What determines the size of giant dunes?

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Physicists at the Laboratory of Physics and Mechanics of Heterogeneous Media (CNRS / Université Paris Diderot / ESPCI ParisTech / Université Pierre et Marie Curie) have shown, in collaboration with scientists from the US and Algeria, that the size of giant dunes is controlled by the depth of the atmospheric convective boundary layer. More specifically, the physicists have shown that such dunes grow through the accumulation of small superimposed dunes, and that their growth is limited by interaction with a part of the atmosphere called the inversion layer, which confines wind flow around the dunes. These findings are published in the 26 February 2009 issue of the journal *Nature*.

The dynamics of dunes are the result of the interaction between the wind, which by transporting sand grains remodels their shape, and the shape of the dune which, in return, controls atmospheric flow. Dunes can take the form of crescents, stars or parallel waves. The smallest dunes appear spontaneously in the form of waves on the sand's surface, with a distance between their crests of a few tens of meters. Physicists have previously shown that this basic size is controlled by the inertia of the grain, which itself depends on the size and density of the grain as well as the density of the fluid sand.

This time, the aim of the researchers was to understand what determines the size of the biggest dunes. They first measured the distance between giant dunes in all the world's deserts by means of satellite images. This distance varies from an average of 300 meters for coastal deserts (along the coasts of Namibia or Peru, for example) to 3,500 meters in the interior of continents (in central China or in the two Great Ergs in

Algeria). This difference in size is linked to the vertical structure of the atmosphere. The lowest layer is the convective boundary layer, which is directly in contact with the Earth's surface: at this level, warming of the ground by the Sun gives rise to thermal convection. Above this, a thin layer called the inversion layer (1) separates the convective layer from the stable part of the atmosphere, located at higher altitude.

The researchers showed that giant dunes form by gradual accumulation of smaller wind-driven structures. This growth process would be unlimited but for the fact that the dunes end up interacting with the inversion layer. This is because the inversion layer confines wind flow around the dunes. As a result, the dunes stabilize at a size that corresponds to the altitude of the inversion layer (or the depth of the convective layer). To obtain this result the researchers used a novel method to estimate the height of the inversion layer. It turns out that the greater the variation in annual temperature, the greater is the height of the inversion layer. For instance, in an oceanic climate, where temperatures only vary by a few degrees between winter and summer, the inversion layer is on average located at an altitude of a few hundreds of meters. This is precisely the order of magnitude of the size of giant dunes in coastal deserts. Conversely, in a continental climate, where temperatures vary greatly over the year, the inversion layer is located several kilometers above the ground, which is the order of magnitude of continental giant dunes.

By combining field measurements, remote sensing and aerodynamic calculations, the scientists have shown the existence of a proportionality relationship between the size of giant dunes and the mean depth of the convective layer, regardless of the shape of the dunes. This interdisciplinary work has made it possible to better understand the phenomena at work when sediments such as sand interact with a fluid (in this case, the atmosphere).

(1) This is where fair-weather cumulus clouds form.

More information: Giant aeolian dune size determined by the average depth of the atmospheric boundary layer. B. Andreotti, A. Fourričre, F. Ould-Kaddour, B. Murray and P. Claudin. *Nature*. 26 February 2009.

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