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WinMISKAM 4.2, microscale flow and dispersion model for built up areas, recent developments

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ABSTACT

WinMISKAM is a numerical microscale prognostic flow and dispersion model for a user friendly determination of air pollutant concentrations in built up areas like street canyons, in the vicinity of multi floor parking houses or underground garages, in the vicinity of high rise buildings etc.. The model has a lot of users in Austria, Germany and Switzerland, meanwhile it is now also available in a French version. Recently it was significantly extended and the validation proceeded. The paper gives a brief description of the basic features and limitations of the model, describes the update and the results of the latest validation efforts and gives an example for an application in France.

Key words: numerical modelling, flow field, air pollutant concentrations, prognostic models, validation.

1. THE MODEL

1.1. Model description summary

WinMISKAM is a user-friendly Windows software containing as core the MISKAM-model of the Meteorological Department of the University of Mainz (Eichhorn, 1988, 1989). MISKAM contains a 3-dimensional non hydrostatic prognostic flow model and an Eulerian dispersion model. The physical basis are the complete 3-dimensional equations of motion of the flow field and the advection-diffusion equation to determine the concentrations of substances with neutral density. The calculated results are the stationary flow- and pressure-field, diffusion coefficients and the concentration field in an area of typically 500 m x 500 m (100 x 100 grid points or more, non equidistant grid). Horizontal grid spacing being typically 1 to 2 (5) meters in a street canyon under consideration, going up to 10 (20) meters at the border of the modelled area.

In addition to MISKAM, WinMISKAM contains a statistics module to determine the statistical values of concentrations (annual mean and 98-percentile, new EU Air Quality Directive Statistics are under construction) and a NO-NO_2-conversion model.

WinMISKAM enables digitising of the buildings from a bitmap, handling of the non equidistant gridding by mouse, easy gridding of the buildings, tools for the interactive preparation of the input files and graphical features to control the input and output.

1.2. Intended field of application

The main application is the determination of the flow and the concentration field in built-up areas (e.g. street canyons, multi story or underground parking garages, vicinity of high rise buildings etc.) where neutral atmospheric stratifications are dominant. As example for a typical building configuration see **Fig. 1**.

1.3. Input parameters

WinMISKAM needs as input: Information about the buildings, the aerodynamic roughness of the areas between the buildings and on the building surfaces as well as position and strength of the sources. Additionally, information about the roughness length of the vertical wind profile, arriving at the lateral inflow boundary of the model is necessary and the reference height for the wind speed. In case, only single situations need to be considered, wind speed and direction for this case and air pollutant emissions in the emitting grid cells have to be given. In case annual mean values and percentiles of the air pollutant concentrations have to be determined, the long-term statistics of wind speed and wind direction is necessary and the air pollutant emission statistics.

