Approach Noise Trials

Technical report for the KTH/Novair project Approach Noise Trails (ANT), spring of 2021

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Sammanfattning
Projektet Approach Noise Trials - ANT har genomförts inom ramen för Centrum för Hållbar Luftfart vid Kungliga Tekniska Högskolan, KTH (https://www.kth.se/en/csa/) . Bakgrunden är de möjligheter som uppstått under pandemin som inneburit att reguljär flygtrafik i perioder minskade med upp till 90%. Denna situation gav upphov till en unik tillgänglighet av både luftrum samt flygplan vilket har utnyttjats i projektet. Projektet har genomfört kontrollerade inflygningar på Arlanda (bana 26) där två flygplan från Novair (Airbus A321) flögs med förutbestämda rutter, hastigheter och konfigurationer (motorpådrag, klaffar, landningsställ). Ljudimission på marken mättes sedan upp inom ramen för projekt ULLA som har utplacerade mätstationer runt Arlanda. Totalt genomfördes 18 flygningar under vecka 14 och ljudet vid passage över en mikrofon spelades in vid 31 positioner. Dessa data omvandlas sedan till tersband i frekvensområdet 25 Hz-20 kHz. Dessutom spelades ljud in binauralt på 5 positioner med så kallade konsthuvuden för att senare nyttjas i psykoakustiska tester. Sammanfattningsvis genomfördes mätningarna och projektet helt enligt den ursprungliga planen. Det kan även nämnas att projektet fick bra medial uppmärksamhet med bla en artikel i Ny Teknik samt ett inslag i SR P1 Dagens Eko.

De data som samlats in kommer i första hand att nyttjas av fem projekt som drivs av Trafikverket med koppling till KTH-Centrum för Hållbar Luftfart (CSA) nämligen: ULLA, CIDER, OPNOP, TREVOL samt ERAS. Efter förfrågning kan data även delas med andra TRV- eller icke-kommersiella projekt.

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1. Background

This project report is conducted within the research frame of the Center for Sustainable Aviation (CSA) at KTH. The projects in this center place particular emphasis on noise from arriving aircrafts. At the center, a possibility has been identified due to the ongoing pandemic caused by the Corona virus. It is now possible to take advantage of the fact that approximately 70% of all aviation operations in Sweden have ceased due to the pandemic. This means that there is therefore accessibility to both aircraft, flight crews and airspace at Arlanda, and that it is thus possible to carry out approach attempts that would in principle be impossible to perform during normal traffic intensity. Similar types of noise measurements are normally made only in connection with the certification of new aircraft or engines, and the focus is then almost without exception on meeting the certification requirements imposed on aircraft or engines. For example, noise is then measured at maximum take-off and landing weight.

From a general environmental point of view, the approximately five hours of flight that is carried out will have an emission-increasing effect, but this is negligible in relation to the benefit in the form of increased knowledge about noise that the project will provide. This assumption has been verified through contacts with the Swedish Environmental Protection Agency and researchers at Strategic Sustainability Studies at KTH [1].

1.1 Purpose

An important aspect of the project is to support The Center for Sustainable Aviation (CSA) at KTH in gaining more detailed knowledge of the occurrence of noise levels on the ground from aircrafts approaching Arlanda. In particular, the proposed project aims to provide the Center with knowledge about noise from aircraft of the current common aircraft type Airbus A321. This concerns how different speeds and how the aircraft's flaps and landing gear are extended affect noise levels on the ground. The new knowledge will be very valuable and will be used by five other projects that are currently linked to the CSA center. The project will also highlight that despite the fact that Sweden is largely affected negatively by the ongoing pandemic, there are opportunities to conduct research aimed at something positive for Swedish aviation and the environment.

1.2 Objectives

The objectives of the project have been the following:

- Create a database for the tested aircraft type where noise levels, frequency content and sound direction dependence (directivity) can be described with regard to the aircraft's speed through the air, use of leading edge and / or trailing edge flaps and landing position. This database will be used, among other things, in the projects ULLA, CIDER, OPNOP, TREVOL and ERAS linked to the center to describe opportunities to influence noise on the ground with flight operational methods.
- Provide new knowledge regarding strengths and weaknesses in the source and distribution models for noise that are currently used nationally and internationally.
- Carry out binaural recordings (art head recording, en.wikipedia.org/wiki/Binaural_recording) in several positions along the approach route to give a description of how different landing

sounds are experienced depending on the aircraft's speed and configuration through listening tests in project ULLA.
- Receive attention from the Swedish media in the form of at least one news item, report or newspaper article.

