CURRENT RESURFACING RATE OF THE NORTH POLAR LAYERED DEPOSITS, MARS. M.E. Landis[1*], S. Byrne[1], I.J. Daubar[2], K.E. Herkenhoff[3], C.M. Dundas[3] [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ (*mlandis@lpl.arizona.edu), [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, [3]United States Geological Survey Astrogeology Science Center, Flagstaff, AZ

Introduction: The North Polar Layered Deposits (NPLD) are made up of layers with varying ice and dust content, interpreted to contain a climate signal [1-3]. The North Polar Residual Ice Cap (NRIC) is commonly thought to be the currently forming layer of the NPLD, and understanding its surface age and mass balance are key to interpreting the remaining layers.

Previous work has placed a range of surface ages on the NRIC, from 8.7 kyr [4] to ~10-20 kyr [5] to <120 kyr [6] based on crater counting with data sets of varying resolutions. The most recent work on this topic concluded from a HiRISE survey of the crater population, that the surface could be as young as ~1.2 kyr [7]. This work also presented lifetimes of craters on the NPLD based on two crater production functions: Hartmann [8] and Daubar et al. [9]. Finally, we know from observations [5,7] of these small (<400 m diameter) craters that some have bright material present within them, suggesting accumulation of some kind is occurring within craters in the present martian climate.

We present work estimating the accumulation rate of the NRIC by using the lifetimes given in [7] and idealized crater geometries to estimate how fast craters are filling in. We then use that information to tune numerical models that tell us more about recent conditions (e.g. atmospheric water vapor content) at the NPLD surface. Using these conditions, we run the same thermal model for flat terrain to estimate the current accumulation rate of the NRIC.

Crater lifetimes: Crater lifetimes for the NPLD were calculated in [7] by dividing the fit to the differential crater size frequency distribution (SFD) (in units of craters km^{-3}) by the production function (PF) (in units of craters km^{-3} yr^{-1}). There is an order of magnitude difference in the lifetimes of craters on the NRIC depending on which production function is used. There is a scaling applied to the crater SFD described in [7] to account for the material strength differences between the targets of craters the PFs were based on (rocky) and the material of the NRIC (icy). This means that the infill rates are likely a minimum, as the surface age is younger when material strengths scaling is included. However, the exact effective material strength of dusty ice is not well known, so scaled lifetimes assuming a 1 MPa estimated strength are reported to illustrate this effect. The lifetime table from [7] is reproduced here as Table 1.

Infill rate within craters: We calculate the infill rate within craters by first assuming that each crater started out as a simple crater with a depth/diameter (d/D) ratio of 0.2. This is consistent with digital terrain models (DTMs) of pristine NPLD craters [7]. We can measure the diameters using High Resolution Imaging Science Experiment (HiRISE) data (the highest resolution images available at time of writing) and then calculate the infill rate necessary to fill the crater in the calculated lifetime. A table showing these values for 200 m and 60 m diameter craters are included in Table 2.

Table 1. Crater lifetimes calculated from the size-frequency distribution and PF.

	Hartmann [2005]	*Daubar et al.* [2013]
Unscaled crater lifetime	4.23×10^{5}* $D(km)^{1.47\pm0.47}$	1.48×10^{3}* $D(km)^{0.07\pm0.59}$
e.g. 100 m diameter crater	14.3 kyr	1.26 kyr
Scaled (1MPa) crater lifetime	1.84×10^{4} $*D(km)^{0.82\pm0.74}$	64.5 $*D(km)^{-0.70\pm0.82}$
e.g. 100 m diameter crater	2.78 kyr	0.32 kyr

Table 2. Crater lifetimes calculated from Table 1 above, and estimated infill rates based on 0.2 d/D crater geometry.

	Daubar et al. (2013)		Hartmann (2005)	
Crater diameter (m)	200	60	200	60
Lifetime without scaling (kyr)	1.3	1.2	39.7	6.8
Average infill rate (cm/yr)	3.0	1.0	0.1	0.2
Earth years to 1 HiRISE bin1 pixel change (assuming 20° slope)	3.6	11.1	108.4	61.6

As a bright icy material fills a crater, it expands in plan-view. We calculate how long it would take for a 1-pixel change in the plan-view radius of the bright material to be expected in HiRISE bin1 (0.3 m/pixel) images assuming a crater wall slope of 20°. A few pixel change is predicted in a few to ~10s of Earth years based on the Daubar et al. [9] PF, while Hartmann [8] implies 10s to ~100 Earth years. One observational test of these two interpretations is to see if changes in the bright deposits within craters do occur during the Mars Reconnaissance Orbiter mission, as only the Daubar et al. [9] PF results predict a ~1 pixel change in a few to ~10s of Earth years.

