



Comparison of Mars Atmospheric Density Estimates from Models to Measurements from Mars Global Surveyor (MGS) Data

Hilary L. Justh¹ and C. G. Justus²

¹NASA, Marshall Space Flight Center, Mail Code EV44, Marshall Space Flight Center, AL 35812, Hilary.L.Justh@nasa.gov

²Stanley Associates, Marshall Space Flight Center, Mail Code EV44, Marshall Space Flight Center, AL 35812, Carl.G.Justus@nasa.gov

Background

- A recent study (Desai, 2008) has shown that the actual landing sites of Mars Pathfinder, the Mars Exploration Rovers (Spirit and Opportunity) and the Phoenix Mars Lander have been further downrange than predicted by models prior to landing
- Desai's reconstruction of their entries into the Martian atmosphere showed that the models consistently predicted higher densities than those found upon entry, descent and landing

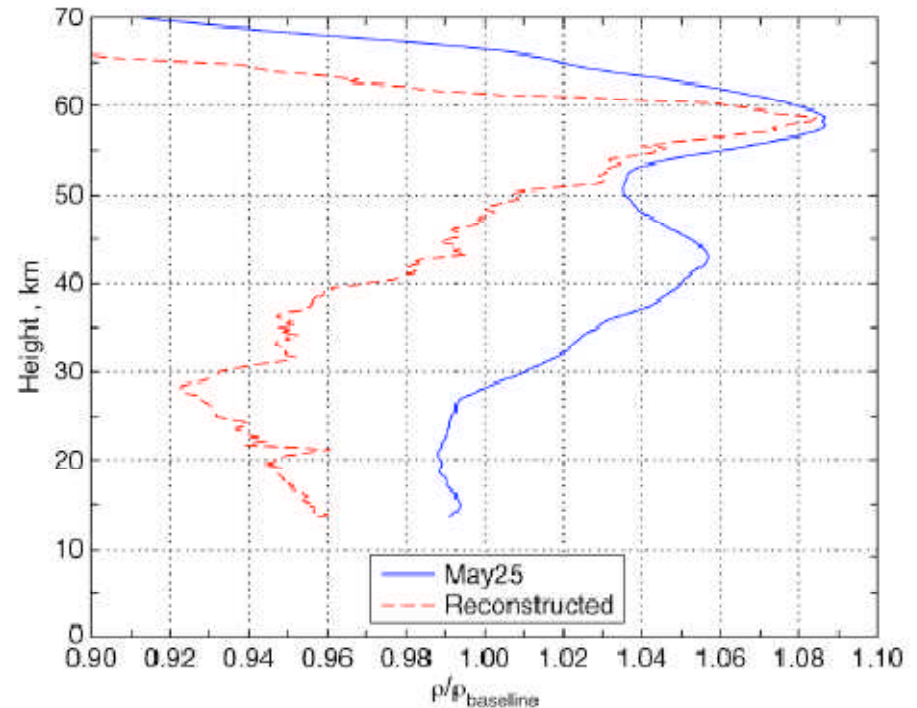


Figure 1. Reconstructed Density for the Phoenix Entry (Desai, 2008)



NEESC Proposal

- Desai's results have raised a question as to whether there is a systemic problem within Mars atmospheric models
- Proposal is to compare Mars atmospheric density estimates from Mars atmospheric models to measurements made by Mars Global Surveyor (MGS)
- Comparison study requires the completion of several tasks that would result in a greater understanding of reasons behind the discrepancy found during recent landings on Mars and possible solutions to this problem

Potential Collaborators

- David Kass (JPL)
- Scot Rafkin (SWRI, Boulder)
- Alicia Dwyer-Cianciolo (LaRC)
- Prasun Desai (LaRC)
- Dick Powell (LaRC)
- Joel Levine (LaRC)



Artist's concept of Mars Global Surveyor
(Courtesy NASA/JPL-Caltech)



Task 1

- Compare nadir and limb data from Mars Global Surveyor Thermal Emission Spectrometer (TES) and limb soundings from Radio Science (RS) Data with results from NASA Ames Mars GCM as implemented in the Mars Global Reference Atmospheric Model (Mars-GRAM 2005)
- Preliminary study indicates that density profiles from RS may be somewhat more accurate than density from TES nadir or limb data
 - RS has better vertical resolution than TES and comparable horizontal resolution
 - RS measures atmospheric refractive index versus altitude, which is more directly related to atmospheric density versus altitude than the temperature versus pressure measurements of TES nadir or limb data
- A more detailed examination is needed to better quantify the relationships among these data types and between data and the current atmospheric model

Mars Global Reference Atmospheric Model (Mars-GRAM)



- 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.
- Traditional Mars-GRAM options for representing the mean atmosphere along entry corridors include:
 - TES Mapping Years 1 and 2, with Mars-GRAM data coming from MGCM model results driven by observed TES dust optical depth
 - 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.
- 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.
- Mars-GRAM 2005 has been validated² against Radio Science data, and both nadir and limb data from the Thermal Emission Spectrometer (TES)³.

