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NOISE CONTROL FOR A BETTER ENVIRONMENT

Comparison of measurements and calculations of shooting noise variations

Van der Eerden, Frits[1]
Wessels, Peter[2]
Salomons, Erik[3]
Van den Berg, Frank[4]

TNO, Organisation for Applied Scientific Research
2597 AK, The Hague, The Netherlands

ABSTRACT

At military training areas acoustic events are created that can be heard up to several kilometers distance. The sound levels are subject to variation, mostly due to changes in the meteorology. The variation of the immission levels of these events is of importance for environmental noise assessment, to interpret either individual events or long term averaged levels. Results for these variations are compared using two techniques: 1) The variation of sound is calculated by applying the method as enforced in the Netherlands that makes use of meteorological classes, and 2) The variation of sound levels is measured with a number of unmanned acoustic sensors at a large training area. The acoustic sensors are also used to detect and localize the events. As the origin of the source is determined, a comparison between measured data and calculated results can be made. Further, the uncertainty for both techniques will be addressed, before the conclusions on the use of both techniques are drawn.

Keywords: Environmental Noise, Shooting noise, Noise measurements, Noise variation
I-INCE Classification of Subject Number: 50

1. INTRODUCTION

Live-fire training is of importance for military operations. As training facilities have neighbouring communities, acoustic environmental management may be necessary, especially when high-energy impulsive events are generated, for example by artillery guns or mortars. These sources can be heard at several kilometres distance. The received levels can vary by tens of decibels depending upon the meteorological conditions at the time of event.

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[1] frits.vandereerden@tno.nl
[2] peter.wessels@tno.nl
[3] erik.salomons@tno.nl
[4] frank.vandenberg@tno.nl

Estimating the sound levels in the surrounding communities, whether long-term or event based, including the assessment of these levels, is challenging. Recent developments combine sound measurements with propagation models, which may be used to further address these challenges. As there are usually many receiver locations, the use of a propagation model can reduce the number of microphones. In Figure 1 such a situation is depicted. The microphones at the training area can detect and localize the source, while the use of a propagation model can extend these results to locations where no measurements were done.

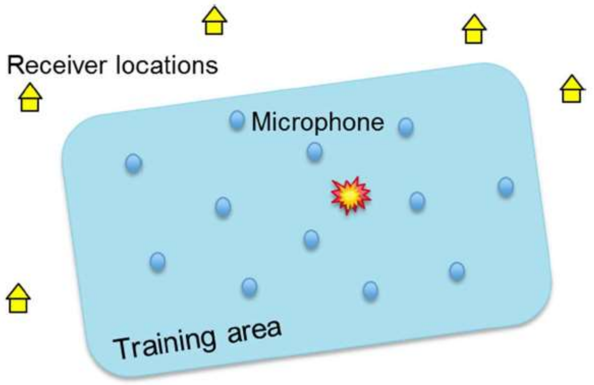

Figure 1. Distribution of unmanned acoustic sensors at a large training area.

In this paper a comparison between shooting noise results from measurements and calculations is presented. For the calculations the Dutch propagation model for shooting noise was used[1]. The measurements were made with 8 unmanned sensor systems at an artillery firing range during 4 weeks. Simultaneously, meteorological measurements were carried out. Figure 2 shows the location of the sensors and the location of the 35 mm gun that was regularly operated during these weeks.

