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INFLUENCE OF THREE DIFFERENT WIND FIELD INITIALIZATIONS IN CALMET MODEL ON DISPERSION MODELLING IN COMPLEX TERRAIN

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Abstract: In the present study we focus on evaluation of results from CALPUFF modelling system around Šoštanj thermal power plant (TPP) in northern Slovenia. Šoštanj TPP presents a significant emission source located in a very complex terrain where local scale dispersion modelling is extremely challenging due to meteorological conditions characterized by weak winds, mesoscale circulations (weak up- and down-slope winds, valley channelled winds) and strong temperature inversions. Consequently, in our study we decided to focus on the influence of different wind field initializationstrategies on modelling results.

Key words: *Wind field initialization, dispersion modelling, complex terrain, CALMET, CALPUFF, ALADIN mesoscale model.*

INTRODUCTION

CALPUFF modelling system consists of diagnostic mass consistent wind field model CALMET and Lagrangian puff model CALPUFF. CALMET is diagnostic mesoscale wind field model with boundary layer modules for calculations of 3D air temperature fields, surface friction velocity, Monin-Obukhov length, mixing height and Pasquill-Gifford-Turner (PGT) stability classes. In CALMET wind field model different ways for wind field initialization can be used. In our study the initialization of CALMET wind fields was prepared in three different ways: 1. wind field initialization using meteorological data from six surface stations around Šoštanj TPP and one vertical profile of radio-sounding data, 2. initialization meteorological fields simulated with operational prognostic mesoscale model ALADIN, and 3. initialization using a combination of data from surface stations, upper-air sounding data and mesoscale model fields.

CALMET diagnostic wind filed model uses a two step procedure for wind field calculation. First guess is prepared at the beginning and than in step 1 the first guess is adjusted to kinematic effects of terrain, slope flows, blocking effects and divergence minimization. In step 2 objective analysis (interpolation), smoothing, vertical velocity adjustment and final divergence minimization is further applied.

The dispersion modelling results obtained from different wind field initialization approaches are discussed with the focus on modelling results relevant for regulatory purposes: limit and target values for the protection of vegetation and for the protection of human health, including annual average value, maximum hourly value and maximum daily value of SO_2. The simulated numbers of exceedences for different limit values are compared and the assessment for upper and lower threshold values was also made.

CONFIGURATION OF MODEL

In Table 8 experiments presenting three different CALMET wind field initialization procedures are shown.

Table 8. Experimental runs.

Experiment	Data used for wind filed initialization
A	surface measurements and vertical profile from radio sounding data
B	analyses from mesoscale prognostic model ALADIN
C	surface measurements and analyses from mesoscale prognostic model ALADIN

In experiment A initialization was made with meteorological data from surface stations and twice daily upper air data from radio-sounding in Zagreb. Eight meteorological and air quality stations exist around Šoštanj TPP, but only six stations have representative wind data and were included in calculations. Because location of radio-sounding measurements is around 100 km away from Šoštanj TPP, these data were used only at upper two levels. At lower levels near surface theoretical wind profile were prepared with CALMET using similarity theory. First guess wind field was prepared with inverse distance interpolation of observations and results from similarity theory. Observations were also included in step 2 of wind filed calculations.

In experiment B no observation data were used and only data from mesoscale model ALADIN were included in wind field initialization. Mesoscale prognostic meteorological model ALADIN is operative model in Slovenia with horizontal resolution of 4400 m. Only six-hour ALADIN meteorological analysis are archived for year 2010, so time interpolation was made to obtain meteorological fields with 1h temporal resolution. Thesedata were used as a first guess wind field.

In experiment C combination of observations data and mesoscale model analyses were included. ALADIN analyses were used as first guess field and observations were included in step 2 calculations.

