Stochastic optimisation of water allocation on a global scale

Oliver Schmitz, Menno Straatsma, Derek Karssenberg, Marc F. P. Bierkens

Universiteit Utrecht
Faculty of Geosciences

Department of Physical Geography, Utrecht University, The Netherlands (o.schmitz@uu.nl)

Motivation and objective

Climate change in combination with increasing population and economic developments will increase the water scarcity in many regions. Water management strategies to close the water gap can opt, for example, to allocate available water with respect to fulfil the demands in the own hydrological unit, or to consider demands from downstream units as well.

We aim to identify an optimal water allocation scheme for catchments by a stochastic optimisation of two parameters for each hydrological unit. These parameters allocate fractions of the total available water to the local demands and reservoir storage, respectively.

Water supplies and demands

PCR-GLOBWB [1] provides the supplies (runoff, interflow and base flow) and demands (domestic, industrial, irrigation, environmental flow) from the years 2006 to 2100 with a monthly time step. On a global scale, we obtained hydrological units with up to 140 hydrological units per catchment.

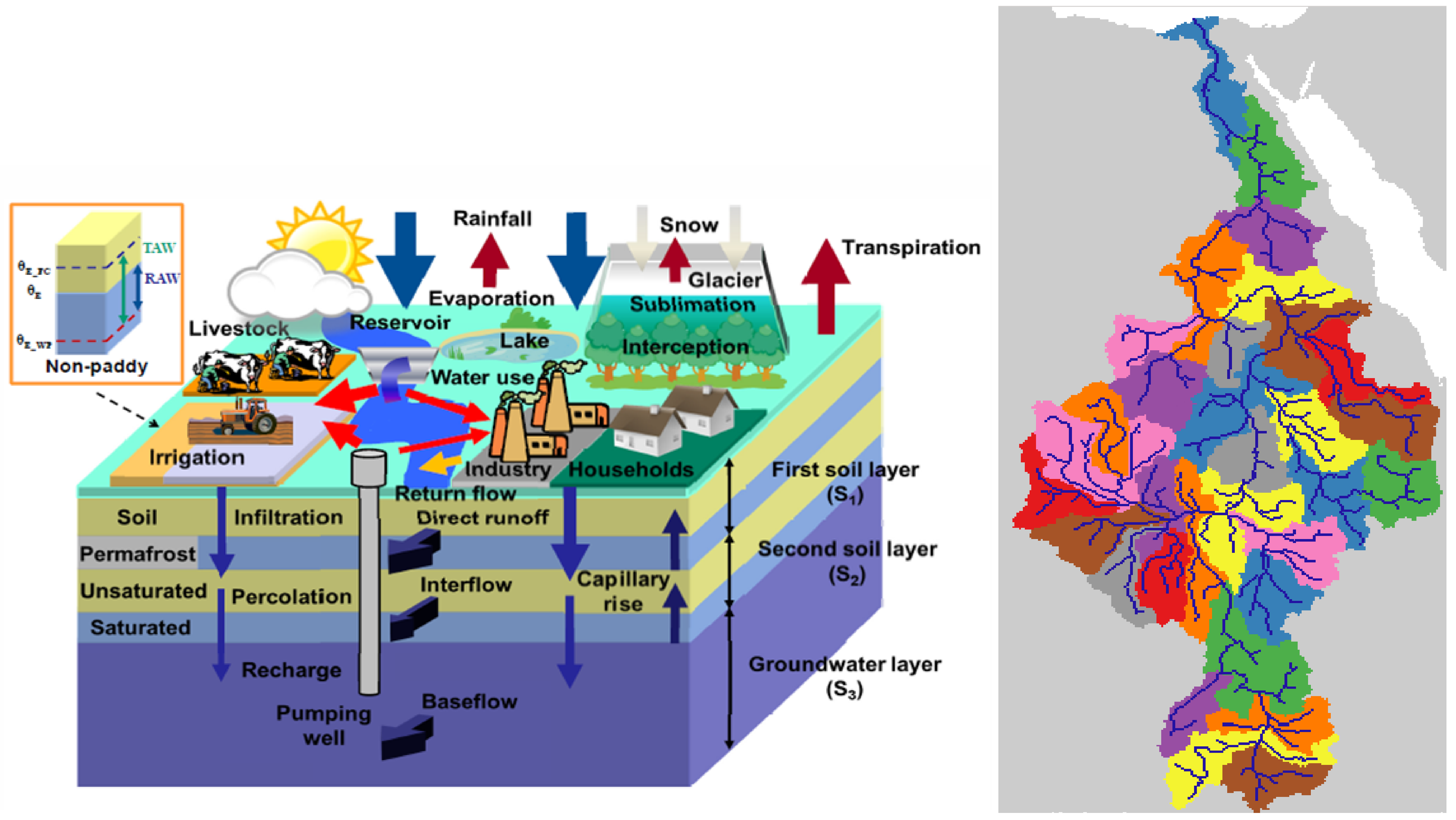
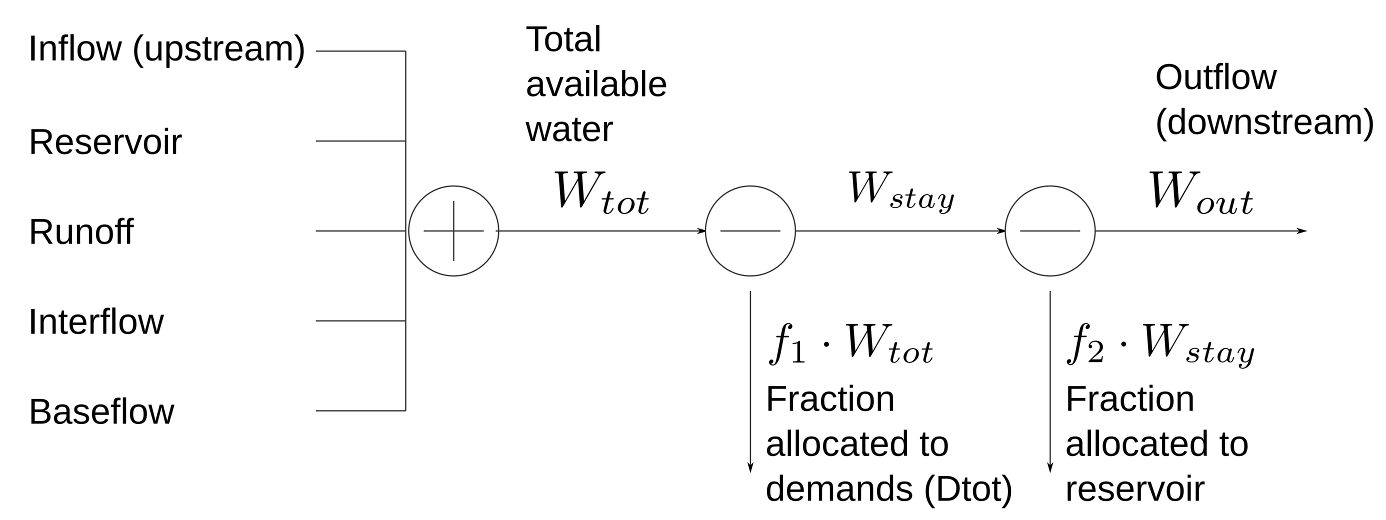


