Assessment of noise level variations of aircraft fly-overs using acoustic arrays

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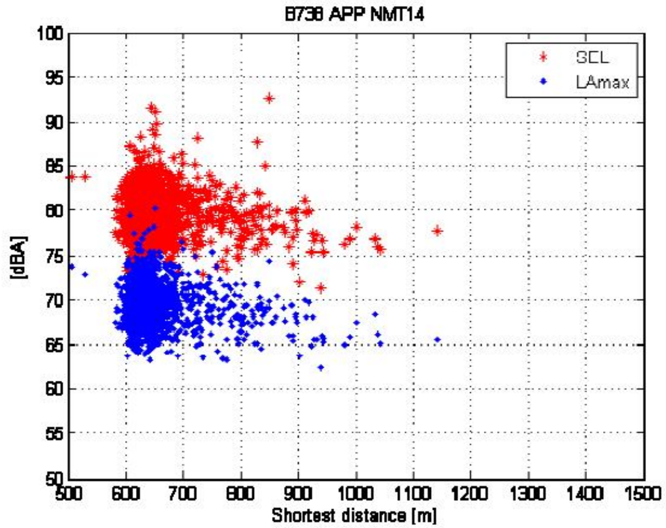
Introduction

- Problem: Noise Power Distance tables for noise contouring show no variability in aircraft noise
  → problem for law enforcement



- Assumption: observed variations in measured noise levels due to the *independent* processes:
  - atmospheric conditions
  - source (aircraft)

- Approach: experiments

Cabauw measurements

Dedicated experiment to measure variability due to atmosphere

- Speaker attached to weather tower (height 100 m)
- Simultaneous measurement of sound and weather parameters

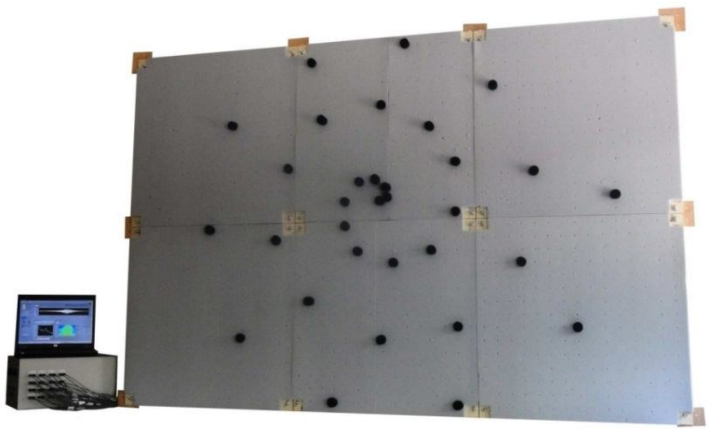
- Conclusion: variations due to atmosphere is negligible: < 2 dB

(Bergmans, Internoise 2011) and (Hebly, Internoise 2013)

Acoustic measurement setup

Experiment to measure variability due to aircraft as noise source

- Measurements done at Rotterdam-The Hague airport
- Acoustic camera located under flight path (from ADS-B) of landing aircraft
- 32 microphones in a spiral configuration
- Fly-over altitude approximately 40m



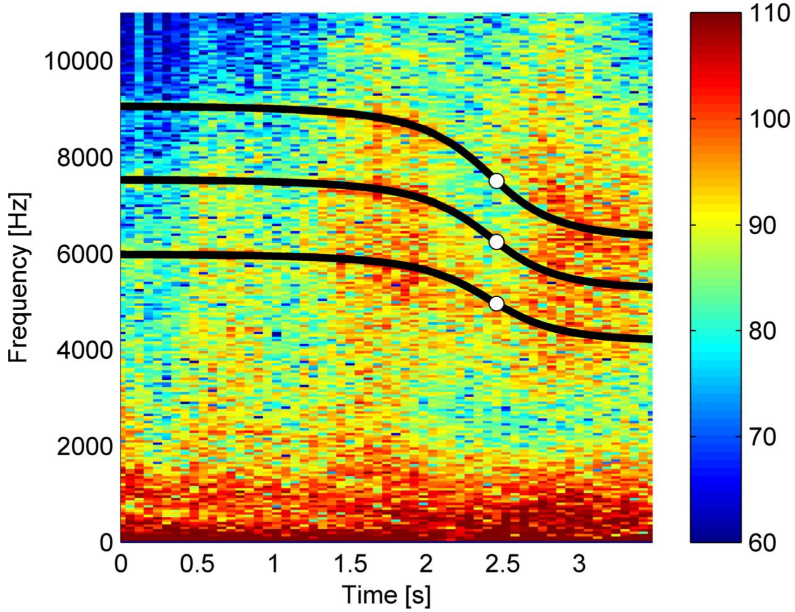
Analysis of acoustic measurements

Engine fan RPM

- Calculate Doppler shift from ADS-B data
- Fit Doppler line on spectrogram
- Engine fan RPM calculated from first harmonic

