COMPARISONS OF MARS CLIMATE DATABASE v4.3.1. AND MARSGRAM2005 ATMOSPHERE MODELS ON EXOMARS 2016 LANDING SITE

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I Introduction:

The ExoMars program is currently undergoing its B2X2 phase with Thales Alenia Space Italia as prime contractor. It foresees two missions for the 2016 and 2018 launch opportunities to Mars.
The 2016 missions is led by ESA and consists of a Tracing Gas Orbiter that will carry the Entry, Descent and Landing Demonstrator Module (EDM) in its entry trajectory to a previously identified landing site on Mars.

The identified landing site is placed in the Meridiani planum (ellipse centered in 6.1W, 1.9 S) and the current interplanetary trajectory will deliver the EDM to encounter the Mars atmosphere at a solar longitude of 244° in the early afternoon hours (13.30-15.30).

Since the performance of an Entry, Descent and Landing system is driven by the encountered atmospheric conditions , the EXM EDM performance analysis is based on the Mars Climate Database (MCD).

In the frame of the EXM project CNES is supporting ESA by performing the comparisons between MCD and MarsGRAM 2005 and the results are presented hereafter.

II Comparisons strategy:

The same sets of profiles have been computed even if the 2 models (MCD and MarsGRAM) do not use the same kind of input parameters. In MCD, the date is defined by the reference Local solar Time (LT) i.e. 14:00 and the reference solar longitude (LS) i.e. 244°. The corresponding date and time in MarsGram simulation is: 4th of September 2018, 23h36min, UTC, Mars Event time.

For the atmosphere models, 3 kind of atmosphere scenarii have been selected in MCD: the Cold case (tau=0.1), The MY24 average case and the Dust Storm average case. These cases represent extreme atmospheric conditions. For each of these cases, nominal scenarios have been selected, i.e. no perturbation has been taken into account.
The guessed equivalent input conditions for the MarsGRAM model have been selected:
- The MCD cold case is compared to a MarsGRAM model with an optical depth (Tau) equal to 0.1,
- The MCD MY24 average case is compared to 2 cases: MarsGram TES1 (corresponding to the same Martian Year 24), and TES2 (corresponding to the Martian Year 25) cases in order to check some variability on a nominal case
- The MCD Dust Storm average case (Tau = 4) is compared to the Tau=3 to 5 MarsGram case.

In this last case, the main parameters tuning the dust atmosphere used in the model data input file are:
- Dustnu = 0.003 (Parameter for vertical distribution of dust density (Haberle et al., J. Geophys. Res., 104, 8957, 1999)),
- Dustdiam = 3.6 (Dust particle diameter (micrometers, assumed monodisperse)),
- Dustdens = 3000 (Dust particle density (kg/m**3)).

Tests have been performed with different Dustdens and Dustdiam parameters but no effect on the results has been noted.

The Tau reference definition is thought to be slightly different from MCD to MarsGRAM and the extreme value of Tau in MarsGRAM is not greater than 3 (greater values give the same results).
The profiles are calculated in two parts, first from ground (about -1.43 km below 0 Mola reference) to 25 km of altitude by step of 20 m, the second from 25 km to 125 km of altitude by step of 250 m.
A set of six output parameters is compared at every altitude step:
- Atmosphere density (in kg/m3),
- Atmosphere pressure (in Pa),
- Temperature (in K),
- Zonal wind (in m/s),
- Meridian Wind (in m/s),
- Dust Mass Mixing Ratio.

III Results:

III.1 Atmosphere density

The following plots show the different density profiles according to the altitude for the different cases (figure 1), and the differences following the cases between MCD and equivalent MarsGram cases (figures 2 and 3). As the differences in average and cold conditions are limited to less than 5 to 10% (from ground to 25 km), the differences are about 20% in Dust Storm average case up to 25 km and even larger at higher altitudes (figure 4). The reference surface pressure at ground level is assumed to be different in the models for tau=3 and may explain some of the differences in this atmosphere scenario. Inaccurate Dust input parameters in MarsGRAM model can also be a reason for these discrepancies.

