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The Effect of Weather on the Propagation and Measurement of Environmental Sound

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Overview

- Weather and the propagation of sound
  - Noise source, propagation path, and receiver
  - Refraction, atmospheric absorption and scattering
- Measurement of environmental sound
  - Correlating measurements with meteorological data
  - Comparisons with predictions
- Guidance
  - Standards
  - Rules of thumb
  - Suggested best practice

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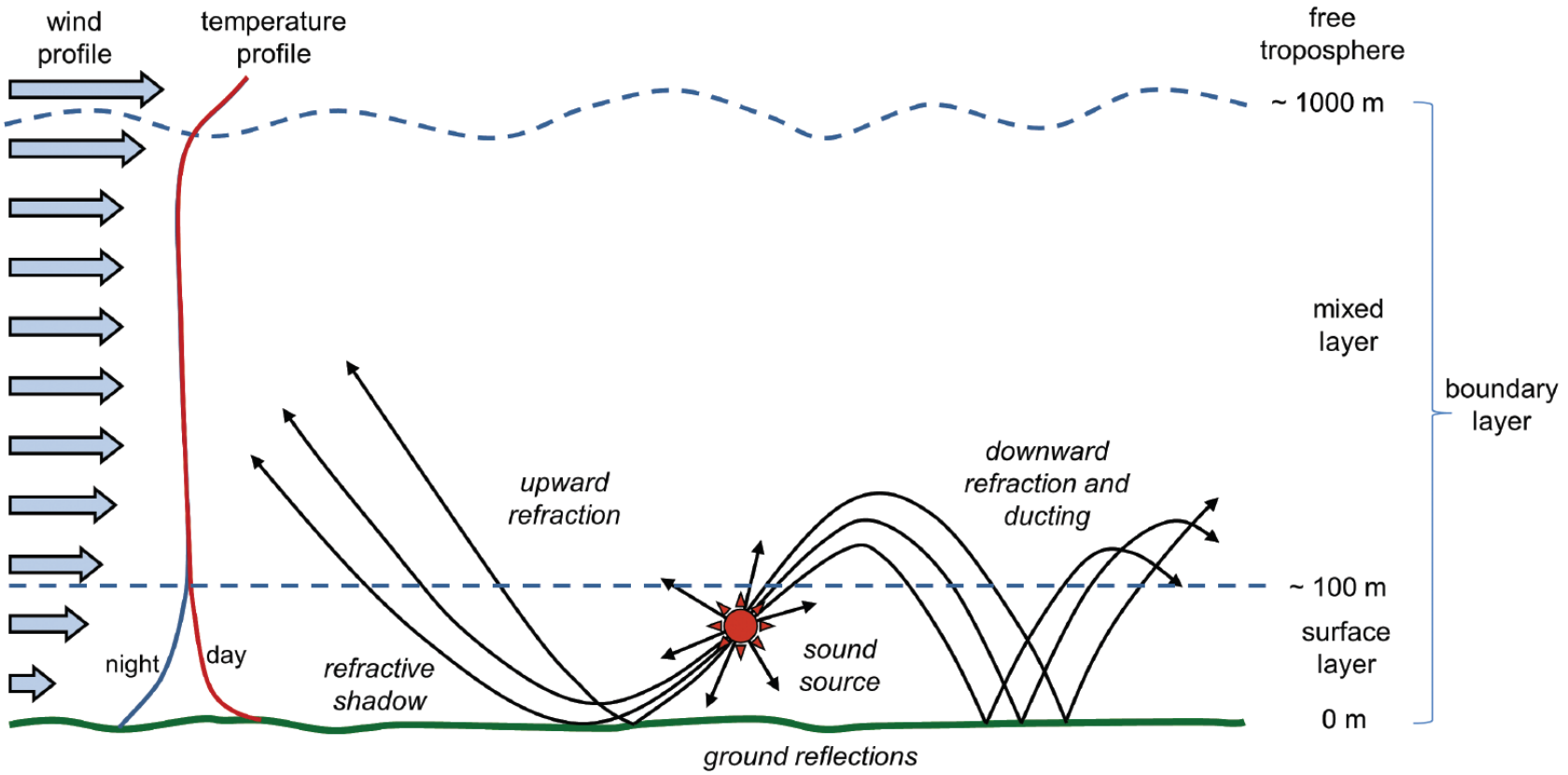
Atmospheric Boundary Layer (ABL)



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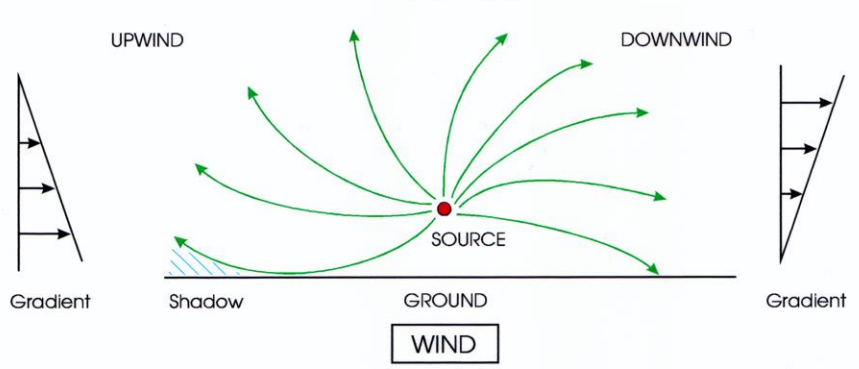
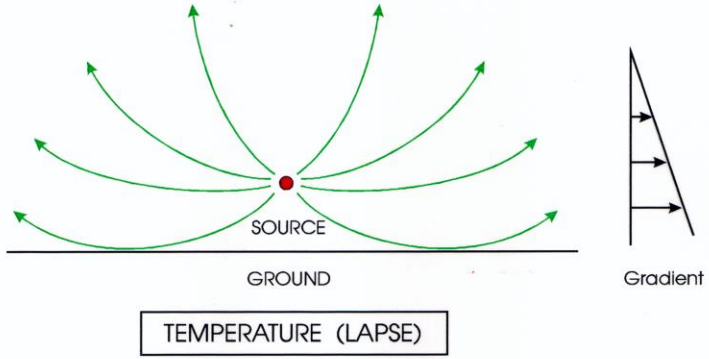
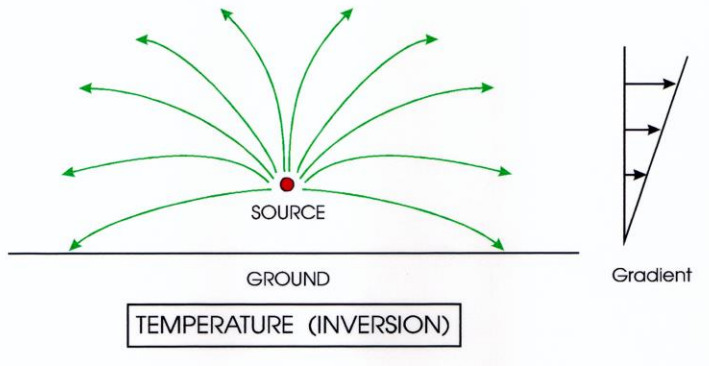
Refraction







