 328).
edly closely associated to the cusp/cap interface, and thus could be used as a simple indicator of dayside cusp position. However, further studies of high latitude broadband wave activity on the dayside (e.g., Engbrotson et al., 1995) showed that it cannot be simply associated with cusp proximity, but, instead, shows coordinated time dependence across several hours of local time. Attempts to find a cause for these widespread temporal variations in the solar wind, IMF, or substorm injections have so far been fruitless.

In contrast to the approach in this paper, the search for specific ULF signatures of boundary phenomena in most previous studies were based on data from isolated stations with limited latitude/longitude coverage. At sub-auroral stations the persistent occurrence of quasi-monochromatic Pc5 pulsations are observed, mostly in early morning hours during substorm and/or storm recovery phase. At higher latitudes broadband long-period variations [Troitskaya and Bolshakova, 1988; Engbrotson et al., 1995], were revealed. However, some case studies with more extended arrays showed a regular transition from irregular broadband (IPCL) pulsations at high latitudes to more intense and monochromatic Pc5 pulsations at lower latitudes [Clauer et al., 1997; Pilipenko et al., 1998]. Thus, these events indicated that Pc5 and IPCL pulsations are not separate wave phenomena, but the manifestations of the same wave process, whereas the difference in their appearance is related to the resonant amplification deeper into the magnetosphere, probably on closed dipole-like field lines. The location of the possible ULF driver is hard to identify, because the secondary maximum in a resonant region is higher than the primary maximum in the source region. Thus, simultaneous occurrence of IPCL and Pc5 near-noon may signify a situation when both the ULF driver and the resonant response are observed on the ground. However, Kleimenova et al. [1998] presented ULF events where IPCL and Pc5 did not accompany each other. Therefore, the problem of the IPCL/Pc5 coupling needs further investigation.

Among all the events considered so far, we never observed a spatial correspondence between the cusp proper and ULF activity peak. Thus, the widely used terms “cusp-related pulsation” or “cusp-associated ULF waves” are likely not adequate in studying real events; probably, the terms “near-noon high-latitude Pc5” or “broad-band ULF activity” would be more adequate. In the event shown here, we found that the spatial peak of ULF activity near noon maps to the inner boundary of the LLBL.

Our finding is in accord with the satellite observations by Takahashi et al. [1991], who reported the occurrence of intense irregular magnetic variations with similar time scales (~5-10 min) inside the LLBL. Coincidence of the probable source region of near-noon Pc5 with the LLBL projection agrees with the simultaneous radar and magnetometer observations discussed by Clauer and Ridley [1995] and Clauer et al. [1997], who attributed the source of these pulsations to the KH instability, excited at the reversal boundary of ionospheric convection associated with the LLBL.

Observations of morning and post-noon Pc5 led earlier workers to the conclusion that the KH instability at the magnetopause or LLBL is a likely candidate for driving Pc5 activity. Later, indications were found that impulsive variations of the dynamic pressure of the solar wind and FTE constitute a possible source of Pc5 wave packets in the magnetosphere. Our analysis often revealed the simultaneous occurrence of three regions of ULF intensification: morning sector, near-noon, and post-noon hours. It is difficult to ascribe them to the same driving mechanism such as the KH instability.

The assumption of the KH instability as a universal driving source of geomagnetic pulsations meets some difficulties. The classical linear theory of instabilities of a tangential discontinuity between two semi-infinite half-spaces predicts that short wave disturbances with lateral scales on the order of the boundary layer thickness are predominantly excited. So, the zone of the flow turbulence and the pulsation scale should be relatively small. But, the observational data give wavelengths in the region of morning Pc5 generation not less than 10 Re. Probably, consideration of mechanisms beyond linear instability theory (such as non-linear convective vortexes due to the inverse turbulence cascade, multi-layer structure of boundary layers, etc.) would be necessary for an adequate model of morning/evening Pc5 wave excitation.

