ERRATUM

REPORT ON AERONOMY

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INTRODUCTION

The Canadian Geophysical Bulletin is an annual report of geophysical research and development in industry, government and universities in Canada. Its main purpose is to inform geophysicists in Canada and abroad of projects, developments and publications in their own and related areas. At the same time it provides an overview for those outside the earth science disciplines, of the extent and directions of scientific research activity in this subject, in Canada. Since 1974 the Bulletin has been published under the authority of the Canadian National Committee for the International Union of Geodesy and Geophysics.

The Mining Geophysics chapter, which was one of three new chapters introduced last year, is now expanded and it is expected that the Petroleum and Engineering chapters will also grow in the next few years to reflect the great importance of these areas. This year's Bulletin contains no Volcanology chapter as the format of that contribution is being modified to better serve the geoscience community. The Aeronomy section was compiled from material kindly provided by the Space Research Facilities Branch, but unfortunately contains a very incomplete bibliography.

Once again the editor wishes to thank his colleagues who have cooperated so readily in supplying the information which makes up the Bulletin, and in particular the compilers of the chapters for the time and effort which they have spent in collecting and organising the material included herein. It is also a pleasure to acknowledge the assistance of Ms. M.S. Bradfield and Ms. J. Breton in preparing the typescript.

The Bulletin is produced and distributed to readers inside and outside Canada by the Earth Physics Branch of the Department of Energy, Mines and Resources, at the request of the Canadian National Committee for the IUGG, and the Canadian Geoscience Council. Anyone wishing individual copies or back issues should request these from:

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M.E. Evans
Editor

INTRODUCTION

Le Bulletin canadien de géophysique est un rapport annuel des recherches et des développements géophysiques dans l'industrie, le gouvernement et les universités au Canada. Le but principal du Bulletin est d'informer les géophysiciens au Canada et à l'étranger des projets, des développements et des publications dans leurs propres disciplines en plus que les disciplines connexes. Pour ceux hors des disciplines des sciences de la terre, il fournit un exposé des étendues et des directions de la recherche scientifique à ce sujet au Canada. Depuis 1974, le Bulletin est publié sous la direction du Comité National du Canada de l'Union Géodésique et Géophysique Internationale.

Le chapitre sur l'exploitation minière, un des trois nouveaux chapitres présentés l'an dernier, a été augmenté et l'on envisage le développement des sections sur le pétrole et l'ingénierie, en raison de l'importance de ces domaines. Cette année, le Bulletin ne contient aucun chapitre sur la volcanologie, puisqu'on modifie actuellement la façon de présenter ce sujet, afin de mieux servir les géoscientifiques. La section sur l'aéronomie, rédigée à partir de matériel fourni par la Direction des installations de recherches spatiales, ne contient qu'une bibliographie très incomplète.

Encore, le rédacteur désire rendre un témoignage reconnaissant à ces collègues pour leurs coopérations en fournissant l'information nécessaire à la composition du Bulletin et en particulier aux compilateurs des chapitres pour le temps et effort dépensé à la collection et à l'organisation du matériel ci-inclus. Nous tenons aussi à remercier Md. M.S. Bradfield et Md. J. Breton pour la préparation des documents pour fins d'impression.

Le bulletin est publié et distribué aux lecteurs au Canada et à l'étranger par la Direction de la physique du globe du Ministère de l'Energie, des Mines et des Ressources à la demande du Comité National du Canada de l'Union Géodésique et Géophysique Internationale et le Conseil Canadien des Sciences de la Terre. Les demandes pour obtenir des exemplaires individuels et des éditions précédentes doivrent être acheminées au:

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M.E. Evans
Rédacteur en chef

CANADIAN GEOPHYSICAL BULLETIN
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ERRATUM

REPORT ON AERONOMY

Compiled by: M.E. Evans

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1. University of Alberta - Institute of Earth and Planetary Physics

This year marked the conclusions of the observational phase of the International Magnetospheric Study and the closure of the University of Alberta magnetometer array. The major effort of the group is now devoted to the analysis of the IMS data suite using data from the Alberta array in conjunction with ground based and satellite data from the many arrays and dedicated spacecraft which have operated during the IMS.

Perhaps one of the most interesting studies carried out in 1979 stemmed from the workshop in August 1978 held in Victoria, B.C. in which nine substorm specialists met to forge an acceptable operation definition for a magnetospheric substorm. Drs. Rostoker, Kawasaki and Kamide represented the University of Alberta and Dr. Rostoker was given responsibility of preparing the consensus definition for publication. This work has now been completed and has been accepted for publication in the Journal of Geophysical Research.

Dr. Rostoker has completed a study of the DPY current system which flows in the polar cleft and whose sense of current flow is known to depend on the polarity of the By component of the IMF. Using spacecraft and ground based magnetometer data from the auroral zone station of Fort Smith, it has been found that there is no change in the level of field-aligned current flow penetrating the auroral oval in the pre-noon sector. This has led to the conclusion that variations in the strength and polarity of the IMF By component do not modulate the strength of the magnetosphere-ionosphere current system but rather influence the direction in which the field-aligned current penetrating the ionosphere decides to diverge.

Dr. Rostoker and Dr. K. Kawasaki have completed their study of auroral arc brightenings associated with substorm onsets. The most interesting finding is that the pi 2 burst associated with the substorm onset occurs at the time of the formation of the auroral bulge (surge) and not at the time of the initial brightening of the auroral arcs. This result has important implications regarding the physical mechanism which initiates substorm expansions in that it suggests that a current limiting instability in the topside ionosphere may be operative.

Some considerable progress has been made in the understanding of pc 5 pulsations over the past year. In collaboration with Dr. Rostoker and Mr. G. Olchowy, Dr. Olson has shown that oscillations of the 30mHz riometer signal in the pc 4,5 range are ultimately connected to the magnetic micropulsations in that their phase variations across the morning sector behave precisely the same as the magnetic pulsation phase variations reported earlier by Olson and Rostoker. One important finding of this study is that the amplitude of the riometer oscillations depends on the general level of the background absorption. Little or no riometer oscillations are observed when the background level of the absorption is low, and the level of the riometer signal (δA) is proportional to the background absorption A as described by the relationship $\delta A = (0.22 \pm 0.04)A + 0.23$ where A and δA are in db. Following on the study of pc 4 giant pulsations by Rostoker, Lam and Olson, Drs. Rostoker and Olson have developed a model for pc micropulsations which accounts for the azimuthal characteristics of these pulsations which shows a considerable degree of organization. Working from the basic equations for a magnetized plasma, they have shown that the pc pulsations can be described by the same physical laws as those responsible for governing the oscillations of a two dimensional (rectangular) membrane. This treatment is an improvement on the older representation of micropulsations as oscillations of magnetic field lines, in which organized azimuthal behaviour was not considered.

In this past year Dr. Olson continued his studies of the dependence of pc micropulsation activity on the interplanetary plasma and field parameters together with colleagues at University of California (Los Angeles) and TRW Industries. In a recent study with E.W. Greenstadt, Dr. Olson has found a clear dependence of the level of pc 3,4 activity on the angle which the IMF makes with the solar ecliptic earth-sun axis. Based on this dependence they conclude that signals in the pc 3 spectral band can be used as a crude monitor of certain extremes of IMF orientation.

Dr. John Samson has spent a considerable amount of time over the last year developing multivariate time series analysis techniques, and he has collaborated with Dr. Olson in the application of these techniques to geomagnetic and riometer data. The techniques center around the separation of polarized signals from a background of random noise. In a study of the geometrical representation of polarization states, the emphasis was on the development of rapid computer algorithms to specify the polarization characteristics of n-dimensional waves of geophysical interest (e.g. plasma waves which are 6-dimensional with three electric and three magnetic field components). Measures of the degree of polarization can be constructed from the n scalar invariants of the n-square spectral matrix which specify the

second-order spectral characteristics of the waves. The measures constructed from the scalar invariants are extremely simple, require minimal computer time and lead directly to the representation of a wave as a vector in a complex space. In a second project, Dr. Samson has carried out a study of Stokes-vector representations of second and higher order stationary processes. In this work a generalization of the Stokes-parameters and Stokes-vectors for n-dimensional processes can be found by expanding the spectral matrix in a trace-orthogonal set of n-square Hermitian matrices. The basis-set for n=2 is trace-orthogonal, and Hermitian, allowing a direct generalization to trace-orthogonal sets for n=2. We have shown how these basis-sets can be constructed from the outer products of complete sets of orthonormal vectors in unitary spaces. The stokes-vector space is an n dimensional Euclidean space which gives objective representations of the information in second order processes of arbitrary randomness. The inner-product in the Stokes-vector space leads directly to a generalization of power-spectra in any "direction" in a real, unitary or non-pure state space. Dr. Samson and Dr. Olson have worked on the development of detectors for waveforms of arbitrary polarization with an emphasis on applications, particularly in detecting specific waves of interest in magnetospheric physics. Much of the mathematical detail follows closely the formalism of quantum-mechanics. The instrument or detector is represented by an n-square Hermitian matrix, and the operation on the information in the waves is given in terms of a full contraction of the outer product of the detector-matrix and the spectral matrix. Some work has been done in constructing non-diagonal matrices for the n-dimensional space in order to detect states in which the signal and noise are non-orthogonal. A number of inner-product representations of detectors in Stokes-vector spaces have also been developed. This formalism appears particularly promising, since various regions of the Stokes-vector space can be "masked" to eliminate the unwanted waves, or noise, in the data. The Stokes-vector representation of the detectors is now used routinely in analysing ULF magnetic pulsations recorded by the magnetometer chain of the University of Alberta. Finally, data adaptive polarization filters which suppress the signal and which have low correlations among the channels of multichannel data have been developed. These filters have been constructed in the frequency domain and use a measure of the degree of polarization in a unitary space in order to suppress any noise which appears unpolarized in the space. The filters can be used to enhance waveforms of arbitrary shape, and require almost no prior knowledge of the spectral content, or temporal features of the signal.

