Report of the Scientific Assessment Panel Response to Decision XXXV/7: ***Emissions of HFC-23***

Authors:

Stephen Montzka, James Burkholder

Coauthors:

Lucy Carpenter, David Fahey, Ken Jucks, Bonfils Safari

Collaborators:

TEAP and TEAP's MCTOC, the Multilateral Fund, and the Ozone Secretariat

Other contributors:

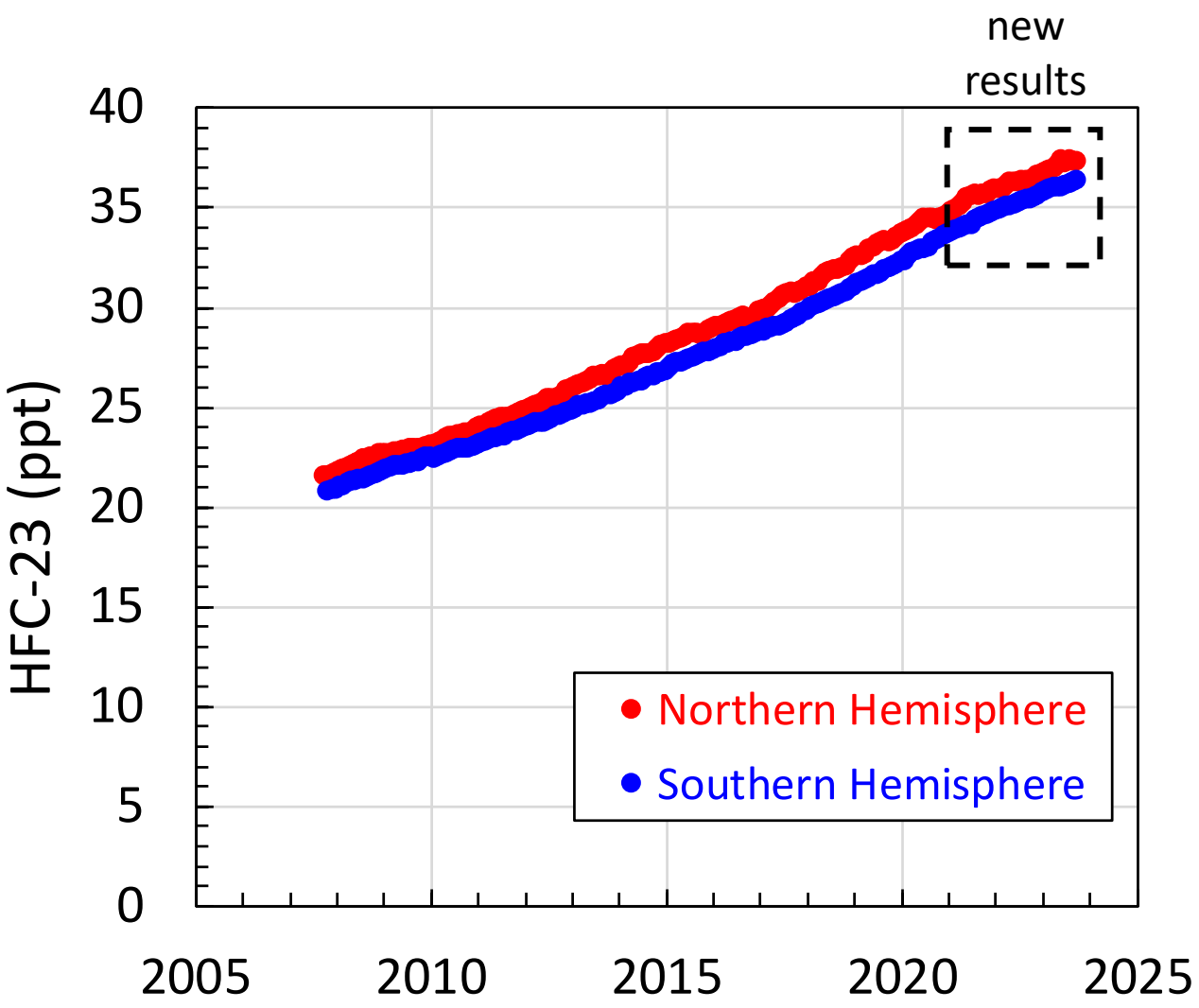
AGAGE scientists and data providers,

L. Western, K.M. Stanley, A.J. Manning, M.K. Vollmer, M. Sulbaek Andersen

Report is available at: https://ozone.unep.org/meetings/thirty-sixth-meeting-parties/pre-session-documents

HFC-23 atmospheric abundance in the remote atmosphere

- **From 2019 to 2022, the global mean atmospheric abundance of HFC-23 increased at Earth's surface by 1.13 ppt yr^{-1},**
- **This rate of increase was 6% slower than the 1.20 ppt yr^{-1} observed during 2016-2020.**
- HFC-23 atmospheric mole fraction reached 35.9 ± 0.9 ppt in 2022, accounting for 6.9 mW m^{-2} of radiative forcing, or about 15% of total radiative forcing from all HFCs (44.1 mW m^{-2} in 2020).
- Recall that HFC-23 has a lifetime of 228 yr and GWP_{100} of 14700.



