

Title: "Short-Lived Halogen Sources and Chemistry in the Community Earth System Model v2 (CESM2-SLH)"

Tracking #: 2024-01975

Authors: Fernandez et al.

Revision: 2nd round

Within this response letter, we use the following text format: Reviewer comments appear in regular black font, while our responses are in blue font. The original manuscript text is shown with double quotes and in *"italic-blue format"*, while the changes introduced in the revised draft are in ***"bold-italic blue"***. Please note that the line numbering used here (e.g., **L528-533**) points at the track-changed version of the revised draft.

Reviewer Comments:

Reviewer #1:

The manuscript has been improved substantially by reorganizing sections and by including a separate user guide in the Appendix. Especially sections 2 and 3 are now much easier to read. The authors have decided to put "2 Implementation of SLH Chemistry in CESM" before "3 CESM2-SLH Release" (reviewer #2 suggested the opposite order of sections 2 and 3), which I also consider to be valid.

The authors responded to all reviewers' comments and implemented the changes, as far as I can tell. However, there are still numerous grammatical errors throughout the text (e.g., singular subject with plural verb or vice-versa). I recommend careful language editing, which can be done as part of the proofreading. The following minor corrections should be implemented before publication as the current version might be misleading or is inaccurate.

GENERAL ANSWER: We thank the reviewer for the very positive feedback and for recognizing the major improvements in the reorganization of the original manuscript following both reviewer's suggestions during the 1st round of revisions. We further appreciate the additional suggestions and recommendations included in this 2nd round of review, all of which had been addressed as detailed below.

Minor corrections (line, figure and table numbers refer to the revised manuscript):

1 Text

R1-C1.0: L205: "*over sea-salt aerosol*" → "on sea-salt aerosol", same for L429, L436

ANSWER: Done.

R1-C1.1: L249: The sentence "*Based on these works, an increasing trend [...]*" still suggests that the trend is applied specifically for use in CESM2. The first sentence could be formulated as "For anthropogenic VSL sources of chlorocarbons, we use the Hossaini et al. (2019) and Claxton et al. (2020) emission inventories, which include time-dependent emission of two major contributors to the organic chlorine load (CH₂Cl₂ and

C₂Cl₄.) as well as surface LBCs for two other compounds (CHCl₃ and C₂H₄Cl₂).” and the sentence starting in L249 be removed.

ANSWER: Thanks for the suggestion and clarification. We have rephrased the text as follows:

L248-250: “For anthropogenic VSL sources of chlorocarbons, *we used the Hossaini et al. (2019) and Claxton et al. (2020) emission inventories, which include time-dependent emission of two major contributors to the organic chlorine load (CH₂Cl₂ and C₂Cl₄.) as well as surface LBCs for two other compounds (CHCl₃ and C₂H₄Cl₂) during the recent past.*”

R1-C1.2: L349: Use “self-contained” instead of “*independent*” here. Independent is potentially misleading as the description/implementation relies on previous work.

ANSWER: Thanks for the suggestion. Done.

R1-C1.3: L380: Cite “*several follow-up papers*” explicitly.

ANSWER: The referred follow-up papers were already cited altogether at the end of the sentence. To avoid confusion, we have rephrased to cite them inline as follows:

L379-382: “Therefore, and supported by experimental measurements (Saiz-Lopez et al., 2014) *followed by observationally-constrained modelling studies demonstrating that considering I_xO_y photolysis was required to reproduce gas-phase (Saiz-Lopez et al., 2015) and particulate iodine (Koenig et al., 2020) vertical profiles, the released CESM2-SLH chemical mechanism is based on the J_{IxOy} scheme for iodine proposed in Saiz-Lopez et al. (2014).*”

R1-C1.4: L445-L459: I think it is not clear in the current version which implementations are valid for WACCM (70 vertical levels), and which are valid for the low-top configurations (32 vertical levels). Are stratospheric heterogeneous reactions only implemented for WACCM, or is the difference the stratospheric sulphate aerosol these reactions happen on?