The techniques described above are presently being applied by Dr. Samson and Dr. Rostoker to geomagnetic micropulsations in the pc and pi classes. In a study of dayside pc 4,5 activity it has been found that substorm onsets in the midnight sector are accompanied within a few minutes by changes in the spectral content of the pc activity near noon at auroral oval latitudes. This study features the determination of the pc source regions with respect to the auroral electrojets, and promises to permit substorm identification in regions well removed from the locale of the instability (which is normally situated near midnight).

Drs. Samson and Rostoker are also exploring the generation of pi 2 micropulsation activity through the study of the spectral content of the pulsations and the evaluation of the region of their origin with respect to the Harang discontinuity. This study will encompass the IMS data suite for all relevant North American stations and should cast some light on the character of the eastward expansion of the substorm disturbed region following the onset of a magnetospheric substorm.

2. University of British Columbia - Department of Geophysics and Astronomy

Investigation of magnetic pulsations through multiple station observations has been in progress for the last four years. It began as a project of International Magnetospheric Study (IMS), involving three institutions, (UBC, University of Victoria and University of Tokyo).

During the IMS period, a chain of stations was set up in Manitoba, covering latitudes from subauroral to auroral regions. Recently, a chain of stations was established in B.C., at Victoria, Vancouver, Pemberton, Williams Lake, Prince George and Fort St. John. This chain covers latitudes from the plasma pause to subauroral regions, lower than the Manitoba Stations. Induction magnetometers were installed at each station of this B.C. chain and the data obtained are being used for investigation not only of magnetic pulsations but also of geomagnetic induced currents in power transmission systems as described later.

A digital processing system has been developed which makes it possible to compare the data from different stations with much more reliable time information. Also, efficient programs to compute cross correlations and spectra have been developed. They are being applied to a relatively weak Pi C event recorded at a chain of stations in Manitoba in September, 1976. A preliminary result suggests that weak Pi C signals travel towards the equator opposite in sense to strong Pi C's.

Investigation of geomagnetic induced currents in power transmission systems (abbrev. with GIC's) has been in progress, in cooperation with the University of Victoria and B.C. Hydro. Hall effect transducers were installed at two B.C. Hydro substations, one at Williston near Prince George and the other at Telkwa near Smithers. They are both on the 500 kv power line connecting Prince George and Skeena, the northernmost major power line in B.C. stretching in the E-W direction. The transducers measure currents flowing between the neutral point of the power transformer and the ground. The measurements were carried out for a two week period during last February and a two month period in late July and August. During the latter period, fluctuations in line current at 60 Hz, 120 Hz and 180 Hz as seen by a current transformer were also recorded at Williston. During the same period, telluric currents were measured at the Prince George Airport, a few miles away from the Williston substation.

Comparison of Williston GIC's with Prince George geomagnetic variations revealed a striking similarity between GIC fluctuations and geomagnetic variations on the N-S component. Telkwa GIC's and Williston GIC's are also

similar in general. A quantitative analysis is under way to find dependence of intensity of harmonic currents on SIC. A theory of generation of excessive harmonic currents has been worked out. Radiation of power harmonics has been confirmed through observation using a VLF receiver. Enhancement in power harmonic radiation has been found to be concurrent with magnetic pulsations.

3. University of Calgary - Department of Physics

(a) X-Ray Astronomy

Balloon Observation of high energy x-rays ($>$20 KeV)

Balloon-borne payloads, particularly at low latitudes (where the background is low) are quite useful for the study of cosmic x-rays above $\sim$20 KeV. Our x-ray payload consists of four NaI (Tl) - CsI (Na) phoswiches with graded shield collimators (square 8° x 8° FWHM, orientator, inclination 19°). The scientific objectives are related to sources HER X-1, CYG X-1 and CYG X-3. The payload, $\sim$190 kg (gross payload $\sim$ 688 kg) was successfully launched from Hyderabad, India at 22-45 LT on April 21, 1979, using a 5.6 million cubic feet balloon. It was a rough launch which resulted in a 6" x 6" tear in the balloon above the reefing sleeve that was discovered after filling. It was patched up and reached an altitude of 39.5 km, with a flight of 2.5 hours. There was a malfunction in the orienter, presumably due to the rough launch. The payload was cut off and recovered. It is now functioning and available for the next launch. The earlier flight on December 16, 1978, was successfully launched at 19-25 LT. Objectives were Crab Nebula and CG195+4. The balloon reached an altitude of 39 km and the flight lasted 4.25 hrs., with the instruments and balloon performing perfectly. Computer software had to be developed for analysis of data. Problems were encountered but these have been resolved and now the data are ready for reduction and analysis. The project is in collaboration with Tata Institute of Fundamental Research, Bombay, India. The collaborators are Professor S. Naranan and B.V. Sreekantan (Director) and the x-ray astronomy group.

Guest Observer Program on x-ray astronomy satellite (HEAO-1)

The identification of HB3 as a soft x-ray source resulted from the U of C - Caltech collaboration studying the data from the low energy detectors of Caltech on HEAO-1 (0.3 - 2.2 KeV). The spectral data have been fitted to a hydrogen thermal Bremsstrahlung model and the physical parameters of the supernova estimated. Upper limits to x-ray flux and luminosity of SN 3C58 have been derived. The results are appearing in a paper in the Astro-physical Journal. Authors are C.M.F. Galas, I.R. Tuohy and C.P. Garmire (Caltech). C.M.F. Galas is currently working on his Ph.D. thesis with Venkatesan.

Guest Observer Program, Einstein Satellite (HEAO-2)

Two proposals were submitted to NASA for Guest Observer Program. Proposal 1 was to obtain surface brightness distribution of x-rays from

HB3 with 3' resolution using Einstein (HEAO-2) detector IPC. One observation has alredy been completed and the data are under analysis. An abstract has been submitted for the upcoming meeting of High Energy Astrophysics Division of the American Astronomical Society in June, 1980. Proposal 2 was to obtain high resolution spectral measurement of x-ray emitting region(s) of HB3 using Einstein (HEAO-2) detector SSS. Unfortunately there are no hot spots, as became clear from first observation. SSS is also out of commission now. One more observation of the source using IPC detector is now planned. Collaborators are Knox Long, Columbia University and S. Naranan, TIFR, Bombay.

(b) Solar Terrestrial Relations

Auroral X-Rays

The auroral program has been pursued at the University of Calgary for the past decade. This has resulted in a number of publications and student theses. The two areas of primary interest at present are (1) Pulsating Aurora and (2) Auroral X-Rays arising from electron precipitation at sub-auroral latitudes (L = 4) connected with plasmapause. Both rocket and balloon-borne payloads have been used. In the former, a payload consisting of NaI crystal with photomultiplier and associated circuits is boosted to $\sim$65-70 km by a Black Brant VI rocket and the ejected payload comes down under parachute making measurements at altitudes above those obtained by balloon-borne payloads. The results of the past three rocket launches including the latest (February 27, 1978) have been analysed. The results are discussed in terms of the currently available theoretical models. The resulting paper is due to appear in the Journal of Geophysical Research.

Data from two other balloon flights - October 11, 1977 from Cold Lake, Alberta and August 28, 1978 from Roberval, Quebec, have been reduced, partial analyses completed, and papers presented at a Conference. Further work is proceeding on both of them. The research programs involving balloons and rockets have been supported by SRFB/NRC, Ottawa.

Two auroral x-ray payloads are currently being built. These are to be launched in January 1980 from La Ronge, Sask. in conjunction with the Pulsating Aurora Campaign. There will be a number of ground-based observations of auroral emissions including the closed circuit TV camera system of Oguti, from Japan. Comparative study of Bremsstrahlung x-rays and optical emissions would enable one to explore the correlations that possibly exist between the low energy and high energy primary electrons which are responsible for the two phenomena.

Cosmic Ray Intensity Variations

Neutron Monitor and Pioneer 10 Data: Comparison of data from the neutron monitor at Sulphur Mountain ($E > 400$ MeV) and from Pioneer 10 data (detector C, $E \gtrsim 80$ MeV) over the period 1972-77 has shown the

presence of high energy Jovian electrons in the interplanetary medium contributing to detector C counting rates. The work also deals with the relative responses of the low and high energy detectors in terms of long-term variation of galactic cosmic ray intensity. The results are to appear in the Journal of Geophysical Research. Collaborators are J.A. Van Allen (Iowa) and S.P. Agrawal (NRC Ottawa).

Solar Particle Events: Study of some thirty ground level events during the eleven-year cycle resulted in three events which have comparable characteristics, although occurring at different levels of the eleven-year solar cycle. This enables us to discuss the solar modulation region. (A paper has been presented at the International Cosmic Ray Conference, Japan, August, 1979.) Collaborators are D. Venkatesan and T. Mathews.

