ICE ACCUMULATION AND FLOW ON MARS: ORIENTATION TRENDS AND IMPLICATIONS FOR CLIMATE IN THE LATE AMAZONIAN. J. L. Dickson, J. W. Head, and C.I. Fassett. Brown University, Dept. of Geo. Sci., Providence, RI. jdickson@brown.edu.

Introduction: The study of Late Amazonian ice has shifted in focus in recent years from the detection of glacial-like landforms to the detailed characterization of their morphology, distribution and present-day composition [1]. While small ice-related features have formed within the last ~10 million years (viscous flow features (VFF) [e.g. 2], gullies [e.g. 3], high-latitude mantling [e.g. 4], polygonally patterned ground [e.g. 5]), glacial features (lobate debris aprons, lineated valley fill, concentric crater fill [1, 6]) are tens to hundreds of millions of years old [1, 7], pre-dating the era when the spin—axis/orbital behavior of Mars are well determined [8]. Hence, we use the nature of these remnant glacial deposits to tighten constraints on the climate of Mars that permitted their emplacement [9].

More specifically, the past climate of Mars should be reflected by the distribution and flow properties of ice-related deposits that we observe. While it is known that mid-latitude glaciers on Mars have been at least a kilometer in thickness [1,10-13], it is unknown whether Mars hosted continental-scale ice sheets (*hemispheric*), plateau ice fields (*regional*), or solely isolated glaciers (*local*). To assess where Late Amazonian Mars falls in this spectrum, we have begun a survey of Context Camera (CTX) [14] data and are cataloging glacial-like features (LDA, LVF, CCF) with two variables in mind that are sensitive to climatic conditions: latitude, and orientation of flow. Detailed mapping of orientation could point back to hemispheric, regional, or local ice accumulation zones.

Method: We have begun analysis of selected CTX imagery through mission phase B09 (May, 2009) and confined to 20°-60° in each hemisphere, due to the relative paucity of ice-related features in the tropics and the obscuration of glacial features at high-latitudes by a pervasive young mantling unit [4, 15]. While all glacial features are being cataloged, orientation measurements are being made only on glacier-like features confined to well-preserved impact craters (traditionally referred to as "concentric crater fill") that provide 360° of available aspect angle upon which ice could accumulate. Orientation measurements are also made on much younger features (gullies and VFF) in order to assess possible parallels among features from separate periods of the Late Amazonian. Measurements are being made in Mercator projection to preserve angles and within a GIS database to prevent redundant sampling.

Preliminary Results: The selection of CTX data will allow us to construct the largest database of ice-related features on Mars (Fig. 1). Glacier-like features are common in each hemisphere poleward of 30°. In the northern hemisphere, glacier-like features are most abundant in regions predicted by climate models [16] to be the most suitable areas for accumulation of ice in the Late Amazonian (Phlegra Montes, Duteronilus/Protonilus Mensae, Acheron Fossae, etc.). The roughness of the southern highlands yields a broader concentration of glacier-like features across the mid-latitudes, though previously recognized regions of increased activity (eastern Hellas, Argyre, etc.) appear to show a higher concentration of remnant features [17-18].

Glacier-like features within well-preserved impact craters, which is the subset we are using to perform our orientation measurements, follow the same global distribution trends as all other glacier-like features (LDA and LVF), suggesting that the only significant distinction among these features is the local topographic setting within which they are found. Equatorward of 45° in each hemisphere, glacier-like features are showing a very strong poleward trend (i.e. they flow from the pole-facing wall towards the floor of the crater) (Figs. 2-3). Small variations between the southern and northern hemispheres appear to be present (the northern hemisphere appears to transition to more concentric flow at a slightly lower latitude than the southern hemisphere), but our accumulating data generally show that the orientation of flow in the mid-latitudes of Mars is symmetric across the equator.

Gullies, which have formed within the last several million years [3, 19-20], also show trends with regard to orientation as a function of latitude [21-26]. The studies that revealed these trends have had difficulty, however, removing (1) potential targeting bias from the comparatively small-footprint of the Mars Orbiter Camera (MOC), and (2) poor statistics from the small sampling of gullies in the northern hemisphere. Therefore, we are including gullies within our broader CTX survey and only measured orientations for those found within craters that are fully imaged.

Our preliminary data suggest that gullies follow the identical latitude-dependent orientation trend as glacier-like features (e.g. Fig. 3). Our measurements thus far are consistent with all surveys of MOC and THEMIS data performed on southern hemisphere gullies [21-23, 25], and the work of *Kneissl et al.* [26], who used High Resolution Stereo Camera (HRSC) data to show that northern hemisphere gullies mirror the orientation trends of their southern hemisphere counterparts.

