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Stochastic optimisation of water allocation on a global scale

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Climate change, increasing population and further economic developments are expected to increase water scarcity for many regions of the world. Optimal water management strategies are required to minimise the water gap between water supply and domestic, industrial and agricultural water demand. A crucial aspect of water allocation is the spatial scale of optimisation. Blue water supply peaks at the upstream parts of large catchments, whereas demands are often largest at the industrialised downstream parts. Two extremes exist in water allocation: (i) 'First come, first serve,' which allows the upstream water demands to be fulfilled without considerations of downstream demands, and (ii) 'All for one, one for all' that satisfies water allocation over the whole catchment. In practice, water treaties govern intermediate solutions. The objective of this study is to determine the effect of these two end members on water allocation optimisation with respect to water scarcity. We conduct this study on a global scale with the year 2100 as temporal horizon.

Water supply is calculated using the hydrological model PCR-GLOBWB, operating at a 5 arcminutes resolution and a daily time step. PCR-GLOBWB is forced with temperature and precipitation fields from the Hadgem2-ES global circulation model that participated in the latest coupled model intercomparison project (CMIP5). Water demands are calculated for representative concentration pathway 6.0 (RCP 6.0) and shared socio-economic pathway scenario 2 (SSP2). To enable the fast computation of the optimisation, we developed a hydrologically correct network of 1800 basin segments with an average size of 100 000 square kilometres. The maximum number of nodes in a network was 140 for the Amazon Basin. Water demands and supplies are aggregated to cubic kilometres per month per segment.

A new open source implementation of the water allocation is developed for the stochastic optimisation of the water allocation. We apply a Genetic Algorithm for each segment to estimate the set of parameters that distribute the water supply for each node. We use the Python programming language and a flexible software architecture allowing to straightforwardly 1) exchange the process description for the nodes such that different water allocation schemes can be tested 2) exchange the objective function 3) apply the optimisation either to the whole catchment or to different sub-levels and 4) use multi-core CPUs concurrently and therefore reducing computation time. We demonstrate the application of the scientific workflow to the model outputs of PCR-GLOBWB and present first results on how water scarcity depends on the choice between the two extremes in water allocation.