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A selection of data from measurements of C4 detonations at Finnskogen in 1994, test case C1

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Sammendrag

Denne rapporten er en del av et pågående arbeid ved Forsvarets forskningsinstitutt (FFI) for å forbedre Forsvarsbygg (FB) sin evne til å estimere støynivået rundt forsvarets skytefelt. FFI sitt arbeid er en del av et samarbeidsprosjekt med FB som oppdragsgiver, der prosjektgruppen består av FFI, SINTEF IKT og NGI (Norges Geotekniske Institutt). For en mer omfattende beskrivelse av FFI sin aktivitet på dette området henvises det til [1, 2, 3, 4].

I 1994 og 1996 ble det foretatt en større målekampanje på Finnskogen i Norge. C4-eksplosiver ble satt av i flere posisjoner. Det var 5 målemaster som registrerte lufttrykk og bakkevibrasjon. Det finnes også data for meteorologi, topografi og bakketyper. Denne store samlingen av målinger er det nå mulig å benytte gjennom databasen NORTRIAL. Databasen er implementert i Matlab, og er tilgjengelig gratis ved kontakt med NGI.

For å gjøre terskelen enda lavere for å ta i bruk denne databasen har vi, som et eksempel, tatt ut et lite utvalg målinger. Vi har kalt dette utvalget C1 (case 1). Denne samlingen med målinger er tenkt å brukes som et utgangspunkt for å evaluere ytelsen til forskjellige beregningskoder. En CD med datafilene som er beskrevet kan fås ved å kontakte forfatteren.

English summary

This report is part of ongoing work being conducted at the Norwegian Defence Research Establishment (FFI), to improve the ability of the Norwegian Defence Estates Agency (FB) to assess noise pollution around military firing ranges. The work conducted by FFI is part of a joint effort with FB as client. The project group consists of FFI, SINTEF IKT and NGI (Norwegian Geotechnical Institute). For a more comprehensive description of the activity at FFI in this field, we refer to [1, 2, 3, 4].

During 1994 and 1996 a large measuring campaign was carried out at Finnskogen in Norway. C4 explosives were detonated at several positions in the woods. There were 5 measuring masts, registering time series of air pressure and ground vibration. Data exists for meteorology, topography and ground conditions. This collection of data can now be accessed through the database NORTRIAL. The database is implemented in Matlab and is freely available by contacting NGI.

To facilitate the usage of this data base we have, as an example, compiled data from a small selection of detonations. We have called this selection of data C1 (case 1). This collection of measurement data is intended to be used as a starting point to assess the accuracy of different simulation codes. A CD with the data files described can be obtained by contacting the author.

Contents

1 Introduction

Thousands of measurements from detonations exist in the database NORTRIAL [5], mainly from Finnskogen in 1994 and 1996. This database is freely available by contacting Norwegian Geotechnical Institute. The database is made in Matlab and is very easy to use. To make it easier to understand what the database contains, we have condensed the information available on 8 detonations in a way that is appealing if one wants to test numerical codes against real data. This report is not meant as a description of NORTRIAL, but as one example of the data that can be obtained from the database. For a description of the NORTRIAL database we refer to [5].

