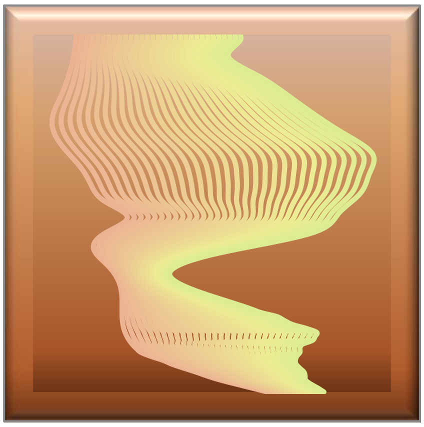


Mars atmosphere

An Orbiter add-on for the atmospheric model of Mars

1. Introduction

This first version of *MarsCristiapiAtm* realistically reproduce the atmospheric model of Mars from an altitude of 200 km to the ground level, based on samples collected by the Viking Landers and on radio occultation data obtained from Mars Global Surveyor and Mars Reconnaissance Orbiter.

From that huge data archive (consisting of about 1.5 million points), only 18 files have been selected to realistically simulate the pressure, temperature and density profiles.

The particularity of this add-on is to simulate the diurnal variation of the parameters as a function of the Sun elevation above the local horizon of a point on the Mars surface. For each parameter, two limiting profiles are defined: one profile is used when the Sun elevation is -90°, while the other profile is used when the Sun elevation is 90°; in-between, a linear transition is used to calculate the profile for the current Sun elevation. Missions to/from Mars will no longer be flown always with the same atmospheric conditions.

2. Important notices

2.1 Runtime libraries

MarsCristiapiAtm.dll needs the files msvcp110.dll and msvcr110.dll; you may already have them installed, in this case, the files included in this add-on can be deleted.

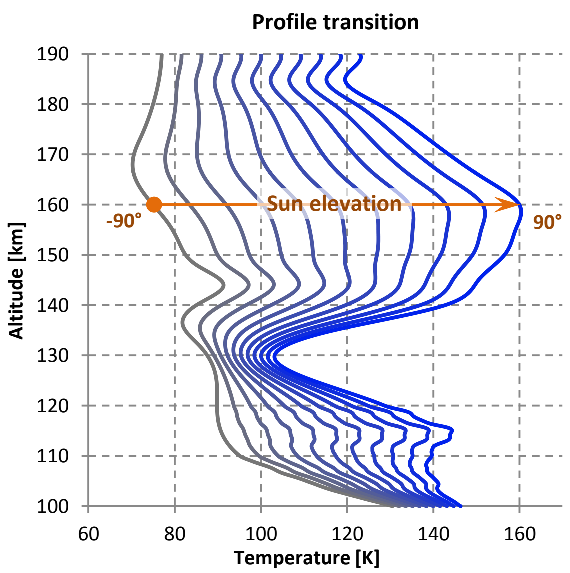
You can also download and install the "Visual C++ Redistributable Packages for Visual Studio 2012" from this link: [http://www.microsoft.com/en-us/download/details.aspx?id=30679.](http://www.microsoft.com/en-us/download/details.aspx?id=30679)

2.2 Atmosphere updating

Since Orbiter doesn't update the atmospheric parameters when a ship is at rest, the surface MFD will show a "static" atmosphere, while this add-on continuously updates the pressure, temperature and density as Mars rotate. If you want to see the updated values, but you don't want to move the ship, a light touch on the RCS thrusters should suffice.

2.3 Dynamic atmosphere

Since Orbiter only considers an atmosphere that changes with the position, but not with the time, when an add-on requests to Orbiter the atmospheric state for a given location (calling, for example, the function oapiGetPlanetAtmParams) this add-on will correctly return the state for that location but always for the current simulation time because the request that comes from Orbiter doesn't include the time (but only the position). This is an Orbiter limitation because this add-on can calculate the atmospheric state for any given time and for any location.



The graph shows how the temperature changes with the Sun elevation (and hence with the time).

Here are plotted only 11 temperature profiles just for the sake of clarity, but a virtually infinite number of profiles are used during the simulation, in other words, the transition doesn't happen in discrete steps (well, the resolution of the steps is the resolution of the double precision floating point numbers: 2^{-53} or 10^{-16}).

