

The continued slowdown in the decline of atmospheric CFC-11

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A. Manning**

Atmospheric CFC-11 (CCl₃F) today:

- The second largest contributor to ozone-depleting chlorine reaching the stratosphere (20-25% of total)
- **Was** the largest contributor to the decline of atmospheric Cl from 2007-2012
- Reported global production has been ~zero **for all uses** since 2007
- Significant emissions persist from a “bank” of chemical in existing equipment (escape rate was ~3 to 4%/yr)

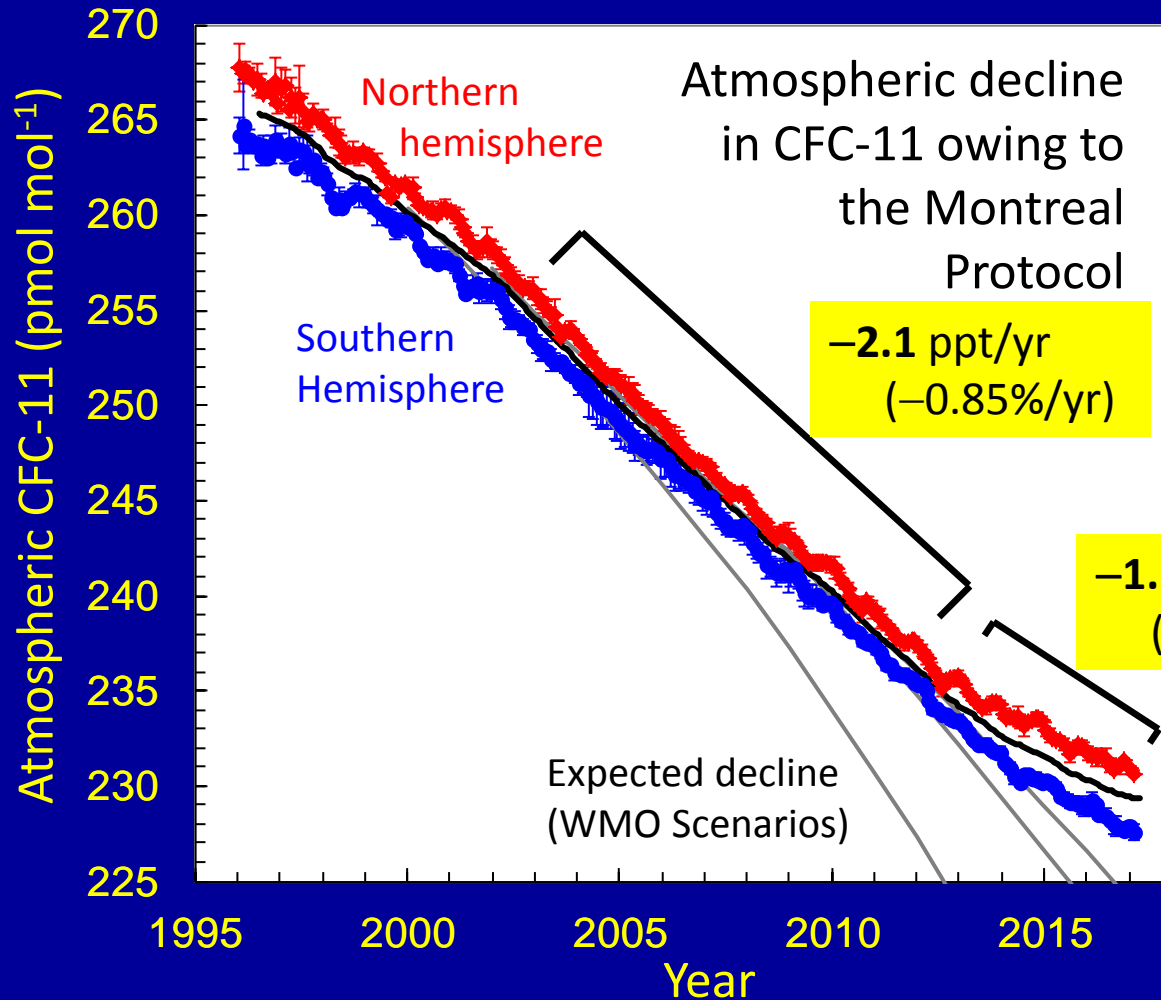
