

An unexpected and persistent increase in global emissions of ozone-depleting CFC-11

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AGAGE community of scientists

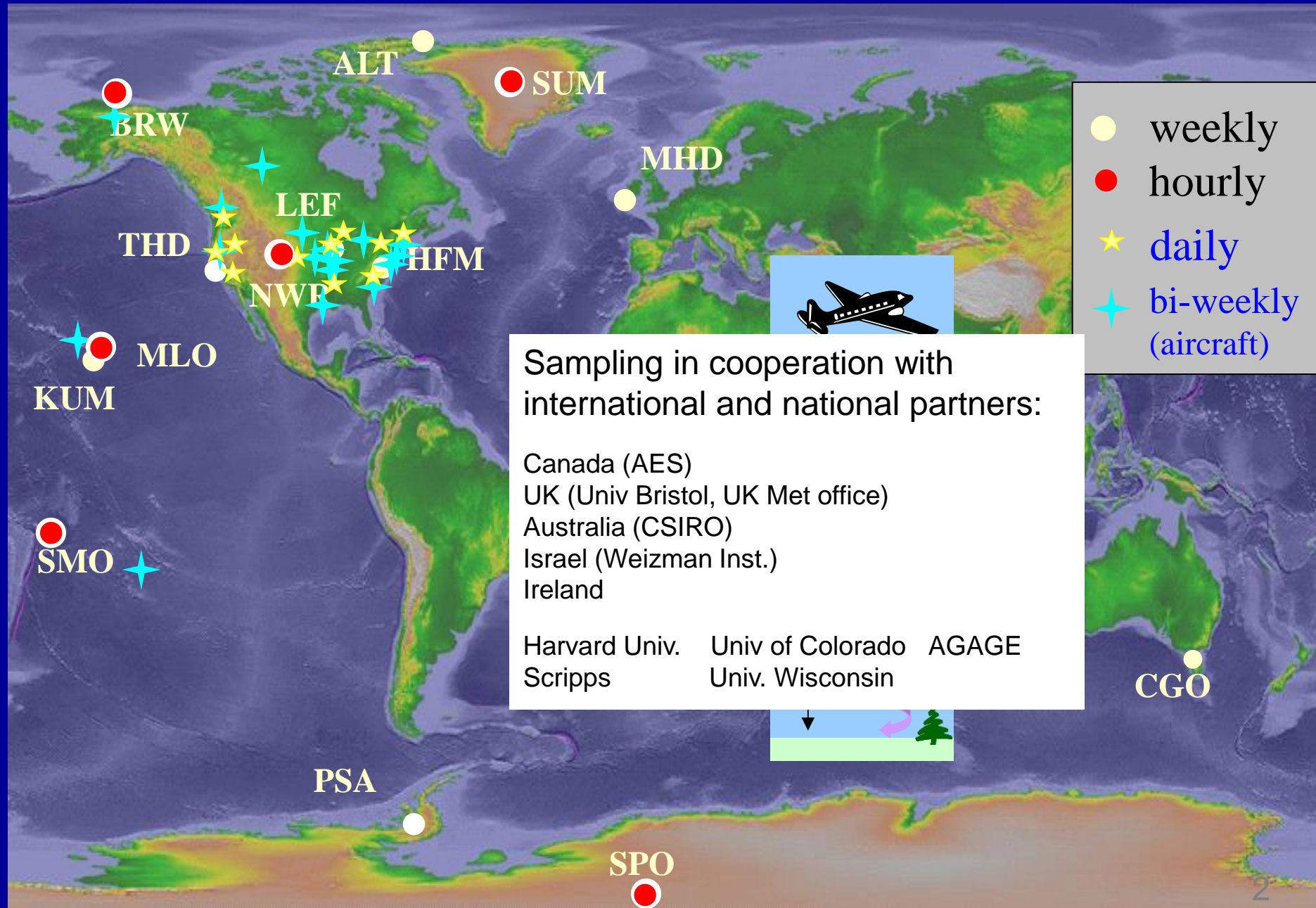
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NOAA R&D High Performance Computing Program,

