Is a more physical representation of aerosol activation needed for simulations of fog? - Author's response

Responding authors: Craig Poku et al.

April 8, 2021

We would to thank the reviewers again for the positive response to our revised manuscript. We've worked through the additional suggested comments to improve the paper's overall clarity.

1 Reviewer comments and responses

Concerning the initialization of aerosol I still do not agree that a single accumulation mode with 100 cm^{-3} is representative of typical measurements for a clean rural site similar to Cardington. In Boutle et al. (2018), it is clearly said that aerosol distribution representative of the clean air typically found at Cardington is 1000 cm^{-3} concentration of Aitken-mode aerosols, 100 cm^{-3} accumulation-mode aerosols and 2 cm^{-3} coarse-mode aerosols. I understand that you have not the possibility for the moment to use a multi-mode aerosol spectrum which is perfectly admissible. But I am not at all convinced that considering 100 cm^{-3} accumulation-mode aerosols is equivalent as you rely on tests not shown. Therefore you have to say that: i) an aerosol distribution of 1000 cm^{-3} concentration of Aitken-mode aerosols, 100 cm^{-3} accumulation-mode aerosols and 2 cm^{-3} coarse-mode aerosols as proposed and used in Boutle et al. (2018) would be better representative of the clean air typically found at Cardington but cannot be used in this paper; ii) the assumption of a single accumulation mode with 100 cm^{-3} probably limits the overestimation of droplet concentration that would lead to a too rapid transition to a thick fog layer.

Thank you for this comment. Based on your feedback, we have rewritten this section discussing aerosol initialisation profiles to say the following:

"During IOP1, there were no direct aerosol or CCN measurements. Therefore, we initially planned to use a multi-mode lognormal aerosol distribution of 1000 cm^{-3} Aitken-mode aerosols (mean diameter 0.05 μm), 100 cm^{-3} accumulation-mode aerosols (mean diameter 0.15 μm) and 2 cm^{-3} coarse-mode aerosols (mean diameter 1 μm), each following a standard deviation of 2.0, as proposed and used in Boutle et al. (2018). Using these values would therefore being representative of the clean air typically found at Cardington. However, our simulations used a single accumulation aerosol mode to maintain consistency

with the tests in the Shipway Box Model, which showed that when considering aerosol activation, the activated N_a for IOP1 can be accounted for by accumulation mode aerosols (not shown). A consequence of assuming a single accumulation mode potentially limits droplet concentration overestimation, which would lead to the fog layer transitioning too quickly in optical thickness. However, based on our offline test results, we believe that using a multi-mode aerosol spectrum would have led to an unnecessary computational expense in this study. This reasoning may be different should these simulations have been run with a prognostic for supersaturation, but this is outside the scope of this work. To reduce computational expense and data storage, 1D diagnostics are output every 1min and 3D diagnostics are output every 5min."

This rephrased section can be found on line 262.

For the visibility calculation, why not to use a direct calculation according to the Koschmieder (1925) equation, linking the visibility to an extinction coefficient function of the DSD, through the Mie theory, instead of a diagnostic from Gultepe et al. (2006), which could be questionable?

Thank you for this comment. We believe that this is a good point and that it is something we are partly addressing in future with the use of the new VERA visibility diagnostic scheme. The VERA scheme is being developed at the Met Office and is an upgrade to the original visibility diagnostic formulated by Clark et al. (2008). The main benefit of using VERA is that it can account for additional aerosol processes as opposed to just changes in aerosol mass. However, as VERA is still being tested, using it in this study is beyond the scope of this work. In the revised manuscript, visibility is only one aspect of the validation with observations, and since none of the simulations perfectly reproduce the observations we don't feel that a more accurate visibility calculation would alter the conclusions.

Line 470: The reference Thouron et al. (2012) for stratocumulus needs to be cited for the prognostic supersaturation in the same way as Lebo et al. (2012) for deep convective clouds.

We have now referenced Thouron et al. (2012) as suggested.

References

Boutle, I., Price, J., Kokkola, H., Romakkaniemi, S., Kudzotsa, I., Kokkola, H., and Romakkaniemi, S. (2018). Aerosol-fog interaction and the transition to well-mixed radiation fog. *Atmos. Chem. Phys*, 18:7827–7840.

Clark, P. A., Harcourt, S. A., Macpherson, B., Mathison, C. T., Cusack, S., and Naylor, M. (2008). Prediction of visibility and aerosol within the operational Met Office Unified Model. I: Model formulation and variational assimilation. *Quarterly Journal of the Royal Meteorological Society*, 134(636):1801–1816.

Gultepe, I., Müller, M. D., Boybeyi, Z., Gultepe, I., Müller, M. D., and Boybeyi, Z. (2006). A New Visibility Parameterization for Warm-Fog Applications in Numerical Weather Prediction Models. *Journal of Applied Meteorology and Climatology*, 45(11):1469–1480.

Lebo, Z. J., Morrison, H., and Seinfeld, J. H. (2012). Are simulated aerosol-induced effects on deep convective clouds strongly dependent on saturation adjustment? *Atmospheric Chemistry and Physics*, 12(20):9941–9964.

Thouron, O., Brenguier, J. L., and Burnet, F. (2012). Supersaturation calculation in large eddy simulation models for prediction of the droplet number concentration. *Geoscientific Model Development*, 5(3):761–772.