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SOREQ

Data Fusion of Electromagnetic and Infrasound Measurements

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Measurements of electric and magnetic (EM) fields have been proposed as a means of supporting and aiding infrasound (IS) signal analysis. As opposed to nuclear explosion, other natural and man-made IS sources do not produce an EM signal. Thus, if an IS signal is not accompanied by an EM pulse, it is known that it is not originated from a nuclear explosion.
Lightning discharges are the main source of EM pulses. Due to their high abundance, fortuitous coincidence of lightning with an IS signal are a common situation. These events may be mistakenly assumed as a nuclear explosion. To avoid this obstacle, a reliable method for lightning detection and identification is required.

In this work we present results of continuous measurements of electromagnetic fields, adjacent to IAMR IS array at Mt. Meron, Israel. Lightning discharges are detected and analyzed, and their abundance is compared with theoretical predictions. We show how information about lightning location can be deduced from recorded waveform. Correlation with IS events is being examined as well. We conclude that lightning signals can be identified and filtered out, and thus the EM signal can be fused with the IS records to provide better performance of the CTBT monitoring system.

Lightning Identification

There are several methods for extracting lightning discharge events out of a continuous EM measurement. Simplest approach is based on local extremum points in time domain. Any value which exceeds a pre-defined threshold is considered as an event. In Fig. 2 we present the number of detected events as function of the threshold, and compare it to a statistical estimation of expected event frequency (assuming IC/GC ratio of 2.5, which is a typical value for Israel).

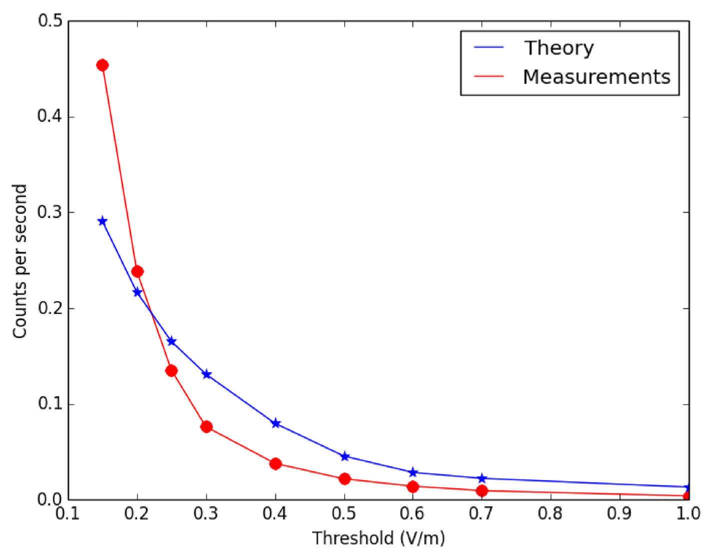

Figure 2. Theoretical estimations and measurements of lightning discharge events detected using different thresholds.

Another option is to identify lightning events from frequency domain. An abrupt rise in the field amplitude in the 5-20 kHz range is an indication to a lightning. This method identifies also weak signals whose peak is in the same order of magnitude as the noise. In addition, it avoids false positive identification due to random spikes.

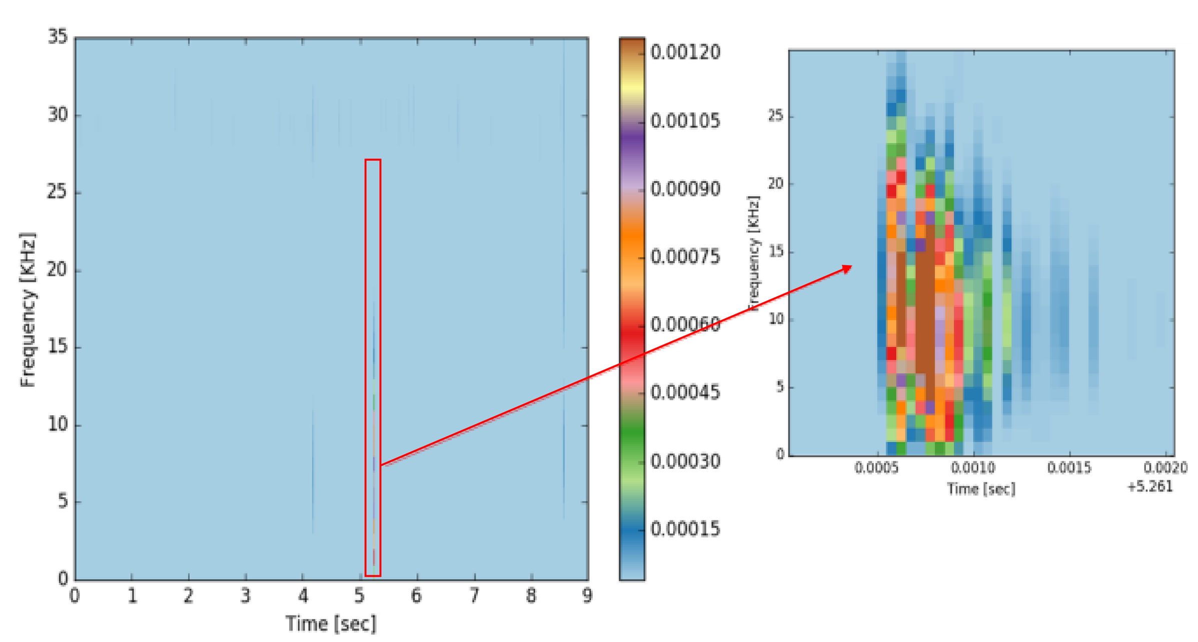

Figure 3. A spectrogram of the measured electric field. A lightning discharge can be identified by the increase in the 5-20 kHz range.

