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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Exploring atmospheric boundary layer characteristics in a severe SO_2 episode in the north-eastern Adriatic" *by* M. T. Prtenjak et al.

M. Telisman Prtenjak

telisman@irb.hr

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We would like to thank to Reviewer 1 for the constructive comments and suggestions. These are handled as follows:

Remark (1.1) The models are well described. My main problem was that I was expecting to see SO2 concentrations simulated and indeed the EMEP models shows some results but the fine scale models concentrate on the meteorological conditions. I was anticipating some estimates of the local SO2 concentration. I accept that the paper states that this will be discussed in a later paper, but then the EMEP SO2 results in this paper should be transferred to that paper.

Reply (1.1) As implied by the title and clearly stated in the Introduction, the goal of the study was not a fine scale modeling of SO2 concentrations, since it requires a fine scale emission inventory, which was unavailable. Instead, it was a detailed inspection of local meteorological conditions, which are found to be responsible for the extremely severe SO2 episode caused by local sources. The EMEP model (Section 3), is developed with an aim to quantify transboundary (i.e., regional-large scale; horizontal resolution of 50 x 50 km2) pollutant fluxes (Berge and Jakobsen, 1998; Simpson et al, 2003; Tarrasón et al., 2003; Fagerli et al., 2004). Thus, it can simulate pollution episodes caused by distant sources. The 50 x 50 km2 EMEP model validation is continuously performed (e.g. http://www.emep.int/index.html; extensive 49-pages manuscript of Jeričević et al. http://www.atmos-chem-phys-discuss.net/9/9597/2009/acpd-9-9597-2009.pdf). Simultaneously, no one can anticipate successful simulations of pollution episodes caused by local sources at resolution of 50 x 50 km2. Therefore, in this study, we employed the EMEP model as a tool for estimation of relative contribution of distant sources to the occurrence of recorded episode. In other words, good agreement between the EMEP 50 x 50 km2 modeled and measured concentrations would imply the major role of distant pollution sources, while the poor agreement suggest the importance of nearby sources. In the meantime, within the ongoing EMEP4HR project (Jeričević et al., 2007) preliminary emission inventory for Croatia at resolution 10 x 10 km2 become available. Thus, apart from EMEP modeled fields at 50 x 50 km2, in the revised version of this paper, we will include preliminary EMEP4HR model results at 10 x 10 km2 resolution, as well as the fine scale (1 x 1 km2) results obtained by widely used (e.g. de Foy et al., 2007) small scale Comprehensive Air quality Model with extensions (CAMx) (http://www.camx.com/) (please see figures shown in Appendixes 1 and 2); and we will discuss performances of all three models. As expected, the poorest agreement between the modeled and measured SO2 concentrations is obtained for the EMEP model at resolution of 50 km (Appendix 2), since the pollution episode was produced by local sources. The agreement is somewhat improved at 10 km resolution (EMEP4HR), while it is the best for 1 km resolution (modeled average SO2 concentration during the episode = 241 ug m-3; measured average SO2 concentration during the episode = 244.9 ug m-3). However, one should be aware that both 10 x 10 km2 emission field and EMEP4HR are still preliminary – currently both are under verification. Therefore, instead of companion paper, we extend current paper.

Remark (1.2) Having performed some impressive meteorological calculations the emphasis of the paper should be on which of the meteorological parameters are key to determining the pollution in the region, setting the scene for the later paper.

Reply (1.2) Although recent results obtained for Rijeka showed that weaker winds can occur during different parts of the year as well (Prtenjak et al., 2006; Prtenjak and Grisogono, 2007), this episode is characterized by the extremely low wind speed (please see Appendix 3; during 3 to 5 February 2002, in Rijeka, recorded wind speeds were mostly below 1 m s-1 with the maximum of 1.3 m s-1) accompanied with simultaneously high static stability and prominent subsidence. Thus, simultaneous occurrence of all these phenomena together with the airflow from industrial zone toward Rijeka town resulted in the unusually severe SO2 episode formation. This will be clearly stated in the revised manuscript.

Remark (1.3) Thus some discussion of why the meso-scale models were set up in the way chosen would have been helpful: WRF 3 domains 9, 3, 1km; MEMO 2 domains 3 1 km and indeed why two models? Most of the results shown are from WRF anyway. One might discuss why this is - nesting, domains and resolution or more fundamental reasons?

Reply (1.3) The MEMO model will be omitted in the revised paper. The used resolution of 9, 3, 1 km in WRF model is chosen according to the well known recommendation in the model's community that the horizontal resolutions of the grids are determined by the ratio1:3. The finest resolution of 1 km and the recommended ratio determine the horizontal resolution of two larger model grids, which are used to produce initial and boundary conditions for the finest grid. With the resolution of 1 km, the ratio of

the energy-containing turbulence scale and the scale of the spatial filter used on the equations of motion is small. It should mostly prevent the overlapping effect between the TKE parameterization and the resolved boundary layer (e.g. Wyngaard, 2004). The model setup will be additionally discussed in the revised Section 4.

Remark (1.4) Meteorological boundary conditions in WRF were set by ECMWF reanalysis, but why not the EMEP meteorology for consistency?

