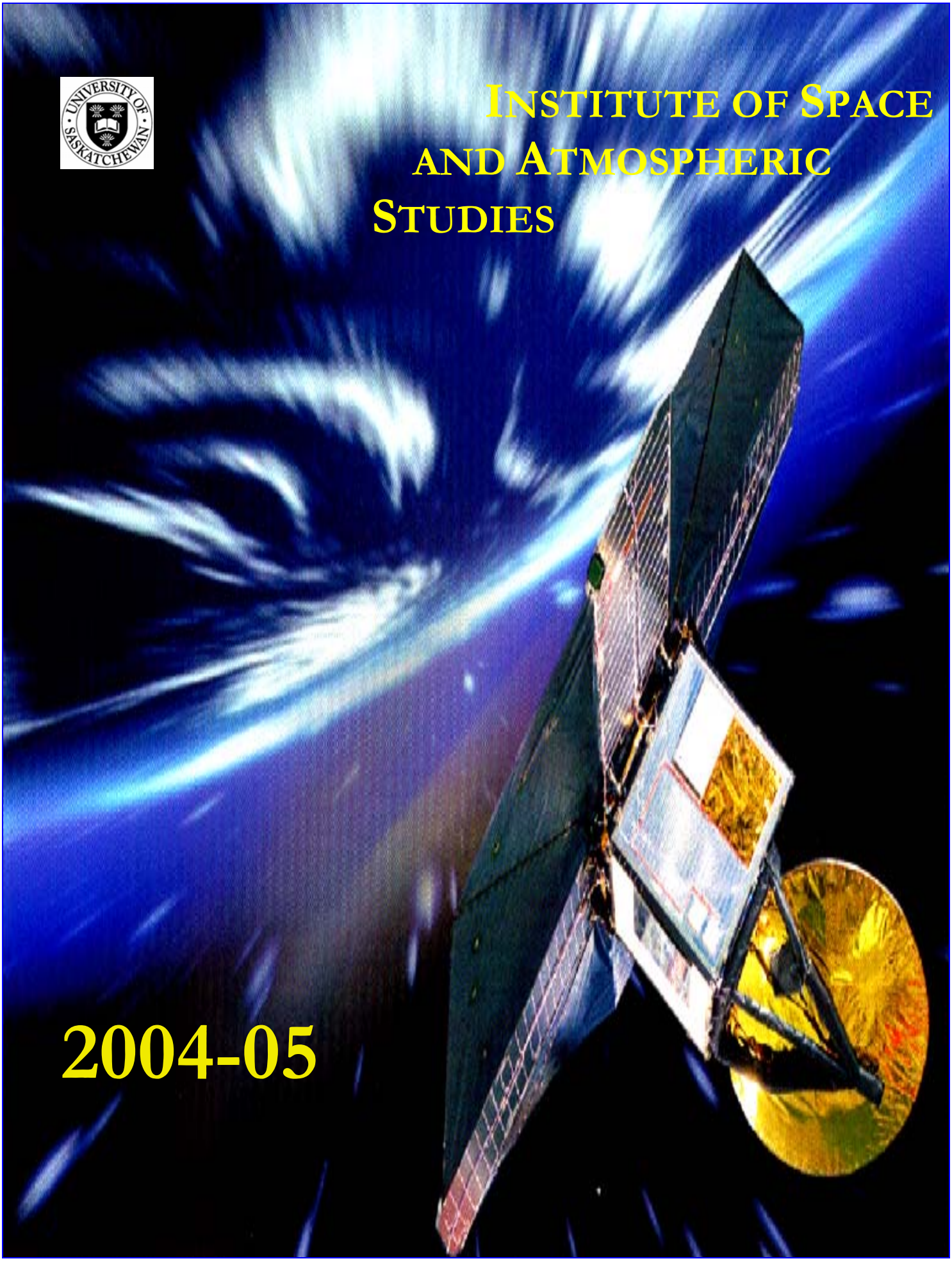
# Institute of Space and Atmospheric Studies



# 2004-05

# Institute of Space and Atmospheric Studies

# Annual Report 2004-05

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**Page layout by: D. Kowaliuk, ISAS**

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# Advisory Committee

## University of Saskatchewan

| | |
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| Peter MacKinnon | President |
| Michael Atkinson | Provost and Vice President (Academic) |
| Designate -Jim Germida | Vice Provost (Academic), Designate to the V-P (Academic) |
| Steven Franklin | Vice President (Research) |
| Bryan Schreiner | Director of the Office of Research Services, Designate to the V-P (Research) |
| Tom Wishart | Dean, College of Graduate Studies/ Associate V-P (Research) |
| Jo-Anne Dillon | Dean, College of Arts and Science |
| Jim Basinger | Associate Dean (Science), College of Arts and Science |
| Ernie Barber | Dean, College of Agriculture |
| Claude Lagüe | Dean, College of Engineering |
| Rob Pywell | Head, Department of Physics and Engineering Physics |
| Alan Manson | Chair, Institute of Space and Atmospheric Studies |

## Government

| | |
|---|---|
| Gordon James | Senior Scientist, Space Science, CRC, Ottawa |
| Larry Newitt | Head, Geomagnetic Laboratory, NRCanada, Ottawa |
| Tom McElroy | Senior Scientist, Atmospheric Sciences and Technology Directorate, Environment Canada, Downsview, ON |
| David Kendall | Director General, Space Science Program, Canadian Space Agency, Ottawa |
| Malcolm Vant | Director General, Defence R&D Canada - Ottawa |
| David Grier | Vice President, Environment and Minerals, Saskatchewan Research Council, Saskatoon |

## Industry

| | |
|---|---|
| Don Epp | Director of Marketing Communication Systems, SED - a division of CALIAN Ltd., Saskatoon |
| Larry Cooper | President, Scientific Instrumentation Ltd., Saskatoon |
| Dennis Johnson | PAKWA Engineering Ltd. (Retired, Director), Saskatoon |

June 2006

# Members of the Institute

## Department of Physics and Engineering Physics Faculty Members

| | | |
|---|---|---|
| **ISAS Chair** | A.H. Manson | B.Sc., Ph.D. (Canterbury, N.Z.), Professor |
| **ISAS Executive** | D.A. Degenstein | B.Sc., B.E., Ph.D. (Saskatchewan) Associate Professor |
| | G.C. Hussey | B.E., M.Sc., Ph.D. (Saskatchewan), P. Eng., Associate Professor |
| | A.V. Koustov | M.Sc. (Leningrad State), Ph.D. (Moscow Institute of Earth Phys.), P. Eng., Assoc. Professor |
| | E.J. Llewellyn | B.Sc., Ph.D. (Exeter), D.Sc. (Saskatchewan) F.R.S.C., P.Eng., Professor |
| | K.A. McWilliams | B.Sc., M.Sc., (Saskatchewan), Commonwealth Fellow, Ph.D. (Leicester), NSERC PDF (Sask.) Assistant Professor |
| | G.J. Sofko | B.A.Sc. (British Columbia), Ph.D. (Saskatchewan), P.Eng., Professor |
| **Canadian Research Chair** | J-P.St-Maurice | B.A., B.Phys. (Quebec), Ph.D. (USA), Professor, Canadian Research Chair (CRC) |
| **Adjunct Professors** | R.L. Gattinger | B.E., M.Sc., Ph.D. (Saskatchewan) |
| | D. R. McDiarmid | B.A.Sc., M.A.Sc., Ph.D. (British Columbia) |

## Institute of Space and Atmospheric Studies Staff

### Professional Research Associates

| | |
|---|---|
| D.A. André | B.Sc. (Erlangen-Nurnberg), Ph.D. (Georg-August, Germany), P.Eng. |
| N.D. Lloyd | B.Sc. (Hons.), Ph.D. (London) |
| C.E. Meek | B.A. (Queen's), M.Sc., Ph.D. (Saskatchewan) |
| M. Watanabe | B.A., M.Sc., Ph.D. (Japan) |

### Research Assistants

| | |
|---|---|
| C. (Qin) Li | Comp. Eng. B.Sc., (China) Data Assistant/ Archivist |
| Z. Fan | Researcher (China), (East Anglia), (Stockholm) (until October, 2004) |

### Research Engineer

| | |
|---|---|
| J. Wiid | B.Eng. (South Africa) |

### Technical and Support Staff

| | |
|---|---|
| D.M. Kowaliuk | ISAS Secretary |
| W.L. Marshall | B.Sc. (Hons.) (Saskatchewan), ISAS Technician |
| S.F. Pfeil | ISAS Assistant (until August, 2005) |
| C. Jelinski | ISAS Assistant (since August 2005) |

# Graduate Students

## Post-Doctoral Fellows (Supervisor)

| | |
|---|---|
| S. Petelina (Llewellyn) | Odin Aerosol Studies |
| J. Drexler (St.-Maurice) | Studies of E & F region field-aligned irregularities (August, 2004 to January, 2005) |
| R. Kumar Choudhary (St.-Maurice) | Studies of E & F region field-aligned irregularities (since August, 2004) |
| J. Liang (Sofko) | Studies of F-region echoes and field-aligned currents using SuperDARN (since Nov. 2004) |
| E. Dupuy (Llewellyn) | Odin Mesospheric Studies |

## Ph.D. Students (Supervisor)

| | |
|---|---|
| L. Benkevitch (Koustov) | Ionospheric conductance effects in high-latitude phenomena |
| B. Hesman (Davis) | Ground-based Planetary Spectroscopy - James Clerk Maxwell Telescope (JCMT) project |
| A. Bourassa (Llewellyn/ Degenstein) | Odin IR operation |
| T. Chshyolkova (Manson) | Planetary Wave Coupling processes in the Middle Atmosphere |
| J. Liang (Sofko) | Multi-instrument Studies of Ionospheric and Magnetospheric Processes (until Oct. 2004) |

## M.Sc. Students (Supervisor)

| | |
|---|---|
| J. Cooper (Hussey) | FMCW VHF radar for the *E*-region |
| K. Lamont (Llewellyn/ Degenstein) | MOPITT-A Instrument |
| P. Loewen (Llewellyn/ Degenstein) | Odin IR Remote Validation |
| T. Wiensz (Llewellyn/ Degenstein) | Odin IR Modelling |
| C. Roth (Llewellyn/ Degenstein) | Odin Radiative Transfer |
| R. Drayton (Koustov) | Study of SAPS with King Salmon SuperDARN radar |
| R. Schwab (Sofko/ McWilliams) | Modelling SAPS flows |
| R. Gillies (Hussey/ Sofko) | Radio Propagation Effects for the e-POP Radio Receiver Instrument (RRI) |

## Graduate and Summer Students (Supervisor)

J. Gorin (Koustov)
A. Gahein (Degenstein)
E. Kulyk (Koustov)
P. Kulyk (Koustov)
P. Ma (St.-Maurice)
J. Pfeifer (McWilliams)
N. Wiebe (Llewellyn/ Degenstein)
M. Hargrove-Gillies (St.-Maurice)
P. Desautels (Llewellyn/ Degenstein)
R. McDonald (Llewellyn/ Degenstein)
M. Stoicescu (Llewellyn/ Degenstein)
J. Wood (Llewellyn/ Degenstein)

# Chair's Report

***The foci of research within the Institute of Space and Atmospheric Studies (ISAS) are the two themes of the Earth's 'Atmospheric Environment' (0-100 km) and the 'Space Environment' (ionosphere, thermosphere, and magnetosphere). The Canadian Space Agency (CSA) now names the area that encompasses our Research, within their Space Science Program, as Solar Terrestrial Science and Atmospheric Science. We shall also use those descriptors, as they are more traditional in our community. The work has prospered (2004/5), due to the energetic leadership of our Professors, who also act as the Executive and as Principle Investigators (PIs) for the main programs of ISAS. The research activities are based upon a strong and diverse set of observational systems, including ground-based radars and optical systems; and optical systems on aircraft and space vehicles. The analysis of the data from these systems leads to complementary theoretical and modeling activities, and strong national and global collaborations.***

***These reports were mainly written during the late summer and fall of 2005, and refer to 2004/5 research. For the first time, this ISAS Annual Report has no printed version, but resides in our Web-site. The size of the individual professorial reports has also been reduced to 2 pages each, with several pages of complementary figures.***

***It has been my observation that my colleagues and I are busier than ever ….. it seems that the pressure from 'Administrators', where ever they are , University, Space Agency or NSERC etc., are becoming more pervasive and intrusive, with methodology and tasks galore. Research time suffers inevitably, and we must find innovative and effective ways to shield our professors and allow the research to flourish. Given this, the year has been very successful. Read and enjoy…….***

## University Administration Changes

As a Research Unit in the Department of Physics and Engineering Physics, which itself is administered within the College of Arts and Science, ISAS depends very much upon the Head and the Deans. Our Head, Professor Rob Pywell continues to be very supportive, and it has been a pleasure to work with him on both ISAS and Departmental matters.

There were no significant changes during 2004/5. The Senior Administrators who affect our world most are these: the Provost and Vice-President Academic, Michael Atkinson; (Designate Jim Germida Vice-Provost); Jo-Anne Dillon (Dean of the College of Arts and Science, September 2004), Claude Lague (Dean, College of Engineering) and Jim Basinger (Associate Dean, Natural Sciences, August 2004); Tom Wishart (Dean, College of Graduate Studies and Research; Assoc. V-P Research); Steven Franklin (V-P Research) and Bryan Schreiner (Director of Research Services; Designate for the V-P). It has been a pleasure to work with these dedicated and fine leaders. We report to Dean Dillon.

The year of 2004/5 saw campus-wide activity with regard to the Integrated Planning process (IP). The President, Peter MacKinnon, had provided a Strategic Directions statement, entitled *Renewing the Dream*, which was endorsed by the Senate, Council and Board of Governors in the spring of 2002. We are now within the four year plan of 2003/4 - 2006/7. The University will be known for International Standards, Academic Pre-eminence, and its Sense of Place. There will be four strategic directions: attract and retain outstanding faculty; increase campus-wide commitment to research, scholarly and artistic work; establish the University as a major presence in graduate education; and recruit and retain a diverse and academically promising body of students, preparing them for success

in the knowledge age. The Institute is identified within the College's Integrated Planning (IP) Document for consideration as an **area of pre-eminence and divisional commitment;** and our research theme of the **Environment** is listed as an **area of emphasis** within the College's document and a major **'strategic initiative'** within the University's IP**,** 2003/4-2006/7. Thus the 2004/5 and 2005/6 years have been, and will be, moderately stable years. Work begins on the next four year plan in the summer and fall of 2006.

# Highlights of the Year

## Atmospheric Sciences

- **Odin-OSIRIS Satellite Mission** Science from this system is now flowing strongly, and the 'bird' continues to operate well. Professors Doug Degenstein and Ted Llewellyn have attended several Odin-OSIRIS meetings, as well as presenting their new data/results at international meetings. The leadership role of a large number of graduate students has been a highlight of this Program, and a fine example of HQP activity. Funding for continued research with OSIRIS has been sought and obtained.

- **SCOSTEP** CAWSES (Climate and Weather of the Sun Earth System). Within the 'Atmospheric Coupling Processes' Theme, Prof Alan Manson is coordinator of "Atmospheric Wave Interactions with the Winter Polar Vortices (0-100 km)". Tatyana Chshyolkova (PhD Grad Student) as leader of the 2004/5 winter campaign (30 radars, satellites, GCM-DAM models) is characterizing the Polar Vortex.

- **The 5th Atmospheric Environment Workshop: Banff Centre May 5-7, 2005** The organization and convening of this, along with production of the Report, was carried out by Prof Manson (Chair of the Canadian Space Agency's Atmospheric Sciences Advisory Sub-Committee): **"A Vision of Atmospheric Sciences for the Next 10 Years (2005-2015**). The ISAS Community was very well represented at this Workshop.

- **Grant Applications** and CANDAC–PEARL (**Canadian Network for the Detection of Atmospheric Change,** PEARL laboratory on Ellesmere Island) - The PI is James Drummond (Uof Toronto) and Alan Manson is one of 14 Co-Is, and PI of a new VHF Meteor Radar. The CFCAS was successful ($5M), and installation of systems at Eureka proceeded this summer (2005).

## Solar Terrestrial Sciences

- **CRC Chair, Environmental Sciences**: Prof. Jean-Pierre St.-Maurice and his team are now very well installed. Prof St-Maurice has visited numbers of countries (Taiwan, France, Brazil, India, and USA) and institutions associated with the Research of his group and of SuperDARN. He has two new PhD students, and the "Environmental and Climate Change" Colloquium of multidisciplinary seminars has begun very successfully.

- **SuperDARN** The radars continue to operate effectively as does the global system. Digital RX has been installed at Saskatoon and at Prince George. Typical research results are shown later in this report, with Profs Sasha Koustov and Kathryn McWilliams being particularly active.

- **PolarDARN, the polar cap addition to SuperDARN, and CADI** This system is associated with the CFI earned by Prof St-Maurice. Under the direction of Prof Sofko, and leadership by Engineer Jan Wiid, the antennas have been installed at Rankin and preliminary work on construction of the second PolarDARN radar at Inuvik is under way. A new CADI has been installed at Inuvik in addition to the operational unit at Rankin Inlet. The STS group assists in the operation

of optical all-sky imagers (U of Calgary) at Prince George and Rankin Inlet. Collaborations with the US-funded AMISR incoherent scatter radar (Resolute Bay) are in the planning stages.

- **e-POP, the next STS-CSA Satellite Mission** Prof Glenn Hussey, with graduate student Rob Gillies and Prof St-Maurice have been particularly active.

### IPY, International Polar Year

Prof Sofko, on behalf of Canadian Space Science Team (NORSTAR, Magnetometers, CADI, and SuperDARN) has applied for NSERC-IPY funding. Profs Alan Manson with Wayne Hocking (UWO) applied for funding for activities of a 'Polar Network of MLT radars', which included CANDAC-PEARL's SKiYMET radar.

## Funding, Staff and Programs

The research programs supported by ISAS are very diverse. This means that funds from NSERC, CFI, CFCAS and the CSA have been sought and secured. The programs of ISAS have therefore been able to flourish during the last decade. Our total incomes have ranged from $1.5-2M over the last 5 years researching peaks at the height of Odin funding ($2.36M 2004/05).

The research and core staff have comprised a total of approximately 30 persons during the last few years. Our numbers have grown recently to circa 40 due to strong CSA programs, SuperDARN and the CRC Chair. There are 8 PIs (Professors), 2 Adjunct Professors, 9 Post Doctoral Fellows/Research Associates, 3 Engineers/Research Assistants, 4 Staff-persons (Technician, Assistant Stores and Finances], Secretary) and 13 graduate students (2004/5). There is 1 Emeritus Professor.

