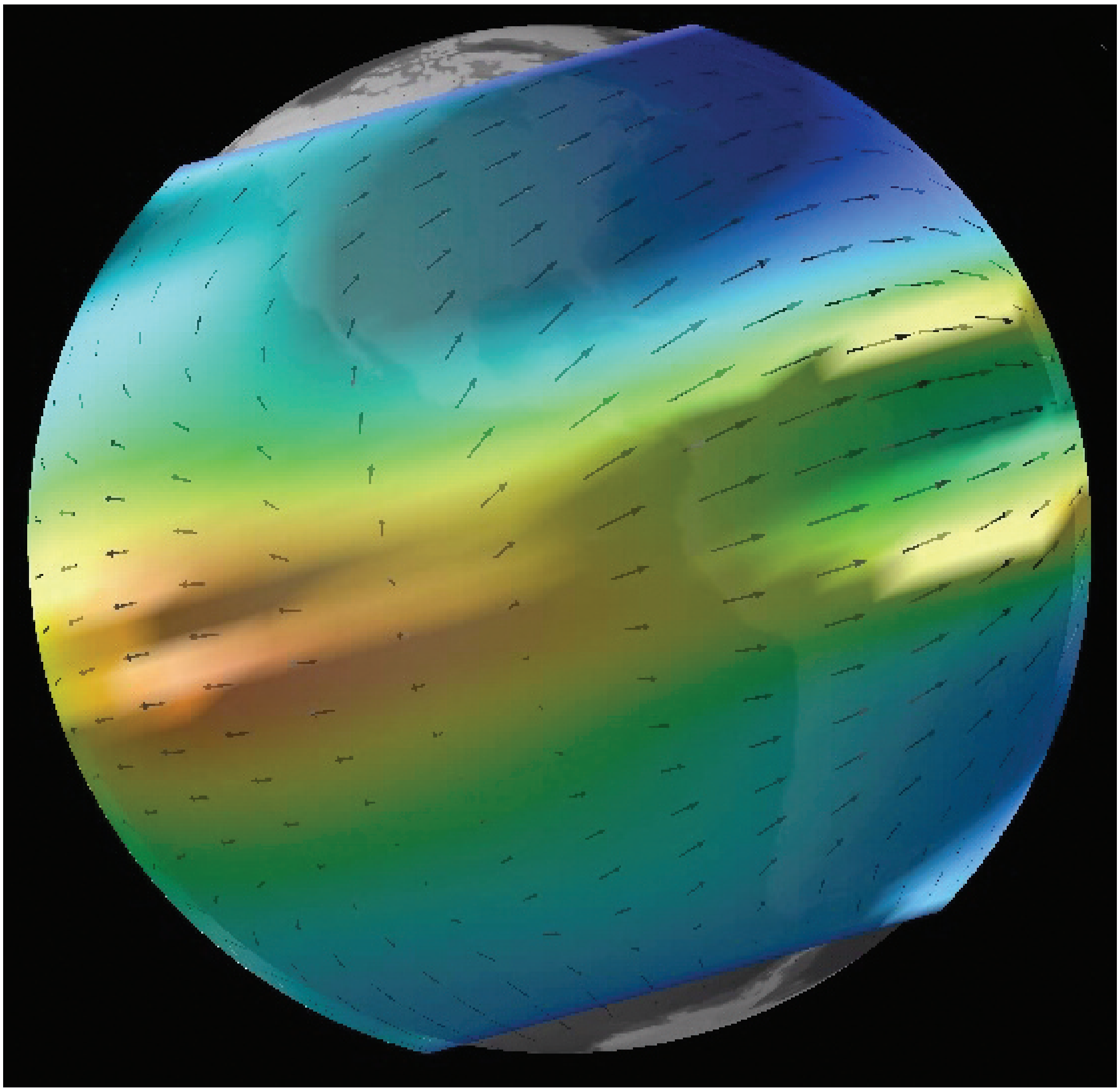
Modeling the Ionosphere/ Thermosphere System



American Geophysical Union Chapman Conference

Charleston, South Carolina, USA

9 - 12 May 2011

AGU Chapman Conference on Modeling the Ionosphere/Thermosphere System

Charleston, South Carolina, USA
9 - 12 May 2011

Conveners

J. D. Huba, Naval Research Laboratory
R. W. Schunk, Utah State University
A. Ridley, University of Michigan

Program Committee

Art Richmond, NCAR HAO
Geoff Crowley, ASTRA
Tim Fuller-Rowell, CIRES
Dave Hysell, Cornell University
Michael Mendillo, Boston University
Hermann Luehr, GFZ Potsdam
Rod Heelis, University of Texas at Dallas

Financial Support

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Cover photo

Simulation of the Earth's ionosphere showing the vertical total electron content (TEC) (color contours) and the F region neutral wind (vectors). The results are obtained from the NRL ionosphere model SAMI3.

AGU Chapman Conference on Modeling the Ionosphere/Thermosphere System

Meeting At A Glance

Sunday, 8 May 2011

1800h – 1930h	Icebreaker

Monday, 9 May 2011

0845h – 0900h	Welcome and Introductory Comments
0900h – 1040h	Physical Processes and Numerical Methods
1040h – 1100h	Break
1100h – 1210h	Physical Processes and Numerical Methods (continued)
1210h – 1230h	Discussion
1230h – 1400h	Lunch
1400h – 1540h	Physical Processes and Numerical Methods (continued)
1540h – 1600h	Break
1600h – 1710h	Physical Processes and Numerical Methods (continued)
1710h – 1730h	Discussion

Tuesday, 10 May 2011

0900h – 1040h	Ionosphere/Thermosphere Models
1040h – 1100h	Break
1100h – 1210h	Ionosphere/Thermosphere Models (continued)
1210h – 1230h	Discussion
1230h – 1400h	Lunch
1400h – 1540h	Response From Forcings Below and Above
1540h – 1600h	Break
1600h – 1710h	Response From Forcings Below and Above (continued)
1710h – 1730h	Discussion
1730h – 1900h	Poster Presentations and Reception

Wednesday, 11 May 2011

0900h – 1030h	Irregularities
1030h – 1100h	Break
1100h – 1210h	Data Assimilation Models
1210h – 1230h	Discussion
1230h – 1400h	Lunch
1400h – 1530h	Metrics and Validation
1530h – 1550h	Break
1550h – 1640h	Metrics and Validation (continued)
1640h – 1700h	Discussion
1800h – 2000h	Conference Banquet

Thursday, 12 May 2011

0900h – 0930h	Space Weather Discussion
0930h – 1030h	Future IT Directions
1030h – 1100h	Break
1100h – 1200h	Panel Discussion – Future of IT Modeling

SCIENTIFIC PROGRAM

SUNDAY, 8 MAY

1800h – 1930h **Conference Icebreaker**

MONDAY, 9 MAY

Welcome
Presiding: Joseph D. Huba
Carolina Ballroom

Physical Processes and Numerical Methods
Presiding: Rod Heelis, David Hysell
Carolina Ballroom

0900h – 0930h **Robert W. Schunk** | Ionosphere-Thermosphere Physics: Current Status and Problems

0930h – 1000h **Philip G. Richards** | Photochemistry and Energetics of the Ionosphere and Thermosphere (*Invited*)

1000h – 1020h **Steven L. Guberman** | The Dissociative Recombination of N_2^{+*}

1020h – 1040h **Roger H. Varney** | Modeling Photoelectron Transport and Nonlocal Heating in the Low Latitude Ionosphere

1040h – 1100h Morning Break

1100h – 1130h **Alan G. Burns** | Energetics and composition in the thermosphere (*Invited*)

1130h – 1150h **Larry C. Gardner** | Charge Exchange in the Mid- to Low-Latitude Ionosphere and its Impacts on the Thermosphere

1150h – 1210h **Feng Tian** | Thermospheres and Ionospheres of Terrestrial Planets under Intense Solar EUV

1210h – 1230h Discussion

1230h – 1400h Lunch

1400h – 1430h **Joseph D. Huba** | Numerical Methods in Ionospheric Modeling

1430h – 1500h **Arthur D. Richmond** | Modeling Ionospheric Electrodynamics (*Invited*)

1500h – 1520h **Paul Song** | Magnetosphere-Ionosphere/Thermosphere Coupling: A Structured Ionosphere with Self-consistent Electromagnetic Fields

1520h – 1540h	**Maxim V. Klimenko** | The problems and advances in numerical simulation of thermosphere/ionosphere response to the geomagnetic storms
1540h – 1600h	Afternoon Break
1600h – 1630h	**Astrid I. Maute** | The Ionospheric Electrostatic Potential (*Invited*)
1630h – 1650h	**Glenn Joyce** | Modeling Global Ionosphere Electrodynamics
1650h – 1710h	**Joseph Werne** | Three Dimensional Modeling of Neutral Turbulence from Strong Shears in the Mesosphere and Lower Thermosphere
1710h – 1730h	Discussion

TUESDAY, 10 MAY

Ionosphere/Thermosphere Models

Presiding: Aaron J. Ridley
Carolina Ballroom

0900h – 0930h	**Geoffrey Crowley** | Overview of the Universe of Ionosphere-Thermosphere Models
0930h – 1000h	**Timothy J. Fuller-Rowell** | Physical Characteristics of the Thermosphere(*Invited*)
1000h – 1020h	**Yue Deng** | Simulation of neutral density enhancement in the cusp region
1020h – 1040h	**Paul A. Bernhardt** | Modeling of Disturbances in the Upper Atmosphere With the Direct Simulation Monte Carlo (DSMC) Method
1040h – 1100h	Morning Break
1100h – 1130h	**Tzu-Wei Fang** | Equatorial-PRIMO (Problems Related to Ionospheric Models and Observations) (*Invited*)
1130h – 1150h	**Alan Burns** | NCAR/TIEGCM: Model Description, Development, and Validation
1150h – 1210h	**Naomi Maruyama** | Response of the coupled IT system to storm time ionospheric electrodynamics
1210h – 1230h	Discussion
1230h – 1400h	Lunch

Response From Forcings Below and Above

Presiding: Art Richmond
Carolina Ballroom

1400h – 1430h	**Roderick Heelis** | A Perspective on Coupling in the Ionosphere Thermosphere

1430h – 1500h	**Rashid A. Akmaev** | Dynamical Coupling between the Lower and Upper Atmosphere in Whole Atmosphere Models (*Invited*)
1500h – 1520h	**David E. Siskind** | Coupling the NRL NOGAPS-ALPHA model to the NCAR TIEGCM
1520h – 1540h	**Elsayed R. Talaat** | Spatial and temporal variability of the ionosphere as revealed by modal decomposition
1540h – 1600h	Afternoon Break
1600h – 1630h	**Aaron J. Ridley** | Magnetospheric Coupling to Ionosphere/Thermosphere Models (*Invited*)
1630h – 1650h	**Stanislav Sazykin** | Simulation Studies of Storm-Time Ionospheric Electrodynamics
1650h – 1710h	**Sebastian Heidenreich** | Relationships between solar wind parameters and the total electron content (TEC)
1710h – 1730h	Discussion
1730h – 1900h	**Poster Presentations and Reception** Carolina Ballroom
T-1	**Tzu-Wei Fang** | Impact of Atmospheric Tides on Ionosphere-Thermosphere System
T-2	**Chandrakant T. More** | Studies on Effects of Solar Activities on VLF Radio Wave Propagation at 19.8 KHz
T-3	**Sheetal Karia** | A Comparision of GPS-TEC data at Surat with IRI-2007 Models for the year 2009
T-4	**David N. Anderson** | Modeling the Daytime, Equatorial Ionospheric Ion Densities Associated with the Observed, 4-cell Longitude Patterns in ExB Drift Velocities
T-5	**Daniel R. Weimer** | Better Predictions of Thermospheric Density From an Empirical Model
T-6	**Jean-yves Chaufray** | 3D GCM-Ionosphere model to describe the Martian ionospheric dynamics and its coupling with neutral atmosphere
T-7	**Maxim V. Klimenko** | Global distribution of the hot O in the earth's atmosphere and its effect on thermosphere and ionosphere parameters
T-8	**Jiannan Tu** | A Self-consistent Dynamic Magnetosphere-Ionosphere/Thermosphere Coupling Model
T-9	**Cheryl Y. Huang** | Tidal structures in the equatorial ionosphere
T-10	**Jan J. Sojka** | Ionospheric Flare Modeling: A New Paradigm
T-11	**Chin S. Lin** | Validation of Low Altitude Neutral Density Modeling

T-12 **Delores J. Knipp** | Poynting Flux: A Statistical View From the DMSP F-15 Satellite

T-13 **Miguel Larsen** | Large winds in the lower thermosphere: Analysis of a TIME-GCM run with enhanced height resolution

T-14 **Andrew C. Nicholas** | WINCS: an instrument suite for Simultaneous Multi-Point Thermospheric/Ionospheric Measurements

T-15 **Jean-Yves Chaufray** | Study of the Martian ionosphere with a ground-to-thermosphere General Circulation Model

T-16 **Frederick D. Wilder** | Interhemispheric Observations of Dayside Convection Under Strongly Northward IMF

T-17 **Ingrid Cnossen** | Modeling the effects of changes in the Earth's magnetic field on the thermosphere-ionosphere system

T-18 **Yi-Jiun Su** | Low-latitude background ionospheric density structures during solar minimum obtained by AFRL physics-based model

T-19 **Liam M. Kilcommons** | Trends in Poynting Flux with IMF Variation and their Association with Neutral Density Enhancements

T-20 **Jung Soo Kim** | Helium effect on the Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM) simulation

T-21 **John Noto** | Sensitive, Automated, and Web-aware Interferometers with Unified Analysis of F-region Dynamics at Upper Atmospheric Facilities

T-22 **Sarah E. McDonald** | Long-term Simulations of the Ionosphere Using SAMI3

T-23 **Joseph Comberiate** | Coordinated Observations of Equatorial Plasma Bubbles, Ionospheric Drift Rates, and Scintillation

T-24 **Elsayed R. Talaat** | Solar rotational effects in the ionosphere

T-25 **Robert F. Pfaff** | On Incorporating Continuous Electric field and Plasma Density Probe Data from the C/NOFS Satellite in Models

T-26 **Xiaoqing Pi** | Estimating Dynamical Forces of the Ionosphere Using GAIM

WEDNESDAY, 11 MAY

Irregularities

Presiding: Robert Schunk
Carolina Ballroom

0900h – 0930h **David L. Hysell** | Ionospheric Irregularities

0930h – 0950h **Jonathan Krall** | Three-Dimensional Simulation of Equatorial Spread-F: Numerical Descriptions of Physical Phenomena

0950h – 1010h **Henrique C. Aveiro** | Three-dimensional simulation of equatorial spread F: modeling scheme and results

1010h – 1030h **Tatsuhiro Yokoyama** | Modeling Nighttime Medium-scale Traveling Ionospheric Disturbances and E-F/Hemispheric Coupling in the Midlatitude Ionosphere

1030h – 1100h Morning Break

Data Assimilation Models

Presiding: Robert Schunk
Carolina Ballroom

1100h – 1130h **Ludger Scherliess** | Data Assimilation Techniques and Their Use for Ionospheric Science and Applications

1130h – 1150h **Tomoko Matsuo** | Upper Atmospheric Data Assimilation with an Ensemble Kalman Filter

1150h – 1210h **Gary Bust** | Scientific Investigations using IDA4D and EMPIRE

1210h – 1230h Discussion

1230h – 1400h Lunch

Metrics and Validation

Presiding: Geoff Crowley
Carolina Ballroom

1400h – 1430h **Claudia Stolle** | Low latitude ionospheric/thermospheric observations of the CHAMP satellite in comparison with physics-based models (*Invited*)

1430h – 1450h **John W. Meriwether** | Comparison of Equatorial Thermospheric Winds with the WAM and HWM Model Predictions for Solar Minimum Activity

1450h – 1510h **Carl L. Siefring** | Integrating the Sun-Earth System (ISES): Comparisons of the SAMI3 Physics Based Ionosphere Model with Global Ionosonde and GPS Observations during Solar Minimum

1510h – 1530h **Miguel Larsen** | Vertical velocities in the thermosphere: An overview of observations and implications for dynamics and modeling

1530h – 1550h Afternoon Break

1550h – 1620h **Masha Kuznetsova** | Systematic Assessment of Ionosphere/Thermosphere Models Using Metrics (*Invited*)

1620h – 1640h **Jan J. Sojka** | EISCAT Svalbard Radar (ESR) Year Long IPY Observations: A Model Climate Variability Study

1640h – 1700h Discussion

1800h – 2000h Conference Banquet

Gold Ballroom

THURSDAY, 12 MAY

0900h – 0930h	**Space Weather Discussion**
	Future IT Directions **Presiding: Tim Fuller-Rowell** Carolina Ballroom
0930h – 1000h	**Robert F. Pfaff** | Understanding Geospace on a Grand Scale: The Global Ionosphere/Thermosphere Constellation
1000h – 1030h	**Joshua L. Semeter** | Accessing the hidden states of the ITM system (*Invited*)
1030h – 1100h	Break
1100h – 1200h	Panel Discussion - Future of IT Modeling

ABSTRACTS

listed by name of presenter

Akmaev, Rashid A.

