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On the origin of thunder infrasound: Reconstruction of lightning flashes, statistical analysis, and modeling

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Thunder from 27 natural lightning flashes of three thunderstorms has been recorded in 2012 in Southern France in the 0.1–180 Hz frequency bandwidth, using a 50 m-wide triangular array of 4 recalibrated microphones in the 0.3–20 km distance range from lightning. Source reconstruction allows the separation, within the acoustical signal, of Cloud-to-Ground (CG) from Intra-Cloud (IC) parts of the discharge. The possibility to separate nearby CG events is shown. A total of 36 CG signals and associated spectra is obtained, along with some IC signals. The combination of reconstruction, separation, and frequency analysis provides new insights on the origin of thunder that will be discussed.

Thunder infrasound is shown unambiguously to originate dominantly from return strokes linking cloud to ground. Our observations contradict one of the theories proposed for thunder infrasound emission, and linking thunder to electrostatic pressure release occurring within the cloud. On the contrary, it is in agreement with the theory explaining thunder as resulting from the sudden and intense air compression and heating – typically 20,000 to 30,000 K – within the lightning stroke. The second main result of our observations is the strong dependence of thunder characteristics with distance between the lightning and the observer. Though a common experience, this dependence had not been clearly put in evidence in the past. Lastly, a link between acoustic energy and impulse Charge Moment Change (iCMC) is also indicated, at least for +CG.

We have developed a theoretical model of thunder in order to explain these features. A tortuous shape for the lightning strike between cloud and ground is randomly chosen, respecting the flash tortuosity statistics. Taking into account the propagation of each part of the lightning channel towards a virtual microphone, the impulsive response of the atmosphere is calculated. This impulsive response is convoluted with the waveform signal emitted by each part of the channel. This waveform is the acoustic wave produced by a giant spark, itself solution of the radiative hydrodynamics equations. Many cases of simulated thunder have been carried out. These results are statistically compared with our recordings. We discuss how many of our observations are qualitatively recovered by the model. Particularly, the extended and cylindrical aspect of the lightning channel enables the generation of the low-frequency content (infrasound) of the thunder, while its tortuosity adds a very strong variability of the spectra when the flash touches down within 1 km of the microphone. The possibility to evaluate the released energy within the flash by acoustical measurement is finally discussed.