MARTIAN ICY OUTLIERS AND CLIMATE HISTORY. J. Bapst$^{1,2,*}$ and S. Byrne$^2$, $^1$Dept. of Earth and Space Sciences, University of Washington, Seattle, WA, 98195, $^2$Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, 85721, *jnbapst@gmail.com

Introduction: Louth Crater (Fig. 1) is a ~36 km diameter crater in the northern plains of Mars and hosts a large ~12 km diameter, quasi-circular water ice mound, which lies off-center on the crater floor [1]. This ice mound, although a common feature in northern plains’ polar craters, represents the most-equatorward ($70^\circ$N) example (i.e., on average, it is the warmest perennial surface ice on the planet). Its position makes it potentially sensitive to ongoing climate change, which may be visible through repeated high-resolution imagery over multiple years.

The recent (~1 Ma) climate of Mars is controlled by the flux of incident sunlight (insolation) at the surface. This value changes depending on Mars’ orbital elements: obliquity, eccentricity and argument of perihelion, which vary with periods of 120, 95, and 51 kyr, respectively [2,3]. The stability of water ice on the surface is sensitive to these changes due to the Clausius-Clapeyron relationship, i.e., the quasi-exponential relationship between temperature and vapor pressure of water. How atmospheric water content changes with time is another important factor that we do not yet address in this study.

Here we wish to get a sense of what changes may be in progress in the extent of the Louth Crater ice today. We begin by using insolation as a proxy for ice temperature and later, we plan to model actual temperatures and sublimation rates. We then compare these expectations to changes seen in multi-year HiRISE observations.

Expectations: Using orbital solutions from [2] we calculate changes in insolation at $70^\circ$N for the past 100 kyr (Fig. 2). Mean-annual insolation undergoes smaller variations (<10%) and is currently increasing at present. Maximum-annual insolation experienced more variation (>30%) and is decreasing at present. Interestingly these insolation proxies point to opposite expectations of how Louth Crater ice may be changing. We argue that maximum-annual insolation is a more useful proxy for ice extent (due to the strong temperature dependence of sublimation), but because of poorly known feedbacks (e.g., ice albedo changes and global atmospheric water levels) this assumption remains uncertain. In spite of these reservations, our current expectation is that ice is becoming more stable as peak insolation decreases.

Observations: Our primary observational approach is to identify and track the ice mound extent using high resolution, multiyear image data. We include data from other orbiting instruments to provide insight into the environmental conditions at Louth. Ice mound stability will be evaluated in light of these analyses and our understanding of the current climate.

We analyzed over 20 High Resolution Imaging Science Experiment (HiRISE) images that cover the ice mound. Images were georeferenced to each other in ArcMap in order to identify changes in ice extent.
Daytime Thermal Emission Spectrometer (TES) bolometric temperature and albedo (not shown) data were retrieved for Louth Crater (Fig. 3). These data are crucial for understanding the current conditions of the ice mound and comparison with the global climate.

![Figure 3](2PM TES temperature data for Louth Crater plotted with time of year (Ls). Two different trends are observed outside of seasons when CO2 ice is present. Lower temperatures correspond to the relatively high albedo ice mound, whereas higher temperatures reflect the surrounding, lower albedo terrain.)

The morphology of the boundary, and change in extent of the ice mound, varies with location about the perimeter. In general we can divide boundary appearance/behavior into two geographic categories: the north and south sides of the mound.

The southern boundary of the mound is diffuse with patchy, light-toned material (likely water ice), extending out 100s of meters from the ice-covered surface. This boundary does not show any changes in extent, neither seasonally nor interannually.

By contrast, the northern boundary is more abrupt, hosting patchy ice in some areas but typically not extending from the ice-covered surface more than 10-20 m. The north-northwest side of the mound exhibits a region (~1 km along the perimeter) where ice extent changes are observed (Fig. 4). No other areas along the ice mound boundary showed variation. These changes in extent range from ~5-10 m and include areas of both advance and retreat.

**Discussion:** No compelling evidence for long-term retreat or advance was observed in HiRISE data. We interpret changes observed on the northern boundary as part of seasonal water ice cover and not evidence for long term advance/retreat.

TES temperature data show the mound remains below 200 K at 2PM even during summer due to its high albedo (Fig. 3). On present-day Mars, the calculated frost point for water is ~200 K in the northern hemisphere based on atmospheric water abundance measurements [4].

This supports the notion that the mound is in, or is close to, equilibrium with the current climate. The data also suggest the stability of the ice mound is dependent on its relatively high albedo. Some of the changes we identified in this work may be due to subtle changes in albedo (e.g., dust deposition during storm events, exposure of large ice grains, etc.).

**Future Work:** Although less sensitive to small changes, Mars Orbiter Camera (MOC) images increases the time between observations significantly (up to 8 MY). Comparing ice boundaries between MOC and HiRISE may show more significant, systematic changes. Modeling of sublimation rates will help us link the lack of long-term change observed to unknown climatic variables such as atmospheric water vapor content.

![Figure 4](A sample of multiyear HiRISE images of the northern boundary of the ice mound where ice extent varied. All images are at Ls = 103° to limit the contribution of seasonal ice. Patchy ice extending ~10 m from the mound shows little change from MY 29 to MY 30 but we see substantial variation between MY 30 and MY 31.)