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LONG-TERM NOISE PREDICTION IN A BUSY AIRPORT

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Abstract

A detailed comparison of measured and simulated aircraft noise events has been carried out. The study has been developed referring to aeronautic operations occurred in an Italian airport, during three busy weeks in 2003. Measured data consist in overflight SEL values gathered in 16 Noise Monitoring Terminals (NMTs) and then matched with radar tracks acquired from ATC. Simulations have been performed using FAA's software INM vers. 6.1, introducing a non-standard single-flight-noise-event approach in order to decrease bias related to statistical modelling of lateral dispersion around a backbone track. Thus, the simulation of each single flight event occurred in the reference time period got to a statistical evaluation of measured and estimated geometric parameters characterizing the three-dimension distance between the track Closest Point of Approach (CPA) and the receptor, defined in terms of 2-D distance, altitude and elevation angle. A set of filtered SEL simulated over estimated values has been analysed achieving a statistical description of INM model performance. As a conclusion, a general underestimation of overflight SEL values is pointed out with the increase of 2-D ground distances between CPA and the receptor. Thus, it is possible to emphasize the influence of SEL variance on daily LA_{eq} based metrics (e.g., L_{VA}).

INTRODUCTION

General framework and motivations

According to Italian environmental legislation, ARPA is the regional public agency in charge of the periodical control of the quality status of airport noise monitoring systems. Thus, a great amount of experimental data acquired by Noise Monitoring Terminals (NMTs) together with airport radar tracks acquired from ATC are available. ARPA also provides technical support to planning decision in terms of estimation of acoustic impact on airport surroundings [7] according to different scenarios (e.g., historical and/or evolutionary frameworks of airport activity) [5]. Noise impact indicators, based on L_{VA} and L_{den} metrics estimation, are obtained by simulations performed with FAA's software INM vers. 6.1, which is assumed as a reference model in airport noise concerns.

A deep work has been carried out in order to match experimental noise data coming from NMTs (SEL_m) and the corresponding estimated quantities (SEL_e), achieved by the introduction of a non-standard single-flight-noise-event approach in INM use. Thanks to those activities, an acoustic databases including information about operation radar tracks, flight noise events at NMTs and simulated noise events at NMT locations has been developed

Aim of this paper is to show the results of a statistical analysis carried out on SEL bias (SEL_m–SEL_e) and SEL residuals (SEL_m/SEL_e) concerning the departure and approach operations occurred in a Northern Italy international airport during three busy weeks in 2003 respectuvely, in winter, spring and summer periods as defined by legislation [7] (**Table 2**).

*Table 2***.** *Three busy weeks in 2003 and number of airport operations occurred.*

Period	**Week**	**Num.Ops**
Spring	18/04 – 24/04	4036
Summer	17/08 – 23/08	4760
Winter	11/10 – 17/10	4149

The comparison between aircraft noise monitoring data and simulated SEL values in correspondence of a set of known receptors leads to the investigation of the geometric parameters affecting the model performance.

Table 1. *Selected aircraft models and number of corresponding noise events.*

Aircraft (INM code)	**N**
737400	611
737800	531
767300	2240
A320	3325
A32123	1894
A330	712
BAE146	540
EMB145	1011
HS748A	597
MD82	9851
Total events	**21312**

Aircraft noise monitoring data (SEL_m)

The available noise monitoring dataset refers to a high traffic international airport in North Italy. The noise monitoring network is composed by 16 remote Noise Monitoring

Terminals (NMTs) and uniformly distributed around the airport.

NMT code	distance (m)	altitudine (m)	N
1	5799	266	1622
2	5690	270	1812
3	5535	273	1074
4	6399	291	1191
5	1452	231	756
6	2268	220	2057
7	3580	214	660
8	4274	208	2346
10	6185	285	1193
19	8413	229	1195
24	4488	211	1356
45	5628	253	1446
47	11631	214	462
48	4528	262	1574
49	4660	260	2015
52	1890	230	553
Total events			21312

Fig.1. 2-D distance of NMTs from the ARP (Airport Reference Point), altitude (m osl) and number of correlated noise events.

