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# Mapping of Wind Streaks on Craters at the Terra Sirenum region

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## Abstract

Wind streaks are albedo features created when wind interacts with elevated hardened material, and are useful for understanding eolian and atmospheric processes as they indicate wind direction. In this study, wind streaks created by craters in the Terra Sirenum region of Mars were observed and studied. Images from the Mars Reconnaissance Orbiter (MRO) were downloaded through the PILOT software created by the USGS and measured using the ENVI program. Quantitative measurements such as crater diameter and area, primary and secondary tail lengths, and coordinates were made in ENVI; qualitative measurements such as tail shape and color, crater age and complexity, and wind direction were made without use of ENVI. It was observed that an increase in crater diameter and/or area increases the likelihood of a wind streak forming, all secondary tails had a dark color, the parallel tail shape was the most common by far, and the dominant wind direction was to the southeast.

## Introduction

“Wind streaks” form when dust and wind interact with hardened material such as hills and, in this case, crater rims. When the wind interacts with a feature with higher elevation, the feature will deflect the wind, causing it to spiral as it flows beyond the feature. This event creates a bright or dark “tail” that contrasts with the surface surrounding the "tail”, which indicates direction to the scientist. The “tail” aims in the opposite direction from where the wind is originating, and it can also be measured. It is important to point out that the “tail” is simply the material underneath the darker or lighter surface that has been exposed thanks to the spiral the wind is creating.

P. Thomas et al. (1981) proposed a classification for these features utilizing a table (Figure 1), which we used for our classification. For purposes of this study, we will only look for these features on craters. The reasoning behind this is time restrictions and how easy it is to measure these features on craters. However, these aeolian features can also happen in troughs and scarps.

Our main objective for this research is to measure those features and obtain a basic understanding of the aeolian activity occurring in the Terra Serinum region. This region is rarely studied for these features, and although it has been studied for these features, an inventory of the measured features is not available for future study. Therefore, we wanted to provide this inventory with multiple measurements so that more research can be done in the future. This research does not measure all of the features in craters in the region due to time restrictions.

TABLE I

CLASSIFICATION OF WIND STREAKS

| Type[a] | Obstacle/Shape[b] | Shapes[c] | Length[d] (km) | Occurrence[e] | Variability[f] | Fig. No. |
|---|---|---|---|---|---|---|
| Bright depositional streaks I(b) | Crater, hill, scarp | Teardrop, tapered, parallel, fan | 5–25 | Low, midlatitude | minor, S. Summer | 3A, B |
| | Trough | Serrate, linear, irregular | 10–100 | Syria Planum, Lab. Noctis, Coprates | rapid, S. Summer, Fall | 3C, E |
| | Sheet | Serrate, linear, irregular | 10–100 | Syria Planum, Lab. Noctis, Coprates | rapid, S. Summer, Fall | 3C |
| Dark erosional streaks I(d) | Crater, scarp | Fan, tapered | 10–30 | 25–40°S; flatter areas | Form ~100 days after duststorms | 4A, B, C, I |
| | Coalesced | Irregular | 5–150 | Regional slopes in Tharsis, Syrtis Major | Same as crater/scarp; mostly after duststorms, some during rest of year | 4D, E, I |
| | Linear | Linear | 5–100 long 0.1–4 wide | Scattered | Insufficient data | 4G, H |
| Mixed tone I(mt) | Crater | Teardrop, tapered | 5–20 | Syrtis Major, Tharsis | Insufficient data | 5B, C |
| Splotch-related streaks II | Crater Splotch | Parallel, tapered | 5–100 | Oxia Palus, 40–60°S, Cerberus | Sporadic– S. Summer | 6 |
| Frost | Craters | Teardrop, tapered | 5–30 | Polar caps; 55–70° Lat. | With $CO_2$ caps | 7 |
| Dune shadow | Craters | Teardrop | 5–20 | N. polar dunes | — | 8 |
| Frost–Sediment | Craters, ejecta | Arrowhead | 5–30 | N. polar region | — | 9 |

[a] No sediment deposit source: Type I. Sediment source: Type II. Dark or bright: streak albedo relative to surroundings in red filter images.
[b] Streaks within each type are arranged by the kind of associated obstacle; or, by streak shape if obstacle is not visible.
[c] See Fig. 1.
[d] Typical lengths in kilometers; not the complete range of lengths.
[e] See also Fig. 2.
[f] See text.

