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Lidar data used in the COFIN project

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Abstract This report presents the Lidar data used in the COFIN project. The Lidar data have been obtained from several ground level dispersion experiments over flat and complex terrain. The method for treating the data and the conditons under which the data were obtained are described in detail. Finally we describe the Tools to extract and visualize the Lidar data. Data, report, and visualisation tools are available on the Risø FTP server.

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Contents

1 Introduction

The Lidar data presented are optical extinction factors deduced from raw measurements of range resolved light backscatter from artificial smokes. The extinction factors may further be converted to absolute concentrations in case a reference measurement by an absolute concentration sensor positioned somewhere along the measuring path is available. In the absence of a fixed reference measurement the extinction profiles may be regarded as relative concentration measurements.

See (Jørgensen, Mikkelsen, Streicher, Herrmann, Werner & Lyck 1997) for further details on the Lidar instrument.

The selected data originates from the following dispersion campaigns:

Borex89 on a German military proving ground (Meppen) with flat terrain and surface roughness $z_0 = 0.01$.

Borris94 on a Danish military proving ground (Borris) with flat terrain and surface roughness $z_0 = 0.01$.

Guardo in a mountainous Spanish area with surface roughness $z_0 = 0.04$.

Fladis on a Swedish safety exercise ground (Landskrona) with flat area ($z_0 = 0.04$) and upstream buildings.

Madona on a British military proving ground (Porton Down) with rolling hills and surface roughness $z_0 = 0.02$.

All experiments applied continuous plumes of artificial generated particles, see below. In FLADIS the smoke were added to an initial heavy gas plume.

2 Experimental design

Figures 1 and 2 show a birds perspective and face view of the general experimental setup. The measuring path of the Lidar was a horizontal beam oriented across the plume at approximately 1.5 meters above terrain. The distances from the source were in the range 100-600 meters. All experiments were supported by turbulence measurements from a sonic-anemometer mounted on near-source masts as indicated in figure 1. Some experiments applied absolute reference concentrations sensors distributed along the measuring path as indicated in figure 2. The typical averaging time of these reference sensors were 10-min although fast-responding ($\approx$20 Hz) UVIC sensors were applied in the Fladis experiments (Nielsen, Ott, Jørgensen, Bengtsson, Nyrén, Winter, Ride & Jones 1997). Based on various reference measurements and inter-calibration test we regard the proportionality factor between extinction and tracer concentration as constant in space and time. This is a natural assumption when particle size distribution is uniform, as expected with constant atmospheric humidity and negligible particle deposition.

Each raw Lidar profile contains 512 measuring range gates. The measuring frequency was 1/5 respective 1/3Hz with an instantaneous time response. However, the Lidar does have a averaging volume due to the length and diameter of the light pulse corresponding to approximately 1.5 meter, as indicated in figure 2. The measurement height of the cross wind profiles was approximately 2 - 3 meter above the ground.

For the Borex89 experiment the measured turbulence is only available as 10 min averages of the shear stress u_*, Monin Obukov length L, heat flux and Speed and temperature. In the other experiments time series of turbulence are also available.

