

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE (DD-MM-YYYY)

10-03-2008

2. REPORT TYPE

Final Report

3. DATES COVERED (From - To)

01/04/2006-30/11/2007

4. TITLE AND SUBTITLE

Development of an Ionosphere-Plasmasphere-Polar Wind Model and

Studies of Storms and Substorms

5a. CONTRACT NUMBER**5b. GRANT NUMBER**

FA9550-06-1-0217

5c. PROGRAM ELEMENT NUMBER**6. AUTHOR(S)**

Dr. Larry C. Gardner

5d. PROJECT NUMBER**5e. TASK NUMBER****5f. WORK UNIT NUMBER****7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**

Center for Atmospheric and
Space Sciences
Utah State University
4405 Old Main Hill
Logan, UT 84322-4405

8. PERFORMING ORGANIZATION REPORT NUMBER**9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)**

AFOSR
875 N Randolph St Suite 325
Rm 3112
Arlington, VA 22203

10. SPONSOR/MONITOR'S ACRONYM(S)**11. SPONSOR/MONITOR'S REPORT NUMBER(S)****12. DISTRIBUTION / AVAILABILITY STATEMENT**

Distribution Statement A: Unlimited

AFRL-SR-AR-TR-08-0137

13. SUPPLEMENTARY NOTES**14. ABSTRACT**

A 3-dimensional, time -dependent, multi -species (O⁺, H⁺, Os, Hs, electrons) model of the ion and neutral polar winds was used to simulate the dynamics during the May 4, 1998 geomagnetic storm. The stormtime simulation was driven by realistic plasma convection and particle precipitation patterns, which pulsed with an approximately 1 -hour time period. This pulsating stormtime energy input to the ionosphere resulted in pulsating ion and neutral polar winds, with the 1 -hour period. The magnitude of the vertical ion and neutral fluxes were correlated with the size of the auroral oval and associated plasma convection pattern. When the oval was expanded, the vertical fluxes tended to be a maximum, and when the oval was contracted the vertical fluxes tended to be a minimum. The largest vertical fluxes were located over the areas where the electron precipitation was the strongest. In general, the vertical fluxes at the top of the ionosphere (1500 km) for O⁺, H⁺, and Os exhibited a significant amount of spatial structure, with the intensity of the vertical fluxes and the location of the structure varying markedly with time. This aspect of the storm simulation supports the suggestion by Peterson et al. (2002) that any attempt to include ionospheric outflow in large -scale models of the magnetosphere should take into account the large variations in outflow.

15. SUBJECT TERMS**16. SECURITY CLASSIFICATION OF:**

a. REPORT

b. ABSTRACT

c. THIS PAGE

17. LIMITATION OF ABSTRACT**18. NUMBER OF PAGES****19a. NAME OF RESPONSIBLE PERSON**

19b. TELEPHONE NUMBER (include area code)

Annual/Final Report

AFOSR Project: Development of an Ionosphere-Plasmasphere-Polar Wind Model and Studies of Storms and Substorms

Award Number: FA9550-06-1-0217, Larry C. Gardner (Herbert C. Carlson)

The focus of this project was on the development of an ionosphere-plasmasphere-polar wind model to study storms and substorms. Four papers were published in the scientific literature, with the titles and abstracts listed below. The topics studied include polar patch formation and dynamics, including their role in neutral stream particle production. The final paper covers a simulation of the May 4 1998 magnetic storm using realistic inputs to drive the model. By using realistic inputs during storms, there is a more realistic, changing character to the model inputs, thereby showing more of the dynamic, changing nature that should be associated with storm, and substorm simulations. The results of the current studies show that in order to model the near earth environment, realistic inputs are necessary, and with the realistic drivers the model produces a more spatially and temporally varying output. This then shows that to model the magnetosphere-ionosphere interactions, the dynamical nature of the ionospheric flows must be taken into account to accurately portray magnetosphere-ionosphere coupling. More detail on this study is included in the appendix in the form of a powerpoint poster which will be displayed at the Fall AGU meeting.