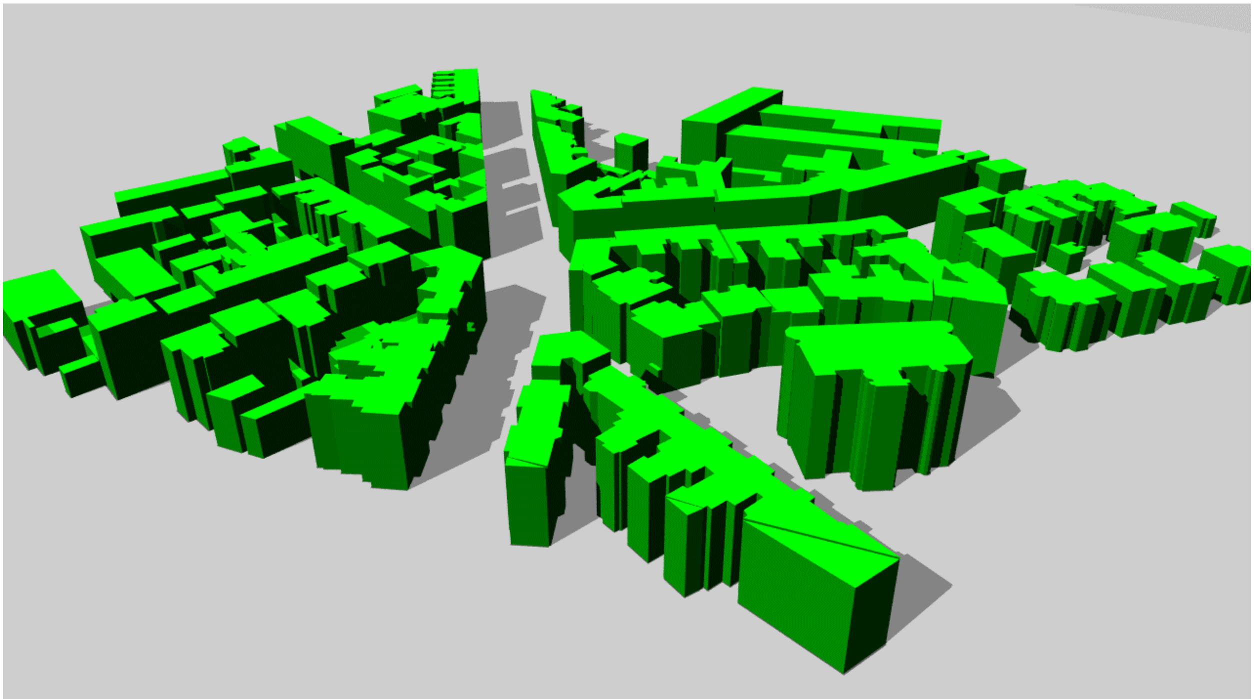


Fig. 1: Digital building model for MISKAM used for the calculations of the flow field for the international Podbi Exercise (Bächlin et al., 2001) and www.Lohmeyer.de/Podbi.

1.4. Model limitations

WinMISKAM is not applicable in topographically strongly structured terrain, if the modelling domain of WinMISKAM is too small to take into account features influencing the flow from outside the modelled area and in case the assumption of neutral atmospheric stratification is not appropriate (including areas with valley drainage flows). For further information about WinMISKAM see the Model Documentation System of the European Topic Centre on Air Quality (ETC-AQ) at www.etcaq.rivm.nl/databases/mds.html or www.sfi-software.de.

WinMISKAM does not contain yet a module to care for the situation at low wind speeds as for example OSPM (Berkowicz, 2000) or the model of Öttl et al. (2001). During low wind speed situations, on and near vehicle roads, the traffic produced turbulence may dominate the atmospheric turbulence thus enhancing the dilution and – in case of the concentrations in a street canyon – reducing the concentration difference between lee – and windward side of the canyon. Thus it might be problematic to calculate single one hour mean values, but we find, that considering the whole year, the annual mean values and the 98-percentiles are represented well by WinMISKAM (Bächlin et al., 2001).

WinMISKAM is commercially available since 1996, since then, it is regularly used in Austria, Denmark, Germany and Switzerland for Environmental Impact Assessments in the frame of regulatory purposes. In the meantime a French version is also available.

2. PROGRESS FROM VERSION 3.6 TO VERSION 4.2

Within the last years, MISKAM was significantly updated and the validation proceeded extraordinary.

2.1 Updates

On the Basis of MISKAM 3.6, released in 1996, the following improvements were executed for MISKAM 4.2:

- Transfer of the complete source code to FORTRAN90 for enhanced clearness.
- Complete revision of the prognostic parts of the model for reduction of CPU time. This is associated with an increase in demand of memory, thus a minimum of 128 MB is recommended now.
- Change of the pressure calculation to Red-Black-SOR, thus elimination of app. 20 % of the steps of the iteration process.
- Improvement of the stability criteria for the calculation of the flow field. After reaching the criteria, no further significant changes occur in the flow- and turbulence field.
- Diagnostic handling of the lowest grid cell in the turbulence model, thus consistency in the influence of the input parameter roughness length z_o on the features of the vertical wind profile.
- Elimination of an inconsistency in the turbulence model: First grid cell above buildings is now treated like first grid cell at the ground.

For further information see www.sfi-software.de/mis4p1p2.htm.

