

**MULTIDIRECTIONAL DUNE DYNAMICS UNDER SEASONAL WINDS ON MARS.** M. Chojnacki<sup>1</sup>, D. A. Vaz<sup>2</sup>, S. Silvestro<sup>3,4</sup>, & I. B. Smith<sup>1</sup>. <sup>1</sup>Planetary Science Institute, Lakewood, CO ([mchojnacki@psi.edu](mailto:mchojnacki@psi.edu)); <sup>2</sup>Centre for Earth and Space Research of the University of Coimbra, Coimbra, Portugal; <sup>3</sup>INAF Osservatorio Astronomico di Capodimonte, Napoli, Italy; <sup>4</sup>SETI Institute, Mountain View, CA.

**Introduction and motivation:** Much of our knowledge about aeolian bedform (dunes and ripples) migration on Mars is thanks to repeat targeting by the High Resolution Imaging Science Experiment (HiRISE; 1) camera. Prior HiRISE surveys of bedforms have focused on simple dune morphologies, such as barchan or transverse dunes (2, 3), as their displacements in a single direction tend to be easiest to quantify. These dunes form under unidirectional or bimodal winds but with a divergence angle (the angle between the two winds) less than 90° (4). Well known examples of such dune fields include Nili Patera (5) and Herschel crater (6).

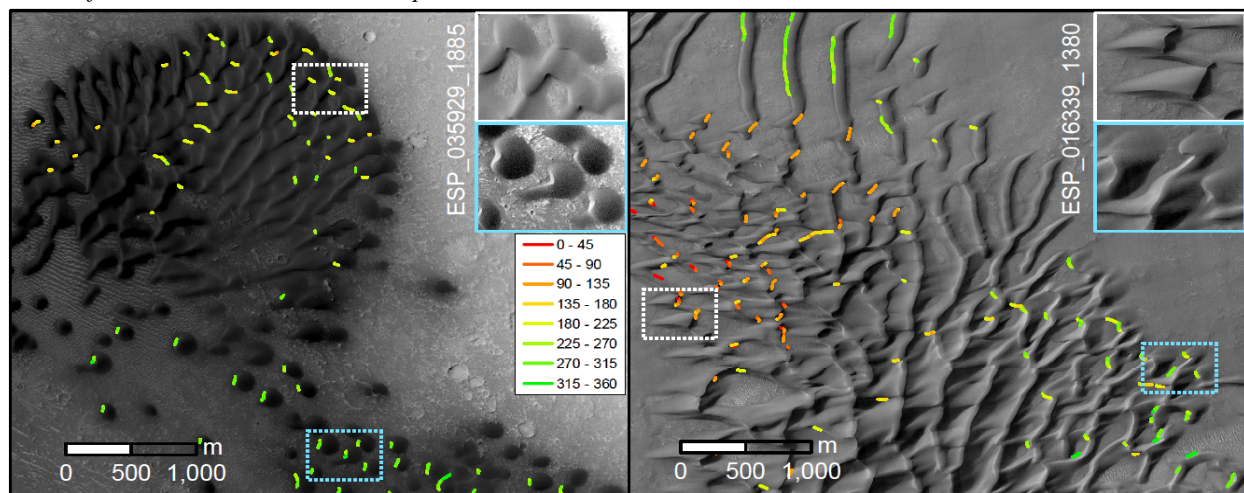
In comparison, some dune field dynamics are subject to multi-directional wind regimes (orthogonal or converging) that are encapsulated within a single HiRISE imaging sequence (5-6 km by 5-15 km). Locally, certain bedforms such as longitudinal or oblique dunes develop when the divergence angle is >100° (4), but more broadly the dominate wind regime can vary for different zones of a dune field. Although dunes under bi- or tri-directional winds have been examined in terms of the morphology (7, 8) any characterization of their seasonal dynamics and sand fluxes has been absent.

The goal of this project is to characterize and explain how Martian aeolian bedform systems evolve spatially under seasonally (and directionally) variable winds (Fig. 1). Driving questions include: *For dunes influenced by multiple wind regimes, what are the variations in sand fluxes and how do those compare with meso-*

*scale modeling? Can the influence of known storm track sequences (e.g., Arcadia (9)), perihelion/aphelion periods, or basin winds be related to bedform dynamics?*

**Study sites:** To better understand bedform dynamics under multi-directional wind regimes, we are conducting analysis at two study sites (Fig. 1). The first site is located at the bottom of a D~23km crater in the Cerberus region and shows morphologies suggestive of various winds impacting a ~5-km-wide dune field (169.2°E, 8.5°N). A second site is located in the west rim of the Hellas Basin (8) where the effects of a multi-directional wind system were first described by Chojnacki et al. (3). This ~20-km-long dune field (45.4°E, 41.5°S) is located on the rugged extra-crater terrain of the (east) Hesperontus Montes mountain range. Dunes and ripples here were documented to be migrating under at least two main wind regimes (Fig. 1 cyan and white; ESE winds in GIF A and WSW wind in GIF B).

**Data sets and methods:** Three objectives are being conducted on these sites. First, displacement measurements were recorded by mapping polylines along the base of each lee face in GIS (10, 11). Along with crest height estimates from HiRISE topography this approach allows dune azimuth, migration, and sand flux metrics to be quantified (see method of (12)). The use of widely separated HiRISE orthoimage pairs allowed the long term (5-7 Mars years) migration patterns to be established and the collective impact of any seasonal effects.



