SAP interim report on increased emissions of CFC-11

Scientific Assessment Panel

SAP co-chairs: Bonfils Safari, John Pyle,

David Fahey, Paul A. Newman

41st Open Ended Working Group
Bangkok, Thailand
July 1-5, 2019

Outline

- Some basics on CFC-11
- CFC-11 observations and global network
- What's in WMO/UNEP [2018]?
- What was said at the CFC-11 Symposium in Vienna in March?
- New paper by Rigby et al. [2019] showing regional emissions
- Plans for CFC-11 research and reporting

Trichlorofluoromethane, CFC-11, $CFCl_3$

- Produced from the fluorination of CCl_4:

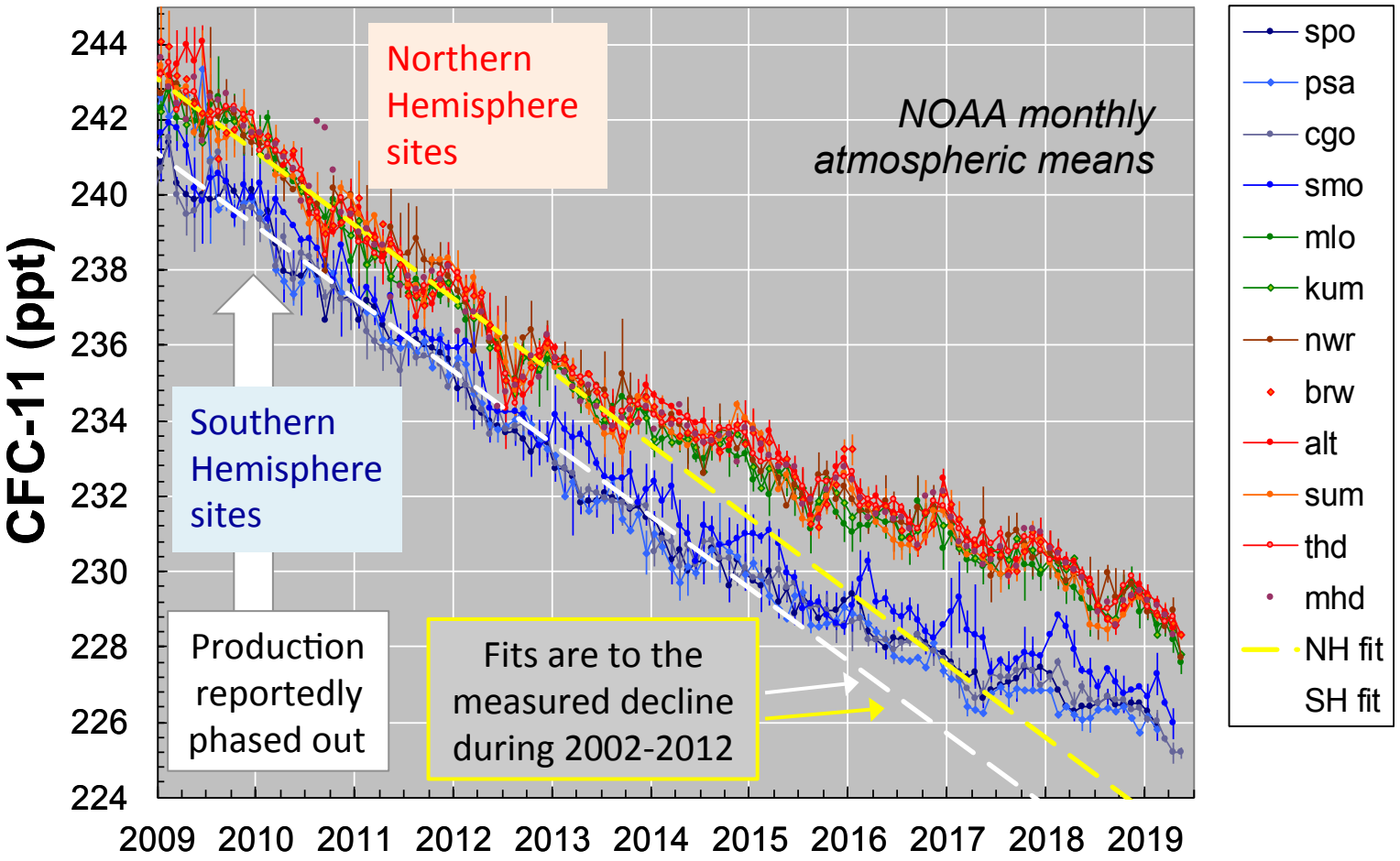
$$CCl_4 + HF \rightarrow CCl_3F + HCl$$

- Used in the past primarily for blowing foams and as a refrigerant; also in other applications (medical devices, as a solvent).
- Atmospheric lifetime due to photolysis in the stratosphere is ~52 years.
- Potent ozone-depleting agent:
  - Ozone depletion potential = 1.0
- Greenhouse gas
  - 100-yr GWP = 5160
- Production reportedly phased out in 2010. Replaced with HCFC-141b, HFC-245fa, & others. See TEAP presentation

Analytical foundation of global and regional ODS emissions determinations

- Precise, accurate, long-term measurements from two ground-based networks are the foundation of all inferences of the magnitude and trends in global and regional ODS emissions.
- Derivation of the magnitude and trends of global emissions use time series of the average global abundance, ODS atmospheric lifetime, and the interhemispheric gradient.
- Magnitude and trends of regional emissions are derived from network measurements combined with meteorological information of prevailing winds from source(s) to measurement sites (back trajectories).
- Global emissions of long-lived species require only a few network stations. Emissions from a specific region require nearby downwind stations.

