# Project 40
# Quantifying Uncertainties in Predicting Aircraft Noise in Real-world Situations

## Motivation

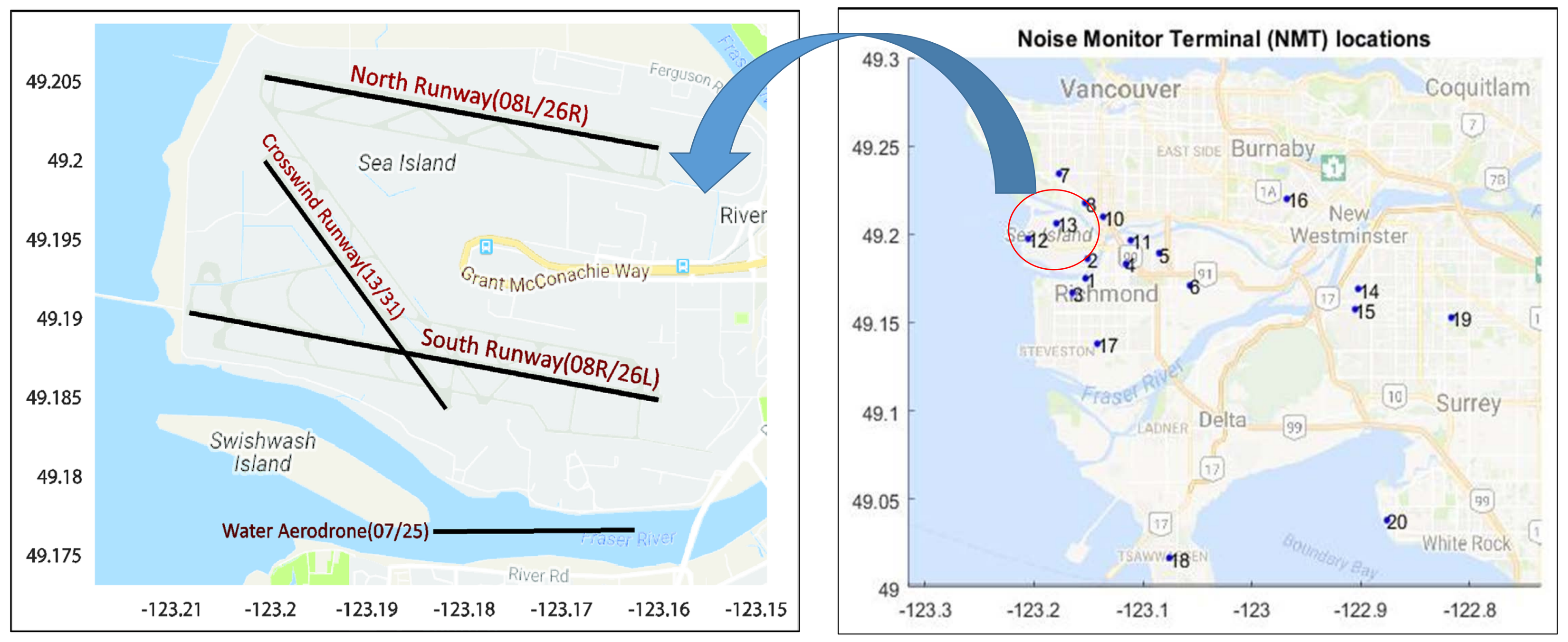
- Improving the understanding of uncertainties for predicting aircraft noise in the current FAA modeling tools
- Need to account for uncertainties in modeling of the aircraft noise (source), meteorological conditions (propagation path) and ground impedance, terrain profile (receiver)

## Objectives

- Analyze measured data obtained from Vancouver Airport Authority (YVR fleet mix, noise events, meteorology data). Validate existing propagation models with the measured data and asses the effect of including a homogenous vs a non-homogenous atmosphere (temperature gradient, wind).
- Analyze DISCOVER/AQ dataset including acoustic and atmospheric data
- Quantify the uncertainties due to the directivity of aircraft, reflections from ground surfaces and shielding effect in forested areas

