OROGRAPHIC PRECIPITATION IN TERRA CIMMERIA: TOWARDS NEW CONSTRAINTS ON THE CLIMATE OF NOACHIAN MARS. K. E. Scanlon[1], J. W. Head[1], J.-B. Madeleine[1], R. D. Wordsworth[2], F. Forget[2] [1]Department of Geological Sciences, Brown University, Providence, RI USA [2]Laboratoire de Météorologie Dynamique, CNRS/UPMC/IPSL, Paris, France.

Introduction: Most of the existing work [e.g. 1] arguing that Mars's Noachian valley networks were nivial or pluvial in origin does so on the basis of drainage density, and as such rejects a groundwater / hydrothermal origin rather than directly confirming snowmelt or rainfall. But if precipitation was responsible, orographic lifting forced by the cratered Noachian terrain would have strongly influenced the distribution of precipitation and hence of the valleys.

To test the idea that the Noachian networks bear the signature of orographic precipitation (OP), we combined a pre-existing parameterization for the orographic component of precipitation with MOLA topography, large-scale climate fields from the LMD's Early Mars GCM [2], and high-resolution imagery of Terra Cimmeria. Within this framework, we hope to develop new constraints on the Noachian climate.

Orographic Precipitation: Topography has multiple influences on the development of clouds and precipitation, most directly by forcing lifting on the windward side of a ridge (causing the air to cool and moisture to condense) and downward motion on the leeward side (causing adiabatic warming and evaporation of any condensed water). Unless the ancient Martian atmosphere was as thin as the present one [3], any Noachian precipitation should have been influenced by these effects. This by itself does not necessarily conflict with the hypothesis that the networks were formed by precipitation in an intertropical convergence zone or in large-scale storms [e.g. 4]; while in some terrestrial climates orographic lifting alone produces rain [e.g. 5], most terrestrial orographic precipitation occurs as local enhancement of precipitation from a synoptic storm [6]. Therefore, if the valley networks were formed by precipitation, at a minimum they should reflect *enhanced* water supply where orographic lifting is predicted.

Methods: In the absence of a mesoscale model for early Mars, a downscaling approach is necessary to enable a feature-by-feature comparison of modeled precipitation and observed networks. The analytical orographic precipitation model of Smith and Barstad [7] uses large scale wind, moisture and temperature profiles to determine the component of precipitation that lifting by a given topography would add to the background precipitation rate. It was developed for terrestrial use, but its derivation contains no assumptions that prevent its application to Mars.

This model was applied to 128 pixel per degree MOLA topography from a region of Terra Cimmeria. Lapse rates, typical wind speeds, and other climate data are from the LMD's Early Mars GCM, run at 25° obliquity with a 1-bar CO_2 atmosphere. While it represents only one of many possible Noachian climate scenarios [2], a GCM run provides plausible and physically self-consistent climate variables. For the results shown here, wind in the OP model was fixed at 5 m/s northerly, and precipitation fall speed was set consistent with snow rather than rain.

Initial results were compared with a recent, publicly available valley network map that was made using 230 meter resolution THEMIS daytime IR imagery [8]. In the region of study, which is densely dissected for Mars, many smaller valleys not mapped by [8] were visible in 100 meter and 50 meter images from THEMIS, CTX and HRSC, and these were mapped and added to the data set.

Results: Comparing the region of interest with the valley networks mapped by [8] and our additions, the correlation between larger valleys and broad regions of precipitation is apparent, e.g. on the northeast-facing slopes of the wide ridge in which Herschel crater is embedded (Figure 1). The south-facing slopes of that ridge (not shown) are also dissected by large valleys, though less heavily than the north slopes. Southerly/westerly winds predominate for part of the year; the south-facing valleys could be explained by water vapor carried from a large source southwest of the ridge, such as Hellas basin.

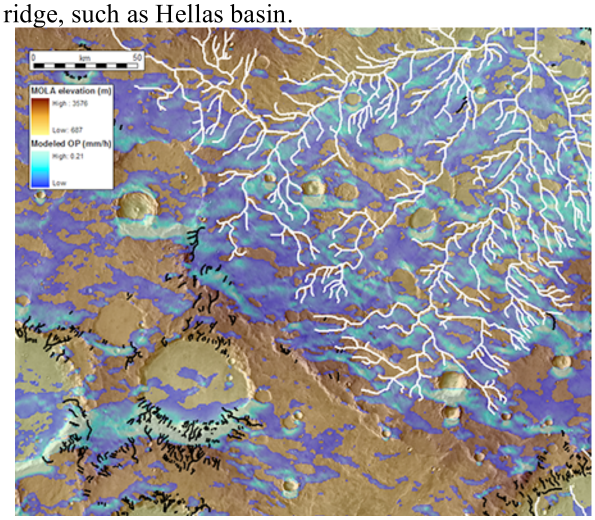

Figure 1. *Modeled Orographic Precipitation (translucent blue) on a MOLA-shaded THEMIS basemap. Valleys mapped by Hynek et al. (2010) are shown in white; newly visible valleys are shown in black. The image is centered near 10°40'S, 125°25'E.*

