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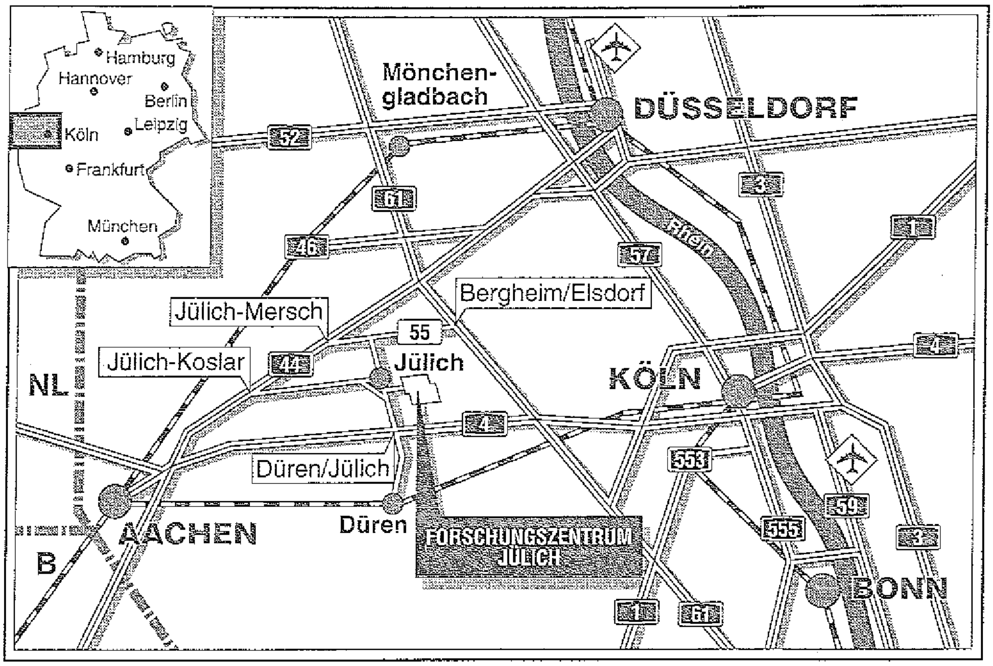
FOURTH FIELD EXPERIMENT ON ATMOSPHERIC DISPERSION AROUND THE ISOLATED HILL SOPHIENHÖHE IN SEPTEMBER 1989

METHODS – EXPERIMENTS – DATA BANK

Edited by
G. Zeuner and K. Heinemann



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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

FOURTH FIELD EXPERIMENT ON ATMOSPHERIC DISPERSION AROUND THE ISOLATED HILL SOPHIENHÖHE IN SEPTEMBER 1989

METHODS – EXPERIMENTS – DATA BANK

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Zusammenfassung

Um eine Datenbasis für die Validierung von fortgeschrittenen Ausbreitungsmodellen zur Verfügung zu stellen, wurden umfangreiche meteorologische Messungen und Ausbreitungsexperimente in einem gut vermessenen nicht ebenem Gelände durchgeführt. Diese Untersuchungen wurden 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 vierten Meßkampagne zusammengestellt.

Abstract

In order to establish 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 were carried out. These investigations became 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 fourth 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.

TABLE OF CONTENTS

List of figures		iii
List of tables		vi
1.	**Introduction** K. Heinemann	1
2.	**Description of the area** G. Zeuner	5
2.1	Topography	5
2.2	Surface structure and roughness	6
3.	**Synoptic conditions** G. Zeuner	8
4.	**Tracer measurements**	21
4.1	Tracer release and sampling network W. Voß, G. Zeuner	21
4.2	SF_6-Tracer measurements by KFA-group W. Voß	25
4.3	SF_6-Tracer measurements by NERI-group E. Lyck	29
4.4	SF_6-Tracer measurements by SCK-group F. Veroustraete	39
4.5	Tracer concentration data G. Zeuner	46
5.	**Meteorological measurements**	62
5.1	Tower and mast measurements G. Zeuner	62
5.2	Tetroon flights M. Möllmann-Coers	74
5.3	Turbulence, Mast and Tethersonde measurements by RISØ-group S. E. Gryning	79
5.4	Tethersonde measurements by IGM-group Ch. Oetz, W. Oetz, G. Zeuner	98
5.5	Radiosonde and Pilotballoon ascents by Wetteramt Essen K. Becker	106

5.6	Doppler-SODAR measurements by TÜV Rheinland, TÜV Essen, KFA W. Bahmann, J. Frank, G. Zeuner	118
5.7	Mobile van by KFA-group IPC H. D. Narres	122
5.8	Wind measurements fire-ladder KFA G. Zeuner	123
6.	**First results and data bank**	125
6.1	Dispersion experiments G. Zeuner	125
6.2	Meteorological data set for a selected period Ch. Plaga, G. Zeuner	137
Literature		158
Appendices		160
A	Intercomparison of SF_6-measurements between NERI, SCK and KFA E. Lyck, F. Veroustraete, W. Voß	161
B	Data of Topography Ch. Plaga, G. Zeuner	164
C	Description of the data-set on magnetic tape Ch. Plaga	165
Addresses of authors		198
Acknowledgements		199
Abbreviations		201

LIST OF FIGURES

Fig. 1.1	Meteorological measurement systems during the Fourth Field Experiment 1989	3
Fig. 2.2.1	Sophienhöhe as seen from southwest	5
Fig. 2.2.2	Estimation of the surface roughness for Sophienhöhe area, 500 m × 500 m grid	7
Fig. 3.1	Surface chart of Sept. 19, 1989, 12:00 UTC	9
Fig. 3.2	Upper level chart (500 hPa) of Sept. 19, 1989, 0:00 UTC	10
Fig. 3.3	Surface chart of Sept. 20, 1989, 12:00 UTC	11
Fig. 3.4	Surface chart of Sept. 21, 1989, 12:00 UTC	12
Fig. 3.5	Surface chart of Sept. 22, 1989, 12:00 UTC	13
Fig. 3.6	Surface chart of Sept. 23, 1989, 12:00 UTC	14
Fig. 3.7	Upper level chart (500 hPa) of Sept. 24, 1989, 0:00 UTC	15
Fig. 3.8	Surface chart of Sept. 24, 1989, 12:00 UTC	16
Fig. 3.9	Surface chart of Sept. 25, 1989, 12:00 UTC	17
Fig. 3.10	Surface chart of Sept. 26, 1989, 12:00 UTC	18
Fig. 3.11	Upper level chart (500 hPa) of Sept. 27, 1989, 0:00 UTC	19
Fig. 3.12	Surface chart of Sept. 27, 1989, 12:00 UTC	20
Fig. 4.1.1	Tracer sampling points for network southwest, network west, both networks southwest and west	24
Fig. 4.2.1	KFA tracer sampling unit	25
Fig. 4.2.2	Schematic drawing of the KFA tracer sampling unit	26
Fig. 4.3.1	A sampling unit positioned for sampling	31
Fig. 4.3.2	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	33
Fig. 4.4.1	Sampling station and PVC sampling bags	41
Fig. 4.4.2	Momentary SF_6-concentrations during experiment IV.3.1	44
Fig. 4.4.3	Momentary SF_6-concentrations during experiment IV.3.2	45
Fig. 5.1.1	The meteorological tower of the Research Center Jülich	63
Fig. 5.1.2	Position of the KFA-tower and masts on Sophienhöhe	67
Fig. 5.1.3a-c	Meteorological measurements at the KFA-tower, Sept. 19, 1989	72
Fig. 5.1.4a-c	Measurements of wind direction WD (a), horizontal (b) and vertical (c) wind speed at KFA-tower and masts 1-5 Sophienhöhe, Sept. 19, 1989	73
Fig. 5.2.1	Tetroon SO8906 and SO8907, slant view	78
Fig. 5.3.1	The mast with the sonic anemometer	80

Fig. 5.3.2	Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 19th of September, period 19:00-22:00 CET	82
Fig. 5.3.3	Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 20th of September, period 18:00-21:00 CET	83
Fig. 5.3.4	Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 23rd of September, period 19:00-22:00 CET	84
Fig. 5.3.5	Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 25th of September, period 19:00-22:00 CET	85
Fig. 5.3.6	Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 27th of September, period 11:00-14:00 CET	86
Fig. 5.3.7	The caravan containing the electronics for the sonic anemometer and the data recording equipment	87
Fig. 5.3.8	Profiles of wind speed and potential temperature measured at Pattern, 19th of September at 19:54 CET	89
Fig. 5.3 9	Profiles of wind speed and potential temperature measured at Pattern, 19th of September at 20:44 CET	89
Fig. 5.3.10	Profiles of wind speed and potential temperature measured at Pattern, 20th of September at 20:33 CET	90
Fig. 5.3.11	Profiles of wind speed and potential temperature measured at Pattern, 23rd of September at 21:20 CET	90
Fig. 5.3.12	Profiles of wind speed and potential temperature measured at Pattern, 25th of September at 20:39 CET	91
Fig. 5.3.13	Profiles of wind speed and potential temperature measured at Pattern, 27th of Septenber at 12:48 CET	91
Fig. 5.3.14	Illustration of the measurements at the small masts on 19th of September, period 19:00-22:00 CET	93
Fig. 5.3.15	Illustration of the measurements at the small masts on 20th of September, period 18:00-21:00 CET	94
Fig. 5.3.16	Illustration of the measurements at the small masts on 23rd of September, period 19:00-22:00 CET	95
Fig. 5.3.17	Illustration of the measurements at the small masts on 25th of September, period 19:00-22:00 CET	96
Fig. 5.3.18	Illustration of the measurements at the small masts on 27th of September, period 11:00-14:00 CET	97
Fig. 5.4.1	Positions of the tethered balloon IGM Köln	99
Fig. 5.4.2	Tethersonde ascent on Sept. 19, 1989, 20:30-21:39	103
Fig. 5.4.3	Tethersonde ascent on Sept. 22, 1989, 07:58-09:03	104
Fig. 5.4.4	Tethersonde ascent on Sept. 23, 1989, 19:21-19:57	105
Fig. 5.5.1	Vertical profiles of wind, temperature and relative humidity during the dispersion experiment at KFA, 19.09.1989	112

Fig. 5.5.2	Vertical profiles of wind, temperature and relative humidity during the dispersion experiment at KFA, 23.09.1989	113
Fig. 5.5.3	Vertical profiles of wind, temperature and relative humidity during the dispersion experiment at KFA, 27.09.1989	114
Fig. 5.5.4	Flight track projection of pilot balloons to surface, 19.09.1989	115
Fig. 5.5.5	Profiles of pilot balloon ascents in the western part of the Sophienhöhe, 19.09.1989	116
Fig. 5.5.6	Flight track projection of pilot balloons to surface, 25.09.1989	117
Fig. 5.6.1	Availability of SODAR data (TÜV Rheinland)	119
Fig. 5.6.2	Frequency distribution of wind direction at 60 m and 400 m height, SODAR TÜV Essen, Sept. 19 - Sept. 22, 1989	121
Fig. 6.1.1	Mean wind around Sophienhöhe on Sept. 19, 1989 20:00-20:30	128
Fig. 6.1.2	Mean wind around Sophienhöhe on Sept. 19, 1989 20:30-21:00	129
Fig. 6.1.3	Mean wind around Sophienhöhe on Sept. 19, 1989 21:00-21:30	130
Fig. 6.1.4	Pattern of the concentration distribution for exp. IV.1.1 and IV.1.2 on Sept. 19, 1989,	131
Fig. 6.1.5	Pattern of the concentration distribution for exp. IV.1.3 on Sept. 19,1988 and IV.2.1 on Sept. 20, 1989	132
Fig. 6.1.6	Mean wind around Sophienhöhe on Sept. 23, 1989, 21:30-22:00	134
Fig. 6.1.7	Pattern of the concentration distribution for exp. IV.3.3 on Sept. 23 and IV.5.1 on Sept. 27, 1989	136

LIST OF TABLES

Tab. 2.2.1	Mean values of z_0	6
Tab. 4.1.1	SF_6-background concentrations during dispersion experiments	21
Tab. 4.1.2	SF_6-tracer release data	22
Tab. 4.1.3	Coordinates of the release points used in the experiments	22
Tab. 4.1.4	Tracer release points planned for dispersion experiments	23
Tab. 4.2.1	Results of calibration at 10/16/89	28
Tab. 4.3.1	Performance of the laboratory and mobil gaschromatographs	32
Tab. 4.3.2	Instantaneous sulphurhexafluoride concentrations for experiment IV.1, 19.09.1989	34
Tab. 4.3.3	Instantaneous sulphurhexafluoride concentrations for experiment IV.2, 20.09.1989	35
Tab. 4.3.4	Instantaneous sulphurhexafluoride concentrations for experiment IV.3, 23.09.1989	36
Tab. 4.3.5	Instantaneous sulphurhexafluoride concentrations for experiment IV.4, 25.09.1989	37
Tab. 4.3.6	Instantaneous sulphurhexafluoride concentrations for experiment IV.5, 27.09.1989	38
Tab. 4.5.1	Tracer concentrations for experiment IV.1.1-IV.1.3, 19.09.1989	47
Tab. 4.5.2	Tracer concentrations for experiment IV.2.1-IV.2.3, 20.09.1989	50
Tab. 4.5.3	Tracer concentrations for experiment IV.3.1-IV.3.3, 23.09.1989	53
Tab. 4.5.4	Tracer concentrations for experiment IV.4.1-IV.4.3, 25.09.1989	56
Tab. 4.5.5	Tracer concentrations for experiment IV.5.1-IV.5.3, 27.09.1989	59
Tab. 5.1.1	Instrumentation at the KFA-tower	64
Tab. 5.1.2	Sonic anemometer measurements at the KFA-tower	65
Tab. 5.1.3	Instrumentation of masts 1-5 on Sophienhöhe	69
Tab. 5.1.4	Location of KFA-tower and masts on the Sophienhöhe	69
Tab. 5.2.1	Technical details of radar and transponder	75
Tab. 5.2.2	Tetroon numbers and dispersion experiments	76
Tab. 5.2.3	Radar and launch positions in Gauß-Krüger coordinates	77
Tab. 5.3.1	Variances and covariances of the turbulence derived from the sonic anemometer measurements	81

Tab. 5.3.2	Measuring periods (Central European Time, CET) for the 10-min averaged turbulence statistics	81
Tab. 5.3.3	Characteristics of the tether sonde sensors	87
Tab. 5.3.4	Measurements with the tethered balloon at Pattern	88
Tab. 5.3.5	Positions of the small masts	92
Tab. 5.3.6	Measurements for all four masts contained in the data bank	92
Tab. 5.4.1	Position of the tethered balloon measurements	100
Tab. 5.4.2	Measurements with the tethered balloon IGM group	100
Tab. 5.4.3	Log-book tether sonde measurements	101
Tab. 5.5.1	Pilot-balloon and radiosonde ascents with radar tracking within the KFA	109
Tab. 5.5.2	Theodolite and launch positions for double-theodolite measurements	110
Tab. 5.5.3	Pilot-balloon ascents with tracking by double-theodolite method in the western area of 'Sophienhöhe'	111
Tab. 5.8.1	Wind measurements fire-ladder, Sept. 20, 1989	123
Tab. 5.8.2	Wind measurements fire-ladder, Sept. 25, 1989	124
Tab. 5.8.3	Wind measurements fire-ladder, Sept. 27, 1989	124
Tab. 6.1.1	Overview of tracer experiments and meteorological conditions	125
Tab. 6.2.1	Meteorological measurements at KFA-tower, 19.09.1989	139
Tab. 6.2.2	Meteorological measurements at Mast Rheinbraun on the Sophienhöhe, 19.09.1989	140
Tab. 6.2.3	Meteorological measurements at Mast 1 Sophienhöhe, 19.09.1989	140
Tab. 6.2.4	Meteorological measurements at Mast 2 Sophienhöhe, 19.09.1989	140
Tab. 6.2.5	Meteorological measurements at Mast 3 Sophienhöhe, 19.09.1989	141
Tab. 6.2.6	Meteorological measurements at Mast 4 Sophienhöhe, 19.09.1989	141
Tab. 6.2.7	Meteorological measurements at Mast 5 Sophienhöhe, 19.09.1989	141
Tab. 6.2.8	Meteorological measurements at sonic KFA and sonic Sophienhöhe, 19.09.1989	143
Tab. 6.2.10	Meteorological measurements at Mast 1 RISØ, 19.09.1989	143
Tab. 6.2.11	Meteorological measurements at Mast 2 RISØ, 19.09.1989	143
Tab. 6.2.12	Meteorological measurements at Mast 3 RISØ, 19.09.1989	143
Tab. 6.2.13	Meteorological measurements at Mast 4 RISØ, 19.09.1989	143

Tab. 6.2.14	Meteorological measurements at Mast IPC, 19.09.1989	143
Tab. 6.2.15	Meteorological measurements at sonic RISØ, 19.09.1989	144
Tab. 6.2.17	Meteorological measurements at SODAR Köln, 19.09.1989	145
Tab. 6.2.18	Meteorological measurements at SODAR Essen, 19.09.1989	147
Tab. 6.2.19	RAWIN-sonde Essen, ascent No. 5, 19.09.1989	149
Tab. 6.2.20a	Pilotballoon Essen, ascent No. 6, 19.09.1989	150
Tab. 6.2.20b	Pilotballoon Essen, ascent No. 8, 31.08.1989	150
Tab. 6.2.21	Radiosonde Essen, ascent No. 2, 19.09.1989	151
Tab. 6.2.22	Tether sonde RISØ, ascent No. 1, 19.09.1989	152
Tab. 6.2.23	Tether sonde Köln, ascent No. 1, 19.09.1989	154
Tab. 6.2.24	Tetroon, ascent No. 1, 19.09.1989	156
Tab. A 1	Analysis by KFA of the calibration mixtures prepared with synthetic air by KFA	161
Tab. A 2	Analysis by NERI of the calibration mixtures prepared with synthetic air by KFA	161
Tab. A 3	Analysis by KFA and NERI of calibration mixtures prepared with nitrogen by KFA	162
Tab. A 4	Results of the intercomparison between NERI and KFA	162
Tab. A 5	Results of the calibration test by SCK and KFA	163
Tab. A 6	Results of the intercomparison between NERI, KFA and SCK	163

1. INTRODUCTION

K. Heinemann

For potential accidents or licensing procedures of a plant dispersion calculations are needed in order to determine the impact of pollutant releases 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)). However the application of the Gaussian plume model is restricted to stationary meteorological conditions and to plain terrains. In general the Gaussian plume model gives good results for long-time dispersion factors (licensing procedures) but it may fail in the case of an accidental release (short-time dispersion factor) during changing meteorological conditions especially in complex terrains.

Many advanced wind field and dispersion models, considering changing weather conditions and complex terrains 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 some comprehensive data sets including

- experimental results of dispersion experiments,
- simultaneous meteorological measurements of the wind and turbulence field, and
- topographical data of the experimental area.

In order to compile such a data set the german 'Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit' financially supported 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 were carried out in the same region where dispersion parameters for the Gaussian plume model have been determined since 1970. In the seventies this area was a flat countryside but since 1980 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 very appropriate for dispersion experiments.

The dispersion experiments were performed with sulfurhexafluorid (SF_6) as tracer, which was released from different locations in a height of 30 m or 50 m AGL. Whereas in the 1970s experiments air concentrations were determined at about 30 positions, in these experiments between 50 and during field experiments up to 140 air samples were taken in the area of the overburden tip.

Continuous meteorological measurements were made at the meteorological tower of the KFA, at five masts built up on the hill and with a Doppler SODAR system. Fig. 1.1 indicates the positions of these devices with respect to the Sophienhöhe.

In field experiments external groups participated with their equipments, so that the information on the meteorological data and the tracer distribution became more complete. Altogether five field experiments, one each year, were carried out during this investigation. The Fourth Field Experiment was carried out from September 19 - September 28, 1989. The focus of the Fourth Field Experiment was to study dispersion under stable atmospheric conditions. The following groups (see also list of abbreviations) participated with their equipments:

DWD	radiosondes with radar tracking, pilot balloons, radar tracking of tetroons
IPC	mobile van
IGM	tether sonde
NERI	sampling stations, gaschromatograph
RWTÜV	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.

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

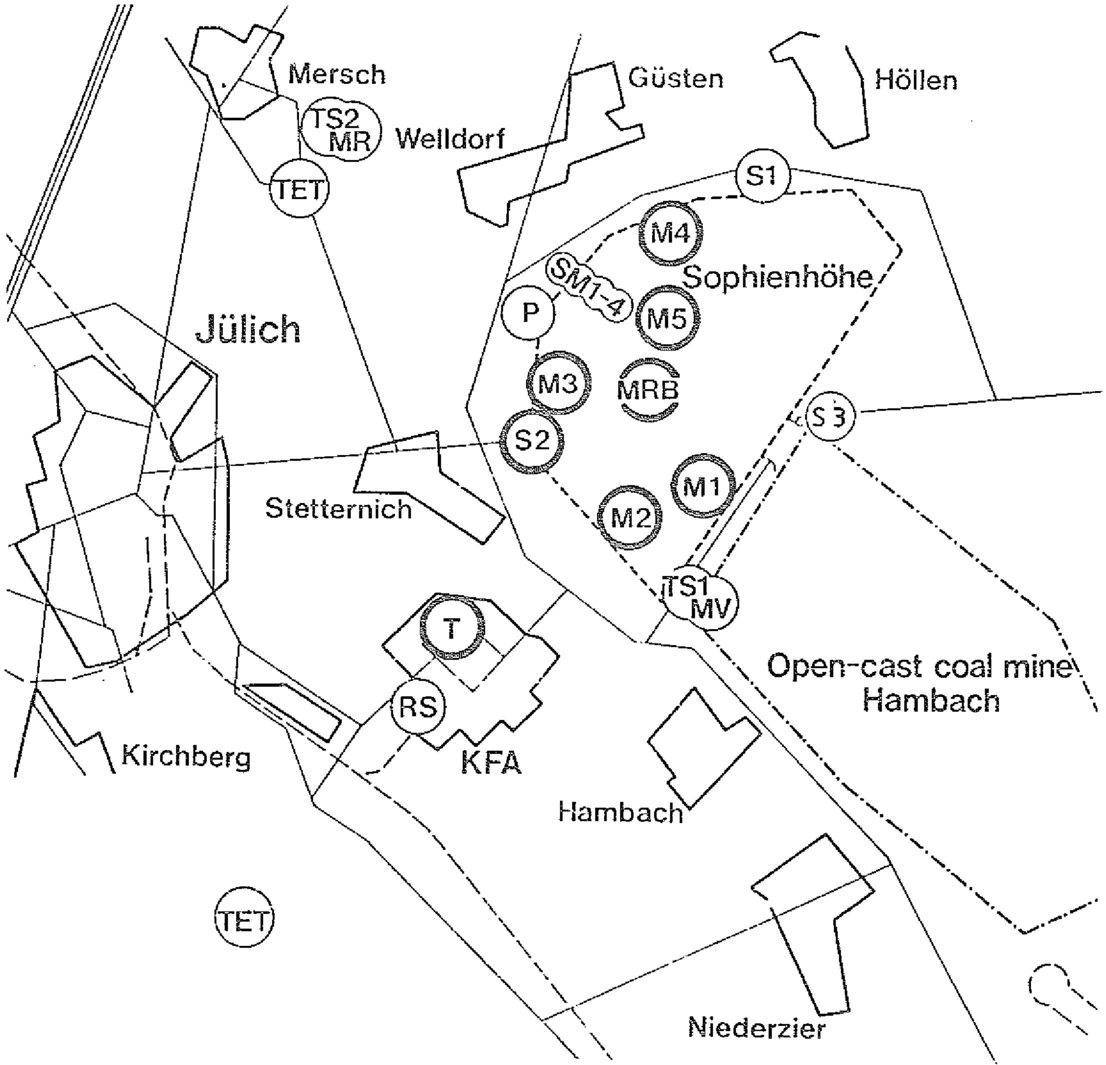


Fig. 1.1: Meteorological measurement systems during the Fourth Field Experiment 1989

◎	continuous measurements	○	measurements by external groups
T	: KFA-tower	RS	: Radiosonde-station Wetteramt Essen
M1-M5	: Masts KFA	TS1	: Tether sonde IGM
MRB	: Mast Rheinbraun	TS2	: Tether sonde RISØ
S2	: Doppler-SODAR KFA	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

This report describes the fourth field experiment with special emphasis on the measuring systems, some experimental results, and the data bank structure. The structure of this report is very similar to the report of the third field experiment (Zeuner and Heinemann, 1990), because the same groups participated with almost the same equipment as in 1988. Therefore the measurement systems here are shortly described, for details it will be referred to the report of the third field experiment. 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 (Sept. 19) 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 tapes.

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 $\simeq 5 \times 3$ km^2 which in 1989 was 230 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.

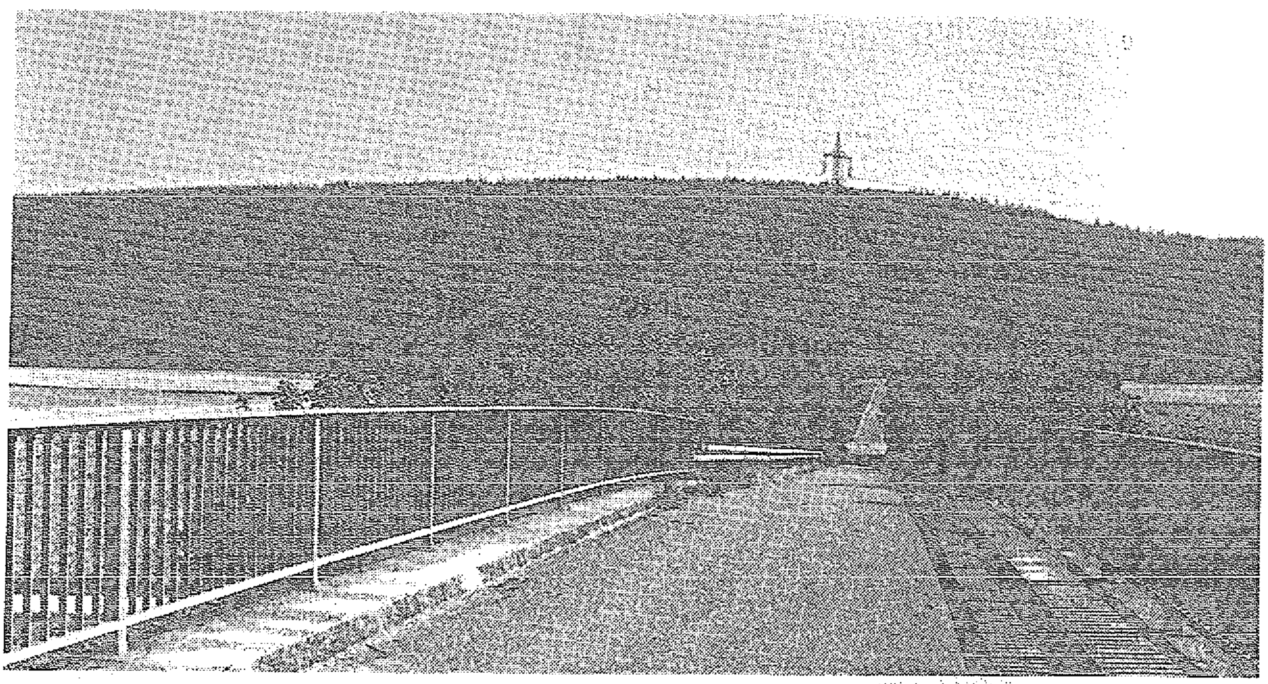


Fig.2.2.1: Sophienhöhe as seen from southwest

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 6 m) high in the southern part and lower than 2 m in the northern part. In the indendations humid biotopes ("ponts and puddles") are embedded. The plateau is characterized by good-natured planting with small 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 about 10 % of the height of the trees, see Kraus (1970). A more accurate roughness length can be derived from wind profile measurements.

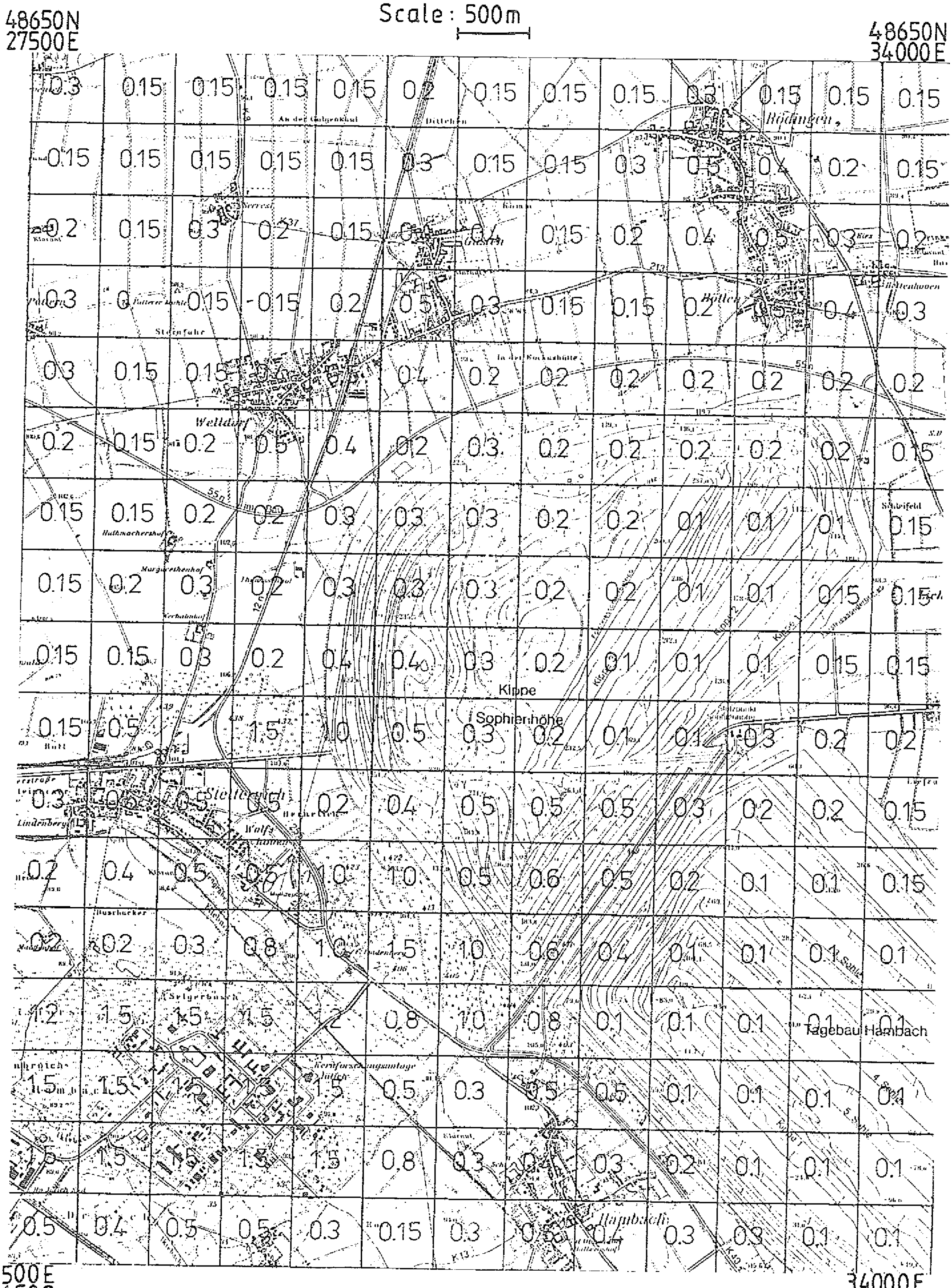


Fig. 2 2 2: Estimation of the surface roughness (in meter) for Sophienhöhe area, 500 m × 500 m grid; the Gauß-Krüger coordinates are given at the corners

3. SYNOPTIC CONDITIONS SEPT. 19 - SEPT. 28, 1989

G. Zeuner

In the beginning of the field campaign, the high-level weather maps (500 hPa) showed a trough over the Atlantic and a high-pressure ridge over the eastern part of Central Europe. This pressure distribution caused a southwesterly airstream in Western Europe which persisted until 23rd of September. On 19th of September, on surface a coldfront coupled with a preceeding convergence zone passed our region. As in higher levels, winds were coming from southwest which are favourable conditions for tracer emission from the meteorological tower. So the first dispersion experiment was already carried out on the first day of the field experiment in the evening under stable atmospheric conditions and little cloudy skies.

Behind the coldfront a high-pressure ridge built-up over Central and Eastern Europe on the following day, September 20, resulting in a southeasterly flow in our area. Because this situation seemed to persist for a few days, another dispersion experiment was planned for the evening with emission east of the hill. During the experiment the wind weakened and turned from southeasterly to southerly directions so that most of the tracer plume didn't hit the hill slope.

On 21st of September, the high-pressure ridge moved eastward and a coldfront coupled with a wave was approaching from the Atlantic. The following day, a convergence zone passed our area and the wind shifted to westerly, northwesterly directions. On 23rd of September the coldfront moved over our region in the morning without any weather activities and wind direction changes. In the evening a tracer experiment with the water tower as emission point was carried out. During the experiment the sky was cloudy, the wind weakened and becam variable.

On 24th of September, a small cyclone over France and a high-pressure ridge over Poland characterized the conditions in the upper levels. This resulted in a southerly, southeasterly high-level airstream over Central Europe. On surface, a high-pressure cell developed over the Northsea. Winds were weak and variable. The next day, September 25, a large high-pressure cell lay over Europe reaching from the Atlantic up to Russia. Winds were mostly westerly but quite variable. The dispersion experiment performed in the evening failed because the wind shifted away during the experiment.

On 26th of September, a coldfront moved over our region causing some rain in the afternoon; the wind shifted to west or northwest. The following day, a high-pressure ridge was approaching from west and the wind oscillated between northwest and north. Around noon it was mostly sunny and the atmosphere was unstable stratified. Then the last dispersion experiment was carried out. On 28th of September, the high-pressure cell over the Atlantic spread eastward.

The weather maps of this period are shown in the following figures 3.1 - 3.12.

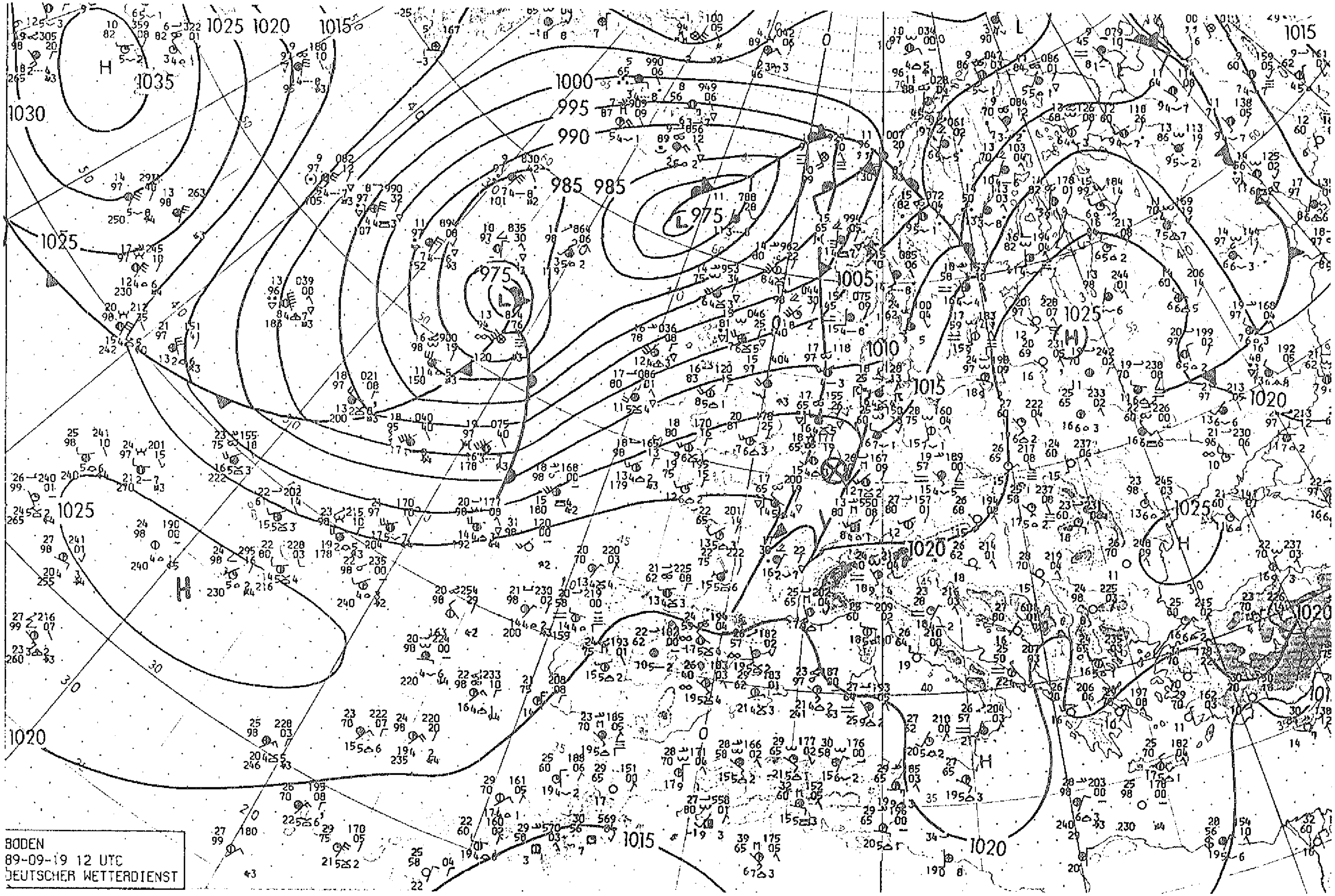


Fig. 3.1 Surface chart of Sept. 19, 1989, 12:00 UTC

⊗ Area of investigation

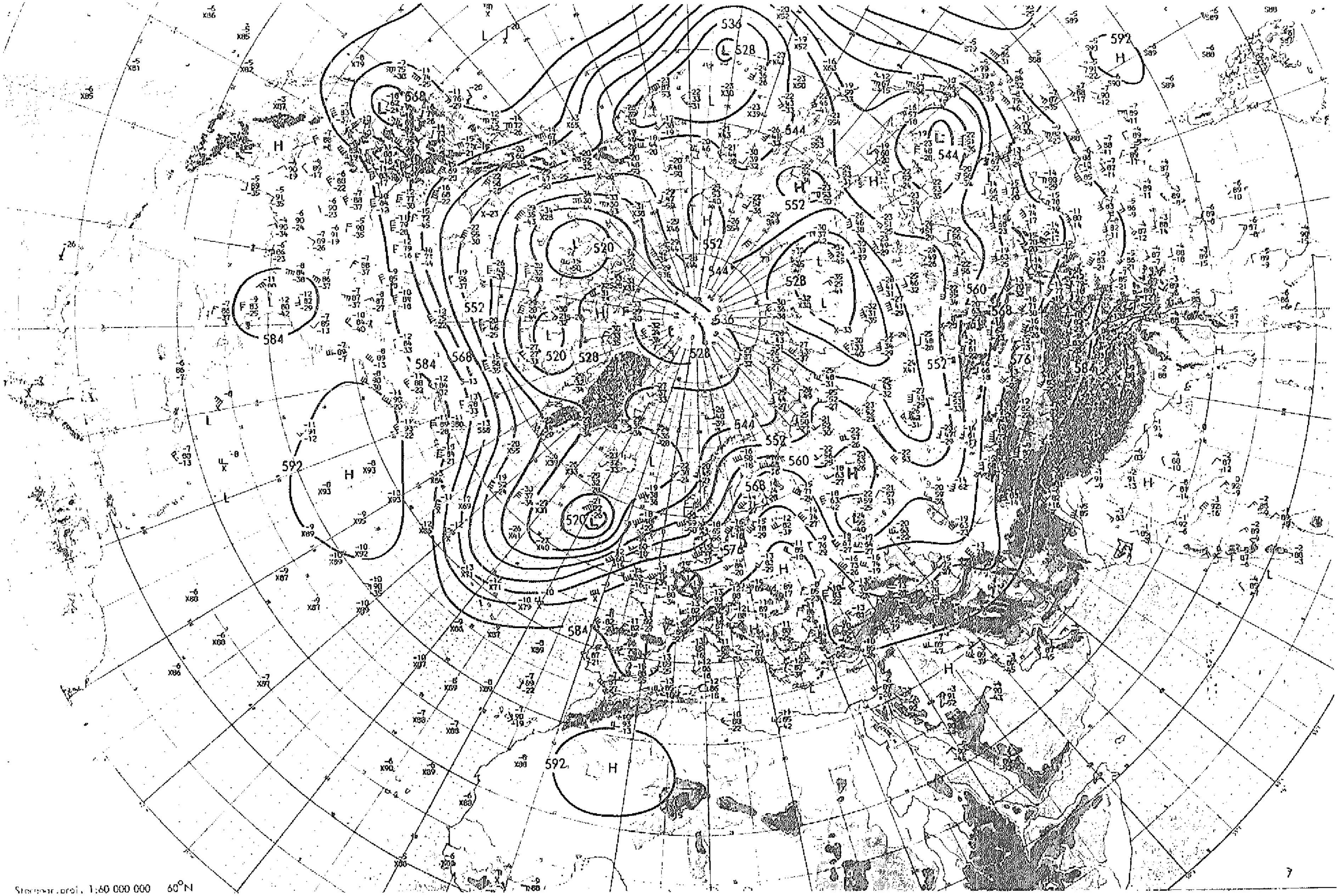


Fig. 3.2 Upper level chart (500 hPa) of Sept. 19, 1989, 0:00 UTC

⊗ Area of investigation

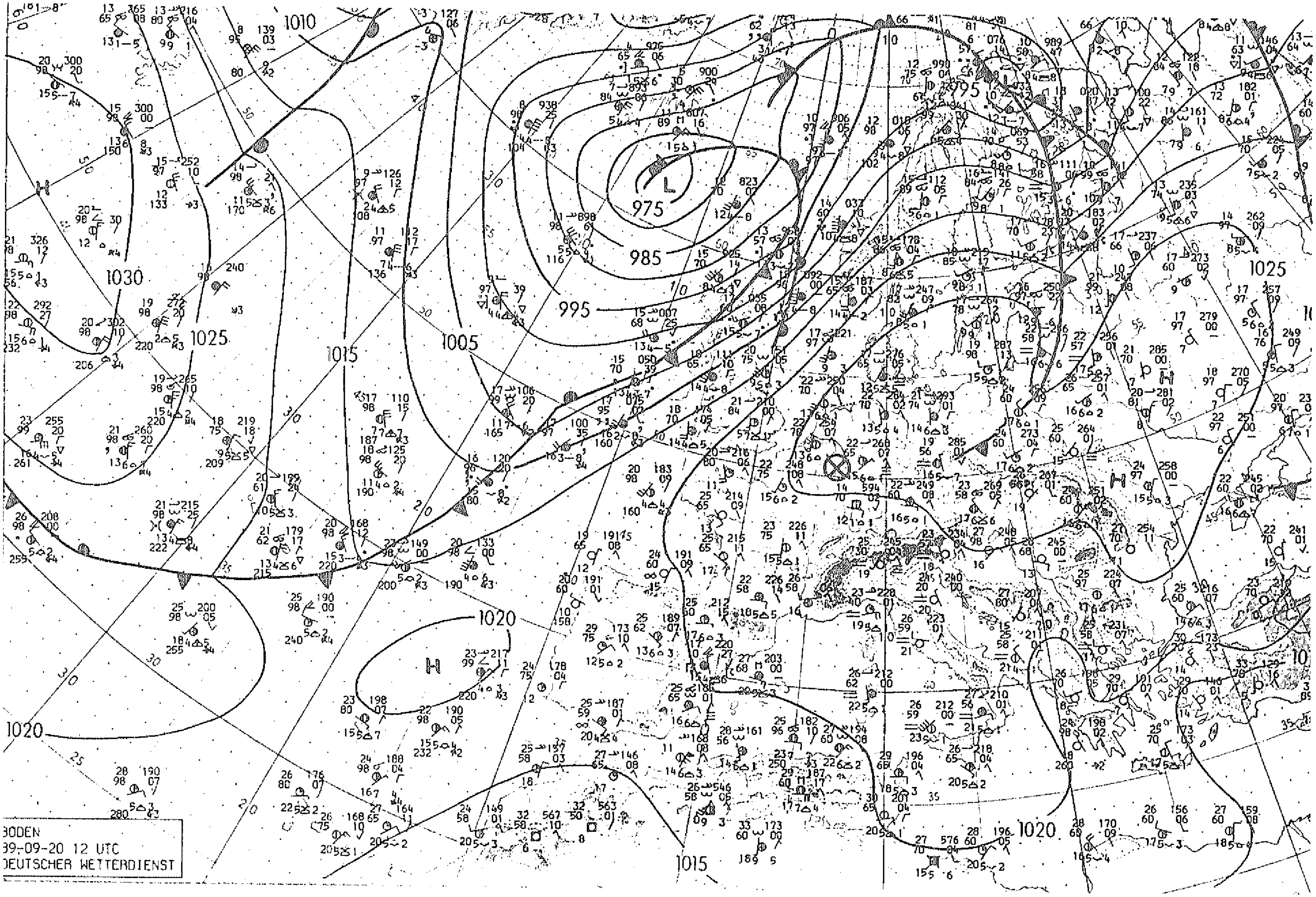


Fig. 3.3 Surface chart of Sept. 20, 1989, 12:00 UTC
⊗ Area of investigation

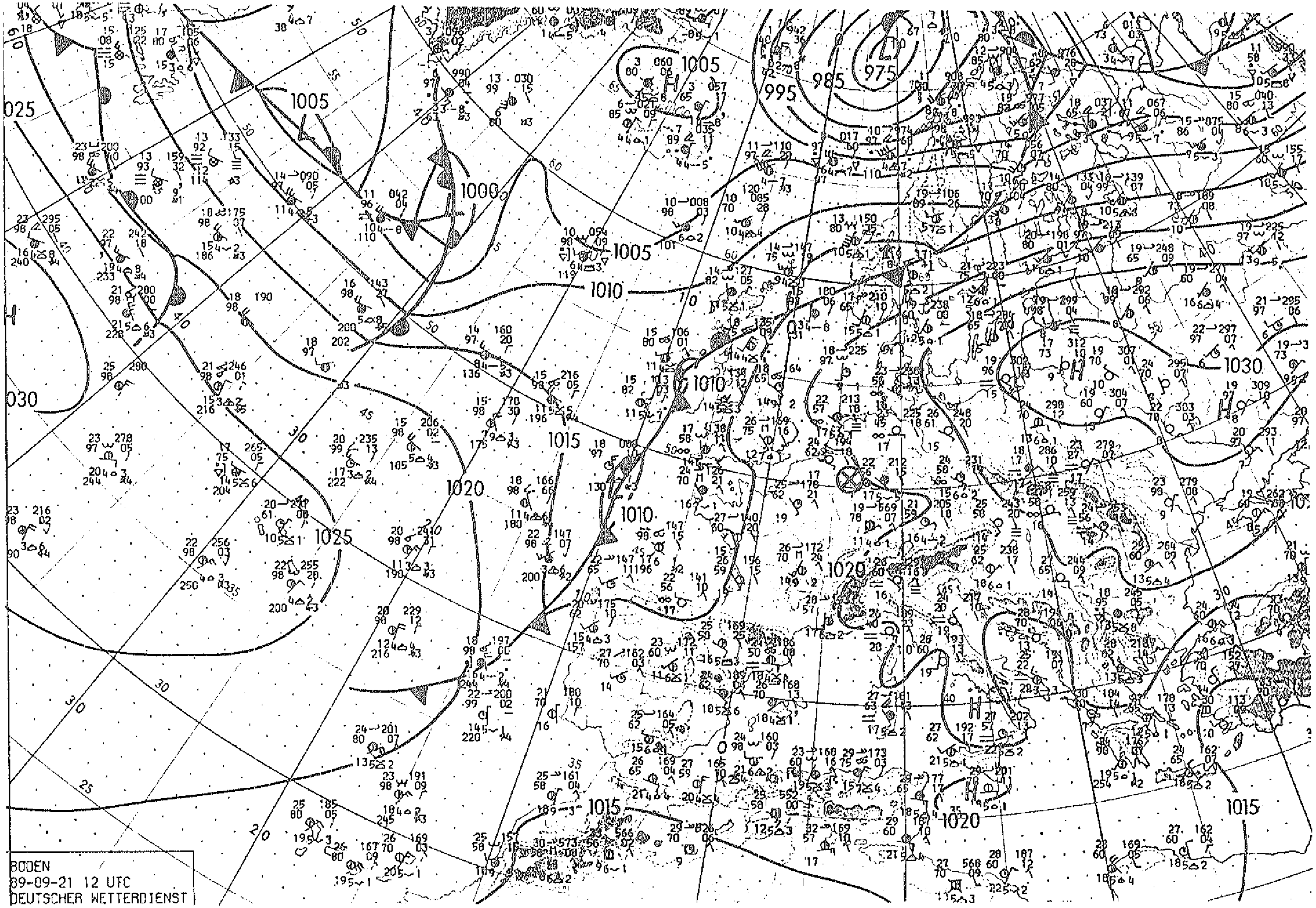


Fig. 3.4 Surface chart of Sept. 21, 1989, 12:00 UTC

⊗ Area of investigation

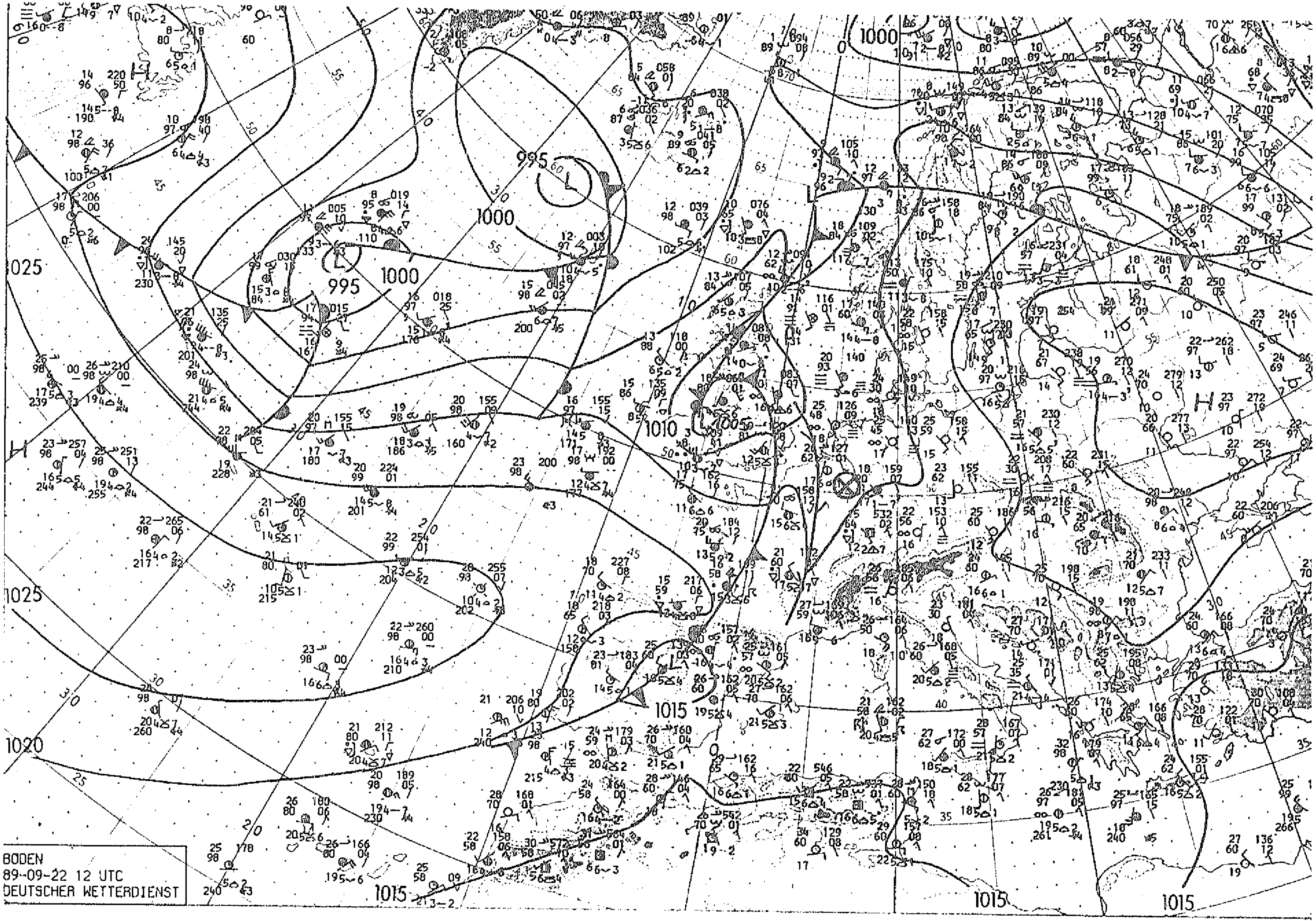


Fig. 3.5 Surface chart of Sept. 22, 1989, 12:00 UTC

⊗ Area of investigation

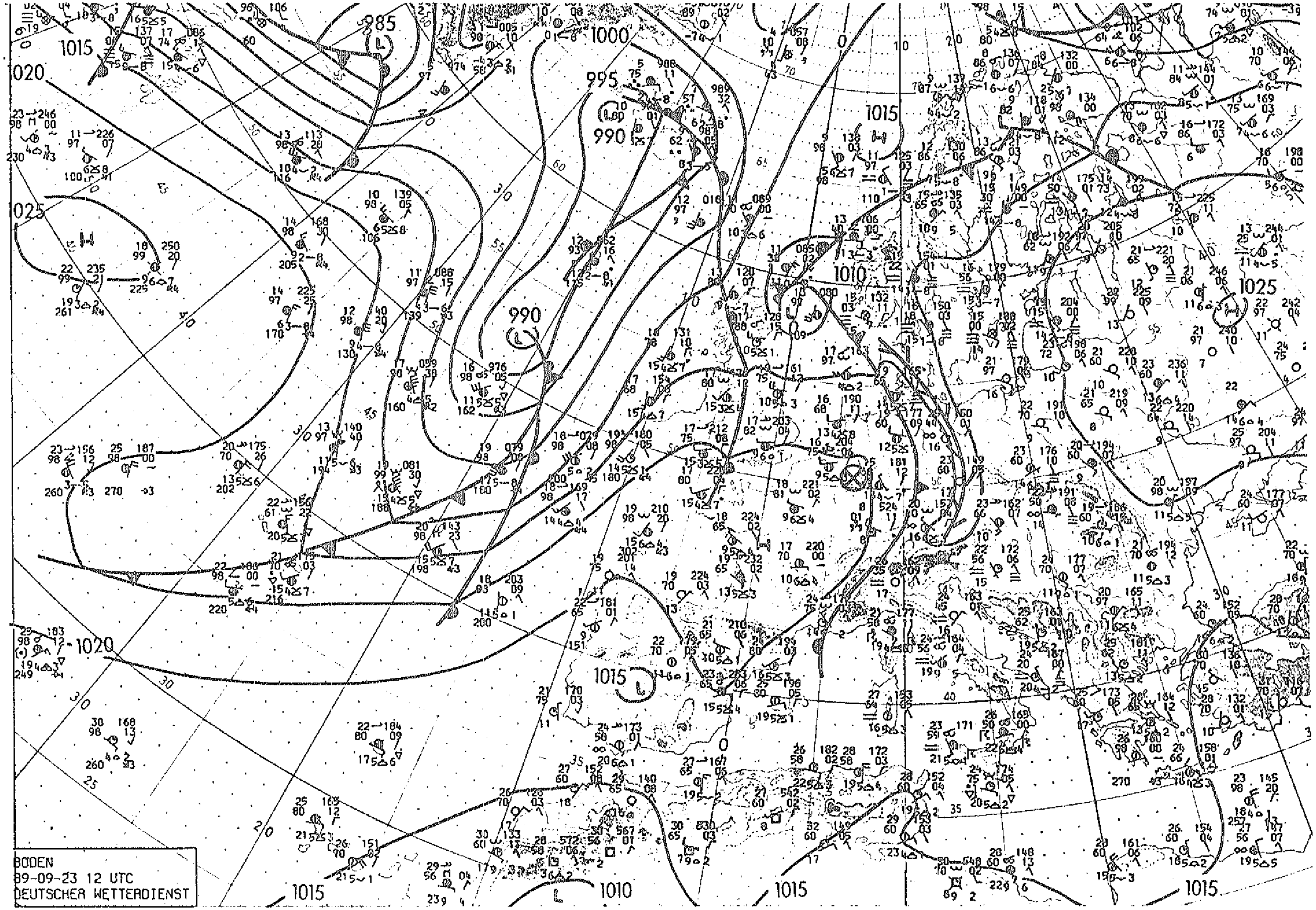


Fig. 3.6 Surface chart of Sept. 23, 1989, 12:00 UTC
⊗ Area of investigation

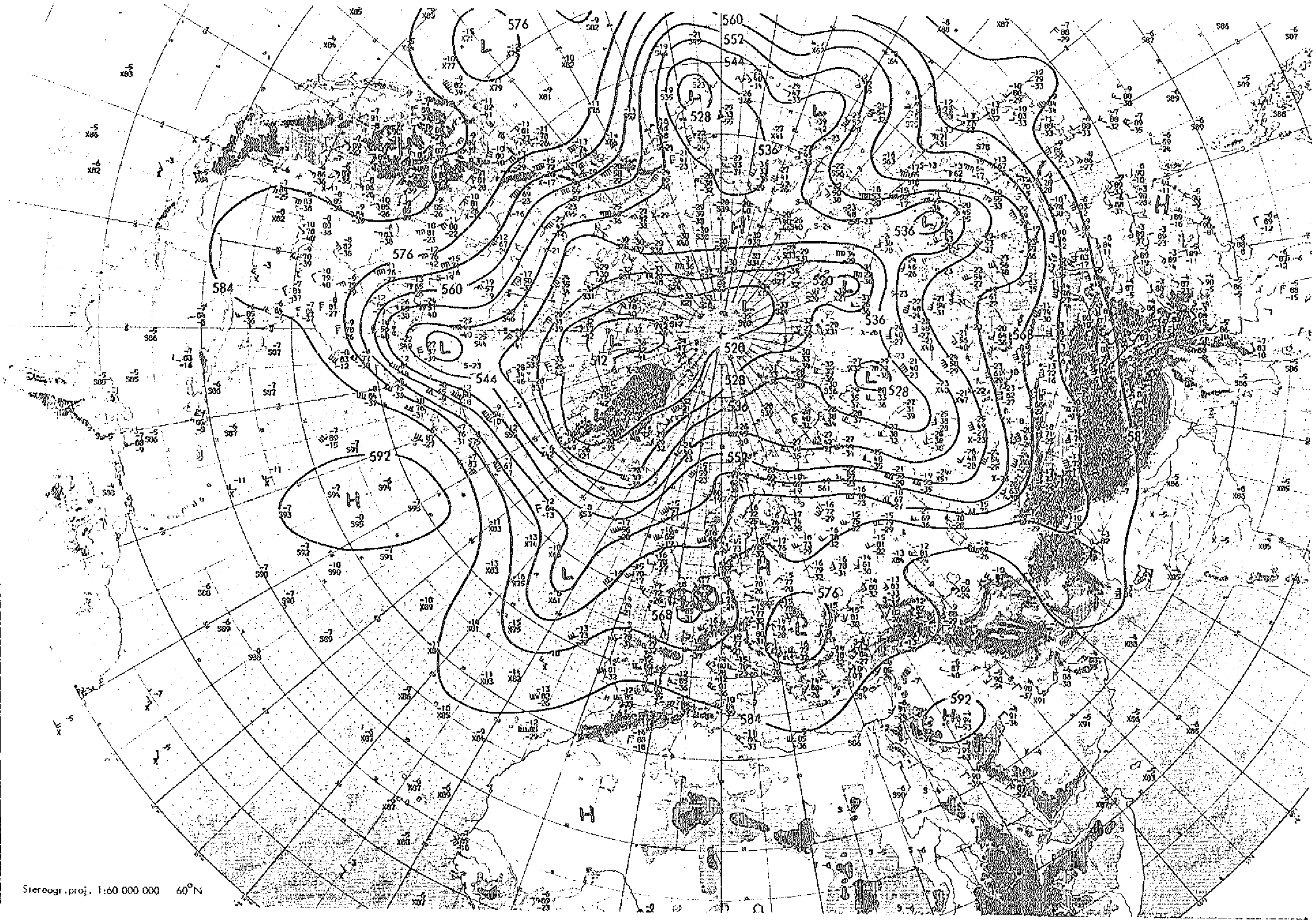


Fig. 3.7 Upper level chart (500 hPa) of Sept. 24, 1989, 0:00 UTC
⊗ Area of investigation

