Investigation of Martian Aeolian Dynamics Using Terrestrial Dune Analogues and Airflow Modelling. C. Cornwall[1], D. W. T. Jackson[1], and M. C. Bourke[2], and J. A. G. Cooper[1], [1]Ulster University (Cromore Road, Coleraine, BT52 1SA, United Kingdom, cornwall-c@email.ulster.ac.uk), [2]Trinity College, Dublin

Introduction: Wind measurements from lander missions, as well as mesoscale and global circulation modeling indicate that Mars' low-density atmosphere rarely exceeds the threshold speed necessary to facilitate sediment saltation [e.g. 1, 2, 3, 4, 5, 6]. However, the surface of Mars is dominated by aeolian features and recent studies involving high resolution images have shown that there are many locations on Mars where ripple and dune modification have occurred over the past few years [e.g. 4, 6, 7, 8, 9, 10, 11, 12, 13, 14] with a few of the sediment fluxes comparable to some terrestrial dunes [15]. Although these observations seem contradictory to circulation modeling, it has been suggested that aeolian modification may be due to strong localized winds generated by topographic obstacles [16], such as craters. Localized winds are complex and cannot be resolved at the resolution of mesoscale and global circulation models.

One of the leading goals in investigating aeolian processes on Mars is to explore the boundary conditions of sediment transport, accumulation, and dune morphology in relation to wind regime as well as to quantify migration rates and sediment flux [17]. This study aims to investigate complex local wind patterns on terrestrial and martian dunes that shape the morphology of aeolian deposits as well as investigate the relationship between flow patterns and slipface activity. Through this analysis, it will be possible to improve constraints and details of sediment flux on Mars including rate, timing and volume which will ultimately lead to a better understanding of sediment source material and dune migration.

Methodology: This study combines terrestrial field observations, three-dimensional computational fluid dynamics (CFD) modeling and remote sensing data from Mars to better constrain grain flow magnitudes and frequencies that occur on slipface slopes of dunes in order to improve estimates of martian dune field migration and sediment flux related to wind velocity and flow patterns.

The chosen study site for the terrestrial dune analog is located in the Maspalomas dune field in Gran Canaria, Spain. This location was chosen due to the aridity of the area, making it a reasonable analog for Martian aeolian systems. Ground-based, high-resolution laser scans collected in the field will be used to generate three-dimensional surface topography and quantify change on a slipface [Fig. 1]. These scans will also be incorporated into a computational fluid dynamics model to investigate interaction with wind velocity, flow patterns and sediment transport.

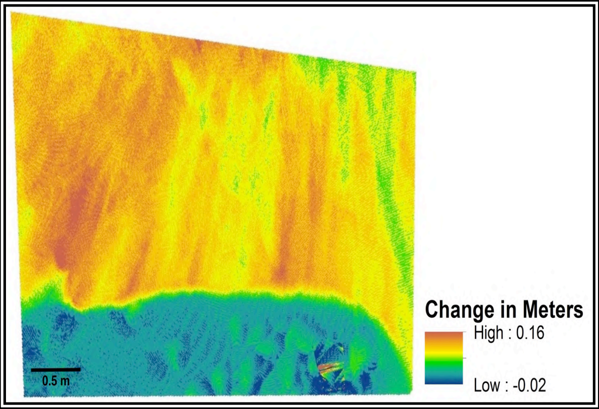

Figure 1. Difference map depicting change in meters on a dune slipface in Maspalomas dune field, Gran Canaria, Spain. This map was created by subtracting two 3D laser scans taken 55 minutes apart. The image shows horizontal dune advancement due to individual avalanche events with little change at the base of the slipface.

This technique will also provide a way to investigate potential triggers for processes on slipface slopes of dunes including, grainflows, formation of alcoves and advancement of the slipface.

Following the investigation of air flow patterns and slipface processes on Maspalomas dunes, remote sensing data of martian dunes will be collected and compared to the results of the Maspalomas dunes. Images from the High Resolution Imaging Science Experiment (HiRISE) on board the Mars Reconnaissance Orbiter (MRO) and photogrammetry will be used to create three-dimensional digital terrain surfaces. The latter will be used with the computational fluid dynamic model OpenFoam in a process similar to the three-dimensional surface topography generated by laser scans of the chosen terrestrial dunes. HiRISE provides the resolution necessary to resolve smaller scale ripples and quantify sediment flux as well as rate and timing of sediment transport of ripples and dunes in conjunction with airflow modeling [Fig. 2; 19].

The project will investigate a variety of dune morphologies on Mars, including transverse ridges, barchanoids, and domes. The chosen dunes will be located in a wide range of latitudes and environments in order to compare differences between aeolian systems. Wind patterns will be analyzed using computational fluid dynamics and surface flow vectors will be superimposed onto three-dimensional HiRISE images with a spatial resolution of 30-60 cm/pixel, which will allow for a direct comparison with local bedforms.

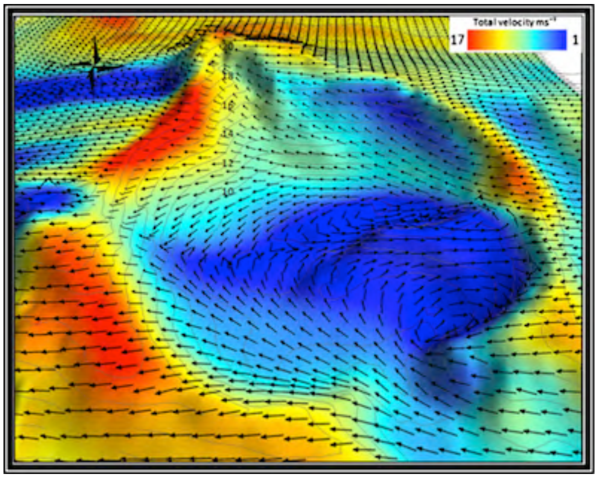

Figure 2. An example of CFD modeling results showing air flow 1 meter above the surface of a dune blow out feature, Ireland. Taken from [20].

Details of sediment flux will be estimated based on terrestrial observations and changes in dune location and evidence of slipface activity which can be identified using repeat coverage of HiRISE images taken inter annually and at various times throughout the martian year.

Significance: This study has valuable application to martian surface geology and evolution as well as terrestrial systems. The results that will be produced can be used for local circulation modeling, especially in locations where wind flow, sediment deposition and dune morphologies are complicated by small-scale topography [4]. A better understanding of the effects of small scale topography on the local wind regime as well as the timing, location and frequency of slipface processes on terrestrial dunes will be provided which will also improve estimates of sediment flux and interpretation of aeolian systems on Mars and other planetary bodies using remote sensing data. For example, many martian dune fields have smaller bedform features superimposed on their surfaces, suggesting a complex wind regime that may be composed of varied magnitude and multidirectional winds influenced by local topography and seasonal changes. In addition to studying local wind regime and slipface processes, constraining the rate, timing, and volume of sediment flux will also lead to a better understanding of the nature and location of the source material for martian dunes and can support future studies focused on recent aeolian activity on Mars including dune migration and morphological changes.

This project has significant implications for studies focused on the processes that form a variety of aeolian deposits with similar morphologies, such as Transverse Aeolian Ridges (TARs), sand ripples, gravel ripples, and mega ripples. Knowledge of localized wind flow patterns will ultimately lead to a better understanding of the conditions in which these morphologies formed and evolve today.

References:

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