OBSERVATIONS OF DEBRIS FLOWS AT THE GREAT KOBUK SAND DUNES, ALASKA: IMPLICATIONS FOR ANALOGOUS FEATURES ON MARS. Donald M. Hooper, Cynthia L. Dinwiddie, Ronald N. McGinnis, Kevin J. Smart, and Marla M. Roberts. Geosciences and Engineering Division, Southwest Research Institute®, 6220 Culebra Road, San Antonio, TX 78238-5166 (DHooper@swri.org).

Introduction: Debris flows with fresh-appearing gullies or erosion tracks occur on the slopes of several mid- to high-latitude dune fields in both Martian hemispheres. They bear a striking resemblance to small meltwater-induced debris flows observed on the lee slopes of large dunes at the 67° N latitude Great Kobuk Sand Dunes (GKSD) in Kobuk Valley, Alaska. The GKSD are variably affected by snowcover for ~70% of each year, which likely has direct analogy to hydro-cryospheric factors that influence debris flow development on Mars. The high-latitude, cold-climate GKSD are a useful terrestrial system within which to conduct a Mars analog study focused on understanding the integrated factors that cause alluvial debris flows to initiate on the slopes of aeolian dunes.

Debris Flow Gullies on Mars: Recent analysis of High Resolution Imaging Science Experiment (HiRISE) and Mars Orbiter Camera (MOC) images by several researchers have revealed the possibility of niveo-aeolian deposits, denivation forms, and debris-flow gullies on Martian sand dunes [1–10]. Martian gullies exhibit the same general morphologic characteristics as their terrestrial counterparts. Whether contemporary meteorological conditions on Mars are capable of generating liquid water on the surface is a complex matter yet to be resolved to the satisfaction of most researchers [1–2,8,11–14]. Other hypotheses employ liquid CO_2, CO_2 frost, or dry granular flows as the primary agent driving the formation of these gullies [10–11,13–14].

Kobuk Valley Climate and Meteorology: The climate at the GKSD is subarctic and semiarid (mean annual air temperature: –4°C; mean annual precipitation: 360 mm) with long, cold winters (January mean: –20°C) and brief, warm summers (July mean: 15°C) [15–16]. Meteorological data from the Kavet Creek remote automated weather station (located 3.6 km from the northern edge of the GKSD) indicates a bimodal wind regime from the east-southeast during November to April and from the west during May to July. Our field work (March 16–31, 2010) coincided with a period of abundant sunshine (relatively strong solar radiation) that helped induce thawing on south- and west-facing slopes.

Niveo-Aeolian Deposits and Denivation Features: Cold-region dunes often include niveo-aeolian deposits composed of interbedded sand, snow, and ice [17–18]. At the GKSD, wind-transported sand and snow accumulates on the lee slopes of large transverse, longitudinal, and barchanoid dunes. Snow banks with intercalated sand layers are especially prominent and thickest on the westward-facing lee slopes at the GKSD. Melting and/or sublimation of snow and ice during warm periods cause distinctive morphologic and sedimentologic phenomena ascribed to denivation features or forms, including spongy and hummocky surfaces, extension cracks, deformed strata, slumping, and compressional structures. Melting niveo-aeolian deposits provide a source of liquid water for alluvial processes.

Field Observations of Debris Flows at the GKSD: During March 2010, we observed niveo-aeolian deposits, denivation features and small debris flows at the GKSD (Figs. 1 and 2). Small debris flows

Figure 1. A small debris flow induced by snowmelt is observed on the lee slope of a large dune and terminates in a lobate depositional fan. Scale is 10 cm long. Big Spring Number Eight sand catcher and 0.5 m weather transmitter in the background.

originate in shallow alcoves near dune crests, become channelized down lee faces, and terminate with depositional fans.

Figure 2. This debris flow is in an incipient stage of gully formation. Denivation has created spongy and hummocky microtopography. Slope aspect and insolation are two factors that control the rate of thawing on south- and west-facing slopes.