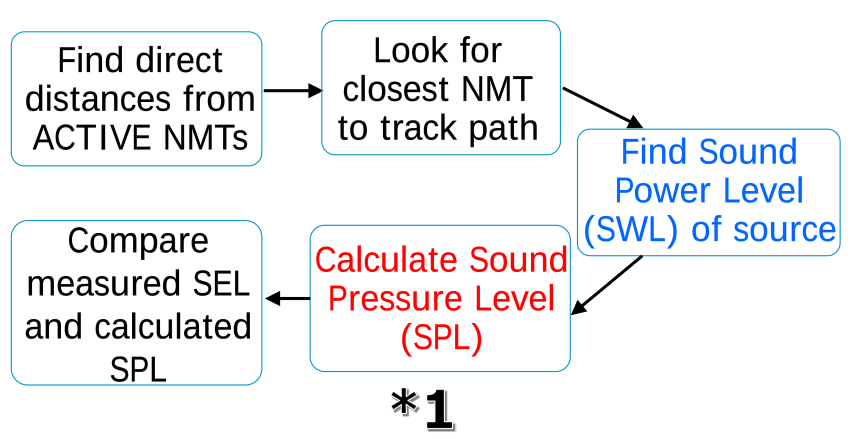
## Approach & Methodology

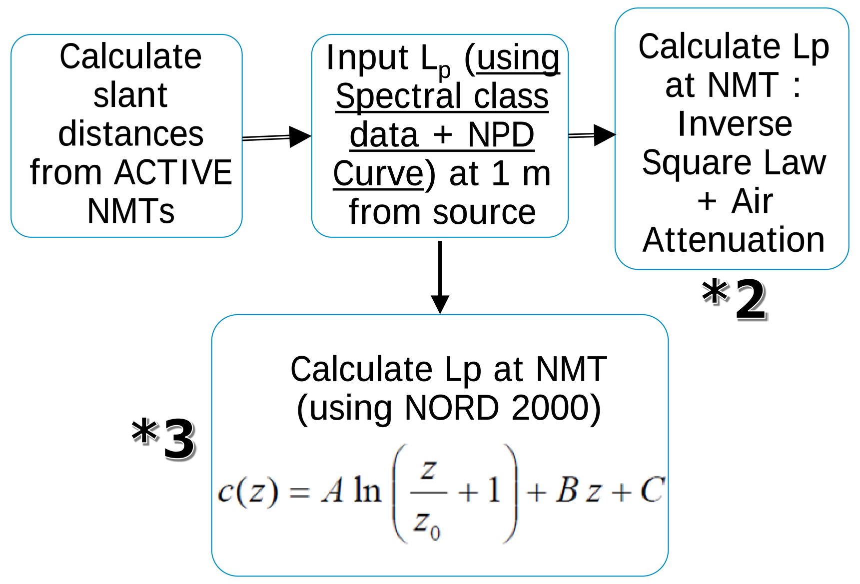
- Data used : Vancouver, Canada airport (noise monitors, meteorological data)
- Propagation to noise monitors during aircraft descent and climb-out analyzed (one flight at a time) to study the effects of real-world meteorological conditions (temperature gradient, wind speed) on noise predictions analyzed.



