AGU CHAPMAN CONFERENCE

Yosemite National Park, California, USA | 9–14 February 2014

Magnetosphere-Ionosphere Coupling in the Solar System

Magnetosphere-Ionosphere Coupling in the Solar System

Yosemite National Park, California, USA
9–14 February 2014

Organizing Committee (Co-Conveners)

Rick Chappell*
Lead Organizer
Vanderbilt University

Bob Schunk
Lead Institution
Utah State University

Andy Nagy*
University of Michigan

Peter Banks*
Local Organizer in California

Jim Burch
Southwest Research Institute

Dan Baker
University of Colorado

*Organizer of original Yosemite meeting in 1974

Program Committee

Tom Moore
NASA/GSFC

Dan Welling
University of Michigan

Margaret Kivelson
University of California, Los Angeles

Jerry Goldstein
Southwest Research Institute

Hunter Waite
Southwest Research Institute

Mary Hudson
Dartmouth University

Rod Heelis
University of Texas at Dallas

Emma Bunce
University of Leicester

Jim Spann
NASA/MSFC

Andrew Coates
University College of London

Michael Mendillo
Boston University

Thank You to Our Sponsors and Partners

The conveners wish to acknowledge the generous support for this conference from our sponsors and partners.

NASA
NSF
VANDERBILT®
UtahStateUniversity
ATMOSPHERIC, OCEANIC & SPACE SCIENCES
UNIVERSITY OF MICHIGAN
AGU
American Geophysical Union™

Note: Attendees at the Chapman conference may be photographed by AGU for archival and marketing purposes. No photography will be permitted during scientific sessions.

Magnetosphere-Ionosphere Coupling in the Solar System

Meeting At A Glance

Sunday, 9 February

5:30 P.M. – 7:00 P.M.	Welcome Reception (*Yosemite Lodge – Cliff/Falls Room*)

Monday, 10 February

8:00 A.M. - 8:45 A.M.	Welcome & Opening Remarks – Rick Chappell, Vanderbilt University Magnetosphere-Ionosphere Coupling – History and Future – Jim Burch, Southwest Research Institute
8:45 A.M. – 10:00 A.M.	The Earth's Ionosphere as a Source I (*Yosemite Lodge – Cliff/Falls Room*)
10:00 A.M. - 10:15 A.M.	Break
10:15 A.M. - 12:20 P.M.	The Earth's Ionosphere as a Source II (*Yosemite Lodge – Cliff/Falls Room*)
12:20 P.M. – 4:30 P.M.	Lunch and activities on your own
4:30 P.M. – 7:40 P.M.	The Earth's Ionosphere as a Source III (*Yosemite Lodge – Cliff/Falls Room*)

Tuesday, 11 February

8:00 A.M. – 10:05 A.M.	The Effect of Low Energy Plasma on the Stability of Energetic Plasmas I (*Yosemite Lodge – Cliff/Falls Room*)
10:05 A.M. - 10:20 A.M.	Break
10:20 A.M. - 12:15 P.M.	The Effect of Low Energy Plasma on the Stability of Energetic Plasmas II (*Yosemite Lodge – Cliff/Falls Room*)
12:15 P.M. – 4:30 P.M.	Lunch and activities on your own
4:30 P.M. - 7:25 P.M.	Role of Currents and Electric/Magnetic Fields in Coupling Ion/Mag (*Yosemite Lodge – Cliff/Falls Room*)

Wednesday, 12 February

8:00 A.M. – 10:05 A.M.	Unified Global Modeling of Ionosphere and Magnetosphere at Earth I (*Yosemite Lodge – Cliff/Falls Room*)
10:05 A.M. - 10:20 A.M.	Break
10:20 A.M. - 12:15 P.M.	Unified Global Modeling of Ionosphere and Magnetosphere at Earth II (*Yosemite Lodge – Cliff/Falls Room*)
12:15 P.M. – 4:30 P.M.	Lunch and activities on your own
4:30 P.M. – 7:10 P.M.	Unified Global Modeling of Ionosphere and Magnetosphere at Earth III (*Yosemite Lodge – Cliff/Falls Room*)

Thursday, 13 February

8:00 A.M. – 9:55 A.M.	The Coupling of the Ionosphere and Magnetosphere at Other Planets and Moons in the Solar System I (*Yosemite Lodge – Cliff/Falls Room*)
9:55 A.M. - 10:10 A.M.	Break
10:10 A.M. - 12:15 P.M.	The Coupling of the Ionosphere and Magnetosphere at Other Planets and Moons in the Solar System II (*Yosemite Lodge – Cliff/Falls Room*)
12:15 P.M. – 4:30 P.M.	Lunch and activities on your own
4:30 P.M. – 6:45 P.M.	The Coupling of the Ionosphere and Magnetosphere at Other Planets and Moons in the Solar System III (*Yosemite Lodge – Cliff/Falls Room*)
6:45 P.M. – 8:15 P.M.	Break
8:15 P.M. – 10:00 P.M.	Banquet Dinner (*Ahwahnee Hotel – Ahwahnee Solarium*)

Friday, 14 February

8:00 A.M. – 10:05 AM	The Unified Modeling of the Ionosphere and Magnetosphere at Other Planets and Moons in the Solar System I (*Yosemite Lodge – Cliff/Falls Room*)
10:05 A.M. - 10:20 A.M.	Break
10:20 A.M. - 12:15 P.M.	The Unified Modeling of the Ionosphere and Magnetosphere at Other Planets and Moons in the Solar System II (*Yosemite Lodge – Cliff/Falls Room*)
12:15 P.M.	Box lunches available
12:45 P.M. - 2:40 P.M.	Future Directions for MI Coupling Research (*Yosemite Lodge – Cliff/Falls Room*)
2:40 P.M. – 2:45 P.M.	Closing Remarks

SCIENTIFIC PROGRAM

SUNDAY, 9 FEBRUARY

5:30 p.m. – 7:00 p.m.	**Registration and Welcome Reception** Cliff/Falls Room

MONDAY, 10 FEBRUARY

	Welcome and Opening Remarks **Presiding: Rick Chappell** Cliff/Falls Room
8:00 a.m. – 8:45 a.m.	**Jim Burch** | Magnetosphere-Ionosphere Coupling—Past and Future
	The Earth's Ionosphere as a Source I **Presiding: Rick Chappell** Cliff/Falls Room
8:45 a.m. – 8:50 a.m.	Video - Ian Axford
8:50 a.m. – 9:00 a.m.	Remarks - Peter Banks
9:00 a.m. – 9:30 a.m.	**Andrew W. Yau** | Measurements of Ion Outflows from the Earth's Ionosphere (Invited)
9:30 a.m. – 10:00 a.m.	**Stein Haaland** | Cold Ion Outflow from the Polar Cap Region:Cluster Results (Invited)
10:00 a.m. – 10:15 a.m.	**Morning Break (Monday)**
	The Earth's Ionosphere as a Source II **Presiding: Jerry Goldstein** Cliff/Falls Room
10:15 a.m. – 10:20 a.m.	Video - Bill Hanson
10:20 a.m. – 10:50 a.m.	**Roderick A. Heelis** | Ionospheric Convection at High Latitudes (Invited)
10:50 a.m. – 11:20 a.m.	**Asgeir Brekke** | IRS - the ultimate instrument for upper polar atmosphere research (Invited)
11:20 a.m. – 11:50 a.m.	**Gang Lu** | Global Dynamic Coupling of the Magnetosphere-Ionosphere-Thermosphere System (Invited)

11:50 a.m. – 12:20 p.m. **John C. Foster** | Cold Plasma Redistribution in the Coupled Ionosphere-Magnetosphere System (Invited)

12:20 p.m. – 4:30 p.m. **On Your Own (Monday)**

The Earth's Ionosphere as a Source III

Presiding: Thomas E. Moore

Cliff/Falls Room

4:30 p.m. – 4:35 p.m. Video - Dick Johnson

4:35 p.m. – 4:40 p.m. Remarks - Rick Chappell

4:40 p.m. – 5:10 p.m. **Lynn M. Kistler** | Impacts of O+ Abundance In the Magnetosphere (Invited)

5:10 p.m. – 5:25 p.m. **Naritoshi Kitamura** | Very-low-energy O^{+} ion outflows during geomagnetic storms

5:25 p.m. – 5:55 p.m. **Robert McPherron** | The Possible Role of Magnetosphere-Ionosphere Coupling in Substorms (Invited)

5:55 p.m. – 6:25 p.m. **Michael W. Liemohn** | Ionospheric Contribution to Magnetospheric Ion Density and Temperature Throughout the Magnetotail (Invited)

6:25 p.m. – 6:55 p.m. **Jerry Goldstein** | Imaging the Magnetosphere (Invited)

6:55 p.m. – 7:25 p.m. **Naritoshi Kitamura** | Photoelectron flow and field-aligned potential drop in the polar wind (Invited)

7:25 p.m. – 7:40 p.m. **Iurii Cherniak** | The plasmaspheric electron content variations during geomagnetic storms

TUESDAY, 11 FEBRUARY

Effect of Low Energy Plasma on the Stability of Energetic Plasmas I

Presiding: Louis J. Lanzerotti

Cliff/Falls Room

8:00 a.m. – 8:05 a.m. Video - Richard Thorne

8:05 a.m. – 8:35 a.m. **Richard M. Thorne** | How whistler-mode waves and thermal plasma density control the global distribution of diffuse auroral precipitation and the dynamical evolution of radiation belt electrons (Invited)

8:35 a.m. – 9:05 a.m. **Daniel N. Baker** | Gradual Diffusion and Punctuated Enhancements of Highly Relativistic Electrons: Van Allen Probes Observations (Invited)

9:05 a.m. – 9:20 a.m. **Zhao Li** | Modeling gradual diffusion and prompt changes in radiation belt electron phase space density for the March 2013 Van Allen Probes case study

9:20 a.m. – 9:50 a.m. **Mary K. Hudson** | Simulated Magnetopause Losses and Van Allen Probe Flux Dropouts (Invited)

9:50 a.m. – 10:05 a.m. **Alexa J. Halford** | Summary of the BARREL 2013 Campaign and Early Results from the 2014 Campaign

10:05 a.m. – 10:20 a.m. **Morning Break (Tuesday)**

Effect of Low Energy Plasma on the Stability of Energetic Plasmas II

Presiding: Mary K. Hudson
Cliff/Falls Room

10:20 a.m. – 10:25 a.m. Video - Chung Park

10:25 a.m. – 10:30 a.m. Remarks - Don Carpenter

10:30 a.m. – 11:00 a.m. **Louis J. Lanzerotti** | Ring Current Measurements from the Van Allen Probes Mission (Invited)

11:00 a.m. – 11:30 a.m. **George B. Hospodarsky** | Plasma Wave Measurements from the Van Allen Probes (Invited)

11:30 a.m. – 12:00 p.m. **Vania K. Jordanova** | Modeling Wave Generation Processes in the Inner Magnetosphere (Invited)

12:00 p.m. – 12:15 p.m. **Yiqun Yu** | Studying Subauroral Polarization Streams (SAPS) During the March 17, 2013 Magnetic Storm: Comparisons between RAM Simulations and Observations

12:15 p.m. – 4:30 p.m. **On Your Own (Tuesday)**

Role of Currents and Electric/Magnetic Fields in Coupling Ion/Mag

Presiding: Roderick A. Heelis
Cliff/Falls Room

4:30 p.m. – 4:35 p.m. Video - George Reid

4:35 p.m. – 4:40 p.m. Remarks - Bob McPherron

4:40 p.m. – 5:10 p.m. **Robert Strangeway** | Ion Outflows: Causes, Consequences, and Comparative Planetology (Invited)

5:10 p.m. – 5:40 p.m. **William Lotko** | Ionospheric Control of Magnetic Reconnection (Invited)

5:40 p.m. – 5:55 p.m. **Michael W. Liemohn** | Nonlinear Magnetosphere-Ionosphere Coupling in Near-Earth Space via Closure of the Partial Ring Current

5:55 p.m. – 6:10 p.m. **Ian J. Cohen** | Sounding rocket observations of precipitation and effects on the ionosphere and model comparisons

6:10 p.m. – 6:40 p.m. **Robert L. Lysak** | Coupling of Magnetosphere and Ionosphere by Alfvén Waves at High and Mid-Latitudes (Invited)

6:40 p.m. – 6:55 p.m. **Yan Song** | Generation of Alfvenic Double Layers and Formation of Discrete Auroras by Nonlinear Electromagnetic Coupling between Magnetosphere and Ionosphere

6:55 p.m. – 7:10 p.m. **Stephen R. Kaeppler** | Closure of Field-Aligned Current Associated with a Discrete Auroral Arc

7:10 p.m. – 7:25 p.m. **Patricia H. Reiff** | Testing MHD Models by Conjugate Aurora Imaging

WEDNESDAY, 12 FEBRUARY

Unified Global Modeling of Ionosphere and Magnetosphere at Earth I

Presiding: Daniel N. Baker
Cliff/Falls Room

8:00 a.m. – 8:05 a.m. Video - Peter Banks

8:05 a.m. – 8:35 a.m. **Robert W. Schunk** | Magnetosphere-Ionosphere Coupling: Past, Present, and Future (Invited)

8:35 a.m. – 9:05 a.m. **Shasha Zou** | Formation of Storm Enhanced Density (SED) during Geomagnetic Storms: Observation and Modeling Study (Invited)

9:05 a.m. – 9:35 a.m. **Michael W. Liemohn** | The Superthermal Electrons Ionosphere-Magnetosphere Transport and Their Role in the Formation of Ion Outflows (Invited)

9:35 a.m. – 10:05 a.m. **Alex Glocer** | Coupling Ionospheric Outflow to Magnetospheric Models (Invited)

10:05 a.m. – 10:20 a.m. **Morning Break (Wednesday)**

Unified Global Modeling of Ionosphere and Magnetosphere at Earth II

Presiding: Peter Banks
Cliff/Falls Room

10:20 a.m. – 10:25 a.m. Video - Dick Wolf

10:25 a.m. – 10:55 a.m.	**Richard Wolf** | Forty five years of the Rice Convection Model (Invited)
10:55 a.m. – 11:25 a.m.	**Daniel T. Welling** | Recent Advances in Ionosphere-Magnetosphere Mass Coupling in Global Models (Invited)
11:25 a.m. – 11:55 a.m.	**Roger Varney** | Review of global simulation studies of the effect of ionospheric outflow on the magnetosphere-ionosphere system dynamics (Invited)
11:55 a.m. – 12:25 p.m.	**Mei-Ching H. Fok** | The Role of Ring Current in Magnetosphere-Ionosphere Coupling (Invited)

12:25 p.m. – 4:30 p.m. **On Your Own (Wednesday)**

Unified Global Modeling of Ionosphere and Magnetosphere at Earth III

Presiding: Daniel T. Welling

Cliff/Falls Room

4:30 p.m. – 4:35 p.m.	Video - Don Fairfield
4:35 p.m. – 4:40 p.m.	Remarks - Jim Slavin
4:40 p.m. – 5:10 p.m.	**Vahe Peroomian** | Large-Scale Kinetic Simulations of Geomagnetic Storms with Realistic Ionospheric Ion Outflow Models (Invited)
5:10 p.m. – 5:25 p.m.	**William K. Peterson** | A quantitative assessment of the role of soft electron precipitation on global ion upwelling
5:25 p.m. – 5:40 p.m.	**Jonathan Krall** | How the Ionosphere-Thermosphere System Shapes the Quiet-Time Plasmasphere
5:40 p.m. – 5:55 p.m.	**Tian Luo** | Effects of Polar Wind Outflow on the Storm-time Ring Current
5:55 p.m. – 6:10 p.m.	**Paul Song** | Inductive-dynamic coupling of the ionosphere with the thermosphere and the magnetosphere
6:10 p.m. – 6:25 p.m.	**Roger H. Varney** | Modeling the Interaction Between Convection and Cusp Outflows
6:25 p.m. – 6:40 p.m.	**Shobhit Garg** | An MHD Study of Geoeffectiveness of a CIR/HSS Storm Event
6:40 p.m. – 6:55 p.m.	**John Meriwether** | Storm-time response of the mid-latitude thermosphere: Observations from a network of Fabry-Perot interferometers
6:55 p.m. – 7:10 p.m.	**Matthew O. Fillingim** | Observations of Ionospheric Oxygen in the Vicinity of the Moon

THURSDAY, 13 FEBRUARY

	The Coupling of the Ionosphere and Magnetosphere at Other Planets and Moons in the Solar System I Presiding: Andrew Coates Cliff/Falls Room
8:00 a.m. – 8:10 a.m.	Video & Remarks - Andy Nagy
8:10 a.m. – 8:40 a.m.	**Fran Bagenal** | Sources of Plasma for Jupiter's Magnetosphere (Invited)
8:40 a.m. – 9:10 a.m.	**Melissa A. McGrath** | Planetary Aurora across the Solar System (Invited)
9:10 a.m. – 9:40 a.m.	**James Slavin** | An Overview of Mercury's Plasma and Magnetic Field Environment (Invited)
9:40 a.m. – 9:55 a.m.	**Larry Kepko** | The Substorm Current Wedge at Earth and Mercury
9:55 a.m. – 10:10 a.m.	**Morning Break (Thursday)**
	The Coupling of the Ionosphere and Magnetosphere at Other Planets and Moons in the Solar System II Presiding: Andrew Nagy Cliff/Falls Room
10:10 a.m. – 10:15 a.m.	Video - Ferd Coroniti
10:15 a.m. – 10:45 a.m.	**Margaret Kivelson** | An Overview of the Field and Plasma Environment of Jupiter and Saturn (and how an ionosphere can wag the tail and everything else) (Invited)
10:45 a.m. – 11:15 a.m.	**George B. Hospodarsky** | Plasma wave observations with Cassini at Saturn (Invited)
11:15 a.m. – 11:45 a.m.	**Andrew Coates** | Plasma Measurements at Non-Magnetic Solar System Bodies (Invited)
11:45 a.m. – 12:15 p.m.	**Joseph H. Westlake** | The Coupling Problem at Titan: Where are the Magnetospheric Influences to Titan's Complex Ionosphere? (Invited)
12:15 p.m. – 4:30 p.m.	**On Your Own (Thursday)**

