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FINAL REPORT

MARTIAN METEOROLOGY: DETERMINATION OF LARGE SCALE WEATHER PATTERNS FROM SURFACE MEASUREMENTS

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We employed numerical modelling of the martian atmosphere, and our expertise in understanding martian atmospheric processes, to better understand the coupling between lower and upper atmosphere processes.

One practical application of this work has been our involvement with the ongoing atmospheric aerobraking which the Mars Global Surveyor (MGS) spacecraft is currently undergoing at Mars. Dr. Murphy is currently a member of the Mars Global Surveyor (MGS) Aerobraking Atmospheric Advisory Group (AAG). He was asked to participate in this activity based upon his knowledge of martian atmospheric dynamical processes. Aerobraking is a process whereby a spacecraft, in an elliptical orbit, passes through the upper layers of the atmosphere (in this instance Mars). This passage through the atmosphere 'drags' upon the spacecraft, gradually reducing its orbital velocity. This has the effect, over time, of converting the elliptical orbit to a circular orbit, which is the desired mapping orbit for MGS. Carrying out aerobraking eliminates the need for carrying large amounts of fuel on the spacecraft to execute an engine burn to acheieve the desired orbit. Eliminating the mass of the fuel reduces the cost of launch.

Damage to one of MGS's solar panels shortly after launch has resulted in a less aggressive / extended in time aerobraking phase which will not end until March, 1999. Phase I extended from Sept. 1997 through March 1998. During this time period, Dr. Murphy particpated almost daily in the AAG meetings, and beginning in December 1997 lead the meeting several times per week. The leader of each of the daily AAG meetings took the results of that meeting (current state of the atmosphere, identification of any time trends or spatial patterns in upper atmosphere densities, etc.) forward to the Aerobraking Planning Group (APG) meeting, at which time the decision was made to not change MGS orbit, to lower the orbit to reach higher densities (greater 'drag'), or raise the orbit to avoid experiencing excessive, possibly damaging densities.

The numerical simulations conducted with the NASA Ames Mars General Circulation Model (GCM), in collaboration with Dr. Haberle, have been for a variety of atmospheric dust loadings and the seasonal range covered by MGS's aerobraking phase I (Sept., 1997 - March, 1998). The results from these experiments have been analyzed, in collaboration with Dr. Bridger, to provide lower boundary conditions for a Mars Thermospheric General Circulation Model (TGCM) operated by Dr. Steve Bougher at the University of Arizona. The nominal top of the Ames Mars GCM is ~100 km, with model conditions above ~90 kilometers being less reliable than those below. The anticipated elevation at which nominal aerobrakingdensitites were expected was ~120 km. Thus, the GCM does not extend to the altitude of interest for MGS aerobraking. The TGCM, on the other hand, does span the thermospheric heights (120-170 km) in which aerobraking will be occurring, but the TGCM does not extend below 70 km altitude. GCM fields at the ~70 km altitude are decomposed into time and longitude averaged quantities, as well as amplitudes of westward travelling thermal tidal variations, using software developed by Drs. Bridger and Murphy previously for other purposes (Bridger and Murphy, 1998). Some of this coupled model work has now been published (Bougher et al., 1998). Additionally, time-evolving dust storms simulated with the Ames GCM have been carried out to determine how rapidly the thermosphere responds to 'explosive' lower-atmosphere processes. It is the development of such a dust storm which was considered to be the most potentially detrimental occurrence during aerobraking. Our model results indicated that the thermosphere responds within on or two sols (martian days) to a developing dust storm. This time-scale was incorporated into the response process

As indicated above, the anticipated minimum altitude above the martian surface at which MGS was expected to be 'flown' to be within the desired atmopheric density range was ~110 km. Upon arrival at Mars it was determined that the actual 'height' for the nominal atmospheric density level was closer to 120 km. Some of this 10 km offset is apparently due to differing definitions of the planets radius used by the atmospheric scientists and flight engineers. Another factor appears to be the too-cold temperatures the models are predicting in the 80-110 km altitude range. We are currently trying to understand these results

On the evening of Nov. 26, 1997 (Thanksgiving eve), a regional scale dust storm developed on Mars. Its development was detected by MGS instruments remotely viewing the planet, as well as direct determination of atmospheric densities aloft, which rose alarmingly in response to the developing storm below. Evasive action was taken by raising the spacecraft's orbit by ~10 km for one week's time until the situation calmed down. We have employed our dust transport capability in the Ames Mars GCM to simulate this storm and understand the processes which allowed this small scale storm to have such a profound effect at large scales at aerobraking altitudes. Modelled changes in atmospheric densioty at 120 km show increase of fifty percent or more in one or two martian days, but even this increase is less than the factor of two change observed.

Several workshops have been held at the Jet Propulsion Lab over the past two years to prepare for the beginning of aerobraking and asses our efforts at the end of Phase I. Dr. Murphy has participated in all such meetings, assisting in their planning, providing updates on the Ames modelling efforts, and collaborating with Dr. Bougher on their coupling of the GCM-TGCM.

