Weather Effects on Outdoor Sound Propagation

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The results of long-term measurement of ambient sound levels at two locations north of Uppsala are presented. These data are interpreted using records of meteorological information that were collected simultaneously at one of the locations. The results are given as sound profiles. These are surface or contour plots of sound level versus the time of the day and the year.

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1. INTRODUCTION

It has long been known that the properties of the atmosphere influence the propagation of sound. A better knowledge of the effects of weather on sound propagation has become necessary because of an increasing awareness of environmental noise problems.

2. METEOROLOGICAL EFFECTS ON SOUND PROPAGATION

Our understanding of sound propagation outdoors has increased considerably over the past few decades.[1-7] Investigations concerning meteorological effects on sound propagation have been carried out at the Department of Meteorology at Uppsala University since 1976. Many experimental and theoretical studies have been undertake. Meteorological effects have been noticeable in these studies even at a distance of twenty-five metres from the source. The effect have been found to increase with decreasing receiver height. Analyses of two long-time studies during two years, 1997 and 1998, are discussed in this paper.

The three most important meteorological effects on sound propagation are: refraction, scattering by turbulence and atmospheric absorption.

Refraction of sound rays occurs if the sound velocity and/or wind speed changes along the ray path, i.e., there are gradients of wind and temperature transverse to the ray paths. The refraction influences the sound level. The angle of sound incidence at the ground changes, which results in different ground attenuation. The sound rays are bent downwards in downwind conditions and/or temperature inversion. They are bent upwards in upwind conditions and/or lapse. Upwind conditions and/or lapse create areas, known as sound shadow zones, where no direct sound rays can reach. The refractive effects of temperature gradients and wind component gradients in the direction of propagation are additive. When the refractive conditions change, the path lengths of the various waves intersecting at the receiver also change. Thus, depending on the phase relationships between these waves, sound propagation at some frequencies will be amplified and at others muted.

Turbulence has a twofold effect on sound propagation. First, temperature fluctuations lead to fluctuations in the velocity of sound. Second, turbulence velocity fluctuations produce additional random distortions of the sound wave front. Turbulence scatters sound into sound shadow zones and causes fluctuations of the phase and the amplitude of the sound waves, thus destroying the interference between different rays reaching the receiver. This gives higher sound levels than expected for frequencies where the ground attenuation has its maximum. The effect of turbulence can be disregarded for low frequencies and distances up to a few hundred metres. When making measurements, integration over many turbulence cycles reduces the effect of turbulence on the sound level. Mean values for 5-10 minutes give more reproducible results than just an instantaneous measurement.

Atmospheric absorption depends on frequency, relative humidity, temperature and atmospheric pressure. Atmospheric absorption increases linearly with distance and becomes more important as the length of the propagation path increases.

Relatively little attenuation is found for low temperatures. Monthly and diurnal variations in relative humidity and temperature introduce large variations in atmospheric absorption. Usually, relative humidity reaches its maximum soon after sunrise and its minimum in the afternoon when temperature is highest. The diurnal variations are greatest during the summer.

The meteorological effect on sound propagation has a diurnal and an annual variation mostly due to changing sun height at the various times of the day and the year. The values of atmospheric absorption need to be calculated for the local climate instead of using some global mean value. The calculations should be based on hourly values of temperature, relative humidity and atmospheric pressure over at least two years.[8] The time has come to use data from local meteorological stations.

3. MEASUREMENT PROCEDURE

Simultaneous long-term measurements of sound level and meteorological variables have been carried out at the Marsta Meteorological Observatory and in a small suburb, L vstal t, 3 km north of the Observatory. Marsta Meteorological Observatory (59°55'N, 17°35'E Degrees), belongs to the Department of Earth Sciences at the Uppsala University. The site is a typical agricultural area with few obstacles. The area around the observatory and the suburb is very flat, the level differing by less than few meters over the nearest km^2. A military airfield is located 3 km south of the Observatory. Temperature, wind speed, wind direction, relative humidity