The ISAS community is an effective and productive group, with strong national and global collaborations due to the diversity of our programs. Graduate Students, Research Scientists and Engineers are involved in the development of state-of-the-art experimental systems, in the analysis of data using sophisticated software and powerful computing systems, and the preparation of research reports and papers. The international research environment for our Professor-PIs is extremely competitive and demanding, as they are also committed university professors, with normal teaching and administrative duties; our competitors in the United States and Europe are often full-time researchers.

Within Canada's 'Space Science' community, the two major research themes are also the 'Space Environment' and 'Atmospheric Environment', or 'Solar-Terrestrial and Atmospheric Science', so ISAS contributes fully to the national agenda. We have two representatives on the CSA's 'SAEAC' Advisory Committee, with Profs Manson and St-Maurice being the Co-Chairs, and also Chairs of the corresponding Atmospheric and Space sub-committees. The principle activities for our ISAS PIs during the last few years, and during 2004/5 in particular, include major programs within the Space Science Programs of the CSA, and other national space agencies e.g. NASA and ESA; as well the global SuperDARN, and programs organized by SCOSTEP (Scientific Committee on Solar Terrestrial Physics) and the US-centered CEDAR (Coupling, Energetics and Dynamics of Atmospheric Regions). We provide leadership in shaping these programs. We are all involved with proposals for future satellite missions which directly or indirectly involve the CSA.

We will celebrate the 50$^{th}$ Anniversary of the founding of ISAS, by Balfour Currie, in 2006/7; in particular at the CAP Congress which will be held at the Uof S in 2007. Given the quality and diversity of our programs, and our fine Staff and Professors, we look forward to continued excellence and leadership in the areas of Solar-Terrestrial Science and Atmospheric Science during the decades of the 21$^{st}$ century.

Alan Manson

# ISAS Facilities

## Observatory Facilities

The majority of the optical and radar systems supporting the programs of the Institute are at the field sites described below. There are a number of additional systems which have been developed or purchased with Institute funds, or are operated for colleagues by ISAS staff.

These include the following:

### Three-component Magnetometer and ULF System

The Three-component Magnetometer and ULF system resumed operations in June 2001, after being damaged in the Park Site fire in 1999. The University of Tokyo operates the Magnetometer and ULF System.

### T.V. All-Sky Camera

This has the following features: 2 filters and shutter to allow observations of specific wave-lengths; PC control for automatic field use; a photo-sensor for computer failure. This all-sky camera was returned to ISAS and is awaiting deployment to another field site.

### Meridian Scanning Photometer (multi-wavelength) MSP

Five single-channel photometers are incorp-orated into this (Iwan Goza for Dr. McEwen, during 1992/93). It is PC (IBM-compatible personal computer) controlled. This MSP has been located at both La Ronge and Rabbit Lake, for Dr. McEwen's CNSR/STEP research; it is now at Rabbit Lake (since the Spring of 1995).

### Spectral Airglow Temperature Imager (SATI-2)

In December 2000 a SATI-2 Imager began operating in the penthouse observatory on the roof of the Physics Building. The SATI-2 Imager was moved from the Physics Building to Park Site in July 2001. The instrument measured perturbations of the rotational temperatures and vertical column emission rate of the O2 Atmospheric nightglow layer at 94 km and the OH Meinel layer at 86 km. The equipment which was on loan from the Institute for Space and Terrestrial Science York University and was returned in June 2003.

## Field Sites

### Rabbit Lake (58°20' N, 103°70' W)

This site was extensively used from 1985-1990 as part of the HILAT and VIKING satellite activities. A new trailer, obtained with CNSR funds, was located at Rabbit Lake during 1992 with a TV all-sky camera. The system was upgraded to a digital recording capability in the Fall of 1993, and operated until Spring of 1996 with visible, red and green filters. The CADI phase-coherent ionosonde system from the University of Western Ontario was removed from the Rabbit Lake site in 2001, and it is now operating at Rankin Inlet. A magnetometer operated by the University of Tokyo is still operating at Rabbit Lake.

### Park Site (52°12' N, 107°7' W)

The field site near Asquith continues to be used by the Atmospheric Dynamics Group with their large MF (2.2 MHz) radar system. This has extensive transmitting and receiving antenna systems for spaced antenna and interferometry studies of the mesosphere and lower thermosphere (60-110 km). Turbulent scatter and meteor trails are used to provide winds, atmospheric waves and turbulence data as well as ionospheric data from *D-, E-* and *F*-regions. This internationally recognized system is fully automated and requires only occasional maintenance; this is normally provided by weekly visits. Data are made available to collaborators in International (e.g. STEP, MLTCS) and National (e.g. CNSR) programs.

In 2001 two experiments were installed at Park Site: 1) A CADI phase-coherent iono-sounde system from the University of Western Ontario, using the Delta antenna, which was later moved to Rankin Inlet, September 2002; and 2) The SATI-2 Imager from York University, moved from the Physics building in July 2001, used to solve the light contamination problem that was prevalent while running in an urban environment. This SATI was returned to York University in June 2003.

The 160-acre site is leased from a local farmer, Mr. Charles Chappell, on a long term rental agreement. On July 13, 1999, a fire caused by lightning destroyed two of the three bays of the main receiver building. The other wing, the MF Radar wing, suffered extensive smoke and water damage. The two fires damaged wings were demolished and the other wing was cleaned and restored. The MF Radar transmitter and receiver systems both had to undergo extensive cleaning before being returned to the field. A new building was completed in April 2000. It was attached to the existing MF Radar Wing. The new building has a 600 sq. ft. cold storage area and a 600 sq. ft. working area. The new working area also contains the optical dome.

### Bakker's Farm (52°15' N, 106°27' W)

In May 1997, SAPPHIRE operations were terminated at the Bakker Farm site. The associated SAPPHIRE transmitter sites at La Crete, Alberta and Gilliam, Manitoba were decommissioned in September 1997. The 6- and 2-meter antenna systems have been left standing to be used on a campaign basis. The building remains ready to be used for radar experiments. Currently the site is being prepared for development and installation of a new and novel 50MHz FMCW E-region experiment, to start operation in 2004.

### Kernen Farm (52°9' N, 106°32' W)

The Kernen Farm is the site of the Saskatoon SuperDARN system. The site is comprised of two antenna arrays:

1. The main array: 16 log-periodic antennas mounted on 15 meter towers. Each connected to a 600W pulsed transmitter.
2. The vertical interferometer array: 4 log-periodic antennas mounted on 15 meter towers connected to an independent receiver to allow angle of arrival calculation. This radar is paired with the US-run radar at Kapuskasing. During 2005 a Fluxgate Magnetometer was successfully tested at Kernen farm to co-exist along with a SuperDARN radar at the same site.

### Prince George (53°59' N, 122°35' W)

A SuperDARN radar was built in 1999 on a site 15 km east of Prince George, British Columbia. The radar system is identical to the SuperDARN radar operating in Saskatoon. The radar has two antenna arrays: a main transmitting array and a vertical interferometer array. The radar point 5° west of north and is paired with a U.S. run radar on Kodiak Island, Alaska.

### Rankin Inlet (a) SAPPHIRE radar site from the CNSR (Canadian Network for Space Research) (62°48' N, 92°10' W)

The SAPPHIRE radar was decommissioned in 1997, but the site was retained by the space radar group in ISAS. Subsequently, in 2000, a NORSTAR all-sky-imager was installed by the U of Calgary team, and in 2002, a CADI (Canadian Advanced Digital Ionosonde) instrument was installed at the site.

### (b) SuperDARN/NORSTAR site (62.82°N, 93.11° W)

In 2004, a PolarDARN HF radar site was established at Rankin Inlet, with the installation of power lines, a road and a 20-foot ship container that will house both the radar electronics and a NORSTAR imager (for which a dome was cut into the roof). The NORSTAR imager will be moved over to this new site from the SAPPHIRE site referred to in (a) above. During 2005, the SuperDARN antenna system was completed at the site. In September 2005, a THERMIS ASI has been put into operation at the site.

### Inuvik (68° 24' 46"N, 133° 46' 10" W)

In 2004, a radar/NORSTAR site was established about 7.5 km north of the town of Inuvik. This is a former Dept. of National Defence over-the-horizon radar site, and was ideal for its purpose of acting as a radar site at which CADI and PolarDARN operations will occur. In 2004, the roads, power lines, and a 20-foot container were installed. The container has a dome that

will allow the site to house a NORSTAR imager. In the fall of 2004, the CADI antenna system was installed by engineer Jan Wiid and technician Bill Marshall, and the CADI system itself was installed in July, 2005. The use of the site as an Inuvik PolarDARN site will await the procurement of the remaining required funding for the radar – to date, only partial funding has been received from the US NSF in conjunction with the AMISR project. The Rankin Inlet and Inuvik radars will be paired to form a SuperDARN Radar.

# Computing Facilities

An Institute with such extensive observational systems, and data analysis programs, requires considerable computing facilities. A wide range of computer systems is available to ISAS scientists and graduate students.

In addition to being used for data analysis, the DEC Alphaserver is mainly used as a mail server for ISAS because of its security against virus attacks. Analysis of the SuperDARN data has been moved from the Hewlett-Packard systems to a Linux based PC, mainly for cost reasons; but also, because the increased storage capacity allows all SuperDARN data to be kept online. The SuperDARN data distribution has been changed from Exabyte tapes to CDs. For this a Rimage Protege CD duplicator and printer and a Young Minds AutoStudio interface to a Linux computer was acquired.

Finally, most of the Institute's observational systems have the capability of real-time analysis of data by dedicated PC systems, which has minimized the need for major main-frame computers or even work stations. The MF radar at Saskatoon (Atmospheric Dynamics Section, Dr. Manson), the VHF radar transmitter/receiver system known as SAPPHIRE, the SuperDARN MF radar at the Kernen Farm, and the Rabbit Lake/ Rankin Inlet All-sky Camera, are each Computer controlled and generate processed data. These are then ready for detailed analysis. In addition, the engineers within ISAS continue to demonstrate leadership by the use of transputer technology.

# Optical And Electronic Laboratory Facilities

The Optical Laboratory is under the direction of Bill Marshall and continues to provide general support for the research programs within the Institute. There are optical calibration standards for visible, UV and IR (200-900 nm). Low brightness sources (LBS) in the UV and IR were developed during the CNSR for medical research (ozone) and stratospheric measurements. In particular, calibrated detectors were obtained for the UV-A and B regions, and there was testing of sources and detectors over the 200 to 400 nm range.

The Electronic Laboratory has network and spectrum analyzers, signal generators and test equipment to allow development of state of the art VHF/HF/MF radars. Marshall also maintains this electronic test equipment and develops new systems/sub-systems for the optical and radar facilities of ISAS. Marshall is supported by ISAS funds (50%), NSERC funds from the MF radar group and the HF/VHF radar group.

Projects of particular note include the following:

- SuperDARN system support
- Park Site MF radar system maintenance and development, and
- General support for the electronic/ mechanical needs of 32-35 ISAS personnel
- CADI system management

## Particle Calibration Facility

The basis of this facility is the Canadian Space Agency electron calibration system (1-400 eV), with a cryogenically pumped vacuum chamber and clean room which was developed for FREJA-CPA, but has also been used for various rocket systems. This facility is within the Optics Lab. It will allow calibrations for electron energies of up to 25 keV, which are of value for satellite and rocket systems sampling auroral electron populations.

## Electronics and Mechanical Stores Facility

Comprehensive electronic and mechanical Stores were maintained and administered by Shirley Pfeil (Dept. Assistant) for ISAS researchers throughout the year 2004-05 Shirley is supported 100% from ISAS funds and her hours remain at .80 FTE.

Shirley handles all of the ISAS accounting and provides in-house monthly and annual budget summaries for all ISAS accounts, which are administered by herself and the ISAS Chair. She is also responsible for the purchasing of all equipment and supplies.

Materials and components are provided at cost and this has been of significant practical assistance in research programs. Turn-over of parts and purchase of equipment, and other related expenses in the year 2004-05 were in excess of half a million dollars in activity, which is consistent with previous years.

# Research Programs

## Atmospheric Science

- **Atmospheric Dynamics Group**
  - **Professor Alan Manson**

- **InfraRed Group**
  - **Aeronomy Research – Odin/ OSIRIS**
  - **Professor E.J. (Ted) Llewellyn**
  - **Professor Doug Degenstein**

## Solar-Terrestrial Science

- **Super DARN/ PolarDARN Group**
  - **Professor George Sofko**
  - **Professor Sasha Koustov**
  - **Professor Kathryn McWilliams**

- **Solar-Terrestrial Relations/ Space Weather**
  - **Professor Jean-Pierre St.-Maurice (CRC)**

- **Ionospheric Physics/ VHF and CADI Radars**
  - **Professor Glenn Hussey**

# Atmospheric Dynamics Group

## Professor A.H. Manson

**Team Members**

| | |
|---|---|
| **Research Associate:** | Dr. Chris E. Meek |
| **Research Assistant:** | Carole (Qin) Li |
| **Technician:** | Bill Marshall |
| **PhD Graduate Student:** | Tatyana Chshyolkova |

The Group continues to operate its three MF Radar systems in Saskatoon, Tromso (Norway) and Platteville (Colorado). These are involved, along with circa 25 radars operated by international colleagues, in three major science themes:

- Comparisons between radar observations (Equatorial to the Arctic) and data from the Canadian Middle Atmosphere (General Circulation) Model (CMAM): the model included interactive chemistry, but with no data assimilation.

- Global studies of linkages between stratospheric planetary waves (PW) and the dynamics of the middle atmosphere using a data assimilation model (U.K. Meteorological Office GCM, MetO) and mesospheric winds from the radars.

- A northern hemisphere Campaign to study the breakdown of the Polar Winter Vortex (2004/5) using observations from the ground to near 100km: this is part of an international Project (2004-2008) within CAWSES (Coupling and Weather of the Sun Earth System). http://www.ngdc.noaa.gov/stp/SCOSTEP The associated Campaign, which involves 25 radars, optical systems, satellite systems (Odin-OSIRIS, TIMED-SABER) and several models (CMAM, TIME-GCM, MetO) is led by Tatyana Chshyolkova. Enhanced understanding of atmospheric dynamics (0-100km) is essential to properly understand the coupling effects within the atmosphere, as well as the sources and sinks of significant chemicals such as ozone. These are also the signals of "Climate Change".

To describe the polar vortex, the methodology developed by Lynn et al. [JGR 107, 2002] has been employed. This involves calculations of the scalar quantity Q that is a measure of the relative contribution of strain and rotation on fluid elements in an Eulerian frame. Closed circulations can be associated with negative Q, while positive Q is typically associated with planetary-wave breaking and related mixing of "vortex-edge" and mid-latitude air. Q, the stream function and potential vorticity (PV) are calculated for 24 different isentropic levels (from 300 to 2000 K) using MetO fields of temperature and horizontal winds. Under certain conditions, PV is used as an indicator of PW breaking and a tracer of fluid motion. Preliminary results show that the vortex was strong during most of the winter 2004/05 (Figure 1), until the end of February/beginning of March when it was significantly distorted and displaced from the pole (Figure 2). The picture is much more complicated as the characteristics of the vortex vary throughout the stratosphere. During stratospheric warmings the mesosphere and stratosphere may become closely connected. To explore this, mesospheric winds from several meteor and MF radars have been analyzed using time and frequency analyses (wavelets, wave number, etc.). As an example, the meridional and zonal

winds are shown in Figure 3 for three stations: Tromso, Saskatoon, and Platteville. The weakening and then reversals of the mesospheric winds during the first part of March (day numbers are 60-75) are clearly seen for all three stations. These events coincide with the strong distortion and displacement of the stratospheric vortex shown in Figures 1 and 2.

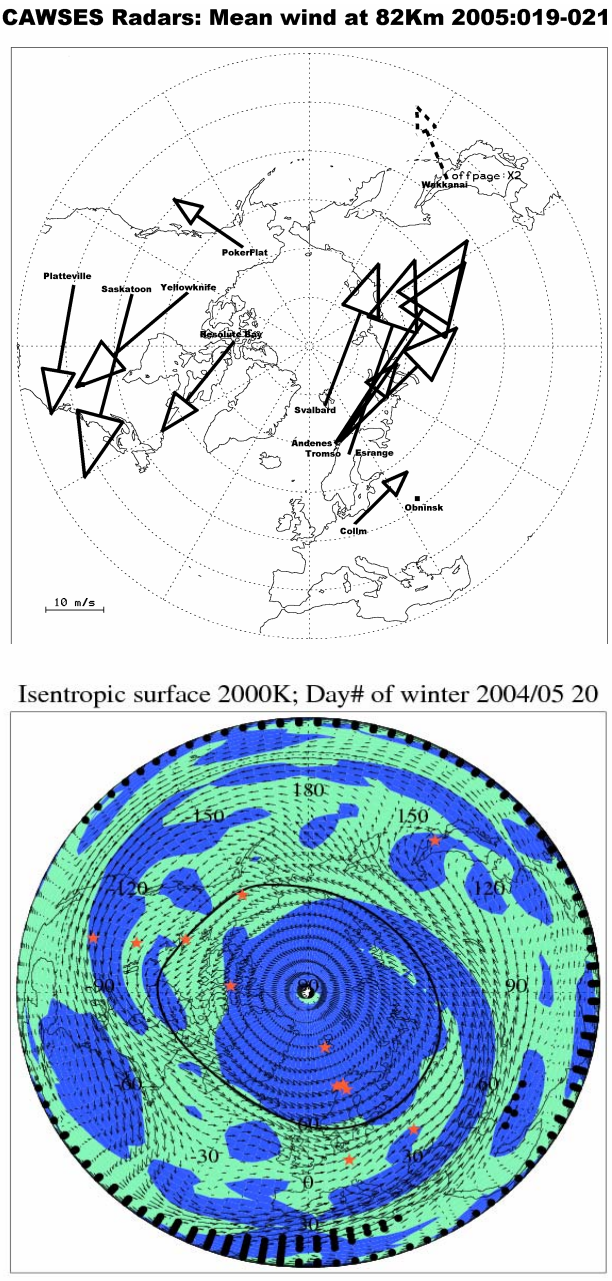


**Figure 1** The mesospheric winds measured by 13 meteor and MF radars at 82-85 km on January 20th are provided at the top of the figure. At the bottom, the Q diagnostic calculated for the 2000 K isentropic surface (~50 km) is shown by blue (negative) and green (positive) colors. In blue regions, the rotation of the flow is dominant, while green regions are expected to be associated with PW breaking and mixing. The thick black line (a stream line for which

integrated Q is near zero) is the estimated edge of the polar vortex. Black circles are potential vorticity with negative values; vectors show winds; and red stars are the locations of the 13 radars. The mesospheric winds, although 35 km higher in altitude are very consistent with the stratospheric polar vortex winds.

