Infrasound from lightning measured in Ivory Coast

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Previous measurement campaign, realized in France in 2005, has shown that an infrasound station can clearly measure thunder when lightning occur within 75 km from the station. In this paper, infrasound data recorded in Ivory Coast since 2005 are analyzed and compared to WWLLN data in order to quantify statistically the main trends observed in 2005. The main results are : (1) the (infrasonic) thunder can be measured in direct propagation up to 50-70 km (depending on the direction of the wind) from the lightning, (2) the thunder amplitude, measured in direct propagation, decreases of one order of magnitude in a range of 50 km, (3) thunder can be also detected when lightning occur in the so called "shadow zone" (70-200 km), and (4) up to 60% of the WWLLN events are correlated with an infrasound event when their location are less than 50 km while about the detection efficiency is about 5% when lightning occur in the shadow zone. To explain these results intensive calculations of thunder shock wave propagation taking into account a real meteorology during 1 year have been performed.

1. General context

It is well established that more than 2,000 thunderstorms occur continuously around the world and that about 45 lightning flashes are produced per second over the globe. Three quarter (45) of the infrasound stations of the International Monitoring System (IMS) of the CTBTO (Comprehensive nuclear Test Ban Treaty Organization) [1] are now certified and routinely measure signals due to natural activity (e.g., airflow over mountains, aurora, microbaroms, surf, volcanoes, severe weather including lightning flashes, …). Some of the IMS stations are located where worldwide lightning detection networks (e.g. WWLLN [2]) have a weak detection capability but lightning activity is high (e.g. Africa, South America). These infrasound stations are well localized to study lightning flash activity and its disparity, which is a good proxy for global warming.

Progress in infrasound array data processing over the past ten years makes such lightning studies possible. For example, Farges and Blanc [3] showed clearly that it is possible to measure lightning infrasound from thunderstorms within a range of distances from the infrasound station. Infrasound from lightning can be detected when the thunderstorm is within about 75 km from the station. The motion of the squall zone is very well measured inside this zone. Up to 25% of lightning flashes can be detected with this technique, giving better results locally than worldwide lightning detection networks.

2. Database and statistical results

2.1. Ivory Coast station database

An IMS infrasound station is installed in Dimbokro (Ivory Coast) since 2003 and produces then continuously data except two gaps of few months. The optical space-based instrument OTD measured a rate of 10-20 flashes/km²/year in that country and showed strong seasonal variations [4]. Ivory Coast is therefore a good place to study infrasound data associated with lightning activity and its temporal variation.

2.2. Statistical study

First statistical results are presented here based on five years of data (2005-2009). About 300 independent thunderstorms have been studied and more than 16,000 infrasound events have been one-to-one correlated with one WWLLN event.

For short lightning distances (less than 20 km), up to 60 % of lightning detected by WWLLN has been one-to-one correlated (Figure 1). Moreover, numerous infrasound events which have the infrasound from lightning signature could not be correlated when thunderstorms were close to the station. Statistical analyses of all correlated infrasound events show an exponential decrease of the infrasound amplitude with the distance of one order of magnitude per 50 km (Figure 2). These analyses show also that the relative position of lightning is important: the detection limit is higher when lightning occur at the East of the station than when they occur at the West. The dominant wind (the Easterlies) could be responsible of this dissymmetry. It also exists a high variability of detection efficiency with the seasons (better efficiency in fall than in spring). Finally, these statistics show clearly a structure inside the shadow zone (from 70 to 200 km away from the station on Figure 3).