Results:

Measurement	RPM	RPM %
1	3093	59.8
2	2862	55.3
3	3023	58.4
4	2724	52.7
8	2912	56.3
1	3071	59.4
14	3148	60.8
18	2808	54.3
19	2690	52.0
20	3213	62.1



Analysis of acoustic measurements

Beamform method

- Conventional beamforming

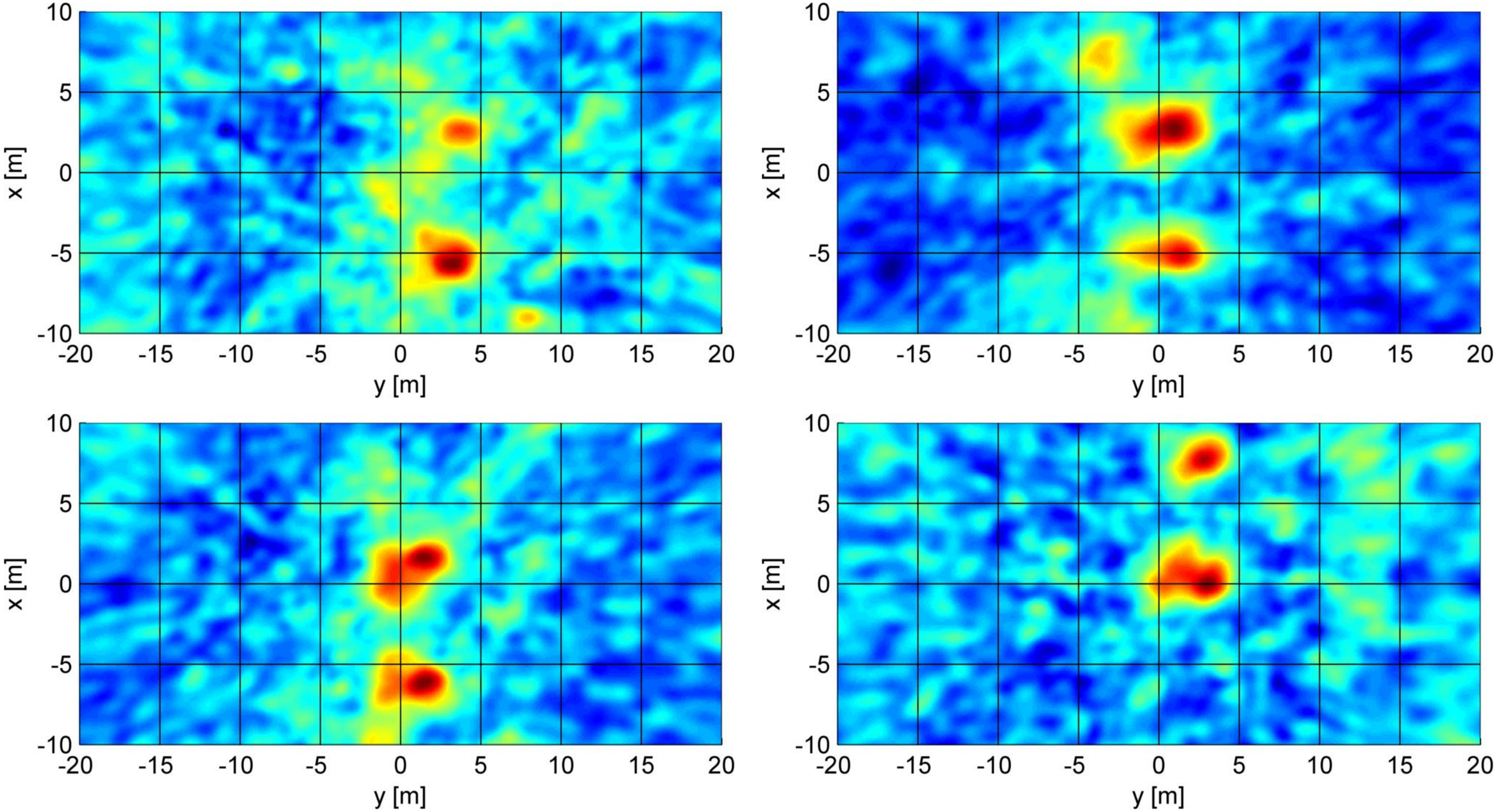
$$A = \frac{1}{2} \frac{\mathbf{g}^* \mathbf{P} \mathbf{P}^* \mathbf{g}}{\|\mathbf{g}\|^4}$$

