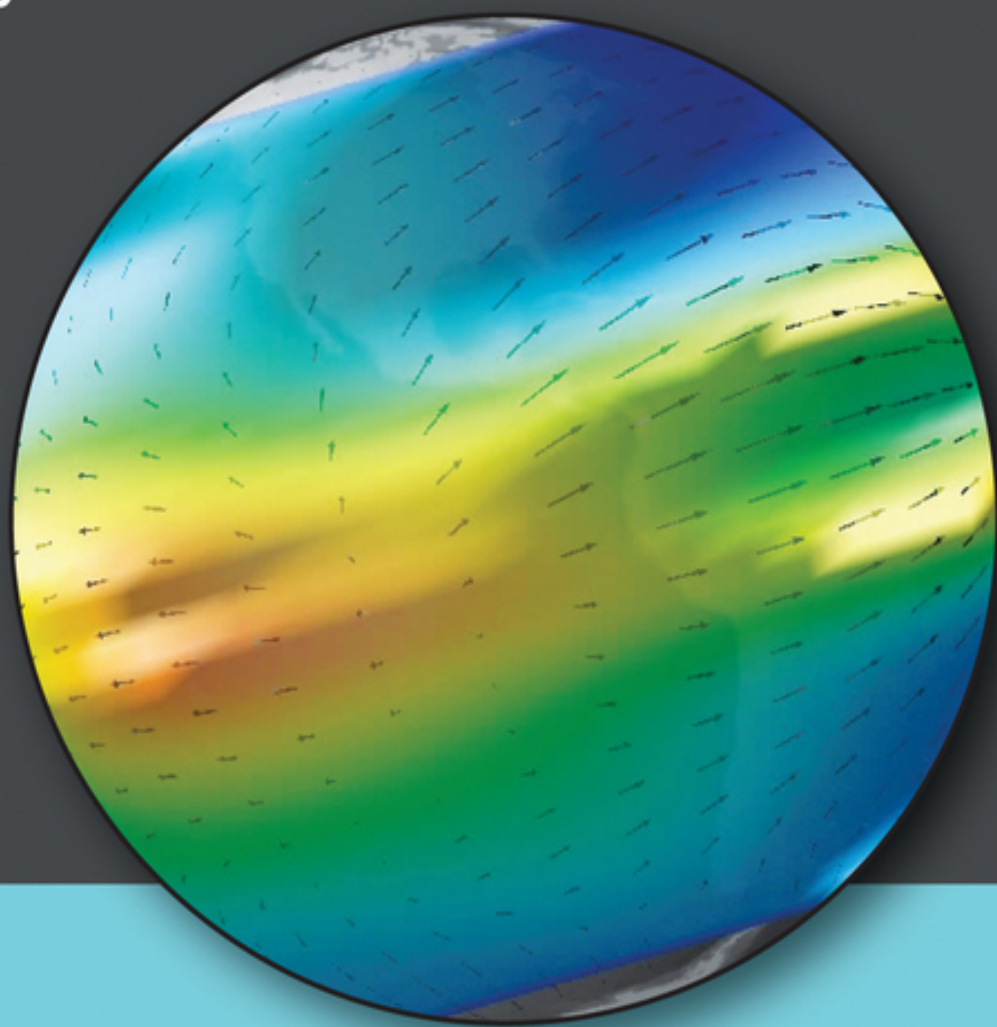


# Modeling the Ionosphere-Thermosphere System



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Editors

# CONTENTS

[Cover](#)

[Series page](#)

[Title page](#)

[Copyright page](#)

[Preface](#)

[Introduction](#)

[Ionosphere-Thermosphere Physics](#)

[1. INTRODUCTION](#)

[2. MISSING PHYSICS IN GLOBAL PHYSICS-BASED  
IONOSPHERE-THERMOSPHERE MODELS](#)

[3. SUMMARY](#)

[REFERENCES](#)

[Physical Characteristics and Modeling of Earth's  
Thermosphere](#)

[1. INTRODUCTION](#)

[2. THE GAS LAW AND HYDROSTATIC BALANCE](#)

[3. CONTINUITY EQUATION](#)

[4. LAGRANGIAN VERSUS EULERIAN FRAMES OF  
REFERENCE](#)

[5. HORIZONTALLY STRATIFIED FLUID AND OTHER  
COMMON ASSUMPTION](#)

[6. CORIOLIS EFFECT](#)

[7. VISCOUS DRAG](#)

[8. ION DRAG](#)

[9. MOMENTUM EQUATION](#)

[10. ENERGY EQUATIONS](#)

11. NEUTRAL COMPOSITION

12. GLOBAL WIND, TEMPERATURE, DENSITY, AND COMPOSITION STRUCTURE

13. THERMAL EXPANSION

14. NEUTRAL COMPOSITION BULGE

15. WINDS AND NONLINEARITIES AT HIGH LATITUDE

16. CONCLUSIONS

REFERENCES

Solar Cycle Changes in the Photochemistry of the Ionosphere and Thermosphere

1. INTRODUCTION

2. RESULTS

3. CONCLUSIONS

REFERENCES

Energetics and Composition in the Thermosphere

1. INTRODUCTION

2. DATA AND MODELS THAT HAVE INCREASED OUR UNDERSTANDING OF THE UPPER ATMOSPHERE

3. THE CONTINUITY EQUATION, THE ENERGY EQUATION, AND BOUNDARY CONDITIONS

4. THE CAUSES OF TEMPERATURE VARIATIONS IN THE LOW AND MIDDLE LATITUDES OF THE UPPER THERMOSPHERE DURING GEOMAGNETIC STORMS

