Atmospheric Chemistry and Physics Discussions

Atmos. Chem. Phys. Discuss., referee comment RC2 https://doi.org/10.5194/acp-2022-152-RC2, 2022

Minor Review

Comment on acp-2022-152

Anonymous Referee #2

We thank the reviewer for their follow up comments. Please see responses marked in blue text below.

Referee comment on "Sensitivity analysis of an aerosol aware microphysics scheme in WRF during case studies of fog in Namibia" by Michael Weston et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-152-RC2, 2022

Many thanks to the authors for their clarifications and changes to the paper, I think this has improved it significantly. I have a few further comments based on the responses and changes, that it would be good to address.

1.

It was not clear to me until after reading the revised paper that the main mechanism of observed fog formation in this area was due to cloud-base lowering, and that the model does not reproduce this, choosing instead to form fog from the lowest level upwards, similar to radiation fog.

I think this point could be worth some further discussion - the arguments presented around the link between cooling and activation (i.e. following Boutle et al 2018, Poku et al 2021) may be representative of how the model is trying to form fog here, but aren't really representative of how reality is trying to form fog here. I

Indeed this may be the reason that a higher minimum updraft improves the model results - reality will have done the activation at a cloud base well above the surface, where updraft speeds will naturally be higher, and then brought these droplets down to surface level.

As the model does not do this, in-situ production of the fog will be much weaker (because of the lack of real updrafts near the surface), and increasing the minimum updraft speed improves matters because it is making the activation more similar to what actually happened at the elevated cloud base in reality.

If the authors agree it would be good to clarify this in the text, as it actually gives some justification for increasing the minimum updraft speed - even though it is wrong in the context of how the model is actually forming fog, it could be representative of how reality formed the fog.

We thank the reviewer for this insight. We have expanded the discussion to include the following:

482-484: “If our fog droplets are indeed from cloud base lowering, it is possible that our applied updraft speed of 0.1 ms-1 may be closer to the real conditions at the cloud base. While there are no upper air observations at the site to verify this, it could explain why when applied at the surface the cloud droplet number concentrations in line with the surface observations.”

2.

My only other comment relates to the response to the vertical resolution query.

Firstly, I think a more correct appraisal of the Boutle et al. 2022 results would be a lowest level of <10m (ideally <5m) and 6 or more levels below 150m is necessary for adequate radiation fog simulation.

Secondly, the inference that this is not necessary in this case because the dominant formation mechanism is cloud base lowering would be okay, if the model actually simulated cloud base lowering fog.

The fact that it does not, and indeed does form fog from the surface upwards, means that the near-surface resolution is important and needs to be investigated.

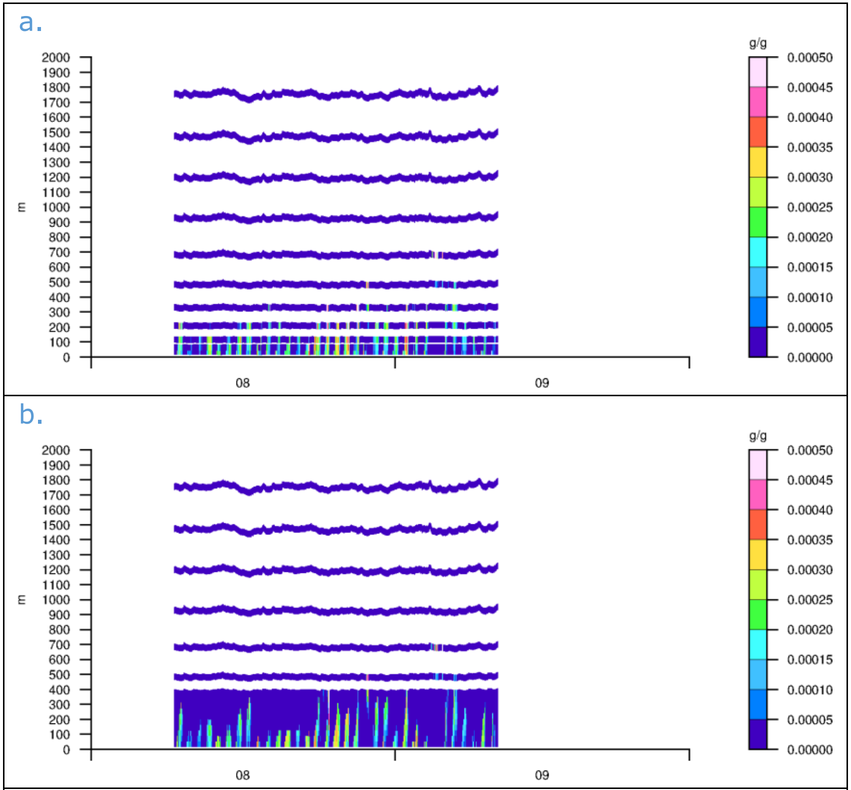
I guess the easiest option may be a simulation with vertical resolution similar to the WRF runs presented in Boutle et al 2022, as that would show what effect this is having on the results?