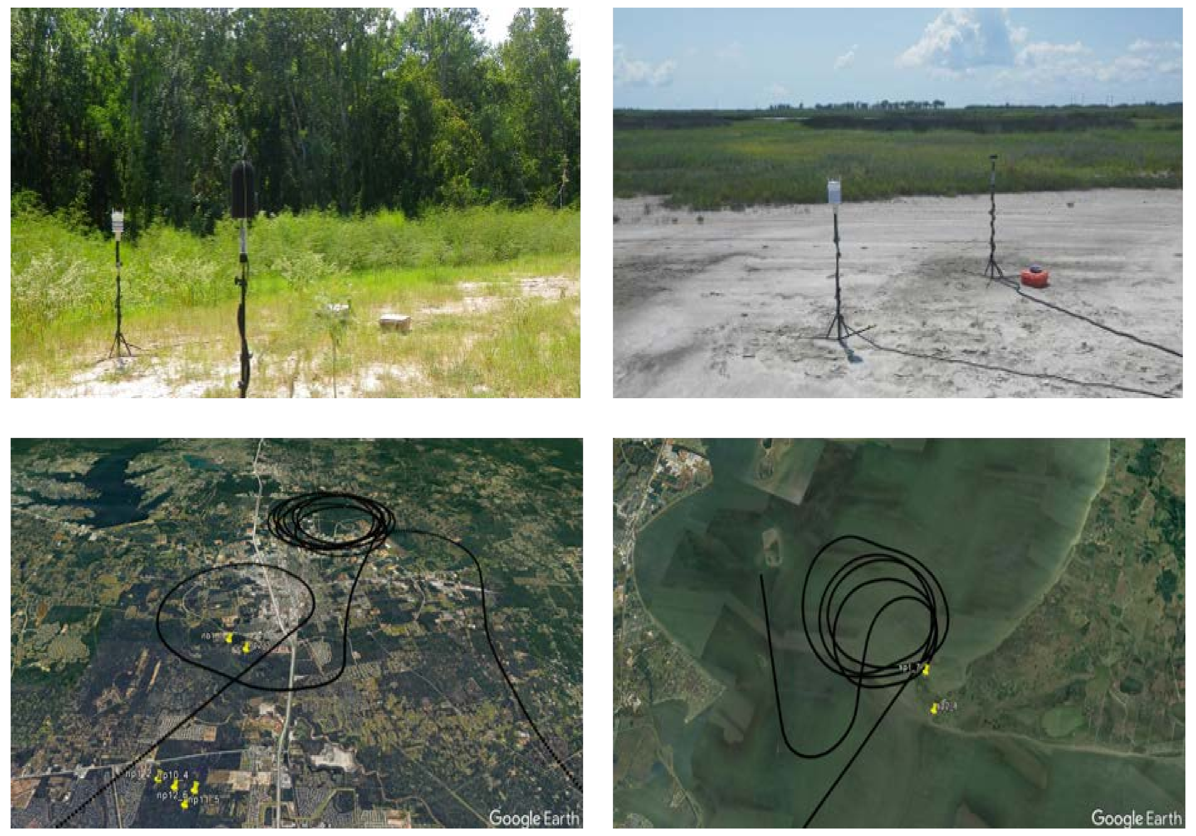

$$SWL = SEL + 20 \times \log_{10}(r) + 11$$

$$SPL = SWL - 20 \times \log_{10}(r) - 11$$




$$c(z) = A \ln\left(\frac{z}{z_0} + 1\right) + Bz + C$$



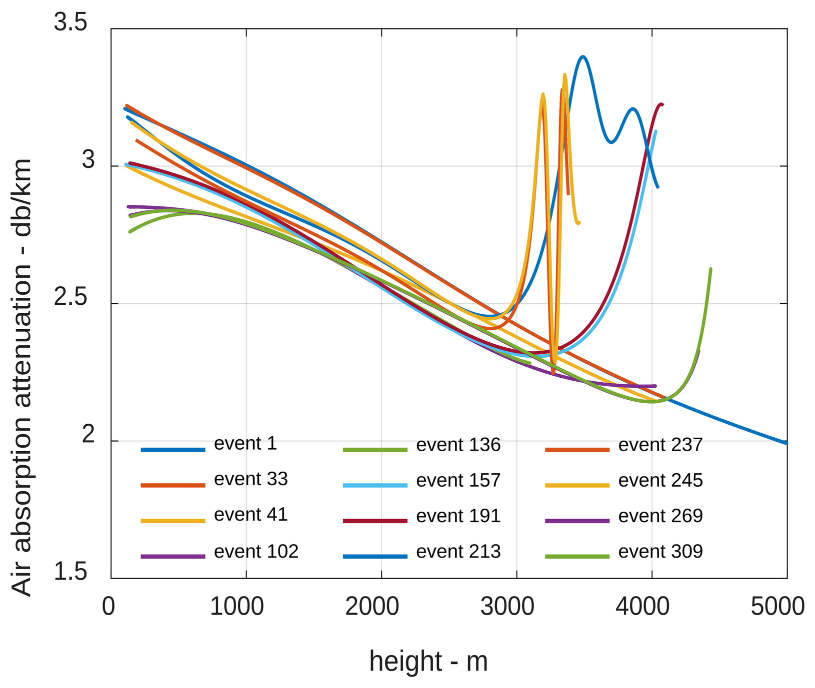
- Identify sites in the DISCOVER/AQ dataset
- Use of satellite pictures, GPS, on-board, balloon and site data for validation of predicted noise levels and quantification of uncertainties

| Uncertainty of the source | Uncertainty in the propagation | Uncertainty near receiver |
|---|---|---|
| Sound source directivity (Engine installation and Doppler effects) | Air absorption(temperature, pressure and humidity) | Effect near the receiver (ground impedance , attenuation and shielding due to ground vegetation) |
| Engine power variation | Terrain effect (barrier effect) | |
| | Acoustic impedance (temperature and pressure) | |
| | Wind and temperature gradients | |

