Comparison of AERMOD and SYMOS'97 models for calculating dispersion of odors: A case study in Uttenweiler

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Data choice - Justification

* The experiment has already been tested;
* High quantity of concentration measurements (tracer and odor intensity);
* High quality data;
* Representative case of real conditions (low stack).

Main Objective

* The main objective of this work is to make a comparative study between the odor dispersion models AERMOD and SYMOS'97 for the Uttenweiler experiment.

How to characterize the odor impact?

Frequency
Intensity
Duration
Offensiveness
Location
(Nicell, 2009)

FIDOL

Note: There are equations that correlate this two variables (Steven's and Weber-Fechner's law). Other options is the use of odour hours (GOSTELOW; PARSONS; STUETZ, 2001).

$$I = kC^n \qquad I = a\log C + b$$

Peak-to-Mean Rate

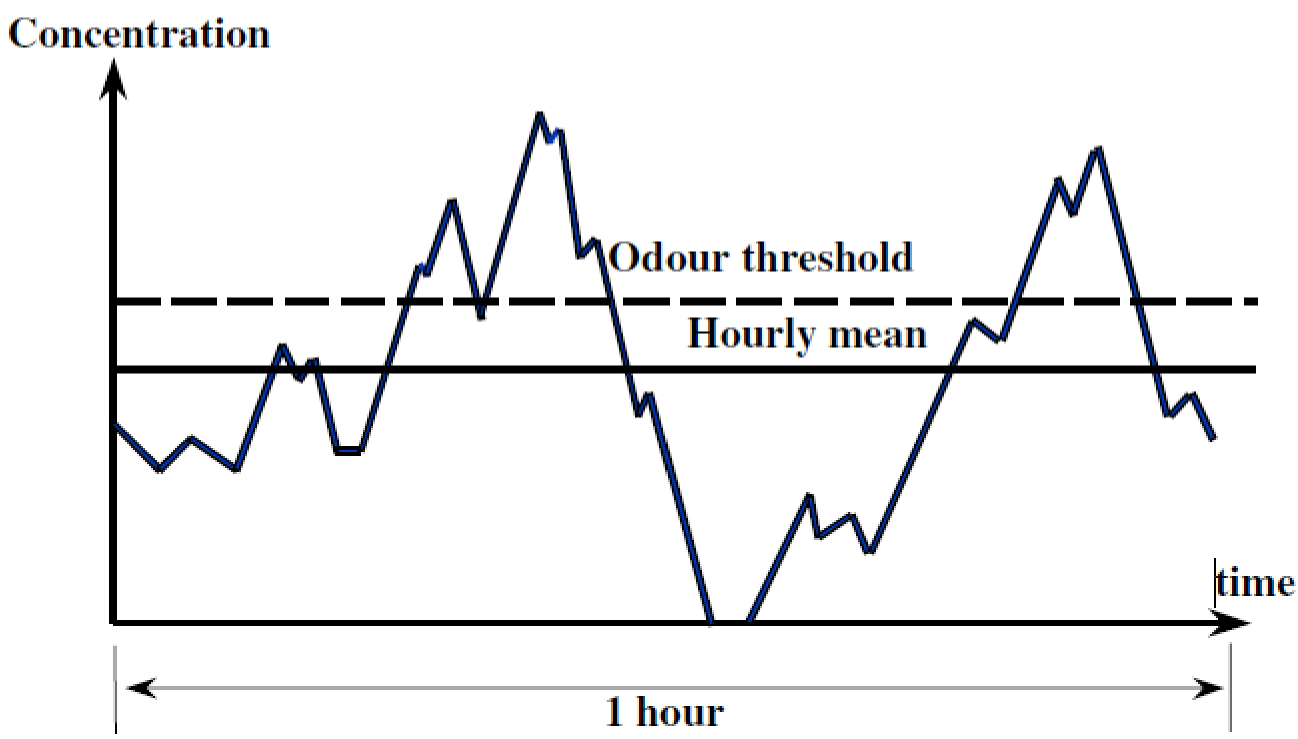


Fig. 1. The classic Gaussian model and short-term fluctuations.

Source: De Melo Lisboa et al. (2006).

SYMOS'97 description

* Source types: point, area, line;
* Terrain types: flat and complex;
* Can simulate obstacles;
* Stability classes: 5 classes (3 stable, 1 neutral and one convective) Bubnik e Koldovsky – Czech Republic;
* Simulations: annual mean, hourly peakconcentrations and annual particulate deposition.
* Not indicated for simulating low wind conditions, the maximum indicated distance for simulations is 100 km.
* Corrected the emission rate to Standard Temperature and Pressure conditions.

AERMOD description

* Source types: point, area, volume and line;
* Terrain types: simple and complex;
* Obstacles: PRIME Algorithm – Building Downwash;
* Atmospheric Stability: similarity theory;
* Simulations: mean annual concentration, maximum receptor concentration, particulate deposition, and was tested for simulating peak concentrations.
* Not indicated for simulating low wind conditions and distances beyond 50 km.

