SAND, WIND, AND ICE: MARS ANALOG AEOLIAN STUDIES AT THE GREAT KOBUK SAND DUNES, ALASKA. C. L. Dinwiddie[1] (cdinwiddie@swri.org), R. N. McGinnis[1], D. E. Stillman[2], D. M. Hooper[1], T. I. Michaels[2], K. L. Bjella[3], R. E. Grimm[2], and M. Necsoiu[1]. [1]Geosciences and Engineering Division, Southwest Research Institute®, 6220 Culebra Road, San Antonio, TX 78238, [2]Space Science and Engineering Division, Southwest Research Institute®, 1050 Walnut Street, Suite 300, Boulder, CO 80302, [3]Cold Regions Research and Engineering Laboratory, U. S. Army Corps of Engineers, Ft. Wainwright, Alaska 99703.

Introduction: High-latitude Martian dunes may have reduced mobility due to seasonal, surficial volatile cycles of H_2O and CO_2 ice/frost and the presence of deeper interior reservoirs of permafrost. This hypothesis is generally consistent with multiple unsuccessful searches of spacecraft imagery {e.g., [1,2]} for robust signs of high-latitude dune activity {an exception is [3]}. During Martian summer, solar heating may remove volatiles from a thin surficial layer of aeolian particles, thereby increasing particle mobility, but their transport may not result in bedform changes significant enough to detect {although an intriguing finding of Martian ripple migration at low latitudes is noted [4]}.

Sparse Martian data forces aeolian scientists to use the theory and lessons from terrestrial dunes to interpret and predict the evolution of Martian dune morphologies. Terrestrial dunes studied as planetary analogs are often warm-climate dunes without perennially frozen volatiles, but cold-climate dunes with perennially frozen volatiles may be significantly more analogous to Martian dunes. There is little detailed knowledge of such terrestrial systems, however, due to their remote locales and demanding logistical efforts required for their study. To begin understanding cold-climate sand mobility and transport, we are undertaking a site characterization and meteorological modeling study of cryospheric, geomorphologic and atmospheric processes active in the 67°N latitude Great Kobuk Sand Dunes (GKSD), Kobuk Valley National Park, Alaska (Fig. 1), as a terrestrial analog for high-latitude Martian dunes.

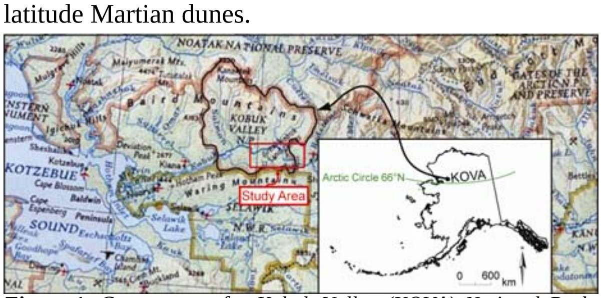

Figure 1. *Context map for Kobuk Valley (KOVA) National Park. Image credit: Alaska Information Services.*

Using this high-latitude, slowly migrating [5] terrestrial aeolian analog to Mars, we will study interactions between the atmosphere above, the cryosphere below, and the geomorphology at the land surface from March 15 until April 2, 2010. We will collect near-surface geophysical, geomorphological, and meteorological data and employ numerical mesoscale (km) to microscale (10–100 m) meteorological modeling capabilities to meet the objectives specified below.

Setting: The GKSD are a result of Pleistocene glaciation in the Brooks Range that produced glacial drift reworked by subsequent meltwater streams. The streams deposited quartzose sand and silt along the Kobuk River valley concurrent with the last glacial advance {24 ka; [6]} and created loess deposits and dune fields. The valley lies ~65 km north of the Arctic Circle and ~160 km inland to the east from Kotzebue Sound within an east–west-oriented hydrologic basin on the Kobuk R. lying between the Baird and Waring mountains to the north and south. The GKSD are subject to an opposite, bimodal wind regime at the macroscale, where the dominant winds are strong polar easterlies from September to May, with a brief wind reversal each summer [6]. The climate is subarctic and semiarid (average annual temperature: –6°C; average precipitation: 400 mm) with long, cold winters (January average: –27°C) and brief warm summers (July average: 15°C).

