Hydrol. Earth Syst. Sci. Discuss., 6, C609–C616, 2009
www.hydrol-earth-syst-sci-discuss.net/6/C609/2009/
© Author(s) 2009. This work is distributed under
the Creative Commons Attribute 3.0 License.

Hydrology and Earth System Sciences Discussions

Interactive comment on "Hierarchy theory in hydropedology" *by* T. F. H. Allen et al.

Anonymous Referee #2

Received and published: 6 May 2009

General Comments

This manuscript is one of the most challenging and thought provoking that I have ever read. In principle, I believe that the authors have made a credible effort to convince this hydropedologist that hierarchy theory has a serious contribution to make to hydropedology. As they state in the manuscript, they are a bit short on details and examples. However, this is not surprising because hierarchy theory has not been applied to hydropedology. For me, and I suspect many hydropedologists, getting the "gist" of applying hierarchy theory to soil processes is most elusive, and I am only sure that I would likely "get it confused somehow". This manuscript makes an excellent case for a systematic approach to applying hierarchy theory to hydropedology; for example, organizing a workshop to prepare a collaborative grant proposal involving hydropedologists and complexity theorists. Choosing a problem to focus on would likely be a major task for such a workshop. The manuscript emphasizes water in the soil, but the concepts

presented are equally appropriate to runoff and erosion. In fact, I suspect that runoff may actually be the process most likely to benefit for a hierarchy-theory approach, because all current runoff models suffer greater uncertainties than models of infiltration and redistribution in the soil.

Specific of comments and questions related to sources of confusion

I support whole-heartedly the authors emphasis on level of analysis, but I have worked only with physical scale; namely, regional, field, plot or laboratory column. In fact, the disconnect the authors point out in mixing a scale hierarchy (hydrology) with a definitional hierarchy (pedology) on page 2937 is a new explanation for why we sought new ways to map the relevant physical properties of the soil over agricultural fields to get the inputs we needed for landscape-scale models of water movement. This was necessary because pedotransfer functions based on traditional classifications were inadequate in both spatial scale and soil property characterization.

On page 2935 line 10, the authors attempt to give an example of "asymmetric relationships", but the example does not illuminate me in the least. I hope that they can make this terminology clearer with re-wording or another example.

On page 2937 line 28, I do not understand what the authors mean by a hydrologic system constraining system behavior, since a hydrologic system includes everything from a hydropedology perspective.

On page 2938 line 2, the authors indicate that a definitional hierarchy may be more useful for soil properties. I would suggest that in hydropedology the definitional hierarchy chosen by pedologists many years ago has limited usefulness in modeling, but we need to use it because that is all there is on our landscapes. Because of the limited usefulness of the pedologists definitional hierarchy for soil characterization, in hydropedology a major effort is underway to develop new methods to map soil properties that are more suitable for modeling.

On page 2940 the authors could cite two perfect examples of “middle number systems”: 1) Macropore channels that are continuously created and altered by soil microfauna and can be responsible for more than 90% of the infiltration capacity of soils, and 2) runoff/erosion processes that can be altered by orders of magnitude on an agricultural field as a result of soil roughness variations from tillage implements; variations that are too small to measure reliably at the present time.

On page 2940 line 20, the authors state “One simply has to change the investigation so it gives a predictable answer to a question that can be answered”. Runoff is one of the most critical processes to predict in hydropedology and it is a “middle number” process. Hierarchy theory provides little to us here because it suggests we get interested in something else; however, interest in runoff is not an academic pursuit, it is what we need to know to serve society. Does this mean that hierarchy theory has little to offer to runoff studies?