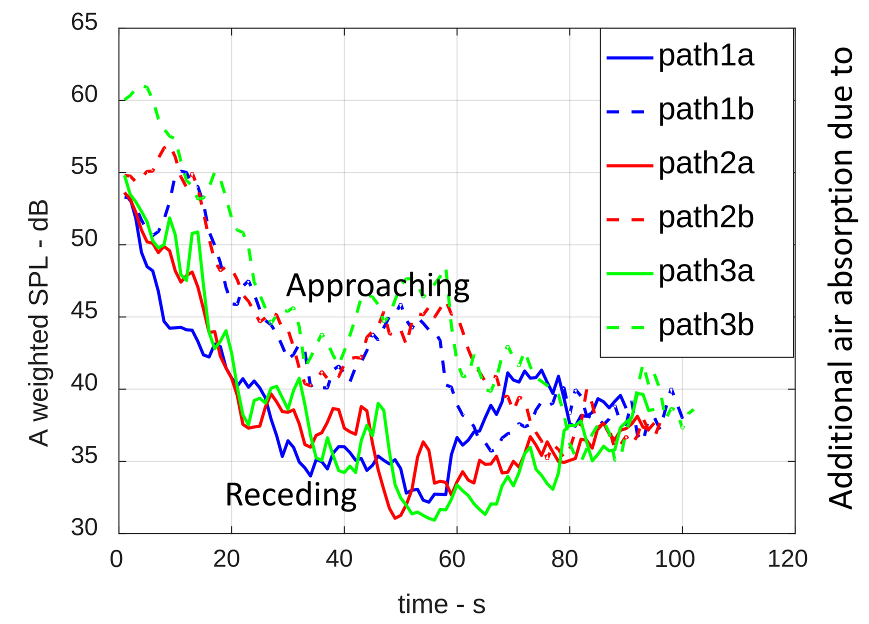
## Results

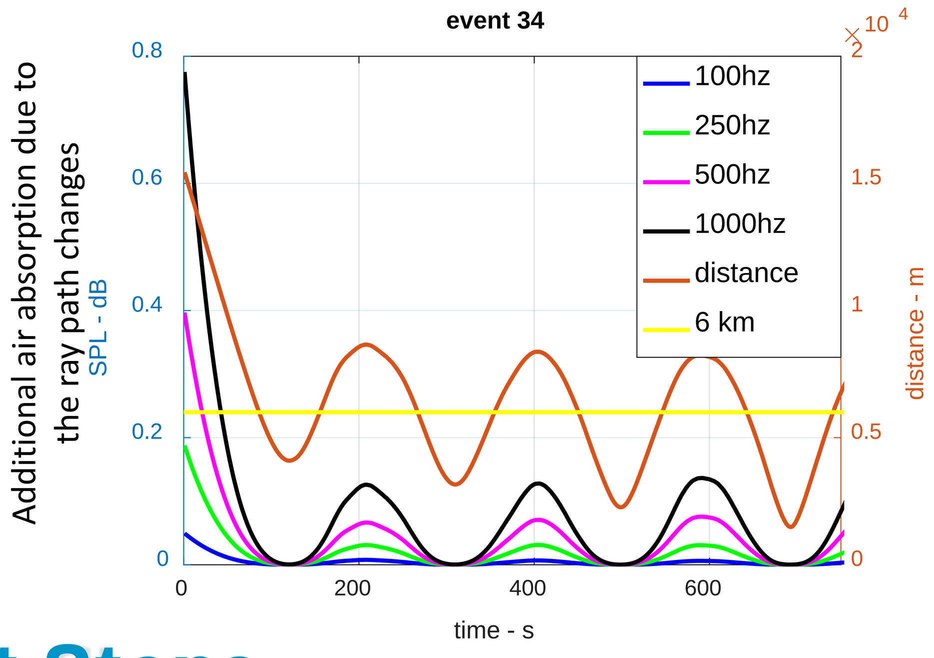
| Input spectrum | Input atmosphere | Method No. | NMT vs. prediction |
|---|---|---|---|
| Overall SWL Back-calculated from NMT SEL | Const Temp & No wind = Homogeneous c | *1 | Poor agreement |
| 1/3rd octave SPL Correct aircraft i/p spectrum from AEDT database | Const Temp & No wind = Homogeneous c | *2 | Satisfactory agreement* |
| | Temp gradient & Wind data = LogLin c(z) | *3 | Overall Better Agreement* |

*NMT is free from immediate reflecting surfaces & background noise is minimal




- Uncertainties due to air absorption is larger than 1 dB/km for 500 Hz sound.
- Doppler effect is significant: up to 10 dB between approaching/receding aircrafts
- Measurements conducted in calm days with small wind and temp. gradients: uncertainties in path length predictions are small. Hence, the predicted SPL due to this uncertainty is within 0.1 dB when the aircraft is 6 km away and the source freq. is less than 1 kHz.




## Next Steps

(Inspired by the work of Wilson et al (2014) [1])

- Use of stochastic sampling techniques to study the effect of uncertainties in the propagation path (meteorological variables) on the aircraft noise levels
- Computationally efficient quantification of uncertainties by: (i) simultaneously sampling over multiple uncertain variables in the propagation path such as temperature, humidity, wind speed (ii) Improving the sampling strategy by using the a-priori knowledge about the spectral content of the source and the nature of propagation path
- Analyze ground effects due to forests with the foliage model and the branch scattering model. Compare with measured data in the forested region and quantify uncertainties due to the type of forest, its estimated heights
- Calculate the total influence due to the uncertainties in the source directivity, the propagation path, the terrain profile and ground vegetation near the receiver locations


[1] Wilson, D. Keith, et al. "Description and quantification of uncertainty in outdoor sound propagation calculations" *The Journal of the Acoustical Society of America* 136.3 (2014): 1013-1028.



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