Thermal modeling of crater interiors: In order to refine estimates of water ice accumulation within craters as well as translate intra-crater accumulation rates to a flat piece of terrain outside of the topographic low, we use a 1D semi-implicit model that solves the heat diffusion equation through a stack of layers. We use a density of 925 kg m^{-3} and a thermal inertia of 2100 J m^{-2} K^{-1} $s^{-1/2}$ for the NRIC ice.

We account for the additional radiation flux from the atmosphere based on [10]. We also include the formation of CO_2 frost when temperatures fall below 150 K and account for the subsequent change in albedo of the surface. We use the model described in [11] in order to describe the sublimation of ice within and outside of craters assuming a dry atmosphere. The initial shape of simple craters (parabolic) is diameter-invariant, so we report crater depth/diameter ratio instead of diameter.

The overall effect of crater walls on shadowing the interior and therefore reducing temperature (Fig. 1) and sublimation (Fig. 2) depends on latitude, though overall 0.2 d/D craters reduce the amount of water ice sublimation relative to surrounding flat terrain. For example, at 80 N (Fig. 1 & 2), a surface at the center of a crater will lose ~50 kg of water ice per Mars year vs. ~82 kg/Mars year for a surface outside of the crater. Varying the latitude from 70-90^o N varies the ratio of water sublimation outside/inside of the crater from 1.4-2. Multiple scattering from topography and a non-dry atmosphere will be included in subsequent versions of the model, as well as incorporating data from HiRISE

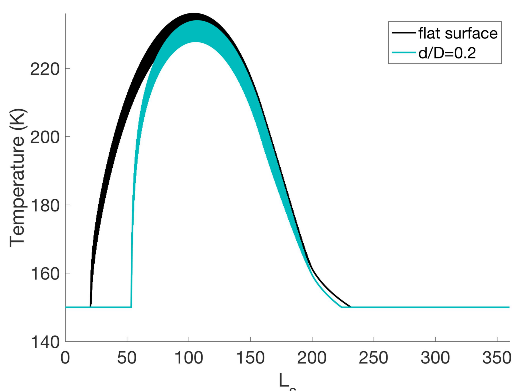

Fig 1. Plot of temperature (K) with season (L_s) for two surfaces at 80^{o}N. The flat surface (black) and surface at the center of a 0.2 d/D crater (teal) reach similar maximum temperatures, though seasonal frost remains longer (shortening the sublimation time) within the crater.

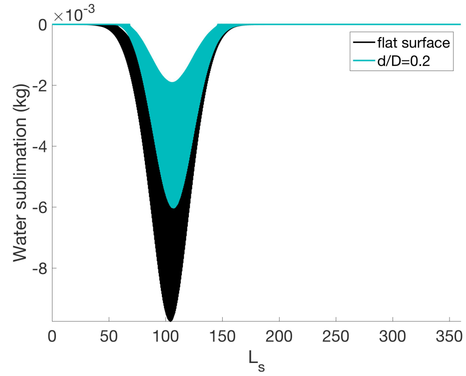

Fig. 2 Water ice sublimation over a year on Mars at 80N is plotted above. The flat surface case (black) results in more sublimation on a diurnal cycle as well as over a Mars year than the case that is at the bottom of a crater (teal).

DTMs to better inform our assumptions about crater geometry.

Preliminary conclusions: While the thermal and accumulation models will be refined in future iterations, a few key results emerge:

(1) Net accumulation within craters is occurring currently on the NRIC at minimum rate of mm to cm a year (depending on which crater PF is used to calculate lifetime). These intracrater accumulation rates are higher than those calculated for the NPLD in the geologically recent past (e.g. [12]).

(2) Craters, while providing shadowing that decreases local surface temperatures, only reduce sublimation of water ice at their centers by a factor of 1.4-2, depending on latitude. Therefore, ice within craters is only weakly protected compared to the surroundings, and the inclusion of water ice condensation in the model is necessary to fully describe the observed infill of bright, icy material within craters.

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