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1967-2017 50 YEARS

Predicting Blast Pressures at Long Range DNV-GL Trial - June 2017

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Introduction

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- Aim
  - Develop a bespoke explosive noise impact model for DNV GL Spadeadam
- Objective
  - Maximise the number of test opportunities while minimising the environmental impact at sensitive receptors
- Field trial results
  - real-time measurement system
  - assessment & development of prediction models

What is the Problem

Predicted Linear Peak Sound Pressure Level (dB lin)	**Risk of Noise Complaints**	**Recommended Action**
<115	Low risk of complaints.	No restriction on operations
115 - 130	Moderate risk of complaints. Threshold of pain for unprotected ears ~ 130dB	Postpone non-critical testing. **No blast allowed at 126 dB or higher** under EPA [9].
130 - 140	High risk of complaints.	Only test in extremely important cases [8]. Not allowed under EPA [9].
>140	Threshold for permanent physiological damage to unprotected ears. High risk of physiological and structural damage claims	Postpone all explosive operations

[8] DOD Operational Noise Manual 2005.

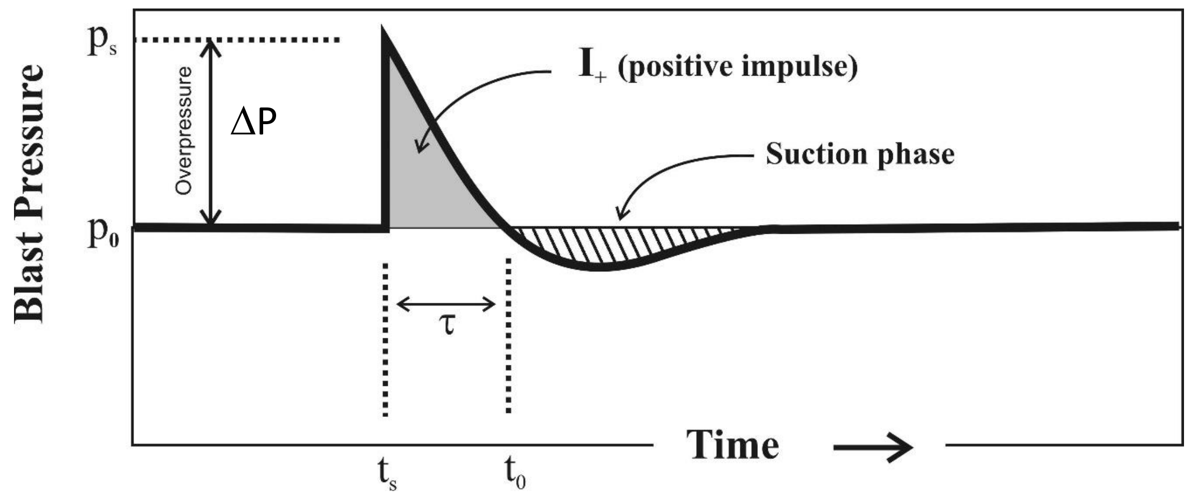
[9] "Environment noise requisite" US Environmental Noise Agency 1974.

Compatible with 125dB noise limit at UK ranges (Shoeburyness).

Presentation Overview

- Introduction to blast waves
- Predicting blast pressures at long range
- Measurements
  - noise
  - meteorology
  - terrain
- Noise management options
- Conclusions and Further work

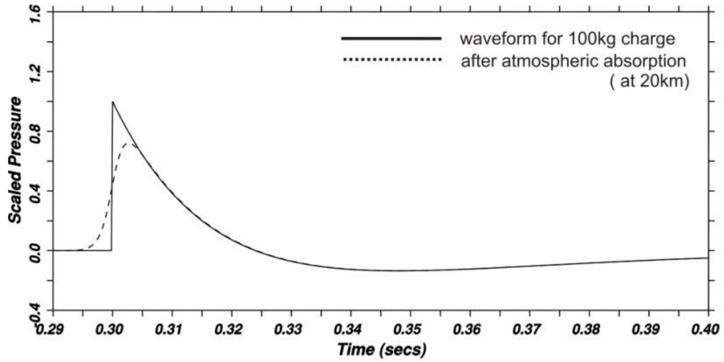
Salient features of blast waves

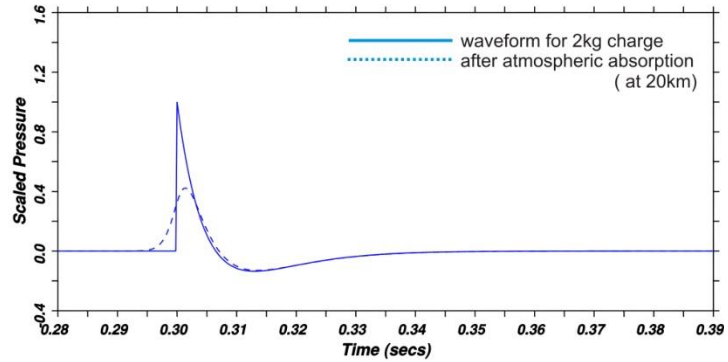


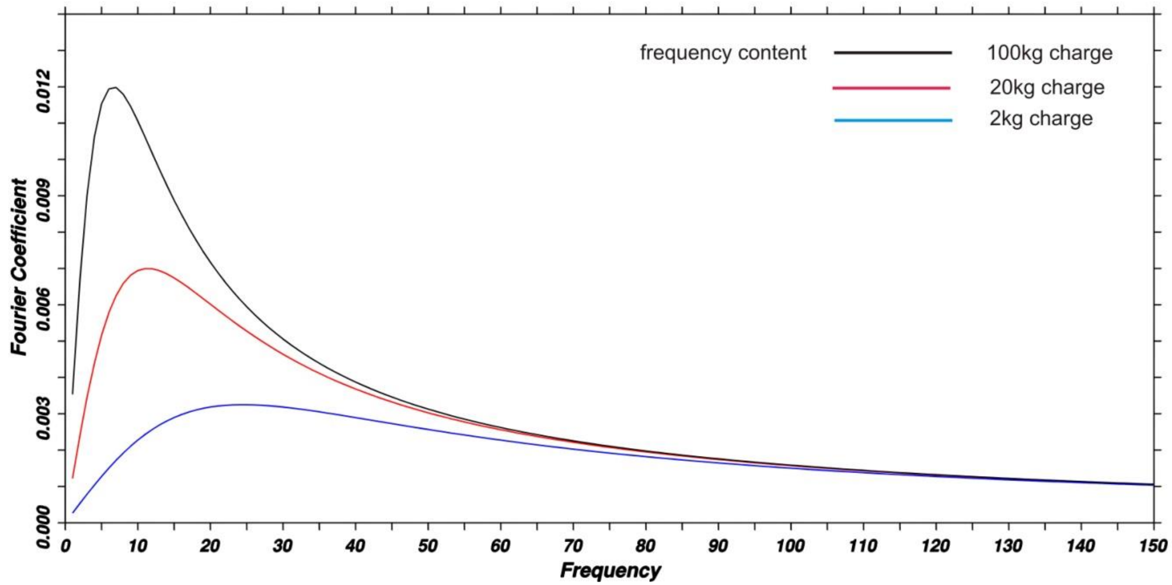
(Friendlander 1946)

For each type of explosive all blast scaling rules tabulate, the blast over-pressure ΔP, duration τ and impulse I_+ as a function of charge weight & distance.

Idealised waveforms for 2kg and 100kg charges and the frequency content

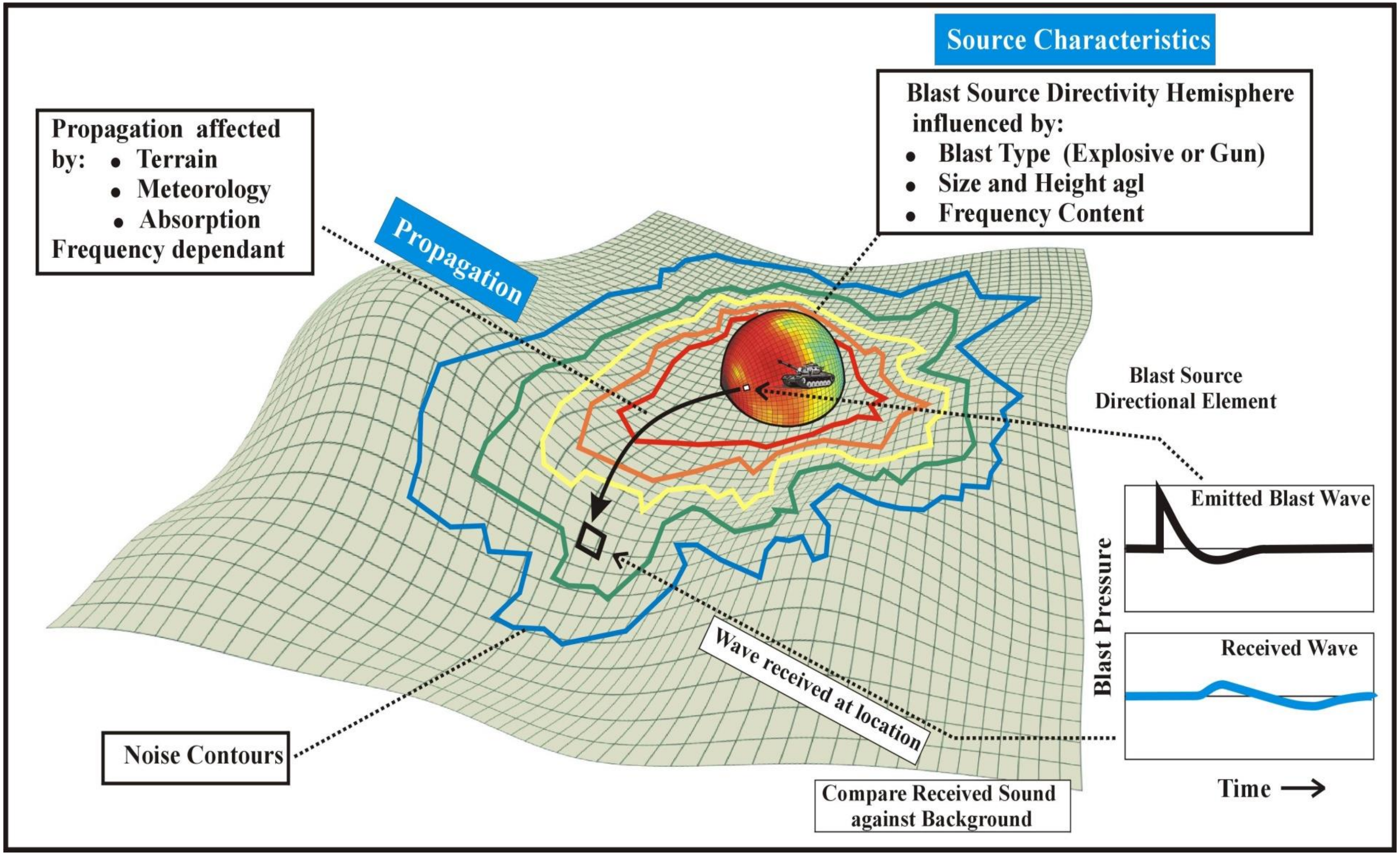






$$P(t) = \sum_{n=-\infty}^{n=\infty} C_n \, G(\alpha_n) \exp\left(-i\,\alpha_n t\right)$$

