URSI AP-RASC, Sydney, Australia, 17-22 August 2025

Lightning corona sheath structure and side needles

G. Maslowski
(1) Rzeszow University of Technology, Poland, e-mail: maslowski@prz.edu.pl

In addition to the development of the longitudinal lightning channel, the dynamics of phenomena occurring transversely to this channel play a very important role in the mechanism of lightning discharges. This results from the close relationship between the charge forming well-conducting core and deposited within the corona sheath during the leader stage, and that which is neutralized in the lightning return-stroke stage. Assuming a specific longitudinal current, the dynamics of the lightning corona sheath were described strictly for the first time in [1].

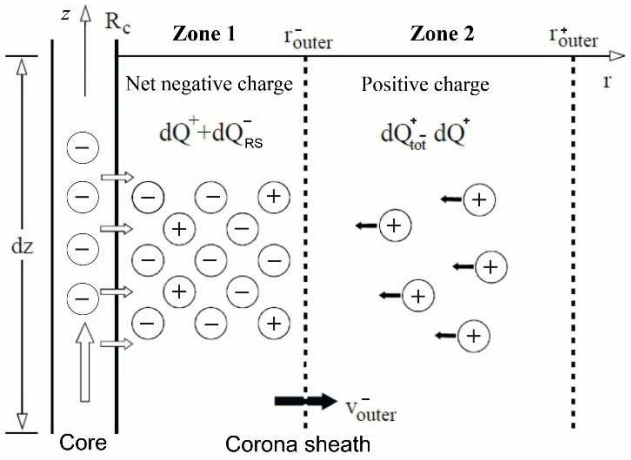

Figure 1. Lightning channel segment of +CG during return stroke stage

The proposed in [1] model predicted: (1) a dynamically developing lightning corona sheath consisting of two zones (sometimes referred to as reverse corona) with positive and negative charges in the lightning return-stroke stage (Fig. 1); (2) electrical conductivity of the return stroke corona sheath of the order of 10^{-6}–10^{-5} S/m; (3) velocity of the return-stroke corona sheath expand that is between 10^4 m/s and 10^5 m/s (except for the first microsecond when this velocity briefly exceeds 10^6 m/s); (4) energy dissipated in the lightning return-stroke corona sheath which is comparable to that dissipated in the channel core.

Such structure and dynamics of the lightning corona sheath make it possible to explain the recently discovered side electric discharges, which were briefly called needles [2]. The needles are observed so far as negatively charged thin plasma structures extending sideways from a positively charged lightning channel. Although the mechanism of the formation of the reverse corona is slightly different in the case of the development of the positive leader and the return stroke stage during the positive cloud to ground lightning (+CG), in both cases we are dealing with a net negative charge distributed close to the channel core and a positive charge outside. Such a structure of the lightning corona sheath can cause in certain places along the channel and under favorable electric field conditions rapid leakage of the negative charge even beyond the outer positive zone of the corona sheath [3].

1. G. Maslowski and V. A. Rakov, "A study of the lightning channel corona sheath," *Journal of Geophysical Research* 2006, Vol. 111, Issue D14, doi: 10.1029/2005jd006858.

2. B. M. Hare, O. Scholten, J. Dwyer, T. N. G. Trinh, S. Buitink, S. Ter Veen, et al., "Needle-like structures discovered on positively charged lightning branches," *Nature* 2019, Vol. 568, Issue 7752, Pages 360-363, doi: 10.1038/s41586-019-1086-6.

3. B. Wu, Q. Qi, W. Lyu, Y. Ma, L. Chen, F. Lyu, et al., "High - Speed Video Observations of Needles Evolving Into Negative Leaders in a Positive Cloud - To - Ground Lightning Flash," *Journal of Geophysical Research: Atmospheres* 2023, Vol. 128, Issue 21, doi: 10.1029/2023jd039523.