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STUDIES OF THE DAYSIDE BOUNDARY LAYER PROCESSES BASED ON GROUND OBSERVATIONS IN THE SVALBARD AREA

A. Egeland
J. A. Holtet
P. E. Sandholt

University of Oslo
Department of Physics
P.O. Box 1049, Blindern
0316 Oslo, NORWAY

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6. AUTHOR(S)
A. Egeland
J.A. Holtet
P.E. Sandholt

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Department of Physics
University of Oslo
P.O.Box 1048, Blindern
0316 OSLO, NORWAY

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Based on extensive, diagnostig ground observations in the Svalbard area (mainly at Ny Ålesund at 76° Λ) together with simultaneous, coordinated measurements from east Greenland, the EISCAT radars as well as DMSP satellite-recordings, structures and dynamics of the dayside cleft and polar cap region have been obtained. This is an important prerequisite to the understanding of the physics of dayside boundary layers processes.

Several papers have been published, many lectures given and a NATO Advanced Workshop related to this program arranged. Possible generation mechanisms of dayside cusp/cleft auroras including magnetic merging, external pressure pulses, Kelvin-Helmholtz-instabilities, and dynamo processes by intruding plasma elements are discussed. Characteristics of boundary layer processes and their ionospheric effects are a major objective of these studies. The Fast Explorer project as well as the new EISCAT radar at Svalbard will give a new dimension to our studies of temporal/spatial structures of dayside auroral processes.

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CONTENTS

1. BACKGROUND INFORMATION

Svalbard is the Arctic archipelago between 10° and 35° East and 74° and 81° North. The geomagnetic latitude spans from approximately 71° to 77° North. The high geographic latitude at geomagnetic latitudes well above 70°, makes Svalbard a unique place for studies of dayside aurora within the cleft, cusp and polar cap, and processes related to magnetospheric boundaries. Its conjugacy to stations in Antarctica makes Svalbard even more attractive.

The observatories at Ny Ålesund and Longyearbyen are the master stations in the Svalbard network which also includes field stations at Hopen, Hornsund, Bjørnøya, Jan Mayen, and since October -92 also Danmarkshavn, Greenland. The latitude separation between neighbour stations ranges within 110-250 km. The core instruments are meridian scanning photometers, optical imagers at different wavelengths, magnetometers and riometers. Since December 1991 an advanced digital ionosonde together with satellite scintillation receivers have been installed at Ny Ålesund. The EISCAT VHF and UHF radars at Tromsø have been coordinated with our Svalbard observations in addition to simultaneous, overhead recordings by the DMSP satellites. The construction of the new EISCAT radar at Longyearbyen started in May 1993 and will be completed in the autumn of 1995. In December 1993 a new auroral TV-Station was installed at Ny Ålesund.

Based on extensive and diagnostic ground observations in the Svalbard region (mainly at Ny Ålesund at 76° Λ) simultaneous, coordinated measurements from Greenland and Heiss Island - spanning ~ 4 hours in magnetic local time, - together with the EISCAT radars as well as DMSP satellite-recordings, essential information on the dynamics of the dayside cusp/cleft and polar cap regions has been obtained. This is an important prerequisite to the understanding of the physics of the dayside boundary layers.

Several papers have been presented and many lectures given related to this program. Possible generation mechanisms of dayside cusp/cleft auroras including magnetic merging, external pressure pulses, Kelvin-Helmholtz-instabilities, and dynamo processes powered by intruding plasma elements are discussed. To determine the characteristic auroral signatures of these

boundary layer processes is a major objective of these studies.

OBSERVATIONS AND THE RESEARCH PROGRAMME AT SVALBARD DURING THIS REPORT PERIOD

The observation programme in this joint cooperation between Ionospheric Effects Division, at Phillips Laboratory, (Coordinator Dr. E. Weber), Hanscom AFB, Bedford, MA and The Group for Space Physics at the University of Oslo, is concentrated on the electrodynamics and spectral properties of the dayside cusp, cleft and cap auroras. The main measurements are carried out with multichannel, meridian scanning photometers and advanced, optical imagers at different wavelengths.

During the contract period the following "campaigns" - where our Svalbard optical observations have been of prime importance - have been carried out:

a. A special EISCAT selected program for comparing ion drifts and the dynamics of dayside aurora (Jan.-93 and Jan.-94).
b. EISCAT - common program (CP4); Dec. and Jan. 1992.
c. Selected event studies including coordinated observations from the satellites DMSP, F-7, 8, 9, 10, and 11. We have selected more than 10 very interesting cases for detailed cooperation.