Role of neutral atmospheric dynamics in cusp density and ionospheric patch formation

Herbert C. Carlson

Center for Atmospheric and Space Sciences, Utah State University, Logan, Utah, USA

Abstract

Ionospheric patches are islands of plasma transiting the polar cap, with density at least double the surrounding background plasma. Since their discovery 25 years ago, many mechanisms for their production have been proposed and examined. However all of these mechanisms consider only electric fields and charged particles as candidate mechanisms for patch formation, particularly transient changes in these electrodynamic terms. Here for the first time, we call attention to the role of thermospheric dynamics in Patch formation. We show that the thermospheric response to transient heating events near the cusp must significantly increase exospheric densities over the cusp, and also that a plausible doubling of these densities near and above 400 km altitude leads to a new patch production mechanism. The underlying processes must drive a solar cycle variation of how many hours UT experience strong polar patches and scintillation. These processes must be added to present thinking and modeling.

Received 12 January 2007; accepted 23 May 2007; published 4 July 2007.

Case for a new process, not mechanism, for cusp irregularity production

Herbert C. Carlson

Center for Atmospheric and Space Sciences, Utah State University, Logan, Utah, USA

Todd Pedersen

Air Force Research Laboratory/VSBXI, Hanscom Air Force Base, Massachusetts, USA

Santimay Basu

Air Force Research Laboratory/VSBXI, Hanscom Air Force Base, Massachusetts, USA

Mike Keskinen

Plasma Physics Division, Naval Research Laboratory, Washington, D. C., USA

Jøran Moen

Department of Physics, University of Oslo, Oslo, Norway

Arctic Geophysics, University Centre in Svalbard, Longyearbyen, Svalbard, Norway

Abstract

Two plasma instability mechanisms are currently thought to dominate formation of plasma irregularities in the F region high-latitude and polar ionosphere: the gradient-drift driven instability and velocity-shear driven instability. The former mechanism is accepted as accounting for structuring plasma in polar cap patches and the latter for structuring plasma in polar cap Sun-aligned arcs. Recent work has established a dominant patch formation process, involving magnetic reconnection driving strong plasma shears repeatedly observed in the cusp. Proceeding from this, we present the case for a needed new plasma structuring process (not new mechanism), whereby shear-driven instabilities first rapidly structure the entering plasma, after which gradient drift instabilities build on these large “seed” irregularities. Correct modeling of cusp and early polar cap patch structuring will not be accomplished without allowing for this compound process. This compound process also explains previously unexplained characteristics of cusp and early polar cap patch irregularities.

Received 5 March 2007; accepted 14 August 2007; published 16 November 2007.

Propagating plasma patch and associated neutral stream flows

Larry C. Gardner, Robert W. Schunk

Center for Atmospheric and Space Sciences, Utah State University, 4405 Old Main Hill, SER 246, Logan, UT 84322-4405, USA

Abstract

Plasma patches are regions of enhanced ionization that are created in the dayside cusp or equatorward of the cusp in the sunlit hemisphere during northward interplanetary magnetic field. After formation, and a change to a southward interplanetary magnetic field, they drift across the polar cap with the prevailing convection speed. As a plasma patch propagates, charge exchange reactions occur, which lead to the production of both ion and neutral particles throughout the patch. In the region directly above the patch, an upward jet of H^+ and O^+ forms. This ion jet, in turn, acts to produce an upward flux of neutral H and O stream particles because of charge exchange reactions between the ion jet and the background neutral atmosphere. A three-dimensional, time-dependent model of the ion and neutral polar winds was used in order to study the evolution of the neutral stream particles that are produced in a 'representative' propagating plasma patch, with the anticipation that the neutral stream particles produced by the ion jet would display a distinct signature. However, the outflow of neutral H atoms above a patch is only slightly visible in the simulation due to a continuous outflow flux of H ($\sim 10^9 \text{ cm}^{-2} \text{ s}^{-1}$) across the entire polar cap. On the other hand, the upward flux of neutral O from the patch is more dependent on both the state of the ionosphere and the amount of heating, with increased upward fluxes over areas where the heating is high. Typically, the upward neutral O streams are predominantly located in the pre-midnight auroral oval.