- Frequency range: 1500Hz – 7500Hz (source maps at each frequency added incoherently)

- Extract individual engine SPL's from source map

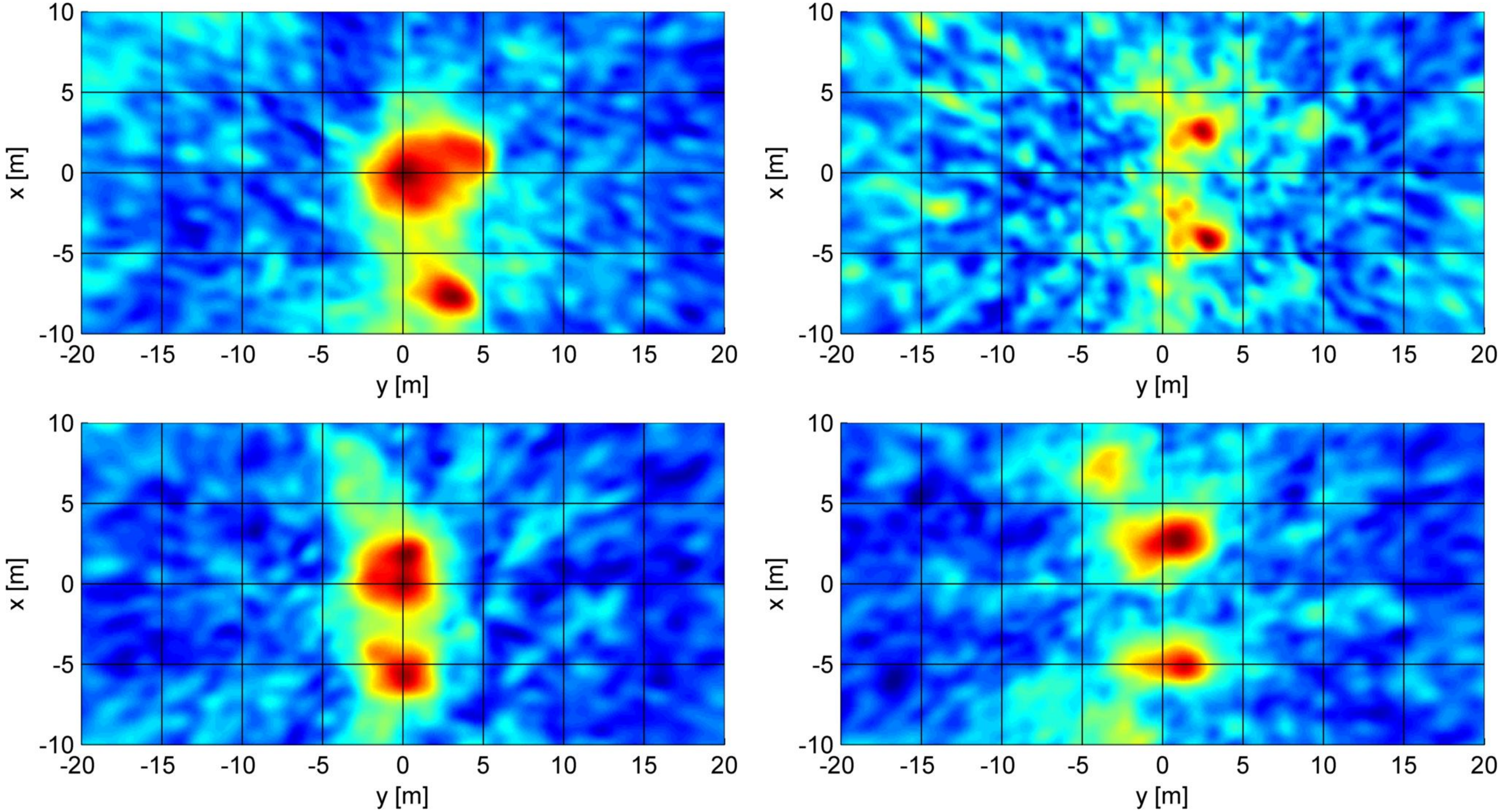
Analysis of acoustic measurements

Beamformed results (overhead block)



