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FORSCHUNGSZENTRUM JÜLICH GmbH
Abteilung Sicherheit und Strahlenschutz

Untersuchungen zur atmosphärischen Ausbreitung von Schadstoffen nach Kurzzeitemissionen in nicht ebenem Gelände

Investigations on Atmospheric Dispersion of Air Pollutants after Short-Time Releases in Complex Terrain

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METHODS – EXPERIMENTS – DATA BANK

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G. Zeuner and K. Heinemann

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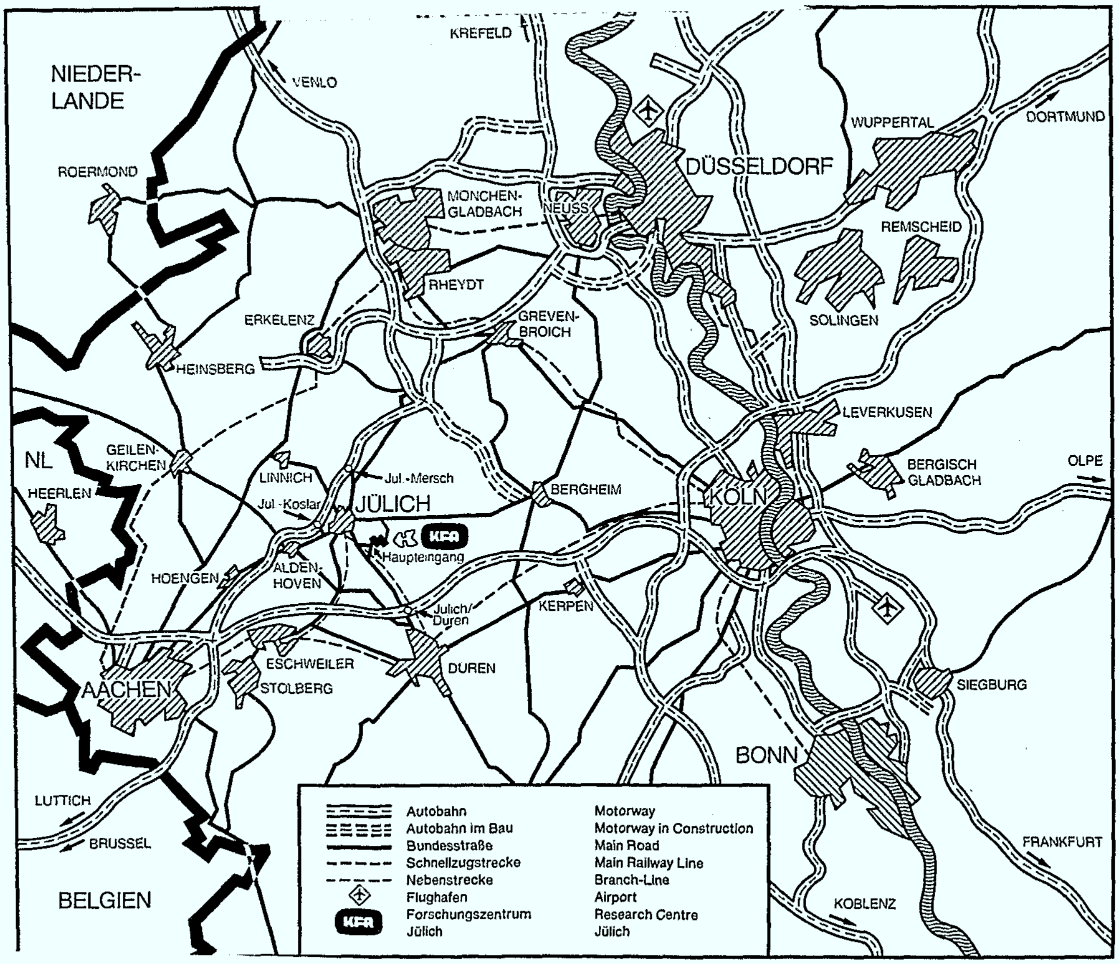

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Untersuchungen zur atmosphärischen Ausbreitung von Schadstoffen nach Kurzzeitemissionen in nicht ebenem Gelände*

Investigations on Atmospheric Dispersion of Air Pollutants after Short-Time Releases in Complex Terrain

THIRD FIELD EXPERIMENT ON ATMOSPHERIC DISPERSION AROUND THE ISOLATED HILL SOPHIENHÖHE IN AUGUST/SEPTEMBER 1988

METHODS – EXPERIMENTS – DATA BANK

W. Bahmann (TÜV Rhl.) K. Becker (DWD) J. Frank (Rh.W.TÜV) S.E. Gryning (RISØ) K. Heinemann; E. Lyck (NERI) O. Mextorf, M. Möllmann-Coers, Ch. Mönig; H.D. Narres (KFA-ICH 4) Ch. Oetz, W. Oetz (IGM) G. Polster; F. Veroustraete (SCK) W. Voß, G. Zeuner

Edited by

G. Zeuner and K. Heinemann

in cooperation with:
Deutscher Wetterdienst, Wetteramt Essen (DWD)
Institut für Chemie 4 des Forschungszentrums Jülich (KFA-ICH 4)
Institut für Geophysik und Meteorologie der Universität zu Köln (IGM)
National Environmental Research Institute, Roskilde, Denmark (NERI)
Rheinisch-Westfälischer Technischer Überwachungsverein e.V., Essen (Rh. W. TÜV)
RISØ National Laboratory, Roskilde, Denmark (RISØ)
Studiecentrum voor Kernenergie, Mol, Belgium (SCK)
Technischer Überwachungsverein Rheinland e.V., Köln (TÜV Rhl.)

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Zusammenfassung

Um eine Datenbasis für die Validierung von fortgeschrittenen Ausbreitungsmodellen zur Verfügung zu stellen, werden umfangreiche meteorologische Messungen und Ausbreitungsexperimente in einem gut vermessenen nicht ebenem Gelände durchgeführt. Diese Untersuchungen werden durch die Zusammenarbeit mit verschiedenen externen Gruppen und die finanzielle Unterstützung des Bundesministers für Umwelt, Naturschutz und Reaktorsicherheit ermöglicht. In diesem Bericht sind die Methoden, die Experimente und die Ergebnisse der dritten Meßkampagne zusammengestellt.

Abstract

In order to set up a data bank for the validation of advanced dispersion models, comprehensive meteorological measurements and dispersion experiments in a complex terrain with a well measured topography are being carried out. These investigations have become possible in cooperation with several external groups and with the financial support of the "Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit". In this report the methods, experiments and results (data bank) of the third field experiment are described.

Keywords

Dispersion experiments, SF_6-tracer, meteorological measurements, complex terrain, isolated hill, data base for the validation of advanced dispersion models.

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1. INTRODUCTION

K. Heinemann

In the licensing procedure of a plant or in the case of an accident with atmospheric releases it is necessary to know the impact of pollutants to the environment. These pollutants are normally released from an elevated point source (stack). One of the main questions in this connection is that of the dilution of pollutants in the atmosphere for a distance range of up to about 10 km from the source, where the most unfavorable point of impact is included.

At present most dispersion factors are calculated by application of the Gaussian plume model. The dispersion parameters used in the Federal Republic of Germany were experimentally determined in Karlsruhe and Jülich at the beginning of the 1970s (Geiß et. al. (1981), Hübschmann et. al. (1980) and Polster (1988)). The Gaussian plume model is very simple. The calculations are not very time intensive and can be done on personal computers in real time. However its application is restricted to stationary meteorological conditions and on plain terrains. In general the Gaussian plume model gives good results for long-time dispersion factors (licensing procedures) but it might fail in the case of an accidental release (short-time dispersion factor) during changing meteorological conditions especially in complex terrains.

Many advanced dispersion models, considering changing weather conditions and complex terrains like the so-called grid, puff, or Lagrange models, have been developed or are under construction by different groups. Before these models are generally accepted they have to be proved by measurements. A careful validation of the models requires a comprehensive data base including

- experimental results of dispersion experiments,
- simultaneous meteorological measurements of the 'wind field', and
- detailed description of the topography of the experimental area.

In this context the expression 'wind field' is used in a very general way and includes also the field of turbulence, of temperature, and of pressure.

In order to compile such a data base the German 'Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit' is financially supporting the project *'Untersuchungen zur atmosphärischen Ausbreitung nach Kurzzeitemissionen in nicht ebenem Gelände' (investigations on the atmospheric dispersion of air pollutants after short-time releases in complex terrain)* for the period of 1986 - 1990. These measurements are carried out in the same region where dispersion parameters for the Gaussian plume model have been determined since 1970. Until the beginning of the 1980s this area was a flat countryside but in the last years the artificial hill 'Sophienhöhe' (an overburden tip) has grown up by the activities of an open-cast coal mining, 2 km away from KFA. This hill, taken as an element of a complex terrain, lays in the main dispersion direction with regard to the meteorological tower of the KFA. Not only this special geographically situation but also a well measured topographical structure including many accessible pathways make this area most appropriate for dispersion experiments. Furthermore, a comparison of the dispersion of pollutants in this area with and without the hill will become possible and might reveal intriguing results.

The dispersion experiments are performed with sulfurhexafluorid. This tracer is released from a height between 30 m and 50 m with a release rate of about 2 g/s. Whereas in the 1970s experiments air concentrations were determined at about 30 positions, in these experiments between 50 and during field experiments 150 air samples are taken in the area of the overburden tip.

The needed meteorological data are determined by continuous measurements and during field experiments discontinuously. For the continuous meteorological measurements the meteorological tower of the KFA, five masts built up on the hill and a Doppler SODAR system are available. Fig. 1.1 indicates the positions of these devices with respect to the Sophienhöhe. In field experiments external groups with their equipments participate, so that the information on the meteorological data and the tracer distribution become more complete.

Based on the experience of 1986 and 1987 from Aug. 30 - Sept. 8 1988, the third field experiment was carried out in cooperation with the following groups (see also list of abbreviations). Their equipments are listed below.

DWD	radiosondes with radar tracking, pilot balloons, radar tracking of tetroons
ICH 4	aerosol tracer, mobile van
IGM	radiosondes and tether sonde
APL, NERI	sampling stations, gaschromatograph
Rh.W.TÜV	Doppler-SODAR
RISØ	tether sonde, ultra sonic anemometer, small masts
SCK	sampling stations, gas analysis
TÜV Rhl.	Doppler-SODAR

The location of the different equipments is shown in Fig. 1.1.

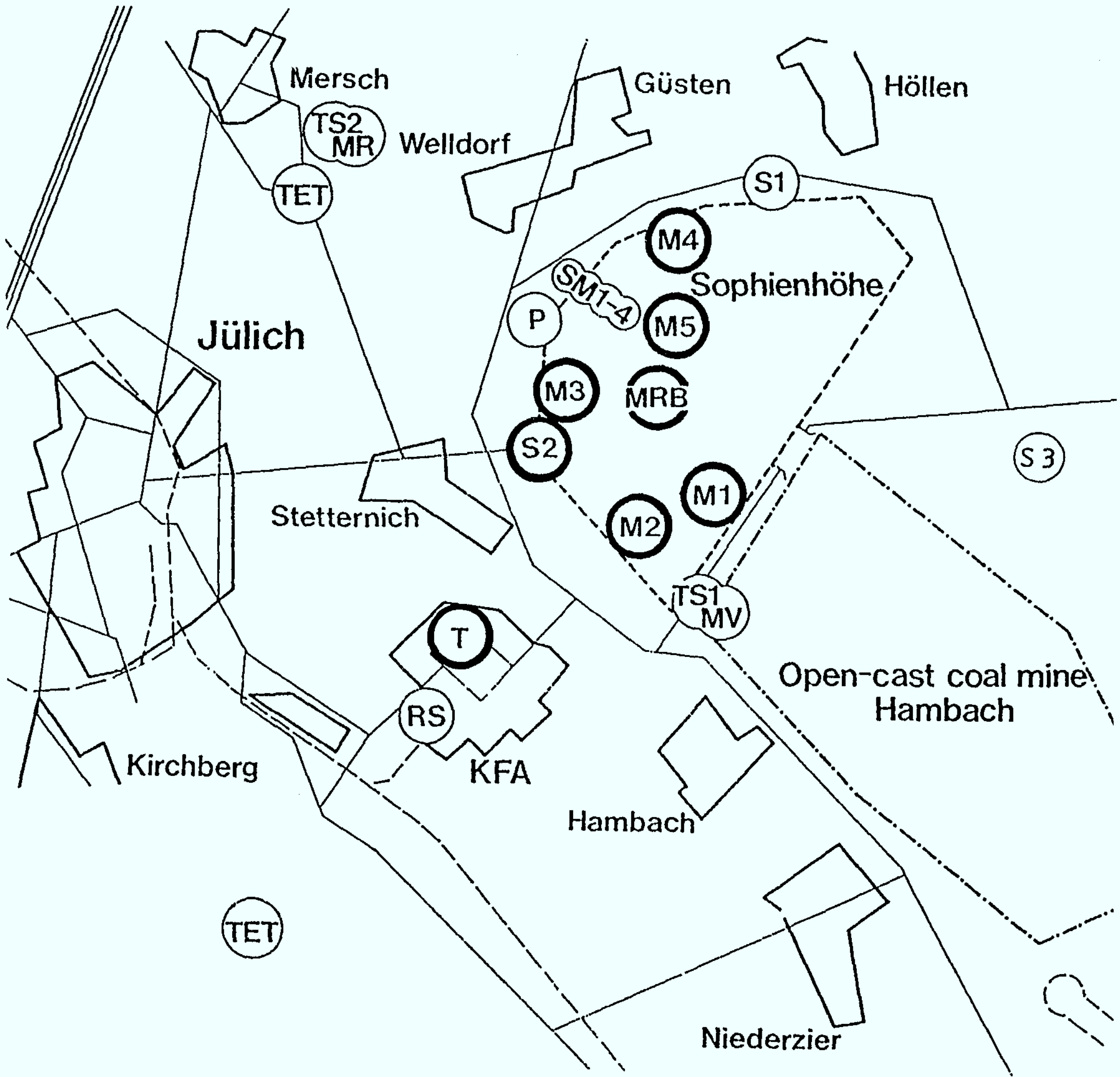


Fig. 1.1: Meteorological measurement systems during the Third Field Experiment 1988

(bold circle)	continous measurements	(thin circle)	measurements by external groups
T	: KFA-tower	RS	: Radiosonde-station Wetteramt Essen, IGM
M1-M5	: Masts KFA		
MRB	: Mast Rheinbraun	TS1	: Tether sonde IGM
S2	: Doppler-SODAR KFA	TS2	: Tether sonde RISØ
		TET	: start point tetroon KFA
S1	: SODAR TÜV Rheinland	P	: one start point pilotballoon Wetteramt Essen
S3	: SODAR TÜV Essen	MR	: Mast RISØ (sonic)
MV	: Measuring van KFA	SM 1-4	: Small masts RISØ

Due to the enormous mass of meteorological data collected during the third field experiment it is impossible to show them all in form of tables. They are stored, instead, on two high density magnetic tapes.

This report describes the third field experiment with special emphasis on the measuring devices, some representative experimental results, and the data bank structure. Beginning with a characterization of the area (chapter 2) and the meteorological conditions during the field experiment (chapter 3), details of the tracer release and sampling network as well as the sample analysis are given in chapter 4. A discussion of the methods of the meteorological measurements follows in chapter 5. In chapter 6 an overview on the dispersion experiments and first results are presented. As an example of the meteorological data set measurements during a selected dispersion experiment (Aug. 31) are summarized in tables.

The appendixes contain the intercomparison of the SF_6 measurements of the different groups, the information on topographical data, and the structure of the data set on magnetic tape.

2. DESCRIPTION OF THE AREA

G. Zeuner

2.1 Topography

The artificial hill Sophienhöhe is 185 m high and covers an area of $\simeq 4 \times 3$ km^2 (Fig. 2.2.1). At the southeast of the hill, the "Hambach mine" has grown, a large open air mining area of $\simeq 5 \times 2.5$ km^2 which in 1988 was 200 m deep and will further be extended to the east. The topographical relief of the surroundings is about 100 m MSL and gently rolls within more than 10 km in all directions. The actual topographical data are available as an 8 m grid and represent an excellent model input.

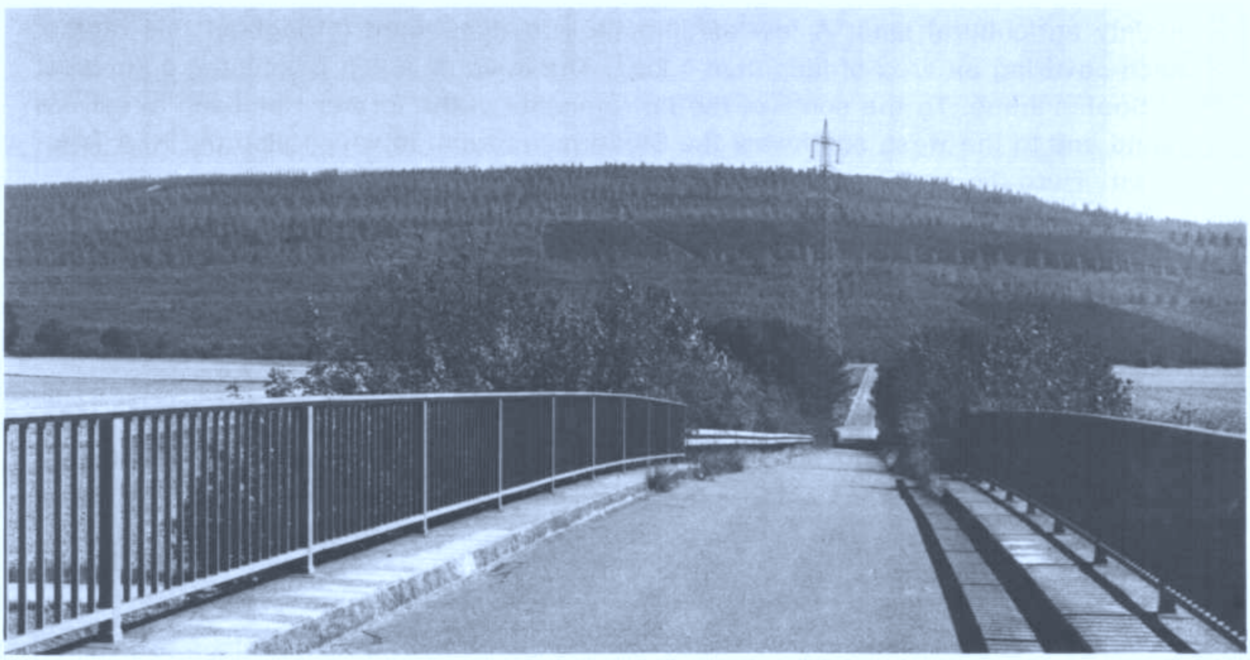


Fig.2.2.1: Sophienhöhe as seen from southwest

The Sophienhöhe is very well accessible with the exception of the northeast/east part of the hill where the overburden soil is still deposited. In a vertical distance of 20 - 35 m, there are accessible pathways, the so-called "Bermes", going around the hill. These "Bermes" are called Berme 125, Berme 150, Berme 185, Berme 220, Berme 240, where the numbers give the approximate height in m above MSL (mean sea level). The pathway at the base of the hill is at the height of $\simeq$ 100 m above MSL. The pathways form an ideal base for the installation of a sampling grid. In deviation from the general appearance of the pathways there are two indentations in the south-western and northern part. There the Bermes reach a width up to 100 m.

The mean slope of the Sophienhöhe is about 15°. In the upper part the slopes are stronger inclined (15° - 20°) than in the lower part of the tip (10° - 15°). The plateau lies in the height range between 230 m - 285 m above MSL, respective 130 m - 185 m above the surroundings, the slope is small and maximal 5°.

2.2 Surface structure and roughness

The area of investigation lies within the Jülicher "fertile plain" in the "Niederrhein basin". The prevailing soils are loess, sand and gravel. The surroundings of the tip is mainly agricultural land. A few settlements are distributed throughout this region, each covering an area of less than 1 km^2. The town of Jülich is situated 4 km west of Sophienhöhe. To the south of the tip remnants of the former Hambach forest are found and to the west, southwest the Stetternich forest, in which also the KFA is located. Here the surface is more inhomogeneous (see Fig. 2.2.2)

The hill became and becomes aforested with trees which are several meters (about 5 - 6 m) high in the southern part and lower than 1 m in the northern part. In the indendations humid biotopes ("ponts and puddles") are embedded. The plateau is characterized by good-natured planting with little trees, bushes, flowers etc..

The surface structure determines the 'roughness' which can be characterized by the roughness length z_0. This parameter is often used as input data for models. The area of investigation was devided in a 500 m × 500 m grid and a roughness length was determined (Fig. 2.2.2). The following mean values of z_0 were used, see Oke (1987):

surface type	**roughness lengths**
agricultural land	15 cm
settlement	50 cm
orchard	50 cm - 100 cm
forest	100 cm - 300 cm

Tab. 2.2.1: Mean values of z_0

For forest areas, where the height of trees was known, as first approximation the roughness length was estimated to 10 % of the height of the trees, see Kraus (1970). A more accurate roughness length can be derived from wind profile measurements.

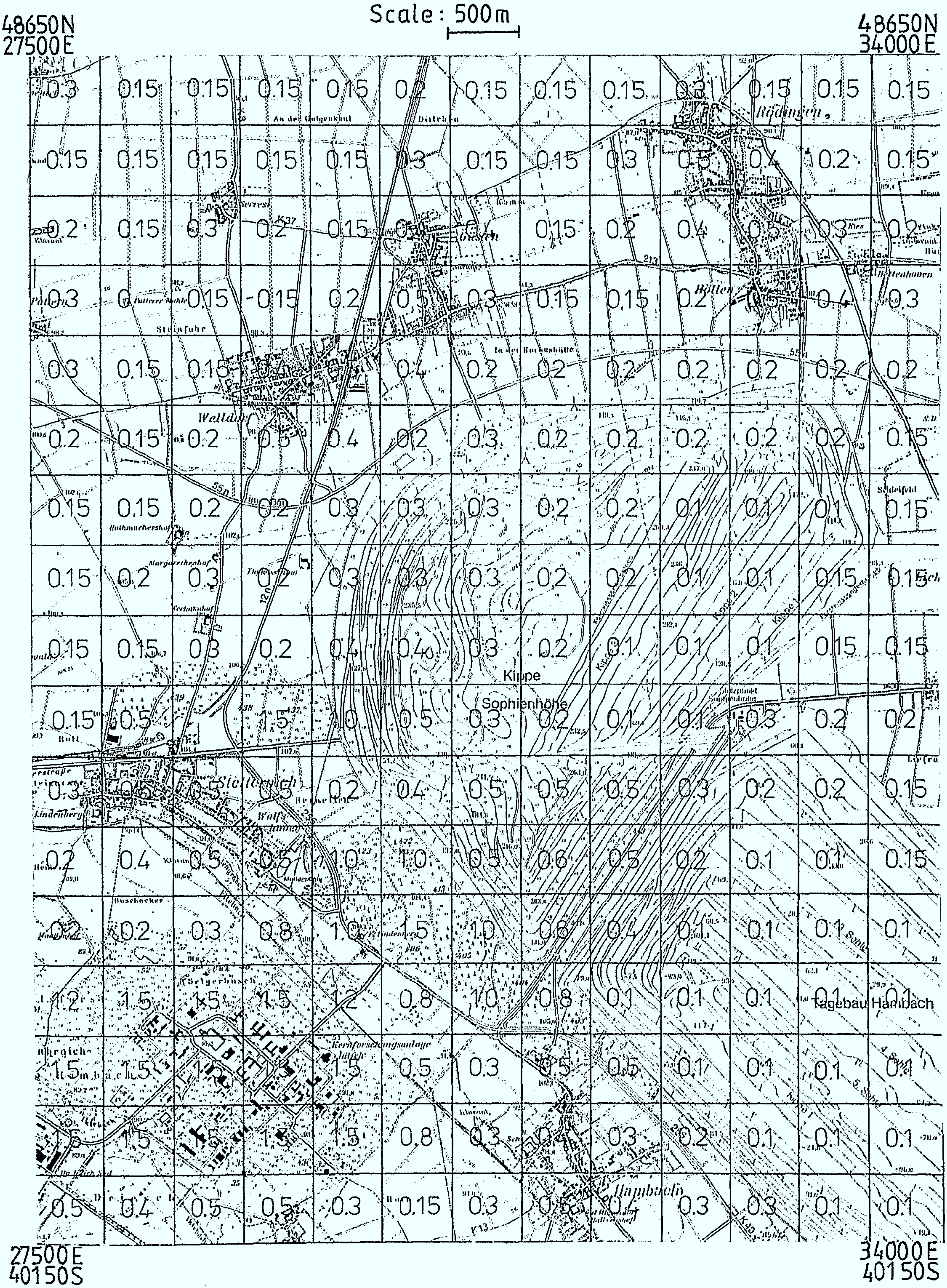


Fig. 2 2 2: Estimation of the surface roughness (in meter) for Sophienhöhe area, 500 m × 500 m grid; the Gauß-Krüger coordinates are given at the corners

3. SYNOPTIC CONDITIONS

G. Polster

For the beginning of the third field experiment the 30th of August 1988 at 12:00, the high-level weather maps (500 hPa) showed a low-pressure centre over the northern part of the atlantic ocean between Iceland, Scotland and Norway and a high-pressure ridge over the Baltic. So, over the middle of Europe and over Western-Germany a southwesterly airstream in the upper levels resulted. On surface, there was a high-pressure zone over Europe with high-pressure-cells over southern France and South-Germany and a low-pressure centre situated southeast of Iceland. In our region there were southwesterly winds, 3/8 of cumulus clouds and some cirrus. All these were favourable conditions for tracer emission from the meteorological tower which was carried out in the afternoon 15:00 until 16:30.

On 31st of August 1988 the conditions in the upper levels were similar to that of the foregoing day: a southwesterly high-level airstream over Europe, but now with a trough building up over the eastern parts of the Atlantic ocean.

On surface there was a high-pressure centre over the eastern parts of Europe, a big low-pressure centre near Iceland and a deepening daughter-cyclone over the Northatlantic ocean. A cold-front over the Northsea moved slowly from west in our region. Ahead of the cold-front the winds were southwesterly in the noon with some cumulus-, altocumulus- and cirrusclouds. Dispersion experiments were conducted in the evening with stable atmospheric conditions and emission from the meteorological tower between 19:00 and 20:30. The weakening cold-front passed our area in the evening after the experiments with some rain and winds shifting from south to north.

On 1st of September 1988 the frontal system of the fully developed cyclone which reached Ireland on its way over the Atlantic ocean passed over Europe with rain in the morning to late evening and the winds blew from south-east shifting slowly to south and later on in the night to south-west. There was some rain in the night and light showers in the forenoon and afternoon of the 2nd of September 1988 after the passage of the frontal system. The winds were fresh coming from south-west. Two wave-cyclones followed over the Atlantic ocean moving in the westerly upper airstream from west towards Europe. The first of them reached the coast of France on 3rd of September1988 in the morning. In front of its warmfront with slightly stable atmospheric conditions and south-south-westerly winds there were performed dispersion experiments in the early morning between 06:30 and 08:00. The wave-cyclone moved further to east during the day with some rain in the noon and some rain and drizzle in the evening. The wind shifted from south to north-east. On the next day, the 4th of September 1988, a weak high-pressure ridge between the two wave-cyclons lay over the middle of Europe. The winds backing to south-west in the fore-noon showed favourable conditions for daytime dispersion experiments in the noon with very unstable stability. They were carried out from 12:00 to 13:30.

On 5th of September 1988 the frontal-system of the second wave-cyclone moved over the middle of Europe from west to east with overcast skies and rain during the morning hours up to the afternoon. The coldfront crossed our region in the afternoon with winds shifting from south-west to north-west. In the evening the sky became clear and with slightly stable conditions in the rear of the coldfront dispersion experiments were performed with emission from the water-tower of Stetternich.

On 6th of September 1988 a high-pressure-centre built up over the north-sea leading to weak variable winds in our region with unfavourable conditions for dispersion-experiments because the wind direction was changing too much. But with the further extension of the high-pressure-centre over Denmark, Sweden and Northern-West-Germany there was expected the development of a strong inversion during the following night. And these inversion-conditions and the dissipation of the inversion were studied in the early morning of the 7th of September 1988 by many meteorological measurements. During daytime the anticyclone over Denmark and Sweden strengthened further to a pressure in its centre of more than 1030 hPa leading in our region to fair weather with south-easterly winds. These conditions were expected to last for the following night and day. The only possibility for dispersion experiments with stable stability conditions was to emit the tracer from the top of the hill "Sophienhöhe", and study the katabatic winds during nighttime hours. This was done in the evening of 7th of September 1988 from 20:00 til 21:30.

On 8th of September 1988 the anticyclone over the northeastern parts of Europe caused fair weather over Western-Germany with southeasterly winds. The third field experiment was finished at this day in the noon.

The weather maps of this period are shown in the following figures 3.1 -3.14.

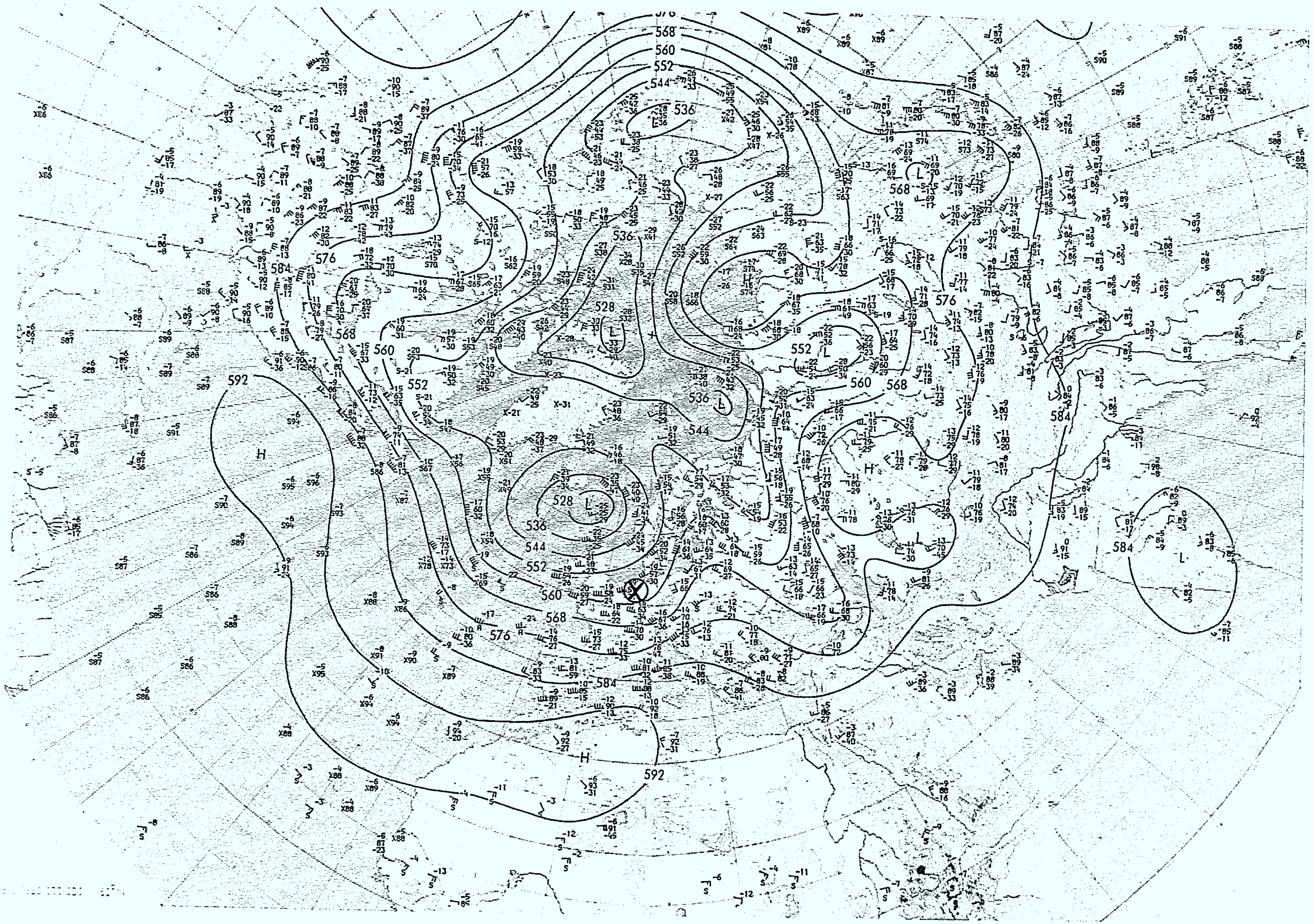


Fig. 3.1: Upper level chart (500hPa) of Aug. 30, 1988, 0:00 UTC
⊗Area of investigation

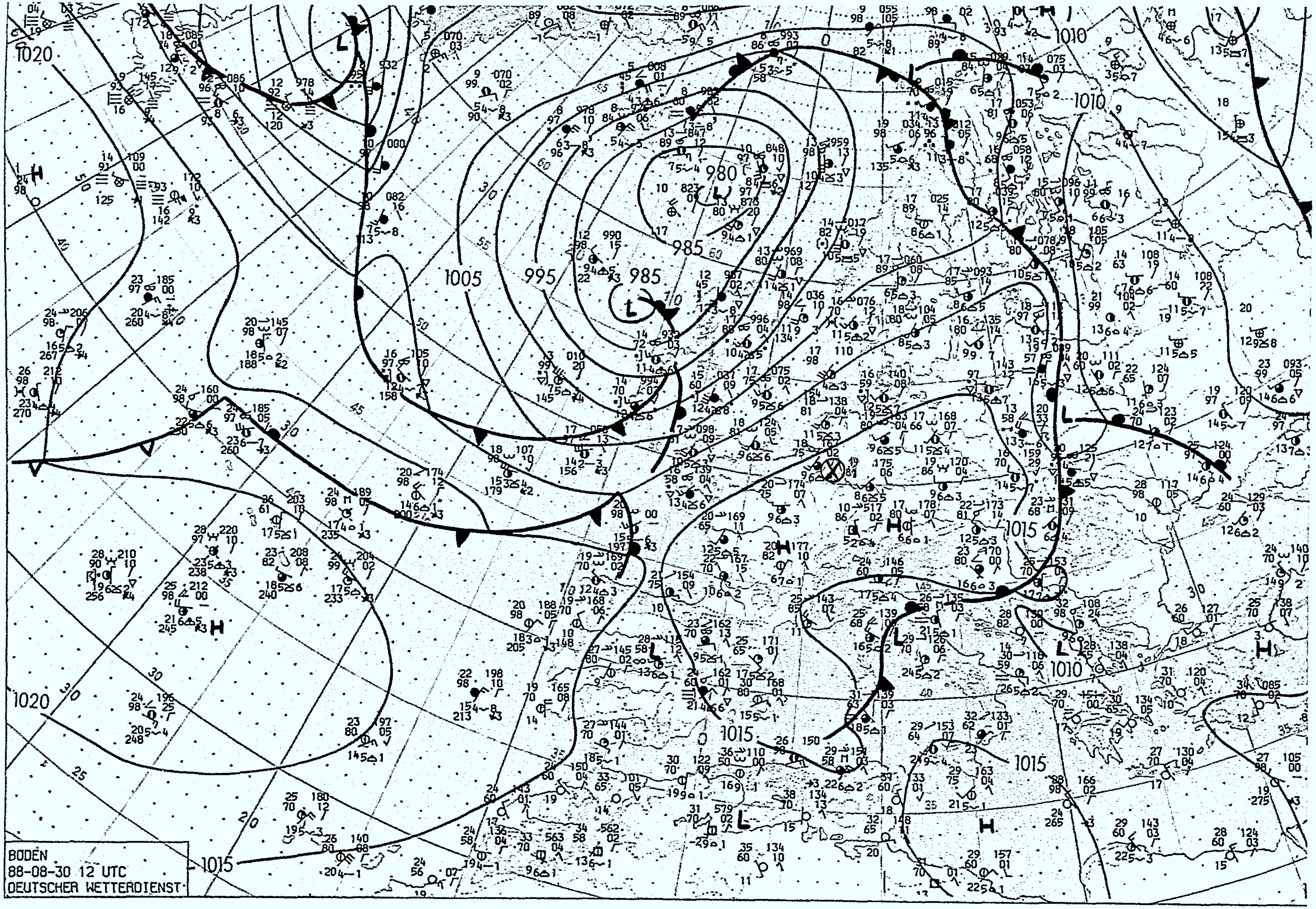


Fig. 3.2: Surface chart of Aug. 30, 1988, 12:00 UTC
⊗ Area of investigation

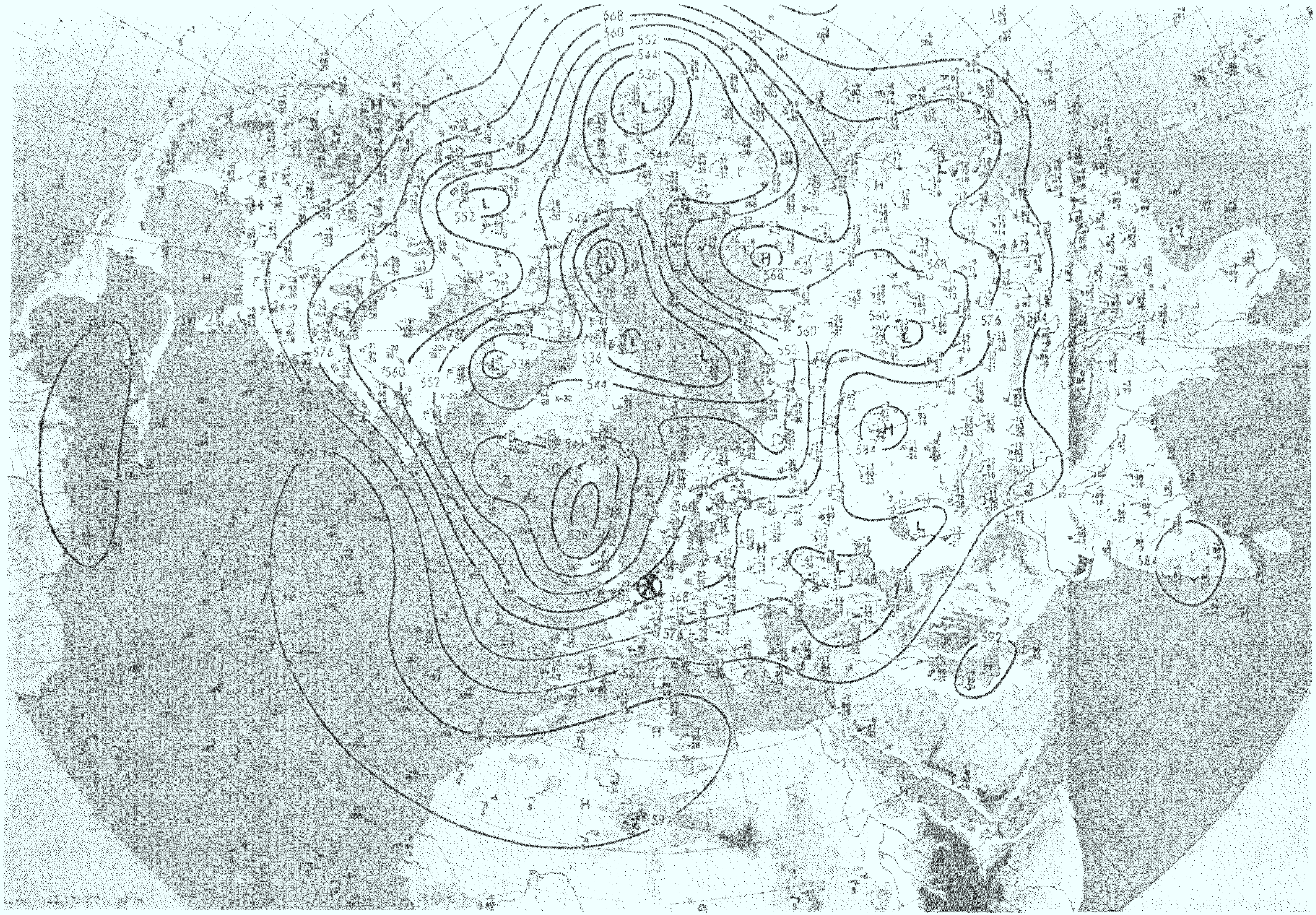


Fig. 3.3: Upper level chart (500hPa) of Aug.31, 1988, 0:00 UTC

⊗ Area of investigation

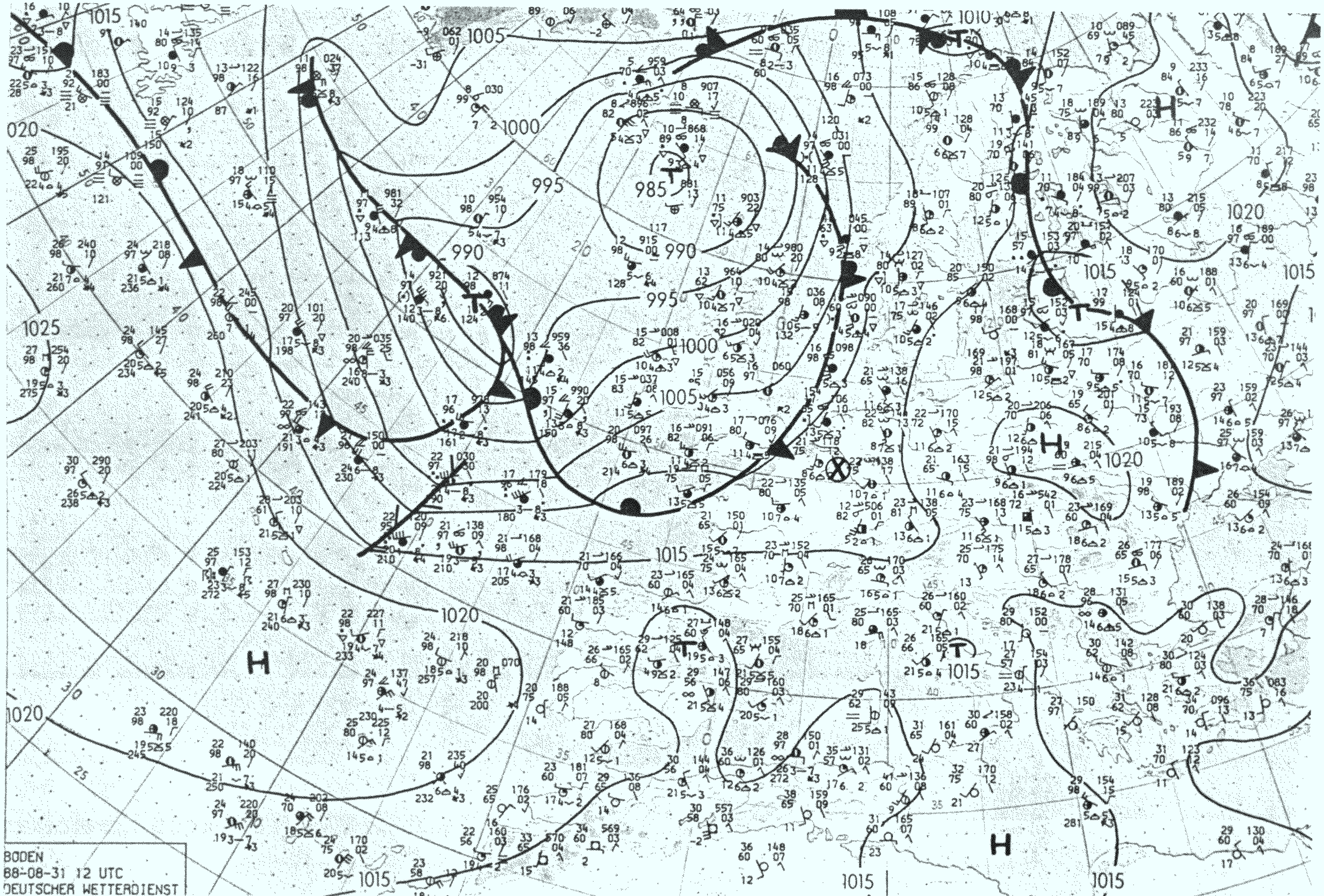


Fig. 3.4: Surface chart of Aug.31, 1988, 12:00 UTC
⊗ Area of investigation

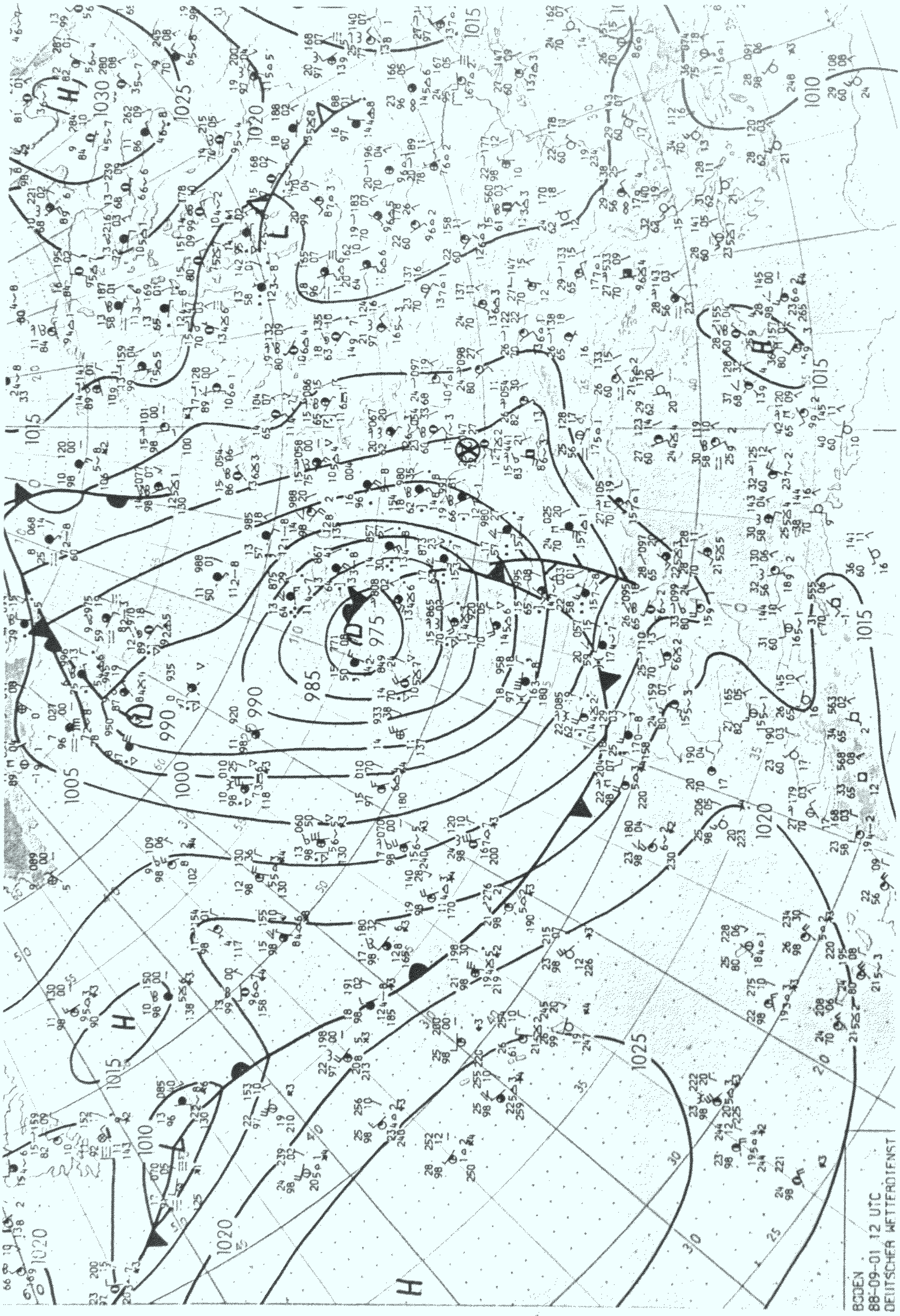


Fig. 3.5: Surface chart of Sept. 1, 1988, 12:00 UTC
⊗ Area of investigation

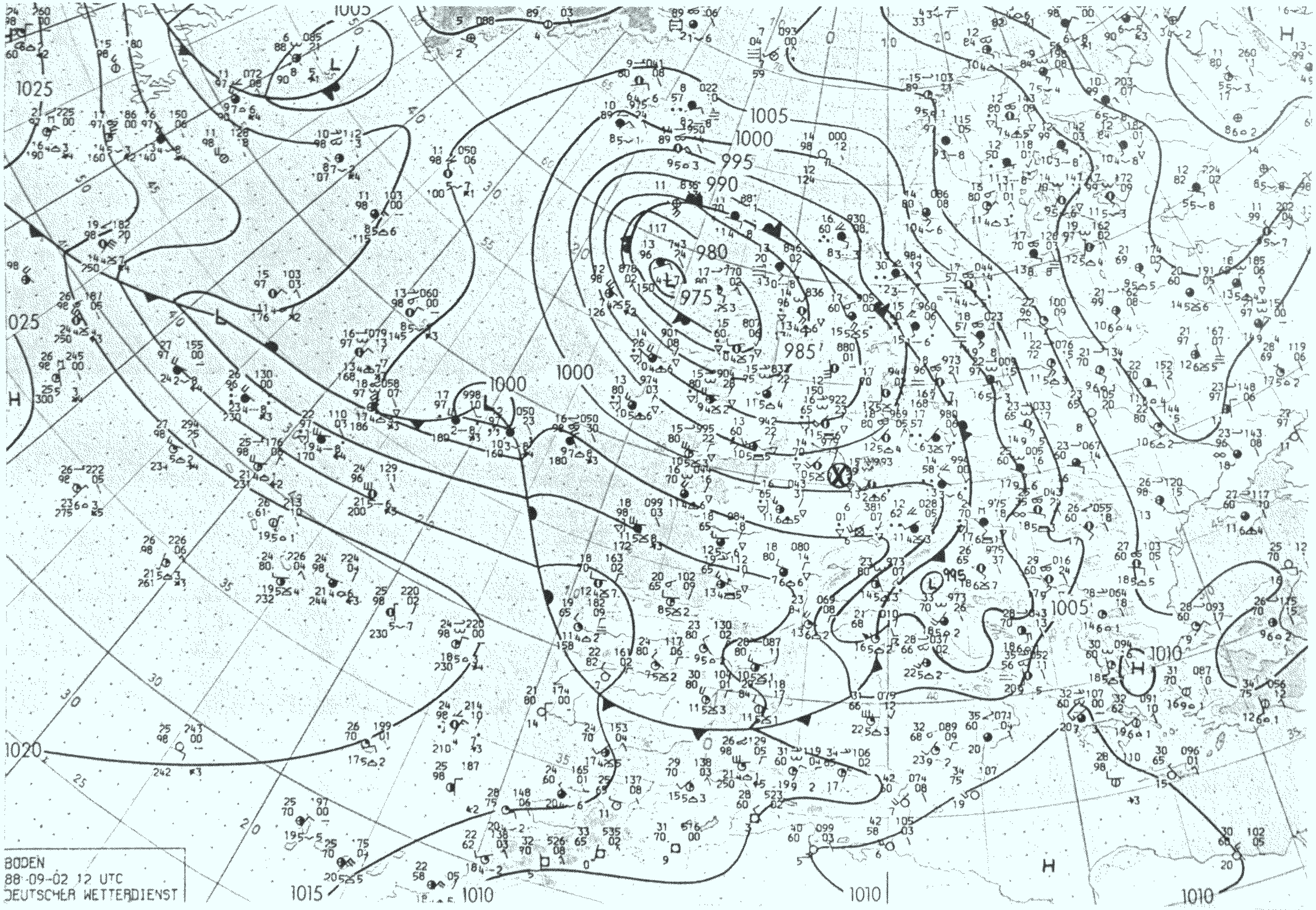


Fig. 3.6: Surface chart of Sept. 2, 1988, 12:00 UTC
⊗ Area of investigation

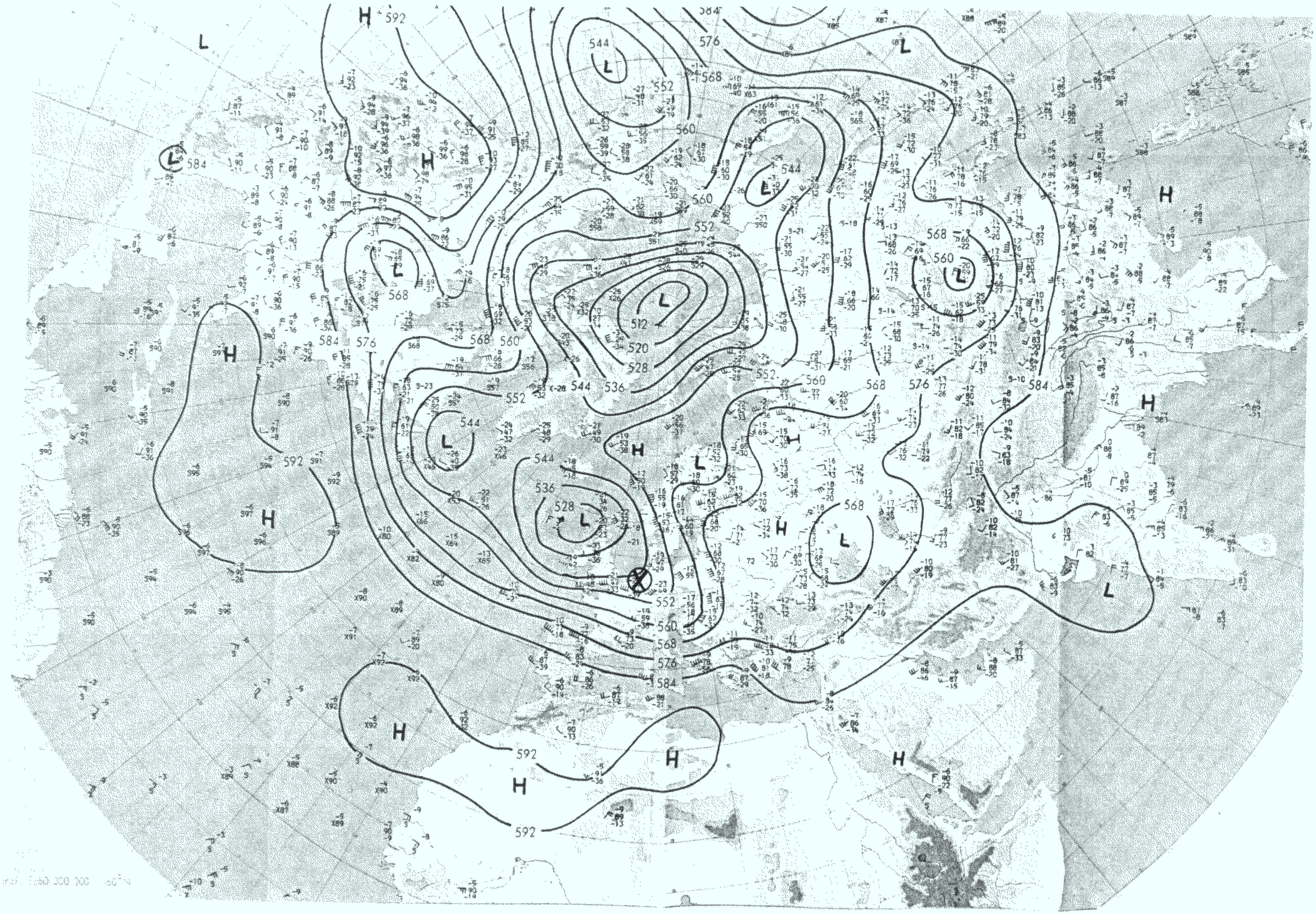


Fig. 3.7: Upper level chart (500hPa) of Sept.3, 1988, 0:00 UTC
⊗ Area of investigation

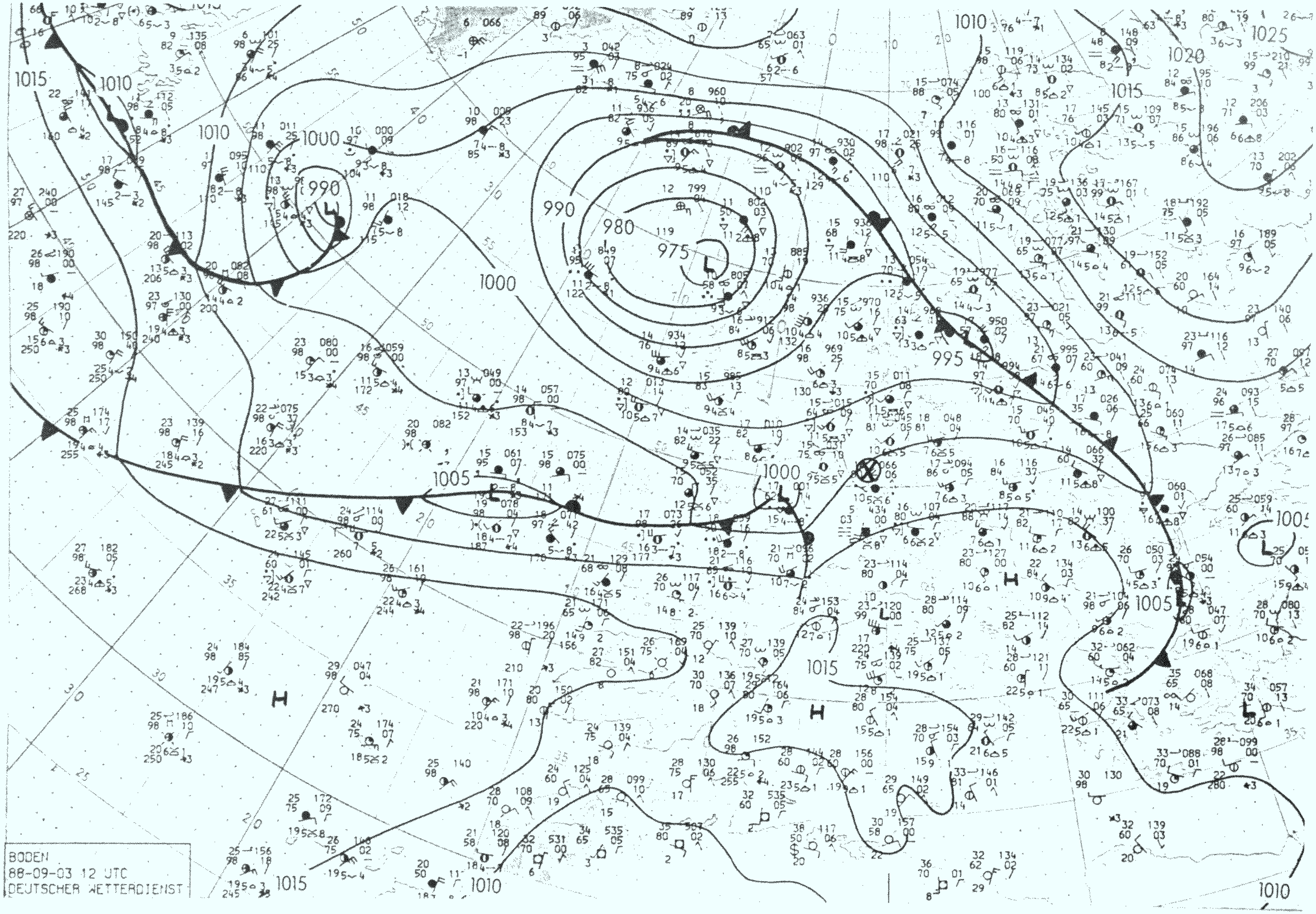


Fig. 3.8: Surface chart of Sept. 3, 1988, 12:00 UTC
⊗ Area of investigation

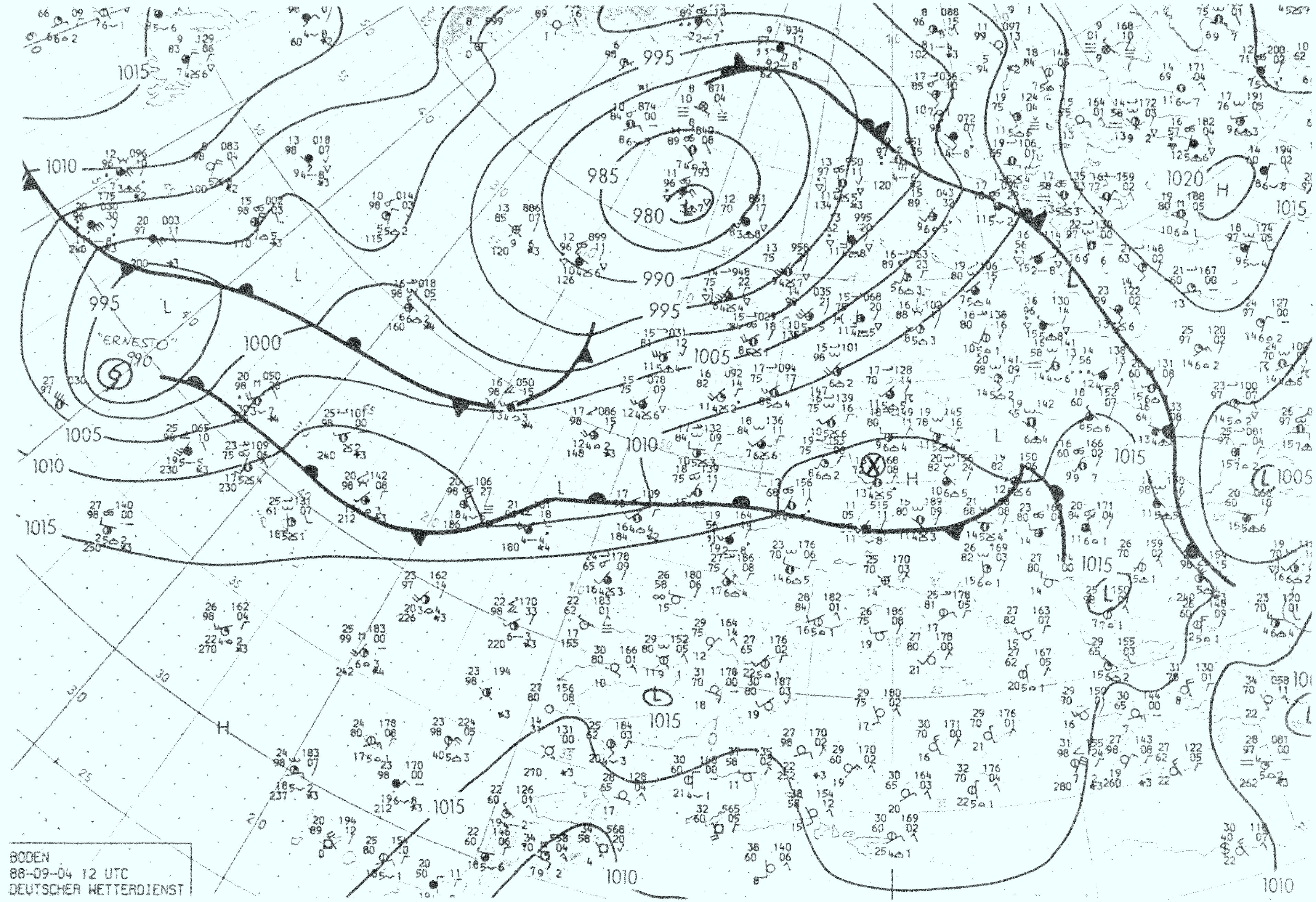


Fig. 3.9: Surface chart of Sept.4, 1988, 12:00 UTC
⊗ Area of investigation

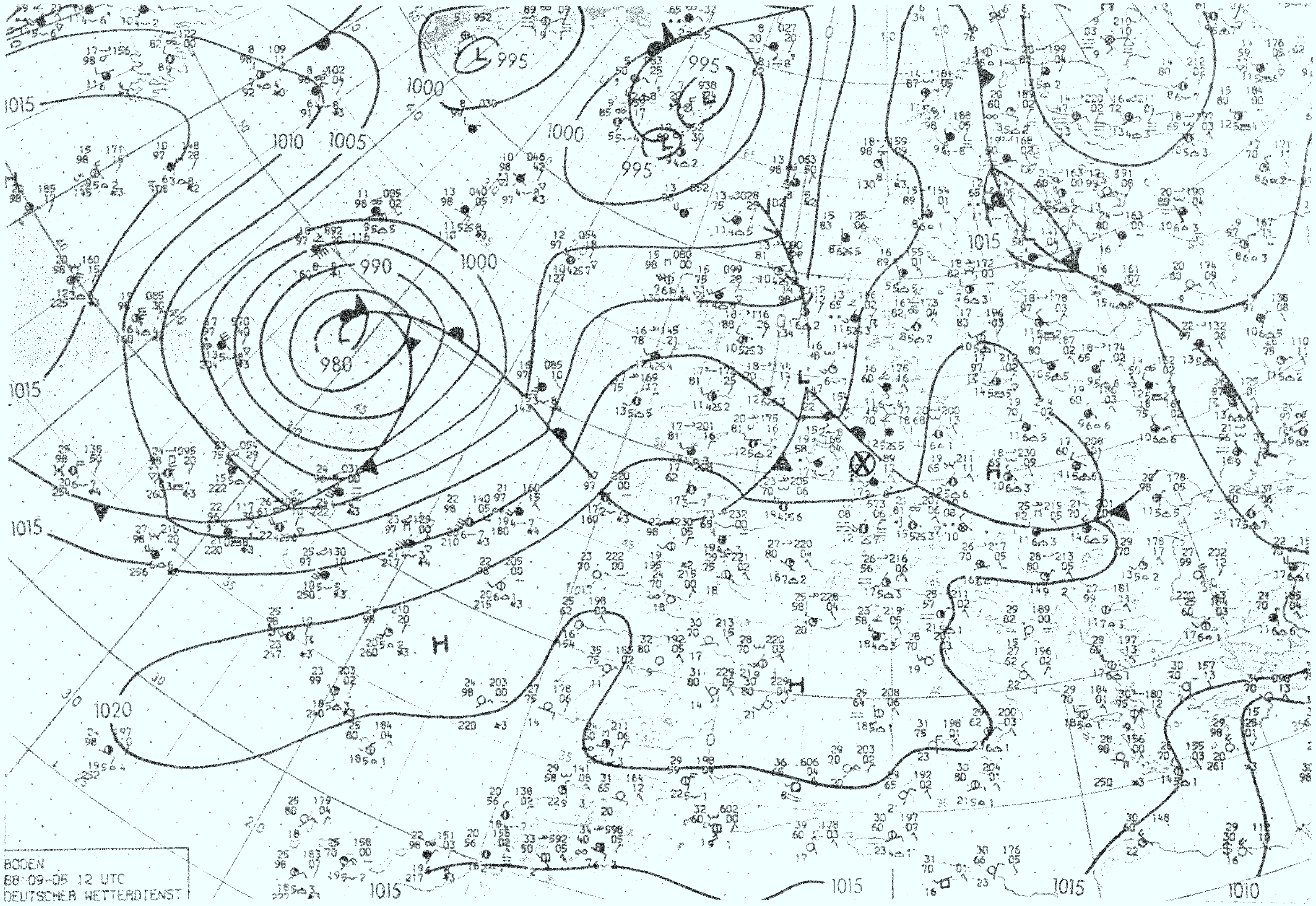


Fig. 3.10: Surface chart of Sept. 5, 1988, 12:00 UTC
⊗Area of investigation

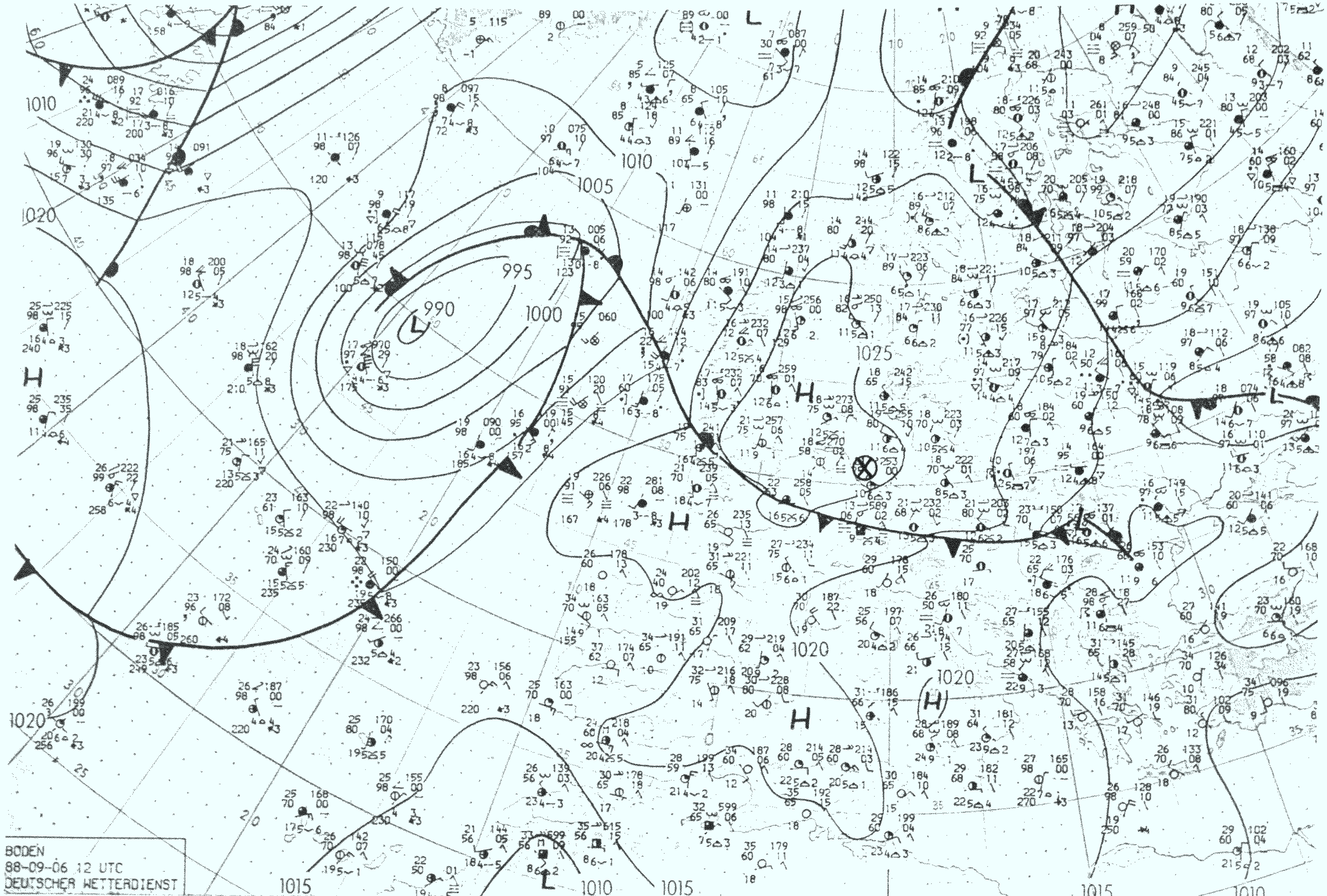


Fig. 3.11: Surface chart of Sept.6, 1988, 12:00 UTC
⊗ Area of investigation

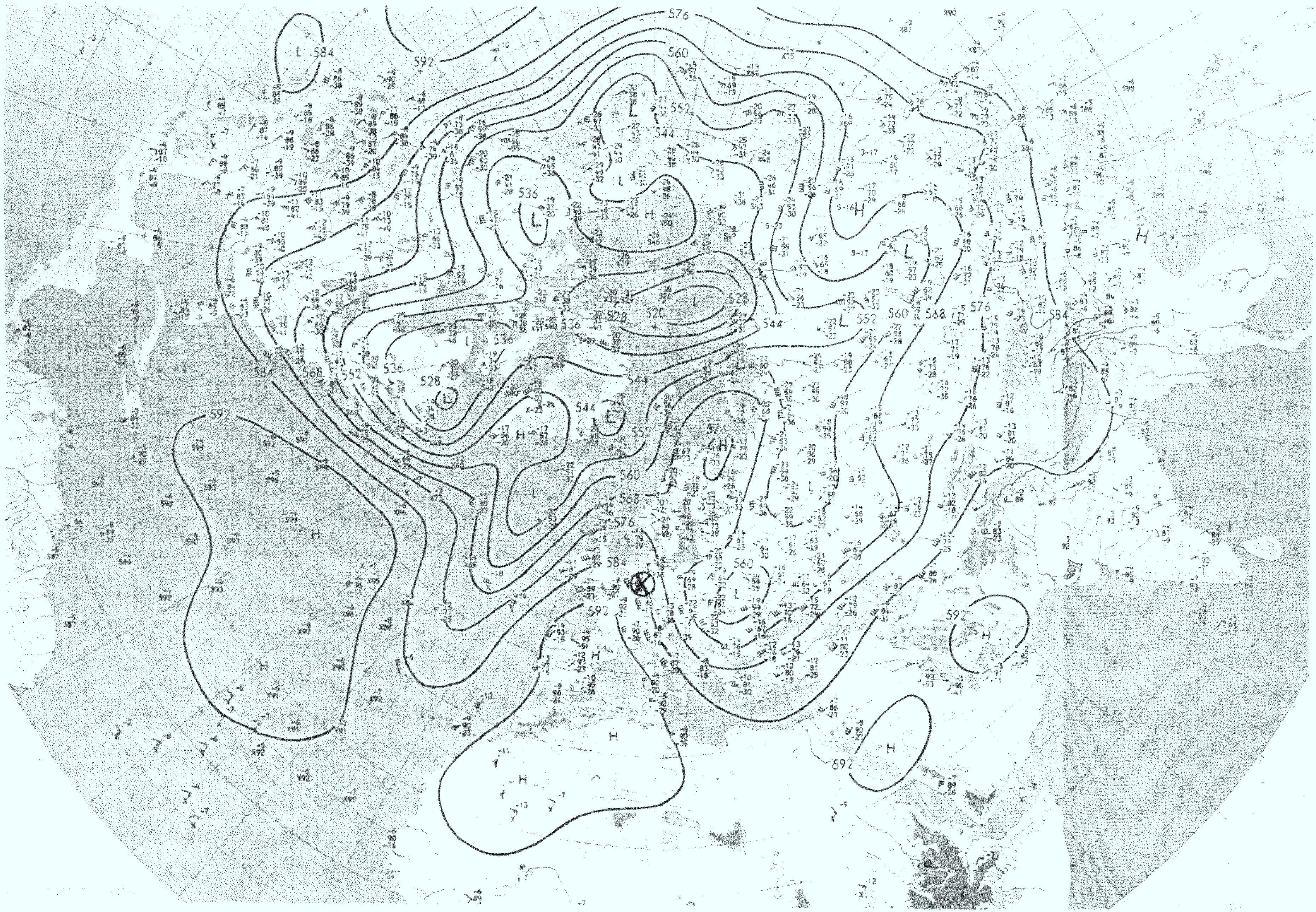


Fig. 3.12: Upper level chart (500hPa) of Sept. 7, 1988, 0:00 UTC
⊗ Area of investigation

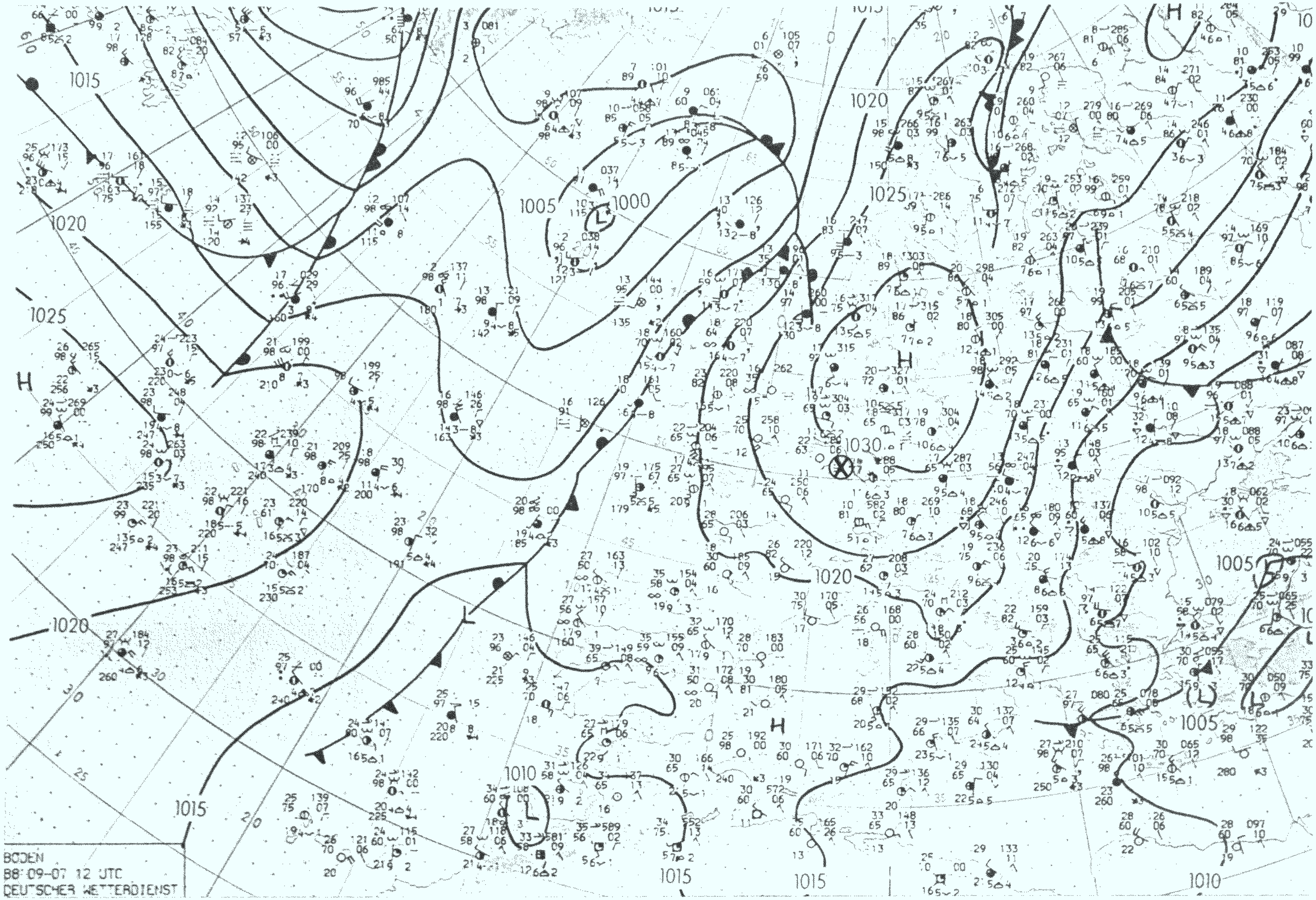


Fig. 3.13: Surface chart of Sept.7, 1988, 12:00 UTC
⊗Area of investigation

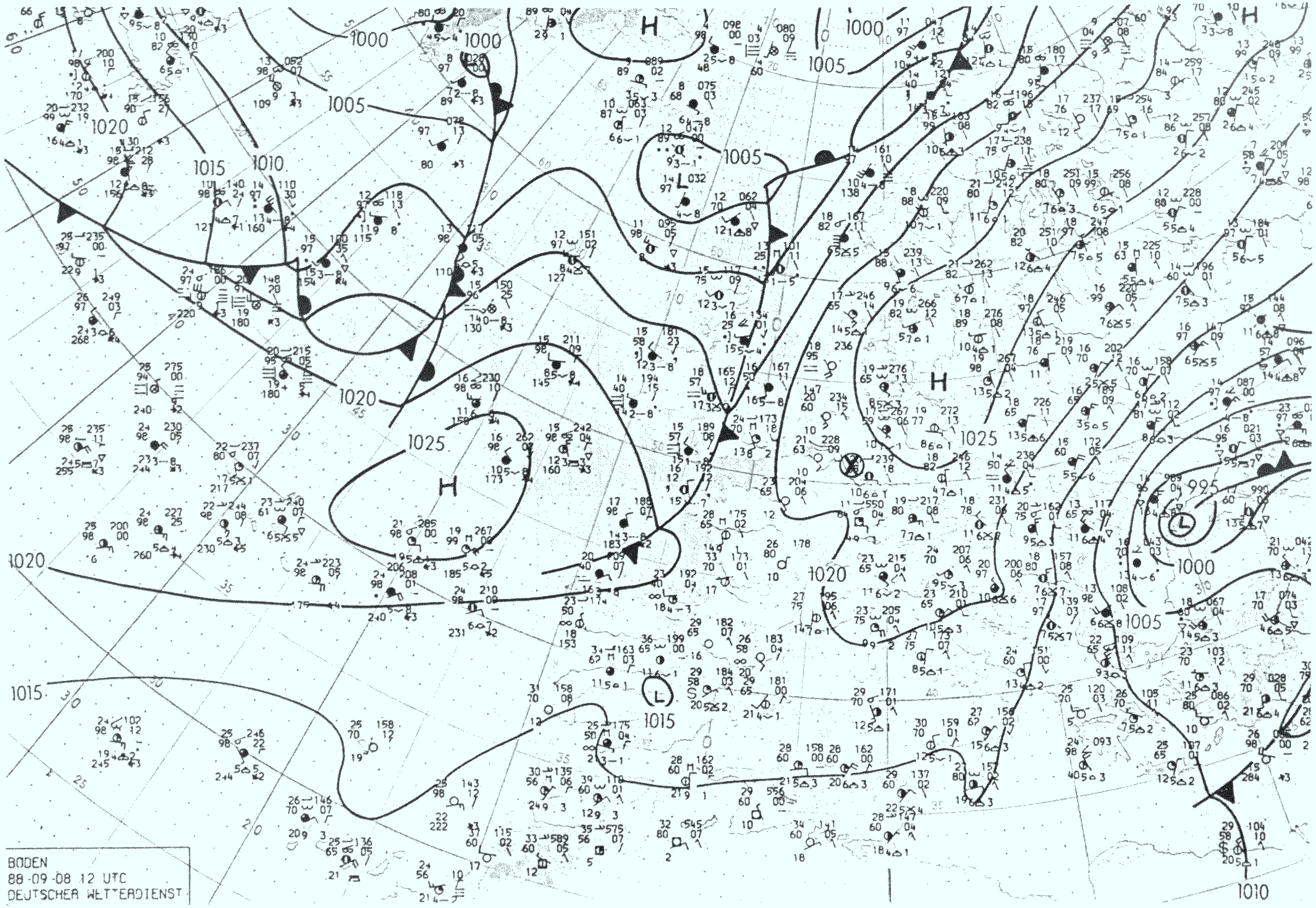


Fig. 3.14: Surface chart of Sept.8, 1988, 12:00 UTC
⊗ Area of investigation

4. TRACER MEASUREMENTS

4.1 Tracer release and sampling network

W.Voß, G.Zeuner

Earlier field experiments showed that the KFA-tower as the only tracer release point can limit the possibility of making dispersion experiments during a field campaign because one needs southwesterly winds. Therefore three additional and prefered tracer release points were selected and the tracer sampling network was extended. Under unusual weather conditions two other release positions were planned. For a special experiment at the end of the field experiment another, not planned, release point was selected. Criterion for choosing the release point was the dominant wind direction.

4.1.1 Tracer release

The tracer used for dispersion experiments is sulphurhexafluoride, SF_6. This is a chemical inert and non-toxic gas. There are no natural and only few man-made sources of SF_6. The background concentration of SF_6 usually is very low, around 1 ppt (10^{-12} parts per part; = 6.36 ng/m^3 at 0°C and 976 mbar). The measured background concentration at the experiment site was 13 $\pm$ 5 ng/m^3. The background concentrations during the experiments are listed in Tab. 4.1.1.

Experiment No.	III-1	III-2	III-3	III-4	III-5	III-6
Background conc. (ng/m^3)	13	11	11	13	11	10

Tab. 4.1.1: SF_6-background concentrations during dispersion experiments

The tracer SF_6 is contained normally as liquid in cylinders. When a cylinder is opened, the SF_6 evaporates. For small release rates (1-3 g/s) as set in the experiments the heat from the surrounding air to the cylinder maintains sufficient evaporation and vapour pressure inside the cylinder. For high discharge intensities (10 g/s) and for prolonged emission times it is necessary to heat the cylinders and alternatively several cylinders may be linked in parallel to have a small flux from each of them.

The gasous SF_6 is emitted directly from the cylinder passing a pressure reduction valve, a stream resistance to achieve a preselected and constant emission rate and a plastic pipe to the release position.

The tracer release rate is calculated from the weight of the cylinders before and after the experiment and from the time of release.

In the actual campaign there were different release positions and rates according to the different wind directions and wind speeds. At two positions, E1 and E2 (KFA-tower, water-tower), the tracer release system was permanent installed. For the other positions the release system could be built-up just before the experiment in a mobile van.

Parallel to one SF_6 experiment the Chemical Institute of the KFA (ICH 4) carried out dispersions experiments using the aerosol-tracer cobalt-nitrate (see chapter 4.5).

The release data of the SF_6-experiments and the coordinates of the release points are given in Tab. 4.1.2 and 4.1.3.

Experiment No. date	**release point and height**	**SF_6-release rate (g/s)**	**release time CET**	**sampling time CET**	**No. of units***
III-1-1 08/30/88	E1	2.5	14:00-16:30	15:00-15:30	124
III-1-2 08/30/88	KFA-tower	2.5		15:30-16:00	137
III-1-3 08/30/88	50 m	2.5		16:00-16:30	131
III-2-1 08/31/88	E1	2.0	18:00-20:30	19:00-19:30	141
III-2-2 08/31/88	KFA-tower	2.0		19:30-20:00	133
III-2-3 08/31/88	50 m	2.0		20:00-20:30	142
III-3-1 09/03/88	E1	2.0	05:30-08:00	06:30-07:00	135
III-3-2 09/03/88	KFA-tower	2.0		07:00-07:30	137
III-3-3 09/03/88	50 m	2.0		07:30-08:00	132
III-4-1 09/04/88	E1	1.6	11:00-13:30	12:00-12:30	146
III-4-2 09/04/88	KFA-tower	1.6		12:30-13:00	149
III-4-3 09/04/88	50 m	1.6		13:00-13:30	148
III-5-1 08/05/88	E2	1.7	19:00-21:30	20:00-20:30	112
III-5-2 09/05/88	water-tower	1.7		20:30-21:00	113
III-5-3 09/05/88	47 m	1.7		21:00-21:30	113
III-6-1 09/07/88	E7	0.14	19:00-21:30	20:00-20:30	132
III-6-2 09/07/88	Mast 5	0.14		20:30-21:00	134
III-6-3 09/07/88	2 m	0.14		21:00-21:30	133
* units without failure					

Tab. 4.1.2: SF_6-tracer release data

release point	**coordinates**			
	Gauß-Krüger		**height in m**	
	x (E-W)	**y (N-S)**	**above ground**	**above MSL**
KFA-tower	28847	41742	50	141
Water tower	28379	44095	47	155
Mast 5	31085	44880	2	273

Tab. 4.1.3: Coordinates of the release points used in the experiments

4.1.2 Tracer sampling network

From the six selected tracer release points, named, Ex, x=1,...,6 (see Fig 4.1.1 and the following Tab. 4.1.4), the points E1 - E4 had been the preferred ones for the dispersion experiment, because they allowed to set up a dense sampling network on the windward side of the hill. The emission points E5 and E6 had the disadvantage that the mining area prohibited the installation of sampling units on a large part of the windward side of the hill. During planning of the campaign these two points were only considered for the case that no dispersion experiment under stable atmospheric conditions was possible for a longer period (more than 3 days), and because winds from southeasterly directions are statistically very frequent for stable stratification in this region.

Emission point	**Emission height (m)**	**Location**	**Necessary wind direction**
E1: KFA-tower	50	KFA	210°-250°
E2: Watertower	45	Stetternich	260°-280°
E3: Fire-ladder	30	In the south of Welldorf	300°-330°
E4: Fire-ladder	30	In the west of Höllen	350°- 20°
E5: Fire-ladder	30	In the south of Lich/Steinstraß	90°-120°
E6: Fire-ladder	30	Playing Field Hambach	160°-170°

Tab. 4.1.4: Tracer release points planned for dispersion experiments

The existing sampling network for release point E1 was extended so that about 150-155 sampling positions could be used during a dispersion experiment. For the release points E2 - E4 new sampling networks were built up. For each of these release points (E1 - E4) between 100 and 150 positions were marked on roads or pathways with an azimuthal distance of $\simeq 5°$ as seen from the release. The distance from the release point to the sampling positions varied between 0.1 and 11 km. This, for the tracer release point KFA-tower, lay in the range where tracer experiments were carried out for flat terrain in the seventies.

The marked positions on the "Bermen" of the hill have been numbered clockwise from the southeastern to the northeastern part of the hill as indicated in Tab. 4.1.5

Marking points Sophienhöhe	Location
100-199	Base of the hill
200-299	Berme 125
300-399	Berme 150
400-499	Berme 185
500-599	Berme 220
600-699	Berme 240
700-720	Top

Tab. 4.1.5: Allocation of position numbers to the location of the hill

Numbers smaller than 100 or greater than 1000 were reserved for sampling positions outside the hill. As an indication for the mean distance of roads, pathways or "Bermen" to the release point the sampling points were assigned to rings (arcs), see for example Fig. 6.1.7. Ring 1, for example, is closest to the release point. During an experiment up to 13 sampling units were placed on one ring, thus assuming the tracer axis lay in the middle of the sampling network, a 60° azimuthal spread of the plume was covered.

Because so many sampling units were available, additional measurements on 10 positions (which did not belong to the sampling network) were made. The positions were selected the last hour before the start of sampling considering actual measurements of the plume. This was done by the RISØ group in cooperation with APL who measured SF_6 with the mobile tracer-analyzing system before the sampling started. With this method additional valuable measurements were possible on positions not covered by the sampling network.

Five experiments could be made with E1 and E2 as release points. During the last days of the campaign the wind direction shifted to east, so none of the six emission points was appropriate for an experiment. Therefore for the last experiment the position of Mast 5 at the top of the hill was chosen as tracer release point (E7 in Fig. 4.1.1 and Tab. 4.1.3). The release height was 2 m. The sampling units were placed on either marked positions of the existing sampling networks or on additional positions marked during the experiment.

In the following the sampling network for the release points E1 and E2 is described in more detail.

Description of the South-West Network (tracer release point E1)

For wind directions between 210° and 250° the tracer has been released from point E1 (KFA tower, about 2 km from the hill) at a height of 50 m. The sampling points were located on 14 rings northeast of the KFA-tower. As seen from the KFA-tower the approximate azimuthal distance of the sampling points on a ring was 10° for ring 1 and 2 and otherwise generally about 5°. Fig. 4.1.1 gives an overview of the sampling positions on rings 1 - 13. Ring 14 is too far away to the release point to be included in this figure.

