A Semi-empirical Field Investigation into the Relationship between L_{A90} and L_{Aeq} Wind Turbine Sound Level Descriptors in New Zealand

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Masters Thesis Submitted by

Lindsay Hannah

Acoustic Engineer - Malcolm Hunt Associates
Noise and Environmental Consultants
www.noise.co.nz

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Master Thesis Supervisor and Presenter

Associate Professor Dr Wyatt Page

Institute of Food Nutrition and Human Health
College of Health, Massey University Wellington
Email: w.h.page@massey.ac.nz

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New Zealand Standard NZS6808

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- The New Zealand Wind Turbine Standard NZS6808 provides guidance on the methods for the prediction, measurement and assessment of sound emissions from wind turbine generators
- Standard places priority on received sound pressure levels measured at dwellings remote from the wind turbine rather than sound emission received on the wind farm site
  - *Where people reside is where potential affects are received*

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NZ Standard NZS6808

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- NZS 6808:1998 Acoustics – *The Assessment and Measurement of Sound from Wind Turbine Generators [Historic Standard]*

- NZS 6808:2010 Acoustics – *Wind Farm Noise [Current Standard]*

NZS6808 Terminology

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- NZS 6808:2010 uses $L_{A90\ [10\ min]}$ for background sound levels, wind farm sound levels and post installation sound levels
- Prediction of expected future wind farm sound uses L_{Aeq}
- '*IEC61400 – Part 11 Acoustic noise measurement techniques*' used to derive sound power levels of wind turbines as L_{Aeq} for predictions and modelling

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NZ Standard NZS6808

- NZS 6808:1998 L_{A95} and L_{Aeq}
- NZS 6808:2010 L_{A90} and L_{Aeq}
  – Expected difference (L_{A90} and L_{A95}) < 1 dB
- Noise Descriptors updated from L_{A95} to L_{A90} in line with international standards and 2008 editions of
  – NZS 6801 Acoustics *Measurement of Environmental Sound* and
  – NZS 6802 Acoustics *Environmental Noise*

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NZS6808 - Assessment Process

- Conduct Background [L_{A90}] sound levels off-site (far-field) at receiving locations
- Derive recommended 'design limits' 40 dB or 5 dB above the measured background sound level [greater of the two]

Background sound level	Noise limit [$L_{A90[10\ min]}$]	High amenity noise limit [$L_{A90[10\ min]}$]
> 35 dB	Background + 5 dB	background + 5 dB
30 – 35 dB	40 dB	
< 30 dB		35 dB

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NZS6808
- Assessment Process

- Compare design limits [L_{A90}] with future predicted wind farm sound level predictions [L_{Aeq}]
- Possible disparity - two different descriptors:

L_{A90} versus L_{Aeq}

- NZS 6808:1998 ~ $L_{A95} = L_{Aeq} - 2.5$ dB
- NZS 6808:2010 ~ $L_{A90} = L_{Aeq}$
  - NZS 6808:2010 Recommends that predicted L_{Aeq} be treated as equivalent to the [L_{A90}] value when setting wind turbine design noise limits

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Purpose of Study?

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- Attempted to quantify by field measurement the potential variability between measured wind turbine generator sound emissions using the descriptors L_{A90} and L_{Aeq} at a remote receiver dwelling location [far-field]

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Implication

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- A key implication under the historic 1998 standard was that wind turbine sounds could potentially exceed the allowable 40 dB(A) design limit [or average background sound level + 5 dB] by up to a further 2.5 dB and still remain in compliance with the limits recommended under the NZ S6808:1998

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Measurement Approach

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Underlying Philosophy

1. Assess the relationship between L_{Aeq} and L_{A90}
2. Capture measured sound pressure levels from the wind turbine generators, free from extraneous noise [unwanted non-turbine noise]

