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Effect of snow accumulation and melt on the stream flow in the Jordan River, East Mediterranean

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Snow melt on high mountains, at low latitudes (<40 degrees N), can be an important component of the surface water flow during the winter and spring seasons. As opposed to snow cover at high latitudes which are persistent due to below zero temperatures, snow cover in warmer climates is rapidly changing, potentially resulting in several complete melting cycles during one winter season. In the Mt. Hermon region (Israel-Lebanon-Syria border, East Mediterranean, ∼33.5 degrees N) previous studies have concluded that snow storage accounts for ∼10% of the Jordan River annual yields.

Here we apply a modified version of HYdrological Model for Karst Environment (HYMKE) to estimate the effect of snow accumulation and snow melt on the timing of stream flow in the Jordan River. It is a system approach, physically based karst hydrology model, which receives daily precipitation and potential evaporation time series as input. The modeled fast flow stream component is correlated with the physical area of the catchment, while the area of the groundwater aquifer is a parameter which is calibrated against the separated measured baseflow. We have added a snowmelt routine before the main equations in HYMKE creating the following model structure: the snow routine (1), surface layer water balance (2), surface ("fast") flow (3), vadose zone flow (4), and groundwater ("base flow", 5). The new snowmelt routine uses the measured precipitation and temperature data, and analyzes it separately to produce snow and snowmelt at 56 discrete stripes of 50 m' height each, ranging in elevation from 75 m' to 2825 m'. It uses a standard HBV (Hydrological Bureau Waterbalance-section) approach based on a degree-day temperature-index. With current available temperature data the actual temperature gradient was calibrated, and the daily temperature at each elevation stripe was evaluated. However, due to the lack of measured snowmelt, several parameters of the model could not be calibrated, and were adopted from the literature on alpine climates.

We show that at higher elevations there is a clear difference between the timing of effective precipitation (precipitation plus snowmelt) compared to precipitation when snowmelt was not taken into account. However, these changes had almost no effect on the final results of the daily stream flow. The proposed explanation is as follows: a. the cumulative area of elevations contributing snowmelt to the stream flow is less than 12% of the entire catchments area. b. Due to the relatively high temperature and high radiation, temperatures often cross the zero threshhold during the winter, resulting in a continuous snowmelt process at almost all elevations, and therefore the delay in snowmelt application compared to the rainfall usually takes only few days. c. Only at extremely high elevations (>2000) is there a significant delay due to snow melt (sometimes till April-May-June) but the contribution to stream flow is minimal because of the small coverage area. d. Since most of the river flow is from groundwater, there are several lagging mechanisms (surface wetness, vadose zone flow and groundwater flow) that effectively balance out the effect of the snow delay on surface precipitation, so that the only real impact on stream flow is dependant upon precipitation amount and not precipitation timing.