A review of current understanding of HFC-23 emissions and contributing source processes

Part 1: Review and interpretation of atmospheric measurements

Steve Montzka *SAP*

Part 2: HFC-23 by-production and emissions

Nick Campbell, Helen Tope *TEAP*

Part 1 Outline:

Review findings of the 2022 Science Assessment Panel Report

* atmospheric abundance; climate impacts; global emission vs expectations

Newly available information

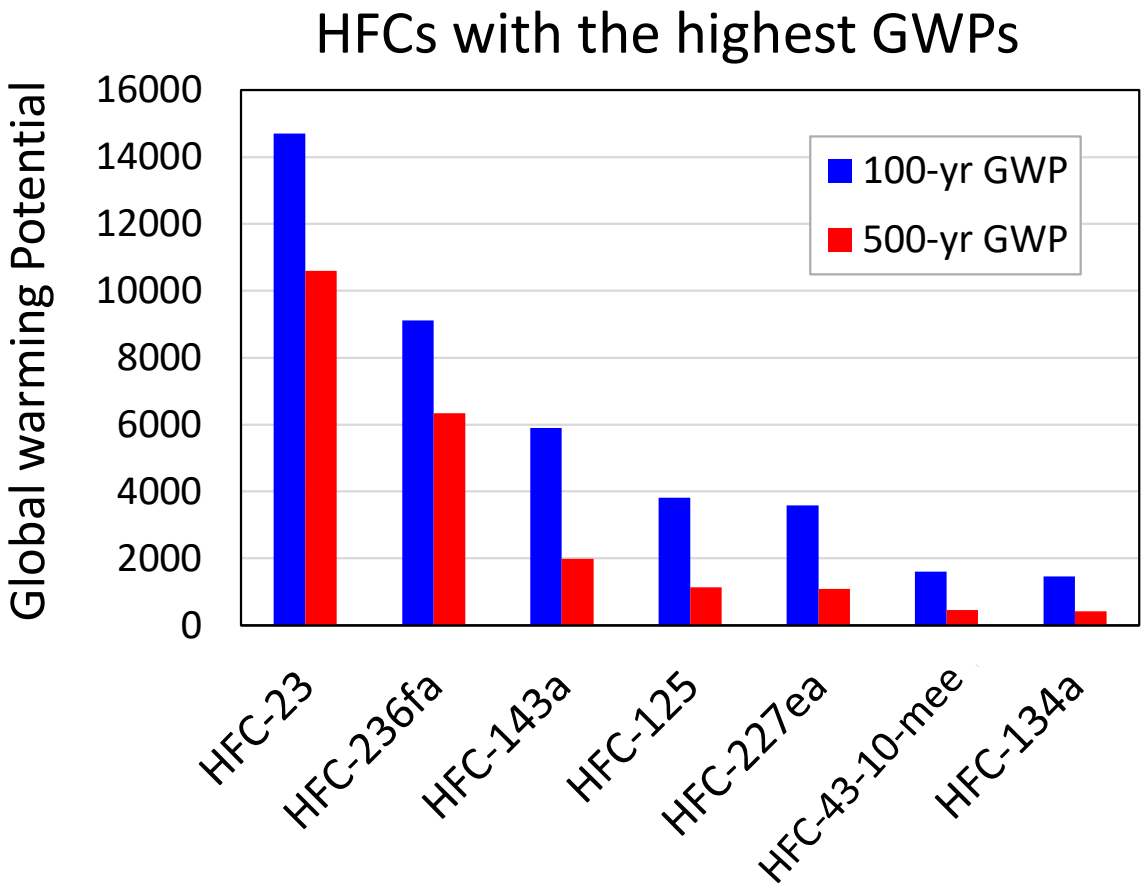
* emissions in eastern Asia and for eastern China *vs.* expectations

2023 studies: Zhao *et al.* 2023; TEAP; Park *et al*. 2023

* Updated global atmospheric trends and emissions (*provided by AGAGE*)

As measured by global warming potential,

HFC-23 emissions have a strong and persistent influence on climate



HFC-23:

- long lifetime (~230 years)
- emissions predominantly from by-production during manufacture of HCFC-22:

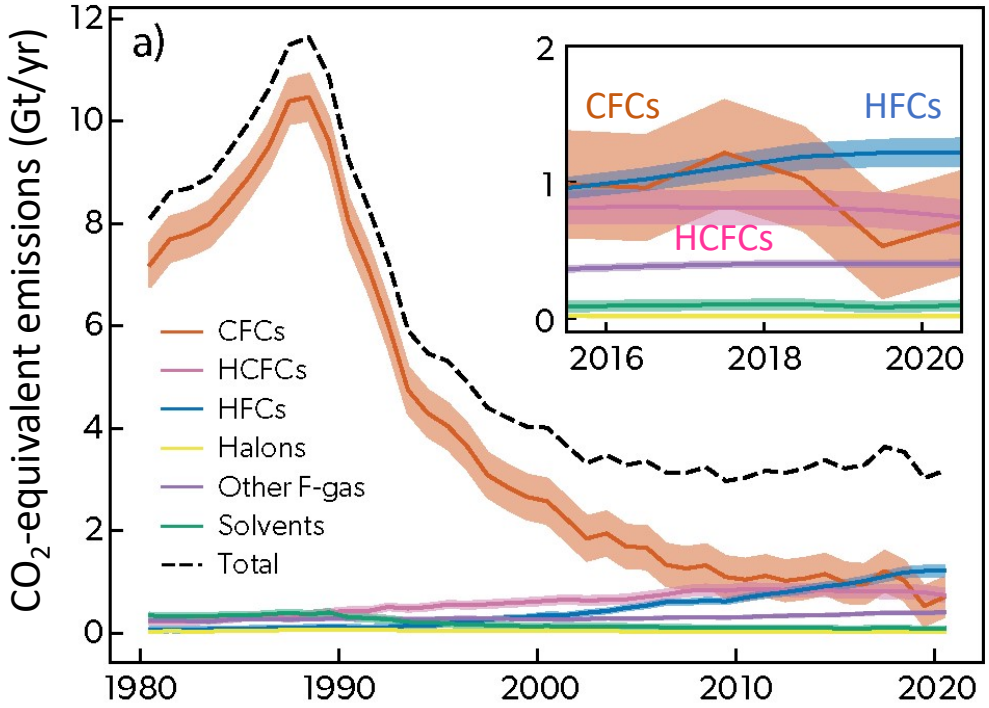
chloroform + 2 fluorine → HCFC-22
*HCFC-22 + fluorine → **HFC-23***

GWPs from the 2022 SAP report

Global emissions of Montreal-Protocol-controlled gases

→ *aggregate HFC emissions > CFCs or HCFCs*

Source: 2022 SAP Report, Figure 1-4



CO_2-eq emissions relative to ODSs

Gt/yr in 2020:

HFCs: **1.22 ± 0.05**

(HFC-23: 0.24 ± 0.01)

CFCs: 0.7 ± 0.4

HCFCs: 0.7 ± 0.1

Sum:

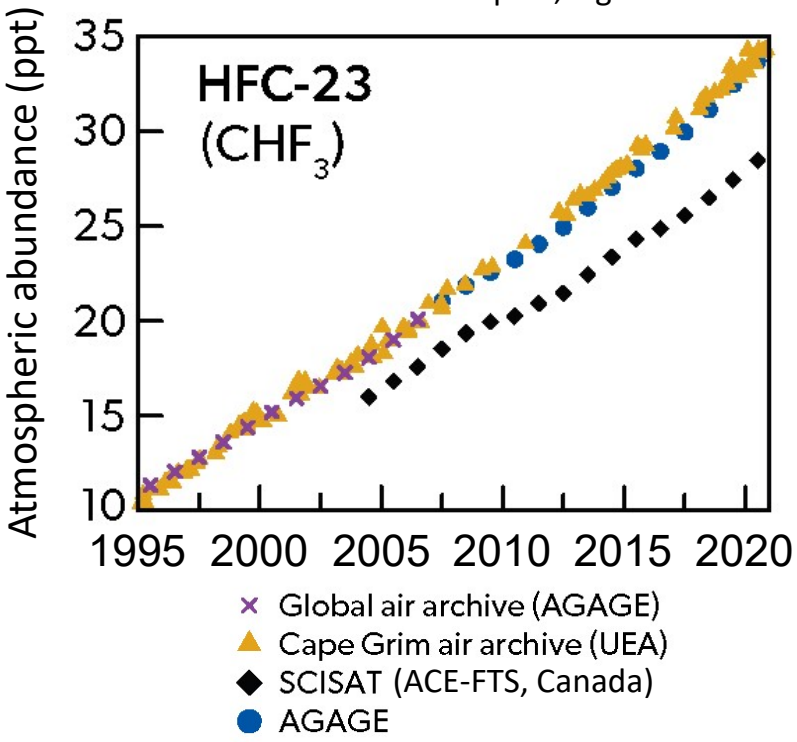
2.82 Gt/yr of emission

(compare to 36 Gt/yr for total fossil-derived CO_2 emission in 2020)