ANSWER: Thanks for the careful reading. The omission become evident when splitting Sections 2 and 3 during the 1st round of revision. To avoid any confusion, we have rephrased the sentence to explicitly mention those processes were implemented in all model configurations as follows:

L449-452: “Based on Cuevas et al. (2022), in CESM2-SLH we extended WACCM developments *to both low-top (32L) and high-top (70L) vertical configurations (see Section 3.1) by mapping equivalent heterogeneous reactions in the stratosphere for the minor halogenated reservoirs (mainly HOCl and HOBr), as well as the previously neglected iodine species (see Table 3).*”

R1-C1.5: L526: Add a reference for the “*old Specified Dynamics approach*” in CESM1. The difference between nudging approaches in CESM1 and CESM2 is still not completely clear, e.g. is it a new methodological implementation or is a different reanalysis product used?

ANSWER: Thanks for the careful reading. Both the old and new approach use the same MERRA2 dataset, although using a different namelist section in the configuration files. This is clearly described and compared

in Davis et al. (2022) as originally cited in the manuscript. To highlight the main differences between both approaches and provide an explicit reference to the old SD approach, we have modified the text as follows:

L525-530: “Similarly, we note that the default dynamical *core namelist options* in CAM6-Chem (Davis et al., 2022) are based on the new nudging approach **considering** MERRA2 (Modern-Era Retrospective analysis for Research and Applications v2) reanalysis (Rienecker et al., 2011). **This new nudging approach allows to select which physical variables (i.e., vertical and horizontal wind velocity, temperature, water vapour and/or pressure) are nudged, defining independent relaxation times for each, while previous CAM4-Chem configurations followed the old Specified Dynamics (SD) approach (Kunz et al., 2011) that forced identical relaxation times for all nudged magnitudes.**”

R1-C1.6: L617: Add long name of acronym AANE: Anthropogenically Amplified Natural Emissions

ANSWER: Done. To define the acronym, we have modified the referred sentence as follows:

L620-624: “Indeed, Saiz-Lopez et al. (2023) found that the SLH influence on global atmospheric composition and radiative balance is dominated by natural SLH emissions, **whose source strength has been amplified by human activity since pre-industrial periods due to the efficient coupling of halogenated species with background air pollutants, e.g. the so called Anthropogenically Amplified Natural Emissions (AANE) sensitivity detailed in Saiz-Lopez et al. (2023).**”

R1-C1.7: L789: “This is explained by the large non-linear response of the [...]” It’s still not completely clear to me what is meant by “non-linear release” here. The release of chlorine and bromine is linearly dependent on SAD_SSA. The reactions lead to a net source of chlorine and bromine, but why is it non-linear?

ANSWER: Thanks for the careful reading. To make the non-linear response explicitly clear, we have modified the text as follows:

L796-800: “This is explained by the non-linear response of Cl₂, Br₂ and BrCl sources **resulting from the online computation of non-stoichiometric heterogeneous reactions described in Table 1 that enhance chlorine (bromine) emissions due to the iterative accumulation of gas-phase HOCl, ClONO₂ and ClNO₂ (HOBr, BrONO₂ and BrNO₂).** As detailed in Section 2.1.3, **this efficient recycling mechanism depends on the parameterized fields of SAD_{SSA} (Fig. S2) and the partitioning shift between different inorganic halogen reservoirs (Fig. 10).**”

R1-C1.8: L829: CC- CC-SLH [2×2-hst] → CC-SLH [2×2-hst]

ANSWER: Thanks a lot for finding the typo, which has now been corrected:

R1-C1.9: L1374: *variability* → difference/change

ANSWER: Done.

R1-C1.10: L1376: The statement does not seem to be consistent with Figure S8, which shows that for surface Br_y: CC-SLH[1x1-ndg] > CC-SLH[2x2-ndg], CC-SLH[x1-hst] < CC-SLH[2x2-hst], BW-SLH[2x2-cpl] > FW-SLH[2x2-ndg]. Please state which simulations you compare against each other.

R1-C1.11: L1379: Please state which simulations you compare against each other.

R1-C1.12: L1382: Are you still referencing Figure S8 here? The difference of Cl_y at the tropopause between BW-SLH[2x2-cpl] and FW-SLH[2x2-ndg] according to Figure S8 is about 50%. Please clarify which simulations you are comparing, and correct the statement if necessary.