2. Method

2.1 Flight description

The flight path consisted of a normal straight ILS approach starting 17 nautical miles (nm), from runway threshold, with entrance to the glide slope at the Final Approach Point (FAP) 7.5. Prior to the glide slope, the aircraft either flew in level flight or descended in a continuous angle depending on the starting approach height at 17 nm. The reason for extension of the flight path to 17 nm, was to facilitate good noise measurements of the aircraft in level flight and in clean configurations with flaps and landing gear retracted.

All of the 18 flights, except the first two, were performed as regular landing approaches according to regular ILS approach standards. However the flights were organized to cover variations in speed, phase of configuration (landing gear deployment and flaps settings) and ILS approach height.
The speed variations were conducted with 10 knots (kt) increments and in a total of four steps. For example, the first flight's starting speed was set to 230 kt at distance 17 nm from the runway. At distance 13 nm, the speed was reduced to 200 kt (to conduct an ILS approach and be within safety margins). The second flight selected a starting speed of 220 kt and at distance 13 nm reduced this to 190 kt, in order to implement a consistent 10 kt speed decrease to the previous flight. The third flight reduced the speed with an additional 10 kt and so on.

The variation of configurational settings was mainly governed by at what distance the landing gears were deployed. Two distances were selected, 5.2 and 6.2 nm, to be representative of a late and early deployment phase. For both phases, the four speed variations were repeated, resulting in 8 flights to cover the variations of speed and configurational settings.

ILS approach height was varied between 2500 and 4000 feet (ft) to mimic the difference of ILS height for runway 26 and 01R and L. For each height the variations of speed and landing gear deployment phase was repeated, resulting in 16 flights to cover every combination.
Besides these 16 flights, two calibration flights were conducted that were identical for both aircrafts. and. In these flights, which were flown at a constant altitude of 2500 ft, the speed was varied together with changes in configuration, including landing gear down.
Deviations to the above general description is present in the appended flight scheme. These alterations were introduced in order to enable elongated recordings of certain aircraft configurations that were of particular interest to the researchers.

Flight Data Recorder FDR-data

Data for position, altitude, speed and other valuable parameters describing the aircraft's configuration, is gathered from the aircraft’s Flight Data Recorder’s (FDR-data). The sample time for FDR-data is 1 sampel/second and over 30 different parameters are recorded in addition to the above mentioned. Among these, are data for thrust-settings and fuel consumption, allowing analysis of environmental impact of the different approach trails. Novair is responsible for extraction of the FDR-data which is compiled into excel-format with UTC-timestamp for every sample row.

As these test flights are ordered solely for this purpose, data from these flights will be available for use without the confidentiality agreements that normally restrict the use of FDR-data. Any dissemination of data for use in other research projects takes place in consultation with CSA.

2.2 Acoustic measurements

To measure noise from approaching flights, a total of 31 microphones were set up at various locations in the vicinity of the airport. Each microphone setup consisted of :-

1. A microphone with its cover,
2. 12 V and 24 Ah Lead battery/ies,
3. Raspberry pi boards,
4. SD cards, and
5. Wiring cords.

Eight of the setups had a sound card each additionally due to a different microphone in operation. To configure the microphone setups, the following had to be taken care of:

1. Lead batteries were to be fully charged.
2. Microphones were to be calibrated to 94.0 dB at 1 kHz.
3. SD cards were to be reset and the required patch installed.

To connect the above components to one another, the wirings were subjected to operations such as soldering and clipping. Three different measurement setups were used during the measurements, ordinary microphones, binaural microphones and one mast mounted microphone and all three types of measurement setups are seen in figure 1.

Measurement setup

Ordinary microphones were placed at 1.2 m height above the ground surface and mounted with the microphone directed towards the sky.

Binaural microphones, that is microphones placed inside dummy heads at 1.2 m height, were placed at five positions along the flight path. This measurement technique was used in order to obtain entire recordings rather than sound levels that later on can be used in listening tests for the TRV ULLA-project.

