High Speed Video Observations of Natural Lightning and Their Implications to Fractal Description of Lightning

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Abstract

Recent high speed video observations of triggered and natural lightning flashes have significantly advanced our understanding of lightning initiation and propagation. For example, they have helped resolve the initiation of lightning leaders [Stolzenburg et al., JGR, 119, 12198, 2014; Montanyà et al, Sci. Rep., 5, 15180, 2015], the stepping of negative leaders [Hill et al., JGR, 116, D16117, 2011], the structure of streamer zone around the leader [Gamerota et al., GRL, 42, 1977, 2015], and transient rebrightening processes occurring during the leader propagation [Stolzenburg et al., JGR, 120, 3408, 2015]. We started an observational campaign in the summer of 2016 to study lightning by using a Phantom high-speed camera on the campus of Florida Institute of Technology, Melbourne, FL. A few interesting natural cloud-to-ground and intracloud lightning discharges have been recorded, including a couple of 8-9 stroke flashes, high peak current flashes, and upward propagating return stroke waves from ground to cloud. The videos show that the propagation of the downward leaders of cloud-to-ground lightning discharges is very complex, particularly for the high-peak current flashes. They tend to develop as multiple branches, and each of them splits repeatedly. For some cases, the propagation characteristics of the leader, such as speed, are subject to sudden changes. In this talk, we present several selected cases to show the complexity of the leader propagation. One of the effective approaches to characterize the structure and propagation of lightning leaders is the fractal description [Mansell et al., JGR, 107, 4075, 2002; Riousset et al., JGR, 112, D15203, 2007; Riousset et al., JGR, 115, A00E10, 2010]. We also present a detailed analysis of the high-speed images of our observations and formulate useful constraints to the fractal description. Finally, we compare the obtained results with fractal simulations conducted by using the model reported in [Riousset et al., 2007, 2010].

Introduction

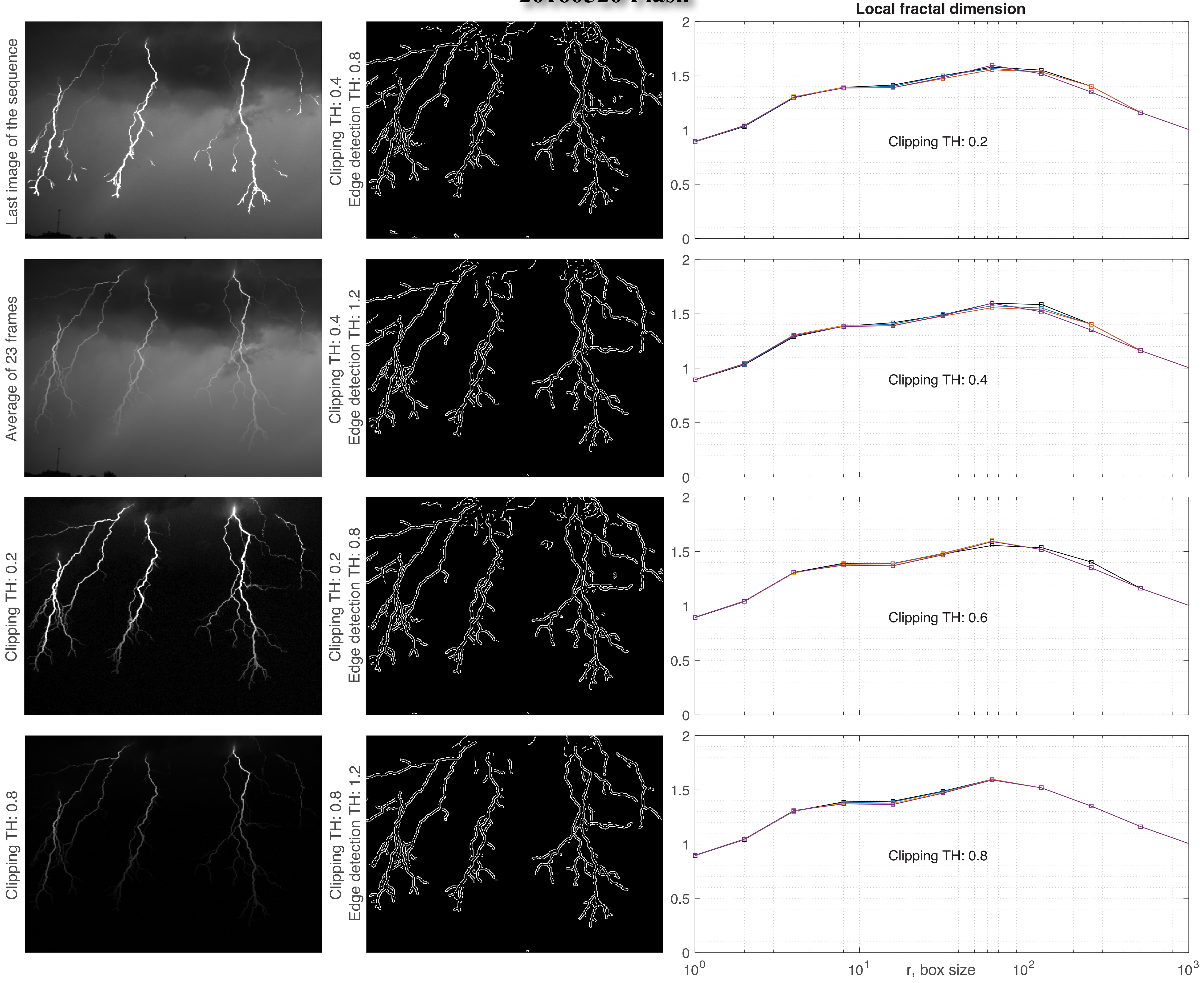
Many recent studies have investigated the details of individual lightning channels or leaders by analyzing the high-speed video observations of lightning [e.g., Hill et al., 2011, Stolzenburg et al. 2014, 2015; Montanyà et al, 2015, Gamerota et al., 2015]. Here we study the overall morphology of lightning with the high-speed images, the fractal dimension of lightning in particular. The images were recorded by a Phantom v1210 camera. Two flashes are analyzed here.