The enclosed copy of the Observation Protocol (Appendix I) lists the most interesting dayside auroral events. Some of these data have already been studied in detail and compared with other relevant space and ground based observations (cf. Publication list at the end of this report). Our conclusion is quite clear, namely: Coordinated ground measurements and in-situ observations from satellites in polar orbit are essential for understanding solar wind - magnetosphere - ionosphere coupling.

The optical auroral data are extensively used as a basis for the study of the dynamics and fine structures of the magnetopause boundary layers. A wide range of spatial scales of optical events as well as their internal structure are observed. Of main importance in this respect is the location of the various optical events in relation to the major particle precipitation boundaries and the large-scale ionospheric ion drift pattern. A careful study of coordinated satellite and ground-based data is therefore required in order to reveal the more subtle signs of the boundary layers.

Coordinated ground- and satellite observations are required in order to study the connection between the dayside forms, the acceleration regions and the region of plasma entry. The problem of pulsed magnetopause reconnection, flux transfer events and their manifestations at different levels in the magnetosphere and in the ionosphere is still a central subject.

As seen from the enclosed list of publications and lectures given, the Group members have been very active during the report period. Ground based auroral structures and dynamics from Svalbard have been compared with simultaneous measurements of energetic electron and ion precipitation as well as horizontal plasma drifts. Brightening and movements (sunward and anti-sunward) of certain discrete auroral forms seem to be connected with external dynamic pressure variations, associated magnetopause perturbations and fundamental modes of magnetosphere - ionosphere coupling, such as kinetic Alfvén waves.

In May 1993 we arranged a new NATO Advanced Workshop close to Oslo when nearly 60 international scientists participated. The main subject for this workshop was Boundary Layer Processes and Their Ionospheric Effects. A Proceedings of the invited talks will be out in a few months.

A few other findings will be briefly summarized:
The observed north-westward motion of auroral forms in the prenoon sector is typical for periods of positive IMF B_Y, whereas auroral events associated with negative IMF B_Y are moving northeastward in the midday and early post-noon sector. These optical events mostly appear as a brightening of the 630.0 nm aurora near the poleward boundary of the persistent cleft/LLBL precipitation . This phenomenon is a characteristic feature of the near cusp region

during periods of expanded oval/enhanced polar cap convection.

Special attention has also been given to the height distribution of dayside auroras and the relation between cusp/cleft emissions and net downward energy flux. It is instructive to compare optical aurora and particle precipitation because these two quantities should be proportional, if the dayside aurora is caused by electron impact. The main findings for quiet events (i.e. the 630 nm emission dominate) indicate 1) that some dayside auroras are emitted at significantly higher altitudes than normally assumed, and 2) that both thermal electron excitation and dissociative recombination may be important additional excitation mechanisms for the red cusp/cleft aurora.

The question of signatures in the dayside aurora related to solar wind - magnetosphere coupling modes has been in focus in recent years. Auroral precipitation signatures of dayside magnetosphere boundary layers have been studied extensively by using data from polar orbiting satellites. Automatic classification schemes have been applied to the DMSP-precipitation data, in order to statistically identify the particle source regions, such as the central plasma sheet, the boundary plasma sheet, the low latitude boundary layer, the cusp, the plasma mantle and polar rain. However, our optical observations may be an alternative interpretations. Within a few years, we hope to have a statistical significant data base for identification of the different dayside regions based on their optical signatures. This data base will be extremely useful for understanding the boundary layer processes.

Several possible generation mechanisms for auroral forms, occurring near magnetic noon, during different IMF conditions are possible. These include magnetic merging poleward of the cusp, variations in the solar wind pressure, Kelvin-Helmholtz instabilities and dynamo processes in the low - and high-latitude boundary layers of the magnetosphere, powered by intruding plasma elements. Some detailed discussions are found in the recent Proceedings from the May 1993 NATO workshop (cf. Holtet and Egeland, 1994).

