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ENVIRONMENTAL IMPACT ASSESSMENT OF A NEW THERMAL POWER PLANT ŠOŠTANJ BLOCK 6 IN HIGHLY COMPLEX TERRAIN

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Abstract: Slovenia is starting a nationally important investment – new block of the thermal power plant in Šoštanj which burns coal from a local mine in Velenje. The new Block 6 will replace several existing blocks that operate now using older technology. With its 600MW it will cover almost one third of Slovenia's needs and it will reduce the present Šoštanj CO_2 emissions by 35%.
The Šoštanj TPP is located in Velenje basin which is characterized with very complex terrain. Because of the TPP location near the high hills the air pollution examination as part of the environmental impact assessment is an interesting example of usage of the modern Lagrangian particle model Spray coupled with diagnostic mass consistent wind field model Minerve for the determination of combined cooling tower (with stack inside) appropriate height determination and for determination of the air pollution impact of the whole future configuration of the TPP.
In the paper we will show the historical evaluation of the modelling of air pollution from Šoštanj TPP. The first successful attempts were reported with the initial version of the same Lagrangian model by this group already at the second Harmonisation workshop (as this conference was called then) in Manno Switzerland. We will show firstly comparison of results from that time to the abilities of our present evaluations.
Then we will show how modelling is presently used for systematic scientific approach to answer the choice of having stack and cooling tower or having combined cooling tower with stack inside. The second question that was evaluated was the appropriate height of one or the other installation to ensure obeying the European standards for ambient air. Due to complexity of the situation this was not an easy question.
We will explain methodology for modelling of one year of meteorological data including SODAR profiles, measured at intervals of every half an hour for a local domain at 150m horizontal resolution. In addition a separate study was done on a larger domain to evaluate possibilities of trans-boundary pollution as the location is only 25 km from the Austrian border.
The study represents an example of good practice of such modelling over Slovenia's highly complex terrain.

Key words: *air pollution, environmental impact assessment, Slovenian complex terrain, Lagrangian particle model Spray, trans-boundary air pollution**,** validation, Šoštanj measuring campaign*

INTRODUCTION

Šoštanj TPP together with Krško Nuclear Power Plant are the two most important energy sources in Slovenia besides several smaller River Hydro Power Plants.

Slovenia is starting a nationally important investment – a new block at the thermal power plant (TPP) in Šoštanj which burns coals from the local mine in Velenje. The new Block 6 will replace several existing blocks that operate now using older technology. With its 600MW it will cover almost one third of Slovenia's needs and it will reduce the present Šoštanj CO2 emissions for 35%.

Most of the Slovenian territory where we have populated towns and cities and where our industry and power plants are installed is very complex orography. The Šoštanj TPP is located in the Velenje basin, characterized by very complex terrain, low winds and often thermal inversions, among the less preferable conditions for the dilution of emissions. Figure 1 shows the location of the TPP on the map of the area.

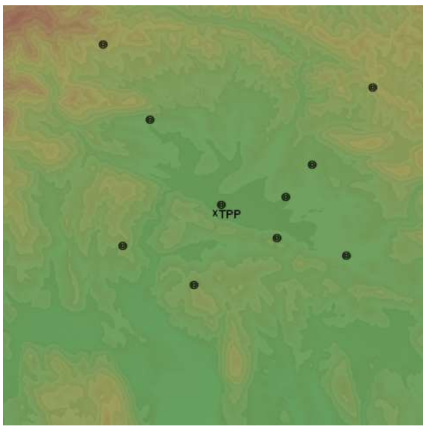

Figure 1: Topography of selected domain with locations of automatic environmental measuring stations and TPP in the centre

TPP Šoštanj has a modern Environmental Information System that collects meteorological and air pollution data from several automatic stations in the TPP vicinity and from emission stations which are installed on the TPP stacks. The first version of a modern automatic ambient and emission measurements system started to operate there in 1990. Therefore the area offered already in the past several measurements suitable for air pollution models validation.

In the paper almost two decades long evaluation, validation and usage of Lagrangian particle model Spray (Tinarelli *et al.*, 2000) coupled with diagnostic wind field model over this area will be presented.

