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Discussions

Interactive comment on "Hydrological model assessment for flood early warning in a tropical high mountain basin" *by* M. C. Rogelis et al.

M. C. Rogelis et al.

c.rogelisprada@unesco-ihe.org

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Response to comments Anonymous Referee 1

We would like to thank the anonymous referee for the review of our manuscript and for providing us with helpful and constructive comments. For ease of reading we have copied the reviewer comments, as well as our response.

GENERAL COMMENTS

(1)This manuscript is a rather comprehensive work that aims to find the most appropriate hydrological model, among a lumped model, a semidistributed model, and a distributed model, to perform discharge/streamflow simulation in a Colombian basin. The results of rainfall-runoff model comparisons may provide

reliable basis for model selection for flood early warning in the selected Colombian basin. However, comparison of different types of rainfall-runoff model has been a constant and classical topic in hydrological research fields, as many similar works have been carried out, for instance recently the research done by Orth et al (2015), where additional soil moisture validation in hydrological model is accounted for and more catchments with different climate regimes are investigated. In general, there is no noteworthy innovation in theory or method except for reinventing the wheel. (2)The time and energy that the authors put into the whole preparation of this manuscript are always to be appreciated.

RESPONSE:

We agree that the comparison of different types of rainfall-runoff models is a constant and classic topic in hydrological research. However, we do feel that it continues to be a relevant issue, particularly as there is likely not a universal answer, with differing results found depending on hydro-climatology as well as on data availability. The reference to Orth et al (2015), is indeed very relevant and we have considered the conclusions they have reached in our discussion. However, we believe that our approach differs from that taken by Orth et al., given the differing hydro-climatology, as well as the availability of data. Since there is comparatively little data available for independent validation, in contrast to the case of Orth et al (2015), our focus is on validating the proposed model structures of differing complexity against a conceptual representation of the hydrological behaviour of the catchment, and identifying how well the proposed models represent the hydrological signatures that reflect that conceptual representation. Models that better reflect the conceptual representation thereby provide an indication of the reliability. As we indicate in our discussion, other authors have proposed flexible model structures (e.g. Fenicia et al., 2013) that try to select model structures based on appropriate representation of such signatures of hydrological processes. However, our approach again differs as we consider the representation of these signatures as way to validate the adequacy of the model structures of off the shelf, commonly used, models, rather than developing new model structures. We have amended the manuscript to provide a clearer description of this contribution.

The manuscript will be modified by including the following:

Reference to Orth et al (2015). The paragraph starting on line 45 in section 5.1.4 will be modified as follows:

Given the results of the flow duration curves and of the KGE, TOPMODEL appears to be the model that best represents the hydrological signatures amongst the three models tested in this analysis. This is supported by the assumptions of TOPMODEL that seem to be able to adequately represent the main characteristics of the response of the páramo soils (Buytaert and Beven, 2011), with the hydrologic response dominated by the topography with no infiltration excess overland flow; and a nonlinear transmissivity profile. In agreement with other studies carried out in the páramo area (Buytaert and Beven, 2011), the assumption of an exponential function of the storage deficit seems to provide a good representation of the processes in these watersheds. TOPMODEL can be considered as the least complex model of the three tested. However, despite this simplicity, which is important in order to avoid over-parametrization, it provides an adequate level of complexity to appropriately represent the dominant hydrological processes (Orth et al., 2015).

In order to clarify the contributions of the paper, the following paragraphs will be added:

One of the innovations of this paper is the approach to exploring model uncertainty, due to structural and input uncertainty, in areas where comprehensive validation

datasets are not available. Alternative information to that traditionally used in model evaluation, such that provided by hydrological signatures can provide a viable alternative to accept or reject potential model structures. In this paper we develop this approach in páramo watersheds, but the approach can equally be applied in watersheds with other hydrological signatures.

The aim of this paper is validating the proposed model structures of differing complexity against a conceptual representation of the hydrological behaviour of the catchment, and identifying how well the proposed models represent the hydrological signatures that reflect that conceptual model. Models that better reflect the conceptual representation thereby provide an indication of the reliability.

