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Hydrology and Earth System Sciences Discussions

Interactive comment on "Land classification based on hydrological landscape units" *by* S. Gharari et al.

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Brief History on the development of the HAND model

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Interactive Discussion

Discussion Paper

A contextualizing narrative

by Antonio Donato Nobre

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From 1999 through 2002 an international team of researchers from the LBA Project set up the first fully instrumented catchment in the Amazon basin, the Igarapé Asu watershed (described in Waterloo et al 2006, Cuartas et al 2007 and Tomasella et al 2008). A few years after installation, the group faced the challenge of representing soil properties and inferring soil water dynamics beyond the point source data of moisture monitoring instruments. Sparse instrument data needed to be interpolated meaningfully over a fairly large area, of difficult access. The use of bi-dimensional surface imaging techniques to estimate likely distribution of soil properties was limited by the impenetrability of dense forest canopy. However, around that time, a number of radar remote sensing missions took place, generating high-resolution surface DEMs (JERS-1, SRTM). We started then to seek for an innovative solution to map soils that could conjugate topography data with hydrologically based inference.

In describing the Amazonian landscape many researchers routinely use qualitative classifications of terrain types, according with the perceived water saturation regimen and position in the local relief (e.g., Sioli 1984; Chauvel et al, 1987). For the Amazonian Hiléia (wide expanse of the basin lying below 600 m altitude A.S.L.) geomorphologic / physiognomic (or physiographic) terms like lowland-or *baixio, slope* and *plateau*–or *terra-firme*, are quite common. Although these qualitative denominations are an almost colloquial way to refer to classes of terrain in the landscape, such terrain classification

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can be taken for its practical value, as an apt semantic description of landscape compartments, based on perceived local properties. Yet they carry little, if any, quantitative capacity. The predictive capacity of that classification scheme was thwarted by the difficulty to make any meaningful quantitative and reproducible association with topography (defined in relation to sea level).

Let's consider a South American example: a swamp could happen anywhere, from near the mouth of the Amazon river at sea level, all the way up to the shores of Lake Titicaca, 4000 m high in the Andes. It is clear then that height above sea level mingles and confuses local hillslope gradients with landscape-wide, continental-scale gradients. We needed to isolate local environments and bring them all to a comparable topographical framework. That was my insight, which propelled our group to seek the development of a new normalized terrain model. The idea appeared very simple, yet to my knowledge, nobody had seen it before. A few years later, within the GEOMA modeling project, we assembled an effort to build a computational tool that could normalize DEMs as I had envisioned (reported later in Rennó et al., 2008), so that local gradients could be made physically comparable over larger areas. And for that task the classification of the landscape into hydrologically relevant terrain classes (described later in Nobre et al., 2011) preceded the HAND algorithm, and actually guided its development.

The colleague that joined the group later, to bring the geoprocessing expertise (C.D. Rennó), could not believe that this landscape normalization had not yet been done, so we spent yet more efforts searching the (vast) literature on topography/hydrology, only to find nothing like the HAND. Confident on the originality of the idea, we conducted the first tests for the Igarapé Asu catchment, circa 2005, which revealed a promising approach. With the DEM tool in hand, we went back to the field-verified terrain classes and conducted a preliminary analysis of the Igarapé Asu ground water data, to test the

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quantitative capacities of the terrain classification. Basing the class allocation on our depth to ground water data, we then nominated the contrasting field classes as waterlogged (saturated to the surface), ecotone (shallow water table), slope and plateau (respectively with thick and thicker vadose zones). This initial applied testing of the HAND algorithm, class estimation and calibration was reported in Rennó et al (2008). The HAND landscape classification was initially meant to resolve an interpolation for a small gauged catchment (13 km2). As we applied the HAND classification to surrounding ungauged catchments near and far from Igarapé Asu we became convinced we had stumbled upon a robust physical property of the landscape: the elusive topographical coherence of soil-water, correlated to a new dimension of terrain, the HAND normalized topology. Nobre et al (2011) introduced formally the HAND terrain model, which captures with physical substance that soil-water new topographical coherence, demonstrating it with extensive validation. The HAND-based land classification was applied and verified for a large catchment (Cuieiras river, 500 km2) and for the lower part of the Rio Negro catchment (18,000 km2), with very robust results (Nobre et al 2011). Since the work done for these papers, we've applied and verified the HAND classification for even larger heterogeneous areas in Brazil (totaling 309 thousand km2). The HAND classification has also been independently validated for two contrasting types of geomorphologies and landcover (see ref. in Nobre et al, 2011), with equally robust results.

Rennó et al (2008) was aimed to the remote sensing community, as it presents the HAND computational tool (or algorithm), and a preliminary landscape classification (for the Asu catchment) vis a vis the SRTM DEM data. Nobre et al (2011) was aimed to the hydrological community, presenting and formally introducing the HAND model, its physical fundaments and a HAND-based landscape classification, with definitions of terrain classes, their calibration and validation. The data for landscape classification presented in both Rennó et al (2008) and Nobre et al (2011) is one and the same, so a much more informative and useful referral to the data is Nobre et al (2011). And Rennó et al (2008) is a better citation for the algorithm itself, with its mathematical formalization.

In conclusion, with the two papers we demonstrated that the old semantic classification based on intuitive perceptions of the groundwater regimen and relative position in the relief could - through the HAND model - finally acquire quantitative and predictive capacity. The HAND relief normalization, and the terrain classification based on it, created an entirely new and revolutionary hydrological perspective on the landscape.

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Credits for the HAND development

Authors

HAND Model

A.D. Nobre: conception, theoretical development, validation and group coordination.

L.A. Cuartas: hydrological development and validation.

M.Hodnet: hydrological review and validation.

Other authors in Nobre et al (2011): valuable inputs and insights

HAND computational tool

C.D. Rennó: DEM analysis and algorithm construction.

A.D. Nobre: coordination, theory and algorithm architecture supervision, calibration and validation.

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L.A. Cuartas: hydrology and algorithm architecture supervision, calibration and validation.

Other authors in Rennó et al (2008): valuable inputs and insights

Institutions

National Institute for Amazonian Research (INPA) National Institute for Space Research (INPE)

Persons

Gerald Jean Francis Banon [HAND algorithm mathematical support]

Carlos Afonso Nobre [INPE Earth System Science Center support]

Paulo Nobre [INPE Earth System Model project support]

Projects

Large Scale Biosphere Atmosphere Experiment in Amazonia (LBA) (http://lba.inpa.gov.br/lba/)

GEOMA [Environmental Modeling Network] (http://www.geoma.lncc.br/)

Ecocarbon [Carbon Ecology in the Rainforest]

CarboSink / CarboAmazonas [Ecophysiological Carbon Accounting]

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