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Trend analysis of Alpine spring discharge in Austria: Interplay between climate and catchment characteristics

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Alpine springs play a critical role in water supply systems across mountainous regions and can also serve as key indicators of environmental change and related part of the water cycle. In this study, we analyzed a 24-year historic dataset of spring discharge (1997 to 2020) from 29 monitoring stations operated by the Austrian Hydrographic Service. Our evaluation focused on trends in the volume and timing of both mean and extreme flows throughout the Austrian Alps, where mean catchment elevations reach as high as 2500 meters above sea level.

After clustering the springs into distinct groups based on the Pardé coefficient and autocorrelation analysis, the Mann-Kendall test and Theil-Sen slope estimator were used to assess trends. Findings indicated that springs under nival regimes, primarily driven by snowmelt, have experienced significant increases in winter discharges. The analysis also revealed variations in summer discharge trends, identifying two primary groups: springs at higher elevations in the western Austrian Alps showing positive discharge trends, and springs in the eastern Northern Alps where summer discharges have declined. Furthermore, we observed shifts in the timing of peak and minimum flows, suggesting changes in timing of the hydrological cycles. A general increase or decrease in spring discharge over this period is however not deduced from the data. By integrating these hydrological observations with regional precipitation trends, the study deepened the understanding of the interplay between meteorological and hydro(geo)logical dynamics, providing new insights into how climatic variables affect the sensitive Alpine runoff. These results highlight the complexity and regional variability of mountain water systems' responses to climate change, underscoring the necessity for adaptive water resource management strategies in these regions.

This study makes a significant contribution to ongoing efforts aimed at modeling and predicting the impacts of climate change on Alpine hydrology. It highlights the critical need for continued monitoring and advanced analytical methodologies to understand the complex relationships between climatic factors and hydrological responses in high-altitude environments.

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