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**Figure 1:** C*lassification table was proposed by P. Thomas et al. (1981) for the features on Mars.*

## Methodology

The images used for this research were taken by the Mars Reconnaissance Orbiter (MRO) from March 23, 2006, to May 5, 2023. The MRO has a spatial resolution of 4–20 meters per pixel (mpp), which works great for the purpose of our research when measuring the fainting tails. The images were specifically taken by the Context Camera (CTX), which is a powerful camera that provides big pictures of the terrain on Mars in high resolution. Black-and-white images were used because the classification methods are made with black-and-white images.

The images were obtained from the Planetary Image Locator Tool (PILOT), which is a website provided by the USGS. The images taken by satellites are open to the public for research. 69 images were downloaded from the website and were divided between the two of us to make the mapping process more efficient. The mapping consists of looking for features in craters and measuring their primary and secondary tails; the primary tails are the ones inside, and the secondary are the ones that form outside. Area of crater, diameter of crater, relative age, type of crater, color of the primary and secondary tails, and form of the tails were some of the measurements done to provide more data on the features in the Terra Sirenum region. All of this data was organized on a sheet, and an ID was given to every category for further organization.

All of the previously mentioned measurements were done using ENVI, and the maps created were done using ArcGIS Pro. To ensure that the measurements provided by ENVI were correct, we decided to import the images to ArcGIS Pro and JMARS (Java Mission-Planning and Analysis for Remote Sensing), which is a program specialized in working with planetary data. Measurements were done in both of them of the same crater in order to verify if the images were well georeferenced and the measurements provided were correct. As mentioned before, ArcGIS Pro was used to create the images, such as figure 2. The decision to use ArcGIS Pro was because it was easier and less time-consuming to make the maps in this program compared with ENVI; therefore, it was a personal decision.


**Figure 2:** Example of a figure created using ArcGIS Pro in order to demonstrate the features, in this case rectangular white wind streaks.

## Results/Discussion

Sixty-three craters were observed and measured; the average crater diameter was 1.4 kilometers, the average crater area was 2.95 kilometers squared, 89.5% of the craters were simple, and 63.5% of them were relatively young. Of the sixty-three craters, fifty of them had wind streaks, and of these fifty, eighteen of them had secondary tails. Most primary tails were bright, all secondary tails were dark, the most common shape for both was the parallel shape, and the most common wind direction was to the southeast.

Several correlations between the data were found. First, as shown in Figures 3 and 4, there is a relationship between the crater area and diameter and the presence of wind streaks. This relationship is directly proportional, since an increase in crater area or diameter makes it more likely that a wind streak will form at that crater. A possible relationship between crater area and diameter and the length of the primary tails can also be seen, shown in Figures 5 and 6. There are, however, several notable outliers, so further studies and a higher sample size would be needed to confirm a linear relationship between these variables. The geographic distribution of both the primary and secondary tails and their colors were also observed, as shown in Figures 7 and 8. The secondary tails had a smaller range of distribution than the primary tails, found in only a few clusters in the region, but this could be a result of a small sample size not covering the entire Terra Sirenum area.

