Available online at www.sciencedirect.com
ScienceDirect
Icarus 191 (2007) 132–140
ICARUS
www.elsevier.com/locate/icarus

Three decades of slope streak activity on Mars

N. Schorghofer [a,*], O. Aharonson [b], M.F. Gerstell [b], L. Tatsumi [c]

[a] *Institute for Astronomy and NASA Astrobiology Institute, 2680 Woodlawn Drive, University of Hawaii, Honolulu, HI 96822, USA*
[b] *Division of Geological and Planetary Sciences, MC 150-21, California Institute of Technology, Pasadena, CA 91125, USA*
[c] *Department of Geology and Geophysics, 1680 East-West Road, University of Hawaii, Honolulu, HI 96822, USA*

Received 7 January 2007; revised 19 March 2007

Available online 5 May 2007

Abstract

Slope streaks are surficial mass movements that are abundant in the dust-covered regions of Mars. Targeting of slope streaks seen in Viking images with the Mars Orbiter Camera provides observations of slope streak dust activity over two to three decades. In all study areas, new and persisting dark slope streaks are observed. Slope streaks disappeared in one area, with persisting streaks nearby. New slope streaks are found to be systematically darker than persisting streaks, which indicates gradual fading. Far more slope streaks formed at the study sites than have faded from visibility. The rate of formation at the study sites was 0.03 new slope streaks per existing streak per Mars year. Bright slope streaks do not presently form in sudden events as dark slope streaks do. Instead, bright streaks might form from old dark slope streaks, perhaps transitioning through a partially faded stage.

© 2007 Elsevier Inc. All rights reserved.

Keywords: Mars, surface; Mars, atmosphere

1. Introduction

Slope streaks are dark narrow fan-shaped features extending downslope, seen in equatorial, high albedo, dust covered regions of Mars (Sullivan et al., 2001; Schorghofer et al., 2002). They were first found in images taken by the Viking Orbiters as early as 1977 (Morris, 1982; Ferguson and Lucchitta, 1984), but at the time it was unknown they were actively forming. New slope streaks were recognized in overlapping images acquired by the Mars Orbiter Camera (MOC) onboard the Mars Global Surveyor spacecraft (Edgett et al., 2000; Sullivan et al., 2001). Since then, overlapping MOC/MOC image pairs have been extensively studied to determine the rate of formation (Aharonson et al., 2003). To date, over 200 new slope streaks have been detected and documented. Fig. 1 shows a particularly dramatic example of a new slope streak. While many new streaks have been documented, no disappearing streaks had ever been observed.

The nature of slope streaks remains uncertain, but they are commonly interpreted as dust avalanches (Sullivan et al., 2001). Recently discovered terrestrial analogs in the Dry Valleys of Antarctica contain moisture (Head et al., 2007). Miyamoto et al. (2004) inferred the bulk viscosity and bulk yield strength of anastomosing slope streaks must be extremely low. Baratoux et al. (2006) present evidence that slope streaks form where the dust cover is thick, and the thickness of the dust cover is in turn related to wind direction. The present work pertains mainly to streak fading over the past two and a half decades since the Viking observations.

2. Viking/MOC overlaps: Three decades of change

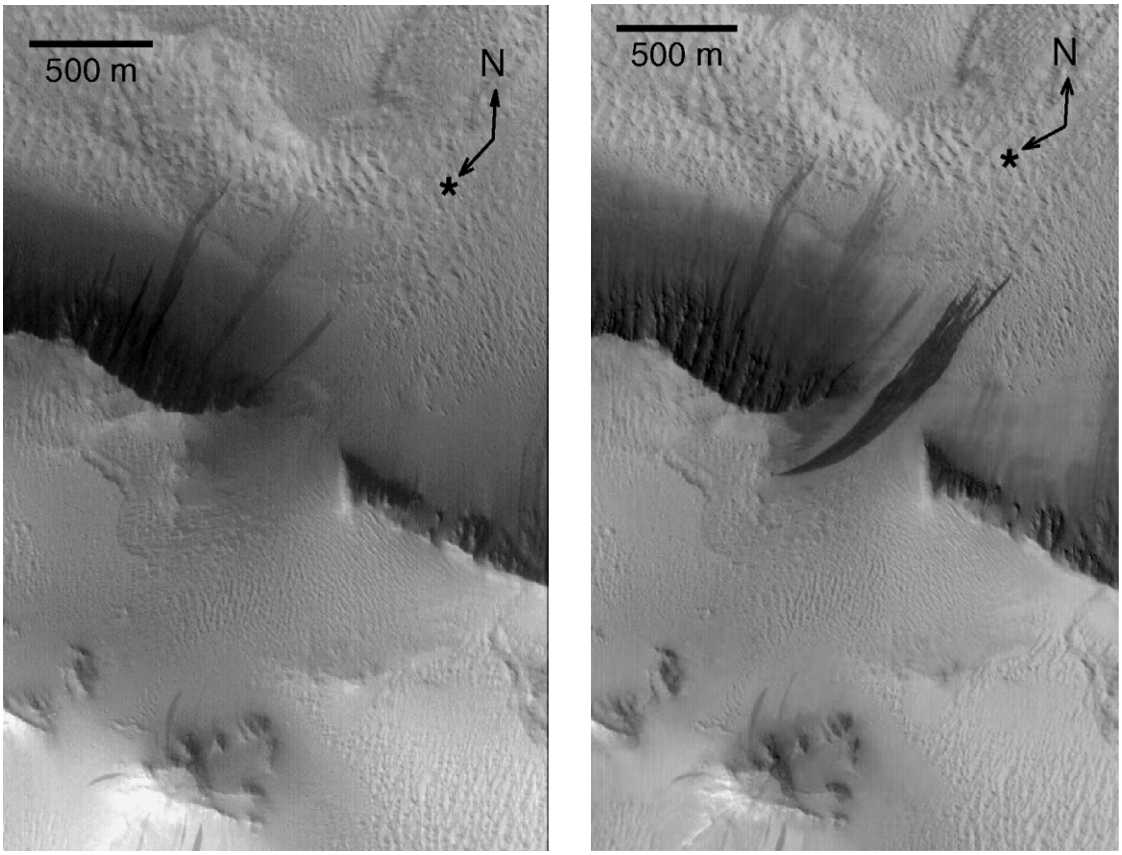
2.1. Study sites

Seeking slope streaks, we surveyed 7887 Viking Orbiter images with a spatial resolution finer than 100 m per pixel. Images from latitudes between 25° S and 45° N and all longitudes where slope streaks are known to occur were included in the survey. Images flagged for likely slope streaks were revisited several times. The final result of this survey was a list of Viking images with unambiguous dark slope streaks, shown in Table 1.

