Monitoring Movement of Active Sand Dunes within Great Sand Dunes National Park and Preserve

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Abstract

We used a Trimble GeoXH handheld differential global positioning system unit to monitor the displacement of several active sand dune crests located adjacent to and on the main dune mass of the Great Sand Dunes National Park and Preserve in south-central Colorado. This equipment provides positional information with a horizontal accuracy of 5 to 15 cm for >95% of the points during a survey. Previous studies used aerial photography to document the movement of parabolic sand dunes outside of the park boundary. Here we report dune movement along the southern edge of the main dune field, close to the area most heavily used by the public when climbing the sand dunes. The dunes we monitored included one whose crest is constantly walked on by hikers going to and from the dune parking area, as well as several dunes less frequently traversed by visitors. There is considerable variability of dune crest location on an annual basis, even along a single dune. For example, portions of the crest of one dune (oriented WNW-ESE) moved >9 m NNE annually over the period from 2014 to 2017, while a N-S-oriented crest on the same dune (within 50 m of the movement just cited) moved annually 0 to 5 m E (and even 3 m W) during the same survey period. A nearby dune displayed a similar NNE overall movement while also showing the growth of an E-W-oriented 'arm' that likely indicates the initiation of a new star dune. When compared to local wind records, dune orientation clearly affects how a dune responds to the dominant wind pattern. These initial results indicate that the micro-topography associated with a steadily shifting array of dune forms can lead to a surprisingly complex movement pattern across a large sand accumulation.

Background

Great Sand Dunes National Park and Preserve, located in the San Luis Valley of south-central Colorado, includes a thick accumulation of active sand dunes banked against the western margin of the Sangre de Cristo Mountains (Figure 1). The main dune field is at the western edge of a large sand sheet that extends far into the San Luis Valley; the sand particles include pieces of volcanic rock exposed along the western side of the valley plus materials transported into the valley by the Rio Grande River (Johnson, 1967; Janke, 2002; Marin et al., 2005; Madole et al., 2008; Madole et al., 2016). The park experiences a bimodal wind regime where the dominant sand transport is westerly, but with frequent easterly winds off the Sangre de Cristo Mountains (Johnson, 1967; Marin et al., 2005). Measurements from aerial photographs were used to determine time-averaged movement rates of ~7 m/yr for parabolic dunes on the sand sheet south of the dune field (Marin et al., 2005). Here we report survey results tracking the movement of active dunes along the southern margin of the main dune field (Figure 2), in the area visited most often by the public when they explore the dunes.

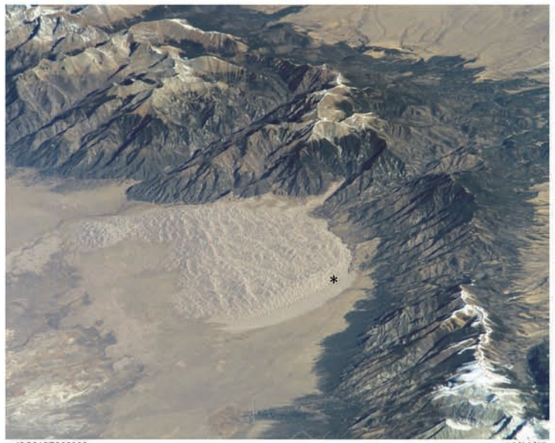

Figure 1. Great Sand Dunes National Park and Preserve photographed by astronaunts on the International Space Station during Expedition 16 using an 800 mm telephoto lens. The dunes are banked against the western slope of the Sangre de Christo Mountains, which include several peaks over 14,000 foot elevation. The asterisk indicates the location of the dunes being monitored as part of this project.

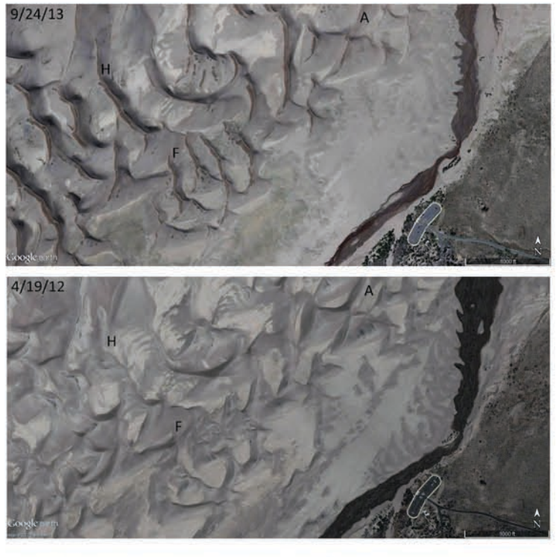

Figure 2. Google Earth Pro images of the study area. The three monitored dunes discussed here are labeled to upper right of the monitored dune. Note subtle differences in dune shape between the two scenes, obtained using the 'Timeline' function. A public parking area is at bottom right, east of Medano Creek.

