Volcanic Degassing A Potential Source of Water Ice Deposits on Mars

IAVCEI 2023 Abstract 1073

S. S. Hamid[1*], L. Kerber[2], and 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: INFLUENCE OF PASSIVE DEGASSING ON MARS

Passive degassing, or persistent, non-eruptive volcanic activity, can influence the surface ice budget of Mars by providing a pathway for water vapor to outgas from the interior into the atmosphere. Over time, passive degassing likely supplied water ice to regions surrounding the volcanic center. If this ice is protected from sublimation by volcanic ash fall [1], it may have served as a source of ice for subsequent volcano-ice or impactor-ice interactions (e.g., rootless cones and pedestal craters).

In this study, we seek to understand the depositional patterns of water ice from volcanic sources and the sensitivity of our resulting distributions to volcanological, orbital, atmospheric, and meteorological conditions.

METHODS: SIMULATING PASSIVE DEGASSING WITH A GLOBAL CLIMATE MODEL

We use the Laboratoire de Météorologie Dynamique Generic Global Climate Model (LMD-GCM) [2], which functions by calculating the temporal evolution of variables that control the planetary climate at points on a 3-D grid spanning the atmosphere. We simulate the dispersal and deposition of volcanic water from various volcanic sources across the planet to represent diverse eras, eruption types, and model ice accumulation from volcanic emissions in corresponding meteorological and orbital regimes. Here, we present only results from Elysium Mons to serve as our example case.