Data provided by the AGAGE science team

Figure 1

Global HFC-23 emissions derived from atmospheric abundances in the remote atmosphere (*and knowledge of the HFC-23 lifetime*)

- **Global emissions of HFC-23 estimated from measured atmospheric abundances have steadily decreased from**

  17.3 ± 0.8 kt in 2019 (254 MMTCO$_2$e) to

  13.9 ± 0.7 kt in 2022 (204 MMTCO$_2$e)

- *This decrease in emissions was observed despite an increase in total production of HCFC-22 reported for all uses from 2019 to 2022*, noting that the principal source of HFC-23 is as a by-product from HCFC-22 production.

- The decline in global HFC-23 emissions while HCFC-22 production was increasing may reflect increased mitigation of HFC-23 emissions as an increasing number of parties ratified the 2016 Kigali Amendment to the Montreal Protocol.

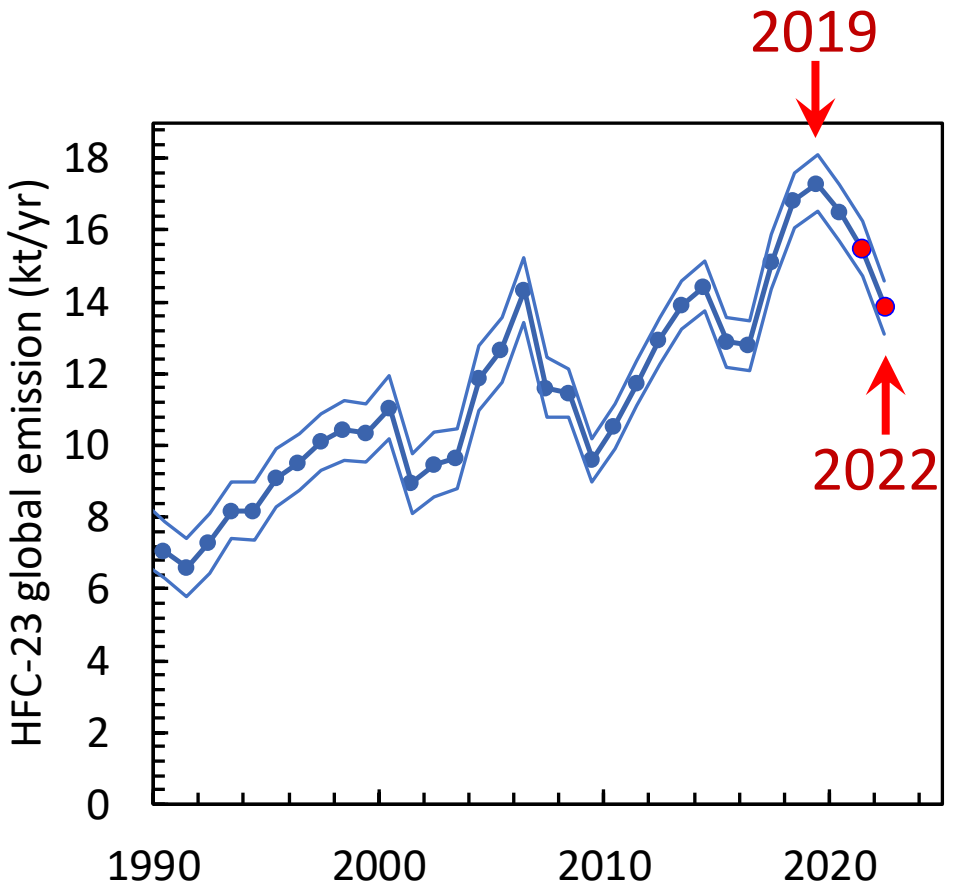


Figure 2

Global emissions: Comparing *atmosphere-derived* to *reporting-based* totals

• Global emissions of HFC-23 estimated from measured atmospheric abundances can be contrasted with values derived from reporting to the United Nations Framework Convention on Climate Change (UNFCCC), the Multilateral Fund for the Implementation of the Montreal Protocol (MLF), and the Ozone Secretariat.

• **From 1995 to 2014, good consistency was observed between estimated and reporting-based global emissions of HFC-23.** This was the case even from 2005 to 2014 when reported HFC-23 destruction, mostly in China and supported by the UNFCCC's Clean Development Mechanism (CDM), peaked near 9 kt yr^{-1}.