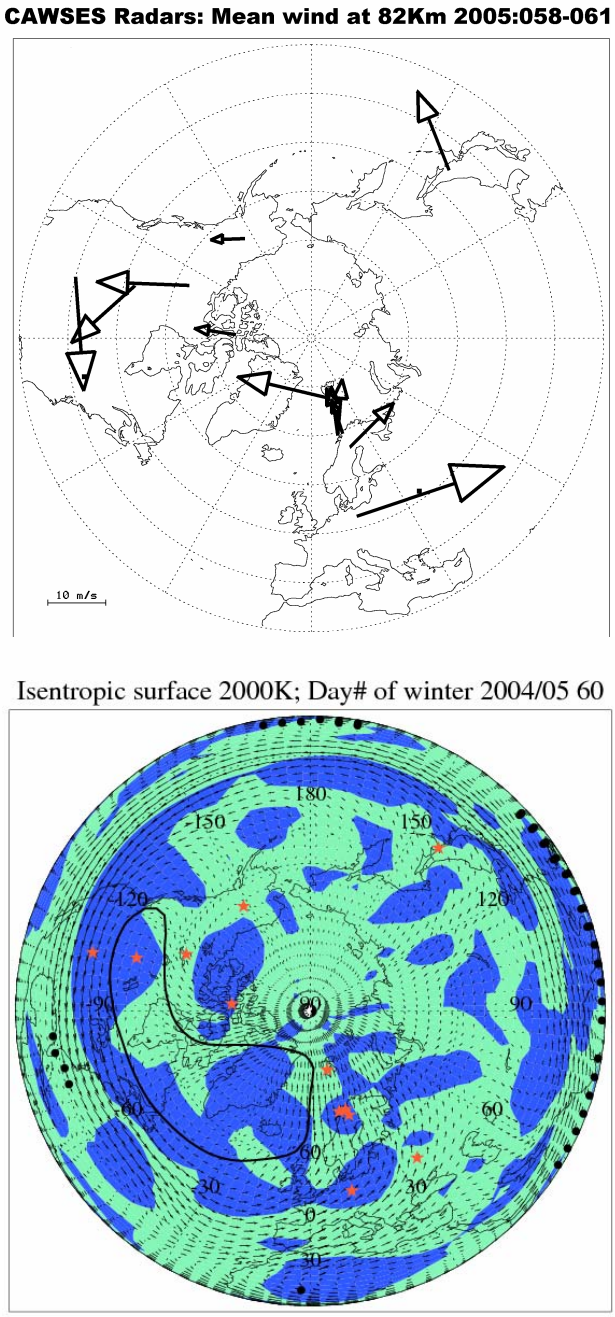


**Figure 2** The same as Figure 1, but for day number 60 (March 1, 2005). During this time the polar vortex is strongly disturbed and displaced equatorward throughout the stratosphere, and almost disappears at this uppermost (50 km) stratospheric level. Mesospheric winds are weaker compared to those in January, and provide no evidence for vortical winds.

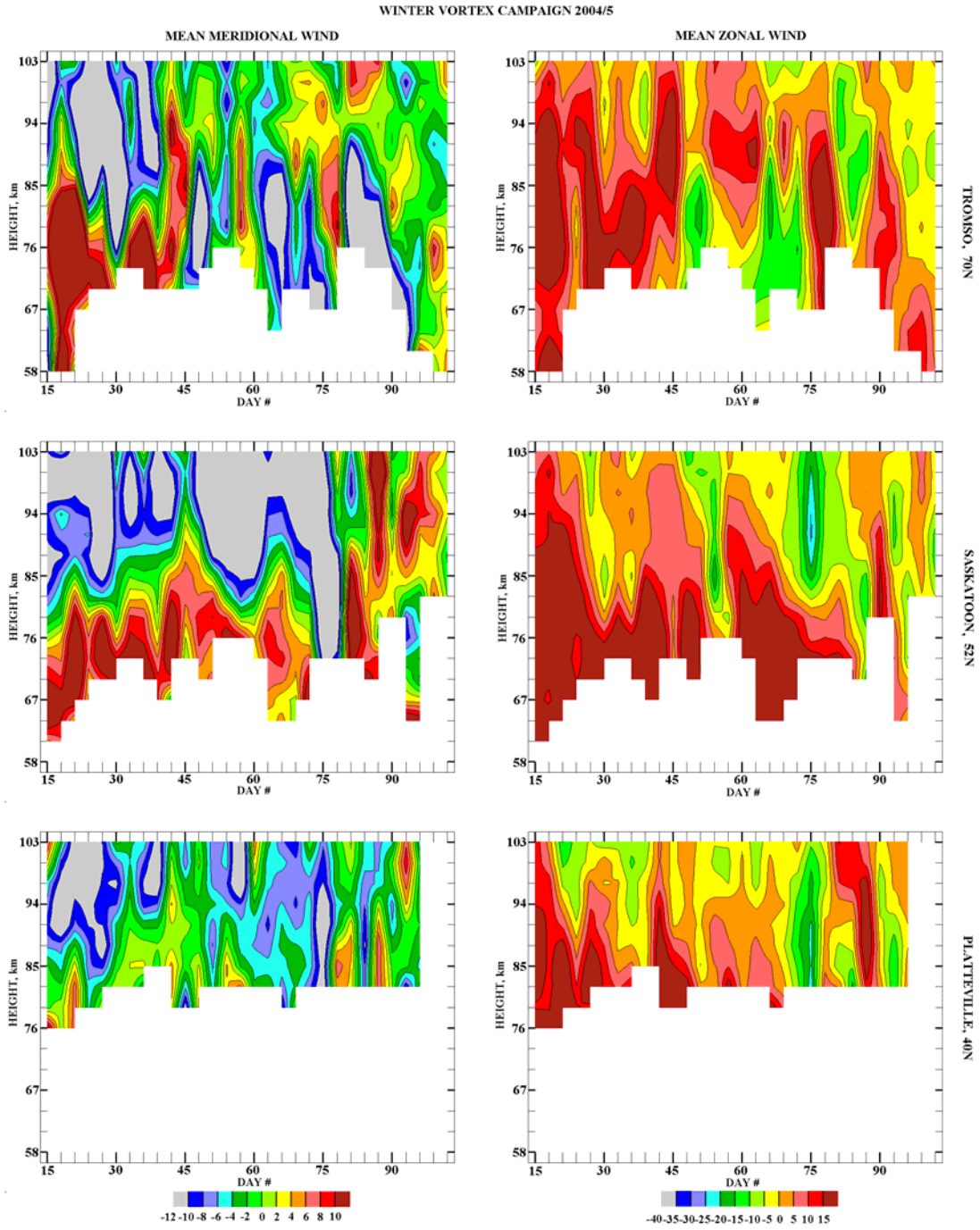


**Figure 3** Mean meridional (left column) and zonal (right column) winds, obtained using 3 day harmonic fits, are shown for the time interval from January 15 to the beginning of April for three stations: Tromso (70N), Saskatoon (52N), and Platteville (40N). At the end of February/beginning of March (day numbers 45-75), typical winter northward and eastward winds (red) became weaker and reversed at all three stations. These reversals have occurred around the time when the stratospheric polar vortex was strongly disturbed and displaced from the pole. The wind reversals are consistent with higher polar temperatures. Increases in PW activity (not shown) also occurred at these times, since vertical propagation is enhanced by the weaker zonal winds.

# Aeronomy - Odin-OSIRIS (IRG)

## Professors E.J. (Ted) Llewellyn and D.A. Degenstein

### Team Members of the Infra Red Group (IRG)

| | | |
|---|---|---|
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| **Research Associate:** | Dr. N.D.Lloyd | Odin Project funded through PWGSC/CSA Contracts |
| **Post Doctoral Fellows:** | Dr. S. Petelina | Odin Project funded through PWGSC/CSA and NSERC Grants<br>Contracts and NSERC Grants |
| | Dr. E. Dupuy | Odin/ACE Collaborative Project funded through NSERC Grants |
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The InfraRed Group (IRG) in the Institute has continued to use observations made with the Canadian built OSIRIS instrument that is in operation on the Swedish satellite Odin. The OSIRIS data set now spans more than four complete years. During the past year members of the IRG have made a number of studies that will assist with the optimization of the forthcoming NASA AIM (Aeronomy of Ice in the Mesosphere) mission that will be launched in 2006. These studies have included the investigation of the geographic distribution of Polar Mesospheric Clouds as well as the sizes and light scattering properties of the ice crystals that make up these clouds. Other PMC studies, which have used data from both OSIRIS and the HALOE instrument on UARS, have investigated the relationship between water vapour content and temperature in the formation of PMC's. This is of particular importance as the knowledge of water vapour concentrations in the presence of PMC's is very uncertain. In related mesospheric investigations there has been effort to make measurements of ground state ($X^2\Pi$, v = 0) hydroxyl concentration from the OSIRIS observations of the resonant OH emission ($A^2\Sigma^+ - X^2\Pi$) feature at 308 nm. The detection of this emission is not a simple matter as it is necessary to remove the large Rayleigh background and to correct for ozone absorption. The emission has been detected previously with the MAHRSI instrument flown on the Space Shuttle (*Conway et al.*, 1999; 2000) while laser induced fluorescence has been used to measure atmospheric OH (*Wennberg et al.,* 1994). Both of these measurements are made with high spectral resolution while the OSIRIS observations are made with a spectral resolution of only 1 nm. The OSIRIS detection is quite remarkable when it is recognized that the incident exciting solar spectrum is extremely structured and that the emitted spectrum is a complicated molecular band. The analysis of the observations has clearly shown that the emission is readily detectable and that it exhibits both a diurnal and seasonal variation. The extended Odin/OSIRIS measurement period, four years, that is available has allowed these variations to be determined with some confidence. An example of these variations is shown in Figure 1. In a related investigation, which takes advantage of the ACE instrument on the Canadian SciSat-I mission, it has been shown that the resonant emission can also be used to

retrieve water vapour concentrations over the altitude range 50-100 km throughout the sunlit atmosphere. The preliminary results presented in Figure 2, which are for a single altitude, show that both the emission and the water vapour concentration exhibit a large longitudinal variation.

The OSIRIS measurement capability has also allowed an extended study of ozone depletion associated with the large solar proton event that occurred in October 2003, the Halloween Storm. The Odin orbit is such that the temporal development of the ozone depletion could be followed. This is clearly apparent in the results presented in Figure 3, which shows the tomographic inversions of the oxygen infra-red atmospheric band emission during the course of a number of successive orbits. The OSIRIS tomographic capability has also provided new information on the tertiary peak in the vertical ozone profile and the fine details of the excitation mechanisms for the singlet delta state of molecular oxygen. This tomographic capability, which is the result of many years work by the IRG, has attracted a significant amount of attention from others in the world-wide aeronomy community and is being used to assist the NASA TIMED/SABER with the interpretation of their satellite observations. In particular it has been shown that the double peak features that are frequently seen in limb profiles is the result of a single enhanced emission region and not a double peak in the vertical profile of the emission.

Other spectral features observed with OSIRIS include the NO-$\gamma$ bands in the spectral region between 280 and 315 nm and the oxygen atmospheric band. While the $\gamma$--intensities are quite low it is possible to use the observations from a number of bands in a sequence to make important measurements in the MLT region where these results can be combined with those from TIMED/SABER observation. The quality of the atmospheric band spectra, Figure 4, are such that the temperature of the emitting region can be reliably determined.

The IRG have also developed SaskTran, a new spherical radiative transfer model, that allows the retrieval of atmospheric ozone, nitrogen dioxide stratospheric sulphate aerosols and the terrestrial albedo. This last quantity is important for the study of global change and shows that direct observations of the terrestrial reflectivity are not required to retrieve important ground information. The new measurements of ozone profiles that are obtained with the application of this model to the OSIRIS data are showing excellent agreement with the limited number of coincident SAGE measurements, Figure 5, and confirms that OSIRIS is producing TOMS-like ozone maps at each 1 km in altitude over the entire sunlit atmosphere. These ozone profiles extend into the lower mesosphere where they overlap with the ozone profiles retrieved from the infrared imager (IRI) section of OSIRIS and so allow the determination of the ozone profile from the troposphere through to the upper mesosphere. Inversions of the OSIRIS observations with the model are also providing retrieval of stratospheric sulphate aerosol extinction parameters.

In addition to the OSIRIS project, members of the IRG are also involved in other Canadian Space Agency satellite projects such as ACE-SCISAT, SHOW, MOPITT-2, WaMI and a new Niche Mission to study the upper troposphere and lower stratosphere region.

Conway, R.R., M.H. Stevens, C.M. Brown, J.G. Cardon, S.E. Zasadil and G.H. Mount, Middle Atmosphere High Resolution Spectrograph Investigation, *J. Geophys. Res.*, **104**, 16327-16348, 1999.
Conway, R.R., M.E. Summers, M.H. Stevens, J.G. Cardon, P. Preusse and D. Offermann, Satellite observations of upper stratospheric and mesospheric OH: The $HO_x$ dilemma, *Geophys. Res. Lett.*, **27**, 2613-2616, 2000.
Wennberg, P.O., R.C. Cohen, N.L. Hazen, L.B. Lapson, N.T. Allen, T.F. Hanisco, J.F. Oliver, N.W. Lanham, J.N. Demusz and J.G. Anderson, Aircraft-borne laser-induced fluorescence instrument for the *in-situ* detection of hydroxyl and hydroperoxyl radicals, *Rev. Sci. Instrum*. **65**, 1858–1876, 1994.

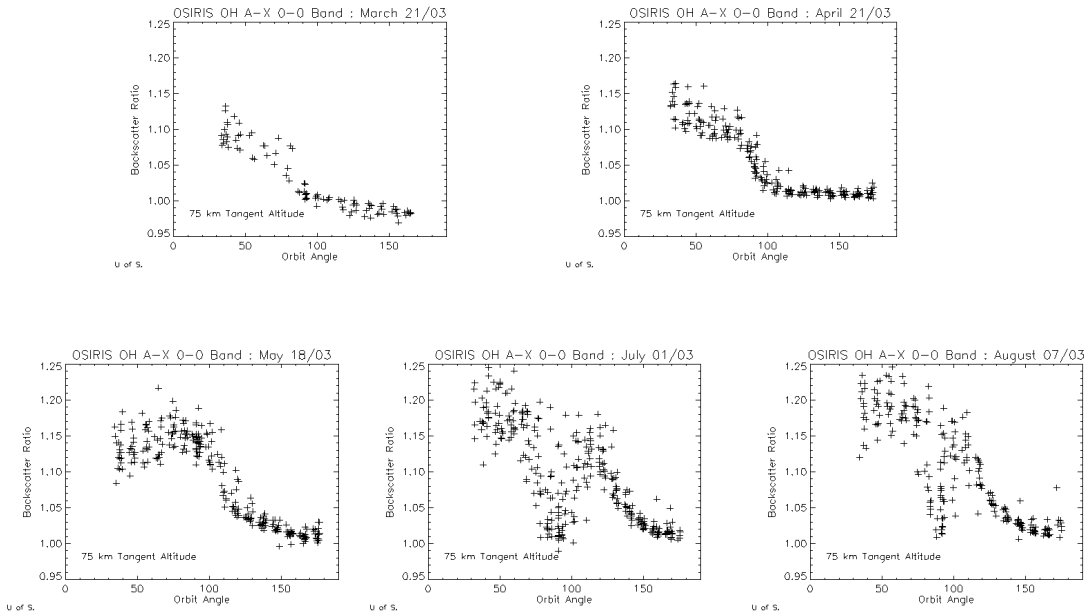


**Figure 1** Seasonal variation of the OH (A-X) emission, at 75 km tangent altitude, as detected with OSIRIS.

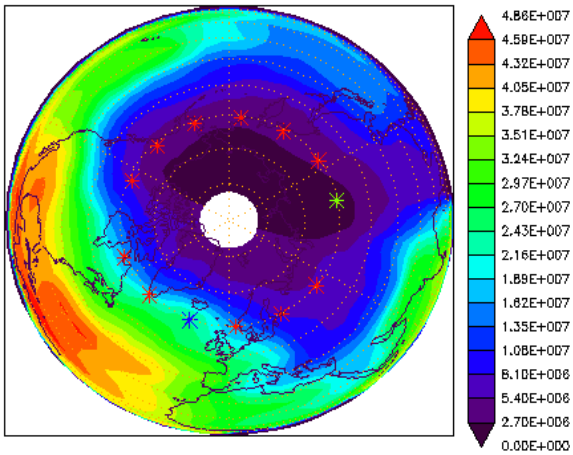


**Figure 2(a)** The 24 March 2005 OSIRIS Northern Hemisphere observed OH density map at an altitude of 80 km for all post-noon profiles. The asterisks indicate the locations of the ACE-FTS occultation measurements, blue and green highlighting the locations of maximum and minimum water vapor mixing ratios, respectively. The OSIRIS OH density variations with longitude along the 60° N latitude circle are very similar to the ACE-FTS water vapor mixing ratio longitude distributions shown in

**Figure 2(b)**

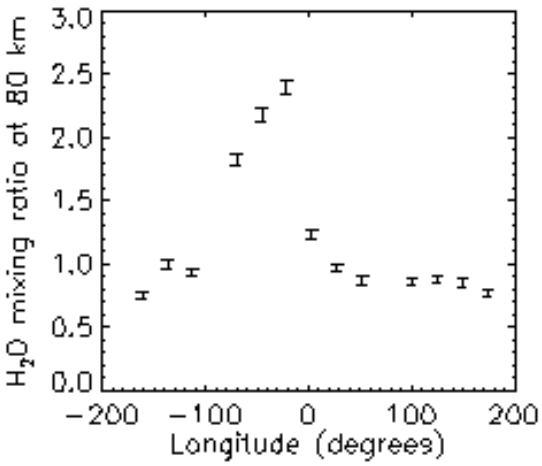


**Figure 2(c)**

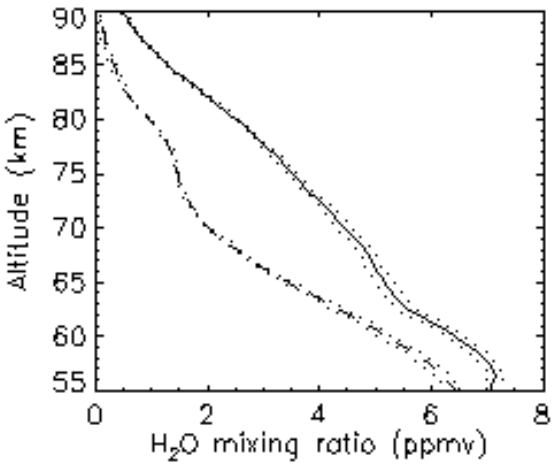


**Figure 2(b)** ACE-FTS water vapor mixing ratios on 24 March 2005 for sunsets at 80 km altitude, 60-62° N latitude. The mixing ratio shows a very pronounced dependence on longitude.