The Coupling of the Ionosphere and Magnetosphere at Other Planets and Moons in the Solar System III

Presiding: Margaret Kivelson
Cliff/Falls Room

4:30 p.m. – 5:00 p.m.	**Thomas Cravens** | Coupling of the Ionosphere and Magnetosphere at Other Planets and Moons in the Solar System (Invited)
5:00 p.m. – 5:30 p.m.	**Ray Walker** | Simulation Studies of Magnetosphere Ionosphere Coupling in Outer Planet Magnetospheres (Invited)
5:30 p.m. – 5:45 p.m.	**Zachary Girazian** | Characterizing the V1 layer in the Venus ionosphere using VeRa observations from Venus Express
5:45 p.m. – 6:00 p.m.	**Paul Withers** | The morphology of the topside ionosphere of Mars under different solar wind conditions: Results of a multi-instrument observing campaign by Mars Express in 2010
6:00 p.m. – 6:15 p.m.	**Laila Andersson** | Solar Wind Erosion of Mars Ionosphere
6:15 p.m. – 6:30 p.m.	**Thomas Cravens** | Magnetosphere-Ionosphere Coupling at Jupiter and Saturn: Evidence from X-Ray Emission

8:15 p.m. – 10:00 p.m. **Banquet Dinner**
Ahwahnee Hotel

FRIDAY, 14 FEBRUARY

The Unified Modeling of the Ionosphere and Magnetosphere at Other Planets and Moons in the Solar System I

Presiding: Jim Burch
Cliff/Falls Room

8:00 a.m. – 8:05 a.m.	Video - Tom Hill and Pat Reiff
8:05 a.m. – 8:35 a.m.	**Thomas W. Hill** | Modeling M-I Coupling at Jupiter and Saturn (Invited)
8:35 a.m. – 9:05 a.m.	**Xianzhe Jia** | Global Modeling of the Space Environments of Jupiter and Saturn (Invited)
9:05 a.m. – 9:35 a.m.	**Ingo Mueller-Wodarg** | Simulation of the Magnetosphere-Ionosphere Connection at Saturn (Invited)
9:35 a.m. – 10:05 a.m.	**Jared M. Bell** | 3-D Modeling of the Magnetosphere-Ionosphere Interaction in the Outer Solar System (Invited)

10:05 a.m. – 10:20 a.m. **Morning Break (Friday)**

The Unified Modeling of the Ionosphere and Magnetosphere at Other Planets and Moons in the Solar System II

Presiding: James F. Spann
Cliff/Falls Room

10:20 a.m. – 10:25 a.m.	Video - Don Williams
10:25 a.m. – 10:30 a.m.	Remarks - TBD
10:30 a.m. – 11:00 a.m.	**Ying-Dong Jia** | Characterizing the Enceladus torus by its contribution to Saturn's Magnetosphere (Invited)
11:00 a.m. – 11:30 a.m.	**Carol S. Paty** | From Ionospheric Electrodyamics at Mars to Mass and Momentum Loading at Saturn: Quantifying the Impact of Neutral-Plasma Interactions using Plasma Dynamic Simulations (Invited)
11:30 a.m. – 12:00 p.m.	**Yingjuan Ma** | The Interaction of Rapidly Flowing Plasmas with Venus, Mars and Titan (Invited)
12:00 p.m. – 12:15 p.m.	**Jan Paral** | Global Simulations of the Asymmetry in Forming Kelvin-Helmholtz Instability at Mercury

12:15 p.m. – 12:45 p.m. **Break - Grab Box Lunch**

Future Directions for MI Coupling Research

Presiding: Robert W. Schunk
Cliff/Falls Room

12:45 p.m. – 12:50 p.m.	Video - Erwin Schmerling and Larry Kavanagh
12:50 p.m. – 12:55 p.m.	Remarks - Peter Banks
12:55 p.m. – 1:25 p.m.	**Thomas E. Moore** | Requirements for a Mission to study Thermosphere-Magnetosphere Coupling (Invited)
1:25 p.m. – 1:40 p.m.	**James F. Spann** | A Novel Concept to Explore the Coupling of the Solar-Terrestrial System
1:40 p.m. – 2:40 p.m.	Panel - Future Directions for MI Coupling in the Solar System (Ray Walker, Dave Klumpar)

2:40 p.m. – 2:45 p.m. **Closing Remarks - Rick Chappell and Andy Nagy**
Cliff/Falls Room

Paper Conservation: In alignment with the priority objectives of AGU's strategic plan, AGU will not provide the full printed abstracts for the Chapman conferences. You may access the abstracts via the on-line itinerary planner (IP) at http://agu-cc13css.abstractcentral.com/itin.jsp.

ABSTRACTS

listed by name of presenter

Andersson, Laila

Solar Wind Erosion of Mars Ionosphere

Andersson, Laila[1]

1. lasp/cu, Boulder, CO, USA

Mars is a small body in the solar wind with no intrinsic magnetic field but strong crustal magnetic fields. This results in, that for some aspects, the solar wind interaction behaves more as a comet while, in other aspects, as an interaction with a planet that has a magnetosphere. At Earth the solar wind coupling to the ionosphere is a multi process path while at Mars the solar wind can almost directly couple to the ionosphere. With the strong asymmetry between the magnetic field topology in North and South, Mars allow us to evaluate how important the magnetic field is for atmospheric loss. Mars is an excellent object where the importance of an existing magnetosphere can be evaluated. In this presentation the hemispheric loss of ionospheric ions are studied. Evidence that the crustal field topology can provide a direct path for the ions from the ionosphere into the plasma sheath through the magnetosphere will be presented and discussed. This ionosphere-magnetosphere coupling is also controlled by the replenish rate of the ionospheric ions.

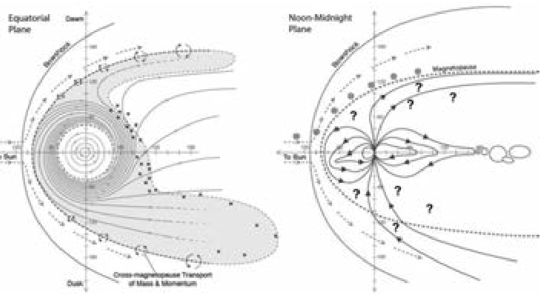
Bagenal, Fran

Sources of Plasma for Jupiter's Magnetosphere (Invited)

Bagenal, Fran[1]

1. U of Colorado, Boulder, CO, USA

Jupiter is the archetype of a rotation-driven magnetosphere dominated by an internal source of plasma. The plasma is predominately produced by the ionization of neutral gases that spew from the volcanic moon Io. While there are observations of protons and helium ions in the magnetosphere, estimates of the sources from the planet's ionosphere and from the solar wind remain poorly constrained. Using a simple model of the plasma disk surrounding Jupiter, based on published measurements of plasma properties, we calculate radial profiles of the distribution of plasma mass, pressure, thermal energy density, kinetic energy density, and energy density of the supra-thermal ion populations. We estimate the mass outflow rate as well as the net sources and sinks of plasma. We also calculate the total energy budget of the system, estimating the total amount of energy that must be added to the system at Jupiter, though the causal processes are not understood. We find that the more extensive, massive disk of sulfur- and oxygen-dominated plasma requires a total input of 3-16 TW to account for the observed energy density at Jupiter.



Baker, Daniel N.

Gradual Diffusion and Punctuated Enhancements of Highly Relativistic Electrons: Van Allen Probes Observations (Invited)

Baker, Daniel N.[1]

1. University of Colorado, Boulder, CO, USA

The dual-spacecraft Van Allen Probes mission has provided a new window into megaelectron Volt (MeV) particle dynamics in the Earth's radiation belts. Observations (up to E ~10 MeV) show clearly the behavior of the outer electron radiation belt at different time scales: months-long periods of gradual inward radial diffusive transport and weak loss being punctuated by dramatic flux changes driven by strong solar wind transient events. For example, analysis of multi-MeV electron flux and phase space density (PSD) changes during March 2013 are presented in the context of the first year of Van Allen Probes operation. This March period demonstrates the classic signatures both of inward radial diffusive energization as well as abrupt localized acceleration deep within the outer Van Allen zone (L ~4.0±0.5). This reveals graphically that both "competing" mechanisms of multi-MeV electron energization are at play in the radiation belts, often acting almost concurrently or at least in rapid succession. It also shows in remarkable ways how the coldest plasmas in the magnetosphere intimately control the most energetic particles.

Bell, Jared M.

3-D Modeling of the Magnetosphere-Ionosphere Interaction in the Outer Solar System (Invited)

Bell, Jared M.[1]; Bougher, Stephen[2]; Waite, Hunter[3, 4]; Ma, Yingjuan[5]; Egert, Austin[4]

1. National Institute of Aerospace, Yorktown, VA, USA
2. AOSS, University of Michigan, Ann Arbor, MI, USA
3. Space Science and Engineering, Southwest Research Institute, San Antonio, TX, USA
4. Physics, University of Texas at San Antonio, San Antonio, TX, USA
5. UCLA, Los Angeles, CA, USA

We present the first results from a newly developed 3-D Jupiter Global Ionosphere-Thermosphere Model (J-GITM),

emphasizing the coupling between the magnetosphere and the upper atmosphere. In particular, we examine the global impacts of the magnetosphere on the thermal structure. We compare these initial results from the J-GITM predecessor model, the Jupiter Thermosphere General Circulation Model (the JTGCM) of Bougher et al. [2005]. We also examine the results from a prototype Saturn Global Ionosphere Thermosphere Model (S-GITM), using inputs and conditions similar to those of Mueller-Wodarg [2006, 2012]. Finally, Saturn's largest moon, Titan, which is immersed in Saturn's magnetospheric plasma, represents another interesting example of magnetospheric interaction with a substantial atmosphere. Current modeling results from an on-going effort at simulating the atmosphere-magnetosphere interaction will be presented.

Brekke, Asgeir

IRS - the ultimate instrument for upper polar atmosphere research (Invited)

Brekke, Asgeir[1]

1. Dept. of Physics and Technology, University of Tromsø-The Arctic University of Norway, Tromsø, Norway

When the incoherent scatter radar (IRS) was installed at Chatanika, Fairbanks, Alaska in the fall of 1971, it opened up a door of magic. As soon as new results from a Chatanika experiment was published, they attracted attention in the science community engaged in the physics of the upper polar atmosphere and the aurora boralis. Time series of altitude profiles of parameters like electric fields and conductivities, electron densities and currents as well as ion composition and neutral winds, had been stronly desired for years by researchers who wanted to test out their models for the very dynamical processes that took place in the auroral ionosphere. We had seen a few rocket experiments presenting snapshots of electron density and ion composition profiles, but time series were outside reach. The observations by Chatanika radar were the first to meet these desires and gave the scientists new inspiration to submerge into the complex field of upper polar atmosphere dynamics where the whirling auroras stood out as evidences of dramatic electrodynamical processes unfolding in near space. Since then IRS's have been introduced to higher latitudes to probe the more central parts of the Polar Cap where the interactions between the solar wind and the upper atmosphere is more direct. In addition to presenting some of the most outstanding findings in the upper polar atmosphere on the basis of IRS observations, a demonstration of some of the most epoch braking signal processing and data handling methods that have evolved throug the last 40 years will be presented; such phased array systems, pulse coding techniques and fast data storage procedures. A presentation of the planned EISCAT_3D in Northern Scandinavia that will offer volumetric images of the polar upper atmosphere with time and spatial resolutions that never have been accomplished before will also be given.

Asgeir Brekke, prof emeritus

Burch, Jim

Magnetosphere-Ionosphere Coupling—Past and Future

Burch, Jim[1]

1. Southwest Research Institute, Xxx, TX, USA

In this talk the status of magnetosphere-ionosphere (MI) coupling research in 1974 will be briefly reviewed as background to a description of recent advances in the field. Outstanding questions and needed experimental research and modeling will be identified and discussed. It is now realized that the magnetosphere and ionosphere comprise one coupled system and that future significant progress will require the deployment of multiple spacecraft with highly targeted measurements and objectives along with sophisticated models that can reveal the global effects of the measured MI interactions. Planetary missions have shown that MI coupling is also very important in other magnetospheres, some of which have strong interactions with the exospheres and ionospheres of their orbiting moons. In rotation-dominated planets such as Jupiter and Saturn the modes of MI coupling are fundamentally different from those at Earth making comparative studies especially important.

Cherniak, Iurii

The plasmaspheric electron content variations during geomagnetic storms

Cherniak, Iurii[1]; Zakharenkova, Irina[1]; Krankowski, Andrzej[1]; Dzubanov, Dmitry[2]

1. Geodynamics Research Laboratory, Olsztyn, Poland
2. Institute of ionosphere NAS and MES of Ukraine, Kharkov, Ukraine

Specification and forecasting of the upper atmosphere plasma distribution is fundamental for mitigation of space weather effects for radio propagation and GNSS applications. The characteristics of the Earth atmosphere ionized part are responding on variations of solar and magnetic activity. Now the GPS measurements are used by the scientific community for the Earth's upper atmosphere studies. The height of GPS orbits is about 20,200 km above the Earth's and most part of the propagation path of a radio signal from a satellite to ground-based GPS receiver is mainly within the plasmasphere. As the electron densities in the plasmasphere (PEC) are several orders of less than in the ionosphere (IEC) the plasmasphere is often ignored at analysis of GPS TEC data. But under certain conditions such low solar activity and geomagnetic disturbances the PEC contribution to the GPS TEC can become significant. In the given study the contribution of PEC to the GPS TEC was estimated from the simultaneous measurements of GPS TEC and IEC. The IEC was retrieved as a result of integration of ionospheric electron density profiles (EDPs). For this aim we used EDPs derived from satellite radio occultation (RO) and ground-based radio-physical measurements. The PEC variations during strong geomagnetic storms at November 2004 were estimated by combining of mid-latitude Kharkov ISR observations and GPS TEC data. The comparison between two independent measurements was performed by analysis of the height-temporal distribution for specific point corresponded to the mid-latitudes of Europe. Percentage contribution of PEC to GPS TEC indicated the clear dependence from the time with maximal values (>70%) during night-time and smaller values (30-45%) during day-time for weak disturbance and quite time and rather high values during strong negative storm (up to 90%) with small changes in time. With similar way we analyzed of ionospheric/plasmaspheric effects of October 11, 2008 geomagnetic storm that occurred on background of the extended solar minimum conditions. For this case we used combining of GNSS and FC3/COSMIC RO measurements. It was observed the strong TEC increasing over European region. Peak electron density (Ne) and F2 maximum height increased simultaneously in comparison with the quiet day. The most pronounced effect of the Ne increase occurred at the altitude ~350 km and considerable at the altitudes >400 km. That illustrated the modification of the topside part of the ionosphere and redistribution of TEC/IEC/PEC ratio. These changes can be explained by the competing effects of electric fields and winds which tend to raise the layer to the region with lower loss rate and movement of ionospheric plasma to protonosphere.

Coates, Andrew

Plasma Measurements at Non-Magnetic Solar System Bodies (Invited)

Coates, Andrew[1]

1. University College London, Dorking, United Kingdom

The solar system includes a number of non-magnetic objects. These include comets, Venus, Mars and the moon, as well as the moons of Saturn, Jupiter and beyond. The plasma interaction depends on upstream conditions, whether that is the solar wind or a planetary magnetosphere, and whether the object itself has any atmosphere. Several space missions have explored these objects so far, with many carrying plasma and fields instrumentation, and have revealed some similarities and differences in the interactions. Processes such as ion pickup are the key to the cometary interaction but is also present in many other locations, and ionospheric processes are important when an atmosphere or exosphere is present. In all cases plasma interacting with the surface or atmosphere can cause escape and modification over time. In this talk we will review plasma measurements at non-magnetic objects from the various missions, and summarise information about the key processes including plasma escape at these objects.

Cohen, Ian J.

Sounding rocket observations of precipitation and effects on the ionosphere and model comparisons

Cohen, Ian J.[1]; Lessard, Marc[1]; Sadler, Francis B.[1]; Lynch, Kristina[2]; Zettergren, Matt[3]; Lund, Eric[1]; Kaeppler, Steve[4, 8]; Bounds, Scott[4]; Kletzing, Craig[4]; Streltsov, Anatoly[3]; Labelle, James[2]; Dombrowski, Micah[2]; Jones, Sarah[6]; Pfaff, Rob[6]; Rowland, Doug[6]; Anderson, Brian[5]; Korth, Haje[5]; Gjerloev, Jesper[5, 7]

1. Space Science Center, University of New Hampshire, Rochester, NH, USA
2. Dartmouth College, Hanover, NH, USA
3. Embry-Riddle Aeronautical University, Daytona, FL, USA
4. University of Iowa, Iowa City, IA, USA
5. Johns Hopkins University, Baltimore, MD, USA
6. NASA GSFC, Greenbelt, MD, USA
7. University of Bergen, Bergen, Norway
8. SRI International, Menlo Park, CA, USA

Auroral precipitation results in multiple effects on the ionosphere, including the heating of ambient ionospheric electrons and the phenomenon of ionospheric feedback. Data and conclusions from several sounding rocket missions and comparisons with models have recently yielded further insight into these effects. A new study shows data from multiple sounding rockets, both on the dayside and nightside and at different altitudes, and compares these observations to modeling predictions. The results provide more understanding if and how heating of ambient electrons in regions of auroral precipitation plays a fundamental role in ion outflow and, possibly, neutral upwelling processes. We also show data from the ACES rocket mission, which obtained the first in situ

measurements indicative of the observational characteristics associated with the ionospheric feedback instability (IFI) as it flew through an auroral arc and its associated return current region. These observations are compared to existing models of IFI and used to develop a new model that decouples the upward and downward current regions and produced results very similar to the ACES observations.