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Principle Study Site

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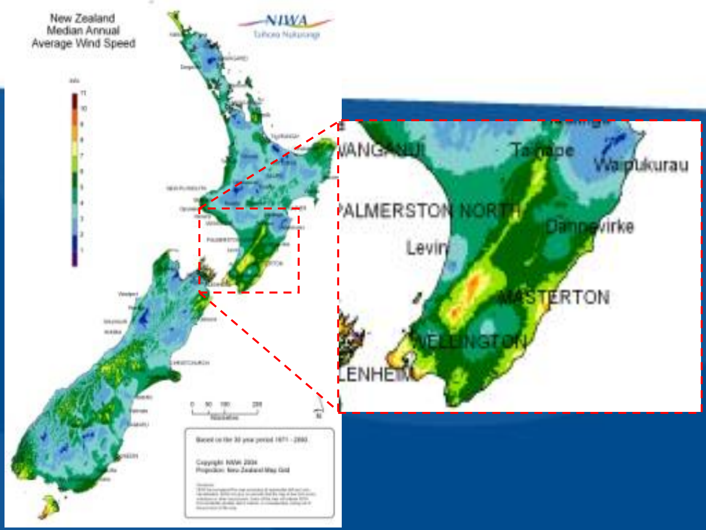
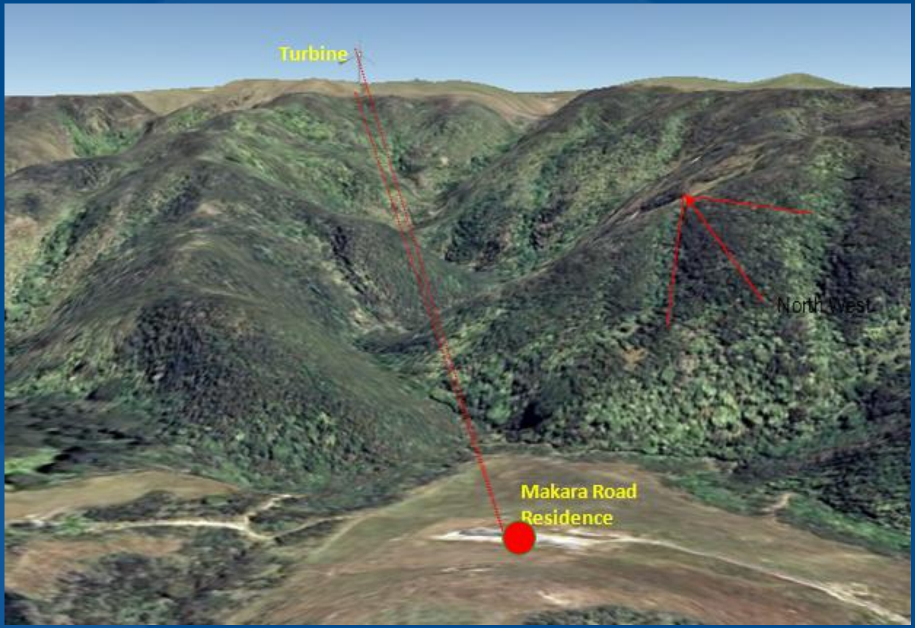


Wind Farm

- Project West Wind [Makara] Wind Farm Wellington



Receiver Location

- Makara Road Residence

Wind Turbine Specifications

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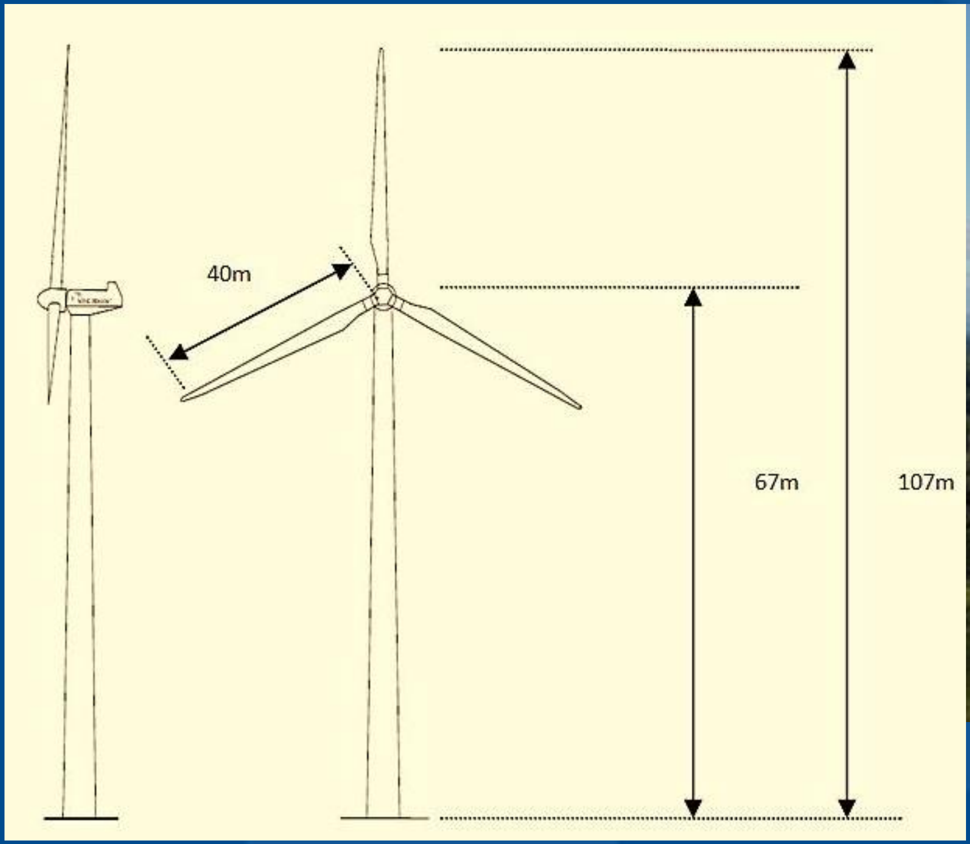
- Siemens SWT 2.3-82V
  - Pitch controlled variable-speed (6-18 rpm)



