TEN (EARTH) YEARS OF CTX OBSERVATIONS OF DUNE MOVEMENT AT NILI PATERA, MARS: A COMPARISON WITH HIRISE. J. M. Davis[1], P. M. Grindrod[1], S. Boazman[1], P. Vermeesch[2], T. Baird[2], [1]Dept. of Earth Sciences, Natural History Museum, London, UK, joel.davis@nhm.ac.uk, [2]Dept. of Earth Sciences, University College London, London, UK.

Introduction: Aeolian processes have modified much of Mars' surface [e.g., 1, 2] and sand transport is observed in many diverse settings [e.g., 2-6], both from orbit and in situ. Since 2006, HiRISE onboard MRO has been imaging Mars at up to 0.25 m/pixel; the acquisition of high-resolution, multi-temporal orbital datasets means that bedform motion can now be tracked in numerous locations across Mars.

One method to quantitatively measure bedform displacement is to use precisely orthorectified, co-registered, and correlated time series HiRISE [7] imagery in COSI-Corr [8], which has previously been used to measure terrestrial glacial movement, fault displacement, as well as bedform motion on Earth and Mars [1, 9-12]. However, the relatively small image footprint of HiRISE when compared to dune field often means that only a small area can be targeted for repeated coverage.

In this study, we use lower spatial resolution CTX (6 m/pixel; [13]) imagery, but which covers a larger surface area, to measure bedform movement as a test case in COSI-Corr. Our study site is the Nili Patera dune field, which comprises active southwest trending barchan and transverse dunes within a caldera complex. Bedform displacement has previously been measured in HiRISE over a period of three Earth years (2007-2010; [3]). Average migration rates were measured as 0.1 and 0.5 m/year for dune ripples and lee fronts, respectively. Here we continue the long-term monitoring campaign of the Nili Patera dune field using time series CTX data over ten Earth years (2007-2016).

Data and Methods: We used time series CTX (6 m/pixel; [13]) imagery to track rates of bedform movement at the Nili Patera dune field (Figure 1). We produced digital elevation models (DEMs) in ISIS3 and SOCET SET according to the method of [14]. We also used SOCET SET to precisely co-register and orthorectify all our CTX time series images.

We then imported the co-registered and orthorectified CTX images into COSI-Corr and ran a series of correlations between a base image (T0) and images of increasing time steps (T1, T2, T3, etc) over a period of 5 Mars years (2007-2016), with step sizes of roughly 1 Mars year. We ran correlations over a sliding window size of 64x64 pixels and a step size of 2 pixels (12 m). We manually inspected the dunes for displacement and then measured the displacement of dune lee fronts using a 3x3 pixel average, taking care to confirm that the displacement was also taking place in HiRISE images.

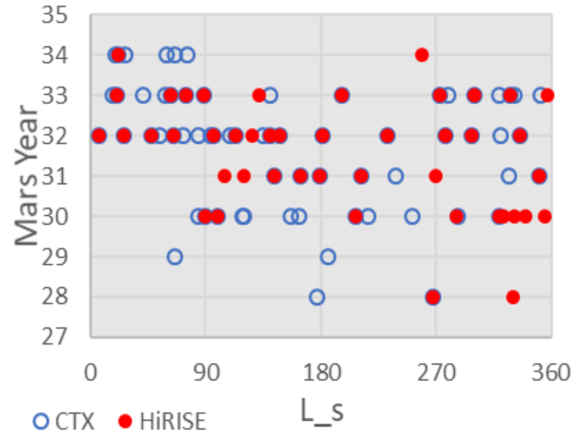

Figure 1: CTX (blue; 65 images) and HiRISE (red; 45 images) coverage of Nili Patera dune field as of late 2018.

Results: The alignment and co-registration between different CTX images was good; qualitatively we have observed a significant improvement compared to results using COSI-Corr to co-register and orthorectify images. We are in the process of quantifying the improvement. Both dune crest and lee front advancement were observed in all the co-registered images in our CTX time series (Figure 2, 3). Dune heights typically range from ~ 5 to 35 m throughout the dune field. The measured rate of lee front advancement increased with each image in the time series. Bedrock mis-registration errors between images produced average displacement values of up to ~ 0.1 m (~ 1/60 of a CTX pixel) and was a minor component of the correlation results.

Over the course of the ten years, dune fronts advanced between ~ 3 and 14 m (in the west-east direction), which produces a migration rate of 0.3-1.4 m/year (Figure 3). The largest advancements were observed in the upwind part of the dune field and variations in terrain type may have changed the rate of migration. The average migration rate was ~ 0.5 m/year (east-west).

Discussion:

Comparison to Previous Results. There appears to be significant variation in the migration rates of different dunes throughout the dune field. Our lee front migration rates compare well to average migration rates from previous studies using HiRISE over a shorter time period (2007-210; [3]). However, we do not yet have enough steps in our time series to assess whether there are significant annual or seasonal variations.

