Water Equivalent Hydrogen variability in the North Polar region: The potential influence of katabatic winds. William C. Feldman[1], Mary C. Bourke[1], Luis F.A. Teodoro[2]. [1]Planetary Science Institute, Tucson, AZ 85719; [2]NASA Ames Research Center, Moffett Field, CA 94035-1000

Introduction: A Water Equivalent Hydrogen content of 30±5% was detected in the near surface of Olympia Undae dunes using Neutron Spectrometer data. These data along with Thermal Inertia data and geomorphic feature analysis suggest that the polar dunes contain ice-cemented layers [1-3]. Teodoro et al [6] have applied Pixon image reconstruction methods to North Polar Epithermal Neutron Data to increase the spatial resolution of the count rates. Their data show that there is spatial heterogeneity in the circum-polar epithermal count rates (Fig. 1). Of particular note are large areas of relatively high epithermal count rates that suggest relatively low water equivalent hydrogen content near the surface [7].

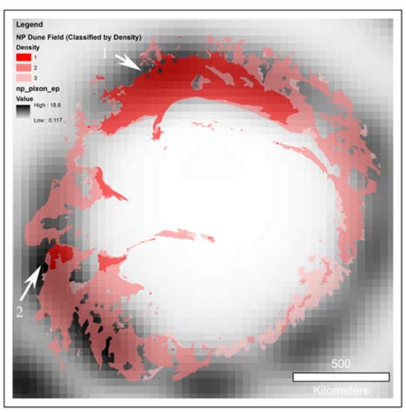

Figure 1. Map of North Polar dunefield density [4] overlying epithermal count [6].

Here we investigate the surface characteristics of two regions of assumed low water content (Sites 1 and 2, Fig. 1).

Surface landforms: A major component of the surface features at both sites is the presence of sand dunes. Figure 1 shows the north polar dune map [4] overlain on the epithermal count rate map [6]. The area of relatively high count rates closely coincide with the distribution of dunes, particularly those that are densely spaced. Closely spaced dunes have sandy inter-dunes (Fig. 2) thus the neutron signal is less likely to reflect an icy substrate.

Winds: Katabatic winds are flows of high density air down a slope under the force of gravity. They form by radiative cooling and warm adiabatically as they descend. They tend to have low humidity and in Antarctica are associated with snow and sand transport, dune building, and ice sublimation [8-10]. On Mars, they are reported to contribute to the formation of Polar Chasma and troughs [11,12], trigger avalanches at polar scarps [13], transport aeolian sediment away from the polar cap [14,15] and sublimate seasonal CO_2 and H_2O ice [16].

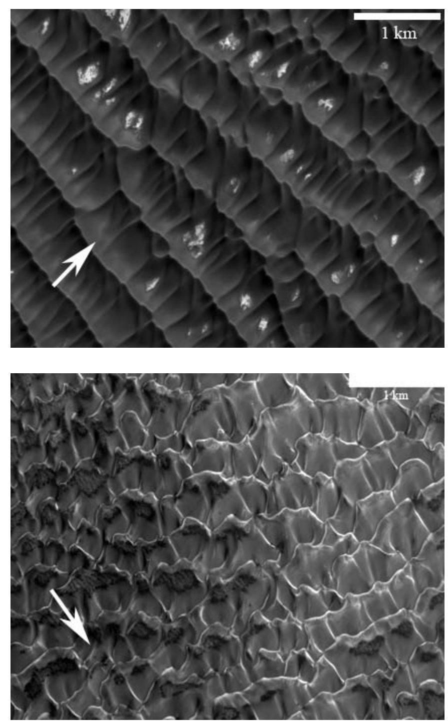

Figure 2: Subset of HiRISE images of dunes in Site 1 (upper) and Site 2 (lower). Arrows indicate dune orientation that lie parallel to modeled katabatic winds [5].