---

[*] Corresponding author. Fax: +1 808 956 7264.
E-mail address: norbert@hawaii.edu (N. Schorghofer).

0019-1035/$ – see front matter © 2007 Elsevier Inc. All rights reserved.
doi:10.1016/j.icarus.2007.04.026



(a) (b)

Fig. 1. A large new slope streak formed, while numerous other streaks persisted. Left is a portion of MOC image M0806884 taken on 1999-10-28, and to the right E1700689 from 2002-06-10. North is up and illumination is from the lower left.

Table 1
Viking images with unambiguous dark slope streaks

Viking Orbiter image id
441B02–441B11, 441B13, 448S11, 448S17, 448S23, 449S15, 449S16, 449S18, 449S19, 449S25, 450S15, 450S17–450S20, 450S25, 450S28, 451S15, 451S29, 452S13, 452S15, 456S02, 458S10, 713A03, 713A13, 713A50, 713A51–713A55, 713A57, 713A67–713A71, 714A53, 714A55, 738A84, 748A03, 748A05, 748A12, 768A54

In addition, Viking image 713A45 was identified as having probable bright slope streaks.

Among these Viking images, we selected those most promising for monitoring and proposed several target sites to Malin Space Science Systems (MSSS), who subsequently imaged all targets with the narrow-angle Mars Orbiter Camera and released the images in the public data archive. One of the target sites included candidates of bright slope streaks. Table 2 provides an overview of the study sites, five sites with dark streaks and one with bright streaks. The overlap area is tens to hundreds of square kilometers large at each site. The time difference ranges from 21 to 28 Earth years, or 11 to 15 Mars years.

2.2. Observations

We have studied the overlap images and identified persisting, new, and disappeared streaks. Fig. 2 displays an example of Viking/MOC overlaps separated by 26 years. Many slope streaks have persisted and are still visible on the MOC images, new streaks have appeared, and, in this particular region, none has disappeared.

In all five study areas with dark streaks, new slope streaks were observed, meaning that over the span of two to three decades all sites with dark slope streaks were active. All study areas also have many persisting streaks.

Streaks are expected to fade with time because of dust settling from the atmosphere. While differences in camera sensitivity would make it difficult to measure albedo changes, the relative contrast of streaks within the very same MOC image can be compared when some of the streaks are known to be younger than others (Sidhu et al., 2005). In Fig. 2, for example, the new slope streaks have a stronger contrast than most or all of the older persisting streaks. We find new slope streaks to be systematically darker than the older slope streaks that are already seen on the Viking image. Hence, the streaks gradually fade with time.

We report the first observation of disappearing slope streaks. In Fig. 3, a group of slope streaks seen on 1977-11-02 has disappeared by 2004-06-24 and that disappearance is confirmed by another MOC image from 2005-01-16. Additional streaks, to the south, might also have disappeared, but the evidence is ambiguous, because there are several faint streaks on this hillslope that may or may not be at exactly the same locations as the

Table 2
List of study areas (most of these overlap images only exist because MOC monitored the areas for slope streak activity)

Viking Orbiter images (resolution)	MOC images	Location	Comments
441B02, 441B03, 441B04, 441B05, 441B08, 441B09 (8 m/pixel)	M0203210, E0501067, R1102947, R1302916, R1801921, R2300240, R2301380, S0200353, S0200620, S0400171, S0902427	148° W, 28° N	Olympus Mons aureole; see also Aharonson et al. (2003)
748A10, 748A12 (18 m/pixel)	M0401105, M0904689, M2100670, M2300452, E0102238	344° W, 2° S	See also Edgett et al. (2000)
713A66, 713A68, 713A70 (21 m/pixel)	R0802542, R0900862, R1001553, R1101493, R1200984, R1602440, R1701963	319° W, 8° N	
713A53, 713A55, 713A57 (23 m/pixel)	R1002664, R1201917, R1601030, R1700498, S1102289	320° W, 9° N	
768A54 (14 m/pixel)	R0901461	149° W, 11° S	
713A45 (25 m/pixel)	R0900170, R0901952	322° W, 10° N	Bright streaks

