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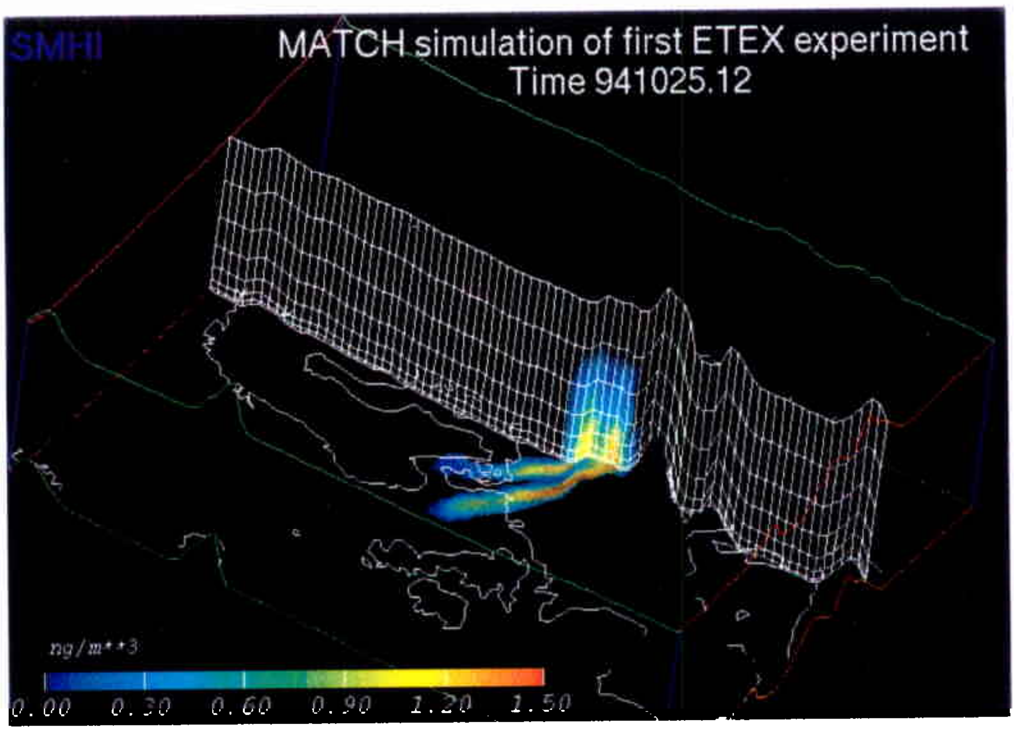
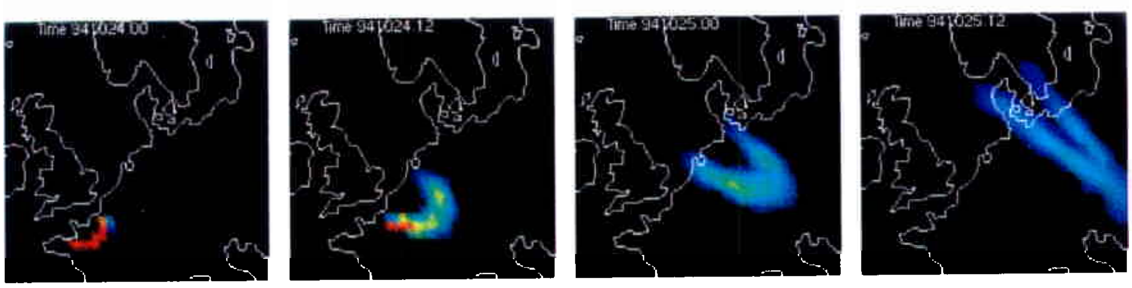
Risø-R-847(EN)
NKS EKO-4(95)1

Report of the Nordic Dispersion-/ Trajectory Model Comparison with the ETEX-1 Fullscale Experiment

NKS/EKO-4 Intercomparison/Validation Exercise Held at Risø, Denmark, 6-7 June 1995

Editors Ulf Tveten, IFE, Kjeller, Norway and Torben Mikkelsen, Risø, Denmark





Risø National Laboratory, Roskilde, Denmark
December 1995

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Abstract On the 6th and 7th June 1995 a meeting was held at Risø, where calculations of the atmospheric transportation and dispersion of the ETEX-1 release carried out by a number of institutions in the Nordic countries were presented. Also presented were the results of the measurements carried out by the National Environmental Research Institute of Denmark, information previously not known to the participants in the meeting. This provided not only an opportunity of intercomparing the models, but also of carrying out a validation exercise. The main points from the concluding discussions are also included in this report.

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Grafisk Service, Risø, 1995

Contents

Introduction

Ulf Tveten, IFE, Kjeller, Norway
and
Torben Mikkelsen, Risø National Laboratory, Roskilde, Denmark

The five Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) have a long tradition of cooperation in a number of fields. Nuclear safety, radiation protection, radioecology and emergency preparedness are examples of this, where the last 20 years of experience may be summarized by three letters: NKS - which stands for Nordic Nuclear Safety Research. NKS is a voluntary cooperative body financed by relevant national authorities, nuclear companies and other Nordic organizations.

One of the projects performed within the 5. NKS-project period (1994-1997) is called EKO-4 (Emergency Exercises and Information).

Now in order to improve both emergency functionality, and also to evaluate models for long range transport with real dispersion data within the Nordic countries, it was proposed to perform an "partial functionality test" in connection with a long range diffusion tests that were conducted independently of NKS in conjunction with the joint European ETEX European Tracer Experiments (October 1994).

A special real-time tracer gas measuring station was operated during the ETEX experiments by the Danish National Environmental Research Institute (DMU). Air samples were taken from the pier of the Risø National Laboratory's harbor, located in the Roskilde Fjord, Denmark. The data from this measurement station were analyzed immediately after the ETEX experiments as opposed to data from the official tracer network operated by JRC Ispra. The official ETEX data were released about one year after the trials, - during the Prague meeting in October 1995, together with a draft report entitled: Real Time Long Range Dispersion Model Evaluation - ETEX first experiment - prepared for ETEX Modellers' Meeting Prague, October 1995).

On this background it was decided, early within the EKO-4 project framework, to take advantage of these circumstances and to use the DMU measurements at Risø as a means for carrying out a realistic functional exercise using real concentration data to test the long-range atmospheric transportation/dispersion models presently used in the Nordic countries.

Nordic functional exercises based on atmospheric dispersion models, but without coexisting dispersion measurements, have previously been carried earlier NKS-project (Tveten, 1994)[1]. The main objectives during the previous exercises have been to test how the long range dispersion models (and their users) functioned under simulated emergency conditions. This aspect is lacking from the present exercise. On the other hand; this new ECO-4 exercise used access to actual dispersion measurements and therefore it presents an opportunity for not only intercomparison of the different models, but also for a partial validation of the emergency forecast models taking part in the exercise.

A meeting was called at Risø National Laboratory (Risø) and at the co-located National Environmental Research Institute (DMU) on the 6th and 7th June 1995. During this meeting DMU first presented their real-time measurement results , which were up till this moment not known to the participants in the meeting, and subsequently each of the participating Nordic institutions presented their models and corresponding model predictions of the measurements at the Risø site from the ETEX-1 cloud passage.

The purpose of the present report is primarily to present a representative selection of the results presented by the various participants at this meeting, but it also serves to a certain

[1] *Tveten, Ulf (Editor) (1994): Dispersion Prognoses and Consequences in the Environment - a Nordic developmemt and harmonization effort. Final report from the Nordic Nuclear Safety Research, Project BER-1. TemaNord 1995:544, 197pp. ISBN 92 9120 663 6. Available from: NKS, P.O.Box 49, DK4000 Roskilde, Denmark (Telefax (+45) 46 32 22 06).*

extent as "minutes of the meeting", with particular emphasis on the comments on the various results presented and the general discussions.

The list of participants is given as Appendix 1; and the program of the meeting as Appendix 2

1 The ETEX Experiment in Rennes, France

Sven-Erik Gryning
Risø National Laboratory
Roskilde, Denmark

On Saturday, 22 October 1994 an e-mail message as well as a phone call was sent to the appropriate persons, including Sven-Erik Gryning, Risø, Denmark, who was to act as manager of the ETEX activities at the site of release near Rennes, France during the two experiments, with the message that the ETEX experiment would now take place, and the release would take place the next day. Sven-Erik Gryning described the events of this and the following days, and the Alert Schedule for the experiment in included here as Table 1.1.

Some photos from the site were shown. The terrain is very flat. The weather was favorable from a release point of view, but otherwise rather unpleasant.

A map showing all the measuring stations distributed over most of Europe is shown in Figure 1.1.

The ETEX-1 experiment began the 23/10/94 at 16:00 UTC and was concluded the 24/10/94 at 3:50 UTC. During this period 5 French and 5 Swiss Constant Level Balloons (CLB's) were launched, one every 4 hours, from the release site of Monterfil (48.06N-2.01W) and followed through 2 - 3 hours to obtain CLB trajectories up to a distance of 100 km.

In Table 1.2 and Figures 1.2 and 1.3 are shown various characteristics of the balloon flights; like flight levels and trajectories. Blow is given a list of positions where balloons were retrieved. As can be seen, half of the balloons were never found, while some of the balloons were found several days after the day of the experiment.

The French CVB 1 was found at Bernay (30 km East of Lisieux)
The French CVB 2 Not found
The French CVB 3 Not found
The French CVB 4 was found at Noyant (30 km East of Angers)
The French CVB 5 was found at Banogne

The Swiss CVB 1Not found
The Swiss CVB 2Not found
The Swiss CVB 3Not found
The Swiss CVB 4 was found near Vitre
The Swiss CVB 5 was found near Alencon

The local weather conditions were as follows:

At 09:00 UTC the 23/10/94 stratocumulus layer (5/8 octa) with base between 500 and 600 meters; locally some showers; the wind SW; the radiosounding shows an air mass humid and stable. During the afternoon, stratocumulus layer is more fractionned, some showers persist always; the wind becomes more W at ground layer; the ground pressure increases from 986.5 hPa at 13:00 UTC to 987.5 at 17:00 UTC.

In the evening, the stratocumulus layer disappears slowly; locally no precipitation; the wind is W at ground level; the radiosounding becomes more dry in altitude with more subsidence effect; the pressure increases to 990.3 hPa at 20:00 UTC.

During the night the sky is clear with some clouds in altitude; the radiosounding is subsident; the ground pressure increases to 994.5 hPa at 00:00 UTC; the wind intensity decreases with W-NW component at 00:00 UTC.

At 04:00 UTC the sky is clear; the wind is W again and decreases in intensity; the ground pressure increases to 995.4 hPa.

Table 1.1 Alert Schedule for 15.10 - 15.12 1994.

Date	Time UTC		From	To
Daily	9:00	Weather forecast	Klug	Nodop
Day-2	9:00	Prealert	Klug	Nodop
	20:30	Confirmation of prealert	Klug Nodop	Nodop Release crews
Day-1	8:30	Confirmation of prealert	Klug Nodop	Nodop Release crews
	9:00	Departure of release crew to site		
	9:30	Alert for saving met. obs. data	Nodop	Meteorological centres
	10:00	Prealert to modellers, ground Sampling networkand, aircrafts	Klug Nodop Nat. contacts	Modellers National contacts Station officers
	10:00	Notifications	Klug	Han v. Dop
	20:30	Alert confirmation	Klug Nodop	Nodop Aircraft
Day	8:30	Final Go with detailed weather information	Klug Nodop Nat. contacts	Nodop National contacts Release crew Aircrafts Station officers
	9:00	Preparations and set up at release site		
	10:00 12:00	Confirmation from stations in F, B, D, NL	Nat. contacts	Nodop
	12:00	Confirmation that stations are ready	Nodop	Klug
	12:00	L. Launch CLB		
	13:00	Information on CLB	Release crew	Klug, Aircrafts
	15:00	Confirmation Release crew ready	Release crew	Klug
	16:00 22:00	Tracer Release Launches CLB		
	17:00	Confirmation Tracer Release has started	Release	Klug
	18:00	Info on CLB	Release	Aircrafts
Day + 1	6:00 18:00	Aircraft flights		
		Tracer plume location	UK aircraft	Klug, Nodop, Release

Release crew	Van Velzen, Benech, Gryning, Schneiter + NAMES!
Aircrafts	CH, D, UK + NAMES!

Information on actual days:
Day-2 will not be on a Saturday, except the 22. and 29. Oct. and 3. and 10. Dec. 1994.
Last possible Day-2 is the 15. Dec. 1994.
We exclude further the following public holidays as Day-2: 11. Nov., 8. Dec.

Table 1.2. CVB flights characteristics.

CVB	Sonde N	Launching Time (UTC)	FINAL Time (UTC)	Flight Level (m)	Comments
1F	54	13:30	15:30	500	Launching delayed due to local shower
1S	441	13:19	13:58	400-100	Idem
2F	49	17:03	18:46	900-700	Launching delayed due to local shower
2S	453	16:34	18:56	1500-500	Idem
3F	44	20:10	21:40	700-500	CVB wet by water deposition
3S	842	20:00	21:47	900-500	Idem
4F	50	00:01	02:40	900-900	CVB wet by water deposition
4S	852	23:59	01:01	550-100	Idem
5F	45	03:54	05:40	900-200	CVB wet by water deposition
5S	340	03:59	05:15	550-100	Idem

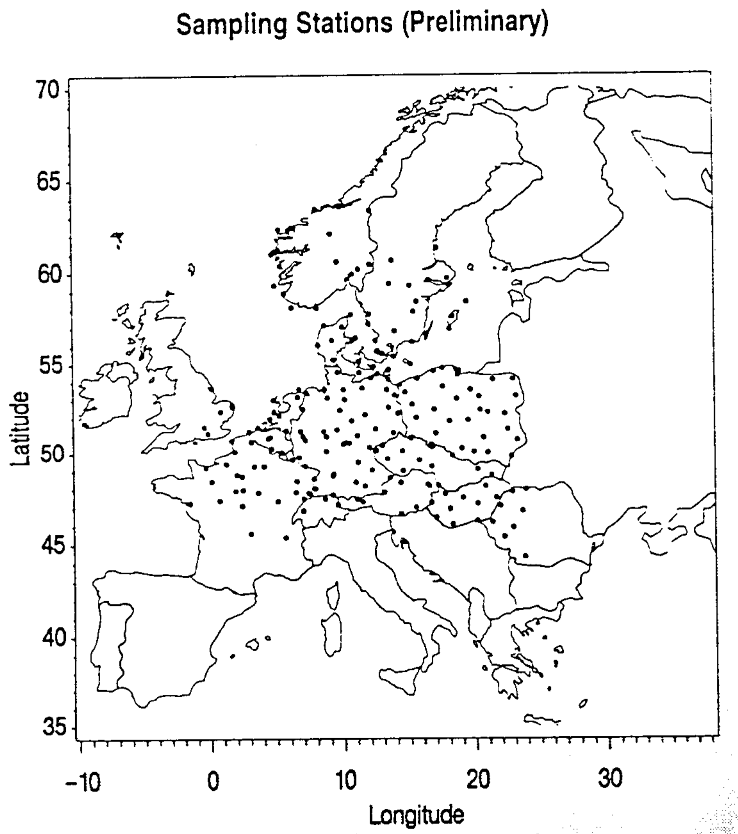


Figure 1.1.

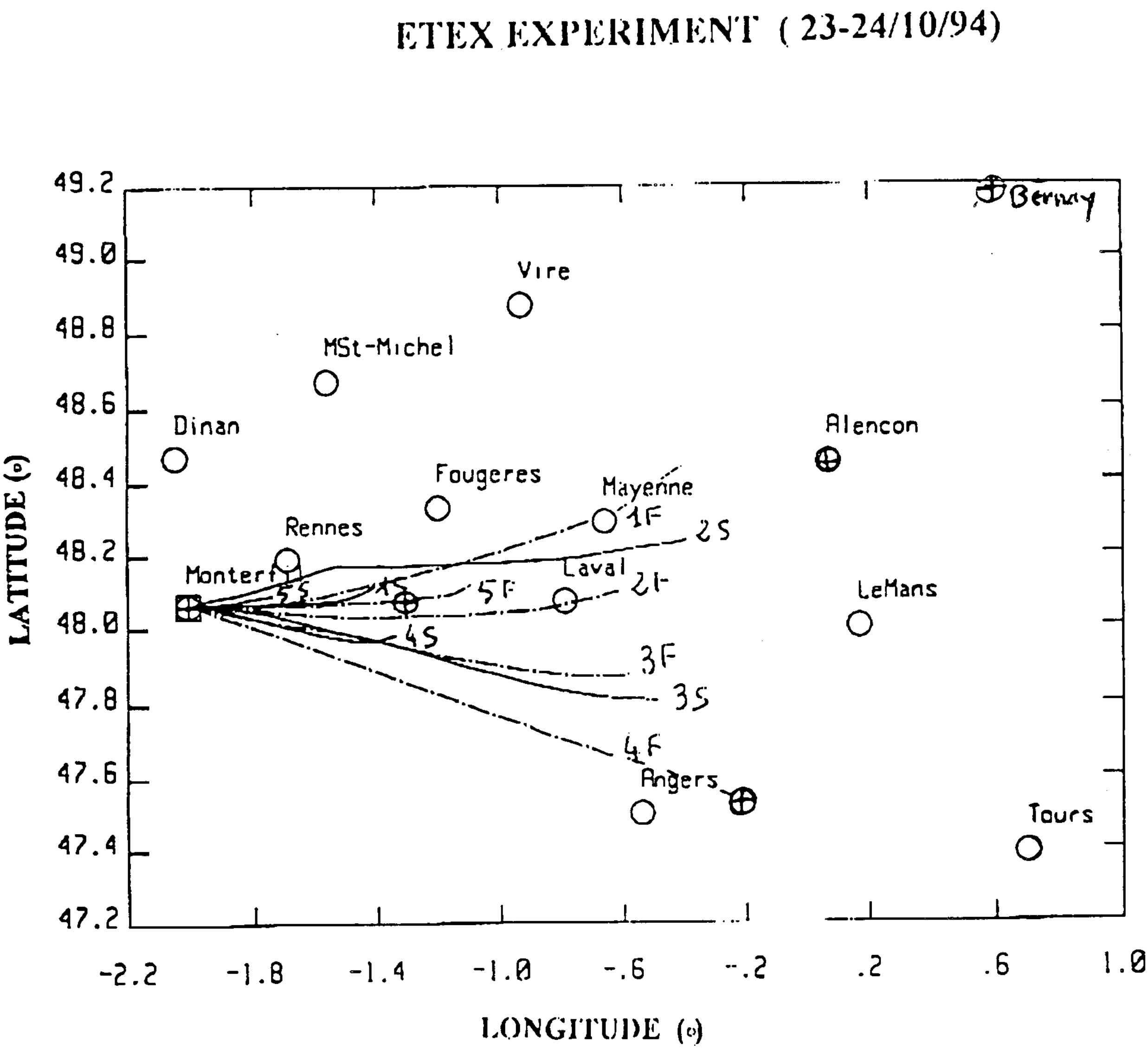


Figure 1.2. Horizontal trajectories of Swiss (continuous line) and French (dotted line) CVB given in latitude and longitude. See table 1 for CVB references. The location of some towns are also plotted. The location of the sites where the CVB 1F, 4F, 4S, 5S have been found are indicated ⊕.

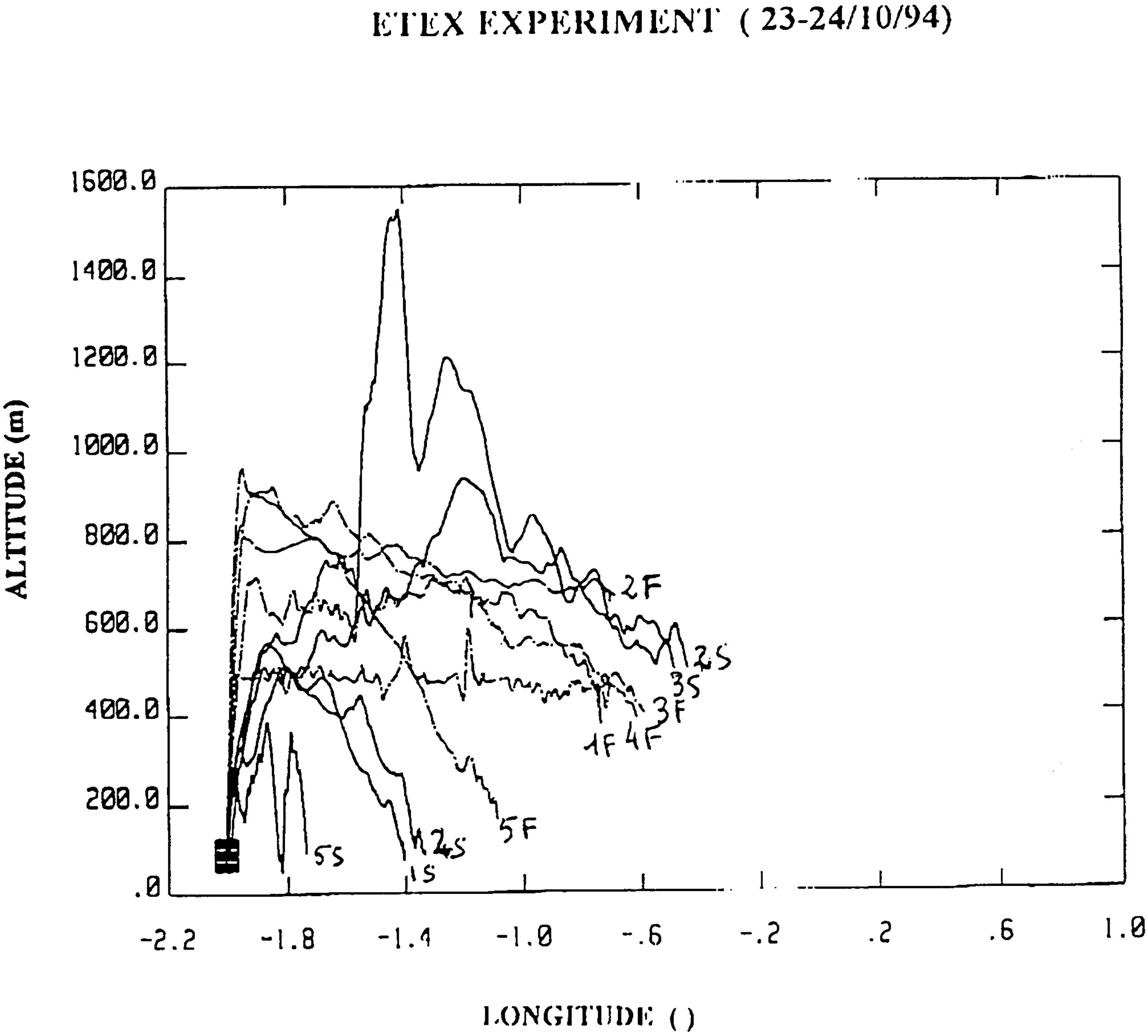


Figure 1.3. Vertical trajectories of Swiss and French CVB are plotted in altitude and longitude. See table 1 for CVB references.

2 ETEX-1 Tracer Measurements at Risø

Thomas Ellermann and Erik Lyck
National Environmental Research Institute
Department of Atmospheric Environment
Roskilde, Denmark

The tracers employed in ETEX were perfluorocarbon tracers; perfluoro-methyl-cyclohexane (PMCH) and perfluoro-methyl-cyclopentane (PMCP) in ETEX-1 and ETEX-2, respectively. The advantage of these tracers are that they are non-toxic, they have little or no wet and dry deposition, and that the atmospheric background concentrations are extremely low (about 0.004 pptv). Moreover, they can be detected down to very low concentrations, i.e. on the order of 0.001 pptv.

During the two campaigns we carried out measurements of the perfluorocarbon tracers outside and upwind of our laboratory at Risø, Roskilde, Denmark; - the coordinates of the sample position are 55°41.69'N and 12°05.37'E. The tracer concentrations of the air samples were analyzed by gas chromatography with electron capture detector, GC-ECD. Calibration of the gas chromatograph was carried out by employment of standard gas mixtures prepared on the basis of permeation tubes. The outdoor air samples were collected both by use of saran sample bags and ETEX sample tubes from Ispra. The saran bags were used to collect one hour mean air samples continuously throughout the campaigns. The ETEX sample tubes were employed to take 6 min. mean air samples collected once every hour. Thirty (30) liter of air samples were upconcentrated in each ETEX sample tube. The starting time for samples taken by both methods was every full hour. Figures 2.1 and 2.2 show typical chromatograms obtained by analysis of ambient air sampled by use of ETEX sample tubes and saran bags. The concentrations of ambient air were determined to 0.0053 and 0.0039 pptv for PMCH and PMCP, respectively, with an estimated uncertainty of ±25%. Our values agree with literature data (see Table 2.1) verifying that our analysis and air sample technique works satisfactorily.

Figure 2.3 shows chromatograms obtained at the arrival of the tracer cloud at Risø. The increase in the concentration of the tracer - PMCH - was clearly measured despite the very low concentration levels. Figure 2.4 shows the hourly mean concentrations of PMCH measured during ETEX-1. The passage of the tracer plume at Risø can easily be observed. The tracer cloud arrived - e.g. at a detectable level - 44 hours after start of the release and the passage took 20 hours. The tracer concentration varied considerable during the passage. Two peaks were observed with maxima of about 13 and 5 times the ambient concentration. This structure was observed both in the data from the saran bags and the ETEX sample tubes. After the passage of the tracer cloud the concentrations returned to the typical ambient concentration observed before the release.

The measurements carried out during ETEX-2 showed that the tracer cloud did not pass Risø.

Table 2.1. Concentrations in ambient air of three perfluorocarbon tracers.

Perfluorocarbon	Concentration 10^{-15} by volume	References[a]
PMCP, C_6F_{12}	2	Lovelock and Ferber, 1982
	3.22	Dietz, 1986
	3.9	This work, 1994
PMCH, C_7F_{14}	3.0	Heffter et al., 1980
	2	Lovelock and Ferber, 1982
	3.4	D'Ottavia et al., 1986
	4.46	Dietz, 1986
	5.3	This work, 1994
PDCH[b], C_8F_{16}	30	Heffter et al., 1980
	26	Lovelock and Ferber, 1982
	22	Dietz, 1986
	22	This work, 1994

a: J.E. Lovelock and G. Ferber, Atmos. Environ. Vol. 16, p 1467-1471, 1982; T.W. D'Ottavio, R.W. Goodrich, and R.N. Dietz, Environ. Sci. Technol., Vol. 20, p 100-104, 1986; J.L. Heffter, G.J. Ferber, and P.W. Krey, Proc. - Semin. Radioact. Releases Their Dispersion Atmos. Hypothetical React. Accid., CEC: Luxemburg, Vol. 2, p 953-69, 1980; R.N. Dietz, Perfluorcarbon tracer technology, in: Regional and Long-Range Transport of Air Pollution, lectures of a course held at the Joint Research centre, Ispra, Italy, S. Sandroni, ed., Elsevier Science Publishers B.V., Amsterdam.

b: PDCH: Perfluoro-dimethyl-cyclohexane. The values correspond to the sum of the isomers.

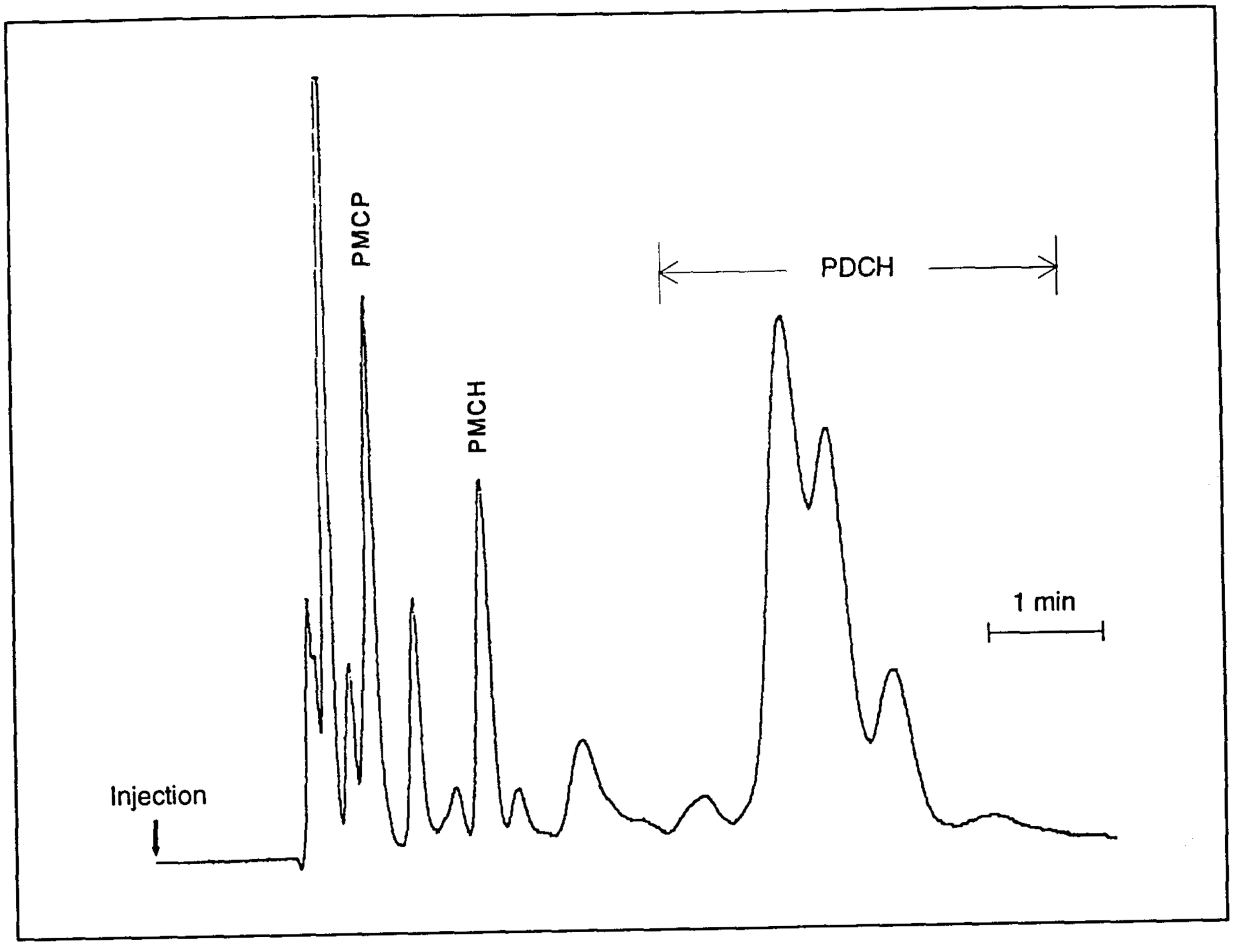


Figure 2.1. Typical chromatogram obtained by analysis of an ambient air sample collected by use of ETEX sample tubes (Ispra). The perfluorocarbon content of a large sample volume (30 litre) is upconcentrated in the sample tubes by absorption on 150 mg carboxen. The sample is collected by pulling air through the tube for a periode of 6 min. Note that perfluoro-dimethyl-cyclohexane (PDCH) have numerous isomers and hence give raise to 5 peaks in the chromatogram.

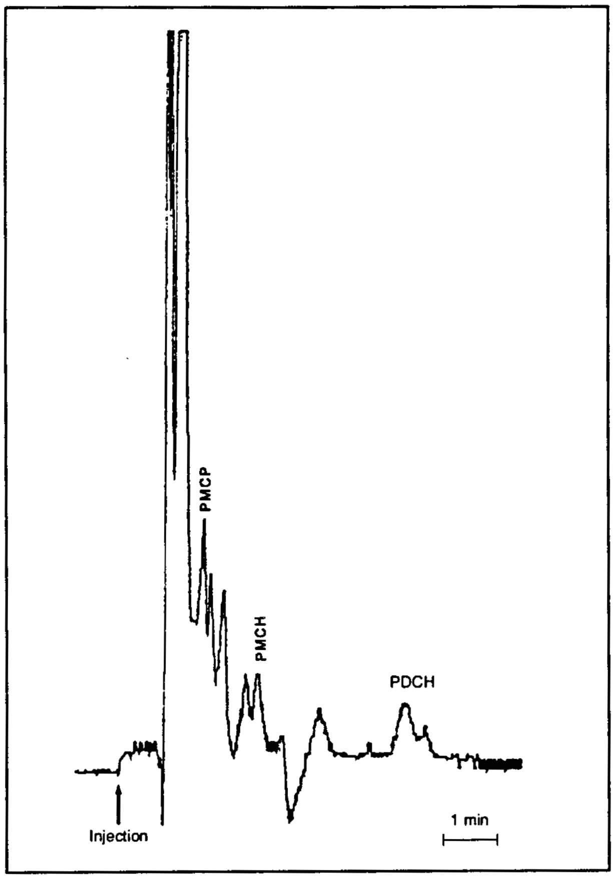


Figure 2.2. Typical chromatogram obtained by analysis of an air sample collected by use of a saran bag. The air volume analysed is 2.2 litre, which is sampled during a one hour periode using our SF_6 sample stations.

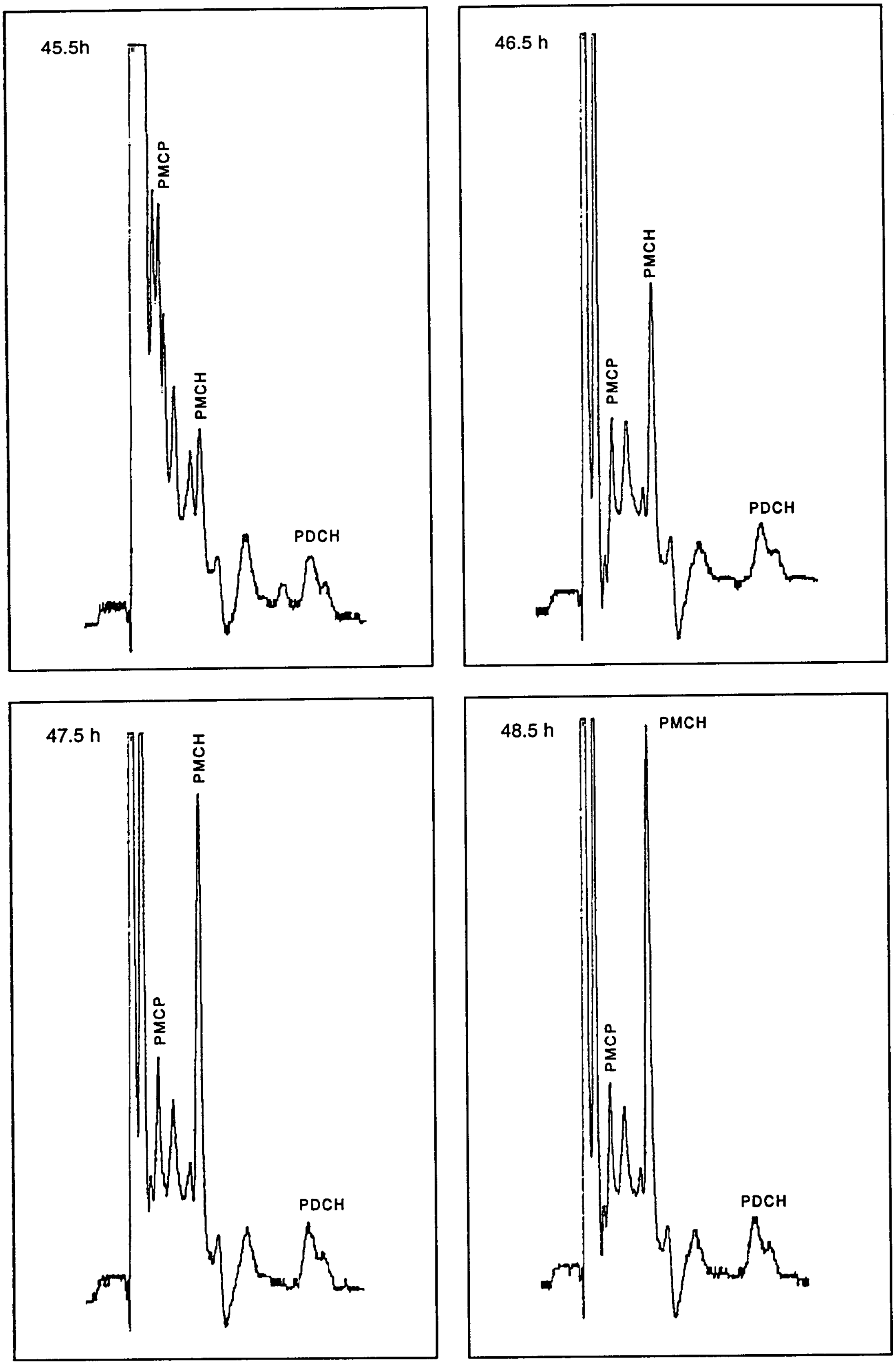


Figure 2.3. Chromatograms illustrating the steep increase of the tracer concentration (PMCH) at the arrival of the tracer cloud at Risø. The chromatograms are obtained by analysis of 1 hour mean air samples taken in saran bags. The time gives hours after the the start of the release. Note that the peak areas of PMCP and PDCH are constant indicating that the response of the GC-ECD is constant throughout the analyses.

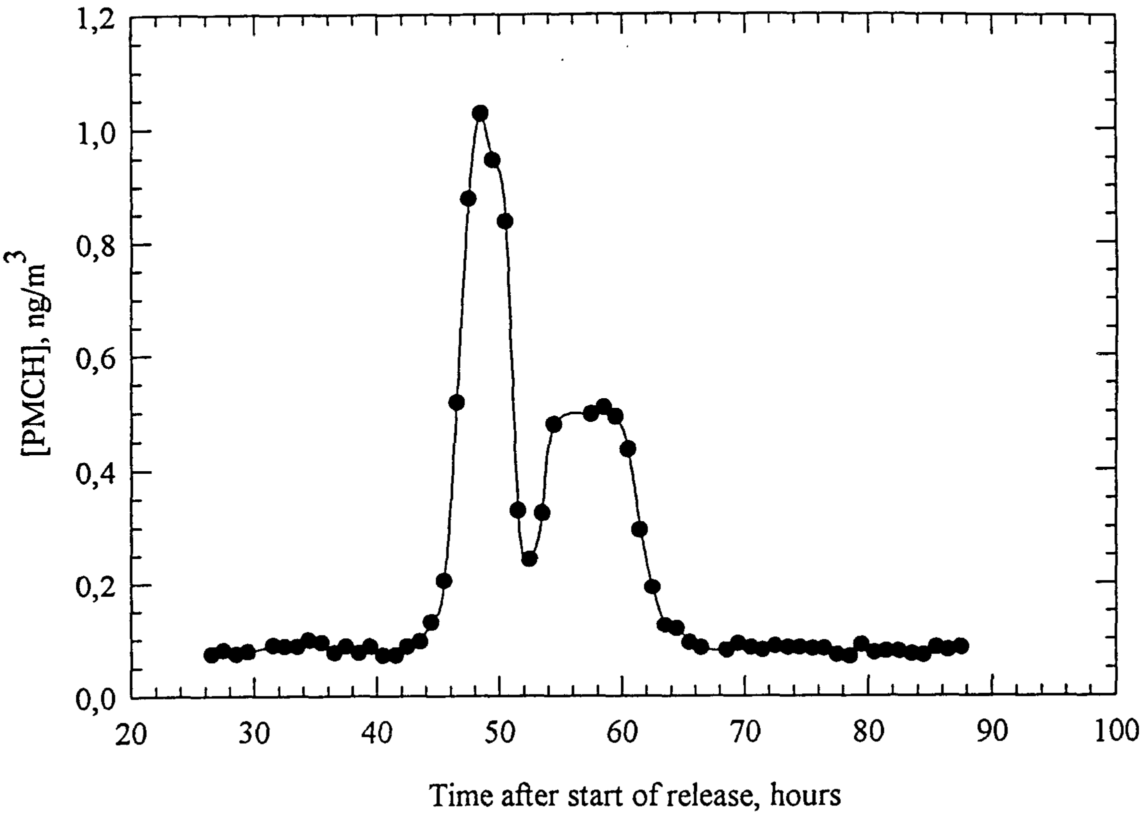


Figure 2.4. One hour mean concentrations measured during the passage of the tracer cloud at Risø during ETEX-1. Air samples collected by use of saran bags.