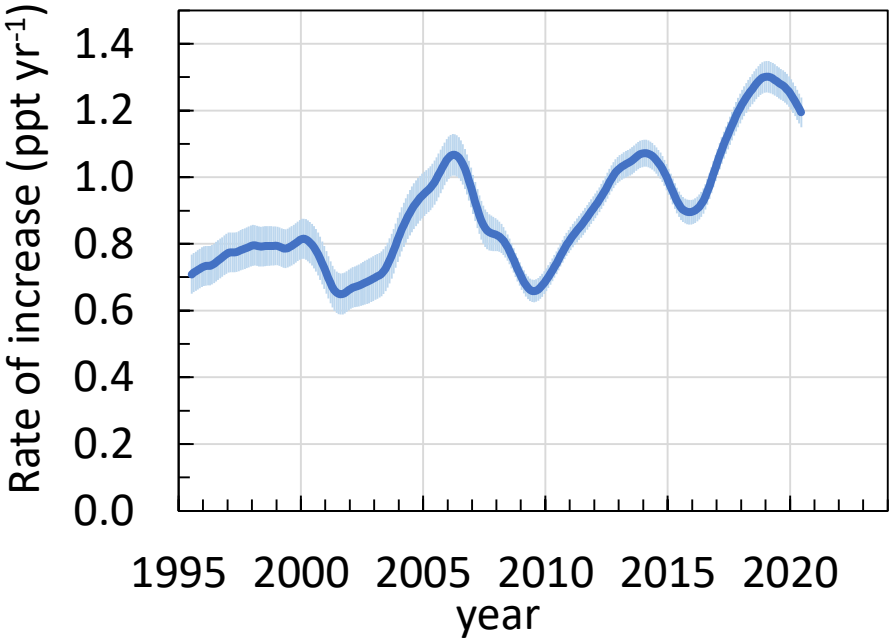
1 Pg = 1 Petagram = 1 Gigaton

HFC-23 atmospheric abundance continues to increase

Source: 2022 SAP Report, Figure 2-1



Rate of change, HFC-23 global concentration

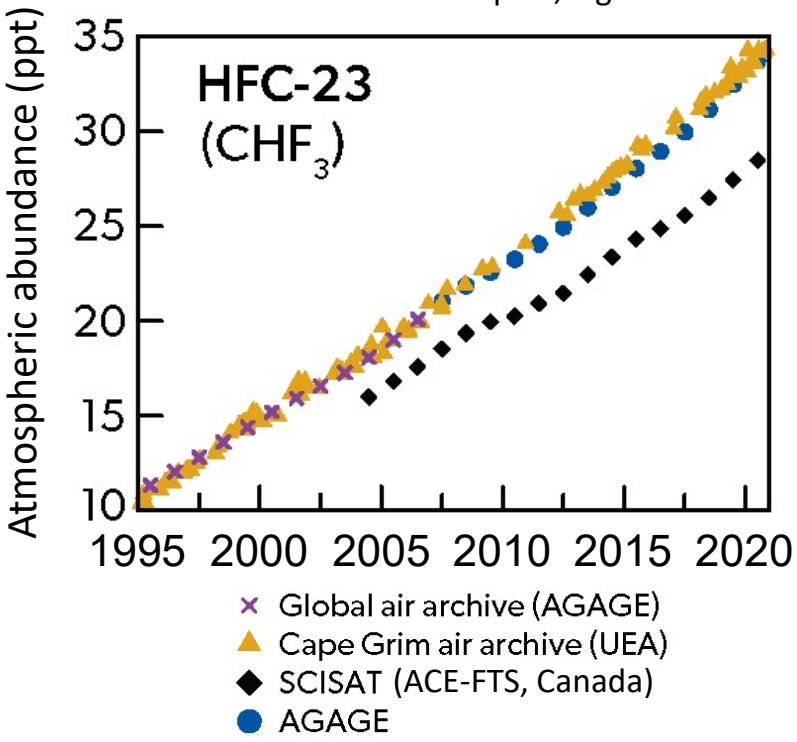


AGAGE remote surface measurements as they appear in the SAP 2022 report

HFC-23 atmospheric abundance continues to increase

→ The mean increase during 2017-2020 was faster than in any previous period

Source: 2022 SAP Report, Figure 2-1



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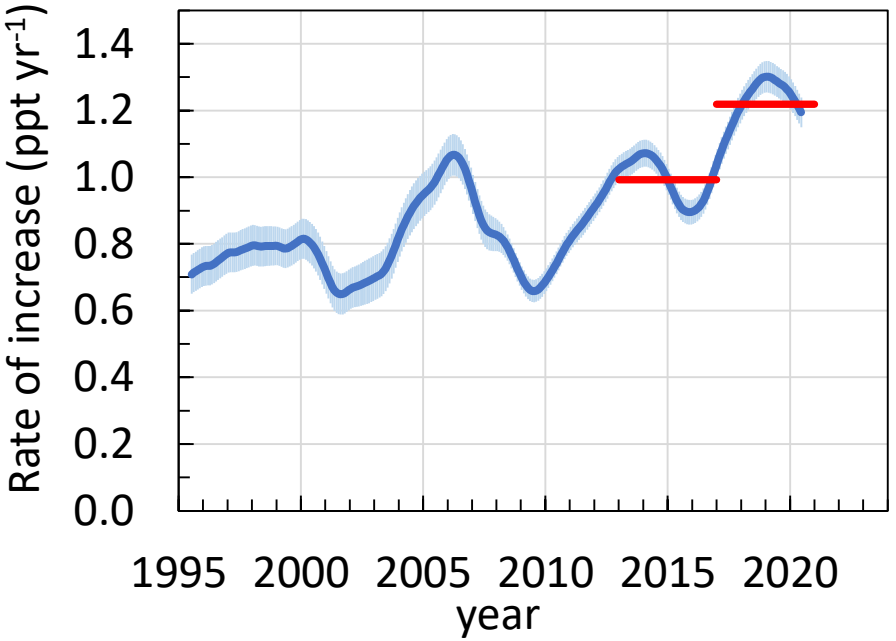
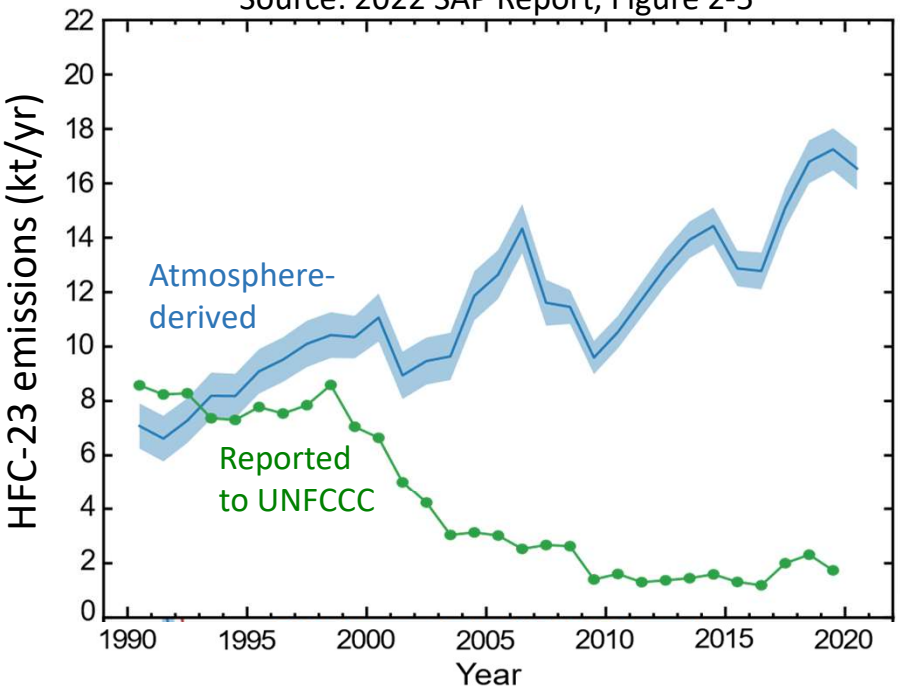


Mean rates indicated by red lines

AGAGE remote surface measurements as they appear in the SAP 2022 report

HFC-23 global emissions and the influence of mitigation measures

Source: 2022 SAP Report, Figure 2-5



Take-home messages:

* **HFC-23 emissions continue to increase**;
  →2016-2020 mean at an all-time high