Solar Polar Coronal Holes: The importance of these has emerged from a study of the asymmetry of the solar polar coronal holes in the two hemispheres and the (N-S) asymmetry in cosmic ray intensity as registered by two detectors essentially scanning in directions perpendicular to the ecliptic plane. The data from the polar stations, Thule and McMurdo, have been used. This was carried out during the Skylab period for which coronal hole areas are available for only five solar rotations. The above results have been investigated for the years 1973-74 using the ground-based observations of K-coronal emission, since it has been established that regions of weak emission as observed during Skylab period clearly demonstrate the important role played by solar polar coronal holes on cosmic ray modulation processes. A detailed paper has been submitted to the Journal of Geophysical Research (October, 1979). Collaborators are L.J. Lanzerotti, Bell Labs, N.J.; S.P. Agrawal, NRC, Ottawa; and R.T. Hansen, NCAR, Boulder, Colorado.

(c) Solar Far Infrared Astronomy

As part of the overall programme of far infrared solar astronomy, a multichannel photometer was flown on the NASA Lear Jet Observatory during the February 26, 1979, total solar eclipse across North America. This flight provided a unique opportunity to observe the sun's extreme limb to high angular resolution at a wavelength which is totally absorbed by the earth's lower atmosphere. Diffraction limitations are severe at these long wavelengths for even the largest telescopes but are circumvented by the eclipse approach. The results from one channel at a wavelength of about 400μm indicates that the sun does not exhibit the limb brightening expected from simple theoretical considerations, demonstrating that, even at the source height in the low chromosphere for this wavelength, the sun is inhomogeneous. Furthermore, this data showed no evidence for the intense limb spike seen in the only other equivalent aircraft experiment during the African eclipse from the Concorde aircraft in 1973. It is hoped to repeat this experiment in August 1980 during the annular eclipse over South America.

The balloon-borne 20 cm solar telescope has been completely redesigned following its last descent in Texas in which it was extensively damaged, and will be flown again in 1980 to measure the absolute solar spectrum at submillimetre wavelengths using a Michelson interferometer and inflight calibration sources.

(d) Astronomy

In addition to ground-based astronomy carried out at the Rothney Astrophysical Observatory at Priddis, Alberta, at the Dominion Astrophysical Observatory, Victoria, and with the Infrared Telescope at the University of Minnesota - U.C.S.D. Mt. Lemmon Observatory (the latter with T.A. Clark), Milone continued a collaboration with Olar Moe (University of Oslo, Norway) on solar UV limb darkening using data from NRL's S082B experiment aboard Skylab.

(e) Balloon-Borne Far Infrared Stratospheric Studies

The stratospheric research programme, concerned with the detection by far infrared absorption and emission spectroscopy of minor constituents at balloon altitudes, continued in 1979 with both the analysis of data from previous flights and the flight of new instrumentation.

Emission spectra taken on two balloon flights at different altitudes in 1976 with a high-resolution Michelson interferometer from Yorkton, Saskatchewan, have been carefully analysed over the spectral range 30 to 110 cm^{-1} to yield values for H_2O and O_3 column densities above 24.5 and 32.5 km which are in close agreement with those measured by other techniques. These spectra are dominated by lines from H_2O and Q branches of O_3 but a series of magnetic dipole lines of O_2, for which the high column density is sufficient to offset the extremely weak line strengths, is also easily detectable. Measurements of minor constituent column densities by the far infrared technique have depended upon these lines for in-flight calibration. However, knowledge of the line strengths for these weak transitions is poor, and no laboratory measurements have been made for many of the resultant lines. The present stratospheric spectra have been used to provide line strength values for these O_2 lines.

Detailed calculations of line positions and strengths for the pure rotational spectrum of OH have recently been carried out for comparison with observed spectra and tentative identification of several of these lines has been made.

The detection of weak lines from other minor constituents such as N_2O, HNO_3, SO_2, NO and CO is expected to be very difficult because of a rich field of weak O_3 lines which blanket the spectral region of interest. Tentative identification has been made of lines of HCl and a Q branch of NO_2 but the level of detectability is severely limited by detector sensitivity and the limit upon spectral resolution imposed by diffraction at these long wavelengths.

A successful flight of an improved Michelson interferometer equipped with both wide and narrow angle limb-scanning capability was made in August, 1979, from Space Research Facility, Gimli, in which high-resolution emission spectra were obtained over a range of elevation angles for day and night time conditions and through the sunset period. Analyses of the data is progressing slowly because of the need to reprogramme upon the acquisition of a new computer at Calgary but initial indications are that the spectra will be of good quality and high resolution.

Stratospheric absorption spectra taken during a successful flight of the balloon-borne solar telescope from Texas in June, 1978, have been analysed in detail to provide column densities of H_2O and O_2 to high precision by a "curve-of-growth" method. These results are independent of the O_2 line strength uncertainties. This data demonstrated the distinct advantages of absorption spectroscopy in providing solar spectra of high signal-to-noise ratio for narrow-beam paths through the atmosphere, a situation difficult to achieve by emission spectroscopy because of the severe diffraction at these long wavelengths. Data transmission problems limited the attainable resolution, but inflight calibration methods were tested in readiness for absolute solar spectrophotometry on projected flights of this instrumentation in 1980.

(f) Plasma Physics

Michael Schroeder and Ranga Sreenivasan are investigating the stability of a positive column sustaining a current under the most general conditions using a rigorous test due to Routh and Hurwitz generalised to complex coefficients.

The topic has direct applications to the heating of plasmas in Tokomaks with neutral beam or electron beam injection as well as the so-called formation of double layers of consequence to magnetospheric and auroral physics. Preliminary results indicate excellent agreement between predictions of this theory and experimental results.

(g) ISIS Group

Analysis of data from the dual wavelength (5577/3914Å) scanning auroral photometer on the ISIS-2 satellite continues as a major activity of the group. With the completion of Syed Ismail's thesis on polar cap aurora and airglow and further studies of cleft aurora and midlatitude airglow, the group is putting more emphasis on a detailed study of spectral intensity ratios around the auroral oval as they relate to specific auroral patterns.

We have also been using the ISIS-2 airglow data base to study temporal and spatial variations in both the E-region and F-region components of 5577Å airglow. Having identified characteristic variations, we are now attempting to relate these to photochemical and dynamical processes. Rob Elphinstone and Neeta Majmudar are presently assisting in this research.

During the coming year, ground-based monochromatic imaging will also be used to study the above effects. Steve Babey's channel plate intensified/CCD imaging system will undergo its first field trials early in 1980, probably at La Ronge in conjunction with the Pulsating Aurora campaign. We are also preparing to assist with the development of a CCD imager for Dr. Shepherd's WAMDII instrument for the Space Shuttle. The CCD work is being carried out in collaboration with J. Haslett and B. Hriskevich in the Dept. of Electrical Engineering.

Our involvement in the NASA Galileo mission Imaging Team has provided useful experience in the area of CCD imaging technology. More recently the need to develop a data analysis plan for Galileo, together with our experience with the ISIS data, has led to a concept for a novel image processing and display system which we hope to see developed at Calgary.

4. Energy, Mines and Resources - Earth Physics Branch

(a) Magnetic Stations

The Division of Geomagnetism continued to operate 11 magnetic observatories, 2 magnetic variations stations with limited absolute control and 8 standard variation stations. The observatories are: Resolute Bay, Mould Bay, Cambridge Bay, Baker Lake, Churchill, Great Whale River, Yellowknife, Meanook, St. John's, Ottawa and Victoria and those with limited absolute control are Alert and Whiteshell. The IMS variation stations are: Pelly Bay*, Rankin Inlet*, Eskimo Point*, Back*, Gillam*, Island Lake*, Thompson and Ft. Severn. A catalogue has been prepared which lists the geographic and geomagnetic locations of these stations, their recording intervals and types of recorders and the cost and availability of these data. Digital and analogue data (magnetograms) are available for all stations. Real-time data from the 6 variation stations indicated with an * are available the following UT day from the U.S. Space Environment Laboratory in Boulder, Colorado. A four-week forecast of magnetic activity is available from the Ottawa Magnetic Observatory on request. An induction magnetometer for Pcl studies was operated at Ottawa.

(b) Auroral Currents and Instabilities in the Vicinity of Arcs

Detailed analysis was continued of the coordinated ground-based and rocket-borne observations across two bright arcs to determine the currents in the arcs and adjacent diffuse regions. The rocket was launched southward from Ft. Churchill on 28 February, 1974 along the Churchill chain of magnetic stations and was nearly coincident with an ISIS II pass. Refined ionospheric models were calculated from the rocket-borne energetic particle and plasma observations and the currents were determined from Ohm's law from the electric field observations. This model was iterated until its magnetic field compared with the magnetic field perturbations observed at the ground-based stations and along the rocket trajectory. Intense currents flowed northeastward on

the poleward edge of the northern arc and southeastward on the equatorial edge of the southern arc. The magnetic fields of these currents nearly cancelled and they were not apparent in the ground-based magnetic observations. Large field-aligned currents ($\sim 130 \mu A/m^2$) which exceeded the topside critical current ($\sim 20 \mu A/m^2$), flowed outward above the arcs. The electric field in the northern arc was periodic and appeared to be related to oscillations in the field-aligned currents and in the aurora.

(c) Joule Heating in the Polar Cap, Cleft and Auroral Zones

The Joule heating of the upper atmosphere in the polar cap, cleft and auroral zones is being investigated during quiet and disturbed times. The heating rate is calculated from ionospheric models and electric field observations in these regions and will be compared with the corresponding magnetic disturbances and other atmospheric parameters.

5. Herzberg Institute of Astrophysics, NRC

(a) Auroral Spectra and Photometry

A campaign to observe the 1.0 to 1.6 μm IR auroral spectrum was carried out in February 1979. Good interferograms were obtained from intense aurora by means of a 2-inch Michelson system constructed by BOMEM Inc. and kindly loaned to us by DREV. These interferograms have been transformed, averaged and corrected for night-glow emissions to provide a very satisfactory auroral spectrum at about 10Å resolution. This is now being matched to synthetic spectra and will extend our quantitative spectral atlas to 16000 Å.