The same transition also happens for the pressure and the density.

3. Installation

Unzip the archive to the Orbiter root folder maintaining the folder structure. The file "MarsCristiapiAtm.dll" will be unpacked in "<Orbiter_root>\Modules\Celbody\Mars\atmosphere" along with the small data file "MarsCristiapiAtm.dat" (**warning**: the name of the two files must not be changed).

If the default Mars.dll is used (as probably is the case for most users), this atmospheric module can be activated via the Launchpad dialog: "Extra → Celestial body configuration → Atmosphere Configuration".

Some celestial body add-ons may require the line: `Module_Atm = MarsCristiapiAtm` in the file "<Orbiter_root>\Config\Mars.cfg" (*CeBoMo* add-on needs that line).

This add-on ("MarsCristiapiAtm.dll") assigns the value to the following atmospheric constants: ground level temperature, pressure and density, gas constant, ratio of specific heats and atmosphere altitude limit. The values assigned by this add-on can be overridden by the lines: `AtmAltLimit`, `AtmGasConstant` and `AtmGamma` written in "Mars.cfg" file which takes precedence over the DLL, while the lines: `AtmPressure0` and `AtmDensity0` are ignored by Orbiter (when this add-on is used).

This add-on assigns `AtmAltLimit` = 200000, and, according to:
http://pds-atmospheres.nmsu.edu/education_and_outreach/encyclopedia/gas_constant.htm
it assigns `AtmGasConstant` = 188.92 and `AtmGamma` = 1.2941.

4. Atmospheric profiles

The graphs in this section show the minimum, the mean (blue plot) and the maximum values for the atmospheric parameters. The orange profiles are reported in the tables with the subscript 1 (like P_1 for the pressure), while the gray profiles have the subscript 2.

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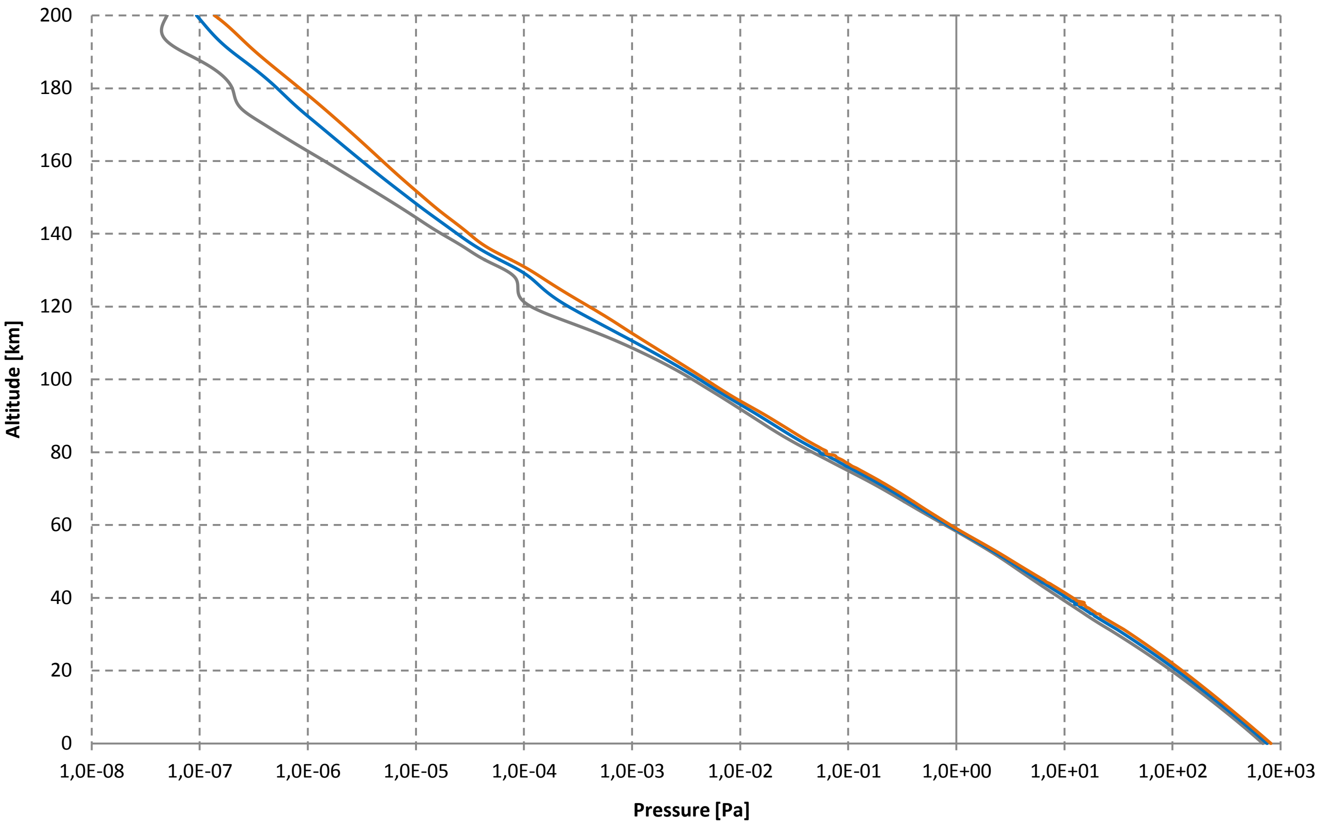
4.1 Pressure