Cravens, Thomas

Coupling of the Ionosphere and Magnetosphere at Other Planets and Moons in the Solar System (Invited)

Cravens, Thomas[1]

1. University of Kansas, Lawrence, KS, USA

An important aspect of solar system plasma physics is the linkage and coupling of denser, colder ionospheric plasma found at planets and satellites with more energetic external plasma environments such as the solar wind and magnetospheres. How energy and momentum are exchanged depends on the coupling processes, and field-aligned electrical currents play an important role in these processes. The nature of the linkage obviously depends on the characteristics of the planets and of the external plasma. Particularly important is the existence of, or lack of, a significant intrinsic magnetic field for the solar system body of interest. For example, the strong magnetic fields at Earth, Jupiter, and Saturn carve out large magnetospheres within which the dynamics is enforced by current systems, some of which close in the respective planetary ionospheres. Auroral emission from the planetary or satellite upper atmospheres often, but not always, accompanies the field-aligned currents. Objects like Venus, and Saturn's satellite Titan, have ionospheres but lack significant intrinsic magnetic fields, but the external plasma, such as the solar wind, still links with the ionospheres and upper atmospheres. A broad review of magnetosphere-ionosphere (MI) coupling at other planets will be given in this talk, but special attention will be given to Jupiter and to the Saturn/Titan system. A brief discussion of how Enceladus, and its water plume, affect Saturn's magnetosphere will also be given. At Jupiter, rotation plus the Io source of plasma are the key determinants of the magnetospheric dynamics and the associated MI coupling and auroral emissions. Precipitation of energetic electrons from the middle magnetosphere is responsible for the main auroral oval at Jupiter, but both energetic electron and ion precipitation take place in the polar caps. X-ray emission observed from Jupiter's polar regions appears to be due to the precipitation of energetic heavy ions from the outer magnetosphere and magnetopause region. The upcoming NASA mission to Juno will shed much light on Jovian MI coupling. Plasma in the ionospheres of non-magnetic bodies flows in response to thermal pressure gradients, magnetic forces associated with induced magnetic fields, gravity, and ion-neutral collisions. Magnetic fields are induced by the external interaction either in the ionospheres or near the "ionopause" boundaries. These fields are not only important for the dynamics but they also control the entry of external energetic particles into the upper atmosphere, thus affecting ionization rates and ionospheric composition and structure. The copious data returned from instruments on the NASA-ESA Cassini Orbiter has improved our understanding of Titan's linkage to Saturn's magnetosphere. Titan usually resides in Saturn's outer magnetosphere, with occasional forays into the magnetosheath, and this determines the external plasma populations (electrons, protons, and water group ions such a oxygen ions) that can possibly be channeled into the upper atmosphere.

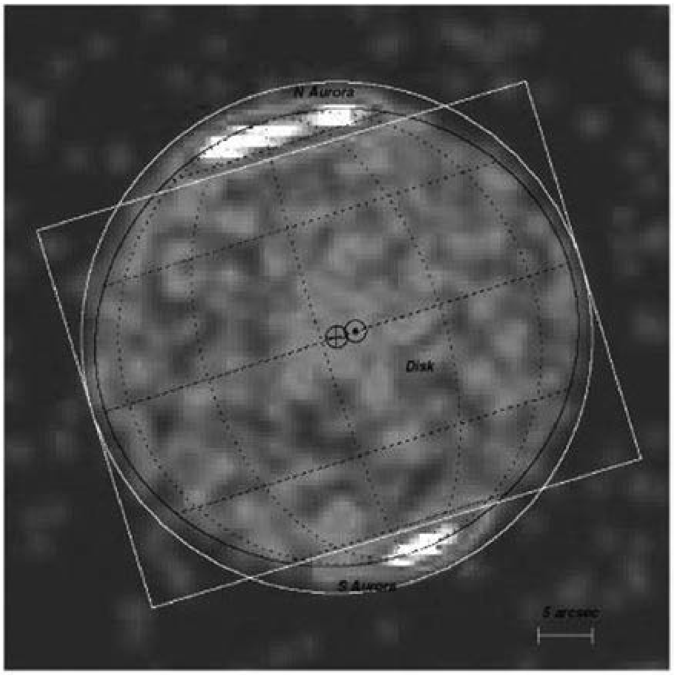
Cravens, Thomas

Magnetosphere-Ionosphere Coupling at Jupiter and Saturn: Evidence from X-Ray Emission

Cravens, Thomas[1]; Ozak, Nataly M.[2]; Schultz, David[3]

1. Physics and Astronomy, University of Kansas, Lawrence, KS, USA
2. Earth and Planetary Sciences, Weizmann Institute of Science, Rehovot, Israel
3. Physics, University of North Texa, Denton, TX, USA

Auroral particle precipitation dominates the chemical and physical environment of the upper atmospheres and ionospheres of the outer planets. Precipitation of energetic electrons from the middle magnetosphere is responsible for the main auroral oval at Jupiter, but both energetic electron and ion precipitation take place in the polar caps. Most focus at both Earth and Jupiter has been on electron precipitation and the associated upward field-aligned current regions. However, x-ray emission that is observed from Jupiter's polar regions appears to be due to the precipitation of energetic heavy ions coming from the outer magnetosphere and magnetopause. Bunce et al. have suggested that magnetic reconnection at the dayside magnetopause is responsible for the downward currents. The ions must be accelerated to MeV energies in order for the sulfur and oxygen ions to lose most of their electrons during collisions with atmospheric molecular hydrogen. Charge exchange collisions follow the electron removal collisions and the product ions emit the observed x-rays. We have used a Monte Carlo code to study the ion precipitation process, including the altitude-dependence of the energy deposition and the x-ray production from charge-exchange collisions. We have also calculated the spectrum of the secondary electrons produced during this process as well as the field-aligned currents. Escaping secondary electrons should be accelerated upward to MeV energies due to the same field-aligned potentials responsible for the downward ion acceleration. Evidence exists for relativistic electrons in the outer magnetosphere. An x-ray aurora has not been observed at Saturn, which is perhaps not surprising given that major differences exist in the two planets magnetosphere-ionosphere (MI) coupling. Ion precipitation processes, particularly those leading to x-ray emission at Jupiter, will be discussed during this talk, as well as the implications for MI coupling at the outer planets.



Chandra X-Ray Observatory image of Jovian X-Ray Aurora. Elsner et al., (2005)

Fillingim, Matthew O.

Observations of Ionospheric Oxygen in the Vicinity of the Moon

Fillingim, Matthew O.[1]; Halekas, Jasper S.[1]; Poppe, Andrew R.[1]; Angelopoulos, Vassilis[2]

1. Space Sciences Laboratory, University of California, Berkeley, CA, USA
2. Institute of Geophysics and Planetary Physics, University of California, Los Angeles, Los Angeles, CA, USA

Using data from the ARTEMIS spacecraft, we report on observations consistent with the detection of ionospheric oxygen ions in the terrestrial magnetosphere at lunar altitudes. Since there is no mass spectrometer onboard the spacecraft, oxygen can only be detected when the outflow velocities are sufficient to separate oxygen from hydrogen in energy (for the same velocity, oxygen will appear to have a higher energy). We catalog the occurrence of such signatures and relate the detection, number density, and energy of ionospheric oxygen ions to geomagnetic activity parameters. These observations shed light on the amount of ionospheric plasma that reaches the Moon in the magnetotail and how this plasma may participate in and contribute to magnetospheric activity and lunar exosphere production.

Fok, Mei-Ching H.

The Role of Ring Current in Magnetosphere-Ionosphere Coupling (Invited)

Fok, Mei-Ching H.[1]

1. Geospace Physics Laboratory, NASA Goddard Space Flight Ctr, Greenbelt, MD, USA

The magnetosphere and ionosphere are two closely coupled systems. Certain features observed in the magnetosphere cannot be understood without examining the characteristics of the ionosphere, and vice versa. The ring current plays a crucial role in magnetosphere-ionosphere coupling. Gradients in the ring current particle pressure produce field-aligned currents flowing in and out from the ionosphere. These currents modify the ionospheric electric potential distribution and alter plasma convection in both the ionosphere and magnetosphere. We have developed simulation tools to study the coupling relationships between the global magnetosphere, the ring current, radiation belts and the ionosphere. We have merged the Comprehensive Ring Current Model (CRCM) and the Radiation Belt Environment (RBE) model to form a Comprehensive Inner Magnetosphere Ionosphere (CIMI) Model. CIMI calculates many essential quantities in the inner magnetosphere and ionosphere, including: ion and electron distributions in the ring current and radiation belts, plasmaspheric density, ionospheric precipitation, Region 2 currents and the convection potential. In this talk, we will discuss how H+ and O+ from the solar wind and ionosphere get access to the ring current, how pressure feedback from the ring current changes the global magnetospheric configuration, and how the electric coupling between the ring current and ionosphere controls the variability in the outer radiation belt. We will also demonstrate how CIMI can be a powerful tool for analyzing and interpreting data from the new Van Allen Probes mission.

Foster, John C.

Cold Plasma Redistribution in the Coupled Ionosphere-Magnetosphere System (Invited)

Foster, John C.[1]

1. MIT Haystack Observatory, Westford, MA, USA

Large-scale cold plasma redistribution is a multi-step geospace system-wide processes involving the equatorial, low, mid, auroral, and polar-latitude regions. Penetration electric fields enhance the equatorial ionization anomaly peaks, while polarization electric field effects at the dusk terminator redistribute the low-latitude TEC in both longitude and latitude to create a preferred longitude for the enhancement total electron content (TEC) in the American sector. This TEC enhancement forms a localized source for the intense storm enhanced density (SED) erosion plumes that are observed over the Americas during major storms. Ring current enhancements generate strong poleward-directed subauroral polarization stream (SAPS) electric fields in the evening sector as field-aligned currents close through the low-conductivity ionosphere. The SAPS electric field overlaps the outer plasmasphere, drawing out SED / plasmasphere erosion plumes. These enhanced cold plasma fluxes traverse the cusp and enter the polar cap forming the polar tongue of ionization (TOI). Antisunward flow in the TOI carries the eroded material into the midnight auroral oval, providing a rich source of heavy ions for magnetospheric injection and acceleration mechanisms which operate both at the cusp and on the nightside. We describe the redistribution process with multi-instrument observations at both ionospheric and magnetospheric altitudes. GPS TEC mapping reveals a continuous plume of storm enhanced density (SED) extending from the dusk sector into and through the cusp region and back across polar latitudes. Incoherent scatter radar and overflights with the DMSP satellites give details of plasma convection velocities and altitude/spatial distributions. The Themis spacecraft observe the erosion plume at the dayside magnetopause, and the Van Allen Probes daily provide multiple crossings of the plasmasphere boundary layer. We examine dusk sector (18 MLT) plasmasphere erosion with simultaneous direct observations of the sunward ion flux at high altitude by the Van Allen Probes RBSP-A (at ~3.5 Re) and at ionospheric heights by DMSP F-18. On March 17, 2013 RBSP-A observed ~6000 m/s high altitude erosion velocity and ~1.2e12 m-2 s-1 sunward ion flux in the erosion plume, while DMSP F-18 measured ~1750 m/s SAPS velocity and sunward flux of ~2.e13 m-2 s-1 in the underlying ionosphere. There was high correspondence between the location, spatial extent, and characteristics of both the SAPS flow and the erosion plume at high and low altitudes. The intermittent transfer of dayside SED plasma across cusp field lines is seen to be a low altitude signature of dayside merging activity at the magnetopause. Significant ion fluxes are involved in the plasma redistribution. For the March 17th storm, we estimate the total fluence of eroded ionospheric / plasmaspheric ions carried antisunward in the polar TOI to be ~5.e25 ions s-1. Concurrently, the RBSP A & B spacecraft observed the redistribution plasma near the magnetic equator at ~ 6 Re altitude in the midnight sector at the point where the TOI exits the polar cap. The observations made during the March 17th event provide quantitative, simultaneous evidence at multiple points within this redistribution chain that significant plasma erosion fluxes are involved both at ionospheric and magnetospheric altitudes.

Garg, Shobhit

An MHD Study of Geoeffectiveness of a CIR/HSS Storm Event

Garg, Shobhit[1]; Peroomian, Vahe[1]; El-Alaoui, Mostafa[1]

1. University of California, Los Angeles, Los Angeles, CA, USA

We investigate how the inner magnetosphere responds to the 8 -9 March 2008 corotating interaction region (CIR)/high-speed stream (HSS) storm event. We examine the storm in detail by carrying out high-resolution global magnetohydrodynamic (MHD) simulations using solar wind and interplanetary magnetic field data from upstream spacecraft. This storm was characterized by the arrival of a density plug associated with a CIR at ~0730 UT on 8 March, followed by the commencement of the HSS at ~1830 on the same day. This was followed by another density plug at ~0140 UT the following day on 9 March, which really is the main phase of this storm. For this storm, we found that the MHD simulation ring current energy density responded linearly to increases in dynamic pressure during the northward IMF intervals of the CIR portion of the event. However, there was no correlation between the ring current energy density and solar wind dynamic pressure during the southward IMF intervals of the CIR portion of the event and during the HSS portion of the event. We also analyzed several other CME- and CIR-driven storms in order to determine the geoeffectiveness of various solar wind drivers during geomagnetic storms. We will also compare our MHD simulation results with observations from the THEMIS spacecraft in the magnetotail.

Girazian, Zachary

Characterizing the V1 layer in the Venus ionosphere using VeRa observations from Venus Express

Girazian, Zachary[1]; Withers, Paul[1]; Fallows, Kathryn[1]; Tarrh, Andrew[1]; Paetzold, Martin[2]; Tellmann, Silvia[2]; Haeusler, Bernd[3]

1. Boston University, Boston, MA, USA
2. University of Cologne, Cologne, Germany
3. Bundeswehr University, Munich, Germany

The Venus Radio Science Experiment (VeRa) on the Venus Express spacecraft sounds the Venus atmosphere during Earth occultations to obtain vertical profiles of electron density in the ionosphere. The resultant profiles reveal the vertical structure of the Venus ionosphere from the topside down to below the lower layers (< 115 km). On the dayside, the dominant plasma layer is the V2 layer at ~142 km, which is produced primarily by photoionization of CO2. Embedded on the bottomside of the V2 layer is the less prominent, and much less studied, V1 layer at ~127 km. The V1 layer is also produced by photoionization of CO2, but secondary ionization due to energetic photoelectrons is much more important. Here we investigate properties of the V1 layer using VeRa profiles from 2006 to 2012 during which the Sun went from the deep solar minimum of Solar Cycle 23 to the rising solar activity levels of Solar Cycle 24. We investigate how the peak electron density and peak altitude of the V1 layer depend on solar zenith angle. We also characterize the shapes of the V1 layer and show how they are related to the solar activity level. Solar spectra from the Solar EUV Experiment (SEE) instrument on the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) spacecraft are used to characterize the shapes of the V1 layer with solar activity.

Glocer, Alex

Coupling Ionospheric Outflow to Magnetospheric Models (Invited)

Glocer, Alex[1]

1. NASA/GSFC, Greenbelt, MD, USA

Plasma of ionospheric origin is ever present in the magnetosphere. This plasma population makes up a significant fraction of the magnetospheric composition. O+, a clear indicator of an ionospheric source, is particularly seen during geomagnetically active times and has consequences for the entire space environment system. The presence of ionospheric outflows affects reconnection, the transport and energization of plasma, the ring current, and it modulates the wave environment in the magnetosphere. This talk presents an overview of efforts to include ionospheric outflow into global models. We will further discuss recent progress in including outflow mechanisms such as wave-particle interactions and superthermal electrons into the coupling paradigm.

Goldstein, Jerry

Imaging the Magnetosphere (Invited)

Goldstein, Jerry[1, 2]

1. Space Science & Eng Div (15), Southwest Research Inst, San Antonio, TX, USA
2. Physics and Astronomy, University of Texas San Antonio, San Antonio, TX, USA

In this talk I present a review of inner magnetospheric (plasmaspheric and ring current) imaging results from two missions: the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE), and Two Wide-angle Imaging Neutral-atom Spectrometers (TWINS). The extreme ultraviolet (EUV) imager onboard IMAGE revolutionized our knowledged and understanding of the Earth's plasmasphere, both by revealing new global density features, and confirming decades-old hypotheses about how cold plasma dynamics is controlled by both the solar wind and magnetosphere-ionosphere (M-I) coupling. TWINS is the first stereoscopic magnetospheric imaging mission, performing simultaneous energetic neutral atom (ENA) imaging from two widely-separated Molniya orbits on two different spacecraft and enabling discovery of previously unknown global dependences of ion pitch angle. Building on results from IMAGE and TWINS, I show an example of how terrestrial electrodynamics may be applied to the study of the interchange instability in the plasmasphere of Saturn. I also discuss prospects for truly global imaging of the entire magnetosphere, to determine causal relationships between solar wind changes and inner magnetospheric responses.

Haaland, Stein

Cold Ion Outflow from the Polar Cap Region:Cluster Results (Invited)

Haaland, Stein[1, 2]

1. Birkeland Center for Space Science, Bergen, Norway
2. Max-Planck Institute, Katlenburg-Lindau, Germany

Every day, the Earth looses a significant amount of mass through ions escaping from the polar ionosphere. Due to spacecraft charging effects and the very low escape energy of ions, in-situ measurements using traditional plasma instruments are typically not able to detect the cold component of the outflow. However, recent advances in instrumentation and methodology, combined with a comprehensive data set from the Cluster constellation of spacecraft have provided far better opportunities to assess the role of the low energy ions. In this study, we have utilized these advantages to determine the source region, transport mechanisms as well as the fate of low energy ions of ionospheric origin. The results suggest that the polar cap region is the primary source of cold outflow, but enhanced outflow from the cusp and auroral zone is observed during disturbed geomagnetic conditions. The transport of cold ions is mainly governed by the convection, and most of the outflowing ions are transported to the nightside plasma sheet. Direct loss along open field lines downtail into the solar wind only takes place during quiet magnetospheric conditions with low or stagnant convection.

Halford, Alexa J.

