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Executive Summary

In the second year as Principal Investigator for a CNSR-Transition Award contract between the Canadian Space Agency and the University of Saskatchewan, Dr. David Steele continued his research into polar upper atmospheric and ionospheric phenomena, primarily using digital images from a dual-imager CCD-based all-sky camera system, the Polar Camera. Three main classes of phenomena were studied, namely structured patches of ionization in the polar *F*-layer ionosphere, polar auroral arcs, and wavelike disturbances in the mesopause and lower thermosphere height range. Collaborative work continued, with Dr. P. Prikryl of the Communications Research Centre, on the origin and evolution of *F*-layer patches, and with Dr. R.A. Doe of SRI International, on tomographic studies of [OI] 630.0 nm emission in polar auroral arcs. A manuscript based on the latter work has been accepted for publication. A collaboration was initiated with Prof. L.L. Cogger of The University of Calgary on wavelike disturbances at the mesopause as reflected in images of OH Meinel (M) (6,2) band emission. This work was delayed by other activities but is now in progress. Most of the proposed studies were delayed significantly by two other activities.

Acting as Principal Investigator on behalf of a team comprising faculty and graduate students from several departments at the University of Saskatchewan, as well as senior personnel of SCI-TEC Instruments, Inc., Dr. Steele submitted a proposal to the Canadian Space Agency for the Small Payloads Program, entitled Nightsky Imaging Tomography Experiment to measure Ozone With starLight (NiteOwl).The students in physics, engineering, and management participated in the context of a graduate course designed to support the development of important career skills. Working under the overall leadership of Dr. Steele, the students, faculty members, and industrial partner staff developed a concept for a rocket experiment to monitor ozone through the stratosphere and upper troposphere at night, using a parachute-borne visible-wavelength slitless spectrograph to perform a self-calibrating stellar occultation experiment. Global Positioning System technology and an attitude video camera would provide precise position and attitude information, and spectral and tomographic analysis of the results would provide ozone distribution data with the spatial resolution and precision required to address current questions regarding ozone in the upper troposphere and lower stratosphere. Dr. Steele coordinated the activities of the eight working groups and led the Optics group, as well as handling external liaison with payload and launch contractors, and pursuing sources for key components. Dr. Steele developed valuable industrial contacts through his participation in the work, and could receive salary support as NiteOwl Principal Investigator if the proposal is funded.

During the summer months the Polar Camera was repaired, refurbished, and recalibrated. The CCD detector systems required routine maintenance, as well as repairs involving extensive trouble-shooting of image degradation problems. Non-imaging functions of the Polar Camera also required trouble-shooting in Saskatoon. Dr. Steele performed a complete laboratory recalibration of the filter passbands and transmissions before the system was returned to the AstrO Laboratory at Eureka, NWT for its fourth winter of observations.

1. Introduction

This report surveys the results of the second year of a CNSR-Transition Award contract let to the University of Saskatchewan, with Dr. D.P. Steele as Principal Investigator (P.I.). The statuses of the various scientific studies to be carried out under the terms of the contract are first reviewed, in three areas, namely *F*-layer patches, polar auroral arcs, and neutral atmosphere dynamics. The P.I.'s efforts to obtain permanent employment are then discussed, along with efforts to obtain alternate funding for the Polar Camera experiment. Finally, other activities generally related to the contract are discussed, namely the preparation of a proposal for the Small Payloads Program, and the repair, refurbishment, and recalibration of the Polar Camera. Publications and other scientific output are summarized in the final section.

Many of the studies discussed below have made little or no progress since the last annual report. This is largely due to two factors: the length of time required to restore the Polar Camera to proper working order and to recalibrate all optical channels, and the P.I.'s extensive participation in the preparation of a proposal in response to the Small Payloads Announcement of Opportunity. Both of these activities are discussed fully in §5 of this report.

2. Status of Proposed Studies

2.1 *F*-layer Patches and the Convection Electric Field

Polar Camera observations during southward IMF often show "patches" of enhanced [OI] 630.0 nm emission drifting generally antisunward over Eureka. The enhanced emission is the optical signature of *F*-layer ionization density enhancements which originate near the dayside cusp, while the patchy, segmented character of the enhancements is caused by dayside processes that are not yet fully understood. The following studies address various aspects of these *F*-layer patches.

2.1.1 Patch Signatures

The patch signature study was to begin on July 1, 1995, to produce an interim report on June 30, 1996, and to conclude with a submission of a scientific paper on June 30, 1997. Comparisons of ionosonde and imager data were reported for one event by Steele and Cogger[1], but no further work has been done on this topic with Polar Camera data.

2.1.2 Inferring Ionospheric Convection from Patch Observations

As amended in April 1996, the convection inference study was to begin on May 1, 1996, with an interim report due on December 31, 1996, and submission of a scientific paper on December 31, 1997. An initial step, in the form of a case study, was taken by Steele and Cogger[1], but the planned statistical survey has not been carried out.

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[1] Steele, D.P., and L.L. Cogger, Polar patches and the "tongue of ionization", **Radio Sci.**, **31**, 667-677, 1996.

2.1.3 IMF Control of Ionospheric Convection for Southward IMF

As amended in April 1996, the southward IMF convection study was to begin on September 1, 1996, with an interim report due on April 30, 1997, and submission of a scientific paper on January 31, 1998. The case study mentioned above made an initial step, in the form of examining the time delay for maximum cross-correlation between the IMF By component and the convection direction at the geomagnetic pole. However, the planned statistical survey has not been carried out.

