Parameter identifiability, estimation and regionalisation for WALRUS

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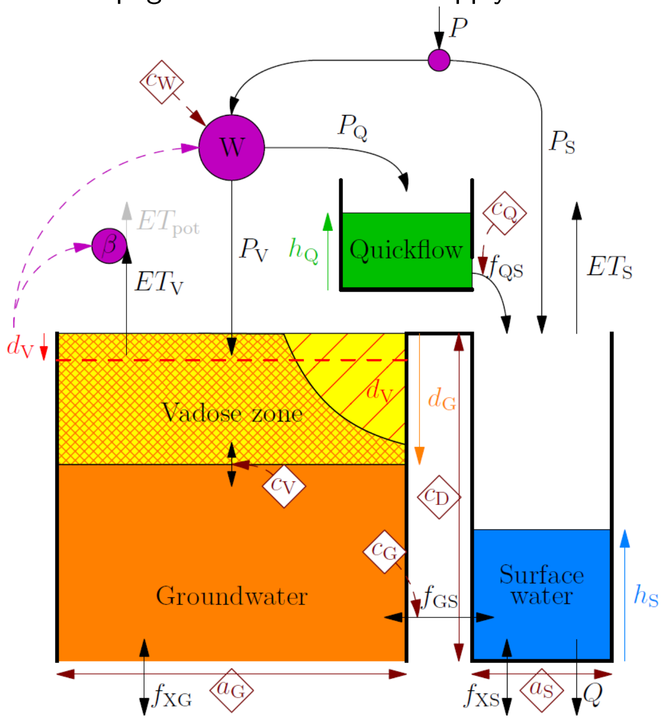
1 Introduction

When developing the Wageningen Lowland Runoff Simulator (WALRUS), special attention was paid to limiting the number of parameters. Here we assess whether the degree of model complexity is appropriate and evaluate several methods for parameter estimation in practical applications.

2 WALRUS

WALRUS was developed to fill the gap between complex, spatially distributed models which are often used in lowland catchments and simple, parametric models which have mostly been developed for sloping catchments. WALRUS explicitly accounts for processes that are important in lowland areas (defined as areas where hydrological processes are influenced by shallow groundwater):

- groundwater-unsaturated zone coupling
- wetness-dependent flow routes
- groundwater-surface water feedbacks
- seepage and surface water supply



3 Model parameters

WALRUS has four parameters which require calibration. They are intended to have a strong, qualitative relation with catchment characteristics.

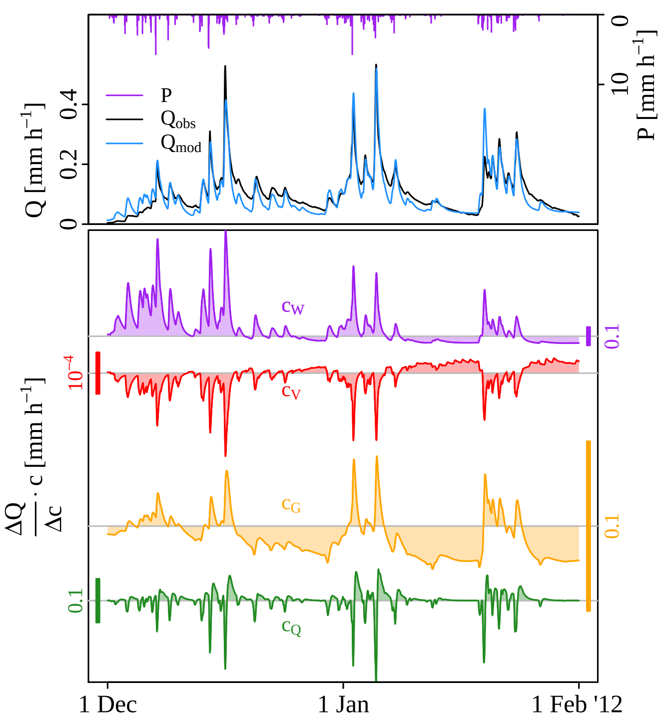
c_W *Wetness index parameter.* Determines how the division between quick and slow flowroutes depends on storage deficit. Depends on field scale drainage density (drainpipes, macropores and soil cracks).

c_V *Vadose zone relaxation time.* Determines the speed with which the groundwater table responds to changes in the unsaturated zone. Depends on soil type.

c_G *Groundwater reservoir constant.* Determines groundwater drainage or surface water infiltration. Depends on geology.

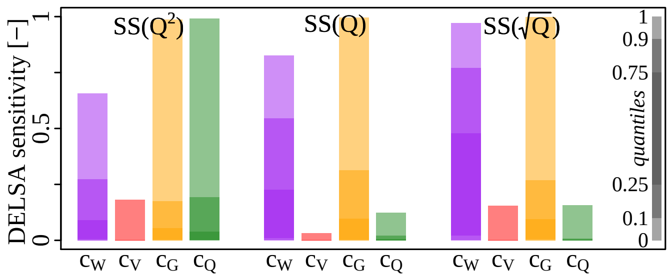
c_Q *Quickflow reservoir constant.* Depends on slope and drainage type.