Received 13 December 2006; received in revised form 12 June 2007; accepted 17 July 2007

Available online 31 July 2007

Pulsating Ion and Neutral Polar Winds

Larry C. Gardner, Robert W. Schunk

Center for Atmospheric and Space Sciences, Utah State University, 4405 Old Main Hill, SER 246, Logan, UT 84322-4405, USA

Abstract

A three-dimensional, time-dependent model of the ion and neutral polar winds was used to study their dynamic evolution during the May 4, 1998 magnetic storm. The simulation tracked the dynamics of five species (O^+ , H^+ , Hs, Os, and electrons) and covered a 9-hour period. During the storm, Dst decreased to -210 nT, A_p reached 300, and K_p was elevated. The IMF B_z component was southward at the start of the storm and for several hours thereafter and then turned northward. However, the magnetospheric energy input to the ionosphere exhibited a 1-hour oscillation, with the plasma convection and particle precipitation patterns expanding and contracting in a periodic manner. As a consequence, the ion and neutral polar winds pulsated with an approximate 1-hour period. The H^+ and O^+ ions displayed cyclic upflows and downflows in the topside ionosphere as well as a highly structured spatial distribution that varied with time. The vertical flux of the neutral Hs atoms was upward at the top of the ionosphere, but the magnitude varied in a cyclic manner in response to the oscillating stormtime energy input. The vertical flux of neutral Os atoms was downward at the top of the ionosphere and varied significantly with the stormtime energy input. For H^+ , O^+ , and Hs, the maximum total (integrated) vertical flux during the storm was upward at the top of the ionosphere, with values of $8-9 \times 10^{25}$ particles/sec for H^+ , $2-4 \times 10^{26}$ particles/sec for O^+ , and $2-3 \times 10^{27}$ particles/sec for Hs. The corresponding total vertical Os flux was predominately downward, with only localized areas with positive fluxes.

Submitted To JASTP October 2007

APPENDIX

Slide 1

Pulsating Ion and Neutral Polar Winds

Larry C. Gardner and Robert W. Schunk
emphyx@yahoo.com robert.schunk@usu.edu

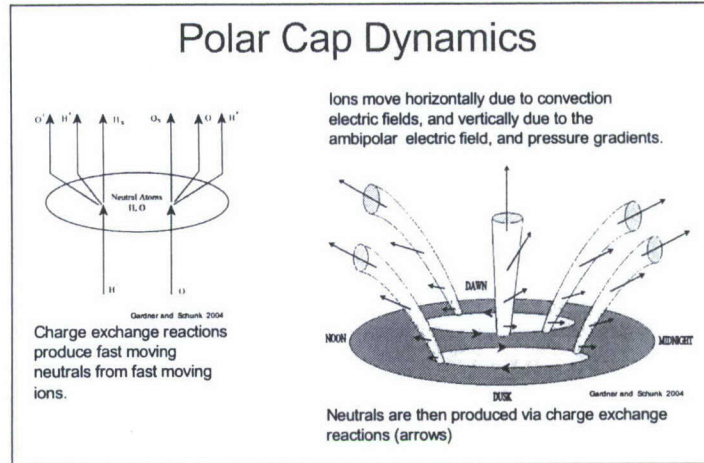
Utah State University
Center for Atmospheric and Space Sciences
Logan, UT 84322

