RYERSON UNIVERSITY

Theoretical Acoustics

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Outdoor Noise Propagation

- INTRODUCTION
- INPM - JASCO
- PROPAGATION MODELS
- SIMPLE RESULTS
- CONCLUSIONS

Outdoor Noise Propagation

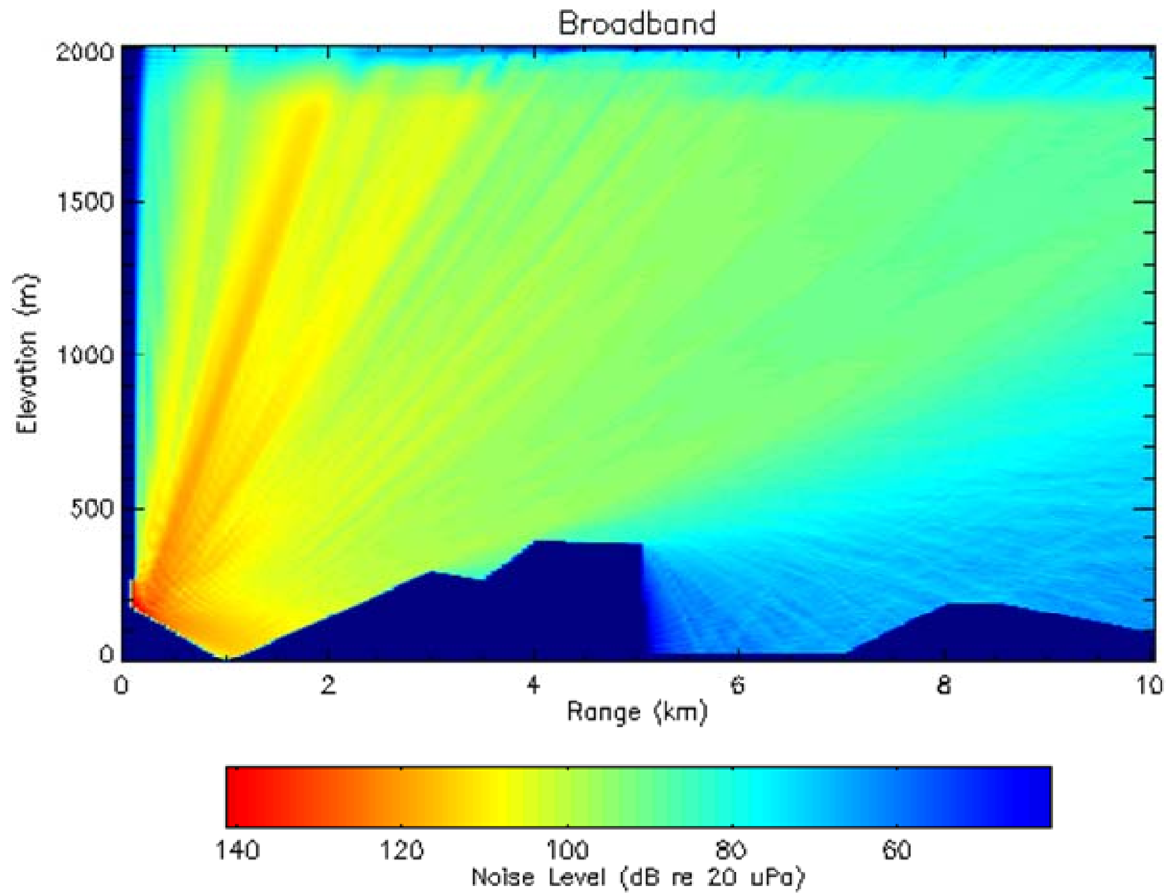
INPM - JASCO

- PWL
- ELEVATION DETAILS – dt0 and dt1
- ATMOSPHERIC DETAILS - BALLOON
- TURBULENCE
- GROUND DETAILS – flow resistivity