First flash. The first flash was recorded at 7000 fps on May 20, 2016. The storm developed over central FL, and reached its maximum intensity as it moved eastward over Melbourne. It then moved offshore and gradually dissipated. At the time of recording, the camera system didn't have a GPS unit, but after comparing relative timings of subsequent lightning flashes/strokes, it is found that the flash likely corresponds to one of these two NLDN events: 19:47:02.265 28.0558 -80.6499 -14kA, 19:47:02.379 28.0561 -80.6507 -29kA. The distance to the camera is about 2.6 km.

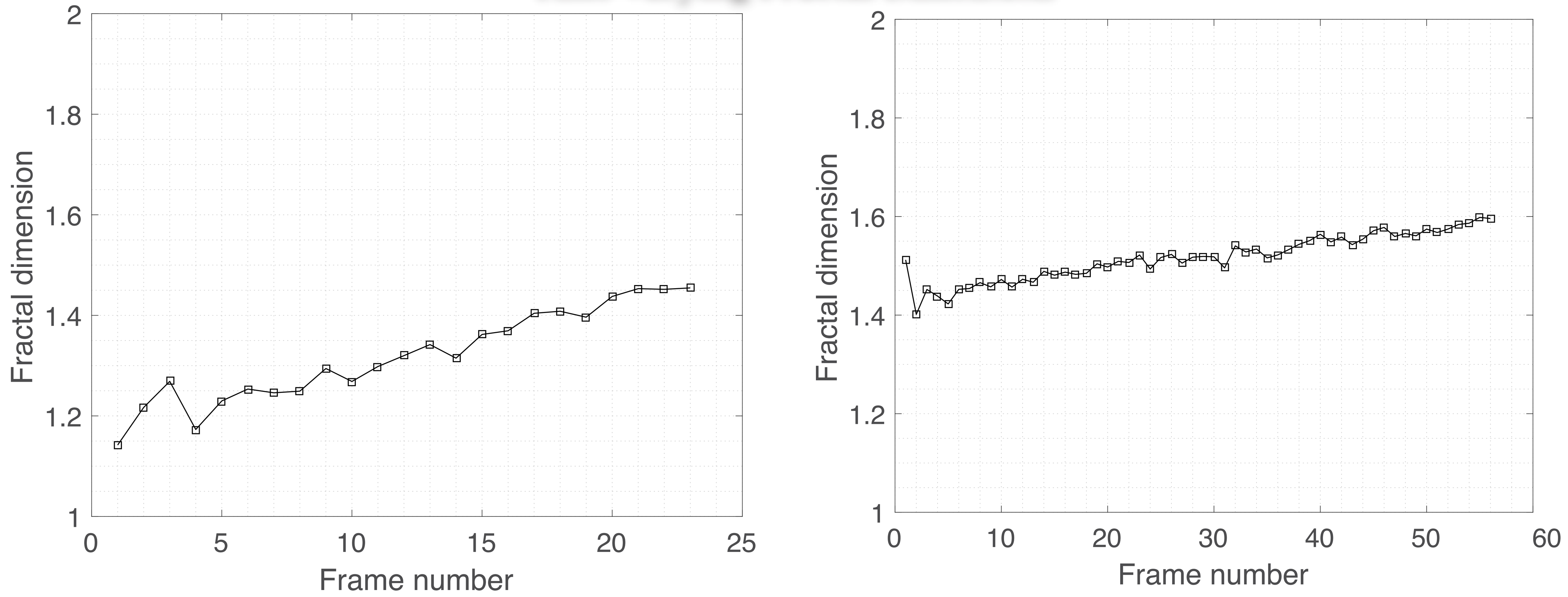
Second flash. The second flash was recorded at 35000 fps on June 14, 2016. It occurred during a short-lived, intense pulse of convection with strong divergence at the cloud top. The flash is a BFB discharge and corresponds to this NLDN record: 20:33:20.005 28.0411 -80.6864 -169.1kA. The distance to the camera is about 6.6 km.