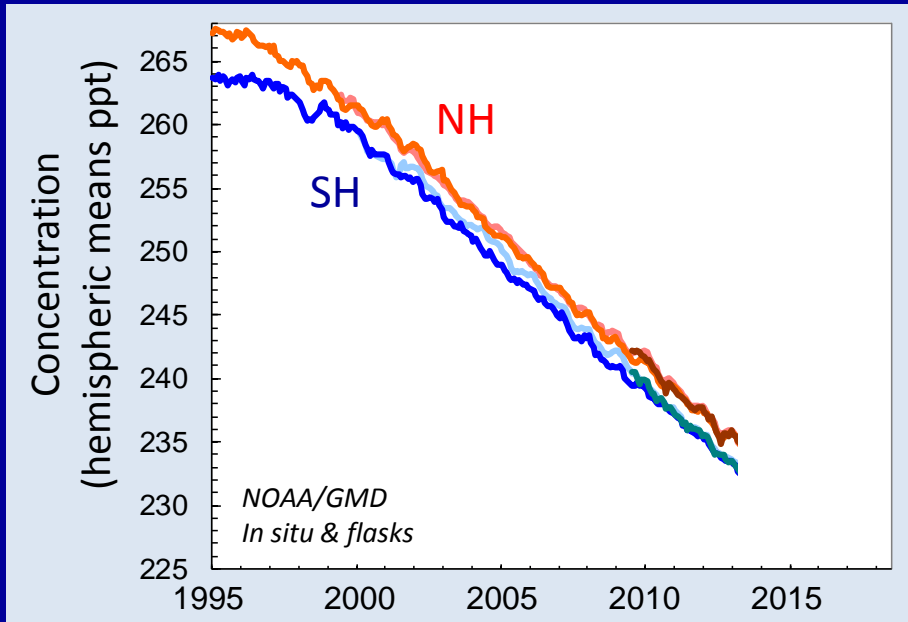
NOAA Climate Program Office's AC4 Program

NSF, and DOE

NOAA/GMD: Tracking ozone-depleting gas concentrations globally



Atmospheric CFC-11



CFC-11:

- **Was the largest contributor to the decline** in total atmospheric Cl from 2007-2012
- **Still accounts for 20-25% of ozone-depleting chlorine**
- **Reported global production became negligible after 2007**

but:

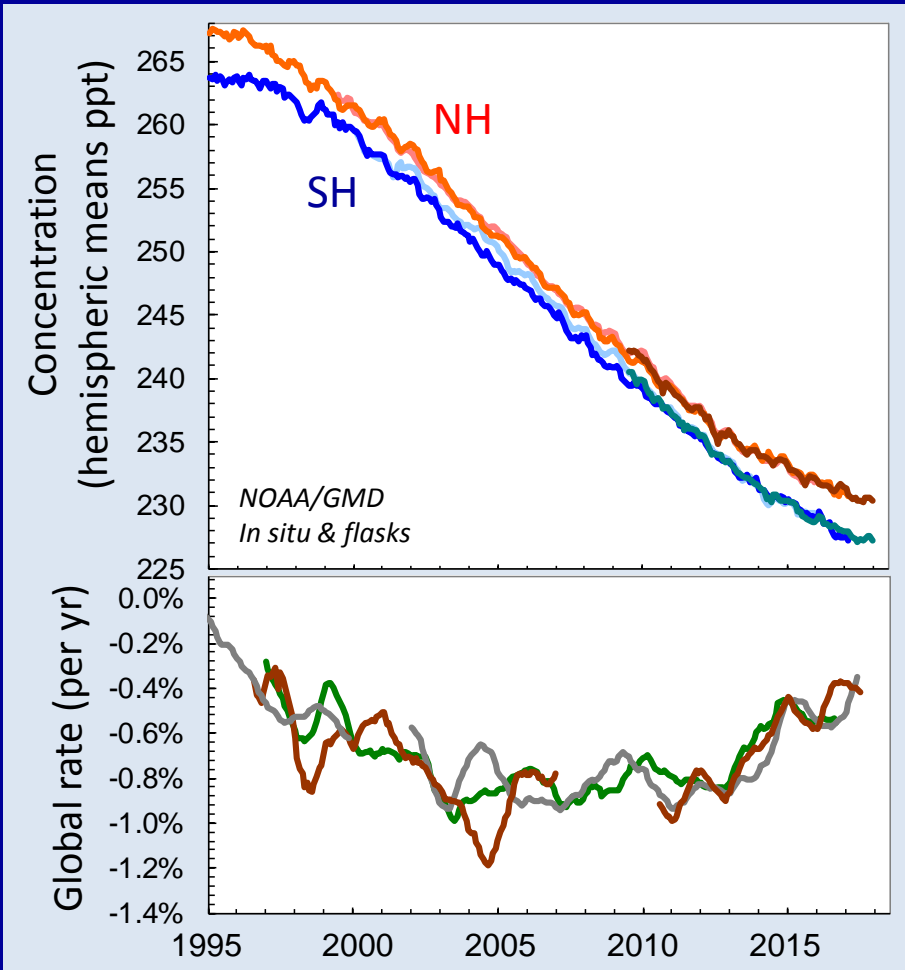
- **Significant emissions persist**, from CFC-11 in old foams (“bank”)

Expectation:

After the production phase-out:

- * emissions should decrease &
- * the concentration decline should accelerate (until it reaches its lifetime-limited value: $-2\%/yr$)