Summary of the BARREL 2013 Campaign and Early Results from the 2014 Campaign

Halford, Alexa J.[1]; Millan, Robyn[1]; Woodger, Leslie[1]; Mann, Ian[2]; Turner, Drew[3]; Breneman, Aaron[4]; Murphys, Kyle[2]

1. Physics, Dartmouth College, White River Junction, VT, USA
2. Physics, University of Alberta, Alberta, AB, Canada
3. Department of Earth and Space Sciences, University of California Los Angeles, Los Angeles, CA, USA
4. School of Physics and Astronomy, University of Minnesota, Minneapolis, MN, USA

BARREL is a multiple- balloon investigation designed to study electron losses from the Earth's Radiation Belts. This mission allows for collaborative studies with many satellite missions including the Van Allen Probes, Cluster, Themis, and GOES. The second of the two BARREL campaigns will be completed January - February 2014 with a total of 20 stratospheric balloons launched from two Antarctic research stations. This creates an array of 5 - 8 slowly drifting payloads in the region that magnetically maps to the radiation belts and often to the CARISMA array in the Northern hemisphere. BARREL provides the first balloon measurements of relativistic electron precipitation while comprehensive in situ measurements of both plasma waves and energetic particle populations are observed by the Van Allen probes and other satellites. We will present a first look at the 2014 campaign as well as summarize the results from the 2013 campaign. Specifically we will look at 26 January 2013 where precipitation due to substorm dynamics is observed. During the geomagnetic storm which started on 26 January 2013, a substorm onset was observed above Alaska at ~8:30 UT. Shortly after the substorm onset, payload 1H in the BARREL array observes precipitation in the same energy range as the injection observed by GOES. Oscillations on different time scales can also be observed at other energies on payload 1H and appear to be related to wave activity observed by Van Allen Probe A. Van Allen Probe A is initially located within 4 hours of MLT and 3 L-values East of the balloon as it comes out of perigee. As the satellite moves into it's apogee it comes within 1 hour of MLT and 0.5 L of payload 1H. With this relatively close conjunction during the substorm combined with GOES and ground based data from the carisma array, the substorm dynamics, wave-particle interactions, and the resultant precipitation can be carefully studied.

Heelis, Roderick A.

Ionospheric Convection at High Latitudes (Invited)

Heelis, Roderick A.[1]

1. University Texas Dallas, Richardson, TX, USA

At high latitudes plasma motions driven by the interaction of the magnetosphere with the solar wind are usually characterized in terms of an instantaneous distribution of the electrostatic potential. This potential distribution typically displays large-scale convection cells within which the direction and magnitude of the plasma flows are dependent on the solar wind speed and the solar wind magnetic field. Early observations show a remarkable consistency between the configuration of the electric potential, the associated current distributions that must accompany them and the auroral precipitation of energetic electrons, which carry a significant fraction of the current. Since the observational description of the convection, the current and the auroral precipitation, models of the solar wind magnetosphere interaction have been utilized to describe the associated interaction between the solar wind and the magnetosphere and the closure paths of the currents that flow through the ionosphere. In this way the drivers for the potential seen in the ionosphere and its dependence on solar wind conditions have been further understood. Still a point of discussion is the relative roles of so-called viscous interaction and merging in developing the ionospheric potential at different times. Currents in the ionosphere may originate from regions near the dayside magnetopause and from regions in the magnetospheric tail and these regions may not operate in unison. Thus, recent observations have focused on describing separately the spatial and temporal evolution of convection features on the dayside and the nightside. Changes in the magnetospheric drivers may be applied over small spatial and temporal scales but produce a more global reconfiguration of the major features of the convection pattern such as the convection reversal boundary and the low latitude extent of the auroral zone, which evolve on time scales of minutes to hours. How the plasma responds to these changes at different local times and latitudes is now being actively studied. Recent observations of ionospheric convection driven by the solar wind/magnetosphere interaction show that the volume over which this influence can be seen extends throughout the ionosphere to the magnetic equator. As the sphere of influence of the convection pattern changes significant changes in the plasma transport properties are produced with sometimes, dramatic changes in the plasma number density also appearing at a given location. In this brief review we will describe some key observations that illustrate the challenges associated with identifying the convection drivers, the ionospheric responses and the effects on the ionospheric plasma.

Hill, Thomas W.

Modeling M-I Coupling at Jupiter and Saturn (Invited)

Hill, Thomas W.[1]

1. Dept Physics & Astronomy, Rice Univ, Houston, TX, USA

Some aspects of M-I coupling are universal from one planet to another, for example, the crucial role played by Birkeland (magnetic-field-aligned) currents that dynamically couple the collisionless magnetosphere to the collisional ionosphere. This talk will focus on rotation-driven magnetospheres (e.g., Jupiter and Saturn) versus solar-wind-driven magnetospheres (e.g., Mercury and Earth). The magnetospheres of Jupiter and Saturn are driven by planetary rotation, through the agency of internal plasma sources delivered by moons internal to the magnetosphere, primarily Io at Jupiter and Enceladus at Saturn. I will review key observations, primarily from Saturn, which is the better-observed example thanks to Cassini, and theoretical and numerical modeling efforts that attempt to explain these observations.

Hospodarsky, George B.

Plasma Wave Measurements from the Van Allen Probes (Invited)

Hospodarsky, George B.[1]; Kurth, William S.[1]; Kletzing, Craig A.[1]; Bounds, Scott R.[1]; Santolik, Ondrej[2]; Wygant, John R.[3]; Bonnell, John W.[4]

1. Dept Physics & Astronomy, Univ Iowa, Iowa City, IA, USA
2. Institute of Atmospheric Physics and Charles Univ, Prague, Czech Republic
3. Department of Physics and Astronomy, University of Minnesota, Minneapolis, MN, USA
4. Space Sciences Laboratory, University of California, Berkley, CA, USA

The twin Van Allen Probes spacecraft were launched on August 30, 2012 to study the Earth's Van Allen radiation belts. The Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) investigation includes a plasma wave instrument (Waves) that simultaneously measures three orthogonal components of the wave magnetic field from ~10 Hz to 12 kHz and, with the support of the Electric Fields and Waves (EFW) instrument sensors, three components of the wave electric field from ~10 Hz to 12 kHz and a single electric component up to ~400 kHz. Since launch, a variety of plasma waves have been detected which are believed to play a role in the dynamics of the radiation belts, including whistler-mode chorus, plasmaspheric hiss, and magnetosonic equatorial noise. Lightning produced whistlers, electron cyclotron harmonic (ECH) emission, and the upper hybrid resonance (UHR) are also often detected. The UHR is used to determine the local electron plasma density (an important parameter of the plasma required for various modeling and simulation studies). Measuring all six components simultaneously allow the wave propagation parameters of these plasma wave emissions, including the Poynting flux, wave normal vector, and polarization, to be obtained. The Waves instrument is able to determine these parameters with both onboard and ground processing at very high time and frequency resolutions. We will summarize the EMFISIS plasma wave observations and discuss their role in the Van Allen Radiation Belt dynamics.

Hospodarsky, George B.

Plasma wave observations with Cassini at Saturn (Invited)

Hospodarsky, George B.[1]; Menietti, John D.[1]; Kurth, William S.[1]; Gurnett, Donald A.[1]; Persoon, Ann M.[1]; Leisner, Jared S.[2]; Averkamp, Terrance F.[1]; Santolik, Ondrej[3]; Louarn, Philippe[4]; Canu, Patrick[5]; Dougherty, Michele K.[6]

1. Dept Physics & Astronomy, Univ Iowa, Iowa City, IA, USA
2. Technical University of Braunschweig,, Braunschweig, Germany
3. Institute of Atmospheric Physics and Charles Univ., Prague, Czech Republic
4. CESR, Toulouse, France
5. Laboratory of Plasma Physic, Palaiseau, France
6. Blackett Lab, Imperial College, London, United Kingdom

Since the Cassini spacecraft arrived at Saturn in 2004, the Radio and Plasma Wave Science (RPWS) investigation has detected a variety of radio and plasma waves in the magnetosphere of Saturn, including whistler mode chorus and hiss, lightning produced whistlers, high latitude auroral hiss, electrostatic electron cyclotron harmonic (ECH) and upper hybrid resonance (UHR) emissions, Z and O-mode narrowband emissions, and Saturn kilometric radiation (SKR). Plasma waves have also been detected in association with the Saturnian moons, including Enceladus and Rhea. We will review these observations, the properties of the various waves, and their importance in wave-particle interactions in the Saturn magnetosphere.

Hudson, Mary K.

Simulated Magnetopause Losses and Van Allen Probe Flux Dropouts (Invited)

Hudson, Mary K.[1, 6]; Li, Zhao[1]; Paral, Jan[1]; Baker, Dan[2]; Jaynes, Allison[2]; Boyd, Alex[3]; Goldstein, Jerry[4]; Toffoletto, Frank[5]; Wiltberger, Mike[6]

1. Physics & Astronomy Dept, Dartmouth College, Hanover, NH, USA
2. LASP, University of Colorado, Boulder, CO, USA
3. Physics Dept, UNH, Durham, NH, USA
4. Space Science Dept, SwRI, San Antonio, TX, USA
5. Physics & Astronomy Dept, Rice University, Houston, TX, USA
6. HAO, NCAR, Boulder, CO, USA

Since the launch of the twin Van Allen Probes spacecraft 30 August 2012, superb data has become available against which to test models of outer zone radiation belt electron variability. Within the first forty days following launch, three MeV-electron flux dropout events were seen, along with disparate timescales for recovery and strong enhancement of electron flux extending up to 8.8 MeV in October 2012. The first two dropouts bracketed the 'storage ring' feature observed by the REPT instrument (Baker et al., Nature, 2013), which was the first particle detector to be commissioned on each spacecraft on 1 September. An interplanetary shock impacted the magnetosphere on 3 September, followed by depletion of outer zone electrons outside a radial distance of 3.5 RE in the equatorial plane. The residual ring of relativistic electrons remained between 3 and 3.5 RE, as the outer zone reformed at larger radial distances within the plasmsphere, until another interplanetary shock arrived on 1 October, removing both the storage ring and reformed outer zone. A third interplanetary shock caused further depletion of flux outside of 3 RE on 8 October, just prior to the strong flux enhancement seen at multi-MeV energies on 9 October. Simulations of these three flux depletion events, and a fourth on 17 March 2013, preceding another strong multi-MeV enhancement, have been performed using the Lyon-Fedder-Mobarry MHD code driven by upstream solar wind parameters measured by the ACE and WIND spacecraft, also coupled to the Rice Convection Model which includes drift physics. Analysis of the MHD fields shows inward motion of the magnetopause for all four events, along with enhanced ULF wave power in the outer magnetosphere. Guiding center test particle simulations of radiation belt electron response to the MHD fields provide evidence for loss due to magnetopause shadowing for these events. In particular, the 'annihilation' of the outer zone between 0600 – 1000 UT on 17 March reported by Baker et al. (Geophys. Res Lett., submitted, 2013b) is confirmed in our simulations. The severe plasmapause erosion which occurred for each of the four storms studied produced conditions conducive to scattering losses by whistler mode chorus and EMIC waves at low L values, augmenting magnetopause losses at higher L values.

Jia, Xianzhe

Global Modeling of the Space Environments of Jupiter and Saturn (Invited)

Jia, Xianzhe[1]; Kivelson, Margaret[1, 2]; Gombosi, Tamas[1]

1. Department of Atmospheric, Oceanic, and Space Sciences, University of Michigan, Ann Arbor, MI, USA
2. Department of Earth and Space Sciences, University of California at Los Angeles, Los Angeles, CA, USA

At orbital distances of 5 AU and beyond, the low solar wind dynamic pressure and weak interplanetary magnetic field (down by an order of magnitude or more relative to values near Earth) interact with the strong planetary magnetic fields of the rapidly rotating giant planets, Jupiter and Saturn, to create magnetospheres that dwarf Earth's magnetosphere. At Earth, the global configuration and dynamics of the magnetosphere are controlled primarily by the interaction with the external solar wind. In contrast, at Jupiter and Saturn, although the form of the magnetospheric cavity is still the result of solar wind stresses, many properties of the two magnetospheres are determined largely by internal processes associated with the

planets' rapid rotation and the stresses arising from internal plasma sources associated with their moons (Io in the case of Jupiter, and, Enceladus in the case of Saturn). Coupling between the ionospheres of these rapidly rotating planets and their magnetospheres through electric currents plays a vital role in determining the global configuration and dynamics of the magnetosphere. As for Earth, global magnetohydrodynamic (MHD) models have been extensively applied to the two gas giants to understand the large-scale behavior of the solar wind-magnetosphere-ionosphere interaction, such as the magnetosphere-ionosphere coupling, global plasma convection and current systems. These simulation models provide global context for interpreting and linking measurements obtained in various parts of the coupled system, thereby extending our knowledge of the space environment beyond that available from localized spacecraft observations. In this presentation, we first review recent advances in global MHD modeling of the magnetospheres of Jupiter and Saturn. We then use the BATSRUS global MHD model of Saturn's magnetosphere as an example to illustrate how localized structures in the ionosphere could impose global effects on the entire magnetosphere. In particular, we discuss model results that offer valuable insight into the physical processes that drive the ubiquitous periodic modulations of particles and fields properties observed in Saturn's magnetosphere.

Jia, Ying-Dong

Characterizing the Enceladus torus by its contribution to Saturn's Magnetosphere (Invited)

Jia, Ying-Dong[1]; Wei, Hanying[1]; Russell, Christopher[1]; Khurana, Krishan[1]; Powell, Ron[1]

1. UCLA-IGPP, Los Angeles, CA, USA

As an essential part of Saturn's Magnetosphere, the Enceladus torus is located in the region dominated by Saturn's internal magnetic field, and is strongly coupled with the ionosphere. The torus is supplied by the ejecta from the south pole of Enceladus, which travels in a circular orbit, and is seen varying in the past years. The cryovolcanic gas and grains are partly ionized, and thus interact with neutrals, plasma, and field in the inner magnetosphere. These interactions significantly distort the internal magnetic field of Saturn, and thus their effect can be used to assess the producting intensity of new materials. We survey the available Cassini observations for signals of such interactions in the past 8 years, and complete the interaction scenario with MHD modeling, to determine the spatial and temporal variation of the Enceladus torus. A wake is seen behind Enceladus, extending along the orbit, with a varying radial distance, suggesting radial flow deflection caused by charged dust particles. In addition to limiting the observed Enceladus activity, this study generates a 3-D model to better understand the dynamics of Saturn's inner magnetosphere, and also practices our multi-fluid MHD theory.

Jordanova, Vania K.

Modeling Wave Generation Processes in the Inner Magnetosphere (Invited)

Jordanova, Vania K.[1]

1. Space Science and Applications, Los Alamos National Laboratory, Los Alamos, NM, USA

Plasma waves play a fundamental role in the energization and loss of charged particles in the inner magnetosphere. The free energy for these waves is supplied from the anisotropic ring current ion and electron velocity distributions that develop during geomagnetic storms. To investigate ring current dynamics on a global scale, we use our four-dimensional (4-D) ring current-atmosphere interactions model (RAM-SCB) which evolves the H+, O+, and He+ ion and electron distribution functions in dynamically varying magnetic and electric fields. A distinct feature of RAM-SCB is the use of a self-consistently calculated magnetic field in force balance with the anisotropic ring current plasma pressure. The model boundary was recently expanded from geosynchronous orbit to 9 Re, where the plasma boundary conditions are specified from the empirical plasma sheet model of Tsyganenko and Mukai [2003] based on Geotail data. We simulate the transport, acceleration, and loss of energetic particles from the magnetotail to the inner magnetosphere during several geomagnetic storms that occurred since the launch of the Van Allen Probes in August 2012. We find increased anisotropies in the ion and electron velocity distributions due to dispersed injections and energy dependent drifts and losses. These unstable distributions induce the growth of plasma waves which further affect the near-Earth radiation environment. The linear growth rate of whistler-mode waves maximizes in the dawn local time sector, while electromagnetic ion cyclotron (EMIC) waves are most intense in the afternoon sector in agreement with previous satellite observations. We compare our results with simultaneous plasma and field observations from the Energetic particle, Composition, and Thermal plasma (ECT) and the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) investigations on the Van Allen Probes. An improved understanding of the highly coupled inner magnetosphere system is provided.

Kaeppler, Stephen R.

Closure of Field-Aligned Current Associated with a Discrete Auroral Arc

Kaeppler, Stephen R.[1]; Nicolls, Michael[1]; Stromme, Anja[1]; Kletzing, Craig[2]; Bounds, Scott[2]; Gjerloev, Jesper[3]; Anderson, Brian[3]; LaBelle, James[4]; Dombrowski, Micah[4]; Lessard, Marc[5]; Pfaff, Robert[6]; Rowland, Douglas[6]; Jones, Sarah[6]

1. SRI International, Menlo Park, CA, USA
2. Department of Physics and Astronomy, University of Iowa, Iowa City, IA, USA
3. Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA
4. Department of Physics and Astronomy, Dartmouth College, Hanover, NH, USA
5. University of New Hampshire, Durham, NH, USA
6. NASA GSFC, Greenbelt, MD, USA

The Auroral Current and Electrodynamics Structure (ACES) mission consisted of two sounding rockets launched nearly simultaneously into a dynamic multiple-arc aurora with the goal of obtaining multi-point observations of the closure of field-aligned current associated with a discrete auroral arc. The payloads were flown along nearly conjugate magnetic field footpoints, separated in altitude with small temporal separation. The high altitude payload (ACES High) took in situ measurements of plasma and electrodynamic parameters that mapped from the magnetosphere that form the input signature into the lower ionosphere. The low-altitude payload (ACES Low) took similar observations within the region where perpendicular cross-field closure current can flow. A case study is presented of a quasi-stable auroral arc crossing, and in situ electron flux, electric field, and magnetic field observations for this event are presented. Poker Flat Incoherent Scatter Radar (PFISR) observations of the electron densities and electric fields are compared with the in-situ observations. A steady-state 2-D model of auroral electrodynamics has been developed to interpret the in-situ data and has been further constrained using PFISR data. A model describing the precipitating auroral electron flux has been developed and the model parameters were adjusted to be consistent with the electron flux observed by the ACES Low payload. The enhanced Hall and Pedersen conductivities resulting from the auroral precipitation are calculated, along with other relevant parameters. For the condition that the divergence of the current is equal to zero within the arc, the perpendicular current structure is determined using in situ electric fields and field-aligned currents as model inputs. The magnetic field perturbations from the modeled currents are compared with the in-situ observations of the residual magnetic field observed by both payloads. Multi-point in-situ data, ground-based data, and modeling are used to investigate the current structure and energy dissipation associated with a discrete auroral arc.