Modelling domain, terrain elevation, location of emission sources, air quality stations, radio-sounding measurements and ALADIN modelling points are shown inFigure 33. White circle represent evaluation area with centre in location of emission source and radius equal to 50 stack heights. Calculations were made in domain with 120 x 120 horizontal gird points with 230 m horizontal resolution and 11 vertical levels(0 m, 20 m, 60 m, 120 m, 180 m, 280 m, 400 m, 550 m, 700 m, 900 m, 1500 m and 2500 m). Constant emissions from two Šoštanj TPP stacks in centre of domain were included in calculations (Table 9).

a) b) c)

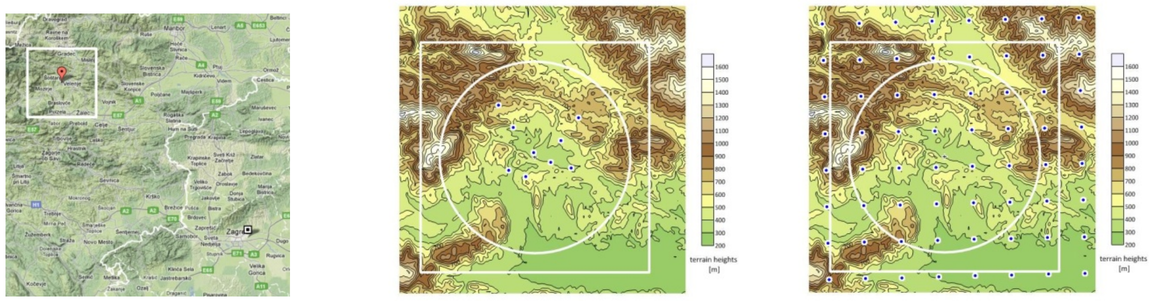

Figure 33. Location of a) modelling domain (white square) with Šoštanj TPP and radio-sounding measuring site in Zagreb, b) air quality stations around Šoštanj TPP, c) grid points of mesoscale model ALADIN. Stacks are located in centre of modelling domain and white circle represents the evaluation area.

Table 9. Stacks location, dimension and emission data in year 2010.

stack	UTMx [m]	UTMy [m]	a.s.l. [m]	H [m]	2r [m]	T [K]	v $[ms^{-1}]$	SO_2 $[kgh^{-1}]$
VKN2	504088	5135471	360	150	6.3	378.0	13.1	241.6
VKN3	504252	5135380	360	230	6.8	370.0	11.7	248.4

RESULTS AND DISCUSSION

CALMET results

Comparison of modelling results frequency distribution of PGT stability classes in centre of domain for all three experiments is shown inFigure 34. There were more stable and unstable situations in experiments A and C than in experiment B, but experiment B has more slightly unstable, neutral and slightly stable situations. Reasons for a lot of stable situation in all three experiments we can find in very complex terrain characterized with low wind speeds and a lot of temperature inversions in winter time.

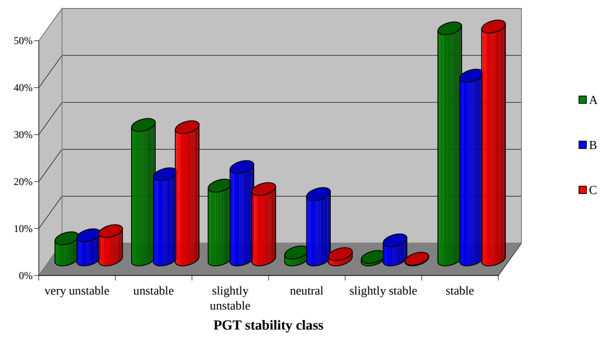

Figure 34. PGT stability classes distribution for one year meteorological data.

Comparison of calculated temperature in centre of domain shows a small difference in calculated temperature between experiment A and B and almost no difference between experiments A and C (Figure 35). Wind speeds in experiments A and C are higher than in experiment B, probably because meteorological analyses of mesoscale model are not so representative near ground (Figure 36). Good correlations are obtained for estimations of mixing heights in all three experiments (Figure 37).