2.1.4 Relation of Cusp Processes to Patch Formation

As amended in April 1996, the cusp processes and patch formation study was to begin January 1, 1997, *subject to suitable progress of the convection inference study*, with an interim report due August 31, 1997, and a final publication to be submitted March 31, 1998. The convection inference study has made no progress, as noted above. However, the P.I. has continued a collaboration, mentioned in the previous annual report, with Dr. P. Prikryl of the Communications Research Centre on a study that addresses this topic within the framework of a larger investigation. The original manuscript submitted to *Journal of Geophysical Research* was, on the suggestions of the referees, divided into two manuscripts, revised, and resubmitted, whereupon the two manuscripts were both rejected outright. Dr. Prikryl is expanding the study to include other events, in order to strengthen the case made, and the P.I. has identified two other events, on January 24 and November 13, 1996, that will be included in the ongoing study.

2.2 Polar Cap Auroras and Magnetic Field Topology

Polar arcs are ubiquitous at Eureka for northward IMF, appearing nearly every day in Polar Camera images down to a threshold of 30 R or less unless cloud or moonlight interfere. The following studies are intended to determine the characteristics of the arcs below the visual threshold, and to use them to trace shears in magnetospheric convection.

2.2.1 Characteristics of Subvisual Polar Cap Auroras

As amended in April 1996, the faint arc characteristics study was to conclude with the submission of a scientific paper on November 30, 1996. The intended work, *i.e.*, the compilation of statistics on arc spectral brightness, multiplicity, orientation, motion, and lifetime, as functions of time throughout the declining phase of the current solar cycle, has not been carried out.

In addition, the phenomenon of "polar diffuse aurora" noted in the previous annual report was to have been the topic of a study to be carried out by a graduate student under the joint supervision of Prof. D.J. McEwen and the P.I. NSERC awarded the P.I. a research grant of $20K over two years to support this study. However, the promising graduate student who had indicated an interest in coming to Saskatoon to work with Prof. McEwen decided instead to go to McGill University. No other student has been found to carry out this study, and therefore it has not gone forward.

However, as mentioned in previous quarterly reports, the P.I. is involved in a collaboration with U.S. scientists to apply tomographic techniques to two-station images of polar arcs, in order to determine the volume emission rate along the meridian joining the stations. Together with other observations from the ground (digital ionosonde, magnetometer, coherent- and incoherent-scatter radar) and from space (topside imaging, particle precipitation, electric and magnetic fields), such observations will support both local and global analyses of magnetosphere-ionosphere coupling and convection. A preliminary study of an arc observed from Resolute Bay, NWT and Eureka on February 17, 1996 has been submitted[2], and two candidate events from a campaign in December 1996 have been identified for further study. Figure 1 shows the evolution of the volume emission rate profile during the February 17, 1996 event, while Figure 2 shows a sequence of modelled energy deposition rate profiles matching the emission rate profiles. The rapid variation in the altitude and magnitude of the peak brightness indicate that magnetospheric processes such as changing electron energy distribution control the arc brightness, rather than thermospheric processes such as neutral heating or plasma diffusion and decay.

2.2.2 Polar Auroras and Magnetospheric Topology

As amended in April 1996, the polar auroras and magnetospheric topology study was to issue an interim report on February 28, 1997, and conclude with submission of a scientific manuscript on February 28, 1998. Apart from the collaborative work mentioned above, no further work has been done on this study since the last annual report.

2.2.3 Polar Auroras and Northward IMF Convection

The polar auroras and northward IMF convection study was to begin on April 1, 1996, with an interim report due March 31, 1997 and submission of a scientific manuscript on March 31, 1998. No work has been done on this study.

2.2.4 Single-Point Stereoscopy of Auroral Arcs

This study was undertaken in the fall of 1995 in collaboration with Dr. I. Oznovich, as reported in my previous annual report. It was planned to extend the study to additional cases, and to publish the results. This has not been done.

2.3 Neutral Atmospheric Dynamics

The Polar Camera is equipped with filters to monitor the R and Q branches of the OH Meinel (M) (6,2) band rovibrational spectrum, as well as the 557.7 nm O(^{1}S) emission. These two species emit in relatively narrow height ranges centered at roughly 87 km and 97 km, respectively, allowing the possibility of observing disturbances as they pass each of these heights, and relating their power

[2] Doe, R.A., J.D. Kelly, J.L. Semeter, and D.P. Steele, Tomographic reconstruction of 630.0 nm emission structure for a polar cap arc, submitted to *Geophysical Research Letters*, November 30, 1996.

spectral and amplitude characteristics to gain further information on the nature of the disturbances. The following study is intended to lay the groundwork for future studies using Polar Camera data.

2.3.1 Wave Spectrum at the Very High Latitude Mesopause

The complex quantity $\eta = (\Delta I/\bar{I})/(\Delta T/\bar{T})$, known as Krassovsky's[3] ratio, relates fractional changes in the brightness I of a nightglow emission and the temperature T of the emitting region. It is widely used to characterize mesopause and lower thermospheric disturbances observed by optical means, and theoretical predictions of Krassovsky's ratio have been made for OH airglow fluctuations driven by gravity waves, tides, and planetary waves[4]. Computation of η for a particular disturbance requires knowledge of the temperature in the disturbed region, and without this it is impossible to use the existing theory to determine the nature of the disturbance.