**Figure 1.** Dune monitoring locations in the (left) Cerberus and (right) East Hesperontus regions. As indicated by slip face azimuth orientations (°) and fine-scale morphology (white vs. cyan 500 m-wide subareas) the bedform sites are subject to near orthogonal or converging multi-directional winds, respectively. North is up in all images.

The second objective examines the sand flux variability in seasonal HiRISE orthoimages (6-8 images separated by  $\sim 60^\circ$  of  $L_s$ ) over the course of a Martian year. Specifically, ripple dynamics are being characterized using the *COSI-Corr* tool suite (5). By comparing seasonal ripple, and annual dune fluxes we will estimate their relative contributions to the aeolian system's sand budget and provide insight into local wind regimes.

A third objective will constrain the seasonal winds at these sites using Laboratoire de Météorologie Dynamique Martian Mesoscale Model (MMM; 13) simulations, but will not be presented here. Additional analysis was carried on bedform wavelength, class, density; see Vaz et al. (this conference).

**Results – Cerberus:** A broadly orthogonal wind regime appears to impact the Cerberus dune field. The southern zone of the field shows a narrow migration corridor of barchans oriented toward the W-WNW (Avg. Azi. of  $276^\circ$ ; **Fig. 1**). The northern zone has barchans and barchanoid dunes that are oriented to the SSE-SW (Avg. Azi. of  $211^\circ$ ), while the central area is a transitional zone with longitudinal and/or oblique dunes. The smaller, swifter ( $0.19$  m/yr) southern barchans show a comparable flux to that of northerly dunes ( $1.4$  vs  $1.2$   $\text{m}^3/\text{m/yr}$ ) that migrate at slower rate ( $0.14$  m/yr) (**Fig. 2**).

The south-oriented dunes may be due to cross-equatorial Hadley circulation that drives daytime winds in southern summer and are typical for these latitudes (e.g., Meridiani (9)). Crater slopes winds could impact the west-oriented bedforms, but also crater floor topography toward the NE (not shown) may have a role in wind flow diversion. Future analysis of season ripple rates will illuminate the timing of these wind regimes.

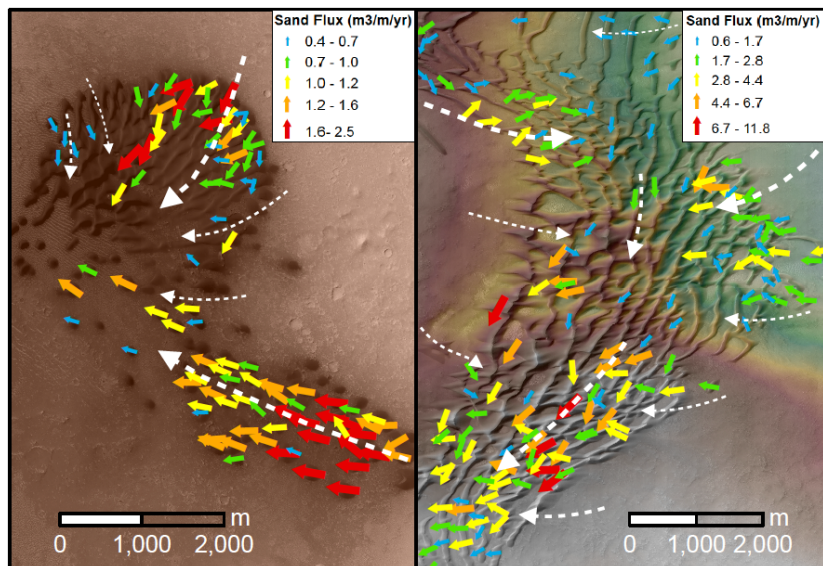
**East Hellespontus:** The second study site is comparatively more complex, in terms of dune azimuthal orientation, sand fluxes and topography (**Fig. 2**). Many slip faces on the western half of Fig. 1 are oriented eastward (Avg. Azi. of  $95^\circ$ ) with some trending SE. In contrast, eastern dunes migrate toward the W-WNW (Avg. Azi. of  $250^\circ$ ). Steady migration rates for most dunes regardless of orientation was  $\sim 0.3$  m/yr while fluxes vary between  $0.6$ - $12$   $\text{m}^3/\text{m/yr}$ . Other areas of the field show analogous dynamics but are influenced by more complicated winds with oblique or reversing dune motion. Many dunes have multiple active slip faces – some show NE-facing slopes propagating NE while SW-facing slopes are migrating SW. The unusual

bedforms are effectively reversing transverse dunes and occur on the south and north extremes of the field. Megaripples, slower bedforms that respond to longer term wind regimes, are also variable in their orientation and migration (see (14)). In contrast, certain areas host quite symmetric dunes that display more pure transverse motion, indicating the extremely localized impact of various wind regimes.

The more prominent west migrating dunes are likely caused by anabatic high-stress winds out of Hellas (15). We hypothesize the eastward winds are occurring in the southern winter when partial  $\text{CO}_2$  frost coverage along the southern rim of Hellas induces thermal circulation enhancing katabatic winds across the montes (16). Updated results to be presented at the workshop.

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**Fig. 2.** Sand flux mapping (colored arrows) at (left) Cerberus and (right) Hellespontus. White dashed arrows provide qualitative assessments of the main winds. Cerberus bedform dynamics suggest they are subject to near orthogonal winds from the east and north. Hellespontus bedforms reveal a more complicated scenario with converging winds and even cross-field flow.