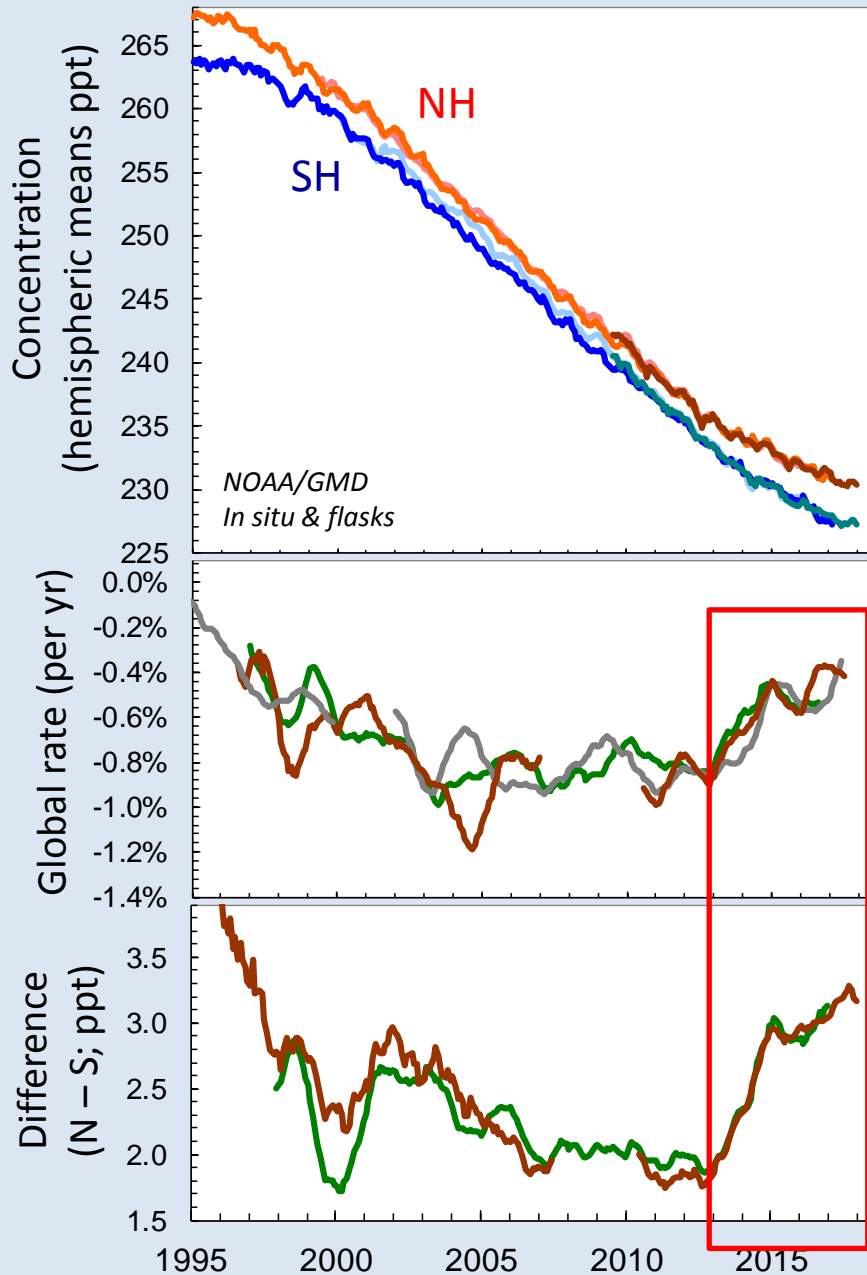
Atmospheric CFC-11



Hemispheric mean concentration

Global rate of change

Atmospheric CFC-11



Hemispheric mean concentration

Global rate of change

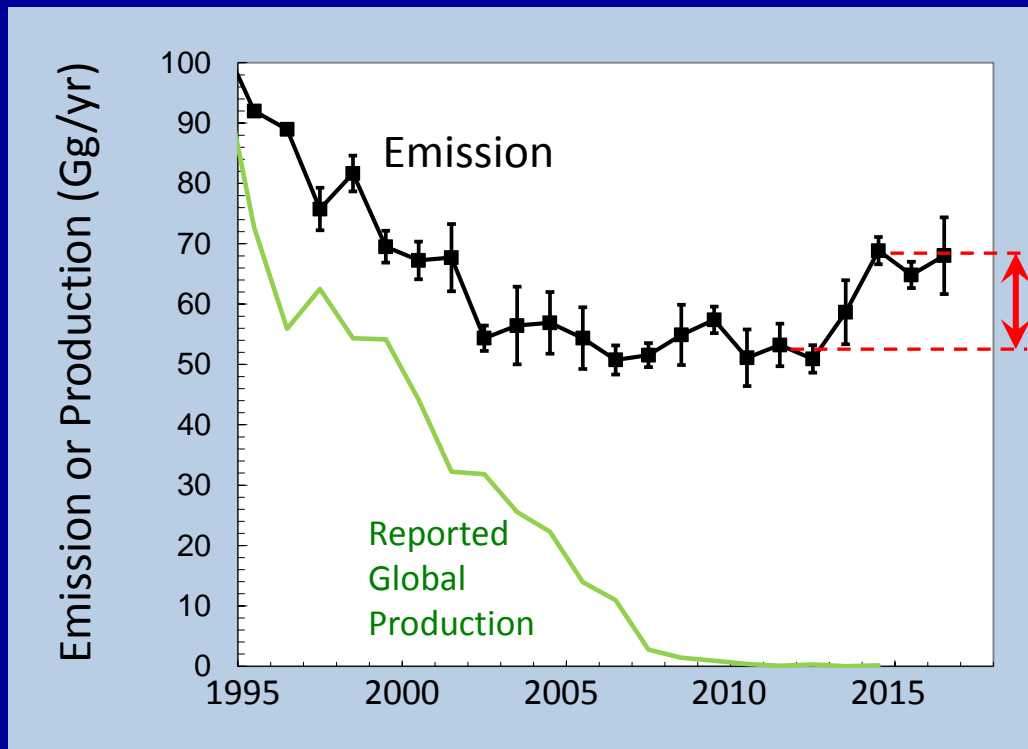
Hemispheric concentration difference

→ Imply an increase in NH CFC-11 emissions

CFC-11 emissions appear to be increasing