**Figure 2(c)** ACE-FTS water vapor mixing ratio profiles on 24 March 2005. The solid line is the profile at 60° N latitude, 21° W longitude, corresponding to the maximum mixing ratio in Figure 2b. The dashed curve is the profile at 61° N, 101° E, located within the longitude range of the minimum mixing ratio in Figure 2b. The dotted lines show the error limits for the ACE-FTS water vapor mixing ratios.

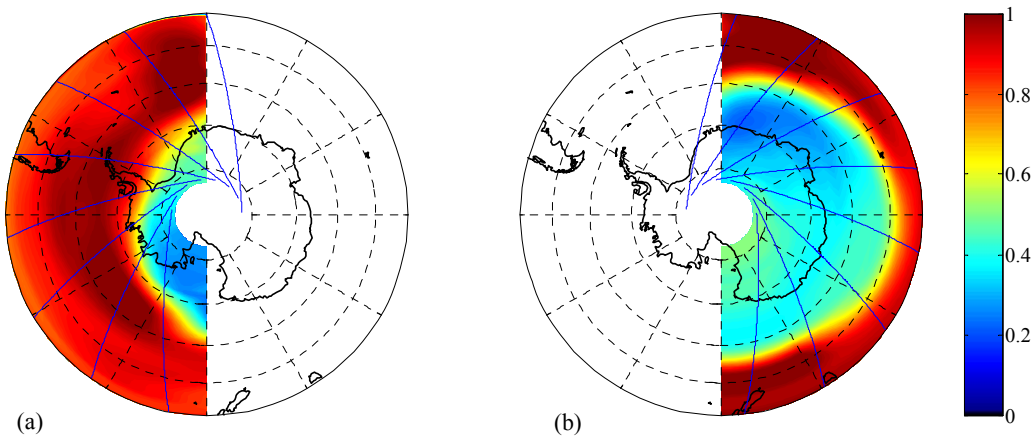


**Figure 3** The two polar plots illustrate the global extent of the fractional ozone depletion at 65 km. The 7 Odin orbits are marked and values between the orbits are interpolated. The data for panel a) was collected on the ascending leg of the orbits while that of panel b) was collected on the descending legs. At any latitude absolute time increases in a counter-clockwise sense so that the global contours also reflect the temporal variation of the ozone depletion.

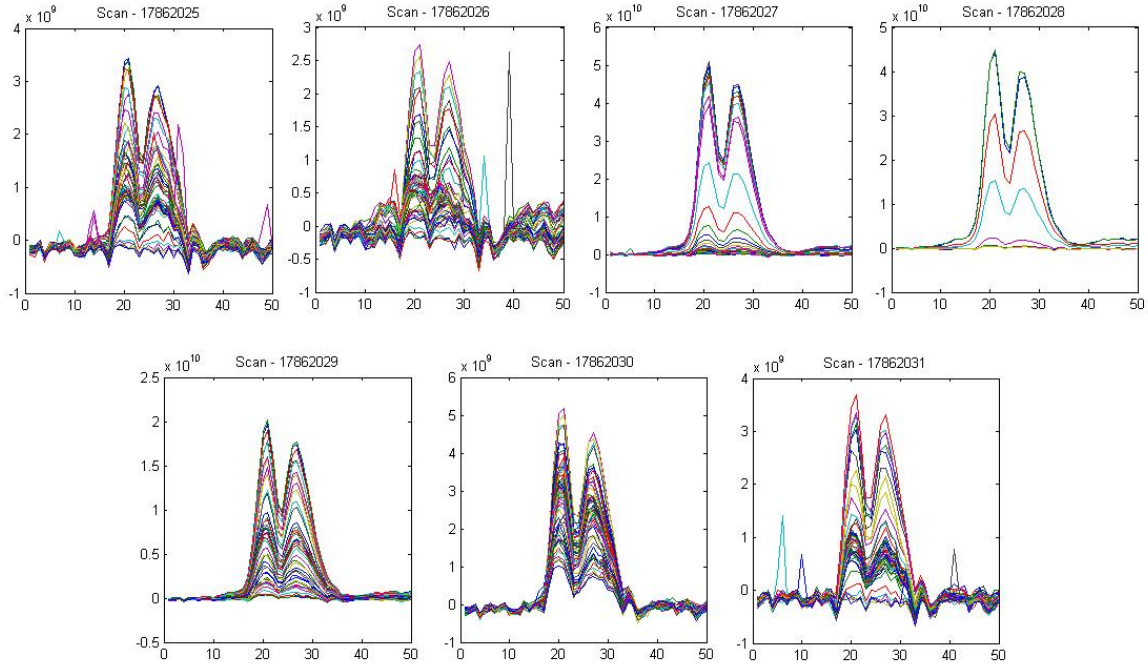


**Figure 4** The oxygen A-band spectrum as recorded with OSIRIS on a number of different limb scans.

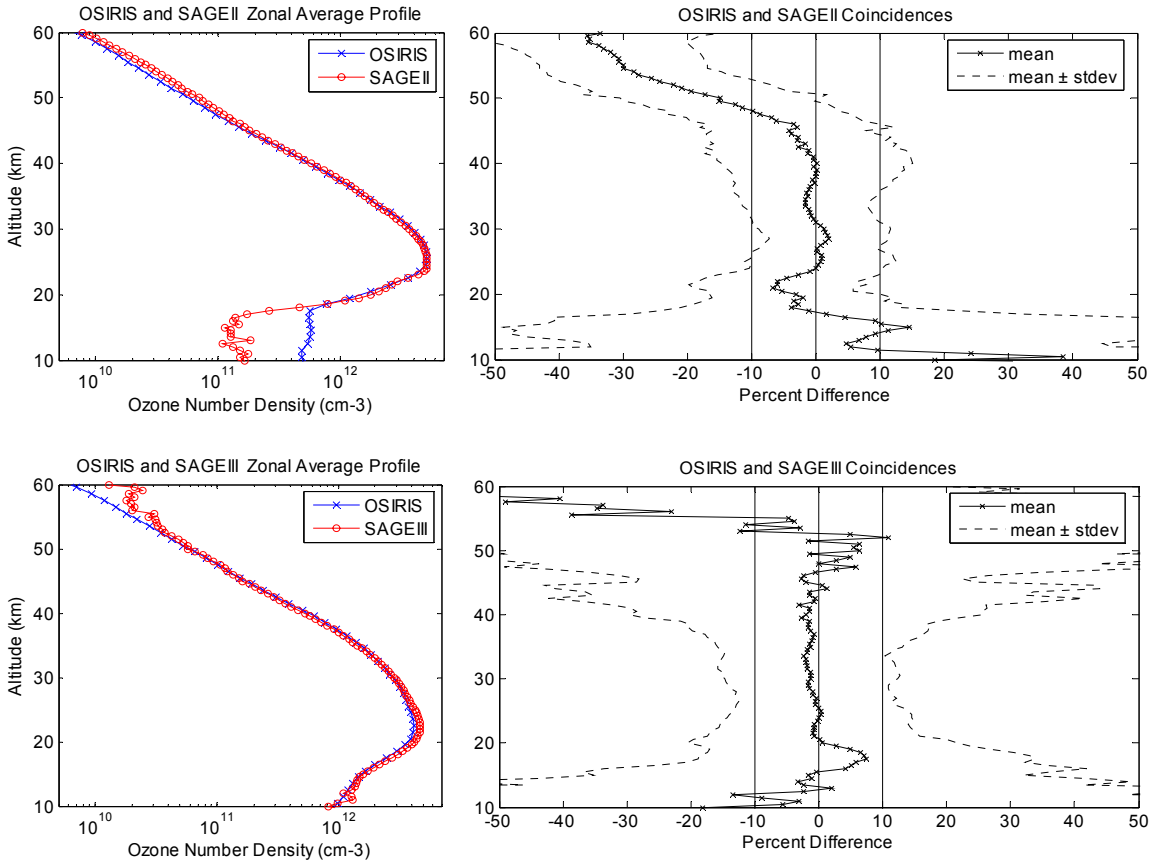


**Figure 5** Excellent agreement is demonstrated between the retrieved OSIRIS ozone profiles and those retrieved from SAGE observations. The left hand plots are a comparison of zonal averages using OSIRIS and both SAGE II and SAGE III. The right hand plots are comparisons of coincident measurements. Note the excellent agreement between SAGE III and OSIRIS in the altitude range from 20 to 50 km. Above 50 km the diurnal effects of ozone photochemistry adversely affect the SAGE measurements. SAGE II only measures Chappuis absorption and this limits there upper altitude to around 40 km.

# SuperDARN/ PolarDARN Group

## Professors G.J. Sofko (P.I.), J-P St.- Maurice, A.V. Koustov, K.A. McWilliams, and G.C. Hussey

### Team Members of SuperDARN (Super Dual Auroral Radar Network)

| | |
|---|---|
| **Research Associates:** | Drs. D. André, M. Watanabe |
| **Head Engineer:** | J. Wiid |
| **Technician:** | B. Marshall |
| **Graduate Students:** | J. Liang, L. Benkevitch, R. Drayton, R. Gillies, R. Schwab |

The "Space Environment" program uses a global-international array of HF radars called "SuperDARN". Currently this array consists of 17 radars, 10 in the northern and 7 in the southern hemisphere. The U of S team is expanding the Northern hemisphere portion of the network by introducing a new pair of radars called PolarDARN (see Figure 1). One of the PolarDARN radars at Rankin Inlet is completely funded (CFI Grant to Canada Research Chair Dr. St.-Maurice). Figure 2 shows views of the "new" wire antenna system during its installation at Rankin Inlet (the only other SuperDARN radar with such an antenna system is the Wallops Island radar). The Rankin radar is expected to be in full operation by spring of 2006. At Inuvik, a building has been erected and power installed, but funding is not yet complete for that radar. The U of S SuperDARN team heads the Canadian participation in SuperDARN, maintains the two radars under Canadian control (Saskatoon and Prince George), operates the International Data Copy and Distribution Facility from which all SuperDARN data are distributed, and coordinates the monthly operating schedules for all radars.

The PolarDARN, Prince George and Saskatoon radars are integral parts of the extensive Canadian GeoSpace Monitoring (CGSM) network of ground-based magnetometers, optical imagers and scanners, and radio/radar systems (HF radars, ionosondes, riometers). The CGSM, shown in Figure 3(a), is a significant expansion of the former CANOPUS network. In addition to CGSM support, the PolarDARN radars will be complemented by the NSF AMISR (Advanced Modular Incoherent Scatter Radar) system at Resolute Bay, which will see the installation of two radar modules. Figure 3(b) shows the excellent spatial overlap of the coherent PolarDARN radars and the incoherent AMISR radars (AMISR beams are purple; their directions had not yet been finalized as of Dec. 2005).

The main aim of SuperDARN is to study the dynamics of the magnetosphere through its coupling to the ionosphere where the radar measurements of the electric field patterns are made. These studies include the determination of "Space Weather" conditions at altitudes where satellites and astronauts operate. Addition of the PolarDARN radars provides an opportunity to study the processes in the polar cap. This is the area of open magnetic field lines which surrounds the Earth's geomagnetic pole and which has been unreachable by the existing SuperDARN radars In particular, the equatorward boundary of the polar cap is the region where merging (reconnection) of the interplanetary magnetic field (IMF) with the

earths field occurs; merging is the main process that drives the magnetospheric convection measured by the HF SuperDARN radars. Reconnection is believed to be an important astrophysical process in stars, but they are highly inaccessible to measurement, whereas PolarDARN and the supporting ground-based and satellite instruments gives us the opportunity to use the Earth to study this important process in detail. The combined CGSM and AMISR projects will provide an unparalleled opportunity to study the convection dynamics resulting from merging on both the dayside and nightside of the polar cap. In addition, the International Polar Year (2007 – 2009) presents a unique opportunity for global studies, and the Canadian CGSM IPY proposal has been incorporated with 23 others to form the international ICESTAR/IHY program led by Dr. Kauristie of the Finnish Meteorological Institute.

Finally, the areal coverage of SuperDARN is ideal for support of satellite projects, in particular the upcoming e-POP mission. On board will be the RRI (Radio Receiver Instrument) which will be used to receive direct (forward propagation) transmissions from one of the SuperDARN radars (e.g. Saskatoon), while at the same time regular backscattering from auroral structures, gravity wave ionospheric perturbations and meteors will be received by the radars. Future collaborations with the SWARM (France), THEMIS (US), Kua Fu (China) and the Radiation Belt Storm Probe/ORBITALS (US/Canada) satellites are in the planning stage.

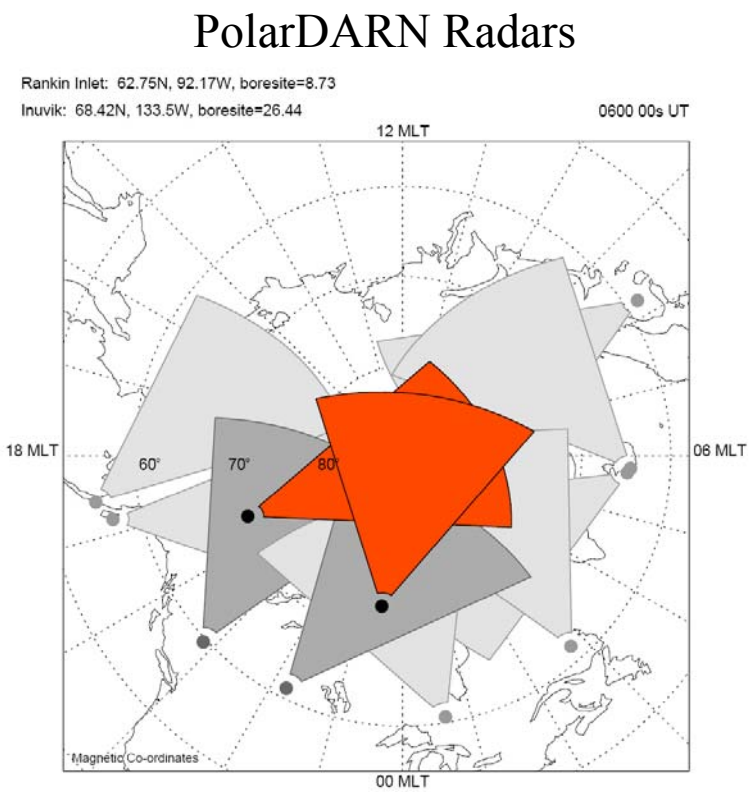


**Figure 1** The PolarDARN radars are shown in red, along with the other nine existing northern hemisphere radars (a new radar is also planned at the eastern end in Finland, lookingeast, and a new radar to the south at Wallops Island, VA, began operating in May, 2005).

**Figure 2(a)** View of the radar building and part of the antenna array at the PolarDARN Radar, Inuvik site.

**Figure 2(b)** Panoramic view from an antenna tower during Rankin antenna erection.

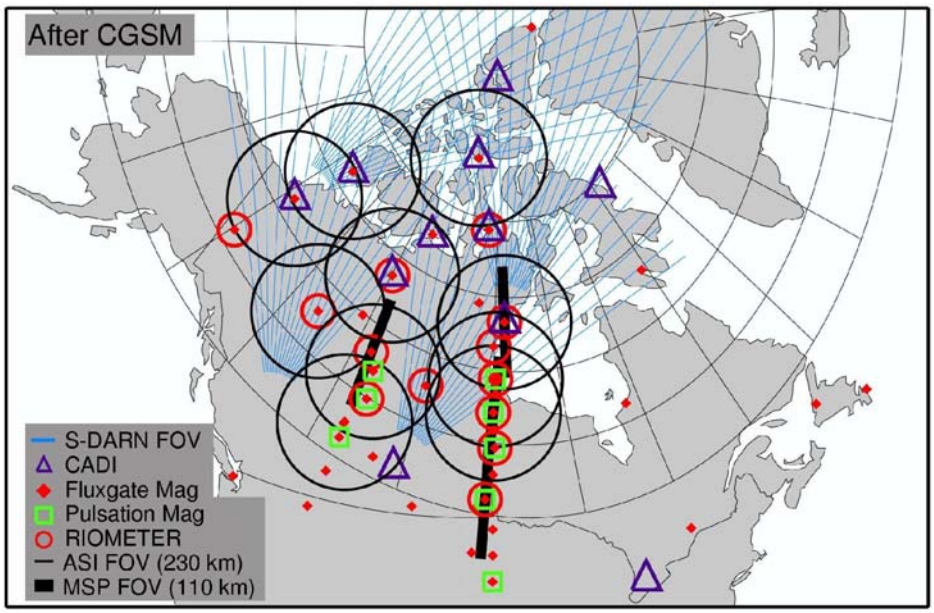


**Figure 3(a)** The CGSM network, showing the four Canadian-operated SuperDARN radars, namely the existing Prince George and Saskatoon radars, and the two PolarDARN radars at Rankin Inlet and Inuvik.

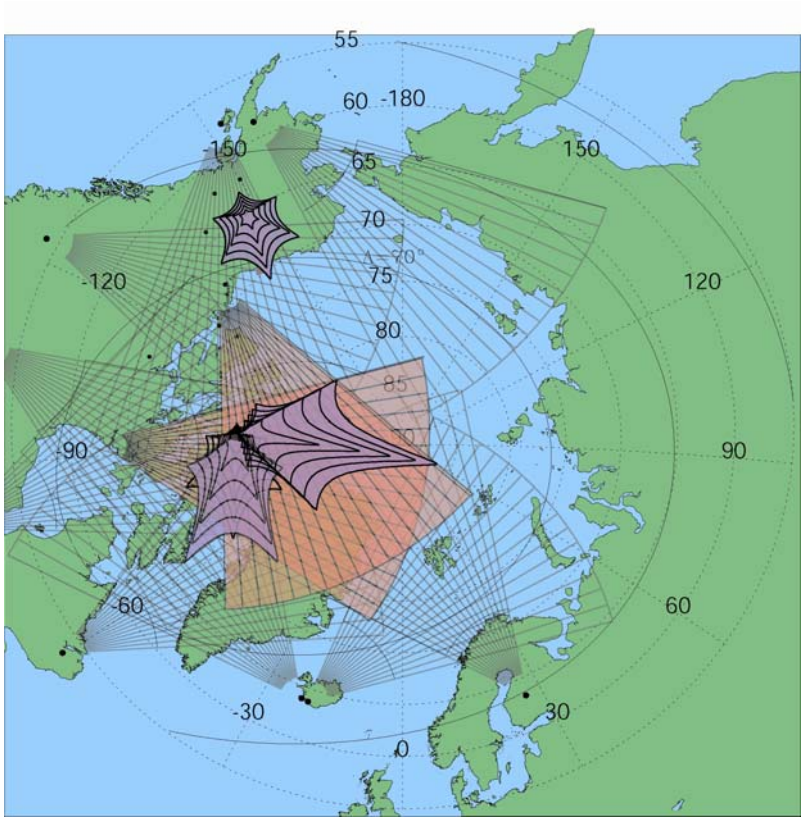


**Figure 3(b)** By 2007, PolarDARN and AMISR should both be completed to form a powerful combination of coherent and incoherent scatter radars to study "polar cap" space weather. The AMISR beam dierections (purple) have not been finalized.