On page 2940 line 25, the authors indicate that the problem with estimating runoff (middle number system) is “. . . not a data problem”. How can they be sure of this? If we developed a new way to measure soil roughness from tillage, the lack of predictability might be largely solved. Alternatively, if we understood better the interaction between rainfall energy and the dynamic altering of soil roughness during events, it might be that more detailed rainfall data could lead to better predictions. If either of these data options were a possibility for improving predictions, then hierarchy theory may take us away from a potential solution by identifying runoff as a “middle number system” when it only appeared that way because of our ignorance. The authors do make the point on page 2946 line 24 that hierarchy theory provides a framework for fostering new approaches. Can it not likewise suggest that the question is not answerable (see comment above) and discourage innovation or divert attention away from other possibilities? Perhaps I do not quite understand what the authors mean by “. . . is not a data problem”.

On page 2941 the discussion about soil water characterization creates some confu-

sion for me, and I suspect that it is not a good example of what the authors mean to communicate. Having worked in this specialty for more than 20years, I believe that a coherent approach is available in soil physics to address all these quantities simultaneously (volumetric water content, gravimetric water content, matric potential, water filled pore space, depth to water table, percent saturation, field capacity and more) at various levels of elegance with some variations in details. Unfortunately non specialists (such as these authors) looking at literature on soil water characterization is not likely to know this, because many scientists is disciplines related to soil physics use various characterizations of soil water as variates (when they are actually interested in something else like microbial activity) based on some convenient or affordable measurement. As a result these scientists do not understand the remarkable coherence of concepts in soil physics, because to do so would require an unreasonable amount of effort and time for their purposes.

On page 2941 at line 28 the authors introduce what I would call “pedotransfer functions” to relate physical properties to pedological properties. I do believe that “pedotransfer functions” are an area where hierarchy theory is most relevant to hydropedology, because “pedotransfer functions” are useful, but suffer from more uncertainty that is generally tolerable for prediction requirements in hydropedology. Also, the necessity for “pedotransfer functions” seems to arise because models operate in a scale hierarchy and pedology operates in a definitional hierarchy with a loose extrapolation to scale; an extrapolation that is too coarse to be acceptable in agriculture. This incongruity is one of the reasons various research groups around the world are working on alternative methods to directly map soil physical properties into a scale hierarchy and bypass the pedotransfer functions necessary to extract soil physical properties from traditional soil maps

On page 2942 lines 1-7 the authors discuss the apparent inconsistencies in the various descriptors for soil water, and this discussion is insightful, just, to me, not really appropriate to the soil water characterization issue. I say this because all the quanti-

ties for describing soil water can be inter-related so that given any quantity, along with a minimal amount of ancillary information, any of the others can be estimated from more or less first principles. This does not void the importance of this paragraph, but a better example is needed. Perhaps the authors might consider exploring the role of soil structure (aggregation) measurements in characterizing saturated hydraulic conductivity? Currently soil structure is recognized as one of the most important factors in influencing ponded infiltration, but essentially no practical models (existing macropore models are either too simple to be credible or too complex to be parameterized for any realistic situation) exist for quantifying its role; therefore, much chaos surrounds its discussion and hierarchy theory may be able to shed some light on this issue. The final sentence of this paragraph, "More data will not force consistency", seems to me to be more appropriate for aggregation issues than the soil water issue.

On page 2943 – 2944 the authors present a fascinating discussion of the mirror image that I found interesting in its own right. However, I have not quite succeeded in translating it into hydropedology. On page 2943 lines 6-10, the authors introduce a profoundly important issue of the use of new ad hoc measurements applied to a specific situation. This, of course, is most common in all fields of natural science; after all, it is the way we explore new measurement strategies that sometimes revolutionize a field of study. For example, the TDR started out as an "ad hoc measurement" and now is a standard. In this case, once the new measurement is introduced, more data is exactly what is needed. However, I am not sure how this is related to the "mirror" discussion so I do not understand how the mirror discussion relates to hydropedology. Perhaps the "ad hoc measurement for a particular situation" is some kind of "semantic argument" or belongs to some kind of "different type"; I just do not understand something here.