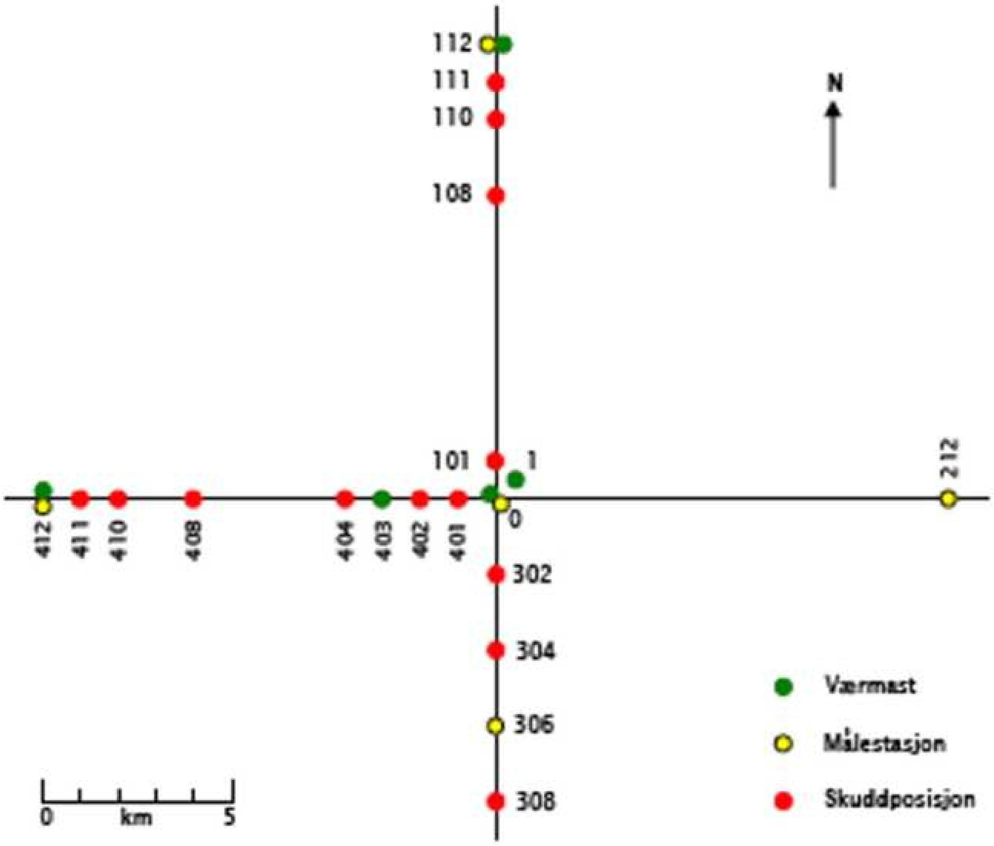

Figure 1.1: Map of detonation position (red), measuring positions (yellow) and weather masts (green) at Finnskogen. The figure is included from [5].

Finnskogen sensors and detonation positions are located along a cross which is 24 km in each direction (Figure 1.1). There are several detonation positions and 5 sensor positions. At each sensor mast there are sensors at several heights, measuring the time series of the pressure. Here we only consider sensors 2 m above the ground. All detonations (mentioned here) are of 1 kg C4-explosives

fileno	date	time	pos 306		pos 0		pos 412		pos 112		pos 212	
70	13-Sep-1994	14:56	A	83.8	A	83.2	-		-		-	
76	13-Sep-1994	15:26	A	87.8	A	80.6	-		-		-	
136	16-Sep-1994	13:25	A	89.9	-		B1	75.7	-		-	
144	19-Sep-1994	11:05	A	85.9	B1	81.2	-		-		-	
150	19-Sep-1994	11:58	A	72.0	B1	82.7	-		-		-	
168	21-Sep-1994	08:15	A	100.1	A	83.6	B1	59.0	B1	71.1	B1	67.7
174	21-Sep-1994	09:00	A	97.2	B1	80.5	B1	58.1	B1	68.7	-	
180	21-Sep-1994	10:00	A	87.3	B1	79.6	B1	58.9	B1	57.2	B1	60.8

Table 2.1: Quality of the signals in C1 and C-weighted sound exposure level i dB.

detonated from the top of a 2 m stick. The distances of sound propagation are between 2 and 16 km.

The collection of measurements we have chosen here we have named C1 (case 1). C1 is one of several cases that have been chosen together with NGI and SINTEF.

The purpose of validation against the data in this report is to evaluate the ability of computational methods to correctly describe reality. These computations will typically be performed with computational kernels relevant for use in MILSTØY, the noise evaluation tool used by FB.

2 Overview of the measurement area

The case C1 consists of 8 detonations which have been chosen by a combination of interesting terrain and good signal quality. The 8 detonations of 1 kg C4-explosives were done at position 304. The signal quality differs, at the 5 measurement masts, . Of the 40 measurements, we have therefore only included data from the 24 measurements with the best quality. Every detonation is defined by a file number (fileno).

Signal quality is graded in the data base. ’A’ is a good signal, B is less good, and so on. The sub codes ’B1’, ’B2’ and ’B3’ mean background noise, instrument noise and overload respectively. It was generally difficult to analyze data with poorer quality than ’B’. We have also chosen to remove some measurements with quality ’B’. An overview of the data is given in Table 2.1.