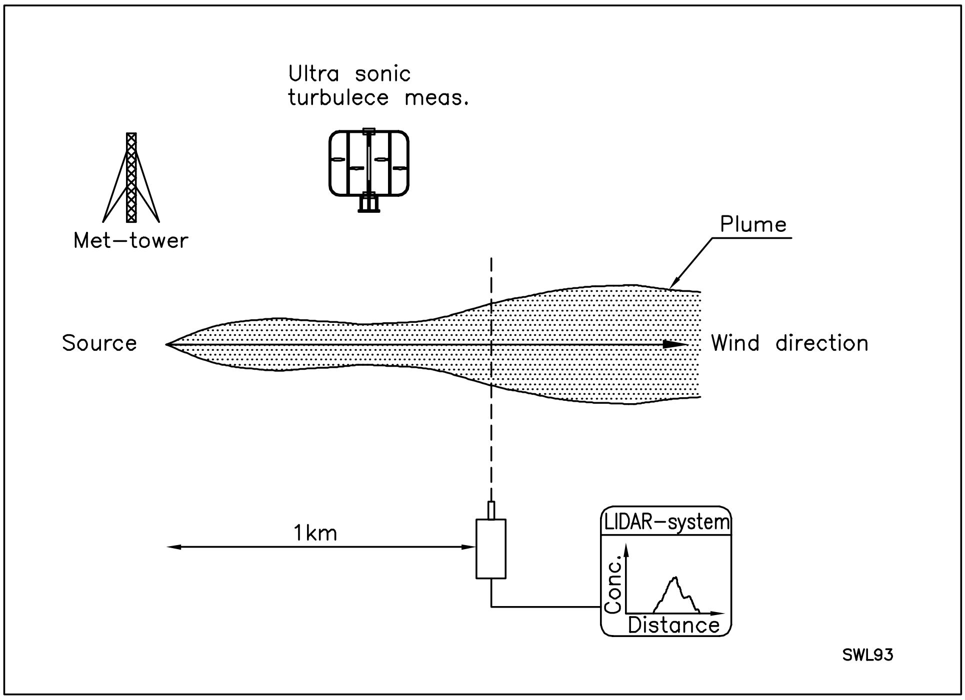

Figure 1. A birds perspective of a reference experiment

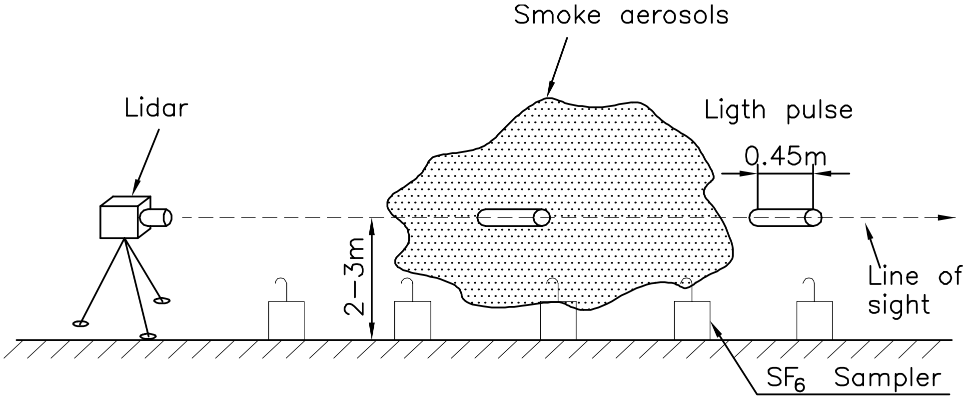

Figure 2. A Cross wind view of a reference experiment

3 Experiments

Table 1 gives an overview of the analyzed experiments and the meteorological conditions under which they were conducted.

The calculated meteorology and turbulence parameters are based on a 7.5 meter mast equipped with a sonic-anemometer, except the experiment at guardo where turbulence was measured at 25 meter (see (**?**)) and the wind-speed were measured at 2 meter. At the Fladis experiments the mean wind speed was based on measurements from a 10 meter tower, and turbulence at 4 meters, see (Nielsen et al. 1997).

