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The Wageningen Lowland Runoff Simulator (WALRUS): development of a novel parametric rainfall-runoff model using field experience

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We present the Wageningen Lowland Runoff Simulator (WALRUS), a novel rainfall-runoff model to fill the gap between complex, spatially distributed models for lowland catchments and simple, parametric models for mountainous catchments. From observations and experience from two Dutch field sites (the Hupsel Brook catchment and the Cabauw polder), we identified key processes for runoff generation in lowland catchments and important feedbacks between components in the hydrological system. We used this knowledge to design a parametric model which can be used all over the world in both freely draining lowland catchments and polders with controlled water levels.

While using only four parameters which require calibration, WALRUS explicitly accounts for processes that are important in lowland areas:

(1) Groundwater-unsaturated zone coupling: WALRUS contains one soil reservoir, which is divided effectively by the (dynamic) groundwater table into a groundwater zone and a vadose zone. The condition of this soil reservoir is described by two strongly dependent variables: the groundwater depth and the storage deficit (the effective thickness of empty pores). This implementation enables capillary rise when the top soil has dried through evapotranspiration.

(2) Wetness-dependent flowroutes: The storage deficit determines the division of rain water between the soil reservoir (slow routes: infiltration, percolation and groundwater flow) and a quickflow reservoir (quick routes: drainpipe, macropore and overland flow).

(3) Groundwater-surface water feedbacks: Surface water forms an explicit part of the model structure. Drainage depends on the difference between surface water level and groundwater level (rather than groundwater level alone), allowing for feedbacks and infiltration of surface water into the soil.

(4) Seepage and surface water supply: Groundwater seepage and surface water supply or extraction (pumping) are added to or subtracted from the soil or surface water reservoir. These external fluxes affect the whole system through the groundwater-surface water feedbacks and saturated-unsaturated zone coupling.

Model verification with artificial examples shows that the implemented feedbacks have the desired effect on the system variables, and validation studies with data from the Hupsel Brook catchment and Cabauw polder yield good results, both in terms of Nash-Sutcliffe efficiency and according to field experience of processes between rainfall and runoff.