2.2 Validation

MISKAM has a comparatively detailed validation now. Among others a successful comparison of the results of MISKAM to the following data from wind tunnel and field measurements was done:

- All applicable CEDVAL data sets (see www.mi.uni-hamburg.de/cedval/ or Leitl, 2000) of the Meteorological Institute of Hamburg University. These high quality validation data sets were acquired under support of the German Federal Env. Prot. Agency by wind tunnel measurements especially for validation purposes.
- MISKAM 4.1 very successfully took part in a comparison of the CFD-models TASCFLOW, CHENSI, PHOENICS, MIMO and MISKAM, executed in the frame of the European research project TRAPOS. See Louka et al. (2001) or www.dmu.dk/atmosphericenvironment/trapos/cfd-wg.htm. The following **Fig. 2** is taken from there. It shows the flow field, calculated by MISKAM, quite reasonably reproducing the results of the wind tunnel measurements done especially for that validation.
- Field measurements of the Danish National Environmental Research Institute (NERI) in the street canyon Jagdveij in Copenhagen. See Ketzel et al. (2000).
- Field measurements in the street canyon Göttinger Straße, Hannover, provided in detail by Lower Saxony State Agency of Ecology (NLÖ). See Ketzel et al. (2000).
- Field measurements of NLÖ from Podbielskistraße, Hannover, as they were used for the Podbi-Exercise (Comparison of concentration predictions, done by different modellers for the same street canyon, see: www.lohmeyer.de/Podbi or Bächlin et al. (2001)).

- **Fig. 3** gives the non dimensional concentration distribution c* which is the concentration times the wind velocity at the reference height above the buildings divided by the source strength. The figure contains the c*-distribution as a function of the wind direction calculated with WinMISKAM 4.2 as well as the measured distribution and the distribution obtained in the wind tunnel of the Met. Inst. of Hamburg University. It can be seen that WinMISKAM 4.2 shows a satisfactory performance. Especially in the range of the wind direction 150 and 330, where the concentrations are in an higher range, the WinMISKAM results match quite well the field measurements and the wind tunnel experiment. For the other wind directions WinMISKAM over predicts the concentrations in Göttinger Straße.