Preparations are under way for the pulsating aurora campaign in 1980. An ISIT TV system acquired by SRFB is being tested and will be set up as an all-sky system having a good capability for quantitative studies over a wide range of auroral intensities. A multi-channel zenith photometer with microprocessor control is being constructed for the study of forbidden emissions in pulsating aurora.

The 12-inch Hβ photometer has been operating at our station near Pakenham, Ontario over the past 12 months and some interesting events have been recorded this winter.

(b) IMS Project

The analysis of the data from the meridian chain of scanning photometers is proceeding. Merged data sets (geomagnetic latitude vs. time) have been plotted for 20 nights from the 1978 campaign. From these a set of well defined substorms have been identified and an attempt is being made to refine earlier schemes for the behaviour of proton aurora in magnetospheric substorms.

Latitude profiles and longitude sectors of current systems associated with the selected substorms are being determined. This will permit comparison of the merged latitude profiles of the auroral emissions with the current systems and make it possible to establish where each profile is in relation to the east and west boundaries of the substorm.

(c) Rocket Photometry

Photometers flown on AMF-NVB-03 provided sufficient data to enable the shape and position of the O_2 Atm (0,0) nightglow layer to be determined.

Interesting data were obtained during a test of the AAF-NVB-06 electron gun payload in the vacuum chamber at the Johnson Space Center. Some of the results have been submitted for publication. The payload is scheduled to be flown in December 1979.

Additional flights this winter will occur in connection with the pulsating aurora campaign and an ion depletion experiment (Waterhole).

(d) Rocket Measurements of Auroral Plasma

Plasma probes were employed on the AAF-NVB-06 electron gun payload test in the Johnson Space Flight Center vacuum chamber. Data obtained during the test led to some modifications in the experiment which will improve the operation during the actual flight in December 1979.

On 26 February 1979, a multiple probe experiment was flown into the total solar eclipse from Red Lake, Ontario. Good data were obtained in the D-region and lower E-region of the ionosphere. An intense geomagnetic storm and particle precipitation which were occurring on eclipse day will make it very difficult to resolve eclipse effect.

Experiments are being readied for flight during the coming winter. These include AAF-NVB-06, ADD-VA-48, ADD-VA-50/52 (pulsating aurora campaign), AAF-1VB-36, and AAF-NVB-07 (Waterhole).

A probe experiment has been developed for flight on the Firewheel satellite which is scheduled for a spring 1980 launch.

(e) Dayside Aurora

Quick look plots for all 1977 (and 1974) Cape Parry data are now available. A detailed investigation is in progress of the burst-like emissions in the early afternoon and of possible correlations between large scale cleft motions and substorm parameters and interplanetary field changes. It appears that there is no energetic precipitation at noon giving rise to burstlike emissions at 5577 Å. However, the onset of these events closely coincides with the cutoff of the observation period due to scattered sunlight.

(f) Radio Aurora

We have just begun a study of 50 MHz radio aurora occurring at relatively high latitudes and aspect angles. It is hoped to shed more light on the following:

The nature of high aspect angle radio aurora.
The nature of radio aurora within the polar cap.
The nature of radio aurora near the poleward boundary of the substorm bulge.

A transportable auroral radar has been developed for operation at Saskatoon during the pulsating aurora campaign. This radar will be able to monitor the radio aurora activity over the rocket launch area at South End.

(g) Pc5 Pulsations

The work on the lumped circuit model of Pc5 pulsations has been completed. Most of the major properties of the pulsations have been reproduced by the model. It is hoped to apply the basic physics of the model to the development of a wave model.

(h) Meteor Research

The meteor radars and cameras at the Springhill Meteor Observatory were operated for brief periods during the year as part of a continuing study of meteor showers. We now have observations of the major meteor showers over a 20-year period. The data on the Geminid meteor shower were analysed in order to determine the cross section of the stream and the distribution of particles around the streams. The slight differences in both distributions depending on the size of the meteoroids are important in assessing the past and continuing evolution of meteor streams. A study of the Quadrantid meteor shower was partially completed.

(i) Infrasound from Meteors

Ability to record low-frequency pressure waves generated by large meteors permits the detection of meteorite entry on a round-the-clock basis. An array of 4 detectors operates near Saskatoon. The system is designed to respond to infrasound generated by large meteorites, so as to complement most effectively the Meteorite Observation and Recovery Project (MORP) network of cameras. Atmospheric pressure variations (via noise-reducing spatial filters) are recorded digitally on magnetic tape on a continuous basis. The infrasonic detectors have a pass band from 0.02 Hz to 0.2 Hz, a dynamic range of about ± 16 microbar, and a resolution of 1/8 microbar.

A recording system at Springhill Meteor Observatory consists also of a 4-microphone array, but is oriented toward detection of smaller meteoroids. The fully automatic digital system is under control of a

microprocessor. Because the data rate is high, observations are carried out for limited periods of time.

A background of natural infrasound continues to be observed, mostly from aurora and from ocean storms. An interesting group of signals was recorded at Saskatoon at the time of the Feb. 26 solar eclipse. The event has been tentatively ascribed to gravity waves induced by the eclipse but the propagation velocity is much lower than seems possible even for high order modes of gravity waves. On Aug. 19, reentry of the rocket body of Soviet satellite MOLNIYA 144 was recorded on the Springhill infrasound system. The weak signal produced by a body of this size and mass is the clinching evidence that infrasound is an impractical mechanism for detecting the fall of meteorites. Before terminating this program a final search will be made for correspondence with fireballs recorded by the MORP camera network.

(j) Meteorite Recovery

The MORP camera network continues to photograph bright meteors although there have been no ground searches for meteorites in the past year. Analysis of the Innisfree meteorite event is continuing. Reduction of those fireballs which penetrated below a height of 30 km indicate the network has recorded at least three meteorite falls of several kg and four other events where a fall of less than 1 kg may have occurred. A statistically unbiased sample of the MORP fireball data is being reduced to study the incoming flux of larger meteoric bodies.

(k) Meteor Spectroscopy

The reduction of spectrographic records on video tape of over 300 meteors recorded at the Springhill Meteor Observatory near Ottawa since 1974 has been continued in cooperation with the Dudley Observatory, Albany, NY; the Smithsonian Astrophysical Observatory, Cambridge, MA; and the NASA Marshall Space Flight Center, Huntsville, AL. These data represent 8 different cometary meteor showers and emphasis is being placed on detecting differences in the chemical composition of the cometary meteoroids from the various showers. Techniques for securing photometric results from video tape are being developed with the help of sophisticated data processing equipment at the Marshall Space Flight Center. The photometry of meteor spectra is necessary if quantitative data on chemical abundances are to be found for the meteoroids observed.

(l) Auroral Plasma Studies

Studies of the electrodynamics of the formation of auroral arcs continue using rocket-borne passive observation as well as active perturbation or tracer techniques.

In the area of passive observations, an energetic ion mass spectrometer with a large geometric factor (one to two orders of magnitude more sensitive than those currently in use) has been developed

for observations in auroral events and is capable of detecting the expected minor ion constituents in auroral precipitation (i.e., O^{6+}, He_3^+, Fe^+, etc.). This device will be flown in a sounding rocket into an auroral form and is expected to yield new information on the auroral ion source regions as well as ion energization, transport and loss processes.

A program ("Falcons") to study the relationship between auroral arcs, field-aligned currents, local electric fields and energetic particle precipitation is planned for January 1981. Two rockets will be launched nearly simultaneously on the same flight azimuth, one to an apogee of 350 km and the other to 800 km over a chain of ground-based magnetometers and into an auroral arc. The ground magnetometers and imaging and photometric scanning systems will provide information on the temporal stability and spatial structure of the auroral forms and currents during the rocket flight.

The rockets will be instrumented with thermal and energetic charged particle detectors and vector electric and magnetic field sensors.

It is anticipated that these observations will result in a definitive determination of the magnitude and location of the auroral current systems and will therefore provide a test of the relevance of current driven instabilities to the auroral electron acceleration mechanism.

Campaigns involving a number of ground-based optical observations (TV imaging, scanning photometers, etc.) along with coordinated sounding rocket launchings are planned for the winters of 1980 and '81.

The first campaign during January and February 1980 has been organized to study the morphology and source mechanism of pulsating auroras and involves the launching of two rockets into pulsating auroral events. The Space Physics Section NRCC will supply the energetic (50 eV - 500 keV) particle detectors for these rockets.

The second campaign, planned for December 1980, will study the "cleft" or dayside aurora from sites near Cape Parry, N.W.T. Two high altitude rockets will be instrumented to measure energetic ion and electron precipitation, ionospheric ion drift velocities, and electric and magnetic fields.

Both rocket campaigns will be supported by extensive ground-based observations.

In the area of active experimentation, a joint NASA/NOAA/NRCC program to study the interaction of electron beams with the ionospheric plasma and to use the beam as a magnetospheric probe is continuing. A programmable electron gun operating in the 1 to 10 keV energy range and capable of producing beam currents from 1 to 100 ma was developed and has been flown in two sounding rockets from Churchill Research Range. Data

from these flights are presently under study. Preliminary analysis indicated that a beam-plasma instability, identified in preflight tests in the large Johnson Space Center vacuum tank also occurred in space.