Each NMT is capable of recognising aircraft noise events according to a, opportunely configured, threshold sound level and event time duration.

A set of 36941 overflight SEL values acquired in the 16 NMTs has been collected. In order to ensure their aeronautical origins, SEL values have been checked by matching each of them with radar tracks of aircraft overflights occurred in the same time period. The correlation between measured SEL data and aeronautical operations is realized by considering radar track points recorded in a given time interval including the measured noise event and then linking the closest radar track point to the NMT location. Thus, a unique relationship between NMT-related noise events and radar tracks is established.

After this data validation, a set of 33267 filtered overflight SEL values has been achieved. Then, a further selection of 21312 event referred to 10 aircraft code has been carried out (**Table. 1.**). Aircraft models have been chosen only if present with at least 10 occurrences for each NMT (**Fig.1.**).

Simulation approach

A non-standard simulation approach has been introduced in the application of INM model. The 2-D ground projections of radar tracks have been imported into the INM airport study and, after a suitable pre-processing phase, they have been stored in INM traffic input files and fully treated as INM ground tracks (**Fig. 2.**). Each of them has been assigned to the corresponding aircraft operation in order to simulate every single flight occurred without introducing any lateral dispersion model [4][6]. Procedural profiles (ICAO A and ICAO B) and stages have been assigned to each aircraft operation according to statistical data based on official statements of the flying companies. As far as the stage number assignation is concerned, in absence of any available information the worst option in terms of noise impact effect has been assumed. SEL metric computation at NMT locations has been performed using the *detailed grid* run setup. As a result, a set of 219895 SEL estimated values (SEL_e) has been calculated, respectively the sum of 12935 overflight events occurred in the three-weeks-long period and detected at each NTM.

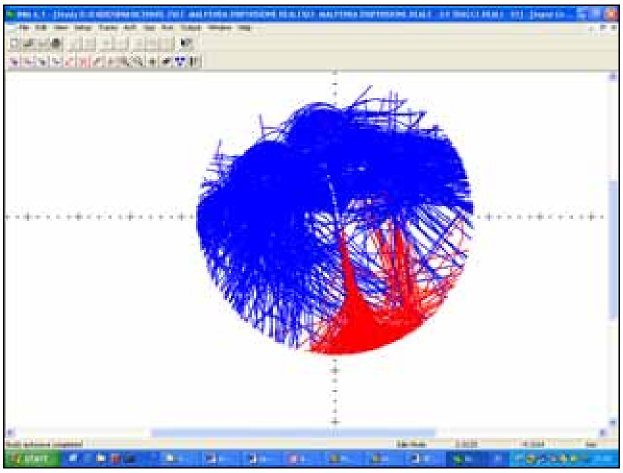

Fig.2. INM input graphics *interface: one week departure (blue) and approach (red) radar tracks implemented as INM tracks.*

A combination of profile and stage provides the INM estimation of track altitude above the terrain elevation and, as a consequence, the three-dimensional localization of the Closest Point of Approach (CPA), as defined in [1].

TOPOLOGICAL FEATURES

INM estimation of geometric parameters

Geometric quantities defining the three-dimensional distance from the noise source (i.e., CPA) and the receptor (i.e., NMT localization) are key parameters in INM overflight SEL event estimation. In **Fig. 3.** segments and angles affecting the calculation of SEL at the receptors are shown.

Setting NMT 3-D position and 2-D track projection as INM input data implies the configuration of the ground distance l_{seg}, while CPA 3-D coordinates and elevation angle β are achieved by INM segment computation algorithm, according to the architectural scheme provided in [1]

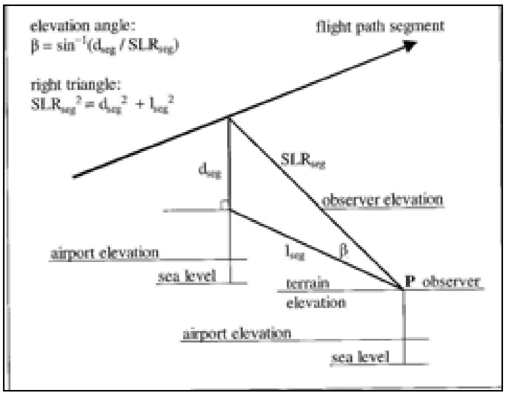

Fig.3. INM lateral attenuation geometry. Source: INM Technical Manual.