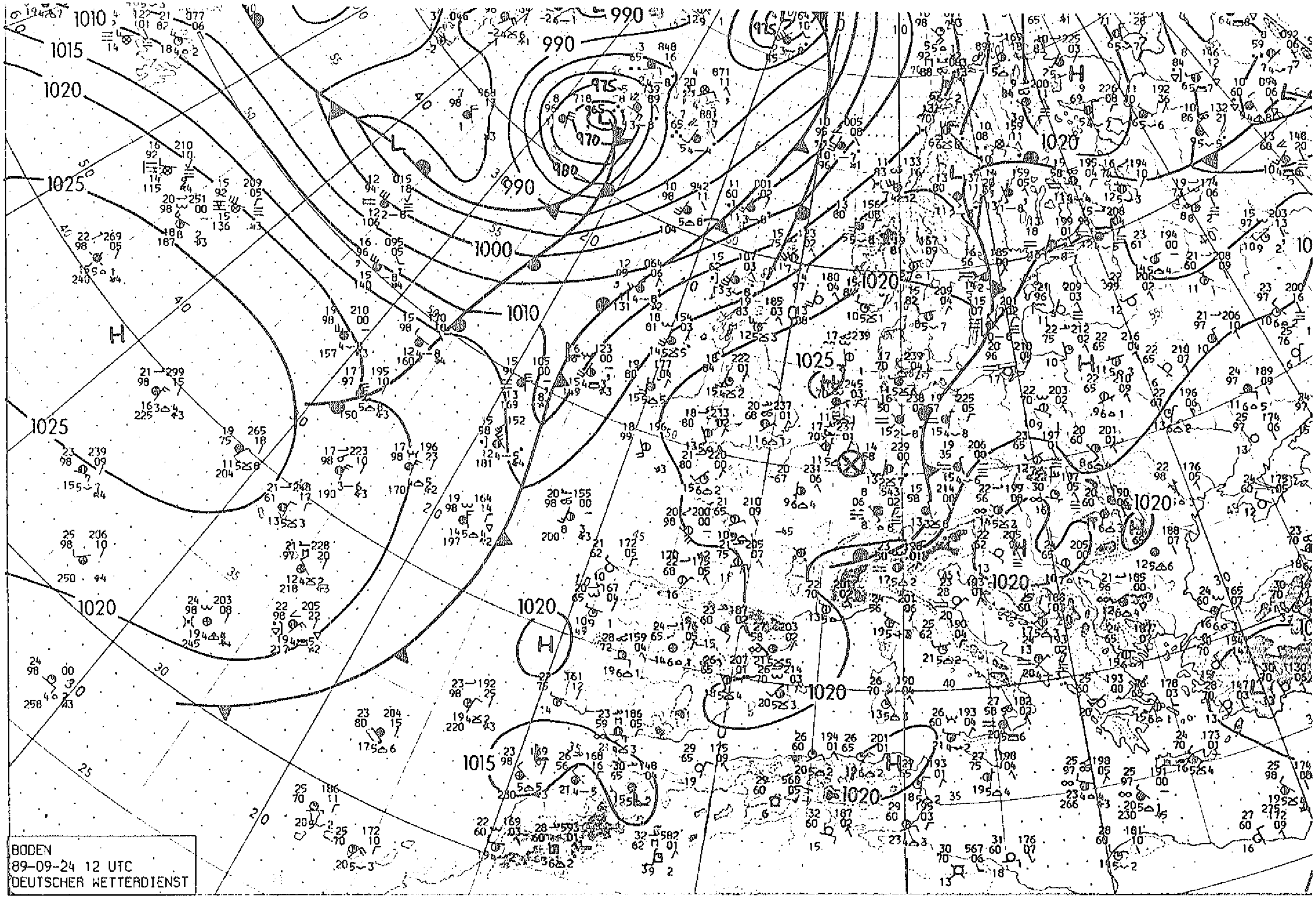


Fig. 3.8 Surface chart of Sept. 24, 1989, 12:00 UTC
⊗ Area of investigation

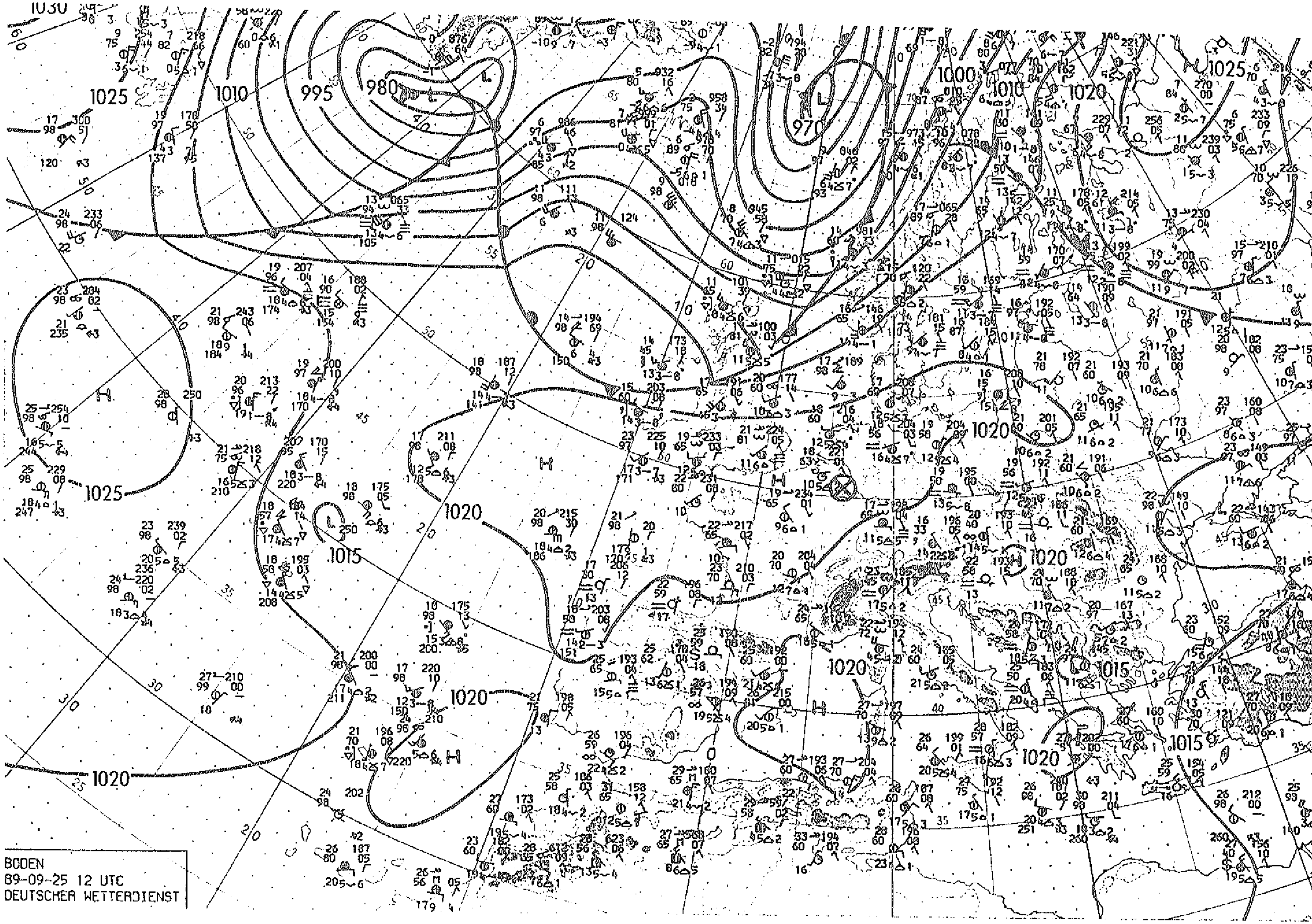


Fig. 3.9 Surface chart of Sept. 25, 1989, 12:00 UTC

⨂ Area of investigation

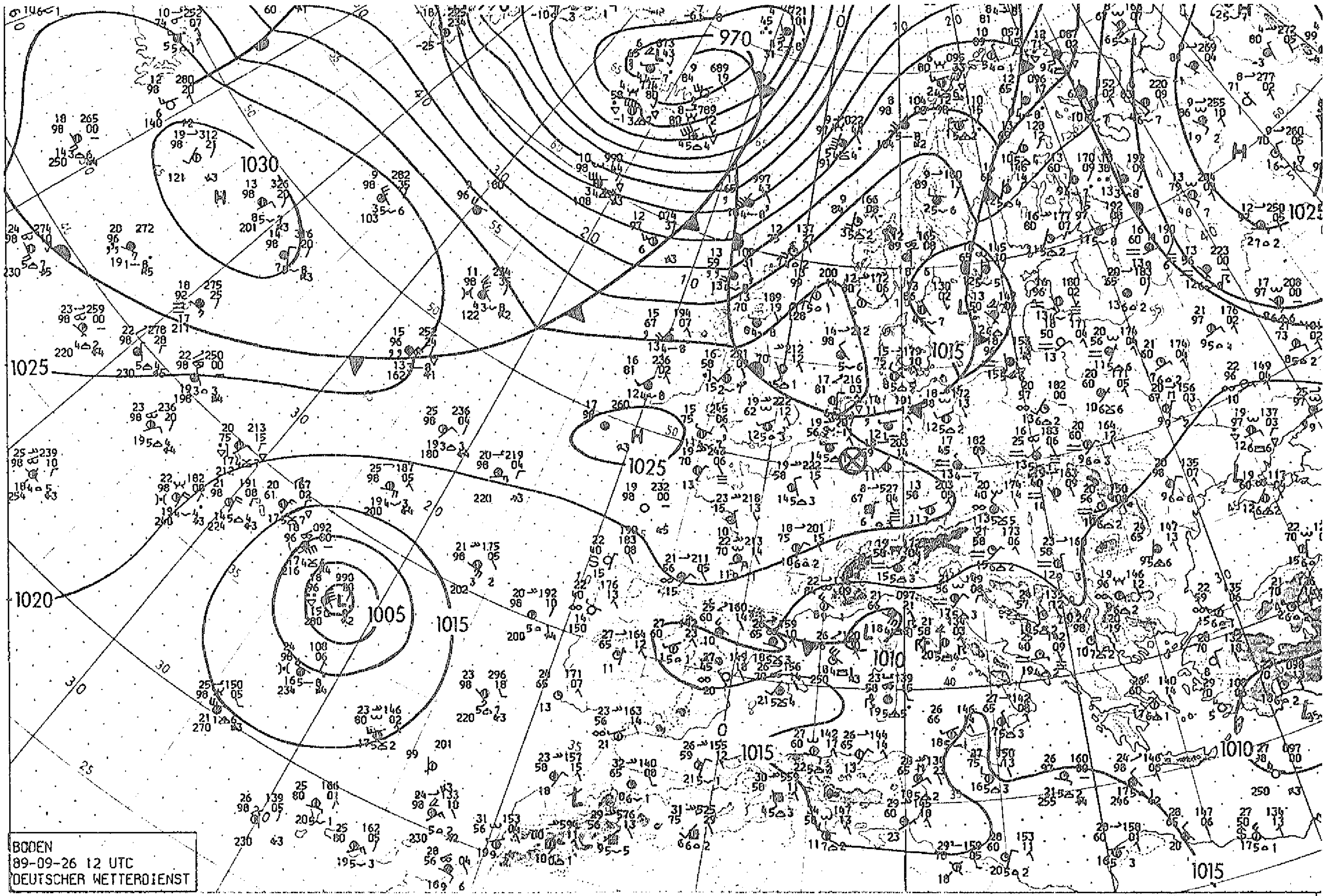


Fig. 3.10 Surface chart of Sept. 26, 1989, 12:00 UTC
⊗ Area of investigation

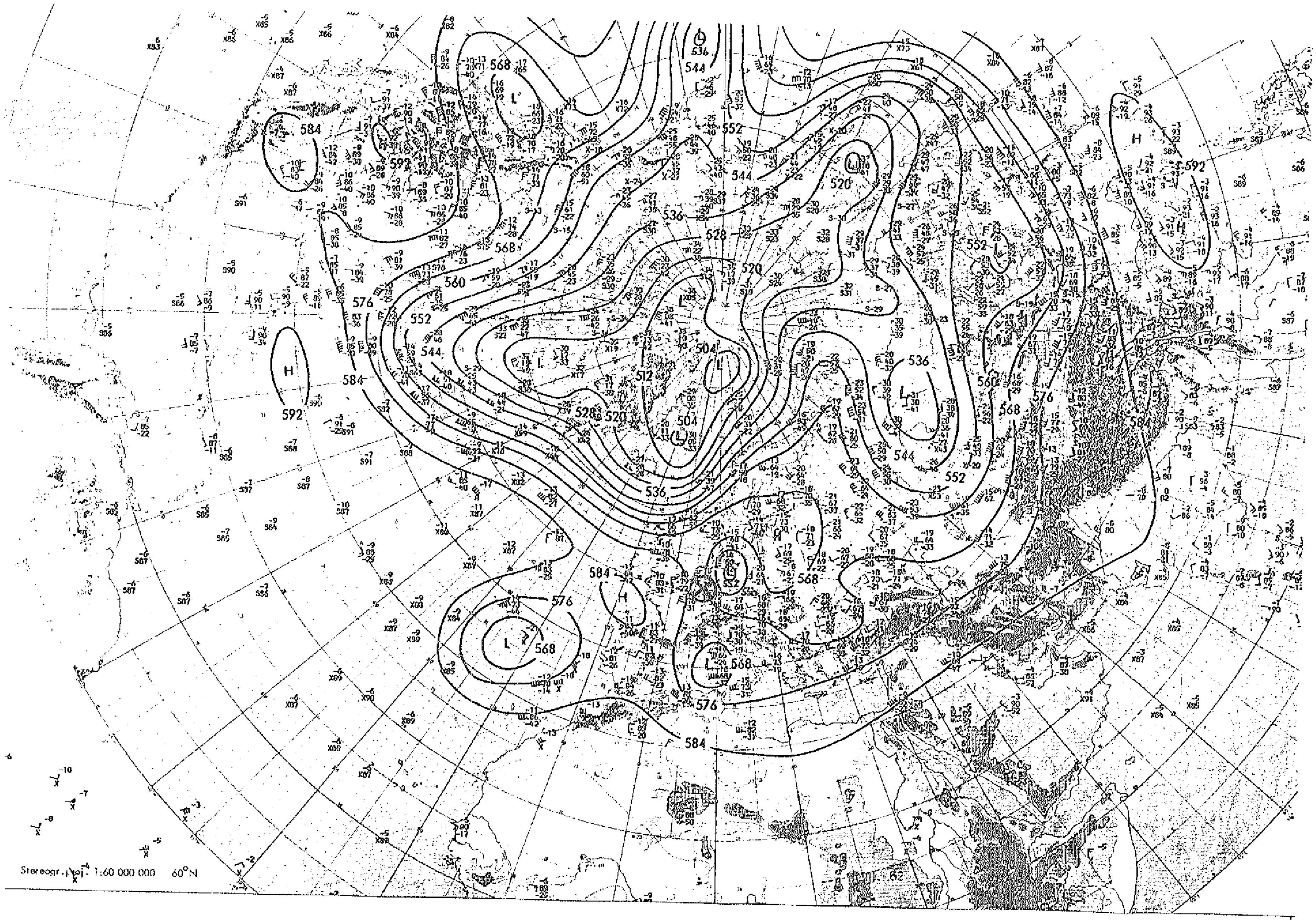


Fig. 3.11 ⊗ Upper level chart (500 hPa) of Sept. 27, 1989, 0:00 UTC
Area of investigation

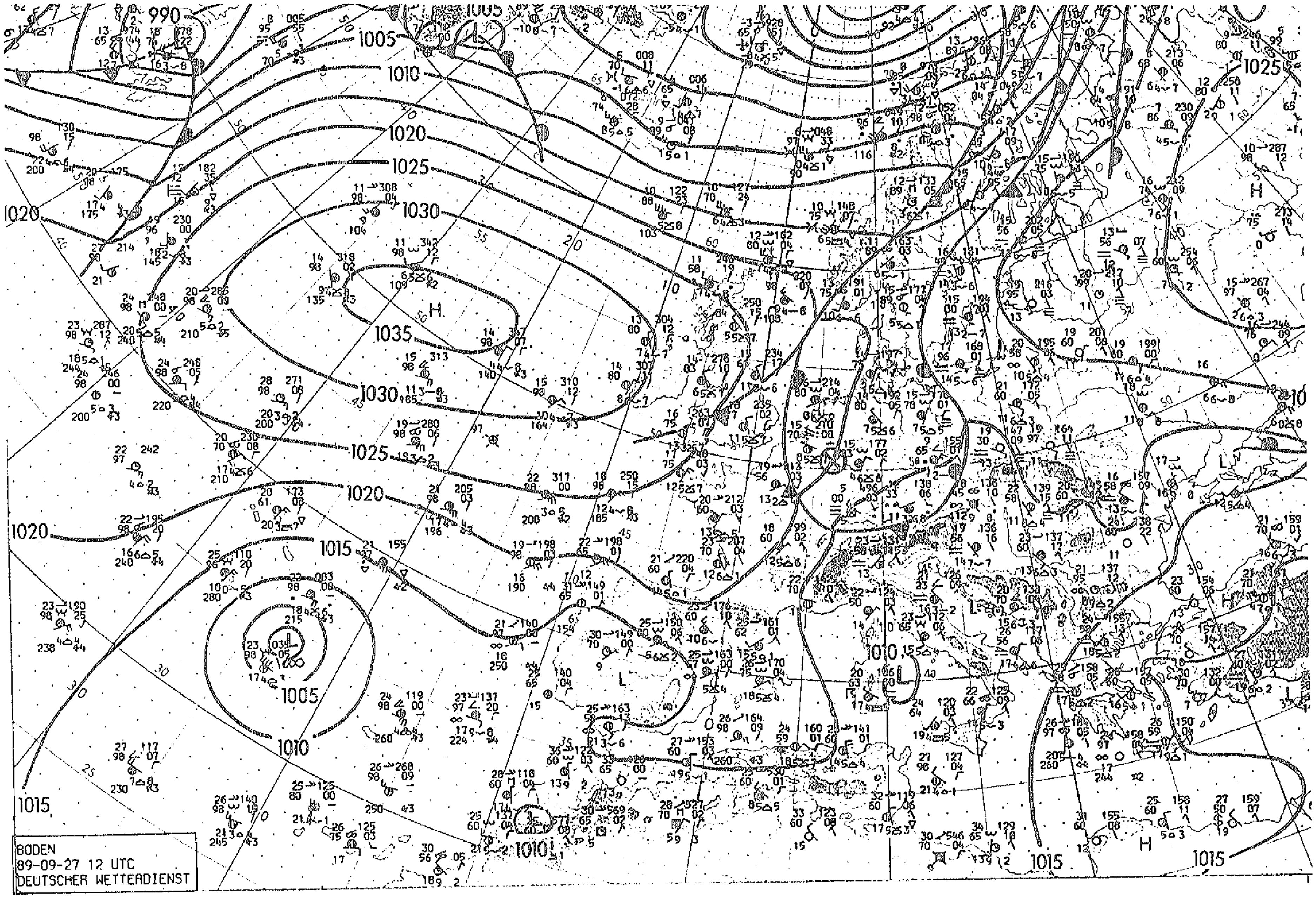


Fig. 3.12 Surface chart of Sept. 27, 1989, 12:00 UTC
⊗ Area of investigation

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 five additional tracer release points were 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/m³ at 0°C and 976 mbar). The measured background concentration at the experiment site was 14 ± 6 ng/m³. 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
Background conc. (ng/m³)	9	14	11	20	14

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 (0.3-1.3 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.

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.

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*
IV.1.1 19/09/89 IV.1.2 19/09/89 IV.1.3 19/09/89	E1 KFA-tower 50 m	1.28 1.28 1.28	19:00-21:30	20:00-20:30 20:30-21:00 21:00-21:30	142
IV.2.1 20/09/89 IV.2.2 20/09/89 IV.2.3 20/09/89	E5 Fire-ladder 30 m	0.60 0.60 0.60	18:30-21:00	19:30-20:00 20:00-20:30 20:30-21:00	100
IV.3.1 23/09/89 IV.3.2 23/09/89 IV.3.3 23/09/89	E2 Water-tower 47 m	0.58 0.58 0.58	19:30-22:00	20:30-21:00 21:00-21:30 21:30-22:00	129
IV.4.1 25/09/89 IV.4.2 25/09/89	E3/1 Fire-ladder 30 m	0.36 0.36	19:30-21:30	20:30-21:00 21:00-21:30	120
IV.5.1 27/09/89 IV.5.2 27/09/89 IV.5.3 27/09/89	E3/2 Fire-ladder 30 m	0.47 0.47 0.47	11:45-14:00	12:30-13:00 13:00-13:30 13:30-14:00	117
* 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
Fire-ladder E5	34190	43460	30	126
Fire-ladder E3/1	29115	45585	30	129
Fire-ladder E3/2	29765	45445	30	128

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

4.1.2 Tracer sampling network

In advance of the field campaign six tracer release points, named E1, E2, E3/1, E3/2, E4, E5 (see Fig 4.1.1 and the following Tab. 4.1.4), were selected. Emission point E3 represents two positions northwest of Sophienhöhe. Emission point E3/2, which is closest to the hill (Tab. 4.1.4), should be used in case of neutral or unstable atmospheric conditions and westerly to northwesterly winds. Then a possible effect of the hill on the concentration field was expected to become more clear, because the mixing of the tracer is not so much effective in giving no concentration changes with height. Emission point E5 should only be considered for the case that winds from southeasterly directions are dominant for a longer period, i. e. 2-3 days.

Emission point	Emission height (m)	Location	Distance to Sophienhöhe (m)	Necessary wind direction
E1: KFA-tower	50	KFA	1800	210°-250°
E2: Watertower	47	Stetternich	1250	260°-280°
E3/1: Fire-ladder	30	South of Welldorf	900	300°-330°
E3/2: Fire-ladder	30	Southeast of Welldorf	200-350	260°-315°
E4: Fire-ladder	30	West of Höllen	850	350°- 20°
E5: Fire-ladder	30	South of Lich/Steinstraß	1000-1500	100°-130°

Tab. 4.1.4: Tracer release points planned for dispersion experiments

For five release points (E1-E4), a dense sampling network was built-up in 1988 and 1989. For each of the release points 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. The sampling network with the two release points KFA-tower and Watertower is shown in Fig. 4.1.1. Futher details about the design of the sampling networks are given in the report on the third field experiment, Zeuner und Heinemann (1990).

In the fourth field campaign, four dispersion experiments were made in the evening using E1, E2, E3/E1 and E5 as release points. The last experiment was carried out around noon with release point E3/2. The sampling units were generally placed on all marked positions of the corresponding network and on additional positions marked by the RISØ group during the experiment.

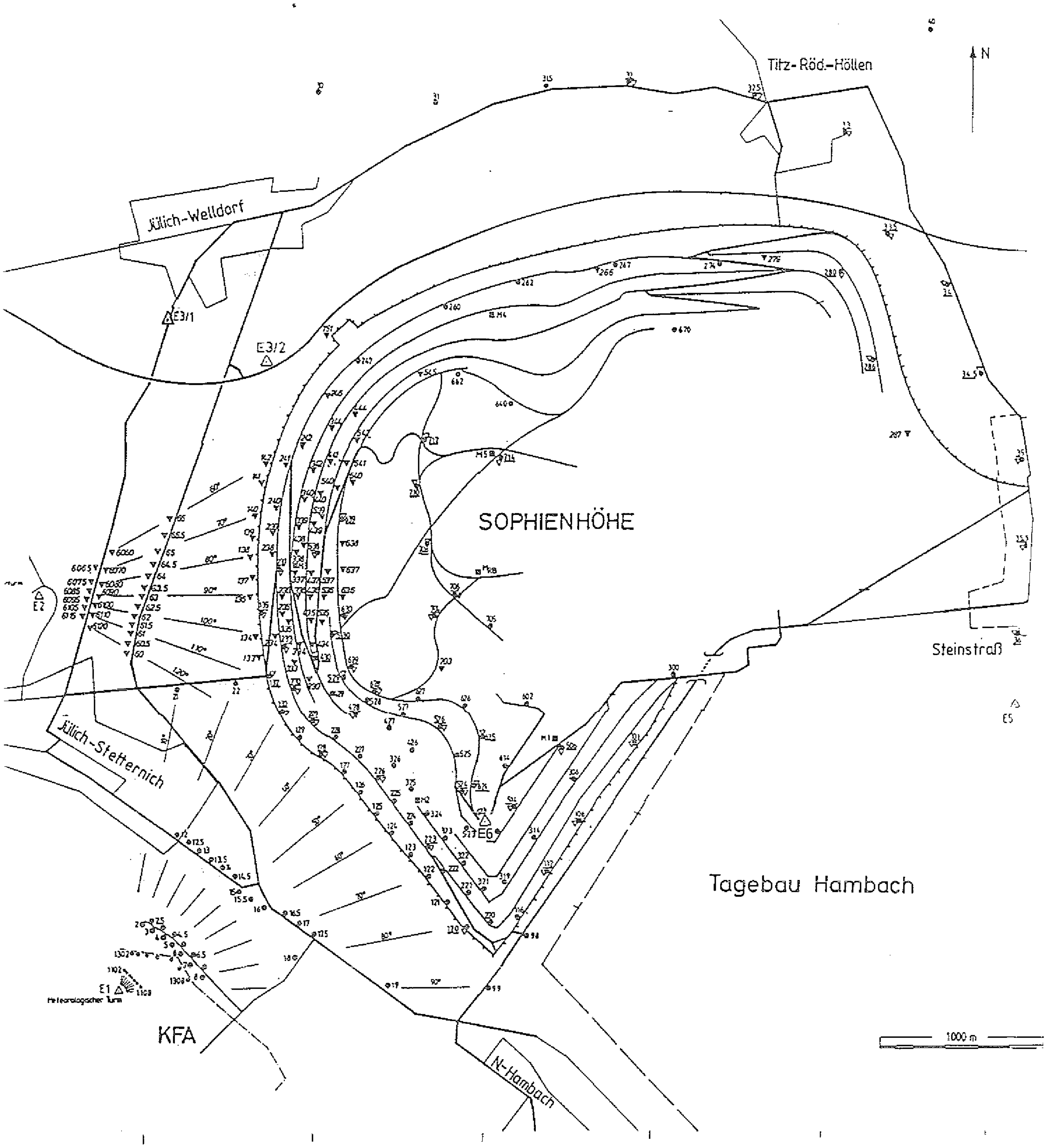


Fig. 4.1.1: Tracer sampling points for network southwest (∘), network west (▽), both networks southwest and west (∘▽); E1 - E5 Tracer release points

4.2 SF_6-Tracer measurements by KFA-Group

W.Voß

4.2.1 The tracer sampling equipment

The tracer sampling units built by the KFA-group are based on sampling of air in plastic bags (Fa. Linde). Each unit can collect up to 3 samples, starting from a pre-fixed time and running for fixed selectable consecutive time intervals (here chosen 30 minutes). Start of sampling is controlled by a calculator through which maximal 15 sampling units can be programmed simultaneously.

In the dispersion experiments about 80 sampling units were used; about 70 of these units were put in position by three KFA-groups. Additional 10 units were installed by RISO just prior to the start of sampling at positions where the plume was expected according to the instantaneous tracer measurements made by NERI.

Figure 4.2.1 is showing one of the samplers in the field experiment and Fig. 4.2.2 shows a schematic drawing.

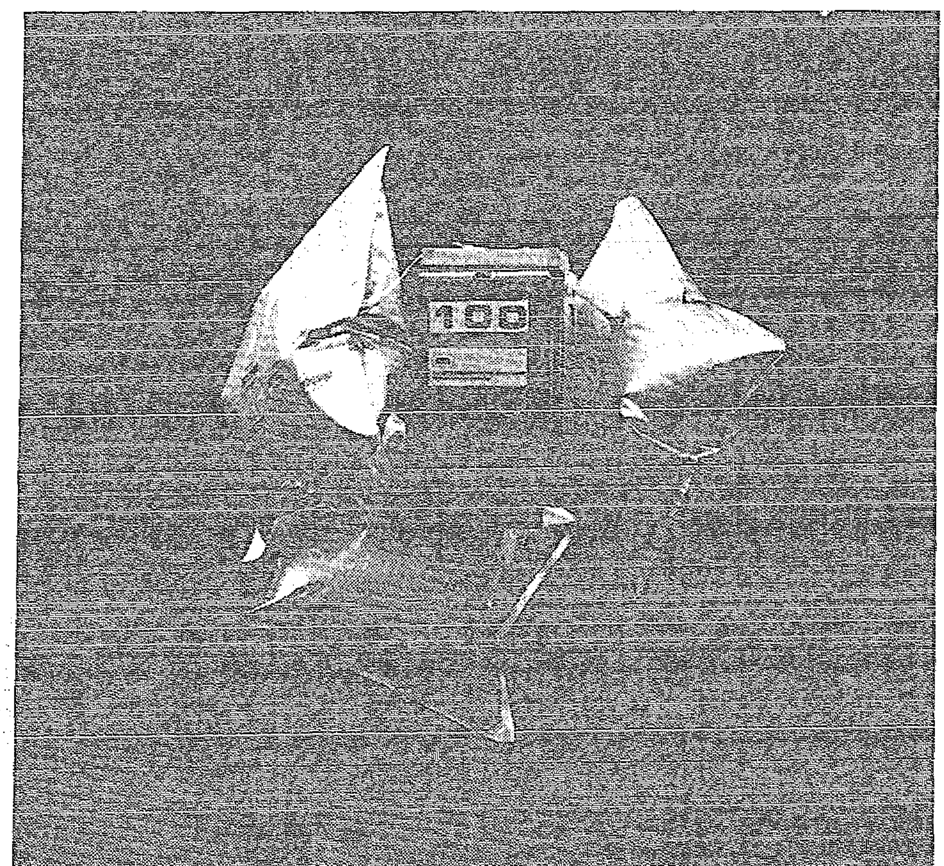
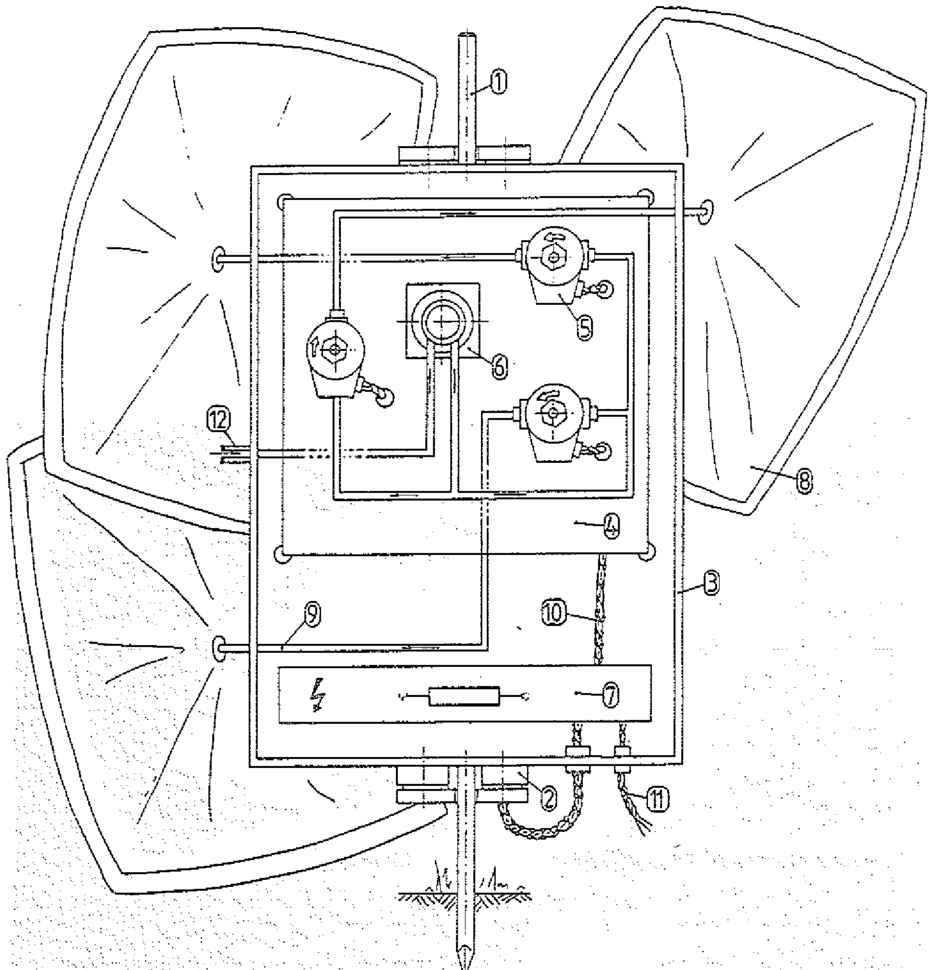


Fig.4.2.1: KFA tracer sampling unit

The air is sucked in through a capillary tube (12) into aluminium coated plastic bags with valves (8) by a small diaphragm pump (6) with a flow rate of about 200 ml/min; for consecutive time intervals air is passing one of the three magnetic valves (5). The switching of the magnetic valves by electric pulse is controlled by an electronic card (7); start of sampling is programmed through the connection to a HP-71B calculator (11). Before programming the sampling units , a short test is run in order to sort out defect ones. Power to the sampling unit is supplied by non-rechargeable batteries (2).

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



(1) ironstick	(2) battery unit
(3) shelter box	(4) mounting plate
(5) magnetic valve	(6) diaphragm pump
(7) electronic card	(8) plastic bag
(9) plastic pipe	(10) wires
(11) connection to calculator	(12) capillary tube (air entrance)

Fig. 4.2.2: Schematic drawing of the KFA tracer sampling unit

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).

To obtain the internal calibration curve, different mixtures of SF_6 calibration dilutions in steps of 10, 30, 50, 70 and 100 ng/m³ were prepared in one or two steps in 1 l or 10 l synthetic air filled volume calibrated aluminium coated plastic bags with syringes of 1 or 10 ml from a Linde Primary Standard containing 102 ppb ±10% SF_6 in N_2. Dilutions greater than 100 ng/m³ (500, 1000, 5000 and 10000 ng/m³) were mixed with a two channel mass flowmeter/controller from Brooks Instruments using the Linde Standard.

To check the response of the gaschromatograph, the dilution of 1000ng/m³ was measured during the campaign everyday before and after analysing the samples from the experiments. After 4 days (09/22/89) the deviation of the dilution increased from 3-7% to 15-19% till the end of the campain. A new internal calibration curve with new different mixtures was done at 10/16/1989. The mixtures were measured with the new internal calibration curve and the curve that was used during the campain. The results are shown in the table 4.2.1.

sample Nr.	theor. conc ng/m^3 (A)	SF_6-conc. (ng/m^3)		rel. ratio Δ(%)*		
		(B)	(C)	B/A	C/A	B/C
1	10	8	11	-22.2	+9.5	-31.6
2	40	39	48	-2.5	+18.2	-20.7
3	70	67	80	-4.4	+13.3	-17.7
4	100	98	108	-2.0	+7.4	-9.4
5	500	493	582	-1.4	+15.2	-16.6
6	1000	996	1167	-0.4	+15.4	-15.8
7	3000	3031	3489	+1.0	+15.1	-14.0
8	5000	5034	5728	+0.7	+13.6	-12.9
9	7500	7437	8373	-0.8	+11.0	-11.8
10	10000	10022	11192	+0.2	+11.2	-11.0
			mean deviation (%):	-1.1	+13.4	**-14.4**

Note: (B) = measured with new calibration curve
(C) = measured with calibration curve during the campain

$$^* \Delta(B/A) = \frac{B - A}{{}^1/_2(B + A)} \times 100$$

Tab. 4.2.1: Results of calibration at 10/16/89

The table shows, that there is a mean deviation by -14.4% between the calibration curve during the campain and the new calibration curve. Therefore all measurements beginning with the 09/22/1989 are corrected by a factor of 0.86.

The detection limit of the gaschromatograph based on the signal to noise ratio was around 10 ng/m^3.

All samples from an experiment were analysed in about 36 houres. The measured concentrations are estimated to be within ±11 to ±15% the true values.

4.3 SF_6-Tracer measurements by NERI-group

E. Lyck

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 time of the sampling units was in the campaign controlled by an electronic timer. 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 as fast as practically possible after the experiment. 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°.

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 the steel cylinder standards was repeated 26 times. The two cylinder standards contained 120 ppt and 319 ppt respectively (±10%). Based on these measurements, the long term (10 days) reproducibility is as good as ±1,3%.

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. In experiments IV.1 to IV.4 the analyses were performed the day after the experiment while in experiment IV.5 the analyses were started on the day of the experiment and finished the day after.

The peak height values of the chromatograms of the samples from the experiments 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.

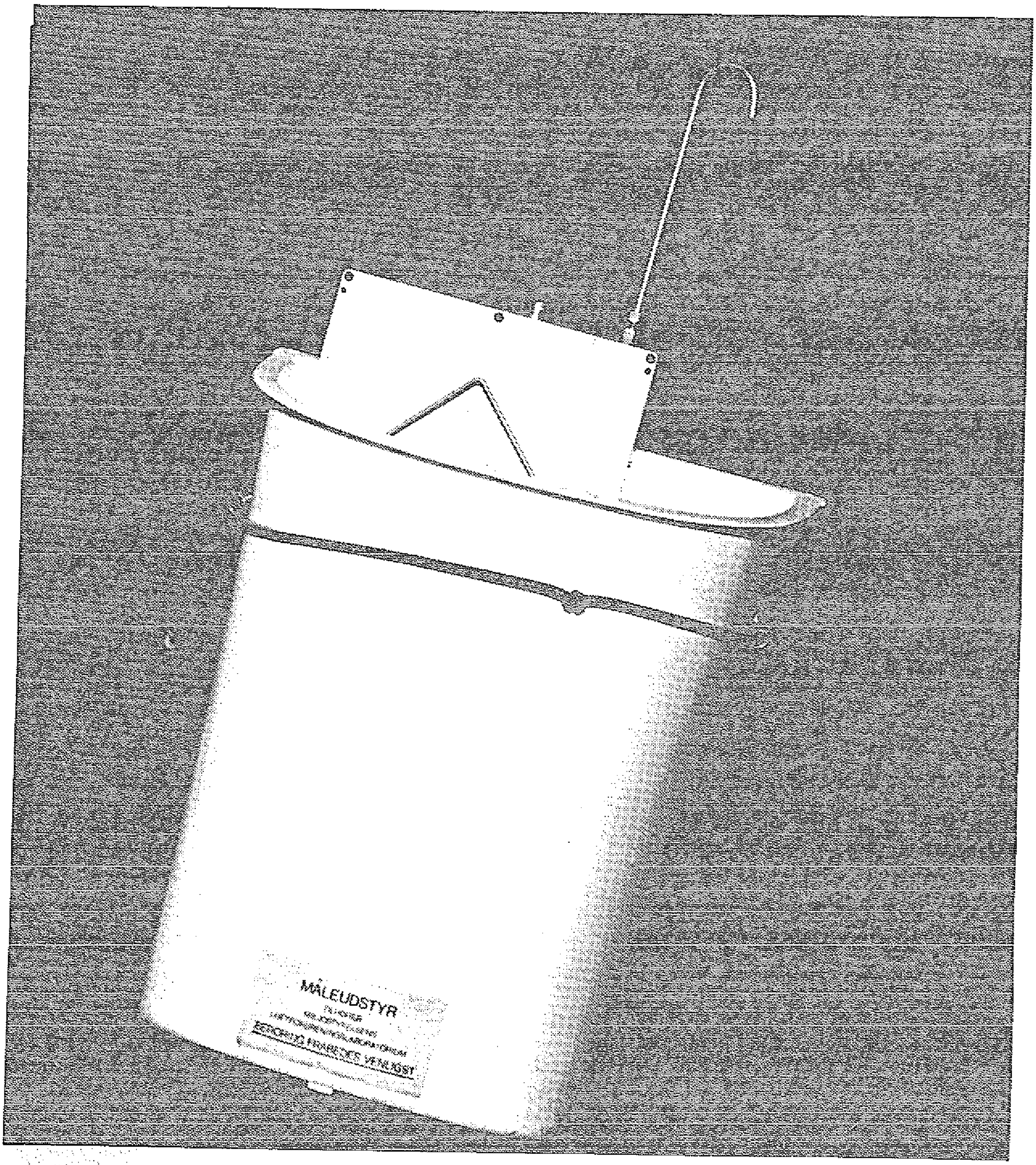


Fig. 4.3.1: A sampling unit positioned for sampling.

Referring to the accuracy of about ±10% stated above and the precision of ±0.3 to 1.6% 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 ratio of 2 was around 1.5 ppt ($\simeq$9 ng/m^3).

4.3.4 Mobile gaschromatograph

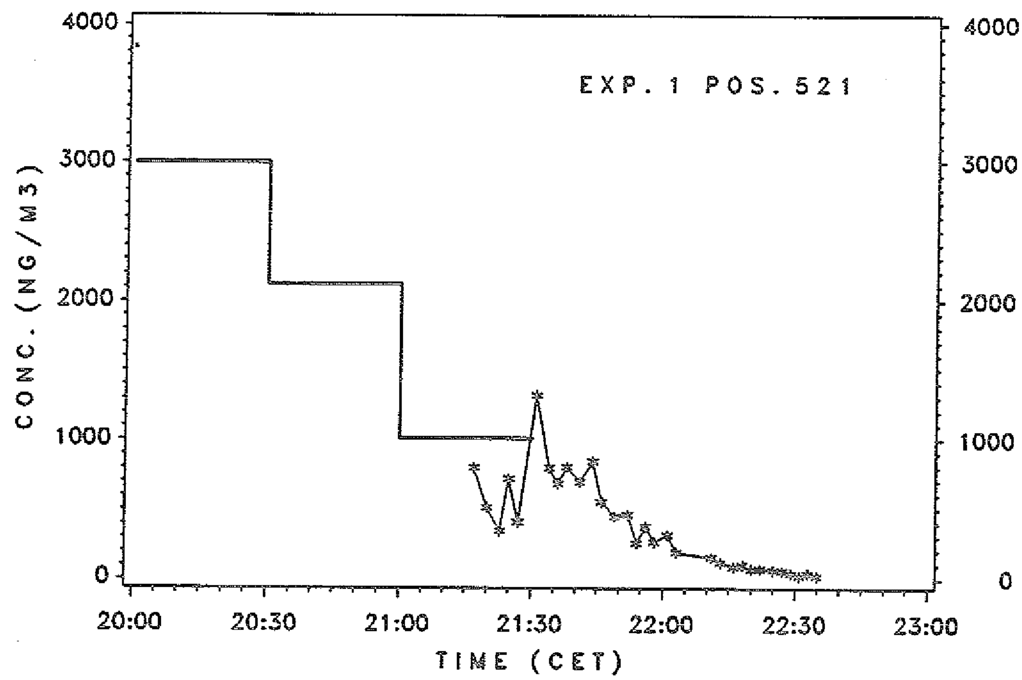
A gaschromatograph was mounted in the van of the Danish tracer group to measure instantaneous concentrations (averaging time around 1 sec.) at selected positions during the experiments. The smallest possible time in between these measurements was 2 minutes due to time necessary to flush oxygen through the detector. The response of this gaschromatograph to test dilutions was repeated 4-5 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 ±1.7 to ±8.7% (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 ±14% of the true values.

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

The instantaneous concentration measurements are shown in Tables 4.3.2 - 4.3.6.

Experiment No.	Date Sept. 89	Analysing Date Sept. 89	Reproducibility of standard (± %)	
			Laboratory	Mobil
IV.1	19	20	1.3	4.3
IV.2	20	21	0.3	1.7
IV.3	23	24	1.6	3.1
IV.4	25	26	1.1	8.7
IV.5	27	27/28	1.0	4.7

Tab. 4.3.1: Performance of the laboratory and mobil gaschromatographs



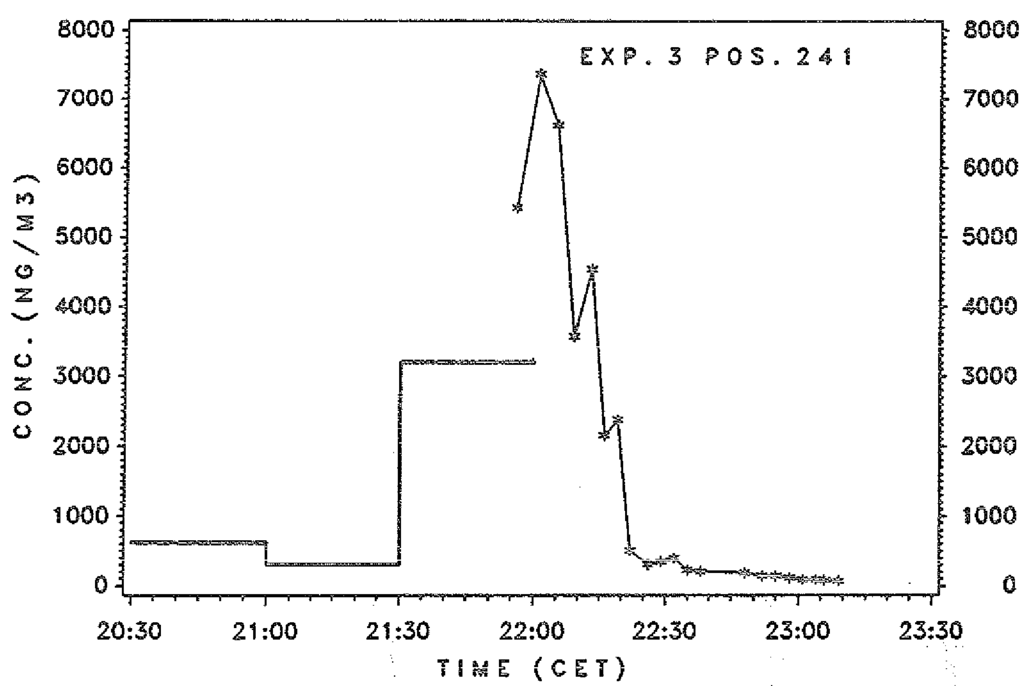


Fig. 4.3.2: Examples of instantaneous SF_6 tracer concentration (stars and thin line) in one position as function of time and time-averaged concentration (broad line) in the same position.

