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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Impacts of increasing the aerosol complexity in the Met Office global NWP model" *by* J. P. Mulcahy et al.

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The authors would like to firstly thank the reviewer for taking the time to review this paper and for the constructive comments received. We have tried to address all comments below:

Specific comments "the results for indirect aerosol effects maybe somewhat tentative"

While the results maybe somewhat tentative in terms of the way the aerosol-cloud interactions are currently modelled, this work does highlight the importance of including a more realistic representation of aerosol-cloud interactions than currently used in most global NWP models. We have included text to further highlight these uncertainties (see

your further comments on this below).

Include a description of how the interactions are handled in the model - extend description of direct and indirect interactions currently in Section 2. Include how the optical properties are calculated. Details of aerosol removal processes. Details of microphysics scheme etc.

We have included a more detailed description of aerosol interactions in Section 2 (see response to comment on Pg 30459, line 1-4)

Abstract: If you make a point out of improving the simulations in tropical regions, maybe you should mention that the aerosol indirect effects are not included in the convective parameterization.

The abstract does not explicitly highlight improvements in the tropics. We highlight improvements in the northern hemisphere and outline the response found due to the indirect effects in the tropics. We have added text in the Conclusions section to further highlight uncertainties in our representation of the aerosol indirect effect in the model. However, we do not feel we need to also add this to the Abstract, as this is just giving a brief overview of key findings in paper.

Pg. 30457, line 11 – 14: That paper was not looking at aerosol interactions versus no aerosol interactions, but only at the impact of a very strong signal from biomass burning (versus no biomass burning). This was done with cloud resolving simulations that included complex chemistry. And the only improvement we could show was in the lower troposphere temperature, moisture and wind forecast. There was no comparison to CAPE with observations. So I would phrase it more like "in high resolution weather forecasting models MAY improve forecasts. . ..", and take the CAPE out.

Text revised: "They and other studies (e.g., Grell et al. 2011) show that coupling aerosols to radiation and microphysics schemes in high resolution weather forecasting models improves forecasts of temperature, wind and also convective available potential energy (CAPE) during a significant wild fire event in Alaska" –> *"They and other studies (e.g., Grell et al. 2011) show that coupling aerosols to radiation and microphysics schemes in high resolution weather forecasting models may improve forecasts of temperature, moisture and wind during a significant wild fire event in Alaska."*

Pg 30459, line 1-4: Is wet scavenging included in the parameterization?

Yes, aerosols are removed via dry and wet deposition processes. Dry deposition is parameterized in a manner analogous to electrical resistance (Seinfeld and Pandis, 2006). The mechanisms for wet removal of hydrophilic aerosols are via in-cloud scavenging by large-scale and convective precipitation and below-cloud (washout) large-scale and convective scavenging of hydrophobic dust aerosol. Re-evaporation of in-cloud aerosol to the accumulation mode is also included when all of the precipitated water does not reach the surface but is re-evaporated. We have modified the text in Section 2.1.1 (CLASSIC aerosol scheme) to include a more detailed description of these processes:

"Aerosols are removed by wet and dry deposition processes. Dry deposition is parameterized analogous to electrical resistance (Seinfeld and Pandis, 2006). The mechanisms for wet removal of hydrophilic aerosols is via in-cloud scavenging by large-scale and convective precipitation and below-cloud (washout) large-scale and convective scavenging of hydrophobic dust aerosol. Re-evaporation of in-cloud aerosol is also included in cases where all of the precipitated water does not reach the surface but is re-evaporated. CLASSIC aerosols have prescribed size distributions and refractive indices as detailed in Table A1 of Bellouin et al. 2011. Aerosol optical properties are calculated offline using Mie calculations and hygroscopic growth is parameterized as a function of relative humidity (Fitzgerald et al. (1975), Haywood et al. (2003)) for the hygroscopic aerosols. The results are stored in look-up tables for use during the model integration."

Pg. 30462, line 13: Aerosol ice interactions are not included. Would you expect this to make a large difference? Could it influence the results that you got for the summertime polar region?

See response to Pg. 30483, line 22-25 below.

