Correlating Albedo with Dune Movement on Mars
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Introduction: Aeolian activity is the primary geologic agent currently influencing the surface of Mars. Now that high resolution cameras have been orbiting Mars for decades, evidence of aeolian activity in the form of mobile dunes has been identified [1-4]. As it is not possible to take multiple high resolution images over many years at every dune field on Mars, we propose a method to estimate dune activity by calculating changes in dune field albedos.

Background: The hypothesis that albedo could correlate to dune movement has been previously proposed. Edgett [5] hypothesized that transverse aeolian ridges (TARs) had higher albedo than other dune fields because the TARs were less active. This is because in active dunes, grains of a certain size will saltate. Once these particles impact the surface, they will hit any dust that has settled on the top of the dune and cause the dust to be suspended. Any dust that settles on top of sand dunes will be removed more efficiently by dunes with higher activity. [6,7]

Chojnacki *et al*. [8] observed variations in albedo with time at the dune fields in Meridiani Planum. They attributed this to deposition and removal of dust.

In a study using THEMIS-VIS color images at Gale crater, Bennett *et al*. [9] showed that dune fields within the crater have different colors. We hypothesize that these color differences are due to the different levels of dust cover on each dune. This in turn, can be used to infer how active each dune field is.

Methods: We selected several dune fields with various levels of activity that had been previously identified [1-4]. We obtained Mars Odyssey Thermal Emission Imaging System, Visible Imaging Subsystem [10; THEMIS-VIS] images and MRO Context Camera [11; CTX] images taken over each dune field. We converted both datasets to Lambert albedo values and conservatively estimated the error at 4% for THEMIS VIS and 20% for CTX [10,12]. We investigated how the albedo at each site changed with time and how the albedo of fast moving dunes compared to the albedo of slower moving dunes. In three out of four cases (Nili Patera, Gale crater, and Ganges Chasma), we analyzed pixels from the exact dunes used in each earlier study that identified the dunes were mobile. At the fourth site (Becquerel) we took an average of several dunes.

In this study, we assume that all dunes on Mars have a similar composition and the albedo of dust-free dunes are the same. While this is not always the case, most dunes exhibit low albedos and are dominated by pyroxene [13] so to first order this assumption is valid.

Results: Figure 1 shows how the CTX albedo of dunes varies with time at two of our sites (Gale crater and Nili Patera). At the Gale crater dunes, the albedo varies roughly from 0.12 to 0.2. In Nili Patera, it varies roughly from 0.1 to 0.15. In general, the highest albedos for each site occurred after 180° solar longitude. There was no CTX coverage of the Becquerel or Ganges dunes after Ls 180°.

Figure 2a shows the CTX albedo of each site plotted against the measured rate of movement of the dune ripples. Figure 2b shows the THEMIS VIS albedo of three sites plotted against the measured rate of movement of the dune ripples.

Discussion: Large-scale Martian dust storms occur after Ls 180° [14], which explains why the albedos of dunes increase after Ls 180°. During dust storms, dust is deposited on top of dunes. Afterwards, as sand particles continue to saltate, the dunes "clean" themselves of dust.

THEMIS-VIS has less coverage than CTX. The limited data points available with THEMIS-VIS show that the Band 4 (749 nm) albedo inversely correlates with dune movement. This preliminary study suggests that THEMIS-VIS albedo may potentially be used to estimate dune activity.

CTX albedo is less straightforward to interpret. Since there are no images after Ls 180° at two of the sites, we should only compare data at Ls < 180°. There does not appear to be a simple inverse relationship between albedo and dune movement. The minimum albedo at three locations was roughly 0.1.

One possible issue with these data is that at Becquerel we were not able to obtain the albedo from the exact dunes that had been previously determined to be moving at 0.33 m/Earth year [1]. It is possible that the dunes we used in this study were moving at a different rate. If this is the case, we should not consider the Becquerel dunes in this study. In the future, we will include more sites and have better statistics which will enable us to reevaluate whether to include Becquerel.

Excluding Becquerel, Figure 2a shows that the slower moving dunes at Gale (0.66 m/ Earth year) [3] have a higher albedo than the faster moving dunes in Ganges Chasma (2.9 m/Earth year) [4] and Nili Patera (9.1 m/Earth year) [2]. However, the relationship does not appear linear. Instead, it is possible that there is a rate where dunes will "clean" off all the dust before the next year's dust storms and the albedo will reach a minimum value that represents a dust-free dune. In this scenario, if the minimum albedo is roughly 0.1, then it meets a minimum threshold of activity required to completely "clean" the dune before the next dust season.

