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Coordinated TLE Campaign using ISUAL and NCKU ULF, ELF/VLF Stations

S. M. Huang (1), L. J. Lee (1), J. K. Chou (1), S. C. Chang (1), A. B. Chen (2), H. T. Su (1), R. R. Hsu (1) , C. L. Kuo (3), H. U. Frey (4), Y. Takahashi (5), and L. C. Lee (3,6).

(1) Department of Physics, National Cheng Kung University (NCKU), Taiwan, (2) Institute of Space, Astrophysical and Plasma Sciences, National Cheng Kung University (NCKU), Taiwan, (3) Institute of Space Science, National Central University, Taiwan, (4) Space Sciences Laboratory, University of California, Berkeley, USA, (5) Department of Cosmosciences, Hokkaido University, Japan, (6) Institute of Earth Sciences, Academia Sinica, Taiwan. (sungming.h@gmail.com or simonh@phys.ncku.edu.tw)

Abstract

Imager of Sprites and Upper Atmospheric Lightning (ISUAL in short) payload on the FORMOSAT-2 satellite and two ULF and ELF/VLF radio band recording stations in Taiwan are used to further study the characteristics and the correlation between transient luminous events (TLEs) and their associated sferics. From June 2009 to June 2012, 7,276 elves, 733 sprites, 415 halos, 1,671 blue jets, and 22 gigantic jets (GJs) were recorded by ISUAL. More than 50% of these TLEs were found to have corresponding sferics. In all, ~0.5% of sprite-inducing lightning and 80% of halo-inducing lightning are inferred to be generated by negative discharges. However, in sharp contrast to previous studies, this work found that more than 90% of elves are induced by negative lightning.

1. Introduction

ISUAL onboard the FORMOSAT-2 satellite is a scientific payload dedicating to the study of TLEs and are operating from 891 km sun-synchronous orbits and covering 45°S to 25°N latitude during the northern summer and 25°S to 45°N latitude during the northern winter [1].

Although, many sferics of TLEs had been studied in previous campaigns, it is still worthy to examine more TLE events and their radio signatures. For this work, we enlist ISUAL recorded TLE events, an ULF (0.3 – 500 Hz) [3], and a tri-axes magnetic and vertical electric ELF/VLF (1.5 Hz – 15 kHz for B-field and 0.1 Hz – 100 kHz for E-field) radio recording systems [4].

From June 2009 to June, 2012, 7,276 pure elves, 415 halos (including 174 pure halos and 241 halos with elves), 733 sprites (including 451 pure sprites, 57 sprites with elves, 146 sprites with halos, and 79 sprites with both halos and elves), and 1,671 pure blue jets were recorded by ISUAL and their ULF and/or ELF/VLF associated sferics are examined. However it should be noted that the 22 observed GJs were too distant to our radio stations and thus their associated sferics tend to have a very low signal-to-noise ratio that renders the further analysis to be impossible.

2. Radio signatures of ISUAL recorded sprites, halos and elves

To ensure the true TLE sferics can be identified, three criteria are employed to screen for the associated sferics. The first criterion is the signal-to-noise ratio of the sferics. Only sferics peaks which have 3 (B-ULF) to 6 (B-VLF) standard deviations above the background are selected as the potential candidates. The second criterion is the arrival time. From the event trigger time and the inferred geo-location of the events from the ISUAL data, we are able to compute the arrival time of the associated sferics with a millisecond-level precision. However, there is a reported time drift ~25 milliseconds in ISUAL clock in the previous works. In this report, we have resolved the ambiguity completely. The ambiguity in the ISUAL trigger time is found to be 1.88 milliseconds. Finally and thirdly, the deviations of the sferics bearing angels are set to be less than 10 degrees for the ULF sferics [3] and 20 degrees for ELF/VLF sferics.

Using the resulting sferics data, the event detection rates of our ULF station for pure elves, halos and sprites are ~50%, ~65% and ~40%, respectively. Among them, ~96%, ~80%, and ~0.5% of these events are induced by negative discharges. For multi-TLE events, the associated sferics detection rate of our ULF station for sprites with elves, sprites with halos, sprites with both halos and elves, and halos with elves are ~55%, ~65%, ~70%, and ~60%, respectively. Among them, ~3%, ~40%, ~60%, and ~85% are triggered by negative discharges. The results indicate that a single ULF station is sufficient to detect the TLE associated sferics in the surrounding hemisphere. In the examined dataset, one negative pure sprite was found to occur over Africa and the ratio of the negative polarity is consistent with these reported in *Williams et al.* [6, 7] and *Newsome and Inan* [5]. More surprisingly, 90% of elves are found to be induced by negative lightning; a ratio which is substantially higher that reported in *Frey et al.* [2].

3. Summary and future works

From the radio sferics associated with ISUAL TLEs (Section 2), many interesting results are deduced, includes the sferics detection rate of our ULF station and discharge polarities leading to each species of ISUAL TLEs. In the near future, we will examine the distant effects of the sferics detection, the differences in the sferics signatures of different TLEs waveforms, the charge moment changes, sprite current and the radio sferics emitted by blue jets.

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