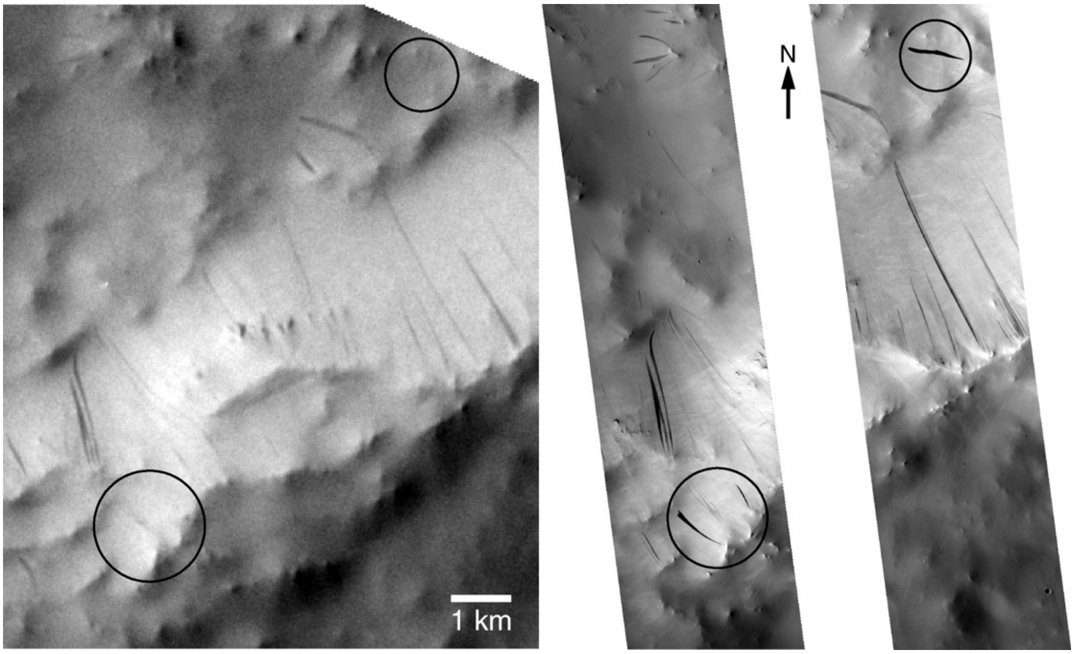


Fig. 2. To the left is a portion of Viking image 713A57 from 1978-06-01. To the right are portions of MOC images R1700498 (2004-05-06) and R1601030 (2004-04-13). Over a period of 26 years, many streaks have persisted and new ones have formed. New streaks tend to have stronger contrast than old streaks in the same MOC image.

Viking streaks. Nearby slope streaks in this region have largely persisted; some are visible on the east side of the images in Fig. 3.

Fig. 4 documents an unusual occurrence, a few kilometers south of the area shown in the previous figure. A portion of a dark slope streak has reversed albedo contrast. A crater visible in both images reveals that the bright albedo feature in the MOC image is at the same location as the dark streak in the Viking image. (Part of this streak is also visible in MOC image R1302916, not shown here.) A streak with a bright–dark transition has been reported by Sullivan et al. (2001), and another example can be found in MOC image E1001447 (not shown). In all three cases, it is the bottom portion that is dark. This observation suggests bright streaks can arise from old dark streaks.

In one region, a dust devil track crosses the upper tip of a new slope streak (Fig. 5). The streak and the dust devil track are also visible four months later in image R1601030. One other example of this kind has been reported by Malin and Edgett (2001). However, most new slope streaks, there are hundreds of examples, do not have discernible dust devil tracks at their origination point.

2.3. Overall balance

We have counted the number of persisting and new streaks, wherever a meaningful assessment could be made. Only slope streaks that are unambiguously new or persisting are included. The MOC resolution exceeds that of Viking images, and only new streaks large enough so that they would be visible on the Viking image are considered new, otherwise they are ignored. Table 3 lists the results. The counts are approximate, because some streaks are close to the limitation of the Viking resolution or could be confused with shadows. In other cases, streaks can be matched individually by their shape and appearance, and an unambiguous distinction between new and persisting could be made. Not included in the table are additional pairs from Table 2 that we studied but contained no useful information.

The first row in Table 3 corresponds to the targeted site in the Olympus Mons aureole, where the disappeared streaks of

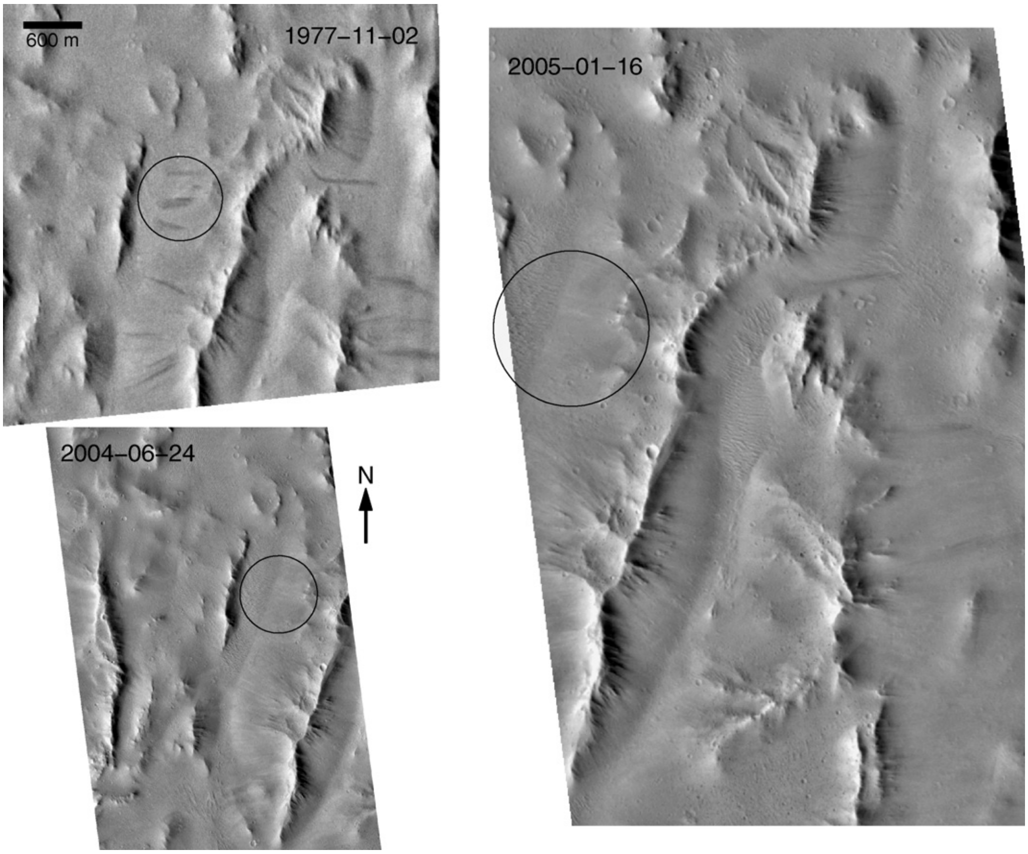


Fig. 3. Three decades of slope streak changes at the Olympus Mons aureole monitoring site: Viking image 441B03 (1977-11-02), MOC image R1801921 (2004-06-24), and MOC image S0200620 (2005-01-16). All images are high-pass filtered to reduce shadows and enhance the overall contrast. The four streaks in the encircled area have disappeared. Nearby streaks, to the east, have largely persisted.