Outdoor Noise Propagation

INPM - JASCO

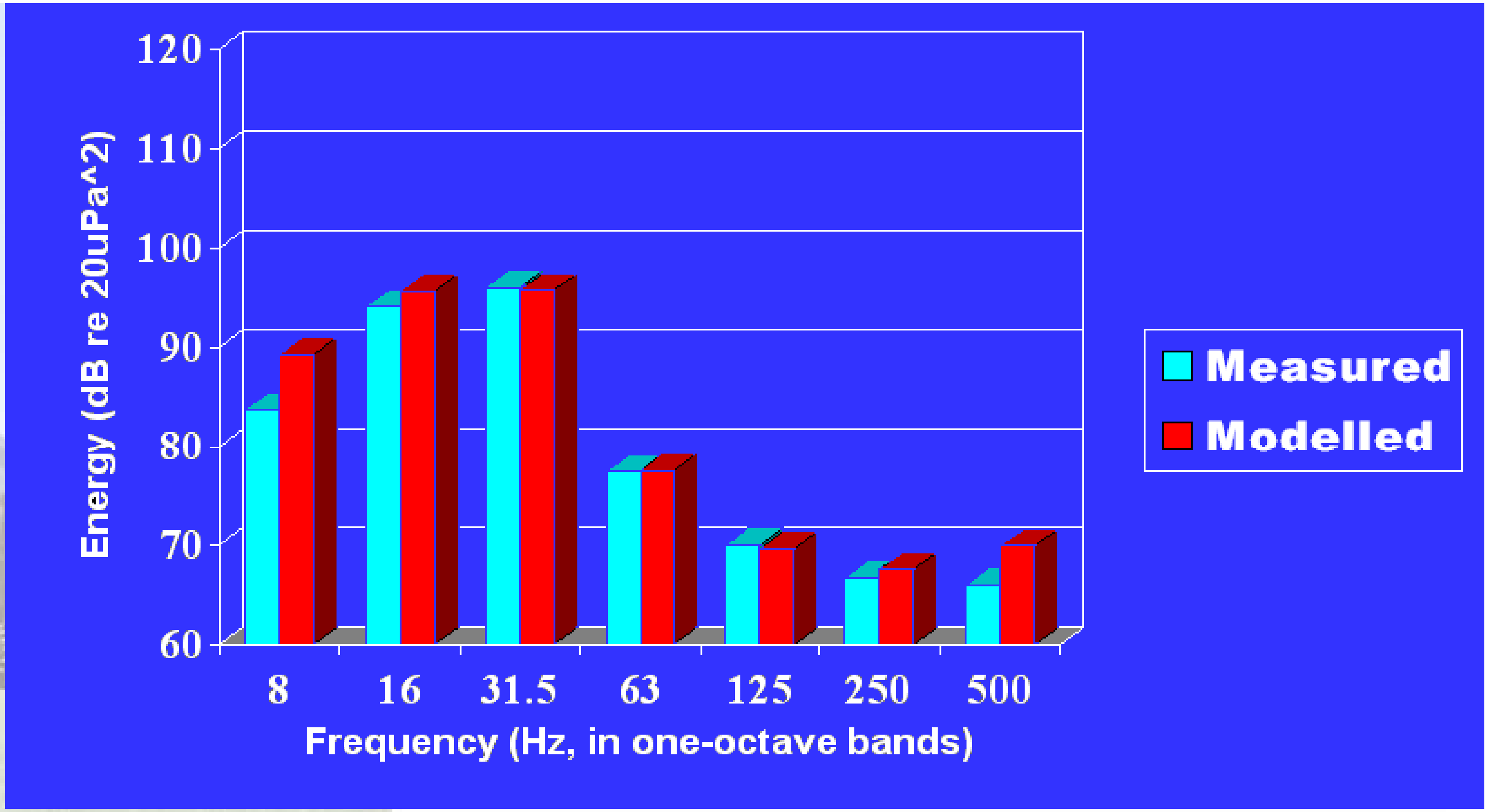
Vertical cross section showing modelled noise field as a function of range and depth



