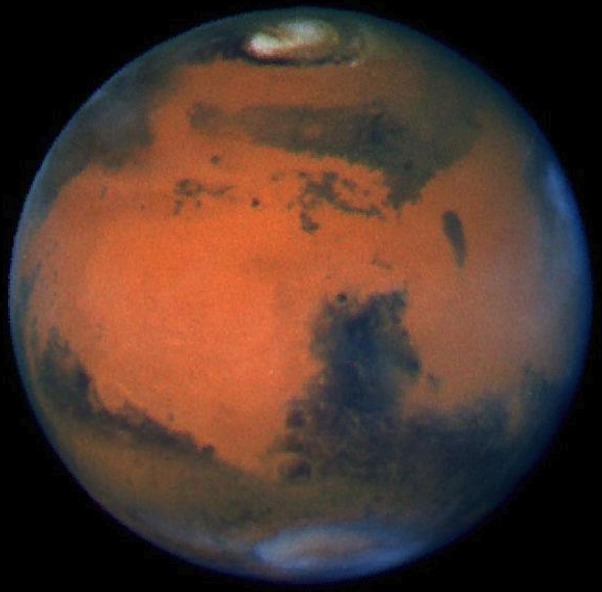
Mars Global Reference Atmospheric Model

GRAM Virtual Workshop

September 21, 2017



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What is Mars-GRAM?

Mars-GRAM is a statistical description of the Martian atmosphere applicable for engineering design analyses, mission planning, and operational decision making.

- Provides mean, dispersed values of atmospheric state variables.
  - Temperature
  - Density
  - Pressure
  - 3-D Wind components
  - Chemical constituents
  - Scale heights
  - Radiative fluxes
- Variability based on numerous independent variables.
  - Latitude
  - Longitude
  - Height
  - Solar activity
  - Local True Solar Time (LTST)
  - Ls (season)
  - Dust optical depth (τ)

Mars-GRAM can be requested at https://software.nasa.gov/software/MFS-33158-1

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Mars-GRAM Customization

- User-selectable inputs specify various analysis scenarios.
  - Uniform dust optical depths or Thermal Emission Spectrometer (TES) observed dust opacities.
  - Scalable perturbations for analyzing dispersed environments.
  - Global and time-evolving local dust storms.
  - Latitude-dependent stationary and propagating density waves.
  - Individual scale parameters for density, wind, and boundary layer dynamics.

- Runtime options provide flexibility.
  - Auto-generated profiles with variable step sizes.
  - Detailed perturbation model for applications in Monte Carlo simulations.
  - User-defined trajectory files.
  - User-specified auxiliary profile option for detailed analysis along an observed corridor.

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Mars-GRAM applications and exclusions

- Mars-GRAM supports analysis throughout mission timeline.
  - Advanced concept development.
  - Mission planning and sequencing; requirements specification.
  - Hardware design and verification.
  - Operations support.
  - Post mission analysis.

- Mars-GRAM is not a prognostic model.
  - Not physics based; no primitive equations of motion.
  - No forward time-stepping; no issues with computational stability or “spin-up.”
  - Does not require assignment of initial or boundary conditions.
  - No nested-grid resolution.

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Mars-GRAM Development History

1988, MG v1.0	Stewart thermosphere with no latitude or longitude variation.
1989, MG v2.0	Improved thermosphere with latitude and longitude variability.
1991-98, MG v3.x	Added local dust storms and wave perturbations, updated input datasets, Monte Carlo support on UNIX and PC, improved computational efficiency.
2000-01, MG 2001	Ad-hoc climate factors replaced by Mars General Circulation Model (MGCM) and Mars Thermospheric General Circulation Model (MTGCM) datasets to express variability from surface to 170 km. New Mars Orbiting Laser Altimeter reference aeroid, solar activity effects, improved boundary layer and dust storm models.
2005-07, MG 2005	Advanced ephemeris, 3-D slope winds, travelling waves, output scaling, advanced perturbation model, TES optical depths, auxiliary profiles.
2010+, MG 2010	Added adjustment factors to agree more with TES limb data from 0-60 km altitude, and with Mars Global Surveyor, Odyssey, and Mars Reconnaissance Orbiter aerobraking observations above 95 km altitude.