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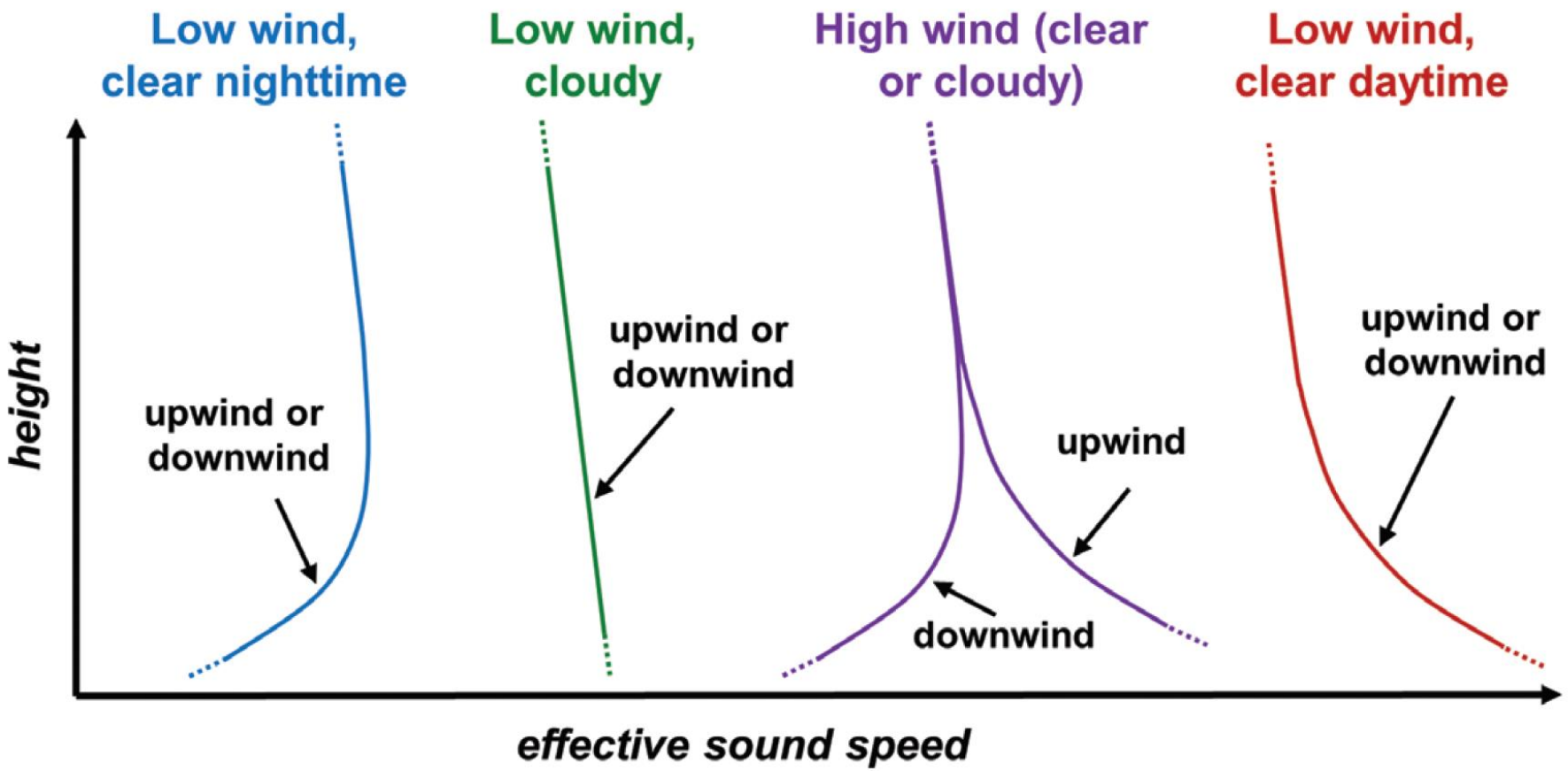
Characteristic sound speed profiles



