

Response to editor and reviewer comments on

“Further constraining the role of in-atmosphere production on the global HFC-23 budget” (*title now revised)

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Response to the Editor

The authors thank the editor for their comments on the paper and appreciate the opportunity to correct the disparity in presented titles and further highlight the importance of the presented study in the abstract.

Regarding the title, the supplement erroneously reflected a previous version of the title. The previous title was amended earlier in the writing process to more accurately represent the existing literature, as Van Hoomissen et al. (2025) already put an upper bound on in-atmosphere HFC-23 production that demonstrated that it was small relative to the global emissions total. We have updated the title to more explicitly reflect the contribution of this work – that is, the application of a full 3D chemical and transport model to the problem – without misrepresenting previous literature. It now reads:

“Confirming the minimal role of in-atmosphere production on the global HFC-23 budget using a 3D chemical and transport model”

We have also made some changes to the abstract to highlight the importance and implications of this study, per the Editor’s suggestion. It now reads:

“A large discrepancy of at least 10 Gg yr⁻¹ exists between reported emissions of the potent greenhouse gas HFC-23 (CHF₃, trifluoromethane) and emissions derived from atmospheric measurements. In-atmosphere production of HFC-23 from the breakdown of fluorinated source gases such as hydrofluorocarbons (HFCs) and hydrofluoroolefins (HFOs) contributes to this gap, but only a conservative upper limit has been estimated for the magnitude of this source. This uncertainty is due, in part, to limited experimental measurements of the photolysis quantum yield of trifluoroacetaldehyde (CF₃CHO), a key degradation product that forms HFC-23 via photolysis. The parameters governing CF₃CHO deposition are also poorly understood. Here, we use a 3D chemistry and transport model, STOCHEM-CRI, to further constrain the magnitude of in-atmosphere HFC-23 production, using recent estimates of source gas emissions and explicitly parametrised photolysis and deposition. Furthermore, we perform an ensemble of simulations to account for the uncertainties in these values. We find that in-atmosphere production of HFC-23 is in the range 0.013 - 0.035 Gg yr⁻¹, substantially lower than previous estimates. This

accounts for < 0.5% of the discrepancy between reported and measurement-derived emissions, suggesting that this source makes a negligible contribution to the overall HFC-23 budget and that unreported direct emissions are likely responsible for the vast majority of the discrepancy. As part of this work, we also calculate indirect global warming potentials for the HFC-23 source gases HFO-1234ze(E), HFO-1336mzz(Z) and HCFO-1233zd(E) and find that their impact on climate is up to ten times higher than previously reported.”

Response to reviewer #2

The authors thank the reviewer for their further comments which have all been addressed as presented below. Line numbers (in **bold**) refer to the revised manuscript, and extracts from this manuscript are in blue.

P4, L100: I would call it here rather “study” than “investigation”.

We have modified the text, which now reads

L100-101:“In this study, we simulated a full year (2023) of HFC-23 in-atmosphere production following an initial spin-up simulation, which was used to initialise the atmospheric conditions and then discarded.”

P4, L100: A full year -> which year exactly? On line 125 you mention 2023. Is this the year you are considering? If yes, this should be clearly written.

We have modified the text to address this (see previous response).

P5, Table 1: Suffices of source gases - thanks for your explanation, but I think I may not be the only reader who wonders what these mean and therefore I would suggest that you provide a short note/explanation as a footnote to the table.

The caption of Table 2 now reads:

“Source gases used in the STOCHEM model, their tropospheric lifetimes taken from Burkholder et al. (2022), and the emissions and northern (NH) and southern (SH) hemispheric background mole fractions used as model inputs. Suffices are used to distinguish structural isomers (see <https://www.ashrae.org/technical-resources/standards-and-guidelines/ashrae-refrigerant-designations>)”

P6, L130: GDP - If I am not mistaken this abbreviation has not been introduced.

We have modified the text to include the definition of GDP:

L134-135: “Firstly, we assume that the adoption and emission of HFOs is correlated with national Gross Domestic Product (GDP) globally.”

P7, L180ff: Add also here the “greek lambda = “ before the mentioned wavelengths.

We have modified the text to include the lambdas:

L181-183: “Sulbaek Andersen et al. (2023) ($\lambda = 254$ nm), Thomson et al. (2024) ($\lambda = 308$ nm) and Van Hoomissen et al. (2025) ($\lambda = 248$ nm, 266 nm, 281 nm and 308 nm).”

P8, L199: Same here or write “wavelengths of.....”

L199-200: “...although Van Hoomissen et al. (2025) showed only a small pressure dependence at $\lambda = 308$ nm and our parametrisation reflects this.”

P9, Fig. 1 caption: “as discussed in the main manuscript” is obsolete here. Refer to the text line or Table 3.

The figure caption has been updated, and the final line now reads:

“The area under each of the lines corresponds to the overall photolysis rate, as per Eq. 3 and Eq. 4”

P15, L357: write clearly “dominated the total HFC-23 production by 80%” instead of putting the 80% in the middle of the sentence in parentheses.

We have rephrased this sentence for clarity:

L357-358: “In that study, the contribution from HFOs made up 80% of the total HFC-23 production”

P15, L362-363: a bias or biases (singular or plural, not a mixture of both).

We have fixed this error. The revised manuscript now reads

L364-365: “The median is used here to avoid introducing biases from the simulations testing extreme parametrisations”

*P16, L379: Check sentence and rephrase.
is modelledand discussed below?*

We have rephrased this sentence:

L379-381: “However, the HFC-23 produced by a single ‘pulse’ emission of these gases is estimated when calculating the indirect GDP of these species (see Sect. 2.5) and is discussed below”

P18, L440: base -> base run or base simulation

This now reads ‘base run’

L441-442: “In the ‘HO₂’ run, in which loss of CF₃CHO via the reversible reaction with HO₂ was included in the chemistry scheme, the relative contribution of the major loss processes was unchanged from the ‘base’ run.”

P17, L389: Supplementary Fig. 1 -> Fig. S1

This has been corrected.

P18, L438: Just mentioning pathway (a) and (b) here is not sufficient. The pathways have been introduced many pages before and to be able to follow you should at least refer to the section or page and give the pathway list also a number.

We have added a clause to clarify which of the pathways are referred to by (a) and (b):

L440-441: “Pathway (b) photolysis, which produces HFC-23, contributed < 0.1% in all runs”

Supplement: The Supplement title differs from the manuscript title.

This has been rectified; see the response to the editor above.