Determination of the Global Conductance Pattern and its Influence on the Dynamics of Geospace

Executive Summary

Recent work has shown that in order to fully understand the dynamic behavior of geospace we must treat the ionosphere and magnetosphere as a fully coupled system. A key aspect in regulating the response of this coupled system is the ionospheric conductivity. It plays an essential role in the closure of field-aligned currents from the magnetosphere and energy deposition in the ionosphere and thermosphere. Direct global measurement of the ionospheric conductance distribution is extraordinarily difficult, so there are major important gaps in our understanding of phenomena that involve this critical system component. The combination of global ground-based and low altitude measurements of magnetic perturbations along with measurements of ionospheric electric drifts allows the full reconstruction of ionospheric electrodynamics, including both the Hall and Pedersen conductance. Key measurements in this reconstruction include inference of field-aligned currents from AMPERE, the derivation of ionospheric equivalent currents from ground magnetometer data such as that provided by SuperMAG, and the measurement of the ionospheric convection from the network of SuperDARN radars. Extensive networks of all-sky imagers, photometers, spectrographs, and riometers enable inferring the regional conductance structure that can be compared with the results of our global reconstruction. Together with recent advances in global modeling these observational capabilities can lead to major breakthroughs in our understanding of how the magnetosphere-ionosphere-thermosphere system operates as a whole. In particular, we can address numerous fundamental questions including the global conductance distribution's role in regulating the state of magnetospheric evolution, polar cap saturation, and connections between Joule heating and ionospheric outflow.

Our outstanding international team conducting this investigation includes scientists from around the world with expertise covering all aspects of the research in our proposal. The focused efforts of this team will lead to significant advances in understanding how the global pattern of conductance affects the evolution of the magnetosphere-ionosphere-thermosphere system. In addition to advancing conductance models used within global simulations we plan to publish a major research paper with the entire team as coauthors.

Team Leader: Michael Wiltberger (United States – NCAR/HAO)

Team Members: Olaf Amm (Finland – FMI)
Eric Donovan (Canada – University of Calgary)
Jesper Gjerloev (United States – JHU/APL)
William Lotko (United States – Dartmouth College)
Viacheslav Merkin (United States – JHU/APL)
Steve Milan (United Kingdom – University of Leicester)
Colin Waters (Australia – University of Newcastle)

1 Scientific Rational

1.1 Overview

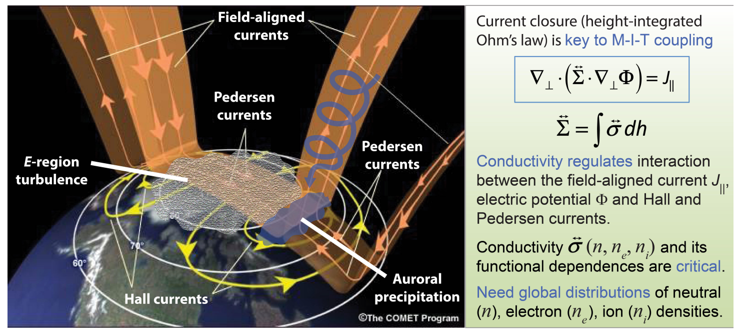

Figure 1 – Ionospheric conductivity plays an essential role in couping throughout the magnetosphere-ionosphere-thermosphere

Near-Earth space, encompassing the magnetosphere-ionosphere-thermosphere (MIT) is a coupled non-linear dynamical system, populated by neutral gas and partially and fully ionized plasmas immersed in Earth's magnetic field. The MIT system, driven by the solar wind flow, interplanetary magnetic field and solar radiation, is an enormous natural laboratory, spanning altitudes from ~50 to ~600,000 km. The system affords study of a many areas of physical science: neutral and plasma fluid dynamics, electromagnetic processes, kinetic and wave-particle interactions, non-linear dynamics, and statistical physics.

As Figure 1 illustrates the formation of the ionosphere, an ionized conducting layer at the upper edge of Earth's atmosphere, plays a key role in MIT dynamics. Ionospheric conductivity enables the closure of electrical currents generated by both low- (thermosphere) and high-altitude (magnetosphere) dynamos and allows exchange of energy and momentum between the neutral and ionized gases. The current closure governs the system electrodynamics and is described by Ohm's law. Its complexity lies in the fact that the conductivity is produced and modified by the interplay of many coupled processes within the MIT system. This interplay among the processes of conductivity formation and evolution, and its implications for scale-interactivity, coupling and feedback of the MIT system is the focus of our team's research.

The ionospheric conductivity is perniciously difficult to characterize directly, because it requires measuring altitude profiles of ionospheric neutral and plasma density on a global scale, including local turbulent and kinetic modifications. The limited state of knowledge of the conductivity and its dynamics has critically impeded our understanding of how the system operates as whole, despite recent advances in global coupled simulations of the MIT system. Fortunately, the emergence of new observational assets, most recently culminating with the acquisition of high-cadence magnetometer data from the >70 satellite Iridium constellation, allows us to characterize the global electrodynamics of the system for the first time in the history of space research.

With the maturity of global simulations and the advent of new global ground-based and satellite observations, the time has come for an international multidisciplinary team to explore opportunities for fundamental breakthroughs in the physics of magnetosphere-ionosphere-thermosphere dynamics and to produce and report a demonstration project that will serve as the testbed for future work in this important area of research.

