The authors would like to thank the reviewer for his comments that helped us to improve our manuscript. We have tried to address all comments appropriately.

Anonymous Referee #1

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GENERAL COMMENTS

This is a well written paper that uses novel techniques (the use of the Garny et al. method and the use of a fixed ODS CCM simulation) to diagnose the contribution of changes in chemistry to projected future changes in ozone in the tropical lower stratosphere. This work will certainly be of interest to the readership of ACP. My comments below are minor in nature and should not take long to implement.

SPECIFIC COMMENTS

The abstract is a little unsatisfying. I had hoped to see statements like: of the ozone decreases observed in the model simulations X% is due to changes in vertical transport, Y% is due to decreases in in-situ ozone production, and Z% is due to increases in in-situ ozone destruction. The abstract at least needs to include more of a sense of direction i.e. ozone goes down because ... goes up and because ... goes down rather than just presenting the possible mechanisms. Try to use the words 'increases' and 'decreases' rather than the word 'changes'. I think that this will improve the abstract in terms of specificity.

We have rewritten the abstract and included quantitative statements (see below).

Line 21: I don't think you can ever use a CCM simulation to assess the success (or not) of the Montreal Protocol since you prescribe Cly and Bry in the model. Of course if you prescribe decreasing Cly and Bry then you're already assuming that the Protocol is successful. So I think that you need to be careful how you word this.

We agree with the reviewer that this sentence is not appropriate. We have rewritten this sentence.

Line 24: I would advise against the use of the term 'super recovery'. What does it mean? You are ill and then you recover from the effects of the illness. What does it mean to 'super-recover'? I would advise that you read Box 3-2 of Chapter 3 of the 2010 WMO-UNEP ozone assessment. The term 'ozone recovery' has a very specific meaning. It means a response in ozone to changes in EESC. Under this definition there is no such thing as super-recovery.

'super-recovery' has been removed.

Line 37: What you say here is true but you don't say why the faster the air rises the less ozone is present in this region. I think that you should.

done

Line 64: But almost all of the stratospheric cooling is from CO2 right?

This is right. We have reformulated this sentence.

Line 75-79: You say here that changes in CH4 and N2O affect ozone but you don't say how. Will increases in CH4 and N2O drive increases or decreases in ozone? Do the increases and decreases vary regionally?

The following sentence has been added:
Revell et al. (2012) show that the increase in N2O surface concentrations between the 1960s and the 2090s will lead to a slightly enhanced ozone loss rate in the tropical upper stratosphere, but to a slowing of the rate elsewhere. The ozone loss rate due to an increase in hydrogen radicals is predicted to increase in the upper stratosphere during the 21st century (e.g., Portmann and Solomon, 2007; Revell et al., 2012).

Line 93: Just one conclusion? Not more?

We have changed the singular to plural.

Line 109: Two years seems quite short as a spin up time. Isn't 10 years more typical?

In our timeslice simulations we have scaled the initial concentrations of the long-lived chemical substances to the value of the respective year, derived from transient simulations with the same model and the same emission scenarios. This reduces the time that is needed to reach an equilibrium state. We found that in these timeslice simulations an equilibrium state is given after approximately 2 years.

Line 123: To study the impact of increasing GHGs on what?

.. on the ozone evolution. We added this.

Line 142: I think that you need to say something about the validity of this assumption that ozone is the main constituent of Ox in the stratosphere.

In fact the word 'assume' is not appropriate in this sentence since it is known that ozone is the main constituent of Ox (e.g., Johnston and Podolske, 1978). We have rewritten this sentence and added the reference.

Line 151-152: I don't understand the sentence "As the total loss and production rates, this separation could also be obtained during the model integration". I am guessing that there is some grammatical error that is the source of my confusion but right now I just don't understand what this sentence is trying to say.

We have clarified this sentence.

Line 174: It's not clear to me what the 'online received terms' refers to.

With 'online received terms' we mean the fields of ozone production and loss that are calculated during the model integration and are part of the model output. We have rewritten the sentence to clarify this.

Figure 1: I think that for both panel (a) and (b) the error bars are so small that they're not worth showing. I would therefore omit them and just state in the text that they're so small that they're not worth showing. It's anyway not clear to me that these error bars are in any way representative of the true uncertainty on those curves.

The bars show no uncertainty but the inter-annual variability in the timeslice simulations. But we agree that it's not necessary to show them. We have removed the bars.

Line 198: Can you please give an indication of how much the total production and loss terms differ between the online and the offline calculations e.g. in percent.

The largest differences in the tropics occur in the lower stratosphere (100-50hPa) with maximal 1% deviation in the annual mean ozone production and 5-8% in the annual mean ozone loss. We have included this information also in the manuscript.

Line 203: It is not clear what is meant by 'reduction of the chemical reactions to the relevant ones for stratospheric chemistry'. I am not sure what this 'reduction' refers to.