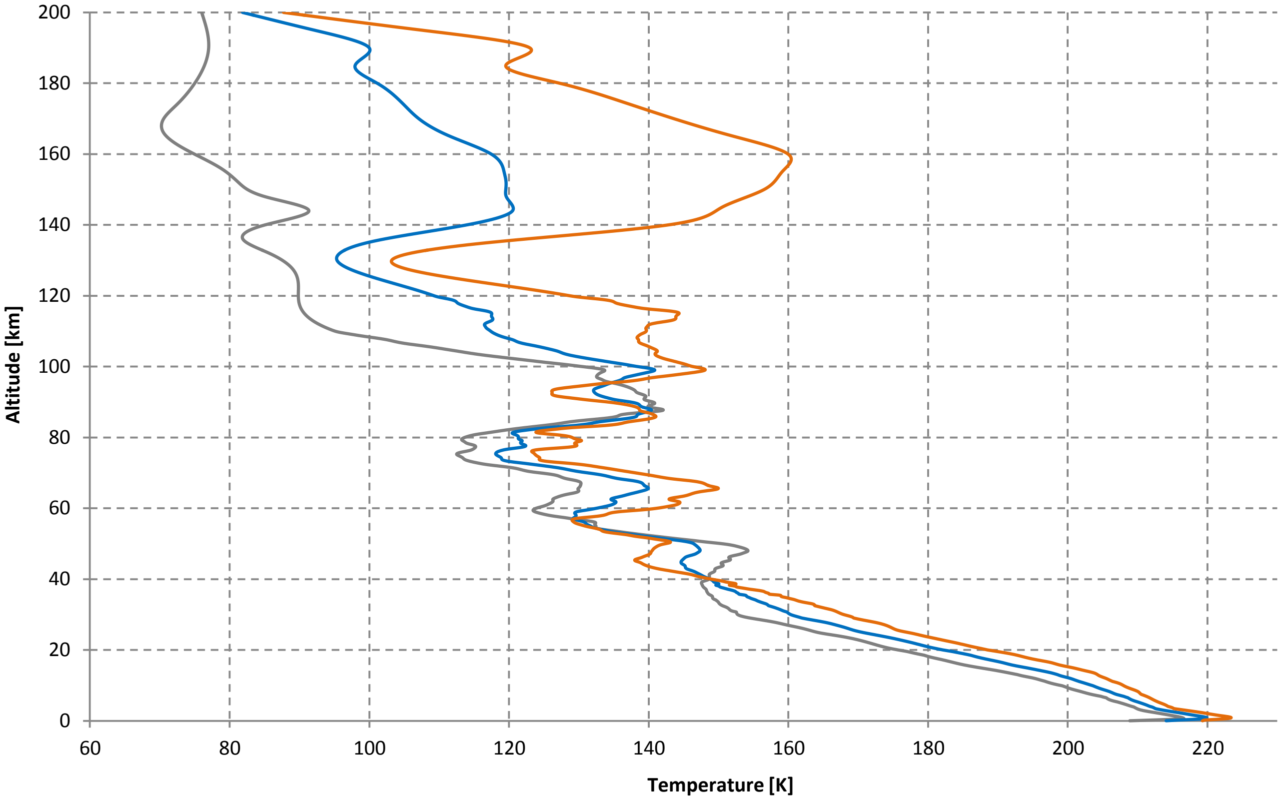
H [km]	P_1 [Pa]	P_2 [Pa]
0	813	686
2	680	575
4	567	480
6	472	399
8	393	330
10	326	272
12	270	224
14	223	183
16	183	149
18	150	121
20	123	97.6
22	99.8	78.4
24	80.7	62.6
26	64.9	49.6
28	51.9	39.1
30	41.3	30.6
32	32.4	23.8
34	24.8	18.5
36	19.3	14.6
38	15.5	11.5
40	12	9.11
42	9.34	7.2
44	7.22	5.71
46	5.58	4.53
48	4.31	3.61
50	3.34	2.88