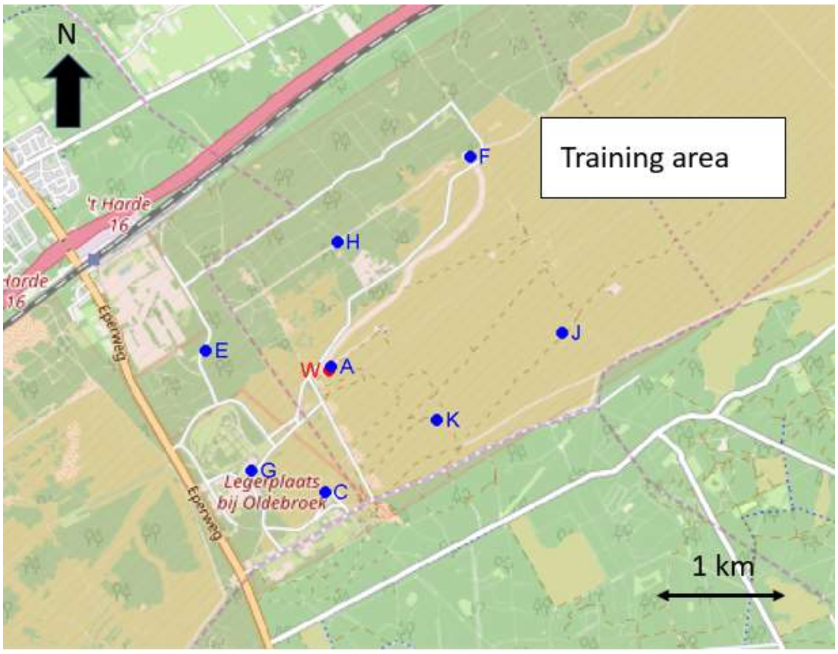

Figure 2. Location of 8 unmanned acoustic sensors, indicated with blue markers, at an artillary firing training area. Location of muzzle blast indicated with red marker.

In section 2 the Dutch calculation method for shooting noise is briefly discussed. Section 3 presents measurement results, and section 4 compares the calculated and measured results. Finally, the conclusions are given in section 5.

2. SOUND PROPAGATION MODEL

A calculation method has been developed in the past for the Netherlands Ministry of Defense to predict the annoyance due to shooting noise around military training ranges in the Netherlands[1]. For the sound propagation in this method, i.e. the excess attenuation due to ground and meteorological effects, a database was generated. A total of 27 representative sound speed profiles were used based on the long-term meteorological data in the Netherlands, see Figure 3. The sound propagation was calculated numerically with a parabolic equation model (PE)[2]. PE-model takes into account, amongst others, the refraction of sound waves and an absorbing ground. Numerous calculations were performed for different source and receiver heights and distances up to 15 km. Three different ground types are used: hard (for roads or water), soft (like sand or grass), and very soft (like heather or forest). The sound propagation over different ground types can be determined by weighting each of the three different propagation results. Also, meteorological weighting factors are used to calculate the yearly averaged noise contours. E.g. the occurrence of a prevailing South-West wind in the Netherlands is taken into account.

For the present study the wind and temperature profiles that were measured during the events, along each source-sensor path, were fitted to one of the 27 profiles. This provides the corresponding sound propagation. By using the known source levels, the sound levels at the surrounding sensor locations could be determined. In this case there is a very small directivity of the muzzle blast (~1 dB) which was further neglected. However, there is a noise barrier on the North-East side that was accounted for in the calculations.

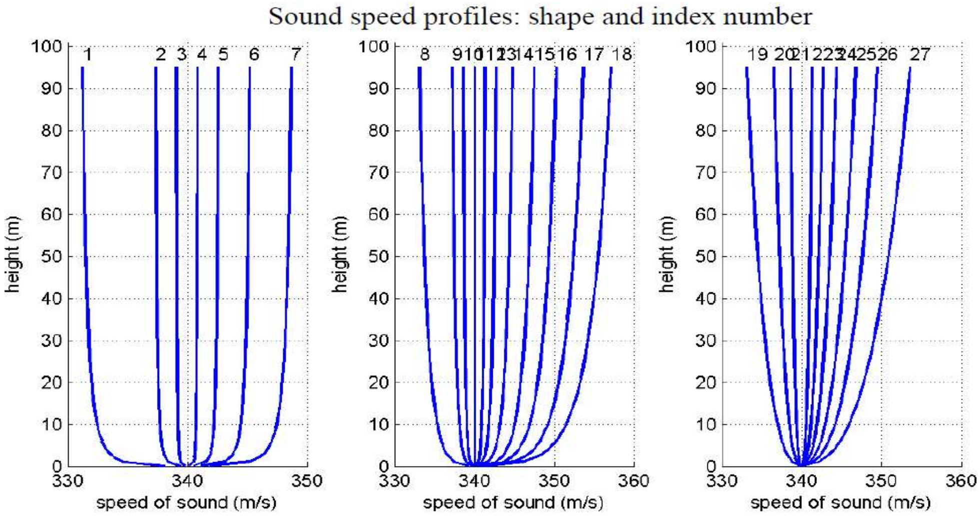

Figure 3. Different sound speed profiles (27) as used for the PE-database with sound propagation results.