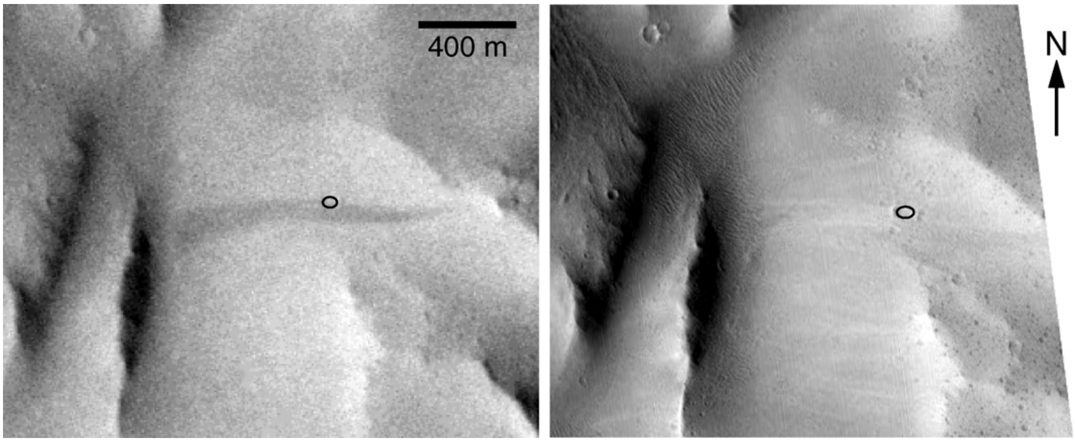


Fig. 4. This area in the Olympus Mons aureole is a few kilometers south from the one shown in the previous figure. A streak turned from dark to partially bright between 1977-11-04 (441B08) and 2004-06-24 (R1801921). The small circle outlines a crater.

Fig. 3 are located. Since this site involves multiple partial overlaps, every streak was tagged individually and tracked through the Viking and MOC images. There are at least 5 streaks, on at least two different hill slopes, that have disappeared. If ambiguous cases had been considered as disappearances of streaks, the count would be no more than twice as high. Of the approximately 47 new streaks, ~13 are seen forming within a MOC pair, while the other ~34 are new on the earliest MOC image that captured the area. All streaks that are new from one MOC image to another are located in MOC pair E0502916 (2001-06-27) and S0400171 (2005-03-04).

The second row involves four collocated MOC images that constrain the timing of events. In the small area they share with the Viking images, there are no new streaks between 1977-11-04 and 1999-06-22, three new ones appeared by 2003-11-17, and no additional streaks had formed by 2005-08-24. In the area common to all four collocated MOC images, larger than the overlap with the Viking images, there are about 15 new

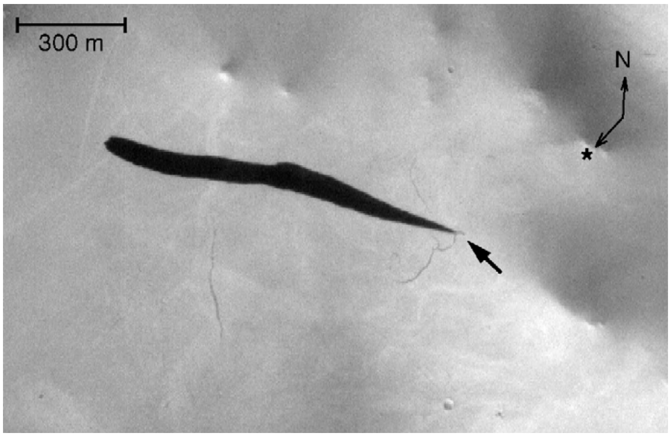


Fig. 5. A dust devil track intersects the upper tip of a slope streak in MOC image R1201917. This streak is new since Viking image 713A57, and might have formed only very recently.

streaks that also formed between 1999-06-22 and 2003-11-17, while there is no subsequent activity. These observations suggest there was a burst of activity sometime between June 1999 and November 2003, and an inactive or less active period the years before and after. A major dust storm appeared in 2001, the largest on record since 1972 (Cantor, 2007), but the information at hand is not sufficient to establish a definite connection between the storm and increased slope streak activity.

Subsequent rows in Table 3 show additional Viking/MOC image groups. A few Viking/THEMIS-visible overlaps with sufficient resolution also exist (V18009018 and V18658008), but they are not included in the counts. They show new and persisting streaks, but no evidence for disappearance of streaks.

In all study areas, new slope streaks were observed, meaning that over the span of decades all five sites with dark slope streaks were active. Using only images where a reliable count could be made, at three study areas, there are a total of ~140 persisting slope streaks and ~70 new streaks. The streak population increased by 50% in two and a half decades. The number of disappeared streaks is much smaller, about 5. Even at the Olympus Mons aureole site, where the disappearances are observed, we identified far more new streaks than streaks that have faded out of visibility. The fading proceeded much more slowly than the creation of new streaks.

A formation rate q can be defined as the number of new streaks per preexisting streak per Mars year. Aharonson et al. (2003) derived formulas for formation rates across multiple image pairs that also take into account that the number of persisting streaks changes with time. For an individual pair with a relatively small number of new streaks, the formation rate is calculated as $q = \Delta n/(n\Delta t)$, where Δn is the number of additional (new) streaks, n the eventual number of streaks (persisting plus new minus disappeared) and Δt the time difference between the images. For multiple pairs, q is implicitly given by $\sum_i n_i \Delta t_i = \sum_i \Delta t_i \Delta n_i/(1-\exp(-q\Delta t_i))$, where the sum is over image pairs.

