The Wageningen Lowland Runoff Simulator (WALRUS)

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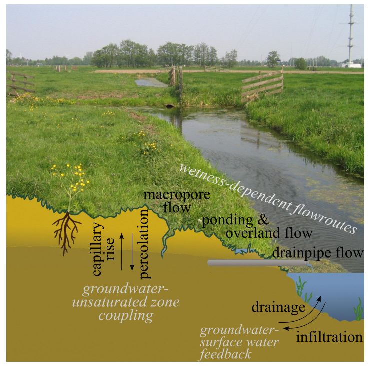
1 Introduction

WALRUS is a novel rainfall-runoff model 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 (for comparisons, see Brauer, 2014a). WALRUS explicitly accounts for processes that are important in lowland areas (defined as areas where hydrological processes are influenced by shallow groundwater):

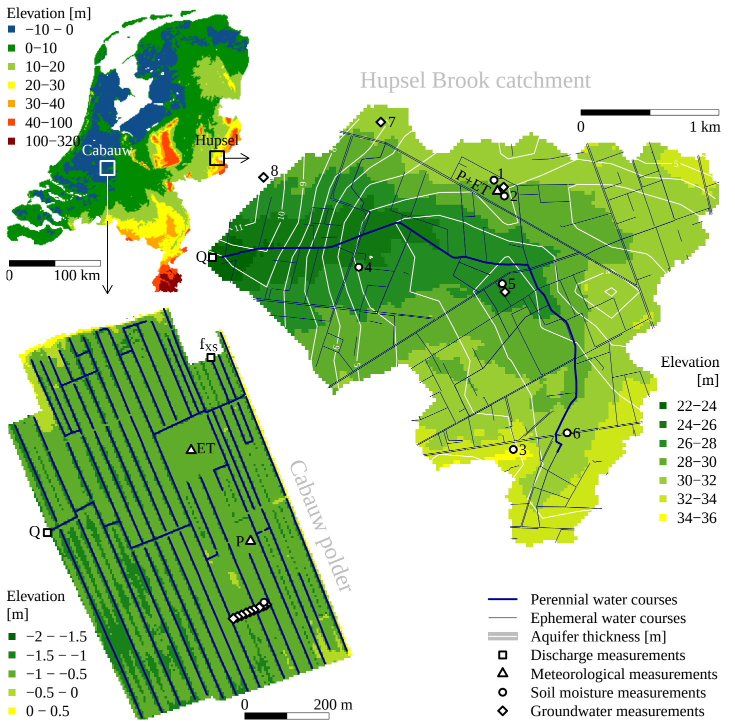


- groundwater-unsaturated zone coupling
- wetness-dependent flow routes
- groundwater-surface water feedbacks
- seepage and surface water supply

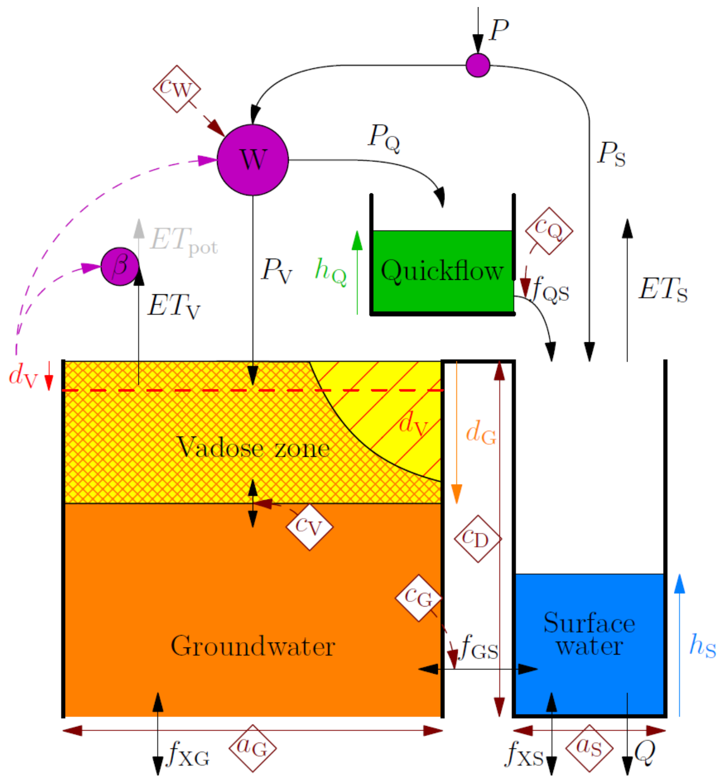
2 Field sites

WALRUS has been developed using data and experience from two experimental catchments:

- The freely draining Hupsel Brook catchment: mildly sloping, 6.5 km^2, 0.2–11 m sand on clay
- Cabauw polder with controlled surface water levels: flat, 0.5 km^2, 0.7 m clay on peat



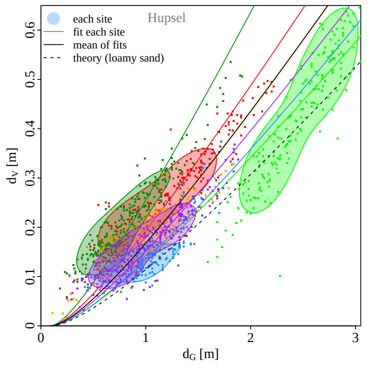
3 Model structure



4 Model equations

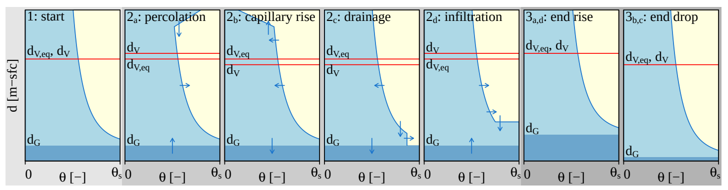
Groundwater depth and storage deficit

There is one soil reservoir including both saturated and unsaturated zone. This accounts for groundwater-unsaturated zone coupling. The storage deficit (the effective depth of empty pores) is the main state; groundwater depth is only used for groundwater drainage.



Change in groundwater depth depends on the difference between storage deficit and equilibrium storage deficit belonging to the current groundwater depth:

$$\frac{dd_G}{dt} = \frac{d_V - d_{V,eq}}{c_V}$$



Wetness index

Wetness index depends on storage deficit. Determines which fraction of the precipitation is lead to the quickflow reservoir. Default relation:

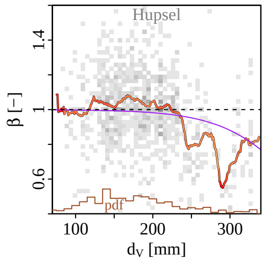
$$W = \frac{1}{2} + \frac{1}{2} \cdot \cos\left(\frac{\max(\min(d_V, c_W), 0) \cdot \pi}{c_W}\right)$$

This accounts for wetness-dependent flowroutes: when the catchment becomes wetter, a larger fraction of the water is discharged via quick flowroutes (macropores, drainpipes).

Evapotranspiration reduction

depends on storage deficit. Default:

$$\beta = \frac{ET_{act}}{ET_{pot}} = \frac{1 - \exp[\zeta_1(d_V - \zeta_2)]}{1 + \exp[\zeta_1(d_V - \zeta_2)]} \cdot \frac{1}{2} + \frac{1}{2}$$



Groundwater drainage/infiltration

depends on difference between groundwater and surface water levels (left term) and contact surface (right term):

$$f_{GS} = \frac{(c_D - d_G - h_S) \cdot \max((c_D - d_G), h_S)}{c_G} \cdot a_G$$

This accounts for groundwater-surface water feedbacks. High surface water levels (caused by surface water supply or during peak flows) limit groundwater drainage or cause infiltration of surface water.

