Geophysical Research Abstracts
Vol. 20, EGU2018-14203, 2018
EGU General Assembly 2018

Chemical impact of halos and elves in the atmosphere produced by different types of lightning discharges

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We have developed two self-consistent electrodynamical models coupled with a set of about 1000 chemical reactions to study the inception and evolution of halos and elves, two lightning-produced Transient Luminous Events (TLEs) taking place near the lower ionosphere. One of these models allows us to simulate the local chemical impact of a halo one second after its extinction, while the other can be used to simulate elves produced by different types of lightning discharges. The chosen chemical scheme is capable of predicting the ro-vibrational spectra of these TLEs and the production of some important atmospheric species.

Cloud-to-ground (CG) lightning discharges produce an electromagnetic field that can trigger the inception of halos and elves. Halos are glow-discharges with a lateral extension of about 50 km, while elves are fast optical emissions with a radius of hundreds of kilometers produced by the heating of electrons. These two types of TLEs can trigger a cascade of chemical reactions that lead to the production of chemical species such as, for instance, N, NO_x or N2O.

Apart from CG lightning, some impulsive discharges can also radiate electromagnetic pulses and produce elves. It is the case of the Compact Intracloud Discharges (CIDs) and the Energetic In-cloud Pulses (EIPs). In addition of triggering elves, EIPs seem to be related with Terrestrial Gamma-ray Flashes (TGFs) [1]. TGFs are observed as bursts of gamma-ray produced in thunderstorms, although their physical production mechanism is still unknown. Therefore, the knowledge of the optical characteristics of elves produced by EIPs could be useful to explore possible inception mechanisms of TGFs.

According to our results, CIDs and EIPs produce the inception of an “elve doublet”, as previously modelled by [2] and [3]. However, the spectra of these TLEs would depend on the lightning peak current instead of on the type of the parent discharge. In addition, we have quantified the local chemical impact of halos and elves. We have used the halo and elve occurrence rate recorded by ISUAL together with our results to provide an approximation to the global chemical impact of these TLEs. According to our estimations, the mesospheric production of NO_x by halos and elves is about 7 orders of magnitude lower than the NO_x produced by lightning discharges in the troposphere.

References

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