Comparison of Different Dispersion Modelling Approaches in Complex Terrain

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ABSTRACT

In the present study we focus on comparison of results of different approaches for passive tracer dispersion modeling in complex terrain. Simulations with three meteorological and dispersion models are performed for selected episodes. Meteorological models included in the study are the diagnostic mass-consistent wind field models and the complete prognostic non-hydrostatic mesoscale model, while lagrangean and eulerian approach are used for modeling the dispersion of pollutants.
Attempts to estimate the average yearly 1h near ground concentrations on the basis of simulations performed for selected characteristic weather-type episodes are also made. This approach may be useful especially when meteorological conditions in simulations performed over longer time period are simulated with a complete non-hydrostatic mesoscale meteorological model.

ESTIMATION OF YEARLY AVERAGE NEAR GROUND POLUTANT DENSITIES

Methodology consisted of the following steps:

- Classification of large scale weather performed over longer time period (40 years). ERA40 700 hPa wind field, 500 hPa and 925 hPa geopotential were used in this classification procedure (Dittmann et al.).
- Second stage classification for calculating subclusters of large scale weather clusters on the basis of radiosounding observations and near ground meteorological measurements.
- Calculation of weather-type frequencies and determination of most representative (characteristic) cluster member (day with minimum distance from cluster centroid).
- Model simulations were carried out for every cluster representative. Yearly 1h average concentration fields were calculated as weighted sum of daily average concentration fields for characteristic days.

Evaluation of results:

- Average yearly 1h near-ground SO_2 concentration field was calculated by simulating dispersion of SO_2 from point source during entire 1-year period (May 2000 – April 2001) by CALMET/CALPUFF modeling system.
- For six different classifications (Table 2) average yearly 1h near-ground SO_2 concentration field was estimated by weighting the characteristic episode concentrations.

Table 2: Some characteristics of performed classifications.

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Number of clusters	11	13	10	7	15	35
First stage classification based on	700 hPa wind sector	700 hPa wind sector	700 hPa wind sector	925, 500 hPa C/A*	925 hPa C/A*	925, 500 hPa C/A*
Fields used for first stage classification	700 hPa U,V	700 hPa U,V	700 hPa U,V	700 hPa U,V; 500,925 hPa Z	700 hPa U,V; 500,925 hPa Z	700 hPa U,V; 500,925 hPa Z; TWC

*C - Cyclonic, A - Anticyclonic

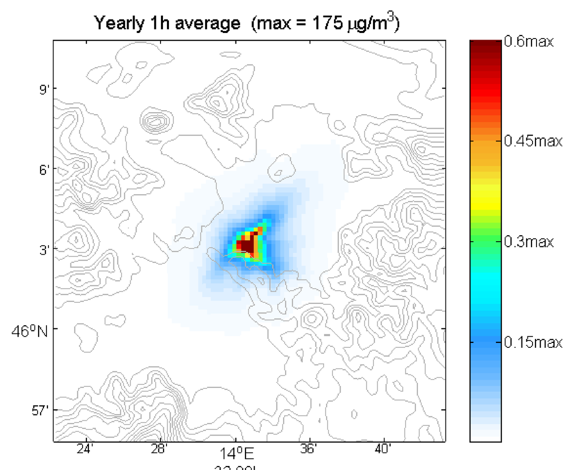

Figure 4: Yearly average 1h near-ground SO_2 values, calculated from results of CALMET/CALPUFF simulations performed for time period May 2000 – April 2001.