1.2 Observations

The basic equations of ionospheric electrodynamics are the Ohm's law, determining the closure of magnetic field-aligned currents (FACs) in the ionosphere ($J_{||}$), and the Biot-Savart law relating magnetic perturbations on the ground ($\delta\mathbf{B}$) to the ionospheric current ($\mathbf{\Sigma}\cdot\mathbf{E}$), where $\mathbf{E}$ is the ionospheric electric field and $\mathbf{\Sigma}$ is the conductance (height-integrated conductivity) tensor consisting of two scalars, Pedersen (Σ_P) and Hall (Σ_H). Given a distribution of measurements $\{J_{||}, \delta\mathbf{B}, \mathbf{E}\}$ one can formally resolve both terms of the conductance tensor. This fact underlies all of the algorithms for reconstruction of ionospheric electrodynamics to date. The problem, however, is that while chains of ground-based magnetometers, e.g.

SuperMAG, and high-frequency (HF) radars, e.g. SuperDARN, allow relatively good coverage of polar caps in both hemispheres, measurements of FACs have only been available from sparse satellite passes. Only now, with emergence of the AMPERE project, are global synoptic observations of FACs are AMPERE provides the missing link in the global reconstruction of the high-latitude ionospheric electrodynamics and will allow us to construct global maps of ionospheric conductivity and conductance tensors. Figure 2 shows the current coverage of observational facilities providing measurements of the key electrodynamic quantities.

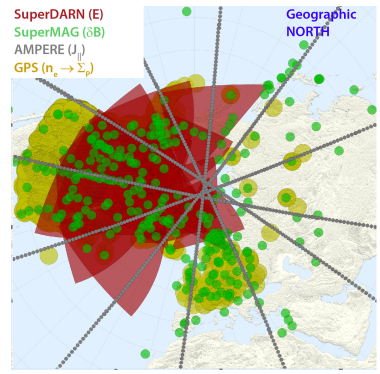

Figure 2 - Current coverage of key observations in the northern hemisphere.

Project Datasets

1. AMPERE utilizes the magnetometer data from a ~70 satellites that make up the Iridium constellation to provide global maps of the field align current patterns with an integration time of 10 minutes providing a 2hr MLT and 0.1 deg latitude resolution [*Waters et al.*, 2001; *Anderson et al.*, 2002].
2. SuperMAG is a worldwide collaboration of organizations and national agencies that currently operate >300 ground-based magnetometers. It provides measurements of magnetic field perturbations from all available stations in the same coordinate system, with identical time resolution and a common baseline removal approach [*Gjerloev*, 2012].
3. SuperDARN is a network of nearly 25 coherent radars in the northern hemisphere and 11 in the southern hemisphere, which allows reconstruction of the polar ionospheric electrostatic potential pattern at a cadence of 1 or 2 minutes [*Chisham et al.*, 2007].
4. The University of Calgary observational suite includes the THEMIS ASI network [*Donovan et al.*, 2006] of 20 white light cameras operating on 5 second cadence and the NORSTAR network of ASIs, photometers, and riometers [*Spanswick et al.*, 2009].

1.3 Theory and Modeling

Numerical modeling of the MIT system has made significant advances in recent years culminating in models such as the Coupled Magnetosphere Ionosphere Thermosphere Model [*Wiltberger et al.*, 2004] that are capable of modeling the entire system by coupling regional models. This model combines the Lyon-Fedder-Mobarry magnetohydrodynamic magnetosphere model [*Lyon et al.*, 2004] with the Thermopshere-Ionosphere-Electrodynamic General Circulation [*Richmond et al.*, 1992] model through the MIX electrodynamic coupler [*Merkin and Lyon*, 2010]. A key aspect of this coupling is how the ionospheric conductance is determined. CMIT currently uses an empirical relationship between MHD parameters to determine the flux and energy of electron precipitation [*Wiltberger et al.*, 2009] with recently developed extensions that allow for better specification of the broadband and diffuse components of the electron precipitation[*Zhang et al.*, 2012].

While it is difficult to measure ionospheric conductance in situ as explained above, they can be derived from remote observations in regions where coverage of suitable data sources exists. One option for this is to combine spatial measurements of the ionospheric electric field, e.g., from ground-based coherent scatter radars, with data of a collocated network of ground magnetometers [*Amm*, 1998]. The ionospheric electric field data can also be combined with multi-satellite observations of field-aligned currents [*Amm*, 2002], as they are available from the Cluster, THEMIS, or AMPERE spacecraft missions. [*Green et al.*, 2007] used the combination of SuperDARN, SuperMAG, and Iridium (the AMPERE precursor) to produce initial global estimates of the ionospheric conductance. Further, the upcoming Swarm mission of three ionospheric spacecraft that are able to measure the full-component electric and magnetic field in high spatio-temporal resolution will make it possible to infer ionospheric conductance along a strip that envelopes the parallel orbits of the spacecraft[*Amm et al.*, 2008].

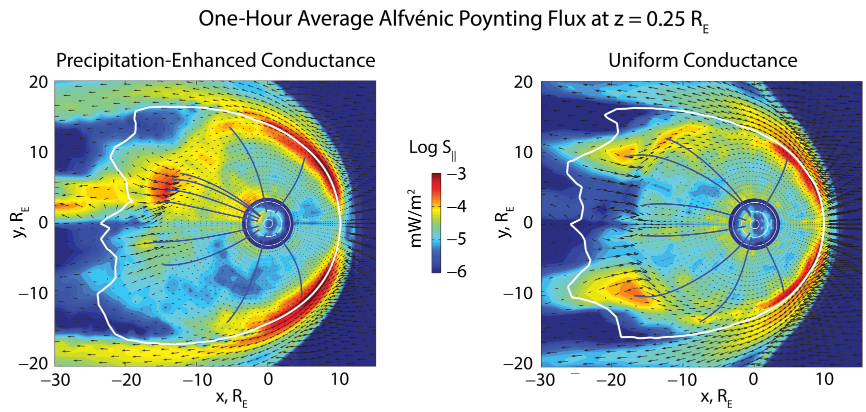

Figure 3 - Comparison of magnetospheric flow structure with precipation enhanced conductance (top) and uniform conductance (bottom) from *Zhang et al.* 2012 illustrates the signifcant role conductance can play in distribution of flows.

