

# SUPPLEMENT: Creation and selection of throughfall pattern

## 1 Approach

To investigate the effect of spatially variable throughfall pattern on soil moisture, we selected the throughfall pattern from the Huewelerbach catchment and used this as input to a numerical model of the hillslope. Hopp and McDonnell [2009] already developed a finite element model of the Panola hillslope. We used the same model domain and identical parameters and combined it with the large-scale Huewelerbach throughfall pattern for our virtual experiment. Since the model domain of Panola is larger than the spatial throughfall pattern we needed to expand the throughfall pattern in a way that the spatial characterization remained the same. Since we did not want to enlarge the pattern, we mapped the pattern in eight different ways onto the Panola hillslope. We used two configurations and four initial patterns (see Figure 1). The four initial patterns are derived by mirroring the throughfall pattern along the vertical and horizontal dashed axes. These four patterns are subsequently mapped on the Panola model domain in two configurations: one where we mapped the initial pattern in the upper right corner of the Panola model domain and subsequently copied this pattern by mirroring along the dashed axes. In the second configuration we started in the upper left corner and then mirrored the pattern. We realize that this expansion method does not encompass all possible patterns that may result in significant different SSF; however, we prefer to retain the spatial characteristics of the original throughfall pattern.

We could also have used a geostatistical simulation method to map the smaller throughfall pattern on the Panola hillslope. However, since our main interest is not the throughfall pattern itself we chose the simpler method of mirroring. After selecting the throughfall pattern we have to verify if the geostatistical properties of the selected pattern have similar geostatistical properties. If these do not differ significantly, our assumption is justified.

To investigate how the different large scale patterns influence subsurface stormflow (SSF) we compare the eight simulations with spatially variable input to the base-case scenario where uniform input was used. We assess the results based on the downslope outflow. The simulation with the highest deviation from the variance of time average segment SSF ( $\bar{Q}_s$ ) divided by total SSF ( $\bar{Q}_t$ ) is used for further analysis ( $\text{var}(Q_s/Q_t)$ ), where only soil moisture patterns are analysed.

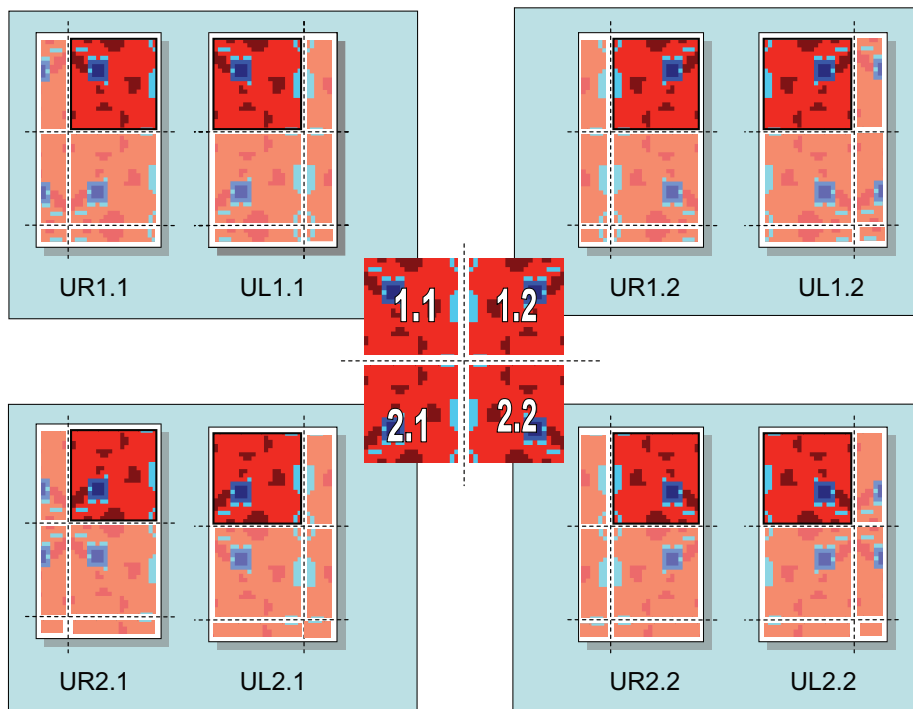


Figure 1: Method to map initial spatial throughfall pattern of Huewelerbach on the Panola hillslope. In the center the four initial patterns. Each initial pattern can be mapped on the hillslope in two ways: the ‘Upper Right’ configuration (UR) and the ‘Upper Left’ configuration (UL).

