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Amplification of annual and diurnal cycles of alpine lightning over the past four decades

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Motivation: The response of lightning to a changing climate is not fully understood. Historic trends of proxies known for fostering convective environments suggest an increase of lightning over large parts of Europe. Since lightning results from the interaction of processes on many scales, as many of these processes as possible must be considered for a comprehensive answer.

Objectives: Our aim is a probabilistic reconstruction of summer lightning over the European Eastern Alps down to its seasonally varying diurnal cycle. This necessitates consideration of many processes which becomes feasible by combining a statistical learning approach with several recent scientific achievements: Decade-long seamless lightning measurements by the Austrian Lightning Detection & Information System (ALDIS) and hourly reanalyses of atmospheric conditions including cloud micro-physics within the fifth generation ECMWF atmospheric reanalysis (ERA5).

Methods: These two data sets have been linked by the statistical learning approach called generalized additive model (GAM). GAMs are capable to identify nonlinear relationships between the target variable (lightning yes/no) and explanatory variables (ERA5). The most important explanatory variables have been selected objectively using a combination of stability selection and gradient boosting. This objective selection has reduced the pool of 85 potential ERA5 variables to the 9 most important ones. This reduced set still represents a large variety of processes including favorable environments for thunderstorms, charge separation and trigger mechanisms. The performance of the resulting GAM has been tested using cross-validation over the period of 2010-2019.

Results: With the resulting GAM lightning for the Eastern Alps and their surroundings has been reconstructed over a period of four decades (1979-2019). The most intense changes occurred over the high Alps where lightning activity doubled in the past decade compared to the 1980s. There, the lightning season reaches a higher maximum and starts one month earlier. Diurnally, the peak is up to 50% stronger with more lightning strikes in the afternoon and evening hours. Signals along the southern and northern alpine rim are similar but weaker whereas the flatlands north of the Alps have no significant trend.