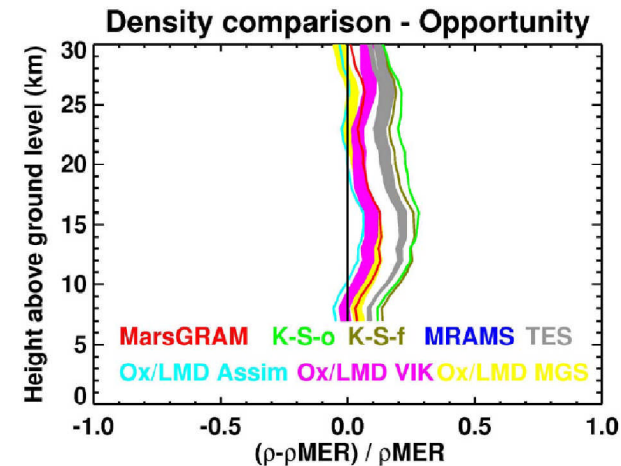
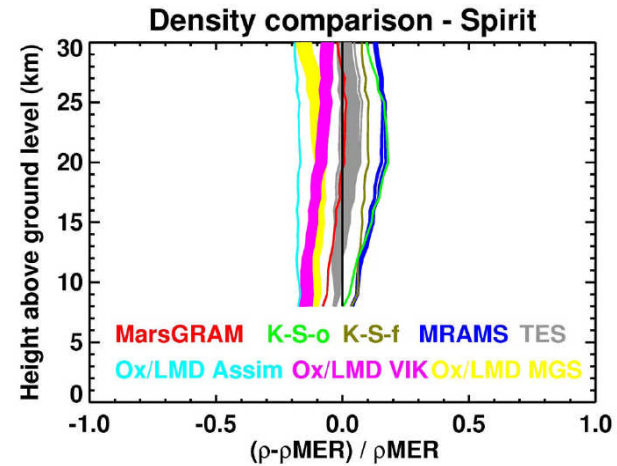


New Features of Mars-GRAM 2005

- Option to use input data sets from MGCM model runs that were designed to closely simulate conditions observed during the first two years of TES observations at Mars
 - TES Year 1 = April 1999 through January 2001
 - TES Year 2 = February 2001 through December 2002
- Option to read and use any auxiliary profile of temperature and density versus altitude. In exercising the auxiliary profile Mars-GRAM option, the values from the auxiliary profile replace data from the original MGCM databases
 - Examples of auxiliary profiles:
 - Data from TES (nadir or limb) observations
 - Mars mesoscale model output at a particular location and time
- Three Mars-GRAM parameters allow standard deviations of Mars-GRAM perturbations to be adjusted
 - rpscale can be used to scale density perturbations up or down
 - rwscale can be used to scale wind perturbations
 - wlscale can be used to adjust wavelengths (spectral range) of the perturbations

