AEOLIAN DUNES AS GROUND TRUTH FOR GCM AND MESOSCALE MODELING ON MARS. R. K. Hayward[1], T. N. Titus[1], T. I. Michaels[2], A. Colaprete[3], C. A. Verba[1], and P. R. Christensen[4], [1]U.S.G.S., 2255 N. Gemini Dr., Flagstaff, AZ 86001, rhayward@usgs.gov, [2]Southwest Research Institute, 1050 Walnut St., Suite 400, Boulder, CO 80302, [3]NASA/Ames Research Center, Moffett Field, CA, [4]Arizona State University, Tempe, AZ.

Introduction: Aeolian dunes preserve a record of the interaction between the atmosphere and surface of Mars, serving as valuable ground truth for atmospheric models. We hypothesize that certain dune characteristics record broad regional atmospheric patterns, while others record topographically controlled local patterns. We test this hypothesis by comparing two dune characteristics, dune centroid azimuth (DCA) and slipface orientation (SF), to both a General Circulation Model (GCM) and a mesoscale model.

Background: Since Viking-era images revealed the presence of Martian dune fields three decades ago, researchers have been using the physical characteristics of those dunes to predict local and global wind patterns [e.g. 1, 2, 3]. The use of Geographic Information Systems (GIS) makes it possible to more effectively compare modeled winds to aeolian features using global databases, such as the Mars Global Digital Dune Database (MGD^3) [4].

Dune Measurement Methodology: We extracted dune characteristics (DCA and SF) from MGD^3. The data presented here are from the equatorial portion of the database (65°N to 65°S), which was released in 2007 [5, 6] (http://pubs.usgs.gov/of/2007/1158/), and the north polar portion of the database (65°N to 90°N), which will be released in 2009.

Dune Centroid Azimuth. DCA, a measure of a dune field's relative location within a crater, may indicate the prevailing wind direction during the period of dune field migration across a crater floor, thus preserving a relatively broad, regional record [4]. ESRI ArcMap® tools were used to locate the centroid (geographic center) of the crater, the centroid of the dune, and to calculate the azimuth of the line connecting the centroids. More than 300 DCAs have been calculated for the 65°N to 65°S region [4], with an additional ~40 calculated for the 65°N to 90°N region.

Slipface Orientation. SF, our second measure of wind direction, probably indicates the direction of prevailing wind during the latest period of major dune modification, thus preserving a relatively short-term, local record. Raw SF was measured from the upwind slope to the slipface, based on gross morphology of dunes formed by unidirectional winds (i.e. barchan, barchanoid and transverse dunes). More than 10,000 raw SFs were measured in the 65°N to 65°S region [4], and more than 5,000 in the 65°N to 90°N region. For ease of plotting and comparison, we averaged the individual (raw) SFs within each dune field.

Atmospheric Models: DCA and SF are compared to wind directions simulated by both the NASA Ames GCM (model description [7]) and the Mars Regional Atmospheric Modeling System (MRAMS; model description [8]).

GCM Wind Direction. The Ames Mars GCM that we used has a low spatial resolution (5° latitude x 6° longitude), so replicating the effects of local topography is not possible. Temporal resolution of output is high, 8 times per Martian sol, for one Martian year. We filter the output, using winds with a shear stress > .0225 N/m^2 for comparison. Haberle et al. [9] have shown that setting a threshold stress of 0.0225 N/m^2 with the Ames Mars GCM will lift dust in spatial patterns that qualitatively agree with observed dust storm occurrences.

Mesoscale Model Wind Direction. In contrast to the Ames Mars GCM, MRAMS uses high spatial resolution topography over a small area, so local topographic effects can be simulated (grid spacing ~1.7 km). Temporal resolution is very high, but for a short period of time. Output was recorded every 20 Martian minutes for one Martian sol (72 times per sol) at L_s ~167°. We chose this L_s, even though TES derived temperatures suggest that H_2O ice may be forming at our study site then, with CO_2 ice forming shortly thereafter, because it is a time when GCM winds agree with the DCA. Thus it may be a time when sand is mobile. It is possible that the direction of wind that dominates immediately prior to CO_2 ice formation is the direction that is preserved. Because we have only one sol of output, we consider all winds regardless of magnitude.

Discussion: *GCM to DCA Comparison.* There are ~340 intracrater dune fields in the equatorial region and ~40 in the north polar region whose dune centroid azimuths were calculated and compared to the GCM. Agreement rate varied with the diameter of the crater. Smaller craters (<25 km diameter) displayed better agreement (~65% to 70%) than larger craters, probably because smaller craters tend to have smoother floors, allowing unimpeded dune migration. This agreement suggests that DCA in small craters may record broad, regional trends and be useful as ground truth for GCMs.

