# ANALYSIS OF SLOPE STREAKS ON MARS USING STEREO PHOTOGRAMMETRY METHODS AND GIS

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**Commission IV, WG IV/8**

**KEY WORDS:** Mars, Slope Streaks, Photogrammetry, Morphometric characteristic, GIS, HiRISE, MRO.

**ABSTRACT:**

Slope streaks [1] are a unique active phenomenon on Mars; they differ from so-called recurring slope lineae in their morphology, settings and mode of occurrence. The mechanism of slope streak formation is not known, but there are two main hypotheses for their origin: "dry", a specific kind of dust avalanche that has never been observed in terrestrial and laboratory environments [2], and "wet", a specific kind of percolation of brines in the shallow subsurface [3]. Slope streaks are formed in equatorial regions with relatively steep slopes and high concentrations of dust, which makes landing and roving on them difficult. Therefore, we use remote sensing data to assess the geometric characteristics of slope streaks to distinguish between these two main types of hypotheses for their origin.

## 1. INTRODUCTION

The "dry" mechanism describes process of formation of slope streaks on the basis of effect of an avalanche. Seismic activity, wind, or finding of critical mass of small particles and sand on a slope surface can be the cause of such effect. After a convergence of the top layer, it is noticeable that a subsurface layer has darker colour.

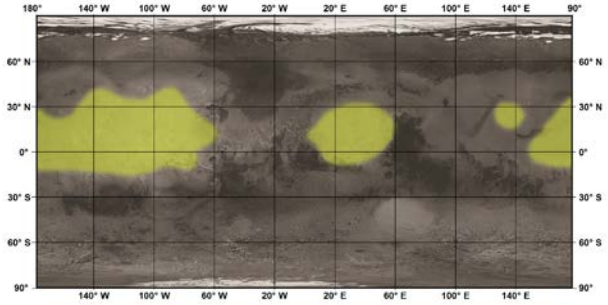


Figure. 1. Regions where slope streaks are observed

According to other scenario of a "wet" origin of streaks, several conditions are necessary: salt availability − calcium chloride, availability of water ice and a certain temperature (from −2.3 to +2°C) [4]. Because of low thermal inertia there is fast heating of a blanket at the expense of what water ice in a surface layer melts. Dissolving salt crystals, the brine (salt water) gets into deeper layers until conditions of thawing of water ice cease to be satisfied. Thus colouring of streaks is explained by a specific microstructure of dust slopes of Mars, which under certain conditions looks darker. Thus, studying of the active geomorphological processes happening on Mars can be a unique source of data on structure and a chemical composition of its surface. The analysis and measurement of morphometric characteristics of slope streaks can furnish the clue to understanding this unique phenomenon, but can also make a contribution to studying of climate of the planet (Fig. 2).

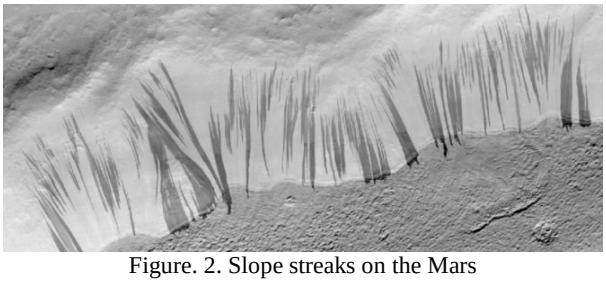

Figure. 2. Slope streaks on the Mars
(HiRISE - PSP_001656_2175)

## 2. STEREO MEASUREMENTS OF SLOPE STREAKS

For our study we use stereo pairs of images obtained by the High Resolution Imaging Science Experiment (HIRISE) on board Mars Reconnaissance Orbiter. For each raw image, parameters of internal and external orientation were computed using SPICE kernels, which enabled photogrammetric measurements [5, 6]. Then, all measurements were carried out by means of the PHOTOMOD software [7], which provides 2D and 3D visualization of measured features. Measurement results then were exported to ESRI ArcGIS [8] and analysed using spatial and statistical tools. The use of PHOTOMOD allows rapid and accurate manual photogrammetric measurements of slopes without the time consuming generation of digital terrain models. The implicit precision of manual parallax measurements by an experienced operator with high-quality HiRISE images is better than one pixel, which, depending on stereo geometry, typically yields about ~0.5-1m vertical precision for full-resolution (2x reduced-resolution) images. This precision provides slope measurement accuracy of ~2º-4º for short ~20 m segments, and proportionally better accuracy for longer segments. We measured the geometric parameters of the streaks: 1) proximal locations where the streak begins, 2) lengths, 3) azimuths, 4) slopes along the streaks, and 5) distal locations of streak terminations. We paid special attention to the proximal (initial uppermost) segments of the streaks because they should bear information about streak triggering mechanisms. We also paid special attention to streaks observed on gentle slopes and searched for any examples of streak

segments propagating uphill. Additionally slopes where slope streaks do not form have been measured. In our survey thus far, we have processed 24 stereo pairs, registered over 600 streaks and measured slopes of over 6000 streak segments; selected examples of slope measurement results are shown in Figure 3.

