

Reply to Reviewer 2

We thank the Reviewer for their careful reading of the revised manuscript. We have clarified the text regarding specific comments 1 and 2, and we have corrected the technical errors as suggested. The Reviewer's comments and our responses are below.

[Specific Comments]

1. In response to my question of “Would you classify the gravitational settling as part of the wet deposition processes?”, the authors mentioned: “The approach for dry deposition of aerosol in GLOMAP-mode within UKCA (where UKCA is the chemistry and aerosol model in UKESM) is the same as that described in Section 2.2.2 of Mann et al.(2010) with a dry deposition velocity (V_d) for each aerosol mode given as the combination of a gravitational settling velocity (V_{grav}) and one-over the sum of the aerodynamic and surface resistances (R_a and R_s) i.e. $V_d = V_{grav} + (1 / R_a + R_s)$.” The authors appear to agree that they should classify the gravitational settling as part of the dry deposition process. However, in the revised manuscript (Line 113), the authors still classify the gravitational settling as part of the wet deposition process just as they did in the previous version of the manuscript. I would rephrase “including gravitational settling and rain out” to something like “including nucleation scavenging within the cloud (rainout) and impact scavenging below the cloud (washout)”, if it correctly describes the representation of wet deposition in UKESM1.

=> AR: We apologise for neglecting to update the manuscript in line with our response to the Reviewer's original comment. Following the reviewer's suggestions, we have now rectified this in Section 1, para. 7 as follows:

'Deposition of $SO_4(2-)$ is mainly via wet processes (approximately 90%, Chin et al., 2000), including nucleation scavenging within the cloud (rain out) and impact scavenging below the cloud (wash out), but dry deposition of $SO_4(2-)$ does occur through gravitational settling.'

2. Paragraph starting from Line 229: After reading Holtslag and de Bruin (1988), I still don't fully agree with the rationale as stated by the authors for lowering the reference height from 50 m to 10 m. Holtslag and de Bruin (1988) used wind speed at 10 m as one of their input parameters while computing the flux-profile relationships up to the height of 80 m. I agree that the Psi function of Holtslag and de Bruin (1988) should work better than that of Dyer (1974) under strongly stable conditions, but I don't necessarily see a point to lower the reference height to 10 m from the argument made by Holtslag and de Bruin. We should note that this change in the reference height also influences the aerodynamic resistance calculation under unstable conditions. As mentioned by the authors in their response to my question, it would be more appropriate to justify the change from the point that the height of the lowest model level is 20 m in UKESM1. It seems also useful to clarify whether UKESM1's dry deposition module takes the value of the Obukhov length (L) directly from the dynamical/physical model component or whether it derives L from other variables computed by the dynamical/physical model component.

=> AR: We thank the reviewer for highlighting several important points regarding the application of the Holtslag and de Bruin (1988) scheme. We clarify that our motivation for dropping the reference height from 50 m to 10 m were (i) it is a more standard approach and (ii) it fits better with the lowest

level of the model and the surface. We have updated the text in Section 2.2.1 (para. 2, L231-235) to better convey our reasons for changing the reference height (z) and to include the reviewer's point that changing z also affects the aerodynamic resistance calculation under unstable conditions.

'Here we update the calculation from that given by Dyer et al. (1974) to that described by Holtslag and de Bruin (1988). We also reduce the reference height for dry deposition (z) from 50 m to 10 m. The reference height is the height below which there is no turbulence in very stable conditions and is also important for calculating Ra. Following Ganzveld and Lelieveld (2005) the reference height should be half the average height of the lowest model layer, which in UKESM1 is 20 m. The changes to z/L and z act to reduce the rate at which the deposition velocity decreases in very stable conditions, although we note that there is also an impact on the calculation of aerodynamic resistance in unstable conditions.'

Regarding the Monin-Obukhov length (L), this is derived locally in the UK Chemistry and Aerosol (UKCA) code using local values of air density, temperature and friction velocity (where the friction velocity is computed in the UM turbulence scheme, so is consistent across subroutines). We have now included this information in Section 2.2.1, para. 2.

[Technical suggestions]

=> AR: We thank the Reviewer for their careful reading of the manuscript and for highlighting the typographical errors below. Except for Suggestion 13 (at Line 753), we have corrected the manuscript as suggested.

1. Lines 80 and 81: You might want to remove “2” from “2 200-300 km” and “2 10-15%”.

=> Corrected.

2. Table 1 caption: “UKEMS1” -> “UKESM1”

=> Corrected.

3. Line 359: Do you need a negative sign in “-1.31”?

=> Corrected.

4. Line 481: “20-45 W” -> “20–45 N”.

=> Corrected.

5. Line 520: Add unit for the dry deposition velocity values.

=> Corrected.

6. Line 523: a factor OF 2-4

=> Corrected.

7. Line 537: “dry deposition burden” -> “dry deposition flux”

=> Corrected.

8. Line 539: “0.54 Tg y⁻¹ and 0.41SO₂” -> “0.54 Tg to 0.41 Tg”

=> Corrected.

9. Line 623: larger THAN

=> Corrected.

10. Line 715: IT is unlikely

=> Corrected.

11. Line 716: Add a comma after “sources”.

=> Corrected.

12. Line 752: “exits” -> “exist”

=> Corrected.

13. Line 753: Drop “and” between “these” and “target”.

We have simplified the sentence from:

'However, it is apparent that other biases exits within the complex sulphur cycle and we highlight some key areas for further investigation to better understand these and target areas for development.'

to:

'However, it is apparent that other biases exist within the complex sulphur cycle and we highlight some key areas for further investigation and development.'

14. Table A1: If the two new formulae for R_{cut} as functions of RH are both taken from Erisman et al. (1994), they should be both marked with double asterisks.

=> Corrected.

15. Table C1: Correct the notation for bisulfite (HSO_3^-), sulfite (SO_3^{2-}) and sulfate (SO_4^{2-}).

=> Corrected.