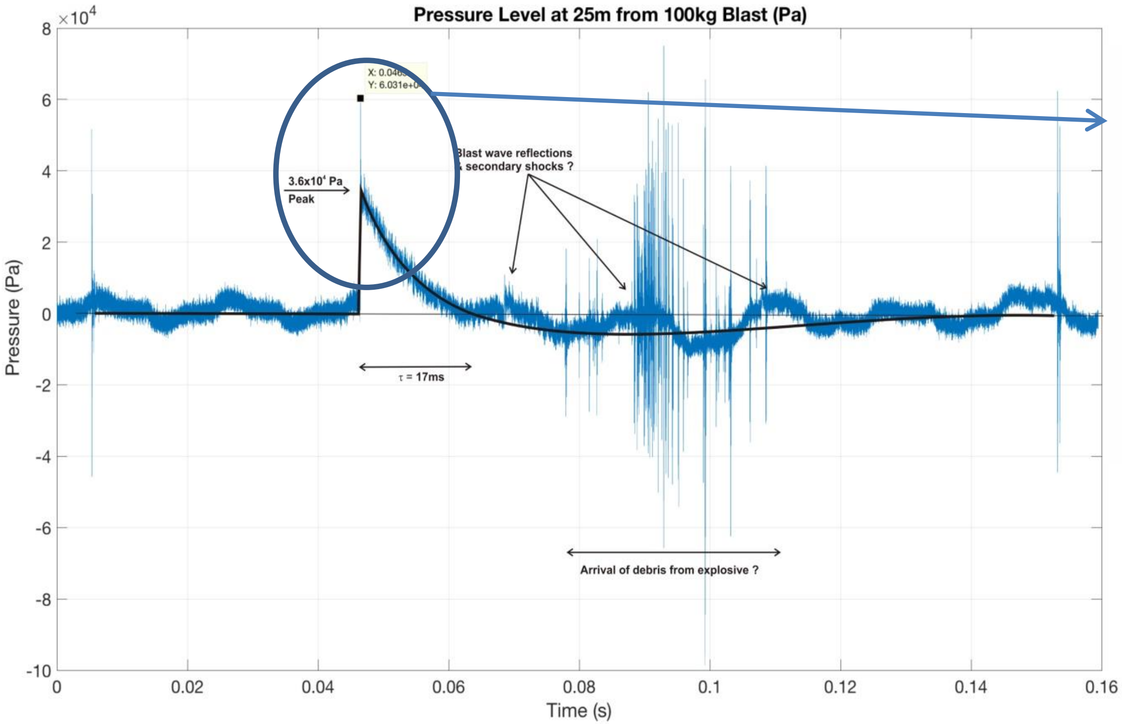
Predicting Blast Pressures at Long Range

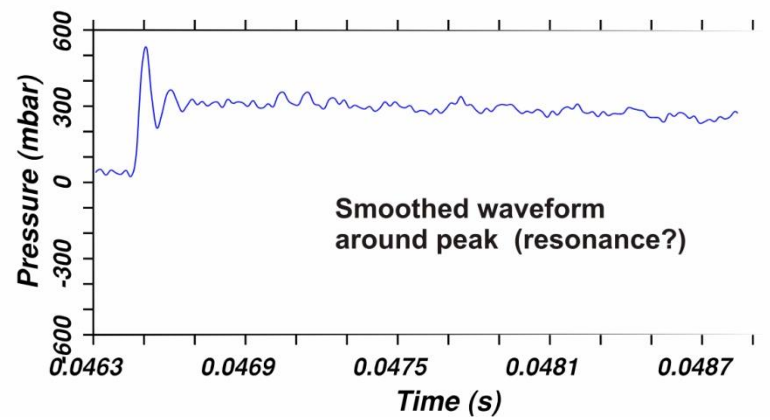


Modelling Requirements

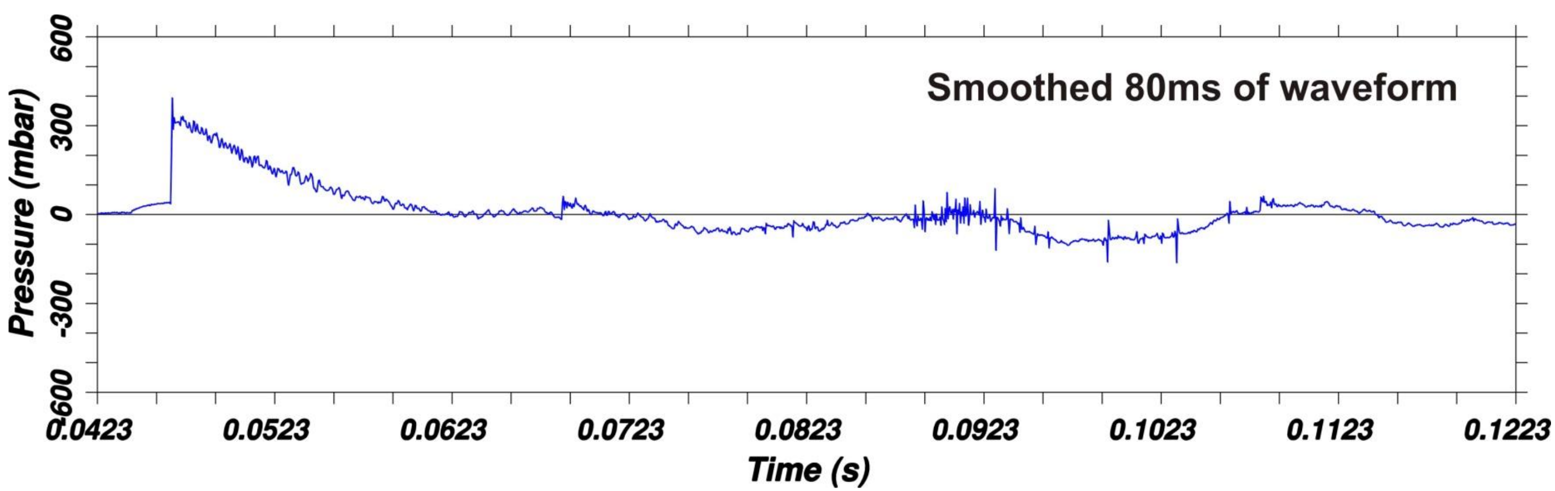
- **Source:** Need the characteristics of the blast near the detonation point of: peak overpressure, duration of positive phase and impulse. Does waveform conform with standard ? Is it directional?
- **Terrain:** Hills, ground condition and vegetation will affect both the propagation characteristics and the meteorology between source and receiver.
- **Meteorology:** This changes during each day and from day to day. It is the most important variable that impacts on the far – field blast pressure level. Accurate detail of vertical profiles of wind and temperature are needed, to predict refraction characteristics between source and receiver, if there is any chance of good prediction of received blast level.
- **Measurement:** This is needed to define source , ground condition and meteorology. It is a necessary component for validation as well as for deducing general links of meteorological conditions which produce enhanced noise.

Source: measurement (on PadC)





Need to understand the source characteristics and differences in expectation.



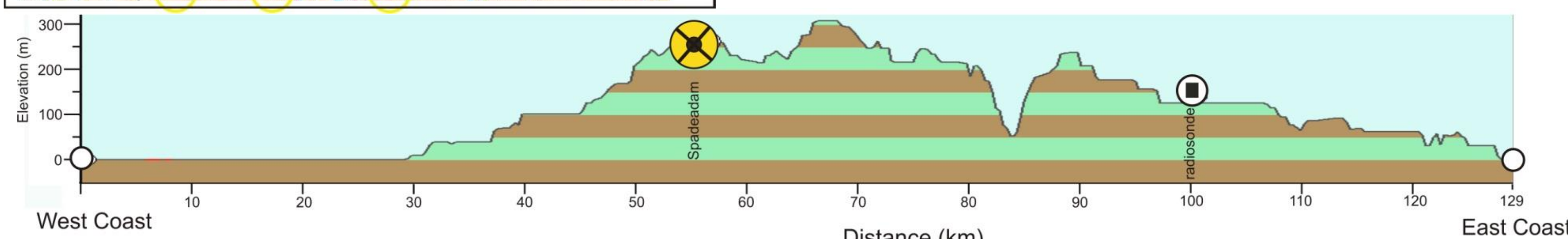
Terrain near Test Site

Spadeadam is at an altitude of 260m on the Northern edge of east-west pass between the **Cheviot Hills** to the North and the **Pennine Hills** to the South .
Both have nearby peaks exceeding 600m

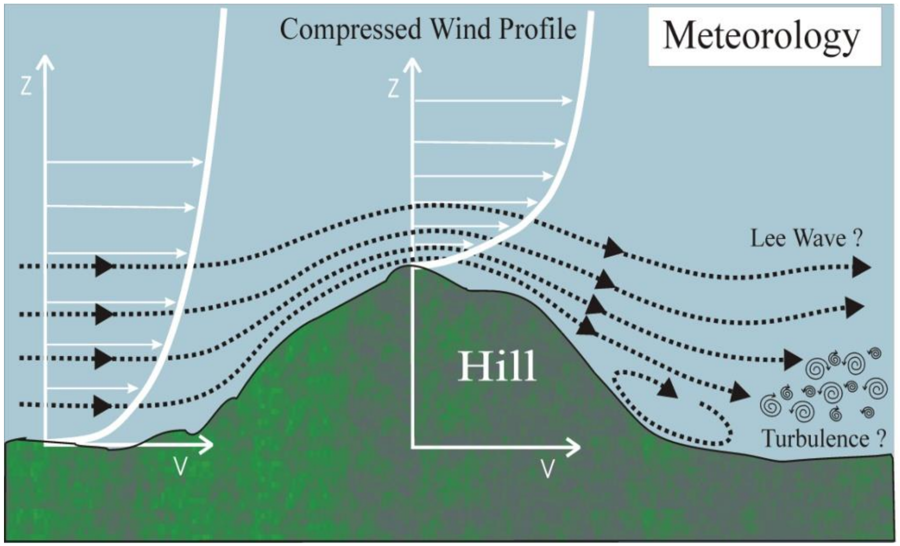
Main impact of the hills is on meteorology. Easterly winds will be funnelled up the pass. Distortions to the wind will occur over the hills which are governed by the Froude number. Compression of wind streamlines will occur, with increasing wind speed with altitude.

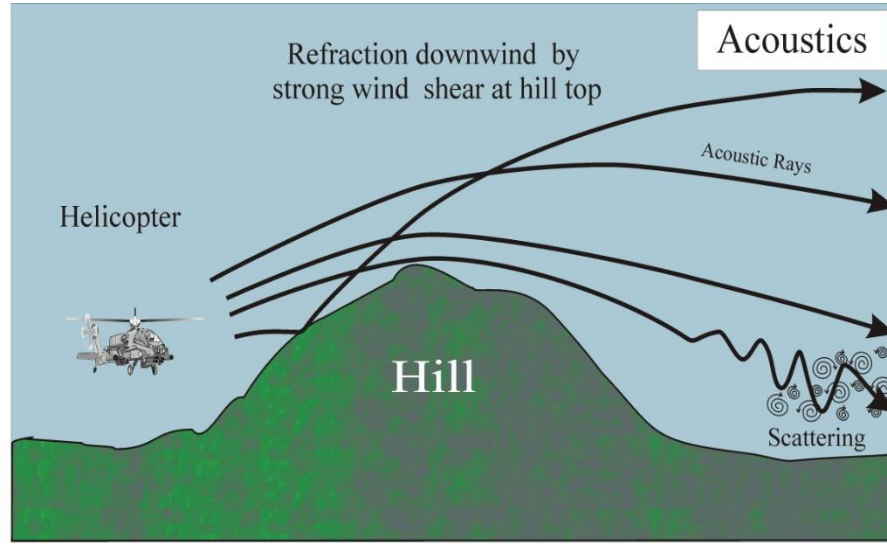
The forest to the NW will absorb acoustic energy. Moorland and pasture will have different absorption characteristics.

Nearest radiosonde is 45km away.



