A Report on

Fluidyn - Super PANACHE

AIR POLLUTION MODEL VALIDATION WITH MOL WORKSHOP MODEL VALIDATION KIT

www.fluidyn.com

This report consists of the following case study

LILLESTROM

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INTRODUCTION

Fluidyn- PANACHE is a self contained, 3-dimensional high precision environmental modeling software package, which is designed to simulate dispersion of pollutants emitted into the atmosphere under different conditions, and for the simulation of environmental hazards and safety analysis in industries.

Fluidyn-PANACHE is based on high-level numerical methods. Fluidyn -PANACHE is capable of predicting wind velocity and temperature distribution over three dimensional complex terrain topography and is capable of modeling terrain topography exactly by generating a body fitted mesh.

For the purpose of validation of fluidyn - Super panache, experimental data sets of Lillestrom given in "Model Validation Kit for the workshop on operational short- range atmospheric dispersion models for environmental impact assessments in Europe " is used. In the entire field experiments the well-known tracer gas sulfur-hexa-fluoride (SF6) has been used. The details of experimental setup, input data (terrain, source and weather) and the simulation options are given separately for each data set.

Maximum SF6 Concentrations obtained by PANACHE are compared with observed values. Further, the predicted results are portrayed in the form of concentration contours and plots.

The PANCHE results are also compared (in the form of tables and plots) with other proprietary model predictions viz., HPDM, IFDM (Immission Frequency Distribution Model), INPUFF, OML and UKADMS, which are given in the annexes.

LILLESTROM CASE

EXPERIMENTAL SETUP

The tracer experiments of concern here took place in the town of Lillestrom (near Oslo), Norway in 1987. They were performed by the Norwegian Institute of Air Research (NILU), which has put the data at the user disposal.

The experiments were carried out in a flat residential area with 6- 10 m high buildings and trees. A tracer system was used in which SF6 was released from a mast 36 m above the ground. Each experiment consisted of two sequential 15 - minute periods. Thus, the sampling period is shorter than for the other experiments considered at the workshop. The meteorological measurements were carried out along the 36 m high mast.

Sonic anemometer measurements were processed to give 10 min average values for wind speed and wind directions at the 10 m level. Further, co variances were determined between velocity components and temperature fluctuations.
The temperature during the tracer experiments was low (approximately -20^{o} C) and the ground was snow covered. The sun was above the horizon but at a very low angle. The surface roughness was about 0.5 m.

Generally, the vertical temperature profiles in the lowest 100 m showed an inversion. For all runs during the experimental campaign, the cross wind profiles of tracer concentrations were well determined, thus making a relatively accurate estimate of cross wind integrated concentration possible. The maximum concentrations given in the data set is the highest observed concentration along each arc.

Geographical co-ordinates for the position of release are: Latitude 59.889 N Longitude 11.051 E the height of terrain is 110 m above mean sea level.

Here we have considered experiments with two sequential 15 - minute periods for 10^{th} Jan and 9^{th} Feb 1987 as they were having high and low wind velocities respectively.

Model Input Data

Table 1 Model Input Data - Lillestrom – I (9.30 – 10.00 AM)

Sl. No.	Particulars	Lillestrom - I	
		Data Set- 1	Data Set- 2
1.	**Terrain Data**		
	Longitude	**11.051**	**11.051**
	Latitude	**59.889**	**59.889**
	Roughness length (m)	**0.50**	**0.50**
	Computation Domain (m^3)	**1000 x 400 x 150**	**1000 x 400 x 150**
	Monitor Point Height (m)	**3.0**	**3.0**
2.	**Source Data**		
	Type of source	**Point**	**Point**
	Exit velocity (m/sec)	**6.50**	**6.50**
	Chemical Species	**SF6**	**SF6**
	Height of source (m)	**36.0**	**36.0**
	Mass flux (Kg/sec)	**0.000102**	**0.000102**
	Temperature (^oC)	**87.0**	**87.0**
	Composition (Mole Fraction)	**1.00**	**1.00**
3.	**Weather Data**		
	Wind speed (m/sec)	**2.10**	**1.70**
	Anemometer height (m)	**10.0**	**10.0**
	Ambient temperature (^oC)	**-25.65**	**-25.65**
	Ambient Pressure (mbars)	**1000.00**	**1000.00**
	Relative humidity (%)	**45.00**	**45.00**
	Cloud cover (10's %)	**0**	**0**
	Wind profile		
	- *Power Law* (Exp)	**0.0995**	**0.0985**
	Temperature profile		
	- Two Step		
	- Lapse Rate ($^oC/m$)	**-3.7e-005**	**-1.46e-005**
	- Mixing Height (m)	**900**	**900**
	- Inversion Lapse Rate ($^oC/m$)	**0.0065**	**0.0065**
4.	**Simulation Option**		
	Mesh size chosen	**46, 19, 11**	**46, 19, 11**
	Grid fineness parameter	**7**	**7**
	Date	**10/01/1987**	**10/01/1987**
	Time (Hrs.)	**9.30 – 9.45**	**9.45 – 10.00**
	Time zone	**1**	**1**
	Fluid type	**Incompressible**	**Incompressible**
	Temperature model	**Solve**	**Solve**
	Wind model	**Solve**	**Solve**
	Buoyancy model	**No Gravity**	**No Gravity**
	Wall type	**Log Law1**	**Log Law1**
	Turbulence model	**K-Diff**	**K-Diff**

Table 2 Model Input Data Lillestrom – II (10.00 – 10.30 AM)

Sl.No.	Particulars	Lillestrom - II	
		Data Set- 1	Data Set- 2
1.	**Terrain Data**		
	Longitude	**11.051**	**11.051**
	Latitude	**59.889**	**59.889**
	Roughness length (m)	**0.50**	**0.50**
	Computation Domain (m^3)	**1000 x 400 x 150**	**1000 x 400 x 150**
	Monitor Point Height (m)	**3.0**	**3.0**
2.	**Source Data**		
	Type of source	**Point**	**Point**
	Exit velocity (m/sec)	**5.75**	**5.75**
	Chemical Species	**SF6**	**SF6**
	Height of source (m)	**36.0**	**36.0**
	Mass flux (Kg/sec)	**0.000102**	**0.000102**
	Temperature (^oC)	**85.0**	**85.0**
	Composition (Mole Fraction)	**1.00**	**1.00**
3.	**Weather Data**		
	Wind speed (m/sec)	**0.50**	**0.40**
	Anemometer height (m)	**10.0**	**10.0**
	Ambient temperature (^oC)	**-12.75**	**-12.75**
	Ambient Pressure (mbars)	**1000.00**	**1000.00**
	Relative humidity (%)	**45.00**	**45.00**
	Cloud cover (10's %)	**4**	**4**
	Wind profile		
	- *Power Law* (Exp)	**0.240**	**0.375**
	Temperature profile		
	- Two Step		
	- Lapse Rate (^oC/m)	**7.32e-005**	**1.83e-003**
	- Mixing Height (m)	**900**	**900**
	- Inversion Lapse Rate (^oC/m)	**0.0065**	**0.0065**
4.	**Simulation Option**		
	Mesh size chosen	**62, 25, 10**	**62, 25, 10**
	Grid fineness parameter	**7**	**7**
	Date	**09/02/1987**	**09/02/1987**
	Time (Hrs.)	**10.00 –10.15**	**10.15 – 10.30**
	Time zone	**1**	**1**
	Fluid type	**Incompressible**	**Incompressible**
	Temperature model	**Solve**	**Solve**
	Wind model	**Solve**	**Solve**
	Buoyancy model	**No Gravity**	**No Gravity**
	Wall type	**Log Law1**	**Log Law1**
	Turbulence model	**K-Diff**	**K-Diff**

NOTE: As the release temperature of SF6 was high, the temperature is solved in order to account for buoyancy-induced dispersion. K - diffusion turbulent model is chosen, because, the experiments were carried out in a flat residential area. Further, incompressible model has been chosen since SF6 is well known as light (tracer) gas.

