Multiple-pulse blue luminous events detected by ASIM

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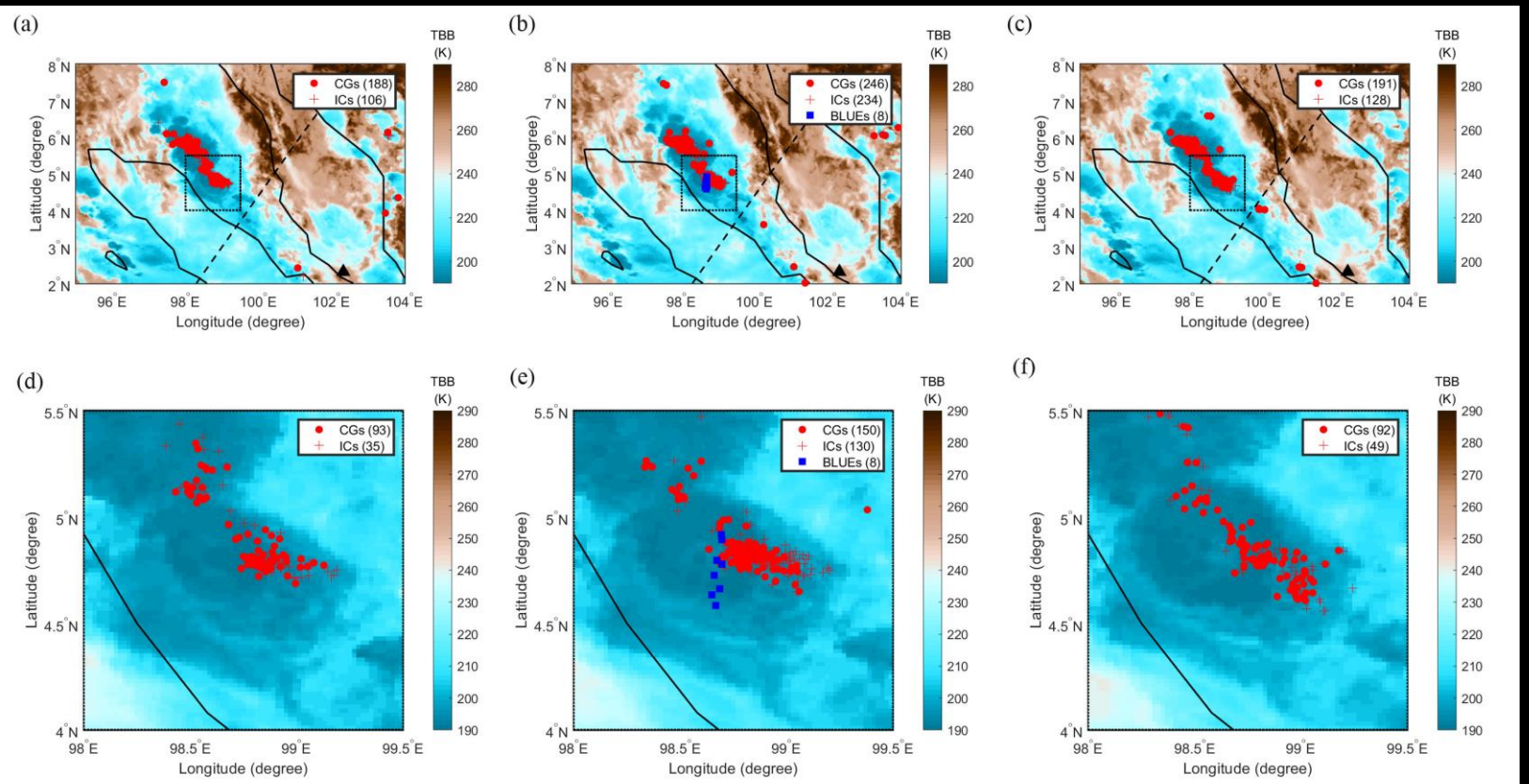
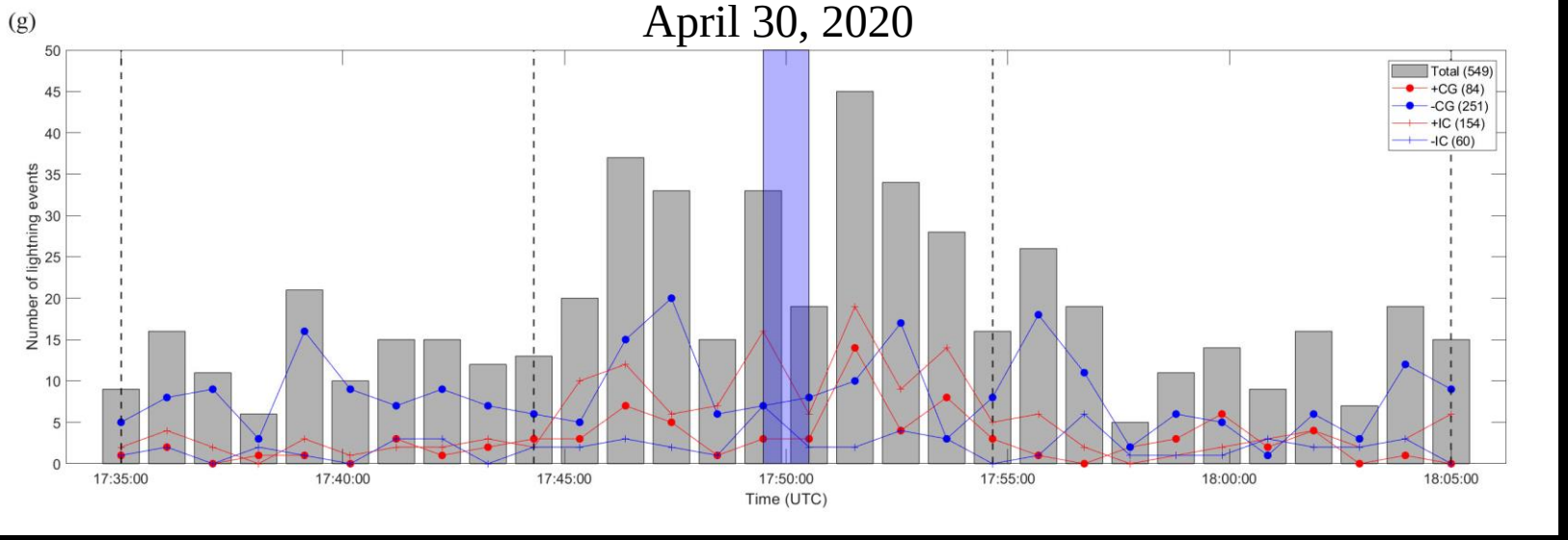