5. SUMMARY

REFERENCES

Numerical Methods in Modeling the Ionosphere

1. INTRODUCTION

- [2. GENERAL EQUATIONS](#)
- [3. FIELD-ALIGNED DYNAMICS](#)
- [4. CROSS-FIELD DYNAMICS](#)
- [5. SUMMARY](#)
- [REFERENCES](#)

### [Ionospheric Electrodynamics Modeling](#)

- [1. INTRODUCTION](#)
- [2. EQUATIONS OF IONOSPHERIC ELECTRODYNAMICS](#)
- [3. MODELING IONOSPHERE- MAGNETOSPHERE COUPLING](#)
- [4. MODELING IONOSPHERIC CONDUCTIVITIES](#)
- [5. MODELING THERMOSPHERIC WINDS](#)
- [6. PLASMA GRAVITY AND PRESSURE- GRADIENT CURRENTS](#)
- [7. SOLVING FOR THE ELECTRIC POTENTIAL](#)
- [8. IONOSPHERIC CURRENT SYSTEM AND GEOMAGNETIC PERTURBATIONS](#)
- [9. FUTURE DIRECTIONS](#)
- [REFERENCES](#)

### [The NCAR TIE-GCM](#)

- [1. INTRODUCTION](#)
- [2. MODEL DEVELOPMENT HISTORY](#)
- [3. MODEL DESCRIPTION](#)
- [4. SOME MODEL VALIDATION EXAMPLES](#)
- [5. FUTURE IMPROVEMENT AND DEVELOPMENT PLANS](#)
- [REFERENCES](#)

### [The Global Ionosphere-Thermosphere Model and the Nonhydrostatic Processes](#)

[1. INTRODUCTION](#)

[2. GLOBAL IONOSPHERE-THERMOSPHERE MODEL](#)

[3. NONHYDROSTATIC PROCESSES](#)

[4. CONCLUSION AND DISCUSSION](#)

[APPENDIX A: EQUATIONS IN GITM MODEL](#)

[A1. CONTINUITY EQUATION](#)

[A2. MOMENTUM EQUATIONS](#)

[A3. ENERGY EQUATION](#)

[A4. EQUATIONS FOR IONS](#)

[REFERENCES](#)

[Traveling Atmospheric Disturbance and Gravity Wave Coupling in the Thermosphere](#)

[1. INTRODUCTION](#)

[2. GLOBAL THERMOSPHERE-IONOSPHERE MODEL](#)

[3. SIMULATION SETUP](#)

[4. SIMULATION RESULTS](#)

[5. SUMMARY](#)

[REFERENCES](#)

[Air Force Low-Latitude Ionospheric Model in Support of the C/NOFS Mission](#)

[1. INTRODUCTION](#)

[2. MODEL DESCRIPTION AND OUTPUT](#)

[3. A STATISTICAL STUDY OF LOW-LATITUDE IONOSPHERIC DENSITIES](#)

[4. SUMMARY AND DISCUSSION](#)

[REFERENCES](#)

[Long-Term Simulations of the Ionosphere Using SAMI3](#)

[1. INTRODUCTION](#)

[2. MODEL DESCRIPTION](#)

3. SAMI3 COMPARISONS WITH IGS TEC DURING THE WHOLE HELIOSPHERE INTERVAL 2008

4. MODELING VERTICAL DRIFTS

5. MODELING THE DESCENDING PHASE OF SOLAR CYCLE 23 (2002-2008).

6. SUMMARY OF RESULTS

REFERENCES

Comparative Studies of Theoretical Models in the Equatorial Ionosphere

1. INTRODUCTION

2. TRANSPORT PROCESSES IN THE IONOSPHERE

3. PARTICIPATING MODELS IN EQUATORIAL-PRIMO

4. MODEL COMPARISONS IN AMERICAN SECTOR (75°W).

5. SOURCES OF MODEL DISCREPANCIES

6. CONCLUSION AND FUTURE PROSPECTS

REFERENCES

Systematic Evaluation of Ionosphere/Thermosphere (IT) Models

1. INTRODUCTION

2. OBSERVATIONAL DATA

3. MODELS

4. METRICS

5. RESULTS

6. DISCUSSION AND CONCLUSIONS

REFERENCES

Aspects of Coupling Processes in the Ionosphere and Thermosphere

1. ION-ELECTRON COLLISIONS

2. ION ELECTRON COLLISIONS

3. ION-NEUTRAL COLLISIONS IN THE UPPER THERMOSPHERE

4. ION-NEUTRAL COLLISIONS IN THE LOWER THERMOSPHERE

5. SUMMARY AND CONCLUSIONS

REFERENCES

Use of NOGAPS-ALPHA as a Bottom Boundary for the NCAR/TIEGCM

1. INTRODUCTION

2. MODEL DESCRIPTIONS

3. MODEL RESULTS

4. CONCLUSION

REFERENCES

WACCM-X Simulation of Tidal and Planetary Wave Variability in the Upper Atmosphere

1. INTRODUCTION

2. THE THERMOSPHERE EXTENSION OF THE WHOLE ATMOSPHERE COMMUNITY CLIMATE MODEL (WACCM-X)

3. MODEL RESULTS

4. DISCUSSION AND SUMMARY

REFERENCES

Inductive-Dynamic Coupling of the Ionosphere With the Thermosphere and the Magnetosphere

