geoconvention
Calgary • Canada • June 20-22 2022

The Search for the World's Fastest Sand Dunes

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Summary

Sand dune migration is an important risk for many communities. Desertification induced by anthropogenic climate change could result in increased encroachment of dunes on farmland and infrastructure. Previous studies have focused on singular dunes or dune systems, but a global study of dune movement is necessary to better understand migration risk. We used Google Earth historical satellite imagery to measure dune migration. We compared our technique to published dune rates for different geographical areas and environments. We then hunted for the world's fastest sand dunes on Google Earth to assess commonalities shared between dune fields with high migration rates. Our results suggest that small barchan dunes in the Sanlongsha Dune Field in the Kumtagh Sand Sea of northwestern China move at rates of more than 70 m/yr, likely making them the fastest in the world. Other fast dune systems come from disparate geographic locations, but all are in arid, vegetation-free areas with strong yearly average windspeeds. We therefore conclude that if vegetation cover and precipitation decline in the face of anthropogenic climate change, there may be a global increase in the rate of dune migration.

Method

Our method relies on using Google Earth's historical imagery function to measure dune displacement through time. In the first part, we compared measurements of dune speed taken from Google Earth to a known database of dune migration rates (Yang et al., 2021). We then searched through 107 dune systems on Google Earth to locate the world's fastest dunes. We captured satellite photographs from approximately 10 years apart at each location that we investigated. Dunes were measured using the free software ImageJ, which allowed us to flip between timesteps and measure both dune displacement in meters and azimuth in degrees from north. From this data we calculated dune velocities.

For the comparison test, we relied on a sampling grid to measure dune crests across the entire field (Fig. 1). We used an initial sampling grid of 100 cells per image. In images where dunes were in a smaller area within the photograph, we highlighted an area of interest surrounding the dunes and placed the 100 grids within that area. To measure the fastest dunes, we instead measured the singular dunes we observed with the greatest displacement.

