Negative sprites produced by consecutive impulse charge transfers in negative strokes

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Abstract.

On June 5, 2013, the SpriteCam network recorded a relatively weak sprite over a thunderstorm in Oklahoma. The broadband magnetic fields recorded at multiple stations consistently indicate that this event was produced by a negative cloud-to-ground (CG) event that probably contained two ground strokes separated by about 3 ms. Although neither stroke caused substantial impulse charge moment change that is sufficient to produce a negative sprite, the contributions of the two strokes are combined so that. The similar sprite-associated sferic waveform is also observed for a negative sprite recorded by ISUAL from space on August 15, 2012. In this case, the negative sprite appeared to be unusually bright due to the electric field enhancement cased by the second stroke. Therefore, the intrinsic complexity in the parent stroke is probably responsible for the observed variance in the morphology of negative sprites.

1. Introduction

Previous observations of sprites produced by negative cloud-to-ground (CG) lightning strokes consistently indicate that the sprite-producing strokes usually generate impulse charge moment change (iCMC) over -450 C km [*1, 2, 3, 4*]. Also, negative sprites typically appear to be dimmer than their positive counterpart although the associated impulse charge moment change could be up to -1050 C km [*4, 5*]. Bright sprites, which are typically accompanied by halo, usually also induce measurable ultra-low frequency (ULF) magnetic pulse at thousands of kilometers range [*6*]. The negative sprites are almost always accompanied by halo, where there is no observation yet of ULF magnetic pulse driven by charge flow along the sprite body. In this paper, we declare that although previous work seems to derive some common features on the morphology of negative sprites, the complexity in the current moment of parent strokes is still capable of causing some variances.

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2. Observations and discussions

On June 5, 2013, the SpriteCam network captured a negative sprite that is not considerably dimmer than previous observations. As shown in Figure 1, the halo feature is discernible (especially in the imaging result from Lubbock, Texas). The very-low frequency (VLF, 50 Hz to 30 kHz) data recorded at 1900 km range near Duke University indicate that this event was probably associated with two negative CG strokes separated by ~3 ms. Both impulse current pulses induced comparable iCMC of about -280 C km. This stroke was about 291 km from the origin of the Oklahoma LMA, and thus the associated in-cloud structure cannot be characterized. However, the examination of lightning data recorded by the U.S. National Lightning Detection Network (NLDN) indicates that this stroke was likely the first event (with a high peak current of -103 kA) of a sequence of at least six strokes in a multi-stroke negative CG flash. The stroke associated with the second current pulse was not detected by the NLDN. However, the low-frequency magnetic fields were recorded at multiple stations, and we are still able to locate this stroke to be within a few hundred meters of the major stroke [*7*]. Therefore, the possible that the magnetic pulses recorded at Duke were driven by two strokes at different places that occurred close in time is excluded. Also, the signal from the preliminary breakdown is not clear in this case, and thus it is very likely that the lightning morphology associated with this event is also different from that identified to be most likely associated with negative strokes [8].