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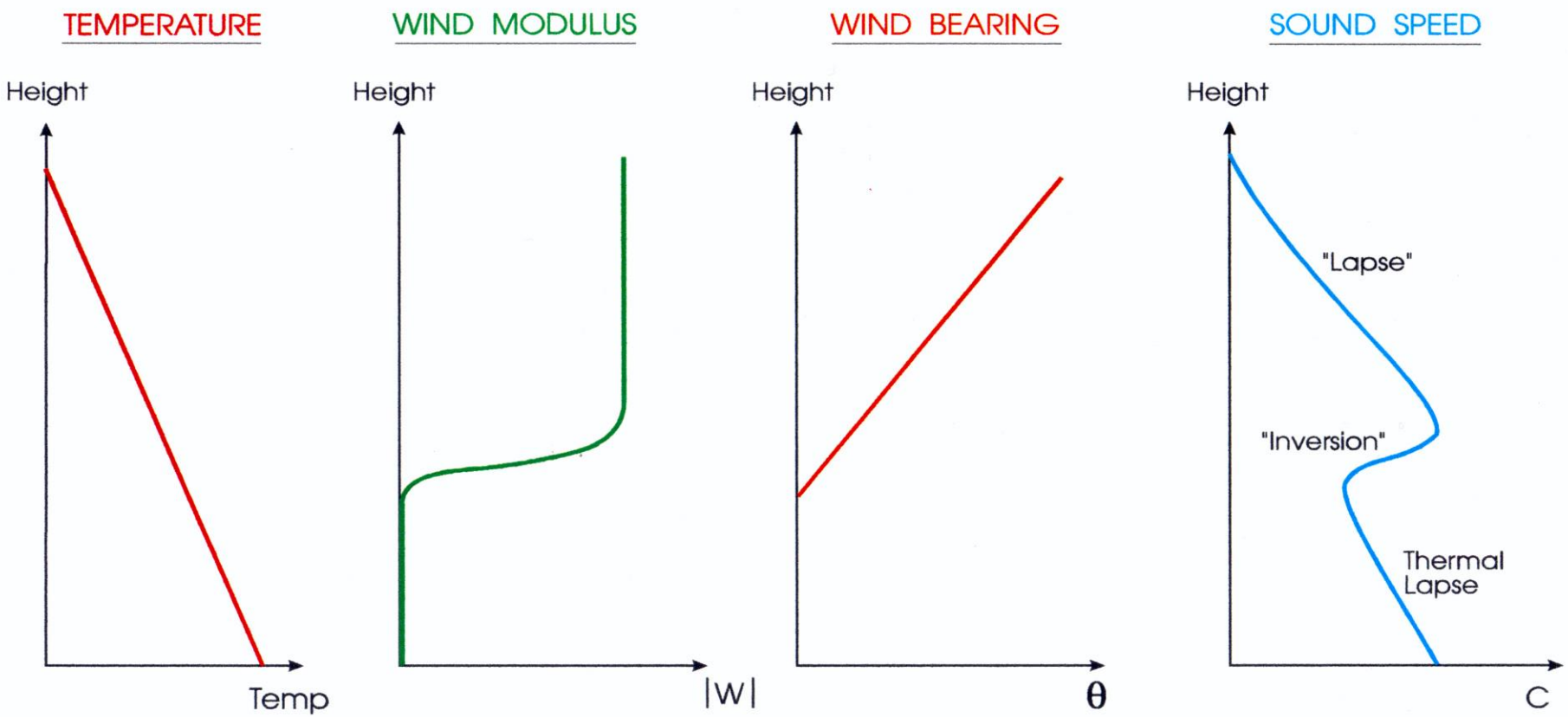

SIMULATED "LAPSE" AND "INVERSION" BY WIND ABOVE A THERMAL LAPSE

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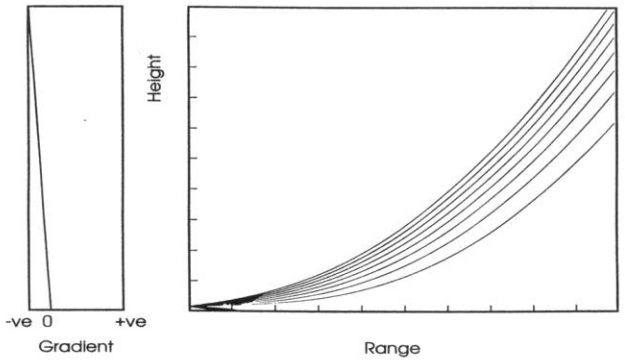
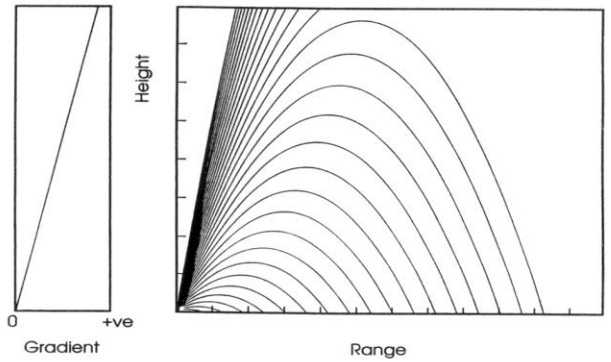
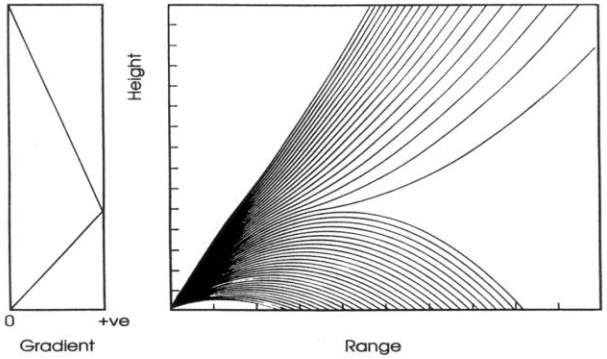


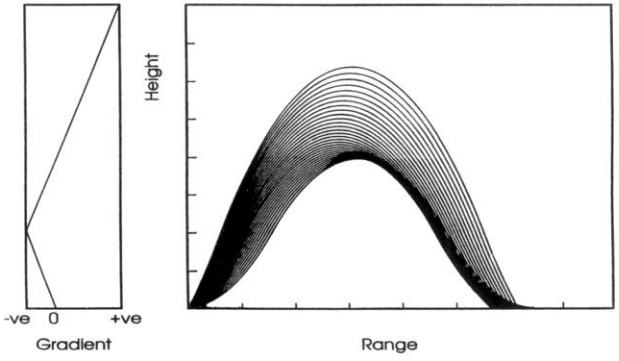
Lapse (Cat 1)



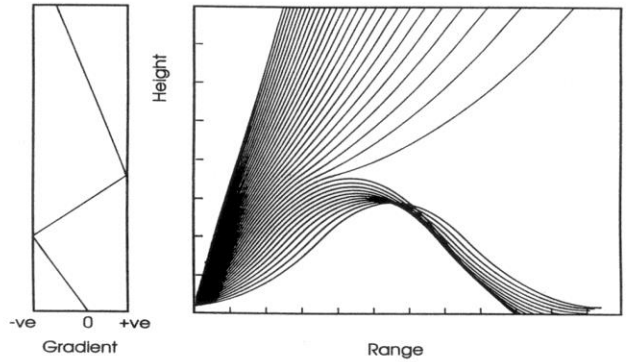
Inversion (Cat 2)