3. MEASUREMENT RESULTS

In the months of October and November of 2018, eight unmanned acoustic sensor systems were deployed at the artillery firing range in the Netherlands. During 4 weeks regular shots were fired with a 35 mm cannon for testing purposes. In Figure 4 the location of the weapon, the target, and the eight sensor positions are shown. Sensor A (or Alfa) was situated at only 36 metres from the muzzle blast (W) to mainly capture the detection time accurately. All sensors are equipped with a gps receiver used for time synchronization. Five sensor systems are located at about 1 km around the source, two systems (F and J) are located at about 2 km from the source. The area between the broken lines indicates that there is also a contribution of projectile sound from the supersonic bullet. A 10 meter high meteorological mast was placed near the weapon, with wind speed sensors at three different heights and temperature sensors at six different heights (see Figure 5).

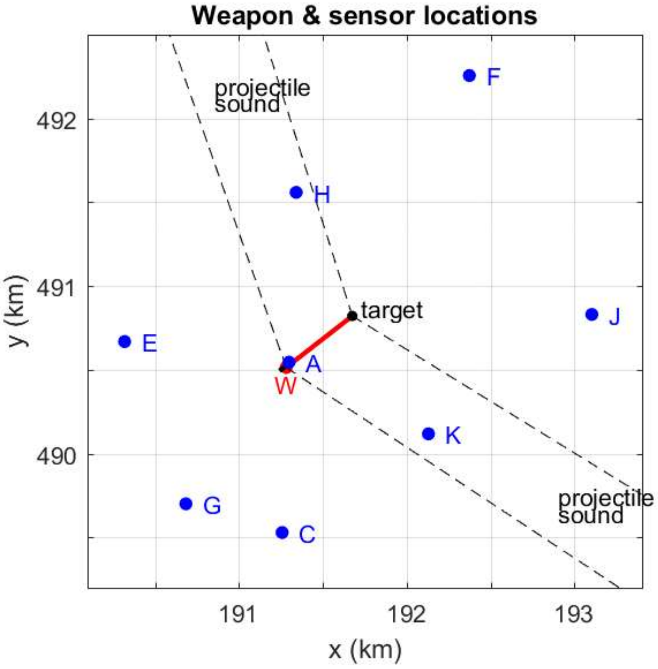

Figure 4. *Geometry of the weapon and sensor locations. The area with projectile sound contributions is indiacted between the broken lines.*

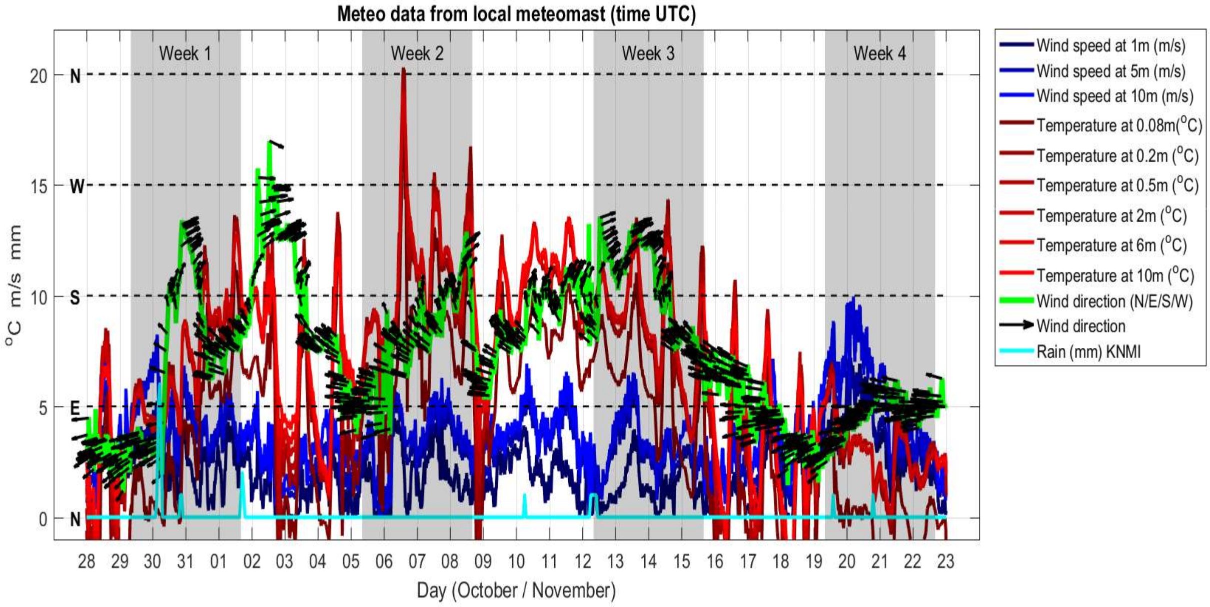

Figure 5. Meteorological data from a 10 meter high local mast at the training area, located near source W.

