LINKING RIPPLES AND DUNE MORPHODYNAMICS ON MARS. David A. Vaz[1,2], S. Silvestro[3,4], Pedro T.K. Sarmento[1], M. Cardinale[5], [1]CITEUC - Centre for Earth and Space Research of the University of Coimbra, Observatório Geofísico e Astronómico da UC, Almas de Freire, 3040-004 Coimbra, Portugal (davidvaz@uc.pt), [2]CERENA, Instituto Superior Técnico, Lisboa, Portugal, [3]INAF Osservatorio Astronomico di Capodimonte, Napoli, Italy, [4]Carl Sagan Center, SETI Institute, CA USA, [5]DiSPUTER, Università Degli Studi G.D'Annunzio, Chieti, Italy.

Introduction: Recent orbital [1, 2] and *in-situ* observations [3] defy our current understanding of Martian large ripples. Here we demonstrate that a combined analysis of dunes and superimposed large ripple patterns can provide further insights on the processes that drive their formation and evolution.

Through a multiscale morphodynamic survey of dunes and ripples on Herschel crater we show that meter-scale Martian ripples are not comparable to terrestrial aeolian impact ripples. We mapped, characterize and assign a morphodynamic meaning to different sets of ripples, which can be correlated with specific dune settings and wind regimes.

Data and methodologies: To provide context for the detailed ripple analysis, dune patterns were mapped using a CTX mosaic and the OBDA (Object-Based Ripple Analysis) mapping technique [4]. The resultant pattern descriptive parameters were used to perform a principal component analysis (PCA) and clustering, in order to highlight distinct dune patterns (Fig. 1a).

We used one HiRISE DTM and two orthorectified images (acquired in 2007 and 2012) to map the lee front dune migration and estimate sand fluxes at a dune field scale (Fig. 1b). The same data set was used to map the ripple patterns automatically using the OBRA (Object-Based Ripple Analysis) technique [5]. This technique generates a set of ripples' pattern descriptors (length, wavelength, directional statistics, etc.) which were spatially integrated with the ripple migration data obtained with COSI-Corr. A wind effect index which accounts for topography induced wind speed-up [1] is also integrated on this dataset, creating a regular grid with 10 m spacing.

We performed a first order segmentation of the ripple patterns using a horizontal form index which relates the length, wavelength and degree of directional uniformity of the ripple patterns [1]. We set a threshold to segment two different sets of ripples: a) a 2D class with long and regular bedforms and b) a 3D ripple class composed by shorter and interlaced bimodal sets of bedforms. The spatial distribution and occurrence settings of the 2D class was further investigated with PCA and clustering (Fig. 2).

Results: At a regional scale the dune fields on Herschel denote a ~N-S transport trend [6]. The average direction of slipface migration in the study area is 162±38º (Fig. 1b) although there are important E-W morphological variations (bimodal slipface trends in the west *vs.* elongated and asymmetric barchans in the east, Fig. 1a) which suggest a bimodal wind regime. A first order upwind-downwind transition is also evident on the migration and height of the barchans (Fig. 1b). The effect of topography on the morphometry and dynamics of the dunes is noticeable, overprinting km-scale variations in the trend, height and celerity of the slipfaces. The described dune morphodynamic variations play an important role on the spatial distribution of the meter-scale ripples. In the mapped region 97.3% of the ripples correspond to the 3D class. This pattern is widespread over the dunes, presenting interlaced morphologies with bimodal trends (45º and 150º) and southward migration direction.

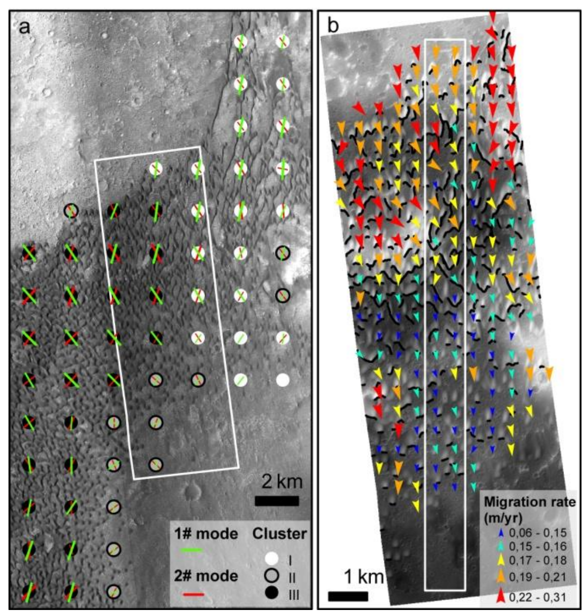

Figure 1 –Dune field spatial analysis. a) primary and secondary slipface trends [4], the different dune classes/clusters correspond to sets of elongated barchans on the east (cluster I), barchans and barchanoids with bimodal slipface trends (III) and dome dunes and sand sheets located downwind of the dune field edge (II); b) average slipface migration rates along the dune field, note the variations associated with major topographic obstacles trending ~NE-SW, the outlined area corresponds to the area where ripple patterns were mapped (Fig. 2).

