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Temporal trend of the snow-related variables in Sierra Nevada in the last years: An analysis combining Earth Observation and hydrological modelling

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Climate change is causing declines in snow-cover extent and duration in European mountain ranges. This is especially important in Mediterranean mountain ranges where the observed trends towards precipitation and higher temperatures can provoke problems of water scarcity.

In this work, we analyzed temporal trends (2000 to 2014) of snow-related variables obtained from satellite and modelling data in Sierra Nevada, a Mediterranean high-mountain range located in Southern Spain, at 37ºN.

Snow cover indicators (snow-cover duration, snow-cover onset dates and snow-cover melting dates) were obtained by processing images of MOD10A2 MODIS product using an automated workflow. Precipitation data were obtained using WiMMed, a complete and fully distributed hydrological model that is used to map the annual rainfall and snowfall with a resolution of 30x30 m over the whole study area. It uses expert algorithms to interpolate precipitation and temperature at an hourly scale, and simulates partition of precipitation into snowfall with several methods.

For each snow-related indicator (snow-covers and snowfall), a trend analysis was applied at the MODIS pixel scale during the study period (2000-2014). We applied Mann-Kendall test and Theil-Sen slope estimation in each of the pixels comprising Sierra Nevada. The trend analysis assesses the intensity, magnitude and degree of statistical significance during the period analysed. The spatial pattern of these trends was explored according to elevation ranges. Finally, we explored the relationship between trends of snow-cover related indicators and precipitation trends.

Our results show that snow-cover has undergone significant changes in the last 14 years. 80 % of the pixels covering Sierra Nevada showed a negative trend in the duration of snow-cover. We also observed a delay in the snow-cover onset date (68.03 % pixels showing a positive trend in the snow-cover onset date) and an advance in the melt date (80.72 % of pixels followed a negative trend for the snow-cover melting date). Precipitation does not show a significant trend for these years, even though its inter-annual variability has been outstanding. The maximum mean annual precipitation of 906 mm/year doubles the mean precipitation, which somehow compensates for the occurrence of a sequence of dry years with a minimum of 250 mm/year.

The assessment of the spatial pattern of snow cover duration shows that both the trend and the slope of the trend becomes more pronounced with elevation. At higher elevations the snow-cover duration decreased an average of 3 days from 2000-2014.

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