Figure showing the conceptual scheme of the PCR-GLOBWB model [2] and the hydrological units and downstream network in the Nile catchment. For each unit in the catchment the different supplies and demands per sector are aggregated on a monthly basis.

Water allocation and optimisation

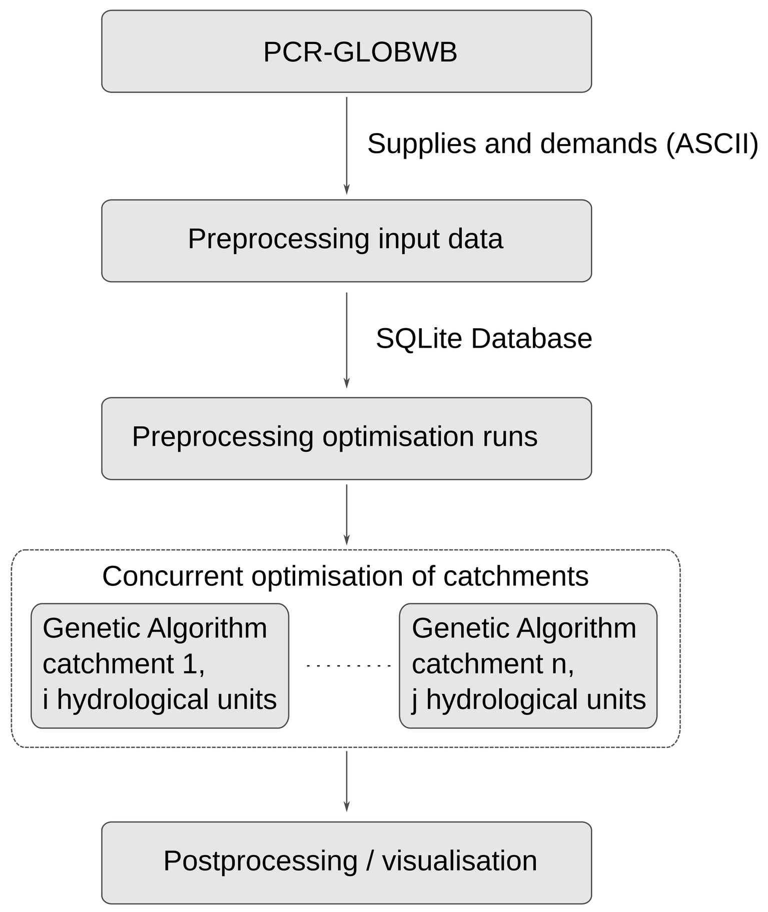
For each hydrological unit in a catchment, the total available water is allocated for each month to demands, reservoir or downstream outflow according to the following scheme:



Different allocation fractions f1 and f2 are computed by a Genetic Algorithm for each month and each hydrological unit. Each catchment is optimised for each year by minimising the differences between the allocated water and actual demands:

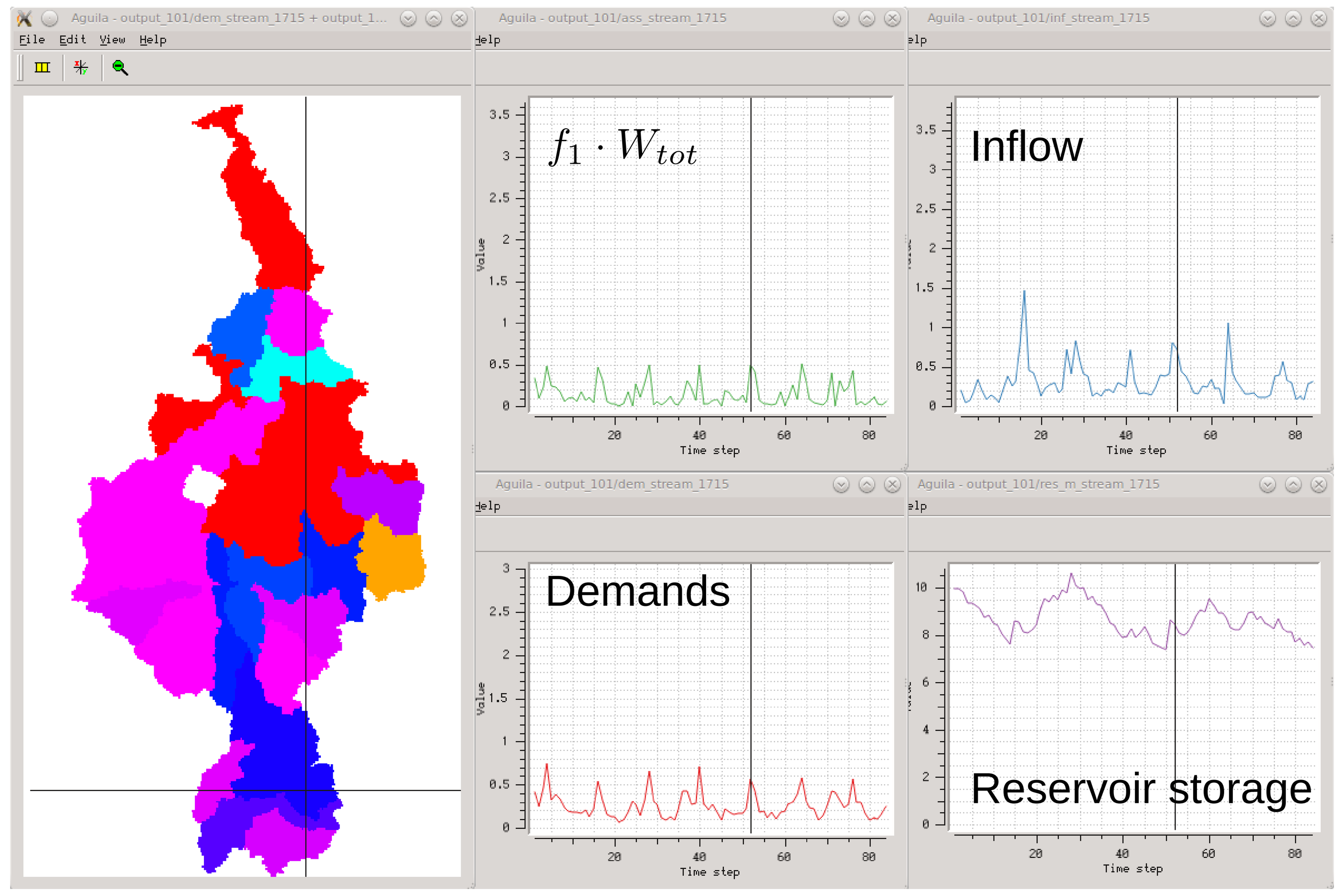
$$\mathrm{OF} = \min \sum_{months}^{12} \sum_{units}^{n} (f_1 \cdot W_{tot} - D_{tot})$$

