Present-day and (very) recent past influences on trough migration: Measuring the spatial variation in ice sublimation of equatorial-facing spiral trough walls.

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Introduction: The topography and albedo of the martian north polar cap (Planum Boreum) strongly influence present-day and past exchange of water vapor between the planet's surface and atmosphere. In this study, we begin to investigate the role that the spiral troughs, which dissect the north polar layered deposits (NPLD), play in the total amount of water vapor sublimated from the Planum Boreum region.

We are interested in whether there is a measurable lateral difference in the amount of water ice sublimating along the trough walls. Our goal is to answer the following question: do local heterogeneities along a trough wall (i.e., trough wall slope, azimuth, and dust veneers) affect the amount of ice being sublimated over 100's to 1,000-year timescales that is measurable today? Answering this question is needed in order to construct a better understanding of the local scale aeolian removal and depositional processes of ice and dust that have shaped the polar cap in the very recent past. This abstract establishes the problem and tasks that lie ahead.

Motivation: *Spiral troughs.* To interpret the environmental records preserved within the troughs, including the NPLD, the processes behind the formation and modification need to be better characterized. Here, we would like to focus attention to the modification processes at the present-day surface. The evidence of spiral trough migration through time from radar data [1] and modeling [2] plus the detections of low altitude spring-summer clouds within troughs suggest that the sublimation and ablation of ice from the troughs via slope winds plays a vital role in the evolution and shape of the polar ice cap [1,3–6]. Understanding how and why recent past and present-day sublimation varies spatially at the pole can be used to help unravel the record of past climate variability in the Amazonian.

Not every trough behaves the same. Regional and local conditions can cause in situ trough ablation and sublimation rate to vary spatially [4]. Spatial variability in the intermediate to long-term sublimation rate could result from the combined variation in topography of the trough wall, albedo (e.g., dust cover or grain size), and thermal inertia (surface material, grain size, porosity). The effects of these surface characteristics on the local trough evolution are not well understood.

Geologic Context: The equatorial-facing (high side) of the trough walls expose the upper and lower sections of the quasi-alternating bright- and dark-toned layers of the NPLD. [7,8] characterized the stratigraphy of an exceptional NPLD trough exposure, designated as site N0 [9], which showed in HiRISE detail the morphologic differences in the NPLD layering both vertically and laterally. Vertically, the layering alternated between rougher dark-toned marker beds [10,8] to smoother brighter toned layers. [9,11] used the rough versus smooth layer characteristics as a proxy for erosional resistance. Using HiRISE digital terrain models (DTM), [9,11] made protrusion profiles of the layers and matched the marker beds to the most protruding later as identified by [8].

At N0, there is lateral variability in the surface characteristics of the equatorial-facing trough wall. These characteristics are the slope and direction of the wall, as well as the amount of dark mantling debris blanketing the exposed NPLD. This observation is common among other troughs as well [12–14]. Tracking westward along high-side of the trough we see the wall changes its orientation from south to south-east before return to south again (Fig. 1). The wall curves outward away from the pole at this section in the trough (Fig. 1 region B). The slope of region B is 5° shallower than the slope of region A (8° average). Following the curvature of the trough we see an increase in the amount of dark debris mantling and slightly obscuring the NPLD textures. The albedo change due to the veneer continues westward along the trough outside of the HiRISE observation (visible in CTX images). We looked at various overlapping CTX

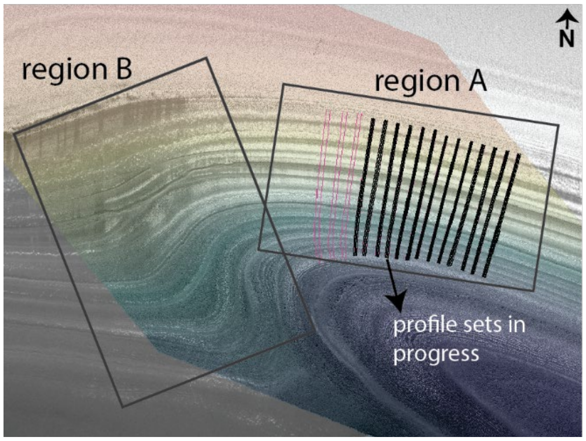

Fig 1. HiRISE DTM (colored) and HiRISE greyscale overlying CTX greyscale image of trough site N0 (87°N 92.8°E). Region A is free mantling dust and debris compared to Region B. Region B is marked by the change in trough direction, shallower slope, and thicker more extensive debris mantle that continues west off of the fig..

observations and HiRISE images from other mars years and found the mantling debris immobile from year-to-year. However, the distribution and extent were likely different 10's and 100's of years in the past.

