Guiding Recovery of Stratospheric Ozone

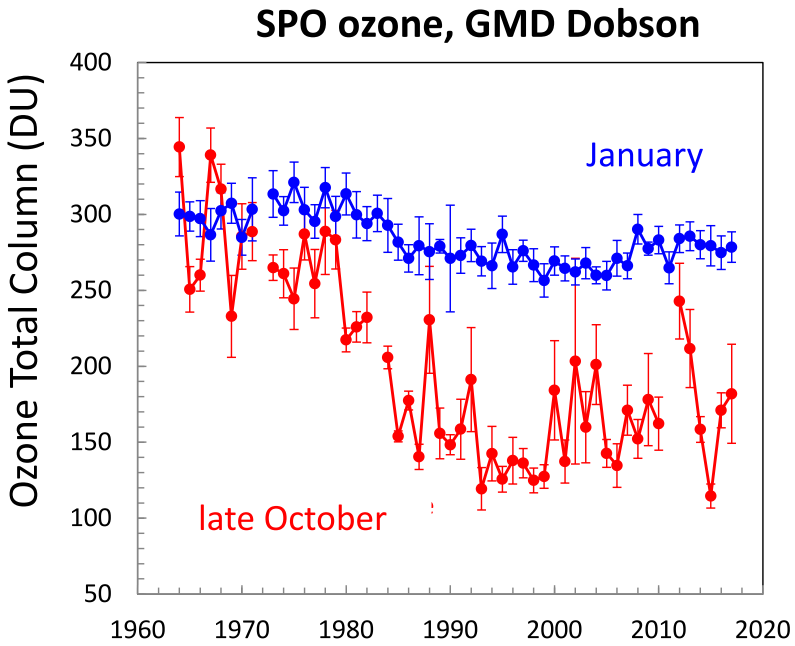
Guiding Recovery of Stratospheric Ozone at GMD

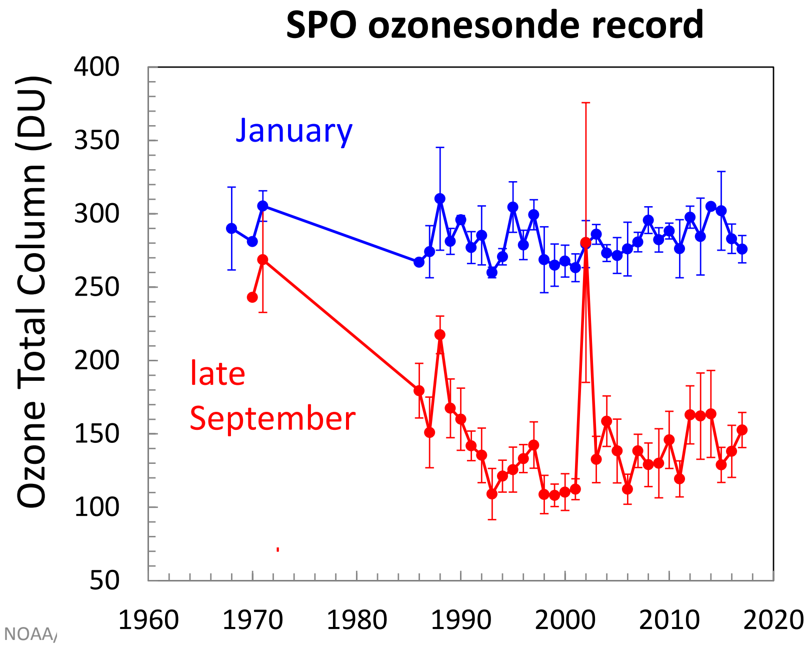
GMD plays a central role in the global effort to monitor stratospheric ozone, ozone-depleting gases, and other processes affecting stratospheric ozone

Our focus:

– ***global-to-regional scale observations*** to assess global changes *and* influences from specific processes and regions (*e.g*., U.S.)
– ***Diagnosing observed changes*** to clarify the relative influence of policy decisions, other human behaviors, and natural processes
– ***To provide the highest-quality, policy-relevant science***

→ *Guiding the recovery of the ozone layer by informing Parties to the Montreal Protocol on the progress of recovery*





Stratospheric ozone depletion

→ a threat to life on Earth.