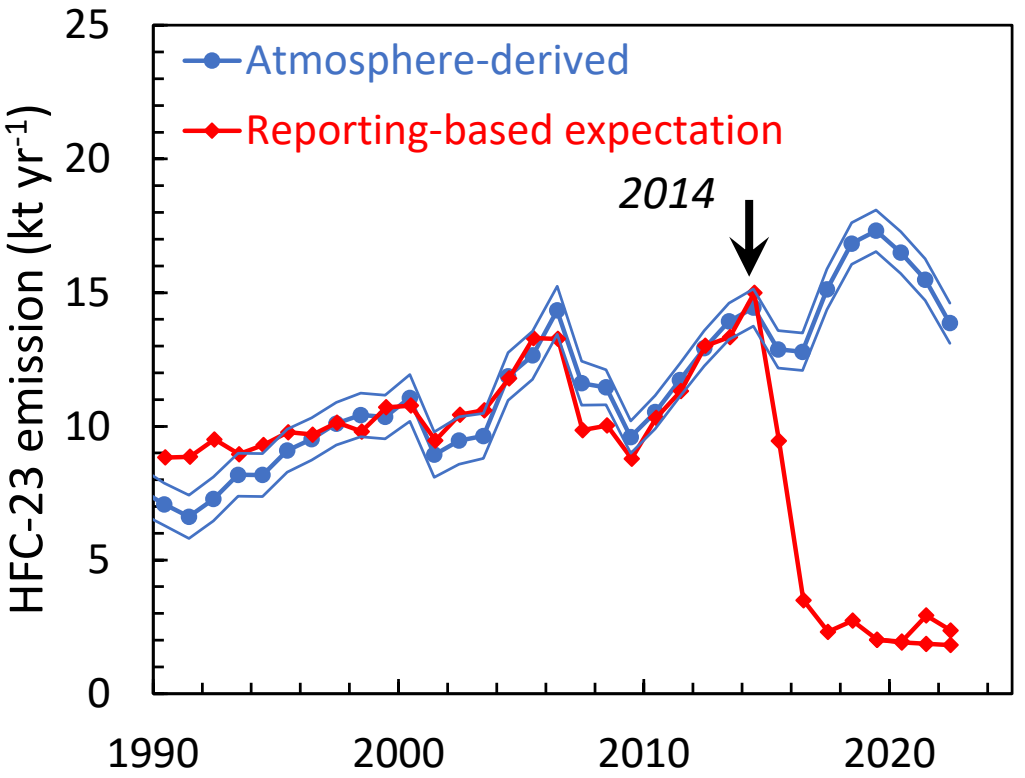


Figure 4

Global emissions: Comparing *atmosphere-derived* to *reporting-based* totals

- After 2014, a difference (or gap) emerged between estimated and reporting-based global emissions of HFC-23.
- The gap grew to reach a peak of 15 kt in 2019 and have decreased in the three years since 2019 to reach approximately 10.5 - 12.5 kt in 2022.

