Comparing catchment scale subsurface celerities estimated from recession analysis and infiltration experiments.

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Catchment scale hydrological models all have some representation of the dynamics of subsurface flow and hence direct or indirect estimates of the velocities (celerities) involved. Parameters representing these celerities (for example recession coefficients of linear reservoirs) are often calibrated against runoff instead of being estimated directly from measured data. Such a procedure, when applied for hydrological models with (too) many parameters to be calibrated, may lead to unrealistic estimates of subsurface velocity due to equifinality issues. Our aim with this study is to obtain an estimate of the distribution of subsurface velocities corresponding to the distribution of saturation levels through recession analysis. Using the recession characteristic $\Lambda=\log(Q(t)/Q(t+\Delta t)$ and looking for sequences of recession in a moving average filtered time series of runoff, we find, for many catchments, no clear structure in the relationship between Q(t) and Λ (see Figure 1).

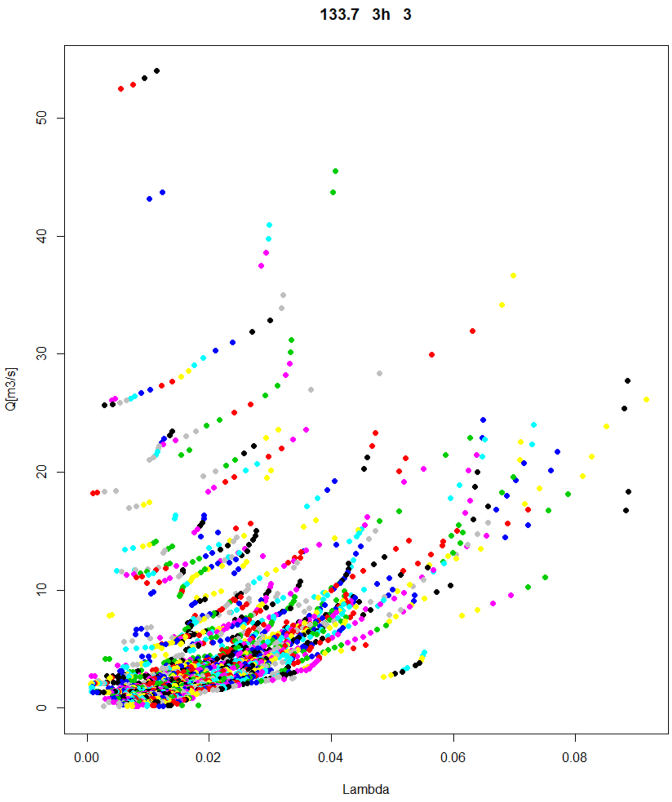

Figure 1 Sequences of screened Q vs Λ for 3h runoff measurements for the catchment 133.7 (mid Norway, catchments size 206.6 km^2).

An obvious problem is that it does not appear to be a one to one relationship between Q and Λ. This can be for many reasons, such as snowmelt, evapotranspiration etc. Figure 2 presents Q-Λ for the tiny Muren catchment (7500 m^2) in southern Norway for 15 min runoff measurements, and a similar behaviour is seen here.

