Acoustic characterization of lightning discharges

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The goal is to study the transformation of the thunder during its propagation from the return stroke towards a sensor, using two complementary approaches. First, the analysis of the acoustic records obtained during the HyMeX-SOP1 campaign (Fall 2012) produces 3D maps of infrasound sources present in the return strokes and in the intra-cloud discharges. We show they are perfectly correlated to precise results obtained from electromagnetic detection tools. Acoustic spectra can be associated to the different phase of the discharges. Propagation effects introduce errors in the localizations for distances greater than 20km. The use of a nonlinear propagation software with realistic wind and sound speed profiles help to understand the misfits.

1. Introduction

Intensively studied during the early Eighties natural shock wave propagation are 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 make them good candidates to test the networks 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

A field campaign named HyMeX-SOP1, and devoted to the observation of intense rain fields and thunderstorms took place from September 6 2012 to November 6 2012 [1]. It was part of the European HyMeX project [2] which aims at better understanding the water cycle in the mediterranean region.

For the field observation campaign an LMA [3] was deployed for the first time in Europe. It's a research network of small size able to map in 3D the detailed structure of lightning discharges with great resolution in space and time. It works in the 60MHz-66MHz electromagnetic range. The CEA deployed two acoustic networks in South-East of France near city of Uzes, inside the covering area of the LMA. The acoustic networks were operational from August 27 2012 to November 20 2012. The first network was composed of four microbarometers placed at the corners of a triangle of 500m side, the fourth sensor was installed on the barycentre of the triangle. The signals were digitized with a sampling frequency of 50Hz. A second network of four microphones placed as a triangle of same orientation as the first one was deployed. The triangle side was 50m, and the last sensor was at its barycentre, co-localized with the central microbarometer. The signals were digitized with a sampling frequency of 500Hz. In the HyMeX framework, the operational detection network EUCLID provides reports of lightning strokes localizations. Météo-France provides results produced by the operational computing code AROME-WMED [4] for the Mediterranean basin, the resolution is 2.5km for latitudes and longitudes. Wind and temperature profiles are provided up to 16km in altitude. The HyMeX database url is http://mistrals.sedoo.fr/HyMeX/, a registration is required to access the data.

3. Exploration of the October 26 2012 thunderstorm

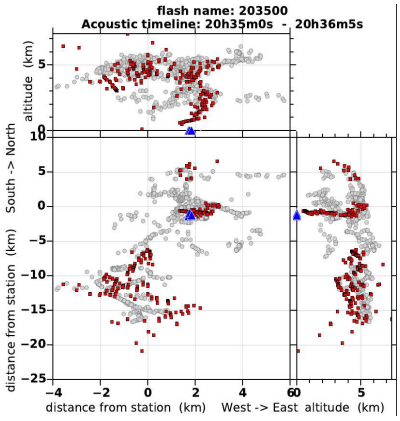
The study of EUCLID detections shows that a thunderstorm cell passed over the acoustic station the October 26 2012 between 18h UTC and 22h UTC. The cell is not too active, lightning stokes can be clearly differentiated. There is little wind noise. The acoustic records are post-processed with the operational PMCC method [5]. 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

As an example the case of a lightning stroke to the ground produced at 20h35m00s UTC is given. We see that PMMC perfectly followed the return stroke, the reconstructed points are clearly associated with EUCLID detections.



Acoustic reconstruction of 20h35m00s UTC discharge. Red squares: PMCC. Gray circles: LMA. Blue symbols: EUCLID.

A statistic was established based 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.

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 [6] 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.

5. Acknowledgements

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3. References

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