H [km]	P_1 [Pa]	P_2 [Pa]
52	2.59	2.27
54	1.99	1.76
56	1.51	1.36
58	1.15	1.04
60	0.884	0.787
62	0.688	0.598
64	0.538	0.456
66	0.423	0.35
68	0.332	0.269
70	0.259	0.205
72	0.199	0.155
74	0.15	0.115
76	0.112	0.0849
78	0.086	0.0631
80	0.0626	0.0467
82	0.0492	0.0349
84	0.0376	0.0264
86	0.0291	0.0204
88	0.0227	0.016
90	0.0175	0.0126
92	0.0134	0.00987
94	0.0101	0.00773
96	0.00779	0.00603
98	0.00608	0.00468
100	0.00479	0.00363
102	0.00377	0.00278

H [km]	P_1 [Pa]	P_2 [Pa]
104	0.00294	0.00209
106	0.0023	0.00154
108	0.00179	0.00112
110	0.00139	0.000794
112	0.00109	0.00055
114	0.000853	0.00037
116	0.00067	0.000245
118	0.000521	0.000163
120	0.000402	0.000117
122	0.000309	9.48e-5
124	0.000238	8.84e-5
126	0.000185	8.76e-5
128	0.000146	8.27e-5
130	0.000114	6.75e-5
132	8.64e-5	4.95e-5
134	6.37e-5	3.71e-5
136	4.76e-5	2.91e-5
138	3.76e-5	2.26e-5
140	3.11e-5	1.73e-5
142	2.56e-5	1.34e-5
144	2.09e-5	1.06e-5
146	1.71e-5	8.36e-6
148	1.41e-5	6.55e-6
150	1.18e-5	5.11e-6
152	9.86e-6	3.97e-6
154	8.24e-6	3.07e-6

H [km]	P_1 [Pa]	P_2 [Pa]
156	6.91e-6	2.38e-6
158	5.81e-6	1.85e-6
160	4.91e-6	1.43e-6
162	4.15e-6	1.1e-6
164	3.5e-6	8.46e-7
166	2.96e-6	6.55e-7
168	2.49e-6	5.1e-7
170	2.09e-6	3.98e-7
172	1.75e-6	3.11e-7
174	1.47e-6	2.51e-7
176	1.22e-6	2.21e-7
178	1.02e-6	2.09e-7
180	8.42e-7	2e-7
182	6.96e-7	1.81e-7
184	5.75e-7	1.55e-7
186	4.76e-7	1.24e-7
188	3.94e-7	9.44e-8
190	3.29e-7	7e-8
192	2.77e-7	5.43e-8
194	2.35e-7	4.64e-8
196	2e-7	4.43e-8
198	1.68e-7	4.62e-8
200	1.37e-7	5e-8