Dynamical Coupling between the Lower and Upper Atmosphere in Whole Atmosphere Models (*Invited*)

Akmaev, Rashid A.[1]

1. NOAA SWPC, Boulder, CO, USA

In a stably stratified atmosphere, perturbations such as flow over topography or diurnally varying solar heating, generate internal buoyancy (aka gravity) waves propagating vertically. Hydrostatic balance between gas pressure and planet's gravity results in an exponential decrease of mass density with altitude. Momentum conservation then requires amplitudes of the waves propagating upward to grow exponentially in the absence of dissipation and wavelike signals become easily detectable. As the large-amplitude waves inevitably begin to dissipate via non-linear interactions and overturning or molecular viscosity and heat conduction, they also impose forcings on the mean flow and structure in the upper atmosphere. Buoyancy waves generated in the lower atmosphere at various scales from global to mesoscale, such as solar tides or "regular" gravity waves, are thus the primary mechanism of the upward coupling. Their signatures have long been observed in the upper atmosphere and ionosphere but new observational evidence has just exploded during the last decade. "Nonmigrating" wavy structures seen in the F-layer ionosphere and in thermosphere neutral densities, and a dramatic response of plasma densities and drifts to sudden stratospheric warmings are just a few recent examples. These long-distance dynamical links are most naturally represented, studied, and potentially predicted with "whole atmosphere models" as outlined in a visionary program advanced by Roble (2000) at the turn of the millennium. The state of the art in this new field will also be briefly reviewed.

Anderson, David N.

Modeling the Daytime, Equatorial Ionospheric Ion Densities Associated with the Observed, 4-cell Longitude Patterns in ExB Drift Velocities

Araujo-Pradere, Eduardo A.[1]; Anderson, David N.[1]; Fang, Tzu-Wei[1]; Fedrizzi, Mariangel[1]

1. CIRES, University of Colorado, Boulder, CO, USA

It has been established from the C/NOFS Ion Velocity Meter (IVM) observations that there exist very sharp longitude gradients in daytime, vertical ExB drift velocities that define the boundaries of the 4-cell, non-migrating, ExB drift structures. These sharp gradients exist on a day-to-day basis. For example, for October 5, 6 and 7, 2009 in the Atlantic sector, the ExB drift velocity gradient is about 1/m/sec/degree while for March 23, 24 and 25, 2009 in the Peruvian sector it is about -4m/sec/degree. At the 2010 Fall AGU meeting, a paper was presented that demonstrated that IVM ion density observations, on a day-to-day basis, reflected the close connection between daytime ExB drifts, their sharp longitude gradients and the magnitude of the Equatorial Ionospheric Anomaly (EIA) ion densities. The periods of observations were for October, November and March, 2009 between 1000 and 1500 LT and the altitudes of the IVM observations were between 400 and 500 km. While sharp gradients in ionospheric parameters such as TOPEX/TEC, and CHAMP/ Ne values have been associated with the 4-cell patterns, these are quantities that have been averaged over months and years. This paper presents theoretically-calculated ion densities as a function of altitude, latitude, longitude and local time incorporating the observed IVM ExB drift velocities for the October, March, and December, 2009 periods. The theoretical model that has been used is the Global Ionosphere and Plasmasphere (GIP) model which has been shown to give realistic, daytime ion density distributions. We compare the calculated ion densities with the observed, IVM ion densities and establish that sharp longitude gradients in ExB drift velocities are responsible for the sharp EIA ion density gradients deduced from IVM observations.

Aveiro, Henrique C.

Three-dimensional simulation of equatorial spread F: modeling scheme and results

Aveiro, Henrique C.[1]; Hysell, David L.[1]

1. Earth and Atmospheric Sciences, Cornell University, Ithaca, NY, USA

A fully 3D numerical scheme for the postsunset equatorial ionosphere dynamics leading to equatorial spread F (ESF) is described. First, the electrostatic ionospheric potential is self-consistently solved using the BiConjugate Gradient Stabilized (BiCGSTAB) method by enforcing the constraints of quasineutrality and momentum conservation for atomic (O+) and molecular (NO+ and O2+) species. Second, the simulation advances the plasma number density based on a discretized version of the continuity equation using a flux assignment scheme based on the total variation diminishing (TVD) condition. Simulations are performed incorporating realistic background circulation including bottomside shear flow and strong vertical current. To initialize the model runs, we derive plasma number densities from the Parameterized Ionospheric Model (PIM), ionospheric composition estimates from the IRI-2007 model, and the characteristics of the neutral atmosphere from the NRL-MSISE00 model. The results are compared to satellite, radar, and airglow observations, and reproduce several important characteristics of equatorial spread F.

Bernhardt, Paul A.

Modeling of Disturbances in the Upper Atmosphere With the Direct Simulation Monte Carlo (DSMC) Method

Bernhardt, Paul A.[1]; Kaplan, Carolyn[1]

1. Naval Research Laboratory, Alexandria, VA, USA

The neutral densities and temperatures of the upper atmosphere may be modeled with either fluid or kinetic techniques. The fluid descriptions are appropriate if the neutral velocity distributions are Maxwellian and if the scale lengths are much larger than the mean-free-paths. Collisionless models are used for short spatial scales and long mean free paths. A kinetic treatment is required for velocity distribution descriptions in the transition between collision dominated and collisionless regions. Boltzmann equation solvers or direct simulation Monte Carlo (DSMC) method are kinetic techniques that may be used when the density gradients in the neutral atmosphere range from smaller than to larger than the ambient mean free path. Boltzmann solvers provide multi-dimensional descriptions of neutral velocity distributions that are translated into fluid properties by velocity-space moments. In complex fluids that span the full range of mean-free-paths, DSMC may provide the best description of density, velocity and temperature in the atmosphere. DSMC uses a small fraction of the total particles in cells to represent the medium. DSMC has been used to simulate the interactions of Space Shuttle exhaust plumes with the upper atmosphere. The simulations were carried out with a two-dimensional, time dependent DSMC code that uses variable hard sphere (VHS) particles with the modified no-time-counter scheme to select collision pairs, and includes translational-rotational energy exchange. The computational domain spans an area of 400 km in width by 200 km in height. These calculations do not include the shuttle engine source geometry, because the size of the Space Shuttle and engine nozzle is negligible in relation to the computational domain, and we are not investigating spacecraft contamination. The background atmosphere includes the species O, O2 and N2 whose concentrations and temperatures are altitude-dependent, and are initially provided with the NRL mass spectrometer incoherent scatter (MSIS) radar model. MSIS describes the concentration and temperature of the neutral atmosphere from the surface to the lower exosphere, as a function of date, time, altitude, latitude, longitude, solar flux and magnetic index. During the initialization subroutine, the DSMC code calls MSIS to calculate the macroscopic concentration and temperature in each computational cell, and then generates particles sampled from a Maxwellian distribution. The DSMC model shows large area disturbances initiated by the firing of the Space Shuttle orbital maneuver subsystem (OMS) engines. A ten second burn of two OMS engines deposits 200 kg of exhaust into the upper atmosphere. This exhaust displaces the ambient atmosphere at 300 km altitude leaving a neutral density depression covering 200 km in horizontal range. The hypersonic exhaust heats the neutral gas to over 10,000 K temperature and produces neutral winds of over 10 km/s. This disturbance in the ionosphere can drive plasma instabilities in the ionosphere. Both neutral waves and ionospheric turbulence can be triggered by the artificial injection of rocket exhaust. The DSMC model provides the source description for plasma models of this turbulence.

Burns, Alan G.

Energetics and composition in the thermosphere (*Invited*)

Burns, Alan G.[1]; Wang, Wenbin[1]; Solomon, Stanley C.[1]; Qian, Liying[1]

1. NCAR, Boulder, CO, USA

The thermosphere is defined by the high temperatures that occur in its upper regions. These high temperatures result from the absorption of energetic EUV radiation combined with weak in situ cooling. Heat is eventually lost from the upper thermosphere primarily through downward heat conduction. This heating and cooling is modified through a variety of processes, the most important of which are heating by compression and cooling by expansion. These thermal processes help to drive the dynamics of the thermosphere, which, in turn, are a major cause of changes in neutral composition. In this presentation we examine all of these thermal and compositional processes globally to describe their variations with season, time of the day and location on the Earth. We also consider the global changes in heating and composition that arise as a result of high latitude energy inputs during geomagnetic storms and ways that we can gain a better understanding of these processes

Burns, Alan

NCAR/TIEGCM: Model Description, Development, and Validation

Qian, Liying[1]; Solomon, Stan[1]; Richmond, Art[1]; Foster, Ben[1]; Burns, Alan[1]; Wang, Wenbin[1]; Emery, Barbara[1]; Maute, Astrid[1]; Liu, Hanli[1]; Lu, Gang[1]; Wiltberger, Mike[1]; Wu, Qian[1]; McInerney, Joe[1]; Luan, Xiaoli[1]

1. National Center for Atmospheric Research, Boulder, CO, USA

NCAR/TIEGCM (National Center for Atmospheric Research thermosphere-ionosphere-electrodynamics general circulation model) is a time-dependent, three-dimensional model that solves the fully coupled, nonlinear, hydrodynamic, thermodynamic, and continuity equations of the neutral gas self-consistently with the ion energy, ion momentum, and ion continuity equations. In this presentation, we will introduce physical and numerical aspects of this model such as its equations, external forcing, boundary conditions, numerical techniques, and electrodynamic coupling of the thermosphere. We will then show a brief history of the model development. Finally, we will discuss model validations using thermosphere and ionosphere measurements such as satellite drag data, neutral density data from CHAMP, ground-based incoherent scatter radar measurements, satellite measurements by the constellation observing system for meteorology, ionosphere and climate (COSMIC), and ground-based GPS data.

Bust, Gary

Scientific Investigations using IDA4D and EMPIRE

Bust, Gary[1]; Datta-Barua, Seebany[2]

1. ASTRA, La Conner, WA, USA
2. Department of Aviation and Technology, San Jose State University, San Jose, CA, USA

Ionospheric Data Assimilation Four Dimensional (IDA4D) is an ionospheric data assimilation algorithm that has been in development for over 15 years. IDA4D takes in a wide variety of data sources, and provides a 3DVAR maximum likelihood estimate of the log of the electron density, along with a formal estimate of the 1-sigma error levels. Estimating Model Parameters from Ionospheric Reverse Engineering (EMPIRE) is a novel estimation technique that inputs a 4D distribution of electron density, plus errors, from IDA4D and by using the continuity equation as a constraint equation, estimates the ionospheric drivers responsible for the 4D distribution of electron density. In particular, EMPIRE has been shown to provide accurate estimates of field-aligned and field-perpendicular drifts during major magnetic storms. Both of these algorithms have been extensively validated over the years. This presentation will begin with a brief review of IDA4D and EMPIRE, and then it will show some validation results for both algorithms. The presentation will then present results from three different scientific investigations. First, IDA4D and EMPIRE will be used to investigate the mid-latitude response of major magnetic storms, focusing on the relative importance of field-aligned drifts (primarily neutral winds) and field-perpendicular drifts in determining the time-evolving distribution of electron density. As an example, Figure 1 presents 6 images of re-integrated vertical TEC from IDA4D over the US sector for November 20, 2003. Second, IDA4D and EMPIRE will be used to investigate conjugate studies between the northern and southern high-latitude ionospheres. With the focus on the large scale F-region horizontal plasma structuring. Finally the talk will focus on comparisons of IDA4D re-integrated TEC as a function of latitude, longitude and time and comparisons with first principle model predictions of TEC. IDA4D will not only provide data-driven estimates of vertical TEC on the same grid and through the same altitude range as the model, it will also provide an estimate of TEC error (error bars) on its results so that quantitative comparisons can be made.

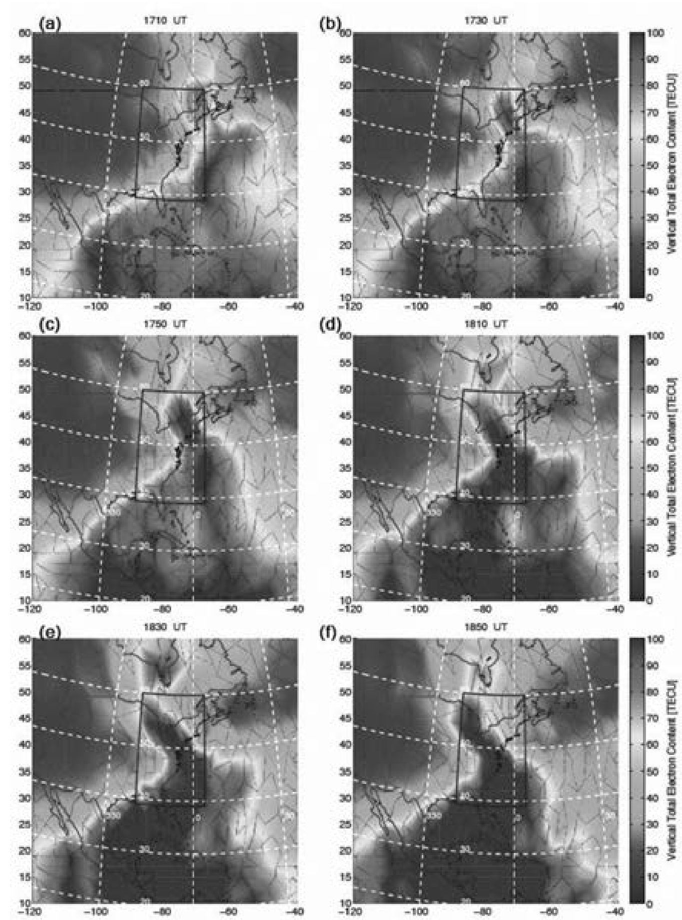

Figure 1: IDA4D TEC on 20 November 2003

Chaufray, Jean-yves

3D GCM-Ionosphere model to describe the Martian ionospheric dynamics and its coupling with neutral atmosphere

Chaufray, Jean-yves[1]; Gonzales-Galindo, Francisco[2]; Forget, François[1]; Lopez-Valverde, Miguel[2]; Leblanc, François[3]; Modolo, Ronan[3]; Yagi, Manabu[3]; Blelly, Pierre-Louis[4]; Witasse, Olivier[5]

1. LMD, Paris, France
2. IAA-CSIC, Granada, Spain
3. LATMOS, Guyancourt, France
4. CESR, Toulouse, France
5. ESA-ESTEC, Noordwijk, Netherlands

Recent observations and simulations showed the importance of the upper atmosphere/ionosphere in the escape processes at Mars. The solar wind interacts with the Martian ionosphere leading to an ionospheric outflow into the Martian induced magnetosphere. In the frame of the HELIOSARES project (PI F. Leblanc), we will present the 3D dynamical ionospheric core implemented in the Martian GCM model developed at LMD. This core solves the ions and electrons dynamics equations including the interaction with the neutral atmosphere and taking into account the effect of polarization electric field due to electronic pressure. The numerical approach used to solve the dynamics equations and the first results of this model will be presented as well as the future improvements.