Pg. 30477, line 15-19: Here is the only place you bring up the possible deficiency with the aerosol indirect effect. This should also be mentioned in the conclusions and should also have an impact on the abstract.

We have added to following to PP30487, L1: *"Representation of aerosol indirect effects remains one of the largest uncertainties in estimates of aerosol forcing on climate (IPCC, 2013). The lack of a coupling between aerosols and convective parameterization in the present study could potentially lead to inaccuracies in the findings particularly for the tropics."*

Pg. 30482, line 20: If some type of aerosols (even simple versions) are included, volcanic ash can also impact NWP and can easily be added. It would almost have to be added, since otherwise any assimilation of AOD may lead to really strange aerosol concentrations.

We have now referenced volcanic ash to highlight its importance as correctly pointed out by reviewer.

Line 20 now reads:*"The potential use of the global NWP configuration of the MetUM to predict significant aerosol events such as large dust storms, volcanic ash events and an increasing number of wild fire episodes would be extremely important due to the high impact these events have on daily lives and health of the general public."*

Pg. 30483, line 22-25: The results for the polar regions are really interesting and revealing. Do you think that inclusion of interaction between aerosols and ice will lead to any qualitative differences?

The authors believe the primary response we are finding in the polar region is the change from an incorrect land-sea split representation of CDNC to more realistic values for the polar region. As a result CDNC values change from values more representative of polluted industrial regions to pristine marine values with a subsequent reduction in low level cloud amounts and a SW warming. The interactions between aerosols and ice are very much outside the scope of this paper and we can therefore only speculate on the impact they would have on the current findings. In Arctic mixed phase cloud ice lies below the super-cooled liquid (Morrison et al. (2012). Aerosols acting as ice nuclei (IN) will impact the relative contributions of ice and liquid in these mixed phase cloud types. While this could impact the LW downward impact at the surface (by increasing LW downward component), the dominant impact is in the SW. Xie et al. (2013) show how inclusion of aerosol-ice interactions in the CAM5 models significantly reduces IN concentrations in the Arctic, reducing low level cloud by approximately 20% and increasing mid-level cloud. The smaller IN concentrations lead to an increased liquid water path and overall brighter clouds, leading to a TOA cooling of about 3 Wm-2. Therefore it is possible that including such interactions would offset the TOA warming found in this study and might impact the LW downward response found at Barrow. However, we believe that this response would be small compared to the magnitude of the response caused by the CNTRL simulation having a totally incorrect representation of CDNC (up to 30 Wm-2). Furthermore, inclusion of aerosol scavenging by ice-phase clouds will impact aerosol concentrations in the Arctic region. While scavenging in this region during the NH summer (covered by this study) will be dominated by warm liquid cloud scavenging, inclusion of ice-phase aerosol removal would be important for getting NH winter aerosol concentrations and CCN correct (Browse et al. 2012).

Fig. 13: It is hard to see (for me) what really is better where. Fig. 17: I cannot read the winds on these figures.

We will make every effort to increase the size and improve the readability of these figures in the final manuscript.

References:

Browse, J. et al. (2012), The scavenging processes controlling the seasonal cycle in Arctic sulphate and black carbon aerosol, ACP, 12, 675-6798
Morrison, H. et al. (2012), Resilience of persistent Arctic mixed-phase clouds, Nature Geosci., 5, 11-17, doi:10.1038/NGEO1332
Xie, S. et al. (2013) Sensitivity of CAM5-simulated Arctic clouds and radiation to ice nucleation parameterization, J. Clim., 26, 5981-5999, doi:10.1175/JCLI-D-12-00517.1
Fitzgerald, J. W. (1975), Approximation formulas for the equilibrium size of an aerosol particle as a function of its dry size and composition and the ambient relative humidity, J. Appl. Meteorol., 14, 1044-1049.
Haywood, J. M. et al. (2003), The mean physical and optical properties of regional haze dominated by biomass burning aerosol measured from the C-130 aircraft during SAFARI 2000, J. Geophys. Res., 108(D13), 8473,doi:10.1029/2002JD002226

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