Mars Global Reference Atmospheric Model (Mars-GRAM) Upgrades

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Introduction

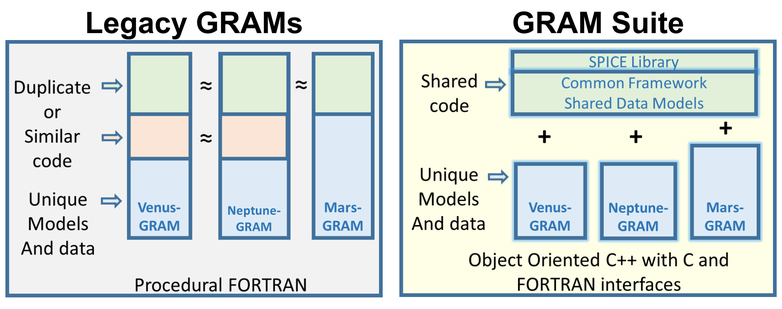
The inability to test planetary spacecraft in the flight environment prior to a mission requires engineers to rely on ground-based testing and models of the vehicle and expected environments. One of the most widely used engineering reference models of planetary atmospheres are the Global Reference Atmospheric Models (GRAMs). The NASA Science Mission Directorate (SMD) has provided funding support to upgrade the GRAMs since Fiscal Year 2018. The GRAM upgrades are being developed by NASA Marshall Space Flight Center and NASA Langley Research Center. This poster provides details regarding recent Mars-GRAM upgrades.

Mars-GRAM

- Engineering-oriented atmospheric model that estimates mean values and statistical variations of atmospheric properties for Mars
- Outputs include atmospheric density, temperature, pressure, chemical composition, radiative fluxes, and wind components along a user-defined path
- Includes seasonal, diurnal, geographic, and altitude variations
- Widely used by the engineering community because of ability to create realistic atmospheric dispersions
- Can be integrated into high fidelity flight dynamic simulations of launch, entry, descent and landing (EDL), aerobraking and aerocapture
- Not a forecast model
- Distributed in the GRAM Suite[1]
- Available through the NASA Software Catalog https://software.nasa.gov/software/MFS-33888-1

GRAM Suite

- Common object-oriented C++ framework that simplifies model updates, integration, testing, and maintenance
  - Supports all solar system destination models
  - Currently contains Venus, Earth, Mars, Jupiter, Titan, Uranus, and Neptune-GRAM
  - Provides a uniform user interface for all GRAMs
  - Includes C++ library with C and Fortran interfaces that can be incorporated in a trajectory or orbit propagation code
  - All future GRAM Upgrades will be released in the GRAM Suite



Initial Upgrades

- GRAM ephemeris upgraded to NASA Navigation and Ancillary Information Facility (NAIF) Spacecraft Planet Instrument C-matrix Events (SPICE) toolkit (version N0067) for increased accuracy
- Improved calculation of the speed of sound
- Renamed input parameters to be more descriptive and reformatted output files
- Updated Mars-GRAM User Guide

Upcoming Upgrades

Mars-GRAM Input Data Upgrades

- Previous releases of Mars-GRAM utilize data tables derived in 2000 from outputs from:
  - NASA Ames Mars General Circulation Model (MGCM)[2,3] for the surface to 80 km altitude
  - University of Michigan Mars Thermospheric General Circulation Model (MTGCM)[4,5] for altitudes above 80 km
- GRAM Team is incorporating into Mars-GRAM:
  - New lower atmosphere data from MGCM[6]
  - Thermosphere data from the Mars Global Ionosphere-Thermosphere Model (M-GITM)[7], the successor to MTGCM
- Incorporation of new MGCM and M-GITM data has resulted in changes to the structure of the Mars-GRAM input data for these two cases
  - Tidal expansions and coefficients are replaced by explicit longitudinal and local time variability
    - New data are output on a longitudinal grid with 6 degree spacing and a local time grid with 1.5 Mars hour spacing
  - The previous globally uniform dust optical depth (τ) scenarios are being replaced with observed dust climatologies for:
    - Nominal dust year (MY-24)
    - High dust year (MY-25)
    - Low dust year (MY-30)
    - Globally uniform high-dust case (τ= 5)
  - MY-24, MY-25, MY-30, and τ= 5 output data are used to configure the explicit dust-storm model in Mars-GRAM.
    - Previously a Mars-GRAM user could specify via input parameters a dust optical depth and solar cycle strength
    - When the new input datasets are utilized the dust optical depth and solar output values are tied to the dust case chosen by the user
- New MGCM and M-GITM data is anticipated to be included the Fall 2024 GRAM Suite Release (dependent upon receipt of complete M-GITM dataset containing the four observed dust climatologies)

Mars-GRAM Topography Data Upgrades

- Topography in Mars-GRAM is specified using Mars Orbiting Laser Altimeter data
- Mars-GRAM uses 2-D (lat/lon) interpolation to deter-mine height values at a given location
- Previous versions of Mars-GRAM contained a 0.5-degree (2 pixels/degree) latitude/longitude grid spacing
  - Coarse topography data could result in an incorrect determination of surface height
- Upgrades to a higher resolution dataset have been completed and are included in the June 2024 GRAM Suite release
- Users can select between resolutions of 2, 4, 16, 32, and 64 pixels/degree
- Option allows users to choose the optimal tradeoff between fidelity and file size/run-time considerations, based on their own analysis needs

Latest Releases

- Recent GRAM Suite releases have included upgrades to Mars-GRAM
- GRAM Suite Version 2.0.0 (Released November 2023) included:
  - Addition of Python Application Program Interface (API)
  - Updated GRAM Programmer's Manual
- GRAM Suite June 2024 Release includes:
  - Mars-GRAM topography data upgrade
  - Updated Mars-GRAM User Guide
  - Updated GRAM Programmer's Manual

Future Releases

- Future Planned Mars-GRAM Upgrades include:
  - Mars-GRAM input model data upgrade
  - Addition of MATLAB API
  - Gravity data upgrade for Mars-GRAM

Conclusions

- Mars-GRAM is a frequently used toolset and vital in assessing effects of atmospheres on spacecraft during the program life cycle process
- Mars-GRAM is contained in the GRAM Suite that is available via the NASA Software Catalog https://software.nasa.gov/software/MFS-33888-1
- Upgrades of Mars-GRAM and the GRAM Suite are continuing
- Updating the inherent data in Mars-GRAM and GRAM Suite to reflect current best estimates
- Next GRAM Suite release in June 2024
- Ongoing discussions with:
  - Modeling groups within NASA and academia regarding status of their models
  - Planetary mission teams (VERITAS, DAVINCI, Dragonfly, MAV, MAVEN, etc.) to determine potential mission support by the GRAM team, utilization of collected atmospheric data, and needed GRAM upgrades
- Feedback regarding the GRAMs is encouraged and welcomed

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