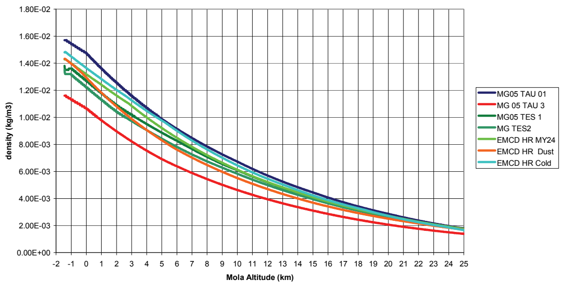

Figure 1:
Density vs altitude (from ground to 25 km) for the different scenarios

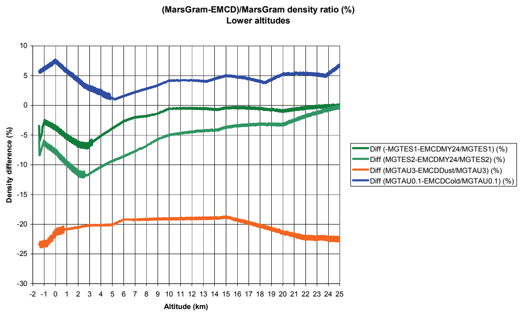

Figure 2:
Difference between models density at low altitudes

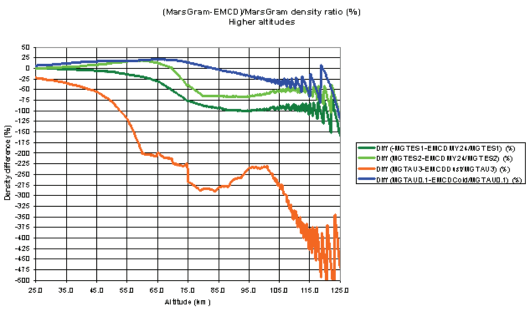

Figure 3:
Difference between models density at high altitudes

MonteCarlo simulations on 1000 MCD profiles with small and large scale perturbations have been performed for dust storm scenario. MCD 3 sigma-to-average density ratio can be compared to nominal Tau=3 MarsGram05 density. It does appear (figure 4) that the nominal MarsGram density is in the same range than the 3 sigma MCD results.

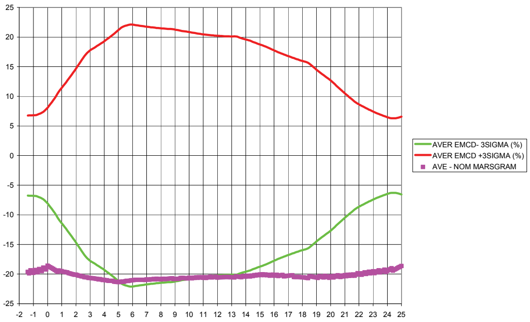

Figure 4:
Dust Storm scenario: Density MCD MonteCarlo dispersion 3 sigma-to-Average value ratio and Nominal MarsGram to MCD Average value ratio

III.2 Temperature profiles

As expected, temperature profiles remain quite close in both models for cold and MY24 average scenarios (Figures 5 and 6, tables 1 and 2). The differences in temperatures are lower than 20K in most of the cases up to 100 km of altitude. For Dust Storm cases, the differences tend to increase with altitude, reaching 80K at 55 km.