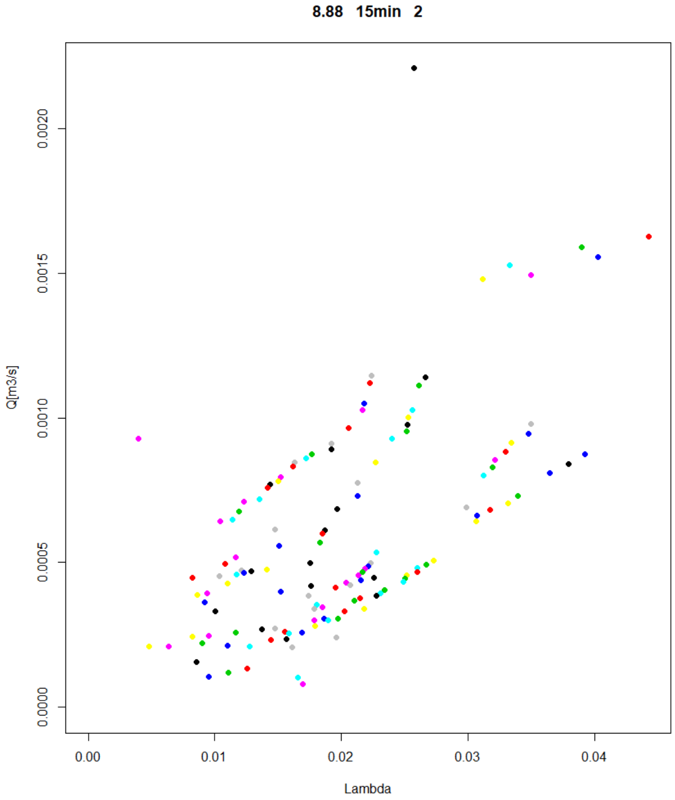

Figure 2. Sequences of screened Q vs Λ for 15 min runoff measurements for the catchment 8.88, Muren (7500 m^2).

In order to better understand the process of recession, a synthetic experiment was carried out. In the experiment, four unit hydrographs(UH), parameterised from GIS derived information of Muren and assumed subsurface velocities were used. The distance distribution (distances from a point in the catchment to the nearest reach of the river network) of Muren provided the shape of the exponential UH, whereas the scale of the UH's are detemined by the subsurface velocity associated with each UH. The UH's are basically sets of weights which distribute in time the input (precipitation/snowmelt).

Table 1 Velocities and temporal scale of synthetic UHs

Unit hydrograph	Velocity [m/s]	Temporal scale (number of 15 min timesteps)
UH1	0.001	55 (13 hours)
UH2	0.0005	109 (27 hours)
UH3	0.00025	218 (55 hours)
UH4	0.00012	454 (114 hours)

In this experiment, we randomly chose how many layers to be filled to (a chosen) capacity and randomly partially filled the layer above that. Such a procedure is used in the Distance Distribution Dynamics model (DDD, Skaugen and Onof, 2014) when rainfall/snowmelt is distributed to the different layers. The slowest layer is filled up first, then the excess goes to the second slowest layer and so forth. Figure 3 shows the relationship between runoff and Λ for the experiment. Only when there is such a systematic build-up of saturation from below do we get a clear structure between $Q(t)$ and Λ, and for each value of $Q(t)$ the maximum Λ represented the true recession to be used for estimating the velocity v, through $v = \frac{\Lambda \bar{d}}{\Delta t}$, where $\bar{d}$ is the mean of the distance distribution and Δt is the temporal resolution (see Skaugen and Onof, 2014). Figure 3 also shows us why the observed recession data can appear so chaotic as seen in figures 1 and 2. If the fastest of the active layers are not filled to capacity, the recession do not follow that ideal for superimposed UHs.