4.2 Temperature



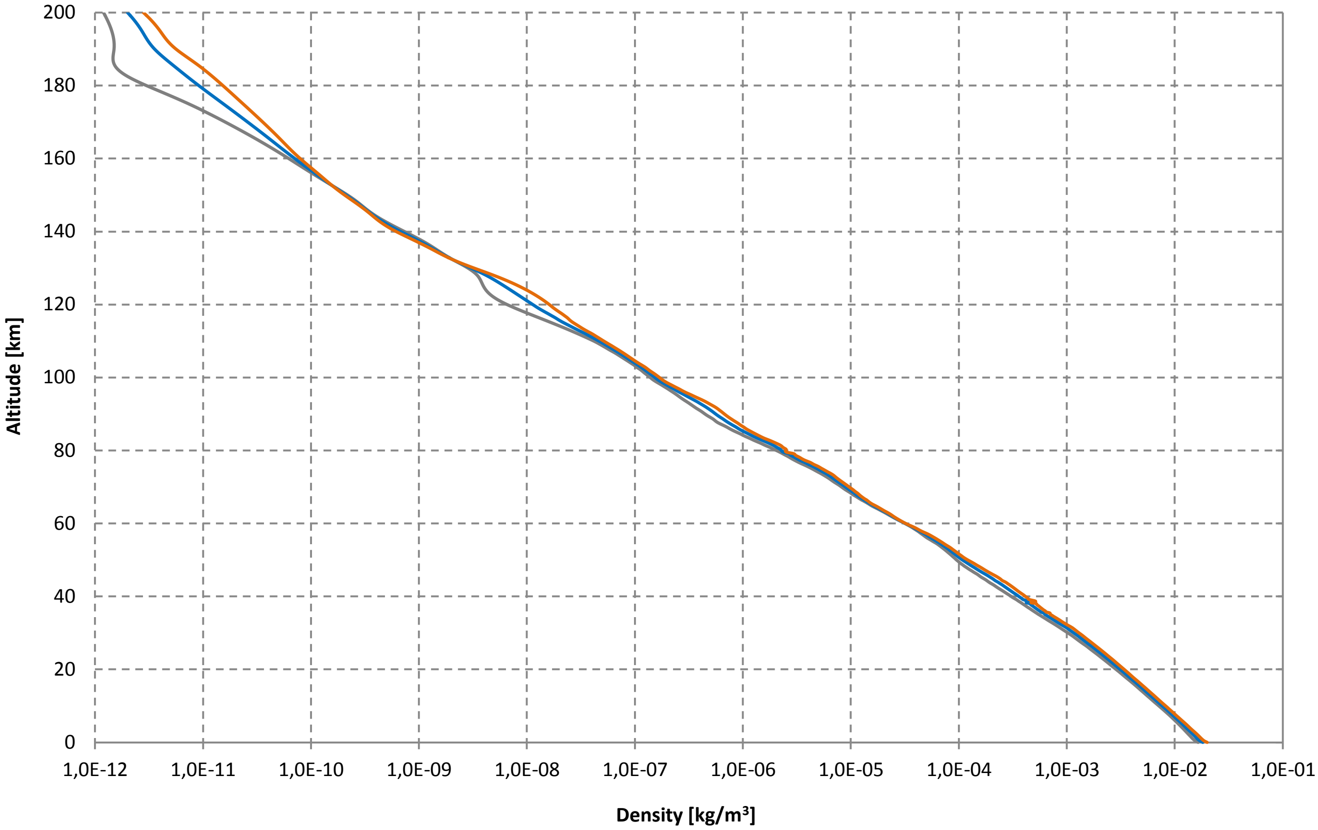
H [km]	T_1 [K]	T_2 [K]
0	219.3	208.9
2	220.1	213.4
4	214.5	209.3
6	212.2	205.9
8	210.2	202.3
10	207.9	198.9
12	205.4	195.2
14	202.8	190.3
16	198.4	184.6
18	193.8	180.3
20	188.5	175.7
22	184.0	171.6
24	179.2	167.0
26	175.1	162.2
28	171.9	157.6
30	167.9	152.7
32	164.8	151.2
34	161.2	149.7
36	157.1	148.5
38	152.4	147.8
40	149.0	148.6
42	144.1	149.3
44	139.4	150.6
46	138.8	151.5
48	140.5	154.2
50	142.4	150.5

