Electromagnetic signatures of different forms of gigantic jets above typhoon

Sung-Ming Huang[1], Rue-Rou Hsu[1], Li-Jou Lee[1], Jung-Kuang Chou[1], Shu-Chun Chang[1], Yen-Jung Wu[1], Han-Tzong Su[1], Cheng-Ling Kuo[1], and Alfred B. Chen[2]

[1]*Department of Physics, National Cheng Kung University, Tainan, Taiwan*
[2]*Institute of Space, Astrophysical and Plasma Sciences, National Cheng Kung University, Tainan, Taiwan*

On 31 August 2010, more than 100 TLEs (including sprites and gigantic jets) were observed above the typhoon LIONROCK during a four-hour observation window. Among them, fourteen negative gigantic jets (GJs) with recognizable morphologies and clear radio frequency signals are analyzed. The optical images indicated these 14 GJs can be grouped into tree-like, carrot-like, and tree-carrot-like forms. The radio signals contain clearly signatures associated with various GJ development stages including the initiating lightning, the leading jet, the fully-developed jet, and the trailing jet. The optical and radio data indicate that different group of GJs exhibits distinct optical and radio characteristics. The tree-like GJs have a large surge current moment (CM) (> 60 kA-km); while a continuing CM of less than 27 kA-km seems to be the dividing value that separates the carrot-like GJs and the tree-carrot-like GJs.

1. Introduction

On 31 August, 2010, during the 2010 Taiwan TLE (transient luminous events) ground campaign, typhoon LIONROCK was chosen as the target of the observation. During the observation period between 15:45 and 20:01 UTC (between 23:45 and 04:01 local time), the storm centre was located at ~270 km to ~167 km southwest of Taiwan and more than 100 TLEs (including sprites and dozens of gigantic jets) were observed to occur over the rain band and the eye wall areas. In this work, only fourteen gigantic jets (GJs) that have clear recognizable forms and identifiable ultra-low frequency (ULF) and extremely-low/very-low frequency (ELF/VLF) data are chosen for detailed analysis.

2. The optical features of the negative gigantic jets

From the optical data, two previous reported forms (tree-like and carrot-like [3]) as well as a new form, termed as “tree-carrot-like GJs” are identified. For the new hybrid tree-carrot-like GJs, the morphology of the fully-developed jets (FDJs) first appears to be carrot-like, having a lower body of bright streamers, a dim middle gap with beads, and an upper diffusive crowning glow. However, in the subsequent frames, beads and streamers in the dim gap brighten to fill in the gap, and the FDJ transforms into the tree-like form.

Beside the morphology, the luminous duration of the FDJ stage and the combined luminous duration of FDJ and trailing jet (TJ) stages are also good quantities to differentiate these GJs. The carrot-like GJs have the longest FDJ duration (7 ~ 9 fields), while the tree-like GJs have the shortest (1 ~ 4 fields). The carrot-like GJ also has the longest combined luminous durations (29 ~ 45 fields), and most of the tree-like and the tree-carrot-like GJs have shorter durations (16 ~ 36 fields and 15 ~ 32 fields, respectively).

3. The ULF and ELF/VLF features of the negative gigantic jets

3.1. The initiating lightning and the leading jet

All the GJs were found to have corresponding impulse signals, which were terms as the gigantic jet initiation [1, 2], in the ULF and ELF/VLF band data. The peak current moment (CM) and the charge moment change (CMC) of the initiating lightning for each type of GJs are inferred. It is interesting to note that different groups of GJs tend to occupy different regimes; indicating that the morphological form of negative GJs is constrained by the GJ initiation.

Due to the obstruction of the near clouds and the light-polluted sky, no leading jet was discernible in the optical image footage. However, every GJ has an ULF signal associated with the leading jet. As it was inferred from the ULF signal, the duration of the leading jet ranges from 24 ms to 225 ms with a medium value of 57 ms. Meanwhile, the CMC was found to fall between 39 and 678 C-km with a medium of 354 C-km.

3.3. The fully-developed jet

At the GJ-ionosphere contact, the ULF waveforms for various forms of negative GJs contain a fast-descending signal from the surge current that flows in the discharge channel. The tree-like GJs have the largest surge CMs, which are all greater than 60 kA-km and even up to 159 kA-km. In contrast, the surge CM for the tree-carrot-like and the carrot-like GJs are relatively small, being less than 36 kA-km

3.4. The trailing jet

The trailing jet appears to have an associated long continuing current waveform that follows the FDJ-associated surge current of the GJs. The peak CM of the continuing current for both the tree-like and the tree-carrot-like GJs has a large peak current moment (> 27 kA-km and > 39 kA-km, respectively) as inferred from the ULF sferics, while that for the carrot-like GJs is relatively small (< 27 kA-km).

4. Discussion and future work

The aforementioned results seem to imply that the magnitude of the surge current is a crucial factor in determining the form of the negative GJs. If a negative GJ starts with a sufficiently large surge CM, > 60 kA-km, for the events analyzed in this work, a tree-like GJ is formed. The deciding factor separating carrot-like or tree-carrot-like GJs appears related to the magnitude of the trailing continuing current. If the follow-up continuing CMs are relatively large, > 39 kA-km, the current will enhance the luminosity of the upper trunk of the FDJs and supplies a bright trailing jet in the case of the tree-carrot-like GJs. If the trailing continuing CMs are less than 27 kA-km, dim carrot-like GJs with very dim trailing jets are formed.

After the analysis to these typical GJs, other TLEs and re-bright events [2] are also being explored and further investigated.

5. References

[1] Cummer, S. A., J. Li, F. Han, G. Lu, N. Jaugey, W. A. Lyons, and T. E. Nelson (2009), Quantification of the troposphere-to-ionosphere charge transfer in a gigantic jet, *Nature Geoscience, 2,* 617-620.

[2] Lu, G., et al. (2011), Lightning development associated with two negative gigantic jets, *Geophysical Research Letters, 38,* 12801.

[3] Su, H. T., R. R. Hsu, A. B. Chen, Y. C. Wang, W. S. Hsiao, W. C. Lai, L. C. Lee, M. Sato, and H. Fukunishi (2003), Gigantic jets between a thundercloud and the ionosphere, *Nature, 423,* 974-976.