Table 1. Ground-release experiments and associated meteorology

Exp.	Date	X	U	T	$v'v'$	u_*	H	E	L	σ_{tot}	σ_p
Bor4c	10/08-89	110	5.6	24.3	1.436	0.42	159.11	1.27	-35	26.3	12.0
Bor5b	10/08-89	170	5.5	27.2	0.950	0.43	27.60	0.93	-220	21.7	11.1
Bor8a	11/08-89	290	5.6	19.6	1.357	0.43	87.36	1.03	-67	33.6	15.8
Bor8b	15/08-89	290	7.4	19.8	0.989	0.53	83.71	1.43	-132	20.9	14.5
Bor11a	15/08-89	370	8.0	26.8	2.187	0.62	210.51	2.52	-86	40.8	19.3
Bor11b	17/08-89	370	8.9	27.2	3.714	0.65	115.98	3.07	-181	41.8	18.3
Bor17a	17/08-89	160	6.2	22.3	2.067	0.50	136.95	1.64	-68	29.4	9.8
Bor17b	17/08-89	160	6.0	22.2	1.861	0.47	92.76	1.54	-84	29.1	10.2
Bor17c	17/08-89	160	5.5	21.9	0.998	0.36	3.26	1.09	-999	21.9	8.9
Bor17e	17/08-89	160	3.3	20.8	0.348	0.18	-17.20	0.32	25	27.3	8.1
Gu30b**	30/11-90	180	4.08	-5.9	0.628	0.56	19.7	1.29	-270	18.2	6.0
borr04b	04/07-94	200	7.7	24.3	1.116	0.539	64.89	2.798	-216	20.5	13.0
borr04c	04/07-94	200	7.0	23.8	2.037	0.485	33.42	2.656	-305	35.0	12.5
borr15d	15/07-94	350	5.4	21.1	1.235	0.463	150.60	2.476	-59	65.1	25.0
b15d_00	15/07-94	350	5.3	21.3	1.328	0.446	151.80	2.567	-52	56.1	28.1
b15d_30	15/07-94	350	5.4	21.1	0.991	0.469	143.04	2.564	-64	62.9	25.8
b15d_60	15/07-94	350	5.6	21.0	1.207	0.477	154.68	2.280	-62	65.3	23.1
mad14h	14/10-92	230	6.9	16.8	1.017	0.497	29.976	1.587	-365	30.3	15.9
mad14i	14/10-92	230	6.7	16.5	1.197	0.506	10.572	1.541	-1095	28.8	13.5
mad14j	14/10-92	230	7.1	16.2	0.817	0.515	5.971	1.386	-2046	21.9	14.1
mad14k	14/10-92	230	6.3	15.5	0.648	0.426	-15.840	1.203	435	22.0	13.2
mad15h	15/10-92	340	7.8	17.3	0.906	0.491	50.724	1.507	-209	27.0	15.8
mad15i	15/10-92	340	7.6	17.0	0.790	0.421	33.684	1.279	-198	28.8	15.4
mad15j	15/10-92	340	7.4	16.5	0.827	0.425	19.716	1.284	-348	25.1	16.0
mad15k	15/10-92	340	5.6	16.5	0.529	0.319	6.768	1.158	-428	28.6	18.1
mad18a	18/10-92	560	2.1	14.8	0.089	0.159	0.238	0.142	-1522	78.4	29.2
mad19e	19/10-92	400	3.2	16.6	0.330	0.225	25.032	0.430	-41	58.2	30.3
mad21g	21/10-92	600	4.4	16.1	0.304	0.245	3.121	0.593	-420	39.1	22.8
mad21k	21/10-92	310	2.3	15.2	0.287	0.109	-0.752	0.380	155	77.7	34.6
trial23***	30/08-94	222	6.6	17	1.220	0.53	106.2	3.463	-112	41.6	17.5
trial25***	30/08-94	222	4.5	17	0.884	0.43	33.1	2.091	-201	31.1	21.0
trialn***	30/08-94	222	4.2	17.3	0.506	0.37	25.2	1.636	-155	32.8	19.6

Headings:

Exp.	Run identifier (bor: Borex89; borr: Borris94; gu: Guardo; mad: Madona; tri: Fladis)
X	Distance [m] from the source to the measuring path.
U	Wind speed [m/s] at a reference height of 7 m above terrain.
U**	Wind speed [m/s] at a reference height of 2 m above terrain.
U***	Wind speed [m/s] at a reference height of 10 m above terrain.
T	Atmospheric temperature [C°].
$v'v'$	Variance [m^2s^{-2}] of wind speed perturbations perpendicular to the average wind direction.
u_*	Friction velocity [m/s]
H	Upward heatflux [W/m^2] estimated by eddy correlation of sonic anemometer measurements.
E	Turbulent kinetic energy $1/2 \cdot (\overline{u'u'} + \overline{v'v'w'w'})$ [m^2s^{-2}] (estimated by sonic anemometer).
L	Monin-Obukhov length [m].
σ_{tot}	Time averaged plume width [m] in a fixed frame of reference.
σ_p	Time averaged plume width [m] in a frame of reference moving with the plume centreline.

3.1 Generation of artificial smoke

For all the experiments artificial smoke was used as a tracer. The particles were generated by mixing two liquid chemicals $NH_4OH_(aq)$ and $SiCl_4(aq)$ producing particles of SiO_2 and NH_4Cl.

The chemicals were mixed in a jet from a fan with a flow of 50 m/s in tube of 10 cm in diameter. The release height for the experiments was approximately 0.5 m and the initial size of the plume was estimated to be approximately 1 meter.

In the Fladis experiment the particles were mixed into a flash boiling jet, see (Nielsen et al. 1997).

4 Data processing

In the following section a short background of the theory used to obtain concentrations from the lidar is presented including some basic theory regarding Lidars.