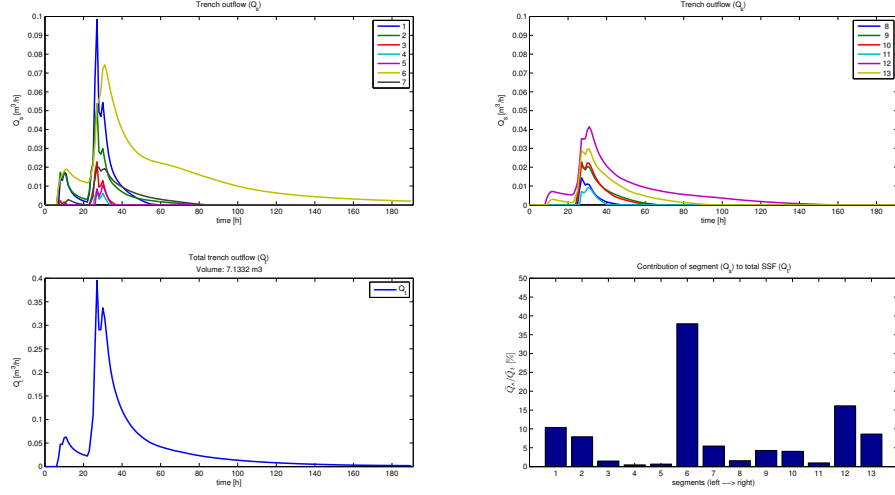
Configuration	Initial pattern	R [mm]	Var( $\bar{Q}_s/\bar{Q}_t$ ) [-]	$Q_p$ [m <sup>3</sup> h <sup>-1</sup> ]	$\Sigma Q_t$ [m <sup>3</sup> ]
Uniform	-	62.8	$10.4 \cdot 10^{-2}$	0.40	7.13
Upper left	1.1	63.0	$11.3 \cdot 10^{-2}$	0.39	7.39
	1.2	63.3	$8.9 \cdot 10^{-2}$	0.36	7.68
	2.1	63.2	$13.0 \cdot 10^{-2}$	0.35	7.24
	2.2	63.3	$11.7 \cdot 10^{-2}$	0.35	7.15
Upper right	1.1	63.2	$11.7 \cdot 10^{-2}$	0.37	7.56
	1.2	63.6	$9.6 \cdot 10^{-2}$	0.37	7.37
	2.1	63.5	$13.7 \cdot 10^{-2}$	0.34	7.35
	2.2	63.3	$11.5 \cdot 10^{-2}$	0.37	7.10

Table 1: Effect of different spatial input patterns on variance in segment subsurface storm flow,  $\text{var}(\bar{Q}_s/\bar{Q}_t)$ , peak discharge ( $Q_p$ ), and total subsurface flow volume ( $\Sigma Q_t$ ).

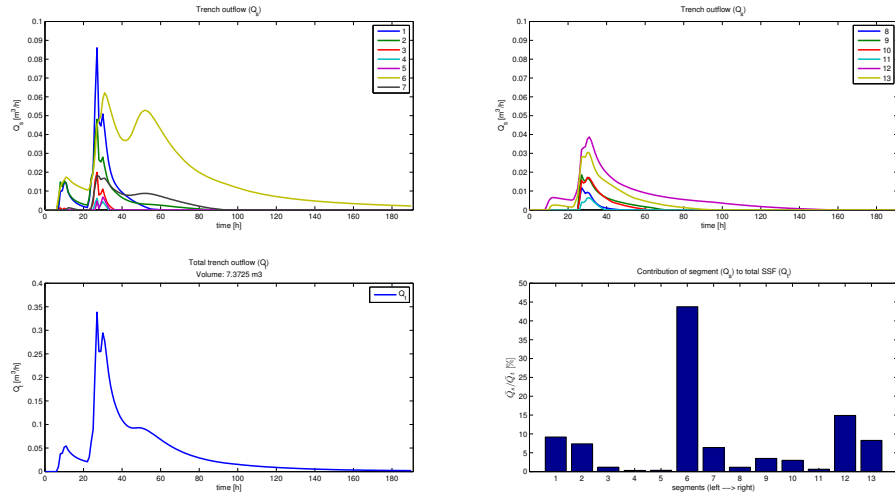
## 2 Impact large scale throughfall patterns on SSF