Elevation angle β affects noise computation at the receptor [2]; in particular, the lateral attenuation term depends on it [1] according to the following equation:

$$
\begin{aligned}
\Lambda(\beta) &= 3.96 - 0.066\beta + 9.9e^{-0.13\beta} \qquad 0° \le \beta \le 60° \\
\Lambda(\beta) &= 0 \qquad 60° \le \beta \le 90°
\end{aligned}
\tag{1}
$$

The estimated geometric parameters of slant distance SLR_{seg}, CPA altitude d_{seg} and elevation angle β , referred to the closest track segment to the receptor, are stored for each operation in INM *detailed grid* output file.

Achievement of real geometric parameter

The analogous real geometric parameters have been calculated for each noise event. This allows cutting off from the reference dataset the aeronautical events for which SEL values may be affected by unsuitable estimation of the track position.

Radar tracks used in INM simulations are correlated to real noise events detected by each NMT. Following INM algorithm, the closest radar track point to the receptor is identified for each coupled NMT event and radar track. Afterwards, the geometric parameters altitude and elevation angle have been calculated.

Finally, a dataset of aeronautical events collecting noise and geometric information have been obtained: it provides both real and estimated parameters of SEL values, CPA altitude, slant distance and elevation angle.

In **Fig. 5.** the estimated versus calculated CPA altitudes are plotted. A general INM underestimation is noticed for increasing altitude values. Several conditions drive this phenomenon: infact, INM altitude depends on profile and stage number assigned to each operation and, on the other side, the calculated real track point altitude may be affected by NMT correlation errors. The overlap of uncertainties make any interpretation to be hard.

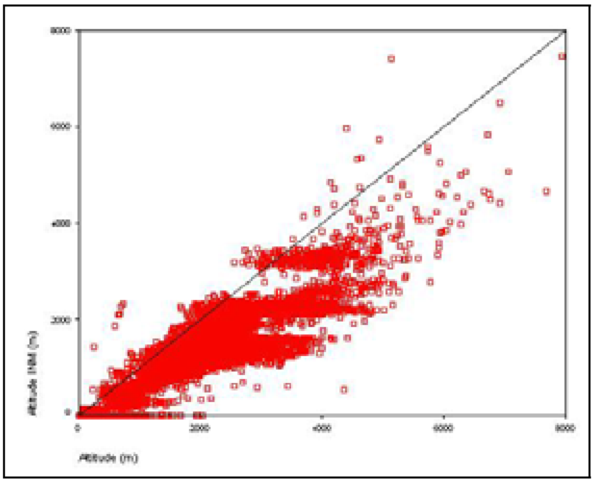

*Fig.5***.** *INM estimated CPA altitude (Y axis) and calculated altitude of the closest track point (X axis) for 21312 selected events.*

Nethertheless, the trend of SEL data in **Fig.6.** shows a general underestimation as well, in opposition with the expected results.

According to this, INM SEL underestimation seems to be driven by other factors (i.e., not directly related to geometry).

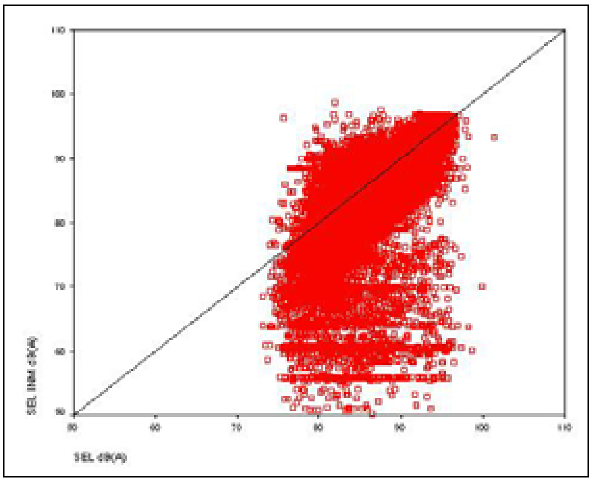

Fig.6. INM SEL estimated values (Y axis) and measured SEL values (X axis) for 21312 selected events.