Why does the trough wall suddenly curve (as do many others)? The answer to this question is likely coupled in understanding the processes the drive the onset of trough formation, which is yet to be fully understood. Has there been a long-term difference in ice sublimation rate between region A and region B (Fig. 1)? Has region A been migrating northward at a faster rate than region B, and why? Can we measure this difference and narrow down the processes responsible?

Methodology: The goal in this work will be to calculate the amount of relative layer protrusion and recession between the erosionally resistant-rough-marker beds and the recessive-smoother-icier layers, which sandwich the marker beds. For this, we focus on trough site N0. We want to see if there is a significant change in the amount that the layers are recessed (via sublimation/ablation) relative to their corresponding protruding marker beds as you move laterally across the trough from region A to B. To do this, we will use the orthorectified HiRISE DTMs [15,16] and take elevation profiles in sets separated by ~100 m. Each profile set will consist of 5 elevation profiles spaced ~10 m apart. This method ensures an average measurement of the protrusion for a given 50 m segment as we move along the trough wall (Fig. 1). Elevation profiles will be drawn near perpendicular to the orientation of the layering.

The elevation profiles will be used to calculate the average protrusion of each 50m segment using methods described by [9,11] as illustrated in Fig. 2a. This method detrends the elevation profile in order to produce a protrusion profile (protrusion in meters vs. elevation) (Fig. 2). Once the protrusion profiles are calculated, the protrusion peaks are identified and matched to their marker-bed as identified by [8,9]. Protrusion measurements are calculated for each marker bed by subtracting the peak protrusion value from the minimum adjacent recessive values connected by a continuum (Fig. 2b). The protrusion calculations for each sandwiched marker bed will be plotted against the trough wall slope, azimuth, and photometrically corrected albedo. We will determine if there is a measurable difference in the lateral in-situ trough ice sublimation and whether any of the following scenarios are possible explanations.

Sublimation Scenarios: If there is a measurable difference between regions A and B, we propose the following scenarios to explain spatial water ice sublimation variability along the high-side of the trough. It is likely a combination of the slope and debris cover cases proposed below. Case 1) thin dust layer would enhance sublimation of ice underneath, which would result in the dust-covered trough to result in more ice being sublimated normal to region B relative to a veneer free region A. Case 2) thick dust cover (>cm) would inhibit sublimation of underlying ice, which would result in region B having lesser difference in the amount of ice sublimated relative to a region A. Case 3) the slope of the trough is shallow, which means seasonal katabatic winds are weaker leading to less ice sublimation relative to adjacent steeper region A. Case 4) the slope of the trough is steep, which means seasonal katabatic winds are stronger, leading to more ice sublimation relative to adjacent shallower sloped wall of region B.

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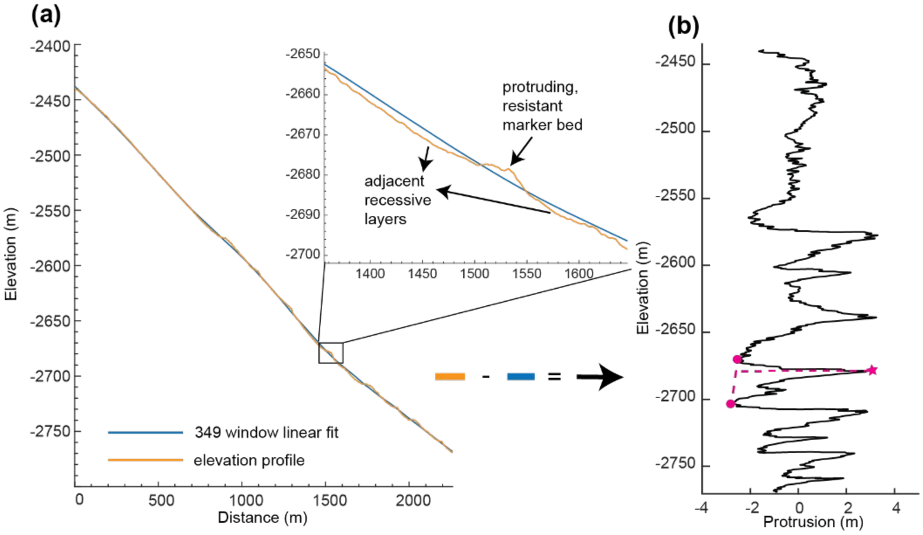

Fig 2. (a) Elevation profile from region A. (b) Protrusion profile made from subtracting the linear fit of the elevation file to the elevation profile. Pink star is the protrusion peak for the marker bed in (a). Pink circles are the minima from the adjacent recessive layers. The pink lines show how protrusion measurements will be calculated for each marker bed using the local minima to create a continuum.