We would like to thank Reviewer 1 for their helpful suggestions. Below, we show the reviewer comments (in bold) and our responses. Please note that we have grouped some of the suggestions together. Amendments/additions to the text are highlighted in blue. The revised manuscript is provided as an additional supplement.

Please also note that ‘LNOx emissions’ has been replaced by ‘LNOx’ throughout the text (see Point 5 in our response to Reviewer 2).

The paper investigates the impact of a future climate on changes in lightning NOx, ozone and OH by means of climate-chemistry model simulations. The paper is well written and certainly suited for publication after revisions.

1a. The lightning changes are not investigated at all. However they are a crucial part of the lightning NOx simulation. I suggest to include some more information why LNOx is increased. Is more convection occurring or is altitude of the convection increasing and hence the parameterisation is increasing the LNOx (5th power)? Note that a different lightning parameterisation is giving a decrease in lightning, because the number in convective events decreased and the increased intensity did not compensate (Grewe, 2009). This result is in agreement with Brinkop (2002) and DelGinio et al. (2007). This should be discussed since it affects significantly the conclusion on the compensation of a reduction of precursor emissions by increased lightning NOx-emissions.

1b. 8761 / Section 3.1 Changes in lightning is a key to this investigation. However, the causes for the changes are not investigated. Figure one suggests that the tropopause altitude increases in a future climate. Is this true for the convective heights? Or is the stratification of the troposphere getting more stable and hence the convective events are getting more intense (higher), but rare? I suggest to include some more analysis on the reasons for the lightning changes in a future climate.

1c. 8754 l9-10 Changes in convection were not investigated!

1d. 8756 l1-4 I think all the mentioned papers parameterise the flash frequency depending on the cloud top heights. It often has been argued that this is a statistical rather than a physical relationship. Other studies using convective mass flow or updraft estimates based on the convective mass flow predict a decrease in lighting NOx production (Grewe, 2009 and Dahlmann et al. 2011). There are studies suggesting that convective activity might decrease in the future in terms of number of events, but the individual events might be stronger. If that is true, what will happen with the lightning NOx? What is the more important parameter, - the decrease in total number of convective events or the increase in intensity of each individual event? It seems that Price and Rind, since the intensity is parameterised with the fifth order is more important and that an updraft parameterisation is less sensitive to the intensity and hence the number of events dominates. This would lead to a decrease in LNOx! See also e.g. Brinkop, 2002 and DelGenio et al., 2007.

Convective cloud-top height (CTH) was diagnosed every hour in our simulations. We have investigated changes in the *intensity* (depth) of convective events by analysing histograms of CTH, which are shown below in Fig. R1 for the Base and ΔCC8.5 runs as examples. Over each of the three convectively active regions, the distribution is shifted towards higher CTH in ΔCC8.5, relative to Base, with the mean increasing by 23.6% (Maritime Continent), 9.3% (Africa) and 4.6% (South America). This indicates an increase in the depth of convection with climate change, which is consistent with an increase in tropopause height. As the reviewer points out, since LNOx is proportional to the ~5^{th}/2^{nd} (continental/marine) order of CTH in the PR92 parameterisation, LNOx is sensitive to even small changes in the upper tail of the distribution. Hence, the increase in intensity of convective events is a driver of increasing LNOx with future climate change in our simulations. The largest increases in CTH occur over the Maritime Continent, leading to the largest increases in LNOx over this region (Fig. R1).

