TERRESTRIAL ANALOGS TO MARS: EAST-CENTRAL SAHARAN DUST DEVIL TRACKS

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Introduction: Dust devil tracks are morphological features left after the passage of dust devil, where fine debris has been removed from the surface, typically leaving a dark track. Seen abundantly on Mars, dust devil tracks are rare aeolian features on Earth presumably due to the active water cycle and bio-modification of the surface. A few locations on Earth (Ténéré Desert, Niger [1]; Turpan Desert, Northwest China [2,3], Coastal Desert, Peru [4]) have been identified previously as sufficiently arid with conditions favorable for producing dust devils and preserving their tracks. Using the publicly available images from Google Earth, this continuing study describes four sites in the east-central Saharan Desert (Libya, Chad, and Egypt) to add to the global inventory of terrestrial dust devil track sites [5,6].

Background: Terrestrial dust devil tracks were first described by Rossi and Marinangeli [1], who identified similar tracks to those presented here, but located in the Ténéré Desert of northern Niger. They described dark, crisscrossing streaks east-northeast of the Aïr Mountains presumably resulting from the removal of fine-grained material by the passage of dust devils. Reiss et al. [2,3] described a different region of dust devil tracks in the Turpan depression of northwestern China just south of the Altay Mountains. Both sites not only have nearby relief, but they are also in close proximity of large dune fields. Hesse reported recently on other tracks discovered in the coastal desert of southern Peru [4], an arid region that has the Andes rising to the east.

Dust devil tracks obviously form in arid regions where dust devils are abundant. However, the controls on their production and preservation are not well understood. Tracks are not always produced in every location of abundant dust devil activity. Presumably the tracks are tied to the strength of the dust devil vortex. The strength of the vortex results from a complex interplay between boundary layer winds, insolation of the surface, and the source of the vorticity that eventually becomes the column. Vorticity can be imparted to the airflow by two main mechanisms. Boundary layer winds interacting with asymmetric rising thermal plumes can develop into vertical vortices that strengthen through vortex stretching as the plume rotates and rises [5]. Rennó et al. [6] suggested that vorticity could be imparted to forming dust devils by horizontally rolling airflow coming off of topography encountering strong daily thermal plumes. The plumes stretch and lift the rolling currents that eventually split becoming two counter-rotating dust devils. Both methods seem equally plausible in the formation of dust devils for any given location. Differences in the strength of the two mechanisms have not been fully explored, and may be important to understanding how and why dust devil tracks form under only certain conditions. Strength of the system in this case would be synonymous with the magnitude of the pressure drop in the core of the vortex, or how tightly wound the dust devil is, which in turn would related to how much sediment could be entrained in the vortex.

Dust Devil Sites: The dust devil tracks in this study are located across the east-central Sahara including southwestern Libya, southern Libya, northeastern Chad, and the Egypt-Libya border. First discussed by [7] and [8], the regions share many similarities to Rossi and Marinangeli's initial discovery. Found in and around local topography and in proximity to dune fields, the dust devil tracks presented here appear dark compared to the background sand suggesting that significant fines have been removed. The best examples have been observed in the southern Libya site (Fig.1), where the tracks are present on a dry riverbed, in a wide canyon. Best preserved, but also most protected, the tracks at this site are similar to familiar images from Mars, including tapering tracks and curlicue morphologies. Those tracks found in northeastern Chad, not previously reported [9], are draped over dunes and seem to originate from the rock outcrops to the north. The Egypt-Libya border tracks are around the proposed Kebira impact crater and are all found in the flat areas between rock outcrops. The southwest Libya tracks are nearly at the limit of resolution of the Google Earth images, and form the farthest from the rock outcrops from the southwest.

Discussion and Conclusions: Dust devil tracks have been used as indicators of dust devil activity on Mars, and rarely seen on Earth. What dust devil tracks actually represent and how to use them effectively in statistical analyses is still very uncertain. Some tracks can persist for multiple dust devil seasons suggesting they take far longer to "erase" or cover up by dust/fine sand deposition than they do to create. This observation artificially inflates statistics where multiple seasons cannot be discerned. Because of only recently discovering these in extremely remote places on Earth, formation mechanisms are also not well studied. It is unclear what the width of the track represents. Is this the size of the core pressure well, or the physical size of the dust devil and debris (saltation) skirt? It has been puzzling that many locations on Mars have been observed to be active with abundant dust devils yet produce no tracks (e.g., Amazonis [10, 11]). Other regions such as Gusev Crater produce wide swaths of dust devil activity [12]. One hypothesis is that track production must be tied to sediment availability (i.e., the right mix of sand and dust so that enough dust gets removed with the passage of dust devils to produce a noticeable track). Ground observations from Gusev Crater on Mars and the Turpan desert in China show similar sediment distributions between sand and dust, but both sites also have surrounding topography, that may lead to stronger dust devils, producing similar results. In the case of the Saharan dust devil tracks, we observe variability in track strength that seems to be tied to proximity to nearby rock outcrops.