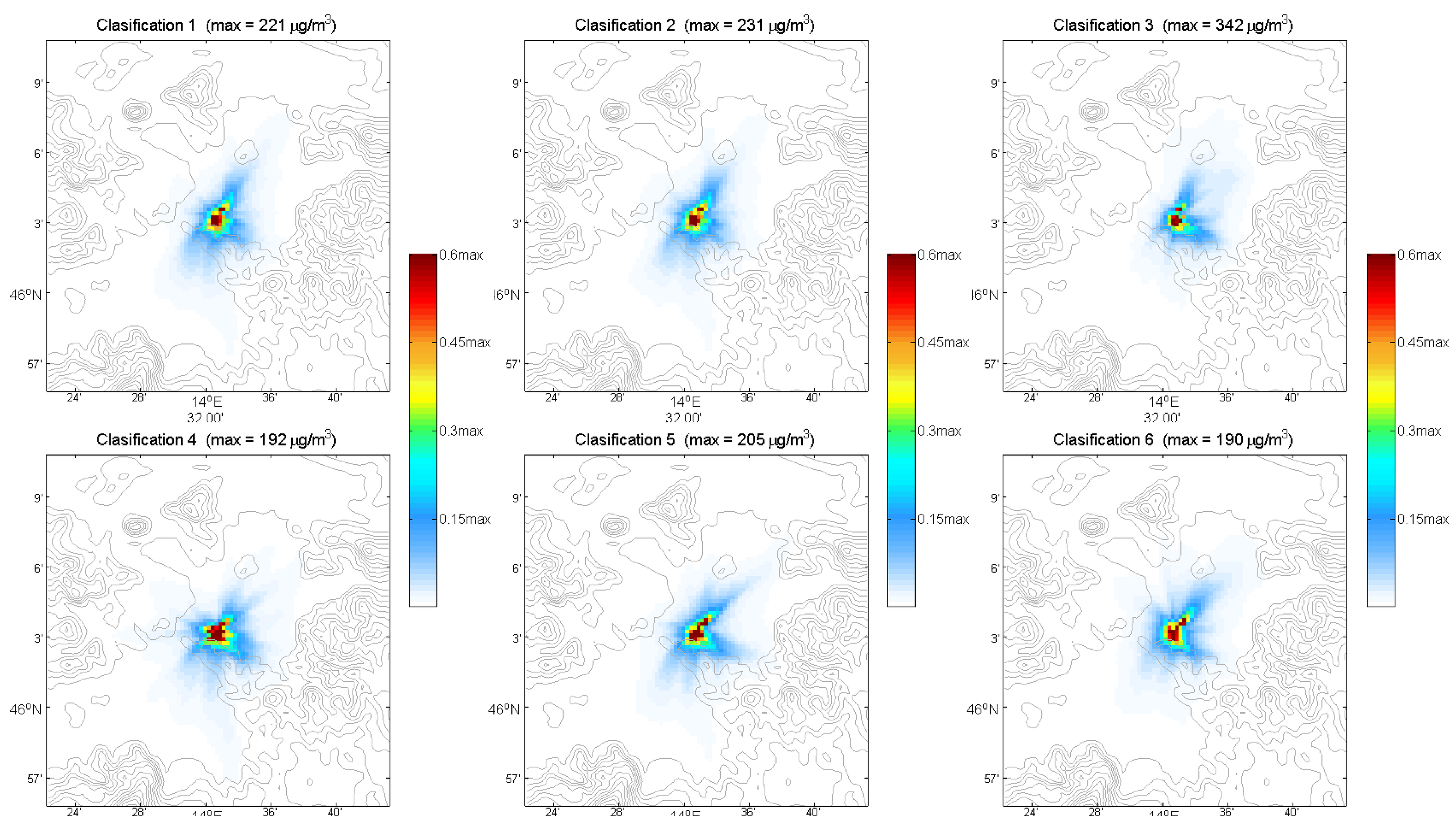

Figure 5: Yearly average 1h near-ground SO_2 values, calculated from CALMET/CALPUFF simulations performed for characteristic days. Legend is relative to the maximum (max) that shown in each of the figure titles.