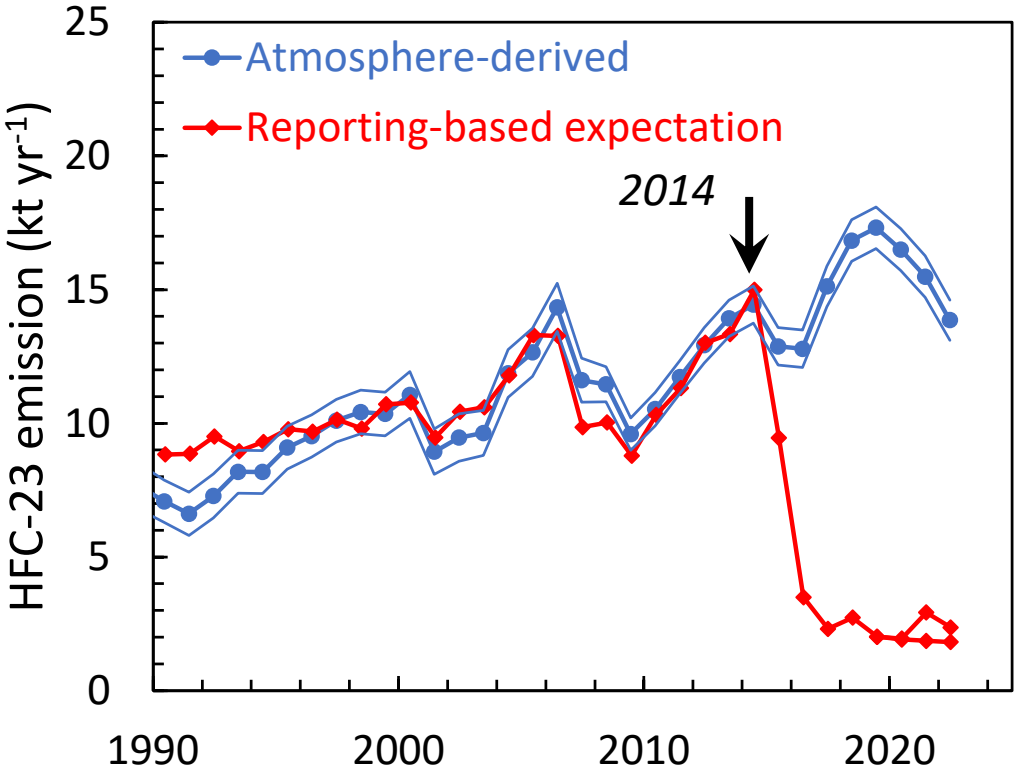


Figure 4

Do other known *industrial* sources explain the gap?

- The Technology and Economic Assessment Panel (TEAP) estimates HFC-23 emissions from all known sources and reported abatements after 2020 to be in the range of 1.47 - 3.54 kt yr^{-1}, *which is substantially smaller than the atmospherically-derived mean of 15 kt yr^{-1} during 2020 to 2022.*