We consider that these observations are pointing to something more fundamental about how tracks are created and possibly a stronger variety of dust devil that are particularly efficient at lifting dust. We hypothesize that the conditions necessary for producing strongly visible dust devil tracks include surrounding topography that allows orographic airflow effects to enhance dust devil production. On Mars this leads to large fields of dust devil tracks downwind of topography. On Earth the signal is more muted possibly due to our thicker atmosphere and moisture-rich weather systems or bio-modification of the surface that allows tracks to be eradicated on shorter time scales.

References: [1] Rossi and Marinangeli (2004), *JGR;* [2] Reiss et al. (2010a), *JGR*; [3] Reiss et al. (2010b), *Icarus*; [4] Hesse (*in press*), *Aeolian Research*; [5] Kanak et al. (2006), *GRL*; [6] Rennó et al., (2004), *JGR*; [7] Whelley et al., (2007), *2nd International Workshop, Exploring Mars, Trento, Italy*; [8] Neakrase et al. (2008), *GSA Proceedings*; [9] Neakrase et al. (*in prep*); [10] Ferri et al. (2005), *JGR*; [11] Stanzel et al. (2008), *Icarus*; [12] Greeley et al. (2006), *JGR*.

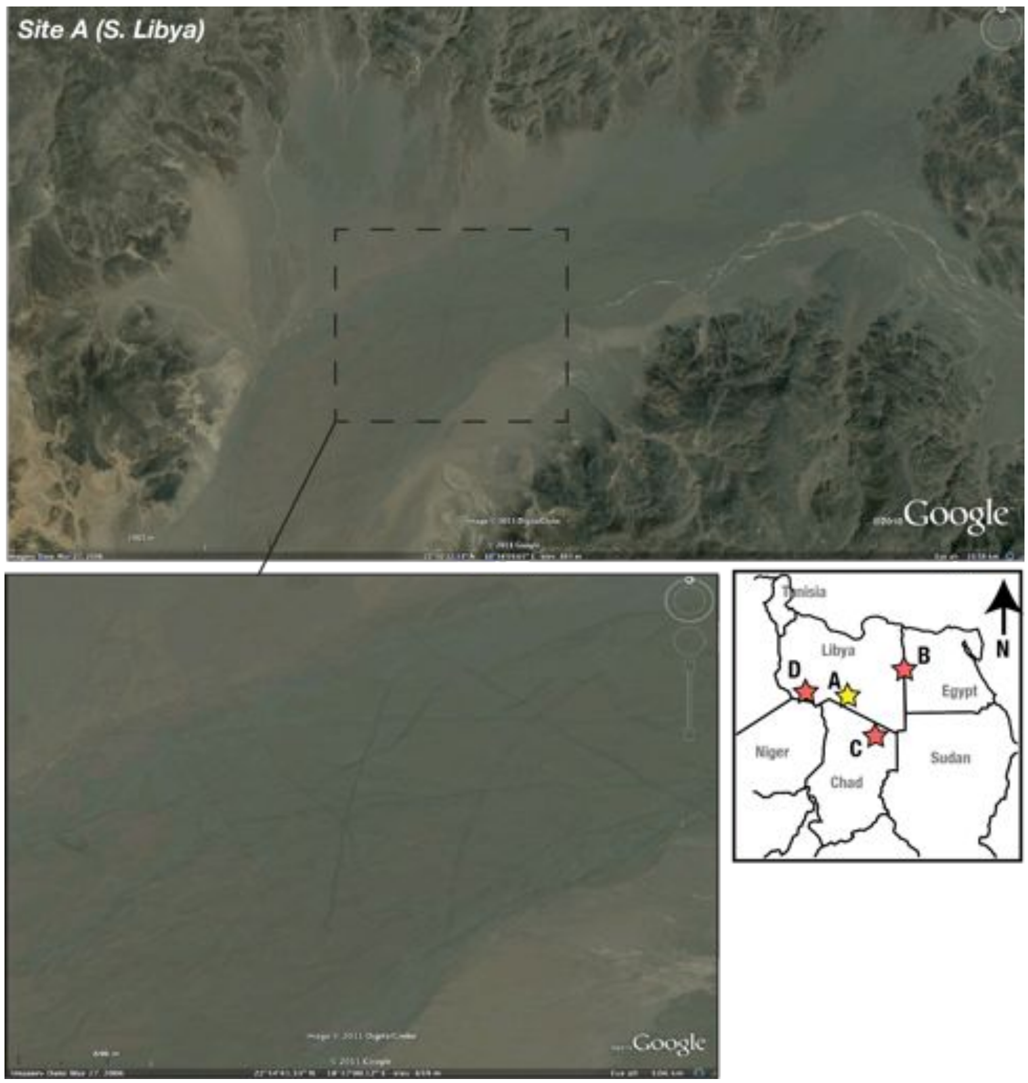

Figure 1. Region of interest showing dust devil tracks on a dry riverbed in south-central Libya.