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SPI-Q : a hydrological statistical model to simulate the river inflow for water reservoirs management

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Conditions of shortage in a water supply system occur when available resources are not able to satisfy the related demands. Concerning surface reservoirs, three main elements should be taken into account in transient conditions: 1) the inflow; 2) the actual amount of water stored in the reservoir; 3) and the water demand. To assess the risk of water shortage (i.e. reliability, resiliency and vulnerability), a simple model able to translate the randomness of climate into reliable scenarios of inflow to the reservoir is extremely useful. In this contest physically-based water balance models (i.e. models based on hydrological processes) often present several limitations due to lack of observations for the calibration/validation procedure and to an over-parameterization.
In this paper a simple statistical method to simulate the inflow to a surface reservoir based on Standardized Precipitation Indices is proposed. It is based on some basic assumptions: a) for management purposes the inflow to the reservoir and the connected water demand, can be assessed at monthly time scale; b) the monthly inflow is determined by the climatic forcing averaged in space over the watershed; c) as a first approximation the discharge is mainly dependent on precipitation taken into account at different time scales and with different "weights"; d) the parameters linking the precipitation regime to the inflow are considered constant over time. On the base of such assumptions, to seek for relationships between the precipitation regime and the inflow a multilinear regression model (called SPI-Q) is calibrated and validated at monthly scale using the least-square method: Q(m,i) = a_SPI1(m)•SPI1(m,i)+ a_SPI3(m)•SPI3(m,i) + a_SPI6(m)•SPI6(m,i) + a0(m), where Q(m,i) is the inflow for the month m, year i; SPI1(m,i), SPI3(m,i) SPI6(m,i) are the Standardized Precipitation Indices computed for the month m, year i on the precipitations cumulated over 1, 3 and 6 months; a_SPI1(m), a_SPI3(m), a_SPI6(m) and a0(m) are the coefficients from the multilinear regression of SPI1, SPI3, SPI6 for the month m. It is worth to note that to suitably calibrate the SPI-Q model a statistically significant dataset (both for inflow and precipitation) is mandatory.
The SPI-Q model has been applied to three basins in Italy, quite different in terms of climate conditions and hydrological features: the Lake Maggiore basin (Switzerland and North Italy), the Ridracoli basin (Central Italy) and the Occhito Basin (South Italy). Simulations resulted in good agreement with observations, mostly for low inflow regime; moreover, the values of the multilinear regression coefficients appeared to be representative of the different hydrological processes that affect the total monthly discharge to the reservoirs: for example, for the case study of the Lake Maggiore, during spring the inflow is mostly affected by the SPI6 that takes into account the snow melting of the cumulated winter precipitations, whereas the inflow to the Occhito reservoir is mostly related to the SPI1. The physical meaning of the coefficients a_SPI1, a_SPI3 and a_SPI6 are widely discussed for the three case studies.