Most of the sampling positions (≃ 130-150) shown in Fig. 4.1.1 were used. A dense sampling network was set-up on ring 4, ring 6 (Berme 125), ring 9 (Berme 220) and ring 13 (leeside of the hill).

A summary of the sampling network is given in Tab. 4.1.6 a-c, where 'short-range' means the region in front of the hill up to about 2 km from the release position:

a) Short-range

The short-range has four rings:

Ring	Sampling points	Number of sampling points	Dispersion direction	Description/Location
1	1102-1108	7	20°-80°	First street close and northeast of KFA-tower
2	1302-1308	7	20°-80°	KFA fence
3	2-8	13	20°-80°	Forest path outside the KFA terrain
4	12-19, 21, 22, 98, 99	18	10°-90°	Street L 12 n KFA-Stetternich, old B 55 to the west of the hill, private road Rheinbraun

b) Sophienhöhe

The sampling points are on 8 rings (ring 5-12):

Ring	Sampling points	Number of sampling points	Dispersion direction	Description/Location
5	120-135	13	20°-80°	Base of the hill (wind ward side)
	101-116	4	65°-80°	Base of the hill (leeside, southeastern part of the hill)
6	220-237	13	20°-80°	Berme 125
7	321-326	6	50°-75°	Berme 150 (windward side)
	300-319	4	60°-75°	Berme 150 (leeside, southeastern part of the hill)
8	426-430	5	30°-50°	Berme 185
9	523-538	9	25°-65°	Berme 220 (windward side)
	506-521	3	60°-80°	Berme 220 (leeside, southeastern part of the hill)
10	602-639	11	25°-65°	Berme 240
11	704-714	7	30°-45°	Top
12a	662, 664, 670	3	30°-40°	Berme 240 (leeside, northeast)
12b	247-286	7	20°-50°	Berme 125 (leeside, northeast)

c) Leeside of the hill

The sampling points are on ring 13 and ring 14:

Ring	Sampling points	Number of sampling points	Dispersion direction	Description/Location
13	30-36	12	15°-70°	Street K 35 at the western fringe of Güsten, L 213 in direction to Höllen, L 12 Höllen- Lich-Steinstraß
14	40-49	10	30°-75°	Street northeast of Rödingen to Kirchtroisdorf, Kirchtroisdorf-Niederembt-Esch- Escherbrück

Tab. 4.1.6: Sampling network Southwest

Description of the West-Network (tracer release point E2)

If the forecasted wind direction was between 260° and 280° the water tower could be used as emission point. The water tower is located in the north of Stetternich and with its shortest distance of 1250 m west of the Sophienhöhe. The meteorological measurements at the KFA-tower, 2.4 km south of the water tower, were regarded as representative for this emission point. The emission source was at the southern side of the water tower, 1.5 m away from the building, at the height of 47 m. There the least influence of vortexes was expected.

The sampling points east of the water tower were marked on 12 rings with an azimuthal distance of ≃5°. At about 120 positions sampling stations were set-up. Fig. 4.1.1 shows the sampling positions for ring 1-11. A dense sampling network (i.e. azimuthal distance as seen from the water tower of ≃5°) was set up on ring 1 and 2, ring 4 (Berme 125), ring 7 (Berme 220) and ring 11 (leeside of the hill).

A summary of the sampling network is given in the following Tab. 4.1.7 a-c:

a) Short-range

The short-range has two rings:

Ring	Sampling points	Number of sampling points	Dispersion direction	Description/Location
1	6060-6120	13	60°-120°	L 213 Stetternich- Werhahnhof
2	60-66	13	60°-120°	L 12 n, new street Stetternich-Welldorf

b) Sophienhöhe

The sampling points are on 8 rings (ring 3-10)

Ring	Sampling points	Number of sampling points	Dispersion direction	Description/Location
3	101-151	18	50°-130°	Base of the hill (windward side and southeastern part of the hill)
4	223-246	15	55°-120°	Berme 125
5	330-344	11	60°-110°	Berme 150
6	428-444	11	60°-110°	Berme 185
7	506-544	16	60°-120°	Berme 220
8	624-640	10	75°-115°	Berme 240
9	703-714	7	70°-100°	Top
10	266-287	5	60°- 80°	Berme 125

c) Leeside of the hill

The sampling points are on ring 11 and ring 12:

Ring	Sampling points	Number of sampling points	Dispersion direction	Description/Location
11	32-36	9	50°-95°	Leeside of the hill (Höllen- Lich-Steinstraß)
12	43-49	7	55°-90°	Leeside of the hill (Kirchtroisdorf-Esch-Escherbrück)

Tab. 4.1.7: Sampling network West

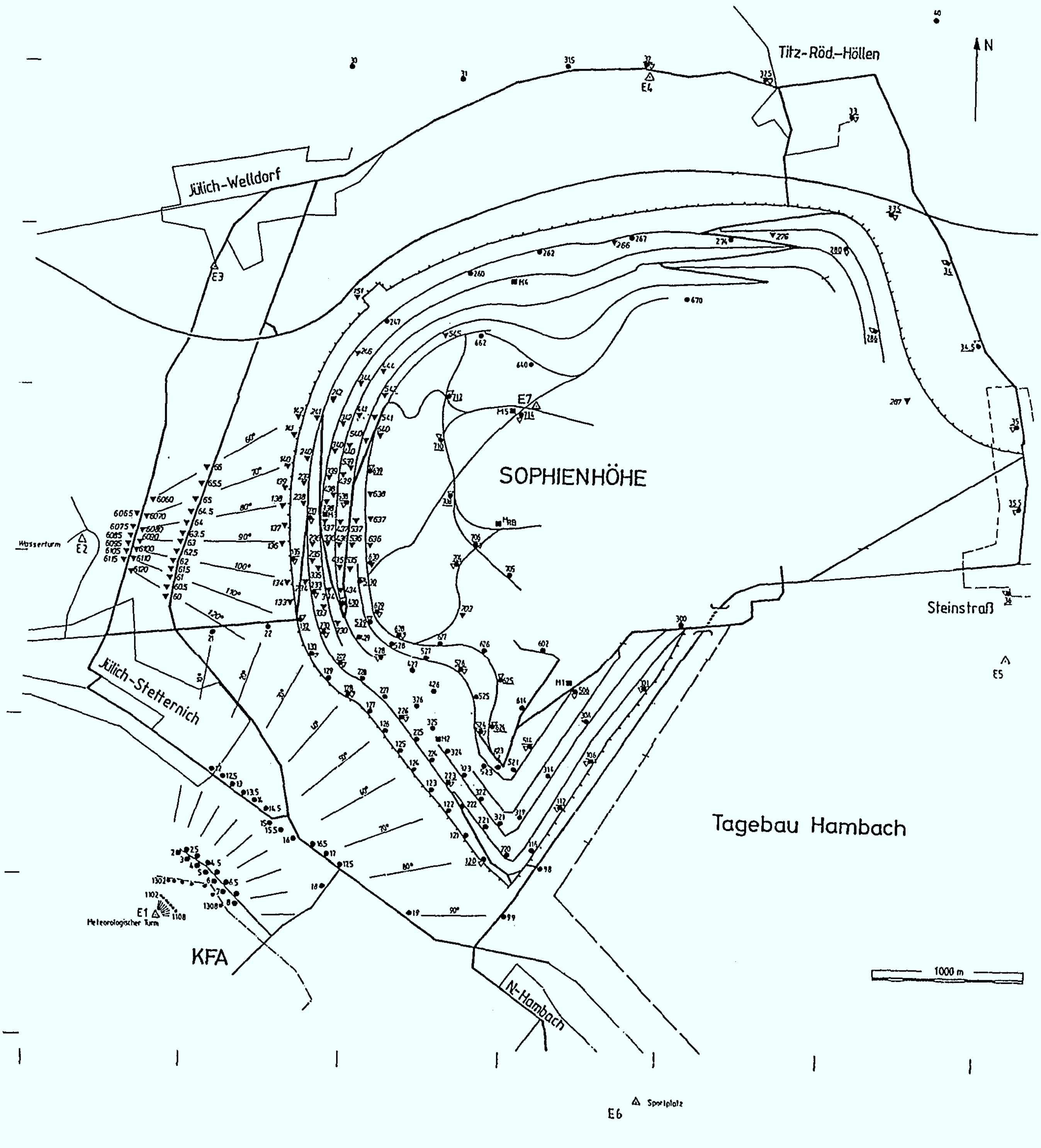


Fig. 4.1.1: Tracer sampling points for network southwest (•), network west (▼), both networks southwest and west (•▽); E1 - E7 Tracer release points

4.2 SF_6-Tracer measurements by KFA-Group

W.Voß

4.2.1 The tracer sampling equipment

For the tracer sampling there were 3 different sampling equipments:

4.2.1.1 Ispra sampling unit "POLYP" from the Ispra Tracer Group, Joint Research Centre

This is a battery operating automatic device, which can collect up to 8 samples, starting from a prefixed time and running for fixed preselectable time intervals. Fig. 4.2.1 shows one of these units, see also Gassmann (1986).

4.2.1.2 Sampling unit "Wasserstation" KFA

Fig. 4.2.2 is showing one of the samplers in the field experiment and Fig. 4.2.3 shows a schematic drawing.

The plexiglas cylinder (3) is completely filled with water. By opening the stopper (8) the water is pouring and the air runs through the valve (4), switched by a preset digital switch timer (6), passes a capillary tube (5) and will be stored in the plexiglas cylinder (3). After the experiment the cylinder is closed by the stopper and in the laboratory the air is passed into the gaschromatograph over the septum (9) by filling up the cylinder with water through the ventilation pipe (10). Power is available by the power supply (7) with non-rechargeable batteries.

4.2.1.3 Sampling unit "automatischer Probensammler" KFA

A schematic drawing of the sampling unit is given in Fig. 4.2.3. Fig. 4.2.2 shows one of the units in the field experiment.

The air is sucked into an aluminium coated plastic bag with valves (12) by a small diaphragm pump (11) with a flow rate of about 200 ml/min; passing a capillary tube (5) and the magnetic valve (4). For switching the magnetic valve there is a programmable digital timer (6). Different sample times for one week can be stored. The power to the whole unit is supplied by non-rechargeable batteries (7).

After analysing, the air bags were evacuated by a vacuum pump.

4.2.2 Tracer analysis and calibration

The tracer concentrations were analysed by means of a gaschromatograph (Siemens, type Sichromat 3) with an electron capture detector. The technical data of the equipment are the following ones:

column:	Molecular sieve 5A, 60-80 mesh, length 4 m, stainless steel 1/8″
carrier:	Purified N_2, 25 ml/min
detector:	ECD, 3.7×10^8 Bq Ni-63
temperature:	100°C
loops (range):	1ml : 0.2-2000 ppt (1-12000 ng/m³ at 20° and 1000 mbar). 100µl: 200-20000 ppt (1000-120000 ng/m³ at 20°C and 1000 mbar).

The signal output of the gaschromatograph was given into an integrator (Spectra Physics, type 4270). The reading of the integrator is directly converted to SF_6 concentration by using an internal calibration curve. A typical integrator output is given in Fig. 4.2.4. To obtain the internal calibration curve, different mixtures of SF_6 calibration dilutions (10, 30, 50, 70, 100 and 500 ng/m³) were prepared in one or two steps in 1 l or 10 l N_2 filled volume calibrated aluminium coated plastic bags with syringes of 1 or 10 ml from a Linde Primary Standard containing 105 ppb ± 10% SF_6 in N_2. Dilutions greater than 500 ng/m³ (1000, 5000, 7500, 10000, 50000, 75000 and 100000 ng/m³) were mixed with a two channel mass flowmeter/controller from Brooks Instruments using the Linde standard and N_2.

To check the response of the gaschromatograph, a dilution of 1000 ng/m³ (±10%) was measured during the campaign everyday before and after analyzing the samples from the experiments. There were altogether 24 measurements. Based on these measurements, the long term reproducibility (12 days) was better than ±4.8%.

Before and after the campaign the response of the gaschromatograph to the dilution of 1000 ng/m³ was repeated 30 times within 3 hours. Based on these measurements, the short term reproducibility was better than ±1%.

All samples from an experiment were analysed in about 1 - 1 1/2 days. The measured concentrations are estimated to be within ±11 to ±15% the true values.

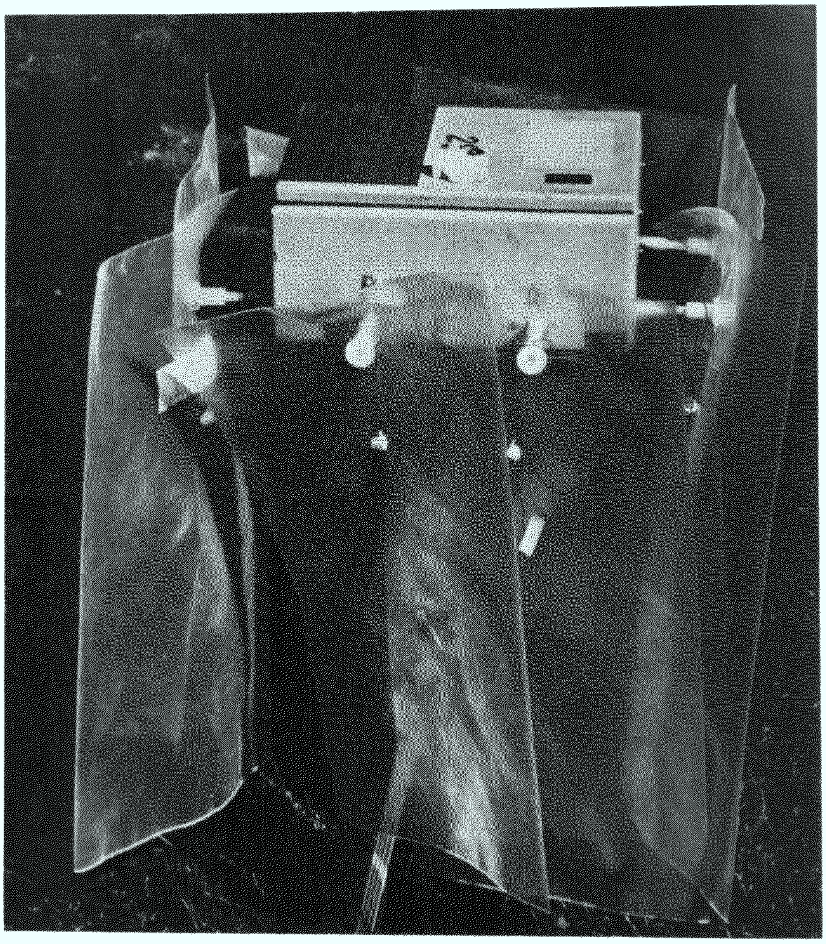


Fig. 4.2.1: Tracer sampling unit "POLYP". Up to 8 bags can be filled consecutively

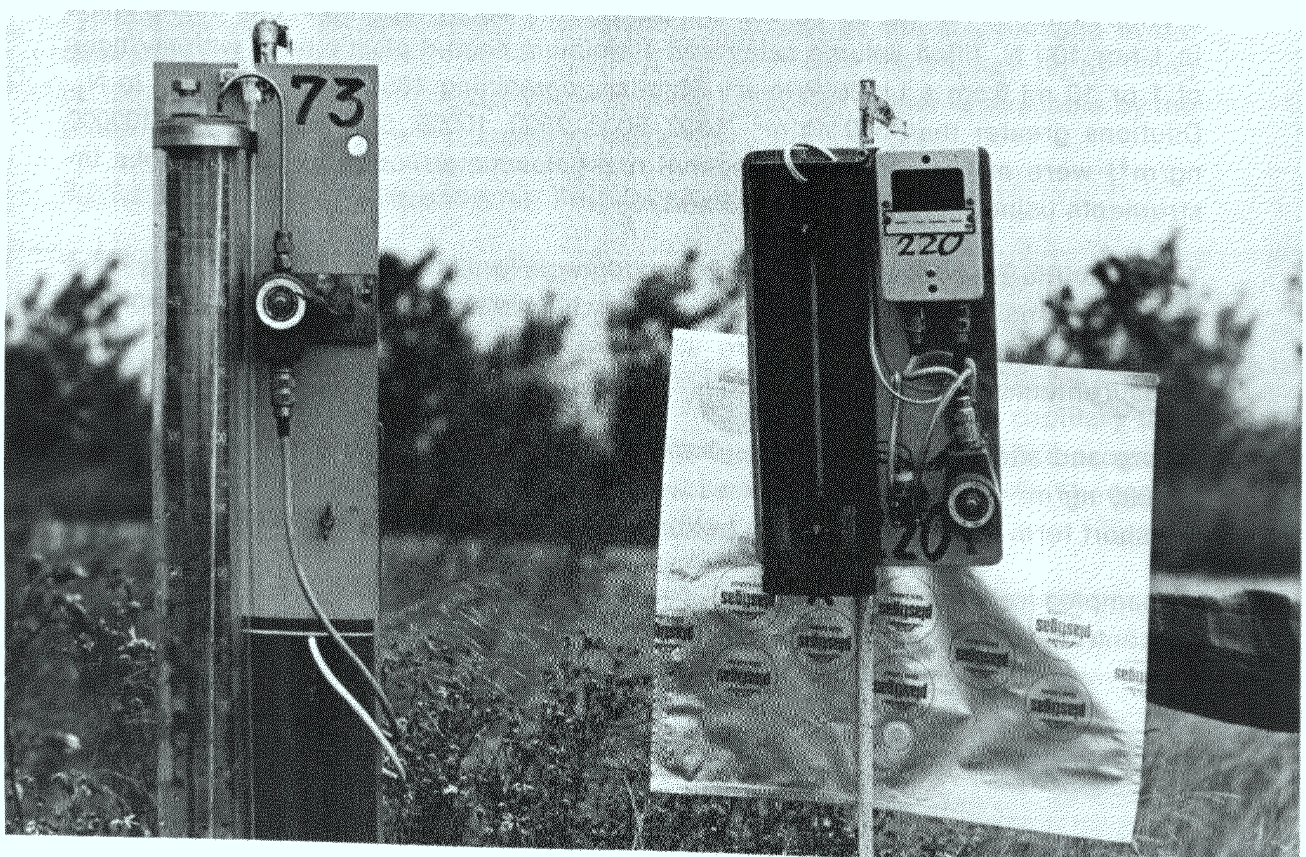
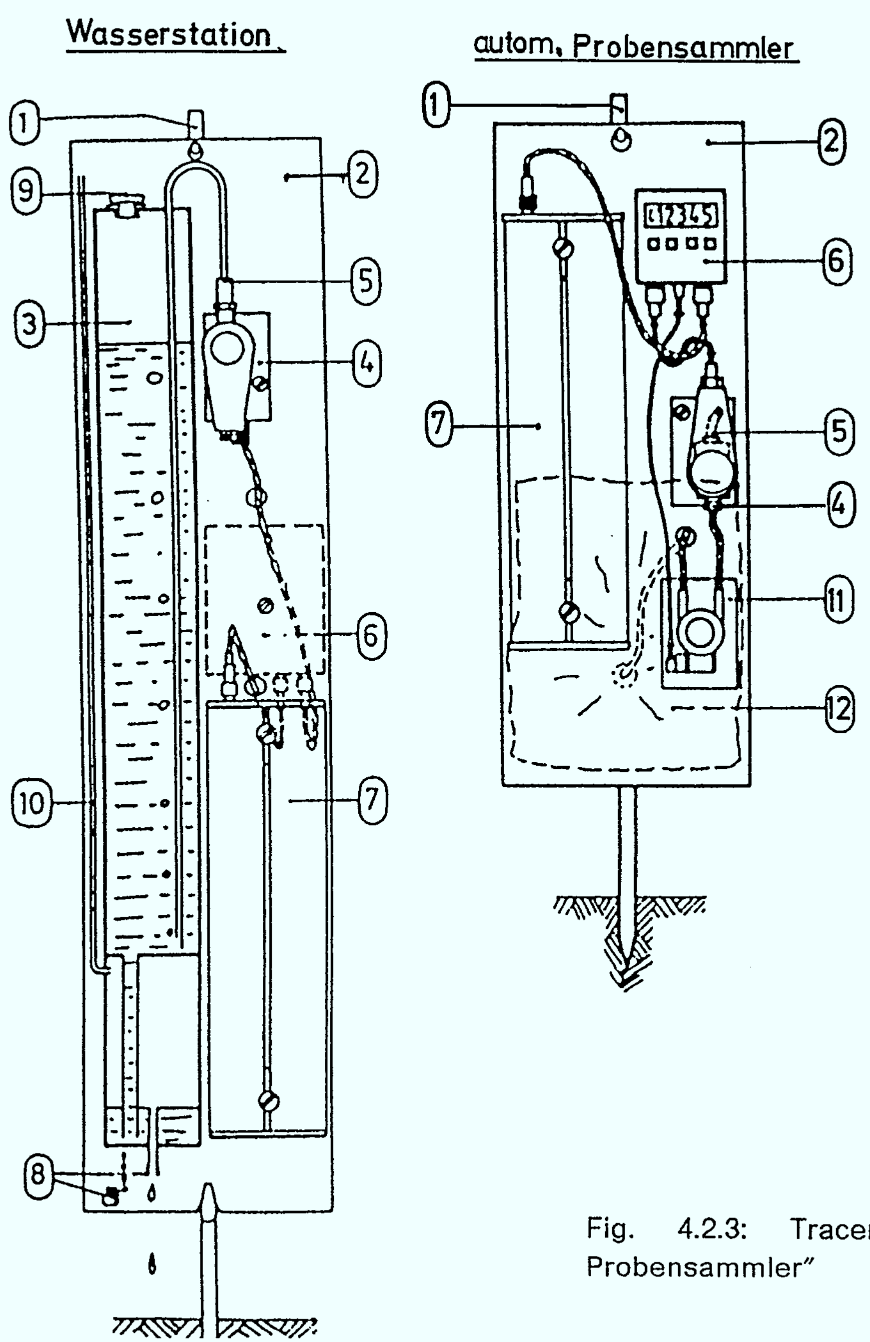


Fig. 4.2.2: KFA sampling units "Wasserstation" and "automatischer Probensammler"



Sampling units for SF-6

(1) ironstick

(2) mounting plate

(3) waterstorage made of plexiglas

(4) magnetic valve which is switched by electric pulse

(5) capillary tube

(6) digital switch timer for timing the magnetic valve

(7) battery unit

(8) water discharge with stopper

(9) water inlet screw with septum

(10) venilation tube

(11) diaphragm pump

(12) aluminium coated plastic bag

Fig. 4.2.3: Tracer sampling units "Wasserstation" and "automatischer Probensammler"

PRINT "********** 125-219-B **********
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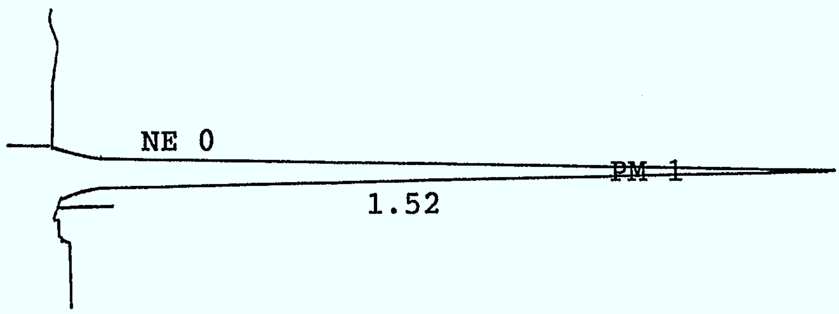
CHANNEL A INJECT 31-08-88 12:29:04



3.INT.MESSPHASE EXP.NR.1 31-08-88 12:29:04 CH= "A" PS= 3

FILE 4. METHOD 5. RUN 26 INDEX 27

ANALYST: VOSS

SAMPLE 1 10-10000NG

NAME	NG/m3	RT	AREA	BC	RF	RRT
SF6	989.104	1.52	229573	01	232.066	1.
TOTALS	989.104		229573			

Fig. 4.2.4: Typical chromatogram of the Spectra Physics integrator

4.3 SF_6-Tracer measurements by NERI-group

E. Lyck

In 1988 when the third field experiment was carried out the participating Danish tracer-group was a part of the Air Pollution Laboratory (APL) in the National Environmental Protection Agency. Since the 1st of January 1989 this tracer-group became a part of the Division of Emissions and Air Pollution in the National Environmental Research Institute (NERI) under the Ministry of the Environment.

4.3.1 Tracer sampling units

Air sampling units constructed by the Danish tracer-group are based on sampling in plastic bags. The components of the unit are contained in a box (25 x 16 x 9 cm^3) and the bags attached to outlets on this box. The box and the bags are during sampling protected by a container (Figure 4.3.1). Air is sucked in through an intake tube by a small diaphragm pump and led to one of the three plastic bags which are inflated with a flow rate of about 200 ml/min. The inflation of the bags is regulated by magnetic valves. The three plastic bags are inflated in sequence, each having a sampling time of 30 minutes. The power is supplied by a rechargeable battery. The batteries are recharged after each experiment.

The proper functioning and the flow rate of the units were controlled several times prior to and during the campaign. The number of units transported to the campaign was 56. For rechargement of batteries, control of flow and proper functioning of the sampling units, this equipment together with the laboratory gaschromatograph was installed in a laboratory at KFA.

The sampling units have two modes by which the sampling time procedure can be controlled either by radiosignals from a central position - usually the release position - sent to a receiver in the sampling unit or by an electronic timer. In this campaign the latter mode was used which means that each of the two vans that deployed sampling units was equipped with a central electronic timer for counting down until the start of the sampling period. These timers could easily be adjusted to times from 0 to 3 hours in steps of 18 minutes. The countdown period was chosen in order to have sufficient time for positioning. A typical countdown period was 2 hours 6 minutes. When mounting a unit on a sampling position, the actual countdown time was transferred from the central timer to the timer of the unit. The units were usually mounted on fences, trees or were placed on the ground (Figure 4.3.1).

The analysis of the tracer concentrations in the sample bags began usually the day after the experiment and was completed the same day. After analysing, the sample bags were emptied, flushed and checked for leaks with purified nitrogen. The sample bags were reused.

4.3.2 Tracer analysis and calibration

The tracer concentrations were measured by means of gaschromatography. The chromatographic data were as follows:

Column	: Molecular Sieve 5A, length 2 m, stainless steel 1/8″ o.d.
Carrier	: Purified N_2, 70 ml/min.
Detector	: Electron capture detector, H^3, temperature 45°, pulse interval 30 μs.

A typical chromatogram is shown in Fig. 4.3.2.

Calibration was performed by a procedure which was used in the Interlaboratory comparison of SF_6 determinations (Vanderborght, 1984) carried out before the actual experimental campaign. Briefly, calibration samples are prepared by one-step dilutions from a Matheson Primary Standard containing 1 ppm ±1% SF_6 in N_2. About 5 l of purified N_2 are metered into a 10 l Tedlar bag equipped with a Teflon-lined septum. The appropriate volume of primary standard is injected by means of a glass/teflon syringe. The accuracy of the concentrations of test dilutions calibrated by this procedure is estimated to about ±10%.

In order to be able to check the sensitivity of the gaschromatograph during the campaign two test dilutions of SF_6 in N_2 were prepared in one liter steel cylinders pressurized to about 7 bar. These test dilutions were in the concentration range normally used in our tracer experiments, and their actual concentrations were determined by the calibration method described above. Calibration including determination of the concentration in the steel cylinders was carried out in our own Danish laboratory before and after the campaign.

The gaschromatograph is linear to at least 1000 ppt. Intercomparison of tracer analyses with the other groups was carried out (see appendix).

4.3.3 Laboratory gaschromatograph

The laboratory gaschromatograph was used to analyse the sample bags from the experiments. It was installed in a laboratorium at the KFA.

During the campaign the response of the gaschromatograph to one of the steel cylinder standards was repeated 30 times. This cylinder standard contained 120 ppt (±10%). Based on these 30 measurements, the long term (10 days) reproducibility is ±3.2%.

All samples from an experiment were analysed in about 8 hours. Repetitions of the cylinder standard during these 8 h give a short term reproducibility (precision) for each experiment, see Table 4.3.1.

The peak height values of the chromatograms of the samples from the experiments (Figure 4.3.2) were measured by hand. These peak heights were converted to concentrations on the basis of the mean value of the chromatograms of the cylinder standard measured during the analysing date.

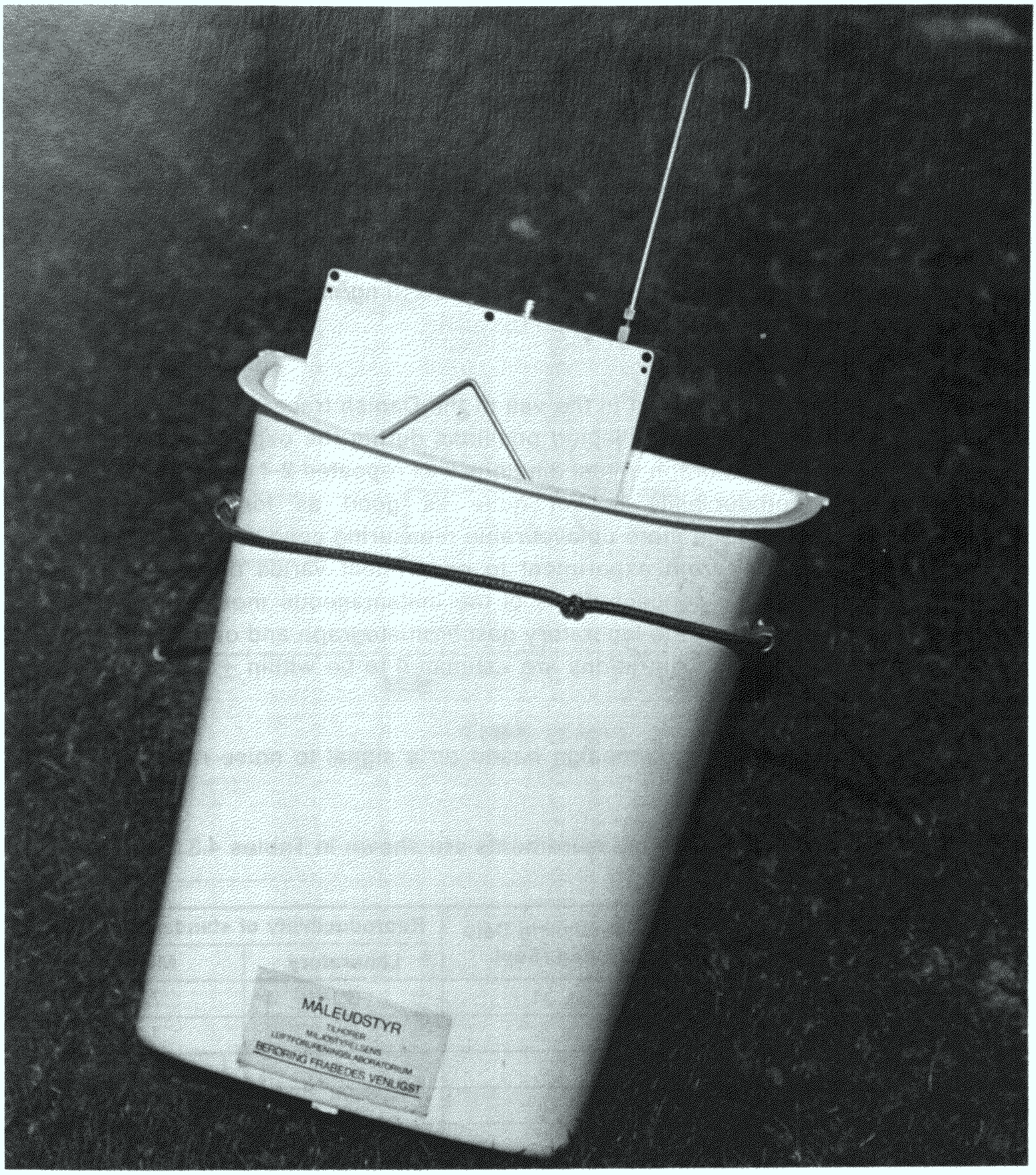


Fig. 4.3.1: A sampling unit positioned for sampling.

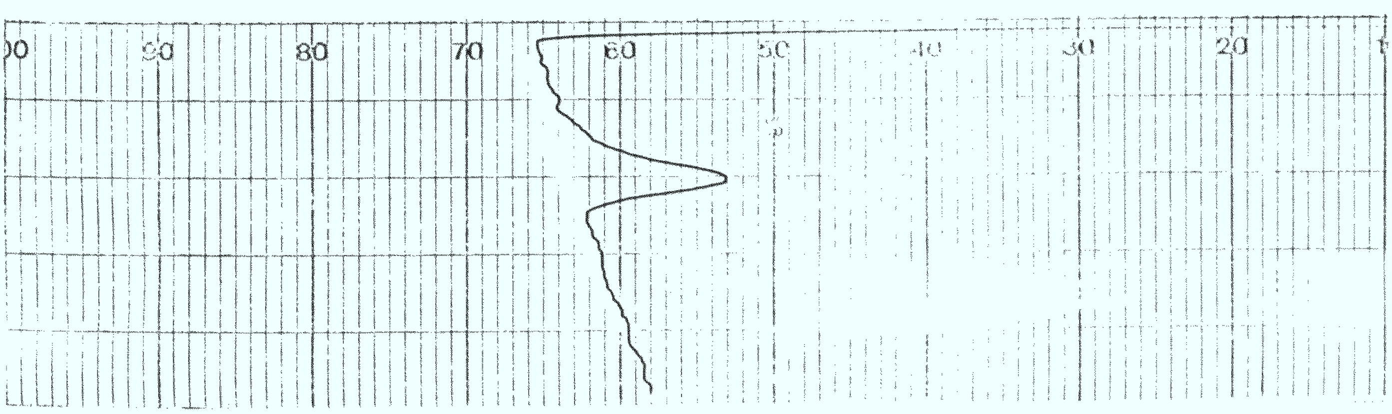


Fig. 4.3.2: The chromatogram (laboratory gaschromatograph) of the 30-min. sample from experiment 1 position 126. The concentration is 97 ng/m³.

Referring to the accuracy of about ±10% stated above and the precision of ±1 to 2.2% the measured concentrations are estimated to be within ±10 to ±12% the true values.

The detection limit during the campaign of the laboratory gaschromatograph based on a signal to noise ration of 2 was around 1.5 ppt (≃10 ng/m^3).

4.3.4 Mobile gaschromatograph

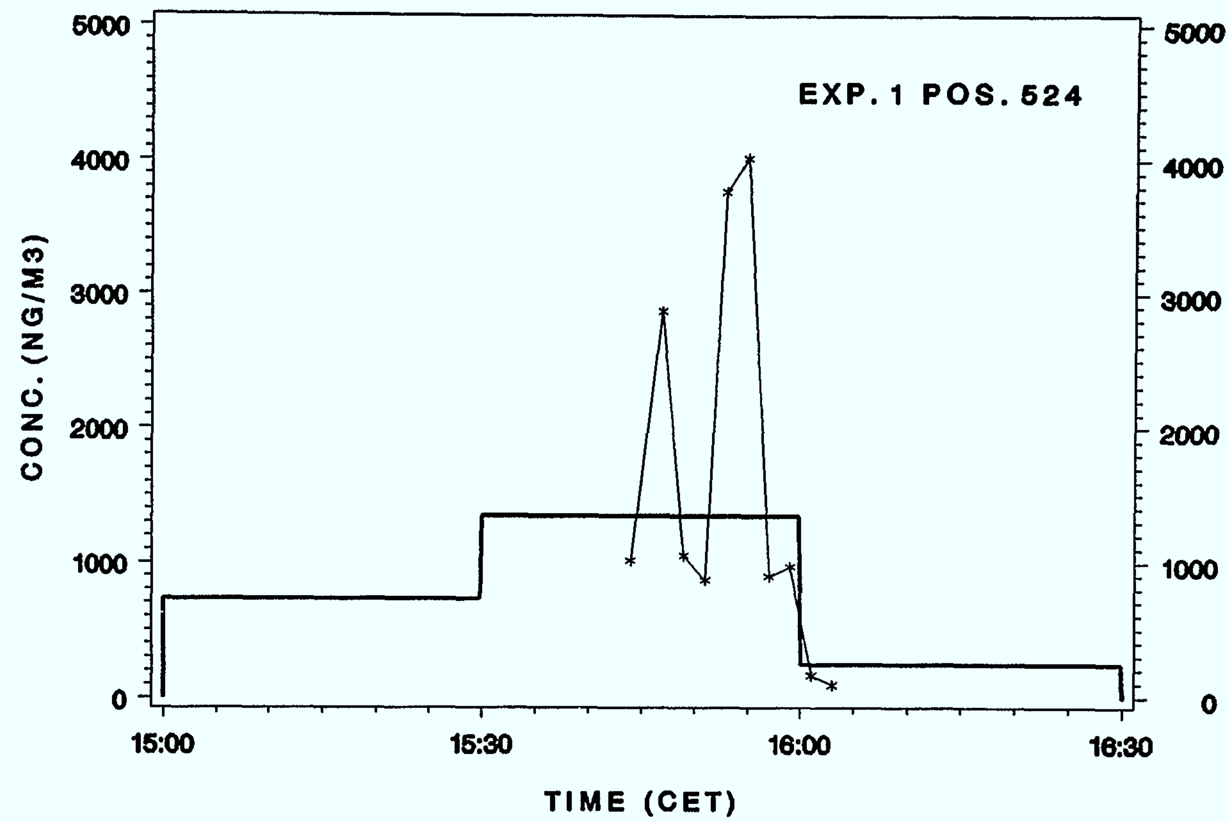
A gaschromatograph was mounted in the van of the Danish tracer group to measure instantaneous concentrations at selected positions during the experiments. The response of this gaschromatograph to test dilutions was repeated 2-4 times during each experiment. The reproducibility is not quite as good as for the laboratory gaschromatograph due to the more unfavourable measuring conditions in a van. The short term reproducibility from experiment to experiment varies between ±1.3 to ±12.2% (Table 4.3.1). The concentrations of the instantaneous measurements are found in the same way as for the laboratory gaschromatograph and on this basis the measured instantaneous concentrations are estimated to be within ±10 to ±16% of the true values.

The detection limit during this campaign based on a signal to noise ratio of 2 was around 2.5 ppt (≃15 ng/m^3).

The instantaneous concentration measurements are shown in Tables 4.3.2 - 4.3.7

Experiment No.	Date Aug./Sept.	Analysing Date Aug./Sept.	Reproducibility of standard (± %)	
			Laboratory	Mobil
III-1	30	31	3.1	7.8
III-2	31	1	2.2	1.3
III-3	3	3	1.5	9.9
III-4	4	5	0.7	6.0
III-5	5	6	2.0	12.2
III-6	7	8	1.0	1.8

Tab. 4.3.1: Performance of the laboratory and mobil gaschromatographs



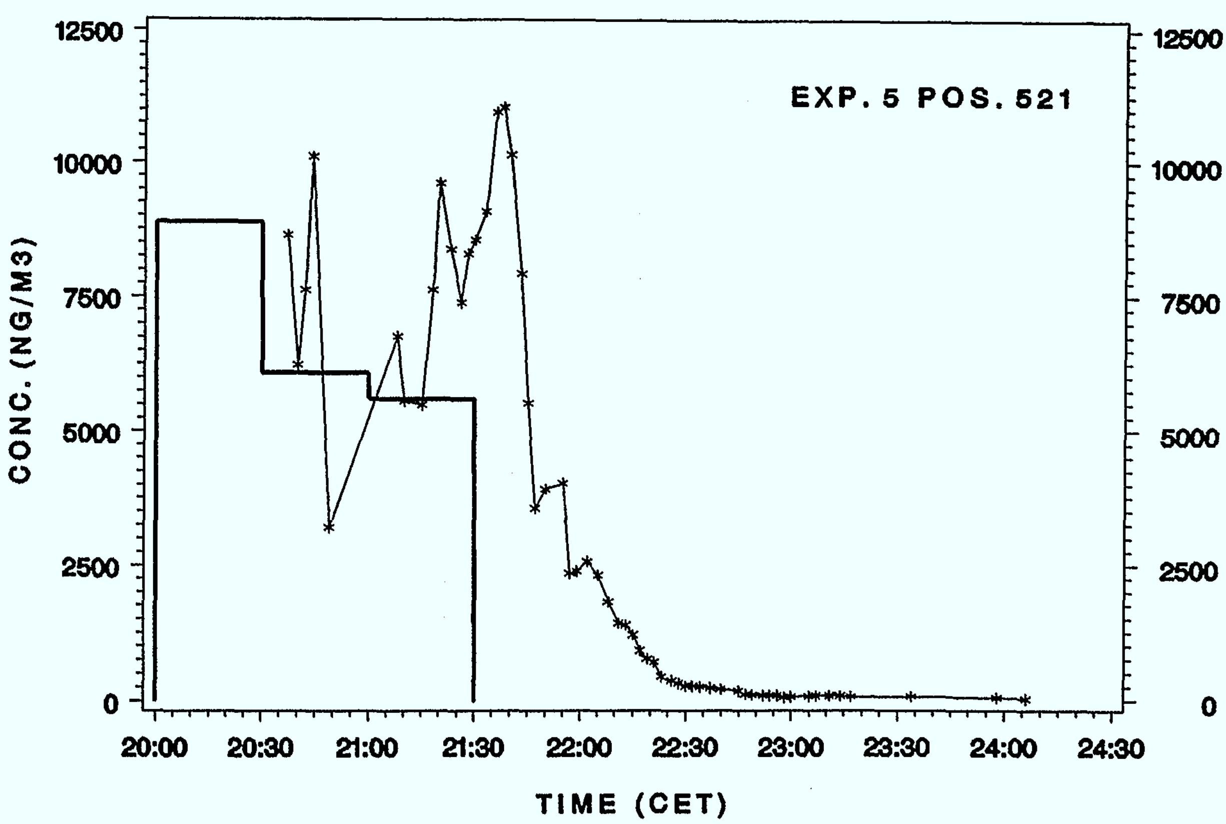


Fig. 4.3.3: Examples of instantaneous SF_6 tracer concentration (stars and thin line) in one position as function of time and time-averaged concentration (broad line) in the same position.

Table 4.3.2: Instantaneous sulphurhexafluoride concentrations for experiment III-1, 30.08.1988

Time CET	Position	Polarcoordinates		Height (m m.s.l.)	Conc. (ng/m^3)
		ϕ (deg.)	R (m)		
14:46	624.0	60.1	2411	231	639
14:49	624.0	60.1	2411	231	381
14:53	624.0	60.1	2411	231	47
15:05	523.5	62.8	2280	217	57
15:08	521.0	68.2	2430	217	625
15:10	521.0	68.2	2430	217	427
15:14	506.0	61.5	2991	209	75
15:19	614.0	60.2	2681	248	1580
15:21	614.0	60.2	2681	248	567
15:24	602.0	55.2	2913	257	811
15:26	602.0	55.2	2913	257	352
15:44	524.0	60.2	2296	216	1016
15:47	524.0	60.2	2296	216	2872
15:49	524.0	60.2	2296	216	1056
15:51	524.0	60.2	2296	216	869
15:53	524.0	60.2	2296	216	3770
15:55	524.0	60.2	2296	216	4021
15:57	524.0	60.2	2296	216	898
15:59	524.0	60.2	2296	216	969
16:01	524.0	60.2	2296	216	165
16:03	524.0	60.2	2296	216	93
16:07	523.0	65.4	2295	218	226
16:12	525.0	55.4	2400	215	29
16:17	526.0	50.7	2431	217	22
16:22	521.0	68.2	2430	217	266
16:24	521.0	68.2	2430	217	226
16:26	521.0	68.2	2430	217	578
16:28	521.0	68.2	2430	217	460
16:30	521.0	68.2	2430	217	851
16:32	521.0	68.2	2430	217	1249
16:34	521.0	68.2	2430	217	1117
16:37	521.0	68.2	2430	217	1170
16:39	521.0	68.2	2430	217	2441
16:42	521.0	68.2	2430	217	2854
16:45	521.0	68.2	2430	217	1669
16:47	521.0	68.2	2430	217	560
16:49	521.0	68.2	2430	217	528
16:51	521.0	68.2	2430	217	442
16:53	521.0	68.2	2430	217	312
16:56	521.0	68.2	2430	217	205
16:58	521.0	68.2	2430	217	108
17:00	521.0	68.2	2430	217	75
17:06	521.0	68.2	2430	217	57
17:08	521.0	68.2	2430	217	36
17:11	521.0	68.2	2430	217	36
17:13	521.0	68.2	2430	217	36

Table 4.3.3: Instantaneous sulphurhexafluoride concentrations for experiment III-2, 31.08.1988

Time CET	Position	Polarcoordinates		Height (m m.s.l.)	Conc. (ng/m^3)
		ϕ (deg.)	R (m)		
18:29	639.0	24.7	3123	229	17
18:38	639.0	24.7	3123	229	21
18:43	630.0	30.5	2525	232	21
18:45	629.0	33.9	2378	232	27
18:48	628.0	40.6	2285	234	707
18:53	627.0	45.7	2392	237	9690
19:22	627.0	45.7	2392	237	14235
19:25	627.0	45.7	2392	237	13720
19:27	627.0	45.7	2392	237	5317
19:30	627.0	45.7	2392	237	2916
19:32	627.0	45.7	2392	237	1921
19:36	628.0	40.6	2285	234	4631
19:38	628.0	40.6	2285	234	2778
19:42	629.0	33.9	2378	232	7958
19:44	629.0	33.9	2378	232	5797
19:47	630.0	30.5	2525	232	7992
19:50	630.0	30.5	2525	232	9981
19:55	639.0	24.7	3123	229	2641
19:58	639.0	24.7	3123	229	2332
20:00	639.0	24.7	3123	229	724
20:06	639.5	24.5	3217	229	367
20:08	639.5	24.5	3217	229	720
20:12	538.0	24.4	2888	211	48
20:14	538.0	24.4	2888	211	34
20:28	199.0	12.3	3324	101	213
20:33	199.0	12.3	3324	101	1166
20:34	199.0	12.3	3324	101	17150

Table 4.3.4: Instantaneous sulphurhexafluoride concentrations for experiment III-3, 03.09.1988

Time CET	Position	Polarcoordinates		Height (m m.s.l.)	Conc. (ng/m^3)
		ϕ (deg.)	R (m)		
6:08	639.0	24.7	3123	229	329
6:11	639.0	24.7	3123	229	186
6:16	641.0	23.8	3404	228	168
6:19	641.0	23.8	3404	228	66
6:26	641.0	23.8	3404	228	358
6:32	538.0	24.4	2888	211	2044
6:34	530.0	30.5	2444	212	6315
6:36	529.0	35.3	2251	212	6023
6:38	528.0	40.8	2217	214	2373
6:41	527.0	45.3	2286	214	358
6:43	526.0	50.7	2431	217	33
6:46	525.0	55.4	2400	215	15
7:06	630.0	30.5	2525	232	1091
7:08	630.0	30.5	2525	232	153
7:11	641.0	23.8	3404	228	2409
7:13	641.0	23.8	3404	228	1467
7:16	641.0	23.8	3404	228	1862
7:20	641.0	23.8	3404	228	2555
7:23	641.0	23.8	3404	228	1606
7:25	641.0	23.8	3404	228	942
7:29	641.0	23.8	3404	228	1588
7:31	641.0	23.8	3404	228	1351
7:34	630.0	30.5	2525	232	73
7:36	629.0	33.9	2378	232	18
7:41	641.0	23.8	3404	228	241
7:45	641.0	23.8	3404	228	179
7:49	641.0	23.8	3404	228	44
7:51	641.0	23.8	3404	228	15
8:04	199.0	12.3	3324	101	2464
8:06	199.0	12.3	3324	101	4070
8:08	199.0	12.3	3324	101	2774
8:11	199.0	12.3	3324	101	1789
8:13	199.0	12.3	3324	101	580
8:15	199.0	12.3	3324	101	934
8:18	199.0	12.3	3324	101	179
8:20	199.0	12.3	3324	101	190
8:23	199.0	12.3	3324	101	277
8:27	199.0	12.3	3324	101	110
8:30	199.0	12.3	3324	101	73
8:34	199.0	12.3	3324	101	110
8:38	199.0	12.3	3324	101	84
8:40	199.0	12.3	3324	101	40
8:42	199.0	12.3	3324	101	29
8:45	199.0	12.3	3324	101	44

Table 4.3.5: Instantaneous sulphurhexafluoride concentrations for experiment III-4, 04.09.1988

Time CET	Position	Polarcoordinates		Height (m MSL)	Conc. (ng/m^3)
		ϕ (deg.)	R (m)		
11:26	628.0	40.6	2285	234	782
11:28	628.0	40.6	2285	234	790
11:30	628.0	40.6	2285	234	69
11:34	630.0	30.5	2525	232	15
11:36	630.0	30.5	2525	232	15
11:39	639.0	24.7	3123	229	12
11:46	641.0	23.8	3404	228	15
11:57	628.0	40.6	2285	234	15
12:00	629.0	33.9	2378	232	15
12:08	627.0	45.7	2392	237	8
12:11	626.0	50.0	2602	243	31
12:13	625.0	55.2	2593	243	31
12:15	624.0	60.1	2411	231	31
12:17	623.0	66.4	2356	226	38
12:27	521.0	68.2	2430	217	54
12:30	523.0	65.4	2295	218	23
12:32	524.0	60.2	2296	216	380
12:35	524.0	60.2	2296	216	583
12:37	525.0	55.4	2400	215	338
12:40	526.0	50.7	2431	217	84
12:42	527.0	45.3	2286	214	499
12:44	528.0	40.8	2217	214	12
12:46	529.0	35.3	2251	212	12
12:55	528.0	40.8	2217	214	61
12:58	528.0	40.8	2217	214	15
13:00	527.0	45.3	2286	214	15
13:02	526.0	50.7	2431	217	88
13:04	526.0	50.7	2431	217	12
13:06	525.0	55.4	2400	215	15
13:09	524.0	60.2	2296	216	12
13:13	523.0	65.4	2295	218	8
13:18	526.0	50.7	2431	217	303
13:20	526.0	50.7	2431	217	107
13:24	527.0	45.3	2286	214	790
13:30	527.0	45.3	2286	214	667
13:32	527.0	45.3	2286	214	207
13:34	527.0	45.3	2286	214	238
13:36	527.0	45.3	2286	214	96
13:39	527.0	45.3	2286	214	69
13:41	527.0	45.3	2286	214	23
13:43	527.0	45.3	2286	214	15
13:52	527.0	45.3	2286	214	15

Table 4.3.6: Instantaneous sulphurhexafluoride concentrations for experiment III-5, 05.09.1988

Time CET	Position	Polarcoordinates		Height (m MSL)	Conc. (ng/m^3)
		ϕ (deg.)	R (m)		
20:08	118.0	128.3	3448	105	53
20:11	118.0	128.3	3448	105	14
20:25	514.0	113.4	3120	213	1257
20:37	514.0	113.4	3120	213	8633
20:40	521.0	118.0	3084	217	6230
20:42	521.0	118.0	3084	217	7618
20:44	521.0	118.0	3084	217	10110
20:49	521.0	118.0	3084	217	3204
20:54	524.0	116.2	2741	216	29
20:57	524.0	116.2	2741	216	278
21:00	524.0	116.2	2741	216	356
21:03	524.0	116.2	2741	216	385
21:08	521.0	118.0	3084	217	6764
21:10	521.0	118.0	3084	217	5554
21:15	521.0	118.0	3084	217	5482
21:18	521.0	118.0	3084	217	7618
21:20	521.0	118.0	3084	217	9612
21:23	521.0	118.0	3084	217	8366
21:26	521.0	118.0	3084	217	7387
21:28	521.0	118.0	3084	217	8277
21:30	521.0	118.0	3084	217	8544
21:33	521.0	118.0	3084	217	9078
21:36	521.0	118.0	3084	217	10947
21:38	521.0	118.0	3084	217	11036
21:40	521.0	118.0	3084	217	10146
21:43	521.0	118.0	3084	217	7921
21:45	521.0	118.0	3084	217	5518
21:47	521.0	118.0	3084	217	3560
21:50	521.0	118.0	3084	217	3916
21:55	521.0	118.0	3084	217	4023
21:57	521.0	118.0	3084	217	2350
21:59	521.0	118.0	3084	217	2385
22:02	521.0	118.0	3084	217	2563
22:05	521.0	118.0	3084	217	2314
22:08	521.0	118.0	3084	217	1816
22:11	521.0	118.0	3084	217	1424
22:13	521.0	118.0	3084	217	1388
22:15	521.0	118.0	3084	217	1210
22:17	521.0	118.0	3084	217	919
22:19	521.0	118.0	3084	217	762
22:21	521.0	118.0	3084	217	708
22:23	521.0	118.0	3084	217	438
22:26	521.0	118.0	3084	217	363
22:28	521.0	118.0	3084	217	317
22:30	521.0	118.0	3084	217	267
22:32	521.0	118.0	3084	217	267
22:34	521.0	118.0	3084	217	253
22:37	521.0	118.0	3084	217	242

Table 4.3.6 continued

Time CET	Position	Polarcoordinates		Height (m MSL)	Conc. (ng/m³)
		ϕ (deg.)	R (m)		
22:40	521.0	118.0	3084	217	207
22:45	521.0	118.0	3084	217	178
22:47	521.0	118.0	3084	217	118
22:49	521.0	118.0	3084	217	107
22:52	521.0	118.0	3084	217	93
22:54	521.0	118.0	3084	217	93
22:56	521.0	118.0	3084	217	93
22:58	521.0	118.0	3084	217	61
23:00	521.0	118.0	3084	217	64
23:05	521.0	118.0	3084	217	78
23:07	521.0	118.0	3084	217	85
23:11	521.0	118.0	3084	217	85
23:14	521.0	118.0	3084	217	85
23:17	521.0	118.0	3084	217	71
23:34	521.0	118.0	3084	217	71
23:58	521.0	118.0	3084	217	57
0:06	521.0	118.0	3084	217	29
0:24	KFA*	-	-	91	21
0:29	KFA*	-	-	91	18

* Measurements at KFA outside the ASS-building

Table 4.3.7: Instantaneous sulphurhexafluoride concentrations for experiment III-6, 07.09.1988

Time CET	Position	Polarcoordinates		Height (m MSL)	Conc. (ng/m^3)
		ϕ (deg.)	R (m)		
18:25	246.00	293.2	1084	123	1336
18:29	246.00	293.2	1084	123	1376
18:33	247.00	298.2	1059	124	401
18:36	247.00	298.2	1059	124	731
18:39	247.00	298.2	1059	124	1493
18:42	248.00	303.5	1038	123	28
18:46	245.00	289.0	1110	124	8096
18:49	245.00	289.0	1110	124	8450
18:52	244.00	284.8	1137	124	6878
18:56	243.00	280.5	1163	125	4421
19:00	242.00	276.0	1200	125	2162
19:02	241.00	270.5	1242	126	645
19:05	240.00	259.5	1306	126	118
19:08	239.00	253.5	1362	127	31
20:19	238.50	249.7	1400	127	16
20:26	240.00	259.5	1306	126	55
20:28	240.50	262.6	1284	125	71
20:34	241.00	270.5	1242	126	43
20:37	241.50	270.2	1232	126	16
20:39	242.00	276.0	1200	125	24
20:42	242.50	277.7	1182	125	24
20:46	243.00	280.5	1163	125	55
20:48	243.50	282.9	1126	125	47
20:52	244.00	284.8	1137	124	102
20:55	244.50	287.2	1120	125	94
20:58	245.00	289.0	1110	124	35
21:01	245.50	291.0	1095	123	63
21:04	246.00	293.2	1084	123	114
21:06	246.50	295.6	1071	124	240
21:10	247.00	298.2	1059	124	566
21:12	247.50	300.9	1045	124	275
21:14	248.00	303.5	1038	123	220
21:17	248.50	306.6	1022	122	700
21:20	249.00	310.5	1010	123	1729
21:23	249.05	313.3	999	123	2063
21:26	249.10	315.6	989	121	2024
21:30	249.15	318.2	985	121	7408
21:33	249.15	318.2	985	121	3734
21:35	249.20	320.4	966	122	7703
21:41	249.25	323.5	962	122	6799
21:45	249.30	325.5	952	122	4480
21:47	249.35	327.5	955	122	1651
21:50	249.40	330.8	951	122	369
21:54	249.45	333.3	948	122	1258
21:57	260.00	336.1	950	123	142
22:00	260.05	338.5	951	123	157
22:04	260.10	341.3	947	122	16
22:18	249.45	333.3	948	122	3832

Table 4.3.7 continued

Time CET	Position	Polarcoordinates		Height (m MSL)	Conc. (ng/m³)
		ϕ (deg.)	R (m)		
22:22	249.45	333.3	948	122	1533
22:26	249.35	327.5	955	122	5423
22:29	249.35	327.5	955	122	5070
22:33	249.25	323.5	962	122	652
22:35	249.25	323.5	962	122	605
22:38	249.15	318.2	985	121	138
22:41	248.50	306.6	1022	122	1572
22:43	248.50	306.6	1022	122	1926
22:47	247.50	300.9	1045	124	4087
22:50	246.50	295.6	1071	124	2633
22:53	245.50	291.0	1095	123	1828
22:56	241.50	270.2	1232	126	24
23:01	247.50	300.9	1045	124	3498
23:04	247.50	300.9	1045	124	2594
23:06	247.50	300.9	1045	124	3498
23:09	247.50	300.9	1045	124	1002
23:12	247.50	300.9	1045	124	267
23:15	247.50	300.9	1045	124	134
23:17	247.50	300.9	1045	124	87
23:23	247.50	300.9	1045	124	145
23:25	247.50	300.9	1045	124	31
23:28	247.50	300.9	1045	124	24
23:30	247.50	300.9	1045	124	24

4.4 SF_6-Tracer measurements by SCK-Group

F. Veroustraete

4.4.1 Measuring procedure

The Mol-group (SCK) participated in the field campaign with a measuring van which beside other detection and monitoring systems had a sulphur hexafluoride prototype monitor. The air samples were taken on the roof top of the measuring van and conducted to the monitor. With the system it was possible to determine half hour mean SF_6 concentration levels, with sampling stations and momentary SF_6 levels measured while driving. Besides the information on the concentration levels, data necessary for the determination of the vans position were collected by a HP3497A data logger. These data were the counted pulses from wheel magnets and the travelling angle measured by a gyroscopic compass (Anschuetz). Immediate processing by a microcomputer gave the position of the van in Lambert coordinates (or other).

In contrast to the classical gas chromatography techniques for the determination of SF_6, the SCK group aimed for a monitoring system which could be integrated in the vans measuring configuration of the monitoring systems in the van. In order to be able to this, some criteria had to be met.

- The monitor has to generate continuous information about the SF_6 concentration levels, which is not achievable with classical gaschromatography.
- The monitor has to have the same sensitivity for SF_6 as with gaschromatography detectors, and a sufficiently fast response time.
- Analysis of sampling bags has to be possible.
- Interfacing and data processing with the existing apparatus has to be possible.

4.4.2 Description of the SCK-SF_6 monitor

The detection of SF_6 by means of electron capture detection is an extremely sensitive method. In classical gaschromatography SF_6 is separated from the other gaseous compounds previous to detection with an ECD detector. Therefore no problems of cross contamination with water or oxygen present in the air can be encountered, since they are separated before analysis.

By applying an electron capture detector to produce a continuous signal with fast response time and without preseparation of gasous compounds, the presence of atmospheric oxygen in the sample air might cause problems because this weak electron absorbing molecule produces a significant response on ECD detectors in high concentrations. In order to avoid a severe loss in sensitivity, a catalytic converter was developed to remove oxygen from the sample stream and to convert it into water.

Fig. 4.4.1 presents a general scheme of the application of this principle for SF_6 monitoring. Air is drawn through a sampling pump and mixed with a hydrogen stream (generated by electrolysis in a hydrogen generator). This gas mixture is fed into a catalytic reactor at a certain temperature. The catalyst is 0.5% platinum on 3 x 3 mm alumina divided in fine pellets. The reactor is kept at a constant temperature by means of a heating control device. According to the temperature in the reactor oxygen and some other organic compounds are decomposed and converted to CO_2 or H_2O. Water is condensed in a peltier element so that the final sample stream only contains nitrogen gas and the analyte. The detector used was a Packard Ni63 electron capture detector at a temperature of 350°C.

An example of a raw plot is given in Fig. 4.4.2 taken with a recorder at 15 cm/min with calibration mixtures of 81, 61, 41, 21 and 12 ppt SF_6.

Fig. 4.4.3 shows the zero response of the monitor in function of the hydrogen flow rate.

Fig. 4.4.4 demonstrates the monitor's response in function of the air stream dew point, without condenser installed.

Fig. 4.4.5 demonstrates the catalytic breakdown of sulphur hexafluoride at different temperatures in the reactor for different hydrogen flow rates.

The temperatures for 50% breakdown for some chlorinated or fluorinated compounds is given below.

- SF_6 : 240°C
- Freon 12 : 220°C
- Freon 22 : 200°C
- Vinylchloride : 240°C

The selectivity of the monitor is determined by two factors: (1) the 50% breakdown temperatures of the compounds, and (2) the selectivity of the ECD itself, which has a far greater sensivity for SF_6 than for other compounds measured (see Fig. 4.4.6).

This leads us to the conclusion that only in exceptional circumstances one has to take account of interferences from other compounds with continuous ECD monitoring.

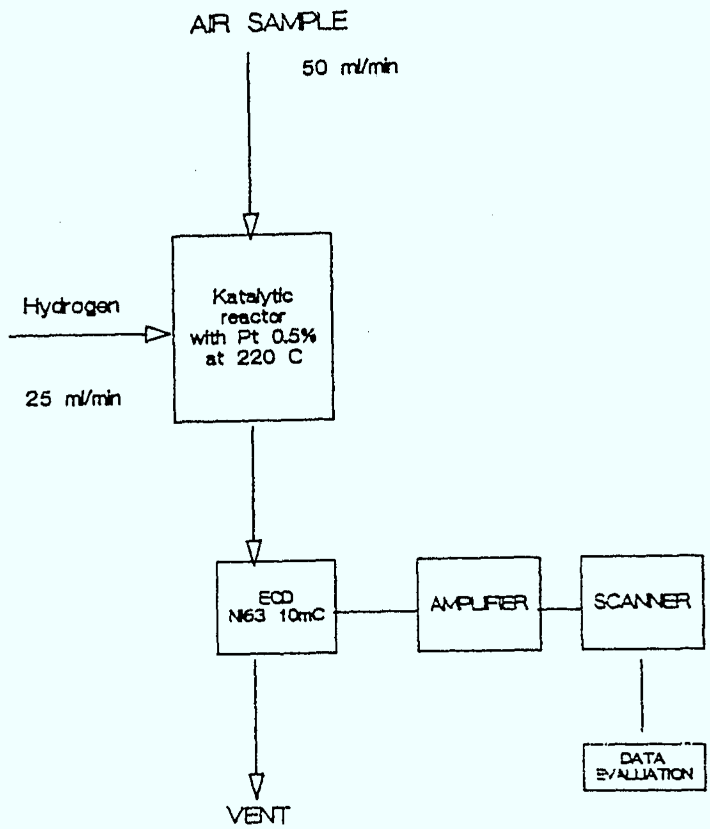


Fig. 4.4.1: Configuration SF_6 monitor

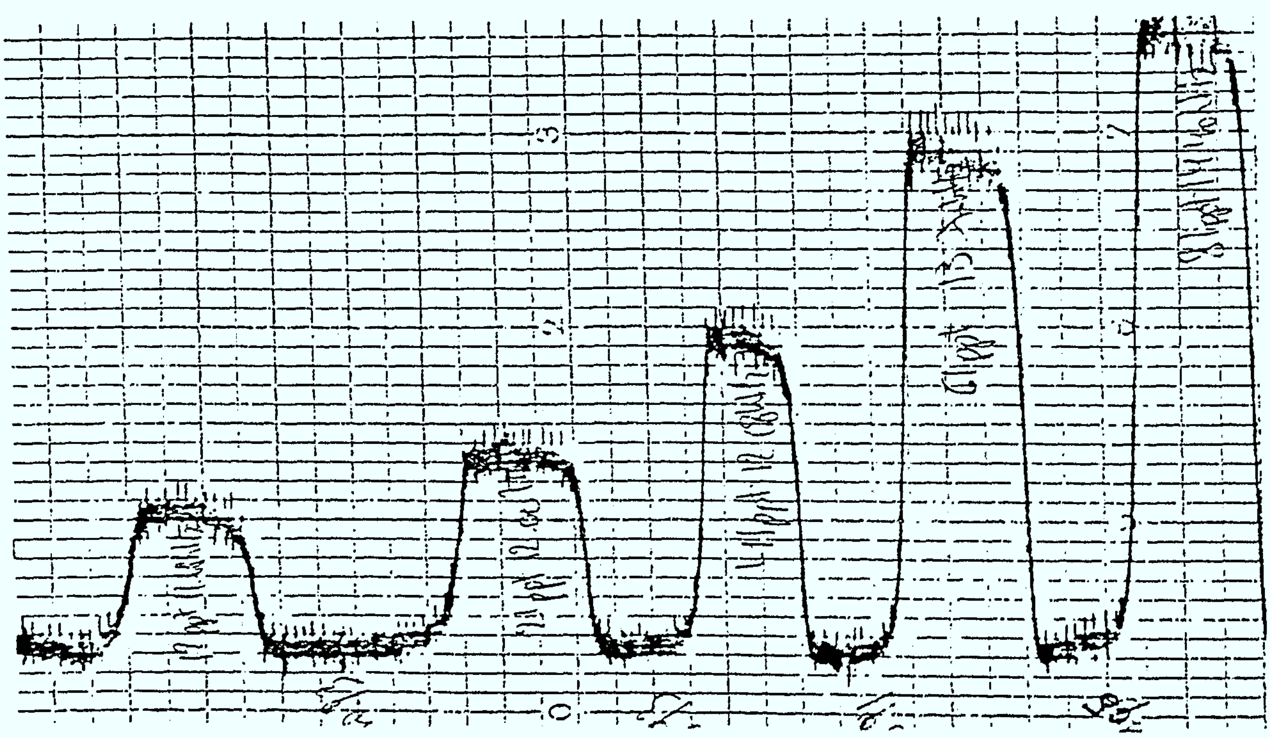


Fig. 4.4.2: Trace of SF_6 concentration on recorder

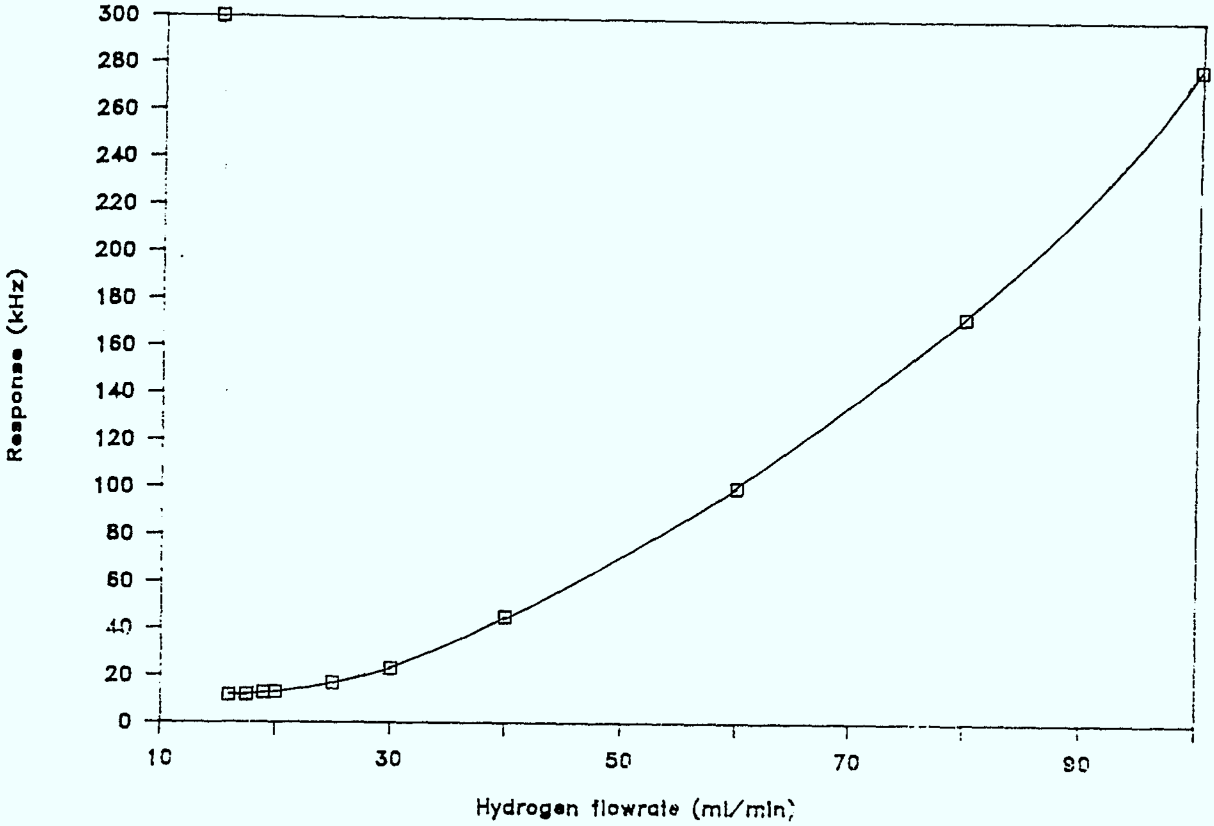


Fig. 4.4.3: Zerosponse in function of Hydrogenflowrate

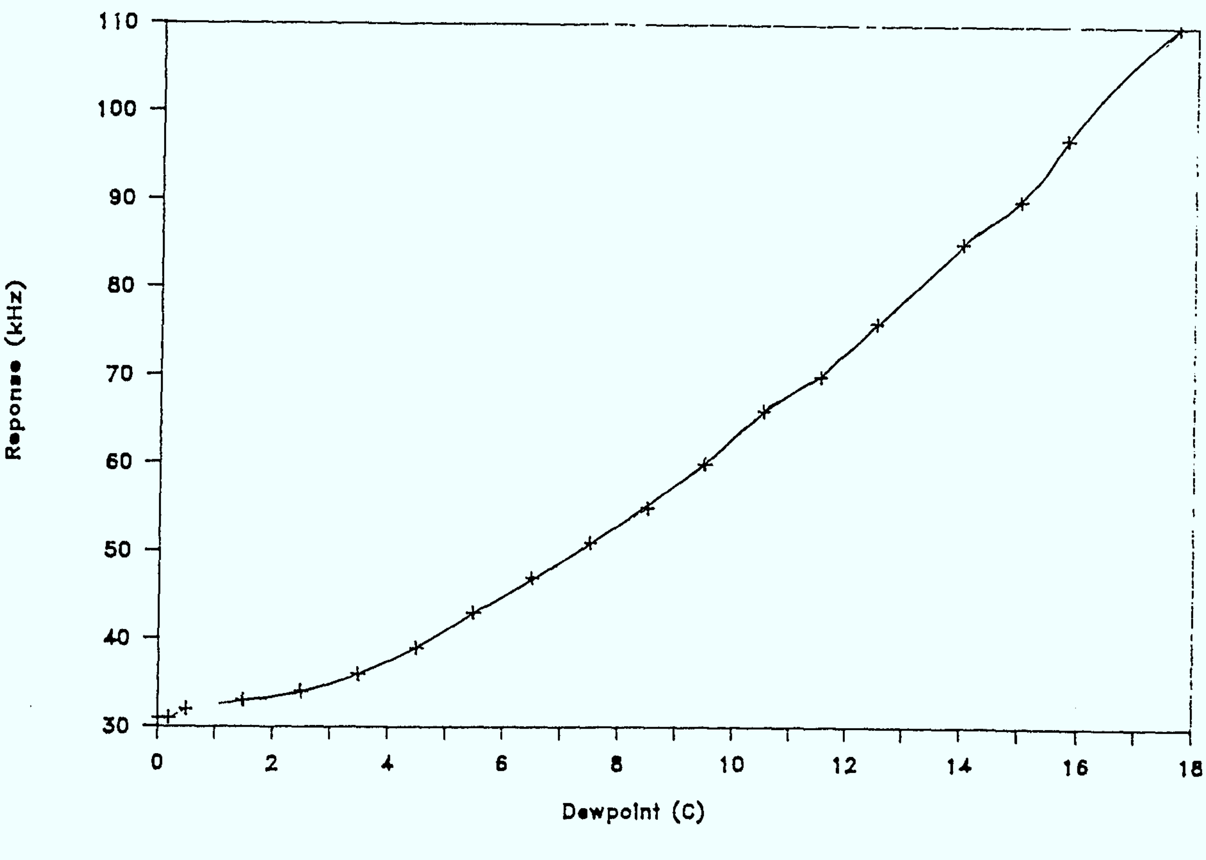


Fig. 4.4.4: Response in function of dewpoint

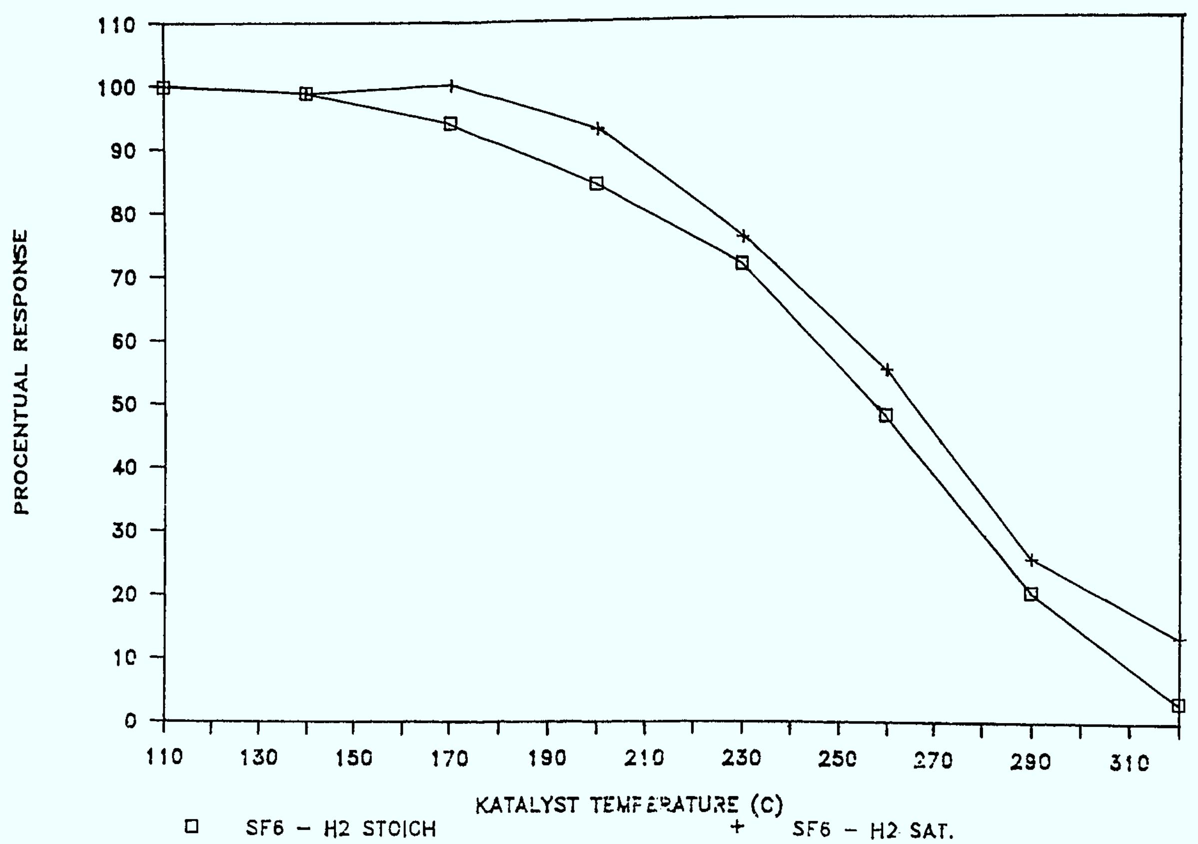


Fig. 4.4.5: Destruction of SF_6: 5ppb

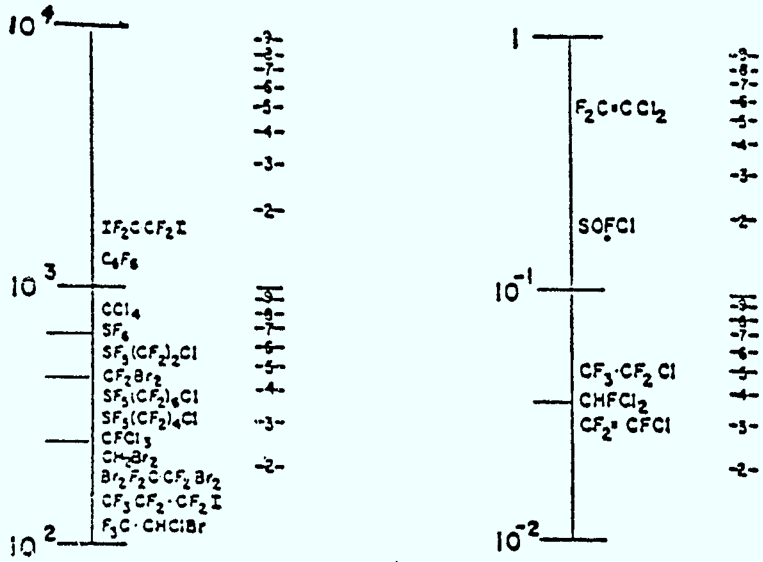


Fig. 4.4.6: Response of halogen containing compounds on ECD (sq inch/ppm)

4.4.3 Calibration procedure

The calibration procedure of the SF_6 monitor is based on dynamically generated SF_6 mixtures with a SCK permeation tube calibrator and subsequent static mixtures prepared in sampling bags and made from the dynamic mixture. The permeation tube (see Fig. 4.4.7) used in the calibration was weighed before and after the field campaign in order to determine its mass flow. The calibrator is a mobile version of a small calibration bank. It contains an SF_6 permeation tube at a temperature of 32°C ± 0.1°C. In this way a constant mass flow of SF_6 can be obtained which can be further diluted with zero air as illustrated in Fig. 4.4.8.

The SF_6 released is carried to a mixer with a flow of 0.1 l/min (R). This stream is mixed with a constant primary dilution stream (Fi) (3 l/min) and a secondary variable dilution stream (Fv) (from 0 to 20 l/min). Both streams are measured with rotameters calibrated with a primary volumetric device. All zero air is purified with active carbon before entering the calibrator.

The calculation of the SF_6 concentration is done with the following formula:

$$F = R + Fi + Fv$$

$$C = \frac{Q}{F} \times 10^3$$

wherein

F: total stream diluting the permeated SF_6 (l/min)
Q: permeation rate of SF_6 permeation tube (μg/min)
C: concentration of SF_6 generated by the calibrator (ng/m^3)

The static mixtures were made with a syringe of a certain volume. The volume is taken from the dynamically generated SF_6 stream, injected into a sampling bag, and diluted with a known volume of zero gas.

The concer ration in the bag is calculated with the following formula:

$$C = Co \times \frac{Vo}{V + Vo}$$

wherein

C : The final concentration of SF_6 (ng/m^3)
Co: The original concentration of SF_6 (ng/m^3
Vo: The volume (ml) of the SF_6 mixture injected into the sampling bag.
V : The volume (ml) of zero gas injected in the sampling bag.

The SF_6 permeation tube history before the measuring campaign was as follows:

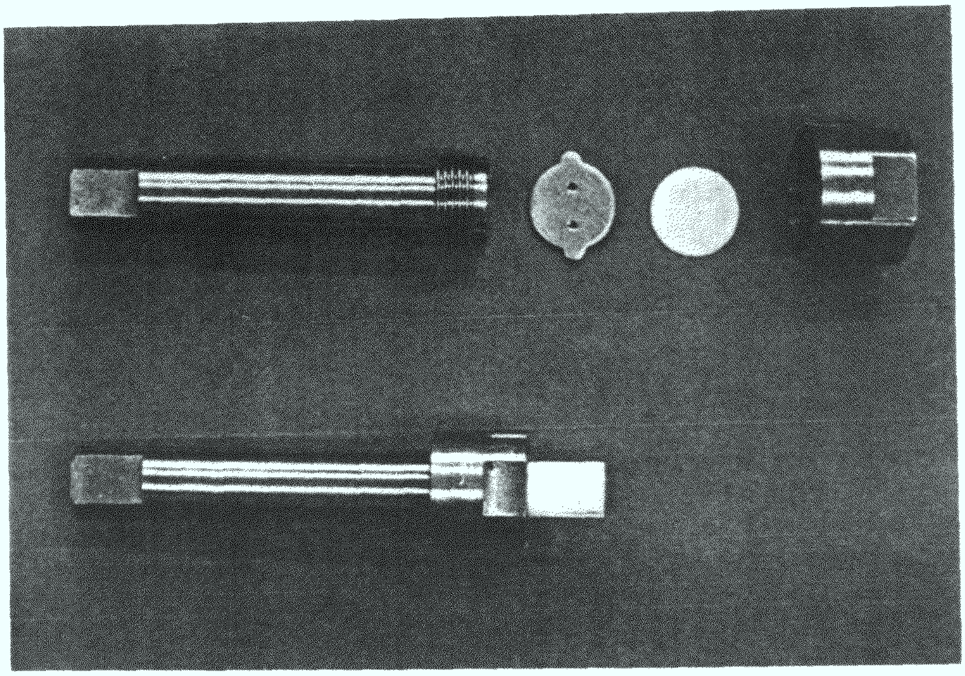


Fig. 4.4.7: Permeation tube for SF_6 (SCK-model)

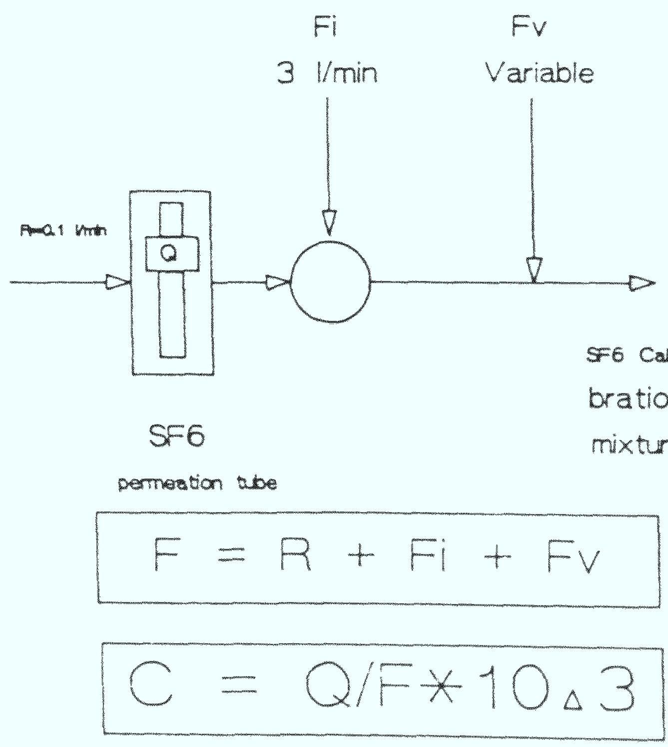


Fig. 4.4.8: SF_6 calibration procedure

Date	Q (μg/min)
04/03/88	0.13
06/05/88	0.15
19/09/88	0.16

Only the mean value of the last two weightings is taken into account to calculate all results. For further calculations in ppt, we used the following relation:

$$1 ng/m^3 = \frac{1}{146.05} \times 22.4 \times \frac{1013 \times 293.15}{273.15 \times P}$$

P: atmospheric pressure (mbar)

We did not take atmospheric pressure differences into account in our calculations and assumed P to be equal to 1013 mbar. At 20°C this conversion factor = 6.075 ng/m^3 for 1 ppt.

4.4.3.1 Stability of SF_6 mixtures in PVC bags

Sampling of SF_6 for the purpose of generating half hour mean values is performed with home made PVC bags of one liter volume. The samples are analysed afterwards with the SF_6 monitor. In this chapter we want to evaluate the effect of the length of time between sampling and analysis on the SF_6 level in the bag.

Samples generated on 02/09/88 with the SCK calibrator were analysed by KFA by means of gaschromatography. Fig. 4.4.9 shows the relative decline of the original SF_6 levels for different SF_6 concentrations. It seems the higher the concentration, the higher the decline can be observed. This result can be caused by different phenomena:

- PVC absorbes SF_6
- PVC reacts with SF_6 however this is highly improbable since SF_6 is a very inert molecule
- PVC is permeable for SF_6 so that SF_6 is lost to the outside. The batch of bags was three years old. This may be too old for stable conservation of SF_6.

On the basis of these phenomena we analyzed the sampling bags always immediately after collection of the samples in order to minimize SF_6 losses.

4.4.4 Sampling procedure and analysis

4.4.4.1 Half hour mean mean values

Half hour mean values of SF_6 were determined by means of 20 programmable sampling stations for the collection of three subsequent half hour mean values in home made PVC bags (see Fig. 4.4.10).

A preset programming time of 190 minutes could be used and allowed us to put all stations on the selected sampling points within a reasonable time limit. After collection of the sampling bags, they were analyzed with the SF_6 monitor. It was calibrated previously according to the procedure described earlier. An example of a calibration curve is given in Fig. 4.4.11. A predetermined scanning procedure was followed to analyse the sampling bags as illustrated in Fig. 4.4.12. Each 10 seconds a mean value of the monitor response in Millivolt (mV) was taken. When a stable signal was obtained (this means that the standard deviation on the signal becomes stable) the value was accepted as a representative span value for the concentration level in the bag. This value was preceded and followed by two zero values (Z1 and Z2) of which a mean value was taken (Z = (Z1 + Z2)/2). The signal proportional with the SF_6 concentration (R) was calculated as the difference between span and zero values:

$$R = S - \frac{Z1 + Z2}{2}$$

The final concentration of SF_6 in the bag is calculated by means of the regression curve obtained with different calibration mixtures fed into the monitor and measured as previously described. From the regression coefficients A (mV/ ng/m^3 SF_6) and the intercept B (mV), the final concentration Cs is calculated as follows:

$$Cs = \frac{R - B}{A} \, (ng/m^3)$$

The detection limit (Dl) was defined as three times the standard deviation on the response, calculated with the same regression curve:

$$Dl = \frac{3 \times Qs - B}{A} \, (ng/m^3)$$

4.4.4.2 Scanning procedure with the measuring van

During the mobile sampling of momentary SF_6 concentration values, mV values of the signal are stored on disc according to the software and hardware procedure described earlier. A starting coordinate (100.000, 100.000 meters) is entered and the scanning cycle started.

After the scanning and collection period the data stored on disc as raw mV values are converted to concentration values with a calibration factor which is obtained before and after each campaign by the calibration procedure described earlier (see chapter 4.4.3). Additionaly coordinate editing generates the final maps of momentary SF_6 values, as presented in the results chapter. The results of one campaign are given in chapter 4.4.5.2.

