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Discussions

Interactive comment on "HydroSCAPE: a multi-scale framework for streamflow routing in large-scale hydrological models" *by* S. Piccolroaz et al.

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Introduction

This document corresponds to a peer review process of the article titled HydroSCAPE: a multi-scale framework for streamflow routing in large-scale hydrological models. The objective is to revise and make comments about findings of the model and its obtained results. This peer review is summarized in the following comments.

We thank thee colleague Fabian Martinez for his interesting comments. Below we reply to the comments, which are copied and emphasized in BLUE.

C5187

Comment 1 The paper states that most of available models inherit the grid approach from the Large Scale Surface Models (LSMs) which works fine for vertical fluxes but provides grid dependency to the surface routing. In most cases routing is performed by solving either the kinematic wave or the de Saint-Venant equation by using the same discretization adopted for resolving the vertical fluxes, thereby leading to scale-dependent inaccuracies in the representation of horizontal fluxes.

- How horizontal and vertical fluxes are defined?

- Are both flow components (vertical and horizontal) considered in the model?

- Are subsurface flows taken into account?

Following a standard definition horizontal fluxes can be defined as the movements of water within the landscape through streams, rivers, and aquifers, while vertical fluxes can be defined as the exchanges of water between atmosphere, land surface, soil, and groundwater (e.g., precipitation, evapotranspiration, infiltration, percolation etc.).

In principle, both horizontal and vertical flows can be considered, depending on the hillslope sub-module that the user decides to adopt. Indeed, the routing scheme that we present here offers the possibility to be easily coupled with any rainfall-runoff model, thereby accounting for different hydrological processes (e.g., surface and sub-surface flows, groundwater etc.). This will be emphasized and clarified in the revised version of the manuscript.

Comment 2

The model emphasizes on the importance of defining proper hillslope-channel within the macro cell that contributes to a certain node. However, it is not explained what is a hillslope-channel area and how they are defined. For example, in Figure 1 several hill-slope areas are colored; but it is not understood under which geomorphological considerations they were defined (slope, elevation, etc.).

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We assume in the paper a classical hillslope-channel topological separation of the entire watershed; however, as we did for other model features, we emphasize that the choice of the hillslope-channel separation methodology may be suitably chosen when the model is applied to a real study case. For example it can be achieved through the application of some of the standard schemes which are listed in the references provided (lines 14-20 at pag. 9061).

Please note that the sketch in Figure 1 does not refer to a real-world case, but is a synthetic scheme created and used as an example, made with the purpose of accounting for the different possible operational cases.

In the application example provided in section 3, the geomorphological hillslope-channel separation criteria adopted are adequately described and supported by appropriate references (see lines 9-16 at pag. 9068).

Comment 3 Based on the kinematic conceptual scheme of the model, water flow produced by the hillslope enters the network system through the hillslope-channel transition site and is subsequently routed through it. The streamflow contribution of the hillslope ', belonging to the macrocell i, to node k is defined in a way that considers a constant stream velocity Vc and it states that this assumption is crucial for the linearity of the process.

- Since stream velocity depends on stream geometry, does this imply that the model considers a constant geometry of the stream network over time?

- How does the model account for seasonal variations of stream velocities associated to variations on channel Manning's n values?

- How does a non constant velocity makes the system non linear?

- We don't explore the variability of velocity associated with temporal variation of local hydraulic characteristics and their effects on the shape of the response func-

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tion. We rather assume a constant velocity, which is a common assumption for the representation of flood events (see the following point for a brief discussion and references).

- We don't account for seasonal or spatial variations of velocity. Using a constant channel velocity for channel routing is a common assumption in rainfall-runoff models adopted in several geomorphological studies. Some of them are already cited in the original manuscript (see lines 16-17 at page 9063: (Gupta et al., 1986; Mesa and Mifflin, 1986; Gupta and Mesa, 1988; Rodríguez-Iturbe and Rinaldo, 1997). Furthermore, this assumption is supported by experimental measurements, especially for high flows (see Pilgrim, D.H., 1976 and 1977 DOI: 10.1029/WR012i003p00487 and 10.1029/WR013i003p00587; the latter references will be introduced in the text).

- Regarding the last comment we note that a temporally varying channel velocity would imply that the response function depends on the shape and intensity of the meteorological forcing, thus making the model non-linear; this assumption is sometimes used in rainfall-runoff models (compare Robinson and Sivapalan, 1996, DOI: 10.1002/(SICI)1099-1085(199606)10:6<845::AID-HYP375>3.0.CO;2-7), but it is not coherent with the simple, linear and parallelizable routing scheme we are presenting.