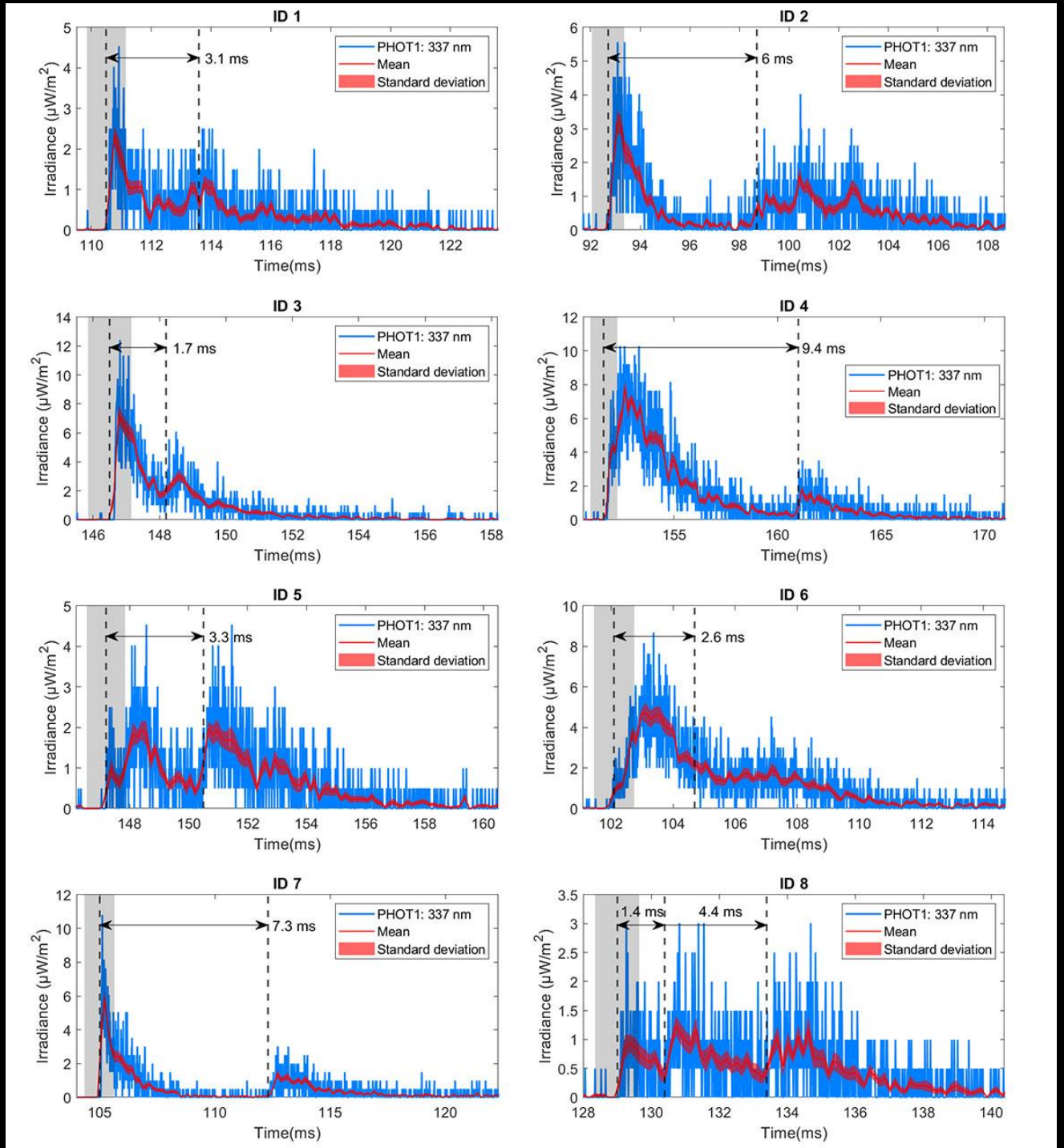
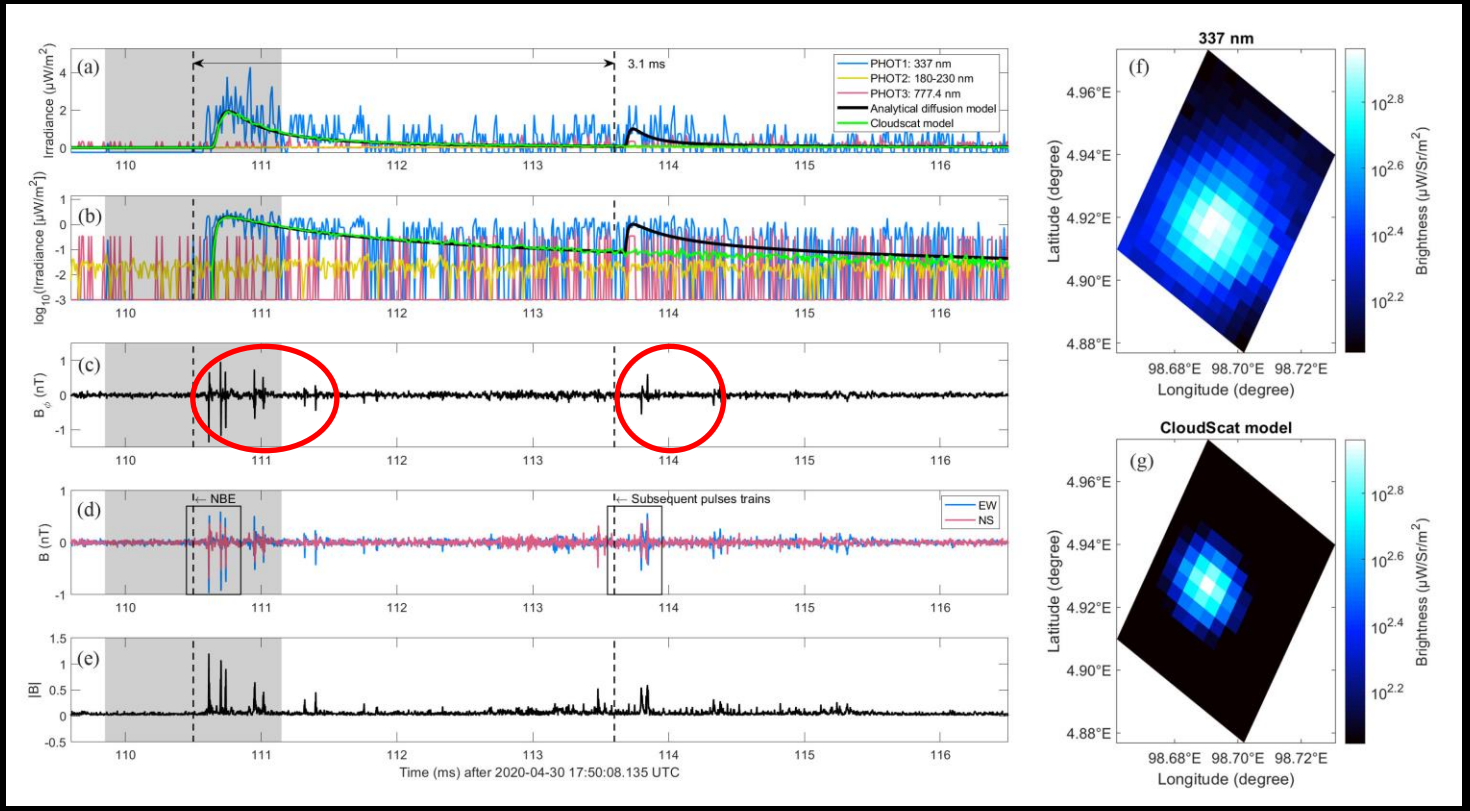




