WIND STREAK MODIFICATIONS ON MARS – A LONG-TERM CHANGE DETECTION STUDY.
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Introduction: Wind streaks are common aeolian features on Mars, forming as surface material is redistributed by prevailing winds. These streaks provide valuable insights into atmospheric dynamics [1,2], surface conditions, the change capacity of dust storms, and the frequency of winds speeds high enough to move fine-grained materials [e.g. 3,4,5]. In the initial phase of a comprehensive surface change detection study, we have analyzed long-term aeolian changes using multi-temporal imagery from various Mars-orbiting spacecraft, captured over several decades across 11 major regions on Mars (Fig. 1).

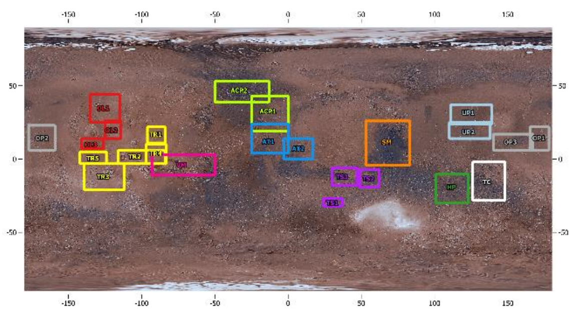

Fig. 1: Overview of the 11 major study regions (one colour each) and their subdivision. OP = Orcus Patera; OL = Olympus Mons region; TR = Tharsis region; VM = Valles Marineris; ACP = Acidalia and Chryse Planitiae; AT = Arabia Terra; TS = Terra Sabaea; SM = Syrtis Major; UP = Utopia Planitia; HP =Hesperia Planum; TC = Terra Cimmeria.

Our observed wind streak variations offer valuable insights into Martian wind patterns and surface-atmosphere interactions since the advent of satellite-based Mars exploration. Here, we focus on the changes in wind streak orientation, length, shape and occurrence and present the initial results for these change types.

Data and Methods: This study is based on the analysis of two main basic data sets: The Viking Mars Digital Imaging Model (MDIM 2.1.; 232m/px) from the Viking orbiter 1 and 2 missions (data from 1976 – 1980) was used as the potential pre-change data set. It was compared to MEx/HRSC high- and low-resolution images (12.5 to 800 m/px; from 2004-2024), which were used as the potential post-change data set. To verify and evaluate potential changes as well as to narrow down the time of an observed change, MGS/MOC wide angle camera data (256 m/px; 1997-2006) and MRO/CTX data (6 m/px; form 2005 onwards) were consulted. The time interval between the compared pre- and post-images is up to 49 Earth years (1976-2024).

All image data sets were thoroughly co-registered to each other to ensure correct co-location and a proper image comparison. Since the Viking MDIM is already referenced to the global MOLA geodetic reference data set for Mars, all other image datasets were co-registered to Viking by tie points in QGIS using the "Georeferencer" plug-in and the Thin Plate Spline algorithm. For the visual comparison, only images with a similar solar azimuth at the time of capture were compared, to rule out the possibility that differences in brightness were not caused by different illumination conditions. For the GIS project, a Lambert Conformal Conical projection was chosen for the raster datasets, which ensures that all angles measured in this work are correct. Since this projection is not true to length, only the calculated differences in the length of the wind streaks can be considered precise and not the measured absolute length values, which is perfectly sufficient for our study to recognize changes. The wind streak orientation, shape and length were mapped in shapefiles and calculations based on values extracted from these shapefiles were done using MS Excel. Our wind streak characterization follows the classification by [3] that includes bright depositional (Type 1b), dark erosional (Type 1d) and dark depositional (Type II) wind streaks, whereas no Type 1d wind streaks have been identified in our study regions.

Results: The types of wind streak modifications identified in this study include changes in orientation (i.e., a different azimuth between the previous and current images), changes in streak length, changes in streak shape, as well as disappearing or newly appearing wind streaks. While individual wind streaks exhibited measurable orientation shifts, the overall regional trends remained relatively stable.

A total of 260 changes in the orientation of bright wind streaks and 5 changes in the orientation of dark wind streaks have been observed in our study regions, whereas mean azimuth changes between 0.15° and up to 22.39° were measured. The largest orientation changes took place in Utopia Planitia, followed by the Olympus Mons region, Syrtis Major (Fig. 2), and Hesperia Planum. The dark wind streaks at western Arabia Terra show the lowest mean orientation change (except for one case, see Fig. 3 bottom). However, the dark wind streaks at Arabia Terra/Oxia Palus exhibit the most significant changes in overall shape (Fig. 3). Such distinct modifications of the dark streaks at Oxia Palus were also previously reported by [6]. At the same time, in some exceptional cases, these streaks show the greatest variations in wind streak length. Here, some dark wind streaks have lengthened up to 19 km whereas others have shortened up to 89 km. The mean change in streak length for the other regions ranges between a few hundred meters and up to 18 km and refers to both, shortening and lengthening. We report of 60 newly observed wind steaks, most of the are Type 1b. 6 wind streaks disappeared within our observation period, at least in our study regions.