Influence of Hills





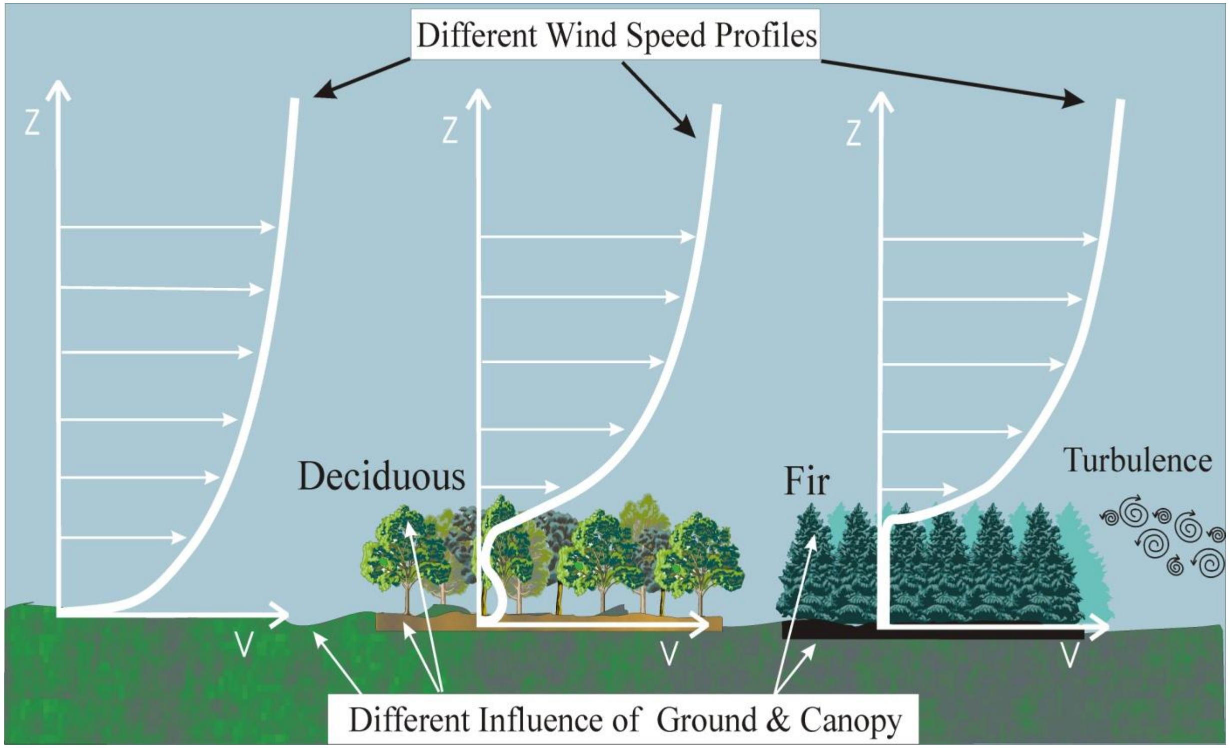
<u>Meteorology depends on:</u>

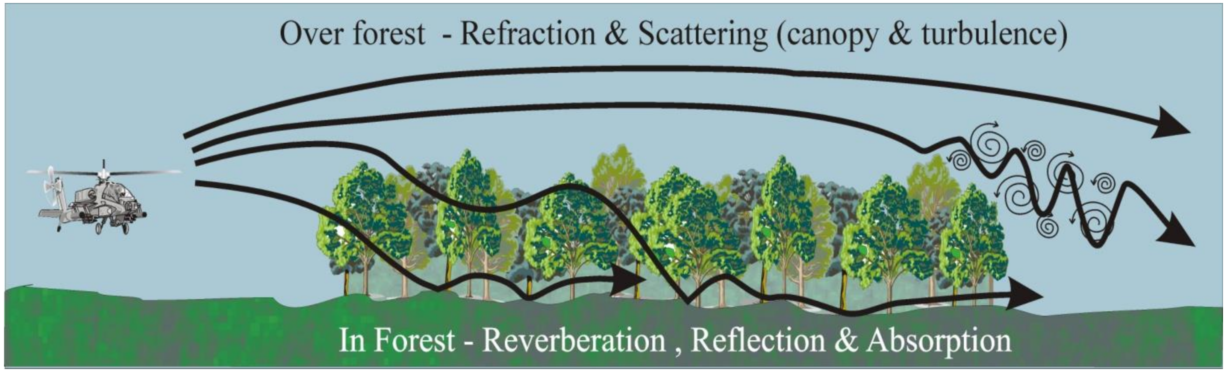
- Froude number
- 3D effects
- Ground conditions

<u>Acoustics depend on:</u>

- Refraction – range varying gradients
- Reflection – range varying ground
- Scattering by turbulence (lee of hill)
- 3D effects (primarily diffraction)

Influence of Trees





Acoustic propagation: significantly influenced by
- ground & vegetation
- profiles of wind & temperature in earth's boundary layer (EBL).

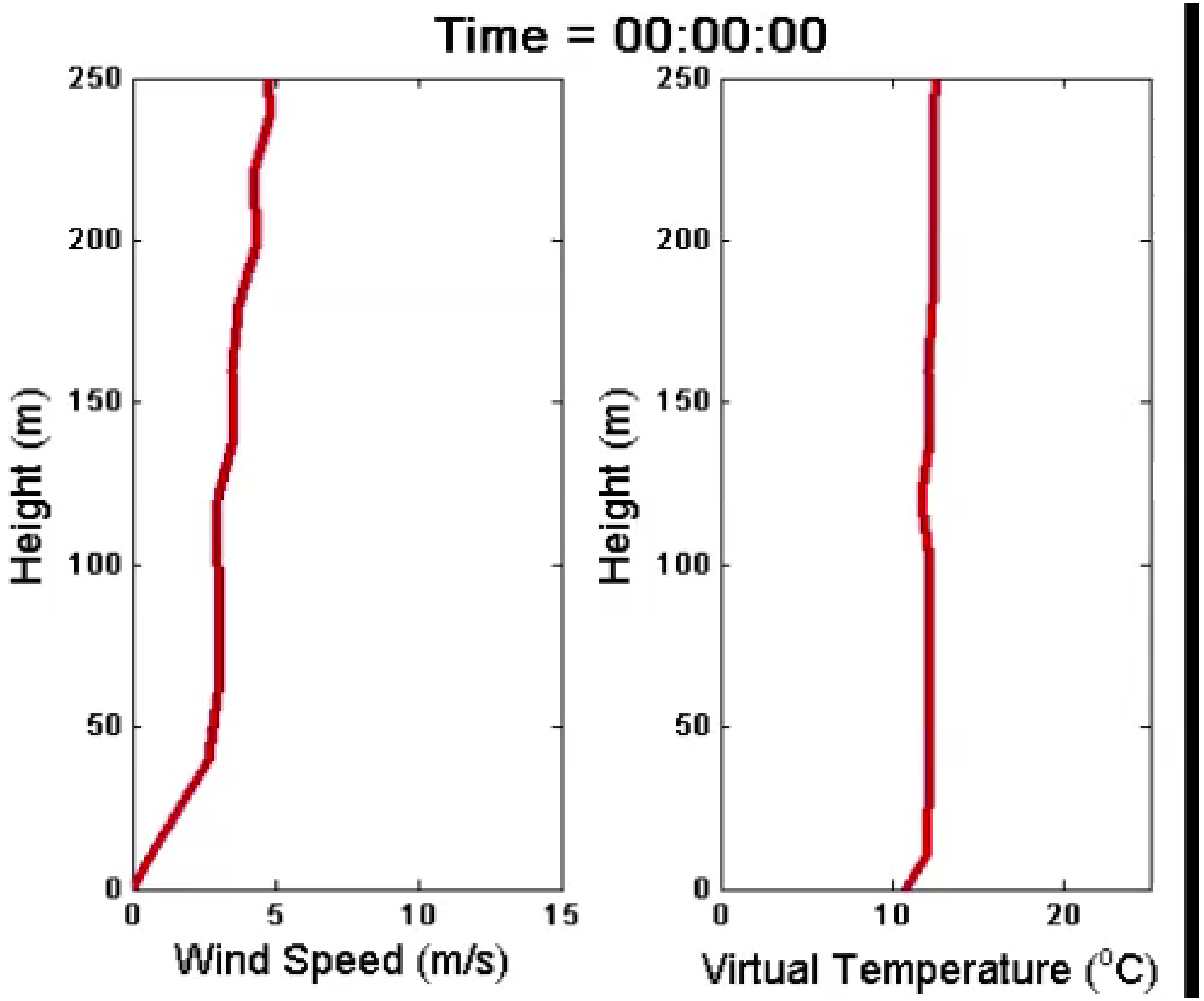
Meteorology within EBL Influenced by:
- Thermal boyancy
  - different thermal radiation from trees
- Terrain roughness
  - different with trees
- Coriolis effects

Depth of EBL varies during the day.

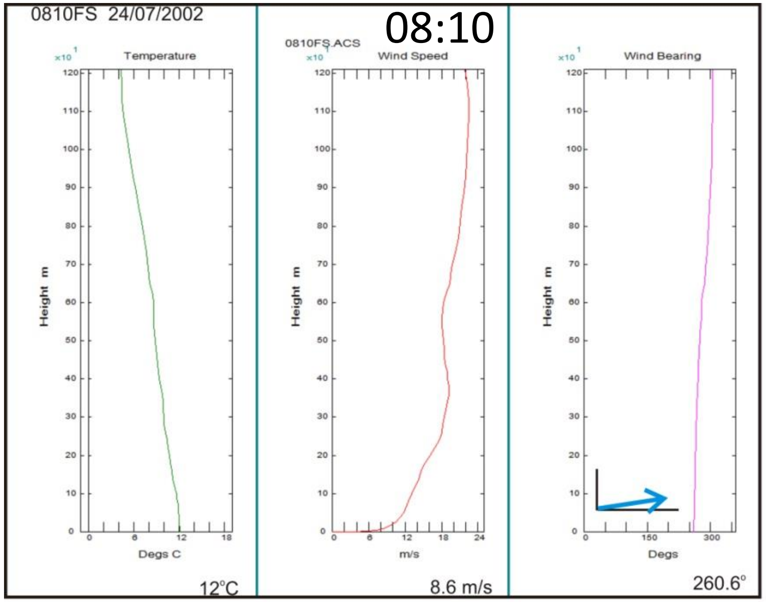
Profiles measured at Spadeadam 2002

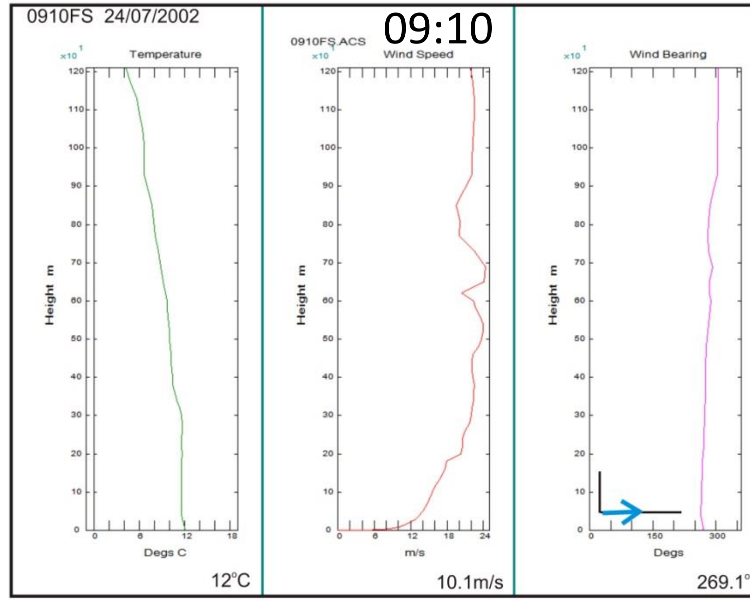
Equipment deployed by University of Salford for helicopter trial to validate Helicopter noise prediction model.