1.4 Integrated Nature of Our Multidisciplinary Work

Recent results reported by [*Zhang et al.*, 2012] highlight the important need for multidisciplinary approach to investigating the MIT system. As shown in Figure 3 the state of the magnetosphere depends significantly on the ionospheric conductance. The top panel shows flows (arrows) and Alfvénic Poynting flux (color) in a magnetosphere simulation with ionospheric conductance dynamically modified by an embedded electron precipitation model. The simulation exhibits a concentration of both Alfvénic Poynting flux high-speed plasma flows and enhanced reconnection in the pre-midnight sector. When the simulation is run for the same solar wind conditions, but with a uniform Pedersen conductance in the ionosphere, the flows become more uniformly distributed throughout the magnetotail.

The proposed international team is uniquely positioned to address key scientific issues where knowledge of the global conductance distribution, as in the example in Fig. 3, is essential. The first step in this endeavor requires a synthesis of the full suite of observations and models to create the first accurate, global specification of the ionospheric conductance. With this foundation, the team will investigate outstanding problems in M-I-T coupling in which the distribution and magnitude of ionospheric conductivity has a major influence. Select problems include:

1. Saturation of cross-polar potential as first reported by [*Hill*, 1984] include examination of the several theories have been put forward to explain this process ranging from Alfven wings[*Kivelson and Ridley*, 2008], distortion of flows in the magnetosheath[*Lopez et al.*, 2012], importance of ionospheric conductance [*Merkine et al.*, 2003; *Merkin et al.*, 2005] and others [*Siscoe et al.*, 2002; *Hairston et al.*, 2005; *Kan et al.*, 2010]
2. Regulation of flows and structure in magnetospheric-ionospheric convection, e.g., as illustrated in Fig. 3, including the distribution and role of ionospheric Joule heating and field-aligned current closure and their effects on ionospheric electrodynamics [e.g. [*Grocott et al.*, 2009; *Zhang et al.*, 2012]].
3. Upwelling of the ionosphere and thermosphere and its influence on the escape and outflow of ionospheric plasma into geospace.

2 Expected Outputs

It is our expectation that the results of the research investigation will lead to one major research paper with the entire team as coauthors. This paper will provide an overview of our system approach to understanding the role of conductance in regulating MIT system. . It is also expected that a significant number of collaborative studies will be initiated between team members, resulting in a number of research papers.

3 Added Value of ISSI

Our proposed research program requires assembling a group of scientists with broad range of expertise including theorists, modelers, and observers and ISSI provides us with a unique venue to accomplish this research. First, answering the fundamental questions posed by our research requires the focused dedication that the ISSI team program requires. Second, by providing a location for the meetings it allows our team to focus closely on conducting the research and building new collaborations that haven't previously existed. Finally, it assures a mechanism for publishing our comprehensive analysis of the global conductance pattern.

4 Confirmed Team Members

Our outstanding international team includes the following scientists from 5 countries:

Dr. Olaf Amm (Olaf.Amm@fmi.fi) from the Finish Meteorological Institute, Finland, is an expert in the developing numerical models of ionospheric electrodynamics.

Dr. Eric Donovan (edonovan@ucalgary.ca) from the University of Calgary, Canada, is a world leader in the deployment and utilization of ground based auroral instruments and their use in interpreting MI coupling.

Dr. Jesper Gjerloev (Jesper.Gjerloev@jhuapl.edu) from the Applied Physics Laboratory, USA, is an authority in the utilization of ground magnetometer data and a leader of the International SuperMAG collaboration.

Dr. William Lotko (William.Lotko@dartmouth.edu) from Dartmouth College, USA, is an authority on MI coupling including the effects of electron precipitation and conductance distributions on the magnetosphere-ionosphere-thermosphere interaction.

Dr. Viacheslav Merkin (Slava.Merkin@jhuapl.edu) from the Applied Physics Laboratory, USA, is a leading developer of electrodynamic coupling components within global simulations and has conducted extensive studies comparing AMPERE data with these simulations.

Dr. Steve Milan (ets@ion.le.ac.uk) from the University of Leicester, UK, is an authority on using SuperDARN data and auroral imagery to study MI coupling.

Dr. Colin Waters (Colin.Waters@newcastle.edu.au) from the University of Newcastle, Australia, is a member of the AMPERE team as well as an expert on the utilization of SuperDARN observations.

Dr. Michael Wiltberger (wiltbemj@ucar.edu) from the High Altitude Observatory at the National Center for Atmospheric Research, USA, will serve as the leader of the team and is an expert in global modeling of geospace.

5 Schedule

We plan to complete this project within 18 months during which time the group will have three meetings at ISSI. The two meetings of the team will occur in September 2013 and March of 2014. During these meetings we will actively engage in research towards meeting the goals of this proposal. At the final meeting of the team in October of 2014 we will summarize our results and determine the schedule for submitting research publications.

6 ISSI Support

All that our team requires from ISSI is to support our team meetings with standard projection equipment and basic Internet connections. The standard financial support package for teams will be adequate for our proposal. We intended to identify a young scientist to join the team once the proposal is selected.

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Spanswick, E., E. Donovan, W. Liu, J. Liang, J. B. Blake, G. Reeves, R. Friedel, B. Jackel, C. Cully, and A. Weatherwax (2009), Global observations of substorm injection region evolution: 27 August 2001, *Ann. Geophys.*, *27*(5), 2019–2025, doi:10.5194/angeo-27-2019-2009.

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Wiltberger, M., R. S. Weigel, W. Lotko, and J. A. Fedder (2009), Modeling seasonal variations of auroral particle precipitation in a global-scale magnetosphere-ionosphere simulation, *J. Geophys. Res.*, *114*(A), 01204, doi:10.1029/2008JA013108.