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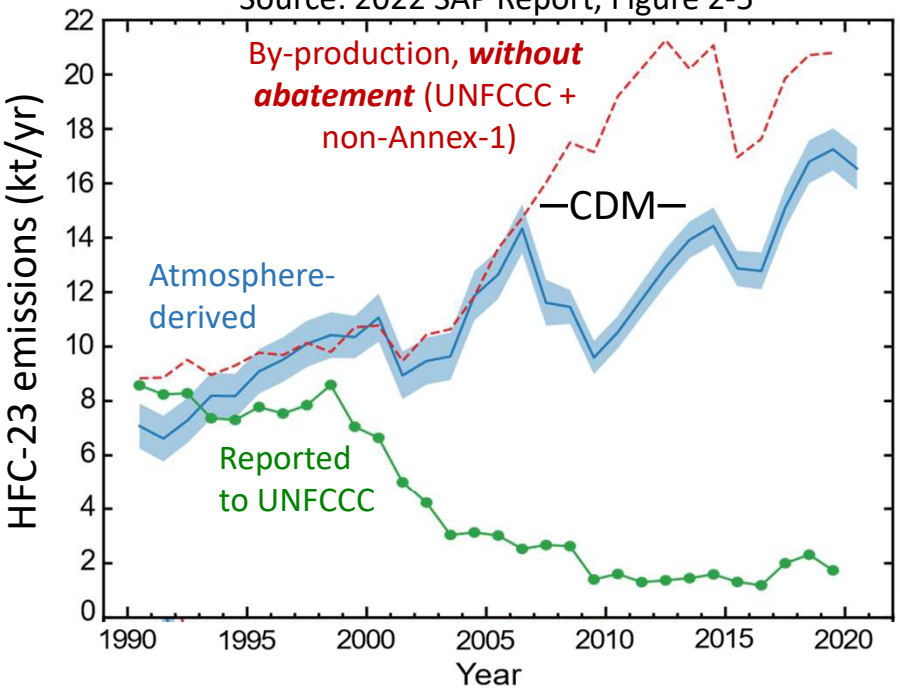

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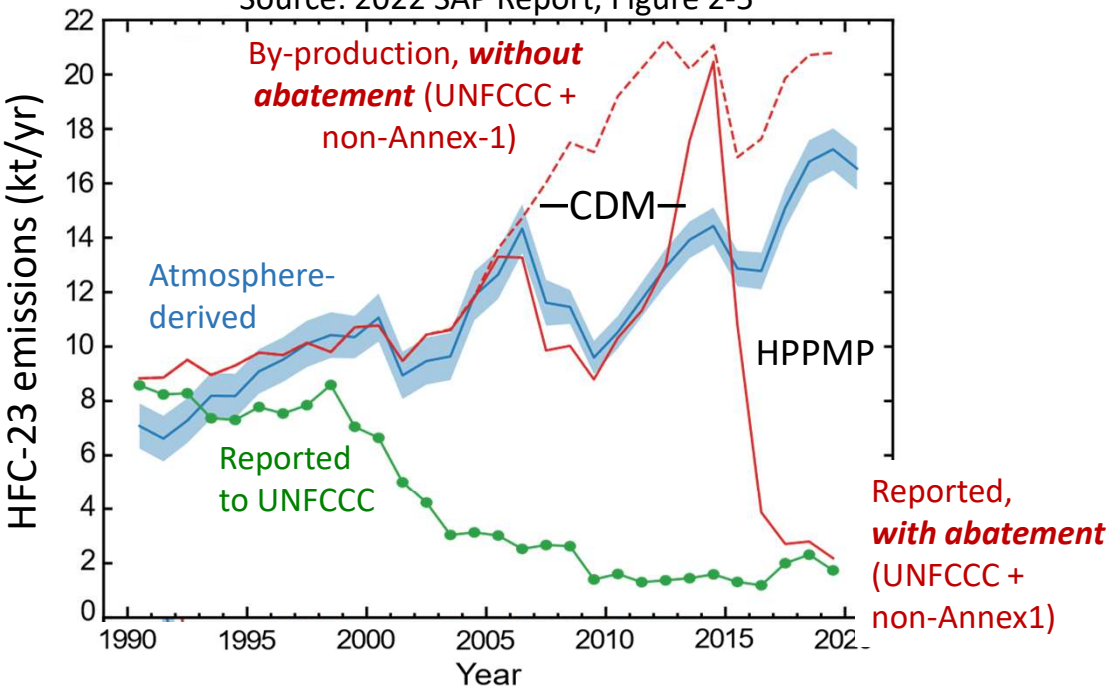

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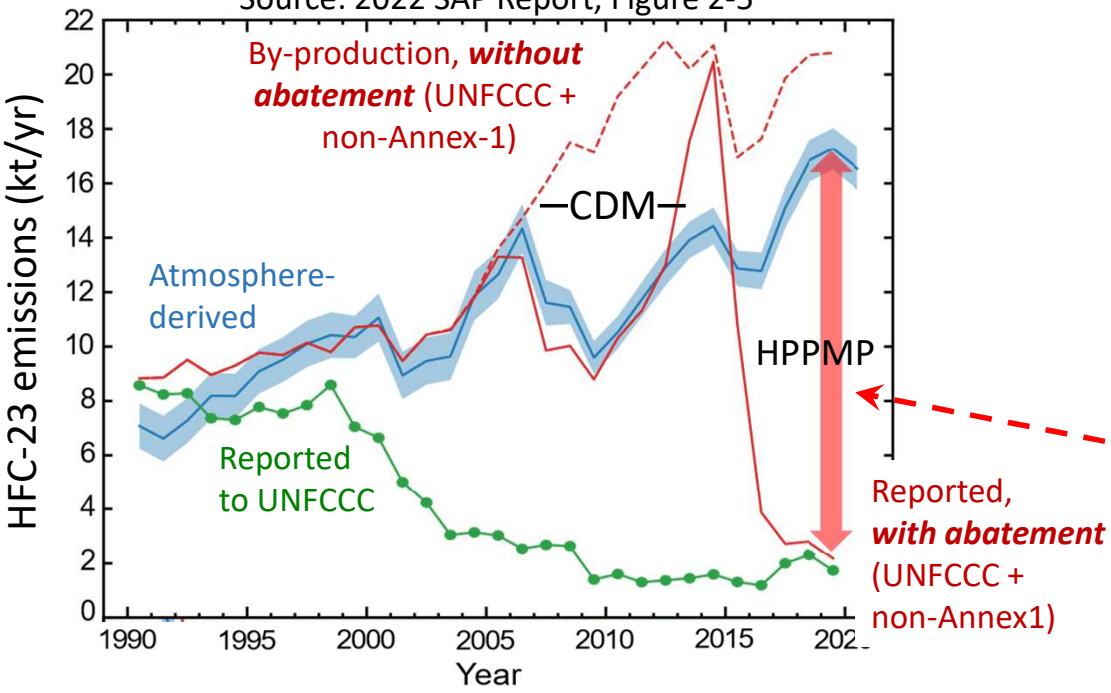

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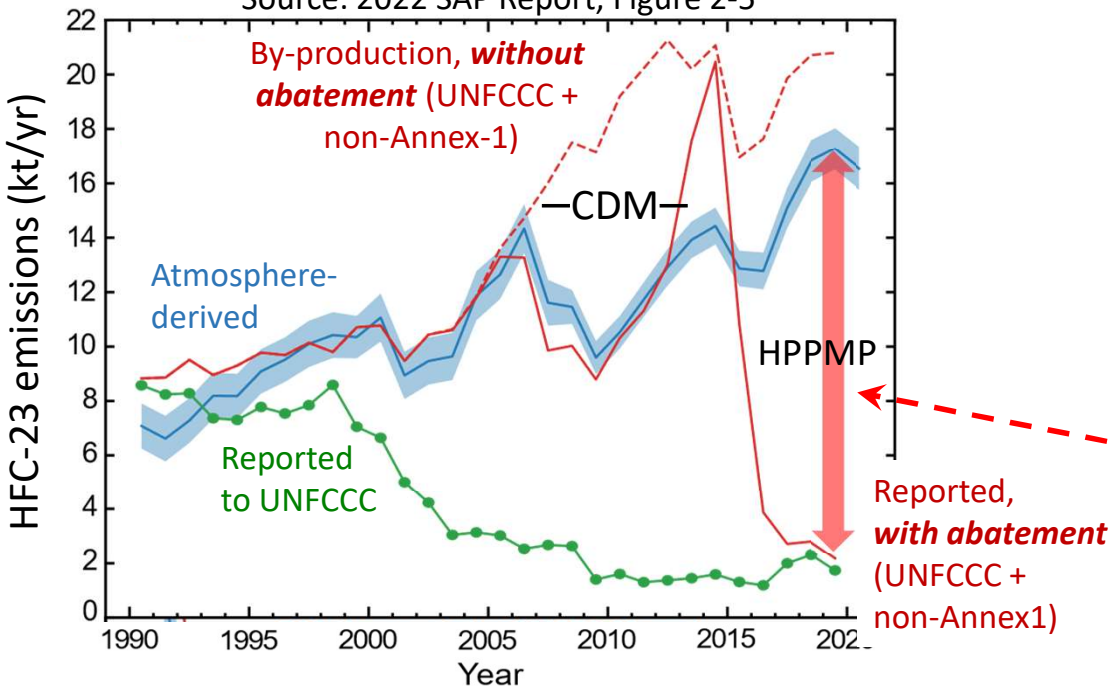

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Relevant considerations:

* Are there other HFC-23 sources?
  → See Part 2 (Nick C. and TEAP)
* observed & expected emissions agreed prior to 2013; what changed after 2014-2015?