Future Work: We plan to extend this work to additional dune fields and visible datasets such as HRSC and HiRISE. Each visible dataset is at a slightly different wavelength and band width. By looking at dunes in each dataset, we can determine which dataset is the most useful in detecting albedo variations at dune fields. We can also compare in-situ data from each rover to our orbital observations. MER-A, MER-B, and MSL all have observed dunes. We can use MARCI data (though at coarser spatial resolution) to tie variations in albedo with time for larger dune fields to individual dust events. Finally, we will compare these results to wind models at our study sites to test whether the albedo of dunes can be used as a first order estimate of the local wind regime.

References:

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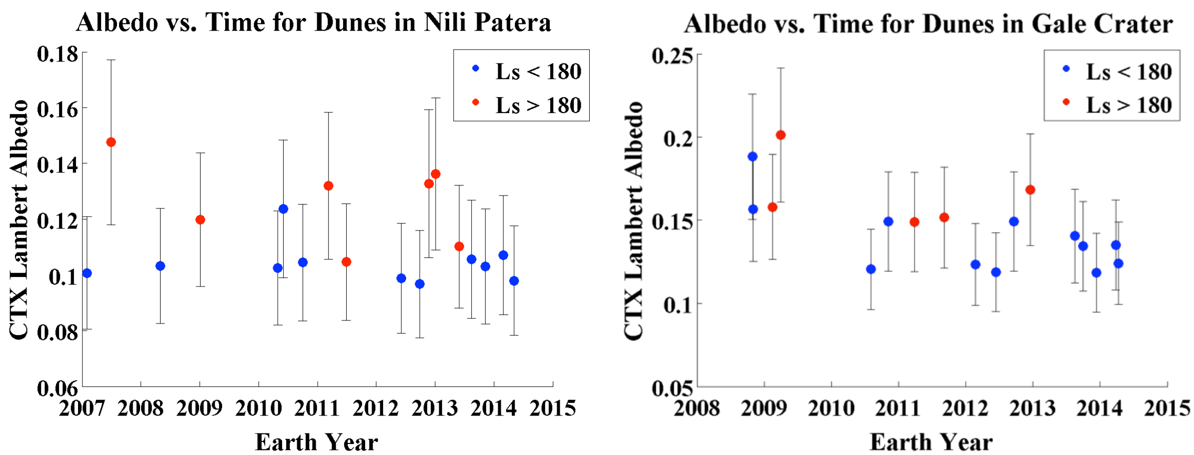

Figure 1: This figure shows how the CTX albedo of dunes varies with time at (left) Nili Patera and (right) Gale crater. We use a conservative error estimate of 20% [12]. In general, the highest albedos at each site occur during Ls > 180° when large dust storms are most common.

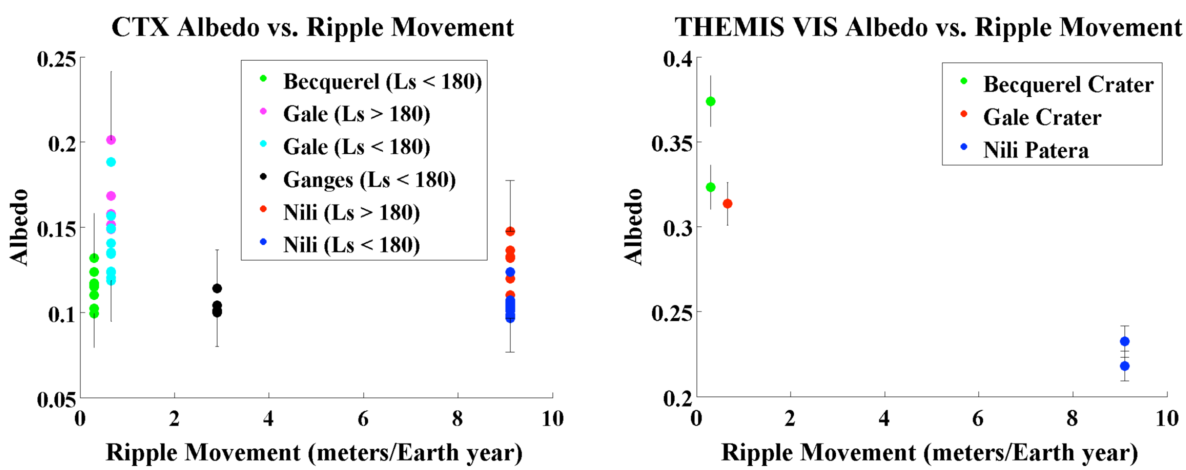

Figure 2: a) (left) The CTX albedo of each dune field plotted against the measured ripple movement. There were no CTX images taken at Ls > 180° for the Becquerel and Ganges dune fields. Error bars of 20% are included only for the minimum and maximum albedos at each site. b) (right) The THEMIS-VIS albedo of three of the dune fields plotted against the measured ripple movement. We use an error estimate of 4% [10]. There was one image that covered the Ganges Chasma dunes, but there was an instrument artifact over the dunes of interest.