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Measurement Approach

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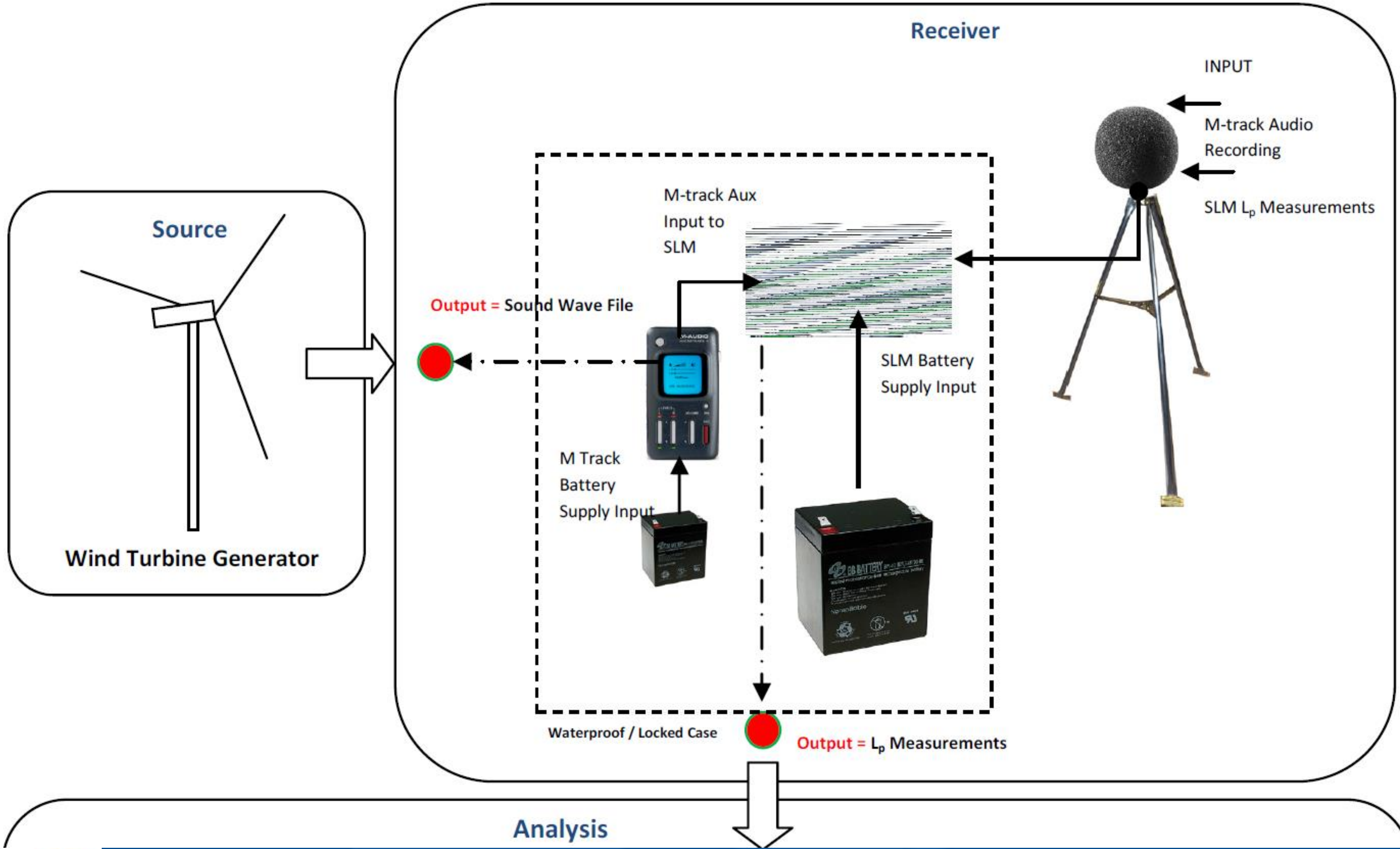
- A number of measurement approaches were initially trialled, including short- and long-term sample periods, in conjunction with concurrent audio recording of the sound

Data Collection



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Data Filtering

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Analysis

Raw Data [n=11,150]

Remove unwanted data pairs [L_{A90} and $L_{Aeq\ 10\ minutes}$] by filtering:

1. All known atypical or miscellaneous data [weather affected data and obvious outliers, missing data].
2. All data not in the denoted downwind wind direction [the defined wind direction sector relative to receiver]
3. All data outside 'Night-time' hours, being defined as 11.00 pm to 5.00 am [5.00 am finish to avoid 'dawn chorus']
4. All data outside wind turbine generator operating turbine speeds between cut-in and cut-out speeds – that is all data when the wind turbine generator is known <u>not</u> to be operating
5. All data above 1.6 m/s [about 5.8 kph] local wind speed [to avoid unwanted sounds from wind and/or vegetation]

