Evaluation of Aeolian Bedform Growth and Evolution at Multiple Scales

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ABSTRACT

Windblown sand produces distinctive bedforms at scales ranging from normal sand ripples to large reversing sand dunes. We explore how aeolian bedforms evolve at both extremes of this range. An investigation of the transition from sand ripples (<1 cm height) to granule-coated megaripples (25 cm height) is underway at Great Sand Dunes National Park and Preserve (GSDNPP) in central Colorado. Sand-to-megaripple transitions at GSDNPP were documented in May and Sept of 2019 using stereophotogrammetry that produced digital terrain models that resolved granule (1-2 mm) particles as well as some sand grains; these data show the spatial distribution of particles across sand ripples whose crests merge directly into crests of mega-ripples. To date we have not observed that sand ripples are a necessary prerequisite for the initiation and growth of megaripples; the spatial density of granule particles appears to influence the evolution of megaripples. Reversing sand dunes are being monitored using differential navigation satellite system data at GSDNPP (up to 10 m height) and at Bruneau Dunes State Park (BDSP) in central Idaho (individual dunes >100 m height). Surveys of the crests of reversing dunes at GSDNPP reveal a northeastward migration of individual dunes along the southern margin of the main dune mass, consistent with dominant local winds, yet the symmetric reversing dune profile is maintained during the translation. Surveys of the crests of large reversing dunes at BDSP reveal variable adjustments of the crests that may be affected by wind flow altered by the bulk of the dunes themselves, sheltering the southern end of the dunes from one of the seasonal bimodal winds. Results to date indicate that the deformable shape of aeolian bedforms affect wind flow at all spatial scales, influencing the evolution of the features over diverse time scales.

Great Sand Dunes National Park and Preserve (GSDNPP), Colorado

Figure 1. Great Sand Dunes National Park and Preserve (GSDNPP) from a photo taken by astronauts on the International Space Station using a image-stabilized 800 mm lens. '2' shows the location of the vertical view in Fig. 2.

Great Sand Dunes National Park and Preserve (GSDNPP) is located in south-central Colorado where the dominant westerly winds have concentrated sand against the lower west base of the Sangre de Cristo Mountains [1]. Slope winds down the west flank of the mountains provides a bimodal wind regime at the dunes. The primary visitor entry road follows the southern edge of the dunes (near the camera in Fig. 1); visitor parking (bottom right of Fig. 2) provides direct access to the dunes across Medano Creek. Areas of study presented here are north of the visitor parking lot (Fig. 2). Multiview Stereo Photogrammetry was applied to digital photographs obtained with a Nikon camera that was motor-driven along a track above the study area (see Fig. 6). The track was manually advanced following each photo traverse. Digital Terrain Models (DTMs) derived from the overlapping photos reveal topography sufficient to resolve the 1-2 mm diameter granules that coat the surface of megaripples (Figs. 3 to 5), as well as the shape of the bedforms and the slope on which the study area was located. Here we present results obtained from images taken using a 35 mm lens, data that will form a georeferenced base for future processing of images using an 85 mm Macro lens. We targeted areas where megaripple crests merge directly with the crests of regular sand ripples, many of which have granules on their surface but not nearly as densely concentrated as on the megaripples. A separate study of the movement of individual reversing dunes at GSDNPP show differing directions of motion (Figs. 8 and 9); differential Global Positioning System (dGPS) surveys document locations to <15 cm.

Figure 2. Great Sand Dunes study sites along the southeastern margin of the main dune mass (see Fig. 1). 'r' indicates ripple-megaripple study site (Figs. 3-7); 'A' and 'F' are left of dGPS-surveyed dunes (Figs. 8 and 9).

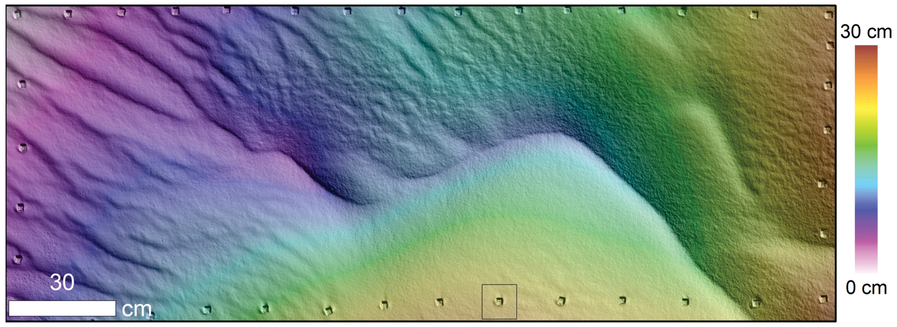

Figure 3. Digital Terrain Model (DTM) of ripple-megaripple transition at GSDNPP (see Figs. 2 and 6). Study area is defined by dice (1.6 cm cubes). Box at bottom is area shown in Fig. 4. See Fig. 5 for a color orthophotomosaic of the DTM area.