Reply (1.4) This was done due to practical reasons. Namely, the EMEP model was developed and it is still routinely run at the Norwegian meteorological institute (NMI). By default it uses routine numerical weather prediction model PARLAM-PS output as an input. The use of PARLAM-PS output as the input for the WRF would require preprocessing of PARLAM-PS data (i.e. new computer programs) in order to produce input fields readable by WRF. Similarly, WRF model is by default adjusted to ECMWF data as an input.

Remark (1.5) Finally are the main SO2 sources within the inner most grid with the 1km resolution.

Reply (1.5) Yes. See Fig 1c in the paper.

Remark (1.6) One major advantage of the meso-scale models is that they permit the tracking of pollutant concentrations at elevated levels above ground which can be of particular interest. Does much pollutant get above the predicted shallow mixed layer during this episode? Information about the depth of the layer is inferred in the discussion from the SO2 concentrations, so it is difficult to separate the meteorological and pollution aspects of the study. I conclude that is not easy to judge this paper without the companion paper on predicted pollution levels and I would encourage the authors to submit both paper together, since the meteorological one on its own leaves questions unanswered.

Reply (1.6) Instead of companion paper, in the revised manuscript, we will include the

Unified EMEP simulations at 10 km resolution coupled meteorological input at same resolution, as well as the Comprehensive Air quality Model with extensions (CAMx) results at 1 km driven with WRF meteorology (please see Appendixes 1 and 2). The models use preliminary emission inventory for Croatia at 10 km resolution. Local source emissions are much better resolved now than in the previous 50-km simulations. The vertical distribution of the SO2 concentrations will also be analyzed in the revised paper.

Remark (1.7) In addition I would like to see some discussion of the numerical setup with general recommendations as to the potential of these powerful complex models.

Reply (1.7) In this study, the combination of selected planetary boundary layer (PBL) and surface schemes and resolution enabled successful reconstruction of meteorological conditions in very complex terrain. It is very difficult to recommend certain model setup (such as nesting, parameterizations and resolution), since it depends on the purpose of the simulation and modeling domain characteristics (i.e. low topography versus Mediterranean complex region). Thus, there is a large number of different schemes (e.g. for PBL) in atmospheric models. Some numerical studies investigated the influence of PBL parameterizations (e.g., Chiao, 2006; Zangl et al., 2008). Extensive and detailed work of Zangl et al. (2008), based on the high-quality dense measurements in Alps, showed that different PBL parameterizations did not produce substantially different airflow and temperature fields. However, they pointed out that "...it is still not sufficiently understood which factors primarily determine the resulting flow structure in a complex numerical model, probably related to the fact that PBL schemes are usually validated in a 1D-column mode against observations over perfectly homogeneous terrain." More information on the WRF model possible setups could be found at http://www.wrf-model.org/index.php.

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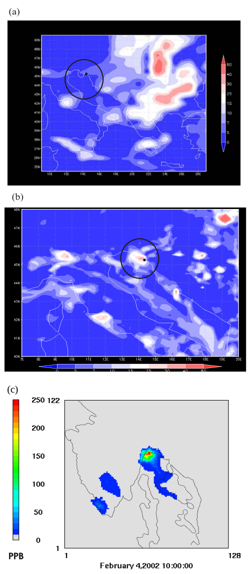
Please also note the Supplement to this comment.

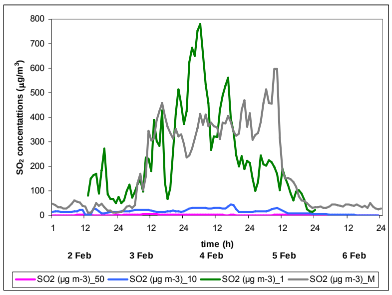
Interactive comment on Atmos. Chem. Phys. Discuss., 9, 6283, 2009.



Appendix 1: The horizontal distribution of hourly surface EMEP SO_2 concentrations on 4 February 2002 at 10:00 UTC (a) with 50-km EMEP model (µgS m^{-3}); (b) with 10-km EMEP4HR model (µgS m^{-3}); and, (c) with 1-km CAMx model over the greater Rijeka area domain (ppb). The black circles and black dots at two upper panels display the studied area (north-eastern Adriatic) and the position of Rijeka town, respectively. The emissions at 1x1 km^2 horizontal resolution (for CAMx) were obtained by interpolation from 10 x10 km^2.

1

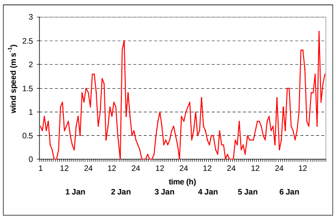
Fig. 1.



Appendix 2: The hourly SO_2 concentrations: EMEP at 50-km resolution (pink), EMEP4HR at 10-km resolution (blue), CAMx at 1-km resolution (green) as well as SO_2 concentrations measured at Rijeka (grey) (station 3B in Table and Fig. 1 in the paper) from 2 to 6 February 2002. (Source for SO_2 measurements: Teaching Institute for Public Health, Rijeka.)

1

Fig. 2.



Measured wind speed in Rijeka station from 1 February 2002, till 6 February 2002

Fig. 3.