SPECIFIC COMMENTS

1. ***As mentioned, the KGE metric used in this manuscript for model calibration is newly proposed and has not been used widely yet. Thus, it is necessary to address the reason why KGE is chosen as the objective function and metric for model performance, instead of NSE (Nash-Sutcliffe efficiency), which is probably the most commonly used objective function in rainfall-runoff modeling. In addition, the equation of calculating the KGE value should be given.***

   RESPONSE:

We thank the reviewer for pointing out the need of clarification of the KGE metric. The paragraph starting on line 39 in section 3.1.3 will be modified as follows:

The initial parameters for the three models were obtained from existing soil, land cover and topographical data of the basin. These are shown in Figure 3b and Figure 3c. Calibration was performed by optimization of the Kling and Gupta efficiency (KGE) (Gupta, 2009) shown in Equation 1 where r is the Pearson product-moment correlation coefficient; α is the ratio between the standard deviation of the simulated values and the standard deviation of the observed ones; and β is the ratio between the mean of the simulated values and the mean of the observed ones. The Shuffled Complex Evolution (SCE) automatic search algorithm (Duan, 1992) was used for the optimization.

$$KGE = 1 - \sqrt{(r-1)^2 + (\alpha-1)^2 + (\beta-1)^2} \tag{1}$$

The KGE was chosen as objective function, since it is derived from the Nash-Sutcliffe efficiency (NSE), but resolves some of its limitations (Gupta, 2009). The three components of the NSE, namely correlation, bias and variability have the same weight in the KGE providing a solution that is simultaneously good for these in contrast to the NSE. This allows reducing the possibility of large volume balance errors and underestimation of variability of simulated flows and also leads to an underestimation of peak flows that is less severe than in the case of the NSE. For a full discussion of the advantages of using KGE over NSE we refer the reader to (Gupta, 2009).

2. ***For table 8, an alternative form such as a figure may be a better choice to present the ensemble discharges for the three models applied in this work, which provides a better visual sense of the uncertainty in the period of analysis.***

   RESPONSE:

   We thank the reviewer for this suggestion, we agree that a figure is more illustrative; therefore we will replace the table by a boxplot. The boxplot file is attached to this response as fig 1.

3. ***Given the purpose of flood early warning, it seems no measures have been taken to place greater emphasis on ensuring the peak flows are simulated accurately.***

   RESPONSE:

   The KGE optimizes bias, correlation and variability, therefore it places emphasis on the peak flows, and has the advantage that the underestimation of peak flows is less severe than in the case of the NSE (Gupta, 2009). We believe that with the modification included in response to comment 1 on the KGE there is more clarity about the objective function and its advantages.

4. ***In this work, the uncertainty of model parameters, another important basis for model selection, does not seem to be taken into consideration.***

RESPONSE:

The reviewer points out an important aspect. We fully agree that uncertainty in model parameters is, next to the uncertainty in model structure, an important factor in model selection. In this paper we have, however, focused only on exploring the uncertainties in model structure. This has been explored both in the selection of different models, as well as choices as to the resolution of the (distributed) models. One of the central aspects of the model comparison is how well the different models represent the characteristic signatures of the watersheds we studied, with the differences between the models stemming primarily from differences in structure and not in parameterisation. Additionally, in our experience, there are few (operational) forecasting systems that explicitly consider parameter uncertainty, focusing instead on the uncertainty of inputs (see also the review of ensemble forecasting systems by Cloke and Pappenberger, 2009). We do, however, concur that exploring the parameter uncertainty is worthy of further research, though we feel it is beyond the scope of this paper. To clarify the approach taken, the paragraph starting on line 49 in section 1 will be modified as follows:

This paper explores the suitability of three differing model concepts to be used for flood forecasting purposes. The aim of the research is to explore the influence of model structure on the ability to simulate the hydrological (flood) response, given the characteristics of the study area and the available data. A lumped model (HECHMS Soil Moisture Accounting), a semi-distributed model (TOPMODEL) and a distributed model (TETIS) were selected. In the case of the semi-distributed and distributed models, the influence of model resolution was explored, in order to identify the most suitable resolution to be used. Finally, the influence of precipitation input uncertainty on model performance is addressed in order to identify the relative importance in the modelling results. Model

parameter uncertainty is highly relevant to model performance, the focus in this paper is placed on the analysis of model structure and precipitation input uncertainty, providing insight into the influence of model structure on the ability to adequately represent the key hydrological processes, as well as the sensitivity to variability in the estimation of precipitation input; leaving parameter uncertainty for a future stage of the research.

5. ***Figure 3 can be improved. For instance, the labels should not cover the river or the boundary.***

RESPONSE:

We thank the reviewer for the suggestion. The figure was improved. The new figure is attached to this response as fig 2.

