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A COMPARISON OF IONOSPHERIC MODEL PREDICTIONS WITH
NITRAS OBSERVATIONS(U) UTAH STATE UNIV LOGAN CENTER
FOR ATMOSPHERIC AND SPACE SCIENCES R M SCHUNK

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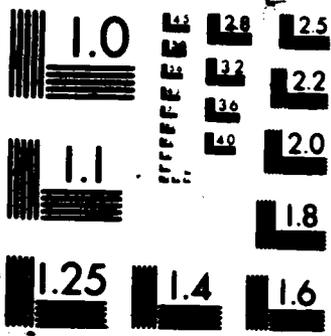
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<p>MITHRAS is a coordinated multiradar program to study the interactions between the magnetosphere, ionosphere, and thermosphere, as well as the phenomena that result from these interactions. The program is based on a data set acquired by the Chatanika, Millstone Hill, and Eiscat incoherent scatter radars between May 1981 and June 1982. A large portion of the data is unique in that it was the only time when three radars, well separated in local and magnetic time, simultaneously probed the high latitude ionosphere.</p> <p>Our effort concerned model-data comparisons. Specifically, we compared the predictions of our 3-dimensional, time-dependent model of the high-latitude ionosphere with MITHRAS data sets. Our research program involved a three-year collaborative effort between Millstone Hill, SRI International, EISCAT, and Utah State University, with our overall goal being a systematic study of the high-latitude ionosphere. Of particular interest were the variations of the ionosphere with altitude, latitude, longitude, universal time, season, and magnetic activity. Model-data comparisons enabled us to determine the adequacy of our current understanding of high-latitude ionospheric dynamics as well as certain magnetosphere-ionosphere-atmosphere coupling processes.</p>			
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A Comparison of Ionospheric Model Predictions
with MITHRAS Observations

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INTRODUCTION

Between May 1981 and June 1982, an intensive campaign of 33 coordinated observations was carried out using three incoherent-scatter radars: Chatanika (Alaska); Millstone Hill (Massachusetts); and EISCAT (Scandinavia). At times the STARE radar (Scandinavia) was able to provide additional coverage. This experimental campaign has become known as the MITHRAS program and the purpose of this program is to study the interactions between the magnetosphere, ionosphere, and thermosphere, as well as the phenomena that result from these interactions. The uniqueness of the program arises from the fact that it was the only time when three radars, well separated in both local and magnetic time, simultaneously probed the high latitude ionosphere.

Our involvement in the MITHRAS program concerns model-data comparisons. Specifically, we compared the predictions of our 3-dimensional time-dependent model of the high-latitude ionosphere with the MITHRAS data sets. Our research was done in collaboration with scientists at Millstone Hill, SRI International, and EISCAT. Our overall goals were to study the variation of the high-latitude ionosphere with altitude, latitude, longitude, universal time, season and geomagnetic activity. We were also interested in the response of the high-latitude ionosphere to magnetic storms and substorms. Some of the important morphological features that we were interested in are the 'main electron density trough', the 'polar hole', the 'aurorally-produced ionization peaks', the 'Harang discontinuity', the 'dayside throat', the 'tongue of ionization' and the 'ionospheric hot spots'.

The model-data comparisons were useful for several reasons. First, the MITHRAS data provided a unique opportunity to check the validity of many of the assumptions that enter into our high-latitude ionospheric model. For instance, the extended coverage of multiple radars was especially important because, at a given UT, it provided information

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separated in local time. Thus, not only could the required inputs to the model be more accurately ascertained, but such phenomena as the UT dependence of the ionosphere could be noted and checked. Therefore, an interaction between modelers and experimentalists was extremely important. From a modeler's point of view, the radar data were necessary to check the basic assumptions and predictions of the model. But a model of the ionosphere was equally important to those making measurements, as it provided a paradigm against which to interpret the mass of data collected and to plan for future experiments.