Quickflow depends on level in (linear) quickflow reservoir:

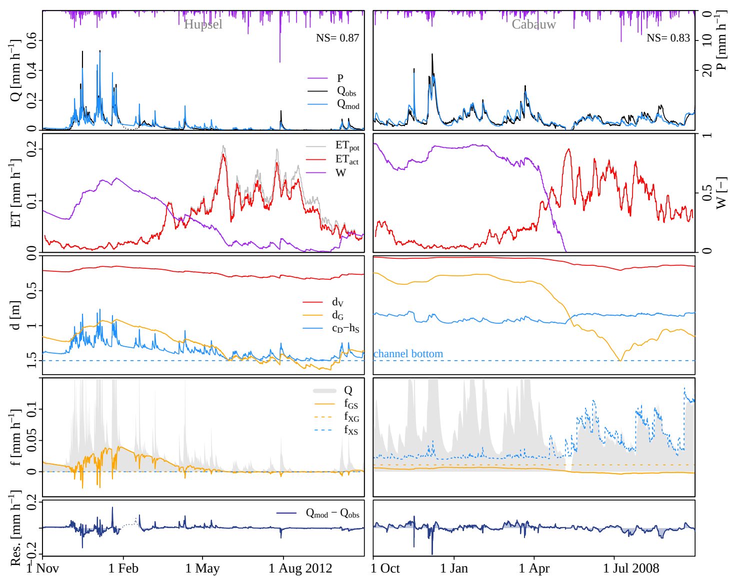
$$f_{QS} = \frac{h_Q}{c_Q} \cdot a_G$$

Discharge depends on surface water level. Supply stage-discharge relation or use default:

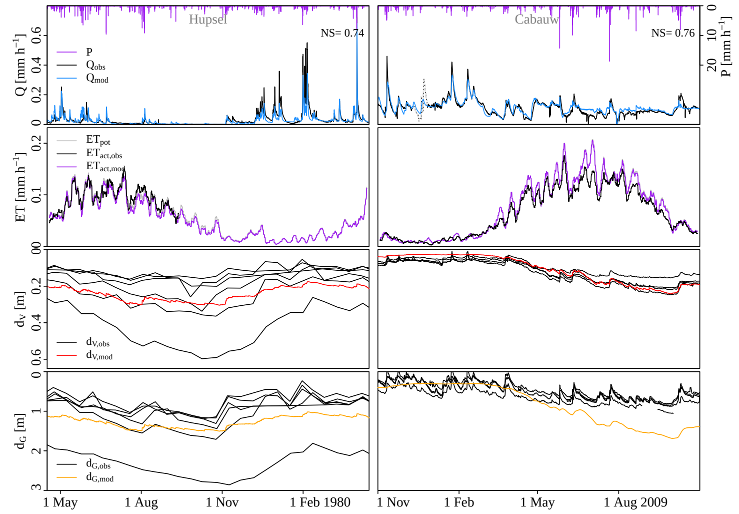
$$Q = c_S \left(\frac{h_S - h_{S,min}}{c_D - h_{S,min}}\right)^{x_S}$$

Seepage (f_{XG}) and surface water supply (f_{XS}) can be added to or extracted from the soil or surface water reservoir.

5 Calibration



6 Validation



7 Application

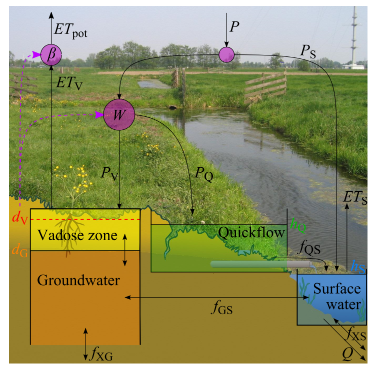
WALRUS has some important advantages:

- applicable to both freely draining and polder areas
- fast
- few parameters (only 4 to calibrate)
- clear (qualitative) relation between model states and measurable variables
- default options for initial conditions and parameterizations, which can easily be changed for research purposes
- open source and freeware (R)

These advantages make WALRUS suitable for operational flood and drought forecasting, real-time control, input for a hydraulic model, risk analyses, scenario analyses, infrastructure design and time series gap filling.

8 Conclusion and outlook

WALRUS performs well, both during calibration and several validation studies. Sensitivity analyses show that parameters are identifiable (see Brauer et al., 2014b). We are working together with end-users to develop WALRUS further. The code will be made available as an R-package.



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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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