Slide 2

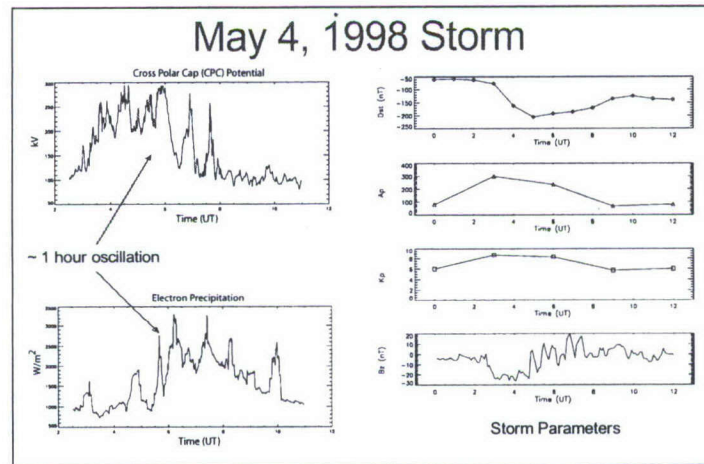
Abstract

A three-dimensional, time-dependent model of the ion and neutral polar winds was used to study their dynamic evolution during the May 4, 1998 magnetic storm. The simulation tracked the dynamics of five species (O^+ , H^+ , H_e , O_e , and electrons) and covered a 9-hour period. During the storm, D_m decreased to ~ 210 nT, A_p reached 300, and K_p was elevated. The IMF B_z component was southward at the start of the storm and for several hours thereafter and then turned northward. However, the magnetospheric energy input to the ionosphere exhibited a 1-hour oscillation, with the plasma convection and particle precipitation patterns expanding and contracting in a periodic manner. As a consequence, the ion and neutral polar winds pulsated with an approximate 1-hour period. The H^+ and O^+ ions displayed cyclic upflows and downflows in the topside ionosphere as well as a highly structured spatial distribution that varied with time. The vertical flux of the neutral H_e atoms was upward at the top of the ionosphere, but the magnitude varied in a cyclic manner in response to the oscillating stormtime energy input. The vertical flux of neutral O_e atoms was downward at the top of the ionosphere and varied significantly with the stormtime energy input. For H^+ , O^+ , and H_e , the maximum total (integrated) vertical flux during the storm was upward at the top of the ionosphere, with values of $8-9 \times 10^{25}$ particles/sec for H^+ , $2-4 \times 10^{26}$ particles/sec for O^+ , and $2-3 \times 10^{27}$ particles/sec for H_e . The corresponding total vertical O_e flux was predominately downward, with only localized areas with positive fluxes.