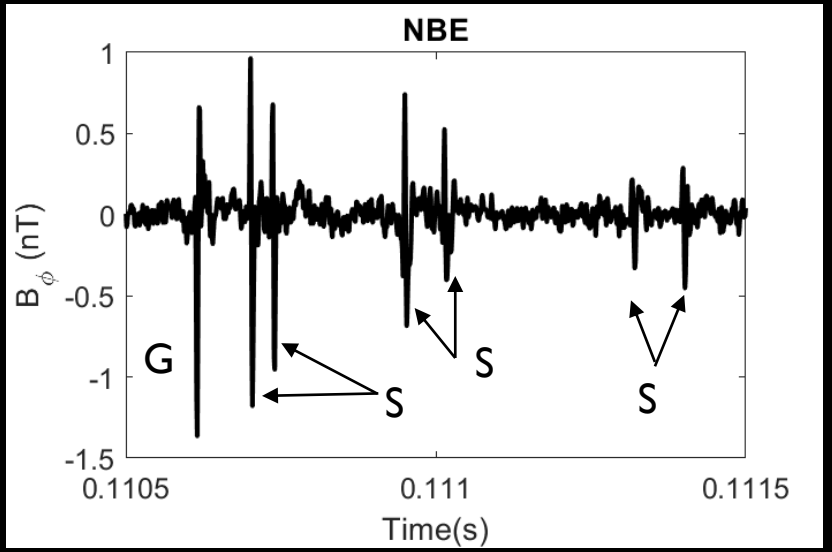
- 16 blue corona discharges (8 single-pulse + 8 multiple-pulse BLUEs).
- The BLUEs occurred nearby the cloud tops.
- The BLUEs are accompanied by the highest concentration of IC and CG lightning with an apparent decrease of the negative CG flash rate.

