VOLCANIC DEGASSING A POTENTIAL SOURCE OF SURFACE WATER ICE NEAR MARTIAN VOLCANOES. S. S. Hamid[1*], L. Kerber[2], A. B. Clarke[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ (*sshamid1@asu.edu), [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA.

Introduction: Passive degassing, or persistent, non-eruptive volcanic activity, can influence the surface ice budget of Mars by providing a pathway for volatile species, such as water vapor, to outgas from the interior into the atmosphere. Passive degassing may have released significant amounts of water, covering volcanic regions in an ice-rich veneer that served as a source of ice for subsequent volcano-ice or impactor-ice interactions.

Using the Laboratoire de Météorologie Dynamique Generic Global Climate Model (LMD-GCM) [1] we simulate the dispersal and deposition of volcanic water from five volcanic sources across various latitudes to represent diverse eras and eruption types and model ice accumulation from volcanic emissions in corresponding meteorological and orbital regimes. As an example of ancient, Noachian to Hesperian-aged degassing on Mars, we choose Apollinaris Mons, Pityusa Patera, and Hadriacus Mons [2]. For Hesperian to Amazonian episodes of degassing, we choose Elysium Mons [2] and for Amazonian-aged degassing, we choose Cerberus Fossae [3].

Methods: The GCM functions by calculating the temporal evolution of variables that control or describe the planetary climate at different points on a 3-D grid spanning the atmosphere up to a height of ~32 km. To simulate the addition of water from passive degassing, we input the coordinates of the volcano and a vertical level that corresponds to the height of the volcano's central vent. As water vapor is released into the GCM it is advected by the wind until it finally deposits onto the surface as ice.

We sweep across several parameters to test the sensitivity of ice distribution to volcanological, orbital, atmospheric, and meteorological conditions: the mass flux of degassing (10^2–10^6 kg s^{-1}), the duration of passive degassing (1 day–1 year), planetary obliquity (0–60°), orbital eccentricity (0 and 0.093), longitude of perihelion (current value and changed by 180° value), atmospheric pressure (6.1 mb–1 bar), season (spring/summer/fall/winter), and dust opacity (mean visible optical depth of 0.2–5). In this study we seek to understand the depositional patterns of water ice from volcanic sources and the sensitivity of our resulting distributions to these various parameters.

Results: Our default parameters include a spatial resolution of ~670×330×32 km (in the longitude, latitude, and altitude), a simulation start at spring equinox, a mass flux of 10^5 kg s^{-1}, a degassing duration of 1 year, and an atmospheric dust opacity that simulates a fairly clear atmosphere (0.2 [4]). We further assume modern-day environmental conditions, such as a present-day obliquity, eccentricity, atmospheric pressure, and longitude of perihelion. Each parameter is then individually varied over a range as described above to test its sensitivity.

Volcanological conditions: The amount of ice deposited to the surface is highly dependent upon the mass flux of passive degassing. One year of degassing at a mass flux of 10^2 kg s^{-1} is too low to form surface ice deposits whereas a nominal mass flux of 10^5 kg s^{-1} will deposit an average of 2 mm of ice around the volcano.

Increasing the duration of degassing increases the availability of water vapor into the atmosphere, leading to thicker ice deposits. For example, after 1 day of degassing at a mass flux of 10^5 kg s^{-1} from Cerberus Fossae, thin deposits of ice averaging 0.1–1 mm in thickness form near the volcano. After one year of degassing, this thickness increases to 2 mm of ice.

Atmospheric and meteorological conditions: Passive degassing under the present-day 6.1 mb atmospheric pressure results in a wider distribution of ice in comparison to a 1 bar atmospheric pressure. Water vapor lingers in the atmosphere for at least two months before depositing to the surface as ice, likely due to the greater holding capacity of the denser atmosphere. Conversely, under a thinner atmosphere ice deposits to the surface more readily (i.e., within one day of degassing).

Dust in the atmosphere can influence the distribution of ice fields that arise from passive degassing. A higher dust loading in the atmosphere leads to an increase in surface and atmospheric temperatures due to the downwelling radiative impacts of dust [5]. As the amount of dust loading in the atmosphere increases, zonal circulation is intensified and the distribution of ice narrows in the latitudinal direction. The effects of atmospheric dust are most noticeable on a global scale and has a lesser influence on the distribution of localized ice deposits surrounding the volcanic region. The season of eruption has an effect on the directionality of the ice deposit due to changing seasonal winds across various latitudes and are largely influenced by perihelion and aphelion [6]. Degassing in the spring, which coincides with aphelion, results in ice fields that spread equatorward where ice otherwise would not survive due to warmer temperatures. As Mars approaches perihelion in the northern fall, there is an increase in solar insolation in the southern hemisphere. As a result, ice fields remain confined to the northern hemisphere. We find that no matter the season, the thickest surface ice deposits are confined to regions surrounding the volcano.