# Comparison of DMSP cross-track ion drifts and SuperDARN line-of-sight velocities.

## A.V. Koustov (jointly with M.Sc. student R. Drayton)

The goal of the project is to investigate consistency of the high-latitude convection data provided by two independent instruments.

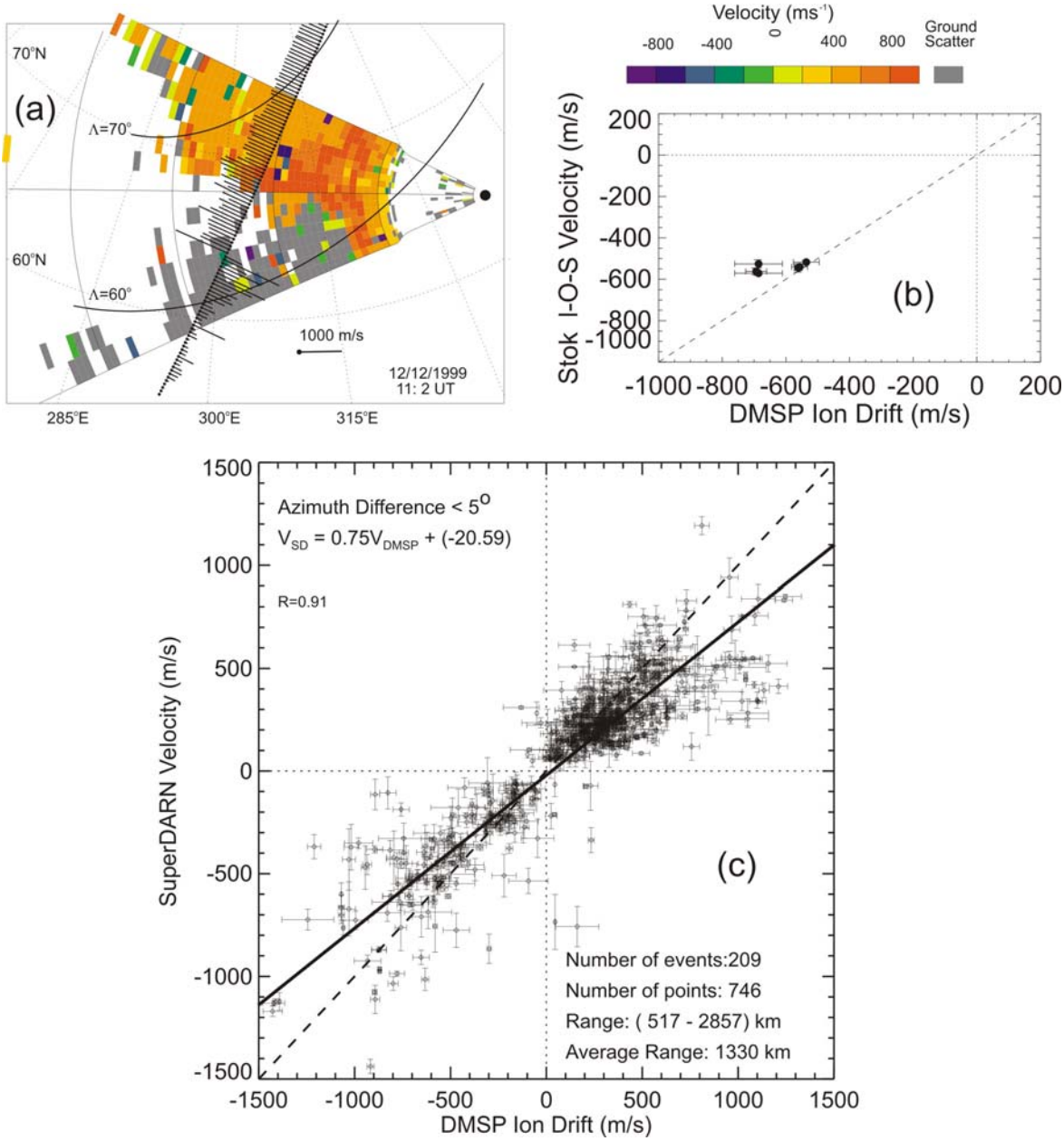


**Figure (a)** Example of SuperDARN (Stokkseyri radar) and DMSP joint observations of plasma flow in the high-latitude ionosphere. We consider only relatively uniform SuperDARN line-of-sight velocity maps that are matched with smoothly changing ion drift measured by various DMSP satellites in the cross-track direction. Also, the comparison was

performed only for those spots at which the difference between the radar beam and satellite cross-track direction was less than $5^0$ and the difference in time was less than 2 min.

**Figure (b)** For the presented event of December 12, 1999 four points are available, and the SuperDARN and DMSP velocities are very close to each other.

**Figure (c)** A scatter plot of the SuperDARN line-of-sight velocity versus the DMSP cross-track ion drift for 9 SuperDARN radars (Hankasalmi, Pikkvibaer, Stokkseyri, Saskatoon, Kodiak, Halley, Sanae, Syowa-South and Syowa–East) and various radar ranges. Total of 746 points is available. The best linear fit line has the slope of 0.75 and the correlation coefficient is 0.91; both parameters indicate that the raw data obtained by the instruments are very comparable.

## Magnetospheric Waveguide Modes Coupling to Field-Line Resonances and Responses to Changes in the Global Magnetospheric Configuration (K. McWilliams)

A superb combination of instruments in critical locations, along with a prolonged quiet period during which waves could develop, allowed for a very detailed examination of wave mode coupling between the solar wind and the magnetosphere.

ACE, located far upstream, observed nearly constant solar wind plasma parameters and occasional magnetic field fluctuations during an interval of generally duskward IMF orientation. No waves were seen at ACE, although Fourier analysis reveals weak power within the range of periods from 8 to 16 min. Wind, located inside the dusk equatorial magnetosphere observed a weak compression of the geomagnetic field just after 12:00 UT. The compression was not related to any variation in the solar wind plasma pressure, but may be related to a decrease in IMF $B_x$, which would remove the foreshock from the region upstream of the Earth's bow shock. Wind observed compressional oscillations from 12:30 to 13:30 UT of the type that have been associated previously with drifting clouds of particles injected by storms and substorms. The Polar VIS Earth Camera provided evidence for substorm activity from 11:50 to 12:20 UT, but LANL saw no characteristic magnetic field variations at geosynchronous altitudes. The wave energy seen at Wind originated from further down-tail than where most observations were made. Geotail, located near the dawn flank magnetopause, observed a series of crossings between the LLBL and the magnetosphere proper. We attribute these crossings to the Kelvin-Helmholtz instability. Ground stations observed weak power, but no clear oscillations, in the period range from 8 to 16 min prior to the 12:00 UT compression, and enhanced wave activity afterwards. Periods for the enhanced wave activity were latitude-dependent, suggesting an interpretation in terms of resonant toroidal mode oscillations.

The chronicle of events that is emerging from the wave mode coupling analysis is one of a solar wind wave source, likely impulsive buffeting by the solar wind, that occurred over a period of many hours, even days, and acted to precondition the magnetosphere to oscillate primarily with a periodicity of 10 min. This 10-min wave was observed in the IMF at ACE,

at the magnetopause by Geotail, at WIND in the middle magnetosphere, and from ground magnetometers and radars. During the preconditioning phase, there was some evidence of harmonics of that driving 10-min wave, with a 5-min wave measured by ground magnetometers at latitudes for which this harmonic was likely a natural frequency and which were later strongly resonant at 5-min periodicity.

The global magnetosphere configuration was subjected to an impulsive event. The trigger, which was likely a rapid IMF field rotation observed upstream, supplied the extra energy needed to couple the compressional waves to Alfvén modes, exciting field-line resonances, which were observed by ground stations.

This investigation has revealed experimental evidence that a waveguide mode can seed the growth of a wave with a high azimuthal wave number whose energy originates from particles, as has been suggested by theory, but for which there is little evidence.

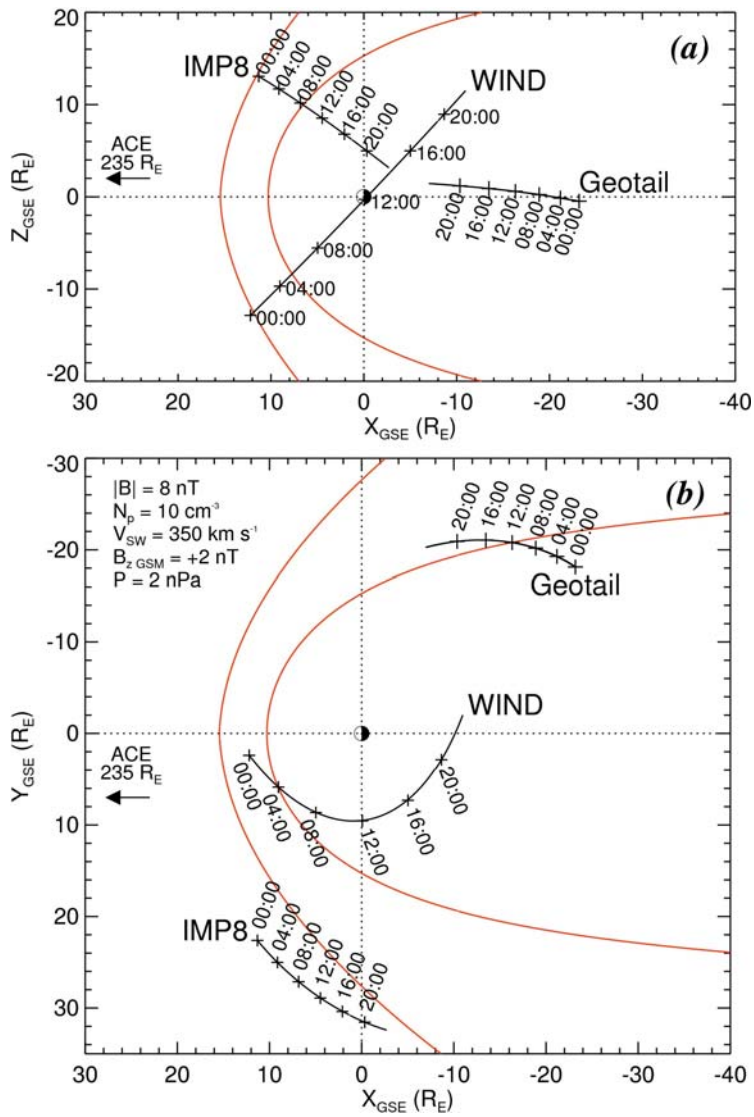


**Figure 1** The trajectories of WIND, Geotail, and IMP-8 in GSE coordinates on the day of interest. A modelled bow shock and magnetopause have been included for reference.

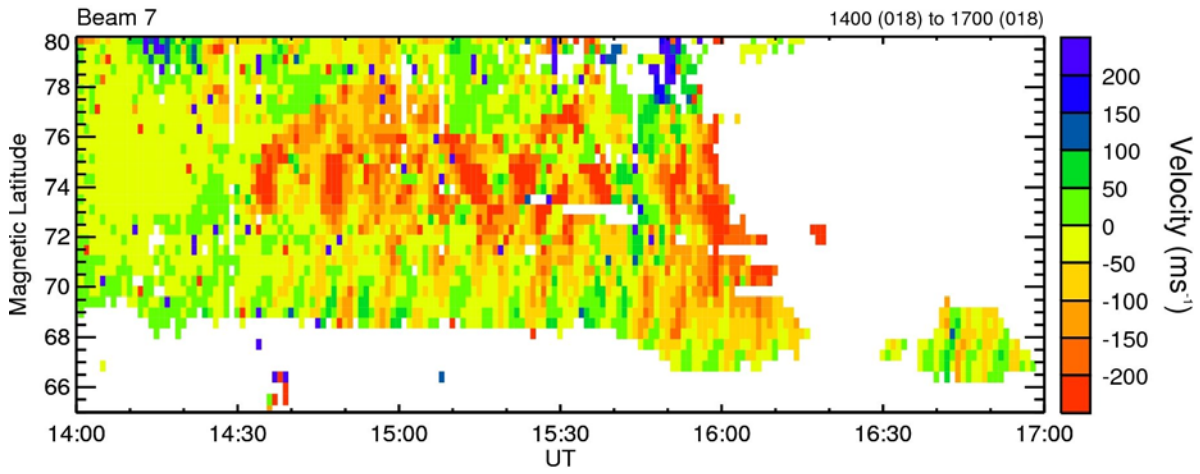


**Figure 2** Ionospheric line-of-sight convection velocities measured by the SuperDARN HF radar at Hankasalmi Finland. The velocity scale is colour coded such that negative velocities (yellow-red) signify flow away from the radar, and positive velocities (green-blue) denote flow towards the radar. The wave frequency (stripes of colour) decreases with increasing latitude, which is common for resonant wave structure in the magnetosphere.

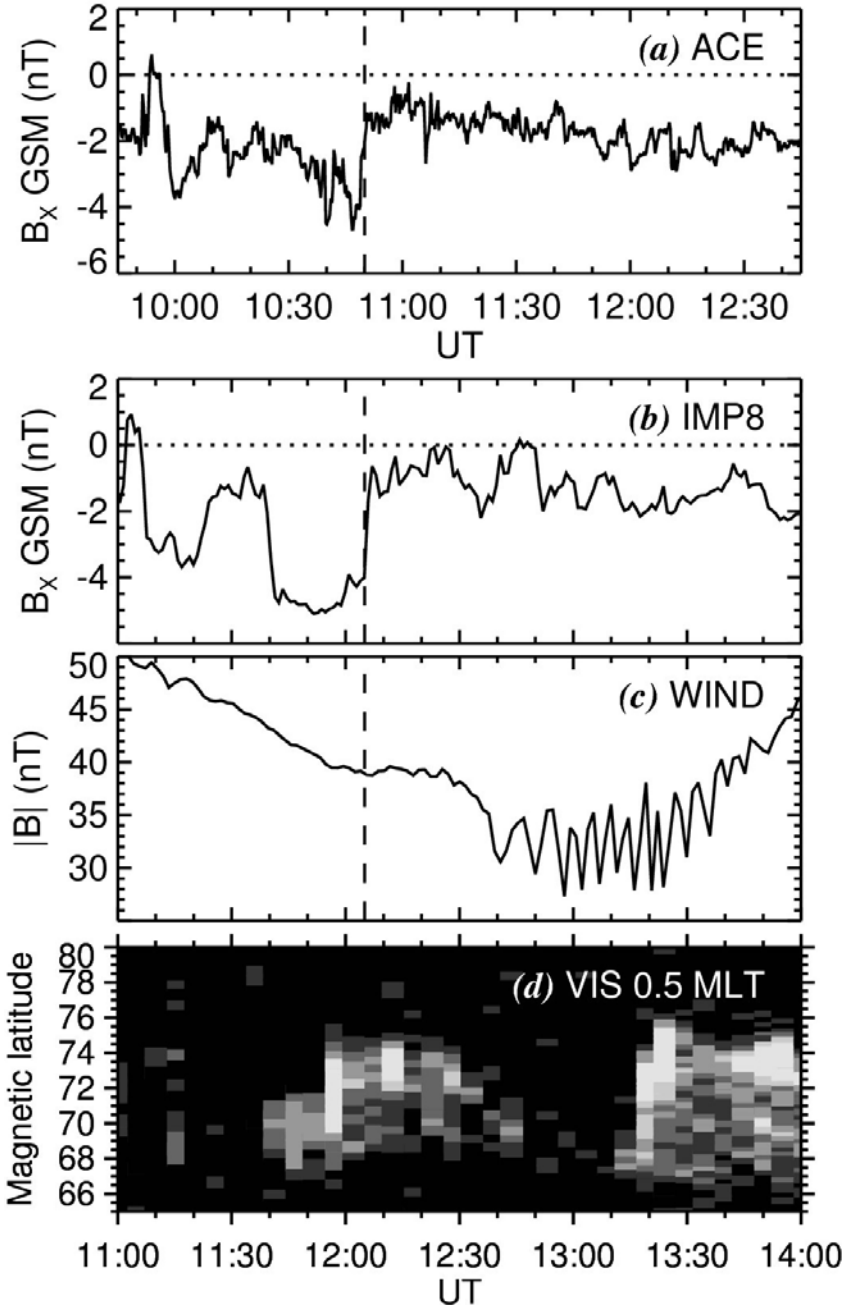


**Figure 3** (a) The *x* GSM component of the IMF at ACE, (b) the *x* GSM component of the IMF at IMP-8, (c) the geomagnetic field strength at WIND, and (d) a keogram of Polar VIS ultraviolet aurora centered on 0.5 magnetic local time. The vertical dashed line marks the feature in the IMF that was used to determine the lag between ACE and IMP-8, which was 75 min.

# Solar-Terrestrial Relations/Space Weather

## Professor J-P. St-Maurice (CRC)

### Team Members

| | | |
|---|---|---|
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| | Dr. L. Kagan | (currently at UWO) |
| | Dr. R. K. Kissack | (part time at UWO) |
| **Post Doctoral Fellows:** | Dr. Josef Drexler | Studies of E & F region field-aligned irregularities (August, 2004 to January, 2005) |
| **Graduate Students:** | | John Ma, Megan Hargrove and Albert Russel (at UWO) |
| **Summer Students:** | | Jennifer Kolhenberg and Sidharth Bansal |

## Ionospheric and thermospheric research centered on St-Maurice's CRC activities

The research activities of the group for the year have focused on two main themes: 1) upper atmospheric dynamics, involving both the ionized species and the thermosphere and 2) better understanding the properties of ionospheric plasma waves and irregularities.

### Upper Atmospheric Dynamics

In the area of electrodynamics, we have continued our investigation of the electrodynamics of the ionosphere in response to electron precipitation. Our message is that the ionosphere itself generates weak but significant electric fields along the magnetic field direction. Sometimes these fields should be large enough to produce much greater current densities than average, particularly along the edge of auroral arcs. These currents are carried by thermal electrons, by contrast to the currents carried by particles ejected from the magnetosphere. In Noel et al (2005) we showed how the currents evolve with time near the edge of an arc for a precipitation pattern that cuts off abruptly while being uniform inside the precipitation region. We also demonstrated that the currents are affected by electron heating lower down in the E region. Figure 1 offers a summary display of the various parameters that we have calculated with our model:the densities of the various densities and their temperatures, as well as the associated conductivities, electric potential, electric field and current densities.