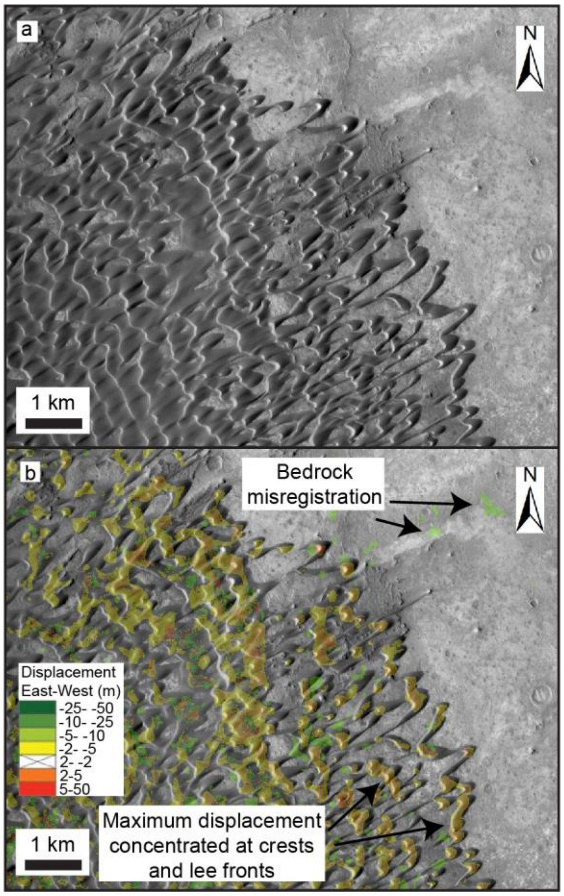

Figure 2: (a) CTX image of Nili Patera dune field. The dunes are migrating towards the southwest. (b) Color map showing east-west displacement between 2007 and 2016 overlaid on a CTX image.

Advantages and Disadvantages of CTX. Whilst the image resolution of CTX is lower when compared to HiRISE (i.e., individual dune ripples are not resolved), the use of CTX in tracking bedform movement has advantages. The wider image footprint of CTX and the potential for more repeat coverage means that larger areas can be investigated. Additionally, CTX has a faster processing time in both SOCET SET and COSI-Corr, allowing large areas to be investigated relatively quickly. However, the inability to resolve individual dune ripples and quantify their migration can be hindering. The future combined use of HiRISE and CTX in dune monitoring and in COSI-Corr will likely be complementary: HiRISE can quantitatively measure dune ripple movement, whereas CTX can provide wider context and examine regional variation. The acquisition of multi-temporal color resolution imagery through the CaSSIS camera onboard TGO may also assist with future dune monitoring studies.

Future Work: Our current time series has step intervals of roughly two Earth years. The availability of CTX imagery (there are currently ~ 65 images of the dune field) means that we can be add to our time series to potentially assess annual or seasonal changes to the dune migration rate.

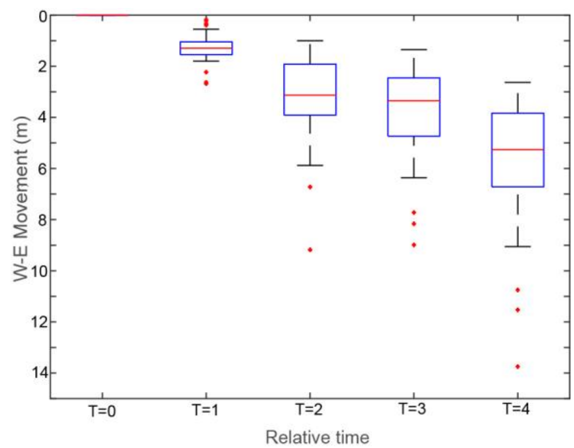

Figure 3: Box and whisker plot showing the mean east-west lee front displacement between 2007 and 2016 (time steps = 2007, 2010, 2012, 2014, 2016) for 33 dunes across the Nili Patera dune field. The blue box shows the interquartile range and the error bars show the range of values (red crosses are considered outlying values) The dune lee fronts have advanced by an average of ~ 5 m over the ten year period.

References: [1] Bourke et al. (2008) *Geomorph*. 94; [2] Bridges et al. (2012a) *Geol.*, 40, 31-34; [3] Bridges et al. (2012b) *Nature* 485, 339-342; [4] Silvestro et al. (2013) *Geol.*, 41, 483-486 [5] Bridges and Elhmann (2017) *J. Geophys. Res.* 123, 3-19; [6] Chojnacki et al., 2011; [7] McEwen et al. (2007) *J. Geophys. Res.* 112, E05S02 [8] Leprince et al., 2007; [9] Herman et al. (2011) *J. Glaciol.*, 57, 202; [10] Hollingsworth et al. (2012) *J. Geophys. Res.* 117, B11407; [11] Vermeesch and Leprince, (2012) *GRL*, 39, L14401; [12] Ayoub et al. (2014) *Nat. Comms.*, 5; [13] Malin et al. (2007) *J. Geophys. Res.*, 112, E05S04; [14] Kirk et al. (2008) *J. Geophys. Res.* 113, E00A24.