DIFFERENCES IN PALEOClimATE RECORDS IN ICE Mounds IN CратERS NEAR THE NORTH AND SOUTH POLES OF MARS. B. M. Checketts1, M. M. Sori1, A. M. Bramson1, B. Horgan1, 1Purdue University (bchecket@purdue.edu)

Introduction: The polar layered deposits (PLDs) on the Martian poles are believed to contain a paleoclimate record [1]. The layers that make up the PLDs are comprised of different proportions of ice and dust, which could tell us about the climate at the time of formation. Similar to the PLDs, there are layered ice mounds in craters that are polar, but at lower latitudes than, and separated from, the PLDs [2, 3]. These mounds could be a more readable paleoclimate record if they are younger, and their lower latitudes make them more sensitive to obliquity changes.

Past work on the climate record of the PLDs have yielded debated results as to their age and orbital forcing history [e.g., 1]. The ice mounds are less studied as paleoclimate records because there are few known ice mounds with exposed layers to analyze and even less with NASA’s High Resolution Imaging Science Experiment (HiRISE) camera digital elevation models (DEMs) available. Orbital control of the climate would be caused by the period of orbital precession and obliquity changes of Mars, which has been hypothesized as a leading cause of climate forcing. Sori et al. [4] analyzed an ice mound in the southern hemisphere, Burroughs crater (72°S, 117°E), for any signals in the layers that are correlated to orbital forcing in the climate record. They found dominant wavelengths in the layers at 15.6 and 6.5 m, which have a ratio equal to that of the orbital forcing ratio (between orbital precession and obliquity changes) of 2.4. Here we aim to analyze an ice mound in the northern hemisphere of Mars using similar techniques to search for evidence of orbital forcing in the climate record.

Topographic Analysis: We analyzed an ice mound (Figure 1) at 79.13°N, 60.92°E in an unnamed crater, identified as crater 663 in [2]. The crater is 24.60 km in diameter, and the ice mound is 15.45 km in diameter and has a maximum thickness of 1017 m. This crater contains the only ice mound in the northern polar region that has extensive exposed layering suitable for paleoclimate analysis with topographic coverage from a HiRISE DEM. Other ice mounds are likely also internally layered as seen in radar [5], but few have large visible exposures.

Our first step to determine if there is a paleoclimate record within the layers was to look at the topographic properties of the ice mound. We used HiRISE images of crater 663 to analyze it in ArcMap and obtain topographic profiles as seen in Figure 2A. We took profiles across the mound perpendicular to the layers and plotted the elevation of each point against the horizontal distance. On average, the thickness of the exposed layers is 429 meters over a lateral distance of 5,750 meters.

From the topographic profiles, we created protrusion profiles, where protrusion is classified as how much the layers protrude from a background slope [6]. This technique was used because layers that protrude more are theorized to have higher dust content, making them more resistant to erosion, which could be used to interpret the climate at the time of layer formation. We defined protrusion as the normal difference between a point on the topographic profile and the line of best fit with a moving window of 350 meters. An example resulting protrusion profile is shown in Figure 2B.

Figure 1. Image of crater 663, located at 79.13°N, 60.92°E. The blue box is the location of HiRISE DEM DTEPC_062543_2595_062306_2595_A01 used in this analysis. Zoom in of the layers here shown on left (HiRISE image ID ESP_062543_2595).

Figure 2. (A) Topographic profile of the ice mound perpendicular to the layers. (B) Protrusion profile derived from the topography in (A).
Spectral Analysis: To determine if there are wavelengths with significance specifically tied to orbital forcing, we performed a Fourier transformation on the protrusion profiles. We then performed Monte Carlo simulations to determine if any wavelengths were significant relative to red noise. Red noise contains higher power at longer wavelengths and can be attained randomly in climate records [7]. We created 20,000 random protrusion profiles with the same mean, standard deviation, and lag-1 autocorrelation as the real protrusion profile. We tested how often the real protrusion profile had spectral power greater than 95% of the random profiles at a given wavelength. Figure 3 shows the results of the transformation and the confidence test for the protrusion profile in Figure 2B.

![Figure 3. Fourier transformation of the protrusion. The black line is the spectral power of the protrusion, red solid line is the red noise, and red dashed line is the 95% confidence level.](image)

As seen in Figure 3, there are some wavelengths that may be significant, but no pair of them have the 2.4 orbital dynamic ratio. Because the precision of HiRISE DEMs are ~1 m, we only consider wavelengths at 4.04 m or greater that have spectral power greater than red noise to potentially be meaningful. We tested different protrusion profiles and the effects of the size of window used in the protrusion calculation. These tests yielded similar results to those shown in Figures 2 and 3.

Interpretations: The initial topographic profiles suggest that the ice mound layers are smooth. This result is quantitatively confirmed with the protrusion profiles which have a range of less than 4 meters. The Fourier transformation reveals that there is no obvious connection between the layers in the ice mound of crater 663 to orbital forcing. These results contrast with the ice mound in Burroughs crater in the southern hemisphere, which had a protrusion ranging over 80 meters and strong evidence of orbital forcing. There are three scenarios that could lead to these outcomes:

- The northern ice mound is too young to have multiple obliquity and precession cycles recorded within the layers.
- The northern ice mound is eroding through a different process or on a different timescale than the ice mounds in the southern hemisphere.
- The northern ice mound has very low dust content, hindering morphological expression of layer variability.

We analyzed the visible brightness of the ice mound in crater 663 in HiRISE images and found that layers had small brightness contrasts compared to the ice mound in Burroughs. This property could be consistent with the hypothesis of low dust content. We also made a comparison between the slope of the area of the ice mounds with the exposed layers and found that the slope for crater 663 is about 5% whereas Burroughs’ slope is 2%. This property could be consistent with either the young age due to less time for erosion or the differently eroding hypothesis. Future work will provide further tests on distinguishing between different hypotheses.

Conclusions: North polar ice mounds on Mars do not contain the same strong evidence of orbital forcing as the Burroughs ice mound in the south polar region. Instead, we conclude that the way climate is expressed in icy records is significantly different between the two Martain hemispheres, which is consistent with the nearby polar ice caps that are also well established to be quite different in many ways, including age [1].

Acknowledgments: We gratefully acknowledge support from NASA MDAP grant 80NSSC23K107, and Max Cabrera and Matt Chojnacki for production of the HiRISE DEM that formed the basis of some of our analysis.