On one **6 m** mast a microphone was mounted in order to measure sound levels that are less affected by the ground than the ordinary ground microphones and could facilitate the work in TRV project CIDER to better assess the effect of ground reflections on aircraft noise.

Figure 1: A photograph of the three different setups used during the measurements. The ordinary microphone setup can be seen at the bottom left side, the binaural recording setup can be seen to the right and in the middle the mast microphone is shown.

Measurement locations

Along the ground track of the flight path a total of 31 microphones were set up, see figure 2 for a satellite photograph with the locations. The main part of the microphones was placed directly under the flight path, and on-average, space one nm apart to cover the total length of the ground track. Each of the microphone positions was carefully selected in order to offer the most continuous measurement possible without interruptions of transitional phases of the aircrafts configurational changes. Care was also taken to find measurement positions that offered acceptable background noise level, for example avoiding close proximity to busy roads or agricultural activity.

Besides these microphones, three “legs” of microphones were positioned lateral to the ground track. These legs consisted of 3-4 microphones each and were positioned at the beginning (15 nm), midsection (6 nm) and end (1.6 nm) of the flight path. Each of the “legs” extended an equivalent distance (depending on flyover height) to cover lateral overflight angles up to 60 degrees.

In addition to the above microphones, 5 Head And Torso Simulators (HATS) were also used for recording of binaural sound. The HATS were set up at distances 1.6, 4.7, 5.5, 8 and 15 nm, directly on the ground track. These positions were chosen to best record the total variance in sound of different landing procedures.