Kepko, Larry

The Substorm Current Wedge at Earth and Mercury

Kepko, Larry[1]; Glassmeier, K. H.[2]; Slavin, J. A.[3]; Sundberg, T.[4]

1. Code 674, NASA GSFC, Greenbelt, MD, USA
2. Institute of Geophysics and Extraterrestrial Physics, Technical University of Braunschweig, Braunschweig, Germany
3. Department of Atmospheric, Oceanic and Space Sciences, University of Michigan, Ann Arbor, MI, USA
4. School of Physics and Astronomy,, Queen Mary University of London, London, United Kingdom

Magnetospheric substorms occur within the magnetospheres of both Earth and Mercury in response to unsteady energy transfer from the solar wind. Substorms at Mercury occur on a much more rapid timescale and with higher relative amplitudes, but phenomenologically, the characteristic features of substorms at both planets are quite similar. An important element of substorms at Earth is the Substorm Current Wedge (SCW). The SCW is created by the braking, pile-up, and diversion of high speed plasma flows that propagate earthward from the reconnection site. The SCW consists of a set of field-aligned and ionospheric closure currents that serves to separate the near-Earth dipolarization and increased pressure gradient from the surrounding plasma, while also communicating the new plasma convection pattern to the ionosphere. Because of its importance in terrestrial substorms researchers have questioned whether a SCW exists at Mercury. Recent MESSENGER observations of dipolarizations during Hermean substorms that are phenomenologically similar to terrestrial dipolarizations has led to renewed interest in the SCW at Mercury, especially considering that Mercury has a low conductivity regolith and does not contain an ionosphere. In this paper, we review observations of substorms and dipolarizations at both Mercury and Earth, and discuss how the different magnetospheres can lead to greater understanding of substorm dynamics.

Kistler, Lynn M.

Impacts of O+ Abundance In the Magnetosphere (Invited)

Kistler, Lynn M.[1]; Mouikis, Christopher[1]; Liao, Jing[1]; Liu, Yanhua[1]

1. SSC, Univ New Hampshire, Durham, NH, USA

The CLUSTER spacecraft have now been operating for 13 years, from 2001 through the present time, covering a full solar cycle. The CODIF instrument has provided a wealth of data over this time, allowing the solar cycle dependence of the ion composition over the energy range 40 eV/e to 40 keV/e throughout the magnetosphere to be determined for the first time. The solar cycle impacts the magnetosphere in a number of ways. As solar activity increases, the increased solar EUV flux increases the ionospheric scale height, which leads to more outflow. The smaller number of CMEs leads to fewer and smaller geomagnetic storms, which also decreases

the outflow, both in the cusp and in the nightside auroral regions. In addition, the solar cycle impacts not only the ionospheric outflow, but also the transport, through changes in convection. Thus, different regions of the magnetosphere are impacted in different ways. In this paper we review recent results on how the solar cycle impacts the ionospheric contribution to the lobes, the ~20 Re plasma sheet, and the inner magnetosphere. In addition, we will discuss the impacts that increased heavy ions may have on the dynamics, including the importance to substorm loading and unloading, and the occurrence of sawtooth events.

Kitamura, Naritoshi

Very-low-energy O^+ ion outflows during geomagnetic storms

Kitamura, Naritoshi[1]; Nishimura, Yukitoshi[2]; Ono, Takayuki[3]; Ebihara, Yusuke[4]; Shinbori, Atsuki[4]; Kumamoto, Atsushi[3]; Terada, Naoki[3]; Abe, Takumi[5]; Yamada, Manabu[6]; Watanabe, Shigeto[7]; Yau, Andrew W.[8]; Chandler, Michael O.[9]; Moore, Thomas E.[10]; Matsuoka, Ayako[5]

1. Solar-Terrestrial Environment Laboratory, Nagoya University, Nagoya, Aichi, Japan
2. Department of Atmospheric and Oceanic Science, University of California, Los Angeles, Los Angeles, CA, USA
3. Department of Geophysics, Tohoku University, Sendai, Japan
4. Research Institute for Sustainable Humanosphere, Kyoto University, Uji, Japan
5. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sagamihara, Japan
6. Planetary Exploration Research Center, Chiba Institute of Technology, Narashino, Japan
7. Earth and Planetary Science Division, Hokkaido University, Sapporo, Japan
8. Department of Physics and Astronomy, University of Calgary, Calgary, AB, Canada
9. EV44 Natural Environments, NASA Marshall Space Flight Center, Huntsville, AL, USA
10. Heliophysics Science Division, NASA Goddard Space Flight Center, Greenbelt, MD, USA

We investigated electron density enhancements at ~9000 km altitude and ion flows in the polar magnetosphere during geomagnetic storms at solar maximum using data obtained by the Akebono and Polar satellites, to understand supply mechanisms of high density plasma from the ionosphere to the regions of enhanced electron densities in the polar magnetosphere, and significance of the high density ions in O^+ ion supply toward the magnetosphere. Event studies indicated that the electron density enhancements (exceeded 1000 /cm^3 (100 /cm^3) at ~7000 (~9000) km altitude, which were higher than the quiet time level with a factor of >10 (>4)) tended to persist through the main phase and around the minimum of the *SYM-H* index of geomagnetic storms. In the region of enhanced electron densities in the dayside polar cap, ions were dominated by O^+ ions with upward velocities of 4–10 km/s (streaming energies of 1.3–8.4 eV). Owing to large spatial scale, long duration, and high densities, the total amount of very-low-energy O^+ ions that flow through the region would be large (~2×10^{26} /s based on a rough estimation). Spatial distributions of parallel velocities in noon-midnight direction and temperatures of ions indicate that the very-low-energy component of the cleft ion fountain that is dominated by O^+ ions drifted deep into the polar cap, and increased the density in the polar cap. Although the energy of O^+ ions were low, the energy is sufficient to reach the near-Earth plasmasheet (GSM X > ~−20 RE) on the basis of trajectory calculations of very-low-energy O^+ ions under strong convection. Thus, these very-low-energy O^+ ions may affect the global dynamics of the magnetosphere (e.g., cross polar cap potential) and triggering of storm-time substorms (reconnection), and would play a major role in the development of geomagnetic storms (ring current formation) at solar maximum.

Kitamura, Naritoshi

Photoelectron flow and field-aligned potential drop in the polar wind (Invited)

Kitamura, Naritoshi[1]; Seki, Kanako[1]; Nishimura, Yukitoshi[2]; Hori, Tomoaki[1]; Terada, Naoki[3]; Ono, Takayuki[3]; Strangeway, Robert J.[4]

1. Solar-Terrestrial Environment Laboratory, Nagoya University, Nagoya, Aichi, Japan
2. Department of Atmospheric and Oceanic Science, University of California, Los Angeles, Los Angeles, CA, USA
3. Department of Geophysics, Tohoku University, Sendai, Japan
4. Institute of Geophysics and Planetary Physics, University of California, Los Angeles, Los Angeles, CA, USA

We have statistically examined photoelectron spectra in the polar cap obtained by the electron spectrometer aboard the Fast Auroral SnapshoT (FAST) satellite at about 3800 km altitude during geomagnetically quiet periods. We frequently find counter-streaming photoelectrons of a few tens of electron volts, indicating existence of a field-aligned potential drop above the altitude of the satellite. The estimated typical magnitude of the field-aligned potential drop above the satellite is ~22 V (July 2002 at solar maximum), which is about a half of that predicted by photoelectron-driven polar wind models with a potential drop at high altitudes. Since this potential drop reflects all electrons with energies below the potential drop, including those below the low energy threshold of the instrument (~4 eV), we can derive net escaping electron number fluxes without uncertainty due to the very low energy component. Under small field-aligned current conditions, the net escaping electron number flux should be nearly equal to the number flux of ions. Thus, the existence of the potential drop enables us to estimate the flux of polar wind ions from observations of photoelectrons. It is suggested that this field-aligned potential drop and the reflected photoelectrons at high altitudes would regulate the polar wind system as follows: The net escaping electron number flux negatively correlates with the magnitude of the potential drop; in cases of a large potential drop, most of photoelectrons are reflected and cannot escape. An increase in the magnitude of

the potential drop increases reflected photoelectrons that precipitate into the ionosphere. Since these reflected photoelectrons become an additional heat source of the topside ionosphere, they help to develop a stronger ambipolar electric field in a classical way, which would increase the flux of polar wind ions (≈ net escaping electron number flux). Thus, the resulting negative feedback would keep the magnitude of the potential drop relatively stable. The most appropriate balance of this polar wind system (equilibrium state) would be achieved near the median of the magnitude of the potential drop. In contrast to geomagnetically quiet periods, our event studies revealed that the potential drop frequently became smaller than ~5 V during the main and early recovery phases of large geomagnetic storms. During geomagnetic storms, additional ions originating from the cusp/cleft ionosphere convect into the polar cap. These additional ions would change the balance of this polar wind system; the net escaping electron number flux should increase to balance the enhanced ion flux. The magnitude of the potential drop would be reduced to let a larger fraction of photoelectrons escape.

Kivelson, Margaret

An Overview of the Field and Plasma Environment of Jupiter and Saturn (and how an ionosphere can wag the tail and everything else) (Invited)

Kivelson, Margaret[1, 2]

1. Earth, Planetary and Space Sciences, UCLA, Los Angeles, CA, USA
2. Atmospheric, Oceanic, and Space Sciences, University of Michigan, Ann Arbor, MI, USA

Thinking back to the first Yosemite meeting in 1974 (a year marked by political and climatic turbulence), it is relevant to remind ourselves that only a few months earlier, in December 1973, Pioneer 10 became the first spacecraft to fly by a gas giant planet. Pioneer 11 would not reach Jupiter until the end of the year, after which it swooped by Saturn on its way towards the heliopause. Today we look back on decades of spacecraft exploration and ground-based observations during which we discovered the many ways in which the outer planet magnetospheres differ from Earth's magnetosphere. The important (dimensionless) parameters of the solar wind change with distance from the Sun and that accounts for some differences. However, many other features of the planetary environments have consequences that can be surprising. Some of the important effects relate to: * Sources of heavy ion plasma The gas giant magnetospheres differ significantly from Earth's magnetosphere because in addition to the sources of plasma familiar at Earth (solar wind, ionosphere) there are major sources of heavy ions in the equatorial inner magnetosphere. These heavy ions, spun up to some fraction of corotation, produce structure and dynamics that differ greatly from what is familiar at Earth. * Rotation At Earth, the speed of corotation matches the typical speed of solar wind-imposed convection inside of 10 RE, and well inside the magnetopause. At Jupiter, rotation speeds dominate solar wind-imposed convection even in the outer magnetosphere. The combination of rapid rotation and heavy ions implies that much of the plasma is interchange unstable and that plasma transport occurs in ways that are atypical for the terrestrial magnetosphere. One can also argue that much of the plasma loss to the solar wind occurs through processes that differ greatly from the type of magnetic reconnection-driven loss familiar at Earth. * Spatial and temporal scales In systems as large as the magnetospheres of Jupiter and Saturn, there are significant delays between input (of almost any sort) and response, purely related to the length of time it takes for signals to carry information over extremely long distances. These delays contribute to significant twists of the magnetic field and to warping of the tail current sheet. At very large distances, the ionosphere loses control of the magnetospheric plasma. * The role of ionospheric anomalies Perhaps it is not yet generally accepted, but there are good reasons to believe that ionospheric anomalies, arising either spontaneously or through coupling with the thermosphere, drive periodic perturbations through Saturn's magnetosphere, thereby imposing periodic variations that we describe as rotating, breathing, and flapping. Such processes have not been observed in Earth's magnetosphere. Although this abstract emphasizes ways in which the magnetospheres of the giant planets differ from Earth's magnetosphere, one should recognize that the underlying laws are universal. The plasma and field properties of the magnetospheres of Jupiter and Saturn teach us lessons that may have applications to our own magnetosphere.

Krall, Jonathan

How the Ionosphere-Thermosphere System Shapes the Quiet-Time Plasmasphere

Krall, Jonathan[1]; Huba, Joseph D.[1]; Denton, Richard E.[2]; Crowley, Geoff[3]; Wu, Tsai-Wei[1]

1. Plasma Physics Division, Naval Research Laboratory, Washington, DC, USA
2. Department of Physics and Astronomy, Dartmouth College, Hanover, NH, USA
3. Atmospheric and Space Technology Research Associates, Boulder, CO, USA

The NRL SAMI3 ionosphere/plasmasphere code[1] has shown that the plasmasphere undergoes diurnal oscillations[2]. We find that those oscillations are consistent with variations found in in situ IMAGE/RPI density measurements during a quiet-time refilling event, 2001 February 01-05 and that the nature of the oscillations is strongly affected by thermospheric winds. The SAMI3 ionosphere code includes 7 ion species (H+, He+, O+, N+, O2+, N2+, NO+), each treated as a separate fluid, with temperature equations being solved for H+, He+, O+ and e-. We include a Weimer potential at high latitudes, driven by the solar wind, and the self-consistent dynamo potential at mid-to-low latitudes, driven by specified winds, such as the HWM07 or HWM93 empirical models or the TIMEGCM thermosphere model. During this quiet-time event, we find that the shape of the plasmasphere at any given time varies significantly with

the wind model. In all cases, however, the diurnal oscillations persist and a similar degree of model-data agreement is found. [1] Huba, J. and J. Krall, 2013, ``Modeling the plasmasphere with SAMI3'', Geophys. Res. Lett. 40, 6-10, doi:10.1029/2012GL054300 [2] Krall, J., and J. D. Huba, 2013, ``SAMI3 simulation of plasmasphere refilling'', Geophys. Res. Lett., 40, 2484-2488, doi:10.1002/GRL.50458 Research supported by NRL base funds and the NASA LWS program.

Lanzerotti, Louis J.

Ring Current Measurements from the Van Allen Probes Mission (Invited)

Lanzerotti, Louis J.[1]; Gerrard, Andrew[1]; Mitchell, Donald[2]; Gklioulidou, Matina[2]; Manweiler, Jerry[3]; Armstrong, Tom[3]

1. Dept Physics, New Jersey Inst Tech, Newark, NJ, USA
2. Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA
3. Fundamental Technologies, Lawrence, KS, USA

The RBSPICE instruments on the Van Probes spacecraft provide measurements of the composition and energy spectra of ring current particles in Earth's magnetosphere. The RBSPICE measurements from the two Van Allen Probe spacecraft yield data on the spatial and temporal variations of the ring current population during quiet and disturbed magnetic intervals. This presentation will summarize analyses to date, with concentrations on the helium and oxygen abundances, and changes in the abundance ratios relative to hydrogen throughout the mission. Following the injection of helium and oxygen into the magnetosphere at the times of geomagnetic disturbances, the oxygen fluxes are found to decay in intensity much more rapidly at all L-values than the helium increases. The relative contributions of the heavy species to the energy densities of the ring current during some disturbed intervals will be discussed. Composition data from the EPAM instrument on the L1 ACE spacecraft are used to investigate the relative contributions of interplanetary particles to the magnetosphere population during disturbed times.

Li, Zhao

Modeling gradual diffusion and prompt changes in radiation belt electron phase space density for the March 2013 Van Allen Probes case study

Li, Zhao[1]; Paral, Jan[1]; Hudson, Mary[1]; Jaynes, Allison[2]

1. Department of Physics and Astronomy, Dartmouth College, Hanover, NH, USA
2. Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO, USA

Two approaches are taken to studying the disparate timescale outer zone electron phenomena which have been identified in March 2013 from Van Allen Probes measurements (Baker et al., 2013). The first is a radial diffusion simulation (Li et al., 2013) which uses an outer boundary constraint based on a statistical model of flux measured by THEMIS at r = 7.5 Re, parameterized by solar wind density and velocity as input (Shin and Lee, 2013). This statistical model has been benchmarked against use of LANL geosynchronous flux for the outer boundary for other CME-driven storms, and both outer boundaries have been tested against GPS measurements at lower L* (Li et al., 2013). In order to investigate flux dropout at higher time resolution on 17 March, MHD test particle simulations were performed. This method uses the Lyon-Fedder-Mobarry global simulation model, coupled with the Rice Convection Model representation of ring current drift physics, to calculate the magnetopause stand-off distance at noon on the dayside, using measured solar wind input at L1 from ACE and Wind. The timescale of the magnetopause evolution in the MHD simulations, when used to advance test particle electron trajectories, includes features which occur on a faster time scale than can be resolved by the radial diffusion code. The two approaches are both compared with data from the ECT instrument on the Van Allen Probes Spacecraft.

Liemohn, Michael W.

Ionospheric Contribution to Magnetospheric Ion Density and Temperature Throughout the Magnetotail (Invited)

Liemohn, Michael W.[1]; Welling, Daniel T.[1]

1. AOSS Department, University of Michigan, Ann Arbor, MI, USA

Outflow from the ionosphere into the magnetosphere is simulated and compared with solar wind entry as a source of ions to the magnetotail and plasma sheet. The coupled codes within the Space Weather Modeling Framework is used to assess the relative contributions of these two populations to geospace composition. The study employs both the multi-species and multi-fluid versions of the BATS-R-US magnetohydrodynamic model to investigate the influence of numerical approach on the resulting source term concentrations within the magnetosphere. Several idealized conditions are considered as well as a few real event cases. The ionospheric outflow within the SWMF is compared against several statistical studies of high-latitude measurements of this population, in particular those from the Polar spacecraft, to assess the validity of the assumed outflow conditions. It is found that during southward interplanetary magnetic field (IMF), the central plasma sheet is dominated by ionospheric material entering the plasma sheet near the midnight meridian. This population then dominates the high temperature and low density plasma delivered to the inner magnetophere, with only a small contribution from the solar wind. However, during northward IMF, solar wind entry on the dayside by double lobe reconnection allows for this population to dominate the ion density everywhere in the outer magnetosphere and provide a cold, dense ion population to near-Earth space.

Liemohn, Michael W.