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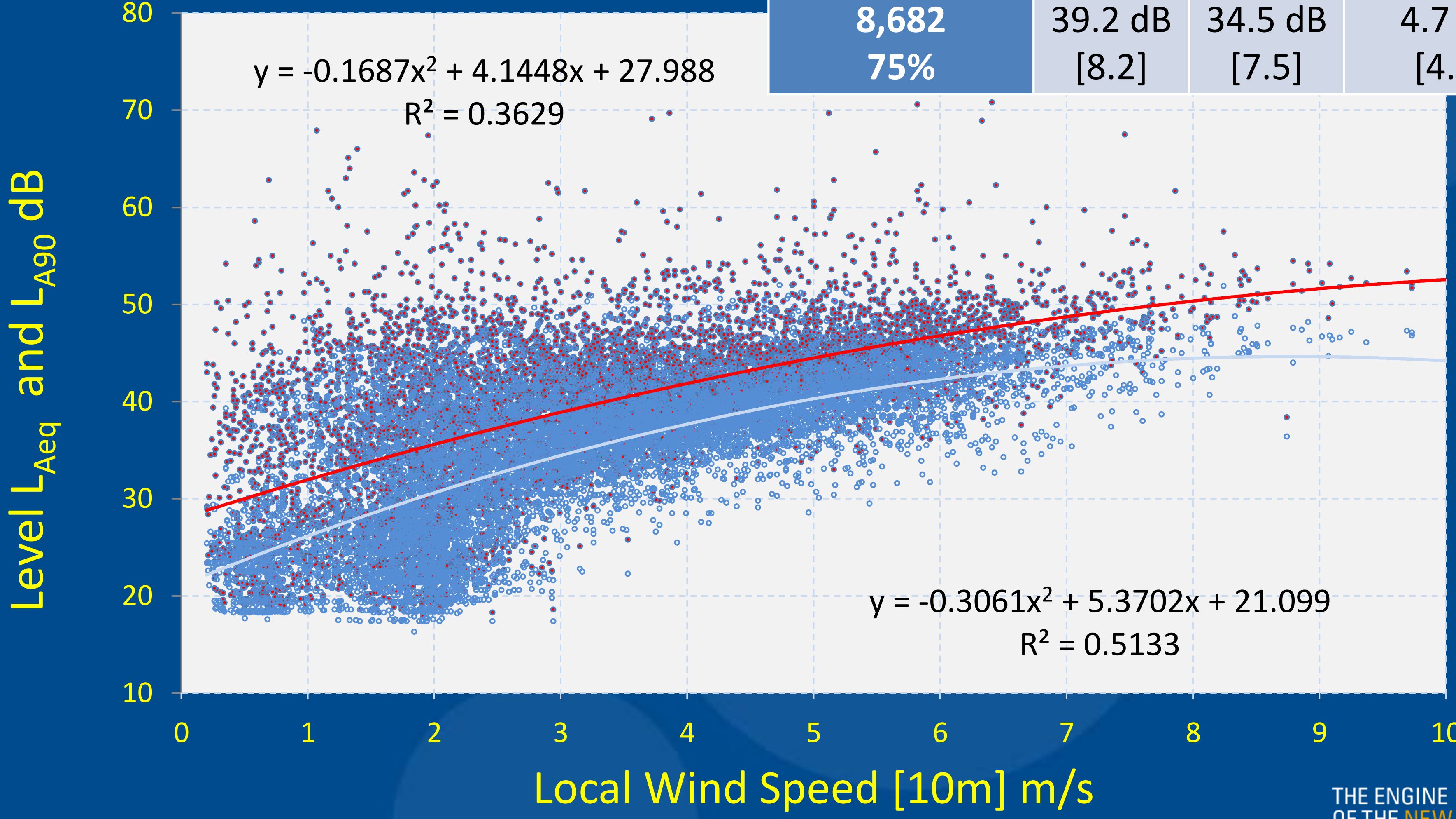
1 Atypical Data removed

N [% raw data]	L_{Aeq} [SD]	L_{A90} [SD]	Mean diff [SD]
8,682 75%	39.2 dB [8.2]	34.5 dB [7.5]	4.7 dB [4.5]



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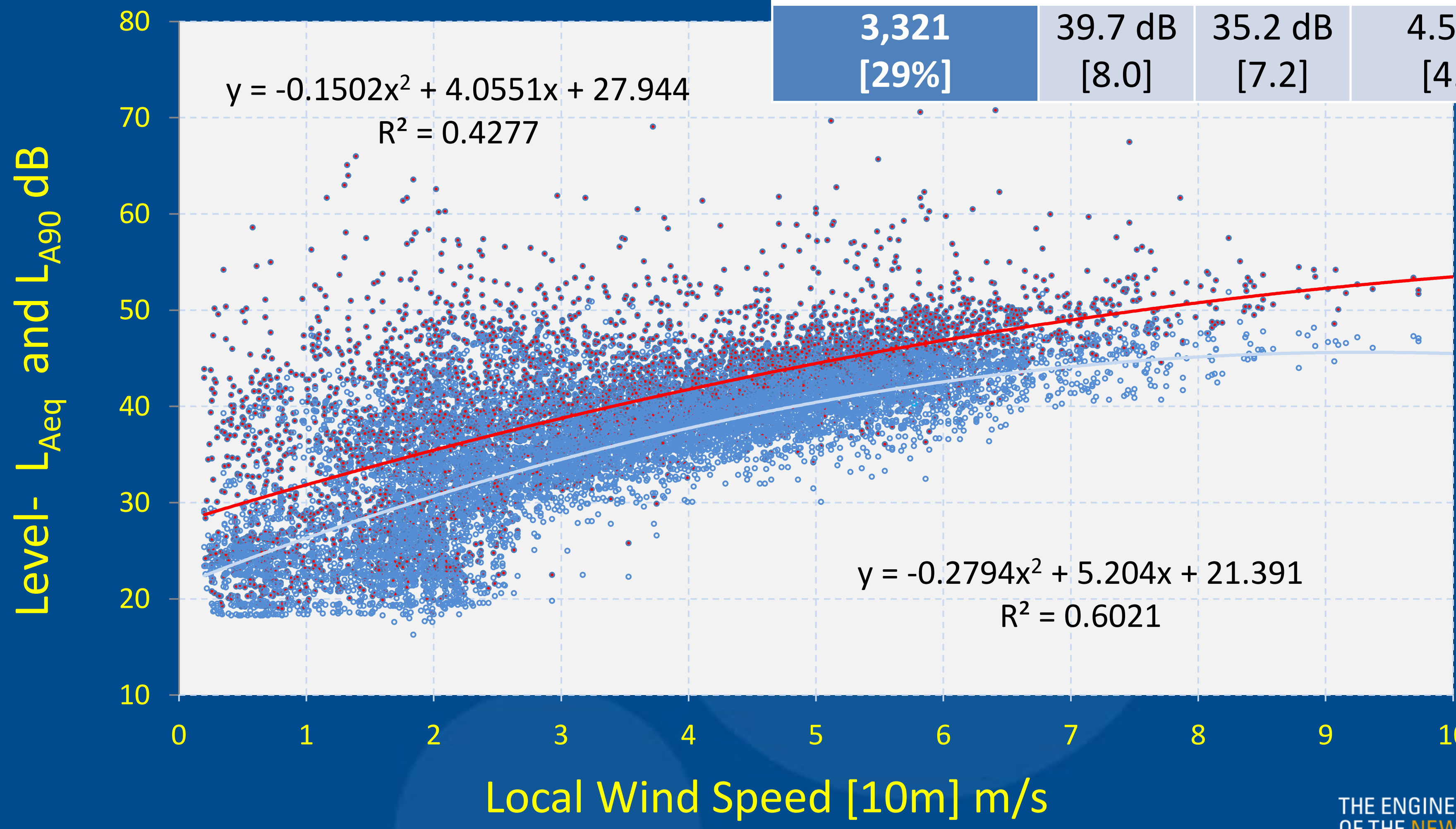
1+2 Downwind