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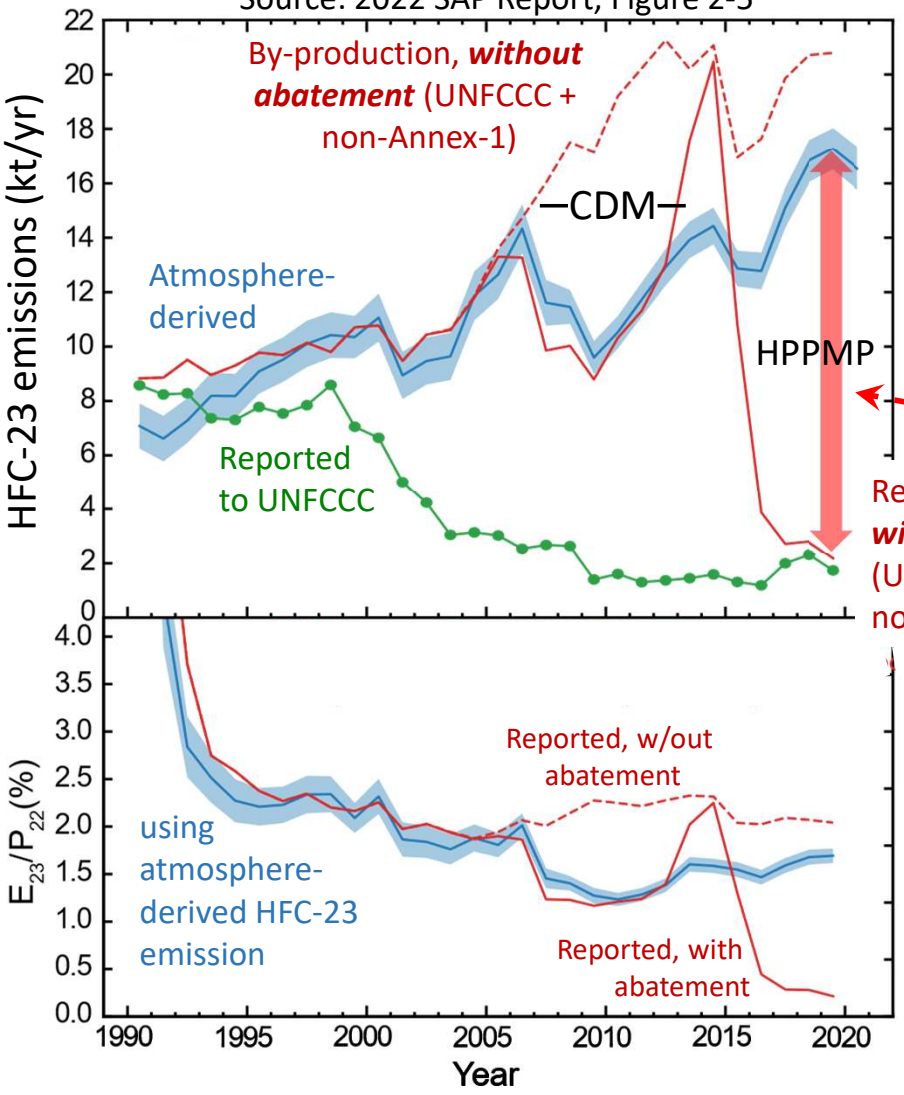

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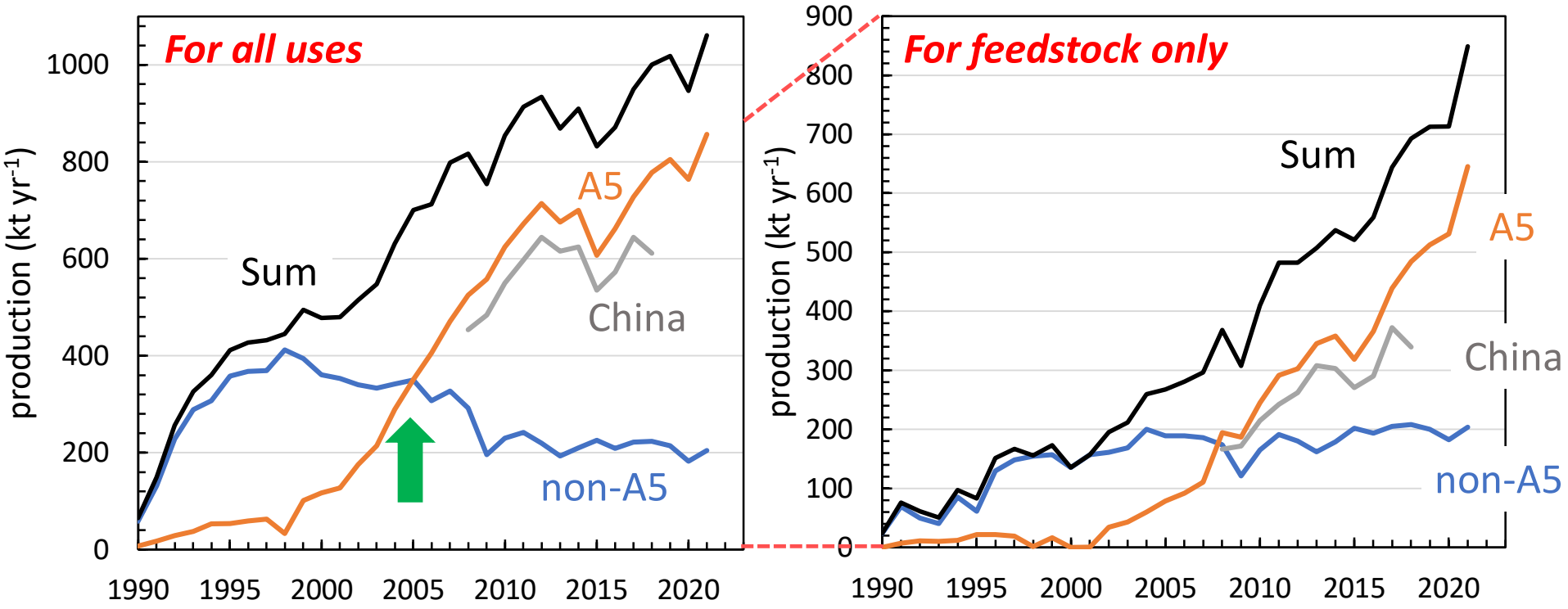
HCFC-22 production continues to increase