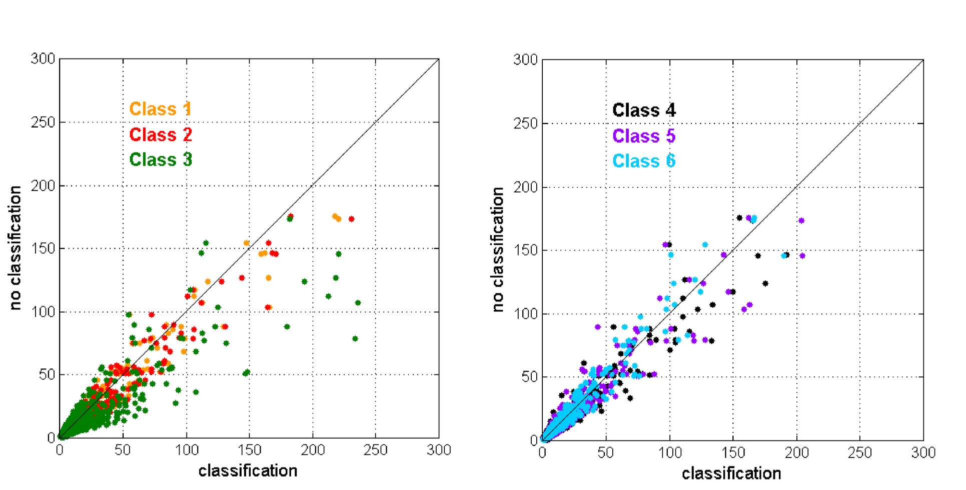

Figure 6: Scatter plots of the calculated yearly average 1h SO_2 values (in μg/m^3) from the CALMET/CALPUFF simulation covering 365 days in comparison to values calculated from the weighted sum of characteristic days for six different classifications. Classifications with the first stage clustering based on cyclonic or anticyclonic conditions (Class 4-6) perform better than classifications with first stage clustering based on 700 hPa wind sector (Class 1-3).

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MODELLING SYSTEMS

Modelling systems used in the study:

- AUSTAL2000 (VDI, 2000).
- CALMET & CALPUFF (Scire et al., 2000a).
- WRF-Chem model (Skamarock et al., 2008; Peckham et al., 2008).

Configuration of models:

- Area of interest centered over the Ljubljana basin.
- Horizontal modeling domain with 100x100 points in 300 m resolution.
- 12 vertical levels from 0 to 2500 m altitude.
- Meteorological measurements at two stations and one radiosounding site used for diagnostic wind field calculations.
- Dispersion of passive tracer from the point source placed in Ljubljana basin.

Additional in the WRF-Chem model configuration:

- 27 additional vertical levels extending up to 50 hPa.
- Three nested domains, the innermost domain cinciding with CALMET/CALPUFF and AUSTAL domain.
- ECMWF analyses used for meteorological initial and lateral boundary conditions.
- Simulations with, and without PBL parameterization.

Table 1: Point source characteristics.

Latitude	Longitude	Stack height	Stack diameter
46.05833 ºN	14.5495 ºE	100 m	6 m

Velocity	Temperature	SO_2 flow
6.4 ms^{-1}	400.1 K	240.3 kgh^{-1}

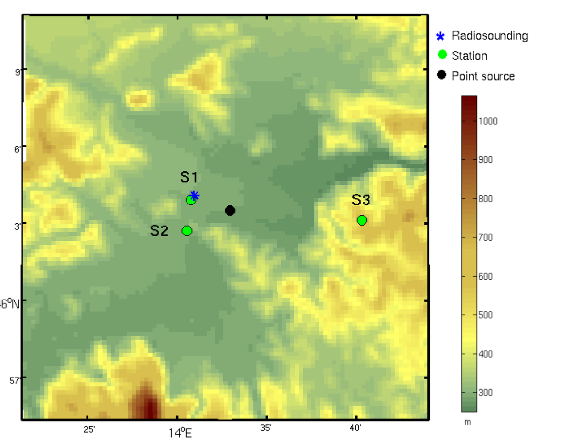

Figure 1: Topography as represented in modelling domain with 100x100 grid points and 300 m resolution.

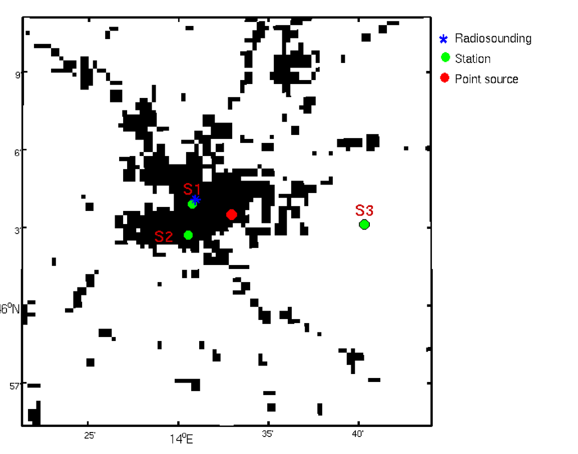

Figure 2: Areas with dominant fraction of urban land cover category (Ljubljana city) in modelling domain with 300 m resolution.