Discussion of Preliminary Results: The apparent poleward trend of glacier-like features in the lower mid-latitudes suggests that the final stage of glaciation across these latitude bands was largely controlled by micro-climates, where pole-facing slopes served as accumulation zones for ice. Conditions appear to have been such at higher latitudes in each hemisphere to permit accumulation of ice on all steep slopes, independent of orientation.

Preliminary data suggest that this trend for glacier-like features appears to be identical to that of gullies, and this may indicate that they formed in the same places for the same reason: each feature is found where ice is most likely to accumulate [27]. This is also where contemporary H_2O frost deposits have been observed [28-30]. Preliminary results suggest that glacier-like features may reflect a period when the climate promoted accumulation on pole-facing slopes at lower latitudes and all slopes at higher latitudes. Under conditions more typical of the last few million years [15], the climate has permitted smaller amounts of accumulation on these same slopes, but also has removed this ice either by sublimation or by melting, contributing to the formation of young gullies.

Since glaciation in the mid-latitudes of Mars is likely to have been cold-based and unlikely to have yielded much or any erosion of the underlying surface, it is possible that hemispheric or regional glaciation was present in the Late Amazonian. Our preliminary results suggest that the most recent phase of glaciation on Mars occurred in a climate conducive to localized accumulation of ice, which formed glaciers that often integrated into larger glacial landsystems [31-32].

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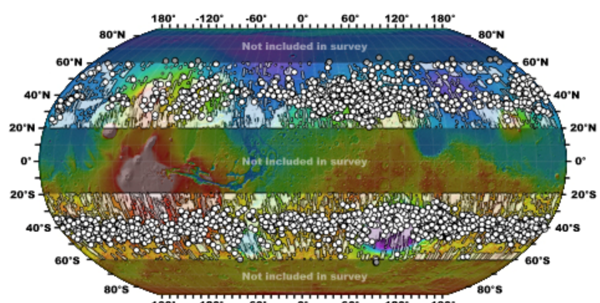

Figure 1. Map of all CTX footprints identified for examinaton; suspected glacial-like features identified in preliminary survey are shown as a separate layer.

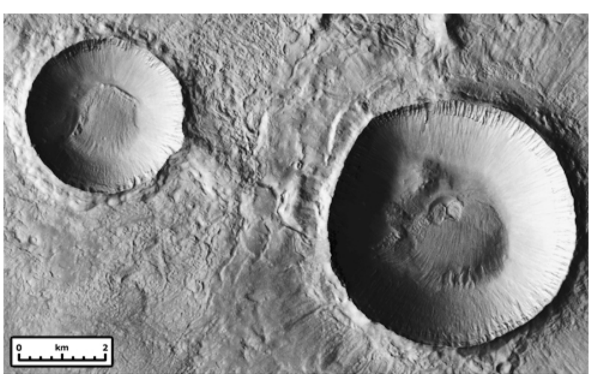

Figure 2. Neighboring craters with identical fill deposits emanating from the southern (pole-facing) slope. CTX orbit P17_007619_2153 (latitude = 34.8°).

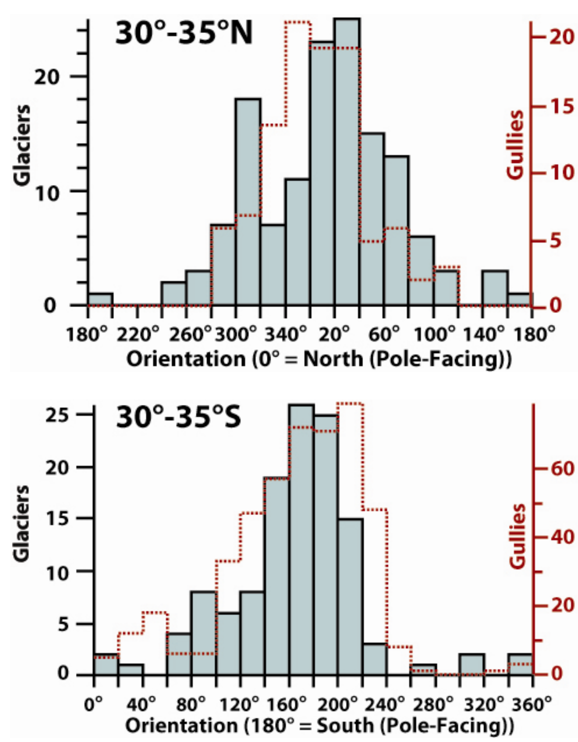

Figure 3. Example of orientation plots of preliminary data for the lower mid-latitudes of the northern (top) and southern (bottom) hemispheres. Glacier-like features are plotted in blue with black outline while gullies are plotted in red.