Building Downwash

$$C_{total} = \gamma C_{PRIME} + (1-\gamma)C_{AERMOD}$$

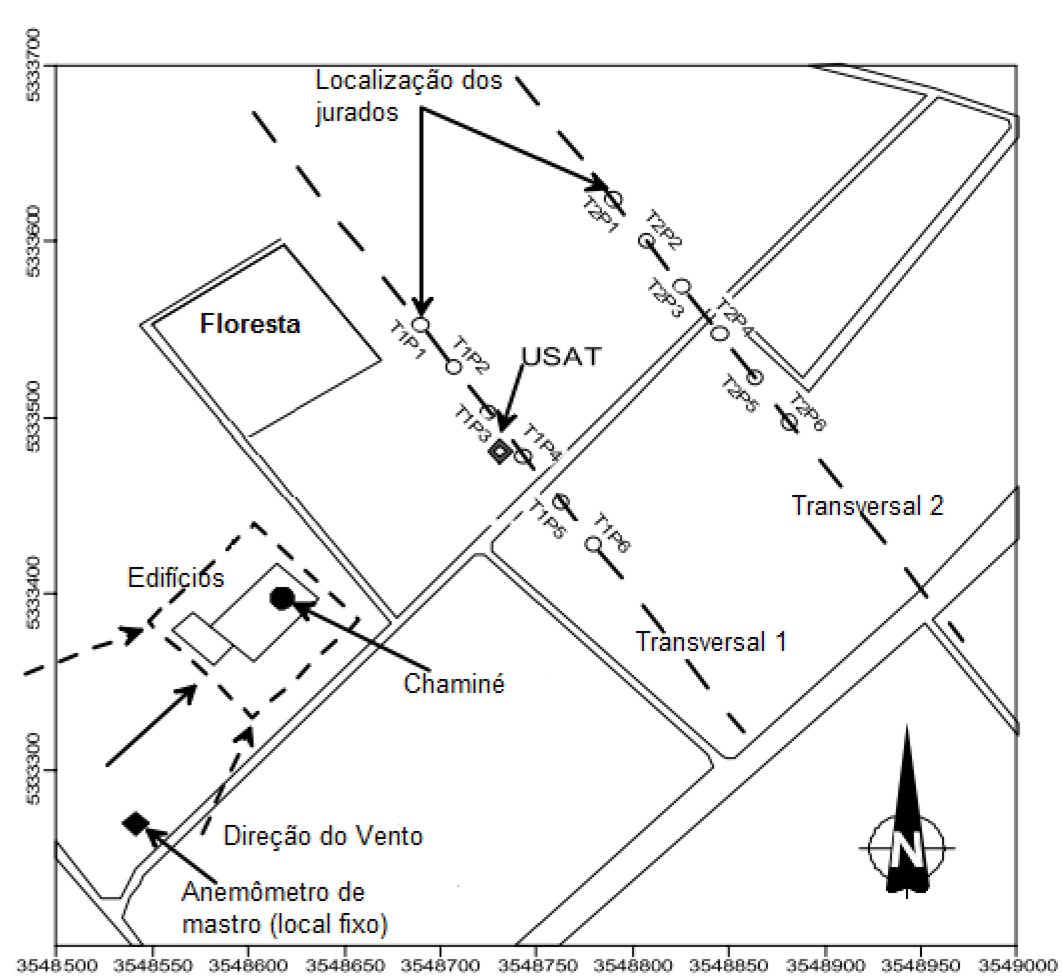
Fonte: Lakes Environment

Source: Cunha (2009).

Description of the Uttenweiler data set

* 1 4 experiments - 3 cloudy days (B – O);
* 10 minute long experiments;
* Quantified parameters:
  - Wind speed and direction every 10 seconds;
  - 2 SF6 tracer mesuarements every 10 seconds;
  - 11/12 trained acessors noting odor intensity (escala 0-5);
  - Stack area 3,6 m^2;
* Atmospheric conditions – slightly neutral and stable.