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Mars-GRAM Mission Support History

- MAVEN (ongoing)
- Mars Global Surveyor
- Mars Odyssey
- Mars Reconnaissance Orbiter
- Mars Exploration Rover
- Mars Science Laboratory
- Human Architecture Team
- InSight
- Mars Pathfinder
- Phoenix Lander
- Mars Aerocapture System Study
- NESC Autonomous Aerobraking

Numerous additional studies and proposals

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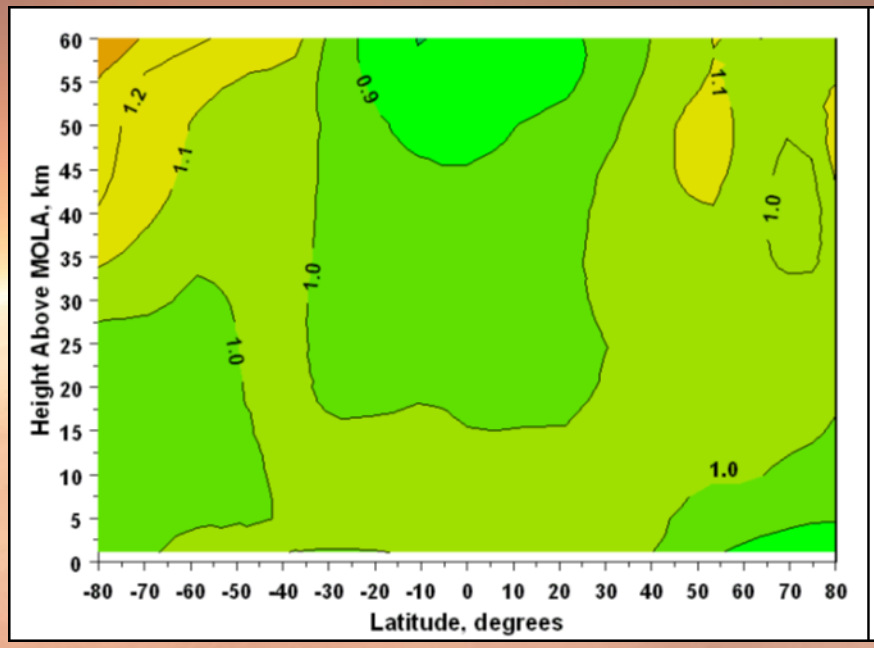
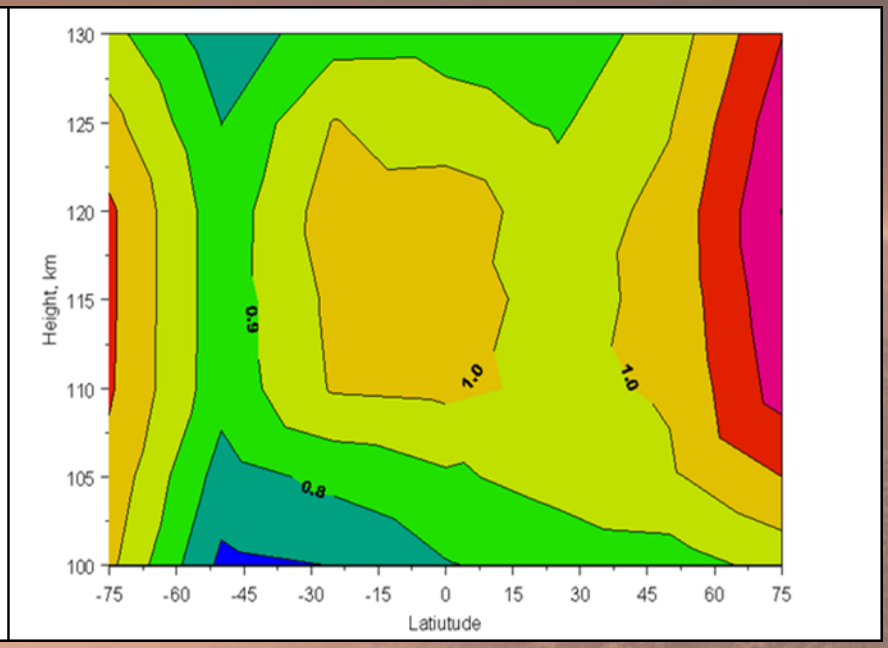
Mars-GRAM Adjustments