This formula is used to calculate formation rates, as shown in the last column of Table 3. The overall formation rate from Viking/MOC overlaps is 3% per Mars year or 1.6% per Earth year. At this rate, the streak population would double in roughly four decades, and if the population number were constant, the turnover time for the streak population would be six decades. The formation rate from Viking/MOC overlaps, spanning the past two and a half decades, is lower than, but comparable to, the global average of 7% per Mars year calculated from 173 MOC/MOC image pairs that span the time period 1998–2002 (Aharonson et al., 2003).

We infer that the fading is slower than the creation of streaks by one order of magnitude, and the number of slope streaks on Mars has increased in the last three decades. It is possible that

Table 3
Approximate number of new, persisting, and faded (disappeared) dark slope streaks

Image ids	Persisting	New	Disappeared	Mean time difference (Mars years)	Formation rate (%/Mars year)
441B02, 441B03, 441B04, 441B05, 441B08, 441B09 / E0501067, R1302916, R1801921, R2300240, R2301380, S0200620, S0400171	86	47	5	14.1	3%
441B04, 441B05 / M0203210, R1102947, S0200353, S0902427	2	3[a]	0	13.6	
748A10 / M2100670, E0102238	⩾3	⩾9	–	12.0	–
748A12 / M0401105, M0904689, M2300452	⩾19	⩾19	–	11.5	
713A68 / R1001553, R1101493, R1200984	⩾9	⩾4	–	13.5	1%
713A68, 713A70 / R0900862, R1602440, R1701963	11	2	0	13.8	
713A70 / R0802542	10	1	0	13.4	
713A53 / S1102289	1	2	0	14.6	3%
713A57 / R1002664, R1700498	17	7	0	13.6	
713A57 / R1201917, R1601030	13	8	0	13.7	
768A54 / R0901461	⩾13	⩾15	–	13.4	–

The prefix "⩾" indicates the number cannot be estimated reliably, but there are convincing examples. A dash "–" indicates no meaningful assessment can be made. Each row corresponds to a group of images that does not overlap with images in another row. The formation rate indicates the average fraction of streaks that are new per Mars year.

[a] The four MOC images are collocated; the earliest MOC image shows no new streak, and subsequent images show several new streaks.

the average "life time" or "half life" of dark slope streaks is not decades but centuries.

To explain the imbalance, it could be hypothesized that the streak population is erased by infrequent dust storms of an intensity that has not occurred since the Viking missions, and rebounds after a storm. If this were the case, then the number of streaks would grow and the formation rate, defined relative to the number of existing streaks, would decrease with time; the Viking/MOC formation rate would be expected to be larger than the MOC/MOC formation rate, contrary to the existing statistics. Hence, there is no evidence for this scenario, which otherwise would have been a plausible explanation for the imbalance. The statistics make more sense if the formation rate changes with time.

2.4. *Discussion of potential observation biases*

The appearance of slope streaks does not depend on illumination. Our experience from studying over one hundred overlap images, including the early phases of the Mars Global Surveyor mission, when illumination conditions varied most, is that illumination plays no role. For example, the two images in Fig. 1 have different illumination and viewing geometry (emission angle 0° and 18°, incidence angle 58° and 28°, and phase angle 58° and 40°, respectively), yet every streak in the first image appears unchanged in the second. Dark streaks always appear dark in repeat images, and bright streaks always appear bright in repeat images, irrespective of illumination and viewing angle.

If the Viking cameras were less contrast sensitive than the MOC, it would lead to a bias in favor of new streaks over disappearing streaks. Most new streaks are found to have stronger contrast than old streaks, which rules out a significant bias in the number of new streaks. But the number of streaks judged to have disappeared might be underestimated, because a faint streak in the Viking image could be unrecognizable, while a streak with the same contrast could be recognizable on the MOC image.

How representative are the five monitoring sites? The study sites are distributed geographically throughout the low-thermal inertia regions. They share many properties: They all have new and persisting streaks and newer streaks tend to have stronger contrast. Only the disappearance of streaks is unique to one site, the site that contains the most streaks.

3. Bright slope streaks

3.1. *Activity*

Bright (light-toned) slope streaks are much rarer than dark slope streaks, but have similar morphological characteristics (Gerstell et al., 2004). Fig. 6 shows streaks of both kinds.

The Viking site with bright slope streaks from 1978 has been imaged by MOC in 2003 (Table 2, last row). There is no indication that new bright streaks have formed or that old bright streaks have disappeared, although the resolution of the Viking image is not high enough to exclude this possibility. A number of MOC/MOC overlap pairs with bright streaks exist. We have not found any new bright streaks in them. Malin et al. (2006) and Malin and Edgett (2006) present specific evidence in this regard. We conclude that bright streaks do not presently form in sudden events as dark slope streaks do, at least not at a rate comparable to that of dark slope streaks.

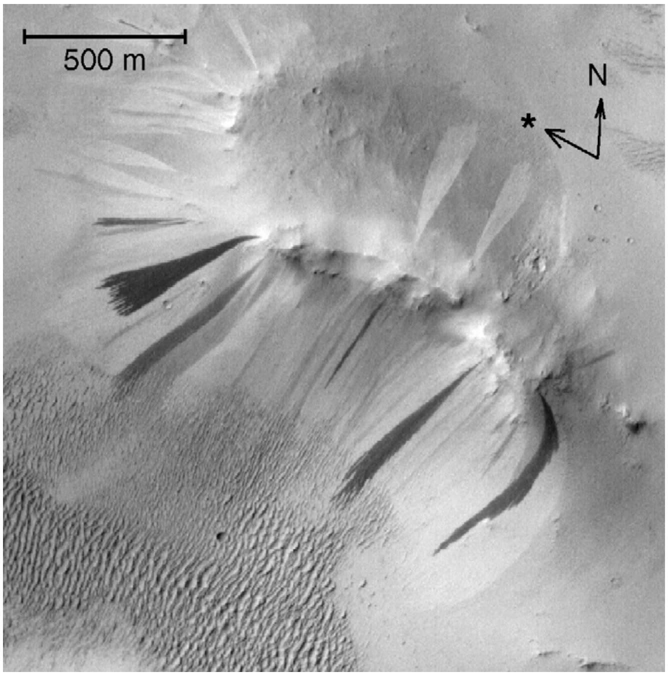


Fig. 6. Dark and bright slope streaks in MOC image M2000701.

