Review report on “Hydrology without dimensions”

by Demetris Koutsoyiannis

Author(s):	Amilcare Porporato
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Recommendation:	Accept as is

Reviewer’s assertion: It is my opinion that a shift from anonymous to eponymous (signed) reviewing would help the scientific community to be more cooperative, democratic, equitable, ethical, productive and responsible. Therefore, it is my choice, consistent with my aesthetic attitude, to sign my reviews. Furthermore, I believe that the current trend in the review system to seek credit for anonymous transactions (by asking recognition for anonymous reviews through Publons) is problematic on ethical and aesthetic grounds.

Reviewer’s clarification: The references included in this review have the same meaning that references have in scientific documents. In brief, they clarify or justify the reviewer’s statements and provide links where further details can be found. They are not necessarily meant to be suggestions for the author(s) to include them in the paper in review (if not already included).

As stated in the acknowledgments, this article by Amilcare Porporato is a contribution invited by EGU and related to the Dalton medal lecture by the author.[1] The depth and breadth of the analyses and the presentation clearly reflect the fact that Porporato is a pioneering scientist well deserving the Dalton medal.

I have no reservation to recommend this article for publication in its current form. On the other hand, for the sake of the dialogue, I tried to find some points of disagreement and focus my discussion on them. I am offering my comments just for the author’s consideration and not necessarily as suggestions for changes in the paper.

Overall, the choice of the paper’s theme is very successful. While scientists working in hydraulics and hydrodynamics are familiar with dimensional consistency and dimensional analysis, this is not always the case in hydrology. We often see in hydrological texts empirical equations that are dimensionally inconsistent, dependent on the choice of units or even wrong. Therefore, I believe the paper is didactic and quite useful in this respect. On the other hand, I must acknowledge that it is not an easy read and at times it becomes a difficult one. I understand that this is because it summarizes a lot of knowledge and examines cases from diverse fields.

[1] I believe this should be stated as a footnote in the first page of the paper.

I particularly liked the section "2.3 Augmented and directional dimensional analysis" and its Appendix examining the question whether temperature can be used as a primary dimension or, alternatively, we should limit the primary dimensions to length, time and energy. However, I had some difficulty to accept the following argument (in Appendix A):

> *This however would imply the use of very small units, because in the usual SI system,* k_B = 1.380649 × 10^{-23} J · K^{-1}. *As a result, apart from systems at the nanoscale, in normal conditions* $k_B d^3 c \sim 0$. *Our everyday experience, on which thermodynamic concepts are based, shows that we can neglect this term in (A3) …*

where equation (A3) is:

$$\frac{h}{d\theta\kappa} = \varphi\left(\frac{vcd}{\kappa},\ k_B d^3 c\right)$$

Since we do not know the function $\varphi(\ )$, I think we cannot know the influence of its second argument ($k_B d^3 c$). In my view, whether or not it is very small does not say anything to us. Perhaps, in the unknown function $\varphi(\ )$, this term could be multiplied by a very large constant and give a considerable effect (even if it were an additive term, which we do not even know). I would understand an argument that the term can be omitted because it is virtually constant, or because it is small *and* additive. But as formulated now, I find it problematic. With all this I do not mean that Rayleigh's (1915) result is wrong; I just think that better reasoning is needed.

Perhaps the framework of augmented and directional dimensional analysis could be explained better. An example (perhaps again in the form of an Appendix) additional to the examined temperature question, but closer to hydrology, would be helpful for a reader to understand the framework of augmented dimensional analysis. (I am thinking of a case of a flow or a wave where the vertical direction (z) could be regarded independent of the horizontal one (l); intuitively this agrees with what we are doing in many of our engineering drawings where we use different horizontal and vertical scales.)

I wonder if the framework of augmented dimensional analysis could also be used as a justification of equation (7), instead of introducing a power law (self-similarity) out of the blue. Personally, I had been amazed by scaling behaviours and power laws decades ago, but progressively, I shaped the opinion that scaling claims need proper foundation in order to stand, and there is no magic in their emergence. As I have tried to show (Koutsoyiannis, 2014; Koutsoyiannis et al., 2018), their emergence is understandable as asymptotic laws, whose exponents can hardly coincide in the lower and upper limits. In other words, expressions like equation (7) could only hold asymptotically. If they hold generally, then there must be some theoretical reason that should have to be explained (perhaps in the frame of augmented dimensional analysis?).

