MSFC-306

Mars Global Reference Atmospheric Model (Mars-GRAM 2005) Applications for Mars Science Laboratory Mission Site Selection Processes

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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 validated[2] 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
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- 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
- Two 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

Applications for Mars Science Laboratory Mission Site Selection:

- In order to assess Mars Science Laboratory (MSL) landing capabilities, three of the candidate sites that represent a wide range of atmospheric conditions were selected for initial study:
  - Terby Crater
  - Melas Chasma
  - Gale Crater
- Two mesoscale models were run for the expected MSL landing season and time of day.
  - Mars Regional Atmospheric Modeling System (MRAMS) of Southwest Research Institute[4]
  - Mars Mesoscale Model number 5 (MMM5) of Oregon State University[5].

Mars Science Laboratory with Power Source and Extended Arm, Artist's Concept (Courtesy NASA/JPL-Caltech)

Mars-GRAM Auxiliary Profiles

- Mars-GRAM auxiliary profiles (either vertical or along the actual entry corridor) were generated by interpolation from the mesoscale model output data.
- Table 1 shows an example Mars-GRAM auxiliary profile from MRAMS model output at the Terby landing site.
- These Mars-GRAM auxiliary profiles are then used in Mars-GRAM to provide detailed MSL entry dynamics simulations.

Table 1 – Example Mars-GRAM Auxiliary Profile – Mean Values from Terby MRAMS Simulation

Other Sources of Mars Atmospheric Data

- To assess likely uncertainty in atmospheric representation at these candidate sites, three other sources of atmospheric data were also analyzed.
  - A global Thermal Emission Spectrometer (TES) database containing averages and standard deviations of temperature, density, and thermal wind components, averaged over 5-by-5 degree latitude bins and 15 degree Ls bins, for each of three Mars years of TES nadir data
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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
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Mean Density Comparisons

- Strictly for reference purposes, density values are represented as percentage difference from MMM5 values.
- A significant bias difference of about 15% is noted between TES nadir and TES limb data, with all of the models tending to agree closer with the limb data than the nadir results.
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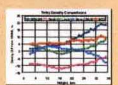

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- Wind results from MRAMS and MMM5 are more consistent than the density results between these two models (Figure 1)
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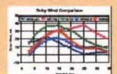

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- Mesoscale-modeled wind standard deviations are slightly larger (by about a factor of 1.1 to 1.2) than Mars-GRAM wind standard deviations.
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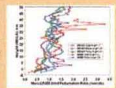

Figure 4 – Mars-GRAM Wind Perturbation Ratio (rwscale) vs Height for MRAMS, MMM5, and Mars-GRAM model output at the Gale, Melas, Terby MSL sites.

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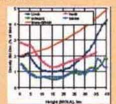

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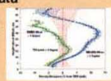

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Conclusions

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Hgt_km	Lat	LonE	Temp_K	Pres_N/m2	Dens_kg/m3	U_m/s	V_m/s
-3.66	-27.466	74.11	180.46	8.12E+02	2.23E-02	1.04	11.63
-2	-27.466	74.11	177.78	6.84E+02	2.01E-02	-0.2	10.3
0	-27.466	74.11	190.04	5.53E+02	1.52E-02	-3.24	2.81
2	-27.466	74.11	196.26	4.53E+02	1.21E-02	-2.35	8.48
4	-27.466	74.11	199.76	3.73E+02	9.76E-03	2.87	10.48
6	-27.466	74.11	199.89	3.06E+02	8.06E-03	9.61	12.16
8	-27.466	74.11	199.29	2.53E+02	6.68E-03	14.96	12.17
10	-27.466	74.11	195.73	2.08E+02	5.57E-03	18.24	12.43
12	-27.466	74.11	193.29	1.71E+02	4.63E-03	20.77	13.58
14	-27.466	74.11	191.06	1.40E+02	3.83E-03	21.44	13.9
16	-27.466	74.11	188.8	1.14E+02	3.17E-03	20.35	12.36
18	-27.466	74.11	186.7	9.32E+01	2.61E-03	17.41	8.87
20	-27.466	74.11	184.2	7.56E+01	2.15E-03	13.57	4.72
22	-27.466	74.11	181.08	6.09E+01	1.76E-03	9.81	-1.48
24	-27.466	74.11	176.57	4.89E+01	1.45E-03	8.38	-7.31
26	-27.466	74.11	171.66	3.93E+01	1.20E-03	9.94	-9.98
28	-27.466	74.11	167.03	3.13E+01	9.81E-04	9.64	-10.77
30	-27.466	74.11	162.61	2.48E+01	7.97E-04	8.01	-10.63
32	-27.466	74.11	158.4	1.94E+01	6.41E-04	6.83	-10.19
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44	-27.466	74.11	152.18	4.19E+00	1.44E-04	-6.77	7.08
46	-27.466	74.11	152.67	3.22E+00	1.10E-04	-5.43	17.36
48	-27.466	74.11	149.79	2.51E+00	8.76E-05	-6.7	19.98
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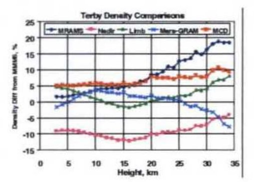

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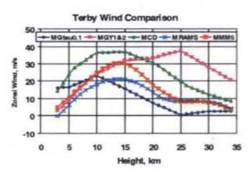

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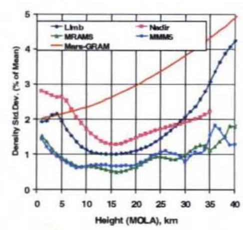

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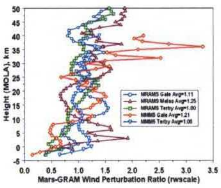

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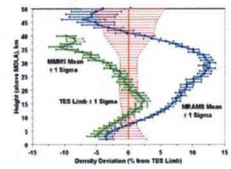

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