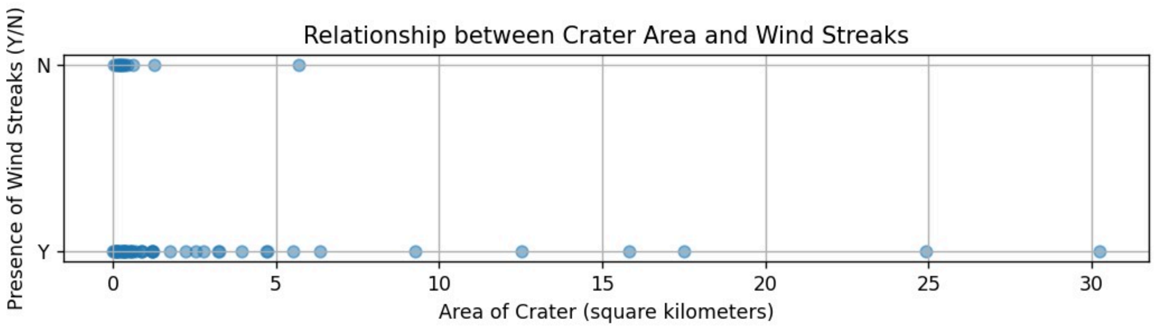


**Figure 3:** Graph showing the relationship between crater area and presence of wind streaks.

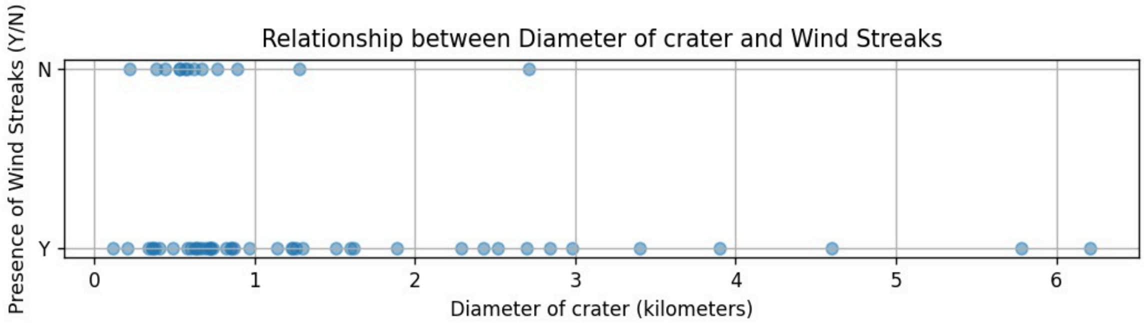


**Figure 4:** Graph showing the relationship between crater diameter and presence of wind streaks.

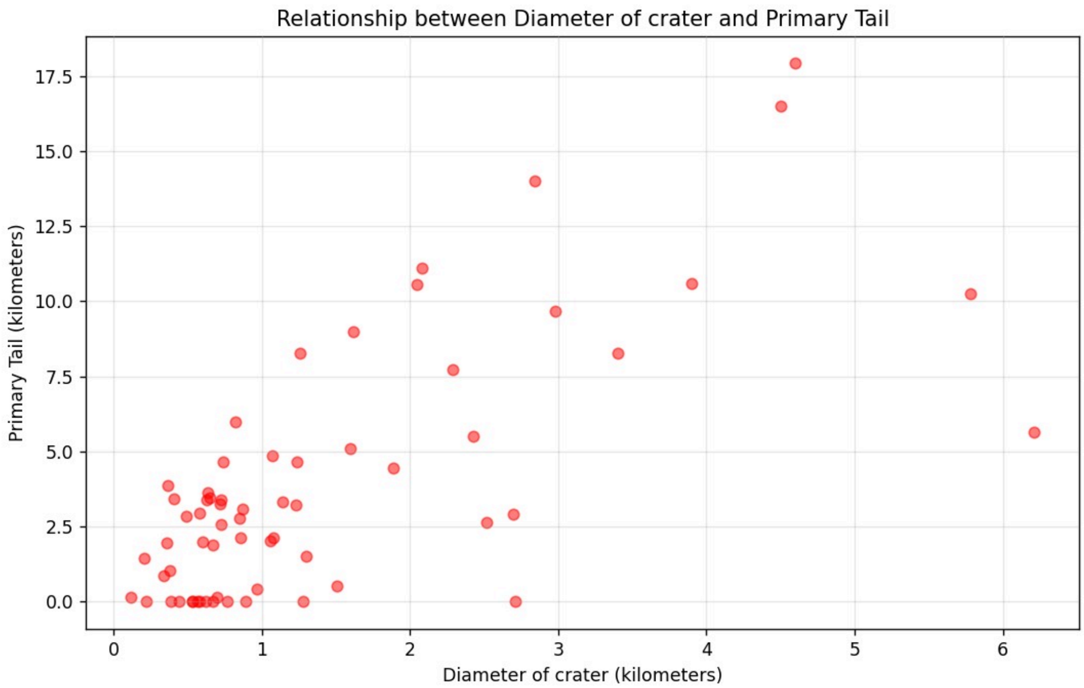


**Figure 5:** Graph showing the relationship between crater diameter and primary tail length.

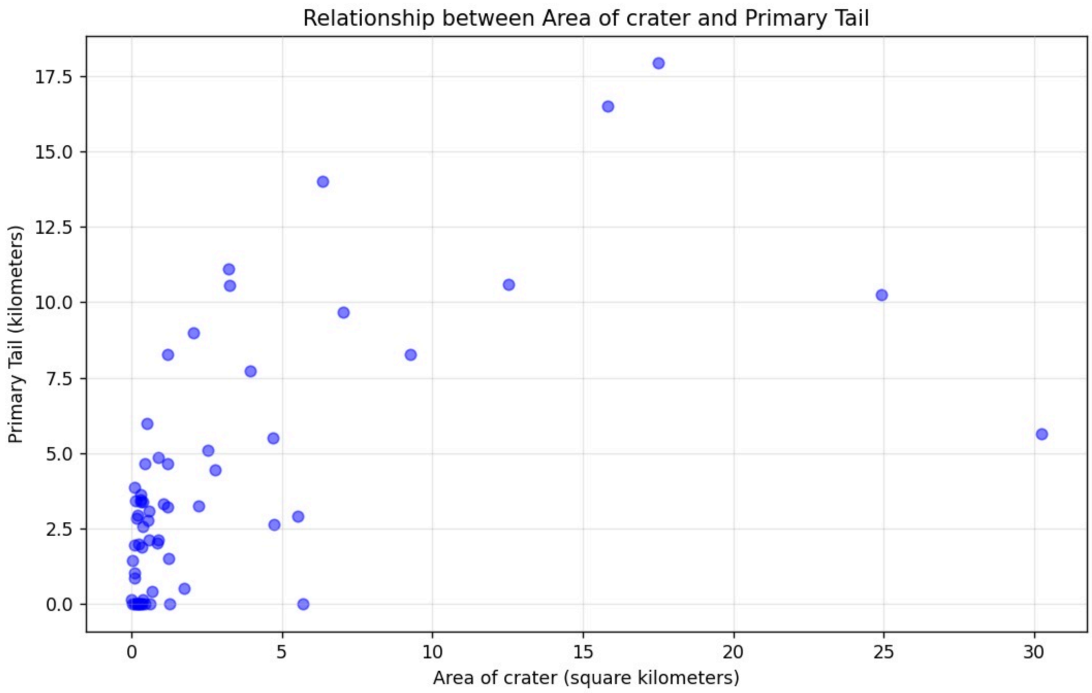


**Figure 6:** Graph showing the relationship between crater area and primary tail length.

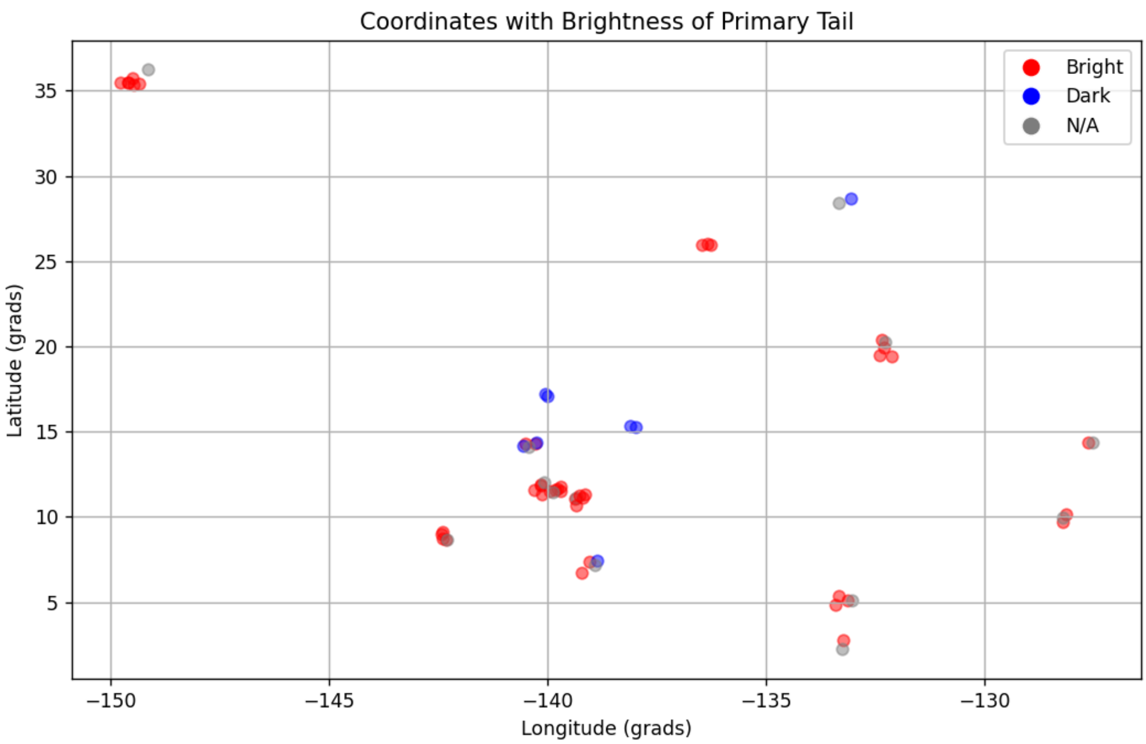


**Figure 7:** Graph showing geographic distribution of primary tails and their colors.

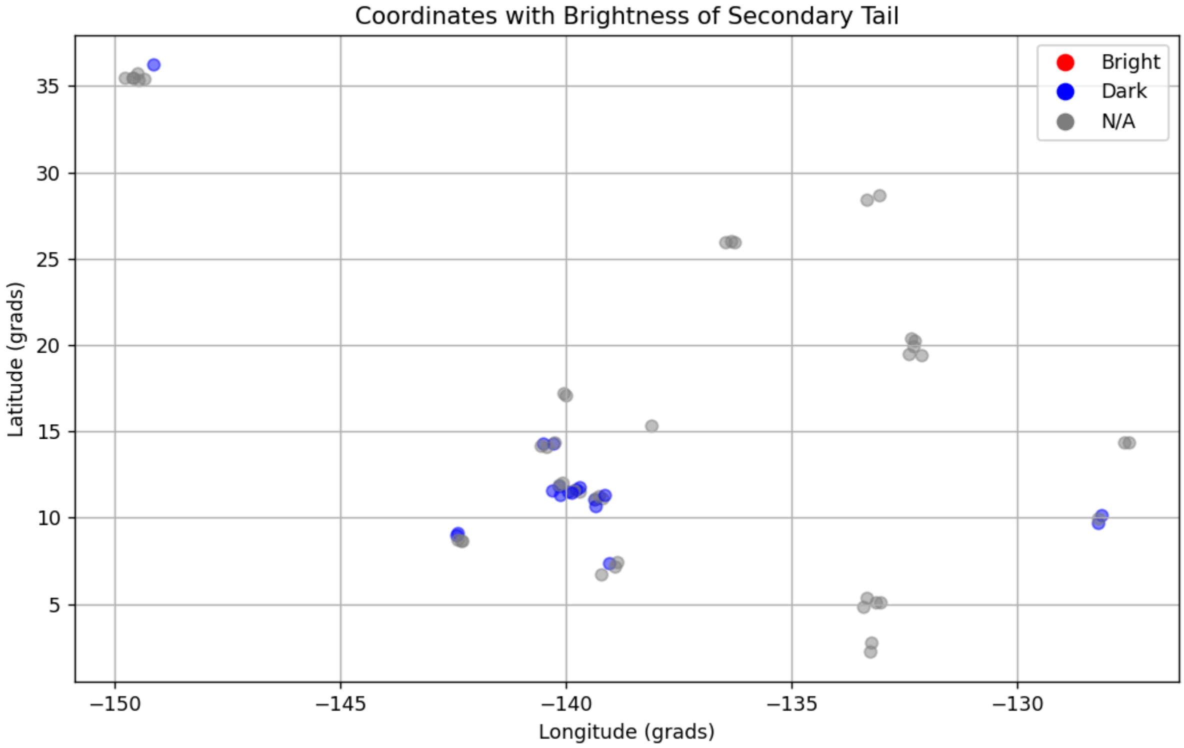


