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Upward lightning at tall structures: Atmospheric drivers for trigger mechanisms and flash type

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Despite its scarcity, upward lightning initiated from tall structures causes more damage than common downward lightning. One particular subtype with a continuous current only is not detectable by conventional lightning location systems (LLS) causing a significantly reduced detection efficiency. Upward lightning has become a major concern due to the recent push in the field of renewable wind energy generation . The growing number of tall wind turbines increased lightning related damages. Upward lightning may be initiated by the tall structure triggering the flash itself (self-triggered) or by a flash striking close by (other-triggered).

The major objective of this study is to find the driving atmospheric conditions influencing whether an upward flash is self-triggered or other-triggered and whether it is of the undetectable subtype. We explore upward flashes directly measured at the Gaisberg Tower in Salzburg (Austria) between 2000 and 2015. These upward flashes are combined with atmospheric reanalysis data stratified into five main meteorological groups: cloud physics, mass field, moisture field, surface exchange and wind field. We use classification methods based on tree-structured ensembles in form of conditional random forests. From these random forests we assess the meteorological influence and find the most important atmospheric drivers for one event or the other, respectively.

Whether upward lightning is self-triggered or other-triggered can be reliably explained by meteorology. The closer the -10 °C isotherm is to the tall structure, the higher is the probability of self-triggered flashes. On the other hand, lower proportions of solid hydrometeors, supercooled liquid water and lower amounts of large scale precipitation increase the probability of an initial continuous current only flash type. However, the occurrence of nearby lightning discharges is about ten times more important for the type of upward flash. No nearby discharges (or them being further than 4 km away) considerably increases the probability of the initial continuous current only flash type.