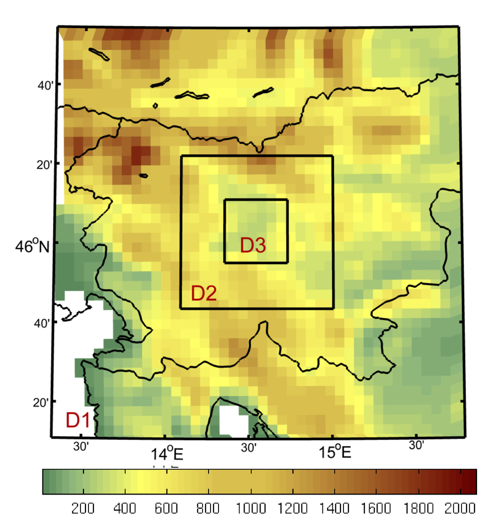

Figure 3: WRF-Chem model domains. D1: 45x45 grid points, 5 km resolution; D2: 81x81, 1 km; D3: 100x100, 300 m. Topography is shown in 5 km resolution.

COMPARISON OF RESULTS FOR SELECTED DAYS

Results of simulations performed with different modelling systems were compared for two days:

- Winter day: 15 February 2008. Summer day: 3 July 2008.
- Both are anticyclonic situations with relatively weak winds in PBL. Radiosounding observations show subsidence temperature inversion between 900 m and 1200 m a.s.l. for the winter day, and nighttime temperature inversion between 250 m and 500 m a.s.l. for the summer day.

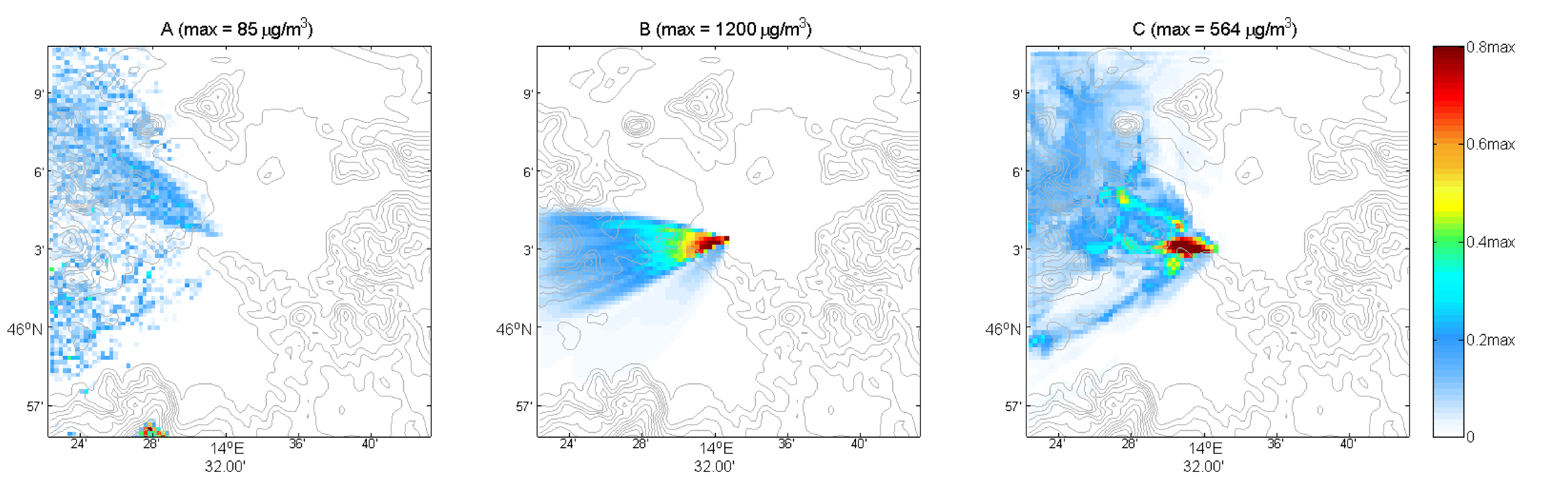

Figure 7: Comparison of ground level 1h daily maxima for experimental runs performed for 15 February 2008. A – AUSTAL2000, B – CALMET/CALPUFF, C – WRF-Chem model.