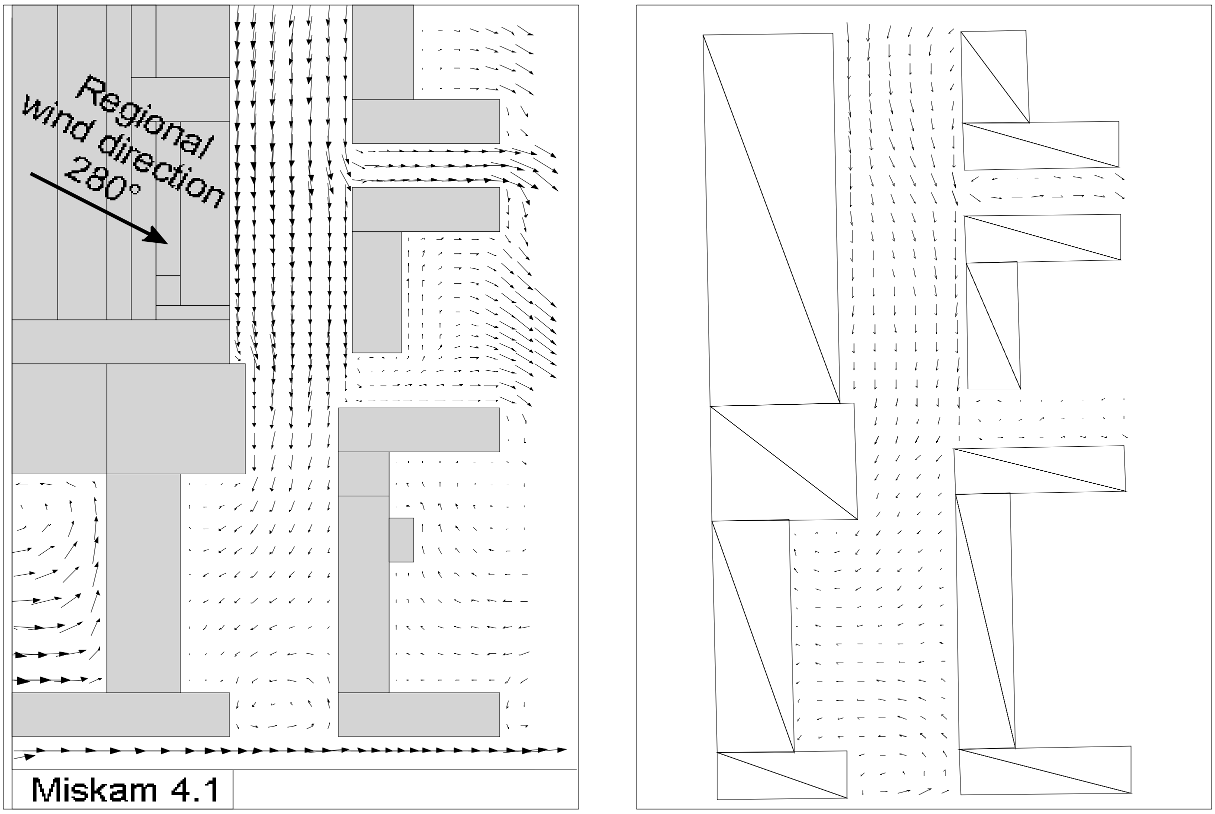


Fig. 2: Flow field in Göttinger Straße, 10 m above ground for a regional wind direction of 280°. Left: Calculated by MISKAM. Right: Measured in the wind tunnel of the Met. Inst. of Hamburg University. Taken from www.dmu.dk/atmosphericenvironment/trapos/cfd-wg.htm.

