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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Effects of various meteorological conditions and spatial emission resolutions on the ozone concentration ROG/NO_x limitation in the Milan area (I)" *by* N. Bärtsch-Ritter et al.

N. Bärtsch-Ritter et al.

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General reply (valid for both reviewers)

Taking both reviewers into account, we were obviously not able to communicate clearly enough the main objectives of this model sensitivity study. Thanks to the reviewers, we got aware of this and can clarify this. The introduction and other parts of the text are changed in order to define the goals more clearly:

It is not the main goal of this paper to do a sensitivity analysis in order to improve the model performance for that same episode. In Baertsch-Ritter et al. (2003, in the meantime published in Atmospheric Environment), data assimilation was used to get

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the meteorology as consistent as possible with the available measurements. The main goal here is to start from this well studied case and investigate how other meteorological conditions (that could for example occur on other days) influence both the ozone production and the limitation of ozone in this region. One of the main ideas was here also to see how robust the findings concerning VOC sensitivity of the ozone production downwind of Milan are. Obviously most changes (even some drastic ones that might be beyond regularly occurring situations) in meteorological conditions do not change the result that the ozone production is VOC sensitive downwind of Milan. In addition, it is very interesting to see how meteorological parameters influence both ozone and the limitation by using systematic variations of the individual meteorological parameters.

Some of the detailed model explanations are not as necessary anymore because of the published Baertsch-Ritter publication.

Reply on comments of Referee #1

- The meteorological variations used do not reflect uncertainties in the pre-processing of the meteorology for that same day. As the referee has pointed out, those uncertainties would be much smaller.
The range of the meteorological variations does rather reflect conditions that could occur on a different day under different conditions. The idea is to see how robust (toward different meteorological conditions) the results are concerning ozone concentrations and the limitation of the ozone production. An important question for example is if on a day with a different mixing height (and otherwise similar conditions) the limitation of ozone would change.

- The variations are in reality not independent as the referee points out. However, it is very interesting to understand which meteorological individual factors are influencing the chemistry to which extent. The mentioned dependence of temperature and humidity is obvious. In this case, we calculated the dependence separately, case B (temperature), case C (humidity) but also combined the variations in a realistic way in

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case D.
To some extent independent variations are possible. For example during North foehn, the humidity is much lower at similarly high temperatures compared to days without North foehn.

- We chose only one hour of one day to exemplify the influence of the meteorological factors. This case is not representative but a case with high ozone concentrations in this area which can occur under conditions that are favoring strong ozone production. The results can thus only be regarded as an example for such high ozone episodes. More long-term modeling would be required to get a representative answer for the whole season. But this is beyond the scope of this paper.

- The tables and figures might be overloaded. The information on peroxide and other parameters than ozone is probably only of real interest to people interested in the indicators that were proposed by Sillman. We will shorten the text and will focus on the discussion of ozone and the limitation of ozone and we will skip to a large extent the discussion on the parameters involved in those indicators.

- The main messages include the general dependence of ozone and of the ozone production limitation on meteorological factors and on the emission resolution in this area. One specific message is that the production of ozone downwind of Milan remains VOC-limited also under strongly altered meteorological conditions.

- The three areas were chosen as most interesting for a decision maker. A decision maker wants to reduce either the maximum ozone concentration in an area (Plume), he wants to reduce the average concentration in a region (Po basin) including rural and urban areas or he wants to reduce ozone where most of the people live (Milan). The influence on the rural areas can be seen in Figure 2.

- Figure 1 will be modified. Figure 2 should be fine in the ACP format.

- The sentence in the abstract including the slope is modified to make it clearer.

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- As visible in Fig. 3 and Fig. 4 the change in humidity strongly alters the areas of NOx and ROG limitation but compared to other variations, the changes in the ozone production are modest.

- p. 735 lines 18-26 and p. 736 lines 1-17 : the whole introduction was rewritten to make it more clear what the idea of this paper is. As the reference Baertsch-Ritter et al. is now published in Atmospheric Environment, the reader can now also get more detailed information on the model base case.

- p. 737: we change the wording everywhere to the passive form. The wind direction is one of the outputs. 'Hybrid' meant that the model is prognostic but also includes some data assimilation. The word 'hybrid' not used anymore in the text.
For this run, SAIMM used as the initial field a prediction of the aLMo (alpine local model) of the Meteo Swiss. For the data assimilation, ground measurements but also wind profiler and the balloon soundings data were used.

- p.738: there is hardly ever enough information on the winds so that a simple interpolation in space would be adequate to obtain a wind field. Because of this, one needs a model that takes into account the physics. However, measured data can be used to improve the forecast by nudging the model toward those informations. A very good and crucial information within this study were the height-resolved 1-hourly wind measurements. Usually, such data can only be obtained every 6 hours by the meteo-soundings. It remains hard to say if the data available was sufficient for a resolution of 3x3 km2. There is not really much additional data available where the model could be objectively evaluated concerning the meteorology. But as already stated, the information here was better than available in a lot of different studies.
Within the most eastern part of the domain, only 33 kilometers were used for the averaging. In this area, the emission gradients are not as large as near Milan center. The most important emissions within the Milano area were thus averaged into 54x54 kilometer grids.