H [km]	T_1 [K]	T_2 [K]
52	138.4	141.4
54	133.0	133.5
56	129.4	132.4
58	133.5	125.8
60	141.2	123.9
62	144.0	126.3
64	146.0	128.5
66	149.5	130.1
68	144.8	129.1
70	138.1	124.4
72	131.7	118.2
74	124.4	113.5
76	123.3	113.6
78	129.6	114.6
80	129.0	113.7
82	125.1	119.2
84	136.2	127.4
86	141.0	135.5
88	138.6	141.8
90	134.2	140.6
92	126.3	139.3
94	127.9	137.3
96	137.7	133.6
98	145.1	132.9
100	146.4	130.5
102	142.6	121.7

H [km]	T_1 [K]	T_2 [K]
104	141.1	113.8
106	139.6	107.1
108	138.4	101.2
110	139.7	95.1
112	140.3	92.7
114	143.9	91.2
116	141.5	90.3
118	135.3	89.9
120	128.7	89.8
122	122.4	89.9
124	115.4	89.8
126	109.1	89.5
128	104.6	88.8
130	103.2	87.6
132	105.9	85.7
134	112.4	83.4
136	122.3	81.9
138	133.5	82.4
140	142.8	85.1
142	147.6	89.1
144	149.7	91.3
146	151.6	89.1
148	154.2	85.1
150	156.5	82.6
152	157.9	81.3
154	158.7	80.1

H [km]	T_1 [K]	T_2 [K]
156	159.6	78.8
158	160.4	77.0
160	160.0	75.0
162	157.7	73.1
164	154.1	71.5
166	150.4	70.6
168	146.9	70.2
170	143.6	70.6
172	140.5	71.4
174	137.4	72.4
176	134.3	73.4
178	131.1	74.3
180	127.3	75.0
182	123.0	75.6
184	120.0	76.2
186	120.1	76.6
188	122.4	76.9
190	123.0	77.0
192	118.9	77.0
194	111.6	76.9
196	103.4	76.6
198	95.5	76.3
200	87.7	76.0

4.3 Density



H [km]	ρ_1 [K]	ρ_2 [K]
0	0.02	0.0164
2	0.0164	0.0136
4	0.0138	0.0117
6	0.0116	0.01
8	0.00979	0.00851
10	0.00823	0.00713
12	0.0069	0.00596
14	0.00579	0.00499
16	0.00485	0.00417
18	0.00405	0.00345
20	0.0034	0.00286
22	0.00283	0.00236
24	0.00235	0.00194
26	0.00194	0.00158
28	0.00159	0.00128
30	0.0013	0.00103
32	0.00104	0.000807
34	0.000808	0.000628
36	0.000632	0.000491
38	0.000522	0.000389
40	0.000414	0.000306
42	0.000334	0.00024
44	0.000267	0.000188
46	0.000207	0.00015
48	0.000159	0.000117
50	0.000121	9.53e-5

H [km]	ρ_1 [K]	ρ_2 [K]
52	9.64e-5	7.99e-5
54	7.7e-5	6.58e-5
56	6.02e-5	5.11e-5
58	4.43e-5	4.12e-5
60	3.22e-5	3.17e-5
62	2.47e-5	2.36e-5
64	1.9e-5	1.77e-5
66	1.46e-5	1.34e-5
68	1.18e-5	1.03e-5
70	9.64e-6	8.21e-6
72	7.77e-6	6.52e-6
74	6.23e-6	5.05e-6
76	4.67e-6	3.73e-6
78	3.4e-6	2.74e-6
80	2.5e-6	2.05e-6
82	2.03e-6	1.46e-6
84	1.42e-6	1.03e-6
86	1.06e-6	7.52e-7
88	8.42e-7	5.62e-7
90	6.74e-7	4.46e-7
92	5.46e-7	3.53e-7
94	4.09e-7	2.8e-7
96	2.91e-7	2.24e-7
98	2.16e-7	1.76e-7
100	1.69e-7	1.39e-7
102	1.36e-7	1.14e-7