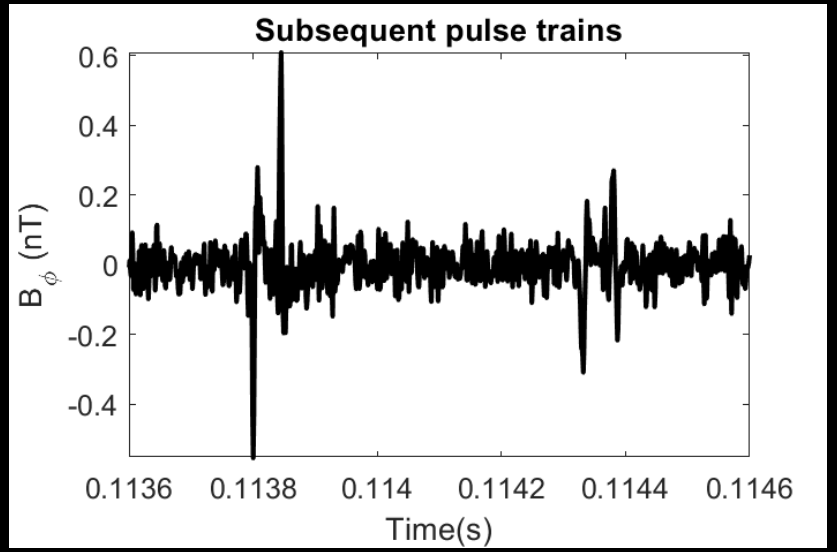


- The multiple-pulse BLUEs include one primary BLUE pulse and one/several subsequent BLUE pulses within 1-9 ms, only detected in 337-nm signal with no/weak signal in 777.4 nm.
- Both primary and secondary BLUE pulses are identified based on the moving average of 15 data points (about 150 μs) of the 337-nm photometer signal and statically significant with their signals above $\mu \pm 5\sigma$ level of the background noise.
- All the multiple-pulse BLUEs are found to be associated with a unique high-altitude +NBE and its subsequent pulse trains in radio signals.

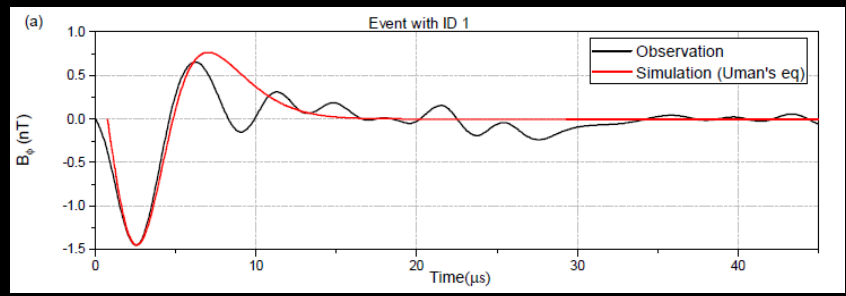


- +NBEs are located at 17.68 km with the optical depth 0.96 km and the subsequent pulse trains are located with the optical depth 0.66 km.
- +NBE is the isolated NBEs without triggering any leader process of lightning discharges.
- For the first time, it indicated that there are subsequent corona discharges following isolated NBEs within a few milliseconds.