N [% raw data]	L_{Aeq} [SD]	L_{A90} [SD]	Mean diff [SD]
3,321 [29%]	39.7 dB [8.0]	35.2 dB [7.2]	4.5 dB [4.3]



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1+2+3 Night-time

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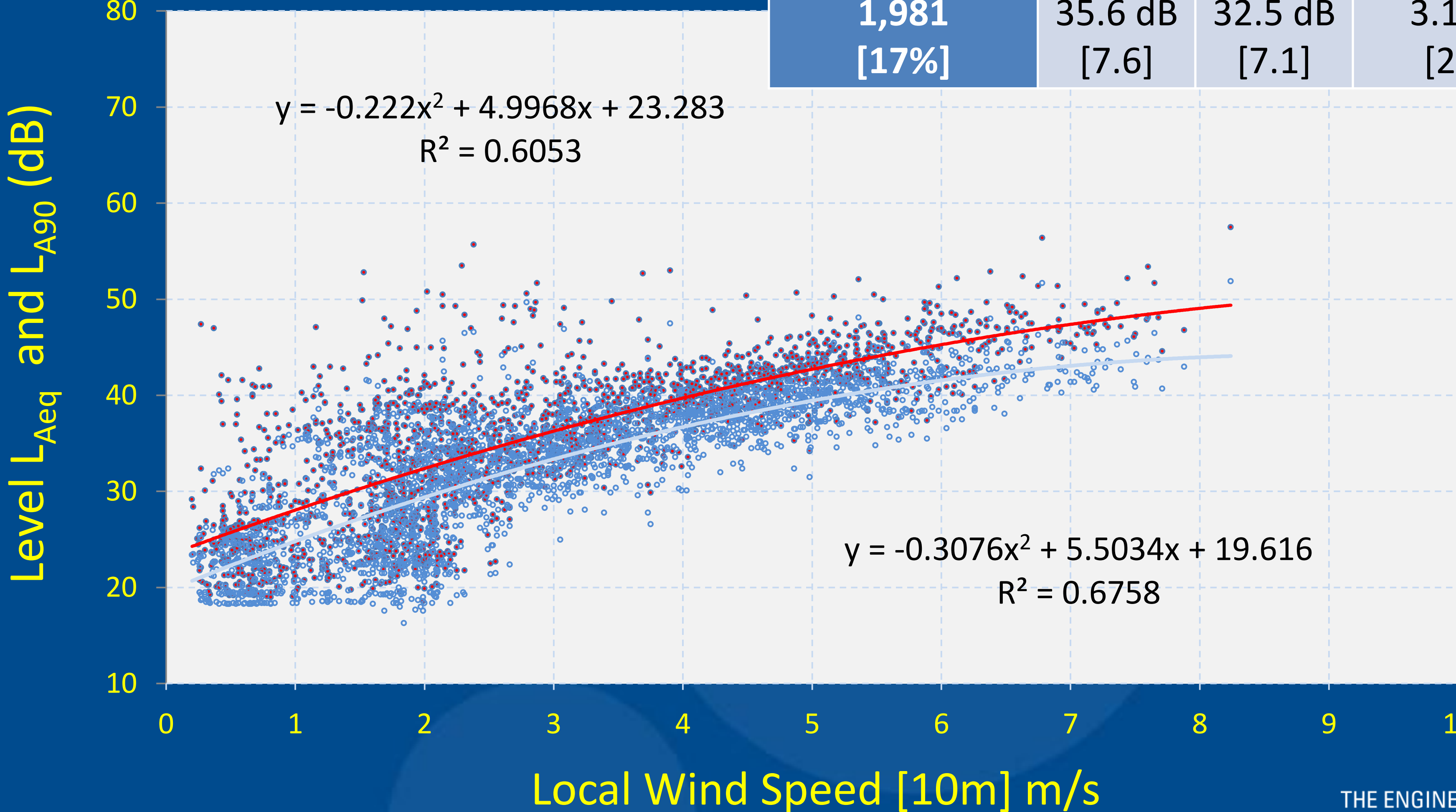
N [% raw data]	L_{Aeq} [SD]	L_{A90} [SD]	Mean diff [SD]
1,981 [17%]	35.6 dB [7.6]	32.5 dB [7.1]	3.1 dB [2.6]