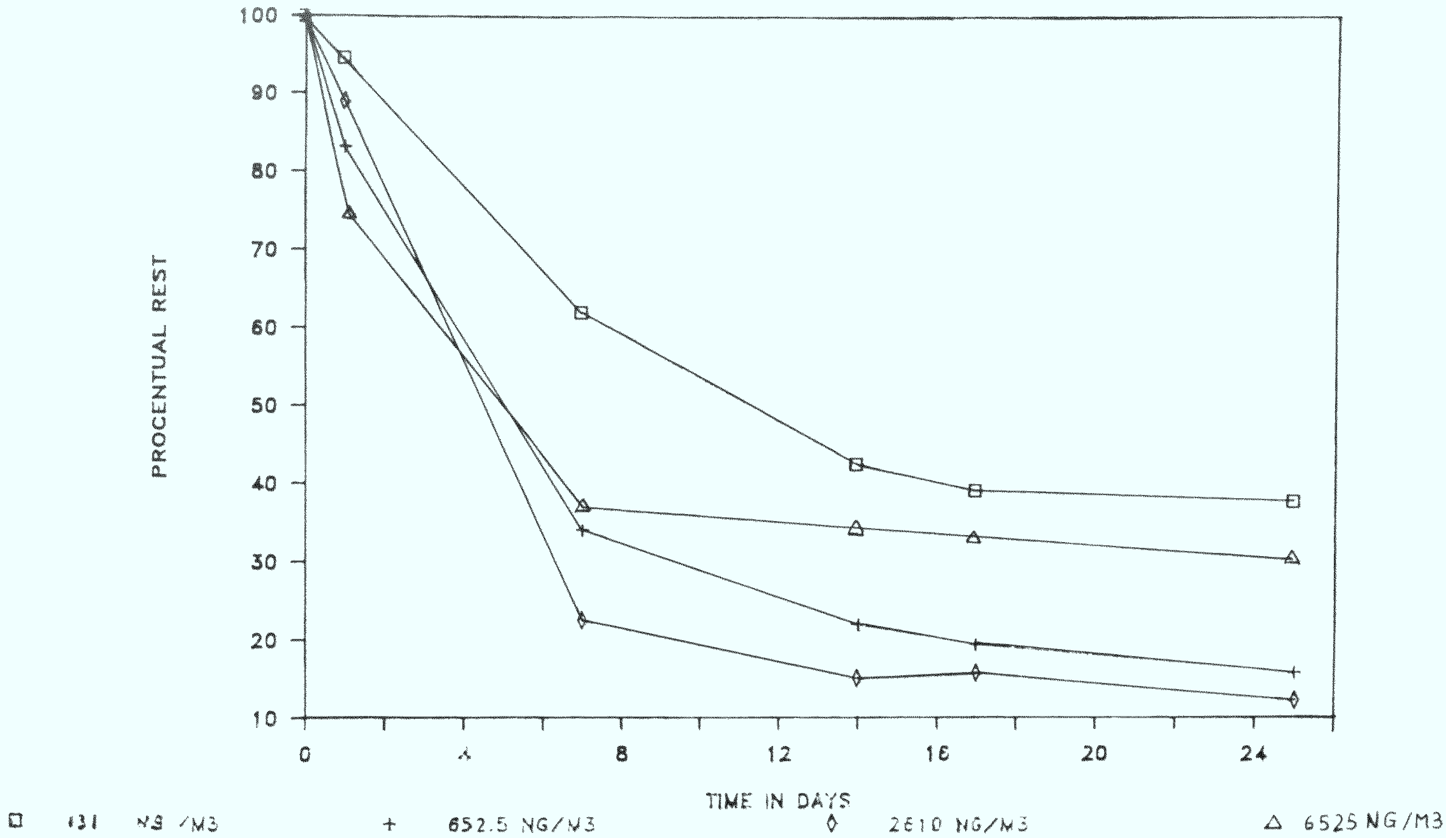


Fig. 4.4.9: Stability of SF_6: SF_6 percental decline in function of time

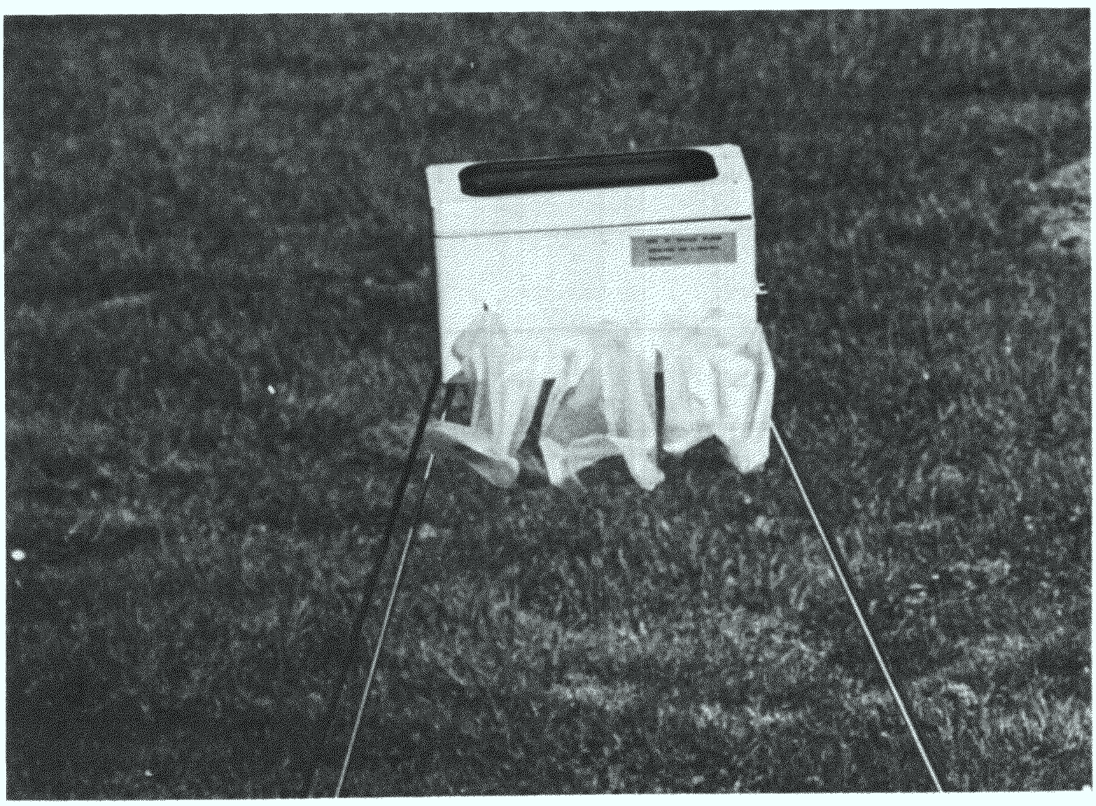


Fig. 4.4.10: Sampling station and PVC sampling bags

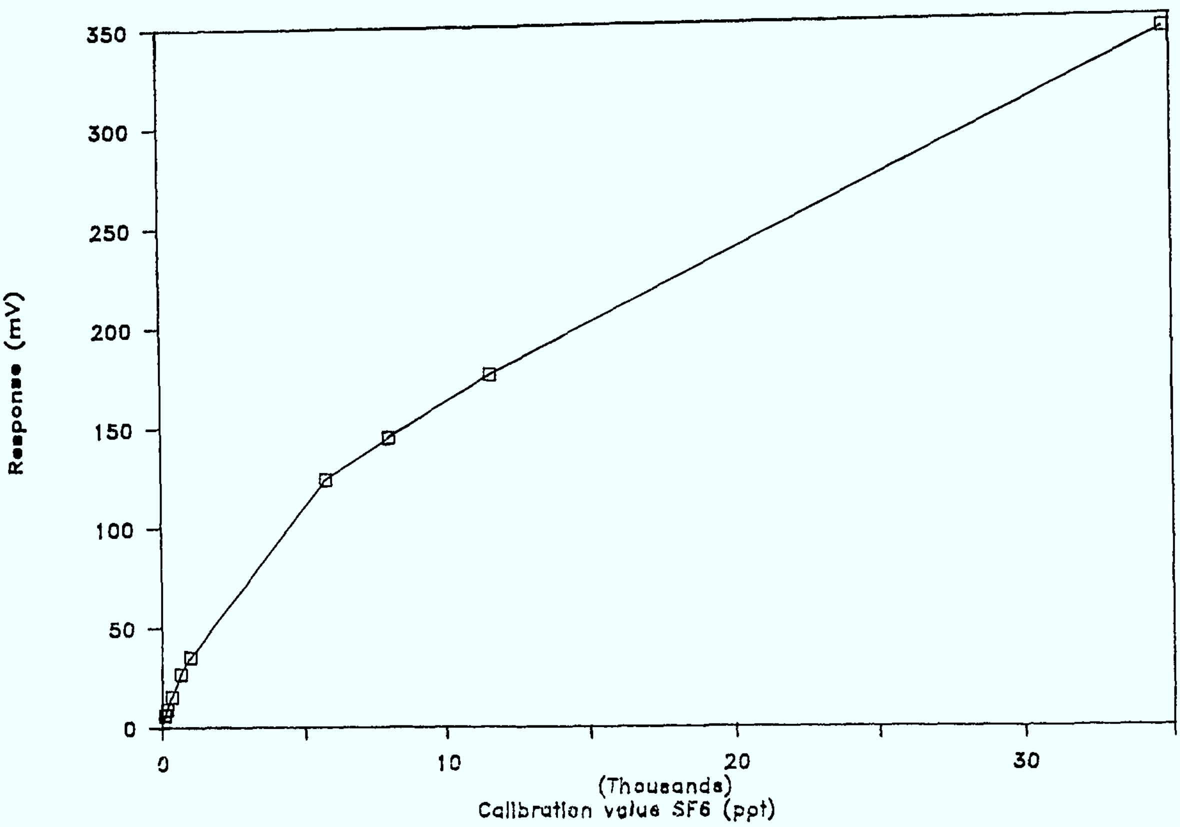


Fig. 4.4.11: Calibration ECD: Broad concentration range to 35 ppb

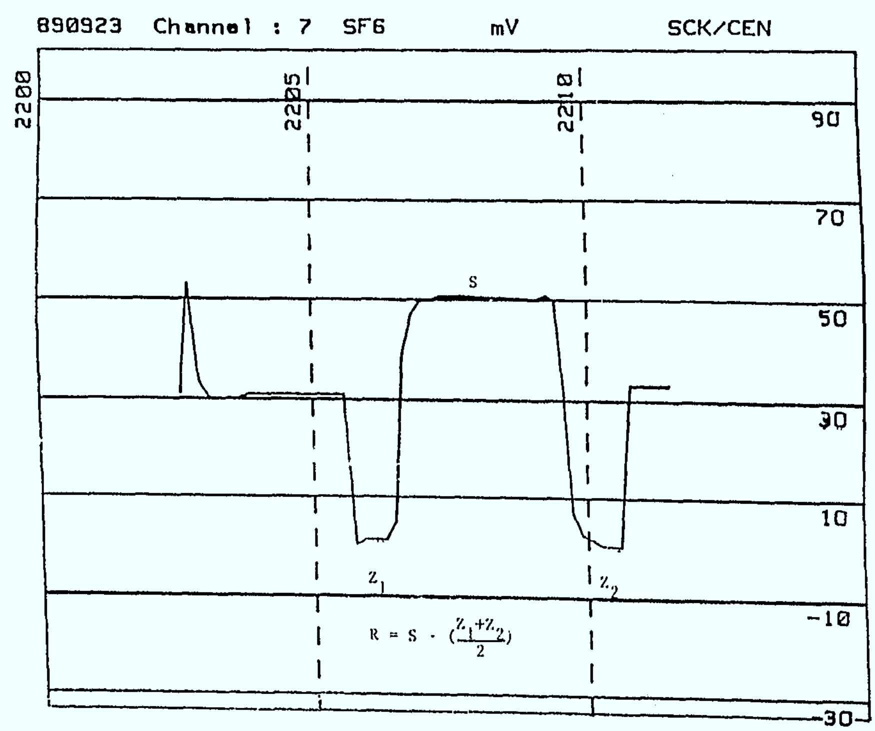


Fig. 4.4.12: Determination of the Monitor Response

4.4.5 Results

4.4.5.1 Results of the SF_6 half-hour mean values

The data are summarized in chapter 4.6 together with the SF_6-measurements of the KFA-group and APL-group.

4.4.5.2 Result of the momentary SF_6 concentration values

Two scans were made with the measuring van on 03/09/88 from 08:24 h to 08:40 h and from 07:41 h to 09:38 h. The profile which was observed at the northwest side of the hill at Berme 240 gave maximal SF_6 levels up to 2734 ng/m^3 or 450 ppt (see Fig. 4.4.13). The half hour values measured at the top of the hill between 07:30 h and 08:30 h varied between 2000 and 3000 ng/m^3, which coincides quite well with the measured momentary values. A complete comparison is however excluded since the measuring sites were not exactly the same. During the second scan (see Fig. 4.4.14) the profiles were at background level after the release period was ended.

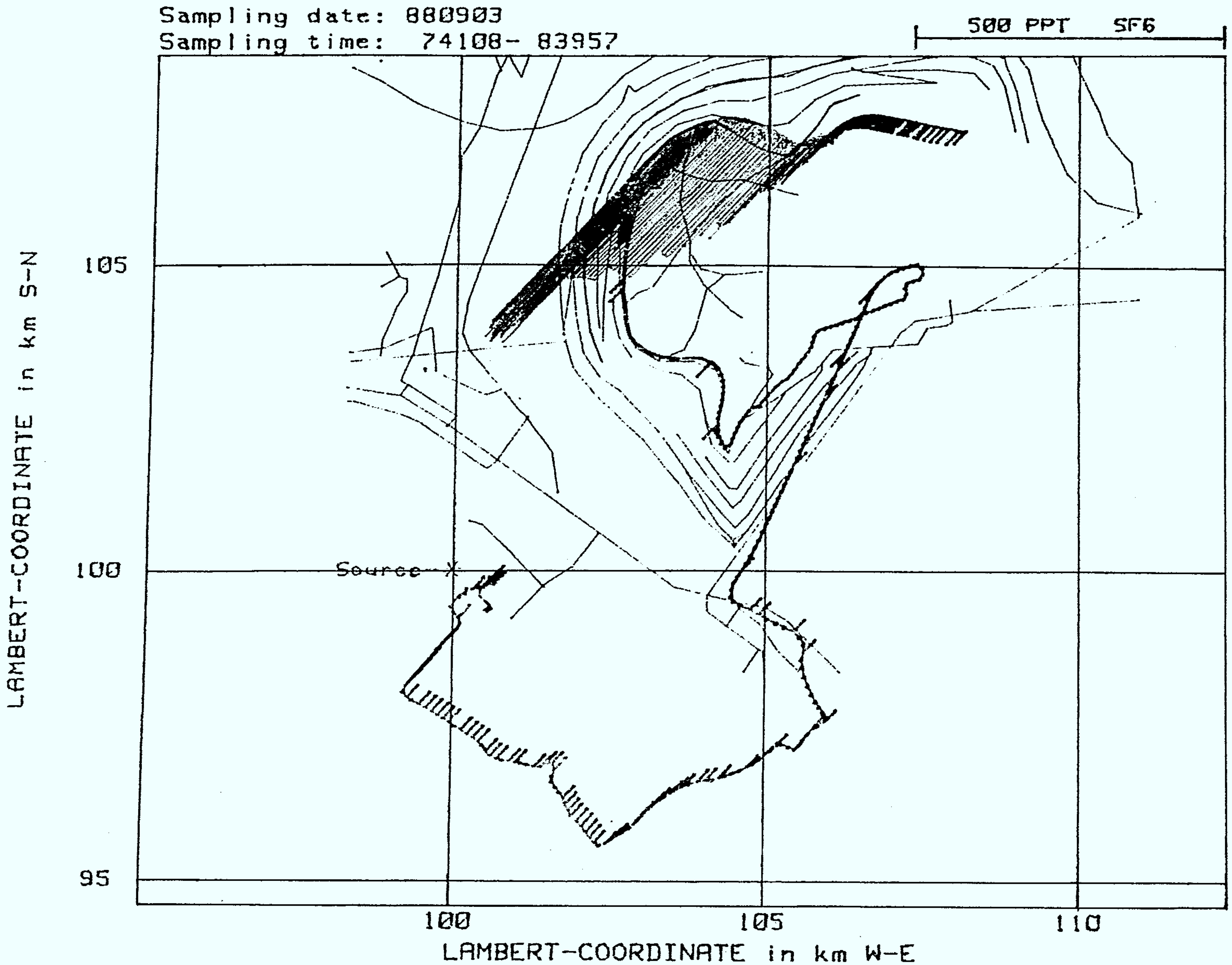


Fig. 4.4.13: SF_6 tracer release experiment KFA Jülich at Sophienhöhe
Scans made with a South-West circulation - Map scale (1/100,000)

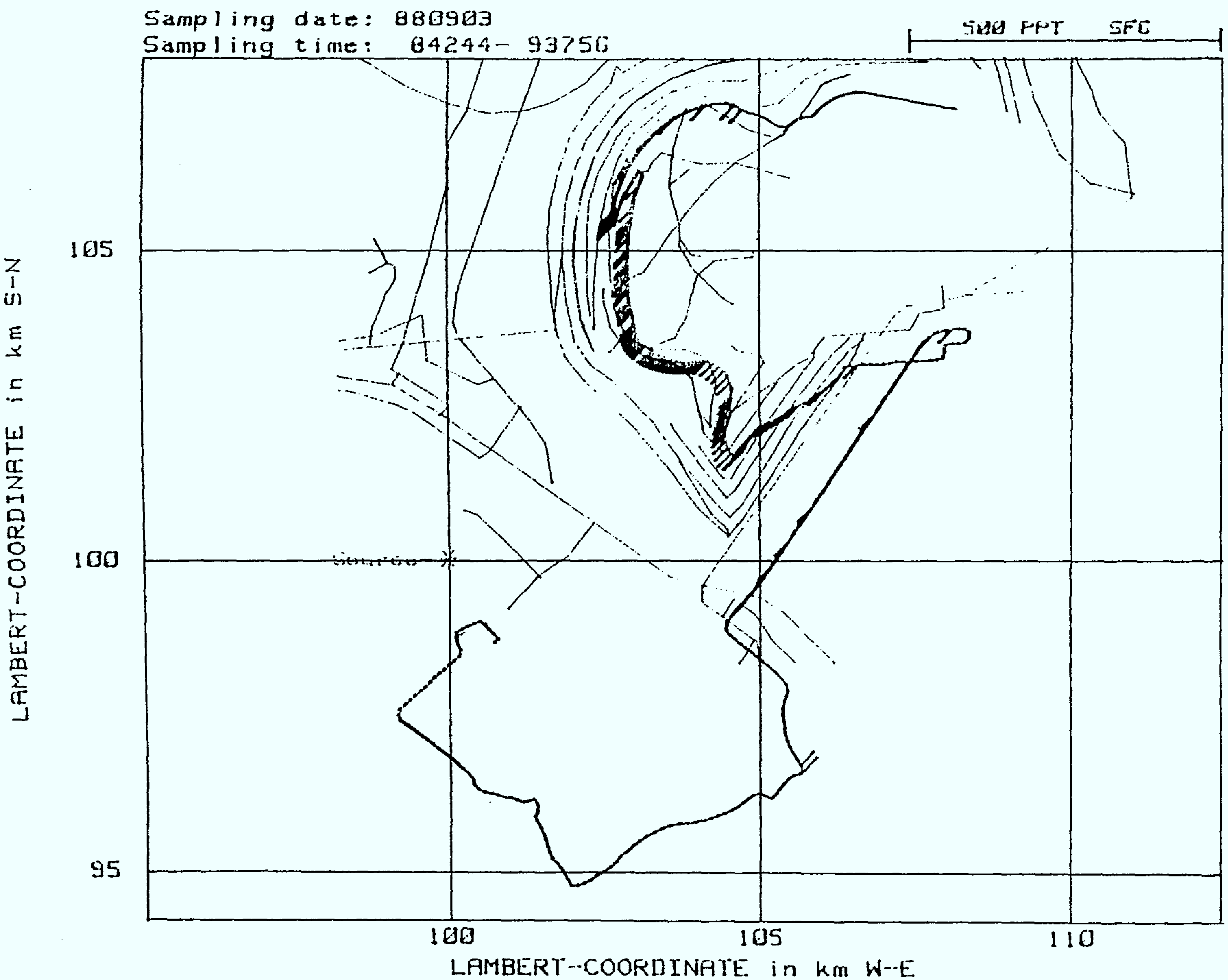


Fig. 4.4.14: SF_6 tracer release experiment KFA Jülich at Sophienhöhe
Scans made with a South-West circulation - Map scale (1/100,000)

4.5 Aerosol-Tracer measurements by KFA-group ICH-4

H. D. Narres

During the third field experiment simultaneous to the SF_6-dispersion experiment III-1 an aerosol tracer was emitted from the KFA-tower. The tracer is a Cobaltnitrate-droplet-collective, which is generated by spraying of a half-saturated Cobaltnitrate solution in water from a nozzle, working after the injection prinziple. Details about the characteristics of this tracer are found in Narres (1989). Following the most important properties are described:

- Size distribution: the particle size, determined with a cascade impactor is a log-normal distributed, polydispersed droplet mixture. The mean particle radius lies between r_g = 2.3 - 3.2 μm with a standard deviation of σ_g = 2.6 - 3.0 μm.
- Hygroscopicity: the water vapour pressure over the emitted Cobaltnitrate-droplets corresponds to the relative humidity of 84%. Changes of droplet radii, anticipated because of balancing with the surrounding air, lie within about 20% for relative humidities between 50% - 90% and therefore have no influence on the dispersion of the tracer.
- Dry deposition: from the radii distribution of the tracer it is possible to calculate a mass-averaged sedimentation velocity following the Stokes law to v_s=0.88 cm/s. The determination of dry deposition of the tracer in field experiments give for artificial grass as acceptor a deposition velocity of v_D = 0.7 cm/s. Based on this for the vegetation structure in the area of investigation (cropland, shrubs, woodland) an average deposition velocity of v_D = 2 cm/s is estimated. A "source-depletion" calculation using this value gives for the region between emission point (KFA-tower) and Sophienhöhe neglectable tracer losses of 8% caused by dry deposition.

The emission of the Cobaltnitrate aerosol was done from the 50 m platform of the meteorological tower. In order to determine the tracer concentration in the air, 25 automatic air dust collectors (throughput 25 m^3/h) were set-up on positions of the southwest network for SF_6-sampling (see chapter 4.1). Hereby the air was sucked through a paper filter. The aerosol deposited on the filter later on was eluated in a defined quantity of 1%-HNO_3. In the resulting solutions the Cobalt content was determined on the base of graphite-furnace atomic-absorption spectroscopy. Details about precision and accuracy of sampling and method of analysis are given in Narres (1989). In dispersion experiments a detection limit for the tracer concentration of 0.08 ng Co/m^3 was obtained. Measurements of the Cobalt-background concentration in the air at the Sophienhöhe indicated no influence from a brown coal power plant, located in 12 km distance in main wind direction southwest.

In Tab. 4.5.1 the result of the dispersion experiment on August 30, 1988 is given. A comparison to the measurements with model calculations applying the volume source model MUSEMET (Straka et al., 1981) is shown in Fig. 4.5.1. As input to the model the meteorological data at the emission point were used, i.e. the data from the cup anemometer, wind vane and vector-wind vane. There the concentrations are illustrated as bars. Further in this figure the result of the SF_6-dispersion experiment is included, assuming that the measured SF_6 and Co-Nitrate concentration is equal at position 1306. It can be seen that both tracers show a similar distribution and that the model gives satisfactory results in this example.

Dispersion experiment on Aug. 30,1988

Emission point: KFA-tower 50 m
Release rate: 10.6 mg Co/s
Emission time: 14:35 - 16:00 CET
Sampling time: 15:00 - 16:00 CET

Position	**Concentration (ng Co/m^3)**
222	3.2
223	3.8
224	3.7
225	3.0
226	2.7
227	1.2
228	0.28
229	0.025
230	0.02
629	0.03
628	0.26
627	0.58
626	0.96
625	1.58
624	2.10
623	2.90
1301	3.1
1302	17.2
1303	31.1
1304	33.9
1305	37.8
1306	58.5
1307	41.1
1308	31.7

Tab.. 4.5.1: Emission data and concentration measurements with the aerosol tracer for dispersion experiment on Aug. 30,1988

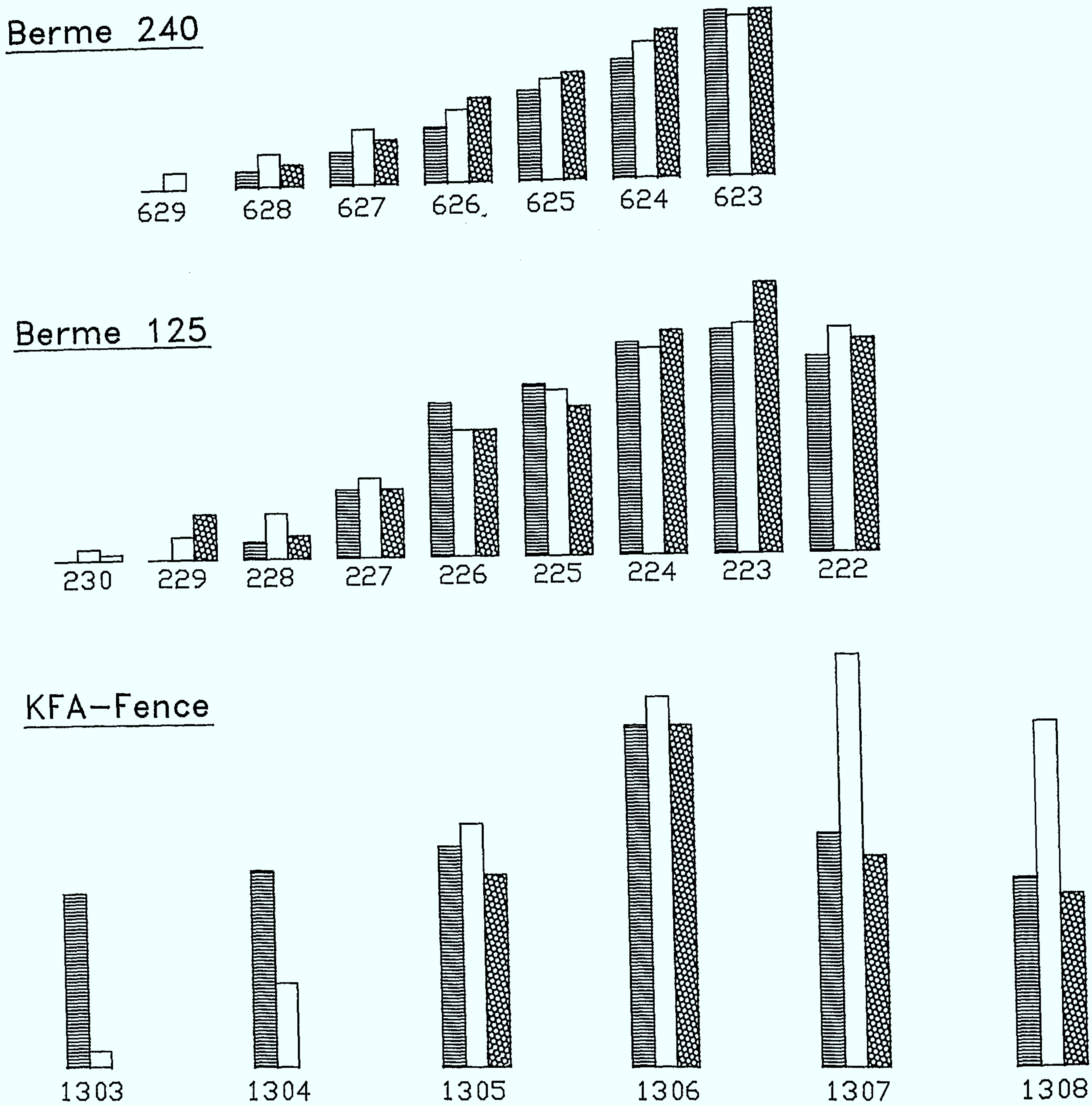


Fig. 4.5.1: Result of double-tracer (Co, SF_6) experiment, Aug. 30, 1988, 15:00-16:00 h

Concentrations: Co-tracer measurements

Co-tracer model calculation

SF_6-tracer measurements

(Assumption: measurements of Co and SF_6 coincide on pos. 1306)

KFA-fence: 10 mm = 10.6 ng Co/m³ = 3700 ng SF_6/m³

Berme 125 + 240: 10 mm = 1 ng Co/m³ = 373 ng SF_6/m³

4.6 Tracer concentration data

G. Zeuner

The tables 4.6.1-4.6.6 give an overview of all tracer measurements, one table for each experiment serie of 3 consecutive sampling periods. The association of the measurements to the experimental groups, APL, KFA and Mol is indicated in the last column. For a given sampling period the mean, 30-minute, brutto concentration as determined by each group is given. The results of the intercomparison tests (see appendix A) show reasonable agreement between the measurements of the different groups. They show that the agreement is in the range of the uncertainty of the tracer measurements ($\pm$15%). Therefore no corrections on the data have been made. Background concentration ($\simeq$13 ng/m^3) was not subtracted from the measurements made by gaschromatography. The concentration -9999 means that the sampling was not correct.

The positions are given in its coordinates in order of the position number where positions 100-714 are assigned to the Sophienhöhe, see also chapter 4.1. In these tables the positions are given in polar coordinates with the angle defined 0° in north direction. The distance (radius) from the emission point to the position is R and the angle between 0° and the vector calculated clockwise is ϕ. In the data bank (see appendix C) the positions are also given in relative Gauß-Krüger coordinates. There the relative distance to the emission point in east-west and north-south direction is calculated with an accuracy of 1 m. In general the accuracy of the positions, determined from maps 1:5000 to 1:10000, is estimated to be within about 10 m - 20 m. The tracer release height in m above m.s.l. is the sum of emission point coordinate z and the emission height (above ground), both given in the data bank.

Table 4.6.1: Tracer concentrations for experiment III.1.1-III.1.3, 30.08.1988

Tracer emission: KFA-tower , 50 m

Group: 1 = KFA
2 = APL
3 = MOL

sampling period: 1 = 15:00 - 15:30
2 = 15:30 - 16:00
3 = 16:00 - 16:30

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
2.00	21.0	446	91	285	6500	1200	1
3.00	31.0	437	90	1030	14016	1900	1
4.00	40.7	441	90	1120	17433	1040	1
4.50	45.4	449	90	-9999	-9999	3829	1
5.00	51.0	452	90	10258	-9999	16830	1
5.50	55.2	451	90	16576	25503	20602	1
6.00	61.0	466	90	16837	22868	19139	1
7.00	70.1	496	90	12982	15080	17331	1
8.00	79.8	547	90	8000	15212	17582	1
12.00	19.8	962	99	19	16	15	1
12.50	25.4	941	99	127	96	13	1
13.00	30.7	927	99	47	293	14	1
13.50	35.3	921	99	26	333	13	1
14.00	40.1	924	97	31	1626	17	1
14.50	45.2	934	96	490	3650	68	1
15.00	51.0	952	99	3500	5300	225	1
15.50	55.9	964	99	-9999	6250	750	1
16.00	60.0	996	99	4900	6300	2100	1
16.50	64.9	1053	99	3700	3911	-9999	1
17.00	70.3	1118	99	2280	3340	4250	1
17.50	75.8	1189	96	1239	2382	4011	1
18.00	80.1	1145	92	-9999	2400	4000	1
19.00	91.0	1599	100	-9999	165	1054	1
21.00	10.3	1837	107	17	16	13	1
22.00	19.8	1951	107	22	15	13	1
30.00	11.9	5582	95	-9999	14	21	1
31.00	19.3	5530	93	22	16	15	1
31.50	25.6	5689	92	-9999	11	16	1
32.00	29.5	6054	89	-9999	60	-9999	1
32.50	35.9	6399	84	-9999	20	-9999	1
33.00	39.8	6528	87	28	16	16	1
33.50	45.2	6197	90	24	18	10	1
34.00	49.6	6410	87	33	-9999	-9999	1
36.00	68.3	5688	94	-9999	-9999	61	1
40.00	29.7	7689	92	-9999	-9999	16	1
41.00	36.1	9277	88	23	13	19	1
42.00	40.6	10582	85	27	15	17	1
43.00	44.4	10986	74	-9999	-9999	84	1
46.00	59.9	10105	81	115	21	-9999	1
47.00	65.7	10002	85	86	89	80	1
49.00	74.5	9522	86	41	60	83	1
89.00	62.9	3779	99	325	-9999	320	1
90.00	64.4	3602	100	333	-9999	446	1
91.00	66.1	3433	101	263	351	554	1
92.00	67.9	3262	103	274	401	635	1
93.00	70.1	3098	104	-9999	468	742	1
94.00	72.3	2938	103	317	576	836	1

Table 4.6.1 continued

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m³)			Group
	ϕ (°)	R (m)		1	2	3	
95.00	74.9	2780	103	306	431	1025	1
96.00	77.7	2627	104	340	276	1042	1
98.00	82.6	2426	105	212	274	-9999	1
98.50	86.0	2300	105	44	58	333	1
99.00	90.0	2180	106	24	17	135	1
101.00	64.7	3469	101	349	485	553	2
106.00	69.3	3016	102	330	522	922	2
112.00	75.0	2667	103	461	405	1274	2
116.00	79.8	2444	104	645	-9999	-9999	2
120.00	80.2	2090	105	585	934	1080	2
122.00	70.2	1939	105	612	1784	764	2
124.00	60.7	1869	105	922	1820	-9999	2
125.00	55.6	1852	105	299	1432	277	2
126.00	50.9	1848	103	97	1322	267	2
127.00	45.7	1852	103	73	874	107	2
128.00	41.2	1839	103	51	313	29	2
130.00	30.2	1896	105	34	29	24	2
132.00	25.1	2045	105	24	19	15	2
135.00	20.1	2380	105	24	19	20	2
220.00	80.2	2220	132	306	631	1310	2
221.00	75.2	2120	133	587	587	1310	2
222.00	70.4	2058	130	813	1747	898	2
223.00	65.0	1993	131	837	2414	-9999	2
224.00	59.8	1965	131	752	1941	447	2
225.00	54.9	1953	132	160	1626	340	2
226.00	50.2	1965	131	138	1359	160	2
227.00	45.1	1945	131	61	789	32	2
228.00	40.4	1933	131	27	240	34	2
229.00	35.0	1926	130	34	510	29	2
230.00	30.2	2007	128	24	29	19	2
233.00	25.8	2199	128	29	19	19	2
237.00	20.4	2641	127	39	-9999	19	2
248.00	20.3	3956	123	23	15	15	1
260.00	21.2	4069	123	22	18	12	1
262.00	29.5	4773	122	21	17	7	1
266.00	33.3	5067	120	24	23	-9999	1
274.00	39.7	5583	119	21	8	17	1
280.00	45.4	5999	117	16	16	17	1
286.00	50.4	5779	119	32	-9999	89	1
300.00	60.5	3642	143	98	357	71	3
306.00	64.8	3082	149	316	321	281	3
314.00	69.7	2694	151	300	252	815	3
319.00	74.3	2424	153	118	667	1797	3
321.00	75.3	2215	157	267	905	1150	3
322.00	70.3	2149	157	569	620	839	3
323.00	65.5	2096	156	716	791	627	3
324.00	60.2	2065	156	375	1077	293	3
325.00	55.0	2101	154	569	581	296	3
326.00	50.6	2108	155	83	688	110	3
426.00	50.8	2224	184	130	1070	48	1

Table 4.6.1 continued

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
427.00	45.4	2147	184	40	566	26	1
428.00	40.9	2122	183	24	229	-9999	1
429.00	34.7	2130	183	-9999	40	15	1
430.00	30.7	2277	183	21	16	14	1
506.00	61.5	2991	209	553	621	301	2
514.00	65.1	2640	213	629	1225	597	2
521.00	68.2	2430	217	568	1354	728	2
523.00	65.4	2295	218	740	1650	507	2
523.50	62.8	2280	217	801	1432	425	2
524.00	60.2	2296	216	728	1347	245	2
525.00	55.4	2400	215	189	1141	129	2
526.00	50.7	2431	217	102	728	121	2
527.00	45.3	2286	214	46	476	32	2
528.00	40.8	2217	214	32	243	22	2
529.00	35.3	2251	212	29	44	19	2
530.00	30.5	2444	212	27	24	19	2
538.00	24.4	2888	211	27	22	19	2
602.00	55.2	2913	257	-9999	480	315	2
614.00	60.2	2681	248	514	934	206	2
623.00	66.4	2356	226	636	1347	704	2
623.50	63.1	2359	227	764	1310	471	2
624.00	60.1	2411	231	643	1177	209	2
625.00	55.2	2593	243	233	1068	121	2
626.00	50.0	2602	243	146	849	53	2
627.00	45.7	2392	237	58	536	34	2
628.00	40.6	2285	234	32	218	24	2
629.00	33.9	2378	232	29	29	19	2
630.00	30.5	2525	232	29	24	24	2
639.00	24.7	3123	229	29	19	17	2
664.00	33.7	4256	236	22	14	13	1
670.00	40.1	5070	235	25	14	13	1
704.00	40.0	2841	260	15	24	31	3
705.00	45.9	3046	264	15	127	63	3
706.00	41.0	3011	262	15	62	15	3
708.00	34.7	3231	267	15	59	28	3
710.00	30.5	3467	263	15	66	15	3
712.00	28.8	3676	252	48	61	15	3
714.00	35.6	3860	271	-9999	15	15	3
1103.00	31.5	93	91	2200	6300	10400	1
1104.00	40.6	92	91	2300	4500	1040	1
1105.00	50.4	90	91	2700	3600	1100	1
1106.00	60.8	104	91	3000	7200	2650	1
1107.00	68.5	101	91	7400	1400	7100	1
1302.00	21.8	236	91	1720	6500	175	1
1303.00	31.2	251	91	12508	8400	6231	1
1304.00	40.8	275	91	8489	15473	1750	1
1305.00	50.5	313	90	8700	14892	6100	1
1306.00	59.6	375	91	10800	29584	27826	1
1307.00	69.8	404	90	10300	15099	26118	1
1308.00	79.7	417	90	3600	17361	24318	1

Table 4.6.2: Tracer concentrations for experiment III.2.1-III.2.3, 31.08.1988

Tracer emission: KFA-tower , 50 m

Group: 1 = KFA; 2 = APL; 3 = MOL

sampling period: 1 = 19:00 - 19:30; 2 = 19:30 - 20:00; 3 = 20:00 - 20:30

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
2.00	21.0	446	91	18200	34841	2500	1
3.00	31.1	437	90	36765	2800	-9999	1
4.00	40.7	441	90	50070	11760	680	1
4.50	45.4	449	90	54774	9000	340	1
5.00	50.0	452	90	48732	7800	400	1
5.50	55.2	451	90	37662	-9999	810	1
6.00	61.0	466	90	30459	4300	500	1
7.00	70.1	496	90	15749	2300	380	1
8.00	79.8	547	90	11000	980	225	1
12.00	19.8	962	99	1800	44099	3500	1
12.50	25.4	941	99	17825	47533	2900	1
13.00	30.7	927	99	18392	31690	3900	1
13.50	35.3	921	99	14351	14589	6500	1
14.00	40.1	924	97	9132	18332	13207	1
14.50	45.2	934	96	23162	19174	15460	1
15.00	51.0	952	99	42890	15236	360	1
15.50	55.9	964	99	31531	8800	5300	1
16.00	60.0	996	99	14247	6300	3000	1
16.50	64.9	1053	99	8500	3222	2793	1
17.00	70.3	1118	99	3190	-9999	2137	1
17.50	75.8	1189	96	650	813	2038	1
18.00	80.1	1145	92	436	650	262	1
19.00	91.0	1599	100	22	90	252	1
21.00	10.3	1837	107	340	13569	1182	1
22.00	19.8	1951	107	-9999	10757	436	1
30.00	11.9	5582	95	10	-9999	6747	1
31.00	19.3	5530	93	17	1393	3443	1
31.50	25.6	5689	92	48	655	-9999	1
32.00	29.5	6054	89	17	147	1254	1
32.50	35.9	6399	84	70	2100	14	1
33.00	39.8	6528	87	175	-9999	120	1
33.50	45.2	6197	90	3565	2581	68	1
34.00	49.6	6410	87	2386	579	36	1
34.50	54.9	6266	83	27	42	38	1
35.00	61.5	6138	87	11	14	17	1
35.50	65.1	5938	87	11	16	19	1
36.00	68.3	5688	94	6	8	16	1
40.00	29.7	7689	92	12	99	1740	1
41.00	36.1	9277	88	21	486	810	1
42.00	40.6	10582	85	779	609	1257	1
43.00	44.4	10986	74	1342	1596	46	1
44.00	49.9	10716	81	704	80	19	1
45.00	55.8	10360	74	15	11	12	1
46.00	59.9	10105	81	12	6	12	1
47.00	65.7	10002	85	12	-9999	11	1
48.00	71.3	9739	84	11	3	-9999	1
49.00	74.5	9522	86	13	-9999	-9999	1
86.00	62.0	4675	90	30	54	29	1

Table 4.6.2 continued

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
87.00	62.3	4571	97	225	295	70	1
88.00	61.8	4414	98	28	-9999	35	1
89.00	62.9	3779	99	122	205	61	1
90.00	64.4	3602	100	-9999	253	56	1
92.00	67.9	3262	103	18	18	-9999	1
94.00	72.3	2938	103	104	225	40	1
96.00	77.7	2627	104	48	84	25	1
98.00	82.6	2426	105	35	51	39	1
99.00	90.0	2180	106	110	41	105	1
101.00	64.7	3469	101	130	273	39	2
106.00	69.3	3016	102	109	338	34	2
112.00	75.0	2667	103	63	85	27	2
116.00	79.8	2444	104	56	41	121	2
120.00	80.2	2090	105	246	116	36	2
122.00	70.2	1939	105	382	580	56	2
124.00	60.7	1869	105	4589	1509	101	2
125.00	55.6	1852	105	5253	3260	418	2
126.00	50.9	1848	103	18716	6158	845	2
127.00	45.7	1852	103	9298	5796	1389	2
128.00	41.2	1839	103	2657	7004	464	2
130.00	30.2	1896	105	2234	9841	256	2
132.00	25.1	2045	105	3767	12920	174	2
135.00	20.1	2380	105	179	14067	3623	2
220.00	80.2	2220	132	63	56	24	2
221.00	75.2	2120	133	176	53	24	2
222.00	70.4	2058	130	-9999	208	29	2
223.00	65.0	1993	131	-9999	500	118	2
224.00	59.8	1965	131	4178	450	63	2
225.00	54.9	1953	132	14671	3019	671	2
226.00	50.2	1965	131	18113	7366	1147	2
227.00	45.1	1945	131	-9999	-9999	816	2
228.00	40.4	1933	131	3924	4468	198	2
229.00	35.0	1926	130	1932	6859	161	2
230.00	30.2	2007	128	1304	8875	384	2
233.00	25.8	2199	128	2198	12256	232	2
237.00	20.4	2641	127	722	12256	592	2
300.00	60.5	3642	143	187	262	37	3
306.00	64.8	3082	149	348	138	89	3
314.00	69.7	2694	151	52	152	35	3
319.00	74.3	2424	153	38	-9999	44	3
321.00	75.3	2215	157	165	113	35	3
322.00	70.3	2149	157	278	485	141	3
323.00	65.5	2096	156	949	355	69	3
324.00	60.2	2065	156	2925	748	106	3
325.00	55.0	2101	154	5500	7110	3269	3
326.00	50.6	2108	155	13709	5376	385	3
426.00	50.8	2224	184	14725	4900	660	1
427.00	45.4	2147	184	-9999	1150	105	1
428.00	40.9	2122	183	2951	1754	-9999	1
429.00	34.7	2130	183	3726	6493	66	1

Table 4.6.2 continued

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m^3)			
	ϕ (°)	R (m)		1	2.c.3	Group	
430.00	30.7	2277	183	1803	7469	81	1
506.00	61.5	2991	209	553	135	29	2
514.00	65.1	2640	213	326	77	24	2
521.00	68.2	2430	217	273	63	19	2
523.00	65.4	2295	218	642	68	19	2
524.00	60.2	2296	216	2584	101	31	2
525.00	55.4	2400	215	7897	565	53	2
526.00	50.7	2431	217	14611	3743	667	2
527.00	45.3	2286	214	5072	2391	203	2
528.00	40.8	2217	214	3333	3260	63	2
529.00	35.3	2251	212	2463	8694	70	2
530.00	30.5	2444	212	155	12498	130	2
538.00	24.4	2888	211	34	4951	302	2
602.00	55.2	2913	257	966	6351	4661	2
614.00	60.2	2681	248	1304	94	15	2
623.00	66.4	2356	226	-9999	261	29	2
624.00	60.1	2411	231	2125	97	24	2
625.00	55.2	2593	243	6231	191	46	2
626.00	50.0	2602	243	16241	1630	89	2
627.00	45.7	2392	237	-9999	2608	-9999	2
627.50	43.2	2332	235	4275	1715	60	2
628.00	40.6	2285	234	2355	3405	58	2
629.00	33.9	2378	232	1280	8936	63	2
630.00	30.5	2525	232	314	4299	94	2
639.00	24.7	3123	229	34	3478	261	2
704.00	40.0	2841	260	1225	4781	68	3
705.00	45.9	3046	264	3851	1697	92	3
706.00	41.0	3011	262	808	4362	148	3
708.00	34.7	3231	267	114	7802	148	3
710.00	30.5	3467	263	44	3425	1301	3
712.00	28.6	3676	252	45	2885	712	3
714.00	35.6	3860	271	69	5909	479	3
1103.00	31.5	93	91	18980	9000	1600	1
1104.00	40.6	92	91	16465	6600	1480	1
1105.00	50.4	90	91	16944	4450	1120	1
1106.00	60.8	104	91	16298	6600	1650	1
1107.00	68.5	101	91	18272	9400	1800	1
1302.00	21.8	236	91	18964	21655	2800	1
1303.00	31.2	251	91	14738	19521	2355	1
1304.00	40.8	275	91	39729	16509	1700	1
1305.00	50.5	313	90	50688	16546	1800	1
1306.00	59.6	375	91	24759	10000	730	1
1307.00	69.8	404	90	21408	3600	460	1
1308.00	79.7	417	90	15686	3200	480	1
2002.00	62.0	4804	96	14	26	167	1
2003.00	62.2	5285	95	10	23	19	1
2004.00	62.9	5820	94	13	15	20	1
2005.00	61.0	5937	91	14	20	30	1
2006.00	55.1	5780	91	300	400	26	1
2007.00	50.6	5895	88	1500	100	57	1

Table 4.6.3: Tracer concentrations for experiment III.3.1-III.3.3, 03.09.1988

Tracer emission: KFA-tower , 50 m

Group: 1 = KFA
2 = APL
3 = MOL

sampling period: 1 = 6:30 - 7:00
2 = 7:00 - 7:30
3 = 7:30 - 8:00

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
3.00	31.1	437	90	8100	1300	130	1
3.50	36.1	439	90	7100	172	158	1
4.00	40.7	441	90	-9999	185	122	1
4.50	45.4	449	90	1523	111	74	1
5.00	51.0	452	90	617	73	52	1
5.50	55.2	451	90	1120	-9999	79	1
6.00	61.0	466	90	1320	107	46	1
6.50	65.3	480	90	336	38	34	1
7.00	70.1	496	90	149	47	19	1
8.00	79.8	547	90	18	35	14	1
12.00	19.8	962	99	5800	25630	10137	1
12.50	25.4	941	99	15006	13115	-9999	1
13.00	30.7	927	99	16358	6400	173	1
13.50	35.3	921	99	13093	720	23	1
14.00	40.1	924	97	5980	-9999	43	1
14.50	45.2	934	96	2000	49	39	1
15.00	51.0	952	99	268	18	29	1
15.50	55.9	964	99	35	13	9	1
16.00	60.0	996	99	91	13	11	1
16.50	64.9	1053	99	17	12	15	1
17.00	70.3	1118	99	14	12	19	1
17.50	75.8	1189	96	14	11	20	1
18.00	80.1	1145	92	13	12	12	1
19.00	91.0	1599	100	33	42	-9999	1
21.00	10.3	1837	107	23	5125	-9999	1
22.00	19.8	1951	107	1440	-9999	1016	1
31.00	19.3	5530	93	29	637	2590	1
32.00	29.5	6054	89	672	913	197	1
33.00	39.8	6528	87	573	-9999	-9999	1
33.50	45.2	6197	90	87	166	18	1
34.00	49.6	6410	87	30	59	18	1
34.50	54.9	6266	83	30	59	18	1
35.00	61.5	6138	87	40	-9999	11	1
36.00	68.3	5688	94	11	11	13	1
40.00	29.7	7689	92	19	290	498	1
41.00	36.1	9277	88	1163	325	15	1
42.00	40.6	10582	85	531	21	42	1
43.00	44.4	10986	74	-9999	12	13	1
44.00	49.9	10716	81	7	26	9	1
45.00	55.8	10360	74	12	11	14	1
46.00	59.9	10105	81	12	11	15	1
47.00	65.7	10002	85	11	14	10	1
48.00	71.3	9739	84	14	12	10	1
49.00	74.5	9522	86	10	11	11	1
89.00	62.9	3779	99	97	-9999	12	1
90.00	64.4	3602	100	14	280	383	1
98.00	82.6	2426	105	126	55	42	1

Table 4.6.3 continued

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m³)			Group
	ϕ (°)	R (m)		1	2	3	
99.00	90.0	2180	106	69	37	125	1
101.00	64.7	3469	101	81	50	83	2
106.00	69.3	3016	102	30	23	23	2
112.00	75.0	2667	103	68	60	60	2
116.00	79.8	2444	104	15	30	30	2
120.00	80.2	2090	105	42	31	30	2
122.00	70.2	1939	105	15	15	15	2
124.00	60.7	1869	105	15	23	23	2
125.00	55.6	1852	105	23	23	15	2
126.00	50.9	1848	103	77	30	30	2
127.00	45.7	1852	103	941	15	15	2
128.00	41.2	1839	103	-9999	30	45	2
130.00	30.2	1896	105	4343	285	38	2
132.00	25.1	2045	105	5694	911	68	2
135.00	20.1	2380	105	3165	2490	263	2
220.00	80.2	2220	132	24	19	17	2
221.00	75.2	2120	133	19	19	21	2
222.00	70.4	2058	130	19	19	19	2
223.00	65.0	1993	131	19	19	19	2
224.00	59.8	1965	131	19	19	19	2
225.00	54.9	1953	132	24	19	19	2
226.00	50.2	1965	131	80	19	19	2
227.00	45.1	1945	131	405	19	24	2
228.00	40.4	1933	131	2919	391	66	2
229.00	35.0	1926	130	2283	381	297	2
230.00	30.2	2007	128	6191	589	28	2
233.00	25.8	2199	128	5508	1106	61	2
237.00	20.4	2641	127	3013	2919	405	2
248.00	20.3	3956	123	486	3000	1820	1
260.00	21.2	4096	123	599	1524	680	1
262.00	29.5	4773	122	1079	1080	130	1
267.00	33.9	5133	120	2380	404	19	1
274.00	39.7	5583	119	1008	66	57	1
276.00	41.5	5758	119	497	17	14	1
280.00	45.4	5999	117	54	13	12	1
287.00	54.7	5648	120	13	11	12	1
300.00	60.5	3642	143	44	15	34	3
306.00	64.8	3082	149	15	15	80	3
314.00	69.7	2694	151	36	110	55	3
319.00	74.3	2424	153	22	147	75	3
321.00	75.3	2215	157	51	15	15	3
322.00	70.3	2149	157	87	15	22	3
323.00	65.5	2096	156	59	25	15	3
324.00	60.2	2065	156	27	184	15	3
325.00	55.0	2101	154	15	206	15	3
326.00	50.6	2108	155	146	15	15	3
426.00	50.8	2224	184	191	41	45	1
427.00	45.4	2147	184	608	125	-9999	1
428.00	40.9	2122	183	1899	-9999	125	1
429.00	34.7	2130	183	4400	240	77	1

Table 4.6.3 continued

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m³)			Group
	ϕ (°)	R (m)		1	2	3	
430.00	30.7	2277	183	5000	800	60	1
506.00	61.5	2991	209	24	19	19	2
514.00	65.1	2640	213	-9999	19	19	2
521.00	68.2	2430	217	19	17	19	2
523.00	65.4	2295	218	21	19	21	2
524.00	60.2	2296	216	24	21	17	2
525.00	55.4	2400	215	24	19	21	2
526.00	50.7	2431	217	80	24	24	2
527.00	45.3	2286	214	584	24	19	2
528.00	40.8	2217	214	1318	33	24	2
529.00	35.3	2251	212	4237	80	24	2
530.00	30.5	2444	212	4331	673	38	2
538.00	24.4	2888	211	2566	2178	346	2
602.00	55.2	2913	257	24	21	19	2
614.00	60.2	2681	248	19	19	24	2
623.00	66.4	2356	226	19	19	21	2
624.00	60.1	2411	231	19	17	21	2
625.00	55.2	2593	243	19	21	19	2
626.00	50.0	2602	243	66	21	24	2
627.00	45.7	2392	237	311	24	28	2
628.00	40.6	2285	234	2260	193	141	2
629.00	33.9	2378	232	4590	365	38	2
630.00	30.5	2525	232	4049	629	28	2
641.00	23.8	3404	228	1389	2142	485	2
704.00	40.0	2841	260	1813	192	44	3
705.00	45.9	3046	264	493	76	15	3
706.00	41.0	3011	262	1130	200	36	3
708.00	34.7	3231	267	3633	267	37	3
710.00	30.5	3467	263	2662	900	163	3
712.00	28.6	3676	252	1571	92	153	3
714.00	35.6	3860	271	3087	2237	129	3
1103.00	31.5	93	91	7500	8400	8000	1
1104.00	40.6	92	91	5900	8000	8600	1
1105.00	50.4	90	91	3200	660	4700	1
1106.00	60.8	104	91	800	104	160	1
1301.00	10.0	225	91	6874	53873	-9999	1
1302.00	21.8	236	91	17486	82685	49009	1
1303.00	31.2	251	91	14713	37703	10200	1
1304.00	40.8	275	91	17805	11525	6312	1
1305.00	50.2	313	90	904	85	50	1
1306.00	59.6	375	91	39	22	27	1
1307.00	69.8	404	90	46	34	38	1
1308.00	79.7	417	90	20	21	20	1
2002.00	62.0	4804	96	19	32	16	1
2003.00	62.2	5285	95	14	12	-9999	1
2004.00	62.9	5820	94	12	14	14	1
2006.00	55.1	5780	91	14	11	12	1
2007.00	50.6	5895	88	12	14	-9999	1
2008.00	48.6	6026	90	77	215	21	1
2009.00	45.6	6089	91	2097	23	12	1

Table 4.6.4: Tracer concentrations for experiment III.4.1-III.4.2, 04.09.1988

Tracer emission: KFA-tower , 50 m

Group: 1 = KFA
2 = APL
3 = MOL

sampling period: 1 = 12:00 - 12:30
2 = 12:30 - 13:00
3 = 13:00 - 13:30

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
2.00	21.0	446	91	190	1580	4620	1
3.00	31.1	437	90	1170	17800	3920	1
4.00	40.7	441	90	3880	-9999	4900	1
4.50	45.4	449	90	8000	14000	1600	1
5.00	51.0	452	90	9000	10500	980	1
5.50	55.2	451	90	15238	13272	1100	1
6.00	61.0	466	90	17609	13888	980	1
7.00	70.1	496	90	11500	4300	110	1
8.00	79.8	547	90	9500	2200	103	1
12.00	19.8	962	99	13	12	-9999	1
12.50	25.4	941	99	14	15	632	1
13.00	30.7	927	99	20	14	600	1
13.50	35.3	921	99	64	100	580	1
14.00	40.1	924	97	230	1100	420	1
14.50	45.2	934	96	832	2487	646	1
15.00	50.0	952	99	1216	2682	-9999	1
15.50	55.9	964	99	1826	2122	488	1
16.00	60.0	996	99	1524	1962	438	1
16.50	64.9	1053	99	1547	971	290	1
17.00	70.3	1118	99	1750	340	148	1
17.50	75.8	1189	96	1300	100	22	1
18.00	80.1	1145	92	1064	54	15	1
19.00	91.0	1599	100	43	14	12	1
21.00	10.3	1837	107	23	18	14	1
22.00	19.8	1951	107	14	7	54	1
30.00	11.9	5582	95	-9999	-9999	16	1
31.00	19.3	5530	93	-9999	16	16	1
32.00	29.5	6054	89	-9999	16	14	1
32.50	35.9	6399	84	-9999	13	28	1
33.00	39.8	6528	87	13	16	56	1
33.50	45.2	6197	90	28	59	32	1
34.00	49.6	6410	87	98	127	72	1
34.50	54.9	6266	83	113	125	24	1
35.00	61.5	6138	87	126	67	13	1
35.50	65.1	5938	87	100	35	18	1
36.00	68.3	5688	94	27	22	16	1
40.00	29.7	7689	92	-9999	15	18	1
41.00	36.1	9277	88	19	13	20	1
42.00	40.6	10582	85	13	11	14	1
43.00	44.4	10986	74	16	18	16	1
44.00	49.9	10716	81	7	42	150	1
45.00	55.8	10360	74	74	-9999	68	1
46.00	59.9	10105	81	33	141	28	1
47.00	65.7	10002	85	17	29	17	1
48.00	71.3	9739	84	3	14	13	1
49.00	74.5	9522	86	67	18	17	1
89.00	62.9	3779	99	189	36	13	1

Table 4.6.4 continued

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
90.00	64.4	3602	100	36	21	12	1
92.00	67.9	3262	103	207	42	18	1
98.00	82.6	2426	105	39	13	-9999	1
99.00	90.0	2180	106	14	13	-9999	1
101.00	64.7	3469	101	181	54	20	2
106.00	69.3	3016	102	147	39	20	2
112.00	75.0	2667	103	117	15	15	2
116.00	79.8	2444	104	49	20	20	2
120.00	80.2	2090	105	176	20	15	2
122.00	70.2	1939	105	127	191	20	2
124.00	60.7	1869	105	364	380	88	2
125.00	55.6	1852	105	271	428	170	2
126.00	50.9	1848	103	247	501	218	2
127.00	45.7	1852	103	93	355	210	2
128.00	41.2	1839	103	20	68	202	2
130.00	30.2	1896	105	10	10	59	2
132.00	25.1	2045	105	10	10	59	2
135.00	20.1	2380	105	10	15	20	2
220.00	80.2	2220	132	176	19	21	2
221.00	75.2	2120	133	171	50	19	2
222.00	70.4	2058	130	119	128	26	2
223.00	65.0	1993	131	131	240	43	2
224.00	59.8	1965	131	325	390	86	2
225.00	54.9	1953	132	252	527	195	2
226.00	50.2	1965	131	303	582	190	2
227.00	45.1	1945	131	88	465	218	2
228.00	40.4	1933	131	34	59	162	2
229.00	35.0	1926	130	20	15	78	2
230.00	30.2	2007	128	20	15	98	2
233.00	25.8	2199	128	20	20	49	2
237.00	20.4	2641	127	20	20	10	2
248.00	20.3	3956	123	17	32	15	1
260.00	21.2	4069	123	4	10	17	1
262.00	29.5	4773	122	3	4	11	1
267.00	33.9	5133	120	12	12	8	1
274.00	39.7	5583	119	14	7	64	1
280.00	45.4	5999	117	33	49	102	1
286.00	50.4	5779	119	100	-9999	70	1
287.00	54.7	5648	120	121	-9999	32	1
300.00	60.5	3642	143	179	92	34	3
306.00	64.8	3082	149	193	15	15	3
314.00	69.7	2694	151	101	78	15	3
319.00	74.3	2424	153	117	15	101	3
321.00	75.3	2215	157	352	15	15	3
322.00	70.3	2149	157	15	151	78	3
323.00	65.5	2096	156	172	482	93	3
324.00	60.2	2065	156	203	715	23	3
325.00	55.0	2101	154	231	369	31	3
326.00	50.6	2108	155	145	375	116	3
426.00	50.8	2224	184	215	320	-9999	1
427.00	45.4	2147	184	61	231	160	1
428.00	40.9	2122	183	-9999	195	140	1
429.00	34.7	2130	183	29	24	150	1
430.00	30.7	2277	183	-9999	68	68	1

Table 4.6.4 continued

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m³)			Group
	ϕ (°)	R (m)		1	2	3	
506.00	61.5	2991	209	230	109	33	2
514.00	65.1	2640	213	140	71	29	2
521.00	68.2	2430	217	124	71	24	2
523.00	65.4	2295	218	152	138	48	2
524.00	60.2	2296	216	233	280	112	2
525.00	55.4	2400	215	242	306	119	2
526.00	50.7	2431	217	214	278	135	2
527.00	45.3	2286	214	64	214	214	2
528.00	40.8	2217	214	38	33	138	2
529.00	35.3	2251	212	26	19	78	2
530.00	30.5	2444	212	19	19	33	2
538.00	24.4	2888	211	19	14	19	2
602.00	55.2	2913	257	280	221	71	2
614.00	60.2	2681	248	266	226	52	2
623.00	66.4	2356	226	131	107	38	2
624.00	60.1	2411	231	257	276	93	2
625.00	55.2	2593	243	266	304	88	2
626.00	50.0	2602	243	173	299	86	2
627.00	45.7	2392	237	59	276	195	2
628.00	40.6	2285	234	36	38	121	2
629.00	33.9	2378	232	19	19	71	2
630.00	30.5	2525	232	19	19	38	2
641.00	23.8	3404	228	19	19	19	2
662.00	28.7	4153	232	15	15	15	3
663.00	31.5	4223	234	18	82	44	1
664.00	33.7	4256	236	15	15	15	3
666.00	37.8	4363	253	22	21	42	1
670.00	40.1	5070	235	15	25	45	3
704.00	40.0	2841	260	15	61	15	3
705.00	45.9	3046	264	82	54	269	3
706.00	41.0	3011	262	34	15	15	3
708.00	34.7	3231	267	58	15	15	3
710.00	30.5	3467	263	97	25	15	3
712.00	28.6	3676	252	15	15	15	3
714.00	35.6	3860	271	54	37	15	3
1104.00	40.6	92	91	26729	4700	13900	1
1105.00	50.4	90	91	2500	25247	880	1
1106.00	60.8	104	91	2000	60947	1350	1
1107.00	68.5	101	91	970	96933	2200	1
1302.00	21.8	236	91	-9999	22350	42666	1
1303.00	31.2	251	91	5200	26076	17000	1
1304.00	40.8	275	91	11200	39790	6400	1
1305.00	50.2	313	90	12100	25000	3150	1
1306.00	59.6	375	91	13400	6000	950	1
1307.00	69.8	404	90	9500	2800	225	1
1308.00	79.7	417	90	5300	173	48	1
2002.00	62.0	4804	96	-9999	44	15	1
2003.00	62.2	5285	95	111	88	-9999	1
2005.00	61.0	5937	91	111	79	86	1
2006.00	55.1	5780	91	158	174	48	1
2007.00	50.6	5895	88	148	169	23	1
2008.00	48.6	6026	90	162	321	41	1
2009.00	45.6	6089	91	3	36	8	1
							1

Table 4.6.5: Tracer concentrations for experiment III.5.1-III.5.3, 05.09.1988

Tracer emission: Water-tower , 47 m

Group: 1 = KFA
2 = APL
3 = MOL

sampling period: 1 = 20:00 - 20:30
2 = 20:30 - 21:00
3 = 21:00 - 21:30

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
32.00	49.8	4517	89	25	30	25	1
32.50	56.1	5081	84	14	14	13	1
33.00	60.2	5355	87	21	13	14	1
33.50	67.5	5265	90	20	16	-9999	1
34.00	71.4	5642	87	13	15	10	1
34.50	77.4	5730	83	13	-9999	25	1
35.00	84.4	5889	87	13	14	16	1
35.50	88.5	5853	87	14	17	34	1
36.00	92.4	5756	94	13	15	68	1
36.50	93.3	5815	98	15	17	13	1
41.00	49.0	7851	88	15	28	16	1
42.00	52.3	9292	85	9	12	12	1
43.00	56.1	9834	74	14	12	12	1
44.00	62.3	9785	81	68	13	13	1
45.00	68.9	9678	74	-9999	17	13	1
46.00	73.6	9602	81	17	-9999	15	1
47.00	79.6	9743	85	35	13	14	1
48.00	85.5	9721	84	22	15	17	1
49.00	88.8	9643	86	25	13	14	1
60.00	120.8	576	106	31958	34595	29281	1
60.50	115.8	560	106	30801	-9999	39545	1
61.00	110.2	558	108	3020	-9999	30555	1
61.50	103.7	568	107	166	156	10810	1
62.00	99.2	585	107	23	41	1200	1
62.50	93.4	611	107	14	41	235	1
63.00	88.0	631	106	30	15	78	1
63.50	84.4	662	106	10	10	31	1
64.00	79.9	690	106	109	12	10	1
64.50	74.1	734	105	14	13	30	1
65.00	69.2	791	104	15	26	30	1
65.50	64.1	861	104	15	12	25	1
66.00	59.2	951	103	15	9	17	1
96.00	120.5	3524	104	2100	3539	3700	1
98.00	125.3	3524	105	120	4600	105	1
99.50	134.5	3573	101	7	19	34	1
100.00	127.7	3374	107	77	121	77	2
101.00	103.5	3705	101	15	15	34	3
106.00	111.3	3531	102	28	233	459	3
110.00	115.8	3476	103	671	2930	3174	2
112.00	118.6	3468	103	24339	5622	4861	3
116.00	123.7	3456	104	2586	1383	1485	2
120.00	128.3	3220	105	314	693	1930	3
128.00	120.0	1938	103	13922	10374	5608	3
130.00	116.6	1589	105	1122	457	794	3
132.00	110.5	1427	105	15	27	15	3
134.00	100.8	1316	106	56	15	15	3
136.00	89.1	1286	103	15	15	15	3

Table 4.6.5 continued

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
138.00	79.6	1313	102	15	42	37	3
140.00	68.9	1416	102	314	55	15	3
142.00	60.0	1592	102	15	27	25	3
151.00	48.7	2271	97	15	15	15	3
223.00	123.6	2729	131	4363	5380	7754	2
226.00	118.9	2260	131	10916	6556	4295	2
229.00	116.2	1753	130	802	780	1741	2
230.00	112.7	1602	128	50	41	194	2
233.00	104.6	1470	128	20	18	23	2
234.00	99.4	1427	128	23	23	23	2
236.00	90.3	1402	127	18	18	18	2
238.00	79.6	1412	127	23	23	23	2
240.00	68.0	1522	126	18	18	18	2
246.00	54.7	2095	123	18	18	18	2
266.00	59.9	3755	120	33	22	23	1
276.00	65.5	4711	119	12	17	30	1
280.00	68.6	5090	117	-9999	16	13	1
286.00	74.9	5097	119	15	15	21	1
287.00	79.8	5158	120	30	79	-9999	1
319.50	124.0	3244	157	2930	3967	7121	2
320.50	124.9	3287	156	879	773	1424	2
330.00	107.8	1630	153	11	11	16	2
334.00	99.4	1518	152	18	18	23	2
335.00	94.7	1489	152	11	11	11	2
425.00	121.3	3139	182	7487	6022	7650	2
428.00	111.9	2001	183	22	38	468	2
434.00	98.6	1620	181	16	16	11	2
436.00	88.8	1583	179	22	11	22	2
438.00	80.1	1611	180	11	11	16	2
440.00	69.4	1740	179	11	11	16	2
444.00	60.5	2093	178	11	11	11	2
506.00	106.6	3229	209	23	124	84	2
514.00	113.4	3120	213	1142	2634	1379	2
521.00	117.0	3084	217	8873	6081	5595	2
524.00	116.2	2741	216	2057	2025	2306	2
526.00	109.0	2485	217	20	23	27	2
528.00	109.4	2032	214	18	18	63	2
529.00	106.2	1842	212	18	20	23	2
530.00	98.2	1724	212	20	23	23	2
535.00	95.3	1706	211	20	18	18	2
536.00	90.4	1695	212	18	23	18	2
623.00	118.2	2981	226	7934	6592	5819	2
624.00	114.2	2802	231	-9999	675	1042	2
625.00	108.5	2740	243	16	22	71	2
628.00	107.5	2048	234	11	11	11	2
703.00	100.0	2430	257	65	15	24	3
704.00	94.4	2301	260	15	15	15	3
706.00	91.9	2445	262	28	15	61	3
708.00	82.5	2325	267	15	15	48	3
710.00	74.1	2316	263	31	15	24	3

Table 4.6.5 continued

Pos.	Polar.Coord.		Height (meter m.s l.)	Mean Concentrations (ng/m³)			Group
	ϕ (°)	R (m)		1	2	3	
712.00	68.5	2391	252	15	34	42	3
714.00	73.9	2825	271	15	15	15	3
2013.00	129.4	3537	105	14	16	17	1
2014.00	137.1	3612	99	13	16	73	1
2015.00	135.9	4047	103	13	57	13	1
2016.00	137.3	4327	97	12	14	-9999	1
2017.00	140.1	4811	96	13	15	13	1
2018.00	139.9	5550	100	14	24	14	1
2019.00	139.8	5723	101	4	4	4	1
2020.00	139.0	6183	102	34	17	20	1
6060.00	57.6	471	106	34	16	14	1
6065.00	62.5	435	106	32	285	500	1
6070.00	68.7	401	107	37	31	35	1
6080.00	78.5	361	107	38	34	995	1
6085.00	83.1	349	107	42	33	3100	1
6090.00	88.2	337	107	41	42	8500	1
6095.00	92.4	328	107	65	2500	16570	1
6100.00	97.6	322	108	7500	14329	36680	1
6105.00	102.3	317	108	29895	33979	67276	1
6110.00	107.0	313	108	41569	35819	81079	1
6115.00	111.9	315	108	42816	35547	73799	1
6120.00	116.9	319	108	36095	30721	67797	1

Table 4.6.6: Tracer concentrations for experiment III.6.1-III.6.3, 07.09.1988

Tracer emission: Mast 5, Sophienhöhe, 2 m

Group: 1 = KFA, 2 = APL, 3 = MOL

sampling period: 1 = 20:00 - 20:30, 2 = 20:30 - 21:00, 3 = 21:00 - 21:30

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
66.00	261.1	1912	103	22	20	22	1
66.30	271.3	1768	103	190	-9999	23	1
73.50	287.9	1680	100	1464	41	46	1
74.00	286.3	1681	101	703	40	34	1
75.50	279.8	1706	102	592	27	31	1
76.00	277.5	1721	102	514	26	22	1
238.50	249.7	1400	127	23	12	12	2
239.00	253.5	1362	127	29	12	12	2
239.50	257.5	1322	126	148	18	12	2
240.00	259.5	1306	126	176	18	12	2
240.50	262.6	1284	125	283	23	12	2
241.00	270.5	1242	126	315	81	35	2
241.50	270.2	1232	126	310	46	33	2
242.00	275.0	1200	125	466	56	19	2
242.50	277.7	1182	125	4210	1879	153	2
243.50	282.9	1126	125	4367	2818	153	2
244.00	284.8	1137	124	2749	139	37	2
244.50	287.2	1120	125	2899	3653	1183	2
245.00	288.0	1110	124	5312	742	46	2
245.50	291.0	1095	123	4801	1137	162	2
246.00	293.2	1084	123	3966	1832	81	2
246.50	295.6	1071	124	1485	3201	139	2
247.00	298.2	1059	124	376	2691	223	2
247.50	300.9	1045	124	107	2088	343	2
248.00	303.5	1038	123	56	1461	584	2
248.50	306.6	1022	122	28	1496	1322	2
249.00	310.5	1010	123	19	1566	3298	2
249.05	313.3	999	123	19	1601	5428	2
249.10	315.6	989	121	19	1508	6785	2
249.15	318.2	985	121	21	1044	8582	2
249.20	320.4	966	122	19	538	10090	2
249.25	323.5	962	122	49	155	8872	2
249.30	325.5	952	122	21	37	5636	2
249.35	327.5	955	122	492	399	1125	2
249.40	330.8	951	122	21	19	195	2
249.45	333.3	948	122	33	21	81	2
260.00	310.5	1010	123	19	19	23	2
260.05	338.5	951	123	33	14	21	2
260.10	341.3	947	122	19	16	28	2
260.15	343.9	950	122	21	23	19	2
260.20	346.9	955	121	19	19	23	2
260.25	349.9	953	121	162	97	60	2
261.00	354.2	963	125	19	23	19	2
261.50	0.1	973	120	19	21	21	2
262.00	6.2	1023	122	19	19	21	2
262.50	9.9	1064	121	21	21	21	2

Table 4.6.6 continued

Pos.	Polar.Coord.		Height (meter m.s.l.)	Mean Concentrations (ng/m³)			Group
	ϕ (°)	R (m)		1	2	3	
263.00	14.1	1100	121	19	19	21	2
263.50	16.8	1103	121	42	33	26	2
264.00	19.3	1117	122	19	19	23	2
265.00	22.8	1162	122	23	21	21	2
266.00	26.3	1224	120	19	19	19	2
267.00	29.2	1284	120	19	21	-9999	2
268.00	32.0	1342	120	19	19	21	2
269.00	35.3	1408	119	23	16	23	2
270.00	38.3	1475	119	-9999	14	16	2
271.00	41.4	1518	119	19	14	23	2
538.00	244.2	1161	211	15	15	15	3
540.00	260.6	995	209	15	15	15	3
540.30	263.8	970	210	15	15	15	3
540.40	266.8	947	210	15	15	15	3
541.00	269.2	929	209	15	15	15	3
541.30	274.8	895	209	15	15	15	3
542.00	280.0	851	209	15	15	15	3
542.10	283.5	838	209	147	15	66	3
542.20	286.6	822	209	387	164	15	3
542.30	289.7	805	209	1193	82	15	3
543.00	292.0	790	209	3438	74	15	3
543.10	294.7	780	209	12870	1138	38	3
543.20	297.6	770	209	6163	2740	40	3
543.30	300.5	758	208	2354	3457	144	3
544.00	302.8	744	209	43	3652	825	3
544.10	306.2	729	208	15	4665	309	3
544.20	308.8	718	208	140	756	727	3
545.00	311.3	707	209	15	5680	4039	3
545.10	314.3	684	208	15	2247	7438	3
545.11	317.7	682	209	12	147	14860	1
545.20	320.2	676	209	11	25	13683	1
545.21	322.7	666	209	13	17	6100	1
545.30	325.5	663	210	10	10	1188	1
545.31	327.6	657	210	10	10	169	1
545.40	330.2	652	210	10	13	14	1
545.41	333.0	648	211	15	15	15	1
547.00	335.5	641	211	12	12	13	1
547.10	340.4	617	211	12	-9999	12	1
562.00	346.6	593	211	13	10	10	1
562.10	350.5	580	212	18	15	12	1
562.20	355.6	559	212	14	20	13	1
563.00	1.8	541	211	13	10	-9999	1
563.10	5.8	542	213	-9999	8	10	1
563.20	10.5	531	212	10	10	10	1
563.30	15.7	527	212	13	-9999	16	1
564.00	19.2	526	214	10	11	14	1
564.10	25.6	522	212	12	11	12	1
564.20	30.3	547	211	13	9	13	1
565.00	32.2	603	211	13	13	14	1
565.10	34.7	682	211	21	12	21	1
566.00	38.5	789	209	13	10	11	1
567.00	39.8	996	209	10	12	15	1
568.00	43.0	1124	206	10	13	15	1
640.00	261.9	901	229	10	-9999	14	1

Table 4.6.6 continued

Pos.	Polar.Coord.		Height (meter m,s.l.)	Mean Concentrations (ng/m³)			Group
	ϕ (°)	R (m)		1	2	3	
641.00	268.5	863	228	24	12	66	1
641.50	272.6	851	228	-9999	22	13	1
642.00	275.6	830	228	19	20	-9999	1
642.50	279.9	799	228	196	51	60	1
643.00	284.1	772	228	1035	-9999	120	1
643.50	289.7	738	228	5127	119	72	1
644.00	293.1	715	228	14179	2643	-9999	1
644.50	301.2	687	228	802	3690	-9999	1
645.00	304.9	674	227	65	3236	184	1
645.30	311.1	644	227	20	4480	932	1
645.70	318.0	617	227	-9999	27	13556	1
647.00	328.3	584	231	17	17	429	1
662.00	334.1	563	232	13	15	-9999	1
662.50	340.8	499	236	-9999	-9999	13	1
662.70	346.4	464	240	-9999	14	14	1
663.00	356.1	465	234	13	13	-9999	1
663.50	1.9	362	248	10	14	15	1
663.70	10.2	333	250	7	290	-9999	1
664.20	30.3	315	253	-9999	14	-9999	1
665.00	45.7	343	255	-9999	14	12	1
712.00	280.7	489	252	152	65	75	1
715.00	287.5	443	251	7076	-9999	393	1
716.00	291.5	478	249	28766	3653	106	1
717.00	297.3	476	246	10613	11043	-9999	1
718.00	302.6	486	244	203	-9999	228	1
2021.00	254.7	2418	106	15	14	-9999	1
2022.00	266.2	2218	104	35	15	18	1
2023.00	274.0	2383	103	228	25	30	1
2024.00	284.7	2695	100	627	13	10	1
2025.00	289.2	3244	100	731	23	16	1
2026.00	292.2	3729	98	62	804	-9999	1
2027.00	297.8	4110	98	141	-9999	15	1
2028.00	302.8	4311	98	14	-9999	214	1
2029.00	308.1	4045	98	-9999	16	79	1
2030.00	311.8	3872	94	14	-9999	34	1
8165.00	30.8	1783	89	15	15	15	1
8170.00	28.9	1745	89	15	13	15	1
8175.00	27.3	1714	88	-9999	13	-9999	1
8180.00	25.9	1686	89	-9999	-9999	15	1
8185.00	24.5	1657	89	15	12	-9999	1
8190.00	22.7	1626	89	-9999	12	14	1
8195.00	20.9	1599	89	-9999	13	-9999	1
8200.00	18.8	1561	90	13	32	-9999	1
8205.00	16.5	1526	91	-9999	12	-9999	1
8210.00	13.5	1485	92	-9999	16	-9999	1
8215.00	9.5	1435	92	12	-9999	13	1
8220.00	4.5	1381	93	12	15	15	1
8220.10	359.9	1340	93	15	-9999	15	1
8220.20	354.9	1303	94	15	11	14	1
8220.30	349.8	1271	94	12	-9999	13	1
8220.40	344.4	1251	94	14	-9999	-9999	1
8220.50	339.0	1245	95	-9999	-9999	15	1
8220.60	333.5	1246	95	16	16	1023	1
8220.70	328.0	1257	95	-9999	39	-9999	1

5. METEOROLOGICAL MEASUREMENTS

5.1 Tower and mast measurements

G. Zeuner

The meteorological network for continuous measurements consists of the KFA - tower, several masts on the hill and the KFA Doppler - SODAR (described in chapter 5.7). Generally the data of these measurements are averaged over 10 minutes, exceptions from this will be mentioned. These instruments, its positions and performance during the field campaign are described here.

Some measurement results are shown in this chapter and in chapter 6.

5.1.1 KFA-tower

The meteorological tower (KFA-tower) has a height of 124 m and is located in a clearing within the terrain of the Research Centre. The base of the tower is 91 m above m.s.l.. The surroundings are characterized by groves, buildings and open areas. As seen from the KFA-tower these surroundings are characteristic up to distances of 500 m - 1000 m in easterly and northerly directions and more than 1000 m in the other directions. The trees around the clearing, with distances of 20 m - 50 m to the tower, have a height of 20 m - 25 m. Thus the lower measurement heights at the tower are more or less sheltered against the wind. The mean roughness length derived from wind profile measurements is 1.7 m.

The KFA-tower can be considered as a base station, representative for flat but very rough terrain. For wind directions between 160° and 360° no or little hill influence is expected at this site. The position of the KFA-tower is given in Tab. 5.1.5.

The meteorological parameters measured at the KFA-tower (see Fig. 5.1.1) are:

- wind speed (cup anemometer), temperature and humidity at 8 levels (2 m, 10 m, 20 m, 30 m, 50 m, 80 m, 100 m, 120 m)
- wind direction (wind vane) in 30 m, 50 m and 120 m
- u, v, w wind components (sonic anemometer) in 50 m and 120 m (for selected periods, during dispersion experiments) as mean values and eddies
- wind fluctuations σ_θ, σ_ϕ
- radiation balance in 30m and sunshine duration in 20 m

The instrumentation at the tower is summarized in Tab. 5.1.1.

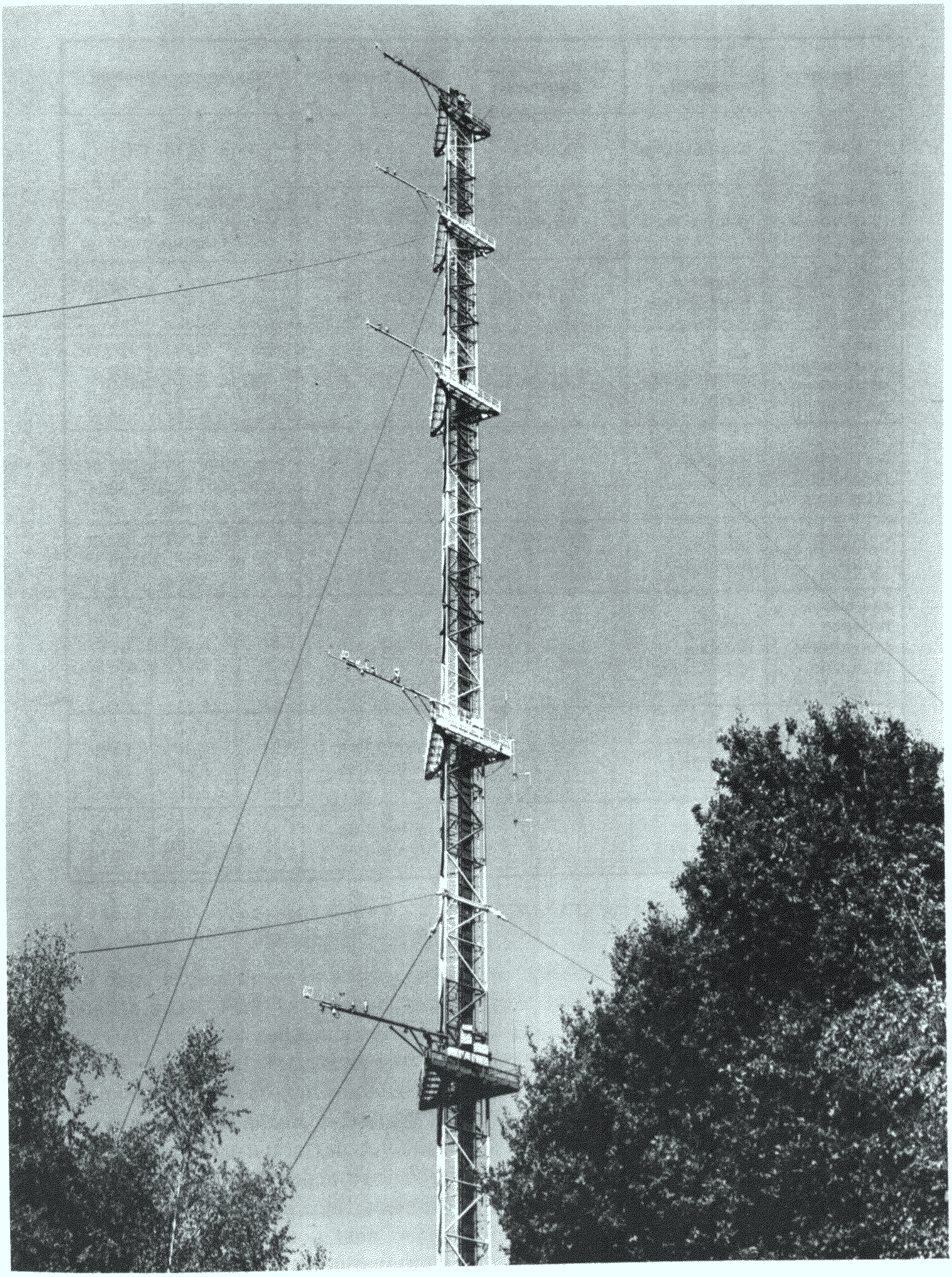


Fig. 5.1.1: The meteorological tower of the Research Center Jülich

Sensor	Measured quantity	Start.speed/Time constant	Samplingtime/ Scan frequen-cy	Measurement height
Wind-vane (Kunkis R-fdsm)	winddirection	0.2 m/s	10 s	30 m, 50 m, 120 m
cup-anem (Lambrecht 1469 I 2m)	windspeed	0.2 m/s	integration 10 minutes	2 m, 10 m, 20 m, 30 m, 50 m, 80 m, 100 m, 120 m
vectorvane (MR I 1053 III)	wind-fluctuations	0.34 m/s	running mean of last 50 minutes	50 m
sonic-anemometer (Kailo-Denki DA 300)	wind-components u,v,w	0.005 m/s	1 s	30 m, 50 m, 120 m
ventil. thermometer (Friedrichs 3 PP 115)	temper-ature	<20 s	1 min	2 m, 10 m, 20 m, 30 m, 50m, 80m, 100m, 120m
humidity meter	relative humidity		10 s	2 m, 10 m, 20 m, 30 m, 50 m, 80 m, 100 m, 120 m
radiation-balance transmitter (Schulze-Lange)	radiation balance (0.3-60 μm)		50 s	30 m
sunshine recorder (Kunkis Helior KS-S)	sunshine-duration		integration 10 minutes	20 m
rain gauge, ombrometer (Thies)	precipi-tation		integration 10 minutes	1 m

Tab.:5.1.1: Instrumentation at the KFA tower

30 - Aug - 88			31 - Aug - 88			03 - Sept - 88		
Time	Hor.Fl. (°)	Vert.Fl. (°)	Time	Hor.Fl. (°)	Vert.Fl. (°)	Time	Hor.Fl. (°)	Vert.Fl. (°)
14:10	19.2	11.6	18:10	15.6	10.5	5:40	14.9	9.7
14:20	17.6	12.3	18:20	15.9	10.7	5:50	15.1	9.5
14:30	17.5	11.8	18:30	15.2	10.3	6:00	14.7	9.2
14:40	18.9	11.8	18:40	14.8	10.0	6:10	14.6	9.2
14:50	18.1	12.6	18:50	14.6	9.6	6:20	14.7	9.0
15:00	18.6	13.1	19:00	14.8	9.4	6:30	14.5	9.9
15:10	20.3	12.8	19:10	14.5	9.1	6:40	15.0	9.9
15:20	20.1	12.6	19:20	13.3	8.8	6:50	15.6	10.3
15:30	20.5	12.4	19:30	12.8	8.6	7:00	16.2	10.9
15:40	20.0	12.7	19:40	12.8	8.2	7:10	16.6	10.9
15:50	19.3	12.2	19:50	11.9	7.7	7:20	16.8	11.0
16:00	19.6	12.4	20:00	11.4	7.2	7:30	16.6	11.2
16:10	19.6	12.1	20:10	10.3	6.6	7:40	17.2	11.5
16:20	18.3	12.2	20:20	10.0	6.1	7:50	17.4	12.1
16:30	18.7	12.4	20:30	9.4	6.0	8:00	17.9	12.4

04 - Sept - 88			05 - Sept - 88			07 - Sept - 88		
Time	Hor.Fl. (°)	Vert.Fl. (°)	Time	Hor.Fl. (°)	Vert.Fl. (°)	Time	Hor.Fl. (°)	Vert.Fl. (°)
11:10	17.2	12.5	19:10	12.8	8.0	18:10	14.3	11.4
11:20	17.7	12.2	19:20	12.5	7.6	18:20	14.2	11.2
11:30	17.3	11.9	19:30	12.3	7.4	18:30	14.0	10.7
11:40	18.3	12.8	19:40	12.3	7.3	18:40	13.2	10.2
11:50	20.4	12.9	19:50	12.1	7.0	18:50	12.3	9.6
12:00	19.3	13.0	20:00	11.8	6.8	19:00	11.7	9.0
12:10	21.1	13.1	20:10	11.8	6.7	19:10	10.9	8.4
12:20	18.5	14.1	20:20	12.3	6.7	19:20	10.4	8.1
12:30	19.1	13.5	20:30	12.1	6.6	19:30	9.9	7.7
12:40	19.1	13.0	20:40	12.2	6.7	19:40	9.1	7.1
12:50	19.5	13.7	20:50	12.1	6.6	19:50	8.8	6.5
13:00	19.6	15.0	21:00	12.4	6.6	20:00	8.4	5.9
13:10	19.9	15.1	21:10	12.5	6.4	20:10	7.6	5.5
13:20	23.8	15.7	21:20	13.7	6.2	20:20	7.3	5.0
13:30	23.9	15.7	21:30	12.4	5.7	20:30	7.0	4.6

Tab. 5.1.2: Running mean averages of horizontal and vertical wind fluctuations measured by vector vane for periods during dispersion experiments.

All data, except those of sonic anemometer measurements, were transfered "on - line" to a DEC PDP11 computer. The data were averaged over 10 minutes, partly on the DEC computer and partly already by sensor electronics, and then transfered to the Computer Centre. The vector-vane data represent running means of approximately 50 minutes and therefore were excluded from the general data set (because they did not represent 10 minute averages). Some data, measured during the dispersion experiments, are listed in Tab. 5.1.2 to give some indication about turbulence in those periods. These data might be used in models applying data averaged over 30 - 60 minutes as input. The sonic anemometer data first are stored as raw data in sensor device coordinates on a tape recorder and later are transfered to the Computer Centre. With a computer program the data can be either transformed in cartesian coordinates (meteorological system) or in natural coordinates (longitudinal and lateral to mean wind direction). The data are averaged over 10 minutes, but are also available in the original form, instantaneous sampled with 1 Hz.

The data stored on magnetic tape (except sonic anemometer data) cover the period of August 30, 0.00 - September 8, 24.00. The sonic anemometers were running as indicated in Tab. 5.1.3

Date	Start	Stop	Height
August 30	14:00	17:00	50 m, 120 m
August 31	17:00	21:30	50 m, 120 m
September 3	4:30	9:00	50 m, 120 m
September 4	10:30	15:00	50 m, 120 m
September 5	19:50	23:30	50 m, 120 m
September 7	5:45	10:15	50 m, 120 m
September 7	18:30	23:00	50 m, 120 m

Tab. 5.1.3: Sonic anemometer measurements at the KFA-tower

5.1.2 Masts on the Sophienhöhe

Three 15 m and two 10 m masts were built up on the hill from September 86 to April 87. Four masts are located on the south-southeast, southwest, west and north-northwest slopes and one mast is placed near the top of the hill. It was intended to install the masts on the slopes at a medium high level in order to detect drainage winds also. However the free choice of positions was in some regions restricted by limited space, accessibility (northeastern part) or high vegetation. The positions finally selected are described below and shown in Fig. 5.1.2.

The standard meteorological measurements, carried out on all the five masts, were:

- wind speed (cup anemometer) at 2 levels
- wind direction (wind vane) and vertical wind speed (Gill anemometer) at the top
- dry-/wet-bulb temperature at 2 levels

All the instruments functioned well throughout the whole campaign.

Three masts, 2, 4 and 5, have additional instrumentation. Mast 2 and mast 4 were equipped with 4 cup anemometers in order to resolve better the surface layer wind profile for the determination of the momentum flux. Mast 5 near the summit has been extended with instruments for the determination of energy balance relevant parameters often needed in models. Profiles of wind speed, temperature and humidity are given by measurements of these parameters in five heights. The overall error in temperature measurements (including accuracy of the sensor and electronics) seems to be a little more than 0.2 K. Because temperature differences between the lowest and highest level (1 m and 13 m) are quite small, measurement errors can result in relative large errors for flux calculations (sensible and latent heat) using the profile method. Some analysis of the data showed that the temperature seems to be $\simeq$ 0.5 K too low at the height of 4 m. No reason could be found for this error, therefore no corrections have been made on the data. Anyway a correction of +0.5 K at this height (dry-bulb temperature) is recommended, because this difference was measured also in a test where this sensor was placed at the height of 2 m and compared with the other sensor at 2 m.

The two residual components of the energy balance, net radiation and soil heat flux were also measured at the site of mast 5. The soil heat flux was directly measured with a heat flux plate which measures the temperature gradient between two 4 mm separated plates through a material with known heat capacity. The heat flux plate lay about 2 mm below the surface. Radiative or convective divergence/convergence above the plates, or reduced thermal contact of the plates with the soil can cause deviations from the real soil heat flux. The measurements made here let suppose underestimation of the soil heat flux as it is expected for this type of surface. Anyway the measurements are valuable in giving insight in the general behaviour of the conductive partitioning in the surface energy balance.

The instrumentation of the masts is summarized in Tab. 5.1.4.

The data were stored by a portable data acquisition unit, based on Hewlett-Packard components and self-developed electronics. Power was supplied by 200 Ah batteries. The Hewlett-Packard Interface Loop system consisted of a HP 3421A digital multimeter, a HP-71B calculator and a HP82161A cassette recorder (128 k Byte storage capacity). The self-developed electronics was used for signal adjustment and noise filtering. The data were sampled with a cycle of 10 seconds, averaged over 10 minutes and stored each hour on tape. Vertical wind speed was separated in upwind and downwind mean values. Data for the 5 masts are available as 10 minute averages (most with standard deviations) throughout the whole field campaign. The measurements contained in the data bank for mast 1-5 are for the period of August 30, 0.00 - September 8, 24.00.

Mast 1

The mast was installed at Berme 220 on the southsoutheast slope of the hill, which inclines towards the mine. A place at lower heights on this slope as chosen for the other masts could not be found because dense and high trees would have falsified the measurements too much. Mast 1, positioned in 209 m above m.s.l. stood 107 m higher than the base of the hill or 118 m higher than the base of the KFA tower. The mast was located near a pathway junction on the downhill side of a road, 1 m away from the slope and was surrounded by $\simeq$ 5 m high trees. The trees had already grown rather dense on the slope. The roads on this site run in southwest-northeast direction (35° - 215°). The wind approaching the hill in this region could be deflected in this direction, especially under stable atmospheric conditions. The slope inclined with $\simeq$ 13° in east-west and $\simeq$ 17° in southeast-northwest direction (see also Fig. 5.1.3 and Tab. 5.1.5).

