Strategies to Improve the Accuracy of Mars-GRAM Sensitivity Studies at Large Optical Depths

Hilary L. Justh[1], Carl G. Justus[2], Andrew M. Badger[3]

[1]NASA, Marshall Space Flight Center, Mail Code EV44, Marshall Space Flight Center, AL 35812, USA Hilary.L.Justh@nasa.gov
[2]Stanley Associates, Marshall Space Flight Center, Mail Code EV44, Marshall Space Flight Center, AL 35812, USA Carl.G.Justus@nasa.gov
[3]Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27695 USA ambadger@ncsu.edu

Background

It has been discovered during the Mars Science Laboratory (MSL) site selection process that the Mars Global Reference Atmospheric Model (Mars-GRAM) when used for sensitivity studies for TES MapYear = 0 and large optical depth values such as tau = 3 is less than realistic.

Mars-GRAM is an engineering-level atmospheric model widely used for diverse mission applications

- Mars-GRAM's perturbation modeling capability is commonly used, in a Monte-Carlo mode, to perform high fidelity engineering end-to-end simulations for entry, descent, and landing (EDL)[1]
- Mars-GRAM 2005 has been validated[2] against Radio Science data, and both nadir and limb data from the Thermal Emission Spectrometer (TES)[3]
- Traditional Mars-GRAM options for representing the mean atmosphere along entry corridors include:
  - TES Mapping Year 0, with user-controlled dust optical depth and Mars-GRAM data interpolated from MGCM model results driven by selected values of globally-uniform dust optical depth.
  - TES Mapping Years 1 and 2, with Mars-GRAM data coming from MGCM model results driven by observed TES dust optical depth
- From the surface to 80 km altitude, Mars-GRAM is based on NASA Ames Mars General Circulation Model (MGCM). Mars-GRAM and MGCM use surface topography from Mars Global Surveyor Mars Orbiter Laser Altimeter (MOLA), with altitudes referenced to the MOLA areoid, or constant potential surface.

MGCM results for Mars-GRAM with MapYear = 0 were from MGCM runs with fixed values of tau (0.3, 1.0, and 3.0) for the entire year at all locations. For the tau = 3 case, it has been determined that:

- Unrealistic energy absorption by uniform atmospheric dust leads to an unrealistic thermal energy balance on the polar caps
- Outcome is an inaccurate cycle of condensation/sublimation of the polar caps and, as a consequence, an inaccurate cycle of total atmospheric mass and global-average surface pressure.
- Under an assumption of unchanged temperature profile and hydrostatic equilibrium, a given percentage change in surface pressure would produce a corresponding percentage change in density at all altitudes
- Consequently, for tau = 3, the final result is an imprecise atmospheric density at all altitudes

Comparison Study Between Mars-GRAM and MGS Data

A comparison study between Mars atmospheric density estimates from Mars-GRAM and measurements by Mars Global Surveyor (MGS) has been undertaken for locations of varying latitudes, Ls, and LTST on Mars for both TES MapYear 1 and 2.

- TES MapYear 1 is from April 1999 through January 2001 - normal conditions
- TES MapYear 2 is from February 2001 through December 2002 - global dust storm

The list of locations is given in Table 1.

Ls	30	45	60	75	90	105
Latitude	62	59	58	60	64	71
LTST	2	2	2	2	2	2

Table 1. Comparison Study Site Locations

The ratios of TES Limb/Radio Science shown in Figure 1 and TES Nadir/Radio Science shown in Figure 2 illustrate how all the observed atmospheric density profiles compare to each other.

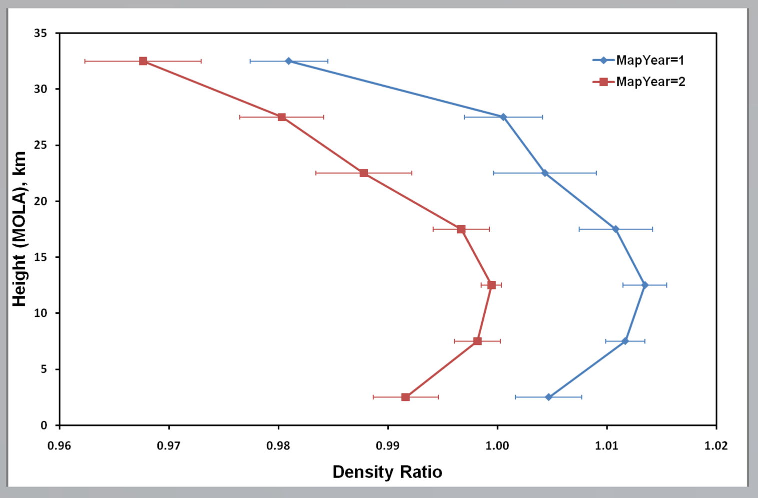

Figure 1. Atmospheric density comparison of ratios and standard deviations for TES Limb/Radio Science