Results

With the above input data set, simulation is done on PANACHE for 15 minutes and the maximum SF6 concentration values so obtained are compared with the observed values reported at the monitoring locations.

Table 3 Comparison of observed and predicted sulfur-hexa-fluoride concentrations (GLC's) – Lillestrom - I

Monitor Point	Distance from Source (Km)		SF6 Concentrations ($\mu g/m^3$)			
			Observed		PANACHE Predicted	
	Data Set-1	Data Set- 2	Data Set-1	Data Set- 2	Data Set-1	Data Set- 2
M1	0.16	0.14	7.6	8.3	6.932	8.121
M2	0.49	0.44	4.8	5.2	4.883	5.286
M3	0.81	0.82	3.7	3.4	2.941	3.577

Table 4 Comparison of observed and predicted sulfur-hexa-fluoride concentrations (GLC's) – Lillestrom - II

Monitor Point	Distance from Source (Km)		SF6 Concentrations ($\mu g/m^3$)			
			Observed		PANACHE Predicted	
	Data Set-1	Data Set- 2	Data Set-1	Data Set- 2	Data Set-1	Data Set- 2
M1	0.19	0.19	29.6	45.8	28.88	44.96
M2	0.41	0.43	9.7	20.0	12.23	22.09

Figure 1 Computational Domain; Lillestrom - I
Data Set- 1

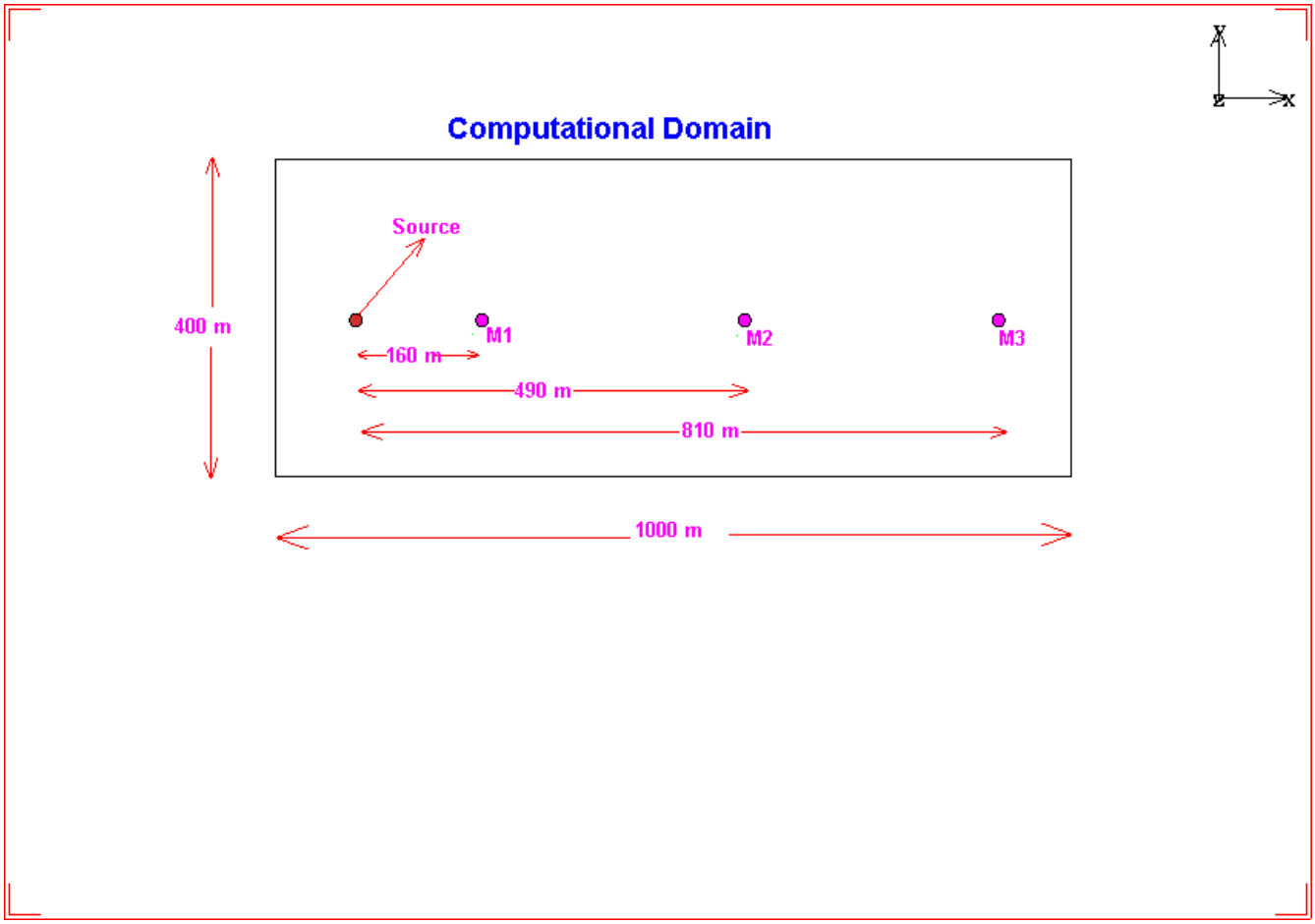


Figure 2 Wind Velocity Vectors; Lillestrom - I
Data Set- 1

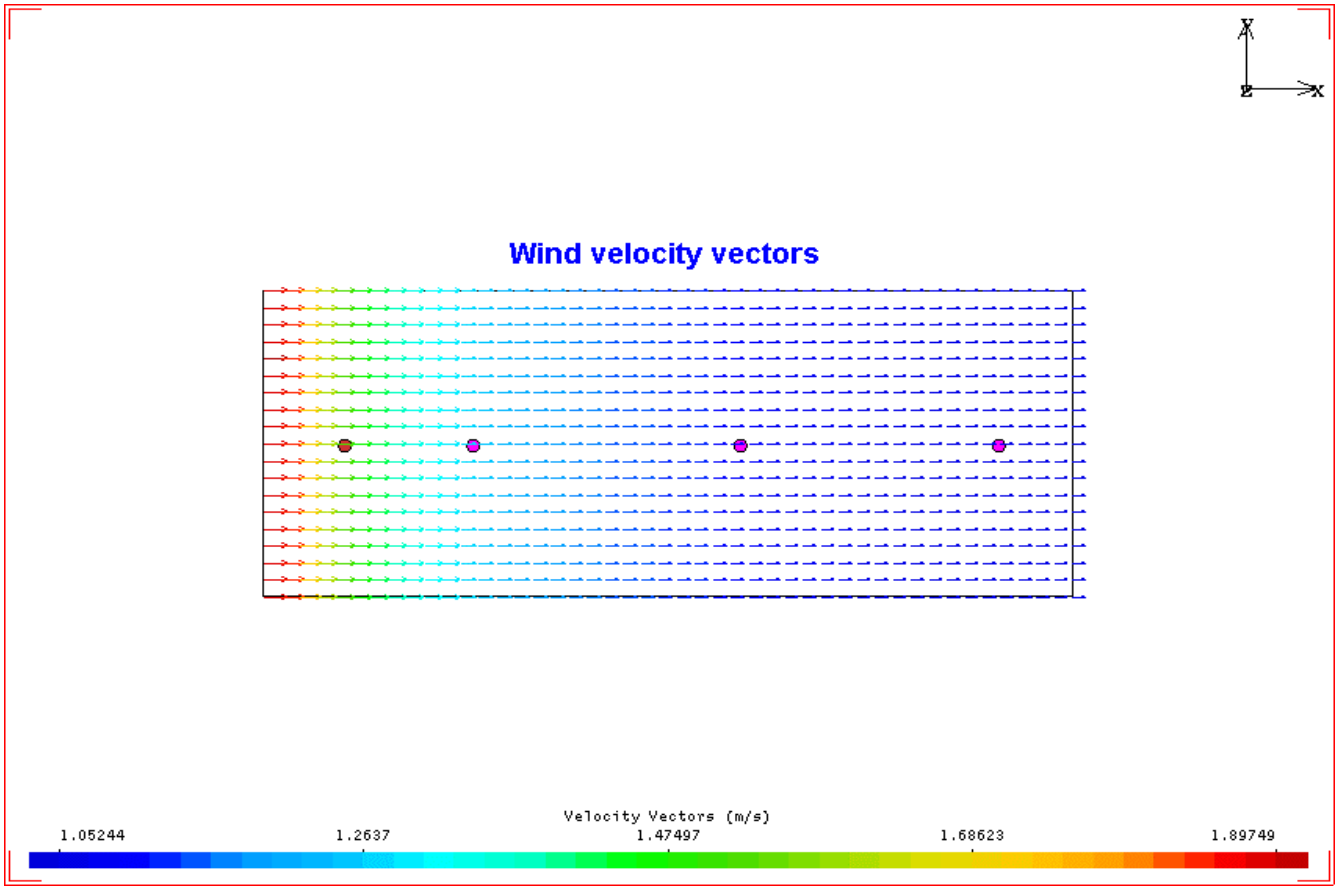


Figure 3 Ground Level Concentration Contours of SF6; Lillestrom - I Data Set- 1

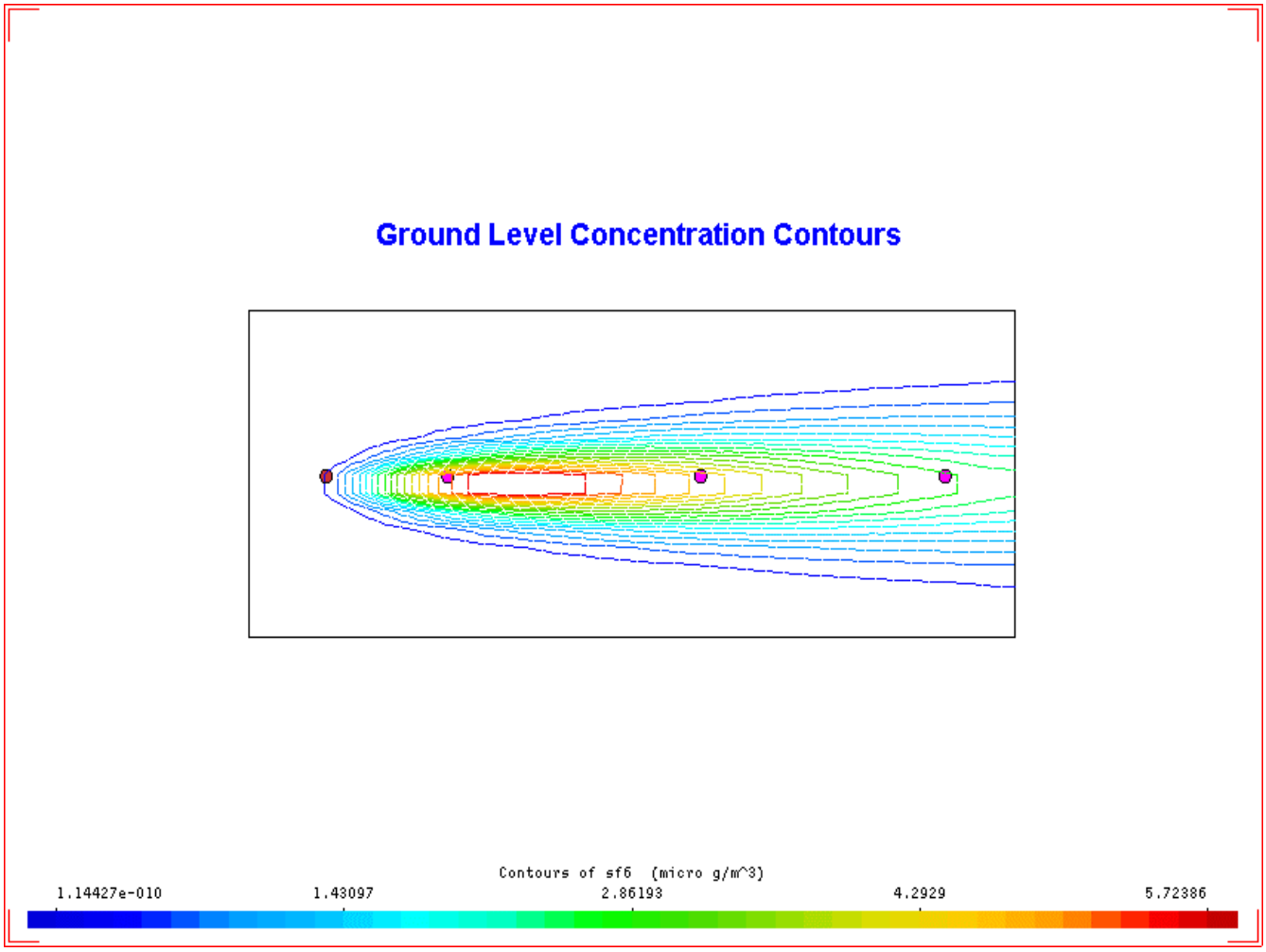


Figure 4 Time V/s Concentration of SF6 at Monitor Points; Lillestrom –I Data Set-1