Table 4.3.2: Instantaneous sulphurhexafluoride concentrations for experiment IV.1, 19.09.1989

Time CET	Position	Polarcoordinates ϕ (deg.)	Polarcoordinates R (m)	Height (m MSL)	Conc. (ng/m^3)
19:15	622.0	67.6	2382	228	9
19:18	622.0	67.6	2382	228	36
19:20	622.0	67.6	2382	228	77
19:23	622.0	67.6	2382	228	18
19:36	106.0	69.3	3016	102	833
19:38	106.0	69.3	3016	102	337
19:41	106.0	69.3	3016	102	968
19:47	112.0	75.0	2667	103	3096
19:49	112.0	75.0	2667	103	3984
19:52	116.0	79.8	2444	104	3779
19:55	116.0	79.8	2444	104	3597
20:00	120.0	80.2	2090	105	1457
20:18	614.0	60.2	2681	248	14
20:22	622.0	67.6	2382	228	18
20:35	525.0	55.4	2400	215	9
20:41	523.0	65.4	2295	218	3642
20:56	523.0	65.4	2295	218	2504
20:59	523.0	65.4	2295	218	2140
21:01	523.0	65.4	2295	218	1047
21:03	523.0	65.4	2295	218	1138
21:06	523.0	65.4	2295	218	1024
21:09	523.0	65.4	2295	218	729
21:17	521.5	68.8	2368	218	797
21:20	521.5	68.8	2368	218	510
21:23	521.5	68.8	2368	218	342
21:25	521.5	68.8	2368	218	719
21:27	521.5	68.8	2368	218	405
21:31	521.5	68.8	2368	218	1320
21:34	521.5	68.8	2368	218	797
21:36	521.5	68.8	2368	218	683
21:38	521.5	68.8	2368	218	804
21:41	521.5	68.8	2368	218	694
21:44	521.5	68.8	2368	218	842
21:46	521.5	68.8	2368	218	551
21:49	521.5	68.8	2368	218	446
21:52	521.5	68.8	2368	218	460
21:54	521.5	68.8	2368	218	255
21:56	521.5	68.8	2368	218	376
21:58	521.5	68.8	2368	218	264
22:01	521.5	68.8	2368	218	314
22:03	521.5	68.8	2368	218	191
22:11	521.5	68.8	2368	218	155
22:13	521.5	68.8	2368	218	118
22:16	521.5	68.8	2368	218	87
22:18	521.5	68.8	2368	218	100
22:20	521.5	68.8	2368	218	68
22:22	521.5	68.8	2368	218	73
22:25	521.5	68.8	2368	218	64
22:27	521.5	68.8	2368	218	59
22:29	521.5	68.8	2368	218	41
22:31	521.5	68.8	2368	218	23
22:33	521.5	68.8	2368	218	41
22:35	521.5	68.8	2368	218	23

Table 4.3.3: Instantaneous sulphurhexafluoride concentrations for experiment IV.2, 20.09.1989

Time CET	Position	Polarcoordinates		Height (m MSL)	Conc. (ng/m^3)
		ϕ (deg.)	R (m)		
20:11	2005.0	352.6	1174	91	838
20:14	2005.0	352.6	1174	91	2755
20:17	2005.0	352.6	1174	91	4651
20:21	2005.0	352.6	1174	91	2914
20:24	2005.0	352.6	1174	91	1254
20:27	2005.0	352.6	1174	91	224
20:30	2005.0	352.6	1174	91	36
20:37	2118.0	342.2	1097	93	32
20:40	2118.0	342.2	1097	93	28
20:47	7777.0	4.6	928	90	2835
20:50	7777.0	4.6	928	90	1258
20:53	7777.0	4.6	928	90	264
21:00	7777.0	4.6	928	90	120
21:03	7777.0	4.6	928	90	72
21:12	7777.0	4.6	928	90	28

Table 4.3.4: Instantaneous sulphurhexafluoride concentrations for experiment IV.3, 23.09.1989

Time CET	Position	Polarcoordinates		Height (m MSL)	Conc. (ng/m^3)
		ϕ (deg.)	R (m)		
19:50	539.0	75.0	1753	209	595
19:53	539.0	75.0	1753	209	930
19:55	539.0	75.0	1753	209	908
19:58	539.0	75.0	1753	209	2251
20:01	539.0	75.0	1753	209	3796
20:05	539.0	75.0	1753	209	3833
20:09	539.0	75.0	1753	209	5284
20:12	539.0	75.0	1753	209	3721
20:15	539.0	75.0	1753	209	3349
20:18	539.0	75.0	1753	209	6400
20:22	539.0	75.0	1753	209	5433
20:25	539.0	75.0	1753	209	5619
20:28	539.0	75.0	1753	209	3796
20:49	636.0	90.0	1749	231	30
20:52	638.0	80.0	1779	230	34
20:55	639.0	74.8	1839	229	30
20:59	640.0	70.1	1928	229	774
21:04	640.0	70.1	1928	229	990
21:07	642.0	65.3	2070	228	261
21:10	642.0	65.3	2070	228	1042
21:22	544.0	60.3	2396	209	298
21:25	544.0	60.3	2396	209	67
21:29	542.0	63.5	2087	209	15
21:31	542.0	63.5	2087	209	15
21:35	540.0	70.2	1832	209	19
21:44	239.0	74.2	1455	127	22
21:49	240.0	69.0	1522	126	6326
21:54	240.0	69.0	1522	126	6549
21:56	241.0	61.5	1666	126	5433
22:01	241.0	61.5	1666	126	7368
22:05	241.0	61.5	1666	126	6624
22:09	241.0	61.5	1666	126	3572
22:13	241.0	61.5	1666	126	4540
22:16	241.0	61.5	1666	126	2158
22:19	241.0	61.5	1666	126	2382
22:22	241.0	61.5	1666	126	506
22:26	241.0	61.5	1666	126	305
22:29	241.0	61.5	1666	126	350
22:32	241.0	61.5	1666	126	398
22:35	241.0	61.5	1666	126	223
22:38	241.0	61.5	1666	126	208
22:48	241.0	61.5	1666	126	186
22:52	241.0	61.5	1666	126	141
22:55	241.0	61.5	1666	126	141
22:58	241.0	61.5	1666	126	112
23:01	241.0	61.5	1666	126	89
23:04	241.0	61.5	1666	126	89
23:06	241.0	61.5	1666	126	82
23:09	241.0	61.5	1666	126	74

Table 4.3.5: Instantaneous sulphurhexafluoride concentrations for experiment IV.4, 25.09.1989

Time CET	Position	Polarcoordinates ϕ (deg.)	Polarcoordinates R (m)	Height (m MSL)	Conc. (ng/m^3)
19:53	538.0	102.9	948	211	21
19:56	539.0	92.0	957	209	21
19:59	540.0	82.5	996	209	21
20:02	541.0	74.9	1078	209	21
20:07	542.0	68.6	1214	209	21
20:10	543.0	64.5	1371	209	25
20:13	544.0	62.6	1515	209	21
20:18	545.0	62.1	1627	209	31
20:21	545.5	61.7	1800	211	21
20:32	264.0	60.0	2700	122	70
20:35	264.0	60.0	2700	122	52
20:38	262.0	57.8	2459	122	59
20:41	261.0	56.2	2253	125	59
20:46	260.0	53.8	1965	123	25
20:49	249.0	51.6	1533	123	21
20:53	248.0	51.9	1404	123	25
21:15	777.0	27.7	2659	94	3739
21:19	777.0	27.7	2659	94	2516
21:22	777.0	27.7	2659	94	1537
21:25	777.0	27.7	2659	94	2306
21:28	777.0	27.7	2659	94	1887
21:32	777.0	27.7	2659	94	4332
21:35	777.0	27.7	2659	94	7687
21:38	777.0	27.7	2659	94	6988
21:41	777.0	27.7	2659	94	3214
21:44	777.0	27.7	2659	94	2236
21:47	777.0	27.7	2659	94	1363
21:50	777.0	27.7	2659	94	978
21:53	777.0	27.7	2659	94	846
21:56	777.0	27.7	2659	94	629
21:59	777.0	27.7	2659	94	601
22:05	777.0	27.7	2659	94	409
22:08	777.0	27.7	2659	94	182
22:14	777.0	27.7	2659	94	112
22:17	777.0	27.7	2659	94	87
22:19	777.0	27.7	2659	94	80
22:22	777.0	27.7	2659	94	66
22:25	777.0	27.7	2659	94	59
22:28	777.0	27.7	2659	94	49

Table 4.3.6: Instantaneous sulphurhexafluoride concentrations for experiment IV.5, 27.09.1989

Time CET	Position	Polarcoordinates		Height (m MSL)	Conc. (ng/m^3)
		ϕ (deg.)	R (m)		
11:50	448.0	87.2	855	180	15
11:59	444.0	126.1	539	178	22
12:03	443.0	134.5	550	177	15
12:06	442.0	144.0	585	178	2377
12:14	441.0	149.4	622	177	914
12:17	440.0	161.8	776	179	146
12:20	439.0	166.5	926	180	2194
12:25	438.0	169.4	1089	180	658
12:27	438.0	169.4	1089	180	139
12:32	439.0	166.5	926	180	5632
12:35	440.0	161.8	776	179	2633
12:38	441.0	149.4	622	177	958
12:41	442.5	138.9	563	177	18
12:44	443.0	134.5	550	177	18
12:47	443.5	130.2	549	177	18
12:49	443.0	134.5	550	177	15
12:53	442.5	138.9	563	177	15
12:56	441.0	149.4	622	177	15
12:59	440.0	161.8	776	179	1317
13:01	439.0	166.5	926	180	10970
13:05	438.0	169.4	1089	180	783
13:08	437.0	170.3	1179	180	293
13:14	434.0	172.3	1607	181	688
13:17	434.0	172.3	1607	181	453
13:21	437.0	170.3	1179	180	124
13:24	438.0	169.4	1089	180	44
13:32	239.0	179.2	952	127	5412
13:36	240.0	177.5	803	126	3218
13:43	137.0	184.6	1241	103	5485
13:47	138.0	184.8	1116	102	12579
13:51	139.0	184.8	984	102	18
13:55	138.0	184.8	1116	102	18
13:58	138.0	184.8	1116	102	428
14:00	138.0	184.8	1116	102	51
14:04	138.0	184.8	1116	102	285
14:07	138.0	184.8	1116	102	219
14:11	138.0	184.8	1116	102	22
14:14	138.0	184.8	1116	102	18
14:22	138.0	184.4	1116	102	15

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. 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 × 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. More details about the monitor system are given in Veroustraete (1990).

In the field campaign the detector had to be changed by a spare one. As a consequence of that, the detector's sensitivity shifted in short term due to stabilisation of the ECD. This resulted very probable in a larger measurement error (see chapter 4.4.5.1).

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. To generate a calibration mixture with SF_6, SF_6 was released in a stream of zero air (R) that is subsequently mixed with a primary flow (Fi) of 10 l/min and secondly with a variable secondary flow (Fv). The amount of SF_6 was inferred from regular weighing of the permeation tube. From these weighings the permeation tube release rate (Q) was determined.

The calculation of the SF_6 concentration was 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 SF_6 permeation tube history before and after the measuring campaign was as follows:

Date	Q (μg/min)
15/09/89	0.4675
04/08/89	0.4645
18/09/89	0.4319
02/10/89	0.4110

A mean value of 0.443 μg was accepted to calculate the concentration of the calibration mixtures in the field campaign.

Calibration problems arose in the field campaign because a spare detector had to be used. New calibrations made before and after each experiment still resulted in a large scatter in the resulting calibration curves.

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. 4.4.1).

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. 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. The detection limit (Dl) was defined as three times the standard deviation on the monitor response.

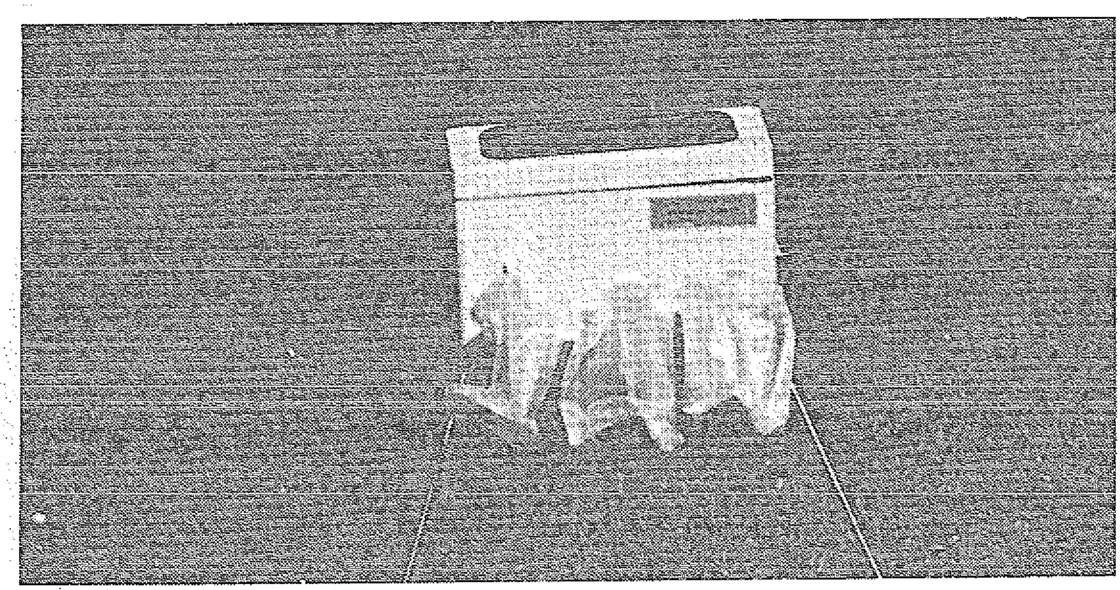


Fig. 4.4.1: Sampling station and PVC sampling bags

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.

4.4.5 Results

4.4.5.1 Results of the SF_6 half-hour mean values

The intercomparison tests of SF_6-measurements between SCK and KFA/NERI-group show only small deviations in the determination of tracer concentrations (Appendix A). In contrast to that SCK air samples taken in the experiments seem to be subject to larger errors.

SCK air samples of experiment IV.1 were also analysed by KFA. Here the detection limit of SCK monitor was pretty high with 600 ng/m^3, therefore only high concentrations could be compared. In experiment IV.5, at 10 postions two sampling stations (one each of SCK- and KFA-group) were installed at the same time. Comparison of the different data sets showed large unsystematic discrepancies between the measurements of both groups (partly more than 50%). In experiment IV.2 and IV.4 the tracer concentrations of all air samples were below the detection limit of the SCK-monitor (350 or 170 ng/m^3). Some SCK air samples of experiment IV.2 were analysed by NERI-group. In experiment IV.3 some SCK air samples were also analysed by NERI-group two days after the experiment and showed differences in the tracer concentrations.

Obviously problems with the SCK-monitor as stabilisation and sensitivity caused measurement errors. Moreover SF_6 loss through the PVC bags cannot be excluded. Because of the uncertainty in the accuracy of the tracer concentrations, only those measurements were included in the data bank as summarized in chapter 4.5 which were analysed either by KFA- or NERI-group and fit to the NERI-data on Sophienhöhe.

4.4.5.2 Result of the momentary SF_6 concentration values

Four scans were made with the measuring van on 23/09/88 during dispersion experiment IV.3. Two profiles of momentary SF_6-concentrations which were observed at the west side and base of the hill are given in Fig. 4.4.2 and Fig. 4.4.3. The length of lines pointing from Sophienhöhe towards southwest are proportional to the tracer concentration. Both profiles show the maximum of the tracer plume east-northeast of the source (tracer emission point) which coincides well with the measured wind direction.

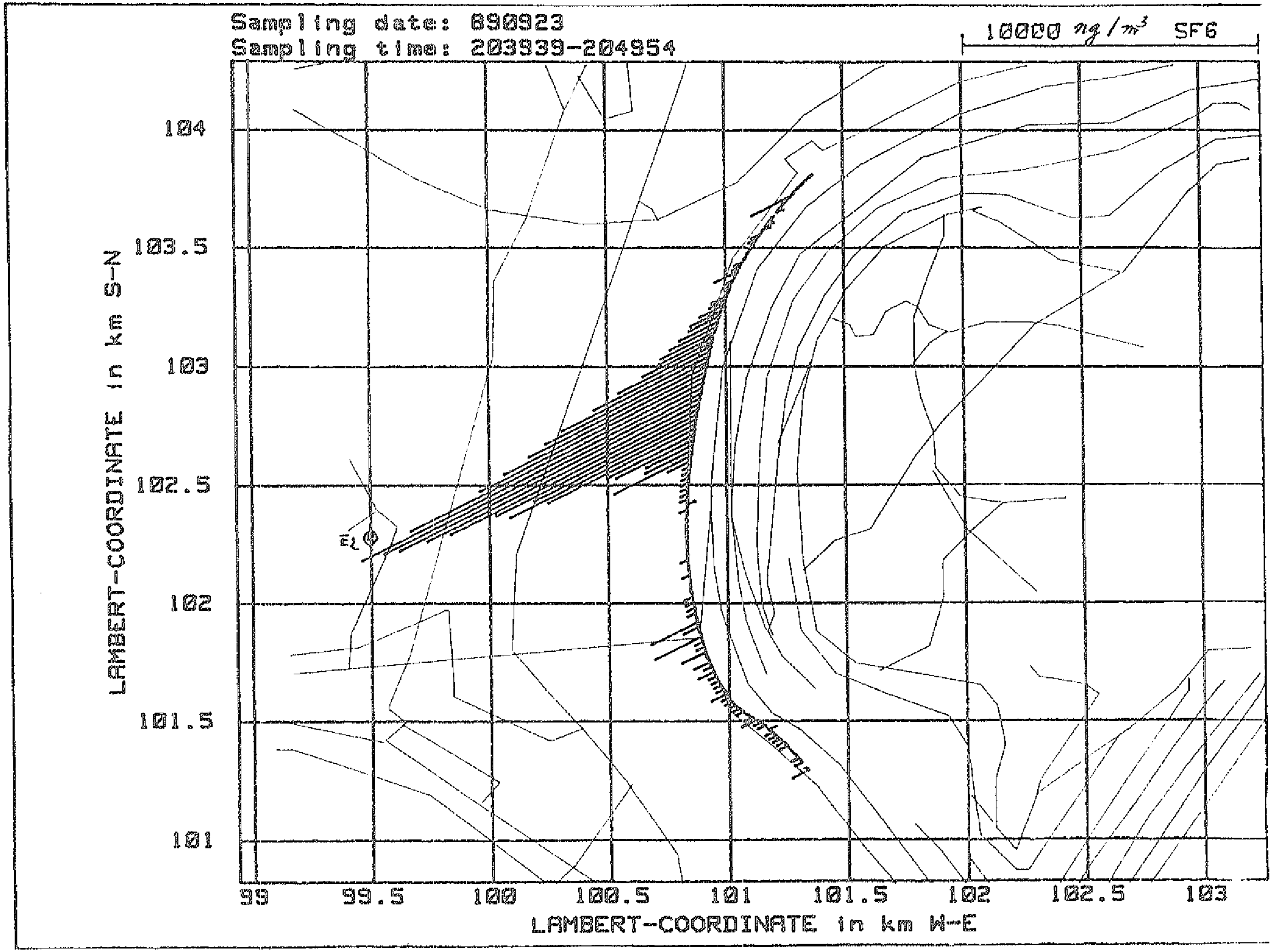


Fig. 4.4.2: Momentary SF_6-concentrations during experiment IV.3.1

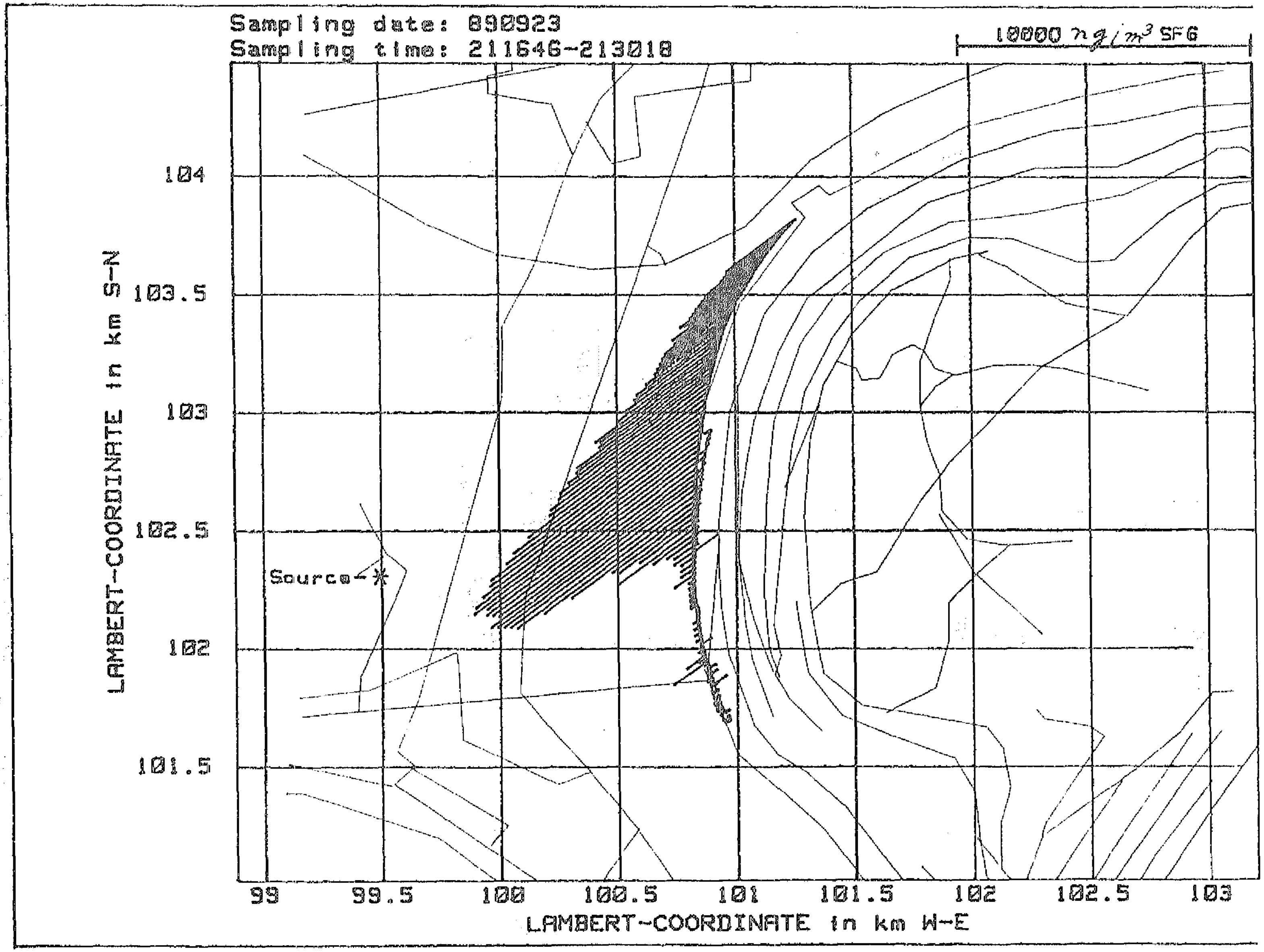


Fig. 4.4.3: Momentary SF_6-concentrations during experiment IV.3.2

4.5 Tracer concentration data

G. Zeuner

The tables 4.5.1-4.6.5 give an overview of all tracer measurements, one table for each experiment serie of 3 consecutive sampling periods. In experiment IV.4 tracer emission stopped at the end of the second sampling period, since a shift in wind direction transported the tracer plume out of the tracer unit set-up. This is confirmed by the measurements in the 3rd sampling period analysed by group 2 which show near background concentrations. The association of the measurements to the experimental groups, NERI, KFA and SCK 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 (±15%). In contrast to the intercomparison test most concentrations analysed by SCK group (group 3) do not fit with data or simultaneous measurements of the other groups and therefore were excluded from the tables (see also chapter 4.4). The tables include only measurements of SCK bags analysed by KFA or NERI group. Background concentration ($\simeq$14 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 figure 4.1.1. 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 i; 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 MSL is the sum of emission point coordinate z and the emission height (above ground), both given in the data bank.

Table 4.5.1: Tracer concentrations for experiment IV.1.1-IV.1.3, 19.09.1989

Tracer emission: KFA-tower , 50 m

Group: 1 = KFA
2 = NERI
3 = SCK,
analysed by 3.1 KFA, 3.2 NERI

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

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
2.00	21.0	446	91	1704	12233	18432	1
3.00	31.1	437	90	6447	51842	30962	1
4.00	40.7	441	90	11149	52833	33386	1
4.50	45.4	449	90	10894	49489	32037	1
5.00	51.0	452	90	12957	48240	39029	1
5.50	55.2	451	90	17367	48987	44793	1
6.00	61.0	466	90	-9999	49997	46630	1
7.00	70.1	496	90	29118	83705	40335	1
8.00	79.8	547	90	16970	87650	29151	1
12.00	19.8	962	99	16	826	27716	1
12.50	25.4	941	99	22	81	26542	1
13.00	30.7	927	99	27	61	18888	1
13.50	35.3	921	99	217	992	20029	1
14.00	40.1	924	97	18	627	9427	1
14.50	45.2	934	96	54	629	10333	1
15.00	51.0	952	99	31	615	9506	1
15.50	55.9	964	99	113	1544	5064	1
16.00	60.0	996	99	1934	1540	4107	1
16.50	64.9	1053	99	5098	559	2437	1
17.00	70.3	1118	99	10189	1320	4251	1
17.50	75.8	1189	96	14581	4465	2883	1
18.00	80.1	1145	92	24456	11818	4623	1
19.00	91.0	1599	100	8574	14782	4610	1
21.00	10.3	1837	107	20	20	14749	1
22.00	19.8	1951	107	20	17	12721	1
30.00	11.9	5582	95	24	17	294	1
31.00	19.3	5530	93	18	72	760	1
31.50	25.6	5689	92	18	17	442	1
32.00	29.5	6054	89	21	19	199	1
32.50	35.9	6399	84	20	17	58	1
33.00	39.8	6528	87	21	18	38	1
33.50	45.2	6197	90	16	16	152	1
34.00	49.6	6410	87	-9999	-9999	-9999	1
34.50	54.9	6266	83	23	2230	-9999	1
35.00	61.5	6138	87	1611	1741	1457	1
35.50	65.1	5938	87	1642	1323	1231	1
36.00	68.3	5688	94	1470	1297	1110	1
40.00	29.7	7689	92	17	17	18	1
41.00	36.1	9277	88	19	16	17	1
42.00	40.6	10582	85	16	15	16	1
43.00	44.4	10986	74	14	19	25	1
44.00	49.9	10716	81	17	142	869	1
45.00	55.8	10360	74	704	1297	983	1
46.00	59.9	10105	81	859	1180	742	1
47.00	65.7	10002	85	561	571	459	1
48.00	71.3	9739	84	74	29	170	1
49.00	74.5	9522	86	23	58	74	1

Table 4.5.1 continued

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
98.00	82.6	2426	105	6464	2668	3217	1
99.00	90.0	2180	106	4678	11670	13139	1
99.50	95.5	2045	101	2366	9538	14009	1
101.00	64.7	3469	101	18	62	1777	2
106.00	69.3	3016	102	335	461	1685	2
110.00	72.6	2789	103	1559	1215	1112	2
112.00	75.0	2667	103	6992	1307	1261	2
116.00	79.8	2444	104	9800	2579	2545	2
120.00	80.2	2090	105	2293	1983	1525	2
121.00	74.9	1994	105	2912	757	4425	2
127.00	45.7	1852	103	9	12	12208	2
128.00	41.2	1839	103	9	12	11692	2
129.00	35.3	1829	104	12	225	-9999	2
130.00	30.2	1896	105	9	112	13297	2
132.00	25.1	2045	105	9	14	7966	2
135.00	20.1	2380	105	28	12	4012	2
220.00	80.2	2220	132	4906	2591	2224	2
221.00	75.2	2120	133	6282	3324	2293	2
222.00	70.4	2058	130	1284	4127	-9999	2
222.50	67.4	2018	131	2109	3232	3118	2
223.00	65.0	1993	131	1697	3622	3015	2
223.50	62.5	1987	131	216	2705	3255	2
224.00	59.8	1965	131	12	1444	4746	2
224.50	57.7	1961	132	9	997	4883	2
225.00	54.9	1953	132	9	825	7886	2
226.00	50.2	1965	131	9	619	13698	2
227.00	45.1	1945	131	12	1914	13927	2
228.00	40.4	1933	131	12	2304	12953	2
229.00	35.0	1926	130	12	2751	12437	2
230.00	30.2	2007	128	23	667	-9999	2
233.00	25.8	2199	128	9	16	4723	2
237.00	20.4	2641	127	21	12	2017	2
247.00	19.7	3865	124	19	1584	491	1
260.00	24.8	4413	123	18	21	308	1
262.00	29.5	4773	122	18	17	357	1
267.00	33.9	5133	120	16	17	269	1
274.00	39.7	5583	119	18	17	233	1
280.00	45.4	5999	117	17	17	-9999	1
286.00	50.4	5779	119	12	18	264	1
300.00	60.5	3642	143	384	84	-9999	3.1
306.00	64.8	3082	149	62	257	984	3.1
314.00	69.7	2694	151	28	34	92	3.1
319.00	74.3	2424	153	2825	1095	1758	3.1
321.00	75.3	2215	157	6183	1983	2061	3.1
322.00	70.3	2149	157	3391	2239	2952	3.1
324.00	60.2	2065	156	27	-9999	-9999	3.1
325.00	55.0	2101	154	33	-9999	-9999	3.1
326.00	50.6	2108	155	37	-9999	-9999	3.1
426.00	50.8	2224	184	21	278	11540	1
427.00	45.4	2147	184	18	2478	14886	1
428.00	40.9	2122	183	18	1613	10399	1
429.00	34.7	2130	183	-9999	-9999	-9999	1
430.00	30.7	2277	183	20	35	4203	1

Table 4.5.1 continued

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
506.00	61.5	2991	209	17	1091	3461	2
514.00	66.2	2556	214	80	-9999	1426	2
521.00	68.2	2430	217	3000	2119	1007	2
523.00	65.4	2295	218	1032	1259	973	2
524.00	60.2	2296	216	34	1108	2811	2
525.00	55.4	2400	215	34	193	7027	2
526.00	50.7	2431	217	29	336	9649	2
527.00	45.3	2286	214	25	159	7656	2
528.00	40.8	2217	214	25	1129	5454	2
529.00	35.3	2251	212	29	97	3063	2
530.00	30.5	2444	212	21	25	2161	2
538.00	24.4	2888	211	29	25	1036	2
602.00	55.2	2913	257	21	1123	9399	2
614.00	60.2	2681	248	12	461	4700	2
622.00	67.6	2382	228	3026	2934	963	2
623.00	66.4	2356	226	2433	2958	1280	2
624.00	60.1	2411	231	9	1846	3015	2
625.00	55.2	2593	243	9	1777	9285	2
626.00	50.0	2602	243	335	3095	13010	2
627.00	45.7	2392	237	12	2338	7737	2
628.00	40.6	2285	234	14	624	5594	2
629.00	33.9	2378	232	21	130	2559	2
630.00	30.5	2525	232	21	21	1951	2
639.00	24.7	3123	229	21	13	705	2
662.00	28.7	4153	232	19	20	680	1
664.00	33.7	4256	236	10	19	669	1
670.00	40.1	5070	235	26	17	417	1
704.00	40.0	2841	260	24	101	732	3.1
705.00	45.9	3046	264	33	64	629	3.1
706.00	41.0	3011	262	25	28	508	3.1
707.00	49.6	3047	266	32	151	1387	3.1
708.00	34.7	3231	267	46	22	181	3.1
710.00	30.5	3467	263	40	33	39	3.1
712.00	28.6	3676	252	99	29	2051	3.1
714.00	35.6	3860	271	24	23	172	3.1
1302.00	21.8	236	91	1591	14315	10633	1
1303.00	31.2	251	91	2060	20633	13114	1
1304.00	40.8	275	91	5429	32405	17483	1
1305.00	50.2	313	90	17237	18284	64261	1
1306.00	59.6	375	91	43272	62864	32849	1
1307.00	69.8	404	90	31574	-9999	50576	1
1308.00	79.7	417	90	29911	71737	56914	1
2100.00	105.4	2555	103	5118	3087	4928	1

Table 4.5.2: Tracer concentrations for experiment IV.2.1-IV.2.3, 20.09.1989

Tracer emission: Fire-ladder, 30 m

Group: 1 = KFA; 2 = NERI; 3 = SCK, analysed by 3.1 KFA, 3.2 NERI

sampling period: 1 = 19:30 - 20:00; 2 = 20:00 - 20:30; 3 = 20:30 - 21:00

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
12.00	260.8	5082	99	44	31	46	1
15.00	256.4	4736	99	-9999	-9999	-9999	1
18.00	250.2	4480	92	34	37	35	1
19.00	245.0	4131	100	35	36	30	1
21.00	271.0	5013	107	44	40	30	1
30.00	311.7	5623	95	34	33	28	1
31.00	314.9	4963	93	31	34	30	1
31.50	319.8	4468	92	102	112	32	1
32.00	326.4	4265	89	734	38	29	1
32.50	335.3	3816	84	729	667	197	1
33.00	340.6	3497	87	770	464	565	1
34.00	349.2	2486	87	296	679	123	1
34.50	353.4	1902	83	245	802	2092	1
86.00	291.4	1305	90	49	64	41	1
87.00	287.4	1358	97	41	114	51	1
87.50	288.2	1358	97	38	272	513	1
88.00	284.2	1499	98	51	35	45	1
88.50	279.9	1817	99	-9999	39	42	1
89.00	270.2	1981	99	404	378	628	1
90.00	265.7	2101	100	75	40	43	1
91.00	261.7	2228	101	30	29	36	1
92.00	258.1	2371	103	62	45	34	1
94.00	252.1	2674	103	34	48	50	1
96.00	247.4	3007	104	24	46	30	1
98.00	244.5	3255	105	35	40	30	1
99.00	241.5	3598	106	33	45	47	1
132.00	271.7	4476	105	55	33	29	1
135.00	276.5	4554	105	39	31	24	1
138.00	280.9	4602	102	40	26	25	1
140.00	284.3	4632	102	67	45	309	1
143.00	289.2	4659	101	38	34	25	1
147.00	293.4	4623	99	37	34	39	1
152.00	299.2	4485	96	42	31	30	1
156.00	303.2	4326	97	39	40	32	1
160.00	307.5	4100	94	198	46	42	1
162.00	311.3	3913	92	47	47	43	1
166.00	316.9	3664	89	69	37	33	1
172.00	322.9	3402	89	345	38	30	1
174.00	325.3	3310	88	566	50	44	1
176.00	328.3	3206	90	779	315	39	1
178.00	333.4	3054	91	957	602	58	1
222.00	253.3	3555	130	19	19	16	3.2
226.00	263.2	3860	131	19	14	12	3.2
228.00	266.6	4097	131	16	14	14	3.2
626.00	269.3	3350	243	19	19	14	3.2
666.00	302.9	3184	253	16	19	14	3.2
667.00	308.4	3185	240	12	16	14	3.2

Table 4.5.2 continued

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
668.00	312.5	3165	237	14	14	32	3.2
670.00	316.1	2997	235	19	19	19	3.2
703.00	273.5	3424	257	14	14	16	3.2
704.00	277.4	3545	260	14	19	14	3.2
708.00	285.0	3629	267	14	14	14	3.2
714.00	294.6	3407	271	14	14	14	3.2
2002.00	296.2	1230	96	41	34	37	1
2002.20	299.3	1185	96	26	31	34	1
2002.30	304.0	1124	96	23	34	43	1
2002.40	307.2	1086	95	32	25	39	1
2003.00	318.2	1000	95	98	34	41	1
2003.10	320.5	998	95	283	35	36	1
2003.20	323.9	970	94	1339	37	36	1
2003.40	326.1	960	94	1601	36	37	1
2003.50	327.8	954	94	2316	58	36	1
2003.60	330.5	948	94	-9999	-9999	-9999	1
2003.70	334.2	938	94	935	860	87	1
2003.80	337.5	935	93	-9999	-9999	-9999	1
2004.00	350.0	954	94	360	3318	9241	1
2005.00	352.6	1174	91	450	2523	6816	1
2006.00	339.3	1700	91	770	165	41	1
2007.00	338.7	2176	88	559	292	37	1
2009.00	338.7	2729	91	693	648	36	1
2101.00	287.9	1524	97	21	23	23	2
2102.00	294.9	1351	94	19	23	23	2
2103.00	299.4	1303	94	21	23	26	2
2104.00	303.9	1264	97	21	23	28	2
2105.00	308.0	1200	95	21	21	23	2
2106.00	310.9	1190	94	21	26	28	2
2107.00	313.9	1166	94	23	23	23	2
2108.00	309.2	1019	93	28	26	26	2
2109.00	319.8	1145	93	42	23	23	2
2110.00	322.7	1138	93	174	162	23	2
2111.00	325.0	1134	92	469	23	26	2
2112.00	328.0	1132	92	951	28	28	2
2114.00	332.6	1131	92	1345	23	28	2
2118.00	342.2	1097	93	905	376	28	2
2201.00	281.5	1877	123	19	23	23	2
2202.00	286.6	1748	123	19	23	23	2
2203.00	292.7	1588	125	19	23	23	2
2205.00	300.4	1461	125	19	21	23	2
2206.00	305.4	1380	125	19	44	46	2
2207.00	309.8	1341	125	21	23	26	2
2208.00	312.7	1319	125	21	26	26	2
2209.00	315.4	1304	125	23	26	26	2
2210.00	319.5	1287	125	21	21	28	2
2212.00	324.4	1279	124	473	65	46	2
2213.00	328.4	1268	124	858	28	26	2
2214.00	332.5	1223	123	1067	35	35	2
2400.00	299.4	7679	97	30	40	29	1
6015.00	303.0	5297	96	-9999	321	543	1
6020.00	297.2	5554	98	-9999	-9999	-9999	1
6030.00	287.3	5590	103	35	257	149	1

Table 4.5.2 continued

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
6035.00	283.3	5484	104	31	32	27	1
6060.00	279.3	5485	106	35	33	1837	1
6110.00	275.6	5537	108	1583	33	31	1

Table 4.5.3: Tracer concentrations for experiment IV.3.1-IV.3.3, 23.09.1989

Tracer emission: Water-tower, 47 m
Group: 1 = KFA
2 = NERI
3 = SCK,
analysed by 3.1 KFA, 3.2 NERI

sampling period: 1 = 20:30 - 21:00
2 = 21:00 - 21:30
3 = 21:30 - 22:00

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
19.00	139.0	3154	100	51	28	26	1
21.00	124.3	966	107	26	21	-9999	1
22.00	114.6	1240	107	-9999	20	21	1
30.00	27.5	3504	95	94	2528	3752	1
31.00	38.7	3671	93	2645	3441	4437	1
31.50	46.5	4034	92	3652	2252	2724	1
32.00	49.8	4517	89	3342	2121	2429	1
32.50	56.1	5081	84	1269	1051	1960	1
33.00	60.2	5355	87	372	193	777	1
33.50	67.5	5265	90	275	197	189	1
34.00	71.4	5642	87	-9999	-9999	-9999	1
34.50	77.4	5730	83	67	30	68	1
35.00	84.4	5889	87	26	24	23	1
35.50	88.5	5853	87	24	25	23	1
36.00	92.4	5756	94	29	27	21	1
40.00	44.7	6085	92	114	1647	2180	1
41.00	49.1	7851	88	22	1277	1733	1
42.00	52.3	9292	85	21	1529	1540	1
43.00	56.1	9834	74	216	1388	1553	1
44.00	62.3	9785	81	172	387	1151	1
45.00	69.0	9678	74	167	70	195	1
46.00	73.6	9602	81	127	30	41	1
47.00	79.6	9743	85	122	25	25	1
48.00	85.5	9721	84	131	30	38	1
49.00	88.8	9643	86	34	25	20	1
60.00	120.8	576	106	24	25	23	1
60.50	115.8	560	106	46	25	26	1
61.00	110.2	558	108	21	27	22	1
61.50	103.7	568	107	54	28	29	1
62.00	99.2	585	107	50	38	59	1
62.50	93.4	611	107	22	20	20	1
63.00	89.0	631	106	91	22	22	1
63.50	84.4	662	106	55	35	132	1
64.00	79.9	690	106	45	20	83	1
64.50	74.1	734	105	38	52	36	1
65.00	69.2	791	104	23	38	29	1
65.50	64.1	861	104	45	25	424	1
66.00	59.2	951	103	234	-9999	1095	1
88.00	93.4	4366	98	31	39	21	1
89.00	99.3	3880	99	20	18	19	1
93.00	110.9	3619	104	21	20	20	1
98.00	125.3	3524	105	20	-9999	18	1
99.00	131.6	3541	106	22	21	25	1
99.50	135.5	3573	101	49	26	28	1
99.50	135.5	3573	101	49	26	28	1
101.00	103.5	3705	101	18	-9999	-9999	3.2
106.00	111.3	3531	102	14	-9999	-9999	3.2

Table 4.5.3 continued

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
112.00	118.6	3468	103	18	-9999	-9999	3.2
120.00	128.3	3220	105	9	-9999	-9999	3.2
128.00	120.0	1938	103	16	-9999	-9999	3.2
132.00	110.5	1427	105	14	-9999	-9999	3.2
136.00	89.1	1286	103	18	-9999	-9999	3.2
138.00	79.6	1313	102	86	-9999	-9999	3.2
223.00	123.6	2729	131	18	14	18	2
226.00	118.9	2260	131	18	18	18	2
229.00	116.2	1753	130	14	14	16	2
230.00	112.7	1602	128	14	23	11	2
233.00	104.6	1470	128	16	14	14	2
234.00	99.4	1427	128	18	14	14	2
235.00	94.5	1306	127	14	14	11	2
236.00	90.3	1402	127	14	11	16	2
237.00	85.0	1393	127	16	14	36	2
238.00	79.6	1412	127	23	16	326	2
239.00	74.2	1455	127	72	18	480	2
240.00	69.0	1522	126	45	50	-9999	2
241.00	61.5	1666	126	625	303	3204	2
242.00	59.0	1765	125	1483	1121	2762	2
246.00	54.7	2095	123	1845	1257	3079	2
266.00	59.9	3755	120	401	356	449	1
276.00	65.5	4711	119	-9999	245	316	1
280.00	68.6	5090	117	281	235	223	1
286.00	74.9	5097	119	391	108	205	1
287.00	79.8	5158	120	58	33	32	1
330.00	107.8	1630	153	9	9	7	2
334.00	99.4	1518	152	7	9	9	2
335.00	94.7	1489	152	14	16	14	2
336.00	90.0	1474	152	11	9	9	2
337.00	85.0	1477	152	14	9	204	2
338.00	80.7	1503	151	18	23	27	2
340.00	69.6	1624	149	344	54	4302	2
428.00	111.9	2001	183	14	14	14	2
434.00	98.6	1620	181	20	23	18	2
436.00	88.8	1583	179	18	18	23	2
438.00	80.1	1611	180	45	18	129	2
440.00	69.4	1740	179	620	131	2955	2
444.00	60.5	2093	178	917	906	2151	2
506.00	106.6	3229	209	20	23	23	2
514.00	115.2	3100	214	20	26	20	2
521.00	118.0	3084	217	30	16	26	2
524.00	116.2	2741	216	20	26	26	2
526.00	109.0	2485	217	20	23	23	2
528.00	109.4	2032	214	20	26	20	2
529.00	106.2	1842	212	26	23	13	2
530.00	98.2	1724	212	13	-9999	-9999	2
535.00	95.3	1706	211	23	26	20	2
536.00	90.4	1695	212	36	26	59	2
537.00	85.5	1690	211	16	23	184	2
538.00	80.5	1684	211	33	20	177	2
539.00	75.0	1753	209	62	16	1379	2
540.00	70.2	1832	209	299	135	3513	2

Table 4.5.3 continued

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
542.00	63.5	2087	209	735	749	2003	2
544.00	60.3	2396	209	827	473	1543	2
628.00	107.5	2048	234	13	23	20	2
629.00	101.9	1833	232	26	20	13	2
636.00	90.0	1749	231	20	16	20	2
638.00	80.0	1779	230	26	26	420	2
639.00	74.8	1839	229	53	26	2265	2
640.00	70.1	1928	229	256	177	3102	2
642.00	65.3	2070	228	460	788	2101	2
703.00	100.0	2430	257	11	-9999	-9999	3.2
704.00	94.4	2301	260	11	-9999	-9999	3.2
706.00	91.9	2445	262	88	-9999	-9999	3.2
708.00	82.5	2325	267	23	-9999	-9999	3.2
714.00	73.9	2825	271	380	-9999	-9999	3.2
2003.00	88.8	5145	95	27	23	21	1
2016.50	139.1	4583	95	55	28	23	1
2100.00	136.0	4219	103	52	27	24	1
6060.00	57.6	471	106	29496	1716	4244	1
6065.00	62.5	435	106	5239	73	604	1
6070.00	68.7	401	107	614	27	505	1
6075.00	74.0	379	107	35	24	944	1
6080.00	78.5	361	107	30	25	329	1
6085.00	83.1	349	107	69	33	2789	1
6090.00	88.2	337	107	23	19	377	1
6095.00	92.4	328	107	50	27	367	1
6100.00	97.6	322	108	65	28	291	1
6105.00	102.3	317	108	23	-9999	75	1
6110.00	107.0	313	108	22	21	14	1
6115.00	111.9	315	108	24	19	21	1
6120.00	116.9	319	108	69	-9999	31	1

Table 4.5.4: Tracer concentrations for experiment IV.4.1-IV.4.3, 25.09.1989

Tracer emission: Fire-ladder, 47 m

Group: 1 = KFA
2 = NERI

sampling period: 1 = 20:30 - 21:00
2 = 21:00 - 21:30
3 = 21:30 - 22:00

Pos.	Polar.Coord. ϕ (°)	R (m)	Height (meter MSL)	Mean Concentrations (ng/m^3) 1	2	3	Group
17.50	160.9	2699	96	-9999	-9999	-9999	1
20.00	188.9	1039	105	35	40	-9999	1
21.00	176.6	1036	107	33	40	-9999	1
22.00	158.7	1080	107	34	38	-9999	1
30.00	18.6	2763	95	4457	7936	-9999	1
31.00	33.3	2842	93	3177	631	-9999	1
31.50	43.8	3167	92	211	89	-9999	1
32.00	48.2	3640	89	1413	93	-9999	1
32.50	56.1	4196	84	2211	151	-9999	1
33.00	61.0	4474	87	1386	199	-9999	1
34.00	74.1	4793	87	-9999	-9999	-9999	1
34.50	81.1	4914	83	57	38	-9999	1
35.00	89.0	5125	87	62	46	-9999	1
35.50	93.7	5125	87	53	60	-9999	1
36.00	98.3	5068	94	54	75	-9999	1
46.00	75.3	8762	81	91	64	-9999	1
47.00	81.8	8937	85	71	61	-9999	1
48.00	88.2	8959	84	63	52	-9999	1
49.00	91.8	8909	86	116	51	-9999	1
70.00	23.6	1203	98	301	58	-9999	1
70.50	23.6	1163	98	133	59	-9999	1
71.00	23.8	1123	98	40	59	-9999	1
71.50	23.8	1084	99	43	63	-9999	1
72.00	24.1	1041	99	40	57	-9999	1
72.50	24.2	990	100	46	57	-9999	1
73.00	24.2	940	100	35	56	-9999	1
73.50	24.5	893	100	38	57	-9999	1
74.00	24.9	846	101	35	54	-9999	1
74.50	25.2	793	101	42	54	-9999	1
75.00	25.5	734	101	36	54	-9999	1
75.50	26.2	652	102	36	48	-9999	1
76.00	26.8	582	102	35	55	-9999	1
88.00	101.8	3700	98	45	50	-9999	1
89.00	109.8	3289	99	50	50	-9999	1
90.00	113.3	3243	100	49	49	-9999	1
92.00	120.3	3193	103	33	49	-9999	1
94.00	127.6	3195	103	69	53	-9999	1
98.00	139.8	3312	105	68	85	-9999	1
99.50	149.8	3515	101	88	87	-9999	1
234.00	137.1	987	128	29	50	36	2
238.00	109.7	693	127	27	45	32	2
240.00	85.3	687	126	27	54	32	2
241.00	67.2	789	126	23	45	29	2
242.00	61.6	882	125	27	41	41	2
243.00	58.4	969	125	27	50	36	2
244.00	56.1	1050	124	32	50	34	2
245.00	54.5	1130	124	23	48	32	2

Table 4.5.4 continued

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
246.00	53.5	1211	123	25	52	32	2
247.00	52.5	1307	124	27	50	32	2
248.00	51.9	1404	123	23	41	25	2
249.00	51.6	1533	123	27	45	23	2
260.00	53.8	1965	123	34	54	-9999	1
260.00	53.8	1965	123	27	41	27	2
261.00	56.2	2253	125	45	36	27	2
262.00	57.8	2459	122	-9999	267	-9999	1
264.00	60.0	2700	122	54	41	34	2
267.00	61.4	2957	120	78	54	-9999	1
274.00	66.2	3603	119	61	34	-9999	1
280.00	71.1	4230	117	73	38	-9999	1
286.00	78.6	4268	119	42	39	-9999	1
287.00	84.5	4361	120	82	55	-9999	1
335.60	154.4	1720	152	72	79	-9999	1
336.00	123.6	886	152	78	75	-9999	1
337.00	116.0	819	152	76	69	-9999	1
339.00	95.4	773	150	42	57	-9999	1
342.00	72.8	867	150	40	204	-9999	1
344.00	63.4	1020	149	270	66	-9999	1
346.00	58.8	1196	149	55	70	-9999	1
348.00	55.9	1400	147	43	60	-9999	1
350.00	55.9	1686	149	34	55	-9999	1
351.00	59.1	2069	151	56	56	-9999	1
352.00	61.8	2400	151	55	-9999	-9999	1
428.00	137.8	1670	183	38	63	-9999	1
430.50	132.5	1196	182	42	66	-9999	1
434.00	130.2	1134	181	42	62	-9999	1
437.00	109.6	900	180	39	-9999	-9999	1
440.00	82.3	901	179	41	56	-9999	1
442.00	68.8	1066	178	68	75	-9999	1
444.00	63.5	1213	178	40	59	-9999	1
446.00	59.1	1454	177	39	61	-9999	1
448.00	59.0	1754	180	37	58	-9999	1
464.00	65.8	2417	183	36	55	-9999	1
467.00	66.0	2852	175	81	92	-9999	1
470.00	66.9	3158	173	38	45	-9999	1
529.00	134.2	1441	212	36	48	36	2
535.00	124.0	1161	211	36	41	32	2
536.00	117.6	1082	212	23	41	34	2
537.00	110.5	1013	211	27	34	32	2
538.00	102.9	948	211	41	45	29	2
538.50	97.2	957	210	41	54	32	2
539.00	92.0	957	209	54	50	27	2
539.50	87.1	971	209	45	50	27	2
540.00	82.5	996	209	41	50	32	2
540.50	78.4	1041	210	32	63	32	2
541.00	74.9	1078	209	59	68	29	2
541.50	71.6	1138	209	41	59	32	2
542.00	68.6	1214	209	50	59	27	2
542.50	66.5	1292	209	41	59	27	2
543.00	64.5	1371	209	45	68	29	2
543.50	63.2	1451	208	32	59	-9999	2

Table 4.5.4 continued

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
544.00	62.6	1515	209	41	54	-9999	2
545.00	62.1	1627	209	29	59	29	2
545.50	61.7	1800	210	32	59	29	2
547.00	62.7	1917	211	68	50	41	2
565.00	70.7	2429	211	32	50	45	2
567.00	67.9	2815	209	27	32	27	2
574.00	72.1	3670	203	32	36	20	2
635.00	120.1	1164	230	27	-9999	-9999	2
637.00	108.2	1064	231	27	27	-9999	2
639.00	90.3	1039	229	23	32	-9999	2
640.00	81.2	1090	229	23	91	-9999	2
641.00	76.2	1139	228	23	41	-9999	2
642.00	71.8	1204	228	140	45	-9999	2
642.50	69.9	1259	228	-9999	43	-9999	2
643.00	68.5	1313	228	23	41	-9999	2
643.50	66.9	1386	228	23	41	-9999	2
644.00	66.3	1432	228	27	45	-9999	2
644.50	64.8	1527	228	27	45	-9999	2
645.00	64.4	1572	227	20	41	-9999	2
646.00	64.2	1779	228	20	41	-9999	2
2300.00	22.5	1423	99	16	84	-9999	1
2301.00	23.2	1321	97	168	-9999	-9999	1

Table 4.5.5: Tracer concentrations for experiment IV.5.1-IV.5.3, 27.09.1989

Tracer emission: Fire-ladder, 47 m

Group: 1 = KFA
2 = NERI
3 = SCK,
analysed by 3.1 KFA, 3.2 NERI

sampling period: 1 = 12:30 - 13:00
2 = 13:00 - 13:30
3 = 13:30 - 14:00

Pos.	Polar.Coord. ϕ (°)	Polar.Coord. R (m)	Height (meter MSL)	Mean Concentrations (ng/m^3) 1	Mean Concentrations (ng/m^3) 2	Mean Concentrations (ng/m^3) 3	Group
88.00	118.5	3382	98	20	20	22	1
89.00	128.9	3143	99	35	23	27	1
90.00	132.6	3164	100	20	20	19	1
92.00	139.6	3249	103	36	19	20	1
93.00	143.0	3312	104	31	23	21	1
94.00	146.2	3381	103	-9999	19	19	1
95.00	149.3	3462	103	23	18	17	1
96.00	152.3	3547	104	63	19	19	1
98.00	156.3	3702	105	292	19	37	1
99.00	161.2	3911	106	150	37	74	1
99.50	164.0	4056	101	146	72	76	1
132.00	181.5	1851	105	29	586	1749	3.1
138.00	184.8	1116	102	376	320	8091	3.1
140.00	184.4	842	102	463	2651	10059	1
141.00	183.7	688	102	668	3900	11867	1
141.50	182.8	620	102	2346	4536	12680	1
142.00	180.7	553	102	4075	4631	11913	1
142.50	180.0	505	101	8415	4431	12739	1
143.00	176.5	447	101	13638	5945	10568	1
143.50	175.0	404	101	20347	4047	10945	1
144.00	171.1	363	101	23093	3216	10036	1
144.50	168.5	326	100	20815	3102	6063	1
145.00	160.7	299	100	6706	574	2405	1
145.50	157.1	274	100	3077	42	25	1
146.00	146.5	255	99	31	36	26	1
146.50	140.2	234	100	37	24	26	1
147.00	128.9	233	99	27	21	23	1
147.50	117.1	230	98	15	19	20	1
148.00	103.9	249	98	18	18	22	1
149.00	90.7	296	97	30	23	23	1
150.00	79.1	358	97	24	19	23	1
151.00	64.9	353	97	22	18	19	1
239.00	179.2	952	127	771	1451	5714	2
240.00	177.5	803	126	1905	2063	5714	2
240.50	176.4	732	125	3016	2472	5442	2
241.00	172.0	559	126	7165	2143	5623	2
241.50	171.1	566	126	8208	1769	662	2
242.00	164.0	456	125	-9999	2268	639	2
242.50	160.0	432	125	8163	1531	3696	2
243.00	153.4	393	125	3923	32	41	2
243.50	144.5	382	125	75	43	36	2
244.00	141.0	351	124	50	30	32	2
244.50	132.8	341	125	18	18	16	2
245.00	126.9	337	124	18	16	18	2
245.50	119.8	343	123	14	14	18	2
246.00	113.1	351	123	18	18	14	2
246.50	105.9	368	124	14	18	18	2

Table 4.5.5 continued

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
247.00	99.3	392	124	16	18	16	2
248.00	89.0	454	123	16	18	18	2
249.00	80.6	559	123	14	14	18	2
337.00	176.0	1223	152	514	988	4435	1
338.00	175.0	1109	151	1132	1497	3748	1
339.00	172.7	941	150	3931	1954	4906	1
340.00	170.1	795	149	-9999	-9999	-9999	1
341.00	167.3	717	150	4408	1629	3735	1
342.00	163.5	629	150	5556	1129	3702	1
342.50	159.7	591	150	6389	1003	1767	1
343.00	156.1	550	150	4080	57	173	1
343.50	150.9	514	149	938	67	21	1
344.00	147.0	480	149	83	27	22	1
345.00	135.4	450	149	23	17	20	1
345.50	129.1	448	149	19	30	19	1
346.00	122.6	443	149	34	22	23	1
347.00	110.0	461	148	20	18	19	1
348.00	98.3	515	147	23	18	21	1
349.00	89.8	597	147	36	29	23	1
350.00	83.4	751	149	18	19	19	1
350.50	80.2	903	150	31	20	24	1
351.00	79.7	1143	151	-9999	-9999	-9999	1
438.00	169.4	1089	180	2549	1397	2549	2
439.00	166.5	926	180	2863	1187	2025	2
440.00	161.8	776	179	3282	510	1083	2
441.00	149.4	622	177	251	18	21	2
442.50	138.9	563	177	21	-9999	21	2
443.00	134.5	550	177	21	28	31	2
443.50	130.2	549	177	14	-9999	11	2
444.00	126.1	539	178	16	18	18	2
444.50	120.0	548	177	18	18	22	2
445.00	112.7	561	177	18	16	16	2
445.50	107.8	572	177	25	20	18	2
446.00	100.6	608	177	18	20	22	2
446.50	95.6	663	178	22	18	22	2
448.00	87.2	855	180	18	18	22	2
538.00	165.6	1106	211	2444	1083	897	2
539.00	161.1	946	209	2654	335	527	2
539.50	158.4	870	209	2986	77	283	2
540.00	155.1	803	209	1292	49	38	2
540.50	150.3	747	210	314	35	21	2
541.00	145.9	697	209	52	35	28	2
541.50	139.3	659	209	21	35	21	2
542.00	130.9	636	209	20	20	18	2
542.50	122.8	636	209	22	22	31	2
543.00	114.5	645	209	20	22	22	2
544.00	103.0	713	209	22	22	18	2
545.00	97.0	794	209	18	18	22	2
638.00	160.6	1101	230	2238	175	542	2
639.00	155.8	949	229	1477	47	72	2
640.00	148.3	813	229	94	20	16	2
641.00	142.1	744	228	18	22	18	2
641.50	138.3	705	228	16	18	18	2

Table 4.5.5 continued

Pos.	Polar.Coord.		Height (meter MSL)	Mean Concentrations (ng/m^3)			Group
	ϕ (°)	R (m)		1	2	3	
702.00	157.0	1531	246	1940	117	30	3.1
704.00	149.2	1777	260	47	39	-9999	3.1
708.00	138.6	1391	267	29	69	28	3.1
2400.00	308.2	2883	97	29	38	29	1
7070.00	204.7	119	99	6223	13479	7592	1
7075.00	198.2	131	99	3162	28099	6043	1
7080.00	193.2	148	99	6328	22401	7659	1
7085.00	188.5	169	100	5730	19232	8800	1
7090.00	185.3	183	100	11317	9256	13787	1
7095.00	183.0	210	100	8079	14200	13482	1
7100.00	180.2	235	100	8761	13990	20516	1
7105.00	178.3	265	100	-9999	-9999	-9999	1
7110.00	176.7	292	100	-9999	-9999	-9999	1
7115.00	176.2	328	100	18999	7963	13246	1
7120.00	181.5	335	100	-9999	-9999	-9999	1
7125.00	185.5	342	100	-9999	7922	18984	1
7130.00	190.1	353	100	1490	10817	6701	1
7135.00	194.0	364	101	-9999	-9999	-9999	1
7140.00	197.7	377	101	1360	8773	535	1
7145.00	201.5	395	101	1011	9334	195	1
7150.00	204.6	408	101	382	8252	94	1
7155.00	207.7	428	101	22	5103	171	1
7160.00	210.4	446	101	34	2179	35	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 5.6). 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 MSL. 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. 5.1.4.