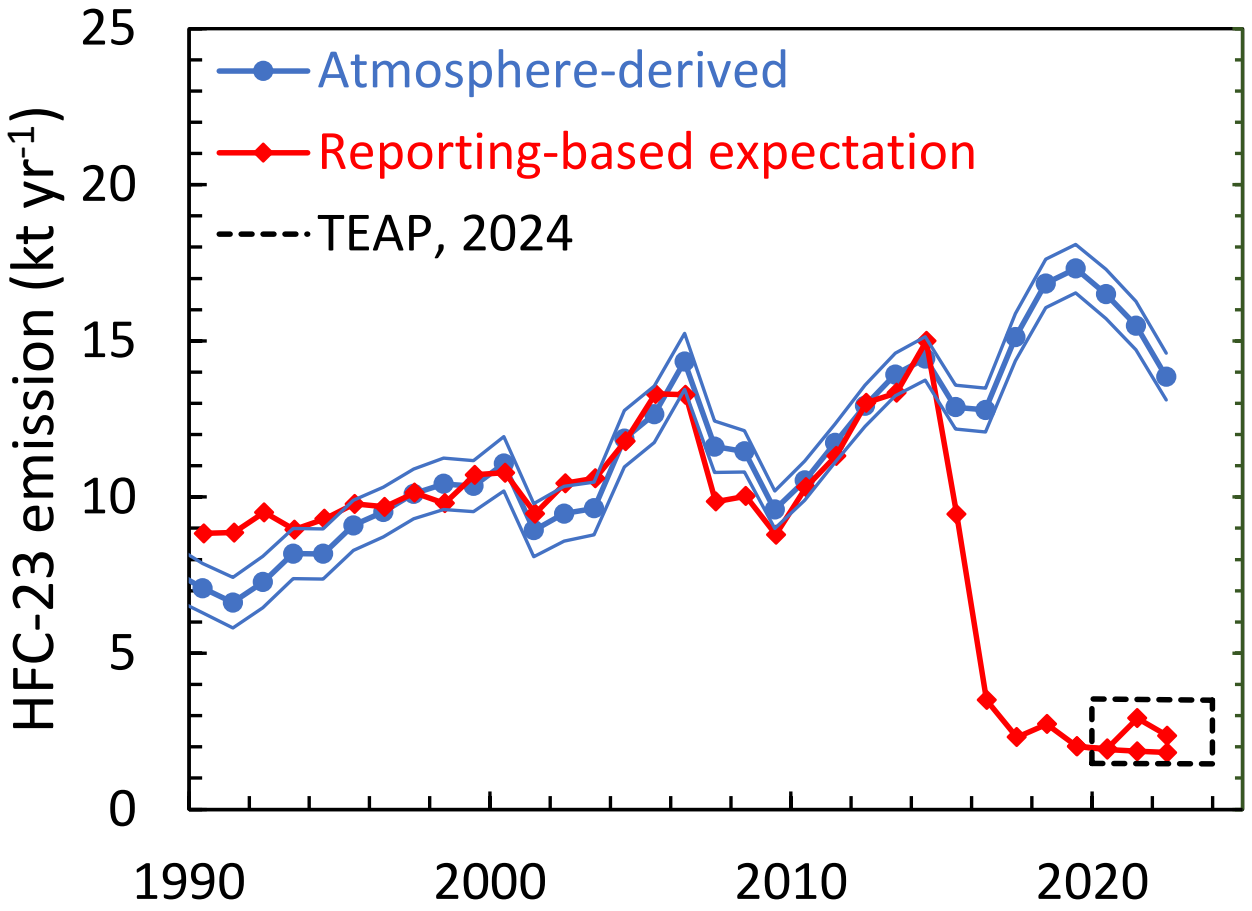


Figure 4

Estimating the HFC-23 source from *atmospheric photochemistry*

- **HFC-23 is produced in the atmosphere from reactions that oxidize *certain* fluorinated gases present in the atmosphere.**
- **An upper limit to this source in 2022 is estimated to be 0.43 kt HFC-23 yr^{-1}, which accounts for less than 3.1% of global HFC-23 emissions in that year.**
- The actual value could be substantially smaller.
- The magnitude of this HFC-23 source is estimated using measured atmospheric abundances of relevant fluorinated gases, where available, and laboratory kinetic studies of the reactions that lead to HFC-23 production.

Contributing gases that have been measured in the atmosphere:

HFC-143a	HFO-1234ze(E)
HFC-245fa	HFO-1336mzz(E)
HFC-365mfc	HCFO-1233zd(E)
HFC-236fa	
HCFC-133a	

→ *Contributing gases have the chemical structure:*

$CF_3CH_2 - R$ *or* $CF_3CH = R$

The gap in global emissions and its change over time

- **The increasing emission gap between 2015 and 2018 is similar in magnitude and coincident in time with the destroyed amounts of HFC-23 reported by China to the MLF**, amounts that are consistent with the country's Hydrochlorofluorocarbon Production Phase-out Management Plan (HPPMP) agreement with the MLF Executive Committee.

