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# Bedform pattern evolution in two horizontal dimensions: Extreme wavelength increases with mixed grain sizes

A. Brad Murray

Nicholas School of the Environment and Earth Sciences, Division of Earth and Ocean Sciences/Center for Nonlinear and Complex Systems, Duke University, abmurray@duke.edu

## 1 Introduction

Bedform patterns often appear relatively disorganized initially, with longer crests and longer wavelengths evolving over time. However, the wavelength of a pattern observed in nature is still commonly assumed to be closely related to the preferred wavelength of the initial instability. The case of wind ripples and megaripples provides an example. Megaripples—which develop where coarser grains are mixed with typical wind blown sand—exhibit wavelengths from several decimeters to several meters. Standard ripples have wavelengths of centimeters to a couple of decimeters. This difference in scale has lead to the natural conjecture that megaripples arise from a fundamentally different instability than do regular ripples ...(e.g. Yizhaq, 2004).

As an alternative hypothesis, it is possible that in some cases the wavelengths observed in nature are only weakly connected to the initial wavelengths; perhaps the wavelengths of bedforms such as megaripples result from an extreme wavelength increase—an extreme 'coarsening.'

## 2 Preliminary Field Observations

Preliminary fieldwork seems to support this extreme coarsening hypothesis. During a brief field campaign, several of us (including Bruno Andreotti, Philippe Claudin, Olivier Pouliquen, Rebecca Hoyle, and Hicham Elbelrhiti) observed on smoothed plots that ripples and megaripples start with the same initial wavelength, on the order of centimeters. However, ripples patterns coarsened by less than an order of magnitude, while megaripple wavelengths increased by well over an order of magnitude in less than a day. If other megaripples develop in this way, the coarsening could approach three orders of magnitude.

**3 Plan-View Pattern Evolution**

More modest coarsening occurs in profile models, as smaller bedforms merge with larger ones in the downstream direction ...(Prigozhin, 1999; Yizhaq, Balmforth, and Provenzale, 2005). Coarsening may be greatly enhanced by bedform interactions that require a plan-view picture to analyze. Werner and Kocurek (1997; 1999) pointed out that the defects in bedform patterns—crest terminations and bifurcations—facilitate merging. In their simplified analytical model, the rate of coarsening is related to the density of defects; when the defects anneal out of the pattern (by migrating together and annihilating) coarsening ceases. This general picture could help explain why wind ripples exhibit only modest coarsening. While the wind blows from one direction, wind ripples rapidly become very long crested. The final, or 'saturated' wavelength may be imposed by some mechanism acting on individual ripples yet to be discovered, or it may result from geometrical constraints: a paucity of defects in a pattern where the bedforms are too consistent in size for merging to be significant without the catalyzing influence of defects.

Extreme coarsening in megaripples could result from the longevity of the features, and the repeated injection of new defects. The coarser grains accumulate on the crests, armoring them so that they are not easily overprinted when the wind shifts direction, as occurs for standard ripples. New short-crested ripples growing with slightly different orientations can interact with preexisting crests, field observations suggest, serving as new defects that could allow further coarsening. Further fieldwork and modeling to test this hypothesis is planned, in conjunction with Haim Tsoar and Hezi Yizhaq.

**4 Another Grain-Size-Sorted Bedform Pattern**

However, in the meantime, a numerical model designed to explore a different kind of bedform provides an analogy. Stripes of coarse material (coarse sand to gravel), separated by domains of fine sand, adorn the seabed of many inner continental shelves around the world. These features, with wavelengths up to kilometers, can appear very bedform like in plan view. In profile view, they exhibit subtle topographic expressions, with coarse material covering the crests and upcurrent flanks, analogous to megaripples. Murray and Thieler (2004) have proposed a novel instability involving the interactions of waves and currents in the presence of a mixed-grainsize seabed, and have developed a numerical model to test the plausibility of the hypothesis that this grain-size sorting instability gives rise to the observed ‘sorted bedforms.’

In the model, the plan view pattern evolution appears amazingly similar to that of eolian bedforms. The initial instability produces a mottled pattern that develops into a better-organized arrangement of bedforms with much longer crests and wavelengths. The wavelengths that emerge are not determined by the scale of the fastest growing initial perturbations, but arise through geometrical constraints including defect interactions.

## 5 Conclusions

It is possible that for both subaqueous sorted bedforms and eolian megaripples, the large scales observed in nature depend on the armoring afforded by coarse grains, which allows the patterns to persist while intrinsically plan-view interactions cause progressive coarsening.

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