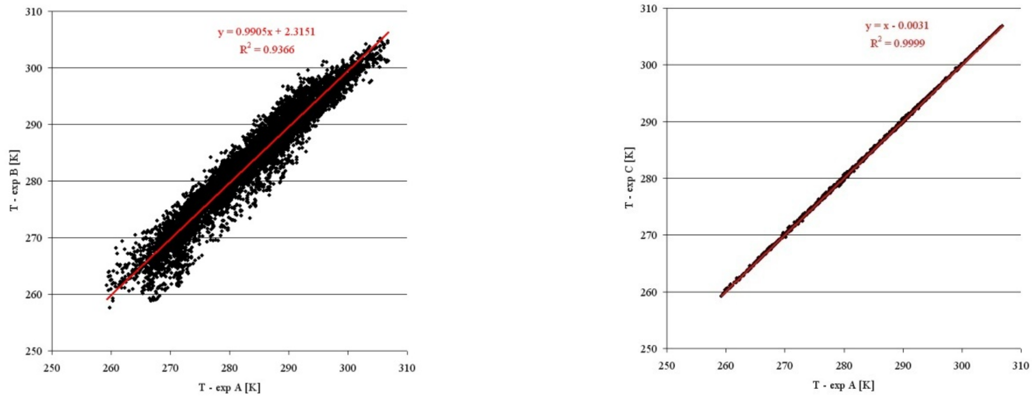

Figure 35. Scatter plot comparing hourly CALMET calculations of ambient temperatures between experiments A and B and between experiments A and C at the location of the stack at height 10 m.

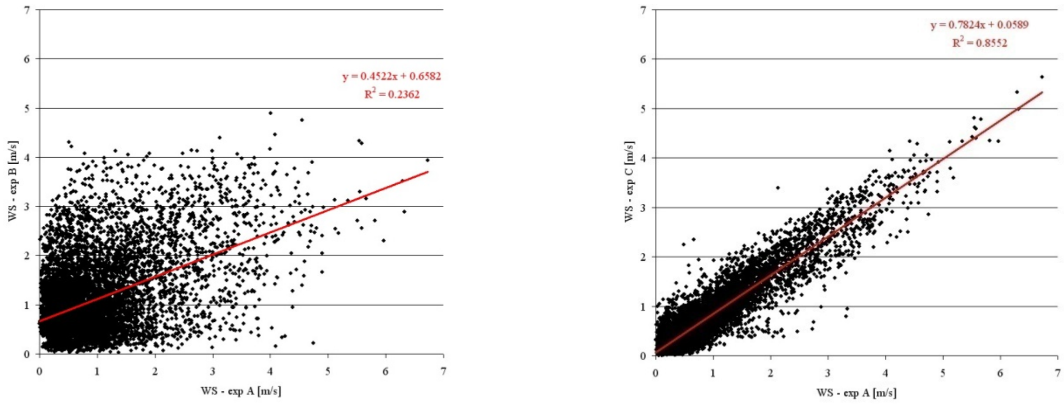

Figure 36. Scatter plot comparing hourly CALMET calculations of wind speeds between experiments A and B and between experiments A and C at the location of the stack at height 10 m.

