DO LARGE DUNES ON MARS MIGRATE? RIPPLE AND DUNE MOVEMENT IN COPRATES CHASMA, VALLES MARINERIS.

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Introduction: Aeolian processes are the main agent for moving material on present day Mars and aeolian bedforms can be used to analyse changing wind speeds and directions. Dunes on Mars have been observed to migrate [1], and the morphology of dune fields can change due to saltation [2]. Saltation causes grain movement, which is one of the main controls on ripple and dune migration [3]. In this study we have measured the rate of ripple migration on the stoss side of some of the largest dunes on Mars over a 7 year time period and tracked the movement of dune crests.

Study Site: The study site (Figure 1), in southern Coprates Chasma, is a large (~11 km in length and ~10 km width) dune field covering 111 km^2, containing barchan, barchanoid and longitudinal dunes. The Coprates Chasma dune field is situated in the eastern part of Valles Marineris, within a steep sided canyon with elevations of ~4000 m on both sides of the valley. This dune field is interesting for two main reasons. First, a potential source region for the dune field is located ~35 km west of the dune field , which could offer an insight into source to sink systems and possibly erosion rates on Mars. Second, the Coprates Chasma dune field contains dunes with a mean height of ~100 m, with the largest dunes reaching heights of ~250 m, thus offering the chance to test whether such large aeolian bedforms are active under the current atmospheric conditions.

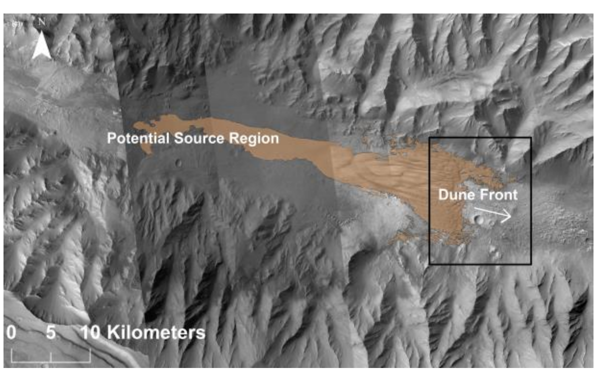

***Figure 1**. The Coprates Chasma dune field study area. CTX image mosaic. Brown polygon shows the dune field at Coprates Chasma, black square indicates the target of this study.*

Morphometry: We measured the morphometry of 115 dunes across the dune front including dune height and length, crest length and orientation of the dunes. The dunes are orientated east to south east with a mean and standard deviation orientation of 112 ± 25.3° respectively, demonstrating that wind direction is also east to south east, down the valley. Dune heights range from 10 m to 248 m, with a mean of 98 m; an order of magnitude greater than the heights of the Bagnold dunes investigated by Curiosity [4]. Dune length varies from 80 to 2135 m and crest length ranges from 98 m to 2159 m. The dune length and crest length both have a large range because of the varying types of dunes present in the dune field.

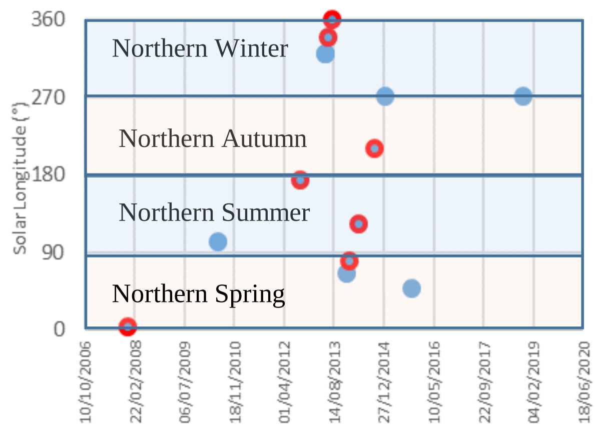

***Figure 2.** The HiRISE image coverage available for our study area, shown by red and blue markers. Red markers highlight the HiRISE images used for this study.*

Movement: We have measured the possible migration of the dune field by studying both the ripples and dune crests using two different methods.

*Ripples***:** The Coprates Chasma dune field provides an excellent opportunity to measure ripple migration rates in Valles Marineris, using sub-pixel correlation of images from the High Resolution Imaging Science Experiment Camera (HiRISE; 25cm/pixel[5]) with the Co-registration of Optically Sensed Images and Correlation (COSI-Corr) software package [6]. Similar methods have been successfully used in previous studies to measure ripple and dune movement across Mars [1,2,7,8,9].

*COSI-Corr***:** A HiRISE Digital Terrain Model (DTM) combined with orthoimages, available from the HiRISE node of the Planetary Data System (PDS), were used in COSI-Corr to measure displacement of the ripples over multiple time periods from 2007-2014. Stacked profiles over 21 dunes at the dune front have been analysed and averaged to give a ripple displacement rate (Figure 3). The ripple displacement combined with assumed ripple height of 40 cm [1,10], allow a ripple flux to be calculated providing information about the local wind regimes in the area.

*Results***:** The observable displacement at these ripples ranged from 0.7 to 18.3 m over the full 7 years, with a mean and standard error of 6 ± 1 m. Thus the mean displacement rate per year across all the studied ripples of 0.9 m. Displacements over a 2, 5 and 6 year time gap were, 2.6 m 3.7 m and 5.1 m respectively, showing the ripples have migrated larger distances over time as expected, thus validating our results. Ripple flux was calculated for each dune for each time period. The minimum flux calculated was 0.1 and maximum flux was 1.5 m^2yr^{-1} with a mean of 0.4 m^2yr^{-1}.