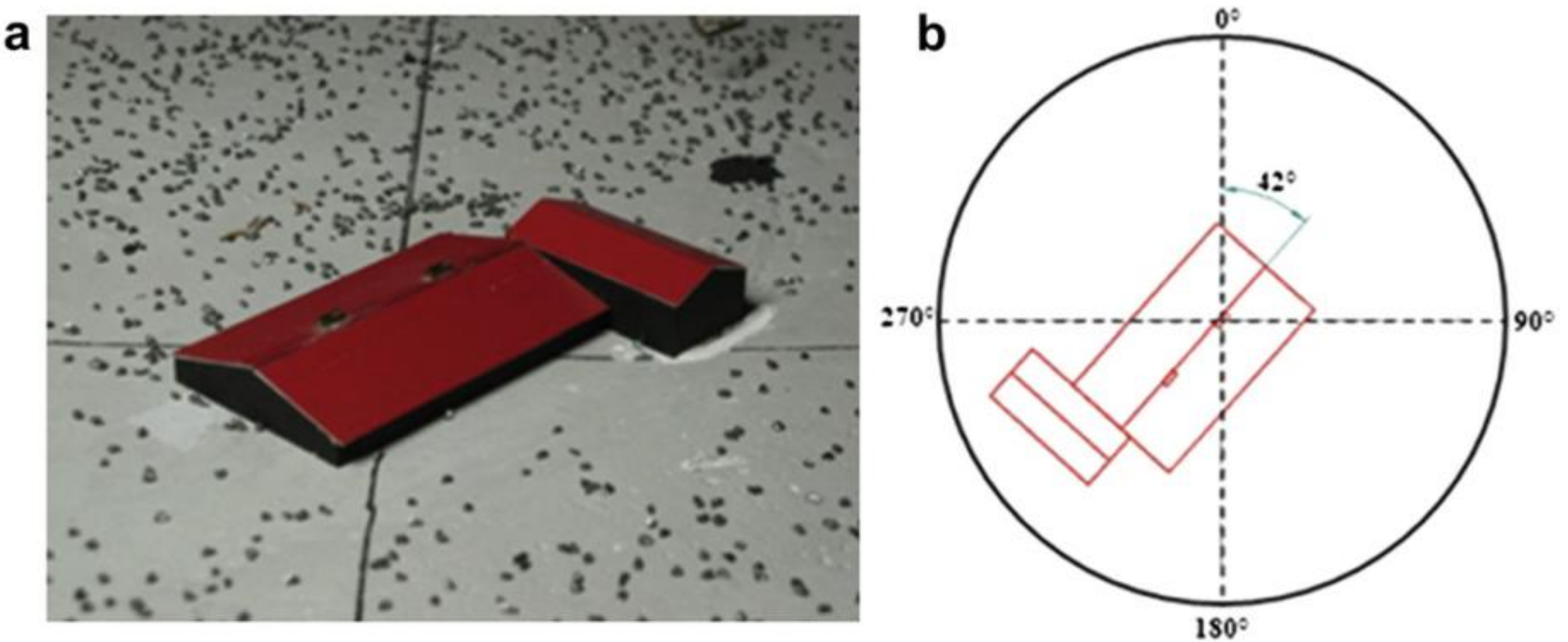
Location description



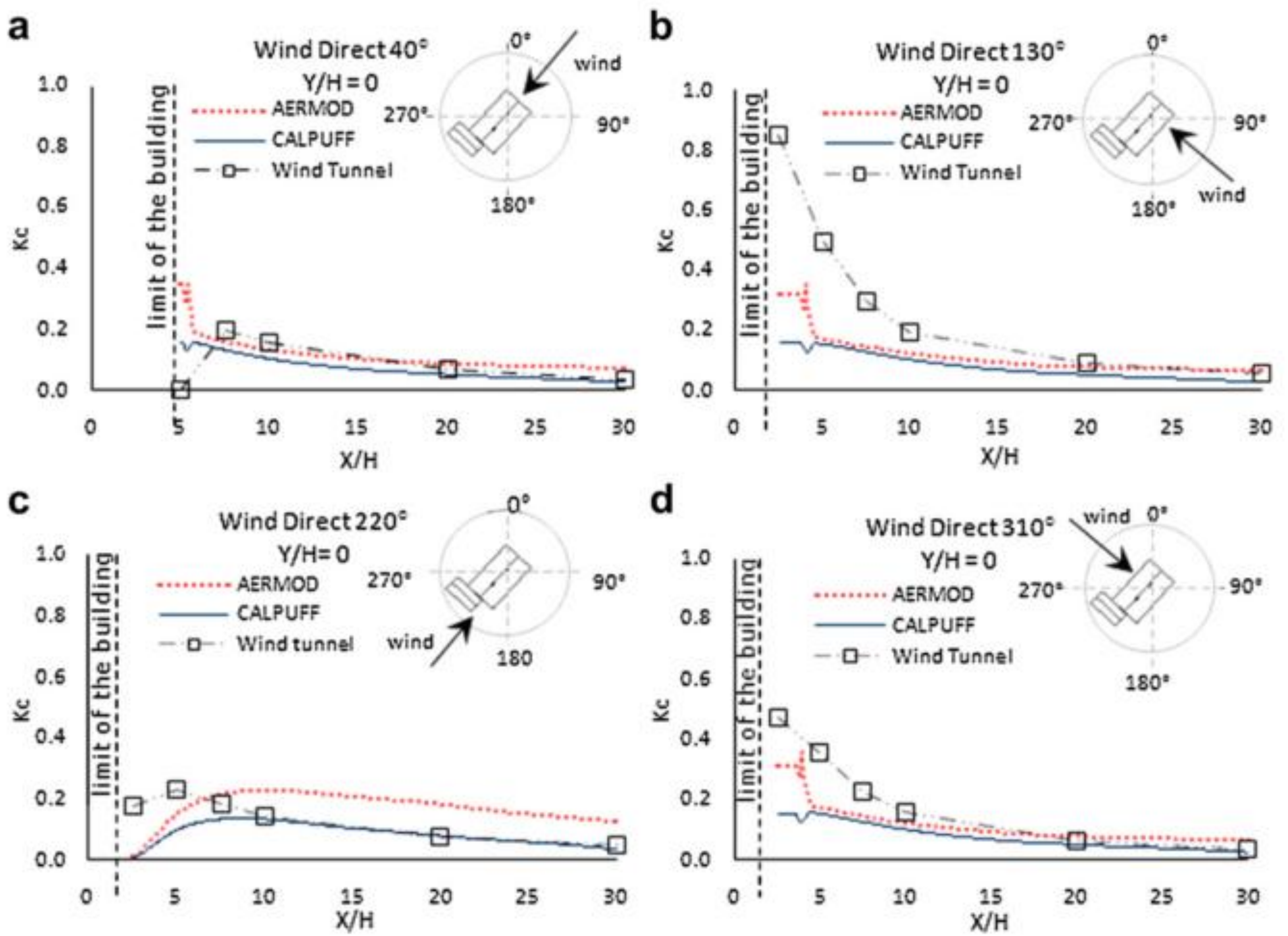
Wind tunnel experiment Aubrun e Leitl (2003)

University of Hamburg
Escale 1:400
Experiments C, F e G
Neutral Conditions

Comparison of AERMOD x CALPUFF VIEIRA DE MELO et al. (2012)



Wind Tunnel Simulation of the Uttenweiler experiment



Validation of GRAL model Pongratz, Öttl e Uhrner (2012)