3 Terrain profiles

Since there were 5 sensor masts, there are 5 terrain profiles. These are plotted in Figures 3.1–3.5

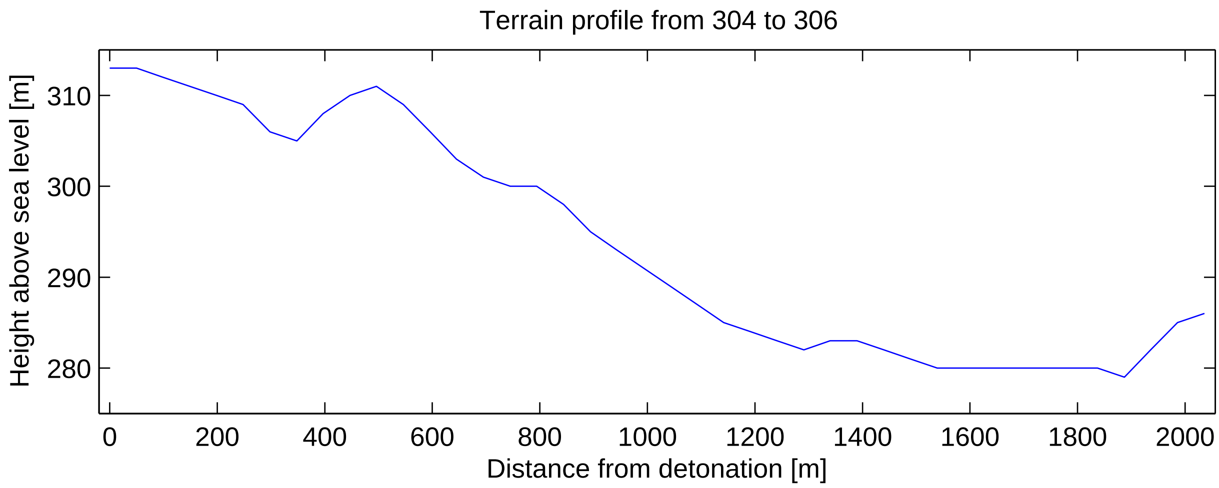

Figure 3.1: Terrain profile from 304 to 306.

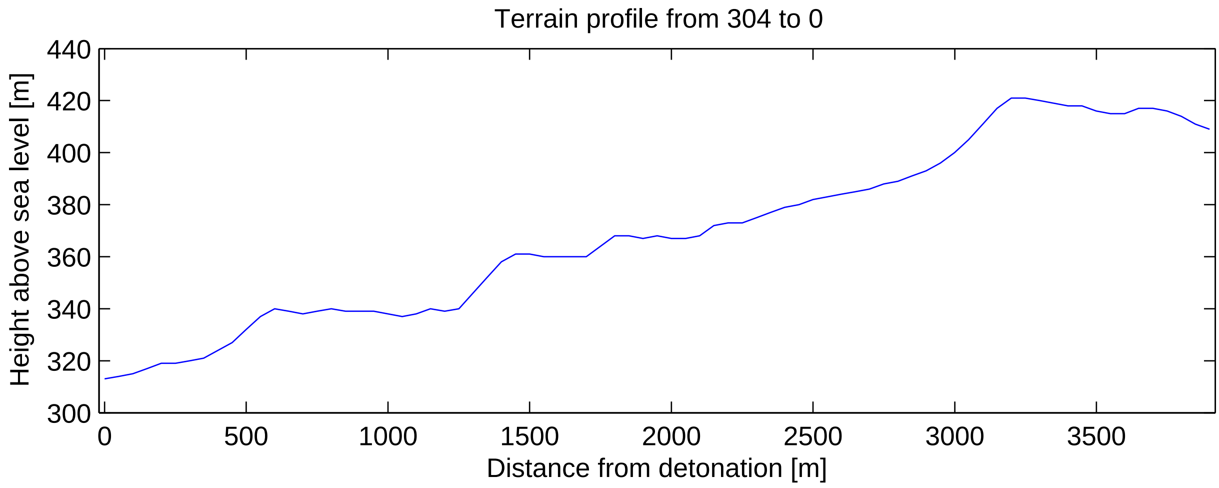

Figure 3.2: Terrain profile from 304 to 0.

