MARS GLOBAL REFERENCE ATMOSPHERIC MODEL (Mars-GRAM): CURRENT UPGRADE ACTIVITIES AND DESIRED DATA PRODUCTS

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Introduction: The Mars-Global Reference Atmospheric Model (Mars-GRAM) [1] is an engineering-level model of the Martian atmosphere used for mission planning, performing early design trade-studies, and supporting operational decision making by providing bounded estimates of expected conditions. Mars-GRAM has been used by many Mars missions including Mars Atmosphere and Volatile Evolution (MAVEN), Mars Global Surveyor, Odyssey, Mars Reconnaissance Orbiter, Mars Exploration Rover, Mars Science Laboratory, and InSight.

Laterally, Mars-GRAM provides coverage at all latitudes and longitudes, and vertically, from the surface through exospheric altitudes. Mars-GRAM provides full diurnal, seasonal (L_s), and solar cycle variability. Standard outputs include wind components, thermodynamics (pressure, temperature, density), and chemical constituents. Robust user-inputs provide multiple methods for specifying dust optical depth (τ), including globally-uniform background values, evolving local and global dust storms, Viking-derived seasonal variation, and explicit modelling from Thermal Emission Spectrometer (TES) values observed during mapping years 1 and 2.

An important feature of Mars-GRAM is the ability to generate realistic dispersions to support Monte Carlo analyses. The model can be run in standalone mode or embedded in trajectory codes to provide atmospheric properties at each integration step. Although implementation details differ significantly, Mars-GRAM is functionally similar to the Mars Climate Database, and favorable comparisons between the two systems have been performed in the past [2]. Mars-GRAM is one of a suite of Global Reference Atmospheric Models (GRAMs) developed by the NASA Marshall Space Flight Center. In addition to Mars, GRAMs currently exist for Earth, Venus, Neptune, and Saturn's moon Titan. GRAMs for new destinations are planned for the near future.

The primary climatology data used in Mars-GRAM is derived from gridded model outputs. From surface to 80 km, the NASA Ames Mars General Circulation Model (MGCM) [3] is used. Above 80 km, the University of Michigan Mars Thermospheric General Circulation Model (MTGCM) [4] is used to the top of its domain, which is 240 km for TES year simulations, and 170 km otherwise. Above the MTGCM domain, a modified Stewart thermosphere model [5] is applied. MGCM and MTGCM are primarily science models, and significant post-processing is required to convert their outputs to formats useable in an engineering model.

The first Mars-GRAM was released in 1988. Subsequent upgrades have added capability enhancements and improved data climatologies. MGCM and MTGCM data were added to Mars-GRAM in the 2000 release and have not been updated since. The most recent release of Mars-GRAM came in 2010 [1]. This release included a set of density adjustment factors to better correspond with recent observations.

Upgrade Activities: Throughout most of its history, Mars-GRAM development has been supported by mission-specific funding. For various reasons, these funding opportunities mostly went away since the release of Mars-GRAM 2010. Recently, the NASA Science Mission Directorate (SMD) has provided direct funding to standardize and upgrade the GRAMs. The GRAM upgrade effort will focus on three primary objectives: upgrade the climatology data within the GRAMs, modernize the GRAM codes, and facilitate regular communication between GRAM users, Mars climate modellers, and GRAM developers.

The model upgrades are being written in C++ using a common framework that will streamline processing, standardize integration of new climatology datasets, improve response to new capability requests from the user community, and generate GRAMs for new destinations. In addition to new code development, a major additional goal of the project is to update the climatology data used in the models.

Existing Climatology Data: Currently, Mars-GRAM uses five series of MGCM and MTGCM outputs as climatology, consisting of five different τ scenarios: three constant, globally uniform values (0.3, 1.0, and 3.0) and two characterizations taken from MGCM simulations initialized using TES observations during mapping years 1 and 2. The MTGCM data also have separate outputs for three values of solar output (F10.7 flux).

For each parameter (temperature, density, pressure, zonal and meridional wind components) zonal mean values as well as amplitudes and phases of diurnal and semi-diurnal tidal components are provided, from which time-of-day variability is derived. Each scenario includes outputs for twelve values of solar longitude, providing seasonal variability.

New Models: The MTGCM has been recently replaced with the Mars-Global Ionosphere Thermosphere Model (M-GITM). M-GITM has been updated to reflect the upper atmosphere observations obtained from the MAVEN mission. Additionally, the MGCM has been updated. The GRAM team will work with the GCM developers to appropriately update the base models in Mars-GRAM. Planetary mission atmospheric data, when available and appropriate, will also be used for verification and validation of Mars-GRAM.

Value of Assimilation Data: The GRAM development team currently uses a data assimilation dataset (National Center for Environmental Prediction Reanalysis) in the Earth-GRAM model, and has experience applying this type of data to the engineering framework. Therefore, understanding the Mars atmospheric data assimilation (MADA) efforts is valuable to the Mars-GRAM development team, and may provide data modeling alternatives for Mars-GRAM. MADA may also provide interesting new capabilities, including higher temporal fidelity, greater emphasis on actual observations with implicit correlations between observed parameters, and more realistic treatments of dust optical depths.

This presentation will provide a brief overview of the suite of GRAM models, with a concentration on Mars-GRAM. A detailed description of the data used in Mars-GRAM will follow, with recent analysis highlighting some of the current deficiencies that will be addressed in the current upgrade activity. A conclusion will summarize the expected benefits that MADA could provide to future GRAM developments based on experiences using similar datasets in other GRAM versions.

References: [1] Justh, H.L. (2014), *NASA TM-2014-217499*. [2] Justus, C.G., et al. (2004), *COSPAR 35*. [3] Haberle, R. M., et al. (1993), *JGR*, *98*, 3093-3123. [4] Bougher, S.W., et al. (1990), *JGR*, 95, 14,811-14,827. [5] Justus, C. G., et al. (1996), *NASA TM 108513*.