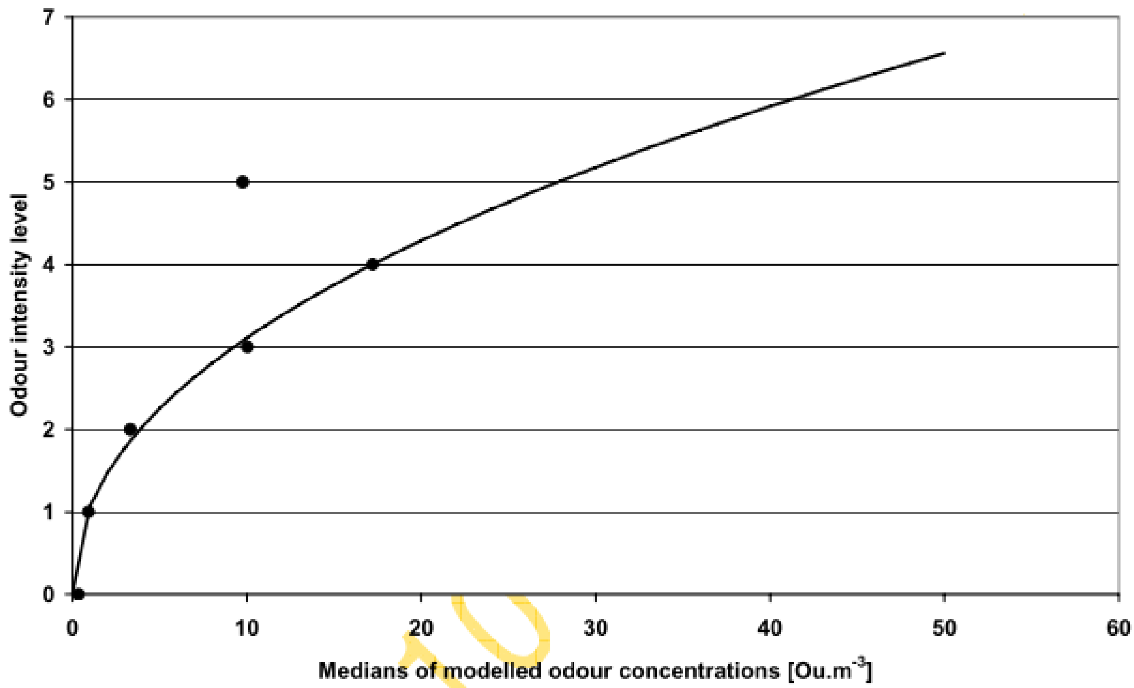
- 26 tested experiments including Uttenweiler's;
- For the Uttenweiler's experiment the performance of the GRAL model with the following models was compared:

  - GRAL, AUSTAL2000, LASAT, GIEBL, ADMS, OENORM M9440, STERN, SCORER.

Keder, Bubnik e Macoun (2003), and Keder (2008)

* Used a peak-to-mean ratio– 2,2 – proposed by Freeman and Cudmore (2002).
* Tested the model SYMOS'97 for simulating Uttenweiler's odor and tracer experiments;
* Flat terrain, hourly concentrations transformed into peak concentrations;
* Used a fit-curve approach due to the absence of a laboratory data correlating intensity and concentration data;
* Median concentration calculation for each intensity class.

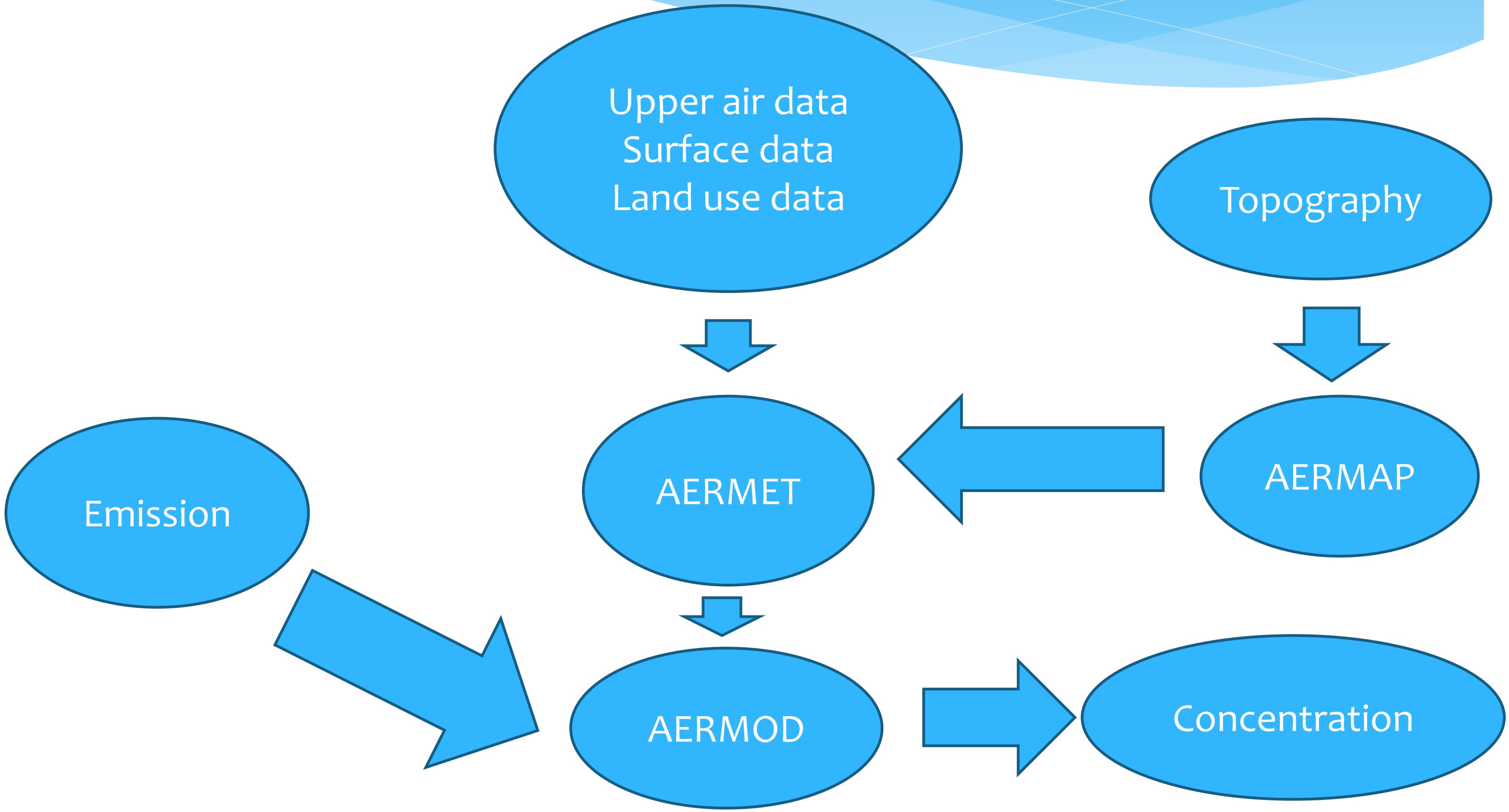
Median concentrations of each intensity class



