REPORT
High latitude lightning atmospherics belonging to transient luminous phenomena

Kolmasova Ivana

Abstract
Parameters of lightning discharges that generate Transient Luminous Events (TLE) are reflected in the properties of atmospherics—very low frequency (VLF) electromagnetic signals that propagate over long distances within the waveguide formed by the Earth's surface and the bottom of the ionosphere. During the PITHIA project, I analyzed VLF waveforms recorded at the SGO station in Kannuslehto. These waveforms correspond to energetic winter lightning strokes over the Adriatic region that produced numerous elves. Additionally, I examined waveforms associated with Narrow Bipolar Events (NBEs) identified by the ENTLN lightning location network. NBEs are believed to generate blue jets. SGO provided the raw VLF data on which this analysis was based.

Objective
The motivation for this project arises from the atmospheric science community's need to identify TLEs in continuous, distant electromagnetic data, which are measured very far from thunderstorms. Optical observations capture only a small fraction of TLEs, whereas VLF recordings are collected at various locations worldwide. Among these, the SGO VLF data are considered to be one of the most sensitive recordings.

Project process
My project proposal, as well as the work on the project, was complementary to the project by O. Santolik (HILALI-SPC). We worked together and discussed the results to achieve the best outcome.

Project steps:

- **BEFORE of selected events:**
- Obtaining the list of the lightning strokes from the Adriatic winter storm occurring from 9 to 10.12.2020 with peak currents exceeding 200 kA (nearly 300 events, 1/5 of them produced elves)
- Obtaining a list of NBEs occurring above the latitudes of 50°N (about 50 events)
- **DURING THE STAY AT SGO:**
- Obtaining the raw VLF data for the time of the Adriatic storm
- Obtaining the raw VLF data for the times of the NBEs occurring at higher latitudes
- Search for the signatures of relevant sferics
- Preliminary analysis of the waveforms
- **AFTER THE STAY AT SGO:**
- Detailed analysis of the waveform properties of selected events on order to distinguish between elves producing strokes and the other strokes.
- Detailed analysis of the waveform properties of detected NBEs
- The analysis of sferics belonging to other types of TLEs will be performed

Data and analyses
The raw VLF magnetic field data were used to perform the preliminary analysis of the waveforms belonging to the very energetic winter lightning discharges and high latitude NBEs