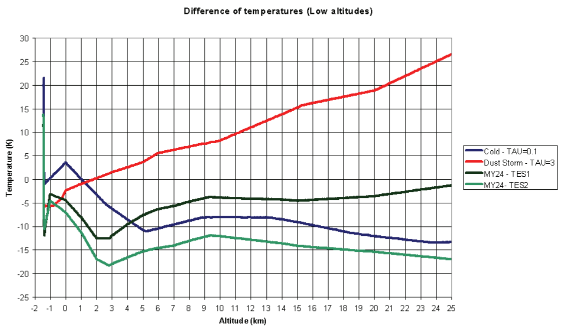

Figure 5:
Temperature differences between models at lower altitudes

Lower altitudes	Cold - TAU=0.1	Dust Storm - TAU=3	MY24 - TES1	MY24- TES2
Average Temp difference	-8.5	10.9	-5.1	-14.0
Max Temp difference	21.4	26.7	11.7	13.9

Table 1:
Average and Max temperature differences between models at lower altitude

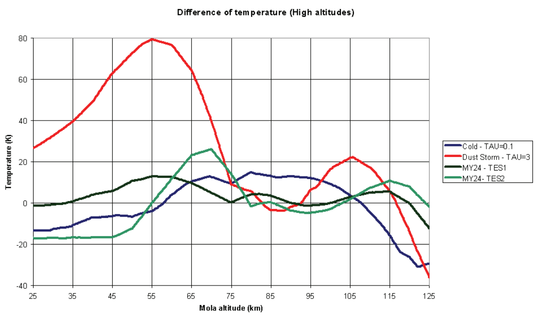

Figure 6:
Temperature differences between models at higher altitudes.

Higher altitudes	Cold - TAU=0.1	Dust Storm - TAU=3	MY24 - TES1	MY24- TES2
Average Temp difference	-0.8	28.7	3.7	0.1
Max Temp difference	15.1	79.5	13.0	26.2

Table 2:
Average and Max temperature differences between models at higher altitude

III.3 Wind profiles

Here again, as presented in figure 7, differences between models remain limited for Cold and MY24 average models and far larger for Dust Storm scenarios. The variability of the winds profile is anyway higher than the ones of density or temperatures. Wind variations would have an impact on landing accuracy mainly but not on EDLS sizing, except at very low altitude.

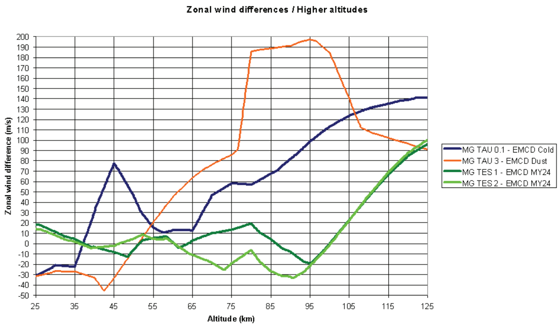

Figure 7:
Zonal winds differences between models at higher altitudes.

III.4 Dust Mass Mixing Ratio

Table 3 gives the Dust Mass Mixing Ratios at ground level for the different scenarios. It can be seen that the values are quite different for the different cases and models. A search of coherency between the models calculation of this value should be performed .

Scenario	MassMixing Ratio (%) at -1.44 Mola altitude
MG TAU 01	2.56E-06
EMCD HR Cold	8.80E-07
MG TAU 3	1.06E-04
EMCD HR Dust	4.14E-05
MG TES 1	2.14E-05
MG TES 2	4.75E-05
EMCD HR MY24	5.44E-06

Table 3: Dust Mass mixing ratio at ground level

IV Planned tasks:

The new MarsGram2010 model is now available and could be added to this comparison activity to see if the discrepancies that have been pointed out between MCD 4.3.1 and MarsGram2005 remain in the same range or not.

Entry and Descent trajectories simulations taking into account a realistic aerodynamic probe shape and the atmosphere models with dispersions could give a good perspective of the impact of atmosphere model predictions and dispersions on EDL trajectories.

V Conclusion

Comparisons between the two atmosphere models show that the results of both are coherent in Cold and Average cases but some notable difference has been identified for Dust Storm cases and shall be clarified.

Simulations using last MarsGram 2010 model shall be included in the next comparison effort..

This study has been performed in CNES orbital maneuvers department upon request of ESA and in collaboration with LMD and TAS-I