ANSWER: We thank the reviewer for the detailed reading and analysis. We agree that the referred sentences can be misunderstood unless explicit assignment to individual simulations are given. Based on all reviewers comments above, as well as comment **R2-C1.12**, we have rephrased the complete paragraph as follows:

L1375-1390: *“Figure 19 shows a comparison of the tropical (20° N–20° S) and global (90° N–90° S) mean vertical profiles of Cl_y , Br_y and I_y for the six SLH experiments shown in Table 7, where the model output of high-top compsets using WACCM 70L have been interpolated with a bi-linear method (i.e., using NCAR interp routine) to the default CAM6-Chem 32L vertical grid. All model experiments result in a very similar profile all the way from the surface to the upper stratosphere, although minor discrepancies in the vertical distribution remain. The corresponding tropospheric percentage **changes range** from –0.4% to +20 % for bromine and –24% to –0.2% for iodine (see Fig. S7), where as expected, the largest percentage differences appear at those heights where the X_y abundance is small. For the particular case of surface Br_y , **fine-resolution CC-SLH [1×1-hst] shows lower abundances than the coarse CC-SLH [2×2-hst] setup, while CC-SLH [1×1-ndg] and BW-SLH [2×2-cpl] experiments show larger values than CC-SLH [2×2-ndg] and FW-SLH [2×2-ndg], respectively. This is attributed to the smaller contribution from SSA-dehalogenation, particularly over the Southern Ocean. However, when integrated over the troposphere, note that the fine CC-SLH [1×1-hst] experiments present a larger Br_y burden than the coarse CC-SLH [2×2-hst] case, although smaller than those predicted for CC-SLH [1×1-ndg] and BW-SLH [2×2-cpl] (see Table S4). Chlorine, which of all halogen species shows the largest range in Cl_y abundance from the surface to the top of the model, results in tropospheric changes that remain below ~7.5% between the different compsets, with peak percentage differences predicted between BW-SLH [2×2-cpl] and FW-SLH [2×2-ndg] experiments close to the tropopause that are rapidly reduced below 10% as soon as LLH_{Cl} are photodecomposed in the lower stratosphere.”***

R1-C1.13: L1412: Explicitly name and reference other models here.

ANSWER: Thanks for the suggestion. We have modified the text as follows:

L1421-1425: *“The quantitative analysis presented in Sections 4.1 and 4.4 shows that the overall tropospheric and stratospheric halogen abundance obtained with the current CESM2-SLH release **is equivalent to (and in any case, smaller than)** that implemented in previous CESM1 and other global models **such as EMAC, TOMCAT and GEOS-Chem** (Hossaini et al., 2016; Saiz-Lopez et al., 2012, 2023; Sherwen et al., 2016; Sinnhuber and Meul, 2015).”*

R1-C1.14: L1418: “could be increased” -> “had to be increased”

ANSWER: Here we highlight that the emission strength might need to be increased by a factor larger than the 15% scaling performed in this work, although the reasons behind the model-observation bias for chlorinated VSL depends on other factors beyond the 15% scaling applied to the inventories. We have rephrased the text as follows:

L1429-1433: *“Therefore the offline emissions and LBCs for anthropogenic chlorinated halocarbons described in Section 2.1.2 **could have been** increased by a factor larger than **the 15% enhancement considered here** to reproduce the observed trend in the recent past (WMO, 2022). **However, we acknowledge that several other factors influence the regional enhancements and recent trends of chlorinated VSLS in the lower stratosphere (Hossaini et al., 2024).**”*

R1-C1.15: L1464: halogens = SLH? Please clarify.

ANSWER: Thanks. Done.

2 Tables

R1-C2.0: Table 1: Explicitly include units kg/kg for mass mixing ratios for clarity.

ANSWER: Thanks. Done.

R1-C2.1: Table 6: Mix-up between “free-running” and “nudged” for upper two compsets. FCnudged_slh has nudged meteorology and FCHIST_slh has free-running meteorology

ANSWER: Thanks for the careful reading and apologies for this important typo.

3 Figures

R1-C3.0: Figure 6: Caption: “Comparison of IO and BrO surface mixing ratio between CC-SLH [2×2-ndg] and observations [...]”; “Measurement campaigns are (a) Cape Verde [...]”