The distribution of intensity among the P, Q, and R branches of the OH M rovibrational band spectra varies with the rotational temperature of the molecule. The Polar Camera was designed to be able to monitor the rotational temperature by imaging both the R and Q branches of the (6,2) band. The R branch intensity increases with increasing temperature, while the Q branch relative intensity is fairly constant. A preliminary attempt to relate the branch intensity ratio to rotational temperature, which was exhibited during the annual review last March, showed encouraging similarities in shape with the rotational temperature measured to the north of Eureka by a Michelson interferometer observing the OH M (3,1) band.

For a rigorous derivation of rotational temperature from the Polar Camera OH images, it is necessary to compute synthetic spectra of the OH (6,2) band for a range of rotational temperatures. Using modelled atmospheric transmission coefficients for the individual rotational lines[5], and measured absolute transmission functions for the Polar Camera filters (see §5.2), it will be possible to determine the ratio of intensities measured by the two channels of the Polar Camera that corresponds to a given rotational temperature. Inverting this relation will allow the temperature to be inferred from the measured intensity ratio.

All of the required elements of the above algorithm are now in hand except the means of computing reliable synthetic spectra. Previous work has been based on the NETBANDS code made available some years ago to the aeronomy community by Prof. V. Degen of the University of Alaska.

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[3]Krassovsky, V.I., Infrasonic variations of OH emission in the upper atmosphere, **Ann. Geophys.**, **28**, 739-746, 1972.

[4]*E.g.*, Tarasick, D.W., and G.G. Shepherd, Effects of gravity waves on complex airglow chemistries, 2, OH emission, **J. Geophys. Res.**, **97**, 3195-3208, 1992; Walterscheid, R.L., and G. Schubert, A dynamical-chemical model of fluctuations in the OH airglow driven by migrating tides, stationary tides and planetary waves, **J. Geophys. Res.**, **100**, 17,443-17,450, 1995.

[5]Espy, P.J., and M.R. Hammond, Atmospheric transmission coefficients for hydroxyl rotational lines used in rotational temperature determinations, **J. Quant. Spectrosc. Radiat. Transfer**, **54**, 879-889, 1995.

This code predates some important recent work on OH[6], and is not considered reliable enough for the present purposes. Therefore, Prof. G.G. Sivjee of Embry Riddle Aeronautical University has been asked to share his IDL code to generate synthetic spectra of the (6,2) band.

In May 1996 the P.I. began a search for periods of high-quality OH data that showed quasi-periodic intensity modulations. A four-day period spanning December 22-25, 1994 was selected for study. A full correlation analysis[7] (FCA) method was applied to search the intensity-corrected OH R and Q branch images for propagating airglow modulations, and found a number of such events. In addition, during a working visit to the University of Calgary to collaborate with Prof. L.L. Cogger, a modified Lomb-Scargle periodogram[8] was applied to detrended time series of zenith brightnesses to detect periodicities in the data. Highly significant power was detected at a number of frequencies close to harmonics of the diurnal tide. In particular, a 42-hour period on Dec. 24-25 showed clear 6-hr modulation of the airglow brightnesses in both the R and Q branch channels. After the visit to Calgary, this work was set aside while the P.I. began the repair, refurbishment, and recalibration of the Polar Camera, which took much of the summer (see §5.2). A recent publication[9] shows other observations of 6-hr oscillations at Eureka in December 1993, and interprets them as a zonally symmetric tide. This interpretation strengthens the need to derive temperatures from the Polar Camera data in order to be able to compare the 6-hr oscillations observed in December 1994 with those from the previous year. As well, computation of Krassovsky's ratio η for the propagating modulations identified by the FCA should settle the question whether they are gravity waves or not.

3. Efforts to Obtain Permanent Employment

In May 1996 the P.I. applied for a faculty position in the Institute of Space and Atmospheric Studies at the University of Saskatchewan. The terms of reference for the position strongly favoured candidates who were Professional Engineers, or who could achieve that qualification relatively quickly. In support of his application for the position, and as suggested during the annual review last year, the P.I. applied to the Association of Professional Engineers of Saskatchewan (A.P.E.S.) for assessment of his academic credentials, preparatory to seeking certification as a Professional Engineer. This involved submitting curriculum descriptions of all relevant science and mathematics courses, and a description of the engineering work involved in all positions held by the P.I. since receiving his B.Sc. in 1982. The P.I. was not selected for the position, and was informed that the two

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[6]*E.g.*, Turnbull, D.N., and R.P. Lowe, New hydroxyl transition probabilities and their importance in airglow studies, **Planet. Space Sci.**, **37**, 723-738, 1989.

[7]Briggs, B.H., G.J. Phillips and D.J. Shinn, **Proc. Phys. Soc. Lond.**, **B63**, 106, 1950; Meek, C.E., An efficient method for analysing ionospheric drifts data, **J. Atmos. Terr. Phys.**, **42**, 835-839, 1980.

[8]Press, W.H., and G.B. Rybicki, Fast algorithm for spectral analysis of unevenly sampled data, **Ap. J.**, **338**, 277-280, 1989.