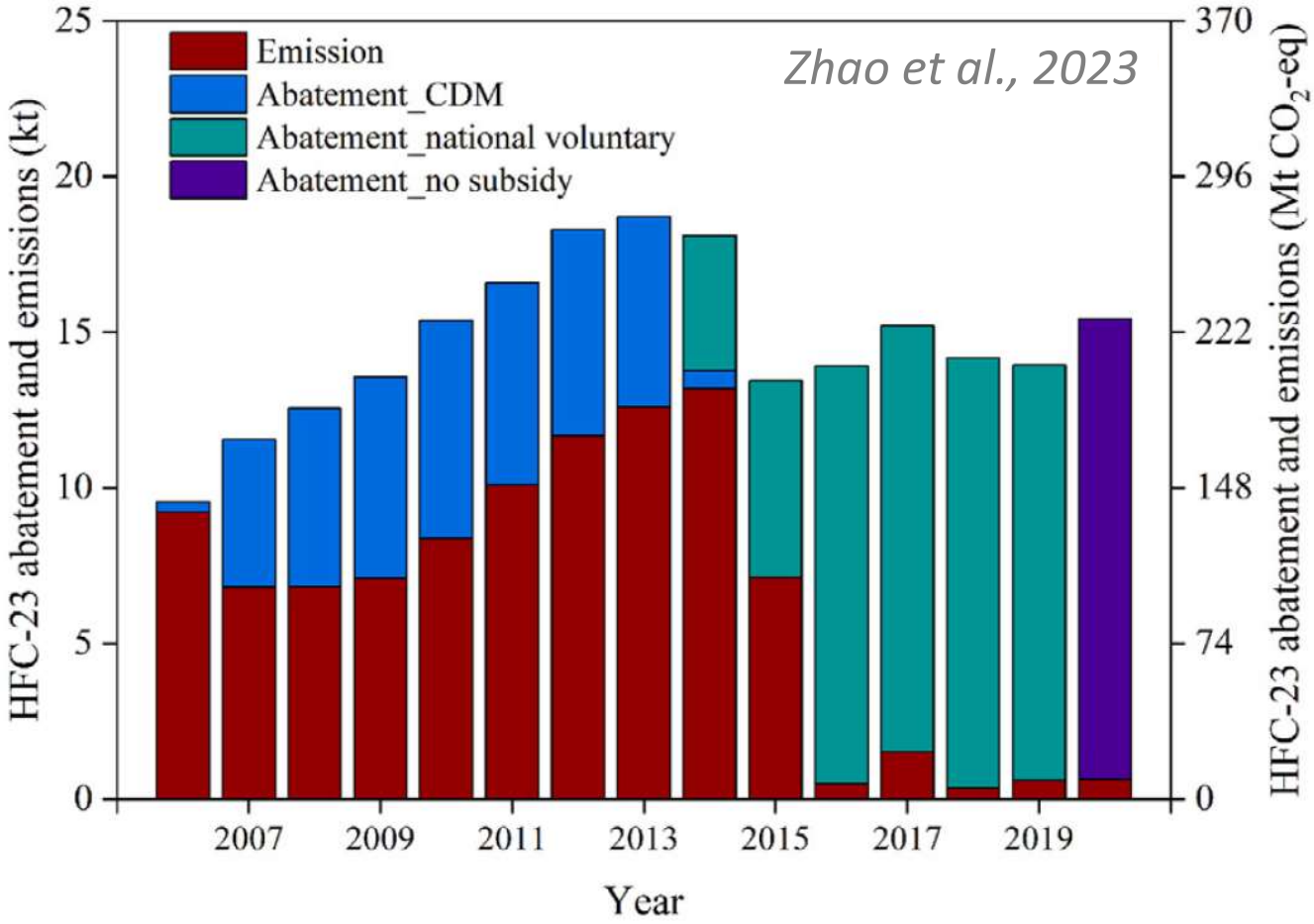
Reported HCFC-22 production:

a) **A5 production now dominates,** it surpassed non-A5 after 2005
b) **The continued increase is from feedstock production**
c) **production in China** is dominant

Sources: G. Mutisya, Ozone Secretariat, 2023; China data from MLF replenishment report (TEAP 2021)

Reporting-based HFC-23 emissions and abatement from China

(accounting related to HCFC-22 production only)



Zhao et al., *Advances in Climate Change Research* 14 (2023) 136e144

based on this reporting, Chinese HFC-23 emissions abatements of **13 to 15 kt yr^{-1}** were expected during 2016 – 2020 from HCFC-22 production.

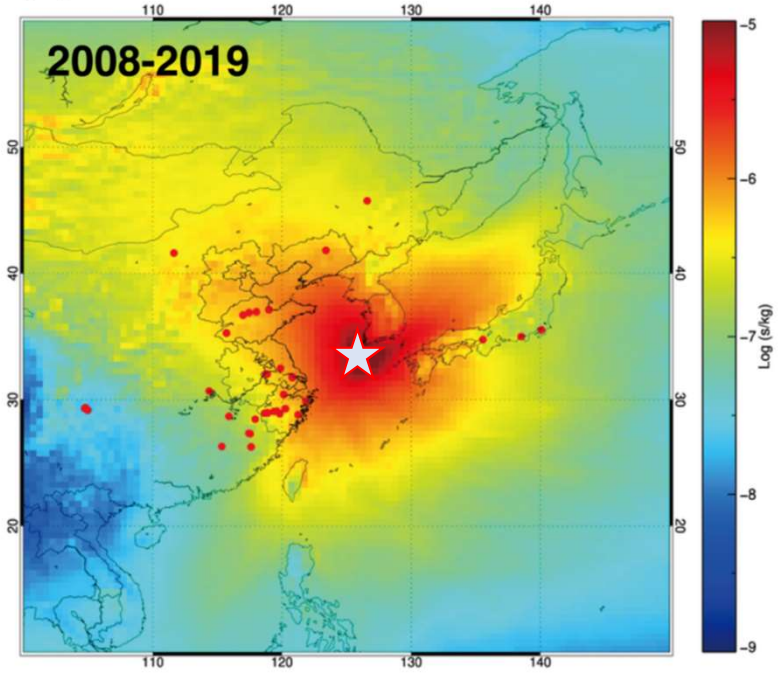
For reference, HFC-23 *by-production* associated with HCFC-22 production from all other A5 countries was approximately 2 kt yr^{-1}

Using atmospheric measurements to assess eastern Asian emissions

(just like the approach for CFC-11)

Recently published paper: Park, H. *et al*. "**A rise in HFC-23 emissions from eastern Asia since 2015**", *Atmospheric Chemistry and Physics*, 2023; https://doi.org/10.5194/acp-23-9401-2023

Regional emission sensitivity for measurements at the Gosan station:



Hotter colors = more sensitivity
Red dots = HCFC-22 production facilities

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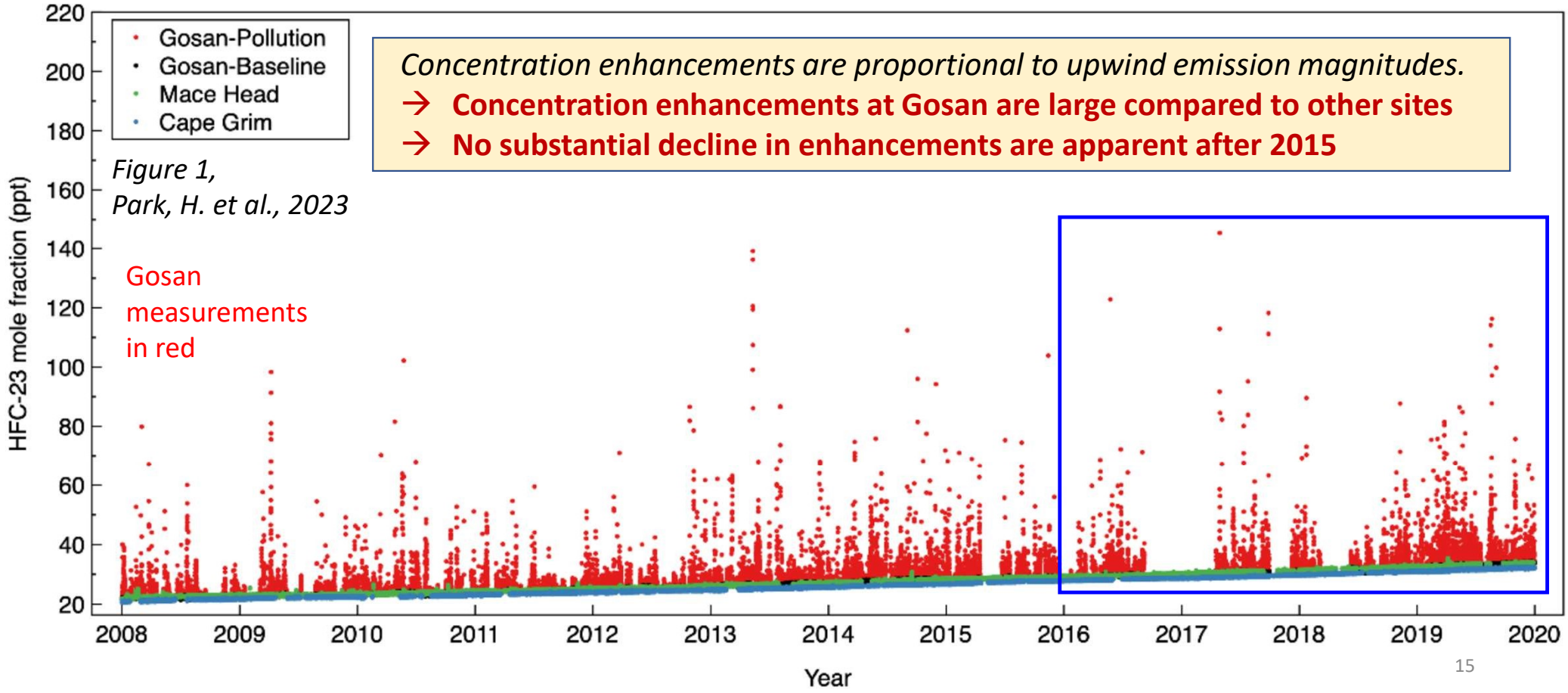


Figure 1, Park, H. et al., 2023

Gosan measurements in red

Concentration enhancements are proportional to upwind emission magnitudes.

