Draft of Final Report for
NSF CEDAR postdoc

Participants
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Paul Withers, Boston University - performed the research reported here
Michael Mendillo, Boston University - supervised Withers
Henry Rishbeth, Boston University - collaborated on comparative studies of ionospheric dynamos and ionospheric responses to solar flares
Dave Hinson, Stanford University - plays a lead role in Mars Global Surveyor observations of the ionosphere of Mars and advised Withers on his use of that dataset
Jafar Arkani-Hamed, McGill University - provided model of the martian magnetic field to Withers and collaborated with Withers on our use of that model
Carlos Martinis, Boston University - collaborated with Withers on improvements to a theoretical model of the martian ionosphere
Luke Moore, Boston University - collaborated with Withers on improvements to a theoretical model of the martian ionosphere
Jody Wilson, Boston University - collaborated with Withers on improvements to a theoretical model of the martian ionosphere
Kent Tobiska, Space Environment Technologies - provided SOLAR2000 model of solar irradiance to Withers
Dave Mitchell, Berkeley - provided Withers with proxy for solar wind properties at Mars
Greg Delory, Berkeley - provided Withers with proxy for flux of solar energetic particles at Mars
Bodo Reinisch, University of Massachussetts - provided Mendillo and Withers with terrestrial ionosonde data for comparative studies of the effects of solar flares on ionospheres

Activities and Findings
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Our major research and education activities have been (A) investigating the response of the martian ionosphere to changes in solar extreme ultraviolet flux due to solar rotation, (B) investigating effects of the martian magnetic field on the martian ionosphere and contrasting dynamo effects at Earth and Mars, (C) studying the density structure of the martian neutral upper atmosphere, which affects the structure of the ionosphere, and (D) investigating the effects of solar flares at Earth and Mars.

Our major findings from these activities are:
(A) Measurements of solar flux at Earth are correlated with peak electron density in the martian ionosphere when the flux measurements are time-shifted to account for solar rotation.
(B) The martian magnetic field changes over lengthscales of a fraction of the planetary radius, unlike the terrestrial case. It is weak over most of the planet, but strong in certain regions. We found small-scale structures, or bite-outs, in the martian ionosphere over

these regions of strong magnetic field. We predicted that localized electrodynamic effects, such as dynamo currents, would be common on Mars.
(C) Accelerometer observations of the martian upper atmosphere revealed new details about its thermal structure, the effects of circulation, and gravity waves.
(D) We reported the first observations of the response of another planet's ionosphere to a solar flare. Analysis of such observations has the potential to improve our understanding of the solar X-ray spectrum and of secondary ionization processes in planetary ionospheres.

Opportunities for training and development
Withers has learnt new research skills concerning ionospheric electrodynamics and sudden ionospheric disturbances.

Outreach Activities. Mendillo and Withers convened a workshop on "Comparative Aeronomy on Earth and Mars" at the 2004 CEDAR meeting. Mendillo and Withers discussed this work with colleagues at several professional meetings and also attended a NASA Mars Aeronomy Workshop (August 2004, Washington DC). Withers has given 8 presentations at professional meetings and 2 presentations at Boston University, summarized below:

Observations of the Effects of Solar Flares on Earth and Mars (2005) Withers et al., Fall American Geophysical Union Meeting, Abstract SA53B-1165

Ionospheric characteristics above martian crustal magnetic anomalies (2005) Withers et al., American Astronomical Society's Division for Planetary Sciences Meeting, Abstract #33.02

The Response of an Ionosphere to Changes in the solar F10.7 flux: Comparison of Venus, Earth, and Mars (2005) Withers and Mendillo, Spring American Geophysical Union Meeting, Abstract SA41A-03

The Martian Ionosphere in Regions of Crustal Magnetic Fields (2004) Withers, Mendillo, Hinson, American Astronomical Society's Division for Planetary Sciences Meeting, Abstract #26.09

The Influence of Solar Variability on the Ionospheres of Earth and Mars (2004) Withers, CEDAR Meeting, Sante Fe, 27 June - 2 July. Interim CEDAR Postdoc Report.

Getting your hands on Mars data and some sample science (2004) Withers, CEDAR Meeting, Sante Fe, 27 June - 2 July. Talk at Comparative Aeronomy on Earth and Mars workshop.

Testing Simple Parameterizations for the Basic Characteristics of the Martian Ionosphere (2004) Withers and Mendillo, Spring American Geophysical Union Meeting, Abstract #SA24A-05

Theoretical Simulations of the Martian Ionosphere and Comparisons to Observations (2004) Withers et al., Spring American Geophysical Union Meeting, Abstract SA14A-04

The effects of solar flares on the ionospheres of Earth and Mars (2004) Withers, Boston University's Center for Space Physics.

How does the Magnetic Field of Mars affect the Ionosphere? (2004) Withers, Boston University's Center for Space Physics.

Products
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The following publications have resulted from this project:

Effects of solar flares on the ionosphere of Mars (2006) Mendillo, Withers, Hinson, Rishbeth, and Reinisch, Science, accepted 13 Jan 2006.

Mars Global Surveyor and Mars Odyssey Accelerometer observations of the martian upper atmosphere during aerobraking (2005) Withers, Geophysical Research Letters, doi:10.1029/2005GL024447.

Response of peak electron densities in the martian ionosphere to day-to-day changes in solar flux due to solar rotation (2005) Withers and Mendillo, Planetary and Space Science, 53, 1401-1418, doi:10.1016/j.pss.2005.07.010.

Ionospheric characteristics above Martian crustal magnetic anomalies (2005) Withers, Mendillo, Rishbeth, Hinson, and Arkani-Hamed, Geophysical Research Letters, 32, L16204, doi:10.1029/2005GL023483.

We have also improved a theoretical model of the martian ionosphere.

Contributions
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Principal discipline: This project has contributed to an understanding of the effects of solar flares and magnetic fields on planetary ionospheres.

Other disciplines: Nothing significant

Development of human resources: This project has strengthened existing collaborations between Boston University and Stanford University and created several new collaborations involving Boston University. Withers, a planetary scientist, has become engaged in the terrestrial aeronomy community as a result of this work.

Infrastructure: Nothing significant

Public Welfare: Nothing significant