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Leader discharge stepping in dry and humid air

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Long spark discharges of about one meter and natural lightning show a polarity asymmetry. While positive discharges propagate continuously, negative discharges propagate in a stepped manner. This stepped propagation is mediated by the so-called space stem, an isolated region in the streamer corona of depleted electron density and enhanced electric field. Kostinskiy et al. 2018 [1] reported the stepping of positive leaders under high humidity conditions and Malagón-Romero et al. 2019 [2] showed that positive leader steps, if they exist, would be shorter and thus harder to observe in experiments.

In this work we present the results of our simulations for the evolution of a space stem precursor [2] under dry and humid air conditions. These results show that the presence of water molecules enhances the electric field and the heating rate of the space stem, reaching 2000 K considerably faster than in dry air. This could make feasible the stepping of positive leader discharges under high humidity conditions as observed by Kostinskiy et al. 2018 [1].

[1] Kostinskiy, A. Y., Syssoev, V. S., Bogatov, N. A., Mareev, E. A., Andreev, M. G., Bulatov, M. U., & Rakov, V. A. (2018). Abrupt elongation (stepping) of negative and positive leaders culminating in an intense corona streamer burst: Observations in long sparks and implications for lightning. *Journal of Geophysical Research: Atmospheres*, 123, 5360–5375.

[2] Malagón-Romero, A., & Luque, A. (2019). Spontaneous emergence of space stems ahead of negative leaders in lightning and long sparks. *Geophysical Research Letters*, 46, 4029–4038. <https://doi.org/10.1029/2019GL082063>