*** In the absence of production,**

→ emissions should decrease over time

→ growth rate should approach lifetime-limited value

...all other things being constant

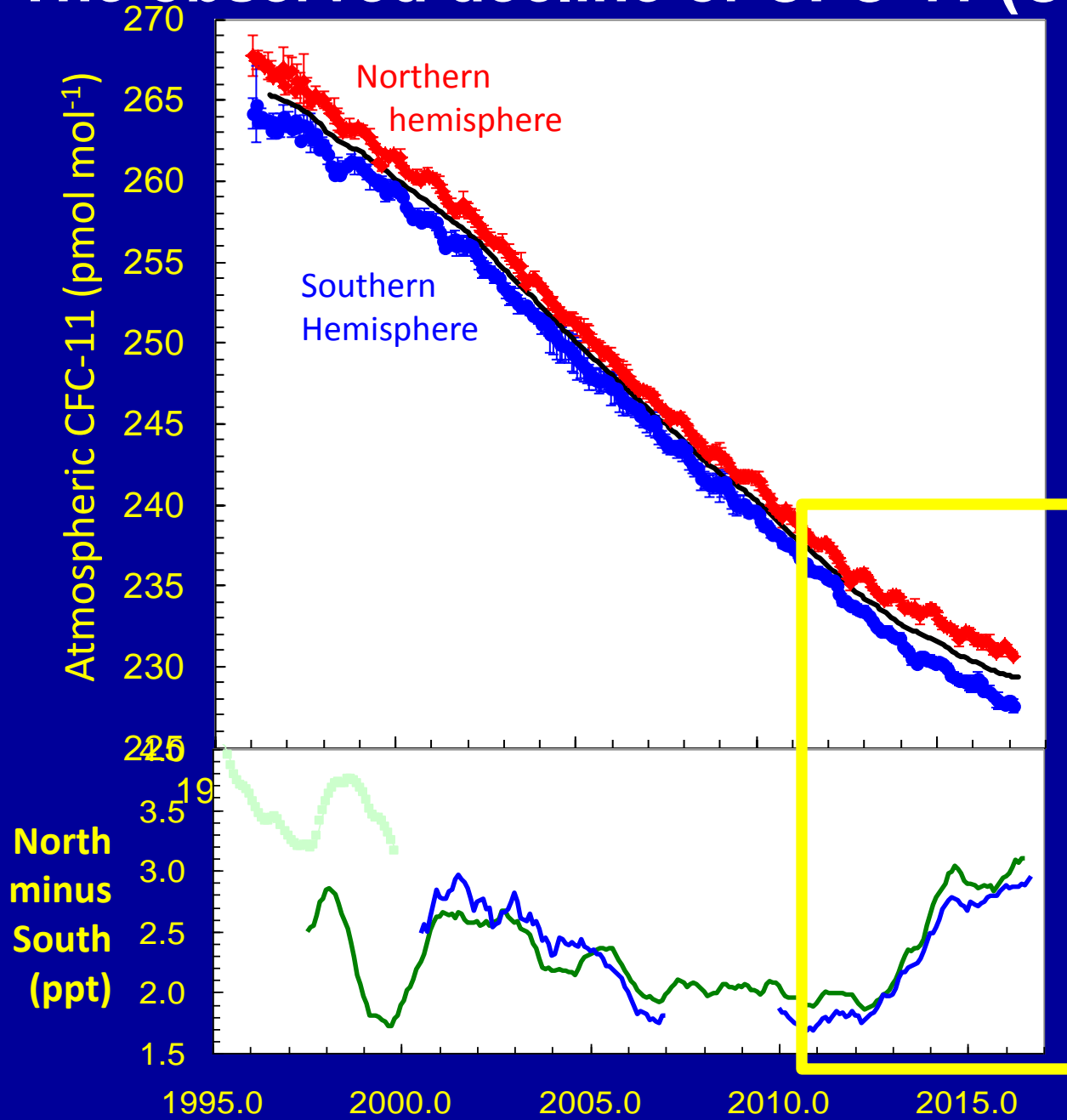
The observed decline of CFC-11 (CCl_3F)



Average of three different NOAA instruments (flask by ECD and MS & insitu ECD)

Slowdown \cong
15-20% increase in
net flux of CFC-11

The observed decline of CFC-11 (CCl₃F)



Slowdown is concurrent with a 50% increase in the hemispheric difference (N – S)

→ Increased flux is primarily northern hemispheric

(no evidence for decreased N – S air mass exchange rate)

Why the slowdown??

