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Long-term experimental database for environmental acoustics

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ABSTRACT

The Long-Term Monitoring Station (LTMS) was set up by Ifsttar (formerly LCPC) for a long observation period (10 years) in the aim of promoting a better understanding of the physical phenomena inherent in the field of environmental acoustics. This paper focuses on the LTMS experimental database, generated over the 2002–2007 periods, and in particular on sound pressure levels (relative to a reference microphone, i.e. attenuations) as well as micrometeorological observables (wind speed and direction, air temperature, etc.) at several points and heights on the experimental site. Most importantly, this paper introduces LTMS_2002–2007 as a reference database with free access (available for downloading on the web page) for the entire scientific community involved in: (i) numerical model validation (both acoustic and micrometeorological models), and (ii) statistical analyses (spatial and temporal representativeness). This paper also provides several examples of experimental data exploration, so as to derive an estimation of the space and time variability of meteorological and acoustic parameters at this complex topography site (valley and viaduct) over short, medium and long-term periods.

1. Introduction

The Long-Term Monitoring Station (LTMS, see Fig. 1) is an experimental site operating 24 h a day 365 days a year, located in Saint-Berthevin (France) and set up by Ifsttar in order to better understand the physical phenomena inherent in the field of environmental acoustics. Though noise disturbance may stem from a variety of sources (road and railway traffic, airplanes, industrial noise, etc.), all display similar characteristics with respect to the physical phenomena involved in long-range acoustic propagation.

This research topic still raises some major scientific obstacles despite the interest shown by the international scientific community and the resources allocated to this field of research over the past several decades. Moreover, regulatory and standard organizations are severely constrained due to public pressure, especially in European countries [1]. The population exposed to noise-related nuisances caused by roads, railways and industries throughout the world is continuously increasing, which in turn has spurred the need to improve the reliability of numerical and experimental tools for estimating sound pressure levels (or other indicators) within the soundscape. Measured and/or modeled sound levels depend on many physical phenomena, including diffraction, diffusion, reflection, etc. More specifically, the combined influence of micrometeorological effects and ground effects leads to tremendous sound dispersion as distance to a sound source increases. The relative influence of those effects on the acoustic field depends on a great extent on both the geometric configuration and propagation conditions, e.g. average vertical wind and temperature gradients, atmospheric turbulence, ground impedance. Such effects differ over highly-variable time scales, from seasonal trends to hourly (even quasi instantaneously) fluctuations. Thus, outdoor sound fields always have an inherent statistical nature, which has to be taken into consideration regarding different time scales [2,3]. Moreover, statistics are also necessary to estimate space representativeness of soundscape indicators and their influent parameters. This raises the difficulty of collecting such input data with high-resolution (both in space and time) for use in analytical [4] or numerical [5] models.

Thus, the LTMS project was adopted in 1999 by the LCPC Laboratory, now named "Ifsttar" (for "French Institute of Science and Technology for Transport, Development and Networks" since the LCPC and INRETS public research institutes merged on January 1st, 2011). This project also garnered support from the CECP (Prototype Design and Construction Center) based in Angers (France) and the Blois LRPC Regional Laboratory (France) for technical solution design and data processing.

This paper is thus dedicated to presenting the experimental reference database output by this LTMS, a key research facility assigned to 2 main objectives:

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Fig. 1. LTMS – general view (looking northeast to southwest).

- Validation of the numerical models for both acoustic and meteorological predictions.
- Statistical analysis of data space and time structures (dispersion, representativeness, uncertainties, etc.).

