DELINEATING WATERSHEDS ON MARS. W. Luo[1], R.A. Craddock[2], A.D. Howard[3], X. Cang[4] [1]Norhtern Illinois University (wluo@niu.edu), [2]Smithsonian Institution (craddockb@si.edu), [3]Planetary Science Institute (ahoward@psi.edu), [4]Unversity of Maryland, Baltimore County (xuezhicang@gmail.com).

Introduction: There is an important conundrum regarding the early Mars climate: while geomorphic, geochemical, and geologic evidence points to an early warm and wet Mars with an active hydrologic cycle, some climate models have difficulties in producing the necessary warm and wet conditions [e.g., 1,2]. Quantitative morphometric analysis of the landforms at basin scale can provide valuable information to infer past processes and climatic conditions that created the observed landforms. Delineating watershed boundary is critical in supporting these types of investigations.

GIS-based tools for the automated delineation of watershed boundaries using digital elevation (DEM) data are common in terrestrial studies. This generally involves the following steps: (1) filling smaller sinks to make the DEM drainable, (2) deriving flow directions based on the steepest surrounding descent at a pixel scale (D8 direction), (3) calculating the flow accumulation along the direction of flow, (4) setting flow accumulation above a threshold as streams, and (5) forming watersheds by grouping cells flowing into streams [e.g., 3-5]. Similar approaches have also been applied to Mars [e.g., 6]. However, higher resolution data is now available [7] and higher fidelity valley networks (VNs) have been mapped/extracted [8-10]. It is time to take advantage of these newly available data and revisit this topic. As part of a project to address the early Mars climate conundrum at a global scale from the basin morphometric analysis perspective, this abstract demonstrates a new approach to delineate Martian watershed basins based on previously mapped VNs and higher resolution topography in the Mare Tyrrhenum (MC-22) quadrangle.

Method: Manually mapped VNs are more integrated and look more similar to terrestrial streams because they are based on high resolution images [e.g., 10]. However, they do not always follow the flow direction as indicated by the topography. Computer extracted VNs based on terrain curvature [8] do follow the flow direction, but they tend to be segmented and disconnected at places. To take advantage of both mapped and extracted VNs, we accept their uncertainties and use them (converted to raster) as the weights for the D-Infinity Decaying Accumulation tool in TauDEM [11] to find VN locations that are consistent with the surrounding topography and use the adjusted VN locations as the basis for deriving the watershed boundaries. D-Infinity Decaying Accumulation was originally designed to find how an input mass load (e.g., pollution) would be distributed across the landscape as it moves in a D-infinity flow field subject to first order decay [11]. There are two key inputs: one is the weight grid, which specify where the mass load is located; the other is decay multiplier grid, which gives the fractional (first order) reduction in accumulating from cell to cell along D-infinity directions [11]. For our purpose, we converted the VN lines to raster and set VN location to 1 as the weight grid; for decay multiplier grid, we set non-VN locations as 0.5 and VN locations as 1. Using this tool this way avoids the indefinite accumulation of flow downstream far beyond the VN locations that would result from using regular flow accumulation in GIS software. Our assumption here is that the mapped/extracted VN provided a good first cut of the VN, and the D-infinity decay accumulation would further adjust their location based on topography and thus lead to better watershed boundary delineation. The other reason we choose the TauDEM is that it is built with full parallel processing capability [11], suitable for processing large global datasets in our project. Specifically the following steps are involved: (1) fill the depressions up to 600 m [6], (2) obtain D-infinity and D8 flow directions, (3) use D-infinity decay accumulation tool as described above to adjust VN location according to topography, (4) threshold the accumulation (using 0.5 as threshold) and group them based on spatial adjacency as pour points (i.e. spatially adjacent cells will receive the same ID and will generate the same watershed in next step), (5) extract watershed flowing into these pour points (still using D8 flow direction since there is no watershed tool for D-infinity direction), (6) eliminate or merge smaller polygons with area less than 10 km^2.

Results: The resulting watersheds and the mapped/extracted VNs are shown in Figure 1. An enlarged view of an example watershed (outlined in red) and the D-infinity decay accumulation are shown in Figure 2. In general, the watershed boundary delineated with this method encloses the mapped/extracted VN. After more refinement of the parameter values, this method will be applied to the whole of Mars to support a number of basin-based morphometric analyses to help test different theoretical climate scenarios, including Hack's law, basin hypsometry, circularity, relief, and valley incision depth. One example of Hack's law exponent for the red watershed is shown in Figure 3, which is similar to typical terrestrial value.

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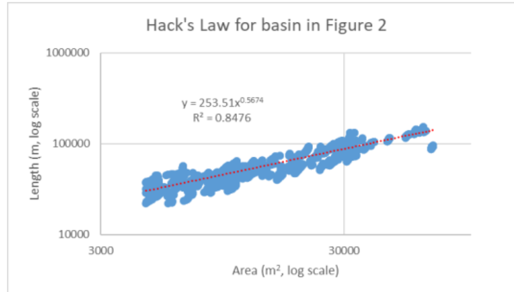

Figure 3. Example Hack's Law for basin in Figure 2.