Analysis of acoustic measurements

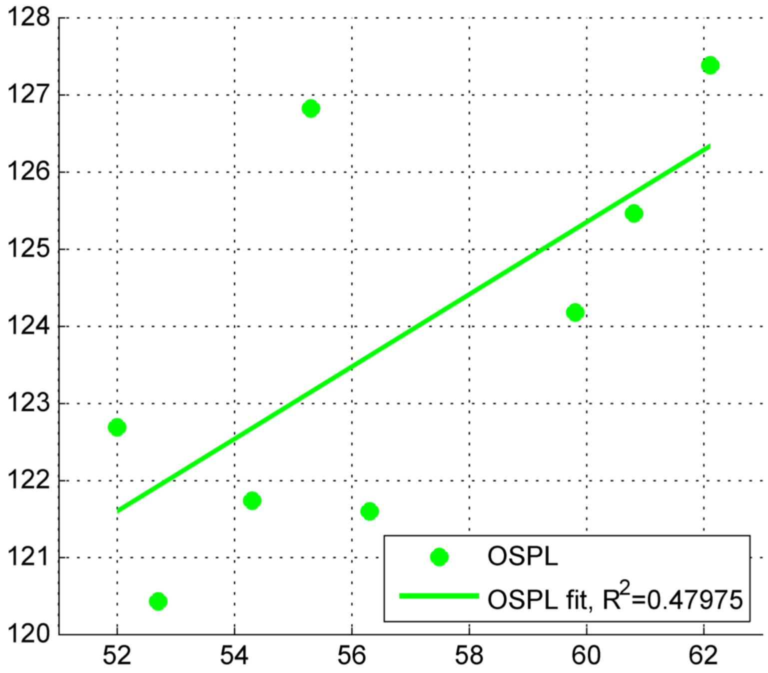
Beamformed results (overhead block)



