11.12 HYDROLOGICAL VALIDATION OF THE TEB SCHEME ON A SUBURBAN CATCHMENT

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1. INTRODUCTION

The aim of this work is to validate the hydrological component of the TEB (Town Energy Balance) scheme (Masson, 2000). The surface energy budgets have been already studied in detail for different cities in dry conditions. A similar study was necessary concerning the parameterization of the water exchanges.
A six-year simulation of a suburban catchment has been realised and the outputs of discharges have been compared with the observations.

2. The experimental catchment

The Rezé site is a little suburban area situated close to Nantes on the french atlantic coast. The catchment (see Fig1) is a residential area composed of only individual one-level houses and gardens. The catchment was instrumented by the LCPC (Laboratoire Central des Ponts et Chaussées) since 1993 (Berthier et al., 1999) and hydrologic data were collected continuously, especially rainfall intensity, discharge and level of the water table. In addition, meteorological data were recorded at the Météo-France station of the airport of Nantes close to the Rezé.

Fig1: the experimental catchment

Previous numerical works by LCPC (Berthier, 1999) and ECN (Ecole Centrale de Nantes) (Dupont, 2001) have shown how some typical urban mechanisms influence the water budget: water infiltration through the roads and water storage capacity of roads and roofs.

3. PRESENTATION OF THE SCHEMES AND THE SIMULATION

The ISBA land-surface scheme parameterises the exchanges for natural covers (Noilhan and Planton, 1989). Three layers (surface root and deep layers) compose the ground. The water-exchange mechanisms are evaporation of the ground, transpiration of vegetation, water diffusion between layers, gravitational drainage and runoff of the root and the deep layers. In this study, no drainage is assumed at the bottom of the third layer, because of the continuous presence of the water table at that level. The urban covers are represented by the TEB scheme (Masson, 2000) based on a 3-D description of the city. The parameterization of the water exchanges is quite simple. The roofs and the roads have their own water reservoir where the rainfall is intercepted. Since the urban surfaces are supposed totally impervious, the evolution equation of the water content of each reservoir depends only on the rainfall rate and the evaporation flux. Maximum water content cannot be exceeded and the water excess leaves the system as a runoff term.
A six-year simulation of the suburban catchment has been realised with both TEB and ISBA schemes used off-line on a single grid point with a timestep of 5 min. We suppose that the runoff leaves the system and is transfered directly in the sewer. The sum of the runoff terms is averaged by hour and directly compared with the discharge observations.

4. THE NUMERICAL RESULTS

4.1. Reference simulation

A first simulation was run with the standard and simplest options of TEB and ISBA. Especially, the maximum water content of roofs and roads reservoirs was fixed at 1 mm. Under such conditions, since the water content of the natural soil stayed always under the saturation, the surface runoff was only produced by the action of the urban surfaces. In summer, only this process contributes to the discharge, allowing directly the hydrological validation of TEB. The simulated discharge is found to be overestimated and occurs too fast compared to the observations (see Fig2) because the urban cover has no inertia and its runoff is varying as the rainfall.

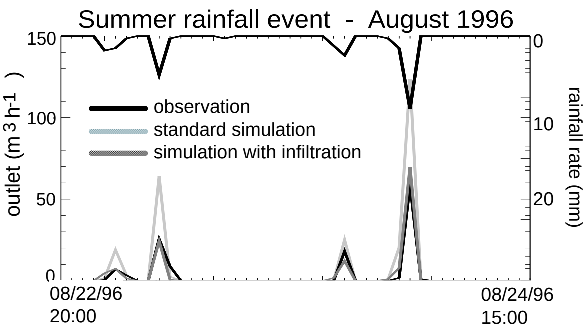

Fig2: comparison between hourly simulated and observed discharge during a rainfall event in the control run

4.2. Modification of the TEB parameterization

The introduction of a water infiltration capacity of the roads in the scheme has allowed decreasing the discharge and delaying the peaks (see Fig2). It is parameterized as a constant water flux (in mm s-1). The infiltrated water reaches the reservoir of the ISBA root layer. In TEB, no soil is considered. Therefore the ISBA hydrological layers are also extended under the builded parts. This assumes an instantaneous horizontal homogeneization of water within the soil. This is, at the scale of a garden, a good approximation, both because of the small horizontal scale and the modification of the soil properties due to human action. The value of the infiltration capacity is directly related with the road condition. Here, different values between 5.E-5 and 5.E-4 mm s-1 were tested. Nash criteria, mean relative and absolute errors were compared for summer months (see Fig3), where the natural covers do not influence the discharge. Note that the Nash criteria is computed using the hourly observed and simulated discharges. Values of 2.E-4 and 3.5E-4 mm s-1 give the best global results on the six different summers. Nevertheless, the water infiltration is not sufficient to improve the simulation of the discharge during short and strong rainfall events. Its effect depends on the water content of the reservoir. If it is too little, the charge and the discharge are very fast. Since evaporation mechanism has always priority on infiltration, the latter has a weak influence. To improve the results, the maximum water content of the roads reservoir has been increased.