Outdoor Noise Propagation

INPM - JASCO

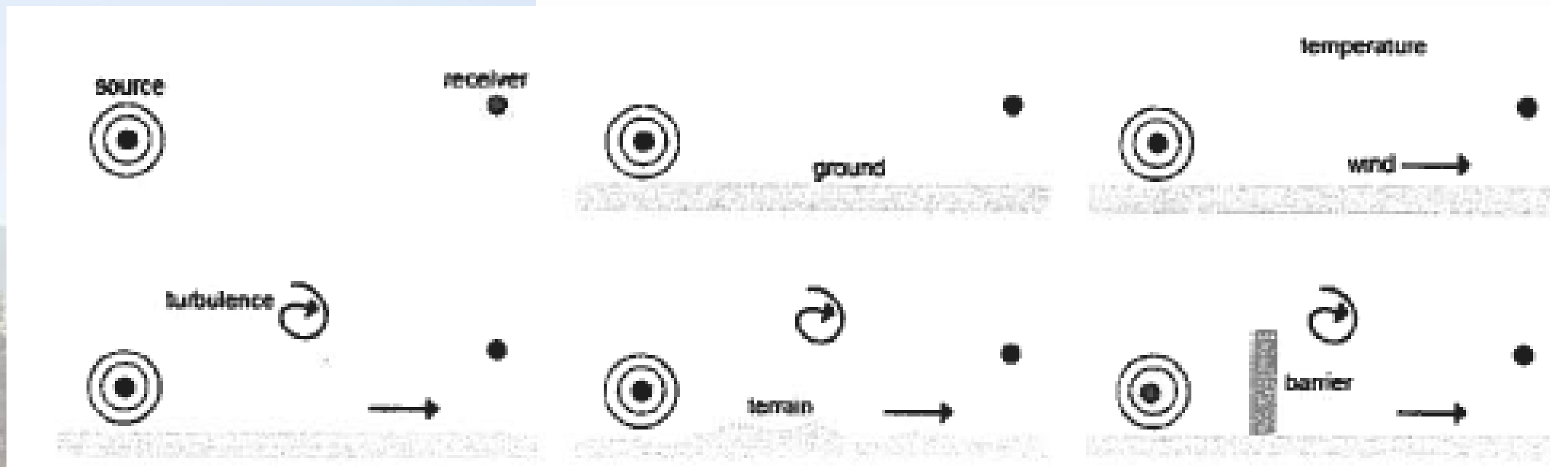
6 lb explosive charge as recorded at 1.6km range. Propagation is over Land



Outdoor Noise Propagation

Available Models – A. Bullmore – Chapter 3 Wind Turbine Noise

➢ PROPAGATION PARAMETERS



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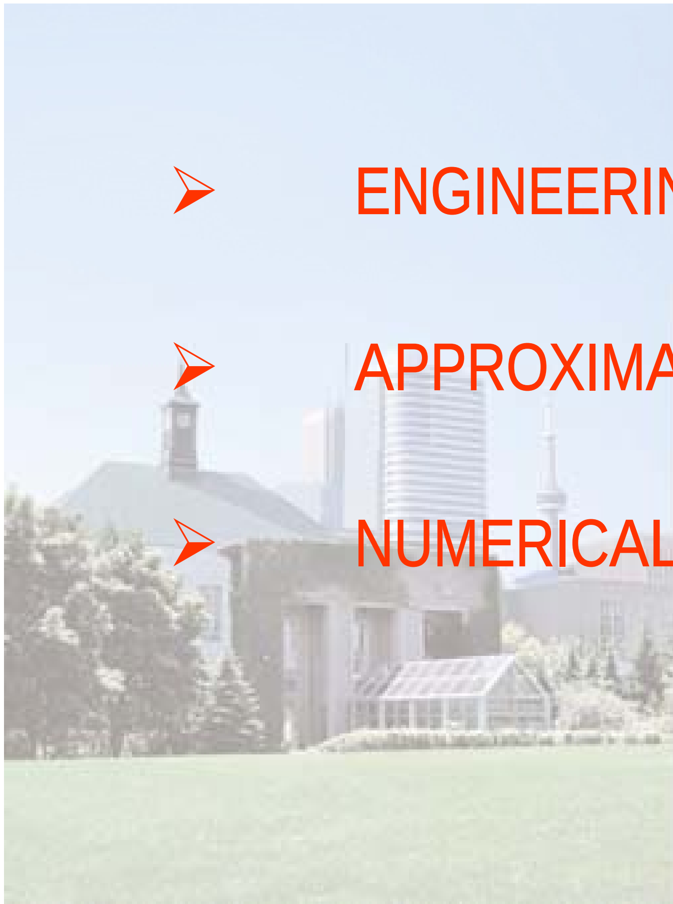

- ENGINEERING METHODS
- APPROXIMATE SEMI-ANALYTICAL METHODS
- NUMERICAL METHODS

Outdoor Noise Propagation

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APPROXIMATE SEMI-ANALYTICAL METHODS

- INDIVIDUAL CONTRIBUTIONS
- SIMPLE ANALYTICAL SOLUTIONS OF WAVE EQUATIONS
- TRACKING OF METEOROLOGICAL CONDITIONS
- SIMPLE RAY TRACING METHODS