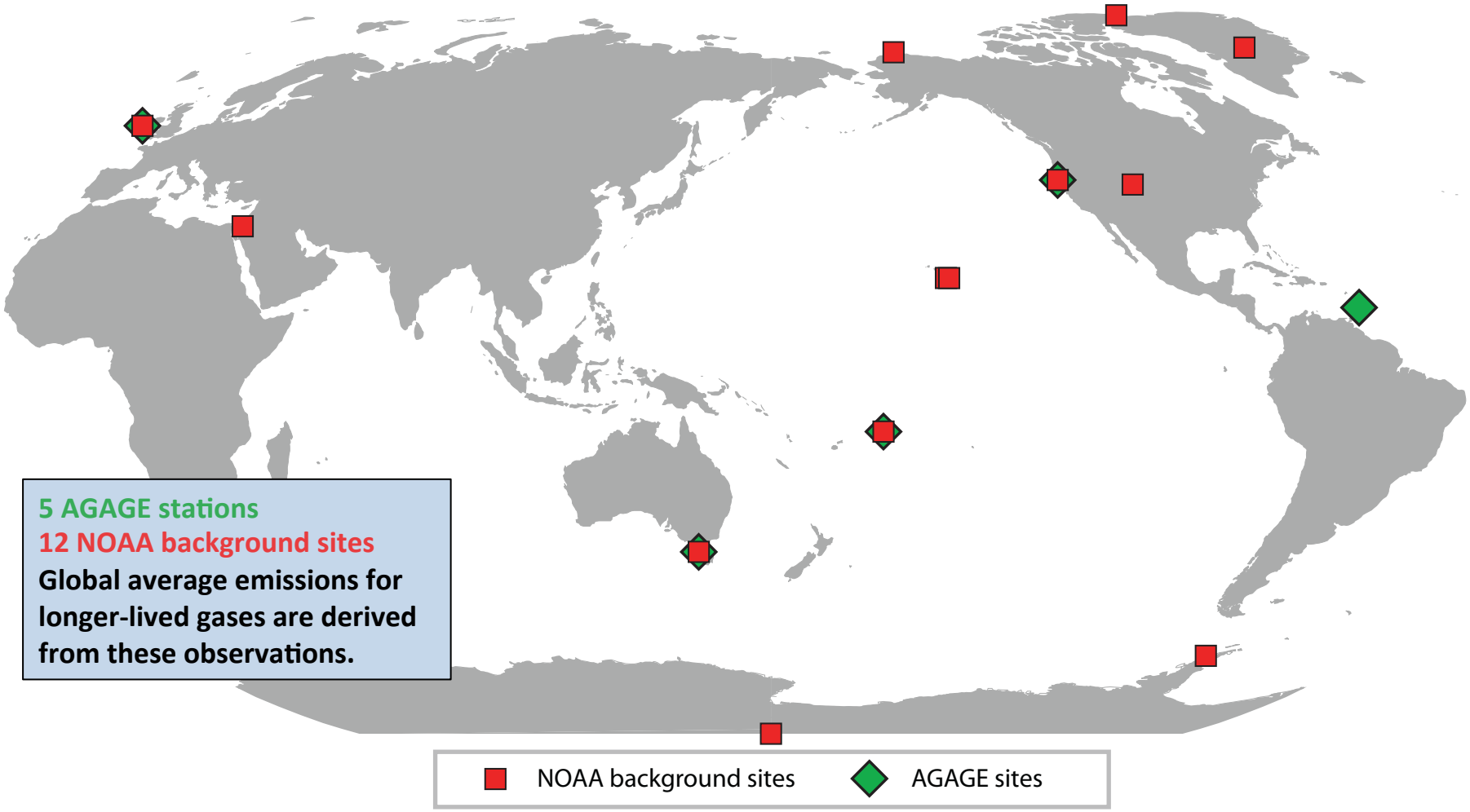
Measured CFC-11 concentrations at multiple sites around the world



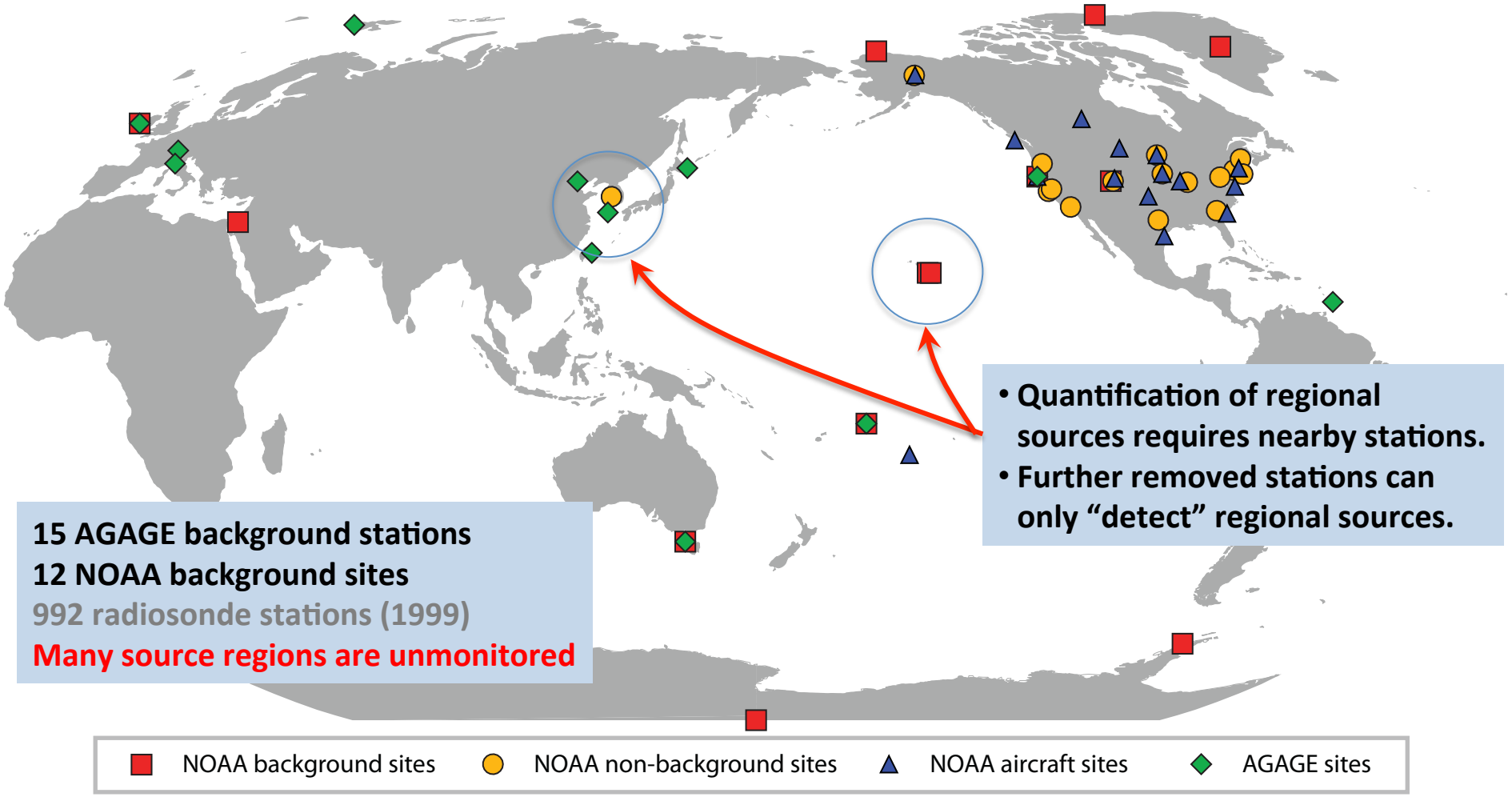
The decline in atmospheric CFC-11 has unexpectedly slowed recently (or since 2013)

Montzka et al. (2018)

Where are the monitoring stations?



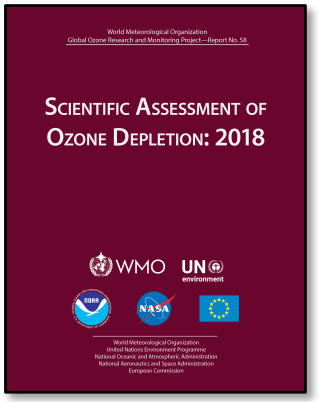
Where are the monitoring stations?