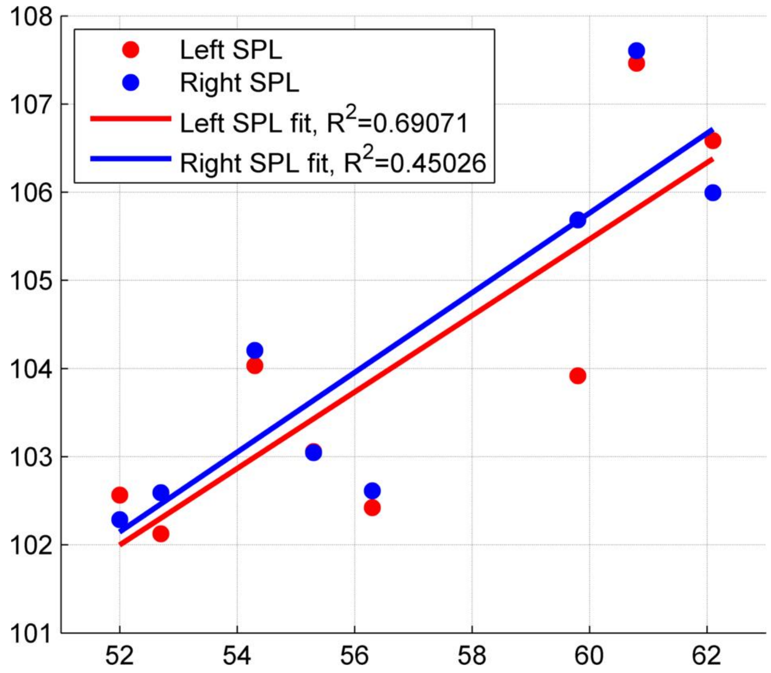
Correlation results

Correlation between engine RPM and SPL in overhead block

Without imaging



With imaging



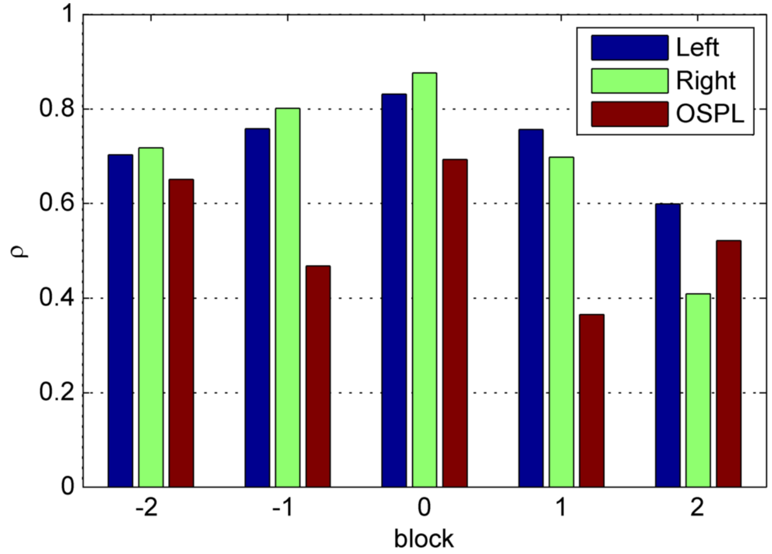
Variability in engine SPL: 6dB

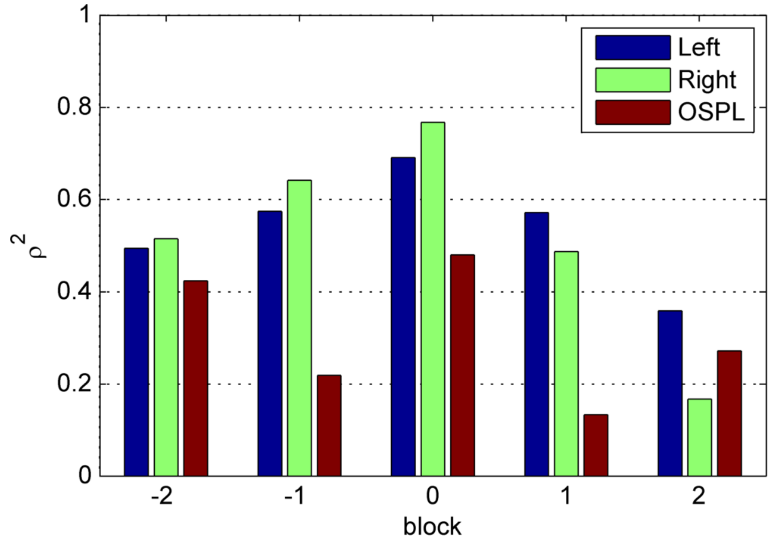
Correlation results

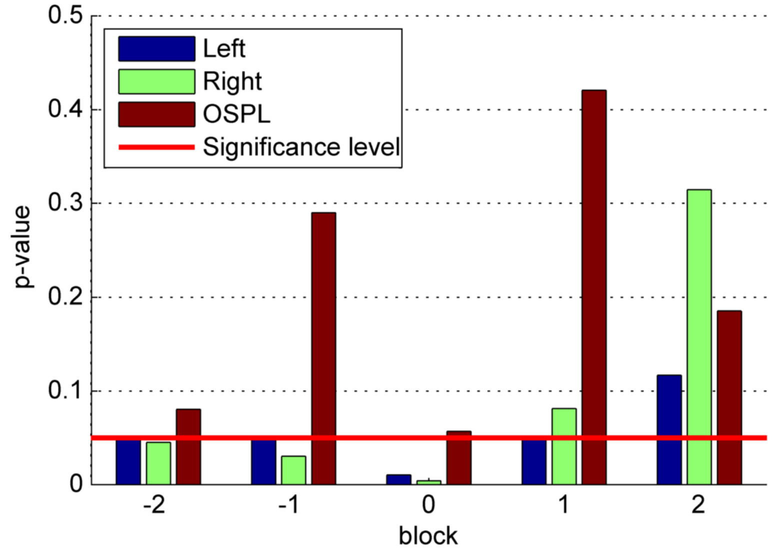
Analysis extended backwards and forwards in time

	ρ			R^2			$p-\text{values}$		
Block	Left	Right	OSPL	Left	Right	OSPL	Left	Right	OSPL
-2	0.7028	0.7173	0.6509	0.4940	0.5146	0.4237	0.0519	0.0452	0.0804
-1	0.7577	0.8008	0.4676	0.5741	0.6412	0.2187	0.0485	0.0305	0.2900
0	0.8311	0.8758	0.6926	0.6907	0.7670	0.4798	0.0106	0.0044	0.0569
1	0.7560	0.6977	0.3653	0.5715	0.4868	0.1334	0.0493	0.0813	0.4204
2	0.5988	0.4090	0.5213	0.3585	0.1673	0.2718	0.1168	0.3144	0.1852

Correlation results (graphically)







Conclusions

- Engine fan RPM can be determined using the spectrogram
- Variability in noise levels is entirely due to source (aircraft)
- Correlation between SPL and fan RPM becomes higher after beamforming (hence beamforming needed!)
- 77 % of 6 dB variability is explained by engine settings: can and should be incorporated in noise contour calculations!

Our new acoustic camera system