ANSWER: Thanks for the suggestion. We have rephrased the figure caption as follows:

L943-948: “Figure 6: Comparison of IO and BrO surface mixing ratios between nudged CC-SLH [2×2-ndg] and observations. The central panel shows the location of a coastal surface station where BrO was measured as well as the routes of three ship-based IO campaigns (coloured markers). Side panels show time series of observations (blue dashed line with reported root-mean square error (RMSE) bars) and model outputs (red line with ± 1 standard deviation), along with modelled vs. observed scatterplots with correlation coefficients (r). Measurement campaigns are (a) Cape Verde; (b) TransBrom; (c) Poseidon and (d) Malaspina. All data corresponds to daytime conditions.”

R1-C3.1: Figure 7: Caption and plot not completely consistent: “LLH” in plot, and “LL” in caption.

ANSWER: Thanks for the careful reading. Corrected here and elsewhere.

R1-C3.2: Figure 17: The order of panelling is mixed up, e.g. should the upper right panel be (c)?

ANSWER: Thanks for the careful reading. We have corrected the panel labels.

Reviewer #2:

1 General comments

Overall quality of the preprint

This manuscript comprehensively presents the implementation short-lived halogen (SLH) sources and very short-lived (VSL) halocarbons into CESM version 2.2.0. It furthermore highlights adaptation measures for widely used emission parameterization to new generations of coupled chemistry climate models.

Comparisons are provided to both previously published CESM1 model integrations and a wide range of observations. Although targeted towards the CESM community, the manuscript provides profound insights that are valuable for other modeling groups, too.

All reviewer comments have been addressed satisfactorily, the overall quality of the manuscript has improved tremendously since its first submission. There are no further objections publishing it. Minor technical refinements as listed below may be applied before final publication.

GENERAL ANSWER: We thank the reviewer for the very positive feedback and for recognizing the major improvements in the revised version following both reviewer's suggestions during the 1st round of revisions. As recognized, the paper is targeted towards the CESM community, although we made our best effort to provide insightful details oriented to provide scientific and technical SLH knowledge to the wider atmospheric-chemistry modelling audience, with the hope current developments are further explored in the future. Below we provide a point-by-point response to each of the remaining minor comments within this 2nd round of review.

2 Specific comments

Individual scientific questions/issues

R2-C2.1: L189–191: SLH chemistry is also included in the standard chemistry mechanism used in ECHAM/MESSy Atmospheric Chemistry (EMAC) model [1].

ANSWER: Thanks for the careful reading and apologies for the omission. We have now added the citation to the EMAC model here and also in Section 5.1 where the comparison between model configurations are presented:

L1421–1425: *“The quantitative analysis presented in Sections 4.1 and 4.4 shows that the overall tropospheric and stratospheric halogen abundance obtained with the current CESM2-SLH release is **equivalent to (and in any case, smaller than)** that implemented in previous CESM1 and other global models **such as EMAC, TOMCAT and GEOS-Chem** (Hossaini et al., 2016; Saiz-Lopez et al., 2012, 2023; Sherwen et al., 2016; Sinnhuber and Meul, 2015).”*

R2-C2.2: L1586–1589: *“The initial condition (ncdata) data has been replaced to ensure background SLH [...]”*. Here you describe the spin-up procedure for SLH. I might have overlooked it, but how did you initialize long-lived green house gases and ozone depleting substances?

ANSWER: We thank the reviewer for the careful reading of the new Appendix. Despite the referred initialization dataset is not related to SLH but to ODSs and GHGs, we have now included a brief description and citation of the main datasets used for spin-up as well as for performing all simulations in CESM2-SLH. To make this clear, we have modified Sections 3.1 and the Appendix as follows:

L555-564: *“Unless stated otherwise, all external forcings and namelist options, including prescribed ocean SST and ice-coverage fields as well as solar radiation, cloud microphysics, gravity-wave dragging and dust emission factors are identical to those used in the base FCHIST and FCnudged configuration of CESM2 (Danabasoglu et al., 2020; Emmons et al., 2020). This includes surface LBCs of ODSs and greenhouse gases (GHGs) based on the Climate Model Intercomparison Project Phase 6 (CMIP6; Meinshausen et al., 2017), as well as anthropogenic and biomass burning pollutant emissions from the Community Emission Data System (CEDS; Van Marle et al., 2017; Hoesly et al., 2018) as described in Emmons et al. (2020). To extend model simulations beyond the historical period, we concatenated prescribed emission and LBC data from CMIP6 until year 2015 (Eyring et al., 2016) with future projections following the CMIP6 Shared Socio-economic Pathway 3.70 (SSP-370) scenario for the period 2016–2100 (IPCC, 2022; Meinshausen et al., 2020).”*

L1600-1604: *“Initialization file: The initial condition (ncdata) data has been expanded from the default CESM initialization files with stabilized ODSs and GHGs and replaced to ensure background SLH species and related atmospheric compounds such as O₃ and OH are in steady state. Note that while 3 years of spin-up are sufficient to achieve tropospheric stabilization of SLH SGs and PGs, for studies focused in the stratosphere we recommend performing at least 7–10 years of spin-up when starting from an initial condition that neglects SLH.”*

R2-C2.3: L1157/1289: Here and in other sections, the authors use two different tropopause definitions – the chemical tropopause compared with a threshold at 150 DU of ozone and the minimum lapse rate pressure. How does this affect the respective results?

ANSWER: We appreciate the reviewer comment and understand he/she refers to 150 ppbv instead of 150 DU. The reasons behind using different definitions (i.e., lapse rate vs. ozone threshold) is to provide equivalent comparisons to the original studies where quantitative evaluation of tropospheric and/or stratospheric SLH composition and influence were performed. In all cases, equivalent interpretations are obtained regardless of the definition considered. To avoid enlarging an already lengthy manuscript, we prefer not to include such an intercomparison in the revised manuscript and decided to keep all Figures and Tables as they were originally compiled. We have made this clear by including the following text at the beginning of Section 4 “Results” and in the footnote of Table 9 and Table 10:

L641-646: *“This section presents a comprehensive description of the main SLH effects on atmospheric composition obtained with the new CESM2-SLH model configuration, and is oriented to provide a general view for new users not familiarized with SLH chemistry. We focus on mean tropical, global, zonal and surface quantities, as well as their integrated values within the troposphere and stratosphere considering the model lapse rate tropopause. Results presented here show the net changes due to the SLH implementation, and, unless stated otherwise, are based on the difference between CC-SLH and CC-NOH experiments for the low-top (32L) and coarse (2°×2°) horizontal resolution.”*

L1168-1170: *“^sThe stratospheric ozone column is expressed in Dobson Units (DU) and computed for O₃ ≥ 150 ppbv. Equivalent CC-SLH – CC-NOH differences are obtained regardless of considering the chemical or lapse rate definition for the tropopause.”*

L1168-1170: *“All tropospheric magnitudes have been computed considering the internal model tropopause (TROP_P, hPa), defined as the pressure level where the minimum temperature lapse rate is derived.”*

R2-C2.4: L1340–1349: In Fig. 18c), the differences between the nudged (CC-SLH [2 × 2–ndg]) and the free-running (CC-SLH [2 × 2–hst]) are quite substantial in the high latitudes ((60 – 90) °N/S). What are the reasons?

ANSWER: We thank the reviewer for the detailed evaluation. The differences between CC-SLH [2 × 2–ndg] – CC-NOH [2 × 2–ndg] and CC-SLH [2 × 2–hst] – CC-NOH [2 × 2–hst] values arise because for the 2nd case, in opposition to the nudged experiments (1st case), the free-running experiments do not share the same identical dynamical state. Note that ozone abundance and reactive halogen chemistry in the lowermost stratosphere strongly depend on temperature, particularly in the high-latitude regions.

In the nudged experiments (CC-SLH [2×2–ndg] and CC-NOH [2×2–ndg]), the atmospheric temperature and winds are prescribed from the same meteorological fields and are therefore fully consistent between simulations. As a result, the ΔO₃ values from the nudged experiments shown in Fig. 18c mainly reflect the isolated impact of SLH chemistry, with relatively smooth latitudinal structure.