When derived with a 3-box-model: $dG_{F11}/dt = \text{Emission} - \text{Loss}$

(changing dynamics?)

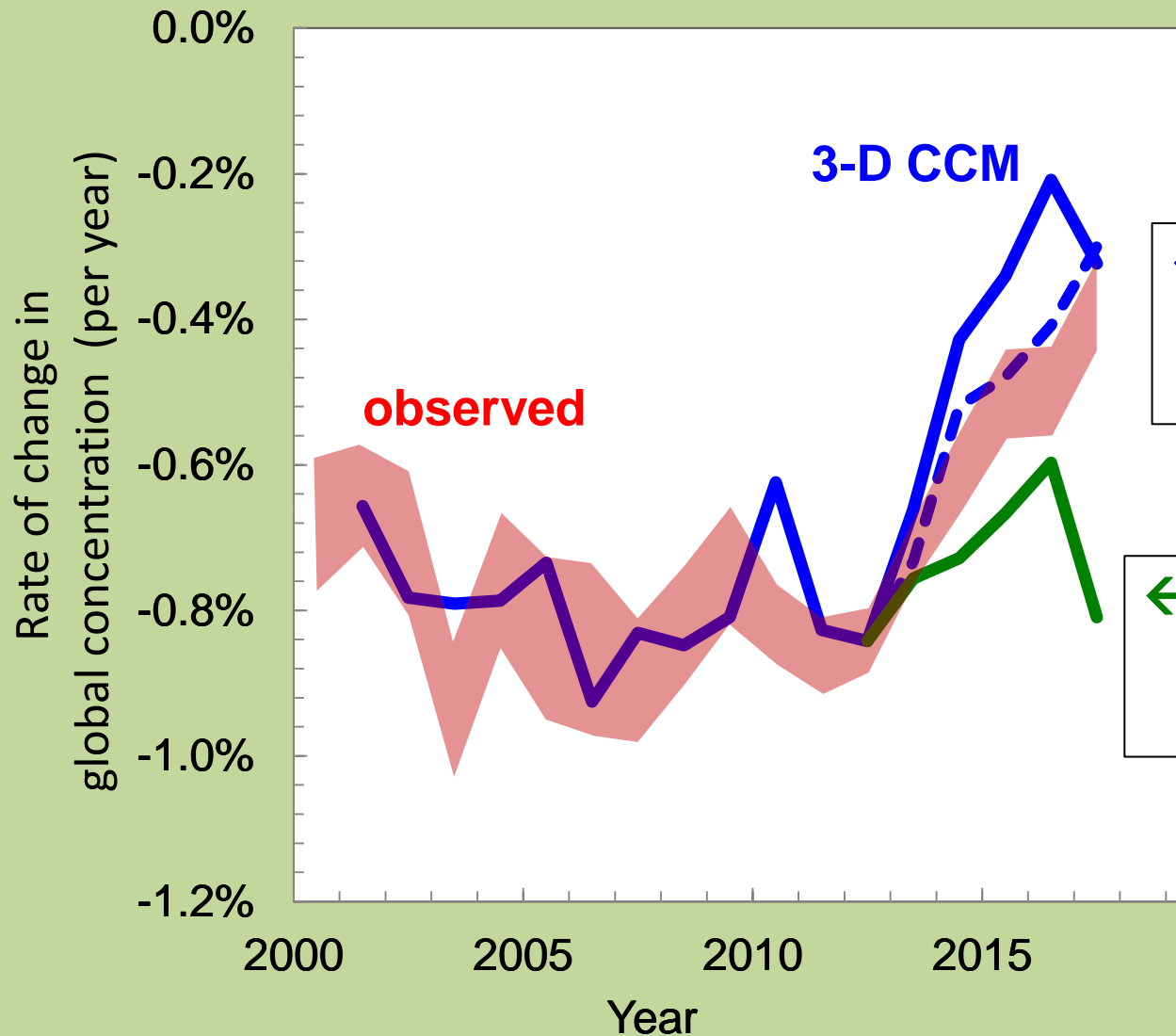


$13 \pm 5 \text{ Gg/yr}$
(25%) increase

Testing this emission record:

- Incorporate emissions into a 3-D CCM using reanalysis meteorology
- Compare CCM-simulated vs. measured trends; differences could suggest changes in dynamics, & incorrect emissions