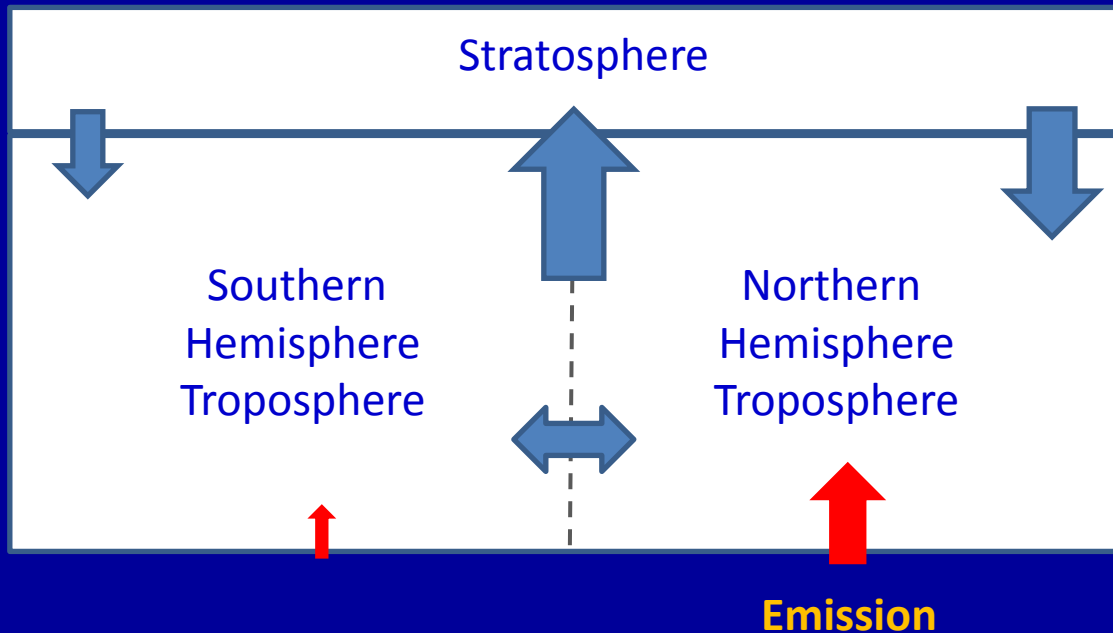
Potential suspects to explain an increasing NH flux:

a) changing emissions, given 90% are from NH

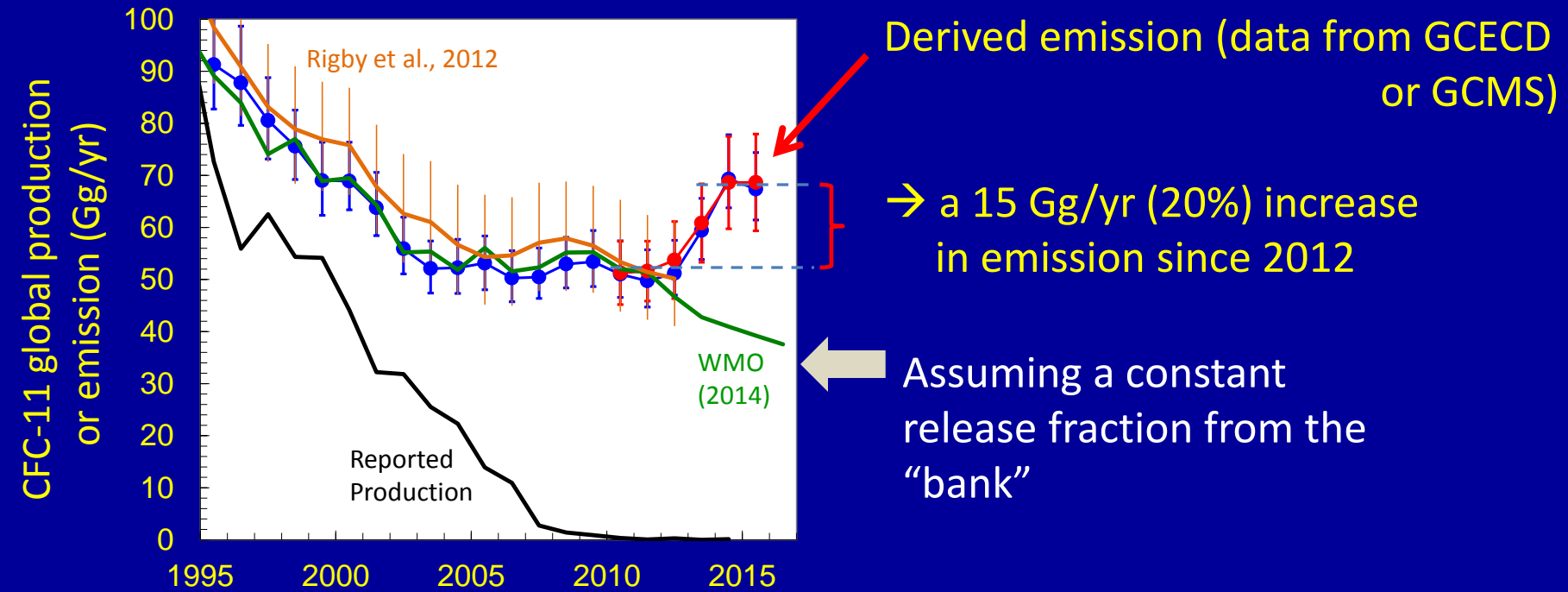
or

b) slowdown in loss (dynamics & chemistry)

→ preferentially in NH



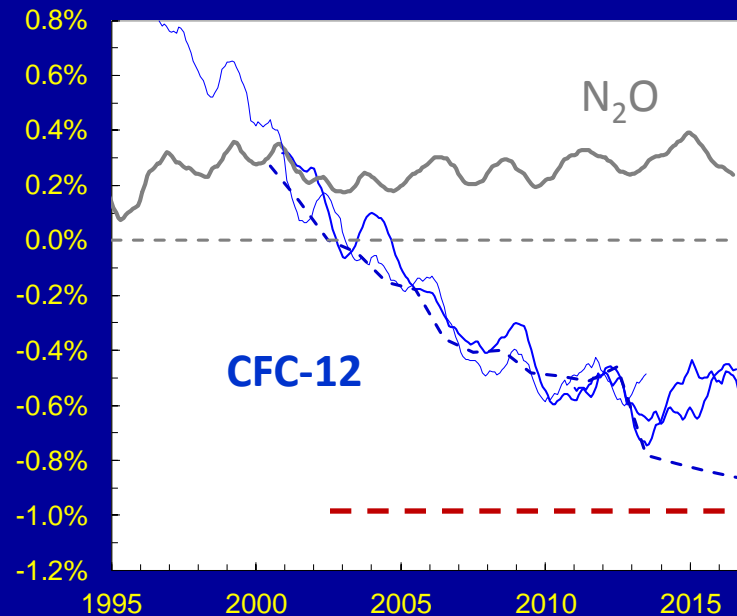
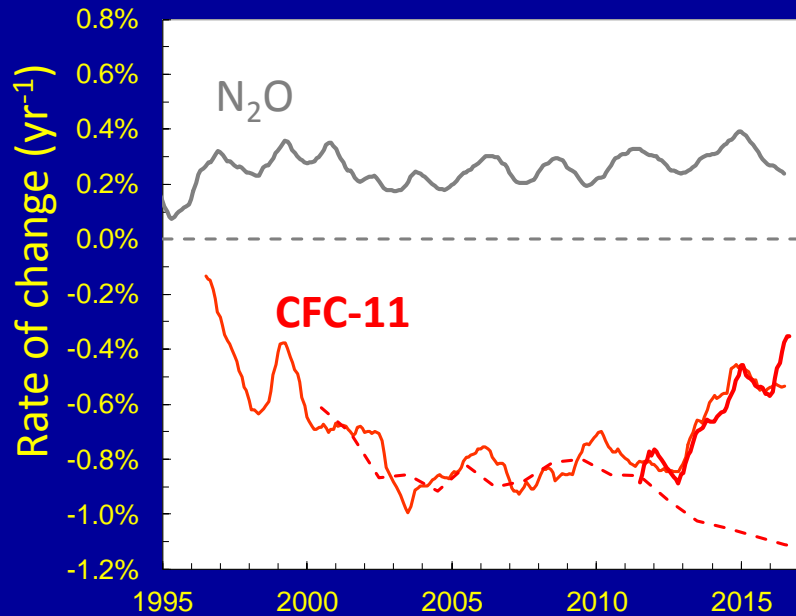
Assuming constant loss frequency and dynamics
Global emissions implied from observations
and a multi-box model:



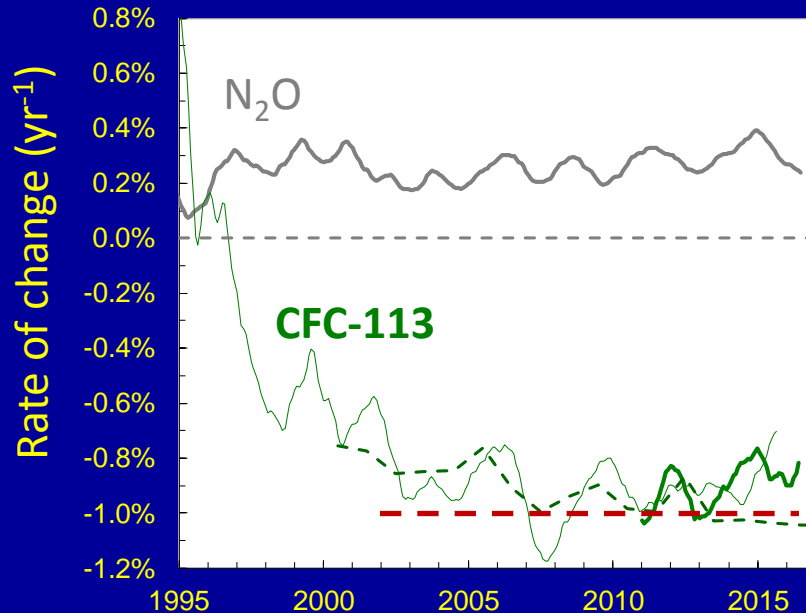
Given production was zero after 2007,
anomaly actually starts as early as 2002...

→ 50-150 Gg of unaccounted CFC-11 is implied

Could it be dynamics?? How about other gases??



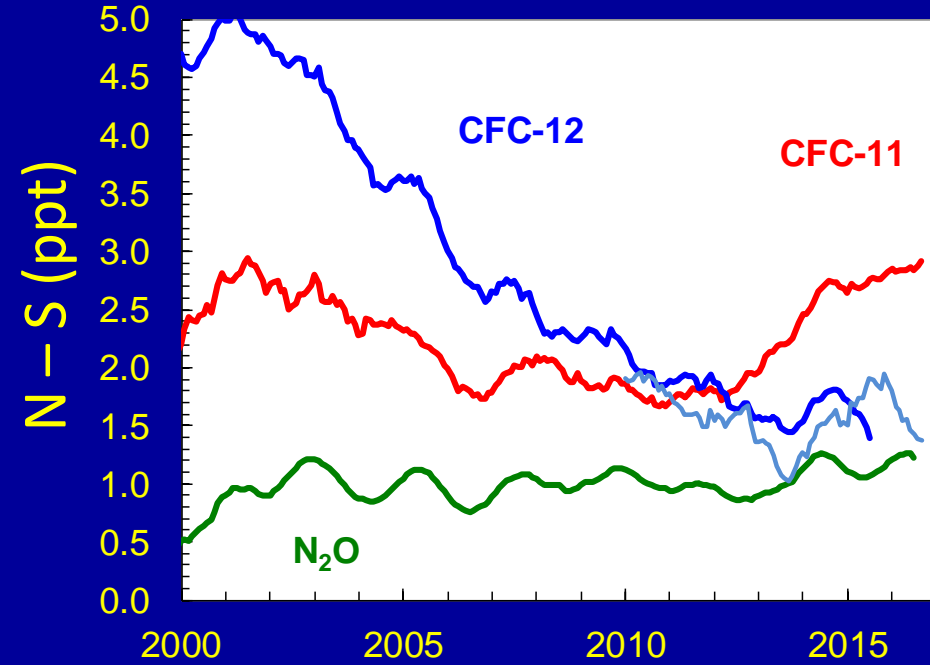
Dashed line =
WMO scenario
(Carpenter &
Reimann et al.,
2014)