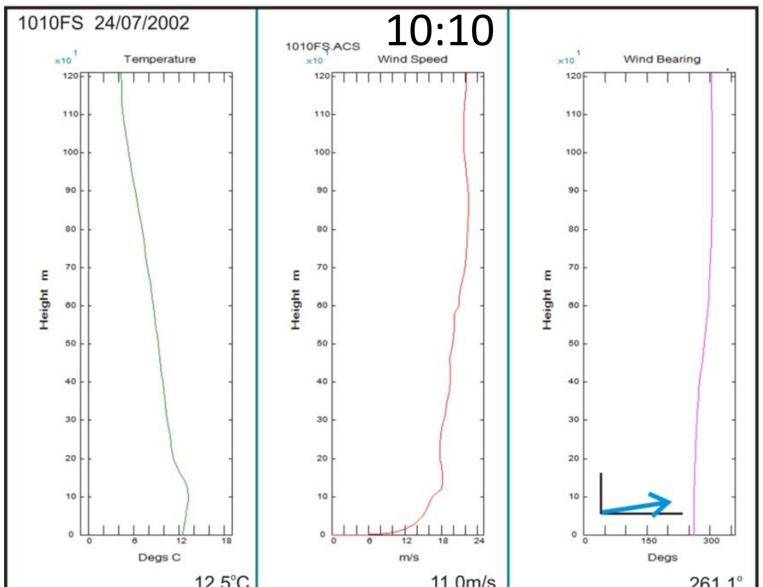
Meteorological Profiles 2002: Animation

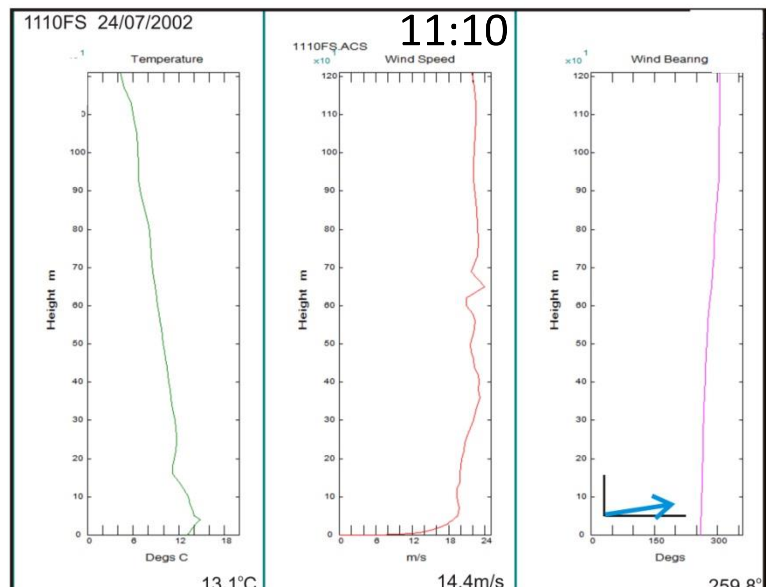


Measured Meteorological Profiles 2002



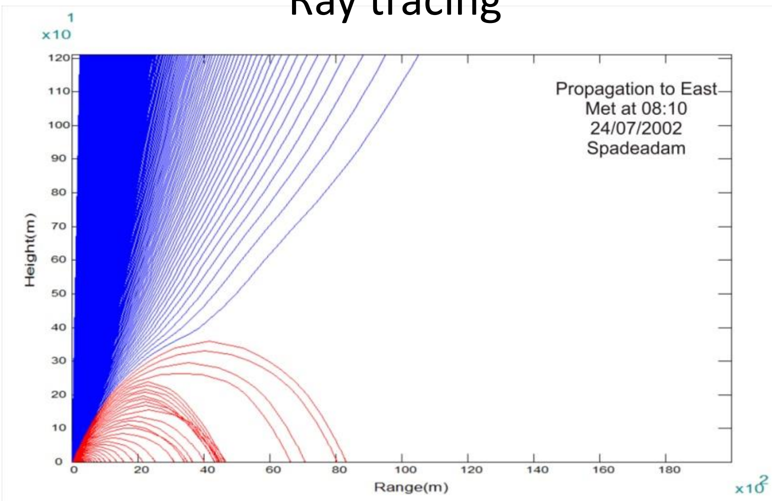


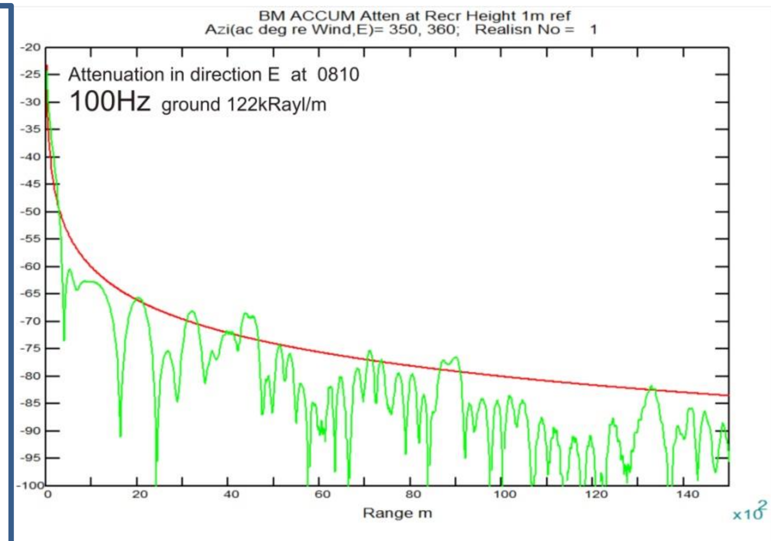


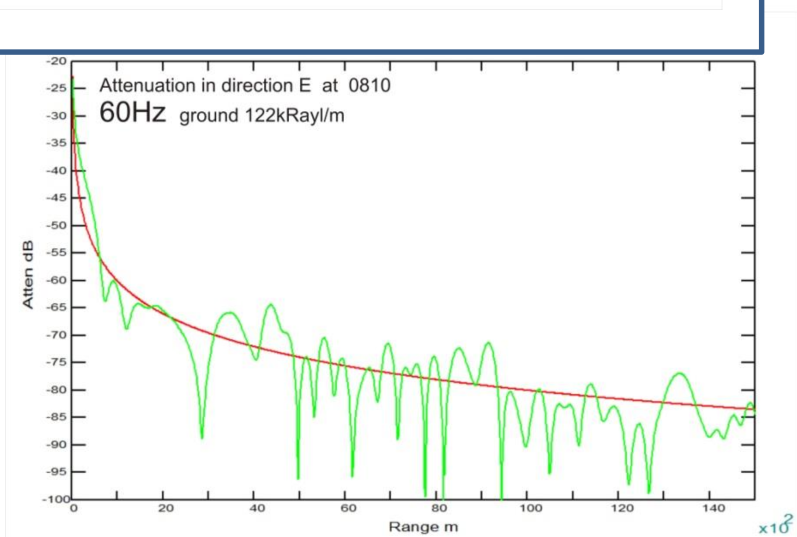


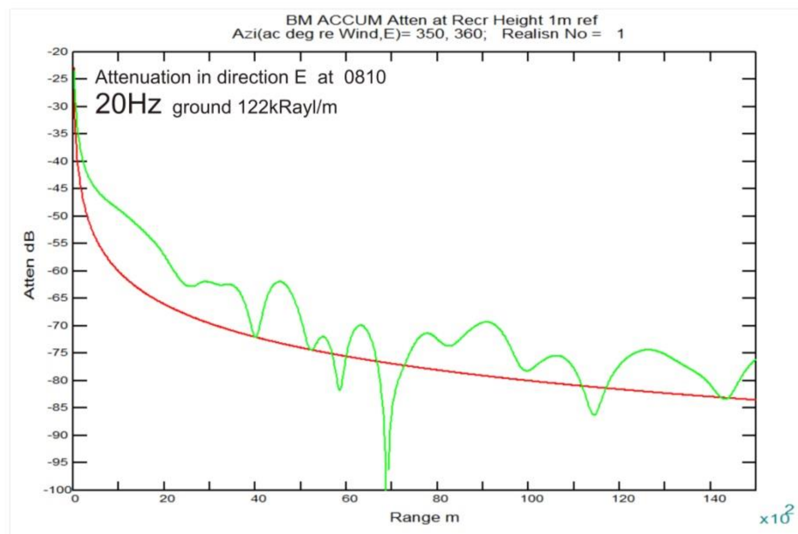
Predicted Attenuation - Varying Frequency