1950s: - **NOAA** begins measuring total column ozone

1970s: - Theory suggesting CFCs will deplete ozone
- **NOAA** and NASA begin measuring CFCs

1980s: - Severe ozone depletion reported in Antarctica
- Montreal Protocol controls CFC production
- Antarctic ozone hole attributed to CFCs and other chemicals

1990s: - US Clean Air Act Amended:

NOAA and NASA

to monitor:

tropospheric chlorine & bromine, & stratospheric ozone depletion

to project:

peak chlorine

the rate of chlorine decline after 2000

the date when chlorine returns to two ppb

** 1996: tropospheric chlorine peaks (NOAA-GMD publication)*

** 2003: tropospheric bromine peaks (NOAA-GMD publication)*

Guiding Recovery of Stratospheric Ozone at GMD

A) Measuring chemicals that cause stratospheric ozone depletion

→ One of two global networks tracking long-term changes in ozone-depleting gases

B) Measuring long-term changes in stratospheric ozone

→ Providing reference-quality long-term measurements of stratospheric ozone

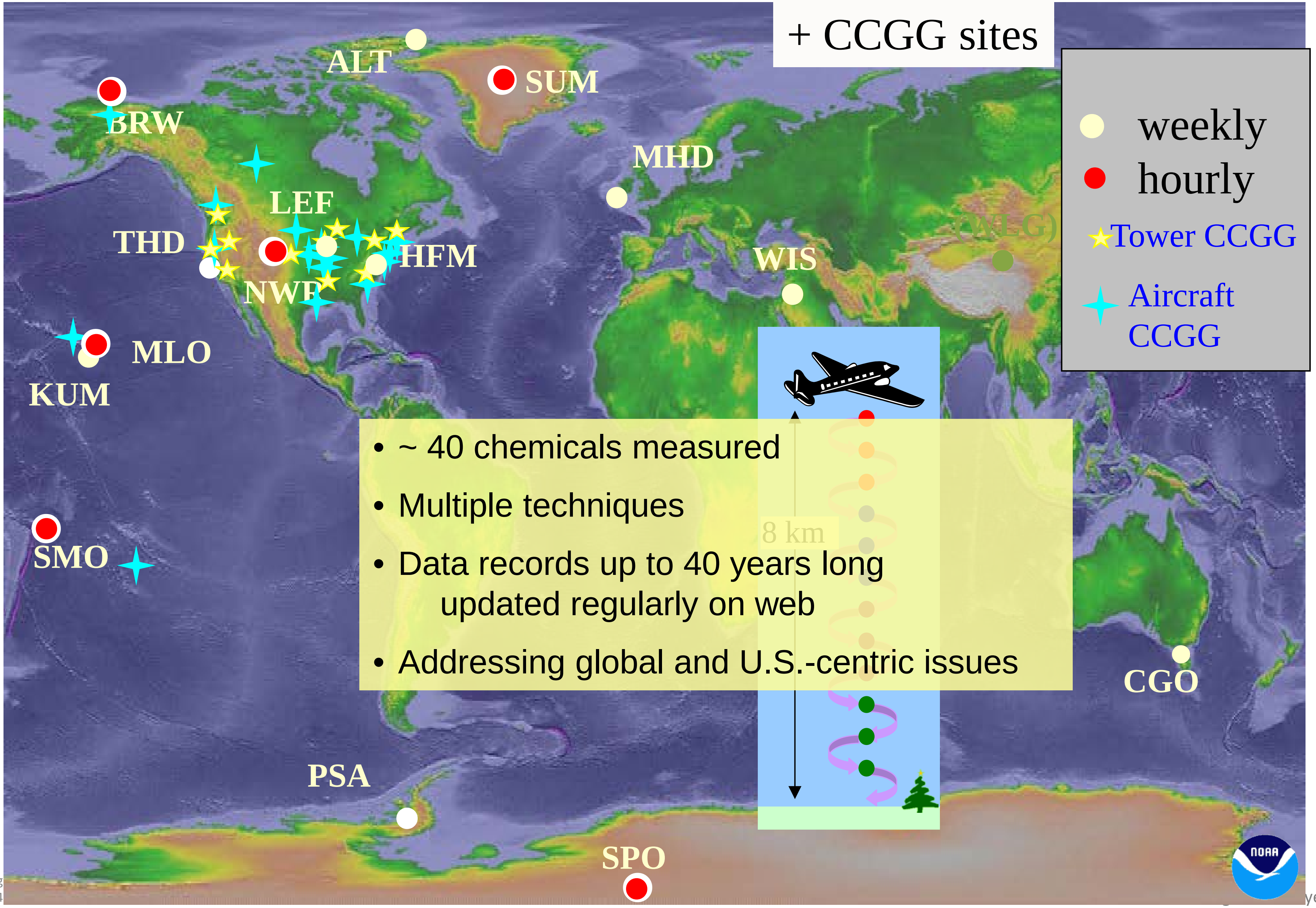
C) Advancing scientific understanding

→ Understanding causes of atmospheric composition change and improving our understanding of atmospheric processes