Mast 2

The mast was placed within an indentation on the southwestern slope of the hill. In the indentation the berme is broader than usual and the roads turn a little towards the centre of the hill. The mast was also surrounded by trees, which were less dense compared to the site of Mast 1. The trees had a height of 4 - 5 m. The wind approach-

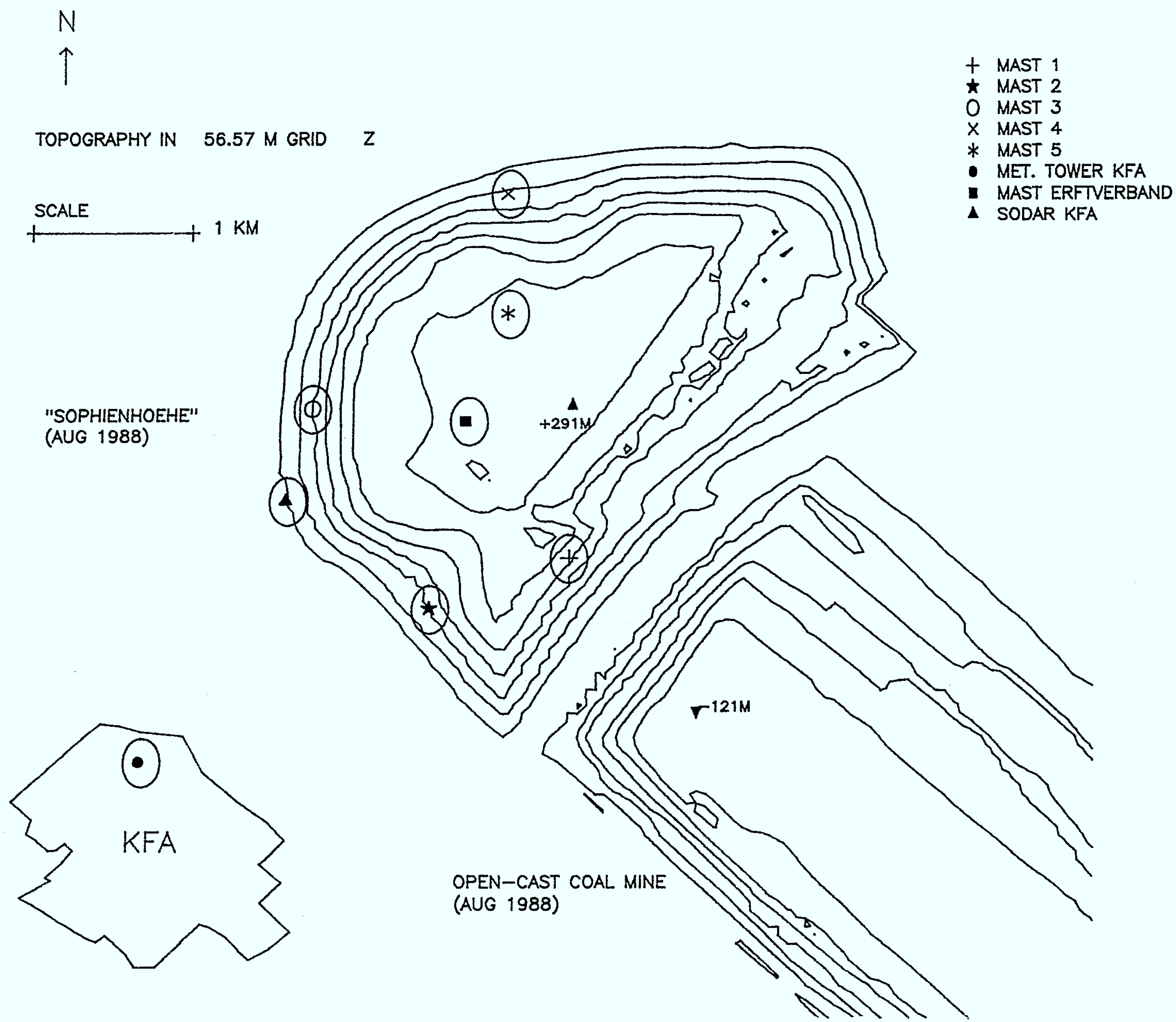


Fig. 5.1.2: Position of KFA-tower and masts on Sophienhöhe

Fig. 5.1.3: Mast 1 at Berme 220 in the SSE-part of the Sophienhöhe (view to northwest)

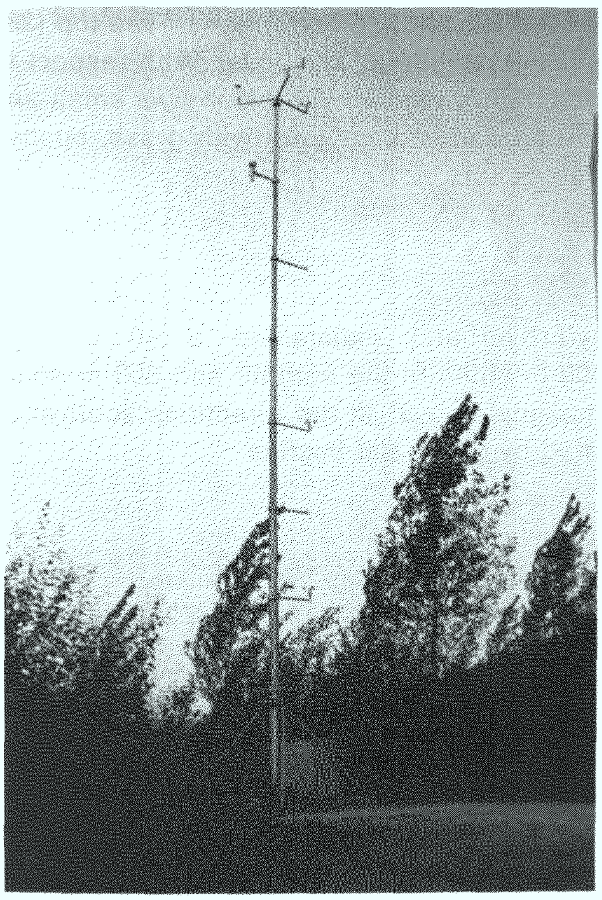


Fig. 5.1.4: Mast 2 at Berme 150 in the SW-part of the Sophienhöhe (view is downslope to west)

ing the hill in this region could be deflected parallel to the roads, running in 140° - 320° direction. The slope inclined in southwest-northeast direction with about 11° (see also Fig. 5.1.4 and Tab. 5.1.5).

Mast 3

On the western slope of Sophienhöhe the 10 m mast was installed. The mast was situated in the middle of a road crossing, 6 m away from the downward slope. The dispersed trees reached a height of 3 - 4 m. The roads ran in north-south direction, the slope inclined with about 15 degrees (see also Fig. 5.1.5 and Tab. 5.1.5). The mast is shown in Fig. 5.1.5, the position is given in Tab. 5.1.5.

Mast 4

The mast was placed within an indentation in the northern part of the Sophienhöhe, 1 m away from the slope. This area was covered with grass, bushes and small, young trees. The slope inclines with $\simeq$ 12° in north-south direction. The wind approaching the hill in this region could be deflected parallel to the roads, running in 80° - 260° direction (see also Fig. 5.1.6 and Tab. 5.1.5).

Mast 5

The mast was located on the plateau near the top of the Sophienhöhe. The top (286 m above MSL) is found 300 m southwest of the position of this mast. With respect to the base of the KFA tower, the mast stood 180 m higher. The slope was small and maximal 4° in northwesterly direction. The ground was covered with grass, bushes and small trees (see also Fig. 5.1.7 and Tab. 5.1.5).

Mast Rheinbraun company/Erftverband

Since 1985 the Rheinbraun company/Erftverband maintained a 10 m high meteorological mast, which was found 500 m south of the summit and 800 m south of Mast 5. The slopes were small and maximal 2° - 3° in the directions southwest, west and north. The surface was dominated by grass and bushes.

The following parameters were measured:

- wind speed in 2 m, 5 m and 10 m
- wind direction in 10 m
- temperature in 0.2 m and 2 m
- relative humidity in 2 m
- precipitation
- global radiation

The instruments and the data acquisition system were manufactured by Lambrecht company.

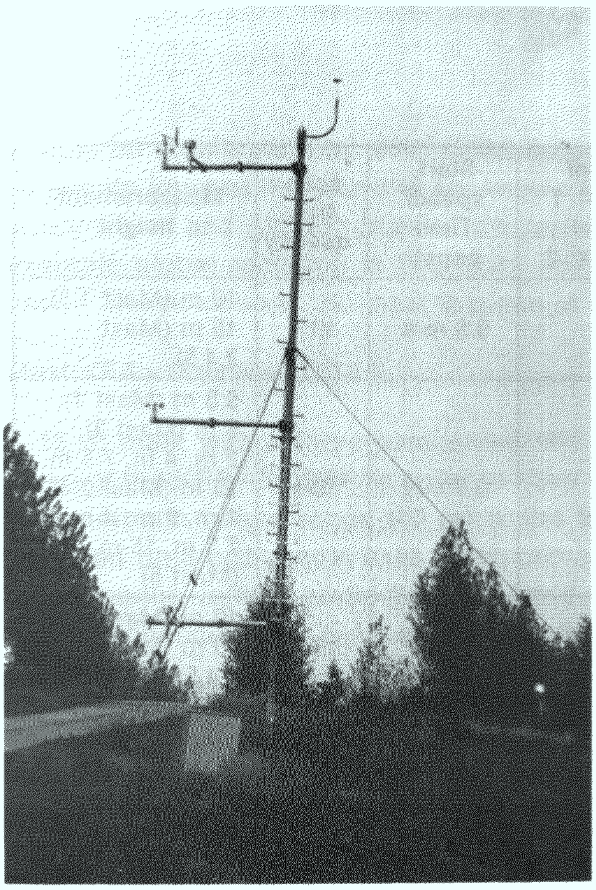


Fig. 5.1.5: Mast 3 at berme 150 in the W-part

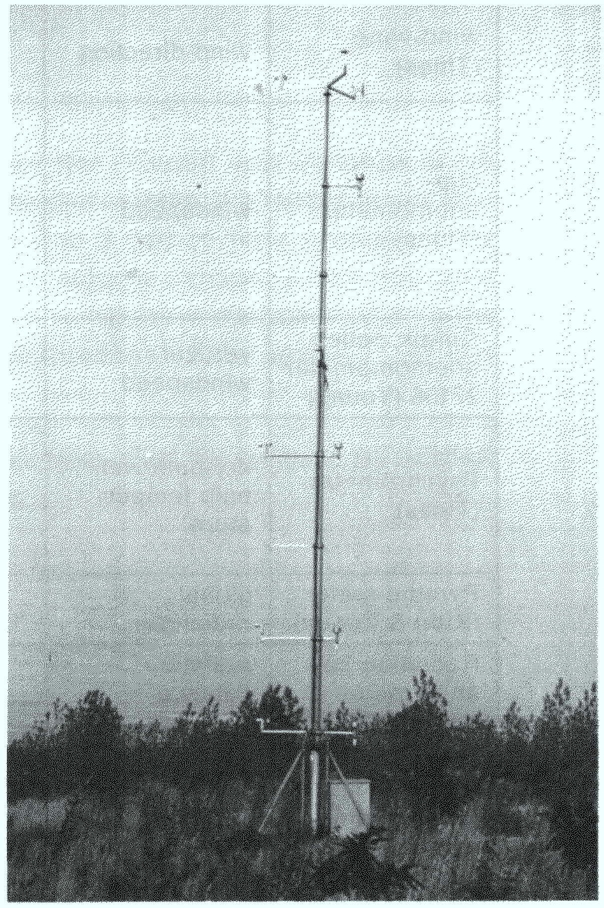


Fig. 5.1.6: Mast 4 at berme 150 in the N-partof the Sophienhöhe (view is downslope)

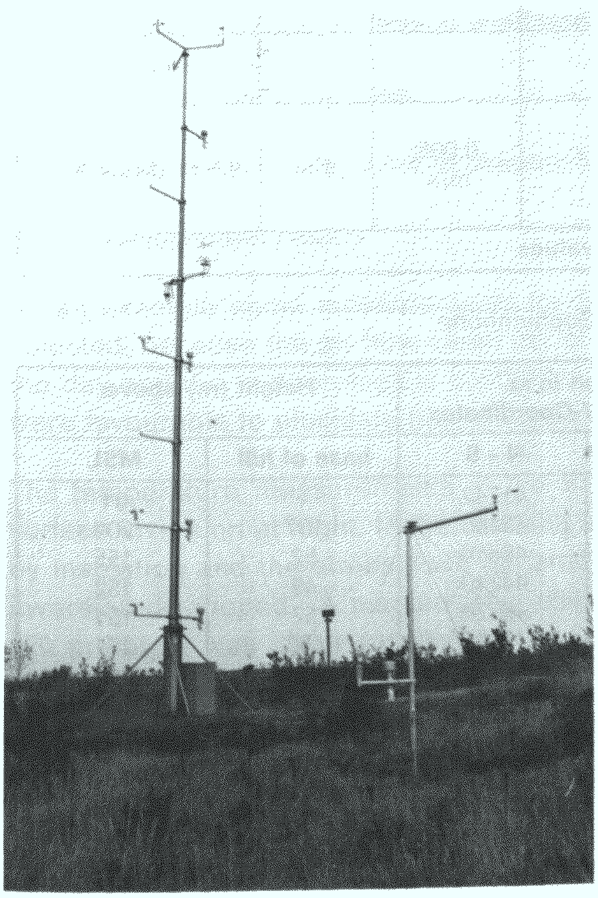


Fig. 5.1.7: Mast 5 near the top of the Sophienhöhe (view to east)

Sensor	Measured quantity	Calc. of Mean = 1 Mean + Sigma = 2	Start. speed/ Time const.	scan fre-quency	Measurement-height
wind-vane (Thies)	wind-direction	2	0.5 m/s	10 s	10 m (Mast 1,3), 15 m (Mast 2,4,5)
cup-anemometer (Thies)	windspeed	2	0.5 m/s	10 s	5.5 m (Mast 1), 5 m (Mast 3), 2 m, 4 m, 7.5 m, 15 m (Mast 2,4), 1 m, 2 m, 4 m, 7.5 m, 15 m (Mast 5)
Gill-propeller-anemomometer 27106 (Young)	vertical windspeed	1*	0.2-0.4 m/s	10 s	10 m (Mast 1,3), 15 m (Mast 2,4,5)
Psychrometer (Thies)	dry-bulb/wet-bulb temper-ature	1	22 s	10 s	1 m (Mast 5), 2 m (Mast 1-5), 4 m (Mast 5), 7.5 m (Mast 5), 13 m (Mast 1-5)
Pyradio-meter (Kipp & Zonen)	global radiation	1			3 m (Mast 5)
Radiation bal-ance meter	radiation balance	1			3 m (Mast 5)
Heat flux plate	surface heat flux	1			-2 cm (Mast 5)
Sonic-anemo-meter (Kaijo-Denki DA 300)	wind-components u,v,w temper-ature	2	0.005 m/s	1 s	9.5 m (Mast 5)
Note: * separated as upwind and downwind values					

Tab. 5.1.4: Instrumentation of masts 1 - 5 on Sophienhöhe

	Position in m Gauss-Krüger-Coordinates		Height (m) above	
	E - W	N - S	base of hill	MSL
KFA-tower	28847	41742	-	91
Mast 1, Berme 220	31465	43165	107	209
Mast 2, Berme 150	30610	42810	52	155
Mast 3, Berme 150	28865	44210	49	152
Mast 4, Berme 150	31075	45720	57	151
Mast 5 near top	31085	44880	168	271
Mast Rheinbraun	30840	44125	165	268
Mast KFA SODAR	29725	43540	-	105

Tab. 5.1.5: Location of KFA-tower and masts on the Sophienhöhe

It must be mentioned that wind direction was measured only once at the end of each 10-minute interval. Further it is not known how good the sensors were calibrated. The temperature and global radiation measurements often showed some offset (see for example global radiation in Tab. 6.2.2 and 6.2.7, Mast 5). These data should not be used. The position of the mast is given in Tab. 5.1.5.

Mast KFA - Doppler-SODAR

A 15 m mast with a three-component Gill anemometer (Young) was installed at the place of the KFA - SODAR in order to have wind measurements at a height lower than the minimum height range (40 m) of the SODAR. The 3 carbon fiber propellers are mounted on 3 orthogonal axes. Each component included a dynamo which delivered a continuous voltage proportional to wind speed. The values were scanned with the same sequence the SODAR sended the beep. The threshold of the anemometer was 0.2 m/s.

The wind components were transformed and averaged over 10 minutes by SODAR software. The following values finally were stored:

- horizontal wind speed in m/s
- vertical wind speed in cm/s
- standard deviation of vertical wind speed in cm/s
- wind direction in degrees

The mast is shown in Fig.5.7.4 in chapter 5.7.

5.1.3 Measurement results

As an example some measurements for Sept. 4 are presented. This day has been selected, because the air flow came out of southwest throughout most of the time of the day and the meteorological conditions - clear day with light to moderate winds - were favourable to elucidate the influence of the hill on the wind field.

The temperature measurements at the KFA tower illustrated in Fig. 5.1.8a show a surface inversion at night. In the morning at about 7:00 h the inversion was dissolved by insolation and the atmosphere became unstable. In the evening a strong surface inversion developed. A marked wind shear from southeast in 30 m to southwest in 120 m height was observed (Fig. 5.1.8b). The wind speed measured in 3 heights is given in Fig. 5.1.8c.

The hill modified the southwesterly flow mainly in the night, early morning and evening hours (Fig. 5.1.9a). The measurements on the windward side of the Sophienhöhe (Mast 2 and 3) at heights of $\simeq$ 60 m above the surroundings indicated an airflow around the hill; the wind turned to south in its western part and to west in its southwestern part. The wind direction at the top of the hill was similar to those at the KFA tower. Around noon when dispersion experiment no. III-4 was carried out, wind deflection by the hill was minor.

The standard deviation of wind direction, e.g. measured by wind vanes as in Fig. 5.1.9b at the masts, can be considered as one possibility to measure turbulence. Turbulence was in general lower in the area of Mast 4 and 5 compared to the other areas (Fig. 5.1.9b). This result can be explained by the smaller roughness lengths and the higher wind speeds measured in the region of these two masts. Wind direction fluctuations were highest either on the leeward slope (Mast 1) or windward slope in the region where the stagnation point was expected (Mast 2).

The results of the wind speed measurements are given in Fig. 5.1.10a,b. Acceleration of the air was found at the top and the north-northwest slope of the Sophienhöhe mainly during the night hours; the former exemplifies the so called speed-up effect and the latter some channelling effect. Very light winds frequently occurred during night hours on the windward slope (stagnation point). During day-time upslope winds up to 0.9 - 1.0 m/s were observed on the windward side of the hill.

More results of the tower and mast measurements are given in chapter 6. As an overview of all parameters measured the data for a 1 1/2 hour period (during dispersion experiment no. III-2-2) are summerized in tables (chapter 6.2).

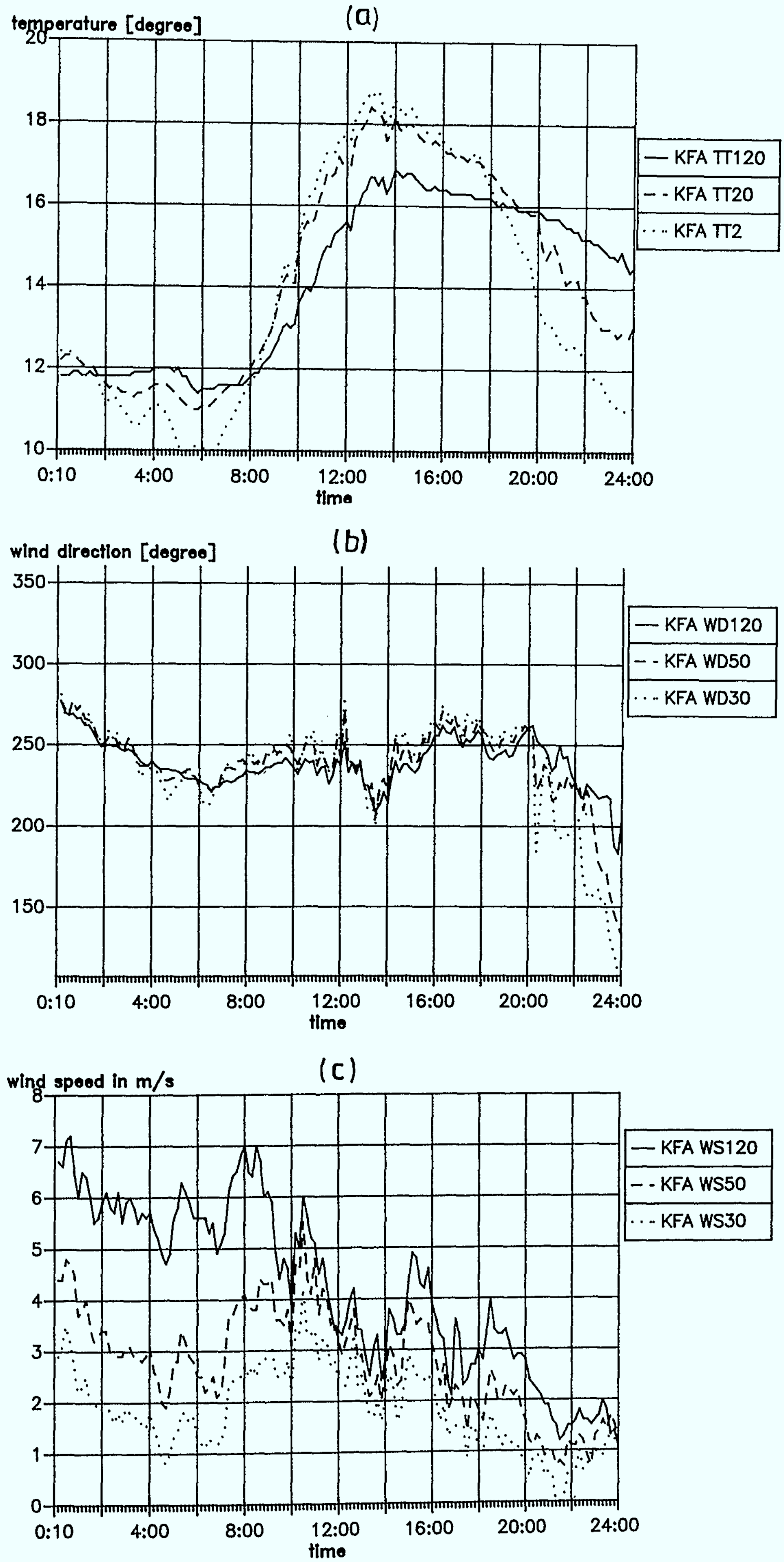
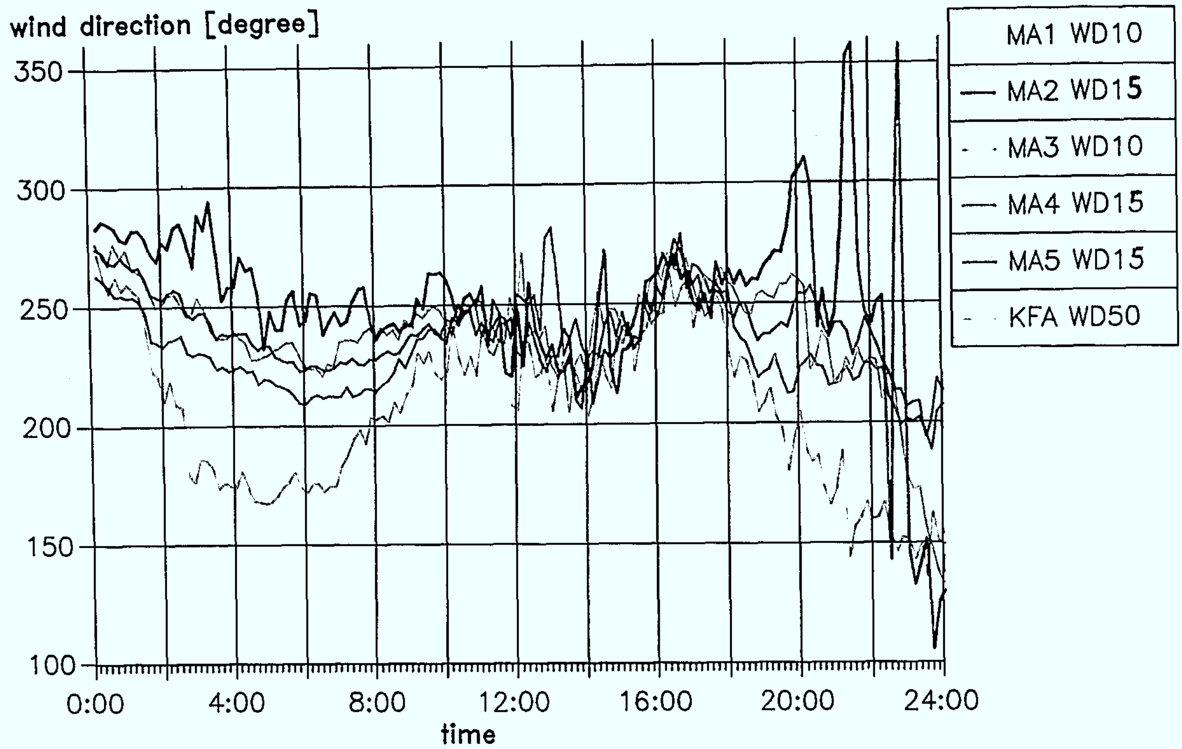


Fig. 5.1.8a-c: Meteorological measurements at the KFA-tower, Sept 4, 1988
TT 2, 20, 120 : Measurements of temperature (TT) in 2m, 20m, 120m
WD 30, 50, 120: Measurements of wind direction (WD) in 30m, 50m, 120m
WS 30, 50, 120 : Measurements of wind speed (WS) in 30m, 50m, 120m

(a)



(b)

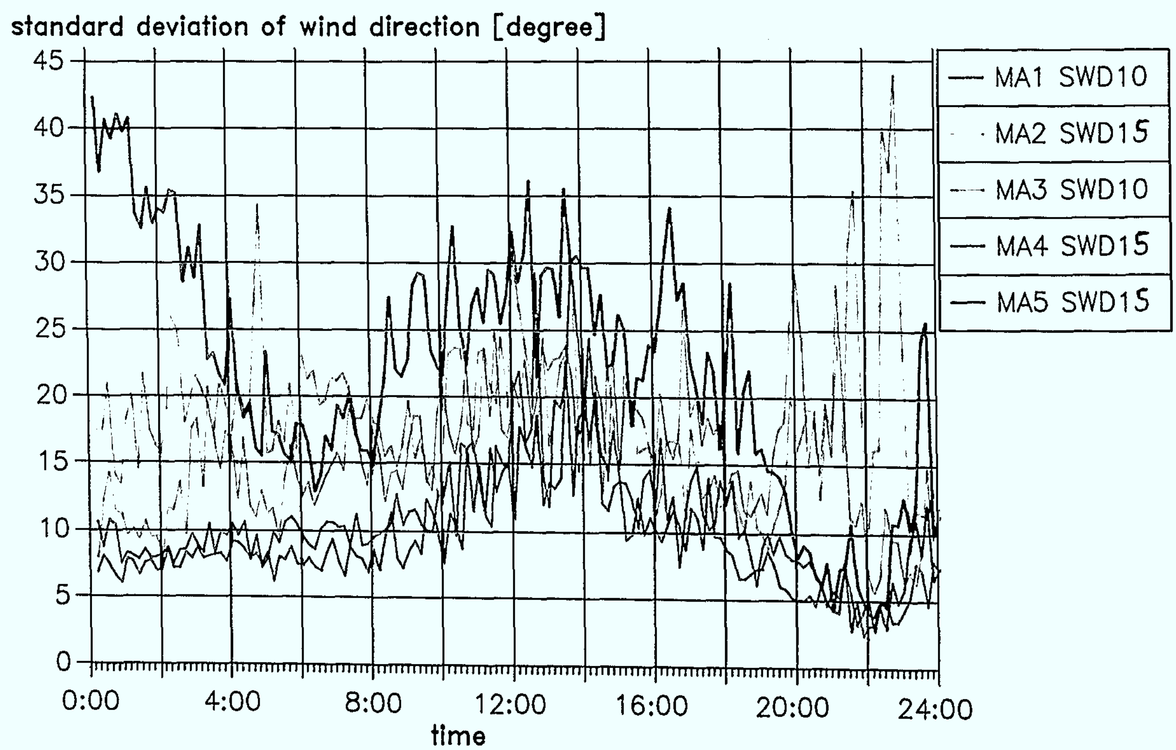
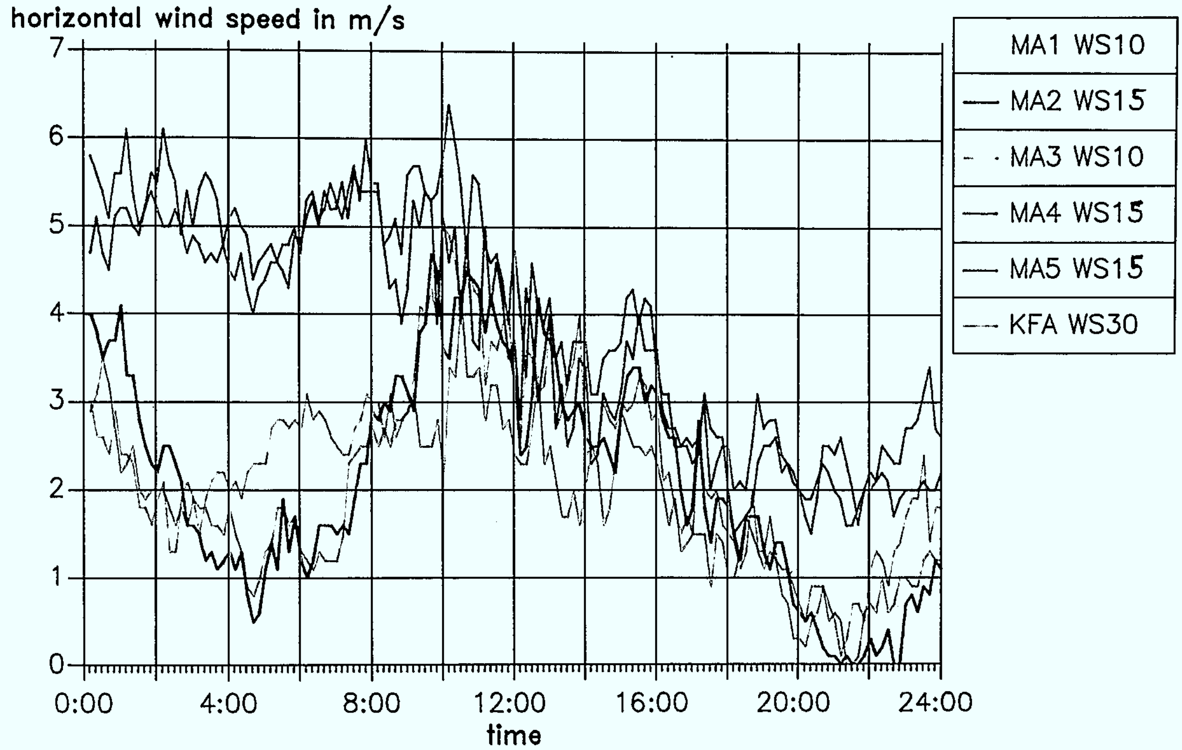


Fig. 5.1.9a, b: Measurements of wind direction WD (a) and standard deviation of wind direction SWD (b) at KFA-tower and masts 1 - 5 Sophienhöhe, Sept 4, 1988
Measurement heights: 10m, 15m, 50m

(a)



(b)

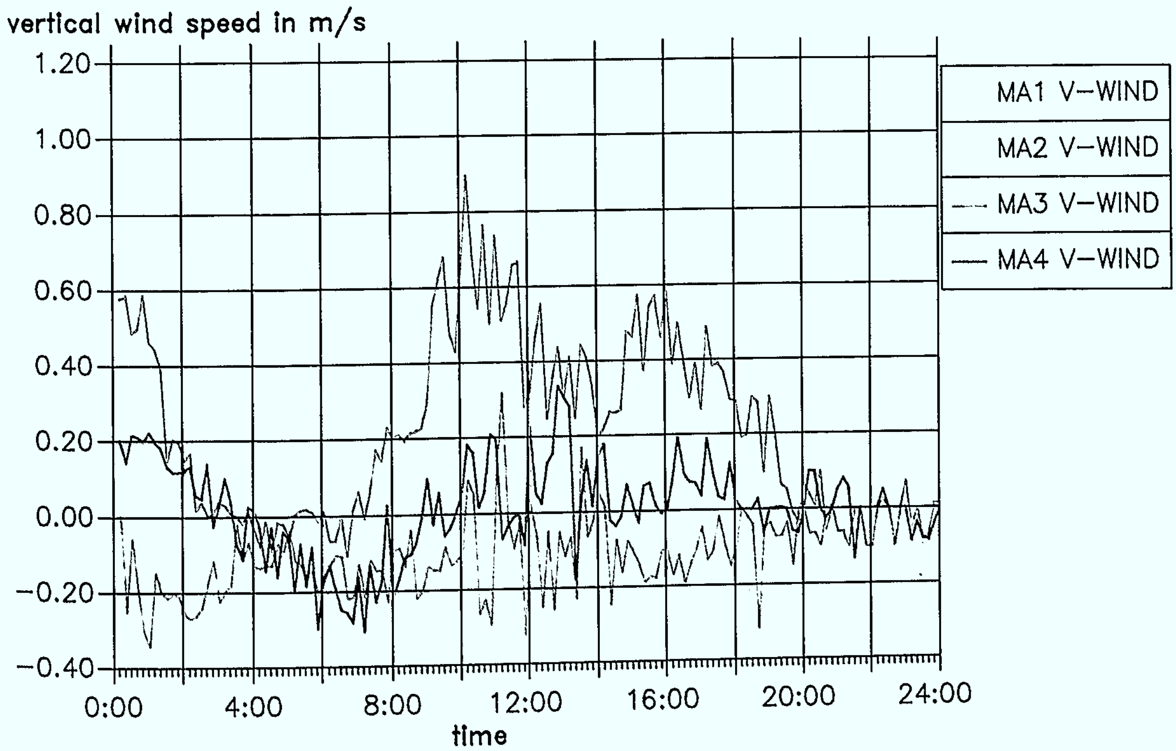


Fig. 5.1.10a, b: Measurements of horizontal (WS) and vertical (V) wind speed at KFA-tower (30m) and masts on Sophienhöhe (10m, 15m)

5.2 The use of tetroons during the third field experiment

M. Möllmann-Coers

5.2.1 The tetroon measuring system

Tetroons (*tetr*aedral ball*oons*), also called CLB (*C*onstant *L*evel *B*alloons), are free flying balloons with constant density. With this measuring system it is possible to investigate air flow in the mesoscale in a Lagrangian sense.

The tetroons used here are made of red 51 μm thick mylar foil, have a dead weight of 0.470 kg, a volume of about 1 m^3 and, when filled with helium, can carry approx. 0.5 kg payload. When they are launched, they rise by bouyancy up to a level, where the density of air and tetroon is identical, and then they move with the air flow like an air particle.

The volume of the tetroons increased negligibly during the ascent as Beemer and Markhardt (1977) showed. They found a change in volume of only 0.5 % up to 50 hPa overpressure in the tetroons. Depending on temperature lapse rate, the tetroons are filled to overpressures between 5 and 40 hPa.

If there are no significant up- and downdrafts, the tetroon moves in a nearly constant flight level. In real atmosphere however, vertical movements of the air often occurr and act on the tetroon. In that case, the vertical movement of the tetroons is not usually that of the surrounding air. To calculate vertical windspeed, Hoecker's (1975) simple scheme can be used to derive vertical air motion from the tetroon's vertical velocity. This technique takes into account the instantaneous deviation from its equilibrium height level.

5.2.2 Experimental design and procedures

The way how to adjust the desired flight level of the tetroons is discussed in detail by Vogt and Thomas (1982). For tracking the tetroons, a mobile WF 100-4 radar system (supplied by Enterprise Electrone Corporation, USA) of the German Weather Service, Essen, was used. The Tetroons are equipped with a transponder (*Trans*mitter - res*ponder*) to eliminate the ground clutter problems. The transponder technique is described by Thomas et al. (1987). The technical data of radar and transponder are listed in Tab. 5.2.1.

	Radar	**Transponder**
Diameter of antenna	1.2 m	
Dimensions	5.85x2.08x3.05 m^3	15x8x8 cm^3
Weight	6.3 t	450 g
Gain of antenna	38 dB	5 dB
Polarization	linear,vertical	linear, vertical
Frequency	9375 MHz	9212 MHz
Peak power	60 kW	180 mW
Pulse repetition frequency	800 Hz.	800 Hz
Pulse repetition length	0.25/1.0 μs	1.0 μs
Range	> 50 km	> 50 km
Operating time	> 5 h	> 5 h

Tab. 5.2.1: Technical details of radar and transponder

During the field experiment, a total of 8 flights were performed on 6 days. For 7 flights the launching site was selected with respect to the large scale wind direction so that travel across 'Sophienhöhe' seemed to be possible in order to reveal the flow pattern nearby the tip. The 8th flight was launched at the south-easterly border of the pit in the late evening hours of September 7. The thermal stratification was very stable with low wind velocity nearby the surface. The tetroon was launched in local equilibrium, i.e., with no buoyancy. This flight was performed to illuminate the air flow within the surface mining area. While the tetroon descended into the pit some ground clutter problems in radar tracking occurred. After a few minutes the tetroon was catched by a safety man. This tetroon data hardly can be evaluated.

5.2.3 Evaluation

The radar tracking data (slant range, angles of elevation and azimuth) were picked every 10 s. For the offline evaluation these data were low-pass filtered using a time window of 100 s (i.e., eleven 10-s-values). With these filtered values the x,y,z-coordinates with respect to the radar position were calculated. Taking the earth curvature into account, real height of the tetroon (above radar) was calculated from:

$$h = z + \frac{d^2}{2R},$$

where R is the radius of the earth and d is the slant range. Refraction of the radar beam is considered by using R as 'equivalent radius' with $\frac{4}{3}$ times the real radius of the earth.

5.2.4 Discussion of the tetroon flights

All tetroon flights were carried out during dispersion experiments. As discussed above, usually one series of experiments were performed by an emission period of two and a half hours and three sampling periods of 30 minutes each. As far as possible from a technical point of view, it was tried to launch two tetroons during each series of experiments. An overview of experiments and tetroon flights is given in Tab. 5.2.2.

Tetroon	Exp. No.	Date	Launch time (CET)	Stability *)
SO8801	15	30. 8.	16.00	u
SO8802	18	31. 8.	19:50	s
SO8803	20	3. 9.	7:00	s
SO8804	22	4. 9.	11:50	u
SO8805	24	4. 9.	13:00	u
SO8806	25	5. 9.	20:00	n
SO8807	27	5. 9.	20:56	s
SO8808	30	7. 9.	21:25	s
*) s=stable, n=neutral, u=unstable				

Tab.5.2.2: Tetroon numbers and dispersion experiments

Three tetroon flights were carried out under unstable thermal conditions, four under stable, and one under neutral conditions.

The first of the tetroons under unstable conditions, SO8801, was launched in the afternoon of August 30, at 16:00 CET. During the whole day there was a strong insolation with a maximum of about 500 $\frac{W}{m^2}$ at noon. Between 16:00 and 17:00 CET a temperature gradient of -1.2 $\frac{C}{100\,m}$ at the KFA meteorological tower was found. The experimental area was sited between a flat high pressure region in the south of Germany and the Vosges and a sharp pressure gradient over the northern part of Germany and the North Sea. The wind direction was very much steady in the afternoon. The Tetroon SO8801 was launched about 1 km north-west of the KFA meteorological tower. For launch and radar positions, please see Tab. 5.2.3. It travelled direct over Sophienhöhe and gained a top height of 820 m above radar position. After its descending down to 400 m the radar lost contact of the tetroon.

Tetroon	Radar position			Launch position	
	x	y	Height MSL	x	y
SO8801	26750	42900	86.m	26883	42841
SO8802	23975	37650	126.m	24643	38446
SO8803	23975	37650	126.m	25342	38707
SO8804	23975	37650	126.m	24854	39992
SO8805	23975	37650	126.m	25293	38381
SO8806	28225	46675	98.m	28322	45743
SO8807	28225	46675	98.m	28404	45514
SO8808	31050	42525	216.m	36260	39929

Tab. 5.2.3: Radar and launch positions in Gauß-Krüger coordinates

The other two tetroon flights under unstable conditions were performed during Experiment No.: III-4-1 and III-4-3 on September 4, in the noon. The meteorological situation is simlar to that of August 30. A high pressure region was located north of the Alps, and a pressure gradient over Great Britain and the North Sea due to a low south

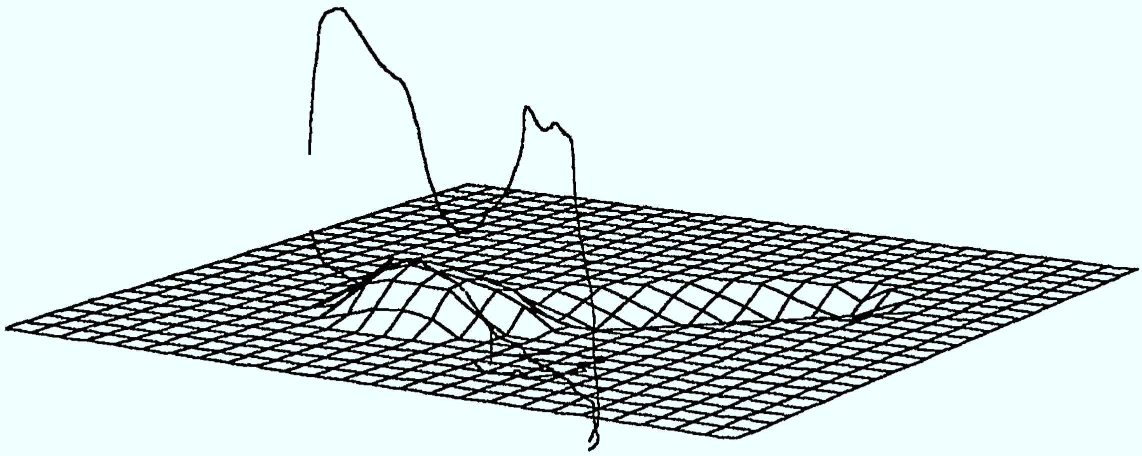


Fig. 5.2.1: Tetroon SO8805, slant view: The flight track and correspondend projection to the surface is shown. In addition the contour of KFA and the position of the KFA meteorological tower is depicted. The view is from south-west, that is in accordance with the surface-near wind direction at the launch position.

of Island. A weak anticyclonic influence was still found at the experimental site. In the late morning hours the inversion has been dissolved, and at the noon the maximum insolation was of about 430 $\frac{W}{m^2}$. Mean wind direction was rather constant at noon with no significant change in wind direction with height at the meteorological tower of the KFA. The tetroon SO8804 passed the Sophienhöhe at a distance of about 2 km. Although the tetroon was always above a nearly flat terrain the flight track was rather fidgety due to the unstable stratification and a mean flight level could hardly be evaluated.

Because tetroon SO8804 failed to hit Sophienhöhe, the launch position of tetroon SO8805 was changed to south. The flight track showed a rather unexpected behaviour (Fig. 5.2.1 in a slant view and Fig. 5.2.2 as height above ground path). After the rise by buoyancy the tetroon seemed to gain its mean flight level. When approaching the KFA, the tetroon ascended to 915 m, but in the luff of Sophienhöhe it descended to 400 m, and over the tip it rised again up to 1150 m. On the lee side it descended again. Radar contact was lost after the tetroon was at a height of 420 m.

The neutral condition tetroon flight SO8806 was launched at the begin of the tracer experiment series (III-5-1 to III-5-3) in the transition period from day time to night time in September 5. In the morning hours of that day a warm front of a flat low north of an extended high pressure region centered over the Alps passed the site of the field experiment. Before the approaching cold front westerly winds prevailed. Due to the

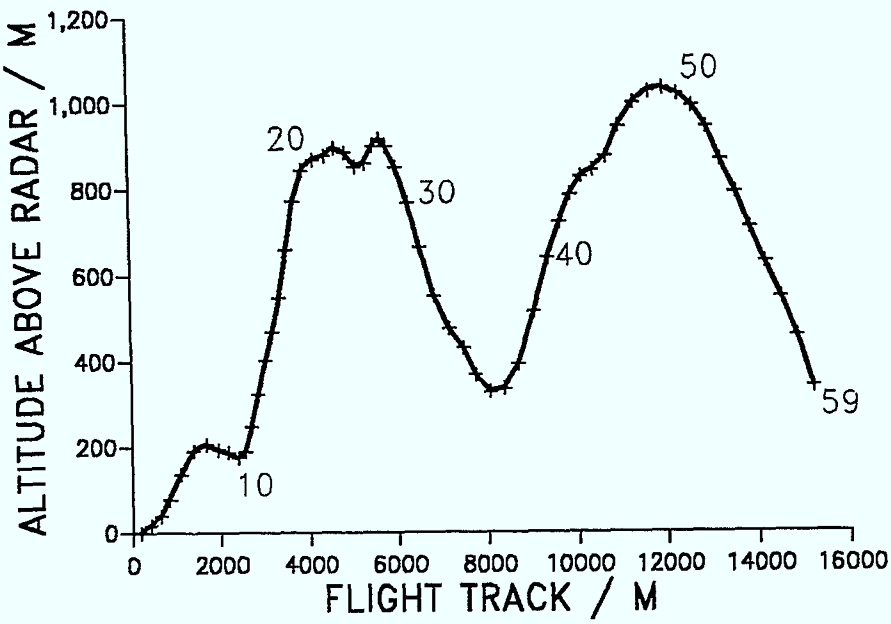


Fig.5.2.2: Tetroon SO8805, flight track: The altitude of the tetroon as a function of the horizontal flight track is shown. The markers indicate time intervalls of one minute. The numbers give the correspondend traveltime.

beginning of nocturnal radiational cooling, thermal stabilization was initiated. Tetroon SO8806 passed over Sophienhöhe with nearly constant distance to the surface. Radar contact was lost when the tetroon descended at the lee side of the tip. Tetroon SO8807, launched one hour later under night time conditions, had a little bit stronger lift due to buoyancy. Its behaviour was very similar to SO8806.

In the evening hours of August 31, the first of the tetroon flights under stable atmospheric conditions was carried out. August 31, was a bright day with strong insolation in the noon and afternoon hours. The synoptic situation was characterized by a high over eastern Europe and an occluded warm front approaching from west. Within the surface layer very weak winds prevailed and the temperature gradient at the meteorological tower of the KFA was $+0.5 \frac{C}{100\,m}$. The tetroon was launched about 5 km south-west of the KFA. It had no significant lift by bouyancy and passed Sophienhöhe at a distance of about 1.5 km. In the last part of the tetroon track a change in wind direction induced by the tip could be recognized.

On September 3, in the early morning hours a dispersion experiment series was performed to investigate the influence of the changing thermal stratification on the dispersion behavior during sunrise. High pressure influence prevailed over Germany while a small low was approaching from France. South-westerly winds preponderate with low wind velocity in the surface layer. At 7:00 CET, when tetroon SO8803 was launched, temperature gradient at the KFA meteorological tower was - 0.6 $\frac{C}{100\,m}$. The tetroon launched about 5 km south-west of the KFA, passed Sophienhöhe on its north-westerly flank with hardly any change in wind direction. The distance to surface was more or less constant along the whole track. At distances of more than 15 km between radar and tetroon some truncation errors in the elevation angle data of the radar beam might have occurred. Since the accuracy of these data is of two decimals, even small corrections in the elevation angle may induce unrealistic vertical movements and positions of the tetroon.

As mentioned above, several problems occured when tetroon flight SO8808 was performed. So this tetroon flight is not discussed here.

5.3 Turbulence, Mast and Tethersonde measurements RISØ-Group

S.E. Gryning

5.3.1 Introduction

This chapter describes the measurements carried out by Risø National Laboratory as part of the Sophienhöhe Experiment. The measurements described here comprise 1) measurements of 10-min averaged turbulence statistics at Pattern throughout the entire campaign; 2) profile measurements by a tethered sonde system of temperature, wet-bulb temperature, pressure, wind speed and direction; these measurements were carried mainly during tracer releases up to a height of about 300 m near Pattern; 3) measurements of wind speed and direction at four small masts every 1-min throughout the entire campaign. The masts were positioned at the northwestern part of Sophienhöhe at Berme 125, 150, 220 (approximate height in meters above mean sea level) and near the top. This chapter contains a technical description of the instruments used and of the position and performance of the instruments. Most of the measurements are illustrated in figures and tables.

5.3.2 Turbulence measurements

Measurements of the turbulent wind and temperature fluctuations were carried out with a three-dimensional sonic anemometer at Pattern, Fig. 5.3.1. This position had the Gauß-Krüger coordinates 27.500, 47.230 (in km) and the height 97 m above m.s.l.

The continuous analog signals were digitized with a sampling frequency of 1 Hz. The digitized signals were processed on-line on a personal computer (PC), calculating the mean values, the variances, and the covariances of the three velocity components and temperature. The calculations were performed over a 10-min averaging period. These consecutive 10-min averaged parameters were measured throughout the whole campaign.

5.3.2.1 Sonic anemometer

The sonic anemometer used was a Kaijo Denki DAT/TR-61B. A sonic anenometer contains no moving parts. Therefore, the problems of hysteresis and starting speed that haunt cup-anemometers are not present in this instrument. The probe was mounted on the top of a 6 m high mast especially erected for this purpose. The height of the probe centre was 6.5 m above the ground. Fig. 5.3.2 shows the mast with the sonic-anemometer probe mounted on the top.

The probe is designed for omnidirectional winds and thus well suited for this type of measurements. Although the operating principle of a sonic anemometer implies that it is an absolute instrument, meaning that the calibration is determined by the design of the instrument only, calibration in a wind tunnel revealed that flow distortion caused by the supporting sticks noticeably affected the measurements. Fig. 5.3.3 shows the reduction of the wind speed caused by the flow distortion from the supporting sticks. The diagram is produced by placing the sonic-anemometer probe in

TS = Tether sonde   SON = Sonic anemometer   SM = small masts

Fig. 5.3.1: Map of the experimental area showing the positions where meteorological measurements were carried out: TS/SON the position at Pattern where turbulence measurements took place, and the tethered balloon was flown. The four small masts are SM1 at Berme 125, SM2 at Berme 150, SM3 at Berme 220, SM4 near the top. (Reproduced with the permission of Bundesamt für Landestopographie).

Fig. 5.3.2: The mast with the sonic anemometer. The sonic anemometer probe can be seen in the top of the mast.

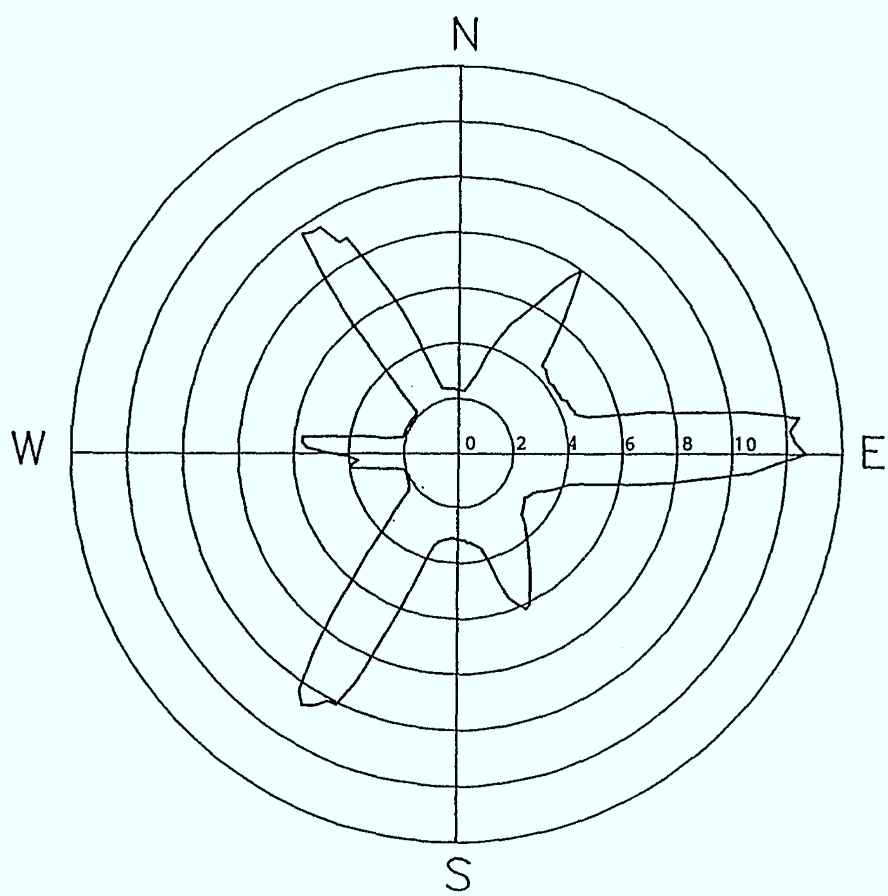


Fig. 5.3.3: Reduction in percentage of the horizontal component of the wind velocity as measured by the sonic anemometer when compared to the wind speed in the wind tunnel. The reduction is shown as a function of the angle between the sonic probe and the wind. The relationship corresponds to a horizontal wind velocity of 10 m/s. *N* indicates the direction marked on the sonic probe. When *N* points to the north, the direction in the figure coincides with the wind direction.

a wind tunnel with a flow velocity of 10 m/s. The probe was positioned completely level and then rotated 360° in steps of 1° around a vertical axis. The wind speed in the wind tunnel and the one indicated by the sonic anemometer are determined for each 1° step. Fig. 5.3.3 shows that the flow distortion is most pronounced when one of the three supporting sticks is set directly upwind of the measuring volume, causing a reduction of the wind speed indicated by the sonic to be as much as 13%. From the figure it can be seen that in general the influence of the flow distortion causes the sonic anemometer to indicate a flow velocity that is 4% less than the velocity in the wind tunnel.

We are currently investigating the relationship between the wind velocity indicated by the sonic anemometer and that of the wind tunnel for a range of wind velocities, using the procedure described above. Furthermore, it is planned to perform similar detailed measurements for a tilted sonic probe. The goal is to determine the effect of flow distortion as a function of wind velocity, wind direction relative to the probe, and the tilting angle (the angle between probe and wind vector). The effect on the measurements of the above-mentioned parameters is unknown at present.

5.3.2.2 Turbulence statistics

The turbulence statistics were determined as 10-min averaged quantities. The analog signals from the sonic anemometer were digitized with a sampling frequency of 1 Hz using a HP 3421A Data Acquisition Control Unit. The digitized data were then read by a HP-85 PC computer for on-line processing. Table 5.3.1 shows the statistical quantities that were derived. The friction velocity and Obukhov length can easily be derived from these quantities.

Input	u	v	w	T
u	$\overline{u'u'}$			
v	$\overline{u'v'}$	$\overline{v'v'}$		
w	$\overline{u'w'}$	$\overline{v'w'}$	$\overline{w'w'}$	
T	$\overline{u'T'}$	$\overline{v'T'}$	$\overline{w'T'}$	$\overline{T'T'}$

Tab. 5.3.1: Variances and covariances of the turbulence derived from the sonic-anemometer measurements. The mean quantities of the wind velocity, wind direction, and temperature were also derived.

The sonic anemometer outputs u_s, v_s, w_s and T being the wind velocity in a certain direction dependent on the direction of the sonic probe, the wind velocity perpendicular to u_s, the vertical wind velocity and temperature. Thus u_s, v_s and w_s are orthogonal. After each scan (every 1 sec) the horizontal components of the wind velocity are adjusted for the effect of flow distortion by the relationship shown in Fig. 5.3.3.

Using the adjusted values the statistics are summed up. After each 10-min sampling period the 10-min averaged statistics are worked upon by a two-step coordinate transformation. First, the coordinate system is rotated around a vertical axis in such a way that $\vec{v} = 0$, $\vec{v}$ being the mean value of v. In this new coordinate system $\vec{u}$ is the

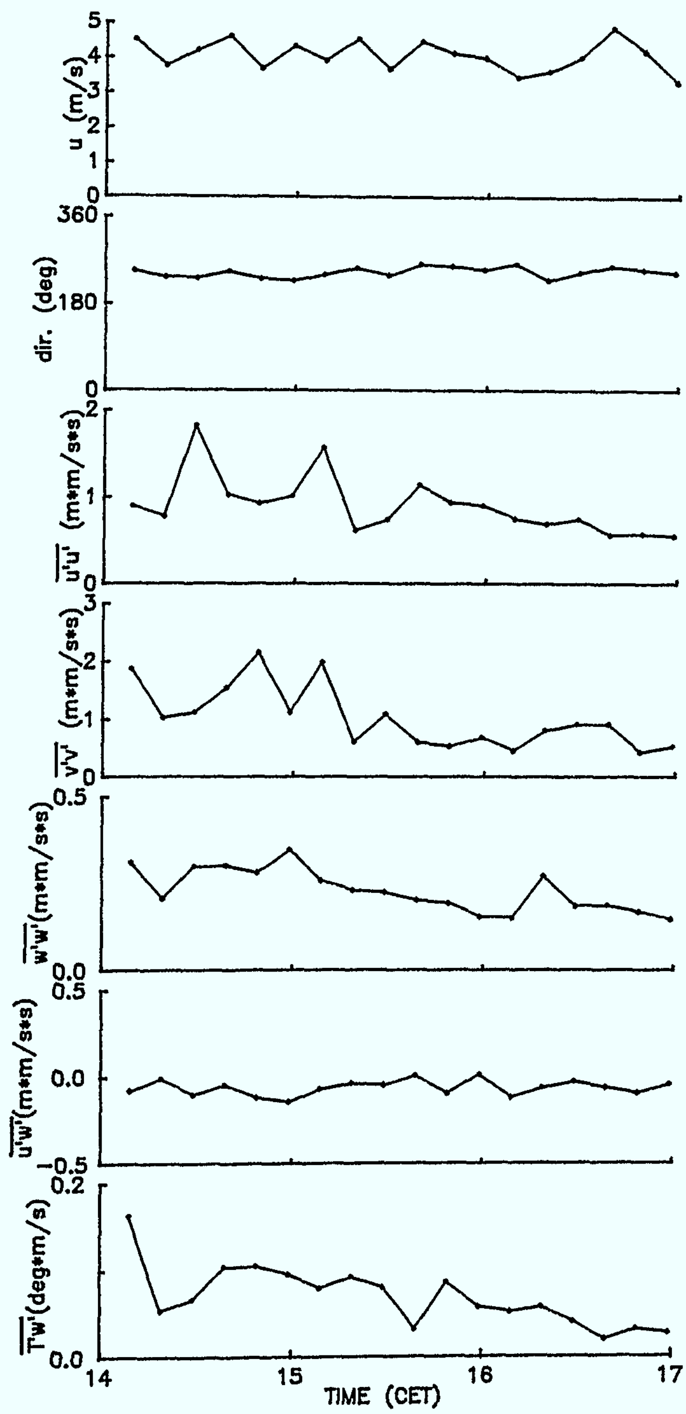


Fig 5.3.4: Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 30th of August, period 14:00 - 17:00 CET.

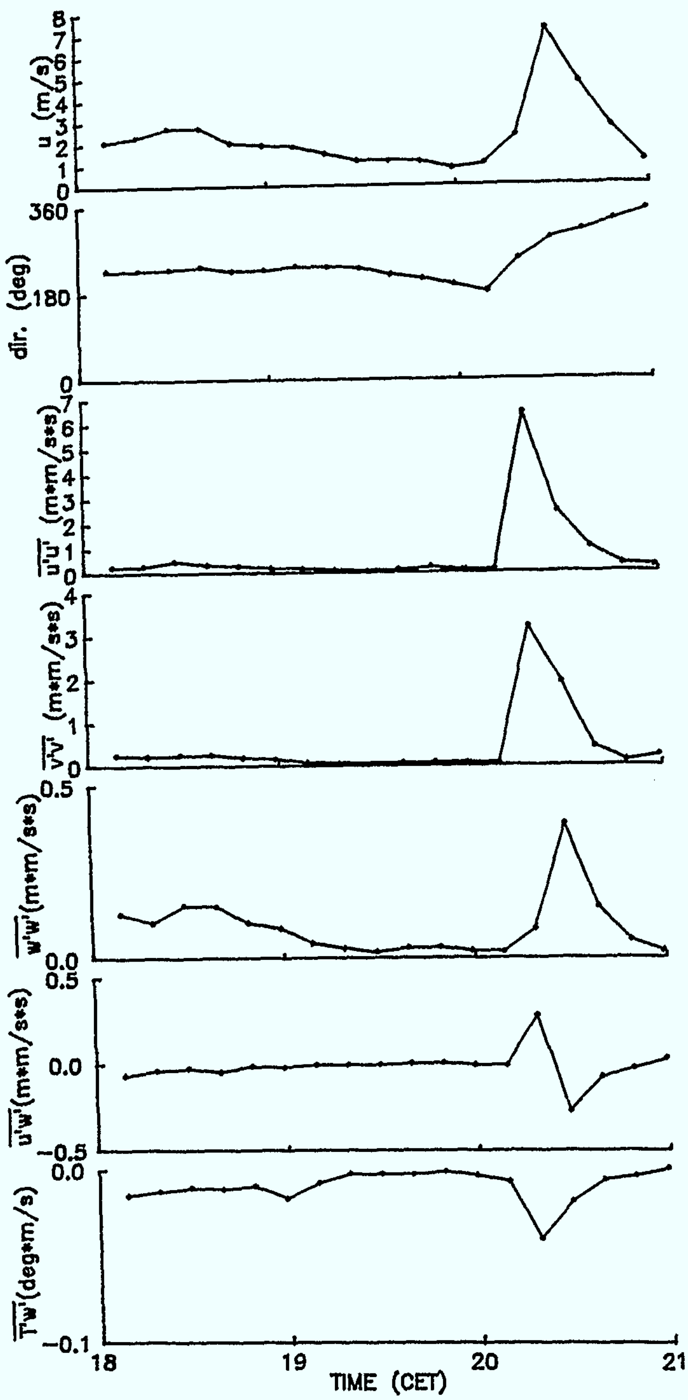


Fig. 5.3.5: Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 31st of August, period 18:00 - 21:00 CET.

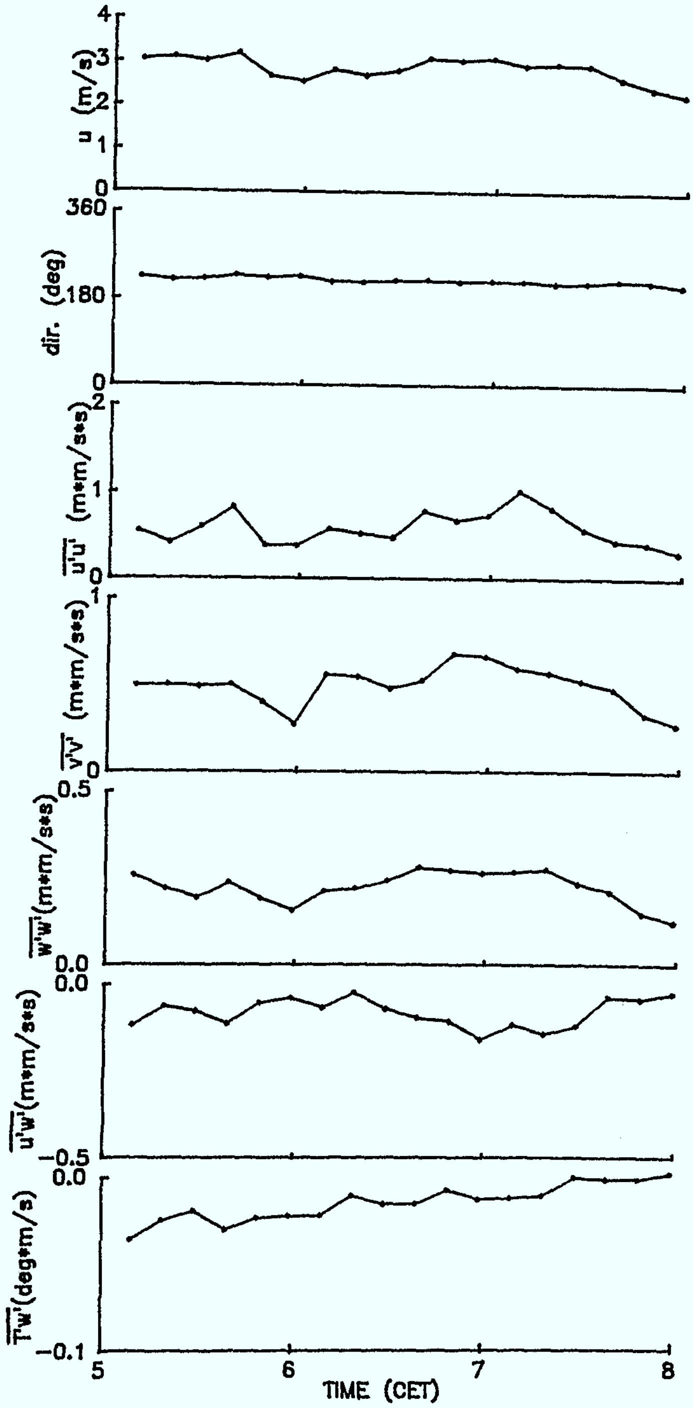


Fig. 5.3.6: Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 3rd of September, period 05:00 - 08:00 CET.

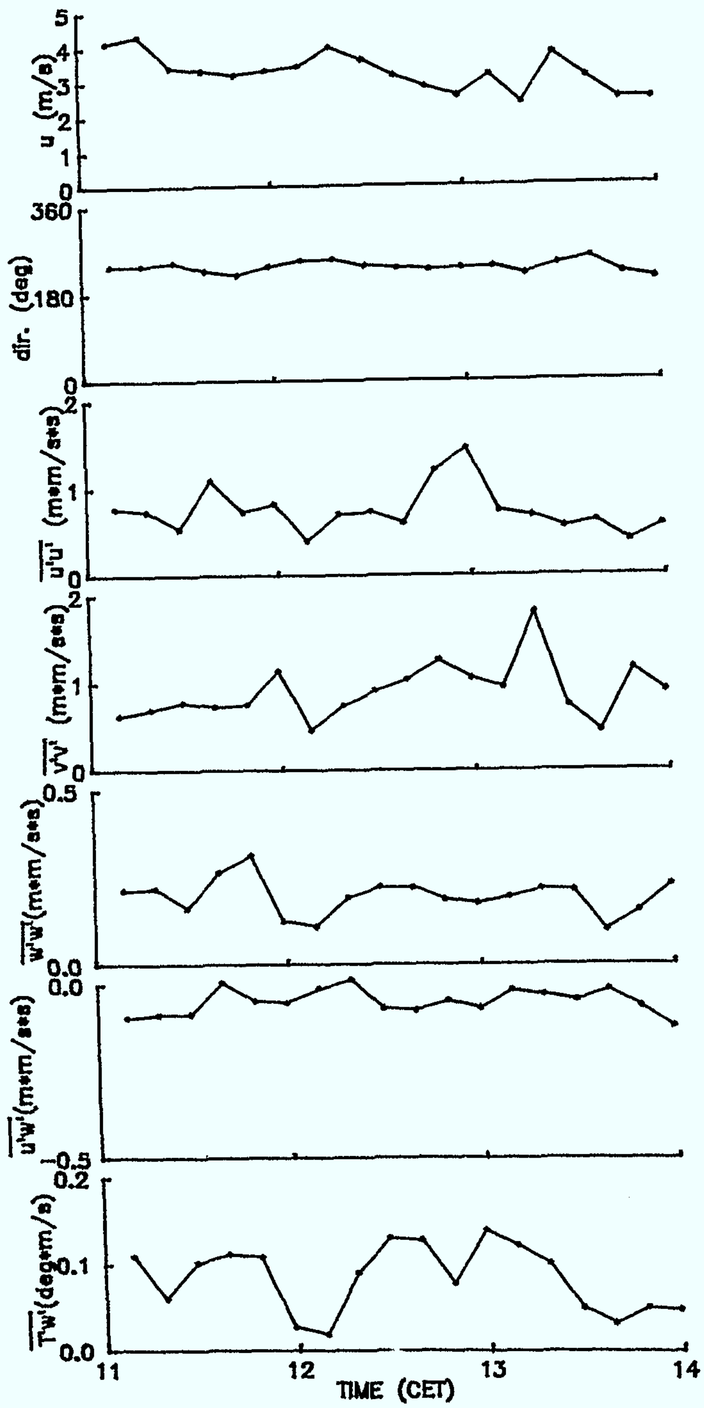


Fig. 5.3.7: Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 4 September, period 11:00 - 14:00 CET.

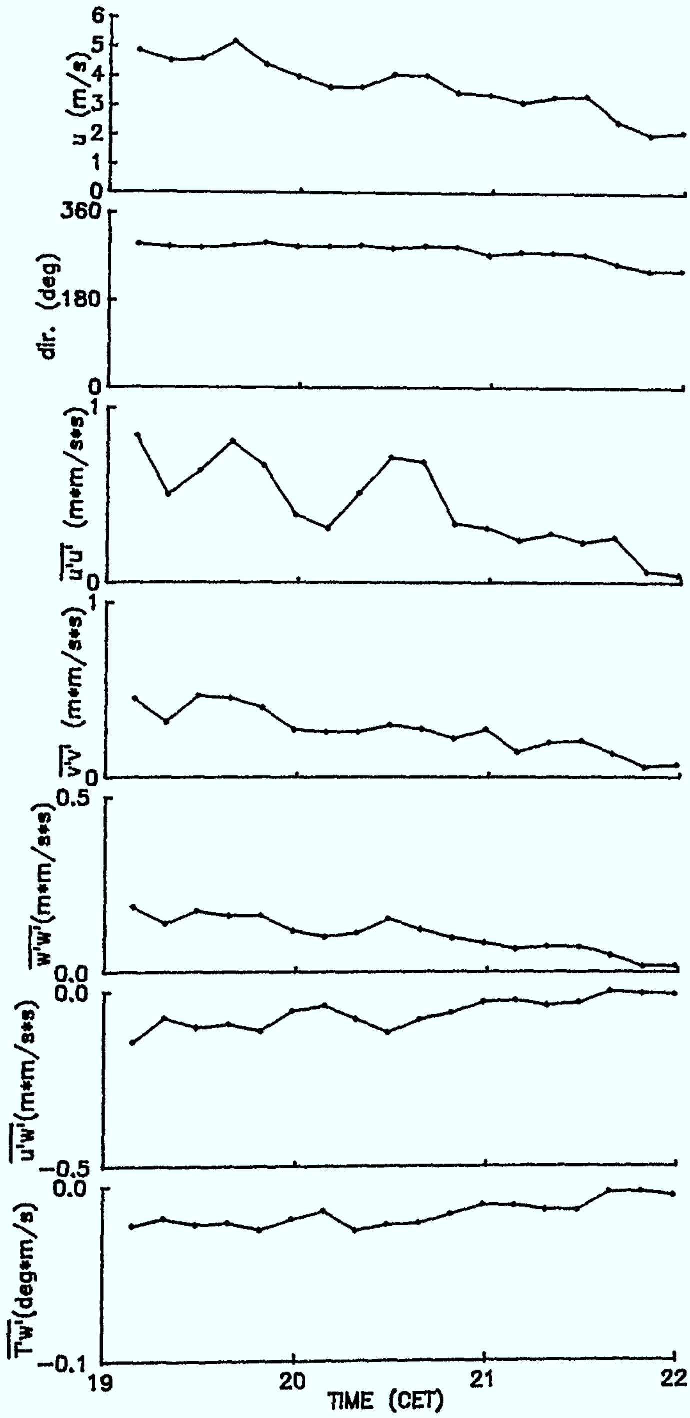


Fig. 5.3.8: Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 5 September, period 19:00 - 22:00 CET.

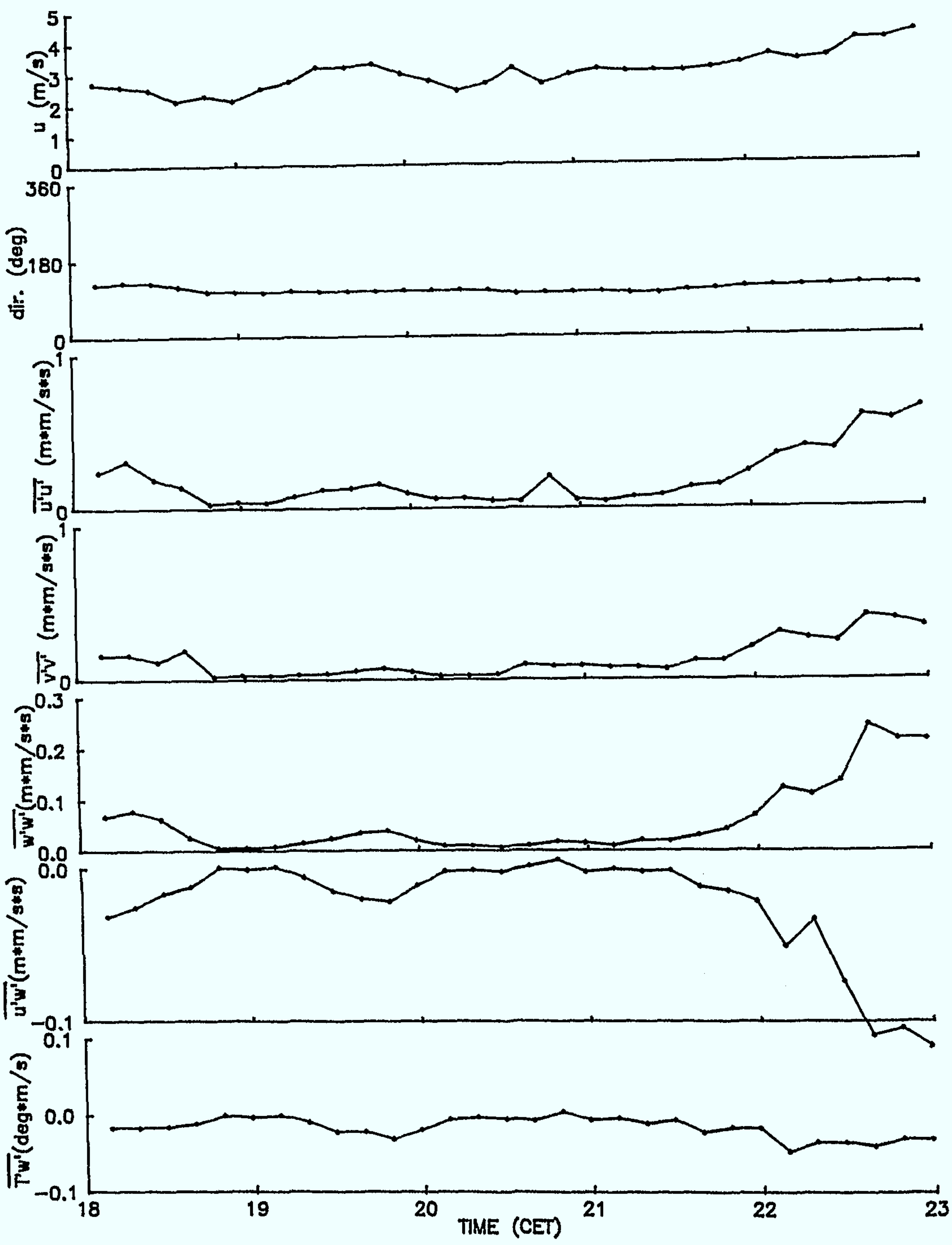


Fig. 5.3.9: Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 7 September, period 18:00 - 23:00 CET.

length of the wind vector projected on the horizontal plane. This new coordinate system is then rotated around a horizontal axis perpendicular to $\bar{u}$ in such a way that $\bar{w} = 0$. This implies us to assume that the vertical wind velocity is zero on the average. It should be noted that if the transformation is carried out in reverse order, a slightly different result will be obtained.

The turbulence statistics in this new coordinate system are stored on magnetic tapes by the HP-85 computer. All data are given in the data bank. The wind velocity is the length of the wind vector, the wind direction is expressed following the usual meteorological conventions, the wind vector tilt angle is the angle between the wind vector and the horizontal plane.

Start	Stop
August 30 12:30	September 3 09:50
September 3 10:00	September 8 11:20

Tab. 5.3.2: Measuring periods (Central European Time, CET) for the 10-min averaged turbulence statistics.

The measurements were carried out throughout the whole experimental campaign except for a 10-min interruption due to change of tape, Tab. 5.3.2. Figures 5.3.4-5.3.9 illustrate the measurements during tracer releases.

5.3.3 Tethered balloon soundings at Pattern

The tether sonde used by RISØ was of the type: Atmospheric Instrumentation Research Company, Boulder (Colorado), model TS-2A. The measured parameters were dry and wet-bulb temperature, wind direction and speed, as well as static air pressure to determine the height above ground. The most important characteristics of the sensors are given in Table 5.3.3.

Measured quantity	Sensor	Time const.	Resolution	Accuracy
dry/wet-bulb temperature	aspirated thermistor	5/50 s	0.1 *K*	0.3 *K*
wind speed	cup anemometer	few sec	0.1 m/s	10%
wind direction	magnetic compass	few sec	1°	20°
differential barom. pressure	aneroid strain gauge	<1 sec	0.1 mb	3 mb

Tab. 5.3.3: Characteristics of the tether sonde sensors.

A 3.5 m^3 balloon (Fig. 5.3.10) filled with helium was used to perform soundings up to approx. 300 m above ground. The winch used allows only operation at wind speeds below $\simeq$10 m/s.

The measured data were transmitted from the sonde to the ground station every 6 sec and stored on magnetic tapes for further processing in the laboratory. Due to low sonde battery voltage the measurements of the atmospheric pressure were erroneous in a number of cases. These erroneous measurements have been deleted.

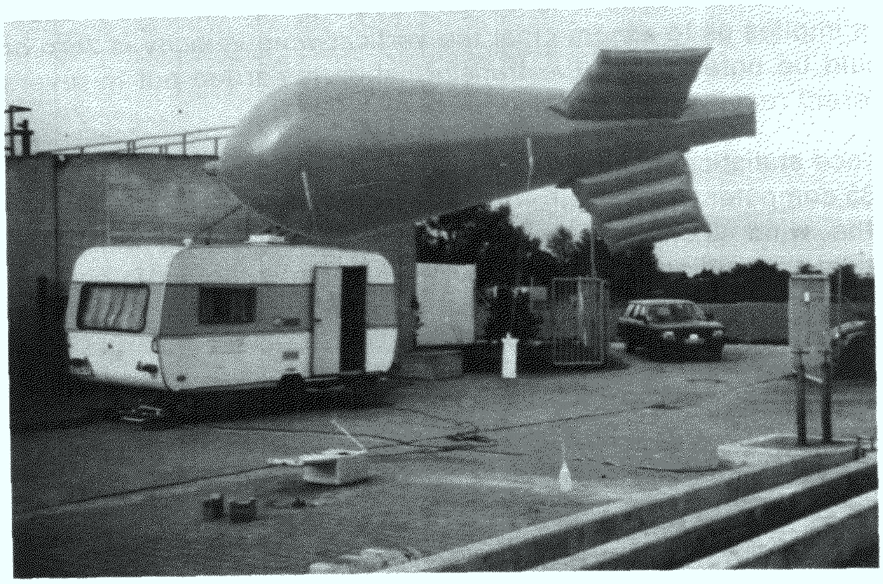


Fig. 5.3.10: The caravan contained the electronics for the sonic anemometer and the data recording equipment. In the front is seen the tether-sonde balloon and its winch.

Thirty-two soundings (15 files in the data bank) were performed up to 200-300 m above ground (depending on wind speed), see Table 4. In Figs. 11-17 are shown some wind-speed and potential-temperature profiles from the tracer experiments. The data bank contains the following parameters from all the soundings

time group	time elapsed since start (min)
wind speed	(m/s)
wind direction	(°)
dry-bulb temperature	(°C)
wet-bulb temperature	(°C)
pressure	(mb)
height above ground	(m)

Date	Start	Stop	Max. height (m)	No. of profiles
30 August	13:52	16:26	374	3
31 August	17:15	20:29	300	4
3 September	05:18	09:26	270	10
4 September	07:09	13:31	351	5
5 September	08:09	10:43	368	2
5 September	21:03	21:37	269	1
7 September	07:55	08:54	336	2
7 September	18:32	22:44	281	5

Tab. 5.3.4: Measurements with the tethered balloon at Pattern.

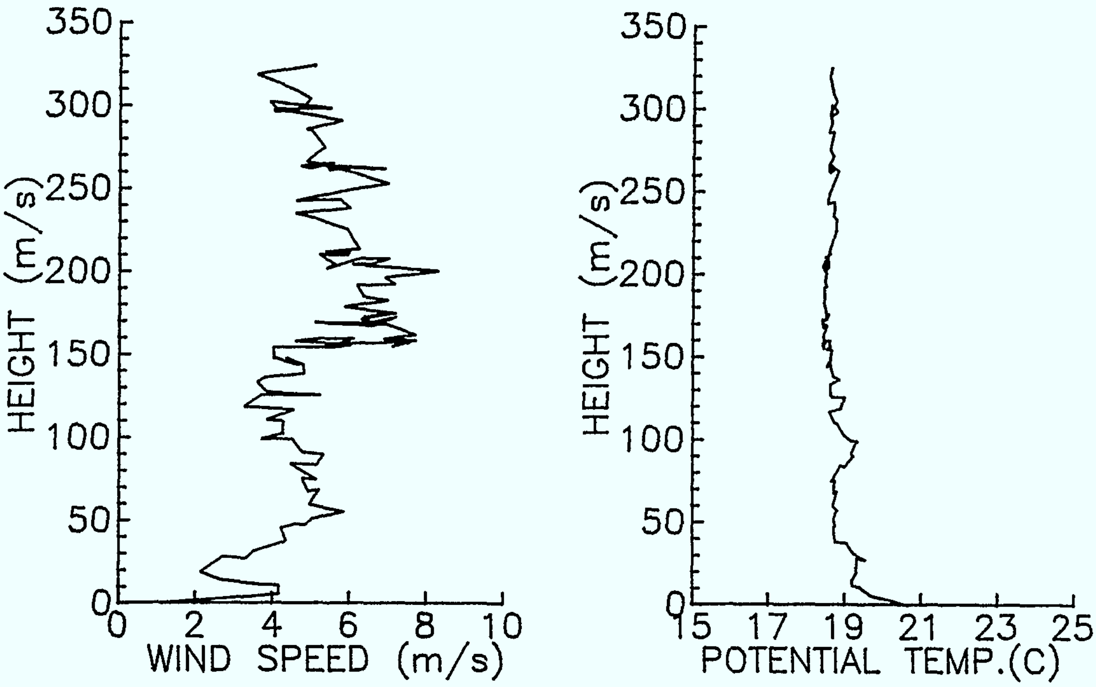


Fig. 5.3.11: Profiles of wind speed and potential temperature measured at Pattern, 30 August at 15:30 CET.

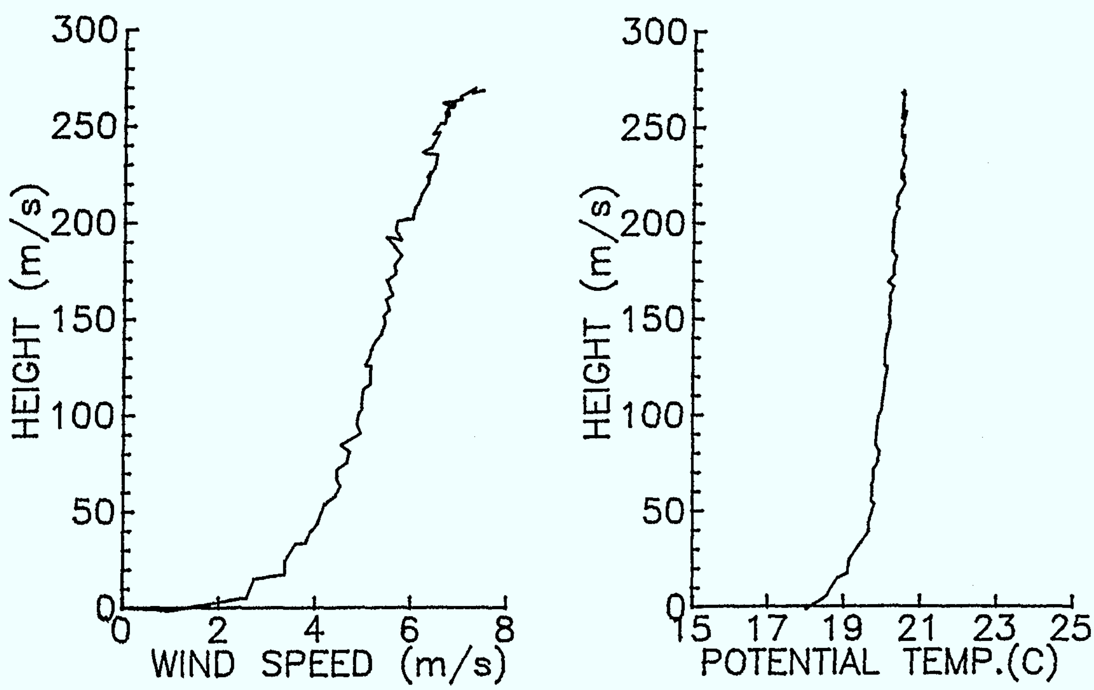


Fig. 5.3.12: Profiles of wind speed and potential temperature measured at Pattern, 31 August at 20:12 CET.

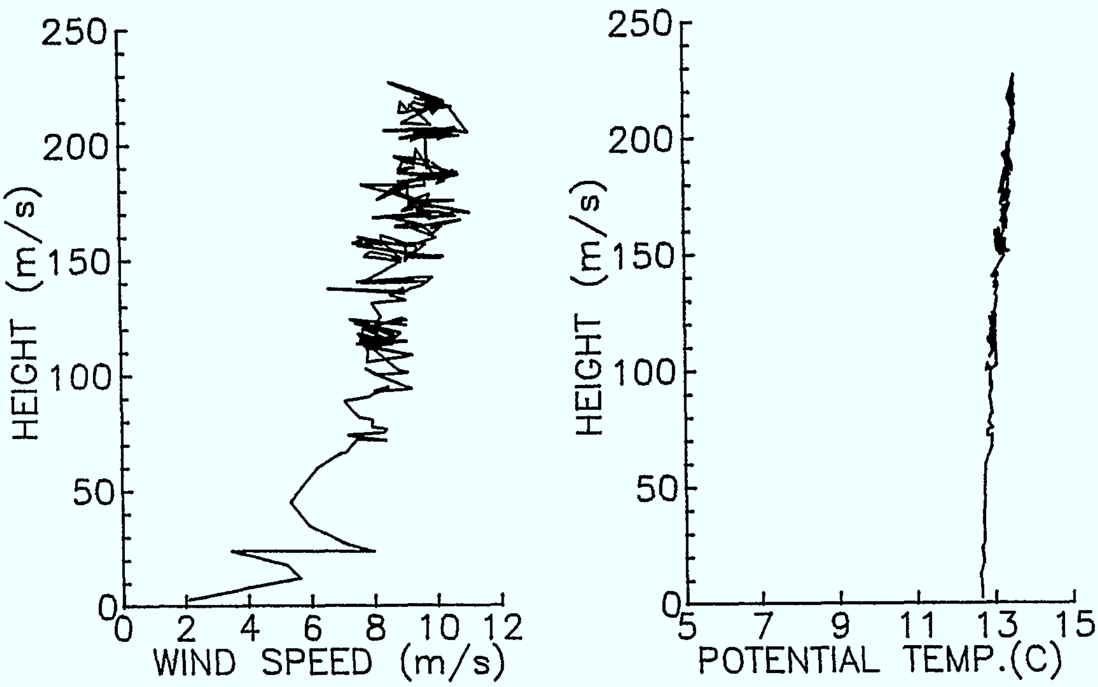


Fig. 5.3.13: Profiles of wind speed and potential temperature measured at Pattern, 3 September at 06:53 CET.

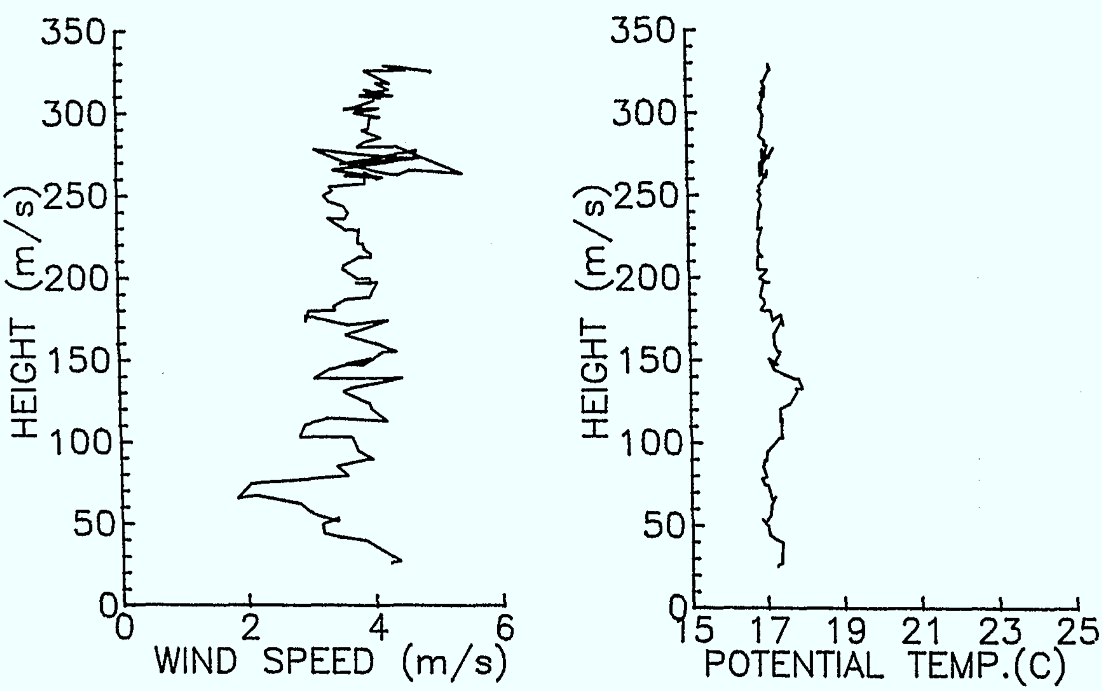


Fig. 5.3.14: Profiles of wind speed and potential temperature measured at Pattern, 4 September at 13:02 CET.