3-D modeling of CFC-11 global concentration decline

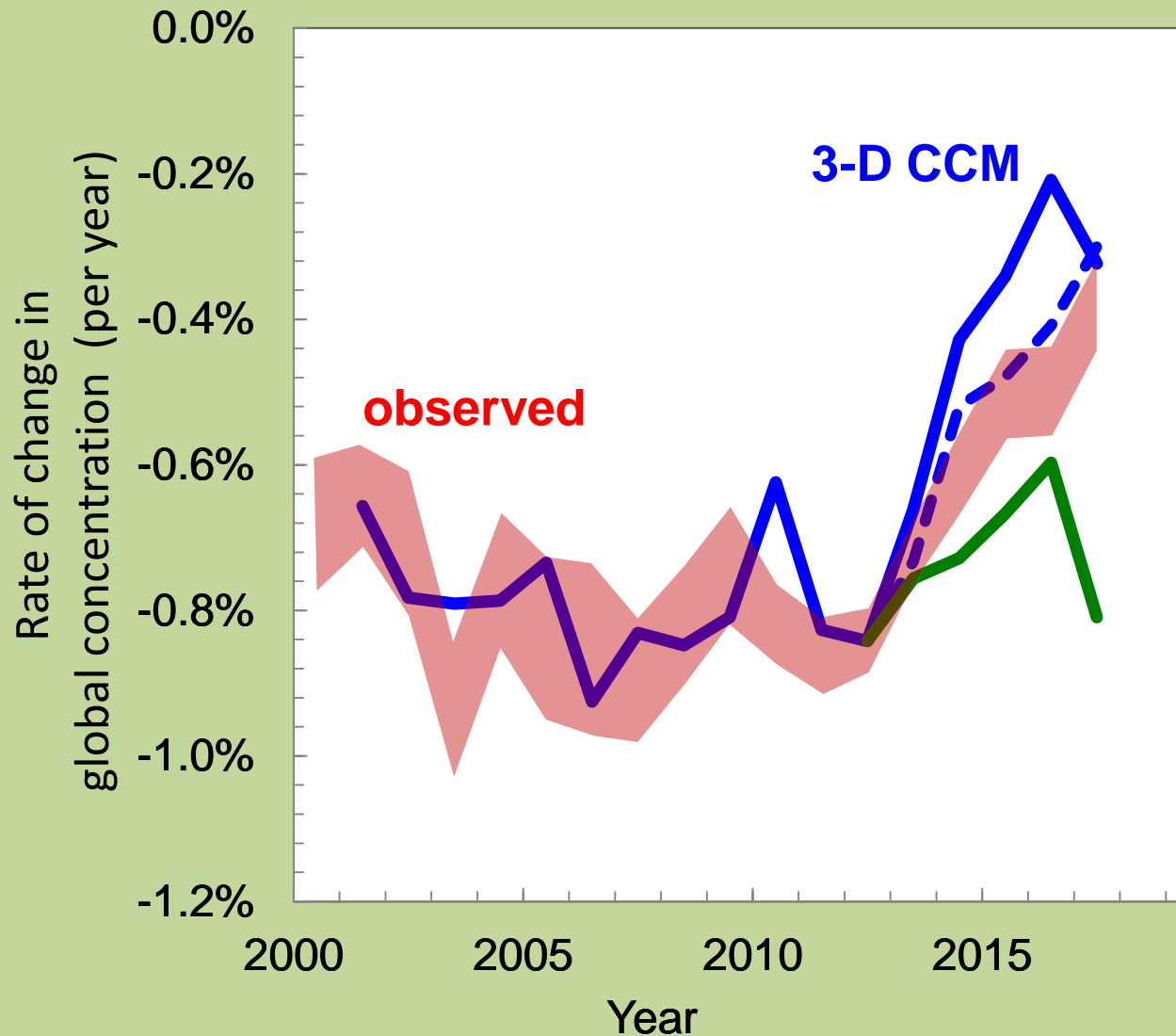


← 3-D CCM with fixed dynamics after 2012

← 3-D CCM with emissions kept constant after 2012

3-D Models:
WACCM or CAM,
Reanalysis met.:
MERRA, MERRA2
or GEOS5

3-D modeling of CFC-11 global concentration decline



Conclude:

Dynamical changes added to the to the CFC-11 slowdown**

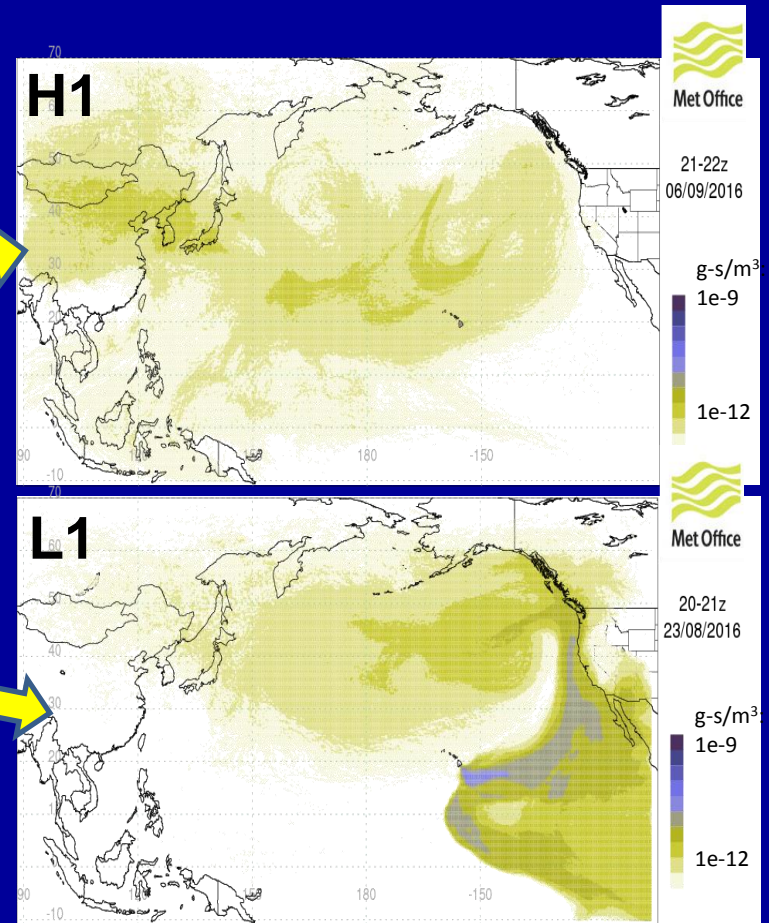
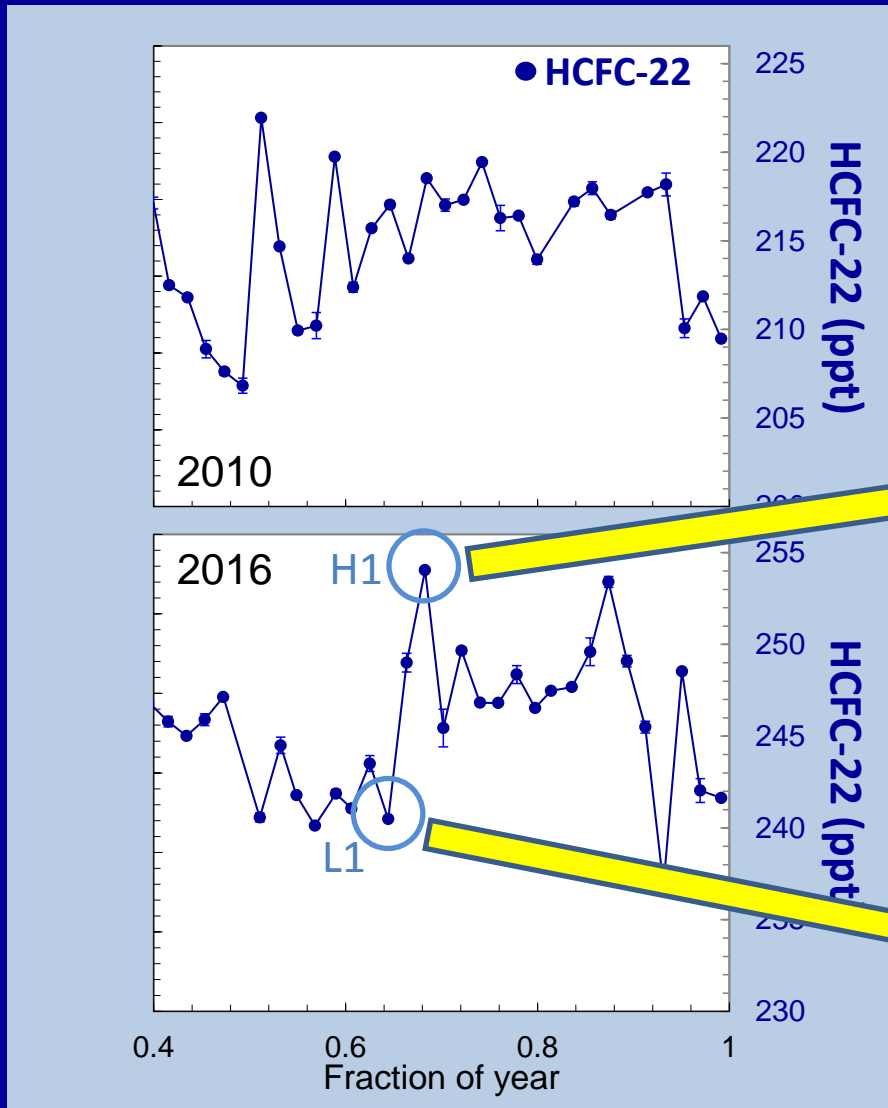
But, data are replicated only with a CFC-11 emission increase.