H [km]	ρ_1 [K]	ρ_2 [K]
104	1.07e-7	9.15e-8
106	8.48e-8	7.17e-8
108	6.65e-8	5.5e-8
110	5.14e-8	4.16e-8
112	4e-8	2.96e-8
114	3.05e-8	2.05e-8
116	2.44e-8	1.39e-8
118	1.98e-8	9.4e-9
120	1.61e-8	6.55e-9
122	1.29e-8	4.94e-9
124	9.9e-9	4.17e-9
126	7.19e-9	3.81e-9
128	4.93e-9	3.47e-9
130	3.23e-9	2.84e-9
132	2.17e-9	2.15e-9
134	1.56e-9	1.65e-9
136	1.16e-9	1.3e-9
138	8.46e-10	9.94e-10
140	6.16e-10	7.35e-10
142	4.71e-10	5.43e-10
144	3.83e-10	4.13e-10
146	3.17e-10	3.3e-10
148	2.56e-10	2.72e-10
150	2.05e-10	2.18e-10
152	1.67e-10	1.7e-10
154	1.38e-10	1.31e-10

H [km]	ρ_1 [K]	ρ_2 [K]
156	1.15e-10	1.02e-10
158	9.54e-11	7.96e-11
160	7.95e-11	6.23e-11
162	6.72e-11	4.85e-11
164	5.75e-11	3.74e-11
166	4.94e-11	2.85e-11
168	4.21e-11	2.15e-11
170	3.58e-11	1.61e-11
172	3.03e-11	1.19e-11
174	2.56e-11	8.7e-12
176	2.16e-11	6.2e-12
178	1.82e-11	4.32e-12
180	1.53e-11	3e-12
182	1.28e-11	2.16e-12
184	1.06e-11	1.69e-12
186	8.65e-12	1.5e-12
188	6.95e-12	1.47e-12
190	5.63e-12	1.5e-12
192	4.78e-12	1.5e-12
194	4.23e-12	1.46e-12
196	3.77e-12	1.39e-12
198	3.29e-12	1.3e-12
200	2.81e-12	1.2e-12

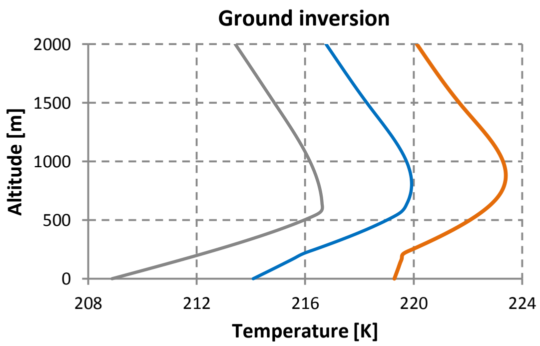
5. Accuracy

The uncertainty on the parameters derived from radio occultation data (which come from Mars Global Surveyor and Mars Reconnaissance Orbiter radio science experiments) is very big for altitudes in the range 25÷40 km (about ±10 K for h= 30 km); see, for example, the graph at this link:
http://atmos.nmsu.edu/data_and_services/atmospheres_data/MARS/tp.html

Above the upper limit of the radio science experiments (about 40 km), the primary data source is the accelerometer of the Viking Landers. Above 120 km, this add-on uses the Upper-Atmosphere Mass Spectrometer data obtained from the Viking Landers and reported in this paper (table 5):
http://atmos.nmsu.edu/data_and_services/atmospheres_data/MARS/viking/logs/Seiff%20JGR%201977.pdf

All that said, it should be noted that the aim of this add-on is to create a realistic dynamic atmosphere for Mars based on real data, but without the intent of reproducing a particular profile present at a given time or location on Mars.

In addition to the diurnal variation of the atmospheric parameters, also the surface temperature inversion is simulated realistically.



The graph shows the low-level inversion modeled by this add-on. The profiles shown here are used for the Sun elevations -90°, 0 and 90° from left to right.

Only three profiles are showed, but as explained in section 1, this add-on calculates a virtually infinite number of profiles because the atmospheric state is updated at every simulation step.

6. Acknowledgment

Special thanks to “*Keithth G*” for the code to calculate the Sun elevation.