Ray tracing

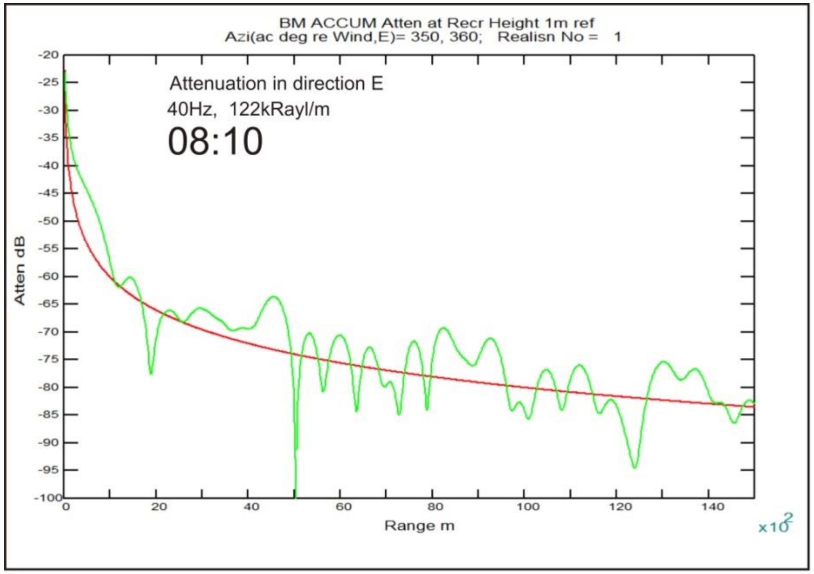


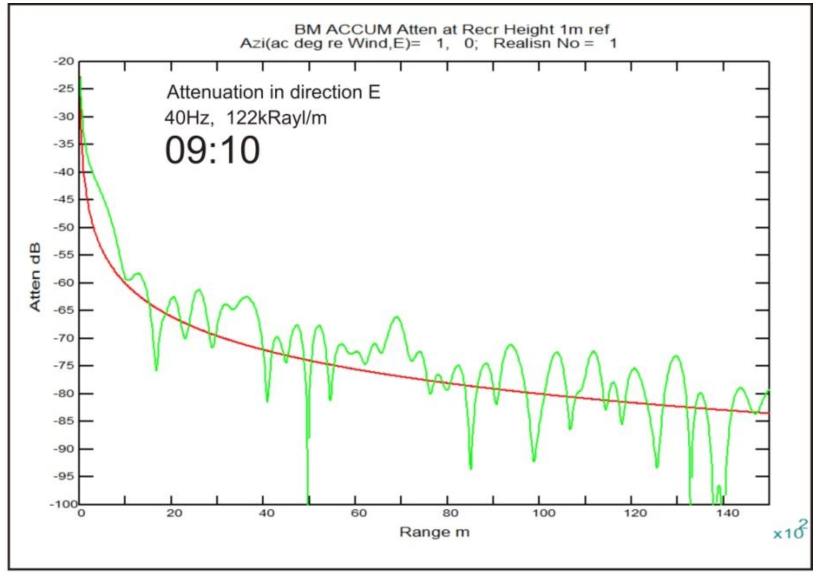


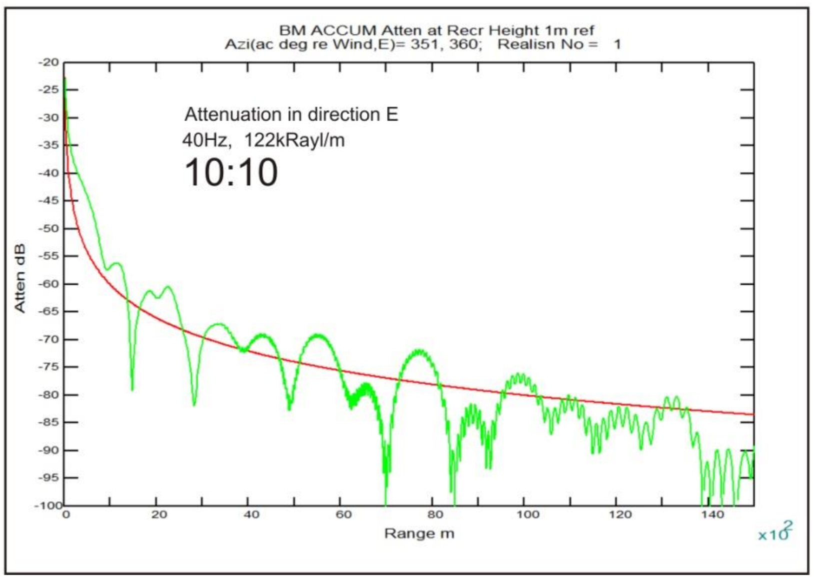


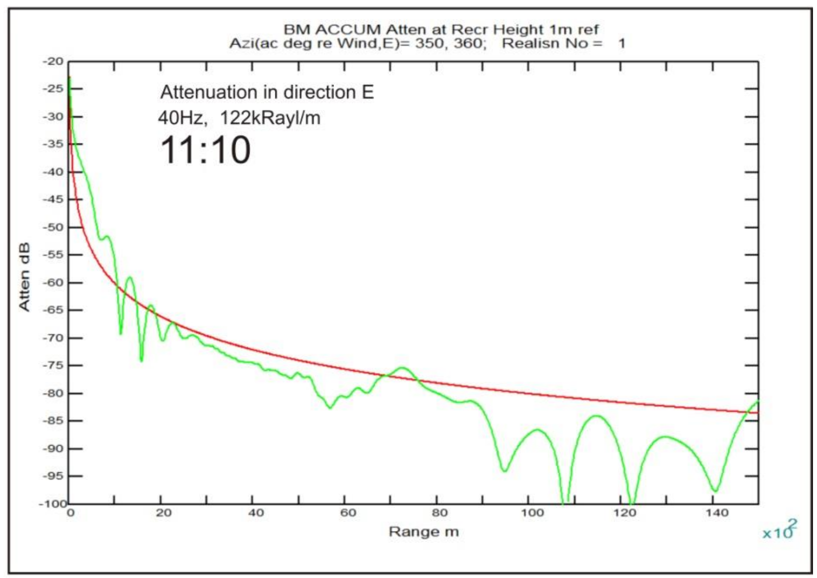


Predicted Attenuation – Varying Time

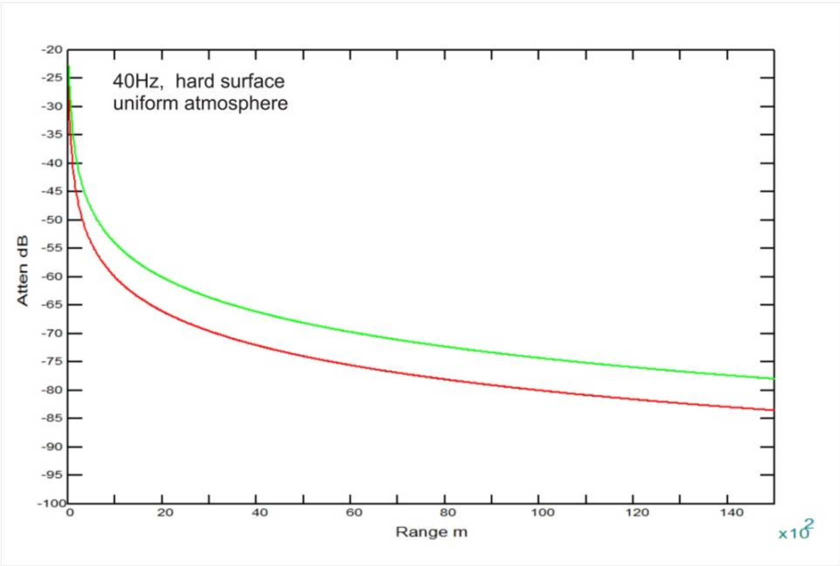


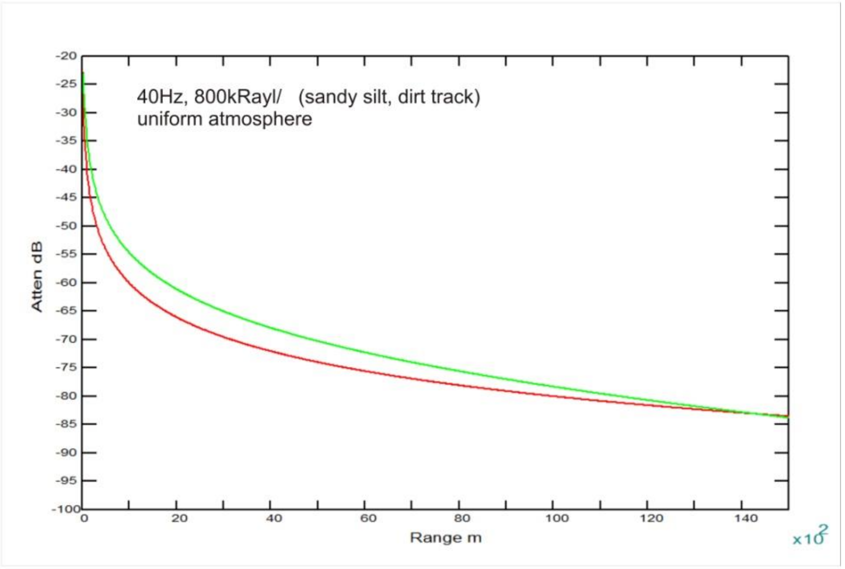


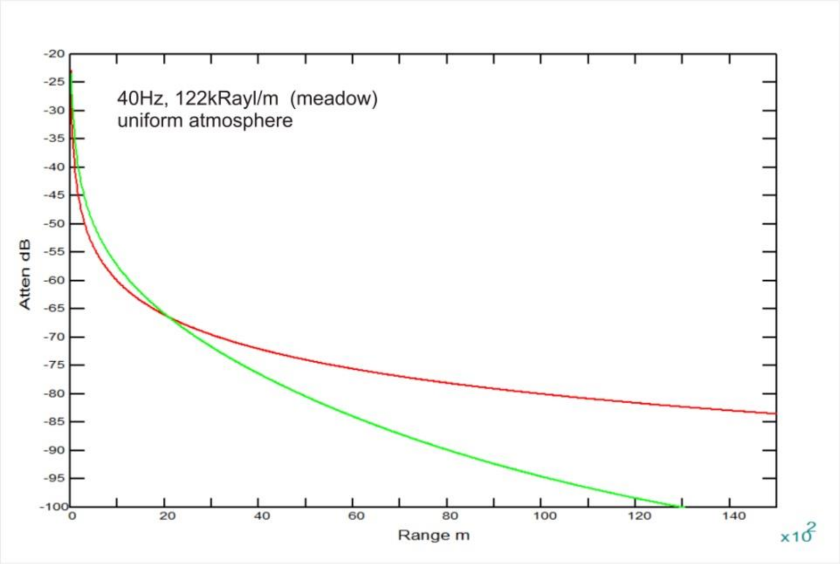


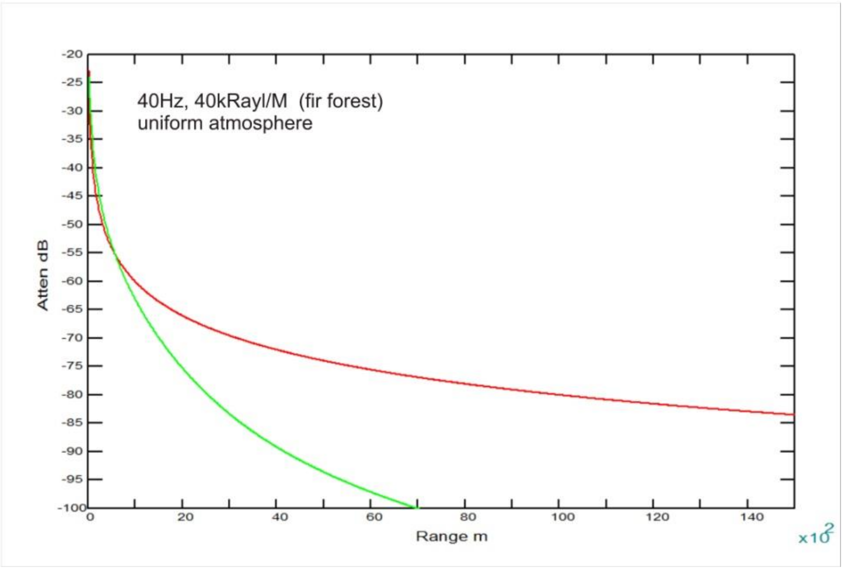


Effect of surface impedance (uniform atmosphere)



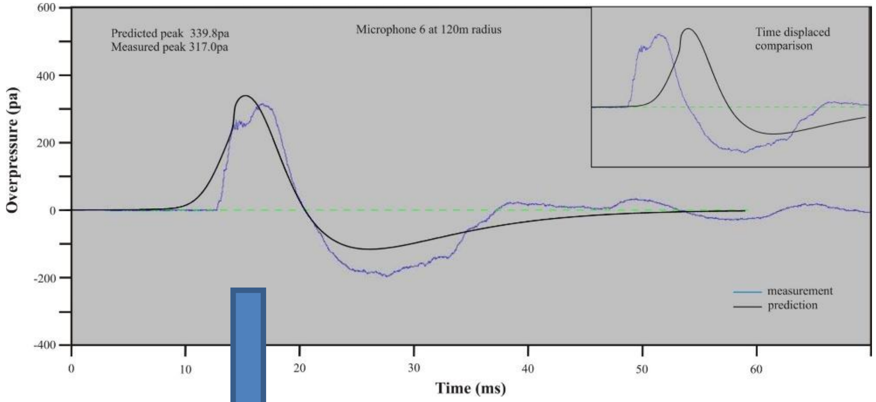


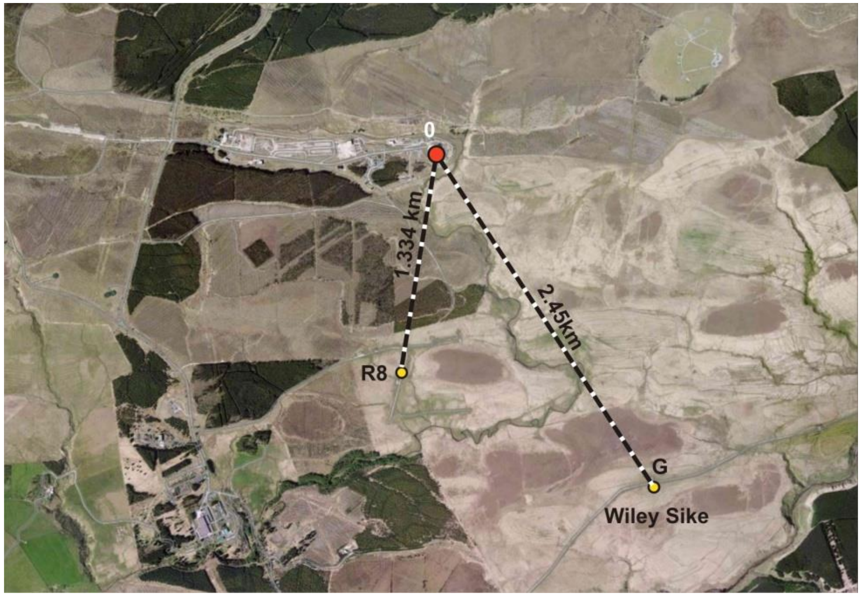


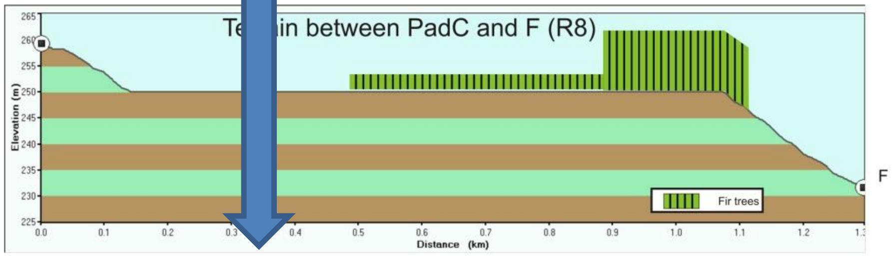


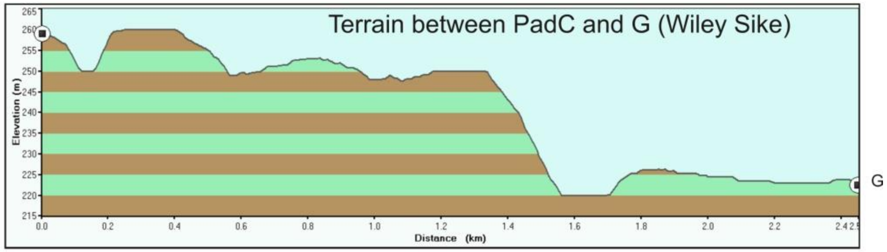
Recordings at F & G for Blast1 (100kg)

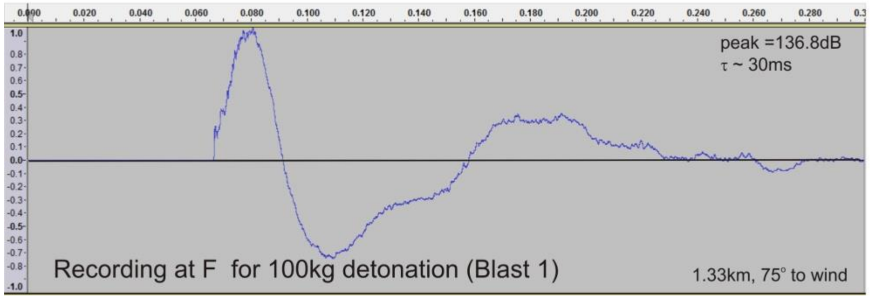
Similar to effects of absorbing ground (scrubland) on gunblast.