Orbital conditions: When the longitude of perihelion is offset by 180°, the result is warmer surface temperatures and more energetic atmospheric circulation during the northern spring, rather than the northern fall. Passive degassing under a reversed longitude of perihelion leads to enhanced surface lifting of ice due to Mars' proximity to the Sun and slightly wider distribution of ice surrounding the volcano.

Ice fields are further influenced by Mars' obliquity. During periods of high obliquities (i.e., 60º), the poles, on average, become warmer than the tropics, causing the volcanic ice to accumulate at lower latitudes. During lower obliquities (i.e., ≤ 25.19º), the tropics are warmer and result in ice that accumulates at the poles and mid-latitudes throughout the year. We find that the thickness of ice fields surrounding the volcano increase if the volcano is located in a latitude where ice preferentially migrates. For example, passive degassing that occurs at a lower latitude (e.g., Cerberus Fossae) under a higher obliquity will lead to more ice depositing around the volcano compared to a lower obliquity.

When the eccentricity is set to 0, (i.e., circular orbit) the seasonal dichotomy diminishes and the total mass of surface ice increases linearly with time due to more muted circulation from the lack of perihelion. As a result, more ice accumulates around the volcano under a circular orbit. Under an eccentric orbit, perihelion causes an increased rate of sublimation due to Mars' proximity to the Sun, pushing more water vapor to the north and south poles where it later deposits as ice.

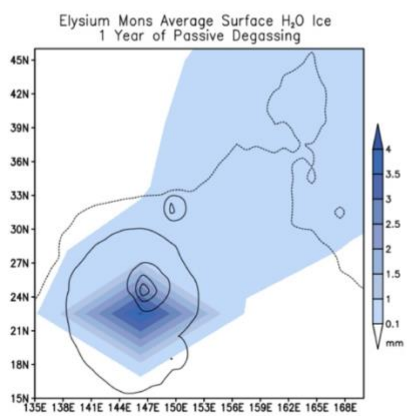

Fig 1: Modeled ice field coincides with the Phlegra Montes (NE of Elysium Mons).

Discussion: *Modeled ice fields coincide with areas indicative of ice-rich substrate:* Across all simulations, ice accumulates around the degassing volcanic center and aligns with areas indicative of an ice-rich substrate at the time of modification. Hadriacus Mons contains evidence that water ice acted as a dominant erosional agent in dissecting channels along its flanks after its formation [7]. Apollinaris Mons and Pityusa Patera both contain evidence of pedestal and ejecta flow craters within their respective calderas, which are interpreted as evidence of impact cratering into an ice-rich substrate [8, 9]. Modeled ice fields from Elysium Mons overlap with the Phlegra Montes, a system of eroded massifs to the northeast of Elysium Rise containing features interpreted to be of glacial origin [10] (Fig 1). Furthermore, modeled ice fields from Cerberus Fossae overlap with the presence of rootless cones, which represents among the strongest evidence of explosive interactions between lava and ice [11].

The influence of volcanic ash on ice preservation: Passive degassing can result in localized ice deposits that persist for a few years before the ice sublimates and restabilizes in cold traps across the planet (e.g., Olympus Mons and the north polar ice cap). However, if ash deposits >3 m mantle these ice fields, they can prevent sublimation by blocking access of water molecules to the atmosphere [12]. If protected from sublimation, ice fields may survive long enough to serve as a source of ice in subsequent volcano-ice and impactor-ice interactions. Otherwise, surface ice sourced from passive degassing may only have a narrow window of time to interact with impactors or lava before sublimating away.

Conclusions: We simulate episodes of passive degassing from various volcanoes and find that regardless of external factors, such as atmospheric, meteorological, and orbital conditions, the thickest deposits of water ice form around the volcano. After repeated episodes of degassing, enough ice may be supplied to the surface for subsequent volcano-ice or impactor-ice interactions, especially if the ice is preserved by ash fall deposits.

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