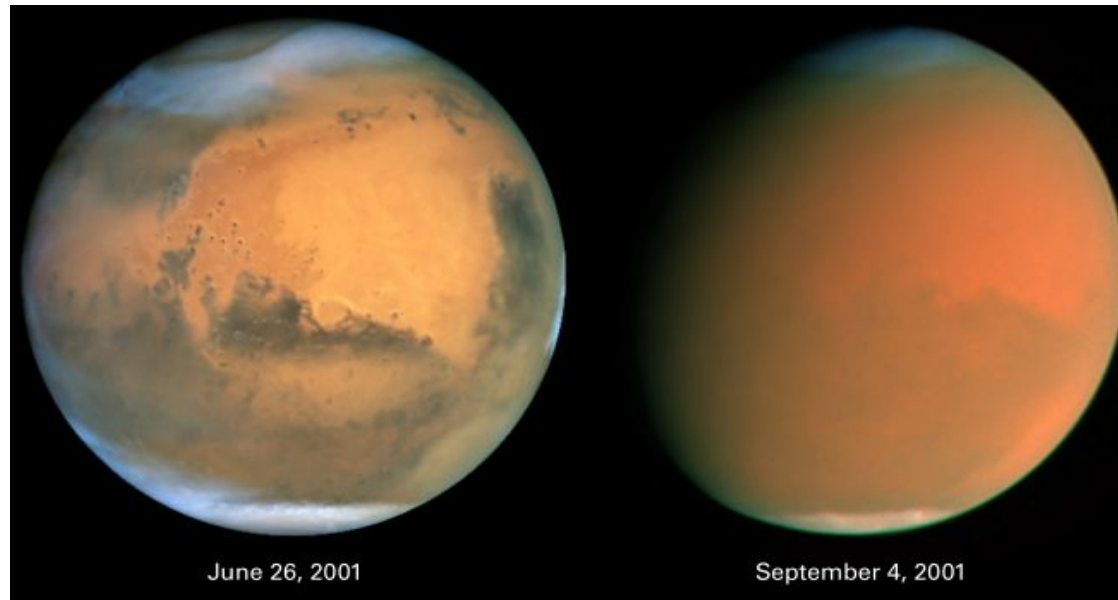
Comparison with MER EDL models

- Paul Withers at Boston University compared the MER EDL data with various models including Mars-GRAM
- Mars-GRAM averages within 5% of the MER values
- For surface-pressure corrected results, Mars-GRAM is one of two models that averages a ratio of 1.0 to the MER data, the other is MGCM (TES dust)



Task 2

- Compare measured and model densities for TES year 1 and 2
 - TES year 1 no global dust storm
 - TES year 2 intense, global-scale dust storm for part of the year.



Global Dust Storms on Mars (Courtesy NASA/JPL-Caltech)



Task 2 Continued

- Comparison will quantify dust storm effects on the measured density data from RS and from TES nadir and limb
- Comparison of measurements and current model treatment of dust storm effects
 - Will help validate the model, or
 - Suggest approaches for improvements in model representation of:
 - The effects of global dust storms
 - Dust effects during regional storms
 - Effects of variable dust loading during non-storm conditions (e.g. normal seasonal variations)



Task 3

- Characterize the degree of density discrepancies at high altitudes between TES limb data and current atmospheric models
- Indications are that the current Ames Mars Global Climate Model (GCM) has too little dust lofted to high altitudes
 - Result is less heating aloft and lower density aloft than consistent with TES limb data.
- Detailed comparisons would quantify the magnitude of these discrepancies and conditions under which these discrepancies occur (latitude range, seasons, etc.)

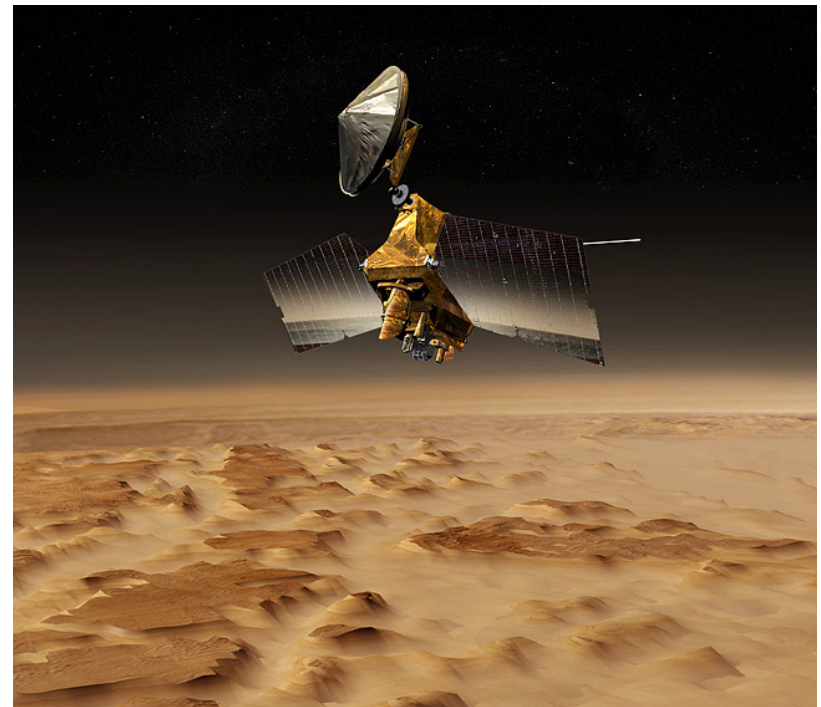


Additional Task 1

- Additional collaborative tasks could also be undertaken pending time and funding constraints
- The first of these tasks would be to obtain detailed model output from the Ames Mars GCM and Mars Regional Atmospheric Modeling System (MRAMS) mesoscale model including optical and thermal effects of higher dust amounts aloft
- Characterize the degree of improvement for model-versus-data comparisons
- Task would involve collaboration with Scot Rafkin at SouthWest Research Institute, Boulder, and additional funding for his part of the study