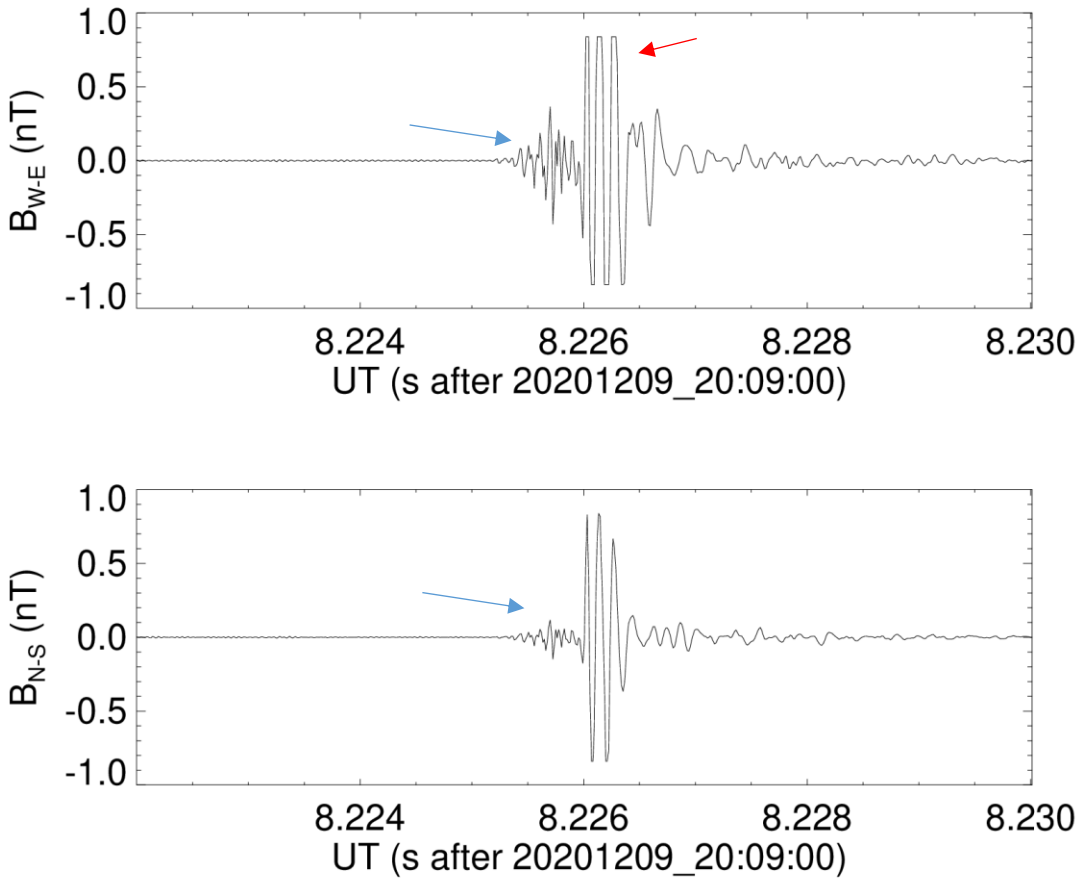
Results

The preliminary waveform analysis revealed that:

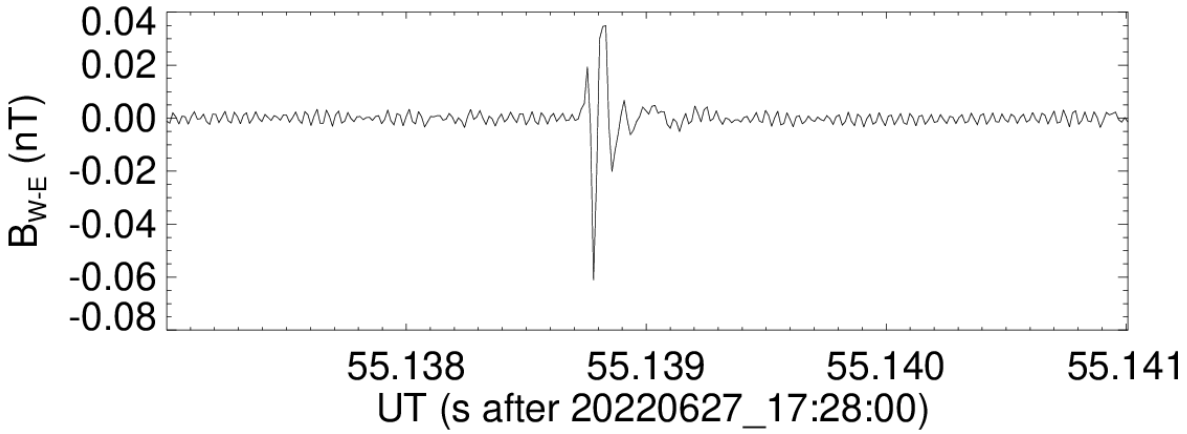
a) The sferics belonging to different strong winter lightning originating in the same thunderstorm surprisingly differ. Moreover, the waveforms belonging to the strongest discharges within the analysed storm differ from the typical sferics waveforms. The sferics belonging to the elves producing discharges exhibit stronger ionospheric reflections.

b) The waveforms belonging to NBEs, which are known to radiate at VHF frequencies, are well recognisable in the SGO VLF waveforms.

Examples of analysed waveforms:



Sferics waveforms belonging to the elves producing stroke occurring on 9/12/2020 at 20:09:08.216501 (43.3942N, 15.4565 S) with a peak current of -639 kA as recorded by two perpendicular magnetic field SGO loops. The blue arrows shows the signatures of the lightning initiation, the red arrow identifies the saturation of the W-E antenna by strong ionospheric sky waves.



An isolated positive narrow bipolar event as seen by the W-E SGO magnetic loop. According to the ENTLN network this intracloud discharge occurred on 27/06/2022 at 17:28:55.133423 (55.5559N, 11.6501E) with a peak current of 16.27 kA.

The added value gained from the TNA

SGO provided the raw VLF data. The possibility of obtaining the ELF magnetic field data for the studied events was discussed and agreed upon.

Summary

The VLF recordings can be used as a useful tool for investigating the properties of different not completely understood lightning phenomena including very energetic lightning, the TLEs and NBEs.

Acknowledgement

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