D) Communicating results to a broader audience** **(stakeholders)

→ through simple indices, web presence, open data policies, publications, and by contributing to national and international Scientific Assessments

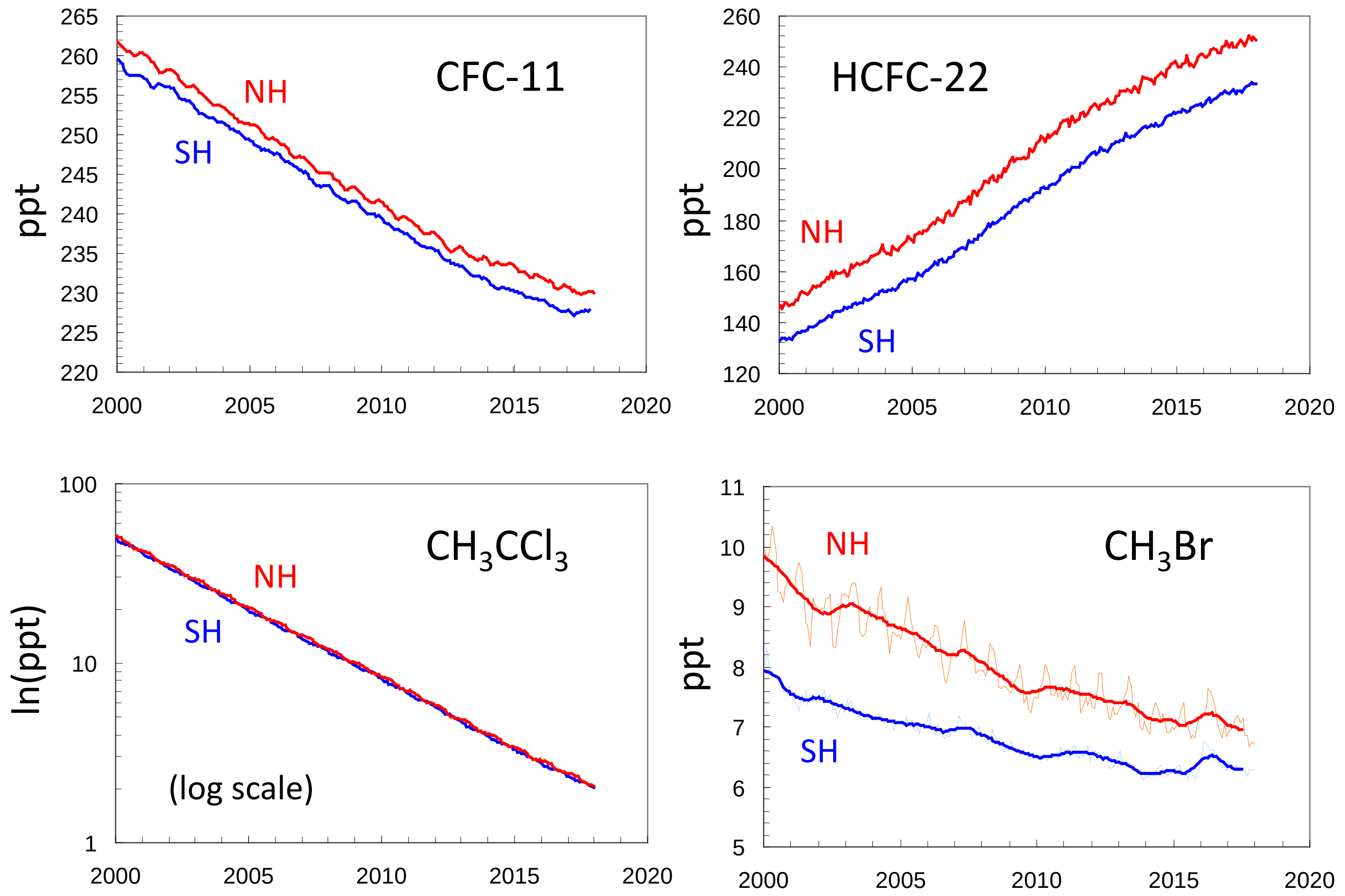
A) Measuring chemicals that cause stratospheric ozone depletion