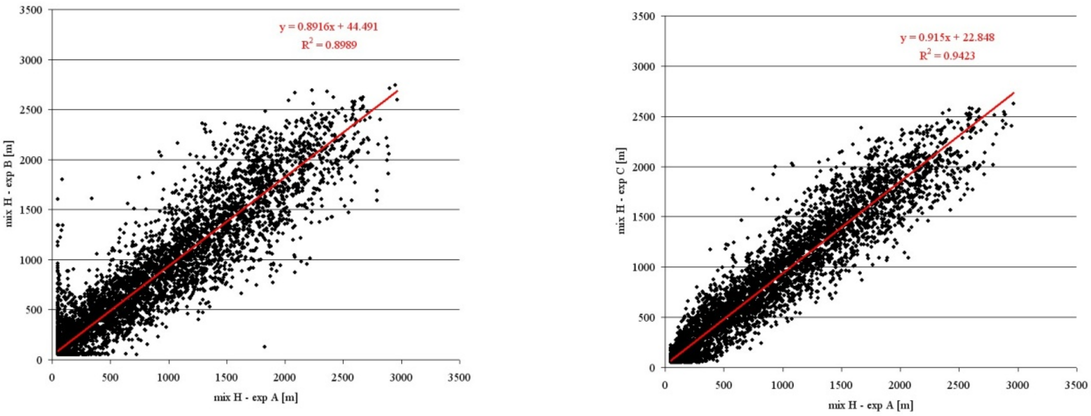

Figure 37. Scatter plot comparing hourly CALMET calculations of mixing heights between experiments A and B and between experiments A and C at the location of the stack.

CALPUFF results

Figures below represent spatial distribution of concentration in the modelling area. All figures have the same colour scale for air pollutions. Red colour is for limit value, blue colour for lower threshold value, yellow colour for upper threshold value and green colour for 3 % of annual limit value. Annual mean values for all 3 experiments are shown in Figure 38. Location of maximum differs between experiments: experiment A has maximum in east site away from stack, experiments B and C have maximum on north-west side. Spatial distributions of hourly and daily maximum are shown in Fig.39 and 40.

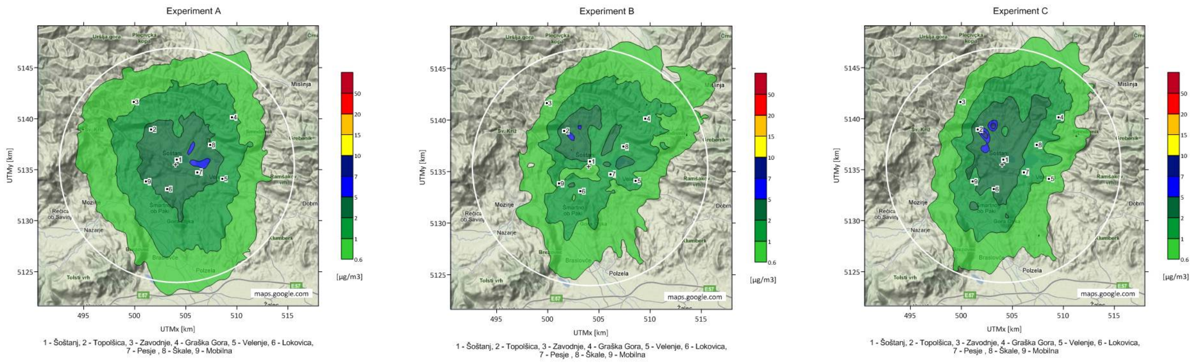

Figure 38. Annual SO_2 concentration.

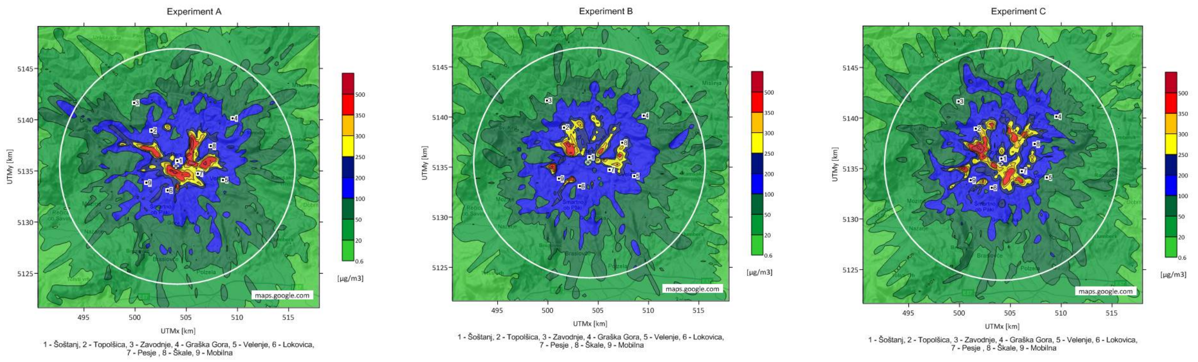

Figure 39. Maximum hourly SO_2 concentration.

