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A 45-year time series of Saharan dune mobility from remote sensing

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Decadal trends in the aeolian dust record of the Sahara affect the global climate system and the nutrient budget of the Atlantic Ocean. One proposed cause of these trends are changes in the frequency and intensity of dust storms, which have hitherto been hard to quantify. Because sand flux scales with the cube of wind speed, dune migration rates can be used as a proxy for storminess. Relative changes in the storminess of the Sahara can thus be monitored by tracking the migration rates of individual sand dunes over time. The Bodélé Depression of northern Chad was selected as a target area for this method, because it is the most important point-source of aeolian dust on the planet and features the largest and fastest dunes on Earth.

A collection of co-registered Landsat, SPOT, and ASTER scenes, combined with declassified American spy satellite images was used to construct a 45 year record of dune migration in the Bodélé Depression. One unexpected outcome of the study was the observation of binary dune interactions in the imagery sequence, which reveals that when two barchan dunes collide, a transfer of mass occurs so that one dune appears to travel through the other unscathed, like a solitary wave. This confirms a controversial numerical model prediction and settles a decade-old debate in aeolian geomorphology.

The COSI-Corr change detection method was used to measure the dune migration rates from 1984 until 1987, 1990, 1996, 2000, 2003, 2005, 2007, 2008, 2009, and 2010. An algorithm was developed to automatically warp the resulting displacement fields back to a common point in time. Thus, individual image pixels of a dune field were tracked over time, allowing the extraction of a time series from the co-registered satellite images without further human intervention. The automated analysis was extended further back into the past by comparison of the 1984 image with declassified American spy satellite (Corona) images from 1965 and 1970. Due to the presence of specks of dust as well as image distortions caused by shrinking of the photographic film, it was not possible to automatically measure the dune displacements of these scenes with COSI-Corr. Instead, the image was georeferenced and coregistered to the 1984 Landsat imagery by third order polynomial fits to 531 tie points, and the displacements of ten large barchan dunes were measured by hand. Thanks to the 19-year time lapse between the two images used for these 'analog' measurements, their precision is better than 5%, which is comparable with that of the automated COSI-Corr analysis. The resulting dune celerities are identical to the automated measurements, which themselves show little or no temporal variability over the subsequent 26 years. The lack of any trend in the time series of dune celerity paints a picture of remarkably stable dune mobility over the past 45 years. None of the distributions fall outside the overall average of 25m/yr.

The constant dune migration rates resulting from our study indicate that there has been no change in the storminess of the Sahara over the past 45 years. The observed dust trends are therefore caused by changes in vegetation cover, which in turn reflect changes in precipitation and land usage. This work highlights the importance of the hyper-arid Bodélé Depression, which provides a steady but finite supply of aeolian dust to the atmosphere without which nutrient fluxes and terrestrial albedo would be more variable than they are today.