INVESTIGATING GEOMORPHOLOGICAL PROCESSES AT NILI PATERA, MARS, USING A MULTI SCALE AIRFLOW MODELLING APPROACH Authors: Love, R.[1], Jackson, D.W.T.[1,2], Michaels, T.I.[3], Smyth, T.A.G.[4], Avouac, J.-P.[1,5], and Cooper, J.A. G.[1,2] 1 School of Geography & Environmental Sciences, Ulster University, Northern Ireland, U.K. 2Geological Sciences, University of KwaZulu-Natal, South Africa 3Carl Sagan Center (at the SETI Institute); 339 Bernardo Ave, Mountain View, CA 94043, USA 4Department of Biological and Geographical Sciences, School of Applied Sciences, University of Huddersfield, England, U.K. 5Division of Geological and Planetary Sciences, CalTech, CA, USA.

Introduction: Aeolian landforms are ubiquitous across the surface of Mars. Until recently, these were thought to be relics from paleo-atmospheric conditions [1-5]. Developments in the observation of Mars' surface, including the HiRISE camera, have shown that dune fields on Mars are in fact capable of undergoing contemporary aeolian modification through transport and deposition processes [3-4, 6]. Such modification has been observed across a range of sites, and flux rates can be as high as terrestrial rates. However, due to a lack of successive lander missions to Mars returning reliable *in situ* meteorological data, the near surface-atmospheric processes forcing this geomorphological change are still not fully understood [7]. Until now, our understanding of wind flow over dune fields has relied heavily on mesoscale (e.g., >2 km grid spacing) atmospheric models, but the resolution of these models is too low to resolve the coupling between air flow and local topography which governs the modification of aeolian landforms on Mars. This study therefore presents a combined modelling approach, dynamically downscaling and combining macro-, meso-, and microscale modelling to examine atmospheric-surface interactions at a sub dune length scale (> 2 m).

Study Site: The Nili Patera caldera (8.8°N, 67.3E°) contains a large barchan dune field (Figure 1), but has not had *in situ* data returned, and has been imaged numerous times by the HiRISE camera over the last 15 years. Analysis of these images using COSI-Corr allows for the quantification of ripple migration and sand flux rates and has shown that this site has sustained sand flux throughout the year, but also experiences seasonal variation [6]. This site provides an opportunity to examine the ability of combined modelling to reproduce the conditions leading to geomorphological change.

Methods: Using a multi-scale modelling approach, we started with the output of a contemporary run of the NASA Ames Global Circulation Model (GCM) [8]. Although the resolution of this model is too coarse to resolve the microscale processes contributing to the geomorphological change on Mars, its output can be used for the initial state and boundary conditions for a mesoscale simulation.

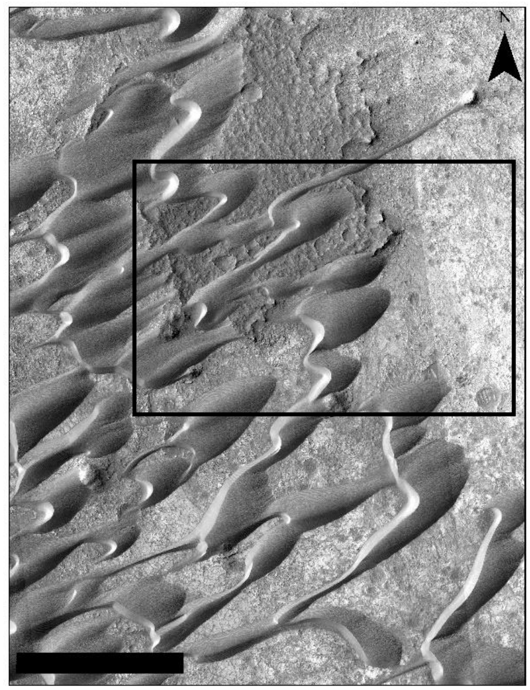

Figure 1: An eastern portion of the Nili Patera dune field, with the area used for CFD simulations outlined in black. Black scale bar is 500m.

