A UNIFYING MODEL FOR PLANFORM STRAIGHTNESS OF RIPPLES AND DUNES IN AIR AND WATER. David. M. Rubin, USGS, 400 Natural Bridges Dr., Santa Cruz, CA 95060; drubin@usgs.gov.

Introduction: Geologists, physicists, and mathematicians have studied ripples and dunes for more than a century, but little attention has been directed at explaining one of the morphologic properties that is most visible in remotely collected images: why are some bedforms straight, continuous, parallel, and uniform in planform geometry (i.e. two-dimensional) whereas others are barchanoid and irregular, with discontinuous crests and troughs (three-dimensional)? We argue that physical coupling along the crest of a bedform is required to produce straight crests and that along-crest flow and sand transport provide effective physical mechanisms for that coupling [1].

Discussion:

Planform geometry in simple unidirectional flows. In unidirectional flows, bedforms generally have crescentic, barchanoid, or irregular planform geometry [2-7]. For a ripple or dune to have a straight continuous crest, some physical mechanism must operate to couple the topography at different along-crest locations. Without such coupling, different sites along a crest need not remain locked in phase and are free to form breaks, bends, or junctions. Hypothetically, if flow and topography along every streamline were completely decoupled from adjacent streamlines, "bedform" crests would be randomly phased from one streamline to another, and coherent bedforms could not exist. The presence of coherent continuous crests implies some degree of along-crest coupling, and straight continuous crests require a greater degree of along-crest coupling.

Situations that enhance two-dimensionality. Ripples and dunes with the straightest and most continuous crests include longitudinal and oblique dunes in unidirectional flows, wave ripples, dunes in reversing flows, wind ripples, and ripples migrating along a slope. At first glance, these bedforms appear quite different (ripples and dunes; air and water; transverse, oblique, and longitudinal orientations relative to the net sand-transport direction), but they all have one property in common: a process that increases the amount of along-crest sand transport (that lengthens and straightens their crests) relative to the across-crest transport (that makes them migrate and take the more typical three-dimensional planform geometry). In unidirectional flows that produce straight bedforms, along-crest transport of sand is caused by along-crest flow (non-transverse bedform orientation), gravitational transport along an inclined crest, or ballistic splash in air. Bedforms in reversing flows (wave ripples, tidal dunes, and eolian dunes in seasonally reversing winds in Figure 1d-f) tend to be straighter than their unidirectional counterparts (Figure 1a-c) because reverse transport across the bedform crest reduces the net across-crest transport (that causes the more typical irregular geometry) relative to the along-crest transport (that smoothes and straightens planform geometry.

Unresolved issues. A variety of processes that might influence planform geometry remain unresolved, including: (a) intersection of two or more sets of bedforms such as those that form in bi-directional flows diverging by ~90° [7-9], (b) formation of superimposed bedforms that become so large that they effect the geometry of the main bedforms [10]), (c) formation of bedforms in flows with three or more vectors, such as combined waves and currents [11] or intersecting sets of waves, (d) formation of bedforms in flows with directional modes that individually transport enough sand to substantially alter bedform morphology, and (e) sorting of sediment by grain size into patches of sediment that respond differently to flow. Nevertheless, the model reviewed here [1] identifies the unifying underlying process that causes two-dimensionality in a wide variety of diverse situations.

References:

[1] Rubin, D. M. (in press) *Earth-Science Reviews*. [2] Bagnold, R. A. (1941) *The Physics of Blown Sand and Desert Dunes*, Methuen, London. [3] Allen, J. R. L. (1966) *Sedimentology*, 6, 153-190. [4] Middleton, G. V., and Southard, J. B. (1984) *Mechanics of Sediment Movement*, Society for Sedimentary Geology, Tulsa. [5] Baas, J. H. (1994) *Sedimentology*, 41, 185–209. [6] Venditti, J. G., Church, M., Bennett, S. J. (2005) *Sedimentology*, 52, 1343-1359. [7] Reffet, E., Courrech du Pont, S., Hersen, P., Douady, S. (2010) *Geology*, 38, 491-494. [8] Dalrymple, R. W., Rhodes, R. N. (1995) *Developments in Sedimentology.* Elsevier, Amsterdam, 53, 359-422. [9] Werner, B. T., Kocurek, G. (1997) *Geology*, 27, 771-774. [10] Brookfield, M. E. (1977) *Sedimentology*, 24, 303-332. [11] Lacy, J. R., Rubin, D. M., Ikeda, H., Mokudai, K., Hanes, D. M. (2007) *J. Geophys. Res*., 112, C10018, doi:10.1029/2006JC003942. [12] Kaplinski, M., Hazel, J. E., Jr., Parnell, R., Breedlove, M., Kohl, K., and Gonzales, M. (2009) *U.S. Geological Survey Open-File Report* 2009–1207. [13] Barnard, P. L., Erikson, L. H., Kvitek, R. G. (2011) *Geo-Marine Letters*, 31, 227-236.