We thank the reviewer for their comments on the vertical resolution.

Firstly, thank you for correcting the recommendations from Boutle et al 2022. We have corrected this in the text.

Secondly, we agree that an increase in vertical resolution should have an improvement on where clouds form near the earth’s surface. A higher resolution near the surface should result in improved simulation of moisture and temperature gradients. Branch et al (2020) (doi: 10.5194/gmd-2020-201) highlighted this for WRF simulations over the United Arab Emirates using 100 vertical levels, with 25 levels below 2000m to better capture convective cases. In addition and as pointed out by the reviewer, Boutle et al (2022) highlight the value of having multiple model levels within a fog bank to better represent the physics at the top and bottom of the simulated fog (e.g. FV3-GFS was an outlier as only 2 model levels were present in the fog bank and the discussion on LWP oscillations in SCMs). We appreciate this point and its value. However, we feel that including an additional simulation within the presented sensitivity analysis is beyond the scope of the paper for the following reasons.

1. Initial simulations in preparation for this paper were rejected due to the lack of vertical resolution in the default WRF vertical levels. Apologies for not including this in the first round response. Additional vertical levels near the surface were included specifically to address the issue of resolving fog top. The decision at the time was that the additional levels and associated vertical resolution was suitable for these cases. From the figure below we can see that multiple model levels are present within the fog layer, in line with recommendations by Boutle et al 2022.



Profiles of liquid water content for a.) Default WRF simulation with default vertical resolution and b.) vertical resolution with 11 levels below 500m.

2. We would like to highlight that the simulations in Boutle et al 2022 are single column models (i.e. not real cases as presented in this paper) and large eddy simulations which are high resolution simulations. The authors have previously increased the number of vertical levels near the surface for real cases over the UAE while keeping the horizontal resolution at 3 or 4 km. The UAE is similar to Namibia in that there is low lying area near sea level and a mountain range above 1000m in the east. The increase in vertical resolution lead to numerical instability in the model over the complex terrain. To avoid this we would most likely need to increase the horizontal and vertical resolution, which becomes a separate sensitivity analysis and falls outside the scope of this study. The number of model levels below the inversion layer where moisture is expected to be trapped are indicated in Figure-9 appear to be a suitable number for these cases.

We have expanded the discussion in the methodology as follows and hope it suitably addresses the comments:

126-137: "A total of 50 vertical levels were used with extra vertical levels added near the surface to allow for 11 model levels below 500 m above ground level (a.g.l). This was decided after initial simulations demonstrated that the default vertical resolution was to coarse near the fog top. The mean height of the lowest 5 levels was 34, 71, 109, 146 and 184 m a.g.l. Boutle et al. (2022) evaluated results from large eddy simulation (LES) and single column models (SCM) for a radiation fog case in the United Kingdom and recommend having a first vertical level less than 10 m and six or more levels below 150 m. An increase in vertical resolution is expected to better simulate strong moisture and temperature gradients in the lower troposphere (e.g. (Branch et al., 2020)). However, Ajjaji et al. (2008) reported that an increase in vertical resolution can have the opposite effect and inhibit cloud formation for fog events over the United Arab Emirates, an arid region similar to Namibia, during a WRF real case (i.e. not SCM) simulation. Furthermore, our set up is in line with the vertical profiles reported in the literature which show that the moisture is trapped below 500 m (e.g. (Andersen et al., 2019; Formenti et al., 2019; Spirig et al., 2019)). ”