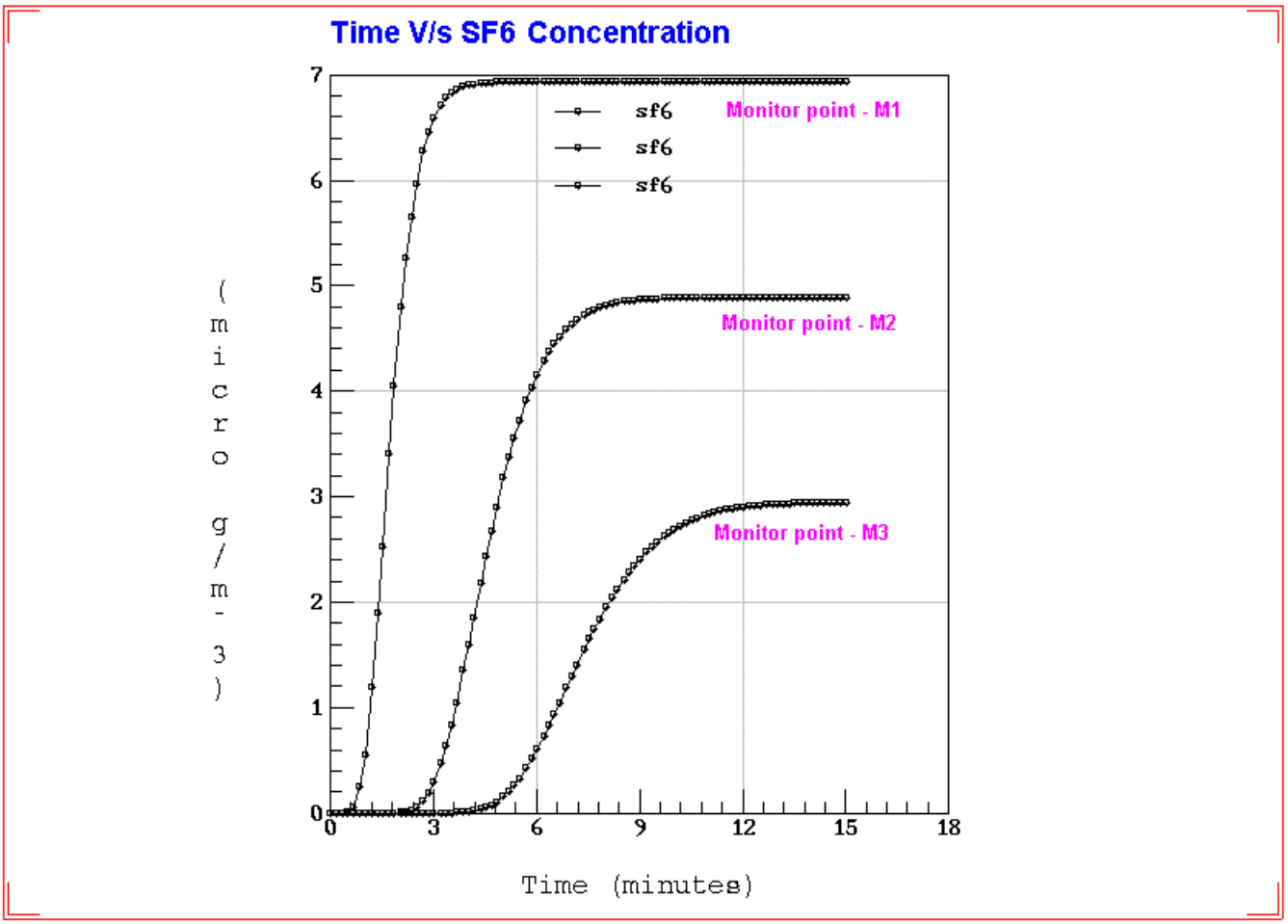


Figure 5 Computational Domain Lillestrom – II
Data Set- 1

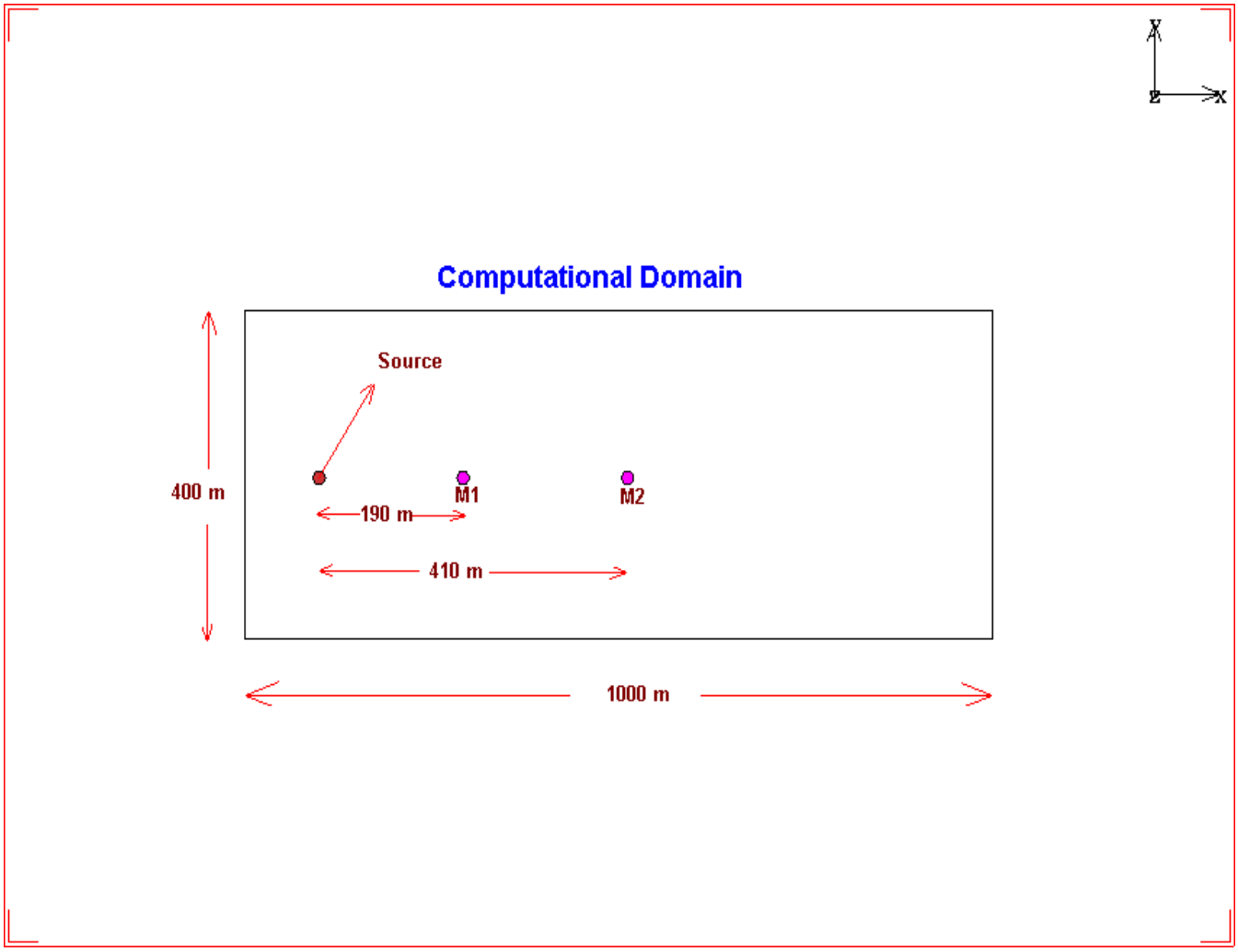


Figure 6 Wind Velocity Vectors Lillestrom – II
Data Set- 1