In a separate study of ionospheric electrodynamics we investigated another phenomenon that seems to be located on the edge of auroral arcs (Kagan and St-Maurice, 2005). In this case people have observed ion outflows as fast as 1 km/s. According to conventional theory we should observe,

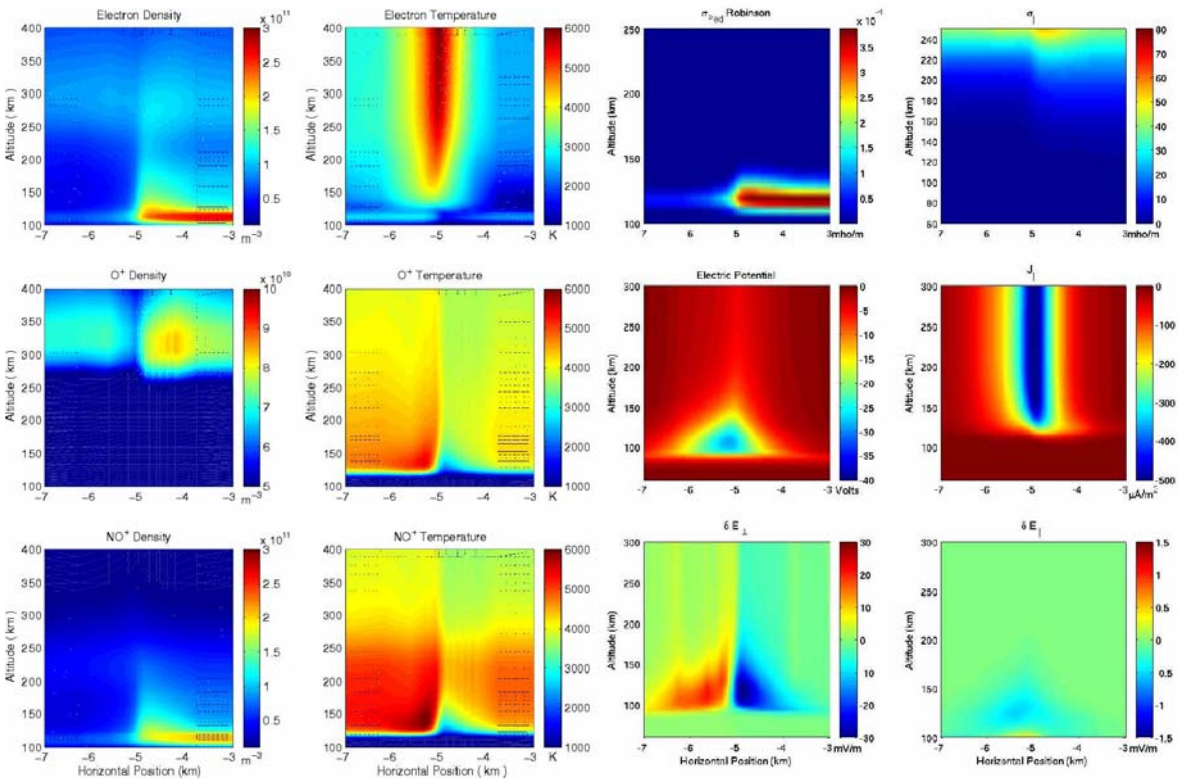


**Figure 1** Electrodynamical effects related to the generation of parallel currents and perturbed electric fields on the edge of auroral arcs. From Noel et al, 2005.

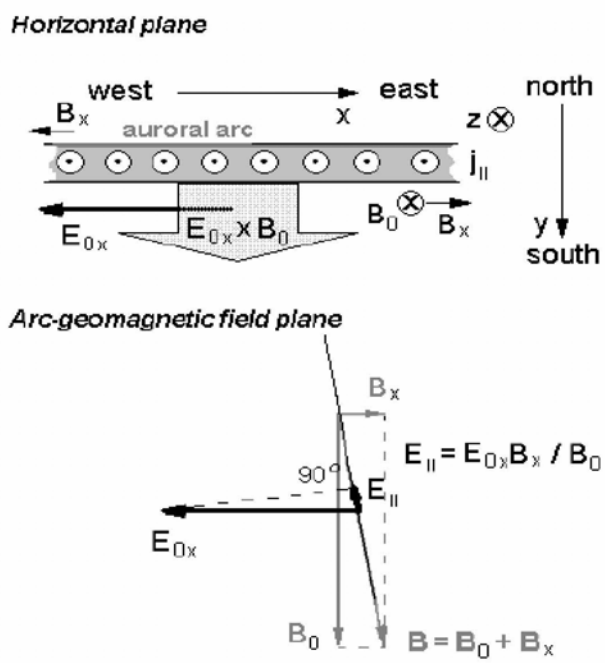


**Figure 2** Cartoon used to describe how electric fields with a component parallel to the geomagnetic field can be generated on the edges of auroral arcs. From Kagan and St-Maurice, 2005.

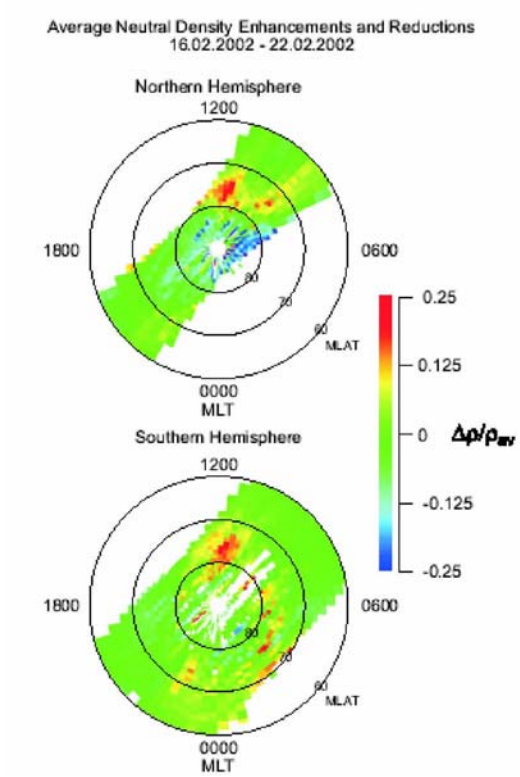


**Figure 3** Density structures observed near 425 km with CHAMP satellite. From Schlegel et al, 2005.

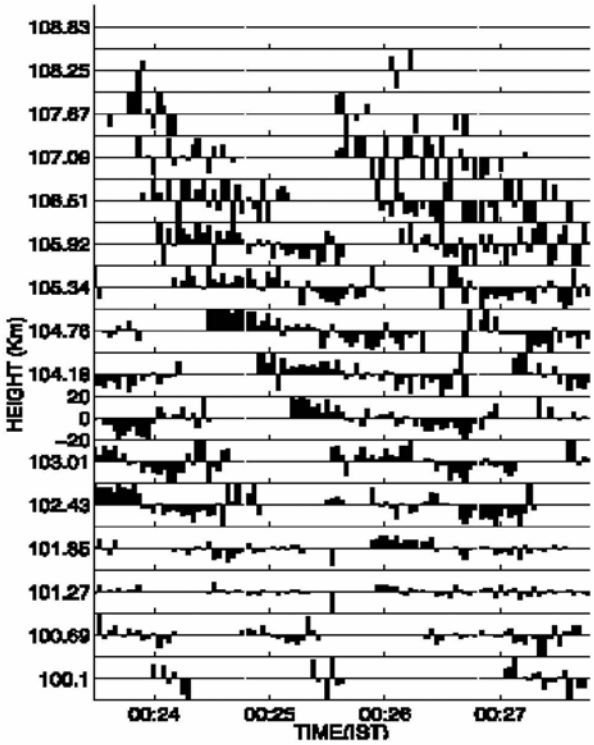


**Figure 4** Kelvin-Helmoltz billows discovered using the Gadanki radar. The figure illustrates how the Doppler shift (neutral wind, in the end) changed as a function of time and height using a radar looking vertically up near the magnetic equator. From Choudhary et al., 2005.

if anything, downgoing ion motions in such regions. We concluded that, once again, an electric field with a component parallel to the geomagnetic field would have to be present. Not only that, but we had evidence to show that, just through very modest turbulence levels, the electrons would be stopped from shorting out the fields, thereby allowing the ions to be accelerated to the observed speeds. In Figure 2 I present a cartoon lifted from our paper. The cartoon was used to illustrate how a combination of auroral currents and east-west electric fields tangential to an arc could lead to the production of the parallel electric fields that have to be behind the observations of the strong ion upflows.

Another highlight of the discoveries we made in our study of the upper atmosphere is, this time, linked to the neutral atmosphere itself. Onboard the CHAMP satellite, at 420 km altitude, we observed (Schlegel et al, 2005) upper atmospheric density changes that were 'localized' (roughly 10 deg of latitude or 1000 km in horizontal extent). The changes were sometimes as large as 40 to 50%. A summary of our findings is presented as Figure 3. The reason this figure is significant is that standard thermospheric model come nowhere close to predicting such structures. Furthermore, while there were indications for auroral currents in the regions that showed the structures, all indications were that the currents were much smaller than expected for Joule heating to be able to heat the atmosphere and cause it to expand. Could the upwelling be ion drag in reverse (ion upflows dragging the neutrals up)? Or might they be related to gravity waves triggered near 100 km by even weak Joule heating event (gravity waves amplify as they travel upward)? This is something that needs to be studied further.

At much lower latitudes, we also uncovered the presence of Kelvin-Helmholtz billows in the neutral atmosphere using a coherent radar positioned at Gadanki, India, near the equator. Figure 4 provides an example of a particularly clear pattern in the Doppler shift of the echoes seen by the radar. This pattern matches quite well the pattern one would expect in the billows, namely, not too long after the onset of the Kelvin-Helmholtz instability known to take place in the atmosphere in the presence of wind shears. The atmosphere near 100 km is now known to have particularly strong shears so that detecting the billows in that height region makes good sense.

## Ionospheric Irregularities

My group continues to investigate ionospheric irregularities. We published 3 papers on the subject in 2004-5. We are interested in the conditions that lead to the development of irregularities and in their properties once their amplitude is large enough to cause ionospheric scattering of radio waves. We published two papers that related primarily to equatorial observations and another related to high latitudes. In the high latitude case we pointed out (Drexler and St-Maurice, 2005) that a subclass of decameter structures seen by SuperDARN radars in the ionospheric E region was likely due to the formation of shocks owing to a nonlocal evolution of the waves. Figure 5 shows how the density of unstable modes suddenly drops with altitude as a function of time as a result of the shocks. We were able to show that the shocks feed slow phase speed modes that have properties very similar to the observations.

A major advantage of studying E region irregularities in the equatorial regions turns out to be that we have many chances to actually see how the properties of the unstable modes change with altitude. A mystery that was uncovered a few years ago was that the phase speed of the irregularities increased with decreasing altitude when it was expected to decrease instead. We found that a zero aspect angle non-isothermal description of the instability was required to explain these observations.

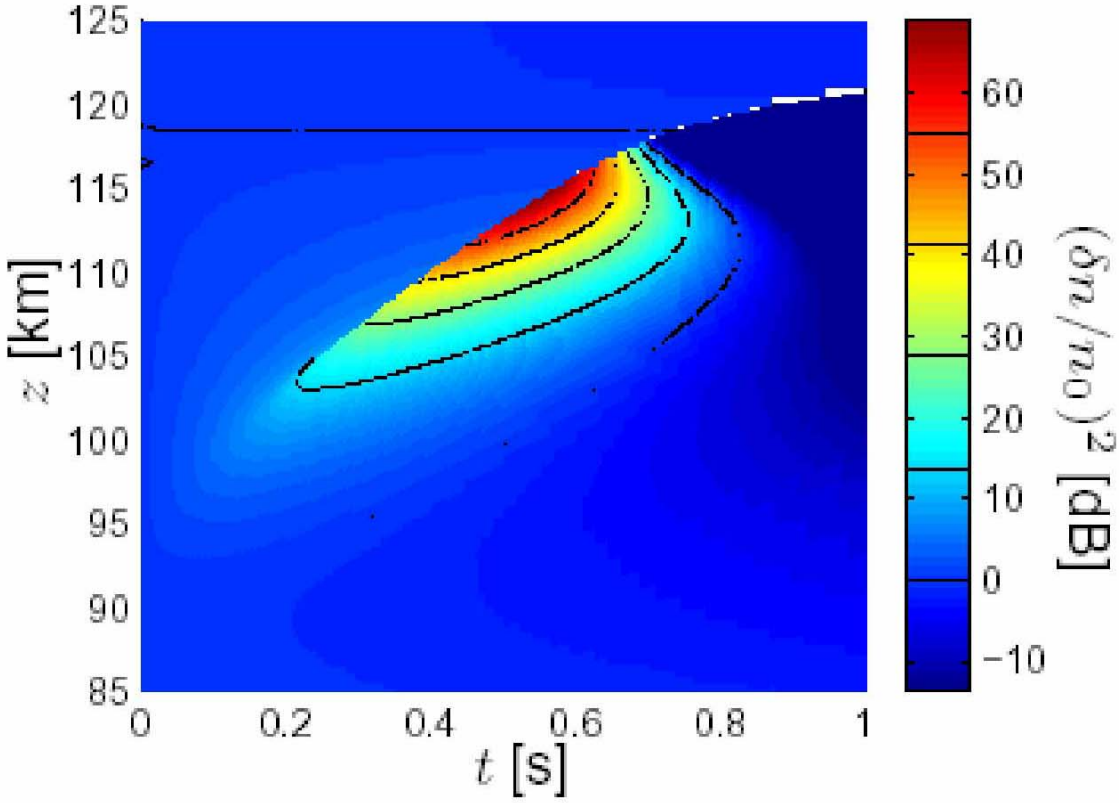


**Figure 5** Amplitude of unstable nonlocal decameter modes as a function of time and space. When the amplitude crashes it feeds decaying modes that are observed to have large aspect angles and very small phase speeds, as observed.

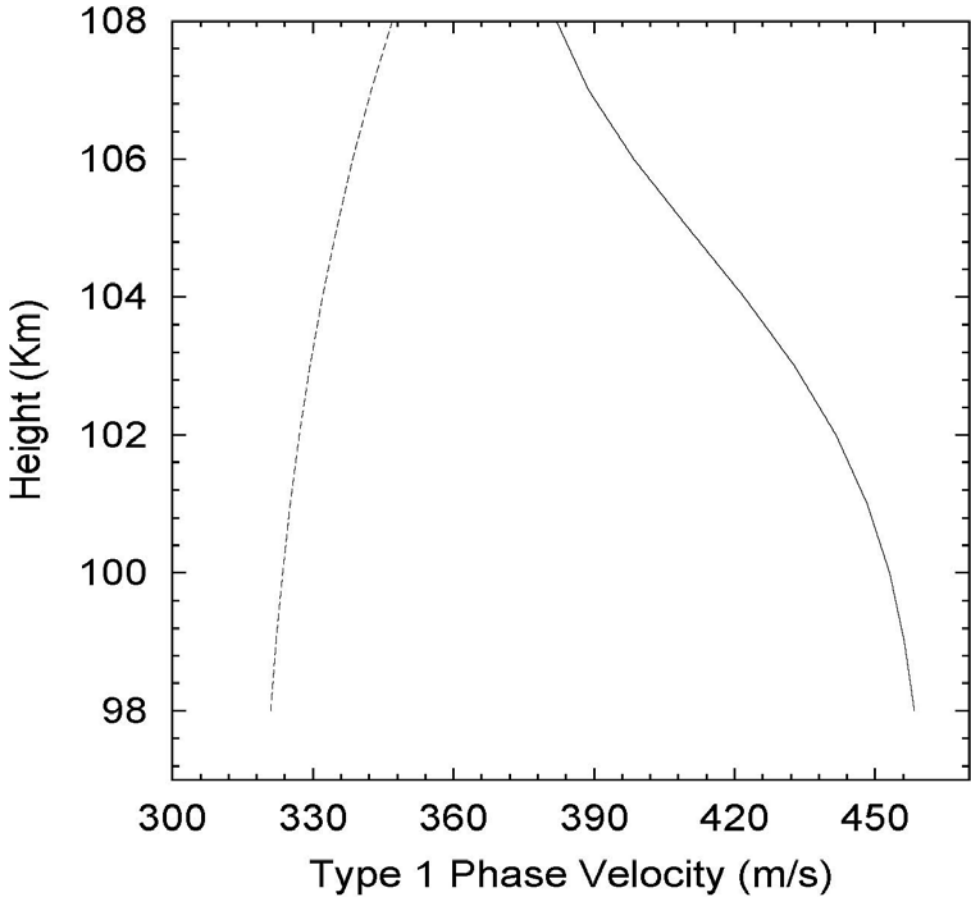


**Figure 6** Broken line: change in the isothermal ion-acoustic speed with altitude. Full line: threshold speed calculated at zero aspect angle for a new non-isothermal theory of the Farley-Buneman instability. Adapted from St-Maurice et al., 2003.

In Figure 6 we reproduce a calculation of the two speeds as functions of altitude. The non-isothermal calculation shown by the full curve turns out to be a near-perfect match to the upper limit of observations made when the electrojet became very strong. Also, no matter what, the data are always much closer to the non-isothermal calculation than to the old isothermal one.

While the observations led credence to the fact that thermal fluctuations are an important part of E region instabilities at lower altitudes, we still had to see how the aspect angle could modify the results: as the aspect angle grows, the irregularities are no longer perfectly field-aligned, and heat flows contribute to a reduction of the temperature fluctuations and a lowering of the phase speed. This work turned out to be algebraically difficult, but we managed to find how the aspect angles changed the results at zero flow angles.