1. INTRODUCTION

2. INDUCTIVE-DYNAMIC COUPLING VERSUS ELECTROSTATIC COUPLING

3. CONCLUSIONS AND DISCUSSION

REFERENCES

Ionospheric Irregularities

1. INTRODUCTION

2. FUNDAMENTALS

3. E REGION IRREGULARITIES

4. F REGION IRREGULARITIES

5. COLLISIONAL DRIFT WAVE INSTABILITIES

6. SUMMARY AND CONCLUSIONS

APPENDIX A: FBGD DISPERSION RELATION

APPENDIX B: BOURRET'S INTEGRAL EQUATION

REFERENCES

Three-Dimensional Numerical Simulations of Equatorial Spread F

1. INTRODUCTION

2. NUMERICAL SIMULATIONS

3. SUMMARY AND DISCUSSIONS

REFERENCES

Density and Temperature Structure of Equatorial Spread F Plumes

1. INTRODUCTION

2. SAMI3 SIMULATIONS

3. IONIZATION CRESTS WITHIN AN ESF PLUME

4. THERMODYNAMICS OF AN ESF PLUME

5. TIME EVOLUTION OF AN ESF PLUME

6. DISCUSSION

REFERENCES

Low-Latitude Ionosphere and Thermosphere

1. INTRODUCTION

2. CHAMP MISSION AND DATA

3. OBSERVATIONS OF THE IONOSPHERE

4. OBSERVATIONS OF THE THERMOSPHERE



## 5. CONCLUSIONS AND OUTLOOK

### REFERENCES

#### Upper Atmosphere Data Assimilation With an Ensemble Kalman Filter

##### 1. INTRODUCTION

##### 2. ENSEMBLE KALMAN FILTER

##### 3. EFFECTS OF SELF-CONSISTENT TREATMENT OF THE THERMOSPHERE AND IONOSPHERE

##### 4. GEOPHYSICAL INFORMATION CONTENT OF DIFFERENT OBSERVATIONS

##### 5. ESTIMATION OF MODEL PARAMETERS

##### 6. MODEL ERROR ISSUES

##### 7. SUMMARY

### REFERENCES

#### Scientific Investigations Using IDA4D and EMPIRE

##### 1. INTRODUCTION

##### 2. IDA4D

##### 3. EMPIRE

##### 4. IDA4D AND EMPIRE SCIENTIFIC INVESTIGATIONS

##### 5. FUTURE RESEARCH: A NEW PLASMASPHERE-IONOSPHERE DATA ASSIMILATION MODEL

##### 6. SUMMARY

### REFERENCES

#### Customers and Requirements for Ionosphere Products and Services

##### 1. INTRODUCTION

##### 2. SPACE WEATHER IMPACTS

##### 3. SYSTEM IMPACTS AND CUSTOMERS

##### 4. OPERATIONAL MODELS

[5. THE SPACE WEATHER PREDICTION TESTBED](#)

[6. CONCLUSION](#)

[REFERENCES](#)

[Model-Based Inversion of Auroral Processes](#)

[1. INTRODUCTION](#)

[2. OVERVIEW OF THE FORWARD PROBLEM](#)

[3. MATHEMATICAL DESCRIPTION OF THE FORWARD PROBLEM](#)

[4. CHARACTERISTIC RESPONSES](#)

[5. FREDHOLM FORMULATION](#)

[6. TIME HISTORY](#)

[7. INVERSION APPROACHES](#)

[8. VALIDATION](#)

[9. FUTURE DIRECTIONS: ACCESSING HIDDEN STATES OF THE I-T SYSTEM](#)

[REFERENCES](#)

[AGU Category Index](#)

[Index](#)

[Eula](#)

## **List of Tables**

Chapter 03

[Table 1. Ion Reaction Rate Coefficients](#)

Chapter 07

[Table 1. Equations Used in the Thermosphere-Ionosphere-Equation, Output Variables Solved by Each Equation, and Physical Terms of Each Equation](#)

[Table 2. Boundary Conditions of Time-Dependent Equations of the TIE-GCM: Output Variables and Their Lower and Upper Boundary Conditions](#)

Chapter 12

[Table 1. Information of the Non-Self-Consistent Models](#)

[Table 2. Information of the Self-Consistent Models](#)

Chapter 13

[Table 1. Models Submitted for the Coupling Energetics and Dynamics of Atmospheric Regions \(CEDAR\) Challenge](#)

[Table 2. Setup of the CEDAR Electrodynamics Thermosphere Ionosphere Challenge](#)

[Table 3. RMS Errors \( \$10^5 \text{ cm}^{-3}\$ \) and PE in Prediction of Electron Density Along the CHAMP Orbits](#)

[Table 4. Ratio \(Max-Min\), and Ratio \(Max\) in Prediction of Electron Density Along the CHAMP Orbits](#)

[Table 5. RMS Errors \( \$10^{-12} \text{ kg m}^{-3}\$ \), and PE in Prediction of Neutral Density Along the CHAMP Orbits](#)

[Table 6. Ratio \(Max-Min\), and Ratio \(Max\) in Prediction of Neutral Density Along the CHAMP Orbits](#)

[Table 7. RMS Errors \( \$\text{m s}^{-1}\$ \) and \(PE\) in Prediction of Vertical Drift at Jicamarca](#)

[Table 8. Ratio \(Max-Min\), and Ratio \(Max\) in Prediction of Vertical Drift at Jicamarca](#)

Chapter 17

[Table 1. Comparison of Steady State Coupling and Dynamic Coupling](#)

Chapter 19

[Table 1. Chemistry of O\(<sup>1</sup>D\) in the Nightglow](#)

Chapter 22

[Table 1. List of the TIEGCM Variables Included in the State Vector x for Each Experiment Presented in the Paper](#)

Chapter 24

[Table 1. A List of Customer Requirements for the Ionosphere-Thermosphere Environment and the Related Ionospheric Phenomena That Addresses Them](#)

[Table 2. GPS/GNSS Customer Needs and Requirements, Impacted by Space Weather, as Determined Through a Space Weather Prediction Center Survey of Customer Requirements](#)

## List of Illustrations

Chapter 01

[Figure 1. A schematic diagram showing the processes that affect the polar wind and energetic ion outflow from the ionosphere at high latitudes. From Schunk and Sojka \[1997\].](#)

[Figure 2. Electron temperature profiles for three values of the field-aligned auroral return current for winter and summer conditions at both solar minimum and maximum. The field-aligned current values are 0 \(solid curves\),  \$-1 \times 10^{-5}\$  \(dotted curves\), and  \$-5 \times 10^{-5}\$  \(dashed curves\) A m<sup>-2</sup>. An upper boundary \(800](#)

km) heat flux of  $-1 \times 10_{10} \text{ eV cm}^{-2} \text{ s}^{-1}$  was used for these simulations to account for the interaction of the ionospheric electrons with the hot polar rain electrons. From Schunk et al. [1987].