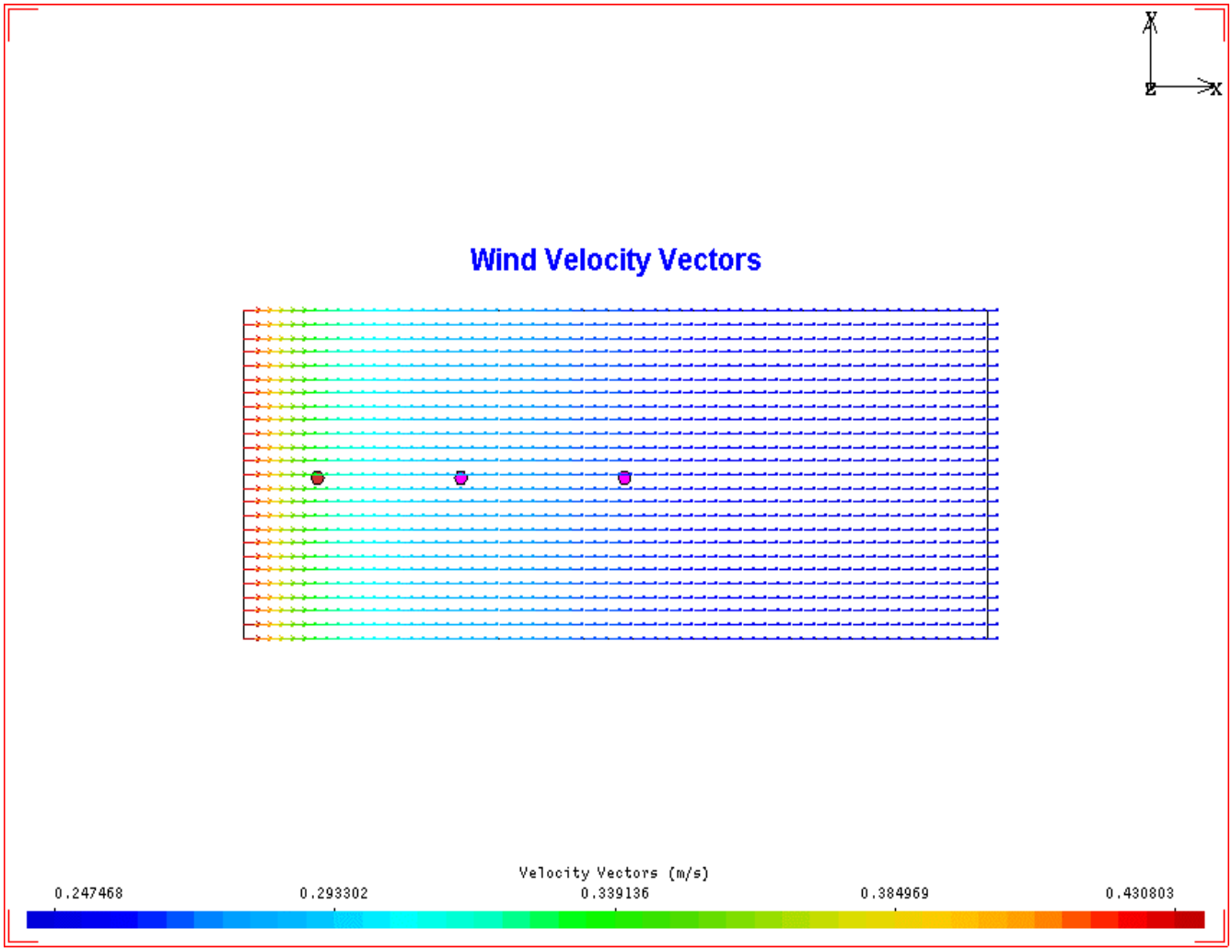


Figure 7 Ground Level Concentrations Contours of SF6 Lillestrom – II Data set -1

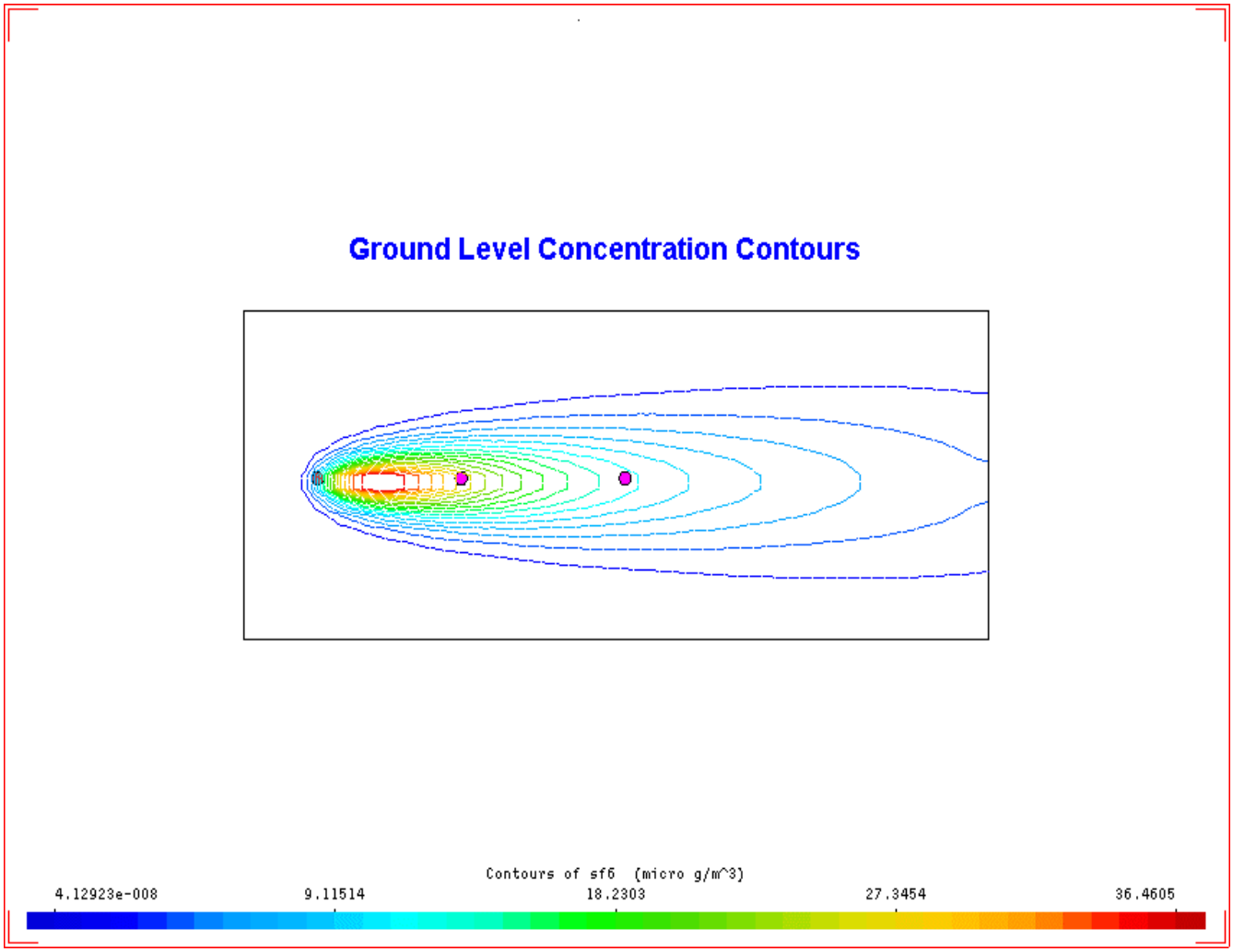
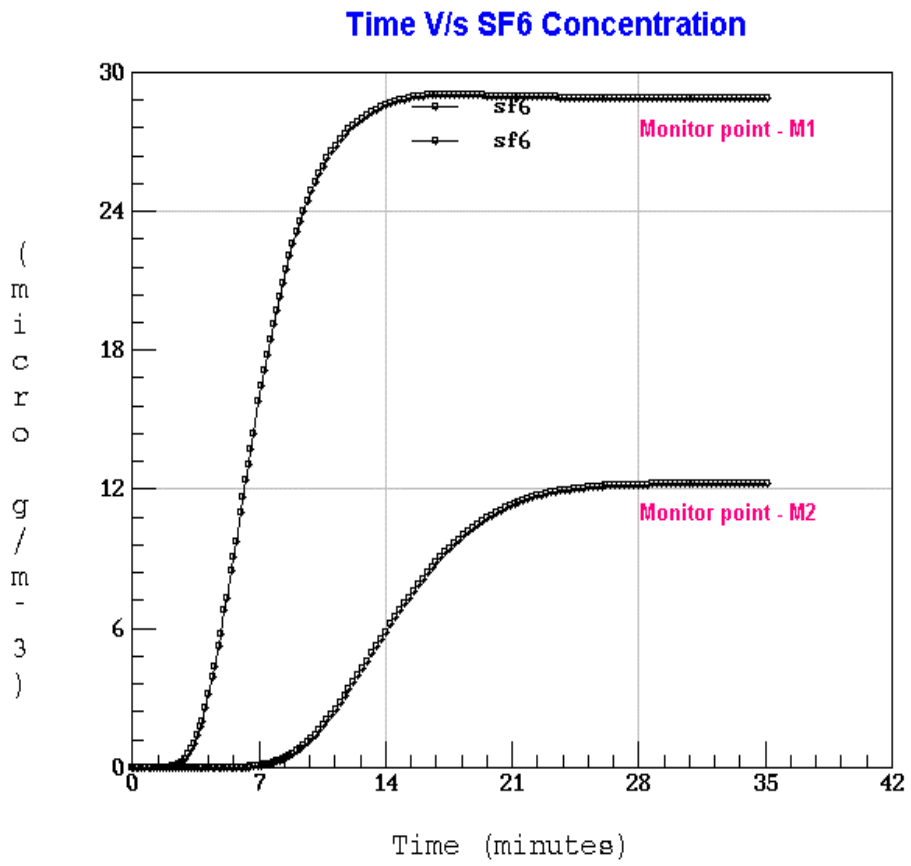