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Short curriculum vitae
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Citizenship: German and Finnish

Professional information

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Education (University Degrees):
Vordiplom (B.Sc.) in Geophysics at University of Münster, Germany, 1990 (mark: "very good")
Diplom (M.Sc.) in Geophysics at University of Münster, Germany, 1994 (mark: "very good with distinction")
Doktor rer. nat. (Ph.D.) at University of Braunschweig, Germany, 1998 (mark: "magna cum laude")
Docent of Space Physics at University of Helsinki, Finland, 2002 (mark: "Excellent")

Main posts:
- Doctoral student and scientist at Technical University of Braunschweig, Germany, 1995-1998 (partly with a research grant of the German Research Community, DFG)
- Guest scientist at Finnish Meteorological Institute (FMI), Helsinki, Finland, 1995-1997 (with a grant from the German Academic Exchange Service, DAAD)
- Guest scientist at Finnish Meteorological Institute, Helsinki, 1998-2000 (partly with a postdoctoral grant from the German Academic Exchange Service, DAAD)
- Senior Scientist at Finnish Meteorological Institute, Helsinki, since 2000
- Visiting associate professor at Solar-Terrestrial Environment Laboratory (STELAB), University of Nagoya, Japan, January-March 2005, and September - November 2009
- Visiting full professor Solar-Terrestrial Environment Laboratory (STELAB), University of Nagoya, Japan, March-May 2012.
- Visiting scientist at ISSI, Bern, Switzerland, September-December 2012

Main research interests:
- Ionospheric electrodynamics
- Magnetosphere-ionosphere coupling
- Potential theory and modeling
- Ionospheric tomography with radio waves

Selected publications regarding studies of ionospheric conductances:
- Amm, O., Method of characteristics in spherical geometry applied to a Harang discontinuity situation, *Ann. Geophys., 16*, 413, 1998.
- Amm, O., The method of characteristics for calculating ionospheric electrodynamics from multi-satellite and ground-based radar data, *J. Geophys. Res., 107* (A10), 1270, doi:10.1029/2001JA005077, 2002.
- Amm, O., A. Aruliah, S.C. Buchert, R. Fujii, J.W. Gjerloev, A. Ieda, T. Matsuo, C. Stolle, H. Vanhamäki, and A. Yoshikawa, Understanding the electrodynamics of the 3-dimensional high-latitude ionosphere: present and future, *Ann. Geophys., 26*, 3913, 2008.

Selected scientific community positions:
- ISSI team leader for two scientific teams: Cluster/ ground-based research (2003-2005), and three-dimensional modelling of the ionosphere and of ionosphere-magnetosphere coupling (2005-2007)
- Associate Editor of Journal of Geophysical Research (JGR) - Space Physics (2010-2014)
- PI of the MIRACLE network of ground-based space observations in Scandinavia
- PI of the TomoScand project for ionospheric tomography in Scandinavia
- PI of ESA project "Exploiting synergies between Swarm and Cluster"

Teaching:
- Lecture series "Potential Theory for Space Physics" at University of Helsinki, Finland, and at University of Uppsala, Sweden (since 2000)
- Lecture "Ionospheric currents and their origin" at the Research School for Electrodynamics, Oulu, Finland (2001)
- Lecture series "Ionospheric Physics" at University of Helsinki, Finland (since 2003)

Eric Donovan – Abridged Curriculum Vitae

Employment History

Full Professor	U. Calgary	2011-present
Canada Research Chair (TII)	U. Calgary	2004-present
Associate Professor	U. Calgary	2002-2011
Assistant Professor	U. Calgary	1997-2002
PDF	U. Alberta; IRF Uppsala; U. Calgary	1993-1997

Degrees

Ph.D. (Physics)	U. Alberta	1993
M.Sc. (Physics)	U. Western Ontario	1988
B.Sc. (Physics)	U. Western Ontario	1986

Research Program and Other Evidence of Impact

The overall theme of Dr. Donovan's research is **geospace energy and mass transport**, with focus on using optical, radar, and riometer data to remote sense magnetospheric dynamics.

Dr. Donovan is the PI of the CSA funded Canadian GeoSpace Monitoring (CGSM) All-Sky Imager and Riometer arrays. His group deployed, operates, and recovers the data from the 16 white light ASIs located in Canada as part of NASA's THEMIS mission, and founded the international GAIA Virtual Observatory program. He conceived of a two-satellite auroral imaging mission (Ravens), a concept developed by Dr. Donovan's team through a Phase A study for 24/7 UV Auroral Imaging on the proposed Canadian PCW satellite mission. He is PI of the Canadian face of the Resolute Bay Incoherent Scatter Radar (RISR), expected online July 2013.

Dr. Donovan is Chair-Elect (2011-2013) and will be Chair (2013-2015) of the NSF GEM Science Steering Committee. He is on ESA's SWARM Mission Advisory Group, and has served on the CEDAR Science Steering Committee, and the EISCAT Science Advisory Committee. He is CoI on NASA's RBSM (for EFW) and THEMIS missions. Together with John Samson and Igor Voronkov, he wrote the science plan for the CANOPUS project in the years 2000 and beyond. He led the Canadian community proposal to the CSA for CGSM, the program that evolved from CANOPUS, and that is now one of the highest funded ongoing CSA science programs.

Dr. Donovan has been the author or co-author of over 170 refereed, and 20 non-refereed publications, and has given over 60 invited talks, colloquia, and seminars.

Representative Publications (underline indicates member of Donovan's group)

Donovan, E., E. Spanswick, J. Liang, J. Grant, B. Jackel, and M. Greffen, Magnetospheric dynamics and the proton aurora, *Auroral Phenomenology and Magnetospheric Processes: Earth and Other Planets, AGU Monograph*, Ed. by Keiling, Donovan, Bagenal, and Karlsson, 2012.