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NUMERICAL METHODS

- DRECTION SOLUTION OF THE WAVE EQUATION
- FFP – PE METHODS
- SPECIFIC METEOROLOGICAL CONDITIONS
- NON-COMPLEX LEVEL TERRAIN CONDITIONS

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ENGINEERING METHODS

- ISO 9613 – PARTS 1 AND 2
- CONCAVE
- BRITISH STANDARD BS5228
- HARMONOISE-NORD2000

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ISO 9613 – PARTS 1 AND 2

$$L_T(DW) = L_w + D_c - A$$

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc}$$

A_{div} is the attenuation due to geometric divergence = **A1**;
A_{atm} is the attenuation due to atmospheric absorption = **A2**;
A_{gr} is the attenuation due to the ground effect = **A3**;
A_{bar} is the attenuation due to a barrier or topographic features = **A5**;
A_{misc} is the attenuation due to propagation through foliage, industrial sites, and housing.

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HARMONOISE AND NORD2000

- SPL IN 1/3 OCTAVE BANDS 25 Hz – 10 kHz
- FACTORS SOLVED SEPARATELY (MINUSED)
- BRITISH STANDARD BS5228

Outdoor Noise Propagation

Available Models – A. Bullmore – Chapter 3 Wind Turbine Noise

HARMONOISE AND NORD2000

- A1 SAME
- A2 ISO9613(1) AND ADJUST FOR OCTAVE BANDS
- A3 - DELANEY AND BAZELY IMPEDANCE PARAMETER
- A4 – RAY PROPAGATION SOUTIONS
- A5 – SEGMENTATION AND BETTER RESOLUTION

Outdoor Noise Propagation

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WAVE MODEL

- WAVE SOLUTION
- BETTER GROUND EFFECT
- NO METEOROLOGICAL CONDIITONS

$$p(x,y,z)=\frac{e^{ikR_1}}{4\pi R_1}+R_p\frac{e^{ikR_2}}{4\pi R_2}+\left[\left(1-R_p\right)F(w)\right]\frac{e^{ikR_2}}{4\pi R_2}$$

Outdoor Noise Propagation

Available Models – A. Bullmore – Chapter 3 Wind Turbine Noise

EXAMPLE – ENGINEERING METHODS

Frequency, Hz	63	125	250	500	1000	2000	4000	8000	dB(A)
Octave band sound power level, dB	118	113	109	106	103	99	92	82	**108**

Frequency, Hz	63	125	250	500	1000	2000	4000	8000	dB(A)
ISO 9613-2	56.1	50.8	46.0	42.9	38.8	32.3	16.6	-	**45**
Wave Solution	58.4	52.5	44.6	40.3	38.7	31.6	20.8	-	**44**
Harmonoise	58.6	52.8	45.0	40.0	39.7	33.5	17.6	4.9	**44**

500 m; 1.5 m above hard ground

Outdoor Noise Propagation

Available Models – A. Bullmore – Chapter 3 Wind Turbine Noise

EXAMPLE – ENGINEERING METHODS

Frequency, Hz	63	125	250	500	1000	2000	4000	8000	dB(A)
Octave band sound power level, dB	118	113	109	106	103	99	92	82	**108**

Frequency, Hz	63	125	250	500	1000	2000	4000	8000	dB(A)
ISO 9613-2	56.1	47.8	40.9	38.9	37.0	30.8	15.1	-	**42**
Wave Solution	59.7	52.0	43.3	40.4	37.1	30.0	18.9	-	**43**
Harmonoise	59.9	52.2	43.8	40.5	38.0	31.3	21.1	4.8	**44**

500 m; 1.5 m above grassland

Outdoor Noise Propagation

Available Models – A. Bullmore – Chapter 3 Wind Turbine Noise

EXAMPLE – ENGINEERING METHODS

Frequency, Hz	63	125	250	500	1000	2000	4000	8000	dB(A)
Octave band sound power level, dB	118	113	109	106	103	99	92	82	**108**

Frequency, Hz	63	125	250	500	1000	2000	4000	8000	dB(A)
ISO 9613-2	46.5	41.0	35.4	31.1	25.3	14.0	-	-	**33**
Wave Solution	49.2	43.8	39.0	32.3	19.1	16.2	3.3	-	**34**
Harmonoise	49.4	44.1	39.6	33.1	19.0	19.1	3.4	4.9	**35**