Chaufray, Jean-Yves

Study of the Martian ionosphere with a ground-to-thermosphere General Circulation Model

Gonzalez-Galindo, Francisco[1]; Chaufray, Jean-Yves[2]; Lopez-Valverde, Miguel Angel[1]; Gilli, Gabriella[1]; Forget, Francois[2]; Leblanc, Francois[3]

1. Instituto de Astrofisica de Andalucia/CSIC, Granada, Spain
2. Laboratoire de Meteorologie Dynamique/IPSL, Paris, France
3. LATMOS/IPSL, Paris, France

Although the Martian ionosphere is much less known than its terrestrial counterpart, data from recent missions like Mars Global Surveyor (1997-2006), Mars Oddyssey (2001-) and Mars Express (2003-) are providing an increasingly complete vision of its main characteristics. In particular, it has been shown that the Martian ionosphere is influenced both by external factors, such as the solar EUV flux and the presence of crustal magnetic fields, as well as by the 3-D structure and variability of the underlying neutral atmosphere. A General Circulation Model (GCM) is a very useful tool to study the ionosphere, since predicted variations (spatial and temporal) in the temperature and composition of the neutral atmosphere are calculated and their effects on the ionosphere straightforwardly taken into account. The LMD-Mars GCM is a model that self-consistently studies the thermal structure, the dynamics and the composition of the Martian atmosphere from the ground up to the exosphere. One of its components is a photochemical model that considers 26 species (including thermal electrons and 9 ions) and 85 reactions between them, including photodissociation and photoionization. A parameterization to calculate the secondary ionization by photoelectrons is also included. While ions are transported by the general circulation, no plasma transport processes are included in the model at this stage, which limits its validity to the photochemically dominated region, below about 200 km altitude. However, a model extension which solves the ions and electrons dynamics is under development. This will allow for a correct description of the upper layers of the ionosphere, and the coupling of this ionospheric/thermospheric model with an exospheric and a Mars-solar wind interaction model. We will present the results of a simulation for a full Martian year performed with the LMD-MGCM, and their comparison with different observational datasets. The major characteristics of the Martian ionosphere as obtained by the different Mars missions are well simulated by our model. In agreement with observations, O_2^+ and not CO_2^+ is the dominant ion at all altitudes below 200 km in our model. We will show how the altitude and density of the main ionospheric peak changes during the Martian year due to the variation of pressure produced by the inflation/contraction of the background neutral atmosphere with seasons and the eccentricity of the Martian orbit.

Cnossen, Ingrid

Modeling the effects of changes in the Earth's magnetic field on the thermosphere-ionosphere system

Cnossen, Ingrid[1]; Richmond, Arthur[1]; Wiltberger, Mike[1]; Schmitt, Peter[1]; Wang, Wen-Bin[1]

1. High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO, USA

In the past we have modeled the effects of changes in the Earth's magnetic field on the ionosphere using the NCAR Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM). Changes that occurred from 1957 to 1997 were found to have a substantial effect on the F2 layer peak height hmF2 (up to ±20 km) and critical frequency foF2 (up to ±0.5 MHz) over South and Central America and the eastern portion of North America. However, these simulations did not take into account any changes in the coupling between the thermosphere-ionosphere system and the Earth's magnetosphere. Therefore we are now embarking on a new project to address these effects with the Coupled Magnetosphere-Ionosphere-Thermosphere (CMIT) model. We are first carrying out a series of idealized experiments in which the dipole moment and the dipole tilt angle are varied. Later, we will also examine the effects of realistic magnetic field changes, as have occurred over the past few hundred years. Preliminary results will be shown.

Comberiate, Joseph

Coordinated Observations of Equatorial Plasma Bubbles, Ionospheric Drift Rates, and Scintillation

Comberiate, Joseph[1]; Miller, Ethan[1]; Paxton, Larry[1]; Selby, Christina[1]; Makela, Jonathan J.[2]

1. JHU/APL, Laurel, MD, USA
2. ECE, University of Illinois, Urbana, IL, USA

While equatorial plasma bubbles and ionospheric scintillation have been studied for decades, assimilative ionospheric models do not currently identify plasma bubbles and link them to occurrences of ionospheric scintillation. Ionospheric plasma bubbles are not adequately modeled as we do not have a full understanding of the seeding mechanism and contributing forces from below. As assimilative models begin to incorporate a higher volume of global measurements and full-physics models include irregularity-generating processes, it should be possible to improve models and forecasts of L1-band scintillation in the near future. In this context, we seek to evaluate the link between space-based UV observations of equatorial plasma bubbles and ground-based observations of GPS scintillation. We have developed a technique that routinely detects equatorial plasma bubbles in TIMED/GUVI and DMSP/SSUSI data from 2002-2007. These observations are coordinated with databases of L1-band scintillation

observations from Hawaii, Chile, and other locations. We present an evaluation of the link between equatorial plasma bubbles occurrence and scintillation as the bubbles drift through the nightside ionosphere and identify effects of drift rate and local time on the percentage of bubbles that cause scintillation at GPS frequencies.

Crowley, Geoffrey

Overview of the Universe of Ionosphere-Thermosphere Models

Crowley, Geoffrey[1]

1. ASTRA, Boulder, CO, USA

There are a large number of models that describe various aspects of the thermosphere and ionosphere. These range from empirical models based on climatological measurements to fully coupled first-principles models. Some models describe average conditions, while others are able to specify changes with geomagnetic activity whether quiet or active. Upper and lower boundary conditions can have a significant effect in some models. The model domain ranges from global coverage to the most localized 1-D model. In each category, the scope of the model output is also variable, with different models providing different kinds of output parameters. Finally, assimilative models of the thermosphere and ionosphere have begun to appear in the model universe, adding to the complexity because they use different assimilation techniques and ingest different data sets. Sometimes it is difficult for the casual observer to recognize the differences between models, or for the user to know which model best fits their needs. This paper attempts to provide an overview of the model universe, highlighting the strengths and weaknesses of various model-types. The purpose of the paper is to provide a background for the other papers in this session.

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Deng, Yue

Simulation of neutral density enhancement in the cusp region

Deng, Yue[1]; Fuller-Rowell, Timothy[2]; Knipp, Delores[2]; Ridley, Aaron[3]

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2. University of Colorado, Boulder, Boulder, CO, USA
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CHAMP observations often show thermospheric density enhancements in the cusp region. Due to the limitation of the observations, the heating mechanism has not been confirmed and no conclusive explanation for the neutral density enhancement has been offered. To unveil the mystery of the neutral density enhancement in the cusp, different heating mechanisms including Poynting flux and soft particle precipitation will be analyzed and simulated in Global Ionosphere Thermosphere Model (GITM). Since the spatial size of the cusp region (5~10deg) is small and comparable with the grid size of some GCM simulations, it is challenging to simulate this region under regular resolution. We will take advantage of the flexible resolution of the GITM model, and compare the simulations under different spatial resolutions.

Fang, Tzu-Wei

Equatorial-PRIMO (Problems Related to Ionospheric Models and Observations) (*Invited*)

Fang, Tzu-Wei[1]; Anderson, David[1]; Fuller-Rowell, Tim[1, 2]; Akmaev, Rashid[2]; Codrescu, Mihail[2]; Millward, George[1]; Sojka, Jan[3]; Scherliess, Ludger[3]; Eccles, Vince[4]; Retterer, John[5]; Huba, Joe[6]; Joyce, Glenn[7]; Richmond, Art[8]; Maute, Astrid[8]; Crowley, Geoff[9]; Ridley, Aaron[10]; Vichare, Geeta[10]

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2. NOAA/Space Weather Prediction Center, Boulder, CO, USA
3. Utah State University/Center for Atmospheric and Space Sciences, Logan, UT, USA
4. Space Environment Corporation, Providence, UT, USA
5. Air Force Research Laboratory, Hanscom AFB, MA, USA
6. Naval Research Laboratory/Plasma Physics Division, Washington, D. C., DC, USA
7. Icarus Research, Inc., Bethesda, MD, USA
8. National Center for Atmospheric Research/High Altitude Observatory, Boulder, CO, USA
9. Atmospheric and Space Technology Research Associates, San Antonio, TX, USA
10. University of Michigan/Center for Space Environment Modeling, Ann Arbor, MI, USA

Since we do not fully understand all the relevant physics of the equatorial ionosphere, current models do not completely agree with each other and are not able to accurately reproduce observations. To understand the strengths and the limitations of theoretical, time-dependent, low-latitude ionospheric models in representing observed ionospheric structure and variability and to better understand the underlying ionospheric physics and develop improved models, we initiated a multi-year Equatorial-PRIMO workshop at the 2010 CEDAR meeting. Two sets of ionosphere-plasmasphere models are participating: non self-consistent models including Ionospheric Forecast Model (IFM), Ionosphere-Plasmasphere Model (IPM), Low Latitude Ionospheric Specification Model (LLIONS), Physically Based Model (PBMOD), Global Ionosphere and Plasmasphere (GIP), SAMI2 is Another Model of the Ionosphere (SAMI2) and self-consistent models including SAMI3 is Also a Model of the Ionosphere (SAMI3), Thermosphere-Ionosphere-Electrodynamics general circulation model (TIE-GCM), Thermosphere-Ionosphere-Mesosphere-Electrodynamics general circulation model (TIME-GCM), Global Ionosphere-Thermosphere Model (GITM), the Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics (CTIPe), Integrated Dynamics through Earth's Atmosphere (IDEA). In order to carry out very preliminary comparisons, these two sets of models theoretically calculated ionospheric parameters in the Peruvian longitude sector, under Equinoctial conditions for an F10.7 cm flux value of 120.

These initial results were presented at the Fall AGU meeting in San Francisco. The main conclusions were 1.) The non self-consistent models are in good agreement with each other, except for the nighttime portion of GIP and in good agreement with IRI, 2.) The self-consistent models produce daytime Nmax values at the crests of the equatorial anomaly that are substantially lower than the non self-consistent model values, 3.) The differences in calculated electron densities between the self-consistent model results are quite significant which implies very different electric fields, neutral composition, winds and temperatures have been calculated by each model. At the Chapman Conference we present 1.) Initial results which reconcile the differences between the two sets of models, 2.) Similar comparisons for the December and June solstice periods and 3.) Comparisons of neutral density, temperature and wind velocity from the self-consistent model calculations.

Fang, Tzu-Wei

Impact of Atmospheric Tides on Ionosphere-Thermosphere System

Fang, Tzu-Wei[1]; Fuller-Rowell, Tim[1]; Akmaev, Rashid[2]; Wu, Fe[1]

1. CU/CIRES, Boulder, CO, USA
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The Coupled Thermosphere Ionosphere Plasmasphere with self-consistent Electrodynamics (CTIPe) model is a nonlinear, coupled thermosphere-ionosphere-plasmasphere code that includes a self-consistent electrodynamics scheme for the computation of neutral wind induced dynamo electric fields. The model consists of a global thermosphere, a high-latitude ionosphere, a mid- and low-latitude ionosphere/plasmasphere and an electrodynamical calculation of the global dynamo electric field. The diurnal and semidiurnal propagating tidal modes are imposed at 80 km altitude with a prescribed amplitude and phase. The Whole Atmosphere Model (WAM) is an extension of the operational weather prediction Global Forecast System (GFS) general circulation model (GCM) to the top of the atmosphere. The model is being built to study and potentially develop a capability to predict the effects of lower atmosphere dynamics and variability on the upper atmosphere and ionosphere. Since atmospheric waves can be important sources in reproducing ionospheric variability and thermospheric phenomena, we implement WAM parameters at the lower boundary of CTIPe. The geopotential height, neutral temperature, zonal and meridional wind which were prescribed by Hough mode at 80 km in CTIPe are replaced by the WAM outputs between 80 and ~100 km. We compare the tidal modes reproduced in CTIPe and WAM thermosphere to validate the wave propagation scheme in CTIPe and to understand their impact on ionospheric electrodynamics. Several thermospheric phenomena such as midnight temperature maximum (MTM) and midnight density maximum (MDM) and influences of planetary waves in ionosphere and thermosphere are also studied using CTIPe with the new boundary condition.

Fuller-Rowell, Timothy J.

Physical Characteristics of the Thermosphere(*Invited*)

Fuller-Rowell, Timothy J.[1]

1. CIRES, University of Colorado, Boulder, CO, USA

Earth's thermosphere, from 100 to about 500 km, has distinct properties that render it unique as an atmospheric layer. Like the lower atmosphere, it is collision dominated up to its top altitude, where it gradually transforms to the collisionless exosphere above. The frequent collisions create the fluid properties of the medium and enable the use of the traditional bulk properties such as gas pressure, temperature, and density. To a large extent it is also hydrostatic, where the balance between gravity and gas pressure are balanced in the vertical direction. Hydrostatic balance has enabled the use of "pressure coordinates" to model the medium, the properties of which are not always intuitive. Unlike the lower atmosphere, however, the thermosphere is not well mixed. Above about 110km altitude the eddy mixing of the atmosphere gives way to diffusive separation of species, so each species tends to a vertical distribution defined by it's own atomic or molecular mass, rather than the weighted average of the gas mixture. The heavier species, such as molecular oxygen and nitrogen, tend to accumulate in the lower thermosphere, and the lighter species, such as atomic oxygen and hydrogen, tend to separate out towards the upper levels. The species separation creates a height dependent mean mass. The daily input of external sources of energy, including solar ultraviolet and extreme ultraviolet radiation and Joule heating from magnetospheric forcing, are a significant fraction of the internal energy, so the medium is strongly forced. Heating causes a thermal expansion of the atmosphere and increased density a scale height above the source. In pressure coordinates, the response to heating is non-intuitive, and does not cause a change in the ratio of species. The regional heating, however, particularly at solstice or during geomagnetic storms, drives a global circulation, which does tends to mix the medium and change neutral composition. Upward and downward vertical winds that close the global circulation, transport species across the gradient in neutral composition. The global circulation in the lower thermosphere is generally close to geostrophic, where horizontal pressure and Coriolis forces balance. In the upper thermosphere, viscous and ion drag begin to dominate. Although the thermosphere is largely a linear system, at high latitudes, the magnetospheric momentum deposition from ion drag drives high velocity neutral winds so that non-linear transport and inertial oscillations becomes important. During these times of impulsive energy input, and on short temporal and spatial scales, hydrostatic balance can also break down, and the thermosphere can support strong acoustic waves.