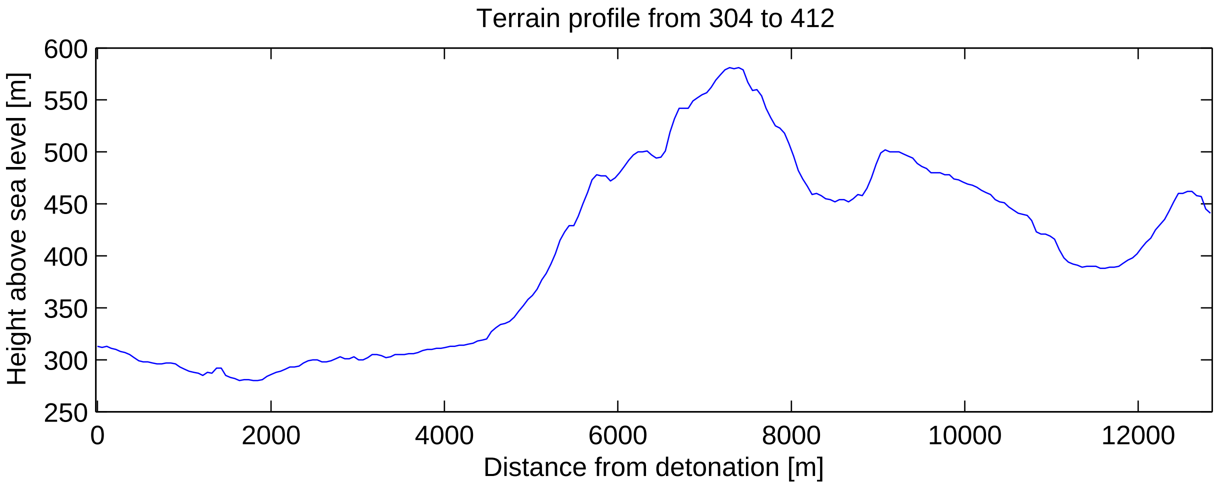

Figure 3.3: Terrain profile from 304 to 412.

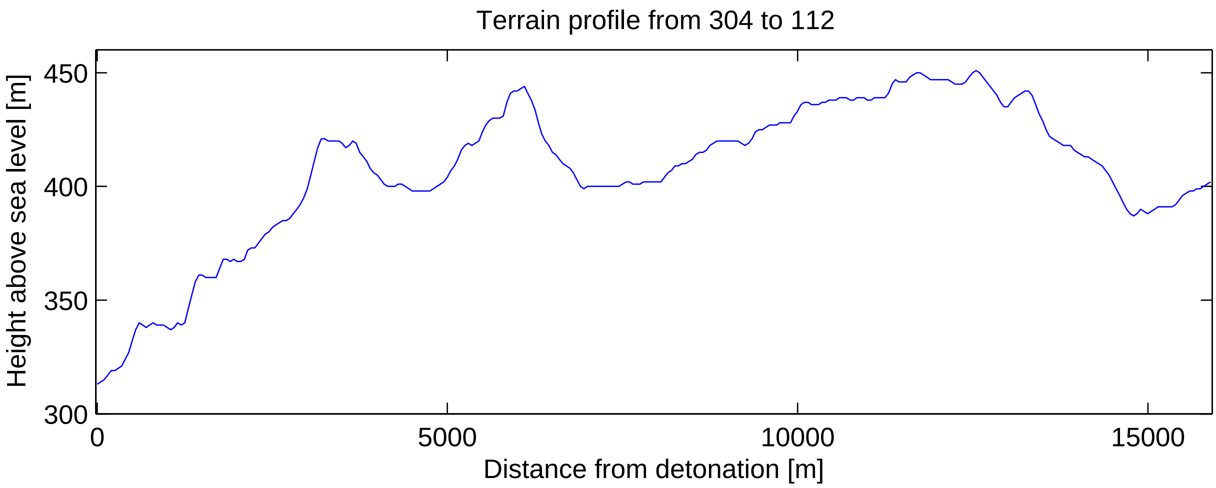

Figure 3.4: Terrain profile from 304 to 112.