→ **Concentration enhancements at Gosan are large compared to other sites**

→ **No substantial decline in enhancements are apparent after 2015**

HFC-23 emissions derived for eastern Asian regions from measurements at Gosan station

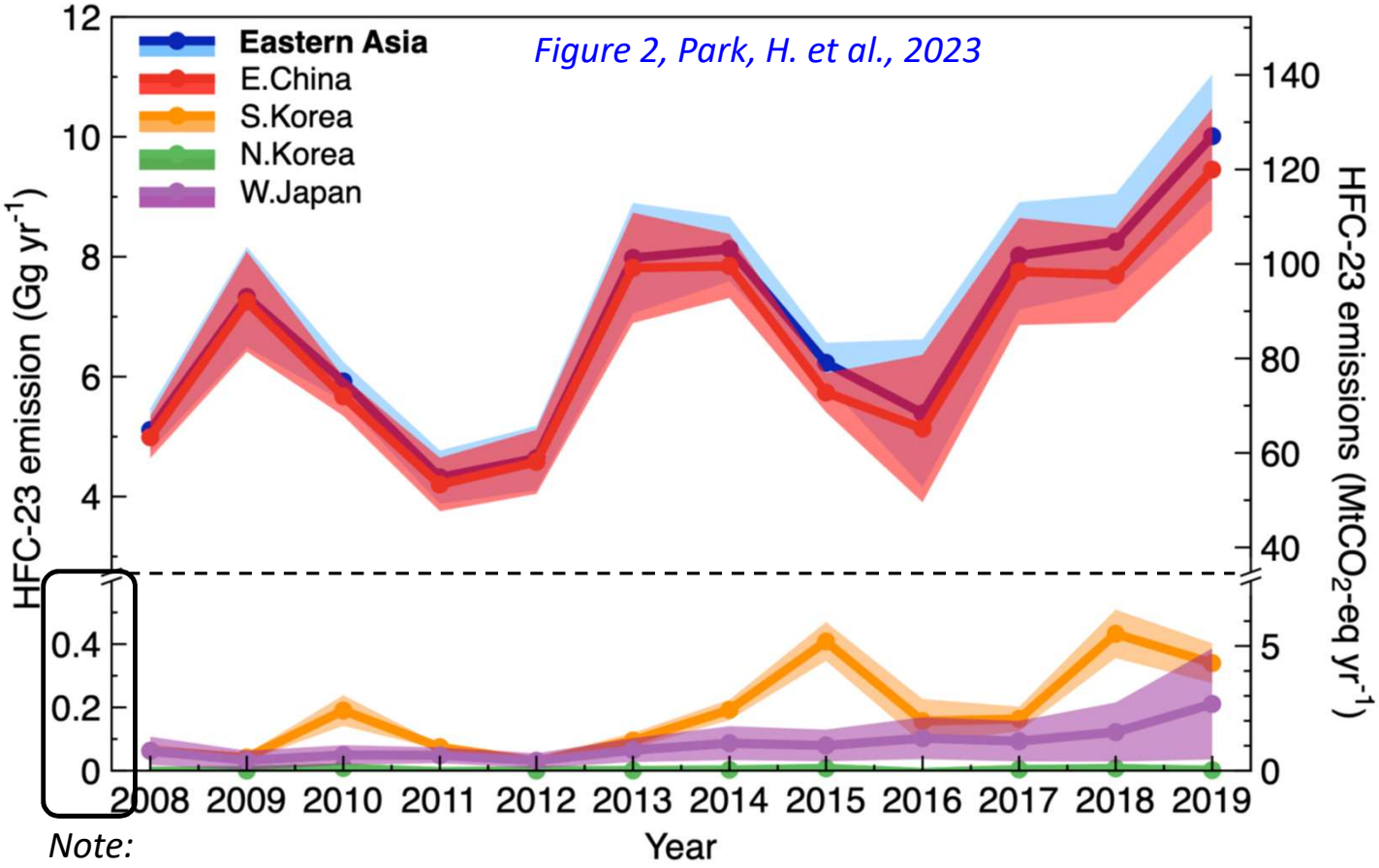


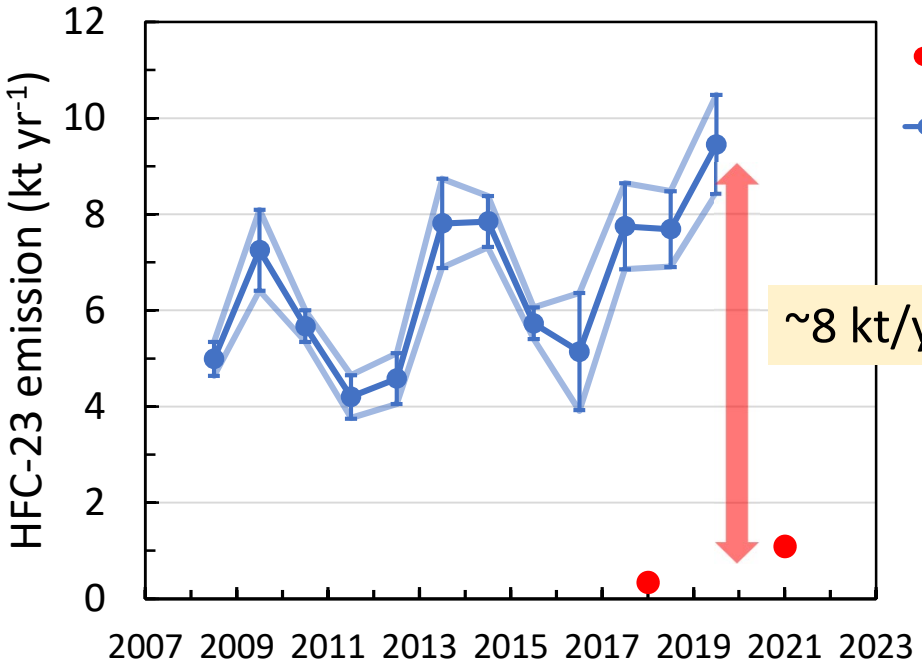
Figure 2, Park, H. et al., 2023

Note: expanded scale

* Emissions in region:
  - ***dominated*** by eastern China
  - ***increased*** after 2015-2016
* Eastern China emissions
  - **continued and increased after 2015**
  - **are inconsistent with reported abatement**.
* Do other sources contribute?

Technical detail:
Method here is comparable with those used in the CFC-11 studies.

Chinese HFC-23 emissions derived from atmospheric measurements



Gosan derived emissions from:
H. Park *et al.*, *ACP*, 2023

- Expected, ***all of China*** (reporting to ExCom, 2021 & 2023)
- Observation-derived, ***eastern China only*** (Gosan inversion)