3 Calculations Performed by the Danish Meteorological Institute

Jens Havskov Sørensen and Alix Rasmussen
Danish Meteorological Institute (DMI)
Copenhagen
Denmark

The calculations by the Danish Meteorological Institute (DMI) were performed by using DMI's recently developed model DERMA (Danish Emergency Response Model for the Atmosphere). DERMA is a three-dimensional high-resolution atmospheric dispersion model based on a multi-level puff parametrisation. DERMA is utilising NWP data from e.g. the different versions of DMI-HIRLAM or from ECMWF.

DMI-HIRLAM

Analyses are prepared each 6 hours. Forecasts are available with a time resolution of 3 hours. Two versions cover the area of interest, DKV-HIRLAM and GRV-HIRLAM, cf. Fig. 3.1. The horizontal resolution and forecast length are given below.

	GRV-HIRLAM	DKV-HIRLAM
Horizontal resolution	46 km	23 km
Forecast length	48 hr	36 hr

The two versions of DMI-HIRLAM have the same vertical resolution with 31 sigma-pressure hybrid levels, cf. Fig. 3.2. To resolve a typical atmospheric boundary layer (ABL) of height 1.5 km, DMI-HIRLAM has 9 levels available.

Diffusion

For the ETEX simulations, the advection time step of DERMA was 15 minutes, which is a typical turn-over time for the large vertical eddies in the ABL. Thus, one may well assume that the released material is well mixed in the ABL within a few time steps. Correspondingly, an assumption of total mixing is employed.

In the model, the released particles (puff centres) are advected by the 3-D NWP wind. A puff is associated with each particle adding up to a total 3-D concentration field.

In the horizontal, a Gaussian distribution is assumed for each puff.

In the vertical, the assumption of total mixing is employed for puff centres inside the ABL. For puff centres above the ABL, a Gaussian distribution is assumed.

The height of the ABL is estimated by a bulk Richardson number approach with a prescribed critical number.

The 12-hour release was covered by about 1.000 puffs.

Model Results

In Figs. 3.3 and 3.4, the calculated surface concentrations are shown for the first ETEX release for every 12 hour from +12h to +108h after release start. These results are based on analysed DKV-HIRLAM data.

In Figs. 3.5 and 3.6, concentrations results for +24h, +48h and +60h after release start based on early forecasts are compared with results based on analysed DKV-HIRLAM data. According to the results based on analysed DKV-HIRLAM data, a south-easterly component of the plume develops. As it appears, this component is missing in the first forecast (Fig. 3.5 left), while the forecast from 12 hours later (Fig. 3.6 left), is showing this feature.

In Fig. 3.7, the instantaneous model concentrations at Risø are compared with the measured results by NERI. The double-peak structure of the measurements is not completely reflected by the model. The model results does, however, have an indication of a shoulder corresponding to the second peak. This figure may indicate that the horizontal diffusion used is too large. Inspection of the positions of the puff centres supports that improved agreement with the observed concentrations would result from using less horizontal diffusion.

In Fig. 3.8, a comparison is made between the doses (time integrated concentrations) based on observations (dashed curve) and the model results (full drawn).

In Figs. 3.9 and 3.10, the model results corresponding to the second ETEX release are shown. In this case, the plume never reached Denmark according to DERMA.

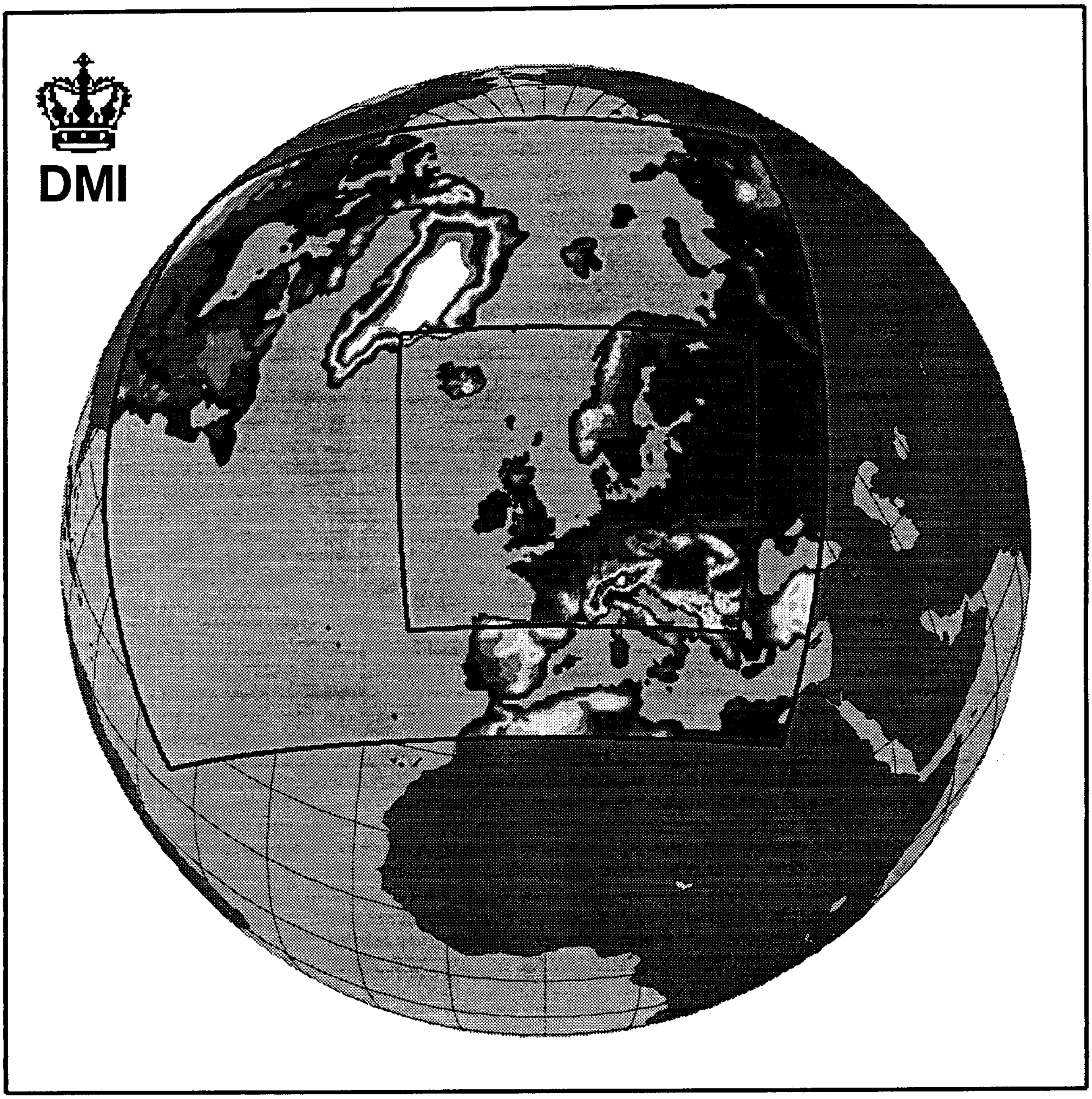
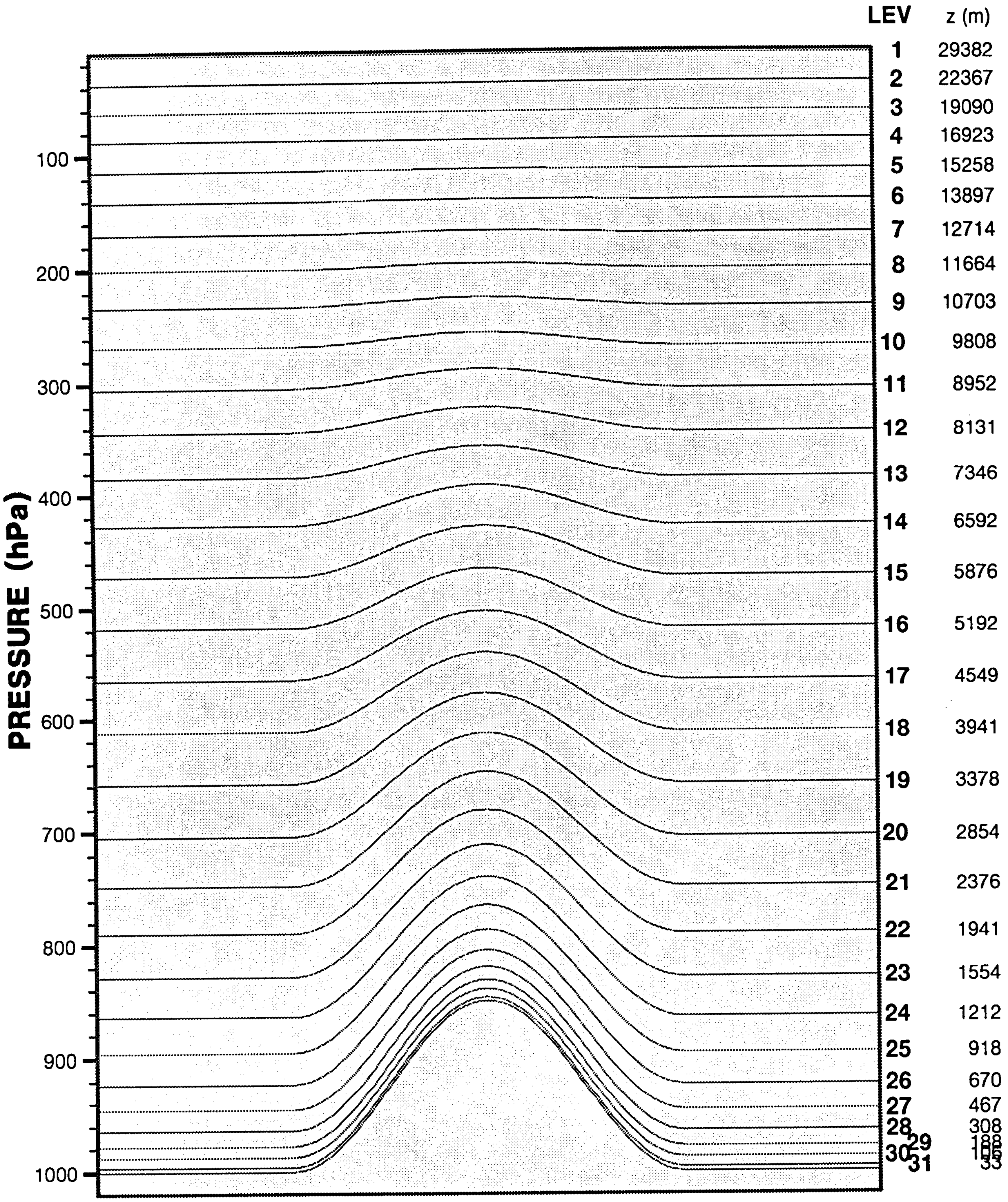


Figure 3.1.



Vertical resolution of the HIRLAM-2 system

Figure 3.2.

DMI

Simulation of First ETEX Release

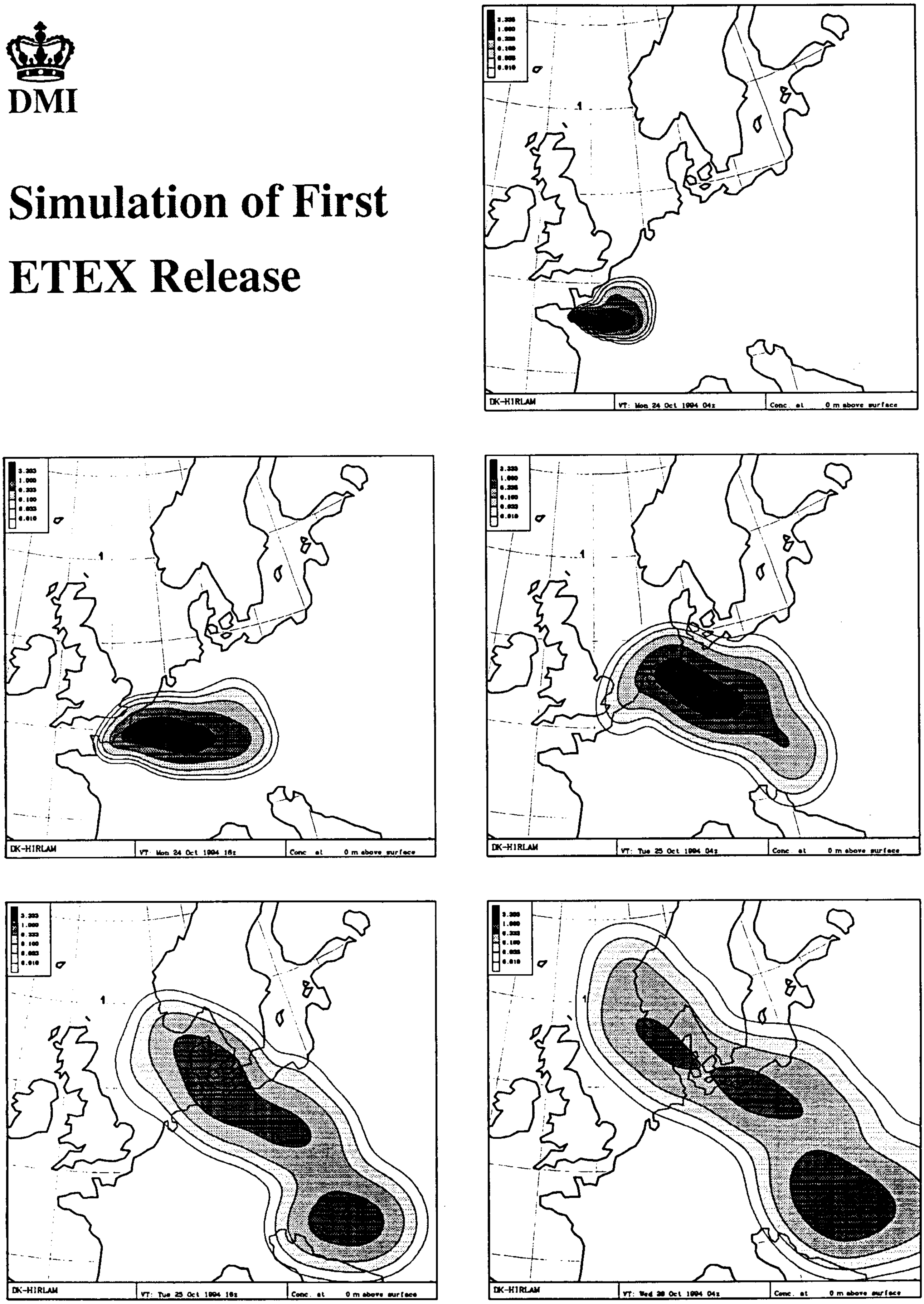
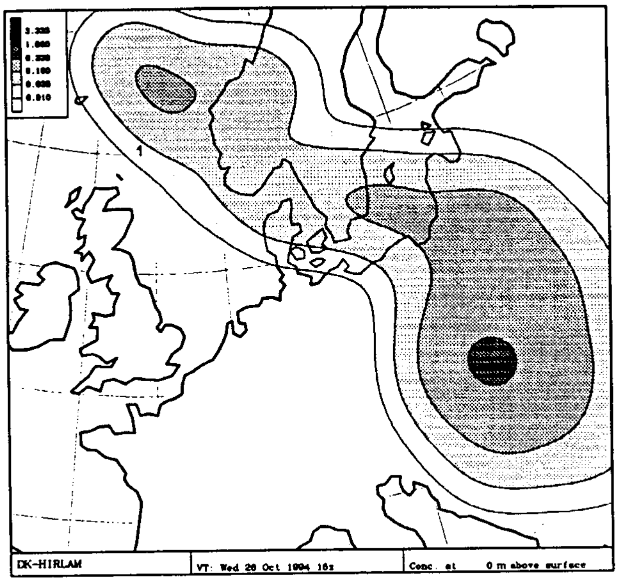
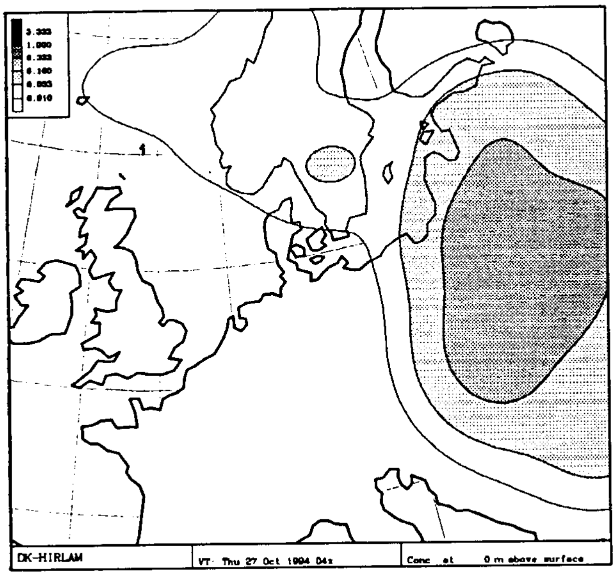


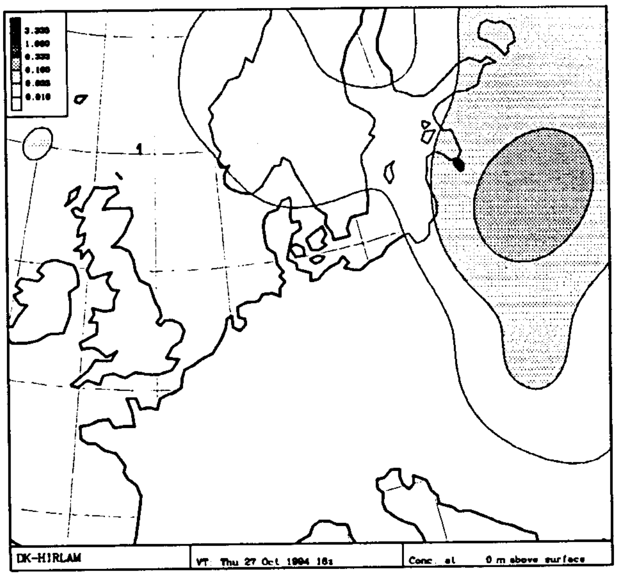
Figure 3.3.

DMI

Simulation of First ETEX Release







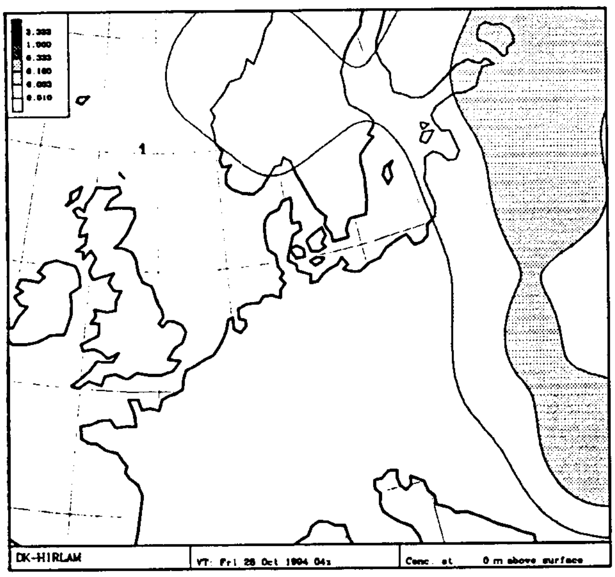


Figure 3.4.

First ETEX Release

DMI

Forecast

Initial Time: 94.10.23 12 UTC

Analysis

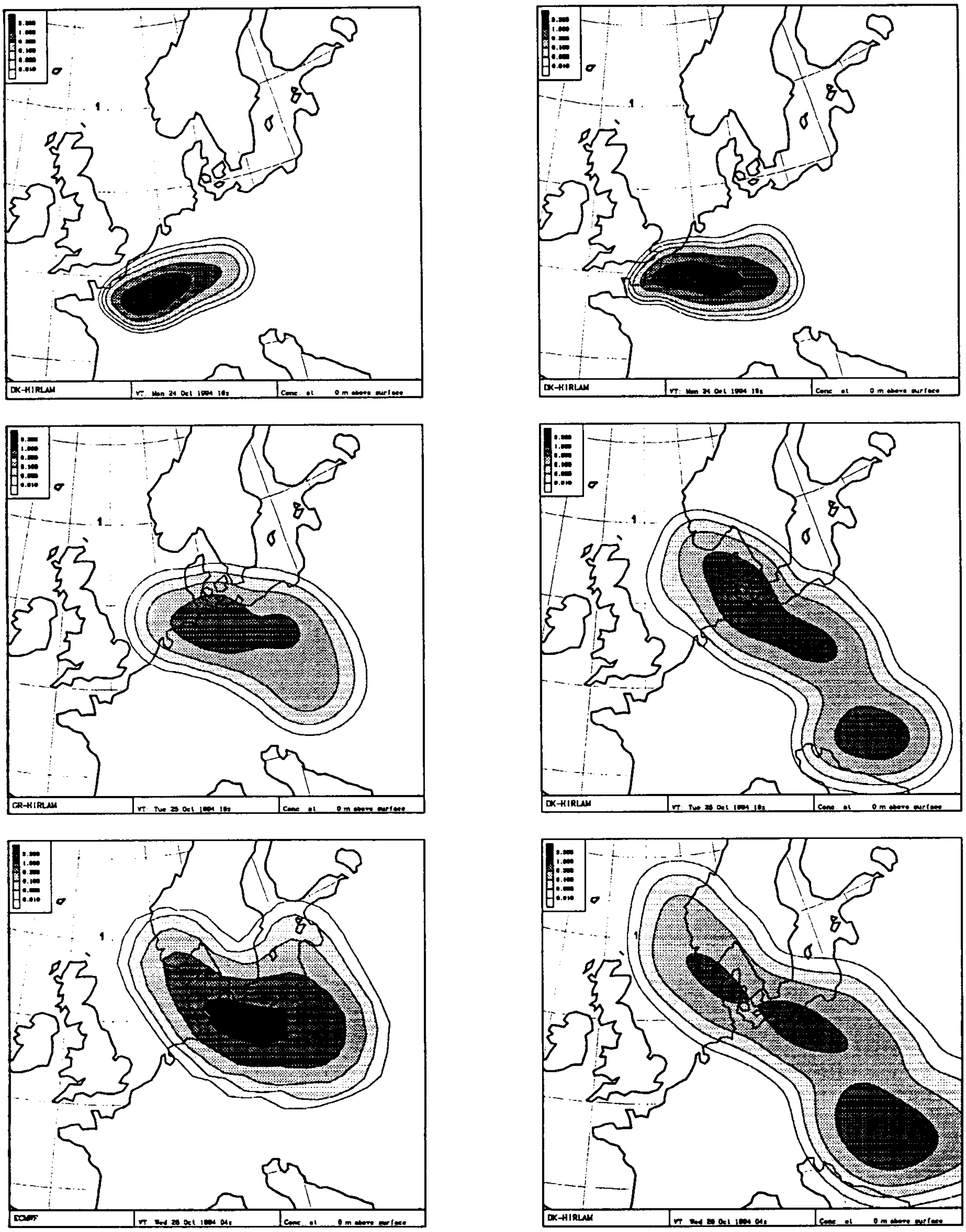


Figure 3.5.

First ETEX Release

DMI

Forecast

Analysis

Initial Time: 94.10.24 00 UTC

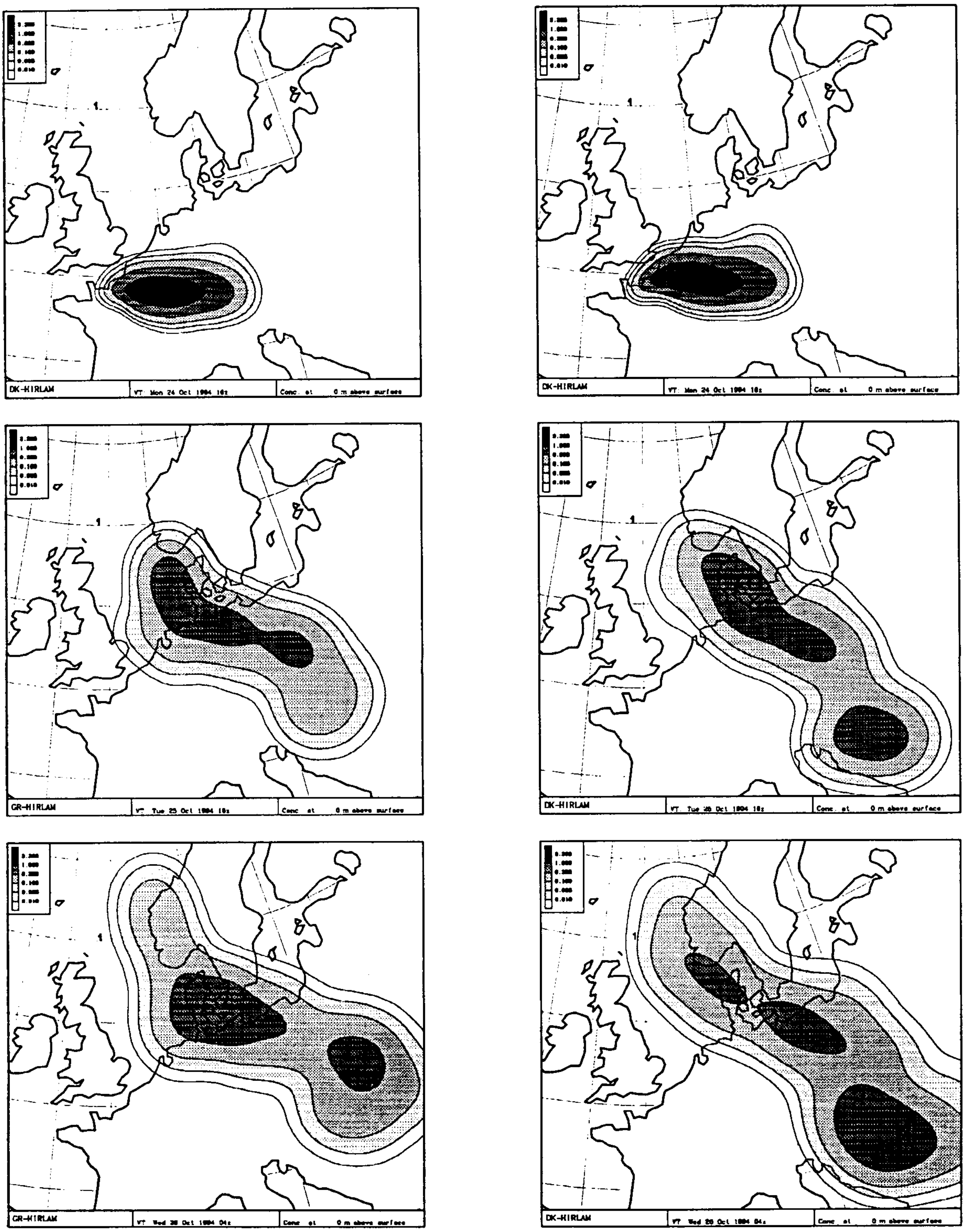


Figure 3.6.

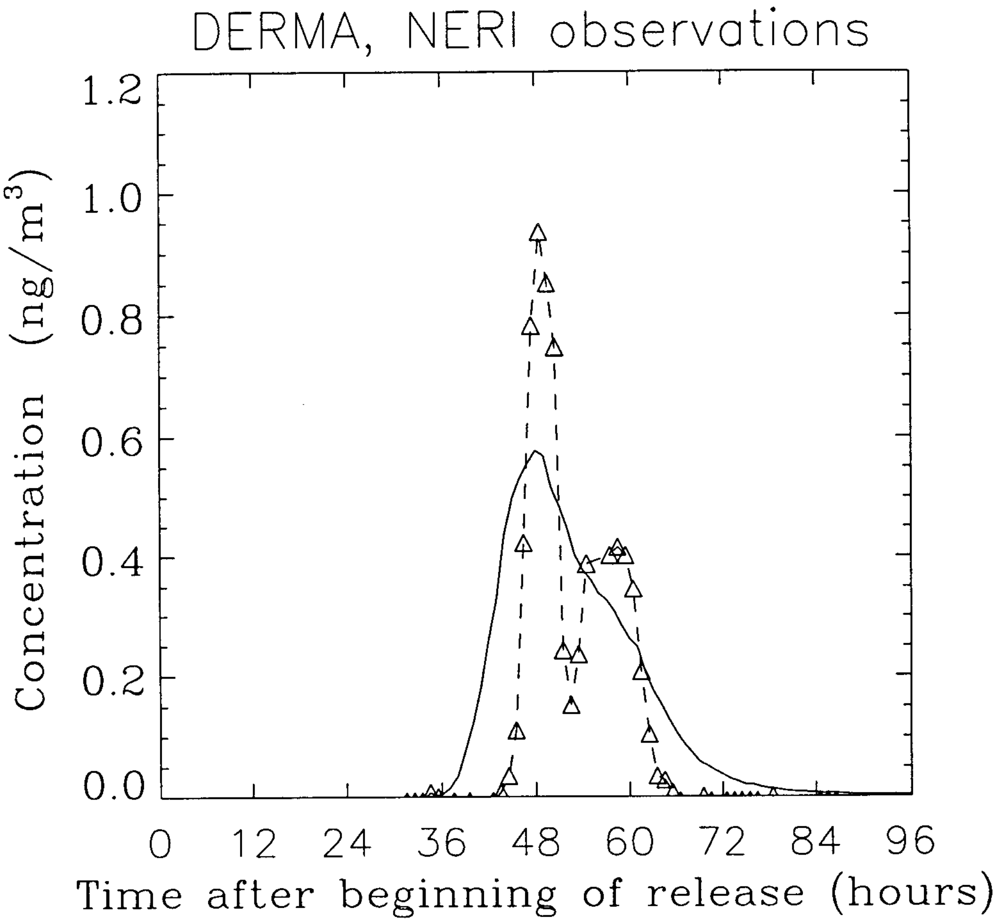

DERMA, NERI observations
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Concentration (ng/m³)
0 12 24 36 48 60 72 84 96
Time after beginning of release (hours)

Figure 3.7.

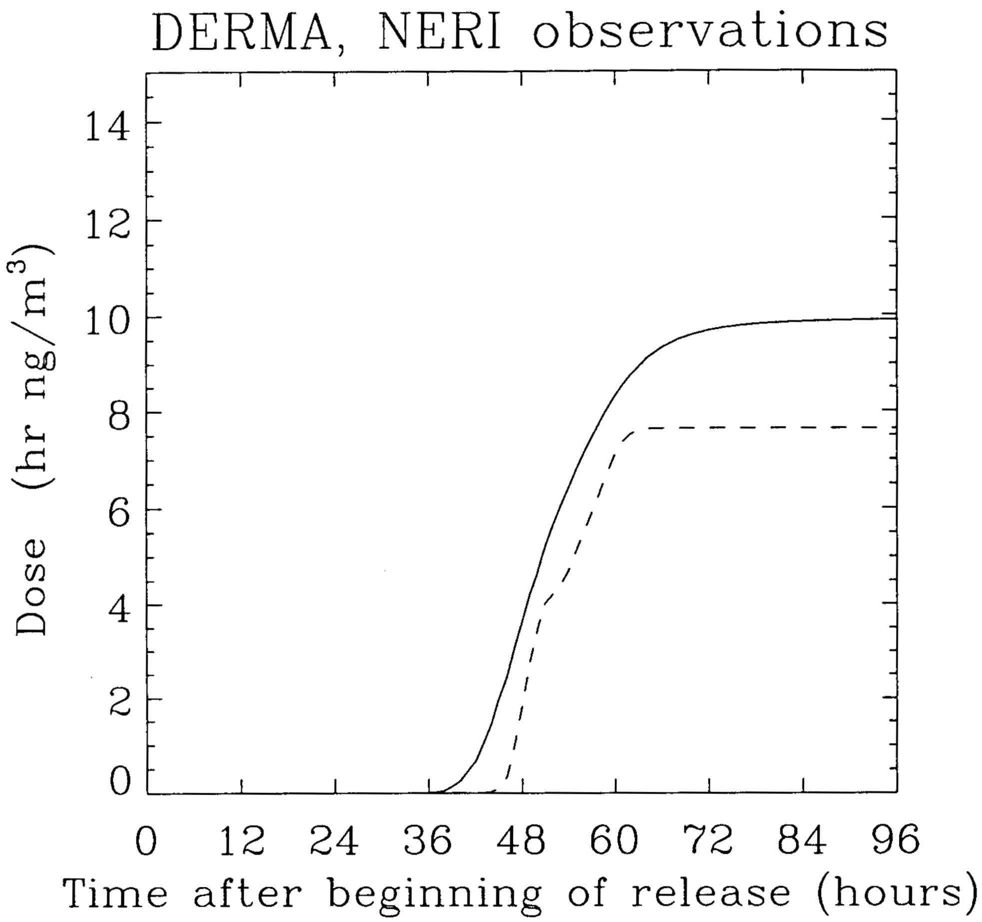
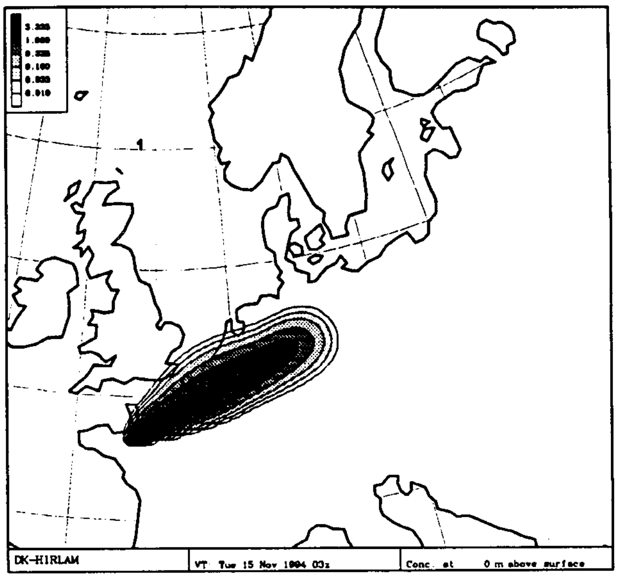
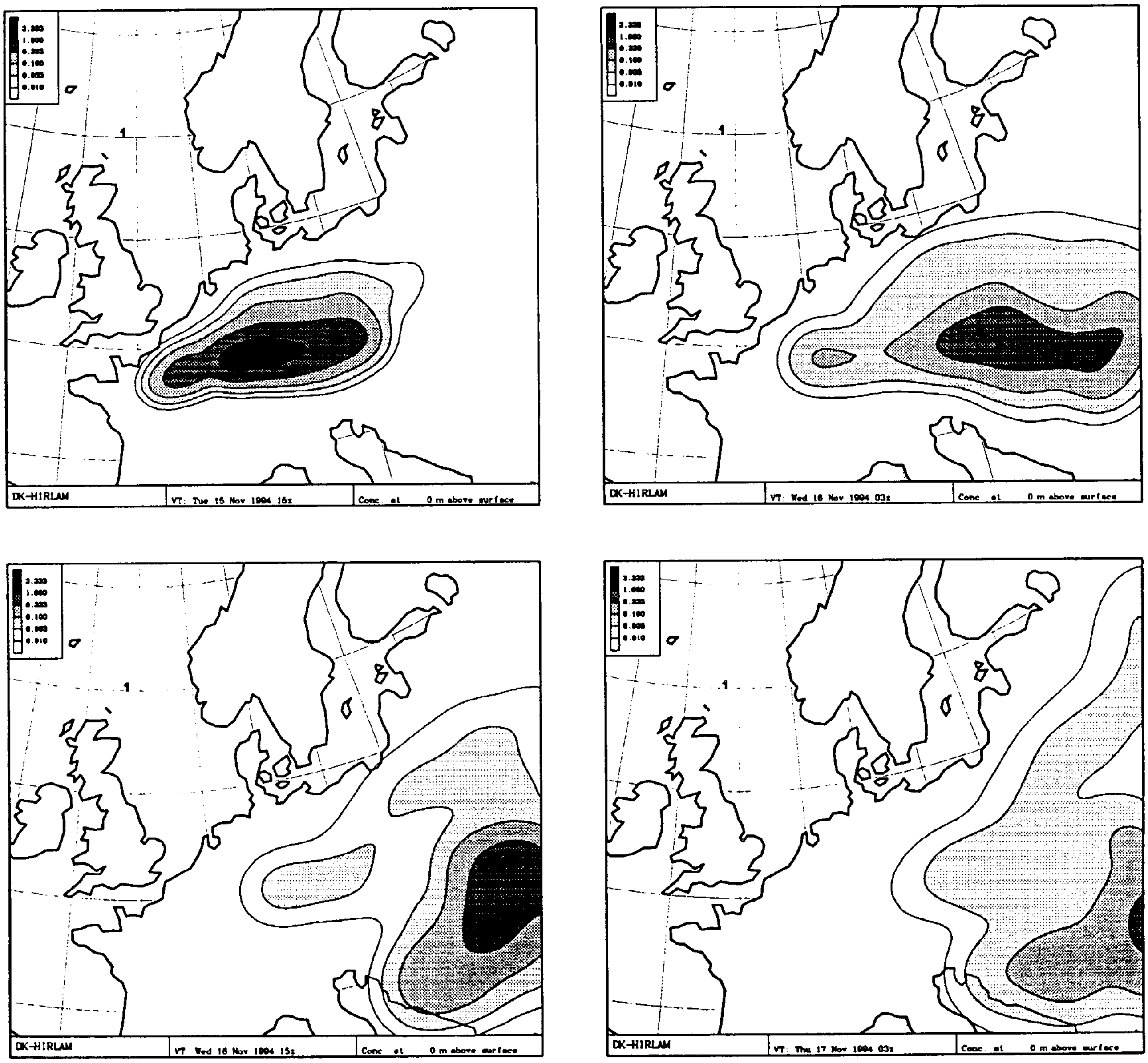

DERMA, NERI observations
Dose (hr ng/m3)
14
12
10
8
6
4
2
0
0
12
24
36
48
60
72
84
96
Time after beginning of release (hours)

Figure 3.8.