Katabatic wind maps have been produced from polar veneer orientations and mesoscale modeling [11,15]. Collectively those data show that Polar Chasma and re-entrants are effective pathways for funneling winds. Site 1 lies downwind of an Olympia Cavi re-entrant. The most recently active dunes in this region were proposed to be formed by katabatic winds from Olympia Cavi [14]. Site 2 lies downwind of the Chasma Boreale katabatic wind system.

Our Hypothesis: Near surface ice deposits in polar dunes are susceptible to enhanced sublimation by drying off-pole katabatic winds, particularly downwind of Chasma.

We estimate the reduction in relative humidity of katabatic winds that blow from the north polar cap at Ls= 110°. The predicted partial pressure of water vapor over the north polar water-ice cap can be estimated using measured temperatures and the Clausius-Clapeyron relation:

$$P_{cap} = P_o \exp\{-\Delta H/RT_{cap}\} \quad \{1\}$$

Where P_o(ice) = 3.47 x 10^{12} Pa, the change in enthalpy required to vaporize one mole of ice to water vapor, ΔH(ice vapor) = 50.87 kJ/mole [17], and R = 8.3147 J/mole/K, the gas constant. Using the measured temperature near the center of the north polar cap of T_{cap} = 223 K, we get a partial pressure of water vapor over the cap of 4.22 Pa.

Katabatic winds off the cap to Olympia Undae, which is 2.6 km below the altitude at the top of the cap, will raise the temperature to 234.7 K. Inserting this temperature into Eq. 1 gives a partial pressure of water vapor in equilibrium with water ice at Olympia Undae of 16.5 Pa. However, the scale height of the total atmospheric pressure is 10.8 km, so the surrounding pressure at Olympia should be reduced by a factor of exp(-2.6/10.8) = 0.781. The water vapor pressure at Olympia Undae is then 4.22/0.781 = 5.4 Pa, which is lower than the frost-point pressure at its observed temperature, 16.5 Pa.

Therefore, water ice initially at or near the surface of the dunes will sublimate to the atmosphere until the relative humidity just above the surface becomes equal to the actual frost-point value. This will increase the thickness of the upper dry layer of the sand. This hypothesis may be tested by looking for geomorphic signatures of near surface ice in the dunes in the study areas.

Conclusions:

- A heterogeneous distribution in the deconvolved epithermal count data suggest variability in the water equivalent hydrogen abundance of polar dunefields.
- Off-pole katabatic winds that drain Chasma have the potential to desiccate regolith, and highly porous dune sands are particularly susceptible.
- Other polar dunefield sites do not show similar levels of desiccation of the upper meter of sediment. This may be due to areas of ice-rich substrate in their interdunes and/or their distance from Chasma.
- Further modeling of katabatic wind interaction with circum-polar dunefields is required.

References: [1] Feldman, W.C. et al., (2008) *Icarus* 196, 422-432. [2] Putzig, N.E. et al., (2010) Planetary Dunes Workshop, abs. #2037. [3] Titus, T.N. et al. Planetary Dunes Workshop, abs. #2034[4] Hayward, R.K., et al., (2010) U.S. Geological Survey Open-File Report 2010-1170. [5] Masse, M. et al., (2012) *EPSL*, 317, 44-55. [6] Teodoro, L.A. et al. (2011) AGU, Abs. # P23A-1705. [7] Teodoro, L. et al. (2010) EGU Abs. [8] Feldman, W.C. et al., (2002) *Science* 297, 75-78. [9] Selby, M.J. et al., (1974) *NZJGG*, 17 (3), 543-562. [10] Lancaster, N., (2002) *AAR* 34 (3), 318-323. [11] Cresswell, R.G., (1988) *GRL*, 15 (4), 342-345. [12] Howard, A.D., (2000) *Icarus* 144 (2), 267-288. [13] Smith, I.B. et al., (2010) *Nature* 465 (7297), 450-453. [14] Russell, P. et al., (2008) *GRL*, 35 (23). [15] Ewing, R. et al., (2010) *JGR*, 15 (E08005). [16] Appéré, T. et al., (2011) *JGR*. 116 (E5), E05001. [17] Möhlmann, D.T.F., (2004) *Icarus* 168, 318-323.