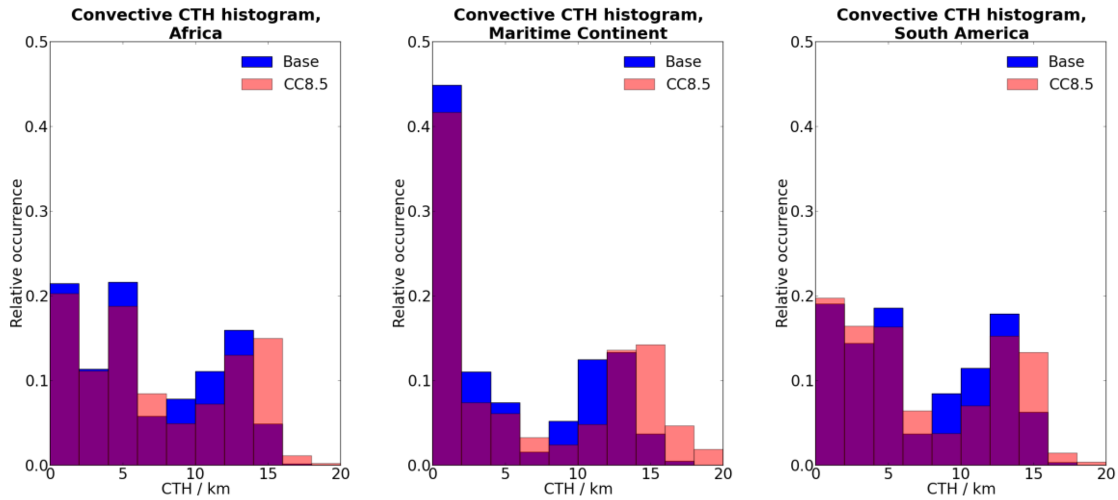

Fig. R1. Histograms of CTH over the convectively active regions of the tropics for the Base and ΔCC8.5 runs. The regions are defined as in Russo et al. (2011). Qualitatively similar changes are seen in histograms of CTH for ΔCC4.5 as for ΔCC8.5, relative to Base.

We have obtained a measure of the *frequency* of convection by counting the (area-weighted) number of convective events (defined as the number of non-missing values of CTH in the model output) and dividing by the total possible number of convective events over all timesteps and all grid cells within a selected region. By this crude measure, the frequency of convective events increases in ΔCC8.5, relative to Base, by 12.4% and 3.6% over the Maritime Continent and Africa respectively, but decreases by 5.2% over South America. The changes in frequency do not scale simply with the radiative forcing between ΔCC4.5 and ΔCC8.5, although changes in the intensity do. We have not investigated the mechanisms behind these changes, but this is beyond the scope of this study (see e.g. Chadwick et al., 2013).

Thus, in our simulations, increases in the intensity of convective events is the major driver of increases in LNOx with future climate change. The increase in the frequency of convective events also plays a role over the Maritime Continent, and, to a lesser extent, over Africa. Over South America, the frequency decreases in ΔCC8.5. Therefore, the effect of increased intensity on LNOx outweighs the decrease in convective frequency.

We agree that a parameterisation based on updraught speed / mass flux could result in different LNOx changes to one based solely on the PR92 method. Analysis of convective updraught mass fluxes (Fig. R2) shows increases in the climatological mass flux with climate change at most altitudes over Africa and the Maritime Continent, and particularly so for the latter. Hence, a parameterisation based on mass flux would also be expected to lead to increases in LNOx over this region with climate change. In contrast, such a parameterisation would likely result in decreases in LNOx over South America due to the general decrease in mass flux. This may, of course, depend on the particular details of the parameterisation.

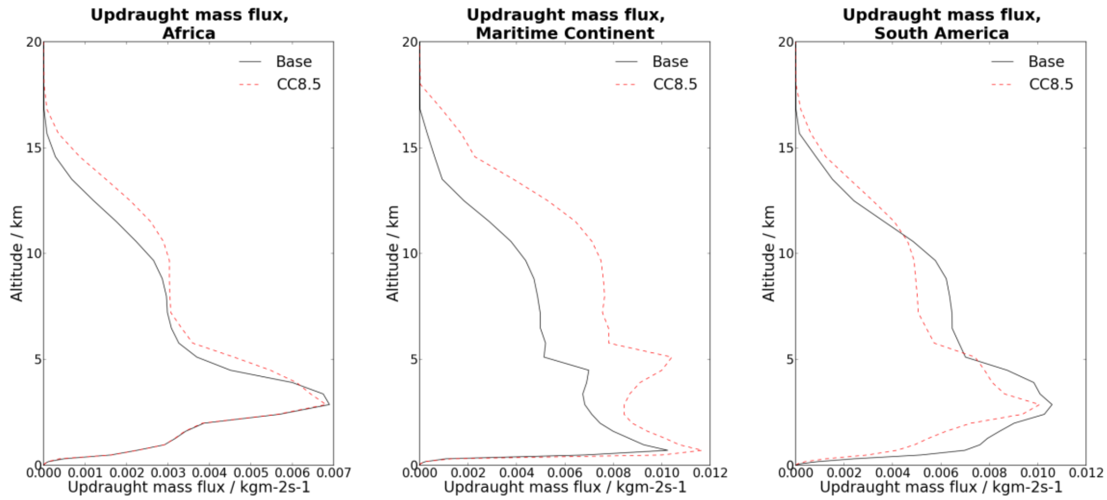

Fig. R2. Climatological updraught mass flux profiles over the convectively active regions of the tropics for the Base and ΔCC8.5 simulations.