4.1 The lidar equation

Interpretation of lidar measurements is based on the theory of propagation of electro-magnetic radiation and attenuation in an optically dense media (here the polluted atmosphere), in combination with scattering from distributed targets. The so-called "lidar equation" accounts to first-order for this complex process: The backscatter lidar principles can be formally expressed by the single-scattering lidar equation:

$$P(r) = P_0 \left(\frac{c\tau}{2}\right) F(r)\, A_t\, \frac{1}{r^2}\, \beta(r)\, \mathrm{e}^{-2\int_{r_0}^{r} \kappa(r')\mathrm{d}r'} \tag{1}$$

$P(r)$ is the power received from the range $r = ct/2$, where c is the speed of light. The factor 2 arises from the travelling of the laser to the distance r and back to the receiver. P_0 is the power transmitted at time t equal to zero. The effective length of the laser pulse is specified as $\frac{c\tau}{2}$. The telescope area is A_t, and divided by r^2 this term defines the "solid angle acceptance $[sr]$". The coaxial design with the laser in front of the telescope (coaxial) results in a geometric overlapping function, $F(r)$, which relates the receiver field of view of the telescope to the width of the laser pulse, (Measures 1984). The quantity $\beta(r)$ $[sr^{-1}m^{-1}]$ is the volume backscattering coefficient of the atmosphere at distance r, and $\kappa(r)$ $[m^{-1}]$ is the volume extinction coefficient in the atmosphere.

The volume backscattering coefficient β is defined here as the fraction of incident energy scattered per solid angle in the backward direction (180°), per unit length. The volume extinction coefficient κ represents the fraction of the energy flux removed in the propagation direction.

Both the backscatter and the extinction properties depend on parameters such as wavelength, particle size distribution, and the optical properties of the media, see e.g. (Measures 1984).

The last term in the lidar equation represents the attenuation through the atmosphere known as Beer's law. The attenuation, along the two-way pulse path between the lidar and the range r, is defined as:

$$T(r) = \mathrm{e}^{-2\int_{0}^{r} \kappa(r')\mathrm{d}r'} \tag{2}$$

The lidar equation (1) applies to a medium where single scatter on a particle is responsible for the backscattered light. The lidar equation compensates for damping of the laser light due too: 1) absorption by particles, 2) range dependency, and 3) the optical geometry of the transmitter and receiver units.

4.2 Backscatter to extinction ratio

The single-scatter lidar equation (1) is a First order integral equation with two unknown quantities. To solve the equation for σ or β a simple relationship between the backscatter and extinction is introduced.

Assuming spherical particles and elastic scattering (no shift between the received and transmitted wavelength, respectively), Mie theory can be applied to obtain a basis for such a relationship, (Bohren & R. 1983). Mie theory describes the scattering of light from spherical particles of a known index of refraction with a size comparable to the wavelength. The intensity of the backscatter light here is proportional to the number of particles per unit volume, or the particle density (in the following assumed to be concentration). The concentration can therefore be related proportionally to the backscatter intensity. The backscatter coefficient per unit volume is here expressed as:

$$\beta = \int_0^\infty \pi a^2\, \mathrm{Q_{back}}(\lambda, m, a)\, \mathrm{N}(a)\, \mathrm{d}a \tag{3}$$

The backscatter cross-section efficiency of a single spherical particle $\mathrm{Q_{back}}(\lambda, m, a)$ can be calculated based on Mie theory and can be shown to depend on the wavelength λ, refractive index m, and size a (diameter) of the sphere, (Bohren & R. 1983). $N(a)$ is the particle size-distribution [(number)/m]. Similarly the volume extinction coefficient per unit length can be expressed as:

$$\sigma = \int_0^\infty \pi a^2\, \mathrm{Q_{ext}}(\lambda, m, a)\, \mathrm{N}(a)\, \mathrm{d}a \tag{4}$$

Here $\mathrm{Q_{ext}}(\lambda, m, a)$ is the extinction cross-section efficiency also to be evaluated from Mie theory.

Now given the following assumptions, a linear relation between the backscatter and extinction can be introduced (Evans 1988):

1. The quantities $\mathrm{Q_{back}}(\lambda, m, a)$ and $\mathrm{Q_{ext}}(\lambda, m, a)$ remain constant with time which means that the optical properties of the particle remain unchanged during a single measuring trial (1/2 - 1 hr.).
2. The shape of the particle size distribution does not change during an experiment. This means that the distribution $N_t(a)$ at time t can be expressed as $N_t(a) = f(t)N_0(a)$ where $f(t)$ contains the time variation in the number of particles, leaving the size distribution $N_0(a)$ unchanged.