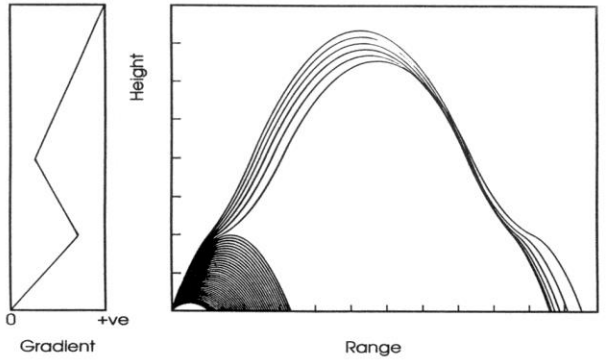
Inversion Below Lapse (Cat 3)



Lapse Below Inversion (Cat 4)



Lapse-Inversion-Lapse (Cat 6)



Inversion-Lapse-Inversion (Cat 7)

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Sound Field Calculations

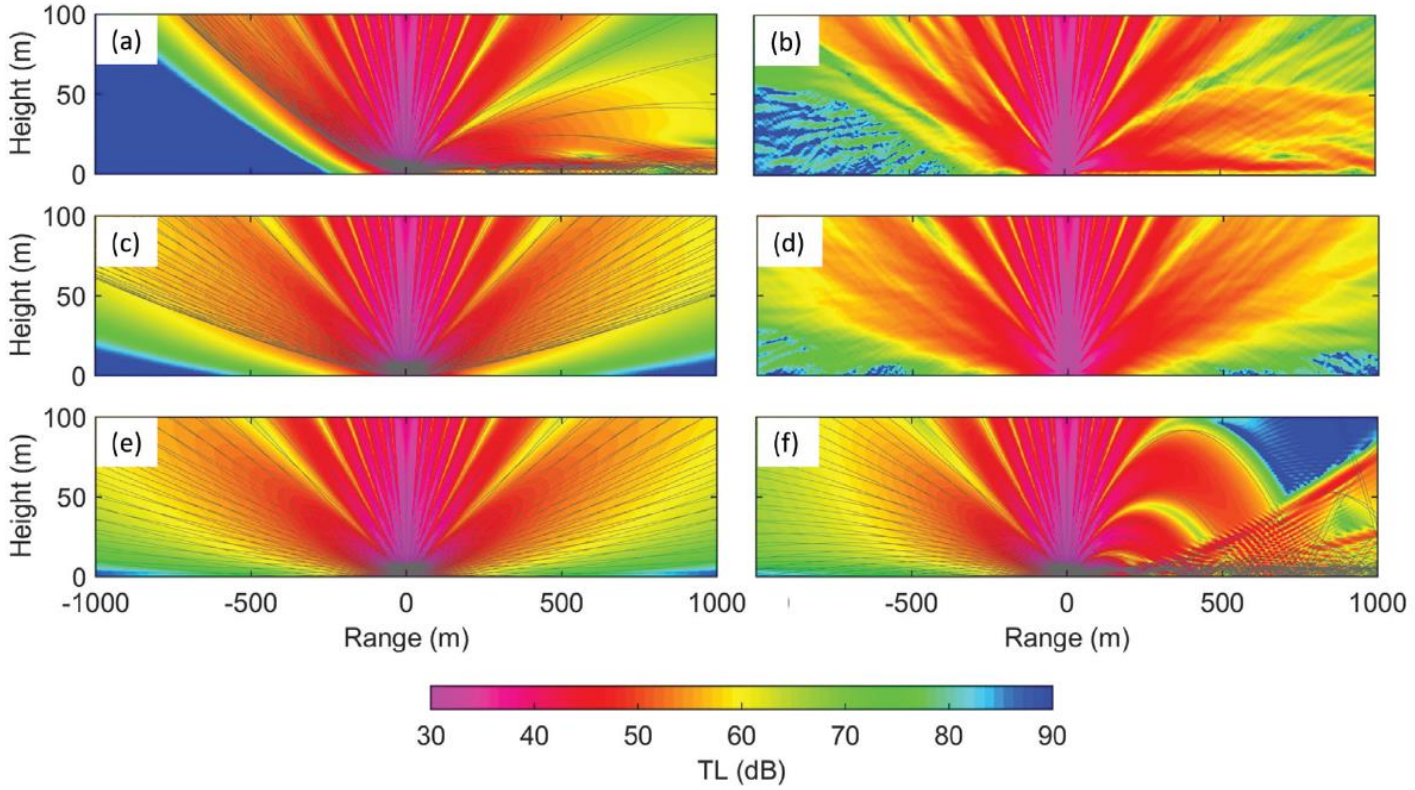

Figure 3. *Sound-field calculations for profiles approximating the 4 conditions shown in Figure 2. The source is at zero range, with upwind propagation negative (to the left) and downwind positive (to the right). (a) and (b) High-wind, neutral conditions. (c) and (d) Low-wind, clear daytime conditions. (e) Zero-wind, cloudy conditions. (f) Low-wind, clear nighttime conditions. Calculations (a), (c), (e), and (f) are without turbulence and ray traces are overlaid. Calculations (b) and (d) incorporate random scattering by turbulence. TL is the transmission loss.*

Absorption and Scattering

- Atmospheric absorption
  - Depends on temperature & humidity
  - Absorption greater at higher frequencies for given temp/humidity
  - Susceptible to sudden changes (after rain)
- Precipitation
  - HF propagate in fog because of high humidity
  - Snow/water significantly affect ground absorption
  - Rainfall and hail cause wideband noise
- Wind/temperature turbulence scatters sound
  - Possibly into quiet zones

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Quantification of Environmental Noise Uncertainties

- "Confidence interval"
  - the margin within which the true value being measured can be said to lie
- "Level of confidence"
  - a number expressing the degree of confidence in the result
- Example
  - Noise level is 55dBA ±5 dBA with a confidence of 95%

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The Uncertainty Budget

- Procedure that considers the uncertainty chain
  - each separate contribution
  - evaluates the value
  - combines them according to set statistical procedures
- Often a spreadsheet
  - Often values of uncertainties may not be known
  - Reasonable estimates based on experience can be made
- Worked example
  - BS4142 measurement