The model was also useful for another reason. The predictions of the model could be compared with experimental data taken by radars in the reference frame of the respective radar, i.e., as an observer at a fixed location on the earth's surface moved in local time. A comparison of the predictions of the model with experimental data — in the reference frame of the radars — allows for a validation of the ionospheric parameters calculated by the model. Once this was established, the data base created by the model could be examined in reference frames that the radars cannot view. For instance, we have shown that a "snapshot" of the polar ionosphere at a given UT can appear substantially different from the data taken by a radar. Also, full latitudinal coverage from 42 degrees to the pole was obtained by the model and this allowed for an accurate extrapolation of the radar data into spatial regions of the ionosphere where the radar coverage cannot reach. This points out one of the most beneficial aspects of the model when used in conjunction with radar data: the ability to "extend" the coverage of the radars into spatial and temporal regions beyond their normal reach.

RESEARCH ACCOMPLISHMENTS

The overall goals of our research were as follows: (1) Study the ionospheric variation with altitude, latitude, and local time; (2) Study the universal time dependence; (3) Study the effect of different convection patterns; (4) Study the seasonal variation; (5) Study the ion and electron temperature morphology; (6) Study ion compositional changes; and (7) Study magnetic storms and substorms.

In the course of pursuing these goals, we published *four papers* in refereed journals and we presented *seventeen papers* at both national and international scientific meetings. A list of the publications and presentations is given at the end of the report. In what follows, we give a brief description of our research.

We published a paper entitled "Comparison of Model High-Latitude Electron Densities with Millstone Hill Observations" in the *Journal of Geophysical Research*. In this study, model predictions for the diurnal variations of plasma convection velocities and electron densities in the high-latitude ionosphere were compared with incoherent scatter radar data obtained from just one radar facility, the Millstone Hill facility in Massachusetts. The observations were for an equinox day on which there was moderate geomagnetic activity. On the observation day, three major morphological features were evident, including a dayside high density region, a nightside mid-latitude trough, and a region of slightly enhanced densities in the auroral zone. Although the dayside high density region was due to solar EUV radiation, it was not symmetrical about local noon (1000–1900 LT sector) owing to the effect of horizontal plasma transport. The nightside mid-latitude trough was the deepest, the widest, and reached its most equatorward latitude in the morning sector. Our time-dependent three-dimensional ionospheric model was able to reproduce these two features quite accurately. However, in the dusk sector, the electron density trough was

filled in and its latitudinal extent was restricted by a discrete arc, a feature not included in the ionospheric model. Except for this arc region, the enhanced electron densities in the auroral zone were adequately described by the average precipitating electron energy fluxes used in the model. We also found that the observed plasma drift velocities were consistent with a two-cell, asymmetric convection pattern with enhanced flow in the dusk sector of the polar region. Further details of this study are described in the published paper.

In a subsequent study, we compared the predictions of our ionospheric model with data taken simultaneously by three radar facilities, including the Millstone Hill radar in Massachusetts, the Chatanika radar in Alaska, and the STARE radar in Scandinavia. The coordinated observations of the polar ionosphere were for a summer day (June 27 & 28, 1981) on which five substorms occurred. Qualitatively, the same features were evident in both the model predictions and the radar data: fairly constant densities on the dayside with a mid-latitude trough forming poleward of 65 degrees around 1900 magnetic local time (MLT). This trough was seen to extend equatorward with increasing MLT, such that the minimum densities in the trough appeared just after midnight around 60 degrees latitude. With the aid of the ionospheric model, these features could be understood in terms of different regions of plasma convection, further influenced by photoionization and vertical plasma transport. Quantitatively, good agreement was obtained between the model predictions and the radar data. The densities predicted by the ionospheric model were typically within 25% of those measured by the three radars, although appreciable differences occurred in some regions of the ionosphere at certain times. Further details of this study are described in a paper entitled "Comparison of Simultaneous Chatanika and Millstone Hill Observations with Ionospheric Model Predictions", which was published in the *Journal of Geophysical Research*.