Some data from probes ejected from the main rocket carrying the electron gun indicate that at times prompt echoes from electron gun firings, perhaps returned by field-aligned electric fields, were detected. This use of the beam to probe for $E_{//}$ was one of the main objectives of the program.

A sounding rocket payload scheduled to be launched in December 1979 was recently operated in the JSC vacuum tank to simulate flight conditions. Vehicle charging effects and beam-plasma instabilities were studied in this controlled environment.

Project "Waterhole" (launch date April 1980) is a perturbation experiment aimed at disturbing the ionosphere-magnetosphere coupling mechanism. A large quantity (100 kg) of chemically reactive vapours (mostly water) will be released into the F region above an auroral arc which will have the net effect of temporarily reducing the local electron density by several orders of magnitude over a diameter of 10 km and by at least an order of magnitude over 50 km diameter. If large magnetic field-aligned currents ($I_{//}$) flow between the magnetosphere and the auroral form, the decrease in thermal electron density will require the electron bulk velocity parallel to B to increase to keep $I_{//}$ continuous through the "hole". This being the case, the ratio of the bulk flow velocity to the thermal velocity will increase and may exceed the threshold for instability. Large amplitude waves, some near the ion cyclotron frequency, and perhaps strong $E_{//}$'s may occur in the "hole" in much the same way as postulated for the more distant magnetosphere.

The rocket will have an ejected explosive release module and will also carry DC and AC electric and magnetic field probes, thermal and energetic charged particle detectors and photometers to make direct observations of the response to the release.

Perturbations of the energetic particle precipitation, if any occur, will also be monitored indirectly by ground-based image intensifier and photometric systems.

On a more speculative note, if ionospheric feedback is a requirement for the formation of auroral arcs and if the "hole" interfers with this feedback system, a gross deformation of the auroral form may occur. Any large scale response of this sort would be a highly significant result.

(m) Magnetospheric Studies

The "Firewheel" satellite will be the main payload for the ARIANE development flight L02 to be launched in May 1980. The experiment involves Barium and Lithium releases in the nightside magnetosphere at 9.5 and 7 R_E, respectively. The scientific objectives are: i) to

study the plasma processes controlling the formation and decay of a magnetic cavity, ii) to study the momentum exchange with the ambient plasma and the magnetospheric perturbation thereby generated, iii) to observe modifications of the trapped energetic particles by self-generated whistler and ion cyclotron waves, and iv) to trace the acceleration and redistribution of the injected ions in the inner magnetosphere.

Four diagnostic subsatellites will be ejected from the main bus which will also carry the chemical releases and other instrumentation. One of the subpayloads is being supplied by the NRCC.

Instrumentation for the NRCC subpayload is designed to measure perturbations of the ambient plasma as well as to monitor the response of the injected ions to the ambient plasma. The subpayload instruments will concentrate on the measurement of charged particle distributions and the local vector magnetic field.

The charged particle detectors, supplied by NRCC, consist of arrays of solid state detectors, cylindrical and spherical plate electrostatic analysers, an r.f.-type energetic ion mass spectrometer and a spherical Langmuir probe. The DC magnetometer will be supplied by GSFC (M. Acuna).

The Space Physics group is collaborating with a group at Lockheed Missiles and Space Corp. on the energetic ion mass spectrometer for the high altitude Dynamics Explorer spacecraft. Along with analysing the results from this instrument, NRC has the prime responsibility to execute coordinated ground-based and sounding rocket observations. Some chemical seeding and tracer experiments will also be coordinated with DE space craft passes.

Studies using the magnetometer and particle data from ISIS-2 are continuing. The objective of the work underway at present is to determine perturbation patterns in the polar cap region at times when the IMF z component is positive. One difficulty with this work is that the magnitude of the perturbations tends to be small under these conditions, making it difficult to determine average patterns. However, a number of individual passes show a clear reversal of the perturbations in the central polar cap when B_z is positive. A few of these passes were recorded at times when solar electrons were present in the polar cap and these particles can be used to give some information about the location of open and closed field lines at these times. In general, the polar cap electron data is consistent with open field lines in the region of the magnetic perturbation reversal. However, in two passes recorded at times when the IMF B_z component was positive and very large the perturbation reversal occurs on closed field lines in a region which is surrounded on the dawn and dusk sides of the polar cap by open field lines. In a qualitative way these observations can be understood in terms of a merging model in which merging takes place just poleward of the dayside cusps. This work suggests that the polar cap, at times of northward B_z, may be a good place to test some of the general implications of magnetic merging models.

A primary goal of the ISIS program has been to encourage investigators to make use of all of the instruments on ISIS-2 which make measurements relevant to any particular problem. As a result, NRC personnel have participated in a number of joint studies and papers. In a number of these, the ISIS-2 photometers (York University and University of Calgary) have been powerful tools in defining the morphology of auroral phenomena such as: i) detached arcs lying equatorward of the auroral oval, ii) sub-auroral red (SAR) arcs, iii) sun aligned arcs in the polar cap, iv) the equatorward limit of the auroral oval, and v) the location of substorm onset. The NRC instrument has provided the detailed measurements of the magnetospheric particle populations causing these emissions. The studies have identified mechanisms for a number of these phenomena. In other correlative work DMSP imagery is being used in the study of pulsating auroras' particle signatures. Correlative studies with ground magnetograms (U. of Alberta) have provided a new understanding of the structure of the eastward electrojet in the sunlit ionosphere near the evening terminator. Opportunities for future correlative studies using IMS data sets are now under review.

The currents which couple the magnetosphere to the ionosphere cause characteristic perturbations of the geomagnetic field. To date, electrodynamic studies have been handicapped because no satellite mission has had the primary goal of making accurate vector measurements of the global field at low altitudes. The Magsat program of NASA's Office of Applications and Space Technology is intended to meet this requirement with the launch of Magsat in September 1979. The Space Physics group is among 27 Investigator Teams selected by NASA to analyse Magsat data. Twenty-four teams will study the internal field (both the main field and the crustal anomalies) while three teams will study the external disturbance fields caused by ionospheric/magnetospheric current systems. Among the latter, NRC will concentrate on high latitude current studies. We expect to extend the study of specific phenomena that have been previously identified with ISIS-2 magnetometers and also to use the 60 month data base to construct models of the average global current system as a function of local magnetic time, solar illumination, geomagnetic latitude, interplanetary magnetic field orientation and geomagnetic disturbance indices. Specific questions that will be investigated are i) the control of current distribution in the dayside cleft by the interplanetary field, ii) the effect of solar illumination on the distribution of currents in the polar cap, and iii) the coupling of magnetospheric and ionospheric current in the auroral oval during quiet geomagnetic conditions and during various phases of substorms.

(n) Cosmic Ray Studies

The NRC Space Physics group continued to operate cosmic ray monitor stations at Deep River, Alert, Inuvik, Goose Bay and Ottawa. Preliminary neutron monitor data summaries and graphs are submitted monthly for publication in Solar-Geophysical Data (NOAA). Final data reports are issued for general distribution yearly.

Continued operation of the near horizontal cosmic ray muon detector array confirms the existence of the sidereal first harmonic anisotropy previously reported. On the basis of 3 years of data, the sidereal diurnal variation for the highest zenith angle interval 88°-83°, corresponding to a median primary rigidity (m.p.r.) of 600 GV, has an amplitude 0.056 ± 0.013% at 3.5 ± 0.9 hours Local Sidereal Time. This value is consistent with those derived from underground measurements at similar or higher m.p.r. The observed sidereal amplitude falls off with decreasing zenith angle and is less than 0.01% in the zenith angle interval corresponding to a m.p.r. of 150 GV. It is the anisotropy in this transition range of m.p.r. which will be most sensitive to reversal of the large scale solar magnetic field which will next occur in 1980-81.

Members of the Space Physics group are collaborating with researchers from the University of Chicago, Imperial College and the Space Science Department of ESA in the development of a multi-telescope cosmic ray and solar particle experiment which will be flown on the ESA spacecraft as part of the International Solar Polar Mission. A major milestone in this project is the delivery of a fully operational engineering model by December 1, 1980.

6. Space Science Co-ordination Office, NRC

The SSCO was established in 1976 to bring together the diverse interests of the space science community in universities, industry, government agencies and elsewhere into a coordinated national scientific program by identifying opportunities and cooperative approaches. While its ultimate task is to formulate and coordinate an integrated space science program for Canada, it set out with a first objective to identify and define the various components of that program. To achieve this objective, a number of working groups examine the fields of aeronomy and space physics, astronomy, life sciences, lasers, large space platforms, satellite solar power systems, atmospheric dynamics and material sciences in space, identify interests and recommend participation in national and international programs. Canada has considerable experience in doing scientific and technological research and development work in space. Programs identified by the SSCO for implementation ensure that Canada will sustain and improve research competence in space science; provide a significant fraction of the new knowledge needed to make science based decisions relating to the use of space; provide for the training of young scientists and engineers in areas that will be the focus of much activity in the future; and provide Canadian industry with a series of challenging opportunities for industrial innovation in the leading edge of space technology.

During 1979 a proposal was put up for governmental consideration. The components of the proposal are:

- a High Energy Ion Mass Spectrometer (HEIMS) which will be used to investigate the properties of electrically-charged atoms and molecules which populate the earth's magnetosphere, using the Space Shuttle/Spacelab as a base of operations

- a Wave Injection Facility (WIF) which will endeavour to determine the response of the earth's ionosphere and magnetosphere to electromagnetic radiation in the frequency range of 0.3 - 30 MHz at an initial radiated power of 0.5 Kw

- a Wide Angle Michelson Doppler Imaging Interferometer (WAMDII) to obtain vertical profiles of winds, and exploratory data on small scale irregularities, in the upper atmosphere

- a ground-based support for NASA's "OPEN" program which will involve U.S. scientists receiving data from ground-based instruments in Canada and at the same time Canadian scientists receiving coordinated data from the "OPEN" satellites

- a Distributed Analysis Network (DAN) to facilitate the interchange of data and ideas among Canadian participants.

