Reply by the authors to the Referee #3's comments on
"Revising global ozone dry deposition estimates based on a new mechanistic parameterisation for air-sea exchange and the multi-year MACC composition reanalysis" (#acp-2017-768)

Anonymous Referee #3 (RC3)

We are grateful to the Referee for his/her comments. In the following, we provide our responses to these comments.

(1) **Comment:** *1 Overview*

The work described in this manuscript builds on the previous work of Luhar et al., 2017 in which the authors developed a more detailed, process based, two layer parametrization for dry deposition of ozone to oceans. In this study the two layer parametrization is refined and then implemented in the UKCA model. The model output is combined with MACC reanalysis data to calculate new estimates for global ozone deposition to water/oceans and total global ozone deposition. These new estimates are considerably less than current estimates of global ozone deposition. The model output combined with MACC reanalysis data is also used to analyse inter-annual trends in ozone dry deposition.

Response: Thank you for your comment.

Changes in manuscript: None.

(2) **Comment:** *2 General comments*

Overall this manuscript is well written and describes an improved parametrization for ozone dry deposition to water. The improved parametrization addresses uncertainty in deposition of ozone to water, which is the main driver of uncertainty in global ozone dry deposition. The manuscript is generally well laid out and the figures are clear. My main comments refer to Section 2. This section is quite important as it describes the new deposition parametrization, but it is a bit hard to follow.

(i) It would helpful if the authors could include a diagram of the different layers that form within the sea surface micro layer (e.g. reaction-diffusion sub-layer, bottom layer) that shows a summary of the processes (e.g. chemistry, chemistry/turbulence and reaction with iodide) that occur for in each layer and the main equations that are used to parameterize these processes.

(ii) I think it would also be helpful in Section 2 if the authors could more clearly describe how their improved scheme differs from that described in Luhar et al., 2017.

Response and changes in manuscript: (i) We agree with the referee. We intend to include two diagrams of the different ocean layers (see Figures 1 and 2 attached).

(ii) The old two-layer scheme assumes that chemical reactivity is present only in the reaction-diffusion sublayer (which is a few microns thick) even though chemical reactivity is observed to be present throughout the ocean mixing layer. The new two-layer scheme eliminates this arbitrary assumption. However, as mentioned in the paper in the 1st paragraph on Page 4 and elsewhere, the results obtained by the two schemes are similar. This is because in the old scheme assuming chemical reactivity only in the reaction-diffusion sublayer was necessary to compensate for the overestimation of the impact of turbulence that results from the use of a waterside turbulent diffusivity parameterisation that is not valid very close to the water surface.

We clarify the differences between the two schemes better in the revised paper, and the addition of Figure 2 (attached) helps in understanding these differences.

(3) Comment: *3 Specific comments*

3.1 Section 1

P4, L13-14: Consider rephrasing to "A more appropriate parametrisation for Kt which varies with zm in the viscous sublayer..." to improve the readability and meaning of the sentence.

Response: Done.

(4) Comment: *P4, L20-22: Could the authors provide a brief description of the "asymptotic behaviour" (also mentioned in the abstract). Or refer the reader to section 2.1.*

Response: Done.

(5) Comment: *3.2 Section 2*

P5, L20-22: Consider rephrasing to "The second layer, which is deeper than the reaction-diffusion sublayer,..." to improve the readability and meaning of the sentence.

Response: Done.

(6) Comment: *P6, L12-13: Consider rephrasing to "The first two, namely the flux at the water surface (z = 0) obtained using Eq. (4) should be equal to F0 and the concentration at the interface..." to improve the readability and meaning of the sentence.*

Response: Done.

(7) Comment: *Figure 1 caption: Consider rephrasing to "Figure 1: Variation of the oceanic component of ozone dry deposition velocity multiplied by ozone solubility as a function of sea surface temperature (SST, ℃), (a, c); and reactivity a (s-1), (b, d). Curves determined using the two-layer deposition scheme (Eq. (16)) for several c0 values used in δm = c0 l m, (a, b) and several δm values, (c, d). The variations obtained using the one-layer deposition scheme with (Eq. (18)) and without (Eq. (19)) waterside turbulent transfer (i.e. reaction-diffusion only) are also shown. The waterside friction velocity (u*w) used was 0.01 m s-1." to improve the readability.*

Response: Done

(8) Comment: *3.3 Section 5.2*

P21, L5-10: Can the authors suggest why there are larger ozone dry deposition velocities in the Northern Hemisphere?

Response and changes in manuscript: We state in the paper that "Oceanic deposition in the Northern Hemisphere (49.0 ± 3.4 Tg yr^{-1}) is somewhat larger than that in the Southern Hemisphere (44.9 ± 4.5 Tg yr^{-1}) due to the higher O_3 concentrations and slightly larger oceanic deposition velocities in the former, although the Earth's area covered by the ocean is larger by approximately 30% in the Southern Hemisphere."