We also completed a paper entitled "Effects of Different Convection Models upon the

High Latitude Ionosphere", which was published in the *Journal of Geophysical Research*. This paper discusses the electron density behavior in response to Volland-Heppner and Heelis-Hanson convection patterns. Since the Chatanika and Millstone Hill data are obtained over a limited magnetic latitude range, the velocity data are not sufficient to resolve the differences between the convection patterns in an unambiguous manner. Consequently, we studied this problem in order to determine whether or not the electron density and temperature data can be used to determine which of the convection patterns is more appropriate. Our study indicated that the different convection patterns do produce distinguishing features in the electron densities and temperatures, but that temporal variations and uncertainties in ionospheric inputs make it difficult to distinguish between the convection patterns if data from only the three MITHRAS radars are used. Further details of this study are described in the published paper.

We also completed a study on the behavior of the ion composition and the electron and ion temperatures in the high-latitude ionosphere, and a paper on this subject has been submitted to the *Journal of Geophysical Research*. This ion compositional study is particularly important because it affects the interpretation of the incoherent scatter radar data. In order to obtain electron and ion temperatures from the radar spectra, it is necessary to know the ion composition. Generally, the data are interpreted assuming that the molecular ions (NO^+ , O_2^+ , N_2^+) dominate below a certain altitude and O^+ dominates above (called a transition altitude). Typically, this altitude is held fixed as the radars make measurements throughout the day. However, our model studies indicate that the molecular/atomic ion transition altitude displays a marked variation with latitude, longitude, universal time and geomagnetic activity (convection pattern). We also found that the *adoption* of an incorrect ion composition can lead to a serious error in the radar-deduced ion and electron temperatures at altitudes below about 300 km.

After the correction of the radar data for ion composition was completed, the ion and electron temperature data obtained by the Chatanika and Millstone Hill radars were compared with the temperatures calculated by our ionospheric model. However, the model required certain inputs, including the heat flux through the upper boundary (800 km) and the volume heating rates due to both precipitating auroral electrons and photoelectrons. Therefore, the results of the ionospheric model were compared with the measurements for a variety of combinations of the required inputs. It was found that the best fit resulted with no heat flux at the upper boundary and a relatively high volume heating rate. However, other combinations of inputs lead to reasonably good fits. We also found a systematic temperature difference of between 200 and 300 K between the Chatanika and Millstone Hill measurements of electron temperature. This difference is unexplained by the modelling efforts.

PUBLICATIONS

1. J. J. Sojka, R. W. Schunk, J. V. Evans, J. M. Holt, and R. H. Wand, Comparison of model high-latitude electron densities with Millstone Hill observations, *J. Geophys. Res.*, *88*, 7783-7793, 1983.
2. C. E. Rasmussen, R. W. Schunk, J. J. Sojka, V. B. Wickwar, O. de la Beaujardiere, J. C. Foster, J. Holt, D. S. Evans, and E. Nielsen, Comparison of simultaneous Chatanika and Millstone Hill observations with ionospheric model predictions, *J. Geophys. Res.*, *91*, 6986-6998, 1986.
3. C. E. Rasmussen, R. W. Schunk, and J. J. Sojka, Effects of different convection models upon the high latitude ionosphere, *J. Geophys. Res.*, *91*, 6999-7005, 1986.
4. C. E. Rasmussen, J. J. Sojka, R. W. Schunk, V. B. Wickwar, O. de la Beaujardiere, J. Foster, and J. Holt, Comparison of simultaneous Chatanika and Millstone Hill temperature measurements with ionospheric model predictions, *J. Geophys. Res.*, in press, 1987.