The IMS ended officially on December 31, 1979. Because of the late launching during the IMS of some spacecraft designed particularly to collect data related to the Earth's magnetosphere some ground-based projects specifically related to the IMS may be continued into and possibly throughout 1980. Although the IMS was planned to be an "active" event in the sense that data would be sent to World Data Centers soon after collection, and would be made available to space scientists who needed them to complement analyses and planning of their paraticular studies, this has only been marginally successful. Lack of manpower and finances have been major factors.

The magnetometer lines operated on Canadian territory have been the source of important data for IMS studies.

A number of campaigns using rockets and high-flying balloons (about 35 km) have taken place or are to take place before the end of 1979, but there have been no long-period expeditions collecting auroral spectral data and micropulsation studies by the Watanabe-Oguti-Horita group (Universities of British Columbia, Victoria and Tokyo collaboration) due to lack of funding and also the substantial amounts of data already collected and the need for its analysis.

Excellent cooperation has existed between Canadian, United States of America, Japanese and Scandinavian scientists on various IMS projects.

A preliminary draft of a manual on IMS activities which have taken place on Canadian territory is under preparation. This lists the various campaigns, expeditions and other activities, the name and address of the project scientist, equipment used, dates, and kinds of data obtained and so on. The manual should provide a convenient reference source for a space scientist seeking data complementary to a project for which he has data, as well as a history of what activity took place. The final draft should be ready for duplication late in November and distribution in December.

7. University of Saskatchewan - Institute of Space and Atmospheric Studies

(a) Aeronomic Studies

The understanding of atmospheric processes, particularly as they relate to atomic oxygen recombination, has been extended from the careful analysis of other airglow rockets. It is now believed that a general picture of atomic recombination has been developed and that the thesis is consistent with the available atmospheric observations both of the aurora and the airglow. These analyses have shown that the transfer mechanisms developed for the interpretation of the airglow have an analogous step in the aurora. Unfortunately some of the required cross-sections are uncertain so that additional laboratory work is needed. This work has also been used in an attempt to determine atomic oxygen concentrations in the upper mesosphere. The derived values are close to 10^{12} cm^{-3} which is significantly larger than that proposed by other investigators but in general agreement with that expected from our present knowledge of atmospheric processes. Some studies of auroral pulsations have been undertaken and it has been shown that the general ideas of energy transfer are consistent with the observations although much work remains to be done.

Photometric observations of the infrared oxygen emission at 1.27μ were also undertaken as part of a general study to improve the historic ozone data base. This investigation, the International Ozone Rocket Intercomparison, was conducted from Wallops Island during October and provided measurements throughout the nominal observing period for each rocket. It is expected that a preliminary analysis will be completed shortly and that a valid comparison with other measurements will be made before December 1980.

The investigations of the OH Meinel emissions in the airglow have been extended and it has been possible to extend the previous work on quenching to provide new transition probabilities which provide agreement with the airglow observations for large Δv bands. The validity of the work has recently been enhanced with the independent laboratory measurement of OH* quenching which is in good agreement with the values derived from the airglow.

(b) Radiowave Investigations

The academic year 1978/79 was spent with the STARE (Scandinavian Twin Auroral Radar Experiment) group, under the direction of Ray Greenwald, at the Max-Planck Institute for Aeronomy in Lindau, Germany. The experiment consists of two Doppler radars, one in southern Norway and one in southern Finland, each having eight narrow beams. These beams intersect over an area of 200,000 km in northern Scandinavia. The most important feature is that, since the Doppler velocity is the velocity of the electrostatic ion waves (either ion-acoustic or gradient-drift) causing the coherent scattering (which occurs when the wavelength of the plasma waves is half the radar wavelength), and since the electrostatic

ion waves move at the electron drift velocity, the measured velocity is the electron drift velocity v_{ed}. This velocity in turn is purely Hall drift

$$\vec{V}_{ed} = \frac{\vec{E} \times \vec{B}}{B^2},$$

so the electric field could be deduced directly. Thus complete 2-dimensional maps of the horizontal electric field over a 200,000 km region could be produced every 20 seconds.

The velocity and E-field maps were used to study:

(i) convection patterns in the auroral oval, particularly the Harang discontinuity during the transition from eastward to westward electrojet in the evening and the similar transition from westward to eastward jet in the morning;

(ii) Pc5 micropulsations, which showed up extremely well, and whose intensity, period, and polarization could be obtained with 20 km x 20 km resolution, which is a marked improvement over ground magnetometer networks;

(iii) auroral substorms, including growth phase and breakup;

(iv) the relationship of the radar aurora with optical aurora structures (from the Finnish all-sky network operated by R. Pellineu);

(v) the relationship between the electron Hall drift and ground magnetometer observations, to infer the Pedersen component that causes the difference between the two measurements;

(vi) the relationship between Birkeland currents on the Triad satellite and the STARE convection;

(vii) the relationship between the ionospheric E-field and the conjugate magnetospheric E-field at geostationary orbit as measured by GEOS-2 (using both a double-probe technique (A. Pedersen and R. Grand) and an electron gyro-orbit perturbation method (G. Haerendel);

(viii) the relationship between ionospheric flow and GEOS-2 hard-particle measurements (electrons and ions 20 keV (A. Korth and B. Wilken) during satellite magnetopause crossings;

(ix) the nature of "subauroral striated scatter", a new type of radar echo originating in the region between the plasmapause and the electrojet in the dawn sector.

So versatile has the STARE experiment proven to be that a second system -- SABRE (Sweden and Britain Radar Experiment) is being built, and

application has been made for one in Canada in conjunction with the OPEN (Origin of Plasma in the Earth's Neighbourhood) satellite campaign.

(c) Dynamical Studies of the Mesosphere and Thermosphere

The partial reflection radiowave system at Park Site has now been used to measure winds, electron densities and characteristics of radiowave scattering processes in the D- and lower E-region for 1 solar cycle (1968-1980). Improved winds analysis methods have been developed since 1976 so that data of excellent quality and quantity is now being obtained. The major technical development has been the use of two microprocessors to completely control the recording and processing of data, so that continuous real-time winds are now available, commencing in September 1978. These constitute 5 minute profiles, from 50-110km, in 3km height intervals (over 14 months of magnificent winds data is now available). This represents a considerable technical and analytical achievement, and lowers the net cost of winds acquisition considerably, making it very cost effective when compared to other systems.

Winds from these 14 months have been analyzed to obtain the amplitudes of planetary, tidal (24,12 hours), and internal gravity (I.G.) waves (10min $\lesssim \tau \lesssim$ 6hrs). Energy densities and scale heights have been found for each month, and lie in the range 10^{-5} - 10^{-2} (J/m^3) and 4 - 10km respectively. In general wave energies are largest in winter months, and dissipation rates smallest. During spring, energies fall off near 80km but dissipation is still quite small. Energies are smallest during early summer, although they increase late in summer and dissipation becomes less as summer circulations develop. These data confirm and expand upon our first estimates of these important parameters made with 1976 data. The characteristics of 12- and 24-hr tides have been studied, and compared with existing theories: the latter are still inadequate to describe the complex interaction between gravity waves and prevailing winds and tides which are occurring. Our data set shows very consistent behavior, and is being used by theorists and modellers to improve their results. Assessment of circulation (zonal & meridional) over the last 11 years, shows a large ratio (5-6) of velocities from solar maximum to minimum years, from 70-100km: this unexpected result is being studied, and sources of energy searched for.

A series of 6 wind observations during 1978/79, which allow the resolution of waves of $\geqslant$4 minutes, has been completed at Saskatoon, and I.G. waves of periods 5 -90 minutes have been identified. The auto-correlation functions of the reflected radiowaves have been used to calculate the turbulent velocity ($\sim$1-5 m/s), turbulent energy dissipation rates (0.01-0.08 W kg^{-1} at 90km) and eddy diffusion coefficients ($\sim$ 1-5 x 10^3 m^2/s at 90km), as well as wave dissipation rates. The energy balance of this region is now being studied in detail.

Finally, the morphology of the lower ionosphere 30-90km is being studied, and related to the precipitation of electrons and protons and their association with auroral events and magnetic storms. Improvements

in the polarimeter being used and the theory of radiowave scatter are being used to provide electron profiles of better accuracy. During the Pulsating Aurora Campaign (Jan/Feb. 1980) the diurnal variation of the particle spectra is being sought, using optical and satellite data from other participants, and estimates of the energy dissipation and chemical perturbations as a function of height will be made from our wind and electron data.

8. University of Victoria - Department of Physics

(a) Plasma Waves

A project with Dr. R. R. Heacock of the University of Alaska is continuing to yield many outstanding examples of chorus and banded hiss recorded at Carib Peak, 8 km north of the Poker Flat Research Range. Analyses of these ELF data include comparison with riometer and ULF data from Carib Peak, Poker Flat, College and Fort Yukon. Thus, for example, precipitation pulsations have been found closely related to concurrent magnetic field pulsations. In addition ELF data were recorded recently when the SCATHA satellite was near the magnetic meridian of Carib Peak to allow ground-satellite comparisons.