Gardner, Larry C.

Charge Exchange in the Mid- to Low-Latitude Ionosphere and its Impacts on the Thermosphere

Gardner, Larry C.[1]; Schunk, Robert W.[1]

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Charge exchange of ionospheric ions in the 500 km to 1500 km height region results in a neutral atom with the velocity of the parent ion. The neutral atoms produced in the charge exchange reactions may then rain down on the thermosphere if they do not have enough energy to escape. For this study 2-D flows along closed magnetic field lines at mid- and low-latitudes is coupled to a neutral charge exchange code to determine the impact these neutral have on the mid- and low-latitude thermosphere. The lighter hydrogen atoms tend to escape, while the heavier oxygen atoms impact the thermosphere near the magnetic equator, after being produced by ions flowing up magnetic field lines from the southern hemisphere. The resulting flow of oxygen atoms then impacts the lower thermosphere with velocities of several hundred m/s.

Guberman, Steven L.

The Dissociative Recombination of N_2^{+*}

Guberman, Steven L.[1]

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Aeronomic interest in N_2^+ has a long history [Torr and Torr, 1982]. Above 300 km, dissociative recombination (DR), i.e. $N_2^+ + e- \rightarrow N + N$, where e^- is an electron, is a well known sink for N_2^+ [Torr and Torr, 1979a,b]. Above 200 km, N_2^+ DR is a major source of $N(^2D)$ and an important source of $N(^2P)$ dayglow emissions at 3466Å and 10,400Å [Torr et al., 1993]. Models of the ionosphere have shown that near 450 km about 50% of the N_2^+ is vibrationally excited [Torr and Torr, 1982; Fox and Dalgarno, 1985; Fox, 1986]. Theoretical quantum chemical calculations are reported for the DR and vibrational relaxation (VR) of the lowest 5 vibrational levels (v) of the N_2^+ ground state. Of the 109 states that arise from the atomic valence states, the $^3\Pi_u$ states are the dominant routes. The calculations take into account direct DR via the dissociative route, indirect DR involving intermediate Rydberg states having both the ion ground state and the $A^2\Pi_u$ state as core, and interference between the direct and indirect DR processes. For the ion ground state, the total calculated rate constant from v=0 is 2.2 x $(T_e/300)^{-0.20}$ x 10^{-7} cm^3/sec for 100 K< T_e<400 K where T_e is the electron temperature. The calculated rate constant is in excellent agreement with many vibrational ground state experimental measurements. There have been no prior theoretical determinations of the rate constant and no prior experimentally or theoretically derived rate constants for v>0. The results indicate that a storage ring measurement of the DR rate coefficient for v=0 was actually a measurement involving an ion in a vibrational population inversion. * This research is supported by NSF under grant ATM-0838061.

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Heelis, Roderick

A Perspective on Coupling in the Ionosphere Thermosphere

Heelis, Roderick[1]

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The Ionosphere-Thermosphere is a partially-ionized magnetized plasma in which the charged and neutral particles interact. Principle among these interactions are those between the ion and neutral particles and between the ions and the electrons. Both the neutral and charged gases have multiple species that also interact with each other. These interactions, which couple the ions, electrons and neutral gases, are important to describing the momentum balance, the energy balance and the chemistry of the region. Since the interaction between the species is itself dependent on their relative velocity and their temperatures, the coupling between the species also drives non-linear feedbacks in the system. In this presentation we discuss the key effects of ion neutral collisions, ion-ion collisions and ion-electron collisions on the dynamics, temperature and composition of the species. We will highlight the physical principles that govern these interactions and highlight examples of their presence in the ionosphere and thermosphere.

Heidenreich, Sebastian

Relationships between solar wind parameters and the total electron content (TEC)

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Besides electromagnetic radiation of the sun also precipitation of solar wind particles has a strong impact on the ionization level in particular at high latitudes. Due to the strong interaction of the solar wind with the the magnetosphere-thermosphere-ionosphere system a number of coupling processes affect the ionospheric plasma significantly. Thus, the plasma density reacts very sensitive to composition changes, perturbation induced electric fields and thermospheric winds. Physical modelling of the pertured magnetosphere-thermosphere-ionosphere requires the knowledge of the behavior of the solar wind key parameters such as speed, density and magnetic field components. In a first step we start to study the relationship between these solar wind parameters and the Total Electron Content (TEC) observed over Europe and over the North Pole area since 2000 in DLR Neustrelitz. Correlation coefficients and time shifts between solar wind parameters and TEC are studied for selected events and by statistical methods.

Huang, Cheryl Y.

Tidal structures in the equatorial ionosphere

Huang, Cheryl Y.[1]; Delay, Susan[2]; Roddy, Patrick[1]; Sutton, Eric[1]; Stoneback, Russell[3]

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3. University of Texas, Dallas, TX, USA

Tidal structures have been noted at altitudes up to 840 km in both neutrals and ions. We present examples of simultaneous ion and neutral tidal structures obtained by the Plasma Langmuir Probe (PLP) on C/NOFS and the SuperStar accelerometer on GRACE. Under the very quiet conditions during solar minimum, the tidal features are very distinct and dominate the overall structure of the ionosphere. The plasma tidal structures on C/NOFS are comparable with the DE-3 neutral tidal modes. In addition, there is a persistent broad plasma decrease (BPD) on the nightside which coincides with downward ion velocity as determined by the Ion Velocity Meter (IVM) on C/NOFS.

Huba, Joseph D.

Numerical Methods in Ionospheric Modeling

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2. Icarus Research, Bethesda, MD, USA

A discussion of numerical methods used in ionospheric models is presented. The focus is on the solution of the continuity, velocity, and temperature equations. Because of the strong geomagnetic field, plasma motion can be split into parallel and perpendicular components. Parallel motion can be described by implicit and semi-implicit algorithms. An overview of each scheme will be presented with examples. Perpendicular motion can be described using a Lagrangian grid or an Eulerian grid. A description of each grid method will be presented. Additionally, a fixed, Eulerian grid can be orthogonal or non-orthogonal. We will describe a finite volume scheme to capture perpendicular transport on an Eulerian grid.

Hysell, David L.

Ionospheric Irregularities

Hysell, David L.[1]

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Irregularities are produced spontaneously at all latitudes and altitudes in the Earth's ionosphere wherever free energy accumulates. In some cases, the effects of the irregularities must be included in numerical simulations of the background state through parameterizations. In other cases, the irregularities are the target of the simulations themselves. Simulating ionospheric irregularities and instabilities can be challenging in view of the extreme plasma inhomogeneity and anisotropy typically involved. This is particularly true when the equipotential magnetic field line assumption cannot be made, as is the case for a number of important ionospheric phenomena. The tremendous span of temporal and spatial scales exhibited by ionospheric irregularities can also pose difficulties. Artificially produced irregularities are particularly challenging to simulate since they include electromagnetic and electrostatic, nonlocal, nonlinear, dissipative, thermal, and magnetoionic aspects, typically at dual spatial and temporal scales. Characteristic features of a number of ionospheric irregularities and instabilities will be presented, and implications for numerical simulations discussed.

Joyce, Glenn

Modeling Global Ionosphere Electrodynamics

Huba, Joseph D.[1]; Joyce, Glenn[2]

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2. Icarus Research, Bethesda, MD, USA

The global ionospheric electric field can be obtained by solving a two-dimensional potential equation of the form $\nabla \cdot \Sigma\nabla\Phi = F(J_{||}, V_n, g)$ where Σ is a 2D conductance matrix comprised of the Pedersen Σ_P and Hall Σ_H conductances, $J_{||}$ are the Region 1 and 2 current systems (in both hemispheres), V_n is the thermospheric wind, and g is gravity. Here, F represents a function describing these input variables. We will derive F based on a dipole description of the geomagnetic field. The potential equation is incorporated into the NRL ionosphere model SAMI3 and solved using Region 1 and 2 current systems from first-principles models (e.g., LFM) and using an empirical wind model (e.g., HWM07). The potential solver used is the Stabilized Error Vector Propagation (SEVP) method developed by Madala (1978). A description of the model will be given and example results. Madala, R.V., *Mon. Wea. Rev. 106*, 1735, 1978. Research supported by ONR.

Karia, Sheetal

A Comparision of GPS-TEC data at Surat with IRI-2007 Models for the year 2009

Karia, Sheetal[1]; Pathak, Kamlesh[1]

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The temporal and seasonal variations of Total Electron Content (TEC) are studied at Surat (Geographic Lat. 21.16 N, Long. 72.78 E,), India, which is in the equatorial anomaly region, for a period of 12 months from 01 January to 31 December, 2009 using a Global Positioning System (GPS) receiver. The mean TEC values show a minimum at 0500 h LT (LT = UT + 5.5 h) and a peak value at about 1400 h LT. The lowest TEC values are observed in winter whereas largest values are observed in equinox and summer. Anomalous variations are found during the period of magnetic disturbances. These results are compared with the TEC derived from IRI-2007 using three different options of topside electron density, NeQuick, IRI01-corr, and IRI-2001. A good agreement is found between the TEC obtained at Surat and those derived from IRI-corr and NeQuick.

Kilcommons, Liam M.

Trends in Poynting Flux with IMF Variation and their Association with Neutral Density Enhancements

Kilcommons, Liam M.[1]; Knipp, Delores[1]

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Our poster will describe a crucial Ionosphere-Thermosphere (I-T) energy link between high latitude thermospheric density and solar wind forcing. Kwak et al. [2009]* examined density response, derived from accelerometer data from the CHAMP satellite during a six-month period of repeated IMF sector switches in 2000-2001. To elucidate trends in density as a function of IMF direction, the data were subdivided by IMF component conditions. Both the total mass density and difference mass density were then individually analyzed for each subset. A large dayside enhancement was observed. They suggested the enhancements were due to a combination of thermospheric winds, which are associated with the ionospheric convection and local Joule heating associated with ionospheric currents, which vary with IMF conditions. Here, we analyze Poynting flux, a crucial indicator and mechanism for Joule heating, which gives rise to such density enhancement during periods of high solar activity. Poynting flux values (derived from the electric field and magnetic perturbation data from the DMSP F15 satellite) are geographically binned and then divided into IMF condition subsets as in Kwak et al. Statistics for each geographic region are compared to the density mappings of Kwak et al. *Kwak, Y.-S. et al., Dependence of the high-latitude thermospheric densities on the interplanetary magnetic field, JGR, Vol. 114, A05304, 2009

Kim, Jung Soo

Helium effect on the Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM) simulation

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2. Electrical Engineering, Penn State University, University Park, PA, USA
3. Electrical Engineering and Meteorology, Penn State University, University Park, PA, USA

The TIE-GCM currently uses the major neutral constituents such as N2, O2, and O for calculating specific heat, molecular viscosity, and molecular thermal conductivity. But these parameters have large uncertainties that affect the estimation of thermospheric neutral density above around 350 km where lighter species such as helium plays an important role in determining these atmospheric values. In this report, we show that specific heat and molecular thermal conductivity have significant differences when helium is included for their calculations using the neutral constituents profile calculated from the Naval Research Laboratory's Mass Spectrometer Incoherent Scatter (NRLMSISE-00) model, while the variation of the molecular viscosity can be negligible. Those deviations tend to increase in accordance with the declination of solar activity. Neutral densities simulations using TIE-GCM are compared to neutral densities from the CHAMP (CHAllenging Minisatellite Payload) accelerometer data from the period 2002 (solar maximum) through 2007 (solar minimum) and the results show that the neutral densities at 400 km from the TIE-GCM has large uncertainties during solar minimum period. We used helium data calculated from the NRLMSISE-00 model along the CHAMP satellite for the simulation of the TIE-GCM in order to examine the effect of helium on the TIE-GCM. Results of the inclusion of helium data to calculate the specific heat, molecular viscosity, and molecular thermal conductivity will be presented and discussed.

Klimenko, Maxim V.

The problems and advances in numerical simulation of thermosphere/ionosphere response to the geomagnetic storms

Klimenko, Maxim V.[1, 2]; Klimenko, Vladimir V.[1]

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2. Kaliningrad State Technical University, Kaliningrad, Russian Federation

In the given research we consider the thermosphere/ionosphere effects of the several strong geomagnetic storms occurred over the period 2000–2006. We used the model calculated results and experimental data of the different digital ionosondes obtained during these storm-time periods. The numerical calculated results were obtained with use of the Global Self-consistent Model of the Thermosphere, Ionosphere and Protonosphere (GSM TIP) developed in West Department of IZMIRAN. We investigated the problem of the model input parameters setting at the simulations of geomagnetic storm effects in the ionosphere. In the numerical experiments such model input parameters as cross-polar cap potential difference, region 2 field-aligned currents, energy and energy fluxes of precipitated particles were set as function of different geomagnetic activity indexes. In addition, we took into account and considered the ionospheric effects of solar flares if they were taken place during the geomagnetic storms. We have analyzed the obtained modeling results for various ionospheric stations; compared the calculated results with observations; investigated the influence of geomagnetic storms on formation and behavior of the vertical profile of electron number density. We gave a particular attention to the main ionospheric drivers, such as electric field dynamo and magnetospheric origin, meridional component of thermospheric wind and neutral atmosphere composition. It is shown that during geomagnetic storms, the non-uniform in height zonal electric field is generated at geomagnetic equator. This electric field forms the additional peaks in the

upper part of the electron density profile (above the maximum that existed at that time in quiet conditions) through the non-uniform in height vertical plasma drift. The thermospheric wind surges are formed during storms in the daytime sector, but do not lead to the formation of additional layer in the area of equatorial anomaly crests, in contrast to suggestions from recent modeling effort. The present study was done under support of the Russian Foundation for Basic Research (Grant No. 08-05-00274).

Klimenko, Maxim V.

Global distribution of the hot O in the earth's atmosphere and its effect on thermosphere and ionosphere parameters

Bessarab, Fedor S.[1]; Korenkov, Yurij N.[1]; Klimenko, Maxim V.[1, 2]; Klimenko, Vladimir V.[1]

1. West Department of IZMIRAN, Kaliningrad, Russian Federation
2. Kaliningrad State Technical University, Kaliningrad, Russian Federation

The hot oxygen (Oh) existence in the upper thermosphere is mainly provided by optical observations of the high-altitude airglow. In these experiments a peak of hot O population was found at an altitude approximately 550 km with a temperature of about 4000 K. Although it was shown that hot O concentration reached a value of 1-2% with respect to ambient (cold) O, realistic concentration profile and temperature global distribution of a hot O have not been established. The presence of non-thermal atoms in the thermosphere leads to variations of the thermo–dynamical regime in the upper atmosphere. The major chemical and dynamical processes of the hot O production were taken into account for the model simulations. Time-dependent, Global Self-consistent Model of Thermosphere, Ionosphere and Protonosphere of the Earth (GCM TIP) was used in order to simulate global distribution of hot O number density and temperature (Th). Calculations were executed for moderate solar, quiet geomagnetic conditions and winter season. It was shown that the maximum (Oh) is located at -60° geomagnetic latitude, 300° geomagnetic longitude at 24:00 UT. The Th maximum is about 2050 K. Such temperature and concentration Oh cause increase in neutral gas temperature at high-altitude thermosphere by ~100 K at a daytime and by ~70 K at night time. Variations of the neutral gas velocity circulation were also calculated. Maximum increase in neutral velocity is about 36 m/s and corresponds to 50° geomagnetic latitude, 180° geomagnetic longitude in the northern and 50° geomagnetic latitude, 270° geomagnetic longitude in the southern hemisphere. Calculation results have shown that reactions with vibrationally exited nitrogen are very important for the hot O production. Plasma population and energy in the protonoshpere may be sufficient support for the altitude profiles of hot O and its temperature. It is possible because thermal electrons from protonoshpere are capable exciting O to O(1D), which through energy transfer processes gave rise a hot O concentration. These processes are simulated by the flux of hot O at the upper boundary for thermosphere block in the model GSM TIP. We also considered the ionospheric effects of hot oxygen existence and its role in ion and electron temperature behavior at F2 region and plasmasphere heights.