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 (vectorvane)
- radiation balance in 30m and sunshine duration in 20 m

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

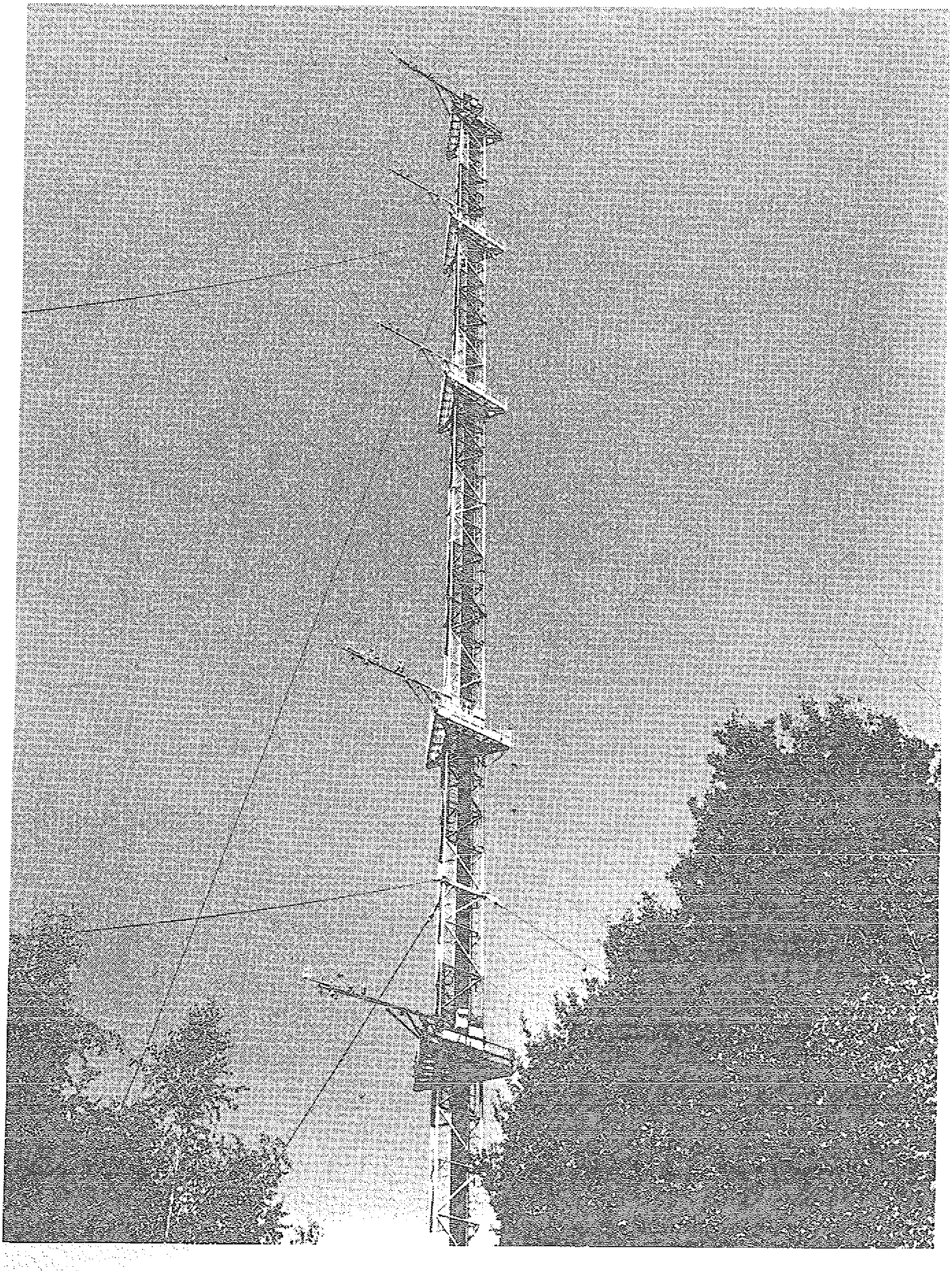


Fig. 5.1.1: The meteorological tower of the Research Center Jülich

Sensor	Measured quantity	Start.speed/Time constant	Samplingtime/ Scan frequency	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 about 10 minutes	50 m
sonic-anemometer (Kaijo-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 meter (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

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 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 September 19, 0.00 - September 28, 24.00. The sonic anemometers were running as indicated in Tab. 5.1.2.

Date	Start	Stop	Height
*September 19	18:10	22:30	30 m, 50 m, 120 m
September 20	17:30	22:00	30 m, 50 m, 120 m
September 23	18:30	23:00	30 m, 50 m, 120 m
September 25	18:30	23:00	30 m, 50 m, 120 m
September 27	11:10	15:40	30 m, 50 m, 120 m

Tab. 5.1.2: 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 are shown in Fig. 5.1.2., the coordinates are given in Tab. 5.1.4.

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 and positions of the masts is summarized in Tab. 5.1.3 and Tab. 5.1.4.

The data were stored by a portable data acquisition unit, based on Hewlett-Packard components and self-developed electronics. 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 September 19, 0.00 - September 28, 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 MSL 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 $\simeq$ 6 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.

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 $\simeq$ 5 m. The wind approach-

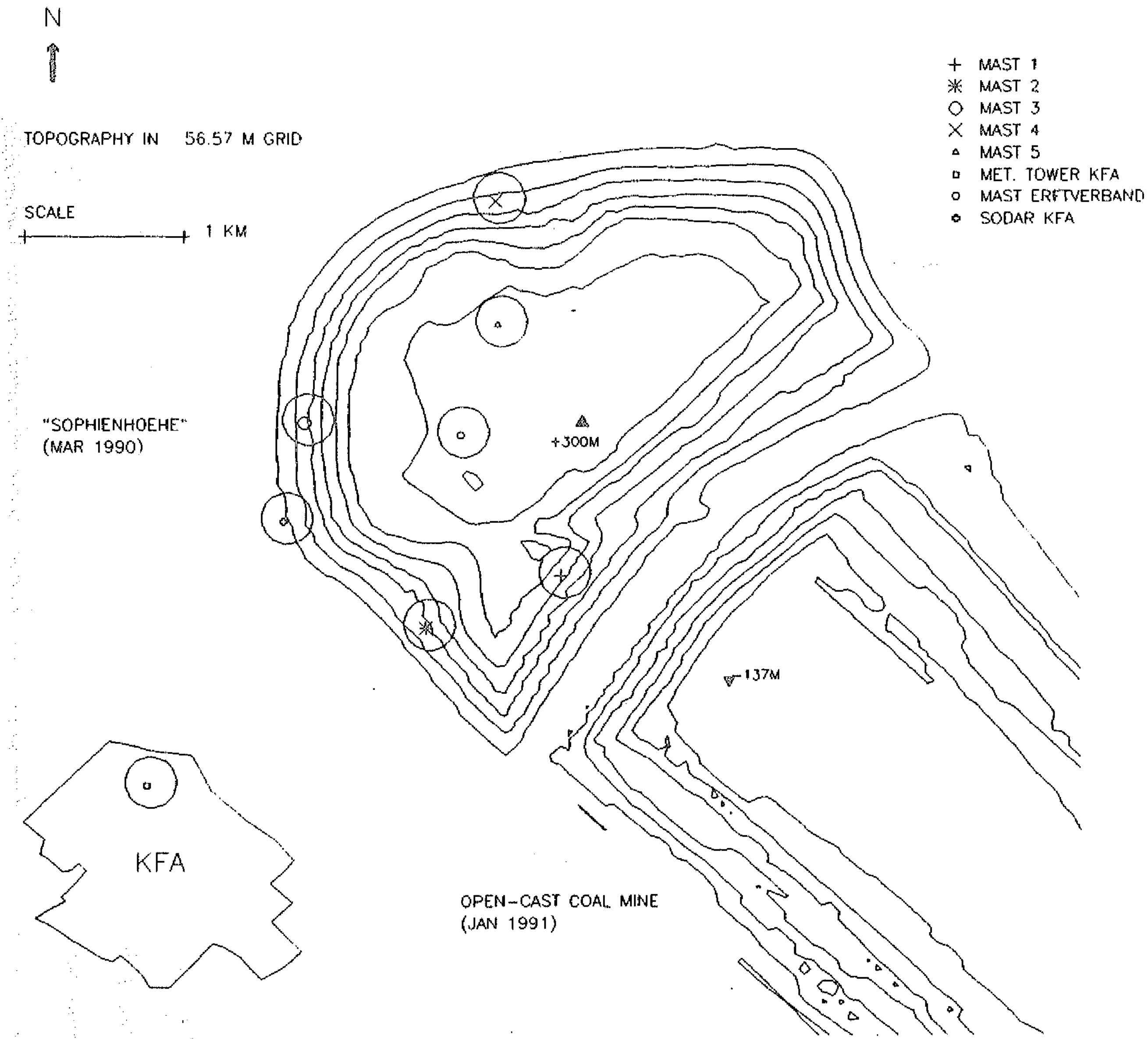


Fig. 5.1.2: Position of KFA-tower and masts on Sophienhöhe

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°.

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 $\simeq$ 4 m. The roads ran in north-south direction, the slope inclined with about 15 degrees.

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 $\simeq$ 2 m high 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.

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 $\simeq$ 1-2 m trees.

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.

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+10 m (Mast 1), 5+10 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)
Pyranometer (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 DAT 300)	wind-components u,v,w and tem-perature	2	0.005 m/s	1 s	9.5 m (Mast 5)
Note: * separated as upwind and downwind values					

Tab. 5.1.3: 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	29865	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. 5.1.4: 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. These data should not be used.

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 wind components 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

5.1.3 Measurement results

As an example some measurements for Sept. 19 are presented. This day has been selected, because it shows very good the influence of the hill on the wind field especially in the evening.

The temperature measurements at the KFA tower are illustrated in Fig. 5.1.3a. At night a cold front moved over our area and the temperature dropped by several degrees. Behind the cold front the air flow became southwesterly (Fig. 5.1.3b). The moderate wind during the day weakend in the evening in the surface layer (Fig. 5.1.3c). After 19:00 h a strong surface inversion developed and the wind shear with height increased.

The deflection of the southwesterly flow caused by the hill could be well observed in the evening and started at about 18:30 h (Fig. 5.1.4a). 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 northwest in its southwestern part. The wind direction at the top of the hill was similar to those at the KFA tower.

Whereas very light winds frequently occurred on the windward slope (Mast 2), accelation of the air was found at the top (Mast 5) and the north-northwest slope of Sophienhöhe (Mast 4), see Fig. 5.1.4b.

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. IV.1.1) are summerized in tables (chapter 6.2).

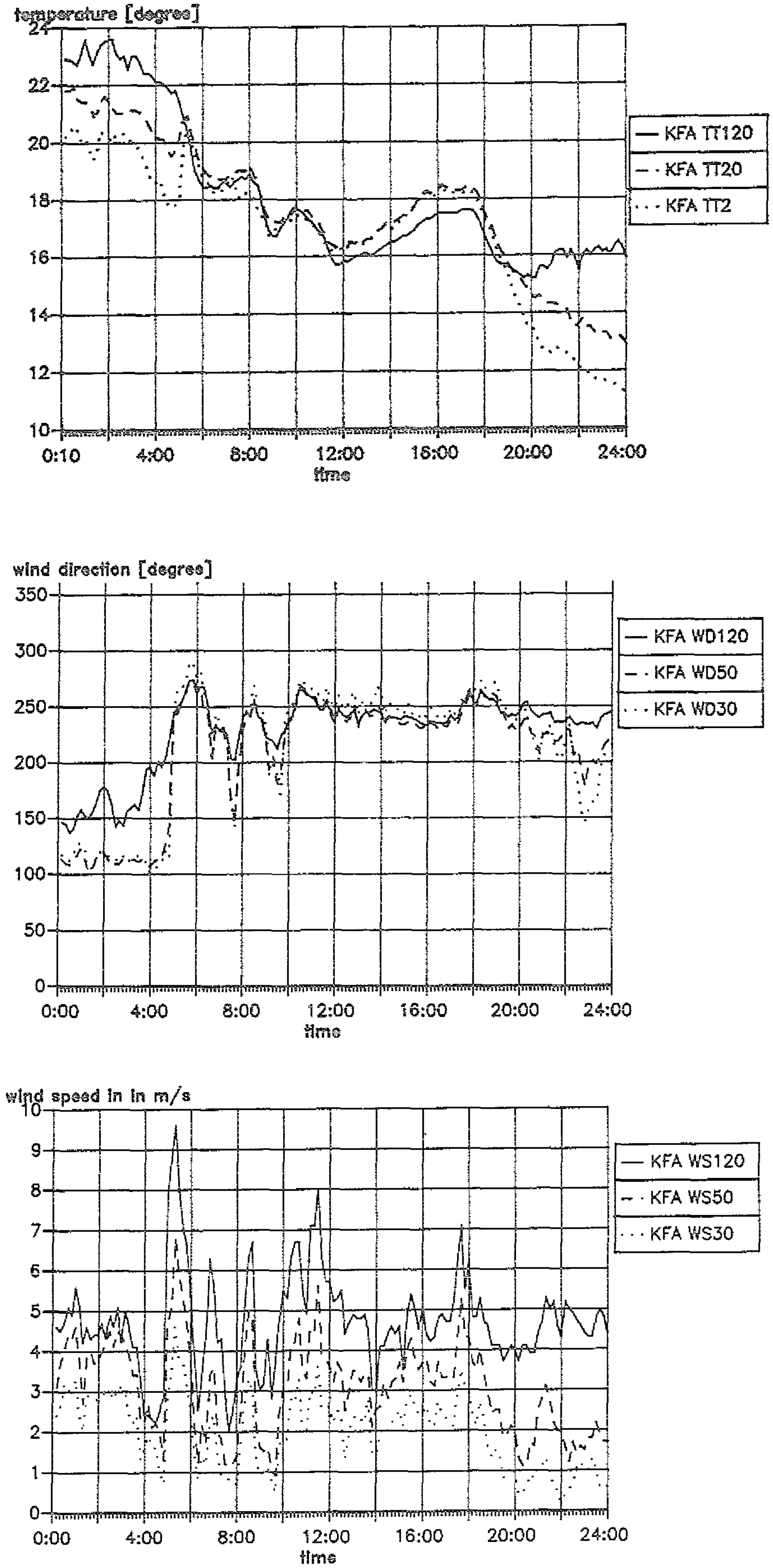


Fig. 5.1.3a-c: Meteorological measurements at the KFA-tower, Sept 19, 1989
TT 2, 20, 120 : Measurements of temperature (TT) in 2m, 20m, 120m
WD 30, 50, 120: Measurements of wind direction (WD) in 30m, 50m, 120m
WS 30, 50, 120 : Measurements of wind speed (WS) in 30m, 50m, 120m

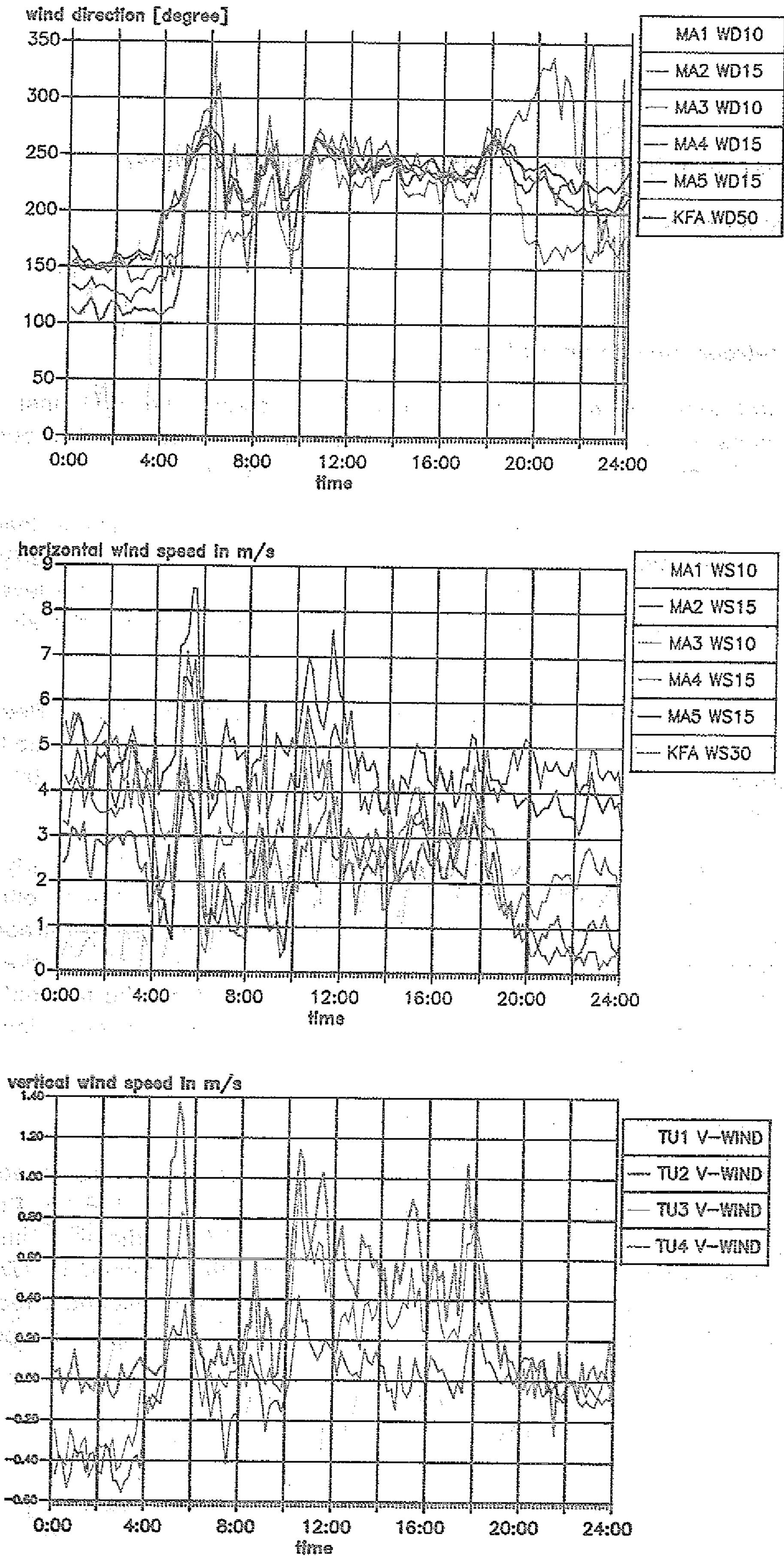


Fig. 5.1.4a, b: Measurements of wind direction WD (a), horizontal (b) and vertical (c) wind speed at KFA-tower and masts 1-5 Sophienhöhe, Sept 19, 1989
Measurement heights: 10m, 15m, 30m, 50m

5.2 The use of tetroons during the fourth field experiment

M. Möllmann-Coers

5.2.1 The tetroon measuring system

Tetroons (*tetr*aedral ball*oons*), also called CLB (Constant *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 increase 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 4th field experiment, a total of 7 flights were performed. 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.

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:

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

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 Table 5.2.2.

Tetroon	Exp. No.	Date	Launch time (CET)	Stability *)
SO8901	IV.1.1	19. 9.	20:15	s
SO8902	IV.1.2	19. 9.	20:40	s
SO8903	IV.2.1	20. 9.	19:30	s
SO8904	IV.2.2	20. 9.	20:15	s
SO8905	IV.4.1	25. 9.	20:50	s
SO8906	IV.5.1	27. 9.	12.40	u
SO8907	IV.5.3	27. 9.	13.50	n
*) s=stable, n=neutral, u=unstable				

Tab.5.2.2: Tetroon numbers and dispersion experiments

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

In the evening hours of September 19, when the tetroons SO8901 and SO8902 were launched during the experiment IV.1 (see Tab. 5.2.2), a flat high pressure region was located in central Europe behind a weak cold front that had passed the experimental site in the morning hours. Southwesterly winds prevailed when due to radiative cooling an inversion has built up. The temperature gradient was $\frac{1\,C°}{100\,m}$ measured at the KFA meteorological tower. The tetroon tracks reveal a very flat layer with easterly air flow at the surface at the launch position (see Tab. 5.2.3) with a thickness of only a few meters. When tetroon SO8901 rised it has been moved with the southwesterly meanflow towards the Sophienhöhe. The radar lost contact to the tetroon SO8901 when it travelled over the tip very close to the surface. Tetroon SO8902 was caught by some trees before it began to rise.

In September 20, the high pressure area has strengthened and its kernel was located over Poland. Therefore southeasterly winds were found in Jülich when experiment IV.2 was carried out, and again a stable stratification of the air developed in the evening hours. Within this experiment, two tetroons (SO8903, SO8904) were launched at the border of the pit east of the Sophienhöhe. These two flights show, that there was a steady state southeasterly mean flow during the experimental period although the wind at the emission point 30 m above the surface turned to south.

Within experiment IV.3 no tetroon could be launched due to technical reasons.

Similar to September 19, in September 25, a flat high pressure area was approaching from west behind a weak front that had passed Germany during the daytime. In the evening hours again a strong inversion has been built up with a temperature gradient of $\frac{4\,C^\circ}{100\,m}$ when the tetroon SO8905 was launched. The tetroon flight reveals a westerly mean flow although at the emission point of experiment IV.4 a wind direction of 207° was found.

In September 27, under the influence of high pressure over the Atlantic and a low over Poland cool maritime air was entering Germany from north. At noon when experiment IV.5 was carried out, varying cloudcover with cumulus clouds was found, and the temperature gradient was also varying between $\frac{-1\,C^\circ}{100\,m}$ and $\frac{-1.4\,C^\circ}{100\,m}$. These variations in the atmosphere have been reflected in the tetroon flights SO8906 and SO8907 that were launched with a time interval of 1h and 10 min (see Fig. 5.2.1). Whereas tetroon SO8906 approached the tip from north, rised with the upslope winds at the Sophienhöhe, and gained a height of about 600m above NN when radar contact to the tetroon was lost, tetroon SO8907 traveled in a northwesterly air flow and rised beginning from the launch position up to a mean height of 450m.

Tetroon	Radar position			Launch position	
	x	y	Height MSL	x	y
SO8901	26772	42917	85.m	27984	42735
SO8902	26772	42917	85.m	28220	42628
SO8903	31055	42600	218.m	35066	41106
SO8904	31055	42600	218.m	35683	40042
SO8905	28172	46707	102.m	28148	45989
SO8906	29022	48767	100.m	30041	47780
SO8907	29022	48767	100.m	30077	47824

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

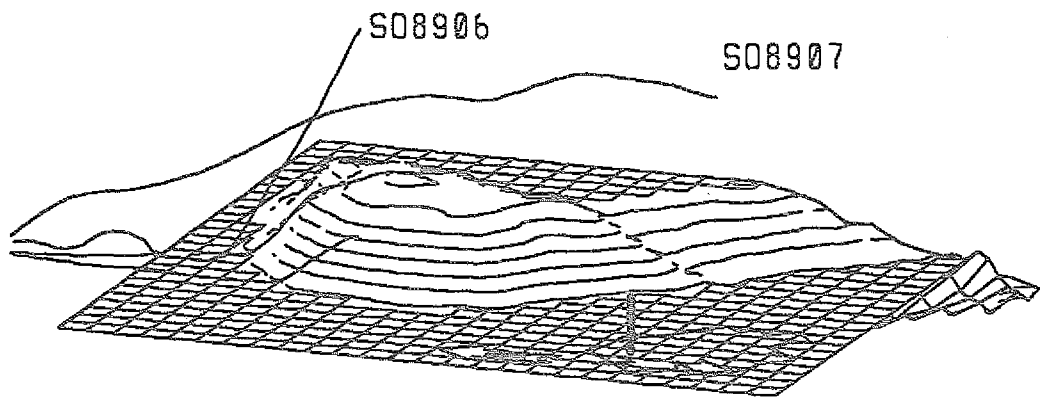


Fig. 5.2.1: Tetroon SO8906 and SO8907, slant view: The flight tracks and correspondend projections to the surface are shown. In addition the contour of KFA and the position of the KFA meteorological tower is depicted. The north direction is given by an arrow. The view is from southwest.

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 out 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 description of the instruments used and of the position and performance of the instruments. Technical details of the instruments are given in Gryning (1990). 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, 4 km north-west of Sophienhöhe, see Fig. 1.1. This position had the Gauß-Krüger coordinates 27.500, 47.230 (in km) and the height 97 m above MSL.

The sonic anemometer used was a Kaijo Denki DAT/TR-61B. 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. 5.3.1 shows the mast with the sonic-anemometer probe mounted on the top.

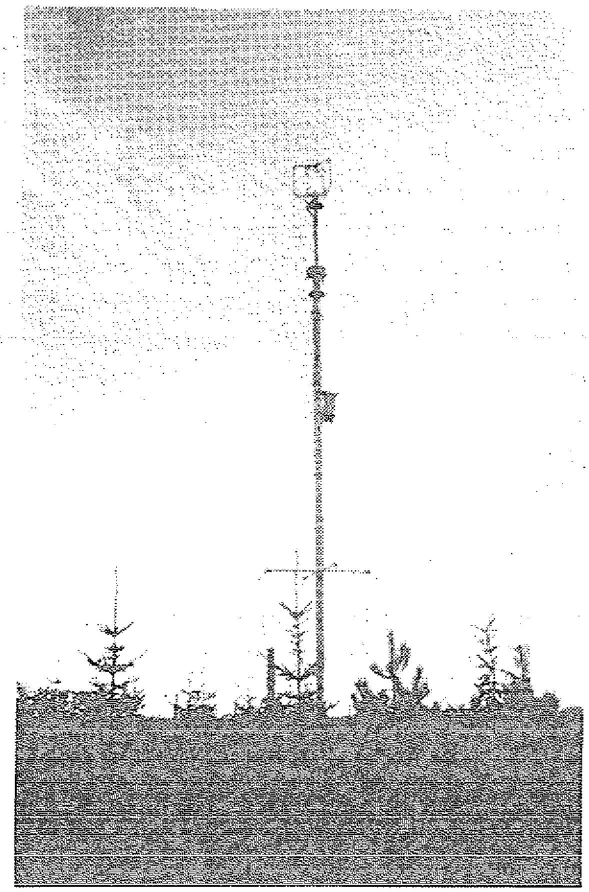


Fig. 5.3.1: The mast with the sonic anemometer. The sonic anemometer probe can be seen in the top of the mast.

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, see Gryning (1990).

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 $\bar{v} = 0$, $\bar{v}$ being the mean value of v. In this new coordinate system $\bar{u}$ is the 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
September 19 11:50	September 25 21:10
September 25 21:40	September 28 12:20

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

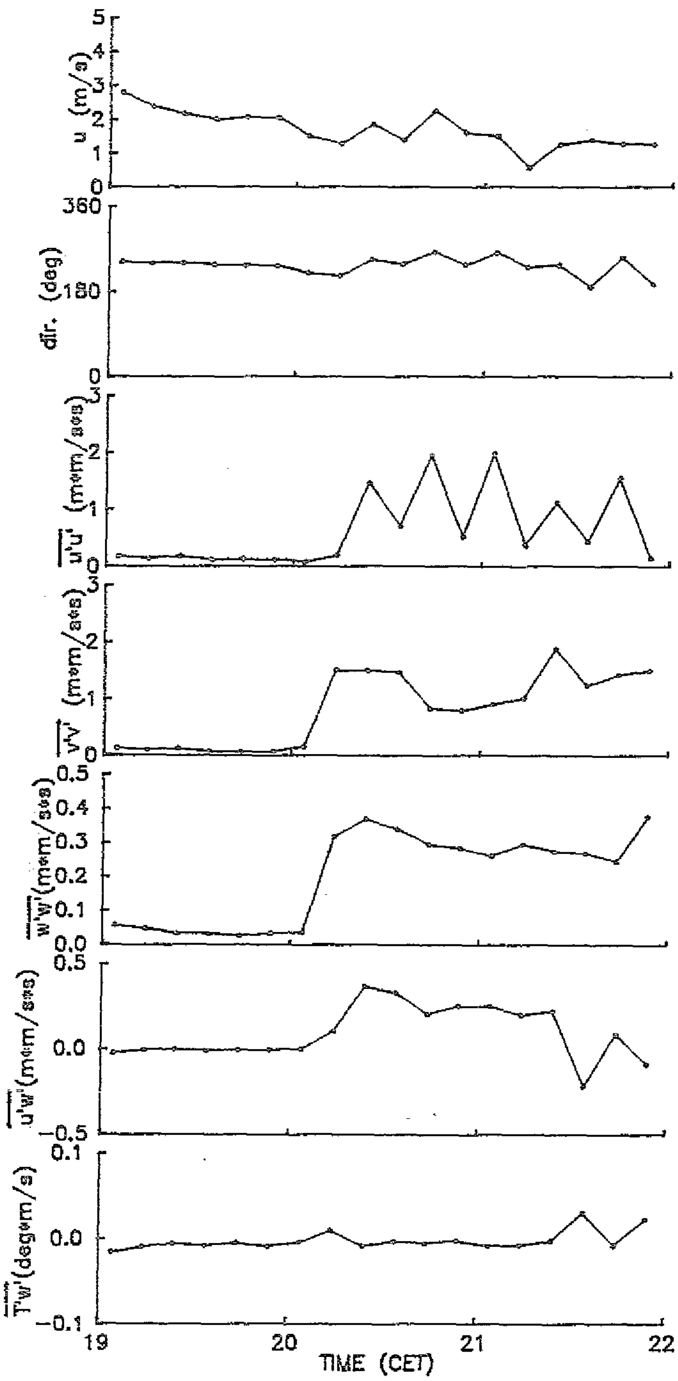


Fig 5.3.2: Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 19 September 1989, period 19:00 - 22:00 CET.

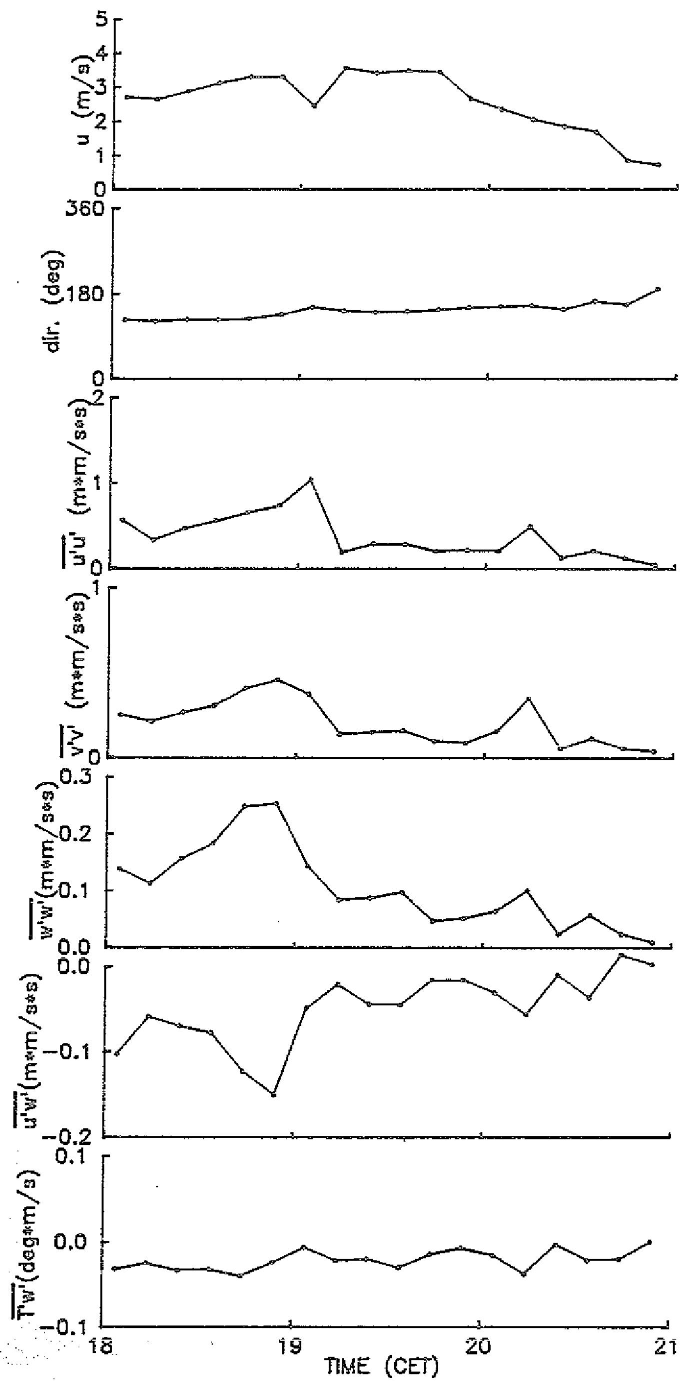


Fig. 5.3.3: Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 20 September 1989, period 18:00 - 21:00 CET.

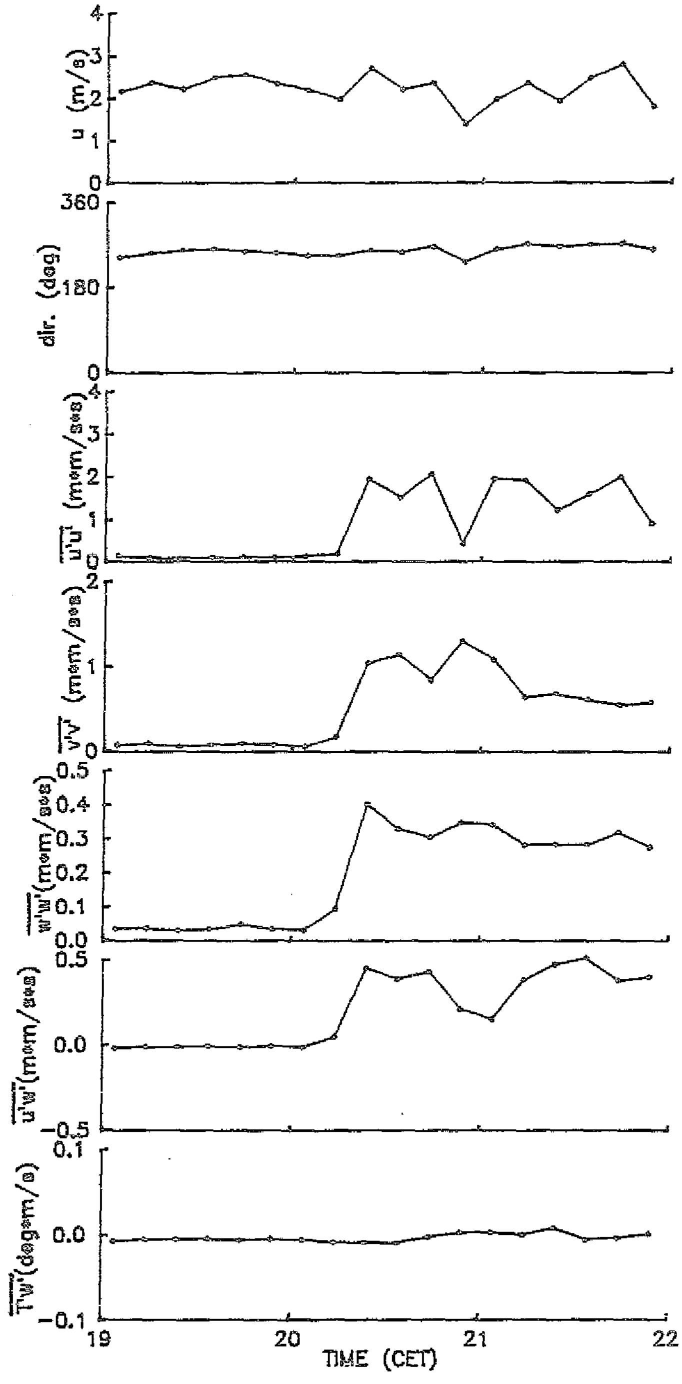


Fig. 5.3.4: Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 23 September 1989, period 19:00 - 22:00 CET.

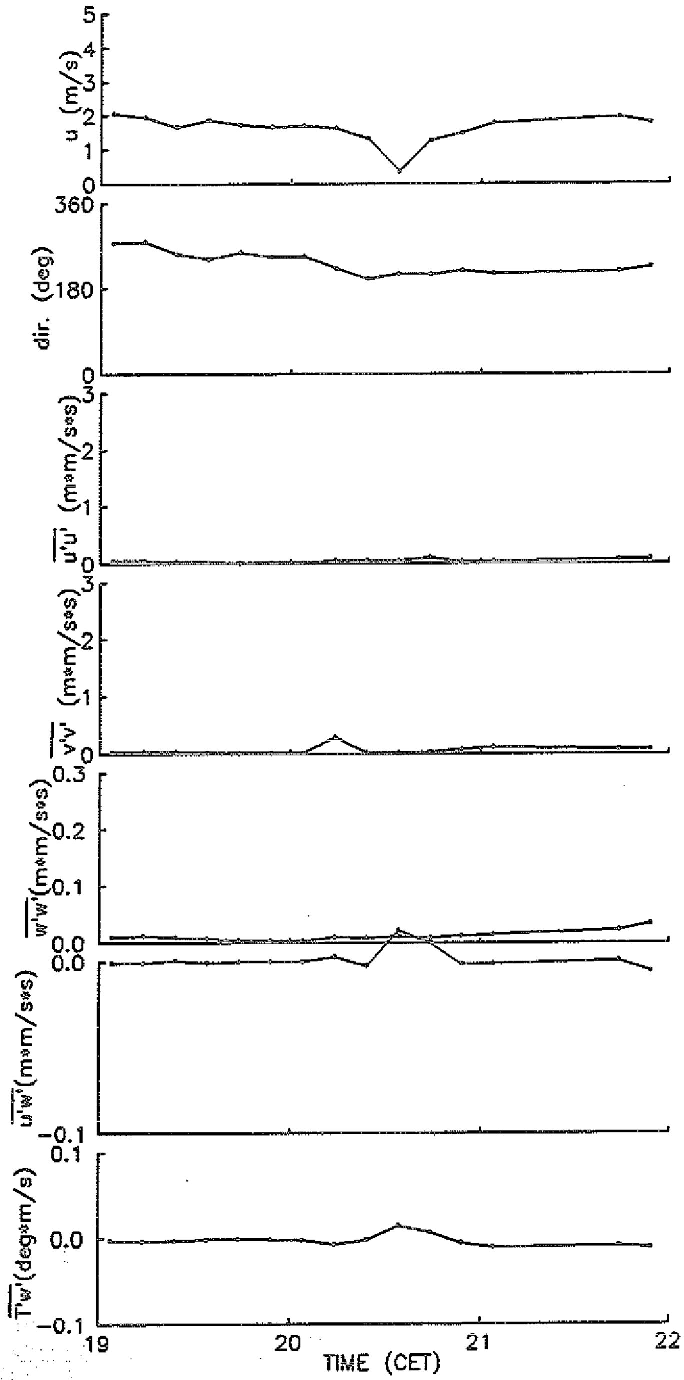


Fig. 5.3.5: Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on September 25, 1989 period 19:00 - 22:00 CET.

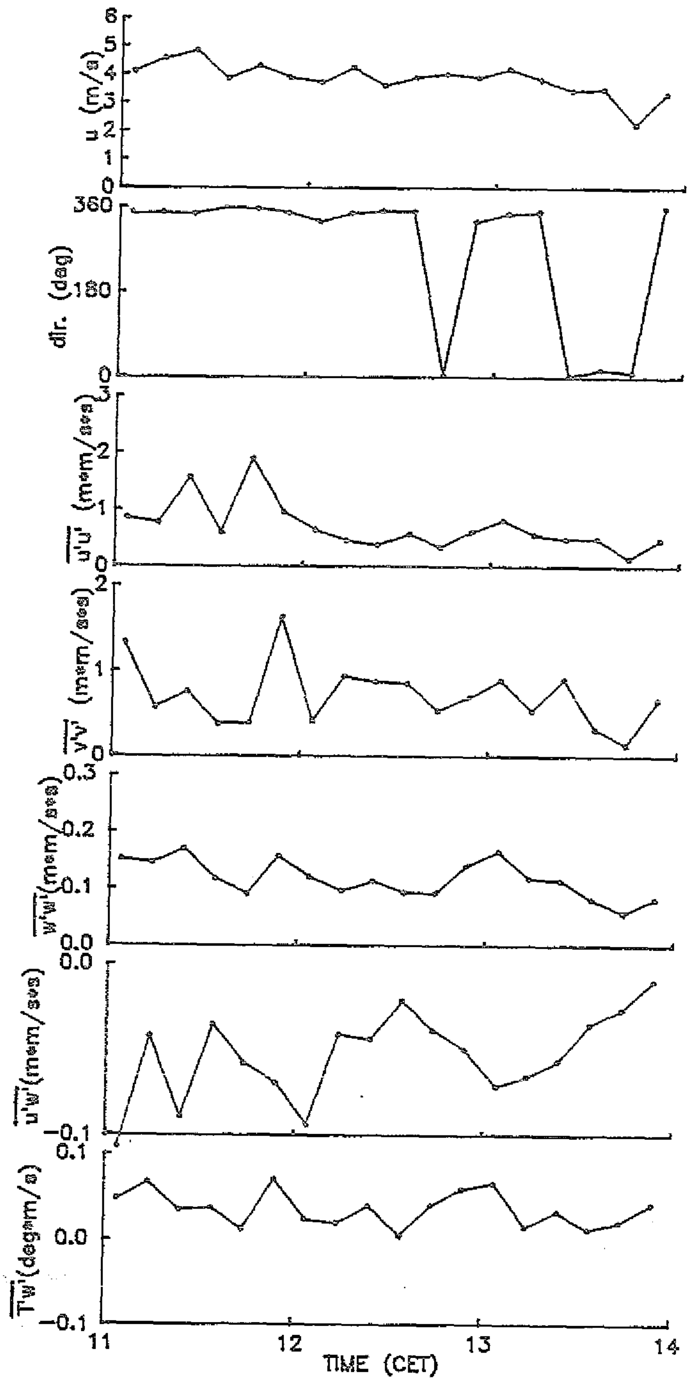


Fig. 5.3.6: Illustration of the 10-min averaged turbulence statistics derived from the sonic-anemometer measurements on 27 September 1989, period 11:00 - 14:00 CET.

The measurements were carried out throughout the whole experimental campaign except for a 30-min interruption due to hardware problems, Tab. 5.3.2. Figures 5.3.2-5.3.6 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. 5.3.7) 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 by a PC on a discette for further processing in the laboratory.

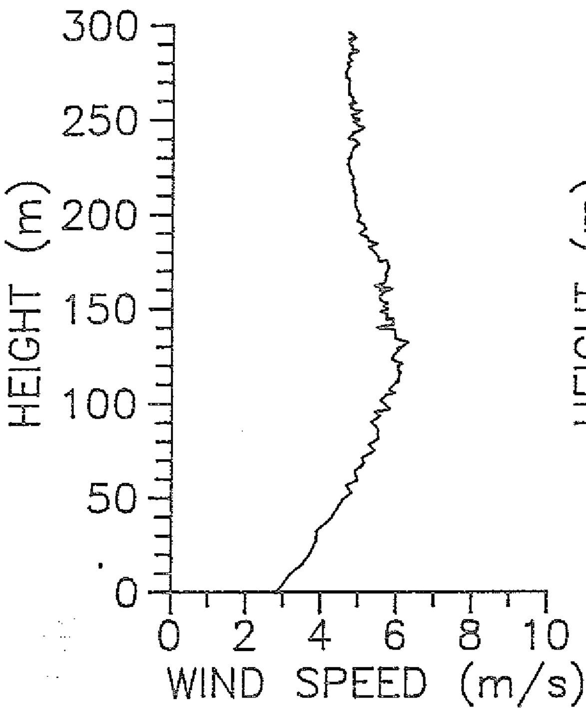
Fig. 5.3.7: The caravan contained the electronics for the sonic anemometer and the data recording equipment. In the front is seen the tether-sonde balloon and its winch.

Fifty-five soundings (9 files in the data bank) were performed up to 200-500 m above ground (depending on wind speed), see Table 5.3.4. In Figs. 5.3.8 - 5.3.13 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
19 September	19:22	21:06	339	3
20 September	18:39	21:11	346	3
22 September	07:09	12:05	658	12
23 September	20:37	21:51	508	4
25 September	08:07	12:20	653	10
25 September	18:04	21:24	482	6
27 September	08:06	10:15	586	6
27 September	11:09	14:43	412	(6)
28 September	08:03	11:33	495	5

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



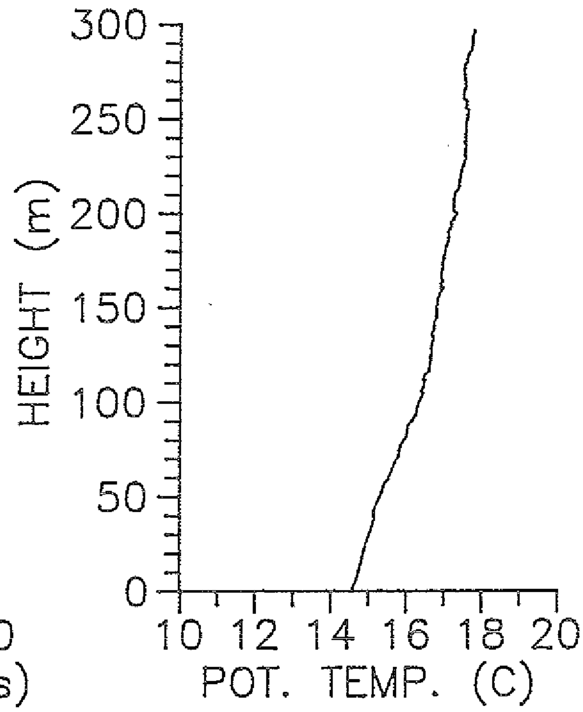
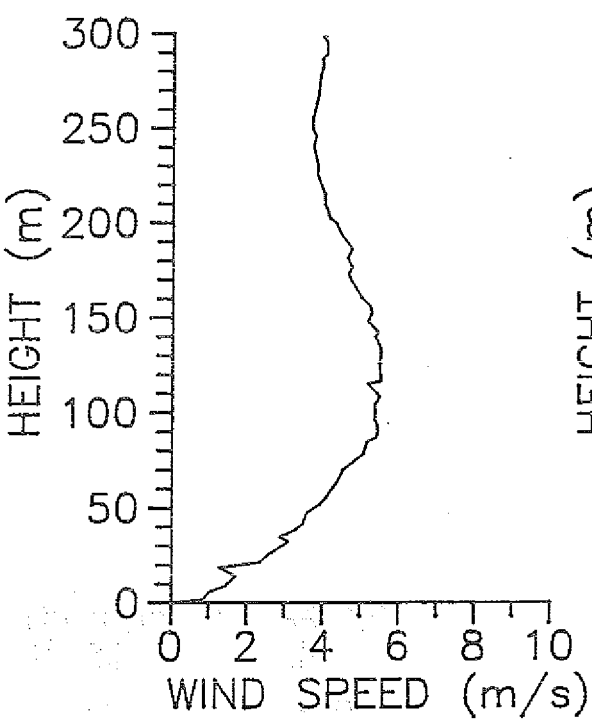


Fig. 5.3.8: Profiles of wind speed and potential temperature measured at Pattern, 19 September 1989, period 19:54 - 20:19 CET.



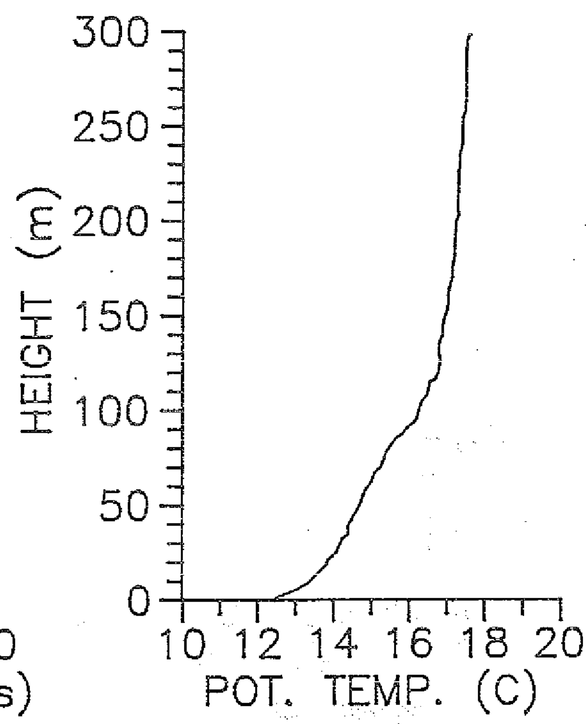


Fig. 5.3.9: Profiles of wind speed and potential temperature measured at Pattern, 19 September 1989, period 20:44 - 21:07 CET.

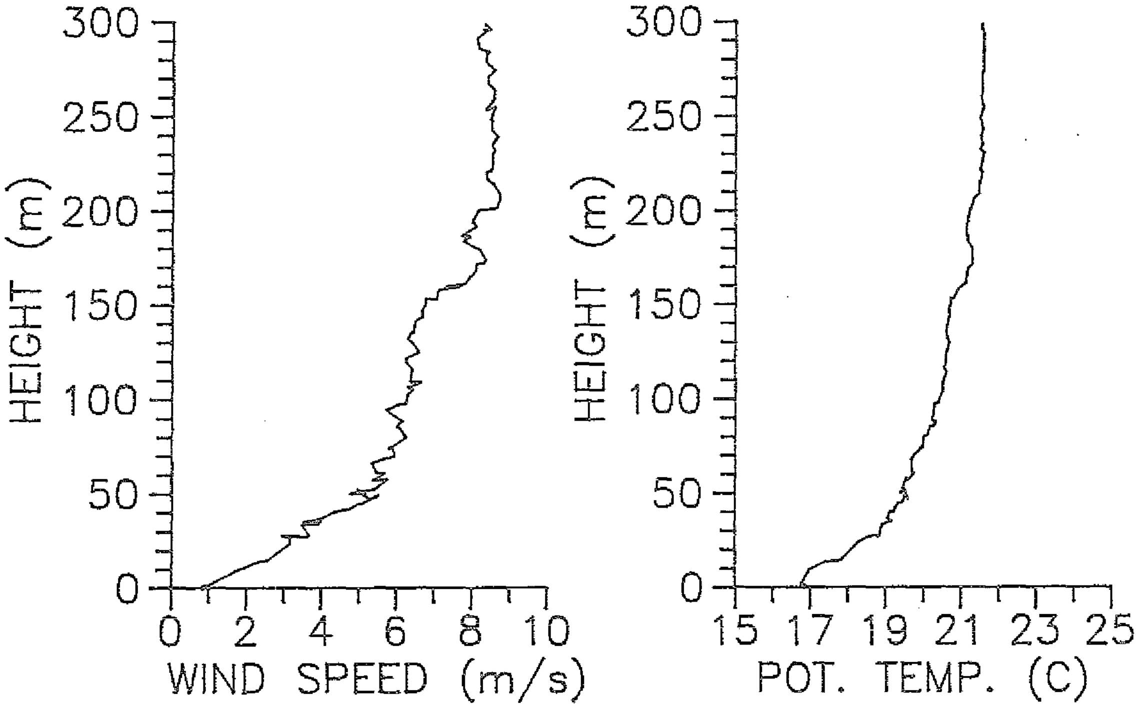


Fig. 5.3.10: Profiles of wind speed and potential temperature measured at Pattern, 20 September 1989 , period 20:33 - 20:58 CET.

