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Interactive comment on "Explicitation of an important scale dependence in TOPMODEL using a dimensionless topographic index" *by* A. Ducharne

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Answers to Prof. Prof. J. Seibert

First of all, the author wishes to thank Prof. Seibert for his insightful comments (below in italic), which will be useful to improve the manuscript.

This manuscript raises an important issue namely the unit of the widely used topographic wetness index ln(a/tanb) which can be somewhat confusing. A paper clarifying the unit of TWI could be of value. However, I have to say that I am not convinced that this manuscript reduces the confusion.

The TWI has (in most applications) the unit [ln(m)]. This is a somewhat 'strange' unit and can be forgotten to be stated explicitly, but I do not see any fundamental problems of having a log-unit. Using the number of pixels, n, instead of the area makes the index look dimensionless but of course the values of the 'dimensionless topographic index' (Eq 17) totally depend on the DEM resolution, because n depends on how large one pixel is.

You are perfectly right that the number of pixels n_i depends on DEM resolution and increases when the pixel length C decreases. Thus, it is true that the new TI is not scale independent, but the paper does not pretend this. What the paper argues is that:

1. the new TI is dimensionless, and having no unit, it is ;
2. the dependence of this new TI on DEM resolution is weaker than the one of the classical TI. As detailed in section 3.1 (using the formalism of single-flow direction methods for simplicity, but a generalization to multiple flow direction methods is given in section 3.2), the classical and dimensionless TIs x_i and y_i relate to each other and to n_i and the local slope S_i by the following equation : $x_i = \ln(n_i\, C/S_i) = \ln(n_i/S_i) + \ln C = y_i + \ln C$.

   In these equations, n_i and S_i depend on C, what similarly influences x_i and y_i. But the classical index x_i is subjected to an additional influence from C, as this variable explicitly appears in the formulation of x_i, whereas this explicit dependence, called the "numerical effect" in the paper, is eliminated in y_i.

To remove the ambiguity revealed by the comment, I propose to better say, in section 3 and in the Conclusions, that n_i and S_i thus the dimensionless TI y_i are dependent on DEM resolution.

In this way, the new index actually seems to be more dependent on DEM resolution than the original formulation. So, while the new index formulation might highlight the *unit issue, it does not really solve the problem and I am afraid the new formulation in the end might be more confusing than helping.*

As explained above, from a mathematical point of view, the dimensionless TI depends less on DEM resolution that does the classical TI. This conclusion would be uninteresting if this reduction in the scale dependence of the TI was not significant in real world case studies. But the analysis of 6 of such cases in section 4.2 completely confirms the mathematics, and furthermore indicates that the "numerical effect" largely dominates the sensitivity of the mean TI to DEM resolution. This result has important consequences, analysed in section 4.2 and summarized in the Conclusions:

- the mean dimensionless TI can be used as an efficient indicator to compare the topographic features of different catchments, regardless of DEM resolution, what is not the case using the classical TI (Fig. 2) ;
- the interplay between DEM resolution and transmissivity in TOPMODEL, that leads to recalibrate T_0 to keep a good fit between predicted and observed discharge when DEM resolution changes, does not vanish when one introduces the dimensionless TI. But using this new TI makes the outflow from the saturated zone depend on T_0/C, which is defined as the transmissivity at saturation per unit contour length, and which is shown to depend much less on DEM resolution than does T_0 (Table 5). The paper explains how this directly relates to the fact that the dimensionless TI varies less with DEM resolution than the classical TI. This result reduces the need to recalibrate TOPMODEL when DEM resolution changes and altogether offers an interesting rescaling framework for this model.

The fact that TWI is dependent on the resolution of the DEM is well-known (see the studies referred to by the author, or for a recent study Sorensen and Seibert (2007)). This is mainly due to the more smoothed DEM for coarser resolutions, which influences the values of both slopes and accumulated area. I don't see that the new index resolves this issue at all.

You are perfectly right that DEMs are smoothed at coarser resolutions, what influences the values of both slopes and accumulated area. I also keep in mind that the terrain-discretization effect is another facet of DEM resolution effect on the classical TI, as discussed by Wolock and McCabe (2000) for instance, using the same kinds of DEM alterations as in Sorensen and Seibert (2007).

What may seem vain in the present paper is that I did not work on the influence of DEM resolution on the TI distribution from a geomorphologist's perspective. What started this work was simply the fact that the classical TI is not dimensionless, which is annoying when trying to ascertain the homogeneity of TOPMODEL's equations, even if it is true that there is no "fundamental problems" in having a log-unit. These considerations led me to work from a purely formal perspective and introduce the dimensionless index, which allowed me to identify what I called the "numerical" effect of DEM resolution on the classical TI. As I also answered to Prof. Kirkby, this analysis is straightforward, it does not change the heart of TOPMODEL since it proceeds from a simple rearrangement of the equations, and one may even say it is completely trivial.

Yet, trivial here does not mean unimportant, as revealed by the results discussed in section 5, showing that this numerical effect largely dominates the sensitivity of the mean TI to DEM resolution in real world case studies. This result sheds a new light upon the widely shared assumption according to which the dependence of the TI on DEM resolution mostly results from changes in terrain information.

Minor comment: In the new index formulation the area per unit contour length is approximated by a=A/C, i.e. it is assumed that the contour length always is the length of a grid cell. Obviously this is a crude simplification and there are more advanced methods to estimate the contour line length (see, for instance, the work by Paul Quinn).

You've already identified this problem in an earlier version of the manuscript, and I would like to thank you for this very pertinent point. In the version that has been published in HESSD, the dimensionless TI is introduced in section 3.1 using the above assumptions of the single-flow direction methods, which have the advantage of simplicity. The important point is that the dimensionless TI y_i relates to the classical TI xi via Eq. 18 : $x_i = y_i + \ln C$.

But this result is then generalized in section 3.2 to the more advanced framework relying on the multiple-flow direction methods introduced by Quinn et al. (1991).

Cited references

Quinn, P., Beven, K., Chevallier, P., and Planchon, O.: The prediction of hillslope flow paths for distributed hydrological modelling using digital terrain models, Hydrological Processes, 5, 59–79, 1991.

Sorensen, R. and Seibert, J., 2007. Effects of DEM resolution on the calculation of topographical indices: TWI and its components, Journal of Hydrology, 347: 79-89.

Wolock, D. and McCabe, G.: Differences in topographic characteristics computed from 100- and 1000-meter resolution digital elevation model data, Hydrol. Process., 14, 987–1002, 2000.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 1621, 2009.