MODERN MARS SIMULATIONS WITH THE ROCKE-3D GCM: SENSITIVITY TO H2O SNOW DEPOSITION AND DUST CYCLE . I. Aleinov[1,2], K. Tsigaridis[1,2,], S. D. Guzewich[3], E. T. Wolf[4], J. P. Perlwitz[5] and M. J. Way[2,6], [1]Center for Climate Systems Research, Columbia University, New York, NY 10025, USA (igor.aleinov@columbia.edu),[2]NASA Goddard Institute for Space Studies, New York, NY, 10025, USA, [3]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA, [4]University of Colorado, Boulder, USA, [5]Climate, Aerosol and Pollution Research, LLC, Bronx, NY 10471, USA, [6]Theoretical Astrophysics, Department of Physics & Astronomy, Uppsala University, Uppsala SE-75120, Sweden

Introduction: The Resolving Orbital and Climate Keys of Earth and Extraterrestrial Environments with Dynamics (ROCKE-3D) [1] General Circulation Model (GCM) was recently adapted to model the modern Martian atmosphere. Here we present preliminary results of such simulations and investigate the sensitivity of the model to the presence of H_2O snow in the polar caps and parametrization of the dust cycle component.

The Model: ROCKE-3D is a three-dimensional atmosphere and ocean GCM which was constructed as an extension of its parent Earth GCM, ModelE [2] developed at NASA Goddard Institute for Space studies (GISS). Both models maintain a close relationship and exchange periodic updates. In this research we use the Planet 2.0 version of ROCKE-3D which is based on E2.1 [3] version of its parent model.

The atmospheric part of the model uses a Cartesian grid based on the Arakawa B-grid [4] formulation. Work is underway to implement a cubed sphere dynamical core, which is expected to be included into Planet 3.0 version (currently being tested in the ModelE parent GCM). The tracers are advected by a 9-moment algorithm [5], which accounts for their variation on a subgrid scale. The vertical discretization employs a sigma coordinate approach near the surface and switches to constant pressure layers for the upper atmosphere.

The model is capable of simulating a complete hydrological cycle with cloud formation, precipitation and proper treatment of water at the surface. The land surface model is represented by six layers of soil and a dynamic three-layer snow model. The soil layers can store liquid and frozen water according to the prescribed texture, and they can exchange liquid water as it is driven by gravity and capillary forces. The model also includes a runoff algorithm with river routing and dynamic lakes, though with modern Mars being mainly below the triple point of water these were not relevant in the work presented here.

The aerosols, including dust, can be treated by ROCKE-3D interactively, taking into account their effect on the radiative balance of the planet. Special care needs to be taken when switching to a different planetary environment, since their sources may need to be re-tuned.

One of distinctive features of Mars' climate is the seasonal condensation of up to 30% of its atmosphere. ROCKE-3D performs it by condensing CO_2 at the surface as a CO_2 frost (CO_2 precipitation is not currently implemented). This is done by checking the ground temperature on each land surface time step and adjusting the ground heat content (including snow) so that the ground temperature never falls below the CO_2 condensation temperature for the current local surface pressure. The energy required to make up the balance is obtained by condensing the appropriate amount of CO_2, which in turn changes the surface pressure. To ensure numerical stability on every time step this procedure is applied iteratively until the amount of CO_2 condensate reaches local equilibrium. Currently, the CO_2 frost optical properties are assumed to be the same as those of H_2O snow, but work is underway to implement proper albedo and emissivity of CO_2 snow.

Experiments: For our experiments we use the version of the model with 4°x5° horizontal resolution (which corresponds to about 200 km x 200 km resolution on equator) and 40 vertical layers with the upper boundary at ~0.7 microbars. For the surface boundary conditions we use modern observed topography and albedo. The bulk atmospheric composition was assumed to be pure CO_2 (with the trace amount of water vapor as simulated by the model).

The dust source function depends on surface type, topography and climatological parameters such as wind speed and moisture. It also applies a tuning factor to dust sources to account for the uncertainty in dust size distribution. Here we use the MOLA14 dataset for topography and investigate the dependence of simulation results on this tuning factor.

We considered several configurations with H_2O snow presence in the polar caps. In particular, we considered a configuration with no snow and a Northern H_2O snow cap ~1000 km in diameter and 4 m of snow water equivalent. Figure 1 shows the results of such experiments for the atmospheric pressure at the Viking 2 landing site. The experiment with H_2O snow cap produces lower pressures (and better fit to the observations) most likely due to lower surface temperatures because of the presence of H_2O snow. An ideal fit was not expected in these experiments, because our model still uses H_2O snow albedo formulation for the CO_2 frost`.

Results: The main goal of this study was to investigate the capability of ROCKE-3D to simulate the modern Mars climate, and here we provide a comparison of the results of our simulations to observed temperature profiles, H_2O ice cloud profiles, dust opacity profiles and optical depth, as well as Viking 2 lander site pressure time series.

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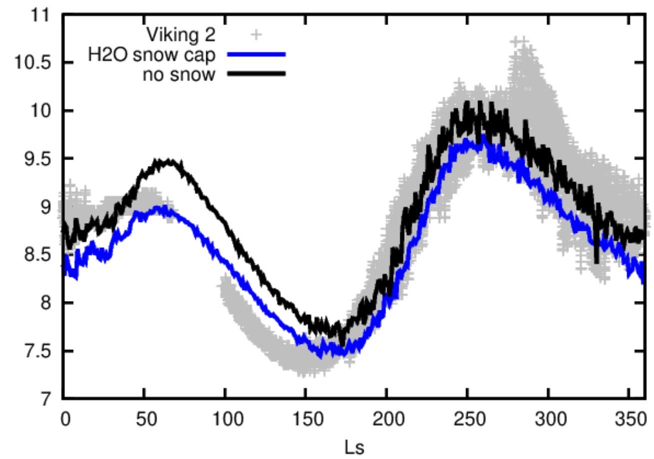

Figure 1. Surface pressure (mb) at Viking 2 landing site.