a model based monitoring system for aircraft noise

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A new approach for an airport noise monitoring system is presented that comprises not only a number of measuring stations, but also a dedicated sound propagation model and an aircraft noise emission model. This approach enables estimation of noise levels in the whole area around the airport and not only at the location of the measuring stations. An additional advantage is that the locations of the measuring stations can be chosen more freely. Traditionally the measuring stations must be located near residential areas where the influence of other noise sources (such as cars or wind) cannot be eliminated. Better locations can be found that yield more reliable data and therefore more reliable noise levels.
To update the sound propagation model frequently, the measuring stations not only measure noise levels, but also other parameters, like temperature and wind profile. The sound emission of the aircraft is derived from measurement results, complemented with a directional aircraft noise emission model.
A tool was developed to visualize the power of combining data and models in this model-based monitoring system. The use of models opens possibilities for interesting applications such as i) short term noise forecasts, ii) scenario studies with various aircraft distributions and iii) enforcement of noise limits.

1 Introduction

There is a lively debate in the Netherlands about changing to a new system for enforcement of noise regulations. Some adhere to a system based on measurements because they distrust the calculation models, others adhere a system based on calculations because they doubt if measurements can be accurate enough to be the foundation of a new legal enforcement system.

Aircraft noise around Amsterdam Airport is continuously monitored by various sensor networks, with microphones at distances up to several tens of kilometres from the airport. As a service to the public these levels are displayed continuously on the internet. Three different systems are used (NOMOS, Geluidsnet and Luistervink). Only the NOMOS system is using radar data, making it possible to relate the noise levels to individual airplane passages. This makes it easier to distinguish the noise from airplanes from other noise sources. Geluidsnet uses sensors which are connected by internet. Transponder data is used to relate the measured noise levels to individual airplane passages.

For noise mapping, noise planning and enforcement of noise regulations only calculations are used. The calculation method is based on a model from the 1970's. Regularly the database of the model has been updated, but it is still based on a complicated scheme of assumptions which does not have to be in line with reality. For instance the input data for each flight procedure are based on predefined thrust and altitude profiles, which do not have to be in accordance with the real conditions along the flight path. Also the sound source strength of the individual airplanes is predefined and based on airplane classes. It does not account for individual differences in source strength between aircrafts of the same class. As a consequence measures to reduce the noise impact – for instance variations in aircraft operation conditions within a flight procedure – do not always have to lead to lower calculated noise levels.

The current enforcement method is difficult to explain. In order to be more transparent and clear to the people living in the neighbourhood, measurements should play an important role. On the other hand there are some technical limitations to monitoring systems, due to background noise from other sources and wind noise. Therefore a new enforcement system cannot be based on measurements alone. It is therefore advisable that a new system should be based on a combination of measurements and calculations.

2 Model based sensor network

A long-term TNO project aims at the general development of model-based sensor networks, i.e. combinations of calculation models and networks of sensors for various (environmental) parameters. A paradigm shift is seen from development of straight forward monitoring systems to intelligent sensor networks. In essence the paradigm shift goes from a single type, often complex sensor and the processing of its measured data to large arrays of simple and cheap sensors of multiple types and an advanced model of extracting sensible information out of a large data flow of measuring data. Part of this project is the development of model-based sensor networks for airport noise. The basic idea is that pure data is often meaningless, and only by combining the data with calculation models, one can draw meaningful conclusions.

As a step in this development, we have performed an experiment with a model based sensor network near a runway of Amsterdam airport and the city of Aalsmeer. Various types of data were collected for a set of aircraft departures, including noise spectra at eleven positions, flight data and meteorological data. Radar data was used to determine the position of the airplane.

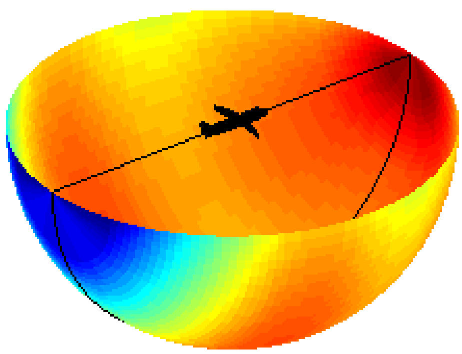

Fig.1 Example of a directional dependent sound source level of an airplane.

The source level of the individual flight tracks has been determined by combining the measured data with a directional aircraft emission model, developed in the European project Imagine (see http://www.imagine-project.org/ and the example of figure 1), and sound propagation calculations through the atmosphere.