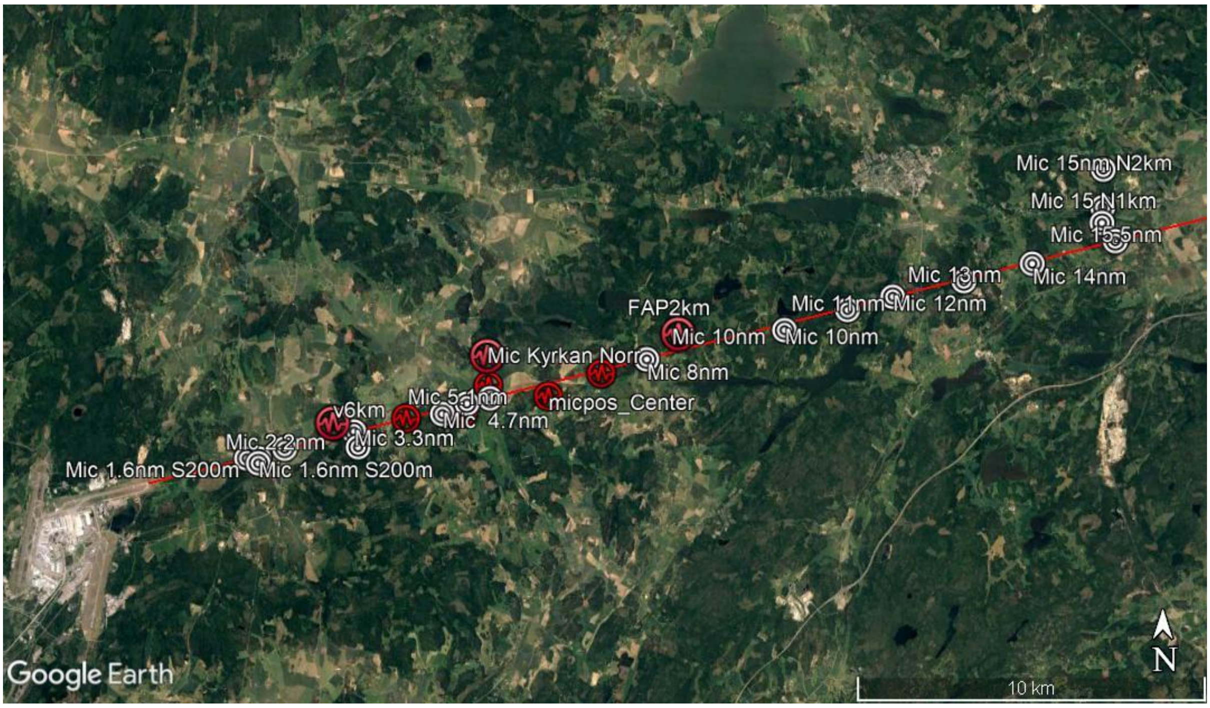

Figure 2: Satellite photograph over the measurement area. Arlanda can be seen at the bottom left corner. The red line, extending out 17 nm from runway 26, marks the ground track all aircraft followed when conducting the scheduled overflights. The red markers mark long term measurement positions for project ULLA and white markers mark the additional measurement positions for project ANT. The microphones are named after the position at which they are positioned.

3. Results

3.1 Flight paths and configurations

In examination of the FDR files and flight trajectories, it was concluded that all the 18 performed flights managed to fulfill the predetermined flight schedule. The FDR files delivered from Novair showed no sign of corruption or missing values, see figure 3 for an example excerpt of FDR-data. In addition to scheduled Novair-flights, regular traffic was also present during the measurement-day and hence recorded. For obvious reasons, FDR-data for these external flights is not available. However, radar-data, with information on position and velocity for these aircraft, is available through the OpenSkyNetwork database.

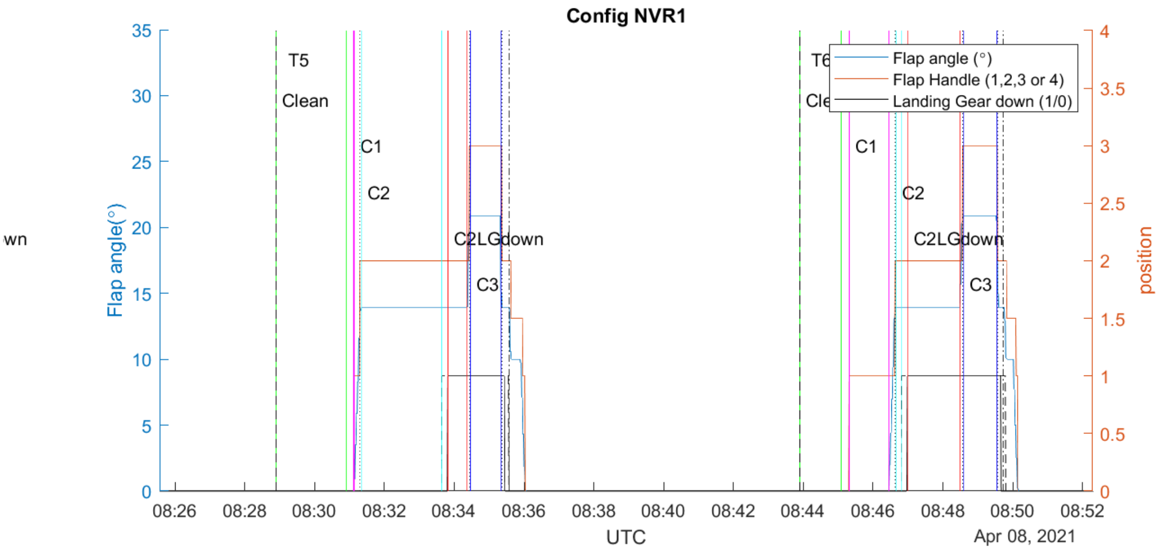

Figure 3: Excerpt from FDR-data showing a time record of configurational changes for two overflights. Clean, C1, C2, C2 and LGdown represents the different stages for high-lift devices and extension of landing gear.

3.2 Acoustical results

The microphones conduct fast measurements, i.e measure every 0.125 seconds and produce files which contain 5 minutes' of data. The data is measured in one-third octave bands, with centre frequencies ranging from 25 Hz to 20 kHz.

Of the 31 microphones deployed, it was found later that four of them had become dysfunctional prior to the experiment, rendering 27 microphones functional throughout the length of the experiment. The microphones, once decommissioned after the experiment, were re-calibrated and the changes in the calibration levels were recorded, to be adjusted in the processing of the data.

The data thus collected from the SD cards were copied to a computer and processed via MATLAB. The data is arranged in a .mat file as well as in an MS-Excel Workbook, in accordance with the time stamps in the FDR data. The workbook has data of 18 microphones, each requiring one sheet for its measured and re-calibrated noise arranged in one-third octave bands in time.