Knipp, Delores J.

Poynting Flux: A Statistical View From the DMSP F-15 Satellite

Knipp, Delores J.[2, 1]; Crowley, Geoff[3]; Kilcommons, Liam[1]

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2. Aerospace Engineering, University of Colorado, Boulder, CO, USA
3. ASTRA, Boulder, CO, USA

This presentation examines the forcing of the I-T system via Poynting flux deposited by field-aligned current systems. The DMSP F-15 satellite samples, in the 09-21 LT sector, the electric fields and magnetic field perturbations that comprise the Poynting flux. Figures 1 and 2 show averaged and binned Poynting flux for the Southern Hemisphere during intervals of extreme quiet and intervals of extreme disturbance. During some events these data reveal remarkable localized energy input in excess of 100 mW/m^2. In addition to comparing the Poynting flux to statistical models of Joule heating, we will quantify the energy deposition based on various types of solar wind forcing, including extreme quiet, normal slow flow, high speed flow and ejecta flow. Additionally, we will show the localized energy deposition and its evolution for specific storm events and discuss the implication for I-T disturbances.

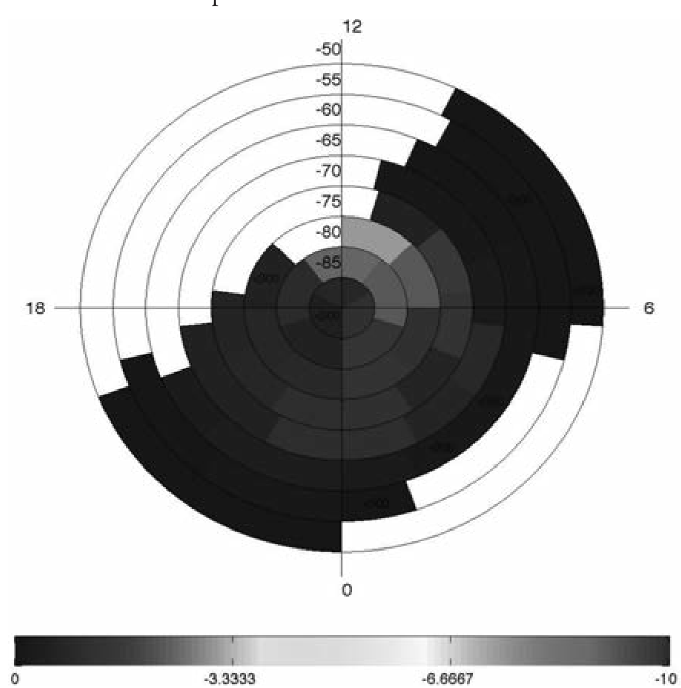

Fig. 1 Southern hemisphere DMSP F-15 Poynting flux for intervals of extreme quiet during January 2005. Units are mW/m^2.

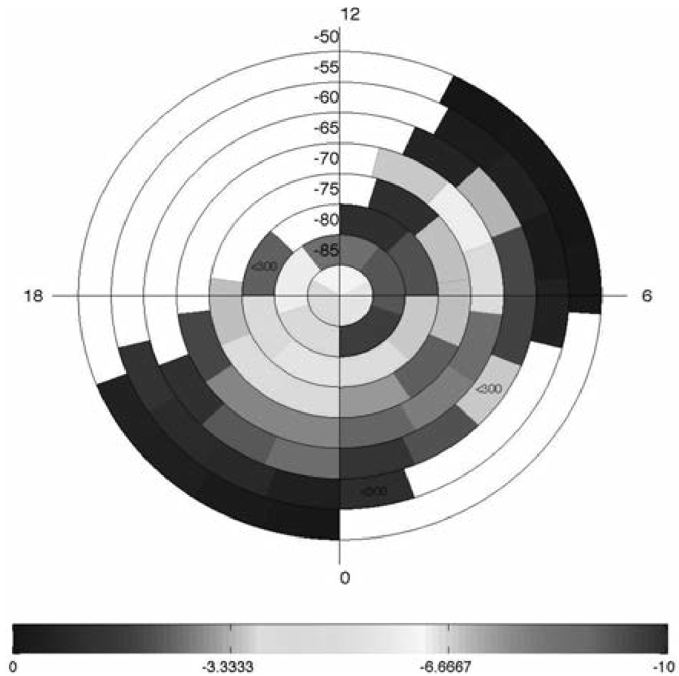

Fig. 2 Southern hemisphere DMSP F-15 Poynting flux for intervals containing solar wind eject during January 2005. Units are mW/m^2.

Krall, Jonathan

Three-Dimensional Simulation of Equatorial Spread-F: Numerical Descriptions of Physical Phenomena

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Results of the NRL SAMI3/ESF three-dimensional simulation code have been shown to compare well to observations of equatorial spread-F (ESF). The SAMI3/ESF "wedge" simulation geometry conforms to a dipole field geometry that extends up to 3200 km at the equator and down to and altitude of 85 km, but extends over only 4-8 degrees in longitude. The full SAMI3 ionosphere equations are solved, providing ion dynamics both along and across the field. The potential is solved in two dimensions in the equatorial plane under a field-line equipotential approximation. We present SAMI3/ESF results in terms of the specific numerical prescriptions corresponding to each observed phenomenon. Phenomena of interest (and underlying numerics) include temperature effects (parallel ion flows, adiabatic and collisional thermal terms), density structure (interacting ion flows, gravity and diffusive forces), compositional signatures (multiple ion equations), "c" shaped bubbles and "ESF airglow" (zonal transport), wind-driven stabilization and plasma blobs (wind-driven transport), and MSTID and gravity-wave seeding (E x B and wind-driven transport). Without the inclusion of multiple ions, ion-neutral and ion-ion interactions, wind-driven transport, vertical and zonal E x B transport, thermal descriptions of multiple ion species, etc., many of these observed phenomena would not have been reproduced by the model.

Kuznetsova, Masha

Systematic Assessment of Ionosphere/Thermosphere Models Using Metrics (*Invited*)

Shim, Ja Soon[1]; Kuznetsova, Masha[2]; Rastatter, Lutz[2]; Hesse, Michael[2]; Bilitza, Dieter[2]; Codrescu, Mihail[3]; Emery, Barbara[4]; Foster, Ben[4]; Fuller-Rowell, Tim[3]; Huba, Joe[5]; Ridley, Aaron[6]; Schunk, Robert[7]; Thompson, Donald[7]; Weimer, Daniel[8]; Anderson, David[9]; Chau, Jorge[10]; Forbes, Jeffrey M.[11]; Sojka, Jan[7]; Sutton, Eric[12]; Rideout, Bill[13]

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5. Plasma Physics Division, Naval Research Laboratory, Washington, DC, USA
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7. CASS, Utah State University, Logan, UT, USA
8. Center for Space Science and Engineering Research, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA
9. CIRES, University of Colorado, Boulder, CO, USA
10. Instituto Geofisico del Peru, Piura, Peru
11. Department of Aerospace Engineering Sciences, University of Colorado, Boulder, CO, USA
12. Air Force Research Laboratory, Bedford, MA, USA
13. Haystack Observatory, Massachusetts Institute of Technology, Westford, MA, USA

The Community Coordinated Modeling Center (CCMC) at the Goddard Space Flight Center performs validation study for a variety of Ionosphere/Thermosphere Models as a main part of the CEDAR Electrodynamics Thermosphere Ionosphere (ETI) Challenge. The goal of the Challenge is to evaluate the current state of the ionosphere/thermosphere models, to track model improvements over time, and to facilitate interaction between research and operation communities in developing metrics for space weather model evaluations. CCMC is supporting the Challenge using their experience with the GEM community and the metric tools available at CCMC. For the challenge, several geomagnetic storm events (3 GEM events, 3 moderate storms and 3 quiet periods) and the March 2007 to March 2008 time-frame, which is the first half of the International Polar Year (IPY) from March 2007 to March 2009, are selected to compare between model outputs and observations. Physical parameters including electron density and neutral density along the CHAMP trajectories, NmF2 and hmF2 from ISRs, and vertical drift at Jicamarca are chosen. Model outputs and observational data used for the challenge will be permanently posted as a resource for the space science communities to use. In this presentation, the preliminary results of the challenge will be presented.

Larsen, Miguel

Large winds in the lower thermosphere: Analysis of a TIME-GCM run with enhanced height resolution

Larsen, Miguel[1]; Fesen, Cassandra G.[1, 2]

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The National Center for Atmospheric Research Thermosphere-Ionosphere-Mesosphere-Electrodynamic General Circulation Model (TIME-GCM) was found to reproduce the enhanced winds in the lower thermosphere detected in a large data set of chemical release wind measurements, as reported by the authors in an earlier article (Ann. Geophys., 2009). Similar distributions of enhanced shears and wind speeds were found later in lidar Doppler wind data from the same altitude range. The important factor in the model run for producing the enhanced winds was an improved height resolution: specifically, a model run with four grid points per scale height, instead of the usual two, showed a maximum in the mid-latitude model winds that was close in altitude, but a few kilometers lower, than the observed maximum. Other changes in the model, such as improved lower boundary forcing or more realistic geomagnetic forcing, did not produce a realistic enhancement in the winds. The model output for this particular run covered a full year. In the earlier paper we presented the overall distribution of the winds for the full year and for all latitudes equatorward of 60 degrees. Here we present a more detailed analysis of the model output, including the latitude, local time, and seasonal distribution of the lower thermosphere winds.

Larsen, Miguel

Vertical velocities in the thermosphere: An overview of observations and implications for dynamics and modeling

Larsen, Miguel[1]; Meriwether, John W.[1]

1. Clemson University, Clemson, SC, USA

Direct measurements of the vertical velocities in the thermosphere have been difficult to obtain, but some measurements are available. The most extensive such data is from the optical Fabry-Perot interferometer technique using either the green-line emission from the lower E region or the red line emission from the F region. A few measurements are also available from sounding rocket chemical releases and are notable in that, in some cases, they have provided altitude profiles of the vertical winds over an extended altitude range. The available observations will be summarized, and the differences between the high-latitude and mid-latitude measurements will be described. In general, the observed vertical winds have magnitudes exceeding 10 m/s at mid latitudes and sometimes much larger magnitudes at high latitudes. Vertical winds of this magnitude are expected to have significant effects on the dynamics, electrodynamics, and chemistry of the region, even if they are transient, as they must be. A puzzling characteristic of the high-latitude winds is not only the even larger magnitudes that are often seen there but also the fact that they often persist for periods of an hour or longer without an associated horizontal divergence in the neutral flow sufficient to support the observed vertical wind. The winds at high latitudes will have even more significant effects in the thermosphere because of the larger magnitudes that often occur there. The implications for the dynamics and for numerical modeling of the region will be discussed.

Lin, Chin S.

Validation of Low Altitude Neutral Density Modeling

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Neutral density variations are the largest source of satellite drag variability, posing significant challenges in meeting space operations requirements for precise satellite orbit determination and prediction. CHAMP and GRACE high resolution satellite accelerometer neutral density data near 400 km altitude were used to validate the physics-based Thermosphere Ionosphere Electrodynamics General Circulation Model (TIEGCM) during the last solar cycle. The validation study indicates a systematic lower bias in TIEGCM neutral density mean compared with CHAMP measurements. The TIEGCM geomagnetic storm response was also tested at low satellite altitudes using a unique historic set of accelerometer neutral density data from satellites flown with perigee altitudes near 170 km in 1982-1983. In addition, to quantify upward propagating thermospheric forcing a sensitivity study of TIEGCM response at 200 and 400 km altitudes to eddy diffusivity was conducted. To understand thermospheric responses to magnetic storms, we estimate energy input from high latitude heating and upper atmosphere tidal forcing required to produce the observed neutral density enhancements. These validations evaluate the capability of current Ionosphere-Thermosphere models to predict orbital drag, particularly with regards to improved satellite reentry forecasts.

Maruyama, Naomi

Response of the coupled IT system to storm time ionospheric electrodynamics

Maruyama, Naomi[1, 2]; Fuller-Rowell, Timothy J.[1, 2]; Codrescu, Mihail[2]; Anderson, David N.[1, 2]; Richmond, Arthur D.[3]; Maute, Astrid[3]; Sazykin, Stanislav[4]; Toffoletto, Frank[4]; Spiro, Robert W.[4]; Wolf, Richard A.[4]

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The main objective of this study is to understand the response of the coupled IT system to storm time ionospheric electrodynamics driven by the balance/imbalance between region 1 and 2 current systems that connect the ionosphere and magnetosphere. Ionospheric electrodynamics depends on the state of the coupled IT system, including ionospheric conductivity, neutral wind, and magnetospheric sources. Furthermore, storm time electric fields interact with the coupled IT system in a non-linear way by altering the ion-neutral processes, resulting in changes in the electric fields. With the use of a model that electrodynamically couples inner magnetosphere, ionosphere, plasmasphere, thermosphere, and electrodynamics, our results demonstrate that the penetration electric field in the post-dusk sector causes uplift of the ionospheric height decreasing the Pedersen conductivity, which results in an increase of the field as a feedback. Furthermore, the effect of the neutral wind tends to increase the penetration electric field. We will discuss the space weather importance of the significant post-dusk uplift in the observed biteout of the equatorial F-layer in great storms (e.g., Greenspan et al., 1991) and address the question whether it could be associated with Storm Enhanced Density (SED).

Matsuo, Tomoko

Upper Atmospheric Data Assimilation with an Ensemble Kalman Filter

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3. Institute for Mathematics Applied to Geosciences, National Center for Atmospheric Research, Boulder, CO, USA

The density of the Earth's upper atmosphere is so tenuous that it lends itself to control by weak external drivers from above and below; nonetheless, it is enough to exert significant drag on orbiting spacecrafts and also its ionized constituents affect telecommunication and navigation, motivating numerous observational and modeling efforts since the dawn of space exploration. While the recent availability of global observations of ionospheric parameters, especially from GPS receivers on low Earth orbiting platforms, has motivated a number of attempts to assimilate ionospheric data, assimilation of sparse irregularly distributed thermosphere observations to global models remains to be a daunting task. On the other hand, because of the thermosphere's relatively long-term memory, thermospheric data assimilation has potential to increase effectiveness of data assimilation in upper atmospheric dynamical systems. In this paper we demonstrate the utility of ensemble Kalman filtering (EnKF) techniques to effectively assimilate a realistic set of space-based observations of the upper atomsphere into a general circulation model of the thermosphere and ionosphere. An EnKF assimilation system has been constructed using the Data Assimilation Research Testbed and the Thermoshere-Ionosphere Electrodynamics General Circulation Model, two sets of community softwares offered by NCAR. We present observing system simulation experiments to assess how well thermospheric density and other model parameters can be inferred not only from the thermosphere observations but also from the GPS-based ionospheric observations. Here, the feedback between the thermosphere and the ionosphere is taken into account in both analysis and forecast steps through coupled dynamics represented self-consistently in the general circulation model. As general circulating models of the thermosphere and ionosphere mature, this approach may further our ability to specify states of the upper atmosphere and some of its external drivers. Finally, we discuss some of the challenges specific to upper atmospheric applications and the roles of auxiliary assimilation algorithms, such as adaptive covariance inflation and localization of covariance, in the EnKF to cope with these challenges. While it is important to account for estimation of model forcing parameters in the EnKF to reduce systematic inconsistency between observations and model states, the quality of the assimilations is affected by model error growth that is almost exclusively controlled by forcing parameters in current thermosphere and ionosphere general circulation models. Covariance inflation techniques can rectify the issue to some extent, but the dilemma calls for more realistic representations of stochasticity due to the forcing variability in models.

