A GLOBAL DISTRIBUTION OF IMPACT-WIND STREAK CRATERS ON MARS. S. N. Quintana[1] and P. H. Schultz[1], [1]Brown University Department of Earth, Environmental, and Planetary Sciences, 324 Brook Street, Providence, RI 02912, stephanie_quintana@brown.edu.

Introduction: Impact-wind streaks represent an enigmatic subset of martian wind streaks that are crater-centered and emerge primarily in nighttime thermal infrared images [1-3]. These streaks are thought to be the result of the impact process itself. We present a distribution map of all craters with these particular impact wind streaks or streak-like characteristics across Mars. This distribution, along with previous computational and laboratory work, yield inferences about the impacts and the processes that formed the streaks.

Background and Previous Work: Prior studies proposed that the wind streaks are produced by winds that develop from either the initial blast or expanding vapor. Based on both models and experiments, winds driven by impact vaporization appear to provide the most reasonable and testable hypothesis. Consequently, we test the hypothesis these crater-centered streaks represent 'vapor-wind streaks' and use this term to describe these features. Vapor-wind streaks are a subset of impact-generated streaks, which could include a variety of origins. In our model, the expanding vapor moves the entire atmospheric column and culminates in intense winds that sweep across the surface of Mars. As previous computational simulations demonstrate [2], these winds can reach speeds of hundreds of meters per second with the ability to entrain surface material on the centimeter scale [4-5]. If the debris-laden winds encounter a topographic obstacle, the obstacle induces horseshoe vortices that can scour the surface or deposit the load [5].

The character of the wind streaks themselves speaks to the violent process that formed them. Thermal inertia can be used in part to distinguish between compositional and morphological variations, including effective surface particle size, that are otherwise not apparent in visible or albedo data [6]. For example, fine grained material will appear dark, while gravel or exposed bedrock will appear bright in thermal emission spectroscopy [6-9]. Therefore, because vapor-wind streaks appear bright, they may consist of materials with larger particle sizes, duricrust, or bedrock. The fact that these streaks are visible today suggests that the high wind speeds that formed them have rarely, if ever, been experienced again.

Previous computational simulations and laboratory experiments support the vapor-coupled wind hypothesis for the formation of the bright streaks [1-3]. 2D and 3D models with the CTH shock physics code [10] explore how vapor might be generated to develop intense winds. These simulations tested the effect of target composition, impactor composition, and atmospheric conditions on vapor and wind development in order to explain why vapor-wind streaks are not found around every crater on Mars [2].

Crater Distribution: Figure 1 is a global distribution of impact-wind streak craters with clear streaks and streak-like characteristics. The most striking initial observation is, with very few exceptions, the distribution of these enigmatic craters appears nearly random. Such a distribution suggests that impact-wind streak craters are not restricted to a particular unit or lithology; hence, they cannot be explained by any particular surface environment or composition.

Stealth regions. Impact-wind streak craters may not be expected in certain regions of Mars. For example, regions with thick, dusty deposits will display few, if any, impact-wind streak craters because the surface material exhibits little contrast in the thermal infrared. These stealth regions include the high latitudes (above about 40° north and south, Arabia Terra, Medussae Fossae, and the Tharsis rise. An exception is in Utopia Planum, which indicates a different surface characteristic and perhaps a regional supply of mobile material.

Application to formation. From previous 3D simulations, impactor composition and impact speed may play a major role in vapor generation, and consequently, wind development. Volatile impactors, such as comets, have a similar effect on vapor generation as does a thick surface volatile layer [2], which implies that surface or near surface volatiles are not necessary to impact vapor generation. Comets are also expected to have a higher impact velocity than asteroids, which additionally increases the likelihood of greater vapor generation and vapor-induced winds. A recent study of comet impacts on the Moon suggests that such impacts may process the surface differently than asteroidal impacts, both thermally and mechanically [11], which may explain the wide distribution and relative paucity of vapor-wind streak craters on Mars.

A cometary formation of vapor-wind streaks does not preclude the contribution of surface characteristics, such as the presence of near-surface volatiles. Yet, few wind streak craters occur in areas of high or moderately high mass fraction of water as derived from gamma ray spectroscopy (Fig. 1 overlay) [12]. Obliquity variations as a source for near-surface volatiles, alternatively, *can* be ruled out. For example, impact wind streak craters are not found near any relict polar deposits or regions with pedestal craters.

Case Study: An approximately 50 km diameter crater in Isidis Planitia located at 94.30° N, 10.23° E is a good case study to add to the craters Santa Fe and Pál discussed previously [1-3]. Based on the statistics of superposed fresh craters, this crater formed < 1 Ga, and is therefore older than many other craters in the impact-wind streak catalog. The long lasting wind streaks related to this crater demonstrate the special conditions that were necessary to form them have not been achieved again in this area.

