A Conceptual Model of Equatorial Ice Sheets on Mars.

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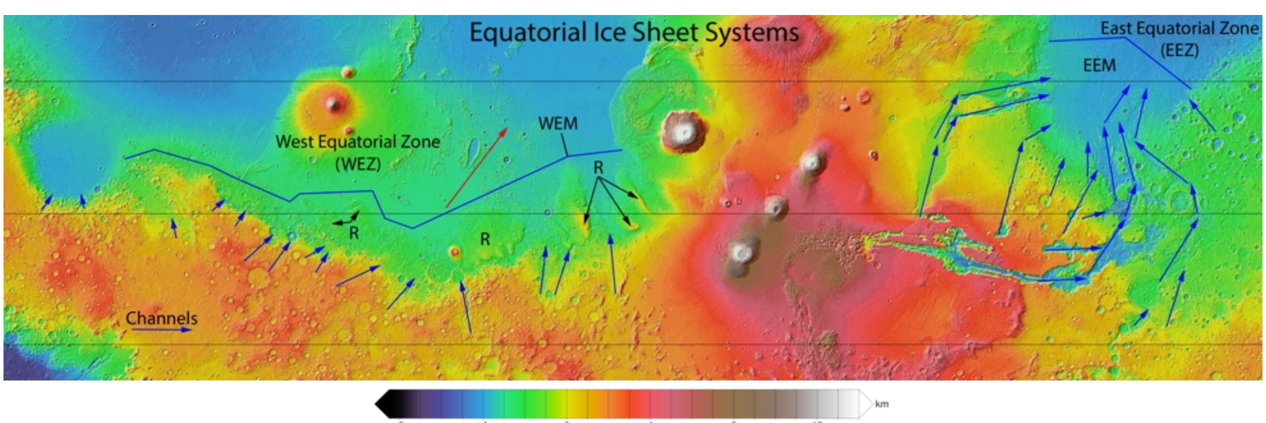
Introduction: Interpretations of mid-latitude ice-rich flow features [1,2] and the new historical perspectives on Mars climate have made the concept of cycles of "snow and glaciation" at mid-latitudes on Mars seem plausible. As mid-latitude glaciation was once thought impossible, so too may it pass for equatorial glaciation. I present a glacial interpretation to the outflow channel problem of the regions east and west of Tharsis, referred to here as the east (EEZ) and west equatorial zones (WEZ) (Figure 1). Ice mantling events during early Mars history, and perhaps more recently to lesser degrees, may have spawned ice sheet systems capable of channel erosion and material transport. I suggest that regional slopes related to the elevation dichotomy of Mars have generated glaciers and ice sheets responsible for erosion and deposition commonly attributed to floods.

I also suggest that two key Valles Marineris east/west erosional disparities are primarily the consequence of a relative lack of glaciation in the west due to elevation related climate restrictions. I suggest that the greater channel widths and chaotic terrains seen in the EEZ, compared to the more restricted channeling in the equatorial regions west of Tharsis, are likely the result of enhanced incision and erosion related to extensional [3] and geothermal effects [4] possibly related to Tharsis intrusions. Ongoing research covers the formation relationships of Dao Vallis [5,6] and Hadriaca Patera, and Elysium Mons and it's flank channels, and how these may shed light on the evolution of equatorial channeling and terrains.

In addition, it seems reasonable now to assume that the curious and probable icy deposits (such as the Medusae Fossae formation) in the WEZ, are remnants (R in Figure 1) of a far more vast ice sheet system that I refer to as the west equatorial mantling (WEM). These remnants have been subjected to a long history of ablation through sublimation and perhaps melting. The stream-lined forms of portions of the remnants suggest some preferential modification. The potential WEM remnants may have been sculpted by wind, with inherent ice fraction inhomogeneities related to ice histories further affecting remnant modification. By contrast, EEM remnants may be restricted to the many repositories of the fretted or chaotic terrains of the EEZ.

Climate Modeling and Glaciation: Interpret and compare "ongoing" mid-latitude glacial activity and glacial erosion dominated terrains with equatorial terrains of presumably similar origins, albeit born of different climate histories. Today, near surfaces out to about 20 degrees latitude or more from the equator are mostly ice free, and the mid-latitude zones (30-50 degrees) are presently in a glacial or post glacial era of some sort. But, what about historically? To solve the surface ice related riddles of Martian history, we must "sync" global geomorphology and surface ages to climate and surface ice redistribution models. Glaciation is key to Mars surface *and* climate history.

