How can we better describe the hydrological impacts of snow droughts in semiarid environments?

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The current hydrological year, 2021-2022, is a clear example of water scarcity in Spain after some years with precipitation below the historical mean threshold, especially in the Mediterranean catchments, which has activated the “alert” warning stage in many areas, the first stage from “normal” (normal-alert-alarm-emergency) in the Spanish Early-Warning decision-making system to face Droughts (EWD). In mountain areas, this decrease in precipitation has resulted in a significant decrease of the seasonal snow, with recent late spring snowfall bringing some expected alleviation for the summer river flow. The Sierra Nevada mountain range is an alpine-climate area in the semiarid southern Spain very close to the Mediterranean sea that can exemplify this situation. During the last hydrological year, the cumulative precipitation registered until the beginning of March was close to the minimum historical observational record, with the precipitation events during March and April breaking this trend and increasing the water storage in the reservoirs downstream. Drought indexes, like the Standardized Precipitation Index (SPI) or the Streamflow Drought Index (SDI), have been widely used to characterize meteorological and hydrological droughts, respectively, in EWDs. However, in high mountain areas, the snow occurrence and evolution play a key role in water resource availability, modify the precipitation-runoff response on a seasonal basis, and determine the water balance on different time scales. Therefore, “snow drought” might result in scarcity conditions even though no warning stage has been reached regarding drought’s alerts yet, and this should also be taken into account in these indexes’ definitions to be locally applied.

This work addresses some questions to assess the relationship between snow droughts and their impact on water scarcity (hydrological drought) in several catchments within the Sierra Nevada area: Do precipitation and snow drought have a similar impact on hydrological droughts? Can the standard drought indexes describe snow droughts and their potential impact on river flow?. Following this, both SPI and an Standardized Snowfall Index (SSI, defined as SPI but using snowfall data) are calculated in the study area on different time scales for a reference period of 40 years (1960-2000), together with SDI from the available streamflow time series. Additionally, the period 2000-2021 was also analyzed to validate the conclusions on the capability of such indexes to describe drought conditions in snow domains.

The joint analysis of SSI and SPI on each time scale has allowed us to classify the four potential situations in relation to the occurrence of hydrological drought in the study catchments. The results show the relevant seasonality of snowfall droughts in this area, and the importance of persistent precipitation drought (i.e. duration longer than two years) as antecedent conditions for the impacts of low-snow years on the spring and summer streamflows. The validation performed points out to an increase of the annual variability of the snowfall regime, very much related to a higher torrentiality of the precipitation regime on an annual basis, with impact on the patchy persistence of the snowpack. These conclusions highlight the need for specific snow drought indexes in the framework of EWSs in high mountain areas in the Mediterranean region.