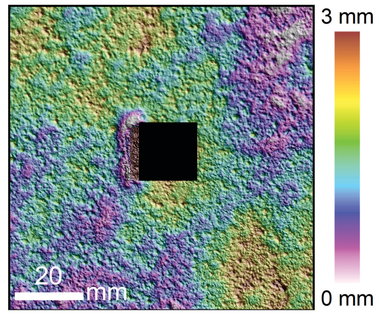

Figure 4. Detail from DTM (box at bottom center of Fig. 3). Die has been removed (black square). Granules (1-2 mm diam.) are resolved (see Fig. 7).

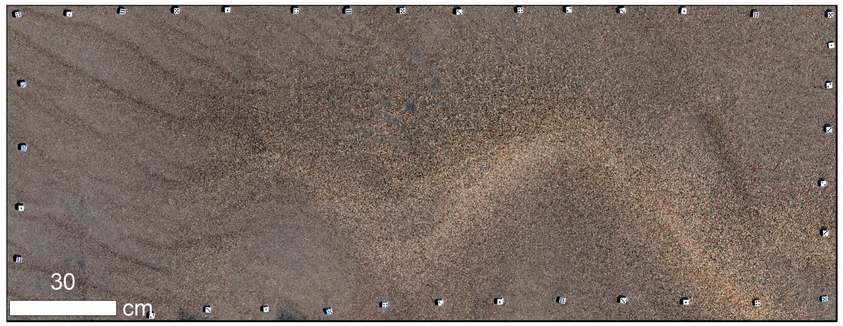

Figure 5. Color orthophotomosaic of DTM area shown in Fig. 3. Quartz and feldspar granules are bright, relative to the sand grains (see Fig. 6). Granules are concentrated along the crest of a sinuous megaripple (center).

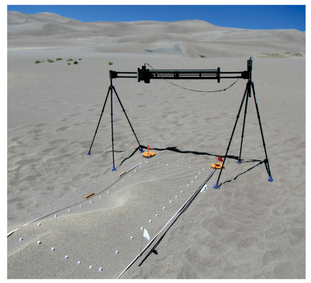

Figure 6. Field set-up for collecting the stereo photos used to produce Figs. 3 to 5. Nikon camera (not shown) is motor-driven along rail, then the rail moved forward.

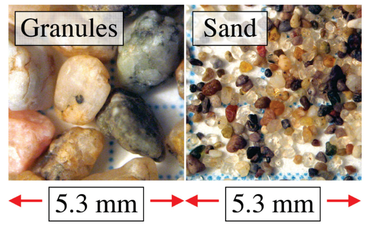

Figure 7. Microscope photos of granules and sand grains from GSDNPP.

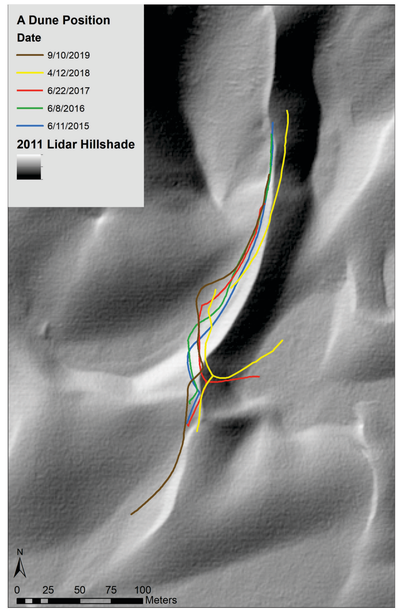

Figure 8. Surveyed crest locations of reversing dune A (see Fig. 2) superposed on 2011 Lidar hillshade. Much of the documented motion is to the NNE.

