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Interactive comment on "Parameterizing the vertical downward dispersion of ship exhaust gas in the near-field" *by* Ronny Badeke et al.

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We appreciate the reviewer's positive feedback on the paper. Thank you very much for the comments.

C1: I would like to see a bit more about the plume rise calculation and the parameterization of entrainment coefficient in MITRAS. Please give one formula for better understanding the physical processes involved in plume rise. This may be helpful for those readers who are not familiar with it.

Answer to C1:

We did not quantify plume rise itself, but the downward dispersion that differs depending on the input parameters that affect vertical movement like exhaust temperature,

exit velocity, wind speed and stability. The prognostic model MITRAS calculates concentration changes based on the Navier-Stokes Equations, continuity equation and conservation equations for scalar properties on an Eulerian grid. Therefore, entrainment is not parameterized in MITRAS, but is rather a result of turbulence caused by the ship and the exhaust temperature. For turbulent kinetic energy and vertical exchange coefficients, we applied the Prandtl-Kolmogorov closure (Chapter 3.4.5 in Schlünzen et al. 2018). Furthermore, advection and diffusion terms in the Reynolds equations are integrated in time by the means of the Adams-Bashfort-scheme (Chapter B.1.1 in Schlünzen et al., 2018).

Reference: Schlünzen, K. H., Boettcher, M., Fock, B. H., Gierisch, A., Grawe, D. and Salim, M.: Scientific Documentation of the Multiscale Model System M-SYS, MEMI Tech. Rep. 4, CEN, Univ. Hambg., 1–153, 2018.

This reference will also replace the Schluenzen et al. (2012) reference in the previous paper version as a more recent reference of the modelling system.

C2: As you mentioned, several authors pointed out that Gaussian pollutant distribution might not be well suited in the near field. When the distribution is asymmetric, the perfect reflection from the surface may not be the best choice. Did the authors consider using a more sophisticated algorithm for reflection?

Answer to C2:

The Eulerian microscale model MITRAS does not assume reflection on the ground, but calculates physical processes like advection and dispersion inside the Eulerian grid volume. It can therefore be considered a more sophisticated model to account for near-surface processes. We will cover the parameterization of the vertical plume profile and the possible uncertainties of a Gaussian profile for vertical plume concentration distribution in a future study.

C3: Two multiple regressions are performed (with and without ship). It would be interesting to vary the prototype shape and include it as independent variable (e.g., aspect ratio, length/width)

Answer to C3:

Yes, this is an interesting suggestion and may be included in a future study. There are numerous factors in the ship geometry that can affect the plume movement (additionally to your mentioned parameters also the location of the stack, the proportion of the vessel above sea surface and the stack height). Including all of these factors may give additional interesting insights, but is beyond the scope of the parameterization in this study and may be solved better by a machine-learning algorithm. As mentioned, we chose the prototype size based on the average cruise ship traffic in Hamburg to investigate the average effect of a cruise-ship sized vessel on pollutant concentrations close to ground. To get an impression, we added an exemplary comparison of MITRAS results for a cruise ship and container vessel in Supplementary S2. The size of the ship has a significant impact on the downward dispersion. For the smaller container vessel, we found a downward dispersion of only 33 % compared to 43 % for the cruise ship for cold plume conditions.

C4: The emission is assumed to occur in grid cell (2m x 2m x 2m), but the real stack is usually round and have a smaller diameter. This is an intrinsic problem of Eulerian modelling. Did the authors consider comparing their results with other dispersion models (e.g., Lagrangian particles models)?

Answer to C4:

Reviewer 1 has raised a similar question. We compared MITRAS results with the integral plume model IBJPluris (Janicke and Janicke 2001). See out response to question 1 by reviewer 1 for a comparison of MITRAS with IBJPluris. We will also include this comparison in the final version of the paper. Regarding the diameter of the stack, it is true that the stack diameter in our study lies in the upper range of real ship stack diameters. However, Bai et al. (2020) reported about plume modeling for container vessels

with measured funnel diameters in the range of 1.38 to 3.0 m. Furthermore, many ships operate multiple smaller stacks that might in sum lead to a similar exhaust behavior. In general, reducing the stack diameter at the same exhaust flow and temperature leads to a reduced plume rise and an increased downward dispersion.

Reference: Bai, S., Wen, Y., He, L., Liu, Y., Zhang, Y., Yu, Q. and Ma, W.: Single-Vessel Plume Dispersion Simulation: Method and a Case Study Using CALPUFF in the Yantian Port Area, Shenzhen (China), Int. J. Environ. Res. Public Health, 1–29, doi:10.3390/ijerph17217831, 2020.

Please also note the supplement to this comment:
https://acp.copernicus.org/preprints/acp-2020-753/acp-2020-753-AC2-supplement.pdf

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