We have made the following modifications to the text to further explain the changes in convection:
P8754 L8 'LNOx is simulated to increase in a year-2100 climate by 33 % (RCP4.5) and 78 % (RCP8.5), primarily as a result of increases in the depth of convection.'
P8761 L5 Taken out ', which reflects changes in convection'
P8762 Inserted paragraph at the end of Sect. 3.1 'Changes in LNOx can result from changes in both the intensity (depth) of individual convective events and the overall frequency of convection. Distributions of convective cloud-top height (CTH) (not shown) indicate a shift towards greater CTH under future climate change. For example, in ΔCC8.5, mean CTH increases by 23.6% (Maritime Continent), 9.3% (Africa) and 4.6% (South America) relative to Base, where the regions are defined as in Russo et al. (2011). These increases in the depth of convection are consistent with rising tropopause heights (Fig. 1). Using the number of CTH occurrences as a crude measure of the overall frequency of convective events, we find increases of 12.4% and 3.6% over the Maritime Continent and Africa, respectively, but a decrease of 5.2% over South America in ΔCC8.5. Since the PR92 parameterisation for LNOx is highly sensitive to the magnitude of CTH, it is the increases in the depth of convection, scaling with the climate forcing, which primarily lead to increases in LNOx in our simulations. The effect of the parameterisation is highlighted over South America in ΔCC8.5, where, although convection occurs less often on average, LNOx still increases due to an increase in the depth of convection. The largest increases in LNOx occur over the Maritime Continent because this region is associated with the largest increases in both the frequency and depth of convection.'
P8766 L4 'We simulate greater LNOx at the year 2100 under two scenarios for future climate change: RCP4.5 and RCP8.5, with LNOx increases of 2 Tg(N) yr^{-1} (33 %) and 4.7 Tg(N) yr^{-1} (78 %), respectively, primarily in response to increases in the depth of convection.'
P8766 Removed L11-12 'Nonetheless, our simulated increase in LNOx in a future climate is in qualitative agreement with most of the ACCMIP models.'

Inserted ‘Note that we have not explored other LNOx parameterisations and some studies using alternate approaches, such as those based on convective mass fluxes, have found different sensitivities for lightning changes under a warmer climate (e.g. Grewe et al., 2009). However, the PR92 method employed here is commonly adopted in state-of-the-art chemistry-climate models, such as most of the ACCMIP models (Lamarque et al., 2013).’

P8766 L17 Inserted at end of paragraph ‘The Maritime Continent is associated with the largest increases in both the overall frequency and depth of convection, which explains the largest increases in LNOx found over this region.’

2a. The paper suggests at several text passages and Figures a linear relationship between lightning NOx, the production of ozone, and the ozone burden. Actually the figures (Fig. 2) and the table 1 clearly shows the saturation of the chemical regime. Only changes in LNOx and changes in P(Ox) are linearly correlated.→ dLNOx ~ dP(Ox). The ozone production (LNOx 6~ P(Ox)) is not linear. And even the changes in the ozone burden react in a non-linear way. A 40% saturation is found. This part should be revised properly. (See also comments below).

2b. 8754 Might sound picky, but I think it is important. P(Ox) increases linearly with increases in LNOx. Not: with total LNOx. dP(O3)=a*dLNOx is ok but certainly not other versions like: P(O3) = a *LNOx or dP(O3)=a*LNOx.

Section 3.2 / Fig. 2 Two notes on the linearity of the system:

2c. It could be worth mentioning the non-linearity of the system. E.g. doubling the LNOx from 6 to 12 TgN is not doubling the P(Ox), since it increases from ~4700 Tg/y to ~5700 Tg/y, only. Only the changes are linear.

2d. 8766 "A positive and linear relationship between LNOx and P(Ox) is found" No that is not true, see above. Linear would imply doubling of LNOx doubles P(Ox) that’s not true. Only the perturbation is linear.

We believe a ‘linear’ relationship between P(Ox) and LNOx implies P(Ox) = a*LNOx + b where b is not necessarily 0. We do not believe it implies *direct* proportionality between the two variables (i.e. b=0). Here, of course, b is not 0 since LNOx is not the only factor contributing to P(Ox). However, to relieve ambiguity in the definition, we have made the following modifications to the manuscript:
P8754 L10 ‘The total tropospheric chemical odd oxygen production (P(Ox)) increases linearly with increases in total LNOx…’
P8762 L11 ‘…a highly linear fit between the changes in P(Ox) and LNOx is found.’
P8766 L18 ‘A positive and linear relationship is simulated between the changes in LNOx and global, tropospheric chemical O_x production…’
P8767 L2 ‘The linear relationship between the increases in LNOx and P(Ox)…’

We do not believe it is necessary to point out that Fig. 2a does not pass through the origin (i.e. doubling LNOx does not double P(Ox)), since this would trivially explain that there are factors other than LNOx which drive chemical ozone production. P8762 L8 points out that LNOx is only one driver of P(Ox) in the troposphere and the paragraph starting at P8762 L16 discusses some of the other important influences.