Liang, J., E. Spanswick, M. Nicolls, **E. Donovan**, D. Lummerzheim, and W. Liu, Multi-instrument observations of soft e- precipitation and its association with magnetospheric flows, *JGR*., 2011.

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Spanswick, E., **E. Donovan**, R. Friedel, and A. Korth, Ground based identification of dispersionless electron injections, *Geophys. Res. Lett*., *34*, 2007.

Representative Invited Talks

The Substorm, *Invited Lecture,* Heliophysics Summer School, Boulder, June, 2012.

Magnetospheric Drivers of the Aurora, *Tutorial*, 38th Annual Meeting for Studies of the Upper Atmosphere by Optical Methods, Helsinki, August, 2011.

Imaging the Aurora, Plenary *Interdisciplinary Lecture*, COSPAR, Montreal, July, 2008.

Curriculum Vitae of Jesper W. Gjerloev, B.S., Master, Ph.D.

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Jesper W. Gjerloev received his bachelor and master degree from the University of Copenhagen and his Ph.D. from the Technical University of Denmark. He won a prestigious travel grant from the University of Copenhagen to work on his master thesis in theoretical plasma physics. He was later awarded the highly competitive grant from the Technical University of Denmark to work on his Ph.D. thesis. The thesis entitled '*Electrodynamics in the high latitude nighttime sector during auroral substorms*' was written under the guidance of Dr. R. A Hoffman at NASA.

After he received his Ph.D. degree he was an employee of the Universities Space Research Association (USRA) for one year continuing his work at NASA. In January 1999 he returned to Denmark where he held a postdoctoral research position at the Danish Space Research Institute. In September 2000 he was awarded a National Research Council postdoctoral position at NASA with Dr. R. R. Vondrak as advisor. He continued as a USRA staff scientist for a year and has since been a senior staff scientist at Johns Hopkins University Applied Physics Laboratory. He is also professor at U. Bergen, Norway.

Jesper is the author of >40 published scientific papers, has made >100 presentations at international scientific meetings, given >40 invited talks and won >20 competitive grants. He has served on NSF and NASA peer review panels and been a referee for a long list of scientific journals. He has taught astronomy at American University, was a tenured professor at University of Bergen, and a master thesis and Ph.D. advisor for 7 students. He was the Co-I for the NASA LCAS "ACES" mission and he is the founder and PI for the global ground based magnetometer initiative SuperMAG. Throughout his career Jesper has been completely self-funded by winning competitive NASA, NSF, ESA and other proposal competitions.

Selected First Author Publications:

Gjerloev, J. W., and R. A. Hoffman, Currents in auroral substorms, *J.Geophys.Res*., *107* (A12): Art. No. 1435 Dec 11 2002.

Gjerloev, J. W., R. A. Hoffman, E. Tanskanen, M. Friel, L. A. Frank, J. B. Sigwarth, Auroral electrojet configuration during substorm growth phase, *Geophys.Res.Lett, 30* (18): Art. No. 1927 Sep 18 2003.

Gjerloev, J. W., R. A. Greenwald, C. L. Waters, K. Takahashi, D. Sibeck, K. Oksavik, R. Barnes, J. Baker, and J. M. Ruohoniemi (2007), Observations of Pi2 pulsations by the Wallops HF radar in association with substorm expansion, *Geophys. Res. Lett*., 34, L20103, doi:10.1029/2007GL030492.

Gjerloev J. W., R. A. Hoffman, J. B. Sigwarth, L. A. Frank (2007), Statistical description of the bulge-type auroral substorm in the far ultraviolet, *J. Geophys. Res*., 112, A07213, doi:10.1029/2006JA012189.

Gjerloev, J. W., R. A. Hoffman J. B. Sigwarth , L. A. Frank, and J. Baker, The typical auroral substorm: A bifurcated oval*, J.Geophys.Res*.,113, A03211, DOI: 10.1029/2007JA012431.

Gjerloev, J. W., R. A. Hoffman, S. Ohtani, J. Weygand, and R. Barnes, Response of the Auroral Electrojet Indices to Abrupt Southward IMF Turnings, *Annales Geophysicae*, 28, 1167-1182, 2010.

Gjerloev, J. W., Ohtani, S., Iijima, T., Anderson, B., Slavin, J., and Le, G.: Characteristics of the terrestrial field-aligned current system, *Annales Geophysicae, 29*, 1713-1729, 2011.

Gjerloev, J. W. (2012), The SuperMAG data processing technique, *J. Geophys. Res.*, *117*, A09213, doi:10.1029/2012JA017683.

William Lotko

Biographical Sketch

Institution: Dartmouth College

Education:

B.S. in Engineering Physics, University of Kansas
Ph.D. in Physics, UCLA

Professional Background:

Professor, Thayer School of Engineering, Dartmouth College, 1984-present
Research Affiliate, HAO/NCAR, 2010-present
Interim Dean, Thayer School of Engineering, 2004-2005
Senior Associate Dean, Thayer School of Engineering, 1999-2004
Director MS/PhD Program, Thayer School of Engineering, 1996-1999
Research Physicist, SSL/UCB, 1981-1984

Project-Relevant Experience:

William Lotko is professor of engineering at Dartmouth College. He is currently investigating and developing simulation models for ionospheric outflows into the magnetosphere, electron precipitation into the high-latitude ionosphere and thermosphere, plasma kinetics that enable superfluent ion outflows and electron precipitation, and the effects of these processes on magnetosphere-ionosphere coupling and global geospace dynamics. Dr. Lotko is principal investigator for Dartmouth's Heliophysics Theory Project, "Dynamics of Magnetosphere-Ionosphere Coupling", sponsored by NASA. He is also PI for an NSF project to improve capabilities to predict electron precipitation in geospace weather and for a NASA project to explore the hypothesis that ionospheric outflows are integral in the development of a planetary-scale oscillation known as the magnetospheric sawtooth mode.