Maute, Astrid I.

The Ionospheric Electrostatic Potential (*Invited*)

Maute, Astrid I.[1]; Richmond, Arthur D.[1]

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The ionospheric electrodynamo is an important element of modeling the ionosphere-thermosphere system. The electrodynamo is driven by thermospheric winds and magnetospheric dynamo processes, with an additional contribution from ionospheric currents driven by gravitational and pressure-gradient forces. The resultant electric fields and currents feed back on ionospheric motions, thermospheric ion drag, and Joule heating. Therefore, modeling the electrodynamics realistically is very important to get the system response right. In general we assume the electric field is electrostatic and the current is

divergence-free if we are interested in time scales of a minute or longer. We further simplify by assuming the magnetic field lines are equipotential, in order to obtain a two-dimensional second-order elliptic partial differential equation (PDE) for the ionospheric electric potential. Solving the PDE has certain difficulties, as follows. In order to take advantage of equipotential geomagnetic-field lines, magnetic coordinates are required, but these are not orthogonal for a realistic magnetic-field configuration. The second-order cross-derivative term does not generally vanish, as it would for orthogonal coordinates. Discretization of the PDE and the equatorial boundary condition has to be conservative to ensure that the current is divergence free. An additional constraint has to be introduced so that the matrix of the PDE is nonsingular. Large values of the Hall-to-Pedersen conductance ratio in the equatorial electrojet can lead to numerical difficulties. When magnetospheric sources are represented in terms of specified geomagnetic-field-aligned currents (FAC), care must be taken to ensure there is no net globally integrated FAC into or out of the ionosphere for the PDE solver. While the potential can usually be considered symmetric between the northern and southern magnetic hemispheres on closed geomagnetic-field lines that are not significantly distorted by magnetospheric currents, it can become strongly asymmetric between the two polar regions, requiring a PDE solver with three coupled regions. We discuss some approaches to dealing with these various difficulties, and present examples of the electric potential associated with different sources.

McDonald, Sarah E.

Long-term Simulations of the Ionosphere Using SAMI3

McDonald, Sarah E.[1]; Lean, Judith L.[1]; Huba, Joseph D.[2]; Joyce, Glenn[3]; Emmert, John T.[1]; Drob, Douglas P.[1]; Siefring, Carl L.[2]

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2. Plasma Physics Division, Naval Research Laboratory, Washington, DC, USA
3. Icarus Research, Inc., Bethesda, MD, USA

The Naval Research Laboratory is conducting an interdisciplinary physics-based space weather model development and validation program called the Integrated Sun-Earth System for the Operational Environment (ISES-OE). The goal of ISES-OE is to improve our quantitative understanding of the space environment, which can disrupt or degrade operational communications and navigation systems, and ultimately to advance our ability to forecast space weather on multiple time scale, from hours to the 11-year solar cycle. The core ISES-OE model is SAMI3, NRL's state-of-the-art ionosphere model. As a part of this program, we have made a comprehensive, systematic validation of SAMI3's current capability to specify the mid-to-low latitude ionosphere and its response to heliospheric forcing and thermospheric oscillations during the solar cycle, including the anomalously long 2008 solar minimum epoch. We have performed an ensemble of simulation runs using SAMI3 for the solar and geomagnetic conditions that existed during the Whole Heliosphere Interval (WHI) in March-April 2008. The simulations are driven with a solar irradiance model based on TIMED/SEE measurements and with daily Ap and F10.7 indices. Thermospheric conditions are specified with empirical models of the neutral composition and temperature (NRLMSISE-00) and the neutral wind (HWM07). Various input parameters are selected or held constant in order to quantify their effects on the ionosphere, which we describe. Additionally, we perform simulations using both empirically specified electric fields and self-consistently calculated fields. Simulation results are compared with various ground and space-based observations including ionosondes and GPS-derived global TEC maps. We also show initial results of a multi-year run of SAMI3 over the descending phase of solar cycle-23 (2002 – 2008).

Meriwether, John W.

Comparison of Equatorial Thermospheric Winds with the WAM and HWM Model Predictions for Solar Minimum Activity

Meriwether, John W.[1]; Makela, J. J.[2]; Akmaev, R.[3]; Buriti, R. A.[4]

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2. Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaigne, Urbana-Champaigne, IL, USA
3. Space Weather Prediction Center, National Oceanic and Atmospheric Administration, Boulder, CO, USA
4. Department of Physics, Federal University of Campina Grande, Campina Grande, Brazil

The climatology of equatorial thermospheric winds and temperatures observed in northeastern Brazil (Cajazeiras, 6.9° S, 38.6° W) for solar minimum activity levels between 70 and 80 sfu has been studied using Fabry-Perot interferometer measurements of the Doppler shifts and Doppler broadenings of the 630.0-nm emission. These results show frequent detections of meridional tidal winds and midnight temperature maximum with a phase lag of 60 to 90 minutes consistently throughout all four seasons. Also evident in these results are meridional winds associated with the cross-hemispheric flow from summer to winter which are poleward in winter and equatorward in summer. The zonal winds show acceleration from evening twilight to 2100-2200 LT from ~25 ms-1 to 100 ms-1 then gradually tapering off to 10-25 ms-1 by dawn for winter measurements. However, for summer, the zonal winds decrease sharply after the early evening peak toward zero between 0000 and 0300 LT and increasing to 25-35 ms-1 after 0300 and before dawn. These results are compared with the model predictions of the Whole Atmosphere Model and with the Horizontal Wind Model for solar minimum activity levels. In addition, they are compared with the thermospheric winds and temperatures measured simultaneously at the Jicamarca Radio Observatory located

at the geomagnetic equator for nights in the August-September 2010 period.

More, Chandrakant T.

Studies on Effects of Solar Activities on VLF Radio Wave Propagation at 19.8 KHz

More, Chandrakant T.[1]; Bhonsle, Rajaram[2]

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Abstract The purpose of this experiment was to study the effect of solar activity on field strength of VLF radio wave reflected from D-region of Ionosphere. For this we built a square loop antenna of 1.5-meter diameter and connected it to the VLF receiver. The VLF field strength monitoring system is installed, at Khatav, India (16.46N, 75.53E). The monitor was tuned for 19.8 kHz to receive the radio wave transmitted by VLF radio station NWC Cape North Australia (22.49S, 114.25E). The field strength of VLF radio wave transmitted by the above station via ionosphere was continuously monitored for more than one year at 5 seconds interval. We observed diurnal and seasonal variation in the field strength .We also observed the effect of solar x-ray flares and annular solar eclipse of January 15, 2010 on the field strength. We present here analysis and interpretation of the data received. Key words: VLF Radio Propagation, diurnal and seasonal variation, Solar X-Ray Flares annular solar eclipse

Nicholas, Andrew C.

WINCS: an instrument suite for Simultaneous Multi-Point Thermospheric/Ionospheric Measurements

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2. NASA Goddard Space Flight Center, Greenbelt, MD, USA
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The Winds-Ions-Neutral Composition Suite (WINCS) instrument was designed and developed jointly by the Naval Research Laboratory (NRL) and NASA/Goddard Space Flight Center (GSFC) for ionosphere-thermosphere investigations in orbit between 120 and 550 km altitude. The WINCS design provides the following measurements in a single package with a low Size, Weight, and Power (SWaP): 7.6 x 7.6 x 7.1 cm outer dimensions, 0.75 kg total mass, and about 1.3 Watt total power: neutral winds, neutral temperature, neutral density, neutral composition, ion drifts, ion temperature, ion density and ion composition. The true benefit of WINCS is providing an extremely small and low cost instrument that could be utilized on almost any spacecraft that is launched - from CubeSats to the International Space Station. Utilizing WINCS in this way will allow multipoint measurements of the IT system, enabling more complete data sets. The ultimate use of WINCS would be on an IT constellation mission that would radically alter our understanding of the IT system dynamics. Such a constellation would allow modelers to truly test their model's ability to capture the dynamics of the ionosphere and thermosphere on a global scale.

Noto, John

Sensitive, Automated, and Web-aware Interferometers with Unified Analysis of F-region Dynamics at Upper Atmospheric Facilities

Kerr, Robert B.[1]; Noto, John[1]; Riccobono, Juanita[1]; Migliozzi, Michael[1]; Kapali, Sudha[1]

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Array detection permitting field-widened multiplexing of the Fabry-Perot interference pattern has increased OI red line and green line sensitivity more than 30-fold at the Millstone Hill Optical Facility in Westford, MA. Perhaps more importantly, automated data taking produces thermospheric winds and temperatures every clear night of any month, with calibration and data taking control from any web connection, or by defining and scheduling events to control the system and acquire data. This capability, producing neutral meridional and zonal wind vectors with 1 m/s errors in 8 minutes, and thermospheric neutral temperatures with statistical errors <15K in 4 minutes, in the quietest of conditions, is now to be extended to Arecibo, and hopefully, to Sondrestrom. Our analysis algorithm begins with raw CCD images, followed by application of automated flat field and dark current corrections and consistent anomalous pixel filtering, and proceeds to the summation of five Fabry-Perot interference orders following Fourier decomposition of the instrument function in each order. This algorithm is applied without user intervention, and is now prepared for real time applications. Uniform application of these instrument automation and analysis techniques should provide a reliable and chain-consistent neutral wind and temperature data stream from our Upper Atmospheric Facilities to the ionospheric modeling community.

Pfaff, Robert F.

On Incorporating Continuous Electric field and Plasma Density Probe Data from the C/NOFS Satellite in Models

Pfaff, Robert F.[1]; Freudenreich, Henry[1]; Klenzing, Jeff[1]; Liebrecht, Carmen[1]; Bromund, Ken[1]

1. NASA/GSFC, Greenbelt, MD, USA

Years of continuous measurements using in situ probes on consecutive orbits of the Air Force C/NOFS satellite enable a variety of physical processes to be examined and understood. For example, the measurements reveal that the plasma density and the electric fields are persistently organized by longitude, in both day and night conditions and at all locations within the satellite orbit. In this talk, we concentrate on in situ measurements of plasma density and DC electric fields gathered with probes on C/NOFS. Including these data in models must be carried out with

care, due to the large variations of the density with altitude and the fact that the fields map along magnetic field lines to other regions of Geospace. Since the density can vary by orders of magnitude within the C/NOFS sampling altitude bins at a given geographic location, averages are difficult and some means of normalization of the data with altitude, perhaps using pre-existing models, appears to be warranted. The electric field data has the added feature that it maps efficiently with altitude along magnetic field lines, and this poses a challenge for interpreting the seat of the measured fields as either local or remote. Ultimately, the orbit characteristics of the measurement platform define the sampling criteria and must be taken into account when interpreting "average" conditions. Despite these cautions, such in situ probe data lend themselves readily to advancing ionospheric models where, ultimately, their utility is most effective. We discuss various aspects of how to best incorporate large quantities of in situ probe data in ionospheric models, using the C/NOFS mission as a starting point.

Pfaff, Robert F.

Understanding Geospace on a Grand Scale: The Global Ionosphere/Thermosphere Constellation

Pfaff, Robert F.[1]; Pesnell, Dean[1]

1. NASA/GSFC, Greenbelt, MD, USA

We present the concept of a constellation of polar orbiting satellites equally spaced in longitude (local time) to systematically sample both the neutral and ionzed gas components of the Earth in circular orbits near 350 km, including their density, temperature, and velocities. The instrumentation would include techniques to measure the height of the ionospheric "F-peak" and its variations along the orbit. The number of satellites (12? 24? 48?) and their configuration would be determined from modeling analysis and expected geophysical phenomena, including their drivers and characteristic time scales. Together with imaging data from separate satellites, the array of satellites with in situ probes would be expected to provide a new picture of (1) high latitude electrodynamics and atmospheric processes and associated coupling with magnetospheric mass and momentum input, (2) the response of the global ionosphere and thermosphere to magnetic storms, and (3) global neutral wind circulation patterns, neutral density structure, tides, planetary waves, and gravity waves. The comprehensive measurements gathered by the IT-Constellation envisioned here would provide a major leap forward in each of these areas, addressing global physical processes and providing fundamental, new knowledge of Geospace. In particular, by its very nature, the constellation addresses "system science", revealing how the ionosphere-thermosphere connects globally to the magnetosphere above and the troposphere below. We present this concept as the next logical step in observing the "whole" space environment using in situ probes in conjunction with imagers. We invite modelers to not only comment on this concept but also to become actively engaged in helping to define it.

Pi, Xiaoqing

Estimating Dynamical Forces of the Ionosphere Using GAIM

Pi, Xiaoqing[1]; Mannucci, Anthony[1]; Wilson, Brian[1]; Komjathy, Attila[1]; Stephens, Philip[1]; Akopian, Vardan[1]; Dumett, Miguel[1]; Verkhoglyadova, Olga[1]; Butala, Mark[1]; Wang, Chunming[2]

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The global assimilative ionospheric model (GAIM) developed at the Jet Propulsion Laboratory and University of Southern California incorporates a first-principles physics model and data assimilation modules. A Kalman filter is used to adjust the ionospheric state (electron densities) based on distributed observations such as GPS-based total electron content measurements. A 4-dimensional variational (4DVAR) approach is also implemented to adjust model drivers such as winds, electric fields and ionization. A successful 4DVAR approach must deal with issues related to imperfect physics modeling, distinguishing the impacts of multiple drivers, robustness of the optimization algorithms, and computational efficiency. This report will highlight recent developments in the GAIM-4DVAR approach and describe our data assimilation experiments conducted using GPS observations and the resulting GAIM adjustments to improve driver estimates.

Richards, Philip G.

Photochemistry and Energetics of the Ionosphere and Thermosphere (*Invited*)

Richards, Philip G.[1]

1. Physics and Astronomy, George Mason university, Fairfax, VA, USA

The energy that is deposited in the thermosphere and ionosphere by solar EUV photons and auroral electrons ultimately ends up heating the ambient neutral gases through the complex set of ion and minor neutral chemical reactions. We summarize the current state of knowledge of the ionospheric and thermospheric chemistry and present new calculations of thermospheric neutral gas heating. With the aid of the Field Line Interhemispheric Plasma (FLIP) model, we show that the latest chemical scheme, solar EUV irradiances, and MSIS thermosphere model can satisfactorily account for most solar cycle and seasonal variations in the daytime peak density of the midlatitude ionosphere during magnetically quiet periods. The model calculations also demonstrate the importance of vibrationally excited N2 in the ionosphere. It is particularly important in producing negative ionosphere storms and also helps explain the rapid recovery after storms.