In contrast, the free-running experiments (CC-SLH [2×2–hst] and CC-NOH [2×2–hst]) computes atmospheric dynamics and temperature online. Consequently, the meteorological conditions evolve independently in each simulation and are not fully dynamically consistent. Hence, because the lower-stratospheric ozone and reactive halogen chemistry are sensitive to transport and temperature, particularly at high latitudes, the resulting ΔO₃ values from the nudged experiments includes not only the chemical impact of SLHs but also a contribution from differences in the simulated dynamics. This additional dynamical component becomes especially important in the polar regions and explains the differences between the free-running and nudged simulations in Fig. 18c.

Indeed, this is the main reason why in Section 5.3 “*User recommendation for CESM2-SLH*” we recommend the *FCnuded_slh compset* for initial evaluations of SLH chemistry, since it allows to accurately isolate chemical perturbations from dynamical variability:

L1487-1491: “Given the large spatio-temporal variability of Cl_y, Br_y and I_y within different regions of the atmosphere, we recommend new-users not familiarized with SLH chemistry to initially select the coarse (2°×2°) resolution, particularly with the *FCnuded_slh compset*. This ensures that **atmospheric transport and temperature are consistently represented across simulations, which is crucial for isolating and quantifying chemical perturbations from dynamical variability** between different model simulations.”

Following the reviewer's concern, we acknowledge that the comparison between nudged and free-running results in Fig. 18c may be misleading, as the differences partly reflect inconsistencies in the simulated dynamics rather than the isolated effect of SLH chemistry. Since this issue does not provide additional insight into the main objectives of the figure and could distract the reader from the main message, we decided to remove the free-running results from Fig. 18c and maintained only the nudged experiments.

R2-C2.5: L1494: “*CESM2-SLH Mendeley repository*”: You may want to include a link/url to said repository if possible.

ANSWER: We have now included the citation in the referred sentence. Note that the published link/doi to the CESM2-SLH Mendeley repository was already provided in the “Code and Data Availability” section.

3 Technical corrections

Purely technical corrections

R2-C3.1: L74: Typo in punctuation: e-g- → e.g.,

R2-C3.2: L197: Wrong hyphens: *-including CESM1 and CESM2-* → *– including CESM1 and CESM2 –*

ANSWER: Thanks. Done.

R2-C3.3: L319: Presumably typos in *het_ss_3–5* (Table 1): $CL_2 \rightarrow Cl_2$

ANSWER: Thanks. Done.

R2-C3.4: L452: *Here, we assumed identical accommodation coefficients and reaction yields for iodine than those used for the equivalent chlorinated and brominated reservoirs. Grammar: than → as.*

ANSWER: Thanks. Done.

R2-C3.5: L487: *IUPAC Atkinson et al. (2007, 2008).* Citation should be set in brackets here. → IUPAC (Atkinson et al., 2007; 2008).

ANSWER: Done.

R2-C3.6: L522: *[...] transport and removal based on 3 (three) individual bins [...]. Compliance with journal style: 3 (three) → three*

ANSWER: Done.

R2-C3.7: L690: *2015-2020.* Wrong hyphen: - → –

R2-C3.8: L862–863: *1.8-2.2 pptv + 2.5-3.0 = 4.3-5.2 pptv.* Same as above. - → –

ANSWER: Done here and elsewhere.

R2-C3.9: L926: *I_y → I_y*

ANSWER: Thanks. Done.

R2-C3.10: L1108: *in previous work (Fernandez et al., 2019, 2024).* Grammar. Plural needed here: *work* → *works*

ANSWER: Thanks. Done.

R2-C3.11: L1237: "*The top-row show [...]*". Grammar: *show* → *shows*

ANSWER: Thanks. Done.

R2-C3.12: L1340: "*Figures 18b and 18c shows [...]*". Grammar: *shows* → *show*

ANSWER: Thanks. Done.

R2-C3.13: L1367: "*6 (six)*". Compliance with journal style: *6 (six)* → *six*

ANSWER: Thanks. Done. Note that following **R1-C2.10-12** and **R2-C3.14** we have rephrased the text as shifted down the referred sentence.

R2-C3.14: L1367-1382: It might make sense to switch the order - first refer to Fig. 19 and afterwards to Fig. S7.