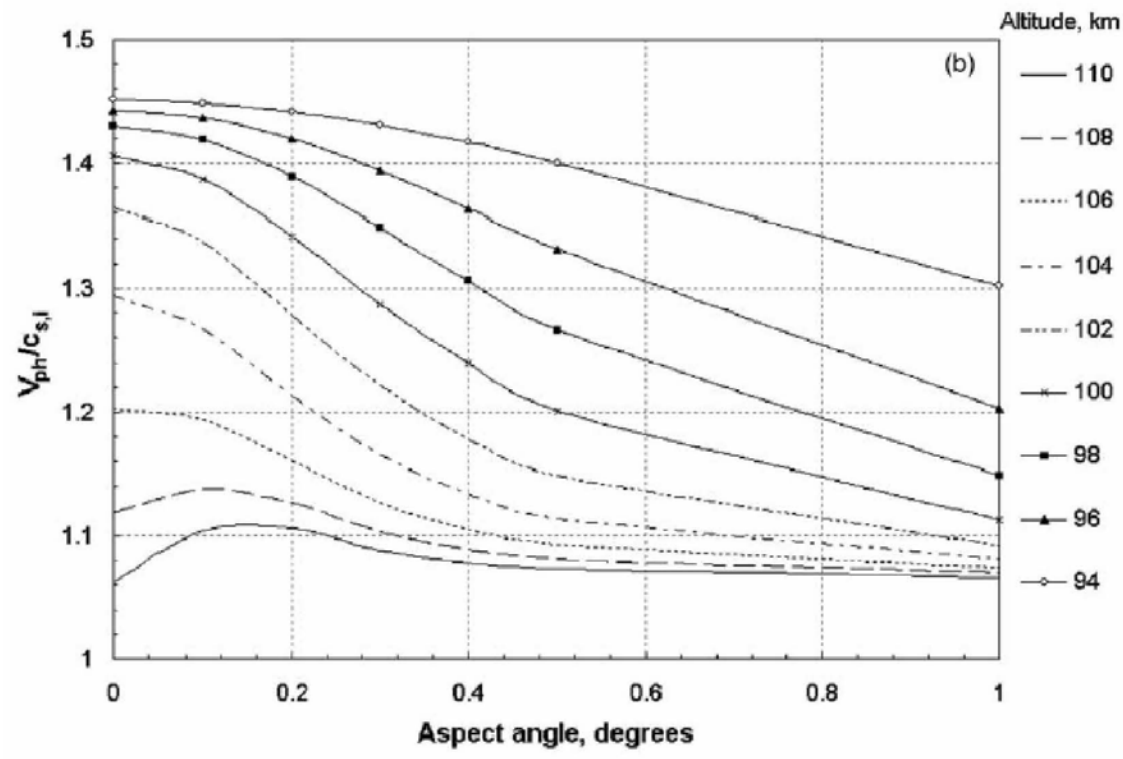


**Figure 7** Ratio of the threshold speed to the isothermal ion-acoustic speed as a function of aspect angle and for various altitudes. From Kagan and St-Maurice, 2005.

# Ionospheric Physics/ VHF and CADI Radars

## Professor G.C. Hussey

### Team Members

**Graduate Students:** R. Gillies, J. Cooper

## Ionospheric Physics (*E*-region)

The current reporting period has been dominated by instrument development.

A prototype of the new 50 MHz FMCW (frequency modulated continuous wave) radar developed and constructed by my graduate student, Joel Cooper, and myself was deployed in the field during the summer of 2004. The impetus for the new radar design was to simultaneously provide excellent temporal and spatial resolutions, which has never before been achieved in *E*-region radar studies, to better understand the plasma processes and motions which occur in the terrestrial *E*-region ionosphere. From a technical point of view the radar operates very well and has proved the concept of an FMCW radar for *E*-region observations; although as the system is a prototype some minor refinements are still desirable but not essential. The temporal resolution is ~5 Hz (~15 m/s), that typical of bistatic CW (continuous wave) *E*-region radars operated in the past, and the range resolution is ~1km, which is as good as or better than most pulsed *E*-region radars.

Unlike pulsed radar systems were Doppler information, representing motions, is measured in the frequency domain and the range information is measured in the time domain, both Doppler and range information are measured in the frequency domain for an FMCW radar system. Therefore, data analysis techniques were developed to extract the range and Doppler information from the FMCW 50 MHz echoes. All four typical *E*-region radar signatures, Type I to Type IV, plus meteor trail echoes, were observed by the radar in the first few months of operation. Figure 1 is an example of a Type I echo observed on 23 July, 2004 at 06:44:33 UT. The ordinate expresses the slant range from the radar and the abscissa expresses the Doppler shift (the speed is 3 the Doppler frequency at 50 MHz) of the scatterer. The colour scale depicts the (normalised) signal-to-noise ratio (SNR) echo power. The signature has a maximum power at a Doppler shift of ~-120 Hz (~-360 m/s) which corresponds to the ion acoustic speed in the *E*-region at a range of ~850 km.

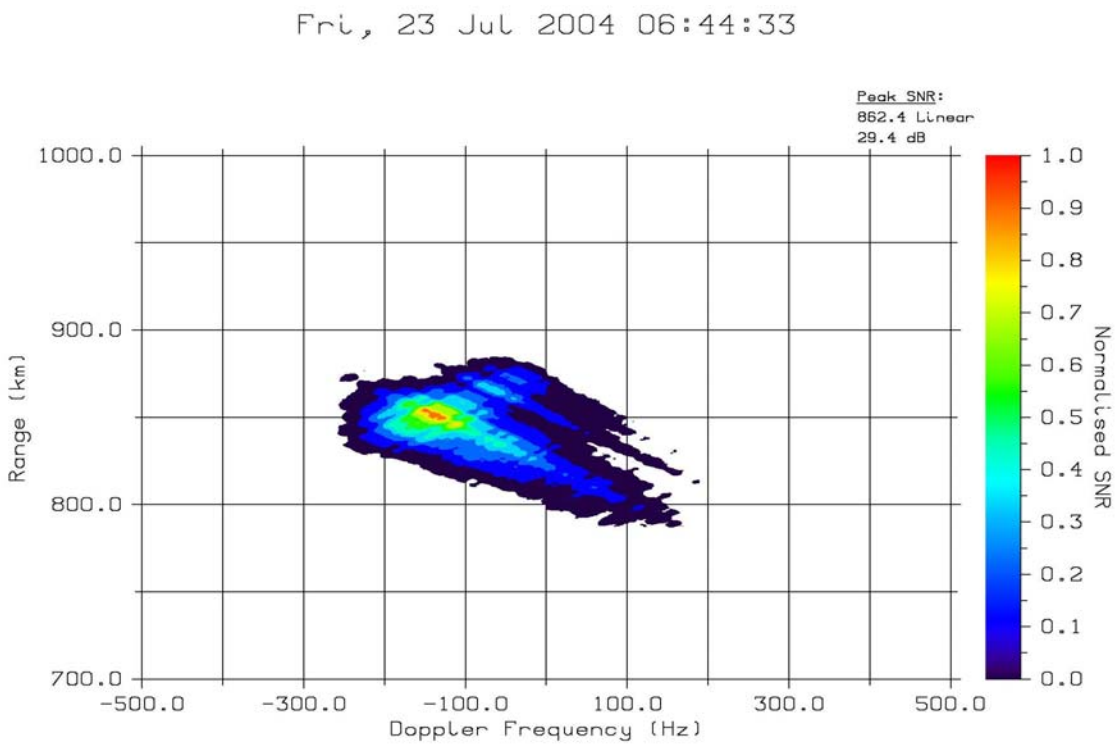


**Figure 1** Range-Doppler map of Type 1 echo from 23 July, 2004 at 06:44:33 UT.

# Ionospheric Physics (*F*-region)

## CADI

The current reporting period has been dominated by instrument development as well as site operations and maintenance.

In 2004 funding was obtained by myself and co-investigator J. MacDougall from the University of Western Ontario for the operation, maintenance and upgrading of the CADI (Canadian Advanced Digital Ionosonde) polar network. Funds were also obtained from NSERC to purchase new equipment for expansion of the network. The CADI polar network currently consists of sites at Eureka, Resolute, and Cambridge Bay, and Rankin Inlet and will expand to include a site at Inuvik.

A CADI instrument was installed at the Rankin Inlet site late in 2002 and a CADI instrument will be installed at the Inuvik site, which will be the future home of one of the PolarDARN (SuperDARN) radars, bringing the total number of CADIs to 5 in the polar network. Both the Rankin Inlet and Inuvik sites were originally established by G. J. Sofko from the

University of Saskatchewan. The site at Rankin Inlet had previously been used for some VHF *E*-region radar experiments (it was too small for the Rankin Inlet PolarDARN radar which has been funded and will become operational in 2006), but currently contains no radar instruments besides CADI and an optical all-sky camera instrument operated by the University of Calgary.

During this reporting period, a significant effort has gone into upgrading the CADI systems from DOS based systems to LINUX based systems. As well, the very old computer systems which housed the instruments have been updated. The updating to a modern operating system such as LINUX will allow for better operation and remote operation of the CADI instruments, where Internet services are available, as well as real-time or near real-time access to the data. All this required both hardware and significant software development. But the development is essentially completed now and the attention will turn to deploying the new systems into the field ---- a significant task as well.

## e-POP

G. Hussey and G. Sofko are also involved with the e-POP satellite mission, specifically with the RRI (Radio Receiver Instrument) instrument and its relation to SuperDARN (SuperDARN will send pulses which are received by the RRI instrument). My M. Sc. graduate student, R. Gillies, has been working on modelling the expected signal to be received by the RRI instrument. The model (ray-tracing) is based on magneto-ionic theory, is three-dimensional, and completely determines the polarisation state of the propagating wave. In order to test the reliability of the model it was applied to ISIS (International Satellites for Ionospheric Studies) II transionospheric observations made during the summer of 1978. The ISIS II experiment is similar to some of the experiment modes which will be available with the RRI instrument on e-POP. Initial modelling results have shown that the ISIS II observations can be simulated remarkably well when ISIS II *in situ* $f_oF2$ values (peak electron density values at the F2 peak) are used. The $f_oF2$ values were obtained from a swept frequency or topside ionogram mode which operated between the transionospheric modes during the ISIS II experiment (this will not be available in the RRI experiment). The $f_oF2$ values were used to scale electron density profiles, one of the critical input parameters in the ray-tracing modelling, which were generated by the IRI (International Reference Ionosphere) model. Research continues to extend and further clarify this work.

# Appendices

**Publications**

**Presentations (Talks, Papers, Posters)**

**Visitors to ISAS**

**Graduate Student Theses**

**Attendance at Meetings or Other Visits**

**Services and Distinctions**

**Vision Statement**

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K. Schlegel, H. Lühr, J.-P. St.-Maurice, G. Crowley, Thermospheric Density Structures over the Polar Regions observed with CHAMP, Annales Geophysicae, 23, 5, 1659-1672, 2005.

St.-Maurice, J.-P., Comment on ‘‘Nonlinear electron heating by resonant shear Alfven waves in the ionosphere’’ by J. Y. Lu et al., Geophys. Res. Lett., 32, L13102, doi:10.1029/ 2005GL022513, 2005.

Choudhary, R. K., J.-P. St.-Maurice, L. M. Kagan and K.K. Mahajan, Quasi-periodic backscatters from the E region at Gadanki: evidence for Kelvin-Helmholtz billows in the lower thermosphere, J. Geophys. Res., 110, A08303, doi:10.1029/2004JA010987, 2005.

Jayachandran , P. T., E.F. Donovan, J. W. MacDougall, D. R. Moorcroft, K. Liou, P. T. Newell, and J.P. St-Maurice, Global and local equatorward expansion of the ion auroral oval before substorm onsets, J. Geophys. Res, 110, A05204, doi:10.1029/ 2004JA010837, 2005.

Drexler, J., and J.-P. St.-Maurice, A possible origin for large aspect angle “HAIR" echoes seen by SuperDARN radars in the E region, Annales Geophysicae, 23, 767-772, 2005.

Kagan, L. M., and J.-P. St.-Maurice, Origin of type-2 thermal-ion upflows in the auroral ionosphere, Ann. Geophys., Ann. Geophys., 23: 13–24, 2005.

Kagan, L. M., and J.-P. St.-Maurice, Impact of electron thermal effects on Farley-Buneman waves at arbitrary aspect angles, J. Geophys. Res., A12302, doi:10.1029/ 2004JA010444, 2005.

Choudhary, R.K, St.-Maurice, J.-P., and K.K. Mahajan, Observation of 150 km echoes away from the dip equator, Geophys. Res. Lett., 31, L19801, doi:10.1029/2004GL020299, 2004.

Sheehan, C. H. and St.-Maurice, J.-P., The dissociative recombination of N2+, O2+, and NO+: rate coefficients for ground state and vibrationnally excited ions, J. Geophys. Res., J. Geophys. Res., 109, A03302, doi:10.1029/ 2003JA010132, 2004.

Sheehan, C. H. and St.-Maurice, J.-P., Dissociative recombination of the methane family ions: rate coefficients and implications for Jovian ionospheres, Advances in Space Research Special issue: Planetary Atmospheres, Ionospheres and Plasma Interactions - Edited by E. Kallio and H. Shinagawa, Vol. 33/2 pp 216-220, 2004.

## Ionospheric Physics/ VHF and CADI Radars

G.C. Hussey, C. Haldoupis, A. Bourdillon, J. Delloue, and J.T. Wiensz, Mid-latitude *E*-region bulk motions inferred from digital ionosonde and HF radar measurements, Annales Geophysicae, 22, 3789-3798, SRef-ID: 1432-0576/ag/2004-22-3789 2004.

T. Bösinger, G.C. Hussey, C. Haldoupis, and K. Schlegel, Auroral *E*-region electron density height profile modification by electric field driven vertical plasma transport: Some evidence in EISCAT CP-1 data statistics, Annales Geophysicae, 22, 901-910, 2004.

# Presentations (Talks, Papers, Posters)

## Aeronomy Research – Odin/ OSIRIS (InfraRed Group)

**2004**

A.E. Bourassa, D.A. Degenstein and E.J. Llewellyn, Climatology of the sub-visible cirrus clouds as seen by OSIRIS on Odin, COSPAR Meeting, Paris, France, July 2004.

A.E. Bourassa, Degenstein, D.A., Gattinger, R.L, and Llewellyn, E.J., Aerosol Retrieval in the Troposphere and Stratosphere with OSIRIS Limb Scattered Sunlight Measurements, *EOS Trans. Amer. Geophys. Un.*, 85(47), Fall Meeting Suppl. A41A-0028, San Francisco, CA, December, 2004.

D.A. Degenstein, J.T. Wiensz, R.L. Gattinger, N.D. Lloyd, A.E. Bourassa and E.J. Llewellyn, Retrievals of a tertiary ozone layer in the mesosphere with data from OSIRIS on Odin, Quadrennial Ozone Symposium, Kos, Greece, June 2004.

D.A. Degenstein, R.L. Gattinger, N.D. Lloyd, J.T. Wiensz, A.E. Bourassa and E.J. Llewellyn, Atmospheric quenching of the singlet delta state of molecular oxygen as measured by OSIRIS on Odin, COSPAR Meeting, Paris, France, July 2004.

D.A. Degenstein, Gattinger, R.L., Lloyd, N.D., Bourassa, A.E., Wiensz, J.T., and Llewellyn, E.J., Evidence for a new Production Mechanism for the Singlet Delta State of Molecular Oxygen, *EOS Trans. Amer. Geophys. Un.*, 85(47), Fall Meeting Suppl. SA41A-1039, San Francisco, CA, December, 2004.

F. Jegou, J. de La Noë, A. Drouin, P. Ricaud, J. Urban, E. Le Flochmoën, E. Dupuy, L. El Amraoui, Y. Planchais, D. P. Murtagh, N. Lautié, P. Eriksson, C. Jimenez, S. Brohede, J. Stegman, E. J. Llewellyn, S. Petelina, D.A. Degenstein, R.L. Gattinger, N.D. Lloyd, C.S. Haley, C. von Savigny, I. McDade, Cross-comparison of ozone profiles measured by the Odin satellite instruments SMR and OSIRIS (1), Quadrennial Ozone Symposium, Kos, Greece, June 2004.

F. Jegou, J. de La Noë, A. Drouin, P. Ricaud, J. Urban, N. Schneider, E. Le Flochmoën, E. Dupuy, L. El Amraoui, Y. Planchais, D. P. Murtagh, N. Lautié, P. Eriksson, C. Jimenez, S. Brohede, J. Stegman, E. J. Llewellyn, S. Petelina, D. A. Degenstein, R. L. Gattinger, N. D. Lloyd, C. S. Haley, C. von Savigny, I. McDade, F. Goutail, A. Bazureau, S. Godin-Beekmann, J.-P. Pommereau, F. Lefèvre, C. Camy-Peyret, S. Payan, P. Gesek, G. Moreau, J.-B. Renard, C. Robert, K. Strong et al., Comparison of ozone profiles measured by the Odin satellite instruments and ground-based, airborne, satellite experiments and model computations, Quadrennial Ozone Symposium, Kos, Greece, June 2004.

E.J. Llewellyn, D.A. Degenstein, N.D. Lloyd, R.L. Gattinger, A.E. Bourassa, J.T. Wiensz, N.S. Wiebe, Dynamical structures in the airglow observed with OSIRIS on Odin, COSPAR Meeting, Paris, France, July 2004.

E.J. Llewellyn, D.A. Degenstein, R.L. Gattinger, N.D. Lloyd, J.T. Wiensz, and A.E. Bourassa, The Response of Mesospheric Ozone to the Solar Storm of October 28, 2003 as seen by OSIRIS on Odin, SPARC Meeting, Victoria, BC, August 2004.

E.J. Llewellyn, R.L. Gattinger, D.A. Degenstein and N.D. Lloyd, UV Remote sensing of the mesosphere with OSIRIS, *EOS Trans. Amer. Geophys. Un.*, 85(47), Fall Meeting Suppl. SA23B-01, San Francisco, CA, December, 2004.

S.V. Petelina, E.J. Llewellyn, N.D. Lloyd, and D.A. Degenstein, Statistical comparisons of Odin/OSIRIS limb-measured stratospheric ozone profiles with other satellite and ozonesonde data, Quadrennial Ozone Symposium, Kos, Greece, June 2004.

S.V. Petelina, E.J. Llewellyn, O.D. Petelin, N.D. Lloyd, M.J. Bathgate, and D.A. Degenstein, Daily global maps of tropospheric ozone derived from OSIRIS and TOMS data, Quadrennial Ozone Symposium, Kos, Greece, June 2004.

S.V. Petelina, Llewellyn, E.J., Degenstein, D.A., Lloyd, N.D., and Gattinger, R L., Validation of the Odin/OSIRIS Stratospheric Ozone Profiles: Statistical Comparisons With Coincident Ozonesonde, POAM III, SAGE II, and SAGE III Measurements, *EOS Trans. Amer. Geophys. Un.*, 85(47), Fall Meeting Suppl. A54A-04, San Francisco, CA, December, 2004.

C. von Savigny, Petelina, S.V., Llewellyn, E.J., Burrows, J.P., Degenstein, D.A., and Lloyd, N.D., Vertical structure of NLCs observed by Odin/OSIRIS, *EOS Trans. Amer. Geophys. Un.*, 85(47), Fall Meeting Suppl. SA21A-0334, San Francisco, CA, December, 2004.