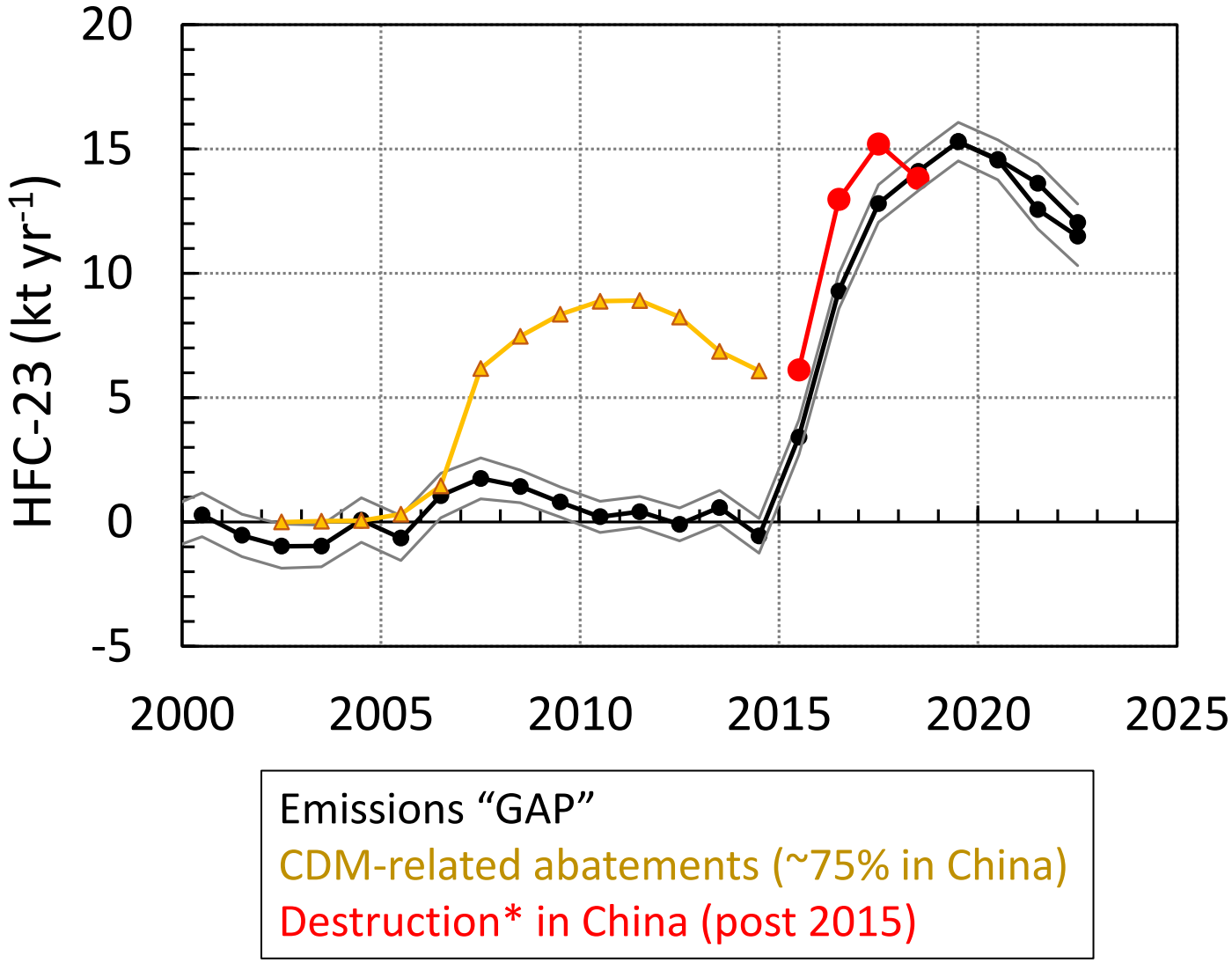


Figure 5

Considering emissions relative to HCFC-22 production

- **The decrease in the gap after 2020 is concurrent with a declining ratio of global atmospherically-derived HFC-23 emissions relative to reported total HCFC-22 production (E_{23}/P_{22}),** suggesting an increase in the inferred overall abatement of HFC-23 emissions.