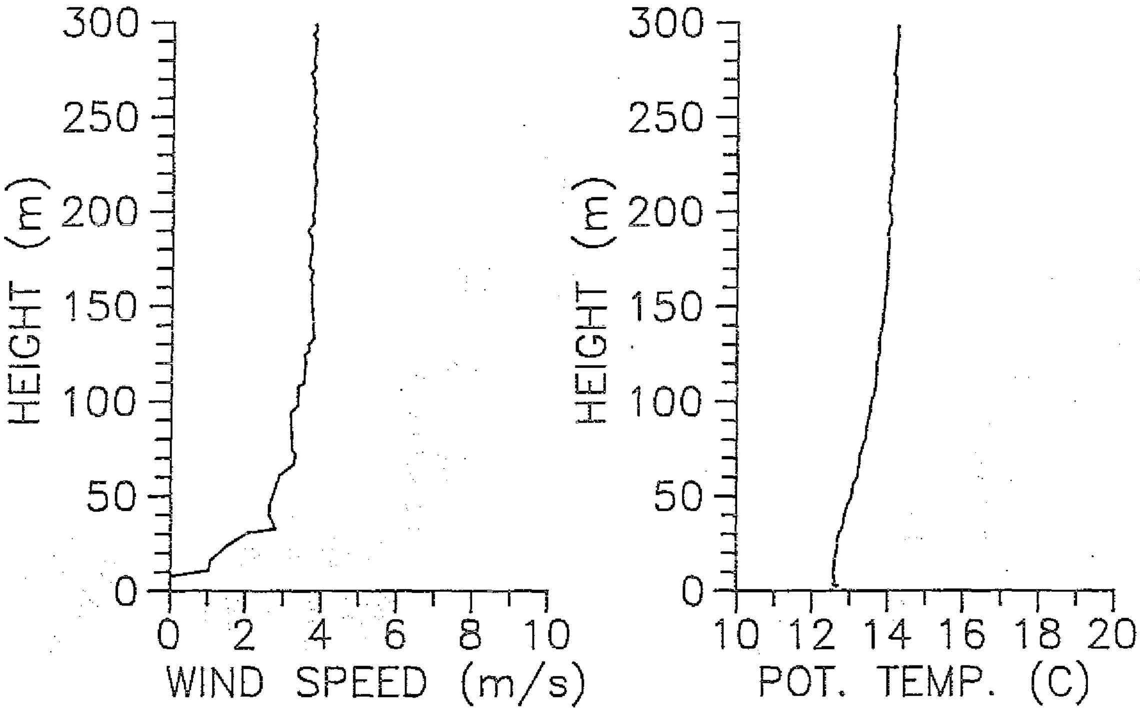


Fig. 5.3.11: Profiles of wind speed and potential temperature measured at Pattern, 23 September 1989, period 21:20 - 21:42 CET.

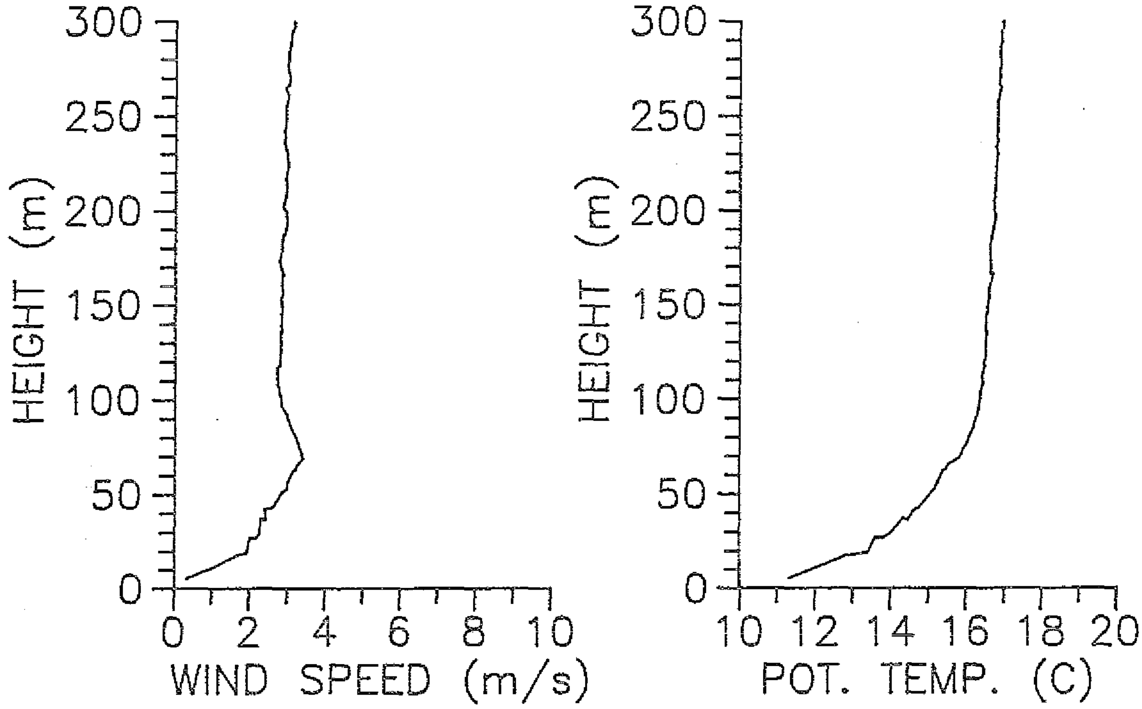


Fig. 5.3.12: Profiles of wind speed and potential temperature measured at Pattern, 25 September 1989, period 20:39 -21:04 CET.

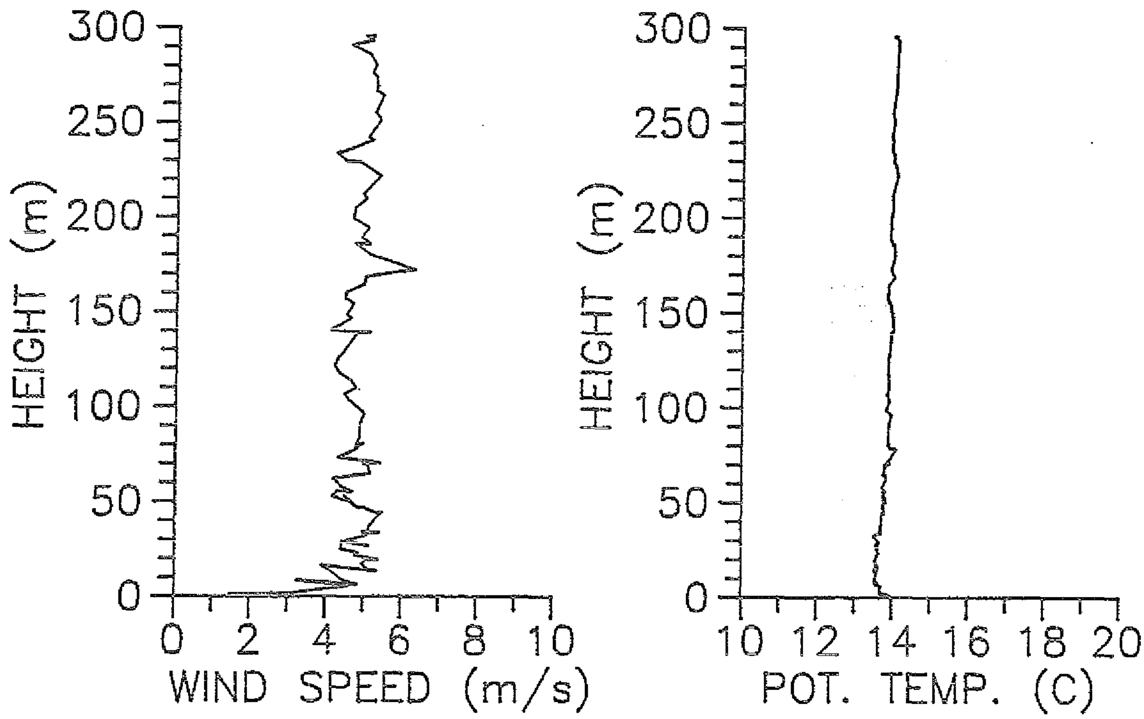


Fig. 5.3.13: Profiles of wind speed and potential temperature measured at Pattern, 27 September 1989, period 12:48 - 13:08 CET.

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. 1.1. The masts were located on the positions that were used in the third field campaign in August-September 1988, table 5.3.5. The four masts were located to reflect the change in wind speed and direction near the surface at the northwestern part of Sophienhöhe.

	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) of the small masts.

The instrumentation of the four masts is identical. A RISØ cup-anemometer model-70 was used as wind speed sensor. The wind direction was measured by a wind vane (Aanderaa Instruments, wind direction sensor 2750). The data registration was carried out by a battery-driven datalogger, the results are stored on magnetic tape. All instruments functioned well during the campaign.

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, table 5.3.6.

September 19	19:00-22:00
September 20	18:00-21:00
September 23	19:00-22:00
September 25	19:00-22:00
September 27	11:00-14:00

Tab. 5.3.6: Measurements for all four masts contained in the data bank.

All measurements given in table 5.3.6. are illustrated in Figs. 5.3.14. - 5.3.18.

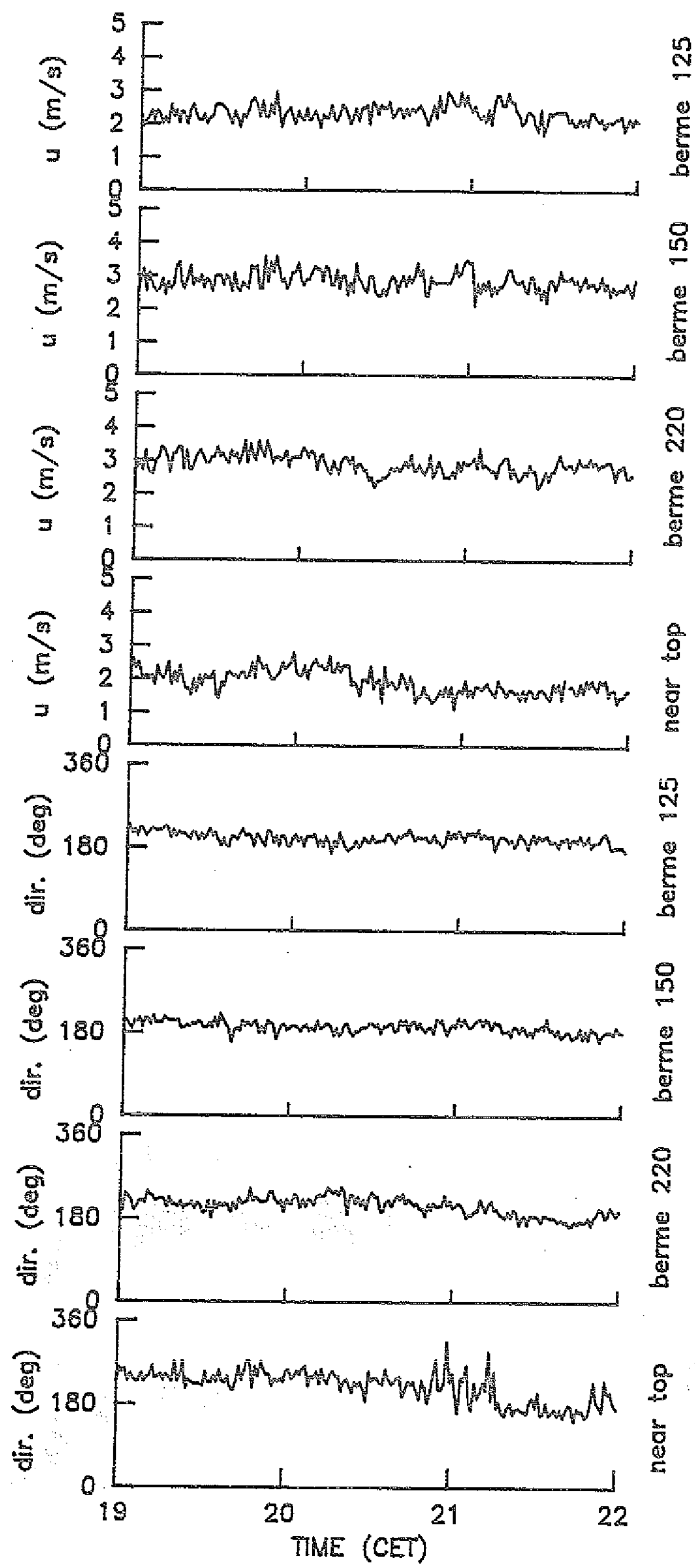


Fig. 5.3.14: Illustration of the measurements at the small masts on 19 September, period 19:00 - 22:00 CET.

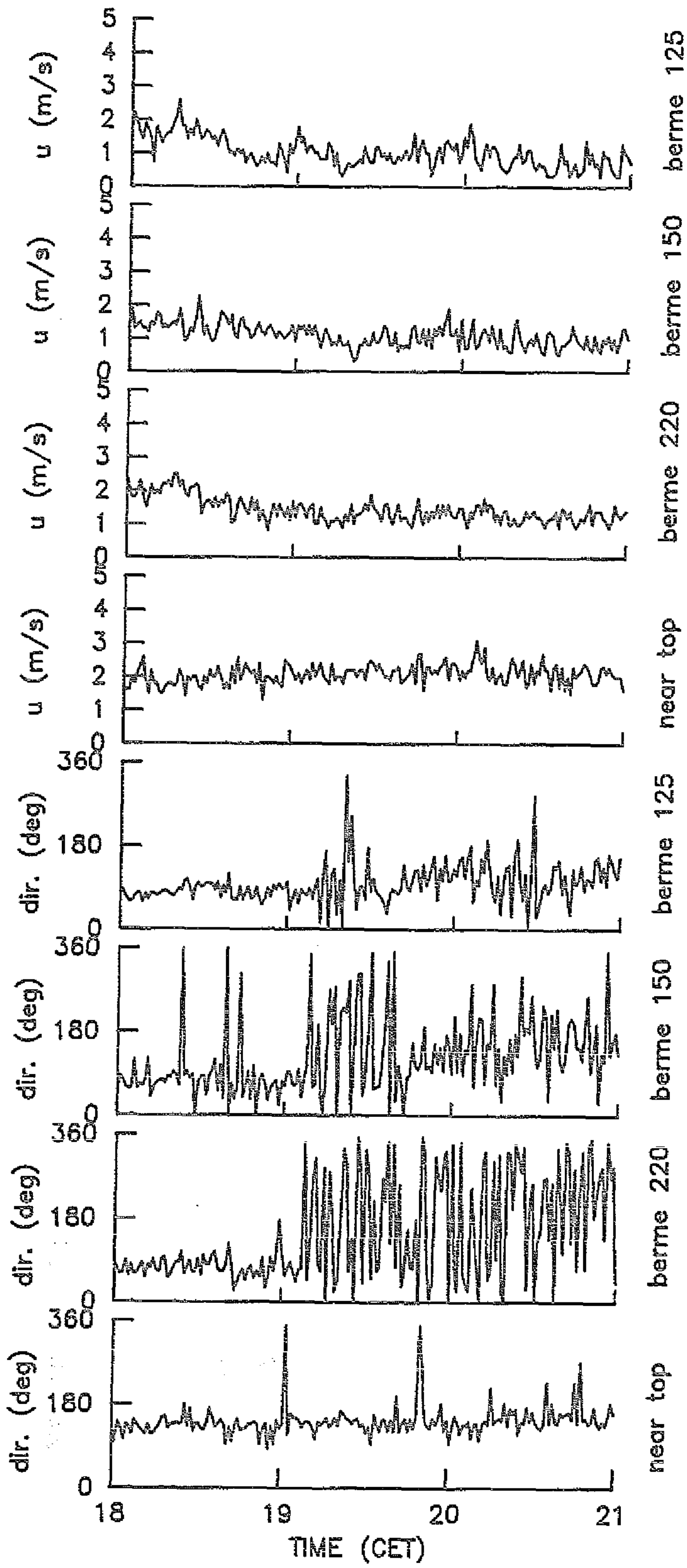


Fig. 5.3.15: Illustration of the measurements at the small masts on 20 September, period 18:00 - 21:00 CET.

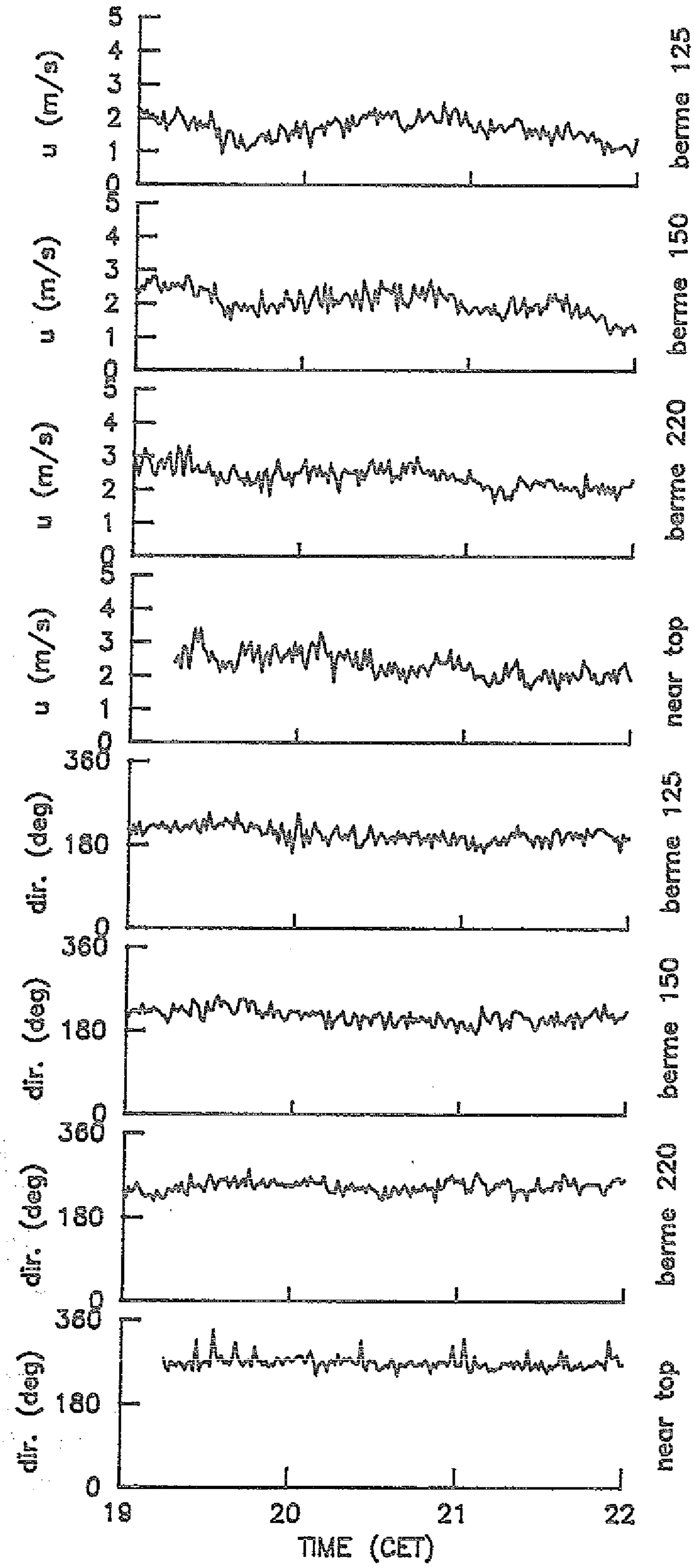


Fig. 5.3.16: Illustration of the measurements at the small masts on 23 September, period 19:00 - 22:00 CET.

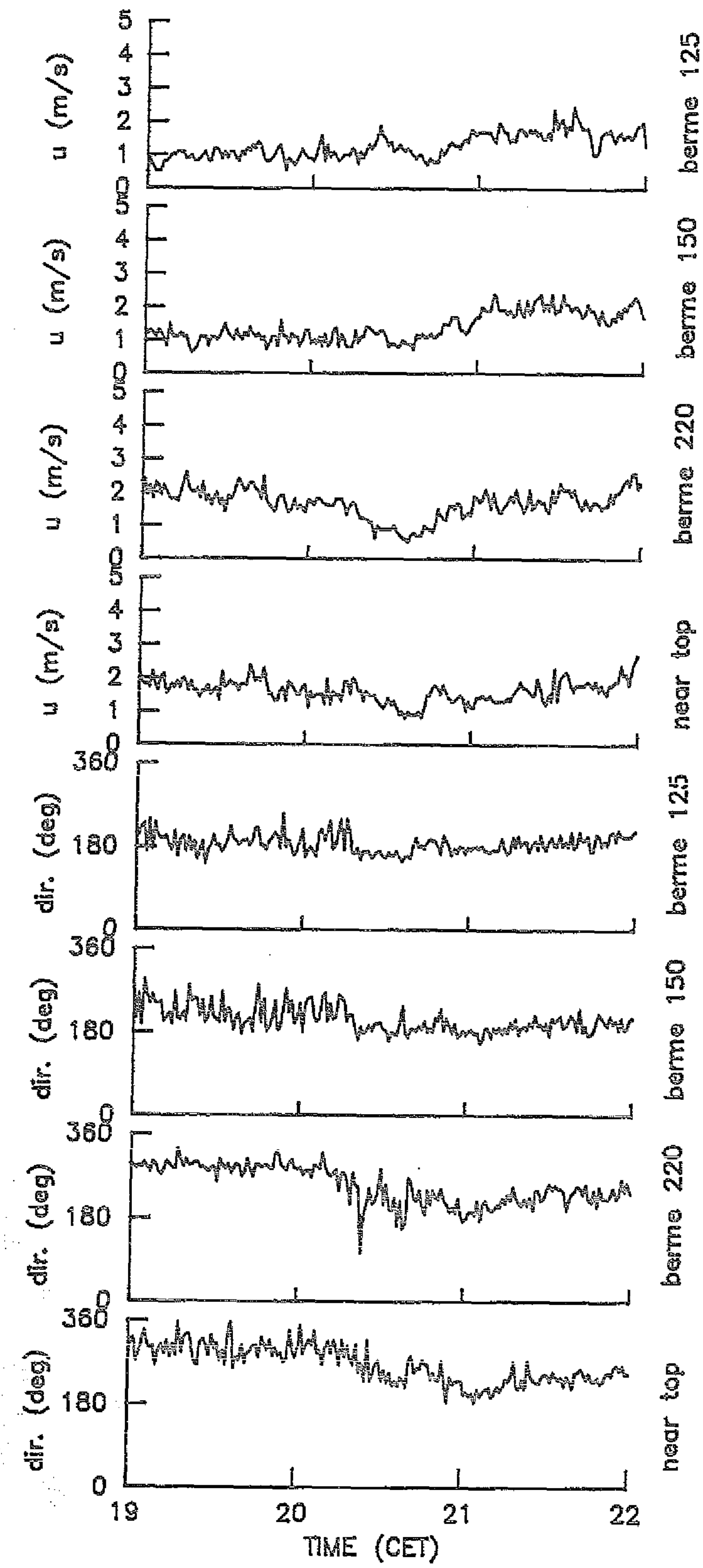


Fig. 5.3.17: Illustration of the measurements at the small masts on 25 September, period 19:00 - 22:00 CET.

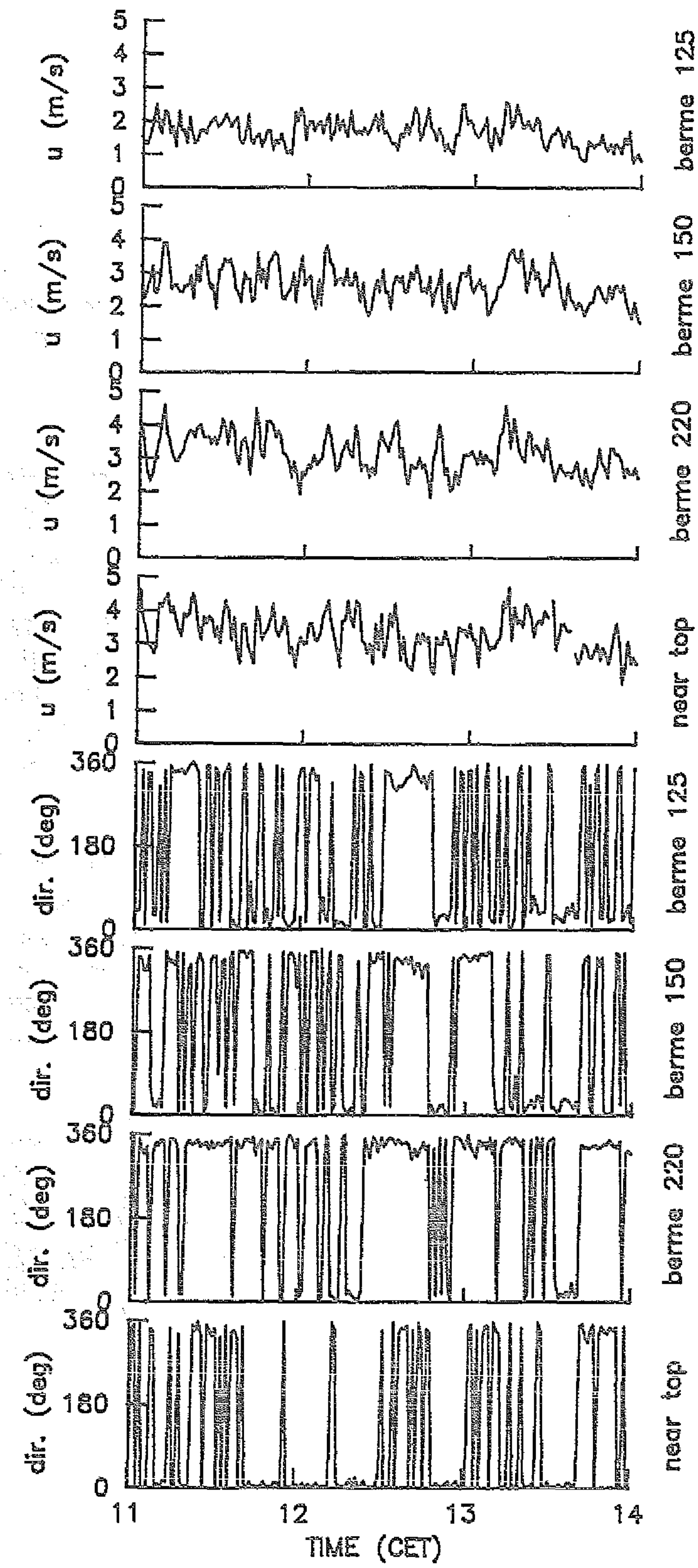


Fig. 5.3.18: Illustration of the measurements at the small masts on 27 September, period 11:00 - 14:00 CET.

5.4 Tether sonde measurements by IGM-group

W. Oetz, Ch. Oetz, G. Zeuner

The soundings of the lower atmosphere with a mobile 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 at different locations. In the following, the measurement system, 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-3A-SP and receiver, model TS-2AR. The tether sonde is a new type and mainly in design different from the RISØ sonde; the sensors and sensor characteristics are similar to those of the RISØ tether sonde and therefore not described here (see chapter 5.3). 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. 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 humidity sensor(wet bulb temperature) didn't work from Sept 23 until the end of the campaign. 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 opto-electronical. Pressure is measured by detecting the change in plate separation of an aneroid capacitance sensor.

The measurements were carried out on seven days. Morning ascents were made synchroneous with the RISØ group to detect the dissolution of inversions. Thirty-one soundings were performed at six positions. Measurements were made at six different locations; the location was selected in dependence of interesting points during dispersion experiments (for example windward side of hill) or for investigating the morning inversion height together with the RISØ-group. Time and position of the tether sonde measurements are given in Tab. 5.4.1 - Tab. 5.4.3. The positions are shown in Fig. 5.4.1.

Fig.5.4.1: Positions of the tethered balloon IGM-Köln

Date	position	Gauß-Krüger Coordinates	Height (m) MSL
Sept 19	S1: Base of hill (West); at position of Doppler-SODAR KFA	29725 43540	105
Sept 20	E5: Emission point south of Steinstraß	34190 43460	126
Sept 23	MV: South side of hill,place of van ICH 4	31340 42000	104
Sept 25	TH: West side of hill, southeast of Thywissenhof	29675 44620	102
Sept 27 (from 10.58h)	M5: Mast 5, top of hill.	31085 44880	271
Sept 20, 25, 27, 28 (morning)	I: 300 m northeast of hill, pump station HE 251	33475 46535	86

Tab. 5.4.1: Positions of the tethered balloon measurements

Date	Start	Stop	Max. height (m)	No. of profiles
Sept 19,1989	19:46	22:39	285	2
Sept 20,1989	19:03	22:08	109	4
Sept 22,1989	07:58	12:53	470	4
Sept 23,1989	19:21	22:59	306	4
Sept 25,1989	08:41	20:57	449	7
Sept 27,1989	08:31	14:38	254	6
Sept 28,1989	08:43	10:49	344	4

Tab 5.4.2: Measurements with the tethered balloon IGM group

As an example of the tether sonde ascents the wind and temperature profiles during tracer experiment IV.1 and IV.3 and in the morning of Sept. 22 are shown in Fig. 5.4.2 - 5.4.4. Fig. 5.4.2 and 5.4.4 illustrates the strong wind shear in the lower stable atmosphere. A well marked elevated inversion above the developing mixed layer can be seen in Fig.5.4.3.

The data bank contains the following parameters

- time since start (local time,i.e. until Sept 23 time=summertime !!)
- height above ground
- wind speed
- wind direction
- temperature (dry-bulb)
- temperature (wet-bulb)
- relative humidity

- pressure

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

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

where the indices 1 and 2 correspond to the measurements of temperature (T) and pressure (p) at two levels. The sum of the calculated thickness $H_n = \sum_{i=1}^{n}(\Delta H)_i$ gives the height above ground.

Date	Start CET	Stop CET	Position	Maximal height (m)	Remarks
19.9.	18:46	20:21	S1	285	humidity wrong 36 minutes
19.9.	20:30	21:39	S1	285	
20.9.	18:03	18:21	E5	109	problems power supply
20.9.	18:41	18:43	E5	40	
20.9.	18:50	19:17	E5	100	stop,strong turbulence
20.9.	20:52	21:09	E5	32	profile fire-ladder
22.9.	06:58	07:53	I	447	measuring inversion height
22.9.	07:58	09:03	I	470	"
22.9.	09:13	10:22	I	438	"
22.9.	10:36	11:54	I	342	"
23.9.	18:21	19:18	MV	200	humidity sensor defect till 28.09.
23.9.	19:21	19:57	MV	149	
23.9.	20:00	20:12	MV	0	defect
23.9.	20:13	21:12	MV	238	
23.9.	21:33	22:00	MV	306	
25.9.	08:41	09:43	I	427	measuring inversion height
25.9.	09:44	10:01	I	339	"
25.9.	10:31	10:58	I	314	"
25.9.	11:00	11:36	I	439	"
25.9.	11:37	12:13	I	449	"
25.9.	18:49	19:54	TH	381	
25.9.	19:56	20.58	TH	425	problems power supply
27.9.	08:31	09:00	M5	135	
27.9.	11:30	12:43	M5	214	
27.9.	13:17	13:48	M5	114	
27.9.	13:50	14:19	M5	50	
27.9.	14:20	14:38	M5	52	

Date	Start CET	Stop CET	Position	Maximal height (m)	Remarks
28.9.	08:43	09:21	I	308	measuring inversion height
28.9.	09:28	09:54	I	320	"
28.9.	09:56	10.24	I	327	"
28.9.	10:25	10:49	I	345	"

Tab. 5.4.3: Log-book tether sonde measurements

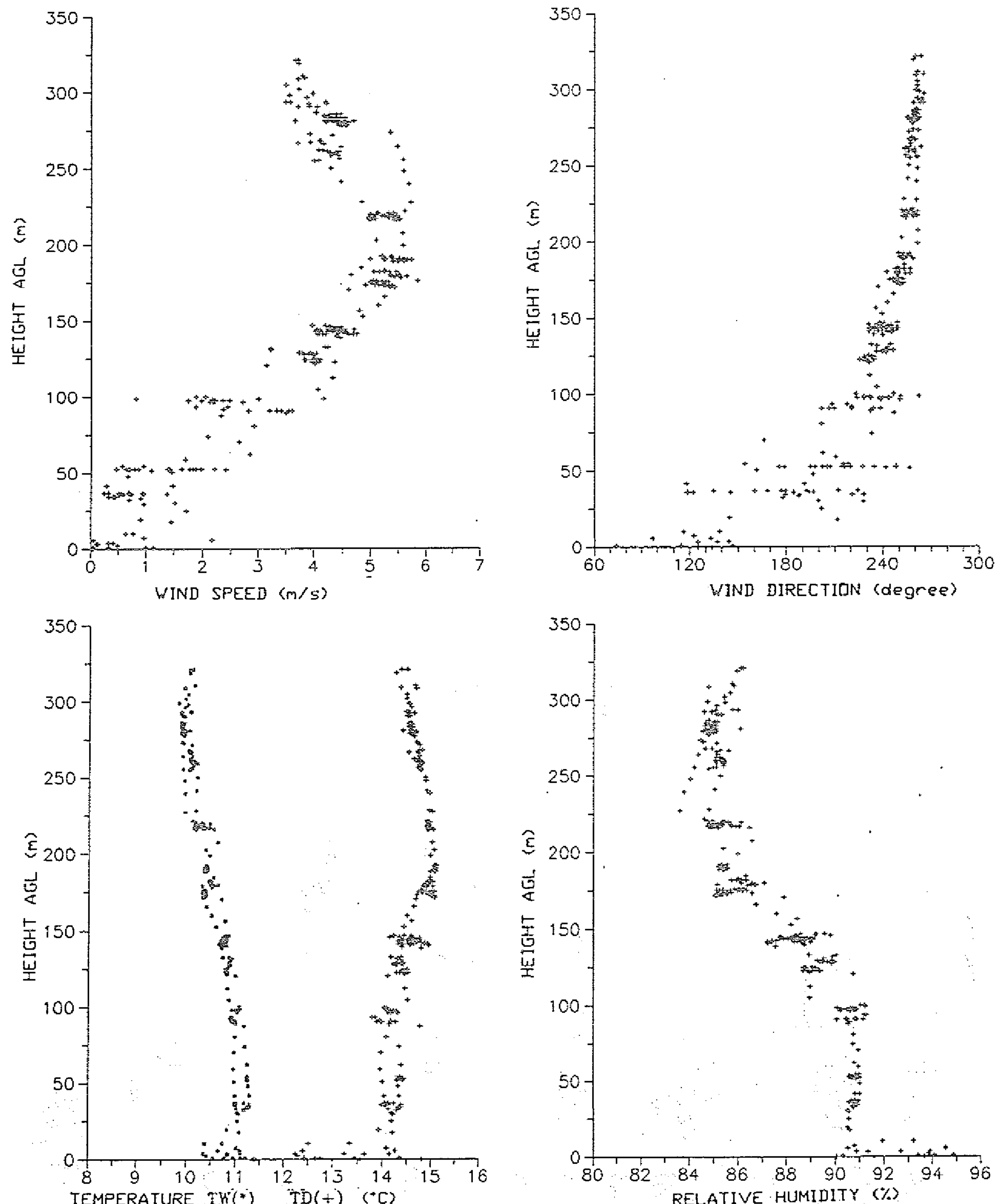


Fig. 5.4.2: Tethersonde ascent on Sept. 19, 1989, 20:30 - 21:39

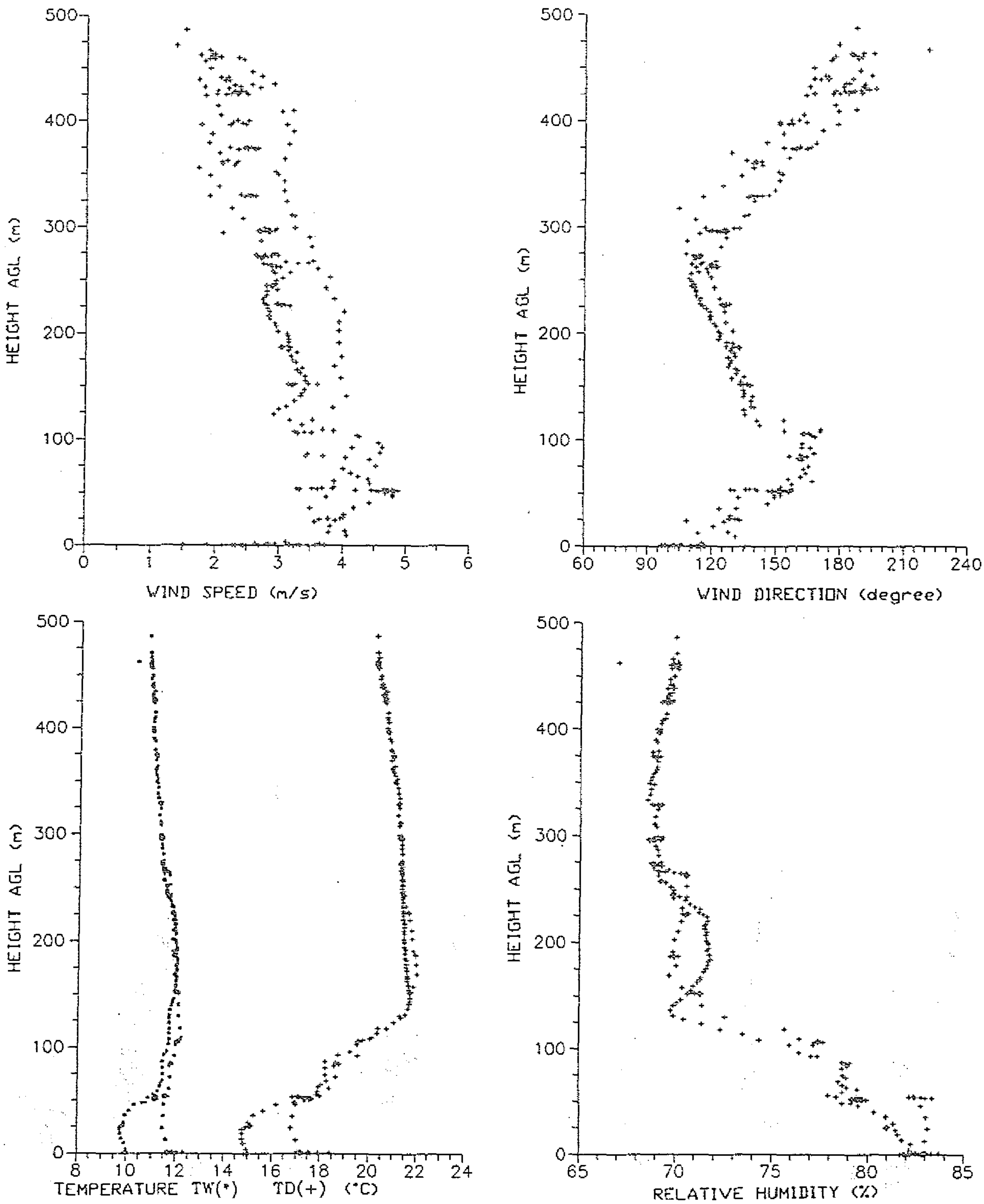


Fig. 5.4.3: Tethersonde ascent on Sept. 22, 1989, 07:58 - 09:03

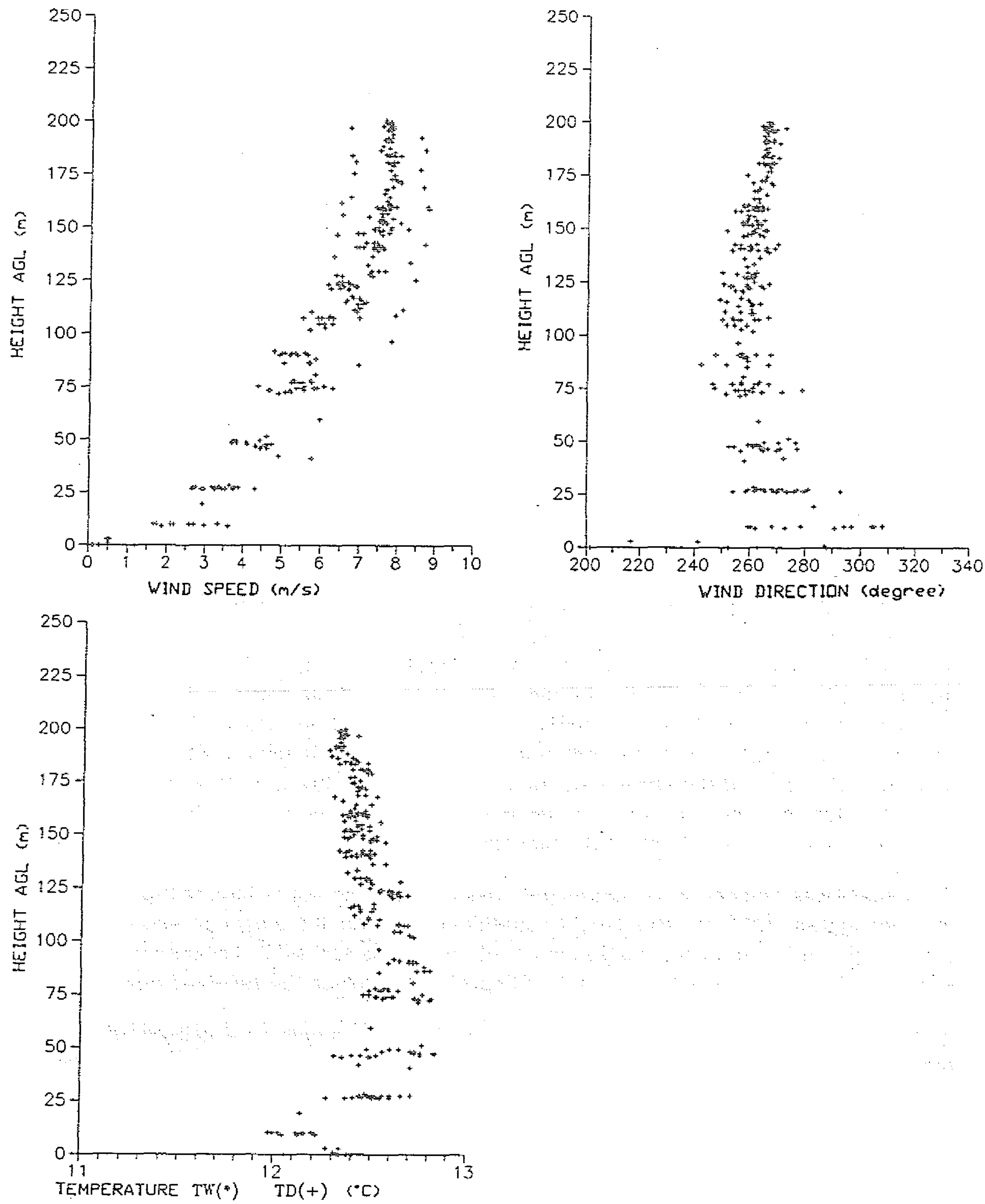


Fig. 5.4.4: Tethersonde ascent on Sept. 23, 1989, 19:21 - 19:57

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 during dispersion experiments from the location 'KFA waste treatment plant'. Tab. 5.5.1 contains a summary of all measurements (altogether 47 pilotballoon ascents and 15 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. 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 MSL 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. The data were checked for completion and plausibility. No data were smoothed.

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 MSL (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)
297	19.09.89	17.40	14.0	2300
298	19.09.89	18.00	18.0	3000
299	19.09.89	18.30	22.5	3590
300 S	19.09.89	19.00	29.0	4290
301 S	19.09.89	20.03	31.0	4490
302 S	19.09.89	21.09	26.0	3900
303	19.09.89	22.00	20.5	3110
304	20.09.89	15.00	21.0	3110
305	20.09.89	17.00	22.0	3170
306	20.09.89	17.30	20.5	3070
307	20.09.89	18.00	20.0	3080
308 S	20.09.89	18.38	22.0	2810
309	20.09.89	19.00	11.5	1680
310 S	20.09.89	19.31	21.0	3040
311	20.09.89	20.00	21.0	3310
312 S	20.09.89	20.30	21.0	3080
313	20.09.89	21.00	20.5	3140
314	20.09.89	21.40	20.0	3180
315	23.09.89	18.00	21.0	3080
316	23.09.89	18.30	21.0	3000
317	23.09.89	19.00	14.5	2160
318 S	23.09.89	19.30	14.0	2210
319	23.09.89	20.00	14.0	2490
320 S	23.09.89	20.35	21.0	3210
321	23.09.89	21.00	20.0	3180
322 S	23.09.89	21.32	19.5	3170
323	23.09.89	22.30	19.0	3130
324	23.09.89	22.30	17.0	2830
325	25.09.89	18.00	21.5	3090
326	25.09.89	18.30	21.0	3050
327	25.09.89	19.00	19.5	3080
328 S	25.09.89	19.30	20.0	3160
329	25.09.89	20.00	20.0	3160
330 S	25.09.89	20.31	21.0	3170
331	25.09.89	21.00	20.5	3290
332 S	25.09.89	21.32	21.5	3130
333	25.09.89	22.00	13.5	2110
334	25.09.89	22.30	19.5	3090
335	27.09.89	10.34	20.5	3100
336	27.09.89	11.00	19.0	3040
337 S	27.09.89	11.31	22.0	3070
338	27.09.89	12.00	20.5	3000
339 S	27.09.89	12.30	18.0	3050
340	27.09.89	13.00	21.0	3130
341 S	27.09.89	13.32	16.0	3060
342	27.09.89	14.00	23.0	3040
343	27.09.89	14.30	23.5	3110

5.5.2 *Pilot-balloon ascents in the area 'Sophienhöhe'*

During dispersion experiments, 45 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 20.09.89) near the base and wind-ward side of "Sophienhöhe". On Sept. 20, balloons were started from the top of the hill. 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 partly "Theo Süd" in the 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 minimize observation errors.

The data sent to KFA were time elapsed since start, elevation angle, azimuthal angle and slant range of "Theo Süd" for further evaluation. With this information the balloon's position in space as well as wind speed and wind direction were computed and are contained in the data bank. As examples the pilotballoon ascents during two dispersion experiments are shown in Fig. 5.5.4 - 5.5.6.