Figure 3. Ion density profiles calculated for a daytime high-latitude ionosphere subjected to a  $100 \text{ mV m}^{-1}$  electric field. The curves labeled 2 were calculated with  $T_j$ , and the curves labeled 1 were calculated with  $T_{j\parallel}$ . From Schunk et al. [1975].

Figure 4. (top) Altitude profiles of the adopted electron, ion, and neutral temperatures used in subauroral red (SAR) arc calculations;  $T_e(1)$  and  $T_e(2)$  are the electron temperatures outside and inside the SAR arc, respectively. (bottom) Calculated ion and electron density profiles in a SAR arc including the effect of  $\text{N}_2$  vibrational excitation and the associated increase in the  $\text{O}^\pm + \text{N}_2 \Rightarrow \text{NO}^\pm + \text{N}$  reaction. From Raitt et al. [1976].

Figure 5. Proton heat flows along  $\mathbf{B}$  for the transport of parallel energy ( $q_p^\parallel$ ), perpendicular energy ( $q_p^\perp$ ), and total energy ( $q_p$ ) along a SAR arc field line, where  $q_p = (q_p^\parallel + 2q_p^\perp)/2$ . Solid curves correspond to the solution of the 16-moment bi-Maxwellian transport equations. The dashed curve is not relevant to the discussion in the paper. From Demars and Schunk [1986].

Figure 6. Electron density as a function of dipole latitude for the (a) single-stream  $\text{H}^\pm$  model and for the (b) two-stream  $\text{H}^\pm$  model. The multiple curves show the temporal evolution of the electron density as the flux tube fills, with the 0 min curves corresponding to the start of the simulations. From Rasmussen and Schunk [1988].

Figure 7a. Effect of multiple propagating plasma patches on the thermosphere at  $t = 3$  h. (left top) The  $N_e$  distribution at 300 km in units of  $\log_{10}N_e$  ( $\text{cm}^{-3}$ ), (right top) the neutral density perturbation at 300 km, and (bottom) the neutral density perturbation versus altitude and latitude across the polar cap. From *Ma and Schunk* [2001].

Figure 7b. Snapshot at  $t = 4.41$  h of the neutral density perturbation due to multiple propagating plasma patches. The neutral perturbation is shown (left) at 300 km and (right) as a function of altitude and latitude across the polar cap. From *Schunk et al.* [2008].

## Chapter 02

Figure 1. Typical global distribution of some of the major model parameters at the December solstice at moderate solar and geomagnetic activity, (left top) The contours of neutral temperature and total wind vector and (right top) the contours of meridional wind on a fixed pressure level in the upper thermosphere close to 300 km. (left bottom) Neutral density at a fixed altitude of 300 km and (right bottom) the height-integrated  $O/N_2$  ratio (figure courtesy of Mariangel Fedrizzi, 2012).

Figure 2. Illustration of the change in the neutral wind at midlatitude and low latitudes at 250 km altitude shortly after a sudden increase in the high-latitude magnetospheric energy input. The region within  $50^\circ$  of the geographic equator is shown at 15 UT, 3 h after the increase in the high-latitude magnetospheric forcing, equivalent to a  $K_p \sim 7$ .

Figure 3. Illustration of the response of the thermosphere to heating and thermal expansion

(figure courtesy of Karen O'Loughlin, 2012).

Figure 4. Illustration of the response and evolution of a composition “bulge” in the summer hemisphere upper thermosphere in response to a 12 h geomagnetic storm from 10° latitude to the pole. The response is followed through 36 h of recovery. The figure shows the increase in mean molecular mass in atomic mass units, compared to a background simulation without a storm, on a fixed pressure level in the upper thermosphere around 300 km altitude, from 10° latitude to the pole.

Figure 5. Illustration of the response to elevated geomagnetic activity ( $K_p \sim 7$ ) of (left) neutral wind and temperature and (right) neutral density. The region poleward of 50° latitude is shown at 200 km altitude.

Figure 6. Illustration of the direction of forces for vortices driven by ion drag in the (left) clockwise and (right) counterclockwise direction. The forces are shown in a “natural” vortex coordinate system as suggested by Holton [1972].

## Chapter 03

Figure 1. Schematic representation of the major processes in the ion chemistry of the Earth's ionosphere based on the work of Richards [2011]. The circles represent the major neutral species, the boxes represent the important ions, and the arrows with labels show the various reactions and ionization processes. Photoelectron impact ionization is labeled  $e^*$ , photoionization is labeled  $h\nu$ , and spontaneous radiation is labeled rad. The chemical reactions are labeled with the reacting species.

Figure 2. Model neutral densities for 5 September 2005 (full lines) and 17 March 1990 (broken lines).

Figure 3. Modeled ion densities (lines) for 6 September 2005 and 17 March 1990. The symbols are the measured ion densities.