Richmond, Arthur D.

Modeling Ionospheric Electrodynamics (*Invited*)

Richmond, Arthur D.[1]; Maute, Astrid[1]

1. High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO, USA

Ionospheric electrodynamics is driven primarily by thermospheric winds and magnetospheric dynamo processes, with smaller contributions from gravitational and pressure-gradient forces on the ionosphere. The resultant electric fields and currents affect the ionosphere and thermosphere through plasma transport, ion-drag forcing, and Joule heating. Magnetic perturbations associated with the currents provide diagnostic information about the current system. Models of ionospheric electrodynamics usually make the approximations that the geomagnetic-field configuration is known, the component of electric field along the geomagnetic field is negligible, the large-scale electric field is electrostatic, current flow in the atmosphere below the ionosphere is negligible, and Ohm's Law with anisotropic conductivities links the conductive current to the electric field in the frame of the thermospheric medium. The conductivity tensor is derived by balancing Lorentz and collisional forces on the ions and electrons. Coupling with the magnetosphere is treated in various ways, for example: assuming an imposed electric potential pattern over the polar region; assuming an imposed distribution of field-aligned currents; approximating the electrodynamics of inner-magnetospheric plasma in terms of equivalent conductances; and coupling with simulation models of magnetospheric electrodynamics and magnetohydrodynamics. Models of ionospheric electrodynamics have been successful in reproducing general features of observed electric fields and currents, but are limited by inadequately known conductivities at night, complex and sometimes nonlinear conductivities in the auroral and equatorial electrojets, and uncertain modes of interaction with the magnetosphere.

Ridley, Aaron J.

Magnetospheric Coupling to Ionosphere/Thermosphere Models (*Invited*)

Ridley, Aaron J.[1]; Yigit, Erdal[1]

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

The magnetosphere can act as a very significant energy source for the ionosphere and thermosphere. It does this through three processes: (1) the magnetosphere has significant motion of field-lines, which, in the ionosphere, is viewed as ion drifts; (2) relatively energetic electrons and ions precipitate into the thermosphere and cause ionization and heating; and (3) thermal electrons precipitating cause a heat flux into the ionosphere. Each of these sources of energy are somewhat related to each other, and each takes place over many different scales. In most discussions, the ion motion, which causes a frictional heating of the thermosphere, is considered the most important heating source at high latitudes. While this is quite true, the amount of heating and the distribution is intimately tied to the electron and ion precipitation, since the neutral gas heating rate is directly proportional to the electron density. Over large scales, the ion flows and the auroral precipitation are relatively well correlated, but on smaller scales, the correlation decreases, and in some places, the ion flows and auroral precipitation are anti-correlated. This implies that the treatment of the frictional heating needs to be done quite carefully in order to capture the structure and dynamics in the high latitude thermosphere. Over global scales, though, this may not be the case. This talk will discuss the interplay between the ion convection and the auroral precipitation across different scales, and the ramification of this interplay on the frictional heating in the thermosphere on both small scales and global scales.

Sazykin, Stanislav

Simulation Studies of Storm-Time Ionospheric Electrodynamics

Sazykin, Stanislav[1]; Wolf, Richard[1]; Spiro, Robert[1]; Huba, Joseph[2]; Joyce, Glenn[3]; Maruyama, Naomi[4]; Fuller-Rowell, Timothy[4]

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2. Naval Research Laboratory, Washington, DC, USA
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4. CIRES University of Colorado, Boulder, CO, USA

Ionospheric electron densities and convection electric field patterns during magnetic storms exhibit significant structuring, with Subauroral Polarization Streams (SAPS) near the auroral oval and plasma plumes (particularly prominent in TEC maps) extending to lower latitudes and in MLT from the nightside toward the afternoon sector. At equatorial latitudes, storm-time response includes severe density depletions and enhanced daytime fountain effect. In this paper, we describe development of two different numerical models of the coupled ionosphere—inner magnetosphere system, and their application to simulation studies attempting to explain these observations. The two ionospheric models (SAMI3 and CTIPe) were coupled to the inner magnetospheric Rice Convection Model (RCM) in a self-consistent manner, with the RCM computing convection electric fields associated with high-latitude convection and region-2 Birkeland currents, and the ionospheric codes providing time-dependent conductances to the RCM. We describe the physics of as well as numerical approaches to such coupling. We then present the latest results in modeling observed ionospheric storm-time structuring during large storms.

Scherliess, Ludger

Data Assimilation Techniques and Their Use for Ionospheric Science and Applications

Scherliess, Ludger[1]; Schunk, Robert W.[1]

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The Earth's space environment is a complex and dynamic system that exhibits weather features at all times. As shown by meteorologists and oceanographers, a powerful way of modeling dynamic systems is with the use of data assimilation models. Over the past decade several data assimilation models for the ionosphere have been developed that employ a variety of different techniques, including 3DVAR, 4DVAR, and various Kalman filter approximations. These models are currently becoming one of the foremost tools for integrating observations from different sources and producing a coherent picture of the ionosphere dynamics, chemistry, and thermodynamics. In general, combining observations from different observation systems, in a manner that is consistent with a physics-based model representation, is a powerful means of extracting the full information content of the observations. For the ionosphere, numerical models that solve the continuity, momentum, and energy equations constitute an ideal framework for a systematic assimilation of data from multiple sources. Data assimilation techniques optimally combine the diverse and incomplete observations with a short-term forecast from the numerical model to produce the best estimate of the variables given by the model. The numerical model serves to maintain the dynamical, physical, and chemical consistency between the time-dependent fields. In this context, data assimilation is the optimal method to directly compare predictions obtained from the numerical model with satellite and ground based observations at corresponding locations and times, and in turn, correct the model trajectory and determine unknown external driving forces and model parameters. Data assimilation is, however, also "a systematic, structured, and open-ended learning process". By continually comparing the numerical model with observations, the data assimilation scheme quantifies the mismatch between the observations and the model forecasts, and provides clues for further model improvements. An overview of the various data assimilation techniques that are being used for ionospheric science and applications will be presented and their advantages and disadvantages will be discussed. Recent results obtained from ionospheric data assimilation models will also be shown.

Schunk, Robert W.

Ionosphere-Thermosphere Physics: Current Status and Problems

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The ionosphere-thermosphere (I-T) system is a highly dynamic and complex medium that varies with altitude, latitude, longitude and time, and this variation is particularly strong during geomagnetic storms and substorms. However, it has been clearly established that the ionosphere-thermosphere system exhibits both a background state (climatology) and a disturbed state (weather). At mid-latitudes, the background ionospheric state is characterized by an electron density distribution that tends to be uniform, with a gradual transition from high electron densities on the dayside to low electron densities on the night-side. At low latitudes, the main characteristic feature is the Equatorial Ionization Anomaly (EIA). The background thermospheic state tends to be uniform, with gentle winds blowing around the globe from the sub-solar point. However, superimposed on these background states are weather features, including storm-time disturbances, mesoscale (100-1000 km) structures, and plasma irregularities. For the ionosphere, these include traveling ionospheric disturbances (TIDs), sporadic E layers, He+ layers in the topside ionosphere, descending intermediate layers, Storm Enhanced Densities (SEDs), a 4-wave signature, spread-F, and equatorial plasma bubbles. For the thermosphere, the weather disturbances include upward propagating waves from the lower atmosphere (planetary, tidal and gravity waves), Traveling Atmospheric Disturbances (TADs) generated at high latitudes, storm-time O/N2 depletions, and neutral gas perturbations at the terminator and in the regions containing equatorial plasma bubbles. The complex nature of the ionosphere-thermosphere system results from a variety of internal processes as well as from processes that link it to the lower atmosphere, plasmasphere, polar wind, and magnetosphere. Basically, the physics underlying the I-T climatology has been clearly established and the I-T models have been able to reproduce the major I-T features. However, the I-T models have been less successful in modeling weather features, especially when attempting long-term forecasts. Part of the problem is associated with the fact that the various physics-based models contain several uncertain parameters and processes as well as missing physics. Further complications arise for coupled physics-based models because of coupling issues and error propagation from model to model. Some of the problems are also associated with the magnetosphere and lower atmosphere drivers, the adopted set of physics-based equations, the parameterization of physical processes, the values adopted for the transport coefficients, the numerical techniques used, the spatial and temporal resolutions adopted, and the uncertainties in the initial and boundary conditions. These and other issues will be discussed.

Semeter, Joshua L.

Accessing the hidden states of the ITM system (*Invited*)

Semeter, Joshua L.[1]

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The ITM community tends to label its members as experimentalists, modelers, theoreticians, etc. Yet many of the seminal advancements in our field have come from scientists for whom such labels are meaningless. In many cases, this "jack of all trades" approach arose of necessity. In the field of incoherent scatter radar, for instance, the amalgam of measurement and modeling is so deeply embedded that many think of the standard data products (Ne, Te, Ti, Vi) as measurements. This talk argues that a similar amalgam, applied to heterogeneous measurements and more complex physical models, represents a pathfinding methodology in ITM system science. As an example, we consider the system comprised of an auroral arc and its surrounding region of influence, and demonstrate that unobserved state parameters of this system (e.g., particle spectra, composition) may be reliably determined through first-principles modeling, suitably constrained by observation. Such an approach is enabled on a global scale by emerging technologies such as multi-core processors, ubiquitous broad-band networks, and cloud computing.

Siefring, Carl L.

Integrating the Sun-Earth System (ISES): Comparisons of the SAMI3 Physics Based Ionosphere Model with Global Ionosonde and GPS Observations during Solar Minimum

Siefring, Carl L.[1]; McDonald, Sarah E.[2]; Huba, Joesph D.[1]; Lean, Judith L.[2]; Joyce, Glenn[3]; Drob, Douglas P.[2]; Emmert, John T.[2]; Bernhardt, Paul A.[1]; Krall, Jonathan F.[1]

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The ISES program at the Naval Research Laboratory is designed to test the ability of state-of-the-art models to specify and predict the ionosphere on multiple time scales. As part of this program, numerous runs of the physics based SAMI3 model have been made and compared to global ionosonde foF2 and hmF2 and GPS Total Electron Content measurements. The comparisons presented will primarily center on Feb. 19 - April 19, 2008 which contains the most recent Whole Heliospheric Interval (WHI). This time period, during solar minimum, has only very modest solar activity and is a good test to validate the SAMI3 simulations of the base-state ionosphere. The results show that knowledge of the neutral winds is a crucial factor limiting the ability of SAMI3 to correctly match the measured ionospheric conditions.

Siskind, David E.

Coupling the NRL NOGAPS-ALPHA model to the NCAR TIEGCM

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One of the most exciting new paradigms in upper atmospheric science is the recognition that processes in the thermosphere and ionosphere can be dramatically impacted by meteorological disturbances which originate in the lower atmosphere. At NRL, we have recently extended the Navy's operational global weather forecast system (NOGAPS) up to near 90-100 km (ALPHA: Advanced Level Physics High Altitude). NOGAPS-ALPHA consists of a physics based forecast model and a 3D variational (3DVAR) data assimilation system. To evaluate the coupling to even higher altitudes we have begun a project to take the temperatures and winds from the top of the NOGAPS-ALPHA model and use them to drive the bottom boundary of the NCAR TIEGCM. Of particular interest are the effects of recent pronounced stratospheric warmings on equatorial winds and electric fields. We present some preliminary results. One issue to be evaluated is the time resolution. The NOGAPS-ALPHA analysis is output every 6 hours; however, the forecast model can be run with 1 hour output. We will discuss the sampling required to properly simulate equatorial tides.

Sojka, Jan J.

Ionospheric Flare Modeling: A New Paradigm

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Ionospheric models require a description of the solar EUV irradiance as the fundamental driver of dayside ionization. Questions have always been asked about this irradiance's dependence on wavelength and temporal variability. In lieu of adequate solar EUV measurements the ionospheric community has developed a suite of proxy solar EUV indices. A similar approach has been used to represent solar flares with the GOES satellite x-ray fluxes temporal variability being used to modulate a pre-flare solar EUV spectrum. With the availability of the NASA Solar Dynamics Observatory (SDO) EUV Variability Experiment (EVE) observations the above shortcomings and modeling procedures are open for review. The EVE instrument provides the solar irradiance spectrum from 0.1 to 105 nm with a spectral resolution of 0.1 nm at a cadence of 10 seconds. In the context of flare modeling even the few M-class flares observed by EVE have provided a new insight on how their solar irradiance evolve in time and wavelength. The most fundamental change is that a flare is not an overall rescaling of the pre-flare EUV spectrum. Nor do spectral components act synchronously as the flare progresses. Select wavelength line emission turn on minutes to hours apart! In this presentation we demonstrate this fundamental change in flare characterization using EVE measurements. We also provide a scheme by which the ionospheric response to the flare can be modeled. This involves the flare being treated as a separate solar EUV input to the background solar EUV spectrum. Indeed the high temporal resolution observations also suggest the background solar EUV spectrum cannot be adequately represented by a once per day solar proxy such as the radio flux index F10.7. This new knowledge is also used to describe monitoring instrumentation best suited for solar EUV monitoring. From ionospheric simulations the importance of the few minute desynchronization of flare emission lines with regards to E- and F-region densities will be shown.

Sojka, Jan J.

EISCAT Svalbard Radar (ESR) Year Long IPY Observations: A Model Climate Variability Study

Sojka, Jan J.[1]; David, Michael[1]; Schunk, Robert W.[1]; van Eyken, Anthony P.[2]; Codrescu, Mihail[3]; Fuller-Rowell, Tim[4]; Fedrizzi, Mariangel[4]; Spain, Tim[5]; Aylward, Alan[5]; Ridley, Aaron[6]; Pawlowski, David[6]; Blelly, Pierre-Louis[7]; Crowley, Geoff[8]; Liu, Ruiyuan[9]; Zhang, Beichen[9]

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The International Polar Year (IPY) began on 1 March 2007 and continued for one year until 29 February 2008. During this entire period the European EISCAT community operated their EISCAT Svalbard Radar (ESR) in the unprecedented 24/7 continuous operations mode. This data base of ionospheric measurements formed the basis for an International Space Sciences Institute (ISSI) ionosphere-thermosphere (I-T) model team study. The authors of this presentation are the core of the ISSI study team. Their challenge was two fold, firstly do their I-T models generate the year long IPY conditions observed at Svalbard? and secondly, how well can their models generate the observed I-T weather? This paper concentrates on the first of these two challenges, the year long solar minimum climatology. The ESR data was organized into seasons and then into four levels of geomagnetic activity. Since the disturbed periods were found to recur in predictable 3-day groups associated with solar wind corotating interaction regions (CIR) the lowest activity days were extracted for this initial study. This resulted in excellent statistically data sets for winter, summer, and equinox. These formed the basis for model-observation comparisons. Each model was adversely challenged in initial blind attempts to simulate these three seasons. All modelers were able to understand their problems and overcome them. But almost all modelers problems were unique! This presentation provides an overview of these problems and how they were resolved.