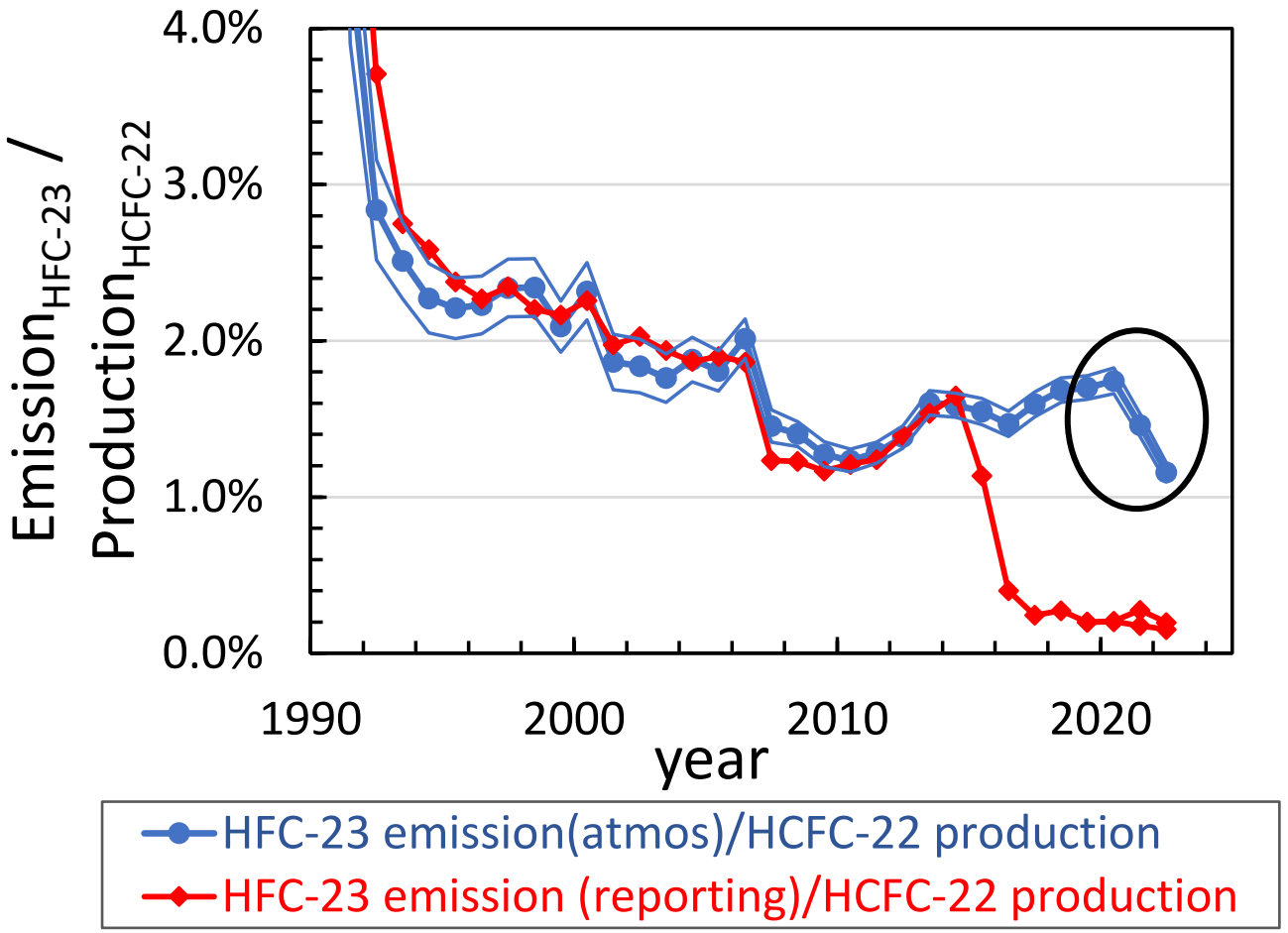


Figure 6

Updated regional emissions of HFC-23

- **New atmospheric measurements have refined the quantification of HFC-23 emissions in some geographic regions.**
- **The sum of available regional emission estimates is less than the global total derived from atmospheric abundances in the remote atmosphere, indicating that not all regional sources are included to date.**
- Indeed, atmosphere-based estimates are not available for all parties producing HCFC-22 in recent years.
- **Estimates have become available** based on atmospheric abundances measured at stations **in and around China**, and new estimates or updates are available from the **United Kingdom, western Japan, Korea, The Netherlands, and portions of Europe**.

Regional HFC-23 emissions from portions of China

- **From 2015 to 2019, regional HFC-23 emission estimates were derived for eastern China from atmospheric abundances measured at the Gosan, Korea, station.**
- **The emissions from eastern China increased during these years from 5.7 ± 0.3 to 9.5 ± 1 kt yr^{-1} despite reporting provided to the MLF showing that by 2018 more than 95% of the HFC-23 generated in China had been destroyed, stored, or used as feedstock**.
- The derived geographical distribution of regional sources is broadly consistent with known locations of fluorochemical production facilities in China, including those producing HCFC-22.

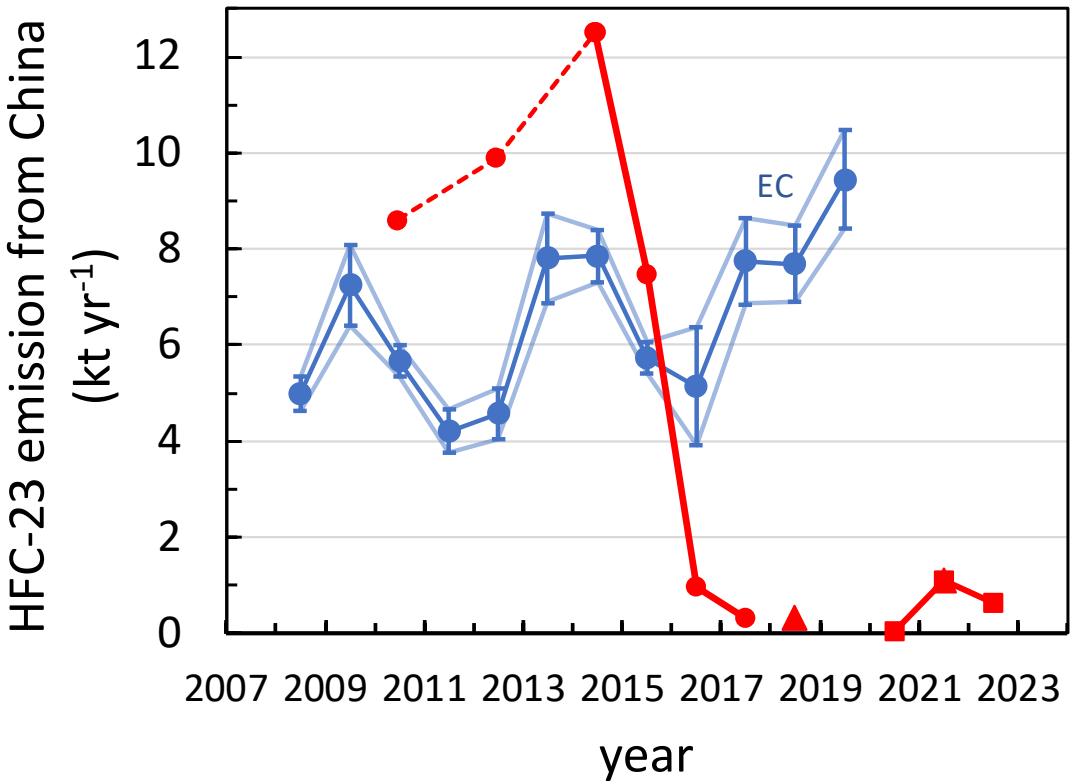


Figure 7

Regional HFC-23 emissions from portions of China (cont'd)

- Since 2020, additional HFC-23 measurements made at multiple sites in China suggest continued emissions of HFC-23 during 2020-2023, in amounts from two different regions of 3.2 ± 0.9 and 6.7 ± 3.1 kt yr^{-1}, which are substantially larger than A7 emissions for controlled processes reported for all of China to the Ozone Secretariat (between 0.5 to 1.1 kt yr^{-1} during 2020 – 2022).
- Based on these studies, unreported emissions from **portions of** China account for approximately 20 to 50% of the **global emissions gap** during 2016 to 2022.