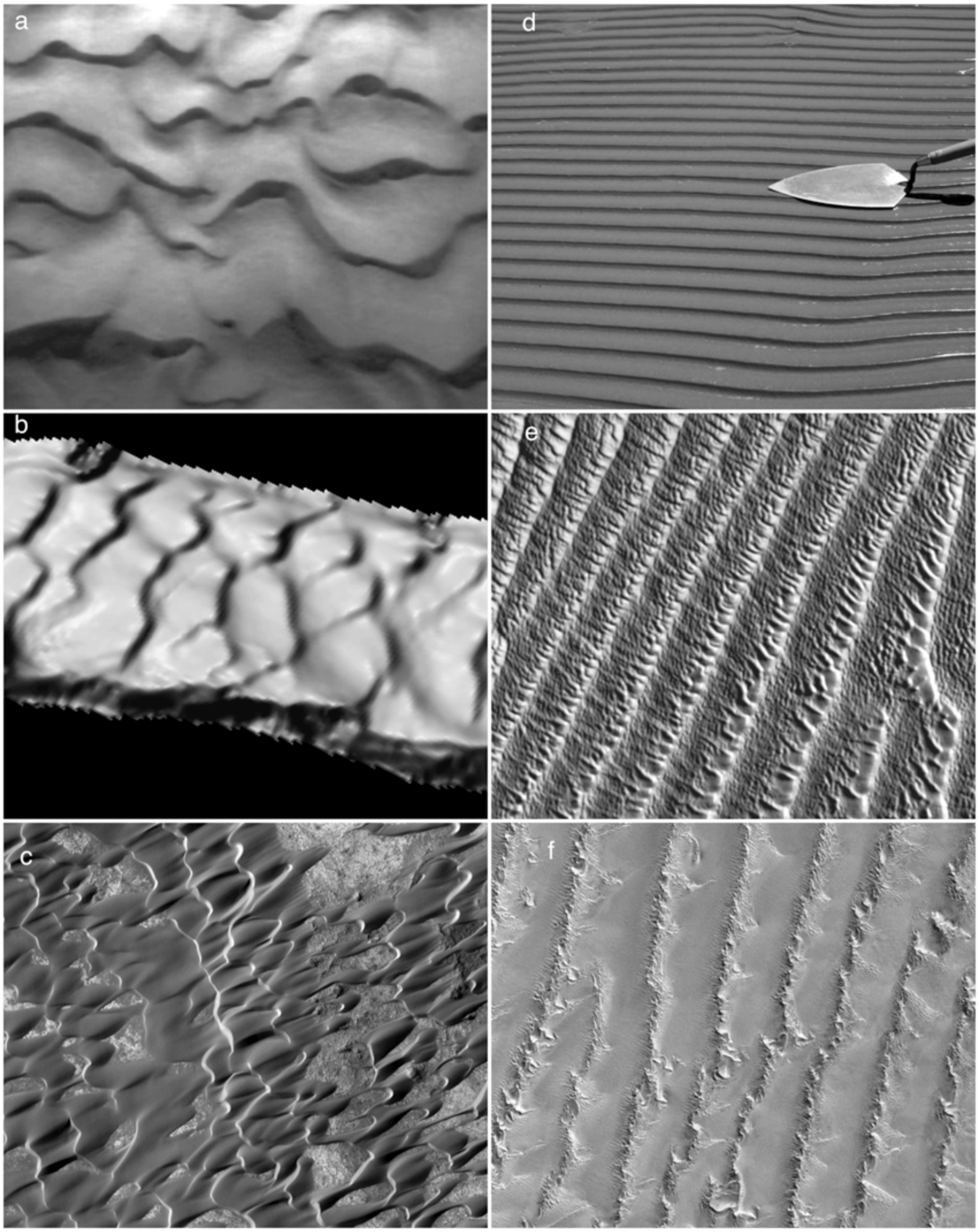

Figure 1. Three-dimensional ripples and dunes in unidirectional flows (left column a-c) and two-dimensional counterparts in reversing flows (right column d-f). (a) Ripples formed by unidirectional flow in a lab flume; flow is from top to bottom; field of view is 40 cm from right to left. (b) Dunes in unidirectional flow in the Colorado River in Grand Canyon viewed by multibeam sonar [12]; channel width is approximately 70 m. (c) Crescentic eolian dunes on Mars (winds roughly from right to left; field of view ~6 km x 6 km); (Image: NASA/JPL/University of Arizona; Nili Patera Ripples ESP_017762_1890). Right column shows straight-crested bedforms created by reversing flows. (d) Ripples formed by reversing wave-generated flow on a sand bar in Colorado River in Grand Canyon. (e) Dunes formed by reversing tidal currents, San Francisco Bay, California [13]; wavelength is 60 m. Superimposed dunes demonstrate along-crest sand transport (from bottom to top in image). (f) Eolian dunes formed by seasonally reversing winds, Namib Desert; dune wavelength is 2 km. Superimposed dunes demonstrate along-crest sand transport (from bottom to top in image). Landsat Earth as Art series; USGS and NASA.