ANSWER: We accepted the reviewer's suggestion and have shifted down the description of Fig. S7 to the next paragraph. Consequently, we reversed the order of Supplementary Figures S7 and S8 to keep consistency with the text. Following **R1-C2.10-12** we have modified the text as follows:

L1375-1390: "*Figure 19 shows a comparison of the tropical (20° N–20° S) and global (90° N–90° S) mean vertical profiles of Cl_y , Br_y and I_y for the **six SLH experiments shown in Table 7**, where the model output of high-top compsets using WACCM 70L have been interpolated with a bi-linear method (i.e., using NCAR interpac routine) to the default CAM6-Chem 32L vertical grid. All model experiments result in a very similar profile all the way from the surface to the upper stratosphere, although minor discrepancies in the vertical distribution remain. The corresponding tropospheric percentage **changes range** from –0.4% to +20 % for bromine and –24% to –0.2% for iodine (see Fig. S7), where as expected, the largest percentage differences appear at those heights where the X_y abundance is small. For the particular case of surface Br_y , ***fine-resolution* CC-SLH [1×1-hst] shows lower abundances than the coarse CC-SLH [2×2-hst] setup, while CC-SLH [1×1-ndg] and BW-SLH [2×2-cpl] experiments show larger values than CC-SLH [2×2-ndg] and FW-SLH [2×2-ndg], respectively. This is attributed to the smaller contribution from SSA-dehalogenation, particularly over the Southern Ocean. However, when integrated over the troposphere, note that the *fine* CC-SLH [1×1-hst] experiments present a larger Br_y burden than the coarse CC-SLH [2×2-hst] case, although smaller than those predicted for CC-SLH [1×1-ndg] and BW-SLH [2×2-cpl] (see Table S4). Chlorine, which of all halogen species shows the largest range in Cl_y abundance from the surface to the top of the model, results in tropospheric changes that remain below ~7.5% between the different compsets, with peak **percentage differences** predicted between BW-SLH [2×2-cpl] and FW-SLH [2×2-ndg] experiments close to the tropopause that are rapidly reduced below 10% as soon as LLH_{Cl} are photodecomposed in the lower stratosphere.***"

R2-C3.15: L1396–1397: "*In this section we highlight the scientific relevance and limitations of including comprehensive halogen chemistry in CESM2-SLH in comparison with previous studies and other models, highlighting the main drivers [...]*". Punctuation and style (word duplication). You may consider slightly rephrasing the sentence: In this section, we highlight [...], pointing out the main drivers that control [...].

ANSWER: Thanks for the suggestion. Done.

R2-C3.16: L1517: "setup" → set up

ANSWER: Thanks. Done.

R2-C3.17: L1516–1523: "[...] this work provides a general but complete intercomparison of organic VSLS and inorganic halogen distributions obtained for the different experiments." Duplicate of L1496–1498 ("The current CESM2 [...] a complete set of CESM compsets.") ? The authors should carefully assess Section 6 and could perhaps combine and condense the first paragraph and parts of the last paragraph to further reduce duplications.

ANSWER: We thank the reviewer for the suggestion. To avoid duplication, we have now removed and rephrased several sentences from the final Section 6 "Summary and Conclusions" as follows:

L1508-1510: *"In this work, we provide a comprehensive summary of the major scientific advances in our understanding of SLH emissions and chemistry on the global atmosphere as well as a complete description of the technical implementation of the main related processes and parameterizations in the widely used CESM chemistry-climate model."*

L1533-1537: *"Most notably, and with the intention of avoiding unintended misevaluation of SLH influence on atmospheric composition for users familiarized with current CESM2 compsets typically used for climate and air quality studies on the global scale, this work provides a general but complete intercomparison of organic VSLS and inorganic halogen distributions between previously published CESM1 results and different CESM2-SLH experiments and resolutions."*

3.1 Figures

R2-C3.18: Figure 10: The dotted, light blue lines in subfigures (b, d, f) are barely visible.

ANSWER: Thanks. We replaced the referred line with a darker colour.

References

[1] Sinnhuber, B., and S. Meul (2015), Simulating the impact of emissions of brominated very short lived substances on past stratospheric ozone trends. *Geophys. Res. Lett.*, 42, 2449–2456. doi:10.1002/2014GL062975.