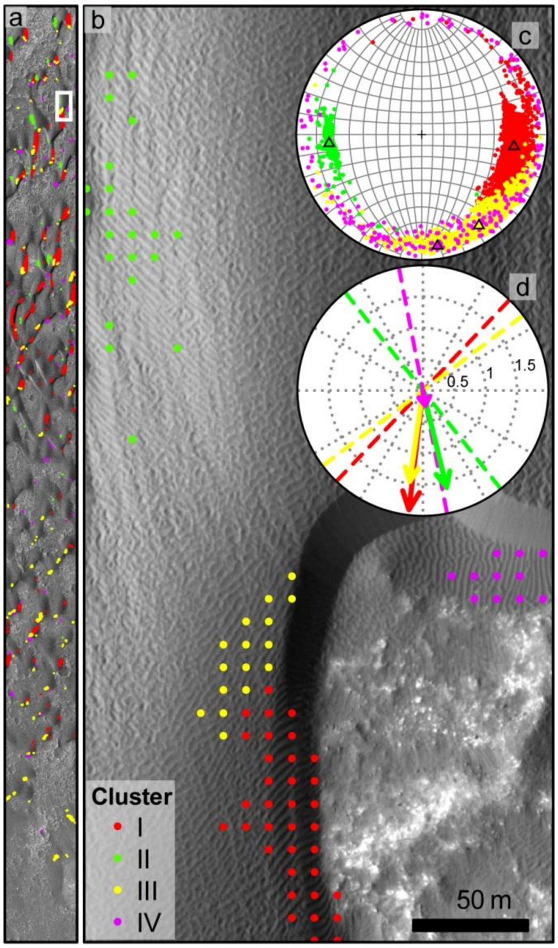

Figure 2 –Spatial analysis and clustering of the 2D ripples. a) 2D bedforms are not randomly distributed (compare with Fig. 1b); b) example of the preferential settings where 2D clusters are located; c) stereographic projection of the attitude of the dune surfaces for each cluster; d) average migration vectors and bedform trends, note the small longitudinal migration of cluster IV and the oblique migration of the other clusters.

The spatial distribution of the 2D bedforms is not uniform (Fig. 2a), presenting a N-S density decrease which can be correlated with the dune celerity. More importantly, we identify four different settings on which 2D ripples form: clusters I and II) dune flanks with high slopes and presenting oblique high migration rates; III) SE gentle dipping surfaces located between the crest and the brink of the dunes with intermediate oblique migration rates; IV) lower dune elevations and gentle slopes dipping preferentially S, with bedforms trending ~N-S and displaying small quasi-longitudinal migration.

This assessment proves that straight to sinuous ripple patterns are scarce (~3%), which means that most of the bedforms that cover the dunes form three-dimensional arrays. A morphometric comparison shows that these bedforms are more akin to subaqueous bedforms than to terrestrial aeolian impact ripples (Fig. 3).

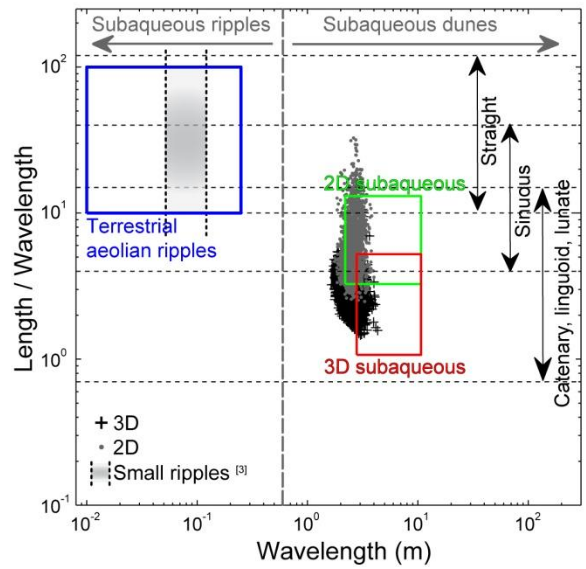

Figure 3 – Comparison of the plan form morphology of the mapped ripples with terrestrial aeolian ripples and other subaqueous bedforms. See [1] for references.

Discussion and conclusion: Long-wavelength topography on Herschel induces dune morphodynamic spatial transitions also recognizable on the distribution of the 2D meter-scale ripples. These do not migrate orthogonally to their trend and their plan view morphology is distinct from terrestrial impact ripples. In addition, contrary to terrestrial ripples, large ripples in Herschel only present a two-dimensional morphology in certain rare cases: in high slope areas and in areas where dune topography favors the occurrence of oblique bedforms.

Additional Information: this abstract is an extract from [1] Vaz et al. (2017) Migrating meter-scale bedforms on Martian dark dunes: Are terrestrial aeolian ripples good analogues? Aeolian Research, *in press*.

References: [1] Vaz D. A., et al. (2017). *Aeolian Research,* In press. [2] Silvestro S., et al. (2016). *Geophys. Res. Lett.*, Vol. 43 (16),8384–8389. [3] Lapotre M. G. A., et al. (2016). *Science*, Vol. 353 (6294),55-58. [4] Vaz D. A., et al. (2015). *Geomorphology*, Vol. 250,128-139. [5] Vaz D. A. and S. Silvestro (2014). *Icarus*, Vol. 230,151-161. [6] Cardinale M., et al. (2016). *Icarus*, Vol. 265,139-148.

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