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The spiral troughs of Mars North Polar Layered Deposits as Cyclic Steps

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The spiral troughs of Mars North Polar Layered Deposits [NPLD] are intriguing features that dominate the polar landscape. Because the stratigraphy of the NPLD is related to deposition of ice and dust, the layers of the NPLD act as a geologic record to recent Martian climate, potentially useful for understanding global processes and validating Global Circulation Models [GCMs]. Stratigraphy related to the spiral troughs is exceptionally rich and offers more variability than lower, subhorizontal layers, so determining the processes controlling trough formation and evolution is an important step in understanding the history of ice and climate on Mars. However, the mechanism behind trough initiation has remained a puzzle.

Recent studies of subsurface stratigraphy and low altitude clouds have indicated that the troughs formation and evolution is intricately tied to atmospheric processes, especially katabatic winds and asymmetric ice accumulation. We utilize stratigraphy collected by the Shallow Radar instrument (SHARAD) on Mars Reconnaissance Orbiter to examine accumulation of layers that record trough evolution and constrain lateral transport of ice. We then employ simulated wind fields from the Laboratoire de Météorologie Dynamique GCM and mesoscale models to calculate Froude numbers associated with katabatic flow. These simulations predict flows that experience katabatic jumps at numerous spiral troughs. Katabatic jumps are the aeolian counterpart of hydraulic jumps in open channel flow and are prominent on Mars near the poles. Next, we present visible images from the Thermal Emission Imaging System (THEMIS) and other optical spectrum instruments to observe low altitude clouds that we interpret as visible indications of katabatic jumps. These clouds potentially serve as mechanisms of deposition.

Finally, we devise a theoretical framework for understanding the origin of the spiral troughs in a Froude supercritical cyclic step model. Cyclic steps are quasi-stable, repeating, and upstream-migrating bedforms that have been studied in terrestrial and submarine environments. The repeating pattern is bounded by katabatic jumps, which act to stabilize the troughs. This model predicts and agrees with ten observations that should be explained for any scenario to satisfactorily describe the spiral troughs' formation and evolution. With this interpretation, we are able to use Froude and geometrical analysis to estimate the rate of upstream migration of the spiral troughs caused by katabatic winds.