

Interactive comment on “HESS Opinions “The art of hydrology”¹ by H. H. G. Savenije

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In my view a fundamentally important and refreshingly artful approach is presented in the Savenije's discussion paper (henceforth DP). To my knowledge it is quite rare in environmental sciences that someone stands questioning the very personality and character of a well established and mainstream discipline, like hydrology. But indeed, if one allows to wonder how a discipline which still lacks a great deal in terms of describing the occurrence and behavior of water above, over and through the Earth (in the DP words) can be well established, then one realizes the timely appropriateness of questioning and pondering on the established (automatic and thoughtless) ethos

¹Invited contribution by H. H. G. Savenije, the EGU Henry Darcy Medallist 2008 for outstanding contributions to Hydrology and Water Resources Management.

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and modus operandi of that discipline. This DP, aided by the very valuable comments which are unfolding in this discussion, suggests that precisely the current personality and standard take in hydrology might be the very source of its persisting difficulty to deal with the growing demands for a complete understanding of water whereabouts in a complex and fast changing Earth System.

In view of the excellent and exciting discussion prompted by the thought provoking DP I would like to add here a short reflection on what I call theory vs data simulation spectrum. On one extreme of the spectrum there is pure theory, as nicely defined by Makarieva & Gorshkov (henceforth MG) in their comment (S2250). They explain that pure theory can exist without or precede the availability of data; one can think of many examples, like the theory of black holes that describe the likely constitution and functioning of that class of directly unobservable cosmic objects. Good physical theories in a cosmos governed by physical laws allow for true and real data-independent predictions of phenomena, like the birth, life and fate of a black hole that develops in any given corner of the cosmos neighborhood. In the other extreme of the spectrum there is pure data like, for example, mountains of data harvested continuously by Google from usage of its search engine in the internet. Elaborate data-mining and statistical correlations made upon tons of pure data allows Google to identify and describe behaviors, interests and activities, deriving without any socio-psychological theory (or model) many usage and preference trends. Still, based on pure data, Google does not presume to predict anything but only reveals real time trends.

In my view environmental modeling fall somewhere in the middle of this spectrum, ending up with the worst of both worlds. Poor theory (when there is truly any, worth of the name, as pointed out by MG) and poor environmental data (if compared to Google and as mentioned in the DP about the difference between hydraulics and hydrology) combine into a modeling stew which generally bears a complicated mix of logical components, where simulation consistency relies heavily on arbitrary adjustments (discretionary addition of manipulative mathematical terms or playing with parameters),

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a somewhat repetitive and tiresome trial-and-error exercise aiming to develop and perfect the capacity to mimic existing data. This state of affairs is identified in the DP to belong to the reductionist hydraulic minded modeler's approach, with the dominant thought that if a model can mimic reality, then it IS reality. Alarming as it sounds in the DP for the hydrology case, this notion, that models are indeed the recreation of reality in powerful computers, is completely widespread in the entire environmental scientific arena and in the public as well. Therefore, the questioning raised by the DP respecting hydrology and shortcomings in its personality, is utterly valid for all of the environmental sciences.

Given the recognized difficulty to accurately understand and formally represent the hydrological phenomena in all its difficulty and seemingly untamable complexity, one has to agree with Savenije that elements of creative and inventive skills and arts (as opposed to rusty engineering with mindless repetition of the same technical recipes on every more powerful computers) are valid and required means to break the mold and make hydrology to really leap forward. Using quite a lot of intuition from field work in an instrumented catchment in the Amazon, our environmental physics group has been trying a combination of fundamental physical theory (hydrostatics) with physically based terrain mapping. Usually physically based distributed hydrological models suffer from the scant availability of spatial soil physical characteristics, as sternly pointed out in the DP (why hydrology should not be confused with hydraulics). As argued in the DP, the water makes its own way, therefore creating a maze of heterogeneities along the way, very difficult indeed to capture in simulations. Our inspiration in hydrostatics to the rescue of terrain mapping came from the realization that first water follows gravitational gradients (a rather obvious and non trivial- almost universal physical ingredient of water movement over and through the Earth) and second that water mostly chooses the flow path of minimum resistance to move from any point on and in the terrain to the nearest point where it becomes a superficial drainage (stream or lake). We then crafted an algorithm (Renno et al, 2008) that normalizes terrain according with relative vertical distances between DEM grid points and respective discharge points in the drainage (along

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respective flow paths), which we called height above the nearest drainage (HAND). This terrain normalization allows mapping zones of equivalent ground water relative heights, what we are also calling grid-point local draining potential. In extended field validation (Nobre et al, in preparation) it turned out these terrains maps generated using only SRTM radar topo data, were quite robust descriptors of spatial distribution of soil ground water saturation levels, which have been identified to be powerful predictors of soil physical and chemical characteristics (soil genesis in the tropics is directly and strongly correlated with water saturation regimes). These maps are allowing us to reveal vast areas of intricate hidden terrains (below dense forest canopies) in countless first and second order catchments. Calibrating top-down rainfall-runoff models for thousands of ungauged catchments does not seem at all feasible. But feeding a good physically based model (or a future hydrological theory, *sensu* MG) with an accurate (down to 90 m pixel) and physically sound spatial description of soils and landcover, can allow for generalizations that will be necessary if hydrology has any aspiration to become useful to global scale Earth system simulations. Our approach seems to run in a similar direction as the catchment classification Savenije proposes, except that we are seeing that good physically based models, if provided with a physically accurate and meaningful soil spatial input layer, can be flexible enough to account for a wide range of contrasting catchment geomorphologies and land covers. Sure our approach has only been validated for Amazonian catchments, but the fundamental physical principle upon which our terrain descriptor rests is an Earth generalized property: gravity.

I effusively commend Savenije for this extraordinary awakening paper, hoping similar initiatives will spread out to other environmental sciences, contaminating specially climate and ecological modeling communities.

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