$$I_{od} = 1.068 C_{od}^{0.4641}$$

Materials and Methods

AERMOD - Flowchart



Emission rate

	Z50 (OU/m³)	Air flow (m³/h)	Emission rate (UO/s)
B	1.260	55.100	19.285,00
C	1.225	55.200	18.738,33
D	1.130	55.200	17.326,67
E	3.000	55.300	46.083,33
F	3.000	53.700	44.750,00
G	3.000	54.100	45.083,33
H	2.520	55.000	38.500,00
I	1.220	56.600	19.181,11
J	1.000	55.700	15.472,22
K	940	56.700	14.805,00
L	870	56.100	13.557,50
M	750	55.700	11.604,17
N	890	56.400	13.943,33
O	940	56.400	14.726,67

AERMOD Configurations
a few tests...

- Cup anemometer x sonic anemometer;
- Surface data (onsite data + Laupheim airport dat);
- Onsite data: Wind speed and direction+ temperature - every 10 seconds (sonic anemometer);
- Laupheim surface data (22 km from site): cloud cover and pressures,
- Sounding (3 per day): Schnarrenberg 84 km from site.

AERMOD Configurations

* Albedo: 0,18;
* Bowen Ration: 0.4;
* Surface roughness length: 0.01 m
* Corrected wind speed and direction because the model rounds this variables;
* Standard deviation of the horizontal wind - SAnn (degrees) and the Standard deviation of the w component of the wind - SWnn (m/s);
* No corrections were made to the emission data rate, we used Standard Ambient Temperature and Pressure (SATP) conditions.

Statistical Analysis

* BIAS;
* FB (fractional BIAS);
* NMSE (normalised mean square error);
* R (correlation);
* MG (geometric mean bias);
* VG (geometric variance);
* FAC2 (factor of two).

Statistical Indices

$$BIAS = \overline{C_0 - C_p} \qquad (1)$$

$$FB = \frac{\overline{C_0} - \overline{C_p}}{0{,}5.(\overline{C_0} + \overline{C_p})} \qquad (2)$$

$$NMSE = \frac{\overline{(C_0 - C_p)^2}}{\overline{C_0} \cdot \overline{C_p}} \qquad (3)$$

Sensible to high values

$$R = \frac{\overline{(C_0 - \overline{C_0})(C_p - \overline{C_p})}}{\sigma_{C_p} \sigma_{C_0}} \qquad (4)$$

Insensible to the multiplication of a constant (sensible to outliers)

$$MG = \exp\left(\overline{lnC_o} - \overline{lnC_p}\right) \qquad (5)$$

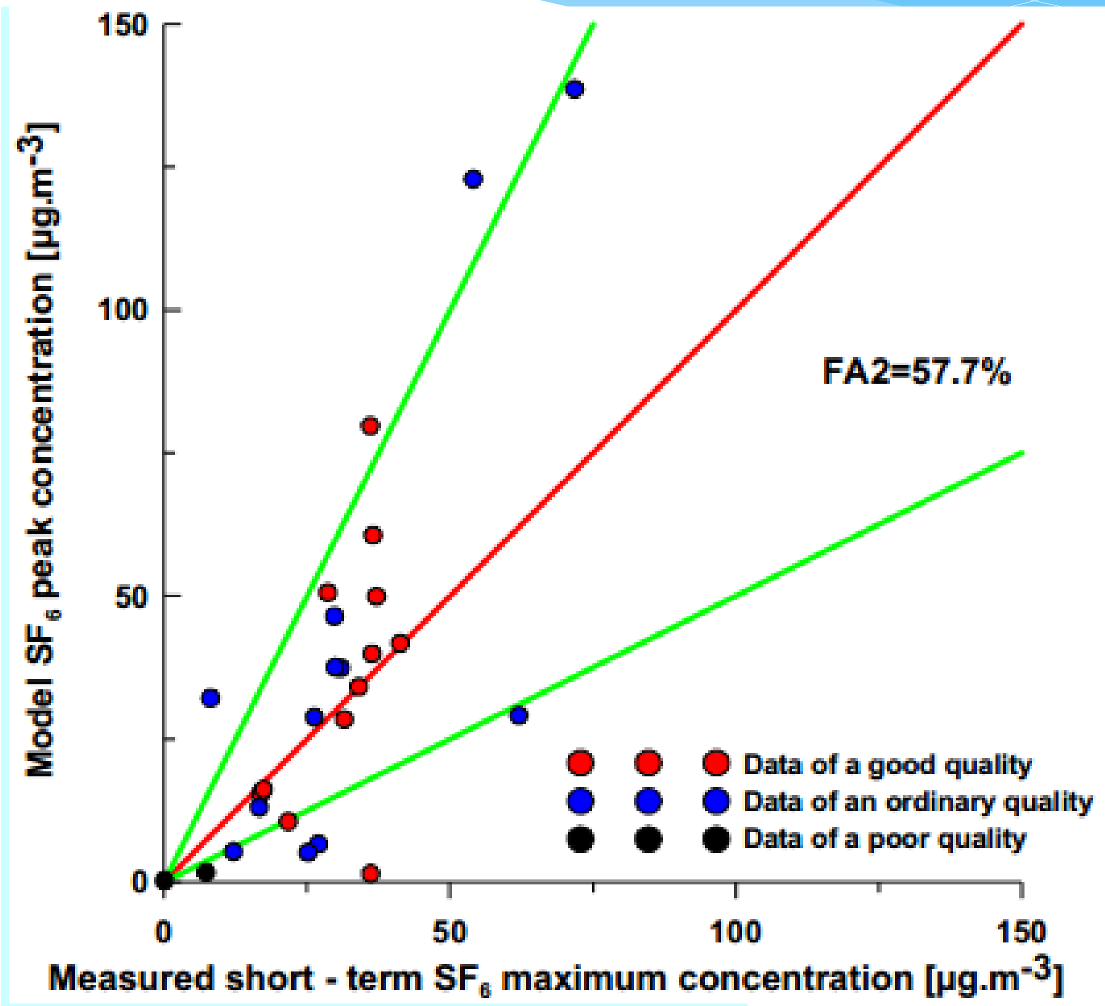
$$VG = \exp\overline{\left[(lnC_0 - lnC_p)^2\right]} \qquad (6)$$