By dividing the two equations (3) and (4) we get the relation:

$$\alpha = \frac{\beta}{\sigma} = \frac{\int_0^\infty \pi a^2\, \mathrm{Q_{back}}(\lambda, m, a)\, \mathrm{N_0}(a)\, \mathrm{d}a}{\int_0^\infty \pi a^2\, \mathrm{Q_{ext}}(\lambda, m, a)\, \mathrm{N_0}(a)\, \mathrm{d}a} \tag{5}$$

During quasi-stationary meteorological conditions with respect to background aerosol level and humidity, we assume that the shape of the particle size distribution is constant, and consequently a constant relation between backscatter and extinction is obtained.

4.3 Concentration of aerosols

With a constant backscatter-to-extinction ratio α, and given either extinction or backscatter, the calculation of aerosol concentrations is now straight forward. The relationship between extinction and concentration is expressed as :

$$k = \frac{\kappa}{\mathrm{c}} = \frac{\int_0^\infty \pi a^2\, \mathrm{Q_{ext}}(\lambda, m, a)\, \mathrm{N}'(a)\, \mathrm{d}a}{\int_0^\infty \frac{4}{3}\pi \rho a^3\, \mathrm{N}'(a)\, \mathrm{d}a} \tag{6}$$

where ρ is the density of the aerosols. The constant k is seen to remain constant under the assumptions mentioned in paragraph 3.1. Calculating the concentration in absolute terms may seem straight forward based on eq. (6), but often the shape of the particle size distribution and the optical parameters Q_{ext} are unknown quantities, and thus an absolute value for the concentration is difficult to specify. Nevertheless, relative rather than absolute concentration measures are still very useful and often sufficient in accounting for the most important plume statistics.

Previous research has shown that measured time averaged cross-plume backscatter values are linearly related to source emission rates, e.g. (Uthe 1981), This supports the use of eq. (6) and justifies the use of aerosol-lidars for smoke-plume particle concentration monitoring.

4.4 Solutions of the lidar equation

Several different methods are proposed in the literature for inversion of the lidar equation to obtain the extinction values. However, all the proposed methods require additional knowledge of boundary conditions.

Here we have used a numerical forward solution that have shown to be robust to initial conditions. By normalization and introducing a linear relation between backscatter and extinction eq. (5), one can obtain the following relationships:

$$S(r) = \frac{P(r)r^2}{K_{\mathrm{sys}}} \tag{7}$$

$$K_{\mathrm{sys}} = P_0(\frac{c\tau}{2})A_t F(r) \tag{8}$$

$$S(r) = \alpha\kappa(r)\mathrm{e}^{-2\int_{r_0}^{r}\kappa(r')\mathrm{d}r'} \tag{9}$$

If we assume that the extinction function $\kappa(r)$ can be approximated by a straight line between close neighbour points so that:

$$\frac{\kappa(\mathrm{r}+\Delta\mathrm{r})-\kappa(\mathrm{r})}{\kappa(\mathrm{r})} \ll 1 \tag{10}$$

for small values of Δr, the normalized signature-equation can be approximated by:

$$S(r) \simeq \alpha\kappa(r)\mathrm{e}^{-2\int_{r_0}^{r-\Delta r}\kappa(r')\mathrm{d}r'}\mathrm{e}^{-2\kappa\Delta r} \tag{11}$$

If we define the transmission from $r = 0$ to $\mathrm{r} - \Delta\mathrm{r}$ as:

$$T'(r) \equiv \mathrm{e}^{-2\int_{r_0}^{r-\Delta r}\kappa(r')\mathrm{d}r'} \tag{12}$$

we obtain the simpler relation:

$$\kappa(r) \simeq \frac{S(r)}{T'\alpha}\mathrm{e}^{-2\kappa\Delta r} \tag{13}$$

This equation is easily solved by an ordinary Newton-Raphson iteration.

4.5 Baseline correction

Due to the r^2 dependency in the lidar equation noise will be amplified and a possible offset in $P(r)$ will create a background error which increases with r^2. The dependence on distance may lead to assymetric profile statistics, and therefore a *new* baseline correction was developed for the Cofin project:

1 The raw profiles $P(r)$ were inverted to extinctions with a constant α in the order of 0.005, see Jørgensen et al 1997.

2 The inverted profiles were inspected visually and the plume positions have been marked by two markers before (x_1) and after (x_2) the plume is present in the signal.