**See next talk by Pengfei Yu

Direct observational evidence for increased CFC-11 emissions:

Measurements at MLO, Hawaii

* air reaching Hawaii in autumn can be influenced by Eurasian emissions,** which brings **higher concentrations** of chemicals known to be emitted from Eurasia: *e.g.*, HCFC-22, CH_2Cl_2 , & CO .

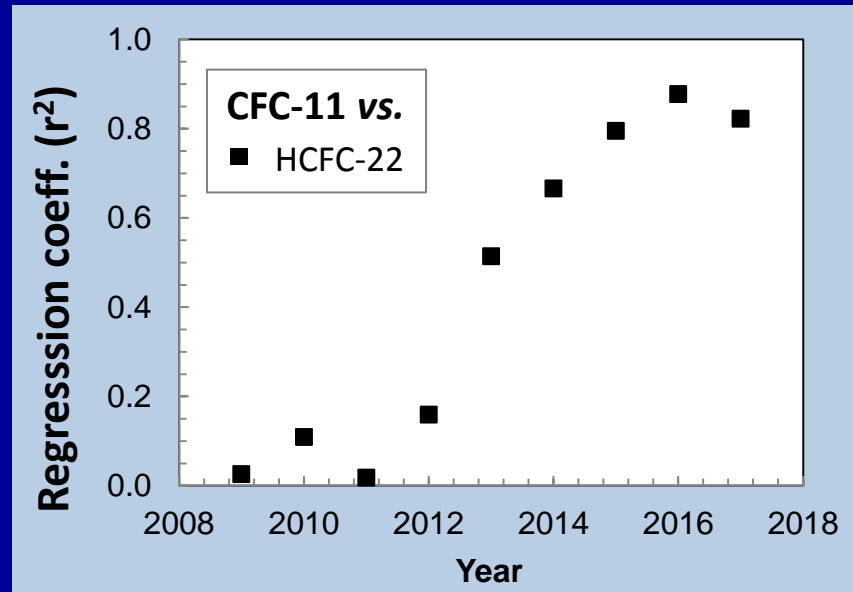
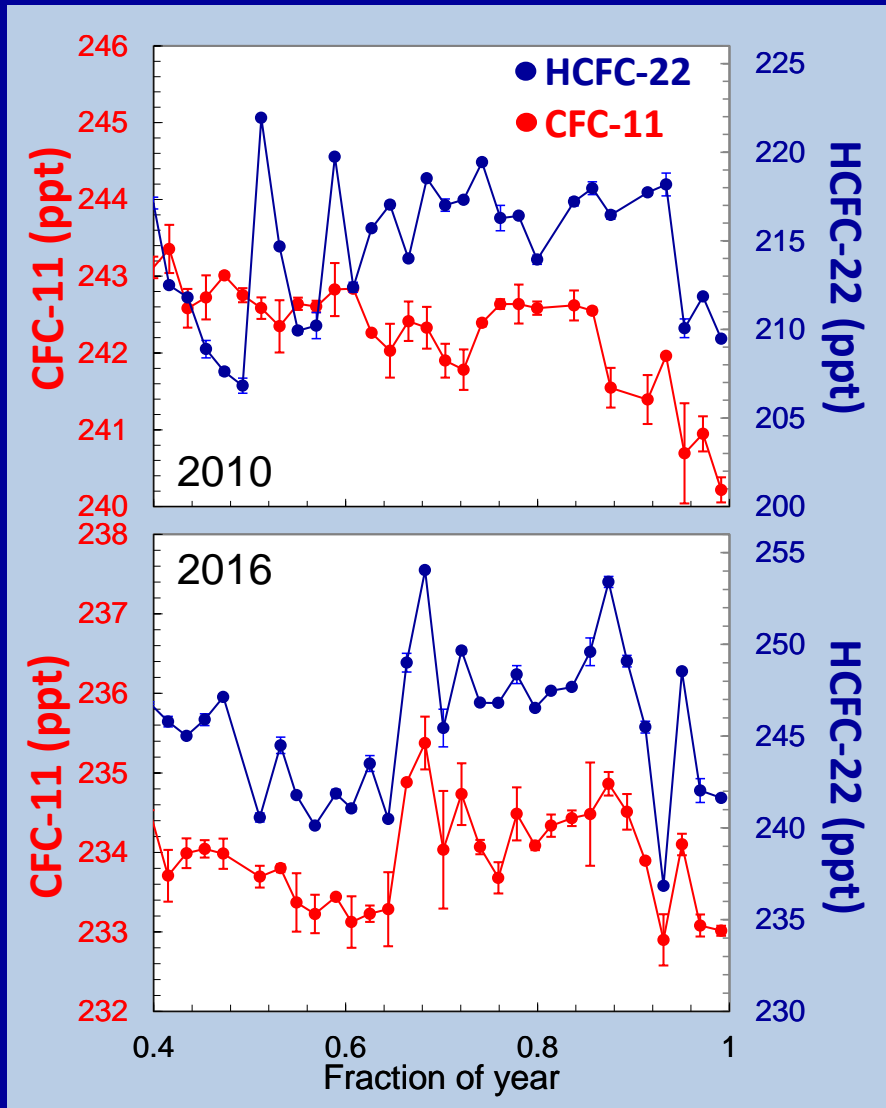