A class of dayside auroral forms is consistent with essential features of the predicted ionospheric signatures of sequences of transient and patchy magnetopause merging events. However, some features of the observations, such as the long decay phase sometimes

observed may not be easily explained by the presently available models. Due to the present limited understanding of ionosphere - magnetosphere field line mapping there is some uncertainty on whether auroral events, associated with "mantle" precipitation poleward of the continuous cleft arc, are coupled to the high-latitude boundary layer or the low-latitude boundary layer. This is a critical point for the identification of the solar wind - magnetosphere coupling mode involved, i.e. merging or viscous process. One of the most specific properties of the merging process is the associated zonal ionospheric ion drift related to the IMF B_Y polarity. The presently available data indicate that a similar motion pattern exists for the optical events. Thus, better statistics on the east-west motion of the auroral events in relation to IMF B_Y will be a crucial test of the present interpretation interms of magnetic merging.

PROGRAM FOR 1994/95

Even if this is The first Technical Report for Grant No AF 49620-92-J-0507, the cooperation with the Ionospheric Effects Division at Phillips Laboratory, Hanscom AFB, Mass. has a long history (cf. e.g. the reports under Grant NO AFOSR-90-0082) and we hope the joint cooperation will continue. During the January - 1993 campaign at Ny Ålesund, several scientists from Phillips Laboratory (headed by Dr. E.J. Weber and Mr. Jürgen Buchau) actively participated. Also during this campaign the continuous ground observations were closely coordinated with simultaneous EISCAT recordings as well as overhead, DMSP satellite measurements.

In January -94 the Oslo-group, in cooperation with University of Bergen, will launch a rocket from Andøya Rocket Range to study pulsating auroras. The in-situ measurements are carried out by several complementary diagnostics, including six separated photometers. A special campaign is planned in connection with this rocket launch and thanks to Dr. Weber two scientists from Phillips Laboratory participate in this rocket campaign with advanced optical TV-instruments.

This winter campaign at Svalbard has been extended to include nightside auroral phenomena inside the polar cap. In addition, coordination with the new, ionospheric satellite FREJA is also planned.

During the autumn of -92, we installed a multichannel, meridian scanning photometer at Danmarkshavn, Greenland. This is a high latitude Danish Auroral Station very conveniently located in relation to Ny Ålesund, and we now operate our instrumentation in Greenland and Svalbard in parallel.

Our graduate student Jøran Moen will defend his Ph.D. thesis which is based on optical auroral observations at Svalbard during the last three years on January 21., 1994.

A special auroral observation campaign is planned in Jan. 1995. Ground-based observations from Ny Ålesund, Svalbard and Greenland will be combined with a new American satellite, named FAST Explorer. This satellite will be launched into an elliptical orbit with apogee at ~4000 km. At this altitude the actual observations in e.g. the cusp/cleft region can be made with much better spatial/temporal resolution compared with the presently available DMSP data (800 km). This is very important in relation to the study of transient injection events and the related Birkeland current structures.

We are also continuously working to improve the observation techniques and the routines for data reduction. A combined hardware/software system for analysis of TV images has thus been developed. We are still working on a new data logging system with modem connection to our and other laboratories. This will provide more direct access to the optical and magnetic data. This modem should be in operation from next autumn.

During the winter 1991/92, an advanced digital ionosonde (with large antennas) together with satellite scintillation receivers were installed and are now in continuous operation at Ny Ålesund. Both these instruments come from The Ionospheric Effect Division at Phillips Laboratory, Hanscom AFB. Jürgen Buchau was responsible for the ionosonde while Santi Basu controls the scintillation measurements.

As the project scientist is responsible for arranging a workshop at the next IAGA meeting entitled "Magnetosheath, Magnetospause, Boundary Layers and Cusp", I hope that several papers related to our Svalbard project will be presented.

EXCHANGE OF SCIENTISTS BETWEEN THE TWO INSTITUTIONS

We have had a close contact with the program manager for this contract, Dr. Edward J. Weber, during the whole period. Dr. Weber and Mr. J. Buchau visited University of Oslo during Jan. 93. The death of Mr. J. Buchau was a big shock to us all and we certainly miss him. In his spirit we will continue this work.

The project scientist spent two weeks at Phillips Laboratory (December 1992). Dr. H. Carlson, the Deputy Chief Scientist at Ionospheric Effects Division, Hanscom AFB, visited us in Oslo in September 1993. Dr. W.F. Denig from the Space Plasma and Field Branch, Phillips Laboratory, spent two months (August and September -92) in our group working with the Svalbard data. This visit was a very important contribution to strengthening the cooperation between the two groups. One of the young members of our Group - research fellow Jøran Moen - spent one month (August 1992) at Ionospheric Effects Division, Phillips Laboratory, while Dr. B. Jacobsen visited the Space Plasma and Field Branch (Drs. W.F. Denig, W.J. Burke and N.C. Maynard) for two weeks in October 1993 and continued the coordinated Svalbard-DMSP data analysis.