DMI

Simulation of Second ETEX Release

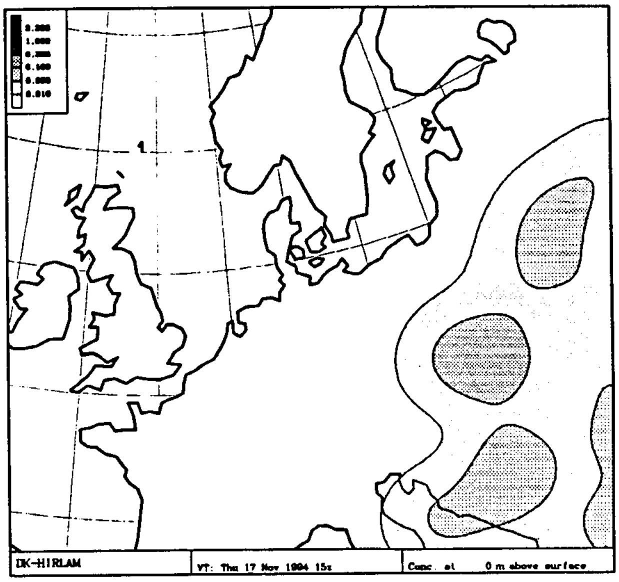




Figurer 3.9.

DMI

Simulation of Second ETEX Release



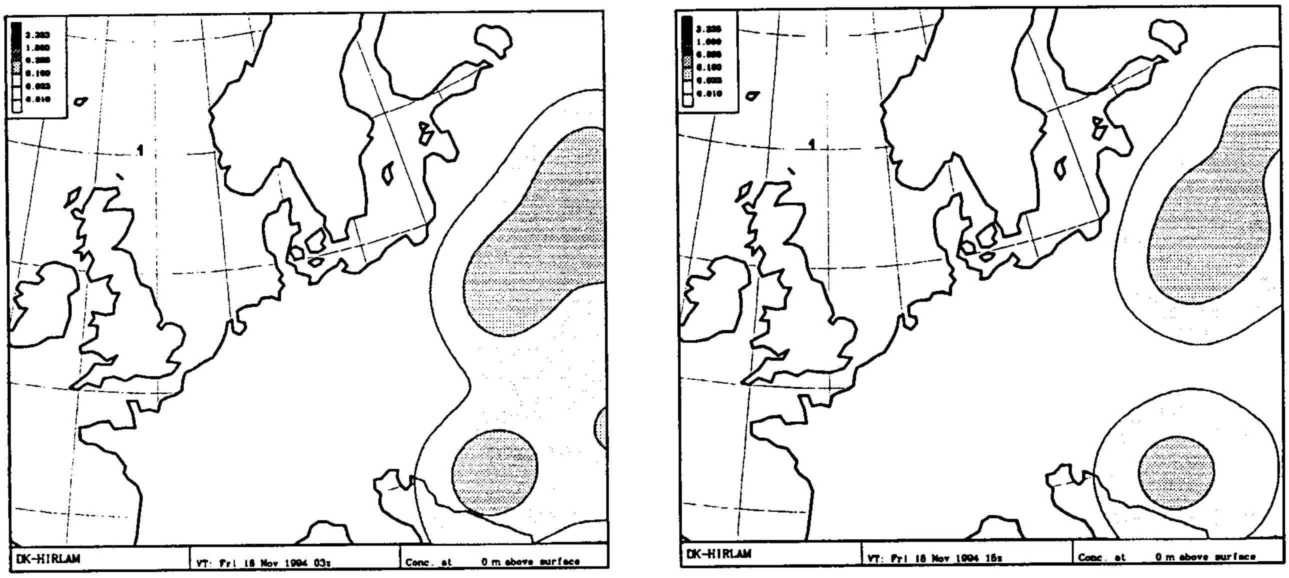


Figure 3.10.

4 Calculations Performed by the Swedish Meteorological and Hydrological Institute

Lennart Robertsson, Joakim Lagner and Christer Persson
Swedish Meteorological and Hydrological Institute (SMHI)
Norrköping, Sweden

The calculations from SMHI were performed with the model MATCH. This is a 3D Eulerian gridpoint model.

The model is adaptive to any specific weather data used. In this exercise HIRLAM data is used, and thus is the vertical and horizontal resolution identical with the HIRLAM hybrid vertical coordinates, and the rotated latitude grid. The transport accounts for the vertical diffusion, 3D advection and vertical pumping due to surface pressure tendencies. The horizontal advection is determined by the means of an integrated flux scheme (Bott, 1989). A particle model is used for initialization of point sources. The model version used in these calculations is still on the developing stage.

Figure 4.1 shows the vertical structure and the horizontal grid.

The SMHI prediction of the ETEX plume has a shape different (Figures 4.2 and 4.3) from the Danish predictions, as it has a distinct horseshoe shape when it is over Northern Germany. The horseshoe shape of tthe cloud has been caught by other models presented at the ETEX meeting in Prague (24-26 Oct., 1996). A reading from a Belgian station (also presented in Prague) confirms that the station is hit twice.

The spread in the lateral direction is much smaller at this point than in the Danish predictions, but more similar when it reaches the Denmark-Sweden area. There is a very definite breakup in two plumes following each other, which then move on in different directions.

The arrival time in Risø, as can be seen from Figure 4.4, is around 35 hours. The concentration in this part of the plume, however, is below the tracer gas detection level 0.10 ng/m^3 of PMCH. The results in Figure 4.4 show that the concentration exceeds this detection level from 45 hours after release.

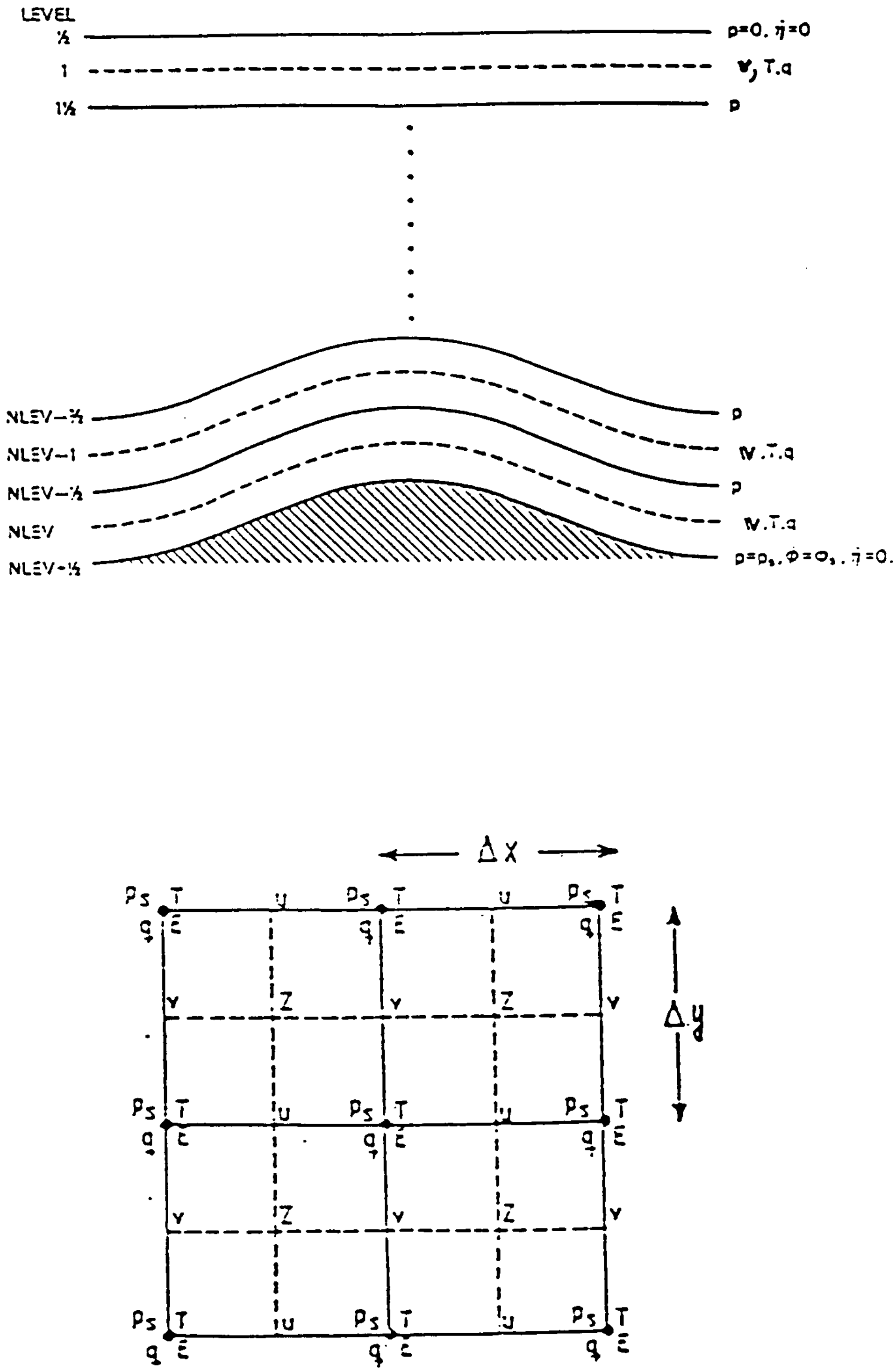


Figure 4.1. Vertical structure and horizontal grid of the HIRLAM LEVEL 1 limited area model.

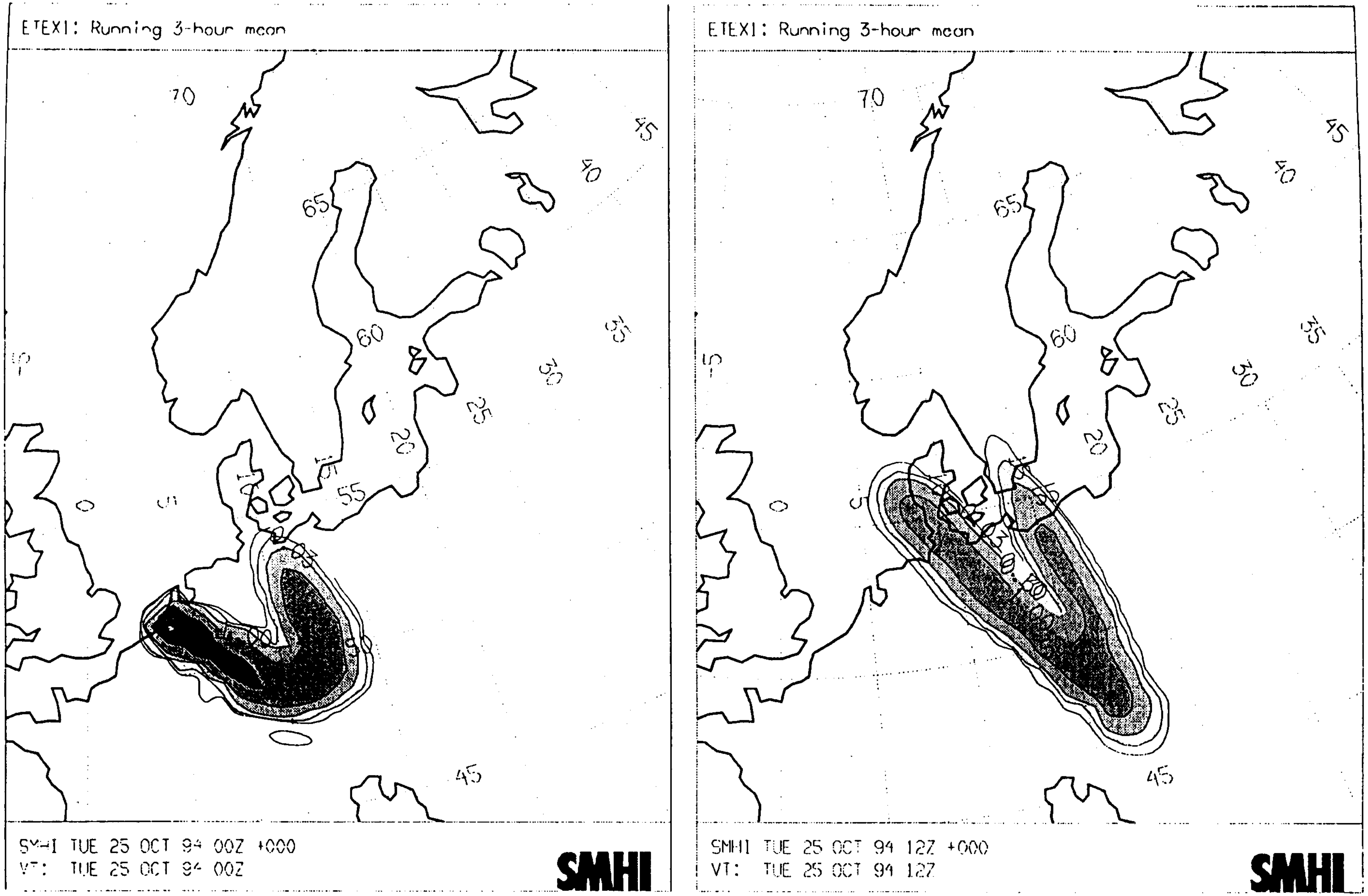

ETEX1: Running 3-hour mean
SMHI TUE 25 OCT 94 00Z +000
VT: TUE 25 OCT 94 00Z
SMHI
ETEX1: Running 3-hour mean
SMHI TUE 25 OCT 94 12Z +000
VT: TUE 25 OCT 94 12Z
SMHI

Figure 4.2.

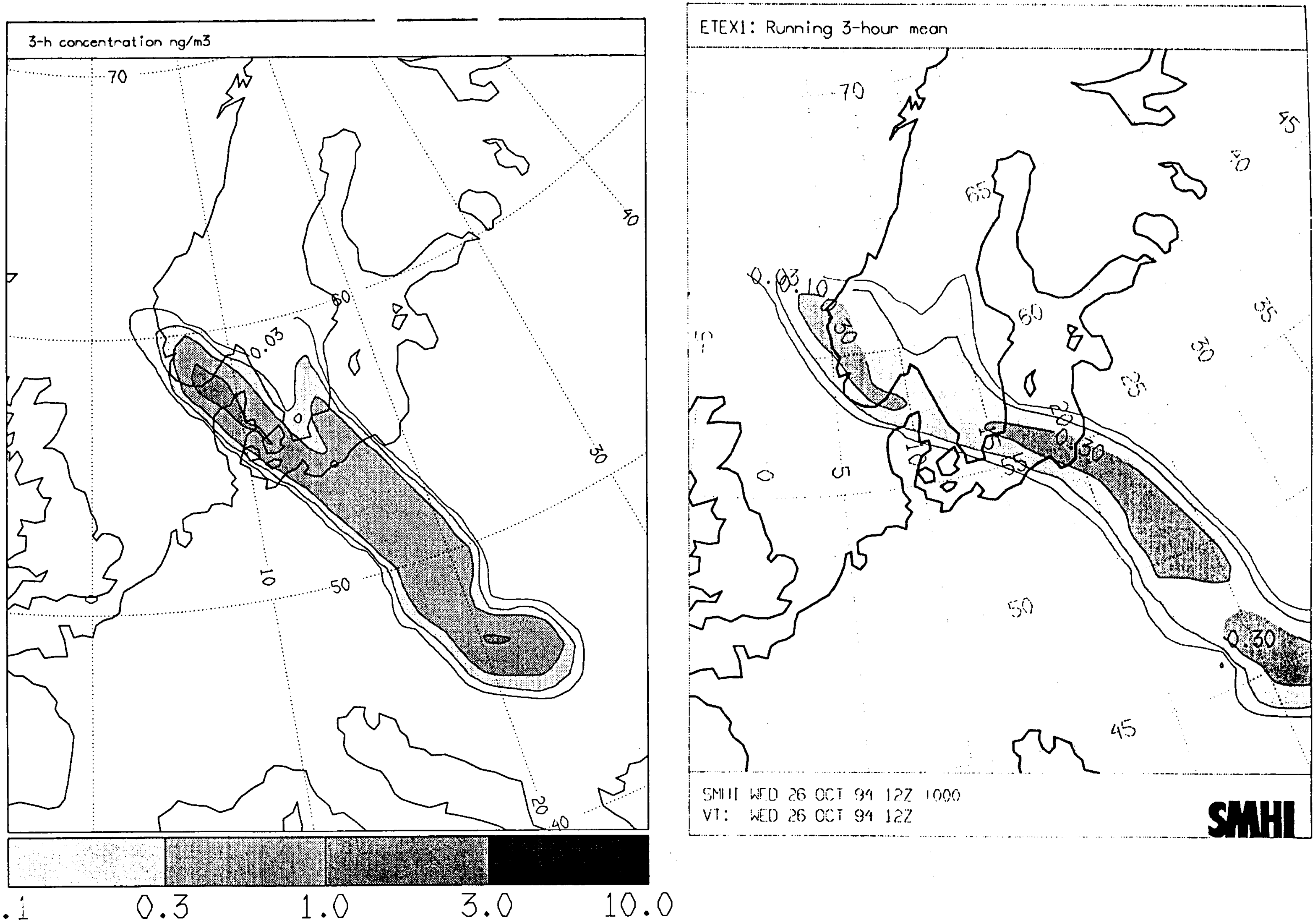

3-h concentration ng/m3
70
60
50
40
30
20
10
0.03
.1
0.3
1.0
3.0
10.0
ETEX1: Running 3-hour mean
SMHI WED 26 OCT 94 12Z 1000
VT: WED 26 OCT 94 12Z
SMHI
0.03
0.10
0.30
65
60
55
50
45
40
35
30
25
20
15
10
5
0

Figure 4.3.

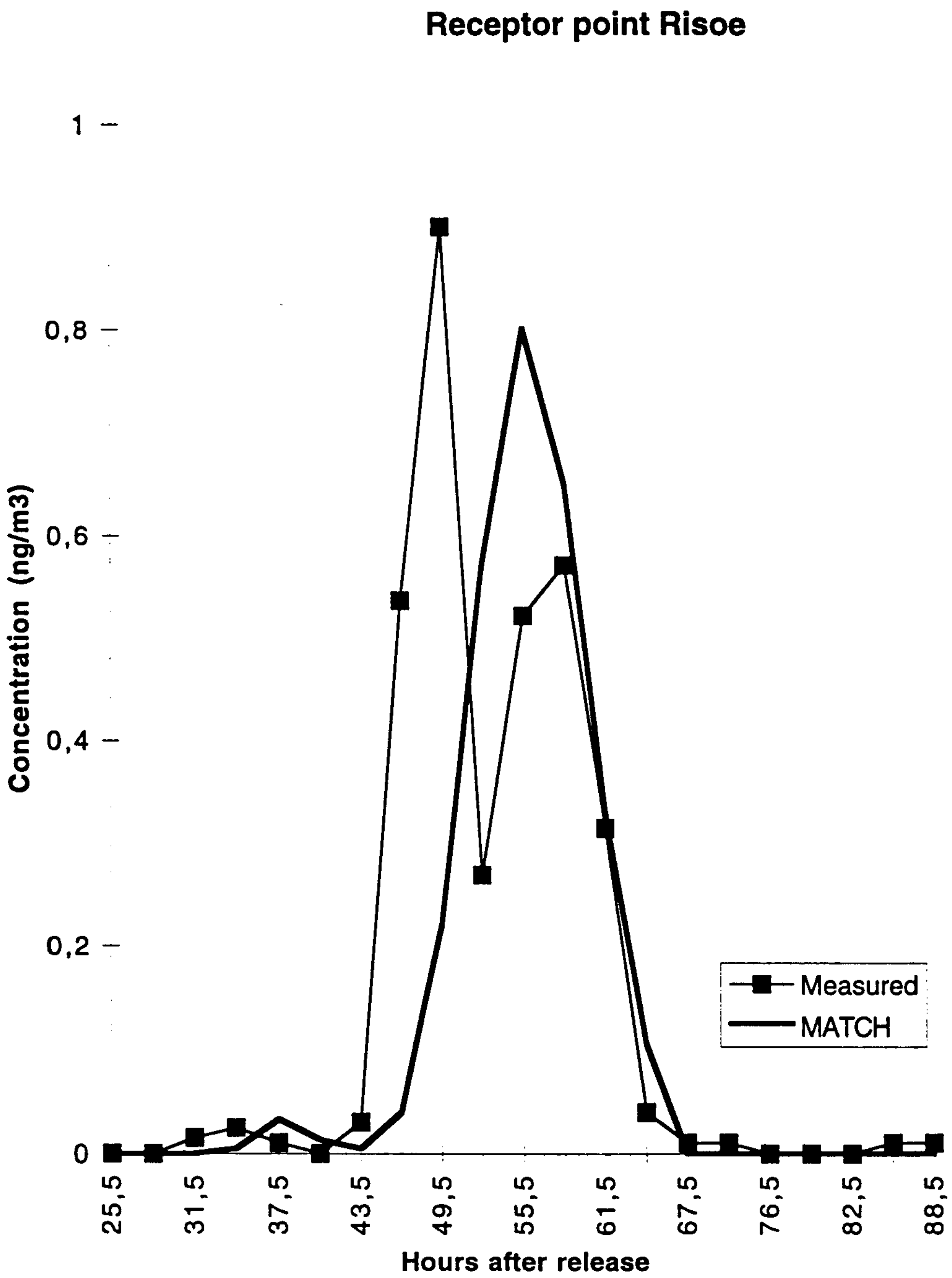

Receptor point Risoe
1
0,8
0,6
0,4
0,2
0
Concentration (ng/m3)
Measured
MATCH
25,5
31,5
37,5
43,5
49,5
55,5
61,5
67,5
76,5
82,5
88,5
Hours after release

Figure 4.4.

5 Using a Combination of Two Models for Calculations Performed by the National or Tracer Simulations. Environmental Research Institute (DMU) and Risø National Laboratory

Jørgen Brandt
Risø National Laboratory and the National Environmental Research Institute
Z. Zlatev
National Environmental Research Institute, Denmark
Torben Mikkelsen and Søren Thykier-Nielsen
Risø National Laboratory, Denmark

The model is a combination of the Danish Eulerian Model and RIMPUFF. The new combined model is called DREAM (the Danish Rimpuff and Eulerian Accidental release Model). The present version of the model is two-dimensional and there is no parameterization of wet and dry deposition and the mixing height is set constant. Discretizations and space domains of the model are given in Table 5.1. The main principles of the coupling between the two models is shown in Table 5.2. In task two shown in the table (the coupling procedure) the single puffs from RIMPUFF are incorporated individually into the Danish Eulerian Model when the puffs reach the boundary of the sub-domain. The combined model has been tested by the well-known rotation test, which gives good numerical results. Problems with oscillations from the sharp gradient of the single source have been eliminated.

Validation calculations on Chernobyl data have been performed, and a couple of these results are included here. Figures 5.1 and 5.2 show the simulated air concentrations at the 850 hPa level of Cs-137 three and six days after start of the release, respectively. Comparison of calculations and measurements at two stations is given in Figure 5.14. The results are very good for Ispra, but some of the calculations for Cassaccia show too high concentrations. There is, however, no deposition in the model. The meteorological input data and measurements were provided by Adolf Ebel and Heinz Hass, Institute of Geophysics and Meteorology at the University of Cologne.

ETEX calculations at the 925 hPa level are shown in Figures 5.3 to 5.7 (ETEX-1) and Figures 5.8 to 5.11 (ETEX-2). The ETEX-1-results do not show the lateral spread found in the other predictions, explained by the fact that two-dimensional models can not simulate dispersion due to vertical wind shear. This is emphasized in Figure 5.12 (ETEX-1), which shows calculations performed at the 1000 hPa level. Figure 5.12 should be compared to Figure 5.6. The simulations of ETEX-2 show that the plume spreads very long in the wind direction and moves very fast. It does not reach Denmark. Meteorological input data for the two ETEX-releases were provided by Real d'Amours, Canadian Meteorological Centre. Figure 5.13 shows calculated and measured concentrations at Risø. Both the arrival time and the duration for the cloud passage is very good, but the model does not resolve the two peaks.

Below follows a list of future plans for further developments of the DREAM model. Extending the model to three dimensions and physical parameterization are important aspects.

1. Improvements of the physical mechanisms used in the coupled model.
   - Diffusion in both models
   - Dry and wet deposition
   - Mixing height
   - Radioactive decay
   - Etc.
2. More precise estimation of the source term (Chernobyl).
3. Further experiments with Chernobyl and ETEX data and further comparison of model results with measurements.
4. Three-dimensional version of the model (essential).
   - Estimation of vertical velocities
   - Vertical diffusion (stability)
5. Preparation of the model for operational (prognostic) use. Real-time runs.
6. A coupling with the meso-scale model MM5 for improvement of the meteorological input data.

Table 5.1.

Discretizations and space domains of the models.

RIMPUFF is at the location of the source, with the source in the centre.

The Danish Eulerian Model covers all or parts of Europe.

Parameters	RIMOPUFF	Danish Eulerian Model
Area	325 × 325 km	4800 × 4800 km (2800 × 2800 km)
Configuration	65 × 65	192 × 192 (112 × 112)
Number of grid-squares	4225	36864 (12544)
Size of a grid-square	5 km × 5 km	25 km × 25 km

25 small grid-squares in the RIUMPUFF discretization correspond to one big grid-square in the Danish Eulerian Model discretization.

Table 5.2.

Main principles used in the combination of the two models.

At every time-step the following tasks are successively performed:

Task	Action during the task
Task 1: RIMPUFF in action	Compute the contributions for the small area by RIMPUFF
Task 2: Coupling procedure	Incorporate the contributions into the large area of the Danish Eulerian Model.
Task 3: The Danish Eulerian Model in action	Calculate the changes of concentrations in the large area by the Danish Eulerian Model.

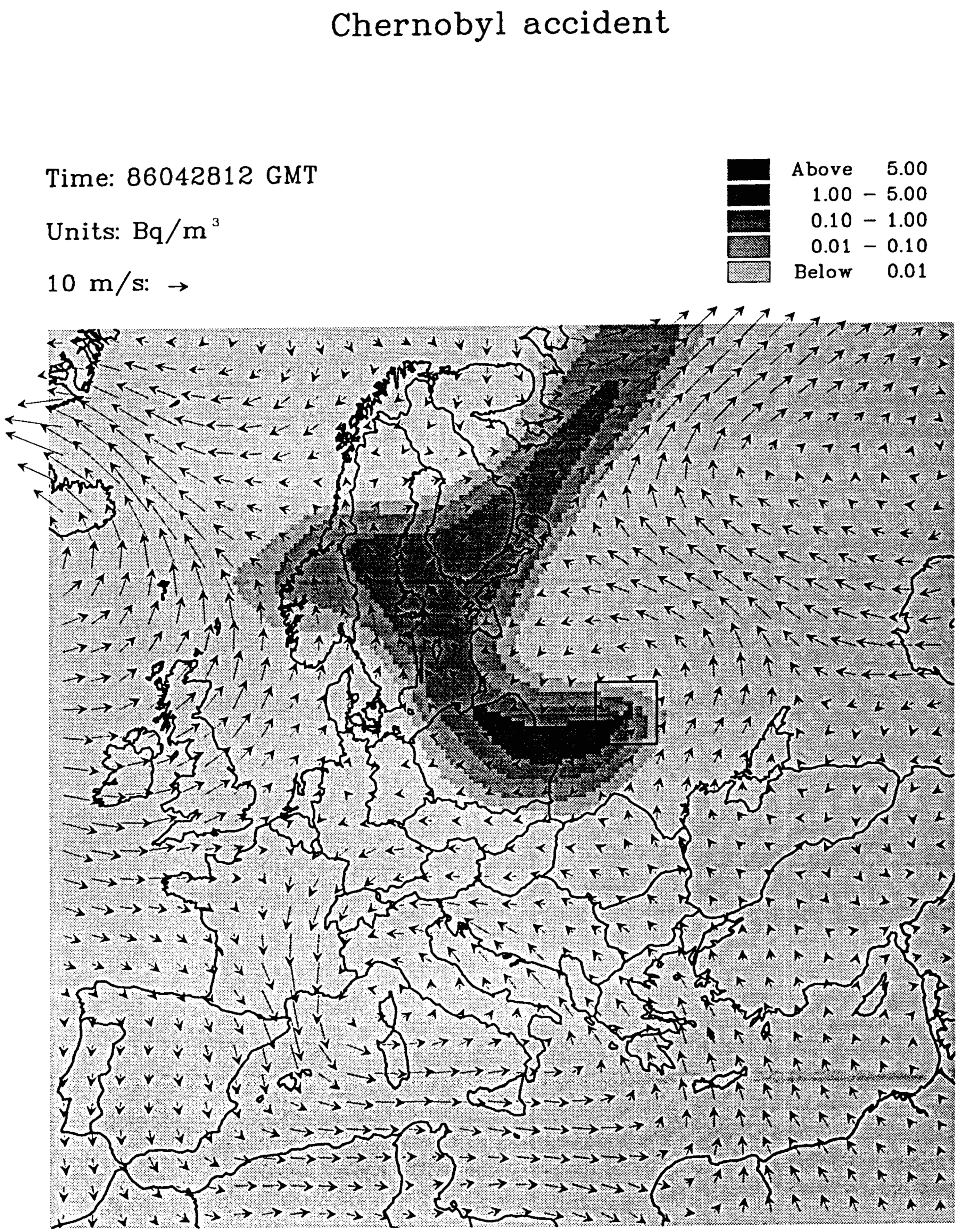

Chernobyl accident
Time: 86042812 GMT
Units: Bq/m³
10 m/s: →
Above 5.00
1.00 – 5.00
0.10 – 1.00
0.01 – 0.10
Below 0.01

Figure 5.1.

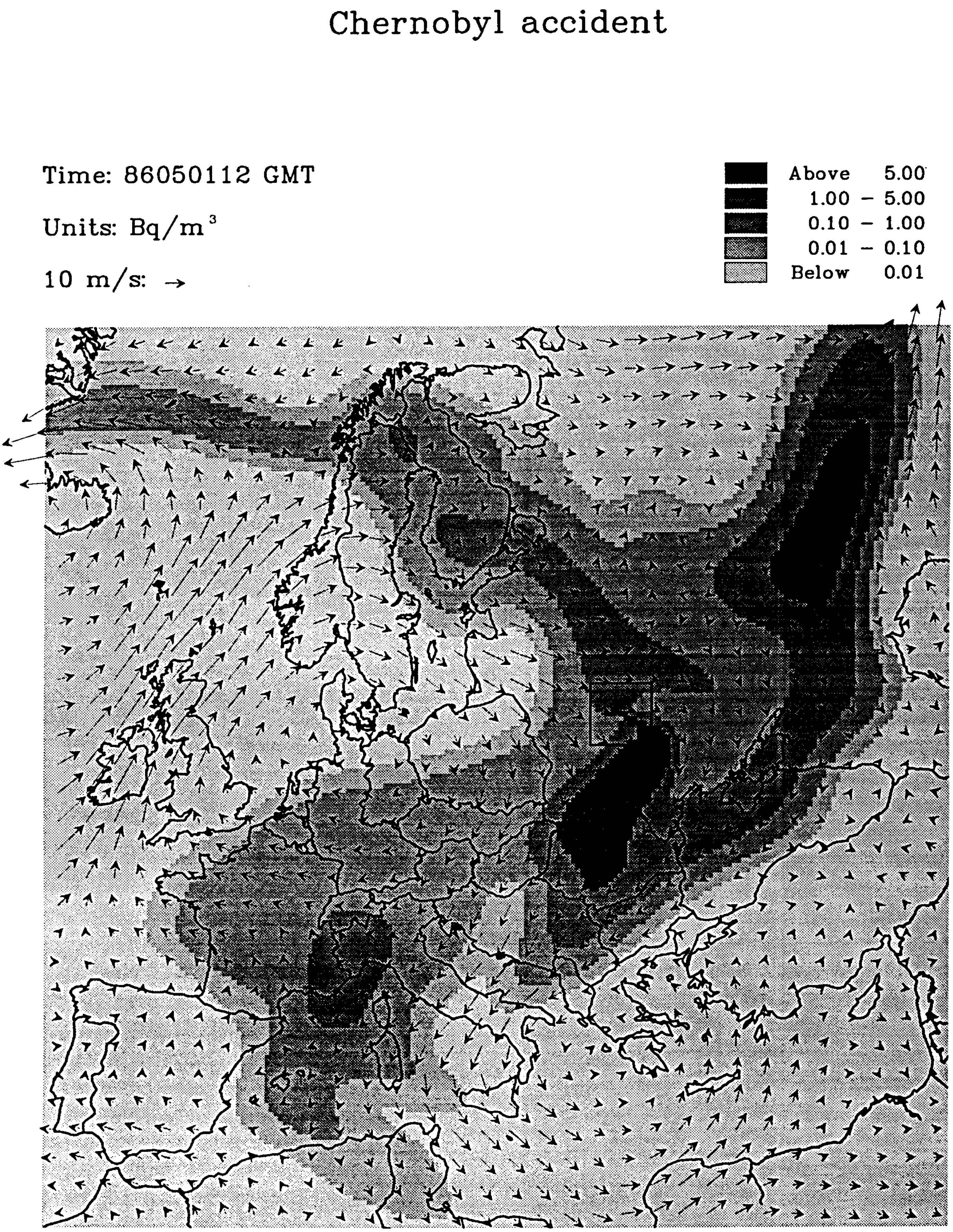

Chernobyl accident
Time: 86050112 GMT
Units: Bq/m³
10 m/s: →
Above 5.00
1.00 – 5.00
0.10 – 1.00
0.01 – 0.10
Below 0.01

Figure 5.2.

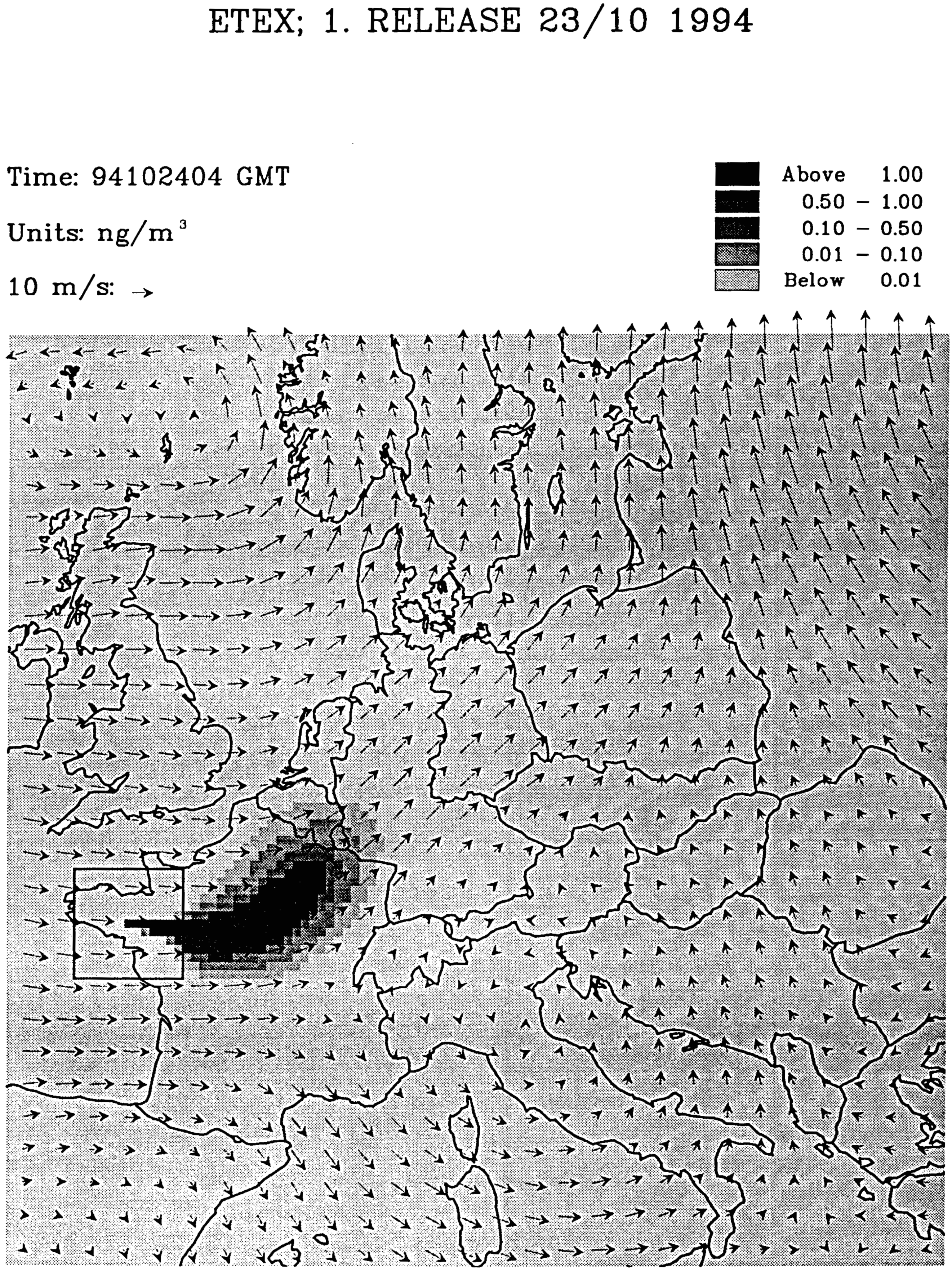

ETEX; 1. RELEASE 23/10 1994
Time: 94102404 GMT
Units: ng/m³
10 m/s: →
Above 1.00
0.50 – 1.00
0.10 – 0.50
0.01 – 0.10
Below 0.01

Figure 5.3.