Density ratios from adjustment factors:
MGCM (0-60 km) and MTGCM (100-160 km)

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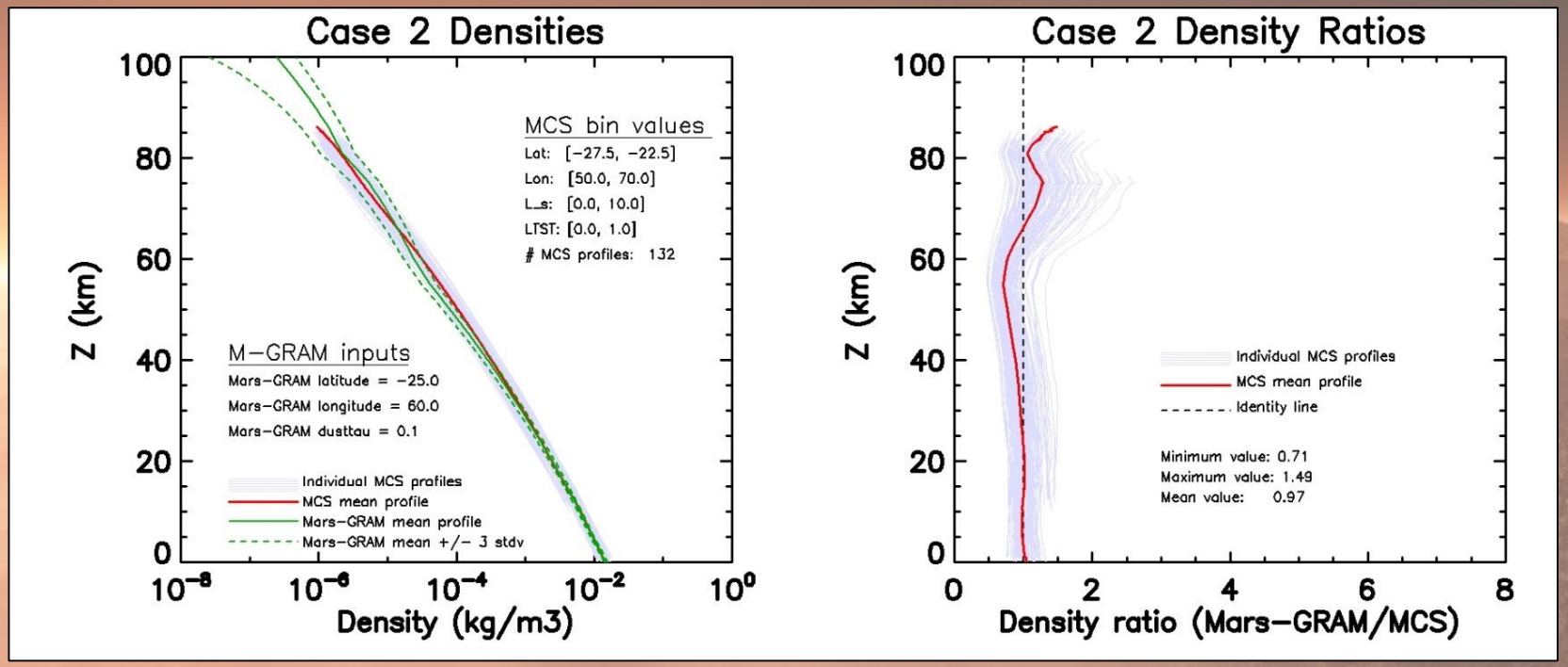
Mars-GRAM/MCS Comparison



Comparing Density values: Mars-GRAM 2010 vs. Mars Climate Sounder (MCS) observations