1991 ŠOŠTANJ MEASURING CAMPAIGN AND VALIDATION OF MODELS

The authors of this paper together with other colleagues started studies of Lagrangian particle model Spray evaluation already in the early nineties. In early spring 1991 a measuring campaign was organised in the Šoštanj TPP surroundings in order to capture data suitable for air pollution model validation in complex terrain case (Elisei *et al.*, 1992). At that time TPP was the only significant source of SO_2 pollution in the area. Desulphurisation plants were not installed yet and concentrations of SO2 were on-line measured in the stacks and on six ambient stations that were measuring also ground level meteorological parameters covering an area of approximately 15 km x 15 km. In addition, one SODAR and one LIDAR were installed in the middle of the basin to capture vertical wind profiles and SO2 concentrations cross-cuts through the emitted plume for plume rise formulas validation. First results of models validation were reported already on the second Harmonisation workshop (as this conference was called then) (Božnar *et al.*, 1993). Several advanced Gaussian and Gaussian puff models were tested, but none of them successfully due to the complexity of the area. First successful attempts were reported with the initial version of the same Lagrangian model Spray as it is presently in a much more developed version used for complex cases evaluation in Slovenia. Spray was used with a 3D mass consistent diagnostic wind field model that took into account ground level wind data and SODAR profiles.

In 1994 a successful validation of a complex pollution of a convective spring day was reported (Božnar *et al.*, 1994). At that time simulations were done on an IBM workstation and were very slow in comparison to the simulations nowadays. It was only possible to simulate one half or one entire day of actual pollution due to relatively low computer resources. Nowadays it is feasible to simulate a whole year by half hour steps with a finer space resolution. In any case, it is important to note that already at that time this successful validations proved that numerical Lagrangian particle model coupled with 3D mass consistent diagnostic wind field model was a tool capable of reproduction of the most complex air pollution cases at a short-scale.

Figure 2 shows reproduction of most important slides from a previous work (Božnar *et al.*, 1994).

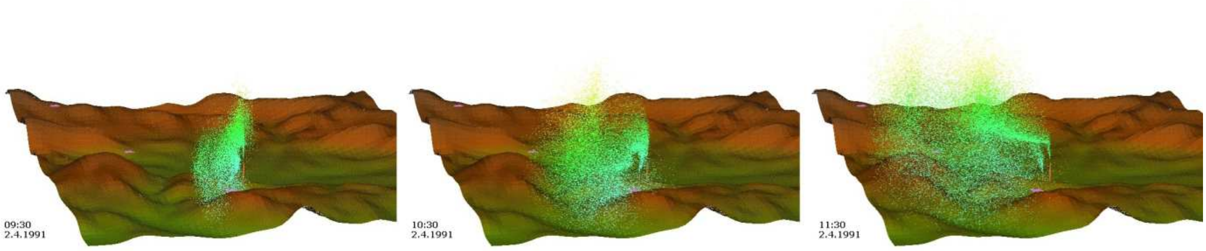

Figure 2. 3D reconstruction of air pollution dispersion done in 1993, reported in Barcelona 1994

Validations with the same data set were repeated in the last years with the present version of Spray model. These validations were very successful and prove that a combination of an advance numerical Lagrangian particle model Spray coupled with the Surfpro turbulence pre-processor (Silibello, 2006) and Minerve (Desiato *et al.*, 1998) 3D mass consistent wind field model based on diagnostic measurements that include vertical wind profile measurements are superior to other used techniques.

The presented technique shows agreement of modelled and measured values in time and space on the cell size of 150m over very complex terrain.

The agreement was shown even on the most complex cases such as air pollution due to accumulation of pollutants because of thermal inversion layer during the night time followed by morning convective mixing during a bright sunny day. In addition the case is characterised by low wind speeds.

The validation methodology and detail results are presented in (Grašič *et al.*, 2007) and (Grašič *et al.*, 2008). The emphasis was on checking concentrations within +/- one half interval time window and +/- one grid cell in all directions.

PLANS FOR NEW BLOCK OF TPP ŠOŠTANJ

A few years ago TPP Šoštanj started to plan a new block that will substitute several old blocks that are environmentally and economically not acceptable any more. New technologies allow for much cleaner emissions and also the efficiency of the new TPP technologies are higher which results also in 35% reduction of CO_2 exhaust for the same electrical power in comparison to the old blocks.

Already in the beginning of the planning process for the new block, TPP ordered a modelling study to calculate the emission impact on ambient air.

