OBSTACLE MARKS: EVIDENCE OF VARIABLE WIND EROSION AND SEDIMENT TRANSPORT, HELLESPONTUS, MARS. Mark A. Bishop[1,2] [1]Barbara Hardy Centre [Terrain Analogue Understanding (TAU) research], School of Natural and Built Environments, University of South Australia, Adelaide, SA, 5000, Australia, mark.bishop@unisa.edu.au [2]Planetary Science Institute, 1700 E. Fort Lowell, Suite 106 Tucson, AZ 85719-2395, USA, bishop@psi.edu.

Introduction:
Obstacle marks, specifically current crescents [1] or scour flutes formed by aeolian erosion, have not been previously identified from orbit on Mars. Apart from the recognition of scour zones around boulders at the Viking 1 and Mars Pathfinder sites [2] and at 'Home Plate' during the traverse by Mars Exploration Rover (MER) Spirit into the Columbia Hills [3], no further appraisal of such features has occurred. However in a recent acquisition from the Extended Science Phase (ESP) for the High Resolution Imaging Science Experiment (HiRISE) camera, images of an unnamed intracrater dune field within the Hellespontus region have shown innumerable scour flutes around fine and medium grade blocks [4]. The types, relative numbers and distributions of scour features can be used collectively by proxy to determine the modes of surface wind-direction and pathways of sediment transport across the crater floor. It is therefore the purpose of this letter to demonstrate the feasibility of meter-scale aeolian current crescents as indicators of recent wind activity (erosion and transport) within an intracrater setting in the Hellespontus region of Mars.

Methods:
From a random selection of blocks and scours (n = 124) across HiRISE image ESP_016036_1370, feature outlines were digitized using ArcGIS 9.3® (Fig. 1). This platform allowed for the determination of centroids for each block and the subsequent measurement of scour orientation (azimuth) from these. The sample for each of U-, R- and O-type taxonomies was 61%, 32% and 7%, respectively. For those scours of U-type morphology (n = 74) the angle of mid-scour was plotted upon a circular histogram and the circular statistics for reference direction and dispersion of modal groups were calculated (Fig. 2).

Results:
Data from the HiRISE camera offers an orbital perspective of Mars at a spatial resolution (25.5 cm/pixel) that capably identifies large-scale (mega-) ripples and scour around obstacles such as boulders and blocks (Fig. 1). Image ESP_06036_1370 comprises an intracrater dunefield (42.7°S, 38.0°E) that shows a wealth of sedimentological features, in particular, aeolian scours. The sediment-limited, block strewn intracrater setting offers an ideal environment in which obstacle marks can form. Most scours identified in this sample cluster into two localities.

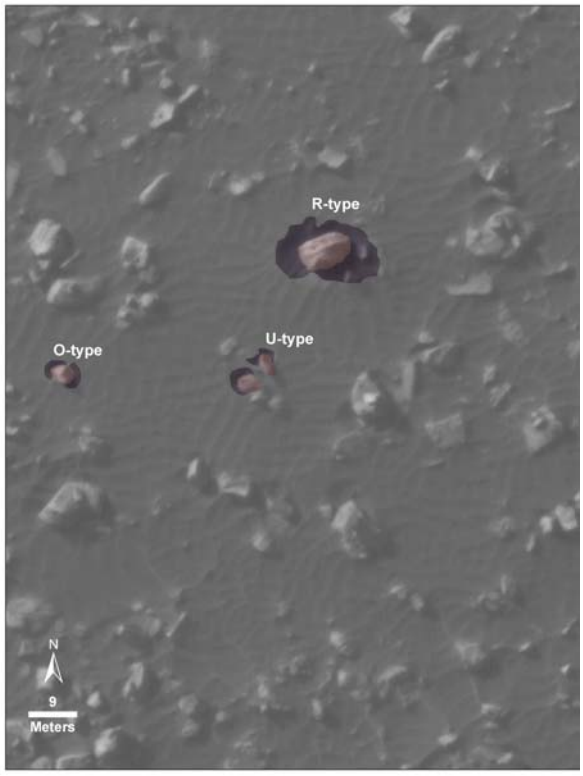

Fig. 1. Scour types (purple outline) across the block laden floor of an unnamed crater in Hellespontus (Ls = 29.8°, southern autumn). The taxonomy of U-, O-, and R-type scours recognises unidirectional, oscillatory (reversing) and rotational (multi-directional) air flow, respectively (adapted from Allen [5]). (Image: ESP_06036_1370_RED, NASA/JPL/University of Arizona).