1+2+3+4 Operating Speeds

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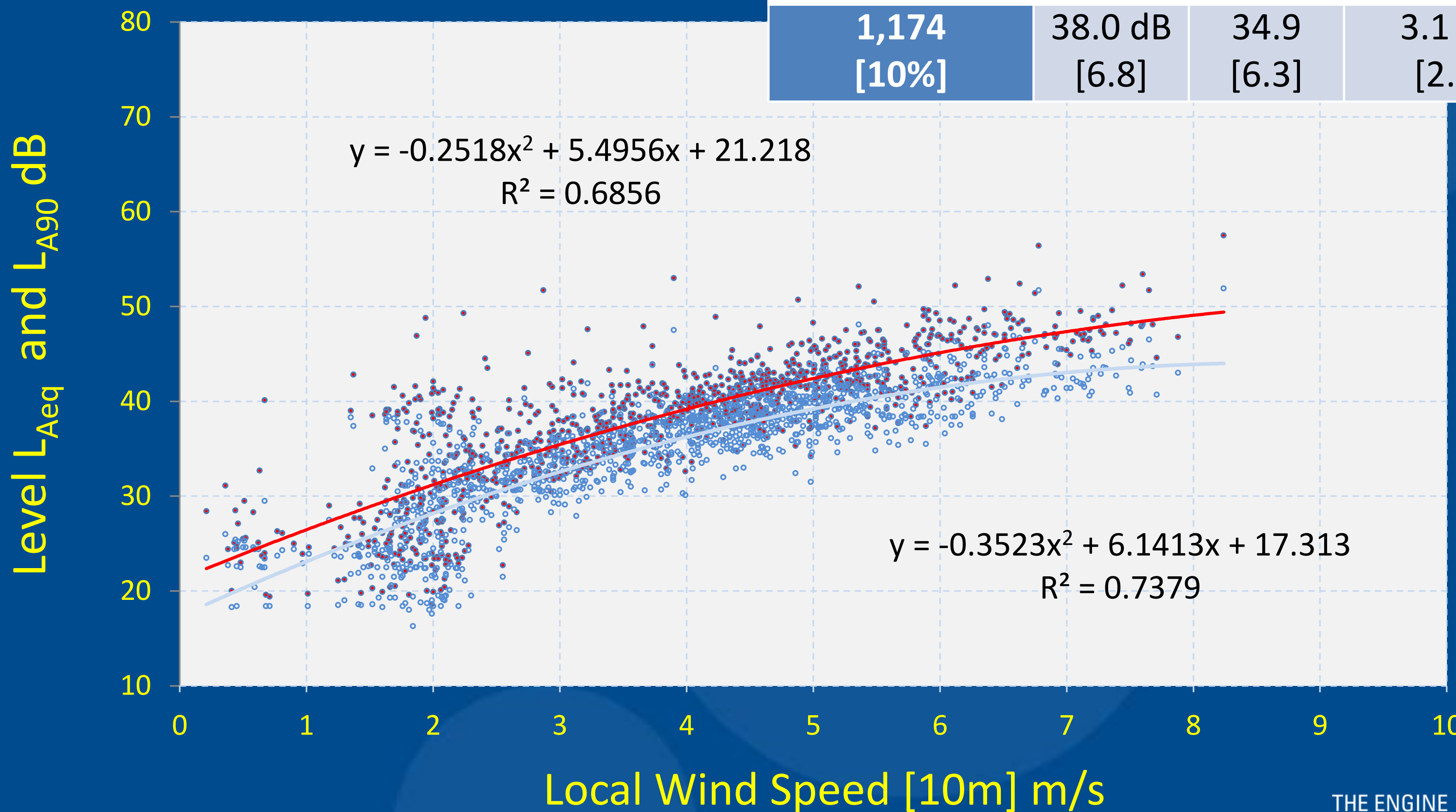
N [% raw data]	L_{Aeq} [SD]	L_{A90} [SD]	Mean diff [SD]
1,174 [10%]	38.0 dB [6.8]	34.9 [6.3]	3.1 dB [2.0]