Nonlinear Magnetosphere-Ionosphere Coupling in Near-Earth Space via Closure of the Partial Ring Current

Liemohn, Michael W.[1]; Katus, Roxanne M.[1]; Smith, Lois K.[1]; Skoug, Ruth M.[2]; Niehof, Jonathan[2]; Smith, Charles W.[3]; Wygant, John R.[4]; Ilie, Raluca[1]; Ganushkina, Natalia Y.[1]

1. AOSS Department, University of Michigan, Ann Arbor, MI, USA
2. ISR-1, Los Alamos National Laboratory, Los Alamos, NM, USA
3. Department of Physics, University of New Hampshire, Durham, NH, USA
4. School of Physics and Astronomy, University of Minnesota, Minneapolis, MN, USA

Localized potential electric field modification is identified in the Van Allen Probes data during magnetic storm times, when significant energetic plasma (above a keV) is injected into the inner magnetosphere. This modification is from the closure of field-aligned currents through the ionosphere in a region of low conductance just equatorward of the auroral oval. Observations from the Van Allen Probe instruments HOPE, RBSPICE, EMFISIS, and EFW are presented for several magnetic storms, showing the relationship of the plasma pressure peak and the magnetic field distortion to the local electric field vector. An assessment of the intensity of the nonlinear feedback on the electric field is made by determining its deviation from the large-scale potential electric field, as observed by EFW outside of the pressure peak. The coupling that emerges is in agreement with numerical simulations of near-Earth space that predict strong perturbation of the local electric field near pressure peaks.

Liemohn, Michael W.

The Superthermal Electrons Ionosphere-Magnetosphere Transport and Their Role in the Formation of Ion Outflows (Invited)

Khazanov, George V.[1]; Liemohn, Michael W.[2]

1. NASA/GSFC, Greenbelt, MD, USA
2. University of Michigan, Ann Arbor, MI, USA

The superthermal electrons (SE) are the major energy contributor to the ionosphere and inner magnetosphere via the Coulomb collision processes. The SE escape from the ionosphere to the plasmasphere is controlled by strong Coulomb coupling with the thermal plasma distribution along the entire magnetic field line. The plasma distribution along the field line, in turn, is controlled by electron and ion temperature distributions that are mostly determined by SE heating of the thermal electrons. The SE also are contribute to the formation of the polar wind and plamaspheric refilling processes. As the plasma flows up and out of the topside ionosphere, the flow conditions change from subsonic to supersonic, from collision-dominated to collisionless, and from O+ dominance to H+ dominance. In the collisionless regime, the ion velocity distributions become highly non-Maxwellian and the coupling between various plasma species occurs through the development of a self-consistent potential. The reason for the formation of a self-consistent potential in the collisionless plasma is quite clear. High mobility electrons tend to overtake ions. As a result, the electric neutrality of the plasma is violated and an electric field appears which constrains the electrons, forcing them, on average, to travel together with the ions. Sources of free energy that power this ion acceleration process include (but not limited) photoelectron, electron precipitation, field-aligned currents, velocity shears, and Alfvénic Poynting flux. The combine effect of all these processes on ionospheric ion outflows will be investigated in a framework of the kinetic model that has been developed in our previous papers in order to study the polar wind transport in the presence of photoelectrons.

Lotko, William

Ionospheric Control of Magnetic Reconnection (Invited)

Lotko, William[1]

1. Thayer School of Engineering, Dartmouth College, Hanover, NH, USA

The ionosphere influences dayside and nightside magnetic reconnection through its electrodynamic and inertial couplings to the magnetosphere. The distribution of high-speed plasma flows observed at distances of 10-30 earth radii in the magnetotail neutral sheet is highly skewed toward the premidnight sector due to electrodynamic coupling. These flows are a product of nightside reconnection, and numerical simulations indicate that the primary causal agent for their observed asymmetry is the meridional gradient in the ionospheric Hall conductance. Ionospheric outflows also have the capacity to change the dynamics and rate of nightside reconnection. Periodic substorms are observed for strong and steady solar wind driving in many data sets, but they occur in geospace simulations only when ionospheric outflows are included. When circulated through the plasmasheet and energized to populate the ring current, ions of ionospheric origin can also inflate the dayside magnetosphere, particularly during storm conditions. The result is a change in the shape of the magnetopause boundary, in the balance between convective and reconnective transport of magnetic flux through the magnetosheath and in the cross polar cap potential. These effects and their physical origins are demonstrated using results from global simulations.

Lu, Gang

Global Dynamic Coupling of the Magnetosphere-Ionosphere-Thermosphere System (Invited)

Lu, Gang[1]

1. HAO, NCAR, Boulder, CO, USA

The Earth's ionosphere and thermosphere are strongly influenced by forcing through the solar wind-magnetosphere interaction. During geomagnetic storms, strong electric fields and currents are transmitted between the high-latitude ionosphere, and enhanced particle precipitation occurs along the auroral oval. The conductivity of the ionosphere increases, neutral winds are accelerated, and the thermosphere is heated, its composition is modified, and plasma and neutral gases are redistributed. In this paper we discuss the effects of the different processes on the ionosphere and thermosphere using the coupled AMIE-TIMEGCM. Observational and modeling results from selected geomagnetic storm events will be shown to illustrate the complex response of the ionosphere and thermosphere to various solar and magnetospheric forcing.

Luo, Tian

Effects of Polar Wind Outflow on the Storm-time Ring Current

Luo, Tian[1]; Xi, Sheng[1]; Lotko, William[1]

1. Thayer School of Engineering, Dartmouth College, Hanover, NH, USA

Ions of ionospheric origin are known to be important in the development of the storm-time ring current. Previous studies have mainly focused on the increased concentration of O+ in the ring current because heavy ions, in contrast with protons, can be easily distinguished from ions of solar wind origin. This study examines the effect of an H+ polar wind outflow on the loss of storm-time ring current. We first conducted two simulations using the coupled LFM-RCM global model, with and without a polar wind outflow, driven by steady IMF Bz at -15 nT. Results show that the maximum energy of the ring current is higher with the H+ outflow than in the baseline run without it. The hypothesis that the increase of ring current energy is due to the reduction of ring-current ions loss was tested by performing four additional simulations with the IMF turning northward after saturation of the ring current in the previous simulations. For two of the simulations, with and without outflow, the RCM's explicit loss terms (ion charge exchange and strong electron pitch-angle scattering) were disabled; they were enabled in the other two for otherwise identical conditions. The results show that, without the polar wind outflow, the RCM's loss terms account for only a small fraction of the ring-current loss. With polar wind outflow included, the RCM loss dominated the ring-current loss, but the loss rate is slower than in the case without outflow. The remaining questions are what cause the reduction of the loss and why is the loss reduced after including the outflow. We analyzed the possible mechanisms that may contribute to this result and found that the flux tube interchange motion in the inner magnetosphere is restrained in the outflow run, so a possible explanation would be a reduction in interchange motion reduces the loss of ring-current ions. We are developing additional diagnostics to answer the second question.

Lysak, Robert L.

Coupling of Magnetosphere and Ionosphere by Alfvén Waves at High and Mid-Latitudes (Invited)

Lysak, Robert L.[1]; Song, Yan[1]; Waters, Colin[2]; Sciffer, Murray[2]

1. School Physics & Astronomy, Univ Minnesota, Minneapolis, MN, USA
2. School of Mathematical and Physical Sciences, University of Newcastle, Callaghan, NSW, Australia

Electrodynamic coupling of the magnetosphere and ionosphere is accomplished by the passage of MHD waves that propagate between these regions. Field-aligned currents can be generated by flow shears in the outer magnetosphere, and these currents are carried to lower latitudes by shear mode Alfvén waves. Pressure changes in the outer magnetosphere drive magnetosonic waves that can propagate throughout the magnetosphere. These waves modes are coupled by gradients in the Alfvén speed across magnetic field lines as well as by the Hall conductivity in the ionosphere, complicating the signals generated by magnetospheric dynamics. A new three-dimensional model of ULF waves in a dipole geometry has been developed that simulates the propagation and coupling of these waves. This model includes distributed conductivities in a height-resolved ionosphere and directly calculates the ground magnetic fields produced by these currents. This model will be applied to the propagation of Pi1/Pc1 waves that interact in the ionospheric Alfvén resonator as well as to lower frequency Pi2 pulsations that propagate globally. Emphasis will be placed on the comparison of magnetic and electric fields observed on the ground, in the ionosphere, and by spacecraft in the magnetosphere.

Ma, Yingjuan

The Interaction of Rapidly Flowing Plasmas with Venus, Mars and Titan (Invited)

Ma, Yingjuan[1]; Russell, Chris T.[1]; Nagy, Andrew F.[2]; Toth, Gabor[2]

1. ESS, UCLA, Los Angeles, CA, USA
2. AOSS, University of Michigan, Ann Arbor, MI, USA

Venus, Mars and Titan are the only three objects in the solar system with substantial atmosphere but no global magnetic field. Even though each object has its own characteristics and their external plasma flows range from supersonic solar wind to subsonic magnetosphere co-rotational flow, the plasma interactions around these objects share similar global structure. As a consequence of the interaction, the external magnetic field lines pile-up and drape over the highly conducting obstacles represented by the ionosphere to form a well-defined induced magnetosphere. The interplay between the induced magnetosphere and the ionosphere is critical to understand the magnetic field signature and ionosphere structure. In this presentation, we will discuss various numerical models being applied to the three objects and discuss what has been learned regarding the interaction of non-magnetized obstacles with their plasma environments.

McGrath, Melissa A.

Planetary Aurora across the Solar System (Invited)

McGrath, Melissa A.[1]

1. NASA Marshall Space Flight Center, Huntsville, AL, USA

One of the most recognizable examples of magnetosphere-ionosphere coupling is bright auroral emissions produced by charged particle excitation of a planetary atmosphere. Although the canonical example has long been Earth, auroral emissions are pervasive across the solar system, not only on other planets (Jupiter, Saturn, Uranus, Neptune, and perhaps Mercury), but also on planetary satellites (most notably the Galilean satellites of Jupiter: Io, Europa, Ganymede, and Callisto). This talk will give a brief overview of auroral emissions seen on planets and satellites other than Earth, with an emphasis on comparison and contrast of the magnetosphere-ionosphere interactions that produce the auroral emissions.

McPherron, Robert

The Possible Role of Magnetosphere-Ionosphere Coupling in Substorms (Invited)

McPherron, Robert[1]

1. University of California, Los Angeles, Los Angeles, CA, USA

The magnetospheric substorm is the primary process by which magnetic field added to the tail lobes by dayside reconnection is returned to the dayside. An isolated substorm has three distinct phases: the growth phase, the expansion phase, and the recovery phase. In the growth phase magnetospheric convection is driven by the flow of plasma to the dayside reconnection site and by increased pressure of open magnetic flux added to the tail lobes. The convecting magnetospheric plasma facilitates particle precipitation to the ionosphere and drives field-aligned currents whose closure through the ionosphere causes heating and the outflow of ions. A delay in the onset of nightside reconnection results in a sequence of changes in the configuration of the tail that within an hour lead to the onset of nightside reconnection. Nightside reconnection produces bursts of high-speed flow that transport newly closed magnetic flux and bubbles of depleted plasma to the midnight magnetosphere. The aurora begins to expand azimuthally and poleward forming a large bulge of active aurora. The pressure gradients and changes in flux tube volume created by these localized changes produce a new field-aligned current system - the substorm current wedge. Up to a million Amps of current is diverted from the tail through the auroral bulge further altering the ionosphere through heating and ion outflow. Within 10-30 minutes the bulge ceases to expand and the current in the wedge reaches its maximum value. In the following one and a half hours the auroral activity disappears and the current wedge dies away. If the interplanetary magnetic field remains southward activity continues. If solar wind driving is moderate the magnetosphere enters a new mode of balanced reconnection where no configuration changes occur and no auroral expansion is observed. This is called steady magnetospheric convection. However, if the driving is strong the magnetosphere enters the sawtooth oscillation mode consisting of a quasi-periodic sequence of large substorms. It has been suggested that this mode is a result of feedback between ion outflow and the magnetotail reconnection process. In this paper we will review recent work on ion outflow during different phases of the substorm and speculate on possible effects of these ions. We will also investigate the temporal response of the substorm electrojet to the solar wind using linear prediction filters. Filters will be calculated for different substorms in a sequence of substorms to determine if there are progressive changes in temporal response that might be explained by the increasing presence of ions in the plasma sheet or by changes in ionospheric conductivity.

Meriwether, John

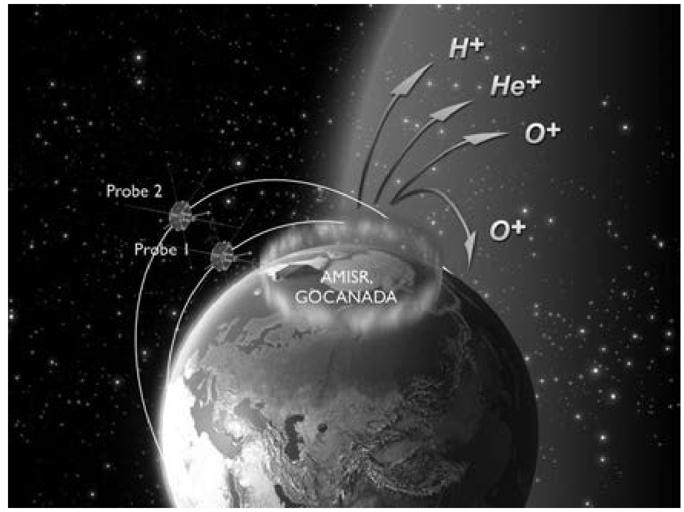
Storm-time response of the mid-latitude thermosphere: Observations from a network of Fabry-Perot interferometers

Meriwether, John[1]; Mesquita, R.[1]; Sanders, S.[1]; Makela, J. J.[2]; Harding, Brian J.[2]; Ridley, A. J.[3]; Castellez, M. W.[4]; Ciocca, M.[5]; Earle, G. D.[6]; Frissell, N.[6]; Hampton, D. L.[7]; Gerrard, A. J.[8]

1. Department of Physics and Astronomy, Clemson University, Xx, SC, USA
2. Dept. of Electrical Engineering, University of Illinois, Urbana-Champaige, IL, USA
3. Atmospheric Oceanic Space Sciences, University of Michigan, Ann Arbor, MI, USA
4. Pisgah Astronomical Research Institute, unknown, NC, USA
5. Department of Physics and Astronomy, Eastern Kentucky University, Richmond, KY, USA
6. Institute for Critical Technologies and Applied Science, Virginia Tech University, Charlottesville, VA, USA
7. Geophysical Institute, University of Alaska, unknown, AK, USA
8. Department of Physics and Astronomy, New Jersey Institute of Technology, unknown, NJ, USA

Observations of thermospheric neutral winds and temperatures obtained from a network of five Fabry-Perot interferometers deployed in the midwest United States during a geomagnetic storm on 2 October 2013 showed that coincident with the commencement of the storm, the horizontal wind was observed to surge westward and southward (towards the equator). Simultaneous with this surge in the horizontal winds, an apparent downward wind of approximately 100 m/s lasting for 6 hours was also observed. The neutral temperature was observed to increase by approximately 400 K over all of the sites. Similar results of downward vertical winds and sustained heating have been seen in other geomagnetic storm events. The large sustained

apparent downward winds are interpreted as arising from the contamination of the nominal spectral profile of the 630.0-nm population distribution, which is thermalized within the thermosphere region, by fast O related to the infusion of low-energy O+ ions that are generated by charge exchange and momentum transfer collisions. This interpretation is supported through simultaneous observations made by the Helium, Oxygen, Proton, and Electron spectrometer instruments on the twin Van Allen Probes spacecrafts, which show an influx of low-energy ions well correlated with the period of apparent downward winds. These results emphasize the importance of distributed networks of instruments in understanding the complex dynamics that occur in the upper atmosphere during disturbed conditions and represent an example of magnetosphere-ionosphere coupling.



Moore, Thomas E.

Requirements for a Mission to study Thermosphere-Magnetosphere Coupling (Invited)

Moore, Thomas E.[1]; Chappell, Charles R.[2]

1. Heliophysics Science Division, NASA Goddard Space Flight Ctr, Greenbelt, MD, USA
2. Vanderbilt University, Nashville, TN, USA

The Heliophysics community needs to find out how gravitationally-trapped volatile matter is being lost from atmospheres by energetic processes, depleting them of key constituents, as has occurred most dramatically at Mars. This process is exemplified in geospace by the dissipation of solar energy to produce ionospheric outflows that feed back on dynamics of the solar wind interaction with Earth's magnetosphere. Proposed mechanisms involve wave-particle heating interactions, upward ambipolar electric fields, or ponderomotive forces. Empirical guidance remains ambiguous concerning their relative importance. Moreover, it is unclear if the waves interact with particles primarily in a cyclotron resonant mode, in a lower hybrid exchange of electron (parallel) and ion (perpendicular) energy, or in a bulk ponderomotive mode. The questions raised by these issues include: Where do the waves that produce mass ejection grow? How do they propagate and transport energy? How can wave amplitudes, heating rates, and escape flows be derived from solar wind conditions? To obtain answers, it appears necessary to observe the magnetospheric and thermospheric boundary conditions applied to the topside ionosphere or exobase layer, and the response of ions and electrons to the ensuing battle between electrodynamic forcing and collisional damping.