** Lin et al., Nature Geosci., 2014

Direct observational evidence for increased CFC-11 emissions:

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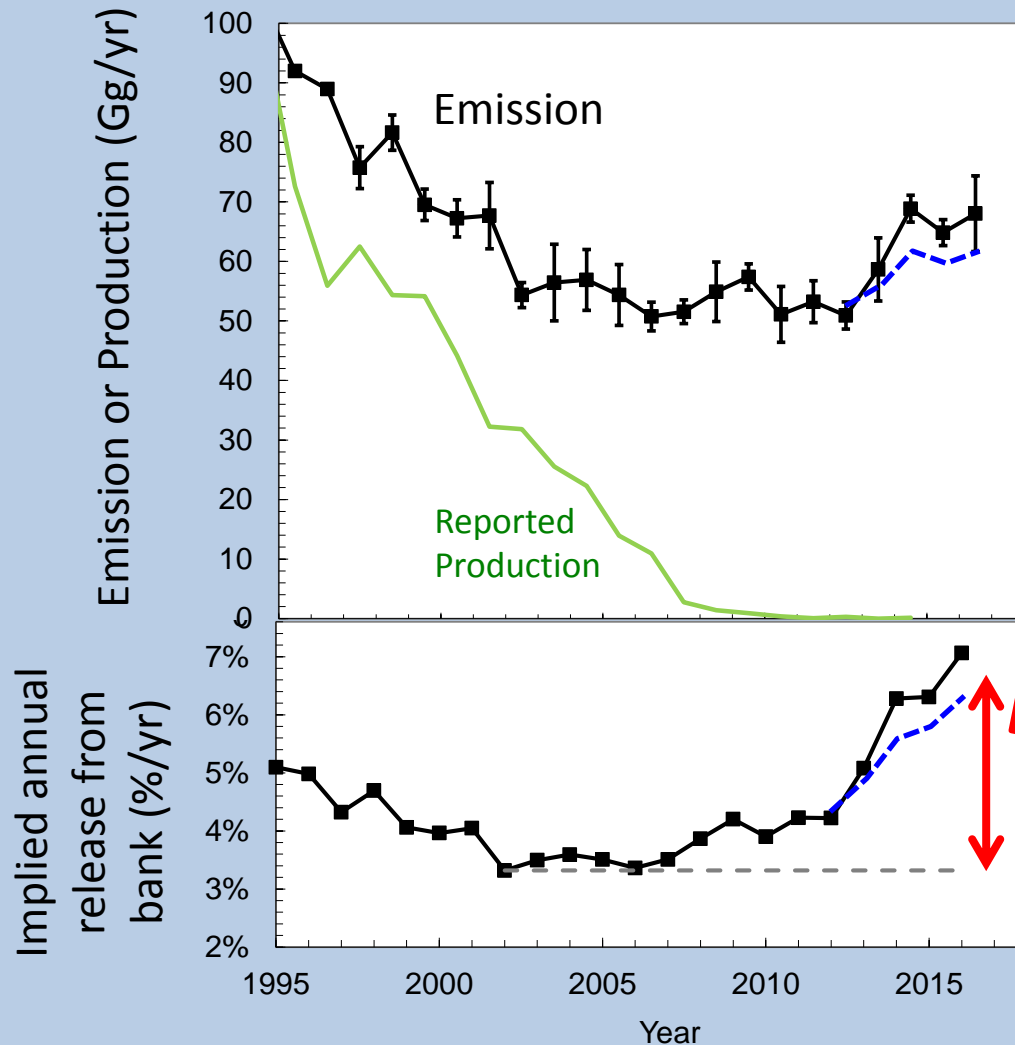
Only after 2012 does air from eastern Asia contain elevated CFC-11 concentrations

Correlations among HCFC-22, CH_2Cl_2 , & CO are strong in all years

Is the Montreal Protocol being violated?

Montreal Protocol controls apply to production and consumption.

→ Are the 'increased' emissions from 'new' production?



OR: Could a change in the escape rate of CFC-11 from the "bank" account for the increased emission?

With no new production, the escape rate from the 'bank' would have had to double...

→ this seems highly unlikely

Conclusions:

Based on an analysis of our atmospheric measurements:

- 1) Emissions of a class 1 ozone-depleting substance, CFC-11, have increased in recent years despite a global ban on production
 - Emissions today are similar to what they were **20 years ago**
 - Decline rates for other gases have **not** slowed similarly.
- 2) The increased CFC-11 emission is likely from eastern Asia.
 - The exact location or country is not yet identified
- 3) The results *suggest* new production, which would be inconsistent with the reported global phase out agreed to in the Montreal Protocol
- 4) Detecting *and* diagnosing atmospheric composition changes requires:
 - **extensive network of high quality measurements**
 - **accurate and sophisticated modeling tools**

...and we are fortunate to have both of these at NOAA