THE ROLE OF ATMOSPHERIC PRESSURE ON MARS SURFACE PROPERTIES AND EARLY MARS CLIMATE MODELING. Michael A. Mischna¹ and Sylvain Piqueux¹, ¹Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA, 91109, USA, michael.a.mischna@jpl.nasa.gov

Introduction: The thermal conductivity of the martian regolith is controlled by atmospheric pressure, via interstitial pore space gas conductivity within the soil. This dependence has an overall effect of raising thermal inertia (TI) values with increased atmospheric pressure, a configuration analogous to having indurated surface material instead of fines. Greater TI will affect the size and timing of areas for which transient liquid water may form. We propose an obliquity-driven cycle of surface evolution that accounts for this behavior.

Background: The atmosphere of early Mars was thicker than the present atmosphere of ~610 Pa, perhaps by as much as 100-fold [1]. This is necessary to explain many of the fluvial features recorded in the geologic record which require both surface temperatures and pressures to be higher than their present-day values.

In order to better understand the martian environment, modelers use general circulation models (GCMs) to simulate Mars’ climate, e.g. [2-4]. These models, typically based on terrestrial climate models, but modified to incorporate martian physics, require knowledge of surface conditions—parameters like surface albedo, TI and topography. Traditionally, early Mars climate modelers have adopted present-day surface conditions to use during early Mars simulations, largely because of lack of any better knowledge of the actual conditions.

Of the surface parameters noted above, TI stands out as having a component that can be readily modified for early Mars conditions, even in the absence of any direct knowledge of surface composition or material properties. Thermal inertia is a compound function of the near-surface regolith thermal conductivity, density and specific heat, with the regolith thermal conductivity being strongly controlled by the atmospheric pressure [X]; hence, we should expect the TI of the surface on early Mars to be somewhat greater than today because of the increased thermal conductivity caused by more atmospheric gas in interstitial pore spaces within the soil.

We have explored this gas-pressure effect on surface TI by running the MarsWRF GCM [4] for both present-day (610 Pa) and early Mars (61,000 Pa) surface pressures, using two global maps of surface TI: 1) a present-day map as calculated by [5], and 2) a modified map calculated for an atmospheric pressure of 61,000 Pa.

Results: To determine the impact of using the proper TI on Mars climate simulations, we use annual average surface temperature as our metric, and compare the difference in this value across the planet using both the present-day and ‘early Mars’ TI maps. Results are shown in Figure 1, which reveals only a marginal difference between the two. In essence, it appears ‘OK’ to use present-day TI for Mars paleoclimate studies.

Figure 1: Annual average surface temperature, assuming 100x present-day surface pressure (61,000 Pa), with (top) TI map for a thick atmosphere or (middle) TI map for the present day thin atmosphere. (bottom) Difference showing a negligible effect of using the ‘wrong’ thermal inertia in paleoclimate studies.

The reverse, though, we have found not to be true, and using larger (i.e. ‘early Mars’) TI values for the present day will yield annual average surface temperatures as much as 10-12 K colder than using the ‘correct’ values. Of course, we have direct measurements of thermal inertia, so this is not generally a modeling concern, but when put into the context of shorter-term, orbitally
driven climate variability on Mars (i.e., on \(10^6-10^7\) year cycles), it presents some interesting questions.

Apart from being a result of higher surface pressure, greater TI is also consistent with having a more indurated surface material (i.e., duricrust). Duricrust can be formed from having both surface salts and more water-rich conditions. The former is widely observed on Mars [6], and the latter may be found during, for example, higher obliquity periods in martian history [7-8]. The combination of moisture and salt will cause loosely bound surface material (dust) to bind together. This will decrease the peak-to-peak range in both diurnal and annual temperatures, and may be expected to occur episodically, any time conditions are right, as during high obliquity periods in martian history.

Presently, on Mars, we observe regions with indurated material, and other regions covered with dust. This suggests an ongoing process of disaggregation and erosion of the bound material back into its constituent dust particles through what is likely an aeolian process [9]. In the absence of adequate moisture in the local environment, such as when obliquity is low, this is irreversible (until, perhaps, the next rise in obliquity). This dusty material has a lower thermal inertia, and a greater peak-to-peak diurnal temperature range than its indurated predecessor, and is the condition we presently observe on Mars. Helping to maintain this state may be the presence of nighttime CO₂ frost, as observed by [10]. Turbidization of the near-surface material from deposition and sublimation of CO₂ frost maintains a disaggregated surface, and helps prevent reformation of indurated surface material.

**Conclusions:** Together, this is consistent with a pattern of behavior on \(10^6-10^7\) year timescales—at least in recent Mars history—when surface properties, particularly TI, are regulated by the obliquity cycle (Figure 2). During periods of higher overall TI, peak surface temperatures do not reach values as high as the present day, with its lower TI. This makes it more difficult to reach the frost point temperature, and to support liquid water at the martian surface (Figure 3).

When modeling the martian climate, then, care must be taken to consider the anticipated conditions of the surface during these ‘higher TI’ periods—it is likely that simulations of recent Mars, using present-day TI values, are overestimating surface temperatures, and the likelihood of surface liquid water.


**Figure 2:** Notional timeline for evolution of martian surface over obliquity cycles, showing the processes modifying surface properties. Red/green/blue curves show relative values (low to high) of peak temperature, obliquity and TI over the obliquity cycle.

**Figure 3:** Map view of Mars from MarsWRF simulations showing number of days per year for which peak daytime temperature >273 K and surface pressure >610 Pa for (left) present-day TI map and (right) higher pressure/greater TI map. The right panel is consistent with more indurated surface material. Differences represent those areas where liquid water can no longer transiently form, or can form over fewer days, during higher obliquity periods due to this TI effect.