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The role of storage capacity in coping with intra-annual runoff variability on a global scale

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Intra-annual variability poses a risk to water security in many basins as runoff is unevenly distributed over the year. Areas such as Northern Africa, Australia and the South-Western USA are characterized by a high coefficient of variability of monthly runoff. Analyzing the global risk of water scarcity, this study examines 680 basin-country units (BCUs) (403 river basins divided by country borders). By calculating the water balance for each BCU, the interplay of runoff on the one hand and domestic, industrial and environmental water needs on the other hand is shown. In contrast to other studies on average water scarcity, this work focuses on variability of water supply as metrics based on annual average water availability and demand can underestimate the risk of scarcity.

The model is based on the assumption that each country-basin with sub-basins and tributaries can be treated as one single reservoir with storage capacity aggregated over that BCU. It includes surface runoff and the possibility to withdraw groundwater as water supply. The storage capacity of each BCU represents the ability to transfer water from wet months to dry months in order to buffer and cope with intra-annual water supply variability and to meet total water demand. Average monthly surface runoff per country-basin for the period 1979 to 2012 is derived from outcomes of the hydrological model Mac-PDM. Mac-PDM is forced with monthly ERAI-Interim reanalysis climate data on a one degree resolution. Groundwater withdrawal capacity, total water demand and storage capacity are taken from the IMPACT model provided by the International Food Research Institute (IFPRI). Storage refers to any kind of surface reservoir whose water can be managed and used for human activities in the industrial, domestic and agricultural sectors. Groundwater withdrawal capacity refers to the technological capacity to pump water rather than the amount of groundwater available. Total water demand includes consumptive water use from the industrial, domestic and agricultural sectors and varies between months. Due to a lack of data, the 2010 figures for groundwater withdrawal capacity are assumed to be equally distributed over 12 months without accounting for possible variation within a year. For runoff and water demand, monthly data are used.

Our study shows that storage capacity helps to cope with intra-annual water variability and thereby decreases the risk of water scarcity. Several cases emerge where water security is critically dependent on transboundary flows such as the Nile in Egypt or the Aral Drainage in Uzbekistan. Furthermore, we calculate environmental flow requirements using the Variable Monthly Flow (VMF) method and analyse the effects of abstraction and dam construction on environmental flows. For each BCU, we examine whether environmental water requirements can be met with given human abstractions. Additionally, water scarcity is examined for the case when water is reserved for the environment and cannot be abstracted for human purposes.