LIST ALL SOURCES OF MEASUREMENT UNCERTAINTY

Noise source — Transmission Path — Receiver

see checklist in section 3.3

DETERMINE THE MAGNITUDE OF THE UNCERTAINTY

Calculate from repeated measurements
or
Take figure from literature
or
Estimate based on experience

CONVERT STANDARD UNCERTAINTY INTO THE SAME UNITS (dB)

STANDARDISE THE CONFIDENCE LEVEL

Standard uncertainty (u) = 68% confidence = one standard deviation

CALCULATE COMBINED UNCERTAINTY (u_c)

$u_c = \sqrt{(u_1^2 + u_2^2 + u_3^2 \ldots)}$

CALCULATE EXPANDED UNCERTAINTY (U)

$U = ku_c$
(coverage factor k=2 for 95% confidence limits)

EXPRESS ANSWER

as [value] ± **U** dB with a confidence level of 95%

Uncertainty Budget

Source of Uncertainty	Notes	Value (half width)	Conver -sion (dBA)	Distrib (divisor)	Std Uncert (dBA)	Ref
SOURCE						
Position	Multiple/area	inc in run				(a)
Movement	Mainly static					(b)
Run condition	Normal - estimate	3dBA	n/a	Rect(√3)	1.73	(c)
Operation	Continuous					(d)
Character						(e)
Enclosure	Fan flaps	inc in env				(f)
Machine cond	inc in run cond	inc in run				(g)
Type of propagation	Point, hemispherical					(h)
Radiation pattern	Omni-directional					(i)
Environmental	Small effect	1dBA	n/a	Rect(√3)	0.58	(j)
TRANSMISSION PATH						
Weather	400 m downwind	3dBA	n/a	Rect(√3)	1.73	(k)
Ground reflection	Very small effect	0.1dBA	n/a	Rect(√3)	0.06	(l)
Barriers	none	nil				(m)
RECEIVER						
Measuring position	Inverse square	10m in 400m	0.22	Rect(√3)	0.13	(n)
Façade	not applicable					(o)
Reflecting surfaces	Minimal 5 m away	neg				(p)
Instrumentation	Type 1 practical	1.9dBA	n/a	Rect(√3)	1.1	(q)
Background noise	BS 4142/diff position					(r)
Night-time		neg				
Daytime		1.0dBA	n/a	Rect(√3)	0.58	
COMBINED uncertainty (root sum of squares)					**2.7(2.8 day) dBA**	
EXPANDED uncertainty (95% confidence [k = 2])					**5.4(5.6 day) dBA**	

Meteorological Effects On Noise Source

- Source levels
  - extra compressors running, cooling louvers are open or closed, whether factory doors left open
  - background noise sources such as rustling leaves and wet roads
- Good practice to determine the likely effect of prevailing weather on the source
  - operating conditions relevant to purpose of survey
  - record and report the prevailing conditions at the time of measurement
- Duration of single or several complete cycles of operation
  - Short-term variations influence the duration required to obtain satisfactory sample
  - Longer-term changes can usually be accounted for by suitable sampling strategies

Meteorological Effects On Transmission

- Variation in propagation conditions in environmental noise measurements
  - Most important source of uncertainty
  - Most difficult source of uncertainty
- The difficulties arise from:
  - Understanding the influence of the various meteorological factors on noise propagation
  - Determining the meteorological profile over the propagation path for the duration of the measurement
- Neither meteorological data nor interpretation generally available
  - Point measurements of meteorology do not suffice
  - The atmosphere is not vertically homogeneous
  - In practice, the atmosphere also has horizontal variations

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Meteorological Effects On Instrumentation

- Wind induced noise
  - Directly on the microphone
  - Indirectly by noise in trees
- Windshield will act as acoustic filter
  - Typically <1dB at any one frequency
  - Corrective filters included to partially equalise this effect
- Always use a windshield
  - Reduce wind noise by ~12db
  - Cushion the microphone

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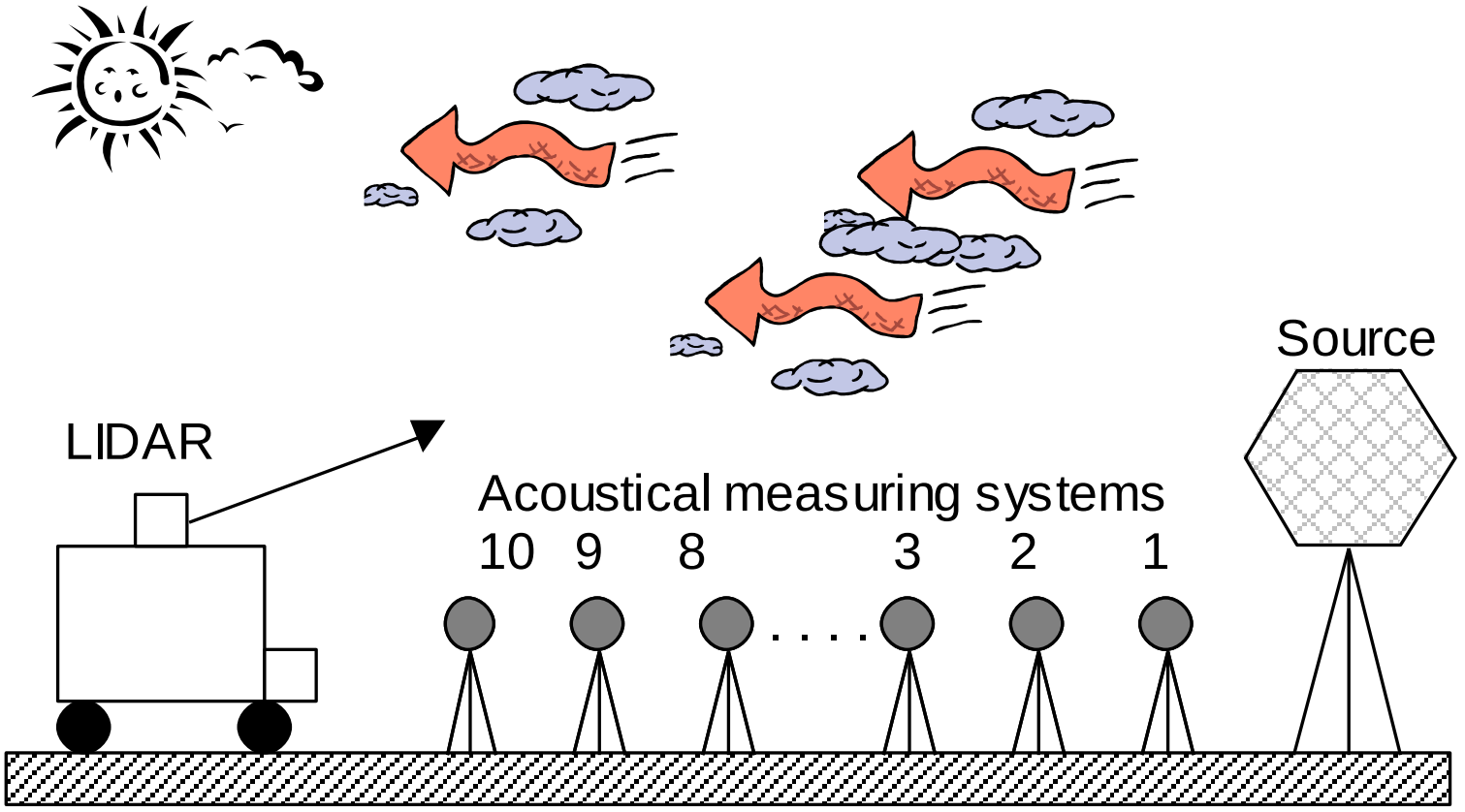
Schematic Of Field Trial