Relevant Publications:

Brambles, O.J., W. Lotko, B. Zhang, M. Wiltberger, J. Lyon, R.J. Strangeway (2011), Magnetosphere sawtooth oscillations induced by ionospheric outflow, *Science 332*, 1183, doi:10.1126/science.1202869.

Brambles, O. J., W. Lotko, P. A. Damiano, B. Zhang, M. Wiltberger, J. Lyon (2010), Effects of causally driven cusp O^+ outflow on the stormtime magnetosphere-ionosphere system using a multifluid global simulation, *J. Geophys. Res. 115*, A00J04, doi:10.1029/2010JA015469.

Lotko, W. (2004), Inductive magnetosphere-ionosphere coupling, *J. Atmos. Solar-Terr. Phys.*, *66*/15-16, 1443-1456, doi:10.1016/j.jastp.2004.03.027.

Lotko, W. (2007), The magnetosphere-ionosphere system from the perspective of plasma circulation: A Tutorial, *J. Atmos. Sol.-Terr. Phys. 69*(3), 191-211, doi:10.1016/j.jastp.2006.08.011.

Streltsov, A.V., W. Lotko (2008), Coupling between density structures, EM waves and ionospheric feedback in the auroral zone, *J. Geophys. Res. 113*(A5), A05212, doi:10.1029/2007JA012594.

Wiltberger, M., R. S. Weigel, W. Lotko, J. A. Fedder (2009), Modeling seasonal variations of auroral particle precipitation in a global-scale magnetosphere-ionosphere simulation, *J. Geophys. Res. 114*, A01204, doi:10.1029/2008JA013108.

Wiltberger, M., W. Lotko, J. G. Lyon, P. Damiano, V. Merkin (2010), Influence of cusp O^+ outflow on magnetotail dynamics in a multifluid MHD model of the magnetosphere, *J. Geophys. Res. 115*, A00J05, doi:10.1029/2010JA015579.

Zhang, B., W. Lotko, M. J. Wiltberger, O. J. Brambles, P. A. Damiano (2011), A statistical study of magnetosphere-ionosphere coupling in the Lyon-Fedder-Mobarry global MHD model, *J. Atmos. Sol.-Terr. Phys*. *73*(5-6), 686-702, doi:10.1016/j.jastp.2010.09.027.

Zhang, B., W. Lotko, O. Brambles, P. Damiano, M. Wiltberger, and J. Lyon (012), Magnetotail origins of auroral Alfvénic power, *J. Geophys. Res. 117*, A09205, doi:10.1029/2012JA017680.

Zhang, B., W. Lotko, O. Brambles, M. Wiltberger, W. Wang, P. Schmitt, and J. Lyon (2012), Enhancement of thermospheric mass density by soft electron precipitation, *Geophys. Res. Lett. 39*, L20102, doi:10.1029/2012GL053519.

Viacheslav G. Merkin
Johns Hopkins University Applied Physics Laboratory
11000 Johns Hopkins Road, Laurel, MD 20723
Phone: 443-778-1756; Email: Viacheslav.Merkin@jhuapl.edu

Role: Global MHD simulations of the inner heliosphere.

Related Education

- Ph.D, Physics, University of Maryland (2004)
- M.S., Physics, Moscow Institute of Physics & Technology (1999)
- B.S., Physics, Moscow Institute of Physics & Technology (1997)

Previous Project Participation

- Center for Integrated Space Weather Modeling, Researcher (2004 - 2012)
- Multiple NASA and NSF grants, PI and co-I, current.

Employment

- Senior Research Scientist, APL (2010 – Present)
- Senior Research Scientist, Center for Space Physics at Boston Univ. (2007 – 2010)
- Lecturer/Visiting Faculty, Boston College (2007 – 2007)
- Research Associate, Center for Space Physics at Boston Univ. (2004 – 2007)

Selected Achievements, Awards & Professional Services

- Top Score, Qualifier Exam Univ. of Md. Dept. of Physics Graduate Program (2000)
- Soros Scholarship in Physics (1996, 1997)

Synergistic Activities and Professional Society Membership

- Scientific paper referee: JGR, GRL, Space Weather Journal, JASTP
- Proposal mail-in and panelist reviewer: NSF, NASA, Swedish National Space Board
- Geospace Environment Modeling (GEM) research area coordinator (2009-2015)
- Member of American Geophysical Union (AGU)

Relevant Publications

Merkin, V. G., B. J. Anderson, J. G. Lyon, H. Korth, M. Wiltberger, T. Motoba, Global evolution of Birkeland currents on 10-min time scales: MHD simulations and observations, *J. Geophys. Res.*, submitted, 2013.

Merkin, V. G., and J. G. Lyon, Effects of the Low-Latitude Ionospheric Boundary Condition on the Global Magnetosphere, *J. Geophys. Res.*, 115, A10202, doi:10.1029/2010JA015461, 2010.

Merkin, V. G., and C. C.Goodrich, Does the polar cap area saturate?, *Geophys. Res. Lett.*, 34, L09107, doi:10.1029/2007GL029357, 2007.

Merkin, V. G., J. G. Lyon, B. J. Anderson, H. Korth, C. C. Goodrich, K. Papadopoulos, A global MHD simulation of an event with a quasi-steady northward IMF component, *Ann. Geophys.*, 25, pp. 1345–1358, 2007.

Merkin, V. G.,, G. Milikh, K. Papadopoulos, A. S. Sharma, J. Lyon, C. Goodrich, Y. S. Dimant, and M. Wiltberger, Effect of anomalous electron heating on the transpolar potential in the LFM global MHD model, *Geophys. Res. Lett.*, 32(22), doi:10.1029/2005GL023315, 2005.