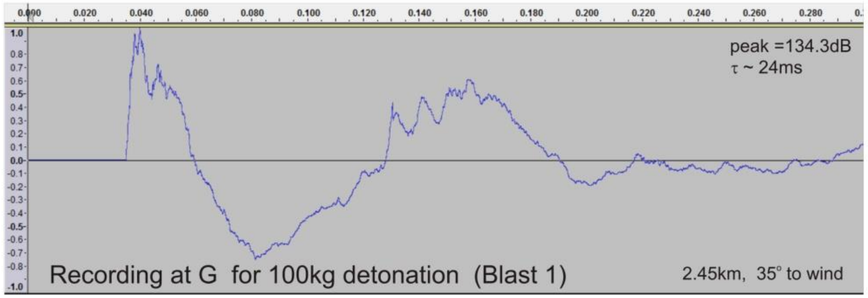




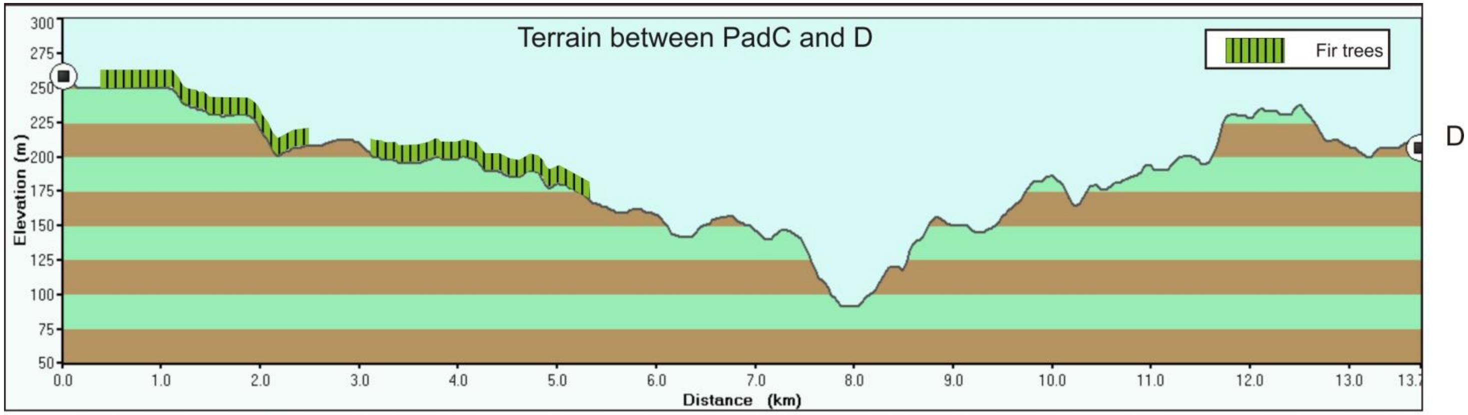


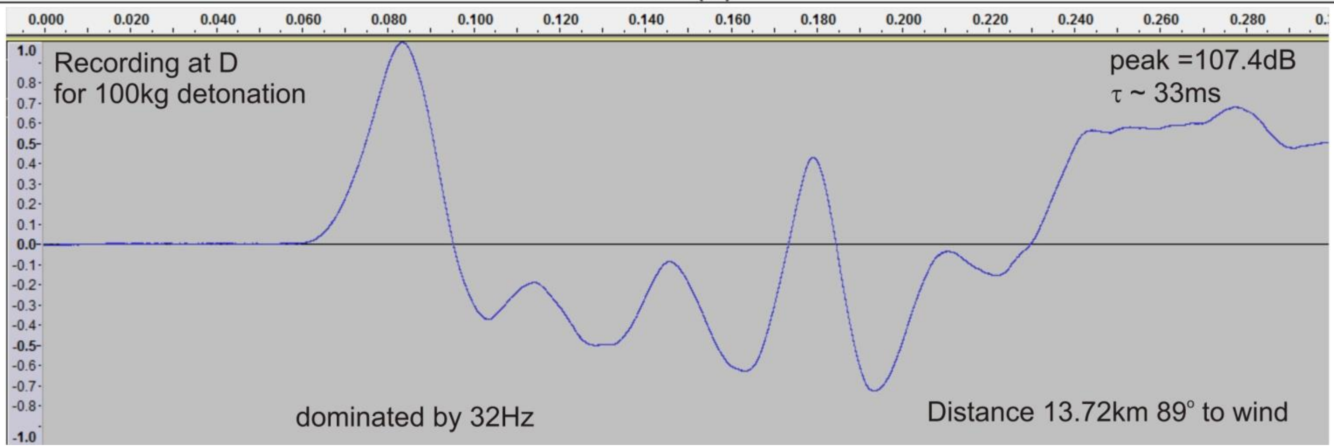




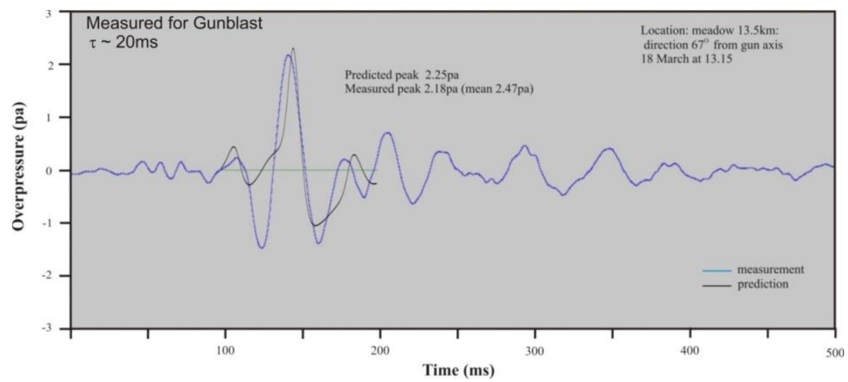


Recording at D (Hallbankgate) for Blast 1

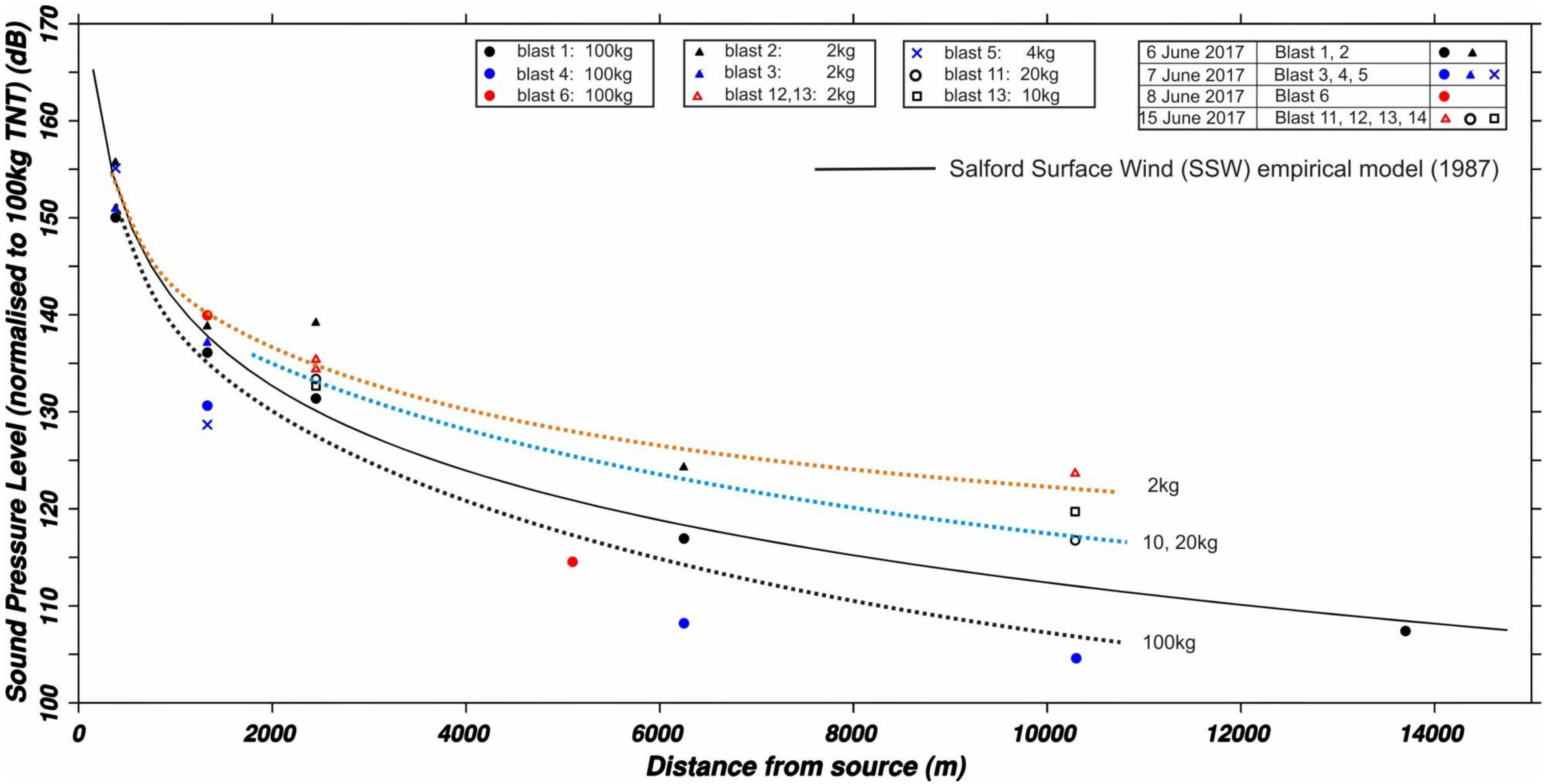




Similar to that measured for gunblast over similar range - 13.5 km



Different correlations for different charge weights



Main Noise Management Options

- **Broad-brush assessment:**

  Identify met conditions likely to produce enhancement.

- **Lookup tables:**

  Archive data to link enhanced noise level with met conditions.

- **Small charge calibration:**

  Proposed for determining propagation characteristics.
  Insufficient data gathered so far to validate approach.

- **Refraction predictions:**

  Require met measurement or forecasts & ground characteristics.

  ray tracing, PE, Monet ?

Sophisticated Prediction Methods

- Ray tracing –

  Good indicator of if and where enhancement may occur, but method might not provide accurate levels.

- Larri –

  Hybrid method based ray tracing & PE/FFP data base; approximate and fast. Designed for use for grass covered surface. Validated. No longer maintained although was still in use on ranges in preference to Monet.