*** no other CFC shows the slowing decline seen for CFC-11**

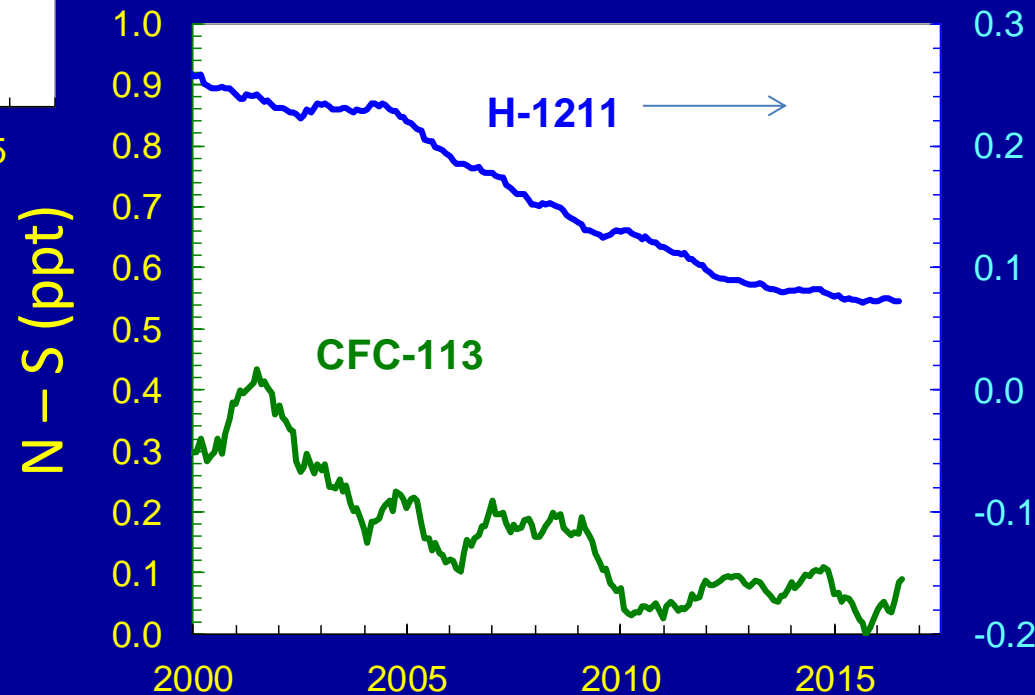
- * *But*, rates for other CFCs have plateaued
- * CFC-113 is near its lifetime limited rate
- * CFC-12 rate seems to have stopped accelerating...

Hemispheric difference (N – S) for other gases:



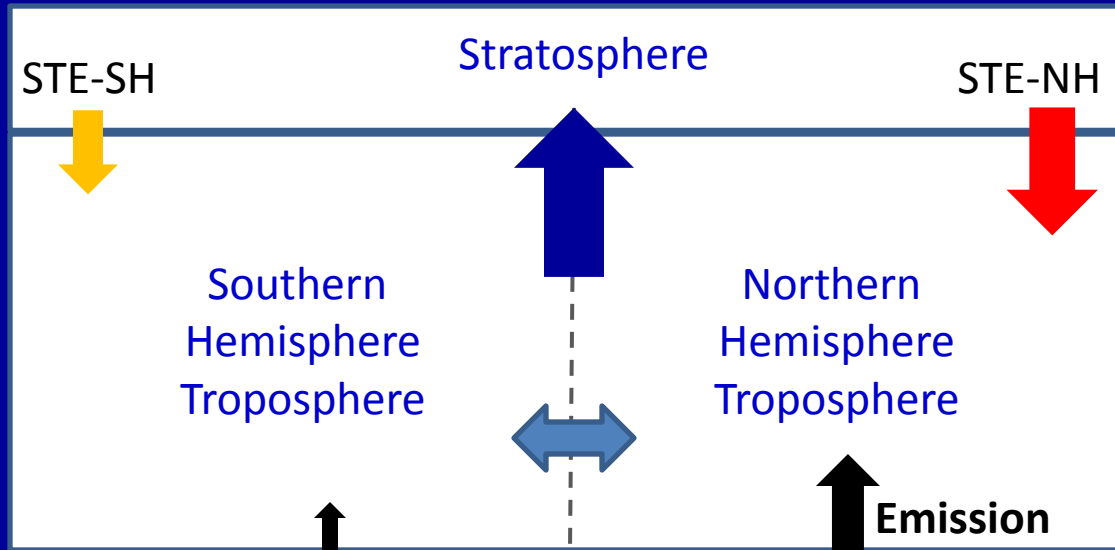
* No other gas shows the **increase** seen for CFC-11