In Figure 2a subsurface stormflow along the downslope trench of the base case scenario ( $R = 63$  mm,  $A = 13^\circ$ ,  $S = 0.62$  m) with uniform input is shown. The upper graphs show the subsurface flow per segment ( $Q_s$ ), the lower left the total subsurface flow ( $Q_t$ ), and the lower right the variation of subsurface flow along the trench. The bar indicates the average flow in time. As can be seen, subsurface flow is variably distributed along the trench (variance  $\bar{Q}_s/\bar{Q}_t = 10.4 \cdot 10^{-2}$ ), especially segment 6 drains the major part of the hillslope. This segment is on the transition of the very shallow soil to the thicker soil and discharges a relatively large upslope area.

The results of the eight different spatial input pattern configurations on the base case scenario are presented in Table 1. We checked if the total storm size of the eight configurations was similar to the storm size of the uniform case, and found a maximum deviation of 1%. The variance of pattern ‘Upper Right-1.2’ ( $9.6 \cdot 10^{-2}$ ) deviates less from the uniform input ( $10.4 \cdot 10^{-2}$ ), and ‘Upper Right-2.1’ ( $13.7 \cdot 10^{-2}$ ) deviates most from the uniform input. Not only is segment 6 discharging even more water, but also the hydrograph of this pattern is significantly different from the uniform pattern mainly caused by segment 6 and 7 (see Figure 2b). While the uniform pattern has a rather smooth recession curve, pattern ‘Upper Right-2.1’ leads to a double peak in segments 6 and 7. All other segment hydrographs do not differ much from the uniform case. The differences in the SSF hydrographs between the uniform and spatially variable input might also be (partly) biased by a ‘wrong’ parametrization of the HYDRUS model. Since the HYDRUS model is parameterized with uniform input, the optimal parameter set is partly compensating for the wrong assumed uniform input (Arnaud et al. [2002]; Zehe et al. [2005]). However, because we are only interested in selecting a (virtual) throughfall configuration and not in attempting to simulate realistic Panola drainage behavior, we neglect this effect although it is important for non-virtual modeling.



(a)



(b)

Figure 2: Subsurface storm flow for the entire width of the hillslope (28 m). The upper graphs show the hydrographs of the 13 segments along the trench ( $Q_s$ ), the lower left the total outflow ( $Q_t$ ) and the lower right the variability along the trench. The bar indicates the average flow in time. (a) Subsurface storm flow of the base case scenario with uniform input; (b) subsurface storm flow of the base case scenario with spatially variable input ‘Upper Right-2.1’ (see Figure 1).

$T_f/P$ [%]	Initial pattern 21 x 22 m	Upper Right-2.1 pattern 28 x 48 m
Mean	73.1%	72.5%
Standard deviation	22.7%	21.0%
Effective range	4.7m	5.2m

Table 2: Comparison of the geostatistical properties of the initial and the Upper Right-2.1 configuration for the percentage throughfall ( $T_f/P$ ).