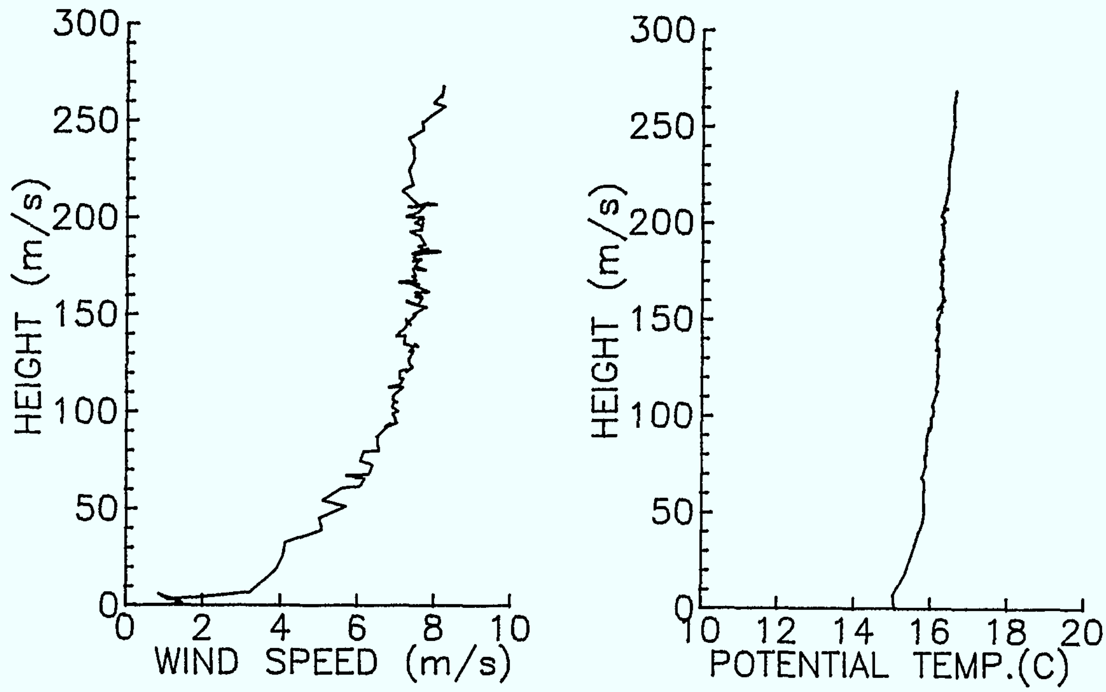


Fig. 5.3.15: Profiles of wind speed and potential temperature measured at Pattern, 5 September at 21:03 CET.

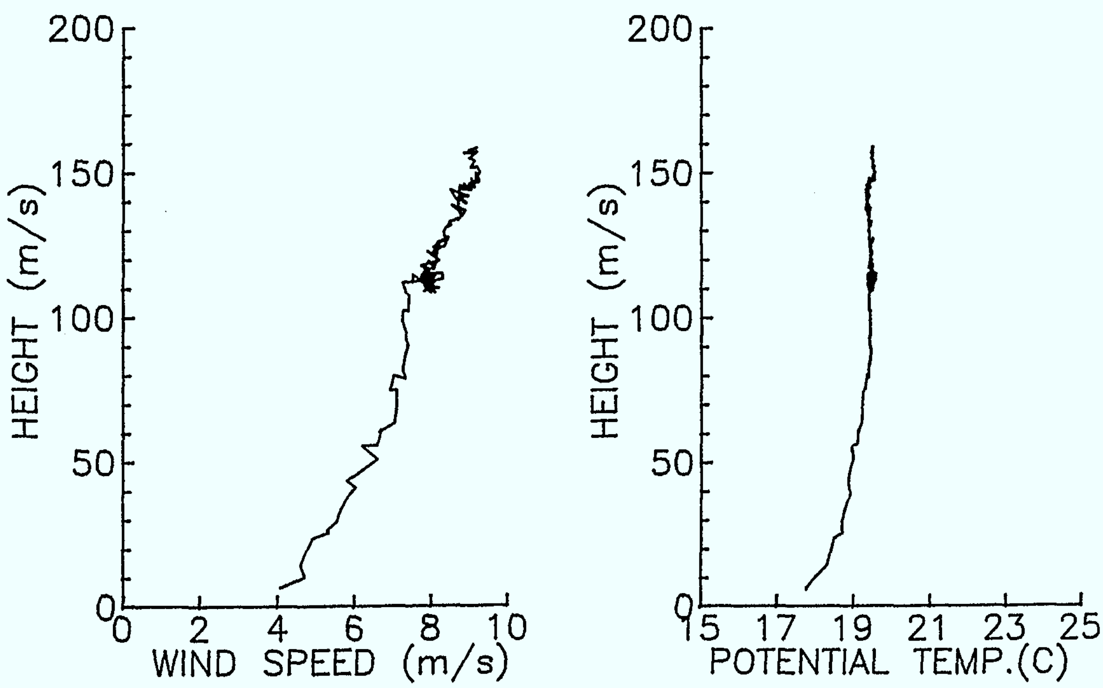


Fig. 5.3.16: Profiles of wind speed and potential temperature measured at Pattern, 7 September at 19:32 CET.

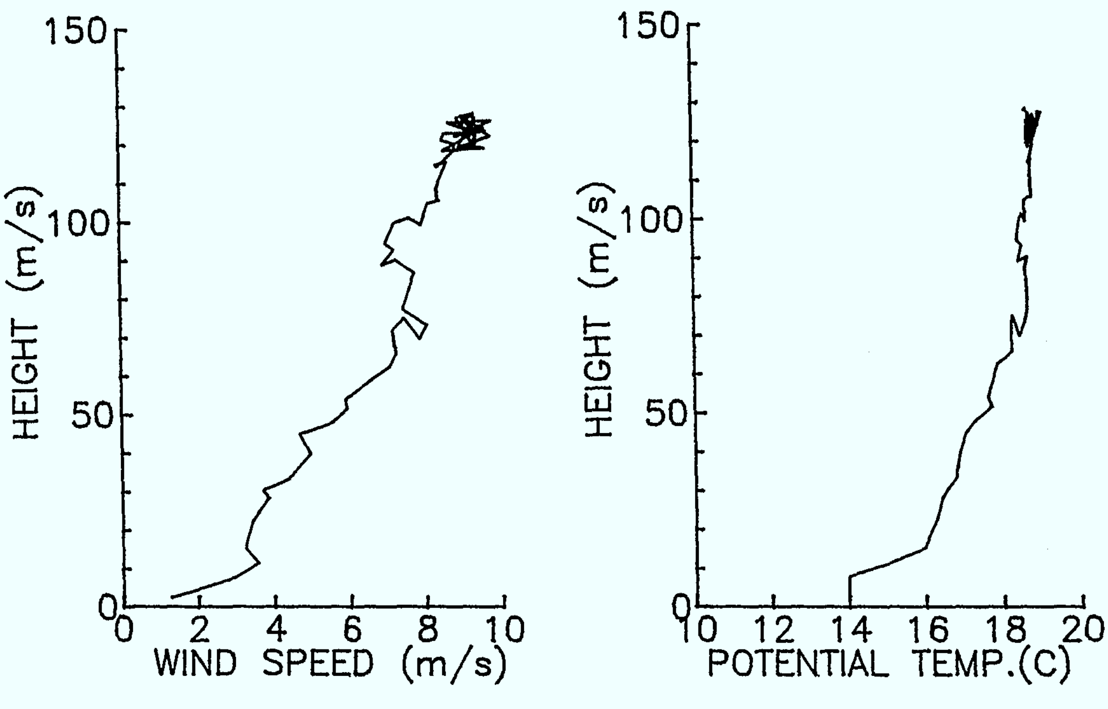


Fig. 5.3.17: Profiles of wind speed and potential temperature measured at Pattern, 7 September at 21:25 CET.

5.3.4 Small masts

Measurements of wind speed and direction were carried out at Berme 125, 150, 220 and near the top of Sophienhöhe, Fig. 5.3.1. The four masts were located to reflect the change in wind speed and direction near the surface at the northwestern part of Sophienhöhe. The instrumentation of the four masts is identical. The measurements were performed with 1-min intervals. The wind speed was averaged over 1-min: the wind direction was the instantaneous value at the time of scanning. Measurements were carried out throughout the entire experimental period, but the data bank only includes measurements from selected periods primarily centered around the tracer experiments.

5.3.4.1 Instruments

A RISØ cup-anemometer model-70 was used as wind speed sensor. It is a light-weight, strong anemometer with cups made of carbon-reinforced plastic. The distance constant is about 1.5 m and the starting speed is 0.25 m/s. The version of the RISØ's model-70 anemometer used here outputs two electric pulses per rotation of the cups. The pulses are counted and the number converted into wind speed. All the cup-anemometers are individually calibrated.

The wind direction was measured by a wind vane (Aanderaa Instruments, wind direction sensor 2750). It consisted of a light wind vane turning on a vertical pivot. The vane is magnetically coupled to an accompanying device inside the housing. The accompanying device is clamped when the direction is read. In the usual configuration the vane movements are artificially damped by filling the space between the pivot and surrounding shaft with silicone oil. Due to the very light winds that were expected at night during the campaign, the oil was removed allowing a very easy turn of the vane. It is our impression that in this special configuration the vane responded in a satisfactory way.

The data registration was carried out by a battery-driven datalogger (Aanderaa DL-1). It contains a mechanical scanner that reads the contents of the six channels every minute. Reading of all the channels takes 25 sec. The results are stored on magnetic tapes.

5.3.4.2 The mast at Berme 125

The meteorology mast was situated on the downhill side of a road bounded by trees 2 m south of position 248 where an opening exists in the line of trees. Fig. 5.3.18 shows the mast, the position is given in Tab. 5.3.5. The instruments at the mast functioned well during the campaign.

5.3.4.3 The mast at Berme 150

The mast was situated 15 m north of position 348 on the downhill side of a road bounded by trees. Fig.5.3.19 shows the mast, the position is given in Tab. 5.3.5. The instruments functioned well throughout the entire experimental campaign, but some of the measurements from the period 29 August 15:14 to 2 September 09:20 were lost because a tape of poor quality was used in the recorder during this period.

5.3.4.4 The mast at Berme 220

The mast is placed at position 544 in an opening of the downhill side of a road bounded by trees, Fig. 5.3.20. The instruments functioned well throughout the campaign.

5.3.4.5 The mast near the top

The meteorology mast was placed rather far from any access road in an area with grass (not trees as usual). Fig. 5.3.21 shows the mast, the position of which is given in Tab. 5.3.5. The instruments functioned well during the campaign.

5.3.4.6 Measurements

The general performance of the masts is given in Tab. 5.3.5 together with the position of each mast. All measurements are are illustrated in Figs. 5.3.22-5.3.27. Each figure shows for selected tracer periods the wind speed at each mast followed by the wind direction. This kind of illustration was chosen in order to facilitate a comparison between the measurements at the four stations.

	Position (km) (Gauss-Krüger Coordinates)		**Height above base of hill (m)**	**mean sea level (m)**
Mast at Berme 125	30.218	45.452	26	123
Mast at Berme 150	30.284	45.382	51	148
Mast at Berme 220	30.460	45.284	112	209
Mast near the top	30.525	45.055	148	245

Tab. 5.3.5: Positions (see Fig. 5.3.1) and performance of the small masts.

Measurements from the following periods for all four masts are contained in the data bank.

August 30	13:00-17:00	(data missing from mast at berme 150)
August 31	17:00-21:30	
September 3	05:00-11:00	
September 4	06:00-15:00	
September 5	07:00-22:30	
September 7/8	07:00-01:00	

Fig. 5.3.18: The mast at Berme 125.

Fig. 5.3.19: The mast at Berme 150.

Fig. 5.3.20: The mast at Berme 220.

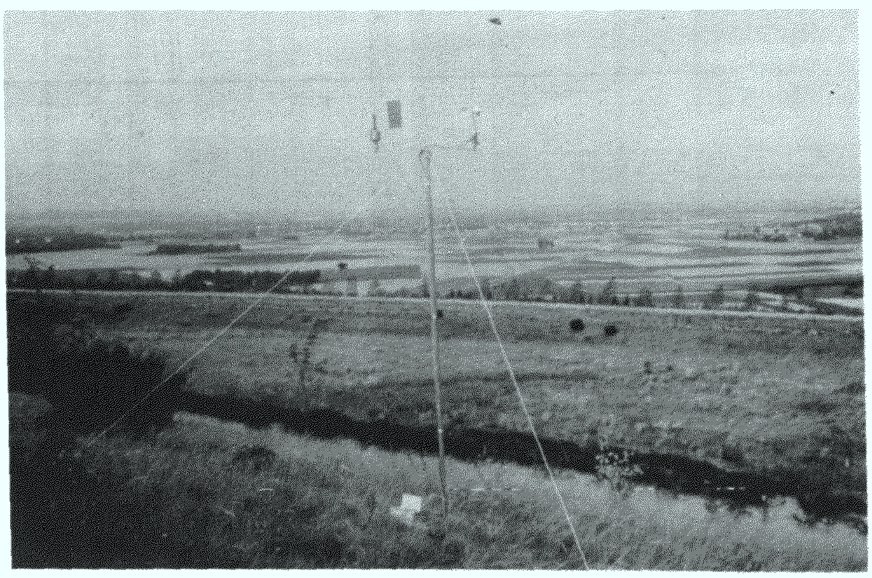


Fig. 5.3.21: The mast near the top.

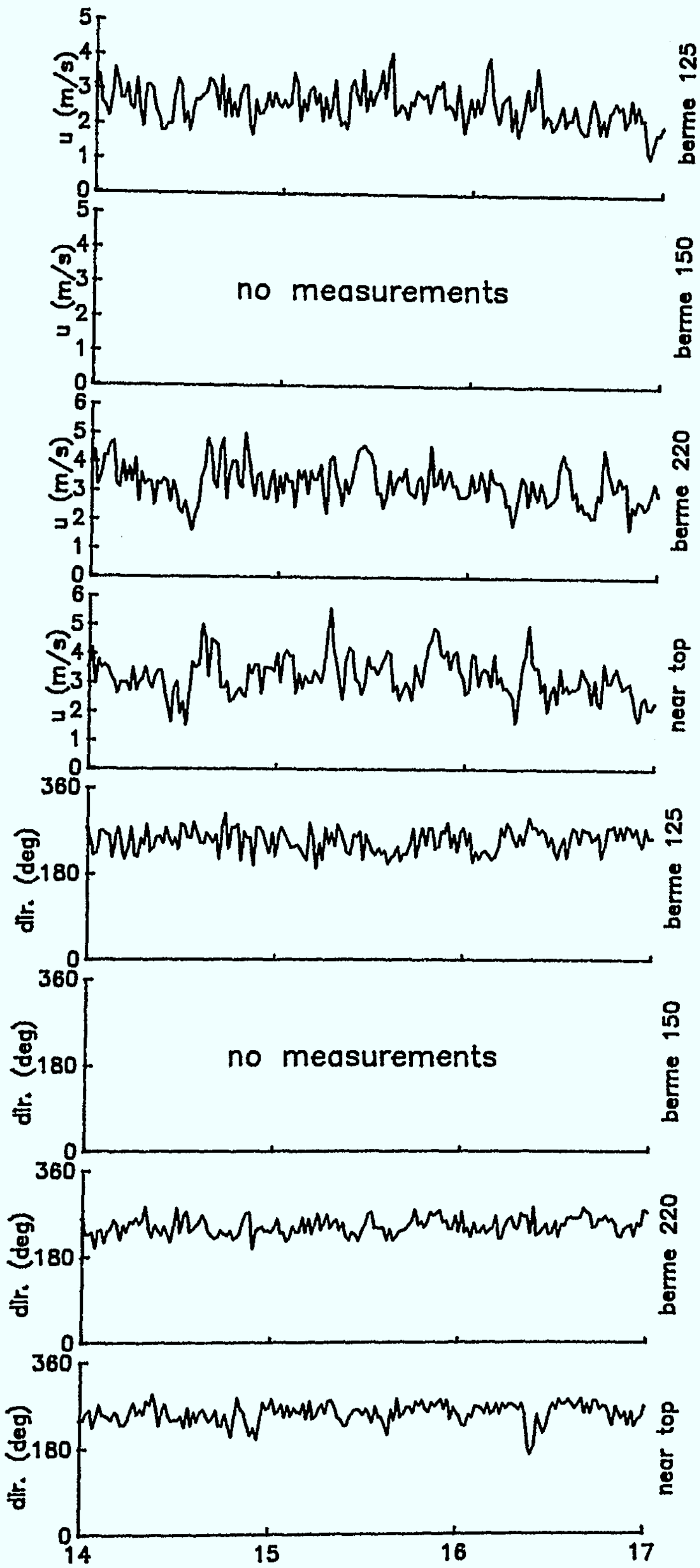


Fig. 5.3.22: Illustration of the measurements at the small masts on 30 August, period 14:00 - 17:00 CET.

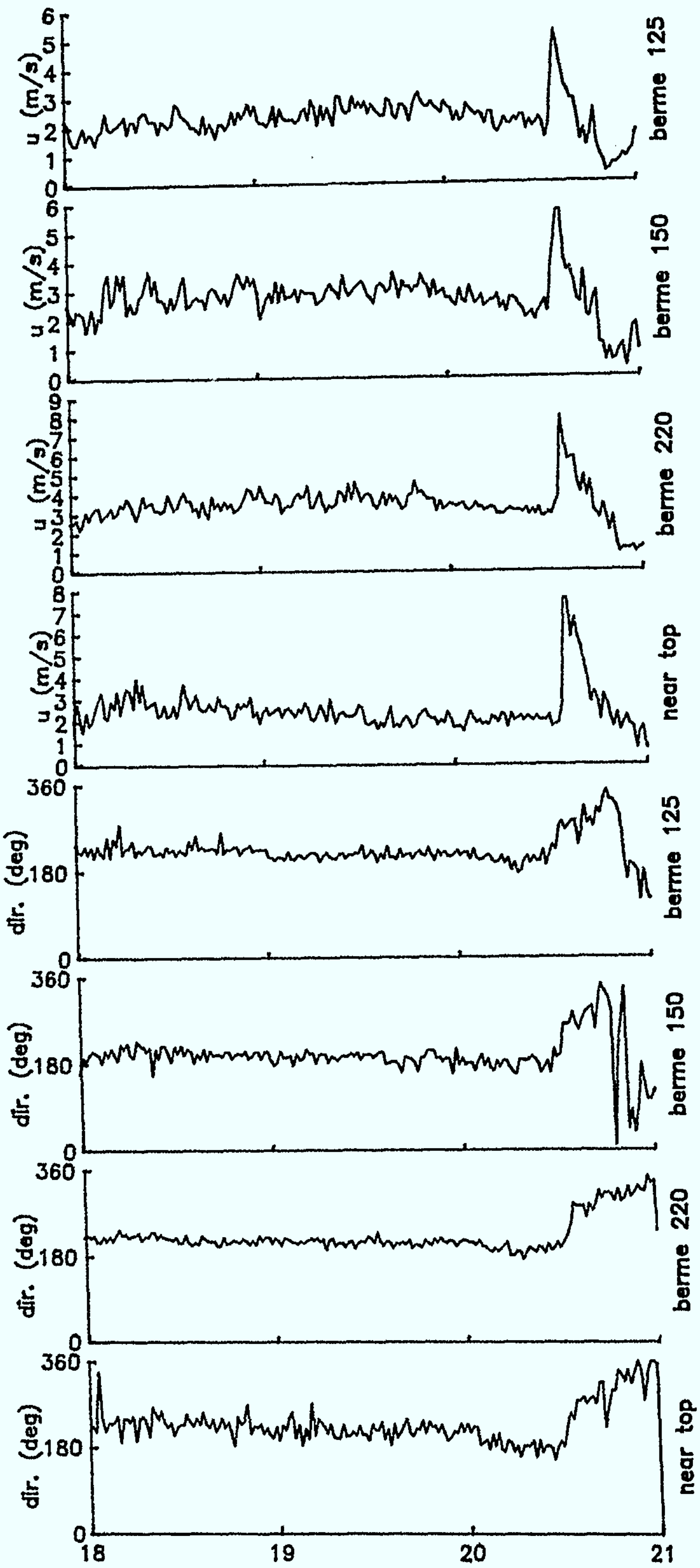


Fig. 5.3.23: Illustration of the measurements at the small masts on 31 August, period 18:00 - 21:00 CET.

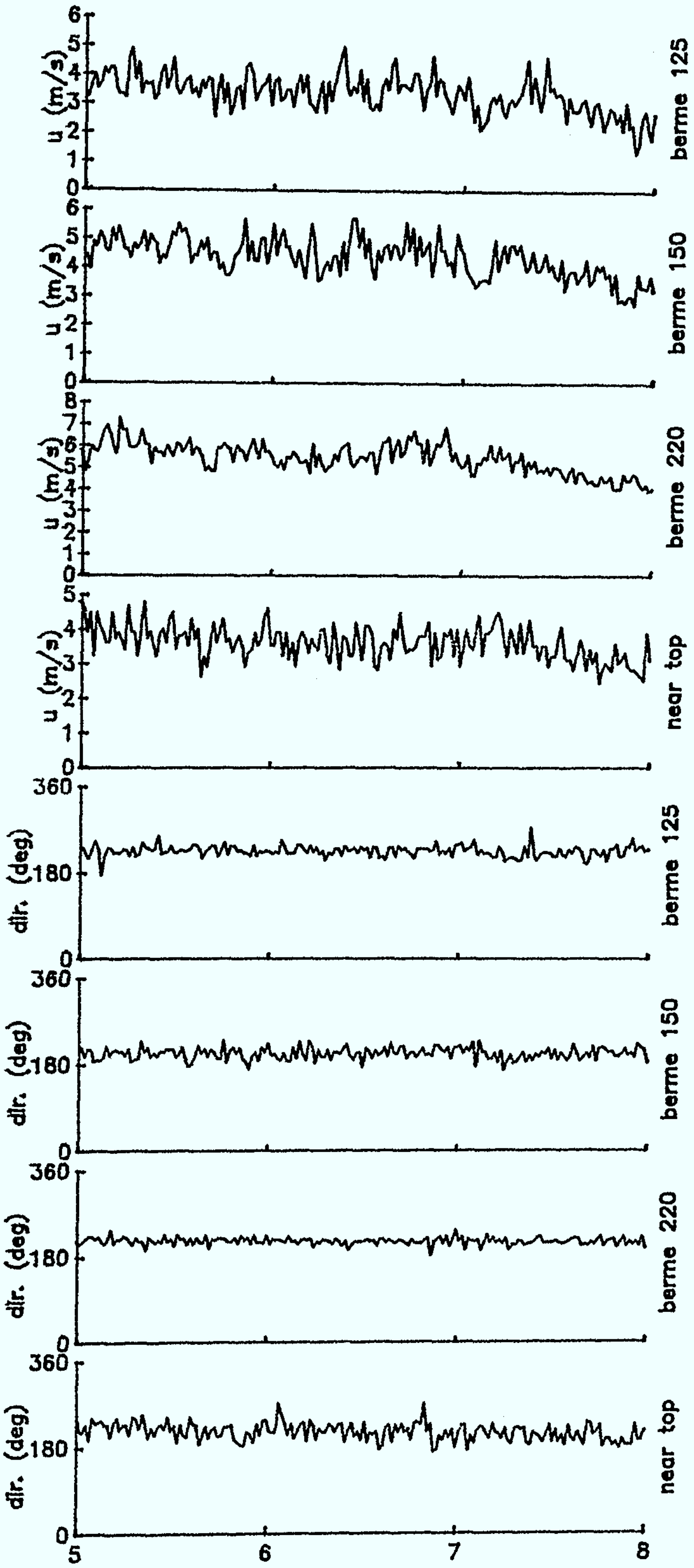


Fig. 5.3.24: Illustration of the measurements at the small masts on 3 September, period 05:00 - 08:00 CET.

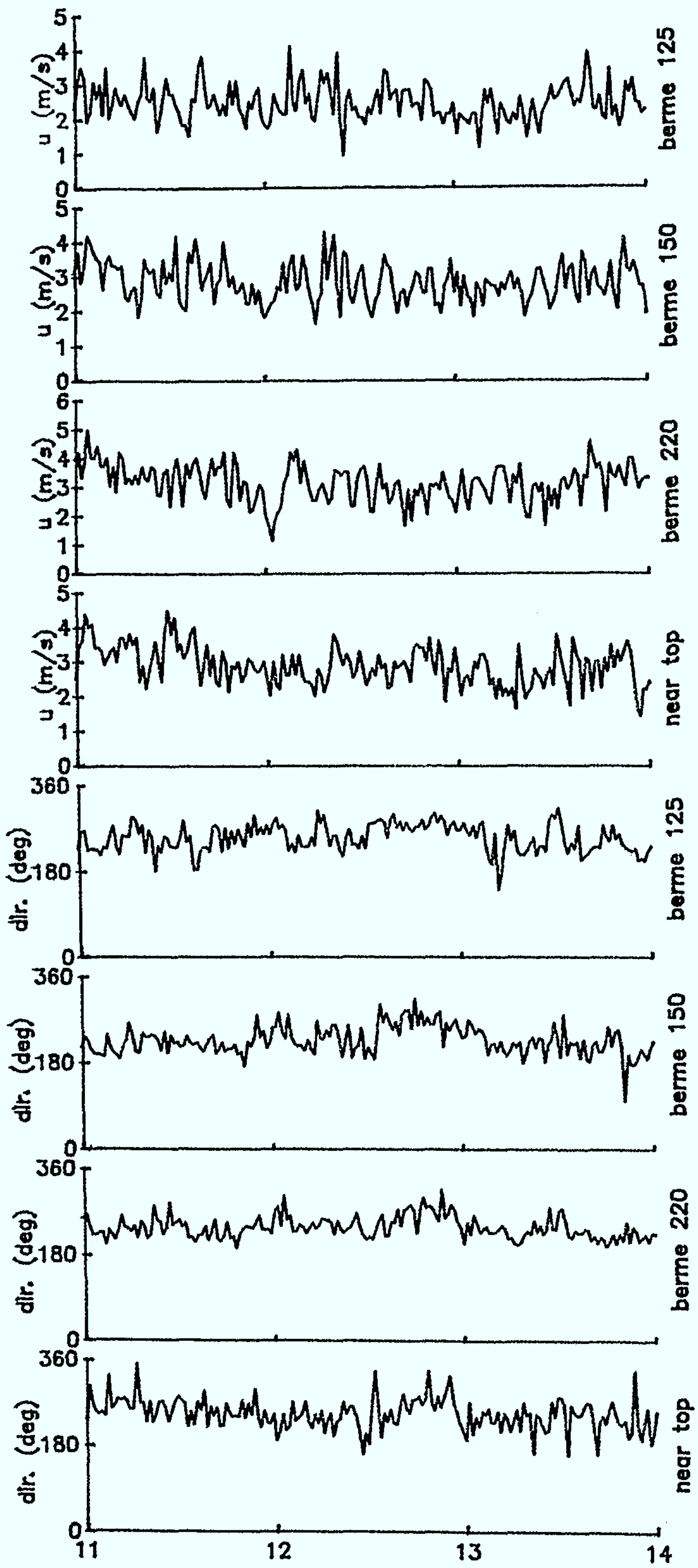


Fig. 5.3.25: Illustration of the measurements at the small masts on 4 September, period 11:00 - 14:00 CET.

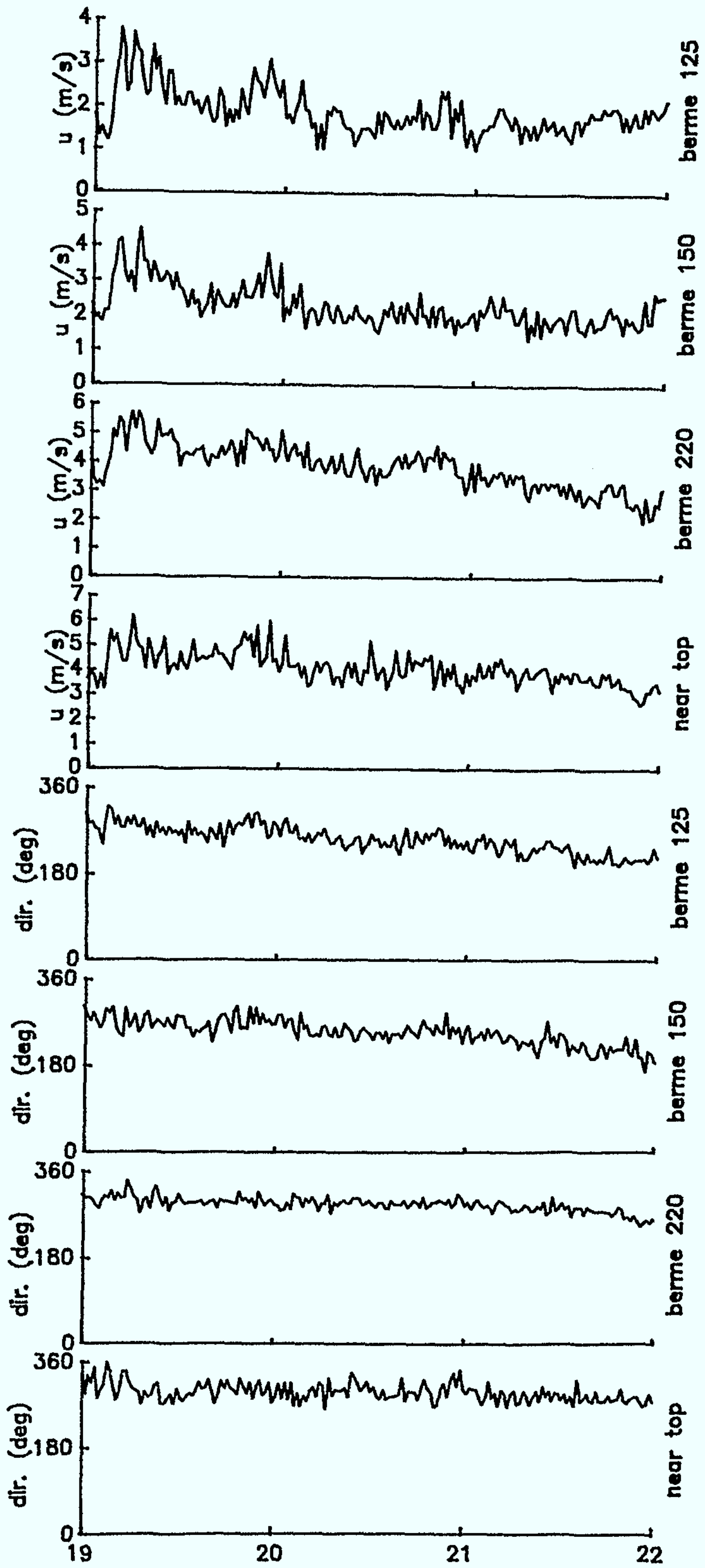


Fig. 5.3.26: Illustration of the measurements at the small masts on 5 September, period 19:00 - 22:00 CET.

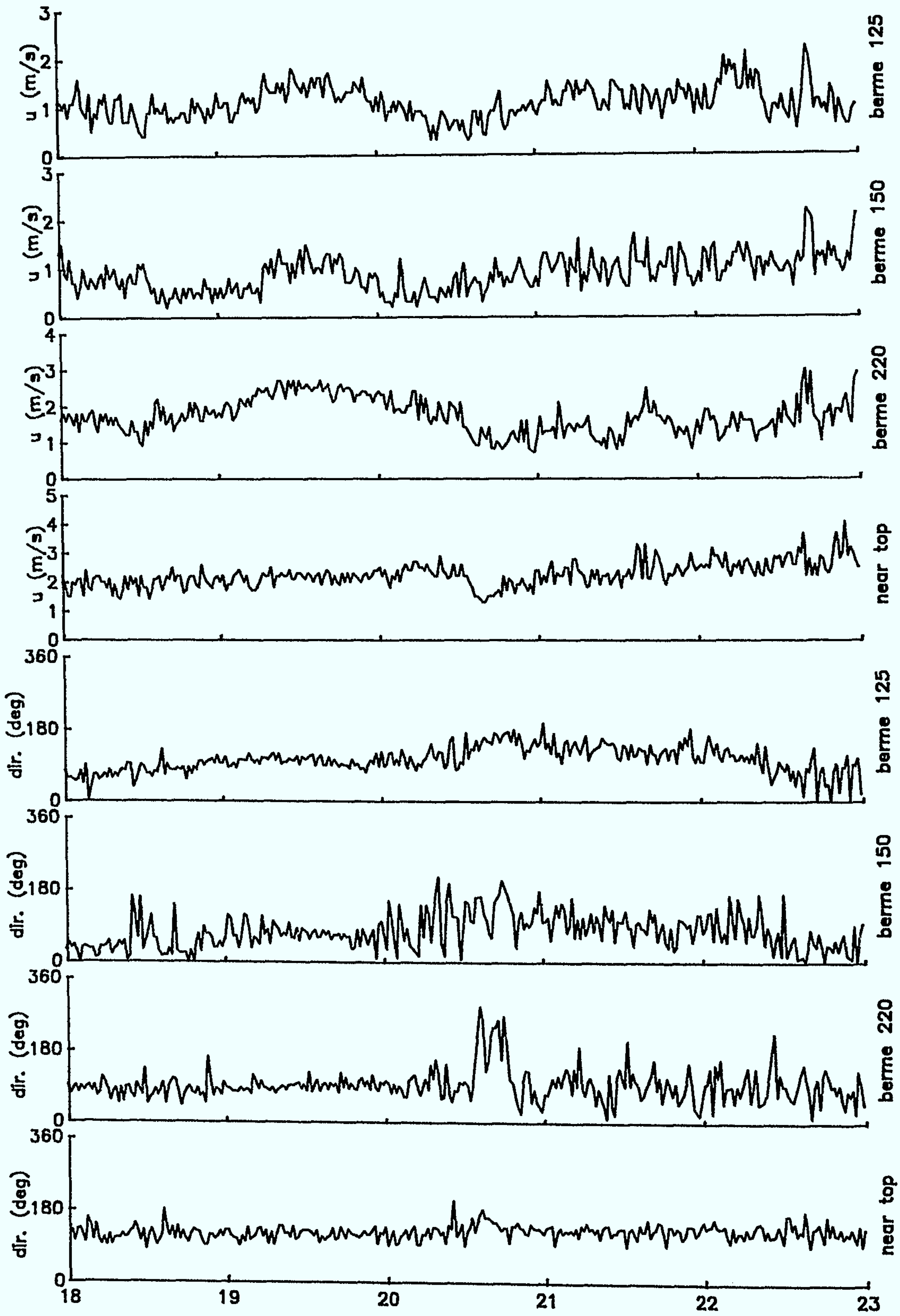


Fig. 5.3.27: Illustration of the measurements at the small masts on 7 September, period 18:00 - 23:00 CET.

5.4 Tether sonde measurements by IGM-group

W. Oetz and Ch. Oetz

The sounding of the lower atmosphere with a tether sonde system were measured by the Institute of Geophysics and Meteorology (IGM), University of Cologne. Profiles of wind direction and speed, dry- and wet bulb temperature were measured in steps of ~20 m up to a height of ~400 m. In the following, the measurement system, the performance of instruments and the measurement periods and positions are described. Some profiles are presented in the figures.

The measurement system is from the Atmospheric Instrumentation Research Company (AIR), Boulder (Colorado) and consists of a tether sonde, model TS-1A-1 and receiver, model TS-2AR. The sensors for temperature (T Dry & T Wet), windspeed (WS), pressure (PRes), wind direction (WD) and transmitter are placed in a box of polystrene, carried below a helium filled 3.5 m^3 balloon (Fig. 5.4.1). Every 9 seconds a 403 MHz FM transmitter telemeters the data to a UHF receiver.

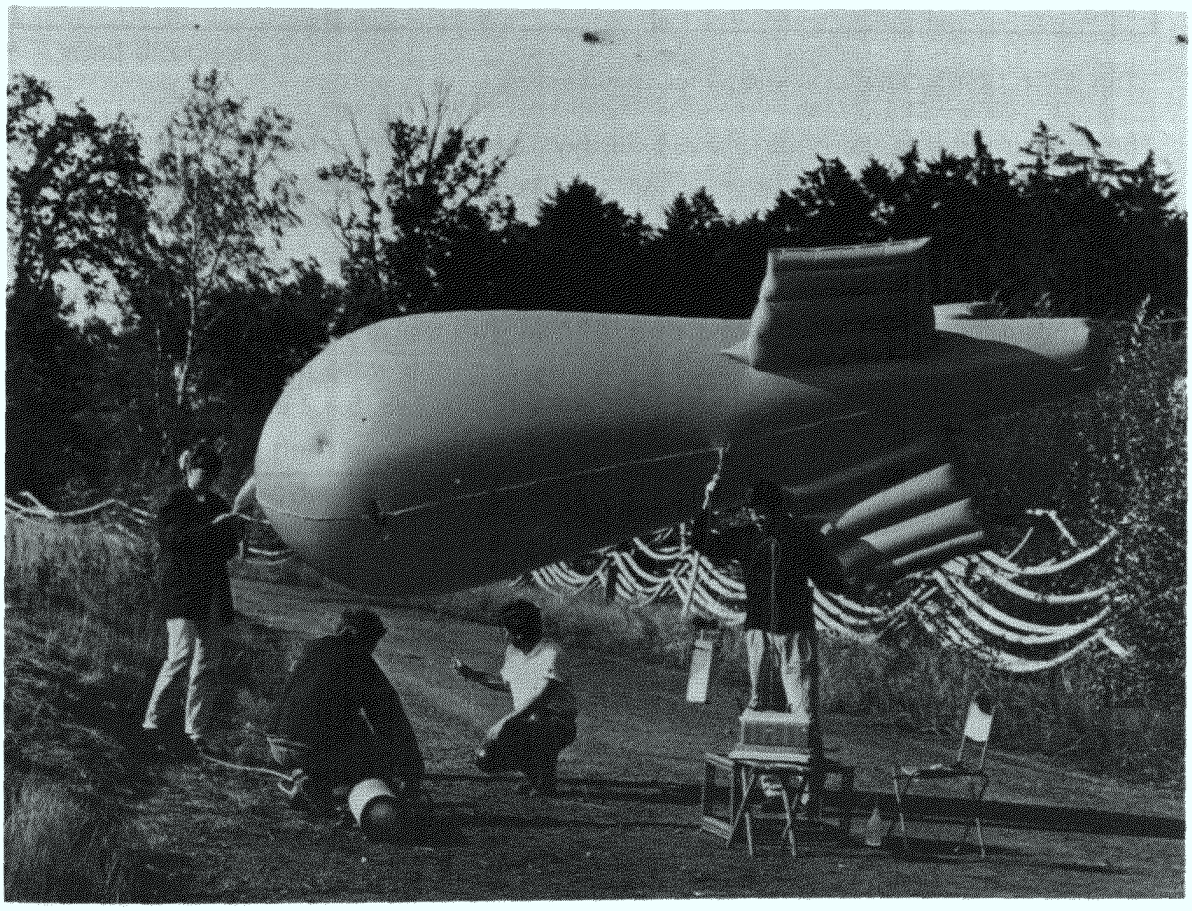


Fig. 5.4.1: Preparing the balloon

With calibrated frequencies in the microcomputer of the receiver, the measurement tones are converted to physical values and stored by an external PC.

Temperatures are measured by thermistors in a psychrometer. The horizontal mounted psychrometer generally prevents radiation errors, but showed some radiation influence during low-lying sun conditions. Wind direction is measured by the position of small electronically read-out magnetic compass which is oriented with the balloon to serve as a wind vane. Wind speed measurements are made by a three cup anemometer and a tacho generator. Pressure is measured by detecting the change in plate separation of an aneroid capacitance sensor. The characteristics of the sensors are compiled in Tab. 5.4.1.

Measured quantity	Sensor	Measuring range	Time constant	Resolution	Accuracy
dry-/wet bulb temperature	aspirated thermistors (psychrometer)	±50°C	5/50 sec	0.1 K	±0.3 K
wind direction	magnetic compass	0-360°	few sec	±1°	20°
wind speed	cup anemometer	0.7-20 m/s	few sec	0.1 m/s	10%
differential barom. pressure	aneroid capacitance	0-100 hPa	<1 sec	0.1 hPa	±3 hPa

Tab. 5.4.1: Characteristics of the tether sonde sensors.

The measurements were carried out all days except Sept 2. Morning ascents were made synchroneous with the RISØ group to detect the dissolution of inversions. Fifty-one soundings were performed at two positions. The main measurement site was the South of Sophienhöhe between hill and mine. On Sept 7, in the afternoon, the tether sonde system was moved to the north-western part of Sophienhöhe when a night-time experiment with tracer release from the top of the hill was planned and profile measurements in the region of the tracer plume were desired. Time and position of the tether sonde measurements are given in Tab. 5.4.2 and Tab. 5.4.3.

Date	position	Gauß-Krüger Coordinates	Height (m)
Aug 30 - Sept 8	Base of hill, in the South (S) between hill and mine (same place as measuring van ICH 4)	31340 42000	104
Sept 7, after 17:30	North west part of hill (NW), at Berme 125	30500 45650	122

Tab. 5.4.2: Position of the tethered balloon measurements

Date	Start	Stop	Max. height (m)	No. of profiles
Aug 30,1988	13:20	16:15	488	3
Aug 31,1988	11:26	21:30	507	6
Sept 1,1988	09:09	15:38	332	6
Sept 3,1988	06:45	10:55	308	4
Sept 4,1988	06:50	21:00	344	5
Sept 5,1988	07:00	15:48	354	4
Sept 6,1988	10:30	20:45	455	9
Sept 7,1988	07:20	22:56	403	12
Sept 8,1988	07:25	11:49	250	4

Tab 5.4.3: Measurements with the tethered balloon IGM group

As an example of the tether sonde ascents the wind and temperature profiles during tracer experiment III-1, III-2 and III-6 are shown in Fig. 5.4.2 - 5.4.4. Fig. 5.4.4 illustrates the strong wind shear in the lower stable atmosphere.

The data bank contains the following parameters

- wind speed
- wind direction
- temperature (dry-bulb)
- temperature (wet-bulb)
- relative humidity
- pressure
- height above ground

The receiver clock time at the beginning of each data set was not available during processing and therefore is not contained in the data bank. Now upon request, a discette including the time can be delivered.

Relative humidity was calculated using the Magnus formula (Möller, 1973). The thickness of each layer or height difference was calculated with the formula

$$\Delta H = 14.636(T_1+T_2)\ \ln(\frac{p_2}{p_1})$$

where the indices 1 and 2 correspond to the measurements of temperature and pressure at two levels. The sum of the calculated thickness $H_n = \sum_{i=1}^{n}(\Delta H)_i$ gives the height above ground. The error in the pressure measurements and changing air pressure can result in negative heights (maximal 40 m) at the end of the ascents. The negative heights should be interpreted as low heights above ground.

Date	Start	Stop	Position S = South W = West	Maximal height (m)	Remarks
30.8.	13:45	14:37	S	488	
30.8.	14:35	16:15	S	353	
31.8.	11:26	12:47	S	464	
31.8.	12:52	14:00	S	507	
31.8.	14:20	15:37	S	260	Pressure sensor calibrated
31.8.	15:45	16:50	S	295	
31.8.	18:30	19:27	S	218	high windspeed forces a stop
31.8.	19:30	21:30	S	289	
1.9.	9:09	10:19	S	272	
1.9.	10:20	11:03	S	166	strong turbulences above 100 m height
1.9.	11:10	12:37	S	218	
1.9.	12:35	13:27	S	224	
1.9.	13:33	14:49	S	333	
1.9.	15:00	15:38	S	175	
3.9.	6:45	7:39	S	308	
3.9.	7:51	8:49	S	240	
3.9.	9:03	10:07	S	270	
3.9.	10:10	10:56	S	180	
4.9.	6:50	8:10	S	245	
4.9.	8:25	9:48	S	208	
4.9.	9:50	10:47	S	247	Sensor-package crash
4.9.	16:30		S		TD, TW wrong readings
4.9.	17:20	18:17	S	334	
4.9.	19:35	20:39	S	344	
5.9.	7:00	8:03	S	555	
5.9.	8:10	9:07	S	398	
5.9.	9:10	10:25	S	368	
5.9.					TD Calibration
5.9.	12:00	15:49	S	207	
6.9.	10:10		S		Testing TD and TW values
6.9.	10:30	11:40	S	410	first launch
6.9.	11:35	12:46	S	455	second launch
6.9.	12:45	13:34	S	363	
6.9.	13:45	14:42	S	371	
6.9.	14:40	15:23	S	329	
6.9.	15:25	15:57	S	295	

Date	Start	Stop	Position S = South W = West	Maximal height (m)	Remarks
6.9.	16:05	18:02	S	374	
6.9.	17:50	18:53	S	434	
7.9.	7:20	8:24	S	325	
7.9.	8:30	9:38	S	268	
7.9.	9:30	10:40	S	284	
7.9.	10:50	11:59	S	403	
7.9.	11:55	12:58	S	289	
7.9.	13:10	14:10	S	303	
7.9.	14:15	14:51	S	276	
7.9.	17:30	18:38	W	270	changing location
7.9.	18:35	19:32	W	274	
7.9.	19:35	20:48	W	257	
7.9.	20:55	21:31	W	107	
7.9.	21:30	22:57	W	168	
8.9.	7:25	8:23	S	209	
8.9.	8:25	9:16	S	253	
8.9.	9:05	9:26	S	165	TD-Display fails
8.9.	9:40	11:50	S	250	

Tab. 5.4.4: Log-book tether sonde measurements

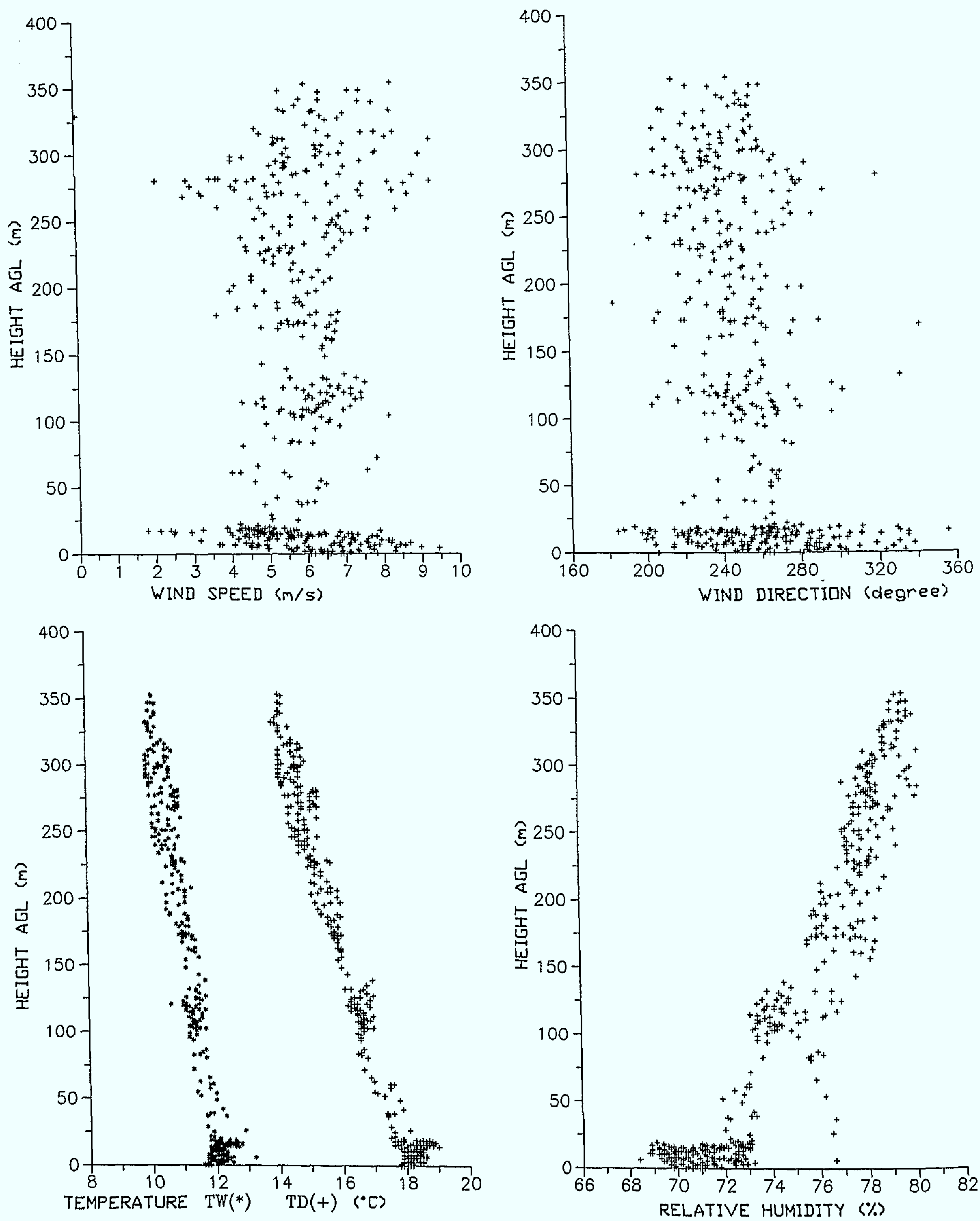


Fig. 5.4.2: Tethersonde ascent on Aug. 30, 1988, 14:35 - 16:15

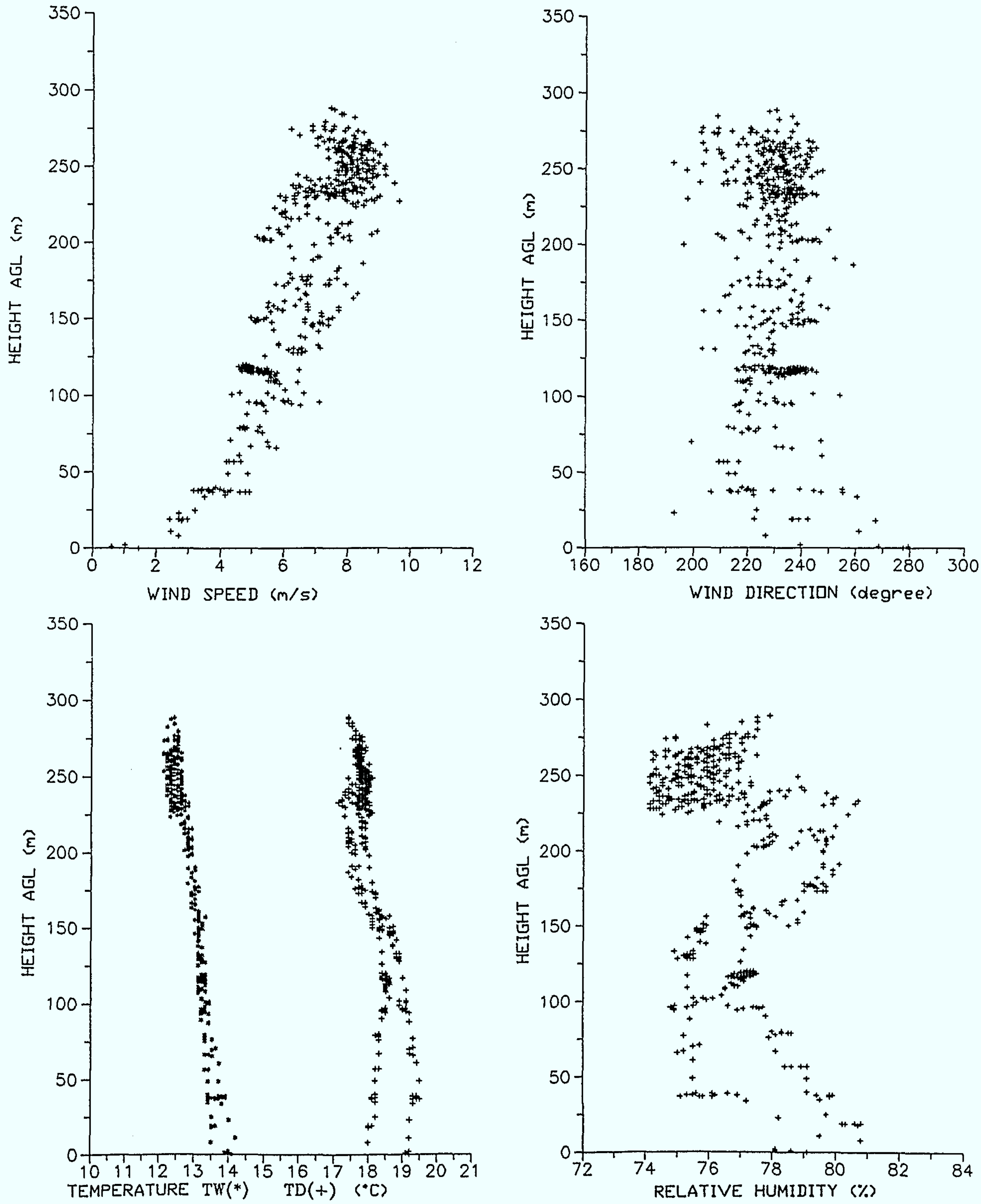


Fig. 5.4.3: Tethersonde ascent on Aug. 31, 1988, 19:30 - 21:30

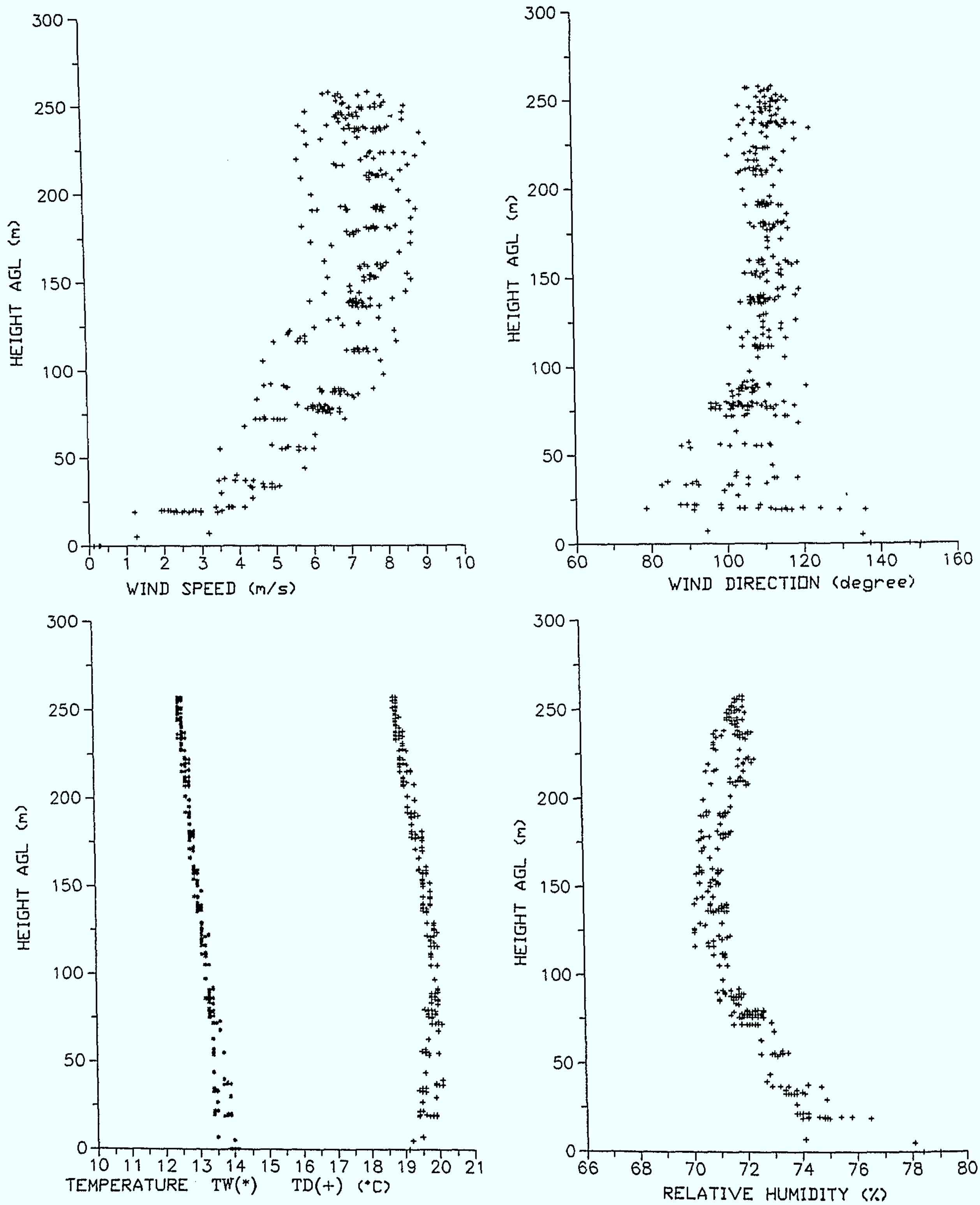


Fig. 5.4.4: Tethersonde ascent on Sept. 7, 1988, 19:35 - 20:48

5.5 Radiosonde and pilot-balloon ascents by Wetteramt Essen

K. Becker

5.5.1 Soundings within the KFA area

Radiosonde and pilot-balloon ascents with radar tracking were carried out daily between 05 and 21 CET from the location 'KFA waste treatment plant'. During dispersion experiments the normal ascent intervall of one hour was reduced to half hour. Tab. 5.5.1 contains a summary of all measurements (altogether 164 pilotballoon ascents and 30 ascents with radiosondes). A selection of vertical profile measurements during dispersion experiments are presented in Fig. 5.5.1 to 5.5.3.

5.5.1.1 Pilot balloons

The pilot-balloon system is equipped with

- a meteorological balloon (net weight 30 grams), filled with a defined volume of helium for an average ascension rate of 150 m/min,
- a small parachute to reduce the descent rate after the burst of the balloon,
- a target (21 cm corner reflector with eight trihedral prisms),
- at night a small battery and lamp for lighting.

To determine the vertical wind profile a mobile EEC WF 100-4 radar system of the German Weather Service, Frankfurt, was used. It is the same system as used for tetroon-flights, for configuration and technical details see chapter 5.2, Tab. 5.2.1. The height of the radar antenna is 4 m above ground. The position of the radar in Gauß-Krüger coordinates: x = 28515 m, y = 40910 m with a height of the ground level 91 m.s.l. During the launching period the antenna must be tracked manually via TV-camera and monitor, because the radar electronic can't separate the ground and target reflections. Normally after a time of 15 seconds the balloon is out of reach of ground reflections and the radar tracks automatically.

The ascent was finished when the balloon has reached the upper limit of the layer to be investigated (3000 m). This height couldn't be reached, if the balloon would cross areas of precipitation or if the elevation angle would be too small because of heavy wind and therefore obstacles (trees, buildings) would reduce the received power.

At an observation interval of 20 seconds the position of the balloon was fixed and the measured results were put out by printer and punched tape with time elapsed since start:

1. data measured by radar are:

   - elevation angle (resolution 0.1 degree)
   - azimuth angle (resolution 0.1 degree)
   - slant range (resolution 10 meter)

2. A HP 9915 modular computer calculated the following data:

   - horizontal distance (m)
   - height above radar antenna (m)
   - mean height (m) (height in the middle of the layer which the balloon traversed during the 20 sec interval)
   - wind direction (degree)
   - wind velocity (m/s)

These data are only suitable for a 'quick look'. The final data processing is a separate procedure after the end of the field experiment by using an IBM PC.

Therefore, at first the data must be transfered from punched tape to the PC. Then, measured data have to be checked for completion and plausibility and transfered to the spreadsheet-program 'LOTUS 1-2-3'. With this program all desired calculations and also simple graphics can be produced.

As an extract of the LOTUS-worksheet a floppy-disk with files of every ascent with values mentioned at a) and b) was sent to KFA to produce standardized datasets. No data were smoothed. The height of the radar antenna with 4 m above ground is considered.

The errors by earth curvature and refraction of the radar-beam are not corrected, because the distances are small (slant range < 15 km) and so the errors are negligible.

5.5.1.2 Ascents with radiosondes

For measuring the dry- and wet temperature and air pressure up to about 600 hPa the radiosonde 'TDFS-82' from the firm Dr. Graw, Nürnberg, is used by German Weather Service. All components, batteries for energy supply, quartz-stabilized transmitter (402...406 MHz) and sensors are arranged in a styropor box with integrated radiation protection.

The temperature bulb is a white plastic-coated bead thermistor with a diameter of 0.5 mm. The measurement of air humidity is based on the psychrometer principle. Therefore a similar thermistor, covered with wet muslin is used; the water supply comes from a water container with a capacity of 0.5 ml.

The air pressure is measured by a temperature compensated capsule aneroid. A lever arm moves across conducting stripes (about 25 hPa) according to the changes of atmospheric pressure. A relay switches cyclically between dry bulb (about 6 seconds) and wet bulb (about 3 seconds); reaching a pressure level this cycle is broken, and a fixed resistor is switched on for 4 seconds. The radiosonde system is configured as a pilot-balloon system, yet a meteorological balloon with a net weight of 100 grams is used, because the attachment is heavier. The ascension rate is normally 150 to 180 m/min. The audio-frequency signal of the radiosonde is transmitted to a voltage, which is registrated by a pen recorder in the ground station. This recording is evaluated manually on the basis of significant points of dry- and wet-bulb temperature. Therefore, the recorded curves are levelled by a straight line, so that the deviations to either side of the line are smaller than 0,5 Kelvin. Their intersections constitute the significant points. The time elapsed since start and the air pressure of the pressure-time curve are allocated.

After the input, first of all following data are calculated:

- height above ground and above MSL (with the barometric height formula and virtual temperature),
- dew point and relative humidity (by using the psychrometer formula according to SPRUNG for the vapor pressure and the MAGNUS formula for the saturation vapor pressure),
- the lapse rate of temperature.

To get a standarized dataset (filetyp 2) following measured values were sent to the KFA:

- index number of the significant point
- air pressure (hPa)
- dry-bulb temperature (degree centigrade)
- wet-bulb temperature (degree centigrade)
- time elapsed since start (minutes)
- height above ground (geopotential meter)
- height above m.s.l. (geopotential meter)
- dew point (degree Centigrade)
- relative humidity (percent)
- lapse rate of temperature (Kelvin/100 meters)

An overview on the ascents is given in Tab. 5.5.1.

Tab. 5.5.1: Pilot-balloon and radiosonde ascents with radar tracking within the KFA (S ≙ ascent with radiosonde)

number of ascent	Date	launch time (CET)	flight time (min)	maximum height (m)
132	30.08.88	13.30	10.0	1760
133	30.08.88	14.00	10.0	1720
134	30.08.88	14.30	18.0	1990
135	30.08.88	15.00	20.0	1950
136	30.08.88	15.30	16.0	2080
137 S	30.08.88	16.00	19.0	3530
138	30.08.88	17.00	13.0	2060
139	30.08.88	18.00	20.7	2950
140 S	30.08.88	19.00	22.0	3650
141	30.08.88	20.00	15.0	2160
142	30.08.88	21.00	16.0	2180
143	31.08.88	05.00	18.0	2040
144	31.08.88	06.00	15.3	2120
145	31.08.88	07.00	15.0	2120
146	31.08.88	08.00	14.0	2160
147	31.08.88	09.00	14.0	2010
148	31.08.88	10.00	19.0	2770
149	31.08.88	11.00	20.0	3180
150	31.08.88	12.00	18.0	3400
151 S	31.08.88	13.00	18.3	4020
152	31.08.88	14.00	17.0	3300
153	31.08.88	15.00	20.0	3040
154	31.08.88	16.00	18.0	3010
155	31.08.88	17.00	19.0	3000
156	31.08.88	18.00	17.0	2570
157	31.08.88	18.30	20.0	3090
158 S	31.08.88	19.00	21.0	3380
159	31.08.88	19.30	20.0	2860
160	31.08.88	20.00	22.0	3160
161	31.08.88	20.30	3.7	930
162 S	31.08.88	21.00	23.0	4080
163	01.09.88	05.00	28.0	3090
164	01.09.88	06.00	21.0	3100
165	01.09.88	07.00	22.0	3150
166	01.09.88	08.00	22.0	2970
167	01.09.88	09.00	20.0	3200
168	01.09.88	10.00	21.0	3260
169	01.09.88	11.00	21.0	3280
170	01.09.88	12.00	21.0	3000
171 S	01.09.88	13.00	19.0	3220
172	01.09.88	14.00	18.3	2940
173	01.09.88	15.00	7.3	1590
174	01.09.88	16.00	6.3	860
175	01.09.88	18.00	11.3	1920
176 S	01.09.88	19.00	18.0	3290
177	01.09.88	20.00	17.0	2740
178	01.09.88	21.00	16.0	2390

number of ascent	Date	launch time (CET)	flight time (min)	maximum height (m)
179	02.09.88	05.00	21.0	3070
180	02.09.88	06.00	21.0	3000
181	02.09.88	07.00	22.0	2960
182	02.09.88	08.00	20.0	3040
183	02.09.88	09.00	24.0	2970
184	02.09.88	10.00	20.0	3020
185	02.09.88	11.00	18.0	3140
186	02.09.88	12.00	13.0	3230
187 S	02.09.88	13.00	9.7	1460
188	02.09.88	14.00	16.0	1560
189	02.09.88	15.00	19.0	3090
190	02.09.88	16.00	3.0	360
191	02.09.88	17.00	5.0	590
192	02.09.88	18.00	10.0	1480
193 S	02.09.88	19.00	11.3	2100
194	02.09.88	20.00	8.7	1360
195	02.09.88	21.00	7.0	990
196	03.09.88	05.00	18.0	2440
197	03.09.88	05.30	20.0	2870
198	03.09.88	06.00	20.0	2990
199	03.09.88	06.30	20.0	3020
200	03.09.88	07.00	20.0	2990
201	03.09.88	07.30	20.0	3070
202	03.09.88	08.00	21.0	3050
203	03.09.88	09.00	22.0	3050
204	03.09.88	10.00	6.0	910
205	03.09.88	11.00	20.0	3130
206	03.09.88	12.00	19.0	3230
207 S	03.09.88	14.00	18.7	3550
208	03.09.88	15.00	19.3	2930
209	03.09.88	16.00	24.3	3020
210	03.09.88	17.00	22.3	3030
211	03.09.88	18.00	19.0	3020
212 S	03.09.88	19.00	4.0	800
214	03.09.88	21.00	25.0	3620
215	04.09.88	05.00	22.0	2810
216 S	04.09.88	06.00	28.0	4660
217	04.09.88	07.00	21.0	3170
218 S	04.09.88	08.00	29.0	4660
219	04.09.88	09.00	22.0	3230
220	04.09.88	10.00	22.0	3210
221	04.09.88	11.00	20.0	3120
222	04.09.88	11.30	20.0	2770
223	04.09.88	12.00	18.0	2850
224	04.09.88	12.30	20.0	3130
225 S	04.09.88	13.00	20.0	3450
226	04.09.88	13.30	20.0	3100
227	04.09.88	14.00	22.0	3080
228	04.09.88	15.00	23.0	3040
229 S	04.09.88	16.00	19.0	3660
230	04.09.88	17.00	22.0	3040
231	04.09.88	18.00	22.0	3220
232 S	04.09.88	19.00	20.0	3320
233	04.09.88	20.00	20.0	3000
234	04.09.88	21.00	22.0	3140

number of ascent	Date	launch time (CET)	flight time (min)	maximum height (m)
235	05.09.88	05.20	17.0	3050
236	05.09.88	06.00	20.0	3150
237	05.09.88	07.00	20.0	3240
238	05.09.88	08.00	21.0	3370
239 S	05.09.88	09.00	16.0	3100
240	05.09.88	10.00	19.0	3250
241	05.09.88	11.15	18.0	3170
242	05.09.88	12.00	16.0	2440
243 S	05.09.88	13.00	8.0	1370
244	05.09.88	14.00	5.0	950
245	05.09.88	15.00	4.3	730
246	05.09.88	16.15	1.7	210
247	05.09.88	17.00	10.0	1570
248	05.09.88	18.00	12.0	1810
249 S	05.09.88	19.00	9.7	1850
250	05.09.88	19.30	10.3	1530
251	05.09.88	20.00	16.0	2500
252	05.09.88	20.30	16.0	2180
253 S	05.09.88	21.00	19.0	3040
254	05.09.88	21.30	14.7	2070
255	06.09.88	09.10	20.0	3270
256	06.09.88	10.00	22.0	3300
257	06.09.88	11.00	20.0	3290
258	06.09.88	12.00	18.0	2910
259 S	06.09.88	13.00	19.0	3450
260	06.09.88	14.00	23.0	3060
261	06.09.88	15.00	25.0	3110
262	06.09.88	16.00	24.0	3040
263	06.09.88	17.00	21.0	2590
264	06.09.88	18.00	22.0	3010
265 S	06.09.88	19.00	20.0	3280
266	06.09.88	20.00	6.7	820
267	06.09.88	21.00	15.7	2180
268	07.09.88	05.15	20.0	3200
269	07.09.88	06.00	20.0	3340
270 S	07.09.88	07.00	21.0	3670
271	07.09.88	08.00	23.0	3350
272 S	07.09.88	09.00	25.0	3770
273	07.09.88	10.00	24.0	3220
274	07.09.88	11.00	25.0	3040
275	07.09.88	12.00	22.0	3140
276 S	07.09.88	13.00	19.3	3310
277	07.09.88	14.00	21.0	3120
278	07.09.88	15.00	24.0	3250
279 S	07.09.88	16.00	26.0	3350
280	07.09.88	17.00	23.0	3130
281	07.09.88	18.00	22.3	3110
282	07.09.88	18.30	21.0	3010
283 S	07.09.88	19.00	22.0	3510
284	07.09.88	19.30	18.0	2620
285	07.09.88	20.00	22.0	3120
286	07.09.88	20.30	2.7	390
287 S	07.09.88	21.00	23.0	3580
288	07.09.88	21.30	21.0	3010
289	07.09.88	22.00	24.0	3430

Tab. 5.5.1 continued

number of ascent	Date	launch time (CET)	flight time (min)	maximum height (m)
290	08.09.88	05.00	22.0	3240
291	08.09.88	06.00	20.0	3240
292	08.09.88	07.00	19.0	3070
293 S	08.09.88	08.00	19.0	3020
294	08.09.88	09.05	22.0	3180
295 S	08.09.88	10.00	23.0	3680
296	08.09.88	11.00	19.0	2900

5.5.2 Pilot-balloon ascents in the area 'Sophienhöhe'

During dispersion experiments, 60 pilot balloons with a very slow ascention rate were started in the western part of the "Sophienhöhe" and tracked by the double-theodolite method (Tab. 5.5.2). The launching points were (exceptional case 07.09.88) near the base and wind-ward side of "Sophienhöhe". Some of them, whose results are not documented, were given a trial with a temperature sonde and higher ascent velocity. Table 5.5.3 contains a summary of all ascents. To get good results the base line should be great enough and lie in a direction approximately at right angle to the prevailing wind. For a long observation time the surrounding must be free of obstacles. These conditiones are restricted in the south-westerly part of the hill, especially by forest areas. The position of the theodolites is indicated by "Theo Nord" and "Theo Süd" in all figures.

For these ascents red or white meteorological balloons of 30 grams were used, inflated with helium. They were charged with plastic ribbons of such a kind, that there is a very small buoyancy, nearly to zero. The balloon tracking is carried out by registering theodolites with a resolution of 0.1 degree from the firm Rosenhagen. The theodolites are adjusted toward each other. Every 20 seconds the two observers have to operate a mechanism which prints the angles on paper tape. The syncronism will be given by a time-signal, sent by radiotelephone.

The balloon's position in space at any particular instant can be computed by simple trigonometric functions. As four angles and the length are disposal with the double-theodolite method, it's easy to minimaze observation errors.

The spreadsheet-program LOTUS is used here as well as for the radar-tracked balloons for various calculations. For instance, a transformation of the coordinates and a conversion of the azimuth angle to the Gauß-Krüger coordinates has to be done, because of the special adjustment of the theodolites for the figure "Flight-track projection to the surface". Of the extensive calculations only an extract of the LOTUS-worksheet with the time elapsed since start, elevation angle, azimuth angle and slant range of "Theo Süd" is sent to KFA for a further evaluation (standarized data). As examples the pilotballoon ascents during two dispersion experiments are shown in Fig. 5.5.4 - 5.5.7.

base No.	Date	ascent No.	base length (m)	'Theo Nord'			'Theo Süd'			launch point		
				X (m)	Y (m)	H (m)	X (m)	Y (m)	H (m)	X (m)	Y (m)	H (m)
I	30.08.88	75..84	530.5	29256	43431	106	29486	42953	105	29424	43248	106
	31.08.88	85..95	"	"	"	"	"	"	"	29424	43250	106
	01.09.88	96..106	"	"	"	"	"	"	"	29511	42989	105
	04.09.88	107..117	"	"	"	"	"	"	"	29495	42981	105
II	05.09.88	118..128	620.5	29378	45130	103	29174	44544	104	29305	44916	104
III	07.09.88	129..139	906.2	30701	45530	231	30559	46245	95	30741	45358	230

Tab. 5.5.2: Theodolite and launch positions for double-theodolite measurements
(X and Y = Gauß-Krüger coordinates, H = height above MSL)

Tab. 5.5.3: Pilot-ballon ascents with tracking by double-theodolite method in the western area of 'Sophienhöhe'

ascent No.	Date	launch time (CET)	flight time (min.)	average height (m)	flight track (m)
75	30.08.88	14.03	3.3	30	675
76	30.08.88	14.13	9.0	200	2020
77	30.08.88	14.24	11.7	410	4300
78	30.08.88	14.46	5.7	155	1795
79	30.08.88	14.55	4.7	100	1425
80	30.08.88	15.05	5.3	110	1720
81	30.08.88	15.19	7.0	250	2800
82	30.08.88	15.32	13.7	645	4165
83	30.08.88	15.53	3.3	175	885
84	30.08.88	16.03	13.7	385	4315
85	31.08.88	18.17	4.0	15	690
86	31.08.88	18.27	4.7	25	745
87	31.08.88	18.34	7.0	120	2235
88	31.08.88	18.49	3.7	30	720
89	31.08.88	18.57	6.0	115	1770
90 S	31.08.88	19.16	10.0	630	5720
91	31.08.88	19.29	5.3	10	395
92	31.08.88	19.43	5.0	40	775
93	31.08.88	19.56	6.0	70	1215
94	31.08.88	20.10	4.3	30	685
95	31.08.88	20.22	6.0	80	1385
96	03.09.88	06.08	5.0	10	730
97	03.09.88	06.18	5.0	110	1790
98	03.09.88	06.28	6.7	95	2345
99 S	03.09.88	06.50	7.0	385	4935
100	03.09.88	07.01	6.0	100	2325
101	03.09.88	07.09	5.7	60	1440
102	03.09.88	07.20	5.0	45	1120
103	03.09.88	07.33	5.7	55	1025
104	03.09.88	07.41	5.0	40	1015
105	03.09.88	07.50	5.7	50	1180
106	03.09.88	08.03	7.3	120	2155
107	04.09.88	10.53	7.3	305	2270
108	04.09.88	11.05	4.7	115	1525
109	04.09.88	11.14	10.3	440	3240
110	04.09.88	11.29	9.0	380	2480
111	04.09.88	11.44	6.7	140	2240
112 S	04.09.88	12.05	12.0	740	3635
113	04.09.88	12.22	1.7	5	350
114	04.09.88	12.30	13.0	570	3985
115	04.09.88	12.47	15.7	375	4810
116	04.09.88	13.08	16.3	730	3385
117	04.09.88	13.33	15.0	495	3885

Tab. 5.5.3 continued

ascent No.	Date	launch time (CET)	flight time (min.)	average height (m)	flight track (m)
118	05.09.88	18.47	5.0	130	1880
119	05.09.88	19.00	5.7	65	1495
120	05.09.88	19.12	4.0	90	1815
121	05.09.88	19.23	4.0	115	1670
122 S	05.09.88	19.39	3.5	265	2195
123	05.09.88	19.55	5.0	45	1135
124	05.09.88	20.13	4.7	85	1460
125	05.09.88	20.28	4.0	70	1095
126	05.09.88	20.43	4.7	110	1800
127	05.09.88	20.56	4.3	70	1175
128 S	05.09.88	21.16	2.5	190	1095
129	07.09.88	18.08	10.0	40	1545
130	07.09.88	18.32	9.0	35	1290
131	07.09.88	18.50	10.3	65	3300
132	07.09.88	19.08	8.3	40	1680
133	07.09.88	19.27	5.3	60	1510
134	07.09.88	19.41	5.7	70	1855
135	07.09.88	19.56	5.7	60	1665
136	07.09.88	20.09	10.3	140	4850
137	07.09.88	20.36	7.7	80	2830
138	07.09.88	20.52	7.3	70	1695
139	07.09.88	21.07	11.0	50	1760

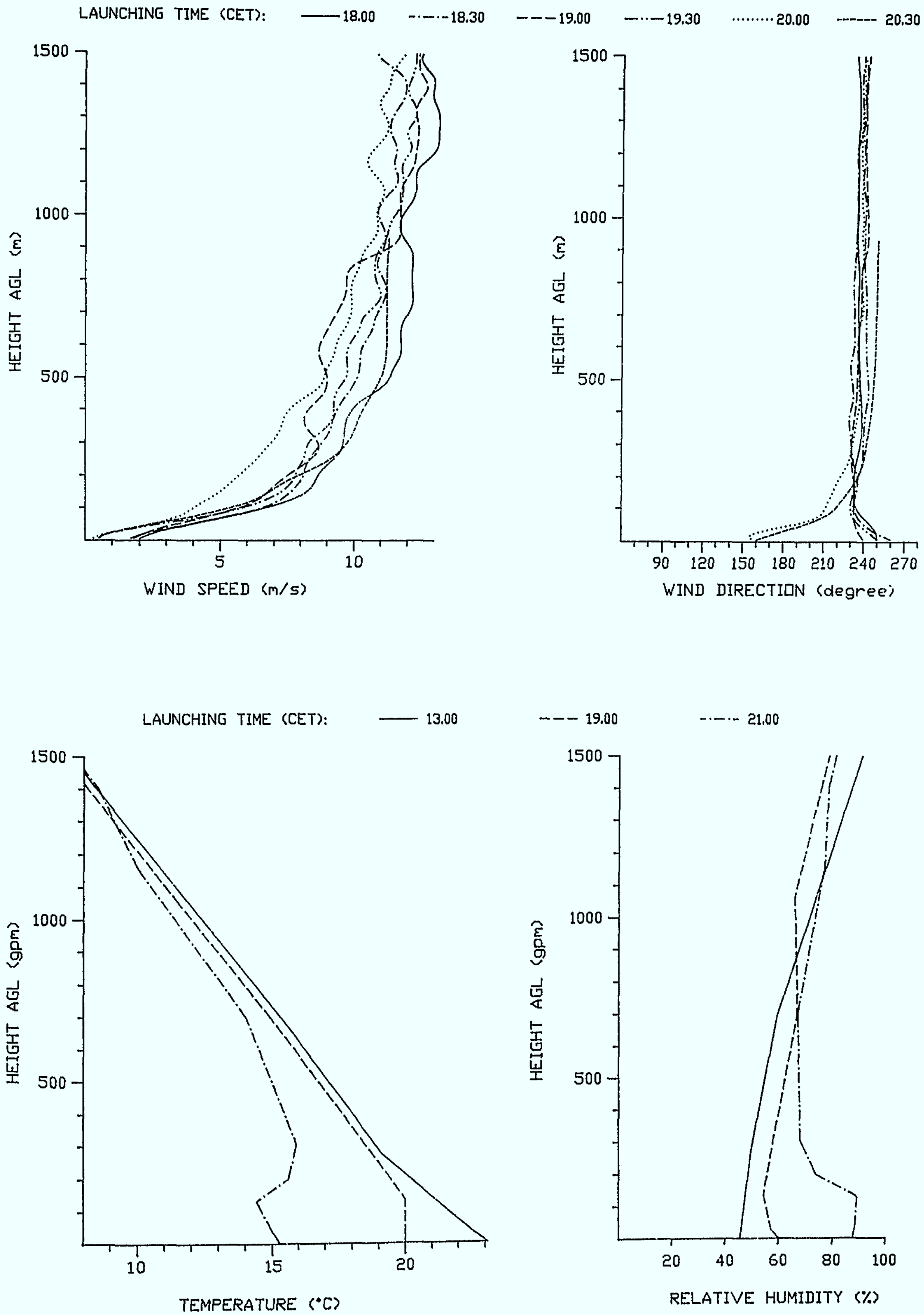
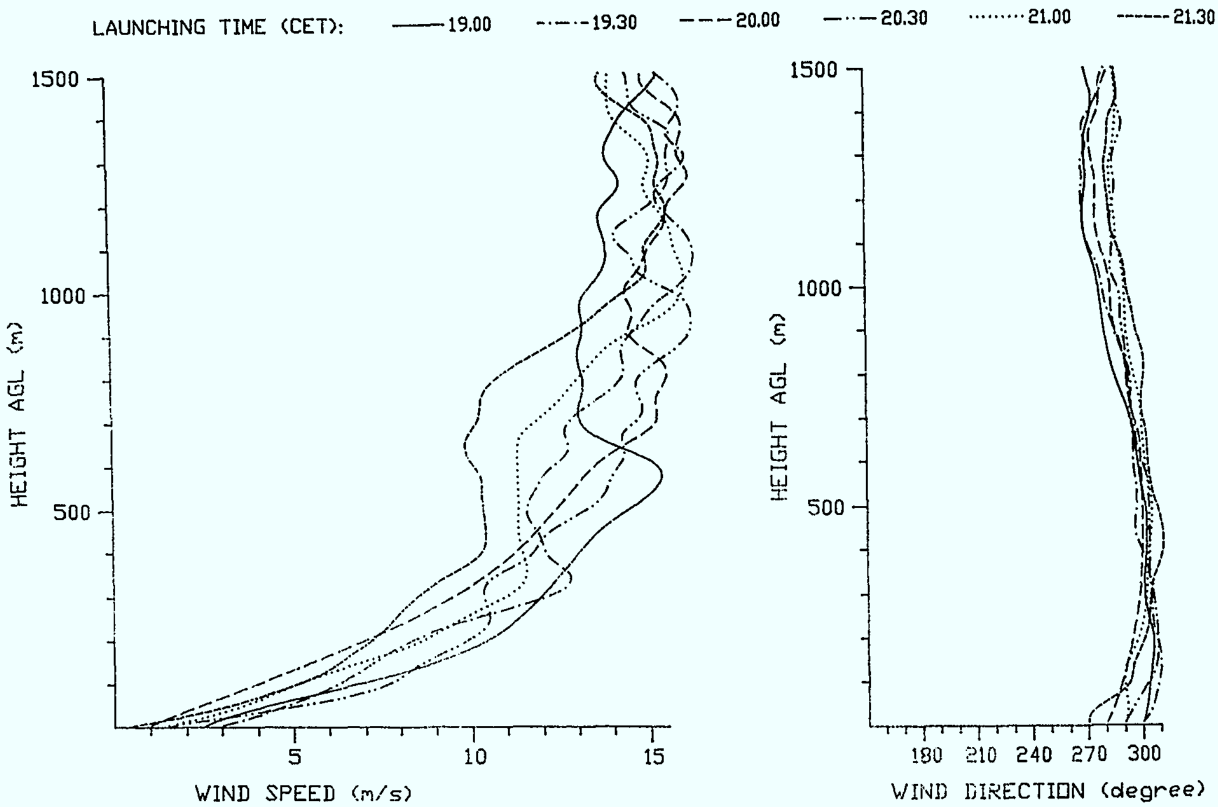


Fig. 5.5.1: Vertical profiles of wind (smoothed), temperature and relative humidity during the dispersion experiment at KFA, 31.08.1988



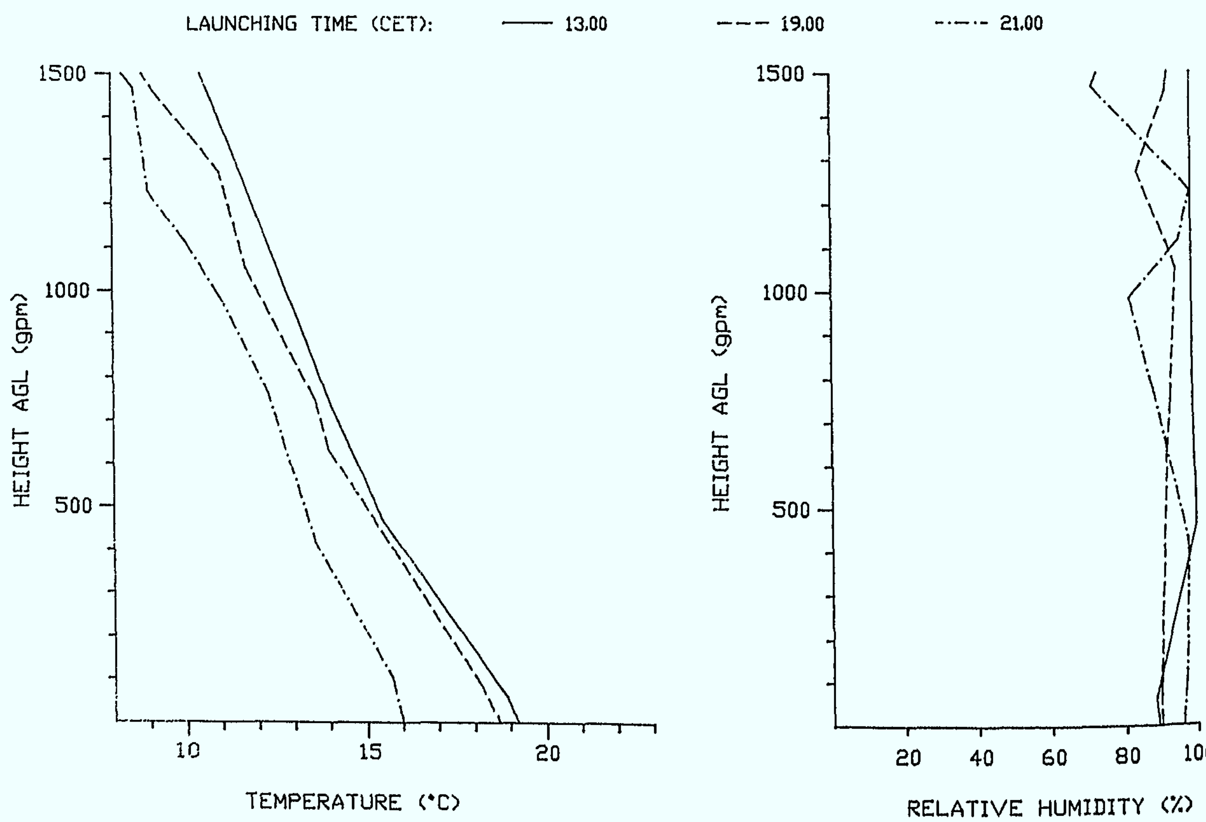


Fig. 5.5.2: Vertical profiles of wind (smoothed), temperature and relative humidity during the dispersion experiment at KFA, 05.09.1988

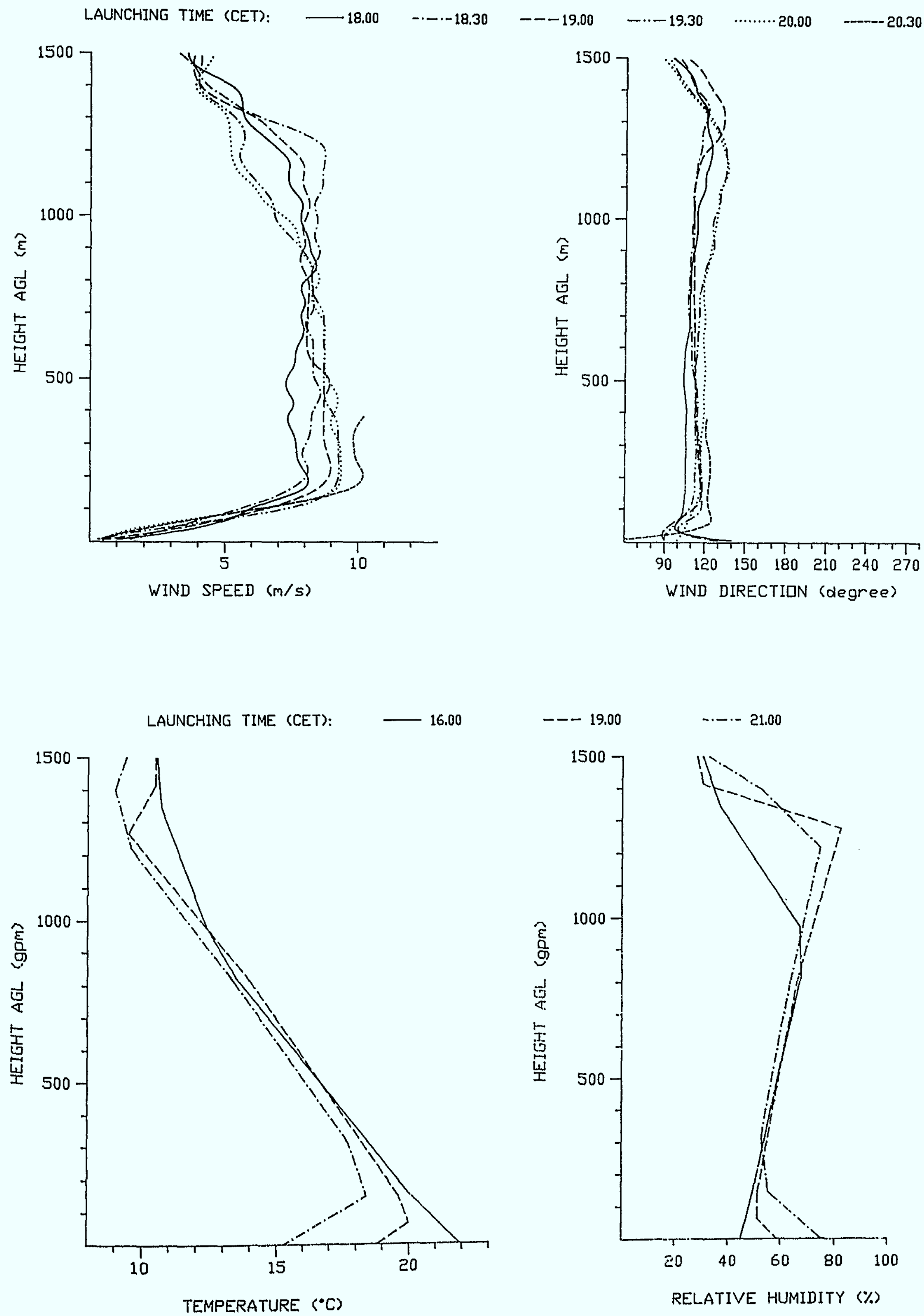


Fig. 5.5.3: Vertical profiles of wind (smoothed), temperature and relative humidity during the dispersion experiment at KFA, 07.09.1988

