News and Views article: “Aeolian sand sorting and megaripple formation”

Megaripples: the missing link between ripples and dunes?

N.M. Vriend[1] and P.A. Jarvis[1,2]
[1] DAMTP, University of Cambridge, [2] University of Geneva

Small centimetre-scaled ripples found in deserts and beaches seem a world apart from large-scale sand dunes that can reach tens or hundreds of meters in length. New research however shows that intermediate megaripples do appear if the conditions are just right.

Sand dunes have captured the attention of desert wanderers, early explorers and scientists alike for centuries. These large piles of sand are formed by the wind and self-organize in fascinating shapes and forms depending on the wind direction variability and sand supply. Aeolian, wind-blown, dunes form by a hydrodynamic instability due to the interaction between the amount of sand transport (“flux”), the topography and the velocity of the wind across a dune (“shear stress”). Even though sand dunes look self-similar and scalable, this interaction results in failure of scale invariance of smaller dunes and a minimum dune height exists. Any traveller wandering the desert will observe that no dunes below ~ 0.5 m can be found in nature, as any smaller bedforms flatten out into sand sheets and are blown away.

To be precise, smaller bedforms do appear in the form of ripples on sand beds, which can even be superimposed on dunes, but these are formed by a different physical process. In ripples, hopping or “saltating” grains picked up by the wind form regular topographic patterns with shadow zones and impact zones. As a result, in most wind-blown natural situations, small ripples and large dunes co-exist, but no bedforms appears in the intermediate “forbidden wavelength gap”.

Writing in Nature Physics, Marc Lämmel and co-workers investigate with theoretical analysis and empirical evidence the notable exception to this observation, by exploring the existence and origin of intermediate bedforms called “megaripples”. They pose that specific erosive conditions can create the necessary prerequisites to create these peculiar bedforms. In order to follow their argument, we need to first consider particle size in your typical children’s sand pit.

Sand is not uniform at all; a grain can have smooth or sharp edges, or be very angular in shape. A sample of sand does not have one unique “grain diameter”, but has a distribution from fine to coarse grains. The bouncing and rolling during centuries in mature desert environments smoothens the grains, and create a rather monodisperse size distribution, as finer grains were blown away and coarser grains have been left behind. Lämmel et al. argue that this monodisperse size distribution can develop into a clear bimodal distribution under the correct specific wind conditions. As a result, the hop length of coarse and fine grains, critical for ripple formation, is strongly bimodal as well. More specifically, the shorter hop length for coarse grains results in a shorter “saturation” length-scale which is a critical parameter to determine minimum dune size. The coarse grains are now forming bedforms, so-called megaripples, at smaller sizes than typical dunes, therefore penetrating the “forbidden wavelength gap”.

These megaripples have been observed in a limited amount of geographical places on Earth, including the southern Negev desert in Israel, …., where sand size distributions are not particular monodisperse. A characteristic of megaripples is that they exhibit strong vertical sand grading, with coarse grains forming the top layer, and are less regular arranged and spaced then their ripples counterparts.

Above we stated that megaripples can appear in the “correct specific wind conditions”. So what are they, and why are they a prerequisite for megaripple formation? Lämmel et al. argue that the key is the available particle size during the formation process and which can change over time. The size distribution of sand has been developed over long geographical time-scales and is strongly dependent on sand origin and upwind conditions. The distribution of grains on the surface however adjusts over much shorter time-scales under intermittent wind regimes. For constant and moderate wind speed, sand is slowly sorted in a strong bimodal distribution, with coarse grains armouring the bed covering fine-grained sand. However, during storms or strong and variable bursts in the wind the particle distribution quickly reverts back to monodisperse. As a result, the formation of megaripples is transient, forms slowly over time, but can quickly disappear.

The formation of megaripples is related to a shorter hop-length of coarse grains and therefore a shorter minimum dune size. Are then the megaripples closer in scaling behaviour to ripples or dunes? Lämmel et al. explore a scaling of mass and velocity between wavelength of megaripples (typical for ripples) or length of megaripples (typical for dunes), and determine that megaripples feature both a broken scale invariance, a minimum megaripple size and an inverse relation between bedform migration speed and bedform length. This all points in the direction that megaripples are very closely related to dunes.

In conclusion, the authors claim megaripples are distinctly different from both ripples and dunes and should be classed as a third type of bedform.

Talk about lack of extensive set of empirical data….