The mesoscale model simulated for this study was the Mars Regional Atmospheric Modelling System (MRAMS) [9]. We used a nested modelling approach, scaling down from a horizontal resolution of 240 km at Grid 1 to a ~2 km resolution at Grid 5. The lowest vertical model layer midpoint was at ~5 m from the ground, and atmospheric conditions at this level were extracted to set the initial boundary conditions for microscale Computational Fluid Dynamics (CFD) simulations. Utilising the output from the mesoscale as input for CFD simulations also allows for the examination of seasonal changes on microscale modelling output.

The HiRISE camera provided topographic data of the dune field, which was incorporated into a computational 3D surface domain. CFD simulations were run at each canonical season on Mars, using the respective MRAMS output data as the atmospheric boundary conditions for the domain. These simulations used the Reynolds Averaged Navier Stokes (RANS) equations due to their performance calculating turbulent flows in microscale simulations [10]. The solver PIMPLE was utilised along with the RNG κ-ε model due to the proven performance of simulating separated flows occurring downwind of aeolian features [11].

Preliminary Results: We compared the CFD simulation results against measurements of ripple migration and sand flux made using COSI-Corr. We find that the output from the CFD simulations using this nested modelling approach is capable of reproducing the sediment flux rates derived from the COSI-Corr measurements, and the impact of topography on wind flow direction over the study site (Figure 2 and Figure 3).

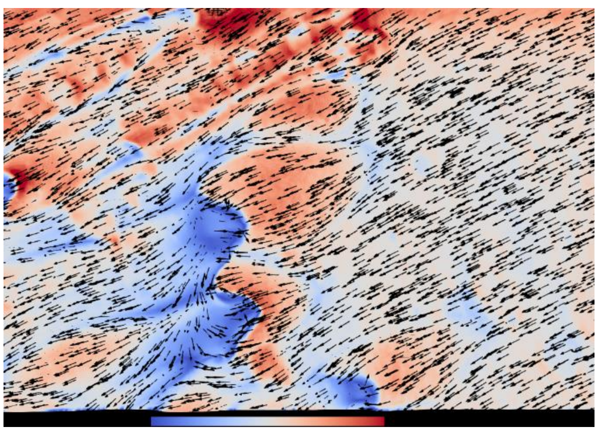

Figure 2: CFD wind vectors over the study site at Ls = 280°, inlet wind direction of 66°. Note: scale bar range is 0 m s^{-1} (blue) to 20 m s^{-1} (red).

However, we observe seasonal variation in the atmospheric conditions occurring over the study site from our modelling, which leads to inconsistencies in the agreement between CFD data and COSI-Corr over the course of a Mars year.

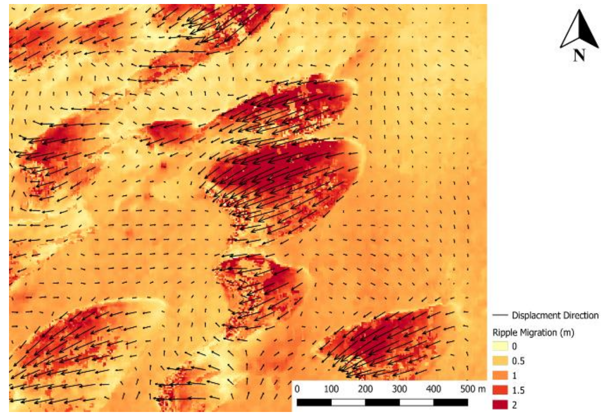

Figure 3: COSI-Corr ripple displacement direction over the study site at Ls = 280° between 23rd January 2015 and 22nd February 2015. Comparison between the COSI-Corr ripple displacement direction shows good agreement with the CFD wind flow direction during this season.

References: [1] Silvestro et al. (2020) *JGR Planets*, 125 (8) [2] Silvestro et al. (2010) *Geophys. R. Letters*, 43 (16) [3] Bridges et al. (2012) *Geology* 40 [4] Runyon et al. (2017) *Earth and Planetary Science Letters*, 457 [5] Golombek et al. (2006) *Geophys, Res.*, 111 [6] Ayoub et al. (2014) *Nature Communications*, 5 [7] Jackson et al. (2015) *Nature Communications*, 6 [8] Haberle et al. (2019) *Icarus*, 333 [9] Rafkin and Michaels (2019) *Atmosphere*, 10 [10] Smyth et al. (2012) *Aeolian Research*, 9 [11] Jackson et al. (2020) *Earth and Planetary Science Letters*, 544.