Reply by the authors to Referee #1's comments on
"Radiative impact of improved global parameterisations of oceanic dry deposition of ozone and lightning-generated NO_x" (#acp-2022-275)

Anonymous Referee #1 (RC1)

We are grateful to the Referee for taking the time to review our manuscript and making a number of valuable comments, which have significantly improved the quality of the manuscript. In the following, we provide our responses to these comments (the Referee's comments are shown in blue). The locations of the changes made refer to those in the non-tracked version of the revised manuscript.

This paper presents an analysis of the radiative impact associated with changes to two model parameterisations: oceanic ozone deposition and production of lightning-generated NOx. The changes to the two parameterisation schemes and the impact on ozone distributions are described in previous papers while in this work the authors focus on a number of model experiments designed to evaluate changes in radiative fluxes and attribute them to changes in ozone and methane.

The topic of the paper and the methods used are sound and make it suitable for publication. In particular, the authors' findings that uncertainty in LNO emissions can have a large impact on global climate modelling has wide implications in the field. However, there is not a lot of analysis on the factors driving the changes in radiative fluxes.

One main concern is on the modelled changes to the shortwave radiation fluxes at the surface. This is an interesting and unexpected result, and therefore grants further investigation as it is not clear what causes this reduction when LiNOx is increased (p15, l13-17 and Fig 2b, 3c and 4c). This is unlikely to be due to increased absorption by increased ozone concentrations (as suggested by the authors) because this is inconsistent with latitudes where changes in downward longwave radiation at the surface (fig 3b) due to increased ozone are largest. Also, most of the shortwave radiation in the wavelength spectrum that ozone can efficiently absorb is already removed by stratospheric ozone (with troposphering ozone only accounting for 1-3 mW/m2 in the shortwave (see Rap et al. 2015). Based on what is shown here (including fig 4c), it seems to me that whilst changes in the longwave are consistent with increased ozone production, as suggested by the authors, changes in the shortwave could instead be driven by some other factors, possibly including some changes in cloud or aerosols between the perturbed parameterisation experiments and the base run. I suggest the authors look at differences in the cloud and aerosols fields between various runs and the base run to further understand what drives differences in the shortwave fluxes at the surface.

Response: We thank the referee for making this point. To further investigate why the incoming shortwave (SW) radiation flux at the surface is reduced given that this behaviour cannot possibly be explained in terms of increased absorption by increased ozone concentrations in response to an increase in LNO_x, we have now analysed changes in the SW flux at the surface vis-à-vis changes in the modelled condensation nuclei (CN) (or aerosol number) concentration and cloud cover. We considered the parameter changes between the model run with both the improved oceanic O_3 dry deposition scheme and the improved lightning flash-rate parameterisation (Run C), and the base model run. This analysis is reported in a new section 3.4 entitled "Changes in incoming surface shortwave radiation, aerosol and cloud cover" with new plots (Figures 1, 6, 7 and 11). The overall conclusion, as suspected by the Referee, is that the aerosol and cloud cover are impacted by changes in LNO_x and that the modelled changes in high-level cloud cover can at least partly explain the differences in the shortwave fluxes at the surface.

One could also possibly examine other modelled parameters such as the cloud condensation nuclei (CCN) concentration or aerosol optical depth (AOD) but the model output for these quantities was not available. We think that the CN and cloud cover analysis reported in the revised paper should suffice to demonstrate that aerosol/cloud can, to some degree, explain the decrease in the SW radiation at the surface with an increase in LNO_x.

The paper by Rap et al. (2015) is now included and commented upon.

Changes in manuscript: As above. New section 3.4 "Changes in incoming surface shortwave radiation, aerosol and cloud cover" now included.

Other minor comments are below.

- replace non-tropics with extra-tropics and non-tropical with extra-tropical throughout the manuscript (including in Table 1 and various figure/table captions).

Changes in manuscript: Point taken.

- p2, l5: replace 'A radiative forcing broadly refers to' with 'Radiative forcing is'.

Changes in manuscript: Point taken.

- p2, l7: ')' is found but it is not preceded by a '('.

Changes in manuscript: Change made.

- p2, l15: add reference for estimated chemical lifetime of ozone.

Changes in manuscript: Reference of Young et al. (2013, https://doi.org/10.5194/acp-13-2063-2013) is now added.

- p3, l12-13: other authors in the literature have come up with different estimates for global LNOx emissions (see e.g. Martin et al. 2007 and more recently Nault et al. 2017); please add a sentence to recognise other work in this field, which further stresses the large uncertainty on the extent of LNOx emissions.

Changes in manuscript: Point taken. We add "Other estimates of global LNO_x emissions include 6 ± 2 Tg N yr^{-1} (Martin et al., 2007) and ~ 9 Tg N yr^{-1} (Nault et al., 2017)."

- p3, l14: please give more details about the methods used to estimate the direct energy dissipated from lightning.

Changes in manuscript: More details are now given in the Supplement S1.

- p6, l2: ‘chemistry transport’ should be ‘chemistry transport models’.

Changes in manuscript: Change made.

- p6, l10: ‘The upper troposphere is where O3 is most potent as a greenhouse gas’ should be rephrased including a description of ozone radiative kernel and adding a reference (see Rap et al. 2015).

Changes in manuscript: We have rephrased it as “A tropospheric ozone radiative kernel for all-sky conditions (i.e., clear, cloud overcast, and partially cloudy skies) derived by Rap et al. (2015) suggests that ozone changes in the tropical upper troposphere are up to 10 times more efficient in altering the Earth’s radiative flux than other regions.”

- p7, l1: replace ‘convective component’ with ‘convection parameterisation scheme’.

Changes in manuscript: Change made.

- p9, l25: replace ‘this increase’ to ‘this change’. This is necessary as one of the explanations for ‘this increase’ in the sentence refers to ‘CH4 loss’ but methane loss produces a decrease. Therefore it is better to describe this as a ‘change’. The next sentence rightly explains the signs of the change in more details.

Changes in manuscript: Change made.

- p10, l16: ‘The contrast in radiation changes over land the ocean…’ should be ‘…land and ocean…’

Changes in manuscript: Change made.

- p17, l19: replace ‘the this’ with ‘this’

Changes in manuscript: Change made.

- Fig 4 caption: there are two instances of b). One needs to be replaced with c)

Changes in manuscript: Change made.