Recent fresh interest in VLF saucers led to a study of this phenomenon as observed on ISIS data with Dr. H.C. James of the Communications Research Centre. Observations of fine structure at harmonics of the proton gyrofrequency in the VLF saucers studied suggest that saucer waves not only propagate upward to the satellite, as is usually assumed, but also downward.

The analyses of data from the University of Tokyo-University of British Columbia-University of Victoria Cooperative IMS Project continue to yield results. A recent paper was presented at the Solar Terrestrial Predictions Workshop in Boulder, Colorado suggesting that geomagnetic disturbances lead to telluric currents which enter power line systems through transformer neutrals and that these currents distort the transformer hysteresis loop, activating harmonics of 60 Hz.

Data from a cooperative project with the University of British Columbia and B.C. Hydro are being analyzed. Comparisons of the data from micropulsation stations at Fort St. John, Prince George, Williams Lake, Pemberton and Albert Head (near Victoria established this past summer with solar induced currents monitored at the Williston (near Prince George) and Telkwa (near Smithers) sub-stations indicate a good correlation between SIC's and the integrated output of the induction magnetometers.

(b) Atmospheric Airglow Emissions

Studies of twilight lithium emissions at Victoria, B.C. using a birefringent photometer continue to show enhancements from time to time.

In particular, enhanced twilight emissions were observed at Victoria three days after metallic lithium vapour was released from Nimbus G satellite over Scandinavia on November 6, 1978. The enhancement was not large, the maximum observed intensity following the release being only about 50 rayleighs; however, it was well defined, the intensity having decreased during the following five days to approximately 10 rayleighs.

A second enhancement was observed, beginning on April 18, 1979, reaching a peak intensity of about 130 rayleighs between April 22 and April 23. By April 27 the intensity had fallen to 20 rayleighs.

The data resulting from the above two enhancements are now being analyzed.

9. University of Western Ontario

(a) Meteor Physics

The meteor physics group now has two image intensifier vidicon cameras sensitive to about + 9.5m stars. These constitute the most important tool for the experimental studies of meteor ablation. A digital system has been developed for processing the video information and this has greatly speeded up the analysis of the observational data. The programme now starting will study in detail several hundred doubly observed television meteors.

A new cw radar meteor observing system is now operational and the necessary software is being developed to enable daily maps of radiant activity to be obtained.

Current theoretical studies are aimed at producing computer programmes to estimate the effects of various perturbation mechanisms on meteoroid orbits in interplanetary space.

(b) Investigations of Ionospheric Structure

Most of the effort over the last year has been devoted to preparations for the Pulsating Aurora Campaign, and participation in Project Waterhole. For each of the three rockets involved in the two projects we will be ejecting a two-frequency coherent transmitter package from the rocket. The signals will be received at two separated ground stations where the differential phase between the two frequencies will be measured. This permits continuous precise determination of the electron content between the package and each ground station. The geometry of the rocket flight makes it likely that the actual spatial distribution of ionization can be deduced from the two receiver records.

For the pulsating aurora campaign we will also be using two similar separated ground stations to receive the coherent signals from the NNSS satellites. The geometry of the satellite passes makes the tomographic problem much more difficult and it is likely that it can be solved only

for relatively simple structures in the ionosphere, or put another way the two-dimensional resolution available in the analyzed data will be much coarser than that of the one dimensional data from each station.

These activities will be a warm-up for the extensive three-year programme which we are starting. This project will use combined data from differential-phase, differential-angle-of-arrival and spaced amplitude receivers in conjunction with a variety of satellite transmitters to compare the nature of the wavefronts arriving at the ground over a broad frequency spectrum. The objective is to provide a useful physical model of the ionospheric structure at both medium and high latitudes.

(c) Closely-Spaced Frequency Study of Radio Aurora

Although this project was completed over a year ago some effort has gone into trying to understand the results. Although the results seem to confirm the nature of the radio-auroral signal as found by others (e.g. Haldoupis and Sofko), the comparison of the instantaneous signals on the closely spaced frequencies (separated by 500 Hz at a frequency of 40 MHz) reveals that at times the signal fluctuations are poorly or negatively correlated. The most obvious interpretation of this phenomenon is that the irregularity generating mechanism (which must be a local phenomenon) is at least indirectly controlled (or modulated) by magnetospheric processes.

(d) Irregularity Structure in Meteor Trails

This experiment which made use of the large receiving array at CRC permitted a detailed investigation of the scattered wavefront from individual meteor trails. While confirming the existing picture of distortion of the trails by atmospheric winds the results on occasion seem to require the simultaneous existence of two trails in a relatively small volume of the atmosphere. This in turn would seem to require the fragmentation of the meteoroids in the high atmosphere or outside the atmosphere.

(e) Long-Line System for Measurement of Ionospheric Electric Fields

The long-line system is an array of receiving stations spaced so as to measure the motion of scintillation causing irregularities. Geostationary satellites are used as the radio source. The system was evaluated during the winter of 1978-79 and showed good results and agreement with other published data on ionospheric electric fields. In order to get the vector component of electric field which is perpendicular to the earth's magnetic field it is necessary to make simultaneous measurements using two geostationary satellites in different directions. Problems arose finding a suitable choice of a satellite pair and eventually a considerable modification of the system was undertaken to permit a wider choice of satellite pairs by increasing the system's stability and sensitivity. The modified system now reinstated is being

evaluated. A microprocessor based data acquisition system has also been assembled and is also being evaluated.

10. Communications Research Centre, DOC

(a) The ISIS Satellite Program

The general objective of the ISIS program is to conduct comprehensive studies of the ionosphere. It involves making measurements over a range of heights and latitudes sufficient to determine conditions in the ionosphere and to achieve a full understanding of this region out to the magnetosphere boundary.

For this purpose, it was arranged by means of Memoranda of Understanding between United States and Canada that Alouette I should be followed by up to four satellites, to be built in Canada and launched by the United States.

Alouette I, the first satellite to be designed and constructed in Canada, was launched by NASA on 29 September 1962. This vehicle carried four experiments and occupied a circular orbit at an altitude of 1000 km. Operations were discontinued on 31 December 1972.

Alouette II was launched by Nasa on 29 November 1965. This vehicle carried five experiments: an ionospheric sounder, VLF receiver, cosmic noise experiment, energetic particle detector and langmuir probe. All systems worked as planned and provided excellent data. In July 1975, the FM telemetry power supply failed and the satellite is no longer used.

ISIS I was launched from the Western Test Range, California, on 30 January 1969, into its prescribed orbit. Orbital elements are: inclination 88.4°, perigee 575 km, apogee 3315 km, period 128.2 minutes. This was the third satellite to be designed and constructed in Canada and is the second in the ISIS series. This spacecraft contains the following ten experiments:

Swept Frequency Sounder - This topside ionospheric sounding experiment covers a frequency range of 0.1 to 20.0 MHz.

Fixed Frequency Sounder - The fixed frequency sounder operates on six crystal controlled frequencies within the range of the swept frequency sounder - 0.250, 0.480, 1.000, 1.950, 4.000 and 9.303 MHz.

Mixed Mode Sounder - This experiment uses a fixed transmitting frequency of 0.833 MHz simultaneous with a receiver which sweeps through the complete frequency range of the topside sounder.

VLF Receiver/Swept Frequency Exciter - This is basically a low frequency receiver covering the frequency range of 50 Hz to 30 Hz, which permits experimental studies of the upper ionosphere and exosphere and the complex interaction between the ionized media and low energy particle streams.

Energetic Particle Detector - This package contains two groups of detectors capable of identifying electrons and protons and measuring their angular distributions and energy spectra over the energy range for electrons from 8 keV to greater than 770 keV and for protons from 50 keV to 20 MeV.

Soft Particle Spectrometer - This spectrometer was designed to measure the energy spectrum, angular anisotropy and spatial and temporal variations of both positive and negative particles in the energy range of 10 eV to 10 keV.

Cylindrical Electrostatic Probe - This is an instrument which measures electron temperature and density. The purpose of this experiment is to extend the satellite measurements into the period of solar maximum.

Spherical Electrostatic Analyzer - The objective of this experiment is the measurement of spatial and temporal variations in the concentration and energy distrubution of charged particles in the altitude region of the satellite.

136/137 MHz Beacon - This instrument consists of two 100 mw transmitters operating at 136.410 and 137.950 MHz (the former being the tracking beacon) and measuring the scintillation in the total electron content of the ionosphere between the satellite and the ground station.

Cosmic Noise - This experiment measures the background radio noise levels with the sweep-frequency receiver orbiting substantially above the F - layer ionization maximum to obtain information on the galactic radio noise in various regions of the galaxy and the variation of this noise with frequency.

Under the terms of special studies conceived by the ISIS experimenters' group, ISIS I gathers data at a typical rate of 1-5 hours per day, although this figure can be increased to 2 hours per day. All experiments, with the exception of the ion mass spectrometer and soft particle spectrometer, are performing as planned. The soft particle spectrometer records data for 10 seconds to 3 minutes after turn on. As well, by using the onboard clock and programmer and tape recorder, much useful data was obtained on the ionosphere over previously unexplored regions of the globe before clock and tape recorder failure during February 1970. One battery is presently out of use but this presents no problems.

ISIS II was launched from the Western Test Range, California, on 1 April 1971, into near nominal orbit. Orbital parameters are: apogee 1,423 km, perigee 1,356 km, inclination 88.16°, period 113.55 minutes. This was the fourth satellite to be designed and constructed in Canada and is the third in the ISIS (International Satellite for Ionospheric Studies) series. This spacecraft contains the following 10 experiments.