Date	ascent No.	'Theo Süd'			launch point		
		X (m)	Y (m)	H (m)	X (m)	Y (m)	H (m)
19.09.89	140..148	29503	42934	106	29263	43475	107
20.09.89	149..159	29148	44582	104	30117	44345	232
23.09.89	160..166	29503	42934	106	29424	43242	106
25.09.89	167..172	29148	44582	105	29399	45161	105
25.09.89	173..175	29148	44582	105	29498	45115	104
27.09.89	176..184	29148	44582	105	29493	45171	105

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)
140	19.09.89	18.43	7.0	114	1640
141	19.09.89	19.05	5.3	32	397
142	19.09.89	19.30	3.0	4	208
143	19.09.89	19.54	6.7	50	641
144	19.09.89	20.14	5.0	6	203
145	19.09.89	20.33	9.0	99	1761
146	19.09.89	20.59	3.7	26	357
147	19.09.89	21.11	5.0	42	517
148	19.09.89	21.33	10.0	198	2637
149	20.09.89	17.47	12.0	73	3456
150	20.09.89	18.12	16.0	79	5999
151	20.09.89	18.33	1.7	100	256
152	20.09.89	18.41	11.0	125	6210
153	20.09.89	18.58	11.0	61	4538
154	20.09.89	19.17	10.0	136	5589
155	20.09.89	19.43	6.0	79	2648
156	20.09.89	20.04	10.0	107	4250
157	20.09.89	20.26	6.0	40	1791
158	20.09.89	20.35	9.3	80	1108
159	20.09.89	20.52	13.0	135	5698
160	23.09.89	19.14	8.3	85	1472
161	23.09.89	20.18	10.0	34	994
162	23.09.89	20.36	10.0	102	1601
163	23.09.89	20.52	8.0	17	307
164	23.09.89	21.09	12.7	77	1358
165	23.09.89	21.42	10.0	105	1570
166	23.09.89	21.59	7.3	21	582
167	25.09.89	19.04	10.0	85	1561
168	25.09.89	19.22	2.3	8	120
169	25.09.89	19.36	12.0	81	1401
170	25.09.89	20.02	9.3	123	1761
171	25.09.89	20.38	13.7	122	2313
172	25.09.89	21.00	2.0	12	264
173	25.09.89	21.27	2.7	8	262
174	25.09.89	21.40	9.7	77	2034
175	25.09.89	21.55	8.3	130	2267
176	27.09.89	11.54	14.0	307	3996
177	27.09.89	12.15	9.3	169	3208
178	27.09.89	12.30	7.0	57	2205
179	27.09.89	12.45	10.3	99	2452
180	27.09.89	13.02	8.0	65	1573
181	27.09.89	13.20	7.0	81	1981
182	27.09.89	13.31	8.0	41	2168
183	27.09.89	13.46	9.0	103	2420
184	27.09.89	14.00	12.0	150	2987

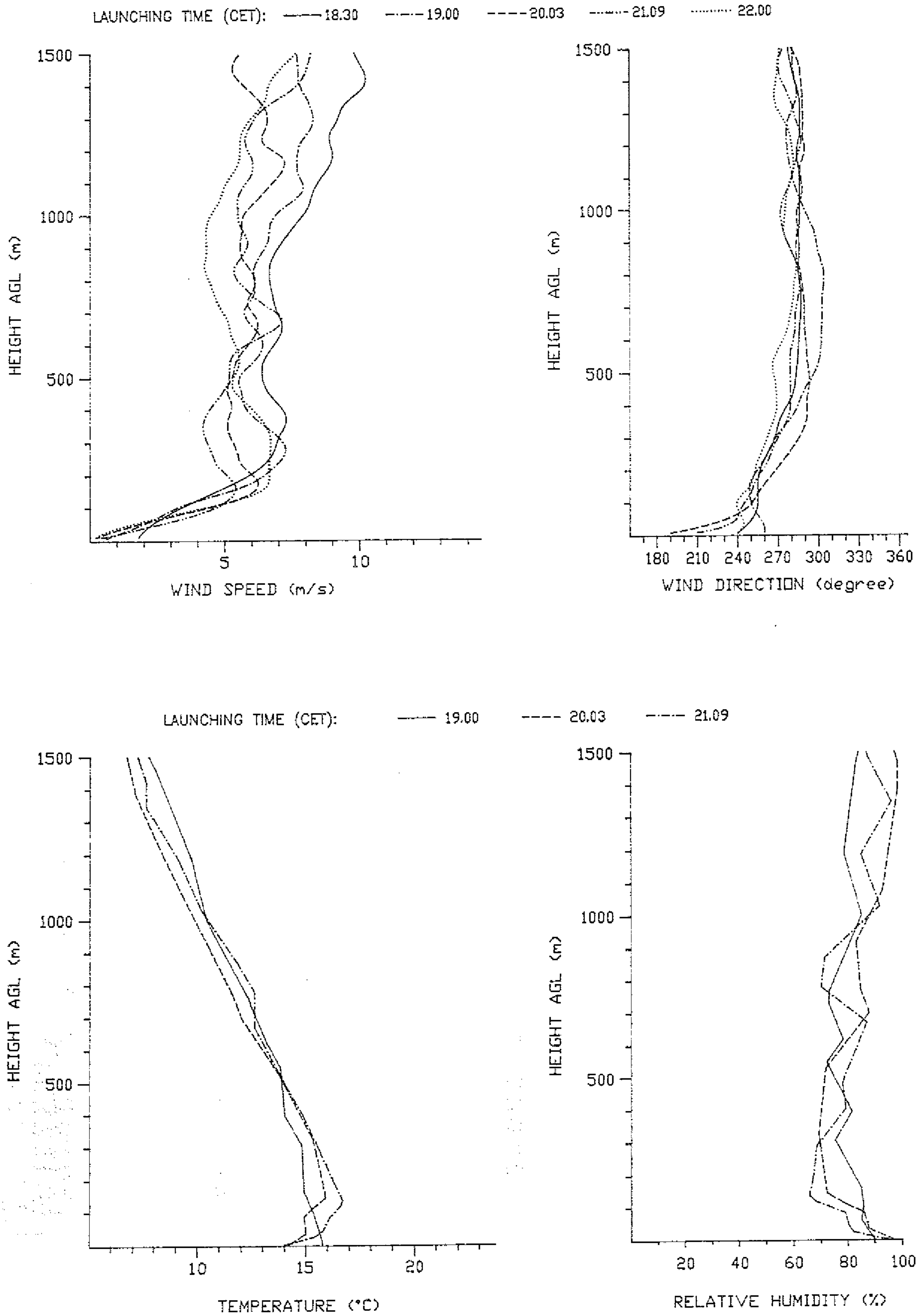


Fig. 5.5.1: Vertical profiles of wind (smoothed), temperature and relative humidity during the dispersion experiment at KFA, 19.09.1989

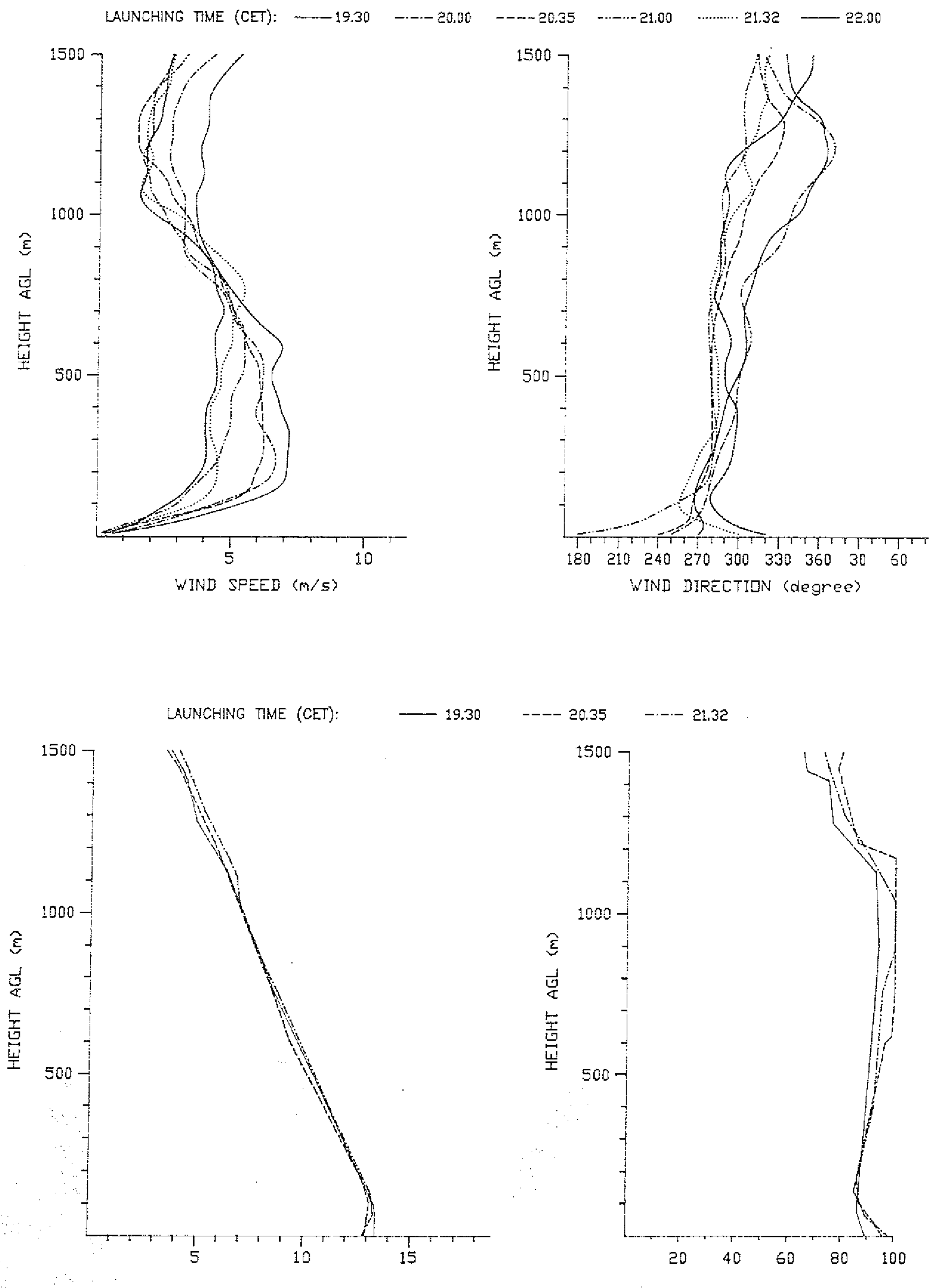


Fig. 5.5.2: Vertical profiles of wind (smoothed), temperature and relative humidity during the dispersion experiment at KFA, 23.09.1989

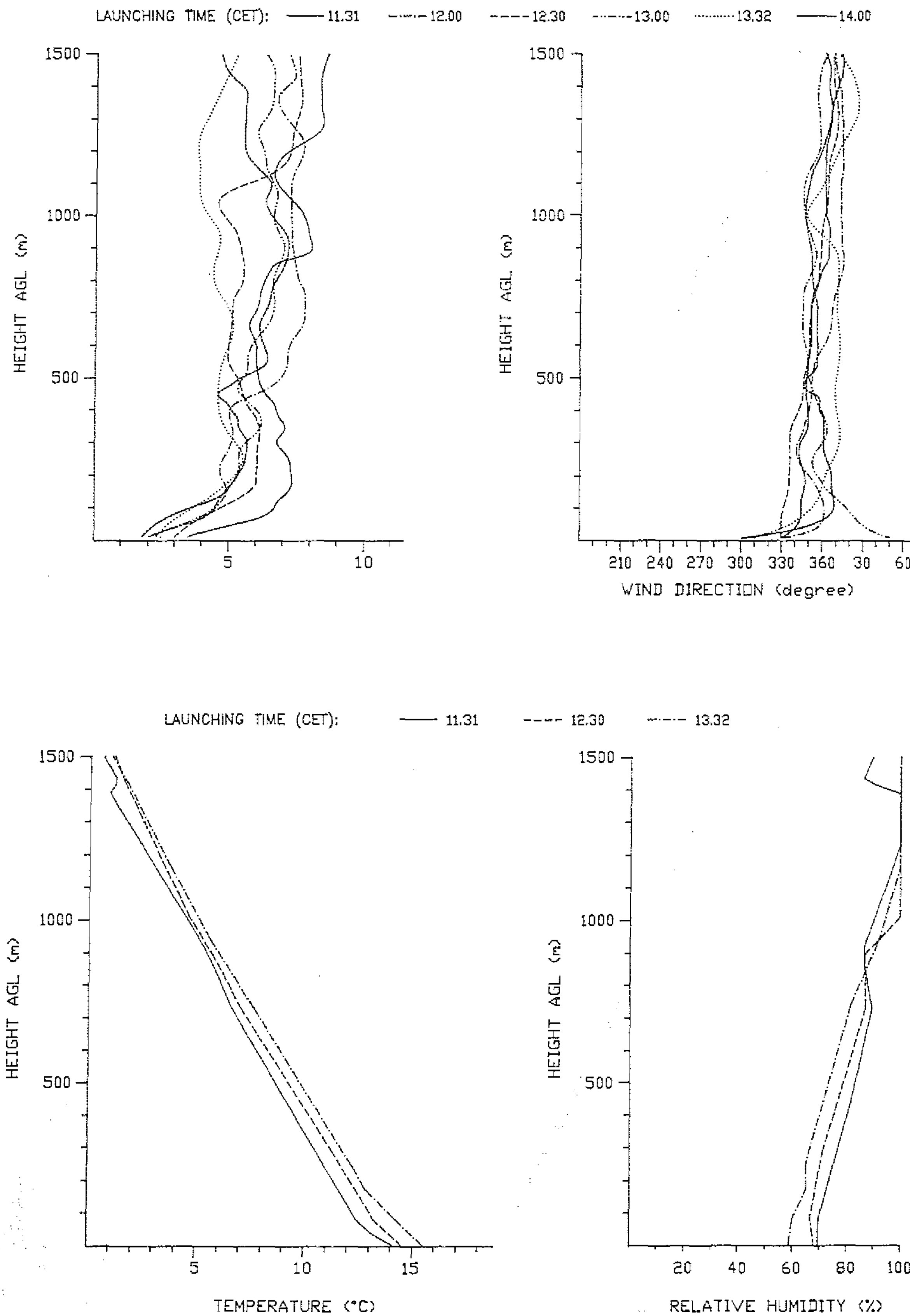


Fig. 5.5.3: Vertical profiles of wind (smoothed), temperature and relative humidity during the dispersion experiment at KFA, 27.09.1989

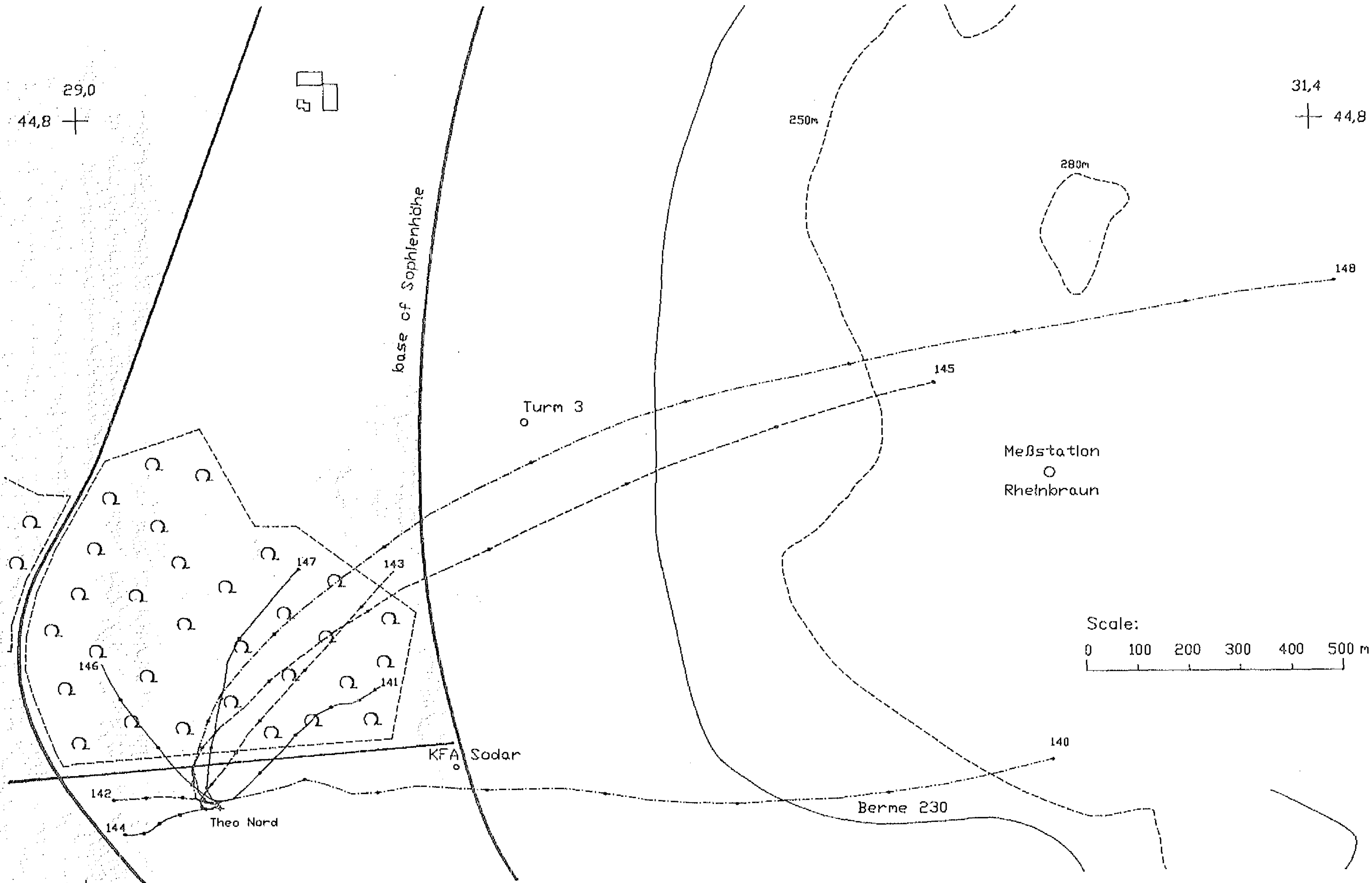


Fig. 5.5.4: Flight-track projection of pilot balloons to surface, 19.09.1989
(the points represent a time interval of one minute; for launch time see Tab. 5.5.3; the Gauß-Krüger coordinates are given in km at the corners)

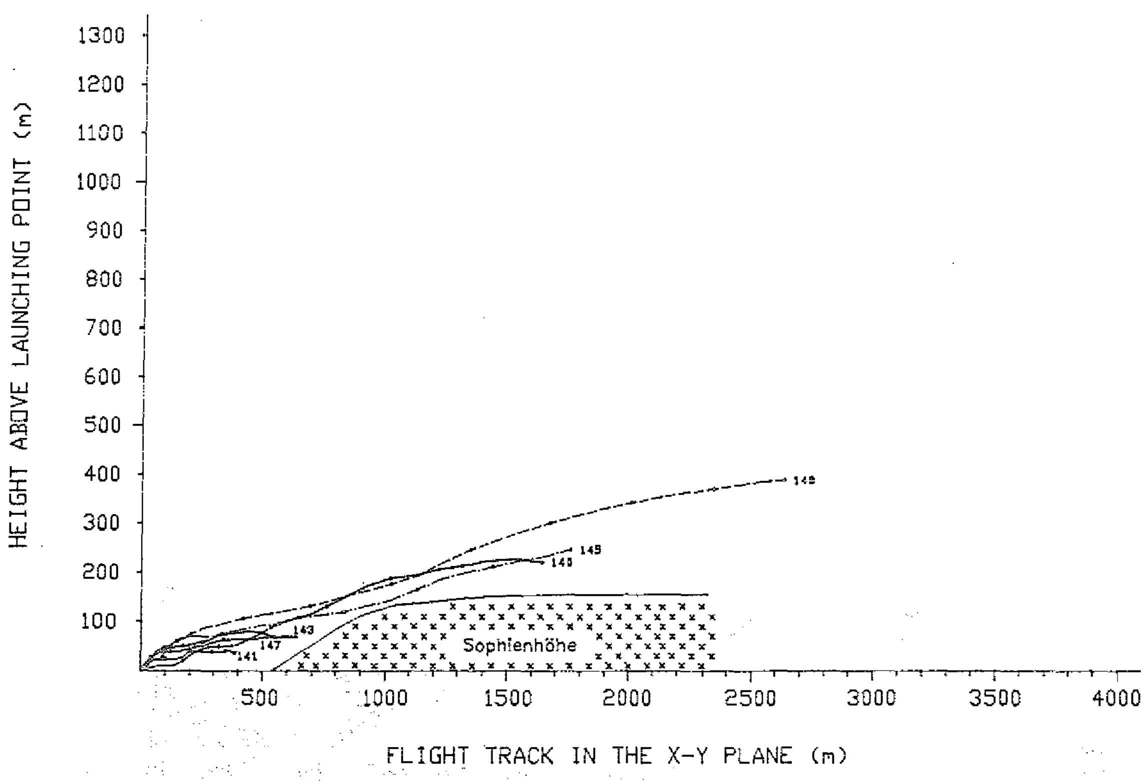


Fig. 5.5.5: Profiles of pilot-balloon ascents in the western part of the Sophienhöhe, 19.09.89 (Points represent a time interval of one minute, for launch time see Tab. 5.5.3)

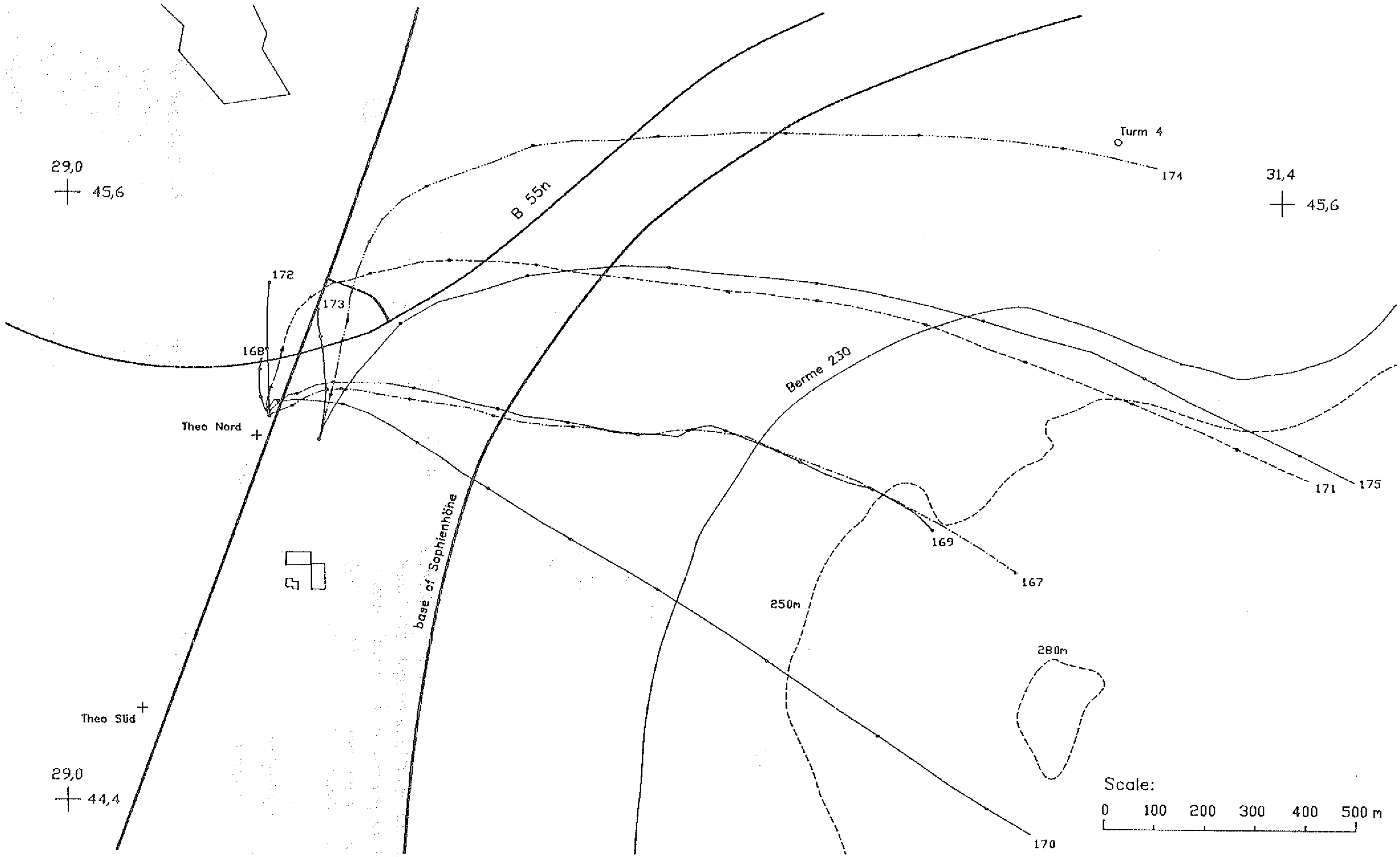


Fig. 5.5.6: Flight-track projection of pilot balloons to surface, 25.09.1989
(the points represent a time interval of one minute, for launch time see Tab. 5.5.3; the Gauß-Krüger coordinates are given in km at the corners)

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

W. Bahmann, J. Frank, G. Zeuner

Three Doppler-SODARs were installed at the base of Sophienhöhe by the groups TÜV Rheinland, TÜV Essen and KFA. The TÜV Rheinland SODAR and KFA SODAR were manufactured by REMTECH (France), the TÜV Essen SODAR was of type DS 100 distributed by the German firm Rosenhagen. A summary of the measuring principle and description of the instrumentation is given in the report of the third field experiment, see Zeuner and Heinemann (1990).

The Doppler-SODAR of TÜV Rheinland was situated at the point S1 (see Fig. 1.1) near to the northern slope of Sophienhöhe (Gauß- Krüger coordinates in m: 31940, 46185; height = 89 m above m. s. l.). Over a range of height from 40m to 420m in steps of 20m, height profiles of the following parameters were measured or derived from measurements:

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

The data were registrated as 10 min mean values. The routine for the determination of σ_θ is not good, therefore σ_θ data should not be used.

The system was in operation during 84% of the time. Between Sept. 22, 17:00 - 22:00 and Sept. 26, 7:00 to Sept. 28, 13:00 the power supply failed. Due to the measuring principle, higher measuring heights have lower system availability (Fig. 5.6.1); highest system availability of greater 90% of the time is found between heights of 60m - 120m.

The TÜV Essen SODAR was located at point S3 (see Fig. 1.1) near to the eastern slope of the hill (Gauß-Krüger coordinates in m: 32780, 43900; height = 97m above m. s. l.). Because the location was near the mining area, environmental noise could influence the measurements. The SODAR measured in 10min intervals over a height range from 40m to 500m (in steps of 20m) the following parameters:

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

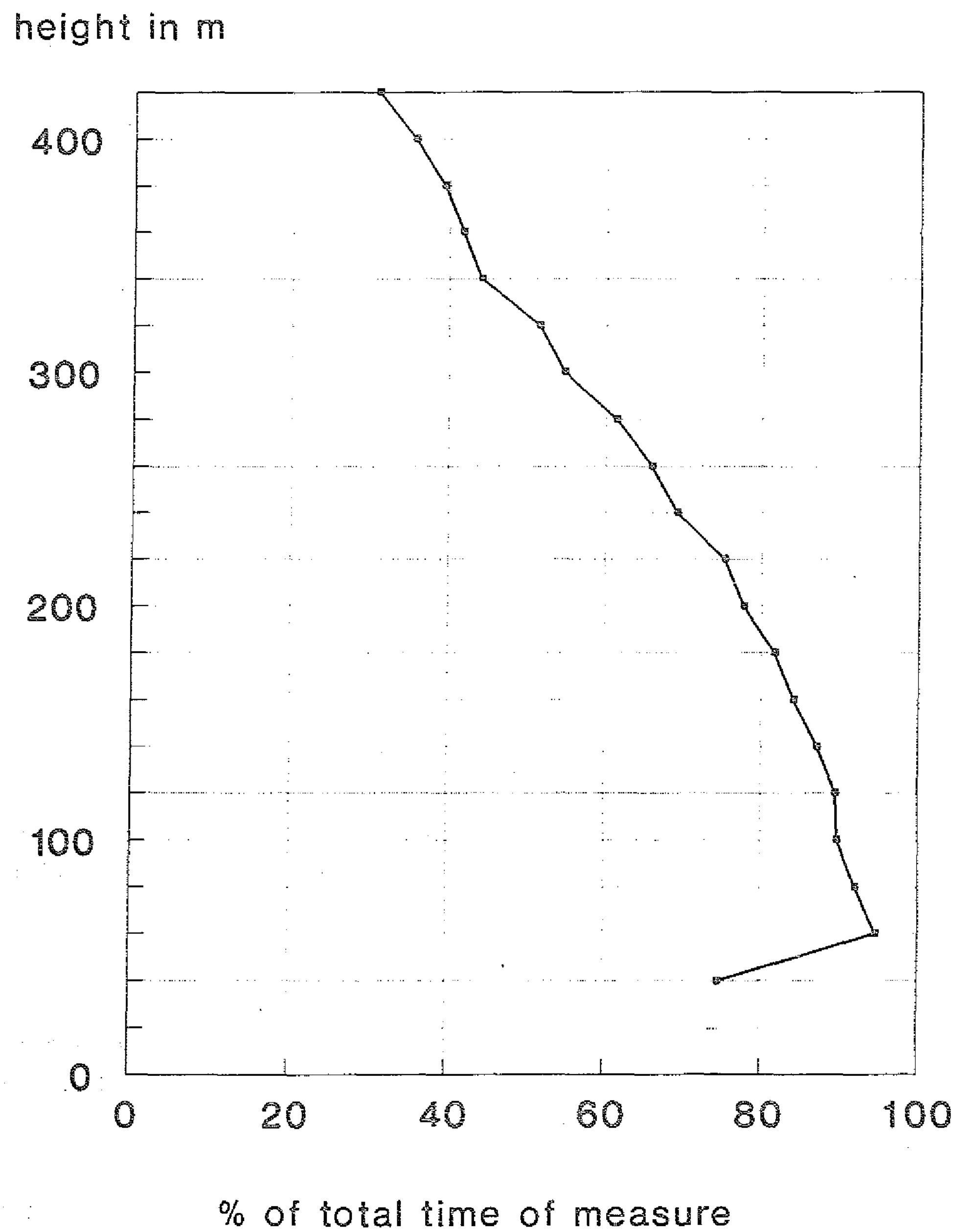


Fig. 5.6.1 : Availability of SODAR data (TÜV Rheinland) Sept 19 - 28, 1989

The system was operating during the whole campaign; data are available from Sept. 19, 16:00 to Sept. 28, 12:00.

As an example of the measurements the frequency distribution of wind direction at two heights (60m and 400m) are compared in Fig. 5.6.2. At the height 200m above hill top winds were coming frequently from west, northwest to northeast and southeast. Easterly and southwesterly wind directions were scarce. At the height of 60m where the hill influences the wind flow, the most frequent wind direction was westsouthwest; northerly and easterly winds were almost absent. The differences in the frequency distributions either result from the increase of frequency of calms, the ekman spiral or hill influence.

The KFA Doppler-SODAR was located at point S2 (see Fig. 1.1) at the western part of Sophienhöhe (Gauß - Krüger coordinates in m: 29725, 43540; height 105m above m. s. l.). Measurements in 10 min intervals of the following parameters were made between 60m and 420m height (in steps of 20m):

- horizontal and vertical wind speed
- wind direction
- echo intensity
- standard deviation of vertical wind speed σ_w, wind direction σ_θ and echo intensity
- dissipation rate (derived parameter)

Before the field campaign there were hardware problems with the SODAR, so no measurements were possible. The SODAR was repaired on the first day of the field experiment and could be started on Sept. 20 around noon. A new software was installed which gave a quite low data availability as was found out later. Moreover the generator for power supply failed during the campaign and the replaced generator was very noisy, so many measurements (from Sept. 23 - Sept. 27) were invalidated. This altogether resulted in a quite high rate of missing data.

The system was operating only during 30% of the time. Measurements are available (with lower availability of data compared to Fig. 5.6.1) for the periods: 1) Sept. 20, 12:00 - Sept. 21, 23:10, 2) Sept. 23, 16:00 - 23:00, 3) Sept. 25, 16:50 - 18:00 and 20:20 - 22:50, 4) Sept. 27, 10:00 - 17:40

The periods of wind measurements made on a 15m mast (Mast SODAR KFA, see chapter 5.1) are the same as for the SODAR.

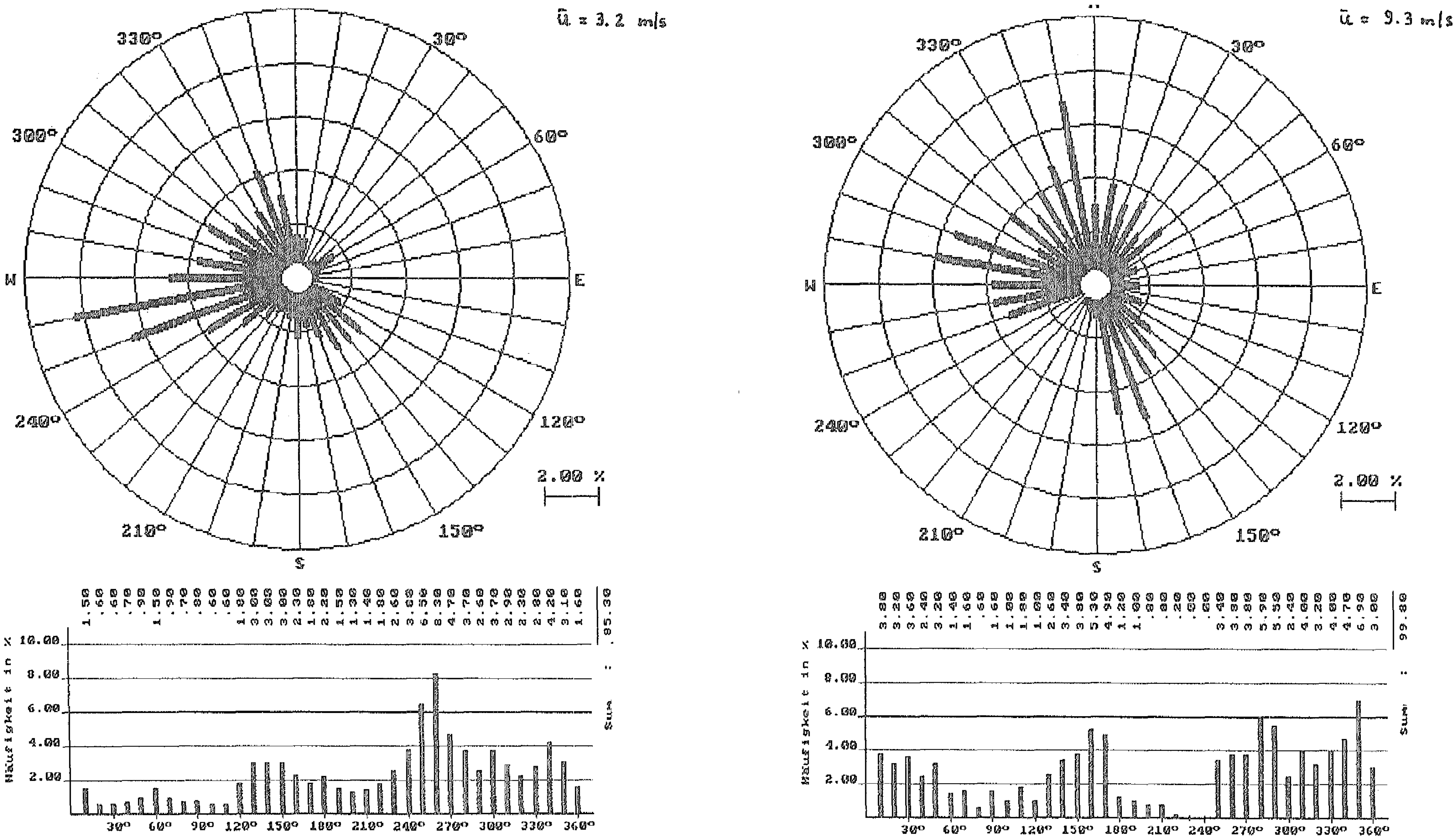


Fig. 5.6.2: Frequency distribution of wind direction at 60m (left) and 400m height (right)
a. g. l. at position of SODAR TÜV Essen (eastside of Sophienhöhe) for Sept 19 - Sept 28, 1989

5.7 Mobile van by KFA-group IPC

H. D. Narres

The mobile van of the Institute of Applied Physical Chemistry (IPC) 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). 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:

September 19, 10:10 hour - 21:50 hour (only wind direction)
September 20, 00:10 hour - 01:50 hour (only wind direction)
September 21, 08:40 hour - September 22, 15:10
September 23, 00:00 hour - 09:10 hour
September 24, 13:20 hour - September 24, 15:00 hour
September 25, 00:00 hour - September 28, 07:10 hour

Some technical problems with the computer system and a defect anemometer at the beginning were the cause for missing data.

5.8 Wind measurements fire-ladder KFA

G. Zeuner

During dispersion experiment IV.2, IV.4 and IV.5 the tracer was emitted from the top of a 30 m fire-ladder.At the top of the fire-ladder also wind measurements were carried out in order to have the important meteorological information at the emission point. Wind direction was measured with a wind vane (Thies). Starting speed of the vane is 0.5 m/s. Wind speed was measured with the cup anemometer LISA (Sikkelkow). Starting speed is 0.1 m/s. The data acquisition system is the same as described in chapter 5.1.2. Both parameters were scanned every 10 seconds and averaged over 10 minutes; also the standard deviation was calculated. The measurement results are summarized in the tables 5.8.1 - 5.8.3.; this data set is not included in the data bank.

The measurements during dispersion experiment IV.2 indicate the shift of wind direction from southeast before 20.00 h to south during tracer sampling (after 20.00 h), see table 5.8.1. This was the reason that the tracer plume passed by the northeastern part of the hill. For the evening of Sept. 25, northwersterly winds were predicted in advance of the dispersion experiment. Therefore an emission point northwest of Sophienhöhe was foreseen. Actually the wind turned from northwest over west to south in the layer near the surface including the emission height (table 5.8.2), so that again the plume passed by the hill. In the last dispersion experiment on Sept. 27, wind direction varied between 330° and 360° (table 5.8.3). Here wind direction was slightly more northerly than was expected before the start of the experiment.

Time (MEZ)	Wind speed (m/s)		Wind direction (deg)	
	Mean	Std.dev.	Mean	Std.dev.
18.50	5.9	0.7	135	7
19.00	6.3	0.6	138	8
19.10	6.4	0.7	139	6
19.20	6.4	0.7	142	8
19.30	6.6	0.8	145	8
19.40	6.3	0.7	146	6
19.50	5.5	0.8	146	7
20.00	4.5	0.8	147	8
20.10	2.9	0.6	160	13
20.20	2.8	0.5	178	13
20.30	2.8	0.3	198	9
20.40	3.2	0.3	180	8
20.50	2.7	0.2	176	7
21.00	2.1	0.2	195	5

Tab. 5.8.1: Wind measurements at the top of fire-ladder, during dispersion experiment IV.2 on Sept. 20, 1989

Time (MEZ)	Wind speed (m/s)		Wind direction (deg)	
	Mean	Std.dev.	Mean	Std.dev.
19.40	2.3	0.0	262	4
19.50	2.1	0.1	264	4
20.00	2.0	0.1	222	15
20.10	1.6	0.1	208	9
20.20	1.9	0.2	233	39
20.30	1.7	0.2	192	9
20.40	1.4	0.3	200	12
20.50	2.0	0.3	218	8
21.00	2.1	0.4	204	13
21.10	2.7	0.2	185	6
21.20	2.6	0.3	195	8
21.30	2.2	0.2	198	6

Tab. 5.8.2: Wind measurements at the top of fire-ladder, during dispersion experiment IV.4 on Sept. 25, 1989

Time (MEZ)	Wind speed (m/s)		Wind direction (deg)	
	Mean	Std.dev.	Mean	Std.dev.
12.00	4.2	0.6	341	9
12.10	4.9	1.1	331	13
12.20	4.6	0.7	347	11
12.30	4.8	0.7	331	10
12.40	4.0	0.6	333	7
12.50	3.0	0.5	357	21
13.00	3.8	0.8	345	21
13.00	2.6	0.9	348	14
13.20	4.6	0.6	359	20
13.30	5.0	0.6	359	25
13.40	4.3	0.4	353	27
13.50	3.4	0.4	338	12
14.00	3.2	0.5	344	15

Tab. 5.8.3: Wind measurements at the top of fire-ladder, during dispersion experiment IV.5 on Sept. 27, 1989

6. FIRST RESULTS AND DATA BANK

6.1 Dispersion experiments

G. Zeuner

6.1.1 Overview

Five 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 four experiment series were carried out during stable (diff. cat. E-F) and one experiment during 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)	
IV.1.1 19/09/89 IV.1.2 19/09/89 IV.1.3 19/09/89	E1 KFA-tower 50 m	20:00-20:30 20:30-21:00 21:00-21:30	234 218 223	1.2 1.9 2.7	1.0 1.5 2.1	F F F
IV.2.1 20/09/89 IV.2.2 20/09/89 IV.2.3 20/09/89	E5 fire-ladder 30 m	19:30-20:00 20:00-20:30 20:30-21:00	146* 179* 184*	5.4* 2.8* 2.7*	1.1 1.5 2.0	E E F
IV.3.1 23/09/89 IV.3.2 23/09/89 IV.3.3 23/09/89	E2 Water-tower 47 m	20:30-21:00 21:00-21:30 21:30-22:00	243 233 272	2.2 0.9 1.3	0.5 0.4 0.7	F F F
IV.4.1 25/09/89 IV.4.2 25/09/89	E3/1 fire-ladder 30 m	20:30-21:00 21:00-21:30	207* 193*	1.8* 2.5*	3.1 3.5	F F
IV.5.1 27/09/89 IV.5.2 27/09/89 IV.5.3 27/09/89	E3/2 fire-ladder 30 m	12:30-13:00 13:00-13:30 13:30-14:o0	345* 355* 345*	3.6* 4.1* 3.6*	-1.2 -1.5 -1.0	B A C
Note: * measurement at release point						

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 6 out of 15 dispersion experiments are illustrated as 3-dimensional plots in the following sub-chapters. Experiment No. IV.1 is described with some more details, using also data, given in chapter 6.2, for interpretation.

The 3D plots in chapter 6.1.2 - 6.1.6 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. 5000 ng/m^3, 1 cm blue line = ca. 25000 ng/m^3), where the concentrations for the experiment series No. 1-5 are scaled to the maximal concentration of 87700 ng/m^3 measured in exp. No. IV.1.2 and a constant emission rate of 1.3 ng/m^3 (single blue line on the right or left side of the figures). So the tracer concentrations can be directly compared among one another.

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 ($\leq$87 ng/m^3) or background.

6.1.2 Dispersion experiment 1

During the first dispersion experiment in the evening of September 19 the boundary layer was characterized by a strong inversion and a weak southwesterly flow approaching Sophienhöhe. This experiment carried out on the first day of the field campaign turned out to be a very successful one and therefore will be discussed here in more detail. The strong influence of the hill on air flow and concentration patterns can be well illustrated.

The wind conditions around Sophienhöhe during the experiment series between 20:00 h and 21:30 h is shown in Fig.6.1.1 - 6.1.3. The measurement results intentionally are illustrated in three separate figures, because the concentration distributions ot the three separate sampling intervals look quite different. At first sight the wind distributions around the hill look very similar for the three successive sampling periods. One can find strong wind shear at the emission point, wind deflection on the windward side and wind acceleration on the plateau and northern slope of the hill. The southwesterly flow approaching the hill was deflected to the south in the western part and to northwest in the southwestern part of Sophienhöhe. In the latter case wind speed almost vanished; this region is the so called "stagnation point". Looking to the three figures in more detail one can find slight modifications of the wind field in the course of the experiment which are important for the interpretation of the concentration distributions. First the dispersion conditions at the emission point are very important. The wind measurements at the height of 120 m indicate no significant change in wind direction; mean half hourly values were 250° - 240° in the three sampling intervals. Wind speed increased somewhat during the last sampling period (table 6.6.1). At 30 m level, 10m above the surrounding trees, the wind was generally very weak. Wind direction was shifting from 240° to 214° - 225° in the course of the experiment. At the emission height of 50 m wind speed was increasing from 1.2 m/s over 1.9 m/s to 2.7 m/s corresponding to wind directions of 238°, 214° and 223° in the three sampling periods. Turbulence was measured at the emission point with vector vane in 50 m height and sonic anemometers in 30 m, 50 m and 120 m height. The vertical wind fluctuations measured by vector vane and sonic anemometers (in brackets) were 3.9° (4.3°), 3.2° (2.7°),2.6° (2.7°); these values can be associated to diffusion category F. Such small wind fluctuations would let anticipate a small plume, but in fact a small plume was not observed. The sonic anemometer measurements in the height of 30 m show compared to 50 m much larger vertical and horizontal wind fluctuations. The wind direction fluctuations vary between 11° and 31° within the nine 10 - minute intervals between 20:00 h and 21:30 h (table 6.2.8). In the course of the experiment the inversion became stronger; the temperature gradient increased from 1.0 K/100 m to 2.1 K/100m.

On Sophienhöhe the southerly flow along the western slope slightly increased during the experiment. The measurements at the top of the hill (mast 5) show only little variations in wind direction and -speed. The measurements at two locations in the northern part of the hill (mast 4 and SODAR) indicate some differences. Whereas close to the northern slope air flow was from southwest to southsouthwest (mast 4), a little further eastward air flow had more a western component (SODAR TÜV Rheinland). Obviously air flow in the region of mast 4 still was influenced by the southern flow in the western part of the hill.

In Fig. 6.1.4 - 6.1.5a the tracer concentration distributions of the experiment serie IV.1.1 to IV.1.3 are illustrated. The measurements show very distinct concentration patterns for the three sampling periods. Any similarities to a Gaussian distribution are not found. In the first sampling period the tracer plume did not move aaccording to the dispersion direction (54°) measured in emission height but passed by the southern part of Sophienhöhe. There the higher concentrations were found in direction 80°. The absolute concentration maximum was measured in 400 m distance to the source in dispersion direction 60°; this short distance is not expected for diffusion category F. No fraction of the plume passed over the top of the hill. Behind Sophienhöhe the tracer plume turned back northward.

The result of tracer experiment IV.1.2, which gives the concentration distribution half an hour later than the experiment described above, shows a splitting of the plume in the middle and lower slope region of Sophienhöhe. While the larger part of the plume moved south around the hill, the smaller part was deflected to the north. Thus the slight wind shift in the surface layer to southsouthwest at the emission point has a considerable influence on the concentration distribution. In the upper slope region a splitting of the plume no more was observed. There in dispersion direction of 60° comparatively high concentrations were measured.

The concentration measurements in the last sampling period show a very complex distribution pattern with an extraordinary broad plume. The concentrations on the windward slope now are remarkable higher compared to the two previous ones. Especially it is noticable, that the plume came under influence of the southern flow in the western part of Sophienhöhe. A small fraction of the plume also reached the hill plateau which among other things could be explained by the increasing wind speed observed in this period. The flow around the hill also is recognized in the measurements on leeside. Hereby one should pay attention to the fact, that the tracer reaches this region in a later time.

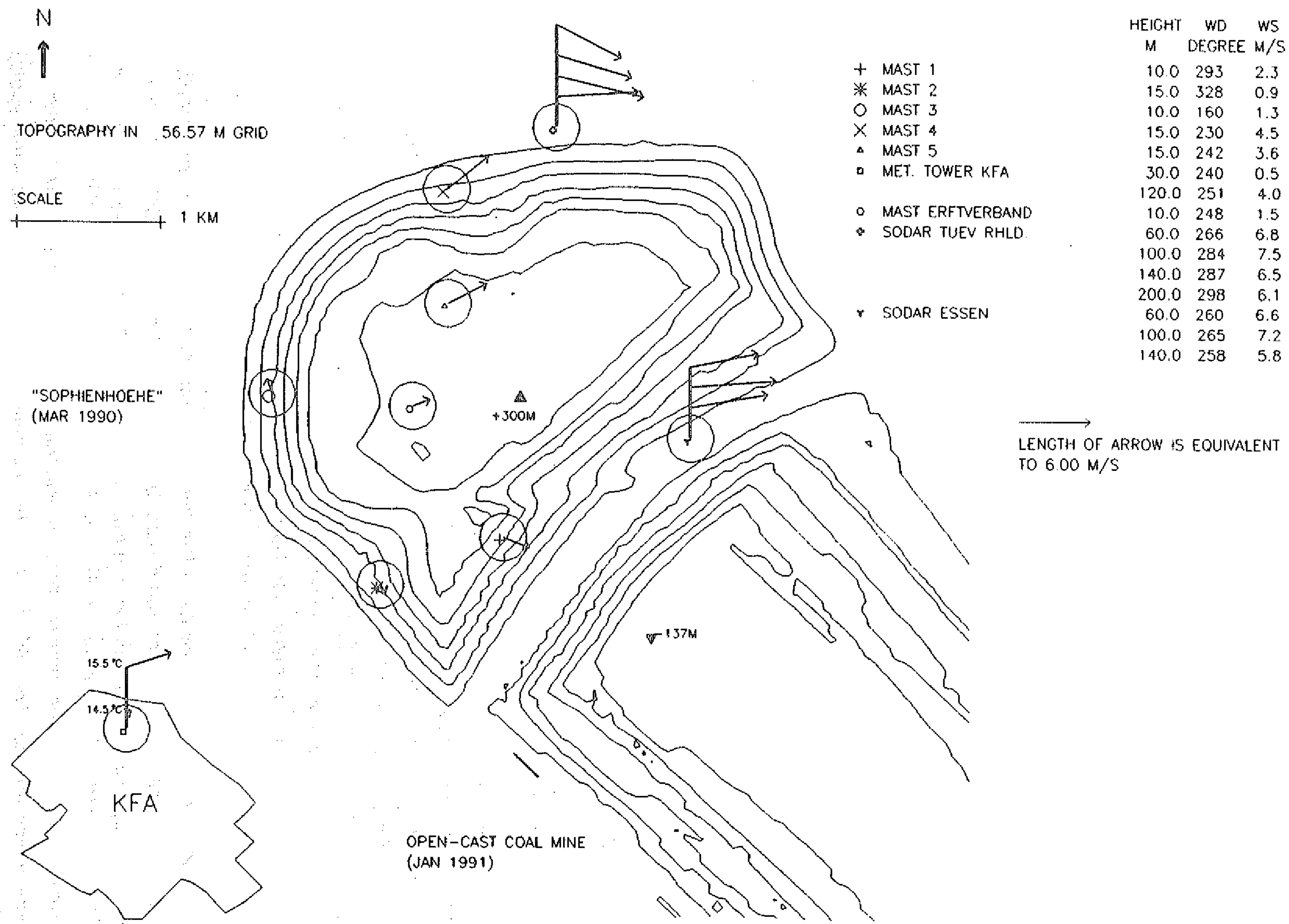


Fig. 6.1.1: Mean wind around Sophienhöhe on Sept. 19, 1989, 20:00-20:30

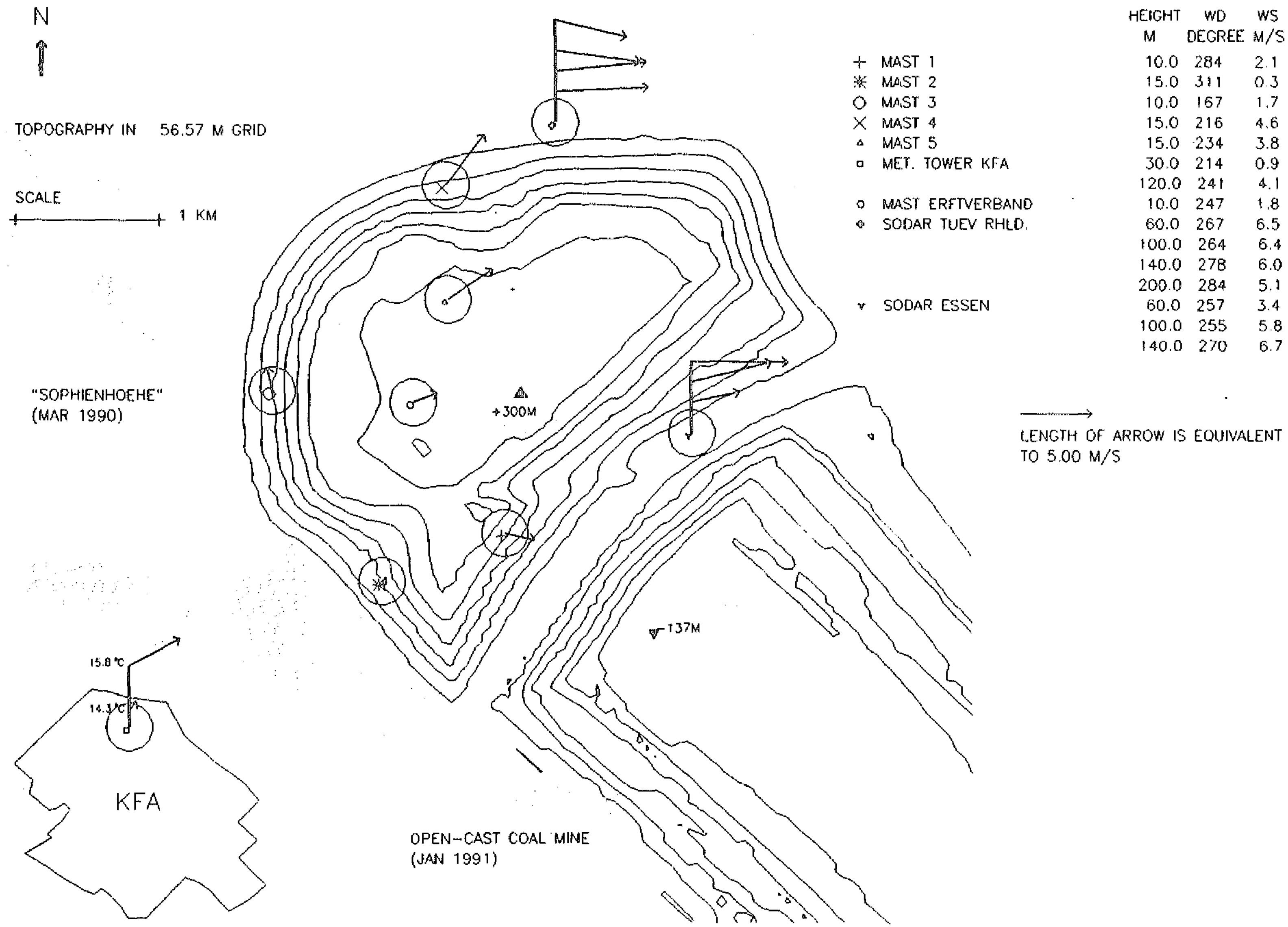


Fig. 6.1.2: Mean wind around Sophienhöhe on Sept. 19, 1989, 20:30-21:00

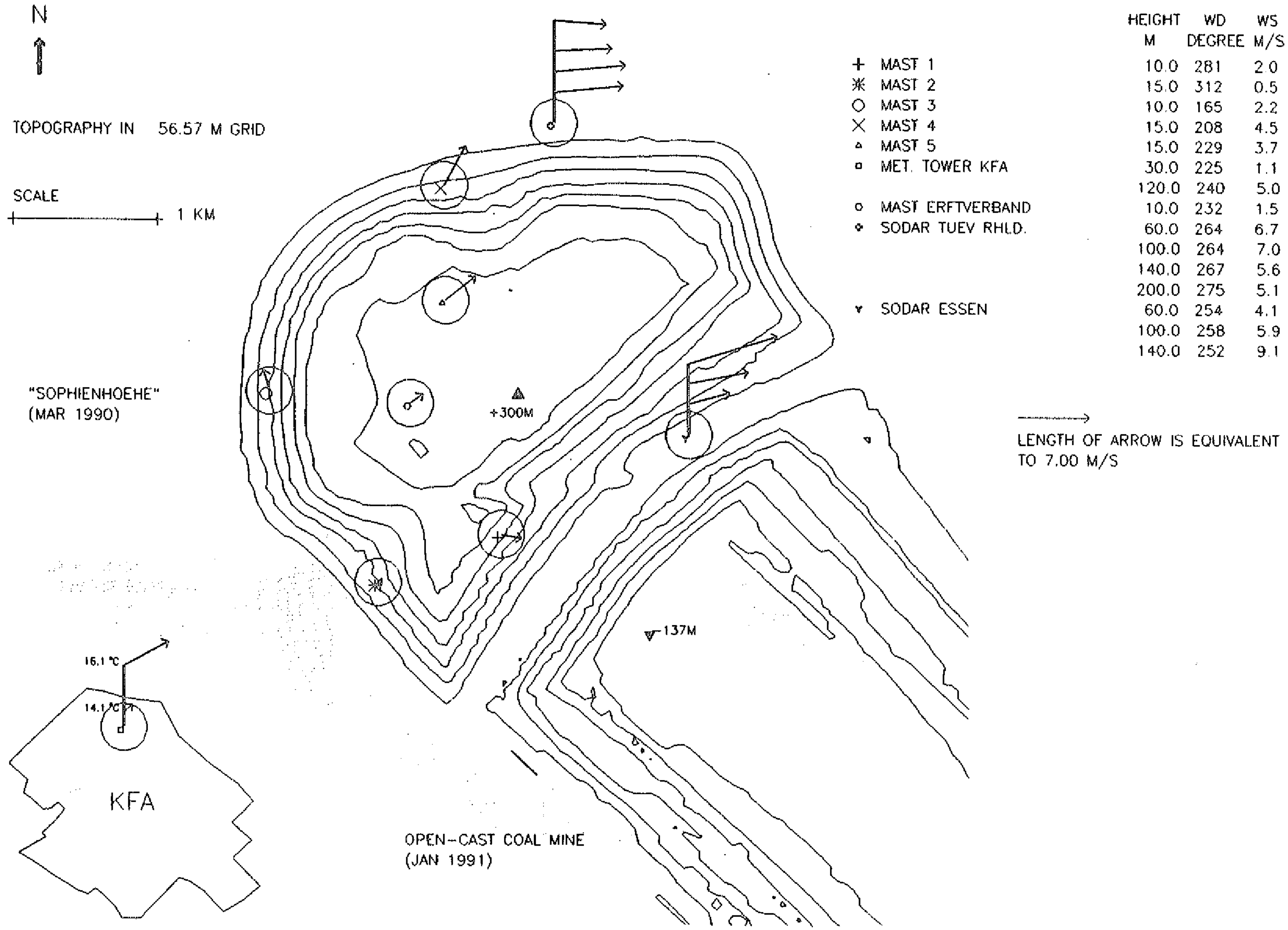


Fig. 6.1.3: Mean wind around Sophienhöhe on Sept. 19, 1989, 21:00-21:30

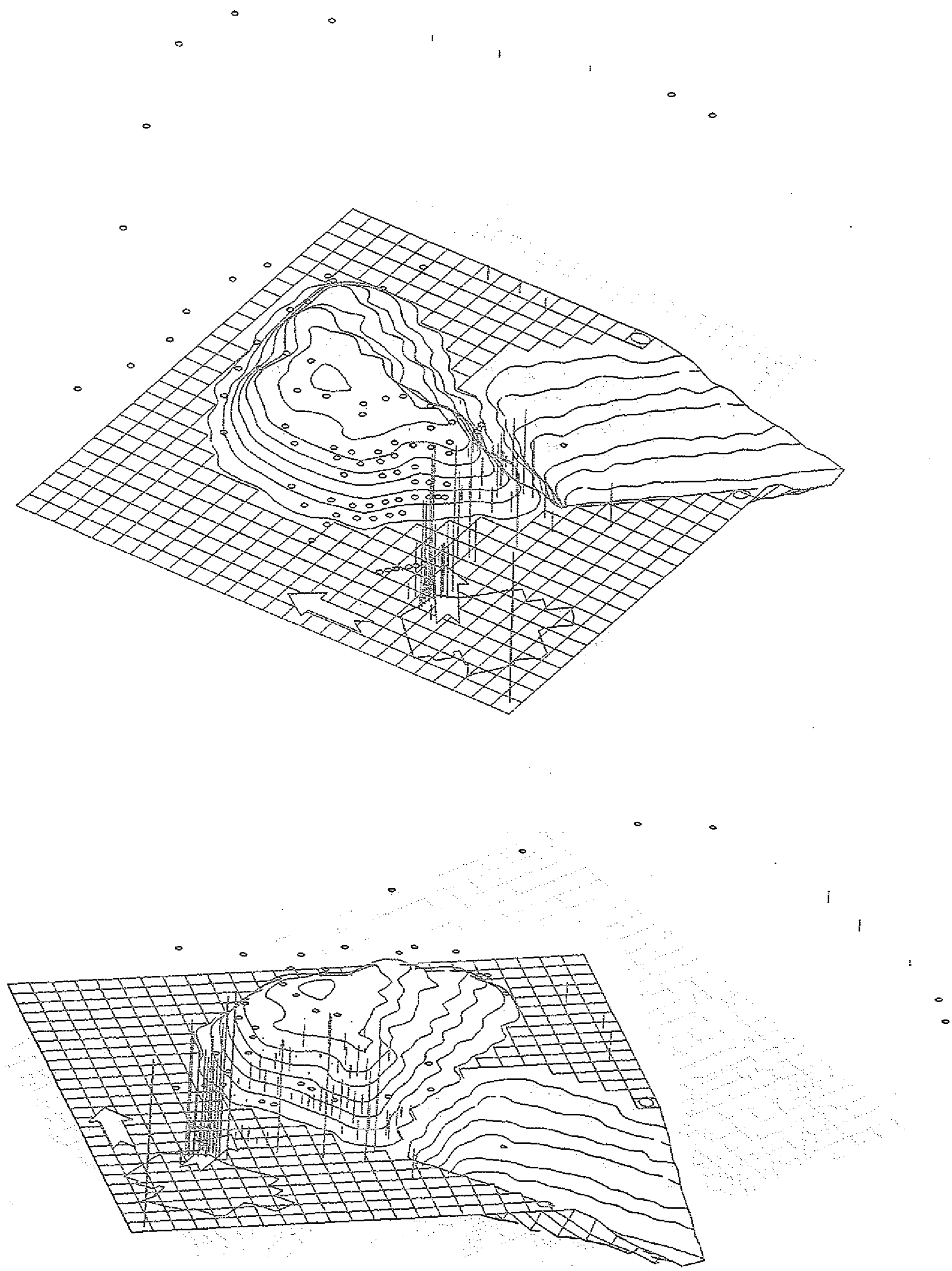


Fig. 6.1.4: Pattern of the concentration distribution for exp. IV-1-1, 20:00-20:30 (a) and exp. IV-1-2, 20:30-21:00 (b) on Sept. 19, 1989
Scale Conc. (single blue line): 87000 ng/m³
Blue circles: Low conc. or background
Red lines enlarged by a factor of 5 against blue lines