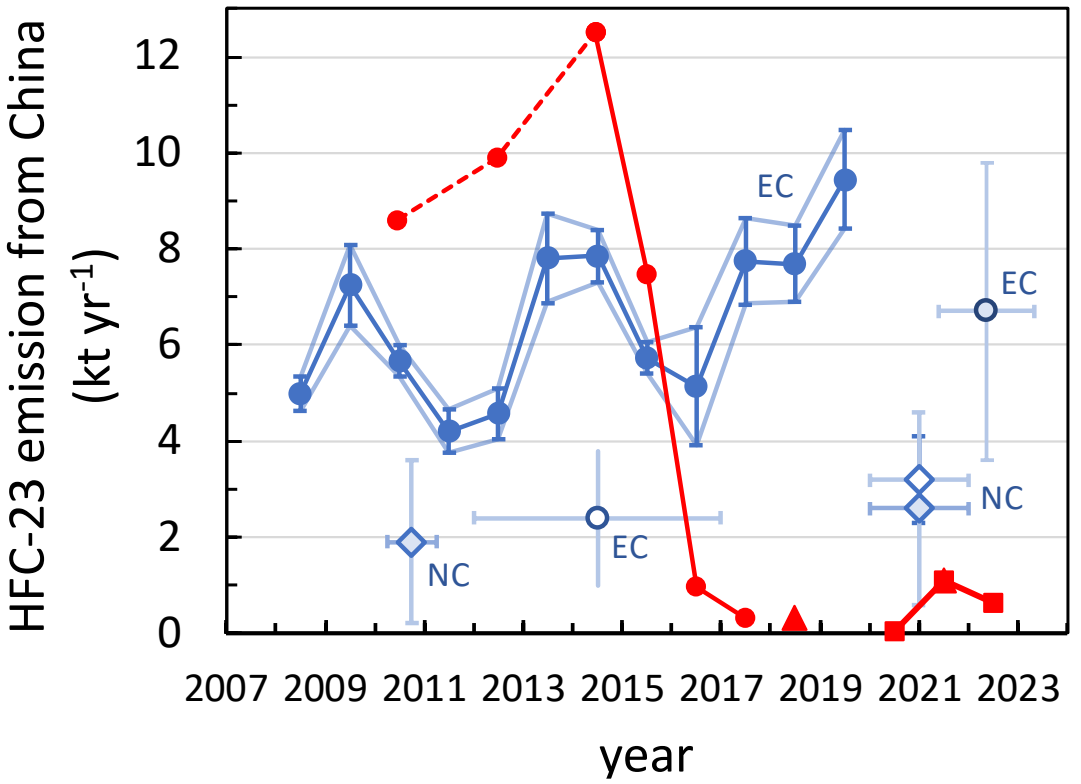


Figure 7

Regional HFC-23 emissions from other locations

• **Estimates of regional emissions of HFC-23 derived from measured atmospheric abundances have also become available during 2008 to 2021 that include these countries:**

→ *Australia, Belgium, Democratic People's Republic of Korea, France, Germany, Ireland, Japan, Luxembourg, Netherlands, Republic of Korea, and the United Kingdom.*

• Summed emissions in recent years from these countries totals 0.75 kt yr^{-1}, which is 0.4 kt yr^{-1} higher than their reporting and **not enough to explain a significant portion of the global emission gap**.

• Together, HCFC-22 production in China and these other regions accounted for about 85% of reported HCFC-22 production in 2022.

•**Atmospherically-derived HFC-23 emission estimates are not available in recent years** for the countries that account for nearly all of the remaining HCFC-22 production reported during 2022: **India, the United States, and the Russian Federation**.

Summary

- **A substantial shortfall (10.5 – 12.5 kt yr^{-1}) remains in the attribution of global emissions of HFC-23 to known sources or regions despite the new information provided in this Supplemental Report.**
- The gap between reported emissions and those inferred from atmospheric abundances is not reconciled by considering all known sources.
- The sum of updated estimates of previously unrecognized or unaccounted sources as provided by TEAP (TEAP, 2024) and the estimated production from the atmospheric oxidation of other fluorinated industrial gases could reduce the emissions gap by as much as 3 kt yr^{-1}.

Summary (cont'd)

- Regional studies conclude that emissions in recent years from regions of China are substantially larger than expected from China as a whole (by as much as 6 kt), and they account for a substantial fraction of the global gap (20 – 50%) even during 2021 – 2022.
- These emissions have not been reported or considered previously in a quantitative assessment of the global gap. In contrast, the total of regional emissions from 11 other countries in recent years are small relative to the gap (less than 4%).
- A regional-scale accounting of global emissions remains incomplete, as atmosphere-based estimates are not available from some regions of the world that are potentially significant sources of HFC-23 emission.

Thank you for your attention