A third line of evidence that bright streaks are old is found in MOC images where dark slope streaks overlie bright slope streaks, such as M0307572, M2300915, E0501983, and R1701963. Additional examples are given in Malin and Edgett (2006). The evidence for albedo inversion in Fig. 4 suggests bright slope streaks form by a different mechanism than dark streaks.

3.2. *Geographic relations*

An earlier systematic survey of close to 30,000 MOC images, which covered all images available at the time within the appropriate latitude range, identified 1386 MOC images with dark or bright slope streaks (Schorghofer et al., 2002; Aharonson et al., 2003). A detailed survey of these 1386 images was carried out and the estimated numbers of streaks were recorded, separately for dark and bright streaks. When streaks were numerous, their number was estimated instead of counted. Every image was visited more than once. Fig. 7a shows a map of the occurrence of bright and dark streaks. The bright streaks are far more common in Arabia than elsewhere, but also exist in other areas where dark slope streaks are found. (The map represents unambiguous streaks only; it still looks similar when ambiguous features are included, whose numbers we have also estimated.)

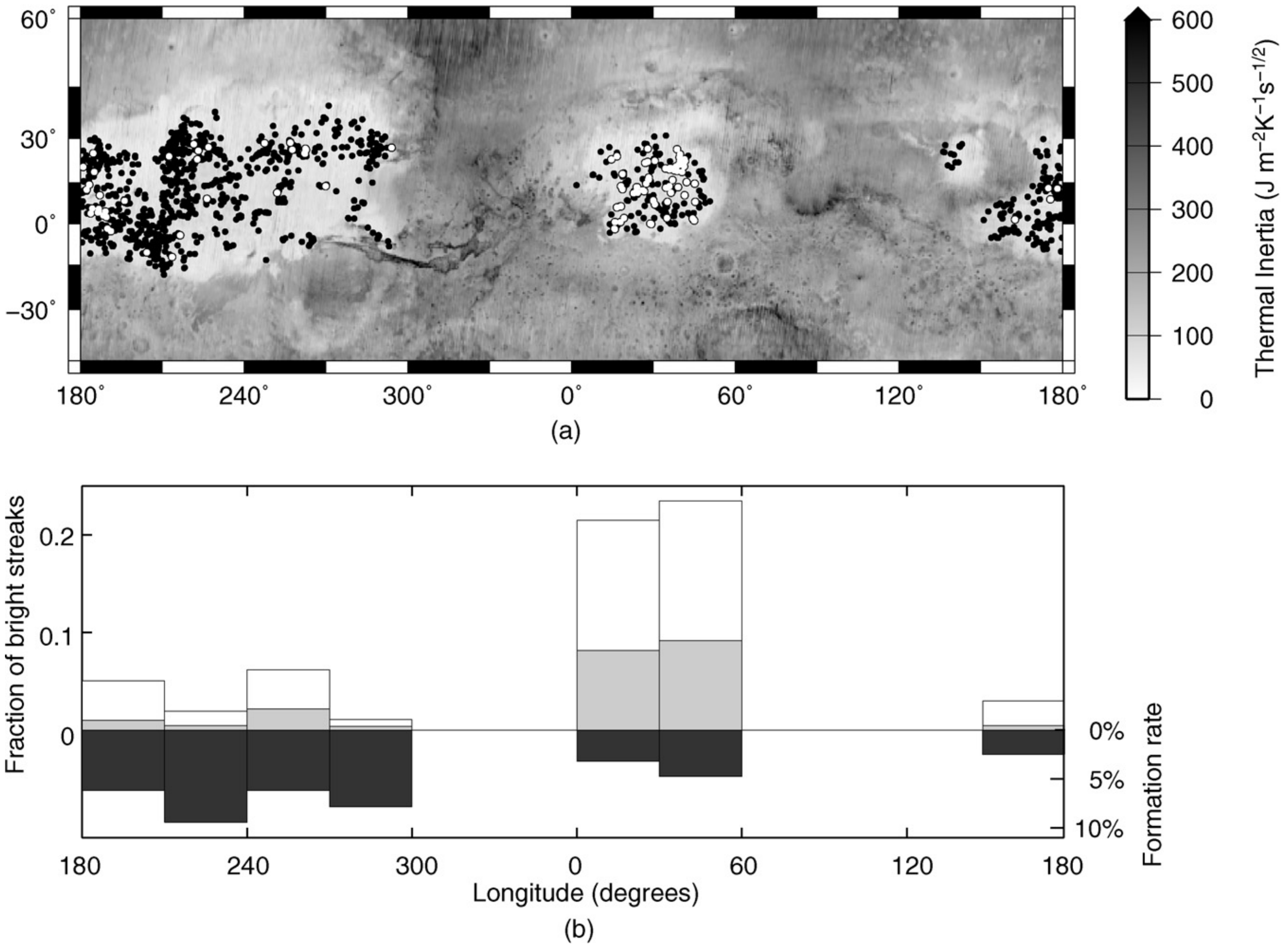


Fig. 7. (a) The result of a survey of MOC images for bright (white dots) and dark (black dots) slope streaks. Images with both, bright and dark streaks, appear as white dots. Bright streaks are more common in Arabia, but also appear in the Tharsis region. The background map is thermal inertia. (b) Histogram (white) of the fraction of MOC images with slope streaks that contain bright slope streaks. The light gray bars show the estimated number of bright streaks relative to the total number of streaks. The two upward histograms are based on 1386 images. Also shown is the local formation rate of dark slope streaks from MOC/MOC pairs, increasing downward (dark gray). Each bin contains 6 to 62 image pairs, with the rightmost one based on the smallest sample. All three quantities are integrated over latitude and shown as a function of longitude.