Comment 4 The article states that if the DEM resolution is high and the total domain A where the model is applied is large, the preprocessing step can be time consuming; the effort is however compensated in the application of the model, particularly if the modeling activity is performed in a multiple run framework.

- What does consist the preprocessing step?

- Why the preprocessing depend on the size of the DEM?

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Please, see lines 9-12 at page 9060 of the original manuscript: pre-processing is needed in order to compute the geomorphological width functions, thereby identifying the river network and the hillslopes. The larger the area A and/or the finer the resolution of the DEM, the higher the number of pixel considered in the pre-processing step, thus the larger the time required to perform these operations. Besides calculating the geomorphological width functions no additional pre-processing operations are required, with the exception of creating the input files (observed streamflow and precipitation) according to the format used in the code.

Comment 5 The DEM used for the case study in the Upper Tiber Basin corresponds to a high resolution 20 m grid size DEM. If it has been established that the model is non dependent on the grid size, why such a high resolution DEM is used? On the other hand, how was associated a CN II number to each DEM cell? A spatially distributed 20m resolution soil classification was available for the site?

In that context, "grid size" refers to the size of macrocells used to subdivide the computational domain, not to the DEM discretization. Using a high resolution DEM allows for a better description of the width function, thus of the geomorphologic response of the watershed. Please, refer to Figure 5, where we show the comparison between the width function derived by the 20 m resolution DEM and the analogous width functions after DEM aggregation at 5, 10 and 50 km. A significant deterioration of the width function is clearly detectable when the DEM is aggregated over cells of increasing size.

Notice that the values of CN II were associated to the macrocells, not to the single DEM cells. The map of CN II was derived from the digital maps of land use and lithological characterization supplied by the European Environmental Agency (Corine Land Cover project) and by Italian Agency for Environmental Protection and Research (ISPRA), respectively (see page 9067 of the original version of the manuscript); both of them are vector maps. Those features were automatically processed though standard

procedures in order to obtain the homogeneous CN II zones; the final value of the CN for each macrocell was obtained by performing a spatial averaging over the macrocell area.

Comment 6 An application of HydroSCAPE flood prediction is presented for the Upper Tiber basin. In order to focus in routing, a simple runoff model was coupled. Hence, subsurface contribution to streamflow is not explicitly considered in the model. In some basins, subsurface flows can be determinant and add an important contribution to the flood. What parameters of the model can be affected if a subsurface flow model is coupled?

Including sub-surface flow means adopting a different hillslope sub-model, thus a different set of parameters. This can be easily done, but it is beyond the scope of the present work.

Comment 7 In the same application example, the superficial runoff at a hillslope is calculated using a classic SCS-CN approach. The procedure assumes that the cumulative rainfall remains constant within a macrocell. This is a very strong assumption depending on the size of the macrocell.

- How valid is this assumption considering the strong spatial variation of rainfall, specially in basins with high orographic influences like the one studied in the application example?

- Based on the previous point, wouldn't be more appropriate to create a macrocell that matches areas with more or less the same accumulated rainfall? It is believed that this would help to not create excessive differences between observed spatial variation of the rainfall and the assumption of a constant value

The smaller the macrocell, the better the description of rainfall spatial variability and patterns, but to a certain point. For example, from basic principles of geostatistics

it is known that using macrocells smaller than IY/4 (i.e., one fourth of the integral scale) does not provide any improvement in the reproduction of precipitation. This is already acknowledged in the text, please refer to lines 24-29 at page 9072 of the original manuscript. "Notice that all cases with the average NSE>0.5 are with a macrocell dimension equal or smaller than the integral scale of the precipitation, which is about 36km (E. Volpi, Modello di struttura spaziale del campo di precipitazione, unpublished technical report). It is therefore clear that the inaccuracies encountered with large macrocells are due to the inaccurate spatial description of the precipitation." In other words, it is true that the macrocell's size should be suitable to reproduce accurately the precipitation field, but this is not by any means a limitation of our scheme, rather a modeling choice.

Concerning the second point: the routing scheme presented here has been designed to share the same computational grid of the meteorological model (we propose to better stress this point in the revised manuscript). The geometry of macrocells is therefore controlled by the meteoclimatic model. Notice that all the meteorological variables, and in particular precipitation, that could be provided by Regional Climate Models or weather forecasting models are assumed constant within their computational cells.

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