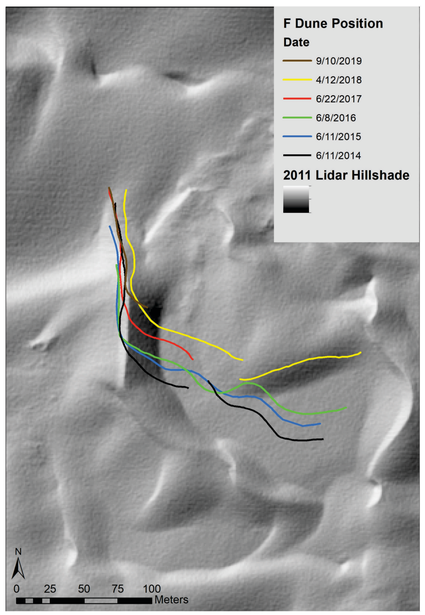

Figure 9. Surveyed crest locations of reversing dune F (see Fig. 2) superposed on 2011 Lidar hillshade. Most of the documented motion is to the N.

Bruneau Dunes State Park (BDSP), Idaho

Figure 10. Google Earth view of Bruneau Dunes, south of lakes where groundwater reaches the surface.

Bruneau Dunes State Park (BDSP) is ~25 km SSE of Mountain Home, Idaho, in an abandoned cutoff meander loop of the Snake River [2]. Seasonally bimodal winds have built reversing dunes >100 m high (Figs. 10 to 12). dGPS surveys (<4 cm prec.) of the crests show that the southern dune crest moved W by >20 m (Fig. 13) and the highest peak moved N during the same time (Fig. 14). The northern dune crest moved variably horizontally (Fig. 15) and the highest peak moved S (Fig. 16). These differences may be related to the bulk of the southern dune blocking some winds from the NW [3].

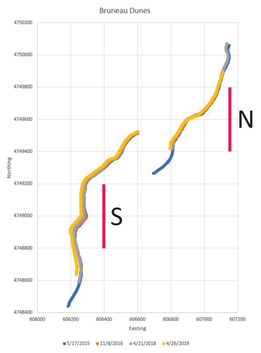

Figure 11. dGPS crest location, BDSP. Red lines, Figs. 13-16.

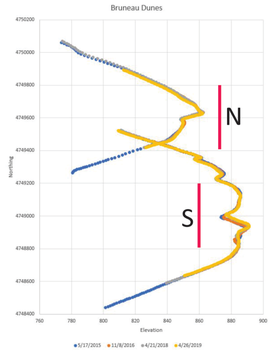

Figure 12. dGPS crest elevation, BDSP. Red lines, Figs. 13-16.

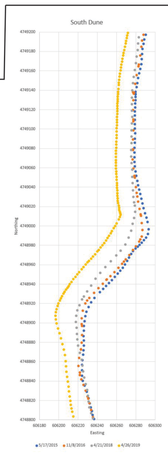

Figure 13. Southern dune crest location.

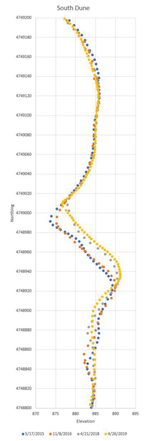

Figure 14. Southern dune crest elevation.

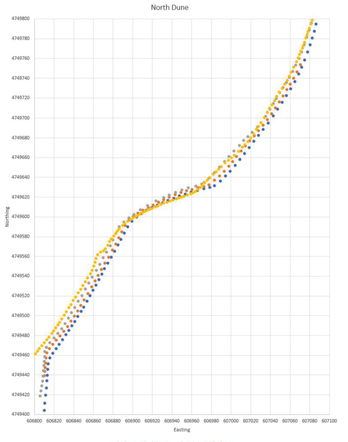

Figure 15. Northern dune crest location.

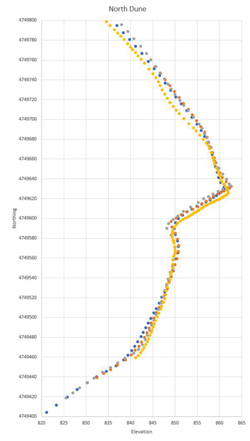

Figure 16. Northern dune crest elevation.

References

[1] Marin, L., S.L. Forman, A. Valdez, F. Bunch (2005) Twentieth century dune migration at the Great Sand Dunes National Park and Preserve, Colorado, relation to drought variability. Geomorphology, 70, 163-183.

[2] Zimbelman, J.R., S.P. Scheidt (2014) Precision topography of a reversing sand dune at Bruneau Dunes, Idaho, as an analog for Transverse Aeolian Ridges on Mars. Icarus, 230, 29-37.

[3] Wishard, C.A., J.R. Zimbelman (2015) Wind patterns on the southern end of the Bruneau Dunes compared to remote automatic weather station data from Mountain Home, Idaho. 4th Int. Planet. Dunes Workshop, Abs. 8016.