Figure 8 Time V/s Concentration of SF6 at Monitor Points Lillestrom – II Data Set - 1



ANNEXURE

Table (i) Comparison of PANACHE Predicted Max. SF6 Concentration with observed and Other Model Predictions – Lillestrom - I - Data set -1

Distance (Km)	Max. SF6 Concentration (μg/m^3)						
	Observed	Predicted					
		PANACHE	*HPDM*	*IFDM*	*INPUFF*	*OML*	*UKADMS*
0.16	7.60	6.932	1.2475	1.4948	0.0011	1.226	0.7379
0.49	4.80	4.883	1.9472	3.7112	1.7329	2.236	1.6399
0.81	3.70	2.941	0.9738	2.442	2.1012	1.189	1.1099

Table (ii) Comparison of PANACHE Predicted Max. SF6 Concentration with observed and Other Model Predictions – Lillestrom - I - Data set -2

Distance (Km)	Max. SF6 Concentration (μg/m^3)						
	Observed	Predicted					
		PANACHE	*HPDM*	*IFDM*	*INPUFF*	*OML*	*UKADMS*
0.14	8.3	8.121	1.194	1.142	0.383	0.359	0.091
0.44	5.2	5.286	2.525	4.831	4.633	2.287	1.170
0.82	3.4	3.577	1.099	2.978	2.791	1.261	0.867

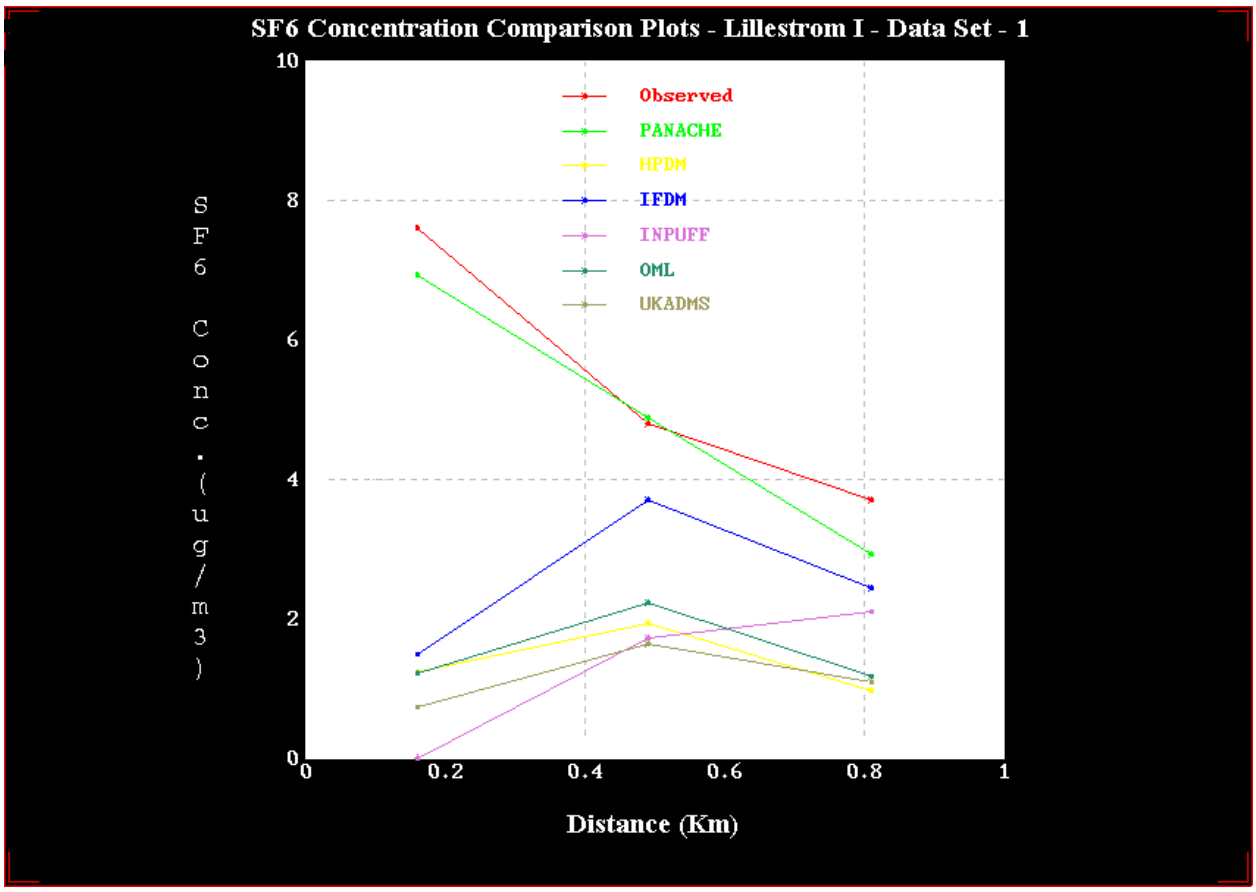
Table (iii) Comparison of PANACHE Predicted Max. SF6 Concentration with observed and Other Model Predictions – Lillestrom - II - Data set -1

Distance (Km)	Max. SF6 Concentration (μg/m^3)						
	Observed	Predicted					
		PANACHE	*HPDM*	*IFDM*	*INPUFF*	*OML*	*UKADMS*
0.19	29.6	28.88	13.77	3.52	4.733	4.567	8.020
0.41	9.7	12.23	8.757	14.32	18.936	4.918	2.400