J.T. Wiensz, D.A. Degenstein and E.J. Llewellyn, Time dependent ozone retrievals with the Oxygen InfraRed Atmospheric band measurements made by OSIRIS on Odin, COSPAR Meeting, Paris, France, July 2004.

J.T. Wiensz, D.A. Degenstein and E.J. Llewellyn, Investigation of Dynamical Structures with OSIRIS on Odin, *EOS Trans. Amer. Geophys. Un.*, 85(47), Fall Meeting Suppl. , San Francisco, CA, December, 2004.

**2005**

D.A. Degenstein, Marsh, D.R, and Llewellyn, E.J., The Singlet Delta Concentrations of Molecular Oxygen in the Mesosphere, a Comparison Between Model and Observation, *EOS Trans. Amer. Geophys. Un.*, 86(17), Spring Meeting Suppl. SA34A-04, New Orleans, LA, May, 2005.

J. Greenhough, J.J. Remedios, A.E. Bourassa, D.A. Degenstein, and E.J. Llewellyn, Cloud observations via infra-red limb sounding: a comparison of the MIPAS and OSIRIS instruments, EGS Meeting, Vienna, Austria, April 2005.

E.J. Llewellyn, Gattinger, R.L., Degenstein, D.A., Bourassa, A.E. and Lloyd, N.D., The Seasonal and Latitudinal Variation of the OH (v = 0) Concentration in the Mesosphere, *EOS Trans. Amer. Geophys. Un.*, 86(17), Spring Meeting Suppl. SA33A-03, New Orleans, LA, May, 2005.

E.J. Llewellyn, in collaboration with the OSIRIS Team, OSIRIS on Odin: Advances Made with OSIRIS Measurements of Atmospheric Ozone, *Physics in Canada*, Congress Issue, SU-A2-4, Vancouver, British Columbia, June 2005.

N.D. Lloyd, D.A. Degenstein, F. Sigernes, E.J. Llewellyn, and D.A. Lorentzen, The red-sky enigma over Svalbard in December 2002: a model using polar stratospheric clouds, Ann. Geophysicae, 23, 1603-1610, 2005.

S.V. Petelina, D.A. Degenstein, E.J. Llewellyn, N.D. Lloyd, Correlation of PMC Relative Brightness and Altitudes observed by Odin/OSIRIS in the Northern Hemisphere in 2002-2003, J. Atmos. Space Terrest. Physics, (in press), doi:10.1016/j.jastp.2005.08.005, 2005.

S.V. Petelina, E.J. Llewellyn, D.A. Degenstein, N.D. Lloyd, Odin/OSIRIS Limb Observations of Polar Mesospheric Clouds in 2001-2003, J. Atmos. Space Terrest. Physics, (in press), doi:10.1016/j.jastp.2005.08.004, 2005.

F. Sigernes, N. Lloyd, D.A. Lorentzen, R. Neuber, U.-P. Hoppe, D. Degenstein, N. Shumilov, J. Moen, Y. Gjessing, O. Havnes, A. Skartveit, E. Raustein, J. B. Ørbæk, and C.S. Deeh, The Red Sky over Svalbard in December 2002: Observations, Annales Geophysicae, 23, 1593-1602, 2005.

## Super DARN/ PolarDARN

**2004**

A.V. Koustov, and R. Drayton, SuperDARN echoes in the vicinity of polarization jets, ORBITALS Science Workshop, The Banff Centre, Banff, 22-24 Sept. 2004.

J., Liang, L. Benkevitch, G. Sofko, and A.V. Koustov, Comparison between ionospheric convection vortices and the associated equivalent currents *Eos Trans. AGU, 85*(47), Fall Meet. Suppl., Abstract SM51C-0383, Fall AGU Meeting in San Francisco, Dec. 2004.

G.J. Sofko, Expanded SuperDARN Program: New Radars, PolarDARN and StormDARN, ORBITALS Science Workshop, The Banff Centre, Banff, 22-24 Sept. 2004.

G.J. Sofko, R. Schwab, J. Liang, K. McWilliams and M. Shinohara, Plasmatrough SAPS Flow and its Implications for Global Patterns of convection and Field-aligned Current, ORBITALS Science Workshop, The Banff Centre, Banff, 22-24 Sept. 2004.

**2005**

G. Hussey, C., K.A. McWilliams, J. W. MacDougall, and G.J. Sofko, 2005. F-region velocity drift measurements as determined by SuperDARN and the Rankin Inlet CADI, DASP 2005 Workshop in Edmonton, Alberta, 23 – 25 February, 2005.

R. Gillies, G., G.C. Hussey, G. James, G.J. Sofko, and D. Andre, 2005. Comparing ISIS II data to Raytracing Simulations as a Basis for Understanding e-POP Models, DASP 2005 Workshop in Edmonton, Alberta, 23 – 25 February, 2005.

R.D. Schwab, G.J. Sofko, and K.A. McWilliams, Supra-thermal Ions Within the Subauroral Polarization Stream, DASP 2005 Workshop in Edmonton, Alberta, 23 – 25 February, 2005.

G.J. Sofko, Status of the Canadian Component of SuperDARN. SuperDARN 2005 International Workshop in Rydal, England – May 16-20, 2005.

G.J. Sofko, J. Liang, R. Schwab and K. McWilliams, Substorms, SAP S and convection cells in the postmidnight sector, SuperDARN 2005 International Workshop in Rydal, England – May 16-20, 2005.

M. Watanabe, G.J. Sofko, D. A Andre, J. M. Ruohoniemi and M. R. Hairston, Ionospheric signatures of internal reconnection for northward interplanetary magnetic field: Observation of "reciprocal cells" , SuperDARN 2005 International Workshop in Rydal, England – May 16-20, 2005.

M. Watanabe, K. Kabin, G. J. Sofko, R. Rankin, T. I Gombosi, A. J. Ridley and C. R. Clauer, Internal reconnection for northward interplanetary magnetic field, SuperDARN 2005 International Workshop in Rydal, England – May 16-20, 2005.

## Solar-Terrestrial Relations/ Space Weather

J.-P. St.-Maurice, "The northern lights: fear fascination and fact", public presentation given at the U of Saskatchewan to celebrate the theme of light in relation to the inauguration of the Canadian Light Source at the U of S campus, October 2004.

J.-P. St.-Maurice, "The not-so-passive role played by the ionosphere in the response of the magnetosphere-ionosphere system to the solar wind input." Presented at the "Sun-Earth Connections Physics Conference" in Merida, Mexico, Nov 8-12, 2004

# Visitors to ISAS

| | | |
|---|---|---|
| C. von Savigny | University of Bremen, Germany | August 8 - 22, 2004 |
| John Burrows | University of Bremen, Germany | August 12 - 15, 2004 |
| Andrew Kavanagh | NCAR, Boulder, Co | August 17 - 21, 2004 |
| Emma Woodfield | NCAR, Boulder, Co | August 17 - 21, 2004 |

# Graduate Student Theses

| | |
|---|---|
| Liang, Jun – Ph.D. | Theses: Multi-instrument Studies of Ionospheric and Magnetospheric Processes<br><br>Oral Defence: October 27, 2004 |

# Attendance at Meetings or Other Visits

| | | |
|---|---|---|
| D. Degenstein, E.J. Llewellyn and A.H. Manson | Paris France re: COSPAR | July 17 - 26, 2004 |
| E.J. Llewellyn | Victoria, BC re: SPARC | August 2 - 8, 2004 |
| E.J. Llewellyn | re: SPIE Meeting, Los Canaras, Spain | Sept. 9 – 19, 2004 |
| A.V. Koustov and G.J. Sofko | Banff, AB re: CSA ORBITALS Workshop | Sept. 22 – 26, 2004 |
| J-P St.-Maurice | Ottawa, ON re: E-POP Team Meeting | Sept. 28 – Oct. 1, 2004 |
| E.J. Llewellyn | re: Odin Science Team, Stockholm | Oct. 6 – 16, 2004 |
| J-P St.-Maurice | Mexico, re: Conf. on Sun-Earth Connection | Nov. 6 - 13, 2004 |
| C. Meek | Toronto, ON re: CANDAC Workshop | Nov. 12, 2004 |
| J-P St.-Maurice | London, ON re: attend Thesis Defense | Nov. 17 - 19, 2004 |
| E.J. Llewellyn | re: Limbs Workshop, Stockholm, Sweden | Nov. 14 – 19, 2004 |
| A.H. Manson and G. J. Sofko | Halifax, NS re: CSA SAEAC workshop | Nov. 24 – 26, 2004 |
| E.J. Llewellyn, D. Degenstein, T. Wiensz, A. Koustov, and K. McWilliams | San Francisco, CA re: AGU meeting | December 13 - 17, 2004 |
| J-P St.-Maurice | Montreal Univ., re: Colloquium plus talks with Solar Physics | Jan. 24 – 31, 2005 |
| K. McWilliams and G. Hussey | Edmonton, AB re: DASP Annual Meeting | Feb. 24 – 25, 2005 |
| J-P St.-Maurice | Edmonton, AB re: public presentations of the Aurora and DASP Annual Meeting | Feb. 24 – 25, 2005 |
| J-P St.-Maurice | Cornell Univ., Ontario and UWO | Mar. 25 – Apr. 4, 2005 |
| E.J. Llewellyn | Helsinki, re: Odin Science Team Meeting | Apr. 11 – 22, 2005 |
| A.V. Koustov | Calgary, AB re: Institution for Space Research Collaboration visit | Apr. 19 – 22, 2005 |
| D. Degenstein | Vienna re: EGU conference | Apr. 22 - May 2, 2005 |
| E.J. Llewellyn, D. Degenstein, N. Lloyd, A.H. Manson, S. Petelina, T. Chshyolkova | Banff, AB re: SAEAC workshop | May 5- 7, 2005 |
| A.V. Koustov ,G. Sofko, K.A. McWilliams, D. Andre and M. Watanabe | Cumbria, UK re: SuperDARN Annual Meeting | May 16 – 20, 2005 |
| A.H. Manson | Montreal \St. Hubert, Que re: SAEAC meeting | June 8 – 10, 2005 |
| J-P St.-Maurice | Taipei, Taiwan, re: ISEAII meeting | May 9-14, 2005 |

# Services and Distinctions

### J.-P. St-Maurice

- Member of the Space Science and Exploration Advisory Group to the CSA (Jan 2006- )
- Member of the SuperDARN Executive Committee
-Co-Chair of SAEAC (CSA) (2005- )
CSA's Space Science Fellowships Selection Committee (2005-2008)
- Elected as DASP representative to NSERC liaison committee with CAP (Nov. 2003)
-Assoc. Editor, Journal of Geophysical Research (1998-2001)
- International representative, Science Steering Committee for Coupling Energetics & Dynamics of Atmospheric Regions (CEDAR) USA 1998-2000)
- External member, Scientific Advisory Committee, EISCAT Observatory, Europe (1998-2000)
National URSI Committee: Commissions G&H Chair (1993-1999)

### D.A. Degenstein

- Participant, Optical Aeronomy and Atmospheric Science experiment (OSIRIS) on the Swedish Odin satellite

### A.H. Manson

- Vice-Chair, Commission C of COSPAR, (2002-2006)
- Member, SAEAC (Space and Atmospheric Environments Advisory Committee) of Canadian Space Agency, (2000-2004)
- Member of Steering Committee for Post-STEP International Programs; S-RAMP (STEP-Results, Applications, and Modelling Phase) (1997-2002)
- Chair of COSPAR Sub-Commission C2, Middle Atmosphere and Lower Ionosphere (1994-1998, 1998-2002)
-Editorial Advisory Board member, "Journal of Atmospheric and Solar-Terrestrial Physics" (1994-present)
-Chair, Institute of Space and Atmospheric Studies, University of Saskatchewan (1991-1997; 1997-2003)

### G.J. Sofko

- The National Aeronautics and Space Administration (NASA) Group Achievement Award for ground based investigation by Team/SuperDARN, 'in recognition of the highly successful exploration of geospace by the Global Geospace Science Program'
- Member of SuperDARN Executive Committee
- Principal Investigator, DSS/CSA contract for System Management at the Saskatoon CANOPUS node
- Principal Investigator, NSERC CSP "The Canadian component of SuperDARN, Phase II"

### G.C. Hussey

-Member of SuperDARN Team

### A.V. Koustov

-Member of CGSM Team
-Member of SuperDARN Team

### K.A. McWilliams

-Member of CGSM Team
-Member of SuperDARN Team
-Member of Ravens Science Team

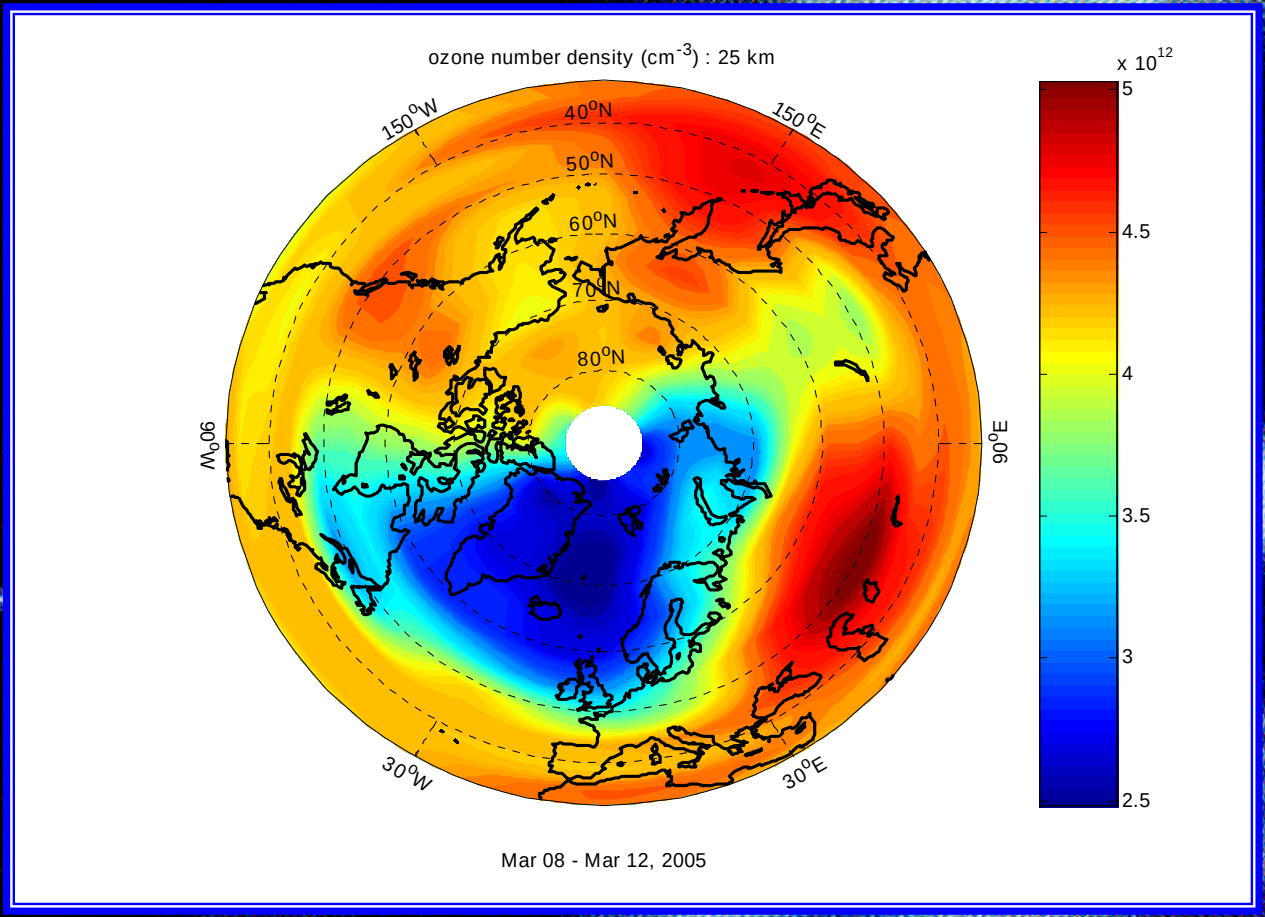
### E.J. Llewellyn

- Distinguished Researcher (2002)
- Principal Investigator, Optical Aeronomy and Atmospheric Science experiment (OSIRIS) on the Swedish Odin satellite
- Principal Investigator, satellite experiment: OGLOW II on STS-52 Mission
- Co-investigator, satellite experiments: OGLOW (STS-17/41G); PHOTONS (STS-19); WINDII (UARS); ACE (Canadian SciSat); AEPI (EOM-1/1) renamed ATLAS; WAMDII; VIKING-UV Imager
- Co-investigator, rocket experiment: GEMINI
- Chairman, Time Allocation Committee for WINDII/UARS
- Member of CAP/NSERC Committee for Review of Physics in Canada
-Chairman, NASA Selection Panel for LCAS
-Associate Editor Canadian Journal of Physics

# Vision for the 21st Century

| | |
|---|---|
| **INVESTIGATE** | the Atmospheric and Geospace Environments of the Planet Earth: the Dynamics and Chemistry of the Middle Atmosphere and Troposphere; the Magnetosphere, Thermosphere and Ionosphere with the imbedded Aurora Borealis. Expand these studies to the other Planets where possible and relevant. |
| **DEVELOP** | a comprehensive suite of observational systems including ground-based, rocket and satellite; and support the development of comprehensive Space and Atmospheric Models consistent with observations. Strive to achieve levels of excellence in research consistent with the highest international standards in Solar Terrestrial Physics. |
| **RELATE** | the investigations and observations to important societal issues such as the Understanding of Atmospheric Processes and Global Climate Change, and Geospace Weather Prediction. |
| **ESTABLISH** | balanced and complementary links with Agencies and Councils involved in Atmospheric and Space Research – CSA, AES, NSERC – and with high-technology industries, especially those in Saskatchewan. |
| **PROVIDE** | a balanced working and educational ENVIRONMENT for graduate students, scientists and engineers, including involvement with local industries, and with the wider life of the University of Saskatchewan – teaching and outreach. |
| **ENCOURAGE** | collaborations within the Institute to maximize opportunities for comprehensive, complementary studies of the Atmosphere and Geospace. |
| **CONTRIBUTE** | to the community of Solar Terrestrial Physicists, and to the international community engaged in Solar Terrestrial Physics. |
| **PROVIDE** | the Saskatoon and Saskatchewan communities, including especially students and the media, with information and opportunities to share in the Solar Terrestrial Physics activity in the Institute; recognizing that these contribute to the economic health, quality of life and knowledge-base of the nation. |

**ISAS - University of Saskatchewan**




**Northern springtime ozone number density at 25 km altitude as measured by OSIRIS during the time period March 08-12, 2005.**

## INSTITUTE OF SPACE AND ATMOSPHERIC STUDIES

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