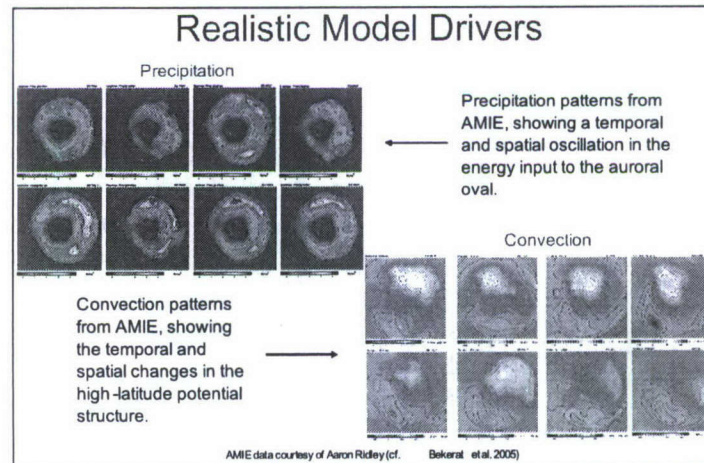
Slide 3



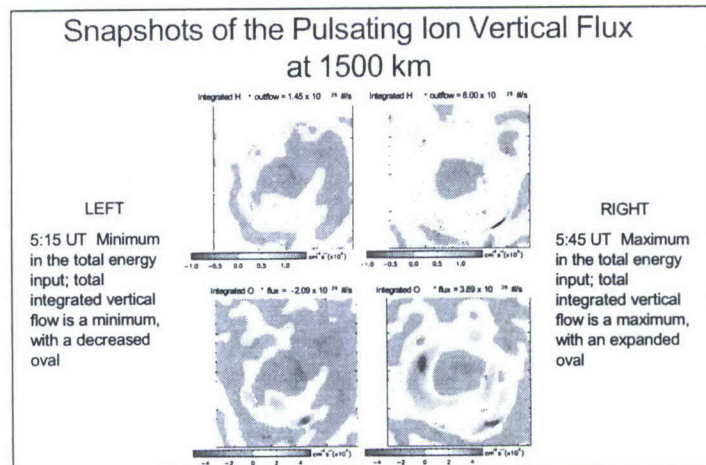
Slide 4



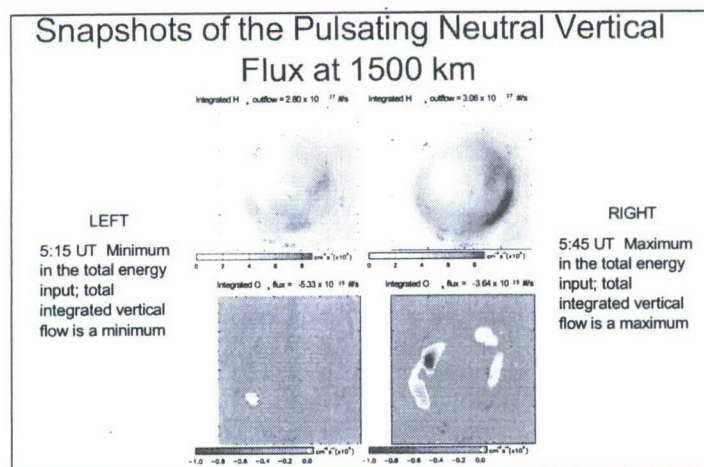
Slide 5



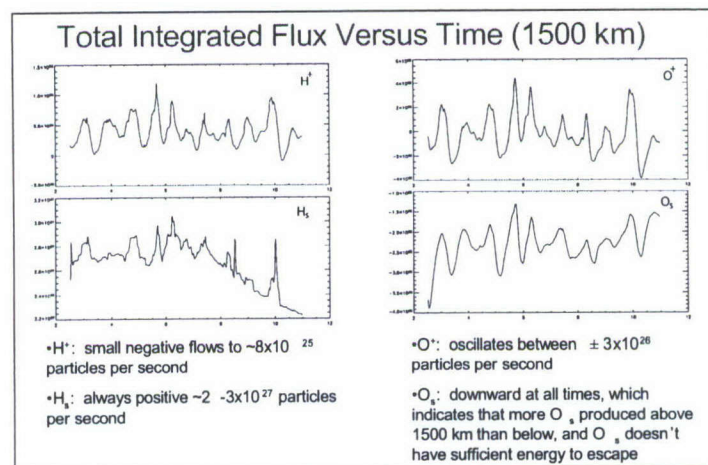
Slide 6



Slide 7



Slide 8



Summary

A 3-dimensional, time-dependent, multi-species (O^+ , H^+ , Os , Hs , electrons) model of the ion and neutral polar winds was used to simulate the dynamics during the May 4, 1998 geomagnetic storm. The stormtime simulation was driven by realistic plasma convection and particle precipitation patterns, which pulsed with an approximately 1-hour time period. This pulsating stormtime energy input to the ionosphere resulted in pulsating ion and neutral polar winds, with the 1-hour period. The magnitude of the vertical ion and neutral fluxes were correlated with the size of the auroral oval and associated plasma convection pattern. When the oval was expanded, the vertical fluxes tended to be a maximum, and when the oval was contracted the vertical fluxes tended to be a minimum. The largest vertical fluxes were located over the areas where the electron precipitation was the strongest. In general, the vertical fluxes at the top of the ionosphere (1500 km) for O^+ , H^+ , and Os exhibited a significant amount of spatial structure, with the intensity of the vertical fluxes and the location of the structure varying markedly with time. This aspect of the storm simulation supports the suggestion by Peterson et al. (2002) that any attempt to include ionospheric outflow in large-scale models of the magnetosphere should take into account the large variations in outflow.