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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

My only concern is the length of period over which this study has been conducted. Whereas I don't doubt that the results would likely stand over longer periods of time, the five weeks considered (17 June-24 July) in this study seem quite short, as only Northern Hemisphere summer is actually studied. However, given the high horizontal and vertical resolutions of the model used (40 km, 70

levels), I can accept the argument about the additional computational expense in the experiments using prognostic aerosols.

The length of the period was limited, as the reviewer mentions, by computational costs of running the model with prognostic aerosols. We are fully aware of the limitations of such a short period, but still ascertain that the results in this short study are interesting and worthy of publication. We are currently carrying out further work looking at the impacts of aerosols during different periods and for different events such as biomass burning events during the SAMBBA campaign and aerosol impacts on the Asian monsoon as part of on-going projects which will be published in the future.

More detailed comments and typos:
l.20: propagate - CORRECTED

l.113: 50 or 30 Wm-2 as quoted in l.1094? l.120: (Allan et al., 2011)

The maximum bias in clear-sky OLR in West Africa shown in Figure 2 of Haywood et al (2005) is 50-55 W m-2 (we have changed the text to reflect this more accurately). The Allan et al. (2011) paper highlights biases of up to 30 Wm-2 in clear-sky OLR based on a climatological mean of an ensemble of 8 climate models. The above line (L113) to which the review refers correctly reflects the bias as related to the MetUM model without any representation of dust. With regards to L.1094 this refers to the resulting negative bias found in this current study using the current dust climatology shown in Figure 6(b). The text has been modified to make this clearer to the reader.

l.214-216: the comments about tropospheric and stratospheric levels should be revised.

We have revised the text removing the references to tropospheric and stratospheric levels.

l.229: which is persisted - CORRECTED

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l.263: hydrophilic - CORRECTED
l.297: FFBC or BCFF (cf. l.384) - CORRECTED
l.357 June/July 2009 is quoted here, whereas June/July 2010is quoted in l.218 - CORRECTED (should be June - July 2009)
l.362: was necessary - CORRECTED
l.367: tropospheric - CORRECTED
l.384: see l.297 - CORRECTED
l.439: Angstrom (with some marks on A and o?) - CORRECTED
l.442: Sentence starting "AOD measurements from MODIS" is likely to be wrong. I would think the Giovanni server allows to get much more than that.

The text was meant to reflect the starting years of data availability from the satellite datasets (2000 and 2002 for Terrra and Aqua respectively) and not that the data was only available for those stated years - the text has been modified to make this clear to the reader as follows: "AOD measurements from MODIS are available from the year 1999 and 2002 from the Terra and Aqua platforms respectively." –> *"AOD measurements from MODIS have been available since 1999 for the Terra platform and since 2002 from the Aqua platform."*

l.462: Same comment as above also applies to MISR data. http://disc.sci.gsfc.nasa.gov/giovanni has daily servings of MODIS and MISR. As of 20131129, the following data appear to be available for download: MODIS Terra between 20000301 and 20131127 including DeepBlue MODIS Aqua between 20020704 and 20131126 including DeepBlue MISR between 20000225 and 20130831

See response to comment above - text modified to make more clear: "Measurements of AOD are available from the year 2000." –> *"Measurements of AOD have been available since the year 2000."*

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l.484: it's? its? - should be "its" - CORRECTED

l.504: Strictly speaking the areas covered by observations and model simulations are not the same, making a comparison of "global means" difficult.

We recognise that the model and satellite observations are not exactly sampled the same. This is why we describe this first part of the aerosol evaluation as "qualitative" in L.505. We have also removed the sentence referring to global mean biases on L.541

l.553: Caribbean - CORRECTED

l.611 and l.618: Sentences starting on these lines are long and could be cut into smaller chunks. – CORRECTED as follows:

L611: "In producing these mean values both model and observations have been cloud-screened by removing values where both the observations and model report cloud amounts greater than 50%, however it is likely that some residual cloud contamination remains along the edge of the 50% contour line in Figure 6." –> *"Both model and observations have been cloud-screened by removing values where both the observations and model report cloud amounts greater than 50%. However, it is likely that some residual cloud contamination remains along the edge of the 50% contour line in Figure 6."*

L618: "Evaluating the radiation biases early in the forecast minimises the role of other model errors such as general circulation and temperature errors and therefore the role of the different aerosol representations on these radiation biases can be more easily assessed." –> *"The impact of aerosols on the model radiation biases is evaluated early in the forecast in order to minimise the role of other model errors such as general circulation and temperature errors."*

l.657: Figures 7 are rather tough to read

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We will make every effort to make this figure more readable in the final manuscript.

l.771 and Figures 12: Top figure is somewhat difficult to read. What about the ARM curve, and the differences to the ARM curve below? Bottom figure does not reference the UM model in the same way as the figures above.