Figure 4. O+(4S) production (solid lines) and loss (broken lines) rates for 6 September 2005 and 17 March 1990. The sources and sinks are labeled with the reacting species. Photoionization is labeled  $h\nu$  and photoelectron impact ionization is labeled  $e^*$ .

Figure 5. O+(2D) production (solid lines) and loss (broken lines) rates for 6 September 2005 and 17 March 1990. The sources and sinks are labeled with the reacting species. Photoionization is labeled  $h\nu$ , and photoelectron impact ionization is labeled  $e^*$ .

Figure 6. O+(2P) production (solid lines) and loss (broken lines) rates for 6 September 2005 and 17 March 1990. The sources and sinks are labeled with the reacting species. Photoionization is labeled  $h\nu$ , and photoelectron impact ionization is labeled  $e^*$ .

Figure 7. production (solid lines) and loss (broken lines) rates for 6 September 2005 and 17 March 1990. The sources and sinks are labeled with the reacting species. Photoionization is labeled  $h\nu$ , and photoelectron impact ionization is labeled  $e^*$ .

Figure 8. production (solid lines) and loss (broken lines) rates for 6 September 2005 and 17 March 1990. The sources and sinks are labeled with the reacting species. Photoionization is labeled  $h\nu$ , and photoelectron impact ionization is labeled  $e^*$ .

Figure 9. NO+ production (solid lines) and loss (broken lines) rates for 6 September 2005 and 17



March 1990. The sources and sinks are labeled with the reacting species.

Figure 10. N<sup>+</sup> production (solid lines) and loss (broken lines) rates for 6 September 2005 and 17 March 1990. The sources and sinks are labeled with the reacting species. Photoionization is labeled hv, and photoelectron impact ionization is labeled e\*.

## Chapter 04

Figure 1. Temperature and density variations with altitude in the thermosphere (from National Research Laboratory-Mass Spectrometer Incoherent Scatter model) [Picone et al., 2002].

Figure 2. Temperatures and horizontal wind vectors before the storm (a) and during the main phase of the storm (b) at 09:00 UT for the z = 2 (~300 km) pressure surface.

Figure 3. Temperatures and winds at midnight plotted as a function of pressure surface and latitude for 4 UTs, from 0400 to 1000 at midnight local time during the main phase of the storm. Pressure level 0 corresponds to about 280 km at quiet time.

Figure 4. Compressional heating and cooling by expansion (in units of K s<sup>-1</sup>) for two times during the main phase of the 15-16 December 2006 geomagnetic storm, plotted as latitude versus pressure surface at midnight (a and b). The same for downward heat conduction (c and d).

## Chapter 05

Figure 1. Hydrogen ion density as a function of time and altitude for several values of n<sub>i</sub>. semi-implicit (black) and fully implicit (red).

Figure 2. Hydrogen ion density as a function altitude at time 13:25 LT on day 4: semi-implicit (black) and fully implicit (red). Here the higher-density profile is in the Southern Hemisphere, and the lower-density profile is in the Northern Hemisphere.

Figure 3. Hydrogen ion velocity as a function altitude at time 13:25 LT on day 4: semi-implicit (black) and fully-implicit (red). Here the negative velocity profile is in the Southern Hemisphere, and the positive velocity profile is in the Northern Hemisphere.

Figure 4. Schematic of “flux tube” motion in the Lagrangian scheme.

## Chapter 06

Figure 1. (top) Electric potential and (bottom) hemispherical average of upward current at the top of the ionosphere on 21 December, 4 UT, with 30 kV cross-polar cap potential drop, with no wind dynamo electric field source. (left) Case A does not use equivalent magnetospheric conductances; (right) case B does. The outer circles are 50° magnetic latitude, with magnetic local time shown.

Figure 2. Thermosphere-ionosphere-electrodynamics general circulation model (TIE-GCM) simulations of magnetic eastward current density as a function of magnetic latitude and height, for March equinox, 12 UT, 14 magnetic local time (approximately 30° geographic longitude), F10.7 = (left) Due to gravity and associated electric field. (right) Due to plasma pressure gradient and associated electric field.

Figure 3. TIME-GCM simulation of upward  $E \times B$  drift at 135 km above the geomagnetic equator at 12 UT due to neutral wind (Wind; long-dashed blue line), gravity and pressure-gradient current (Jpg, short-

dashed orange line), penetration electric field (PE, dashed- dotted red line), and the sum of all sources (All, solid green line). Shown for comparison is the Scherliess/Fejer empirical model [Scherliess and Fejer, 1999] (thin purple double-dotted line) (figure reproduced from Maute et al. [2012]).

Figure 4. (opposite) (left) TIE-GCM simulation of ionospheric currents and (right) geomagnetic perturbations as a function of magnetic local time and magnetic latitude for solar minimum, 8 June, 17 UT (when the subsolar point is at its northernmost magnetic latitude). For currents, arrows show the height-integrated sheet current density,  $K$ , and colors show the upward component of field-aligned current density at the top of the current sheet,  $J_{\parallel}$ . For magnetic perturbations, arrows show the horizontal components and, colors, the vertical component (positive downward). (top left) The total density, (middle left) the residual current, and (bottom left) the equivalent current. See main text for definitions of residual and equivalent currents. (top right) Magnetic perturbations at 400 km altitude due to equivalent current and (middle right) residual current, and (bottom left) magnetic perturbations at the ground, which by definition are due only to the equivalent current.

## Chapter 07

Figure 1. (a) Data-model comparison of thermospheric neutral density at satellite perigees for satellite #12388 from 2002 to 2008. Black, satellite drag-derived density; red: thermosphere-ionosphere-electrodynamics general circulation model (TIE-GCM) simulation. (b) Corresponding F10.7 and  $A_p$  indices. Satellite #12388 (Cosmos

1236) has moderately eccentric orbits with perigees varying between 385 and 415 km and apogees varying between 1448 and 1585 km. The satellite perigees precess in latitude and LT, with approximately three latitude cycles and five local time cycles in a year.