Discussion & Conclusion: Wind streak changes due to dust settlement exhibit the highest variation, whereas dark depositional wind streaks, requiring dune sand transport, show the least change with some exceptions. The observed modifications suggest that only strong, infrequent dust storms significantly impact their orientation, albedo and shape, either by dust settlement (Type 1b) or material redistribution (Type 1d and II) (cf., 2). Moreover, our analysis implements that the current state of the changed wind streaks evolved gradually over a long period rather than through periodic positional shifts. Some wind streaks exhibited length variations without significant orientation shifts, indicating material redistribution rather than complete reformation. Additionally, the persistence of neighboring streaks suggests that factors such as surface material composition and crater rim height may influence streak stability. By consulting imagery from intermediate time steps, we can rule out the possibility that the wind streaks temporarily pointed in a different direction before being redirected to their current position. Instead, their orientation has been achieved through single or few change events.

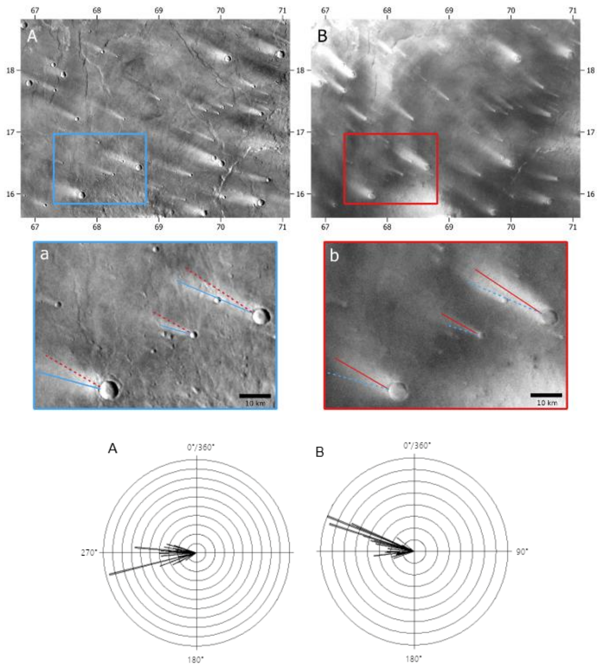

Fig. 2: *Top*: Example images for wind streak orientation (WSO) change of Type 1b streaks at Syrtis Major in at least 41 years. A/a/ blue=Viking MDIM; B/b/red=HRSC hm612_0000). Dashed lines show the respective WSO in the comparison image. *Bottom*: Rose diagrams compare the WSO in Viking (A) and HRSC (B) of all changed streaks at Syrtis Major (n=54) along with their relative length changes, where each ring represents a 10 km increment.

References: [1] Greeley, R. et al. (1993) *JGR, 98,* 3183-3196. [2] Day, M. & Rebolledo, L. (2019), *GRL, 46,* 12747-12755. [3] Thomas, P, et al. (1981) *Icarus, 45,* 124-153. [4] Greeley, R. & Iversen, J.D. (1985), *Cambridge Univ. Press.* [5] Cantor, B. et al. (2001), *JGR 106,* 23653-23687. [6] Thomas P. & Veverka, J. (1979), *JGR 84,* 8131–8146.

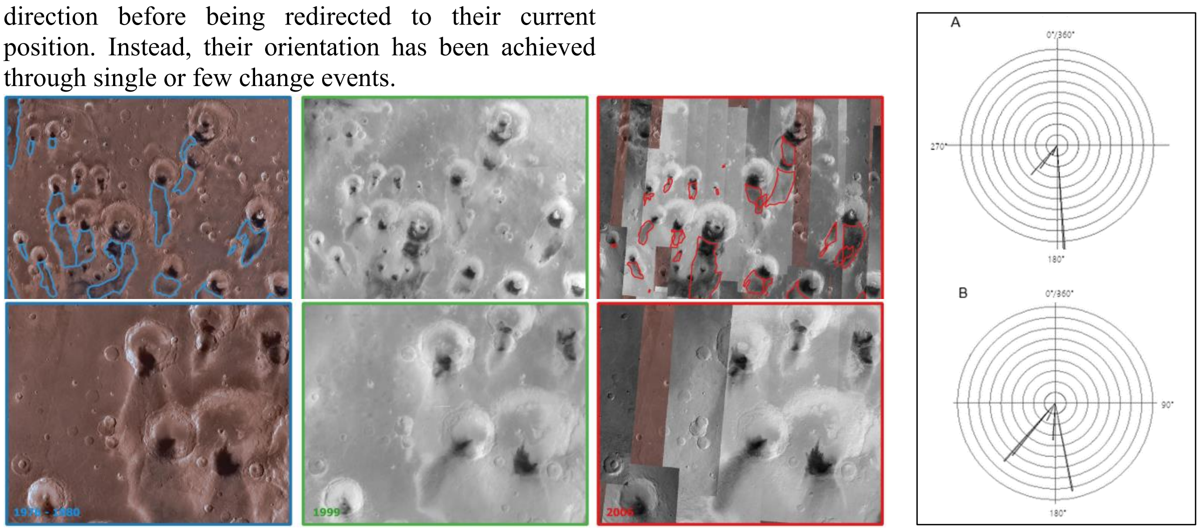

Fig. 3: Dark wind streak changes at Arabia Terra/Oxia Palus (subregion AT1) in regional (*top*) and close-up view (*bottom*) showing shape and length changes but only few orientation changes over the course of at least 26 years. Left/blue: Viking; Middle/green: MOC; Right/red: HRSC. The MOC images show that some changes took place prior to 1999/MY 24. *Right panel*: Rose diagrams visualizing the WSO in Viking (A) and HRSC (B) of all changed dark streaks at Arabia Terra (n=5) along with their relative length changes, where each ring represents a ~17 km (A) and 10 km increment, respectively.