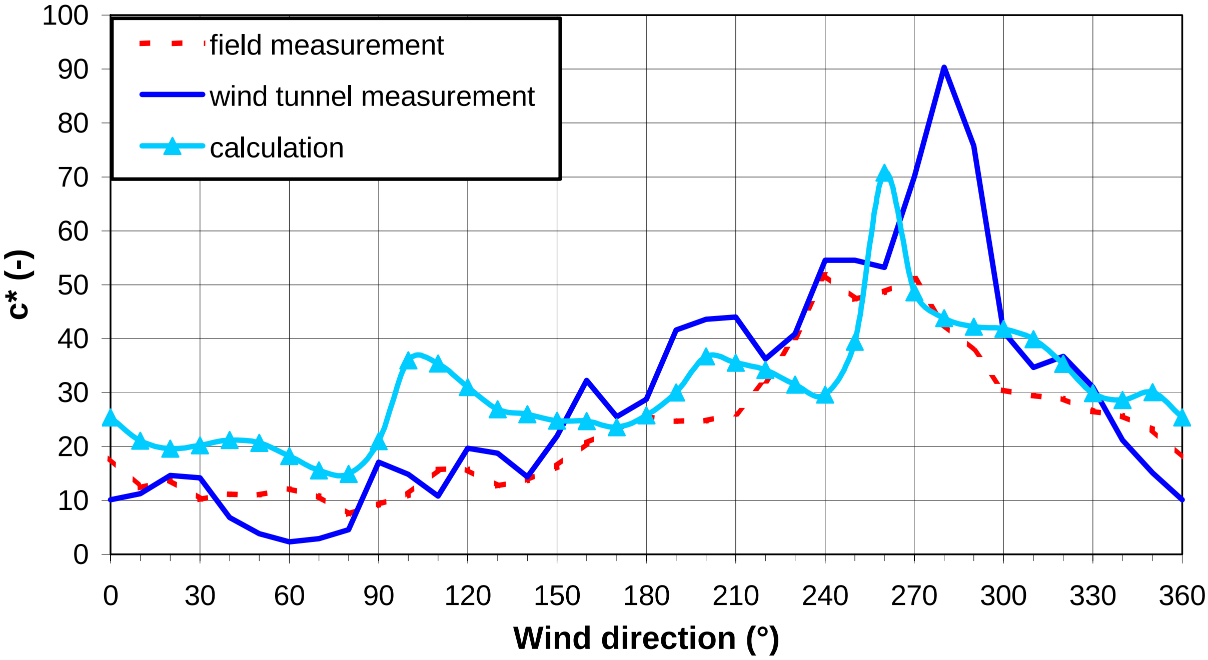


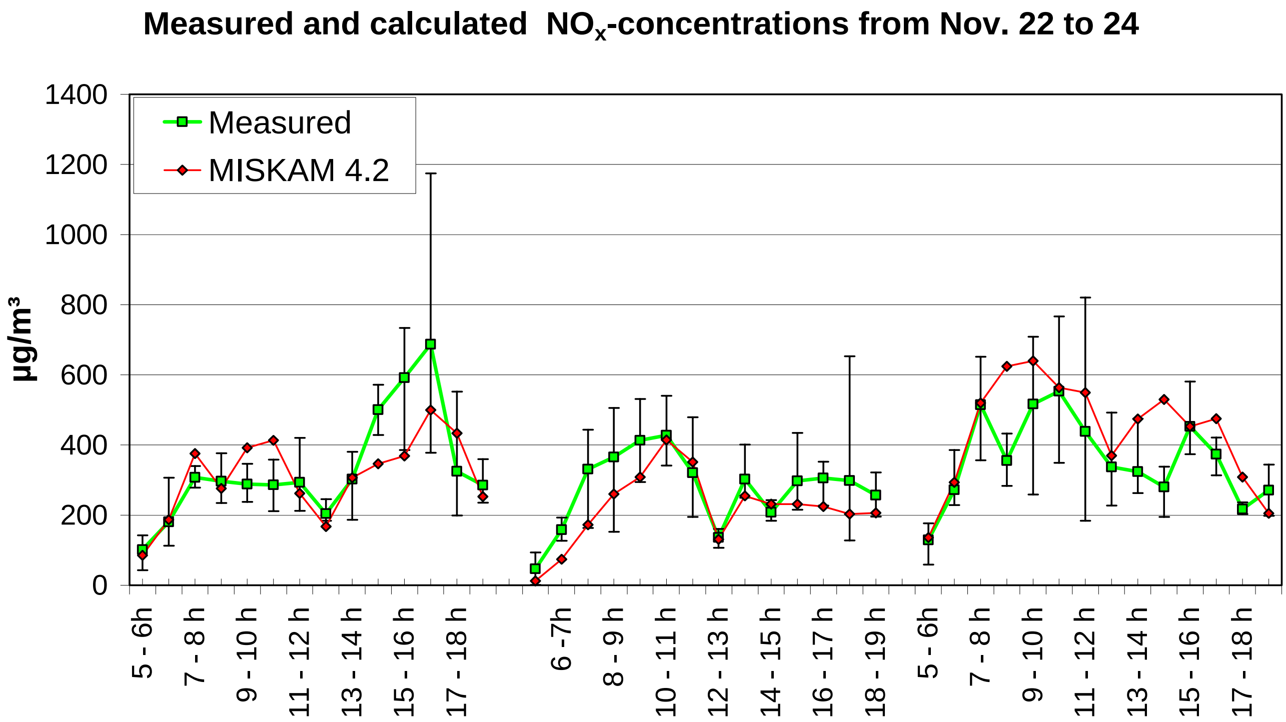
Fig. 3: Comparison of results from field monitoring station Göttinger Straße to calculation by MISKAM 4.2. Display of the non dimensional concentration c* versus wind direction.

3. WinMISKAM IN FRANCE

In the frame of the EU project HEAVEN, the operator of the Paris Air Quality Monitoring Stations, AIRPARIF, asked Kisters France SAS to develop information about a possible use of WinMISKAM 4.2 for calculating hourly means of the concentrations on the basis of pre-calculated c*-values as it is done in STREET. The study is still going on, but the first results already indicate that it is possible in principle.

Fig. 4 shows the calculated hourly mean concentrations, based on hourly values of wind speed, wind direction and emission, compared to results of field measurements. Concentration values are available with an averaging time of 15 minutes. Thus in **Fig. 4**. the hourly concentration is the mean of 4 measured values. In addition the error bars give the variation of the measured concentrations based on the 4 available values within each hour. As it was mentioned before MISKAM does not yet account for the special conditions during low wind speeds, but nevertheless the comparison between calculation and measurement is satisfactory for the 3 days under consideration. The deviations seem to be caused mostly by the inaccurate knowledge of the change of the fleet composition in the course of the day. Additional comparisons with an exact input of the fleet composition are presently under way.

The following **Fig. 5** and **Fig. 6** show the correlation between modelled and measured results. For the daily means for these 3 days, the deviations are less than ± 30 %, no systematic deviation seems to exist and even the hourly mean values show deviations of less than a factor of 2.