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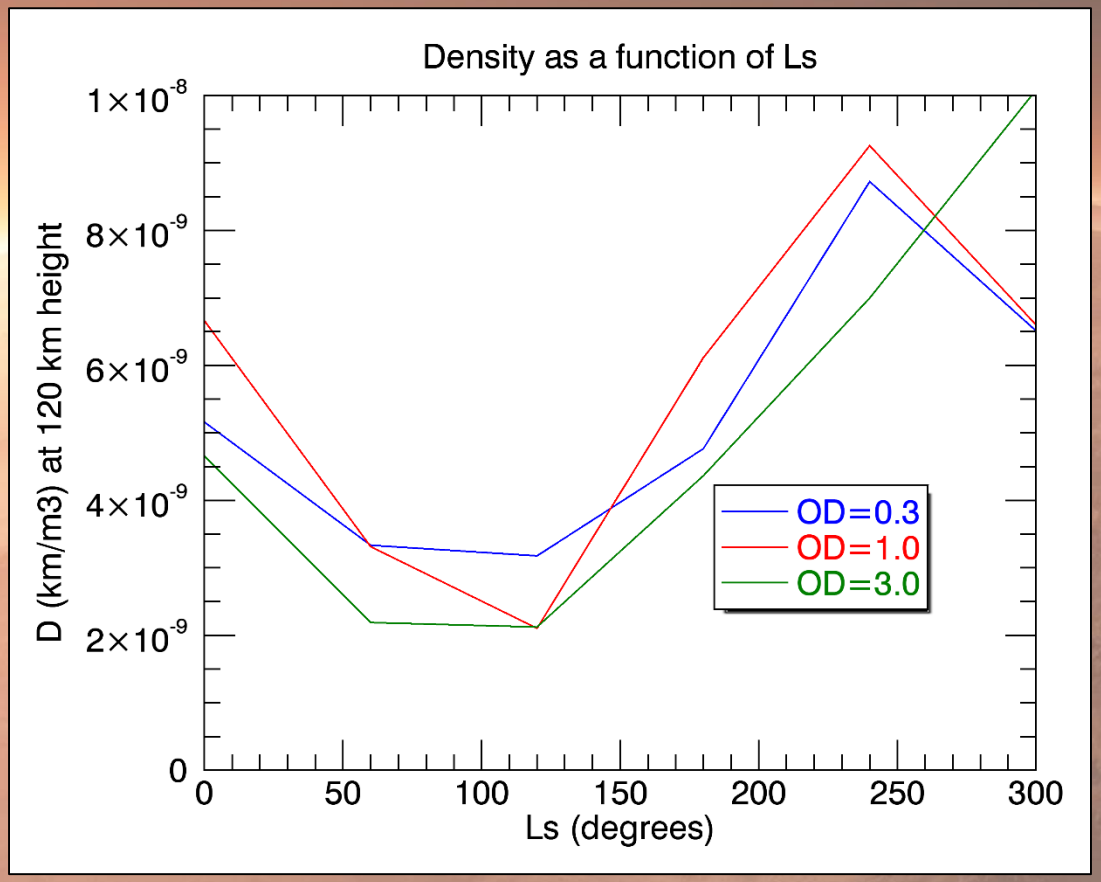
Mars-GRAM Examples



Seasonal variation of Density, for three values of dust optical depth.
Height = 120 km; LTST = 12.0; Latitude = 0 degrees; Longitude = 120 degrees W

