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Interactive comment on "Hortonian overland flow closure relations in the Representative Elementary Watershed Framework evaluated with observations" *by* E. Vannametee et al.

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We would like to thank the reviewer for the constructive comments. Our previous publication referred to by the reviewer (Vannametee et al., 2012) proposes an alternative approach for deriving the closure relations for Hortonian infiltration and runoff fluxes representative for geomorphological response units (GRU). The approach proposed was an upscaling technique that derives hydrological fluxes representative at the GRU scale from local-scale infiltration parameters, boundary conditions, and geometry of the geomorphological response unit. The upscaling method proposed in the previous

publication is generic in the sense that it is assumed to be transferable and applicable to any response unit, as it performs scale transfer using upscaling functions. The method proposed was, however, purely based upon (and evaluated against) an extensive synthetic data set of rainfall-runoff responses generated with a physically-based model. Thus, a logical next step is to evaluate the proposed method using empirical data, which is done in the current paper by using the observed data set of rainstorm events and discharge at three small catchments. In addition, the upscaling technique proposed in the first paper is compared with a benchmark model, which is a simple lumped rainfall-infiltration-runoff model without considering the spatial processes and scaling effects of the GRU in runoff generation. However, this benchmark model is not much simpler than what is often used in the large-scale model when no information is available on the geomorphology within catchments. This exercise was not done in the previous paper. In our opinion, the empirical evaluation of the approach presented in this paper is an essential next step. We would like to stress that our aim is not to develop a 'final' catchment-scale runoff model, but rather evaluate the performance of our closure relation for the real-world case studies. In our opinion, the evaluation results provide important information for future modifications and improvements of the approach.

A number of reviewers criticize our manuscript for placing our work in the Representative Elementary Watershed framework. We agree that this is an important issue. In the previous paper, we defined a function (i.e. closure relation) calculating macro-scale fluxes, more particularly for the infiltration and Hortonian overland flow using macro-scale boundary conditions and state variables. The macro scale was chosen to be the representative support unit of a hillslope or geomorphological feature. We made the account that the closure relation had to include functional relations between the geometry (length, slope) of the support unit, local-scale parameter values, and macro-scale fluxes because macro-scale Hortonian overland flow fluxes are highly dependent on flow path length and spatial variation within units (e.g., Karssenberg, 2006; Van de Giesen et al., 2011). This relation was represented by a function with three conceptual parameters. The functional relations were defined using an extensive synthetic data set of rainstorm characteristics and representative units with different geometries and physical properties, aiming to have a closure relation that is generic and to avoid identification of closure relation's parameters in an 'ad-hoc' manner (i.e. calibration for specific catchments). The rationale behind the use of Geomorphological Response Units (GRU) as the control volume is that GRUs represent areas of hydrological similarity from which a set of uniform (i.e. lumped) parameters describing the averaged unit characteristics (i.e. geometry and physical properties) can be easily defined. Furthermore, our study area is relatively small (i.e. 15 km2). It is possible to derive the representative units at a scale smaller than sub-catchments by field observation.

In hindsight, our approach does not exactly fit in the original REW framework. This is mainly because, as noted by the reviewer, we do not consider the entire set of conservation equations for momentum and/or energy, but only focus on the mass balance component. More importantly, we use point-scale parameter values to derive the macro-scale mass balance fluxes. And, our representative areas (geomorphological units) are also defined in a somewhat different manner compared to the original REW framework. So we agree with the reviewers that our work might be better placed outside the REW framework. As our study is more related to work on upscaling, it might indeed to make a connection to the concept of Hydrological Response Units. We would like to note here, as a friendly remark, that, approaches in defining closure relations proposed in our previous study (i.e. using local-scale parameters, local-scale variation , or geometry of macro-scale units) have been placed in the framework of REW modelling by Lee et al. (2005, 2007) and Zehe et al. (2006).