We will make every effort to make this figure larger and more easily readable, making the comparison between model and observations clear and correct labelling.

l.820: Each set of experiments has its own analysis. Would it be possible to get a comment on how these analyses differ (not much, I imagine)? The main improvements described in 6.1 therefore come from the forecasts, not from a potential change in analysis. I suspect that in Figure 13, there is a "story" hidden in the better results for T and RH obtained by AER_DIR and AER_CLIM wrt the other four around 700 hPa for the Northern hemisphere. Have you seen any change in convective precipitation, convective clouds? In discussion of Figure 14., I would point specifically to the areas where an improvement is to be seen or provide a figure showing DIR+INDIR-Analysis.

The verifying analyses used to calculate the mean errors shown in Figure 13 differ by very little between the model simulations (< 0.03K, 0.1m, and 0.2% for temperature, height and RH NH profiles respectively). The results found at 700hPa for T and RH are most likely caused by a cooling above the aerosol layer in the direct only simulations. The Cusack aerosol climatology (used in the CNTRL simulation) has a constant vertical profile in the boundary layer (defined by a set number of model levels up to approximately 700-750hPa (Cusack et al., 1998)) before reducing sharply in the free troposphere. The NH cooling seen in Figure 13 is concentrated over the NH continents and is consistent with a shift in the vertical profile of continental aerosol type of Cusack which is quite absorbing in the boundary layer. Above this Cusack has less aerosol than either the revised climatologies (AER_CLIM) or the prognostic aerosol (AER_DIR)

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which results in a cooling due the enhanced scattering. The improved aerosol representations in the form of the aerosol climatologies and prognostic aerosols leads to a more realistic aerosol vertical distribution and subsequent beneficial impacts on temperature and RH forecasts. Inclusion of the aerosol indirect effects leads to an overall warming and drying in the troposphere in the NH due to impacts on the cloud fields in this region. This is predominantly found over the NH land regions of northern Canada, Scandinavia and Siberia (where the change in CDNC is largest as shown in Figure 10) and we will refer to the exact areas where these impacts are found in the revised manuscript.

l.864: The increase in Sc by 20% in AER_DIR_INDIR and INIT_DIR_INDIR off-coast Chile and Namibia is not so obvious from Figure 15d and f?

We will improve the readability and clarity of this figure in the final manuscript.

l.921L over across? - CORRECTED

l.951: sentence improperly linked - Sentence removed
l.956: CNTRL - CORRECTED
l.959: negligible - CORRECTED
l.982: Could you put explicitly where previously it has been addressed. - CORRECTED (discussed in Section 6.2 (Clouds and precipitation))

l.1062: Here or in the conclusions, might be a place to stress that not all dusts have the same optical properties with for example various imaginary part of their refractive indices. In this respect, modelling aerosols for NWP will continue to be tough given the constraints of computer costs.

We have added the following text: *"Dust optical properties vary depending on the par-*

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ticle size, chemical composition and distance from source (Ryder et al. 2013b). Using a single set of dust optical properties to model the global radiative impacts is therefore a known limitation in global high resolution dust modelling but is currently necessary given the computational requirements of using regionally varying optical properties as well as the uncertainties in the characterization of dust physical and optical properties."

l.1070: This is what - CORRECTED

l.1094: 30 or 50 Wm-2 as quoted in l.113? –

Please see earlier response to comment on L. 113. We have amended the text as follows: "However, comparisons of model OLR against GERB observations suggest that the model reduces the OLR by too much in West Africa leading to a significant negative bias of up to 30 W m-2. This is most likely due to inaccuracies in the representation of mineral dust in the climatology." –> *"However, the comparison of model OLR against GERB observations in this study suggests that the dust climatology leads to a significant reduction in the OLR over West Africa resulting in a negative bias of up to 30 W m-2. This is most likely due to inaccuracies in the representation of mineral dust in the climatology."*

l.1122: Apart from this (?) - CORRECTED
l.1128: The potential of using = the potential use of the global NWP ... - CORRECTED
l.1212: from NWP to climate, an objective in the development ... (?) - CORRECTED
l.1216-1221: This paragraph sounds a bit too much as "Ten-year plan gobbledygook". Any possibly to say the same thing with more than one sentence?

We have amended the text as follows:

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"Near real-time verification of aerosol forecasts produced using short-range high resolution forecasting systems with the wealth of near real-time aerosol observations would feed directly back into the aerosol model development and subsequently would lead to improved predictions of aerosol forcing on climate." –> *"Furthermore, aerosol forecasts produced using short-range high resolution forecasting systems can be more easily evaluated against a wide range of near real-time aerosol observations. Findings from such routine evaluations would feedback into aerosol model development and lead to improved aerosol predictions on both NWP and climate timescales and subsequently improve our estimates of the direct and indirect aerosol forcing on climate."*

l.1227: was? - CORRECTED

l.1301: upper level tropical ... - CORRECTED

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 30453, 2013.