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- p. 739 line 15-16: formulation was changed

- p. 740: In the very original emission inventory, a small fraction of the NOx emissions are given as N2O5 (lower than 1%). However we do not know of a study that would confirm such emissions. We finally decided to skip those emissions. A sensitivity run showed that these emissions had no measurable impact on the modelled ozone concentrations or the limitation of the ozone production. We forgot to remove the N2O5 emissions from the text which is done now.

- p. 741: The text is changed as suggested.

- p. 742: The 'Po basin' is the middle square in Figure 1.
The signs are correct in the formulas : an example : base case O3: 90 ppb, O3 (-35% ROG) : 60 ppb, O3 (-35% NOx): 80 ppb O3lim. = 60-80 ppb = -20 ppb.
This case is VOC sensitive and the obtained sign of O3lim. is negative. 'two areas and on peak ozone': this refers to the three areas Po basin, Milan and the ozone plume (Figure 1). The wording is changed.

- p.743: the text in sections A, B, C will be more focussed on the discussion on ozone and the limitation.

- p.744: the referee is right. Concerning the formation and decomposition of PAN. One needs to write it the way it is suggested or one could call it net PAN production.
The NOy concentrations were very high and the NOy concentrations and the PAN concentrations are well simulated. The measured concentrations of nitrate however were lower than the modelled nitric acid (see Baertsch-Ritter et al., 2003).
The change in the net PAN production is the most important factor within the chemical mechanism. By only changing the rate constants of reactions involving PAN corresponding to different changes, far more than 50% of the ozone production change was already found. This was actually already found by Sillman.

- p.750: the referee is right

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- we have added a more quantitative recommendation, saying that a resolution of better than 10 kilometers should be chosen to include the main regional photochemical influences of large urban plumes.

Reply on comments of anonymous referee #3:

- Concerning the general comments, see the general reply at the beginning.

- The abstract was modified in order to include more clearly the major findings

- 734, line 26, the expression is changed.

- 735, line 12: 'unsatisfactory' is changed to 'unrealistic'. One could write pages about how one defines unrealistic. However this is not the goal here. The goal here is only to show the sensitivity of the model output taking variations in meteorological parameters into account. The variations are not chosen to represent possible errors in the model but to rather represent other possible meteorological conditions that could occur on a different day.

- 735, line 14: the intercomparison between measurements and the model output is done in Baertsch-Ritter et al. (2003). This study is rather a pure model sensitivity study that starts from this evaluated base case.

- 735, line 16. Probably 'often' is a too strong word. One should make some statistics about how often only ozone is used for validation. We agree that there are many studies around that have done a proper job and sometimes there is just not more reliable data than ozone. Anyway, (at least) sometimes (that is the word we are using in the text now) only ozone is compared.

- The two best equipped stations Verzago and Bresso were used in Baertsch-Ritter et al. (2003) for the intercomparison. At a lot of other stations, only ozone is reliably measured.

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- As the paper Baertsch-Ritter et al. is now available from Atmospheric Environment, we can better refer to that study which describes the intercomparison and how the base case of this study was obtained including the data assimilation etc. As pointed out already, here we show a dependence of the model on various meteorological conditions (as they could occur on different days) in order to find out how strong the findings on ozone production and the limitation of the ozone production depends on these individual meteorological parameters.

- Figure 1 will be improved. - Line 25, page 739: In the very original meteorological run, the mixing height was too high compared to measurements. Maybe this was partially due to the resolution of 500 meters at the height of the boundary layer. To obtain the base run as mentioned in the model description, the vertical profile of the vertical turbulent exchange coefficients were changed in order to get a mixing altitude corresponding to the measurements and to produce a sharper distinction between the boundary layer and the layers above by a stronger drop of the exchange coefficient (Baertsch-Ritter et al., 2003). Due to the vertical resolution of the model, the mixing height could only changed by around 500 meters. It seemed to us that this procedure was the best way to study the influence of mixing height separately from other meteorological influences. Possibly there are other ways doing such an analysis.
Mixing heights of 500 meters are most unlikely in summer afternoon with high solar radiation, but mixing heights of 1500 meters or 2000 meters do occur on significant amounts of days.

- The temperature and humidity was varied systematically all over the domain. The water mixing ratio within the boundary layer is usually rather constant. The range of variation was partially chosen arbitrarily. The meteorological variations are mostly within possible meteorological conditions that could occur on other days that still would favour high production of ozone. Only temperatures of up to 10 degrees higher than on that day are unlikely. Anyway, the interesting results are how the production of ozone and how the sensitivity of the ozone production changes when some of the

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major meteorological factors are changed systematically (to some extent even beyond very likely conditions).

- The enhancements in the wind speed within the Po basin were very similar to the changes in the wind data that was used for the nudging. A detailed comparison of all the measured and modelled winds is beyond the scope of this paper. This would need an inclusion of lots of details concerning the representativity of the ground measurements, etc. The most important and representative measurements were the wind profiler measurements that are not strongly influenced by very local effects. In Baertsch-Ritter et al. (2003) it was mentioned that the wind in the base case agreed well with the profiler wind measurements.

Interactive comment on Atmos. Chem. Phys. Discuss., 3, 733, 2003.