IMPACT BLAST WIND SCOURING ON MARS. P. H. Schultz and S. Quintana, Department of Geological Sciences, Box 1846, Brown University, Providence, RI 02912, peter_schultz@brown.edu.

Introduction: Bright and dark wind streaks across Mars record wind patterns reflecting atmospheric circulation patterns. In some cases these streaks represent erosion of a surface veneer; in others, they indicate sand grains mobilized by strong vortices shed off of positive relief, such as crater rims. Here, we focus on impact-generated winds that can extend more than 500km away from the parent crater and correspond to a subset of permanent wind streaks.

Observations: While many streaks change length or orientation over time, others not only remain unchanged but also may indicate a completely different wind direction. These permanent streaks could reflect past circulation patterns in response to conditions related to orbital forcing [e.g., 1, 2]. However, THEMIS nighttime images reveal distinctive wind streaks radiating from fresh impact craters. While they resemble secondary craters, corresponding high-resolution images confirm that these streaks extend from pre-existing smaller craters (1-3km).

Selected examples document the presence of far-reaching, strong winds created by an impact: Santa Fe Crater in Chryse Planitia and the oblique impact Hale Crater [3]. Streaks radiating from the 20km-diameter Santa Fe crater (Fig. 1A) extend from pre-existing craters and ridges, indicative of vortices shed off disruption of the boundary layer. Twin streaks coming off either side of crater rims are nearly parallel (Fig. 1B), not fading until relatively far "downstream." The parallelism of the streaks indicates sustained winds, while their higher thermal inertia reflects intensities capable of mobilizing coarse materials or scouring fines.

Streaks trailing downwind from craters are familiar features on Mars [4-6]. Classic wind-tunnel experiments and models demonstrated the process of formation supported by aerodynamics theory [5]. In this very subsonic case, two horseshoe vortices develop on the leeward of the crater rim resulting in zones of deposition (outward) and erosion downwind (inward). The sense of rotation of the vortex results in deposition on the outside of the wind tail, on either side of the rim. Farther downwind, the two counter-rotating vortices join to form the distinctive tail. Horseshoe-shaped vortices, however, also can develop near the laminar-turbulent transition at hypersonic speeds as a result of instabilities similar to cross-flow or Görtler vortices [7].

Process: On planetary bodies with an atmosphere (Mars, Earth, Venus, Titan), impact-generated vapor expansion generates an intense shock that precedes most of the ejecta products. On Venus, high atmospheric density slows vapor expansion near the surface to the point where melt condenses and rains out to form massive flows preceding emplacement by the atmospherically decelerated and entrained ejecta [8, 9]. On Mars, however, the tenuous atmosphere allows the vapor to expand to great distances, e.g., [8, 10].

Impact-generated turbulence have been proposed in order to understand the scouring of inner ejecta facies around craters on Mars [11, 12, 13, 14]; lobate ejecta deposits 10-15 crater radii from the crater [e.g., [13]; distal surface fines [13; 16]; pedestal craters [10]; and radiating wind streaks [3]. The angle of ejection due to the presence of buried ice also should play a role in the sequence of deposition, further contributing to scouring of the inner facies [17].

Hydrocode models of an impact forming a 6km transient crater (1 km impactor impacting at 15km/s) reveal that vapor expansion initially fills the void behind the shock (Fig. 2), thereby creating long-lasting outward blast winds [10]. For high-angle impacts, the initially cavity-contained vapor "blooms" above the crater resulting in much greater wind speeds aloft [18, 19]. With time the atmospheric shock decouples from the expanding vapor, moving rapidly across the surface. At an altitude of 1km, wind speeds exceed 300m/s; at 8km > 1000m/s but still reaching 125m/s within one crater diameter (apparent transient diameter) after 25s, prior to ejecta emplacement.

Implications: Results from this study provides insight into global atmospheric circulation (by eliminating unrelated patterns), the location of near-surface volatiles, possible signature of impact speeds for certain craters, latitudinal limits on the effects of orbital forcing, and new constraints on Hesperian gradation (erosion, deposition) rates of surface materials.

Not all large fresh impact craters exhibit radiating wind streaks. Expression depends on the geologic setting (e.g., wind-sensitive surface materials), history of active resurfacing (e.g., high latitude mantling deposits), and/or impactor variables (speed and composition). At very high latitudes (>50°), subtle ejecta flow lobes and linear scours extend to enormous distances (8 to 12 crater diameters), much farther than the continuous ejecta facies. This enigmatic run out formed the basis for suggesting the role of vapor-driven wind flow and the formation of high-latitude pedestal craters [10]. There, the expanding vapor plume likely swept up fines near the crater preceding ejecta emplacement resulting in long run-out lobes.