The largest groups occur in the north-west of the image, where block fields coexist with 'patches' of unconsolidated aeolian sediment, while a second grouping occurs upon the interdune and lower plinths of dunes in the south-east. Although numerous scour flutes have occurred across the region; a ubiquitous wind current moves from the north-west producing the zone of widest and deepest scour. The statistics for scour distribution have collectively shown that U-type forms are orientated with a mean vector of 326° (median of 322°). The null hypothesis of distribution

regularity is rejected, as a high value (0.79) for the length of the mean vector was determined. High length values within the theoretical range (0, 1) imply the sample to be clustered closely around the mean [6]. This observation is further supported by the sample's circular variance (V) where $0 \leq V \leq 1$, and a small value ($V = 0.21$) as found here, implies the existence of a concentrated distribution. Furthermore, the statistic of concentration ($\kappa = 2.75$) where uniformity is shown by $\kappa = 0$, also endorses an increasing concentration about the reference direction [6]. Simply, the distribution of U-type current crescents is not isotropic, but recognizes a preferred orientation.

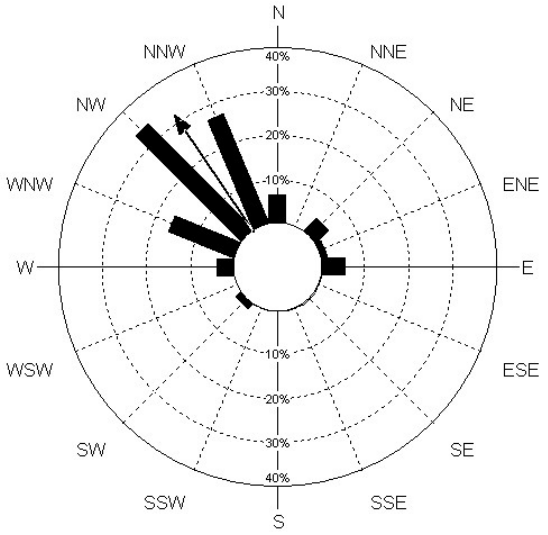

Fig. 2. Circular histogram showing the reference direction (arrow) and modal distribution of U-type scours.

Discussion:

The overarching character of the dune field is crescentic, and exhibits a transverse morphology. However it is the linear-like characteristic of the dune field which best gives a sense of a bi-modal wind system at the regional scale. The preferred orientation of the U-type scours is normal from the direction of the dunes' leeward slopes, hence direction of migration, and implies that the dunes have formed under winds that are primarily from the south-west. The southern portion of the dunefield also shows a suite of ripple trains which are oriented both parallel and orthogonal to the direction of the dunes. The dominance of the north-westerly reference direction for the scour flutes, as well as the south-easterly orientation of the dunes, and corresponding orientations of large-scale ripples supports the existence of two major modes of air flow capable of significant sand transport. In addition, the dominance of a preferred orientation for U-type scours infers that substantial surficial erosion and sediment transport occurs towards the south-east. Accordingly, this may explain why many of the dunes are relatively low, symmetrical forms with poorly developed slip-faces, and in part, a transitional morphology between crescentic and longitudinal.

Conclusions:

The orientation of U-type scour flutes across the intracrater dunefield indicates a dominant north-westerly air stream that is not identified by dune orientation. The coexistence of bedforms (dunes and ripples) and scour features with both equivalent and contrasting orientations implies that the intracrater wind regime has two major directions, one that is north-westerly, and the other south-westerly. Furthermore, the considerable numbers of R-type scours as well as the orientation of ripple trains and their interference patterns denote the likely interaction of transitional winds, either seasonal or diurnal.

In the absence of 'in-field' measurements of wind directions and strengths, surficial sedimentary structures such as scour flutes, offer detailed data from which planetary boundary conditions at the surface-air interface can be better interpreted. Moreover, this data can be used for conducting risk analyses for the siting and operation of landers and rovers on planetary surfaces. Monitoring studies of scour features and ripples would also better define aeolian erosion rates and sediment mobility for Mars, than does dune monitoring alone.

References: [1] Peabody F.E. (1947) *J. Sediment. Petrol.* 17, 73-76. [2] Greeley R. et al. (2002) *JGR* 107 (E1) 5005. [3] Greeley R. et al. (2008) *JGR*, 113, E06S06. [4] Blair T.C. and J.G. McPherson (1999) *J. Sediment. Petrol.* 69 (1) 6-19. [5] Allen J.R.L. (1984) *Sedimentary Structures: Their Character and Physical Basis*. Developments in Sedimentology, Amsterdam: Elsevier. [6] Fisher, N.I. (1995) *Statistical analysis of circular data*. Cambridge University Press.