Conceptual Model: We propose that these debris flows are generated when high pore-water pressures develop in thawed, near-surface niveo-aeolian deposits due to impeded infiltration by frozen sand and pore ice. The thawing and sublimation of niveo-aeolian deposits, perhaps aided by solar insolation, is one possible trigger for generating both terrestrial and Martian debris flows and is a likely mechanism in the formation of the associated gullies [1–2,8,19–21] (Fig. 3).

Conclusions: Debris flows on dune slopes at the GKSD are activated by seasonal thawing and consist of a mixture of sand and liquid water cascading down the dune slipface. The gullies observed in Martian dune fields may be formed by an analogous process. The presence of Martian gullies with a youthful appearance is a topic of considerable importance because of the possible presence of liquid water. Detailed knowledge of the processes involved in niveo-aeolian transport, deposition, and reworking is relatively sparse and poorly understood. Our investigation provides insights into the interactions between niveo-aeolian deposition, thawing, insolation, slope aspect, and initiation of alluvial processes.

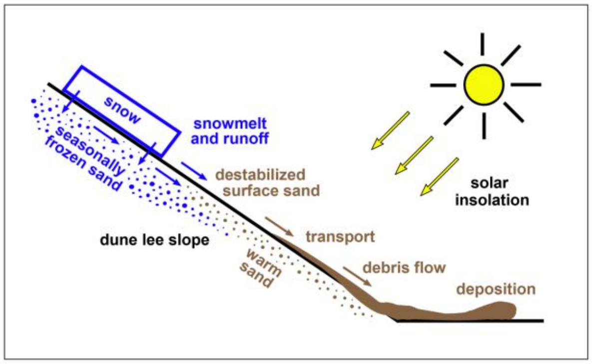

Figure 3. This figure illustrates the conceptual model as a time series of key slope processes and mechanisms.

Acknowledgments: Field work to the Great Kobuk Sand Dunes was funded by SwRI®'s Internal Research and Development Program (20.R8136) and by NASA grant NNX08AN65G. We thank Stuart Stothoff and Gary Walter for constructive reviews.

References: [1] Reiss D. and Jaumann R. (2003) *GRL 30*, 1321. [2] Mangold N. et al. (2003) *JGR 108*(E4), 5027. [3] Bourke M. C. (2004) *Eos Trans. AGU, 85*(47), Abstract #P21B-01. [4] Miyamoto H. et al. (2004) *GRL 31*, L13701. [5] Bourke M. C. (2005) *LPS XXXVI*, Abstract #2373. [6] Diniega S. et al. (2010) *Geology 38*, 1047–1050. [7] Dundas C. M. et al. (2010) *GRL 37*, L07202. [8] Reiss D. et al. (2010) *GRL 37*, L06203. [9] Horgan B. et al. (2010) *LPS 41*, Abstract #1325. [10] Hansen C. J. et al. (2011) *Science 331*, 575–578. [11] Musselwhite D. S. et al. (2001) *GRL 28*, 1283–1286. [12] Hecht M. H. (2002) *Icarus 156*, 373–386. [13] Treiman A. H. (2003) *JGR 108*(E4), 8031. [14] Shinbrot T. et al. (2004) *Proc. Natl. Acad. Sci. 101*(23), 8542–8546. [15] Gibson W. (2009) Mean Precipitation for Alaska 1971–2000. NPS, AK Regional Office GIS Team. Geospatial Dataset 2170508. PRISM: www.ocs.orst.edu/prism/stat_products/ak.maps.html. [16] WRCC (Western Regional Climate Center) (2011) Kavet Creek, Alaska (Climate Summary, March 2010). WRCC: Desert Research Institute, Reno, NV. www.raws.dri.edu/cgi-bin/rawMAIN.pl?akAKAV. [17] Koster E. A. (1988) *J. Quat. Sci. 3*(1), 69–83. [18] Koster E. A. and Dijkmans J. W. A. (1988) *Ear. Surf. Proc. Land. 13*, 153–170. [19] Williams K. E. et al. (2009) *Icarus 200*, 418–425. [20] Kereszturi A. et al. (2009) *Icarus 201*, 492–503. [21] Hugenholtz C. H. et al. (2007) *J. Sediment. Res. 77*, 607–614.