In preparation for Phase II of aerobraking, scheduled to begin in mid-September 1998 and conclude in March of 1999, the Ames GCM has been run for the seasons of interest (martian northern hemisphere spring and summer) and anticipated (minimal) atmospheric dust load. These results, similar to those from Phase I, will be used to broadly characterize the states of the lower and upper atmosphere, and to provide lower boundary conditions for the TGCM. Additionally, patterns of of observed aerobraking-altitude densities fixed in location will be studied to determine if they persist throughout the year (not anticipated) and if they are due to topography (mountains and valleys), as has been assumed thus far.

One planned activity which did not work out during this effort was the use of Mars Pathfinder Lander data in support of MGS activities. We had hoped to use the Pathfinder surface meteorology data, and images of the sky, to determine weather conditions and relate them to the MGS aerobraking observations aloft. Unfortunately, Mars Pathfinder ceased functioning on Sept. 27, 1998, only two weeks after MGS arrived in orbit, and only several orbits afetr aerobraking began (when MGS had an orbital period of 45 hours; its orbit period at the end of Phase I is 11.5 hours).

REFERENCES

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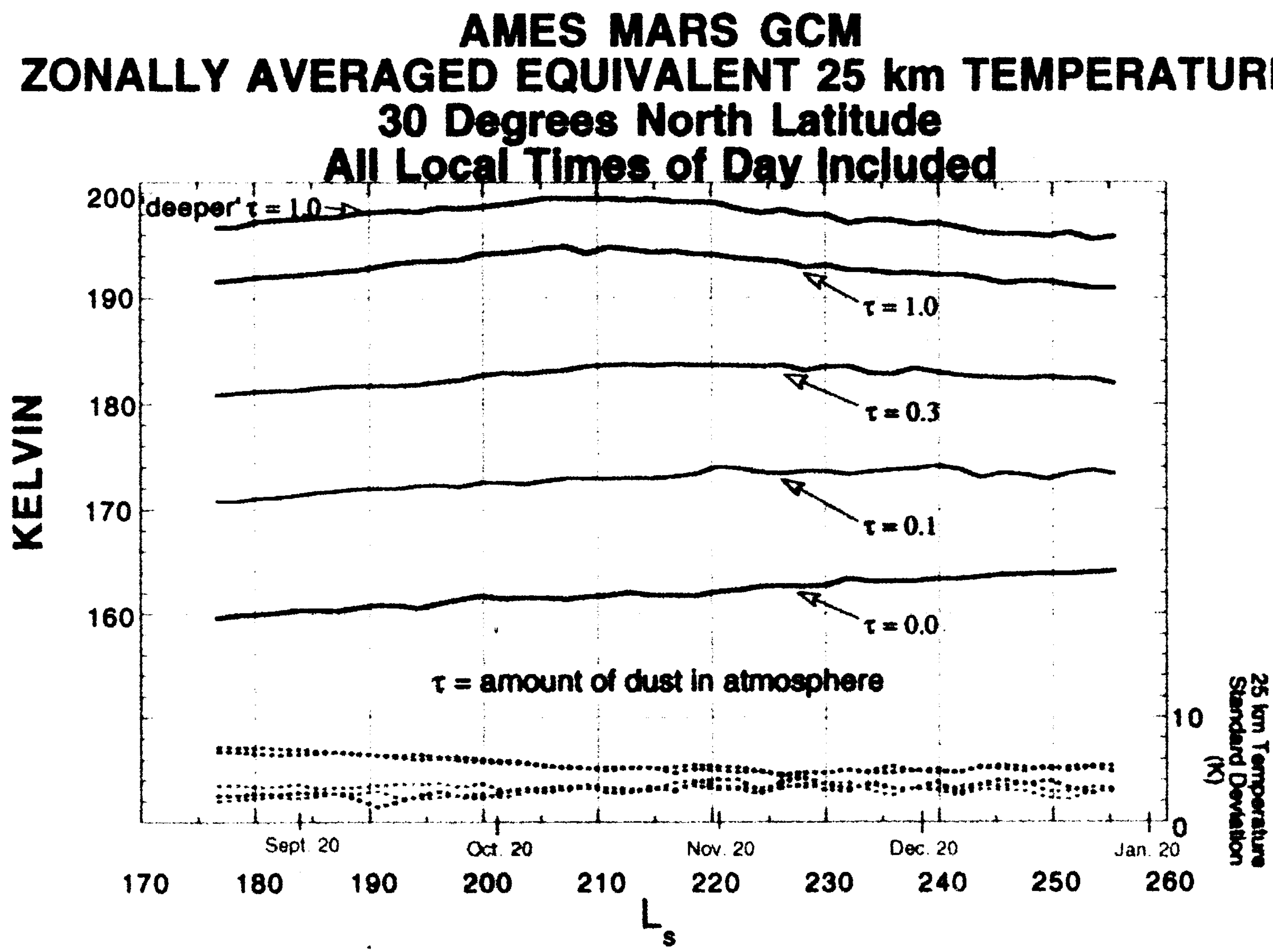
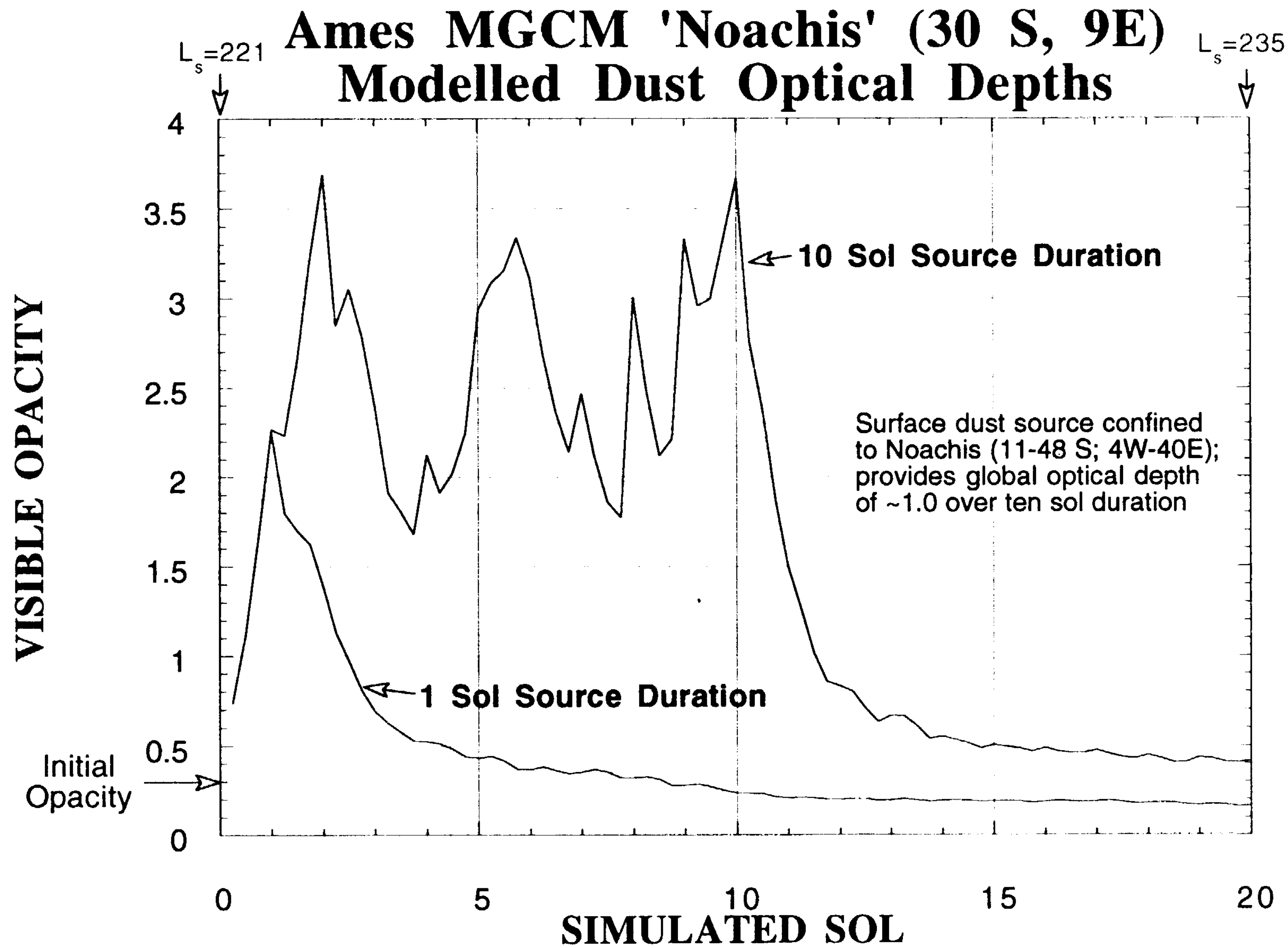


AMES MARS GCM
ZONALLY AVERAGED EQUIVALENT 25 km TEMPERATURI
30 Degrees North Latitude
All Local Times of Day Included
KELVIN
200
190
180
170
160
deeper' τ = 1.0
τ = 1.0
τ = 0.3
τ = 0.1
τ = 0.0
τ = amount of dust in atmosphere
Sept. 20
Oct. 20
Nov. 20
Dec. 20
Jan. 20
170
180
190
200
210
220
230
240
250
260
L_s
0
10
25 km Temperature Standard Deviation (K)


Ames MGCM 'Noachis' (30 S, 9E)
Modelled Dust Optical Depths
L_s=221
L_s=235
VISIBLE OPACITY
4
3.5
3
2.5
2
1.5
1
0.5
0
Initial Opacity
0
5
10
15
20
SIMULATED SOL
10 Sol Source Duration
1 Sol Source Duration
Surface dust source confined to Noachis (11-48 S; 4W-40E); provides global optical depth of ~1.0 over ten sol duration