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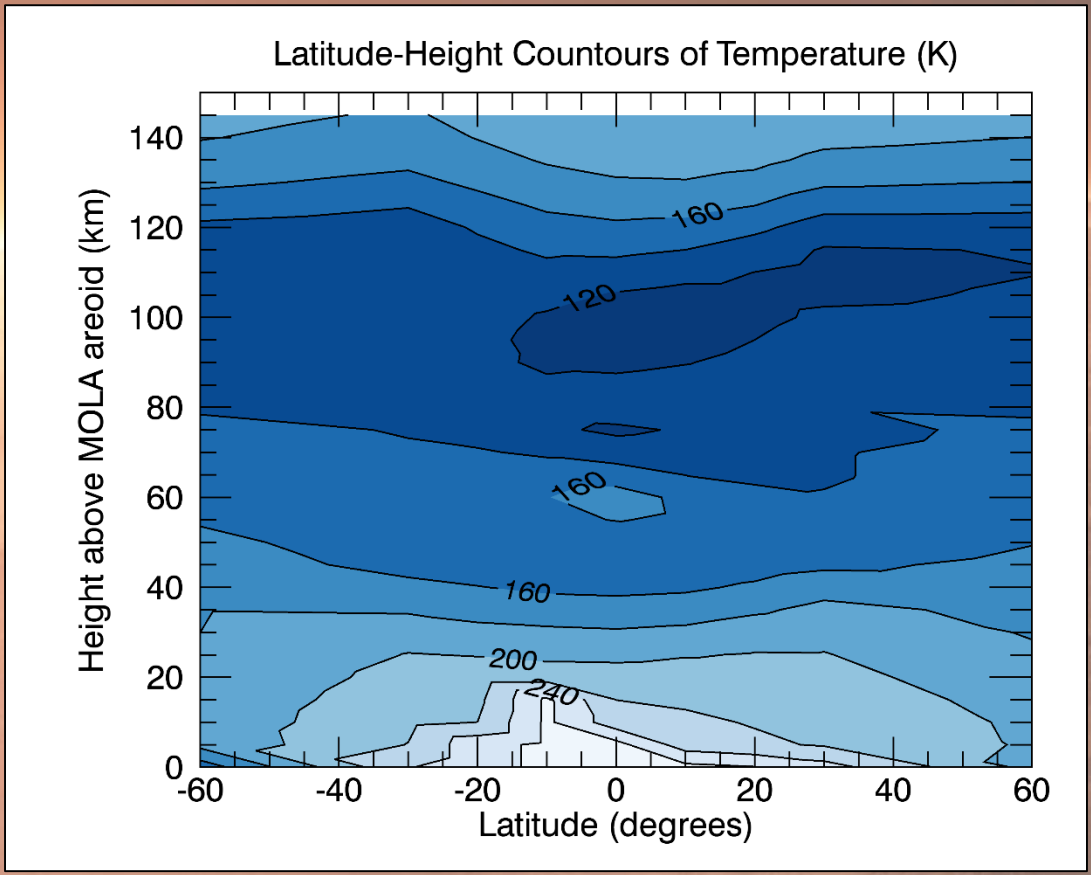
Mars-GRAM Examples



Latitude-Height contours of temperature.
Ls = 180; τ = 1.0; LTST = 12.0; Longitude = 120 degrees W

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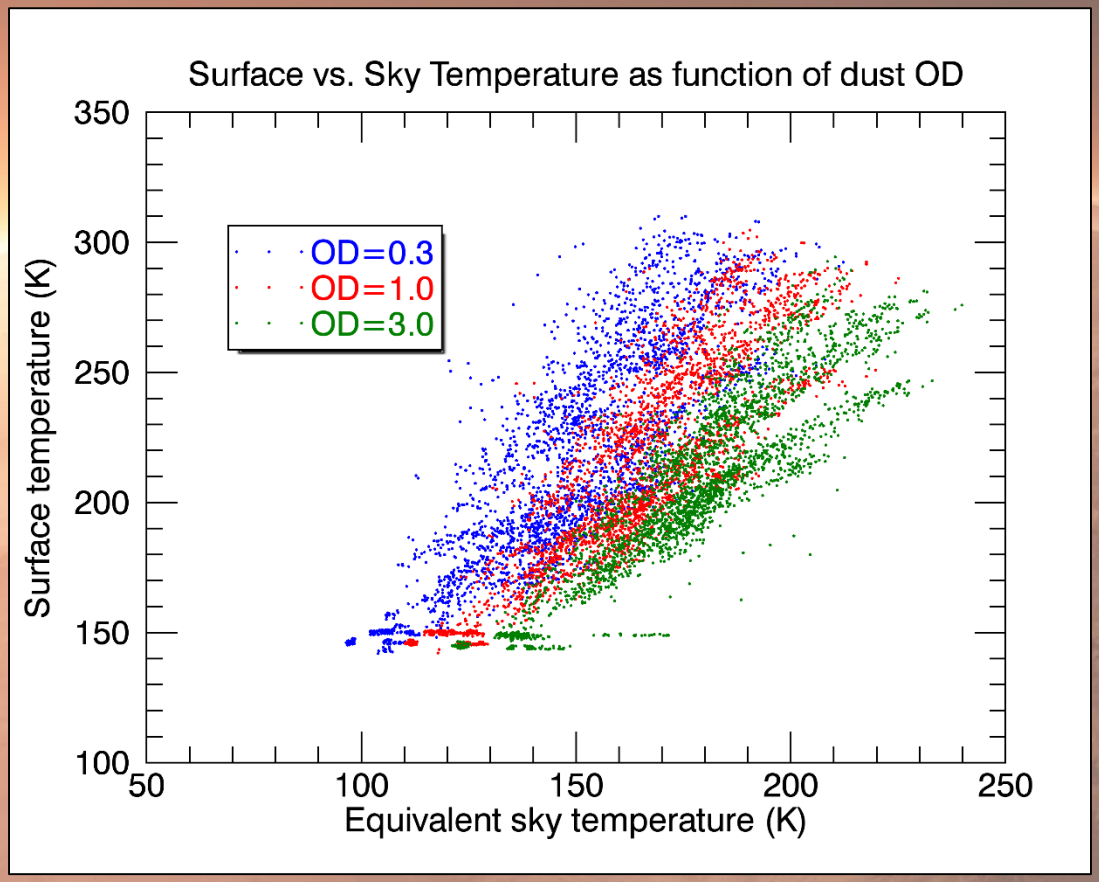
Mars-GRAM Examples