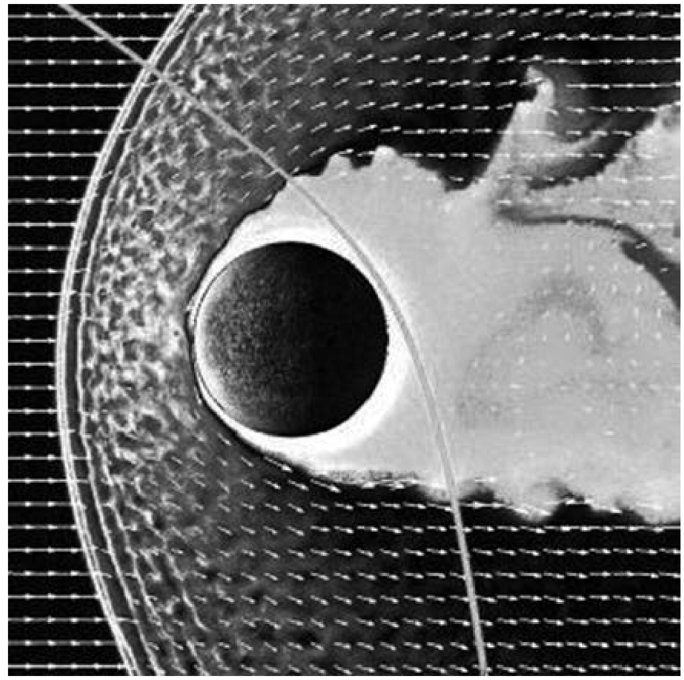
Mueller-Wodarg, Ingo

Simulation of the Magnetosphere-Ionosphere Connection at Saturn (Invited)

Mueller-Wodarg, Ingo[1, 2]; Moore, Luke[2]; Jia, Xianzhe[3]; Galand, Marina[1, 2]; Miller, Steve[4]; Mendillo, Michael[2]

1. Blackett Laboratory, Imperial College London, London, United Kingdom
2. Center for Space Physics, Boston University, Boston, MA, USA
3. Atmospheric, Oceanic and Space Sciences, University of Michigan, Ann Arbor, MI, USA
4. Department of Physics, University College London, London, United Kingdom

The giant planets in our solar system such as Saturn and Jupiter represent fascinating worlds which exhibit a range of electro-magnetic, collisional and chemical processes coupling the upper atmospheres with the magnetospheres and some of their moons. Observationally, they are explored either in-situ through magnetic and electric field as well as plasma observations, or remotely by observing auroral emissions or atmospheric occultations. Magnetosphere-ionosphere coupling has over the past decades been studied in depth on Earth and matured as a field, but for the giant planets our understanding is still in its early stages. A key aid for our understanding of the underlying physics are numerical models which simulate the relevant neutral-ion and ion-magnetosphere coupling processes. Some of the key currently unresolved science questions for Saturn include the origin of its high thermosphere temperatures ("energy crisis"), of its highly variable and structured ionosphere as well as the observed variations of Saturn's apparent rotation rate. Work over the past years has shown that these all in one way or another rely on understanding magnetosphere-atmosphere coupling. Comparisons of Saturn and Earth are particularly interesting as well, as similar physical processes - well studied for Earth - act on both, but under different boundary conditions. Using our Saturn Thermosphere-Ionosphere model (STIM) with inputs from the University of Michigan Block Adaptive Tree Solar wind Roe-type Upwind Scheme (BATSRUS) MHD model, we calculate the coupling of Saturn's magnetosphere with the planet's upper atmosphere. At high latitudes STIM relies on electric fields and incident energetic particle fluxes which in turn ionise the upper atmosphere and generate ionospheric currents. These, in turn, lead to westward (anti-corotational) acceleration of ions and thereby neutral winds, whereby angular momentum is transferred from atmosphere to magnetospheric plasma. Within the atmosphere, strong auroral heating occurs which drives a complex system of global circulation and energy redistribution. For the first time we present calculations made at high spatial resolution and illustrate the relevance of that. By examining the time-dependent response of Saturn's atmosphere to variations in solar wind pressure (via its magnetosphere), we infer the relevant physical processes and intrinsic atmospheric time scales. Our Saturn calculations are constrained by and compared with key observations, and parallels are drawn to any terrestrial equivalents in behaviour. We address the energy crisis and discuss possible solutions. Our simulations and tools, in tandem with Cassini and ground based observations form an important step towards understanding "space weather" on Saturn.



Paral, Jan

Global Simulations of the Asymmetry in Forming Kelvin-Helmholtz Instability at Mercury

Paral, Jan[1, 2]; Rankin, Robert[2]

1. Physics, Dartmouth College, Hanover, NH, USA
2. Department of Physics, University of Alberta, Edmonton, AB, Canada

MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) is the first spacecraft to provide data from the orbit of Mercury. After the probe's insertion into the orbit on March 2011, the in situ measurements revealed a dawn dusk asymmetry in the observations of Kelvin-Helmholtz (KH) instability. This instability forms at the magnetopause boundary due to the high shear of the plasma flows. The asymmetry in the observations is unexpected and largely unexplained, although it has been speculated that finite ion gyroradius effect plays an important role. The large gyroradius implies that kinetic effects are important and thus must be taken into account. We employ global ion hybrid kinetic simulations to obtain a 2D model of Mercury's magnetosphere. This code treats ions as particles and follows the full trajectory while electrons act as a charge neutralizing fluid. The planet is treated as the perfect conductor placed in the streaming solar wind to form a quasi steady state of the magnetosphere. By placing a virtual probe in the simulation domain we obtain time series of the plasma parameters which can be compared to the observations by the MESSENGER spacecraft. The comparison of the KH instability is remarkably close to the observations of MESSENGER; to within a factor of two. The model also confirms the asymmetry in the observations.

Paty, Carol S.

From Ionospheric Electrodyamics at Mars to Mass and Momentum Loading at Saturn: Quantifying the Impact of Neutral-Plasma Interactions using Plasma Dynamic Simulations (Invited)

Paty, Carol S.[1]; Riousset, Jeremy A.[1]; Rajendar, Ashok[1]

1. Earth & Atmospheric Science, Georgia Inst. of Technology, Atlanta, GA, USA

Planetary environments provide compelling natural laboratories for exploring and quantifying the various expressions of plasma-neutral interactions in magnetospheric systems. Quantifying these interactions requires consideration of momentum and energy exchange between neutral and plasma populations, tracking of plasma sources and losses, and propagation of these effects into the generation of currents and fields. We have incorporated these interactions into a multifluid plasma dynamic modeling infrastructure in order to examine their influence in two very different planetary environments: Mars and Saturn. For Mars we consider the coupling of the neutral atmosphere to the ionospheric plasma throughout the atmospheric column and in the presence of remanent crustal magnetic fields. At altitudes where the collision frequency between charged species and neutrals becomes larger than the gyrofrequecy, these charged particles become demagnetized and follow the neutral flow. In the atmospheric dynamo region (100–250 km altitude), ions depart from the gyropath due to collisions with moving neutral particles (i.e., winds), while electron motion remains governed by electromagnetic drift. In our simulations, we track this differential motion of the ions and electrons and calculate the associated electric currents and induced perturbation field generated in the dynamo region. We also examine how the overall electromagnetic changes may ultimately alter the behavior of the local ionosphere beyond

the dynamo region. At Saturn, we incorporated the same types of physical interactions into a global scale magnetospheric simulation in order to capture the interaction of the extended neutral cloud with Saturn's rapidly rotating magnetosphere. We included an empirical representation of Saturn's neutral cloud and again modified the multifluid equations to include the collisions necessary to quantify the globally distributed mass- and momentum-loading on the system. Collision cross-sections between ions, electrons, and neutrals were calculated as functions of closure velocity and energy at each grid point and time step, enabling us to simulate the spatially and temporally varying plasma-neutral interactions. We use this updated multifluid simulation to investigate the dynamics of Saturn's magnetosphere, focusing specifically on the production of new plasma, the resulting radial outflow, interchange events, and corotation lag profiles.

Peroomian, Vahe

Large-Scale Kinetic Simulations of Geomagnetic Storms with Realistic Ionospheric Ion Outflow Models (Invited)

Peroomian, Vahe[1]; Garg, Shobhit[1]; El-Alaoui, Mostafa[1]

1. Physics and Astronomy, UCLA, Los Angeles, CA, USA

During the last several years, we have investigated the access and energization of ionospheric ions as well as the entry and acceleration of solar wind ions in the magnetotail during geomagnetic storms. For each of the storms studied, we ran a global magnetohydrodynamic (MHD) simulation of the event using upstream solar wind and IMF data. We then launched ions originating from the solar wind and from the ionosphere in the global, time-dependent electric and magnetic fields obtained from the MHD simulation of the event. We present results from storms driven by coronal mass ejections (CMEs) and by corotating interaction regions (CIRs) and high-speed streams (HSS). We compare ion densities in the magnetotail, the geoeffectiveness of ion outflows, and the modulation of ion outflow on ion densities in the magnetotail.

Peterson, William K.

A quantitative assessment of the role of soft electron precipitation on global ion upwelling

Peterson, William K.[1]; Redmon, Robert J.[2]; Andersson, Laila K.[1]; Richards, Philip G.[3]

1. LASP, University of Colorado, Boulder, CO, USA
2. NOAA, Boulder, CO, USA
3. George Mason University, Farifax, VA, USA

We find that, in general, existing models of electron precipitation underestimate the soft electron component which is a prime driver of O+ upwelling. Our conclusion is supported by a detailed study of the relative influence of electron precipitation on upwelling O+ during quiet times producing upwelling O+ in the nightside auroral zone. We use the Field Line Interhemispheric Plasma (FLIP) ionospheric model to study the upwelling O+ on 40 field lines distributed across the auroral zone and magnetic local times, turning precipitation on and off as field lines move in and out of the auroral zone. We investigate the efficacy of electron precipitation patterns derived from the OVATION Prime and Hardy et al., [2008] models to produce upwelling O+ as a function of MLT and latitude. Our results indicate that during quiet times soft e- precipitation in the evening hours plays a critical role in controlling upwelling O+ in the cold night-side ionosphere but plays a relatively modest role in facilitating energetic O+ escape on the dayside. Detailed comparisons between the model output and statistical DMSP observations at 850 km show that the combination of using the output of two standard precipitation models during a quiet equinoctial period (Kp = 2, Ap = 7) as a single Maxwellian precipitating electron distribution input to this model does not sufficiently reproduce average observed upwelling fluxes in the nightside auroral zone. It is likely that an influential quantity of electron energy flux at sub 100 eV characteristic energies is unaccounted for in the standard models of electron precipitation. We have then devised an auroral electron precipitation pattern consisting of single modal Maxwellian distributions, which produces upwelling O+ fluxes that are in reasonable agreement with the DMSP observations as reported by Redmon et al., [2010].

Reiff, Patricia H.

Testing MHD Models by Conjugate Aurora Imaging

Reiff, Patricia H.[1]; Longley, William[1]; Reistad, Jone[2]; Ostgaard, Nikolai[2]

1. Rice Space Institute, Rice University, Houston, TX, USA
2. University of Bergen, Bergen, Norway

In times when the Y-component of the IMF is dominant, the pull of the magnetic fields cause the polar caps to skew, with one cap shifted towards dusk and the other polar cap shifted towards dawn. A case with two hours of continuous dual-cap auroral imaging provides us with "ground truth" to test the amount of dawn-dusk shift predicted by commonly-used MHD models. With IMAGE/WIC observing in ultraviolet over the Earth's sunlit northern pole and Polar/VIS over the dark southern pole, the skew is readily observed and mapped to the surface using Apex coordinates. The dawn/dusk offset for this case, measured as the difference of the colatitude of the polar cap boundary at dawn minus that at dusk, is up to ten degrees for this extreme case with By ~ 30nT. Four MHD models have been run through the CCMC at GFSC, using the real time solar wind propagated to the models. Only the LFM model yields a skew which is comparable in size to the that observed in the imaging data. The other models predict skews which are smaller or even of the wrong sense.

Schunk, Robert W.

Magnetosphere-Ionosphere Coupling: Past, Present, and Future (Invited)

Schunk, Robert W.[1]

1. Ctr. Atmospheric & Space Sci., Utah State University, Logan, UT, USA

Significant progress has been made during the last forty years in identifying the processes that couple the magnetosphere and ionosphere. The progress was achieved with the aid of new measurement techniques, enhanced data coverage, sophisticated global models, and extensive model-data comparisons. It is now clear that the magnetosphere-ionosphere system exhibits a significant amount of spatial structure and rapid temporal variations. This variability is associated with magnetic storms and sub-storms, nonlinear processes that operate over a range of spatial scales, time delays, and feedback mechanisms between the two domains. The variability and resultant structure of the ionosphere can appear in the form of propagating plasma patches, polar wind jets, pulsing of the ion and neutral polar winds, auroral and boundary blobs, and ionization channels associated with sun-aligned polar cap arcs, discrete auroral arcs, and storm-enhanced densities (SEDs). The variability and structure of the thermosphere can appear in the form of propagating atmospheric holes, neutral gas fountains, neutral density patches, transient neutral jets and supersonic winds. Advances that were made during the last forty years in modeling the variability and structure associated with magnetosphere-ionosphere coupling will be presented. Speculation on where the field is headed will also be presented.

Slavin, James

An Overview of Mercury's Plasma and Magnetic Field Environment (Invited)

Slavin, James[1]

1. Dept. Atmospheric, Oceanic and Space Sciences, University of Michigan, Ann Arbor, MI, USA

MESSEGNER plasma and magnetic field measurements in Mercury's magnetosphere are reviewed and comparisons are drawn with Earth. The magnetosphere created by the solar wind interaction with Mercury's dipolar spin-axis aligned magnetic field resembles that of Earth in many respects. The magnetic field intensities and plasma densities and temperatures are all higher at Mercury due to the increased solar wind pressures in the inner solar system. Magnetospheric plasma at Mercury appears to be primarily of solar wind origin, but with 10% Na+ due to solar EUV ionization of exospheric Na. The low plasma β (i.e., ratio of plasma thermal to magnetic pressure) magnetosheath at Mercury results in strong plasma depletion layers adjacent to the magnetopause. In this environment magnetopause reconnection does not exhibit the "half-wave rectifier" response to interplanetary magnetic direction (i.e. low latitude reconnection is only observed at large magnetic shear angles) found at Earth. The comparable magnetic field intensities on the two sides of the magnetopause current layer support reconnection for all non-zero shear angles with plasma β as the primary parameter controlling the rate. Flux transfer events (FTEs) are observed at most magnetopause crossings, often in "showers" with FTEs being encountered every ~ 10 s for several minutes. Unlike at Earth where FTEs account for only order 1% of the magnetic flux driving the Dungey cycle, the contribution of FTEs at Mercury appears nearly comparable to that of steady magnetopause reconnection at a single X-line. Mercury's magnetotail sometimes displays similar loading/unloading to that observed at Earth during isolated substorms. The primary difference is that the Dungey cycle-time at Mercury is ~ 2 – 3 min as compared to ~ 1 hr at Earth. Mercury's magnetosphere can also exhibit Earth-like steady magnetospheric convection with quasi-periodic plasmoid ejection down the tail and dipolarizations closer to the planet. Mercury's highly resistive crust inhibits strong, long duration coupling via field aligned currents, but its large, highly conducting iron core supports strong "inductive" coupling. The currents induced in the outermost layers of the core by increased solar wind pressure, such as during coronal mass ejections and high-speed streams, are observed to decrease the compressibility of Mercury's dayside magnetosphere. The effects of this inductive magnetosphere – core coupling on other aspects of magnetospheric dynamics at Mercury remain to be determined.

Song, Paul

Inductive-dynamic coupling of the ionosphere with the thermosphere and the magnetosphere

Song, Paul[1]; Vasyliunas, Vytenis[1, 2]; Tu, Jiannan[1]

1. UMASS Lowell, Lowell, MA, USA
2. Max-Plank-Institute, Lindau, Germany

Over the past decades, countless studies have been dedicated to describing the magnetosphere-ionosphere/thermosphere coupling and the influences of the magnetospheric variations on the ionosphere/thermosphere system. The models that have been used for practical purposes in global sense are with either a static ionosphere or a height-integrated ionosphere, both of which are not valid or adequate to describe the transient ionospheric processes such as substorms or auroral brightenings. A framework of theory has been proposed and is being developed to self-consistently describe an electromagnetically coupled collisional plasma-neutral system with the inductive and plasma as well as neutral dynamic effects. In this presentation, we describe the new approach of multi-fluid inductive dynamic magnetosphere-ionosphere-thermosphere (MID-MIT) coupling, in which ions and neutrals are treated dynamically as multiple fluids. The magnetic field can vary with time and in space: its temporal variations induce electric field and its spatial variations produce currents. The conventional concepts of mapping the electric potential, magnetic field, and field-aligned currents become invalid during the dynamic stage. We compare the differences between this inductive-dynamic theory and the conventional magnetosphere-ionosphere/thermosphere coupling mechanisms. The inductive-dynamic theory shows that the transition for the ionosphere to respond to a magnetospheric change lasts for about 20-30 min, the critical time scale for most of ionospheric dynamic processes. During the transition period, large-amplitude fluctuations, enhanced heating, and upward flow are expected and present in one-dimensional numerical simulations.

Song, Yan

Generation of Alfvenic Double Layers and Formation of Discrete Auroras by Nonlinear Electromagnetic Coupling between Magnetosphere and Ionosphere

Song, Yan[1]; Lysak, Robert L.[1]

1. School of Physics & Astronomy, University of Minnesota, Minneapolis, MN, USA

It has been recently proposed that nonlinear electromagnetic coupling between magnetosphere and ionosphere can create non-propagating electromagnetic-plasma structures, such as transverse Alfvenic double layers and charge holes in auroral acceleration regions, which are responsible for auroral particle acceleration and the formation of both Alfvenic and quasi-static inverted-V discrete auroras. These non-propagating dynamical structures are often characterized by localized strong electrostatic electric fields, density cavities and enhanced magnetic or velocity stresses. The energy stored in such stresses can support the generation of strong non-polarized electric fields as well as charged particle acceleration and energization. Alfvenic double layers and charge holes are generated by nonlinear electromagnetic interaction between incident and reflected Alfven wave packets in the magnetosphere and ionosphere coupling region. Similar electromagnetic-plasma structures should also be generated in other cosmic plasma environments, and would constitute effective high energy accelerators of charged particles in cosmic plasmas.

Spann, James F.

A Novel Concept to Explore the Coupling of the Solar-Terrestrial System

Spann, James F.[1]

1. Science Research Office, NASA MSFC, Huntsville, AL, USA

A revolutionary opportunity to explore the consequences of reconnection in the ionosphere as never before will be presented. It is a revolutionary opportunity to explore key Aeronomy emissions on a global scale with spatial and temporal resolution not possible today. For example, observations of the signature of dayside merging and nightside reconnection that are reflected in the auroral oval evolution during disturbed periods and quiet times, will be described; observations that will open a window of discovery for coupling phenomena within Geospace and with the solar wind. The description of this new concept will be presented, and its impact and contribution to understanding magnetic merging will be discussed.