The Station

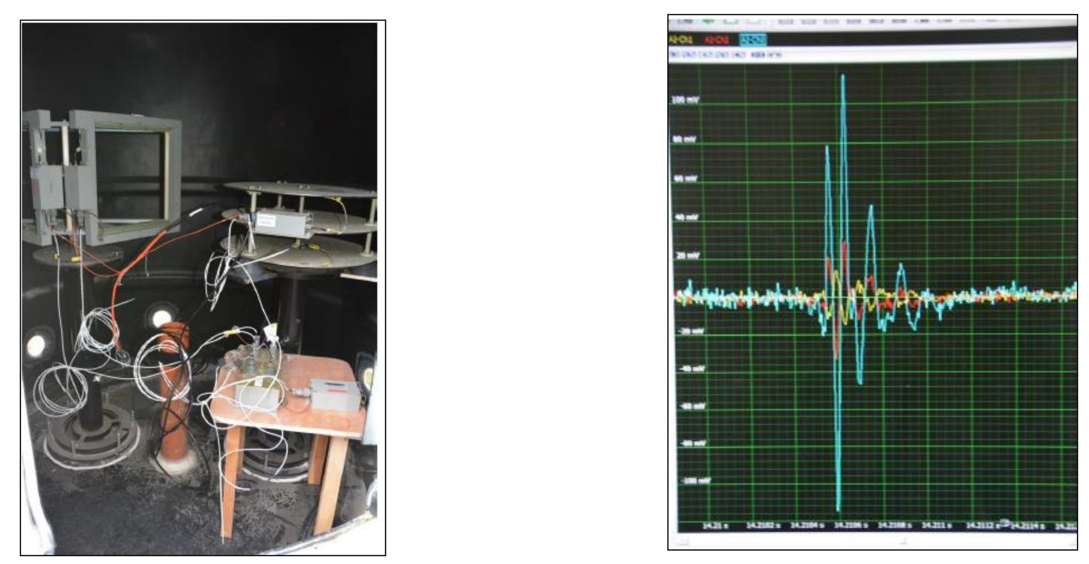

Figure 1. **Left**: The capacitor antenna and loop antenna, receiving electric and magnetic fields, respectively. **Right**: An example of one lightning discharge as recorded by the receiver. The electric field is in cyan. The red and yellow lines are the two components of the magnetic field.

Locating the EMP Source

Propagation of lightning discharge signals have been simulated, using a standard lightning EMP model as a source. Signals were broadcasted from various distances to the receiver. Correlation of actual received signals with the simulated ones were calculated. It was found that actual signal are highly correlated with synthetic signals from certain distances, whereas their correlation with signals from other locations is poor. Thus, correlation with simulations serves as an indication to source location.
Similar methodology may apply to locating the source of a nuclear EMP, once a proper initial pulse model is given.

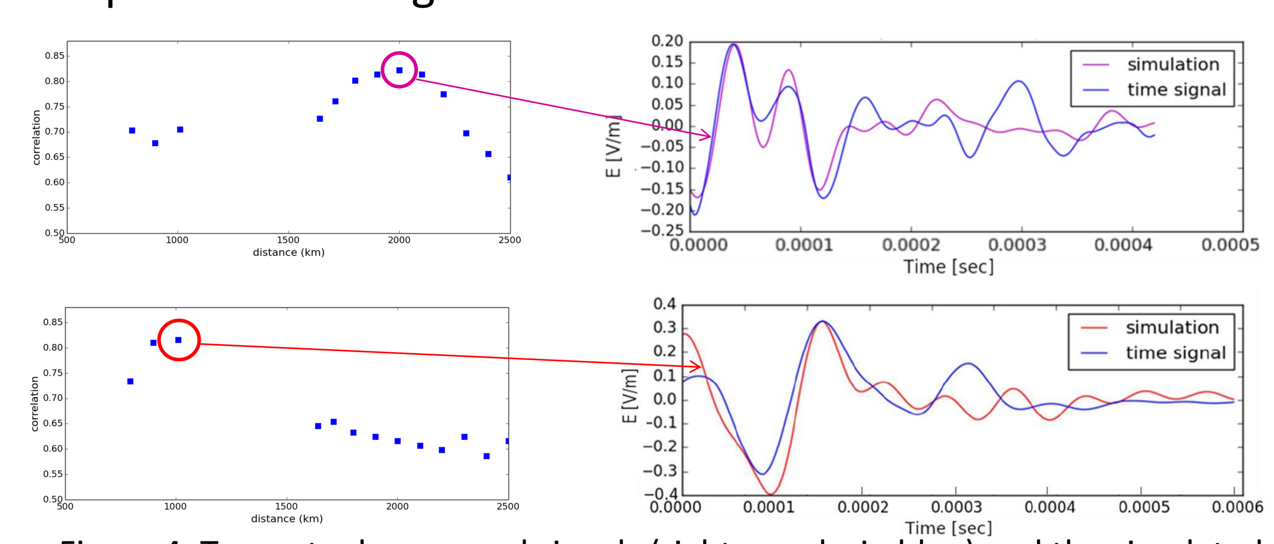

Figure 4. Two actual measured signals (right panels, in blue) and the simulated respective signals. Correlation with signals from other distances is shown in left panels.

