Hydrol. Earth Syst. Sci. Discuss., 2, S617–S623, 2005
www.copernicus.org/EGU/hess/hessd/2/S617/
European Geosciences Union

Hydrology and
Earth System
Sciences
Discussions

Interactive comment on "Distributed hydrological modelling of total dissolved phosphorus transport in an agricultural landscape, part I: distributed runoff generation" *by* P. Gérard-Marchant et al.

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Received and published: 1 September 2005

1. General Comments

The paper presents an application of a distributed hydrological model to a small rural catchment (164 ha), validated with both runoff and soil moisture data. As stated in the introduction, the main objective of this paper is to validate the distributed model both against runoff data collected at the catchment outlet and "distributed" data, such as soil moisture data collected at given transects. The model is applied in order to "identify the location and the evolution of variable source areas for overland flow generation and to estimate water fluxes to streams and groundwater".

Large part of the paper illustrates the hydrological model applied.

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Discussion Paper

The model herein applied is the SDMR model, with some variations from the versions published in previous papers (among all, see Frankenberger et al., 1999). These variations are outlined throughout the paper. As I could understand, the main two changes are that the soil column is simplified into a single soil layer (instead of a superimposition of structural layers) and the deep groundwater reservoir storage is omitted.

The SDMR model is terrain-based, since lateral flow is driven by topographic gradients only (Grayson et al. 1992). This means that the spatial pattern of lateral flow direction and distribution is stationary and do not depend on the actual hydraulic gradients. This pattern is defined by the Dinf algorithm (Tarboton, 1998). This modelling approach has been employed in many other distributed models. It is easy for me to recall the papers close to my experience, based on Thales, a distributed model originally developed on a contour network (Grayson et al. 1992; Western et al., 1999; Chirico et al., 2003b) and then generalised to a grid network (Chirico et al., 2003a).

The distributed model herein presented is routed at the daily time-step. For many aspects the model structure herein presented is similar to that employed in (Western et al., 1999; Western and Grayson, 2000). Western and Grayson (2000) provides an example of distributed model applied at daily time-step on a rural catchment (the Tarrawarra catchment), validated against both runoff and soil moisture patterns.

In this application, most of the SDMR model parameters have been defined from field observations, published soil database and literature data.

Just one parameter has been actually calibrated. This is the fraction of the deep percolation delivered directly to the stream and conceptualised as baseflow. This parameter has been adjusted in order to optimise the simulated flow during one season (summer 1997).

The model has been validated against 8 years of streamflow data, starting after one year run in order to remove the effect of the initial conditions. The validation cannot be considered successful, since during the entire validation period the model performance are significantly worse than in the calibration period (summer 1997). I believe that this is due to a wrong model conceptualisation that I will discuss in the next section.

The model has been also validated against soil moisture data and a map of "frequently saturated areas".

The collection of soil moisture data and other spatially distributed data for validating a distributed model is a valuable effort. Indeed coupling direct and indirect (surrogate) patterns appears to be a good strategy for validating complex distributed models (Grayson and Blöschl, 2000).

This paper presents new soil moisture data (first 6 cm) collected in two different days (8 June and 5 December 2001), with 10 m spacing along 3 transects (190m, 340 m and 390 m long). These soil moisture data, along with other data already published (among all see Frankenberger et al., 1999) are employed to validate the simulated soil water content. There is a good agreement between observed and simulated soil water content, although soil water content is generally overestimated during (simulated) wet periods.

The authors derived the map of "frequently saturated areas" from a detailed survey of hydrological features, field observations and farmer interviews.

This map of "frequently saturated areas" (FSAs) has been compared with two maps of average simulated seasonal overland flow, respectively in summer and winter. It is difficult to agree with the authors that "the areas mapped as frequently saturated from field observations are properly reproduced by the model". From Figure 8, the only conclusion that I can draw is that most of FSAs fall within the region with seasonal overland flow above 0.05 mm in summer and 0.10 mm in winter. This region corresponds to the "fragipan-restricted lower terrains of the watershed". Within this region I cannot see any correlation between FSAs and overland flow patterns.