Strangeway, Robert

Ion Outflows: Causes, Consequences, and Comparative Planetology (Invited)

Strangeway, Robert[1]

1. University of California, Los Angeles, Los Angeles, CA, USA

Both particle and electromagnetic energy flow into the Earth's high latitude ionosphere. This energy results in heating of the topside ionosphere, causing ionospheric upwelling. The upwelling ions are subject to additional heating through wave-particle interactions. The hot ions then constitute a significant mass outflow as they are transported into the magnetosphere through the magnetic mirror force. Since these ions include oxygen, the mass density is increased, and this can affect to the time-scale for magnetospheric processes through lowering the Alfvén speed, which could reduce the reconnection rate at the magnetopause, for example. Depending on the energy and source location for the outflowing ions, the ions may be trapped within the magnetosphere, or may escape to interplanetary space. This escape could be either direct, along lobe field lines, or indirect, through transport to the dayside magnetopause. Integrated outflow rates can be as high as 1026 ions/s, although average rates are more typically of the order 1024 – 1025 ions/s. What is less clear is what fraction of these ions ultimately escape, but we note that oxygen outflow rates for the unmagnetized planets Venus and Mars are of the same order. It is conventional wisdom that oxygen outflows at these planets corresponds to water loss, and further this is one of the reasons why Venus and Mars are dry. Related to this is the idea that the Earth's magnetic field shields the ionosphere from direct interaction with the solar wind, and the Earth has therefore not lost water from its atmosphere, unlike Venus and Mars. The magnetic shield is not total, however, as reconnection allows energy from the solar wind to flow into the polar ionosphere, driving the outflows. If a large fraction of the ions escaping from the Earth's ionosphere are ultimately lost, then, given that the Earth clearly has retained its water, we may need to revisit the concept that oxygen outflows at the unmagnetized planets are equivalent to water loss.

Thorne, Richard M.

How whistler-mode waves and thermal plasma density control the global distribution of diffuse auroral precipitation and the dynamical evolution of radiation belt electrons (Invited)

Thorne, Richard M.[1]

1. Department of Atmospheric and Oceanic Scioences, UCLA, Los Angeles, CA, USA

Whistler mode chorus emissions are excited as plasma sheet electrons are injected into the inner magnetosphere during geomagnetically active conditions. Recent theoretical analysis has demonstrated that the chorus emissions are primarily responsible for the precipitation of 100 eV - 30 keV electrons into the upper atmosphere and the global distribution of the diffuse and pulsating aurora. Chorus emissions can also cause local stochastic acceleration of the injected electron population to relativistic energies leading to peaks in relativistic electron phase space density in the heart of the radiation belts during magnetic storms. Such local acceleration is most effective when the solar wind dynamic pressure is low and when the thermal plasma density outside the plasmapause is reduced due to rapid magnetospheric convection. Following such acceleration the outward expansion of the plasmapause leaves the injected ultra-relativistic electron population electron in a relatively stable region where they can persist for months subject only to slow decay due to scattering by another whistler-mode emission called plasmaspheric hiss. Since natural whistler-mode emissions play such a fundamental role in controlling energetic electron dynamics in the Earth's magnetosphere, it is likely that similar processes could occur in other magnetized astrophysical objects, such as Jupiter and Saturn.

Varney, Roger

Review of global simulation studies of the effect of ionospheric outflow on the magnetosphere-ionosphere system dynamics (Invited)

Wiltberger, Michael J.[1]; Varney, Roger[1]

1. HAO, NCAR, Boulder, CO, USA

Since the detection of O^+ ions by satellites in the 1970s it has been known that the ionosphere is an important source of plasma in the Earth's magnetotail. More recent observations have shown that these ions can become a dominant component of the plasma in the plasmasheet. Early work in substorm research considered a role for O+ in the onset of plasma instabilities and their relationship to substorm onset. Theoretical analysis of reconnection in multi-fluid plasmas has shown that the presence of a heavy ion slows the reconnection rate raising interesting implications for the occurrence rate of substorms. Global scale simulations have been used to effectively model the interaction of the solar wind with the tightly coupled magnetosphere-ionosphere-thermosphere system. These models are now beginning to develop methods to include mass outflows from the ionosphere. Techniques for including these outflows include both empirical and first principle models. In the empirical techniques the relationship between observed parameters such as Poynting flux and outflow are used to specify both the location and intensity of the outflow coming from the cusp and auroral regions. First principle models of the polar wind typically use a large set of single flux tube simulations to describe the plasma flowing out over the entire polar cap. In both approaches significant impacts on the state of the magnetosphere are seen when the ionospheric plasma is included. These affects include improved agreement with Dst observations, changes in the cross polar cap potential, and alteration of the length of the magnetotail. Furthermore, some simulation results have demonstrated a role for O+ in the transition from steady magnetospheric convection into the sawtooth intervals containing multiple storage and release segments.

Varney, Roger H.

Modeling the Interaction Between Convection and Cusp Outflows

Varney, Roger H.[1]; Wiltberger, Michael[1]; Lotko, William[2]; Zhang, Binzheng[2]

1. High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO, USA
2. Dartmouth College, Hanover, NH, USA

The cusp/cleft ion fountain is a significant source of ion outflow coming from the dayside polar ionosphere. The conic ion distributions observed in this region indicate that these outflows involve transverse acceleration mechanisms that are challenging to model from first principles. Empirical relationships between magnetospheric inputs and the observed outflows are available, but these local relationships ignore any dependence of the outflows on the large-scale state of the ionosphere. The convection pattern determines the time a flux tube dwells in the cusp, and thus the time it is exposed to Joule heating, soft precipitation, and wave-particle heating. The convection also determines the centrifugal forces. We examine the interplay between these various processes using a polar wind model that includes a phenomenological treatment of transversely accelerated ions (TAIs) in the cusp. The TAIs are included as an extra fluid that obeys transport equations appropriate for a conic distribution. This model can be driven by inputs from the Coupled Magnetosphere Ionosphere Thermosphere (CMIT) model. We compare runs with identical precipitation and transverse heating inputs but with the high-latitude potentials scaled up and down. The characteristics of the modeled ion fountains are compared in terms of morphology, ion velocities and energies achieved, and ion fluxes.

Walker, Ray

Simulation Studies of Magnetosphere Ionosphere Coupling in Outer Planet Magnetospheres (Invited)

Walker, Ray[1, 2]; Fukazawa, Keiichiro[3]; Ogino, Tatsuki[4]

1. Department of Earth, Planetary and Space Sciences, University of California, Los Angeles, Los Angeles, CA, USA
2. National Science Foundation, Arlington, VA, USA
3. Research Institute for Information Technology, Kyushu University, Kyushu, Japan
4. Solar Terrestrial Environment Laboratory, Nagoya University, Nagoya, Japan

The magnetospheres of the giant outer planets Jupiter and Saturn are characterized by strong intrinsic magnetic fields, atmospherically driven corotation and plasma sources located within the magnetospheres. Compared to the Earth both planets rotate rapidly (~10 hours at Jupiter and ~11 hours at Saturn) and flows within the magnetosphere are driven toward corotation by coupling between the magnetosphere and the ionosphere. Field aligned currents driven by the atmosphere transmit stresses to the magnetosphere. In the magnetospheres the field aligned currents are closed by radial equatorial currents such that the resulting J×B force is in the direction to drive the magnetospheric plasma toward coronation. Rotational flows extend to the dayside magnetopause. In addition the magnetospheric plasma is dominated by heavy ions whose ultimate source is the volcanic moon Io at Jupiter and ice geysers on the moon Enceledus at Saturn. In this talk we will present results from a series of magnetohydrodynamic simulations of the solar wind magnetosphere and ionosphere systems at Jupiter and Saturn. Emphasis in the presentation will be on the current systems in the outer planet magnetospheres and their coupling to the ionosphere. Reconnection within the outer planets' magnetospheres can occur internally (Vasyliunas cycle) or driven by reconnection at the dayside magnetopause (Dungey cycle). We will examine the resulting current systems and closure in the ionosphere. In addition at Saturn we will consider the effects of Kelvin-Helmholz waves at the magnetopause and the corresponding currents into the ionosphere.

Welling, Daniel T.

Recent Advances in Ionosphere-Magnetosphere Mass Coupling in Global Models (Invited)

Welling, Daniel T.[1]

1. AOSS, Univ. of Michigan, Ann Arbor, MI, USA

Global magnetohydrodynamic models are valuable tools for investigating the magnetospheric system. However, for many years, they have neglected a dynamic, causal, ionospheric source of light and heavy ions. Numerous observations have demonstrated the importance of this source, especially during active periods. The omission of an ionospheric source represents a demonstrable contradiction with observable reality. Recent work by MHD modelers has rectified this shortcoming. Results of simulations that include ionospheric outflow demonstrate that this source doesn't merely add additional mass to the system, but affects nearly every aspect of solar-magnetosphere-ionosphere coupling. This paper presents recent MHD simulations using driven ionospheric outflow. The impacts on the magnetosphere and on magnetosphere-ionosphere coupling are analyzed and quantified. It is found that outflow of ionospheric plasma is tightly coupled to the non-linear global system.

Westlake, Joseph H.

The Coupling Problem at Titan: Where are the Magnetospheric Influences to Titan's Complex Ionosphere? (Invited)

Westlake, Joseph H.[1]; Mitchell, Donald G.[1]; Waite, Jack H.[2]; Luhmann, Janet G.[3]

1. Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA
2. Southwest Research Institute, San Antonio, TX, USA
3. University of California Berkeley, Berkeley, CA, USA

Since the arrival of Cassini to the Saturn system in 2004 the suite of in-situ and remote sensing instruments onboard have sampled Titan nearly 100 times. Even with this large number of samples the coverage in the multitude of geospatial, magnetospheric, solar, and seasonal configurations is rather sparse resulting in an incomplete understanding of the coupling (if present) between the complex ionosphere of Titan and Saturn's corotational magnetospheric plasma. Studies by the in-situ CAPS, INMS, and LP data have shown a clear ionospheric dependence on solar parameters, however several flybys show unique properties implying some magnetospheric influence manifest in rather abrupt heating events in the thermosphere. In this talk we review the Cassini observations from multiple instruments at Titan and attempt to piece together a cohesive picture of the Saturn magnetosphere-Titan ionosphere-Titan thermosphere interaction.

Withers, Paul

The morphology of the topside ionosphere of Mars under different solar wind conditions: Results of a multi-instrument observing campaign by Mars Express in 2010

Withers, Paul[1]

1. Boston University, Boston, MA, USA

Since the internally-generated magnetic field of Mars is weak, strong coupling is expected between the solar wind, planetary magnetosphere, and planetary ionosphere. However, few previous observational studies of this coupling incorporated data that extended from the solar wind to deep into the ionosphere. Here we use solar wind, magnetosphere, and ionosphere data obtained by the Mars Express spacecraft during March/April 2010, when Earth and Mars were aligned on the same branch of the solar wind's Parker spiral, to investigate this coupling. We focus on three pairs of ionospheric electron density profiles measured by radio occultations, where the two profiles in each pair were obtained from the same location only a few days apart. We find that high dynamic pressures in the solar wind are associated with compression of the magnetosphere, heating of the magnetosheath, and reduction in the vertical extent of the ionosphere. Identifiable ionopauses, or large, abrupt decreases in plasma density at the top of the ionosphere, are also associated with strong solar wind.

Wolf, Richard

Forty five years of the Rice Convection Model (Invited)

Wolf, Richard[1]; Spiro, Robert W.[1]; Stanislav, Sazykin Y.[1]; Toffoletto, Frank[1]; Yang, Jian[1]

1. Rice University, Houston, TX, USA

The concept behind the Rice Convection Model (RCM) dates back to an attempt, starting in the late 1960s, to mathematize an idea of Schield, Freeman, and Dessler that predicted the pattern of Birkeland currents in Earth's magnetosphere. The original version of the RCM was an elliptic solver that computed the ionospheric potential distribution by assuming a pattern of ionospheric Hall and Pedersen conductances, including day-night asymmetry and auroral enhancement. Ionospheric potential patterns were mapped along equipotential magnetic field lines to predict magnetosphere flow patterns and plasmasphere shapes. A key milestone was the inclusion, a few years later, of a simple mono-energetic plasma sheet and calculation of field-aligned currents resulting from pressure gradients in the magnetosphere. Results exhibited shielding of the inner magnetosphere from the full effects of magnetospheric convection and also predicted most basic characteristics of region-2 currents shortly before the currents were identified observationally. By the late 1970s, the plasma sheet in the RCM had a realistic energy spectrum of both ions and electrons and was exhibiting a number of features that were consistent with observations. Since the 1970s, the RCM has used time-varying magnetic field models, which further improved consistency with observations. A key discrepancy was the tendency for modeled region-2 currents to be too narrow in latitude. Another deep difficulty arose in the late 1970s, when we found that the observed average magnetic field configuration was inconsistent with the idea of simple sunward adiabatic convection in the plasma sheet (pressure balance inconsistency). A milestone, in the early 1980s, was the use of model-calculated electron precipitation from the plasma sheet to produce an approximation of the diffuse aurora and associated ionospheric conductance enhancement. Better prescriptions of plasma sources on the tailward boundary were shown to produce region-1 and Harang-discontinuity currents flowing on closed field lines. The RCM was adapted to treat interchange-driven transport in the Jovian magnetosphere, and that code was later applied to Saturn. In the late 1990s and early 2000s, we mated the RCM with an MHD-friction code, allowing us to keep the magnetic field in force balance with the RCM-computed particle pressure (RCM-E). A change in numerical methods in the early 2000s made it easy to vary the boundary-condition distribution function in both space and time, allowing investigation of interchange instability for Earth. We present new RCM-E results that include effects of bursty bulk flows as well as first attempts to simulate major discrete auroral features. Initial results suggest that the inclusion of these mesoscale features may help resolve two old conundrums: the pressure-balance inconsistency and latitude distribution of Birkeland currents. We will also address our present code development efforts aimed at including field-aligned electric fields and inertial currents. Forty-five years of work have yielded a numerical model that seems to represent most of the physics involved in large-scale coupling of the inner and middle magnetosphere with the ionosphere.

Yau, Andrew W.

Measurements of Ion Outflows from the Earth's Ionosphere (Invited)

Yau, Andrew W.[1]; Peterson, William K.[2]; Abe, Takumi[3]

1. Physics and Astronomy, University of Calgary, Calgary, AB, Canada
2. LASP, University of Colorado, Boulder, CO, USA
3. ISAS, JAXA, Sagamihara, Japan

Since the pioneering observation of Shelley et al. shortly before the first Yosemite space physics meeting, observations from several satellites and from sounding rockets and ground-based radar have contributed to shape our present view of ionospheric ion outflows and their central role in magnetosphere-ionosphere-thermosphere coupling. This view comprises of two categories of outflow populations: thermal outflows, including the polar wind and auroral bulk ion up-flow, and suprathermal ion outflows, including ion beams, ion conics, transversely accelerated ions and upwelling ions – with the former constituting an important source of low-energy plasma for the latter at higher altitudes. Both ion outflow categories are strongly influenced by the solar EUV irradiance and solar wind energy input and the state of the magnetosphere-ionosphere-thermosphere. In this talk, we will focus on the interconnection between different outflow populations and the gaps in our current knowledge on this interconnection.

Yu, Yiqun

Studying Subauroral Polarization Streams (SAPS) During the March 17, 2013 Magnetic Storm: Comparisons between RAM Simulations and Observations (Invited)

Yu, Yiqun[1]; Jordanova, Vania[1]; Zou, Shasha[2]

1. Los Alamos National Laboratory, Los Alamos, NM, USA
2. University of Michigan, Ann Arbor, MI, USA

The subauroral polarization streams (SAPS) are one of the most important features in characterizing magnetosphere-ionosphere coupling processes. In this study, we simulate one SAPS event during the March 17, 2013 storm event using the inner magnetosphere model RAM-SCB two-way coupled with the global MHD model BATS-R-US. Both ionospheric and magnetospheric signatures are analyzed and compared to observations including global convective maps from SuperDARN, cross-track ion drift from DMSP, AMPERE, and in-situ observations from the recently launched Van Allen Probes (RBSP). Parametric study of the boundary conditions for the inner magnetosphere RAM is also carried out to demonstrate the effect on the strength and evolution of

SAPS. Results indicate that the model can reasonably capture the global feature of SAPS but their spatial distribution (e.g., latitudinal location and width) can be influenced by model parameters. A self-consistent electric field coupling between the inner magnetosphere model and an ionospheric potential solver appears to be an important factor.

Zou, Shasha

Formation of Storm Enhanced Density (SED) during Geomagnetic Storms: Observation and Modeling Study (Invited)

Zou, Shasha[1]; Ridley, Aaron J.[1]; Moldwin, Mark B.[1]; Nicolls, Michael J.[2]; Coster, Anthea J.[3]; IIie, Raluca[1]; Liemohn, Michael W.[1]; Thomas, Evan[4]; Ruohoniemi, J. Michael[4]

1. Department of Atmospheric, Oceanic and Space Sciences, University of Michigan, Ann Arbor, MI, USA
2. Center for Geospace Studies, SRI Internaitonal, Menlo Park, CA, USA
3. Haystack Observatory, Massachusetts Institute of Technology, Westford, MD, USA
4. Department of Electrical & Computer Engineering, Virginia Tech, Blacksburg, VA, USA

Ionospheric density often exhibits significant variations, which affect the propagation of radio signals that pass through or are reflected by the ionosphere. One example of these effects is the loss of phase lock and range errors in Global Navigation Satellite Systems (GNSS) signals. Because our modern society increasingly relies on ground-to-ground and ground-to-space communications and navigation, understanding the sources of the ionospheric density variation and monitoring its dynamics during space weather events have great importance. Storm-enhanced density (SED) is one of the most prominent ionospheric density structures that can have significant space weather impact. In this presentation, we present multi-instrument observations and modeling results of the SED events, focusing on the formation processes. Formation and the subsequent evolution of the SED and the mid-latitude trough are revealed by global GPS vertical total electron content (VTEC) maps. High time resolution Poker Flat Advanced Modular Incoherent Scatter Radar (PFISR) observations are used to reveal the ionospheric characteristics within the SED when available. In addition, field-aligned current data from Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) and large-scale convection flow pattern measured by the Super Dual Auroral Radar Network (SuperDARN) will also be used to provide large-scale context. Based on these observations, we will discuss the role of energetic particle precipitation, enhanced thermospheric wind, and enhanced convection flows, including subauroral polarization streams (SAPS), in creating the SED. In the modeling part, we use the Global Ionosphere Thermosphere Model (GITM) to study the SED formation. Various high-latitude drivers, such as the potential patterns from the Weimer model, outputs from the Assimilative Mapping of Ionospheric Electrodynamics (AMIE) and the Hot Electron Ion Drift Integrator Model (HEIDI) are used to drive GITM. Effects of different drivers as well as different physical processes on creating SEDs are assessed.