Under the physical conditions of present-day Mars, it is difficult to form or maintain liquid water\(^1\). With the total pressure of the atmosphere near the triple point pressure of water, evaporative cooling of ice is high near the melting point. Here, a suite of quantitative models is used to investigate whether melting of seasonal water frost can occur on present-day Mars\(^2\).

Beyond the pole-facing side of a boulder, CO\(_2\) and H\(_2\)O frost can accumulate seasonally for hundreds of sols, and once the sun re-emerges, the CO\(_2\) frost disappears, the water frost is heated to near melting temperature. A rapid transition from cold to hot involves little sublimation loss. Temperatures at the Habitable Worlds Program.

### 1 Introduction

The total pressure of the atmosphere lies near the triple point pressure (Fig. 1), so that ice near 0°C sublimes so rapidly that evaporative cooling becomes significant, and in fact exceeds the solar constant\(^3\). In winter, CO\(_2\) from the atmosphere freezes out and the first day of spring without seasonal CO\(_2\) frost is referred to as "crocus date".

### 2 Updated formula for rate of free convection

When the water vapor content of the atmosphere is a non-negligible fraction of the total atmosphere pressure, as will be the case near melting, there is a strong buoyancy force that leads to free convection and therefore strong evaporative cooling.

The expression from Ingersoll\(^4\) is

$$E = 0.17D_0 \rho D_0 \left( \frac{\rho g D_0}{\rho} \right)^{1/3}$$  \(1\)

where \(\rho\) is the density of water vapor, \(D_0\) the molecular diffusivity, \(g\) the specific surface gravity, and \(\nu\) the kinematic viscosity. The relative density difference, \(\Delta \rho/\rho\), is

$$\frac{\Delta \rho}{\rho} = \frac{p_0(M - M_o)}{p(1 - M_o)}$$  \(2\)

where \(M\) is the molecular weight.

In the limit \(p_0 \rightarrow p\), the sublimation rate must diverge. Hence, eq. (2) is replaced with

$$\frac{\Delta \rho}{\rho} = \frac{p_0(M_o - M)}{p(1 - M_o)}$$  \(3\)

which gives almost identical results for small \(p_0\), but diverges at \(p_0\) as desired. The proposed new parametrization\(^5\) is

$$E = 0.14D_0 \rho \left( \frac{\rho g D_0}{\rho} \right)^{1/3} \left( \frac{M_o}{M} \cos \theta \right)^{1/3}$$  \(4\)

It updates the prefactor, diverges at \(p_0\) and includes the inclination effect for a slope angle \(\theta\). For H\(_2\)O in CO\(_2\), 0.14 × \(\cos \theta\)^{1/3} \(\approx\) 0.12.

Figure 2 compares the parametrizations of Ingersoll\(^1\) and the updated version. The most significant difference is the divergence of the updated parametrization when the partial H\(_2\)O pressure approaches the total atmospheric pressure.

### 3 Surface Energy Balance with Three-Dimensional Topography

To evaluate the thermal evolution, a numerical model is used that includes direct insolation, subsurface conduction, horizons, and radiative energy exchange between surface elements (terrain irradiance)\(^6\).

Figure 3 shows model results for a bowl-shaped crater. Water frost accumulates continuously for up to hundreds of sols. However, at least 95 sols pass between the end of continuous water frost accumulation and the first time 273 K is reached, so this geometry is not suitable for the melting of frost.

For a boulder, idealized as a half-sphere that sticks out from the atmosphere freezes out and the first day of spring without seasonal CO\(_2\) frost is referred to as "crocus date".

### References