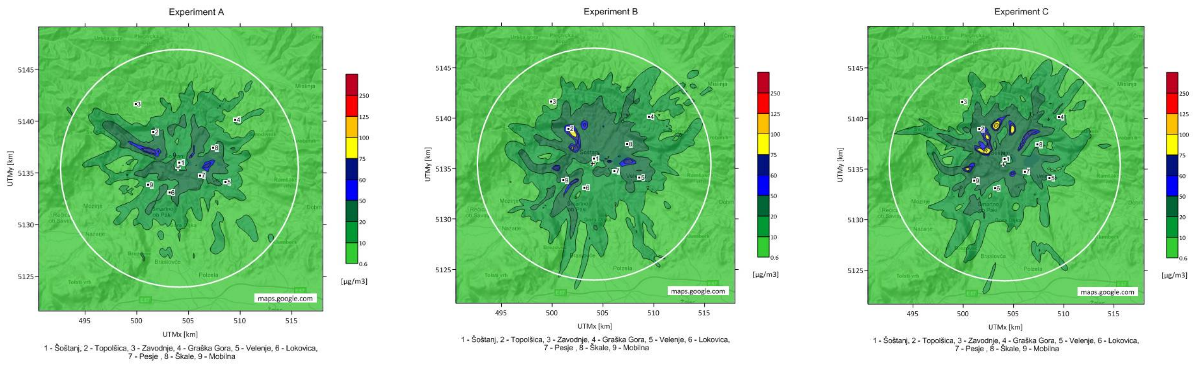

Figure 40. Maximum daily SO_2 concentration.

Maximum values from Fig. 38, 39 and 40 are shown in Table 10. Highest annual concentrations appear in experiment C but in all three experiments calculated annual SO_2 concentrations are smaller than the half of annual limit value. Experiment A provides highest hourly maximum and also the highest number of exceedings for hourly limit value. Hourly maximum and number of exceedings are higher in experiment C than in experiment B. Reason for that we could find in Figure 34 where experiments A and C have more stable situations than in experiment B. Usually mesoscale models have problems with calculations of temperature inversions. More inversions are measured than modelled and this is also the reason for highest concentrations in experiment A.

Table 10. Maximum values in space.

Value	Experiment A	Experiment B	Experiment C	Limit value
Annual SO_2 concentration [μgm^{-3}]	6.9	6.1	8.8	20.0
Maximum hourly SO_2 concentration [μgm^{-3}]	785.0	585.4	759.2	350.0
Number of exceedings of limit SO_2 hourly value	18	5	11	24
Maximum daily SO_2 concentration[μgm^{-3}]	73.5	90.0	119.5	125.0
Number of exceedings of limit SO_2 daily value	0	0	0	3

CONCLUSION

In this study comparison of different possibilities for wind field initialization with model CALMET were prepared. Results differ between experiments and it is hard to take decision which experiment gives better results. If radio-sounding would be near the TPP, probably a combination with wind data from surface stations in experiment A would be the best option. Calculations with principle from experiment B are good solution for areas without any observation data at surface and for prediction of air pollution dispersion. Also mesoscale model results have better time and spatial resolution than the upper-air soundings and this is advantage of experiment C against experiment A. In our case radio-sounding measurements are far away from TPP, so we could conclude that in our circumstances experiment C probably provides the best results.

In this study only six-hour meteorological analyses from mesoscale model ALADIN were included in calculations because only analyses were archived in year 2010. Results with hourly ALADIN prognostic fields may improve the final results, but in this case also 'spin-up' effect would be involved. Archive for ALADIN prognostic fields predictions started in June 2011, so in further studies this data could be included in calculations.

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