For a reliable study additional measurements of wind profiles with a SODAR were done in the middle of the basin for one year period. This data were complimentary to 10 ground level automatic stations meteorological measurements on the hills and in the basin, well covering a 15 km x 15 km area around the plant. In a situation characterized by such complex terrain features, diagnostic meteorological model fields that include measured wind profiles still can be superior to the results of prognostic meteorological modelling when a horizontal resolution below 200m is needed to capture terrain properly.

For a reliable statistical study of air pollution impact of an industrial plant in complex terrain, modelling of at least one year in short averaging intervals (half hour or at least one hour) is mandatory. Based on results of such a study all regulated values can be reliably calculated. This includes for every ground level cell of the domain the calculation of yearly average values of pollutants and more importantly also the number of incidences of hourly or daily limit values such as number of incidences of NOx hourly limit values, SO_2 hourly and daily limit values. The latter ones much better represent the degree of pollution in the area than the yearly average values.

POSSIBLE STACK GEOMETRIES

Modelling as described in the previous paragraph was used for a systematic scientific approach to answer the choice of having classic stand alone stack and separate cooling tower or having combined cooling tower with stack inside. The second question that was evaluated was the appropriate height of one or the other installation to ensure obeying the European standards for ambient air. Due to complexity of the situation this was not an easy question.

In addition it was required to model also existing Block 5 as it will be used as a cold-reserve and might in certain time operate in parallel to the new block in case of failure of other main Slovene power plants. We were therefore seeking the solution of appropriate new block geometry that will be environmentally acceptable together with the existing block for the whole year, because it is not possible to forecast if they will operate together in good or bad weather conditions (from the air pollution point of view).

Around ten different configurations of the proposed geometries were simulated in order to find the optimum geometry that proved to be environmentally acceptable and that was also economically suitable. Simulations were done over the area of 15 km x 15 km, with horizontal cell size of 150m and vertical terrain following layers. Surfpro meteo pre-processor was used together with 3D mass consistent wind field model Minerve. Air pollution was simulated with numerical Lagrangian particle model Spray. To model properly the plume rise from the cooling tower in addition the scheme based on (Anfossi *et al.*, 1979) and (Marzorati, 1992) studies was introduced.

The studies result show that the optimum configuration is a 157m high combined cooling tower that was then the final choice of the investors. The elaboration was done for the period July 2006 - June 2007 in half-hour intervals.

Figures 3 and 4 show some 3D simulation results (particles over the area) and side view of plume passing over the nearby lying hills in one of the most unfavourable meteorological situations.

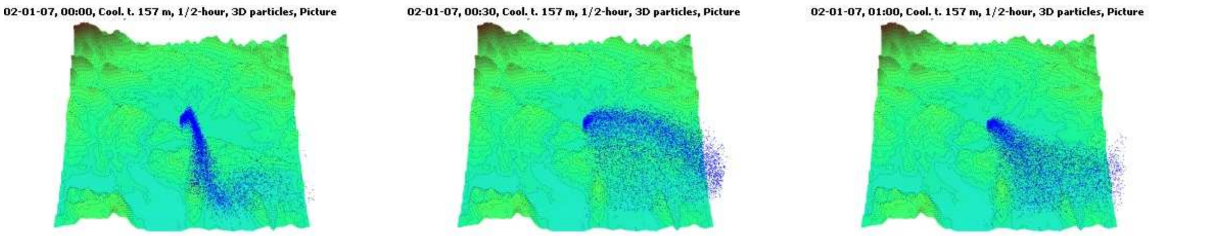

Figure 3: 3D simulation results present dispersion of air pollution for three successive time intervals over selected domain

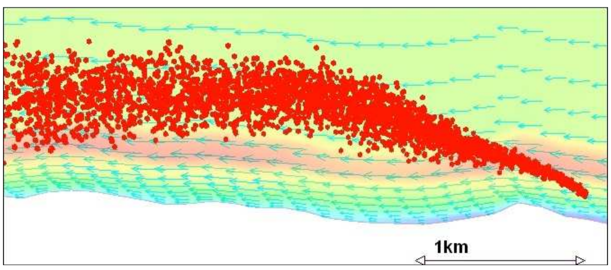

Figure 4. Air pollution dispersion in vertical projection oriented South-North nearby TPP presented by virtual particles in red colour, the arrows present wind direction and the foreground colour the wind speed, plume is spreading to south, terrain is presented in white

TRANS-BOUNDARY POLLUTION STUDY

Because of the Šoštanj TPP location that is rather close to the border with Austria the question of trans-boundary pollution possibilities was also correctly addressed.