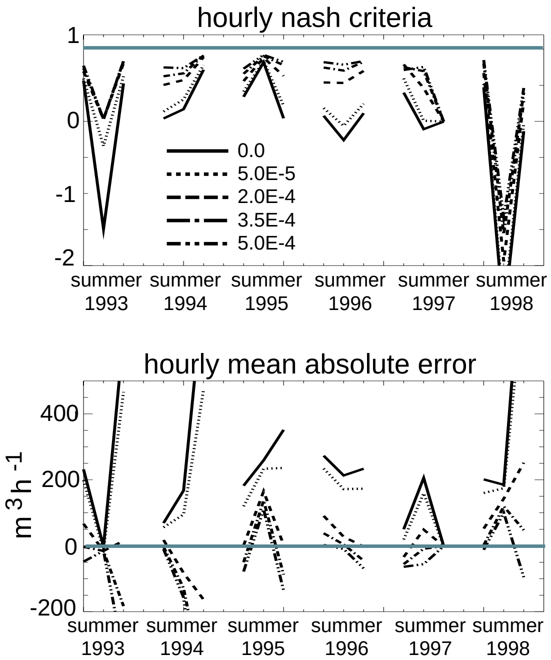

Fig3: calibration of the water infiltration capacity of the roads

When the rainfall is under 5 mm h^{-1}, the discharge is often underestimated. Consequently, the maximum water content of the roofs reservoir has been decreased for quickly filling the reservoir and producing runoff. This choice is justified because all the roofs are sloping and cannot hold a lot of water.

Finally, the calibrations give the following results:

Infiltration capacity	3.5 E-4 mm s^{-1}
Max interception capacity of road	4.0 mm
Max interception capacity of roof	0.5 mm

4.3. Results

During the winter, in addition to the artificial surfaces runoff, the action of the natural covers is no more negligible due to direct infiltration from the deep soil into the sewer system. Indeed the observations show that the level of the water table is less than 50 cm from the surface.

ISBA is able to reproduce this runoff: partly from the third layer which becomes saturated during winter and from the second layer as a sub-grid runoff. Both water quantities are leaving the system but we suppose that only about 60% of the lateral drainage is joining the sewer, according to the observations of the LCPC. The results are really satisfying. Fig4 shows the statistical scores by trimester for the total runoff (artificial and natural covers). The scores for the six-year simulation are as following:

Global hourly Nash criteria = 0.789
Global mean relative error = +0.78%

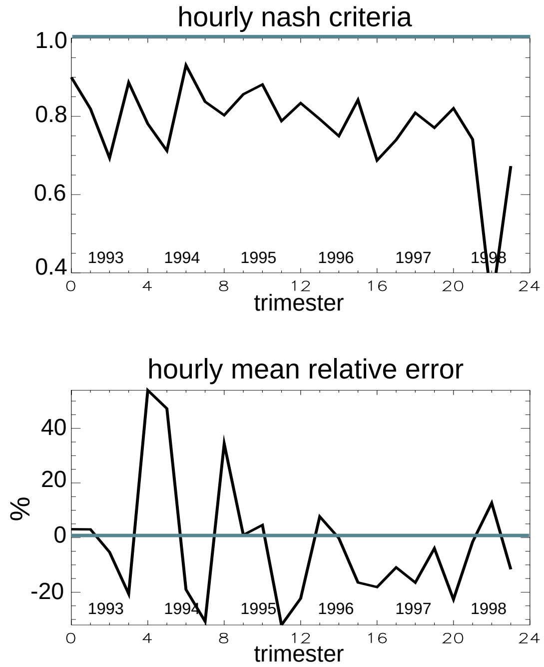

Fig4: 3-months statistical scores

5. Conclusion

This study underscores the influence of specific urban mechanisms which were not included in the initial version of TEB. Firstly, the inclusion of water infiltration through the roads improves the simulation since it represents 60% of the rainfall over roads and induces a better timing of the discharge peaks. Secondly, a calibration of the maximum interception capacity has been done in order to have a more realistic water storage on roofs and roads. Both effects have a significant impact on the water budget. Consequently, the improved parameterization allows having better simulation of the discharges and probably of the evaporation too.

6. References

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