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Review Kumar et al.

Anonymous Referee #2

Referee comment on "Evaluation of the coupled high-resolution atmospheric chemistry model system MECO(n) using in situ and MAX-DOAS NO_2 measurements" by Vinod Kumar et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-23-RC2, 2021

Kumar et al. present a confrontation of NO_2 simulations performed with a high-resolution atmospheric chemistry model, set up over southwest Germany, with surface mixing ratio observations and ground-based MAX-DOAS observations of NO_2 vertical column densities and differential slant column densities. The simulations are performed using two emission inventories with different spatial resolutions and emission totals. An additional simulation is performed where sector-specific temporal emission profiles are applied for the high-resolution inventory. The authors report the best model performance using the high-resolution inventory with temporal variation in emissions. Next, the authors derive differential slant column densities from the model simulations and compare these to MAX-DOAS observations under different viewing angles. This allows an evaluation of the spatial and vertical distribution of NO_2 in the vicinity of the MAX-DOAS instrument.

The evaluation of the atmospheric chemistry model is comprehensive and detailed. The evaluation of dSCDs to evaluate the spatial and vertical distribution of NO_2 in the lower atmosphere seems innovative and reproducible in other model evaluation studies (from my atmospheric chemistry modelling perspective). The overall quality of the presented figures and tables, as well as their discussion in the text, is of good quality. Therefore, the manuscript is suitable for publication in AMT after addressing the following questions.

- The difference between the TNO-MACC-III and UBA anthropogenic emission inventories (70%) is remarkable and deserves further discussion.
  - Can anything be concluded regarding the agreement per source sector?
  - How do EDGAR emission totals compare to both inventories (as an independent estimate)?
  - I believe TNO-MACC-III distinguishes between gridded sources (which have unit mass per grid cell per year) and point sources (which have unit mass per year). The latter should be added after interpolation to the destination model grid in order to conserve the mass balance. Not accounting for this leads to inaccurate representations of local emission peaks, and may affect domain emission totals. Please further discuss the strategy to interpolate emission data.
  - It would be good to embed this finding in the context of the literature: e.g. Travis et al. (2016) suggest sector-specific emission reductions of 30-60% over the Southeast

US, and Visser et al. (2019) report European satellite-derived emission totals of ±50% higher compared to TNO-MACC.

- Based on the model comparison with MAX-DOAS observations, can anything be concluded regarding the representativeness of surface emissions from different sources in relation to the model-observation agreement (e.g. T2 in direction of Mainz (anthropogenic footprint), vs. T4 in direction of agricultural areas).
- Appendix B: this is a highly relevant discussion, and most (if not all) models struggle to accurately capture the diurnal cycle in O_3. I believe this section can be strengthened by pointing this out, for example by referring to regional model intercomparison efforts with similar results (e.g. Solazzo et al. 2012; Im et al., 2015). Why are O_3 simulations only moderately sensitive to substantial NO_x emission differences? Can you detect an effect of model resolution on O_3 mixing ratios (e.g. by comparing domains CM07 and CM02)?

Specific comments

- Line 96: change '6 hourly' to '6-hourly'
- Figure 1: Please increase the font size of the annotated text in the zoomed panel for increased legibility
- Line 151-154: I suggest to give some more context to the soil NO_x emission totals and how they compare to other estimates. This is especially relevant in the context of the increasing importance of soil NO_x due to decreasing anthropogenic NO_x sources (see e.g. Skiba et al. 2020)
- Line 370-371: The reference to Figure C1 now refers to the cloud classification figure, and I cannot find the figure showing Pi-MAX VCDs elsewhere in the text. Please include this figure.
- Line 589: change 'deposited' to 'deposition'

References

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