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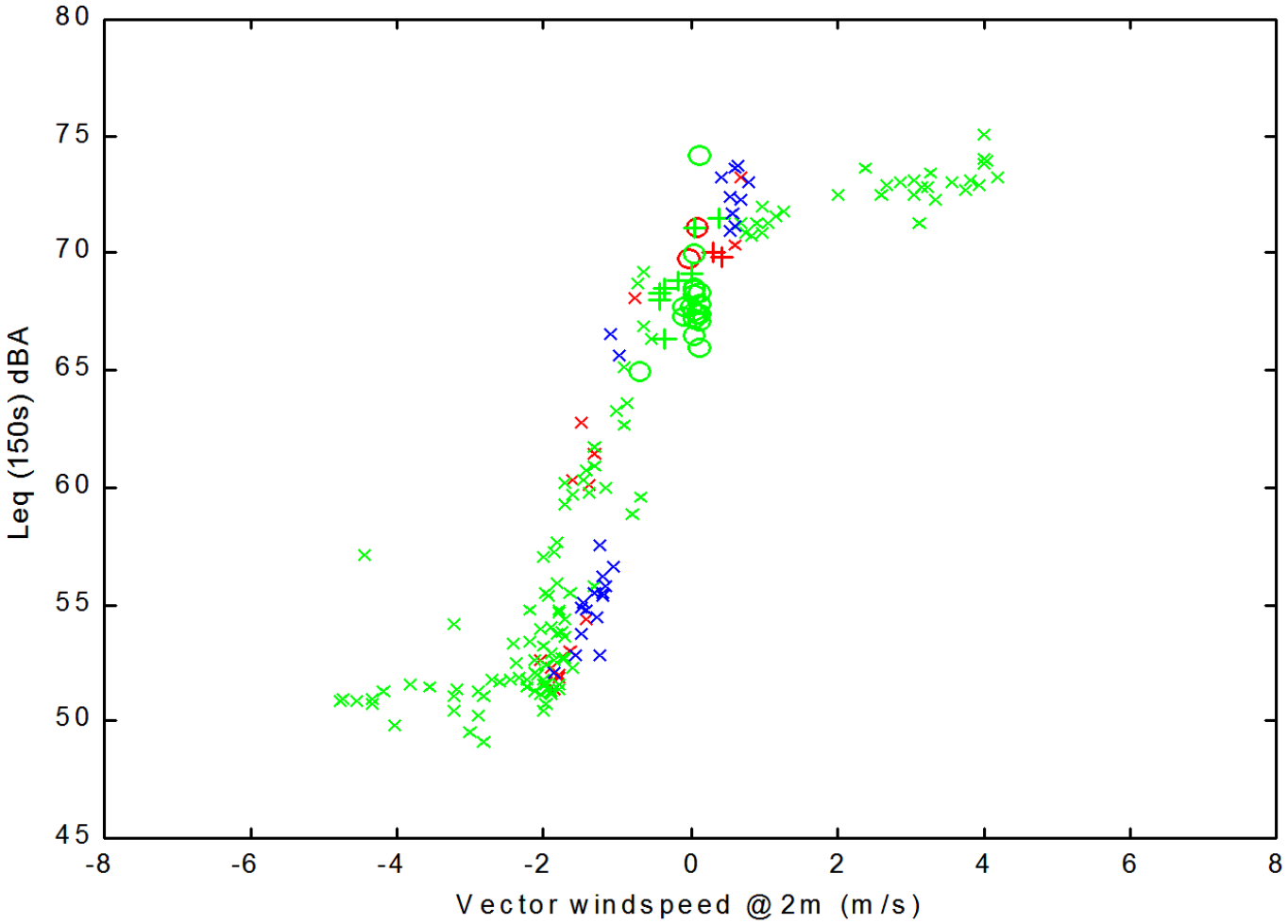
LAeq / vector wind speed @112m