A

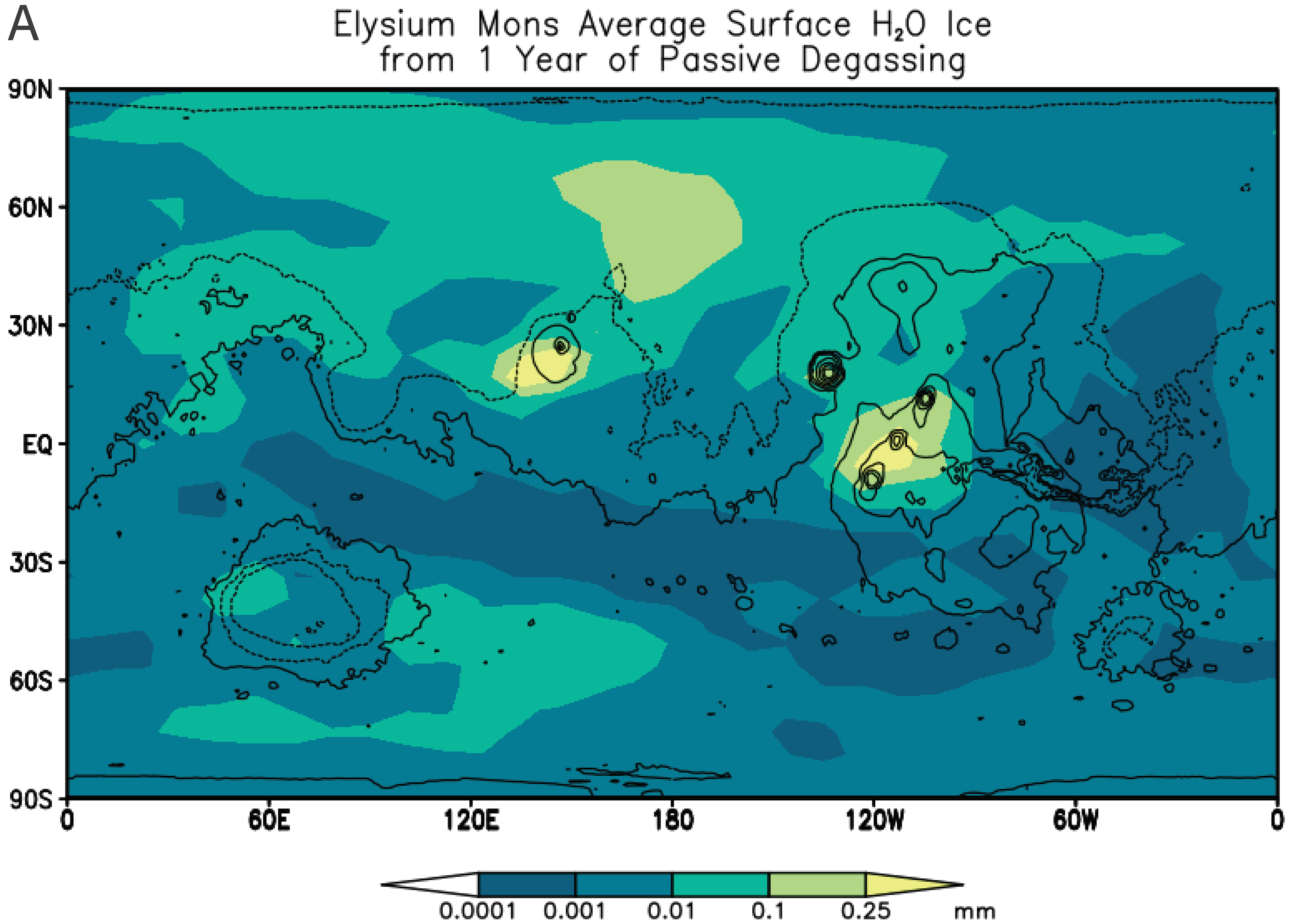
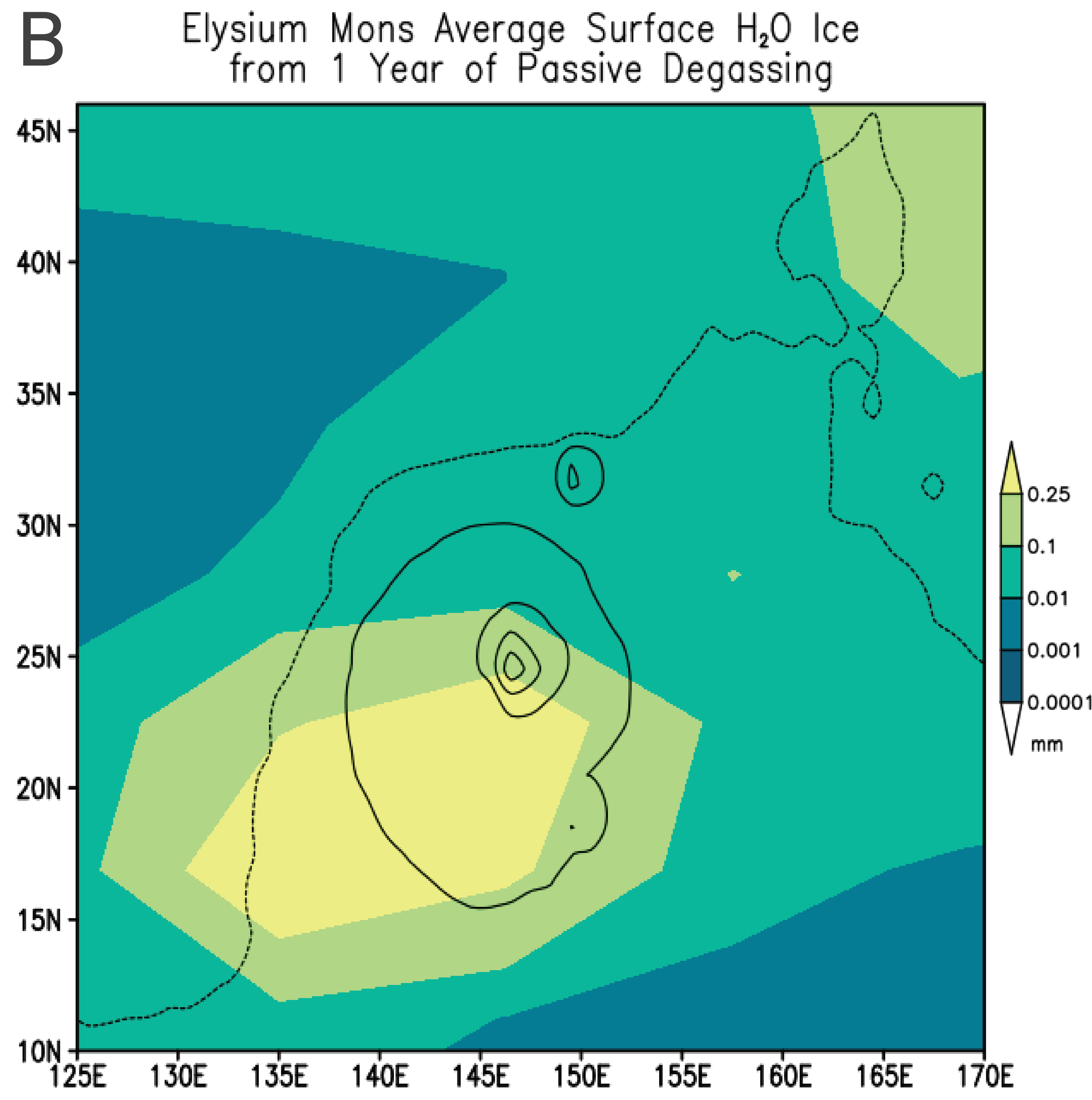