Among the A-weighted noise levels ("A-gathered"), let us look into two microphones; at 1.6 nautical miles 200 m south of the trajectory (figure 4 a-b) and at 13 nautical miles (figure 5) away from the runway.

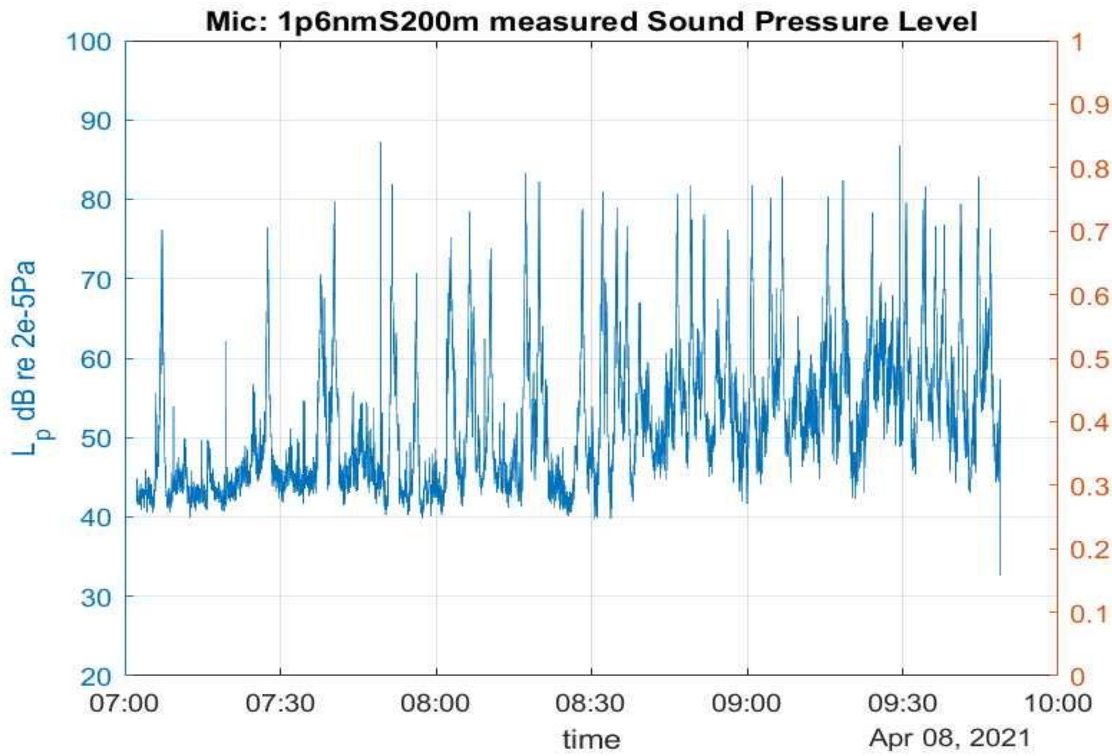

Figure: 4(a)