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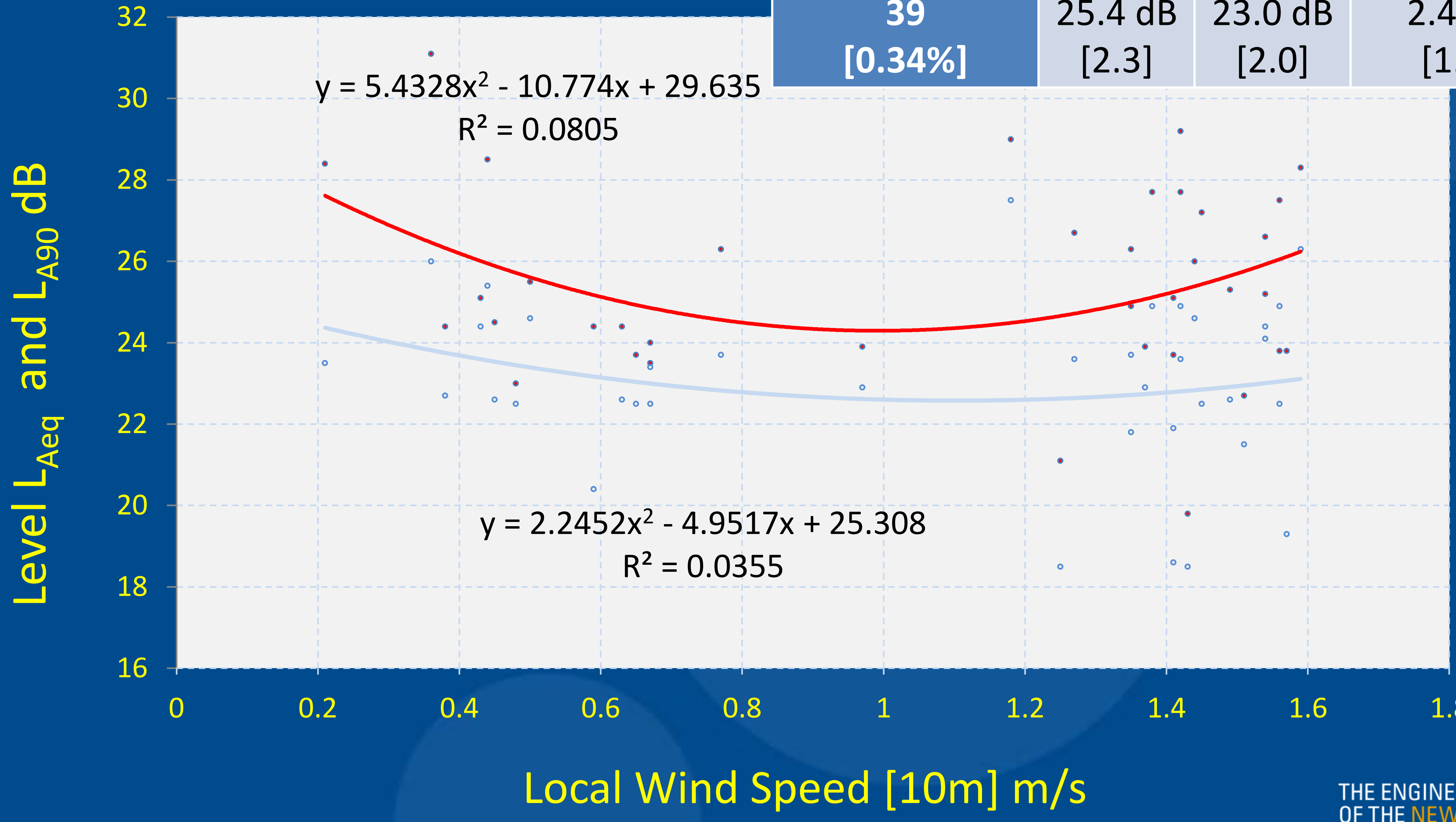
1+2+3+5 Local wind speeds

N [% raw data]	L_{Aeq} [SD]	L_{A90} [SD]	Mean diff [SD]
39 [0.34%]	25.4 dB [2.3]	23.0 dB [2.0]	2.4 dB [1.4]



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Results…

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- N=11,150 10-minute sound pressure level sample pairs recorded over a 12 month period
- After post-analysis filtering to remove samples contaminated by extraneous noise:
  - N = 39 = 0.34 % remained for final analysis
  - Mean-difference between the descriptors, (measured at a residential location remote from the wind farm) was 2.4 dB with an SD = 1.4 dB
  - So for 95% confidence, the upper limit of the mean-difference is about 5.2 dB

How strong is the relationship between L_{Aeq} and L_{A90}?