It is difficult to attribute the near-noon Pc5 to the KH instability because in this region the velocity of the magnetosheath plasma flow is not high. The occurrence of Pc5/IPCL activity at the near-noon hours can be considered as an indicator of internally generated turbulence or external magnetosheath turbulence. In line with this idea, analysis of a series of IPCL bursts under moderate geomagnetic activity showed that these signals possess rather distinctive features, typical for a system near a critical transition to a chaotic regime [Kurazkowskaya and Klein, 2000]. Thus, the near-noon broadband pulsations in the Pc5 band might be a manifestation of the development of dynamic turbulence in field-aligned currents in the cusp region. The difference in source mechanisms of the noon and morning Pc5 should reveal itself in the spatial structure (e.g. azimuthal phase velocity) of pulsations, which is to be verified in further studies.

4. CONCLUSIONS

The density of ULF magnetic stations over the northern hemisphere has reached by now a level that enables a researcher to move from an examination of 1D profiles to a study of instantaneous 2D distributions of ULF intensity. Here we have presented examples of our ongoing efforts to develop an effective technique to render snapshots of ULF
wave power in the context of global ionosphere-magnetosphere electrodynamics. In our opinion, even this preliminary consideration has raised a number of interesting problems.

The mapping technique presented here reveals that in most cases in the morning sector, the region of downward FAC corresponds to the LLBL, whereas the upward FAC corresponds to the CPS, that fits the notion about the LLBL is a driver of the R1 current system, at least in the morning sector.

Often, three regions of ULF excitation are simultaneously observed: during morning hours, near noon, and during afternoon hours, that may indicate the simultaneous occurrence of several drivers of ULF waves. In the morning sector, the peak of ULF intensity is commonly situated equatorward of the boundary of downward R1 FACs, probably in the region of the auroral electrojet.

The resonant monochromatic response to Pc5 driving is observed near the CPS/BPS interface. The latitude of the spatial distribution peak of broadband ULF pulsations in the Pc5 range near noon, which has at times been named "cusp-related pulsations", in fact coincides with the equatorward boundary of the LLBL.

Clearly, these observations need further statistical evaluation. Further we intend to advance this technique by adding the facilities to map simultaneous electrodynamics from the AMIE modelling technique (www.hao.ucar.edu/public-research/itso/amie/AMIE_head.html), auroral oval from cross-calibrated satellite-ground based data (http://sd-www.ftp.apl.edu/Aurora/ovation/index.html), and satellite (Polar, Image) UVI images.

Acknowledgements. Magnetic data for this study were provided by the CANOPUS and IMAGE teams, and the Danish Meteorological Institute (J. Watermann), whom we gratefully acknowledge. The help of J. Skura in obtaining the DMSP data is appreciated. Solar wind/IMF parameters were downloaded from NSSDC OMNI website (nssdc.gsfc.nasa.gov/omniewb/ow.html). The research of V.A.P. and M.I.J. was supported by U.S. National Science Foundation grant ATM-0000339, V.A.M-B by the grant 01-05-64710 from the Russian Fund for Basic Research, and V.O.P by the NSF grant OPP-9614175. Constructive comments of both referees are appreciated.

REFERENCES


Kleimenova N.G., O.V. Kozyreva, J. Bitterly, and M. Bitterly, Long-period (T=8-10 min) geomagnetic pulsations at high latitudes, Geomagn. Aeronomy, 38, 38, 1998.


HIGH-LATITUDE MAPPING OF ULF ACTIVITY


M.J. Engebretson, Augsburg College, Minneapolis, MN 55454. (e-mail: engebret@augsburg.edu)

P.T. Newell, Applied Physics Laboratory, Johns Hopkins University, Laurel, MD 20723. (e-mail: Patrick.Newell@jhuapl.edu)

V.A. Martines-Bedenko, and V.A. Pilipenko, Institute of the Physics of the Earth, Moscow 123995, Russia. (e-mail: vpilipenko@ipe-ras.ru)

V.O. Papitashvili, Space Physics Research Laboratory, University of Michigan, Ann Arbor, MI 48109. (e-mail: papita@umich.edu)