Surface vs. equivalent sky temperature for 8300 Mars-GRAM 2010 runs iterating over Latitude, Longitude, Ls, τ, and solar activity. Plot highlights variability based on optical depth.

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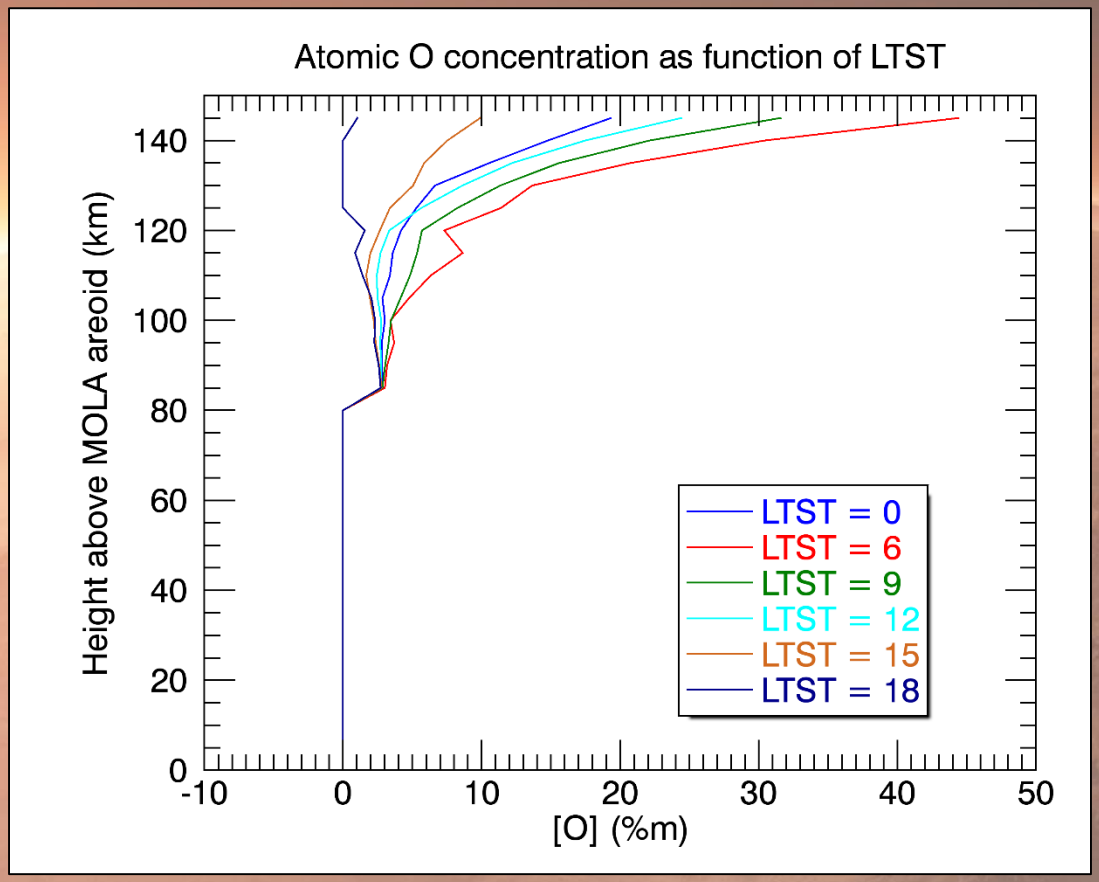
Mars-GRAM Examples