3 The plume markers were then used to identify two background areas i.e from from zero to x_1 and from x_2 to the end of the data record. Based on these data a background $\bar{\epsilon}$ for each *i'the* profile is fitted to the form :

$$\bar{\epsilon(r)}_i = a_i + b_i r^2 \tag{14}$$

4 This background was subtracted from the calculated extinction to obtain the corrected extinction κ_c:

$$\kappa_c(r)_i = \kappa(r)_i - \bar{\epsilon}_i; \tag{15}$$

An example of an analysed profile of extinction is shown in figure 3 without the background corrections. The background is fitted outside the plume area and is also shown on the figure.

Figure 4 shows the corresponding profile without the background. It is essential to operated only on the plume area identified inbetween the marked area as noise otherwise corrupts the calculated statistic such as mean profiles etc.

5 Data format

The lidar measurements are stored as binary files made in a Turbo pascal compiler or Delphi compiler (without 32 bit alignment). The nomenclature of the file name is in general as follows :

```
      namexxy.axt
where
      name  : refers to the campaign (e.g. mad for madona etc.)
      xx    : date (01..31) of performance
      y     : a letter (a....x) specifying order of experiment
```

The file namexxy.axt consists of records, i.e., each profile measurement (a lidar shot every third or fifth second) represents a record and the precise formulation of the record (in the turbo pascal language) is as follows:

```
Type {declaration part}

   _dat_array_ext =  array[1..512] of single ;


   _datasheet  {Structure of the data record } = record
     nummer       {Actual no. of org.Measurement}    : string[4];
     user         {Name of user}                     : string[20];
     verst        {Internal variable }               : string[4];
     bereich      {Abtastbereich in m}               : string[5];
     azimut       {Not in use    }                   : string[6];
     elevat       {Elevation 0-360, 1000 = 1)      : string[6];
     bemerkung    {comments}                         : string[30];
     sichtweite   {Visibility in Km}                 : string[3];
     datum        {Date of measurement}              : string[10];
     zeit         {time of measurement}              : string[10];
     tag          {Weekday}                          : string[10];
     wiederholung {not used }                        : string[3];
     anzahl       {total amount of measurement }     : string[4];
     entfernungsoffset{zero point internal}          :string[4];
     energie      {Energy in the Laser in mJ XX.XX} : string[5];
     extin        {calculated extinctionvalues}      :_dat_array_ext;
   end;
```

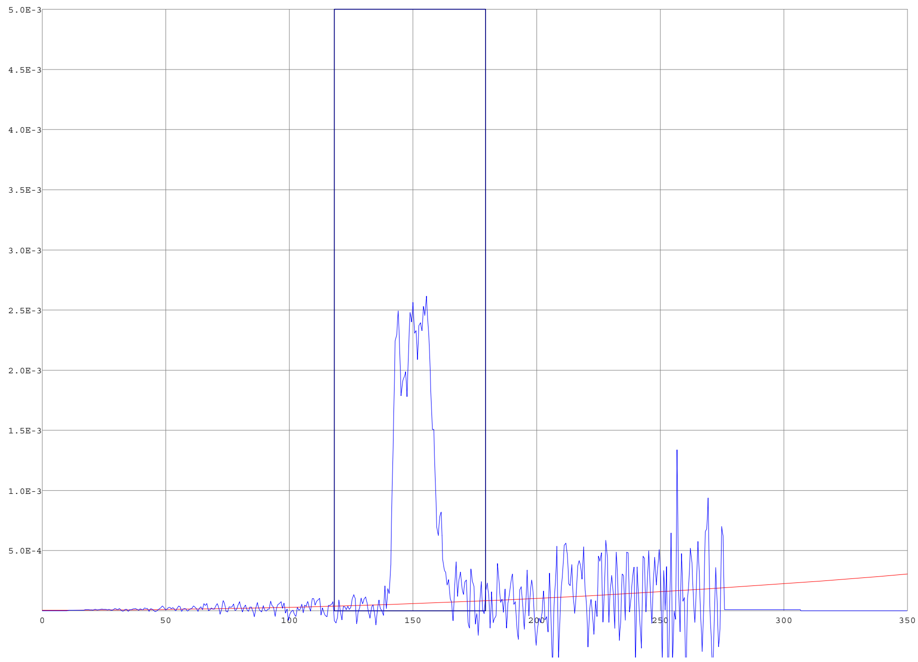

Figure 3. An example of a Lidar profile without baseline correction.