The LTMS has been operating since 2000. As a certified "Research Facility", this site was not designed to generate studies directly, but instead to enhance scientific knowledge in the field of outdoor acoustic propagation, a mission accomplished by utilizing the extensive LTMS experimental database in order to pursue numerical model validation [6,2–14] and (geo)statistical data analysis [15–22]. Moreover, this site has been selected to contribute to the European "HARMONOISE" project (6th R&D Framework Program), in which Ifsttar was involved during the 2002–2004 period [23]. The benefit of implementing such a continuous monitoring site for a long observation period (at least 10 years) lies in quantifying the influence of micrometeorological conditions on acoustic field variability at the local scale (i.e. the site scale), in contrast with the regional scale (i.e. *Météo-France* weather stations). Such research efforts therefore focus on spatial aspects (site effects, influence of topography, see Fig. 2) as well as on temporal aspects (short *vs* long term), in the aim of deriving an estimation of space and time variability for sound pressure levels (SPL) on any site over short, medium and long-term periods.

This paper constitutes the first journal article to introduce the LTMS_2002–2007 database. The next section (Section 2) will provide a general presentation of the LTMS site, the installed sensors and the corresponding data validation procedure (post-processing) leading to a high-quality ("reference") database. The third section will then be dedicated to application of the LTMS_2002–2007 database, featuring its data structure, data extraction and data analysis (along with examples).

2. LTMS database

2.1. General presentation

The LTMS data are available between the end of the trial period (2001) and the beginning of the LTMS evolution during 2008, hence 6 years of available and validated experimental data (2002–2007). During 2008, some sensors were replaced (e.g. for acoustics: 1/1 octave $\gg$ 1/3 octave) and/or added (e.g. for meteorological applications: 3D ultrasonic anemometers, sky nebulosity), but these new sensors are not considered in the present paper, which only deals with the 2002–2007 periods. The considered sensors are spread across the LTMS site, as illustrated in Fig. 3.

Over this 2002–2007 periods (6 years), site equipment has provided for permanent acquisition (monitoring) with a 10-s temporal sampling interval, leading to the following recorded parameters (Fig. 3).

- Acoustic data:
  - 5 Acoustic masts.
  - L_{eq10s} (global "A" and 1/1 octave from 125 Hz to 4 kHz).
  - Recorded at 2 m (AiM2, i = 2, 3, 4, 5) and 5 m (AiM5, i = 2, 3, 4, 5) aboveground.
  - Except for the reference microphone, which is only 5 m aboveground (A1M5).

- Micrometeorological data:
  - 4 Meteorological towers.
  - 10-s Mean values (average on 5 raw values, i.e. 2-s sampling rate for meteorological acquisition) for wind speed and direction, air and ground temperature, relative air humidity, rainfall and solar insulation.
  - Recorded on two 25-m high meteorological towers (M1 and M4, with three sensor heights: 3 m, 10 m and 25 m aboveground), and two 10-m high towers (M2 and M3, 2 sensor heights: 3 m and 10 m aboveground).

- Road traffic data:

In conjunction with the acoustic and micrometeorological devices, an onsite traffic counting station has also been operating 24 h a day 365 days a year (located close to the highway, Fig. 3). These sensors (piezoelectric system + electromagnetic loops) provide four data for each event, i.e. for each vehicle pass (which then get collated into the 10-s assessment):

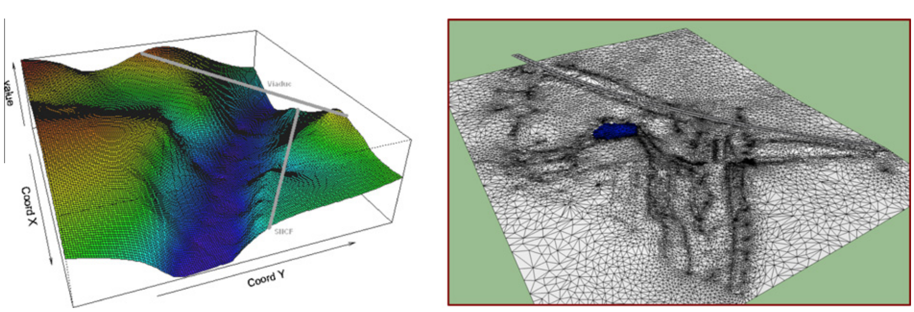

Fig. 2. LTMS topography – 3D schematic representations extracted from the Terrain Numerical Model (TNM), supplied with the LTMS_2002–2007 database [24].