Additional Task 2

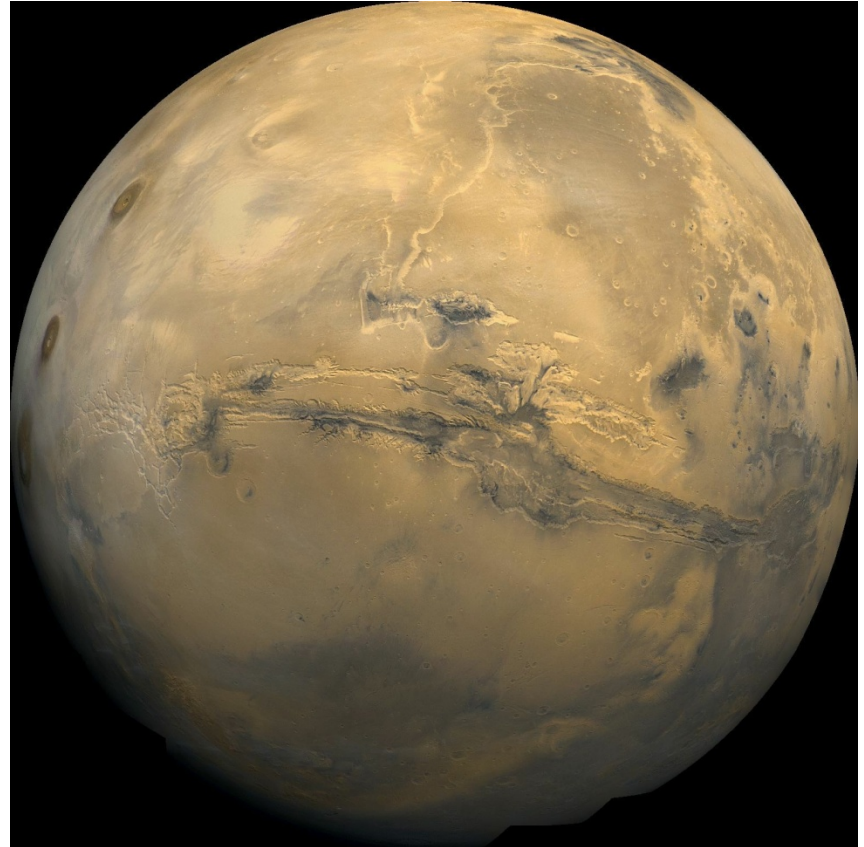
- Another additional task would be to get access to data results from the Mars Climate Sounder on Mars Reconnaissance Orbiter
 - Dust optical depth, temperature and density profiles, etc.
- Model-versus-data comparisons similar to Tasks 1-3 would be completed for this data
- Task would involve collaboration with David Kass at JPL, and additional funding for his part of that study



The Mars Reconnaissance Orbiter over the martian landscape (Courtesy NASA/JPL-Caltech)

Products of this study

- Upon completion of these tasks, it is anticipated that a NASA Technical Memo would be produced detailing the results of this study
- Changes to Mars-GRAM and other models will be implemented based on the specific findings of this study



Mars (Image Courtesy of: NASA/JPL/USGS)



References

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



Backup Slides



Characteristics of TES Nadir Database

- Three TES Mapping Years
 - Yr 1 = 4/99 – 2/01
 - Yr 2 = 2/01 – 1/03
 - Yr 3 = 1/03 – 11/04
- Global TES Nadir Data Set - Means and Standard Deviations for temperature, density, and thermal wind components :
 - 5-by-5 degree Lat-Lon bins
 - 15 degree Ls bins
 - Local Solar Time = 2 or 14 hours
 - Up to 21 Pressure Levels, automatically converted to Geometric Height by Database Query Program
 - Query program gives output at TES pressure levels or interpolated to 1-km altitude intervals
 - Output automatically formatted for Mars-GRAM input as Auxiliary Profile



Characteristics of TES Limb Database

- Data for TES Mapping Years 1 and 2 and ~1/2 of TES Mapping Year 3
- Query Program Allows User to Select Lat-Lon, and Ls Bins and Local True Solar Time
 - Input desired Lat-Lon and select Lat-Lon Bin widths
 - Input desired Ls and select Ls Bin width
 - Choose LTST = 2 or 14 hours (or both)
- Query Program outputs all individual profiles that match criteria, plus average and standard deviation of temperature and density of all output profiles
 - Up to 38 Pressure levels, automatically converted to geometric altitude
 - Output at pressure levels, or interpolated to 1-km altitude intervals
 - Output automatically formatted for Mars-GRAM input as Auxiliary Profile