DEVELOPMENT OF A SURFACE-TO-EXOSPHERE MARS ATMOSPHERE MODEL.

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Introduction:

Of major scientific interest is the understanding of diurnal, seasonal and epochal water transport and volatile loss on Mars. Volatile loss is a cornerstone of a number of important science questions because it must be understood to help explain the current atmospheric state and the relative lack of water on the planet. A complete GCM which considers volatile loss processes must include explicit ground interaction with the lower atmosphere, vertical transport of H_2O, and enough chemistry to reasonably represent the loss of H and H_2 (and heavier species) from the upper atmosphere and exosphere. Including these regions in a Mars GCM allows for the estimation of global escape fluxes for the present time, which can then be extrapolated backward in time to post-cast the atmospheric state at significantly earlier time periods with different orbital elements.

We are in the process of creating a new Mars GCM that will extend from the planetary surface to altitudes of about 500km, thus coupling the lower and upper atmospheres. It explicitly includes interactions between the ground and the atmosphere, such as gas phase and dust particle exchange between the two regions, and the effects of topography. Volatile transport will be simulated over both short (daily) and geological timescales to study the water distribution and to predict the D/H ratio of the present day atmosphere, thereby helping to constrain the history of water on the planet.

This surface-to-exosphere Mars GCM has as its heritage the successful terrestrial middle atmosphere model, ASPEN. The ASPEN model and its adaptation to address issues of Mars atmospheric science are described in the following sections.

The ASPEN Terrestrial Atmosphere Model

The Advanced SPace ENvironment (ASPEN) model was conceived and developed as a tool for understanding the complex terrestrial middle atmosphere. ASPEN is based on the well-known Thermosphere Ionosphere Mesosphere Electrodynamics General Circulation Model (TIMEGCM), which was developed at the National Center for Atmospheric Research (NCAR). The TIMEGCM was described by *Roble and Ridley* [1994], and is the latest in a series of 3-D models developed at NCAR. TIMEGCM has its lower boundary at 10 mb (~30 km) and includes the upper stratosphere and mesosphere as well as the thermosphere. It predicts winds, temperatures, major and minor composition, and electrodynamic quantities globally from 30 km to about 500 km. It does this by solving the momentum, hydrostatic, energy and continuity equations with the appropriate physics and chemistry for each altitude. The 3D model is formulated in the corotating geographic frame with a horizontal grid resolution of ~500 km (5^o latitude by 5^o longitude), and a vertical resolution of 0.25 pressure scale heights. The Eulerian nature of the model makes it natural to develop a solution for the entire 3D grid at every time step. The model is typically run with a 3-minute time step. The regular Eulerian grid simplifies full parallelization of the code.

ASPEN extends the performance of the TIMEGCM by the use of a different gridding scheme, and a different structure for passing information between grid points in the model [*Crowley and Freitas*, 2000; *Freitas and Crowley*, 1999].

The inputs required by ASPEN include the solar flux at 57 key wavelengths, auroral particle precipitation, high latitude electric fields, and tides propagating up from below the 10mb lower boundary. A gravity wave drag parameterization specifies the momentum deposition, heating and turbulent mixing associated with gravity waves interacting with the general circulation. This parameterization allows the model to simulate both the mean circulation and tides in the upper mesosphere for equinox and solstice conditions [*Crowley et al.*, 2002; *Roble et al.*, 1997].

Mesospheric chemistry is essentially the same as that described by *Allen et al.* [1984] and *Brasseur and Solomon* [1986] using the JPL-90 reaction and photoabsorption rates and updates. Validation of the middle atmosphere portion of ASPEN and the TIMEGCM has progressed by study of various parameters. ASPEN has been successfully used in the modeling effort of the mesospheric nightglow investigations of *Yee et al.* [1997]. ASPEN is currently being used to investigate the mesospheric thermal structure and energetics [*Crowley et al.*, 2002], and the effects of particles on the middle atmosphere [*Crowley et al.*, 1998; *Crowley et al.*, 1999; *Frahm et al.*, 1997; *Sharber et al.*, 2000].

Mars GCM Design Approach

The new Mars GCM will include simulations of the transfer of water from the planetary regolith into the atmosphere through boundary layer processes. We will also explore the role that mesoscale dynamical processes play in lofting dust into the atmosphere. The role of the dust and clouds in the planetary heat budget will be included through the use of specific microphysical and radiative transfer modules. The Mars ionosphere will be simulated with a detailed suite of chemical reactions, and over the long-term, the evolution of the D/H ratio will be predicted.

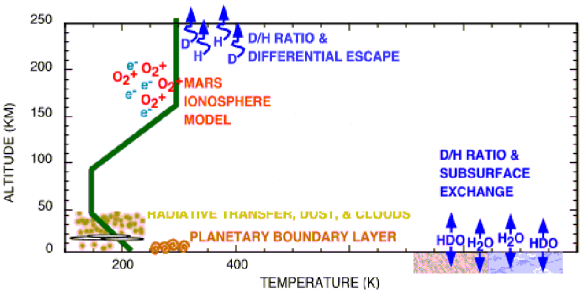

Figure 1. Major components of the new ASPEN-based Mars GCM.

The ASPEN model will be modified to represent Mars characteristics, and new modules will be developed to handle the unique Mars issues such as dust effects. Figure 1 summarizes the breadth of physics to be included in this new Mars GCM. One of the most significant changes to ASPEN required to model Mars is the inclusion of Planetary Boundary Layer (PBL) processes. It is at the ground surface where the fluid atmosphere interfaces to important sources and repositories of energy (thermal and viscous) and mass (chemical species and particles). The model will thus predict volatile loss, including the effect of ground interaction. Cloud interactions will be studied using an embedded microphysical cloud model. An embedded ionospheric module will provide improved ionospheric specifications needed to accurately simulate the D/H response. The new Mars GCM will also generate internally the tides and gravity waves that propagate into the upper atmosphere and have important consequences to vehicle maneuvering (specifically aerobraking). An outline of the model will be presented, together with an update on its development.

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