An impression of the recorded sound exposure levels is given in Figure 6, for a series of 20 shots. The top figure shows the nearby microphone results and the sound exposure levels for each shot (time resolution each second). The red markers indicate the times of arrival. On the right-hand side the averaged shot level and the standard deviation is depicted.

The middle and lower figure show the results for the sensor locations C (Charlie) an F (Foxtrot). The estimated arrival times are indicated with black markers, with a later arrival for Foxtrot as it is located at 2 km distance, while Charlie is at 1 km distance. For this series the wind direction is towards Foxtrot. In some cases there are clear peaks visible below the black dots, in other cases the peaks are less clear.

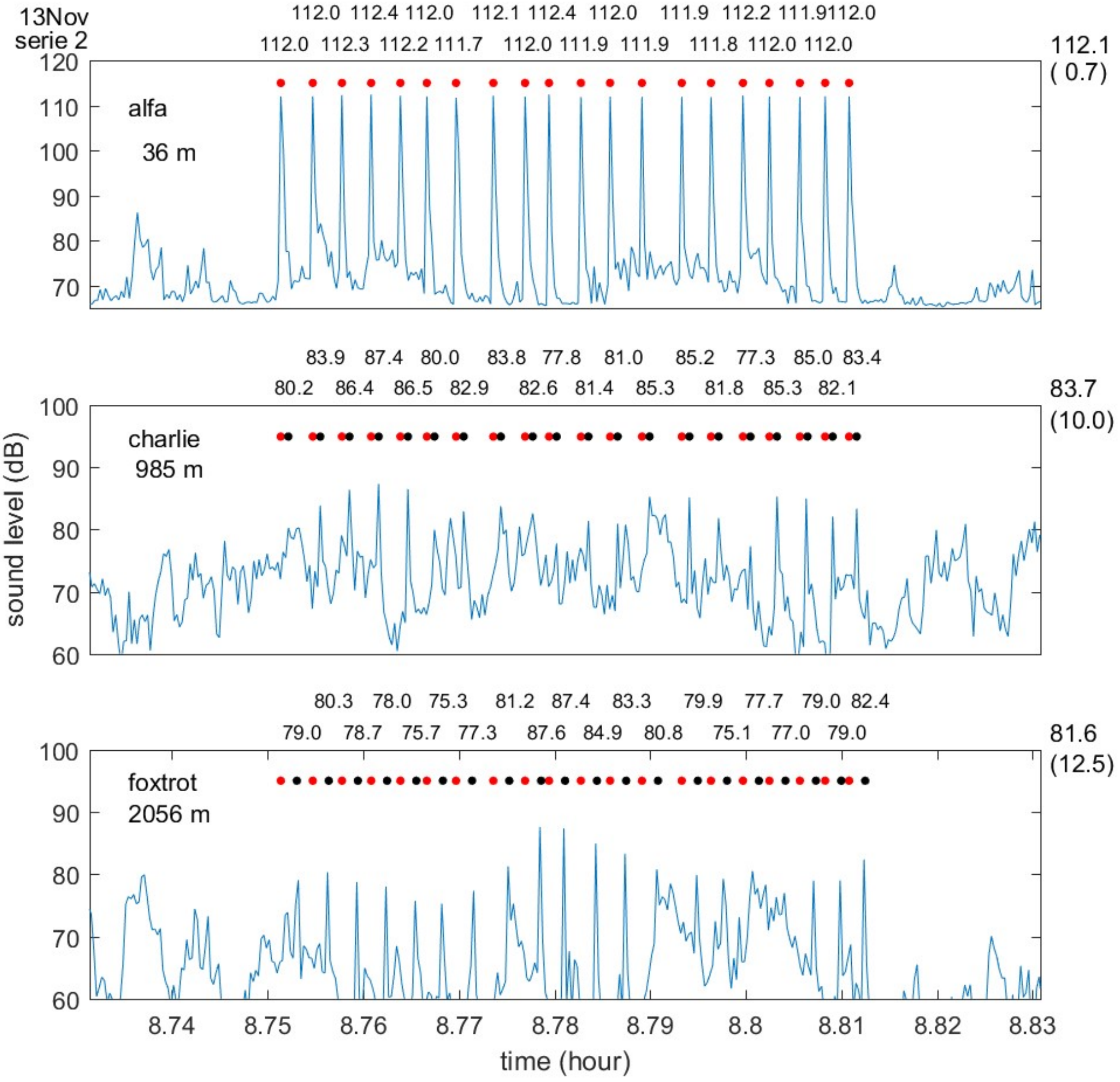

Figure 6. Unweighted sound exposure levels recorded during a series of 20 shots on 13 November for 3 microphones. Red markers indicate time of arival for the close-by microphone 'alfa', black markers are for the more distant microphones. On the right-hand side the average and standard deviation of the sound exposure level which could be assigned to the shots.

4. COMPARING MEASUREMENTS AND CALCULATIONS

The measured sound exposure levels for 7 sensor locations are shown in Figure 7, using a red colour. These are averaged for 4 series of 20 shots. The left-hand figure shows the levels on 13 November (as also shown in Figure 6). The wind is coming from South-West, as indicated in the top left. The figure also shows the calculated sound level, using a blue colour. This is also an averaged level, but one of the 27 sound speed profiles has been used for each shot depending on the variation of the meteorology. A rather good correspondence can be seen; for the downwind locations F and J the difference is 1 and 2 dB.

