A GLOBAL EMPIRICAL MODEL OF THE THERMOSPHERE OF MARS BASED ON IN SITU MASS SPECTROMETER DATA.

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Introduction

Empirical models of planetary thermospheres have proven to be a valuable resource to the scientific community. They quantify the global variations of the thermosphere, provide a benchmark to compare new observations against, and can be used as a boundary condition in physics-based models of planetary ionospheres. Although empirical models of the thermospheres of Earth (MSIS) and Venus (VTS3) have been around for several decades (*Hedin et al.*, 1977, 1983), an empirical model for Mars has yet to be developed, primarily due to lack of observations. However, the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission (*Jakosky et al.*, 2015) has been ongoing since 2014, and we now have sufficient observations to develop an empirical model of the thermosphere of Mars. The model, which is currently in development, will provide vertical profiles of neutral densities and the neutral temperature between 150-300 km for a given solar zenith angle (SZA), latitude, season (L_s), and solar activity.

Model Formulation

The model will be based on in situ observations of CO_2, O, CO, N_2, NO, and Ar from the MAVEN Neutral Gas and Ion Mass Spectrometer (NGIMS) (*Mahaffy et al.*, 2015). The NGIMS observational coverage in altitude, SZA, and latitude through July 2016 is shown in Figure 1.

The basic architecture of the model will follow that of the Venus VTS3 model, which was developed using analogous observations from the Pioneer Venus Orbiter Mass Spectrometer. Using the fitting routines developed by *Hedin et al.* (1983) for VTS3, we will fit the neutral densities to a spherical harmonic expansion that includes a Bates-Walker neutral temperature profile (*Bates*, 1959; *Walker*, 1965). The harmonic expansion function will include linear terms for SZA, latitude, and L_s, and a nonlinear term for solar activity.

As shown in Figure 1, the SZA, latitude, and sesonal parameter space is not fully sampled by NGIMS. To fill these gaps, we will use neutral densities from the Mars Global Ionosphere-Thermosphere Model (M-GITM) (*Bougher et al.*, 2015), which will ensure a stable solution to the spherical harmonic fits.

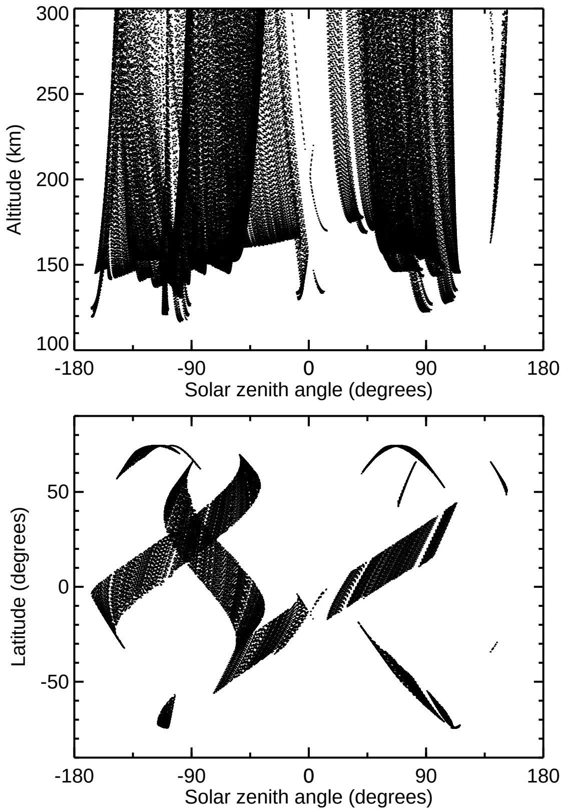

Figure 1: Altitude and latitude distribution of the NGIMS observations as a function of solar zenith angle (SZA). Negative SZAs correspond to local times before noon and positive SZAs to local times after noon.

The Empirical Model

The fitting procedure will provide the best-fit coefficients to the spherical harmonic expansion. We will then incorporate these coefficients into a user-friendly computer program and provide it to the community. The program will take a user-supplied SZA, latitude, L_s, and solar activity of interest, and output altitude profiles of the neutral temperature and the CO_2, O, CO, N_2, NO, and Ar densities. An example of what the output will look like is shown in Figure 2.

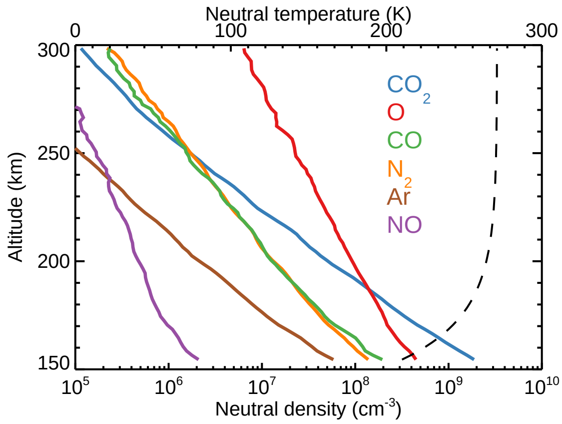

Figure 2: An example of what the empirical model program will output. Altitude profiles of the neutral densities are shown in different colors and the neutral temperature profile is shown with the dashed line scaled to the top horizontal axis. This example is illustrative only but shows NGIMS observations at a SZA of 85°.

References

Bates, D. R., Some Problems concerning the Terrestrial Atmosphere above about the 100 km Level, *Proc. R. Soc. London, Ser. A.*, *253*, 451–462, doi: 10.1098/rspa.1959.0207, 1959.

Bougher, S. W., D. Pawlowski, J. M. Bell, S. Nelli, T. McDunn, J. R. Murphy, M. Chizek, and A. Ridley, Mars Global Ionosphere-Thermosphere Model: Solar cycle, seasonal, and diurnal variations of the Mars upper atmosphere, *J. Geophys. Res.*, *120*, 311–342, doi: 10.1002/2014JE004715, 2015.

Hedin, A. E., C. A. Reber, G. P. Newton, N. W. Spencer, J. E. Salah, J. V. Evans, D. C. Kayser, D. Alcayde, P. Bauer, and L. Cogger, A global thermospheric model based on mass spectrometer and incoherent scatter data MSIS. I - N2 density and temperature, *J. Geophys. Res.*, *82*, 2139–2147, doi: 10.1029/JA082i016p02139, 1977.

Hedin, A. E., H. B. Niemann, W. T. Kasprzak, and A. Seiff, Global empirical model of the Venus thermosphere, *J. Geophys. Res.*, *88*, 73–83, doi: 10.1029/JA088iA01p00073, 1983.

Jakosky, B. M., J. M. Grebowsky, J. G. Luhmann, and D. A. Brain, Initial results from the MAVEN mission to Mars, *Geophys. Res. Lett.*, *42*, 8791–8802, doi: 10.1002/2015GL065271, 2015.

Mahaffy, P. R., M. Benna, M. Elrod, R. V. Yelle, S. W. Bougher, S. W. Stone, and B. M. Jakosky, Structure and composition of the neutral upper atmosphere of Mars from the MAVEN NGIMS investigation, *Geophys. Res. Lett.*, *42*, 8951–8957, doi: 10.1002/2015GL065329, 2015.

Walker, J. C. G., Analytic Representation of Upper Atmosphere Densities Based on Jacchia's Static Diffusion Models., *J. Atmos. Sci.*, *22*, 462–462, 1965.