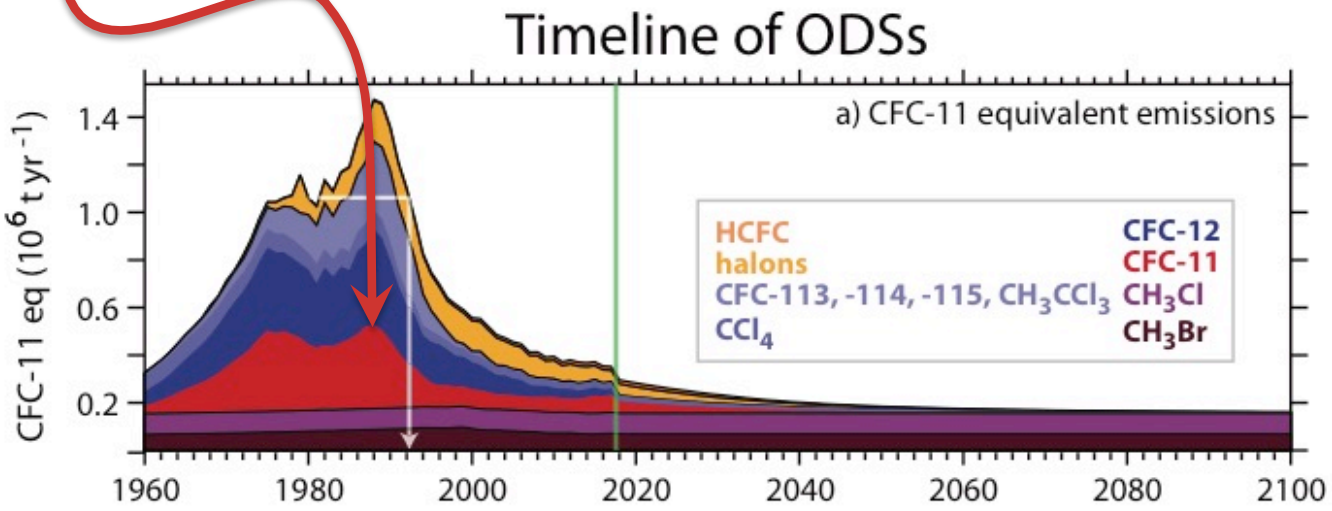
CFC-11 in the Executive Summary WMO/UNEP [2019]

There has been an unexpected increase in global total emissions of CFC-11.

- Global CFC-11 emissions derived from measurements by two independent networks increased after 2012, thereby slowing the steady decrease in atmospheric concentrations reported in previous Assessments.
- The global concentration decline over 2014 to 2016 was only two-thirds as fast as it was from 2002 to 2012.
- While the emissions of CFC-11 from eastern Asia have increased since 2012, the contribution of this region to the global emission rise is not well known. The country or countries in which emissions have increased have not been identified. [ES Section 1]

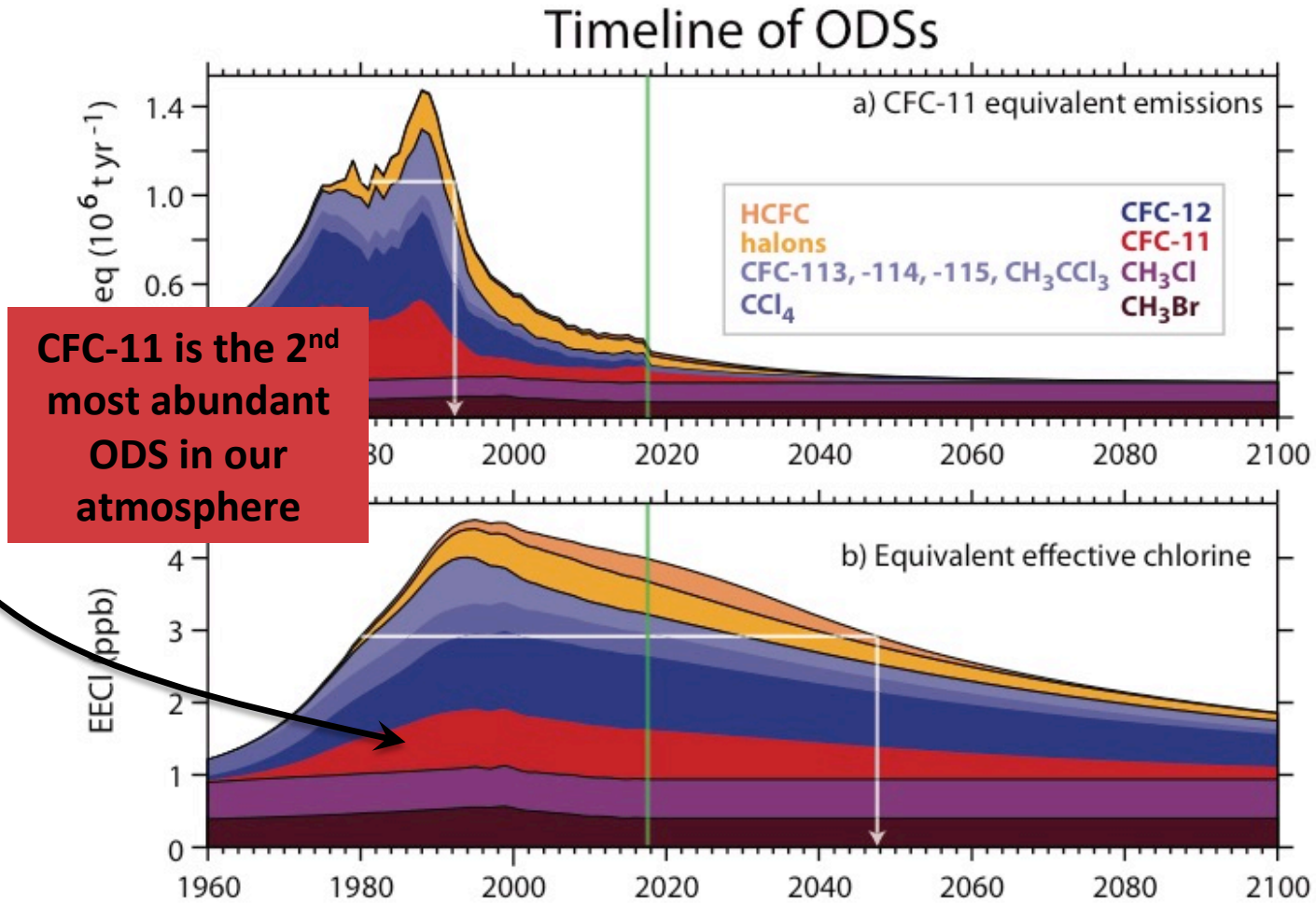


CFC-11 emissions peaked in the late-1980s and have greatly declined



WMO [2019] Figure ES-1

With its 52-year atmospheric lifetime, CFC-11 will persist through the 21st century



CFC-11 is the 2nd most abundant ODS in our atmosphere

WMO [2019] Figure ES-1

Reported CFC-11 has declined

- **Reported CFC-11 production and consumption to UN Environment was nearly zero by 2010**