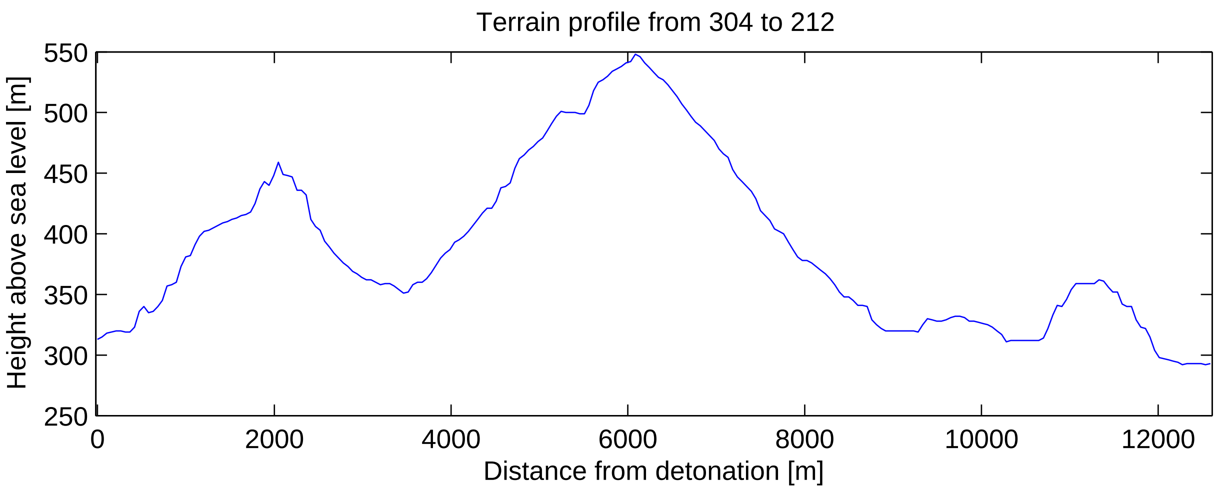

Figure 3.5: Terrain profile from 304 to 212.

4 Data files

Here we go through the files given on the accompanying CD. There are 3 types of files on the CD:

1. Terrain data: 5 files of the type 'topo_304_306.dat'. There is one terrain profile for each sensor mast (i.e. propagation path). The name indicates that it is topographical data, that the source is in position 304, and that the sensor is in position 306.
2. Meteorology data: 8 files of the type 'met_403_f174.dat'. There is one meteorology file for each detonation. Here 403 is the position of the meteorological sensors, and f174 indicate that the measurement is from the time most suitable to be used with the detonation with file number (fileno) 174.
3. Time series of the pressure: 20 files of type 'pressure_304_306_f174.dat'. The name indicates that the source is in position 304, the sensor in position 306, and that the measured time series of the pressure is from the detonation with file number (fileno) 174.

4.1 Terrain data

There are 5 terrain profiles for C1, one for each mast. These give data along the path from source to sensor. The data is given as a matrix with 5 columns. The first column is the distance from the source in meters. The second column is height above sea level in meters. The third column is flow resistivity in $\mathrm{Pa} \cdot \mathrm{s}/\mathrm{m}^2$.

The fourth and fifth column are classification of the ground. These have been used to find the flow resistivity, and need not be used any further. The fourth column represents ground type where the ground type is interpolated over a narrow corridor from source to sensor. The fifth column represents a broader interpolation corridor. The ground types are given in [5]. Values for the flow resistivity for the different classes are also given there. These are reprodused from [6]. The ground types in column 4 and 5 are described in the following way:

0 Conifer forest (Pine and Spruce), mixed tree sizes

1. Water
2. Dense and tall conifer forest
3. Sparse forest on former felling area
4. Felling area with some single trees
5. Young (conifer) forest on former felling area
6. Grassland, boggy-land, open area

7. Crop land
8. Marsh field, boggy-land
9. Marsh field, boggy-land
10. Cultivated grassland, meadow
11. Crop land

For a more comprehensive description we refer to [5].

4.2 Meteorology data

We have several types of meteorology data in NORTRIAL. As a starting point we have chosen data from a tethersond to find temperature and wind profile. These go continuously up and down. Typically we have a profile for each 1–2 hours. One example on meteorology data is plotted in Figure 4.1. In addition there exist measurements 10 and 30 m above ground. Here we have data each 10 min. This gives us more updated data, but no profiles.