3a. (repeat of comment 2a) **The paper suggests at several text pasages and Figures a linear relationship between lightning NOx, the production of ozone, and the ozone burden. Actually the figures (Fig. 2) and the table 1 clearly shows the saturation of the chemical regime. Only changes in LNOx and changes in P(Ox) are linearly correlated.→ dLNOx ~ dP(Ox). The ozone production (LNOx 6~ P(Ox)) is not linear. And even the changes in the ozone burden react in a non-linear way. A 40% saturation is found. This part should be revised properly. (See also comments below).**

3b. The ozone burden change seems to react pretty non-linear on the LNOx increase. Fg. 2b: blue line base->CC4.5 gives an increase of 30 TgO3 per 2.04 TgN changes. This rate of change would (linearly) give 70 TgO3 for the run CC8.5, but only 43 TgO3 increase is found, which is already a deviation from lienarity by 40%. A remarkable saturation effect! And this is true for all sets of simulation. I propose not to fit the data in Fig. 2b but to draw lines betwen the individual data points and further discuss this non-linearity in the section.

Due to this apparent saturation effect, which is not evident for P(Ox), we have not asserted anywhere in the text that the ozone burden increases linearly with increases in LNOx (only that the burden does increase). LNOx changes are the dominant driver of changes in P(Ox) with climate change in our simulations; in contrast, several factors are important in driving changes in the burden. The deviation from linearity arises due to the increased dominance of humidity driven losses and non-linear increases in STE (with increases in LNOx). We agree that the linear fits in Fig. 2b could be misleading. We will now show lines connecting the data points. The figure and its caption will be amended accordingly:
Fig. 2 Caption 'Linear fits in (a) and connecting lines in (b) are drawn between runs which differ only in their climate states.'

We have also added the following text to describe the effect:
P8763 L3 'In contrast to P(Ox), the changes in ozone burden and LNOx are non-linearly related, since several factors, and not just LNOx, contribute significantly to changes in the burden in a warmer climate. From Fig. 2b, it is also evident that the decrease in burden of 34 ± 4 $Tg(O_3)\ yr^{-1}$ due to ΔO3pre…'

4a. The conclusions are to some extend exaggerated. I do not think that ozone from lightning is one of the key parameters for climate simulations. Ocean, sea-ice, carbon-cycle, feedbacks are key parameters. The tropospheric ozone is only a part in climate simulations.

Our focus is on chemistry-climate interactions. Of course, there are many major factors which affect the climate but the title of our paper, and we believe the text, make it clear that we are not discussing those other processes.

4b. 8754 l24 Projections of future climate might be too general. Ozone changes are only contributing by a small part to climate change and LNOx is then a part of that. Still it is important. The conclusion should focus more on future ozone projections. And it is not consistent with the argument given on page 8760 l 20 'Our goal ...'

The conclusions, including the concluding paragraph, primarily assert that changes in climate will impact on chemistry, and not vice versa. We focus on ramifications for future tropospheric oxidising capacity (ozone, OH, methane lifetime), which is consistent with P8760 L20-23. The subsequent

feedbacks onto climate are only postulated as *potentially* important and magnitudes are not given. E.g. radiative forcings associated with changes in tropospheric ozone are not discussed; the radiative feedback of changes in methane concentration is mentioned only qualitatively on P8765 L9-10 and P8767 L25-26. We have amended the abstract to make this clear:
P8754 L22 'We emphasise that it is important to improve our understanding of LNOx in order to gain confidence in model projections of composition change under future climate.'

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Del Genio A. D., M.-S. Yao, J. Jonas, Will moist convection be stronger in a warmer climate?, Geophys. Res. Lett., 34, L16703, doi:10.1029/2007GL030525, 2007.

Grewe, V., Impact of Lightning on Air Chemistry and Climate, In: Lightning: Principles, Instruments and Applications Review of Modern Lightning Research, Betz, Hans Dieter; Schumann, Ulrich; Laroche, Pierre (Eds.), 524-551, Springer Verlag, 2009.

References added to text:

Grewe, V., Impact of Lightning on Air Chemistry and Climate, in: Lightning: Principles, Instruments and Applications, Review of Modern Lightning Research, edited by: Betz, H. D., Schumann, U., Laroche, P., Springer Science+Business Media B. V., 524-551, doi:10.1007/978-1-4020-9079-0_25, 2009.

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