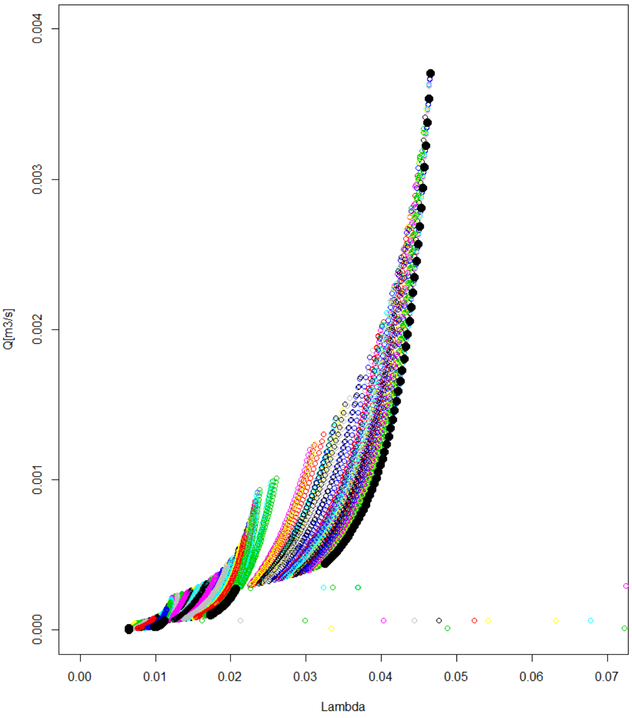

Figure 3. Synthetic experiment with four UH's, where the number of UHs filled to capacity is random, and the UH above that is partially filled. The large black circles represent all UHs filled to capacity.

At the Muren catchment we estimated the saturated hydraulic conductivity to be 0.00045 m/s using an automatic double ring infiltrometer (see Figure 4) which used 7 m^3 of water in 14 hours!