- ~ 40 chemicals measured
- Multiple techniques
- Data records up to 40 years long updated regularly on web
- Addressing global and U.S.-centric issues

A) Measuring chemicals that deplete stratospheric ozone

– Concentrations of ozone-depleting chemicals for which **PRODUCTION IS CONTROLLED** by the Montreal Protocol



All major ozone-depleting gases are measured at NOAA/GMD.

Emphasis is on high precision and accuracy.

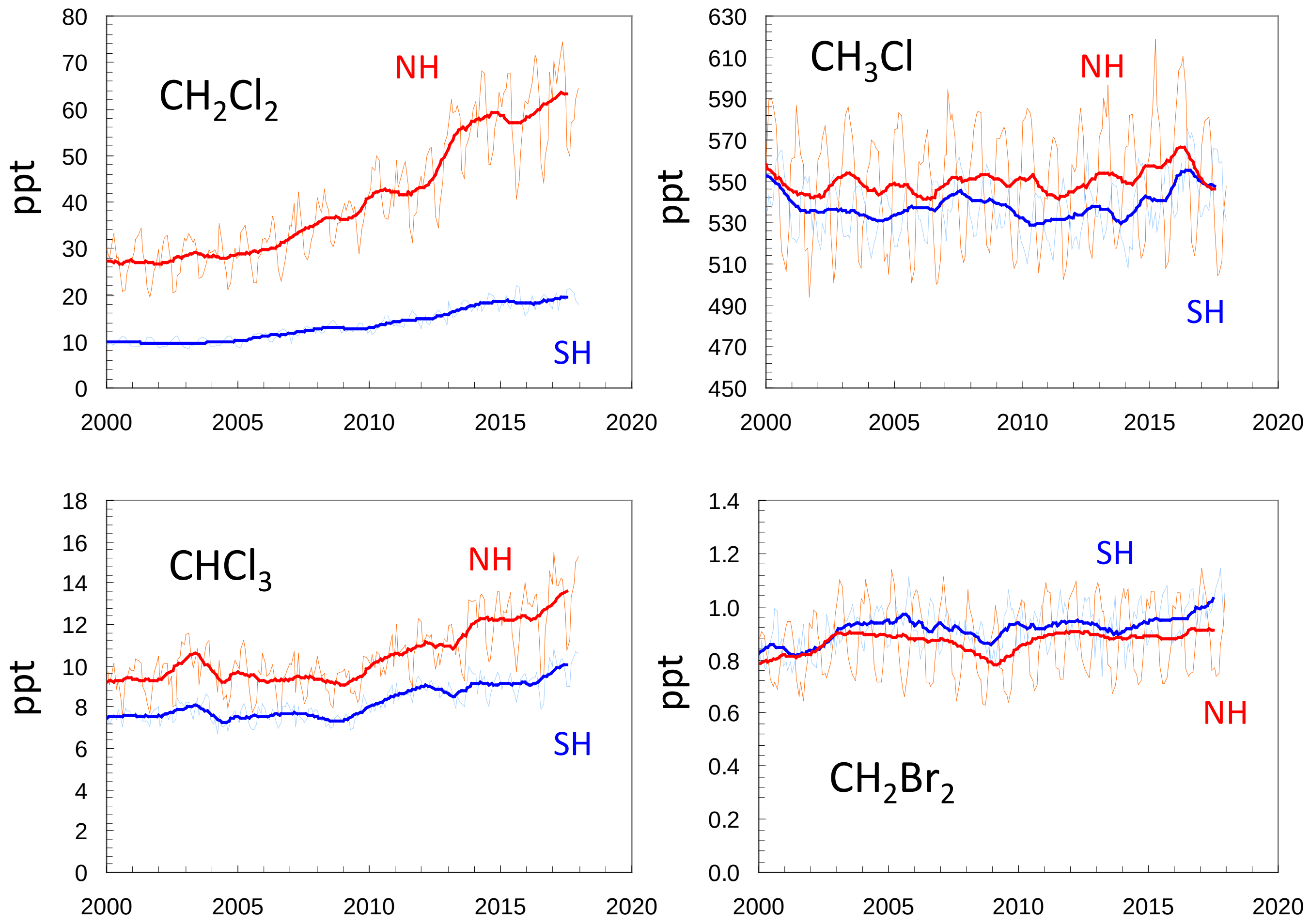
→the better the measurement, the more one can learn…