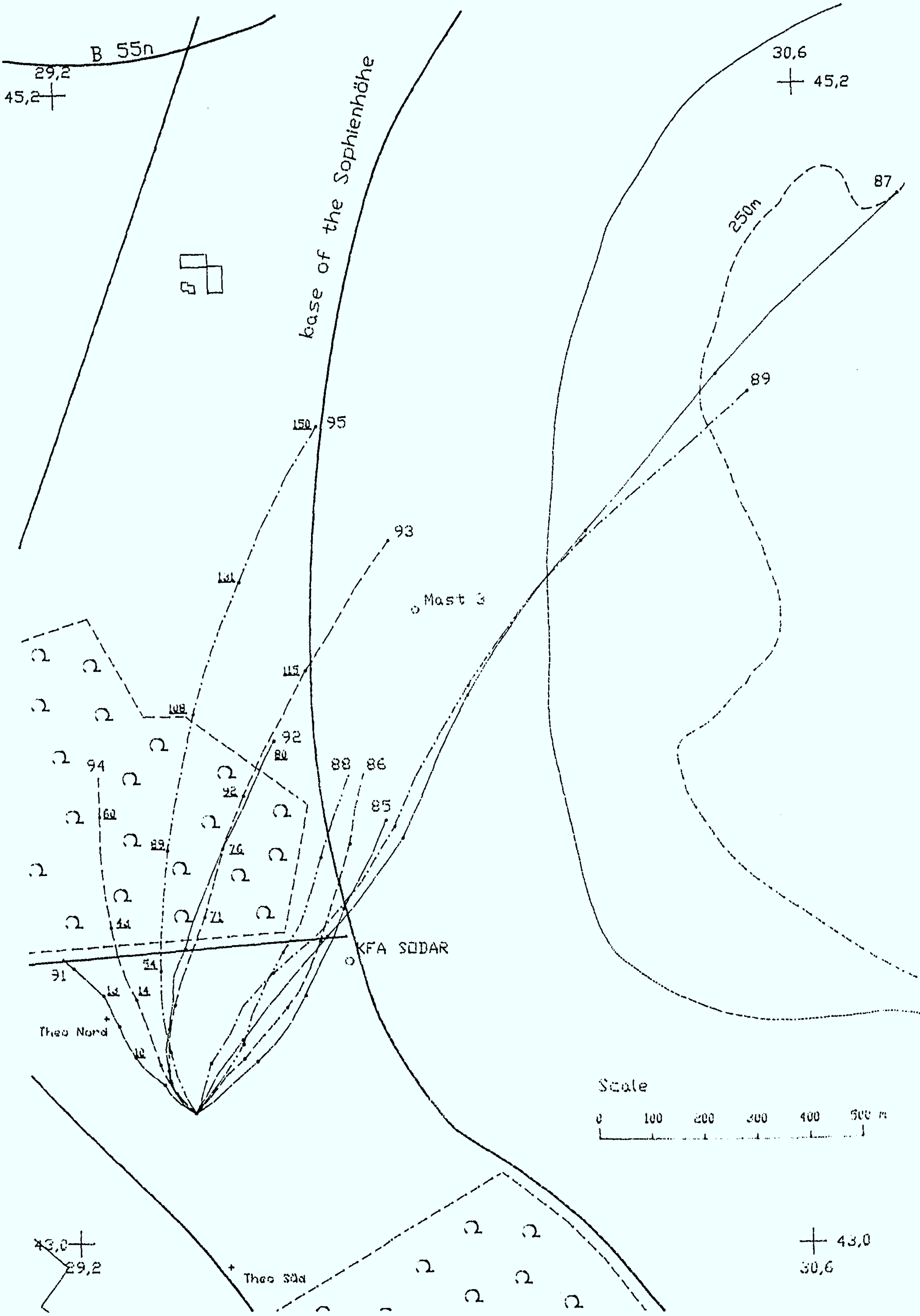


Fig. 5.5.4: Flight-track projection of pilot balloons to surface, 31.08.1988 (the points represent a time interval of one minute and the underlined numbers give the height in m above launching point for some flights (not shown in fig. 5.5.5); for launch time see Tab. 5.5.3, the Gauß-Krüger coordinates are given in km at the corners)

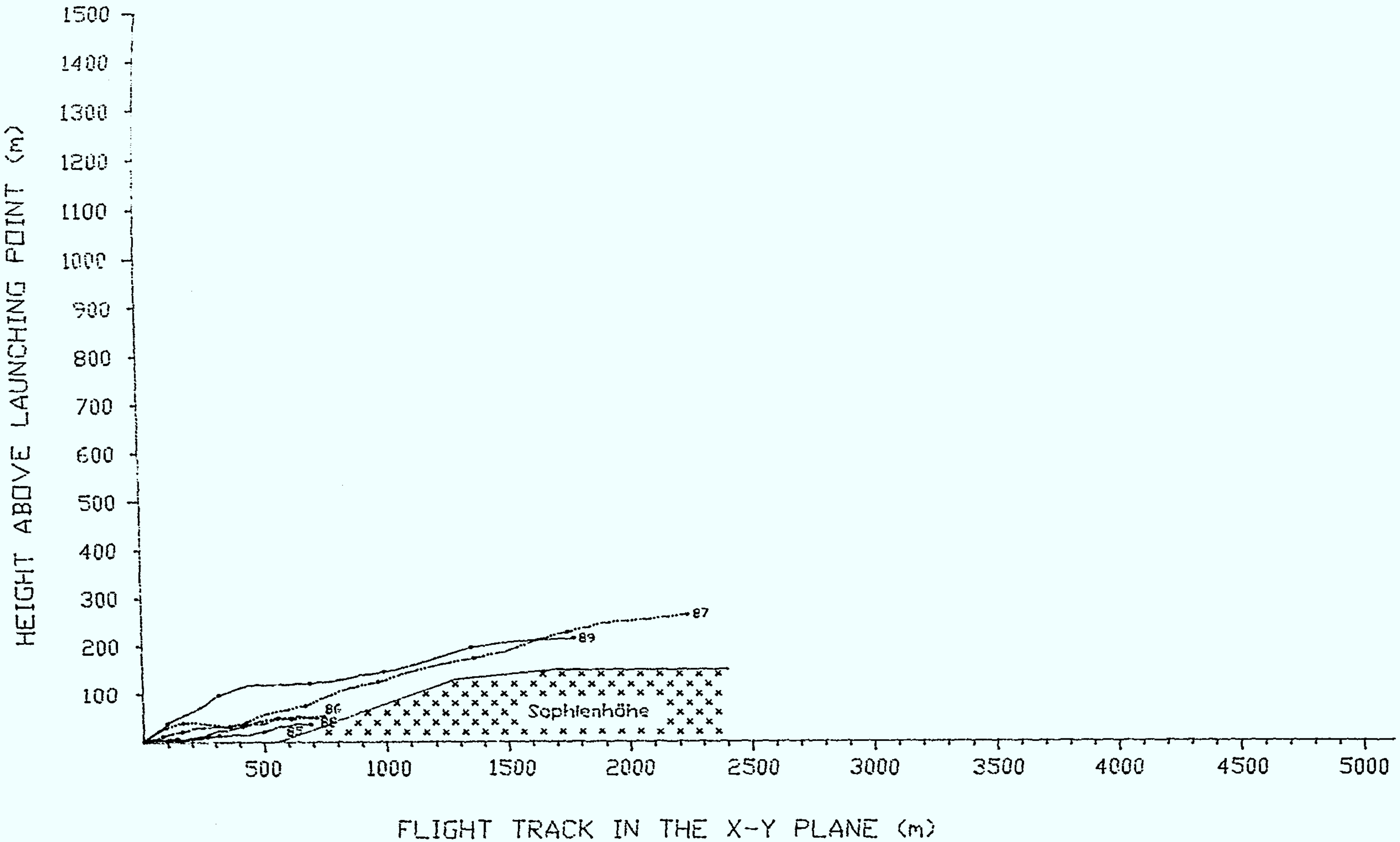


Fig. 5.5.5: Some profiles of pilot-balloon ascents in the western part of Sophienhöhe, 31.08.88 (The contour of the hill is shown schematic, points represent a time interval of one minute, for launch time see Tab. 5.5.3)

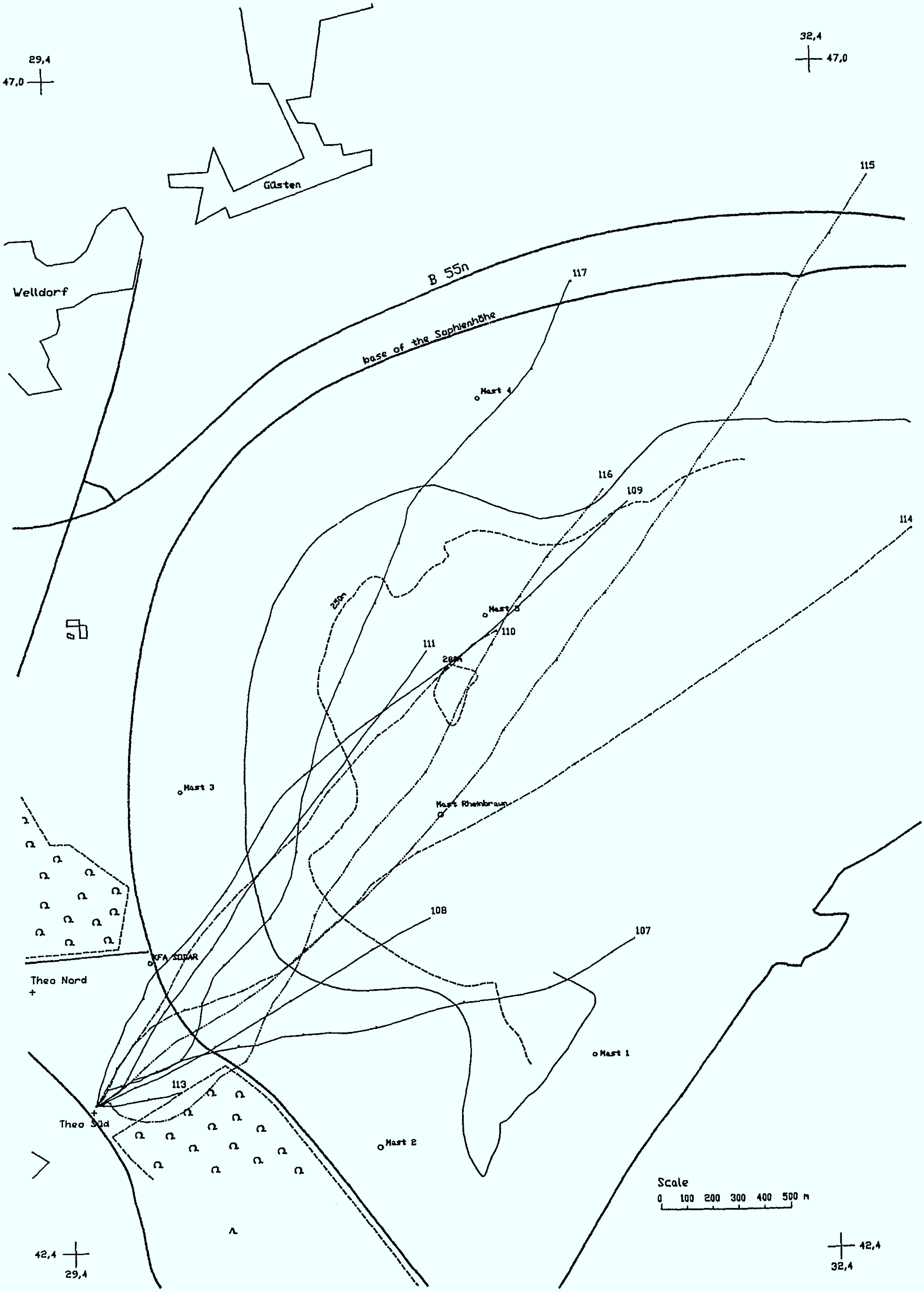


Fig. 5.5.6: Flight-track projection of pilot balloons to surface, 04.09.1988
(the points represent a time interval of one minute, for launch time see Tab. 5.5.3, the Gauß-Krüger coordinates are given in km at the corners)

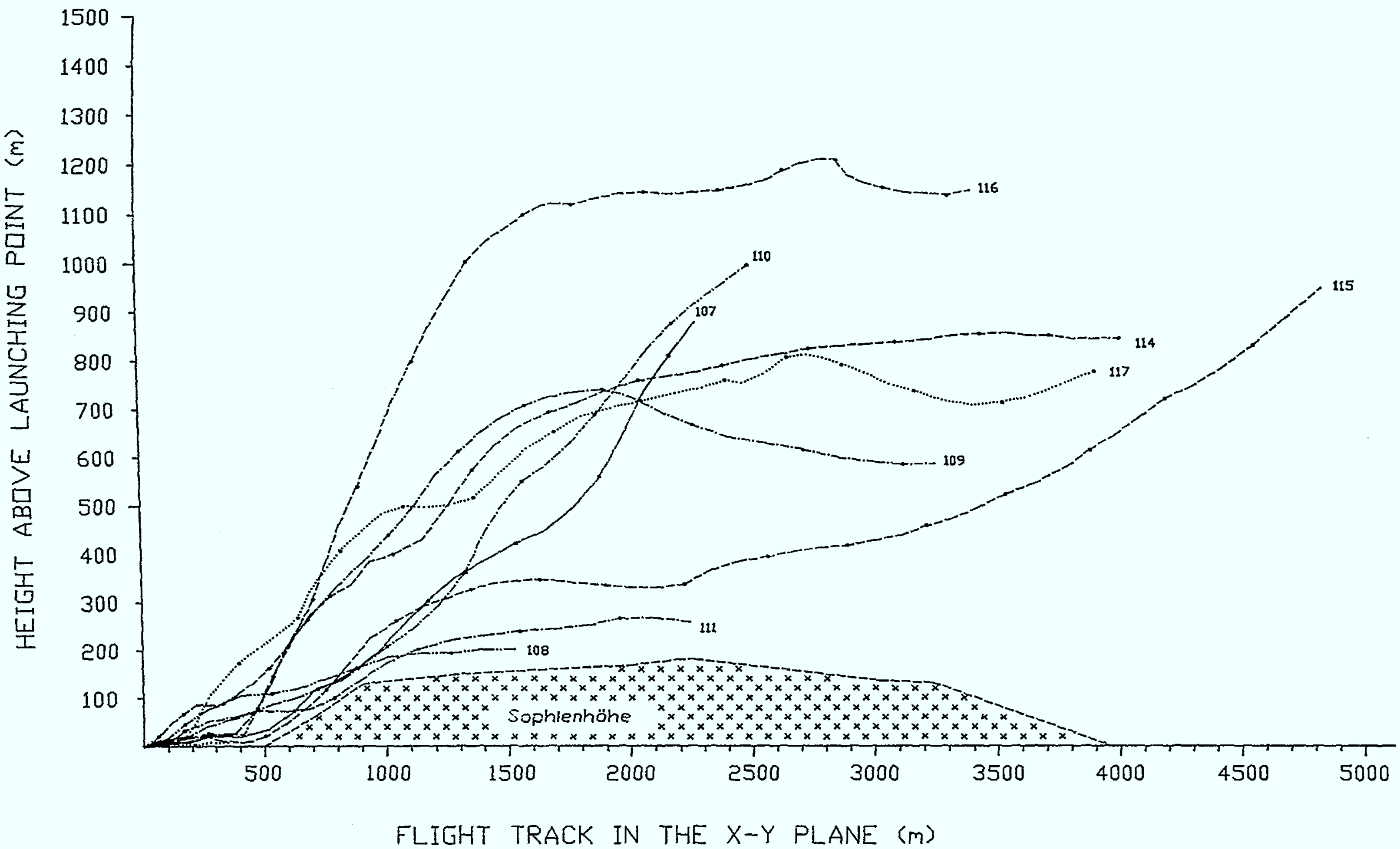


Fig. 5.5.7: Profiles of pilot-balloon ascents in the western part of the Sophienhöhe, 04.09.88 (The contour of the hill is shown schematic, points represent a time interval of one minute, for launch time see Tab. 5.5.3)

5.6 Radiosonde ascents by IGM-group

G. Zeuner

Radiosonde ascents were also carried out by the IGM-Group from the same KFA-site as Wetteramt Essen. All together 20 soundings were performed between Aug. 31 and Sept. 7, 1988 in the morning and around noon (afternoon and evening ascents were made by the Wetteramt Essen). The radiosonde used was of the type Vaisala RS 80-15. Three parameters were measured: pressure, temperature and humidity.

The characteristics of the sensors are summarized in Tab. 5.6.1. For temperature and humidity the time response (lag) of the sensors was calibrated at the factory. For a flow of 6 m/s at 1000 mb a lag of 2.3 s for the temperature sensor and 1 s for the humidity sensor is specified.

The transfer time was about 10 seconds for one parameter, so that within 30 seconds a complete data set was transfered. The mean ascent speed was around 100 m/minute. Signals were received by a Vaisala PTU processor PP11 and stored on a flexible disc. Dependend on horizontal direction and elevation angle of the sonde receiver disturbances in form of too small field intensities appeared. This was caused by a shadowing effect. The antenna was small ($\simeq$2.5 m) and located close to a building. Therefore also erroneous data were stored. Because of this the data were proved regarding noise or unrealistic values before they were compiled to the data bank. First the three parameters pressure, temperature and humidity had to lie within certain limits, for example relative humidity data must be between 0 and 100%. Second the data were checked from one time step to another (successive data sets) if a certain limit, e.g. 5 K for temperature, was exceeded. With these procedures all or almost all erroneous data could be eliminated.

Measured parameters	Sensor type	Measuring range	Resolution	Accuracy (standard deviation)
pressure	capacitive aneroid	1060 mb - 3 mb	0.1 mb	$\pm$5 mb
temper-ature	capacitive bead	+60°C - −90°C	0.1 K	$\pm$0.2°C
humidity	HUMICAP thin film capacitor	0% RH - 100% RH	1% RH	$\pm$2% RH

Tab. 5.6.1: Meteorological sensors Vaisala Radiosonde RS 80-15

The measurements are summarized in Tab. 5.6.2. The data bank contains also the height above ground which was calculated according to the formula given in appendix C. Only data up to 5000 m above ground have been considered.

Date	Start	End
31.08.88	05:55	06:37
31.08.88	09:55	10:40
31.08.88	12:02	12:46
01.09.88	10:52	11:46
02.09.88	06:66	07:29
02.09.88	09:27	09:56
02.09.88	11:09	11:39
03.09.88	06:05	06:37
03.09.88	08:03	08:29
03.09.88	09:58	10:24
03.09.88	11:59	12:00
04.09.88	10:30	11:01
04.09.88	12:27	12:59
05.09.88	08:08	08:35
05.09.88	12:01	12:38
06.09.99	11:06	11:45
06.09.88	12:57	13:25
07.09.88	07:06	07:49
07.09.88	09:11	09:50
07.09.88	12:06	12:48

Tab. 5.6.2: Radiosonde ascents at KFA (IGM-group)

5.7 Doppler-SODAR measurements by TÜV Rheinland, TÜV Essen, KFA

5.7.1 *Doppler-SODAR measurements by TÜV Rheinland*

W. Bahmann

5.7.1.1 Measuring principle and description of instrumentation

"SODAR" means a measuring technique which resembles to RADAR. The first letter , however, stands for "sound" instead of "radio", indicating that sound waves are used instead of electromagnetic waves to determine the kinetic properties of objects without direct contact (remote sensing). In our case the object of interest is the lower part of the atmosphere.

The SODAR (or more exactly: monostatic 3-component Doppler-SODAR) which was used in the measurements consists of three big sound-wave antennas. Each antenna contains a loudspeaker-/microphone-combination fixed in the focal point of a parabolic reflector. The conical shaped housing of each antenna helps together with the reflector in focussing the acoustic radiation and shields against environmental noise. The TÜV Rheinland SODAR was fabricated in France by REMTECH S.A.

Fig. 5.7.1 shows the principle of Doppler-SODAR measurement. In a cyclic mode the loudspeakers are triggered to emit a 1600 Hz sound pulse ("beep") of a duration of 150 ms. Immediately after each emission the electronic control device switches over to reception. The echoes which are due to reverberation of the sound pulse by density inhomogenities in the atmosphere are received, filtered and then analyzed by software (PDP 11-computer as processor/analyser). In the analysis use is made of Fast Fourier Transformation (FFT). By means of the time difference between the release of the beep and the arrival of the echo the height of the backscattering structure can be determined. From the Doppler shift for each of the three antennas a radial component of the antennas (angles of declination and azimuth) being taken into account.

Measuring intervals can be chosen arbitrarily; in case the sampling time was set to 10 min. At the end of each time interval the computer program not only calculates the height profile of mean horizontal wind speed and wind direction but also gives out profiles of the following parameters: vertical wind speed, standard deviation of vertical wind speed, stability class (also diffusion class). An existent inversion in most cases can be detected by a special algorithm and the height of the inversion layer can be determined (see chapter 5.7.1.2).

The range of the SODAR (maximum measuring height) depends on atmospheric propagation conditions and in general lies between 200 m and 800 m above ground. Due to the finite switching time from the emission mode to the reception mode (dead time) a minimal measuring height of about 30 m above ground has to be accepted. In the present application measuring data were taken as mean values from layers of

20 m thickness. 20 layers have been inspected, so that the following values appear as mean measuring heights: 40, 60, 80, ..., 380, 400, 420 m.

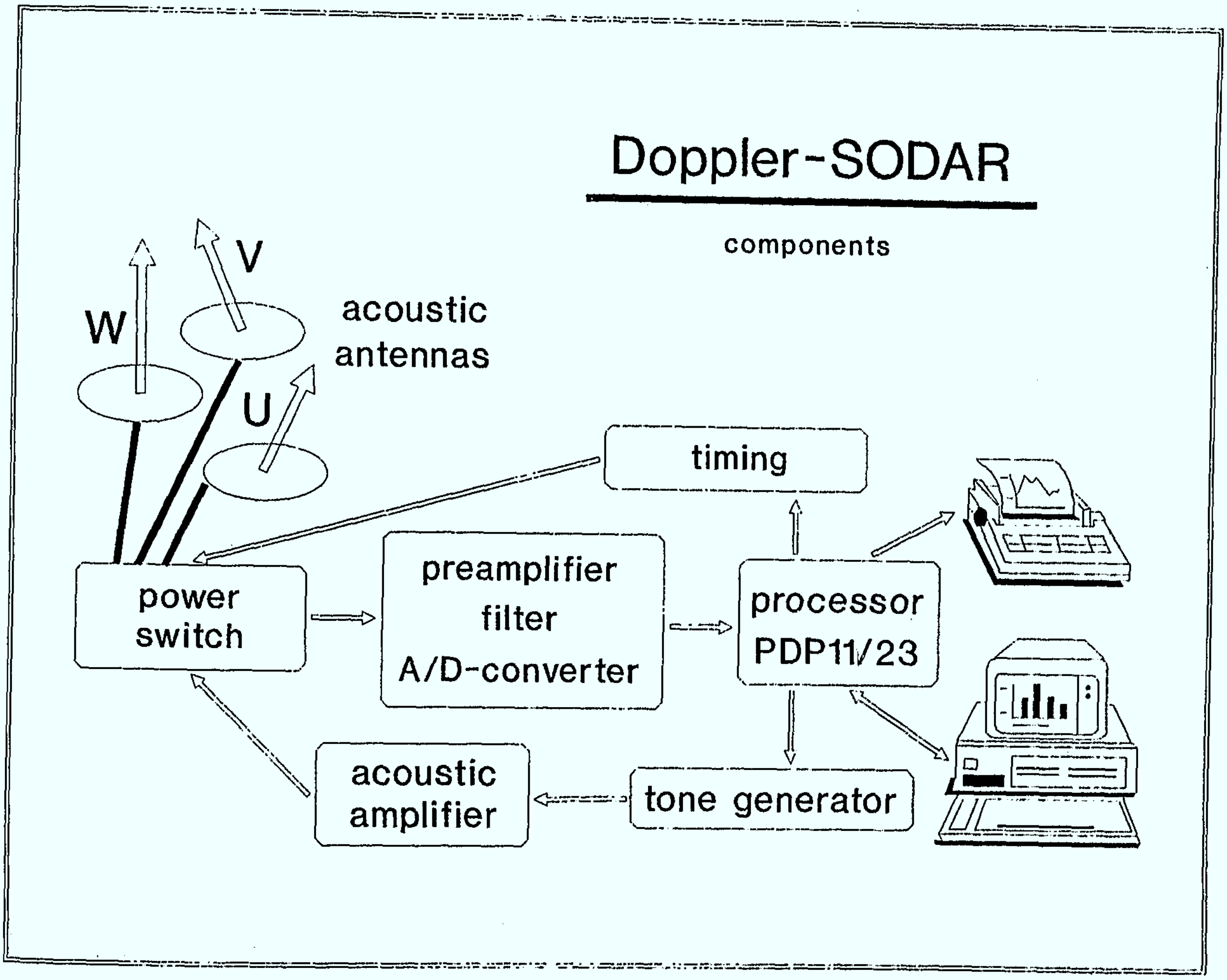


Fig. 5.7.1: Measuring principle of Doppler-SODAR

5.7.1.2 Inversion detection by Doppler-SODAR (REMTECH)

In a SODAR measurement, small space fluctuations of temperature are detected by their backscattering property. Although direct measurements of temperature by SODAR is impossible, many investigations have agreed in finding out that a temperature inversion (stable statification of air) in general is characterized by strong echoes.

However since there is no stringent connection between echo and existence of inversion, a stable stratification can occur without any indication in echo registration, and vice versa. Multilayer inversions can make a situation even more complicated. As a consequence, a purely echo structure dependent automatic inversion detection cannot be estimated as sufficient. So the equipment used in these measurements is supplied with a multiple detection facility. Hereby not only the echo structure but also other informations like

- echo fluctuation
- vertical gradient of wind speed
- indicators of turbulence (horizontal and vertical)

are taken into account. These data which exist as vertical profiles help to confirm a decision on the existence of an inversion layer and to determine its height.

The detection method has been developed and tested with data derived from conventional measuring techniques (mast, sonde). Due to the indirect measurement the detection method of course cannot be absolutely reliable. The advantage of the method however is to yield continuous information "around the clock" without considerable personal effort (as compared for instance to sonde ascents).

5.7.1.3 Position of the TÜV Rheinland SODAR and remarks on data availability

The Doppler-SODAR of TÜV Rheinland was situated at the point S1 (see Fig. 1.1) near to the northern slope of Sophienhöhe, yet still on the flat territory surrounding the isolated hill. (Gauß-Krüger coordinates in m: 31940, 46185; height=89 m above m.s.l.)

During all the measuring campagne the SODAR registrated the data as 10 min mean values. Over a range of height from 40 m to 420 m in steps of 20 m height profiles of the following parameters were measured:

- wind speed (horizontal and vertical)
- wind direction
- echo intensity
- standard deviation of wind direction
- stability class
- inversion marker

The operation of the instrument can be disturbed by environmental influence (environmental noise, reflections by surrounding objects etc.) or the measuring range can be shortened by atmospheric conditions. Fig. 5.7.2 shows the availability of SODAR data during the experiment in dependece from measuring height.

The system was in operation during 97.6% of the time. Due to the measuring principle, higher measuring heights have lower system availability so that for the highest measuring height of 420 m a data availability of 54% of the time was achieved.

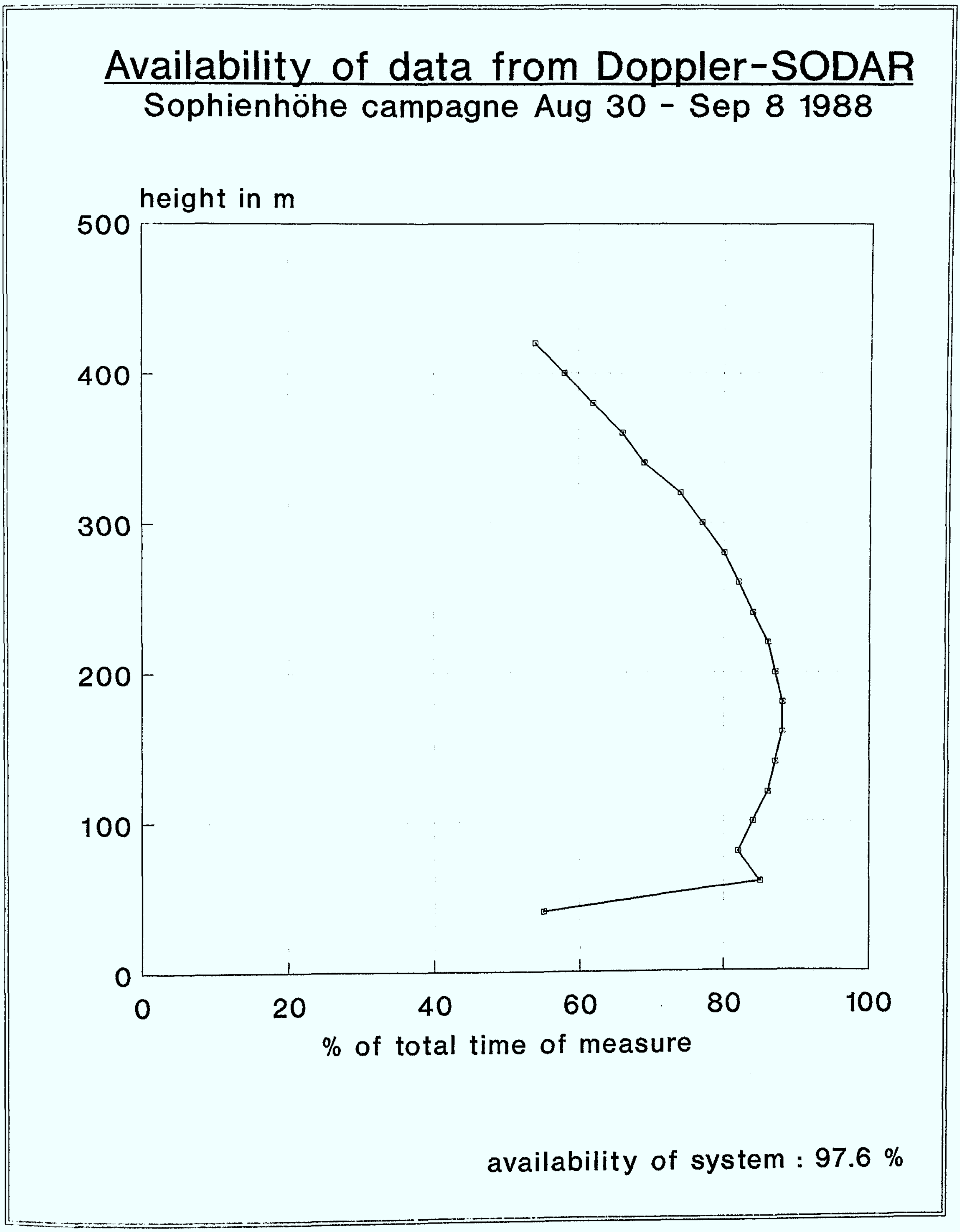


Fig. 5.7.2: Availability of SODAR data (TÜV Rheinland)

5.7.2 Doppler-SODAR measurements by TÜV Essen

J. Frank

5.7.2.1 Measuring principle and description of instrumentation

The TÜV Essen Doppler SODAR DS 100 has been developed at the Meteorological Institute of the Hamburg University and has been operated by the TÜV Essen for more than 10 years.

The DS 100 is a ground based remote sensing system which measures profiles of the mean wind vector and the variance of vertical wind fluctuations. Moreover the existence and altitude of temperature inversions can be detected.

The measuring method is based on the scattering of sound at natural fluctuations of the refractive index in the atmosphere due to turbulences. The refractive index of sound is determined by the temperature, to a smaller extent by the humidity and in special situations by the chemical composition of the air (for instance in stack plumes). The effect of wind on the propagation of sound is also described by a corresponding contribution to the refractive index.

The inhomogeneities contributing to back scattering have a scale which is comparable to the length of sound waves (Bragg scattering). In accordance with the sound frequency applied (1-2 kc/s), this is in order of 10 cm. Inhomogeneities of this scale have only a relatively low movement of their own so that they are advected essentially by the mean wind in the scattering volume. This causes a Doppler shift of the frequency of the scattered sound which is evaluated in the receiver of the SODAR for measuring the wind.

Moreover this intensity of the scattered signal supplies informations about the thermal stratification and turbulence intensity of the atmosphere.

The DS 100 is a monostatic 3 components Doppler SODAR system.

"Monostatic" means that the transmitter and receiver antennas are located at the same place. (Systems with transmitter-receiver antennas located far from each other are called "multistatic"). The monostatic SODAR makes use of the backscattering of sound whereas multistatic systems operate with scattering angles <180°.

With a multistatic system one can reach higher measuring altitudes according to the scatter theory. However, the monostatic system has a number of practical advantages. Some of them are:

- lower minimum altitude
- more favourable orientation of the measured wind components
- less space required for the location of the antennas
- possibility of mobile application

"3 components" means, that the signals from 3 differently orientated sound antennas are processed in order to evaluate the wind vector. Different modes of operation and signal processing are available.

"Doppler" means that the frequency spectrum of the scattered signal is compared with the frequency of the transmitter pulse.

In this way the wind components parallel to the alignment of each sound antenna are determined. These wind components are called "radial components" from now on.

The assignment of the measured values to a definite altitude ensues from the time shift between the transmit pulse and the receive signal (propagation time), the sound velocity, and the zenith angle of the antenna.

The DS 100 can be subdivided in 3 essential groups which are described more closely in the following sections:

- Sound antennas:
  comprising acoustic shield, swivel mechanics, sound transducer, transmit-receive switch, power amplifier (transmitter), pre-amplifier (reception), output power supply, power quard electronics

- control electronics:
  comprising transmit pulse generator, antenna commuter, spectrum analyser (digital filter bank), synchronisation circuits for frequency and pulse repetition rate, amplifier control, measuring range shift.

- on line computer:
  with several interface circuits to control electronics, freely available analogue inputs for additionally measured quantities and standard line interfaces.

The software controls the measuring process, evaluates the frequency spectra taken from the digital filter bank, passes the measured values desired in different formates to the connected periphery, accepts instructions from the operator, and supports operation and service by numerous system status messages.

5.7.2.2 Position of the TÜV Essen SODAR and remarks on data availability

The TÜV Essen SODAR was located east-southeast of Sophienhöhe, southeast of the village Steinstraß (Fig. 5.7.3). The Gauß-Kruger coordinates in m were 34480 and 43500. The surroundings of this site was flat and dominated by agricultural land. The height was 93 m above m.s.l. The distance to the base of the hill was about 1500 m. A place closer to the hill could not be found because of heavy mining activities with a very high noise level. The shortest distance to the mining area, southwest of the Doppler-SODAR was 700 m. So, some environmental noise still could influence the measurements.

Fig. 5.7.3: Doppler-SODAR TÜV Essen (view from east to Sophienhöhe) The SODAR measured over a range height from 40 m to 500 m (in steps of 20 m) the following parameters:

- horizontal wind speed
- vertical wind speed
- standard deviation of vertical wind speed
- wind direction
- echo intensity

The system was operating during the whole campaign. Because of some storage problems some data are missing. Data are available for the periods: 1) Aug. 30, 12:00-14:50, 2) Aug. 31, 09:20-Sept. 4, 10:10, 3) Sept. 4, 11:00-13:30, 4) Sept. 6, 18:10-Sept. 8, 11:00.

5.7.3 Doppler-SODAR measurements by KFA

G. Zeuner

5.7.3.1 Description of the instrumentation and data

The KFA Doppler-SODAR is a monostatic system with three fibreglass paraboloid antennas (AO) like the TÜV Rheinland SODAR and was manufactured by REMTECH (France) in 1986. A short description of the measuring principle is already given in chapter 5.7.1. For more details see e.g. REMTECH (1985), Adiga and Zeuner (1990).

Fig. 5.7.4 shows the arrangement of the SODAR system: 1) A trailer with 3 antennas, 2) a caravan for SODAR electronics, computer plus periphery (terminals, printer) and a power supply system, 3) a trailer with generator. The power supply was installed for compensation of possible voltage and frequency fluctuations from the generator. In addition a three-dimensional gill anemometer, connected to a SODAR analog interface, was running on a 15 m mast beside the caravan (see chapter 5.1).

In order to improve the antenna gain characteristics of the loudspeaker (microphone) each antenna has a funnel-shaped shelter with a height of 1.74 m and diameters of 1.20 m (bottom) to 2.36 m (top). On the inner wall of the shelter sound-absorbing foam is attached to reduce, respective prevent sound reflections. The axis of two antennas are tilted by 18 degrees to the vertical.

The REMTECH software used was dated on May 10, 1987. This version was especially developed for the system configuration of the KFA-SODAR. The intgrated DEC computer, a micro PDP 11/73, was running under the operating system RT 11 SJ with version 5.0. The following operating parameters were selected:

Acoustic pulse length	: 200 msec
Averaging period	: 10 minutes
Minimum height	: 40 meters
Number of layers (20m interval)	: 30
Maximum height	: 620 meters
minimal signal to noise ratio	: 20

The sampling rate was ≃5 seconds for one component. The data transfered to a printer and stored on disc contain the following parameters:

- echo intensity
- standard deviation of echo intensity
- horizontal wind speed
- wind direction
- standard deviation of horizontal wind direction
- vertical wind speed

- standard deviation of vertical wind speed
- dissipation rate

Within the averaging period of 10 minutes as many as possible validated single measurements of each component were collected and averaged to a mean. A validation program gives a sufficient reliability for most of the parameters. An exeption is the very conservative modus in checking the standard deviation of horizontal wind direction σ_θ. Here too many data are rejected and a few, but unrealistic standard deviations are given as output. Comparable measurements of σ_θ with a similar system at Karlsruhe showed very poor correlation with that measured at the tower (von Holleufer-Kypke et al., 1985).

Beside the data printed or stored on disc a facsimile record gives the average intensity (averaged over 5 pulses) of the echo (from vertical antenna) as a function of height.

During the field campaign construction work on a nearby barbecue cottage temporarily increased the environmental noise level during day-time. So fewer single measurements may be available for a given averaging period because software invalidates individual measurements in case of low signal to noise ratio.

Beside of a few 10-minute intervals data are available for: August 3, 1988, 00:10 - September 8, 1988, 13:20 CET.

5.7.3.2 Position of the KFA-SODAR

The Doppler-SODAR of KFA was located at point S2 (see Fig. 1.1 and 5.7.4) at the western part of Sophienhöhe (Gauß-Krüger coordinates in m: 29725, 43540; height: 105 m above m.s.l.). The antennas were situated 20 m away from the base of the hill. The axes of the two tilted antennas were pointing towards Sophienhöhe in order to measure the wind field close to the slope. The REMTECH software has a test routine to look for fixed echos which might be caused by obtacles or ground. No fixed echos were detected at this position. The surroundings of the SODAR in southerly to westerly directions is characterized by agricultural land with a fetch of about 600 m. Winds coming from west to northwest pass parts of the Stetternich forests with about 25 m high trees for a range of 300 m - 1000 m. This forest will increase turbulence and noise level. The slope of the hill was planted with 4 m - 6 m high trees.

5.7.3.3 Results

The strength of the backscattered signal (intensity of echo) from a specific layer in the atmosphere is dependent on the magnitude of temperature inhomogenities in this layer. In the facsimile record the darkness is proportional to the intensity of echo. With this, at least qualitatively, it is possible to identify thermal plumes during convective conditions and ground based or elevated inversions.

Two facsimile records, given in Fig. 5.7.5 and 5.7.6, illustrate for a period of 7.5 - 8 hours the intensity of echo (from vertical antenna) as a function of height between 40 m and 515 m. In the first record (Aug. 31/Sept. 1) it can be seen that the echo intensity

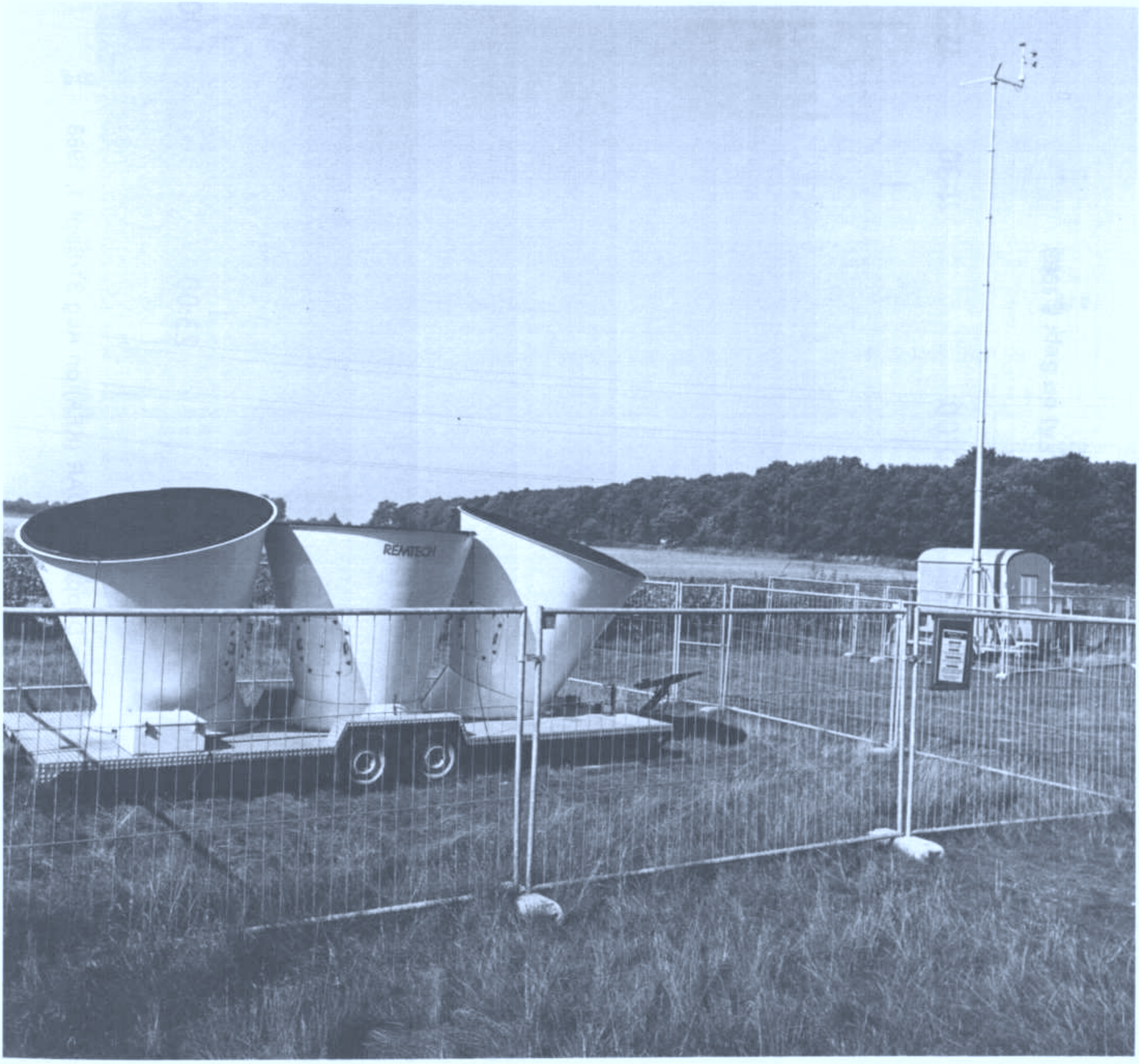


Fig. 5.7.4: Doppler-SODAR KFA at the western part of Sophienhöhe (view to west)
TÜV Rheinland SODAR has same antennas on two trailers

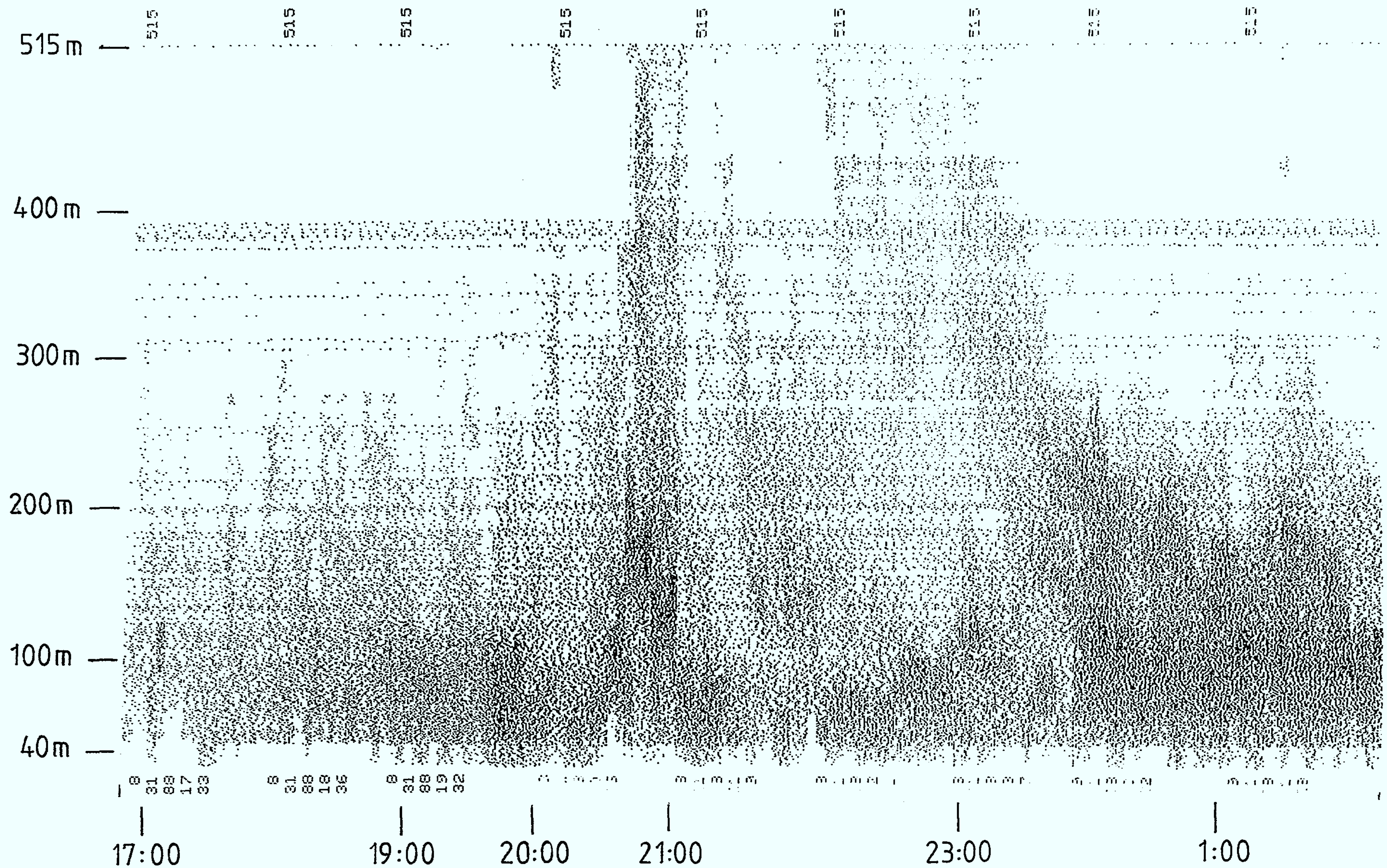


Fig. 5.7.5: Facsimile record from the Doppler-SODAR (KFA) on Aug 31/Sept 1, 1988

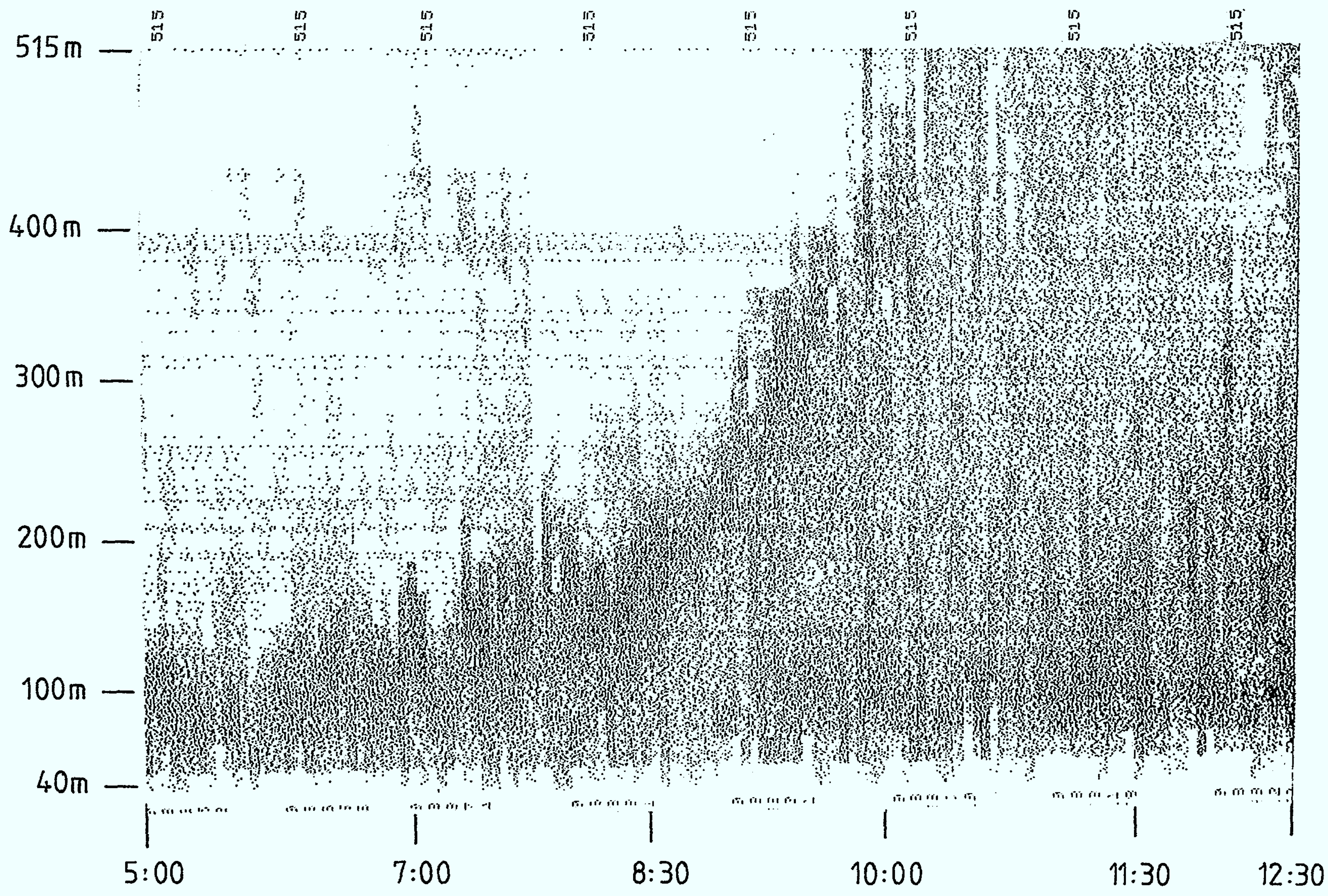


Fig. 5.7.6: Facsimile record from the Doppler-SODAR (KFA) on Sept 8,1988

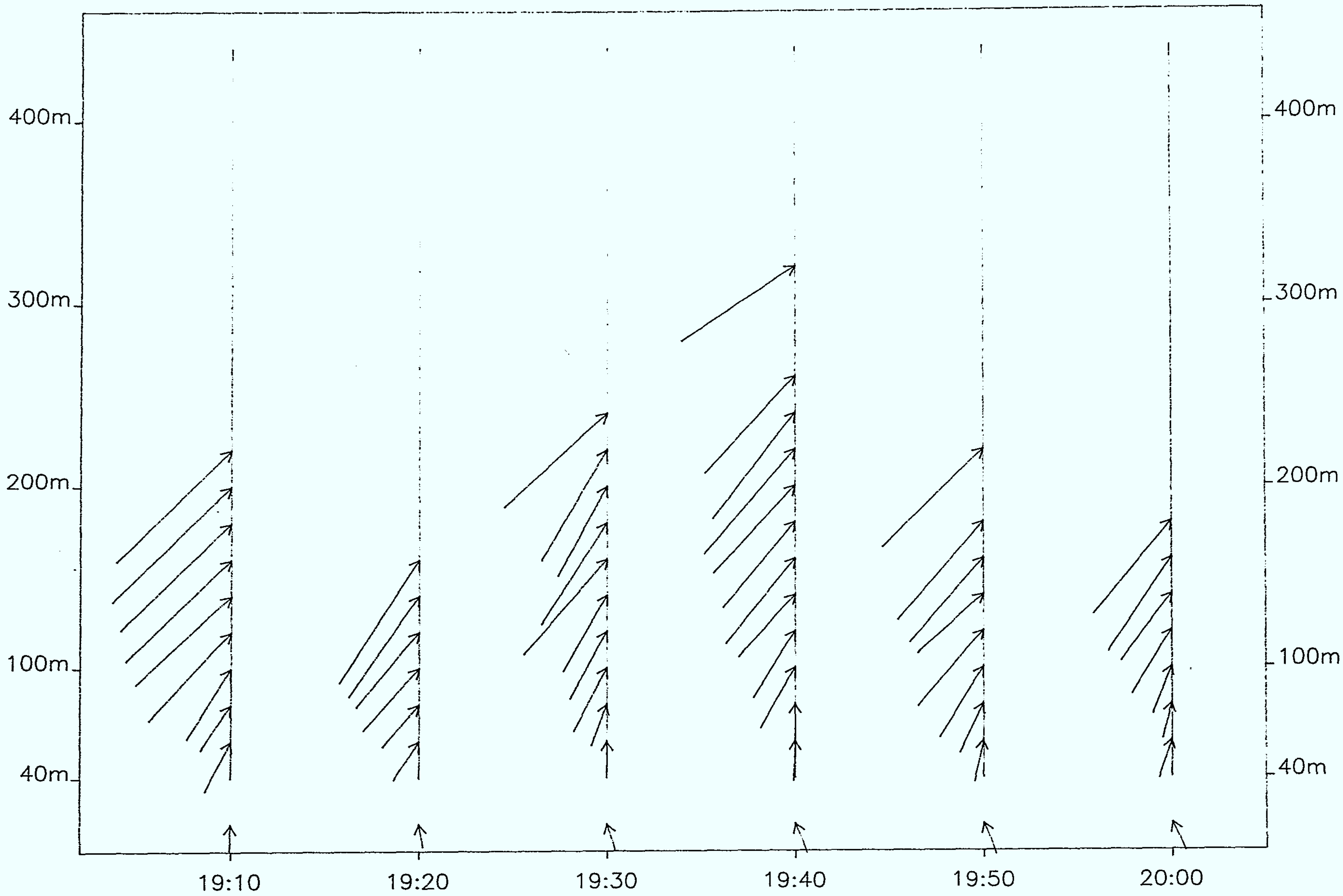


Fig. 5.7.7: Vectorial plot of 10 min. average wind from 15m mast and SODAR at position S1 on Aug 31, 1988 - Scale: 1.3cm = 4 m/s

increased late in the afternoon, i.e. a surface inversion developed. Just after dispersion experiment No.III-2 was over, a cold front with a rain shower passed our area, the wind became stronger and turned from southwest to northwest. These conditions caused a strong echo signal at all heights between 20:30 and 21:00 hour. Later in the evening a surface inversion developed again and extended up to a height of 200 m - 250 m around midnight.

The second record (Sept. 8) shows a typical facsimile during sunrise after a clear night with weak winds. The dark, in the morning with height increasing structure , was caused by strong wind shear, near the inversion base. The strong backscattered echo is reflected in the dark pattern in the facsimile. Later in the morning typical convective patterns can be seen in the lower layers.

For a one hour period during dispersion experiment No.2 on August 31, a vectorial plot of wind in the 400 m layer is shown in Fig. 5.7.7. The length of vector is proportional to horizontal wind speed and the orientation indicates the wind direction. Each of these profiles is of 10 minute averaging time. The measurements of the lowest height come from the 15 m mast. It can be seen that in the upper layers (above 100 m) the wind flow was southwesterly with only little change to southsouthwesterly at the end of this period. In the lower layers the wind turned to southerly and at 15 m height even to southsoutheasterly directions. This shows the strong deflection of the wind by the hill in the lower layers at times when the lower atmosphere became stable. Light winds in the lower layers (below 80 m) and moderate winds in the upper layers also reflect the shear of wind speed.

5.7.4 Comparison of results from the different SODARs

G. Zeuner

As an example for simultaneous measurements by all the three SODARs set-up at the base of Sophienhöhe, profiles of important parameters are given in Fig. 5.7.8. For a stable stratified surface layer one 10-minute interval during dispersion experiment III-2-2 has been selected. A maximum of echo intensity (upper left figure), normalized with the echo value in 100 m, is well defined for the TÜV Rheinland SODAR at the height of 80 m and also for the TÜV Essen SODAR around 100 m - 140 m. For the KFA-SODAR the 40 m value is missing so that the interpretation is not that clear.

The shear in wind direction is more or less apparent for all SODARs but especially for the KFA-SODAR. Vertical wind speed is low for two SODARs (KFA, TÜV Essen). In contrast the TÜV Rheinland SODAR shows a strong downward directed wind of 60..120 cm/s in all layers. Wind was accelerated at this location on the leeside of Sophienhöhe. The standard deviation of vertical wind as a measure of turbulence shows little turbulence for two SODARs (KFA, TÜV Rhld.). The third SODAR (TÜV Essen) was placed close to the mining area which probably increased the turbulence level.

The above examples demonstrate that it is possible to find the influence of Sohienhöhe on the wind flow in the SODAR measurements. The deflection of the wind in the lower layers, as detected for example with the KFA-SODAR on the western side of Sophienhöhe, was also reflected in the concentration distribution, for example in experiment III-2-2 (see chapter 6.1). Moreover the SODAR can give important input parameters for sophisticated wind flow and dispersion models.

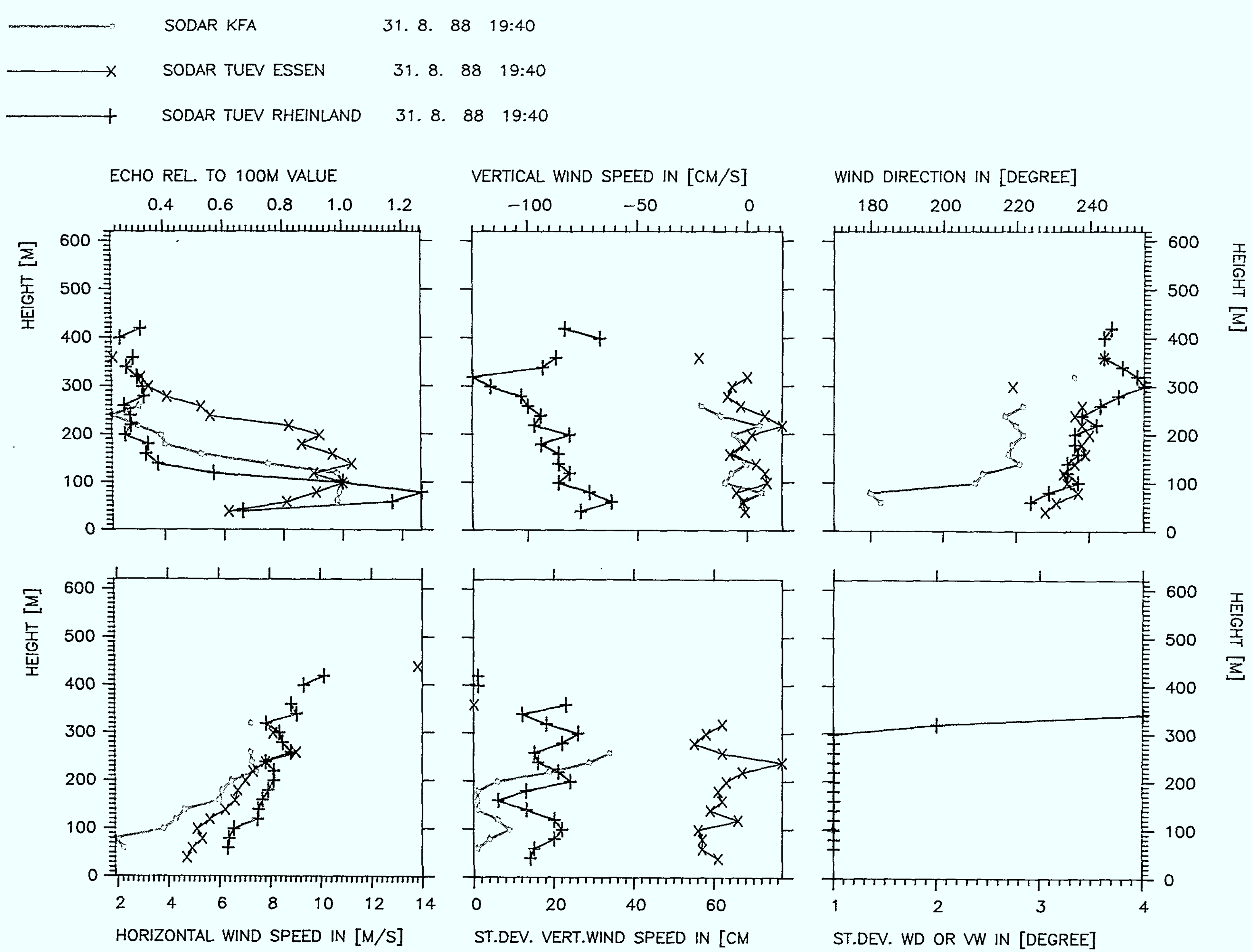


Fig. 5.7.8: Vertical profiles of SODAR measurements on Aug. 31, 19:30 - 19:40

5.8 Mobile van by KFA-group ICH-4

H. D. Narres

The mobile van of the Institute of Chemistry 4 (ICH 4) equipped with a wind mast was located in the south of Sophienhöhe between hill and mine (Gauß-Krüger coordinates: x = 31340 m, y = 42000 m; height: 104 m m.s.l). At this place also most of the tether sonde measurements by IGM-group were carried out. The position was near a viewpoint of the Hambach mine on a broad pathway which ran from southwest to northeast with a distance of 150 m parallel to the hill base. A small woodland area with about 6 m high trees began 15 m away northwest from the mast. The border of the mining terrain began within a few meters in easterly direction.

On the roof of the van a 3.5 m mast was erected where on its top wind speed and direction was measured every 10 seconds with a combined windmeter (Thies company) and averaged every 10 minutes. The measurement height was 7.20 m above ground.

The data bank contains mean and standard deviation of wind speed and direction for the following periods:

August 30, 10:40 hour - September 4, 10:40 hour
September 5, 0:00 hour - 20:30 hour
September 6, 0:00 hour - 7:20 hour
September 7, 0:00 hour - 13:40 hour
September 7, 14:30 hour - September 8, 12:30 hour

Some technical problems with the computer system were the cause for missing data.

6. FIRST RESULTS AND DATA BANK

6.1 Dispersion experiments

G. Zeuner

6.1.1 Overview

Six dispersion experiment series were carried out during the field campaign. Some important data, including wind conditions at the emission point and diffusion category derived from temperature gradient and wind measurements at the KFA-tower, are summarized in Tab. 6.1.1. Information over emission time and -rate as well as number of measurements (samples) has already been given in Tab. 4.1.1. It can be seen from Tab. 6.1.1 that two experiment series were carried out each during stable (diff. cat. E-F), neutral to slightly stable (diff. cat D-E) and unstable (diff. cat. A-B) atmospheric conditions.

Experiment No. date	release point and height	sampling time CET	Meteorological data KFA-tower			diffusion category
			wind direction (deg)	wind speed (m/s)	temp. grad. (120m -20m)	
III-1-1 08/30/88	E1	15:00-15:30	250	4.4	-1.5	B
III-1-2 08/30/88	KFA-tower	15:30-16:00	251	4.4	-1.5	B
III-1-3 08/30/88	50 m	16:00-16:30	257	3.5	-1.2	B
III-2-1 08/31/88	E1	19:00-19:30	230	2.5	+0.4	F
III-2-2 08/31/88	KFA-tower	19:30-20:00	216	2.1	+0.5	F
III-2-3 08/31/88	50 m	20:00-20:30	193	1.6	+0.6	F
III-3-1 09/03/88	E1	06:30-07:00	217	3.4	-0.6	D
III-3-2 09/03/88	KFA-tower	07:00-07:30	210	3.6	-0.6	E
III-3-3 09/03/88	50 m	07:30-08:00	201	2.4	-0.7	D
III-4-1 09/04/88	E1	12:00-12:30	249	3.2	-1.4	A
III-4-2 09/04/88	KFA-tower	12:30-13:00	234	3.2	-1.6	A
III-4-3 09/04/88	50 m	13:00-13:30	217	2.2	-1.5	A
III-5-1 08/05/88	E2	20:00-20:30	300	5.2	-0.2	D
III-5-2 09/05/88	water-tower	20:30-21:00	294	4.7	-0.2	D
III-5-3 09/05/88	47 m	21:00-21:30	295	2.9	-0.3	E
III-6-1 09/07/88	E7	20:00-20:30	116*	2.5*	+1.9	E
III-6-2 09/07/88	Mast 5	20:30-21:00	126*	2.0*	+1.7	E
III-6-3 09/07/88	2 m	21:00-21:30	139*	1.3*	+1.8	E
Note: * measurement at release point (mast 5)						

Tab. 6.1.1: Overview of tracer experiments and meteorological conditions

To give a first impression of the tracer-concentration field around Sophienhöhe and how good the plume was found with the sampling network, the SF_6-concentrations for 11 out of 18 dispersion experiments are illustrated as 3-dimensional plots in the following sub-chapters. Experiment No. III-2-2 is described with some more details, using also data, given in chapter 6.2, for interpretation.

The 3D plots in chapter 6.1.2 - 6.1.7 contain the tracer sampling positions and concentrations in the area around the Sophienhöhe. The grid elements for flat terrain have a size of 250 m × 250 m. The contour lines of Sophienhöhe and mining area are drawn with height distances of 25 m. The area of the research centre KFA is indicated in turquoise. The emission point is drawn as a black line. The tracer concentrations are shown in form of vertical red and blue lines or blue circles. The length of the lines is proportional to the measured concentrations (1cm red line = ca. 3700 ng/m^3, 1 cm blue line = ca. 18500 ng/m^3), where the concentrations for the experiment series No. 1-5 are scaled to the maximal concentration of 97000 ng/m^3 measured in exp. No. III-4-2 (single blue line on the right or left side of the figures). So the tracer concentrations can be compared among one another assuming tracer emission rates are almost constant. Actually the emission rates vary between 2.5 g/s and 1.6 g/s within the experiment series 1-5.

The measured values illustrated as blue lines are reduced by a factor of 5 compared to the red lines, i.e. blue lines represent high concentrations. Blue circles represent low concentration measurements (≤97 ng/m^3) or background.

6.1.2 Dispersion experiment 1

During the first experiment on Aug. 30 the boundary layer was slightly unstable stratified. The meteorological conditions at the emission point stayed quite constant. The concentration distribution for experiment III-1-1 and III-1-2 are shown in the figures 6.1.1 and 6.1.2. The tracer plume moved over the hill on its southern/southwestern side. The measured concentration maximum lay in a distance of 450 m from the emission point. In sampling period 2 the concentrations were about double as high compared to period 1. Also the plume hit a larger area of the hill in the second sampling period. This can be explained by means of the meteorological measurements. On the wind ward slope wind direction changed from 263° in period 1 to 248° in period 2. So, in the later period, the wind brought the plume to a larger area on the windward side of the hill.

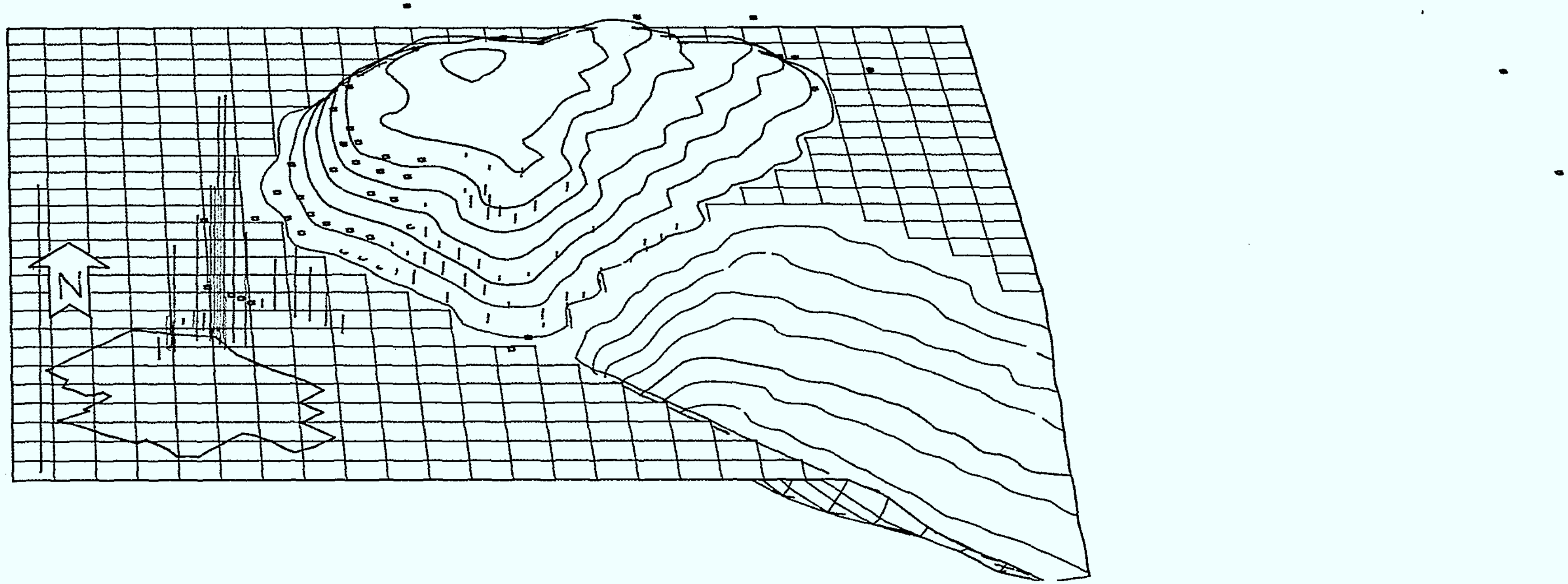


Fig. 6.1.1: Pattern of the concentration distribution for exp. III-1-1 on Aug. 30, 1988, 15:00-15:30
Scale Conc. (single blue line): 97000 ng/m³
Blue circles: Low conc. or background
Red lines enlarged by a factor of 5 against blue lines

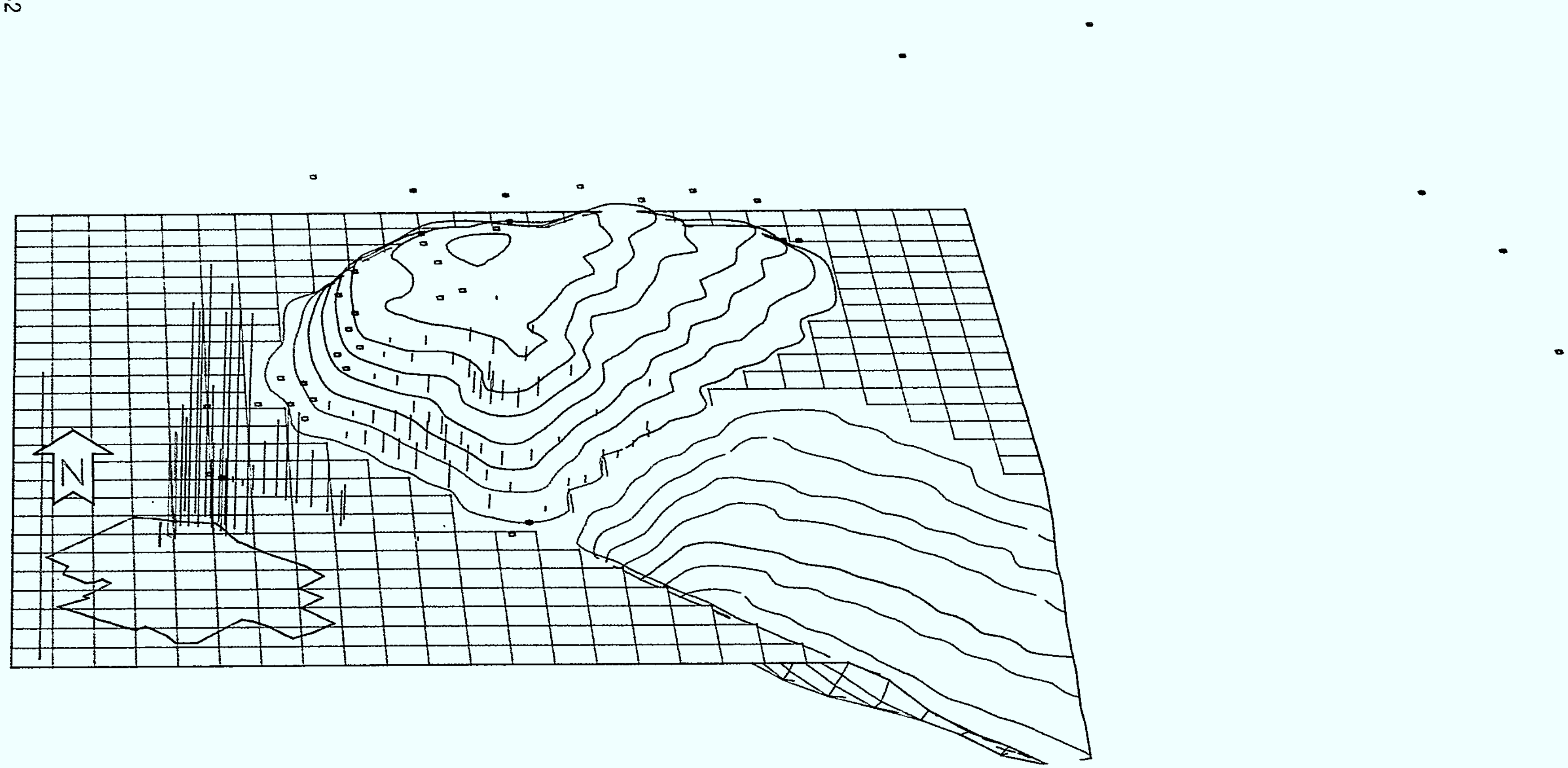


Fig. 6.1.2: Pattern of the concentration distribution for exp. III-1-2 on Aug. 30, 1988, 15:30-16:00
Scale Conc. (single blue line): 97000 ng/m³
Blue circles: Low conc. or background
Red lines enlarged by a factor of 5 against blue lines

6.1.3 Dispersion experiment 2

This experiment was carried out in the evening when the boundary layer was stable stratified. The meteorological measurements at the emission point (KFA-tower) show a wind shift from southwest (start of emission) to southsouthwest (end of emission). In the course of the experiment the wind velocity dropped from 3.7 m/s to 1.8 m/s and the horizontal wind fluctuations expressed as the standard deviation of wind direction decreased from 11°-13° to 5°-7° in emission height. Much higher wind fluctuations were observed at the height of 30 m (see Tab. 6.2.1). The wind shift within each of the three sampling periods was 13°, considering ten-minute averages. Low wind speed and a positive temperature gradient (surface inversion) give as stability classification of diffusion category F.

The measurements on the Sophienhöhe illustrate the deflection of the southwesterly flow to southerly directions in the lower layers and western region of the hill (Fig. 6.1.3). Looking to the KFA-SODAR data, the wind shear with height is well demonstrated.

In chapter 6.2 the continuous meteorological measurements from all sites are tabulated for the period 18:30-20:00 hour on August 31. Hence, the last half hour falls in the sampling period of experiment III-2-2. Also, one balloon ascent from each system which took place in or near this sampling period, is given as an example.

In Fig. 6.1.4-6.1.6 the concentration distributions for the three sampling periods of the experiment serie III-2-1 to III-2-3 is shown. During the first sampling period the tracer plume passed over the hill and some part of the plume was deflected to the north. The SF_6-concentrations on the hill are quite high and amount to 18000 ng/m^3 at the tracer axis in the lower slope region. The highest tracer concentration found along the dispersion direction of 50° which coincides with the wind direction of 230° measured at the KFA-tower. The deflection of the wind in the western part of Sophienhöhe is also reflected in the concentration distribution; the plume extended further north from the tracer axis than to the south. For example, in dispersion direction 25°, concentrations of 2200 ng/m^3 - 3800 ng/m^3 were measured at lower levels but background at higher levels. Striking of the concentration pattern is the width of the plume which is relative broad for stable stratification. Behind the hill the SF_6-concentrations are still remarkable. The maximal concentrations were found in front of the hill with tracer concentrations of 40000 ng/m^3 - 55000 ng/m^3 at distances of 300 m - 950 m from the emission point. The plume also is broad which might be caused among other things by the observed wind shift, strong wind shear, increased turbulence at levels lower than the emission point.

An overview of the result of experiment III-2-2 gives Fig. 6.1.5. The concentration maximum was measured 950 m away from the emission point (see also Tab. 5.6.2) and lay $\simeq$10° north of the "expected" tracer axis in direction 34° (wind direction 214° at the emission point). As can be seen from Tab. 6.2.1, wind direction in 30 m was also 10° more southerly than in 50 m height which would be in agreement with the tracer axis found at the ground. The plume again was pretty broad. The broad plume also was found on the Sophienhöhe. There the largest concentrations were measured at lower levels north of the assumed (=expected) dispersion direction. In con-

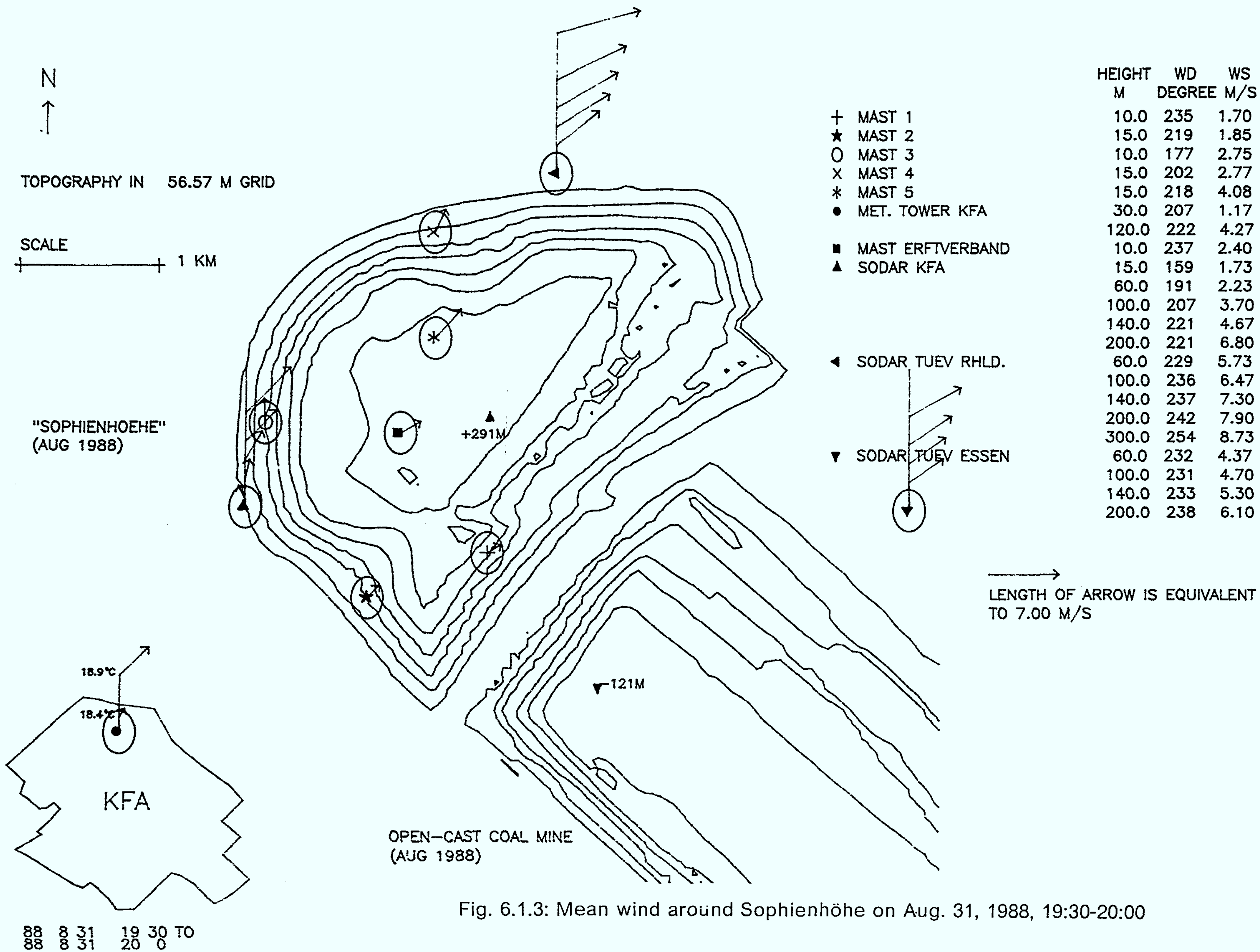


Fig. 6.1.3: Mean wind around Sophienhöhe on Aug. 31, 1988, 19:30-20:00

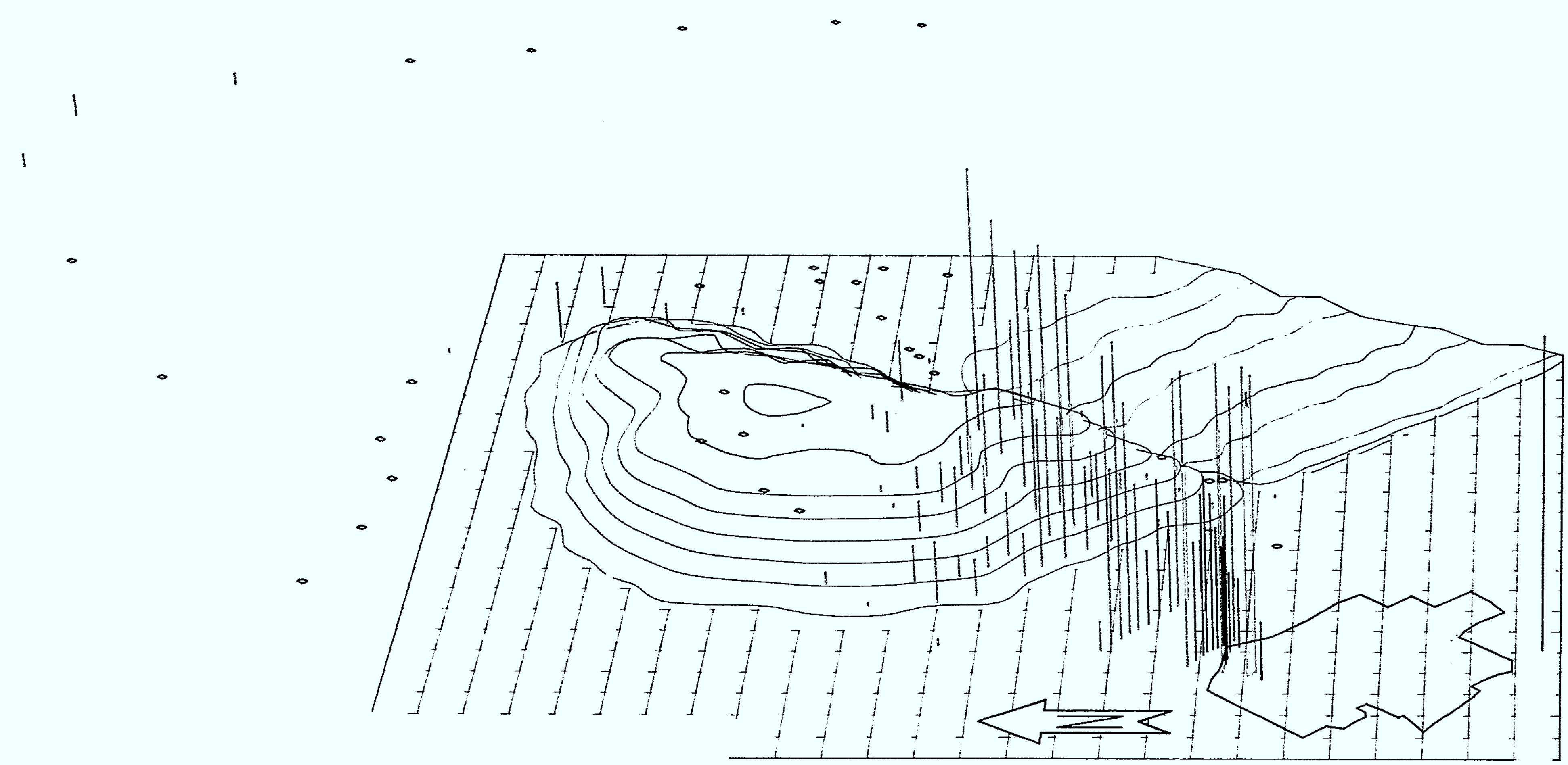


Fig. 6.1.4: Pattern of the concentration distribution for exp. III-2-1 on Aug. 31, 1988, 19:00-19:30

Scale Conc. (single blue line): 97000 ng/m³

Blue circles: Low conc. or background

Red lines enlarged by a factor of 5 against blue lines

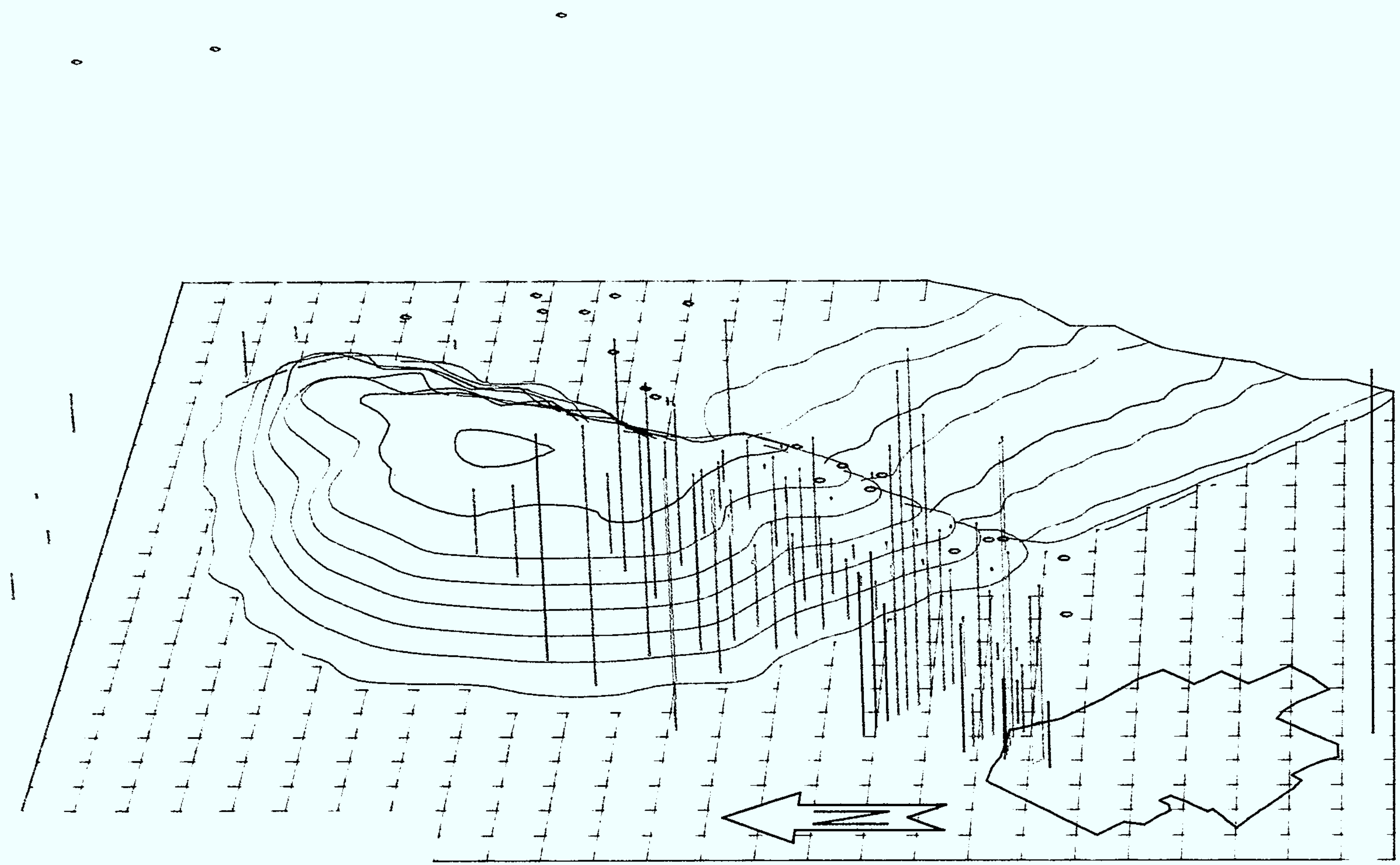


Fig. 6.1.5: Pattern of the concentration distribution for exp. III-2-2 on Aug. 31, 1988, 19:30-20:00

Scale Conc. (single blue line): 97000 ng/m^3

Blue circles: Low conc. or background

Red lines enlarged by a factor of 5 against blue lines

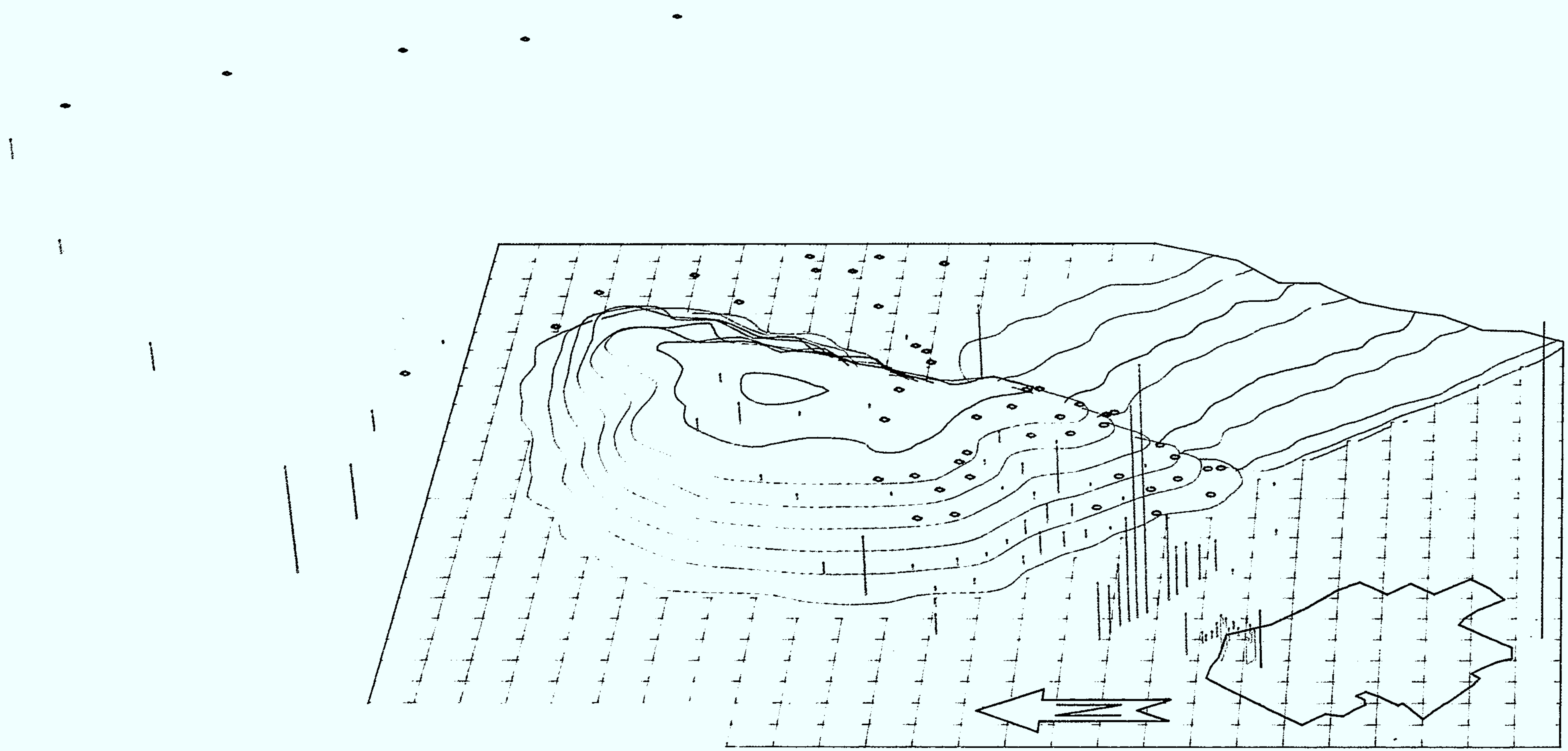
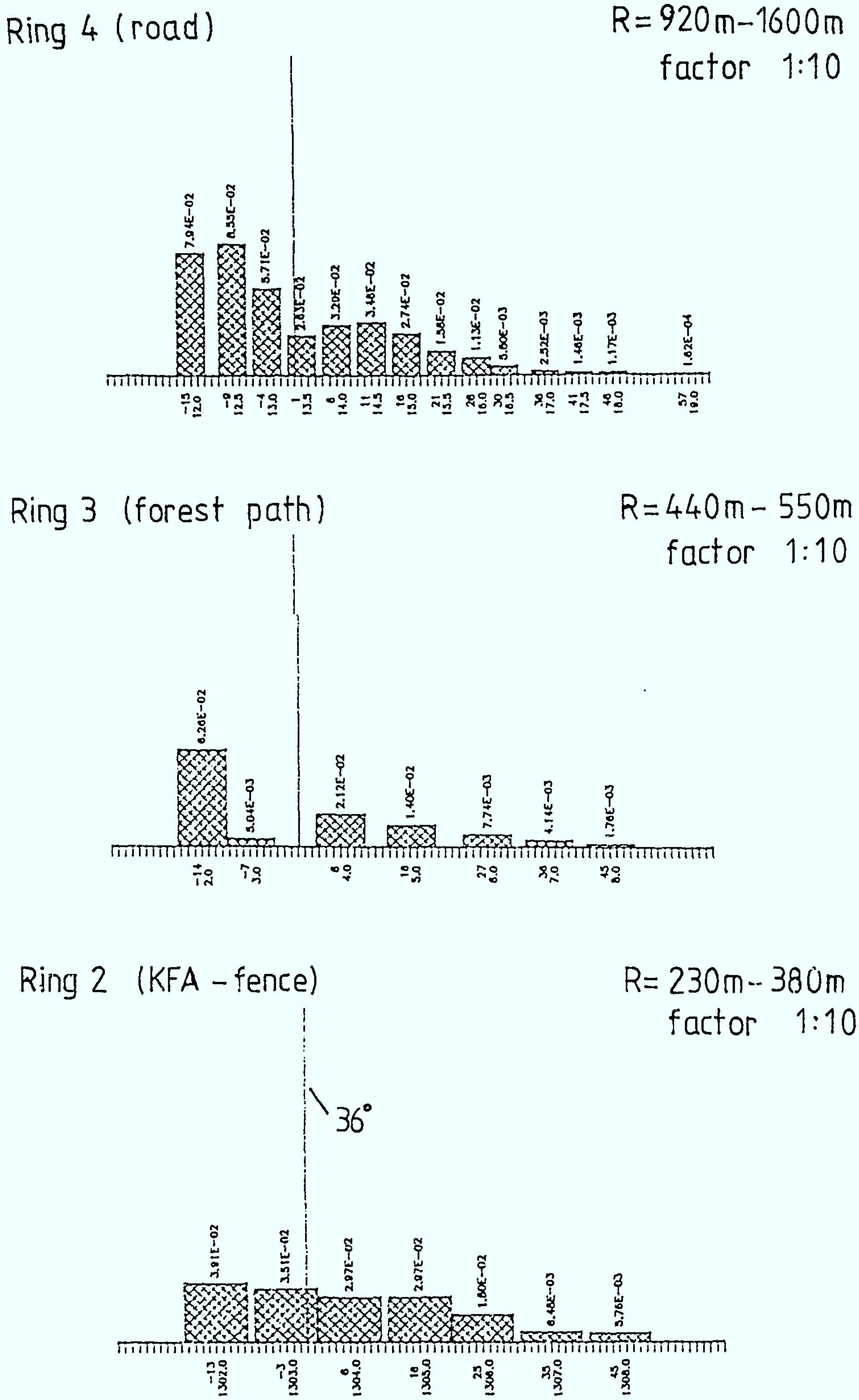


Fig. 6.1.6: Pattern of the concentration distribution for exp. III-2-3 on Aug. 31, 1988, 20:00-20:30
Scale Conc. (single blue line): 97000 ng/m³
Blue circles: Low conc. or background
Red lines enlarged by a factor of 5 against blue lines

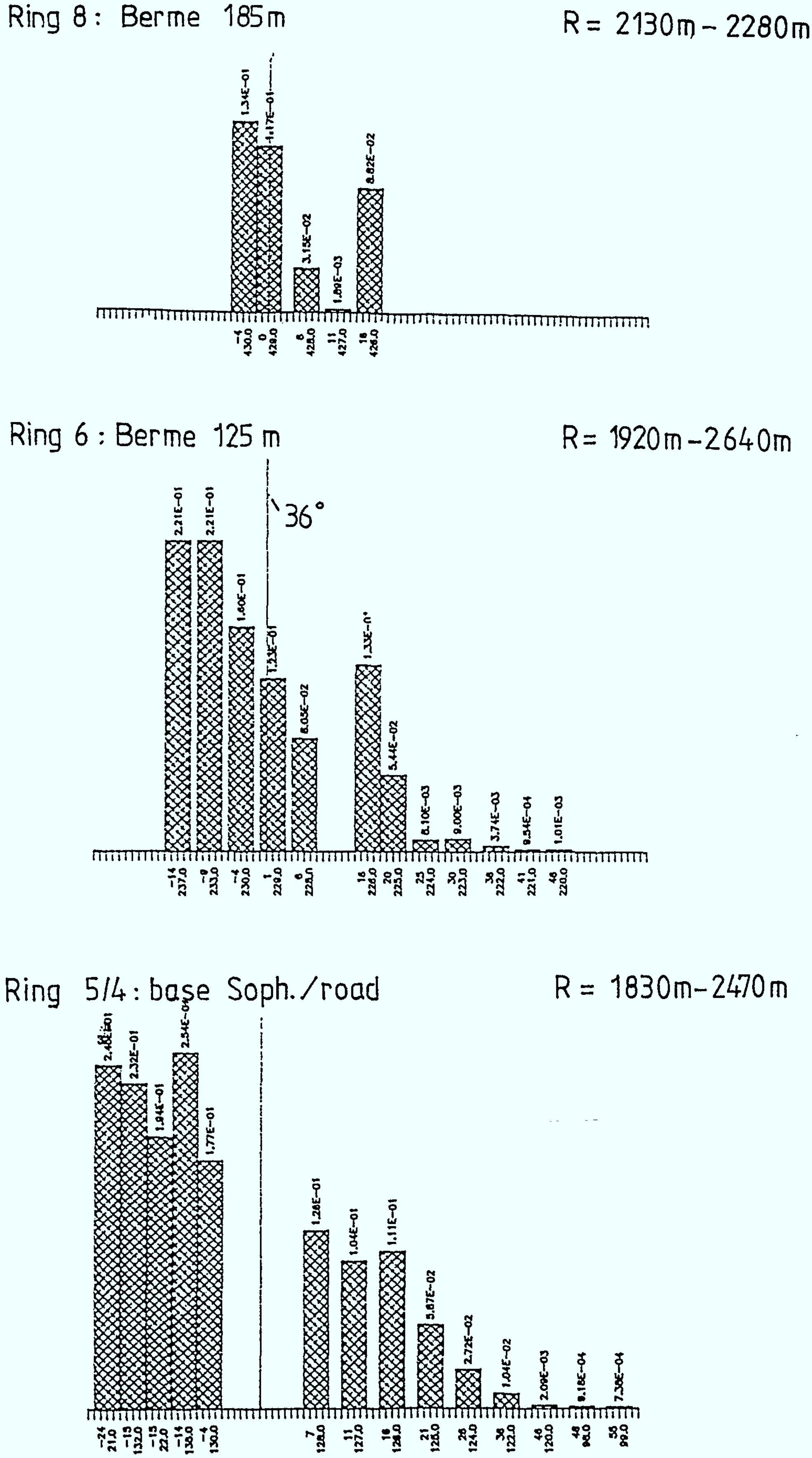


Abscissa: Azimuthal (angular) deviation from dispersion direction in degrees and number of sampling point

Fig. 6.1.7a: Time-integrated concentration in (g×s/m^3) for exp. III-2-2 on Aug. 31, 1988, 19:30-20:00

R = radius sampling points-emission point

Concentrations are plotted with a factor of 10 reduced compared to 6.1.7b/c (for explanation see text)



Abscissa: Azimuthal (angular) deviation from dispersion direction in degrees and number of sampling point

Fig. 6.1.7b: Time-integrated concentration in (g×s/m³) for exp. III-2-2 on Aug. 31, 1988, 19:30-20:00

R = radius sampling points-emission point trast highest concentrations in the upper slope region were more in line with dispersion direction 34°. This pattern corresponds well with the meteorological measurements and the observed wind shear. The concentration distribution on the leeside of Sophienhöhe indicates that one part of the plume passed over and one part passed by the western flank of the hill.