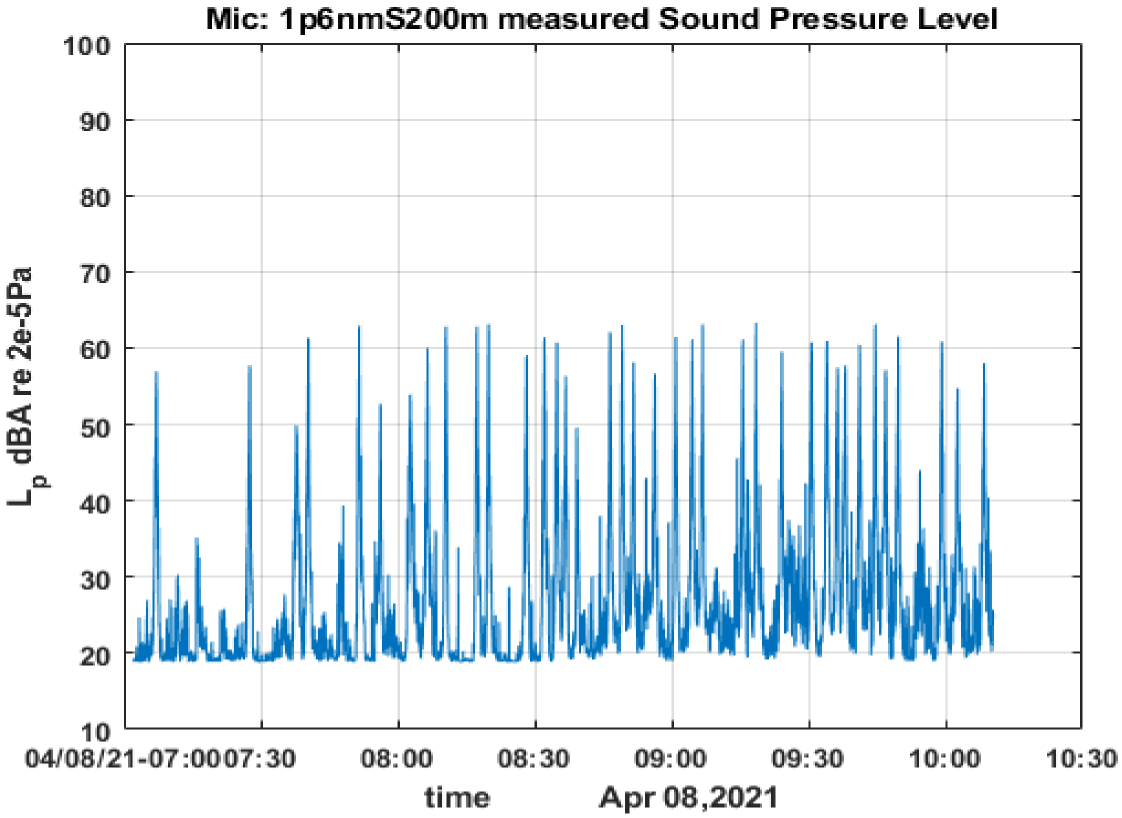

Figure: 4(b) Plot of sound pressure levels recorded by the microphone at 1.6 nautical miles away from the runway and 200m south of the trajectory. (a) is without weights while (b) is A-weighted.

It can be noticed that the maximum SPL crosses 80 dB and 60 dBA consistently for the microphone closer to the runway. Meanwhile, from about 9:00 am, the troughs in SPL are higher, indicating higher noise when the aeroplanes are further away. This is explained by higher unwanted background noise, due to the howling of wind, rustling of leaves in trees, grass, etc. Fortunately, this background noise does not affect the peaks in SPL as they are more than 20 dB above background noise.