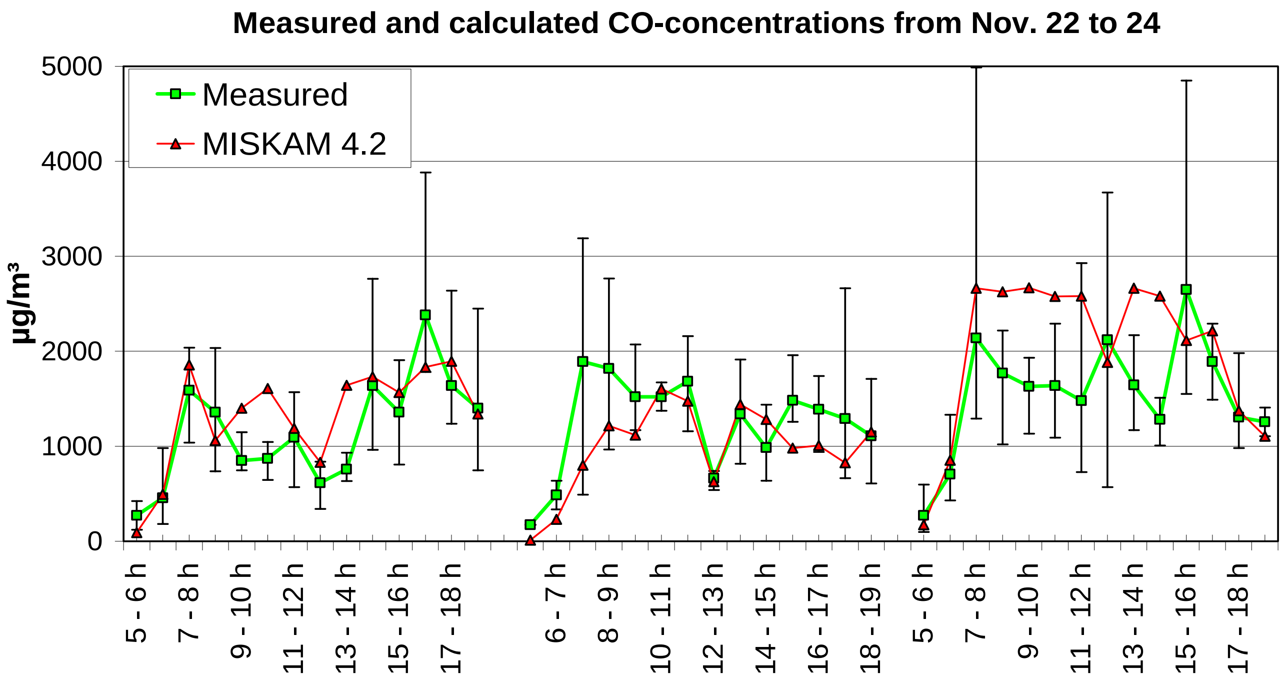


Fig. 4: Time series of calculated hourly means of concentrations (MISKAM) compared to field measurements