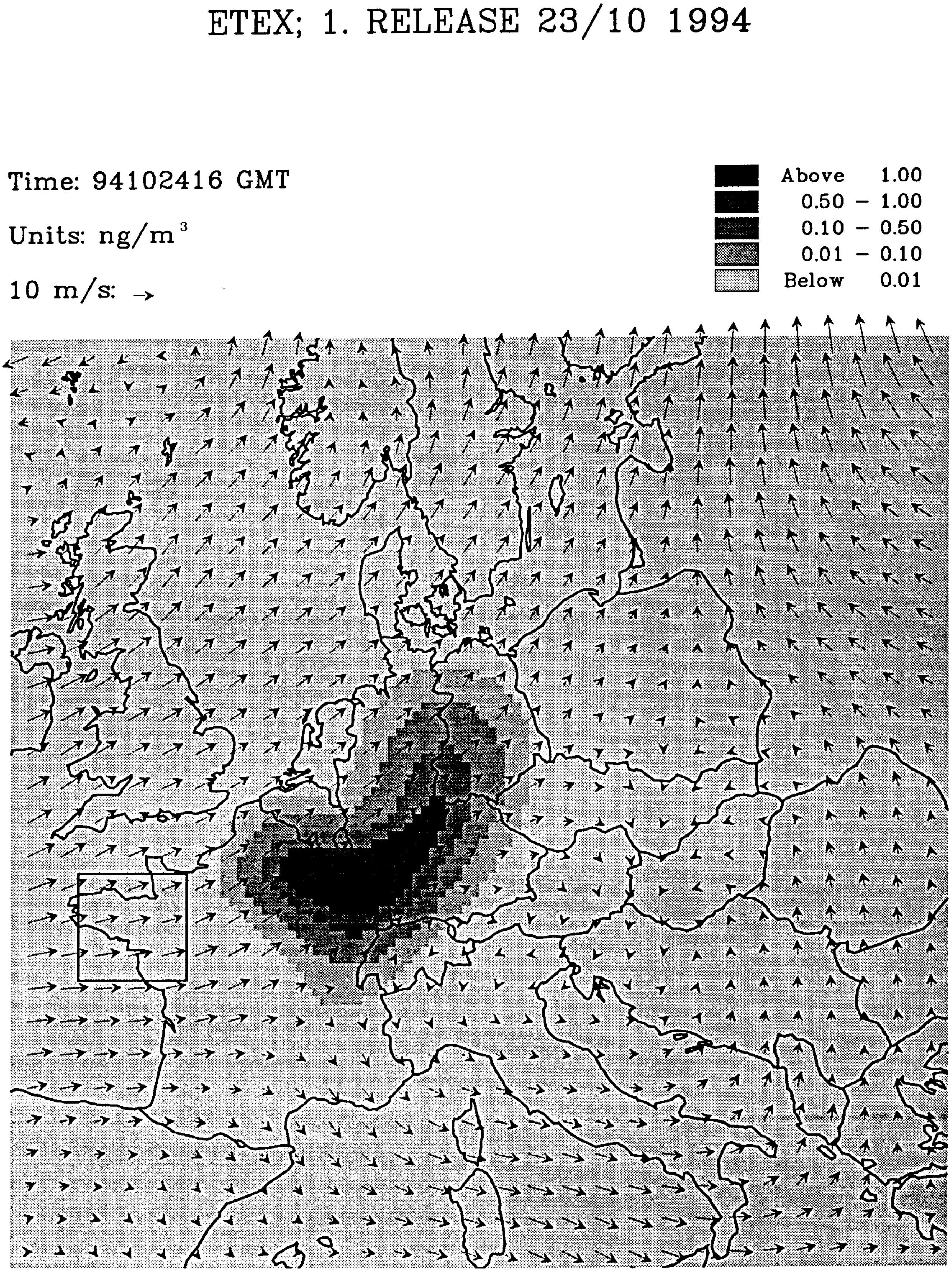

ETEX; 1. RELEASE 23/10 1994
Time: 94102416 GMT
Units: ng/m³
10 m/s: →
Above 1.00
0.50 – 1.00
0.10 – 0.50
0.01 – 0.10
Below 0.01

Figure 5.4.

ETEX; 1. RELEASE 23/10 1994

Time: 94102504 GMT

Units: ng/m³

10 m/s: →

■	Above 1.00
■	0.50 – 1.00
■	0.10 – 0.50
■	0.01 – 0.10
■	Below 0.01

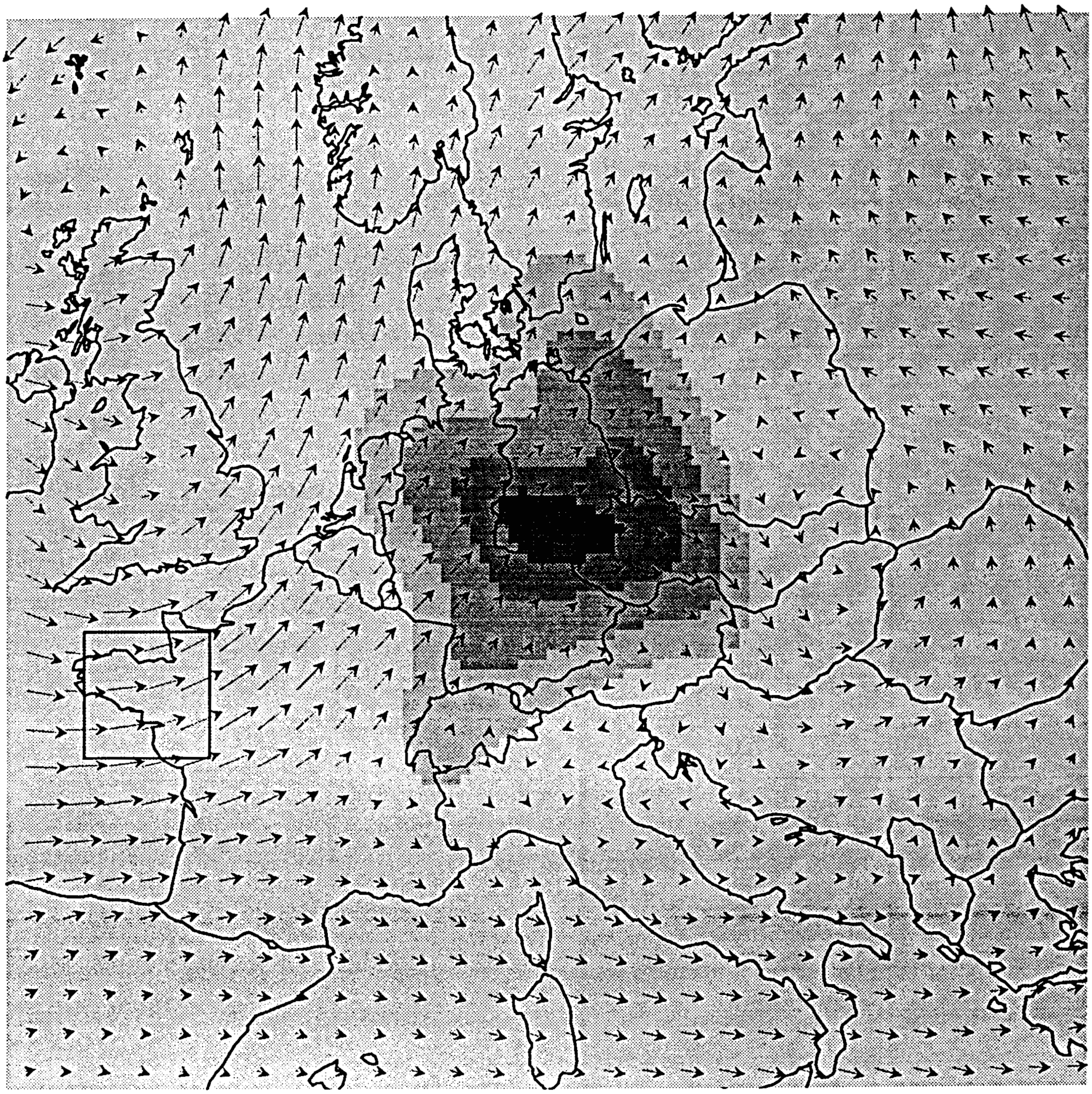


Figure 5.5.

ETEX; 1. RELEASE 23/10 1994

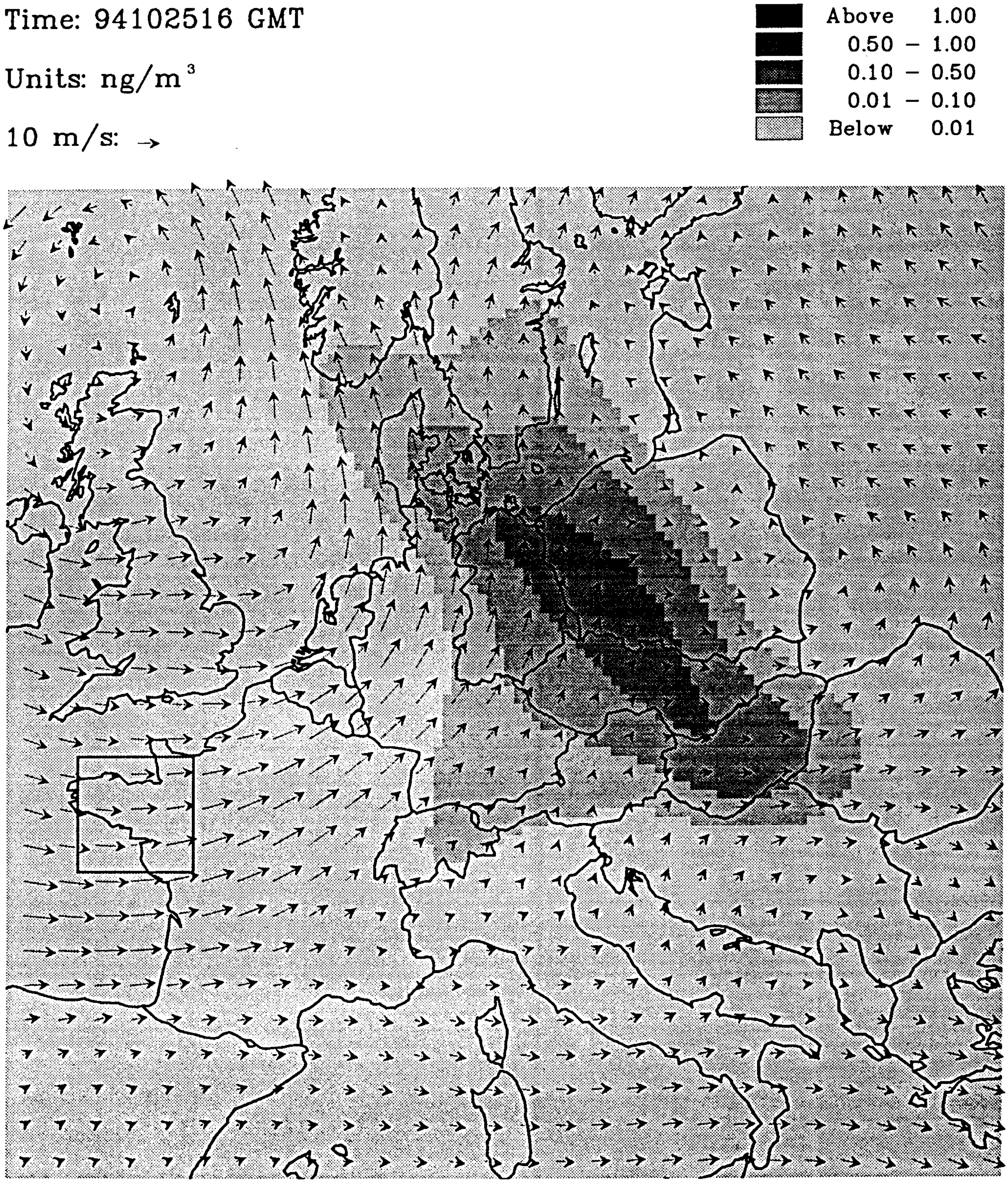


Figure 5.6.

ETEX; 1. RELEASE 23/10 1994

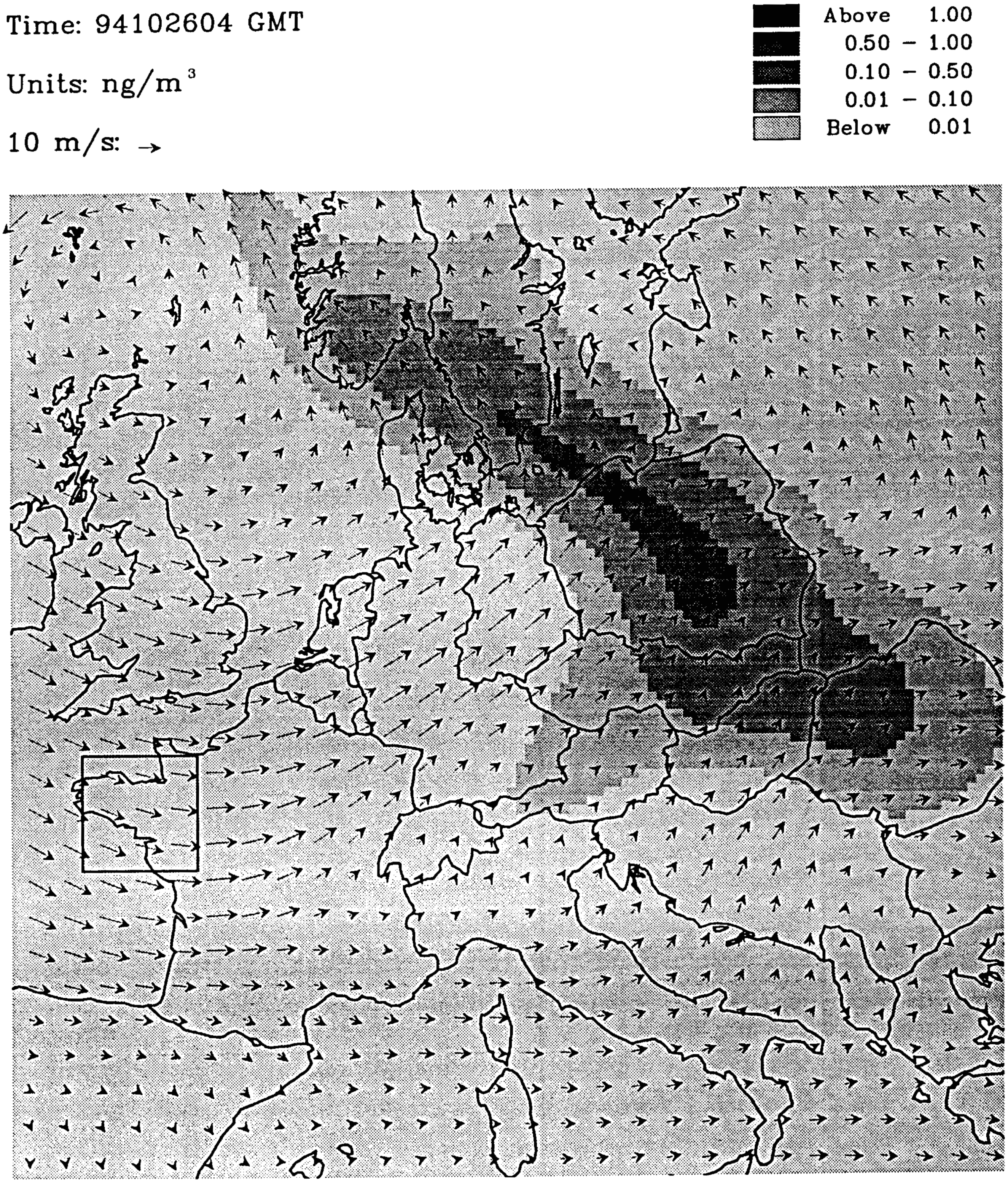


Figure 5.7.

ETEX; 2. RELEASE 14/11 1994

Time: 94111503 GMT

Units: ng/m^3

10 m/s: →

■	Above 1.00
■	0.50 – 1.00
■	0.10 – 0.50
■	0.01 – 0.10
■	Below 0.01

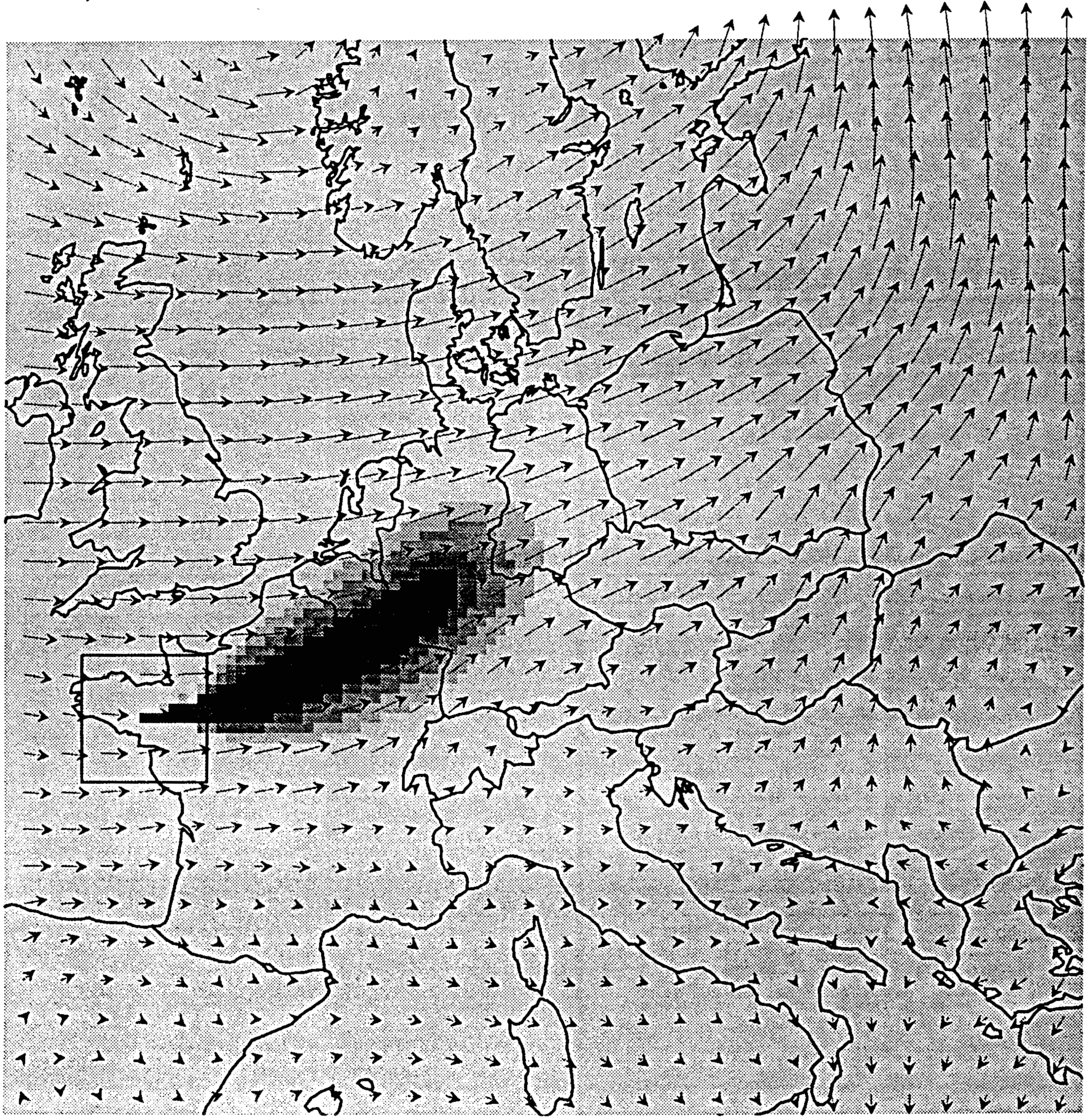


Figure 5.8.

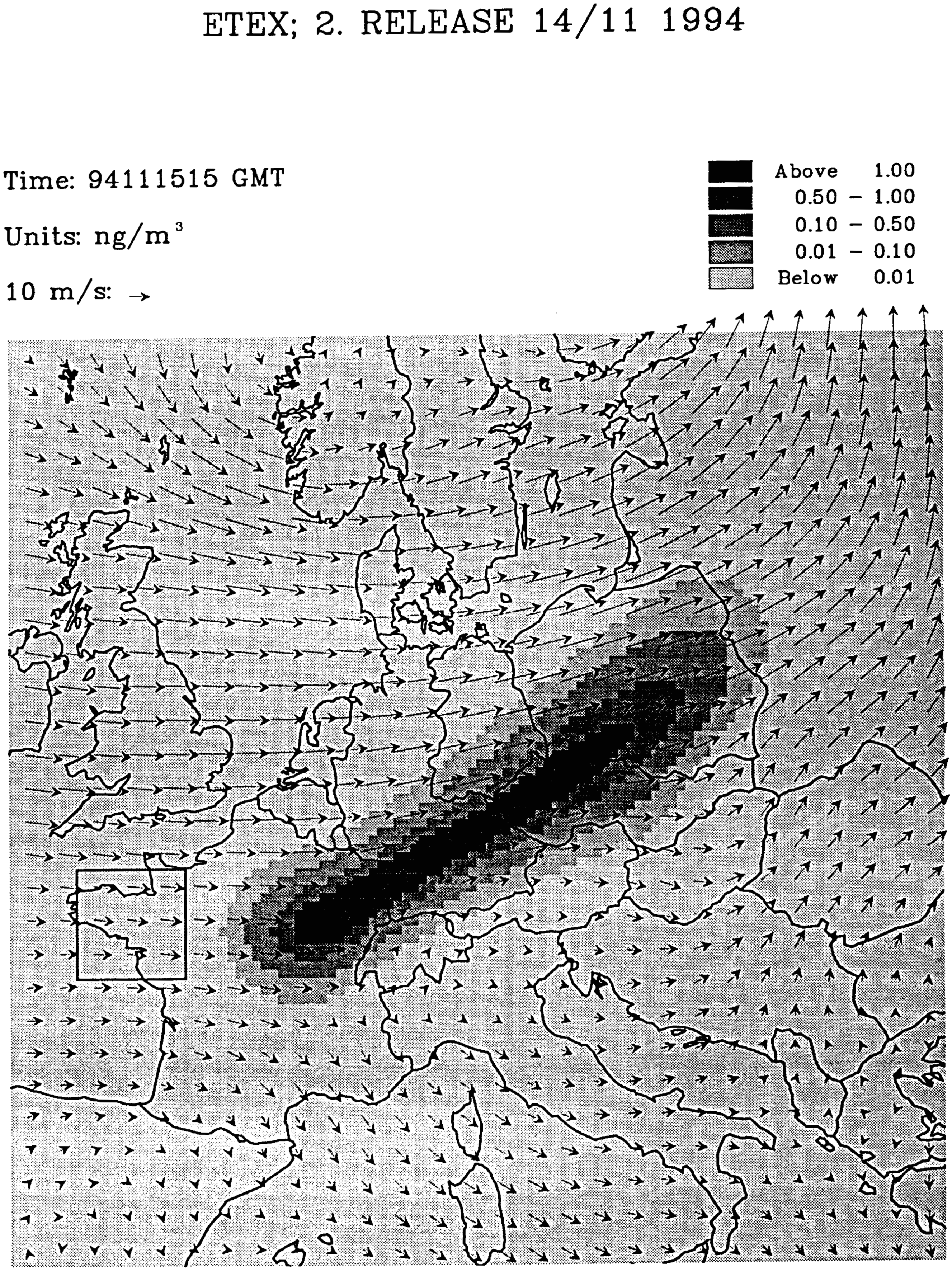

ETEX; 2. RELEASE 14/11 1994
Time: 94111515 GMT
Units: ng/m³
10 m/s:
Above 1.00
0.50 – 1.00
0.10 – 0.50
0.01 – 0.10
Below 0.01

Figure 5.9.

ETEX; 2. RELEASE 14/11 1994

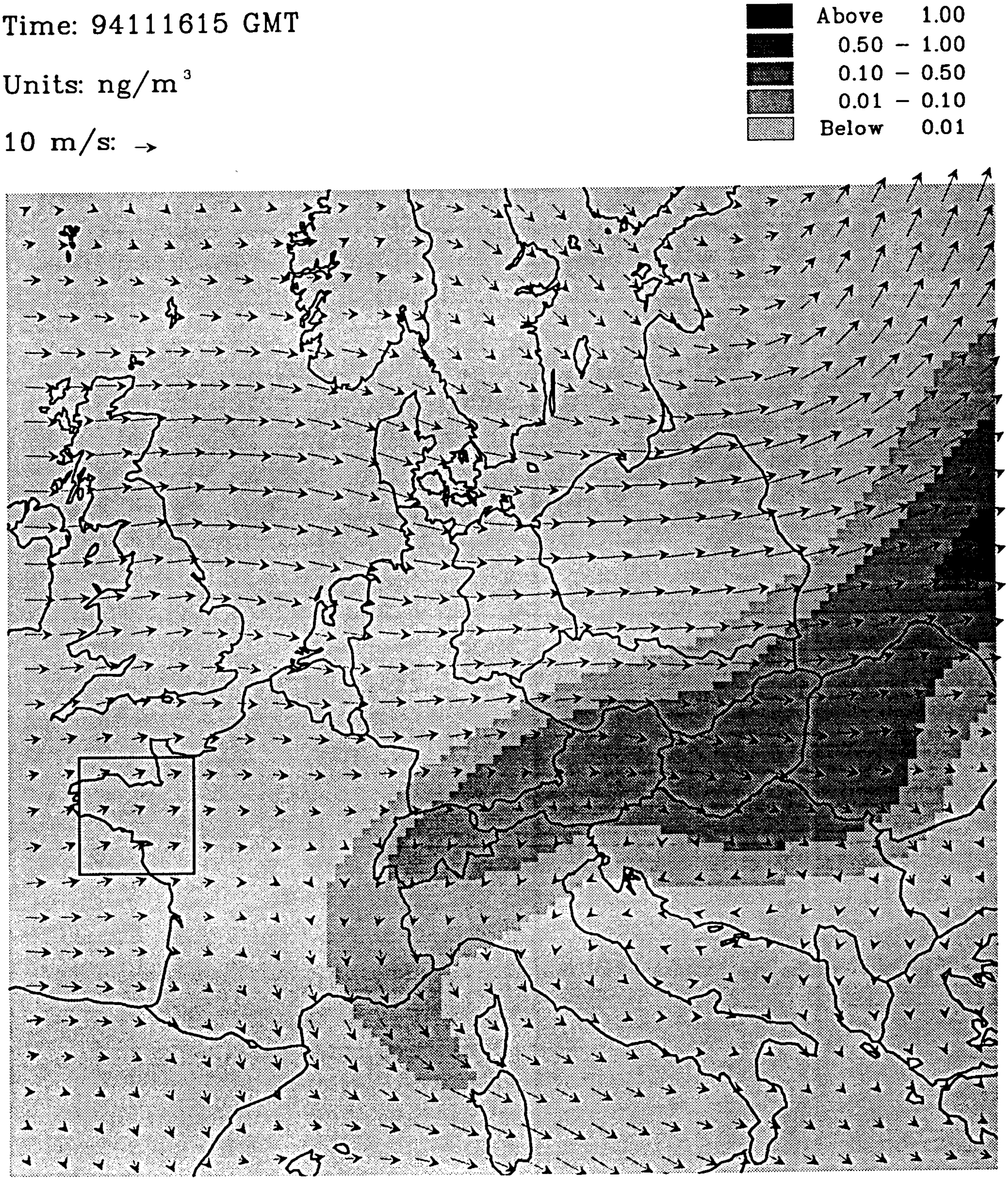


Figure 5.10.

ETEX; 2. RELEASE 14/11 1994

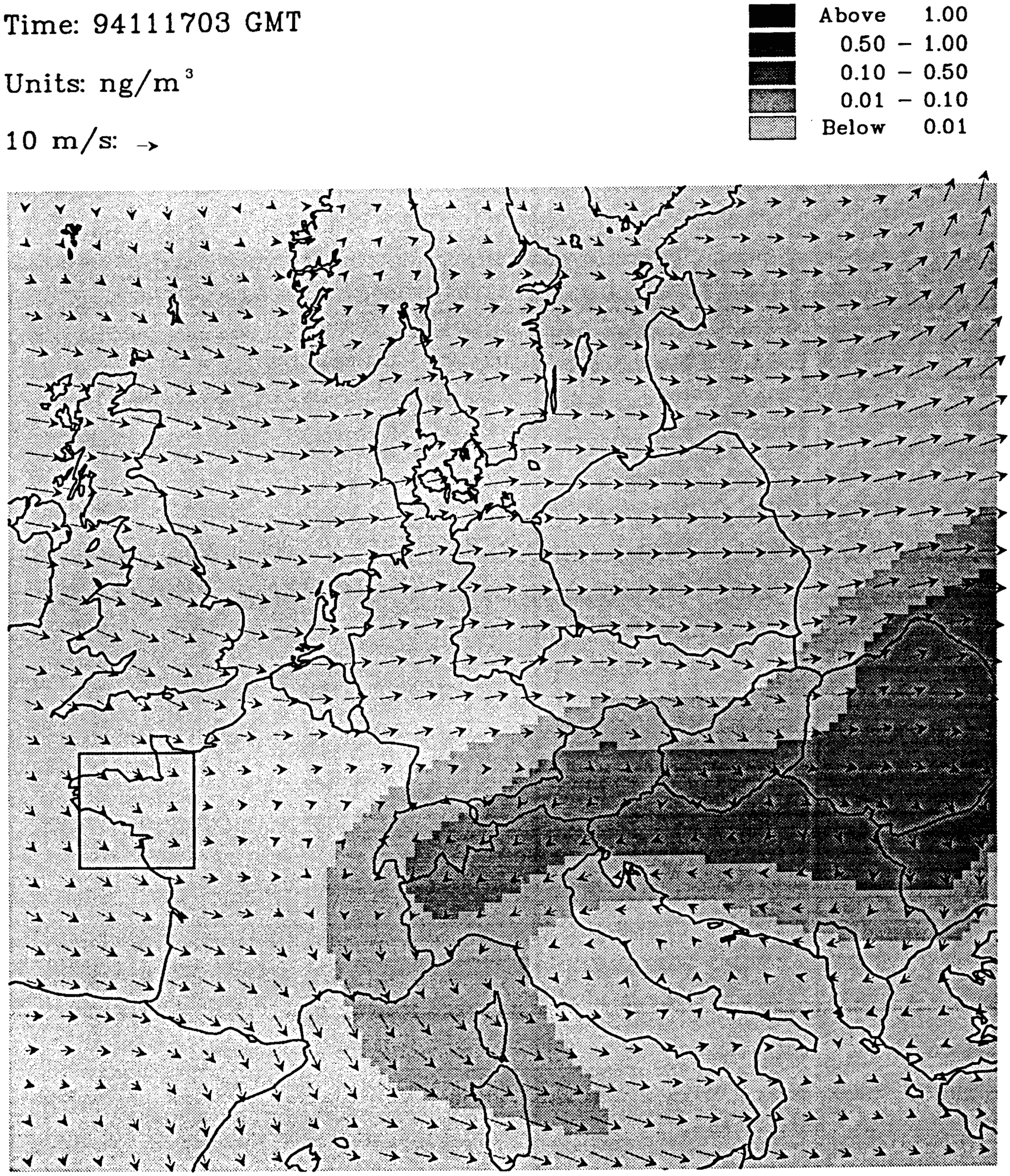


Figure 5.11.

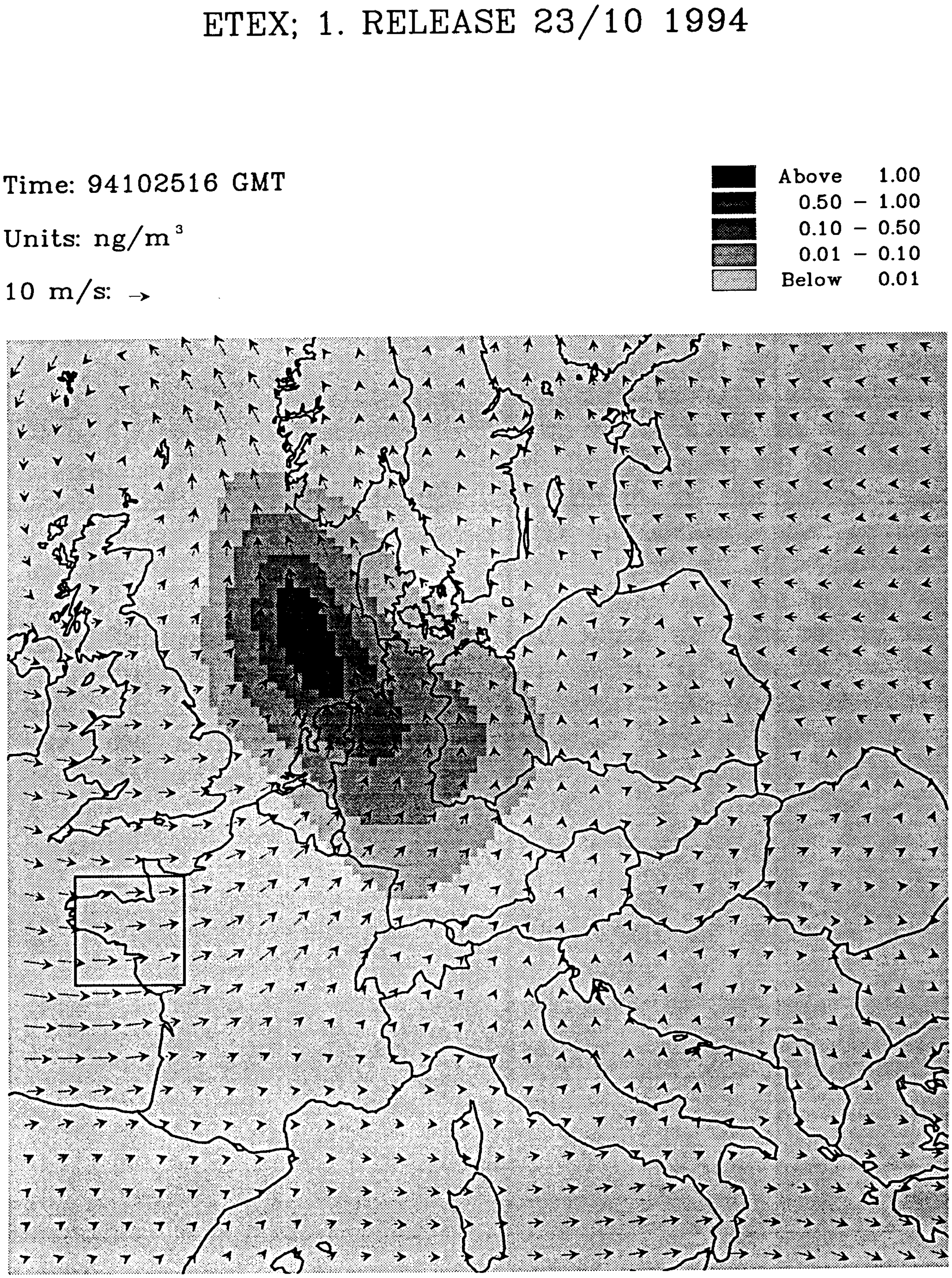

ETEX; 1. RELEASE 23/10 1994
Time: 94102516 GMT
Units: ng/m³
10 m/s:
Above 1.00
0.50 – 1.00
0.10 – 0.50
0.01 – 0.10
Below 0.01

Figure 5.12.

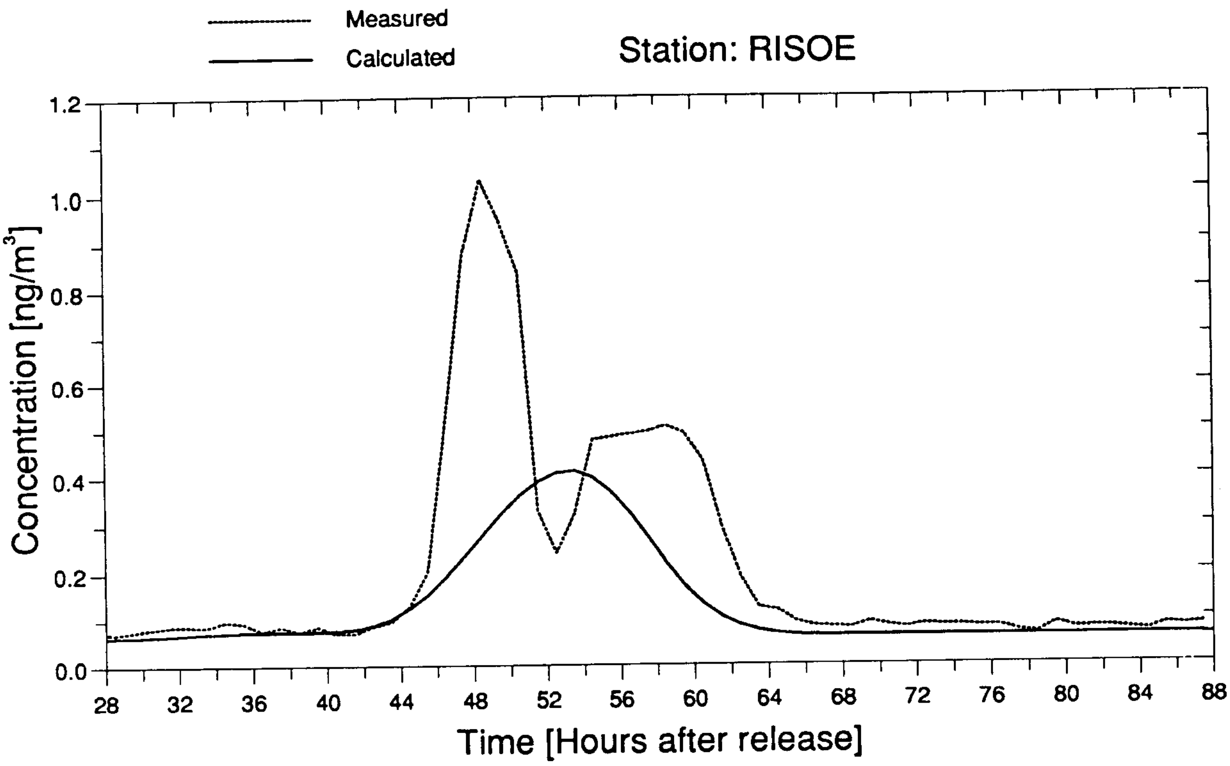

Measured
Calculated
Station: RISOE
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Concentration [ng/m³]
28
32
36
40
44
48
52
56
60
64
68
72
76
80
84
88
Time [Hours after release]

Figure 5.13.

