Acoustic characterization of lightning discharges

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1. Introduction

Intensively studied during the early Eighties natural shock wave propagation is nowadays of great interest through the design of the International Monitoring System for the respect of the Comprehensive Nuclear-Test-Ban Treaty (CTBTO). Acoustic shock waves generated by lightning discharges are the most common explosion-like sources. Their acoustic content in the frequency range from 1Hz to 20Hz produces important background noise at the CTBTO infrasound stations located in regions where lightning activity is important. But on the other hand, the great variability of lightning discharges makes them good candidates to test the network detection capabilities for propagation distances less than 100km.

2. The acoustic and electromagnetic field observation campaign deployed in South-East of France during Fall 2012

For the SOP1 campaign, a Lightning Mapping Array (LMA) was deployed for the first time in Europe. This instrument is able to map in 3D the detailed structure of lightning discharges with great resolution in space and time. The CEA deployed a four microphones network in South-East of France inside the covering area of the LMA. Sensors were placed as a triangle of 50m side with the last sensor was at its barycentre. The signals were digitized with a sampling frequency of 500Hz. The operational detection network EUCLID provides also reports of lightning strokes localizations. The acoustic data are available on the HyMeX database.

3. Exploration of the October 26 2012 thunderstorm

The study of EUCLID detections shows that a thunderstorm cell passed over the acoustic station the October 26 2012 between 18h UTC and 22h UTC. The cell is not too active, lightning stokes can be clearly differentiated. There is little wind noise. The acoustic records are post-processed with the operational Progressive Multi-Channel Correlation (PMCC) method. It constructs a set of acoustic detections coherent through the network. It gives for each detection: the azimuth, the elevation angle, the frequency and the amplitude of the potential acoustic source in the lightning discharges which induced the detection.

For a given discharge, the LMA gives a date of the flash. It's then possible to construct from PMCC detections associated to the discharge the 3D geometry of the acoustic sources.

4. Acoustic reconstruction example

Several examples of reconstruction of single lightning will be shown. We see that reconstructed acoustic sources perfectly followed the return stroke; the reconstructed points are clearly associated with EUCLID detections.

Statistics were established on the excellent reconstructions of 56 lightning flashes. Several results on the acoustic frequency content of the discharges were also obtained.

It appears clearly that acoustic records produces data which are complementary to those provided by electromagnetic methods. Misfits in the acoustic reconstructions are explained by propagation effects with the help of a nonlinear numerical propagation code with heterogeneities and flows. Wind and temperature profiles are provided by AROME-WMED code are used for these calculations.

5. Conclusion

The acoustic records show that thunder spectra associated to return strokes extends from the infrasounds (about 1Hz to 20Hz) to the higher frequencies. The lower parts of the return strokes, between 0km and 2km in altitude are perfectly reconstructed by the acoustic method, for discharges nearby the acoustic networks. Misfits in the reconstructed altitude appear for distant acoustic sources. These errors are interpreted with a nonlinear propagation software for point sources at different altitudes. It shows that propagation is greatly affected by the wind profiles near the ground for sources at lower altitudes.