The left-hand figure also shows that for the upwind conditions the difference can be larger; for this situation the effect of turbulence is more pronounced. For example, in the calculation there is little difference between the locations C and G, but the measurements show a difference of 10 dB. Location G is more shielded from the wind and location C is more uphill (10-20m higher), this may explain the 10 dB difference for these unweighted results.

The right-hand figure shows similar results, but for an almost opposite North-East wind direction. Both the calculations and the measurements show a difference of about 10 to 15 dB difference between the downwind and upwind conditions. The locations C and G are now a downwind situation and the correspondence between measurements and calculations is good.

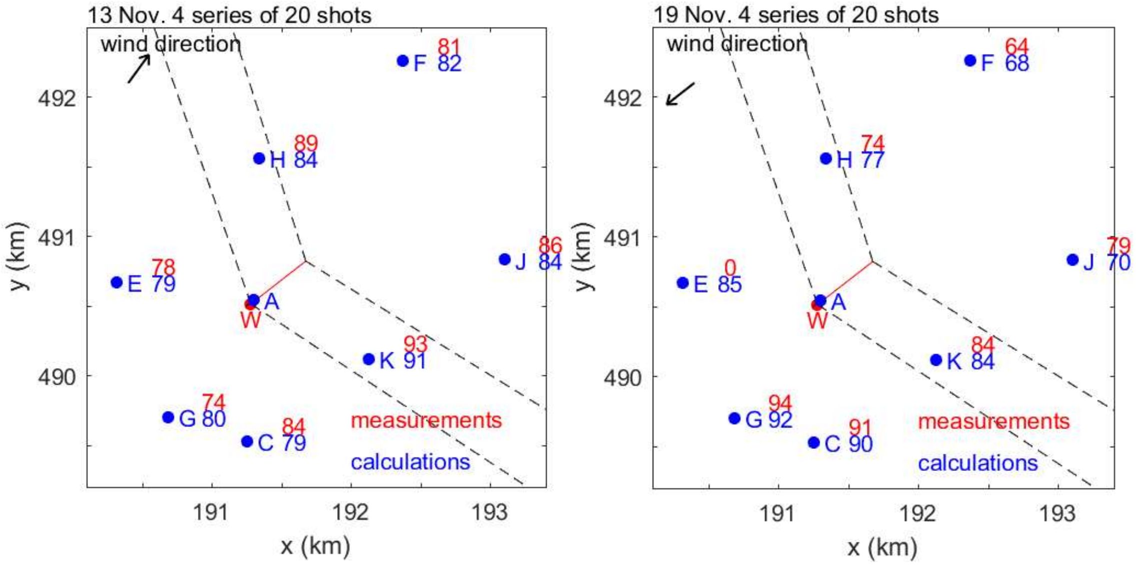

Figure 7. *Sound exposure levels, averaged over four series of 20 shots. Comparions of measured and calculated results. Left: for a South-West average wind direction. Right: for a North-East average wind direction.*

Figure 7 shows the comparison between the averaged measurement and calculation results for two separate days. The sound exposure levels for all events during the four weeks are shown in Figure 8, again for the locations Charlie and Foxtrot. On the horizontal axis the effective wind speed during the event is used, which is the difference between the speed of sound in the direction from source-to-microphone at 10 and 0 meter height. Positive values correspond to a downwind refraction, while negative ones correspond to an upward refraction. One-minute average results from the meteorological mast were used and these were fitted to one of the 27 profiles.