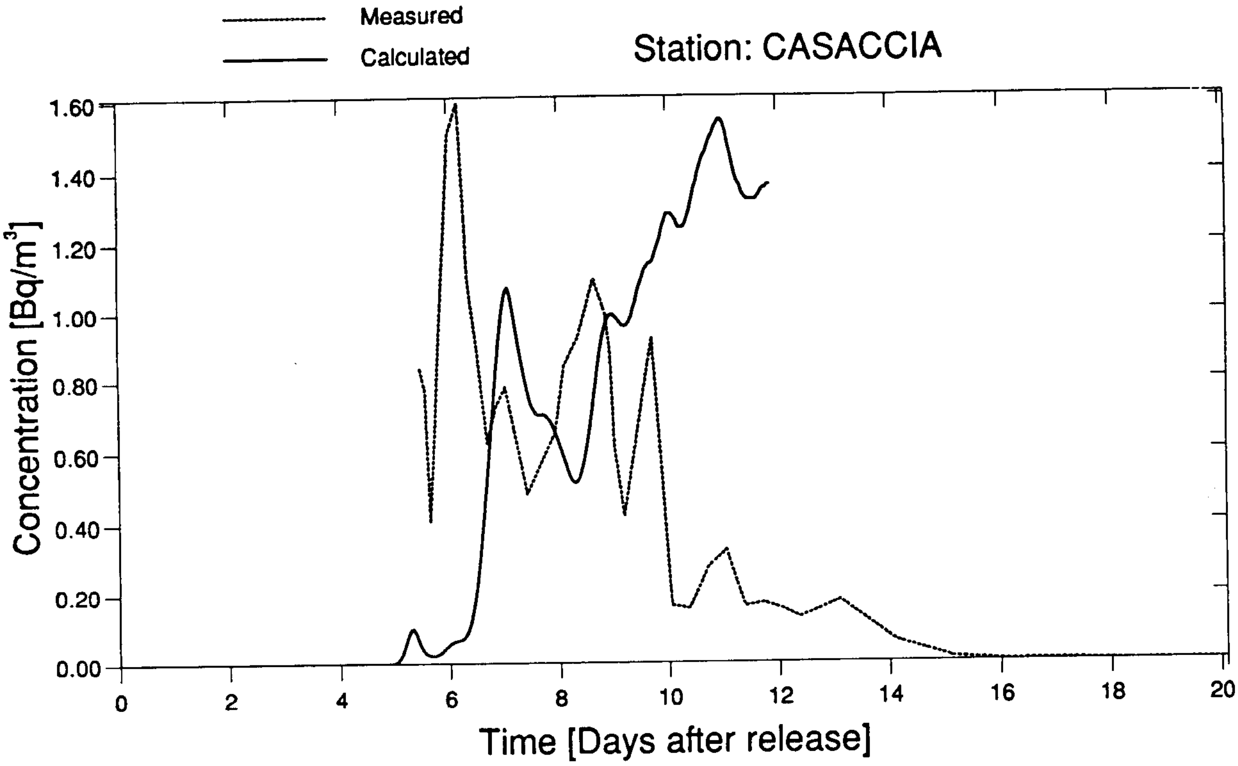


Figure 5.14a.

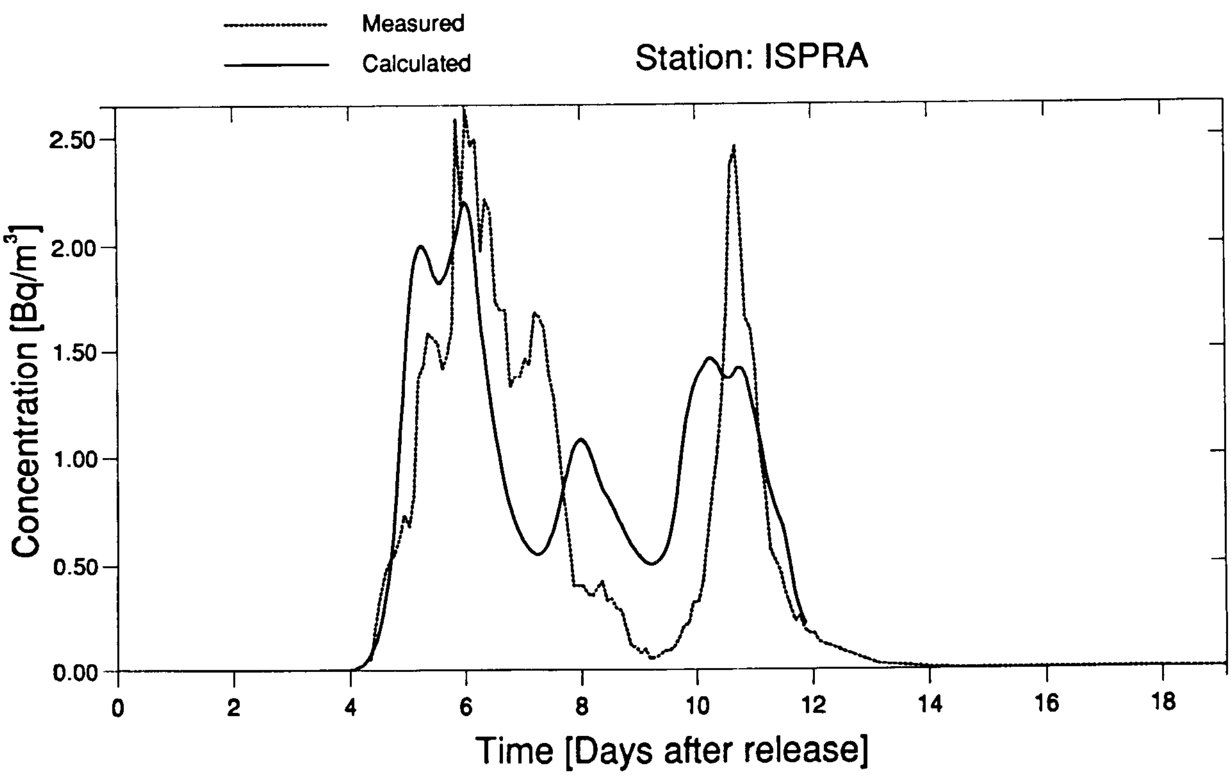


Figure 5.14b.

6 Calculations Performed by the Swedish Defense Research Institute (FOA)

Lennart Thaning and Per-Erik Johansson
Swedish Defense Research Institute
Umeå, Sweden

The calculations at FOA were performed using MATHEW/ADPIC. This is originally a program from Lawrence Livermore National Laboratory (Lange, 1978), but the input and output are modified. Input is weather data from ECMWF, Reading, output is graphic. Figure 6.1 shows the modified program configuration.

The results of the simulations are shown in Figures 6.2 to 6.8. When viewing the particles from above (Figures 6.2 and 6.3) the results seem somewhat different from the others. Around 60 hours after the start of the release the main portion of the cloud seems to go up over Norway, rather more markedly than in the other simulations. However this is mainly an effect of looking at the particles at all heights which is obvious when comparing to the surface concentrations (Figure 6.4). The trajectories in Figure 6.5 together with Figures 6.6 to 6.8 are illustrative. Looking at the trajectories it seems that only the very first part and the later part of the release are moving towards Scandinavia, while looking at particles released in 3-hour intervals show that all parts of the release reach Scandinavia. These figures clearly show the difficulties in using trajectories at specific levels to determine the areas affected by a release. However, it is obvious that the "wisp" going northward ahead of the rest of the plume (which is also seen in e.g. the DMI simulation) originates from the early part (times 16 to 19) of the release.

Figures 6.9 to 6.10 show the time variation of the concentrations at Risø at different levels. In the lower graph in Figure 6.10 a mixing height of 1000 meter is assumed, while 500 meter is assumed in the other graphs. The simulation with mixing height equal to 1000 meter gives better fit to the measured maximum concentration. The arrival time is good (about 40 hours). Figure 6.11 show concentration at different levels at Risø. The concentration profiles show a maximum at 50 meter, which is difficult or impossible to explain. This phenomenon is found in all the concentration profile calculations. However, it is interesting to note that the plume arrives and leaves earlier at higher levels.

FOA will not build further on this model in the future, but use HIRLAM data and a new stochastic particle model, developed by Erik Näslund at FOA.

Reference: R. Lange, 1978. ADPIC - A three-dimensional particle-in-cell model for the dispersal of Atmospheric pollutants and its comparison to regional tracer studies. J. Appl. Meteoro. 17, 320-329.

PROGRAM CONFIGURATION

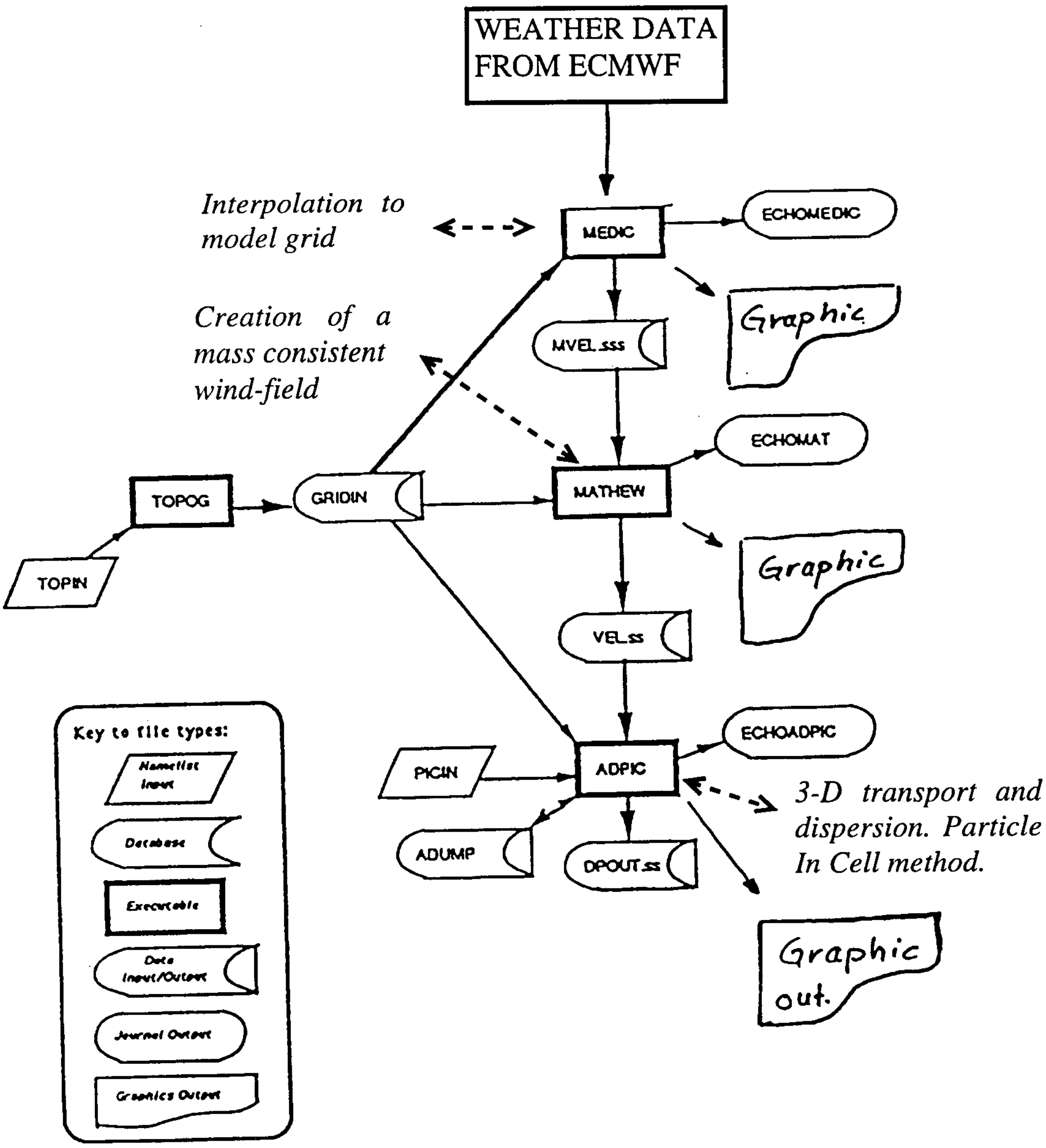


Figure 6.1. Program configuration of the MATHEW/ADPIC model at FOA with short description of the submodels.

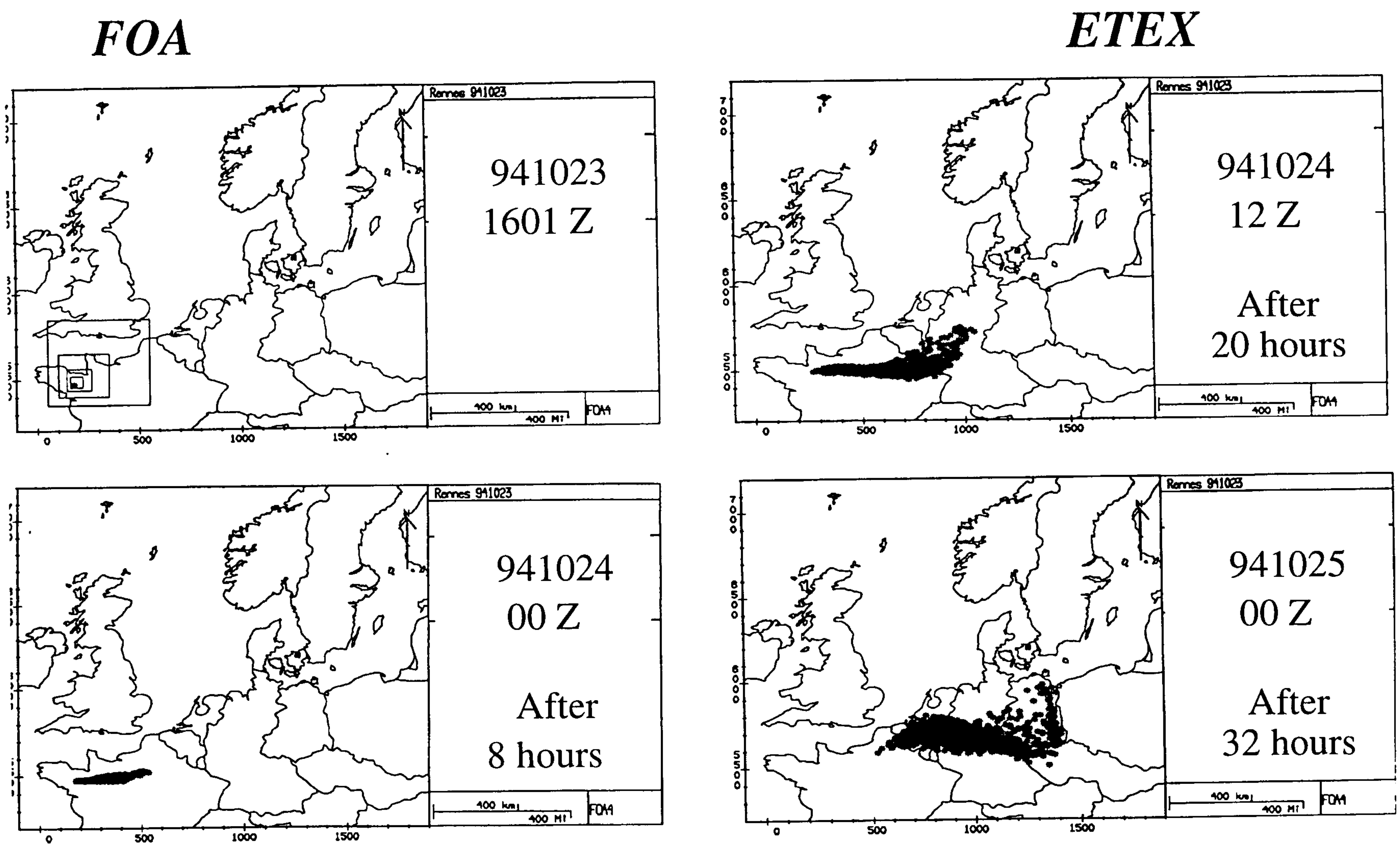


Figure 6.2. The cloud seen from above at different times. Note that model particles at all heights are depictured.

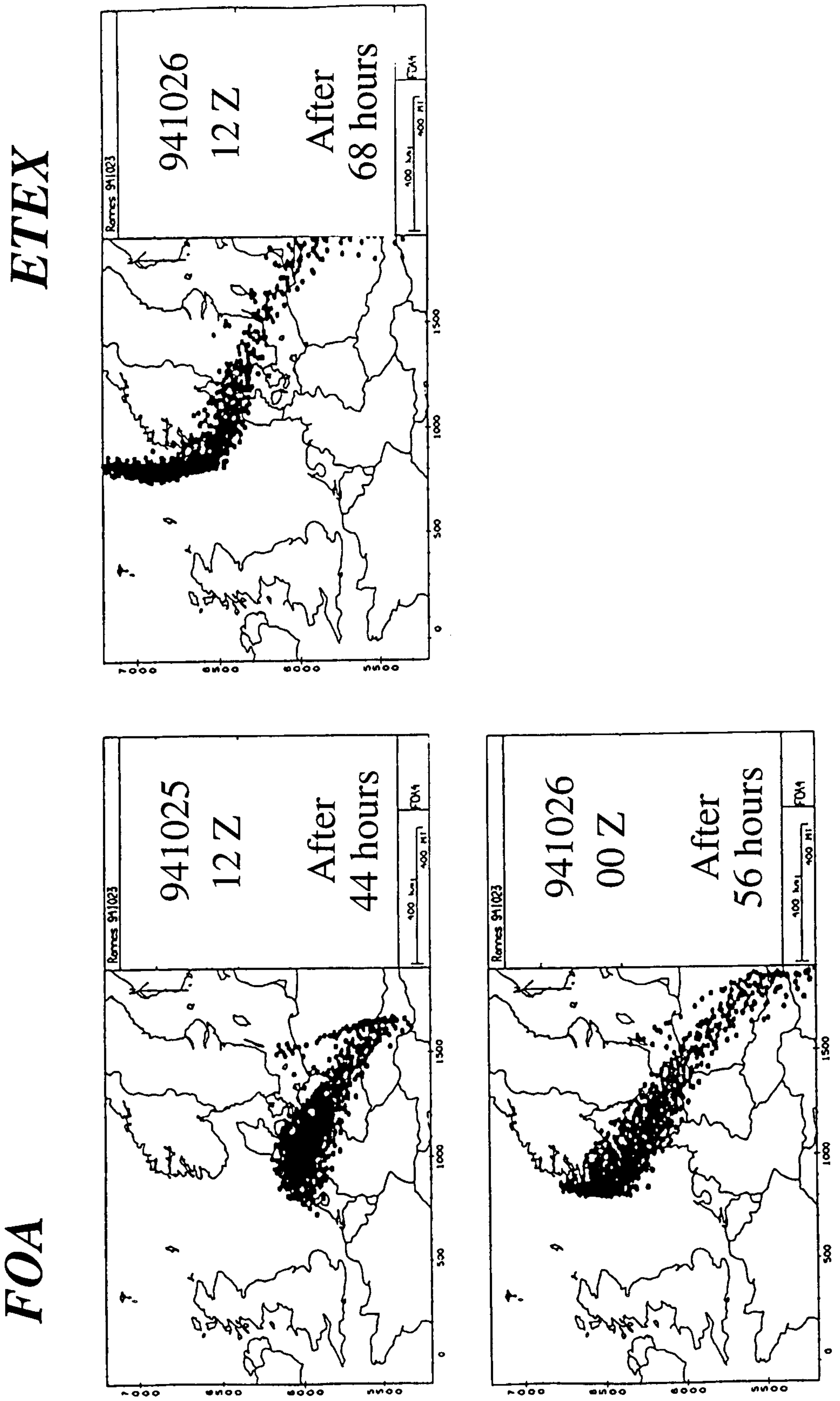


Figure 6.3. The cloud seen from above at different times. Note that models particles at all heights are depictured.

FOA Surface concentrations in ng/m^3 . **ETEX**

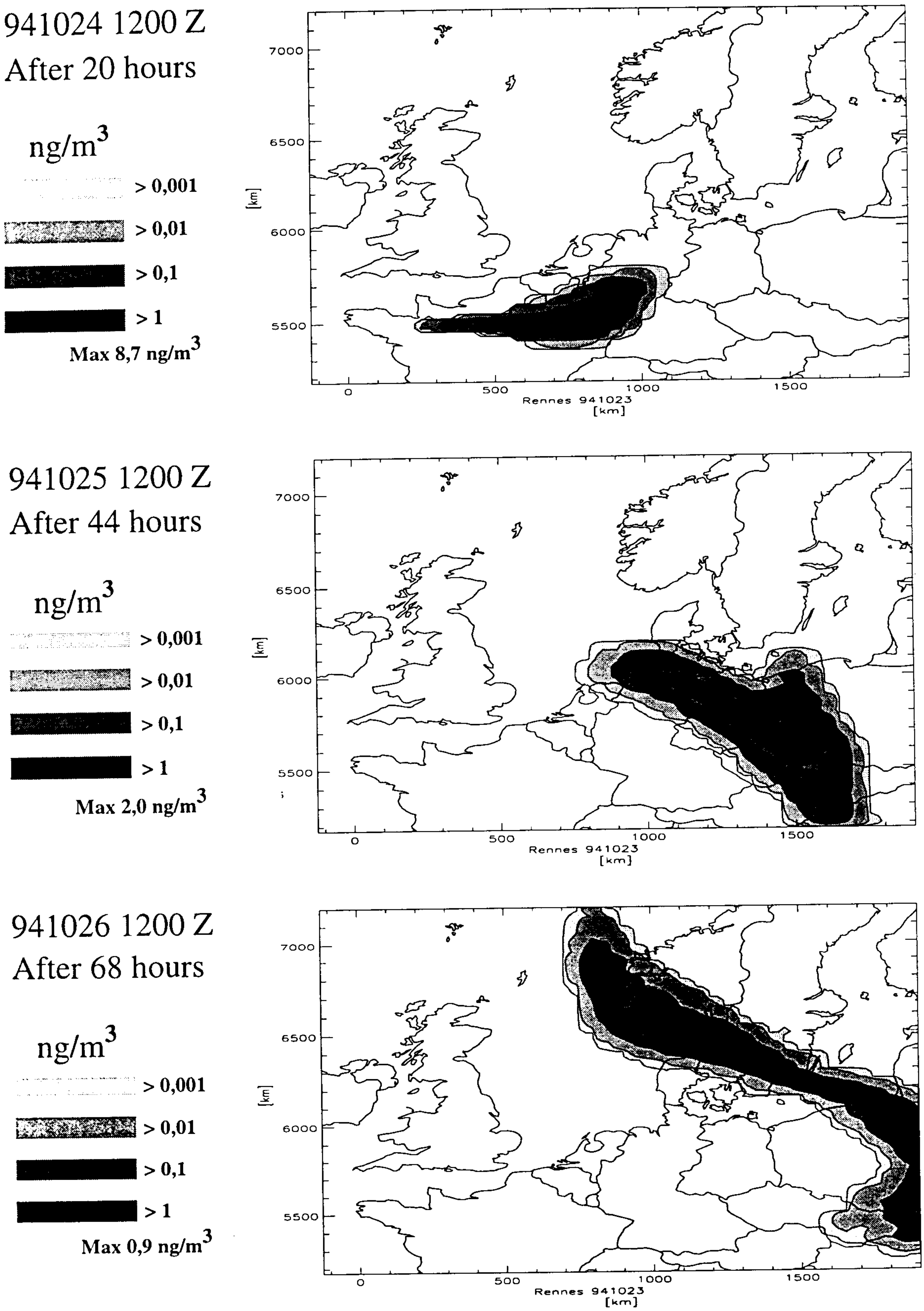


Figure 6.4. Concentrations at 2 m height.

Trajectories starting in Rennes at different times

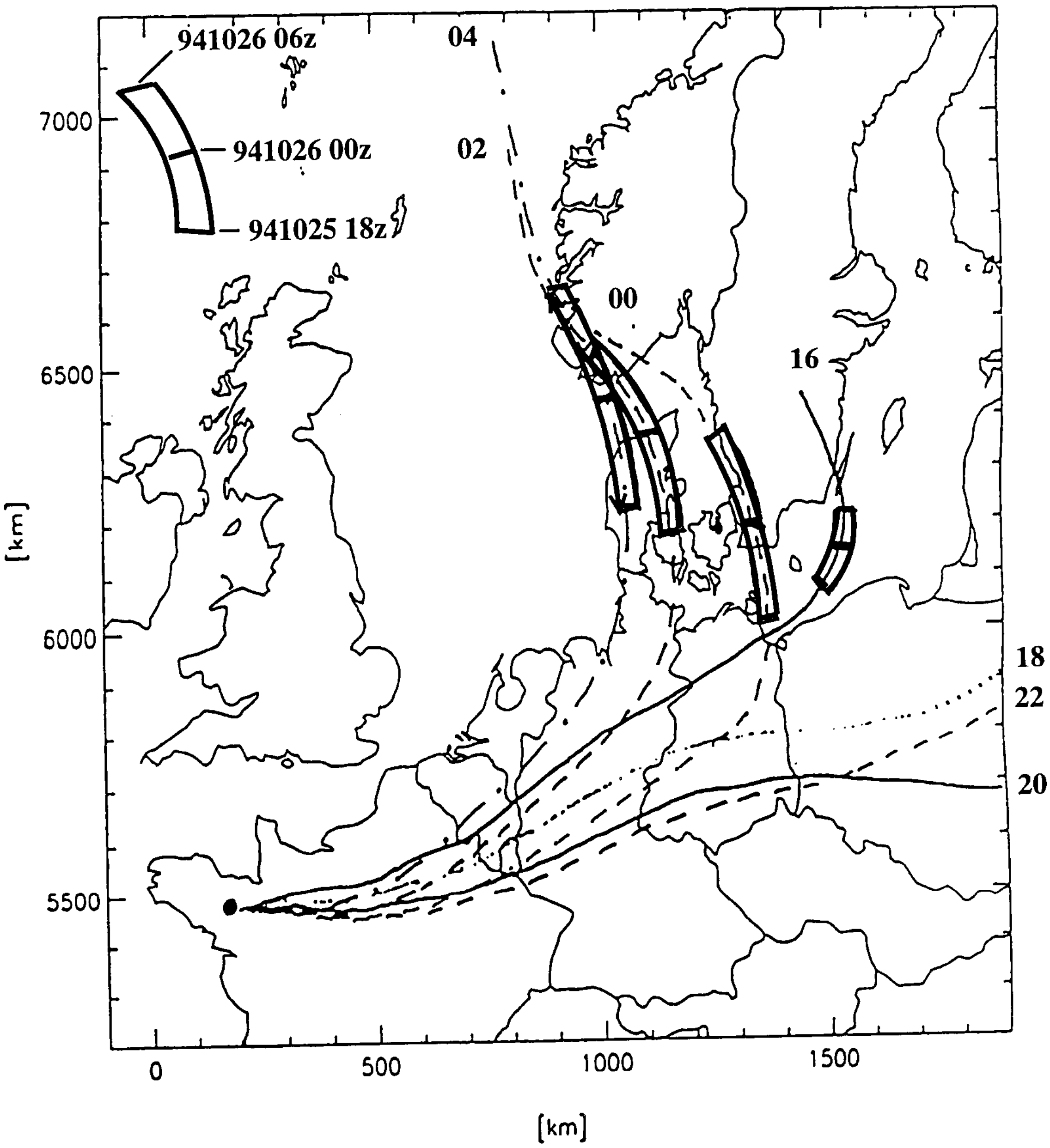
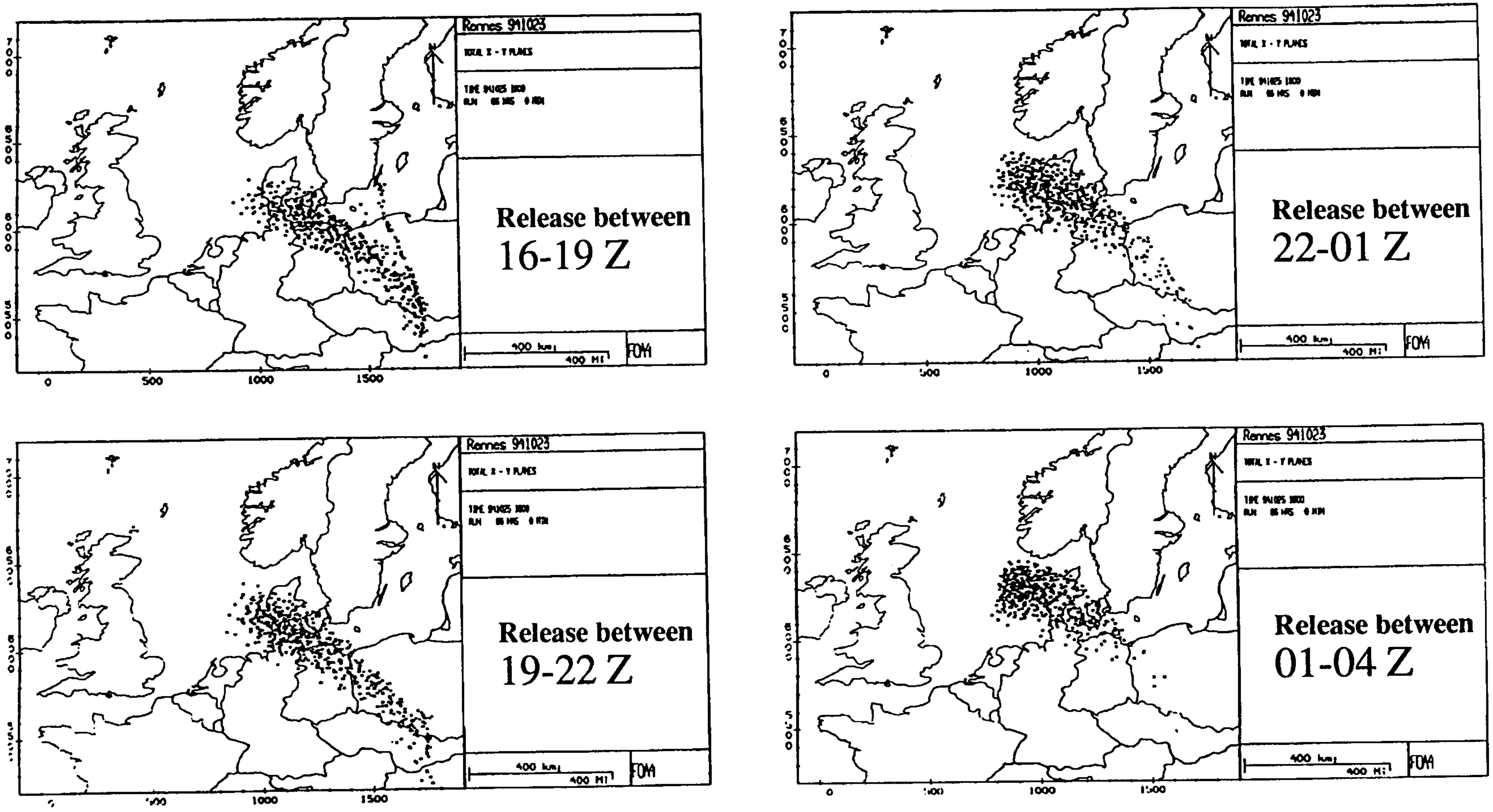


Figure 6.5. 2-D trajectories at 400 m height, starting from the release point in Rennes at 941023 16Z, 18Z, 20Z, 22Z and 941024 00Z, 02Z 04Z.

The different trajectories are marked with their starting hours at the endpoints.

The positions at 941025 18Z, 941026 00Z and 06Z are marked on trajectories passing close to Risø.

FOA Different parts of the release at 941025 18Z *ETEX*



Figurer 6.6. Different parts of the release viewed from above at 941025 18Z (after 50 hours). Note that model particles at all heights are depictured.

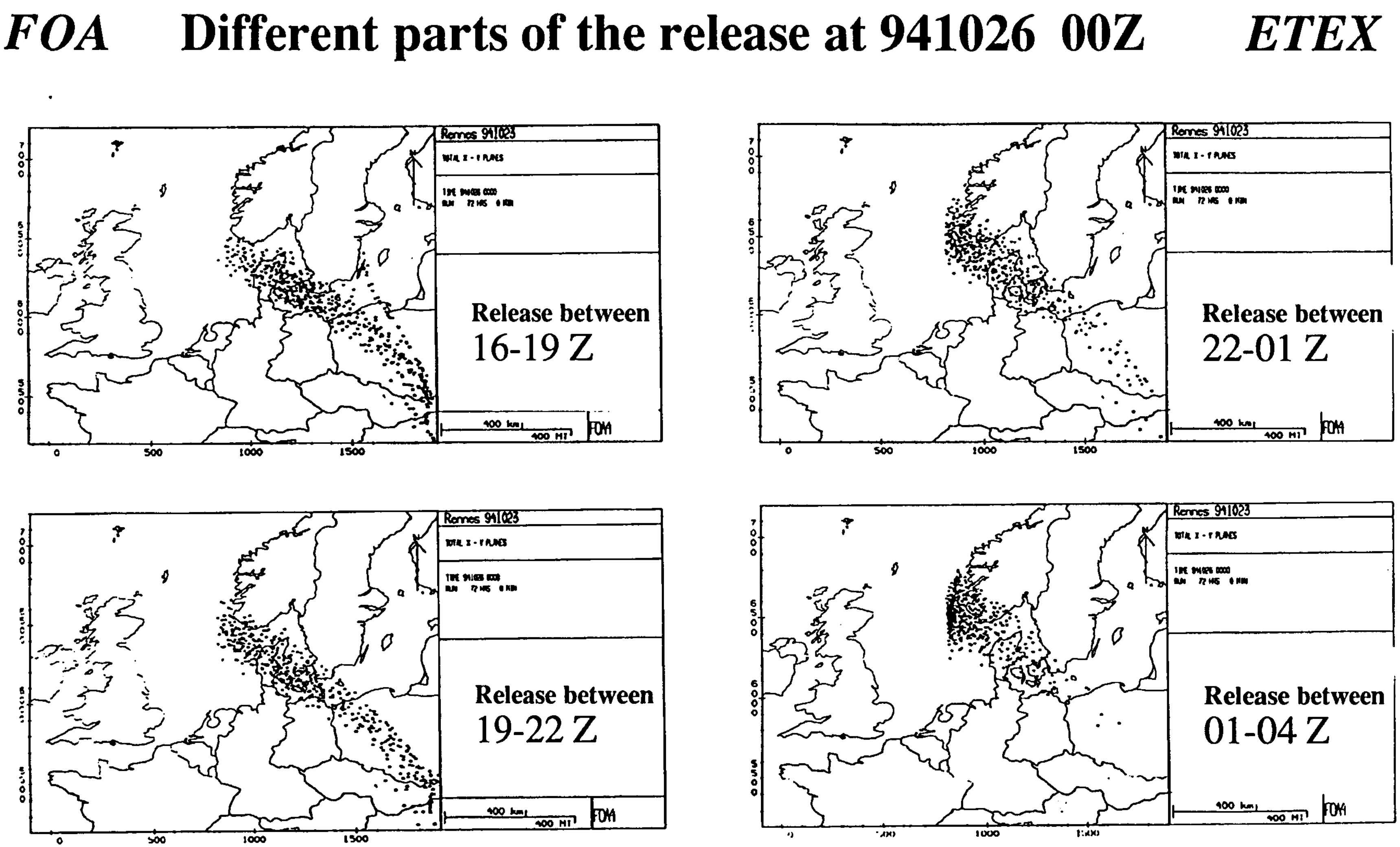


Figure 6.7. Different parts of the release viewed from above at 941026 00Z (after 56 hours). Note that model particles at all heights are depictured.

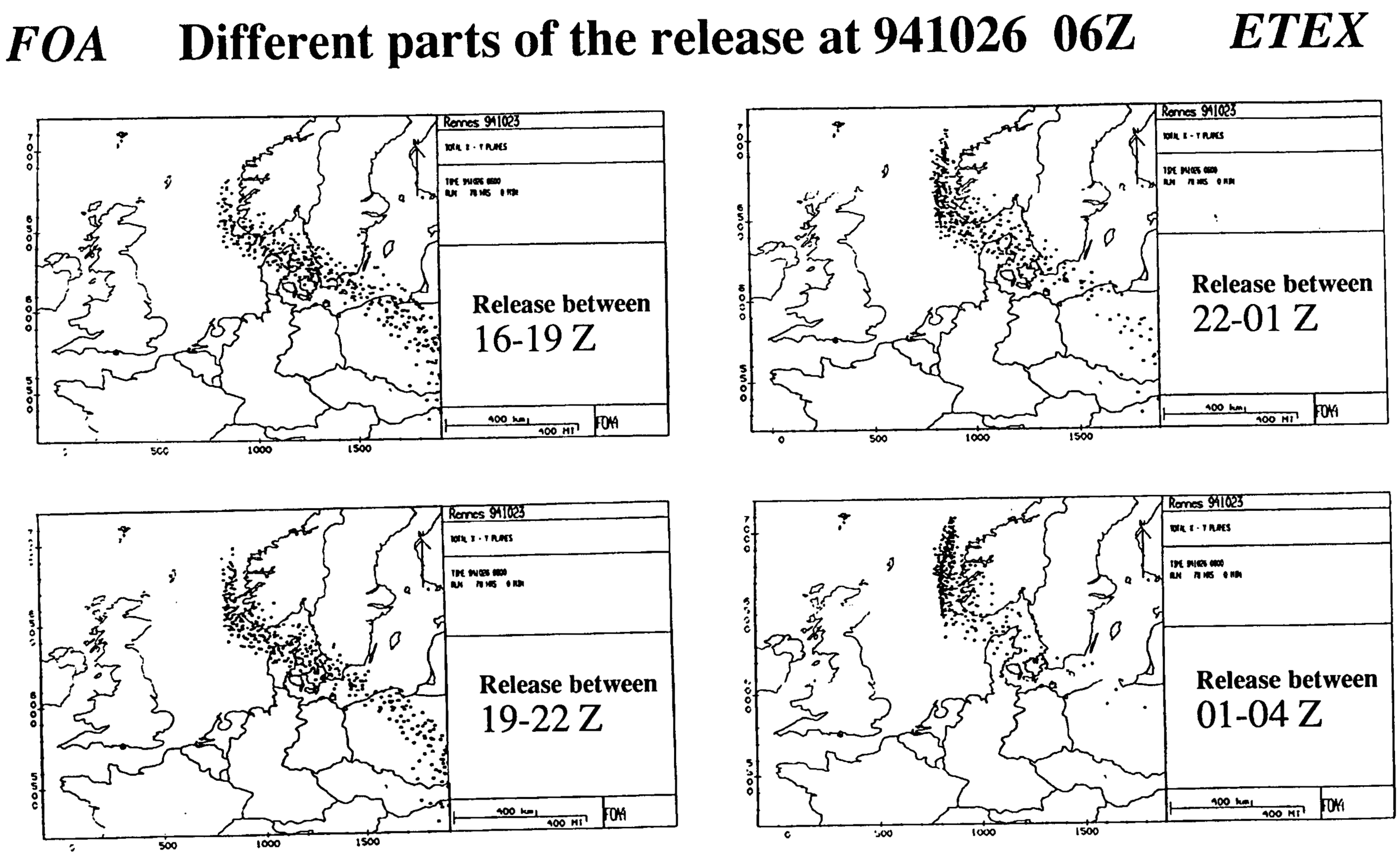


Figure 6.8. Different parts of the release viewed from above at 941026 06Z (after 62 hours). Note that model particles at all heights are depicted.

Calculated concentrations at Riso

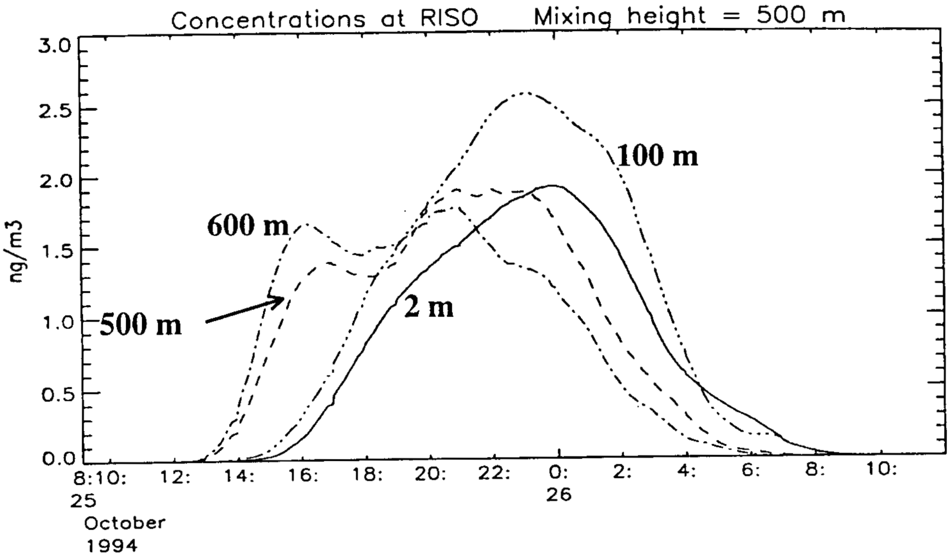


Figure 6.9a. Calculated time variations of the concentration (ng/m³) at different heights.