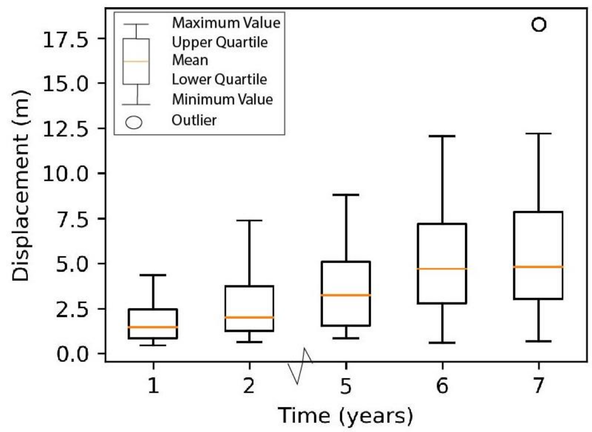

***Figure 3**. Mean displacement of the ripples on 21 study dunes across the study region over 7 years.*

*Dune Fronts***:** Dune crest migration has been measured over the same time period as ripple migration. Dune crests have been manually mapped using Arc Map to show changes in the dune crest shape and the migration of the crests over-time. The movement of the crests is not a simple advancement, with some localized areas of both advance and retreat, depending on the grain movement and slope collapse. Nonetheless, we have measured advancements of the dune crests up to 1.9 m over the full 7 years, equal to a migration rate of 0.3 myr^{-1}. We are currently refining our method of measuring dune crest migration for direct comparison with ripple results.

Conclusions: COSI-Corr has been successfully used with HiRISE imagery to show the displacement of ripples along the stoss side of dunes at Coprates Chasma. The displacement of the ripples increases linearly with time and the displacement rates calculated are similar to rates previously calculated on Mars. The large sand fluxes in the area suggest there are fast wind speeds, likely to be due to the local wind regime in the valley.

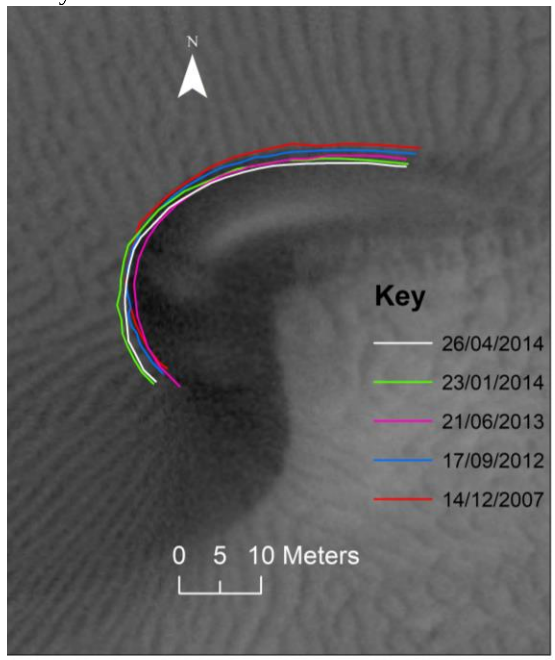

***Figure 4:** HiRISE Image (PSP_006480_1660). Mapped dune crests, showing how the dune crest has migrated over time and how the shape of the dune has changed.*

References: [1] Bridges, N. T. *et al.:* Earth-like sand fluxes on Mars. *Nature,485,339-342* 2012. [2] Runyon, K. D., *et al,*:An integrated model for dune morphology and sand fluxes on Mars. *Earth Planet. Sci. Lett.* 457**,** 204–212, 2017. [3] Kok, J. F. Difference in the wind speeds required for initiation versus continuation of sand transport on mars: Implications for dunes and dust storms. *Phys. Rev. Lett 104,* 2010. [4] Bridges,N.T. *et al*.: Martian aeolian activity at the Bagnold Dunes, Gale Crater: The view from the surface and orbit. *J.Geophys.Res.E:Planets,122,2077-2110,*2017 [5] McEwen,A.S.,*et al.*:Mars Reconnaissance Orbiter's High Resolution Imaging Science Experiment (HiRISE). J.Geophys.Res.E:Planets, *112,* E05S02,2007. [6] Leprince, S., *et al,*:Automatic, Precise, Ortho-rectification and Coregistration for satellite Image Correlation, Application to Ground Deformation Measurement. *IEEE J. Geosci. Rem. Sens.* 45**,** 1529–1558, 2007. [7] Ayoub,F. *et al,*:Threshold for sand mobility on Mars calibrated from seasonal variations of sand flux. *Nature Communications*,5,2014.[8] Cardinale,M. *et al,:* Present-day aeolian activity in Herschel Crater, Mars. *Icarus*,265,139-148,2016. [9] Silvestro,S. *et al,:* Dune-like dunamic of Martian Aeolian large ripples. *J.Geophys.Res.E:Planet*, 43,8384-8389,2016. [10] Lapotre.G.A, *et al.:* Large wind ripples on Mars: A record of atmospheric evolution. *Science*,354,55-58,2016.