GROUND ICE DYNAMICS AT BEACON VALLEY, ANTARCTICA AND ITS APPLICATION TO THE POTENTIAL PERSISTENCE OF GROUND ICE AT GALE ON MARS

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Introduction: In the Dry Valleys of Antarctica, ground ice may be present as remnants from past glacial events, or may form due to current or past climatic conditions. Ground ice is fundamentally important as a reservoir of water [1], an archive of paleoclimatic information [2-3], and a major component controlling periglacial landscapes [4-6]. Furthermore, subsurface ice in the Dry Valleys is an instructive analog for Martian ground ice; it also plays an important role in the formation of many Martian landforms [7-9]. Ground ice has been detected on Mars a few centimeters below the surface at mid- and high-latitude regions [10-11]. In the equatorial region, subsurface ice is generally viewed as unstable and sublimating at least within the upper meter of the regolith with respect to sublimation under the prevailing cold-dry conditions [10, 12-14].

While factors controlling the stability of ground ice are generally understood, physical-based models predict shallow ground ice should not be present for long periods of time in the Dry Valleys, yet it is pervasive there. Ground ice sublimation rates due to water vapor diffusion have been modeled using meteorological and soil data, including air temperature, relative humidity, and soil temperature. Results from such models suggest a net loss of water vapor from the ground ice to the atmosphere in the MDV at a rate of about 0.1 – 0.5 mm_{ice} a^{-1} [15-20]. Ground ice sublimation rates have also been estimated using cosmogenic isotopes, but the rates are much lower than those derived from physical-based modeling [21-23].

Here, we study the long-term stability of ancient ground ice in Beacon Valley using an enhanced water vapor diffusion model, and apply similar approach to study the ground ice at Gale on Mars.

Beacon Valley, Antarctica: Beacon Valley has received much interest because it was reported that it contains the oldest known ice on Earth and the ice is believed to be a remnant from a past advance of Taylor Glacier. The initial report by Sugden et al. [24] suggested that the ice had been stable since the Miocene based on the dating of volcanic ash in the overlying till to be 8.2 Ma. This report led to a number of studies to understand the nature of the buried ice, its stability, and potential value as a paleo-archive.

To examine the stability of ground ice in Beacon Valley, we developed an enhanced vapor diffusion model that utilizes our long-term hourly-record of air temperature, relative humidity, and subsurface temperatures. Field measurements of episodic snow cover and snowmelt events were also included in the model for the first time.

Model results indicate that these episodic snow events slow down the sublimation rate by 30%. Furthermore, the modeled sublimation rate was extended to the last 200 ka based on ice-core climate records and a new correction accounting for the general relationship between humidity and temperature. Preliminary results indicate the long-term sublimation rate of ground ice at Beacon Valley is 0.09 mm_{ice} a^{-1} (Figure 1), which is comparable to that calculated by cosmogenic isotopes (0.05 mm_{ice} a^{-1}) [21].

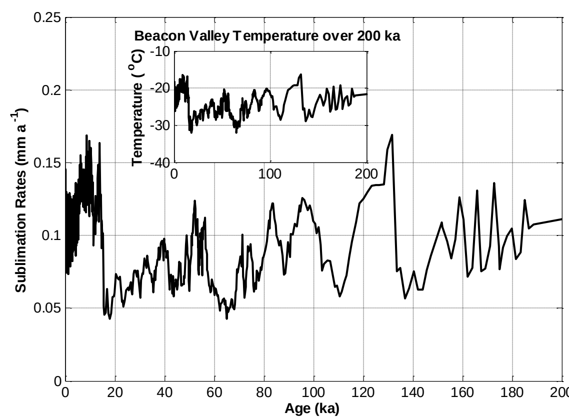

Figure 1 Estimated sublimation rates of ground ice at Beacon Valley for the last 200 ka. The insert is the temperature for Beacon Valley over this period reconstructed from Taylor Dome ice-core records.

Gale Crater, Mars: In the Martian equatorial region, the current Martian climate, in particular, the atmospheric water content and the mean surface temperature suggests that subsurface ice is unstable with respect to sublimation [10, 12-14]. This is consistent with the observed distribution of leakage neutrons measured by the Neutron Spectrometer instrument of the Mars Odyssey spacecraft's Gamma Ray Spectrometer instrument suite [25].

Compared to Earth, Mars undergoes relatively large changes in its obiliquity [26]. Lower-latitude ground ice may have formed or was at the very least stable during high obliquities (>30°), which occurred most recently ~400,000 years ago [27]. In addition, polygonal patterned ground with distinct troughs suggest the possibility for remnant ground ice in these regions [9, 28-33].

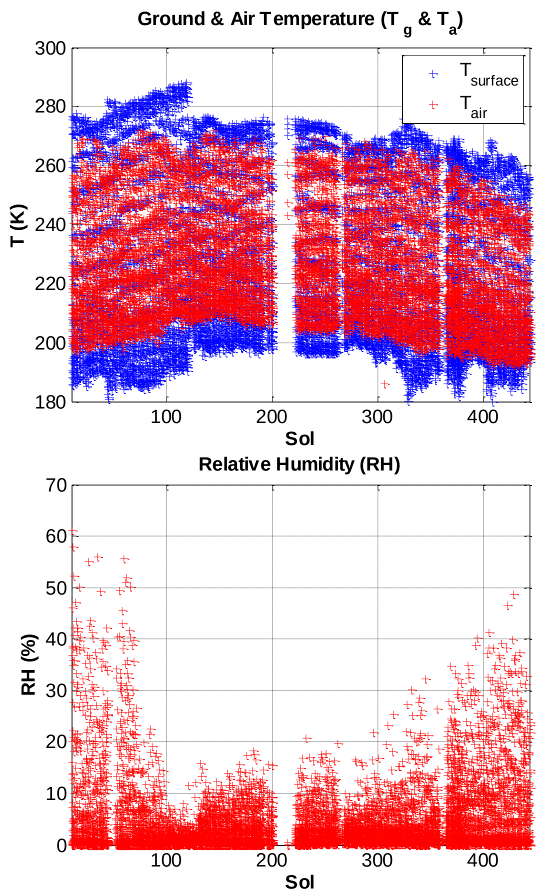

Figure 2 Curiosity Rover in-situ measurements of ground surface temperature, air temperature, and relative humidity.

Here, we propose to apply the model we developed for Beacon Valley to study the long-term stability of deep ground ice at Gale Crater on Mars using in-situ climate data collected by Curiosity (Figure 2). We will use a 1-D time-dependent, coupled heat and vapor diffusion model, to calculate rates of ice sublimation and condensation on and below the surface. This model uses local environmental data to provide us insights into the dynamics of ice gain/loss and potential persistence of ground ice at Gale under current climate conditions. We will also consider the role of hydrated salts, such as perchlorates which are known to be present on Mars, to slow sublimation rates [34].

Ultimately, the focus of this work is to explore the possibility of preservation of old equatorial ground ice, understand how ground ice responds due to changes in obliquity, and how these results relate to present-day observations.

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