CONCLUSION

The cooperation with the scientists at the Phillips Laboratory, Geophysics Directorate have been both fruitful and enjoyable. This is clearly demonstrated by our publication list for 1992 and 1993 (cf. pages 9-11). Without the financial support via this Grant it would not been possible for our Group to cover each winter period with continuous auroral observations at Svalbard, neither likely that we could have sent graduate students to the Phillips Laboratory.

The new Grant (F 49620-92-J-0507) will allow us to continue and hopefully extend the described cooperation. The recorded parameters at Svalbard should be of great importance for understanding the physics of the dayside ionosphere and the magnetospheric boundary layer processes. We should also learn more about the generation, characteristics and the drift of the polar cap F-region patches.

The planned satellite project FAST Explorer represents a new dimension to the ongoing active study of temporal/spatial structure of various boundary layer processes.

PUBLICATIONS/REPORTS

The following papers/reports, pertinent to this contract, have been published during the contract period:

1. Carlson, H. and A. Egeland; The Aurora and the Polar Ionosphere. Chapter 14 to a new textbook in Space Physics (Kivelson and Russell, eds.), Cambridge Press.

2. Denig, W.F., W.J. Burke, N.C. Maynard, F.J. Rich, B. Jacobsen, P.E. Sandholt, A. Egeland, S. Leontjev, and V.G. Vorobjev: Ionospheric signatures of dayside magnetospause transients: A case study using satellite and ground measurements, J. Geophys.Res. 98, 5969, 1993.

3. Egeland, A., W.J. Burke, N.C. Maynard, E.M. Basinska, J.A. Slavin, J.D. Winningham, and C.S. Deehr; Prenoon Ground and Satellite Observations near the Time of a Sudden Storm Commencement, J. Geophys. Res., in press, 1992.

4. Egeland, A., H.C. Carlson, W.F. Denig, K. Fukui, E. Weber: Day-side Auroral Signatures Based on Simultaneous, Coordinated Observations at Svalbard and Greenland, IEEE Transactions on Plasma Science; Third Special Issue, in press 1992.

5. Moen, J., W.J. Burke, and P.E. Sandholt: A rotating midday auroral event with northward IMF, J. Geophys. Res., 98, 13731, 1993.

6. Moen, J., P.E. Sandholt, M. Lockwood, A. Egeland, and K. Fukui, Multiple, discrete arcs on sunward convecting field lines in the 14 - 15 MLT region, J. Geophys. Res., in press, 1993.

7. Pudovkin, M.I., S.A. Zaitseva, P.E. Sandholt, and A. Egeland: Dynamics of aurora in the cusp region and characteristics of magnetic reconnection at the magnetospause, Planet. Space Sci., 40, 879, 1992.

8. Sandholt, P.E. and P.T. Newell: Ground and satellite observations of an auroral event at the cusp/cleft equatorward boundary, J. Geophys. Res., 97, 8685, 1992.

9. Sandholt, P.E., M. Lockwood, W.F. Denig, R.C. Elphic, and S. Leontjev: Dynamical auroral structure in the vicinity of the polar cusp: Multipoint observations during southward and northward IMF, Ann. Geophys., 10, 483, 1992.

10. Sandholt, P.E.: Dayside auroral activity and magnetospheric transient events, in European Space Agency Spec. Publ., Noordwijk, The Netherlands, 1992, ESA SP-335, pp. 83-88.

11. Sandholt, P.E., J. Moen and D. Opsvik, Periodic auroral events at the midday polar cap boundary: Implications for solar wind-magnetosphere coupling, Geophys. Res. Lett., 19, 1223-1226, 1992.

12. Sandholt, P.E., J. Moen, D. Opsvik, W.F. Denig and W.J. Burke, Auroral event sequence at the dayside polar cap boundary: Signature of time-varying solar wind - magnetos-phere - ionosphere coupling, Adv. Space. Res., 13, (4) 7, 1993.

13. Sandholt, P.E., J. Moen, A. Rudland, D. Opsvik, W.F. Denig, and T. Hansen, Auroral event sequences at the dayside polar cap boundary for positive and negative IMF B_Y, J. Geophys. Res., 98, 7737, 1993.

14. Sandholt, P.E., Magnetospause plasma transients: Mapping into the auroral ionosphere, IEEE Transactions on Plasma Science, 20, 715, 1992.