4 Parameter identifiability



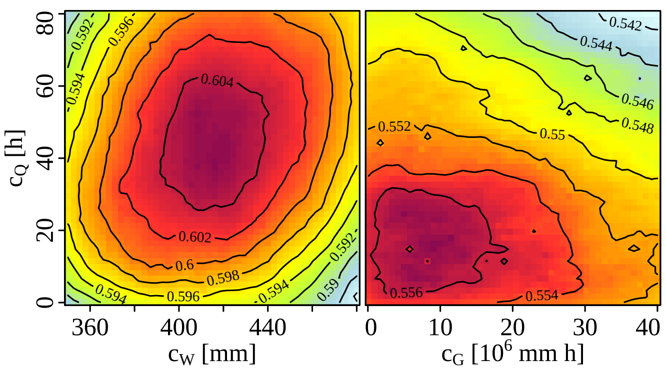
Identifiability of model parameters in the discharge time series. The effect of c_W, c_G, and c_Q can be distinguished, but the effect of c_V is small and similar to c_W.

5 Parameter sensitivity



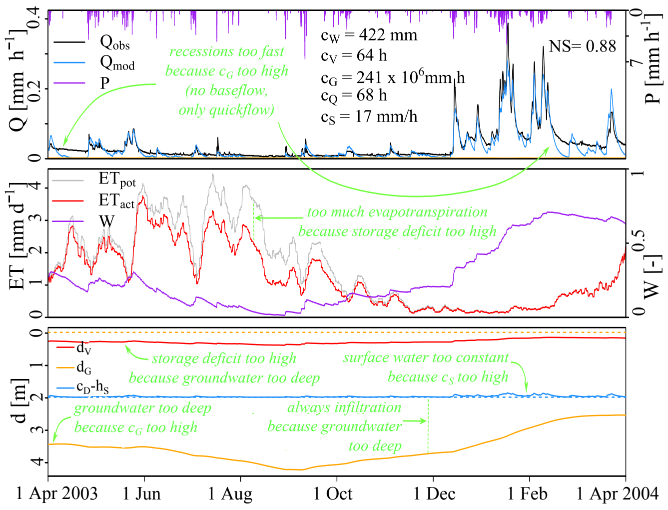
Parameter sensitivity computed with Distributed Evaluation of Local Sensitivity Analysis (DELSA; Rakovec et al. 2014) for 3 performance measures (sum of squares of Q^2, Q and $\sqrt{Q}$). WALRUS is most sensitive to c_W (especially for low flows; $\sqrt{Q}$) and c_G, sensitive to c_Q when focussing on peaks (Q^2) and hardly sensitive to c_V.

6 Parameter dependence



Response surfaces showing parameter dependence. Hardly any dependence between some parameters (left), but some dependence (although correlation is weak) between others (right). Also, c_Q has a different optimum with c_W than c_G.

7 Parameter estimation



The result of automatic calibration without a posteriori evaluation. Catchment knowledge is necessary to avoid unrealistic model results, but difficult to translate into an objection function.

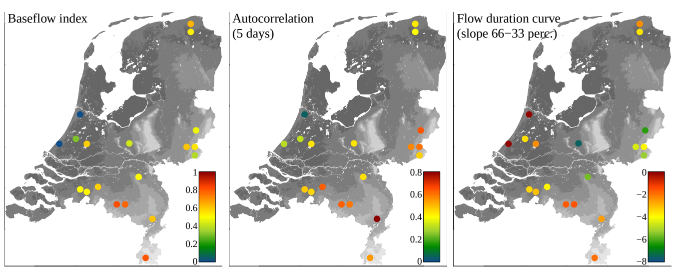
8 Parameter regularisation

To avoid unrealistic parameter values, a penalty for straining too far from a priori parameter values can be added:

$$\text{obj. func.} = \underbrace{\frac{\sum(Q_{mod}-Q_{obs})^2}{\mathrm{var}(Q_{obs})}}_{\textit{Sum of squares}} + \alpha \underbrace{\sum_{i=1}^{4} \frac{(c_i - c_i^*)^2}{\mathrm{var}(c_i)}}_{\textit{Regularisation term}}$$

c_i^* = a priori parameter estimates (based on other runs or catchments); α = regularisation parameter (confidence in a priori values). Division by variances is for normalisation.

9 Parameter regionalisation



Streamflow indices showing similarity between catchments. Parameter values from a similar catchment can be used as a priori value in regularisation or as best guess for ungauged basins.

10 Conclusion

- Feedbacks between unsaturated zone, groundwater and surface water are necessary to simulate the rainfall-runoff processes in lowland catchments adequately, but increase the risk of parameter dependence and equifinality.
- Automatic calibration can lead to physically unrealistic results → additional checks (with optional tuning) necessary.

11 Outlook

We are working together with end-users to develop WALRUS further and test it on many catchments. The WALRUS R-package will be posted on `www.github.com/ClaudiaBrauer/WALRUS`.

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C.C. Brauer, A.J. Teuling, P.J.J.F. Torfs, R. Uijlenhoet (2014a): The Wageningen Lowland Runoff Simulator (WALRUS): a lumped rainfall-runoff model for catchments with shallow groundwater, *Geoscientific Model Development*.

C.C. Brauer, P.J.J.F. Torfs, A.J. Teuling, R. Uijlenhoet (2014b): The Wageningen Lowland Runoff Simulator (WALRUS): application to the Hupsel Brook catchment and Cabauw polder, *Hydrology and Earth System Sciences*.

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