Sensible to low values (analysis should establish boundaries)

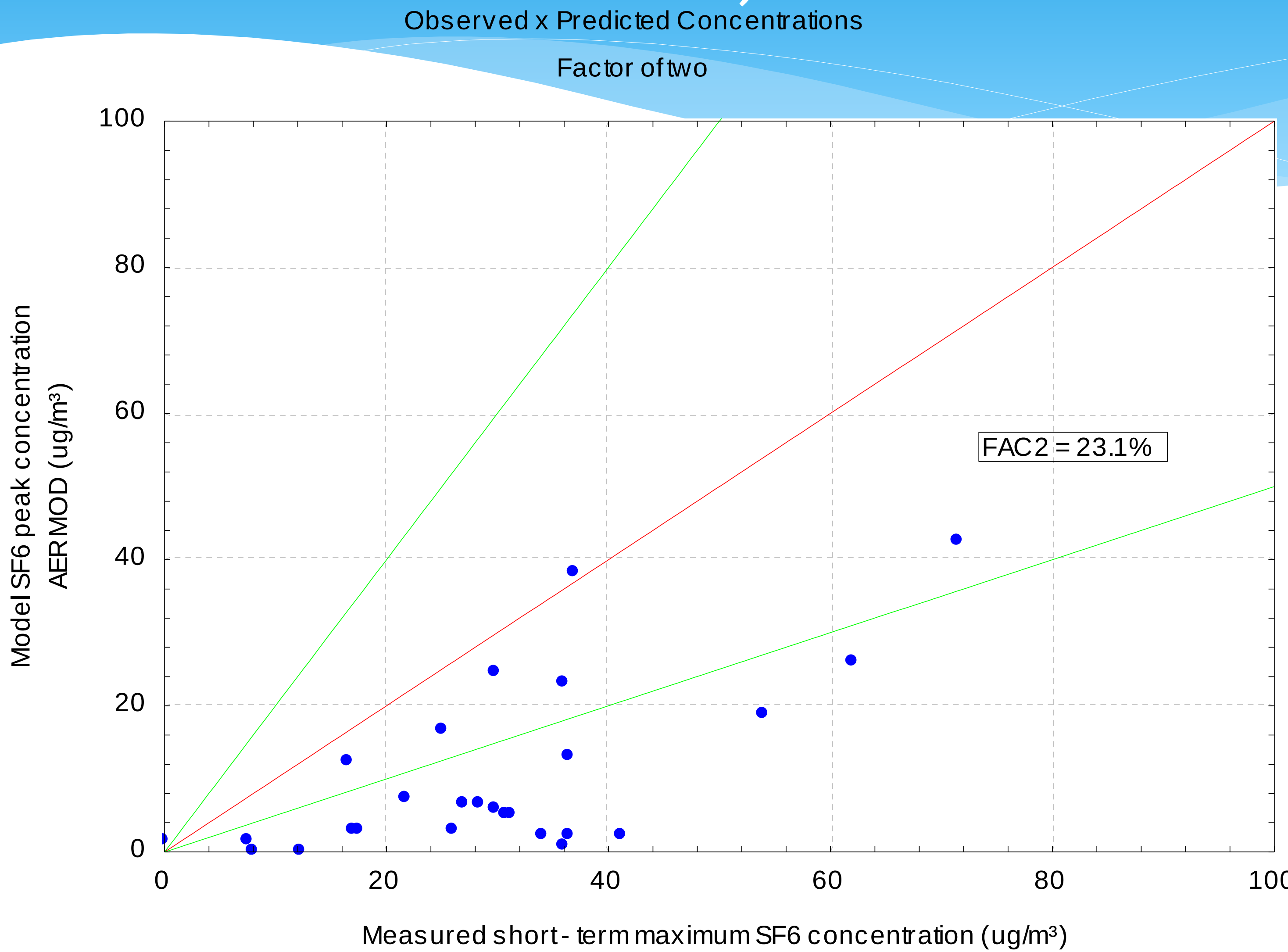
$$FAC2 = fração\ dos\ dados\ que\ satisfaz\ 0.5 \leq \frac{C_p}{C_0} \leq 2, \qquad (7)$$