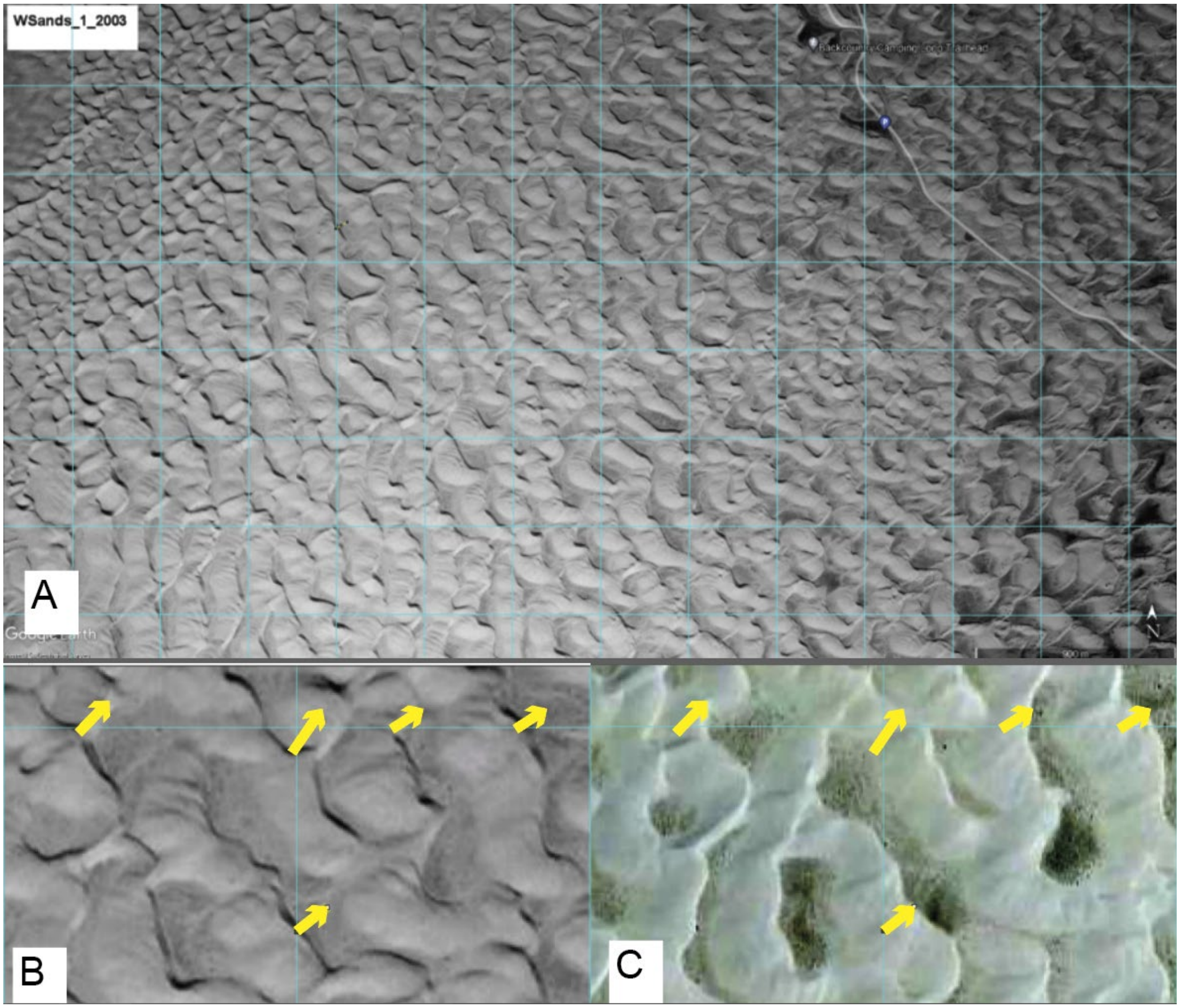

Figure 1: An overview of how dune measurements are made in the ImageJ software. Stacks of the timesteps are made in the software, and a sampling grid is placed over the image (A). Then the images are switched back and forth and displacement of dune crests that cross the sampling grid are measured (B: older timestep; C: Younger timestep). Yellow arrows show the measured displacement of the sampled dune crests from the older time (B) to the younger time (C). Images taken from Google Earth, provided by the United States Geological Survey.

Results, Observations, Conclusions

Overall, our method compares favorably to the published results in Yang et al. (2021; Fig. 2). Our Google Earth measurements tended to be on the low end of those reported Yang et al. (2021). Our method samples the more common, larger and more slowly moving dunes. Previous studies instead specifically sampled smaller, faster-moving dunes. We feel that our use of the sampling grid therefore provides a more comprehensive overview of average migration rates for entire dune fields compared to previous methods.