Fig. A shows the global ice distribution assuming default parameters: a spatial resolution ~670×330×32 km (in the longitude, latitude, and altitude), start at spring equinox, a mass flux of 10^5 kg s^{-1}, a duration of 1 year, a fairly clear atmospheric dust opacity (0.2 [3]), and modern environmental conditions: present-day obliquity, eccentricity, atmospheric pressure, and longitude of perihelion.

B



C

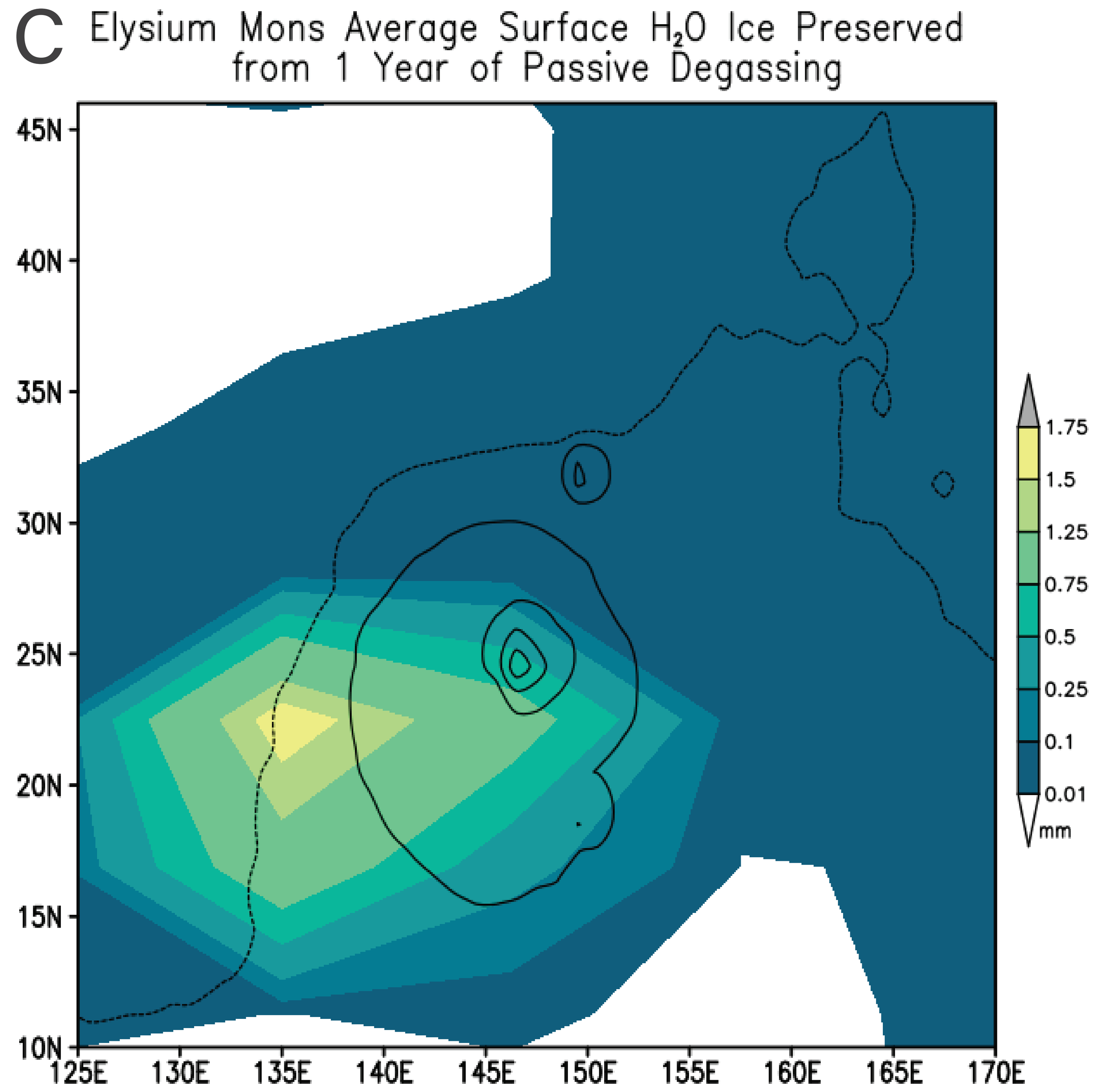
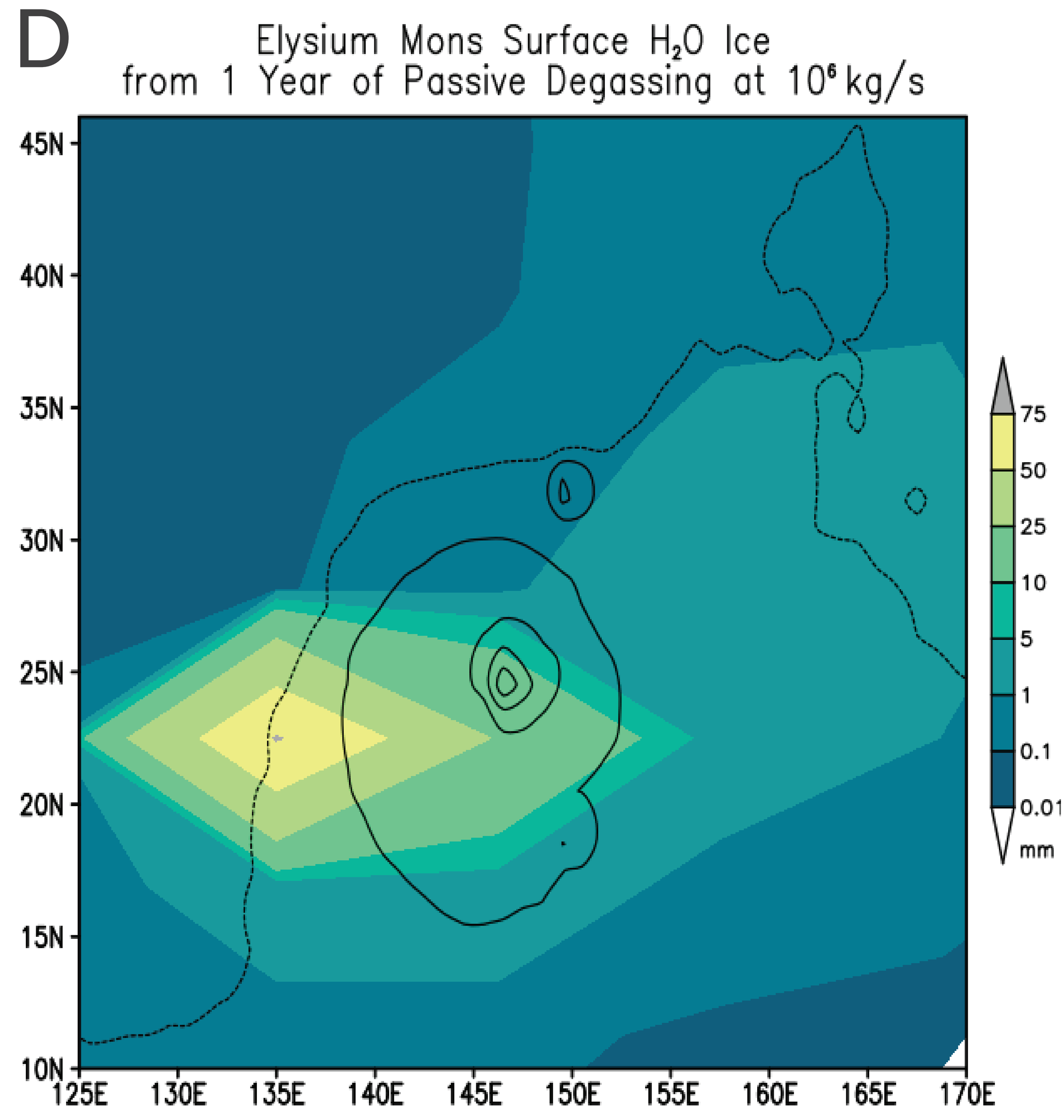