Song, Paul

Magnetosphere-Ionosphere/Thermosphere Coupling: A Structured Ionosphere with Self-consistent Electromagnetic Fields

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Over the last few years, the framework of a new theory has been developed to self-consistently describe the coupled system of the magnetosphere and ionosphere/thermosphere, on the basis of a three-fluid (electrons, ions, and neutrals) approach. In this theory, the electromagnetic fields as well as the collisions between the neutral thermosphere and the ionospheric plasma are all treated self-consistently. The ionosphere is structured instead of being merely a height-integrated boundary. Most importantly, the magnetic field varies in time, and the electric current is consistent with the magnetic field variations as well as with the electron and ion motions. The electric field is no longer assumed static, and inductive effects are taken into account. The dynamics of the magnetosphere-ionosphere coupling are included in the model. The physical mechanism of magnetosphere-ionosphere/thermosphere coupling that emerges from this treatment is that the coupling is primarily via magnetic tension force rather than by mapped electric field or field-aligned current. Heating is produced primarily by the collisional friction between the plasma and the neutrals. Significant differences from treatments based on the (conventional) ionospheric Ohm's law and a (static) electric potential or field-aligned current mapping appear at time scales shorter than about 20 Alfvén speed transit times or <20-30 minutes, which includes the time scales of many important magnetospheric and ionospheric dynamical phenomena.

Stolle, Claudia

Low latitude ionospheric/thermospheric observations of the CHAMP satellite in comparison with physics-based models (*Invited*)

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3. Academy of Science of Czech Republic, Inst. of Atmospheric Research, Prague, Czech Republic
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In recent years a growing number of satellite measurements in the ionosphere and thermosphere provide long and continuous data records which enable the investigation of climatological trends and the quantification of regular variations or isolated events. Joint analyses by combining observations with results of advanced physics-based models help to understand underlying processes. The CHAMP mission provides a valuable base of in situ measurements of the ionosphere and thermosphere between 300 and 400 km altitude and for years from 2000 to 2010. In our presentation we will discuss an example of the analysis of observed electron temperature (Te) and density together with FLIP model results investigating the equatorial Te morning overshoot (MO). A prominent maximum of Te occurs near the dip equator around 06 LT, and Te gradually decreases towards larger dip angles. This latitudinal distribution is regarded to be due to the role of heat conduction in regions where the magnetic field is inclined. At the dip equator local cooling/heating dominates. Both, data and model revealed an anti-correlation between the equatorial MO amplitude and solar EUV flux. As another example, we look into the spatial scales of equatorial plasma irregularities. Based on CHAMP observations we find small-scale structures of electron density irregularities within fluxtubes of higher apex altitude. In case of depleted fluxtubes of lower apex altitude the irregularity structures are of larger scale. Analyzed together with vertical plasma drift data this suggests that the plasma irregularities are highly structured at their bottom side and show larger structures on their upper edge. Support to this observation has been provided by 3-D numerical modeling (Aveiro and Hysell, 2010).

Su, Yi-Jiun

Low-latitude background ionospheric density structures during solar minimum obtained by AFRL physics-based model

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An important parameter in determining low-latitude ionospheric plasma density is the plasma drift. Two instruments on-board the Communication/Navigation Outage System (C/NOFS) satellite were designed to directly or indirectly measure the plasma drifts: the Ion Velocity Drift Meter (IVM) and the Vector Electric Field Instrument (VEFI). By using the electric field measurements obtained from VEFI, the physics-based model (PBMOD) developed at the Air Force Research Laboratory (AFRL) has been shown to qualitatively reproduce post-midnight density trenches observed in June 2008. In contrast, the model produces no plasma depletions at these local times when driven by a climatological specification of Scherliess-Fejer plasma drift. Moreover, an empirical drift model during solar minimum has been developed using two-year averaged IVM and VEFI data from C/NOFS. The background ionospheric densities of PBMOD driven by observed plasma drifts indicate wave-3 or wave-4 structures similar to those observed by the Planar Langmuir Probe (PLP). In contrast, these density structures, which might be associated with atmospheric tides, were absent when PBMOD was driven by the Scherliess-Fejer drift model. Model results have been quantitatively compared with in-situ density measurements obtained from C/NOFS, DMSP, and CHAMP satellites at altitudes ranging from ~300 to 860 km.

Talaat, Elsayed R.

Spatial and temporal variability of the ionosphere as revealed by modal decomposition

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We examine two approaches to capture the modes of spatial and temporal variability observed in the ionosphere: 1. decomposition into modes as functions of local time and zonal wavenumber and 2. analysis using empirical orthogonal function (EOF) decomposition and the corresponding principal component analysis (PCA)

technique. The spectral analysis of the different time series of reveals how different mechanisms such as solar flux variation, change of the orbital declination, nonlinear mode coupling and geomagnetic activity are separated and expressed in different modes. We examine similar analysis performed on output from the Thermosphere- Ionosphere-Electrodynamics General Circulation Model (TIE-GCM) to provide insight for the interpretation of the observed phenomena. In particular, we examine the relationship between the variability observed in mesospheric and lower thermospheric dynamical fields to modal variations observed in the low latitude ionosphere using these long-term global satellite observations and through simulations using the TIE-GCM.

Talaat, Elsayed R.

Solar rotational effects in the ionosphere

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The solar rotational signal has been detected in several ionospheric datasets including topside densities and temperatures, TEC and foF2, as well as incoherent scatter radar. These previous studies have established that the 27-day solar rotational signal is indeed present in the ionosphere and they typically correlate the variation with solar indices such as F10.7 or sunspot number. However, a comprehensive picture of precisely what spectral bands in the XUV are responsible for modifying which parts of the ionosphere still remains lacking. We analyze the solar rotational signal in several data sets including TOPEX/Jason (TEC), DMSP/SSIES (topside ionosphere), DMSP SSUSI (twilight/nighttime ionosphere profile), and COSMIC (global occultation measurements). These differing measurements provide complementary perspectives into the global and altitudinal response of the ionosphere to the solar rotational signal. The TIE-GCM is used mechanistically to examine the solar rotational effect on both the ionosphere and thermosphere. We examine under what conditions the solar rotational signal is significant on the bottom-side ionosphere.

Tian, Feng

Thermospheres and Ionospheres of Terrestrial Planets under Intense Solar EUV

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The thermospheres and ionospheres of solar system terrestrial planets (Earth, Mars, and Venus) all respond to solar EUV radiation by elevating the altitudes and the temperatures of the exobases. This effect causes the main channel of hydrogen escape from present Earth to change from the charge exchange process during solar minimum to the Jeans escape during solar maximum. How would the thermospheres and ionospheres of terrestrial planets responded to the much stronger solar EUV condtion which likely existed during the early evolutionary history of the Sun is an important question concerning the long term evolution of planetary atmospheres. In this work we use one-dimensional thermosphere-ionosphere model to investigate the thermospheres ad ionospheres of terrestrial planets under intense solar EUV condition. We find that these thermospheres and ionospheres should have been in a hydrodynamic state under intense solar EUV and atmosphere escape should have been rapid from all three solar system terrestrial planets. The type of major gases lost from the planets depends on the composition of the atmospheres. This work highlights the importance of thermosphere-ionosphere research on planetary atmosphere evolution.

Tu, Jiannan

A Self-consistent Dynamic Magnetosphere-Ionosphere/Thermosphere Coupling Model

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In this study we present a model based on three-fluid (electrons, ions, and neutrals) and time-dependent (retaining time derivatives) electromagnetic field theory to describe the solar wind-magnetosphere-ionosphere/thermosphere coupling. The present model is an extension of the previous model of Song et al. (J. Geophys. Res., 114, A08213, doi:10.1029/2008JA013629) with solutions of the continuity and energy equations incorporated. The present model self-consistently solves time-dependent continuity, momentum, and energy equations for the electrons, ions and neutrals, as well as Maxwell equations (Ampere's and Faraday's laws). The numerical solutions for a simple 1-D ionosphere/thermosphere in response to an imposed convection velocity at the top boundary are used to illustrate the physics of the dynamic magnetosphere-ionosphere/thermosphere coupling. We discuss the response of the ionosphere/thermosphere to the perturbations from the magnetosphere during the transit stage when the steady-state assumption is not valid. Particularly we show that the heating of the ionosphere/thermosphere is not Ohmic but, more accurately, frictional. The conventional Joule heating significantly underestimates the heating rate (up to 50% lower). The simulation results demonstrate that the time derivative terms in the momentum equations and induction of the magnetic field must be retained in order to correctly understand the magnetosphere-ionosphere/thermosphere coupling. The system reaches the steady state in about 20 Alfven times which are in a time scale of many most important phenomena, such as substorms, when the whole solar wind-magnetosphere-ionosphere/thermosphere system is considered.

Varney, Roger H.

Modeling Photoelectron Transport and Nonlocal Heating in the Low Latitude Ionosphere

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A recent study of the plasma temperatures in the low latitude topside ionosphere using both the SAMI2 model and a newly developed steady state model has revealed the importance of nonlocal heating processes. Changes to both the neutral winds and electric fields alter the arrangement of plasma throughout the entire low latitude ionosphere, including the locations and densities of the equatorial arcs. These changes have a much larger effect on the topside temperatures above the equator than changing the local advection or expansion alone because the topside equatorial temperatures are strongly coupled to the off-equatorial F-regions by field aligned thermal diffusion and photoelectron transport. The current treatment of nonlocal photoelectron heating in SAMI2 and the new steady state model is simplistic and includes an arbitrary tunable parameter. We have adapted the two stream photoelectron transport model originally developed for FLIP for use with SAMI2 and developed our own multistream model. We discuss the relative accuracies and computational limitations associated with the various photoelectron transport models.

Weimer, Daniel R.

Better Predictions of Thermospheric Density From an Empirical Model

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An empirical model uses the solar wind and interplanetary magnetic field (IMF) to compute the total Poynting flux into both polar hemispheres as a function of time. These calculations have been compared with neutral density measurements in the thermosphere at two altitudes, as are obtained from satellite drag measurements from the CHAMP and GRACE missions. The Jacchia-Bowman 2008 empirical thermospheric density model (JB2008) is used to facilitate the comparison. This model calculates a background level for the ``global nighttime minimum exospheric temperature,'' Tc from solar indices. Corrections to this background level due to auroral heating, ΔTc, are at present computed from the Dst index. A new technique is used whereby a proxy measurement of this temperature difference, ΔTc, is obtained by matching the CHAMP and GRACE density measurements with the JB2008 model. The orbit-averaged ΔTc measurements on the two satellites are in good agreement, even though their orbits are at different altitudes. Through the use of a differential equation that incorporates the total polar heating, as well as an exponential cooling, the ΔTc correction can be predicted from IMF values. The resulting calculations agree very well with the orbit-averaged measurements of ΔTc. Results indicate that the thermospheric cooling rate is faster just after time periods with significant ionospheric heating. The enhanced cooling is likely due to nitric oxide (NO) that is produced at a higher rate in proportion to the ionospheric heating. The ΔTc predictions use a variable that represents the amount by which the relative concentration of NO grows and decays, which in turn controls the cooling rate of the thermosphere. The ΔTc temperature correction from this model can be used as a direct substitute for the Dst-derived correction that is now used in JB2008; statistical comparisons show that it is more accurate, in addition to having the capability to be available in near real-time. The ability to predict the thermospheric temperature changes in advance could lead to improved tracking of satellites and orbital debris.

Werne, Joseph

Three Dimensional Modeling of Neutral Turbulence from Strong Shears in the Mesosphere and Lower Thermosphere

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At altitudes near 100 km, strong wind shears are found at all latitudes. These large amplitude winds have three effects on metallic ion layers of the sporadic-E region. First the shears compress the layers and increase their density. The E-layer maximum density forms near the node of the zonal component of the wind shear. Second, the wind shear can drive an interchange instability that ripples the plasma layer. Third, a strong wind shear becomes unstable yielding billow structures by the Kelvin-Helmholtz (KH) instability. The combination of the three effects produces dense irregular layers near 100 km altitude. The non-linear evolution of the neutral KH instability is computed in three-dimensions. Dynamics and morphology of a stratified turbulent shear layer in the mesosphere is examined using hydrodynamic equations governing the hydrodynamic flow of a viscous fluid of varying density and temperature. To simulate the non-linear evolution of the Kelvin-Helmholtz instability and subsequent turbulence dynamics, we begin with the Boussinesq approximation in a Cartesian geometry. A stream background flow is initiated with a constant peak velocity, scale-length, and vertical coordinate. The background temperature is initially linear with a constant mean thermal gradient. The equations of motion describing mass conservation, momentum, heat, are coupled by thermal expansion, thermal diffusivity, and the acceleration due to gravity. These equations have been solve numerically in 3D

for high Reynolds numbers for a planer speed shear with to give the turbulent flow distribution. The turbulent mixing generated by the Kelvin-Helmholtz (KH) instability in the mesosphere will use the same numerical simulation model with a more realistic, turning shear for the wind. The ratio of out-of-plane to in plane wind speed is parameterized. The transition between a pure planer shear and a pure turning shear is computed to determine the effects on the KH billows. The measured wind shears in the mesosphere typically are described by partial turning shears. The Reynolds number for these simulations will vary between about 3000 at 100 km altitude and 300 at 120 km altitude. The lower Reynolds number simulations will be less turbulent. Exploration of the neutral dynamics for a turning shear for a variety of Reynolds numbers is the objective of the modeling.

Computed vorticity of turbulence produced by a strong wind shear in the mesosphere.

Wilder, Frederick D.

Interhemispheric Observations of Dayside Convection Under Strongly Northward IMF

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We report the results of an investigation of the day-side polar cap electric field during periods of large northward interplanetary magnetic field (IMF). Using SuperDARN VLOS measurements, we demonstrate statistically that the reverse convection electric field under northward IMF saturates at a larger value in the summer hemisphere than in the winter. We also demonstrate that the opposite trend occurs under southward IMF. This cannot be explained by conductivity alone, so a case study near solstice is presented. We observe stronger reverse convection in the summer hemisphere, as well as particle precipitation characteristics in the winter hemisphere that indicate reverse convection cells centered on closed field lines. Reverse convection on open field lines is observed in the summer hemisphere. This implies that the reconnection driving reverse convection in the winter hemisphere is internal merging between over-draped summer lobe field lines and winter lobe field lines. The drastic difference in reverse convection electric field implies that internal reconnection is less effective at transmitting the interplanetary electric field into the polar cap than direct merging between lobe field lines and the IMF.

Yokoyama, Tatsuhiro

Modeling Nighttime Medium-scale Traveling Ionospheric Disturbances and E-F/Hemispheric Coupling in the Midlatitude Ionosphere

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Nighttime medium-scale traveling ionospheric disturbances (MSTIDs) in the midlatitude ionosphere often have an intriguing plasma density structure elongated from northwest to southeast (NW-SE) (from northeast to southwest) and propagate southwestward (northwestward) in the Northern (Southern) Hemisphere. We have been developing a three-dimensional numerical model of the midlatitude ionosphere in order to study the generation mechanism of MSTIDs and proposed that the electrodynamical coupling between the E and F regions is quite important for a rapid growth of MSTIDs, which cannot be accounted for by the Perkins instability alone in the F region [e.g., Yokoyama et al., 2009]. Recently, Yokoyama and Hysell [2010] have developed a new midlatitude ionosphere electrodynamics coupling model (MIECO) which can model the coupling process between the E and F regions with dipole magnetic field lines. Using the new model, MSTID structure is reproduced from random perturbation on an Es layer by the coupled Perkins and sporadic-E (Es)-layer instabilities in a wide latitudinal range. The next step is to study the coupling between two hemispheres because the MSTIDs have been simultaneously observed at the magnetic conjugate locations. To this purpose, two simulation domains of MIECO are prepared for each hemisphere and connected by equipotential magnetic field lines. A polarization potential is solved by integrating conductivities of both hemispheres. The growth of MSTIDs under the different background conditions in the summer and winter hemispheres will be discussed.