[9]Walterscheid, R.L., and G.G. Sivjee, Very high frequency tides observed in the airglow over Eureka (80°), **Geophys. Res. Lett.**, **23**, 3651-3654, 1996.

main disqualifications were (1) that he would have to do a great deal of preparatory work to qualify as a Professional Engineer, and (2) that he was perceived by the selection committee for the position as being unwilling to teach. The first is indisputable; the A.P.E.S. Academic Assessment committee determined that the P.I. would have to pass eight examinations in various areas of engineering practice to become an Engineer in Training, and would then have to spend a considerable further time in training before being eligible for certification as a Professional Engineer. The perception behind the second disqualification is inaccurate, in the view of the P.I.

The previous annual report contains a discussion of the circumstances under which the P.I. taught EP 324.3 during the Winter 1996 term. The P.I. threw himself enthusiastically into teaching, working hard to acquire a sufficient knowledge of the subject to be able to offer a course that would meet the needs of the students. In May 1996 he approached the Head of Physics and Engineering Physics to discuss the CSA's requirement that he restrict time spent teaching to 5% or less of his total working time. He expressed doubt that he could teach an adequate course in 8 hours per week, saying that he judged significant additional time would be required to prepare lectures that met the required standard for a second offering of the course. The P.I. at no time indicated an unwillingness to teach, saying only that he found himself unwilling to absent himself from his family for the routine 12-hour working days that would enable him to spend 12 hours per week on the course while staying within the 5% ceiling. The Head gave his opinion that the 5% number indicated the order of magnitude allowed, and it was agreed to maintain the *status quo*, namely that the P.I. would teach EP 324.3 in Winter 1997. After Dr. G. Hussey was appointed to the faculty position, he was given responsibility for the course, so the P.I. has had no formal teaching responsibilities during this year of the contract.

The P.I. has also applied for the faculty position in experimental space science at the University of Calgary.

Given that any future positions in the University of Saskatchewan Department of Physics and Engineering Physics will go to Professional Engineers, it seems unlikely that the P.I. will obtain a faculty position at the University of Saskatchewan. He has therefore taken steps to pursue a career in industry. He has accepted responsibility for Technology Transfer liaison between the Institute of Space and Atmospheric Studies and local high-technology companies, as a way of facilitating contacts with possible local employers. He has also asked the Vice-President of Research, Development, and Engineering at SCI-TEC Instruments, Inc., who is well connected to the high technology community in Canada, to pass on information on any opportunities for permanent employment he hears of.

4. Efforts to Obtain Alternate Equipment Funding

As mentioned in the previous annual report, the P.I. sought funding to maintain and operate the Polar Camera for the next four years from NSERC as part of his research grant application. A nominal amount was awarded for two years, which is sufficient for partial support of a graduate student, but inadequate to maintain the Polar Camera as well. Therefore, the Polar Camera maintenance and operation have been supported by the P.I.'s contract, with Prof. L.L. Cogger providing partial support for the detector system maintenance and repair in 1996.

5. Other Activities

5.1 Response to Small Payloads Announcement of Opportunity

It is acknowledged that the activity to be described in this section lay outside the terms of the P.I.'s contractual responsibilities, being unrelated to the studies described above, unlikely to lead directly to scientific publications, and similarly unlikely to lead directly to permanent employment. The P.I.'s participation could therefore be seen as inappropriate. The P.I. chose to participate because he saw in the activity significant opportunities for professional development in the areas of proposal development, collaboration and team-building, and expanding his knowledge of atmospheric science. In addition, the proposal offered the possibility of continued funding, and the opportunity to expand his contacts with local industry. Finally, the P.I. wished to contribute to enhancing the professional development and career options of the graduate student participants.

Therefore, in response to the Announcement of Opportunity for Small Payloads issued July 31, 1996, the P.I. led a cross-disciplinary team in preparing a proposal for a rocket experiment to measure stratospheric ozone at night by optical means. The Nightsky Imaging Tomography Experiment to measure Ozone With starLight (NiteOwl) submission team included faculty and graduate students from five departments in three Colleges of the University of Saskatchewan, and senior management, science, and engineering personnel of SCI-TEC Instruments, Inc. of Saskatoon. The experiment logo is shown in Figure 3.

The Executive Summary of the NiteOwl proposal is as follows:

> The NiteOwl experiment has as its primary objective to develop and validate an instrument capable of providing high resolution data on spatial variations of atmospheric ozone. The NiteOwl project is a joint venture of the University of Saskatchewan and SCI-TEC Instruments, Inc. of Saskatoon. A compact slitless imaging spectrograph will be developed for stellar occultation measurements with 3 - 5 nm spectral resolution at wavelengths from 400 to 780 nm. It will be used to measure column ozone concentrations during an Arctic winter night. Using visible wavelength absorption in the Chappuis bands provides ozone measurement capabilities in the scientifically important height range of the upper troposphere and lower stratosphere. Ozone observations in this region will provide data needed for both the analysis of global ozone trends and studies of local ozone transport and ozone production at tropospheric altitudes.
>
> The NiteOwl mission will be carried out from SpacePort Canada at Churchill, MB. The parachute-borne imaging spectrograph will be deployed from a rocket at apogee near 80 km, and will return to the ground while spinning slowly to scan the horizon. Global Positioning System technology will fix the payload position and an attitude video camera will provide accurate pointing information with high time resolution. Observations of unocculted stellar spectra will first be acquired above 60 km and used to normalize occulted spectra subsequently observed from within the ozone layer. In this way the NiteOwl instrument will be self-calibrating. The normalized wavelength profiles of absorption depth will be inverted to yield column concentrations of ozone, total molecular density, and possibly NO_2 and NO_3. Vertical and horizontal distributions of ozone at altitudes from 10 to 50 km will be determined from column ozone concentrations by tomographic reconstruction, with expected resolutions of 3 km vertically and 100 - 200 km horizontally.
>
> The NiteOwl project will provide an excellent training ground for young Canadian scientists and engineers, by virtue of the important ozone science objectives and the unique opportunities provided by

