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TI: Valley Formation Mechanisms and Short-Term Methane Precipitation Rates on Titan

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AB: Dendritic valley networks near the landing site of the Huygens probe on Titan imply that fluid has eroded the surface. The fluid was most likely methane, which forms several percent of Titan's atmosphere and can exist as a liquid at the surface. The morphology of the valley networks and the nature of Titan's surface environment are inconsistent with a primary valley formation process involving thermal, chemical, or seepage erosion. The valleys were more likely eroded mechanically by surface runoff associated with methane precipitation. If mechanical erosion did occur, the flows must first have been able to mobilize any sediment accumulated in the valleys. We develop a model that links precipitation, open-channel flow, and sediment transport to calculate the minimum precipitation rate required to mobilize sediment and initiate erosion. Using data from two monitored watersheds in the Alps, we show that the model is able to predict precipitation rates in small drainage basins on Earth. The calculated precipitation rate is most sensitive to the sediment grain size. For a grain diameter of 1--10 cm, a range that brackets the median size observed at the Huygens landing site, the minimum precipitation rate required to mobilize sediment in the nearby branching networks is 0.5-- 15 mm hr^{-1}. We show that this range is reasonable by calculating the column depth of methane that could condense in a convective plume in Titan's troposphere, and comparing this depth with observed lifetimes of tropospheric clouds. We validate our approach by performing the same calculation for tropical convective storms on Earth. The minimum precipitation rates inferred from the dendritic valley networks can be compared with observations of tropospheric cloud activity and theoretical predictions of methane precipitation rates to further test the hypothesis that runoff eroded the valleys.