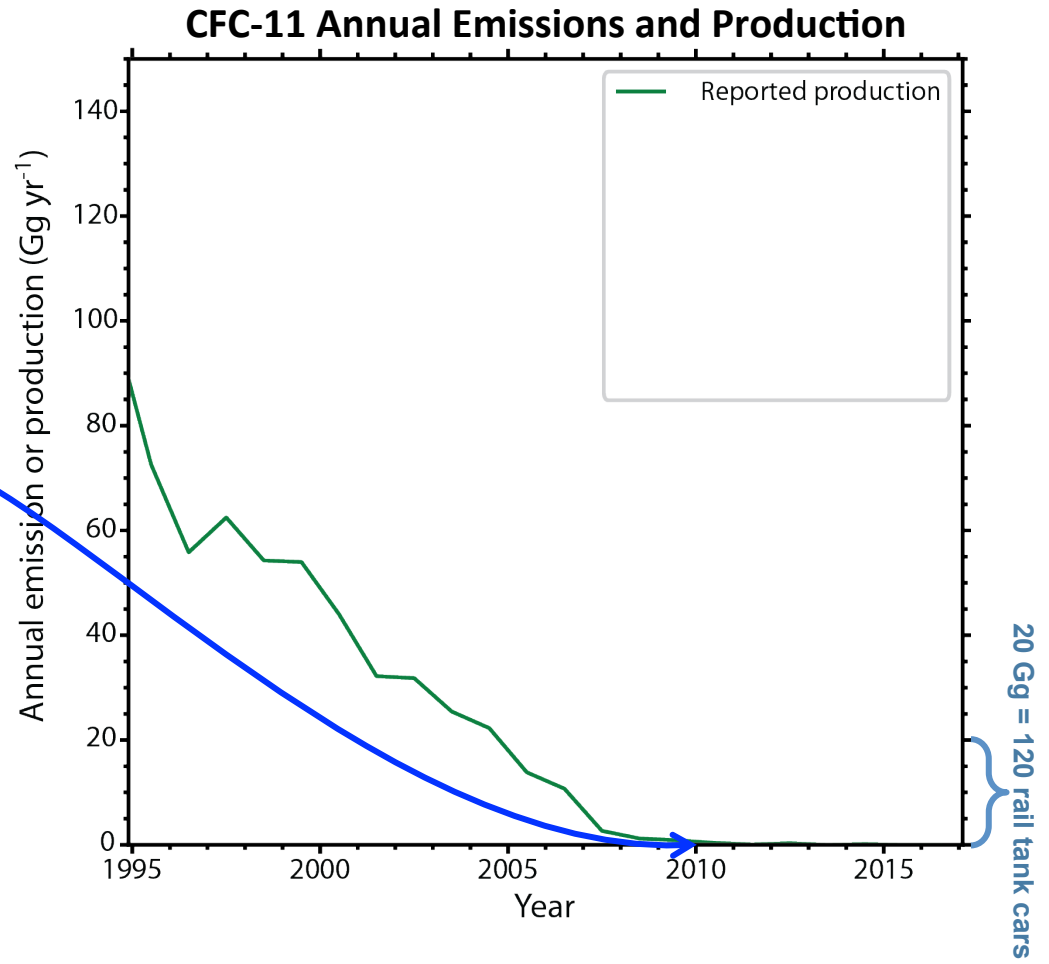


Figure ES-2

Emission projections in the WMO/UNEP [2006] Assessment were downward

- **Through the 2006 assessment, the trajectory of the CFC-11 emissions was downward**

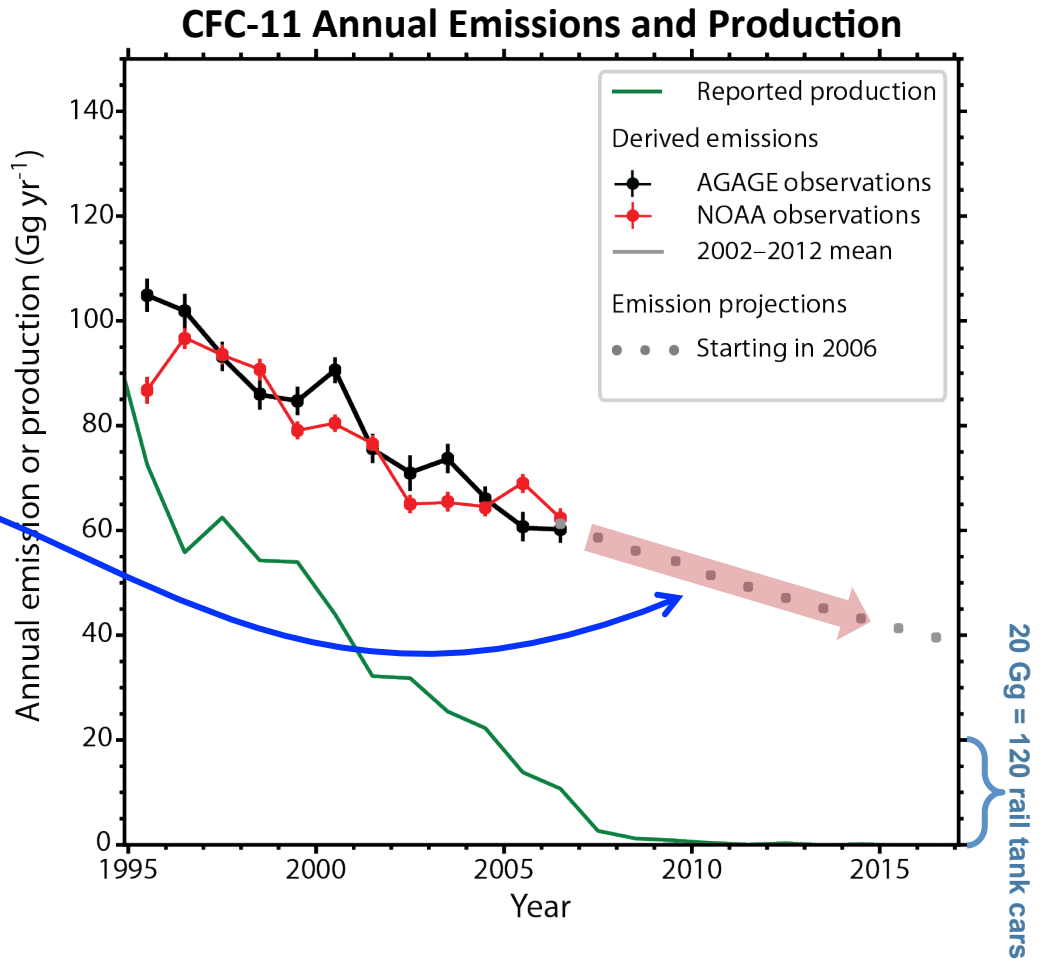


Figure ES-2

The decline of CFC-11 emissions slowed in the 2005-2012 period

For the 2005-2012 period, CFC-11 emissions had stopped declining, and stabilized at about 60-70 Gg per year.