> a multidisciplinary project team working closely with an industrial partner. The synergy that has been developed between SCI-TEC Instruments, Inc. and several units of the University of Saskatchewan in preparing this proposal will lead to a successful outcome, both scientifically and from the broader economic perspective of enhanced opportunities for competition and employment.
>
> The NiteOwl project is intended to pave the way for a Canadian microsatellite-based system for global ozone monitoring. Such a system would be an efficient low-cost national initiative with key advantages over currently operating and proposed systems (*e.g.*, TOMS, GOMOS). It would provide important and timely information about the ozone layer to the Canadian public and the atmospheric science community, and could lead to the development of new industrial capabilities and wealth generation for SCI-TEC Instruments, Inc.

The submission team, possessing a wide range of applicable knowledge and experience but little prior involvement with space missions, was assembled to pursue a new approach to preparing proposals for space experiments, suggested by Dr. E. J. Llewellyn, which involved graduate students directly in every aspect of the proposal, from concept elaboration and mission planning to locating vendors and writing the actual proposal. The graduate students' participation was in the context of a special-topics graduate course in Physics, with the submission of a compliant proposal on time being the criterion on which a pass/fail decision was taken. Four of the students were M.Sc. candidates in the Department of Physics and Engineering Physics, one was a M.Sc. candidate in Mechanical Engineering, one was a Ph.D. candidate in Electrical Engineering, and the remaining two were MBA candidates in the College of Commerce. The latter two students participated for credit in an MBA special topics course, with preparation of the management plan required by the AO, and all related financial and organizational aspects of the proposal, being the work on which course credit was based. In addition, each of the students gained practical experience in proposing a new experiment and a "three-month interview" with SCI-TEC, as their personnel worked closely with the University members of the NiteOwl team on the science, engineering, management, and cost of the proposed experiment.

Prof. E.J. Llewellyn provided the idea for the experiment (together with Dr. R.L. Gattinger of NRC), invited candidate participants to two initial meetings, and served as the instructor of record for the Physics graduate course, as well as providing the required heritage in rocket and satellite experimentation. In early September the P.I. accepted the invitation to become the Principal Investigator on the proposal, and thereafter assumed full responsibility for the conduct of the proposal preparation. Eight working groups with overlapping membership were assembled to handle the following areas: Science, Optics, Mechanical, Electrical/GPS/Firmware, Onboard Data Handling, Ground-based Data Handling, Risk/Reliability, and Management Plan. Each group was led by a faculty member, but the work of the groups was fully collegial. Starting in many cases with the proverbial blank sheet of paper, each group first identified the important questions and then tried to answer them using the scientific and industrial literature, design studies, and mathematical modelling. Interactions between various areas required careful trade-offs; e.g., flight dynamics on the parachute (mechanical engineering) constrains the field of view and exposure time of the imager (optics), which in turn limit the sensitivity and achievable signal-to-noise ratio of the data (ground-based data handling).

In addition to exercising overall oversight for the proposal, and calling and chairing periodic plenary meetings, the P.I. led the Optics team which designed the slitless spectrograph, and handled

liaison with SCI-TEC and other external organizations, including Bristol Aerospace Limited, the payload contractor, and Akjuit Aerospace Inc., the launch contractor. This liaison included meeting, together with Prof. Llewellyn, with representatives of Bristol and Akjuit in Winnipeg in mid-November to present the experiment concept and requirements. The P.I. coordinated two weekend work sessions in late November during which the bulk of the first draft of the proposal was written. As the term drew to an end and students were occupied with other course responsibilities, the work of contacting vendors and locating appropriate components fell increasingly to the P.I. The final drafts of the proposal were prepared by the P.I. with the assistance of an editing team comprising four faculty members.

5.2 Polar Camera Repair, Refurbishment, and Recalibration

During the 1995-96 observing season at Eureka, several unexpected events occurred. Both imagers developed an apparent change in sensitivity that varied systematically with wavelength (see Figure 4). Defects in Polar Camera images that had appeared only infrequently during the first two winters began to occur more frequently, to the point of having a marked effect on the quality of the data. In addition, in mid-February 1996 two major problems essentially ended the acquisition of useful data for the winter. One of the two imagers, designated Camera 0, developed a fault which caused image data to be "stretched" and "wrapped around" before being written to image files, as illustrated in Figure 5. The filter wheel in the other imager stopped moving with the 820 nm background filter in the optics chain. Because of these faults, the entire experiment was packed and shipped to Saskatoon after the end of the observing season.