These results suggest

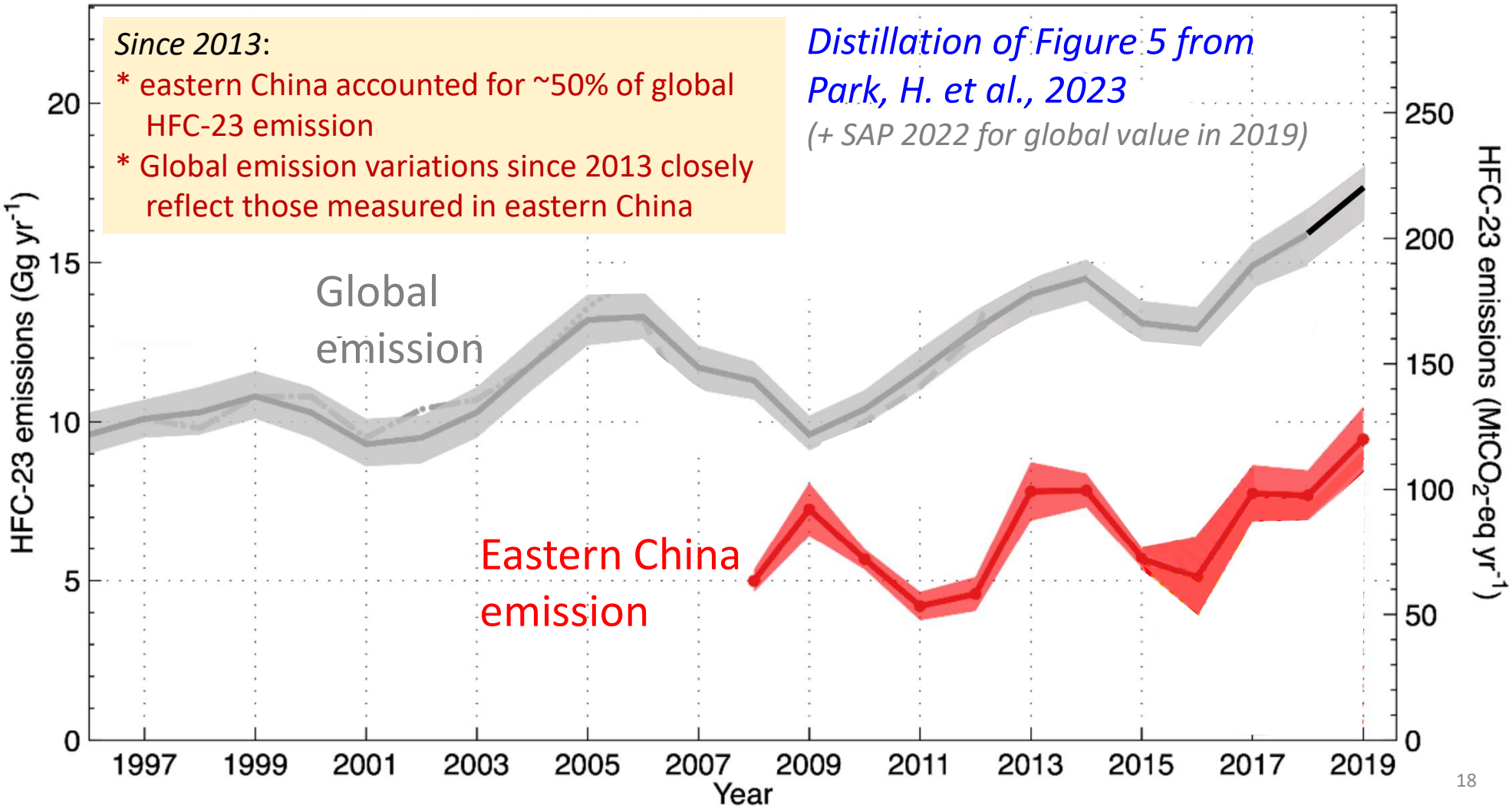
1) substantial continued emissions from eastern China after 2015
2) Emissions from eastern China ***account for about half of the global gap*** in emissions of 15 kt/yr

Substantial emissions Chinese have also been confirmed with measurements from a site in northern China (Shiangdianz), but the magnitudes are very uncertain

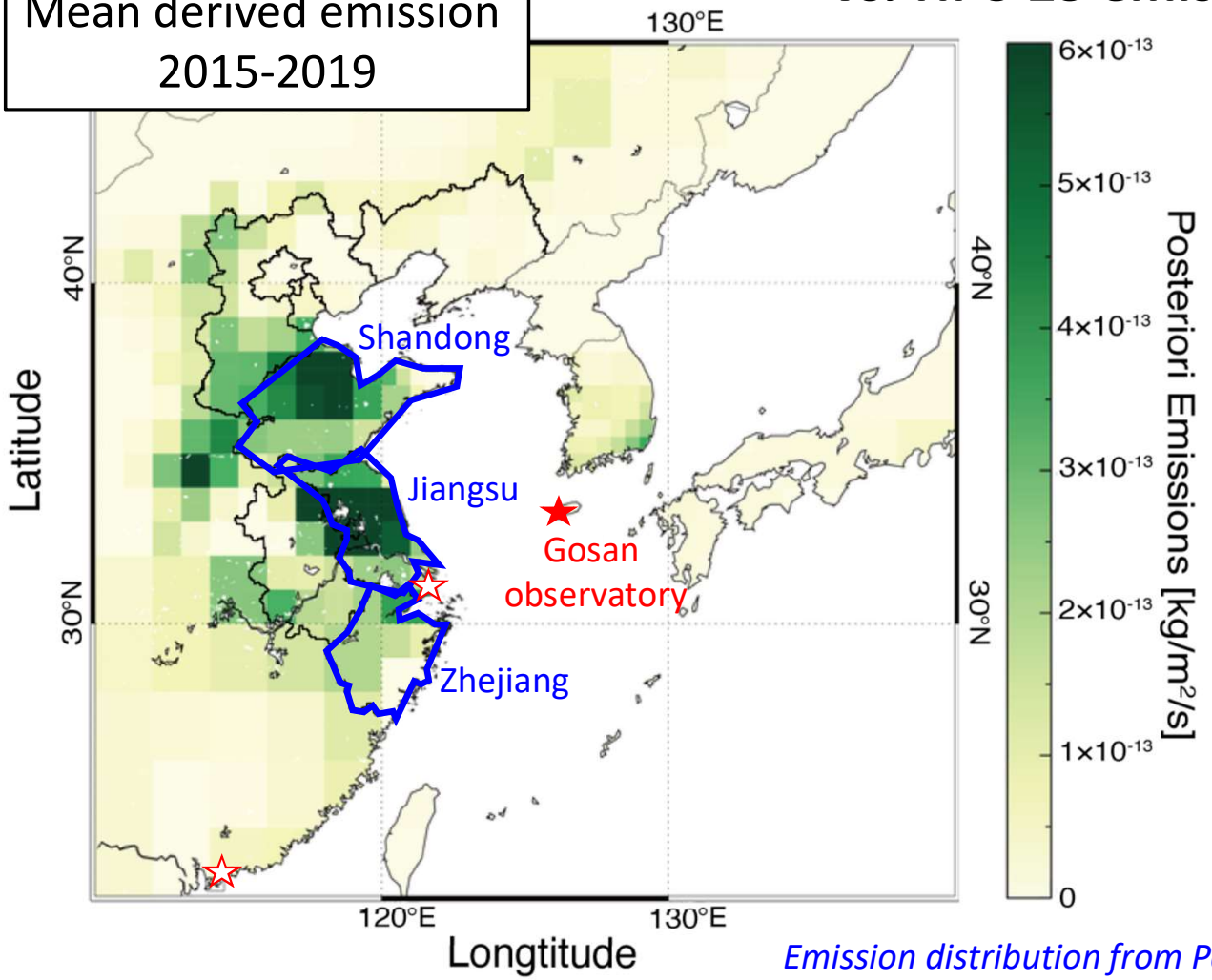
Comparing recent emission changes: Global totals *vs* eastern China:

Since 2013:
* eastern China accounted for ~50% of global HFC-23 emission
* Global emission variations since 2013 closely reflect those measured in eastern China

Distillation of Figure 5 from Park, H. et al., 2023
(+ SAP 2022 for global value in 2019)



Considering spatial information: distribution of reported HCFC-22 production *vs.* HFC-23 emission derived with Gosan data



2018 production of HCFC-22 in China for all uses was provided for 11 plants (TEAP, 2023):

Shandong, 1 plants, 2018 total = 207 kt
Jiangsu, 3 plants, total = 179 kt
Zhejiang, 6 plants, total = 190kt

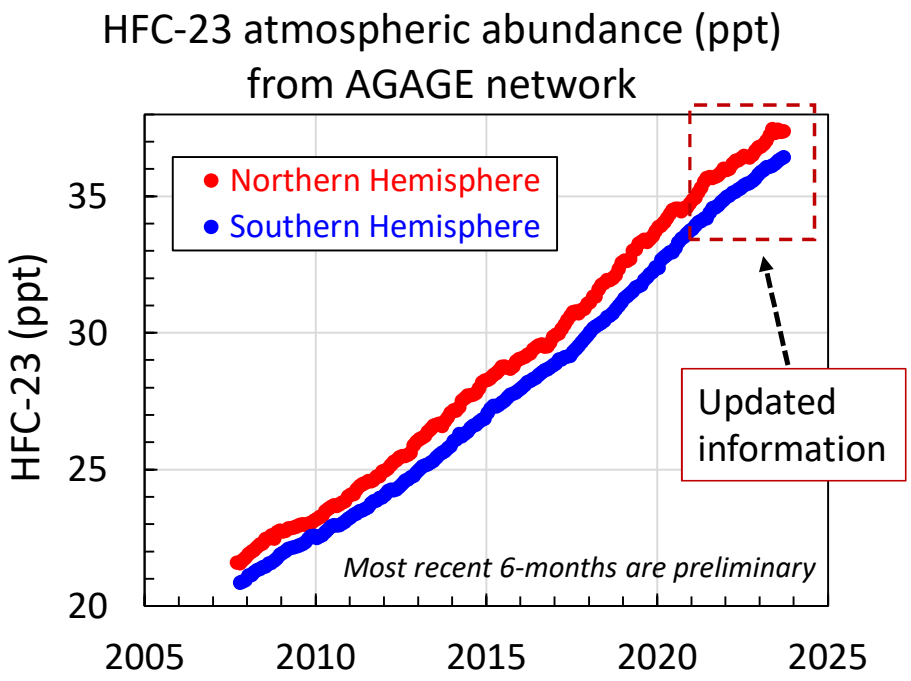
Production in these three provinces accounts for 94% of total reporting from China in 2018 (TEAP 2021 & TEAP 2023)

