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Evolution of the persistence of snow over Sierra Nevada Mountain (southern, Spain) in the last 55 years

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Snow plays a crucial role in mountainous areas, not only as water resources for human supply, irrigation and energy production, but also for the ecosystem, flora and fauna, over these areas. Sierra Nevada Mountains, southern Spain, constitutes a rich reservoir of endemic wildlife species, and it is considered the most important center of biodiversity in the wester Mediterranean region. The highest regions of the range were declared UNESCO Biosphere Reserve, Natural and National Parks. Climate trends over the last decades put a lot of pressure on both snowfall occurrence and snow persistence; this poses a risk for biodiversity and has led to its inclusion in the Global Change Observatory Network.

This work quantifies the evolution of the persistence of snow over the Sierra Nevada area during the last fifty-five years (1960-2015) as a basis to assess the vulnerability of its ecosystem services. For this, the spatial distribution of the annual number of days with snow, SDS, was analyzed over a study area of 4583 km^2 (140-3479 m.a.s.l.), which comprises the head of the five basins in these mountains. The following indicator variables were studied over the whole area and each one of the five head regions identified: 1) the trend of SDS; 2) the annual area where SDS exceeded selected percentiles in its distribution; and 3) the annual minimum altitude where SDS exceeded those percentiles. SDS was obtained during the study period by means of the snow module in WiMMed (*Watershed Integrated Model in Mediterranean Environment*), a physically-based hydrological model developed, calibrated and validated in the area; the model is based on an energy-mass balance over the snowpack that is spatially distributed through the use of depletion curves, and is operational at hourly and daily scales.

A general decreasing trend of SDS (0.25 days $year^{-1}$) was found over the whole study area for the study period. This value is higher in the more humid basins (0.45 and 0.41 days $year^{-1}$) than in the drier ones (0.15 and 0.18 days $year^{-1}$) where the snow is significant only in very wet years. The minimum altitude at which SDS is higher than the 25^{th} percentile of SDS distribution is increasing at a mean rate of 0.0016 m $year^{-1}$ during the 55-yr period; however, marked differences were found among these years, with and absolute range from 557 to 1594 m.a.s.l., showing the highly variable character of the climate in this region. The observed trend of temperature rather than precipitation seems to be more determining for the snow persistence, with an average correlation coefficient for the whole study period of -0.9 and 0.7 between SDS and the annual mean daily temperature and annual precipitation, respectively. The results led to the further identification of zones facing a significant reduction of the snow presence in the medium and long term, and they constitute a relevant basis to assess the decision-making process for both planning and adaptation actions in the Natural and National Park area.