The image degradation suggested one or more faults in the imager detector systems, which had been in service for five years without maintenance. Therefore it was planned to return both systems to the manufacturer, Photometrics Inc. of Tucson, AZ, for preventive maintenance and repair. However, before this could be done, it was desired to acquire a "before" laboratory calibration of the imager sensitivities, for comparison with a similar calibration "after" the repairs had been made. Thus the filter wheel problem had to be solved first. The fault was located in a failed electromechanical relay, which was replaced. However, after this the temperatures and other housekeeping data returned from each of the imagers to the control computer were found to be invalid, and attempting to actuate the filter wheel motor would hang communications between the computer and the imager. Considerable time was spent tracking down this fault, which was finally traced to improperly seated IC's in the auxiliary function board on one camera. The "before" calibrations were finally taken, and the detector systems removed and shipped to Tucson.

While in Tucson, both CCD housings were repeatedly pumped and baked to remove residual absorbed gas, and recalibrated to verify linearity, dark current level, full well potential, quantization level, and cooling performance. A cooling problem with Camera 0 and a broken trace on Camera 1 were repaired, and the imaging problems with Camera 0 were eliminated by changing a jumper on the serial clock board. On their return, the detectors were reinstalled into the imagers, and another sensitivity calibration was taken.

It was also desirable to recalibrate the filters in the imager filter wheels, some of which were also five years old. While the detectors were in Tucson, the P.I. spent two weeks calibrating the

passbands and absolute transmissions of the filters, taking considerable pains to ensure the stability and appropriate *f*/# (*f*/4.6) of the incident light, the accuracy of the monochromator wavelength scale, the effectiveness of the blocking filters for rejecting higher orders, and the stability of the PMT high voltage and output. The filter transmissions were found, in each case, to be substantially less than the values that had been previously measured in Calgary, using the same technique, although the shapes of the passbands agreed acceptably with those measured earlier. After the imagers were reassembled, the P.I. remeasured the filter transmission curves with the filter wheels in place in the imagers, measuring the absolute transmission by comparing the signal with the filter in the optics chain with that measured with no filter in place. The absolute transmissions measured using this method agreed closely with those measured previously in Calgary by the same technique. The source of the discrepancy between the results of the two measurements techniques remains unknown at this writing, but the later, higher, filter transmissions are being used to reduce calibrations and field data from this winter.

5.3 Polar Camera Data Reduction and Archiving

Data reduction activities have continued at a moderate level, sufficient to keep up with the flow of data this winter, and to catch up with unreduced data from the previous winter, when the P.I.'s teaching activities interfered with normal reduction. All data acquired by the Polar Camera are reduced to yield intensity images, and data from a given UT day that show good viewing conditions and significant 630.0 nm emission (either aurora or *F*-layer patches) are archived. Quick-look plots of zenith brightnesses, system temperatures, and hourly images are generated and retained for all days of operation.

In August of 1996 the P.I. changed to a new method of archiving reduced data from the Polar Camera that appeared worth retaining. Reduced data were formerly archived onto 4-mm DAT as 'tar' archives. This was a convenient method of data storage and retrieval in the Unix environment at the University of Calgary, but is less so in the predominantly PC environment at the University of Saskatchewan. In early 1996 several research groups in the Institute of Space and Atmospheric Studies adopted CD-recordable (CD-R) as their archive medium, and since August the P.I. has been archiving processed data onto CD-R, using the facilities of Prof. G.J. Sofko's SuperDARN group. One CD can hold four days of fully reduced images, and image access time with a 4X CD-ROM is comparable with that from a hard disk drive for most purposes.

6. Concluding Remarks

Last year in this space, the P.I. stressed the need for each of the proposed research efforts to be (or become) fully collaborative in order to complete the work in the available time. Despite this, no major changes have taken place in the ensuing year, although certain constructive steps were taken (*e.g.*, see §§2.2.1 and 2.3.1). Because of the P.I.'s continued largely solitary approach to research, and the additional, arguably necessary or useful but so far scientifically unproductive, activities in which he engaged, the scientific output resulting from this year of his contract support is very limited. It may be argued that his participation in the NiteOwl proposal improved his chances of finding permanent employment in a position where he can contribute to the health of Canadian space science

and technology. However, the question remains whether these activities were sufficiently focussed upon locating permanent employment to satisfy the requirements of the contract.

7. Scientific Output

7.1 Manuscripts (accepted and submitted)

1. Steele, D.P., and L.L. Cogger, Polar patches and the "tongue of ionization", **Radio Sci.**, **31**, 667-677, 1996.

2. Doe, R.A., J.D. Kelly, J.L. Semeter, and D.P. Steele, Tomographic reconstruction of 630.0 nm emission structure for a polar cap arc, accepted for publication in *Geophysical Research Letters*, February 28, 1997.

7.2 Conference Presentations

1. Doe, R.A., J.D. Kelly, J.L. Semeter, D.P. Steele, Q. Wu, T.L. Killeen, and J. MacDougall, Multistation imaging of polar cap arcs, paper SA11B-10 presented at 1996 AGU Spring Meeting, Baltimore, MD, May 1996.

