THE OBSERVED WINTER CIRCULATION AT INSIGHT'S LANDING SITE AND ITS IMPACT ON UNDERSTANDING THE YEAR-ROUND CIRCULATION AND AEOLIAN ACTIVITY IN ELYSIUM PLANITIA AND GALE CRATER.

Claire E. Newman[1], Daniel Viudez-Moreiras[2], Mariah Baker[3], Kevin Lewis[3], Javier Gomez-Elvira[2], Sara Navarro[2], Josefina Torres[2], Aymeric Spiga[4], Don Banfield[5], Nick Teanby[6], Francois Forget[4], Jorge Pla-Garcia[2,7], Stephen R. Lewis[8], Maria Banks[9], Sébastien Rodriguez[10] and Antoine Lucas[10], [1]Aeolis Research, 600 N Rosemead Blvd, Pasadena, CA, USA, claire@aeolisresearch.com, [2]Centro de Astrobiología & Spanish National Institute for Aerospace Technology, Madrid, Spain, [3]Department of Earth & Planetary Sciences, Johns Hopkins, Baltimore, MD, USA, [4]Laboratoire de Meteorologie Dynamique, Sorbonne Universite, Centre National de la Recherche Scientifique, Paris, France, [5]Cornell Center for Astrophysics and Planetary Science, Cornell University, Ithaca, NY, USA, [6]University of Bristol, UK, [7]Space Science Institute, 4750 Walnut St, Ste 205, Boulder, CO, USA, [8]The Open University, Milton Keynes, UK, [9]Goddard Space Flight Center, Greenbelt, MD, USA, [10]Planetary and Space Sciences, Institut de Physique du Globe de Paris, Paris, France.

Introduction: The InSight lander landed at 135.62°E, 4.50°N in Elysium Planitia, less than 550km from the landing site of the Mars Science Laboratory Curiosity rover, at 137.44°E, 4.59°S in Gale Crater. Both missions carried a suite of meteorological instruments, but regrettably MSL's wind sensor was damaged on landing and failed completely after ~two Mars years [1]. The resultant data gaps and biases made it very difficult to properly characterize the diurnal and seasonal cycles of wind speed and direction in Gale Crater, a region of extreme topography containing numerous aeolian features.

Fortunately, InSight's wind sensor does not appear to have been damaged on landing, and is returning excellent wind data for the landing season (Ls~300°, northern winter). This valuable dataset has already allowed us to characterize the Elysium Planitia circulation at one time of year, and - in combination with atmospheric models - provides vital insight into what controls the circulation in this region of Mars. In turn, this better understanding of the regional circulation allows us to better interpret the local scale winds partially measured by MSL.

Methodology: In this work we first use Mars atmospheric models, run at ~km to 5km scale resolution over the MSL/InSight region, to provide predictions of the circulation based on our current understanding of the underlying physics. For example, the MarsWRF multi-scale model is run with higher-resolution domains 'nested' inside its global domain, with a threefold increase in resolution from nest to nest [1,2]. The nests used for modeling the circulation at InSight's landing site are shown in Figure 1; for modeling the circulation seen by MSL, domain 4 is moved to sit over Gale Crater and an additional nest is added inside it, in order to resolve the internal crater topography.

We then improve the models by modifying their set-up, physical parameterizations, etc. to better match the circulation at InSight in northern winter (the period measured thus far), and use these results to better understand the circulation in Gale Crater. Finally, we extend our simulations over a full Mars year to provide insight into the orientation, morphology, and motion of aeolian features in the vicinity of InSight and MSL.

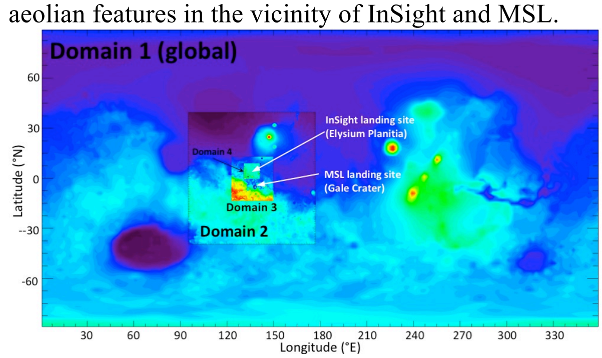

Figure 1: Topography in each domain of a nested MarsWRF simulation of InSight's landing site circulation; contour intervals change in each domain to cover only the range of values present. InSight and MSL's locations are also marked.

Regional Winds in the Vicinity of InSight and MSL: Both missions landed within 5° of the equator and within 1° of 136.5°E. In this region, the large-scale circulation is largely controlled by the seasonal Hadley circulation, with near-surface ('return flow') winds blowing from ~south to north in northern summer and ~north to south in northern winter. Both landing sites also sit on or close to the hemispheric dichotomy boundary (see e.g. Figure 1), which results in daytime upslope flows (from ~north to south) and nighttime downslope flows (from ~south to north); these tend to enhance the Hadley circulation during the daytime in northern winter and at night in northern summer.

For InSight's location, most models predict winds from between the ~north and the west virtually all sol long in northern winter (Ls~300°) - see e.g. Figure 2 and [3] - although there is much more model-to-model variation in wind speed.

In Gale Crater, however, the situation is complicated by the presence of very large topographic gradients at the crater rim and on the slopes of Aeolis Mons in the crater's center. MSL operates in the NW quadrant of the crater, where models suggest that in northern winter the ~north-to-south Hadley circulation winds are enhanced at night by strong downslope winds on the northern rim slopes, resulting in very strong winds at the location of the rover (e.g. Figure 3 and [4]).

