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Elevation-dependent response of snow cover to climate change in the Romanian Carpathians using satellite imagery

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Highly sensitive to the changes in temperature and precipitation, seasonal snow cover (SC) is an essential climate variable for characterizing the mountain climate and is currently recognized as a primary indicator of climate change. The recent warming was found to alter the spatial distribution patterns and seasonal timing of SC in many mountain regions worldwide. This study focusses on the Romanian Carpathians, where the long-term observational data from the weather stations above 800 m suggest a widespread and significant warming, particularly strong and faster in their low and mid-elevation areas. This study takes the benefits of the space-borne remote sensing to investigate the recent changes in the space-time distribution of SC across the Romanian Carpathians and to depict evidence of elevation-dependent response to climate warming. Combining daily imagery from the moderate resolution sensor of two NASA satellites (MODIS-Terra and MODIS-AQUA), covering the 2001-2017 period, with historical data from a gridded climatic dataset of the EU-CarpatClim project over 2001-2010, we developed a 15-year daily SC dataset to analyse and to understand the vertical anomalies in its spatial distribution (snowline – SL). The ArcGIS Pro for Desktop, with some specialized tools for space-time and emerging hot-spot analyses, and Python batch scripts using ESRI ArcPy API have been employed to download, subset, process and mask each remote sensing product.
The results highlight the sensitivity of SC, but also the complexity of its response to the ongoing climate warming. The main key findings revealed a dominant decreasing frequency of SC days, a trend towards earlier spring snow melt and visible vertical shifts in SL, sometimes placed above 1,700 m during some warm and snow-scarce winter seasons (e.g. 2006/07, 2012/13, 2015/16). The observed changes in SC extent, SC depletion rates and the SL shifts could explain some of the changes in the timing of spring plant growth, the shorter ski seasons, the low hydropower productions or the occurrence of some snow-related events (e.g. snow avalanche).