We mean that only those reactions are accounted for in the offline tool which lead to a net change in ozone and which are dominant in the stratosphere. In the chemistry module of the model, however, a considerably larger set of reactions is included, also for tropospheric chemistry. In the lowermost stratosphere the efficiency of other reactions, which are not part of StratO3Bud, becomes larger leading to a discrepancy between the online and the offline calculated loss and production values. We have rewritten the sentence .

Line 294: In what way is a change from 62% to 68% 'significant'?

We removed the word 'significant'.

Lines 305-307: This sentence is a non sequitur. Essentially it says "changes in the reaction rate coefficients due to.... contribute to changes in the reaction rates". It is the temperature changes, in the context of temperature dependent reaction rates, that contribute to changes in reaction rates.

This is right. We have rewritten this sentence.

GRAMMAR AND TYPOGRAPHICAL ERRORS

Line 2: Replace 'simulations with' with 'simulations made with'.

done

Line 5: Replace 'Different studies showed before that' with 'Previous studies have shown that'.

done

Line 10: Why is the word 'relative' needed here?

The method to separate the contributions is based on relative changes. But it is not essential in this sentence and we removed it.

Line 10: Replace 'The causes for' with 'The causes of'.

done

Line 12: Replace 'the production' with 'the production of ozone'.

done

Line 13: Replace 'are determined' with 'is determined'.

We have rewritten the whole abstract.

Line 21: The impact of increases GHGs on what? You don't say.

We have rewritten the whole abstract.

Line 22: Replace 'growing rate' with 'growth rate'.

done

Line 30: Replace 'increase of' with 'increase in'.

done

Line 30: I think that this would read better if you replace 'As in the' with 'Since in the'.

done

Line 35: Replace 'ratios for ozone' with 'ratios of ozone'.

done

Line 55: Replace 'In a future climate not only the tropical upwelling and the accumulation of ozone will change due' with 'In a future climate it is not only the tropical upwelling and the accumulation of ozone that will change due'.

done

Line 56: Replace 'Moreover, the' with 'The'.

done

Line 62: Replace 'carbondioxid' with 'carbon dioxide'.

done

Line 69: I don't know what you mean by 'denote' here? Should this be 'are the rate limiting steps'?

done

Line 103: Replace 'as SW' with 'as the SW'.

done

Line 202: Replace 'can not' with 'cannot'.

done

Line 202: Replace 'lower polar wintertime stratosphere' with 'wintertime polar lower stratosphere'.

done

Line 208: Replace 'causes for' with 'causes of'.

done

Line 213: Replace 'expressed by' with 'expressed as'.

done

Line 234: Replace 'calculated as residuum for' with 'calculated as the residual for'.

done

Line 237: Replace 'can not' with 'cannot'.

done

Line 238: Replace 'tool, which allows to identify' with 'tool which allows the identification of'.

done

Line 254: Replace 'causes for' with 'causes of'.

done

Line 299: Replace 'A decrease of' with 'A decrease in'.

done

Line 300: Replace 'amount of ozone molecules that is available' with 'number of ozone molecules that are available'.

done

Line 308: Replace 'it should be pointed to the comparison of' with 'it should be pointed out that'.

done

Line 328: Replace 'lower tropical stratosphere' with 'tropical lower stratosphere'.

done

Line 399: Replace 'enlarge the amount' with 'enhance the amount' and likewise on the next line.

done

Line 409: Replace 'lowermost tropical stratosphere' with 'tropical lowermost stratosphere'.

done

Line 429: Replace 'photolysis in 50 and 70 hPa' with 'photolysis at 50 and 70 hPa'.

done

Abstract.

The future evolution of tropical ozone in a changing climate is investigated by analyzing timeslice simulations made with the Chemistry-Climate Model EMAC. Between the present and the end of the 21st century a significant increase in ozone is found globally for the upper stratosphere and the extratropical lower stratosphere, while in the tropical lower stratosphere ozone decreases significantly by up to 30 %. Previous studies have shown that this decrease is connected to changes in tropical upwelling. Here the dominant role of transport for the future ozone decrease is confirmed, but it is found that both, changes in chemical ozone production and destruction do contribute to the ozone changes in the tropical lower stratosphere. Between 50 and 30 hPa the dynamically induced ozone decrease of up to 22 % is amplified by 11-19 % due to a reduced ozone production. This is counteracted by a decrease in the ozone loss causing an ozone increase by 15-28%. At 70 hPa the large ozone decrease due to transport (~-50 %) is reduced by an enhanced photochemical ozone production (+28 %) but slightly increased (-5 %) due to an enhanced ozone loss. It is found that the increase in the ozone production in the lowermost stratosphere is mainly due to a transport induced decrease in the overlying ozone column while at higher altitudes the ozone production decreases as a consequence of a chemically induced increase in the overlying ozone column. The ozone increase that is attributed to changes in ozone loss between 50 and 30 hPa is mainly caused by a slowing of the ClOx and NOx loss cycles. The enhanced ozone destruction below 70 hPa can be attributed to an increased efficiency of the HOx loss cycle. The role of ozone transport in determining the ozone trend in this region is found to depend on the changes in the net production as a reduced net production also reduces the amount of ozone that can be transported within an air parcel.