The result of experiment III-2-2 described above can be seen in more detail in Fig. 6.1.7a-c where the 30 minute integrated concentrations are illustrated as vertical bars for 9 out of the 14 rings of the sampling network (see Tab. 4.1.5). The vertical line near the middle of each ring corresponds to the assumed dispersion direction of 34°. The abscissa axis gives the azimuthal deviation of the sampling point from direction 34° (= wind direction 214°) in degrees as seen from the emission point. Beneath the number of the sampling points is indicated. For example, sampling point 12.5 (Ring 4) lay in direction 25° and so corresponds to the angle given in polar coordinates in Tab. 5.6.2.

Generally one can say that from all experiments in the field campaign the highest concentrations on the hill slope were found in the experiments described above.

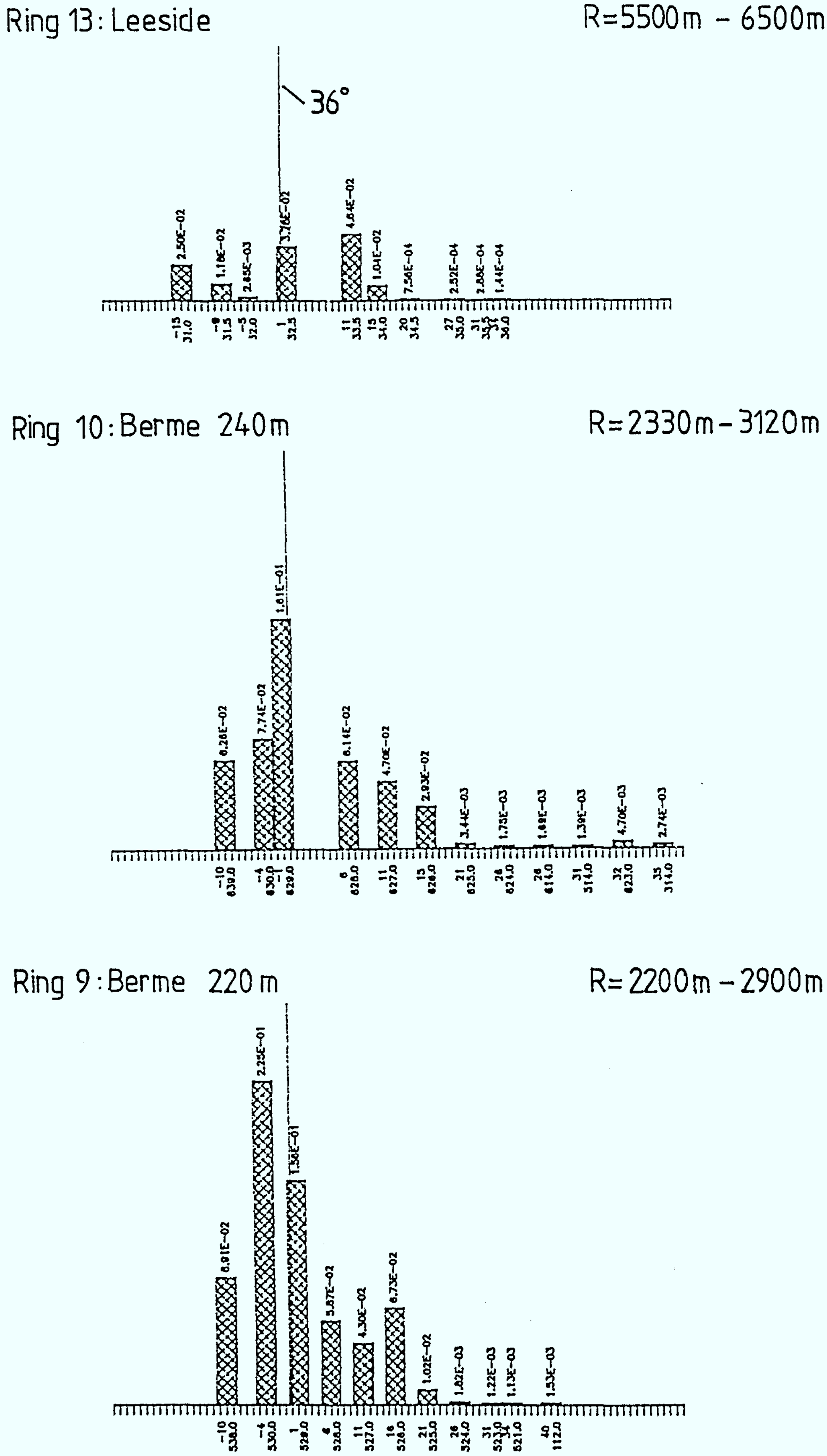
During the last sampling period (Fig. 6.1.6) most of tracer passed the west of Sophienhöhe. Some part of the plume still is seen in front of the hill and on the slope where wind speeds were very low (below 2 m/s). Behind the hill tracer concentrations are still relative high (1000 ng/m^3 to 7000 ng/m^3).

6.1.4 Dispersion experiment 3

The intention of this early morning experiment was to study dispersion around sunrise when the stable boundary layer becomes destroyed by insolation. During such conditions high surface concentrations are possible (fumigation). In this night and morning on Sept. 3, it turned out that wind speeds were too high (3-5 m/s) for the development of an inversion. So we had near neutral, slightly stable conditions. Futhermore the wind turned from southwesterly to southerly directions during the experiment. Therefore, only the concentration distribution of the first sampling period is shown here (Fig. 6.1.8). In the second period, less than half of the plume was covered by the installed sampling network. In the last sampling period the plume passed the west of Sophienhöhe. In experiment III-3-1 wind direction shifted a little from 223° to 212°. The maximal tracer concentrations were measured at distances of 250 m and 950 m from the emission point in direction 20°-40° as seen from the release point. The plume moved over the hill. On the hill, maximal concentration was measured on Berme 125, 25 m above the base, in direction 30°. On the top of the hill the maximal measured concentration was about half of those measured on Berme 125 in the same direction. On the lee slope of Sophienhöhe the plume was well detected with quite high concentrations (almost half of those on the windward slope).

6.1.5 Dispersion experiment 4

This dispersion experiment was carried out around noon on Sept. 4 during very unstable atmospheric conditions (diffusion category A). Some meteorological measurements were already described in chapter 5.1.



Abscissa: Azimuthal (angular) deviation from dispersion direction in degrees and number of sampling point

Fig. 6.1.7c: Time-integrated concentration in (g×s/m³) for exp. III-2-2 on Aug. 31, 1988, 19:30-20:00
R = radius sampling points-emission point

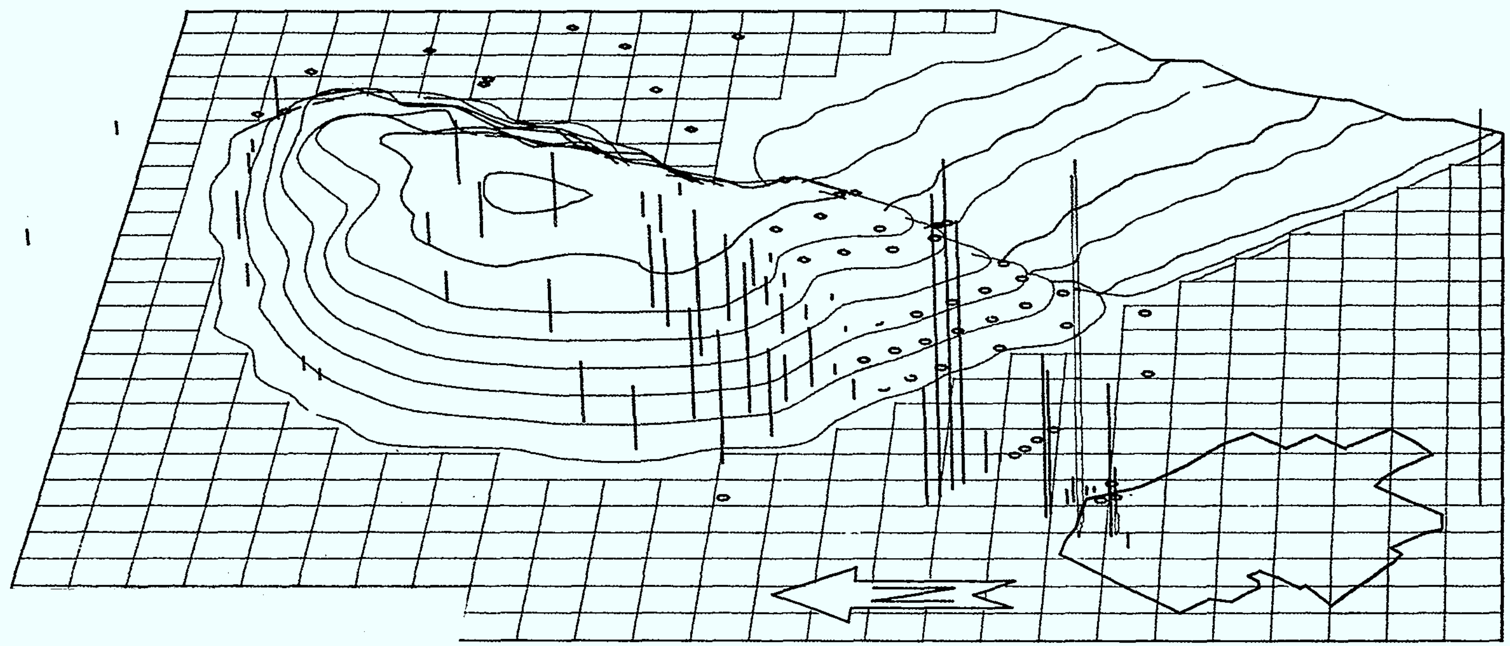


Fig. 6.1.8: Pattern of the concentration distribution for exp. III-3-1 on Sept. 3, 1988, 06:30-07:00
Scale Conc. (single blue line): 97000 ng/m^3
Blue circles: Low conc. or background
Red lines enlarged by a factor of 5 against blue lines

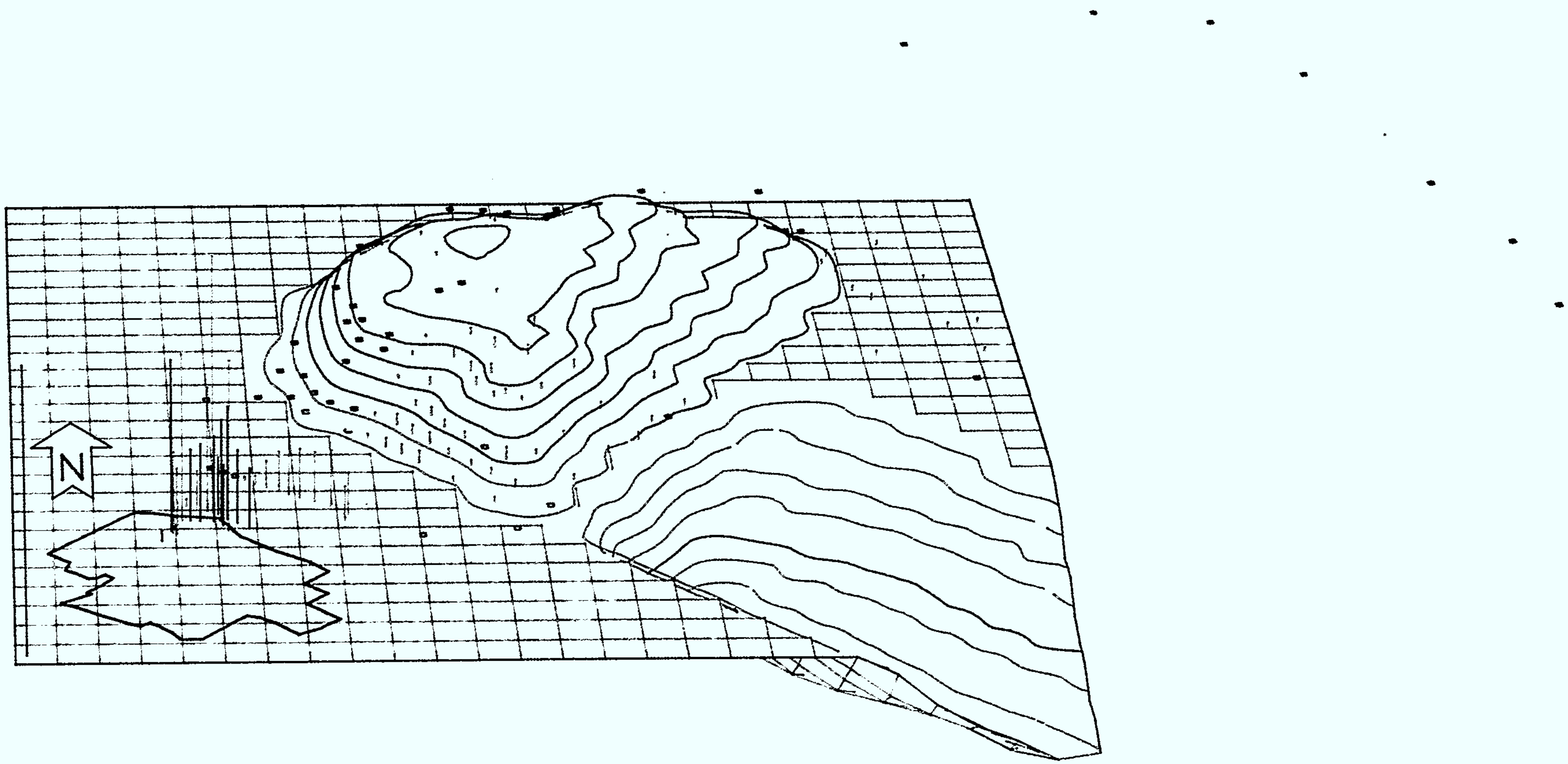


Fig. 6.1.9: Pattern of the concentration distribution for exp. III-4-1 on Sept. 4, 1988, 12:00-12:30
Scale Conc. (single blue line): 97000 ng/m^3
Blue circles: Low conc. or background
Red lines enlarged by a factor of 5 against blue lines

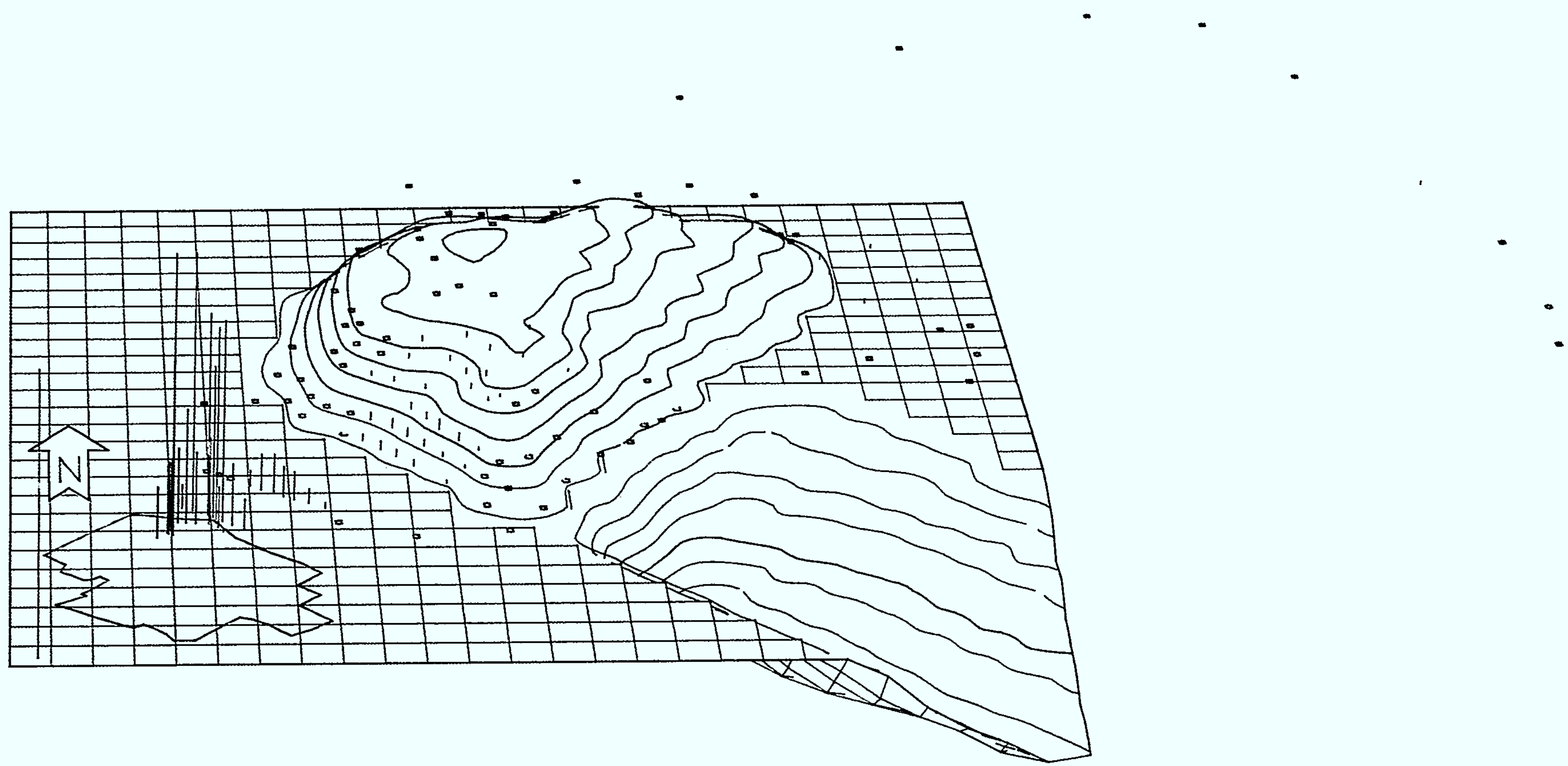


Fig. 6.1.10: Pattern of the concentration distribution for exp. III-4-2 on Sept. 4, 1988, 12:30-13:00

Scale Conc. (single blue line): 97000 ng/m^3

Blue circles: Low conc. or background

Red lines enlarged by a factor of 5 against blue lines

The whole plume was found in the tracer measurements for all three sampling periods. The concentration distributions of the first two sampling periods are illustrated in Fig. 6.1.9 and 6.1.10. From the figures one can see that the plume goes over Sophienhöhe and the tracer concentrations were low in the region of the hill, as for example compared to experiment III-1. The cross tracer distribution is quite flat. Maximal concentrations were found very close to the emission point.

6.1.6 Dispersion experiment 5

As emission point the water tower west of Sophienhöhe was selected because westerly winds were expected. One hour before the emission started, the wind turned a little to northwest and stayed there during the experiment. Therefore the plume could not be completely measured with the sampling units. In the course of the experiment the wind weakened, so that diffusion category E was reached in the last sampling period.

The tracer concentrations measured in the first and third sampling period are illustrated in Fig. 6.1.11 and 6.1.12. The concentration distribution for the second period looks very similar to the first one. In all the three experiments maximum concentration was measured 300 m downwind of the source in dispersion direction 100°-115°. The plume moved over the southwestern, southern part of Sophienhöhe. On the hill the maximum concentration was found in dispersion direction of $\simeq$120°, where the maximum for the first sampling period was found leeside at the base of the hill. On the upslope side of the tracer axis, concentrations dropped rapidly to background (see also Tab. 4.6.3).

6.1.7 Dispersion experiment 6

The emission point of the last experiment lay at the top of the hill (Mast 5). The atmosphere was stable stratified and the wind was blowing from east-southeast. The standard deviation of wind direction at the emission point was 6°-8°.

The concentration distribution for the last sampling period is shown in Fig. 6.1.13. The plume moved downslope to northwest. At Berme 220 (120 m above the base of the hill) the plume had a width of $\simeq$25° with a maximum in direction 317°-320°. At Berme 125 the plume is broader (about 55°) with a maximum in direction 320° and a secondary maximum in direction 287° as seen from the emission point.

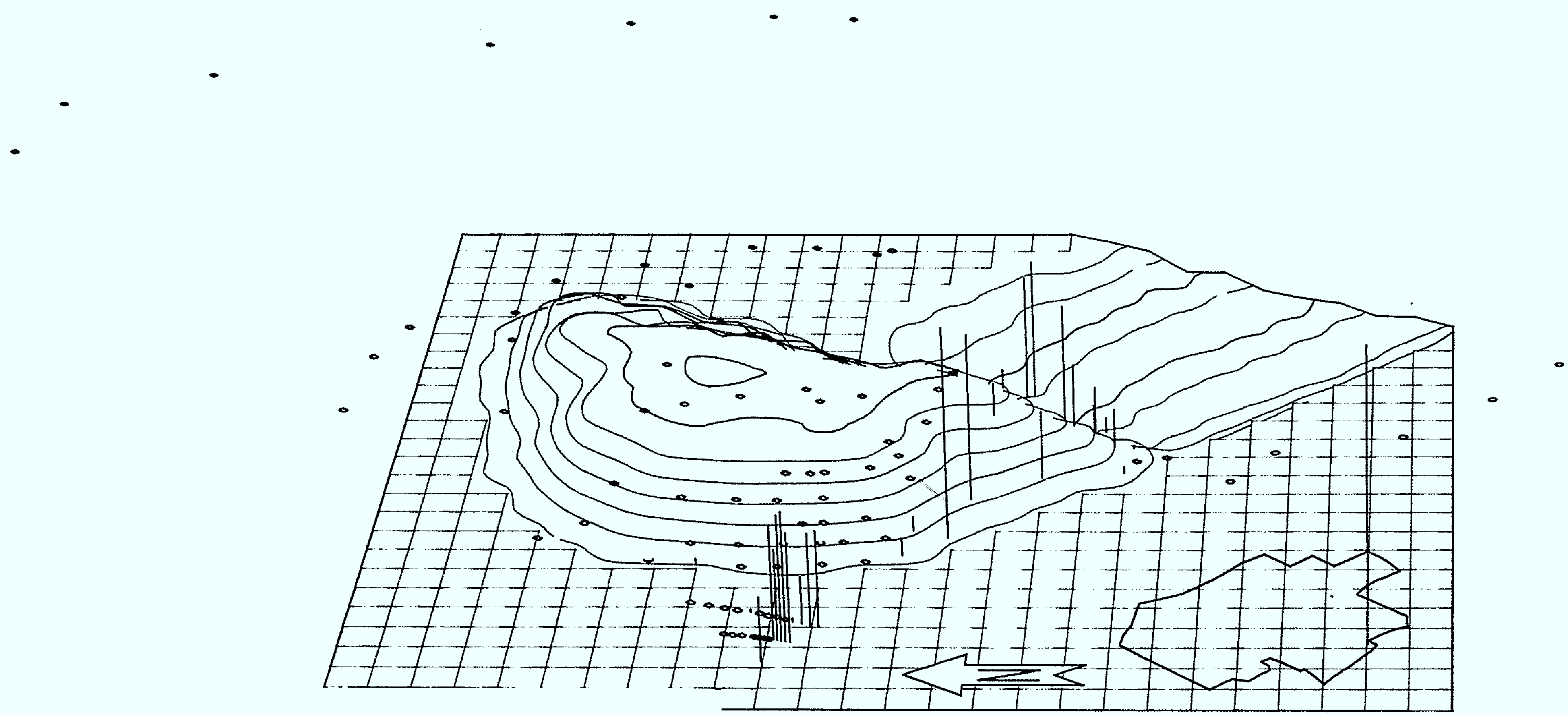


Fig. 6.1.11: Pattern of the concentration distribution for exp. III-5-1 on Sept. 5, 1988, 20:00-20:30
Scale Conc. (single blue line): 97000 ng/m^3
Blue circles: Low conc. or backgrouund
Red lines enlarged by a factor of 5 against blue lines

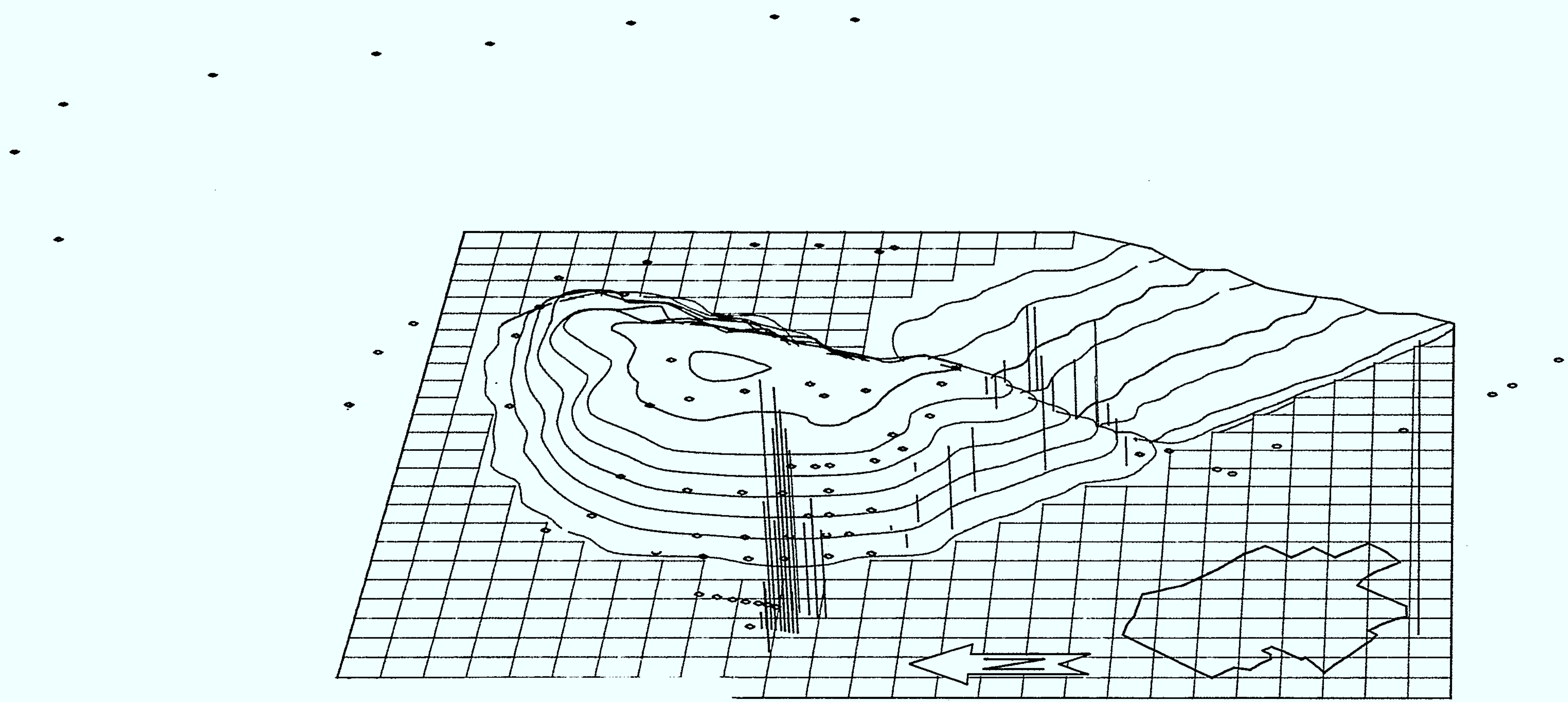


Fig. 6.1.12: Pattern of the concentration distribution for exp. III-5-3 on Sept. 5, 1988, 21:00-21:30
Scale Conc. (single blue line): 97000 ng/m^3
Blue circles: Low conc. or background
Red lines enlarged by a factor of 5 against blue lines

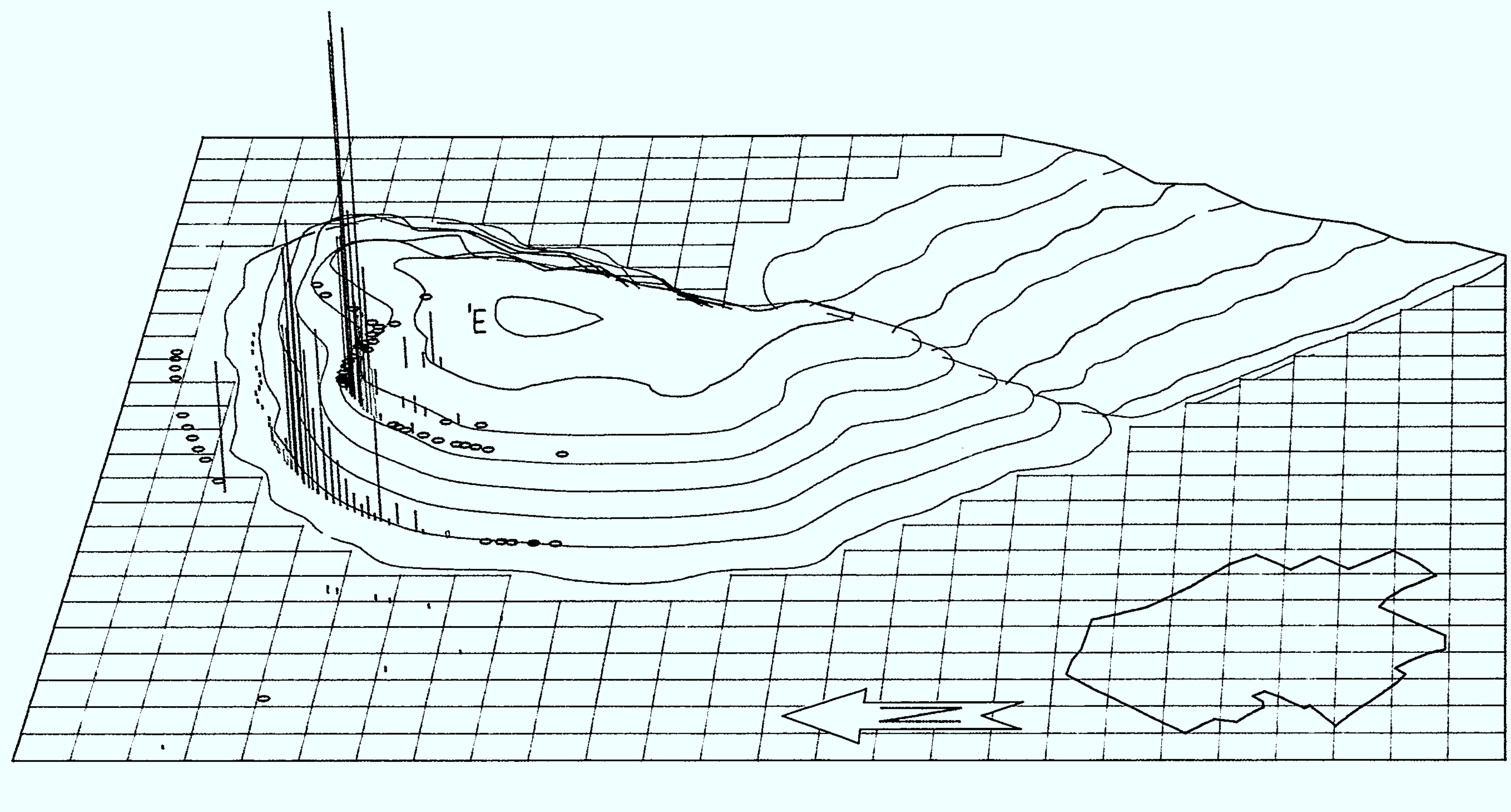


Fig. 6.1.13: Pattern of the concentration distribution for exp. III-6-3 on Sept. 7, 1988, 21:00-21:30
Maximal conc.: 15000 ng/m³ Blue circles: Background Red lines enlarged by a factor of 5 against blue lines

6.2 Meteorological data set for a selected period

Ch. Mönig

In the data bank (appendix C) all meteorological and tracer measurements are contained in a standardized form. The very large amount of data only allows to show the tracer data tabulated, these data are described in chapter 4.3 and 4.6. The meteorological measurements are divided in two types of data in the data bank, see chapter in appendix C: 1) data of continuous measuring stations, and 2) data of balloon and sonde ascents. To each measurement system a station number was assigned. Stations 1-18 belong to the continuous measurement systems (KFA tower, masts on Sophienhöhe, sonic anemometers, SODARs) and stations 19-25 belong to the ascents or flights of radio- and rawin sonde, tether sonde, pilotballoon and tetroons.

In order to illustrate the comprehensive meteorological measurements carried out during the field campaign exemplary for each measurement system, the data of a selected period during dispersion experiment III-2 are compiled in the following tables 6.2.1 - 6.2.25.

Data from the continuous measurements are shown for the time interval 18:30 - 20:00 hour on August 31. Hereby the last half hour coincides with the period of dispersion experiment III-2-2 (see also discussion in 6.1.3). Because for the application of the data in dispersion models meteorological information also in advance of a tracer experiment is needed, the data from one hour before until the end of tracer experiment III-2-2 are summarized in the following tables. So these data directly can be used for model validation.

From the tables the meteorological parameters measured by several balloon systems also become evident. In order to limit the amount of tables, here only the data from some ascents made during experiment III-2 are shown.

The table numbers correspond to the station numbers in appendix C as is summarized in the following table:

Table No.	Measurement station
1	Tower KFA
2	Mast Rheinbraun
3-7	Mast 1-5
8	Sonic anemometer KFA tower, Sophienhöhe
9	Mast SODAR KFA
10-13	Small masts 1-4 RISØ
14	Mast mobile van ICH 4
15	Sonic anemometer RISø
16	SODAR KFA
17	SODAR TÜV Rhl.
18	SODAR TÜV Essen
19	Rawin-sonde Wetteramt Essen
20	Pilotballoon Sophienhöhe Wetteramt Essen
21	Radiosonde Wetteramt Essen
22*	(Radiosonde IGM Köln)
23	Tether sonde RISØ
24	Tether sonde IGM Köln
25	tetroons
Note: Table 6.2.22 is missing, because no measurements were made in the evening.	

The selected data set summarized in this chapter is upon request available on flexible disk.

Abbreviations in Tab. 6.2.3 - 6.2.7
Meteorological measurements at masts Sophienhöhe

WS5, WS10, WS1, WS2, WS4, WS7.5, WS15	Wind speed in m/s at the heights of 5m, 10m, 1m, 2m, 4m, 7.5m, 15m
SWS5, SWS10, SWS1, SWS2, SWS4, SWS7.5, SWS15	Standard deviation of wind speed in m/s at the hights of 5m, 10m, 1m, 2m, 4m, 7.5m, 15m
WD	Wind direction in degrees
SWD	Standard deviation of wind direction in degrees
VWSD	Vertical wind speed, downward in m/s
VWSU	Vertical wind speed, upward
-N, +N	Number of samples vertical wind speed, downward respective upward (maximal number = 60)
DT2, DT10, DT1, DT2, DT4, DT7.5, DT13	Dry-bulb temperature in degrees C at 2m, 10m, 1m, 2m, 4m, 7.5m 13m
WT2, WT10, WT1, WT2, WT4, WT7.5, WT13	Wet-bulb temperature in degrees C at 2m, 10m, 1m, 2m, 4m, 7.5m, 13m
SOL	Solar radiation (global radiation) in W/m^2
RABAL	Radiation balance in W/m^2
HTFL	Heat flux in the soil (surface heat flux) in W/m^2

TABLE 6.2.1: METEOROLOGICAL MEASUREMENTS AT KFA TOWER, 31.08.88

TIME	WIND SPEED IN (m/s) 2m	10m	20m	30m	50m	80m	100m	120m	WIND DIRECTION IN (degree) 30m	50m	120m	STANDARD DEVIATION WIND DIRECTION IN (degree) 30m	50m	120m
18:40	0.4	0.7	1.5	2.5	3.7	4.7	5.3	5.7	239	235	230	19	11	4
18:50	0.3	0.5	1.3	2.3	3.8	4.9	5.6	6.1	236	233	227	18	10	4
19:00	0.4	0.4	1.1	2.0	3.1	4.4	5.0	5.5	235	237	230	17	9	4
19:10	0.3	0.4	1.2	1.9	3.2	4.5	5.1	5.4	236	238	229	14	9	3
19:20	0.0	0.1	0.8	1.3	2.5	3.7	4.4	4.8	228	229	223	18	8	4
19:30	0.1	0.0	0.6	1.1	2.0	3.2	3.9	4.5	218	223	224	18	12	5
19:40	0.0	0.0	0.6	1.1	2.4	3.9	4.7	5.1	214	225	228	18	7	3
19:50	0.0	0.2	0.8	1.2	2.1	3.2	3.6	4.0	205	214	222	18	7	5
20:00	0.0	0.0	0.8	1.2	1.8	3.2	3.5	3.7	201	210	216	18	8	4

TIME	TEMPERATURE IN (degree C) 2m	10m	20m	30m	50m	80m	100m	120m	RADIATION BALANCE IN (W/m**2) 30m	SUNSHINE DURATION IN (min) 20m	PRECIPITATION IN (mm/10min)
18:40	19.3	19.7	19.8	19.8	19.9	19.6	19.5	19.5	-41.86	0.00	0.00
18:50	19.0	19.5	19.6	19.7	19.8	19.5	19.4	19.4	-48.84	0.00	0.00
19:00	18.8	19.3	19.3	19.5	19.6	19.4	19.3	19.3	-62.79	0.00	0.00
19:10	17.9	18.8	19.0	19.2	19.4	19.3	19.3	19.3	-76.75	0.00	0.00
19:20	17.1	18.4	18.7	18.9	19.2	19.2	19.2	19.2	-76.75	0.00	0.00
19:30	16.9	18.0	18.6	18.8	19.0	19.0	19.0	19.1	-69.77	0.00	0.00
19:40	16.5	17.6	18.5	18.6	18.9	19.1	19.1	19.1	-69.77	0.00	0.00
19:50	16.4	17.5	18.4	18.5	18.8	18.9	18.8	18.9	-55.82	0.00	0.00
20:00	16.4	17.3	18.3	18.4	18.8	18.9	18.8	18.8	-55.82	0.00	0.00

TIME	RELATIVE HUMIDITY IN (%) 2m	10m	20m	30m	50m	80m	100m	120m	PRESSURE IN (hPa)	DIFFUSION CATEGORY BY TEMP.GRAD. 120m-20m A. WIND SPEED 30m
18:40	48.6	46.7	45.2	45.7	48.2	46.7	44.8	44.8	1001.9	D
18:50	50.6	48.0	46.4	46.6	48.9	47.6	45.4	45.3	1002.0	D
19:00	51.6	48.9	47.5	47.6	49.7	48.2	46.3	46.2	1002.0	E
19:10	55.9	50.9	48.8	49.1	50.7	48.8	46.7	46.9	1002.1	F
19:20	60.3	53.1	50.5	50.0	51.7	49.5	47.0	46.9	1002.0	F
19:30	63.3	55.3	51.5	50.9	52.1	50.2	47.4	47.1	1002.1	F
19:40	67.2	57.4	51.8	51.1	52.0	50.0	46.8	46.3	1002.2	F
19:50	69.2	58.4	52.3	51.6	52.3	50.3	47.9	47.1	1002.3	F
20:00	70.3	59.9	53.0	52.5	53.2	50.6	48.4	47.9	1002.3	F

TABLE 6.2.2: METEOROLOGICAL MEASUREMENTS AT MAST RHEINBRAUN ON THE SOPHIENHOEHE, 31.08.88
(WIND DIRECTION AS ACTUAL VALUE AT THE END OF EVERY TEN MINUTE INTERVAL)

TIME	REL.HUMIDITY IN (%) 2m	WIND DIRECTION IN (degree) 10m	WIND SPEED IN (m/s) 2m	5m	10m	PRECIPITATION IN (mm/10min)	GLOBAL RADIATION IN (W/m**2)
18:40	53.8	232	2.5	3.1	3.3	0.00	120.91
18:50	55.4	230	2.5	2.9	3.4	0.00	117.27
19:00	56.2	226	1.8	2.4	2.9	0.00	110.91
19:10	58.2	244	1.9	2.2	2.9	0.00	100.91
19:20	59.5	250	1.8	2.3	2.9	0.00	96.36
19:30	60.8	230	1.4	1.9	2.4	0.00	93.64
19:40	60.9	244	1.4	1.9	2.5	0.00	91.82
19:50	61.3	241	1.3	1.9	2.5	0.00	90.91
20:00	61.4	227	1.2	1.6	2.2	0.00	90.00

TABLE 6.2.3: METEOROLOGICAL MEASUREMENTS AT MAST 1 SOPHIENHOEHE, 31.08.88

TIME	WS5	WS10	SWS5	SWS10	WD	SWD	VWSD	-N	VWSU	+N	DT2	DT10	WT2	WT10
18:40	1.6	2.5	0.6	0.7	238	20	-0.28	38	0.20	13	18.2	18.4	12.9	12.7
18:50	1.4	2.2	0.7	0.7	231	17	-0.22	23	0.19	16	17.9	18.3	12.9	12.7
19:00	1.2	2.1	0.8	0.8	240	21	-0.30	24	0.18	18	17.8	18.1	12.9	12.7
19:10	0.9	1.7	0.5	0.5	239	16	-0.17	20	0.11	15	17.4	17.9	12.8	12.6
19:20	0.7	1.5	0.4	0.4	240	14	-0.13	16	0.08	10	16.6	17.6	12.7	12.6
19:30	1.1	1.9	0.6	0.6	237	15	-0.21	21	0.14	18	17.0	17.7	12.7	12.6
19:40	0.9	1.7	0.5	0.5	234	19	-0.21	18	0.14	16	17.0	17.6	12.6	12.5
19:50	0.8	1.7	0.4	0.4	234	12	-0.13	17	0.11	19	16.6	17.5	12.6	12.5
20:00	1.0	1.7	0.3	0.3	236	11	-0.18	19	0.09	12	16.6	17.5	12.7	12.6

TABLE 6.2.4: METEOROLOGICAL MEASUREMENTS AT MAST 2 SOPHIENHOEHE, 31.08.88

TIME	WS2	WS4	WS7.5	WS15	SWS2	SWS4	SWS7.5	SWS15	WD	SWD	VWSD	-N	VWSU	+N	DT2	DT13	WT2	WT13
18:40	0.5	1.4	2.3	2.8	0.2	0.4	0.6	0.7	235	17	0.00	0	0.93	60	18.7	19.5	13.0	13.1
18:50	0.5	1.4	2.3	2.7	0.2	0.5	0.7	0.6	236	15	-0.11	1	0.84	59	18.8	19.5	13.0	13.1
19:00	0.5	1.3	2.1	2.5	0.2	0.4	0.5	0.5	239	14	-0.08	1	0.72	56	18.5	19.4	12.9	13.2
19:10	0.4	1.2	1.9	2.3	0.3	0.5	0.6	0.6	238	14	-0.36	1	0.63	55	18.2	19.3	12.8	13.2
19:20	0.1	0.8	1.3	1.6	0.1	0.3	0.3	0.3	248	14	0.00	0	0.46	57	17.3	19.1	12.6	13.1
19:30	0.2	0.5	1.3	1.5	0.1	0.4	0.7	0.6	222	19	0.00	0	0.48	59	17.1	19.0	12.6	13.1
19:40	0.1	0.9	1.7	2.2	0.1	0.4	0.4	0.4	221	11	0.00	0	0.51	58	16.9	19.0	12.6	13.1
19:50	0.0	0.6	1.4	1.9	0.0	0.3	0.3	0.3	217	11	0.00	0	0.60	60	16.6	18.8	12.6	13.0
20:00	0.1	0.5	1.2	1.5	0.0	0.4	0.4	0.4	220	15	-0.06	1	0.40	49	17.1	18.8	12.7	13.0

TABLE 6.2.5: METEOROLOGICAL MEASUREMENTS AT MAST 3 SOPHIENHOEHE, 31.08.88

TIME	WS5	WS10	SWS5	SWS10	WD	SWD	VWSD	-N	VWSU	+N	DT2	DT10	WT2	WT10
18:40	2.0	3.3	0.5	0.7	203	11	-0.16	9	0.32	46	19.3	19.6	13.1	12.9
18:50	2.0	3.4	0.7	0.8	199	13	-0.23	12	0.32	42	19.1	19.5	13.1	13.0
19:00	2.0	3.3	0.5	0.7	196	13	-0.19	9	0.37	39	19.1	19.4	13.1	13.0
19:10	2.0	2.8	0.5	0.6	187	11	-0.26	18	0.20	26	18.8	19.3	13.1	13.0
19:20	1.9	2.7	0.4	0.5	188	12	-0.23	17	0.25	33	18.7	19.1	13.1	13.0
19:30	1.9	2.6	0.4	0.5	183	11	-0.19	18	0.21	26	18.8	19.1	13.1	13.0
19:40	2.0	2.5	0.3	0.4	179	9	-0.17	23	0.15	20	18.5	18.9	13.0	12.9
19:50	2.3	2.9	0.3	0.3	175	9	-0.20	22	0.20	21	18.6	18.9	13.0	12.8
20:00	2.2	2.8	0.3	0.4	175	8	-0.19	27	0.16	18	18.6	18.9	13.0	12.8

TABLE 6.2.6: METEOROLOGICAL MEASUREMENTS AT MAST 4 SOPHIENHOEHE, 31.08.88

TIME	WS2	WS4	WS7.5	WS15	SWS2	SWS4	SWS7.5	SWS15	WD	SWD	VWSD	-N	VWSU	+N	DT2	DT13	WT2	WT13
18:40	1.3	1.8	2.3	3.1	0.5	0.7	0.7	0.8	221	13	-0.32	26	0.20	19	18.9	19.6	13.1	12.8
18:50	1.1	1.6	2.1	2.9	0.4	0.5	0.5	0.7	221	14	-0.33	26	0.14	13	18.7	19.5	13.1	12.8
19:00	1.1	1.6	2.1	3.1	0.3	0.4	0.5	0.7	215	14	-0.40	30	0.15	9	18.4	19.3	13.1	12.9
19:10	1.1	1.5	1.9	2.8	0.3	0.4	0.5	0.6	210	12	-0.30	30	0.16	13	17.9	19.1	13.1	12.8
19:20	1.2	1.6	1.9	2.7	0.3	0.4	0.4	0.6	208	12	-0.31	18	0.13	14	17.3	18.8	12.9	12.8
19:30	1.2	1.6	2.2	2.9	0.2	0.4	0.3	0.5	206	9	-0.31	24	0.09	11	17.3	18.8	12.9	12.8
19:40	1.2	1.5	2.1	2.6	0.2	0.3	0.4	0.4	200	9	-0.35	21	0.10	11	17.1	18.6	12.9	12.8
19:50	1.3	1.5	2.2	2.9	0.2	0.3	0.3	0.5	200	10	-0.25	25	0.12	6	17.0	18.5	12.8	12.7
20:00	1.3	1.6	2.1	2.8	0.2	0.4	0.3	0.4	206	10	-0.28	30	0.12	9	17.3	18.6	12.9	12.7

TABLE 6.2.7: METEOROLOGICAL MEASUREMENTS AT MAST 5 SOPHIENHOEHE, 31.08.88

TIME	WS2	WS4	WS1	WS15	SWS2	SWS4	SWS1	SWS15	WD	SWD	VWSD	-N	VWSU	+N	DT2	DT15	WT2	WT15
18:40	3.0	3.5	2.4	4.8	0.7	0.9	0.6	0.7	229	11	-0.13	8	0.33	47	17.8	18.4	12.5	12.7
18:50	2.8	3.3	2.2	4.7	0.6	0.7	0.5	0.8	225	9	-0.18	9	0.27	46	17.6	18.2	12.5	12.7
19:00	2.6	3.1	2.1	4.5	0.6	0.6	0.6	0.6	223	9	-0.19	12	0.25	43	17.4	18.0	12.5	12.7
19:10	2.3	2.7	1.8	4.2	0.4	0.5	0.5	0.7	224	9	-0.14	7	0.24	40	17.1	17.8	12.3	12.6
19:20	2.2	2.6	1.8	4.3	0.4	0.5	0.4	0.4	220	8	-0.15	9	0.19	40	16.8	17.7	12.3	12.6
19:30	2.1	2.3	1.6	4.0	0.5	0.5	0.4	0.5	219	8	-0.12	12	0.22	32	16.8	17.6	12.3	12.6
19:40	2.3	2.6	1.6	4.1	0.5	0.6	0.4	0.5	220	7	-0.22	14	0.20	37	16.8	17.6	12.3	12.5
19:50	2.1	2.5	1.6	4.1	0.4	0.4	0.4	0.4	220	7	-0.12	13	0.17	39	16.8	17.6	12.2	12.5
20:00	2.2	2.4	1.4	4.0	0.4	0.5	0.4	0.5	215	7	-0.13	14	0.17	37	16.8	17.5	12.2	12.5

TIME	DT4	WT4	DT7.5	WT7.5	DT1	WT1	SOL	HTFL	RABAL	WS7.5	SWS7.5
18:40	17.7	12.5	18.2	12.8	18.0	12.9	32.7	-6.0	-10.6	4.0	0.9
18:50	17.5	12.5	18.1	12.8	17.8	12.9	25.7	-6.7	-25.6	3.8	0.6
19:00	17.3	12.5	17.9	12.8	17.5	12.8	20.3	-7.7	-30.9	3.7	0.6
19:10	17.0	12.4	17.6	12.8	17.1	12.7	8.9	-8.6	-55.0	3.3	0.6
19:20	16.8	12.4	17.5	12.7	16.9	12.6	5.1	-9.9	-48.2	3.3	0.5
19:30	16.8	12.4	17.4	12.7	16.9	12.7	3.3	-10.8	-40.6	3.1	0.5
19:40	16.8	12.3	17.4	12.7	16.8	12.6	2.1	-11.1	-44.9	3.1	0.5
19:50	16.7	12.3	17.4	12.6	16.9	12.6	2.1	-11.2	-30.3	3.1	0.5
20:00	16.8	12.3	17.3	12.6	16.9	12.6	2.5	-10.7	-25.2	3.0	0.5

TABLE 6.2.8: METEOROLOGICAL MEASUREMENTS AT SONIC KFA (50M,120M), 31. 8.88
AND SONIC SOPHIENHOEHE (MAST 5, 9.5M)
(WIND SPEED IN (M/S), WIND DIRECTION IN (DEGREE))

TIME	WIND SPEED 9.5m	50m	120m	VERTICAL WIND SPEED 9.5m	50m	120m	WIND DIRECTION 9.5m	50m	120m	STANDARD DEVIATION WIND SPEED 9.5m	50m	120m	STANDARD DEVIATION VERTICAL WIND SPEED 9.5m	50m	120m
18:40	3.93	3.99	6.15	0.05	-0.11	-0.18	232	233	233	1.03	1.20	0.65	0.42	0.53	0.32
18:50	4.31	4.14	6.56	0.07	-0.12	-0.24	231	231	230	1.16	1.15	0.71	0.46	0.49	0.33
19: 0	4.11	3.65	6.00	0.07	-0.15	-0.16	228	234	232	1.18	1.10	0.66	0.47	0.46	0.29
19:10	4.02	3.68	5.96	0.06	-0.21	-0.13	225	235	231	1.02	0.83	0.51	0.46	0.41	0.22
19:20	3.80	2.92	5.32	0.04	-0.09	-0.03	225	229	226	0.92	0.69	0.70	0.43	0.31	0.31
19:30	3.47	2.46	4.96	0.05	-0.07	-0.03	224	222	226	0.81	0.69	0.64	0.38	0.34	0.28
19:40	3.60	2.87	5.67	0.02	-0.10	-0.12	222	222	231	0.80	0.58	0.44	0.35	0.28	0.19
19:50	3.21	2.60	4.53	0.03	-0.15	-0.12	218	213	226	0.72	0.54	0.57	0.33	0.23	0.16
20: 0	3.42	2.64	4.21	0.01	-0.13	-0.12	218	208	219	0.87	0.47	0.34	0.39	0.20	0.11

TIME	STANDARD DEVIATION WIND DIRECTION 9.5m	50m	120m	STANDARD DEVIATION VERTICAL WIND DIRECTION 9.5m	50m	120m	STANDARD DEVIATION HORIZONTAL WIND SPEED LONGITUDINAL 9.5m	50m	120m	STANDARD DEVIATION HORIZONTAL WIND SPEED LATERAL 9.5m	50m	120m
18:40	10	12	5	6	8	3	0.77	0.93	0.42	0.68	0.76	0.50
18:50	10	10	4	6	7	3	0.92	0.92	0.55	0.70	0.69	0.45
19: 0	10	10	4	7	7	3	0.94	0.93	0.52	0.71	0.61	0.40
19:10	10	8	3	7	6	2	0.80	0.69	0.39	0.64	0.46	0.32
19:20	9	9	4	6	6	3	0.70	0.51	0.59	0.59	0.47	0.38
19:30	9	10	5	6	8	3	0.62	0.55	0.51	0.52	0.42	0.38
19:40	8	7	3	6	6	2	0.64	0.47	0.33	0.49	0.35	0.30
19:50	9	8	5	6	5	2	0.54	0.39	0.42	0.47	0.37	0.38
20: 0	9	8	4	7	4	2	0.67	0.32	0.16	0.56	0.35	0.30

TABLE 6.2.9: METEOROLOGICAL MEASUREMENTS AT MAST SODAR KFA, 31. 8.88
(ALL PARAMETERS AT 15 m)

TIME	WIND SPEED IN (m/s)	VERTICAL WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)	STANDARD DEVIATION VERTICAL WIND SPEED IN (cm/s)
18:40	1.97	0.19	203	29.00
18:50	1.97	0.20	205	25.00
19: 0	1.76	0.24	194	23.00
19:10	1.42	0.13	183	29.00
19:20	1.26	0.10	171	25.00
19:30	1.56	0.07	164	21.00
19:40	1.74	0.18	160	22.00
19:50	1.84	0.15	160	18.00
20: 0	1.71	0.09	156	19.00

TABLE 6.2.10: METEOROLOGICAL MEASUREMENTS AT MAST 1 RISOE, 31.08.88 (ALL PARAMETERS AT 3.3 M)

TIME	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
18:40	2.28	228
18:50	1.97	228
19: 0	2.38	225
19:10	2.24	208
19:20	2.35	212
19:30	2.52	214
19:40	2.61	212
19:50	2.51	213
20: 0	2.71	215

TABLE 6.2.11: METEOROLOGICAL MEASUREMENTS AT MAST 2 RISOE, 31.08.88 (ALL PARAMETERS AT 3.3 M)

TIME	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
18:40	2.71	200.
18:50	2.80	199.
19: 0	3.16	198.
19:10	2.71	189.
19:20	2.81	195.
19:30	3.67	194.
19:40	3.01	190.
19:50	3.09	187.
20: 0	3.03	188.

TABLE 6.2.12: METEOROLOGICAL MEASUREMENTS AT MAST 3 RISOE, 31.08.88 (ALL PARAMETERS AT 3.3 M)

TIME	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
18:40	3.59	210.
18:50	3.32	208.
19: 0	3.75	212.
19:10	3.55	209.
19:20	3.78	210.
19:30	3.77	208.
19:40	3.70	207.
19:50	3.78	205.
20: 0	3.58	209.

TABLE 6.2.13: METEOROLOGICAL MEASUREMENTS AT MAST 4 RISOE, 31.08.88 (ALL PARAMETERS AT 3.3 M)

TIME	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
18:40	2.82	232.
18:50	2.61	228.
19: 0	2.51	212.
19:10	2.43	222.
19:20	2.38	215.
19:30	2.35	209.
19:40	2.01	214.
19:50	1.95	218.
20: 0	2.08	213.

TABLE 6.2.14: METEOROLOGICAL MEASUREMENTS AT MAST ICH4, 31.08.88 (ALL PARAMETERS AT 7.2 M)

TIME	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)	STANDARD DEVIATION WIND SPEED IN (m/s)	STANDARD DEVIATION WIND DIRECTION IN (degree)
18:40	2.10	255	0.70	20
18:50	1.80	260	0.70	21
19: 0	1.70	269	0.80	22
19:10	1.70	264	0.60	20
19:20	1.90	281	0.50	14
19:30	1.70	278	0.40	14
19:40	1.80	277	0.40	13
19:50	2.00	293	0.30	8
20: 0	1.70	292	0.40	9

TABLE 6.2.15: METEOROLOGICAL MEASUREMENTS AT SONIC RISOE, 31.08.88
(ALL PARAMETERS AT 6.5 M)

TIME	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)	TEMPERATURE IN (degree C)	WINDVECTOR TILT IN (degree)	VARIANCE u'u' IN ((m/s)**2)	COVARIANCE u'v' IN ((m/s)**2)	COVARIANCE u'w' IN ((m/s)**2)
18:40	2.74	231	20.7	-4.48	0.51	-0.06	-0.02
18:50	2.69	235	20.5	-3.90	0.33	-0.04	-0.05
19: 0	1.99	225	20.3	-3.51	0.28	0.03	-0.01
19:10	1.88	228	20.1	-4.06	0.20	0.01	-0.02
19:20	1.81	235	19.8	-6.00	0.16	-0.01	0.00
19:30	1.47	233	19.6	-5.60	0.10	0.02	0.00
19:40	1.15	230	19.4	-6.99	0.05	-0.01	0.00
19:50	1.14	216	19.4	-9.14	0.11	-0.02	0.01
20: 0	1.11	208	19.5	-8.76	0.23	-0.08	0.01

TIME	COVARIANCE u'T' IN (m/s)(degree C)	VARIANCE v'v' IN ((m/s)**2)	COVARIANCE v'w' IN ((m/s)**2)	COVARIANCE v'T' IN (m/s)(degree C)	VARIANCE w'w' IN ((m/s)**2)	COVARIANCE w'T' IN (m/s)(degree C)	VARIANCE T'T' IN ((degree C)**2
18:40	0.04	0.27	-0.03	0.00	0.15	-0.01	0.01
18:50	0.03	0.26	-0.03	-0.01	0.15	-0.01	0.01
19: 0	0.04	0.19	0.00	0.00	0.10	-0.01	0.03
19:10	0.04	0.16	-0.01	0.01	0.09	-0.02	0.03
19:20	0.04	0.07	0.00	0.00	0.04	-0.01	0.03
19:30	0.03	0.06	0.00	0.01	0.03	0.00	0.02
19:40	0.02	0.05	0.00	0.00	0.02	0.00	0.02
19:50	0.02	0.06	-0.01	0.00	0.03	0.00	0.02
20: 0	0.04	0.08	-0.01	-0.01	0.03	0.00	0.02

TABLE 6.2.16: METEOROLOGICAL MEASUREMENTS AT SODAR KFA, 31.08.88

WIND SPEED IN (m/s)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40		1.8	2.3	3.8	5.3	6.4	8.1	8.5	6.7	6.0														
18:50		2.6	2.9	4.9	6.5	7.1	8.9	9.0	6.9	7.1														
19: 0		2.3	2.8	3.2	4.7	6.4	6.9	7.1	8.4	7.2	8.3	9.0												
19:10		3.0	2.9	4.5	6.5	7.0	7.9	8.3	8.0	8.6														
19:20		2.5	3.0	4.5	5.3	6.7	8.0																	
19:30		1.8	2.4	3.9	4.2	4.8	6.9	6.6	5.6	7.0	7.5													
19:40		2.2	1.9	3.8	4.3	4.6	6.0	6.1	6.5	7.5	7.3	7.2			7.3									
19:50		2.3	3.0	4.5	5.4	4.8	6.1	7.1		7.6														
20: 0		2.2	2.0	2.8	4.1	4.6	6.2	6.6																

VERTICAL WIND SPEED IN (m/s)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40		0.3	0.2	0.1	0.2	0.3	0.2	0.0	0.4	0.5														
18:50		0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.3	0.4														
19: 0		0.1	0.1	0.3	0.3	0.1	0.2	0.3	0.2	0.3	0.1	0.1												
19:10		0.0	0.1	0.1	0.2	0.2	0.2	0.0	0.2	0.1														
19:20		-0.1	-0.1	0.1	0.0	0.1	-0.1																	
19:30		0.1	0.0	0.0	0.2	0.3	0.1	0.2	0.3	0.2	0.2													
19:40		0.0	0.1	-0.1	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	-0.2												
19:50		-0.1	-0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.0														
20: 0		-0.1	0.0	0.0	0.1	0.1	0.1	-0.1																

WIND DIRECTION IN (degree)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40		196	197	203	209	215	224	223	219	225														
18:50		205	190	211	214	214	221	222	214	209														
19: 0		203	211	209	213	220	216	218	224	220	228	225												
19:10		207	213	211	222	226	225	225	225	225														
19:20		213	220	221	219	214	212																	
19:30		180	200	207	208	209	220	212	208	210	227													
19:40		183	180	209	211	221	218	219	222	220	217	222			236									
19:50		192	205	211	220	227	220	220		225														
20: 0		198	194	201	211	216	213	219																

ECHO INTENSITY IN (mV)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40		289	321	298	244	191	145	133	177	127														
18:50		316	333	328	250	210	174	122	129	102														
19: 0		315	318	317	278	238	198	159	147	118	105	134												
19:10		352	398	352	277	198	155	96	89	89														
19:20		349	414	461	320	217	116																	
19:30		344	377	353	328	269	176	122	122	107	77													
19:40		336	339	342	336	257	180	138	134	107	77	109												
19:50		337	420	442	332	193	94	103	104	124														
20: 0		321	366	302	247	196	159	116																

TABLE 6.2.16 CONTINUED

STANDARD DEVIATION VERTICAL WIND SPEED IN (m/s)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40		0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.1														
18:50		0.0	0.1	0.2	0.1	0.1	0.2	0.2	0.1	0.1														
19: 0		0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.1	0.0												
19:10		0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.2														
19:20		0.2	0.1	0.0	0.1	0.0	0.0																	
19:30		0.1	0.1	0.1	0.1	0.0	0.1	0.2	0.2	0.2	0.2													
19:40		0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.2	0.3	0.3												
19:50		0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0														
20: 0		0.0	0.0	0.0	0.0	0.1	0.2	0.1																

STANDARD DEVIATION WIND DIRECTION IN (degree)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40				1		1																		
18:50			1	1																				
19: 0				1		1		6																
19:10			1	1	3																			
19:20				1																				
19:30																								
19:40		12		1																				
19:50		1	1	1	4																			
20: 0		1																						

STANDARD DEVIATION ECHO INTENSITY IN (mV)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40		17	33	32	28	31	17	27	27	27														
18:50		10	24	20	28	38	33	19	21	18														
19: 0		8	30	25	48	31	33	44	18	17	15	36												
19:10		12	19	25	41	27	28	18	24	21														
19:20		11	15	20	37	50	34																	
19:30		11	17	25	24	39	19	29	36	34	17													
19:40		13	13	33	30	31	41	29	50	29	30	32												
19:50		13	18	20	25	28	29	17	14	21														
20: 0		15	17	36	36	39	153	27																

DISSIPATION RATE IN (mm**2/s**3)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40		69	55	52	52	46	54	59	53	31														
18:50		3	40	46	39	31	45	46	19	29														
19: 0		3	35	35	31	42	45	53	72	65	27	3												
19:10		3	28	28	39	40	17	3	15	41														
19:20		44	14	10	16	10	3																	
19:30		34	28	21	21	12	16	45	59	49	46													
19:40		3	14	25	17	4	3	3	18	47	67	77			0									
19:50		33	11	7	16	15	15	23	20	8														
20: 0		3	3	8	13	29	43	24																

TABLE 6.2.17: METEOROLOGICAL MEASUREMENTS AT SODAR KOELN, 31.08.88

WIND SPEED IN (m/s)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m
18:40		4.2	5.0	6.1	6.2	5.9	7.1	7.0	7.9	7.6	8.7	8.7	8.7	8.8	8.6	8.4	8.5	8.7	9.7	
18:50	3.7	4.2	5.1	5.4	5.9	6.7	6.4	6.6	7.2	6.5	7.4	7.8	8.2	7.7	8.1	8.0	7.8	7.9	8.1	9.8
19: 0	4.1	4.5	5.3	5.7	6.6	8.3	7.6	7.2	7.7	7.9	8.6	8.4	9.0	9.6	10.1	9.0	8.4	9.3	8.9	8.0
19:10		6.0	5.5	6.4	6.6	7.4	7.5	8.0	8.0	8.1	7.9	8.3	9.4	9.8	8.6	8.6	7.9			
19:20		5.0	6.0	6.5	6.6	7.2	7.5	7.8	9.1	7.8	7.7	9.3	9.3	8.9	8.9	9.4	8.7	9.5	8.8	
19:30	4.6	5.2	5.5	5.7	6.3	6.9	8.2	7.5	7.1	7.5	7.6	7.4	7.4	7.2	8.5	7.2	7.7	8.5	7.8	9.2
19:40		6.3	6.4	6.6	7.5	7.5	7.7	7.9	8.1	8.1	7.8	8.8	8.5	8.4	7.8	9.0	8.8		9.3	10.1
19:50	5.9	5.7	6.2	6.3	6.7	6.9	7.9	7.7	8.0	7.7	7.9	8.6	8.0	8.5	9.0			10.1	9.3	
20: 0	4.2	5.2	6.3	6.6	6.6	7.5	7.5	7.0	7.6	8.1	8.0	8.6	8.5	9.4	9.0	8.8	9.1			

VERTICAL WIND SPEED IN (m/s)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m
18:40	-0.5	-0.5	-0.8	-0.8	-0.7	-1.0	-1.0	-1.1	-1.0	-1.0	-0.9	-1.0	-1.0	-0.9	-0.9	-0.9	-0.9	-0.8	-1.1	
18:50	-0.5	-0.7	-0.8	-1.0	-0.9	-0.9	-0.9	-1.0	-0.9	-1.1	-1.0	-1.0	-0.9	-1.1	-1.0	-1.0	-1.1	-1.0	-0.9	-0.8
19: 0	-0.6	-0.8	-1.0	-1.1	-0.9	-0.8	-1.0	-1.1	-1.0	-1.1	-1.2	-1.3	-1.2	-1.1	-1.1	-1.3	-1.2	-1.2	-0.9	-1.0
19:10	-0.5	-0.8	-1.0	-0.9	-1.0	-1,1	-1.1	-1.1	-1.2	-1.1	-1.2	-1.1	-1.1	-1.1	-1.1	-1.1	-1.0			
19:20	-1.1	-0.7	-1.0	-0.9	-1.0	-1.0	-0.9	-1.0	-1.1	-1.1	-1.1	-1.1	-1.1	-1.2	-1.0	-1.0	-1.1	-1.1	-1.1	
19:30	-0.6	-0.7	-0.9	-1.0	-0.9	-0.8	-0.7	-0.8	-1.0	-0.9	-0.9	-0.8	-0.7	-0.9	-0.8	-0.9	-0.9	-1.1	-0.8	-1.0
19:40	-0.8	-0.6	-0.7	-0.9	-0.8	-0.9	-0.9	-0.9	-0.8	-1.0	-0.9	-1.0	-1.0	-1.2	-1.3	-0.9	-0.9		-0.7	-0.8
19:50	-0.8	-0.8	-0.8	-0.8	-0.9	-0.9	-0.8	-0.9	-0.9	-1.0	-1.1	-1.0	-1.1	-1.0	-1.2			-1.1	-1.0	
20: 0	-0.9	-1.0	-0.9	-1.1	-0.9	-0.9	-0.9	-1.0	-1.0	-1.0	-0.9	-0.9	-0.9	-0.9	-1.1	-1.3	-1.1			

WIND DIRECTION IN (degree)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m
18:40		233	234	238	240	249	243	246	245	244	236	242	241	245	240	235	238	233	249	
18:50	236	245	245	248	244	242	242	244	239	245	246	244	242	247	248	243	249	245	242	231
19: 0	232	244	246	248	232	235	236	245	236	241	245	249	248	242	240	252	249	246	242	247
19:10		229	242	237	243	244	246	243	245	248	250	241	243	246	243	244	238			
19:20		238	245	234	243	244	241	243	243	246	248	245	247	253	244	237	248	248	236	
19:30	219	227	235	237	234	233	232	237	238	238	241	237	233	240	239	239	240	251	240	241
19:40		224	229	237	234	234	237	236	236	242	238	243	248	255	253	249	244		244	246
19:50	227	224	230	229	234	238	232	237	240	244	247	244	248	251	252			253	250	
20: 0	228	239	235	242	238	240	244	245	249	250	251	250	253	255	251	260	259			

ECHO INTENSITY IN (mV)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m
18:40	250	360	410	400	346	318	299	210	163	154	146	113	106	95	91	82	77	80	86	
18:50	257	451	457	429	371	272	238	184	152	147	147	96	89	88	77	92	77	74	68	70
19: 0	244	459	508	490	413	281	231	202	175	169	139	130	118	104	97	80	69	67	74	63
19:10	257	457	490	455	405	269	219	161	145	138	108	89	69	70	68	68	60			
19:20	255	458	573	474	367	258	203	159	141	131	110	93	79	78	64	64	56	46	48	
19:30	246	466	476	290	166	110	84	90	105	86	88	86	77	84	80	97	79	76	98	74
19:40	259	456	495	391	221	148	132	135	105	113	112	104	130	128	121	107	116		99	126
19:50	245	456	502	347	286	222	207	192	180	127	122	112	131	98	101			99	100	
20: 0	263	427	422	287	249	183	167	140	134	159	89	112	109	110	95	104	79			

TABLE 6.2.17 CONTINUED

STANDARD DEVIATION VERTICAL WIND SPEED IN (m/s)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m
18:40	0.3	0.3	0.2	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.3	
18:50	0.0	0.2	0.2	0.1	0.1	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.3
19: 0	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.3	0.3	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.4
19:10	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.2	0.3	0.2	0.2	0.2	0.1	0.2	0.2			
19:20	0.0	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.4	0.3	
19:30	0.3	0.1	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.3
19:40	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.2	0.3	0.2	0.1	0.2		0.0	0.0
19:50	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.0			0.0	0.4	
20: 0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.0	0.1	0.2	0.1	0.0	0.1	0.2	0.3			

STANDARD DEVIATION WIND DIRECTION IN (degree)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m
18:40		1	1	2	2	3	4	3	1	1	1	1	1	1						
18:50		1	1	1	1	1	1	1	1	1	1	1	1	1	3		1			
19: 0		1	1	1	1	1	1	1	1	1	1	1	1	1						
19:10		1	1	1	1	1	1	1	1	1	1									
19:20			1	1	1	1	1	1	1	1	1	1	1			1				
19:30		1	1	1	1	1	2	1	1	1		1	1							
19:40		1	1	1	1	1	1	1	1	1	1	1	1	1	2	4				
19:50		1	1	1	1	1	1	1	1	1		1								
20: 0		1	1	1		1	1	1	1	1	1	1	1							

STANDARD DEVIATION ECHO INTENSITY IN (mV)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m
18:40	12	26	31	30	37	33	38	41	28	42	42	34	37	46	27	37	28	34	29	
18:50	7	13	24	34	32	42	55	40	35	55	55	40	43	30	27	38	31	35	41	51
19: 0	11	15	22	36	38	35	25	34	32	33	32	45	51	31	33	39	39	37	34	60
19:10	11	15	19	28	42	36	42	34	31	47	33	38	47	38	26	32	32			
19:20	14	14	16	25	32	36	45	45	30	35	44	38	39	87	38	38	26	29	34	
19:30	11	11	21	34	40	41	32	38	28	27	37	31	22	27	24	48	42	41	41	38
19:40	7	17	24	30	31	36	36	30	32	31	25	28	31	42	28	20	31		26	25
19:50	6	15	29	31	43	29	37	43	50	34	44	38	27	36	40			27	32	
20: 0	13	12	26	32	34	35	33	27	38	71	43	34	45	27	27	25	26			

STABILITY CLASS (1=STABLE TO 5=UNSTABLE)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m
18:40		2	2	1	2	2	2	2	2	2	1	1	1	1						
18:50	1	2	2	1	1	1	2	1	1	1	1	1	1	2	2		1			
19: 0		1	1	1	1	1	1	1	1	1	2	1	1	1						
19:10		1	1	1	1	1	1	1	1	1	2									
19:20			2	2	2	1	1	1	1	1	1	1	1			1				
19:30		1	1	1	1	1	2	2	1	1		1	1							
19:40		1	1	1	1	1	1	1	1	1	1	1	1	1	1	2				
19:50		1	1	1	1	1	1	1	1	1		1								
20: 0		1	1	1		1	1	1	1	1	1	1	1							

TABLE 6.2.17 CONTINUED

INVERSION MARKER (0 OR -1, -1=INVERSION)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m
18:40	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0
18:50	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19: 0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19:10	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19:20	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19:30	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19:40	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19:50	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20: 0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 6.2.18: METEOROLOGICAL MEASUREMENTS AT SODAR ESSEN, 31.08.88

WIND SPEED IN (m/s)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40	5.0	5.0	5.5	5.5	5.4	5.9	5.1	5.4	5.3	6.2	6.6	5.6		6.3				9.7						
18:50	4.5	4.6	4.8	4.8	4.6	5.1	5.5	5.4	5.4	5.0	4.9													
19: 0	4.6	5.0	5.1	5.0	5.1	5.3	5.1	5.0	5.4	5.2	5.3	6.8		7.4			9.0							
19:10	4.3	5.0	5.1	5.3	5.1	5.5	5.3	5.4	5.7	6.0	6.0	7.2	7.9	8.4	8.8	8.2								
19:20	4.6	4.4	4.6	5.0	4.9	4.9	5.7	5.6	6.3	5.8	5.8	6.8	6.4		6.9									
19:30	4.6	4.4	4.7	5.2	5.4	5.8	5.9	6.6	6.6	6.9	8.1	6.7	6.6	6.7										
19:40	4.7	4.9	5.3	5.1	5.6	6.2	6.6	6.7	7.0	7.3	7.8	9.0		8.1			23.4				13.8			
19:50	4.5	4.8	5.1	5.0	4.9	5.0	5.1	5.7	5.9	6.6		8.5												
20: 0	2.8	3.4	3.7	4.0	4.3	4.7	5.0	5.6	5.4	6.2	5.7	5.8	5.5		6.6		16.4							

VERTICAL WIND SPEED IN (m/s)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40	0.1	0.0	-0.1	0.0	0.0	-0.1	0.1	-0.1	0.0	-0.1	-0.1	0.0	-0.1	-0.1	-0.1	0.1	0.0	0.0	0.1	0.6	0.7	0.3	0.7	0.4
18:50	0.0	0.1	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.1	1.2			
19: 0	0.0	-0.2	-0.3	-0.2	-0.1	-0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.1	-0.1	0.1	-0.1	0.1	0.0	-0.1	0.0	0.0	0.0	-0.8
19:10	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.3	0.1	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.1	0.3	0.0	
19:20	-0.1	-0.1	0.0	-0.1	0.0	0.0	-0.1	-0.1	-0.1	0.1	0.2	0.0	0.2	0.2	0.2	0.1	0.1	0.0	-0.3	0.1		0.1	-0.1	
19:30	-0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.2	0.0		0.1		0.3	0.2			
19:40	0.0	0.0	-0.1	0.1	0.1	0.0	-0.1	0.0	0.0	0.2	0.1	0.0	-0.1	-0.1	0.0		-0.2							
19:50	0.0	-0.1	-0.1	0.0	0.1	0.1	0.2	0.2	0.2	0.0	0.3	0.0	0.4	0.3										
20: 0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.2	-0.1	-0.1	0.0	0.1	0.1	0.1	0.0	0.2	-0.1	0.0	0.3			0.1

TABLE 6.2.18 CONTINUED

WIND DIRECTION IN (degree)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40	241	235	241	240	237	240	233	236	242	222	226	235		250				213						
18:50	239	224	231	229	233	229	231	232	234	235	236													
19: 0	236	226	231	229	237	235	226	235	232	238	235	238		241			242							
19:10	235	227	233	238	230	235	236	234	235	235	235	238	243	240	241	241								
19:20	228	232	228	225	227	233	236	239	235	233	226	236	234		233									
19:30	233	231	223	229	230	231	232	234	239	241	241	237	245	231										
19:40	228	231	237	234	233	236	239	238	240	238	236	238		219			244				81			
19:50																								
20: 0	233	234	233	229	221	230	229	233	236	226	244	242	244		243		180							

ECHO INTENSITY IN (mV)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40	434	465	497	536	567	600	580	479	475	516	470	417	415	517	524	408	428	475	347	346	298	281	321	368
18:50	491	498	529	567	564	517	582	539	554	552	557	567	538	521	473	452	471	384	391	318	357			
19: 0	579	721	721	751	910	807	734	749	845	680	698	712	606	586	567	467	472	404	388	408	425	428	383	347
19:10	534	651	657	772	860	900	854	1030	970	1000	916	886	880	768	632	556	526	547	512	415	357	387	338	
19:20																								
19:30	622	837	981	1009	1066	1194	1438	1184	936	864	583	522	461	459	387	398		301		298	261			
19:40	720	949	1067	1171	1056	1207	1131	1009	1081	960	649	614	480	407	378		268							
19:50	610	752	874	996	981	1062	1062	775	568	535	419	440	476	546										
20: 0																								

STANDARD DEVIATION VERTICAL WIND SPEED IN (m/s)

TIME	40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
18:40	0.7	0.6	0.6	0.7	0.5	0.6	0.7	0.6	0.8	0.3	0.6	0.8	0.5	0.3	0.7	0.0	0.5	0.5	0.4	0.0	0.0	0.0	0.0	0.0
18:50	0.6	0.6	0.7	0.6	0.7	0.7	0.6	0.7	0.6	0.6	0.6	0.6	0.4	0.6	0.8	0.3	0.7	0.8	0.7	0.0	0.5			
19: 0	0.6	0.6	0.7	0.7	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.8	0.7	0.8	0.7	0.8	0.8	1.1	0.7
19:10	0.6	0.5	0.6	0.6	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.7	0.7	0.8	0.6	1.1	1.1	0.0	0.6	
19:20	0.6	0.7	0.6	0.6	0.7	0.6	0.7	0.7	0.7	0.7	0.8	0.6	0.7	0.7	0.7	0.7	0.6	0.7	0.8	0.6		0.4	0.6	
19:30	0.6	0.6	0.5	0.6	0.7	0.7	0.6	0.6	0.6	0.6	0.4	0.5	0.6	0.7	0.7	0.8		0.8		0.5	0.0			
19:40	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.7	0.8	0.6	0.6	0.6	0.6		0.0							
19:50	0.6	0.5	0.6	0.5	0.5	0.6	0.6	0.7	0.7	0.6	0.7	0.8	0.9	0.9										
20: 0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.5	0.6	0.5	0.8	0.6	0.7	0.8	0.3	0.0	0.7	0.0			0.9

TABLE 6.2.19: RAWIN-SONDE ESSEN, ASCENT NR.28 31.08.88
FROM 19:30 TO 19:50

TIME ELAPSED SINCE START IN (min)	HEIGHT ABOVE GROUND IN (m)	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
0.00	5	0.50	250
0.33	25	0.60	245
0.67	69	4.60	229
1.00	116	6.60	230
1.33	165	7.70	233
1.67	211	7.80	236
2.00	257	8.20	240
2.33	306	8.20	239
2.67	355	9.20	240
3.00	404	9.30	241
3.33	453	9.20	244
3.67	502	9.80	242
4.00	551	9.70	241
4.33	600	9.70	241
4.67	648	10.30	241
5.00	695	10.30	241
5.33	745	11.20	241
5.67	797	10.70	240
6.00	846	10.70	239
6.33	890	10.80	239
6.67	934	11.30	239
7.00	981	11.30	239
7.33	1027	11.80	240
7.67	1073	11.80	239
8.00	1117	11.80	237
8.33	1164	11.70	239
8.67	1211	12.30	239
9.00	1257	11.80	236
9.33	1301	12.40	239
9.67	1345	12.30	236
10.00	1392	11.80	236
10.33	1438	12.30	236
10.67	1484	12.30	238
11.00	1529	12.30	235
11.33	1575	12.80	238
11.67	1620	12.30	241
12.00	1662	12.40	241
12.33	1711	12.40	248
12.67	1759	12.40	245
13.00	1806	11.90	249
13.33	1858	11.80	246
13.67	1908	10.80	247
14.00	1957	11.30	247
14.33	2009	11.90	251
14.67	2060	11.50	252
15.00	2109	11.00	253
15.33	2156	10.60	255
15.67	2203	11.00	255
16.00	2250	10.60	256
16.33	2296	10.60	256
16.67	2342	11.10	256
17.00	2392	11.80	261
17.33	2443	12.10	256
17.67	2494	11.40	253
18.00	2544	11.40	253
18.33	2596	12.10	258
18.67	2648	12.10	258
19.00	2700	12.10	259
19.33	2753	11.90	255
19.67	2805	11.80	250