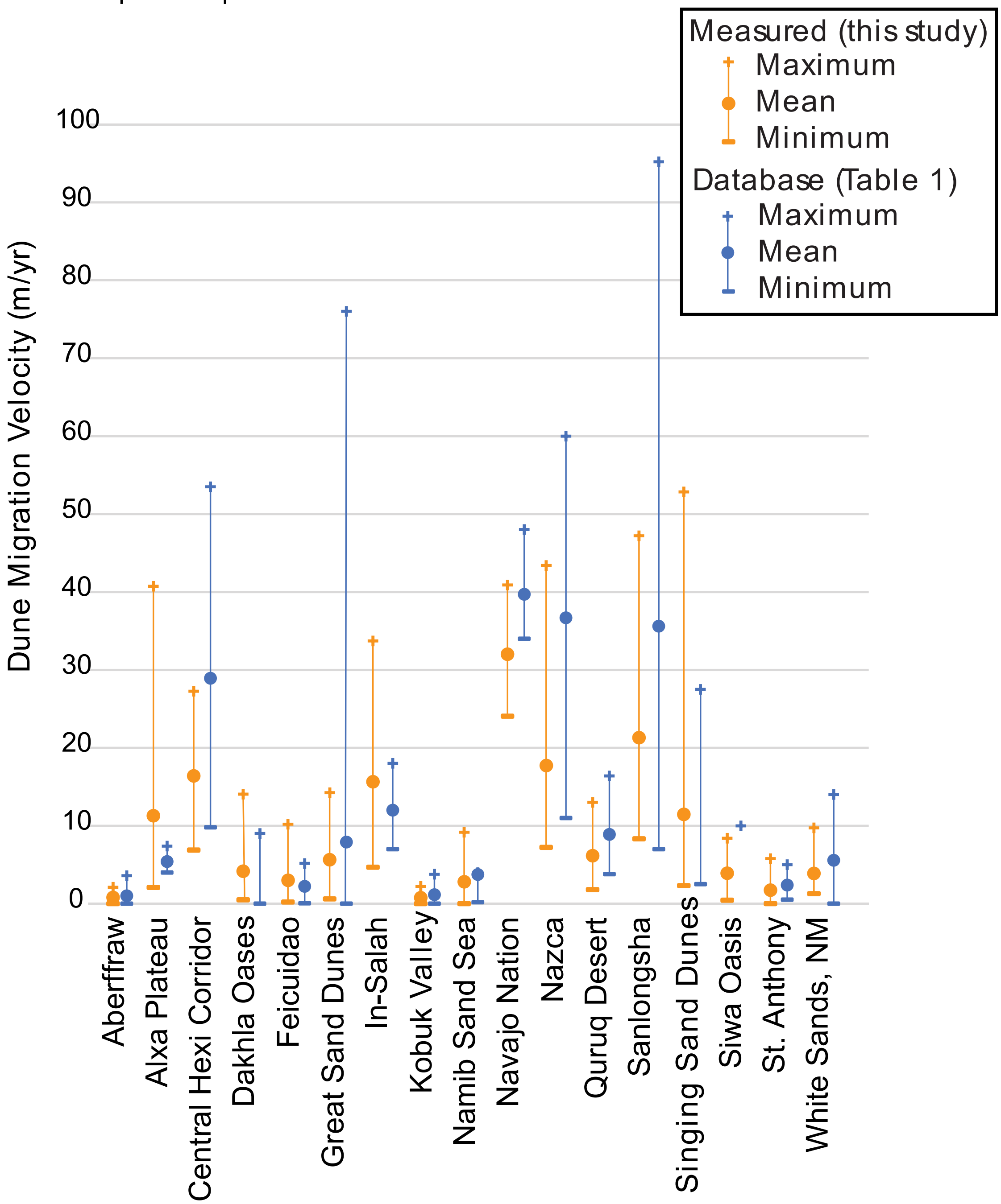

Figure 2: The results of our comparison test of dune velocities (m/yr) with our results in orange and the published migration rates in blue. Minimum, mean, and maximum values are shown. For the most part our measured ranges fall within the published ranges, although our method tends to underestimate the maximum value due to the rarity of small, fast-moving dunes in these systems.

We found that three dune fields contain the world's fastest dunes (Fig. 3): Sanlongsha Dune Field of northwestern China (73.8 m/yr), the barchan beach dunes of Nosy Ve-Androka National Park in Madagascar (71.6m/yr), and the dunes of the Bodélé Depression in Chad (69.2 m/yr). These dune fields all are in disparate geographical locations and dissimilar climate zones. We also did not observe any relationship between mean annual windspeed and maximum dune velocity.

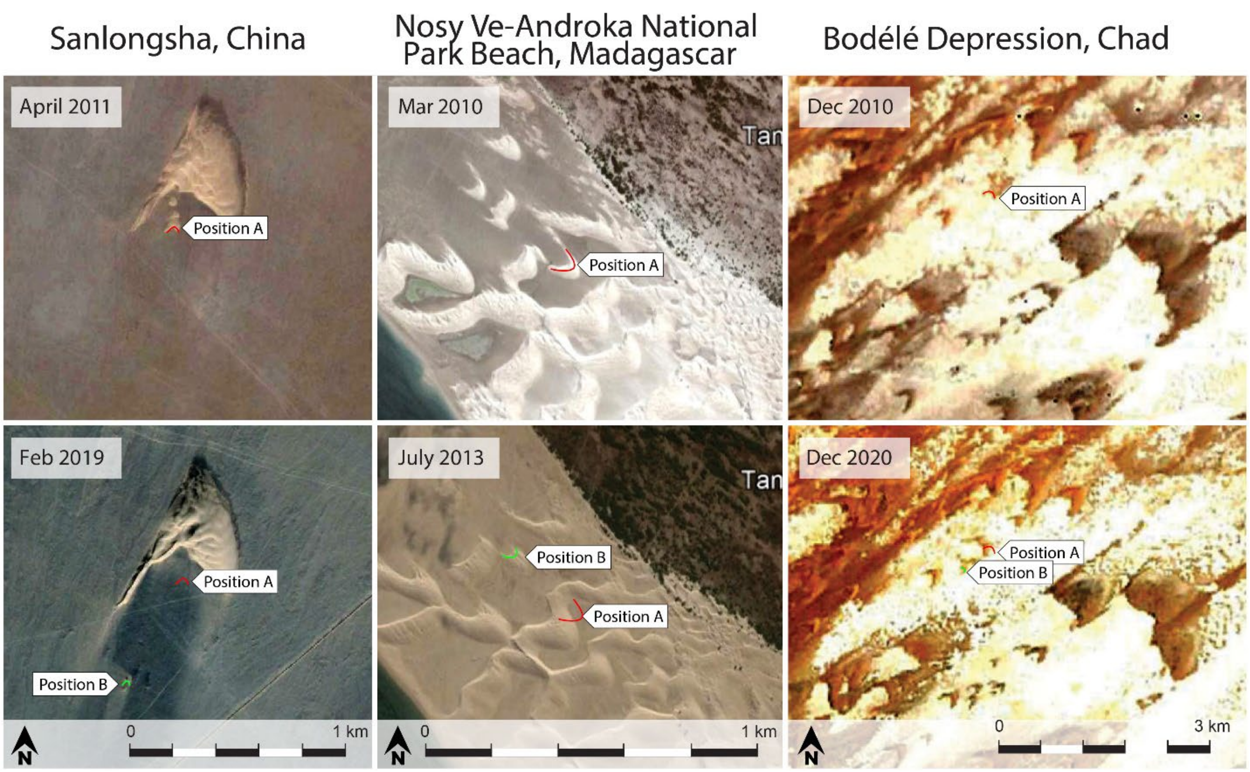

Figure 3. The fastest dunes at the top three fields from our measurements. The most rapidly moving dunes are marked with the white arrow. The top row shows the first timestep and the bottom row shows the second timestep. All images taken from Google Earth.

All the world's fastest dunes are small barchan dunes from dry areas with no vegetation cover. Previous studies have likewise connected fast moving barchans to strong, unidirectional winds, low to moderate sand supply, and low vegetation cover (e.g., Boulghobra, 2016; Yang et al., 2019). We therefore suggest that if desertification is to increase in the future, and vegetation cover lessens, global dune migration rates may increase.

Acknowledgements

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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