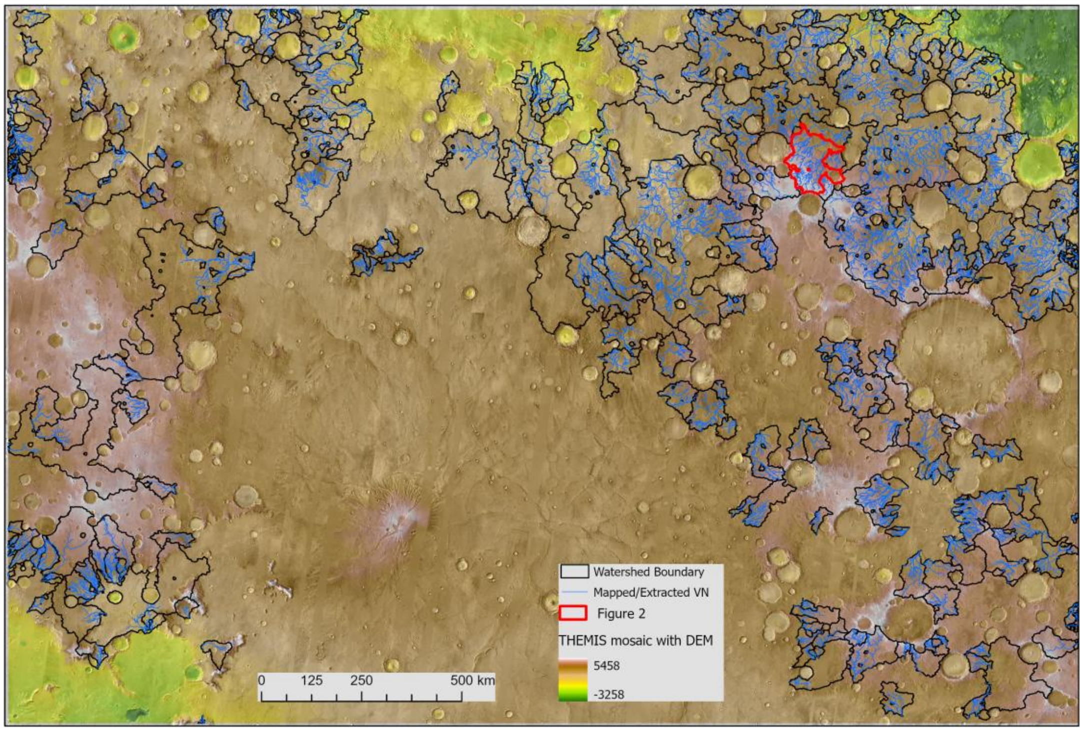

Figure 1. Watershed extracted for Mare Tyrrhenum (MC-22) quadrangle.

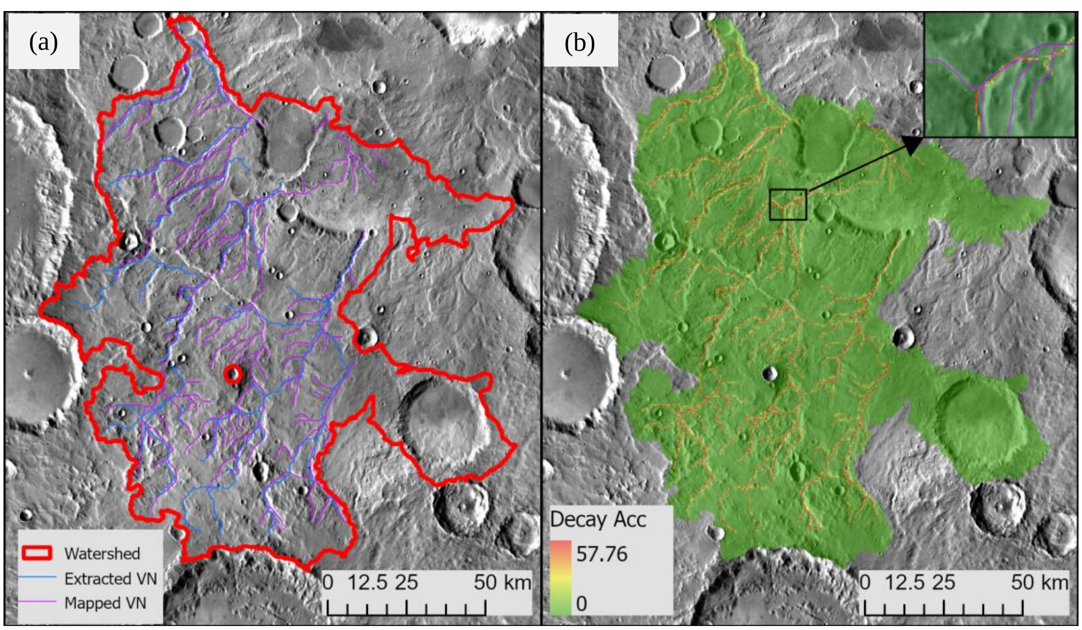

Figure 2. Zoomed-in view of red watershed in Figure 1. (a) VNs with THEMIS mosaic in the background. (b) D-infinity decay accumulation with THEMIS mosaic in the background. The inset map shows a close-up of the boxed area with mapped VN and D-infinity decay accumulation, adjusting VN location to follow topography.