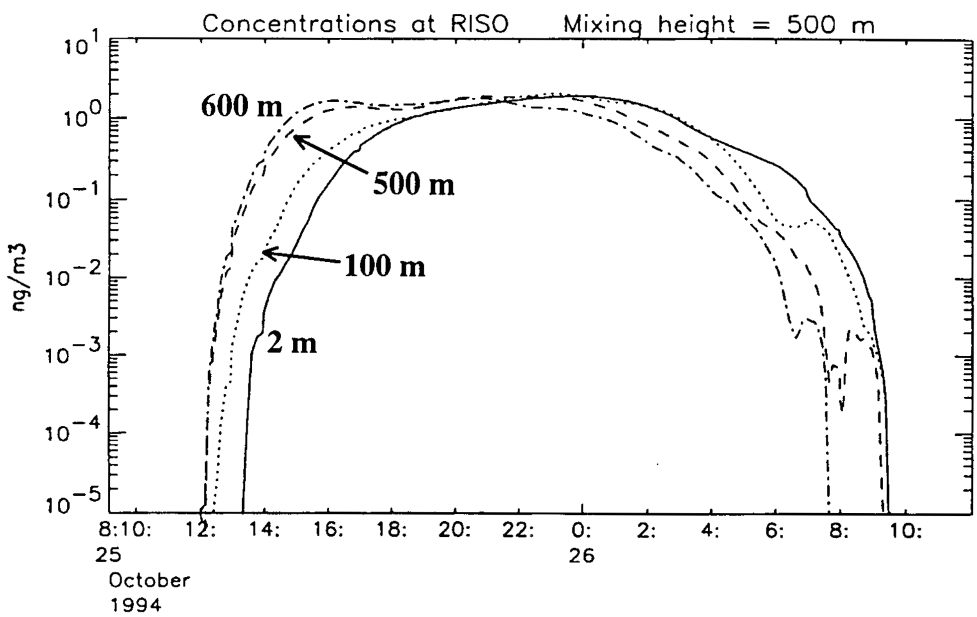


Figure 6.9b. Same as Figure 6.9a but logarithmic scale.

Calculated concentrations at Riso

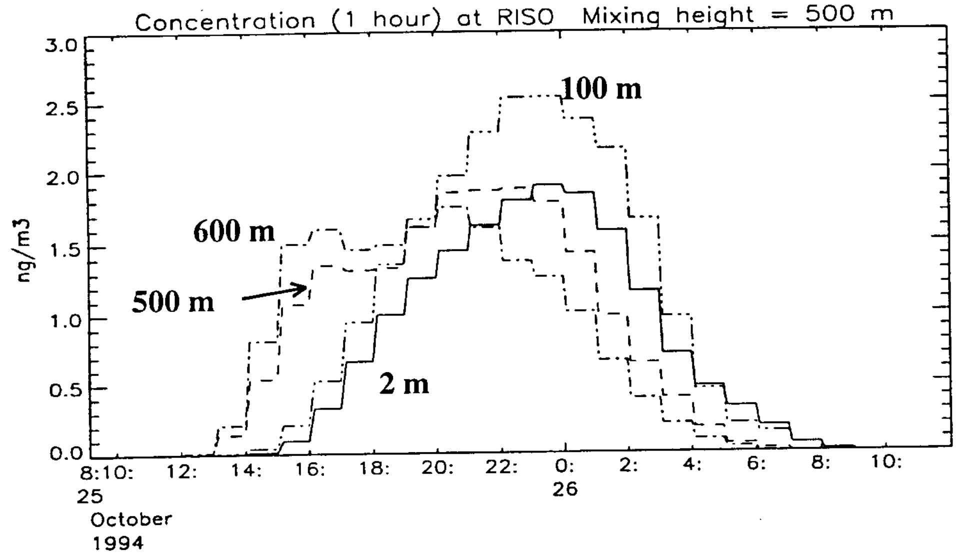


Figure 6.10a. Calculated time variations of the concentration (1-hour averages) at different heights.

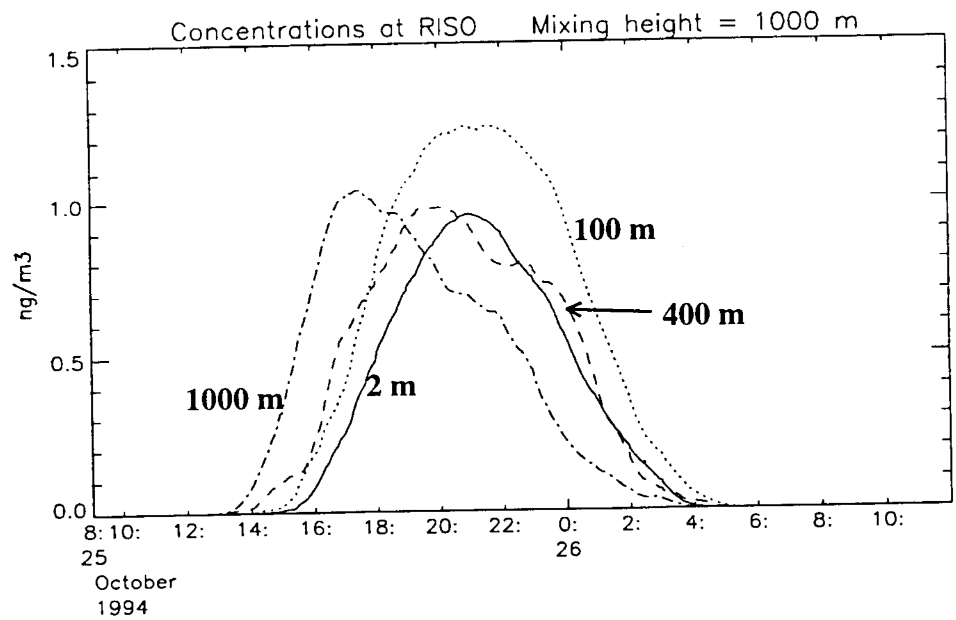


Figure 6.10b. Calculated time variations of the concentration at different heights. Note, mixing height = 1000 m.

Calculated concentration profiles at Riso

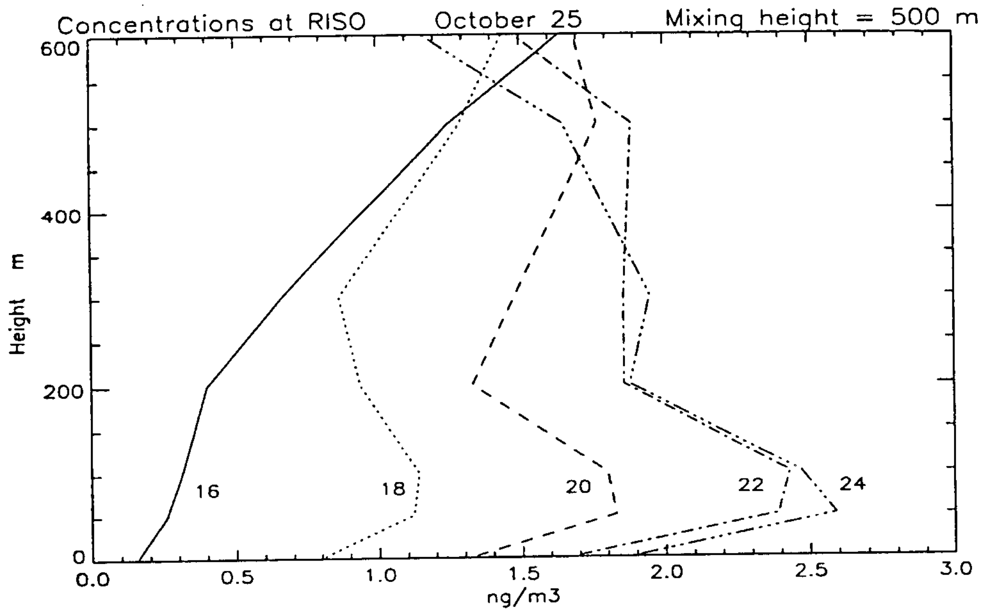


Figure 6.11a. Vertical concentration profiles at different times on the 25th of October. The mixing height was set to 500 m. The profiles are marked with the time in hours (UTC).

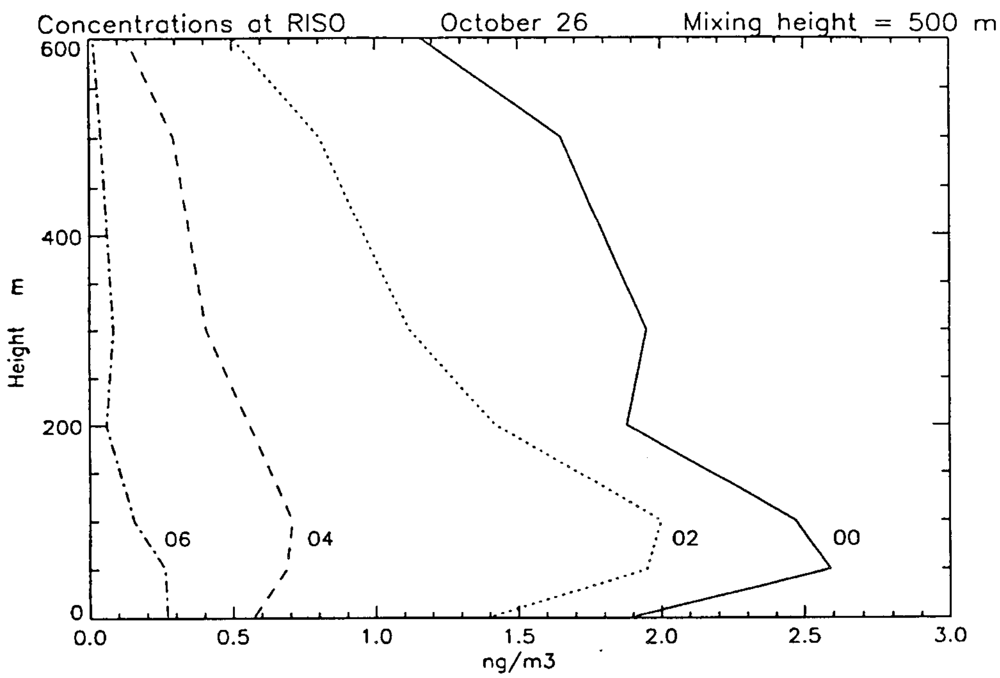


Figure 6.11b. Same as Figure 611a but on the 26th of October..

7 Calculations Performed in Finland

Mika Salonoja
Finnish Meteorological Institute (FMI)
Helsinki, Finland
Mikko Ilvonen
Technical Research Centre of Finland (VTT)
Espoo, Finland

A new modeling effort is under way in Finland, as the model TRADOS, which has been used up till now both in a probabilistic risk analysis version and a real-time version, is not thought to be satisfactory any more for real-time application. The name of the new model will probably be SILJA. The new model will be programmed in Fortran90, on a new Cray.

Mikko Ilvonen gave a short explanation of the design of the TRADOS model. Development of this model started in 1980. Partially within the BER-1 project the model was extended for use of the program to real-time situations, and graphic interface in UNIX/X Window system was added.

Figure 7.1 shows the flowchart for TRADOS. There is only one velocity for the trajectory. When moving along the trajectory the velocity changes according to the wind field. All dose exposure pathways are included. Vertical dispersion is not actually calculated in a traditional manner, but solved numerically from the K-theory. If the height of the mixed layer increases, all material is allowed to spread upwards. Deposible materials reach a non-uniform stationary vertical profile, but if the mixing height decreases, the upper layer acts as a storage layer (the materials do not deposit). Non-deposible materials spread to fill the height of the mixed layer uniformly. The release is divided into three-hour periods and for each period there is a central trajectory. Horizontal dispersion is calculated based upon neighboring trajectories. Basic lateral spread is halfway to the neighboring trajectory. In addition, one applies a half-Gaussian approach, because otherwise some situations (crossing trajectories etc.) could lead to problems.

Figures 7.2 and 7.3 show two different ETEX forecasts. In the first forecast, the cloud does not reach Risø, and most of the plume is actually over the sea. Forecast set two (not included in this report) is not very different. Number three (not included) gives a spread much further to the East. But it goes much more to the North than the others, and not to the SE at all. Forecast number 5 (Figure 7.3) is more similar to the results calculated by the other participants, and forecast number 6 (Figure 7.4), called the «analysis set», gives results even more in agreement with the others. Problems with choosing the proper height were mentioned. It should not quite be the actual release height, but a height representative of the whole boundary layer; a good height is 700 - 800 meters.

Figures 7.5 to 7.10 show the concentration calculations for ETEX corresponding to forecast set 6 (Figure 7.4). The concentration figures look much more like the other models, even if the cloud does not go so far to SE. But it is similar to the others in the way that there is the «wisp» which is ahead of the rest of the plume. But the plume is unphysically long and narrow in the lateral direction. Figure 7.11 is a close-up over Denmark and Southern Sweden. Arrival in Risø at 57 - 60 hours after release (in the figure this appears to be 60 hours, but is in fact the average of the preceding 3 hours). The concentrations shown in the figures are three-hour averages.

Table 7.1 summarizes the concentration-at-Risø results for the different forecasts. The first two forecasts predict that the cloud never pass over Risø. In the other forecasts, there are non-zero concentrations at Risø only for one three-hour time period, while in reality the passing time was about 20 hours. Results between 1 - 2 ng/m^3, which is not bad at all, though a little high.

Some new Chernobyl calculations with TRADOS, using the HIRLAM data from DMI, have been performed (by Ilkka Valkama and Mika Salonoja from FMI and Harri Toivonen, Juhani Lahtinen and R. Pöllänen from the Finnish Centre for Radiation and Nuclear Safety (STUK)). These calculations are "sister" calculations to the ones performed at the Swedish Meteorological and Hydrological Institute (SMHI) within the BER-1 project. Like the SMHI calculations, the plume passage over Western Scandinavia is too far to the North.

Presented were also some recent Sosnovyy Bor-calculations with TRADOS. The calculations were based on two years of meteorological data, and the number of cloud passages for a number of larger Nordic cities found in the data is given in Table 7.2. For each cloud passage over each city, the air concentrations of I-131, external dose rates and doses, as well as inhalation doses, were calculated. These results are shown in graphical form, in Figures 7.12 to 7.15.

Table 7.1. Non-zero concentrations of PFC at Risø (55.70 N, 12.08 E) as predicted by the Finnish model TRADOS during the ETEX experiment of October 23, 1994.

In each forecast set, there is either zero or only one three hours' time period with non-zero concentration for Risø.

Forecast set #1:

Zero concentrations only (cloud is not predicted to pass over Risø).

Forecast set #2:

Zero concentrations only (cloud is not predicted to pass over Risø).

Forecast set #3:

0.99523 ng/m^3 as averaged between 22.00 UTC, October 25, and 01.00 UTC, October 26.

Forecast set #4:

2.1453 ng/m^3 as averaged between 01.00 UTC and 04.00 UTC, October 26.

Forecast set #5:

0.98664 ng/m^3 as averaged between 01.00 UTC and 04.00 UTC, October 26.

Forecast set #6:

2.3165 ng/m^3 as averaged between 01.00 UTC and 04.00 UTC, October 26.

Table 7.2. Nordic and Baltic cities that have been studied using TRADOS, based on two years' meteorological data. The distances given in the table are calculated from Sosnovyy Bor. The last column gives the total number of cloud passages over the city found in the data.

no.	longitude	latitude	name	distance	inhabitants	passages
Finland:						
01	25.00 E	60.19 N	Helsinki	229 km	485800	245
02	24.62 E	60.19 N	Espoo	250 km	179100	232
03	23.76 E	61.49 N	Tampere	339 km	174900	210
04	22.24 E	60.45 N	Turku	383 km	159900	178
05	25.00 E	60.19 N	Vantaa	229 km	159200	245
06	25.50 E	65.00 N	Oulu	597 km	103500	187
Sweden:						
07	18.05 E	59.34 N	Stockholm	623 km	1533100	104
08	11.96 E	57.70 N	Göteborg	1014 km	432100	58
09	13.00 E	55.60 N	Malmö	1065 km	234800	68
10	17.60 E	59.84 N	Uppsala	641 km	170100	104
11	15.64 E	58.40 N	Linköping	784 km	124400	91
12	15.19 E	59.28 N	Örebro	784 km	122000	81
13	16.18 E	58.60 N	Norrköping	747 km	120800	102
14	16.51 E	59.63 N	Västerås	704 km	120400	86
15	14.18 E	57.79 N	Jönköping	888 km	112300	89
16	12.72 E	56.07 N	Helsingborg	1052 km	110200	61
17	12.95 E	57.72 N	Borås	958 km	102400	70
Norway:						
18	10.74 E	59.92 N	Oslo	1020 km	749900	71
19	5.47 E	60.40 N	Bergen	1302 km	216100	51
20	10.32 E	63.44 N	Trondheim	1062 km	139600	48
21	5.77 E	58.98 N	Stavanger	1316 km	99800	55
Denmark:						
22	12.54 E	55.67 N	København	1085 km	1339400	64
23	10.17 E	56.14 N	Århus	1186 km	271300	70
24	10.37 E	55.40 N	Odense	1216 km	180800	47
25	9.91 E	57.03 N	Ålborg	1156 km	157300	60
Other countries:						
26	-22.00 E	64.14 N	Reykjavik	2634 km	149500	0
27	24.15 E	56.94 N	Riga	437 km	910200	125
28	26.59 E	55.92 N	Daugavpils	467 km	129000	132
29	21.05 E	56.58 N	Liepaja	598 km	114900	108
30	25.36 E	54.71 N	Vilnius	619 km	596900	76
31	24.00 E	54.92 N	Kaunas	632 km	433600	79
32	21.19 E	55.75 N	Klaipeda	657 km	208300	108
33	23.37 E	55.94 N	Šiauliai	555 km	149000	117
34	24.37 E	55.75 N	Panevezys	539 km	132300	94
35	24.72 E	59.43 N	Tallinn	251 km	471600	261
36	26.74 E	58.38 N	Tartu	216 km	113400	173
37	28.77 E	60.71 N	Viipuri	92 km	81100	444
38	30.38 E	59.93 N	St.Petersburg	73 km	5035000	470
39	28.16 E	59.40 N	Narva	76 km		256

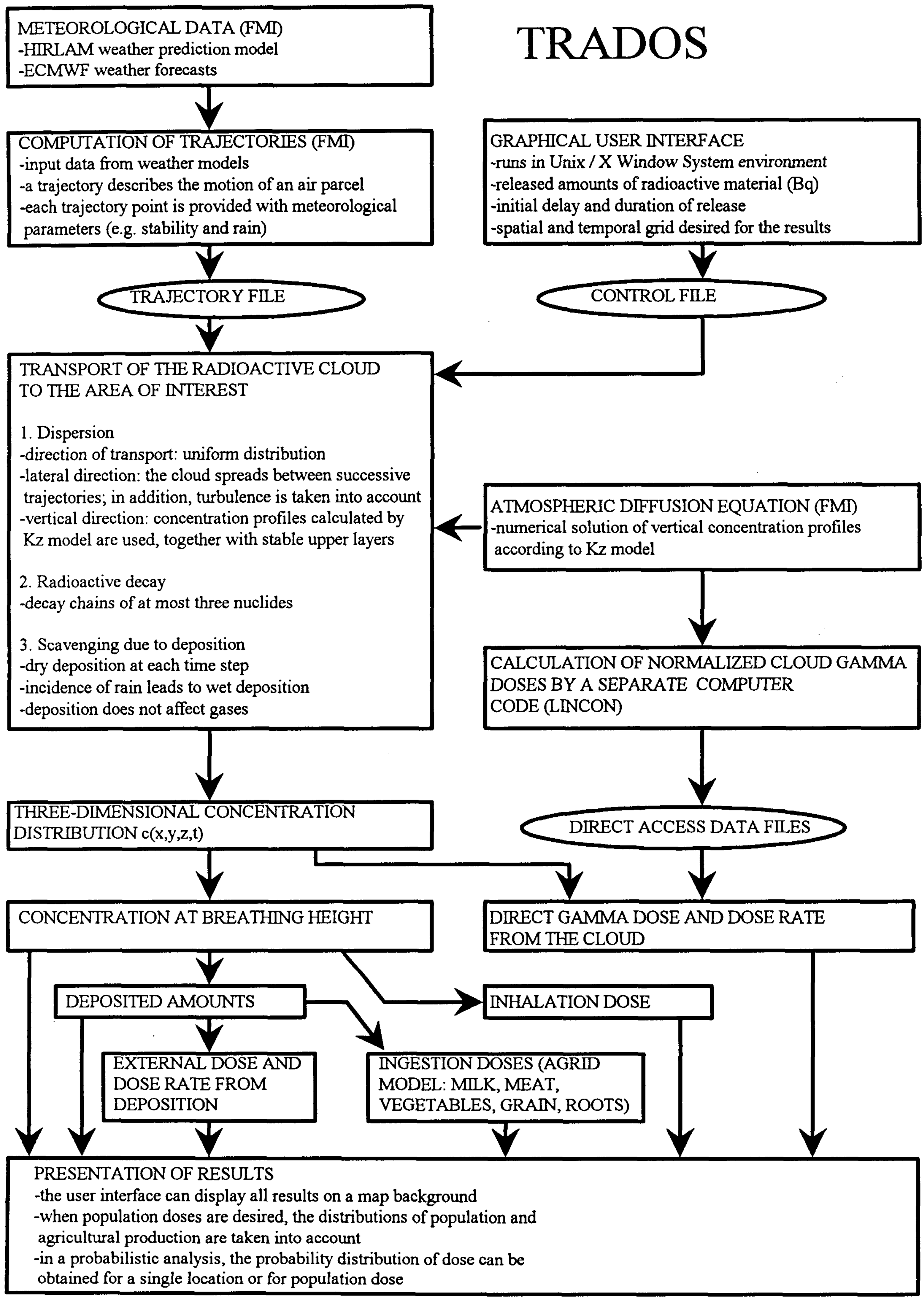
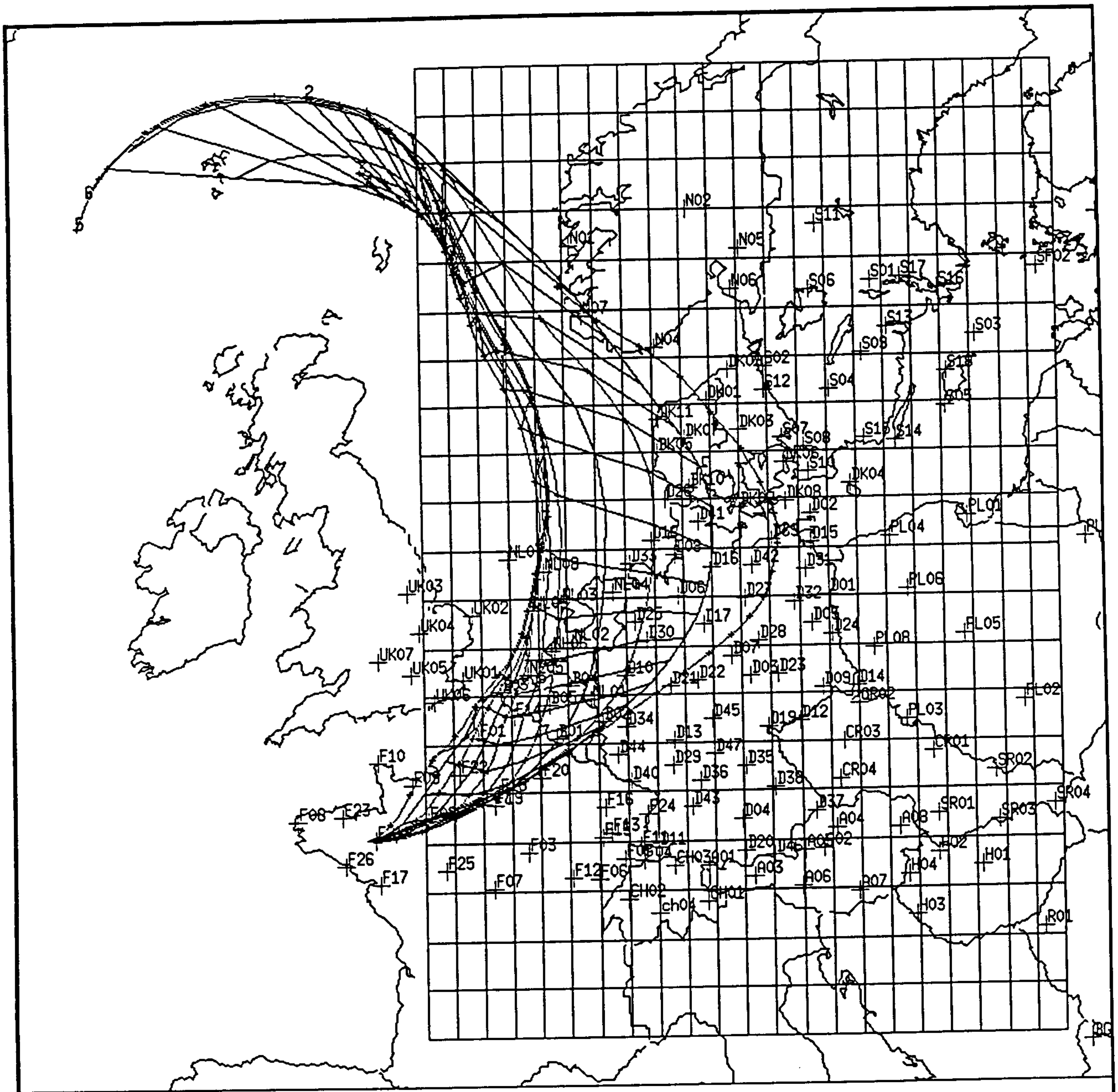
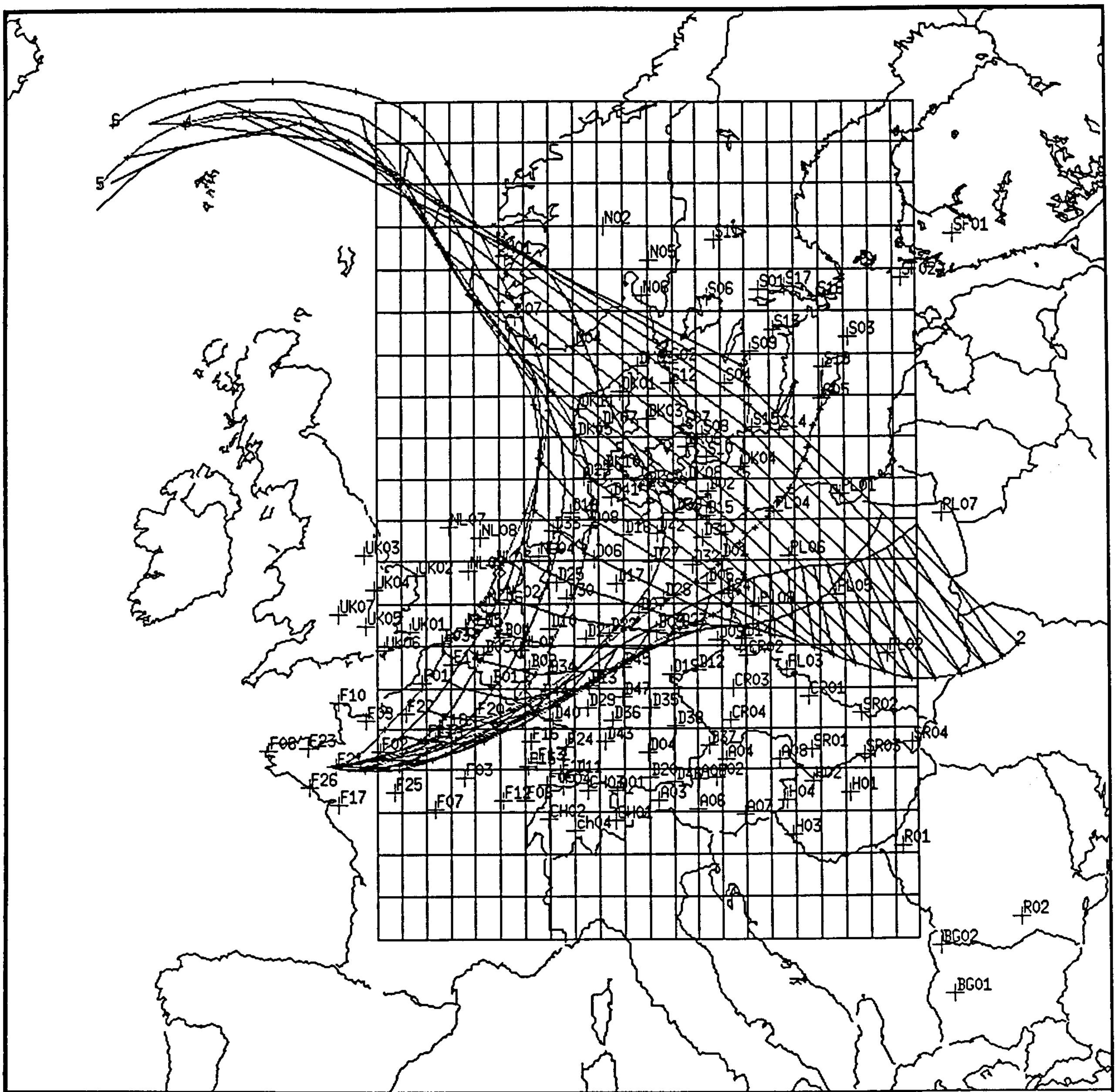

TRADOS
METEOROLOGICAL DATA (FMI)
-HIRLAM weather prediction model
-ECMWF weather forecasts
COMPUTATION OF TRAJECTORIES (FMI)
-input data from weather models
-a trajectory describes the motion of an air parcel
-each trajectory point is provided with meteorological parameters (e.g. stability and rain)
GRAPHICAL USER INTERFACE
-runs in Unix / X Window System environment
-released amounts of radioactive material (Bq)
-initial delay and duration of release
-spatial and temporal grid desired for the results
TRAJECTORY FILE
CONTROL FILE
TRANSPORT OF THE RADIOACTIVE CLOUD TO THE AREA OF INTEREST
1. Dispersion
-direction of transport: uniform distribution
-lateral direction: the cloud spreads between successive trajectories; in addition, turbulence is taken into account
-vertical direction: concentration profiles calculated by Kz model are used, together with stable upper layers
2. Radioactive decay
-decay chains of at most three nuclides
3. Scavenging due to deposition
-dry deposition at each time step
-incidence of rain leads to wet deposition
-deposition does not affect gases
ATMOSPHERIC DIFFUSION EQUATION (FMI)
-numerical solution of vertical concentration profiles according to Kz model
CALCULATION OF NORMALIZED CLOUD GAMMA DOSES BY A SEPARATE COMPUTER CODE (LINCON)
THREE-DIMENSIONAL CONCENTRATION DISTRIBUTION c(x,y,z,t)
DIRECT ACCESS DATA FILES
CONCENTRATION AT BREATHING HEIGHT
DIRECT GAMMA DOSE AND DOSE RATE FROM THE CLOUD
DEPOSITED AMOUNTS
INHALATION DOSE
EXTERNAL DOSE AND DOSE RATE FROM DEPOSITION
INGESTION DOSES (AGRID MODEL: MILK, MEAT, VEGETABLES, GRAIN, ROOTS)
PRESENTATION OF RESULTS
-the user interface can display all results on a map background
-when population doses are desired, the distributions of population and agricultural production are taken into account
-in a probabilistic analysis, the probability distribution of dose can be obtained for a single location or for population dose

Figure 7.1.



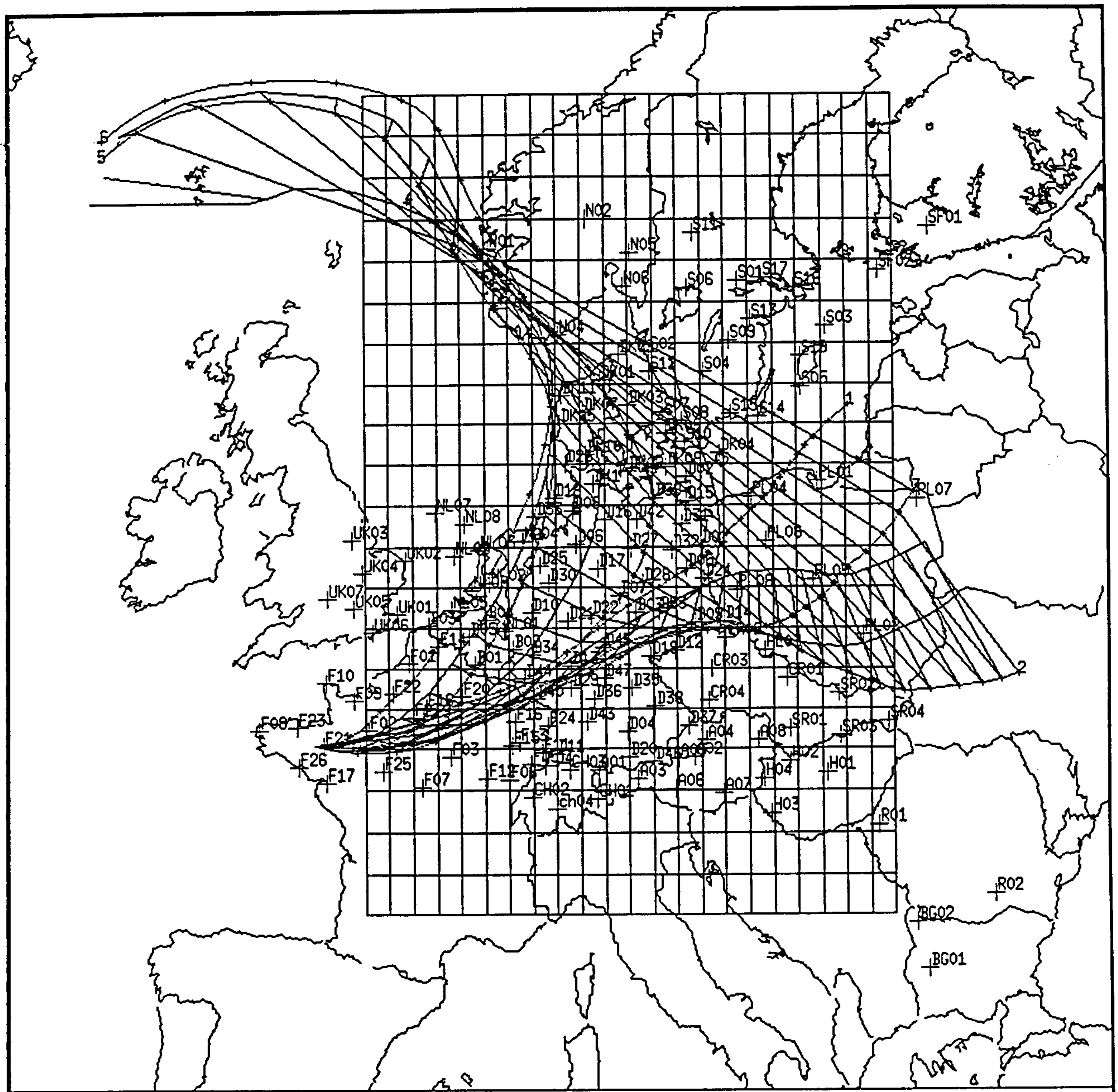
1. ETEX real experiment 23.10.1994
Release location: Rennes, France
Duration of release: 16.00 - 04.00 UTC
Material: Kr-85, 7.9 g/s
Forecast set #1
Blue color indicates total area affected by cloud

Figure 7.2.



1. ETEX real experiment 23.10.1994
Release location: Rennes, France
Duration of release: 16.00 - 04.00 UTC
Material: Kr-85, 7.9 g/s
Forecast set #5
Blue color indicates total area affected by cloud

Figure 7.3.



1. ETEX real experiment 23.10.1994
Release location: Rennes, France
Duration of release: 16.00 - 04.00 UTC
Material: Kr-85, 7.9 g/s
Forecast set #6
Blue color indicates total area affected by cloud

Figure 7.4.

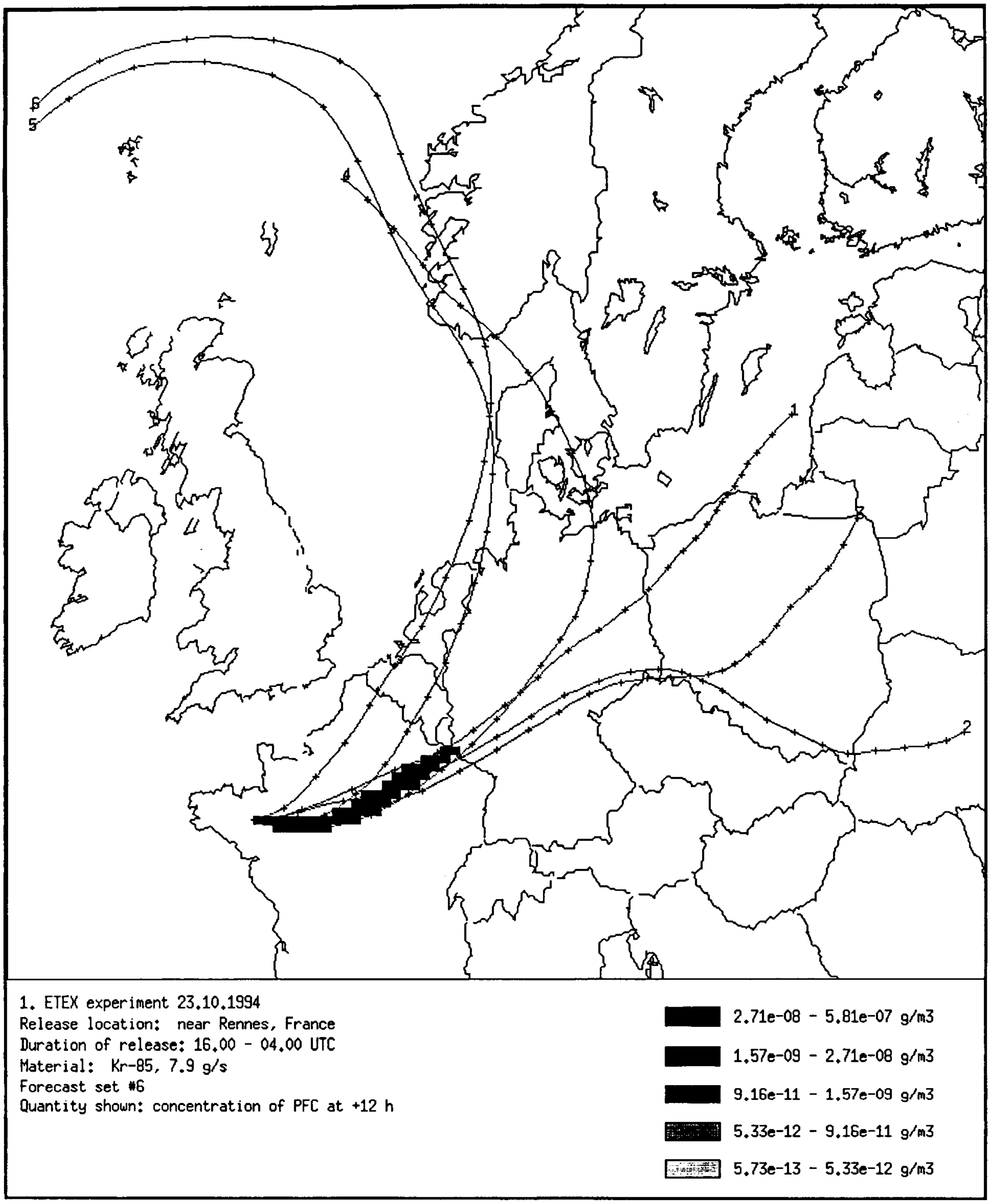

6
5
4
1
2
1. ETEX experiment 23.10.1994
Release location: near Rennes, France
Duration of release: 16.00 - 04.00 UTC
Material: Kr-85, 7.9 g/s
Forecast set #6
Quantity shown: concentration of PFC at +12 h
2.71e-08 - 5.81e-07 g/m3
1.57e-09 - 2.71e-08 g/m3
9.16e-11 - 1.57e-09 g/m3
5.33e-12 - 9.16e-11 g/m3
5.73e-13 - 5.33e-12 g/m3

Figure 7.5.