8. Figures

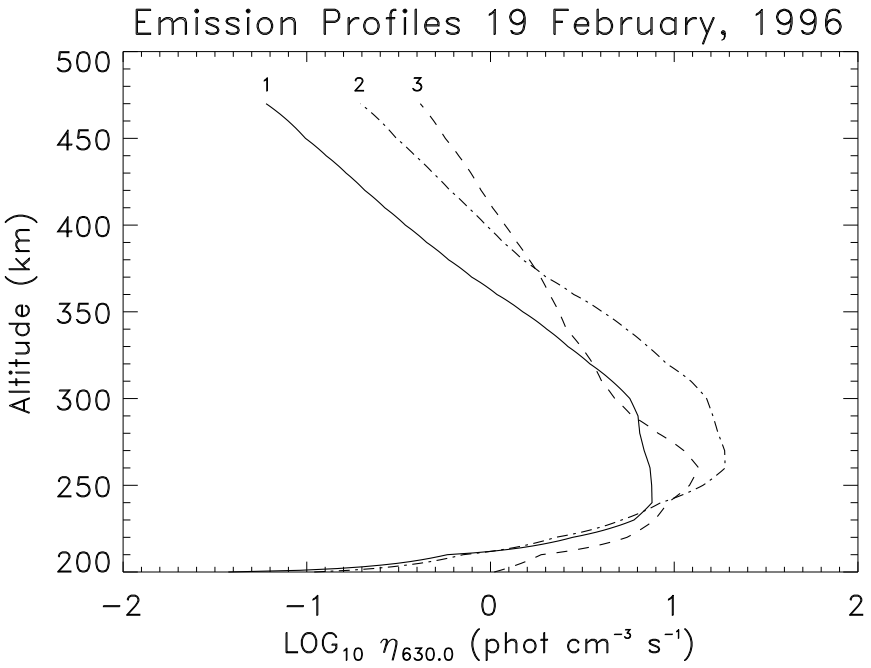

Figure 1: Three vertical profiles of 630.0 nm emission rate through the central core of the tomographically reconstructed arc.

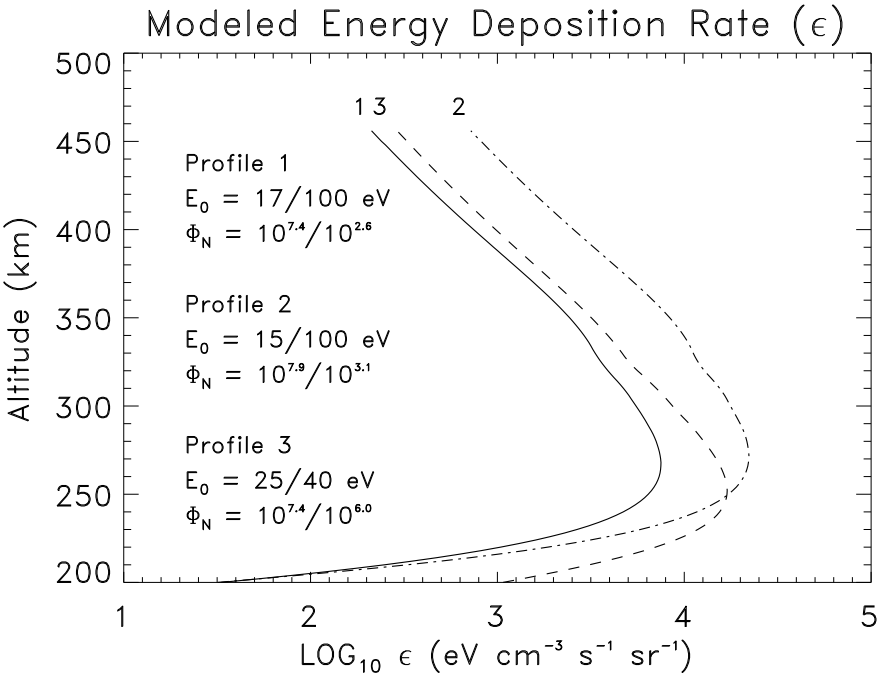

Figure 2: Model precipitating electron energy deposition profiles for the specified quasi-Maxwellian spectra, showing shapes similar to the 630.0 nm emission profiles above.

Figure 3: NiteOwl project logo.