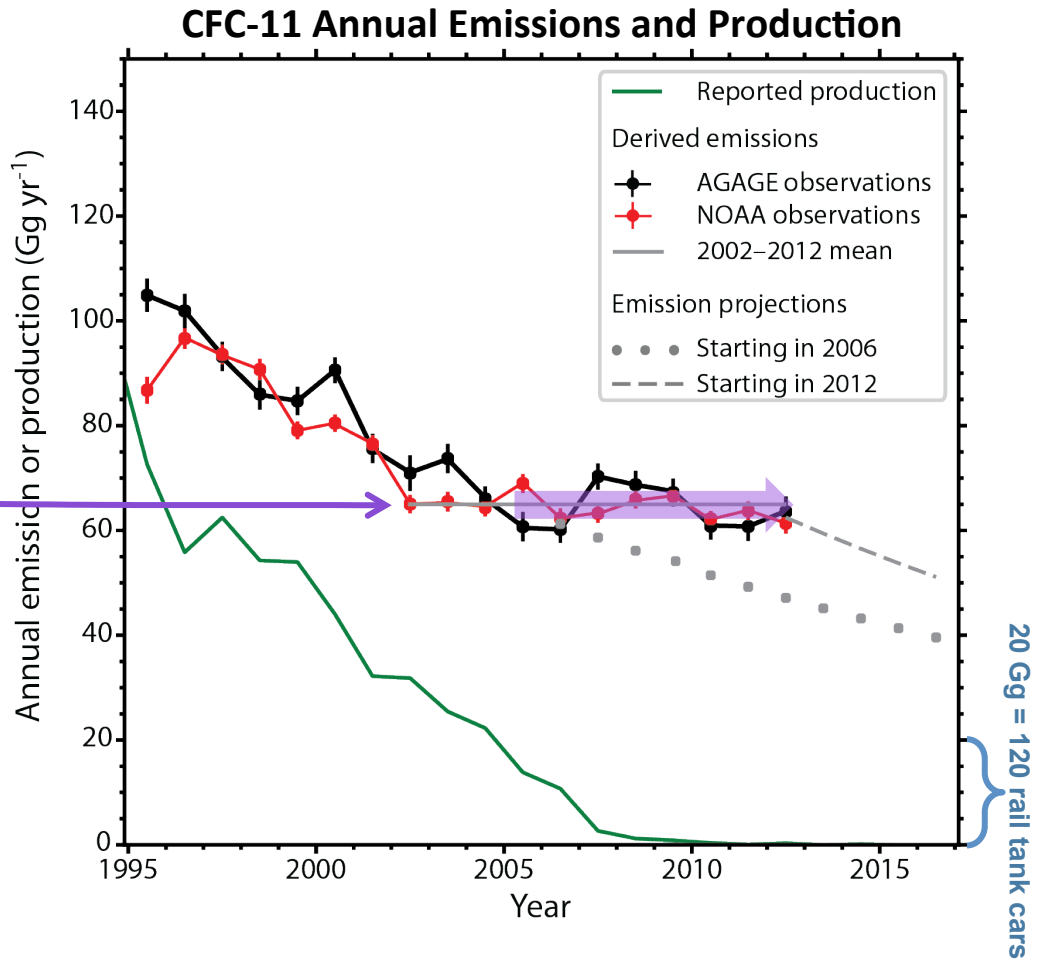


Figure ES-2

CFC-11 emissions are increasing

- There has been an unexpected and unreported ***increase*** in global total CFC-11 emissions in the 2014-2016 period.

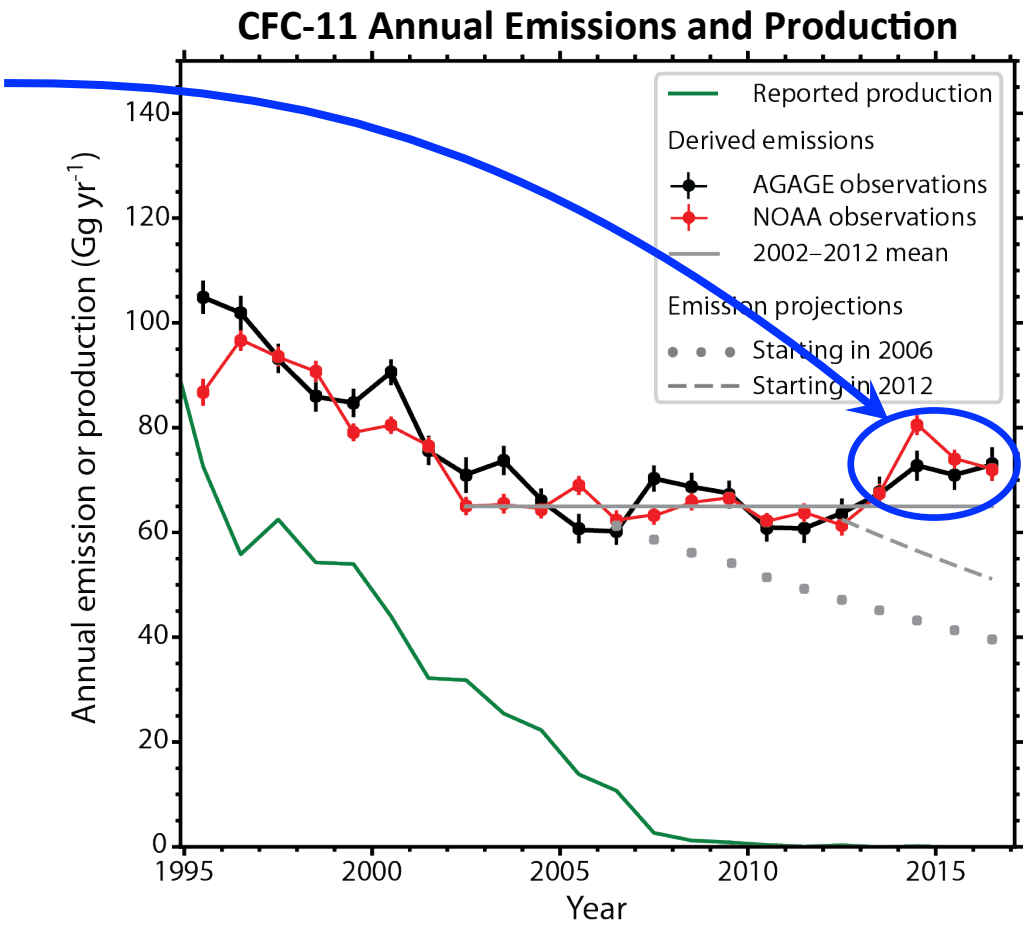


Figure ES-2

CFC-11 emissions are increasing

- There has been an unexpected and unreported ***increase*** in global total CFC-11 emissions in the last 4-5 years.
- Estimated increase in global emissions of approximately **10 Gg yr^{-1} (~15%)** is found for 2014–2016, compared to 2002–2012
  - Unlikely to be explained by increasing emissions from banks (reservoirs)
  - Findings may indicate new production not reported to the UN Environment. Source region has been described as 'eastern Asia'.
  - Emissions are **not currently** a threat to the ozone layer.