TABLE 6.2.20A: PILOTBALLOON ESSEN, ASCENT NR.16 31.08.88
FROM 19:16 TO 19:26

TIME ELAPSED SINCE START IN (min)	X-COORDINATE IN (m)	Y-COORDINATE IN (m)	Z-COORDINATE IN (m above MSL)	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
0.00	29424	43252	110	0.00	0
0.50	29469	43316	183	2.63	215
1.00	29589	43444	245	5.85	223
1.50	29726	43598	315	6.87	222
2.00	29885	43767	387	7.71	223
2.50	30064	43918	462	7.82	230
3.00	30263	44075	527	8.47	232
3.50	30479	44246	600	9.17	232
4.00	30742	44419	669	10.49	237
4.50	30990	44565	716	9.60	239
5.00	31268	44723	773	10.66	241
5.50	31543	44871	822	10.43	242
6.00	31822	45035	873	10.77	240
6.50	32099	45201	920	10.77	239
7.00	32398	45379	973	11.59	239
7.50	32655	45546	1013	10.22	237
8.00	32902	45709	1062	9.86	237
8.50	33187	45897	1110	11.40	237
9.00	33448	46071	1149	10.46	236
9.50	33754	46264	1204	12.04	238
10.00	34105	46485	1277	13.85	238

TABLE 6.2.20B: PILOTBALLOON ESSEN, ASCENT NR.17 31.08.88
FROM 19:29 TO 19:35

TIME ELAPSED SINCE START IN (min)	X-COORDINATE IN (m)	Y-COORDINATE IN (m)	Z-COORDINATE IN (m above MSL)	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
0.00	29424	43251	107	0.00	0
0.33	29397	43266	110	1.57	120
0.67	29377	43286	113	1.36	135
1.00	29365	43304	111	1.09	146
1.33	29345	43320	112	1.29	129
1.67	29325	43339	113	1.39	132
2.00	29311	43356	115	1.14	142
2.33	29302	43371	115	0.86	148
2.67	29289	43394	116	1.31	151
3.00	29280	43416	119	1.20	158
3.33	29271	43437	120	1.15	156
3.67	29262	43456	118	1.05	156
4.00	29251	43476	118	1.11	151
4.33	29236	43489	114	1.04	132
4.67	29216	43510	117	1.43	135
5.00	29195	43529	118	1.39	133
5.33	29174	43547	117	1.40	131

TABLE 6.2.20C: PILOTBALLOON ESSEN, ASCENT NR.18 31.08.88
FROM 19:43 TO 19:48

TIME ELAPSED SINCE START IN (min)	X-COORDINATE IN (m)	Y-COORDINATE IN (m)	Z-COORDINATE IN (m above MSL)	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
0.00	29425	43250	107	0.00	0
0.33	29402	43265	112	1.34	125
0.67	29386	43289	115	1.47	146
1.00	29376	43312	117	1.25	157
1.33	29373	43338	120	1.31	172
1.67	29368	43367	125	1.45	171
2.00	29376	43411	132	2.24	190
2.33	29385	43464	134	2.69	189
2.67	29387	43514	143	2.49	183
3.00	29410	43564	154	2.76	204
3.33	29427	43619	167	2.88	197
3.67	29455	43687	176	3.67	203
4.00	29486	43757	181	3.84	204
4.33	29526	43834	187	4.33	208
4.67	29555	43899	184	3.56	204
5.00	29587	43963	185	3.55	206

TABLE 6.2.20D: PILOTBALLOON ESSEN, ASCENT NR.19 31.08.88
FROM 19:56 TO 20: 2

TIME ELAPSED SINCE START IN (min)	X-COORDINATE IN (m)	Y-COORDINATE IN (m)	Z-COORDINATE IN (m above MSL)	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
0.00	29424	43251	106	0.00	0
0.33	29399	43272	115	1.66	131
0.67	29381	43297	122	1.51	145
1.00	29374	43331	129	1.74	168
1.33	29374	43369	133	1.91	180
1.67	29378	43411	139	2.11	185
2.00	29388	43457	145	2.35	193
2.33	29401	43505	156	2.51	196
2.67	29423	43560	165	2.94	202
3.00	29448	43626	176	3.55	201
3.33	29469	43697	187	3.70	196
3.67	29493	43778	189	4.20	197
4.00	29527	43858	197	4.38	203
4.33	29567	43944	206	4.71	205
4.67	29612	44023	214	4.55	209
5.00	29651	44095	220	4.11	208
5.33	29698	44167	228	4.27	214
5.67	29751	44255	235	5.16	211
6.00	29814	44343	237	5.41	216

TABLE 6.2.21: RADIOSONDE ESSEN, ASCENT NR. 4 31.08.88
FROM 19: 0 TO 19:35

TIME ELAPSED SINCE START IN (min)	HEIGHT ABOVE GROUND IN (m)	TEMPERATURE IN (degree C)	WET-BULB TEMPERATURE IN (degree C)	HUMIDITY IN (%)	PRESSURE IN (hPa)
0.00	1	20.0	15.2	60	1003
0.10	30	20.0	14.8	57	1000
0.50	134	20.0	14.4	54	988
3.50	698	14.9	11.4	67	925
5.40	1060	11.4	8.1	66	886
7.50	1405	8.1	6.0	76	850
12.20	2128	2.2	2.0	97	778
14.20	2478	0.3	-0.2	92	745
17.30	2974	-3.9	-3.9	100	700
19.50	3378	-5.0	-6.3	77	665
20.10	3461	-5.1	-7.7	55	658
21.60	3715	-7.0	-9.3	57	637
23.10	3976	-8.7	-9.5	84	616
24.60	4231	-9.5	-12.0	44	596
25.90	4428	-10.5	-11.8	64	581
26.80	4601	-12.2	-13.0	72	568
27.40	4696	-12.0	-13.6	56	561
30.30	5244	-15.2	-16.8	48	522
32.00	5568	-18.0	-19.4	46	500
32.60	5673	-18.5	-20.1	39	493
34.50	5996	-21.3	-22.0	59	472

TABLE 6.2.23: TETHER SONDE RISOE, ASCENT NR. 3 31.08.88
FROM 18:12 TO 19:46 (LAST PART OF ASCENT)

TIME ELAPSED SINCE START IN (min)	HEIGHT ABOVE GROUND IN (m)	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)	TEMPERATURE IN (degree C)	WET-BULB TEMPERATURE IN (degree C)	PRESSURE IN (hPa)
60.06	238	9.26	242	18.5	12.9	974
60.25	237	9.52	251	18.5	12.9	975
60.44	234	8.43	214	18.5	12.9	975
60.63	235	8.44	225	18.6	12.9	975
60.75	230	9.13	229	18.6	13.0	975
60.94	225	9.78	247	18.6	12.9	976
61.13	221	9.99	235	18.6	12.9	976
61.31	220	9.35	209	18.7	13.0	976
61.44	224	8.68	225	18.6	13.0	976
61.63	224	7.71	217	18.6	13.1	976
61.81	217	8.20	244	18.6	13.0	977
62.00	217	8.55	220	18.6	13.0	977
62.13	210	8.48	236	18.7	13.1	978
62.31	209	7.50	215	18.7	13.1	978
62.50	202	8.13	226	18.7	13.1	979
62.69	199	8.40	243	18.7	13.1	979
62.81	195	7.22	210	18.9	13.2	979
63.00	190	7.50	230	18.8	13.2	980
63.19	183	8.17	220	18.9	13.1	981
63.38	178	9.01	250	18.9	13.2	981
63.56	172	8.49	238	19.0	13.3	982
63.69	170	8.32	231	19.0	13.3	982
63.88	168	8.02	244	19.0	13.3	982
64.06	164	7.27	202	19.0	13.4	983
64.25	162	7.98	235	19.0	13.4	983
64.38	158	7.89	248	19.1	13.3	984
64.56	154	8.37	252	19.1	13.4	984
64.75	147	7.97	247	19.2	13.4	985
64.88	145	7.15	227	19.1	13.4	985
65.06	142	7.54	248	19.1	13.4	985
65.25	136	6.45	217	19.2	13.5	986
65.44	132	6.55	214	19.2	13.4	987
65.56	130	6.13	209	19.3	13.5	987
65.75	123	6.98	230	19.4	13.6	988
65.94	116	6.33	229	19.4	13.6	988
66.13	113	5.86	195	19.4	13.6	989
66.31	108	6.98	257	19.4	13.6	989
66.44	103	6.00	223	19.4	13.6	990
66.63	99	6.57	247	19.4	13.7	990
66.81	90	5.37	208	19.4	13.7	991
67.00	86	5.88	237	19.4	13.7	992
67.13	80	4.87	206	19.4	13.7	992
67.31	76	6.09	244	19.6	13.8	993
67.50	65	4.41	202	19.6	13.8	994
67.63	59	5.57	246	19.6	13.8	995
67.81	51	4.16	211	19.6	13.8	996
68.00	44	4.35	226	19.6	13.9	997
68.19	33	3.81	228	19.7	13.9	998
68.38	25	4.03	240	19.6	13.9	999
68.50	19	3.21	218	19.6	14.0	1000
68.69	14	3.31	250	19.6	14.1	1000
68.88	2	2.36	257	19.4	14.1	1002
69.06	-4	1.52	227	19.3	14.1	1002
69.75	-2	0.21	253	19.2	14.2	1002
69.88	-2	*****	252	19.1	14.2	1002
70.06	-3	0.17	252	19.3	14.3	1002
70.25	-4	0.05	264	19.4	14.5	1002
70.38	-3	*****	257	19.3	14.6	1002
70.56	5	0.26	311	19.4	14.4	1001

Table 6.2.23 continued

TIME ELAPSED SINCE START IN (min)	HEIGHT ABOVE GROUND IN (m)	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)	TEMPERATURE IN (degree C)	WET-BULB TEMPERATURE IN (degree C)	PRESSURE IN (hPa)
70.75	3	0.28	293	19.4	14.7	1001
71.13	-2	*****	251	19.1	14.3	1002
71.31	-1	*****	250	19.5	14.8	1002
71.44	-1	*****	249	19.2	14.4	1002
71.63	-1	*****	249	19.1	14.4	1002
71.81	-1	*****	249	19.1	14.3	1002
71.94	-1	*****	249	19.1	14.3	1002
72.13	-2	*****	250	19.0	14.3	1002
73.00	-1	0.03	250	18.7	14.2	1002
73.19	-2	0.43	257	18.8	14.2	1002
73.31	1	0.27	251	18.8	14.2	1002
73.50	-1	0.05	252	18.9	14.2	1002
74.06	4	1.39	181	19.0	14.2	1001
74.19	13	2.88	225	19.0	14.1	1000
74.38	17	2.57	208	19.3	14.0	1000
74.56	23	2.24	255	19.3	14.0	999
74.75	24	3.37	232	19.3	14.0	999
74.88	29	3.54	231	19.4	14.0	998
75.06	34	3.57	229	19.4	13.9	998
75.25	41	3.88	228	19.5	14.0	997
75.38	45	3.90	228	19.5	13.9	997
75.56	51	4.04	228	19.5	13.9	996
75.75	56	3.99	227	19.5	13.9	995
75.94	59	4.21	226	19.5	13.9	995
76.13	68	4.11	228	19.5	13.9	994
76.25	68	4.10	228	19.5	13.9	994
76.44	73	4.24	226	19.5	13.9	993
76.63	80	4.24	224	19.4	13.9	992
76.81	82	4.12	231	19.4	13.9	992
76.94	88	4.25	227	19.3	13.8	992
77.13	92	4.64	231	19.3	13.8	991
77.31	98	4.77	231	19.3	13.7	990
77.50	100	4.68	233	19.3	13.7	990
77.63	108	4.78	230	19.2	13.7	989
77.81	109	4.71	229	19.2	13.7	989
78.00	114	5.11	202	19.2	13.6	989
78.13	118	5.53	229	19.2	13.6	988
78.31	121	5.31	224	19.2	13.6	988
78.50	126	5.47	232	19.1	13.6	987
78.69	132	5.31	236	19.1	13.5	987
78.88	136	5.34	228	19.1	13.5	986
79.00	144	5.53	231	19.1	13.5	985
79.19	147	5.60	226	19.0	13.5	985
79.38	146	5.50	234	19.0	13.4	985
79.56	150	5.66	235	19.0	13.4	984
79.69	153	5.83	234	19.1	13.4	984
79.88	157	5.92	235	19.0	13.3	984
80.06	161	5.79	235	19.1	13.4	983
80.25	162	5.92	222	19.0	13.3	983
80.38	168	5.92	230	19.0	13.3	982
80.56	171	6.14	228	18.9	13.3	982
80.75	173	5.98	237	18.9	13.3	982
80.94	177	5.94	238	18.8	13.2	981
81.06	186	6.10	238	18.9	13.3	980
81.25	186	6.16	228	18.8	13.2	980
81.44	189	6.11	231	18.8	13.2	980
81.63	197	6.04	236	18.8	13.2	979
81.81	195	6.09	231	18.7	13.1	979
81.94	199	6.05	230	18.7	13.1	979
82.13	201	6.22	230	18.7	13.1	979
82.31	204	6.22	232	18.6	13.1	978
82.50	207	6.17	230	18.6	13.1	978

Table 6.2.23 continued

TIME ELAPSED SINCE START IN (min)	HEIGHT ABOVE GROUND IN (m)	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)	TEMPERATURE IN (degree C)	WET-BULB TEMPERATURE IN (degree C)	PRESSURE IN (hPa)
82.63	212	6.16	233	18.6	13.1	977
82.81	216	6.20	239	18.5	13.0	977
83.00	220	6.04	234	18.5	13.0	976
83.13	224	6.13	233	18.5	13.0	976
83.31	224	5.98	233	18.5	13.0	976
83.50	227	6.39	225	18.4	13.0	976
83.69	231	6.66	229	18.5	12.9	975
83.81	230	6.59	232	18.5	12.9	975
84.00	231	6.58	235	18.4	12.7	975
84.19	235	6.56	229	18.5	12.8	975
84.38	236	6.55	232	18.4	12.8	975
84.56	240	6.59	233	18.4	12.8	974
84.69	245	6.62	234	18.4	12.8	974
84.88	246	6.27	232	18.4	12.8	973
85.06	249	6.34	233	18.3	12.7	973
85.25	251	6.58	232	18.3	12.7	973
85.38	252	6.52	234	18.3	12.7	973
85.56	256	6.65	236	18.2	12.7	972
85.75	260	6.50	231	18.2	12.6	972
85.88	261	6.68	234	18.2	12.6	972
86.25	264	6.90	233	18.2	12.6	972
86.44	266	6.75	232	18.2	12.6	971
86.63	267	7.00	233	18.1	12.5	971
86.94	265	7.10	232	18.2	12.6	971
87.13	264	6.98	234	18.2	12.5	971
87.31	264	6.94	234	18.2	12.5	971
87.44	264	7.03	232	18.2	12.5	971
87.63	267	6.78	241	18.2	12.4	971
87.81	273	6.65	231	18.2	12.5	971
88.00	272	6.79	233	18.2	12.4	971
88.13	273	6.90	238	18.2	12.5	970
88.31	277	6.74	231	18.2	12.5	970
88.50	279	6.98	232	18.1	12.4	970
88.63	280	7.18	229	18.1	12.4	970
88.81	286	7.01	241	18.1	12.4	969
89.00	284	6.83	232	18.1	12.4	969
89.19	285	7.03	237	18.0	12.4	969
89.38	288	7.25	232	17.9	12.3	969
89.50	290	6.95	234	18.0	12.3	969
89.69	292	7.24	229	17.9	12.3	968
89.88	294	7.20	238	17.9	12.3	968
90.06	300	7.07	237	18.0	12.3	967
90.19	300	7.38	231	17.9	12.2	967
90.38	296	7.32	235	17.9	12.3	968
90.56	297	7.45	234	17.9	12.3	968
90.75	297	7.46	234	17.9	12.3	968
90.88	297	7.26	235	17.9	12.2	968
91.06	293	7.62	229	17.9	12.2	968
91.25	293	7.33	234	17.9	12.2	968
91.44	293	7.45	233	17.9	12.3	968
91.56	294	7.36	234	17.9	12.2	968
91.75	292	7.30	238	17.9	12.3	968
91.94	290	7.58	234	17.8	12.2	969
92.13	294	7.36	235	17.9	12.3	968
92.31	290	7.52	238	17.9	12.3	969
92.44	291	7.27	231	17.9	12.3	968
92.63	288	7.64	233	17.9	12.2	969
92.81	286	7.62	236	17.9	12.3	969
93.00	286	7.65	236	18.0	12.3	969
93.13	285	7.70	232	17.9	12.3	969
93.31	285	7.40	234	18.0	12.3	969

TABLE 6.2.24: TETHER-SONDE KOELN, ASCENT NR.10 31.08.88
FROM 19:30 TO 21:30

HEIGHT ABOVE GROUND IN (m)	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)	TEMPERATURE IN (degree C)	WET-BULB TEMPERATURE IN (degree C)	HUMIDITY IN (%)	PRESSURE IN (hPa)
0	0.83	270	19.1	14.0	79	1002
6	1.72	255	19.2	14.1	79	1001
16	2.15	225	19.2	14.1	79	1000
36	3.72	232	19.4	13.7	76	998
42	4.74	216	19.5	13.7	75	997
54	4.54	231	19.5	13.7	75	996
66	4.91	231	19.3	13.5	75	994
71	5.45	230	19.3	13.5	75	994
82	5.01	222	19.2	13.4	75	993
96	5.61	230	19.0	13.3	75	991
96	6.57	220	19.1	13.4	75	991
104	6.54	226	19.1	13.4	75	990
111	6.45	234	19.1	13.3	75	989
127	6.35	224	18.9	13.2	75	987
135	6.35	224	18.7	13.2	76	987
132	6.85	217	18.8	13.1	75	987
136	7.07	225	18.9	13.1	75	986
149	6.98	228	18.5	13.1	76	985
154	6.79	222	18.0	13.1	79	984
172	6.69	229	17.8	13.0	79	982
168	7.02	234	17.7	13.0	79	983
171	6.65	232	17.8	13.0	79	982
184	7.13	238	17.6	13.0	80	981
170	7.50	224	17.8	13.0	79	982
173	7.25	218	17.8	13.0	79	982
183	7.29	226	17.6	13.0	79	981
194	6.87	217	17.6	12.9	79	980
208	7.43	224	17.5	12.8	79	978
203	7.76	228	17.5	12.8	79	979
208	7.23	217	17.4	12.8	80	978
218	6.89	224	17.4	12.9	80	977
232	7.35	226	17.3	12.7	79	975
233	7.36	228	17.4	12.6	78	975
234	7.66	220	17.5	12.6	78	975
242	8.73	224	17.5	12.6	78	974
238	9.01	233	17.6	12.4	77	975
227	8.57	222	17.9	12.5	76	976
227	7.91	223	18.1	12.6	75	976
248	8.31	226	17.9	12.6	76	973
260	8.57	234	17.9	12.5	75	972
249	8.10	227	18.0	12.6	76	973
267	7.56	223	17.7	12.5	77	971
268	6.96	218	17.7	12.4	76	971
266	7.67	220	17.6	12.3	76	971
252	8.11	221	17.7	12.4	76	973
255	7.55	227	17.7	12.5	77	973
256	7.22	216	17.7	12.5	76	973
269	6.55	216	17.6	12.5	77	971
282	7.48	223	17.5	12.4	77	970
276	8.09	219	17.6	12.1	75	970
263	8.09	224	17.7	12.1	74	972
261	7.57	233	17.8	12.2	75	972
269	7.12	228	17.7	12.2	75	971
258	8.26	230	17.7	12.3	75	972
238	0.00	0	17.8	12.4	75	975
208	5.77	235	17.9	12.8	77	978
192	6.24	235	18.0	12.8	77	980
183	6.25	237	18.1	12.8	77	981

TABLE 6.2.24 CONTINUED

HEIGHT ABOVE GROUND IN (m)	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)	TEMPERATURE IN (degree C)	WET-BULB TEMPERATURE IN (degree C)	HUMIDITY IN (%)	PRESSURE IN (hPa)
172	6.10	234	18.2	12.9	77	982
165	6.48	237	18.2	13.0	77	983
157	5.85	235	18.3	13.1	77	984
156	5.81	239	18.3	13.1	77	984
148	5.21	240	18.3	13.1	77	985
145	5.38	236	18.3	13.1	77	985
137	5.77	229	18.3	13.1	77	986
129	5.62	228	18.4	13.1	77	987
115	0.00	0	18.5	13.2	77	989
94	5.33	225	18.5	13.2	77	991
78	4.89	220	18.3	13.3	78	993
70	5.10	225	18.3	13.3	78	994
57	4.44	216	18.3	13.4	79	995
52	4.33	211	18.2	13.4	79	996
38	3.74	216	18.2	13.4	79	998
29	3.69	223	18.2	13.4	79	999
19	2.73	238	18.1	13.5	80	1000
12	2.58	248	18.0	13.5	81	1001

TABLE 6.2.25: TETROON, ASCENT NR. 2 31.08.88
FROM 19:50 TO 20:29

TIME ELAPSED SINCE START IN (min)	x- COORDINATE IN (m)	y- COORDINATE IN (m)	z- COORDINATE IN (m a. MSL)	FLIGHTPATH IN x,y PLANE IN (m)	FLIGHTPATH IN x,y,z SPACE IN (m)	TETROON SPEED-COMPONENT u IN (m/s)	TETROON SPEED-COMPONENT v IN (m/s)	TETROON SPEED-COMPONENT w IN (m/s)
1.00	24643	38446	127	190	190	2.00	2.95	0.17
1.17	24663	38477	128	227	227	2.16	3.17	0.15
1.33	24686	38510	130	267	267	2.26	3.32	0.17
1.50	24708	38543	132	307	307	2.28	3.36	0.21
1.67	24731	38577	134	348	348	2.32	3.38	0.15
1.83	24755	38611	135	389	389	2.34	3.43	0.14
2.00	24778	38645	137	431	431	2.41	3.54	0.21
2.17	24803	38682	139	475	475	2.49	3.60	0.16
2.33	24828	38717	140	519	519	2.51	3.63	0.16
2.50	24853	38754	142	563	564	2.53	3.68	0.18
2.67	24878	38791	143	608	608	2.54	3.73	0.11
2.83	24904	38829	144	653	654	2.56	3.77	0.12
3.00	24930	38866	146	699	700	2.53	3.74	0.13
3.17	24955	38903	147	744	744	2.52	3.74	0.13
3.33	24980	38941	148	789	790	2.49	3.71	0.11
3.50	25004	38978	149	833	833	2.42	3.64	0.09
3.67	25029	39014	150	877	877	2.42	3.65	0.05
3.83	25053	39050	150	920	921	2.38	3.62	-0.01
4.00	25076	39086	150	963	964	2.38	3.67	-0.03
4.17	25100	39124	150	1008	1009	2.33	3.66	0.01
4.33	25123	39160	150	1050	1051	2.25	3.60	0.03
4.50	25145	39196	150	1093	1094	2.23	3.61	0.01
4.67	25167	39232	150	1135	1136	2.18	3.59	0.02
4.83	25189	39268	151	1177	1178	2.15	3.61	-0.01
5.00	25210	39304	150	1219	1220	2.14	3.63	-0.06
5.17	25232	39340	149	1261	1262	2.13	3.68	0.02
5.33	25253	39378	150	1304	1305	2.14	3.73	0.07
5.50	25275	39415	151	1347	1348	2.09	3.71	0.07
5.67	25295	39452	152	1389	1390	2.03	3.64	0.10
5.83	25315	39488	153	1430	1431	2.03	3.58	0.12
6.00	25335	39524	154	1472	1472	2.07	3.66	0.15
6.17	25356	39561	156	1515	1515	2.12	3.74	0.15
6.33	25378	39598	157	1558	1558	2.17	3.76	0.13
6.50	25400	39636	158	1601	1602	2.18	3.80	0.12
6.67	25421	39674	159	1645	1646	2.11	3.80	0.20
6.83	25442	39712	162	1688	1689	2.05	3.78	0.28
7.00	25462	39750	165	1731	1732	2.05	3.78	0.17
7.17	25483	39788	166	1774	1775	2.06	3.83	0.11
7.33	25504	39827	167	1818	1819	2.09	3.86	0.13
7.50	25525	39865	168	1862	1863	2.07	3.93	0.16
7.67	25545	39905	170	1907	1908	2.00	3.98	0.18
7.83	25565	39945	172	1951	1952	1.99	3.93	0.07
8.00	25585	39984	172	1995	1996	1.95	3.85	0.03
8.17	25604	40021	173	2037	2039	1.90	3.82	0.07
8.33	25623	40060	173	2081	2082	1.91	3.82	-0.14
8.50	25642	40098	170	2123	2124	1.91	3.76	-0.26
8.67	25661	40135	168	2165	2166	1.89	3.72	-0.13
8.83	25680	40172	167	2206	2208	1.83	3.65	-0.04
9.00	25698	40208	167	2247	2248	1.74	3.59	0.01
9.17	25715	40244	167	2286	2287	1.71	3.62	0.00
9.33	25732	40281	167	2327	2328	1.77	3.69	-0.07
9.50	25750	40318	166	2368	2369	1.73	3.66	-0.18
9.67	25766	40354	164	2408	2409	1.65	3.60	-0.18
9.83	25783	40390	162	2447	2449	1.63	3.61	-0.14
10.00	25799	40426	161	2487	2488	1.55	3.55	-0.06
10.17	25814	40461	161	2525	2526	1.53	3.56	0.23
10.33	25830	40497	166	2564	2566	1.59	3.63	0.34
10.50	25846	40533	168	2604	2606	1.65	3.70	0.19

TABLE 6.2.25 CONTINUED

TIME ELAPSED SINCE START IN (min)	X-COORDINATE IN (m)	Y-COORDINATE IN (m)	Z-COORDINATE IN (m a. MSL)	FLIGHTPATH IN x,y PLANE IN (m)	FLIGHTPATH IN x,y,z SPACE IN (m)	TETROON SPEED-COMPONENT u IN (m/s)	TETROON SPEED-COMPONENT v IN (m/s)	TETROON SPEED-COMPONENT w IN (m/s)
10.67	25863	40571	169	2645	2647	1.71	3.76	0.11
10.83	25880	40609	170	2686	2688	1.77	3.78	0.03
11.00	25898	40647	170	2729	2730	1.81	3.76	0.00
11.17	25916	40684	170	2770	2772	1.84	3.68	0.05
11.33	25935	40720	171	2811	2813	1.93	3.67	0.14
11.50	25955	40757	173	2853	2855	1.97	3.70	0.20
11.67	25975	40794	175	2895	2897	2.04	3.76	0.18
11.83	25995	40833	176	2938	2940	2.16	3.85	0.09
12.00	26018	40871	177	2983	2985	2.16	3.85	0.03
12.17	26039	40910	177	3027	3029	2.18	3.89	0.00
12.33	26061	40949	177	3072	3074	2.22	3.92	0.00
12.50	26083	40988	177	3117	3119	2.24	3.96	0.03
12.67	26106	41028	177	3163	3165	2.26	4.00	0.06
12.83	26128	41068	178	3209	3211	2.26	4.00	0.09
13.00	26151	41108	179	3255	3257	2.20	3.98	0.09
13.17	26172	41148	180	3300	3302	2.17	3.95	0.03
13.33	26195	41187	180	3345	3347	2.30	3.98	-0.11
13.50	26218	41227	178	3392	3394	2.30	3.98	-0.28
13.67	26241	41267	174	3437	3439	2.16	3.96	-0.35
13.83	26261	41307	171	3482	3484	2.10	3.94	-0.19
14.00	26283	41346	170	3527	3529	2.02	3.88	0.05
14.17	26302	41384	172	3570	3572	1.93	3.83	0.08
14.33	26321	41422	172	3612	3615	1.93	3.83	0.08
14.50	26340	41461	173	3655	3658	1.92	3.84	0.08
14.67	26360	41499	174	3698	3701	1.92	3.78	0.01
14.83	26379	41537	173	3740	3743	1.94	3.82	0.01
15.00	26399	41576	174	3784	3786	1.87	3.87	0.08
15.17	26416	41614	175	3826	3828	1.70	3.81	0.23
15.33	26433	41652	179	3867	3870	1.69	3.81	0.46
15.50	26450	41690	184	3910	3912	1.76	3.82	0.58
15.67	26468	41728	190	3952	3955	1.79	3.80	0.40
15.83	26486	41766	192	3994	3997	1.79	3.81	0.10
16.00	26504	41804	192	4036	4039	1.80	3.85	-0.02
16.17	26522	41843	192	4079	4082	1.80	3.86	-0.06
16.33	26539	41881	191	4121	4124	1.75	3.88	-0.06
16.50	26557	41921	191	4164	4167	1.79	3.96	0.02
16.67	26575	41961	191	4208	4211	1.80	3.91	0.02
16.83	26593	41999	191	4250	4253	1.81	3.95	-0.10
17.00	26612	42040	189	4295	4298	1.85	4.03	-0.27
17.17	26630	42080	186	4339	4342	1.84	3.94	-0.44
17.33	26648	42118	180	4382	4385	1.83	3.94	-0.61
17.50	26666	42158	173	4426	4430	1.85	3.99	-0.67
17.67	26685	42198	167	4469	4474	1.93	3.98	-0.51
17.83	26705	42238	163	4514	4519	1.88	3.91	-0.31
18.00	26723	42276	161	4556	4561	1.83	3.83	-0.18
18.17	26742	42315	159	4599	4604	1.86	3.81	-0.14
18.33	26760	42353	158	4641	4646	1.77	3.76	-0.10
18.50	26777	42390	157	4682	4687	1.71	3.74	-0.06
18.67	26794	42427	157	4723	4728	1.65	3.67	0.02
18.83	26810	42463	158	4763	4768	1.62	3.63	0.20
19.00	26827	42500	161	4803	4808	1.63	3.73	0.34
19.17	26843	42538	165	4844	4850	1.60	3.70	0.43
19.33	26859	42574	170	4883	4889	1.58	3.60	0.48
19.50	26874	42610	174	4923	4929	1.54	3.63	0.35
19.67	26889	42647	177	4962	4968	1.54	3.73	0.17
19.83	26905	42685	178	5003	5010	1.58	3.81	0.08
20.00	26921	42723	178	5045	5051	1.61	3.79	0.09
20.17	26937	42761	180	5086	5092	1.61	3.80	0.04
20.33	26953	42799	179	5127	5133	1.66	3.82	-0.06
20.50	26971	42837	178	5169	5175	1.83	3.83	-0.10

TABLE 6.2.25 CONTINUED

TIME ELAPSED SINCE START IN (min)	X-COORDINATE IN (m)	Y-COORDINATE IN (m)	Z-COORDINATE IN (m a. MSL)	FLIGHTPATH IN x,y PLANE IN (m)	FLIGHTPATH IN x,y,z SPACE IN (m)	TETROON SPEED-COMPONENT u IN (m/s)	TETROON SPEED-COMPONENT v IN (m/s)	TETROON SPEED-COMPONENT w IN (m/s)
20.67	26990	42875	177	5212	5218	1.89	3.85	-0.20
20.83	27009	42914	174	5255	5261	1.86	3.81	-0.30
21.00	27027	42952	171	5297	5303	1.84	3.88	-0.35
21.17	27045	42991	167	5341	5347	1.84	3.98	-0.36
21.33	27064	43031	164	5385	5391	1.87	3.96	-0.32
21.50	27083	43070	161	5428	5435	2.00	3.89	-0.32
21.67	27104	43109	157	5472	5479	2.04	3.86	-0.38
21.83	27124	43148	154	5516	5523	2.06	3.90	-0.38
22.00	27145	43187	150	5560	5567	2.22	3.97	-0.39
22.17	27168	43227	146	5607	5614	2.19	4.04	-0.29
22.33	27189	43268	144	5652	5660	2.06	4.01	-0.14
22.50	27209	43307	143	5697	5704	2.03	3.97	-0.04
22.67	27229	43347	143	5741	5749	2.07	4.05	0.07
22.83	27250	43388	144	5788	5795	2.16	4.10	0.12
23.00	27273	43429	146	5834	5842	2.21	4.08	0.17
23.17	27295	43470	148	5880	5888	2.18	4.15	0.23
23.33	27316	43512	150	5928	5935	2.15	4.21	0.23
23.50	27338	43554	153	5975	5983	2.15	4.21	0.24
23.67	27359	43596	155	6022	6030	2.05	4.27	0.24
23.83	27379	43639	157	6070	6078	1.96	4.22	0.24
24.00	27398	43681	160	6115	6123	2.05	4.17	0.19
24.17	27420	43723	161	6163	6171	2.09	4.25	0.14
24.33	27440	43766	163	6210	6218	2.08	4.36	0.14
24.50	27461	43810	164	6259	6267	2.13	4.33	0.08
24.67	27483	43852	164	6307	6314	2.08	4.25	0.08
24.83	27503	43895	166	6354	6362	2.08	4.26	0.14
25.00	27524	43937	167	6401	6409	2.10	4.19	0.14
25.17	27545	43979	169	6448	6456	2.03	4.18	0.15
25.33	27565	44021	170	6494	6502	1.90	4.20	0.15
25.50	27583	44063	171	6540	6548	1.95	4.17	0.09
25.67	27604	44104	172	6586	6594	1.91	4.24	0.09
25.83	27621	44148	173	6633	6641	1.73	4.29	0.21
26.00	27638	44190	176	6679	6687	1.80	4.31	0.21
26.17	27657	44234	177	6726	6734	1.84	4.28	0.21
26.33	27675	44276	180	6772	6780	1.71	4.30	0.28
26.50	27692	44320	183	6819	6827	1.71	4.30	0.22
26.67	27709	44362	185	6865	6873	1.65	4.34	-0.02
26.83	27724	44407	183	6912	6920	1.61	4.41	-0.15
27.00	27742	44450	182	6959	6967	1.68	4.43	-0.21
27.17	27758	44495	178	7006	7015	1.75	4.44	-0.28
27.33	27776	44539	176	7054	7063	1.72	4.40	-0.28
27.50	27792	44583	173	7101	7110	1.73	4.45	-0.35
27.67	27811	44628	169	7149	7158	1.82	4.50	-0.35
27.83	27829	44673	166	7198	7207	1.74	4.49	-0.35
28.00	27846	44718	162	7246	7255	1.68	4.53	-0.42
28.17	27862	44764	157	7295	7304	1.75	4.54	-0.49
28.33	27881	44808	152	7343	7353	1.76	4.58	-0.37
28.50	27897	44855	150	7393	7402	1.75	4.58	-0.11
28.67	27916	44900	150	7441	7451	1.78	4.51	-0.11
28.83	27933	44945	148	7490	7500	1.70	4.51	-0.12
29.00	27950	44990	148	7538	7547	1.75	4.48	0.02
29.17	27968	45035	148	7586	7596	1.82	4.49	0.02
29.33	27986	45080	148	7635	7644	1.77	4.41	0.02
29.50	28004	45123	148	7681	7691	1.81	4.34	-0.05
29.67	28022	45167	147	7729	7738	1.84	4.43	0.02
29.83	28040	45212	148	7777	7787	1.90	4.40	0.22
30.00	28060	45255	151	7824	7834	2.00	4.29	0.29
30.17	28080	45298	154	7872	7882	1.97	4.26	0.16
30.33	28100	45340	154	7918	7928	1.97	4.26	0.09
30.50	28120	45383	156	7966	7976	2.01	4.34	0.16

TABLE 6.2.25 CONTINUED

TIME ELAPSED SINCE START IN (min)	X-COORDINATE IN (m)	Y-COORDINATE IN (m)	Z-COORDINATE IN (m a. MSL)	FLIGHTPATH IN x,y PLANE IN (m)	FLIGHTPATH IN x,y,z SPACE IN (m)	TETROON SPEED-COMPONENT u IN (m/s)	TETROON SPEED-COMPONENT v IN (m/s)	TETROON SPEED-COMPONENT w IN (m/s)
30.67	28140	45427	158	8014	8024	2.11	4.39	0.16
30.83	28162	45471	159	8063	8073	2.11	4.39	0.09
31.00	28182	45514	159	8111	8121	2.09	4.35	0.16
31.17	28204	45558	163	8159	8170	2.17	4.36	0.24
31.33	28226	45602	164	8209	8219	2.17	4.36	0.24
31.50	28247	45645	167	8257	8267	2.27	4.25	0.17
31.67	28271	45686	168	8305	8315	2.36	4.26	0.03
31.83	28294	45730	168	8354	8364	2.27	4.40	0.25
32.00	28316	45775	172	8404	8414	2.38	4.45	0.32
32.17	28342	45819	174	8455	8465	2.53	4.42	0.18
32.33	28367	45863	176	8506	8516	2.49	4.34	0.25
32.50	28391	45906	179	8555	8566	2.53	4.26	0.40
32.67	28418	45948	184	8605	8616	2.62	4.27	0.41
32.83	28444	45991	187	8655	8666	2.65	4.30	0.11
33.00	28471	46034	186	8706	8717	2.76	4.35	-0.04
33.17	28499	46078	187	8758	8769	2.94	4.35	-0.04
33.33	28529	46121	185	8811	8822	3.01	4.32	-0.04
33.50	28559	46164	186	8863	8874	2.93	4.31	-0.04
33.67	28588	46208	185	8915	8926	2.94	4.31	-0.20
33.83	28618	46250	182	8968	8979	3.10	4.27	-0.20
34.00	28650	46293	181	9021	9032	3.17	4.23	-0.20
34.17	28682	46335	178	9073	9084	3.20	4.26	-0.36
34.33	28714	46378	173	9128	9139	3.30	4.26	-0.52
34.50	28748	46420	167	9181	9193	3.40	4.26	-0.53
34.67	28782	46463	163	9237	9248	3.45	4.33	-0.29
34.83	28817	46507	161	9292	9304	3.42	4.25	-0.14
35.00	28850	46548	160	9345	9357	3.35	4.28	-0.22
35.17	28884	46592	157	9401	9413	3.41	4.35	-0.30
35.33	28918	46635	154	9456	9468	3.60	4.35	-0.31
35.50	28956	46679	151	9514	9526	3.68	4.30	-0.31
35.67	28992	46721	148	9569	9582	3.60	4.30	-0.23
35.83	29028	46765	146	9626	9638	3.67	4.41	-0.07
36.00	29066	46810	146	9684	9696	3.81	4.28	0.01
36.17	29104	46851	147	9740	9752	3.70	4.23	0.10
36.33	29140	46894	148	9797	9809	3.75	4.31	0.10
36.50	29179	46937	149	9855	9867	3.89	4.18	0.02
36.67	29217	46978	149	9911	9923	3.90	4.17	0.02
36.83	29257	47020	149	9969	9981	4.01	4.16	0.19
37.00	29298	47061	153	10026	10039	4.15	4.02	0.19
37.17	29340	47101	153	10084	10097	4.14	3.97	0.02
37.33	29380	47140	153	10141	10153	4.18	4.00	-0.16
37.50	29423	47181	150	10200	10212	4.29	3.99	-0.24
37.67	29466	47220	148	10258	10271	4.26	3.90	-0.25
37.83	29508	47259	145	10315	10328	4.34	4.01	-0.25
38.00	29553	47300	143	10376	10389	4.60	4.06	-0.34
38.17	29600	47340	138	10438	10451	4.49	4.02	-0.43
38.33	29643	47381	134	10497	10510	4.25	4.10	-0.35
38.50	29685	47422	131	10556	10569	4.29	3.97	-0.26
38.67	29728	47460	129	10614	10627	4.28	3.92	-0.36

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APPENDICES

A Intercomparison of SF6-measurements between KFA, APL and SCK

E. Lyck, W. Voß, F. Veroustraete

A 1 Intercomparison between KFA and APL

Two intercomparison tests of SF_6 measurements were carried out, the first one in December 1987/January 1988 and the second one during the third field experiment 1988.

In the first test six calibration mixtures were prepared by the KFA from a Linde primary standard containing 105 ppb ± 10% SF_6. With this six calibration mixtures the KFA-gaschromatograph was calibrated at 14/12/1987, measured at 18/12/1987 by APL at their laboratory and measured again by the KFA at 01/07/1988. The results are given in the Tab. A 1 below.

sample No.	date of analysis and SF_6-concentration in ng/m^3				
	KFA 12/14/87	APL 12/18/87	KFA 01/07/88	mean KFA	Δ (%) *
1	20	24	20	20	-18.2
2	50	52	53	51.5	-1.0
3	100	99	100	100	-1.0
4	500	489	460	480	-1.9
5	1000	933	950	975	+4.4
6	5000	4473	5400	5200	+15.0

Note: * $\Delta = \frac{KFA - APL}{1/2(KFA + APL)} \times 100$

Tab. A 1: Results of 1st calibration test by KFA and APL

This shows, that there is a good agreement for four samples. The sample no.1 has SF_6-concentration close to the detection limit of the gaschromatograph. The sample No. 6 might be near the upper linear range limit.

In the second test there were mixed five different SF_6-concentrations by the KFA from the Linde standard. They were measured at the same day by the KFA, one day later by the APL and the KFA and two days later by the KFA. The results are given in the Tab. A 2 (upper port). In the lower part of Tab. A 2, the single measurements (three of each group) are averaged and the mean values are compared.

Sample No.	theor. conc. ng/m³	date of analysis and SF_6-conc. (ng/m³)					
		KFA 09/06/88	KFA 09/07/88	KFA 09/08/88	APL 09/06/88	APL 09/06/88	APL 09/06/88
1	40	43	42	42	47	52	41
2	100	102	94	92	118	106	90
3	1000	1080	1015	956	1164	1147	1181
4	5000	4763	4391	4210	5267	5290	5018
5	10000	9176	8098	8269	10455	10059	9946

Sample No.	theor. conc. ng/m³ (A)	SF_6-conc. (ng/m³)		ratio Δ (%)		
		mean APL (B)	mean KFA (C)	B:A*	C:A	B:C
1	40	47	42	+16.1	+4.9	+11.2
2	100	105	96	+4.9	-4.1	+9.0
3	1000	1164	1017	+15.2	+1.7	+13.5
4	5000	5192	4455	+3.8	-11.5	+15.3
5	10000	10153	8514	+1.5	-16.0	+17.6

Note: * $\Delta(B:A) = \frac{B - A}{1/2(B + A)} \times 100$

Tab. A 2: Results of second calibration test by KFA and APL

The results between the theoretical and measured concentrations are in reasonable agreement. The agreement between APL and KFA is also reasonable.

A 2 Intercomparison between SCK and KFA

A 2.1 SF_6 loss in PVC bags

With the half hour sampling procedure performed with the sampling stations described earlier (chapter 4.2), it was made use of home made PVC bags. Samples are analysed immediately after collection. During the intercalibration, mixtures which were exchanged and compared in concentration between measured and real values. On 02 September 1988 calibration mixtures were prepared with the SCK calibrator and measured with the KFA gaschromatograph. The results are given in the Tab. A 3 below.

Days after mixture	Original concentration ng/m³			
	131	652	2610	6525
	Percentage from original concentration			
0	100	100	100	100
1	95	83	89	75
7	62	34	23	37
14	43	22	15	35
17	39	19	16	34
25	38	16	12	31

Tab. A 3: Decrease of SCK mixtures

From Tab. A 3 one can argue that there is a clearcut drop in concentration after longer time intervals storage in the PVC bags. Absorption, reaction or permeability of SF_6 could be the reason for the concentration drop. Therefore a procedure was adapted our procedure in the way as to keep the time between analysis and sampling as small as possible.

A 2.2 Intercalibration KFA-SCK

Two intercalibration tests of SF_6 measurements were made on Sept. 6 and Nov. 8, 1988.

Intercalibration on 06/09/88:

In the first test KFA filled Linde bags which were analysed by SCK. The calibration mixtures produced by KFA were static mixtures. The results show systematically too low values for SCK (Mean deviation 31%). A systematic error due to a wrong estimate of the permeation tube emission rate could be the result of this difference.

Intercalibration 08/11/88:

Because the intercalibration test in September did not give satisfactory results, a second one was done in November. This time SCK produced PVC bags which were analysed by KFA. They were made with the SCK calibrator as static mixtures in PVC bags. The results of the intercalibration are shown in the next table.

Sample No.	**SF_6 conc. (ng/m^3)**		**Δ (%) ***
	SCK (08/11/88)	**KFA (08/11/88)**	
1	7017	7620	-8
2	3509	4104	-16
3	3117	3731	-18
4	2006	2300	-14
5	1167	973	+18
6	633	687	-8
7	227	191	+17

Note: $^{*}\Delta = \frac{(SCK - KFA)}{1/2(SCK + KFA)} \times 100$ Mean deviation -4%

Tab. A 4: Intercalibration 08/11/88 SCK

This intercalibration shows better results, even down to the low concentration levels with a mean deviation of -4%.

On the same day the KFA group prepared concentrations in Linde bags as described in chapter 4.2.2. These theoretical concentrations were analysed by the KFA gaschromatograph (measured concentrations). The results are shown in the next table.

Sample No.	SF_6 in ng/m^3		Δ (%) *
	KFA theoretical (KFAt)	KFA measured (KFAm)	
1	10000	8922	11
2	7500	6608	13
3	5000	4517	10
4	2500	2281	9
5	1000	919	8
6	500	476	5
7	250	209	16
8	100	104	4
Note: * $\Delta = \frac{(KFAt - KFAr)}{1/2(KFAt + KFAr)} \times 100$	Mean deviation 10%		

Tab. A 5: Intercalibration 08/11/88 KFA

The mean deviation between measured and calculated (theoretical) concentrations for KFA is 10%.

Concerning second intercalibration the SCK measurements fall well within the limits, when bags are analysed immediately after sampling.

B Data of topography

Ch. Mönig, G. Zeuner

Topographical data of the area of investigation including Sophienhöhe and mine are available from the Rheinbraun company in a 8-m grid. This grid - called Rheinbraun system - is rotated by 45° against the Gauß-Krüger system. In this system the origin x_0, y_0 (2549 km, 5596 km) lies south of our experimental area. The grid comprises 5504 data points to northeast and a variable number of data points to northwest. We received an extract data set including grid point number and height for Sophienhöhe and mining area. The data in northwest direction comprise 8.8 km.

The actual topography is dated from August 1988.

For our purposes a computer program was developed to transform the data from the Rheinbraun system to a North-South system. As smallest x-coordinate, for example the western edge of the KFA can be selected. For areas where no value for height is available the grid can be extended and a constant height will be appointed. Also the raster density is variable and controlled with a parameter GD. The distance of the grid points is then: $GD \times 8 \times \sqrt{2}$ m in the North-South orientated system. For example with GD = 5 we have a grid distance of 56.6 m which was used to plot Fig. 5.1.2. This gives an enormous reduction of data.

The following parameters are given as output:

- x coordinate of the grid in m relative to the origin of the Rheinbraun system
- y coordinate of the grid in m relative to the Rheinbraun system
- z height in m above MSL
- n number of grid points in x direction
- m number of grid points in y direction
- z_{min}, z_{max} lowest, greatest height for z
- I_{min}, I_{max} row-, column index of the lowest, greatest height in z

These data are not included in the general data set (appendix C), for scientific purposes they are available upon request.

C Description of the dataset on magnetic tape

O. Mextorf

From the 30th of August to the 8th of September 1988 the 3rd field experiment took place at the region of the wastehill 'Sophienhöhe'. The data that was collected during that period has been standardized and was written to two magnetic-tapes, labeled KFAIMP88_1 and KFAIMP88_2.

C 1 Characteristics of the tapes

Name:	KFAIMP88_1
Code:	EBCDIC, formatted
Density:	6250 Bpl
Tracks:	9
Label:	NL
Recordformat:	F
Recordlength:	filedependent
Contents:	20 datafiles

Name:	KFAIMP88_2
Code:	EBCDIC, formatted
Density:	6250 Bpl
Tracks:	9
Label:	NL
Recordformat:	F
Recordlength:	filedependent
Contents:	17 datafiles, 1 programfile

C 2 Structure of the meteorological data

Filetype 1

The data of continuous measuring stations is organized in the following form, further refered to as type 1.

- 1st record:
  - number of the station,
  - name of the station,
  - beginning and ending date
    (respective year,month,day,hour given in MEZ)
  - number np of parameters

  Format: A(2), A(30), 8 F(3), F(3)

- Following np records:
  - parameteridentification (ref. -- Heading id 'anh2' unknown --)
  - number of measuring heights (m_i ; i = 1,..., np)
  - m_i heights

  Format: F(2), F(2), m_i F(6,1)

- Following records:
  either:
  - data mark ('1')
  - date of the ten-minutes interval (month,day,hour,minute (MEZ))
  - data (for each parameter respective all heights) (mp $= \sum_{i=1}^{np} m_i$)
    (9.9999E + 04 means a missing value)

  Format: A(1), F(5), 3F(3), mp E(11,4)

  or:
  - missing data mark ('2')
  - number of missing ten-minutes intervals

  Format: A(1), F(5)

Example type 1

Print of the first records of station 1

```
01TURM KFA                          88  8 30  1 88  9  8 24  8
  1 8   2.0  10.0  20.0  30.0  50.0  80.0 100.0 117.5
  7 3  30.0  50.0 117.5
 10 8   2.0  10.0  20.0  30.0  50.0  80.0 100.0 117.5
 13 1   1.0
 14 1   1.0
 15 1  30.0
 16 1  30.0
 20 3  30.0  50.0 117.5
  .
  .
  .
```

Filetype 2

The data of balloon and sonde ascents is organized in the following form, further refered to as type 2:

- 1st record:
  - number of the station
  - name of the station

  Format: A(2), A(30)

- 2nd record:
  - number of parameters (np)
  - number of ascents (na)

  Format: F(3), F(3)

- 3rd record:
  - np parameteridentifications (ref. -- Heading id 'anh2' unknown --)

  Format: np F(3)

- 4th to (na + 3)th record:
  - number of records of each ascent

  Format: F(4)

- following records: one headerrecord and the specified number of datarecords for each ascent

  Headerrecord:

  - 'H' identification of headerrecord
  - beginning and ending date of the ascent
    (respective year,month,day,hour,minute given in MEZ)

  Format: A(1), 10 F(3)

  Datarecord:

  - 'D' identification of datarecord
  - data; all parameters at a specific height and time
    (9.9999E + 04 stands for missing value)

  Format: A(1), np E(11,4)

Example type 2

Print of the first records of station 23

```
  23TETHER SONDE RISOE
    7 15
    1  7 10 11 13 23 24
  821
  285
  508
   97
 1348
  897
  891
  170
  241
  276
  190
  329
  634
  452
  170
H 88  8 30 13 52 88  8 30 16 27
D 1.8800E+00 2.4500E+02 2.0550E+01 1.3980E+01 1.0060E+03 0.0000E+00 3.7500E-01
D 2.2300E+00 2.4500E+02 2.0340E+01 1.3980E+01 1.0061E+03-9.0000E-01 9.3750E-01
D 2.3900E+00 2.4500E+02 2.0530E+01 1.4250E+01 1.0058E+03 2.1000E+00 1.1250E+00
D 2.0200E+00 2.4500E+02 2.0500E+01 1.4330E+01 1.0060E+03 2.0000E-01 1.2500E+00
D 1.8000E+00 2.4500E+02 2.0410E+01 1.4050E+01 1.0059E+03 1.0000E+00 1.4375E+00
D 1.2100E+00 2.4500E+02 2.0600E+01 1.4600E+01 1.0060E+03 1.0000E-01 1.6250E+00
D 1.5700E+00 2.4500E+02 2.0100E+01 1.4020E+01 1.0060E+03 3.0000E-01 1.8125E+00
D 2.0700E+00 2.4500E+02 2.0610E+01 1.4220E+01 1.0060E+03 3.0000E-01 1.9375E+00
  .
  .
  .
```

C 3 Information concerning the meteorological datafiles

1.

- Station: TOWER KFA
- Tape: KFAIMP88_1
- Label: 1
- Number of records: 1449
- Format: F, LRECL 301
- Structure: type 1
- Parameters: wind speed(2,10,20,30,50,80,100,117.5m), wind direction(30,50,117.5m), temperature(2,10,20,30,50,80,100,117.5m), pressure(1m), precipitation(1m), duration of sunshine(30m), net radiation(30m), standard deviation wind direction(30,50,117.5m)

2.

- Station: MAST RHEINBRAUN
- Tape: KFAIMP88_1
- Label: 2
- Number of records: 1447
- Format: F, LRECL 114
- Structure: type 1
- Parameters: wind speed (2,5,10m), wind direction (10m), temperature(0.2,2m), humidity(2m), precipitation, global radiation

3.

- Station: MAST 1 SOPHIENHOEHE
- Tape: KFAIMP88_1
- Label: 3
- Number of records: 1452
- Format: F, LRECL 180

- Structure: type 1
- Parameters: wind speed(5.5, 10m), vertical wind speed(10m),
  vertical wind speed downwards(10m),
  frequency downwind(10m),
  vertical wind speed upwards(10m),
  frequency upwind(10m),
  wind direction(10m), temperature(2,10m),
  wet-bulb temperature(2,10m),
  standard deviation wind speed(5.5,10m),
  standard deviation wind direction(10m)

4.

- Station: MAST 2 SOPHIENHOEHE
- Tape: KFAIMP88_1
- Label: 4
- Number of records: 1452
- Format: F, LRECL 224
- Structure: type 1
- Parameters: wind speed(2,4,7.5,15m),
  vertical wind speed(15m),
  vertical wind speed downwards(15m),
  frequency downwind(15m),
  vertical wind speed upwards(15m),
  frequency upwind(15m),
  wind direction(15m), temperature(2,13m),
  wet-bulb temperature(2,13m),
  standard deviation wind speed(2,4,7.5,15m),
  standard deviation wind direction(15m)

5.

- Station: MAST 3 SOPHIENHOEHE
- Tape: KFAIMP88_1
- Label: 5
- Number of records: 1452
- Format: F, LRECL 180
- Structure: type 1
- Parameters: wind speed(5.5, 10m), vertical wind speed(10m),

vertical wind speed downwards(10m),
frequency downwind(10m),
vertical wind speed upwards(10m),
frequency upwind(10m),
wind direction(10m), temperature(2,10m),
wet-bulb temperature(2,10m),
standard deviation wind speed(5.5,10m),
standard deviation wind direction(10m)

6.

- Station: MAST 4 SOPHIENHOEHE
- Tape: KFAIMP88_1
- Label: 6
- Number of records: 1448
- Format: F, LRECL 224
- Structure: type 1
- Parameters: wind speed(2,4,7.5,15m),
  vertical wind speed(15m),
  vertical wind speed downwards(15m),
  frequency downwind(15m),
  vertical wind speed upwards(15m),
  frequency upwind(15m),
  wind direction(15m), temperature(2,13m),
  wet-bulb temperature(2,13m),
  standard deviation wind speed(2,4,7.5,15m),
  standard deviation wind direction(15m)

7.

- Station: MAST 5 SOPHIENHOEHE
- Tape: KFAIMP88_1
- Label: 7
- Number of records: 1420
- Format: F, LRECL 345
- Structure: type 1
- Parameters: wind speed(1,2,4,7.5,15m),
  vertical wind speed(15m),
  vertical wind speed downwards(15m),
  frequency downwind(15m),

vertical wind speed upwards(15m),
frequency upwind(15m),
wind direction(15m), temperature(1,2,4,7.5,13m),
wet-bulb temperature(1,2,4,7.5,13m),
net radiation,
standard deviation wind speed(1,2,4,7.5,15m),
standard deviation wind direction(15m)
global radiation, heatflow

8.

- Station: SONIC KFA
- Tape: KFAIMP88_1
- Label: 8
- Number of records: 206
- Format: F, LRECL 312
- Structure: type 1
- Parameters: wind speed, vertical wind speed,
  wind direction,
  standard deviation wind speed,
  standard deviation vertical wind speed,
  standard deviation wind direction,
  standard deviation vertical wind [degree],
  standard deviation horizontal wind speed
  longitudinal, standard deviation horizontal
  wind speed lateral
  all parameters at 9.5, 50 and 120 m

9.

- Station: MAST SODAR KFA
- Tape: KFAIMP88_1
- Label: 9
- Number of records: 1377
- Format: F, LRECL 59
- Structure: type 1
- Parameters: wind speed, vertical wind speed,
  wind direction,
  standard deviation vertical wind speed [cm/s]
  all parameters at 15 m

10.

- Station: MAST 1 RISOE
- Tape: KFAIMP88_1
- Label: 10
- Number of records: 352
- Format: F, LRECL 59
- Structure: type 1
- Parameters: wind speed, wind direction
  both parameters at 3.3 m

11.

- Station: MAST 2 RISOE
- Tape: KFAIMP88_1
- Label: 11
- Number of records: 327
- Format: F, LRECL 59
- Structure: type 1
- Parameters: wind speed, wind direction
  both parameters at 3.3 m

12.

- Station: MAST 3 RISOE
- Tape: KFAIMP88_1
- Label: 12
- Number of records: 352
- Format: F, LRECL 59
- Structure: type 1
- Parameters: wind speed, wind direction
  both parameters at 3.3 m

13.

- Station: MAST 4 RISOE

- Tape: KFAIMP88_1
- Label: 13
- Number of records: 352
- Format: F, LRECL 59
- Structure: type 1
- Parameters: wind speed, wind direction
  both parameters at 3.3 m

14.

- Station: MAST ICH4
- Tape: KFAIMP88_1
- Label: 14
- Number of records: 1117
- Format: F, LRECL 59
- Structure: type 1
- Parameters: wind speed, wind direction,
  standard deviation wind speed,
  standard deviation wind direction
  all parameters at 7.2 m

15.

- Station: SONIC RISOE
- Tape: KFAIMP88_1
- Label: 15
- Number of records: 1306
- Format: F, LRECL 169
- Structure: type 1
- Parameters: wind speed, wind direction,
  temperature, windvector tilt,
  variance u'u', covariance u'v', covariance u'w',
  covariance u'T', variance v'v', covariance v'w',
  covariance v'T', variance w'w', covariance w'T',
  variance T'T'
  all parameters at 6.5 m

16.

- Station: SODAR KFA
- Tape: KFAIMP88_1
- Label: 16
- Number of records: 1373
- Format: F, LRECL 2127
- Structure: type 1
- Parameters: wind speed, vertical wind speed, wind direction, echo intensity, standard deviation vertical wind speed, standard deviation wind direction, standard deviation echo intensity, dissipation rate
  all parameters from 40 m up to 500 m by 20 m steps

17.

- Station: SODAR KOELN
- Tape: KFAIMP88_1
- Label: 17
- Number of records: 1283
- Format: F, LRECL 1995
- Structure: type 1
- Parameters: wind speed, vertical wind speed, wind direction, echo intensity, standard deviation vertical wind speed, standard deviation wind direction, standard deviation echo intensity, stability class, inversion marker
  all parameters from 40 m up to 420 m by 20 m steps

18.

- Station: SODAR ESSEN
- Tape: KFAIMP88_1

- Label: 18
- Number of records: 878
- Format: F, LRECL 1335
- Structure: type 1
- Parameters: wind speed, vertical wind speed, wind direction, echo intensity, standard deviation vertical wind speed, all parameters from 40 m up to 500 m by 20 m steps

19.

- Station: RAWIN-SONDE ESSEN
- Tape: KFAIMP88_1
- Label: 19
- Number of ascents: 164
- Number of records: 9080
- Format: F, LRECL 45
- Structure: type 2
- Parameters: wind speed, wind direction, height above ground (starting place), time elapsed since start

20.

- Station: PILOTBALLOON ESSEN
- Tape: KFAIMP88_1
- Label: 20
- Number of ascents: 65
- Number of records: 1522
- Format: F, LRECL 67
- Structure: type 2
- Parameters: wind speed, wind direction, time elapsed since start, x-coordinate,

y-coordinate, z-coordinate

21.

- Station: RADIOSONDE ESSEN
- Tape: KFAIMP88_2
- Label: 1
- Number of ascents: 30
- Number of records: 639
- Format: F, LRECL 67
- Structure: type 2
- Parameters: temperature, wet-bulb temperature, humidity, pressure, height above ground, time elapsed since start

22.

- Station: RADIOSONDE KOELN
- Tape: KFAIMP88_2
- Label: 2
- Number of ascents: 20
- Number of records: 25321
- Format: F, LRECL 56
- Structure: type 2
- Parameters: temperature, humidity, pressure, height above ground, time elapsed since start
- Remark:
  - only data up to 5000 m above ground has been considered
  - height has been calculated from pressure and temperature:

$$z = z_0 - \frac{T_m * R}{g} * \ln\left(\frac{p}{p_0}\right)$$

$$\text{with: } T_m = \frac{T_0 + T}{2}$$

z_0, T_0, p_0 at level n
z, T, p at level n+1
$R = 286.8\ J*Kg^{-1}*grd^{-1}$
$g = 9.81\ m*sec^{-2}$
$T\ [^0K]$, $p\ [hPa]$, $z\ [m]$

23.

- Station: TETHER SONDE RISOE
- Tape: KFAIMP88_2
- Label: 3
- Number of ascents: 15
- Number of records: 7342
- Format: F, LRECL 78
- Structure: type 2
- Parameters: wind speed, wind direction, temperature, wet bulb temperature, pressure, height above ground, time elapsed since start

24.

- Station: TETHER SONDE KOELN
- Tape: KFAIMP88_2
- Label: 4
- Number of ascents: 55
- Number of records: 3929
- Format: F, LRECL 78
- Structure: type 2
- Parameters: wind speed, wind direction,

temperature, wet bulb temperature,
humidity, pressure,
height above ground

25.

- Station: TETROON
- Tape: KFAIMP88_2
- Label: 5
- Number of ascents: 8
- Number of records: 1572
- Format: F, LRECL 100
- Structure: type 2
- Parameters: time elapsed since start, x-coordinate,
  y-coordinate, z-coordinate,
  flightpath in x,y plane,
  flightpath in x,y,z space,
  tetroon speedcomponent u,
  tetroon speedcomponent v,
  tetroon speedcomponent w

C 4 Structure of the dispersion data

Mean tracer concentrations

The data of the dispersion experiments (30-minutes averages) are organized in the following form:

- 1st record:
  - number of the experiment
  - day,month,year of the experiment

  Format: F(3), X(5), 3 F(2)
- 2nd record:
  - emission point coordinates (x,y,z) [m]

  Format: F(5), 2 (X(2), F(5))
- 3rd record:
  - emission height above ground [m]
  - release rate [g/s]

  Format: F(3), X(2), F(5,1)
- 4th record:
  - start of emission (hour, minute)
  - end of emission (hour, minute)

  Format: 2 F(2), X(2), 2 F(2)
- 5th record:
  - start of first sampling period (hour, minute)
  - end of first sampling period (hour, minute)

  Format: 2 F(2), X(2), 2 F(2)
- 6th record:
  - start of second sampling period (hour, minute)
  - end of second sampling period (hour, minute)

  Format: 2 F(2), X(2), 2 F(2)

- 7th record:
  - start of third sampling period (hour, minute)
  - end of third sampling period (hour, minute)

  Format: 2 F(2), X(2), 2 F(2)

- following records:
  - number of the sampling position
  - angle ϕ between north and the sampling position measured at the emission point [degree] (clockwise)
  - distance between sampling position and emission point, radius [m]
  - distance between sampling position and emission point in east-west direction, x-coordinate [m]
  - distance between sampling position and emission point in north-south direction, y-coordinate [m]
  - height of the sampling position [m above MSL]
  - measured concentration during first sampling period [ng/m^3]
  - measured concentration during second sampling period [ng/m^3]
  - measured concentration during third sampling period [ng/m^3]
  - measuring group (1 = KFA, 2 = APL, 3 = MOL)

  Format: F(8,2), 9 F(7)

(-9999 means a missing value)

Example of a dispersion datafile

Print of the first records of the first experiment

```
  1     30 888
28847  41742     91
 50    2.5
14 0  1630
15 0  1530
1530  16 0
16 0  1630
    2.00     21    446     160     417      91     285   6500   1200      1
    3.00     31    437     226     375      90    1030  14016   1900      1
    4.00     40    441     288     335      90    1120  17433   1040      1
    4.50     45    449     320     316      90   -9999  -9999   3829      1
    5.00     50    452     351     285      90   10258  -9999  16830      1
    5.50     55    451     371     258      90   16576  25503  20602      1
    6.00     61    466     408     226      90   16837  22868  19139      1
    7.00     70    496     467     169      90   12982  15080  17331      1
    8.00     79    547     539      97      90    8000  15212  17582      1
   12.00     19    962     326     906      99      19     16     15      1
 .
 .
 .
```

Instantaneous SF6 concentrations APL-group

The data of the dispersion experiments are organized in the following form:

- 1st record:
  - number of the experiment
  - day,month,year of the experiment

  Format: F(3), X(5), 3 F(2)
- 2nd record:
  - emission point coordinates (x,y,z) [m]

  Format: F(5), 2 (X(2), F(5))
- 3rd record:
  - emission height above ground [m]
  - release rate [g/s]

  Format: F(3), X(2), F(5,1)

- 4th record:
  - background concentration [ng/m³]

  Format: F(3)

- following records:
  - time (CET), hour:minutes
  - number of the sampling position
  - angle ϕ between north and the sampling position measured at the emission point [degree] (clockwise)
  - distance between sampling position and emission point, radius [m]
  - height of the sampling position [m above MSL]
  - measured concentration [ng/m³]

  Format: A(5), F(8,2), F(8,1), 3 F(7)

Example of a dispersion datafile

Print of the first records of the first experiment

```
  1      300888
28847  41742      91
 50   2.50
 13
14:46  624.00     60.1   2411     231     639
14:49  624.00     60.1   2411     231     381
14:53  624.00     60.1   2411     231      47
15:05  523.50     62.8   2280     217      57
15:08  521.00     68.2   2430     217     625
15:10  521.00     68.2   2430     217     427
15:14  506.00     61.5   2991     209      75
15:19  614.00     60.2   2681     248    1580
15:21  614.00     60.2   2681     248     567
15:24  602.00     55.2   2913     257     811
  .
  .
  .
```

C 5 Information concerning the dispersion datafiles

Mean tracer concentrations

1.

- Experiment number: 1
- Date: 30.08.88, 14:00
- Tape: KFAIMP88_2
- Label: 6
- Number of records: 154
- Format: F, LRECL 71

2.

- Experiment number: 2
- Date: 31.08.88, 18:00
- Tape: KFAIMP88_2
- Label: 7
- Number of records: 155
- Format: F, LRECL 71

3.

- Experiment number: 3
- Date: 03.09.88, 05:30
- Tape: KFAIMP88_2
- Label: 8
- Number of records: 154
- Format: F, LRECL 71

4.

- Experiment number: 4
- Date: 04.09.88, 11:00
- Tape: KFAIMP88_2

- Label: 9
- Number of records: 161
- Format: F, LRECL 71

5.

- Experiment number: 5
- Date: 05.09.88, 19:00
- Tape: KFAIMP88_2
- Label: 10
- Number of records: 126
- Format: F, LRECL 71

6.

- Experiment number: 6
- Date: 07.09.88, 18:00
- Tape: KFAIMP88_2
- Label: 11
- Number of records: 161
- Format: F, LRECL 71

Instantaneous SF6 concentrations APL-group

1.

- Experiment number: 1
- Date: 30.08.88, 14:00
- Tape: KFAIMP88_2
- Label: 12
- Number of records: 50
- Format: F, LRECL 42

2.

- Experiment number: 2
- Date: 31.08.88, 18:00
- Tape: KFAIMP88_2
- Label: 13
- Number of records: 31
- Format: F, LRECL 42

3.

- Experiment number: 3
- Date: 03.09.88, 05:30
- Tape: KFAIMP88_2
- Label: 14
- Number of records: 48
- Format: F, LRECL 42

4.

- Experiment number: 4
- Date: 04.09.88, 11:00
- Tape: KFAIMP88_2
- Label: 15

- Number of records: 46
- Format: F, LRECL 42

5.

- Experiment number: 5
- Date: 05.09.88, 19:00
- Tape: KFAIMP88_2
- Label: 16
- Number of records: 71
- Format: F, LRECL 42

6.

- Experiment number: 6
- Date: 07.09.88, 18:00
- Tape: KFAIMP88_2
- Label: 17
- Number of records: 75
- Format: F, LRECL 42

C 6 Program IMPLES

Name of the program

IMPLES

Purpose of the program

reading meteorological data from the tapes

Position at the tape KFAIMP88_2

label 18

Recordlength

80

Programming language

PL/I

Call

CALL IMPLES2

Input data

list of the numbers of the stations to be printed (one number a line)

Output data

meteorological data of the stations, sorted by parameter, height and time

Programlisting

```
IMPLES2: PROC OPTIONS(MAIN);

/*      READING THE METEOROLOGICAL DATA OF THE FIELD EXPERIMENT      */
/*      IN 1988 FROM MAGNETIC TAPE.                                  */
/*                                                                   */
/*      O. MEXTORF, 06.02.90                                         */


/*      CONSTANTS:                                                   */

        DCL  ANZSTAT INIT(25) BIN FIXED(31),
             STAT_TYP(ANZSTAT) INIT((18) 1, (7) 2) BIN FIXED(31),
             STAT_RECL(ANZSTAT) INIT(301,114,180,224,180,224,345,
                312,(6) 59,169,2127,1995,1335,45,67,67,56,78,78,100)
                    BIN FIXED(31),
             MAXPAR INIT(53) BIN FIXED(31),
             MAXHOE INIT(24) BIN FIXED(31),
             MAXAUF INIT(40) BIN FIXED(31),
             PARTXT(MAXPAR) INIT('WS','VWS','VWSDOW','FREQDOW',
               'VWSUP','FREQUP','WD','SIGTHE','SIGPHI','DT','WT',
               'HUMIDITY','PRESS','PRECIP','DURSUN','NETRAD','ECHO',
               'SDWS','SDVWS','SDWD','SDTT','SDNETRAD','HEIGHT',
               'TIME','X-CO','Y-CO','Z-CO','XY-PATH','XYZ-PATH',
               'SCOMPU','SCOMPV','SCOMPW','XY-WD','GLOBRAD','HTFLOW',
               'SDVW_DEG','SDHWSLON','SDHWSLAT','WVECTILT','U''U''',
               'U''V''','U''W''','U''T''','V''V''','V''W''','V''T''',
               'W''W''','W''T''','T''T''','SDECHO','DISSRAT',
               'STABCL','INVMARK')
                    CHAR(9);




        DCL (STATNUM, STATNUME, TAG(4), MONAT(4), JAHR(4), STUNDE(4),
             MINUTE(4), SEKUNDE(4), NA, NP, NH, PARKEN(MAXPAR),
             ANZHOE(MAXPAR), ANZWERTE, IPOS, IRECL, I, J, K, L, M,
             REC_AUF(MAXAUF)) BIN FIXED(31),
            HOEHE(MAXPAR,MAXHOE) DEC FLOAT(6),
            ENDFRCK     LABEL,
            STATNAM     CHAR(30),
            TITEL       CHAR(6) INIT('STAT  '),
            KENNUNG     CHAR(1),
            EINZEI      CHAR(*) CTL,
            EOF         BIT(1),
            MIN         BUILTIN,
```

```
    SUBSTR     BUILTIN,
    STRING     BUILTIN,
    SYSIN      FILE STREAM INPUT,
    TAPE       FILE STREAM INPUT,
    SYSPRINT   FILE STREAM OUTPUT;


ON ENDFILE(TAPE) BEGIN;
  EOF='1'B;
  GOTO ENDFRCK;
END;

ON ENDFILE(SYSIN) GOTO $ENDE;

ON ENDPAGE(SYSPRINT) BEGIN;
  IF (STAT_TYP(STATNUME)=2) THEN DO;
    PUT EDIT('STATION',STATNUME,', ',STATNAM,' FROM ',
     TAG(1),'.',MONAT(1),'.',JAHR(1),STUNDE(1),':',
     MINUTE(1),' UP TO ',TAG(2),'.',MONAT(2),'.',
     JAHR(2),STUNDE(2),':',MINUTE(2))
     (PAGE,A,F(3),3 A,2(2 (P'99',A),P'99',
      X(1),P'99',A,P'99',A));
    PUT EDIT((PARTXT(PARKEN(K)) DO K=1 TO NP))
            (SKIP(2),X(2),(NP) (X(2),A,X(2)));
    PUT EDIT('') (SKIP,A);
  END;
  ELSE DO;
    PUT EDIT('STATION',STATNUME,', ',STATNAM,' FROM ',
     TAG(1),'.',MONAT(1),'.',JAHR(1),STUNDE(1),':00',
     ' UP TO ',TAG(2),'.',MONAT(2),'.',
     JAHR(2),STUNDE(2),':00')
     (PAGE,A,F(3),3 A,2(2 (P'99',A),P'99',
      X(1),P'99',2 A));
    PUT EDIT('') (SKIP(2),A);
  END;
END;

OPEN FILE(SYSPRINT) LINESIZE(132);


/*      GET NUMBER OF DESIRED STATION:                              */

DO WHILE(1=1);
GET SKIP LIST(STATNUME);
PUT STRING(SUBSTR(TITEL,5,2)) EDIT(STATNUME) (P'99');
```

```
/*      USING FORMAT TYPE 1:                                          */

        IF (STAT_TYP(STATNUME)=1) THEN DO;
          ENDFRCK=$ENDST1;
          OPEN FILE(TAPE) TITLE(TITEL);


/*      GET THE FIRST RECORD:                                         */

          GET FILE(TAPE) EDIT(STATNUM,STATNAM,(JAHR(I),MONAT(I),TAG(I),
                              STUNDE(I)  DO I=1 TO 2),NP)
                             (COL(1),F(2),A(30),8 F(3),F(3));


/*      GET THE PARAMETERIDENTIFICATION AND THE MEASURING HEIGHTS:  */

          ANZWERTE=0;
          DO I=1 TO NP;
            GET FILE(TAPE) EDIT(PARKEN(I),ANZHOE(I),
                                (HOEHE(I,J) DO J=1 TO ANZHOE(I)))
                               (COL(1),F(2),F(2),(ANZHOE(I)) F(6,1));
            ANZWERTE=ANZWERTE+ANZHOE(I);
          END;  /* DO I=1 TO NP */
          STUNDE(1)=STUNDE(1)-1;
          IF (STUNDE(1)=-1) THEN STUNDE(1)=23;
          SIGNAL ENDPAGE(SYSPRINT);


/*      READ THE DATA:                                                */

          IRECL=15+ANZWERTE*11;
          ALLOCATE EINZEI CHAR(IRECL);

          EOF='0'B;
          DO WHILE(      EOF);

          GET FILE(TAPE) EDIT(EINZEI) (COL(1),A(IRECL));


/*      DATA RECORD OR MISSING VALUE ?                                */

          GET STRING(EINZEI) EDIT (KENNUNG) (A(1));
          IF (KENNUNG='1') THEN DO;
            GET STRING(EINZEI) EDIT (MONAT(3),TAG(3),STUNDE(3),
                                     MINUTE(3)) (X(1),F(5),3 F(3));
```

```
/*      WRITE HEIGHTS AND CORRESPONDING VALUES:                              */

           PUT EDIT(TAG(3),'.',MONAT(3),'.',JAHR(1),STUNDE(3),':',
                    MINUTE(3))
                   (SKIP(2),P'99',A,P'99',A,P'99',X(1),P'99',A,P'99');
           IPOS=5;

           DO I=1 TO NP;
             DO K=1 TO ANZHOE(I)/10+1;
               L=(K-1)*10;
               M=MIN(10,ANZHOE(I)-L);
               PUT EDIT('          ',(HOEHE(I,J+L),'M' DO J=1 TO M))
                       (SKIP,A,(M) (X(2),F(6,1),X(1),A(1),X(2)));
               PUT EDIT(PARTXT(PARKEN(I)),
                   (SUBSTR(EINZEI,IPOS+J*11,11)  DO J=1 TO M))
                   (SKIP,A,(M) (X(1),A(11)));
               IPOS=IPOS+M*11;
             END;
           END;
         END;


/*      MISSING VALUES:                                                      */

         ELSE DO;
           GET STRING(EINZEI) EDIT(I) (X(1),F(5));
           PUT SKIP(2) EDIT('>>>>> MISSING VALUES AT ',I,
                            ' TEN-MINUTES INTERVALS <<<<<')
                           (A,F(4),A);
         END;
$ENDST1:END;  /* DO WHILE¬EOF) */
        FREE EINZEI;
        PARTXT(20)='STWR';
        END;  /* IF STAT_TYP()=1 */


/*      IT'S FORMAT TYPE 2:                                                  */

        ELSE IF (STAT_TYP(STATNUME)=2) THEN DO;
          ENDFRCK=$ENDST2;
          OPEN FILE(TAPE) TITLE(TITEL);


/*      GET INFORMATION ABOUT THE STATION:                                   */

          GET FILE(TAPE) EDIT (STATNUM,STATNAM) (COL(1),F(2),A(30));
          GET FILE(TAPE) EDIT (NP,NA) (COL(1),2 F(3));
```

```
        IRECL=NP*11+1;
        ALLOCATE EINZEI CHAR(IRECL);
        GET FILE(TAPE) EDIT ((PARKEN(I) DO I=1 TO NP))
                            (COL(1),(NP) F(3));
        GET FILE(TAPE) EDIT ((REC_AUF(I) DO I=1 TO NA))
                            ((NA) (COL(1),F(4)));
        GET FILE(TAPE) EDIT(EINZEI) (COL(1), A(IRECL));

        EOF='0'B;
        DO WHILE(      EOF);


/*      BEGINNING AND ENDING DATE OF THE ASCENT:                       */

        GET STRING(EINZEI) EDIT (KENNUNG,(JAHR(I),MONAT(I),TAG(I),
                                 STUNDE(I),MINUTE(I) DO I=1 TO 2))
                                (A(1),10 F(3));


/*      PRINT THE HEADER LINE:                                         */

        PUT EDIT('>>>>> BEGIN OF THE ASCENT <<<<<') (PAGE,A);
        PUT EDIT('STATION',STATNUME,', ',STATNAM,' FROM ',
           TAG(1),'.',MONAT(1),'.',JAHR(1),STUNDE(1),':',
           MINUTE(1),' UP TO ',TAG(2),'.',MONAT(2),'.',
           JAHR(2),STUNDE(2),':',MINUTE(2))
           (SKIP,A,F(3),3 A,2(2 (P'99',A),P'99',
            X(1),P'99',A,P'99',A));
        PUT EDIT((PARTXT(PARKEN(K)) DO K=1 TO NP))
                (SKIP(2),X(2),(NP) (X(2),A,X(2)));

        GET FILE(TAPE) EDIT(EINZEI) (COL(1), A(IRECL));
        KENNUNG=SUBSTR(EINZEI,1,1);


/*      READ THE DATE AND PRINT IT:                                    */

        DO WHILE(KENNUNG='D');
          PUT EDIT((SUBSTR(EINZEI,2+I*11,11) DO I=0 TO NP-1))
                  (SKIP,(NP) (X(1),A(11),X(1)));
          GET FILE(TAPE) EDIT(EINZEI) (COL(1), A(IRECL));
          KENNUNG=SUBSTR(EINZEI,1,1);
        END;


$ENDST2:  END;  /* DO WHIEØF) */
        FREE EINZEI;
```

```
        END;  /* IF STAT_TYP()=2 */
        CLOSE FILE(TAPE);
        END;  /* DO WHILE(1=1) */
$ENDE:  END;  /* IMPLES2 */
```

Output examples

Type 1

```
STATION  1, TOWER KFA                    FROM 30.08.88 00:00 UP TO 08.09.88 24:00

30.08.88 00:10
                 2.0 M       10.0 M       20.0 M       30.0 M       50.0 M...
WS          2.3333E-01   4.1333E-01   1.4567E+00   2.6833E+00   4.2200E+00
                30.0 M       50.0 M      117.5 M
WD          2.3900E+02   2.3800E+02   2.3500E+02
                 2.0 M       10.0 M       20.0 M       30.0 M       50.0 M...
DT          1.0736E+01   1.1250E+01   1.1394E+01   1.1706E+01   1.2033E+01
                 1.0 M
PRESS       1.0042E+03
                 1.0 M
PRECIP      0.0000E+00
                30.0 M
DURSUN      0.0000E+00
                30.0 M
NETRAD     -7.6758E+01
                30.0 M       50.0 M      117.5 M
SDWD        1.0200E+01   5.3000E+00   2.2000E+00
30.08.88 00:20
                 2.0 M       10.0 M       20.0 M       30.0 M       50.0 M...
WS          3.0333E-01   4.4667E-01   1.2133E+00   2.3800E+00   4.2600E+00
                30.0 M       50.0 M      117.5 M
WD          2.3800E+02   2.3500E+02   2.3400E+02
                 2.0 M       10.0 M       20.0 M       30.0 M       50.0 M...
DT          1.0778E+01   1.1276E+01   1.1378E+01   1.1648E+01   1.1985E+01
                 1.0 M
PRESS       1.0043E+03
                 1.0 M
PRECIP      0.0000E+00
                30.0 M
DURSUN      0.0000E+00
                30.0 M
NETRAD     -8.3736E+01
                30.0 M       50.0 M      117.5 M
SDWD        1.7000E+01   8.4000E+00   2.8000E+00
  .
  .
  .
```

Type 2

>>>>> BEGIN OF THE ASCENT <<<<<

STATION 20, PILOTBALLOON ESSEN FROM 30.08.88 14:03 UP TO 30.08.88 14:07

WS	WD	TIME	X-CO	Y-CO	Z-CO
0.0000E+00	0.0000E+00	0.0000E+00	2.9425E+04	4.3247E+04	1.0742E+02
3.4875E+00	2.2662E+02	3.3333E-01	2.9476E+04	4.3295E+04	1.1614E+02
3.3461E+00	2.3759E+02	6.6667E-01	2.9532E+04	4.3331E+04	1.2673E+02
3.8939E+00	2.5603E+02	1.0000E+00	2.9608E+04	4.3349E+04	1.2145E+02
3.6480E+00	2.2374E+02	1.3333E+00	2.9658E+04	4.3402E+04	1.0732E+02
3.6214E+00	2.2434E+02	1.6667E+00	2.9709E+04	4.3454E+04	1.3353E+02
2.7193E+00	2.5119E+02	2.0000E+00	2.9760E+04	4.3471E+04	1.4582E+02
2.9226E+00	2.2123E+02	2.3333E+00	2.9799E+04	4.3515E+04	1.4755E+02
3.2958E+00	2.2652E+02	2.6667E+00	2.9847E+04	4.3561E+04	1.4679E+02
3.4026E+00	2.3640E+02	3.0000E+00	2.9904E+04	4.3598E+04	1.5047E+02
3.3321E+00	2.4999E+02	3.3333E+00	2.9966E+04	4.3621E+04	1.6522E+02

>>>>> BEGIN OF THE ASCENT <<<<<

STATION 20, PILOTBALLOON ESSEN FROM 30.08.88 14:13 UP TO 30.08.88 14:22

WS	WD	TIME	X-CO	Y-CO	Z-CO
0.0000E+00	0.0000E+00	0.0000E+00	2.9425E+04	4.3248E+04	1.0638E+02
1.5339E+00	2.3412E+02	3.3333E-01	2.9450E+04	4.3266E+04	1.1579E+02
2.1972E+00	2.3544E+02	6.6667E-01	2.9486E+04	4.3291E+04	1.2013E+02
2.1839E+00	2.3331E+02	1.0000E+00	2.9521E+04	4.3317E+04	1.2523E+02
2.0990E+00	2.2571E+02	1.3333E+00	2.9551E+04	4.3346E+04	1.2638E+02
1.9702E+00	2.3102E+02	1.6667E+00	2.9582E+04	4.3371E+04	1.3854E+02
2.2197E+00	2.1014E+02	2.0000E+00	2.9604E+04	4.3409E+04	1.6433E+02
2.2152E+00	2.0738E+02	2.3333E+00	2.9624E+04	4.3449E+04	1.9275E+02
2.0850E+00	2.2311E+02	2.6667E+00	2.9653E+04	4.3479E+04	2.1107E+02
2.0556E+00	2.1815E+02	3.0000E+00	2.9678E+04	4.3511E+04	2.2173E+02
1.6660E+00	2.2814E+02	3.3333E+00	2.9703E+04	4.3534E+04	2.3316E+02
1.6021E+00	2.3242E+02	3.6667E+00	2.9728E+04	4.3553E+04	2.3884E+02
1.7550E+00	2.2592E+02	4.0000E+00	2.9754E+04	4.3578E+04	2.5544E+02
2.0147E+00	2.2508E+02	4.3333E+00	2.9782E+04	4.3606E+04	2.8358E+02
2.2639E+00	2.3039E+02	4.6667E+00	2.9817E+04	4.3635E+04	3.1644E+02
2.8102E+00	2.3436E+02	5.0000E+00	2.9863E+04	4.3668E+04	3.4563E+02
3.2610E+00	2.2964E+02	5.3333E+00	2.9912E+04	4.3710E+04	3.6544E+02
2.9802E+00	2.2353E+02	5.6667E+00	2.9954E+04	4.3753E+04	3.8811E+02
3.9265E+00	2.3523E+02	6.0000E+00	3.0018E+04	4.3798E+04	4.3306E+02

C 7 List of parameters

id. number	*parameter*
1	wind speed [m/s]
2	vertical wind speed [m/s]
3	vertical wind speed downwards [m/s]
4	frequency of downwind
5	vertical wind speed upwards [m/s]
6	frequency of upwind
7	wind direction [degree]
8	sigma θ [degree]
9	sigma ϕ [degree]
10	temperature [°C]
11	wet-bulb temperature [°C]
12	humidity [%]
13	pressure [hPa]
14	precipitation [mm]
15	duration of sunshine [min]
16	net radiation [W/m^2]
17	echo intensity [mV]
18	standard deviation wind speed [m/s]
19	standard deviation vertical wind speed [m/s]
20	standard deviation wind direction [degree]
21	standard deviation temperature [°C]
22	standard deviation net radiation [W/m^2]
23	height above ground (starting place) [m]
24	time elapsed since start [min]
25	x-coordinate [m]
26	y-coordinate [m]
27	z-coordinate [m above MSL]

28	flightpath in x,y plane [m]
29	flightpath in x,y,z space [m]
30	balloon or tetroon speedcomponent u [m/s]
31	balloon or tetroon speedcomponent v [m/s]
32	balloon or tetroon speedcomponent w [m/s]
33	actual wind direction in x,y plane [degree]
34	global radiation $[W/m^2]$
35	heatflow $[W/m^2]$
36	standard deviation vertical wind [degree]
37	standard deviation horizontal wind speed longitudinal [m/s]
38	standard deviation horizontal wind speed lateral [m/s]
39	windvector tilt [Grad]
40	variance u'u' $[(m/s)^2]$
41	covariance u'v' $[(m/s)^2]$
42	covariance u'w' $[(m/s)^2]$
43	covariance u'T' [(m/s)(°C)]
44	variance v'v' $[(m/s)^2]$
45	covariance v'w' $[(m/s)^2]$
46	covariance v'T' [(m/s)(°C)]
47	variance w'w' $[(m/s)^2]$
48	covariance w'T' [(m/s)(°C)]
49	variance T'T' $[(°C)^2]$
50	standard deviation echo intensity [mV]
51	dissipation rate $[m^2/s^3]$
52	stability class (1 = stable to 5 = unstable)
53	inversion marker (0 or -1, -1 = inversion)

ADDRESSES OF AUTHORS

Wolfram Bahmann
Technischer Überwachungsverein Rheinland e.V.
Institut für Energietechnik und Umweltschutz
Postfach 101750
D-5000 Köln 91, F.R.G.

Klaus Becker
Deutscher Wetterdienst, Wetteramt Essen
Wallneyerstr. 10
D-4300 Essen 1, F.R.G.

Jürgen Frank
Rheinisch-Westfälischer Technischer Überwachungsverein e.V.
Postfach 103261
D-4300 Essen, F.R.G.

Sven-Erik Gryning
Risø National Laboratory
Department of Meteorology and Wind Energy
DK-4000 Roskilde, Denmark

Erik Lyck
National Environmental Research Institute
Division of Emissions and Air Pollution
Frederiksborgvej 399
DK-4000 Roskilde, Denmark

Hans Dieter Narres
Institut für Chemie 4 (Angewandte physikalische Chemie)
Forschungszentrum Jülich, Postfach 1913
D-5170 Jülich, F.R.G.

Christa Oetz, Wolfgang Oetz
Institut für Geophysik und Meteorologie
Universität zu Köln
Kerperner Str. 13
D-5000 Köln 41, F.R.G.

Frank Veroustraete
Analytic Chemistry Dept.
S.C.K./C.E.N.
Boerestang 200
B-2400 Mol, Belgium

Günter Zeuner, Karl Heinemann, Olaf Mextorf,
Michael Möllmann-Coers, Christina Mönig,
Gebhard Polster, Winfried Voß
Abteilung Sicherheit und Strahlenschutz
Forschungszentrum Jülich KFA
Postfach 1913
D-5170 Jülich, F.R.G.

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LIST OF ABBREVIATIONS

a) Institutions

ASS	Abteilung Sicherheit und Strahlenschutz (KFA)
DWD	Deutscher Wetterdienst, Wetteramt Essen
ICH 4	Institut für Angewandte Physikalische Chemie (KFA)
IGM	Institut für Geophysik und Meteorologie der Universität zu Köln
ISPRA	Ispra Tracer Group, Joint Research Center, Ispra, Italy
KFA	Forschungszentrum Jülich KFA
NERI	National Environmental Research Institute, Roskilde, Denmark
Rh.W.TÜV	Rheinisch-Westfälischer Technischer Überwachungsverein e.V., Essen
RISØ	RISØ National Laboratory, Roskilde, Denmark
SCK	Studiecentrum voor Kernenergie, Mol, Belgium
TÜV Rhl.	Technischer Überwachungsverein Rheinland e.V., Köln

b) Notation in text

MSL	(above) mean sea level
AGL	above ground level