Validation of FLULA, a time-step model for aircraft noise calculations

The aircraft noise program FLULA, developed at EMPA and used for aircraft noise calculations of Swiss airports, was validated by carefully controled measurements at distances up to 10 km away from the runway. Overall agreement between FLULA calculations and measured values was within a fraction of a decibel. These findings assure confidence in FLULA for accurate aircraft noise calculations.

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The aircraft simulation program FLULA was developed at EMPA. An example of aircraft noise contours produced with FLULA for airport Zurich is shown in Fig. 1. Aircraft noise is a political issue because areas with high aircraft noise are subject to restrictions in land use. Therefore, it was important to demonstrate that FLULA produces reliable results, i.e. that the calculated levels correspond to the levels measured at specific locations. The validation presented here was made in summer 2000 when the departure procedures at airport Zurich were changed to straight take-off during construction work on runway 28. This was the occasion to measure well-defined, straight flight paths and to compare them with the corresponding calculations.

For over 60 aircraft types, the database of FLULA includes information on spectra and on the level of sound emission in function of the emission angle. These so called "directivity characteristics" are based on measurements at Zurich airport and have been evaluated over many years. The validation was the final task in consolidating that data base. There was one additional question to answer: how good was the acoustic modelling of the power reduction pilots usually apply at an altitude of 450 m? During two days in summer 2000, measurements were taken simultaneously at five locations below the flight path of the straight departures. The closest location was 4 km away from start of roll, and the farthest was 10 km away. In total, 260 departures were measured. The radar information on flight paths and the identification of aircraft was provided by the airport. Fig. 2 shows some climb profiles extracted from radar measurements for aircraft MD83. The climb profile shows the altitude (height) of the aircraft in function of the distance to the runway. In Fig. 2 it is evident that depending on take-off weight, the aircraft is climbing differently. For instance for a location at 10'000 m away from the runway, some aircrafts have reached a height of 1500 m whereas others have only reached 900 m. Definitely, sound levels must be different for these two distances. Therefore, there was a simulation for each individual flight in order to individually compare measurement and calculation. The speciality of FLULA is the capability to reproduce the time history of the sound level in the same way as if it would have been measured. As an example, the measured and the calculated curve of the same flight for a location at 7 km from start of roll is shown in Fig. 3. Usually, aircraft noise is characterised by the acoustic energy of a single event, denoted L_{AE}. For the situation of Fig. 3, the measured L_{AE} was 92.6 dB and the calculated L_{AE} was 91.9 dB. The comparison of 768 measurements from 200 individual flights with the corresponding simulations produced the results shown in Fig. 4. There, the differences "measurement minus simulation" of the L_{AE} are listed in function of the height of the aircraft, i.e. basically in function of the distance from the aircraft to the observer. Of course, in individual cases there are rather large deviations up to 5 dB, but standard deviation is at 1.7 dB, and, most important, the average is at only 0.1 dB. The following conclusions can be drawn: The average being close to zero indicates that there is no systematic error in the way FLULA calculates aircraft noise. Also, neither the results at low altitudes (e.g. 250 m) nor those at high altitudes (e.g. 1000 m) have any important bias, which shows that the transition in the power setting of the aircraft at about 450 m height is modeled correctly, and that FLULA provides reliable results also for regions at several kilometres away from the airport.

Support: BUWAL (earlier phase)

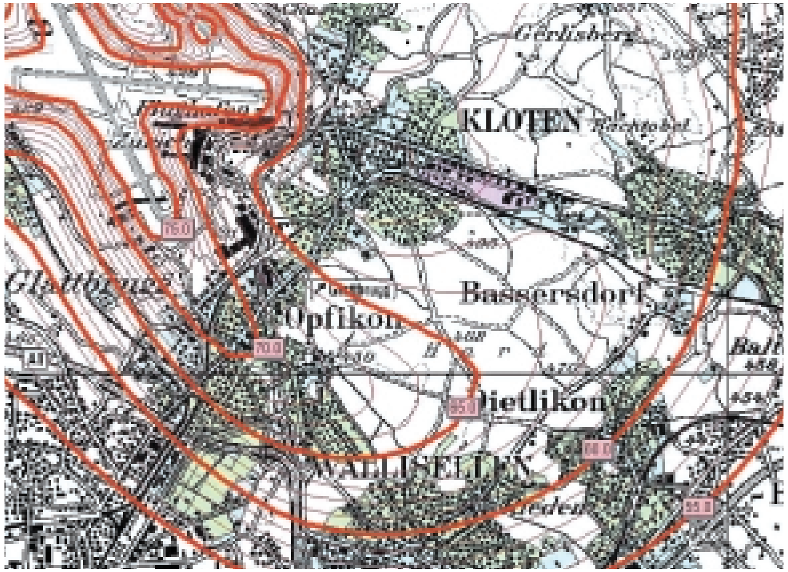

__Fig. 1:__ Example of an aircraft noise calculation for Zurich airport. The red lines indicate the average noise loads L_{eq} in dB for the 16 hour period of the day.

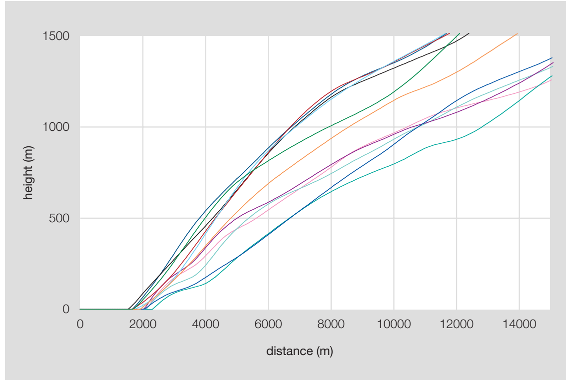

__Fig. 2:__ Climb profiles MD 83.

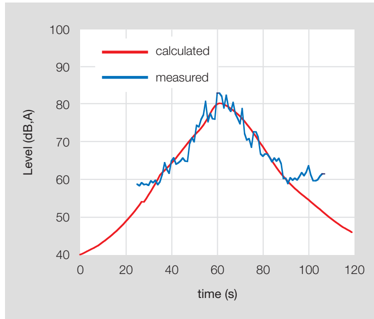

__Fig. 3:__ Example: Measured and computed levels for the same flight of an MD83.

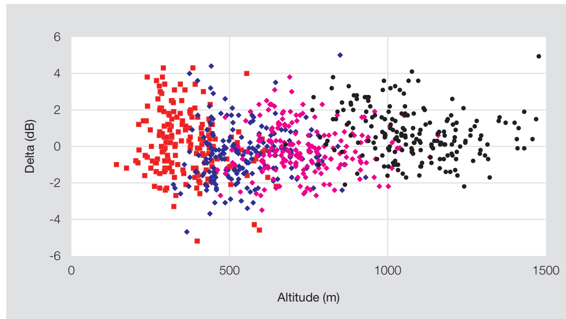

__Fig. 4:__ Differences of measured L_{AE} minus simulated L_{AE} using FLULA. The altitude is the distance in meters of the aircraft above the measurement point. Data were measured at four points in different distances from the runway.

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References: *R. Bütikofer et al., Conf. Internoise, NL The Hague, Conf.Proceed. (2001)*