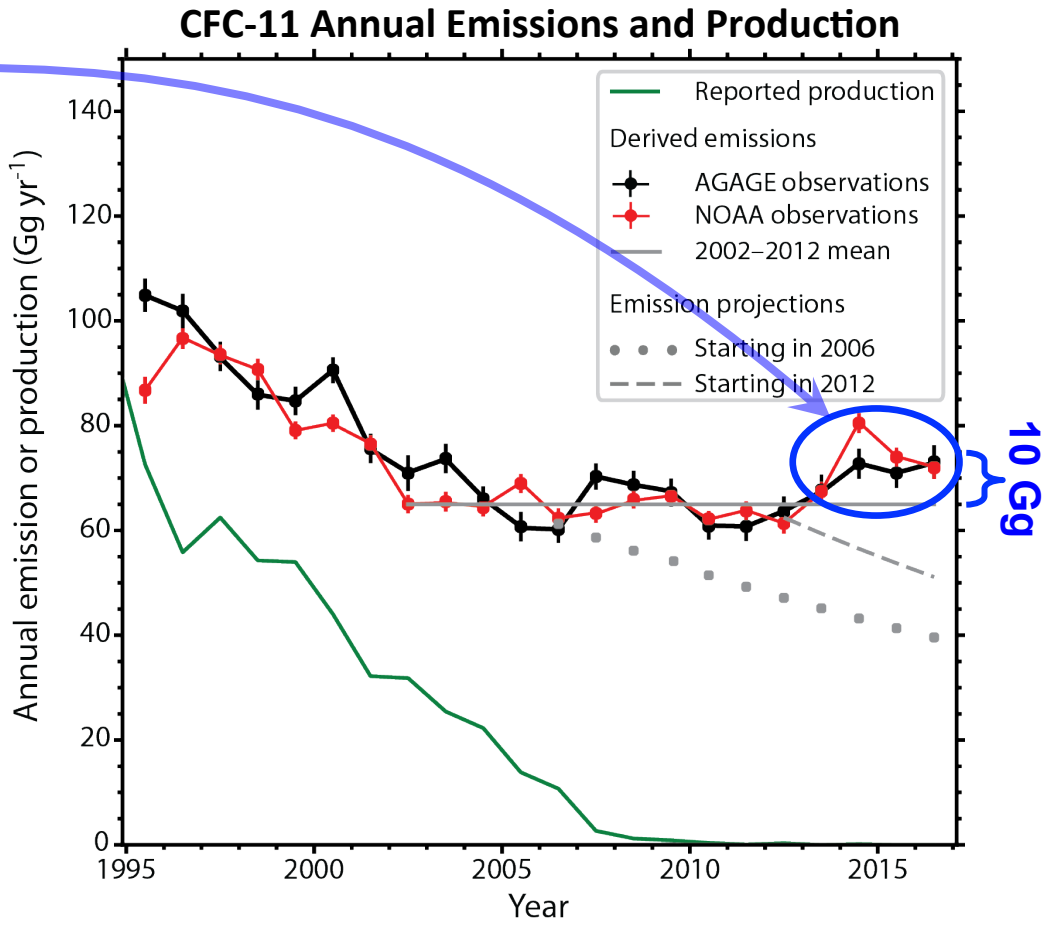


Figure ES-2

The International Symposium on the Unexpected Increase in Emissions of Ozone-Depleting CFC-11

- **25 - 27 March 2019, United Nations Office, Vienna, Austria:** Closed scientific and technical meeting for the exchange of new ideas and information
- **Organizing Committee:** Geir Braathen (WMO), Neil Harris (SPARC), Paul A. Newman (SAP), Bella Maranion (TEAP), Sophia Mylona (Ozone Secretariat)
- **Scientific Programme Committee**: Tina Birmpili (Ozone Secretariat), Geir Braathen (WMO), Neil Harris (SPARC), Jianxin Hu (Univ. Beijing), Ken Jucks (NASA), Paul Newman (SAP), Bella Maranion (TEAP), Steve Montzka (NOAA), Sophia Mylona (Ozone Secretariat), Sun Young Park (Korea), Stefan Reimann (Empa), Matt Rigby (Univ. Bristol), Takuya Saito (Japan), Helen Tope (TEAP)
- **Participants:** 71 (22 countries), with 37 presentations. Representatives of the SAP, TEAP, and EEAP attended.

Report on the International Symposium on the Unexpected Increase in Emissions of Ozone-Depleting CFC-11

OEWG Conference Portal

- Brought together international community of experts to exchange information on CFC-11 (feed stocks → production → products → observations → emissions → impacts).
- Unpublished new and updated results based on observations and models
- Field studies of the mixture of gases emitted by a number of sources
- Technical assessment of possible new sources of CFC-11 emissions (see TEAP report).
- Atmospheric modelling studies of the impact of continuing new emissions on stratospheric ozone.
- Generated a set of research directions and recommendations for improving monitoring of ODSs and understanding the CFC-11 issues.

Report on the International Symposium on the Unexpected Increase in Emissions of Ozone-Depleting CFC-11

Neil R. P. Harris[1], Stephen A. Montzka[2], Paul A. Newman[3], with generous contributions from the Symposium attendees

[1]Centre for Environmental and Agricultural Informatics, Cranfield University, UK, [2]ESRL, NOAA, Boulder, CO, USA, [3]NASA/GSFC, Greenbelt , MD, USA.

DATES:
5 - 27 March 2019

ORGANIZING COMMITTEE:
Geir Braathen (WMO), Neil Harris (SPARC), Paul Newman (SAP), Bella Maranion (TEAP), Sophia Mylona (Ozone Secretariat)

SCIENTIFIC PROGRAMME COMMITTEE:
Tina Birmpili (Ozone Secretariat), Geir Braathen (WMO), Neil Harris (SPARC), Jianxin Hu (Univ. Beijing), Ken Jucks (NASA), Paul Newman (SAP), Bella Maranion (TEAP), Steve Montzka (NOAA), Sophia Mylona (Ozone Secretariat), Sun Young Park (Korea), Stefan Reimann (Empa), Matt Rigby (Univ. Bristol), Takuya Saito (Japan), Helen Tope (TEAP)

MEETING VENUE:
United Nations, Vienna, Austria

NUMBER OF PARTICIPANTS: 71

SPONSORS:

WEBSITE:
https://www.sparc-climate.org/meetings/meetingscfc-11-workshop-march-2019-in-vienna/

I. The state of understanding before the Symposium

Recent findings of an unexpected emission increase of chlorofluorocarbon-11 (trichlorofluoromethane, CFC-11, CCl_3F) [Montzka *et al.*, 2018][1] has raised important issues within the atmospheric sciences and policy communities. CFC-11 is a long-lasting man-made compound (52-year lifetime in the atmosphere) that is not only a powerful ozone depleting substance (ODS) but also a powerful greenhouse gas with a 100-year global warming potential of 5,160. Growth of emissions could indicate that releases from CFC-11 banks are accelerating, that the atmospheric circulation is changing such that our estimates of emissions based on observed concentrations increase, or that unreported production is leading to increased CFC-11 emissions.

Global CFC-11 emissions in the 2014-2016 period derived by Montzka *et al.* [2018] were shown to be about 13 gigagrams per year (Gg/yr) higher than the 2002-2012 average. Montzka *et al.* further showed that emissions from eastern Asia had also increased during this period. The "Scientific Assessment of Ozone Depletion: 2018" [WMO, 2018] provided additional information to that from Montzka *et al.* [2018] using both NOAA and AGAGE CFC-11 observations, along with some simple model simulations of impacts of these emissions. The independent AGAGE observations also showed CFC-11 emissions increased after 2012. The combined networks indicated an annual increase of 10 Gg/yr in the 2014-2016 period over the 2002-2012 baseline, consistent with the Montzka *et al.* estimate. While such an emission increase was highly unexpected given the reported production phase-out, the discrepancy between expected and observationally-derived emissions may have begun as early as 2007 (Figure 1). These emission increases slowed the otherwise steady decrease in atmospheric concentrations reported in previous Assessments. The global decline in CFC-11 concentration over 2014 to 2016 was only 2/3rds as fast as it was from 2002 to 2012. While the CFC-11 emissions from eastern Asia have increased since 2012, the contribution of this region to the global emission rise was not well known, and the country or countries in which emissions have increased had not been identified.