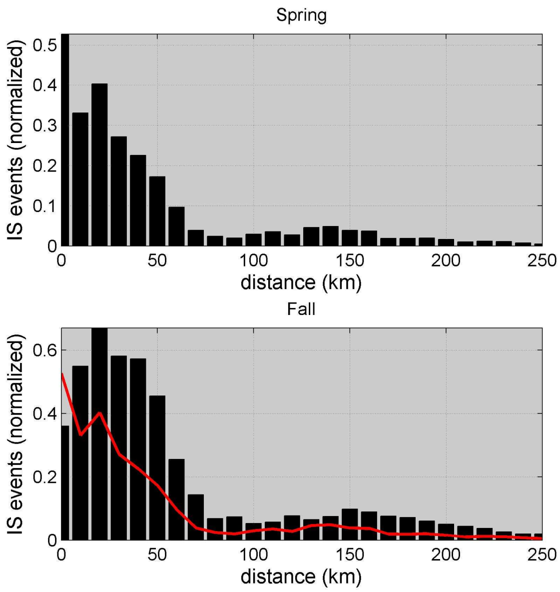

Figure 1: Distribution of the number of infrasound events in comparison with the lightning distance for spring (top) and fall (bottom). It is normalized with the respective distribution of lightning measured by WWLLN. The distribution takes into account only correlated events with WWLLN database. The red line on the bottom graph is the distribution plotted on the upper graph.

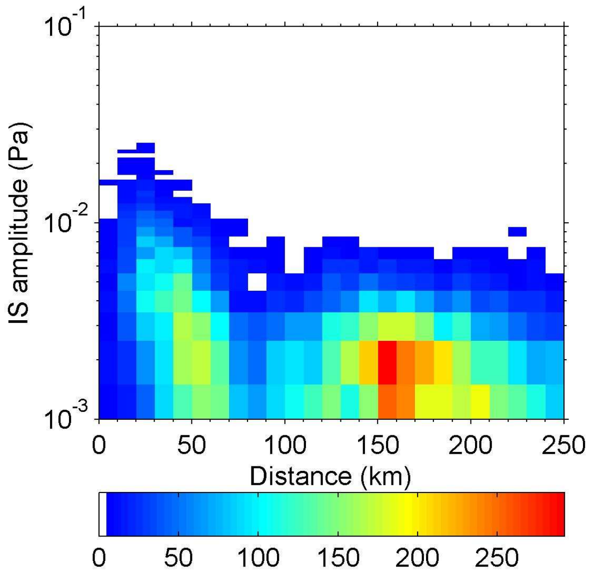

Figure 2: Distribution of thunder infrasound amplitude in comparison with the lightning distance. The color indicates the number of events having the same amplitude for a fixed distance range.

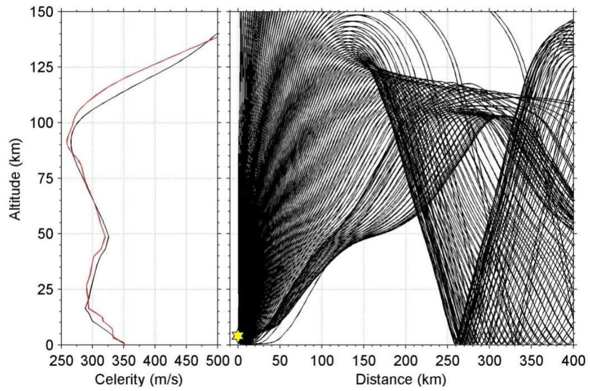

Figure 3: Ray-tracing propagation calculation for an isotropic point source located at 4-km height. The shadow zone is the region where no acoustic ray hits the ground, here from 50 – 250 km.

2.3. Numerical simulations

These results will be compared with intensive numerical simulations. The simulations are separated in two parts: the simulation of the near-field blast wave generated by a lightning and the simulation of the non-linear propagation of the shock front through a realistic atmosphere. By comparing our numerical results to recorded data over a full 1-year period, we aim to show that dominant features of the statistics at the IMS station may be explained by the meteorological variability.

3. References

[1] more information on CTBTO: www.ctbto.org

[2] more information on the World Wide Lightning Location Network: www.wwlln.net

[3] Farges, T., and E. Blanc (2010), Characteristics of infrasound from lightning and sprites near thunderstorm areas, *J. Geophys. Res.*, 115, A00E31, doi:10.1029/2009JA014700.

[4] Christian, H. J., et al. (2003), Global frequency and distribution of lightning as observed from space by the Optical Transient Detector, *J. Geophys. Res.*, 108(D1), 4005, doi:10.1029/2002JD002347.