Tracer dispersion experiment
SF_6

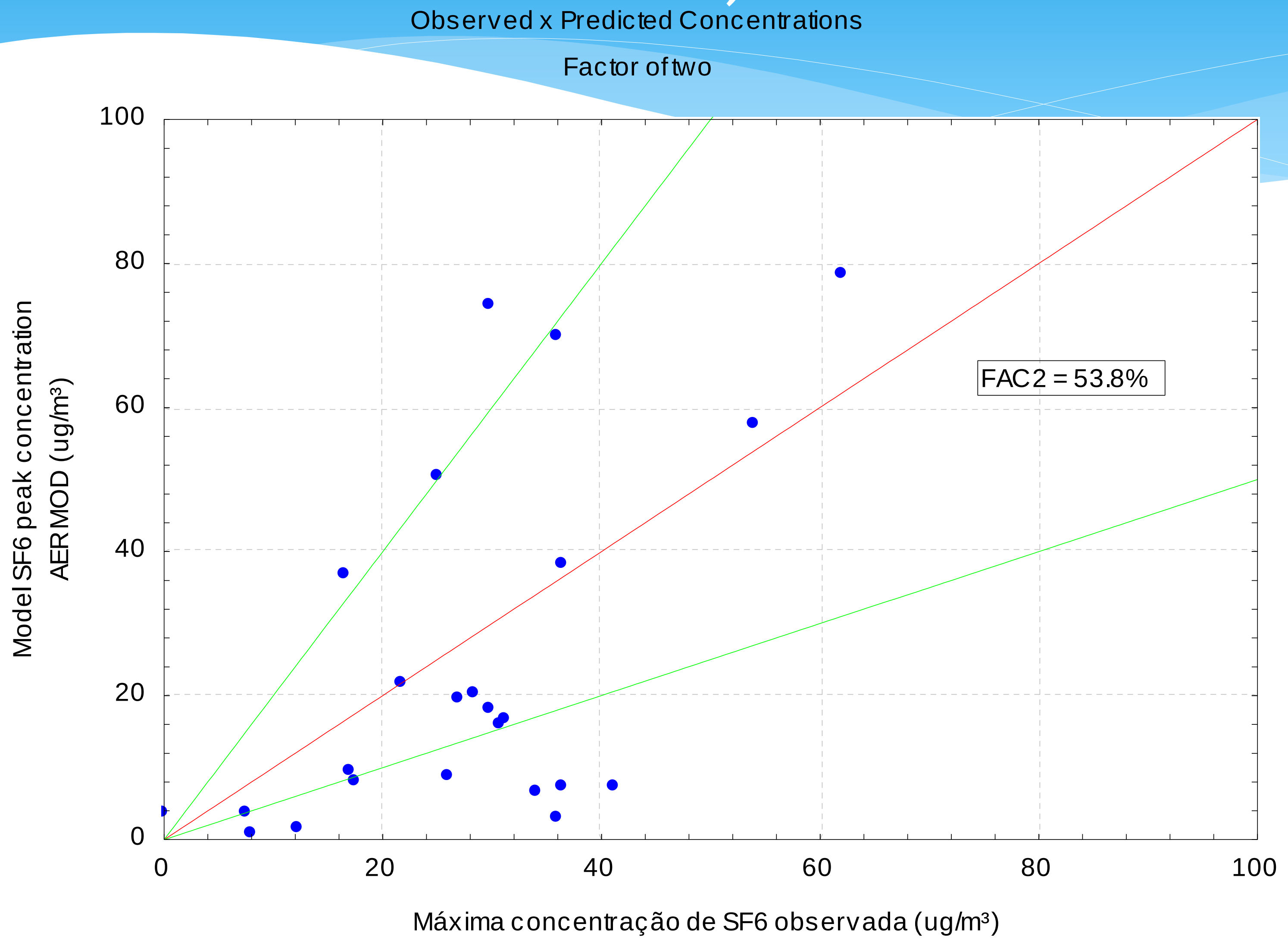
Factor of 2 - Keder (2008)



OBSERVED X SIMULATED PM 2,2



OBSERVADO X SIMULATED PM 6,6



AERMOD X SYMOS'97 – SF6

	AERMOD PM 2.2	AERMOD PM 6.6	SYMOS'97 PM 2.2	Perfect Model (CHANG; HANNA, 2005)	Boundaries (CHANG; HANNA, 2005)
BIAS	19.34	-1.63	6.08	0.0	<0.3
FB	0.96	- 0.05	0.18	0.0	<0.3
NMSE	1.64	0.77	0.60	0.0	<1.5
R	0.67	0.67	0.74	1.0	Close to 1
MG	4.35	1.45	0.88	1.0	0.7<MG<1.3
VG	53.66	7.11	1.02	1.0	<4
FAC2 (%)	23.1	53.8	57.7	100.0	>50

Comparação do AERMOD com outros modelos para o experimento do traçador SF6

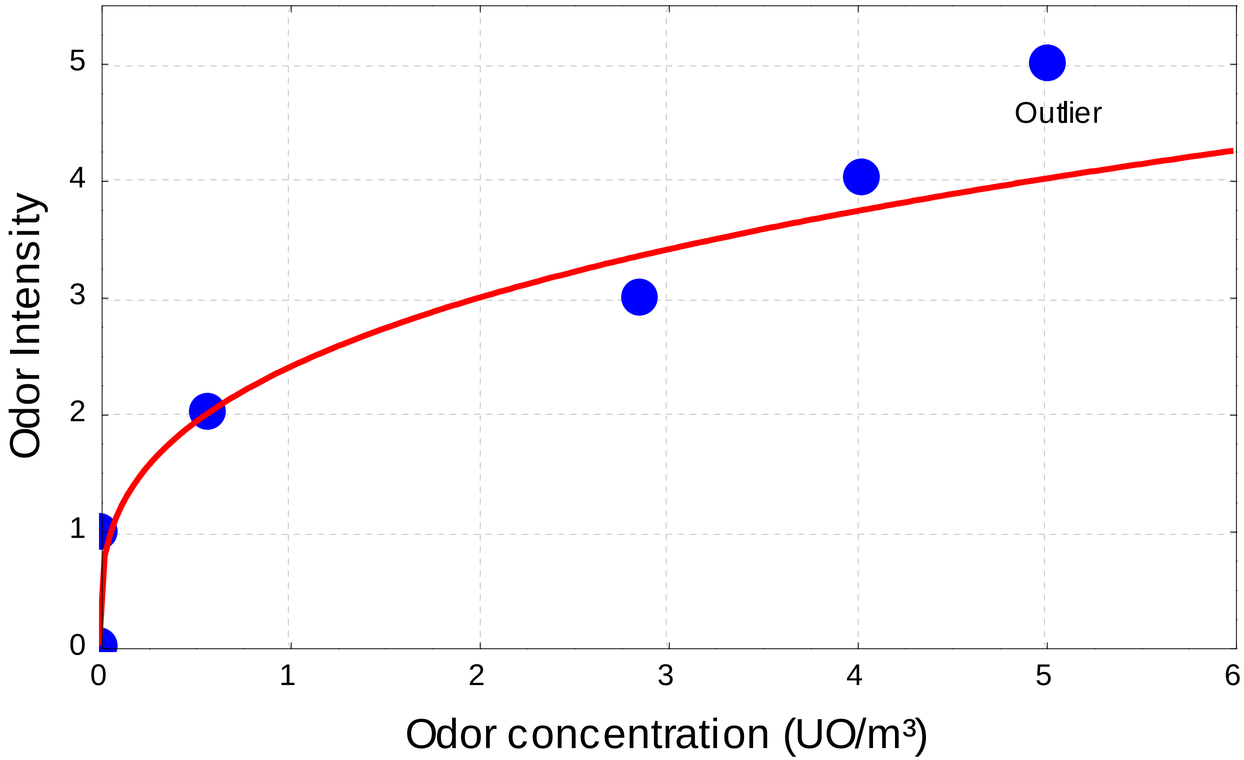
Model	NMSE	FB
SYMOS'97	0.6	0.18
AERMOD	0.77	-0.05
AUSTAL2000	0.8	-0.1
GRAL 12.5/level2	1	0.1
GRAL 12.5/level1	1	-0.3
LASAT	1.1	0
AERMOD – 2.2	1.64	0.96
OENORM M9440	1.8	0.5
GRAL 12.5	2.6	0.7
STERN	3.6	0.8
ADMS 3.1	5.8	1.3
GIEBL	9.1	1.1
SCORER	21.3	1.6