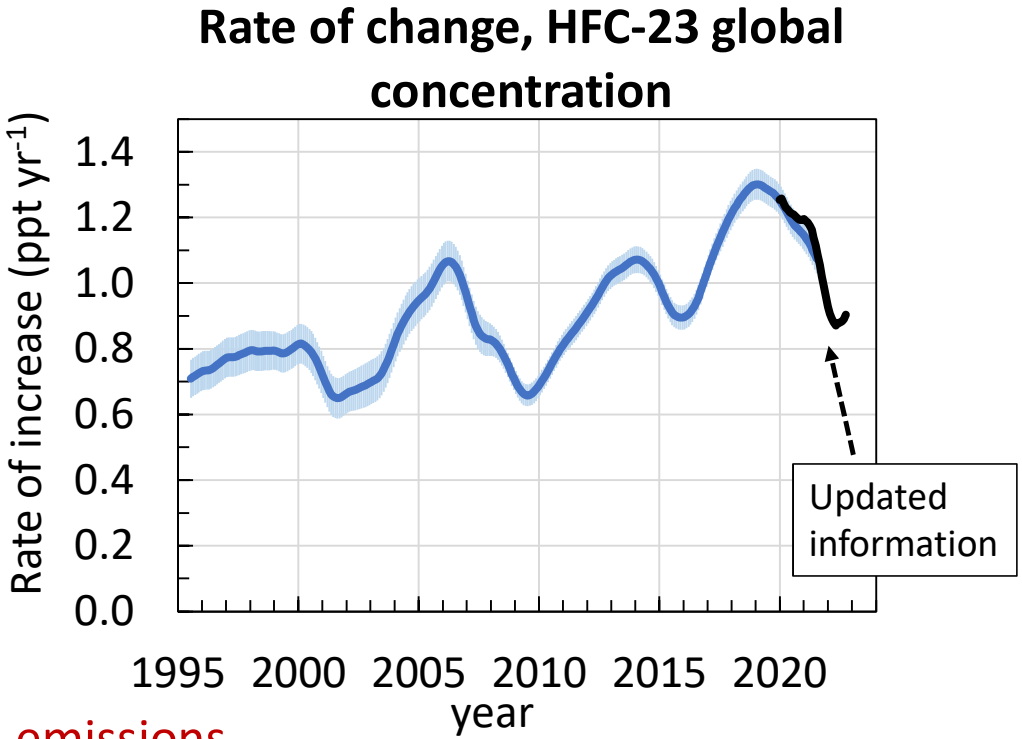
- Some known HCFC-22 production locations roughly align with emission "hot spots" identified for 2015-2019 by Gosan data.
- New sites in China coming on line now

Emission distribution from Park et al., 2023, Figure 4

Updated HFC-23 atmospheric changes since the 2022 SAP Report

– from the *AGAGE network* *(data in recent 6 months are preliminary)*





* NH emissions are >> SH emissions

* 2021 emissions are slightly lower than 2020

Thanks to R. Prinn, R. Weiss, L Western and the AGAGE science team for sharing updated data (up to summer 2023)

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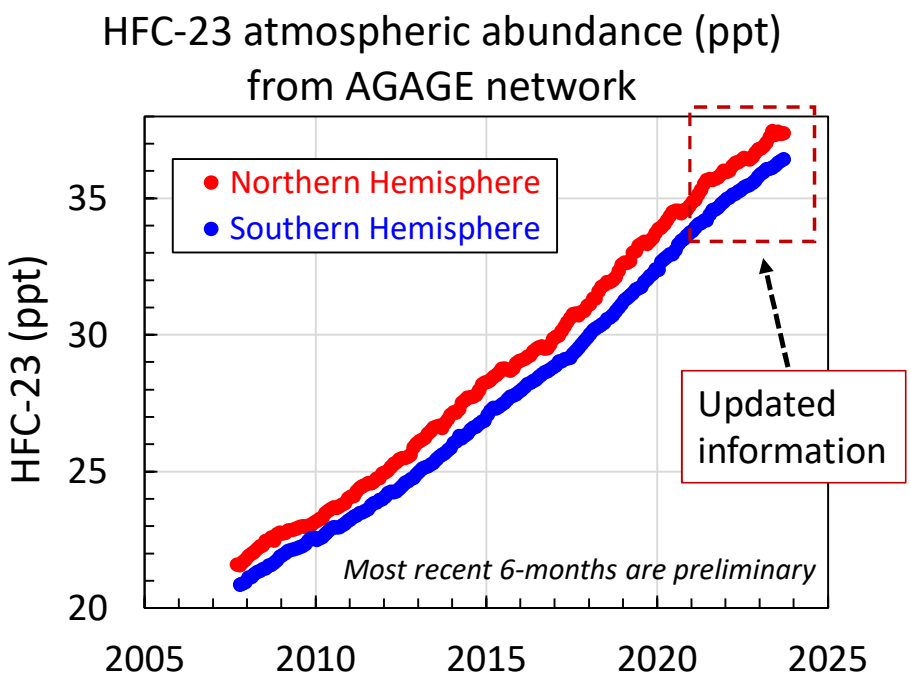

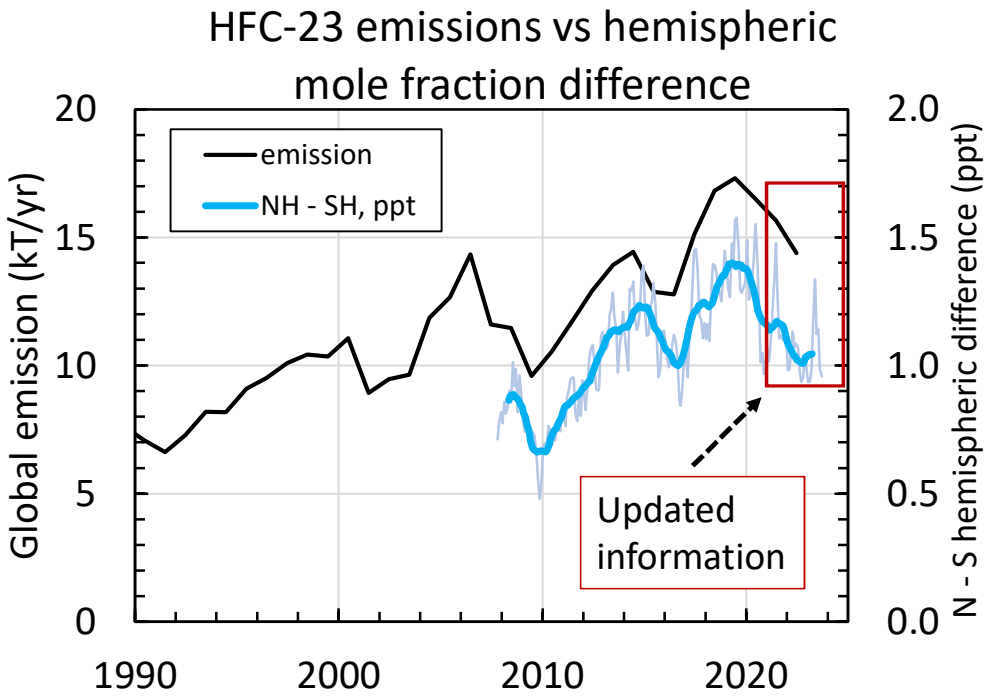

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Summary:

Emissions of HFC-23 have a higher GWP_{100} than any other hydrofluorocarbon

During 2016-2020

- *Atmospheric concentrations of HFC-23*
  - **-increased more rapidly than at any other time;** UPDATE: *the increase slowed slightly after 2019*
- *Global emissions of HFC-23*
  - **-were larger than at any other time;** UPDATE**:** *emissions declined slightly after 2019*
  - **-were substantially larger than expected** given reports of mitigation (17.2 ± 0.8 vs 2.2 kt yr^{-1} in 2019)
  - *-are **"inconsistent with new information suggesting a substantial rise in abatement independent of Kigali Amendment controls." (SAP 2022)***

The effective global ratio $Emission_{HFC\text{-}23}$ / $Production_{HCFC\text{-}22}$ has not decreased in recent years.

HFC-23 emissions from eastern China:

* **account for ~50% of global emissions** *and about half of the global gap in emission in 2016-2019*

* **increased since 2015-16,** despite reporting of substantial mitigation during that time (HPPMP)

- New atmospheric measurement sites are coming on-line in China now
- Enhanced availability of quantitative production and destruction values (by chemical, disaggregated) would enhance our understanding of the HFC-23 budget