Šoštanj TPP lies approximately 25 km from the border of Austria and Slovenia. To evaluate properly the influence of TPP to Austrian towns relatively close to border, a domain of size 80 km x 80 km was selected (Figure 5). As a dense meteorological network is only available in vicinity of the TPP and only some stations are available in the other parts of the selected area and due to the fact that the whole area is very complex (it includes Karavanke Alps over the border) another approach to acquire meteorological fields was chosen.

Reconstruction was made through the RAMS/ISAN prognostic code and Minerve diagnostic code combination using MINNI fields (Zanini *et al.*, 2004) for the period January 2005 - December 2005 in half-hour intervals. In addition local measurements were integrated into data at local scale in the diagnostic code. Only those meteorological stations in the region were taken into account whose location is representative for wider area. The MINNI 2005 meteorological fields cover the following domains (red rectangles):

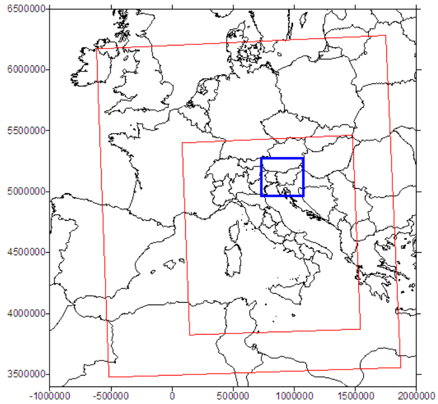

Figure 5. Selected domains for inputs for trans-boundary pollution study

The smaller MINNI 'national' domain has a horizontal resolution of 20x20 km. RAMS/ISAN was nested at 4km resolution (blue rectangle) and in addition integrating local ground level data and then a further nesting was performed using ISAN, the RAMS pre-processor, which successfully assimilated background fields (4km RAMS) and local data on the target domain.

Then the classical Minerve/Surfpro chain was used to build non-divergent fields over complex terrain suitable for Spray.

Finally, the Spray air pollution Lagrangian particle model was applied at the final 1 km horizontal cell size resolution over the 80km square area. Further on, yearly elaborations were done as explained before near by TPP domain.

The elaborations prove that the influence of the TPP on the Austrian territory near the border is much below the 3% of yearly limit values of the major pollutants and the new TPP block is acceptable also from this point of view.

CONCLUSIONS

Most of the Slovene territory where major industrial and power plants are installed is characterized by very complex terrain. The complexity is represented by terrain consisting of several small valleys, basins, hills and mountains. In addition most of the area is characterised by low winds and often winter thermal inversions. Therefore the most advanced models are needed to get reliable environmental impact assessment for existing and for new industrial and power plants with emission of pollutants into the atmosphere.

The crucial impact in such conditions is always in the close vicinity of the plant. Therefore the models are needed that give reliable results in fine resolution (below 200m) when evaluating point sources. Lagrangian particle model coupled with 3D diagnostic mass consistent wind field model proved to be a successful combination that gives results that show agreement with measurements in time and space which is very important for the local inhabitants.

Reliable environmental impact reconstruction in such conditions can only be achieved using appropriate meteorological measurements that include several ground level stations and at least one remote vertical wind profiler. At least one year of meteorological measurements should be elaborated.

As an example of good practice of environmental impact evaluation of the possible air pollution from new emission source the studies for new block of Thermal Power Plant Šoštanj were presented.

For these studies to be reliable, it is very important to use the set of models (meteorological and air pollution dispersion) successfully validated in similar conditions.

In this case of Šoštanj TPP a long time validation was made on exactly the same domain and therefore the results are very reliable. Unfortunately such validation on the same domain is rarely possible, but it is mandatory that the models are fit to the purpose and that validation is always made before regulatory usage of the model and that validation is made on similar conditions (in terms of domain size, grid, time step, terrain similarities and especially similar meteorological conditions) as it is also required by FAIRMODE (FAIRMODE, 2009).

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