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Earth System Dynamics Discussions

Interactive comment on "Yardangs and Dunes: Minimum- and Maximum-Dissipation Aeolian Landforms" *by* Ralph D. Lorenz

Hisashi Ozawa (Referee)

hozawa@hiroshima-u.ac.jp

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General comments

This paper investigates the formation process of two typical landforms (yardangs and dunes) and their thermodynamic properties associated with the landform formation. It is shown that yardangs, which are formed by a wind-driven erosion process, tend to take the form that minimizes the wind drag force and minimizes kinetic energy dissipation due to the wind drag force. In contrast, dunes, which are formed under the balance between the erosion and accumulation processes, tend to take the form that maximizes the wind drag force and maximizes dissipation of kinetic energy of turbulent flows associated with the dunes. While the physical mechanism that determines

the significant difference between the two distinctive landforms is not fully explained, this paper provides a good introductory review on this subject and can be regarded as a thought-provoking, informative paper. The text is very well written, and there is no serious technical error in this paper. I therefore recommend publication of this paper. However, I have several comments and suggestions that may be helpful for improving the quality of this paper before the publication.

Specific comments

1. Line 46: Yardangs is a Turkic word.

I am not sure, but someone says it is Uighur (e.g. Wang et al. 2011, PRE). It may be good to check the word's origin.

2. Line 114-115: their size tends to be limited by the height of the atmospheric boundary layer.

The atmospheric boundary layer is defined as the lowermost atmospheric layer that is influenced by the surface drag force. So, the height can vary with the surface topography - as the density and height of dunes increase, the BL height may become higher. If so, I am not clearly sure if they can really be "capped" or limited by the variable BL. Can you make this point clearer?

3. Line 132: heat flow.

Here it may be good to state that this heat flow is conduction only. In this case, the governing equation is of the Laplace type (without a nonlinear advection/convection term), and everything is solvable.

4. Line 138: there is no unique solution.

There is no unique solution because the heat transport rate for a movable fluid includes a nonlinear advection term - the heat transport rate can change according to a change in dynamic motion, whose analytical solution has not yet been obtained.

5. Line 154-155: a fixed-flow pipe system requires MinEP, but ... chooses MaxEP.

Probably, the situation is opposite: a fixed-head system prefers MinEP whereas a fixed-flow system exhibits MaxEP - please check Robert's paper. I do not know the reason, but please note that the transition in this case refers to a laminar to turbulence transition, not a selection among multiple steady sates of a turbulent fluid system.

6. Line 165 (Fig. 6): a constrained situation where the minimum... emerges.

Perhaps, this is one of the most important findings of this paper. This idea is interesting. But, I have a slightly different opinion on the yardang/dune/finger formation.

Yardangs tend to take a form that reduces the wind drag force because they are produced by a one-way erosion process from the wind (+ sands) to the solid surface. The erosion rate, which is roughly proportional to the wind drag force, is largest at edge/vertex parts of an obstacle exposed to wind. The edge/vertex parts will thus be eroded away and tend to be 'flatten' as time goes on - so we observe a streamlined shape for yardangs in due course. The erosion process is one-way (nearly linear), and there is no (nonlinear) feedback from the eroded sand particles. Note also that yardongs are NOT in a steady balanced state, but in a transient eroding state: they will eventually disappear when we observe them over a very long time period (t -> infinity). On the other hand, dunes tend to take a form that increases the wind drag force because they are produced through mutual interactions between wind fields and sand-accumulated surfaces. Their shape is determined not only by a simple erosion process but by a balance between the erosion and accumulation processes - the wind field determines the erosion rate, but the eroded sands accumulate on a land surface which largely affects the wind velocity and the drag force by producing a certain dune shape. There is a kind of mutual interaction between wind and sand surfaces with nonlinear feedbacks associated with large and distinctive turbulent eddies adjacent to the landforms. In this situation, the system tends to be in a state with MaxEP as we have seen in many other similar examples (thermal convection, shear turbulence, general

circulations, etc.).

From this viewpoint 'finger' dunes can be seen to be a special limiting case of an initial development under limited sand supply. There seems to be only a one-way process from wind to the sand surface (finger), and there may be no sands-to-wind feedback during a developing stage of finger dunes. In a matured stage, however, a finger dune tends to disintegrate into a series of smaller dunes under unidirectional wind conditions (Gao et al. 2015).

7. Line 234- (references).

Some literature (Taniguchi et al., Ward and Greeley, Niven...) seems to be missing from the list. Please check.

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