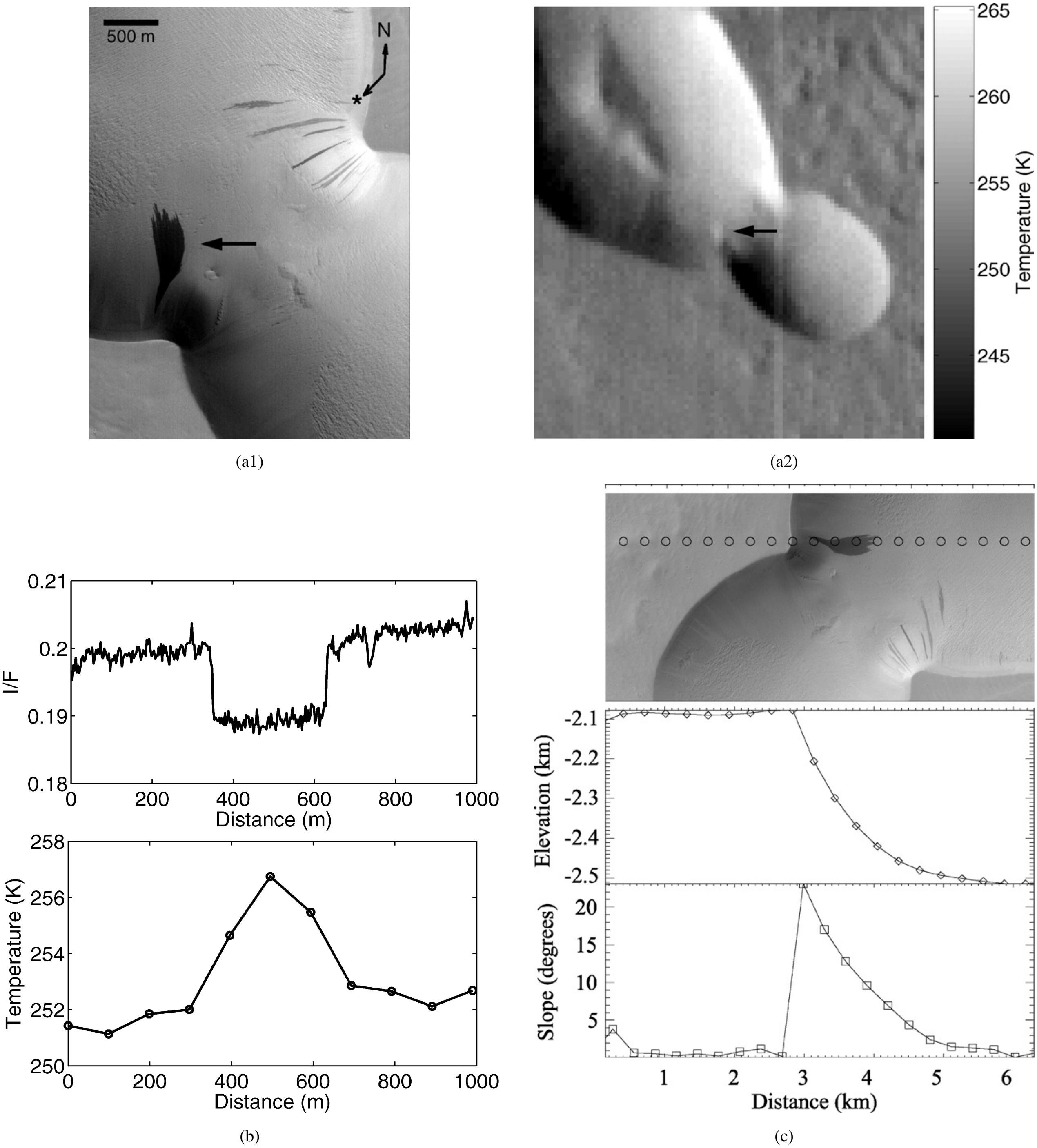
A quantitative analysis of the occurrence of bright streaks is shown in form of a histogram in Fig. 7b. Each bin in the histogram includes images from all latitudes, and it confirms the aforementioned relative abundance of bright streaks around Arabia, while they are rarer but not absent elsewhere. Two histograms are shown, one represents the fraction of streaks and the other the fraction of images. Both are a measure of the abundance of bright streaks relative to that of dark streaks, and both show the same trends. For comparison, the local formation rate of dark slope streaks from MOC/MOC overlaps (Aharonson et al., 2003) is also plotted in Fig. 7b, increasing downward. In areas with relatively many bright slope streaks, in particular Arabia, the pace of dark slope streak formation is slow, and vice versa. Since both, the fraction of bright streaks and the formation rate are normalized by the number of existing streaks, this amounts to a strong negative correlation between the number of bright streaks and the annual number of new dark streaks.

4. MOC/THEMIS-infrared overlaps: An approach to thermophysical properties

We have recorded the width of the widest slope streak in many MOC images, and used the resulting list of images with exceptionally large streaks to search for overlaps with Thermal Emission Imaging System (THEMIS) infrared images that have a typical resolution of 100 m/pixels. Fig. 8a shows images in infrared and visible wavelengths. Slope streaks appear brighter in the infrared (warmer) than their surrounding. Other examples of MOC-NA/THEMIS-IR overlaps where dark slope streaks appear bright in the infrared are M1000662/I01952006 and M0402746/I02458005 (not shown here).

Fig. 8b shows the albedo and temperature contrast obtained from the visible and infrared images in Fig. 8a. At a local time of 15:25pm, the streak is warmer by about 4 K. Incidentally, a Mars Orbiter Laser Altimeter (MOLA) track passes over this streak, and its topography is known, as shown in Fig. 8c.