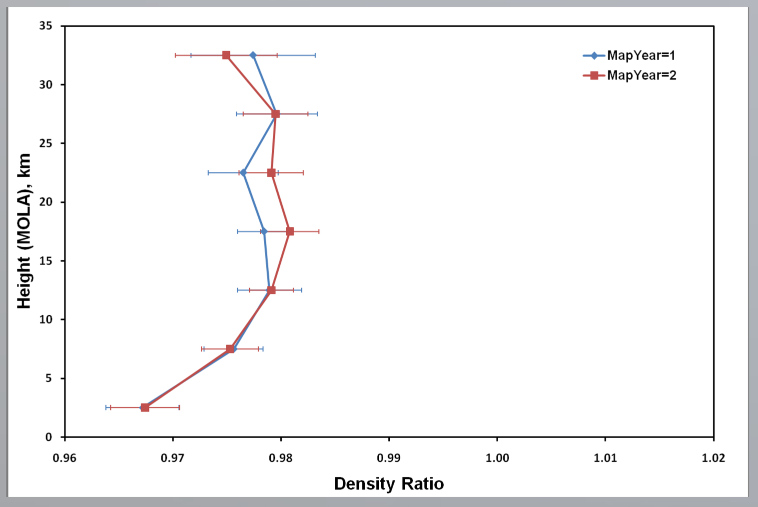

Figure 2. Atmospheric density comparison of ratios and standard deviations for TES Nadir/Radio Science

As Figures 1 and 2 show, the density ratios never varied by more than 0.04 from 1 and were always within 0.02 of each other. These results demonstrate that the observational profiles are consistent with each other and thus, validate the TES limb data.

References

[1]Striepe S. A. at al. (2002), AIAA Atmospheric Flight Mechanics Conference and Exhibit, Abstract # 2002-4412.
[2]Justus C. G. et al. (2005) "Mars Aerocapture and Validation of Mars-GRAM with TES Data", 53rd JANNAF Propulsion Meeting.
[3]Smith M. D. (2004) Icarus, 167, 148-165.

Background Image of Mars Sunset Courtesy NASA/JPL/Texas A&M/Cornell

Solving the Sensitivity Study Discrepancy for Large Optical Depths

In determining a solution to the discrepancy shown in the sensitivity study results for TES MapYear = 0 and large optical depths, the TES Limb profiles were chosen for comparison because they extend to approximately 50 km.

- TES Radio Science and TES Nadir data extend only to approximately 35 km.
- This allows the Mars-GRAM and TES Limb profiles to be compared in the upper atmosphere.

This approach to solving this problem was derived by doing comparisons between Mars-GRAM Mapyear = 0 and Mapyear = 2 output.

- Mapyear = 2 contains a large global dust storm, and so has a large number of tau = 3 values.
- Separately, it was verified that Mars-GRAM Mapyear = 2 output agreed fairly well with TES limb observations.

Conclusions

A preliminary fix has been made to Mars-GRAM by adding a density factor value that was determined for tau = 0.3, 1 and 3.

- This factor adjusts the input values of MGCM MapYear 0 pressure and density to achieve a better match of Mars-GRAM MapYear 0 with MapYears 1 and 2 MGCM output at comparable dust loading.
- This factor multiplies the tau = 3 densities and pressures by about 1.2, but leaves the tau = 0.3 and 1.0 densities and pressures almost unchanged (multipliers near 1.0).
- These factors will automatically take care of intermediate tau values between 1.0 and 3.0, since the tau-interpolated values will have effective multipliers between 1.0 and 1.2.

These updates can be found in Mars-GRAM 2005 Release 1.3.

Future Work

Currently, these density factors are fixed values for all latitudes and Ls. Presently, work is being done to derive better multipliers by including possible variation with latitude and/or Ls by comparison of Mapyear = 0 output directly against TES limb data. By comparing Mapyear = 0 output directly against TES limb data, better multipliers can be determined, including possible variation with latitude and/or Ls.

- Preliminary results for tau = 3 have shown some latitude dependence.
- The tau = 3 values occurred in the limb data only near Ls = 210, so no Ls dependence could be determined for the high density cases.
- There are significantly more cases for tau = 1 and tau = 0.3 and will hopefully provide more information into the latitude and Ls variations.