Fig B: Focused view of modeled ice fields from Elysium Mons coincides with the Phlegra Montes, a system of eroded massifs containing geomorphological features indicative of glacial origin (e.g., eskers, lobate debris aprons, and lineated valley fill). Fig C shows the resultant ice field distribution assuming the ice is protected from sublimation by the blanketing of volcanic ash. Fig. D shows the average ice distribution that results from a degassing mass flux of 10^6 kg s^{-1}.

SENSITIVITY TESTS

D



Volcanological parameters:

Mass flux (10^2 kg s^{-1} –10^6 kg s^{-1}): The amount of ice deposited to the surface is highly dependent upon the mass flux of passive degassing. A minimum mass flux of 10^3 kg s^{-1} is needed for surface ice deposits to form around the volcano. A mass flux of 10^6 kg s^{-1} after 1 year will deposit an average of 75 mm of ice around the volcano (Fig D).

Duration (1 day– 1 year): Increasing the duration of degassing increases the availability of water vapor into the atmosphere, leading to thicker ice deposits.

Atmospheric and meteorological conditions:

Atmospheric pressure (6.1 mb–1 bar): Water vapor can linger in a 1 bar atmosphere for at least two months before depositing to the surface as ice, due to the greater holding capacity of the denser atmosphere. Conversely, under a thinner atmosphere ice deposits within one day of degassing.

Atmospheric dust (mean visible optical depth of 0.2–5): As the amount of dust loading in the atmosphere increases, zonal circulation is intensified and the distribution of ice narrows and remains more stable near the mid-latitudes and poles.

Seasons (spring/summer/fall/winter): 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 [4].

Orbital conditions:

Longitude of Perihelion (current value and changed by 180° value): When the longitude of perihelion is offset by 180°, the result is warmer surface temperatures and a more energetic atmospheric circulation during the northern spring, rather than the northern fall, and a slightly wider distribution of ice surrounding the volcano.

Planetary obliquity (0–60°): During periods of high obliquities (i.e., 60°), the poles, on average, become warmer than the tropics, causing the volcanic ice to accumulate at lower latitudes. During lower obliquities (i.e., ≤ 25.19°), the tropics are warmer and result in ice that accumulates at the poles and mid-latitudes throughout the year.

Orbital eccentricity (0 and 0.093): When the eccentricity is set to a 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.

CONCLUSIONS: IMPLICATIONS FOR MARS' ICE BUDGET

- We simulate episodes of passive degassing from various volcanoes and find that ice fields are most sensitive to the mass flux of passive degassing.
- 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.

Acknowledgments: This work is supported by the Gerald A. Soffen Memorial Fund and the National Science Foundation Graduate Research Fellowship under Grant No. 026257-001. Kerber's participation is supported by NASA Solar System Workings Grant No. 20-SSW20-0086. We thank Tyler Paladino and Ehouarn Millour for their help with model installation and debugging. **References**: [1] Wilson and Head (2009) JVGR, 185. [2] Forget, et al. (1999), JGR, 124. [3] forget et al. (2001), Technical note for ESA contract 11369/95/NL/JG, Work Package 7. [4] Mischna (2018), Dynamic Mars.