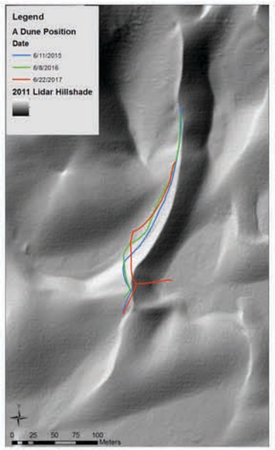

Figure 3. Surveyed crest locations for dune A, superposed on a LiDAR base collected in September 2011.

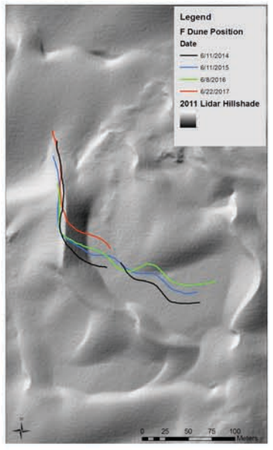

Figure 4. Surveyed crest locations for dune F, superposed on a LiDAR base collected in September 2011.

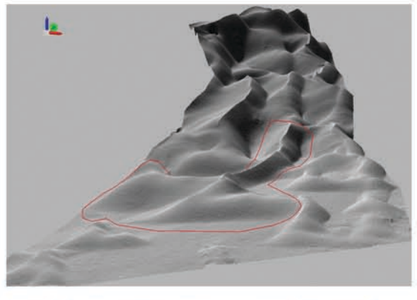

Figure 6. Dune A outlined (in red) on a shaded relief version of LiDAR data from September 2011. Vertical scale is exaggerated by a factor of 2.

Figure 8. Looking south along the crest of dune F as co-author Valdez begins a survey. JRZ photo, 6/22/17.

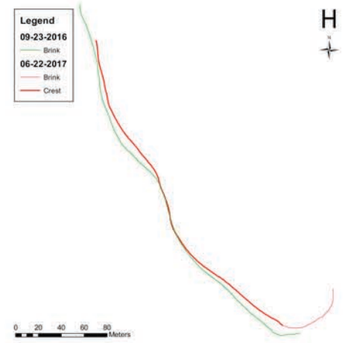

Figure 5. Surveyed crest locations for dune H, located up the southern slope of the dune field, north of dune F (see Figure 2).

Figure 7. Looking north along the crest of dune A. JRZ photo, 6/22/17.

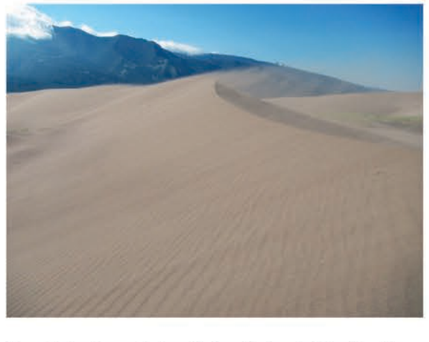

Figure 9. Looking south along the 'smoking' crest of dune F on the morning of 6/23/17 resulting from a strong easterly wind. Handheld anemometer at 1.5 m height showed a steady wind of 9 m/s, with gusts to 12 m/s. JRZ photo.

Methodology

We used a Trimble GeoXH handheld differential Global Positioning System (dGPS) to repeatedly survey the crests of several active dunes (Figures 3 to 5). The Trimble system documents locations in three dimensions to within 5 to 15 cm for >95% of the surveyed points, an accuracy sufficient to delineate changes in crest location on an annual basis. In September of 2011 an airborne LiDAR survey was obtained for the park; the LiDAR data provide an additional time referent for the manually surveyed dunes (Figures 3 and 4), as well as a 3D hillshade base for viewing the local setting (Figure 6). Field photographs were collected during the dGPS surveys (Figures 7 to 9).

Results

The surveyed dune crests show a predominant easterly trend to their movement at a rate of 5 to 10 m/yr, but with considerable variability within horizontal distances of <50 m (Figures 3 to 5). Superposed on this easterly movement is evidence of a spatially variable northerly movement, such as for the peak of a star dune (Figure 4), along with the northerly extension of some monitored dunes at a rate of 1 to 3 m/yr. Dunes with crests oriented N-S, typical of many of the large dunes in the study area, show considerable variability in the movement (or lack thereof) of their crests, including a few places where the crest moved to the west (Figures 4 and 5). Dune movement is much more complex adjacent to the thick dune mass than it is in the western plains (Marin et al., 2005).

Conclusions

- dGPS surveys represent a cost-effective way to monitor the spatially variable movement of sand dune crests.

- Dune movement is primarily easterly at rates of 5 to 10 m/yr, but …

- There is evidence of spatially variable northerly movement at rates of 1 to 3 m/yr, representing the dune forms moving UP the steep southern margin of the dune field.

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