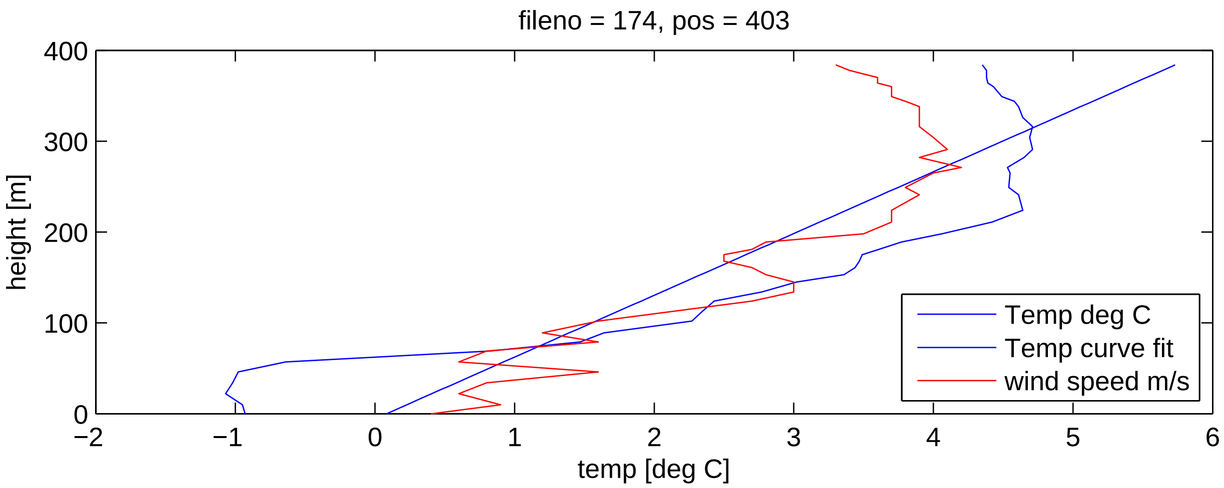

Figure 4.1: Measured temperature and wind speed up to 400 m above ground, for fileno 174.

4.2.1 Temperature and wind as a function of height above ground

We have 8 sets of meteorology data, one for each detonation. This data is from the tethersond in position 403. Several detonations have occurred during one tethersond trip, so data for these will be identical. At the present time, the meteorology was (had to be) taken from raw data. In a few (maybe 10) samples the measured value is 88888888. We then perform a manual interpolation. Because of the large number of sample points, this is not a problem. It is, however, not ideal that some time

fileno	date	time	A	B
70	13-Sep-1994	15:00	9.68	-0.721
76	13-Sep-1994	15:30	9.68	-0.721
136	16-Sep-1994	13:20	7.07	-0.820
144	19-Sep-1994	11:00	5.66	-0.278
150	19-Sep-1994	12:00	5.66	-0.278
168	21-Sep-1994	08:10	-1.73	2.410
174	21-Sep-1994	09:00	0.08	1.472
180	21-Sep-1994	10:00	0.37	1.368

Table 4.1: Coefficients for curve fitted temperature profile.

may have elapsed from the time a meteorology profile is measured until the detonation finds place. There are 10 columns in the files with meteorology data:

1. Date
2. Time
3. Temperature (deg C)
4. Wet-bulb temperature (deg C)
5. Air pressure (millibar)
6. Wind speed (m/s)
7. Wind direction (degrees). Wind direction 0 means that the wind blows from north to south.
8. Relative humidity
9. Battery voltage (V)
10. Height above ground (m).

For temperature it is usual to use column 3.