The 62-km^2 [7] active GKSD are characterized by a variety of dune forms, including transverse, barchanoid, star, and coppice (nebkha) dunes and sand sheets [6,7,8]. The dunes range from 33 to 170 m amsl and occur within a plateaus/highlands physiographic region with a 10° slope; this system mainly lies within the Kavet Creek watershed [9]. Several tributaries to the Kobuk R. (Fig. 2) offer cutbank exposures. Kavet Cr. is diverted to the dune field margin at the downwind side of the GKSD (Fig. 2). Alcove-shaped springs drain the base of the dune field to Kavet Cr. and Ahnewetut Cr. [6,7]. Ahnewetut Cr. dissects the GKSD (Fig. 2), exposing inactive precipitation ridges in cross-section and separating the larger northwesterly lobe of the GKSD from the smaller southeasterly lobe; in the region surrounding this divide, barchanoid climbing dunes move upslope and encroach on the base of the Waring Mountains [6]. Like Kavet Cr., Niaktuvik Cr. is diverted to the dune field margin on the southeast edge of the smaller lobe (Fig. 2). The downwind side of GKSD is characterized by a main body of large transverse to barchanoid dune ridges and flat, locally ponded interdune areas [6]. The brief westerly summer winds form secondary lee slipfaces on dune crests [7]. The main body of sand is dry with a large sand supply, whereas the upwind, older portion of the system is moister and vegetated [6,10]. Several thermokarst lakes abut the dune boundary of an up-wind sand sheet on the north side of the northwest GKSD lobe (Fig. 2).

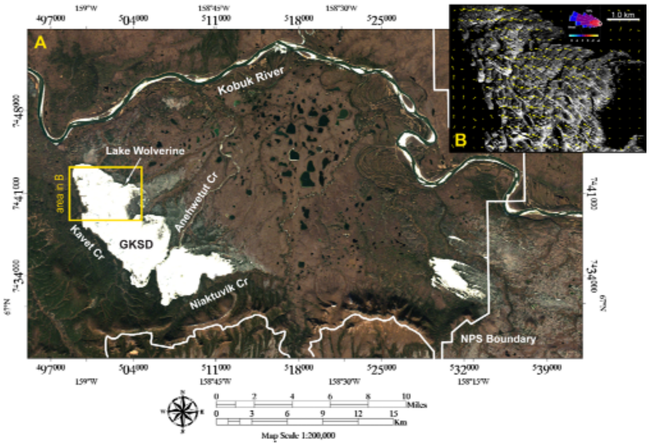

Figure 2. A. *AVNIR-2 contrast-enhanced context image (bands 3, 2, 1) of KOVA and the GKSD.* ***B.*** *Migration vectors calculated by [5] superimposed on a SPOT panchromatic image.*

Niveo-aeolian sedimentation of wind-blown snow and sand occurs at the GKSD [7]. Annual denivation forms include snow ramparts, sinkholes, hummocks, microridges, meltwater fans, contorted bedding, open and sand-filled tensional cracks of varying geometries, and dimpled/pelleted/spongy/air-bubbly wet sand covers [7]. The role of sublimation in the dissipation of snow during the early spring is uncertain because research here has typically been undertaken during clement months and detailed information on winter niveo-aeolian transportation and deposition processes is limited. Our planned observations during March 2010 will augment this knowledge base.

The presence of permafrost within the GKSD combined with the opposite, bimodal wind regime of Kobuk Valley is thought to lead to a lower than average dune migration rate [7,10], and SwRI's multispectral data displacement analysis quantitatively supports this hypothesis, yielding an average GKSD migration rate of only ~1 m/yr over a recent 5-year period [5].

Objectives: Through this late-winter field campaign and atmospheric modeling study we will begin to provide answers to the following science questions:

- What factors (e.g., sediment source, wind regime, grain size, water content, basinal topographic confinement) are relevant (at this site) to the control of dune size, spacing, orientation, and form?
- What is the late-winter reversing dune signature, given the bimodal wind regime?
- Given the apparently very slow migration rate of the dunes, what is the relative importance of permafrost, a seasonally frozen active layer, and niveo-aeolian deposits on mechanical arrest of dune movement?
- Is mechanical arrest of the dunes a more important factor to migration rate than bimodal wind regime and topographic confinement?
- What are the microscale circulation dynamics of the atmospheric boundary layer of this aeolian system, and how do they interact with local topography and aeolian geomorphology?

Methodology: NASA Mars Fundamental Research grant NNX08AN65G, "Ground-Penetrating Radar Investigations of Mars Analog Permafrost Sites in Alaska," has funded our late-winter, March 2010 geophysical characterization of the cryosphere of the GKSD. This study will provide ground truth for interpretation of depth to potentially recoverable massive water ice and other cryospheric signatures in radar data, and a foundation upon which to assess broadband radar performance in a cold, volatile-rich environment.

Because we are convinced of the broader value of the GKSD as a cold-climate terrestrial analog to Martian aeolian systems, SwRI's IR&D program is augmenting the March 2010 field study by funding a study to simultaneously collect hydrometeorological and geomorphological data.

Together, these two projects will enable us to begin construction of a season-specific library of Mars-relevant meteorologic, geomorphic, and cryospheric modeling parameters.

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