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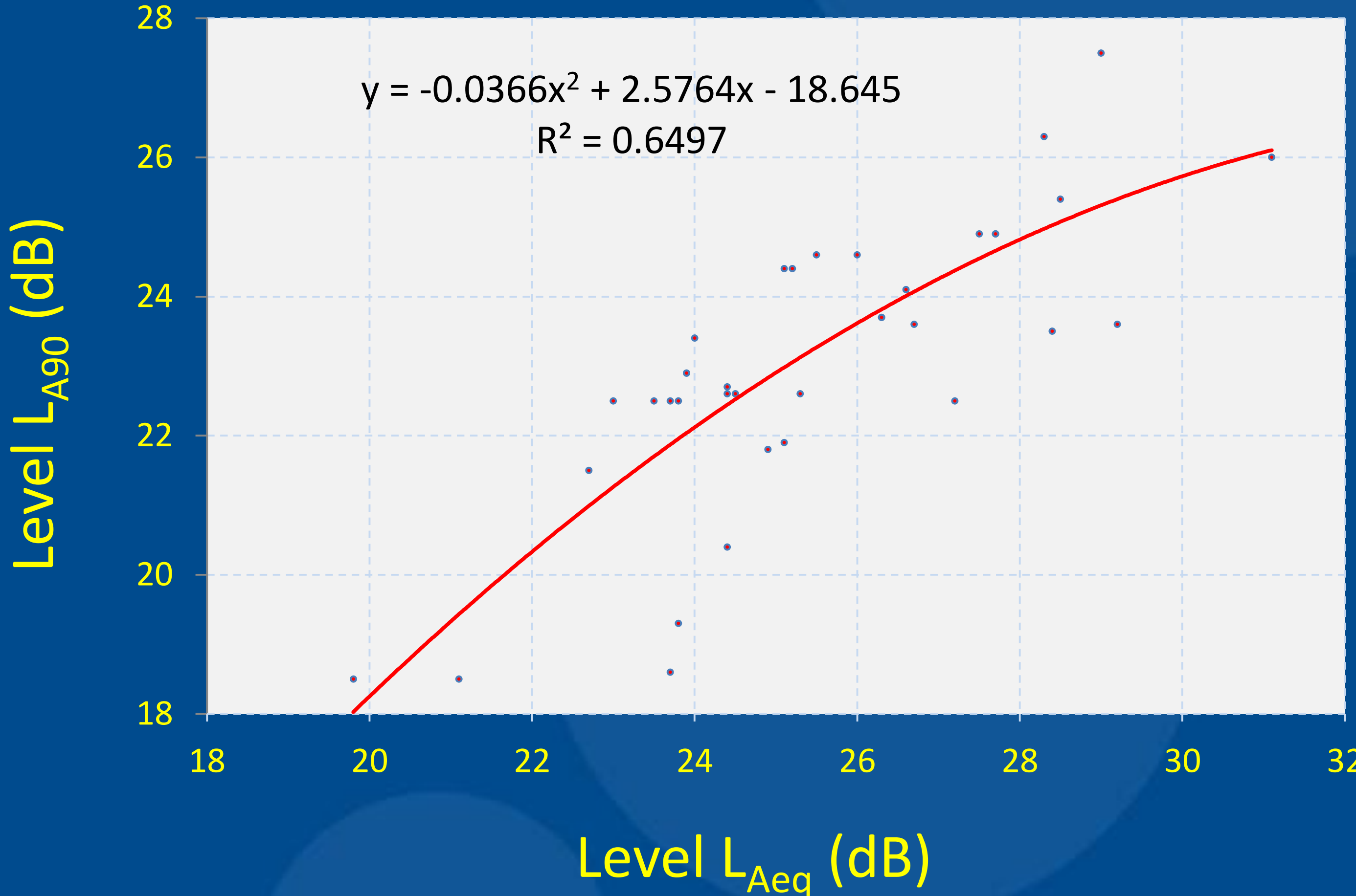

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How strong is the relationship between L_{Aeq} and L_{A90}?

- The relationship appears non-linear so two rank-based correlation tests were applied
  - Spearman's Rank Correlation Coefficient = 0.8
    - A value of 1 for the Spearman Rank Correlation Coefficient implies that two variables are monotonically related - A value of 0.8 illustrates a strong correlation between the two descriptors
  - Kendall's tau Rank Correlation Coefficient (t) = 0.64
    - A value of t = +1 means a perfect positive correlation between the data sets, that is, the two sets are exactly the same. A value of 0.64 illustrates a strong correlation between the two descriptors

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Study Limitations

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- Limited to 12 month / 1 year study
- Limited in raw and filtered sample sizes
- Limited to single receiver site
- Limited to single test turbine
- Limited analysis of overall levels [dB] only
- Limited equipment, time and site access…..

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Possible Alternative Methods

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- Long Term Environmental Monitoring Stations with powerful quantitative analysis tools
- Such systems have expensive capital cost and require highly skilled personnel to use system and produce accurate analysis
- Such systems outside scope of study but available to wind farm operators

Conclusions

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- Due to the high number of intervening variables it is difficult to collect a large robust sample set of wind turbine sound levels that does not include any superfluous sounds
- Sound level difference off-site (far-field) is prone to change with complex intervening variables
- The study showed a quantifiable difference between L_{A90} and L_{Aeq} with an upper-limit of about +5 dB
  - Note: Current wind turbine noise standard [NZS6808:2010] assumes $L_{Aeq} = L_{A90}$ when carrying out the assessment process

Questions

MalcolmHuntAssociates
noise and environmental consultants
First floor, Arco House, 47 Cuba Street, PO Box 11-294, Wellington
Telephone 04 472 5689 Fax 04 473 0456
mha@noise.co.nz www.noise.co.nz

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Thank you

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Results - Summary

Filter	Number of samples [N]	% Of raw data	L_{Aeq} [SD] dB	L_{A90} [SD] dB	Mean difference [SD] dB
0 All raw data	11,500	100%	-	-	-
1 Atypical data	8,682	75%	39.2 dB [8.2]	34.5 dB [7.5]	4.7 dB [4.5]
1+2 Downwind	3,321	29%	39.7 dB [8.0]	35.2 dB [7.2]	4.5 dB [4.3]
1+2+3 Night-time	1,981	17%	35.6 dB [7.6]	32.5 dB [7.1]	3.1 dB [2.6]
1+2+3+4 Operating speeds	1,174	10%	38.0 dB [6.8]	34.9 [6.3]	3.1 dB [2.0]
1+2+3+4+5 Local wind speeds	39	0.34%	25.4 dB [2.3]	23.0 dB [2.0]	2.4 dB [1.4]

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