Generally, scaling, self-similarity and fractal behaviour look to be overemphasized or overpraised in the paper, perhaps unjustifiably. For example, below Figure 4 it is stated "Both these expressions are suggestive of self-similarity". However, I have some difficulty to locate self-similarity both in the expressions and the figure. I rather see a curve similar to the Budyko curve in Figure 2 (yet less smooth). Asymptotically this curve seems to have a constant slope on the left and a constant value (zero slope) on the right. Perhaps I have missed the point, but I would not think that such a curve reflects self-similarity. Also, contrary to what is stated in the paper, I do not see "self-similarity […] in the Moody diagram for the friction factor in the fully rough regime".

Since the deterministic relationships examined do not look to be in perfect agreement with the data (see e.g. Figure 2), I would expect some involvement, or at least mentioning of stochastics (by way of replacing one-to-one relationships with many-to-many). But this is my personal taste, which perhaps the author does not share.

I like the fact that the paper cites good old works, starting from the 1880s with Lodge (1888; I guess it would be a real headache for him to combine in his paper the different length units he uses, miles, yards, feet, inches, and products thereof!), and Williams (1890). On the other hand, while Kolmogorov's ideas are mentioned (and named) several times, I think it is a pity that he is not cited at all. Furthermore, Strahler (1958) is perhaps miscited; I doubt if he envisaged that "that dimensional analysis will become increasingly useful in ecohydrology" (did he know the term "ecohydrology"?). The modern literature is well represented, yet I think that the recent papers by Theodoratos et al. (2018), and Theodoratos and Kirchner (2020, 2021) whose subject is dimensional analysis on landscape evolution are relevant and could be cited.

As regards the presentation, the paper is carefully written with very few typing errors which will certainly be spotted in the proof-reading phase. (To mention just one typing error, in the caption of Figure 7, with "on the left", is it not meant "on the right"?) The notation and terminology are both fine. An exception in terminology is perhaps the terms "climatic forcing" which looks not to be meant as such (see e.g. the meaning of this term in Wikipedia). Perhaps just "climate" or "atmospheric processes" are more accurate within the paper's scope.

References

Koutsoyiannis, D.: Random musings on stochastics (Lorenz Lecture), AGU 2014 Fall Meeting, San Francisco, USA, doi: 10.13140/RG.2.1.2852.8804, American Geophysical Union, 2014.

Koutsoyiannis, D., Dimitriadis, P., Lombardo, F., and Stevens, S.: From fractals to stochastics: Seeking theoretical consistency in analysis of geophysical data, *Advances in Nonlinear Geosciences*, edited by A.A. Tsonis, 237–278, doi: 10.1007/978-3-319-58895-7_14, Springer, 2018.

Lodge, A.: The multiplication and division of concrete quantities, General Report, Association for the Improvement of Geometrical Teaching, 14, 47–70, 1888.

Rayleigh, L.: The principle of similitude, *Nature*, 95, 66, 1915a.

Strahler, A.N.: Dimensional analysis applied to fluvially eroded landforms, *Geological Society of America Bulletin*, 69, 279–300, 1958

Theodoratos, N. and Kirchner, J.W.: Dimensional analysis of a landscape evolution model with incision threshold, *Earth Surf. Dynam.*, 8, 505–526, doi: 10.5194/esurf-8-505-2020, 2020.

Theodoratos, N. and Kirchner, J.W.: Graphically interpreting how incision thresholds influence topographic and scaling properties of modeled landscapes, *Earth Surf. Dynam. Discuss.* [preprint; accepted], doi: 10.5194/esurf-2020-45, 2021.

Theodoratos, N., Seybold, H., and Kirchner, J.W.: Scaling and similarity of a stream-power incision and linear diffusion landscape evolution model, *Earth Surf. Dynam.,* 6, 779–808, doi: 10.5194/esurf-6-779-2018, 2018.

Williams, W.: On the relation of the dimensions of physical quantities to directions in space, *Proceedings of the Physical Society of London*, 1874-1925, 11, 357, 1890.