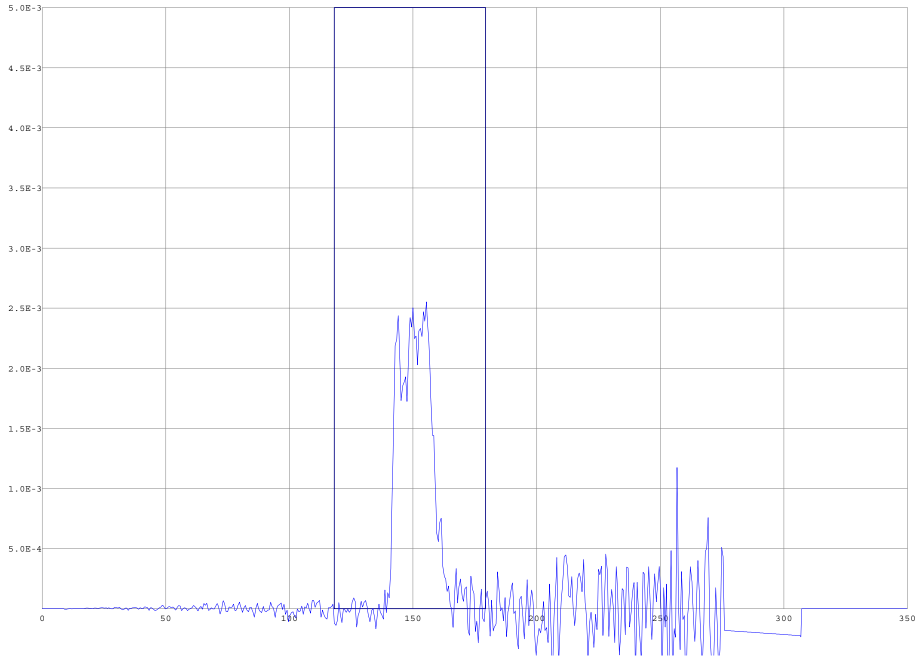

Figure 4. An example of a Lidar profile with baseline correction.

The lidar file $*.AXT$ is then declared as a: "file of _datasheet", and each single lidar measurement is declared as a profile of datasheet. The variable declaration part of a turbo pascal program could look like the following:

```
VAR
   datafile : file of _datasheet ;
```

```
   profile  : _datasheet;
   etc....,
```

The concentration values are contained in the array $profile.extin[i]$ where the counter i ranges from 1 to 512. The distance DX between each measurement point is 0.6 or 1.5 meter depending on the value of profile.bereich. In the case of $profile.bereich =' 300'$ then DX = 0.6 m, or if $profile.bereich =' 750'$ then DX = 1.5 m.

5.1 Plume markings

The files **.opt* contain markers of the range where the plume has been identified. These markers are set partly by visual and automated procedures. The format of the files are as follows.

The file **.opt* is in the same way as the file **.axt* build of records, i.e., each pair of plume markers represents a record and the precise formulation of the record (in the turbo pascal language) is as follows:

```
  T_option = record      {data type for position of plume}
           x1 : smallint ;       {start and end }
           x2 : smallint ;
         end;
```

the values are specified in meters and to use them one has to withdraw the value *profile.entfernungsoffset* in the lidar record data

5.2 Transformation from binary to ASCII file under DOS

The program AXT2ASCI.EXE transforms the Lidar data file from the binary structure to an ASCII format. The information in the **.opt* files is not included in the transformation. The syntax of the program is as follows :

```
   AXT2ASCI madxxy /R+ path x1 x2 rec1 rec2
where
   madxxy : the axt filename to be transferred
   /R     : specifies weather a ramdisk is used (drive e:)(/R+ ram on)
   path   : path to the data (e.g. c:\work\
   x1     : starting range of cross wind values to be transferred
   x2     : stopping range of cross wind values to be transferred
   rec1   : first profile no. to be transferred
   rec2   : Last profile no. to be transferred
```

If the parameters x1 ...rec2 are omitted default values results in a transformation of all the values in the binary file *.axt to ASCII format. The output file of AXT2ASCI is `madxxy.ASC`. The format of resulting ASCII file is as follows :

```
** no. **
D:H:M:S       { date:hour:min:sec of the measured profile   }
DX            { Distance between measurements points in [m] }
XSTART  XSTOP { Start and stop range of the measurement}
ELEVATION
C[XSTART/DX] ......................... C[(XSTART/DX +8)]
 .......................................................
 ..........................C[(XSTOP/DX)]
etc ..
```

5.3 Utility programs under NT and WIN 95

A similar but more extended program under Windows 95 or NT *LAP.exe* is also included in the utility programs. The program has the following facillites.

