

We thank Reviewer #2 for great and constructive comments. To address both reviewers' comments and concerns, we have revised our manuscript accordingly. In particular, we have revised the model description section significantly to elaborate in details the chemistry scheme, convection and wet scavenging scheme, the convection sensitivity studies. Below is our one-to-one correspondence to the comments (original comments in italic).

*P655, lines 20-22: Despite the paper's main conclusion that the ratio of soluble and insoluble Br<sub>y</sub> is critical in determining PGI to the stratosphere, only simple chemistry is considered in the troposphere assuming all tropospheric Br<sub>y</sub> is highly soluble. Other studies indicate a significant portion of tropospheric Br<sub>y</sub> is present in insoluble form as BrO. Could the authors justify their use of such a simple scheme, and also be more specific about the regions in which simple and fully interactive chemistry are considered.*

The full stratospheric chemistry scheme, including interactive CHBr<sub>3</sub> and CH<sub>2</sub>Br<sub>2</sub>, are carried out above the 27th eta layer (approximately ~350 hPa), which includes the entire TTL and stratosphere. A previous detailed tropospheric chemistry model using the Harvard GEOS-Chem model and VSLS emissions from Liang et al (2010) shows a small fraction of Br<sub>y</sub> exists as BrO (0.1-0.2 ppt) below 10km in the tropics (Parrella et al., 2012), thus the impact of the absence of this tropospheric BrO is small compared to the current ~4 ppt PGI to the stratosphere in this study. Our current setup should be adequate to address the chemistry, transport and scavenging of VSLS and its degradation products across the TTL into the stratosphere. This is now clarified in the revised manuscript (section 2).

Parrella, J. P., D. J. Jacob, Q. Liang, Y. Zhang, L. J. Mickley, B. Miller, M. J. Evans, X. Yang, J. A. Pyle, N. Theys, and M. Van Roozendaal, Atmos. Chem. Phys., 12, 6723-6720, 2012.

*P656, lines 20-24: Could more detail be added as to how the convection/precipitation changes in the model between minimum and maximum conditions? They are described as 'extremes', but the resulting profiles do not look that dissimilar. Does 'minimum' convection result in shallower convection, or a reduced geographical area of convection or both? How does precipitation change? The result that more PGI VSLS- originated bromine reaches the stratosphere under 'minimum' convection conditions will be dependent on the representation of precipitation in the model and how this changes between scenarios – how well is precipitation represented in the model?*

*A comment on how well a relatively low-resolution model simulation (2.5 x 2 degrees) is able to represent precipitation would also be useful (i.e. could it lead to too much precipitation/scavenging in convective regions if the entire grid box is precipitating, and hence influence the calculated PGI to the stratosphere? Could this influence the calculated difference in PGI between minimum and maximum scenarios?).*

We have modified the model section in the revised manuscript so it has a more detailed description of the five parameters, what they control in the convective scheme, and a more accurate description of the minimum and maximum conditions (the strongest (MAXCNV) and the weakest (MINCNV) representations of convection considered reasonable) and the results changes. The details of how wet scavenging is treated are also included, e.g. how the fraction of a grid box that experience large-scale and convective precipitation are calculated. The values used for the five convective parameters for the minimum and maximum conditions have been tested extensively in a previous ensemble analysis that they produce reasonable precipitation patterns when compared with data from the Global Precipitation Climatology Project (GPCP) that were compiled from satellite and rain gauge observations (Ott et al., 2011). The correlation coefficients between the standard run, MAXCNV and MINCNV simulations and the GPCP data sets are 0.65, 0.64, 0.62, respectively (Ott et al., 2011). The wet scavenging of the soluble inorganic bromine are computed with the Giorgi and Chameides (1986) parameterization which uses the GEOS-5 model calculated large-scale and convective precipitation rate and the assumed fraction of grid square area,  $F$ , that actually experiences precipitation (Balkanski et al., 1993). For large-scale precipitation, the global mean  $F$  is about 2.5% for all grid boxes and the median value is 10%, with values exceeding 40% in 10% of the grid boxes (Balkanski et al., 1993; Liu et al., 2001). The global mean  $F$  for convective precipitation is much smaller, only 0.4% (Liu et al., 2001).

*P658, lines 2-5: Useful to remind the reader that the fully interactive chemistry scheme is not used in the troposphere.*

We have changed this to “fully interactive chemistry scheme in the TTL and the stratosphere”.

*P660, lines 6-7: Does the model include in-cloud rainout in the lower stratosphere?*

Yes. The model’s in-cloud rainout is carried out at all grid-points where there are clouds present, whether in the troposphere or in the stratosphere. We have added a detailed description of the wet scavenging scheme in the revised manuscript.

*P663, line 16: It would be interesting to also say how much of VSLS bromine is removed by wet scavenging in the troposphere as well as TTL. Presumably this is negligible given the proportion reaching the stratosphere? & Figure 5: This figure shows that a significant portion of total VSLS bromine is present in the form of  $Br_y$  in the troposphere. If all tropospheric  $Br_y$  is assumed to be highly soluble, how is such a large fraction reaching the stratosphere?*

To answer the reviewer’s question and to better explain this in the text, we have modified Figure 5 (now Figure 6) to show all inorganic bromine from  $CHBr_3$  and  $CH_2Br_2$  degradation, instead of the sum of  $Br_y$ . Although tropospheric  $Br_y$  are assumed highly soluble, only a fraction of the grid boxes and a fractional area of the precipitating grid boxes actually experience precipitation/scavenging. On average, of all inorganic bromine (~4 ppt) produced from  $CHBr_3$  and  $CH_2Br_2$  in the tropical troposphere, about 50% (~2 ppt) is removed below 500hPa, mainly by large-scale precipitation (Liang et al., 2010),

with an additional few 10ths ppt scavenged in the upper troposphere. Together, about 1.5 ppt of HBr and HOBr survive large-scale and convective scavenging and remain in the tropical upper troposphere. In addition, the current chemistry scheme does allow Br, BrO, and BrONO<sub>2</sub> production above ~350hPa, the majority of which survive scavenging and enters the lower stratosphere (see new Figure 6). We have added this in the revised manuscript.

*P664, line 1: Again, could be authors be specific about the region in which the full chemistry scheme is used.*

We have changed this to “fully interactive chemistry scheme in the TTL and the stratosphere”.

#### *Technical Corrections*

*P655, line 20: change to ‘below the tropopause’*

Corrected.

*P655, line 21: change ‘partition’ to ‘partitions’*

Corrected.

*P658, line 13: change to ‘and this work are likely due. ..’*

Corrected.

*P650, line 1: change ‘ascend’ to ‘ascent’*

Corrected.

*P659, line 19: change ‘Aschfold’ to ‘Ashfold’*

Corrected.

*P660, line 4: change ‘happen’ to ‘happens’*

Corrected.

*P661, line 22: change ‘enter’ to ‘enters’*

Corrected.

*P663, line 28: change ‘products in full’ to ‘products in a full’*

Corrected.