Figure 2. Global NO cooling power, integrated over the globe and in the altitude range from 100 to 200 km, from 2002 to 2006. Black, TIMED/SABER; red, TIE-GCM simulation. The estimated uncertainty of SABER NO cooling rates is ~15% (adapted from the work of Qian et al. [2010a]).

Figure 3. NmF2 observed by Constellation Observing System for Meteorology Ionosphere and Climate, estimated by the International Reference Ionosphere, and simulated by TIE-GCM, during 2008. NmF2 is averaged over 10:00–13:00 LT and over the months shown in each panel.

Figure 4. Electron density profiles observed by Millstone Hill incoherent scatter radar (ISR), calculated by the ISR ionospheric model, and simulated by the TIE-GCM, at 12:00 and 15:00 LT, on 30 March 2007 and 21 June 2007.

## Chapter 08

Figure 1. Temporal variation of (top) interplanetary magnetic field  $B_z$ , (middle) CPCP and (bottom) hemispheric integrated Joule heating in the Southern Hemisphere.

Figure 2. Temporal variation of the distributions of (a) buoyancy acceleration ( $\text{m s}^{-2}$ ) and (b) vertical wind ( $\text{m s}^{-1}$ ) in the Southern Hemisphere at 300 km altitude. The outside ring is  $-40^\circ$ , and the time is

indicated at the top of each distribution. (left) Dusk and (top) noon.

Figure 3. The time versus altitude distribution of (a) buoyancy acceleration ( $\text{m s}^{-2}$ ) and (b) vertical wind ( $\text{m s}^{-1}$ ) at  $77.5^\circ\text{S}$ ,  $22.5^\circ\text{E}$  during 15 min, 1 h, and 2 h time intervals. The location has been shown in Figure 2a.

Figure 4. (a) The temporal variation of the altitudinal profiles of Joule heating per unit volume ( $\text{W m}^{-3}$ ) at ( $77.5^\circ\text{S}$ ;  $22.5^\circ\text{E}$ ) for (left) case 1 and (right) case 2. The numbers and arrows attached to the color bars indicate the minimum and maximum values in the color contour. (top) The line plots show the variations at 300 km altitude, and (right) the numbers represent the average value of the corresponding line plots. (b) is the same as (a), except for the buoyancy acceleration ( $\text{ms}^{-2}$ ). The Joule heating (a) is plotted on a logarithmic scale, and the buoyancy acceleration (b) is plotted on a linear scale.

Figure 5. The same as Figure 4, except for the vertical velocity ( $\text{m s}^{-1}$ ) (a), and the percentage difference of neutral density compared with the value in the background case (b), respectively.

Figure 6. (opposite) (a) Neutral density ( $\text{kg m}^{-3}$ ) distribution at 130 km altitude at 07:00 UT in the Southern Hemisphere. The neutral wind velocity vectors are plotted out on top of the neutral density, and the outside ring is  $-40^\circ\text{C}$ . (b) Neutral density ( $\text{kg m}^{-3}$ ) distribution at 300 km altitude at 07:00 UT in the Southern Hemisphere. The logarithmic scale has been used for (a) and (b). (c) The same as (b) except for the percentage difference of neutral density at 300 km compared with the background case.

## Chapter 10

Figure 1. The flowchart of the Air Force physics-based model (PBMOD).

Figure 2. (a) Integrated Rayleigh-Taylor (R-T) instability growth rate. (b) Plume simulation of bubble formation corresponding to the positive R-T growth rate (a). (c, e, g) Estimated S4 values from PBMOD, where the black curve represents the Communication/Navigation Outage Forecasting System (C/NOFS) orbit, the blue line represents the density perturbations observed by Planar Langmuir Probe (PLP), and the red line represents the meridional drift obtained from Vector Electric Field Instrument (VEFI). The red curve above and below the orbit indicates upward and downward drift, respectively. (d, f, h) Comparison between PBMOD-estimated S4 (black) and observed S4 at ~250 MHz (red) from three Scintillation Network Decision Aid (SCINDA) stations at Ancon, Peru, Christmas Island, and Kwajalein Atoll (KWA), respectively. Three SCINDA stations are also marked as blue squares (a, c, e, g).

Figure 3. Log electron densities are displayed as a function of altitude and horizontal distance from incoherent scatter returns on Advanced Research Project Agency (ARPA) Long-range Tracking and Identification Radar on the evening of 28 April 2009. Coherent (Bragg) backscatter from irregularities in UHF scans with the radar beam pointing perpendicular to the local magnetic field (Perp-B) at 300 km, scans (a) and (c), are unshaded (white). The look angle of the SCINDAVHF data link is marked with a red line. For the Off-Perp scans (b) and (d), the steerable 46 m dish is tilted to the north

approximately 6° from perpendicularity with B. The absence of Bragg scatter provides a complete picture of the density depletions across a 1000 km longitudinal region centered on KWA.

Figure 4. Simulations of PBMOD during the northern fall of 2009 were driven by four drift models: (a) the Scherliess-Fejer (SF) empirical model, (b) the 67 day averaged drifts from Ion Velocity Drift Meter (IVM), (c) the averaged drifts from VEFI, and (d) the averaged drift from both IVM and VEFI, where the red and blue represent upward and downward drifts respectively.

