System Feasibility of Transient Luminous Events Observation at the Summit of Mt. Fuji

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Abstract. We conducted a summer observation campaign of transient luminous events (TLEs) in 2019 at the summit of Mt. Fuji. A newly developed color full-HD remote camera system, monochrome charge-coupled device (CCD) cameras, and the receiver of very low frequency (VLF) band lightning detection system operated by Blitzortung.org were installed there. During the observation period, we obtained many events of the parent thunderstorm associated with lightning strikes identified by Blitzortung.org and the color optical flash image. Moreover, a sprite (one of TLEs) and the sprite-producing strike were detected by a monochrome CCD camera and Blitzortung lightning detection network, respectively. It was reasonable to estimate the location of lightning strikes in the Kanto area of Japan using Blitzortung.org. The results show that the observation system at the Mt. Fuji is feasible to promote the TLEs study.

Keywords: transient luminous events, lightning, Mt. Fuji, color full-HD remote camera

1. Introduction

Transient luminous events (TLEs) are generated over the thunderstorm at the troposphere and mesosphere. The examples of TLEs family are red sprite, halo, blue jet, elves, and gigantic jet. The TLEs are produced by huge thunderstorm systems, which generate vigorous cloud-to-ground strokes (CG), such as mesoscale convective systems (MCSs), and by winter thunderstorm with a huge charge. The sprite and elves are produced at the sub-ionosphere. Both phenomena are generated by the interaction between intense CG and the ionosphere and induced by the CG. The sprite is generated by a quasi-electric field above the thunderstorm produced by +CG. The elves is generated due to an electromagnetic pulse generated by intense CG. The blue jet and gigantic jet develop directly from the top of the thunderstorm toward the ionosphere. The development of a blue jet terminates up to the stratosphere. The gigantic jet reaches the ionosphere. The TLEs are associated with intense and vigorous CG activity. Such strong CG activity also occurs in Kanto, Japan, during the summer (Ishii et al., 2014). This would suggest that many TLEs occur above the Kanto plains. The TLEs occur above the thunderstorm but TLEs are generally observed from the ground. The success of observation depends on the weather condition between the TLEs and the observer. In other words, the TLEs cannot be observed when a cloud interrupts the view of sight. To resolve the issue, we have conducted the TLEs observation at the summit of Mt. Fuji during the summer since 2013. Mt. Fuji is an isolated mountain and its altitude is 3776 m. Our observation would not be interrupted by the low cloud. Therefore, the Mt. Fuji is ideal place.

In general, some of TLEs have been hardly captured even by sensitive and precise Very High Frequency (VHF) lightning observation, because the amplitude of some TLEs-related VHF signals would be very weak (Krehbiel et al., 2008). Therefore, optically capturing TLEs and lightning flash in color images are ideal to understand both the properties of TLEs and their-producing lightning. In addition, two-dimensional lightning location system with recording the radio waveform data provides the location and properties of their-producing lightning. Blitzortung lighting detection network at Very Low Frequency (VLF) band provided the two-dimensional CG location and the observed waveform data. More than 50 detection receivers have been deployed in Japan (Narita et al., 2018). We participate in Blitzortung lighting detection network and make plan to
In this paper, we introduce the newly-designed color full-HD camera system and Blitzortung lightning detection network. Then, we report the feasibility of Blitzortung lightning detection network and the preliminary results of TLEs observation campaign.

2. Instruments

The color full-HD camera in the system was high-sensitivity color digital single-lens reflex camera SONY Alpha 7S with Sonnar T* FE55mm F1.8 ZA lens. Movie and picture are outputted from a High-Definition Multimedia Interface (HDMI) port of Alpha 7S and are inputted into a laptop personal computer (PC) via a video capture device. This system provides time-lapse pictures and movies. The maximum transfer rates to the capture device of time-lapse pictures and full-HD movies (1280x960 pixels) are every 1 second and 29.97 frames per second, respectively. Time-lapse pictures were taken by a remote camera control software. Movies were captured by motion-detection-time-shifted video-recording software (UFO Capture HD2). Alpha 7S with a lens was housed in the all-weather clear waterproof case. The other components, such as a PC and capture device, were stored in the other waterproof case. Both cases were mounted at the outside of MFRS (Figure 1). Alpha 7S was set to automatic iris mode. Shutter speed was fixed 1/60s. The time-lapse pictures were taken every 1 minute in the daytime. The movies initiated by motion detection were captured in the nighttime. This camera was set toward the north-northeast. To validate an event captured by Alpha 7S, we also installed two monochrome CCD cameras WATE-902H3U with the lens of focal length 4mm, which produces VGA (640x480) image. Two cameras were aimed toward the north-northeast and northeast to cover the view from Kanto to the middle of Tohoku. A Blitzortung lightning detection network operated by Blitzortung.org is maintained by volunteers. The Blitzortung network locates electromagnetic signal sources generated by lightning strikes in very low frequency (VLF; 3-3 kHz) band. Lightning source locating is based on the estimation of the time of arrival (TOA) and time of group arrival (TOGA) method. The network consists of more than 500 lightning receivers and some central processing servers. Each receiver is synchronized Global Positioning System (GPS) time. The lightning signals are recorded in one millisecond with a sampling rate of more than 500 kHz. The
recorded signal data stamped by the GPS time is sent to processing servers via the internet. The lightning positions data is provided in a raw format accessible only to users participating in Blitzortung.org. However, the precise detection rate and accuracy of the Blitzortung lightning detection network have not been investigated in detail. Many Blitzortung receivers have been in operation in Japan by volunteers (Narita et al., 2018). We also deployed about 10 receivers in Japan. Especially, two receivers with three magnetic core coil antennae were installed inside of the MFRS and the Gotenba (South-east foot of Mt. Fuji) observatory of the MFRS during the campaign of 2019.