- *But*, perhaps some haven't continued on the same path in recent years



What change in dynamics is implied if emissions haven't changed?

What change in strat-trop exchange is required to fit the recent CFC-11 changes
WITHOUT AN INCREASE IN EMISSIONS?



a) 3-box model analysis:

* Requires a ~20% decline in global strat-trop exchange, with that decrease being almost entirely in the NH

b) 3-Dimensional model analysis using specified dynamics:

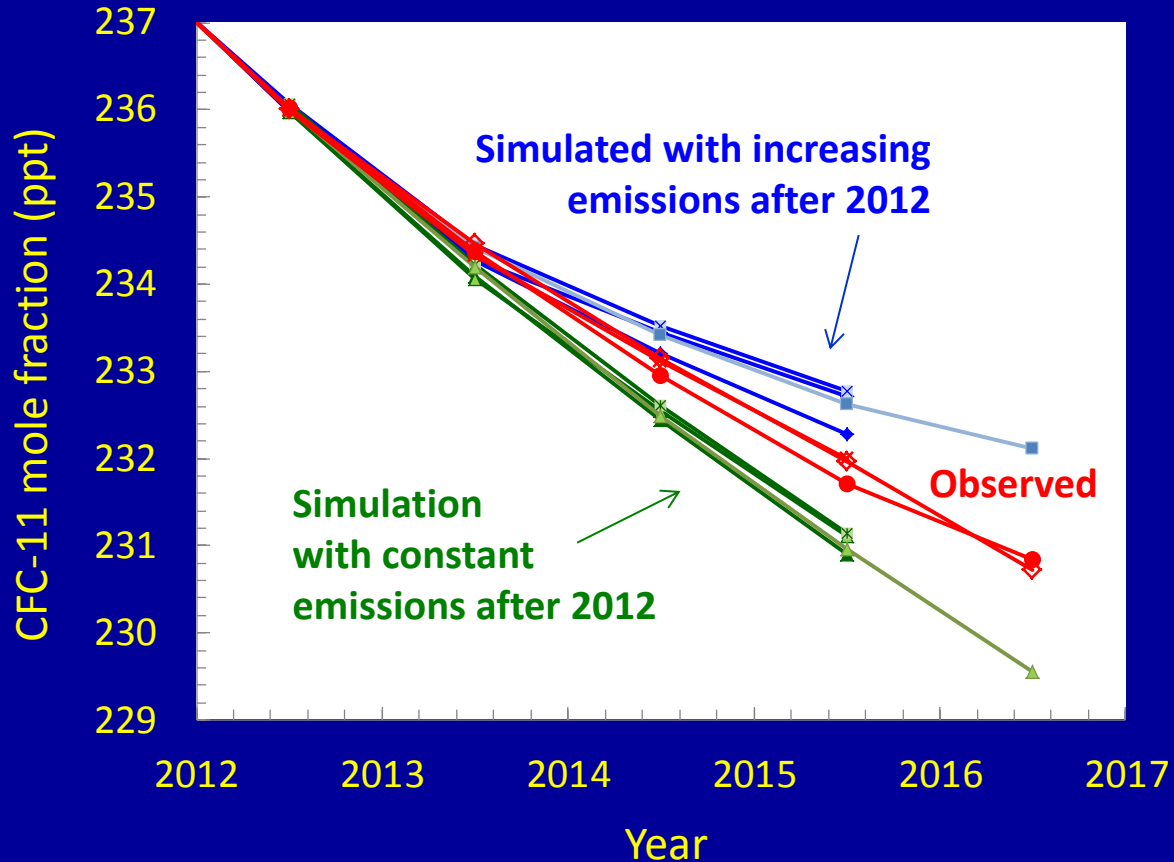
WACCM, CAM5.3 with MERRA1, MERRA2, and GEOS5

3-box model emissions included in forward runs of the 3-D model...