Conclusion: Impact-wind streaks occur around some, but not all craters on Mars. Computational simulations and laboratory experiments suggest that these wind streaks are formed as a result of impact vapor expansion; as the vapor couples to the atmosphere, it sets up intense winds that can mobilize centimeter sized surface material, cause surface preconditioning, and can scour the surface around preexisting obstacles. Today, surface modification is apparent in bright wind streaks visible primarily in thermal infrared spectroscopy.

Enhanced impact vaporization necessary to mobilize intense winds and create vapor-wind streaks can be the result of surface characteristics (e.g. near-surface volatiles), or it can result from impactor characteristics (e.g. composition and impact velocity). The random distribution of vapor wind streak craters suggests that near-surface characteristics do not necessarily control the formation of the streaks and that impactor composition and speed are necessary considerations.

Acknowledgements: This material is based upon work supported by the National Science Foundation Graduate Research Fellowship, Grant No. DGE-1058262 and the NASA Mars Fundamental Research Program (MFRP), Grant No. NNX13AG43G.

References: [1] Schultz, P. H. and Quintana, S. (2013), *LPSC 44*, Abstract #2697. [2] Quintana, S.N. and Schultz, P.H. (2014), *LPSC 45*, Abstract #1971. [3] Quintana, S.N., et al. (2015), *LPSC 46*, Abstract #2469. [4] Iversen et al. 1976, *Icarus* **29**, 381-393. [5] Greeley, R. and Iversen, J.D. (1985), Cambridge Univ. Press. [6] Fergason et al. (2006), *JGR* 111, E12004. [7] Christensen (1982), *JGR* 87, B12. 9985-9998. [8] Kieffer et al. (1973), *JGR* 78, No. 20. [9] Fergason et al. (2006), 111, E02S21. [10] McGlaun, J.M. et al., (1990), *Int'l J. of Impact Eng.*, *10*(1-4), 351-360. [11] Bruck Syal and Schultz (2015), *Icarus* 257, 194-206. [12] Karunatillake, S., et al. (2014), *GRL* 41, 22, 7987-7996.

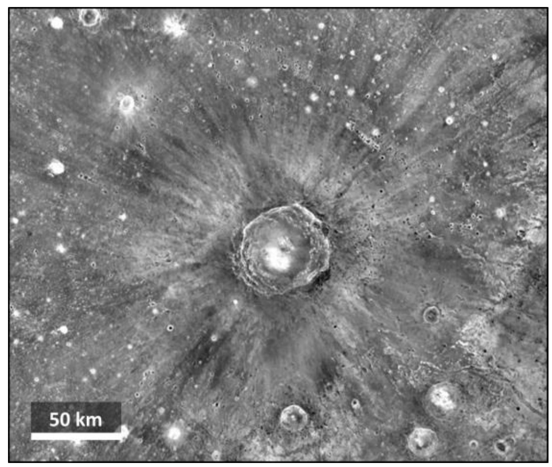

Figure 2 - THEMIS nighttime infrared image of a crater in Isidis Planitia demonstrating the longevity of impact-wind streaks

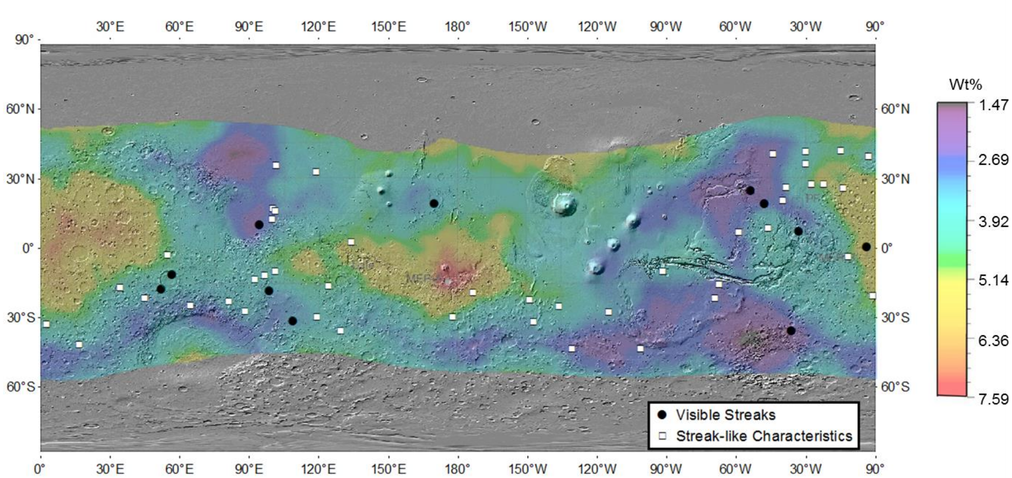

Figure 1 - Global distribution map of impact-wind streak craters with visible wind streaks (black circles) and streak-like characteristics (white squares) over MOLA topography. Overlay is stoichiometrically equivalent H_2O mass fractions from gamma ray spectroscopy [12].