SEL residual analysis

SEL ratios have been analysed in order to investigate further driving factors of INM underestimation. It is clearly underlined in box plot representation of SEL residuals grouped by 2-D ground distance categories (**Fig. 7.**). INM model performances get worse with the increasing 2-D ground distance of the noise source from the receptor, starting from 6000 m..

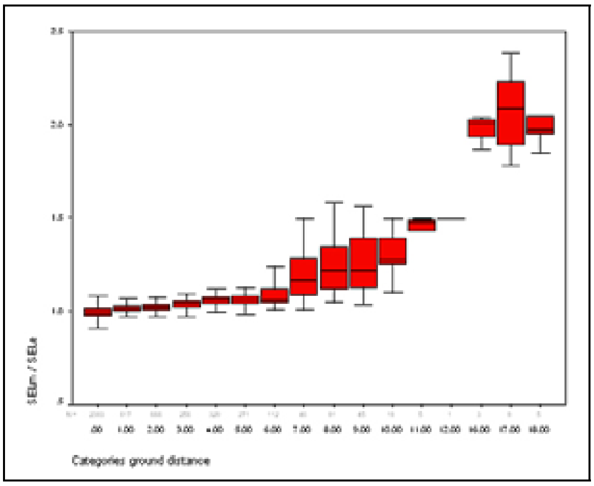

Fig.7. Box plot description of SEL_m/SEL_e ratios for groups defined by 2-D ground distance classes.

Factors ruling this behaviour may concern:

- the lateral attenuation term, described in Eq. (1), which might get unsuitable for high 2-D ground distances;
- NPD curves might get unreliable for high 2-D ground distances;
- NMT operating and/or correlation errors, which might lead to overestimation of SEL measures for high 2-D ground distance.

CONCLUSIONS

A statistical analysis of flight noise SEL bias (SEL_m–SEL_e) and residuals (SEL_m/SEL_e) has been carried out. Noise data have been achieved by linking aircraft noise monitoring data and estimated SEL values in correspondence of a set of known receptors. Simulations are perfomed by using INM model vers.6.1, implementing a non-standard-single-flight noise event approach.

A high level of uncertainties in aircraft profile setup and the overimposition of multiple errors, not last systematic errors in NMT noise event acquisition, does not allow the identification of the cause-effect relationship but, as a preliminary conclusion, it is reliable to state that the increase of 2-D ground distance between aircraft track and receptor, together with the decrease of elevation angle get INM performances get worse. In particular, an underestimation of simuated SEL values is marked.

Nethertheless, as shown in **Fig. 8.**, SEL residuals tend to increase for low estimated SEL: it implies that INM underestimation does not highly affect long term noise estimators like L_{VA}.

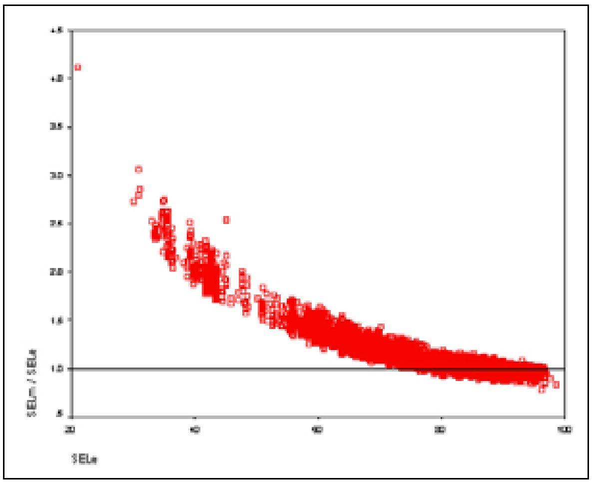

Fig.8. SEL_m/SEL_e ratio in function of SEL_e Sample of 21312 noise events.

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