ROCKE-3D GCM FOR MODERN MARS: PRELIMINARY RESULTS.

I. Aleinov[1,2], K. Tsigaridis[1,2,], S. D. Guzewich[3], E. T. Wolf[4], J. P. Perlwitz[5], M. J. Way[1,6], and M. Kelley[1,7], [1]NASA Goddard Institute for Space Studies, New York, NY, 10025, USA (igor.aleinov@nasa.gov), [2]Center for Climate Systems Research, Columbia University, 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, [7]SciSpace, LLC, New York, NY, USA

Introduction: Resolving Orbital and Climate Keys of Earth and Extraterrestrial Environments with Dynamics (ROCKE-3D) [1] is a three-dimensional atmosphere & ocean General Circulation Model (GCM), specially adapted from its parent GCM, GISS ModelE [2], for general terrestrial planetary needs. Both models by design are kept in sync, so that any new development in ModelE is automatically absorbed by ROCKE-3D. The latest version of ROCKE-3D, referred to as Planet 2.0 (R3D2), is based on the ModelE_2.1 version of its parent model [3]. In this study we investigate the abilities of R3D2 to simulate the climate of modern Mars.

The Model: R3DP2 is a Cartesian gridpoint model capable of running at 2°x2.5° latitude-longitude atmospheric resolution with 40 vertical layers. Generally for terrestrial planetary needs it is run at a coarser 4°x5° horizontal resolution. The R3D2 dynamical core uses finite differences with atmospheric velocity points on the Arakawa B-grid [4]. For tracers, nine higher-order moments are carried, as well as the mean tracer amount in each grid box, yielding an effective resolution that is higher than the nominal model resolution [5]. The vertical discretization uses a sigma coordinate from the surface to ~0.1 of surface pressure, and switches to constant pressure layers above.

The general planetary adaptations in R3DP2 relevant to Mars simulations included the effort to expand the capabilities of ModelE_2.1 to handle a broader range of atmospheric conditions, including higher and lower atmospheric pressures, more diverse chemistries and compositions, larger and smaller planet radii and gravity and different rotation rates.

For our Mars simulations we use modern observed Mars topography and albedo datasets. The atmospheric composition was set to pure CO_2 and trace amount of water.

A few necessary modifications were unique to Mars. Mars experiences a seasonal atmospheric condensation (up to 30% of the atmospheric mass) and such physics needed to be incorporated into the model. This was done by allowing the atmosphere to condense at the ground. At each time step the energy balance at the surface is checked, and if it would cause the ground temperature to drop below the CO_2 condensation point, the temperature is kept at condensation level, and the condensate is formed in the amount to compensate for energy deficiency. The atmospheric pressure is updated accordingly.

Dust can be calculated interactively in R3D2 [1]. The source function depends on surface type and orography, as well as wind speed and soil moisture. We used MOLA14 topography data to construct a map of preferred dust sources based on the topography of the planet. Every global model that simulates dust interactively applies a tuning factor to dust sources, due to the large uncertainty related with the dust size distribution at emission time and transport of large particles. This tuning factor will be different between Earth and Mars. Figure 1 shows surface pressure calculated for the Viking 2 landing site for two sets of dust tuning parameters. The red line is with the tuning factor same as for Earth (which underestimates dust on Mars), and the black line with the factor increased by an order of magnitude. The effect of dust is mainly due to the fact that its absorption alters the distribution of radiation in the model, and results in different temperatures and pressures.

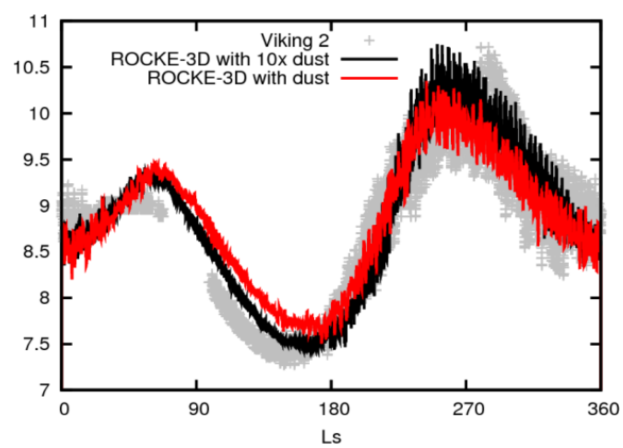

Figure 1. Surface pressure (mb) at Viking 2 landing site.

Results: In this study we do a thorough analysis of our Mars model and provide a comparison to observed temperature profiles, H2O ice cloud profiles, dust opacity profiles and optical depth, as well as Viking 2 lander pressure time series.

Acknowledgments: This research was supported by NASA Nexus for Exoplanet System Science. Computing resources were provided by NASA Center for Climate Simulation.

References: [1] Way M. J. et al. (2017) *ApJS, 231*, 12. [2] Schmidt, G.A. et al. (2014) Adv. Model. Earth Syst., **6**, no. 1, 141-184. [3] Kelley, M. et al. (2020) J. Adv. Model. Earth Syst., submitted. [4] Hansen, J. et al. (1983) Mon. Weather Rev., 111, 609–662 [5] Prather, M. J. (1986) J. Geophys. Res., 91, 6671–6680.