Merkine, V. G.,, K. Papadopoulos, G. Milikh, A. S. Sharma, X. Shao, J. Lyon, and C. Goodrich, Effects of the solar wind electric field and ionospheric conductance on the cross polar cap potential: results of global MHD modeling, Geophys. Res. Lett., 30(23), 2180, doi:10.1029/2003GL017903, 2003.

Prof. Steve Milan

Lecturer, Department of Physics and Astronomy, University of Leicester, Leicester LE1 7RH, UK
Tel: +44 116 223 1896, Fax: +44 116 252 3555, steve.milan@ion.le.ac.uk

Education:

1990	B.Sc. (Physics with Astrophysics), University of Leicester.
1995	Ph.D. (HF radiowave propagation at polar latitudes), University of Leicester.

Awards:

1996	"Young Scientist Award", URSI.
2001	"Young Scientists' Publication Award", European Geophysical Society.
2005	ESA award for outstanding contribution to the Cluster mission.
2013	Royal Astronomical Society Chapman Medal.

Positions held:

2003—	Principle Investigator of ground-based support for Cluster and Double Star Program satellite missions.
2005—	Chair of ESA Cluster Active Archive (CAA) review board.
2006—	Secretary for Magnetospheres, EGU Division of Solar-Terrestrial Sciences.
2007—2009	Associate Editor, *Geophysical Research Letters*.
2009—	Member editorial board, *International Journal of Geophysics*
2009—	Associate Editor, *Journal of Geophysical Research*.

Instrument involvement:

PI	Falkland Islands SuperDARN radar.
Co-I	CUTLASS (Co-ordinated UK Twin-Located Auroral Sounding System).
Co-I	MIXS (Mercury Imaging X-ray Spectrometer) instrument, BepiColombo.

Research interests:

Magnetospheric physics; planetary magnetospheres, Mercury, Earth, Jupiter, Saturn;
Solar wind-magnetosphere-ionosphere coupling; ionospheric convection;
Coordinated ground- and space-based studies; auroral physics and imagery;
Magnetic reconnection, flux transfer events;
Magnetospheric structure and dynamics, esp. substorm cycle, magnetotail;
Magnetohydrodynamic waves, esp. ULF waves;
Ionospheric physics; ionospheric morphology; auroral ionosphere;
Collisional plasma instability mechanisms; E region irregularities;
Radar techniques; HF radio propagation; impact of auroral processes on HF radio propagation.

Selected publications (186 in total):

Milan, S. E., M. Lester, S. W. H. Cowley, J. Moen, P. E. Sandholt, and C. J. Owen, Meridian-scanning photometer, coherent HF radar, and magnetometer observations of the cusp: a case study, *Ann. Geophysicae*, 17, 159-172, 1999.

Milan, S. E., M. Lester, S. W. H. Cowley, and M. Brittnacher, The convection and auroral response to a southward turning of the IMF: POLAR UVI, CUTLASS, and IMAGE signatures of transient magnetic flux transfer at the magnetopause, *J. Geophys. Res.*, 105, 15741-15756, 2000.

Milan, S. E., and M. Lester, Interhemispheric differences in the HF radar signature of the cusp region: A review through the study of a case example, *Adv. Polar Upper Atmos. Res.*, 15, 159-177, 2001.

Milan, S. E., M. Lester, S. W. H. Cowley, K. Oksavik, M. Brittnacher, R. A. Greenwald, G. Sofko, and J.-P. Villain, Variations in polar cap area during two substorm cycles, *Ann. Geophysicae*, 21, 1121-1140, 2003.

Milan, S. E., S. W. H. Cowley, M. Lester, D. M. Wright, J. A. Slavin, M. Fillingim, C. W. Carlson and H. J. Singer, Response of the magnetotail to changes in open flux content of the magnetosphere, *J. Geophys. Res.*, 109, A04220, doi: 10.1029/2003JA010350, 2004.

Milan, S. E., B. Hubert, and A. Grocott, Formation and motion of a transpolar arc in response to dayside and nightside reconnection, *J. Geophys. Res.*, *110*, A01212, doi: 10.1029/2004JA010835, 2005.

Milan, S. E., G. Provan, and B. Hubert, Magnetic flux transport in the Dungey cycle: A survey of dayside and nightside reconnection rates, *J. Geophys. Res.*, *112*, A01209, doi: 10.1029/2006JA011642, 2007.

Brief CV – A/Prof Colin Waters

B.Ed.(Sc.), Dip.Sc.(Hons), PhD.(University of Newcastle)

Appointments

1987 Lecturer in Physics, Avondale College of Advanced Education
1993 Post-Doctoral Fellow, Canadian Network for Space Research, Edmonton, Alberta, Canada
1994 Lecturer Level A, Physics Department, University of Newcastle
1997 Lecturer Level B, Physics Discipline, University of Newcastle
2000 Research Fellow, The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, U.S.A
2003 Senior Lecturer, Physics Discipline, University of Newcastle
2007 Associate Professor, Physics Discipline, University of Newcastle