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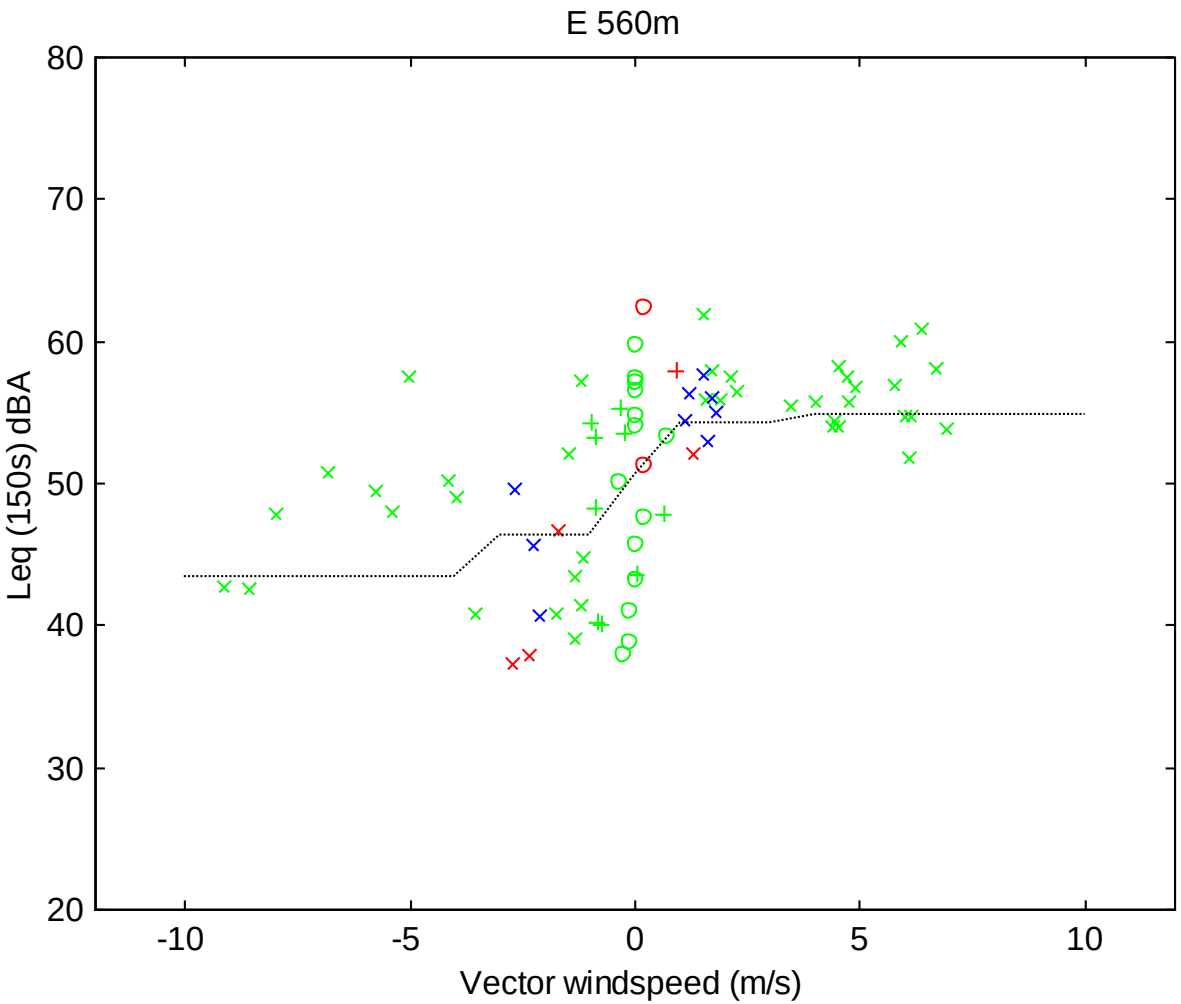
@560m



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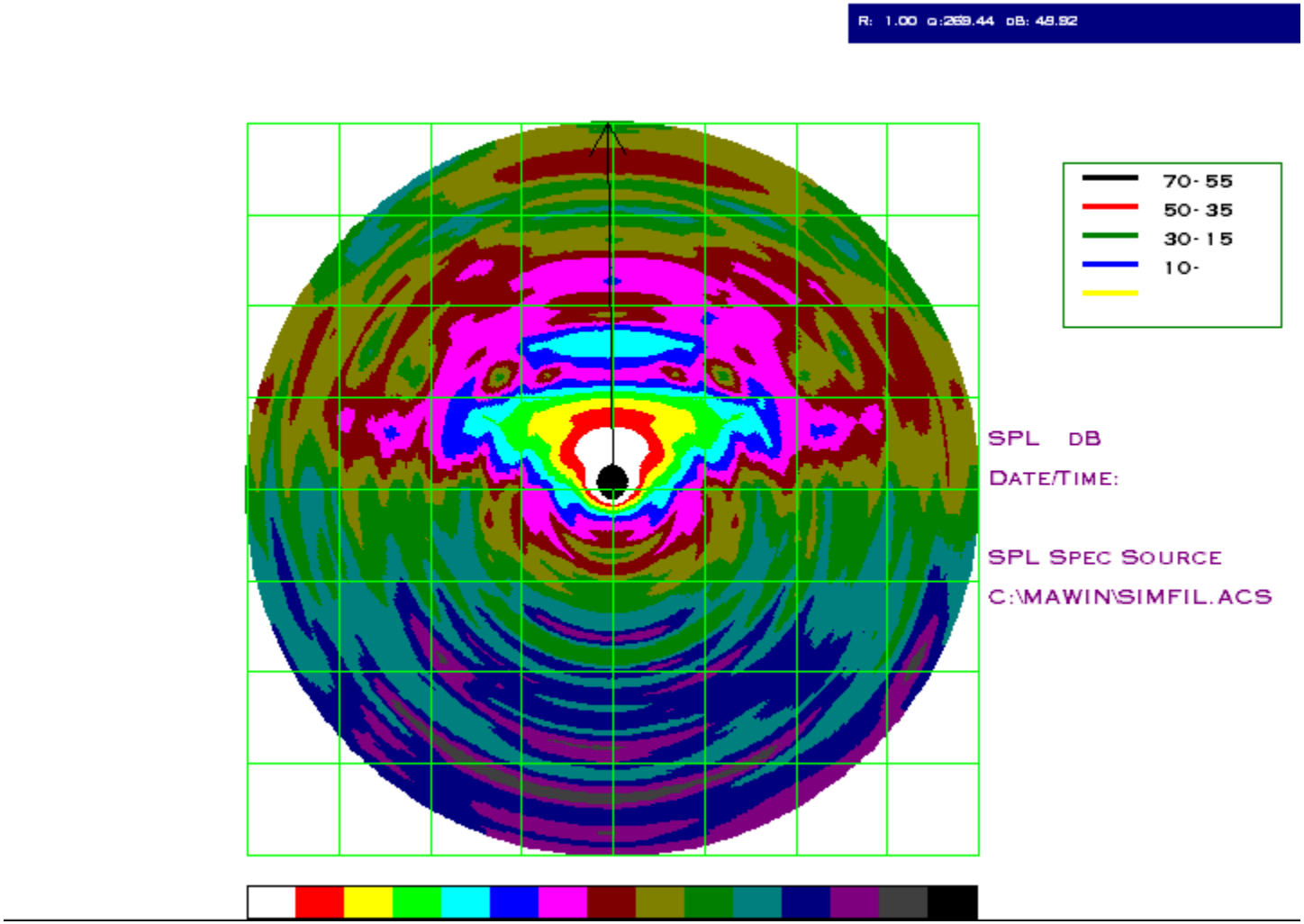
Multi-Azimuth Parabolic Equation Predictions