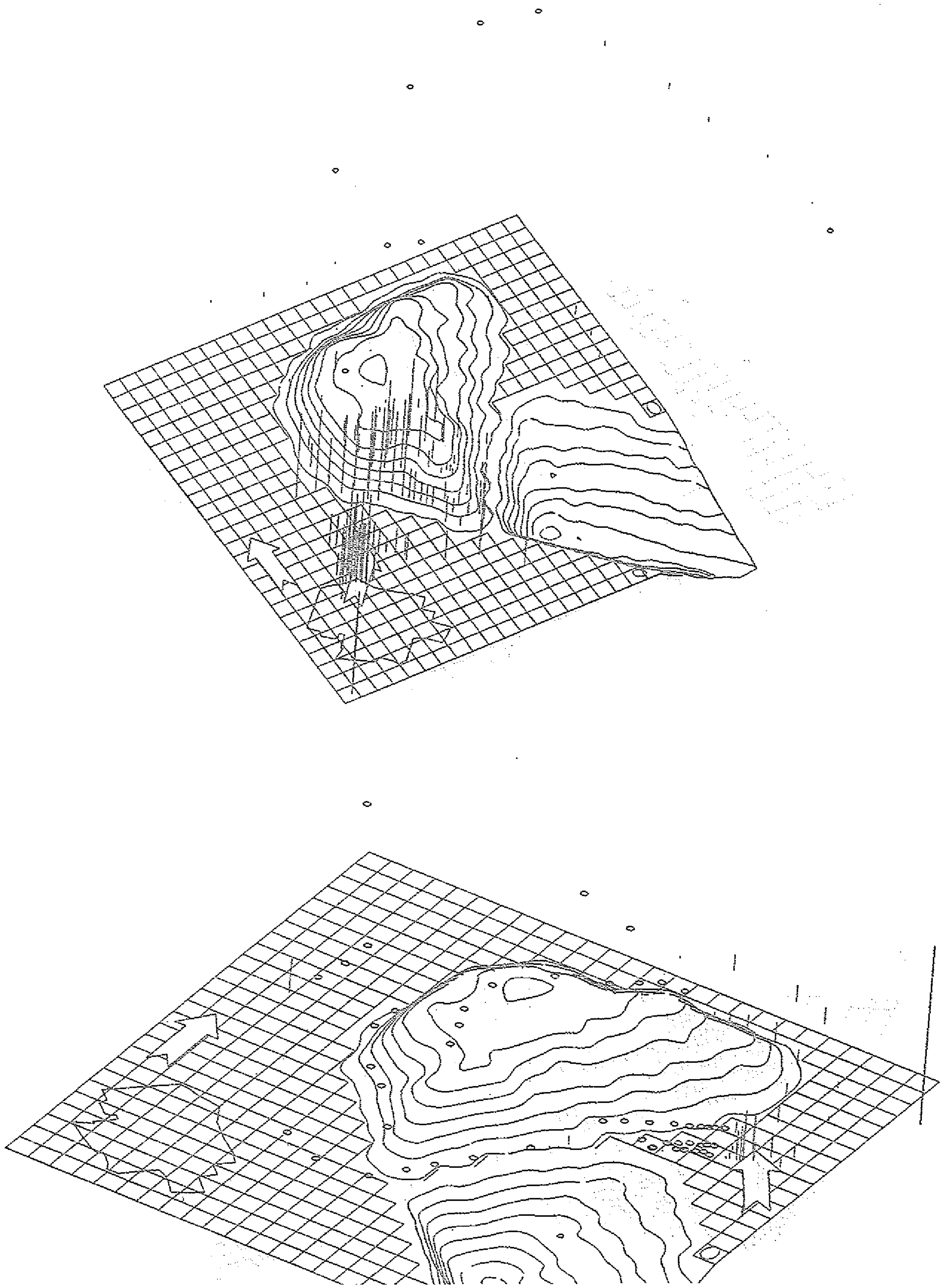


Fig. 6.1.5: Pattern of the concentration distribution for exp. IV-1-3, Sept. 19, 21:00-21:30 (a) and exp. IV-2-1, Sept. 20, 19:30-20:00 (b)
Scale Conc. (single blue line): 87000 ng/m³
Blue circles: Low conc. or background
Red lines enlarged by a factor of 5 against blue lines

6.1.3 Dispersion experiment 2

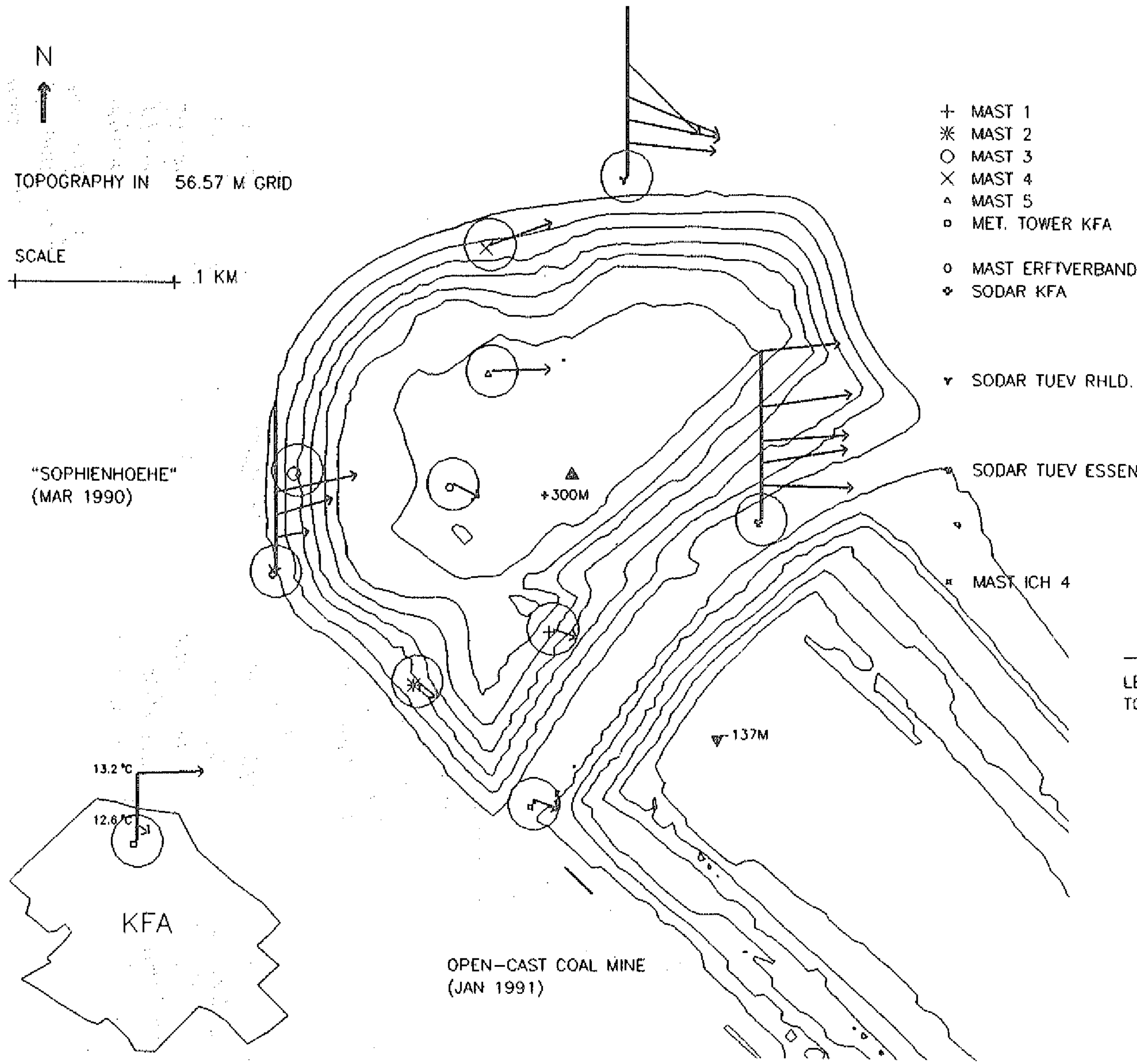
Considering the synoptic situation on September 20 the persistance of a southeasterly flow in our area was expected for a few days (chapter 3). Therefore an evening experiment under stable conditions was planned on Sept. 20 with tracer emission east of Sophienhöhe. The wind measurements at the KFA-tower at levels of 30 m and 50 m indicate a constant wind direction around 130° - 135° during the experiment between 19:30 - 21:00 h. An inversion with strength of 1.1K - 2.0K built-up. Wind speed at 30 m height dropped from 3.9 m/s to 1.9 m/s. So these measurements gave hope for a good experiment. In contrast on the other side of the hill wind conditions were different. With the start of tracer emission at 18:30 h a moderate strong wind blew out of direction 135° - 145° (see table 5.8.1). When tracer sampling started at 19:30 h, the measured wind direction was 146° at the top of the fire-ladder. After 20:00 h air flow was turning in southerly direction so that the largest part of the plume passed by the northeastern part of Sophienhöhe.

The result of the experiment in the first sampling period is given in Fig. 6.1.5b. In front of the hill the maximum concentration was found in dispersion direction 148° in a distance of 950 m to the emission point; so the plume axis agreed well with the measured wind direction. On and behind the northeastern part of the hill, higher concentrations with about a factor 2 lower than in front of the hill were found in direction 46° - 60° 3 - 4 km away from the source. The reason for the relative high concentration found in all sampling intervals at one position west of Sophienhöhe is not known.

6.1.4 Dispersion experiment 3

The third experiment was carried out in the evening of September 23, again under stable atmospheric conditions. A westerly flow was predicted in advance of the experiment so that the water tower was selected as emission point. The water tower is located 2.4 km north of the KFA-tower. The meteorological measurements at the KFA-tower are considered as representative also for the region of the water tower. Nethertheless deviations in the wind field at both places might occur especially in stable conditions. First the water tower has only half the distance to the hill compared to the KFA-tower; second the surface roughness at the water tower is characterized by agricultural land to the north and forest to the south. Moreover the water tower itself may influence the wind flow and especially the turbulence field.

In the height of 120 m at the KFA-tower a moderate and constant westerly air flow was observed during the experiment; similar wind conditions were found on the plateau of Sophienhöhe. In lower levels (KFA-tower) wind was generally weak in the range of 2.2 m/s - 0.9 m/s in 50 m height. Wind direction was not as stable as compared to upper levels but oscillated between southwest (first two sampling periods) and west/northwest (last sampling period). The wind measurements on Sophienhöhe show the deflection of the air flow on the windward side, i.e. the flow was going around the hill. In the western part of Sophienhöhe a southerly flow was observed between 20:30 - 21:30 h; in the last sampling period after 21:30 wind was calm in this region (Fig. 6.1.6).



	HEIGHT M	WD DEGREE	WS M/S
MAST 1	10.0	291	1.2
MAST 2	15.0	310	1.3
MAST 3	10.0	255	0.1
MAST 4	15.0	249	3.3
MAST 5	15.0	268	2.9
MET. TOWER KFA	30.0	307	0.8
	120.0	268	3.4
MAST ERFTVERBAND	10.0	299	1.5
SODAR KFA	15.0	15	0.5
	60.0	259	1.7
	100.0	253	3.0
	140.0	257	4.2
SODAR TUEV RHLD.	60.0	276	4.5
	100.0	282	4.8
	140.0	293	5.0
	200.0	316	5.2
SODAR TUEV ESSEN	60.0	271	4.6
	100.0	260	4.4
	140.0	266	4.4
	200.0	261	4.6
	300.0	264	4.0
MAST ICH 4	6.5	290	1.3

Fig. 6.1.6: Mean wind around Sophienhöhe on Sept. 23, 1989,21:30-22:00

The result of the tracer experiment in the third sampling interval is illustrated in Fig. 6.1.7a. Near the emission source, i.e. in a distance of 300 m - 400 m, two concentration maxima were found in direction 58° and 83°. On Sophienhöhe concentrations of comparable magnitude were observed in direction 55° - 60° (Berme 125) and 60° - 70° in the upper slope region (Berme 220 - 240). Thus it can be inferred that the plume is slightly deflected to the north in the lower slope area. Leeside of the hill still remarkable concentrations were found in direction 38° - 62° as seen from the emission point. The concentration patterns for the two previous sampling intervals show the plume slightly more displaced to the northwest part of the hill.

6.1.5 Dispersion experiment 4

The fourth dispersion experiment under stable conditions was conducted in the evening of September 25. Because winds from northwest were anticipated a few hours before the experiment the fire-ladder was used for tracer emission in the region northwest of the hill. Tracer emission started at 19:30 h, tracer sampling at 20:30 h. The wind measurements at the KFA-tower show the following development in the course of the experiment. From 19:30 h - 20:10 h wind came out of direction 280° - 310° in all measurement levels (30 m - 120 m). At 20:10 h wind direction began to turn in southwesterly/southerly directions (50 m height) respective southwesterly to southeasterly directions (30 m height). The prevailing wind direction in the height of 120 m was west. At the position of the fire-ladder wind direction shifted from west to southwest or south at 20:00 h (table 5.8.2). Because of this strong wind shear developing in the stable boundary layer the tracer plume dispersed north-/northeastward without reaching the Sophienhöhe.

6.1.6 Dispersion experiment 5

This dispersion experiment was carried out in the early afternoon when the boundary layer was unstable stratified. The tracer was emitted at a distance of about 200 m northwest of Sophienhöhe, because northwesterly winds were expected in the planning phase of the experiment. Actually winds from north to northwest were observed at the emission point (table 5.8.3) with only minor changes on Sophienhöhe. Average wind speed in emission height (30 m) was 3.6 - 4.1 m/s, in the height of 10 m 2.2m/s - 2.8 m/s in the western part and 3.0 - 3.6 m/s in the northern part and on top of Sophienhöhe.

The tracer axis was found south of the emission point with maxima close to the base of the hill. On Sophienhöhe the plume passed over the western slope; the location of the tracer axis slightly changed in the course of the experiment from 160°/ 170° to 180°. Highest concentrations were measured in the lower slope region. As an example the result of experiment IV.5.1 is shown in Fig. 6.1.7b.

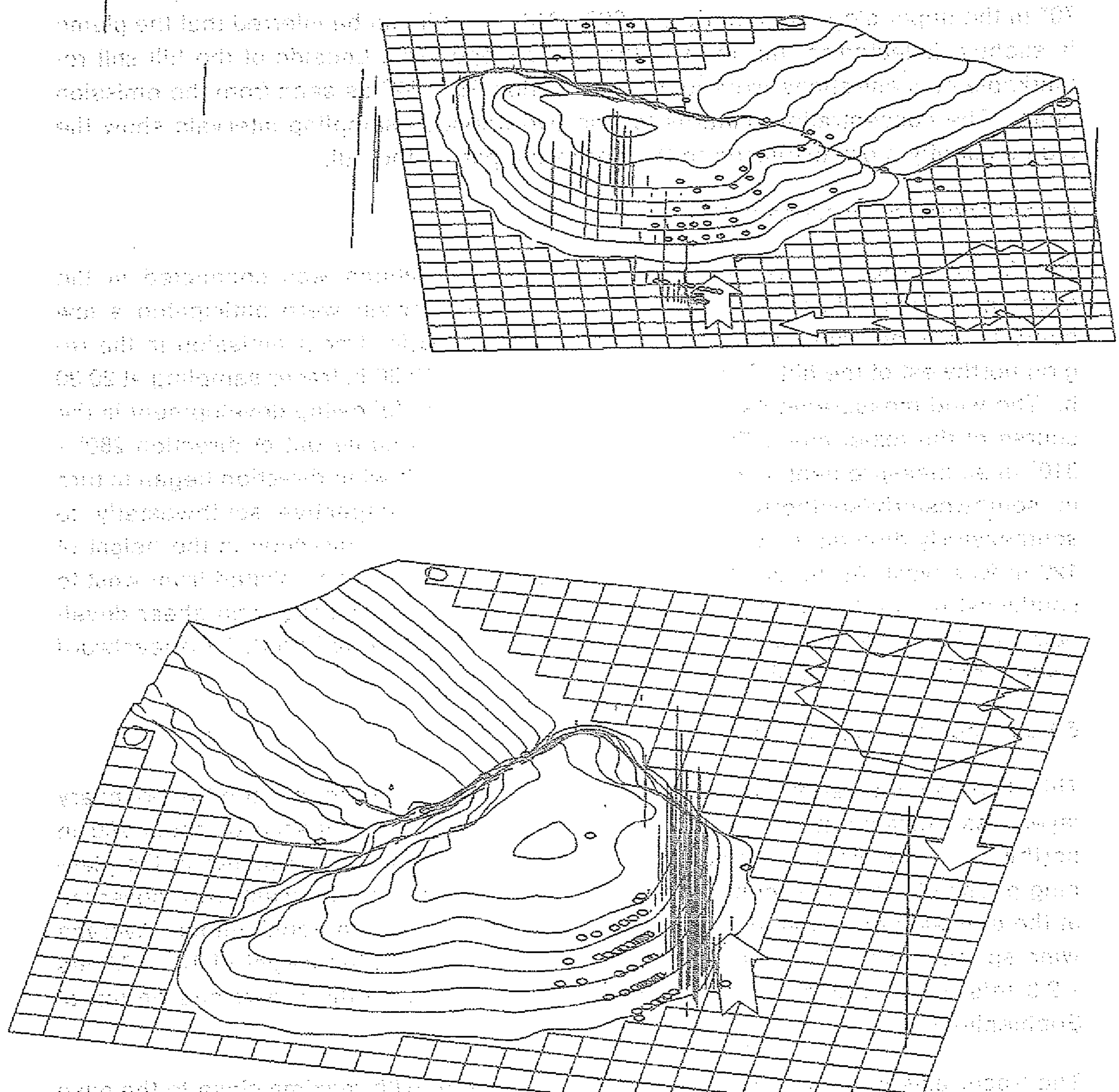


Fig. 6.1.7: Pattern of the concentration distribution for exp. IV-3-3, Sept. 23, 21:30-22:00 (a) and exp. IV-5-1, Sept. 27, 12:30-13:00 (b)
Scale Conc. (single blue line): 87000 ng/m³
Blue circles: Low conc. or background
Red lines enlarged by a factor of 5 against blue lines

6.2 Meteorological data set for a selected period

Ch. Plaga

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 19-24 belong to the ascents or flights of radio- and rawin sonde, tether sonde, pilotballoon and tetroon.

In order to illustrate the comprehensive meteorological measurements carried out during the field campaign examplary for each measurement system, the data of a selected period during dispersion experiment IV.1 are compiled in the following tables 6.2.1 - 6.2.24 (this selected data set is upon request available on flexible disk).

Data from the continuous measurements are shown for the time interval 19:00 - 21:30 hour (KFA-tower) or 20:00-21:30 hour (all other stations) on September 19,1989. 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 IV.1 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 IPC
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	Tether sonde RISØ
23	Tether sonde IGM Köln
24	tetroons
Note: Table 6.2.9 and 6.2.16 are missing, because no measurements were made.	

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, 19.09.89

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
19:10	0.1	0.2	0.7	1.5	2.5	3.4	3.7	4.1	255	245	244	14	8	4
19:20	0.1	0.2	0.5	1.4	2.5	3.3	3.7	4.1	252	242	244	11	6	4
19:30	0.1	0.1	0.3	0.8	1.8	2.7	3.2	3.7	241	229	240	20	10	5
19:40	0.0	0.0	0.3	0.9	1.9	2.9	3.4	3.9	242	233	242	10	7	3
19:50	0.1	0.0	0.2	1.1	2.1	2.9	3.5	4.1	236	228	241	5	4	3
20:00	0.1	0.0	0.3	0.9	2.0	2.9	3.4	4.0	247	228	244	13	5	4
20:10	0.1	0.0	0.1	0.4	1.3	2.3	2.9	3.7	250	237	252	13	8	4
20:20	0.0	0.0	0.1	0.4	1.1	2.1	3.2	4.1	243	239	254	8	7	4
20:30	0.0	0.0	0.3	0.6	1.1	2.3	3.2	4.1	226	225	246	5	7	3
20:40	0.0	0.0	0.4	0.9	1.7	2.6	3.2	3.9	214	222	242	12	4	3
20:50	0.0	0.0	0.3	0.8	1.6	2.4	3.1	3.9	200	208	239	14	6	2
21:00	0.0	0.0	0.4	1.1	2.5	3.6	4.2	4.4	227	224	242	12	6	2
21:10	0.0	0.0	0.3	1.1	2.8	4.4	4.8	4.7	229	226	242	10	5	3
21:20	0.0	0.0	0.4	1.3	3.1	4.3	4.9	5.3	232	225	244	13	5	4
21:30	0.0	0.0	0.5	0.9	2.7	4.4	4.6	5.0	213	218	235	18	6	2

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)
19:10	14.9		15.5				15.5	15.5	-62.79	0.00	0.00
19:20	14.5		15.3				15.4	15.4	-69.77	0.00	0.00
19:30	14.2		15.2				15.3	15.3	-69.77	0.00	0.00
19:40	13.9		15.0				15.2	15.2	-69.77	0.00	0.00
19:50	13.5		14.8				15.2	15.3	-69.77	0.00	0.00
20:00	13.5		14.6				15.1	15.2	-69.77	0.00	0.00
20:10	13.3		14.5				15.1	15.2	-69.77	0.00	0.00
20:20	12.9		14.6				15.3	15.6	-69.77	0.00	0.00
20:30	12.7		14.4				15.4	15.6	-69.77	0.00	0.00
20:40	12.6		14.3				15.3	15.5	-69.77	0.00	0.00
20:50	12.6		14.3				15.4	15.7	-48.84	0.00	0.00
21:00	12.8		14.3				15.7	16.1	-55.82	0.00	0.00
21:10	12.7		14.2				16.0	16.2	-69.77	0.00	0.00
21:20	12.6		14.1				15.8	16.2	-69.77	0.00	0.00
21:30	12.6		14.1				15.6	15.9	-69.77	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	HORIZ.FLUCT. IN (degree)	VERT.FLUCT. IN (degree)
19:10		94.5	90.8	87.2				89.5	1011.6	E	7.7	5.9
19:20		95.6	91.2	87.6				90.1	1011.6	F	7.2	5.1
19:30		97.5	91.9	88.6				90.9	1011.7	F	7.5	5.3
19:40		98.5	92.3	89.0				90.9	1011.9	F	7.8	5.1
19:50		98.6	92.6	90.4				91.3	1012.1	F	6.7	4.4
20:00		99.4	93.4	90.9				91.0	1012.3	F	5.9	3.8
20:10		99.6	93.4	90.9				90.7	1012.4	F	6.0	3.6
20:20		99.8	93.5	91.0				87.0	1012.4	F	5.1	3.8
20:30		99.9	93.5	90.8				85.0	1012.7	F	5.3	4.2
20:40		99.9	93.5	90.2				85.0	1012.9	F	5.4	3.7
20:50		99.9	93.5	89.9				84.4	1013.0	F	4.8	3.1
21:00		99.8	93.5	90.1				78.7	1013.0	F	5.4	2.7
21:10		99.9	93.6	91.3				77.2	1013.2	F	4.6	2.7
21:20		99.9	93.6	91.8				77.7	1013.2	F	3.6	2.4
21:30		99.9	93.5	92.0				83.4	1013.4	F	3.9	2.6

TABLE 6.2.2: METEOROLOGICAL MEASUREMENTS AT MAST RHEINBRAUN ON THE SOPHIENHOEHE, 19.09.89
(WIND DIRECTION AS ACTUAL VALUE AT THE END OF EVERY TEN MINUTE INTERVALL)

TIME	REL.HUMIDITY IN (%) 2m	WIND DIRECTION IN (degree) 10m	WIND SPEED IN (m/s) 2m	5m	10m	PRECIPITATION IN (mm/10min)
20:10	99.4	247	0.6	1.2	1.6	0.00
20:20	99.4	248	0.2	0.8	1.3	0.00
20:30	99.4	249	0.3	1.0	1.5	0.00
20:40	99.4	249	0.8	1.2	1.8	0.00
20:50	99.3	243	0.7	1.3	1.5	0.00
21:00	99.4	249	0.8	1.3	2.0	0.00
21:10	99.4	225	0.3	1.0	1.6	0.00
21:20	99.4	238	0.8	1.2	1.8	0.00
21:30	99.4	233	0.1	0.9	1.0	0.00

TABLE 6.2.3: METEOROLOGICAL MEASUREMENTS AT MAST 1 SOPHIENHOEHE, 19.09.89

TIME	WS5	WS10	SWS5	SWS10	WD	SWD	VWSD	-N	VWSU	+N	DT2	DT10	WT2	WT10
20:10	1.8	2.4	0.3	0.5	292	15	-0.37	40	0.16	7	13.8	13.9	13.0	12.8
20:20	1.9	2.4	0.4	0.5	295	14	-0.52	37	0.16	7	14.0	14.0	12.9	12.8
20:30	1.7	2.3	0.3	0.4	291	12	-0.31	34	0.16	12	14.0	14.1	12.8	12.7
20:40	1.8	2.3	0.3	0.4	286	12	-0.32	35	0.12	9	14.0	14.2	12.8	12.7
20:50	1.6	2.0	0.3	0.3	284	11	-0.25	33	0.09	8	13.9	14.1	12.7	12.6
21:00	1.7	2.0	0.4	0.4	281	12	-0.24	26	0.15	9	13.8	14.0	12.7	12.6
21:10	1.7	2.2	0.3	0.4	280	14	-0.31	31	0.12	9	13.8	13.9	12.6	12.5
21:20	1.7	2.1	0.5	0.5	280	14	-0.36	26	0.18	18	14.0	14.1	12.8	12.7
21:30	1.3	1.7	0.5	0.5	282	17	-0.33	24	0.14	11	13.8	14.1	12.8	12.7

TABLE 6.2.4: METEOROLOGICAL MEASUREMENTS AT MAST 2 SOPHIENHOEHE, 19.09.89

TIME	WS2	WS4	WS7.5	WS15	SWS2	SWS4	SWS7.5	SWS15	WD	SWD	VWSD	-N	VWSU	+N	DT2	DT13	WT2	WT13
20:10	0.0	0.5	0.8	1.0	0.0	0.2	0.4	0.3	329	18	-0.24	1	0.05	4	13.2	14.9	12.3	13.4
20:20	0.1	0.4	0.7	0.9	0.0	0.2	0.3	0.2	328	20	-0.09	4	0.07	7	13.4	15.0	12.4	13.4
20:30	0.1	0.2	0.4	0.6	0.0	0.2	0.3	0.3	327	29	0.00	0	0.12	10	13.4	15.1	12.3	13.3
20:40	0.1	0.2	0.3	0.4	0.0	0.1	0.1	0.3	337	26	-0.30	3	0.07	2	13.5	15.1	12.4	13.3
20:50	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0.2	311	33	-0.17	1	0.16	4	14.0	15.1	12.5	13.2
21:00	0.0	0.0	0.1	0.2	0.0	0.1	0.2	0.3	283	32	0.00	0	0.09	4	13.8	15.1	12.4	13.2
21:10	0.1	0.1	0.1	0.4	0.1	0.1	0.2	0.3	322	40	-0.12	3	0.05	3	13.8	15.0	12.4	13.1
21:20	0.2	0.4	0.5	0.6	0.2	0.3	0.4	0.4	316	43	-0.25	5	0.16	6	13.8	15.0	12.4	13.2
21:30	0.2	0.2	0.3	0.4	0.2	0.2	0.3	0.4	299	44	-0.85	6	0.14	7	14.3	15.0	12.7	13.3

TABLE 6.2.5: METEOROLOGICAL MEASUREMENTS AT MAST 3 SOPHIENHOEHE, 19.09.89

TIME	WS5	WS10	SWS5	SWS10	WD	SWD	VWSD	-N	VWSU	+N	DT2	DT10	WT2	WT10
20:10	1.2	1.5	0.3	0.4	168	19	-0.10	14	0.20	17	14.4	15.3	13.4	13.3
20:20	1.0	1.3	0.4	0.4	154	17	-0.23	11	0.10	9	14.6	15.4	13.3	13.2
20:30	0.8	1.2	0.3	0.3	158	19	-0.15	8	0.10	7	14.5	15.6	13.1	13.1
20:40	1.3	1.6	0.4	0.3	166	13	-0.18	12	0.11	10	14.3	15.4	13.1	13.1
20:50	1.2	1.6	0.3	0.3	170	15	-0.16	14	0.14	11	14.3	15.3	13.1	13.0
21:00	1.5	1.9	0.3	0.3	166	15	-0.21	17	0.12	12	14.6	15.4	13.1	13.0
21:10	1.8	2.2	0.4	0.5	158	12	-0.22	20	0.18	20	14.5	15.5	13.0	12.9
21:20	1.8	2.2	0.4	0.4	172	14	-0.23	21	0.19	22	14.4	15.2	13.1	13.0
21:30	1.6	2.1	0.5	0.6	166	15	-0.17	15	0.18	13	14.4	15.3	13.1	13.0

TABLE 6.2.6: METEOROLOGICAL MEASUREMENTS AT MAST 4 SOPHIENHOEHE, 19.09.89
MAST 4

TIME	WS2	WS4	WS7.5	WS15	SWS2	SWS4	SWS7.5	SWS15	WD	SWD	VWSD	-N	VWSU	+N	DT2	DT13	WT2	WT13
20:10	1.9	2.5	3.7	4.9	0.5	0.4	0.7	0.6	230	7	-0.18	11	0.30	31	14.6	15.7	13.3	13.1
20:20	1.6	2.2	3.2	4.6	0.4	0.4	0.6	0.6	234	7	-0.24	11	0.26	39	14.5	15.7	13.1	12.9
20:30	1.7	2.1	2.9	4.1	0.4	0.4	0.6	0.5	225	10	-0.09	9	0.31	25	14.4	15.6	13.0	12.9
20:40	2.1	2.4	3.1	4.7	0.4	0.4	0.4	0.4	218	7	-0.14	22	0.19	23	14.3	15.6	12.9	12.8
20:50	2.1	2.4	3.0	4.5	0.4	0.5	0.5	0.4	217	7	-0.13	14	0.22	28	14.4	15.7	12.9	12.8
21:00	2.3	2.4	3.3	4.5	0.3	0.4	0.5	0.3	212	6	-0.17	9	0.23	21	14.2	15.5	12.9	12.8
21:10	2.3	2.5	3.4	4.7	0.4	0.4	0.5	0.4	210	6	-0.16	24	0.17	20	14.3	15.6	12.8	12.7
21:20	2.4	2.3	3.3	4.5	0.4	0.5	0.5	0.4	206	9	-0.24	25	0.17	23	14.4	15.6	12.8	12.6
21:30	2.2	2.2	3.3	4.4	0.3	0.3	0.6	0.4	206	7	-0.20	21	0.23	19	14.4	15.7	12.9	12.7

TABLE 6.2.7: METEOROLOGICAL MEASUREMENTS AT MAST 5 SOPHIENHOEHE, 19.09.89

TIME	WS2	WS4	WS1	WS15	SWS2	SWS4	SWS1	SWS15	WD	SWD	VWSD	-N	VWSU	+N	DT2	DT15	WT2	WT15
20:10	2.2	2.5	1.8	3.8	0.3	0.3	0.3	0.4	241	7	-0.04	1			13.7	14.1	12.4	12.4
20:20	2.0	2.3	1.6	3.5	0.4	0.4	0.3	0.4	244	7					13.8	14.2	12.2	12.2
20:30	2.1	2.4	1.7	3.6	0.4	0.3	0.3	0.3	240	7			0.04	1	13.9	14.4	12.2	12.2
20:40	2.2	2.5	1.8	3.7	0.3	0.3	0.3	0.3	235	7					13.9	14.5	12.1	12.2
20:50	2.2	2.5	1.8	3.7	0.4	0.4	0.3	0.3	234	8					13.8	14.4	12.2	12.2
21:00	2.2	2.5	1.8	3.9	0.3	0.3	0.3	0.4	234	6					13.8	14.4	12.1	12.1
21:10	2.2	2.5	1.8	4.1	0.3	0.3	0.3	0.3	231	5					13.8	14.5	12.0	12.0
21:20	2.0	2.4	1.6	3.7	0.3	0.4	0.3	0.3	226	9					13.8	14.3	12.0	12.1
21:30	1.9	2.1	1.5	3.5	0.3	0.2	0.2	0.3	231	7					13.8	14.5	12.0	12.1

TIME	DT4	WT4	DT7.5	WT7.5	DT1	WT1	SOL	HTFL	RABAL	WS7.5	SWS7.5
20:10	13.5	12.4	14.2	12.8	13.5	12.1	0.9	-6.8	-63.6	3.0	0.4
20:20	13.6	12.3	14.3	12.6	13.5	12.0	0.6	-6.7	-63.5	2.7	0.4
20:30	13.7	12.2	14.4	12.6	13.6	11.9	0.6	-6.8	-63.6	2.8	0.4
20:40	13.8	12.2	14.5	12.6	13.6	11.9	0.6	-6.9	-63.4	3.0	0.3
20:50	13.6	12.2	14.3	12.6	13.5	11.9	0.7	-6.9	-61.3	2.9	0.4
21:00	13.6	12.1	14.3	12.5	13.5	11.8	0.8	-7.0	-61.4	3.0	0.4
21:10	13.6	12.0	14.4	12.4	13.5	11.7	0.6	-7.0	-63.9	3.1	0.4
21:20	13.6	12.1	14.2	12.4	13.4	11.7	0.6	-7.1	-65.4	2.8	0.4
21:30	13.6	12.1	14.4	12.5	13.4	11.7	0.6	-7.1	-63.4	2.6	0.3

TABLE 6.2.8: METEOROLOGICAL MEASUREMENTS AT SONIC KFA (30m,50m,120m) AND SONIC SOPHIENHOEHE (MAST 5, 9.5m) (WIND SPEED IN (m/s), WIND DIRECTION IN (degree)) 19.09.89

TIME	WIND SPEED				VERTICAL WIND SPEED				WIND DIRECTION				STANDARD DEVIATION WIND SPEED			
	9.5m	30m	50m	120m	9.5m	30m	50m	120m	9.5m	30m	50m	120m	9.5m	30m	50m	120m
20:10	3.42	0.50	1.68	4.30	0.05	-0.07	-0.13	-0.04	240	268	245	253	0.66	0.33	0.40	0.46
20:20	3.28	0.50	1.42	4.84	0.05	-0.06	-0.11	-0.04	239	237	252	256	0.67	0.27	0.30	0.43
20:30	3.48	0.69	1.42	4.80	0.02	-0.03	-0.12	-0.10	235	198	235	249	0.62	0.24	0.32	0.39
20:40	3.49	1.02	2.08	4.75	0.02	-0.07	-0.15	-0.10	232	202	230	244	0.62	0.29	0.31	0.38
20:50	3.57	0.88	2.07	4.74	0.03	-0.07	-0.12	-0.13	230	196	215	240	0.64	0.32	0.40	0.30
21: 0	3.54	1.19	2.86	5.16	0.04	-0.13	-0.19	-0.13	229	216	230	243	0.62	0.45	0.51	0.40
21:10	3.52	1.14	3.18	5.53	0.01	-0.09	-0.19	-0.13	223	223	233	242	0.73	0.47	0.45	0.30
21:20	3.25	1.44	3.68	6.20	0.02	-0.09	-0.20	-0.10	225	229	233	246	0.53	0.67	0.40	0.50
21:30	3.04	0.90	3.13	5.80	0.03	-0.08	-0.14	-0.12	219	203	226	236	0.64	0.46	0.46	0.30

TIME	STANDARD DEVIATION VERTICAL WIND SPEED				STANDARD DEVIATION WIND DIRECTION				STANDARD DEVIATION VERTICAL WIND DIRECTION				STANDARD DEVIATION HORIZONTAL WIND SPEED LONGITUDINAL			
	9.5m	30m	50m	120m	9.5m	30m	50m	120m	9.5m	30m	50m	120m	9.5m	30m	50m	120m
20:10	0.30	0.13	0.11	0.18	8	31	11	5	5	15	4	2	0.48	0.21	0.26	0.30
20:20	0.28	0.09	0.11	0.16	7	27	8	3	5	10	4	2	0.54	0.17	0.21	0.35
20:30	0.26	0.10	0.13	0.14	7	14	8	4	4	8	5	2	0.44	0.17	0.25	0.25
20:40	0.27	0.14	0.12	0.11	7	11	4	4	4	8	3	1	0.47	0.22	0.27	0.22
20:50	0.27	0.13	0.09	0.09	7	14	8	2	4	9	2	1	0.50	0.25	0.28	0.23
21: 0	0.27	0.18	0.16	0.10	7	15	7	3	4	9	3	1	0.46	0.32	0.38	0.32
21:10	0.29	0.19	0.14	0.05	10	18	5	2	5	10	3	1	0.47	0.33	0.37	0.19
21:20	0.23	0.21	0.15	0.05	6	19	5	4	4	8	2	1	0.38	0.55	0.24	0.22
21:30	0.24	0.23	0.19	0.05	10	22	5	2	5	14	3	1	0.38	0.32	0.36	0.22

TIME	STANDARD DEVIATION HORIZONTAL WIND SPEED LATERAL				FRICTION VELOCITY IN (m/s)				TEMPERATURE IN (degree C)				COVARIANCE w'T' IN [(m/s)(degree C)]			
	9.5m	30m	50m	120m	9.5m	30m	50m	120m	9.5m	30m	50m	120m	9.5m	30m	50m	120m
20:10	0.46	0.25	0.31	0.35	0.237	0.106	0.065	0.157	14.25				-0.022			
20:20	0.40	0.22	0.21	0.25	0.263	0.079	0.071	0.150	14.36				-0.024			
20:30	0.43	0.16	0.21	0.29	0.187	0.071	0.096	0.104	14.55				-0.013			
20:40	0.40	0.20	0.16	0.31	0.222	0.112	0.115	0.065	14.54				-0.015			
20:50	0.40	0.20	0.29	0.19	0.233	0.117	0.069	0.057	14.39				-0.023			
21: 0	0.42	0.32	0.34	0.24	0.237	0.128	0.136	0.131	14.39				-0.020			
21:10	0.56	0.35	0.25	0.23	0.215	0.158	0.149	0.033	14.46				-0.020			
21:20	0.37	0.38	0.32	0.45	0.196	0.195	0.121	0.061	14.38				-0.011			
21:30	0.51	0.34	0.29	0.20	0.174	0.169	0.145	0.050	14.36				-0.013			

TABLE 6.2.10 : METEOROLOGICAL MEASUREMENTS AT MAST 1 RISOE, 19.09.89 (ALL PARAMETERS AT 3.3 m)

TIME	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
20:10	2.26	199
20:20	2.28	191
20:30	2.48	189
20:40	2.41	199
20:50	2.41	205
21: 0	2.73	200
21:10	2.39	210
21:20	2.53	198
21:30	2.18	197

TABLE 6.2.11: METEOROLOGICAL MEASUREMENTS AT MAST 2 RISOE, 19.09.89 (ALL PARAMETERS AT 3.3 m)

TIME	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
20:10	3.06	190
20:20	2.83	189
20:30	2.67	189
20:40	2.79	193
20:50	2.88	197
21: 0	3.06	194
21:10	2.76	202
21:20	2.86	195
21:30	2.63	185

TABLE 6.2.12: METEOROLOGICAL MEASUREMENTS AT MAST 3 RISOE, 19.09.89 (ALL PARAMETERS AT 3.3 m)

TIME	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
20:10	3.13	217
20:20	2.89	232
20:30	2.57	220
20:40	2.72	217
20:50	2.80	216
21: 0	2.72	209
21:10	2.93	198
21:20	2.76	201
21:30	2.58	185

TABLE 6.2.13: METEOROLOGICAL MEASUREMENTS AT MAST 4 RISOE, 19.09.89 (ALL PARAMETERS AT 3.3 m)

TIME	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
20:10	2.30	243
20:20	2.36	239
20:30	1.89	222
20:40	1.90	230
20:50	1.61	219
21: 0	1.56	228
21:10	1.73	215
21:20	1.68	205
21:30	1.59	168

TABLE 6.2.14: METEOROLOGICAL MEASUREMENTS AT MAST IPC, 19.09.89 (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)
20:10		302		18
20:20		301		15
20:30		291		10
20:40		286		10
20:50		287		12
21: 0		291		11
21:10		293		11
21:20		289		11
21:30		287		8

TABLE 6.2.15: METEOROLOGICAL MEASUREMENTS AT SONIC RISOE, 19.09.89
(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)
20:10	2.04	235	15.4	-4.61	0.11	-0.01	-0.01
20:20	1.50	219	15.3	-5.63	0.07	-0.05	0.00
20:30	1.26	212	14.9	5.94	0.19	-0.20	0.10
20:40	1.85	248	15.0	12.10	1.46	-1.19	0.37
20:50	1.38	238	14.9	7.14	0.69	-0.85	0.33
21: 0	2.26	265	14.9	16.30	1.95	-0.92	0.20
21:10	1.59	235	15.0	0.43	0.50	-0.41	0.25
21:20	1.49	263	14.9	15.60	1.98	-0.97	0.25
21:30	0.57	231	14.8	2.54	0.37	-0.45	0.20

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
20:10	0.03	0.06	0.00	0.00	0.03	-0.01	0.03
20:20	0.02	0.15	0.00	-0.01	0.04	0.00	0.02
20:30	0.01	1.51	-0.53	-0.06	0.32	0.01	0.05
20:40	0.08	1.49	-0.35	-0.04	0.37	-0.01	0.10
20:50	0.02	1.46	-0.45	-0.01	0.34	0.00	0.03
21: 0	0.04	0.82	-0.10	-0.01	0.29	-0.01	0.02
21:10	0.07	0.78	-0.34	-0.01	0.28	0.00	0.05
21:20	0.04	0.90	-0.13	0.02	0.26	-0.01	0.04
21:30	0.03	1.01	-0.39	0.00	0.30	-0.01	0.08

TABLE 6.2.17: METEOROLOGICAL MEASUREMENTS AT SODAR KOELN, 19.09.89

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
20:10	6.8	7.0	8.5	9.2	8.4	8.0	7.4	7.8	7.5	6.6	6.5	6.5	6.8							
20:20	6.2	7.2	7.8	7.5	6.3	6.7	6.3	5.8	5.5	5.5	5.8	6.4					6.8		6.6	
20:30	5.6	6.1	7.3		5.8	4.9	5.6	5.2	5.4	4.6	4.7	5.0	4.3	5.6		5.3	5.2			
20:40	5.0	5.7	6.3	5.8	5.9	5.4	5.3	4.9	4.6	4.3										
20:50	6.5	6.7	7.0	7.3	6.7	6.6	5.4	5.6	5.4	5.5	5.0	4.7	4.6							
21: 0		6.9	7.4	6.0	5.9	5.9	5.8	5.7	5.4	5.2	5.3	5.4					4.8			
21:10			7.0	7.0	5.8	5.6	5.9	5.0	5.4	5.0	5.3	5.8	4.8							
21:20		6.1		7.1	5.5	5.5	5.4	5.3	4.7	5.0	4.9	4.7	5.4							
21:30		7.1		6.9	5.6	5.8	5.6	5.3	5.1	5.5	5.3	5.4	5.0	5.1	5.2	5.5	5.6	5.1	5.1	

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
20:10	-74	-69	-58	-74	-64	-66	-62	-74	-63	-52	-50	-49	-46							
20:20	-77	-68	-68	-65	-70	-63	-69	-60	-45	-50	-51	-36	-42			8	-37	-39	-30	
20:30	-63	-49	-39	-31	-43	-37	-44	-35	-37	-24	-31	-18	-23	-13		-28	-17			
20:40	-69	-82	-51	-59	-49	-42	-46	-37	-37	-37										
20:50	-74	-72	-69	-63	-67	-71	-62	-57	-54	-49	-48	-32	-59							
21: 0		-71	-80	-53	-53	-55	-51	-53	-47	-45	-22	-43	-35			-13	-26			
21:10			-73	-64	-61	-50	-37	-57	-47	-23	-46	-47	-34							
21:20		-70		-52	-48	-34	-39	-39	-32	-35	-25	-32	-36							
21:30		-77		-50	-60	-51	-44	-58	-48	-36	-51	-29	-36	-45	-42	-40	-42	-14	-47	

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
20:10	264	263	265	282	279	285	284	294	293	291	281	298	286							
20:20	269	269	280	286	283	291	297	297	296	304	308	313					314		315	
20:30	266	266	268		284	284	296	278	306	289	306	301	316	304		316	308			
20:40	274	273	264	263	274	276	284	286	289	290										
20:50	264	262	262	265	271	278	282	283	281	290	294	283	306							
21: 0		267	276	264	273	280	273	284	283	285	268	316					285			
21:10			264	266	271	266	263	275	274	262	286	295	288							
21:20		259		268	270	266	266	275	272	284	271	288	284							
21:30		269		259	271	270	273	286	278	276	288	268	280	300	296	295	291	287	289	

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
20:10	224	478	456	317	162	124	125	135	129	110	113	67	34							
20:20	242	480	541	207	137	149	149	165	161	212	131	75	50			31	67	46	50	
20:30	226	498	561	211	128	107	110	133	116	87	47	38	31	30		38	45			
20:40	231	380	293	156	117	120	102	120	121	103										
20:50	237	462	312	148	119	91	108	120	148	163	165	140	36							
21: 0		483	417	157	111	101	94	87	93	79	82	37	23			36	45			
21:10			305	181	157	112	104	77	93	117	87	71	46							
21:20		457		116	144	128	127	101	88	91	97	114	97							
21:30		445		102	111	107	94	81	79	69	60	53	57	92	83	82	76	43	49	

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
20:10	21	28	24	16	9	4	7	11	5	1	3	4	1							
20:20	1	14	13	9	11	11	16	16	10	15	20	27	47			1	13	14	12	
20:30	16	19	13	14	17	18	17	15	10	11	15	9	3	1		1	18			
20:40	19	14	6	5	10	13	17	16	6	1										
20:50	48	26	9	10	13	6	1	2	1	5	10	15	30							
21: 0		29	8	4	8	9	11	11	5	7	22	22	1			10	38			
21:10			1	5	3	3	12	22	21	18	22	16	5							
21:20		31		14	15	8	6	12	18	16	6	6	12							
21:30		25		1	1	3	10	13	6	7	14	7	5	13	13	9	11	13	22	

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
20:10		4		4	2	1	1	1	2	2	2	3								
20:20		4				2	2	3	4	5	2	1								
20:30		8	7		6	6	5	5	3	1	1	1								
20:40		1		6	6	4	3	4	3											
20:50		6		2	2	1	1	1	1	1	3	4								
21: 0		2		4	2	3	3	1	1	1										
21:10			1	2	3	2	1	1	1	1										
21:20		1		1	1	1	1	1												
21:30				7	4	4	2	2	3	1	1	1	1	1	1	1	2			

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
20:10	9	9	18	52	37	34	36	22	23	30	28	29	38							
20:20	13	14	18	33	43	34	39	45	38	38	49	43	39			66	48	40	39	
20:30	9	10	24	25	33	40	41	36	27	59	34	60	42	51		42	50			
20:40	10	18	58	40	41	43	27	35	40	64										
20:50	14	13	32	28	39	60	28	26	41	31	37	75	27							
21: 0		13	41	33	20	30	35	36	30	33	87	25	15			34	38			
21:10			30	38	34	40	37	41	36	27	26	36	42							
21:20		13		27	49	49	33	28	53	38	53	43	40							
21:30		13		62	59	59	49	41	40	51	37	35	55	39	34	33	57	25	52	

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
20:10		2		2	1	1	1	1	1	1	1	1								
20:20		2				1	2	2	2	2	2	2								
20:30		3	3		3	3	2	2	2	1	1	1								
20:40		1		2	2	2	2	2	2											
20:50		3		1	1	1	1	1	1	1	2	2								
21: 0		2		2	1	2	2	1	1	1										
21:10			1	1	1	1	1	2	1	1										
21:20		2		1	1	1	1	1												
21:30				2	2	2	2	2	1	1	1	1	1	1	1	1	1			

TABLE 6.2.17 CONTINUED

TIME	INVERSION MARKER (0 OR -1, -1=INVERSION) 40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m
20:10	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20:20	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0
20:30	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0
20:40	0	0	-1	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0
20:50	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0
21: 0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21:10	0	0	-1	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0
21:20	0	0	-1	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0
21:30	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0

TABLE 6.2.18: METEOROLOGICAL MEASUREMENTS AT SODAR ESSEN, 19.09.89

TIME	WIND SPEED IN (m/s) 40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
20:10	5.8	6.5	7.3	8.4	8.0	7.4	6.4		21.4	17.0				19.0					16.0		14.8		16.9	
20:20	5.7	6.7	6.6	6.7	6.2	4.9	5.3	8.8			16.1	12.2										13.3	19.1	
20:30	6.0	6.5	6.5	6.4	4.9	5.0							26.9								21.3			
20:40	3.0	4.4	5.2	6.3	5.7	6.1	8.6												25.4				18.2	
20:50	2.7	3.0	3.3	5.1	5.6	6.4	7.1	6.4		9.1		8.1							8.2					
21: 0	3.4	2.9	4.3	5.9	6.0	7.6	6.1	5.0	9.5		22.9											25.3	15.2	
21:10	3.5	5.0	5.2	6.6	10.2	8.8		17.2														2.7		
21:20	3.6	4.0	5.3	5.4					8.0				12.4								22.7			
21:30	2.7	3.4	4.7	5.8	5.2	9.4							34.5	23.8				34.5		26.8	25.9	27.0	25.2	34.5

TIME	VERTICAL WIND SPEED IN (cm/s) 40m	60m	80m	100m	120m	140m	160m	180m	200m	220m	240m	260m	280m	300m	320m	340m	360m	380m	400m	420m	440m	460m	480m	500m
20:10	10	14	5	-1	1	1																		
20:20	4	4	-2	0	-3	-5																		
20:30	19	9	9	10	13	21																		
20:40	87	94	121	104	133	121																		
20:50	26	71	104	123	140	141	131	124	97															
21: 0	43	88	90	99	131	98	127	118																
21:10	60	69	89	99		60	67																	
21:20	69	93	71	126																				
21:30	75	99	84	76	121																			

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
20:10	257	259	259	258	264	261	277		23	25				22					24		27		16	
20:20	261	262	265	270	267	256	277	314			28	177										21	309	
20:30	262	258	266	267	268	257							45								250			
20:40	287	265	274	269	282	279	252												52				162	
20:50	249	249	254	252	255	265	277	273		250		247							17					
21: 0	245	258	245	245	248	267	260	283	241		186											202	211	
21:10	252	252	252	265	248	257		249														254		
21:20	263	254	242	264					218				253								233			
21:30	258	255	250	245	246	247							27	69				27		46	50	45	53	27

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
20:10	721	709	645	634	747	556																		
20:20	800	835	828	709	449	435																		
20:30	819	867	737	504	387	397																		
20:40	738	997	984	725	654	521																		
20:50	717	915	1254	1431	1093	438	525	498	416															
21: 0	644	935	1160	995	419	390	300	422																
21:10	750	1057	900	236		301	353																	
21:20	998	1288	1488	307																				
21:30	1156	1629	1892	999	718																			

STANDARD DEVIATION VERTICAL WIND SPEED IN (cm/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
20:10	52	58	61	60	51	54																		
20:20	50	51	52	44	35	46																		
20:30	53	53	46	38	21	34																		
20:40	66	60	60	62	60	65																		
20:50	59	65	65	58	52	59	52	69	38															
21: 0	68	59	55	45	0	53	75	47																
21:10	60	58	48	0		64	67																	
21:20	65	67	56	81																				
21:30	66	63	60	77	93																			

TABLE 6.2.19: RAWIN-SONDE ESSEN, ASCENT NR. 5 19. 9.89
FROM 20: 3 TO 20:34 (HERE 24 MINUTES)

TIME ELAPSED SINCE START IN (min)	HEIGHT ABOVE GROUND IN (m)	WIND SPEED IN (m/s)	WIND DIRECTION IN (degree)
0.00	10	0.20	190
0.33	33	0.80	223
0.67	80	3.20	250
1.00	128	5.90	254
1.33	179	6.50	264
1.67	228	5.50	274
2.00	276	5.50	282
2.33	323	5.10	289
2.67	368	5.00	292
3.00	415	5.40	291
3.33	460	4.90	294
3.67	504	5.40	293
4.00	547	5.30	291
4.33	590	5.70	291
4.67	637	6.20	289
5.00	683	6.20	290
5.33	728	5.60	289
5.67	773	6.20	288
6.00	820	6.10	286
6.33	866	5.50	282
6.67	912	5.60	285
7.00	956	5.70	285
7.33	999	5.60	283
7.67	1043	6.20	289
8.00	1088	6.60	287
8.33	1135	7.20	286
8.67	1179	7.30	292
9.00	1224	6.10	288
9.33	1271	6.60	290
9.67	1319	6.60	288
10.00	1365	6.20	289
10.33	1410	5.60	287
10.67	1454	5.10	287
11.00	1498	5.60	280
11.50	1553	6.00	275
12.00	1619	6.80	271
12.50	1682	8.20	265
13.00	1745	8.30	259
13.50	1809	8.60	254
14.00	1880	9.30	257
14.50	1961	10.50	259
15.00	2044	12.00	258
15.50	2119	10.70	257
16.00	2186	10.40	254
16.50	2259	10.50	250
17.00	2337	10.80	251
17.50	2415	11.20	245
18.00	2493	12.50	239
18.50	2575	11.00	239
19.00	2654	10.10	240
19.50	2729	10.20	238
20.00	2803	10.50	234
20.50	2876	9.90	240
21.00	2946	10.20	232
21.50	3020	11.10	236
22.00	3103	12.00	234
22.50	3186	11.80	231
23.00	3258	11.80	236
24.00	3360	11.30	239