Box counting method. The fractal dimension of the lightning leader is found by using the box counting method. The image is covered by a grid with a mesh size r, and the grid boxes that contain any part of the lightning leader are counted. The obtained number N(r) depends on the size r. The fractal dimension is the ratio of the logarithms of N(r) and 1/r.

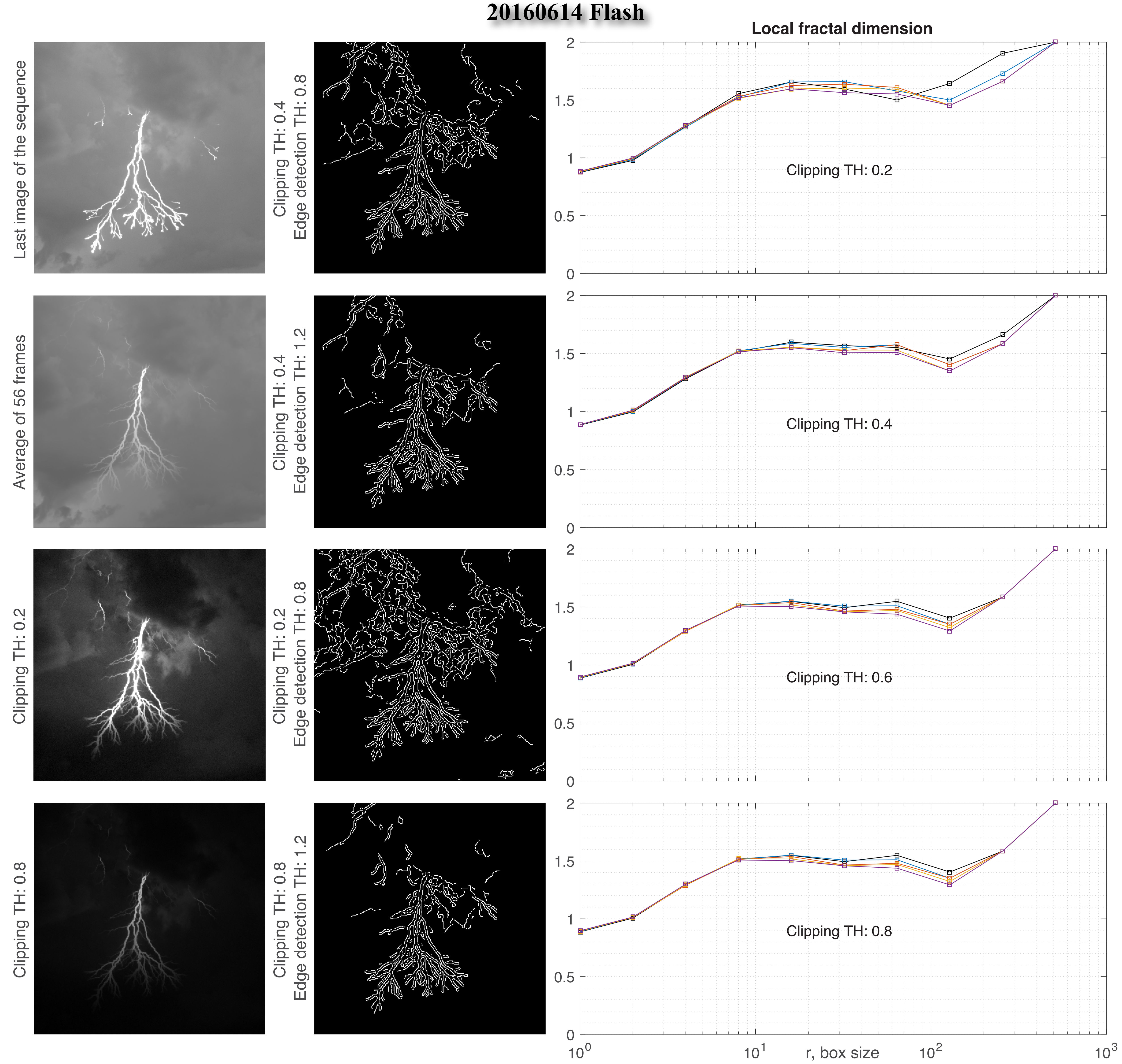
20160520 Flash



Time-varying Fractal Dimension



20160614 Flash



Summary and Conclusion

1. The high-speed images of the two lightning flashes analyzed in this study show they have complex temporal and spatial properties.

2. The fractal dimension of the lightning leader found by using the box counting method varies from 1.4 to 1.6 for one flash and from 1.5 to 1.6 for the other, when the lightning almost reaches ground.

3. As the lightning leader propagates downward, the fractal dimension increases. The rate of the increase is different between the two flashes.

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