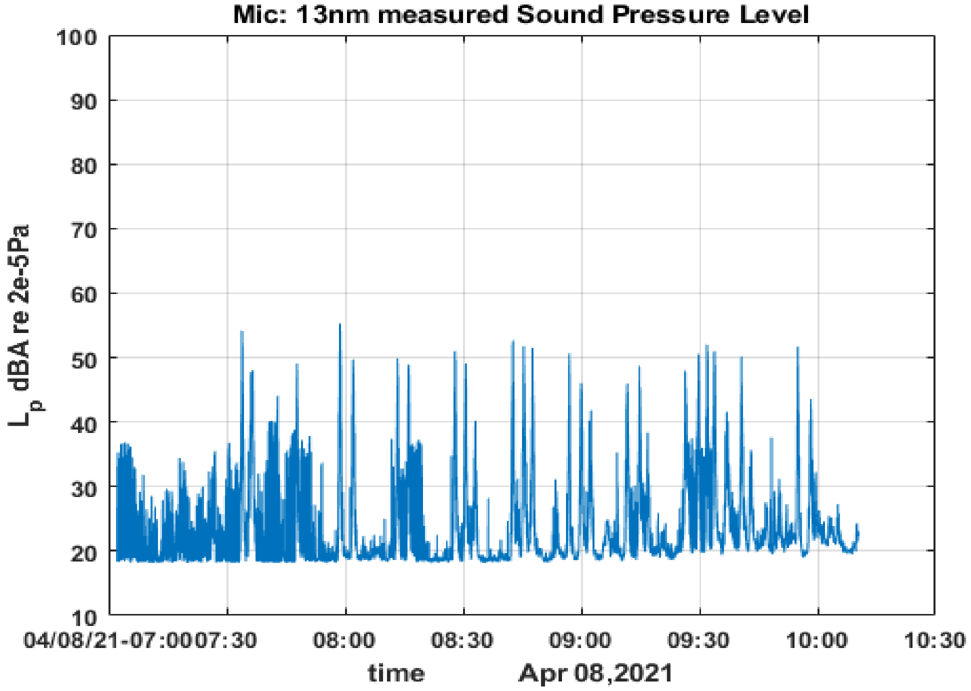

Figure: 5 Plot of sound pressure levels recorded by the microphone at 13 nautical miles from the runway. (a) is without weights while (b) is A-weighted.

Observations similar to the ones made about the closer microphone can be made with the one 13 nm away from the runway as well, see figure 5. Peaks in SPL consistently cross 70 dB and 50 dBA. Additionally, there is an effect of an increase in background noise over time as well. Yet, the effect is less pronounced here, which can be attributed to a more open surrounding and topology of the location.

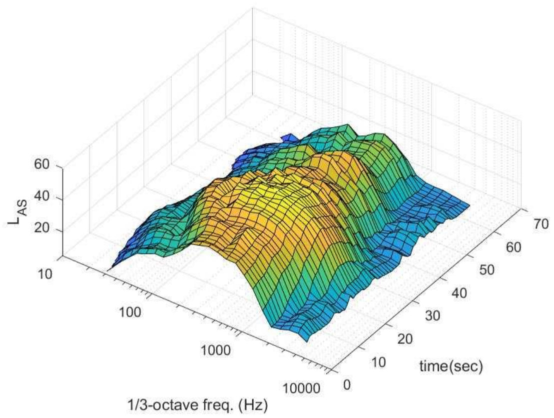

Figure: 6(a)

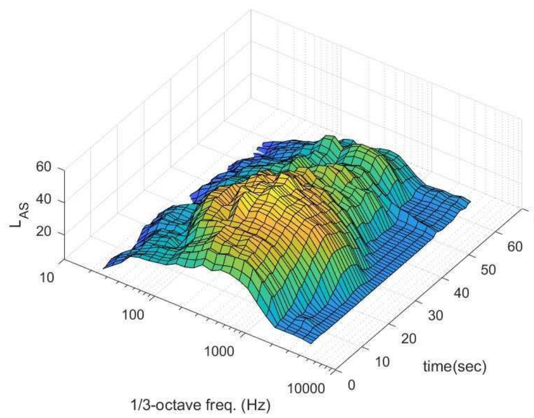

Figure: 6(b)

Figure 6: comprises two spectrograms; (a) where the landing gear is up, and (b) where the landing gear is down.

In Figure :6, spectrograms of the noise measured by the microphone at 5.5 nautical miles from the runway are provided. Fig: 6(a) has the landing gear pulled up whereas in Fig: 6(b), the landing gear is down. It can be observed that the noise is higher in the latter, especially in the mid-frequency region. This can be attributed to noise generated due to flow separation around the landing gear, leading to tonal noise. Any turbulence and vortex shedding also leads to higher noise levels.

4. Media coverage

With support from the KTH media responsible Peter Ardell a short text with figures was published on the KTH website. This led to at least two related publications [2,3] and two interviews by Ny teknik [4] and SR P1 Dagens eko (2021.04.10). Also one of the project partners Swedavia published information about the project on their website. In order to spread the knowledge and data of this project this project report has been written in English.

5. Conclusions

The project has been able to be performed due to the Covid19 pandemic and the resulting decrease of air traffic. The designated aircraft configurations have successfully been implemented in the approach trials. During the flyovers wind speeds increased with resulting increasing background noise for the measurements, partly due to increased noise in vegetation and partly due to increased levels of wind induced oscillations of the microphone membranes although the background levels did not mask the levels from any of the aircraft flyovers.

The database of the sound levels will be made available for all TRV/CSA projects who are interested. Use by other non-commercial research projects can also be discussed. To request access to the data please contact Dr.Karl Bolin <kbolin@kth.se> or Anders Johansson <aebjo@kth.se>.

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References

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