- **Transformation of binary files to ASCII**
  The binary data is here transformed into an ascii file with optional baseline correction by the method described in section 4.5. The format of the file is described in the help menu in the transformation form. The output file **.asc* is generated in i.e same location as the original file **.axt.*The plume markings x1 and x2 is also included.
- **Movie program.**
  The movie module shows the instantaneous crosswind profiles and the user is able to inspect individual profiles or a sequence of these.
- **Calculation of Mean Plume statistic**.
  General mean statistics both in moving and fixed frame can be calculated. The output files generated the same directory as the original file and the format is described in the help menu.
- **Extraction of time-series** The user can specify specify the measuring positions and extract timeseries of local concentration. Available options are :

  1 moving and fixed frame timeserie, and the cross wind position in relative or fixed coordinates from the timeserie should be extracted (max five positions are allowed).

  2 Improving the statistics by selecting measuring points nearby the selected position to be included in the extracted timeserie. Either by a mirror option (i.e. same relative position on the other side of the plume) or by selecting neighbouring points. The points are then multiplexed into the timeserie as $((x1x2x3),(x1x2x3)...etc)$. The timerseries are name *mtime_xxx.tse* or *time_xxx.tse* specifying whether it is a moving or fixed timeserie, xxx specifies the location.

The format of the timeseries are files of single and can be tranformed into a ascii file by the dos program BIN2ASCI.exe

6 Distribution method

The data are found at the Risø ftp server *risrms1.risoe.dk* (USER: anonymous, Password: e-mail address) in the directory *met-haej\cofin*. The directory contains three directories with the following content :

- *met-haej\cofin\data*: Contains the lidar data
- *met-haej\cofin\report*: describtion of the data and data format
- *met-haej\cofin\utility* : programs to extract the data and perform simple statistics.

In case the files are missing please write an e-mail to *hans.e.joergensenrisoe.dk* or *n.m.nielsenrisoe.dk* and ask us for a reload.

The data are packed in **.zip* which you download and extract on a PC disk with a minimum of 50 MB free space plus 10 MB for the temporary files.

The data files **.axt* are written in a binary format which may be inspected and translated to ACSII by the program *lap.exe* (Lidar analysis program). To install *lap.exe* on your system download and execute *setup.exe*.

Visual inspection is recommended before using the data a as a few amount of the analysed profiles may have an odd background and create artificial and weird background in the corrected profiles.

7 Summary

A brief description of how to access the Lidar data used in the Cofin project has been given, including background information of how LIDARs work. The intention of the report is that the participants in the project will be able to understand how to use and work with the data.

References

Bohren, C. & R., H. D. (1983). *Absorpation and Scattering of Light by Small Particles*, John Wiley & Sons.

Evans, B. (1988). Sensitivity of the backscatter/extinction ratio to changes in the aerosol properties: implication of lidar, *Applied Optics*, **27**, 3229.

Jørgensen, H. E., Mikkelsen, T., Streicher, J., Herrmann, H., Werner, C. & Lyck, E. (1997). Lidar calibration experiments, , **64**, 355–361.

Measures, R. M. (1984). *Laser Remote Sensing- Fundametals and applications*, John Wiley & Sons.

Nielsen, M., Ott, S., Jørgensen, H. E., Bengtsson, R., Nyrén, K., Winter, S., Ride, D. & Jones, C. (1997). Field experiments with dispersion of pressure liquefied ammonia, , **56**, 59–105.

Uthe, E. (1981). Lidar evaluation studies of smoke and dust clouds, *Applied Optics*, **20**, 1503–1510.

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Abstract (Max. 2000 char.)

Abstract This report presents the Lidar data used in the COFIN project. The Lidar data have been obtained from several ground level dispersion experiments over flat and complex terrain. The method for treating the data and the conditons under which the data were obtained are described in detail. Finally we describe the Tools to extract and visualize the Lidar data. Data, report, and visualisation tools are available on the Risø FTP server.

Descriptors INIS/EDB

AEROSOLS; DATA ANALYSIS; FIELD TESTS; METEOROLOGY; OPTICAL RADAR; PLUMES;