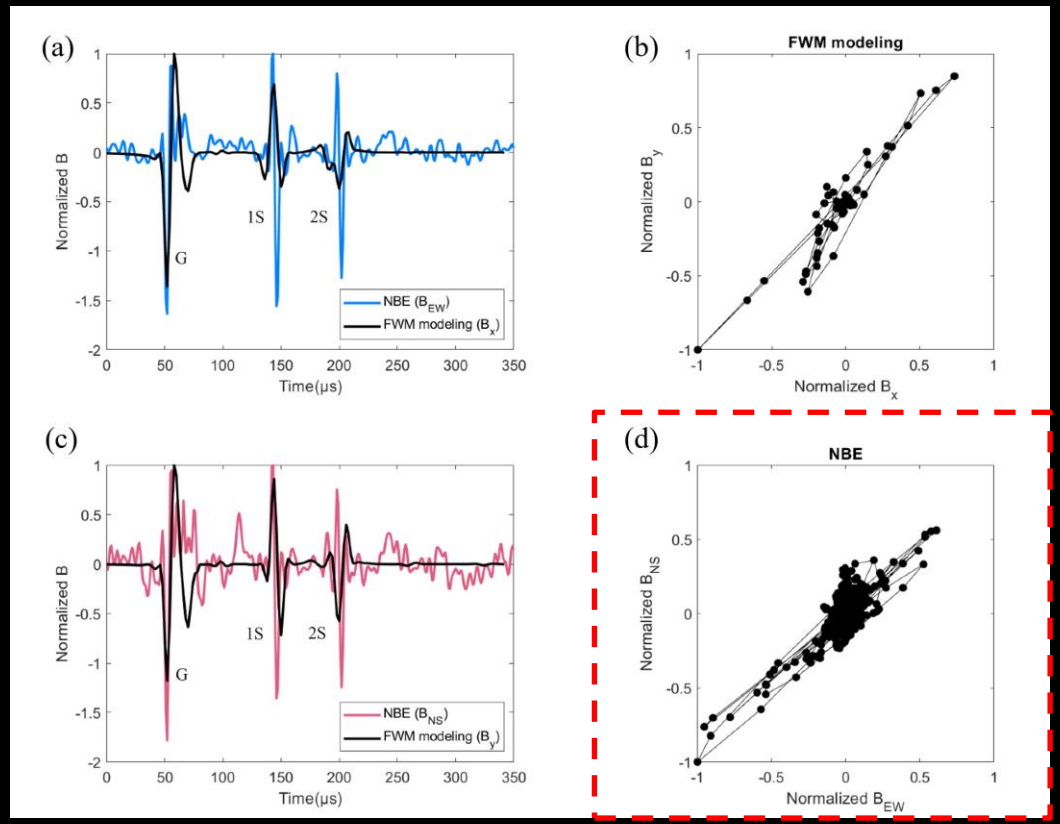




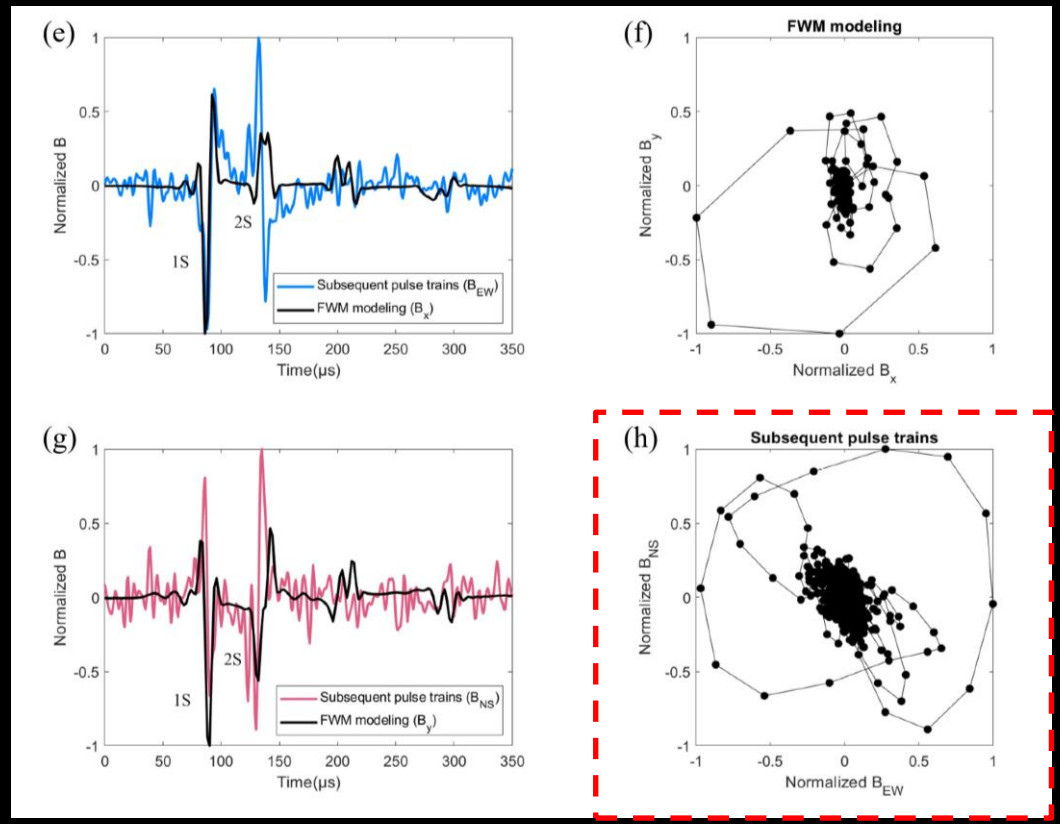
Ground wave of NBE



NBE

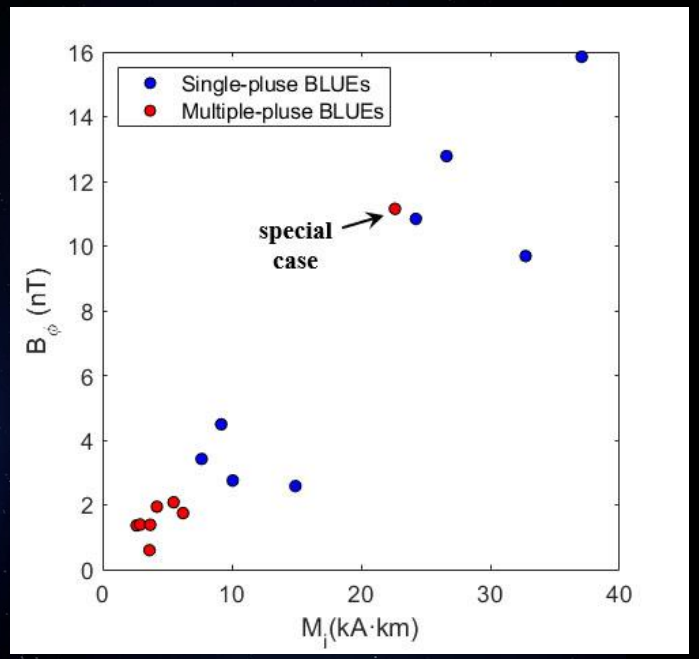


Subsequent pulse trains



- NBE pulses & tight linear relationship of two B fields -> The propagation of EM wave for a vertical discharge
- Subsequent pulses & elliptical polarization of two B fields -> The propagation of EM wave for a horizontal discharge

The simulations of FWM model support our hypothesis of a horizontal discharge triggered by the primary, vertical breakdown that generates the NBE.



- The primary pulses of the multiple-pulse BLUEs have relatively weaker current moments and amplitudes than those corresponding to the single-pulse BLUEs.
- Subsequent optical pulses captured by ASIM are related to horizontally oriented corona discharges which emitted weak radio signals and have been ignored by the radio observations so far.
- The class of horizontally oriented corona discharges might cast light on the differences between the isolated and lightning-initiation corona discharges.

Li, D., Luque, A., Lehtinen, N., Gordillo-Vazquez, F. J., Neubert, T., Lu, G., . . . Reglero, V. (2022). Multi-pulse corona discharges in thunderclouds observed in optical and radio bands. Earth and Space Science Open Archive, 13. doi 10.1002/essoar.10511013.1.

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