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Guidance from BS4142

- Section 6.3 describes precautions to "minimise the influence on measurements from sources of interference "
  - "wind, passing over the diaphragm"
    - Windshields are generally effective up to windspeeds of 5 m/s.
  - "rain, falling on the microphone windshield or nearby surfaces…"
  - "use an effective windshield to minimise turbulence at the microphone"
  - "temperature"

BS 4142:2014, Methods for rating and assessing industrial and commercial sound.

6.4 Weather conditions

Record the weather conditions that could affect measurements. Monitor wind speed at the measurement location, using an anemometer, and record the wind speed together with the wind direction. Exercise caution when making measurements in poor weather conditions such as wind speeds greater than 5 ms^{-1}.

Visually estimate cloud cover by eye as either a percentage of sky covered by cloud or in oktas. Record all forms of precipitation together with the period over which the precipitation occurred, having regard to how this might affect uncertainty (see Clause **10** and Annex B).

Record the temperature at the measurement location, in °C, at the beginning and the end of the measurement period, and at any other appropriate time if there is a change in the weather conditions.

Where appropriate, use instruments for measuring meteorological parameters during long-term unattended measurements by means of a logging meteorological station at the measurement location.

NOTE 1 Weather conditions can affect sound levels by influencing sound propagation or generating sound which can be pertinent to the assessment.

NOTE 2 Whilst regional weather forecasts are useful in planning when to measure, local conditions can often vary significantly from the regional forecast. Forecasts should not be used instead of site measurements of the actual weather during the survey.

NOTE 3 It might be appropriate to make more than one assessment to account for varying weather conditions.

Guidance from BS4142

- 12 Information to be reported

h) Weather conditions, including:

1) wind speed(s) and direction(s);
2) presence of conditions likely to lead to temperature inversion (e.g. calm nights with little cloud cover);
3) precipitation;
4) fog;
5) wet ground;
6) frozen ground or snow coverage
7) temperature; and
8) cloud cover.

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Guidance from BS4142

- 8 Background sound

8.1.1 As appropriate, for each of the following situations, conduct background sound level measurements under weather conditions that are representative and comparable to the weather conditions when the specific sound occurs or could occur:

- 10 Uncertainty

NOTE The level of uncertainty associated with a measurement of sound level depends upon a number of factors, including:

i) the range of suitable weather conditions during which measurements have been taken;

Although the level of uncertainty due to the instrumentation system can be quantified, this is unlikely to be practicable for some of the other measurement uncertainties. The level of uncertainty can be reduced by several methods, including taking more measurements, for longer measurement time intervals, on different occasions over longer periods of time, under differing suitable weather conditions. What is appropriate will depend upon the particular circumstances of each assessment, including the scale of the proposed development and the risk of it causing significant adverse impact. Consideration should be given to any published information that is relevant to the assessment.

BS 4142:2014, Methods for rating and assessing industrial and commercial sound.

Guidance from BS4142

- Annex B Consideration of uncertainty

B.2.3 Good practice guidelines: transmission path

B.2.3.1 General

- Use weather forecasts when planning measurement sessions.
- Record meteorological conditions at appropriate times across the duration of the measurement and report.
- Unless circumstances appropriate to the assessment dictate otherwise, it is preferable to measure during meteorological conditions favourable to propagation. These conditions are for downwind propagation, namely when the wind direction is within an angle of ±45° of the direction connecting the centre of the dominant source and the centre of the specified receiver region and with the wind blowing from source to receiver [ISO 9613-2, ANSI/ASA S12.18].
- Measurements should be avoided when atmospheric conditions give rise to temperature inversions or complex lapse/inversion situations which can give rise to anomalous sound propagation unless circumstances appropriate to the assessment dictate otherwise

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Guidance from ISO1996

7.2.5 Propagation conditions

For outdoor transmission of sound, changes in meteorological conditions may influence the received sound pressure level. In such cases, the noise limits shall be based on an average value for either all relevant propagation conditions or for a single specified condition.

ISO 1996-1:2016 Acoustics. Description, measurement and assessment of environmental noise. Basic quantities and assessment procedures

Rules of Thumb

- In general, monitoring should be avoided when:
  - the wind speed exceeds 5 m/s,
  - the temperature is below 3 degrees C, or
  - when there is significant precipitation
- Unless these are the normal conditions for the area

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Best Practice

- If complaints under particular weather
  - measure under those conditions
- Otherwise measure under reasonably stable downwind refracting meteorological conditions
  - no strong temperature gradients near the ground
  - wind direction within ± 45° from source to measurement position
  - wind speed 2-3m/s at 3m to 11m height
- This means that:
  - propagation falls off uniformly with distance
  - reasonably steady over an extended period
  - This will improve reproducibility

Conclusions: Propagation

- Downwind
  - noise levels may increase by a few dB
  - depends on wind speed
- Upwind or sidewind level
  - decreases in excess of 20 dB
  - turbulence tends to decrease this with distance in practice
- Temperature gradients under with no wind
  - variations of same order as strong vector winds

Conclusions: Measurement

- The Uncertainty Budget
  - detailed assessment of all sources of error
- To reduce uncertainties in environmental noise measurements
  - use weather forecasts when planning
  - measure under favourable propagation conditions unless specific conditions are required
  - record and report meteorological conditions
- For long term averages
  - determine statistical spread of weather classes
  - plan measurement sessions accordingly

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Further Information: usir.salford.ac.uk

DTI Good Practice Guide

A Good Practice Guide on the sources and magnitude of uncertainty arising in the practical measurement of environmental noise

N.J.Craven, G.Kerry

University of Salford 2001 (revised 2007)

ISBN: 0-9541649-0-3

Available free at http://usir.salford.ac.uk/20640