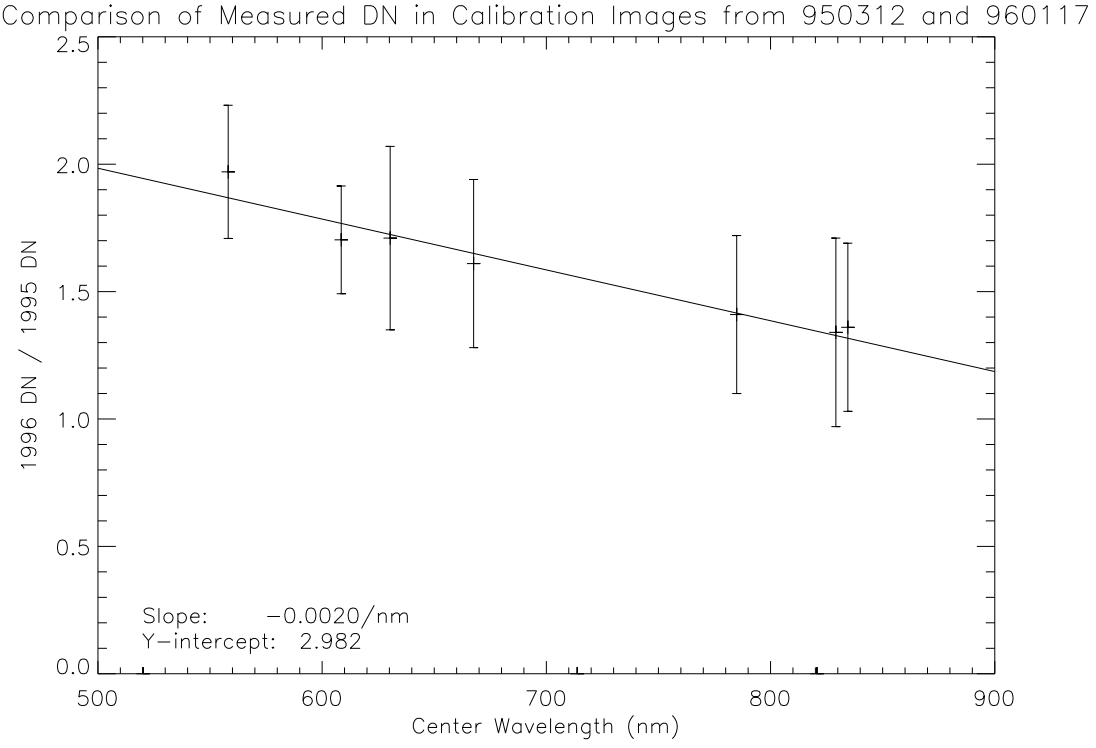

Figure 4: Ratio of 1995-96 and 1994-95 Polar Camera count rates when viewing calibration source.

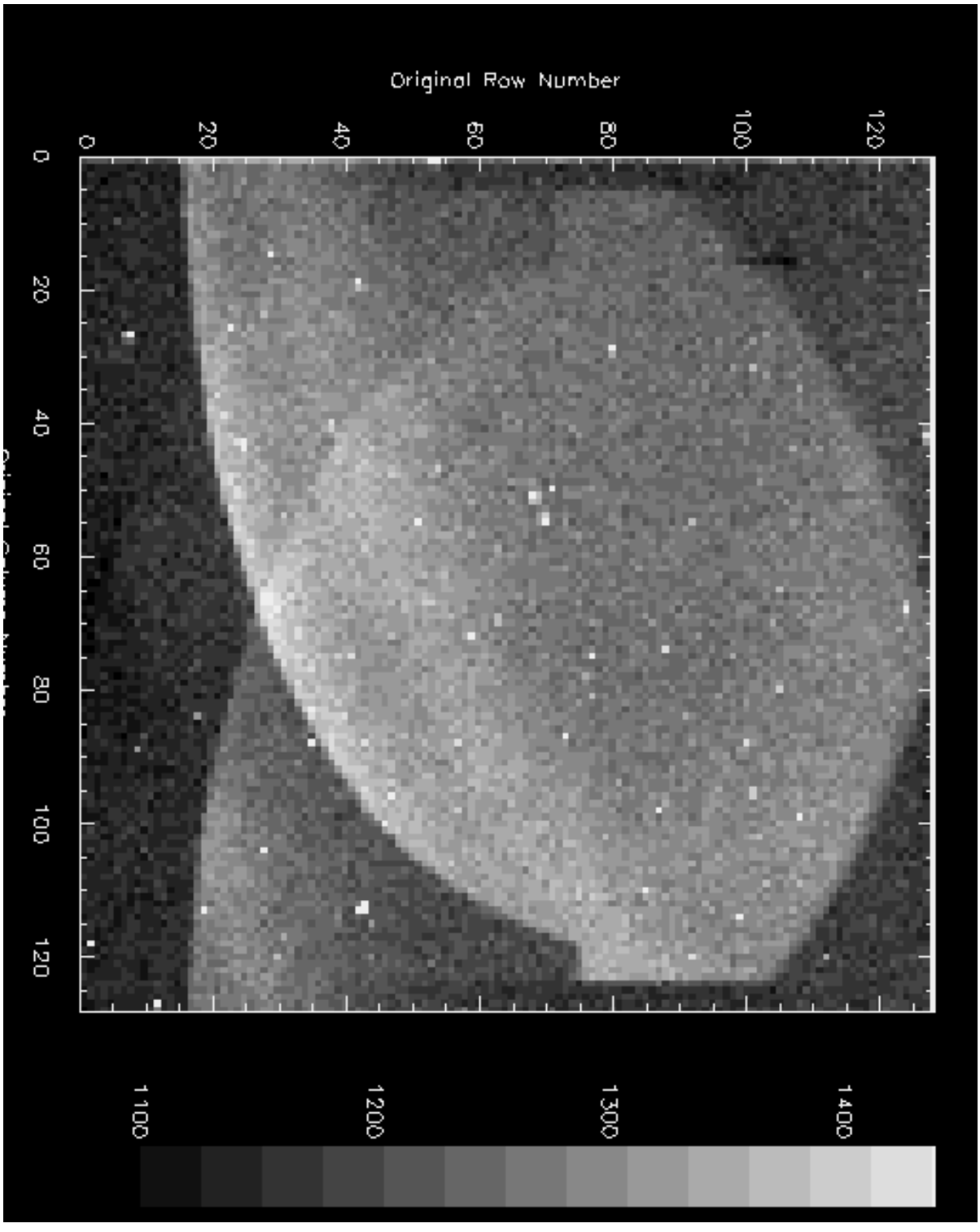

Figure 5: Sample image from Camera 0 of the Polar Camera, illustrating the "stretching" and "wrapping around" caused by the fault in the readout electronics.