[1] Citations are indicated by square brackets []. Italicized citations were Symposium presentations with only the lead presentation author cited, while regular font citations are peer-reviewed publications.

www.sparc-climate.org

SPARC newsletter n°53 - July 2019 9

Rigby et al. [2019]

LETTER

nature
International journal of science

https://doi.org/10.1038/s41586-019-1193-4

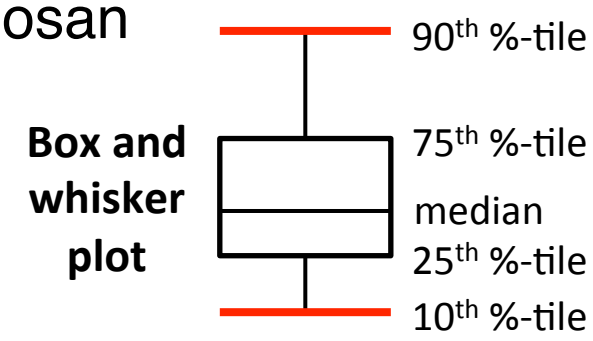
Increase in CFC-11 emissions from eastern China based on atmospheric observations

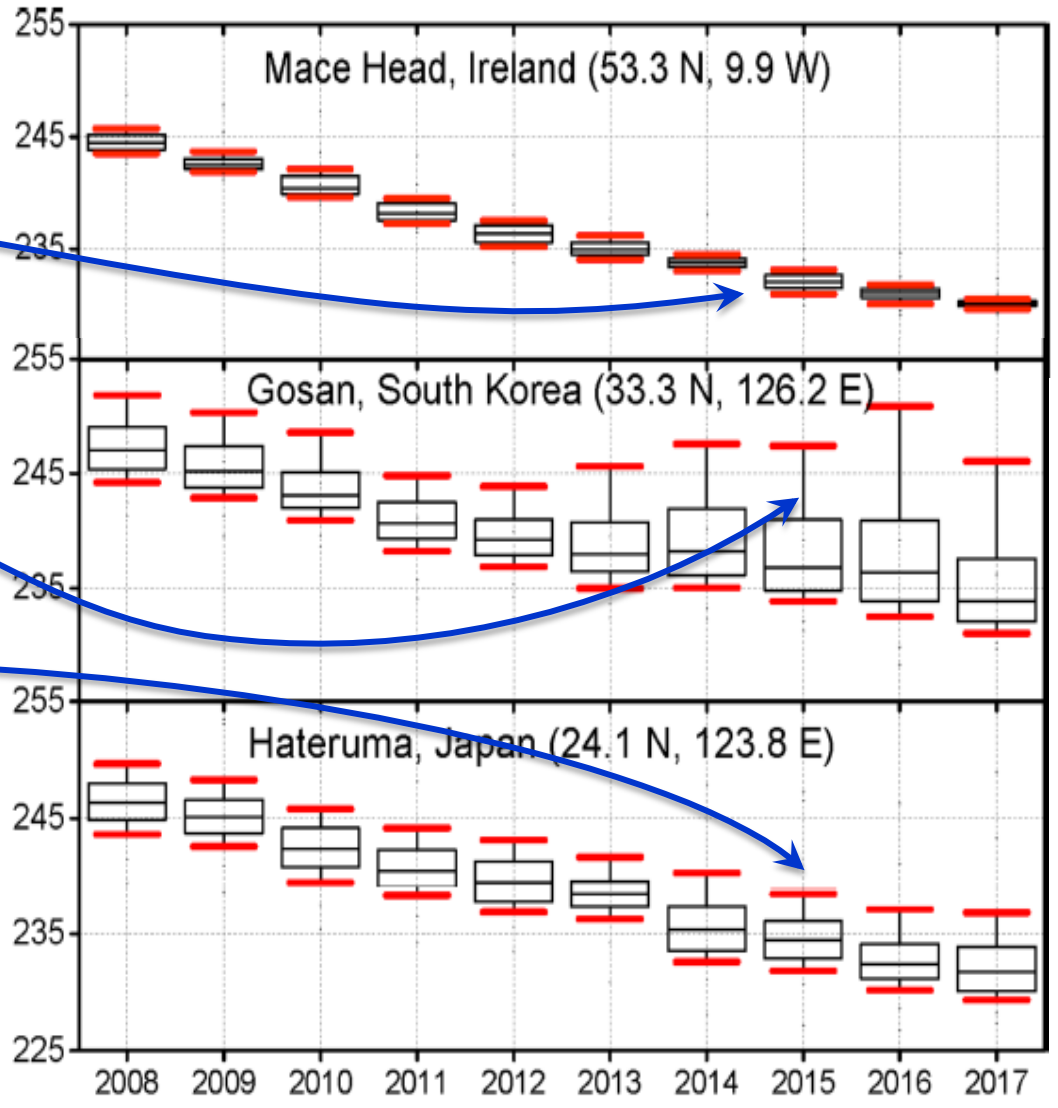
M. Rigby[1,15], S. Park[2,15]*, T. Saito[3,15], L. M. Western[1,15], A. L. Redington[4,15], X. Fang[5,15], S. Henne[6], A. J. Manning[4], R. G. Prinn[5], G. S. Dutton[7,8], P. J. Fraser[9], A. L. Ganesan[10], B. D. Hall[7], C. M. Harth[11], J. Kim[11], K.-R. Kim[2], P. B. Krummel[9], T. Lee[2], S. Li[12], Q. Liang[13], M. F. Lunt[14], S. A. Montzka[7], J. Mühle[11], S. O'Doherty[1], M.-K. Park[12], S. Reimann[6], P. K. Salameh[11], P. Simmonds[1], R. L. Tunnicliffe[1], R. F. Weiss[11], Y. Yokouchi[3] & D. Young[1]

- High-frequency atmospheric observations from Gosan, South Korea, and Hateruma, Japan, along with global data and atmospheric chemical transport models
- Emissions from eastern mainland China are 7.0 ± 3.0 (±1σ) Gg yr^{-1} higher in 2014–2017 than in 2008–2012
- Emission increase arises primarily around the northeastern provinces of Shandong and Hebei