Software architecture

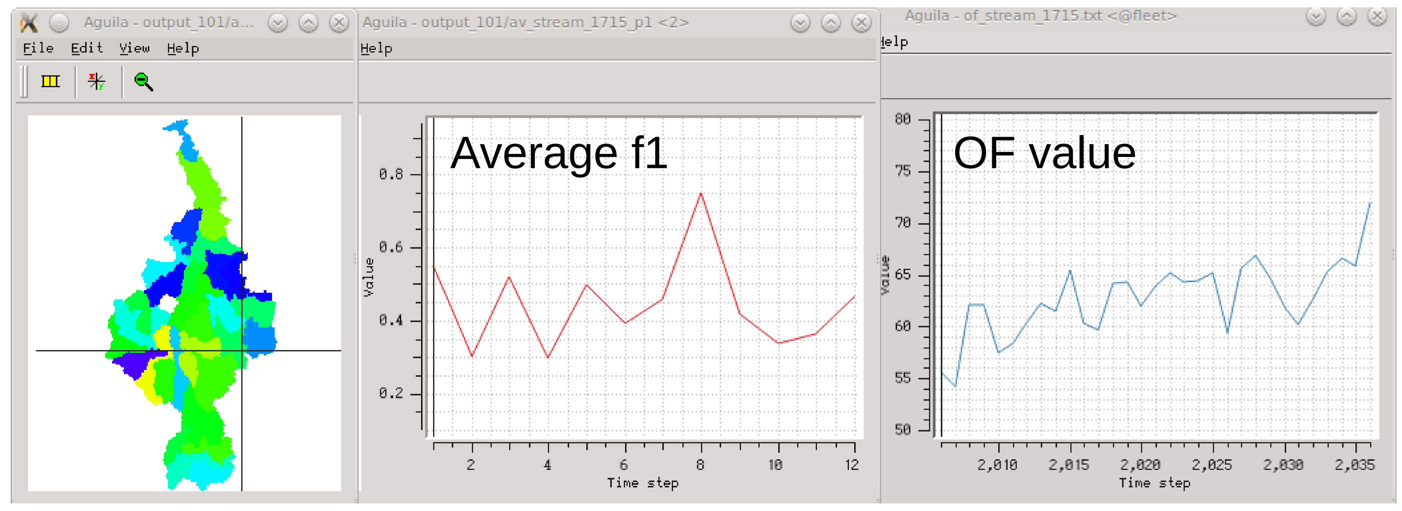


The output data obtained from PCR-GLOBWB is segmented per catchment to allow for a concurrent optimisation of all catchments. The Python programming language with the PCRaster modelling framework [3] are used to implement the water allocation per hydrological unit and the interactions between units. The stochastic optimisation is provided by an existing Genetic Algorithm implementation [4].

Outputs



Screenshot showing the hydrological units and examples for the associated monthly values for the optimal allocation. Allocated water, upstream inflow, demands and reservoir storage are shown as timeseries for the selected hydrological unit.



Screenshot showing monthly averaged values for the fractions allocating water to the demands (left) and the development of the objective function value for the Nile catchment indicating an increasing water gap until 2036.

References

[1] Van Beek, L.P.H., Wada, Y., & Bierkens, M.F.P. (2011). Global monthly water stress: 1. Water balance and water availability. WRR, 47
[2].Wada, Y., Wisser, D., Bierkens, M.F.P. (2014), Global modeling of withdrawal, allocation and consumptive use of surface water and groundwater resources. Earth System Dynamics 5(1).
[3] Karssenberg, D., Schmitz, O., and Salamon, P., de Jong, K., Bierkens, M.F.P. (2010) A software framework for construction of process-based stochastic spatio-temporal models and data assimilation. Environmental Modelling & Software, 25 (4).
[4] http://sourceforge.net/projects/amori/