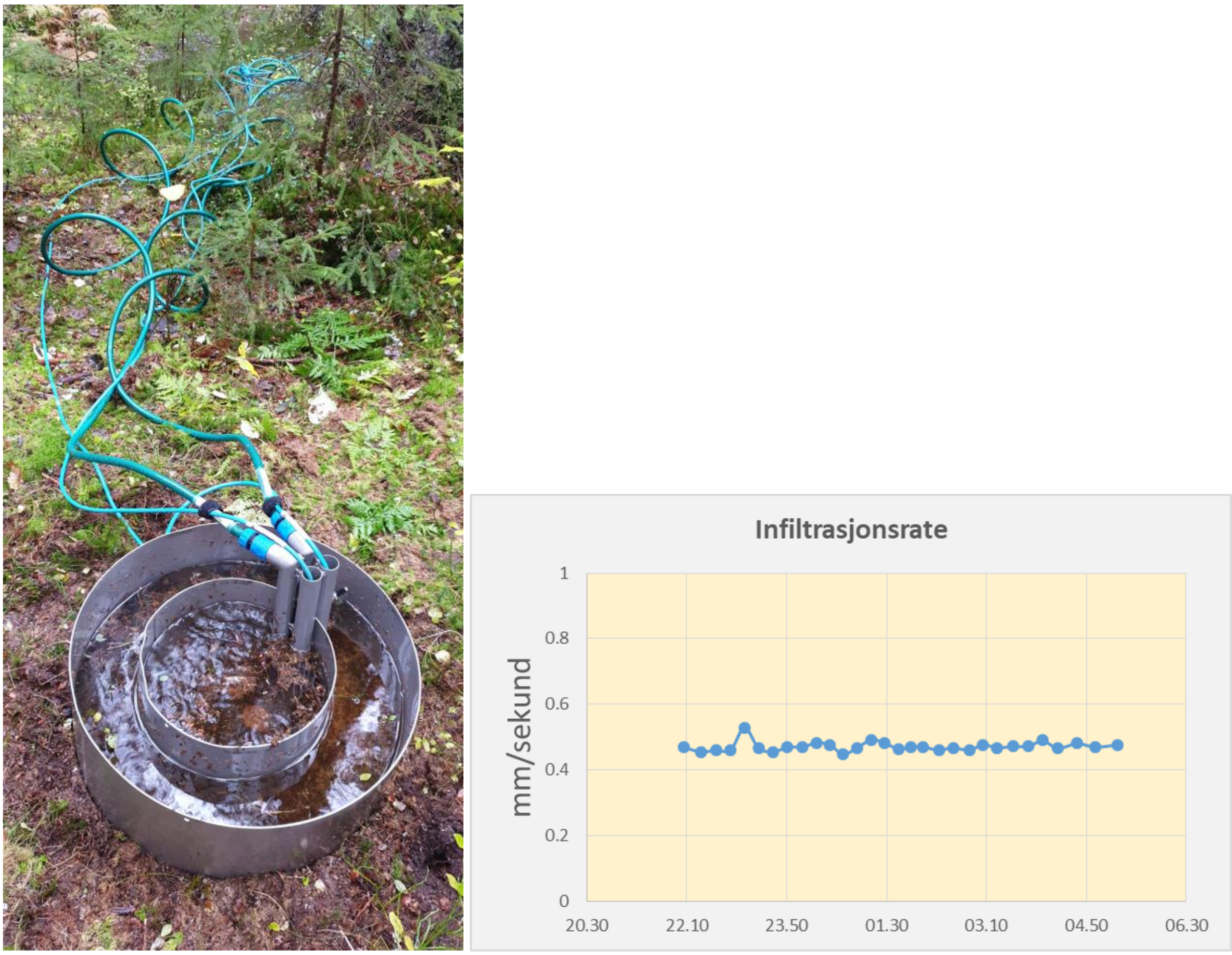

Figure 4. Infiltration test at Muren (Photo K, Møen NVE).

The mean celerity estimated from recession analysis for the same catchment was found to be 0.0004 m/s, and we could estimate the distribution of velocities from the recession analysis (see Figure 5).