TABLE 6.2.20A: PILOTBALLOON ESSEN, ASCENT NR. 6 19.09.89
FROM 20:33 TO 20:42

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	29263	43474	108	0.00	0
0.33	29254	43469	115	0.52	60
0.67	29243	43472	122	0.57	108
1.00	29231	43481	126	0.72	128
1.33	29221	43494	129	0.81	142
1.67	29219	43511	130	0.89	172
2.00	29212	43528	133	0.90	157
2.33	29209	43533	139	0.29	154
2.67	29213	43544	150	0.59	199
3.00	29230	43580	167	1.98	205
3.33	29267	43620	176	2.71	223
3.67	29313	43657	175	2.98	231
4.00	29362	43709	181	3.55	224
4.33	29425	43756	190	3.94	233
4.67	29489	43803	198	3.97	234
5.00	29555	43843	202	3.87	239
5.33	29623	43887	216	4.04	237
5.67	29708	43926	220	4.66	246
6.00	29792	43963	226	4.61	246
6.33	29878	44006	238	4.79	244
6.67	29969	44047	250	4.97	245
7.00	30062	44090	271	5.12	245
7.33	30152	44129	293	4.90	247
7.67	30250	44163	306	5.22	251
8.00	30354	44200	318	5.50	250
8.33	30461	44234	331	5.62	253
8.67	30560	44262	339	5.13	254
9.00	30661	44285	353	5.18	257

TABLE 6.2.20B: PILOTBALLOON ESSEN, ASCENT NR. 8 19.09.89
FROM 21:11 TO 21:16

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	29263	43474	108	0.00	0
0.33	29249	43480	116	0.75	112
0.67	29241	43494	125	0.84	151
1.00	29238	43502	133	0.39	163
1.67	29244	43548	146	1.17	186
2.00	29248	43579	145	1.56	187
2.33	29256	43609	145	1.56	196
2.67	29261	43641	150	1.63	189
3.00	29269	43676	154	1.76	194
3.33	29278	43709	157	1.74	194
3.67	29282	43746	164	1.83	187
4.00	29305	43791	170	2.54	206
4.33	29344	43837	171	2.99	220
4.67	29380	43880	170	2.82	220
5.00	29421	43925	176	3.07	222

TABLE 6.2.21: RADIOSONDE ESSEN, ASCENT NR. 2 19. 9.89
FROM 20: 3 TO 20:28

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	14.2	13.9	97	1013
0.25	35	15.0	13.8	88	1009
0.60	86	14.9	13.5	86	1003
0.77	111	15.3	13.2	79	1000
0.98	145	15.9	13.0	72	996
2.20	326	15.3	12.1	69	975
3.68	528	13.7	10.9	72	952
4.96	698	12.0	10.9	88	933
5.50	770	11.6	10.2	85	925
6.60	916	10.5	9.0	83	909
7.75	1073	9.3	8.7	93	892
8.55	1195	8.4	8.0	95	879
10.00	1385	7.1	7.0	99	859
10.70	1472	6.8	6.7	99	850
14.15	1938	5.1	3.2	76	803
17.10	2407	2.1	1.1	86	758
17.50	2471	2.5	0.5	73	752
19.05	2711	1.2	-0.5	76	730
21.40	3047	-1.5	-2.4	86	700
22.65	3231	-2.8	-3.2	93	684
24.65	3513	-5.0	-6.5	74	660

TABLE 6.2.22: TETHER SONDE RISOE, ASCENT NR. 1 19.09.89
FROM 19:22 TO 21: 7 (BEGINNING OF ASCENT, 21 MINUTES)

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)
0.25	0	2.86	275	15.7	14.4	1011
0.38	0	3.60	209	15.7	14.4	1011
0.56	3	3.74	235	15.9	14.4	1011
0.75	6	3.44	230	15.9	14.4	1010
0.94	11	4.07	240	15.9	14.4	1010
1.13	11	4.21	246	15.9	14.3	1010
1.25	20	4.10	237	15.9	14.4	1009
1.44	17	4.23	220	15.9	14.3	1009
1.63	21	4.43	248	16.0	14.3	1009
1.81	23	4.55	234	16.0	14.4	1008
1.94	26	4.85	239	16.0	14.3	1008
2.13	28	4.79	241	16.0	14.3	1008
2.31	32	4.91	237	16.1	14.3	1007
2.50	34	4.82	240	16.0	14.3	1007
2.63	38	4.76	227	16.0	14.3	1007
2.81	40	4.90	242	16.0	14.3	1006
3.00	43	4.98	241	16.0	14.3	1006
3.19	48	5.27	239	15.9	14.2	1005
3.31	52	5.22	239	16.0	14.2	1005
3.50	50	5.10	222	15.9	14.2	1005
3.69	55	5.45	229	15.9	14.2	1005
3.88	59	5.63	236	15.9	14.2	1004
4.06	61	5.74	232	15.9	14.1	1004
4.19	63	6.02	236	15.9	14.1	1004
4.38	64	6.08	220	15.9	14.1	1003
4.56	64	5.73	233	15.8	14.1	1003
4.75	67	5.70	237	15.8	14.1	1003
4.88	68	6.16	238	15.8	14.1	1003
5.06	70	6.09	244	15.8	14.0	1003
5.25	75	5.80	232	15.8	14.0	1002
5.38	73	6.14	238	15.8	14.0	1002
5.56	73	6.45	242	15.8	13.9	1002
5.75	76	5.67	238	15.8	14.0	1002
5.94	79	6.11	236	15.8	14.0	1002
6.13	79	6.17	239	15.8	13.9	1002
6.25	83	6.44	242	15.8	13.9	1001
6.44	82	6.49	235	15.9	13.9	1001
6.63	87	6.59	238	15.9	13.9	1001
6.81	87	6.39	237	15.9	13.9	1001
6.94	87	6.10	235	15.9	13.8	1001
7.13	92	6.09	237	15.9	13.9	1000
7.31	92	6.18	240	15.8	13.8	1000
7.50	96	6.37	238	15.9	13.8	1000
7.63	95	6.28	240	15.8	13.7	1000
7.81	100	6.34	240	15.9	13.8	999
8.00	101	6.23	241	15.9	13.7	999
8.19	102	6.16	241	16.0	13.7	999
8.31	101	6.28	241	15.9	13.7	999
8.50	106	6.41	244	15.9	13.6	999
8.69	105	6.33	242	15.8	13.6	999
8.88	109	6.40	240	15.9	13.6	998
9.06	109	6.21	244	15.9	13.6	998
9.19	112	6.28	242	15.9	13.6	998
9.38	114	6.34	243	15.9	13.6	998
9.56	117	6.32	240	15.9	13.6	997
9.75	119	6.44	243	15.9	13.6	997
9.88	122	6.44	243	15.8	13.5	997
10.06	123	6.44	243	15.9	13.5	997

TABLE 6.2.22 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)
10.25	124	6.45	245	15.9	13.5	996
10.38	125	6.47	245	15.9	13.5	996
10.56	126	6.39	244	15.9	13.5	996
10.75	128	6.33	245	15.9	13.4	996
10.94	132	6.28	245	15.9	13.4	995
11.13	132	6.40	244	15.9	13.4	996
11.25	133	6.46	244	15.9	13.5	995
11.44	135	6.30	244	15.9	13.4	995
11.63	138	6.29	245	15.9	13.4	995
11.81	138	6.26	245	16.0	13.4	995
11.94	142	6.64	249	15.9	13.4	994
12.13	143	6.28	245	15.9	13.4	994
12.31	145	6.27	245	15.9	13.4	994
12.50	150	6.03	247	15.9	13.4	993
12.63	150	6.32	246	16.0	13.4	993
12.81	151	6.52	248	16.0	13.4	993
13.00	154	6.38	247	16.0	13.3	993
13.19	153	6.07	246	16.0	13.3	993
13.31	156	6.23	244	16.0	13.2	993
13.50	161	6.44	253	16.1	13.2	992
13.69	161	6.17	249	16.0	13.2	992
13.88	162	6.24	251	16.0	13.2	992
14.06	166	6.32	251	16.0	13.2	991
14.19	170	6.07	249	16.0	13.2	991
14.38	169	6.25	250	16.0	13.1	991
14.56	173	6.11	251	16.0	13.1	991
14.75	172	6.01	249	16.0	13.1	991
14.88	174	5.95	249	16.0	13.1	991
15.06	175	6.12	255	16.0	13.1	990
15.25	177	5.96	256	16.0	13.1	990
15.38	178	5.97	253	16.0	13.1	990
15.56	181	5.93	254	15.9	13.1	990
15.75	184	6.03	254	16.0	13.1	989
15.94	182	5.99	255	15.9	13.0	990
16.13	183	6.07	253	16.0	13.0	989
16.25	187	6.09	257	15.9	13.0	989
16.44	187	5.96	255	15.9	13.0	989
16.63	191	6.07	252	15.9	13.0	989
16.81	195	6.05	253	15.9	13.0	988
16.94	192	5.91	255	15.9	13.0	988
17.13	194	5.71	256	15.9	13.0	988
17.31	197	5.90	257	15.9	13.0	988
17.50	197	5.89	259	15.9	13.0	988
17.63	199	5.92	256	15.9	13.0	988
17.81	200	5.82	259	15.8	12.9	988
18.00	202	5.58	260	15.8	12.9	987
18.19	206	5.68	259	15.8	12.9	987
18.31	208	5.60	259	15.8	12.9	987
18.50	205	5.42	261	15.8	12.9	987
18.69	210	5.59	260	15.8	12.9	986
18.88	209	5.79	260	15.9	13.0	986
19.06	210	5.83	260	15.9	12.9	986
19.19	211	5.76	258	15.8	12.9	986
19.38	213	5.44	260	15.8	12.9	986
19.56	215	5.75	261	15.8	12.8	986
19.75	218	5.65	262	15.8	12.9	985
19.88	215	5.66	260	15.7	12.8	986
20.06	217	5.64	262	15.8	12.8	986
20.25	219	5.50	262	15.7	12.8	985
20.38	219	5.50	261	15.7	12.8	985

TABLE 6.2.23: TETHER-SONDE KOELN, ASCENT NR. 1 19.09.89
FROM 19:46 TO 21:27 (BEGINNING OF ASCENT, 21 MINUTES)

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)	HUMIDITY IN (%)	PRESSURE IN (hPa)
0.05	2	1.76	294	15.1			917
0.22	5	3.99	285	15.2			916
0.38	21	3.23	269	15.2			914
0.55	34	3.20	283	15.2			913
0.73	34	3.97	258	15.1			913
0.90	32	3.58	261	15.1			913
1.07	32	3.76	260	15.1			913
1.25	30	3.63	277	15.1			913
1.45	27	3.03	260	15.1			914
1.58	34	2.64	256	15.1			913
1.75	30	2.91	278	15.0			913
1.93	32	2.41	286	15.0			913
2.10	32	2.43	273	15.0			913
2.27	33	3.03	289	15.0			913
2.45	33	2.61	273	15.0			913
2.62	33	2.44	265	15.0			913
2.78	33	2.77	273	15.0			913
2.97	32	3.10	285	15.0			913
3.13	33	2.98	268	15.0			913
3.30	34	2.52	287	15.0			913
3.47	33	2.09	283	15.0			913
3.65	32	2.05	269	15.0			913
3.82	34	2.01	256	15.0			913
3.98	33	2.02	248	15.0			913
4.17	33	2.29	285	15.0			913
4.33	34	2.67	254	15.0			913
4.50	33	2.22	262	14.9			913
4.68	33	2.76	296	15.0			913
4.85	33	2.30	279	15.1			913
5.02	33	2.81	251	15.0			913
5.18	33	3.14	261	15.1			913
5.37	33	3.00	276	15.1			913
5.53	33	2.87	252	15.0			913
5.70	34	2.45	266	15.0			913
5.88	34	1.82	272	15.0			913
6.05	33	1.75	285	15.0			913
6.22	34	1.59	273	15.0			913
6.38	33	1.47	284	15.0			913
6.57	34	1.23	275	15.0			913
6.73	34	1.05	272	14.9			913
6.90	33	1.14	276	14.9			913
7.08	33	1.37	265	15.0			913
7.25	33	1.43	256	15.0			913
7.42	34	2.01	258	14.9			913
7.58	33	1.70	239	14.9			913
7.77	33	2.84	224	15.0			913
7.93	33	2.07	268	15.0			913
8.10	34	1.42	269	14.9			913
8.28	34	1.73	263	14.9			913
8.45	33	1.72	248	15.0			913
8.62	34	1.67	264	15.0			913
8.80	34	1.50	262	15.0			913
8.97	33	1.53	289	14.9			913
9.13	34	2.16	236	14.9			913
9.30	33	1.65	254	14.9			913
9.48	33	1.66	247	14.9			913
9.65	33	1.81	256	14.9			913
9.82	33	1.73	256	14.9			913

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)	HUMIDITY IN (%)	PRESSURE IN (hPa)
10.00	32	1.91	262	14.9			913
10.17	32	1.53	248	14.9			913
10.33	32	1.10	284	14.9			913
10.52	33	1.03	267	14.9			913
10.68	34	1.65	229	14.9			913
10.85	48	2.20	257	14.9			911
11.02	64	2.63	283	14.8			910
11.20	70	1.64	256	14.7			909
11.37	68	2.53	252	14.7			909
11.53	69	2.65	262	14.7			909
11.72	69	2.26	263	14.6			909
11.88	69	2.55	254	14.7			909
12.05	69	2.34	273	14.6			909
12.22	70	2.24	265	14.7			909
12.40	70	2.30	266	14.8			909
12.57	68	2.52	243	14.7			909
12.73	68	2.48	256	14.7			909
12.92	69	2.76	263	14.7			909
13.08	69	2.56	256	14.7			909
13.25	69	2.33	237	14.7			909
13.43	68	2.14	250	14.6			909
13.60	69	2.41	266	14.6			909
13.77	70	2.37	259	14.7			909
13.93	68	2.22	248	14.7			909
14.12	82	3.45	257	14.6			908
14.28	95	3.19	233	14.7			906
14.45	109	3.15	245	14.7			905
14.63	106	3.29	268	14.7			905
14.80	108	3.76	274	14.7			905
14.97	104	3.95	255	14.6			905
15.15	110	4.02	222	14.6			906
15.32	113	3.78	252	14.5			905
15.48	109	2.96	235	14.4			905
15.65	107	3.59	250	14.4			905
15.83	108	2.95	262	14.4			905
16.00	109	2.83	246	14.3			905
16.17	110	2.80	254	14.3			905
16.35	109	2.60	250	14.3			905
16.52	111	2.49	235	14.3			905
16.68	111	3.14	239	14.3			905
16.85	105	3.35	244	14.4			905
17.03	107	3.44	245	14.5			905
17.20	108	3.03	253	14.5			905
17.37	110	3.21	256	14.5			905
17.55	122	3.80	242	14.4			903
17.72	139	3.03	238	14.2			902
17.88	149	3.14	250	14.1			901
18.05	150	3.37	249	14.1			900
18.23	141	4.21	245	14.1			901
18.40	142	4.26	240	14.2			901
18.57	139	4.87	246	14.3			902
18.75	141	4.66	242	14.3			901
18.92	139	4.61	244	14.3			902
19.08	140	4.75	256	14.2			901
19.27	142	4.48	242	14.2			901
19.43	141	4.71	252	14.2			901
19.60	150	4.44	244	14.2			900
19.77	162	4.39	249	14.2			899
19.95	173	4.68	250	14.1			898
20.12	171	5.00	251	14.1			898

TABLE 6.2.24: TETROON, ASCENT NR. 1 19.09.89
FROM 20:15 TO 20:33

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)
1.17	27984	42735	84	35	36	-0.64	0.05	-0.04
1.33	27979	42736	84	40	42	-1.71	0.27	-0.01
1.50	27950	42741	84	69	71	-1.71	0.26	0.00
1.67	27944	42741	84	75	76	-0.49	0.09	0.02
1.83	27940	42743	84	79	81	-0.58	0.10	0.01
2.00	27933	42743	84	87	88	-0.68	0.07	0.02
2.17	27926	42744	85	93	94	-0.50	0.06	0.04
2.33	27923	42745	85	97	98	-0.28	-0.01	0.01
2.50	27921	42744	85	99	100	-0.19	-0.05	0.02
2.67	27919	42743	85	101	102	-0.14	-0.03	0.03
2.83	27918	42743	85	102	103	-0.14	0.01	0.01
3.00	27916	42744	85	103	105	-0.33	-0.02	0.05
3.17	27912	42743	86	108	110	0.75	-0.23	0.16
3.33	27931	42739	89	128	130	0.81	-0.11	0.26
3.50	27928	42741	92	132	135	-0.29	0.20	0.31
3.67	27925	42743	95	136	140	-0.18	0.34	0.37
3.83	27924	42747	99	140	146	-0.08	0.41	0.41
4.00	27924	42751	103	144	152	0.01	0.46	0.46
4.17	27924	42756	108	149	159	0.15	0.52	0.54
4.33	27927	42762	114	155	167	0.34	0.61	0.62
4.50	27931	42769	121	163	177	0.58	0.72	0.68
4.67	27938	42776	128	173	190	0.90	0.84	0.74
4.83	27949	42785	135	188	206	1.27	1.00	0.74
5.00	27964	42796	142	206	226	1.59	1.12	0.66
5.17	27981	42808	149	227	247	1.95	1.16	0.59
5.33	28003	42819	154	251	272	2.30	1.16	0.57
5.50	28027	42831	160	278	300	2.61	1.22	0.56
5.67	28055	42844	165	309	331	2.92	1.37	0.55
5.83	28085	42858	171	343	365	3.18	1.49	0.52
6.00	28118	42874	176	379	402	3.39	1.57	0.46
6.17	28153	42890	180	417	441	3.56	1.62	0.40
6.33	28189	42906	184	457	481	3.72	1.64	0.36
6.50	28228	42923	187	499	522	3.89	1.67	0.37
6.67	28267	42939	191	542	566	4.01	1.66	0.37
6.83	28308	42956	195	585	609	4.08	1.63	0.34
7.00	28349	42972	198	630	654	4.12	1.57	0.35
7.17	28390	42987	202	673	698	4.11	1.51	0.36
7.33	28431	43002	205	717	742	4.05	1.46	0.35
7.50	28471	43016	209	760	784	4.05	1.38	0.37
7.67	28512	43030	212	803	827	4.08	1.37	0.39
7.83	28553	43044	216	846	871	4.08	1.38	0.39
8.00	28593	43057	220	889	914	4.11	1.41	0.40
8.17	28635	43072	224	933	958	4.11	1.41	0.39
8.33	28676	43086	228	976	1001	4.11	1.34	0.36
8.50	28717	43099	232	1019	1045	4.20	1.28	0.35
8.67	28760	43111	235	1064	1089	4.30	1.23	0.36
8.83	28803	43123	239	1109	1135	4.39	1.21	0.32
9.00	28847	43136	242	1155	1181	4.44	1.22	0.22
9.17	28892	43148	243	1201	1227	4.44	1.21	0.15
9.33	28936	43160	245	1247	1273	4.49	1.22	0.11
9.50	28982	43172	245	1294	1320	4.58	1.19	0.05
9.67	29028	43184	246	1341	1367	4.64	1.15	0.01
9.83	29074	43195	246	1389	1415	4.64	1.10	0.00
10.00	29121	43205	246	1437	1463	4.64	1.08	-0.04
10.17	29167	43217	245	1485	1511	4.64	1.12	-0.07
10.33	29214	43228	244	1532	1558	4.59	1.16	-0.09
10.50	29259	43240	243	1579	1605	4.54	1.19	-0.13

TABLE 6.2.24 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	29304	43252	242	1626	1652	4.49	1.23	-0.12
10.83	29349	43264	241	1672	1698	4.47	1.25	-0.03
11.00	29394	43277	241	1719	1745	4.52	1.21	0.04
11.17	29439	43288	242	1766	1792	4.48	1.18	0.05
11.33	29483	43300	242	1812	1838	4.38	1.17	0.09
11.50	29527	43312	243	1856	1883	4.34	1.16	0.10
11.67	29570	43323	244	1901	1927	4.33	1.17	0.07
11.83	29613	43335	245	1946	1972	4.34	1.14	0.07
12.00	29657	43346	245	1991	2017	4.34	1.11	0.06
12.17	29700	43358	246	2036	2062	4.34	1.15	0.01
12.33	29744	43369	245	2081	2107	4.38	1.20	-0.02
12.50	29788	43381	246	2127	2153	4.38	1.19	0.00
12.67	29831	43393	245	2172	2198	4.33	1.22	-0.04
12.83	29874	43406	245	2217	2243	4.31	1.31	-0.07
13.00	29917	43419	244	2262	2288	4.25	1.37	-0.03
13.17	29959	43433	244	2306	2332	4.24	1.41	0.04
13.33	30002	43448	245	2351	2377	4.28	1.44	0.09
13.50	30045	43462	246	2396	2422	4.33	1.41	0.14
13.67	30089	43476	248	2442	2468	4.36	1.44	0.19
13.83	30132	43491	250	2488	2514	4.35	1.48	0.22
14.00	30176	43506	252	2534	2560	4.35	1.50	0.28
14.17	30219	43521	255	2580	2606	4.29	1.51	0.30
14.33	30262	43536	258	2625	2652	4.33	1.54	0.28
14.50	30306	43552	261	2672	2699	4.42	1.55	0.31
14.67	30350	43567	264	2719	2746	4.46	1.57	0.38
14.83	30395	43583	268	2767	2794	4.50	1.60	0.35
15.00	30440	43599	271	2814	2841	4.51	1.56	0.24
15.17	30485	43614	273	2862	2889	4.51	1.61	0.15
15.33	30530	43631	274	2910	2937	4.45	1.65	0.08
15.50	30574	43647	275	2957	2984	4.46	1.64	0.05
15.67	30619	43664	275	3005	3032	4.45	1.69	0.04
15.83	30663	43681	276	3052	3079	4.45	1.67	0.01
16.00	30708	43697	275	3100	3127	4.45	1.66	0.00
16.17	30752	43714	276	3147	3174	4.41	1.64	-0.01
16.33	30796	43730	275	3194	3221	4.32	1.60	-0.02
16.50	30839	43746	275	3239	3266	4.23	1.60	-0.03
16.67	30881	43762	275	3284	3312	4.28	1.56	-0.03
16.83	30924	43778	275	3330	3358	4.27	1.61	0.00
17.00	30966	43794	275	3376	3403	4.22	1.61	-0.01
17.17	31009	43810	274	3421	3448	4.21	1.63	-0.01
17.33	31051	43826	274	3466	3493	4.15	1.70	-0.02
17.50	31092	43844	274	3511	3538	4.15	1.68	-0.02
17.67	31134	43860	274	3556	3583	4.16	1.66	0.01
17.83	31175	43877	274	3600	3627	4.16	1.64	0.01
18.00	31217	43893	274	3645	3672	4.29	1.68	0.05

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APPENDICES

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

E. Lyck, F. Veroustraete, W Voß

A 1 Intercomparison between NERI and KFA

An intercomparison test of SF_6 measurements was carried out during the fourth field experiment.

Nine calibration mixtures were prepared by KFA from a Linde primary standard containing 102 ppb ±10% SF_6 (compare chapter 4.2.2) and measured before, during and after the field experiment by KFA. The results are given in Tab. A1.

sample No.	theor. conc. ng/m³	date of analysis and SF_6-concentration in ng/m³				
		09/11/89	**09/19/89**	**09/19/89**	**09/22/89***	**10/16/89***
1	10	9	8	7	9	9
2	30	26	27	27	29	28
3	50	44	42	47	49	46
4	70	61	63	66	66	66
5	100	85	88	93	87	87
6	500	534	510	532	498	501
7	1000	1072	1033	1072	993	1015
8	5000	5107	4907	5030	4629	4889
9	10000	9781	9399	9682	9837	9421
Note: * corrected by the factor 0.86 (see chapter 4.2.2)						

Tab. A 1: Analysis by KFA of the calibration mixtures prepared with synthetic air by KFA.

By the analysis of calibration mixtures by NERI it unfortunately turned out that the content of synthetic air in the mixtures caused problems with irregularities of the baseline of the chromatograms. This made the proper determination of concentration in these mixtures below about 100 ng/m³ impossible. The results of the analysis of mixtures above 100 ng/m³ are given in Tab. A2.

Sample No.	theor. conc. ng/m³	date of analysis and SF_6-conc. (ng/m³)			
		09/19/89	**09/19/89**	**09/22/89**	**09/22/89**
6	500	469	464	475	472
7	1000	961	961	995	972
8	5000	4803	4757	4837	4768
9	10000	9206	9149	8853	9084

Tab. A 2: Analysis by NERI of calibration mixtures prepared with synthetic air by KFA.

In order to include concentrations below 100ng/m^3 in the intercomparison four calibration samples were prepared as described before but with purified nitrogen instead of synthetic air. Tab. A3 gives the results of analysis of these mixtures by KFA and NERI.

Sample No.	theor. conc. ng/m^3	date of analysis and SF_6-conc. (ng/m^3)			
		KFA 09/23/89*	KFA 09/23/89*	NERI 09/25/89	NERI 09/25/89
10	12	10	10	9	9
11	40	33	33	32	32
12	70	59	58	53	48
13	90	75	73	66	64
Note: * corrected by the factor 0.86					

Tab. A 3: Analysis by KFA and NERI of the calibration mixtures prepared with nitrogen by KFA.

In Tab. A4 the single measurements of KFA and NERI are averaged and the mean values are compared.

Sample No.	theor. conc. ng/m^3 (A)	SF_6-conc. (ng/m^3)		relative ratio (%)		
		mean NERI (B)	mean KFA (C)	B:A*	C:A	B:C
10	12	9	10	-28.6	-18.2	-10.5
11	40	32	33	-22.2	-19.2	-3.1
12	70	50	58	-33.3	-18.8	-14.8
13	90	65	74	-32.2	-19.5	-12.9
6	500	470	515	-6.2	+3.0	-9.1
7	1000	972	1037	-2.8	+3.6	-6.5
8	5000	4791	4912	-4.3	-1.8	-2.5
9	10000	9073	9624	-9.7	-3.8	-5.9
Note: * $(B:A) = \frac{B-A}{1/2(B+A)} \times 100$						

Tab. A 4: Results of the intercomparison between NERI and KFA based on calibration mixtures made by KFA.

The agreement between NERI and KFA is good, remembering the overall uncertainty of the analysis mentioned in chapter 4.2.2 and 4.3.2. The deviation between the measured concentrations and the theoretical values indicates a systematic error which might result from the preparation of the calibration mixtures.

A 2 Intercomparison between SCK and KFA

An intercomparison test of SF_6 measurements was carried out at 09/22/89. Four different SF_6 concentrations were mixed with the two channel mass flowmeter/controller using the Linde standard and synthetic air. The results are given in Tab. A5.

Sample No.	theor. conc. ng/m^3 (A)	SF_6-conc. (ng/m^3)		relative ratio (%)		
		SCK (B)	KFA (C)	B:A*	C:A	B:C
1	600	668	601	+10.7	+0.2	+10.6
2	800	1057	795	+27.7	-0.6	+28.3
3	2000	2018	1950	+0.9	-2.5	+3.4
4	3000	3368	2867	+11.6	-4.5	+16.1
Note: * $(B{:}A) = \frac{B-A}{1/2(B+A)} \times 100$						

Tab. A 5: Results of the calibration test by SCK and KFA.

The agreement between SCK and KFA is reasonable.

A 3 Intercomparison between NERI, KFA and SCK

There was carried out only one test. Seven samples taken by NERI during the experiments were measured by the three groups. The results are given in Tab. A6.

Sample NERI-bags No.	SF_6-conc. (ng/m^3)			relative ratio (%) *		
	NERI (A)	KFA (B)	SCK (C)	B:A	C:A	C:B
41.1	29	34	218	+15.9	+153.0	+146.0
41.3	43	55	117	+24.5	+92.5	+72.1
49.2	132	149	379	+12.1	+96.7	+87.1
2.3	188	203	258	+7.7	+31.4	+23.9
9.3	1003	990	956	-1.3	-4.8	-3.5
5.2	1065	1057	1005	-0.8	-5.8	-5.0
59.3	2046	1992	2085	-2.7	+1.9	+4.5
Note: * $(B{:}A) = \frac{B-A}{1/2(B+A)} \times 100$						

Tab. A 6: Results of the intercomparison between NERI, KFA and SCK.

The measured SF_6 concentrations are in good agreement between all groups, remembering the SCK-group can only measure SF_6 concentrations ≥ 600 ng/m^3 with reasonable accuracy (Tab. A5).

B Data of topography

Ch. Plaga, 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 March 1990 (Sophienhöhe) respective January 1991 (mining area).

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

Ch. Plaga

From the 19th to the 28th of September 1989 the 4th 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 KFAIMP89_1 and KFAIMP89_2.

C 1 Characteristics of the tapes

Name:	KFAIMP89_1
Code:	EBCDIC, formatted
Density:	6250 Bpl
Tracks:	9
Label:	NL
Recordformat:	F
Recordlength:	filedependent
Contents:	20 datafiles

Name:	KFAIMP89_2
Code:	EBCDIC, formatted
Density:	6250 Bpl
Tracks:	9
Label:	NL
Recordformat:	F
Recordlength:	filedependent
Contents:	14 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 CET)
  - 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 (CET))
  - 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                          89   9 19   1 89   9 28 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 CET)

  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 22

```
 22TETHER SONDE RISOE
   7  9
   1  7 10 11 13 23 24
  459
  289
 1440
  429
 1247
  826
  713
  975
  880
H 89  9 19 19 22 89  9 19 21  7
D 2.8600E+00 2.7500E+02 1.5670E+01 1.4380E+01 1.0110E+03 1.0000E-01 2.5000E-01
D 3.6000E+00 2.0900E+02 1.5730E+01 1.4360E+01 1.0110E+03 3.0000E-01 3.7500E-01
D 3.7400E+00 2.3500E+02 1.5870E+01 1.4440E+01 1.0107E+03 2.6000E+00 5.6250E-01
D 3.4400E+00 2.3000E+02 1.5880E+01 1.4440E+01 1.0102E+03 6.4000E+00 7.5000E-01
D 4.0700E+00 2.4000E+02 1.5880E+01 1.4390E+01 1.0097E+03 1.1000E+01 9.3750E-01
D 4.2100E+00 2.4600E+02 1.5880E+01 1.4330E+01 1.0097E+03 1.1300E+01 1.1250E+00
D 4.1000E+00 2.3700E+02 1.5930E+01 1.4370E+01 1.0086E+03 2.0000E+01 1.2500E+00
D 4.2300E+00 2.2000E+02 1.5870E+01 1.4320E+01 1.0090E+03 1.7000E+01 1.4375E+00
  .
  .
  .
```

C 3 Information concerning the meteorological datafiles

1.

- Station: TOWER KFA
- Tape: KFAIMP89_1
- Label: 1
- Number of records: 1451
- Format: F, LRECL 323
- Structure: type 1
- Parameters: wind speed(2,10,20,30,50,80,100,117.5m), wind direction(30,50,117.5m), sigma θ(50m), sigma ϕ(50m), 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: KFAIMP89_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: KFAIMP89_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: KFAIMP89_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: KFAIMP89_1
- Label: 5
- Number of records: 1452
- Format: F, LRECL 180
- Structure: type 1

- Parameters: wind speed(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(5,10m), standard deviation wind direction(10m)

6.

- Station: MAST 4 SOPHIENHOEHE
- Tape: KFAIMP89_1
- Label: 6
- Number of records: 1429
- 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: KFAIMP89_1
- Label: 7
- Number of records: 1455
- 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: SONICS KFA, SONIC Sophienhöhe
- Tape: KFAIMP89_1
- Label: 8
- Number of records: 154
- Format: F, LRECL 543
- 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, friction velocity, temperature, covariance w'T' (only Soph.höhe) all parameters at 9.5, 30, 50 and 120 m

9.

- Station: MAST SODAR KFA
- Tape: KFAIMP89_1
- Label: 9
- Number of records: 434
- 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: KFAIMP89_1
- Label: 10
- Number of records: 99
- Format: F, LRECL 59
- Structure: type 1
- Parameters: wind speed, wind direction
  both parameters at 3.3 m

11.

- Station: MAST 2 RISOE
- Tape: KFAIMP89_1
- Label: 11
- Number of records: 99
- Format: F, LRECL 59
- Structure: type 1
- Parameters: wind speed, wind direction
  both parameters at 3.3 m

12.

- Station: MAST 3 RISOE
- Tape: KFAIMP89_1
- Label: 12
- Number of records: 99
- Format: F, LRECL 59
- Structure: type 1
- Parameters: wind speed, wind direction
  both parameters at 3.3 m

13.

- Station: MAST 4 RISOE
- Tape: KFAIMP89_1
- Label: 13
- Number of records: 99
- Format: F, LRECL 59
- Structure: type 1
- Parameters: wind speed, wind direction
  both parameters at 3.3 m

14.

- Station: MAST IPC
- Tape: KFAIMP88_1
- Label: 14
- Number of records: 965
- 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: KFAIMP89_1
- Label: 15
- Number of records: 1314
- 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: KFAIMP89_1
- Label: 16
- Number of records: 345
- Format: F, LRECL 1775
- Structure: type 1
- Parameters: wind speed, vertical wind speed [cm/s], wind direction, echo intensity, standard deviation vertical wind speed [cm/s], standard deviation wind direction, standard deviation echo intensity, dissipation rate
  all parameters from 60 m up to 440 m by 20 m steps

17.

- Station: SODAR KOELN
- Tape: KFAIMP89_1
- Label: 17
- Number of records: 1109
- Format: F, LRECL 1995
- Structure: type 1
- Parameters: wind speed, vertical wind speed [cm/s], wind direction, echo intensity, standard deviation vertical wind speed[cm/s], 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: KFAIMP89_1
- Label: 18
- Number of records: 1279
- Format: F, LRECL 1335
- Structure: type 1
- Parameters: wind speed, vertical wind speed [cm/s], wind direction, echo intensity, standard deviation vertical wind speed [cm/s], all parameters from 40 m up to 500 m by 20 m steps

19.

- Station: RAWIN-SONDE ESSEN
- Tape: KFAIMP89_1
- Label: 19
- Number of ascents: 47
- Number of records: 2502
- 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: KFAIMP89_1
- Label: 20
- Number of ascents: 45
- Number of records: 1205
- 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: KFAIMP89_2
- Label: 1
- Number of ascents: 15
- Number of records: 387
- Format: F, LRECL 67
- Structure: type 2
- Parameters: temperature, wet-bulb temperature, humidity, pressure, height above ground, time elapsed since start

22.

- Station: TETHER SONDE RISOE
- Tape: KFAIMP89_2
- Label: 2
- Number of ascents: 9
- Number of records: 7279
- Format: F, LRECL 78
- Structure: type 2
- Parameters: wind speed, wind direction, temperature, wet bulb temperature, pressure, height above ground, time elapsed since start

23.

- Station: TETHER SONDE KOELN
- Tape: KFAIMP89_2
- Label: 3

- Number of ascents: 32
- Number of records: 7787
- Format: F, LRECL 89
- Structure: type 2
- Parameters: wind speed, wind direction,
  temperature, wet bulb temperature,
  humidity, pressure,
  height above ground,
  time elapsed since start

24.

- Station: TETROON
- Tape: KFAIMP89_2
- Label: 4
- Number of ascents: 7
- Number of records: 631
- 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(6,2)
- 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]
  - 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), F(8,1), 6 F(7)

(-9999 means a missing value)

Example of a dispersion datafile

Print of the first records of the first experiment

```
  1      190989
28847  41742      91
 50     1.28
1900   2130
2000   2030
2030   2100
2100   2130
    2.00      21.0      446      91    1704   12233   18432        1
    3.00      31.1      437      90    6447   51842   30962        1
    4.00      40.7      441      90   11149   52833   33386        1
    4.50      45.4      449      90   10894   49489   32037        1
    5.00      51.0      452      90   12957   48240   39029        1
    5.50      55.2      451      90   17367   48987   44793        1
    6.00      61.0      466      90   -9999   49997   46630        1
    7.00      70.1      496      90   29118   83705   40335        1
    8.00      79.8      547      90   16970   87650   29151        1
   12.00      19.8      962      99      16     826   27716        1
 .
 .
 .
```

Instantaneous SF6 concentrations NERI-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(6,2)

- 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/m^3]

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

Example of a dispersion datafile

Print of the first records of the first experiment

```
  1      190989
28847   41742     50
 50     1.28
19:15    622.0     67.6    2382     228       9
19:18    622.0     67.6    2382     228      36
19:20    622.0     67.6    2382     228      77
19:23    622.0     67.6    2382     228      18
19:36    106.0     69.3    3016     102     833
19:38    106.0     69.3    3016     102     337
19:41    106.0     69.3    3016     102     968
19:47    112.0     75.0    2667     103    3096
19:49    112.0     75.0    2667     103    3984
19:52    116.0     79.8    2444     104    3779
19:55    116.0     79.8    2444     104    3597
 .
 .
 .
```

C 5 Information concerning the dispersion datafiles

Mean tracer concentrations

1.

- Experiment number: 1
- Date: 19.09.89, 19:00
- Tape: KFAIMP89_2
- Label: 5
- Number of records: 150
- Format: F, LRECL 58

2.

- Experiment number: 2
- Date: 20.09.89, 18:30
- Tape: KFAIMP89_2
- Label: 6
- Number of records: 110
- Format: F, LRECL 58

3.

- Experiment number: 3
- Date: 23.09.89, 19:30
- Tape: KFAIMP89_2
- Label: 7
- Number of records: 137
- Format: F, LRECL 58

4.

- Experiment number: 4
- Date: 25.09.89, 19:30
- Tape: KFAIMP89_2

- Label: 8
- Number of records: 129
- Format: F, LRECL 58
- Remark: only 2 sampling periods

5.

- Experiment number: 5
- Date: 27.09.89, 11:45
- Tape: KFAIMP89_2
- Label: 9
- Number of records: 130
- Format: F, LRECL 58

Instantaneous SF6 concentrations NERI-group

1.

- Experiment number: 1
- Date: 19.09.89, 19:15
- Tape: KFAIMP89_2
- Label: 10
- Number of records: 56
- Format: F, LRECL 42

2.

- Experiment number: 2
- Date: 20.09.89, 20:11
- Tape: KFAIMP89_2
- Label: 11
- Number of records: 18
- Format: F, LRECL 42

3.

- Experiment number: 3
- Date: 23.09.89, 19:50
- Tape: KFAIMP89_2
- Label: 12
- Number of records: 52
- Format: F, LRECL 42

4.

- Experiment number: 4
- Date: 25.09.89, 19:53
- Tape: KFAIMP89_2
- Label: 13

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

5.

- Experiment number: 5
- Date: 27.09.89, 11:50
- Tape: KFAIMP89_2
- Label: 14
- Number of records: 42
- Format: F, LRECL 42

C 6 Program IMPLES89

Name of the program

IMPLES89

Purpose of the program

reading meteorological data from the tapes

.Position at the tape KFAIMP89_2

label 15

Recordlength

72

Programming language

FORTRAN

Call

CALL IMPLES89

.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

```
@PROCESS CHARLEN(3000)
*****************************************************************************
*       READING THE METEOROLOGICAL DATA OF THE FIELD EXPERIMENT     *
*       IN 1989 FROM MAGNETIC TAPE                                  *
*                                                                   *
*       CH. MOENIG, 16.04.91                                        *
*****************************************************************************

      PROGRAM IMPLES89


*     VARIABLES

      INTEGER   STTYP(24), STRECL(24), STNUM, STNUME, TAG(4), MONAT(4),
     >          JAHR(4), STUNDE(4), MINUTE(4), NA, NP, PARKEN(54),
     >          ANZHOE(54), IPOS, I, J, K, L, M, RECAUF(54)

      REAL      HOEHE(54,24)

      CHARACTER STNAM*30, TITEL*6, KENN*1, EINZEI*2127, HILF*29,
     >          HELP*7,PARTXT(54)*9

      DATA      STRECL/323,114,180,224,180,224,345,543,6*59,169,
     >                 1775,1995,1335,45,67,67,78,89,100/,
     >          PARTXT/'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',
     >                 'FRICVEL'/
     >         STTYP/18*1,7*2/

      TITEL='STAT  '


*     GET NUMBER OF DESIRED STATION:

      READ(5,'(I2)',END=110) STNUME
      WRITE(TITEL(5:6),'(I2.2)') STNUME
```

```
      HELP='(A    )'
      WRITE(HELP(3:6),'(I4)') STRECL(STNUME)


*     USING FORMAT TYPE 1:

      IF (STTYP(STNUME).EQ.1) THEN

         OPEN(7,FILE=TITEL)


*     GET THE FIRST RECORD:

         READ(7,'(I2,A30,8I3,I3)') STNUM,STNAM,(JAHR(I),MONAT(I),TAG(I),
     >                             STUNDE(I),I=1,2),NP


*     GET THE PARAMETERIDENTIFICATION AND THE MEASURING HEIGHTS:

         DO 10 I=1,NP
            READ(7,HELP) EINZEI
            READ(EINZEI,'(2I2)') PARKEN(I),ANZHOE(I)
            HILF='(4X,  F6.1)'
            WRITE(HILF(5:6),'(I2)') ANZHOE(I)
            READ(EINZEI,HILF) (HOEHE(I,J),J=1,ANZHOE(I))
   10    CONTINUE
         STUNDE(1)=STUNDE(1)-1
         IF (STUNDE(1).EQ.-1) STUNDE(1)=23


*     WRITE THE TITEL

         WRITE(6,'(1X,A,I3,3A,2(2(I2,A),I2,1X,I2,2A))')
     >         'STATION',STNUME,', ',STNAM,' FROM ',
     >         TAG(1),'.',MONAT(1),'.',JAHR(1),STUNDE(1),
     >         ':00',' UP TO ',TAG(2),'.',MONAT(2),'.',
     >         JAHR(2),STUNDE(2),':00'
         WRITE(6,*)


*     READ THE DATA:


   30    READ(7,HELP,END=100) EINZEI


*     DATA RECORD OR MISSING VALUE ?
```

```
      READ(EINZEI,'(A1)') KENN

      IF (KENN.EQ.'1') THEN
         READ(EINZEI,'(1X,I5,3I3)') MONAT(3),TAG(3),STUNDE(3),
     >                              MINUTE(3)


*     WRITE HEIGHTS AND CORRESPONDING VALUES:

         WRITE(6,'(1X,I2,A,I2,A,I2,1X,I2,A,I2)')
     >         TAG(3),'.',MONAT(3),'.',JAHR(1),STUNDE(3),':',
     >         MINUTE(3)
         IPOS=5

         DO 50 I=1,NP
            DO 40 K=1,ANZHOE(I)/10+1
               L=(K-1)*10
               M=MIN(10,ANZHOE(I)-L)
               IF (M.EQ.0) GOTO 50
               HILF='(1X,A10,  (2X,F6.1,1X,A1,2X))'
               WRITE(HILF(9:10),'(I2)') M
               WRITE(6,HILF) '          ',(HOEHE(I,J+L),'M',J=1,M)
               HILF='(1X,A9,  (1X,A11))'
               WRITE(HILF(8:9),'(I2)') M
               WRITE(6,HILF) PARTXT(PARKEN(I)),
     >              (EINZEI(IPOS+J*11:IPOS+J*11+10),J=1,M)
               IPOS=IPOS+M*11
 40         CONTINUE
 50      CONTINUE

      ELSE


*     MISSING VALUES:

         READ(EINZEI,'(1X,I5)') I
         WRITE(6,*)
         WRITE(6,'(1X,A,I4,A)') '>>>>> MISSING VALUES AT ',I,
     >                          ' TEN-MINUTES INTERVALS <<<<<'
      ENDIF
      GOTO 30


*     IT'S FORMAT TYPE 2:

      ELSE
```

```
      OPEN(7,FILE=TITEL)

*     GET INFORMATION ABOUT THE STATION:

      READ(7,'(I2,A30)') STNUM,STNAM
      READ(7,'(2I3)') NP,NA
      HILF='(   I3)'
      WRITE(HILF(2:3),'(I2)') NP
      READ(7,HILF) (PARKEN(I),I=1,NP)
      DO 60 I=1,NA
         READ(7,'(I4)') RECAUF(I)
   60 CONTINUE

      READ(7,'(A31)',END=100) EINZEI

*     BEGINNING AND ENDING DATE OF THE ASCENT:

   70 READ(EINZEI,'(A1,10I3)') KENN,(JAHR(I),MONAT(I),TAG(I),
     >                         STUNDE(I),MINUTE(I),I=1,2)

*     PRINT THE HEADER LINE:

      WRITE(6,'(A1,A)') '1','>>>>> BEGIN OF THE ASCENT <<<<<'
      WRITE(6,'(1X,A,I3,3A,2(2(I2,A),I2,1X,I2,A,I2,A))')
     >       'STATION',STNUME,', ',STNAM,' FROM ',
     >       TAG(1),'.',MONAT(1),'.',JAHR(1),STUNDE(1),':',
     >       MINUTE(1),' UP TO ',TAG(2),'.',MONAT(2),'.',
     >       JAHR(2),STUNDE(2),':',MINUTE(2)
      WRITE(6,*)
      HILF='(3X,   (2X,A,2X))'
      WRITE(HILF(5:6),'(I2)') NP
      WRITE(6,HILF) (PARTXT(PARKEN(K)),K=1,NP)

   80 READ(7,HELP,END=100) EINZEI
      KENN=EINZEI(1:1)

*     READ THE DATE AND PRINT IT:

      IF (KENN.EQ.'D') THEN
         HILF='(1X,   (1X,A11,1X))'
         WRITE(HILF(5:6),'(I2)') NP
         WRITE(6,HILF) (EINZEI((2+I*11):(2+I*11+10)),I=0,NP-1)
```

```
            GOTO 80
         ELSE
            GOTO 70
         ENDIF
      ENDIF

100 CLOSE(7)
110 END
```

Output examples

Type 1:

```
STATION  1, TOWER KFA                    FROM 19. 9.89  0:00 UP TO 28. 9.89 24:00

19. 9.89  0:10
               2.0 M       10.0 M       20.0 M       30.0 M       50.0 M .... 80.0 M
WS          2.8667E-01  8.0333E-01  1.5633E+00  2.3800E+00  3.0633E+00
              30.0 M       50.0 M      117.5 M
WD          1.1700E+02  1.1300E+02  1.4600E+02
              50.0 M
SIGTHE      8.9400E+00
              50.0 M
SIGPHI      6.6900E+00
               2.0 M       10.0 M       20.0 M       30.0 M       50.0 M .... 80.0 M
DT          2.0216E+01  9.9999E+04  2.1777E+01  9.9999E+04  9.9999E+04
               1.0 M
PRESS       1.0020E+03
               1.0 M
PRECIP      0.0000E+00
              30.0 M
DURSUN      0.0000E+00
              30.0 M
NETRAD     -4.1868E+01
              30.0 M       50.0 M      117.5 M
SDWD        1.1800E+01

>>>>> MISSING VALUES AT   15 TEN-MINUTES INTERVALS <<<<<
19. 9.89  0:20
               2.0 M       10.0 M       20.0 M       30.0 M       50.0 M .... 80.0 M
WS          2.0000E-01  9.4333E-01  1.7933E+00  2.5900E+00  3.6700E+00
              30.0 M       50.0 M      117.5 M
WD          1.1300E+02  1.0900E+02  1.4500E+02
              50.0 M
SIGTHE      9.1950E+00
              50.0 M
SIGPHI      6.3450E+00
               2.0 M       10.0 M       20.0 M       30.0 M       50.0 M .... 80.0 M
DT          2.0316E+01  9.9999E+04  2.1787E+01  9.9999E+04  9.9999E+04
               1.0 M
PRESS       1.0018E+03
               1.0 M
PRECIP      0.0000E+00
 .
 .
```

Type 2:

>>>>> BEGIN OF THE ASCENT <<<<<

STATION 20, PILOTBALLOON ESSEN FROM 19. 9.89 18:43 UP TO 19. 9.89 18:50

WS	WD	TIME	X-CO	Y-CO	Z-CO
0.0000E+00	0.0000E+00	0.0000E+00	2.9263E+04	4.3474E+04	1.0753E+02
3.6124E+00	2.5751E+02	3.3333E-01	2.9333E+04	4.3490E+04	1.1664E+02
2.9874E+00	2.5689E+02	6.6667E-01	2.9391E+04	4.3503E+04	1.1561E+02
2.0238E+00	2.4982E+02	1.0000E+00	2.9429E+04	4.3517E+04	1.2600E+02
2.2029E+00	2.8439E+02	1.3333E+00	2.9472E+04	4.3506E+04	1.4154E+02
2.6187E+00	2.8944E+02	1.6667E+00	2.9521E+04	4.3489E+04	1.5408E+02
2.5080E+00	2.6656E+02	2.0000E+00	2.9571E+04	4.3492E+04	1.5566E+02
3.8320E+00	2.6096E+02	2.3333E+00	2.9647E+04	4.3504E+04	1.5895E+02
3.7415E+00	2.7436E+02	2.6667E+00	2.9722E+04	4.3498E+04	1.7650E+02
3.1001E+00	2.7326E+02	3.0000E+00	2.9784E+04	4.3494E+04	1.9460E+02
2.9939E+00	2.6830E+02	3.3333E+00	2.9844E+04	4.3496E+04	2.0709E+02
4.1212E+00	2.6928E+02	3.6667E+00	2.9926E+04	4.3497E+04	2.1681E+02
4.3735E+00	2.7717E+02	4.0000E+00	3.0013E+04	4.3486E+04	2.3768E+02
4.0984E+00	2.7916E+02	4.3333E+00	3.0094E+04	4.3473E+04	2.5763E+02
4.2136E+00	2.7443E+02	4.6667E+00	3.0178E+04	4.3467E+04	2.7985E+02
4.6292E+00	2.7096E+02	5.0000E+00	3.0270E+04	4.3465E+04	2.9467E+02
4.8033E+00	2.6643E+02	5.3333E+00	3.0366E+04	4.3471E+04	3.0044E+02
4.9772E+00	2.6830E+02	5.6667E+00	3.0466E+04	4.3474E+04	3.1308E+02
5.0032E+00	2.6277E+02	6.0000E+00	3.0565E+04	4.3487E+04	3.1975E+02
5.3706E+00	2.6223E+02	6.3333E+00	3.0671E+04	4.3501E+04	3.3084E+02
5.4047E+00	2.5854E+02	6.6667E+00	3.0777E+04	4.3523E+04	3.3385E+02
5.6066E+00	2.5607E+02	7.0000E+00	3.0886E+04	4.3550E+04	3.2736E+02

>>>>> BEGIN OF THE ASCENT <<<<<

STATION 20, PILOTBALLOON ESSEN FROM 19. 9.89 19: 5 UP TO 19. 9.89 19:11

WS	WD	TIME	X-CO	Y-CO	Z-CO
0.0000E+00	0.0000E+00	0.0000E+00	2.9263E+04	4.3474E+04	1.0753E+02
1.3019E+00	2.5660E+02	3.3333E-01	2.9288E+04	4.3480E+04	1.2289E+02
1.5260E+00	2.3120E+02	6.6667E-01	2.9312E+04	4.3499E+04	1.2942E+02
2.1763E+00	2.2429E+02	1.0000E+00	2.9342E+04	4.3530E+04	1.3022E+02
2.1172E+00	2.2528E+02	1.3333E+00	2.9372E+04	4.3560E+04	1.3107E+02
1.4752E+00	2.2671E+02	1.6667E+00	2.9394E+04	4.3580E+04	1.3397E+02
1.4275E+00	2.1835E+02	2.0000E+00	2.9411E+04	4.3603E+04	1.4541E+02
1.6403E+00	2.3014E+02	2.3333E+00	2.9437E+04	4.3624E+04	1.4645E+02
1.3342E+00	2.2257E+02	2.6667E+00	2.9455E+04	4.3643E+04	1.4500E+02
1.5809E+00	2.4288E+02	3.0000E+00	2.9483E+04	4.3658E+04	1.4444E+02
9.9766E-01	2.5168E+02	3.3333E+00	2.9502E+04	4.3664E+04	1.4476E+02
1.0893E+00	2.6550E+02	3.6667E+00	2.9523E+04	4.3666E+04	1.4486E+02
6.8652E-01	2.5108E+02	4.0000E+00	2.9536E+04	4.3670E+04	1.4641E+02
6.5134E-01	2.3558E+02	4.3333E+00	2.9547E+04	4.3678E+04	1.4814E+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)
54	friction velocity [m/s]

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LIST OF ABBREVIATIONS

a) Institutions

ASS	Abteilung Sicherheit und Strahlenschutz (KFA)
DWD	Deutscher Wetterdienst, Wetteramt Essen
IPC	Institut für Angewandte Physikalische Chemie (KFA)
IGM	Institut für Geophysik und Meteorologie der Universität zu Köln
KFA	Forschungszentrum Jülich KFA
NERI	National Environmental Research Institute, Roskilde, Denmark
RWTÜV	Rheinisch-Westfälischer Technischer Überwachungsverein e.V., Essen
RISØ	RISØ National Laboratory, Roskilde, Denmark
SCK	Studiecentrum voor Kernenergie, Mol, Belgium
RWTH	Rheinisch-Westfälische Technische Hochschule Aachen
TÜV Rhl.	Technischer Überwachungsverein Rheinland e.V., Köln
ZAR	Zarnoviec Nuclear Power Plant, Nadole, Poland

b) Notation in text

MSL, m.s.l.	(above) mean sea level
AGL, a.g.l.	above ground level

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