Azimuth of source location is estimated by the ratio between the two magnetic field components. Putting together distance and azimuth yields an independent estimation of the location from which the signal had been originated.

IS Signal from Lightnings

On February 12th 2019, a thunder storm took place in vicinity of the IS station. A few hundreds lightning discharges have been recorded and located (by the WWLLN – World Wide Lightning Location Network) within 100 km to the station. For each of these, the expected time of IS signal arrival was calculated, and the IS signal was examined for traces of the lightning. About 25% of lightning taking place within 80 km from the station could be identified in the IS. Above this radius, rate of identification was significantly lower. This implies that as far as distant events are concerned, we do not expect a systematic coincidence of EM signals with IS events.
These results are explained by simple energy arguments. Estimations of the electrostatic energy of a lightning discharge are at most in order of GJ. This energy is equivalent to few hundreds kg of TNT – way below the detection threshold of the IMS.

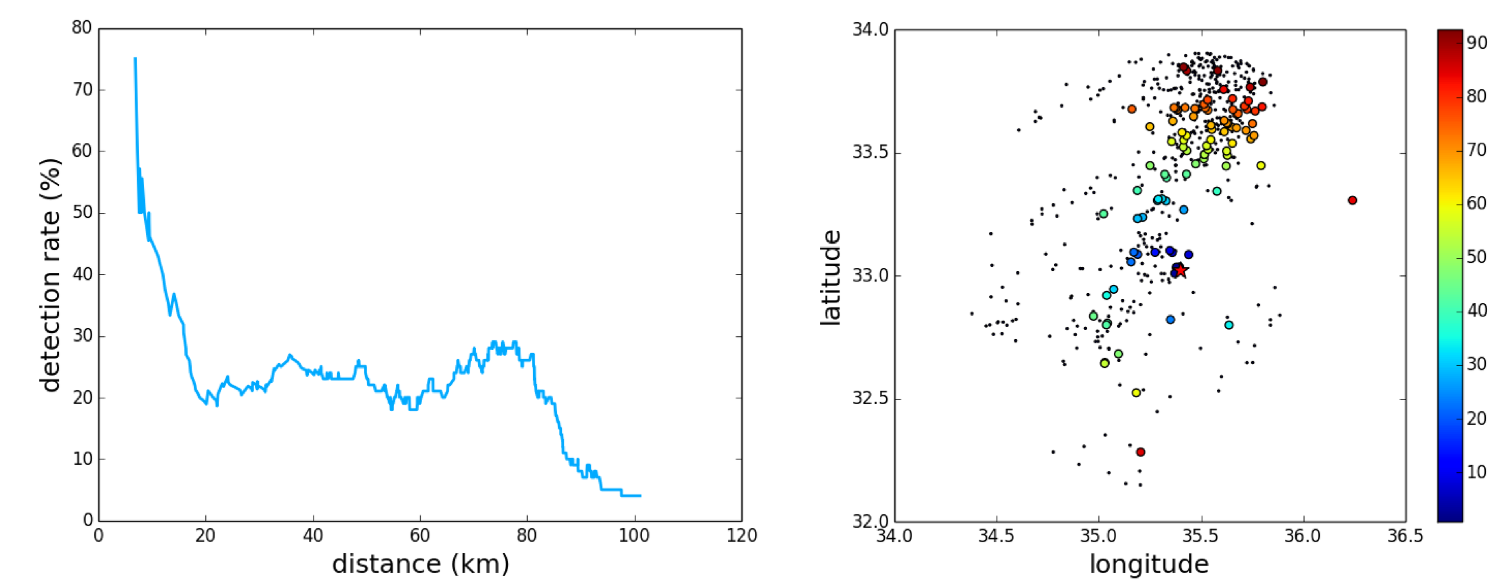

Figure 5. **Left**: Coincidence rate of lightning and IS, computed as percentage of IS signals out of running window of 100 lightning discharges. **Right**: All lightning events (dots) and lightning events with IS signal detected (circles, colored by distance).

Data Fusion

EM signals are detected and independently located. Most of these are lightning discharges which may be identified and filtered out. Atmospheric nuclear explosions emit unique EMPs that are distinguished from lightning discharge signals. Thus, is an IS event is not accompanied by an EM pulse, it is known that it has not originated from a nuclear explosion. Merging data from IS bulletins with EM measurements easily highlights the events which are not relevant to the CTBT and those who require further analyses to figure out their nature.