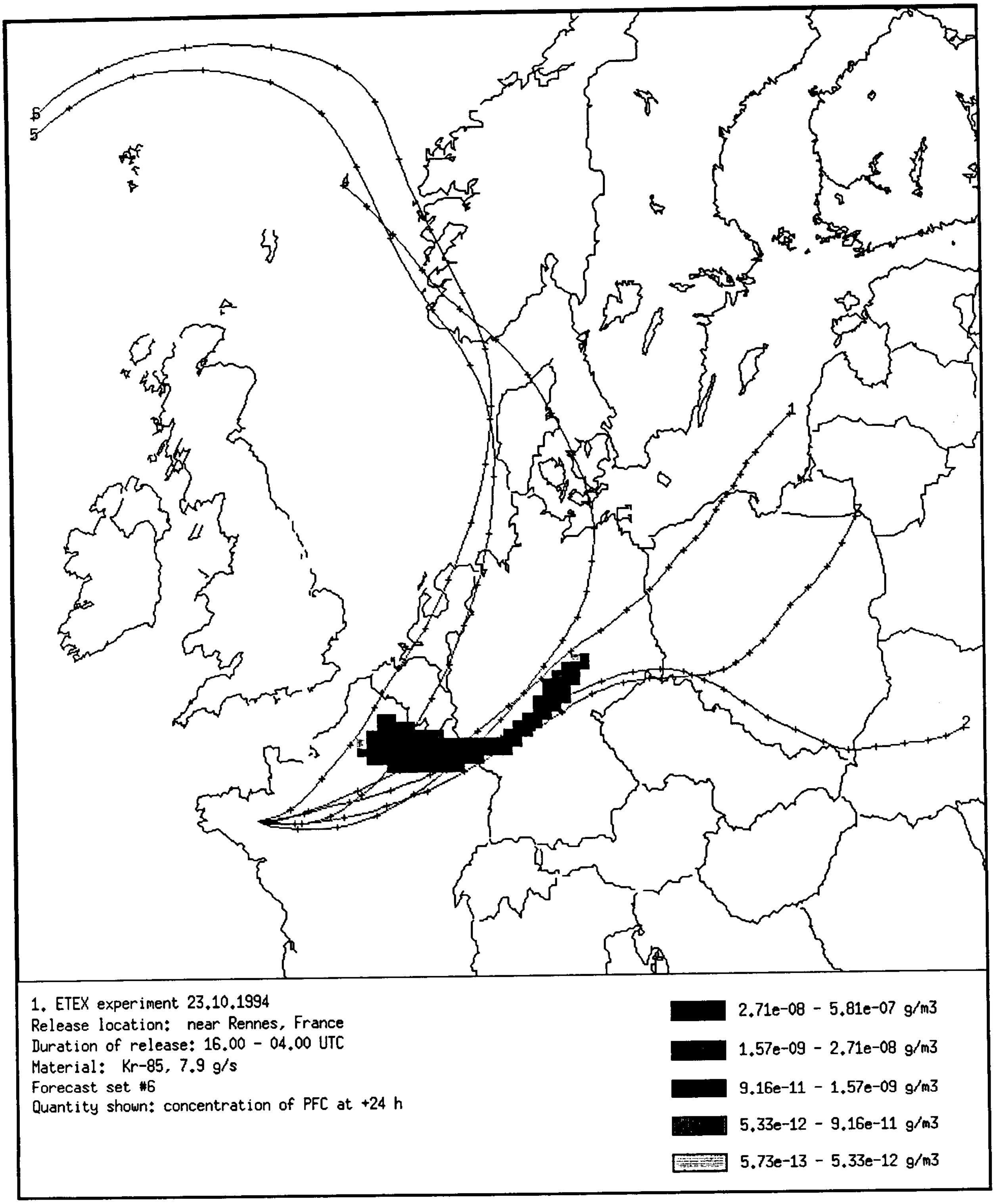

6
5
1
2
1. ETEX experiment 23.10.1994
Release location: near Rennes, France
Duration of release: 16.00 - 04.00 UTC
Material: Kr-85, 7.9 g/s
Forecast set #6
Quantity shown: concentration of PFC at +24 h
2.71e-08 - 5.81e-07 g/m3
1.57e-09 - 2.71e-08 g/m3
9.16e-11 - 1.57e-09 g/m3
5.33e-12 - 9.16e-11 g/m3
5.73e-13 - 5.33e-12 g/m3

Figure 7.6.

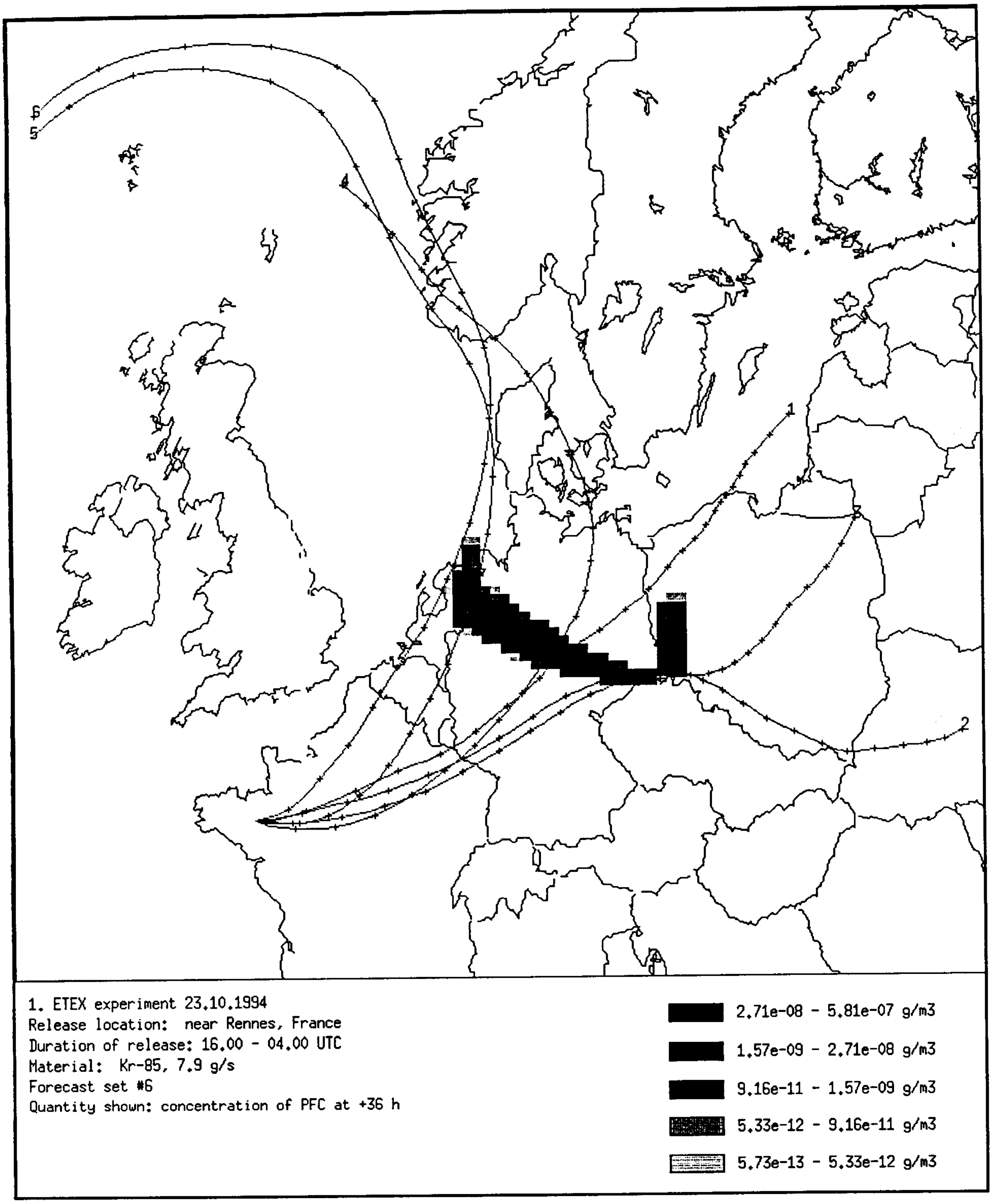

1. ETEX experiment 23.10.1994
Release location: near Rennes, France
Duration of release: 16.00 - 04.00 UTC
Material: Kr-85, 7.9 g/s
Forecast set #6
Quantity shown: concentration of PFC at +36 h
2.71e-08 - 5.81e-07 g/m3
1.57e-09 - 2.71e-08 g/m3
9.16e-11 - 1.57e-09 g/m3
5.33e-12 - 9.16e-11 g/m3
5.73e-13 - 5.33e-12 g/m3

Figure 7.7.

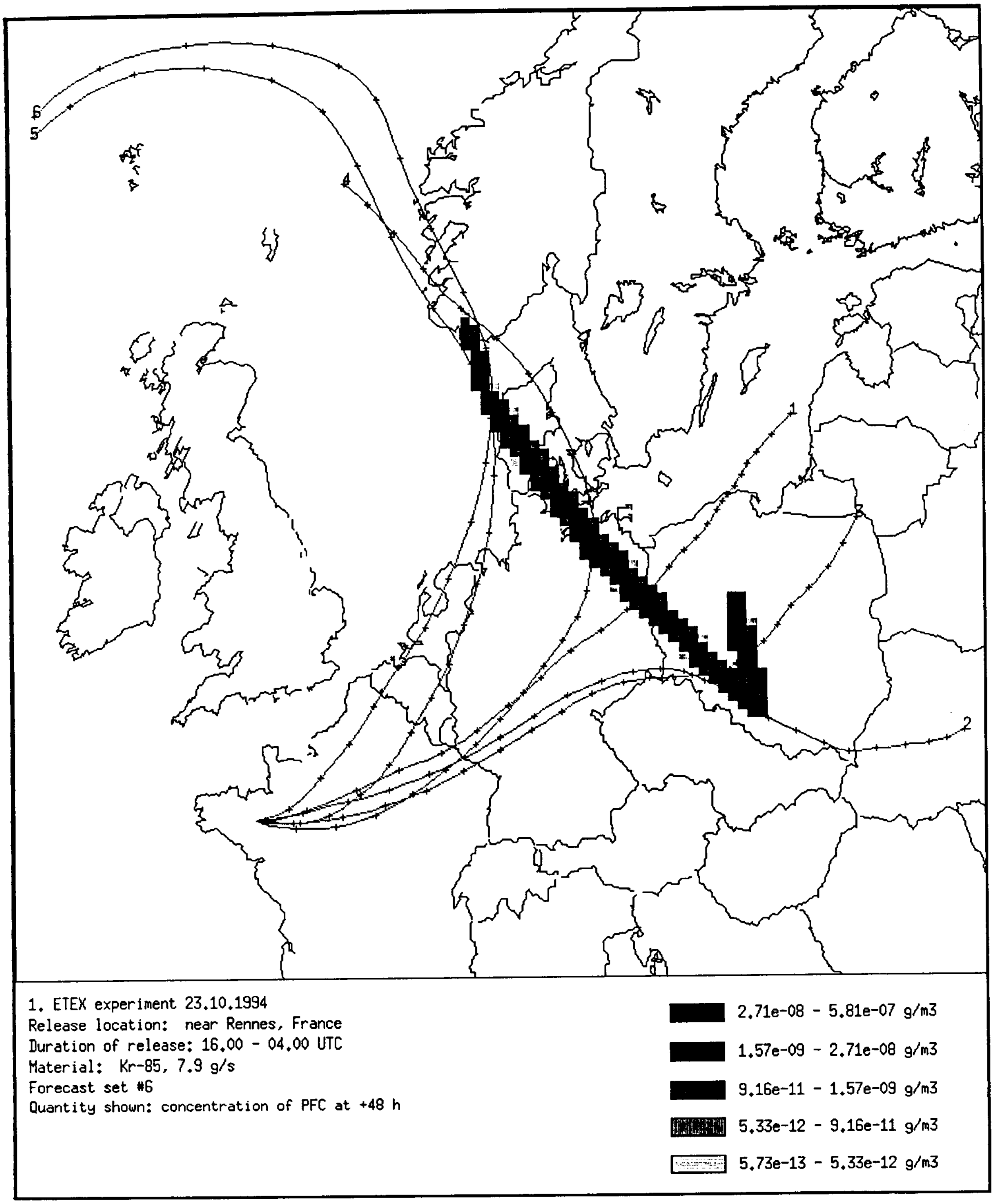

1. ETEX experiment 23.10.1994
Release location: near Rennes, France
Duration of release: 16.00 - 04.00 UTC
Material: Kr-85, 7.9 g/s
Forecast set #6
Quantity shown: concentration of PFC at +48 h
2.71e-08 - 5.81e-07 g/m3
1.57e-09 - 2.71e-08 g/m3
9.16e-11 - 1.57e-09 g/m3
5.33e-12 - 9.16e-11 g/m3
5.73e-13 - 5.33e-12 g/m3

Figure 7.8.

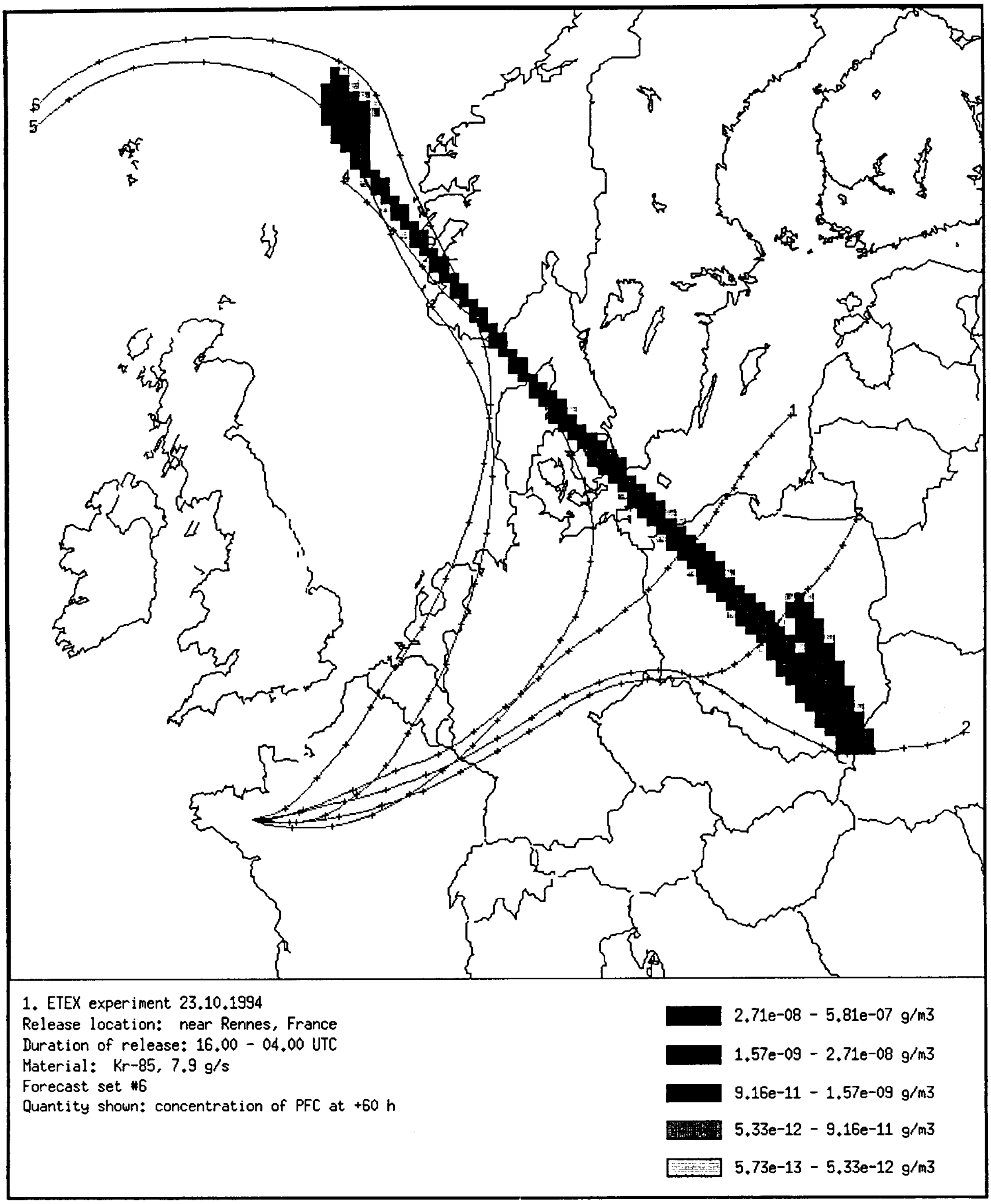

1. ETEX experiment 23.10.1994
Release location: near Rennes, France
Duration of release: 16.00 - 04.00 UTC
Material: Kr-85, 7.9 g/s
Forecast set #6
Quantity shown: concentration of PFC at +60 h
2.71e-08 - 5.81e-07 g/m3
1.57e-09 - 2.71e-08 g/m3
9.16e-11 - 1.57e-09 g/m3
5.33e-12 - 9.16e-11 g/m3
5.73e-13 - 5.33e-12 g/m3

Figure 7.9.

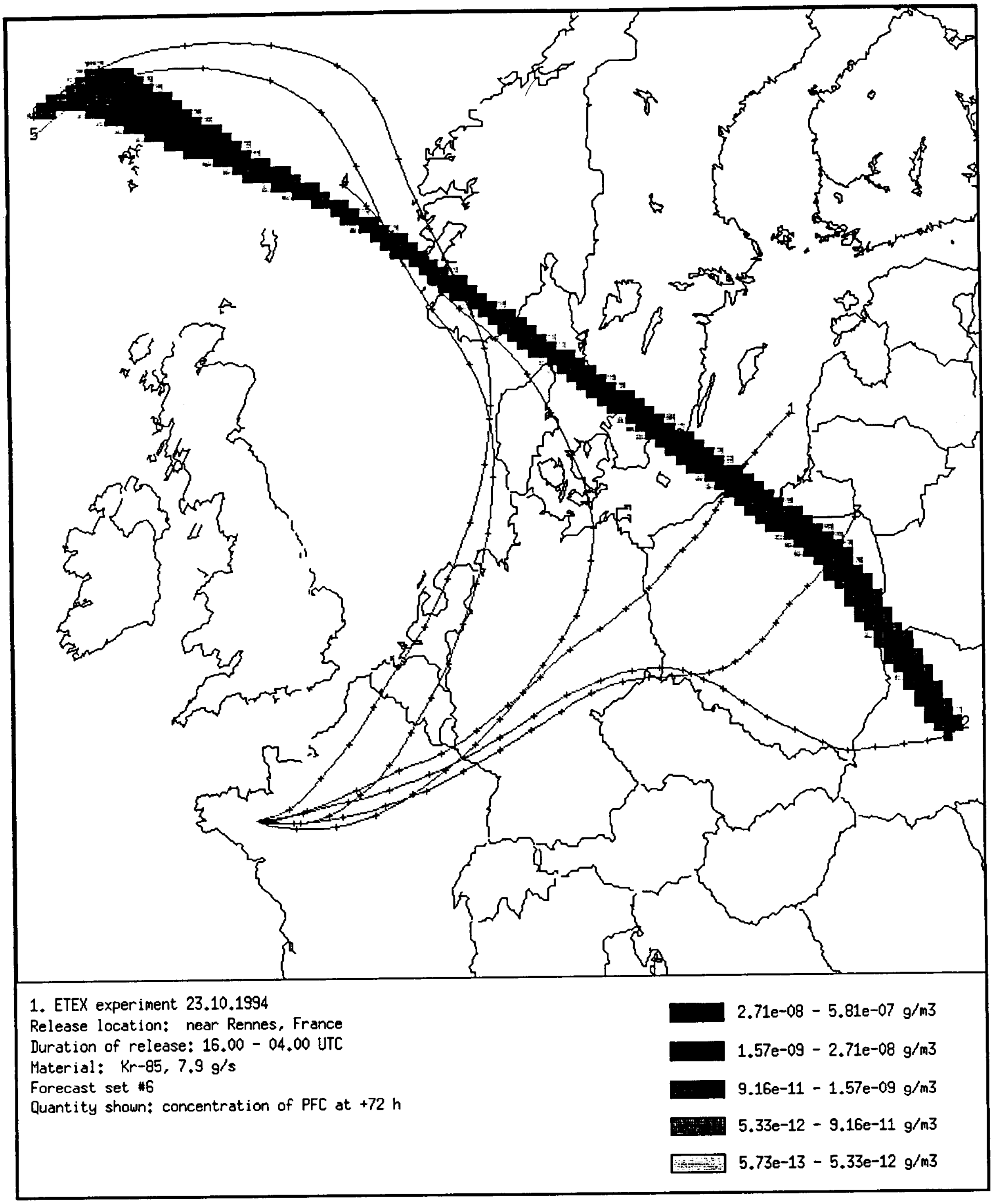

1. ETEX experiment 23.10.1994
Release location: near Rennes, France
Duration of release: 16.00 - 04.00 UTC
Material: Kr-85, 7.9 g/s
Forecast set #6
Quantity shown: concentration of PFC at +72 h
2.71e-08 - 5.81e-07 g/m3
1.57e-09 - 2.71e-08 g/m3
9.16e-11 - 1.57e-09 g/m3
5.33e-12 - 9.16e-11 g/m3
5.73e-13 - 5.33e-12 g/m3

Figure 7.10.

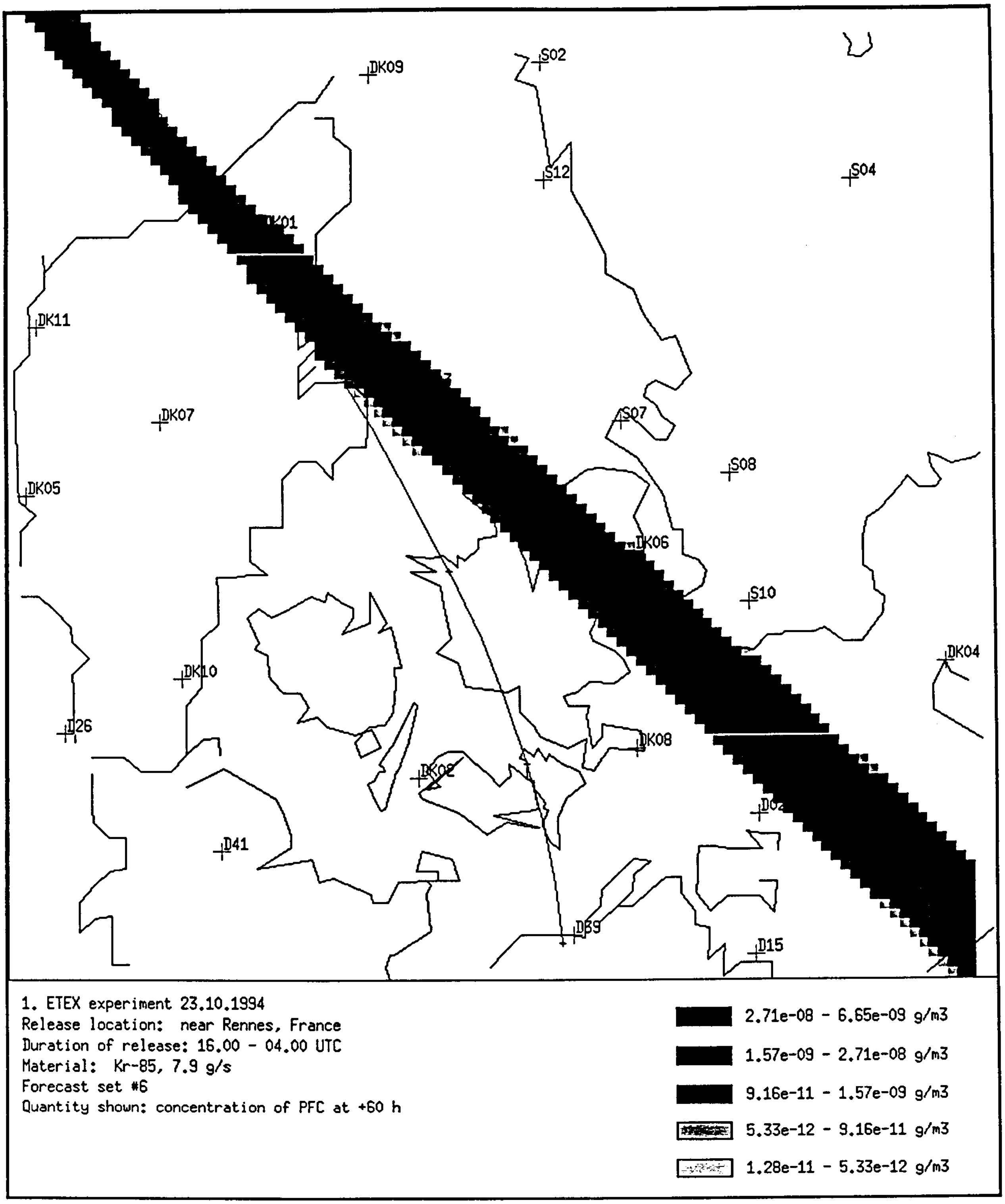

DK09
S02
S12
S04
DK01
DK11
DK07
S07
S08
DK05
DK06
S10
DK04
DK10
I26
DK08
DK02
D41
D59
D15
1. ETEX experiment 23.10.1994
Release location: near Rennes, France
Duration of release: 16.00 - 04.00 UTC
Material: Kr-85, 7.9 g/s
Forecast set #6
Quantity shown: concentration of PFC at +60 h
2.71e-08 - 6.65e-09 g/m3
1.57e-09 - 2.71e-08 g/m3
9.16e-11 - 1.57e-09 g/m3
5.33e-12 - 9.16e-11 g/m3
1.28e-11 - 5.33e-12 g/m3

Figure 7.11.

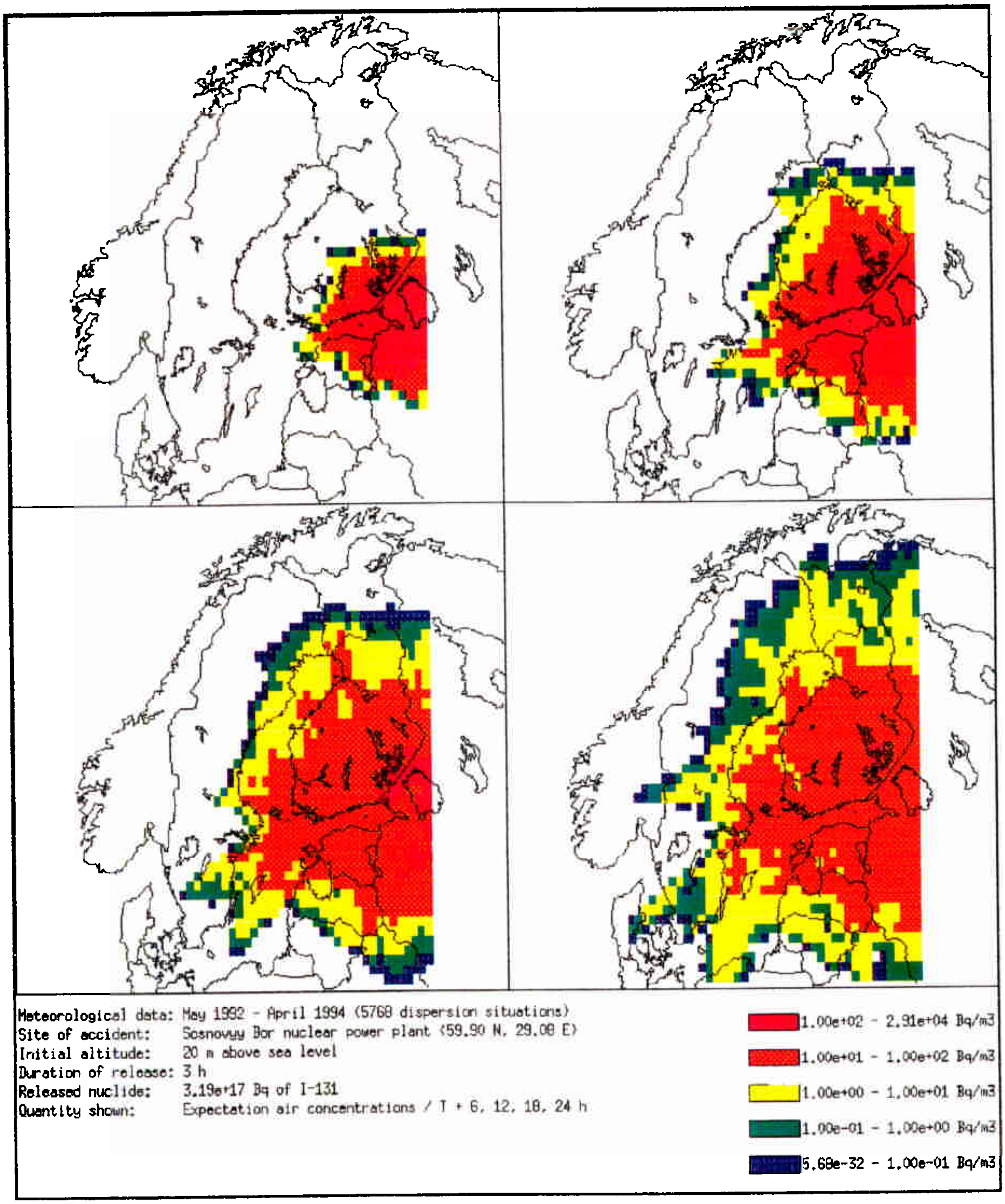

Meteorological data: May 1992 - April 1994 (5768 dispersion situations)
Site of accident: Sosnovyy Bor nuclear power plant (59.90 N, 29.08 E)
Initial altitude: 20 m above sea level
Duration of release: 3 h
Released nuclide: 3.19e+17 Bq of I-131
Quantity shown: Expectation air concentrations / T + 6, 12, 18, 24 h
1.00e+02 - 2.91e+04 Bq/m3
1.00e+01 - 1.00e+02 Bq/m3
1.00e+00 - 1.00e+01 Bq/m3
1.00e-01 - 1.00e+00 Bq/m3
5.68e-32 - 1.00e-01 Bq/m3

Figure 7.12.

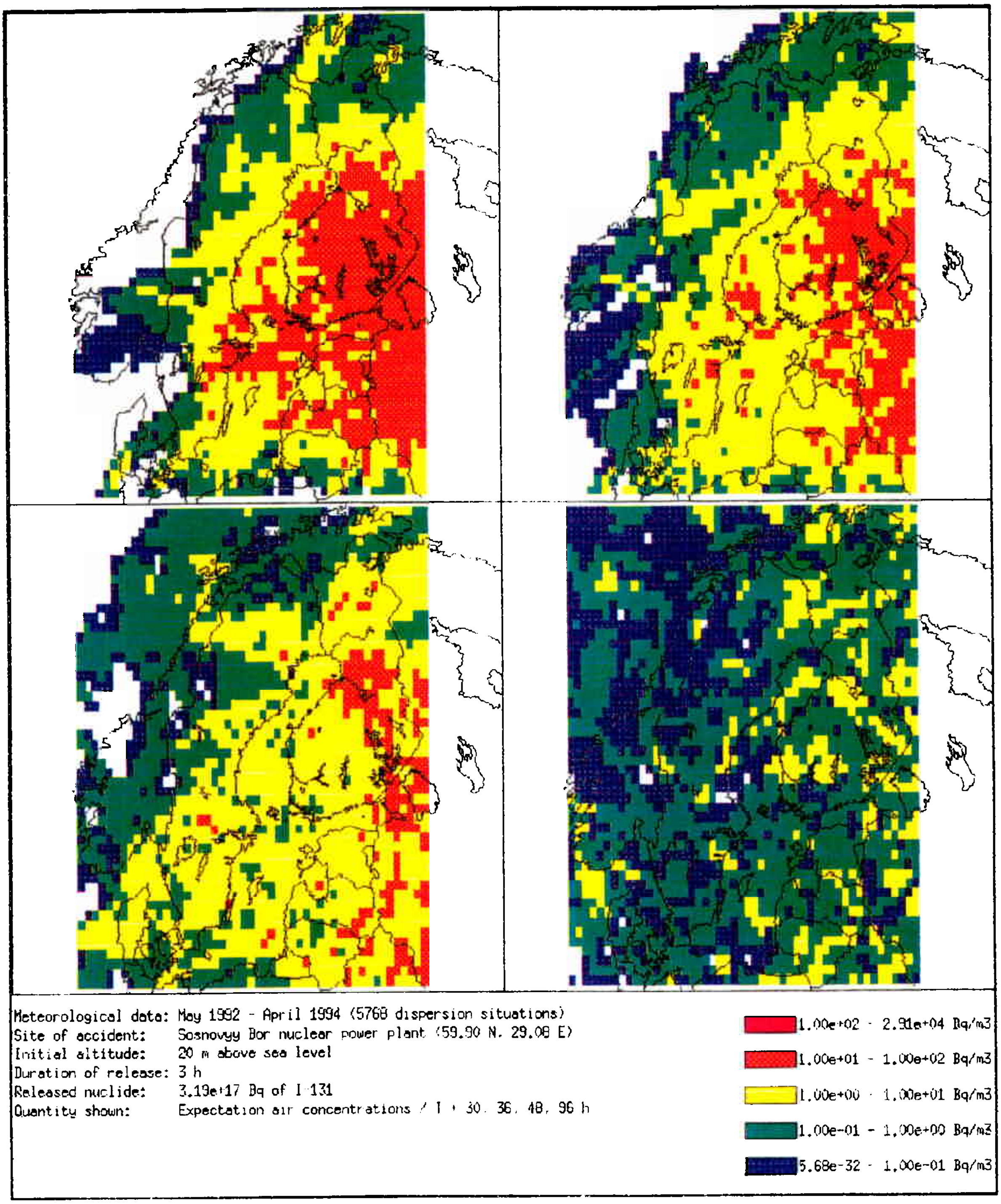

Meteorological data: May 1992 - April 1994 (5768 dispersion situations)
Site of accident: Sosnovyy Bor nuclear power plant (59.90 N. 29.08 E)
Initial altitude: 20 m above sea level
Duration of release: 3 h
Released nuclide: 3.19e+17 Bq of I-131
Quantity shown: Expectation air concentrations / T + 30. 36. 48. 96 h
1.00e+02 - 2.91e+04 Bq/m3
1.00e+01 - 1.00e+02 Bq/m3
1.00e+00 - 1.00e+01 Bq/m3
1.00e-01 - 1.00e+00 Bq/m3
5.68e-32 - 1.00e-01 Bq/m3

Figure 7.13.

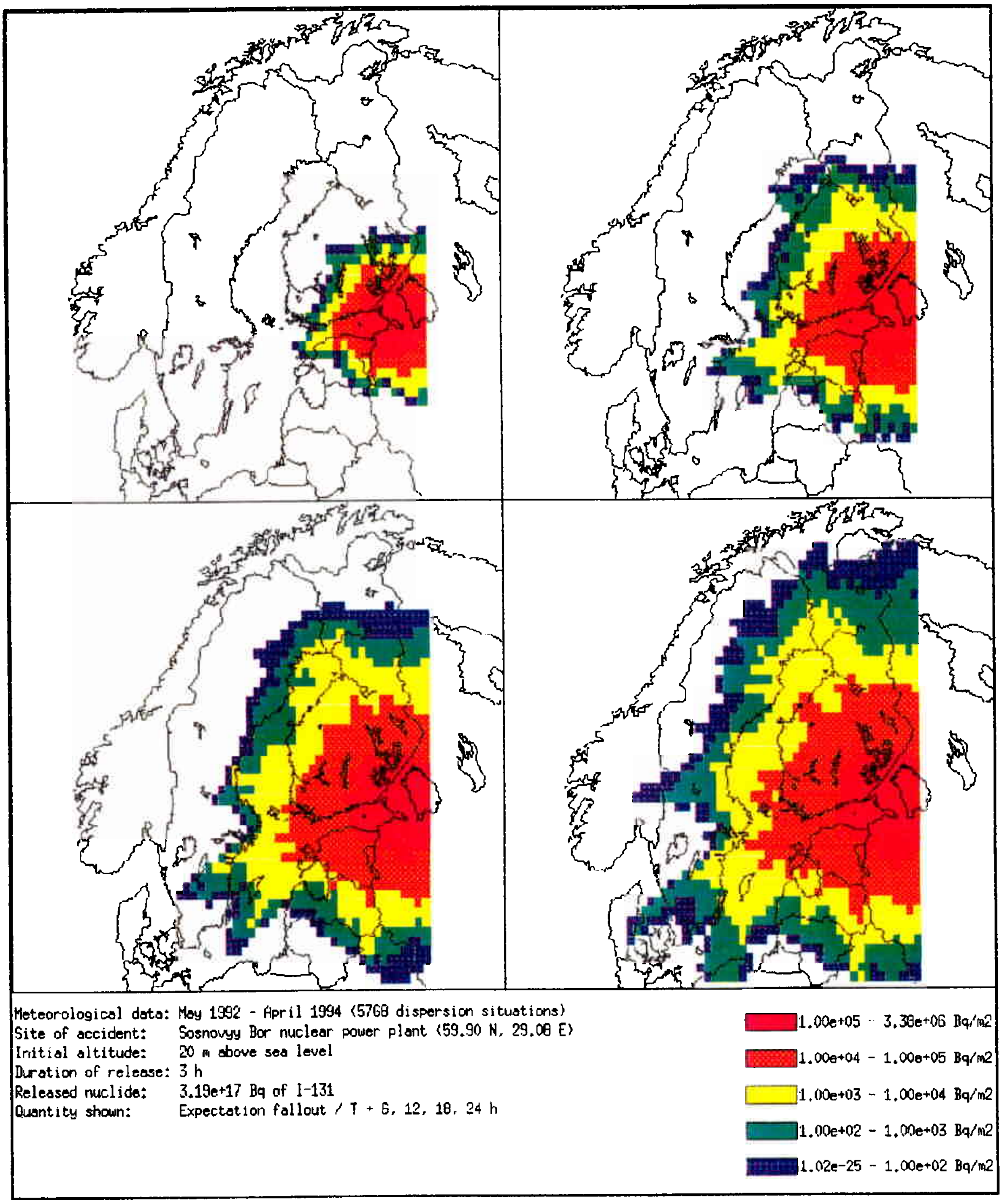

Meteorological data: May 1992 - April 1994 (5768 dispersion situations)
Site of accident: Sosnovyy Bor nuclear power plant (59.90 N, 29.08 E)
Initial altitude: 20 m above sea level
Duration of release: 3 h
Released nuclide: 3.19e+17 Bq of I-131
Quantity shown: Expectation fallout / T + 6, 12, 18, 24 h
1.00e+05 - 3.38e+06 Bq/m2
1.00e+04 - 1.00e+05 Bq/m2
1.00e+03 - 1.00e+04 Bq/m2
1.00e+02 - 1.00e+03 Bq/m2
1.02e-25 - 1.00e+02 Bq/m2

Figure 7.14.