PRESENTATIONS

1. *R. W. Schunk* and *J. J. Sojka*, Problems with deducing plasma convection patterns from multiple radar observations, AGU Fall Meeting, San Francisco, California; December, 1983.
2. *R. W. Schunk*, Comparison of ionospheric model predictions with incoherent scatter radar observations, Presented at the Arecibo Observatory, Arecibo, Puerto Rico; July, 1984.
3. *R. W. Schunk*, Thermospheric structure and circulation in the polar cap, Presented at the Chapman conference on the *Magnetospheric Polar Cap*, Fairbanks, Alaska; August, 1984.
4. *R. W. Schunk*, High latitude ionospheric predictions, Presented at the GISMOS workshop, Boulder, Colorado; October, 1984.
5. *R. W. Schunk*, Global models of ionospheric parameters, Presented at the GISMOS workshop, Boulder, Colorado; October, 1984.
6. *R. W. Schunk* and *J. J. Sojka*, Critical tests of a global ionospheric model, AGU Fall Meeting, San Francisco, California; December, 1984.
7. *C. E. Rasmussen*, *R. W. Schunk* and *J. J. Sojka*, Modeling of the polar ionosphere, Presented at the *2nd International School for Space Simulation*, Kauai, Hawaii; February, 1985.
8. *C. E. Rasmussen*, *R. W. Schunk*, *J. J. Sojka*, *V. B. Wickwar*, *O. de la Beaujardiere*, *J. C. Foster*, *J. Holt*, *D. S. Evans*, and *E. Nielsen*, Comparison of simultaneous Chatanika and Millstone Hill observations with ionospheric model predictions, AGU Spring Meeting, Baltimore, Maryland; May, 1985.
9. *R. W. Schunk* and *J. J. Sojka*, A model of the global ionosphere, *Invited Review*, Presented at the *1985 North American Radio Science Meeting*, Vancouver, Canada; June, 1985.
10. *C. E. Rasmussen*, *R. W. Schunk*, *J. J. Sojka*, *V. B. Wickwar*, *O. de la Beaujardiere*,

- J. C. Foster, J. Holt, D. S. Evans, and E. Nielsen, Comparison of simultaneous Chatanika and Millstone Hill observations with ionospheric model predictions, 1985 North American Radio Science Meeting, Vancouver, Canada; June, 1985.
11. R. W. Schunk, Models of the terrestrial high latitude ionosphere, *Invited Review*, 5th IAGA Scientific Assembly, Prague, Czechoslovakia; August, 1985.
 12. R. W. Schunk, A theoretical global ionospheric *F*-region model and its predictive aspects, *Invited Lecture*, Presented at the *SUNDIAL Workshop*, McLean, Virginia; September, 1985.
 13. R. W. Schunk and J. J. Sojka, Magnetospheric control of ionospheric processes, *Invited Review*, AGU Fall Meeting, San Francisco, California; *EOS*, 66, 995, 1985.
 14. J. J. Sojka and R. W. Schunk, Ionospheric modelling of the GISMOS campaign, *Invited Talk*, AGU Fall Meeting, San Francisco, California; *EOS*, 66, 994, 1985.
 15. C. E. Rasmussen, R. W. Schunk, and J. J. Sojka, Effects of different convection models upon the high-latitude ionosphere, AGU Fall Meeting, San Francisco, California; *EOS*, 66, 996, 1985.
 16. R. W. Schunk, Ionosphere-thermosphere modelling: Current status, *Invited Review*, Presented at the International Symposium on Large-Scale Processes in the Ionospheric-Thermospheric System, Boulder, Colorado; December, 1986.
 17. C. E. Rasmussen, J. J. Sojka, R. W. Schunk, V. B. Wickwar, O. de la Beaujardiere, J. C. Foster, and J. M. Holt, Comparison of simultaneous Chatanika and Millstone Hill temperature measurements with ionospheric model predictions, Presented at the International Symposium on Large-Scale Processes in the Ionospheric-Thermospheric System, Boulder, Colorado; December, 1986.

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