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Surface change analysis of a small scaled Martian valley system based on an erosion-accumulation model

Vilmos Steinmann[1,2] and Ákos Kereszturi[2]
[1]Department of Physical Geography, Faculty of Science, Eötvös Loránd University, Budapest, Hungary (steinmann.vilmos@gmail.com)
[2]Konkoly Thege Miklós Astronomical Institute, Research Centre for Astronomy and Earth Sciences, Budapest, Hungary

Introduction: Simulating the fluvial activity produced landscape changes on the Earth is difficult and even harder on another planet, like Mars. There are several erosion models (eg. USLE, RUSLE), which can be well used in terrestrial environments, but these models are not able to be applied for Mars. The SIMWE erosion-accumulation model [1] is a good one to simulate fluvial surface modification in a short timescale, because the model uses only physically based parameters, in contrast the most used terrestrial model USLE uses two theoretical parameters (C and P parameters).

The SIMWE model was used already in the Martian environment [2] but not properly. This new version of the adopted SIMWE model produced more realistic results for the erosion-accumulation of the analysed valley system. This fluvial valley can be found next to the Palos crater and Tinto Vallis, for this reason called Tinto-B.

Data and Methods: To perform the erosion-accumulation model, digital elevation model (DEM) from the High Resolution Stereo Camera (HRSC) with 50 meter/pixel (m/px) resolution and thermal inertia data (TI) from the Thermal Emission Imaging System (THEMIS) with 100 m/px resolution were used. For the erosion-accumulation model the SIMulated Water Erosion Model (SIMWE) was used, which is integrated into GRASS GIS. The tool simulates the erosion-accumulation of a terrain using several physical based parameters, like water depth and shear stress. The estimated maximal flow depth depends on the flow width, which was calculated in SAGA GIS, and the upstream slope, which was calculated in GRASS GIS. To run the model, beside the original DEM, the estimated water depth and the estimated specific volumetric transport [3] were used as transport coefficient. The detachment coefficient depends on the sediment diameter size.

The formation timescale [3] was based on the full water depth, which was estimated in SAGA GIS and the already mentioned volumetric sediment transport.

Results: The erosion-accumulation model was used in four different durations. The model used 60, 720 and 1440-minutes erosion-accumulation periods. The average water depth used in the simulation was 5.8 meters with an average 3.73 m/s flow velocity. In all cases the accumulation dominates the analysed area.

The formation timescale represents how much time (in year) needed to erode the sediment volume, which is represented by the full water depth, to the original surface. The average time of the erosion is 153344 years.

Discussion: The model was tested at a longer timescale than 24 hours, but there aren't any significant differences. To simulate longer time, the 24 hours results were multiplied by 365.25, which represent one terrestrial year and multiplied again with the results of the formation time-scale calculation. These erosion-accumulation results do not represent properly the long time landscape changes, but in shorter times (1000 years) work well.

References: [1] Mitasova et al, 2004, Path Sampling Method for Modeling Overland Water Flow, Sediment Transport, and Short Term Terrain Evolution in Open Source GIS; [2] Steinmann et al, 2020, Geomorphological analysis of Tinto-B Vallis on Mars; [3] Kelinhans et al, 2010, Paleoflow reconstruction from fan delta morphology on Mars