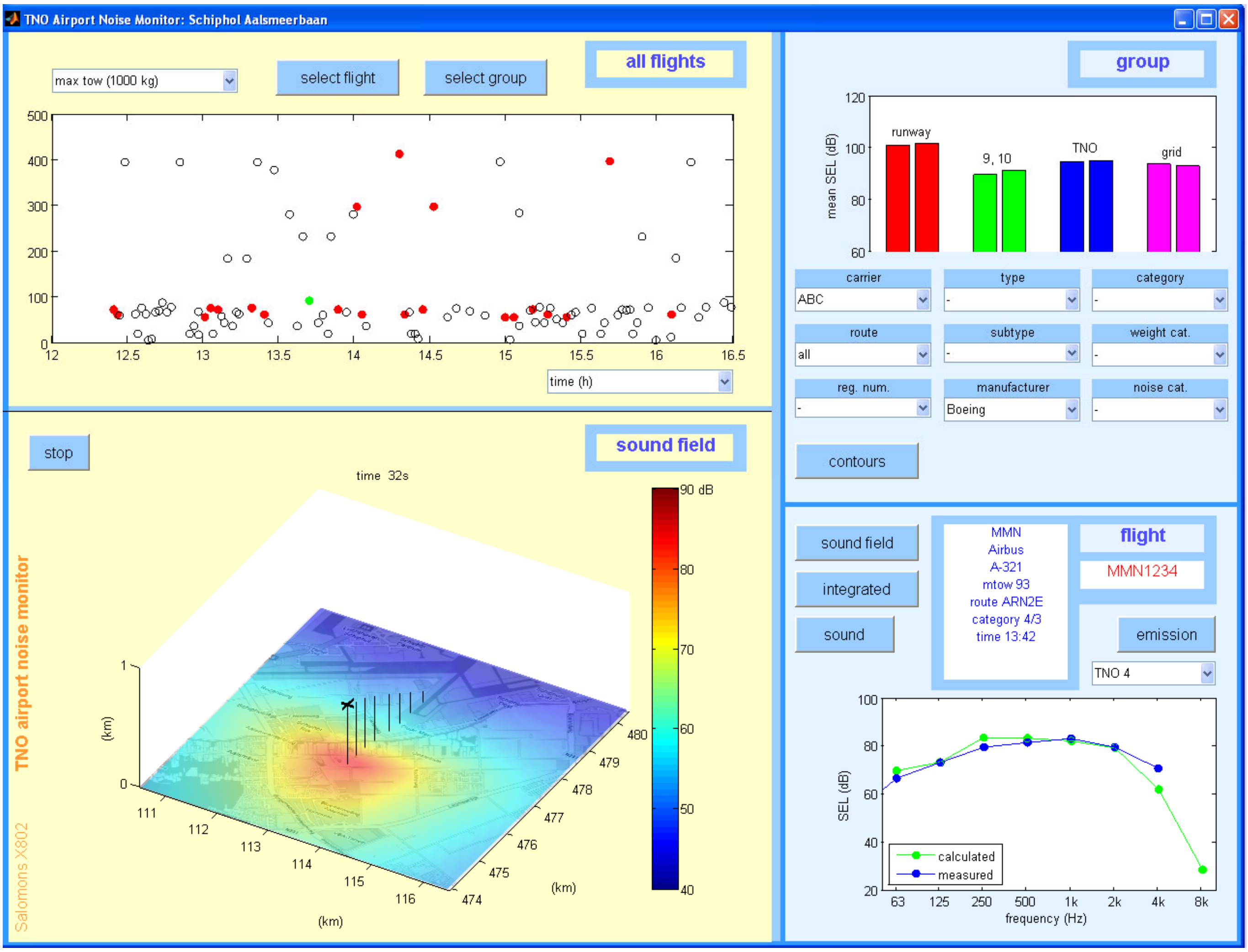

Fig. 2: Snap shot of the user interface of a tool by which the data and the model results can be visualized.

Using a sound propagation model (given the sound source level, the flight path of the airplane, meteorological data and properties of the ground) it was possible to estimate a footprint of the sound level from the airplane (see figure 2).

A versatile tool was developed to visualize the data and the model results. With this tool, one can investigate relations between various quantities: flight parameters and noise levels at various positions. The tool clearly demonstrates the power of the combination of data and models. The models yield noise levels at all positions around the airport runway (not only at the measurement positions), and noise contours for single flights and groups of flights.

By comparing calculated noise levels with noise measurements it is possible to continuously update the parameters of the model. In situations where measurements are occasionally not possible (for instance due to an increase in background noise by an increase in wind speed or by other sources) the calculation model still yields levels based on the latest information. For areas on larger distances to the airport where the noise levels from the airplanes are too low to be measured, only calculations can be used. However these calculations can be based on previous measurements on shorter distances to the same airplane (source strength) in combination with data from the airplane (transponder and radar data) and the local meteorological situation.

The sound measurements for this model-based monitoring system should preferably be performed at silent locations. Densely populated areas and locations near motorways should therefore be avoided. On the other hand it is difficult to explain to the public that the measurements for the enforcement system are not performed in habitat areas. If measuring stations are placed in a habitat area the results should be comparable. It is therefore not recommended that for instance one microphone is placed on a balcony, another one near a window and a third one on a roof. As there are in the Netherlands a lot of houses which have a horizontal roof it is advisable that measurement locations should be chosen at the centre of the horizontal roof close to the roof surface. This is comparable with the well known plate measurement technique which is commonly used in measuring high sources. Besides that this lay-out gives comparable results, it has also the advantage that noise from street traffic is shielded.

Using a large number of sensors is preferable to increase the accuracy of the system by averaging out possible errors of individual measuring stations. Combining sensor networks like NOMOS, Geluidsnet and Luistervink as mentioned before with advanced sound propagation models will result in accurate noise maps for a large area around the airport, which can be used for many purposes.

3 Conclusion

The use of a large amount of measuring stations in combination with advanced propagation models leads to many possibilities for interesting applications for monitoring aircraft noise. The combination of measurements and calculations reduces shortcomings from both techniques: calculations are used when measurements give unreliable results and measurements are frequently used to update and validate the calculation model to reduce errors as much as possible. This model based monitoring system can be used for enforcement of noise regulations, planning purposes and scenario studies. It is also possible to estimate a short term noise forecast, using meteorological data derived from weather forecast models. A comparable application is developed for shooting noise [1].

Acknowledgments

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References

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