Honours, Distinctions, Societies and Committees

Member, Australian Institute of Physics.
Member, American Geophysical Union.
Member, Australian Academy of Science National Committee for Radio Science, (2006 - 2011).
Member Callaghan College governing board (2013-)
Bachelor of Science program convenor (2013-)
Australia representative, Commission H of URSI (2008-2011)
Scientific Program Committee, AGU Chapman Conference, Korea (2014)
Program Convenor IAGA div III session, Mexico, (2013)
Visiting Professor, University of Alberta, Edmonton, Canada (2012)
Visiting Research Scientist; University of Leicester, UK; Johns Hopkins University Applied Physics Laboratory (JHU/APL) and University of Minnesota, USA (2012)
Faculty of Science and Information Technology Teaching Excellence Award (2011).
New South Wales, HSC Examination Committee (2010).
Assistant Dean (Marketing and Community) (2007-2010).
SuperMAG international magnetometer network steering committee (2010-).
Chair, organizing committee international SuperDARN conference (2008).
Program committee, Western Pacific Geophysics meeting (2008).
Chair, Sun-to Earth working group, National Committee for Space Science decadal plan (2006-2007).
International science team: Scientific Operation of Fluxgate Magnetometers in the Expanded Canadian Array for Real-time Investigations of Magnetic Activity (CARISMA) (2007)
Member International FITACF working group for over the horizon radar research (2004-2006).
Visiting Research Scientist (JHU/APL) (2000)
Interviewed by media at American Geophysical Union, San Francisco (2000) on Iridium satellite data research (2000)
Convenor IAGA and IUGG Symposia 1999 (Birmingham, UK), 2005 (Toulouse, France), Chapman Conference 2005 (San Diego, USA)
HSC Examination committee (1998)
Various Faculty Committees (Computer, Teaching and Learning, Postgraduate Student Progress)
Post-Doctoral Fellowship Award, Canadian Network for Space Research (1993)
Awarded Australian Institute of Physics Prize in Physics IV (1986)

Research Summary

Co-author of monograph: F. W. Menk and C. L Waters, Magnetoseismology: Ground-based remote sensing of the Earth's magnetosphere, John Wiley & Sons, ISBN: 978-3-527-41027-9, 244 pages, published 20 March, 2013.
Presently Chief Investigator on ARC-DP Grant
ARC-Linkage grant application to study geomagnetic induced currents in the Australian electricity supply network
Johns Hopkins University Applied Physics Laboratory Iridium satellite data processing software and research (2007-2013).
Science data manager on the CRC for Satellite Systems satellite, *FedSat* (2004-2007)
Authored 80 DEST, C1 category journal papers (1991-2011), 150 conference papers (15 invited)
Research at Australian and International Antarctic bases

Research within the Space Physics Group, Australia's leading centre for research on the properties of near-Earth space, extending from the ionosphere to beyond the influence of the geomagnetic field (~60,000 km). Research interests include:
i) Data and modelling of Doppler clutter in over-the-horizon HF radar systems.
ii) Magnetosphere and ionosphere coupling by the Birkeland currents using data from the Iridium satellite constellation.
iii) Data and modelling of effects of geomagnetic induced currents on technology including gas pipeline corrosion and electricity supply grids.

Teaching Summary

University teaching of Physics at all levels.
Course coordinator roles for first year Introductory Physics and 2nd and 3rd year Electromagnetism courses. This involves delivery of material, run tutorial classes, design assessments and do all the grading for assignments and exams.
I also teach Honours (4th year) courses in Plasma Physics, Digital Signal Processing, Magnetosphere and Ionosphere Physics.
Member of Faculty Board, as Bachelor of Science program convenor (make decisions on credit transfers for all B.Sc majors, manage degree reviews and responses etc.).

Michael Wiltberger

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Birth date July 5, 1970

Education

Ph.D, Space Plasma Physics, 1998
University of Maryland College Park, MD 20742
M.S., Physics, 1997
University of Maryland College Park, MD 20742
B.S., Physics, Magna Cum Laude, 1993
Clarkson University Potsdam, NY 13699

Research and Work Experience

Scientist — High Altitude Observatory
2003 to present — National Center for Atmospheric Research

Assistant Adjoint Professor — Astrophysical & Planetary Sciences Department
2007 to present — University of Colorado at Boulder

Research Assistant Professor — Department of Physics and Astronomy
1999 to 2003 — Dartmouth College

Faculty Research Assistant — Space Plasma Physics Group
1998 to 1999 — University of Maryland

Honors and Awards

Group Achievement Award, National Aeronautics and Space Administration, 1998

Research Interests

I work as research scientist within the High Altitude Observatory whose main area of research is the modeling of the magnetosphere and its interaction with the solar wind and coupled thermosphere-ionosphere system. This work includes efforts to develop new models, analysis of model results, and dissemination of research results through peer review journals and presentations at meetings. I also work on understanding the basic physical processes involved in the coupling of the magnetosphere with the ionosphere.

Relevant Publications

2.77. Brambles, O. J., W. Lotko, B. Zhang, M. Wiltberger, J. Lyon, R. J. Strangeway (2011), Magnetosphere Sawtooth Oscillations Induced by Ionospheric Outflow, *Science*, 332, 1183-1186, doi:10.1126/science.1202869.

Wiltberger, M., R. S. Weigel, W. Lotko, and J. A. Fedder, "Modeling seasonal variations in auroral particle precipitation", *J. Geophys. Res.*, doi:10.1029/2008JAJA013108, 2009.

Claudepierre, S. G. and S. R. Elkington and M. Wiltberger, "Solar wind driving of magnetospheric ULF waves: Pulsations driven by velocity shear at the magnetopause", *J. Geophys. Res.*, 113, doi:10.1029/2007JA012890, 2008.

Wiltberger, M., R. S. Weigel, M. Gehmeyr, and T. Guild, "Analysis and Visualization of Space Science Model Output and Data with CISM-DX", *J. Geophys. Res.*, doi:10.1029/2004JA010956, 2005.

Wiltberger, M., W. Wang, A. Burns, S. Solomon, J. G. Lyon, and C. C. Goodrich, "Intial results from the Coupled Magnetosphere Ionosphere Thermosphere Model: Magnetospheric and Ionospheric Responses", *J. Atmos. Solar Terr. Phys.*, 66, 1411, doi:10.1016/jastp.2004.04.026, 2004.

Graduate Advisor Dennis Papadopoulos, Department of Physics, University of Maryland