Figure 1: The west equatorial zone (WEZ) is separated from the east equatorial zone (EEZ) by the Tharsis rise, but share potential ice sheet generating slopes of the crustal elevation dichotomy (transition from orange to green nearer the equator). *Blue Arrows:* Lines of arrows indicate major channel locations, arrow heads indicate flow directions. *Blue lines:* Indicates my "conservative" interpretation of the downslope extent of the proposed west equatorial mantling (WEM) and east equatorial mantling (EEM), based on geomorphology. Looking eastward, I propose that the outflow channels were primarily glacially eroded as a consequence of one or more east equatorial mantling (EEM) events. In the west, formations interpreted here as WEM remnants (R) stand kilometers high in some cases, suggesting a "relatively recent" equatorial mantling event. *Red arrow:* Channels that extend beyond WEM, suggesting more expansive WEM advances or other processes. Horizontal lines indicate the equator and the thirty degrees latitudes. Thirty degrees of latitude spans 1,779 km. MOLA.



Analogs: Think of ice streams sharing a common slope. Useful analogs for more confining topography are the outlet glaciers of the dry valleys of Antarctica. They are polythermal valley glaciers in form, but flow out of ice sheets in cold based accumulation zones. They spread to fill and erode confining topography like valleys, waxing and waning through history. For less confining topography, good analogs are the ice streams generated within ice sheets, which flow through and from them like ice declaring independence via basal sliding. However, to find terrestrial analogs that share such constant and expansive slopes as those of the Mars elevation dichotomy is impossible. Thus we must examine relevant elements of present day glacial systems to better interpret and explain the proposed equatorial or "elevation dichotomy" glaciations of Mars.

Ice Sheet Modeling: Polythermal ice sheet systems on the Earth are capable of limited erosion and this probably describes the general erosive state Mars - a planet as much like the Moon as it is like the Earth in terms of what degree it's surface has been modified since formation. Figure 2 shows a conceptual profile of a polythermal ice sheet or ice stream. At higher elevations (zone 1), accumulations are not of adequate thicknesses due to elevation and climatic to induce significant regional flow, or slopes are less than those required for significant regional flow. Moving downslope to zone 2, ice flow is limited to the cold based variety, which do not experience basal sliding, meaning very little to no erosion can occur. Further downslope in zone 3, the pressure melting point of ice can be attained at the base of the ice sheet (represented by 273 K), inducing basal sliding and erosion. Downslope of the basal 273 K point, the ice sheet may experience reducing thicknesses due to warmer average surface temperatures. Further downslope in zone 4, where accumulation may lag ablation and slopes may decrease, deposition occurs. In terminal zones (zone 5), where ice fractions are generally minimal, depositional suites may mark the furthest extent of previous advances. In both zones 4 and 5, ice fractions are much reduced and thus ice sheets may take on more varied debris-covered to rock glacier ranges of assemblages.

Thicknesses and velocities: Thicknesses of ice sheets are partly controlled by geothermal gradients because of feedback effects. The heat budget is also impacted by frictional heating. Thicknesses decrease downslope because of increasing average surface temperatures, which reduces the thickness necessary for basal 273 K. Flow velocities are greater where basal sliding occurs, leading to a loss of ice volume and consequent thinning. Velocities increase downslope from accumulation zones due to increasing wet-lubricated sliding. Thicknesses relate directly to velocities because there must be an ice mass balance of accumulation, transport, sublimation, and melting. Put simply, geotherms relate to basal sliding, which relates to thicknesses in a mass balance feedback loop. Moving further downslope, ablation rates increase to the point that thicknesses become less predictable.

References: [1] Arfstrom J. D. and Hartmann W. K. Icarus, 174, 321-335. [2] Arfstrom, J.D. LPSC Abstract, XXXIV, 1050. [3] Arfstrom, J.D. LPSC Abstract, XXXV, 1193. [4] Arfstrom, J.D. LPSC Abstract, XXXV, 1105. [5] Arfstrom, J.D. LPSC Abstract, XXXIV, 1208. [6] Arfstrom, J.D. LPSC Abstract, XXXIII, 1092.

Figure 2: A Polythermal Ice Sheet Model (PISM) Profile. Zone 1: Pre-accumulation zone. Inadequate accumulation for thicknesses or slopes required for significant regional flow. Zone 2: Accumulation zone. Cold based. Zone 3: Erosional zone. Polythermal based. Zone 4: Depositional/ablation zone. Zone 5. Terminal zone. Maximum advances.