2. Specific comments

2.1 The modelled baseflow - validation against streamflow data

It is striking to see that a fraction of deep percolation is routed directly to the outlet without any delay. In this way, especially during dry periods, the water reaches the outlet more rapidly by deep percolation than by lateral subsurface flow. I believe that this is conceptually wrong, especially if this component of the water flux is conceptualised as baseflow. This baseflow, as is modelled, appears more like an "adjustment" of the global contribute of the lateral subsurface flow to the outlet. It is not surprising that this "adjustment" works only during the calibration period (summer 1997). Given the network of ditches, drains and streams in this catchment, I suspect that there is a (permanent or seasonal) water table that is drained by this network and contribute to the base flow. The effect of this draining network across the catchment should be better modelled also because can be significant for phosphorous transport.

2.2 Validation against soil moisture data

The authors do not clarify how they compare surface soil moisture data (first 6 cm) with the simulated water content that, I presume, is averaged over the entire soil column.

2.3 Validation "observed" frequently saturated areas

I believe that this map of "frequently saturated areas" should be better parameterised (for instance, how "frequently"? in wet or dry periods?). The comparison between FSAs and overland flow patterns should be expressed numerically.

3. Technical corrections

Page 1538, line 8 (abstract). The model assumes that overland flow is produced by saturation excess only, not just "most" of it.

Page 1538, line 14 (abstract). The model is validated against 8 years flow data, not 9 years.

Page 1539, lines 5-10 (introduction). The statement "saturation excess (SE) overland

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Interactive Discussion

Discussion Paper

flow occurs when rainfall falls on a saturated soil" is not completely correct. Infiltration excess (IE) also occurs when rainfall falls on saturated soil. The difference is that SE occurs when rainfall falls on soil saturated from the bottom, i.e. it is the lower boundary condition of the modelled soil column (rising deep water table or shallow perched water table rising above a less conductive soil horizon) that controls the saturation of the soil surface and, therefore, the production of overland flow. IE occurs when the top boundary condition of the modelled soil column switch from unsaturated to saturated condition (from Neumann to Dirichlet boundary condition) while the gradients of the soil matric potential are still negative downward into the soil column, i.e. the soil column underneath the soil surface is still unsaturated.

Page 1540, line 9 (introduction). There are TOPMODEL versions that consider the possibility that the soil column has a finite depth. The main difference between TOPMODEL and SDMR is that TOPMODEL employs a distribution function to assess the soil moisture patterns across the catchment that is equivalent to assume an infinite celerity of the subsurface lateral flow (steady-state assumption). SDMR explicitly resolves the lateral subsurface flow at each grid cell.

Page 1541, line 9. I do not think it is appropriate to consider the potential evapotranspiration as part of the weather data set. Generally potential evapotranspiration is the result of a model which employs climatic data and reference vegetation characteristics to estimate reference evapotranspiration fluxes.

Page 1543, line 8-22. The statement "lateral outflow are calculated with a simplified Darcy's law" is not correct. Darcy's law is another thing and it is just part of the theory behind the subsurface model employed. The subsurface lateral flow model herein presented is equivalent to a kinematic wave model, where the local hydraulic conductivity and surface slope is employed to define the lateral celerity. This model is also known as kinematic storage model (Sloan and Moore, 1984). The numerical scheme adopted (equations 1-3) is equivalent to a finite different scheme of the kinematic wave model. This scheme is fully implicit, unconditionally stable, i.e. the stability does not dependent

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Interactive Discussion

Discussion Paper

from the actual celerity, the computational time-step and the grid size (for details see Smith, 1980 and Chirico, 2003a).

Page 1551, line 22. I believe it is superfluous to consider the peakflow timing for evaluating the performance of a model routed at daily time-step in a catchment that has a response time of a few minutes. There will always be perfect “timing” between rainfall, simulated and observed peak flow at daily scale. The fact that peak flow intensities and hydrograph recessions are well simulated should be shown numerically.

Page 1555. The index i in the formulae (10a) and (10b) should start from 1 and not from 0, I believe.

Figure 7. The figure caption should clarify what VSAs means.

Figure 8. I think would be more significant to represent the patterns of runoff volumes in mm with respect to single pixel size rather than to the entire catchment.

4. Cited references (not in the reviewed paper)

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Interactive comment on Hydrology and Earth System Sciences Discussions, 2, 1537, 2005.