Swine Odor dispersion experiment

AERMOD fit curve for this work

Concentration to Intensisty equation

$$I = 2,378.C^{0.3223}$$

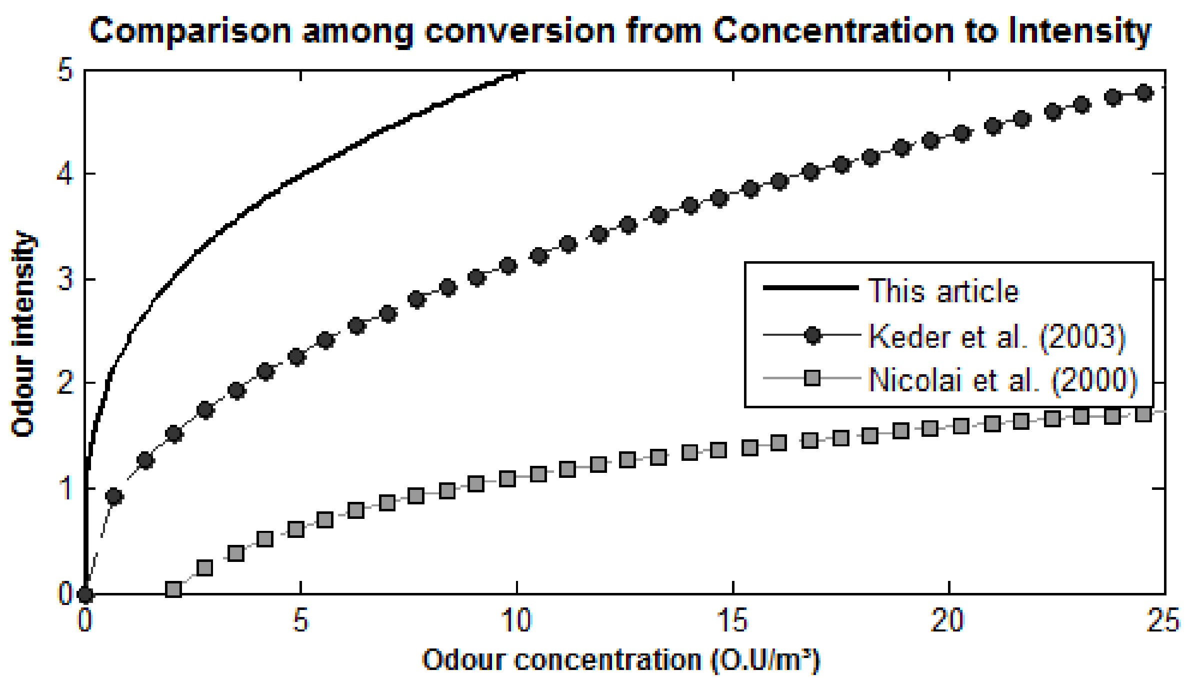


Comparison among fit curves

$$I_{od} = 2.378(C_{od})^{0.3223} - \text{this article;}$$

$$I_{od} = 1.086(C_{od})^{0.464} - (\text{Keder, Bubnik, and Macoun 2003});$$

$$I_{od} = 1.57(log_{10}C_{od}) - 0.466 - (\text{Nicolai et al., 2000});$$



AERMOD – Fit Curves

	SOUZA	KEDER	Perfect Model (CHANG; HANNA, 2005)	Boundaries (CHANG; HANNA, 2005)
BIAS	0.73	1.34	0.0	<0.3
FB	0.30	0.63	0.0	<0.3
NMSE	2.47	1.08	0.0	<1.5
R	0.59	0.55	1.0	Close to 1
MG	1.91	0.74	1.0	0.7<MG<1.3
VG	2.79	22.48	1.0	<4
FAC2 (%)	66.7	45.3	100.0	>50

Conclusion

* Further validating studies are necessary, specially under low wind conditions, when the odor concentrations gets higher;
* AERMOD under estimated the concentrations for the Uttenweiler's experiment;
* The fit curve approach isn't the most adequate once it tries to correct part of the model mistakes;
* A better peak to mean approach was able to improve AERMOD's performance;
* Both gaussian models, SYMOS'97 and AERMOD, reached good results for FB and NMSE, although this indices aren't so sensible to low values witch is the case of Utteweiler's experiment.