We agree to the reviewer's proposition to rename the article to avoid the conflicts with the previous REW works and respect the original ideas of REW. In the revised manuscript, we propose to make the following changes: 1) As our approach essentially defines the representative units according to geomorphological features, we will replace the term 'REW' with 'Geomorphological Response Units' (GRU) throughout the

manuscript, as suggested by the reviewers; 2) we will rename the manuscript title to 'Hortonain runoff mass-balance closure relations using observable watershed characteristics: application to the geomorphologic response units'; 3) As a consequence, we will revise the introduction, by shortly summarizing the theoretical framework presented in the previous paper, indicating that our work is related to Hydrological Response Units and how it is different from the original REW framework. We will modify the content in the Discussion section as well to make our work fit into the new context.

About the remark on Nash Sutcliffe efficiency values, we agree that these values are not very impressive. In our opinion, however, they are still acceptable mainly because:

- Our study mainly aims at comparing the proposed closure relation with a benchmark model. The proposed closure relation clearly outperforms the benchmark model regarding the Nash Sutcliffe efficiency (both without and with calibration), as well as for total discharge. Nash Sutcliffe coefficients are acceptable for a comparison between the two models.

- We present results without calibration (a typical ungauged catchment simulation) or by calibration of only one parameter (KSat) and neglecting seasonality in vegetation. By calibrating a large number of parameters and including seasonality, lower values of the Nash Sutcliffe efficiency would be found, but as mentioned above, it was not our aim to find optimal Nash Sutcliffe efficiency values. We mainly aim at comparing our model with a benchmark.

- The median Nash Sutcliffe efficiency values without calibration are indeed low (Table 5 in the original manuscript). After calibration, however, a number of events have a Nash Sutcliffe efficiency value above 0.5, when using the model that incorporates our upscaling technique (Figure 5A, closure relation C).

- It is notably hard to perform event based hydrograph prediction for small catchments, because errors due to spatial variation in boundary conditions, model parameters or processes are hardly averaged out, as is the case for large catchments. Other studies on events for small catchments find comparable low values of the Nash Sutcliffe efficiency (e.g., Meng et al., 2008).

In the revised manuscript, we will somewhat weaken our statement about the performance of our closure relation. In our opinion, E > 0.5 is probably too high in our case. We would rather propose E> 0.4 as a threshold to consider as good performance. A term ‘satisfactory’ will be used to describe the prediction with E between 0-0.4.

References:

Karssenberg, D.: Upscaling of saturated conductivity for Hortonian runoff modelling, Adv. Water Resour., 29, 735–759, 2006.

Lee, H., Sivapalan, M., and Zehe, E.: Representative Elementary Watershed (REW) approch, a new blueprint for distributed hydrological modelling at the catchment scale, in Predictions in Ungauged Basins: International Perspectives on the State of the Art and Pathways Forward, edited by: Franks, S. W., Sivapalan, M., Takeuchi, K., and Tachikawa, Y., 159–188, IAHS Publication, 301, Mepple, 2005.

Lee, H., Zehe, E., and Sivapalan, M.: Predictions of rainfall-runoff response and soil moisture dynamics in a microscale catchment using the CREW model, Hydrol. Earth Syst. Sci., 11, 819–849, 2007.

Meng, H., Green, T.R., Salas, J.D., and Ahuja L.R. M.: Development and testing of a terrain-based hydrologic model for spatial Hortonian Infiltration and Runoff/On, Environ. Modell. Softw., 23, 794–812, 2008. Van de Giesen, N., Stomph, T.J., Ajayi, A.E., and Bagayoko F.: Scale effects in Hortonian surface runoff on agricultural slopes in West Africa: Field data and models, Agr. Ecosyst. Environ., 142, 2011.

Vannametee, E., Karssenberg, D., and Bierkens, M. F. P.: Towards closure relations in the Representative Elementary Watershed (REW) framework containing observable parameters: relations for Hortonian overland flow, Adv. Water Resour., 43, 52–66.

Zehe, E., Lee, H., and Sivapalan, M.: Dynamical process upscaling for deriving catchment scale state variables and constitutive relations for meso-scale process models, Hydrol. Earth Syst. Sci., 10, 981–996, 2006.

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