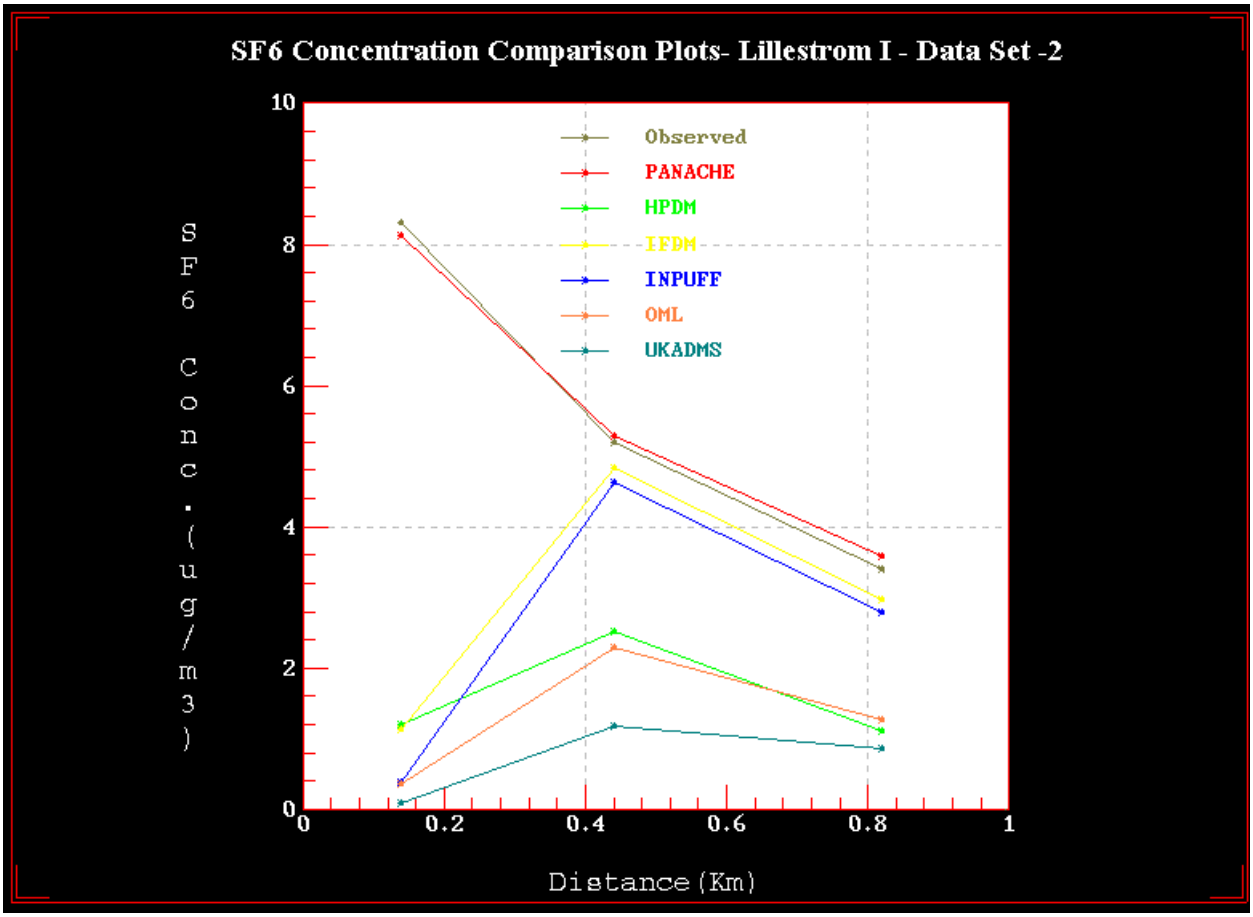
Table (iv) Comparison of PANACHE Predicted Max. SF6 Concentration with observed and Other Model Predictions – Lillestrom - II - Data set -2

Distance (Km)	Max. SF6 Concentration (μg/m^3)						
	Observed	Predicted					
		PANACHE	*HPDM*	*IFDM*	*INPUFF*	*OML*	*UKADMS*
0.19	45.80	44.96	9.535	4.403	5.281	---	---
0.43	20.0	22.09	6.551	18.132	16.157	---	---

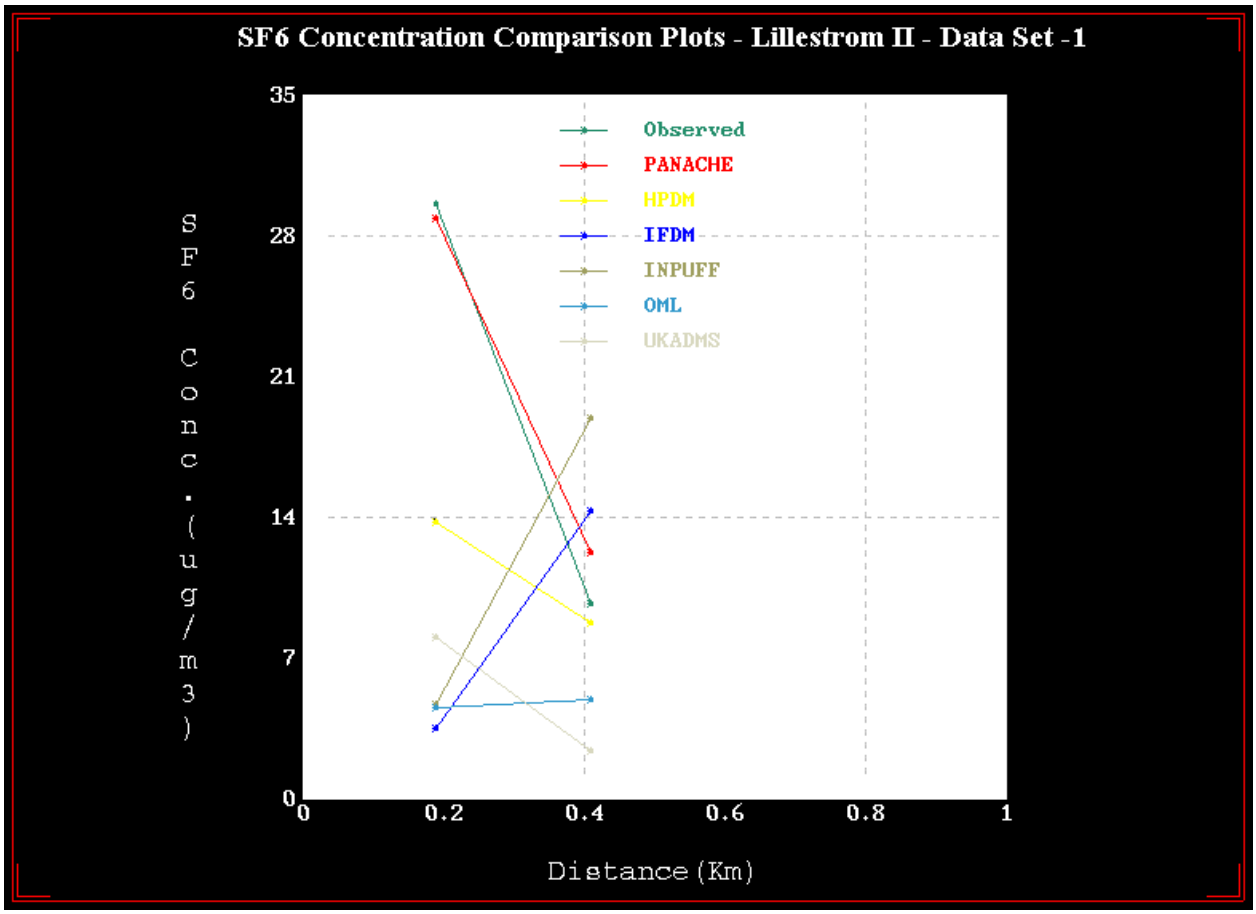
Plot-1


SF6 Concentration Comparison Plots - Lillestrom I - Data Set - 1
Observed
PANACHE
HPDM
IFDM
INPUFF
OML
UKADMS
SF6 Conc.(ug/m3)
10
8
6
4
2
0
0
0.2
0.4
0.6
0.8
1
Distance (Km)