15. Sandholt P.E., Magnetospause plasma transients: Signatures in the auroral ionosphere, J. Atm. Terr. Phys., 55, 1699, 1993.

16. Farrugia, C.J., P.E. Sandholt and L. Burlaga, Auroral activity in the postnoon sector during interplanetary magnetic cloud passage with large negative B_Y: Interpretation in terms of combined viscous coupling and magnetic reconnection, J. Geophys. Res., submitted 1993.

17. Yagordkina, O.I., V.G. Vorobjev, S.V. Leontjev, P.E. Sandholt and A. Egeland, Bursts of geomagnetic pulsations and their relationship with dayside auroral forms, Planet. Space Sci., 40, 1303 - 1309, 1992.

18. Lockwood, M., H.C. Carlson Jr., and P.E. Sandholt, Implications of the altitude of transient 630-nm dayside auroral emissions, J. Geophys. Res., 98, 15571, 1993.

19. Sandholt, P.E. et al., cusp/cleft auroral activity in relation to solar wind dynamic pressure, IMFB_Z and B_Y, J. Geophys. Res., in press 1994.

20. Burke, W.J., B. Jacobsen, P.E. Sandholt, W.F. Denig, N.C. Maynard, and P.T. Newell, Optical signatures and sources of prenoon auroral precipitation, J. Geophys. Res, 98, 11,52¦-11,529, 1993.

21. Jacobsen, B., P.E. Sandholt, W.J. Burke, W.F. Denig, and N.C. Maynard, Optical signatures of prenoon auroral precipitation: Sources and responses to solar wind variations, submitted to the Journal of Geophysical Research, december 1993.

22. Holtet, J.A. and A. Egeland (eds.): Physical Signatures of Magnetospheric Boundary Layer Processes: (Proceedings from the NATO ARW at Sundvollen, Norway, May 9-14, 1993) Kleiwer Academic Publishers, Dordrecht. (in press)

CONFERENCE CONTRIBUTIONS AND LECTURES:

Lectures and papers based on the cusp/cleft/cap observations at Svalbard (pertinent to this contract) were presented at the following international meetings in 1993:

a) NATO ARW Physical Signatures of Magnetospheric Boundary Layer Processes, Sundvollen, Norway, May 9-14.

b) ESA PAC Meeting, Montreux, Switzerland, May 24-26.

c) 20 Annual European Meeting on Atmospheric Studies by Optical Methods, Apatity, Russia, 14-18 Sept.

d) 1993 Magnetopause Workshop, Fairbanks, Alaska, Sept. 20-23.

e) Cluster Ground-based WG Workshop, Didcot, U.K. Oct. 21-22.

f) Two papers at the IAGA meeting at Bueno Aires, Argentina, August.

g) The Oguti Symposium, Tokyo, Japan, June 1-3.

h) The Japanese-Norwegian Workshop, University of Tokyo, 7-8 October, 1993.

Appendix I

1992/93 Ny Ålesund Campaign

Days of good optical observing conditions:

Date	Observation interval	Interesting interval	Comments
Nov. 19, 1992	0800 - 1730 UT		Quiet day
Nov. 25, "	0440 - 1630		Active day
Nov. 26, "	0450 - 2010		Quiet day
Nov. 27, "	0435 - 1750		
Nov. 30, "	0435 - 1840		
Dec. 2, "	0435 - 1430		
Dec. 15, "	0620 - 2130		Active day
Dec. 17, " *	0500 - 1945	0720 - 1300 UT	Active day
Dec. 19, "	0500 - 1300	1020 - 1130	
Dec. 21, " *	0710 -	0830 - 1200	
Dec. 23, "		0900 - 1020, 1115 - 1200	
Jan. 10, 1993 *	0515 - 1430 UT	0515 - 1130	
Jan. 11, " *	0500 - 1320?	0840 - 1200	
Jan. 12, "	0500 - 1630	0645 (poleward motion of main arc)	
Jan. 13, "	0505 - 1400	1040 - 1300	
Jan. 14, "	0400 - 1600?	1000 - 1400	
Jan. 15, "	0510 - 1050		Some clouds
Jan. 16, "	1050 - 1430		Some clouds, nice aurora
Jan. 17, "	0505 - 1500	0900 - 1230	
Jan. 18, "	0500 - 1140		Haze and clouds, quiet day

* Very interesting day

IMP-8 data: Dec. 17, 1992 - Jan. 18, 1993.