GCM to SF Comparison. In both the equatorial and north polar regions, the GCM to SF agreement for intracrater dune fields was not as good (~40%) as that of GCM and DCA. In the circumpolar erg, where the dunes are not in craters, GCM to SF agreement was good, except where winds locally funnel down chasmata. The poor agreement between GCM and SF in topographically complex areas suggests that locally controlled winds may dominate SF development in such areas. Thus, SF may be more appropriate as ground truth for mesoscale models. Figure 1 shows an example where agreement is good between GCM and DCA, and poor between GCM and SF.

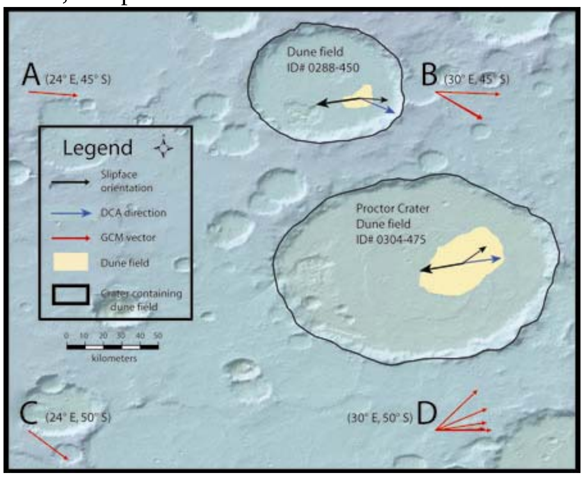

Figure 1. Proctor crater area (~30°E, 48°S). GCM modeled winds (red) in good agreement with DCA (blue), but in opposition to dominant SF (large black arrow). MOLA background.

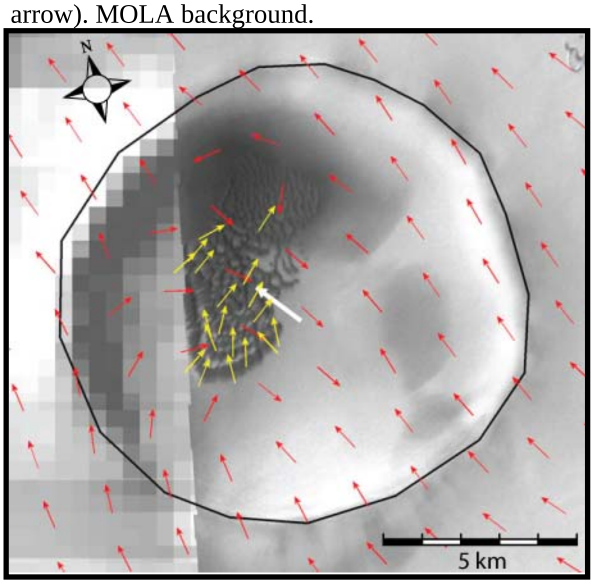

Figure 2. Eastern portion of mesoscale study area (figure is centered at 15°E, 74.9°N) showing mesoscale modeled winds (red) at ~1800 LMST that are consistent with both SF (yellow) and DCA (white) directions. Background MOLA and THEMIS VIS image V12457002 (resolution 36 m/pixel).

Mesoscale Model Comparison. Our mesoscale study site (centered at 14.5°E, 75°N) includes two small craters, each with an intracrater dune field. The eastern crater is shown in Figure 2. The GCM wind direction (not shown in Figure 2) agrees with the DCA of each dune field and disagrees with their SFs. Therefore, the location is ideally suited to test whether mesoscale modeling can simulate topographically controlled local winds consistent with the SF. The mesoscale model output (red) is compared to both the SF (yellow) and DCA (white) for the intracrater dune field. The model output, while not in perfect agreement with SF, shows similar wind direction. Model output also preserves the regional trend, and thus shows some consistency with the DCA, suggesting that both SF and DCA may be useful as ground truth for mesoscale models. Note that for purposes of illustration we have chosen a time of day, ~1800 Local Mean Standard Time (LMST), when model output is consistent with DCA and SF, even though wind magnitudes are lower than at other times of day when the patterns do not agree as well.

Summary: A comparison of GCM and mesoscale models to DCA and SF shows that: 1) Prevailing GCM wind directions have a good rate of agreement with DCA in small/smooth-floored craters. 2) GCM modeled winds have a poor agreement rate with SF in intracrater dunes and chasmata, suggesting local topographic effects are important. 3) In our study area, mesoscale modeled winds at ~1800 LMST were consistent with both SF and DCA. These findings support our hypothesis that aeolian dunes record local and regional trends and may provide ground truth for both GCM and mesoscale models. Comparison with mesoscale models at a variety of L_s may further the understanding of how seasonal and diurnal changes influence dune formation.

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