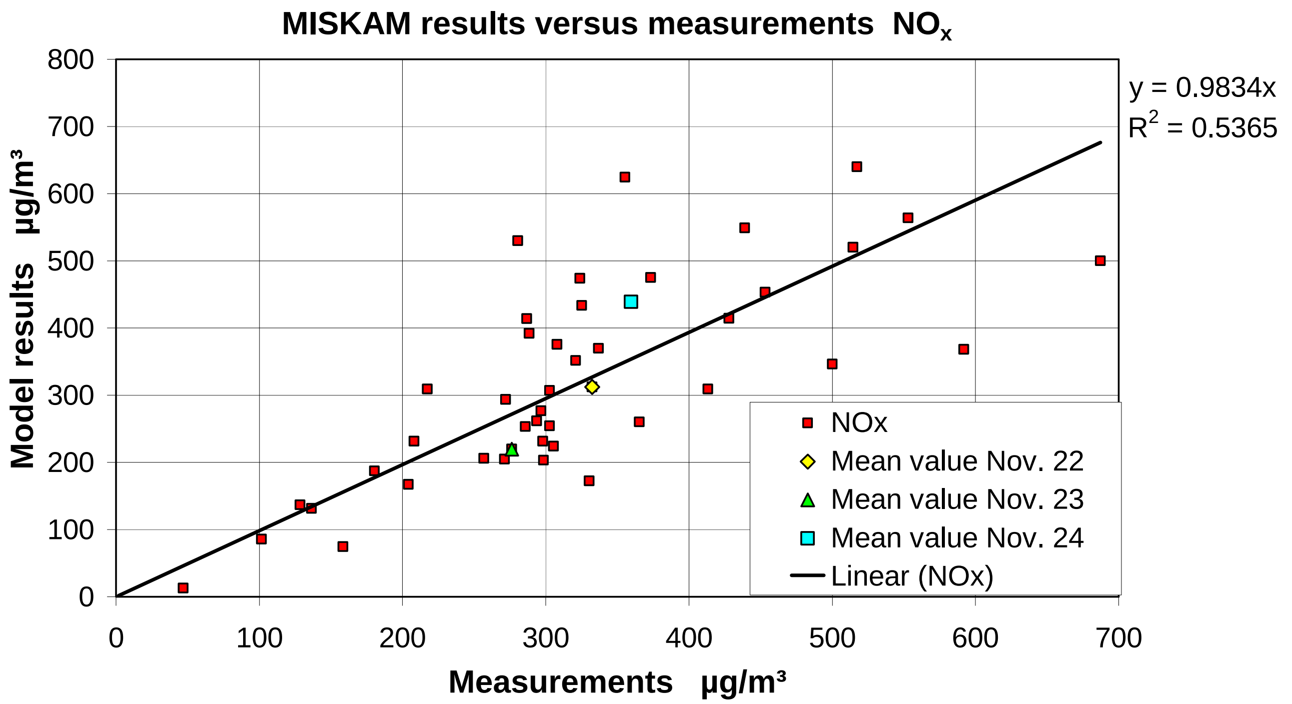


Fig. 5: Comparison of calculated and measured NO_x-concentrations

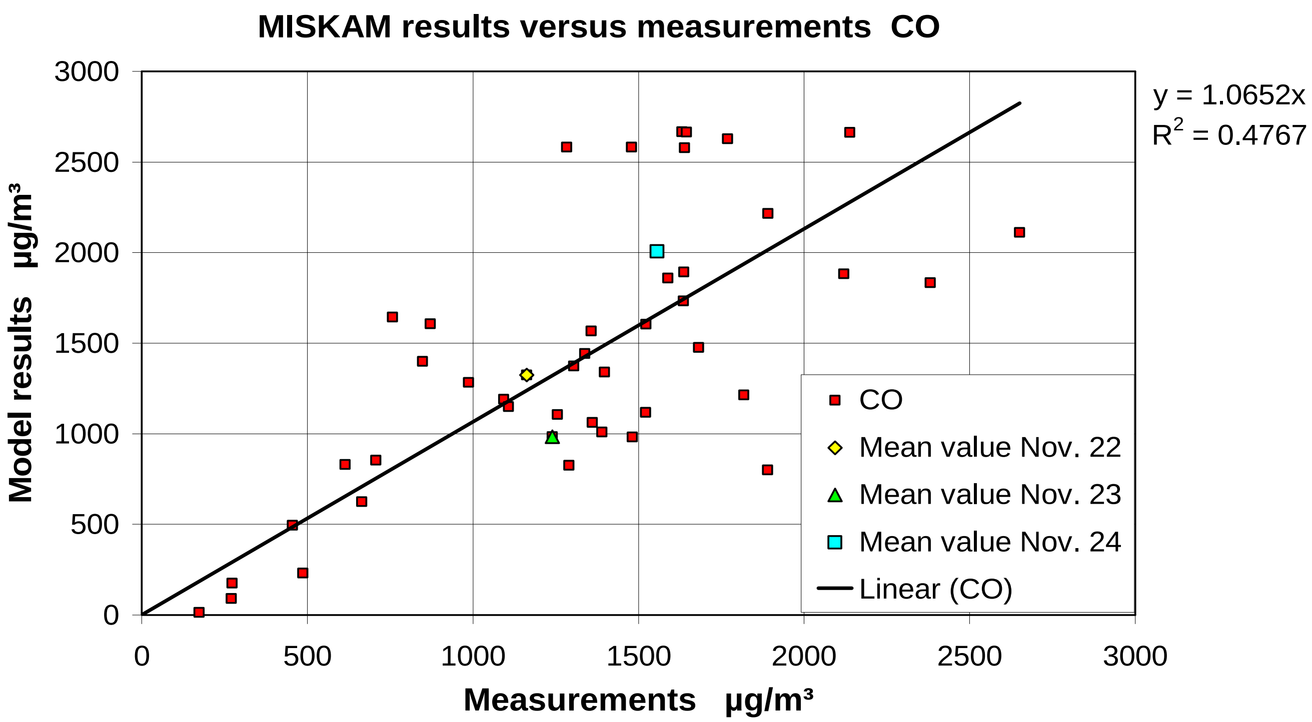


Fig. 6: Comparison of calculated and measured CO-concentrations

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