Some computational codes use only a few simple parameters as input. For the temperature profile we have used the least squares method to fit the curve $T(z) = A + (B/100m)z$ to the data. Here A is the ground temperature and B is the temperature variation pr. 100 m (Table 4.1).

fileno	date	time	pos 0			pos 412			pos 112			
			10 m	Dir	30 m	10 m	Dir	30 m	10 m	Dir	30 m	Pres
			m/s	deg N	m/s	m/s	deg N	m/s	m/s	deg N	m/s	hPa
70	13-Sep-1994	15:00	0.7	95	1.2	0.7	33	1.5	1.5	119	2.5	953.4
76	13-Sep-1994	15:30	0.4	97	1.1	1.0	94	2.2	0.6	80	1.1	953.4
136	16-Sep-1994	13:20	2.3	71	4.9	0.6	346	2.7	2.8	42	4.3	948.9
144	19-Sep-1994	11:00	0.7	180	2.4	2.5	161	3.4	1.4	201	1.9	971.3
150	19-Sep-1994	12:00	1.1	196	3.0	2.5	187	3.4	1.8	204	2.6	971.0
168	21-Sep-1994	08:10	1.0	21	2.6	0.4	352	1.1	0.4	326	1.5	972.1
174	21-Sep-1994	09:00	1.0	44	1.6	0.7	356	1.6	1.1	343	2.2	972.3
180	21-Sep-1994	10:00	0.2	250	0.8	0.4	354	0.4	0.5	17	0.7	972.4

Table 4.2: Wind data at 10 and 30 m height from automatic weather mast at positions 0, 412 and 112.

4.2.2 Wind data 10 m above ground

Here we have considered wind data from automatic weather stations in positions 0, 412 and 112. The measurements at these stations are done each 10 min. Mean wind velocity is measured. When a detonation has found place exactly between two weather measurements, we have used the measurement that was done before the detonation. Wind velocity is measured 10 and 30 m above ground (Table 4.2).

4.3 Measured sound pressure

There are two columns in the files, time in seconds and pressure in Pa. One example of a time series is plotted in Figure 4.2.

4.3.1 Sound Exposure Level

We have calculated L_{CE} (C-weighted Sound Exposure Level) for each of the measured time series of the pressure. Details of the calculation method are described in [2]. In the cases where we have a good signal to noise ratio we have cut out 1 s of the signal starting right before it arrives at the sensor. For the case with fileno 168 and sensor position 212, we have cut out the signal starting at $t = 4.10$ s with a duration of 0.135 s. For measuring position 0, the length of the measured signals are shorter than 1 s. When the signal to noise ratio is good, it is of no consequence how much of the signal is cut out, as long as the main pulse is included. The calculated L_{CE} is given in Table 2.1.

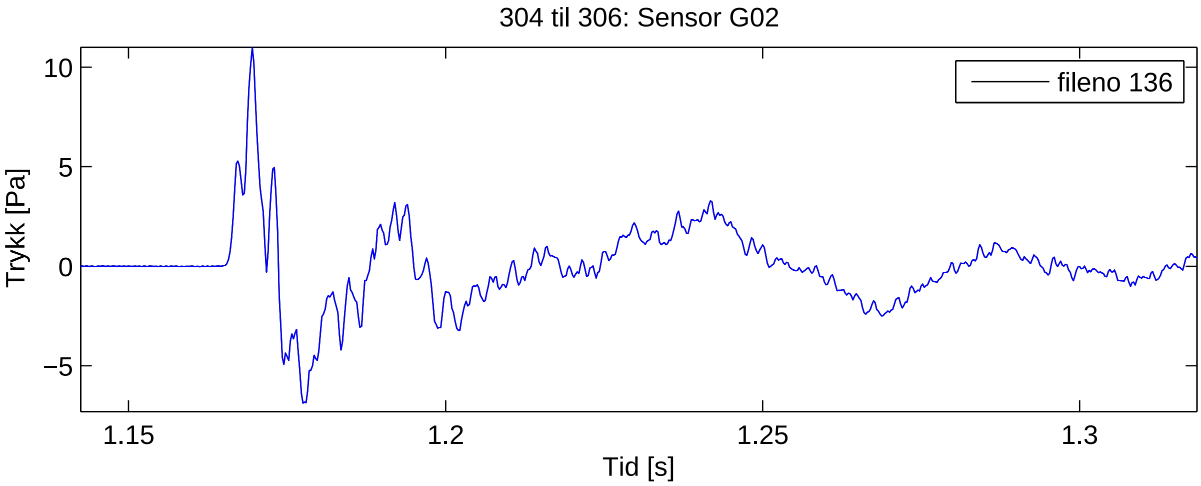

Figure 4.2: Measured sound pressure 2 m above ground, at mast 306 for fileno 136.

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