Diurnal variation of Atomic Oxygen concentration versus height.
Latitude = 60 degrees N; Longitude = 0 degrees W; τ = 1.0; Ls = 240 degrees.

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Current Mars-GRAM Limitations

- Source data is not current.
- Simplistic treatment of boundary layer processes and vertical winds.
- Users have requested a version written in a modern programming language, such as C++. Current version is written in Fortran-90.
- Numerous user-requested feature additions and capability enhancements.

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Mars-GRAM Current Status

- Mars-GRAM 2010 is the most recent release.
- Uses MGCM (Ames Research Center) and MTGCM (University of Michigan) outputs as background climatology.
- Current climatology data was generated ~1999, first included in Mars-GRAM 2000.
- Subsequent observations were not fully consistent with Mars-GRAM (2005) climatology, particularly at high dust optical depths. Adjustment factors were added to nudge the climatology toward the newer observations, and were released in Mars-GRAM 2010.

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Mars-GRAM Current Status

- Mars-GRAM 2010 has recently been re-written, slightly re-structured, and massively commented in an unreleased internal version. No new features, capabilities, or climatology data are included. One minor bug has been corrected that produced bogus daily maximum and minimum density values very near the surface and close to the poles. This internal version will be the baseline for all future developments.

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Mars-GRAM Near-Term Plans

- A new version of Mars-GRAM is being written in C++, with planned release in 2019 (assuming new climatology data availability).
- Currently, the basic framework (with limited functionality) has been developed and is undergoing alpha testing.
- Once alpha testing of basic framework is completed, remaining functionality will be added and tested.
- Once all development and alpha testing are completed, Mars-GRAM 2019 version 0.0 will be released for beta testing.
- Once beta testing is complete and all identified issues have been addressed, and new climatology data has been added, Mars-GRAM 2019 version 1.0 will be available for general release.
- Work will then continue to add new capabilities and features in additional future releases.

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A Word About New Climatology Data

- We have informal agreements from modelers to provide new climatology data.
- Steve Bougher (University of Michigan) is providing outputs from the Mars Global Ionosphere-Thermosphere Model (M-GITM).
- Hoping to obtain new MGCM outputs from the Ames Research Center/Mars Climate Modeling Center.
- Additional data sources (Mars Climate Database, other models, direct observations) have been investigated and determined to be less desirable.
- Generating data is time consuming and we have requested a LOT of individual runs.
- Model data is currently being offered out of generosity of the two modeling groups without formal contracts or schedules (possible future funding may accelerate this).

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Mars-GRAM Future Development Ideas

- Expanded use of “auxiliary profile” option.
  - Currently, user can provide a single auxiliary profile with application ranges.
  - Could implement capability for multiple “standard” auxiliary profiles.
  - Idea is to develop a (large) set of observed profiles to augment model climatology.
  - Also considering the application of mesoscale model outputs as auxiliary profiles to provide synergy between the higher resolution/fidelity of the mesoscale models and the Monte Carlo perturbation and dispersion capabilities of Mars-GRAM.
- Include additional sets of climatology data from model simulations of actual Mars years initialized with observed data. These would supplement the current TES year 1 and 2 options.

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Mars-GRAM Future Development Ideas

- Allow time of day and season inputs in Mars-specific values. Currently, time/date inputs are in Earth time/calendar values, and Mars-specific values are computed internally.
- Use recent observations to constrain and improve parameterizations.
- Use higher-resolution topography (currently 1° lat/lon resolution; resolution up to 1/32° is available.
- Improve boundary layer representation.
- We are actively seeking suggestions from our user community!

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Questions?

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