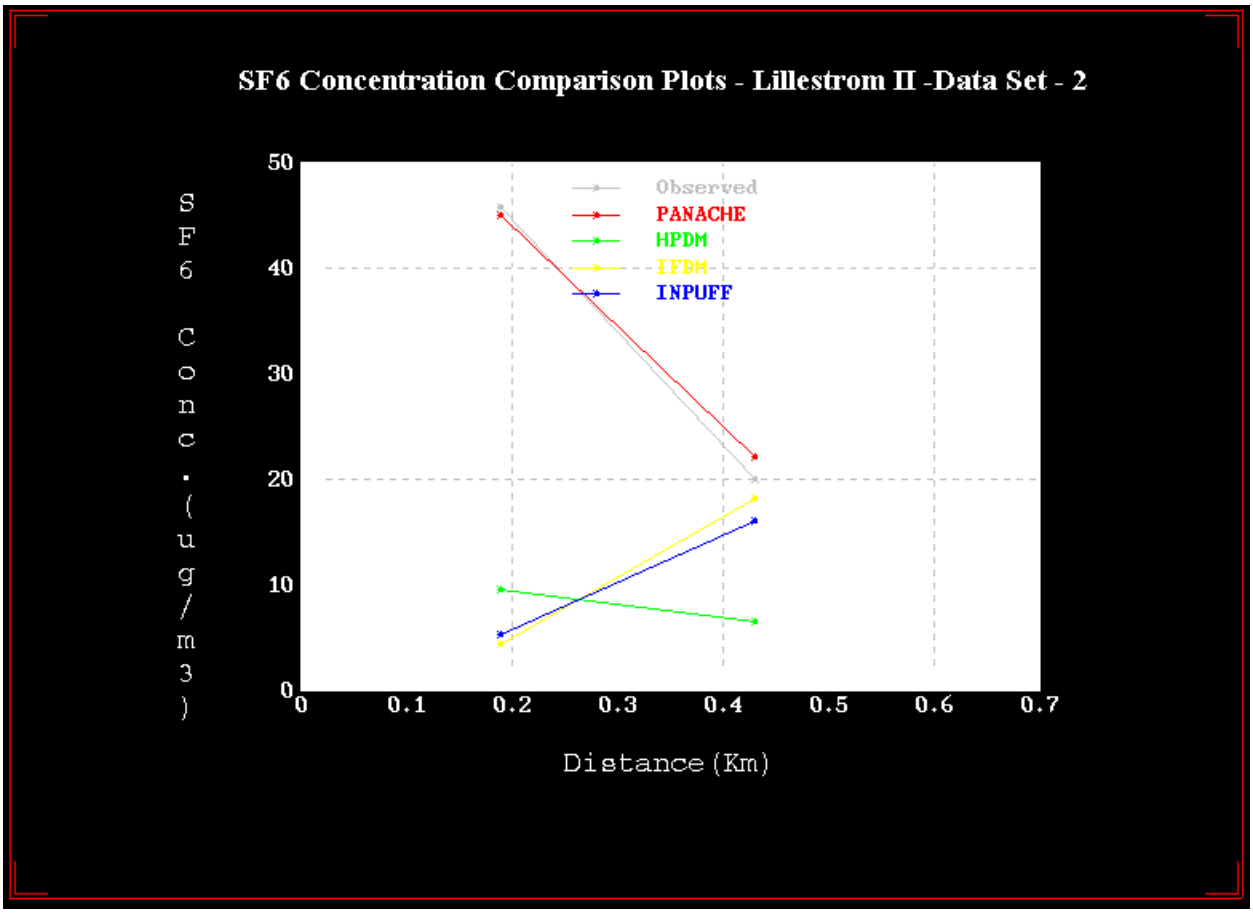
Plot-2


SF6 Concentration Comparison Plots- Lillestrom I - Data Set -2
Observed
PANACHE
HPDM
IFDM
INPUFF
OML
UKADMS
SF6 Conc.(ug/m3)
10
8
6
4
2
0
0
0.2
0.4
0.6
0.8
1
Distance(Km)

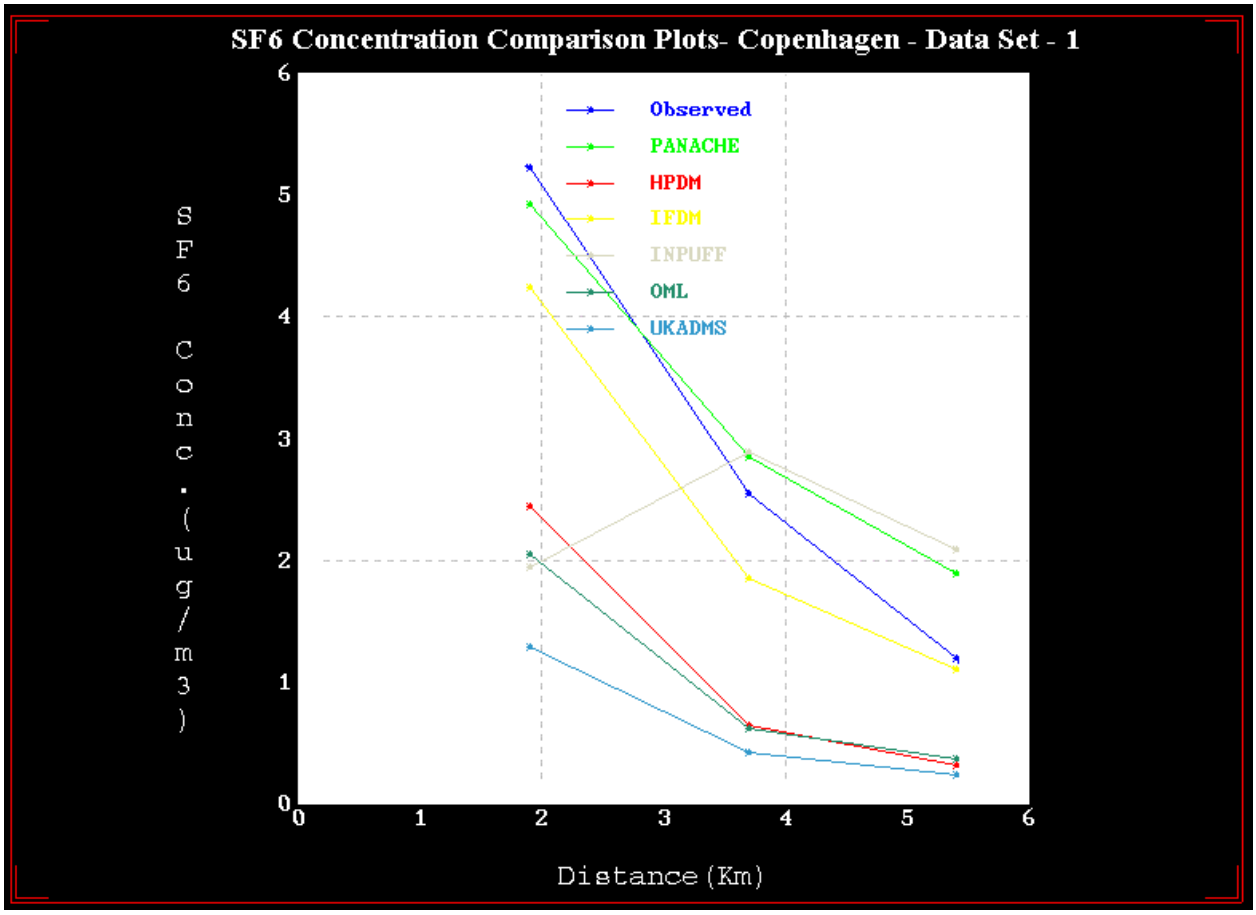
Plot-3


SF6 Concentration Comparison Plots - Lillestrom II - Data Set -1
Observed
PANACHE
HPDM
IFDM
INPUFF
OML
UKADMS
SF6 Conc.(ug/m3)
35
28
21
14
7
0
0
0.2
0.4
0.6
0.8
1
Distance(Km)

Plot-4


SF6 Concentration Comparison Plots - Lillestrom II -Data Set - 2
SF6 Conc.(ug/m3)
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Distance(Km)
Observed
PANACHE
HPDM
IFDM
INPUFF

Plot-5


SF6 Concentration Comparison Plots- Copenhagen - Data Set - 1
Observed
PANACHE
HPDM
IFDM
INPUFF
OML
UKADMS
SF6 Conc.(ug/m3)
Distance(Km)
0
1
2
3
4
5
6