## 3. RESULT AND CONCLUSIONS

In total 44 images HiRISE of high resolution (22 stereo pairs) were collected and processed. Based on these images 600 slope streaks (more than 6000 segments) have been studied including measurements of geometrical parameters. Some DEMs on some sites with interesting examples of streaks have been processed (Fig.3). For the analysis and interpretation of the collected data (Fig.4) we use ArcGIS 10.2 [9].

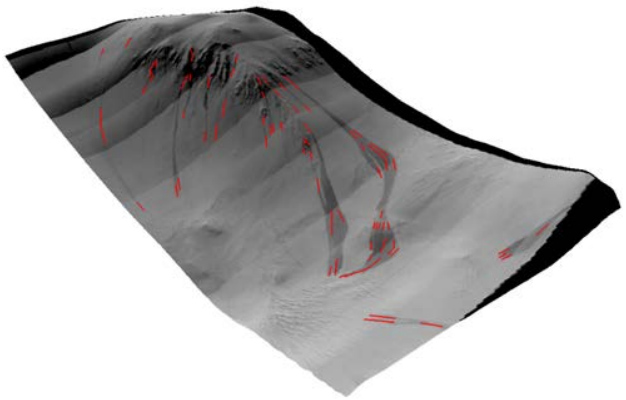

Figure 3. Slope Streaks on new HiRISE DEM (image ESP_017585_2080)

The observations that the streaks turn in direction, follow the slope, and seem not to propagate uphill are consistent with earlier conclusions [7] that the streak-forming process is not associated with appreciable inertia. The observed propagation of slope streaks for long distances on gentle slopes (Fig. 3) is very difficult to reconcile with any dry granular flow model. The typical dynamic angle of repose for dry granular materials is much steeper, even if lower gravity is taken into account [8]. Thus, a "dry" formation mechanism for this example would require very unusual microphysics for dust avalanches that would necessarily dramatically decrease the dynamic angle of repose.

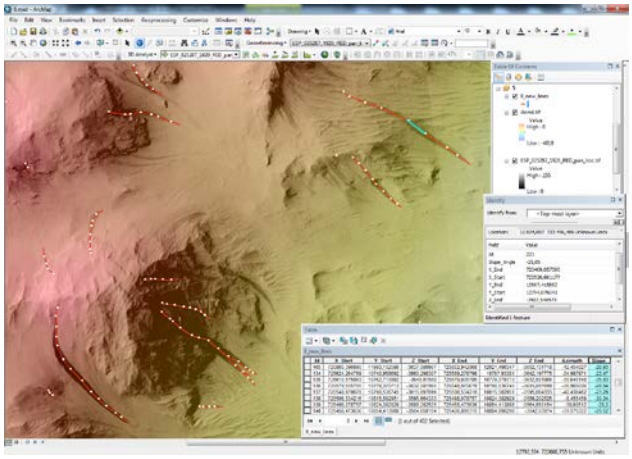

Figure 4. Slope Streaks analysis using ArcGIS tools based on new high resolution HiRISE DEM


## ACKNOWLEDGEMENTS

This work was carried out in MIIGAiK and supported by Russian Science Foundation, project 14-22-00197.


## REFERENCES


1. Morris E. (1982). Aureole deposits of the Martian volcano Olympus Mons. Geophysical Research Letters, vol. 87.
2. Sullivan R., Thomas P., Veverka J., Malin M. and Edgett E. (2001). Mass movement slope streaks imaged by the Mars Orbiter Camera. Geophysical Research letters, vol. 106.
3. Kreslavsky M. and Head J. (2009). Slope streaks on Mars: A new “wet” mechanism. Icarus, 201.
4. McEwen A., Dundas C., Mattson S., Toigo A., Ojha L., Wray J., Chojnacki M., Byrne S., Murchie S. and Thomas N. (2014). Recurring slope lineae in equatorial regions of Mars. Nature Geoscience, 7.
5. Zubarev A.E. and Patratiy V.D. (2013). The effective tool for data processing of remote sensing of celestial bodies — SPICE. Izvestiya VUZov “Geodesy and Remote sensing”, #1 (in Russian).
6. SPICE API: http://naif.jpl.nasa.gov/naif/
7. PHOTOMOD: http://www.racurs.ru/
8. ArcGIS: http://www.arcgis.com/