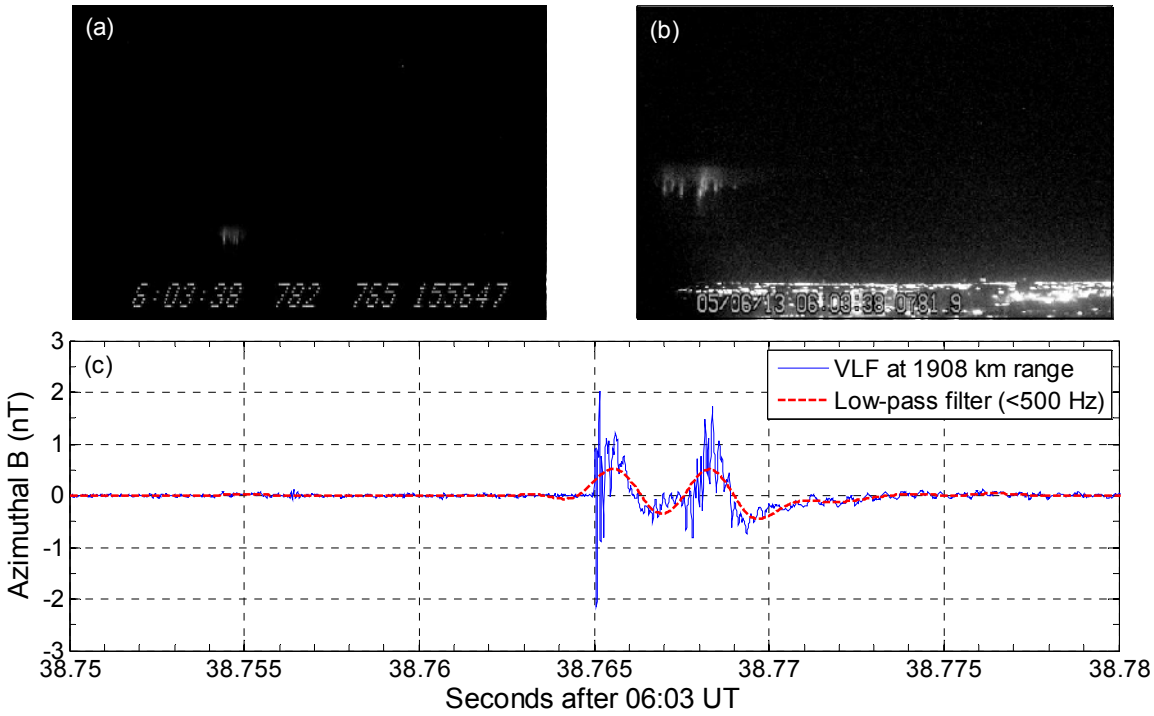

Figure 1. (a,b) Observation of a negative sprite by two low-light level video cameras located in Hawley and Lubbock in Texas. (c) Broadband very-low frequency magnetic fields recorded at 1980 km range near Duke University indicate that this sprite might be associated with two strokes that produced comparable impulse charge moment change (approximately -280 C km).

The electrical field perturbation caused by these two strokes at 80 km altitude, as calculated from a numerical model using the finite-difference time domain (FDTD) method [*9*], is comparable to a single negative stroke with iCMC of -450 C km.

The similar current moment waveform associated with negative sprite are also identified in the dataset of ISUAL, where the negative sprite was unusually bright, as shown in Figure 2. The impulse charge moment change of the first stroke (-450 C km, with peak current of -99 kA) was actually sufficient to produce sprite, while the subsequent stroke with an extra impulse charge moment change (about -200 C km) seems to contribute to the abnormal brightness of the event. In previous observations, the negative sprite appeared to be dim, which is most likely due to that the intense continuing current is very rare for negative strokes [*4*]. However, the occurrence of a subsequent stroke with short delay plays a similar role to the continuing current and thus the streamer part in the negative sprite is capable of developing further. Note that it is also possible that the second magnetic pulse was actually driven by the current flow along the sprite body, which has been frequently observed for positive sprites (10). Nevertheless, this sprite is very unusual in its remarkable brightness and the associated current moment waveform. These two possibilities will be further discussed with data available.

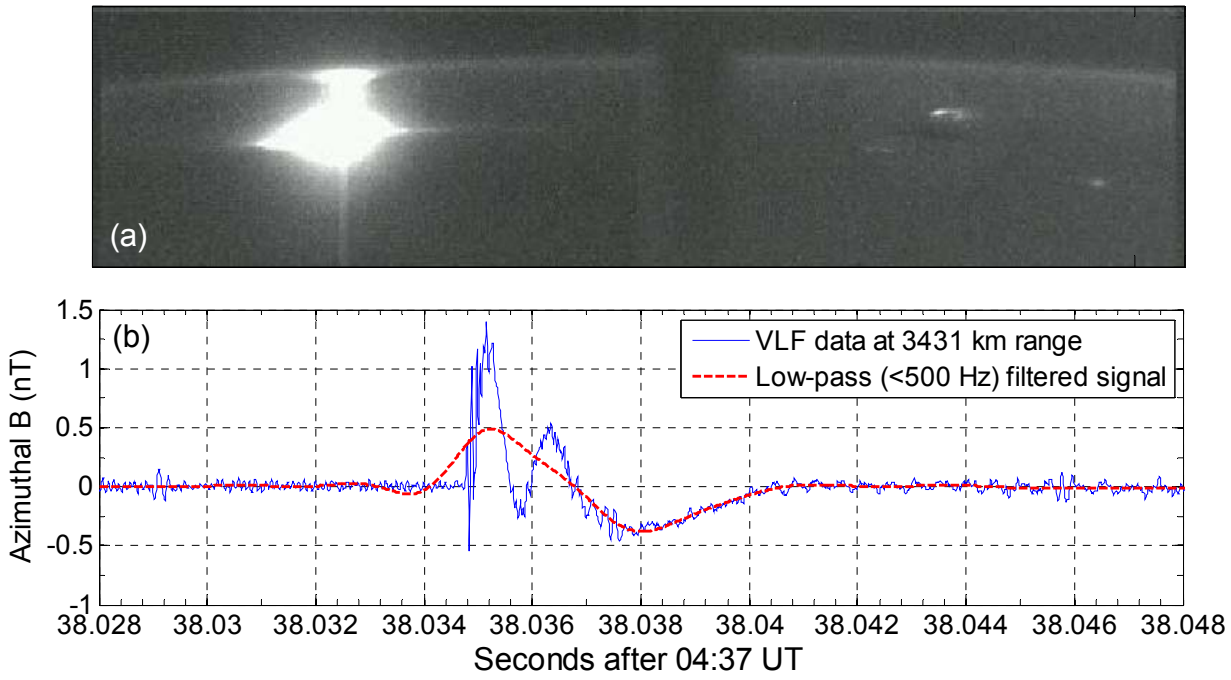

Figure 2. (a) Observation of a negative sprite by ISUAL on August 15, 2012. (b) Broadband very-low frequency magnetic fields recorded at 3431 km range near Duke University indicate that this sprite might be associated with two strokes that produced comparable impulse charge moment change (approximately -450 C km). Note that the photometric array data cannot exclude the possibility that the second current pulse was actually produced by the current along the sprite body, which is also very unusual if that is the case here.

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4. References

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