References: [1] Thomas, P. and Veverka, J. (1979), *J. Geophys. Res. 84***,** 8131-8446; [2] Veverka, J. *et al*., (1981), *Icarus 45*, 154- 166; [3] Schultz, P. H. and Wrobel, K. (2012); *Jour. Geophys.* 117, E04001, doi:10.1029/2011JE003843; [4] Veverka, J. (1975), *Icarus 25*, 595-601; [5] Greeley, R. and Iverson, J. D. (1987), *Wind as a Geological Process on Earth, Mars, Venus, and Titan*, Cambridge Univ. Press, NY; [6] Greeley, R. *et al*. (1992), In *Mars*, edited by Kieffer H. H *et al*., The University of Arizona Press. pp. 730-766; [7] Chang, C. L. *et al.* (2010), *48th AIAA Aerospace Science Meeting*, AIAA 2010-1572; [8] Schultz, P. H. (1992), *J. Geophys. Res.*, 97, 16183-16248; [9] Sugita, S. and Schultz, P. H. (2001), *J. Geophys. Res.*, *103,* 19,427-19,441; [10] Wrobel, K. *et al*. (2006), *MAPS 41*, Issue 10, p.1539-1550; [11] Schultz, P. H. and Singer, J. (1980) *Proc. Lunar Planet. Sci. Conf. XI*, 2243-2259; [12] Mouginis-Mark, P. (1981), *Icarus 45*, 60–76; [13] Schultz, P. H. (1992), *J. Geophys. Res*. *97*, 11623-11662; [14] Barnouin-Jha, O. S. and Schultz, P. H. (1996), *J. Geophys. Res*. *101*, 21099-21115; [15] Barnouin-Jha *et al*., (1999), *J. Geophys. Res.104*, 27117-27131; [16] Ghent, R. R. et al. (2010), *Icarus*, *209*(2), 818–835; [17] Senft and Stewart, (2008), *MAPS*, *43*, 1993-2013; [18] Crawford, D. *et al*. (1995), *Int. J. Impact Eng*., *17*, 253-262; [19] Schultz, P. H. (1996), *J. Geophys. Res.*, *101*, 21,117-21,136; [21] Rybakov, V. A. *et al*. (1997), *J. Geophys. Res.102*, 9211–9220.

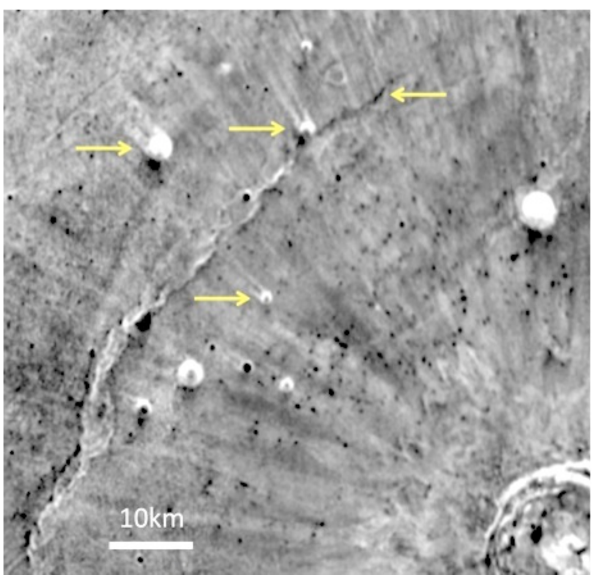

Figure 1A. Night-time THEMIS image of Santa Fe Crater (24km in diameter, lower right) on Chryse Planitia. Streaks exted radially from pre-existing craters and ridges (arrows), well beyond the continuous ejecta deposits. High-resolution images reveal wind scouring.

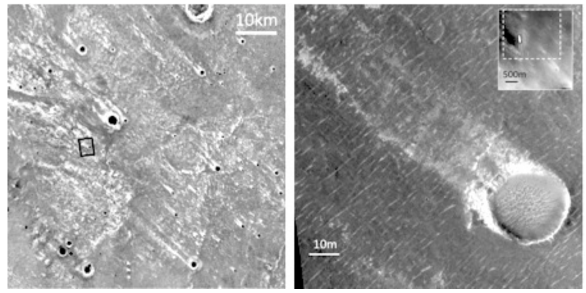

Figure 1B: THEMIS (left) and MOC (right) images of impact-related streak extending radially from the crater Hale, located 350km to the southeast. Inset shows context image. Streaks developed by scouring behind pre-existing relief downrange from Hale.

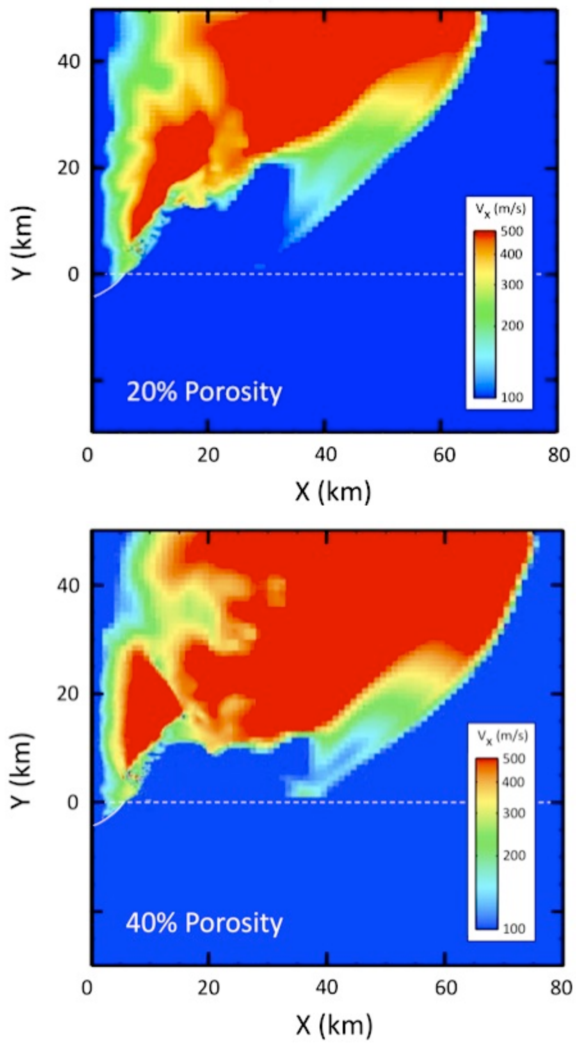

Figure 2: Wind speeds generated by vapor blast in the tenous Martian atmosphere 50s after impact by a 1km-diameter projectile into a layer of water ice of lower (top) and higher (bottom) porosity. Higher porosity results in greater coupling of winds scouring the surface.