1500 m; 1.5 m above hard ground

Outdoor Noise Propagation

Available Models – A. Bullmore – Chapter 3 Wind Turbine Noise

EXAMPLE – ENGINEERING METHODS

Frequency, Hz	63	125	250	500	1000	2000	4000	8000	dB(A)
Octave band sound power level, dB	118	113	109	106	103	99	92	82	**108**

Frequency, Hz	63	125	250	500	1000	2000	4000	8000	dB(A)
ISO 9613-2	46.5	36.8	30.4	27.1	23.5	12.5	-	-	**29**
Wave Solution	46.8	39.4	30.9	24.8	25.5	14.2	3.4	-	**30**
Harmonoise	47.1	39.8	31.5	25.0	26.6	17.0	5.7	4.9	**31**

1500 m; 1.5 m above grassland

Outdoor Noise Propagation

Available Models – A. Bullmore – Chapter 3 Wind Turbine Noise

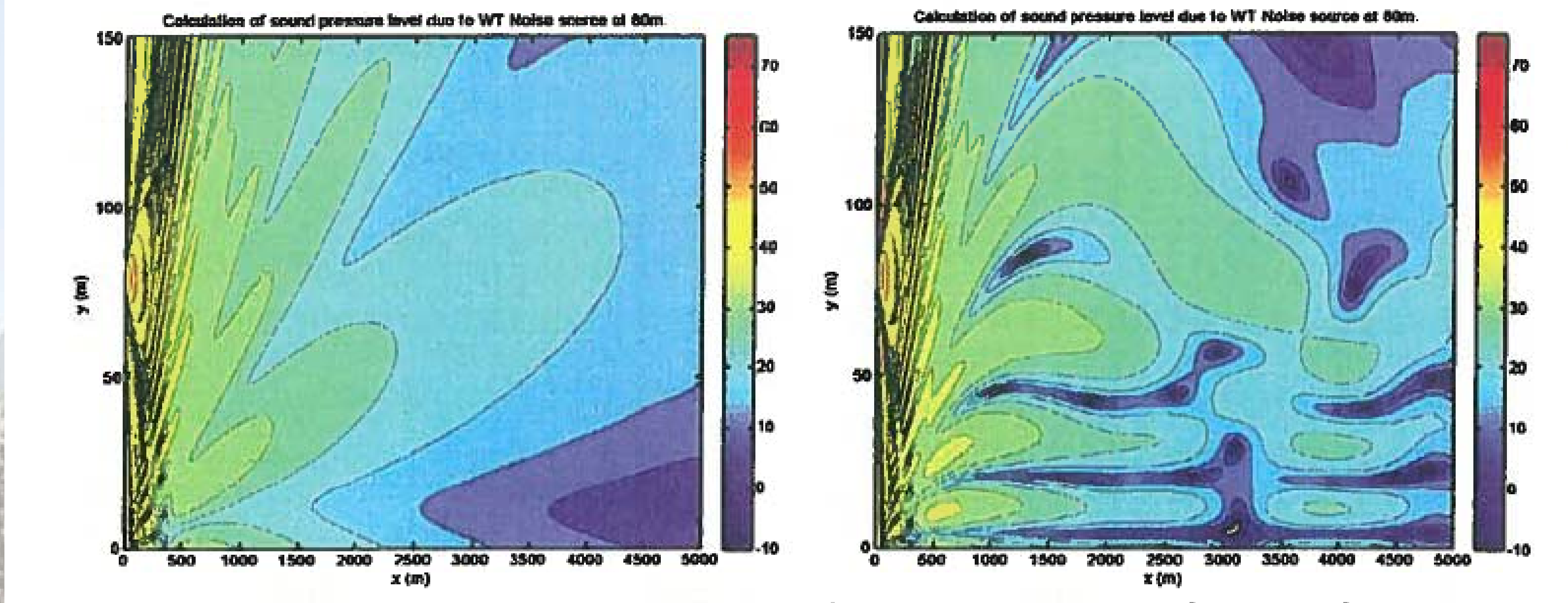
EXAMPLE – EXACT METHODS

$$2ik_0 \frac{\partial u}{\partial r} + \frac{\partial^2 u}{\partial z^2} + k_0^2\left(n^2(r,z)-1\right)u = 0$$