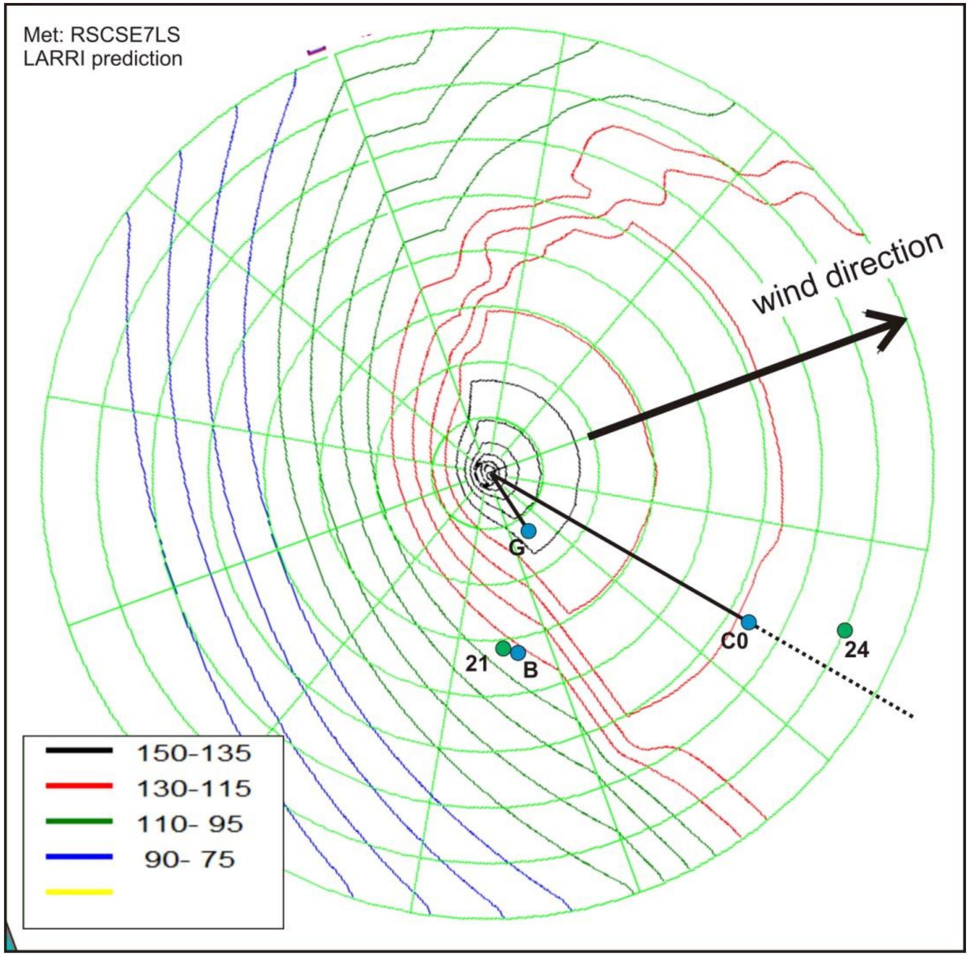
- Monet –

  Approximate (split step) version of PE, assumes either hard or soft surface condition. Fixed frequency. Concern over accuracy. Validation status has not been published .

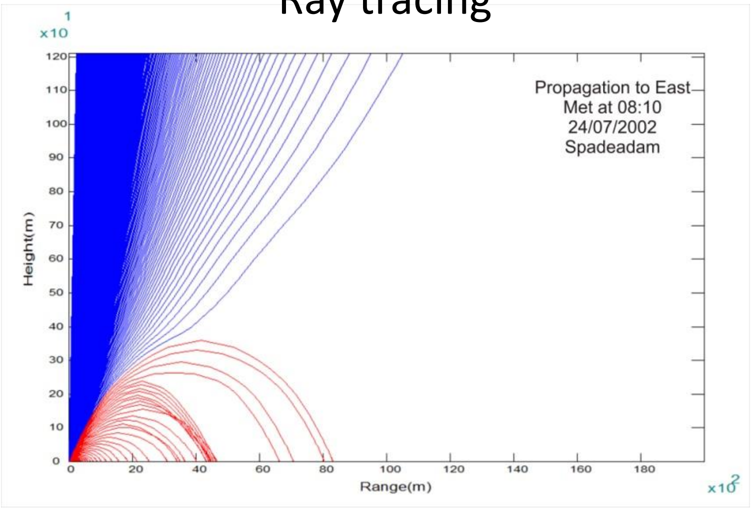
- PE methods –

  MAPE would cover most situations. Rigorously validated - but it is no longer supported. New GFPE method is available but validation status unknown. Other non-commercial PE methods are available. PE could be coded for the project.

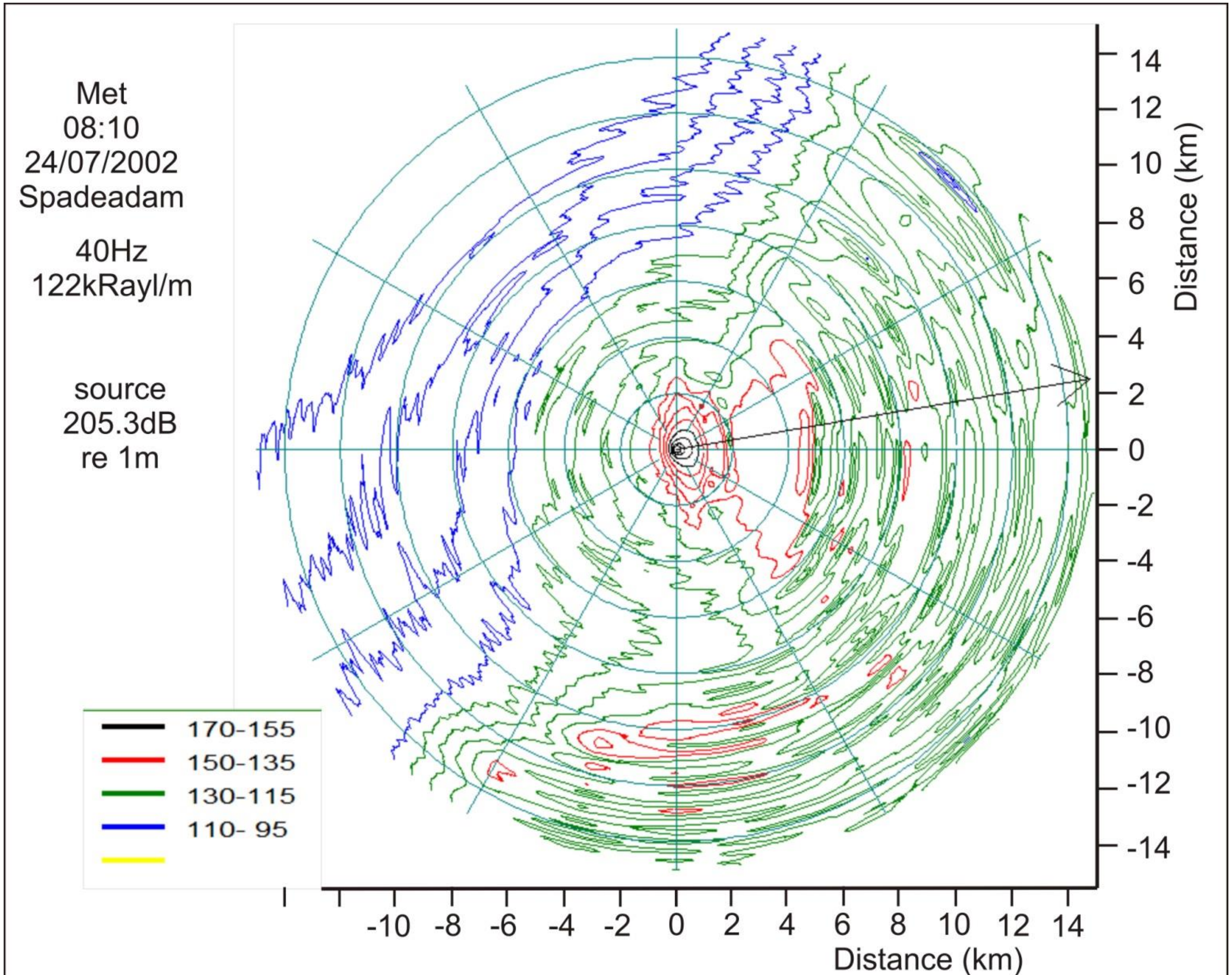
LARRI predicted noise contours



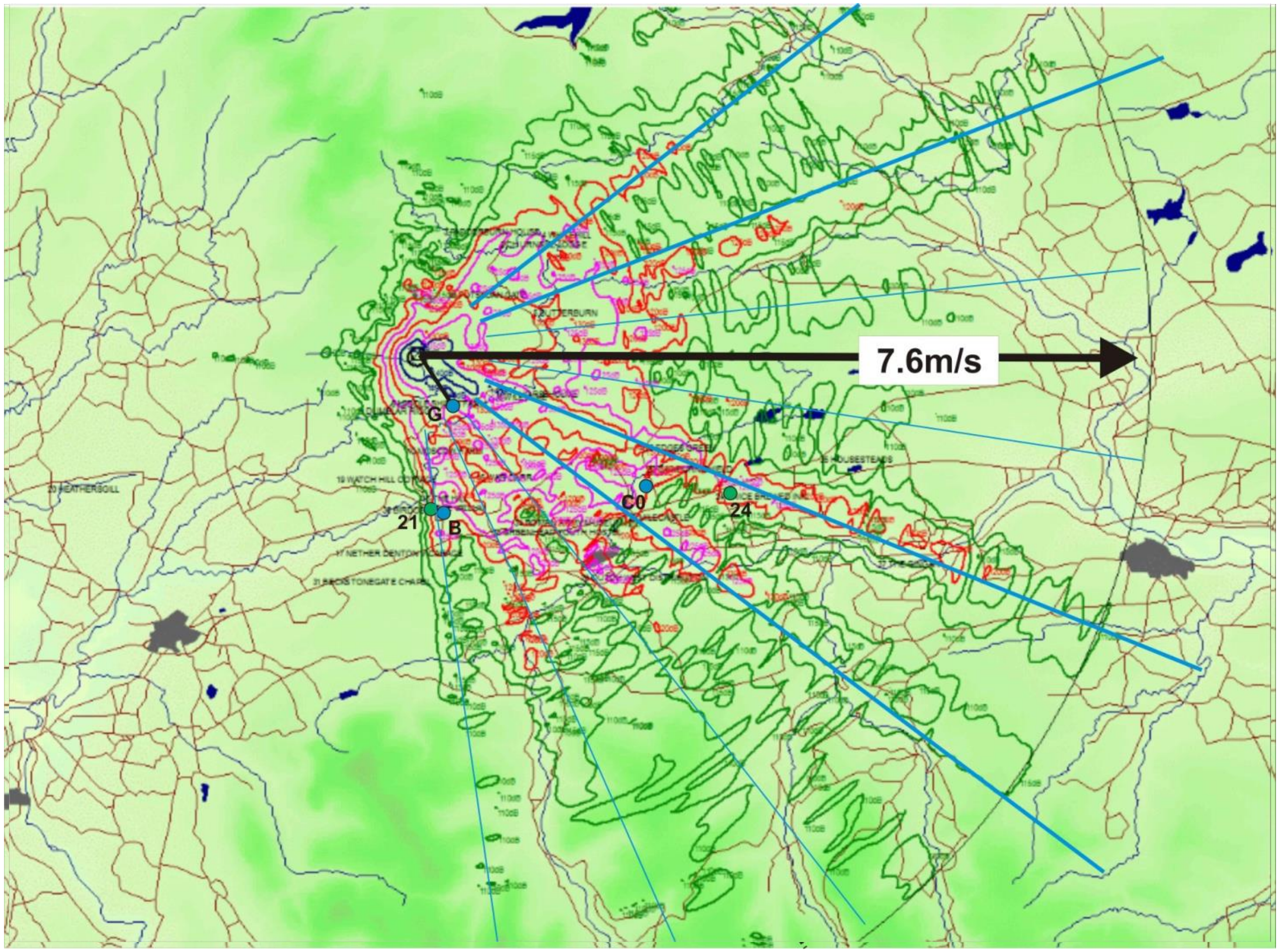
Ray tracing



PE Calculation of noise contours



Monet prediction of noise contours 100kg TNT, run 375 11:00 14:00 7 June (Blast 4)



When and where might refraction create high noise levels.

