METASTABILITY OF LIQUID WATER ON MARS. M. H. Hecht, Jet Propulsion Laboratory, California Institute of Technology. Email: michael.h.hecht@jpl.nasa.gov..

Introduction: The phrase "liquid water is not stable on present-day Mars" introduces many publications on water-related features. While technically correct, the statement is misleading. On Earth or Mars, water is ordinarily *meta*stable, slowly evaporating or freezing. An exception is found on Earth when the relative humidity reaches 100%. On Mars, water will crust over with ice when the atmospheric pressure falls below approximately 6.1 mbar.

It has long been known that water could conceivably flow and ice could conceivably melt on Mars as a transient event. Such an event need not be catastrophic, as the re-freezing rates are on the scale of hours or days.

This talk reviews reasonable spatial and temporal scales for such melting and flowing events, and relates them to plausible Martian conditions. It is shown that seasonal accumulation of snow and ice on cold peaks could melt and flow in the summer sun, explaining gullies recently observed by Malin & Edgett [1]. Further, it can be concluded that summer wetting may frequently occur where seasonal ice is present.

The Balance Sheet: Ice will melt on Mars when the heat input from the sun exceeds the sum of the heat loss processes. Figure 1 shows a *typical* "balance sheet" in histogrammic form. In this scenario there is insufficient heat input to melt ice. The following sections explore the *optimal* balance sheet under favorable meteorological and geometrical circumstances.

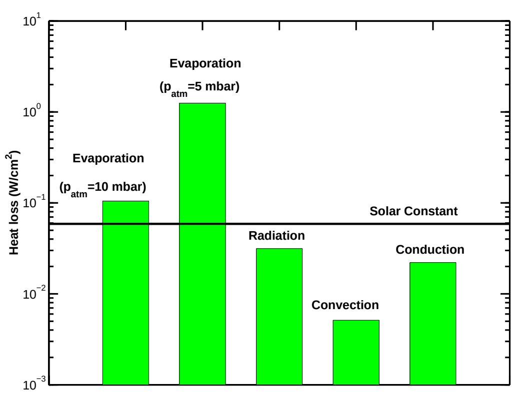

FIGURE 1.*Worst case heat loss from various sources for water, compared to solar constant. Note that conduction is calculated after 1 hr equilibration on -100ºC soil.*

Evaporative and Convective Cooling: Consider a body of liquid water, possibly ice-encrusted, on Mars. There is a very large temperature gradient, ΔT, relative to the cold Martian atmosphere -- particularly at the high latitudes where Malin and Edgett have reported features consistent with recent runoff. This body of water may be compared to a pool on Earth under a similarly cold atmosphere. The ratio of convective cooling to evaporative cooling is proportional to the atmospheric density, ρ [2]. Thus, because the atmosphere of Mars is so thin, convective cooling is equivalent to that produced by only a few degrees of ΔT on Earth. By contrast, the evaporative cooling of this water on Mars is substantially greater on Earth. The net cooling (and freezing) rate is actually *less* for the Martian pool than the terrestrial one.

It follows that the cold martian atmosphere is of little relevance to freezing and melting, but phenomena that might reduce the evaporation rate (e.g. salinity or polar surface films) might substantially enhance melting.

Insolation and radiative cooling: Optical depth on Mars ranges from 0.1-1.0, with low values expected at the higher altitudes in question. At the low end, surfaces *with favorable local slopes* receive insolation close to the solar constant, even at the poles.

Radiative cooling to the cold martian sky would seem to be a dominant factor in determining thermal balance. However, even shallow basins provide sufficient "shade" to reduce radiative loss by factors of two or more. This can be dramatically observed in recent MGS photos of frost in craters (figure 2). The absence of frost near the walls corresponds to regions suffering the least radiative cooling (figure 3).

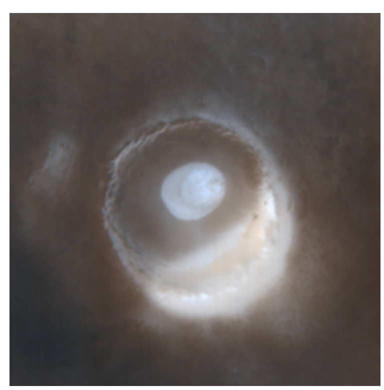

FIGURE 2: MOC2-258b, Northern Spring, 71°N, 257°W, Unnamed Crater, October 6, 2000, 48 km (30 mi) across (Image Credit: NASA/JPL/Malin Space Science Systems)

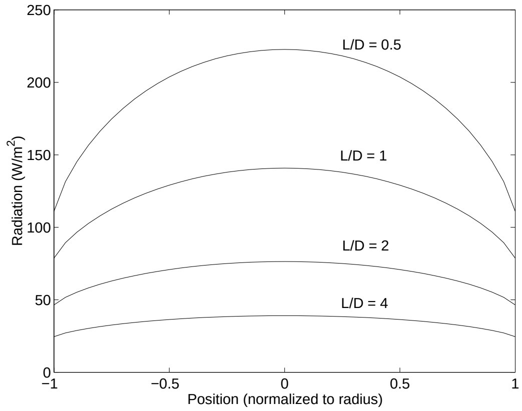

FIGURE 3: Relative radiative loss to sky across the floor of a crater, for various depth to diameter ratios

Among the structures that would be shielded from radiation are gullies that might carry water, or the alcoves where gullies are seen to originate.

Conductive cooling: The martian soil, being pathologically dry, is a superb insulator. Ice, by comparison, is highly conducting. Thus the areas most conducive to melting are those in which thin ice overlays dry soil.

The Final Balance Sheet: Under the favorable circumstances described here, shallow basins, sun-facing slopes, clear skies, and ice overlying soil, the balance sheet (figure 4) indicates that 100 W/m^2 net heat input is available for melting ice. It has been shown elsewhere [3] that liquid water can readily flow for many hours without significant refreezing. This suggests that, even under contemporary conditions, the flow of small quantities of liquid water over short distances may result from ice-melt at high martian latitudes. Even more extreme conditions (e.g. lower evaporation rates) could enhance the rate of melt.

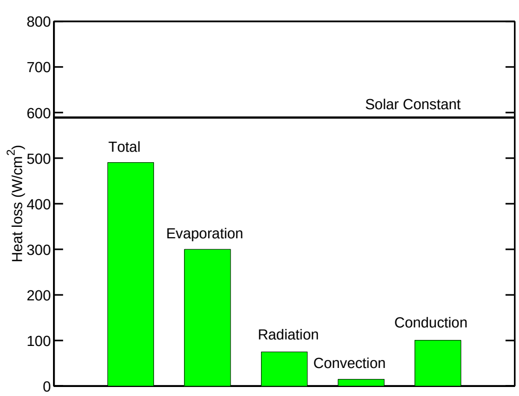

FIGURE 4. *Best case heat balance, indicating100 W/m^2 available for melting (corresponding to melt rate of 1 mm/hr).*

References:

[1] Malin M.C. & Edgett K.S. (2000) *Science 288*, p. 2330. [2] See, for example, Holman J.P. (1990), *Heat Transfer (7th Edition)*, McGraw-Hill, New York. [3] See, for example, Carr M.H. (1983), *Icarus* 56, p. 476.

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