We have used a one-dimensional thermal model (Aharonson and Schorghofer, 2006) to estimate the temperature difference



(a1) (a2)

(b) (c)

Fig. 8. (a) Slope streak in visible and infrared. To the left is MOC image M1000967, and to the right daytime THEMIS image I01665006 with temperatures estimated from the 12.6 μm band. (b) Estimated albedo along a transverse section in the MOC image (resolution 2.9 m/pixel) and temperature along a transverse in the THEMIS infrared image (resolution 99 m/pixel). (c) Topography of the same slope streak from a MOLA track. The slope at the upper end of the streak is about 20°, on a 300 m baseline, and at its lower end, it is about 10°.

on a slope on the day and time of the THEMIS observation (areocentric longitude 5.9°, latitude 7.1° N). The expected difference between an albedo of 0.20 and 0.19 is barely 1 K, on either a 10° or 20° slope, and for a thermal inertia of 80 as well as 120 $\mathrm{J\,m^{-2}\,K^{-1}\,s^{-1/2}}$. This suggests the temperature difference is caused not only by albedo but also requires a difference in thermophysical properties, as, for example, a decrease in thermal conductivity.

5. Conclusions and discussion

Dark slope streaks are observed in five monitoring areas between Viking observations in 1977–1980 and MOC observations 1998–2005. Disappearance of streaks is seen in one of the regions. We also detect fading of slope streaks indirectly, through the strong contrast of new streaks compared to old streaks. These observations establish that slope streaks fade over decades.

In all study areas, new and persisting dark slope streaks are observed. The rate of formation at the study sites was 0.03 new slope streaks per existing streak per Mars year, about half of the rate estimated from observations spanning only the past few years. Dark slope streaks have formed in many areas and many times, and despite circumstantial evidence that some areas or times are more active than others, streak formation appears to be overall a continuous process, because streak forming events have been constraint to many nonoverlapping time intervals and, in the long term, there are no inactive sites.

Overall, the number of newly formed slope streaks is significantly higher than the number of streaks that have disappeared. The reason for the imbalance remains unclear, and we are not yet able to use slope streaks as markers of dust deposition history.

Bright slope streaks, which have similar geographic distribution as dark slope streaks, apparently do not presently form in sudden events as dark slope streaks do. Instead bright slope streaks might form from old dark slope streaks, perhaps transitioning through a partially faded stage. Geographically, there is a negative correlation between the number of bright streaks and the annual number of new dark streaks, that is, an area with relatively many bright streaks tends to be less active.

Dark slope streaks are warmer than their surroundings in afternoon infrared images. In one case, where data from three instruments can be combined, the temperature difference is larger than expected based on the albedo contrast. Independence of dark slope streak appearance form illumination and viewing geometry implies there is no strong photometric effect.

Acknowledgments

We thank Taharih Motazedian and David Gremminger for their help with image surveys, Ken Edgett and Nicolas Mangold for insightful discussions, and MSSS for the Viking slope streak monitoring. This work was supported by the NASA Mars Data Analysis Program and by the NASA Astrobiology Institute under Cooperative Agreement No. NNA04CC08A issued through the Office of Space Science. LT was supported by a Space Grant fellowship.

References

Aharonson, O., Schorghofer, N., 2006. Subsurface ice on Mars with rough topography. J. Geophys. Res. 111 (E11). E11007.

Aharonson, O., Schorghofer, N., Gerstell, M., 2003. Slope-streak formation and dust deposition rates on Mars. J. Geophys. Res. 108 (E12). 5138.

Baratoux, D., Mangold, N., Forget, F., Cord, A., Pinet, P., Daydou, Y., Jehl, A., Masson, P., Neukum, G., 2006. The role of the wind-transported dust in slope streaks activity: Evidence from the HRSC data. Icarus 183, 30–45.

Cantor, B.A., 2007. MOC observations of the 2001 Mars planet-encircling dust storm. Icarus 186, 60–96.

Edgett, K.S., Malin, M.C., Sullivan, R.J., Thomas, P., Veverka, J., 2000. Dynamic Mars: New dark slope streaks observed on annual and decadal time scales. Lunar Planet. Sci. XXXI. Abstract 1058.

Ferguson, H.M., Lucchitta, B.K., 1984. Dark streaks on talus slopes, Mars. In: Planetary Geology and Geophysics Program Report, pp. 188–190.

Gerstell, M., Aharonson, O., Schorghofer, N., 2004. A distinct class of avalanche scars on Mars. Icarus 168, 122–130.

Head, J.W., Marchant, D.R., Dickson, J.L., Levy, J.S., Morgan, G.A., 2007. Slope streaks in the Antarctic Dry Valleys: Characteristics, candidate formation mechanisms, and implications for slope streak formation in the martian environment. Lunar Planet. Sci. XXXVIII. Abstract 1935.

Malin, M.C., Edgett, K.S., 2001. Mars Global Surveyor Mars Orbiter Camera: Interplanetary cruise through primary mission. J. Geophys. Res. 106 (E10), 23429–23570.

Malin, M.C., Edgett, K.S., 2006. Why the new gully deposits are not dry dust slope streaks. NASA's Planetary Photojournal, http://photojournal.jpl.nasa.gov/catalog/PIA09030.

Malin, M.C., Edgett, K.S., Posiolova, L.V., McColley, S.M., Dobrea, E.Z.N., 2006. Present-day impact cratering rate and contemporary gully activity on Mars. Science 314, 1573–1577.

Miyamoto, H., Dohm, J.M., Beyer, R.A., Baker, V.R., 2004. Fluid dynamical implications of anastomosing slope streaks on Mars. J. Geophys. Res. 109 (E6). E06008.

Morris, E.C., 1982. Auerole deposits of the martian volcano Olympus Mons. J. Geophys. Res. 87, 1164–1178.

Schorghofer, N., Aharonson, O., Khatiwala, S., 2002. Slope streaks on Mars: Correlations with surface properties and the potential role of water. Geophys. Res. Lett. 29 (23). 2126.

Sidhu, S.K., Phillips, C.B., Chyba, C.F., 2005. Changes in dark slope streaks on Mars. Astrobiology 5 (2), 318. Abstract 880.

Sullivan, R., Thomas, P., Veverka, J., Malin, M., Edgett, K.S., 2001. Mass movement slope streaks imaged by the Mars Orbiter Camera. J. Geophys. Res. 106 (E10), 23607–23633.