- **Wind direction**:
  - generally produces enhancement in the downwind direction and attenuation upwind
  - level of enhancement/attenuation depends on a number of factors including terrain, vegetation, temperature profile and meteorological stability.
- **Temperature inversions**:
  - Regulary occurs, reaching ground level, on clear-sky nights with low wind. **Stable meteorology**.
  - Enhanced noise in all directions when little wind .
  - May persist in morning until warmed out
  - More prevalent in winter
- **Temperature lapse**:
  - Normal feature during the daylight hours which competes to reduce the effects of wind.
  - On warm clear-sky days with low wind the noise level is attenuated in all directions. **Unstable meteorology**.
- **Elevated temperature inversion**:

  Usually associated with fronts

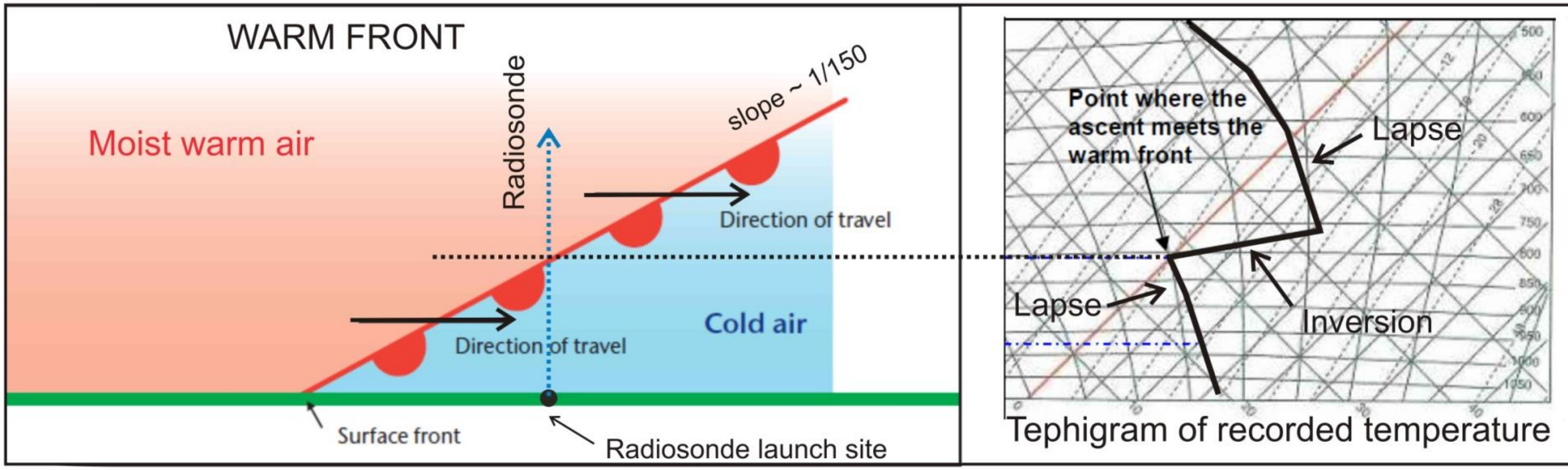
  cold front: warm air is undercut by advancing cold air

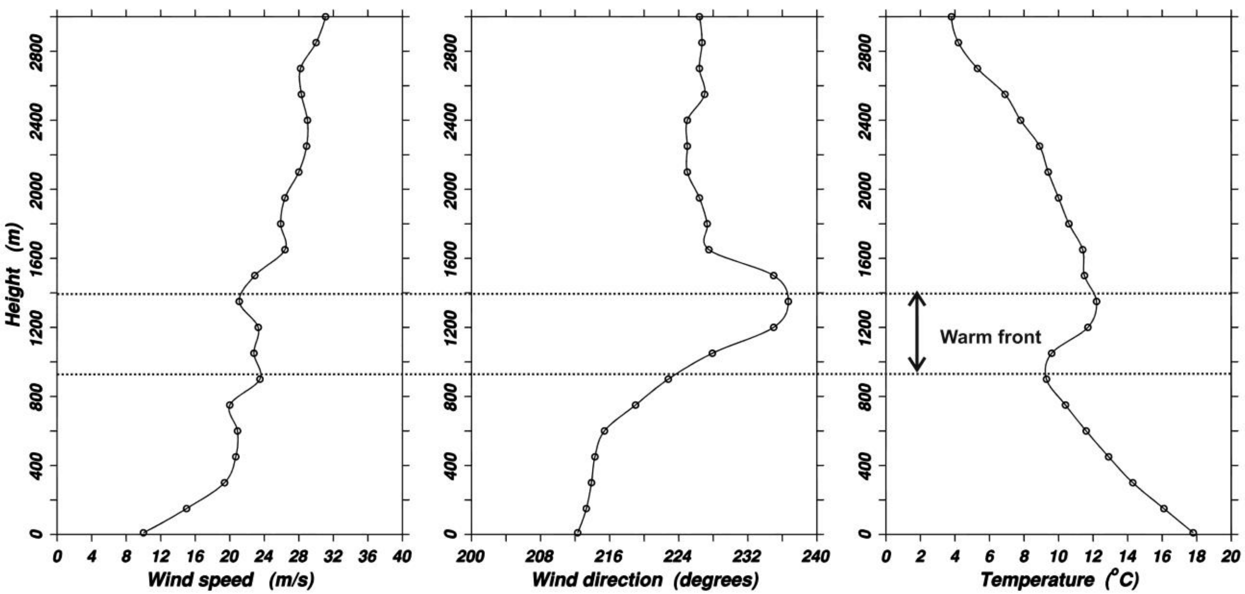
  warm front: warm air rises over cold air (strong acoustic effect) - example

  - Leads to regions of focused high levels of noise at considerable distance from source.

    Focus not in direction of ground wind vector
  - Also occurs in the top of the earth's boundary "capping layer"

Warm-front Example. Inversion Aloft



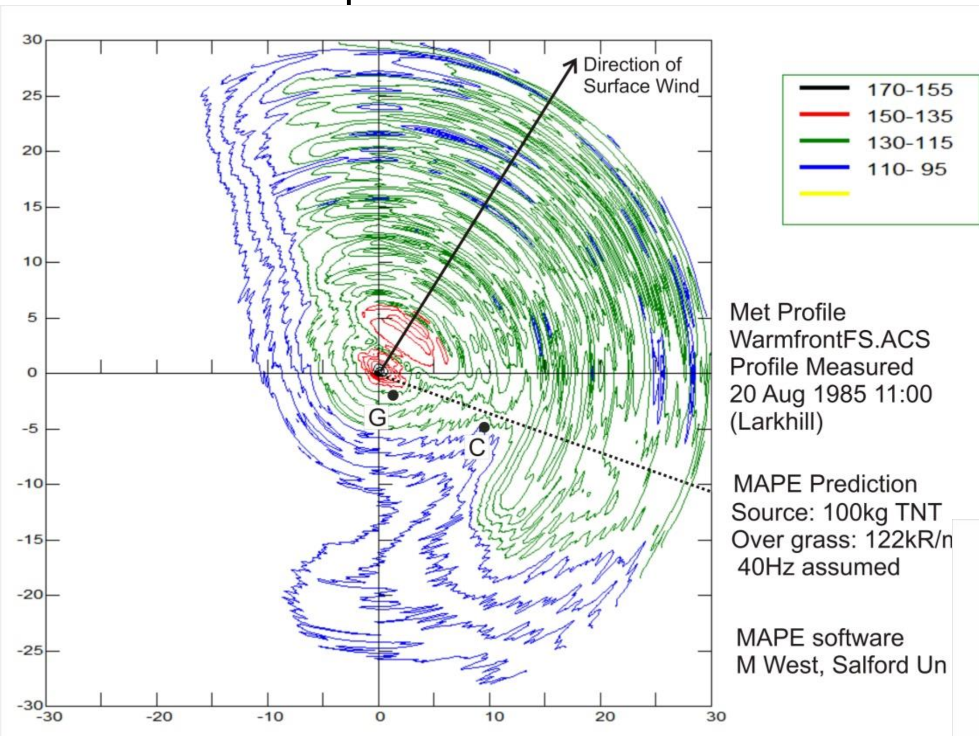


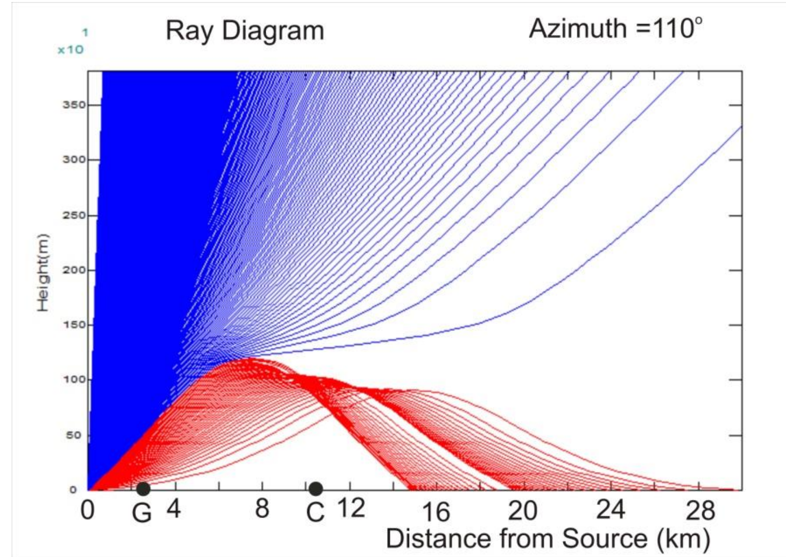
Measured wind and temperature profiles (Larkhill).

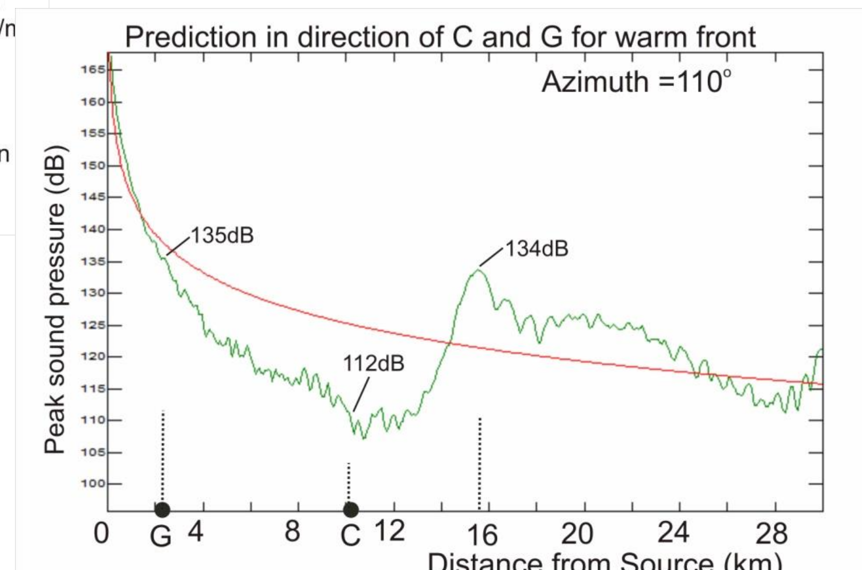
Warm front aloft at 900m to 1400m

Predicted effects of warm front

MAPE prediction







Propagation from a 100kg charge

Unknowns needed for Prediction

- **Meteorological profiles:** Currently not available to project but vital for prediction.
- **Frequency:** We need to establish if a prediction based on a single frequency is sufficient to determine blast pressure levels in the far field.
- **Surface Condition:** Unknown average impedance between source and receiver - varies with direction and frequency. But could be established using small charges in neutral meteorological conditions (dawn).

Conclusions & Further work

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- Real-time monitoring system successfully demonstrated
  - Further work needed to select best locations
- Directions of enhanced noise were predictable
- Levels were, as expected, influenced by trees & terrain
  - Further work needed on topography & topology

Conclusions & Further work

- Monet predictions in error
  - Further work to check MONET implementation and validation
- Other prediction methods are worth trying
  - Further work needed on characteristics of ground and vertical meteorology
- Small charge to get propagation characteristics for larger blast is promising
  - More comparison cases needed

Acknowledgements

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- This project is partly funded by DNG VL and the University of Salford
- Thanks to Dave Hughes for assistance with the field trials
- Special thanks to Steve Thomas of Acoustic1 for loan of the real-time monitors

Predicting Blast Pressures

END

Questions ?