3-D Chemical transport analyses of the CFC-11 anomaly

Two different models with 3 different meteorology fields (WACCM and CAM5.3 with MERRA1, GEOS5, or MERRA2)

Normalized to 2011-2012



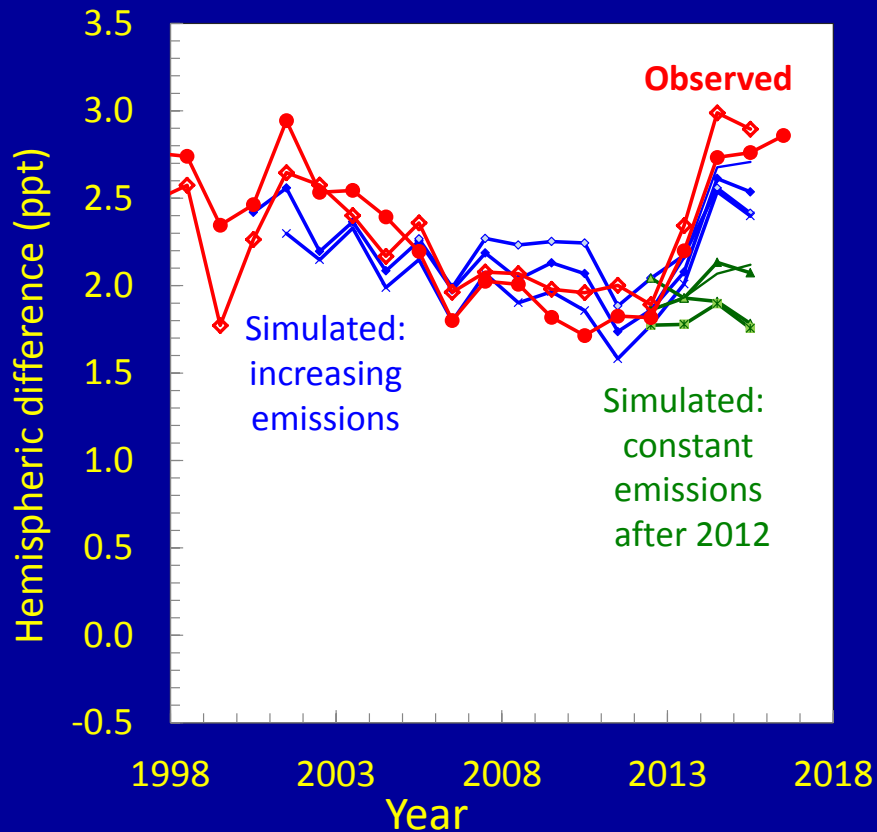
Key finding:

3-D model result shows:

- 1) The post-2012 emission increase is overestimated without consideration of dynamical changes...
 - 2) Changes in dynamics after 2012 slow the CFC-11 decline.
 - 3) But, some emission increase is required to simulate the slowdown
- The slowdown isn't all dynamics...

3-D Chemical transport analyses of the CFC-11 anomaly

Specified dynamics with different reanalyses



Key finding:

Dynamics do not cause an appreciable increase in the N – S difference (see constant emission lines (green)).

An increase in the N – S difference is only simulated with an increase in emissions.

**all runs performed with same emission distribution (except “homogeneous Emiss” distribution)
Thin lines: Fixed dynamics (MERRA)

Conclusions:

- 1) Atmospheric decline of CFC-11 has been slower than expected since 2002, and became 50% slower during 2013-2016.
Decline rates for other gases have not slowed similarly.
- 2) The slowdown was concurrent with an increased north – south difference.
Implies a 20% increase in NH flux
This *increase* is unique to CFC-11
- 3) The recent slowdown can be explained with a 20% increase in emissions since 2012 (~15 Gg/yr) despite near-zero global production since ~2007. (Assuming constant dynamics)
Such an emission increase is very difficult to reconcile with reported production.
- 4) An analysis with reanalysis meteorology in 3-D models suggests the slowdown has contributions from both:
 - * **changing dynamics**
 - and
 - * **a significant increase in CFC-11 emission**