Figure 8 shows the measurements with red markers and the calculations with blue ones. The number of recorded shots is indicated in the figure. As the Foxtrot sensor was not fully operational during the four weeks, less shots were captured.

The measured and calculated levels are approximated by an S-curve for a more easy comparison The levels for the positive effective wind speeds are typically 10 dB higher than the levels for the negative effective wind speeds.

By comparing the S-curves, it can be seen that the correspondence between the measurements and the calculations is rather good. Nevertheless, the variation of the sound levels for the measurements is larger than for the calculations. The calculation method accounts for turbulence on a basic level for upwind conditions only. In a previous study[3] it was shown that these large variations can be expected, especially for the upwind condition. For upwind conditions, turbulence effects are the dominant cause for the variation of the sound levels.

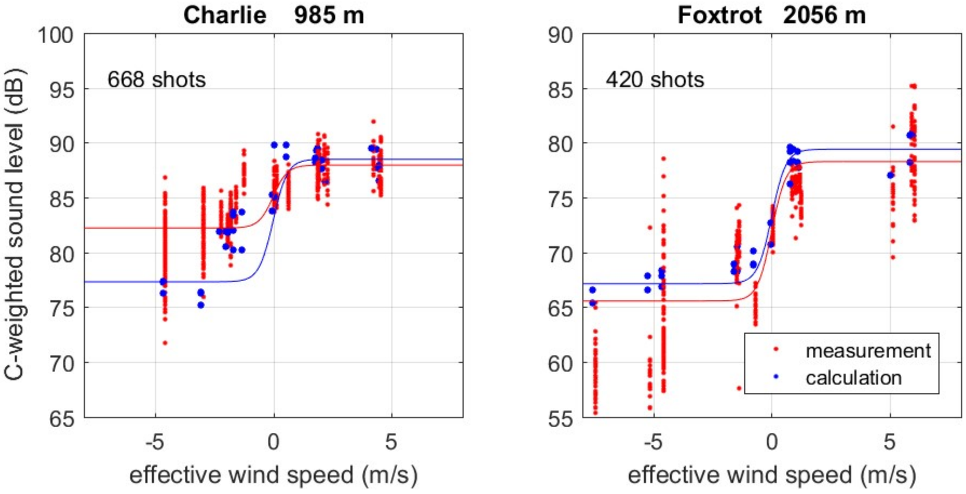

Figure 8. C-weighted sound exposure levels as a function of the effective wind speed. Comparison of measured and calculated results through the use of an indicative S-curve.

When using a model-based measurement system, that combines measurements and a sound propagation model, the uncertainty due to turbulence effects cannot be reduced. Nevertheless, the expected variation of the sound exposure levels can be indicated. For downwind conditions it was seen that a good estimate of the ground absorption in the propagation model can be reduce the uncertainty.

In this study a microphone was used close to the weapon. As a side note, preliminary results show that detection and localisation can also be done without using this microphone. Also, other source locations can be determined with a distribution of sensor systems.

5. CONCLUSIONS

The variations of shooting noise levels on an artillery firing training range have been measured for a period of four weeks. Seven unmanned acoustic systems were used at distances of 1 and 2 km around the muzzle blast of a 35 mm canon. It was found that changes in the averaged sound levels could be well explained by changes in meteorological conditions. Also, a good correspondence was found with calculated results that are based on the Dutch sound propagation model for shooting noise, especially for downwind conditions.

The measured variations around the average levels have shown to be large, ranging from 10 dB for downwind conditions up to more than 20 dB for upwind conditions. The variation obtained from the national model is not so large, mainly due to the absence of turbulence effects. When using a measurement system, that is combined with model-based sound propagation results, these results are an indication of the uncertainty that can be expected. Especially at locations where no measurements are being done. These measurements also provide insight into the feasibility of semi-automatic measurements of shooting noise.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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