Swept Frequency Sounder - The objective of the experiment is to determine the electron number density at and below the satellite down to the peak of the F - layer and to study the size and location of irregularities in the ionosphere.

Fixed Frequency Sounder - The fixed frequency sounder is designed to provide observation of small-scale irregularities which are too limited in extent to be easily investigated by the swept frequency sounder and to complement the swept frequency sounder, particularly where rapid horizontal variations occur. The fixed frequencies are 0.120, 0.480, 1.000, 1.950, 4.000 and 9.303 MHz.

VLF Experiment - This experiment is basically a low frequency receiver covering the frequency range from .05 kHz to 30 kHz. Because of the large range in amplitude of naturally occurring VLF signals, the receiver has a dynamic range of about 80 dB, which is achieved by the use of an AGC system.

Cosmic Noise - This experiment measures the so-called cosmic noise, or more specifically the natural background radio noise level, with a sweep frequency receiver orbiting substantially above the F-layer ionization maximum. In general the background noise level is determined by galactic noise, (but with contributions from plasma processes) and information on its variation with direction in the galaxy and with observing frequency is desired.

Retarding Potential Analyzer - The objective is to measure the positive ion density, composition, and temperature in the vicinity of the spacecraft. The secondary objective is to measure the thermal electron density and temperature, and the flux of suprathermal electrons.

Soft Particle Spectrometer - This experiment is an improved version of the experiment flown on ISIS I which provided good detailed information on the fluxes and energy spectra. The energy resolution has been improved to provide better data on the spectral line width and shape. Particles are detected in two separate beams to provide a check on the variability of the flux on a short time scale.

The experiment is designed to measure intensity, angular distributions and energy spectra of electrons and protons. An energy range of 1 keV to 1 MeV is covered for electrons. There are two energy ranges for protons, auroral energies 2-20 keV and "solar flare" energies 0.9 - 30 MeV.

Beacon Experiment - The beacon experiment aboard ISIS II is an improved version of the equipment aboard ISIS I. The purpose of the experiment is to detect and measure inhomogeneities in the ionosphere between the spacecraft and a number of ground stations.

Cylindrical Electrostatic Probe - The main objective of the experiment is to extend through the 11-year solar cycle the study of the global behaviour of electron temperatures and density that was begun with the combined data from the Alouette II and Explorer XXXI and with data from the ISIS I satellite .

Red Line Photometer - The purpose of this experiment is to map the global distribution in the intensity of 6300 Å line emission from the D level of atomic oxygen.

Auroral Scanner Photometer - The scanning photometer is designed to map the distribution of auroral emissions at 5577Å and 3914Å over the portion of the dark earth visible to the spacecraft.

Most experiments and spacecraft systems are working well. The exceptions are the tape recorder (failed late 1971), soft-particle spectrometer (deteriorated 1973-1974), spacecraft clock (1974) and most of the channels on the energetic particle detector (1976-78). The cylindrical electrostatic probe became intermittent in April 1978. The low-mass channel of the Ion Mass Spectrometer experienced a decrease in sensitivity in 1974 and failed in 1979. Data are acquired at a typical rate of 2.5 hours per day, all for special studies.

The operational program of both ISIS satellites continues to be coordinated by the ISIS Working Group, as provided for in the 1964 Memorandum of Understanding. During the past five years the program has ceased to concentrate on routine data acquisition and analysis, and instead has been devoted almost exclusively to special studies. Such studies may be defined on the basis of some special feature identified in the data, on some more fundamental basis for which satellite data specific for the purpose are acquired, or on the basis of some other, non-ISIS, observations or experiment where collaboration with some ISIS experiment is desired. Coordination of these special studies is provided by the ISIS Experimenter's Committee.

(b) Radio Studies of the Ionosphere

Within the past year, NASA has tentatively selected an American proposal for the "Waves in Space Plasmas" (WISP) system, formerly the Wave Injection Facility. It was made known to NRC, however, that the American team was interested in having Canada supply the medium frequency - high frequency (MF-HF) parts of the equipment. Accordingly, CRC personnel supported NRC Space Science Coordination Office in writing a letter-of-intent-to-propose to NASA regarding the WISP/MFHF system. CRC also assisted NRC in overseeing a cost estimate contract for the WISP/HF system, in performing a cost estimate for a dedicated MF-HF crossed-dipole antenna to be used with WISP/HF, and in writing the Statement of Work for the Request for Proposal issued by DSS. This request invites Canadian industries to make proposals for a conceptual design and Program Definition Phase (PDP). Unofficial agreement between the Canadian and American scientists about the hardware to be built in

Canada has been achieved. Subject to government approval of the NRC space science activity package for Fiscal Year '80-81, a binational team of co-investigators should be constituted early in 1980 and the PDP should begin later in the year.

Auroral Kilometric Radiation is an intense band of natural radio noise emitted from the high latitude magnetosphere in the frequency range 50 - 700 kHz. This phenomenon is detected by the sounder receiver of the ISIS-I spacecraft during apogee passes over the auroral zones. The spin of the dipole connected to the sounder receiver on the ISIS I spacecraft has been used by H.G. James to study the direction of propagation of auroral kilometric radiation (AKR). On the basis of fixed-frequency measurements at 0.48 MHz, it is concluded that in the generation region the wave vectors make an angle between about 60° and 90° with respect to the local magnetic field. That is, they are predominantly downcoming. Also, the plasma frequency is very much less than the gyrofrequency in the generation region. When the ISIS observations are combined with previous evidence on AKR, in particular that it propagates predominantly in the right-hand polarized X mode, serious disagreement with current theories results. However, two quite different theories, direct cyclotron radiation and a 3-wave interaction involving an ELF/VLF wave, give some prospect of accommodating all the observations.

Data from the ISIS I and ISIS II sounder transmitters have been used by H.G. James to test driving-point impedance theories for the long (73 m tip-to-tip) sounder dipole in an ionospheric plasma. A peak rf voltage detector was included in the design of the output of the sounder power amplifiers as a means of monitoring their operation after launch. Data gathered subsequently have revealed that this voltage responds consistently to changes in the ambient ionospheric plasma. The observed dependence of the output voltage on frequency, which is swept from 0.1 to 20.0 MHz, is determined by the values of the local characteristic frequencies. These have a considerable range in the ISIS data. Impedance theories for an ionospheric dipole have been tested by comparing observed curves of voltage versus sounder frequency with computed curves based on those theories. In cases where the plasma frequency is low, around 0.1 MHz, a realistic curve is obtained using standard vacuum dipole theory. For higher plasma frequencies, the observed response departs significantly from the low-density case at frequencies close to the electron characteristic frequencies. For fixed working frequency and plasma parameters, the voltage exhibits a slight dependence on antenna orientation. Attempts to explain these results for higher plasma frequencies using a transmission-line theory have qualified success when a vacuum sheath of 1-m radius is assumed. The need for a large sheath is just one kind of evidence that the sounder rf fields profoundly change the nature of the plasma near the dipole.

It was found, by D.P. Muldrew, that the formation of equatorial spread F and magnetospheric ducts and the initiation of a type of equatorial ionospheric irregularity called "bubbles" result from electric currents flowing from one hemisphere of the earth to the other along

magnetic field lines. This conclusion was drawn from the observations that ducts and spread F maximize near the December solstice at western longitudes and near the June solstice at eastern longitudes. An additional study of bubbles on Alouette I ionograms supported the above results. The statistical occurrence of bubbles in the topside ionosphere was also determined as a function of month, local time, height and longitude.

An explanation for long delay echoes, that is radio echoes received seconds after transmission, has been presented by D.B. Muldrew in terms of slowly propagating electrostatic waves.

An F-region model of the ionosphere over North America is nearing completion by J.C. Gladwin and D.B. Muldrew using approximately one million Alouette I ionograms and 50,000 electron density profiles. This will give F layer critical frequencies, layer thickness and spread-F conditions as a function of sun-spot number, season, local time, magnetic index, latitude and longitude.

11. MPB Technologies Incorporated

The following are abstracts from papers published during 1979.

(i) Attenuation and cross-polarization due to precipitation are calculated for five drop size distribution functions, namely Laws-Parsons, Marshall-Palmer, Joss drizzle, Joss thunderstorm, and a renormalization of the latter. Propagation paths from the Communications Technology Satellite (CTS) and Comstar D1 synchronous satellites to Ottawa are considered. Clear weather antenna isolation effects are included in the results. We find that various drop size distributions introduce substantial deviations only in the attenuation versus rain rate curves. A proper normalization of the Joss thunderstorm model is important for attenuation. The deviations are much less in the cross-polarization versus attenuation plots, which are close together for all five drop size distributions. This is so even for the thunderstorm model at 28.56 GHz of Comstar D1, where the differential phase per unit length is decreasing at high rain rates. Unexpectedly, it is also found that for attenuation values not too long, the thunderstorm model provides less depolarization for a given attenuation as compared with the other models.

(ii) The theory on compensation requirements for dual-polarized uplink signals using a single-polarized downlink signal is investigated for the Anik C satellite-earth communication system. Rain and hail crystal depolarization mechanisms are analyzed, and the theory is extended to include both. The decomposition of the downlink information into required parameters is performed, the scaling of these parameters from downlink to uplink frequency is provided, and the use of these scaled parameters to construct two elliptical signals on ground for the uplink channels is demonstrated. The various uncertainties in these operations are discussed. A novel suboptimal compensation scheme is described which

improves the isolation by 6dB. In this system, the unwanted cross-polarized levels of the two signals that arrive at the satellite are minimized through making them equal by constructing proper elliptical signals at the ground transmitter.

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