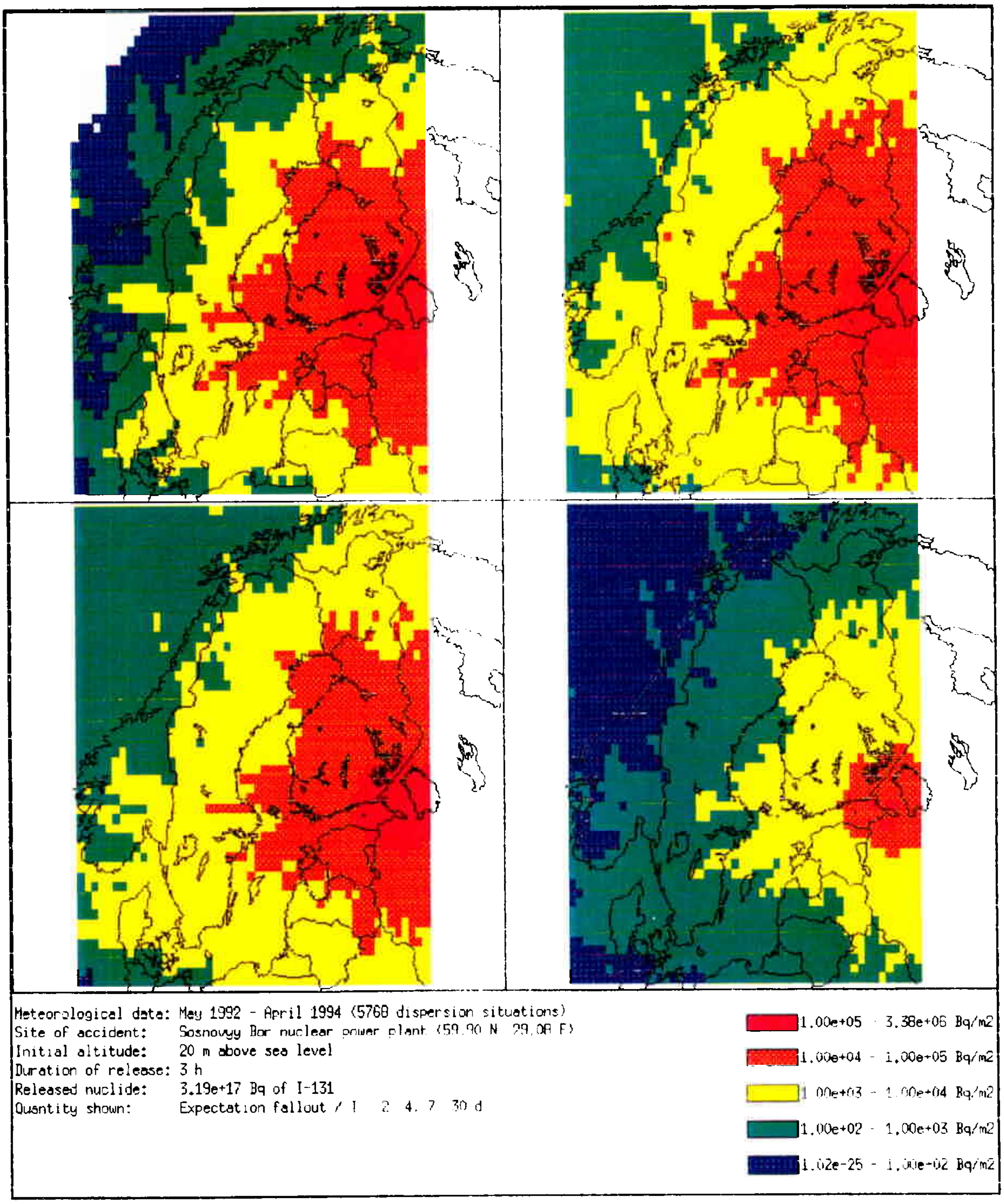

Meteorological data: May 1992 - April 1994 (5768 dispersion situations)
Site of accident: Sosnovyy Bor nuclear power plant (59.90 N 29.08 E)
Initial altitude: 20 m above sea level
Duration of release: 3 h
Released nuclide: 3.19e+17 Bq of I-131
Quantity shown: Expectation fallout / 1 2 4 7 30 d
1.00e+05 - 3.38e+06 Bq/m2
1.00e+04 - 1.00e+05 Bq/m2
1.00e+03 - 1.00e+04 Bq/m2
1.00e+02 - 1.00e+03 Bq/m2
1.02e-25 - 1.00e-02 Bq/m2

Figure 7 15

8 Calculations Performed by the Norwegian Meteorological Institute (DNMI)

Jørgen Saltbones, Anstein Foss and Jerzy Bartnicki
Norwegian Meteorological Institute
Blindern, Norway

A description was given of the on-line real-time SNAP (Severe Nuclear Accident Program) model, which is now operational. The model is based upon program NAME from the UK Meteorological Office and has been developed by Jørgen Saltbones, Anstein Foss and Jerzy Bartnicki.

SNAP is a Lagrangian particle model. Advection is calculated horizontally and vertically, diffusion is calculated using a random walk approach, and there is a vertical entrainment layer. Dry (assumed to affect selected particles in the ABL) and wet deposition (rain affects all particles, but in a manner so that the particles lose a certain fraction of their mass) are incorporated, and LAM50S is used as a weather prediction model. LAM50S will soon be replaced by the Nordic weather model HIRLAM. There are three options for vertical profile: homogenous in boundary layer, 30% above boundary layer, or user-specified. Two time profiles, either constant or constant a certain time and then gradual decrease. Vertical structure: 14 layers. Orography taken into account, as shown on figure 8.1, which shows a crossection through a mountain area. Further details about model characteristics are found in Figures 8.2 to 8.5, as well as in the following paragraphs:

Advection:

$$\vec{\chi}'_{t+\Delta t} = \vec{\chi}_t + \vec{v}(\vec{\chi}_t)\Delta t$$

Diffusion (random walk):

$$\chi'' = \chi' + r_\chi l$$

$$y'' = y' + r_y l$$

$$\sigma'' = \sigma' + r_\sigma l_\sigma$$

SNAP is operated on SGI (Silicon Graphics INDIGO) workstations.

A 48 hours forecast with meteorological data from LAM50S (HIRLAM) takes about 25 minutes of real time.

Typical parameter values: 900 part./Δt (max. ~300,000), Δt = 15 minutes.

There is on-screen and off-line graphics.

A demonstration of the SNAP-results on video was given. No displays of concentrations were shown, only the particles seen from above. General trends were similar to what was presented by the other participants in this meeting. Arrival time at Risø was at about 48 hours. "Snap-shots" of the cloud are given in Figures 8.6 to 8.8. It is difficult to determine what the concentrations are from the figures when the cloud passes Risø, but it is of the order of 10^{-9} g/m^3.

SNAP - Vertical Structure

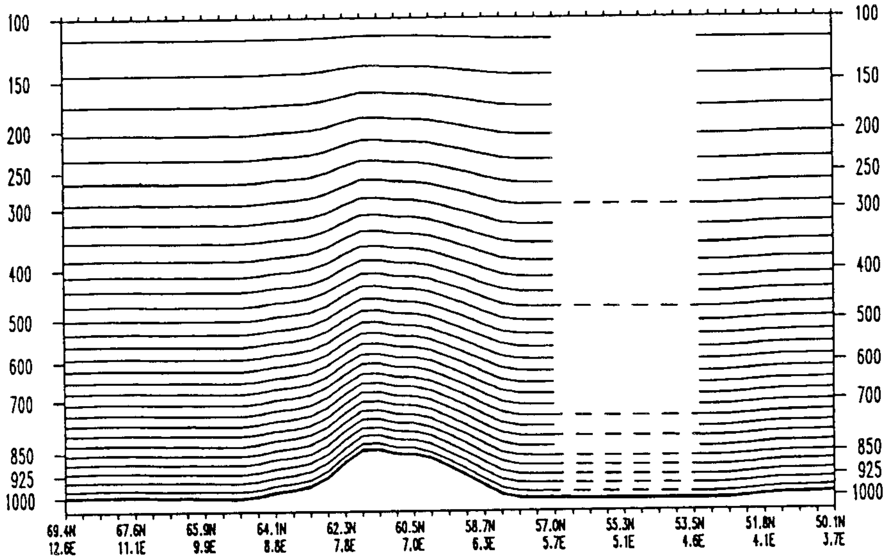


Figure 8.1.

SNAP - assumptions

- Particle model

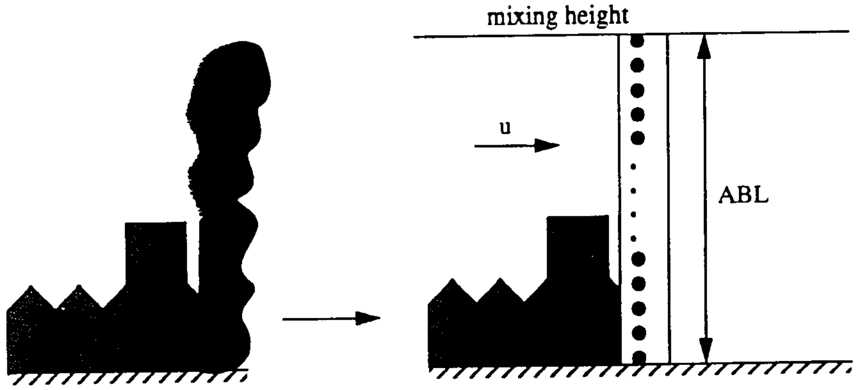


Figure 8.2.

$M_p = M_p(t)$ - particle mass

$x_p = x_p(t)$

$y_p = y_p(t)$ - particle position

$z_p = z_p(t)$

- Processes during the transport: advection, diffusion, dry deposition, wet deposition, radioactive decay

SNAP - Vertical Diffusion

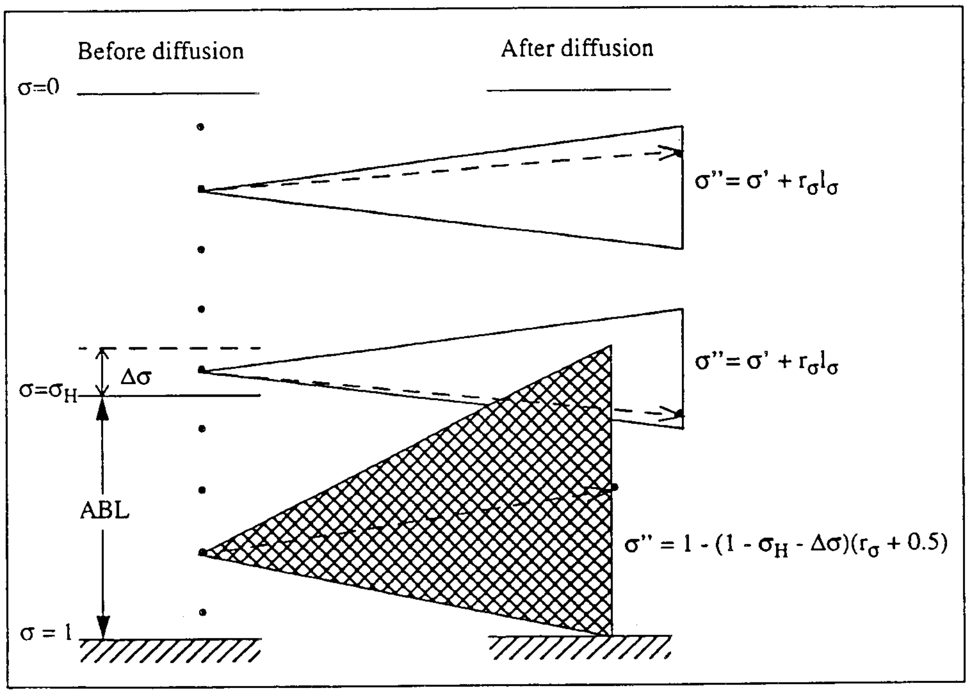


Figure 8.3.

SNAP - Dry Deposition

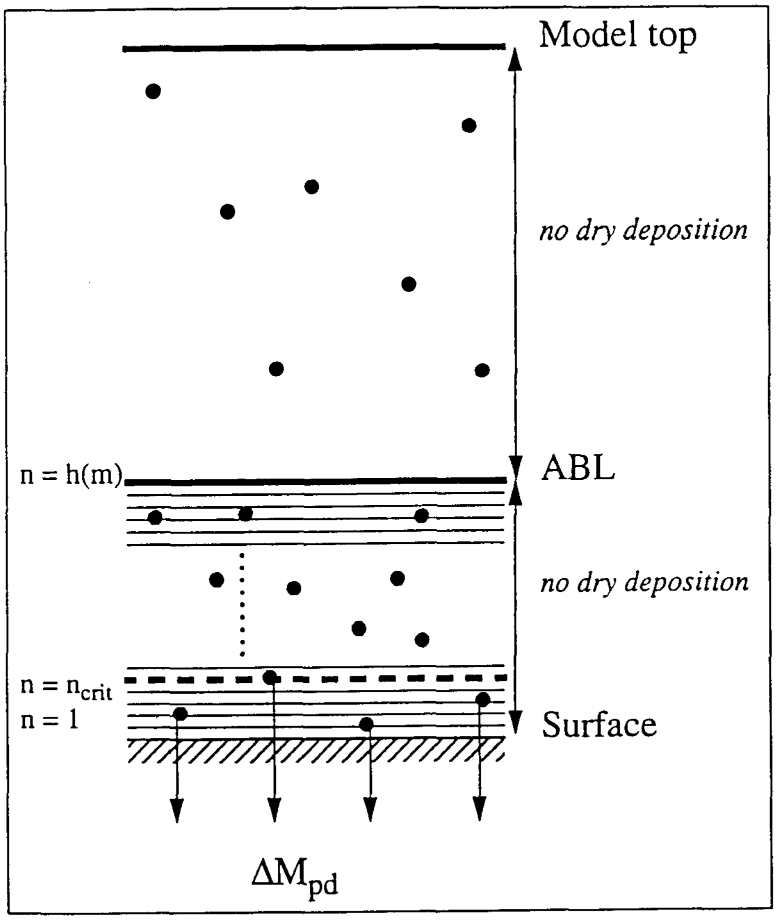


Figure 8.4.

Wet Deposition

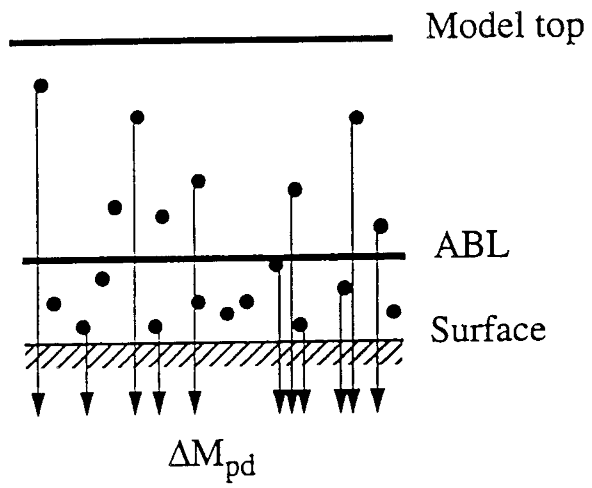


Figure 8.5a.

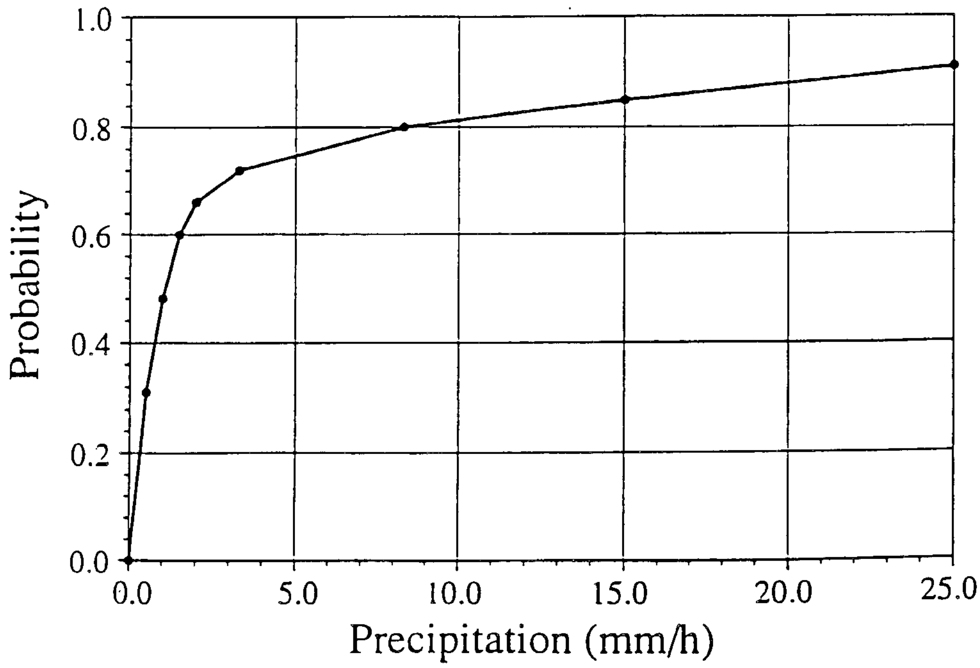


Figure 8.5b.

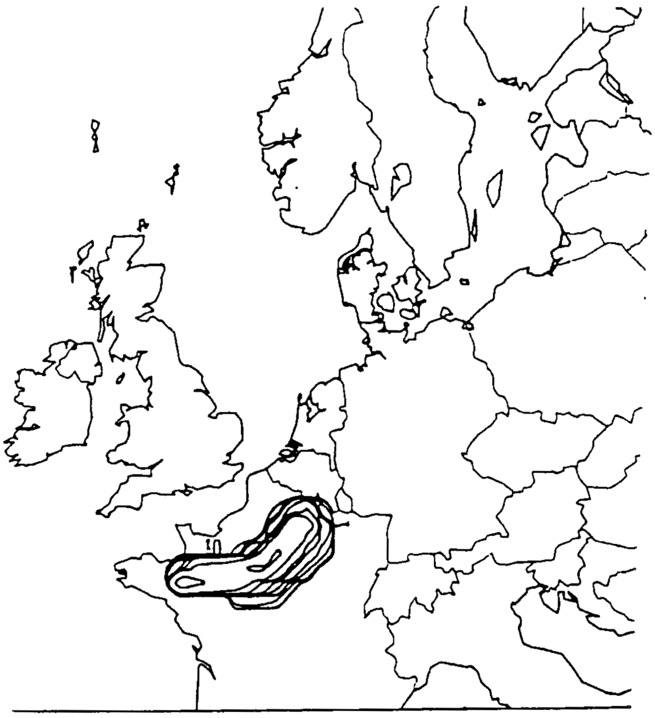


*Figure 8.6. SNAP-LAM50S: Concentration of PFC in the atmospheric boundary layer. Time: 24.10.1994 04 UTC - 12 hours after start of release. The tracer gas PFC was released at ground level at a source strength of 7.9 g/s. Iso-pleths in Fig. 8.6 - Fig. 8.8 are 'n' * 10^{-12} g/m^3, where 'n' equals are 1, 3, 10, 30, 100, 300, 1000, 3000, etc.*

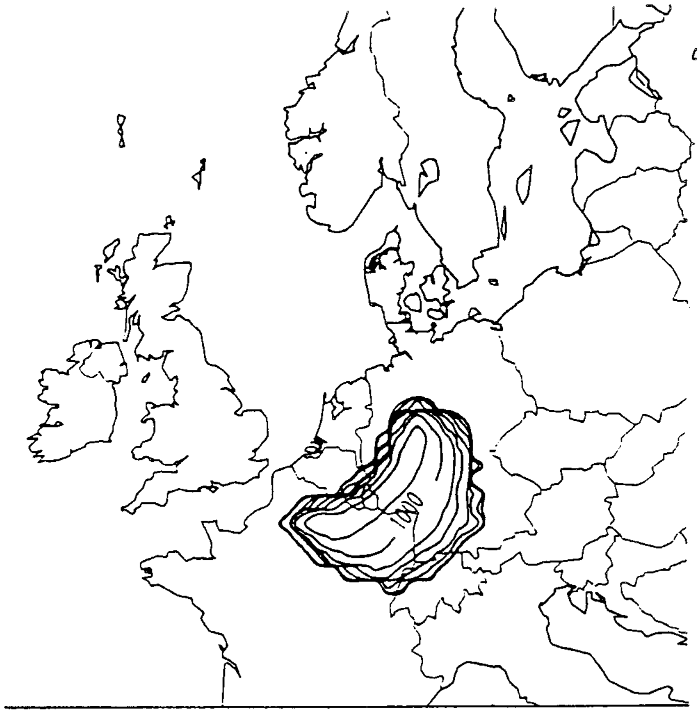


*Figure 8.7a. SNAP-LAM50S: Concentration of PFC in the atmospheric boundary layer. Time: 24.10.1994 16 UTC - 24 hours after start of release. Iso-pleths: 'n' * 10^{-12} g/m^3, where 'n' equals are 1, 3, 10, 30, 100, 300, etc.*

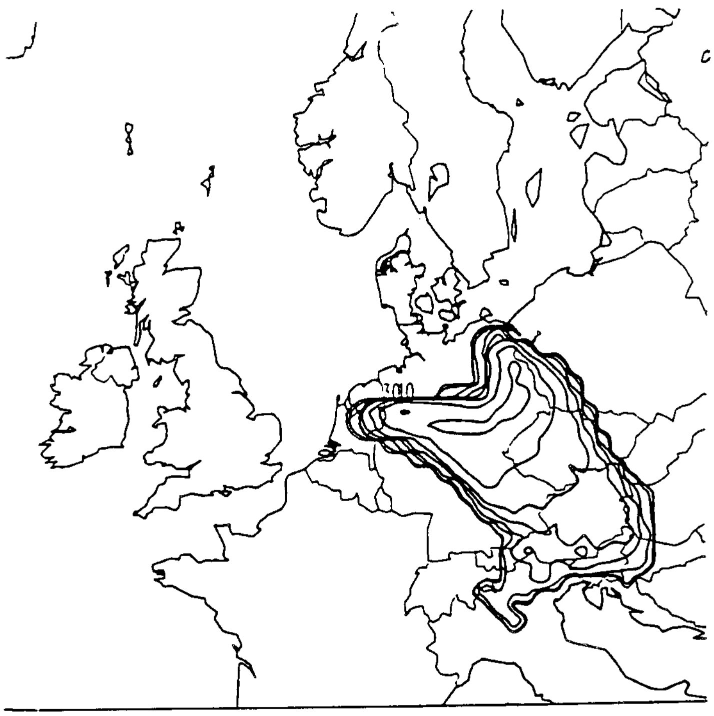


*Figure 8.7b. SNAP-LAM50S: Concentration of PFC in the atmospheric boundary layer. Time: 25.10.1994 04 UTC - 36 hours after start of release. Iso-pleths: 'n' * 10^{-12} g/m^3, where 'n' equals are 1, 3, 10, 30, 100, 300, etc.*

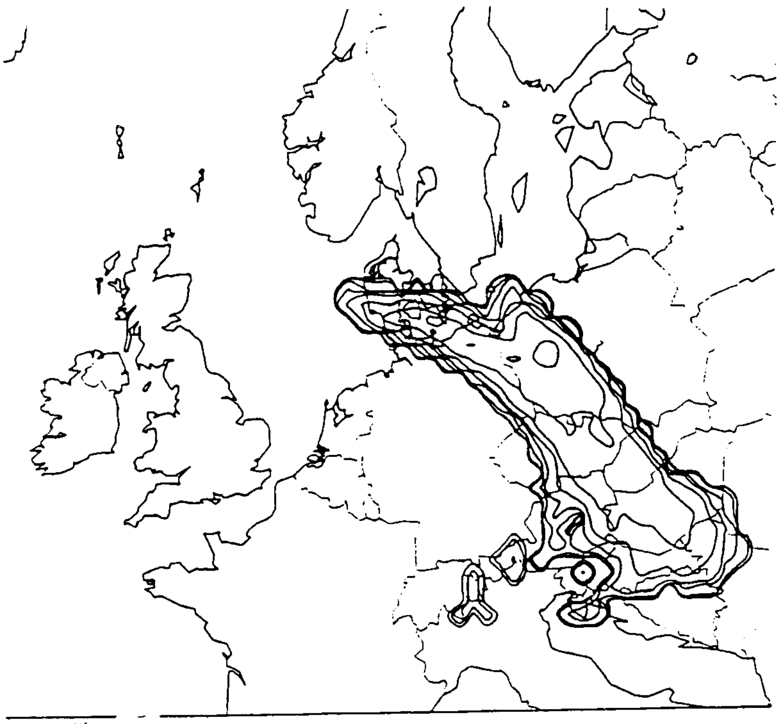


*Figure 8.8a. SNAP-LAM50S: Concentration of PFC in the atmospheric boundary layer. Time: 25.10.1994 16 UTC - 48 hours after start of release. Iso-pleths: 'n' * 10^{-12} g/m^3, where 'n' equals are 1, 3, 10, 30, 100, 300, etc.*

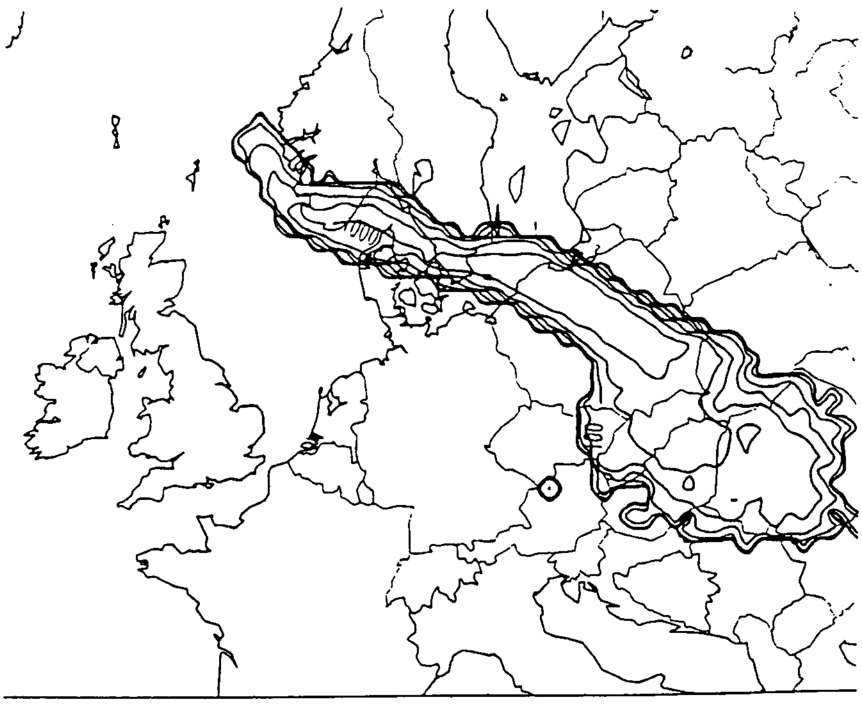


*Figure 8.8b. SNAP-LAM50S: Concentration of PFC in the atmospheric boundary layer. Time: 26.10.1994 04 UTC - 60 hours after start of release. Iso-pleths: 'n' * 10^{-12} g/m^3, where 'n' equals are 1, 3, 10, 30, 100, 300, etc.*

9 Additional Presentations

Anne Grete Straume, working at Ispra, in close cooperation with Katrin Nodop, but stationed at DNMI for the moment, gave information on the progress at Ispra. The measurements from the 90 stations, taken during ETEX-1 will be analyzed by the end of June. The results will be distributed to the participating modellers only. There will be a modellers workshop in Prague in October 1995, and the final ETEX meeting will be held in the autumn of 1996. There are now 4 persons and 2 machines working with the sampling analysis in Ispra.

Juhani Lahtinen from the Finnish Centre for Radiation and Nuclear Safety (STUK), gave a presentation on STUK's role in a radiological emergency. This was a very different presentation from the others. Juhani Lahtinen described what tools and aiding systems STUK would want to have access to in different types of situations. He also described the present modeling situation:

AINO is under development.

OIVA is operational. OIVA uses data calculated by FMI's model YDINO. It will probably be updated in the future to to accept output of the new dispersion model (known as SILJA) currently under development at the FMI.

STUK has a Meteorological work station, so that one has access to the data of FMI. However, a system for displaying TRADOS results at STUK is also needed. The system of monitoring stations in Finland was mentioned. In the future there will also be the EU-system for emergencies, which is now under development, RODOS.

Torben Mikkelsen concluded the workshop by presenting an "off-the-schedule" description of the joint European Real-time On-line Decision support system named RODOS, which is under development with support by the Commision of the European Communities, and he also made references to the corresponding Danish emergency system ARGOS-NT and to the Norwegian MEMbrain system also under development for assisting decision support during major industrial and radioecological accidents.

10 Summary of Results

Torben Mikkelsen
Risø National Laboratory
Roskilde, Denmark

The Table below summarizes the key parameters of the exercise including:

1. The clouds arrival time at Risø (in hours after start of release)
2. The duration in hours of above detection-level concentration (in hours), and
3. The maximum (peak) concentration in nanogram PFC pr. cubic meter.

The tabel is based on a measured air concentration significant level of 0.083 ng/m^3.

The first row shows the actual ETEX-1 measurement values, subsequent follows the models predictions from DMI, SMHI, DMU/RISØ, FOA, FMI and DNMI:

	Arrival time at Risø (hr.)	Duration (hr.)	Max. conc. (ng[1])
ETEX-1 Data	44	20	1.08[1]
DMI DERMA	44±1	20	0.6
SMHI MATCH	45	24	1
DMU/RISØ DREAM	44 ±2	18	0.4 - 0.5
FOA MATHEW/ADPIC	46.5	19	1 - 1.6
FMI[2] TRADOS	55±5	2-4	1.5 - 2.7
DNMI SNAP	48±2	12±2	1 - 3

[1] The measured maximum concentration at Risø is about 13 times above the global background concentration of PFC.
[2] TRADOS is a trajectory model. Uncertainty in reading arrival times is estimated to ±15%.

11 Main Issues from the Discussions

Ulf Tveten
IFE
Kjeller, Norway

The main topics and questions raised during the Discussions were as follows:

I. Uncertainty:
Do the uncertainties come mainly from the Meteorology or from the Dispersion module?

This important question was raised in the discussion session, along with a second, related question: "How do we discriminate between advection and diffusion uncertainty?"

All six participating institutes have made use of a combination of an advecting windfield (calculated by a European or a Global scale meteorological weather prediction model (e.g. HIRLAM or ECMWF), in combination with a dispersion module, which is either of Eulerian type (a K- model), or of Lagrangian type (i.e. either a puff or a trajectory type model).

In order to properly intercompare the different dispersion models in this exercise, calculations should furthermore have been based on: 1) a single wind (meteorological) model, and visa versa: in order to intercompare the wind models, calculations should also: 2) have made use of the same dispersion model.

A more detailed ETEX-1/model intercomparison test along these lines could be one of more tasks to be undertaken during a continuation of this inter-Nordic exercise. Such a study is important to discriminate the uncertainty and the modeling differences and relate them to the two different types of models involved.

II. Improvements in the modeling performance from increased spatial and temporal resolution:

DNMI reported in their presentation the potential of increasing the model accuracy by planned increases in space and time resolution in their models. One drawback of increased resolution is of course the larger demands on storage and transfer times in case of on-line data transmission. Transmission times are important, for instance, in the EURODOS real-time on-line decision support system, where huge amounts of data is transferred via computer networks between Numerical Weather Prediction centers and nuclear accident decision support centers located throughout all of Central and Eastern Europe.

Also the cost-benefit performance with increased resolution, both for the meteorological and for the dispersion part, is an important item, that is relevant for a further investigation during a future continuation of this EKO-4 project activity.

III. Uncertainty from increased forecast period:

Also a study of the deterioration in prediction ability with increased forecast period is an important item for further investigation. The Risø-ETEX-1 exercise was for all parts based on "analyzed" meteorological fields only, i.e., the best meteorological fits to actual observations. Evaluation in this study of the additional uncertainty coming from the forecasting itself is therefore eliminated. Therefore, its worthwhile to investigate the additional uncertainty resulting from the prolongation of the forecast periods - out to maybe +36 or +48 Hours before the ETEX-1 release took place.

IV: Should HIRLAM forecast data be on-line inter-connected between the institutes in the Nordic countries?

This question was brought up by Mika Salonoja, who remarked that it is strange that, even if all four countries are now using HIRLAM, if one computer is down in one of the countries, it is impossible to get the weather data from one of the other countries. The different versions of HIRLAM have small differences that make exchange impossible. These problems are related to the file-structure for the output.

V: General observation.

It was acknowledged that, at least in this connection, the Gaussian plume is no longer a satisfactory alternative. The trajectory models also seem to be inadequate, as the trajectory model results presented at this meeting were rather different from the dispersion model results.

VI: Call for an ETEX-1 follow-up EKO-4 exercise end 1996?

At the end of the discussions it was recommended to promote the arrangements of a

" 2nd Nordic Long Range Modellers uncertainty exercise based on ETEX-1 measurements"

with the more specific purpose of evaluating, intercomparing and collaborating on the results from this exercise. Also the full set of data will soon be available from JRC-Ispra's data evaluation of the full European sampling network.

A second Nordic ETEX model intercomparison exercise could advantageously be scheduled at the end of 1996.

Appendix 1

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Appendix 2

Meeting agenda

Tuesday June 6, 1995:

SESSION I

11:00-11:15	Welcome address - Eldri Naadlund, NRPA and Torben Mikkelsen, Risø
11:15-12:00	Experiences from the BER-1 exercises 1991-1994 - Ulf Tveten, IFE
12:00-13:00	Lunch
13:10-13:30	ETEX-1 On-site Meteorologi - Sven-Erik Gryning, Risø
13:30-14:15	ETEX-1 Tracer measurements at Risø - Thomas Ellermann and Erik Lyck, DMU
14:15-14:45	Coffee

SESSION II

Presentation of ETEX-1 prognoses: Trajectories and doses

14:45:15:20	Results from the Meteorological Institute of Denmark - Alix Rasmussen and Jens Havskov Sørensen, DMI
15:20-15:55	Results from the Meteorological and Hydrological Institute of Sweden - Lennart Robertsson, SMHI
15:55-16:30	National Environmental Research Institute - Jørgen Brandt, DMU
17:00	Meeting adjurned
18:45	"EKO4-Dinner" in Tivoli Gardens, Copenhagen

Wedensday, June 7, 1995

SESSION III

Presentation of ETEX-1 prognoses: Trajectories and doses, Continued.

09:00-09:30	National Defence Research Establishment - FOA 4 - Per-Erik Johansson, FOA	
09:30-10:00	Meteorological Institute of Finland - Mika Salonoja, FMI	
10:00-10:30	Coffee	
10:30-11:15	Meteorological Institute of Norway: ETEX seen from DNMI	
	A:	Presentation of DNMI's real-time dispersion model SNAP (Severe Nuclear Accident Program) - Jerzy Bartnicki
	B:	Video of SNAP simulations from ETEX-1 - Jørgen Saltbones
	C:	ETEX - seen from CEC/JRC in ISPRA, and plans for the use of ETEX results - Anne Grete Straume
12:00-13:00	Lunch	

SESSION IV

Authorities: Discussions; Conclusions

13:10-13:30	Remarks on experiments and dispersion modelling from the point of view of an authority, - Jujani Lahtinen., STUK
13:30-14:00	ETEX-1 Exercise Evaluation and Discussion
14:00-14:15	Coffee
14:15-15:00	Conclusions Layout of report Next Meeting

Meeting adjourned at 15:00

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Abstract (Max. 2000 characters)

On the 6th and 7th June 1995 a meeting was held at Risø, where calculations of the atmospheric transportation and dispersion of the ETEX-1 release carried out by a number of institutions in the Nordic countries were presented. Also presented were the results of the measurements carried out by the National Environmental Research Institute of Denmark, information previously not known to the participants in the meeting. This provided not only an opportunity of intercomparing the models, but also of carrying out a validation exercise. The main points from the concluding discussions are also included in this report.

Descriptors INIS/EDB

ATMOSPHERIC CIRCULATION; DENMARK; EXPERIMENTAL DATA; FIELD TESTS; FINLAND; FISSION PRODUCT RELEASE; FLUORINATED ALIPHATIC HYDROCARBON; LONG-RANGE TRANSPORT; MATHEMATICAL MODELS; METEOROLOGY; NORWAY; PLUMES; SAMPLING; SIMULATION; SWEDEN; TRACER TECHNIQUES; TRAJECTORIES; VALIDATION

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RISØ

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The objective of Risø's research is to provide industry and society with new potential in three main areas:

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- *Patenting and licencing activities*

To the scientific world through:

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- *Co-operation in national and international networks*
- *PhD- and Post Doc. education*

Key Figures

Risø has a staff of just over 900, of which more than 300 are scientists and 80 are PhD and Post Doc. students. Risø's 1995 budget totals DKK 476m, of which 45% come from research programmes and commercial contracts, while the remainder is covered by government appropriations.

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