Electrostatic Mechanism of Lightning Associated Infrasonic Pulses

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This paper focuses on electrostatic mechanism of production of infrasonic pulses from thunderstorms predicted by C. T. R. Wilson [Phil. Trans. R. Soc. London A, 221, 73, 1920]. Thunderstorms represent significant sources of infrasonic wave activity spanning a broad altitude range from the troposphere and up to the thermosphere [e.g., Blanc, Ann. Geophys., 3, 673, 1985; Few, in Handbook of Atmospheric Electrodynamics, Vol. 2, edited by H. Volland, pp. 1-31, CRC Press, 1995; Drob et al., JGR, 108, 4680, 2003]. The observations of electrostatically produced of 0.1-1 Hz infrasonic waves from thunderclouds [Few, 1995] and recent discovery of infrasound from lightning induced transient luminous events in the mesosphere called sprites [Liszka, J. Low Freq. Noise Vibr. Active Control, 23, 85, 2004; Farges et al., GRL, 32, L13824, 2005; Liszka and Hobara, JASTP, 68, 1179, 2006] represent two examples of thunderstorm related infrasonic waves. The understanding and classification of different infrasonic waves and their sources is of great current interest from a Comprehensive Nuclear-Test-Ban Treaty (CTBT) verification perspective [e.g., Assink et al., GRL, 35, L15802, 2008]. It has been pointed many decades ago by C. T. R. Wilson [1920] that sudden reduction of the electric field inside a thundercloud immediately following a lightning discharge should produce an infrasound signature. Wilson [1920] noted that the pressure within a charged cloud must be less than the pressure outside, similarly to that within a charged soap bubble. In contrast to the sudden expansion of the air along the track of a lightning flash, the sudden contraction of a large volume of air must furnish a measurable rarefaction pulse [Wilson, 1920]. Many experimental and theoretical contributions followed these predictions by C. T. R. Wilson (see [Few, JGR, 90, 6175, 1985] and extensive list of references therein). In the present work, a model based on linearized equations of acoustics with classical viscosity and atmospheric gravitational stratification effects is employed to study electrostatic production of 0.1-1 Hz infrasonic waves from thunderclouds, with particular emphasis on the still poorly understood initial compression phase of the observed infrasonic waveforms. It is demonstrated that a growth of charge density in thundercloud prior to lightning discharge on time scales on the order of 2 to 6 seconds, comparable to typical documented time scales of generation of charge in thunderclouds, leads to formation of a pressure reduction in thundercloud, which is always accompanied by emission of compression waves closely resembling those observed in experiments prior to arrival of a rarefaction pulse generated in accordance with the electrostatic mechanism originally proposed by Wilson [1920] and further developed by Dessler [JGR, 78, 1889, 1973] and Few [1985]. The arguments advanced in the present study agree with the ideas by Bohannon et al. [GRL, 4, 49, 1977] indicating a rapid intensification of the field prior to the lightning discharge. However, we provide a quantitative demonstration that the intensification does not need to be as fast as 0.5 seconds proposed in [Bohannon et al., 1977].