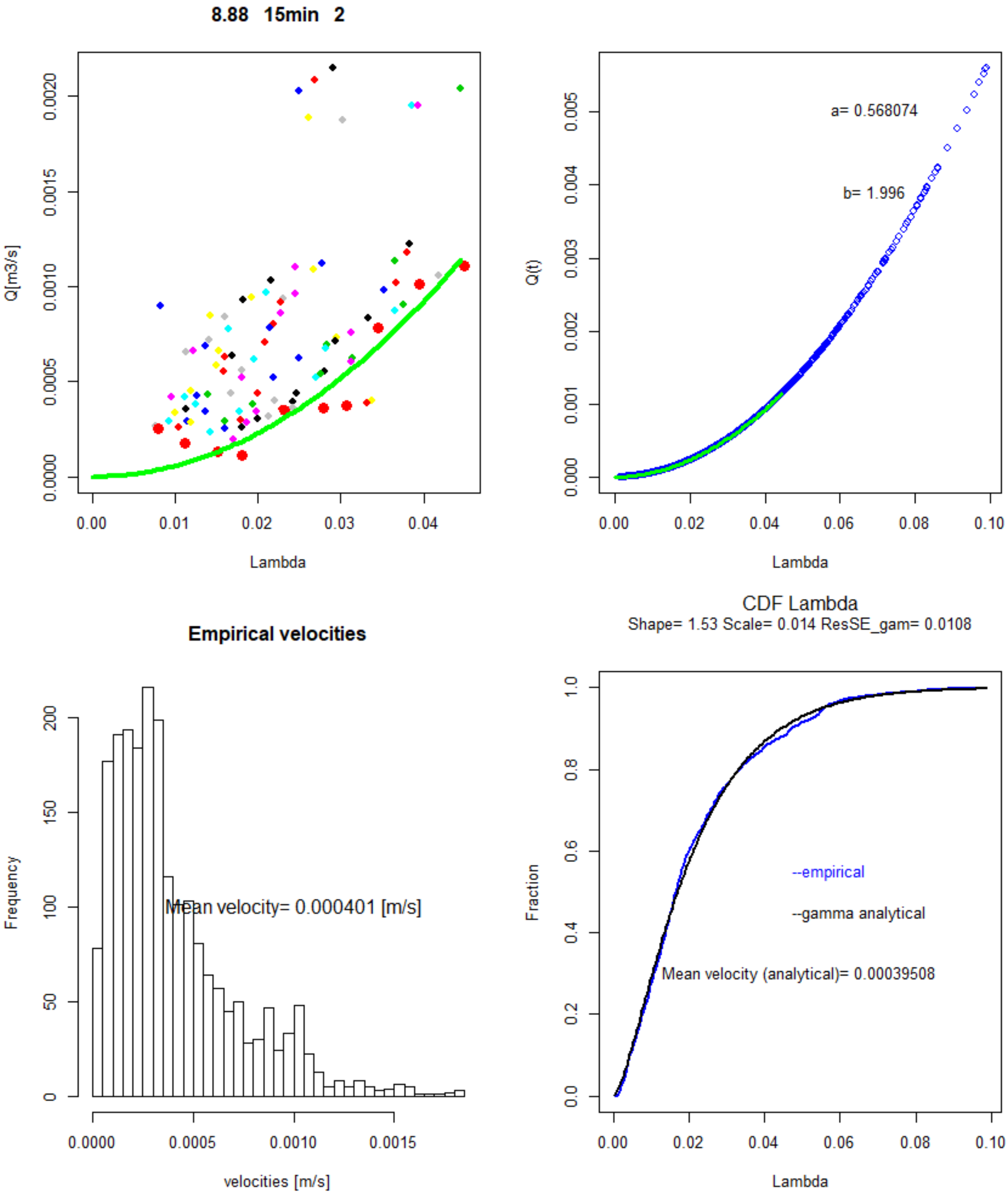

Figure 5. Recession and subsurface velocity analysis for Muren

The parameterised velocity distribution was further used in the Distance Distribution Dynamics (DDD) rainfall runoff model a Kling Gupta efficiency criterion of KGE = 0.86 was obtained for runoff simulations at 15 minutes temporal resolution (see Figure 6). The simulation is not perfect: the model appears to be too responsive for smaller events, but the some of the peaks seem to be well simulated and inspires further work on this topic.

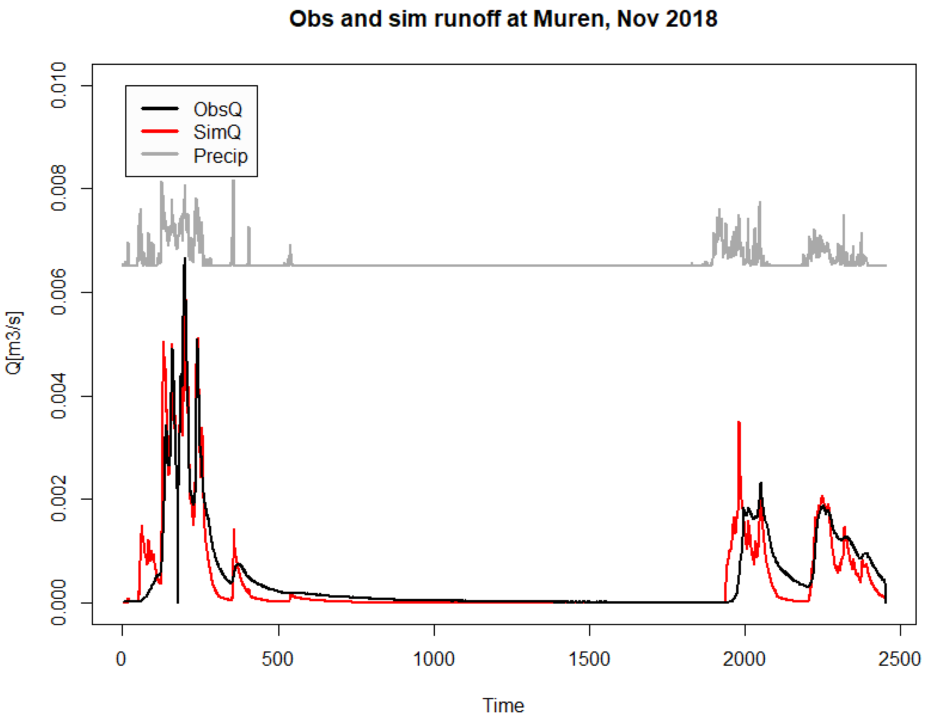

Figure 6. Observed and observed runoff at Muren November 2018 (15 min temporal resolution)

References

Skaugen T. and C. Onof, 2014. A rainfall runoff model parameterized form GIS and runoff data. *Hydrol. Process*. **28**, 4529-4542,DOI:10.1002/hyp.9968