The results also closely resemble observations at small scales. Figure 2 shows one of the better fits, where the only major apparent mismatches are due to younger superposed craters on the crater's southeast rim. Figure 3 shows one of the poorer fits in the region of study, where a large arc of valleys on the eastern rim is unaccounted for by the OP model. This may reflect wind direction variability that cannot be accounted for in a single run of the OP model, or that non-orographic background (e.g. convective) precipitation was significant in this region.

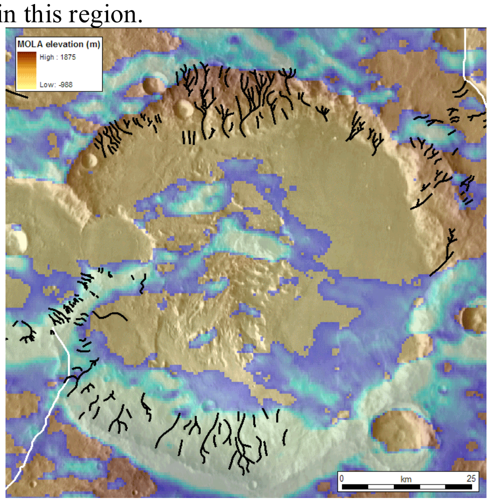

Figure 2. *A crater whose valleys are well explained by precipitation from orographic lifting in a northerly wind. The image is centered near 2°58'S, 115°44'E.*

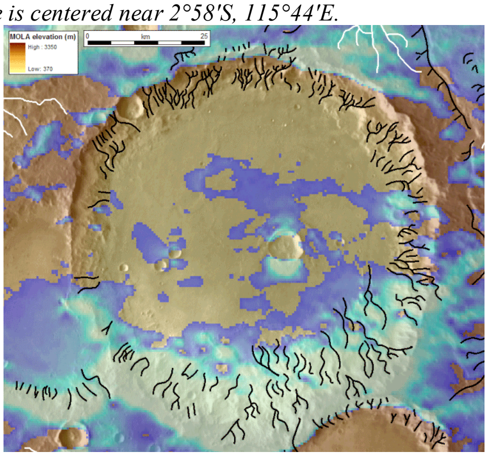

Figure 3. *A crater whose valleys are less fully explained by precipitation from orographic lifting in a northerly wind. The image is centered near 5°49'S, 122°6'E.*

Phase also affects the distribution of orographic precipitation: liquid hydrometeors fall faster than solid and are thus less likely to drift over a topographic ridge. OP model runs using a rain falling speed instead of snow were less consistent with observations in many places for this reason.

Given the variability in wind direction in time and space, and the probability that this region experienced comparatively moist winds from both north and south, the approach for our continuing work will be to run the OP model once in every GCM grid box for every sol of the Martian year and sum the resulting precipitation.

Conclusions and Future Work: Valley networks are asymmetrically distributed across the craters and ridges on Noachian-aged martian terrain. Our preliminary results indicate that this asymmetry may have been caused by the effects of topographic lifting of moist air masses originating over a northern ocean, an ocean in the Hellas basin, and possibly crater lakes.

These preliminary results are more consistent with snowfall than with rainfall for two reasons. First, the faster fall time of liquid hydrometeors does not allow for the observed spillover onto lee sides of ridges. The version of the orographic precipitation model used in this study is known to overpredict lee side drying, however, and ongoing investigation with an improved version [9] may alter this conclusion. Secondly, the low precipitation rates indicate that snowmelt is more likely to provide sufficient erosive power to create the observed valleys, owing to its ability to build up and melt seasonally rather than immediately infiltrating into the regolith upon precipitation. The low rates may be a function of the cold and arid climate used in this study, which would not allow rain regardless. Investigation with a wider range of climates is underway, but given that even 1 bar may be an unrealistically thick Noachian atmosphere the relevance of thicker atmospheres is questionable [2].

A survey of other regions is in progress, as is an assessment of non-precipitation controls on network extent and morphology (e.g. erosion, evaporation, runoff speed). Finally, a major weakness of the analytical orographic precipitation model used here is its necessary inability to account for the drying of a moist air mass by rainout as it becomes more distant from its source. Future work will address the problem using the LMD's mesoscale Mars model, adapted to work with warmer climates.

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