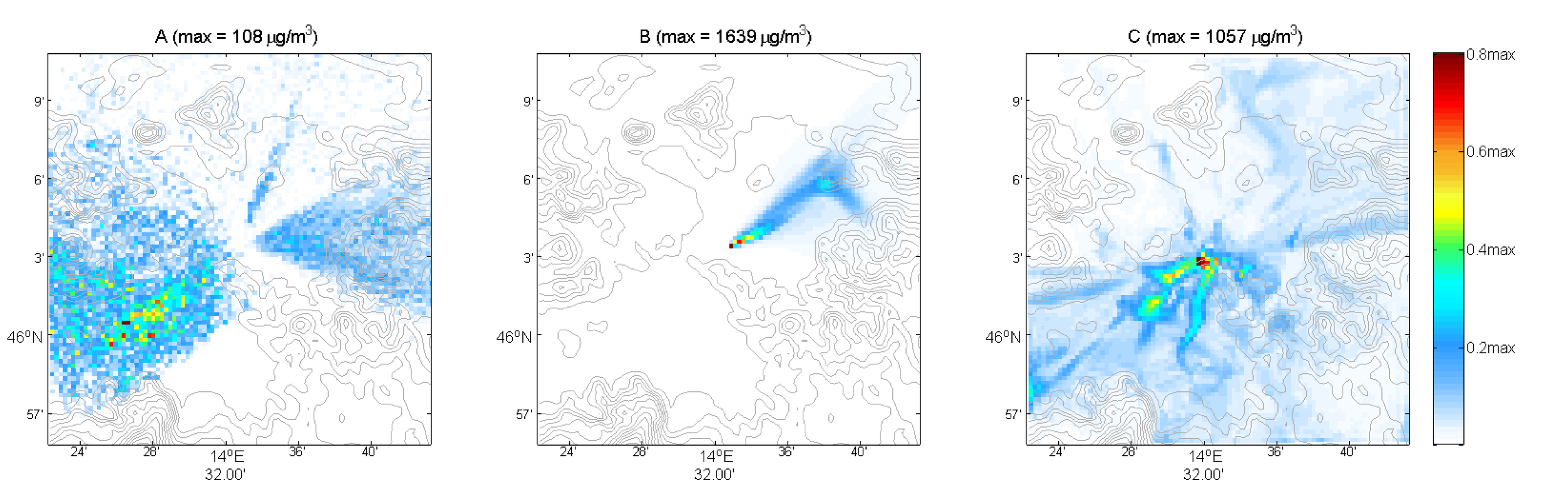

Figure 8: Comparison of ground level 1h daily maxima for experimental runs performed for 3 July 2008. A – AUSTAL2000, B – CALMET/CALPUFF, C – WRF-Chem model.

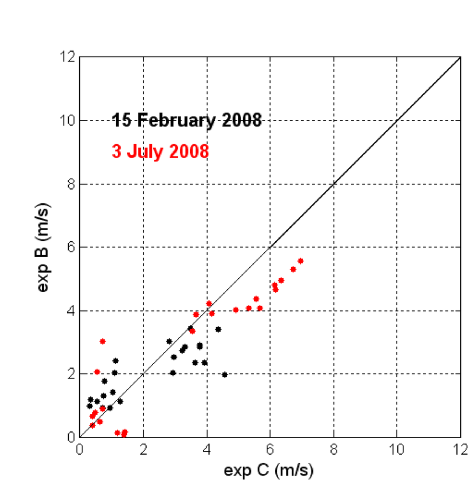

Figure 9: Scatter plot comparing the hourly wind speed values of experiments B and C at point source location, separately for winter and summer day.

Table 3: Comparison of absolute 1h daily SO_2 maximum concentrations (in μg/m^3) - regardless the time and the location of occurence.

	AUSTAL	CALMET	WR-CHEM
Winter day	85	1200	565
Summer day	108	1639	1201