Figure 5. (a) The C/NOFS-PLP density measurements, (b) the model output of background densities driven by the SF empirical drift model, (c) the model output driven by the averaged IVM drifts, (d) the model output driven by the averaged VEFI measurements, and (e) the model output driven by the averaged drifts from IVM and VEFI measurements at altitude between 490 and 570 km during the northern fall of 2009. (f) Estimated density errors as a function of altitudes from simulations driven from four different drifts: SF (black), IVM (red), VEFI (dark blue), and IVM-VEFI (light blue). The positive values (right of the vertical dashed line) represent that the model overestimates the background density compared to observations, while the negative values (left of the vertical dashed line) indicate an underestimation of the density by the model.

## Chapter 11

Figure 1. A schematic of models that comprise the Integrated Sun-Earth System for the Operational Environment and the various inputs used to drive the models. Model output, including

ionospheric/thermospheric composition, temperature, electric fields, and neutral winds are being validated against observations. Derived products include total electron content (TEC), NmF2, hmF2, and total mass density.

Figure 2. (a) Solar EUV irradiance from the NRL's Solar Spectral Irradiance (NRLSSI) 2C and 3C models. (b) Geomagnetic and solar indices during the WHI 2008 interval. Bz turned negative at the onset of a weak geomagnetic storm due to a corotating interaction region on day 85 (dashed vertical line).

Figure 3. Daily global mean TEC from 1 March through 16 April 2008 is shown for the International Global Navigation Satellite Systems (GNSS) Service (IGS) GPS-derived TEC maps along with that for several A Model of the Ionosphere (SAMI3) simulations.

Figure 4. Daily global mean TEC is shown for the SAMI3 simulation using NRLSSI2C EUV irradiances. The dashed line shows the case in which only the day-of-year was allowed to vary. The dot-dashed line shows the case in which only the Ap index is held constant. The long-dashed line shows the case in which neutral winds are turned off.

Figure 5. A 2 h global mean IGS TEC is shown for days 80-90 during WHI 2008. The 15 min global mean TEC for SAMI3 using the NRLSSI 3C model is also shown. On most days, there appears to be a 180° phase shift in the diurnal variation of TEC between the data and model.

Figure 6. TEC at 10, 18, and 22 UT on day 86 and 10 UT on day 87 during WHI 2008 for (top) IGS, (middle) SAMI3, and (bottom) SAMI-SC. On day 86 at 22 UT,



the IGS TEC is quite strong, whereas the SAMI3 TEC is much weaker in the equatorial ionization anomaly (EIA) region. SAMI3-SC shows no significant separation of the EIA crests in comparison with SAMI3.

Figure 7. SAMI3-SC vertical plasma drifts are shown for day 80 (March equinox), day 172 (June solstice), day 264 (September equinox), and day 355 (December solstice) for the solar maximum year 2002. SAMI3-SC simulations are performed using (left) HWM07, (right) HWM93 and are compared with the (middle) Scherliess-Fejer vertical drift model.

Figure 8. Same as Figure 7, but in this case, the simulations were performed for the year 2006.

Figure 9. SAMI3-SC vertical drift on day 80 (March 2006) using HWM07. The vertical drift at 12 UT is shown as a function of longitude. Several different runs are performed to assess the sensitivity of the vertical drift to the coarseness of the SAMI3-SC grid (gray dashed line), alteration of the O–O+ collision frequency by increasing the Burnside factor from 1.3 to 1.7 (dot dashed line), and reduction of the nighttime photoionization (long-dashed line).

Figure 10. Daily global mean TEC for the descending phase of Solar Cycle 23 (2002 through 2008) are shown for IGS (black) and SAMI3 (gray).

## Chapter 12

Figure 1. Impacts of vertical drifts at March equinox at the Northern Hemisphere (a-c), neutral winds at June solstice at the Southern Hemisphere (d-f), and Burnside factors at March equinox at the Northern Hemisphere (g-i) on electron density profiles simulated by the global ionosphere plasmasphere

model at three different locations. Notice the difference in the x axis scales. See text for more details.

Figure 2. Comparisons of NmF2 (m-3, left) and hmF2 (km, right) at 2, 10, 14, and 20 LT from six non-self-consistent models (colored lines), International Reference Ionosphere (IRI) (black lines), and observations (triangles). Gray lines are the one standard deviation of the observations.

Figure 3. Comparisons of NmF2 (m-3, left) and hmF2 (km, right) at 2, 10, 14, and 20 LT from five self-consistent models (colored lines), the IRI (black lines), and observations (triangles). Gray lines are the one standard deviation of the observations.

Figure 4. Diurnal variation of vertical drift velocities above the magnetic equator at the American sector simulated by five self-consistent models and the empirical model of Scherliess and Fejer [1999].

Figure 5. Comparisons of NmF2 (m-3, left) and hmF2 (km, right) at 14 LT at 120°E under three different cases (top to bottom) from six non-self-consistent models. See section 5 for more details.

## Chapter 14

Figure 1. Schematic illustration of coupling processes in the ionosphere, thermosphere, and their relationships to external drivers.

Figure 2. Characteristics of the ion and electron temperatures in the topside ionosphere revealed by the Sami is Another Model of the Ionosphere (SAMI2) model. Note the separation of the constituent ion temperatures and the electron temperature following sunrise.

Figure 3. Observations of the ion temperature from DMSP just following sunrise show ion temperatures that differ by 500 K when the dominant ion changes from O+ to H+. This apparent change is due entirely to the ionospheric composition.

Figure 4. Observations of the electron temperature across the high-latitude region show departures from an expected baseline, estimated by the black line, that are indicative of heat input to the ionosphere. Knowledge of the heat flux at the top of the ionosphere is required to reconcile these measurements.

Figure 5. Measurements of the ion and neutral velocities from the Dynamics Explorer satellite show regions near 85, 100 s in the top panel where the ion-neutral velocity is very high. In these regions, the ion/electron density, shown in the third panel is decreased, and the time for coupling to the neutrals, shown in the lowest panel, is increased [after Killeen et al., 1984].