Outdoor Noise Propagation

Available Models – A. Bullmore – Chapter 3 Wind Turbine Noise

EXAMPLE – EXACT METHODS



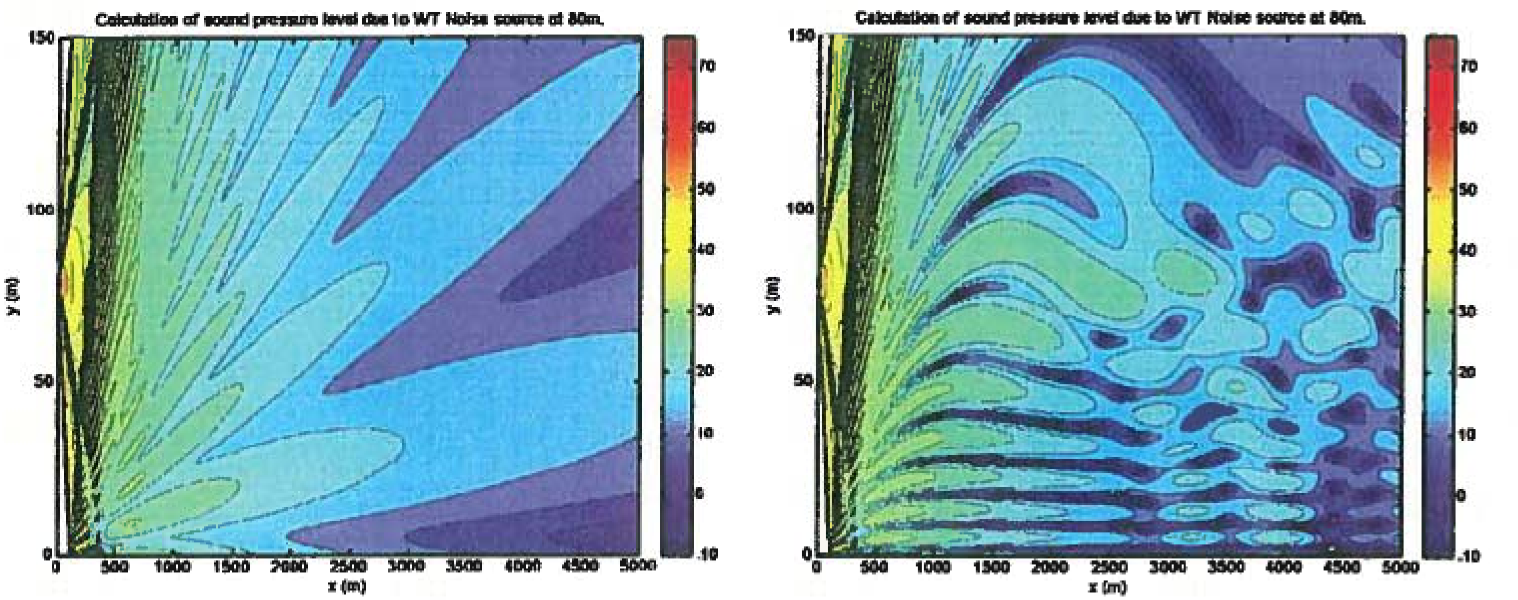
(a) Neutral conditions. f = 63 Hz

(b) Downwind conditions 8m/s at 10m. f = 63 Hz

Outdoor Noise Propagation

Available Models – A. Bullmore – Chapter 3 Wind Turbine Noise

EXAMPLE – EXACT METHODS



(c) Neutral conditions. f = 125 Hz

(d) Downwind conditions 8m/s at 10m. f = 125 Hz

Outdoor Noise Propagation

Available Models – A. Bullmore – Chapter 3 Wind Turbine Noise

Characteristic	Engineering			Hybrid modelling methods			
				Approximate / analytical		Numerical	
	NORD2000	HARMONOISE	ISO 9613	Ray tracing	WAVE	PE	GFPE
Computing time (Present)	Fast	Fast	Fast	Fast	Fast	Slow	Medium
Accuracy (Relative)	High	High	Poor	Medium	Exact	Very good	Good
Ideal frequency range	All freq	All freq	All freq.	High frequency	All	Low frequency	Low and mid frequency
Range-dependent conditions	NO	NO	NO	NO	NO	NO	YES
Shadows and caustics	NO	NO	NO	NO	NO	NO	NO
Elevated sources	YES	YES	YES	YES	YES	YES	NO
Met Conditions	YES	YES	~	NO	NO	YES	YES
Banded freq	YES	YES	YES	NO	NO	NO	NO

Outdoor Noise Propagation

CONCLUSIONS

Any Questions?