The average oceanic deposition velocity (weighted by the grid-cell area) for the Northern Hemisphere is slightly larger than that for the Southern Hemisphere (i.e. 0.020 vs. 0.017 cm s^{-1} for the year 2005). The main reason for this difference is that the average sea surface temperature (SST) (weighted by the grid-cell area) for the Northern Hemisphere is larger than that for the Southern Hemisphere (i.e. 295.3 K vs. 291.2 K for the same year). As mentioned in the paper, in our formulation of deposition velocity to the ocean is dominated by the surface-resistance term (r_c) which in turn depends on SST. Overall the higher the SST the higher the oceanic deposition velocity.

We now include the above clarification in the paper.

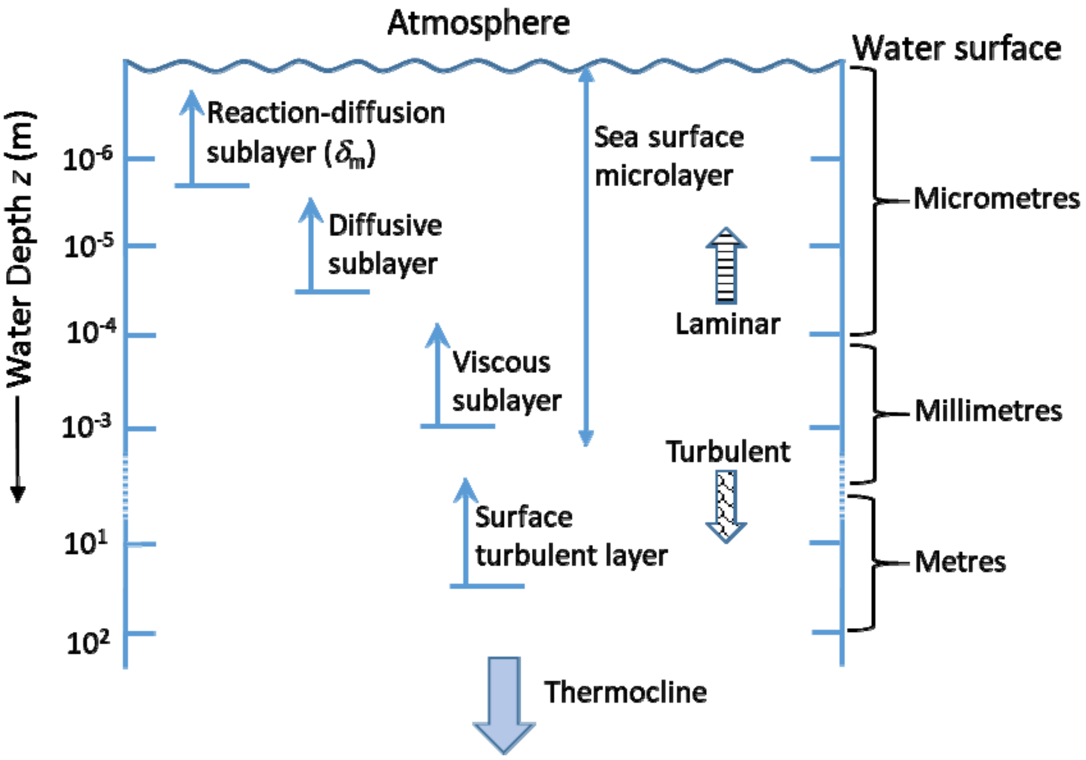

Figure 1: Idealised representation of the vertical structure of the top few metres of sea water. The depth of the reaction-diffusion sublayer will vary according to the chemical reactivity of the ocean water to ozone

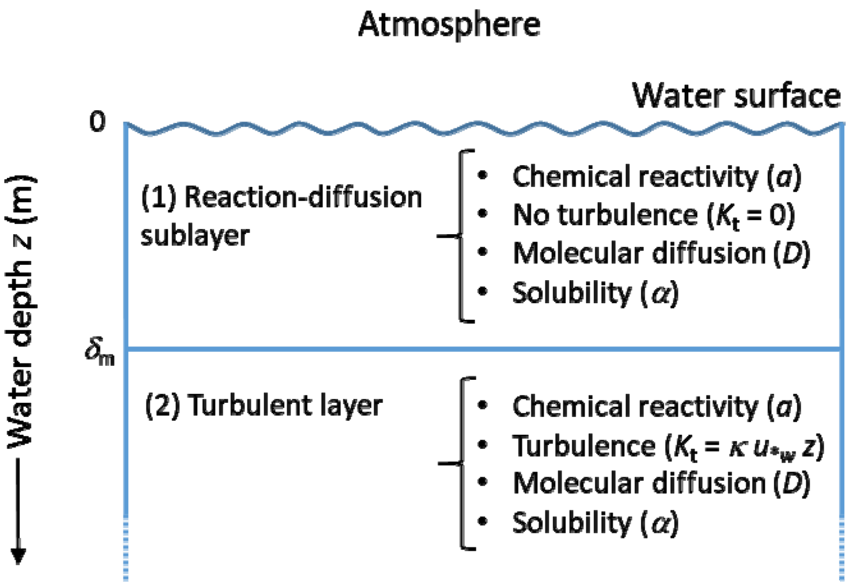

Figure 2: A simplified model version of Figure 1 used and the processes included in the calculation ozone dry deposition to sea water.