3. Results and Discussion
We detected many lightning flashes and the parent thunderstorm using the color camera system and monochrome CCD cameras during the campaign of 2019. The first simultaneous observations between lightning flash observed by optical observations and lightning strikes identified by the Blitzortung system were successful. Moreover, we found the first sprite event associated with strikes identified by the Blitzortung system. The sprite could not be captured by color full-HD movie, because hard disc storage was full due to active lightning recorded before the detection of sprites. However, the monochrome CCD camera could capture the sprite. We show the following two events: one is an optical flash event associated with lightning strikes, and the other is the sprite event associated with lightning strikes. Both events were analyzed with the color full-HD movie, Blitzortung strike, and Japan Meteorological Agency’s (JMA) composite radar data.

Figure 2 shows that the images for lightning flash and its parent thunderstorm at 11:20UTC on Aug. 2 of 2019 clipped from the color full-HD movie. We can find time series of lightning flash and luminosity inside the cloud in the pictures. Stars were also seen in the images in addition to the flash, thunderstorm, and upper cloud. This sighting shows that Alpha 7S has the

![Figure 3. JMA radar echo at 11:20 UTC on Aug. 2 of 2019. Right panel is an enlarged image in the square in left panel. The flash in Figure 2 was generated by the isolated thunderstorm (Solid circle). Blitzortung strikes from 11:10 to 11:20 UTC are shown. White and black dots correspond to the flash shown in Figure 2 and other strikes, respectively.](image)

![Figure 4. A sprite observed from Mt. Fuji (event time: 12:04:39.333UTC, Aug. 8 of 2019).](image)
capability of a very wide dynamic range to detect weak light.

Figure 3 shows JMA radar echo image with Blitzortung strikes associated with the flash shown in Figure 2. It is found that the parent thunderstorm was an isolated thunderstorm. The flash shown in Figure 2 and the Blitzortung strikes were simultaneously observed. Note that the time accuracy of the flash occurrence was less than 1s.

Figure 4 shows the only sprite observed in this campaign, including several elements in the different morphology. The several columnar sprites and intermediate one were generated.

Figure 5 shows the JMA radar echo and Blitzortung strikes in the sprite event in Figure 4. The sprite-producing strike is located at the stratiform precipitation region of MCSs. This fact implies that the estimation of strike points in the thunderstorm would be convincing.

4. Conclusion

We conducted TLEs observation campaign during the summer of 2019 at the MFRS at the summit of Mt Fuji. The newly-designed color full-HD camera system and Blitzortung lightning detection receivers were operated. Many flashes generated by thunderstorms were captured by the color full-HD camera. Although TLEs were not recorded by the new camera system due to the storage issue, the sprite was observed by a monochrome camera. We found that two cases succeeded in simultaneous observations among Blitzortung strikes, a flash of ordinary lightning, and a sprite event. We further emphasize that the same lightning was detected by Blitzortung and cameras.

In general, most of the lightning strikes were located in the convective region with strong precipitation. Most sprite-producing cloud-to-ground strikes were also located under the stratiform region with relatively weak precipitation. The results of JMA radar and Blitzortung strike points (Figures 3 and 5) correspond to these general properties.

From this campaign, we found that the new color full-HD camera system is feasible for observing optical lightning flash in the thunderstorm. We also show that the Blitzortung strike points related to sprite and ordinary lightning flash are appropriate for the spatio-temporal estimation, at least, in Kanto.

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References

Ishii, K. S. Hayashi, and F. Fujibe (2014), Statistical Analysis of Temporal and Spatial Distributions of Cloud-to-Ground Lightning in Japan from 2002 to 2008, *J. Atmos. Electr.*, Vol.34, No.2, 2014, pp.79-86.

Krehbiel, P. R., J. A. Riouset, V. P. Pasko, R. J. Thomas, W. Rison, M. A. Stanley, and H. E. Edens (2008), Upward electrical discharges from thunderstorms, *Nature Geoscience*, doi:10.1038/ngeo162.

Narita, T., et al. (2018), A study of lightning location system (Blitz) based on VLF sferics, 2018 34th Int. Conf. Lightning Protection (ICLP), Rzeszow, pp. 1-7.