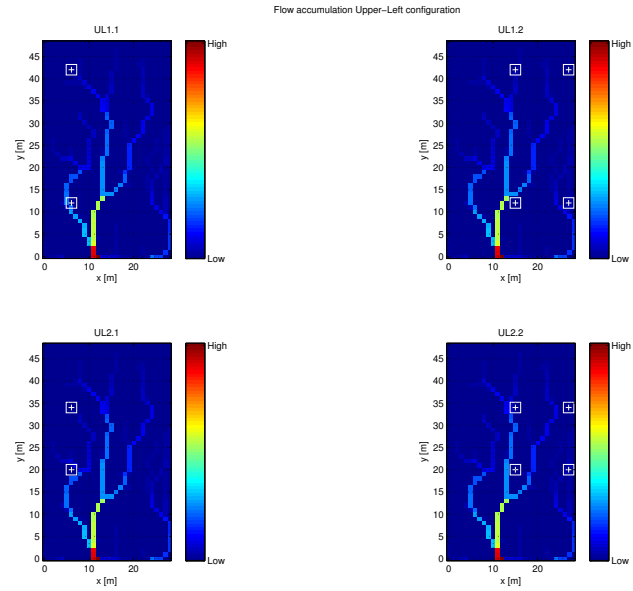
The double peak is probably caused by the location of the hotspot of high throughfall. If two hotspots are located above a ‘channel’ of high flow accumulation, this causes quick drainage of two flow peaks. In Figure 3 the flow accumulation map of the bedrock topography is presented with the location of the throughfall hotspots of the eight different input patterns. Segment 6, has the largest drainage area. The reason why pattern ‘Upper-Right 2.1’ is extremely responsive, is because four hotspots are located in the flow accumulation channel of segment 6 and two of them are at about the same travel distance from segment 6. Hence the spatial pattern does influence subsurface stormflow. It determines the variance in subsurface flow along the trench and, even more importantly the shape of the hydrograph.

The spatial pattern with the highest impact on the subsurface storm flow (SSF) has been used for further analysis. Based on the variance in segment SSF ‘Upper Right-2.1’ (UR2.1) deviates most from the uniform input (Figure 4).

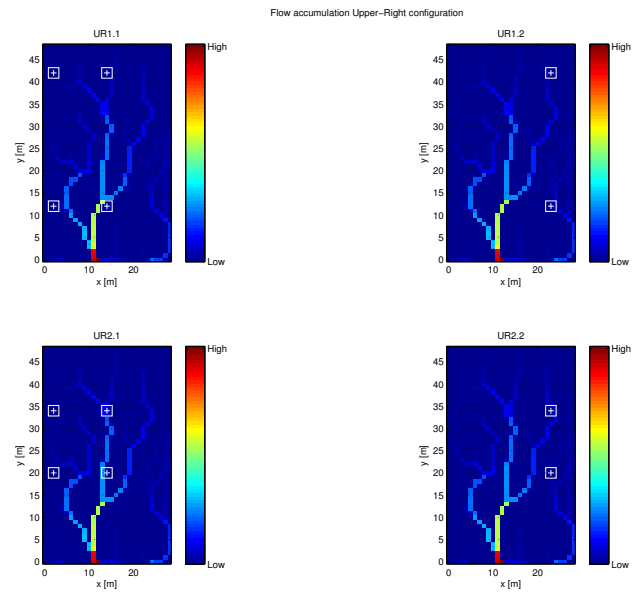
To verify if the ‘Upper Right-2.1’ pattern has still similar geostatistical properties as the initial pattern a comparison is made in Table 2. As can be seen, the two patterns have similar properties. Hence we conclude that using the simple method of mirroring (instead of using a geostatistically method) is in this case justified to enlarge the Huewelerbach pattern.

## References

- Arnaud, P., Bouvier, C., Cisneros, L., Domingues, R., 2002. Influence of rainfall spatial variability on flood prediction. *Journal of Hydrology* 260, 216–230.
- Hopp, L., McDonnell, J. J., 2009. Connectivity at the hillslope scale: Identifying interactions between storm size, bedrock permeability, slope angle and soil depth. *Journal of Hydrology* 376, 378–391.
- Zehe, E., Becker, R., Bárdossy, A., Plate, E., 2005. Uncertainty of simulated catchment runoff response in the presence of threshold processes: Role of initial soil moisture and precipitation. *Journal of Hydrology* 315, 183–202.



(a)



(b)

Figure 3: Flow accumulation map of bedrock topography and location of hotspots in Upper-Left configuration (a) and in the Upper-Right configuration (b).

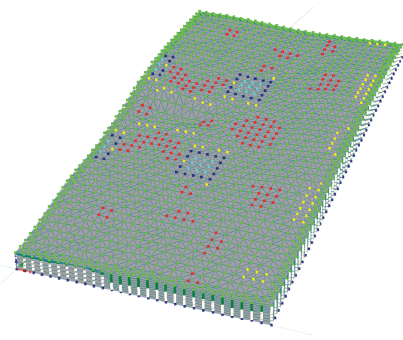


Figure 4: Input pattern 'Upper Right-2.1' on Panola hillslope with highest impact on subsurface outflow compared to uniform input.