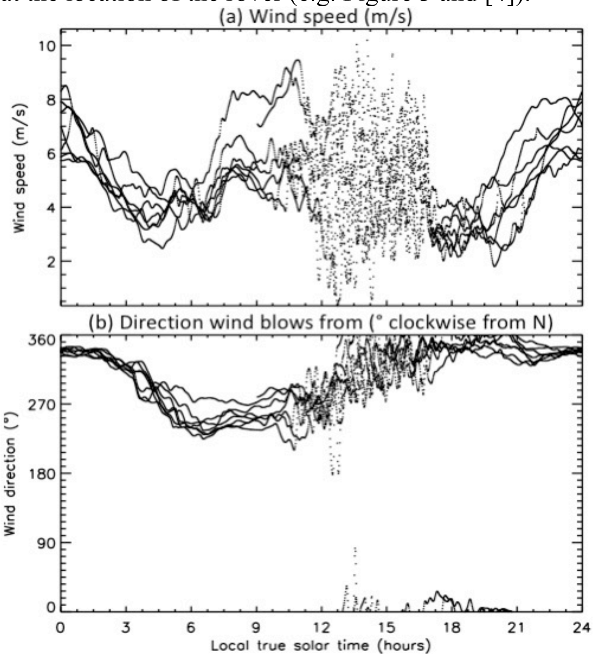

Figure 2: MarsWRF predictions of wind speed and direction at 1.5m above the surface as a function of time of sol over 7 sols at the InSight landing site at Ls~300°.

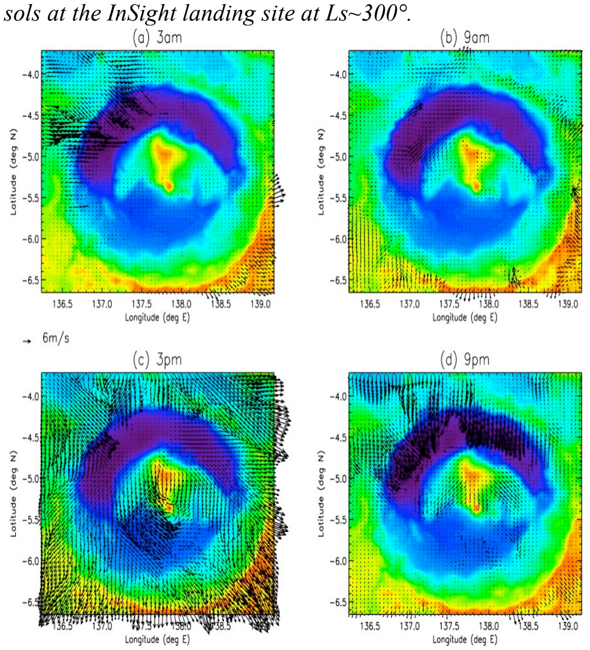

Figure 3: MarsWRF predictions of winds at 1.5m above the surface (arrows) at four times of sol for the region of Gale Crater at Ls~270°. Topography is shown as contours.

Unfortunately, while evidence points toward most aeolian activity in northern winter occurring at night [5], MSL's wind sensor was unable to measure nighttime winds well due to increased electronic noise at the coldest times of sol [1]. By measuring regional winds over the full diurnal cycle in northern winter, InSight wind data allow us to (i) directly measure the winds approaching Gale Crater from the ~north, (ii) constrain and improve MarsWRF and other models, and hence (iii) better understand the true nature of the winds in Gale Crater also.

Aeolian Features in Elysium Planitia and Gale Crater: While the immediate InSight landing site is (by design) largely devoid of aeolian features, Elysium Planitia as viewed from HiRISE (Figure 4) contains numerous aeolian features that indicate the net sand transport direction over an annual cycle, such as bright sand in and around craters. Gale Crater also contains numerous aeolian features - ranging from small-scale ripples and ventifacts seen by MSL, to the Bagnold Dunes seen both by HiRISE and *in situ* by MSL - which reflect the long-term transport of sand by winds. The goal of this work is to develop a model of the seasonal cycle of winds over the entire region which simultaneously matches the InSight and partial MSL wind datasets *and* the observed aeolian features.

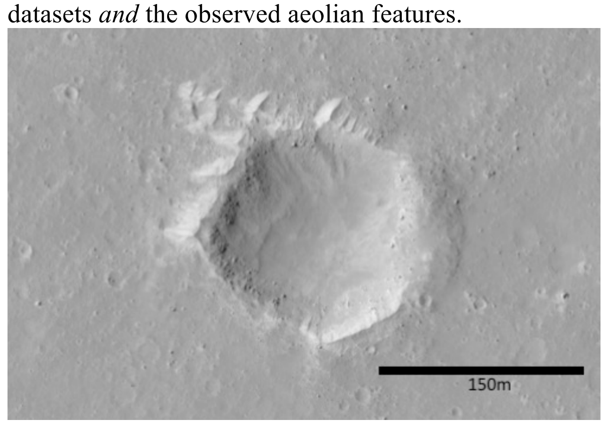

Figure 4: Example of aeolian features around craters in the vicinity of the InSight landing site (portion of HiRISE image ESP_036761_1845).

Summary: We will present results from MarsWRF and other models, run at ~km to 5km scale resolution over the InSight/MSL region. We will compare these results with observations of winds and aeolian features, and demonstrate how those observations allow us to constrain and improve the models, resulting in a better understanding of near-surface winds and aeolian processes, both locally and across the planet.

References: [1] Newman, C. E. et al. (2017) *Icarus*, *291*, 203–231. [2] Richardson, M. I. et al. (2007) *JGR (Planets)*, *112*, E09001. [3] Spiga et al. (2018) *SSR, 214:109*. [4] Pla-Garcia, J. et al. (2016), *Icarus*, *280,* 103-113. [5] Viúdez-Moreiras, D. et al. (2019), *Icarus*, *319*, 909-925.