Gosan and Hateruma observations show large events that have increased since 2012

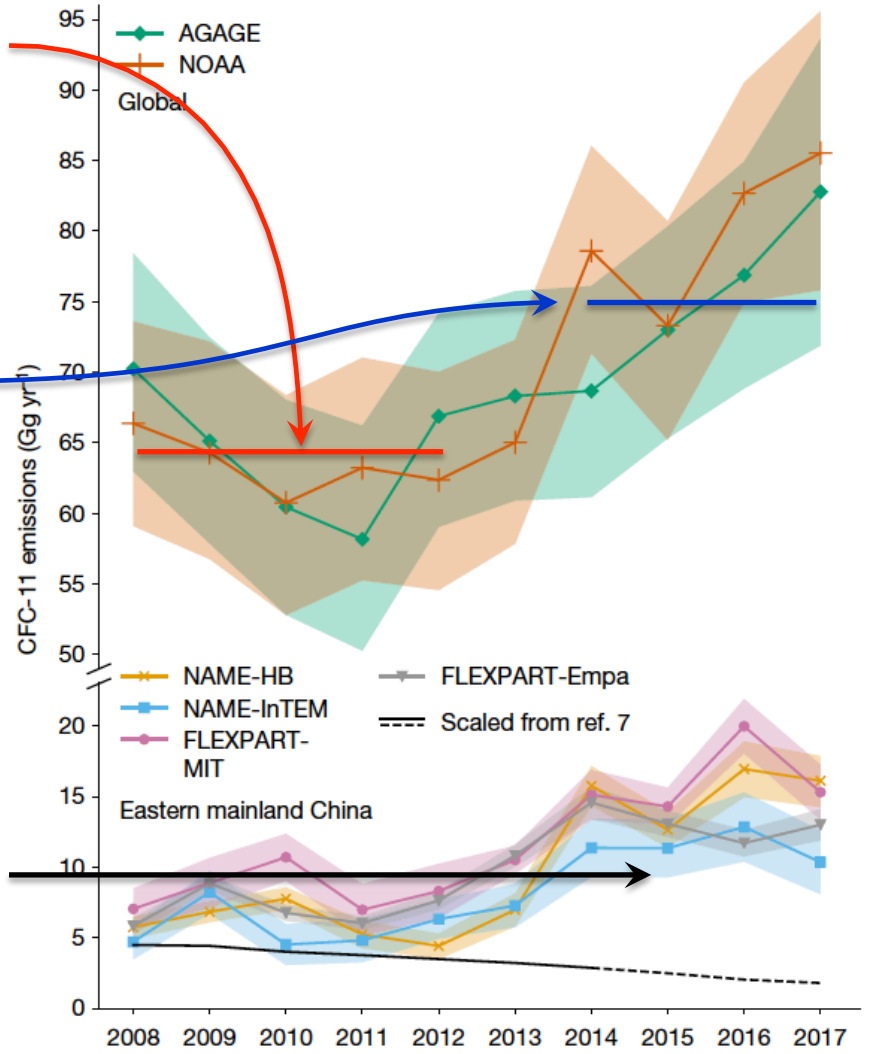
- Ireland data show a steady decline with virtually no elevated events
- Gosan data show elevated events dramatically increased after 2012
- Hateruma data show elevated events, but of small magnitude than Gosan





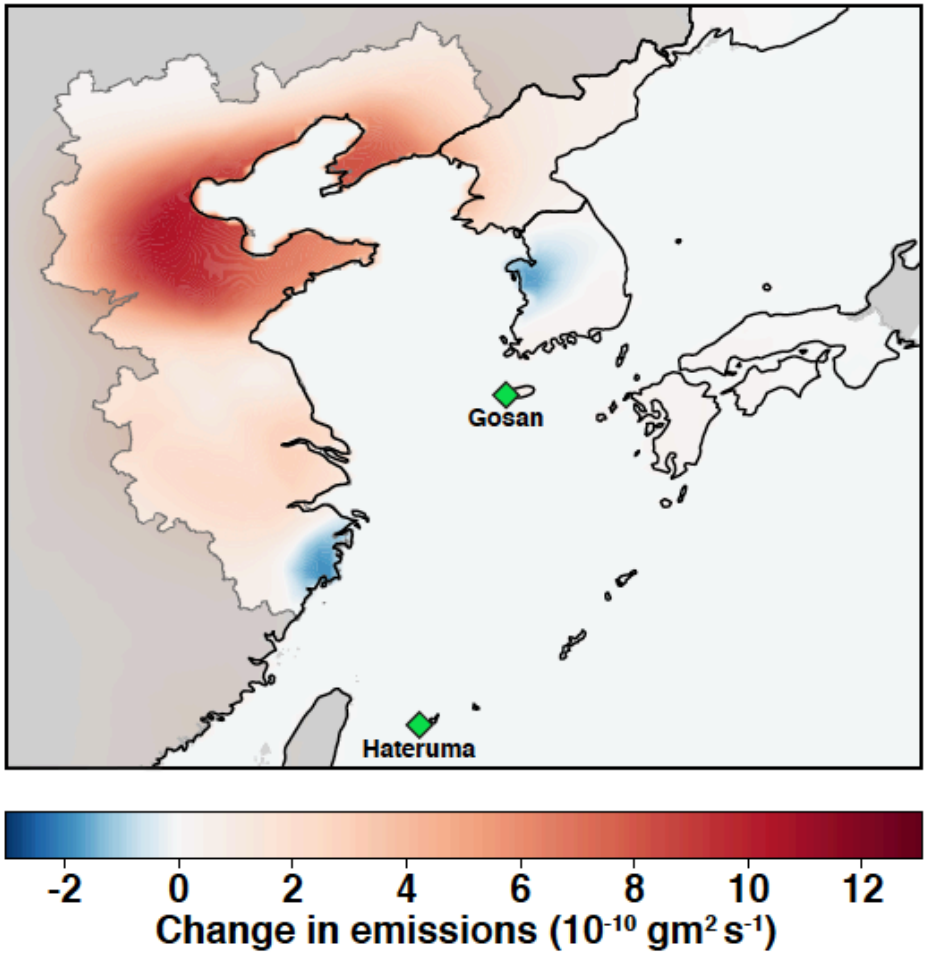
Global with eastern China emissions [Rigby et al., 2019]

- Emissions of 64 ±2 Gg yr^{-1} or 63 ±2 Gg yr^{-1} of CFC-11 were emitted on average between 2008-2012
- Emissions increased to a mean value of 75 ±3 Gg yr^{-1} or 80 ±3 Gg yr^{-1} for 2014-2017
- A rise (2018-12 to 2014-17) of:
  - AGAGE: 11±3 Gg yr^{-1} (17±5%)
  - NOAA: 17±3 Gg yr^{-1} (26±5%)
- The 7±3 Gg yr^{-1} is from eastern China



CFC-11 emissions have increased in eastern China between the 2014-17 and 2008-12 periods

See Rigby et al. paper discussion by Dr. Steve Montzka - 1:00 PM today, CR-3 (lunch provided)



Western et al. [Vienna Symposium], and Rigby et al. [2019]

Figure 3. Change in the derived CFC-11 fluxes in the NAME-HB inversion from 2008–2012 to 2014–2017. Green diamonds show the Gosan and Hateruma stations. Gray shaded areas indicate regions which have low sensitivity, and therefore, from the derived emissions have high uncertainty. Adapted from Rigby et al. [2019] Figure 3c.

CFC-11 science timeline

- **March 2019:** Vienna Symposium
- **Dec. 2019:** CFC-11 Special Session at AGU Fall meeting. https://agu.confex.com/agu/fm19/prelim.cgi/Session/78200
  - Abstract submission open: https://www2.agu.org/Fall-Meeting/Pages/Submit-an-abstract
- **May 2019:** Commentary solicited from the science community (> 100 scientists and technologists) about the contents of the CFC-11 Report.
- **June 2019:** SAP Report outline established, Report will be peer-reviewed, and published by WMO. Authors are now being recruited from the science community.

Assessment Report on the Unreported Emissions of CFC-11

1. Introduction (Co-chairs)
2. Observations
3. Global emissions
4. Regional emissions
5. Modeling of emission impacts
6. Summary

Summary

- CFC-11 is both a powerful ODS and GHG
- Atmospheric CFC-11 levels continue to decline, but at a much lower rate than expected
- There has been an unexpected increase of CFC-11 emissions
- New research (not yet fully assessed) has found 40-60% of these emission increases to have originated in eastern China
- A new Assessment of these emission increases is in formulation and will be presented at the 2020 MOP

The End

Thank you for your attention