**Figure 8:** Graph showing the geographic distribution of secondary tails and their colors.

## Conclusion

In conclusion, the main findings were that an increase in crater diameter and/or area increases the likelihood of a wind streak forming, all secondary tails had a dark color, the parallel tail shape was the most common by far, and the dominant wind direction was to the southeast. This project was limited by time constraints and could be improved in several ways. Mainly, a higher sample size would help with more accurate statistics and with defining if there are clear mathematical relationships between the data obtained. It would also be beneficial to verify the wind directions measured with independent data of Mars, as well as making a map of the relative wind directions observed in this study. Finally, another aspect that could be studied is the mineral composition of the Terra Sirenum region and try to see if there is a relationship between the mineral composition of the surface and the color or behavior of the wind streaks studied.

## Referefences

1- Thomas, P.C., Veverka, J., Lee, S., and Bloom, A.A., 1981, Classification of wind streaks on Mars: Icarus, v. 124–153, doi:10.1016/0019-1035(81)90010-5.

2- Winds of Mars: Aeolian Activity and Landforms, https://www.lpi.usra.edu/publications/slidesets/winds/.

3- Mars Education | Developing the Next Generation of Explorers, https://marsed.asu.edu/mep/wind/wind-streaks.

4-Encyclopedia of Planetary Landforms SpringerLink, https://link.springer.com/referencework/10.1007/978-1-4614-9213-9.

## Appendix

Here we provide the link to the google sheet so that it is accessible for the public:

https://docs.google.com/spreadsheets/d/1tggTu0N0jL_1bqO7rEzLHnG2rfcrk8to1z1fQtEqLj8/edit?usp=sharing