Figure 6. Observations of ion drift and precipitating electrons made from the DMSP satellite show a rapid subauroral flow in the absence of any large field-aligned current. This implies that the conductivity of the medium must behave in a manner that is similar to the drift itself (courtesy, P.C. Anderson).

Figure 7. Calculations of the ion number density variation produced by altitude gradients in the neutral wind show that the contribution of vertical drifts due to zonal winds perpendicular to B and vertical drifts due to meridional winds parallel to B are the same at about 130 km altitude [after Osterman et al., 1995].

## Chapter 15

Figure 1. Summary of meteorological variability in January 2009 from the Navy Operational Global Atmospheric Prediction System-Advanced Level Physics High Altitude (NOGAPS-ALPHA) assimilation product of Eckermann et al. [2009]. This product is used to initialize a series of six hourly forecasts (see text).

Figure 2. Monthly mean zonal winds from the thermosphere ionosphere electrodynamics general circulation model (TIEGCM) for (a) a bottom boundary with migrating tides from the global-scale wind model (GSWM) model and a globally invariant temperature. (b) The same migrating tides as in (a) but with a time-independent, latitudinally varying zonal mean temperature and winds from NOGAPS-ALPHA and (c) the complete varying wind and temperature fields from the NOGAPS-ALPHA forecast model for January 2009.

Figure 3. Difference fields for the TIEGCM calculations shown in Figure 1. (a) The middle panel of Figure 1 minus the left-hand panel (zonal mean + GSWM — pure GSWM). (b) The right panel of Figure 1 minus the middle (full NOGAPS — (zonal mean + GSWM)).

Figure 4. (top 4) Monthly averaged amplitudes of four tidal components for temperature and (bottom 4) zonal wind. The temperature amplitudes are in degrees K, the zonal wind amplitudes are in  $\text{m s}^{-1}$ . The four components are diurnal westward wave 1, semidiurnal westward wave 2, terdiurnal westward wave 3, and diurnal eastward wave 3. See text for the specific definitions of diurnal, semidiurnal, and terdiurnal.

Figure 5. Comparison of monthly averaged latitudinally variation of four tidal components of temperature (T) and zonal wind (U) tides calculated by NOGAPS-ALPHA and the TIEGCM. The dashed curve in each panel is the particular tidal component calculated from the NOGAPS-ALPHA input to the TIEGCM bottom boundary at the  $Z = -7$  log-pressure level. The dotted and solid curves in each panel are the tidal components taken from the TIEGCM T and U solution at the lowest midpoint level ( $Z = -6.75$ ). The solid curves are from the case where the TIEGCM U and V fields at  $Z = -6.75$  are nudged by NOGAPS; the dotted curves are from the case without nudging. See text for a definition of the TIEGCM pressure levels and their relationship to NOGAPS-ALPHA pressure levels.

Figure 6. Comparison of monthly averaged profiles of the four zonal wind tides for the two approaches to proscribing the TIEGCM bottom boundary discussed in Figure 5. The solid lines result from nudging the U and V fields; the dashed lines are from the case without nudging. For reference, the migrating tides from a GSWM December solstice solution are presented as the dotted lines. Each panel is an average over a different range of latitudes associated with the peak of the tide. (a) An average from  $22.5^{\circ}\text{N}$  to  $32.5^{\circ}\text{N}$ , (b) an average from  $52.5^{\circ}\text{N}$  to  $62.5^{\circ}\text{N}$ , (c) an average from  $52.5^{\circ}\text{N}$  to  $62.5^{\circ}\text{N}$ , and (d) from  $7.5^{\circ}\text{S}$  to  $7.5^{\circ}\text{N}$ .

Figure 7. Snapshot of zonal wind variation at  $Z = -3.75$  (about 120 km) as a function of longitude at 12 UT for  $37^{\circ}\text{N}$  on 10 January (solid curve) and 24 January (dashed curve).

Figure 8. A 2-D spectrum of zonal wind variation for the same location as in Figure 7, for two 5 day intervals (a) for 10-14 January 2009, a 5 day period before the major sudden stratospheric warming, and (b) for 20-24 January 2009, during the warming. The contours are in intervals of 5 m s<sup>-1</sup> the peak magnitude of the large blotch at wave 2, 2 cycles d<sup>-1</sup> in (a) is 40.5 m s<sup>-1</sup>

## Chapter 16

Figure 1. Temperature at 90°N and 10h Pa of (a) January of the first year, (b) first year, and (c) 20 years of Whole Atmosphere Community Climate Model with thermosphere extension (WACCM-X) simulations. The geopotential height amplitude of wave 1 at 60°N and 1 hPa for the same time periods (d-f). (a-b) and (d-e) The solid lines are daily values, and the dotted lines are climatological values from the 20 years of simulation (see text for details), (c) and (f) The solid lines are monthly mean values, and the dashed lines are daily values.

Figure 2. Temperature at 90°S and 10 hPa of (a) first year and (b) 20 years of WACCM-X simulations. The geopotential height amplitude of wave 1 at 60°N and 1 hPa for the same time periods (c-d). (a) and (c) The solid lines are daily values, and the dotted lines are climatological values from the 20 years of simulation (see text for details). (b) and (d) The solid lines are monthly mean values, and the dashed lines are daily values.

Figure 3. Similar to Figure 1, but for diurnal westward propagating wave 1 (DW1) at 20°N and semidiurnal westward propagating wave 2 (SW2) at 52°N, both at 10-4 hPa. (c) and (f) The dark dashed lines are the equatorial zonal mean zonal wind at 30