On page 2944 line 19 the authors continue the discussion of "different types" with the example of gravitational water versus matric or possibly even bound water comparisons. They apparently consider these "different types" and suggest hierarchy theory can sort these things out. It seems to me, as one entrapped in the deterministic

paradigm of quantitative science (and trying desperately to appreciate hierarchy theory) that physical chemistry has already sorted out these quantities. The unifying concept of chemical potential of water, often referred to as water potential, has reconciled the various kinds of factors that can influence the energy state of water anywhere; even in soils. To this end, the effect of many seemingly different types or factors can be added together is a single equation to determine the final outcome for water in some defined system. In the example cited in the manuscript, gravitational potential dominates under some conditions and pressure potential (often referred to matric potential in the case of negative pressure) dominates under other conditions, but both exist always in a soil. Because of this limited understanding of the thermodynamics of water in a porous media, I fail to understand the usefulness of hierarchy theory. I hope the authors can assist me here?

My tendency here is to see hierarchy theory as unnecessarily complicating our understanding and generating interpretations that "see" different types and semantics where thermodynamics "sees" one type. Because of my ignorance of hierarchy theory, I see it as arbitrarily complicating our analysis and providing little assistance. I want to be educated here but I am struggling mightily. Perhaps a different application of the concept of the importance of semantics could clear this up; say, applying it to potential, energy, position, intensive versus extensive properties etc.

Beginning on page 2945, the discussion of "narratives" is, to me, profoundly important. Personally, I believe that the absence of this discussion in traditional science has permitted us to drift into a closed, incestuous loop of proposal-review-research-publication-review-proposal etc. that unnecessarily isolates much of the scientific community from the constituency we serve. That constituency operates on narratives and we scientists operate without narratives so communication is difficult. Viewing quantitative models as part of the narrative is an excellent holistic perspective for capturing how what we are doing serves society as a whole, now or in the future. I am reminded of a paper some years ago, perhaps authored by Keith Bevin, raising concerns about too many

tunable parameters in hydrologic models so they become futile academic exercises rather than useful steps in the solution of actual problems.

On page 2946 lines 24-26, the authors suggest that hierarchy theory may provide a path to new narratives and new intellectual frameworks; this is the reason we desperately need this new perspective in hydropedology. Our major challenge will be getting support from the research community as a whole to pursue this, with commensurate effort to convince funding agencies that it is a useful pathway to their goals of serving society.

On pages 2948 – 1949, the authors describe an experiment on plants related to the effects of wind. I wonder if it might be interesting to speculate on an experiment closer to hydropedology?

Suppose we were to consider the interaction between soil fauna and macropores that facilitate water infiltration? This certainly is a complex system and it might be interesting to explore how a part of the system might take a "hit" to protect the functionality of the whole system. We could equate functionality to minimal runoff and drainage or maximum storage of rain for living things in the soil. Clearly water is one of the most limiting quantities for terrestrial life. We can imagine a series of experiments where the porous media increases in complexity from glass beads to sand to sand + peat to loam + plants + fumigation to loam + plants + bacteria + fungi to a full system of loam + plants + bacteria + fungi + fauna. We might estimate functionality by the fraction of rainfall that is stored in the medium, suggesting that is proportional to the amount of "life".

Minor editorial details

Page Line No.

2939 24 The word "one" seems to be left out of this sentence. "The idea that only one . . . "

25 The word "increase" should be "increasing" ". . . increasing temperature will .."

2940 8 The word "to" should be removed. ". . . to many parts to model . . . "

2941 1 The word "it" should be replaced with "water". ". . . how tightly water is held . . . "

2943 6 The word "as" needs to be added. ". . . system such as those in . . . "

11-13 This sentence really needs to be re-worded because it is difficult to understand even after numerous readings.

2950 5 I would think "ped/voide" should be "ped/void".

12 I did not find theSchneider et al. (2007) reference is the citation list.

2952 4 The word "consist" should be "consistent". ". . . internally consistent, is the . . . "

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 2931, 2009.