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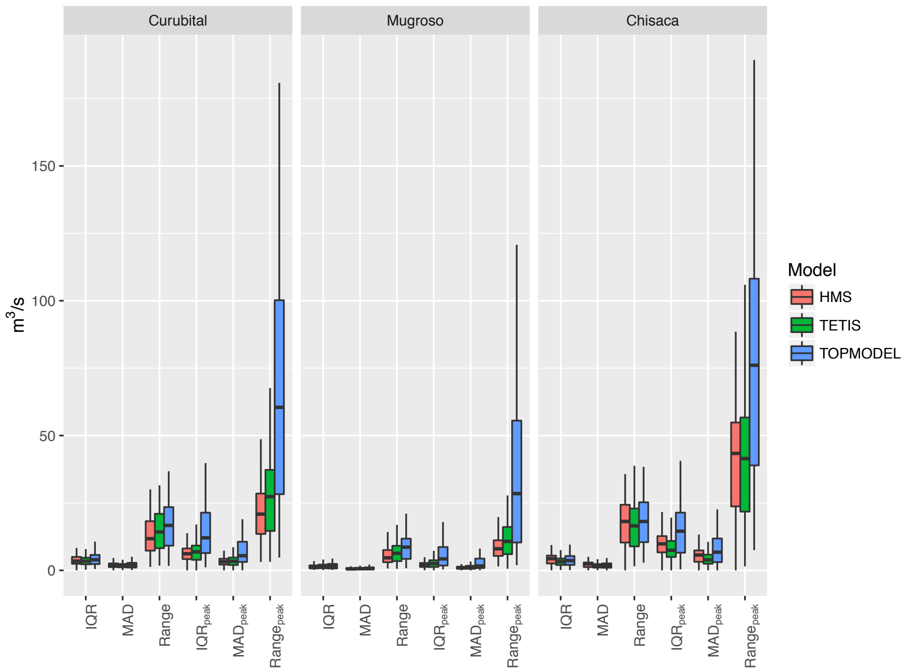

Fig. 1.

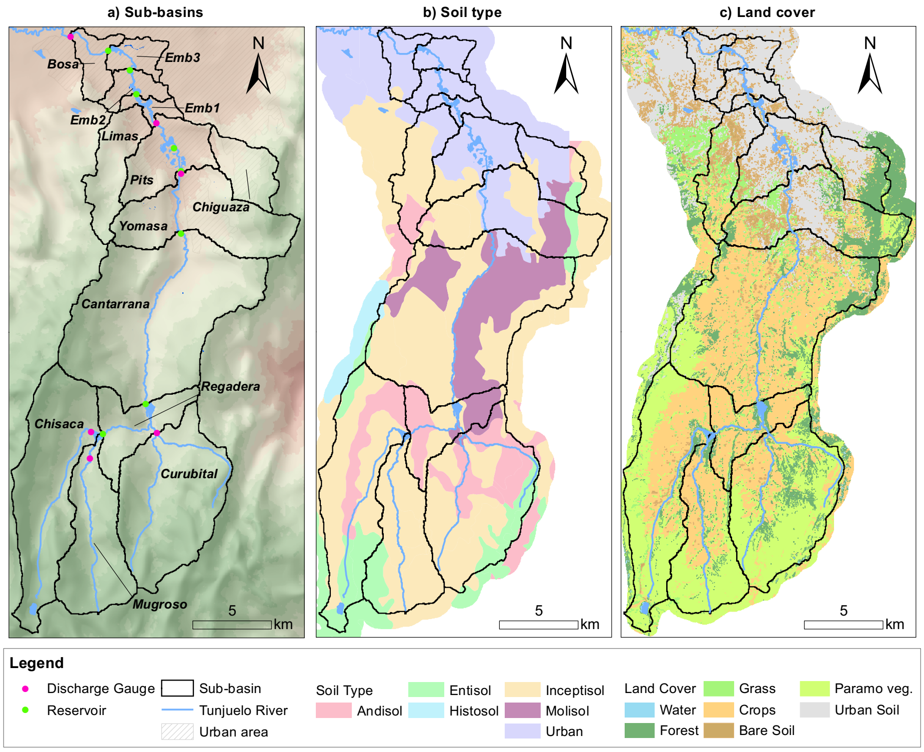
a) Sub-basins
b) Soil type
c) Land cover
N
Bosa
Emb3
Emb1
Emb2
Limas
Pits
Chiguaza
Yomasa
Cantarrana
Regadera
Chisaca
Curubital
Mugroso
5
km
Legend
Discharge Gauge
Reservoir
Sub-basin
Tunjuelo River
Urban area
Soil Type
Andisol
Entisol
Histosol
Inceptisol
Molisol
Urban
Land Cover
Water
Forest
Grass
Crops
Bare Soil
Paramo veg.
Urban Soil

Fig. 2.