See talks by S. Montzka, and by P. Yu

Recent related pubs: Montzka *et al.*, 2015; 2018; Rigby *et al.*, 2017

A) Measuring chemicals that deplete stratospheric ozone

– Concentrations of halogenated chemicals **NOT CONTROLLED** by the Montreal Protocol, but that can influence stratospheric ozone:



Shorter-lived gases also add chlorine and bromine to the atmosphere.

→ having human and natural sources.

→ changing over time?

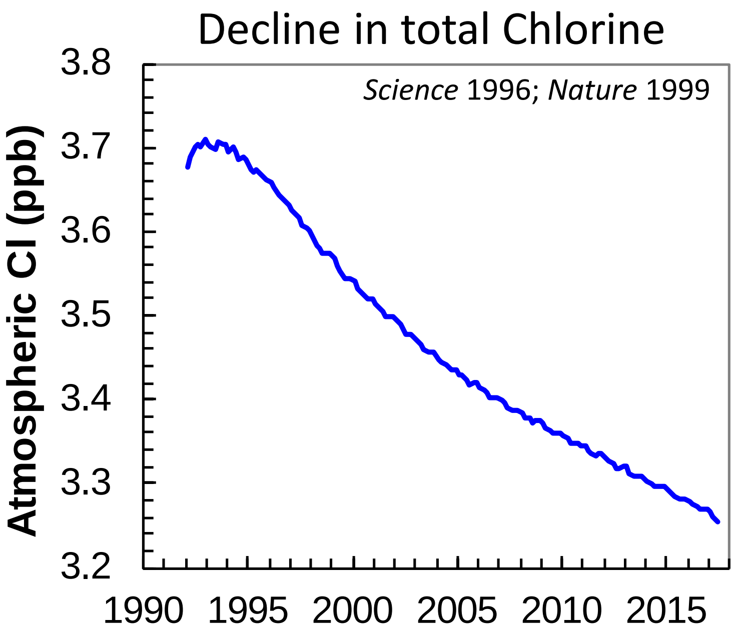
Also: N_2O, COS

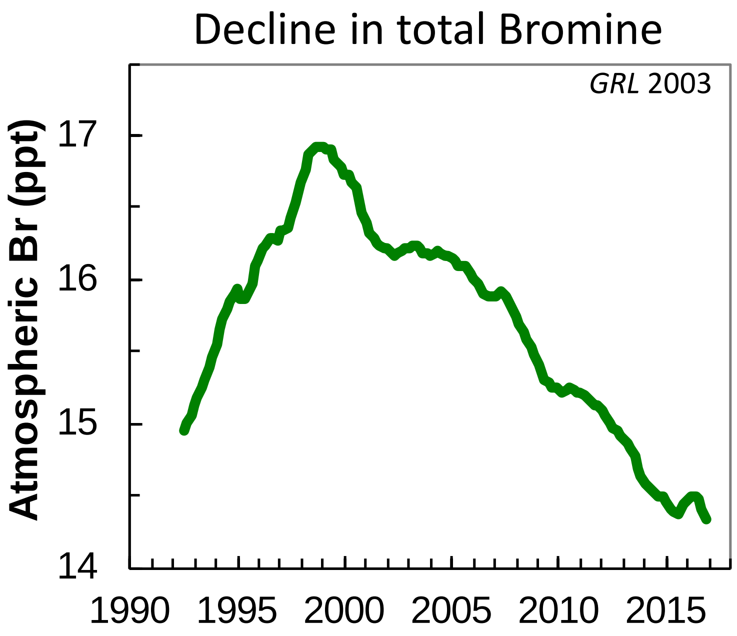
See poster by G. Dutton

Recent related pubs: Hossaini *et al.*, 2016; 2017

A) Measuring chemicals that deplete stratospheric ozone

– Changes in "controlled" tropospheric chlorine and bromine:





→ Sum of all controlled gases measured at GMD

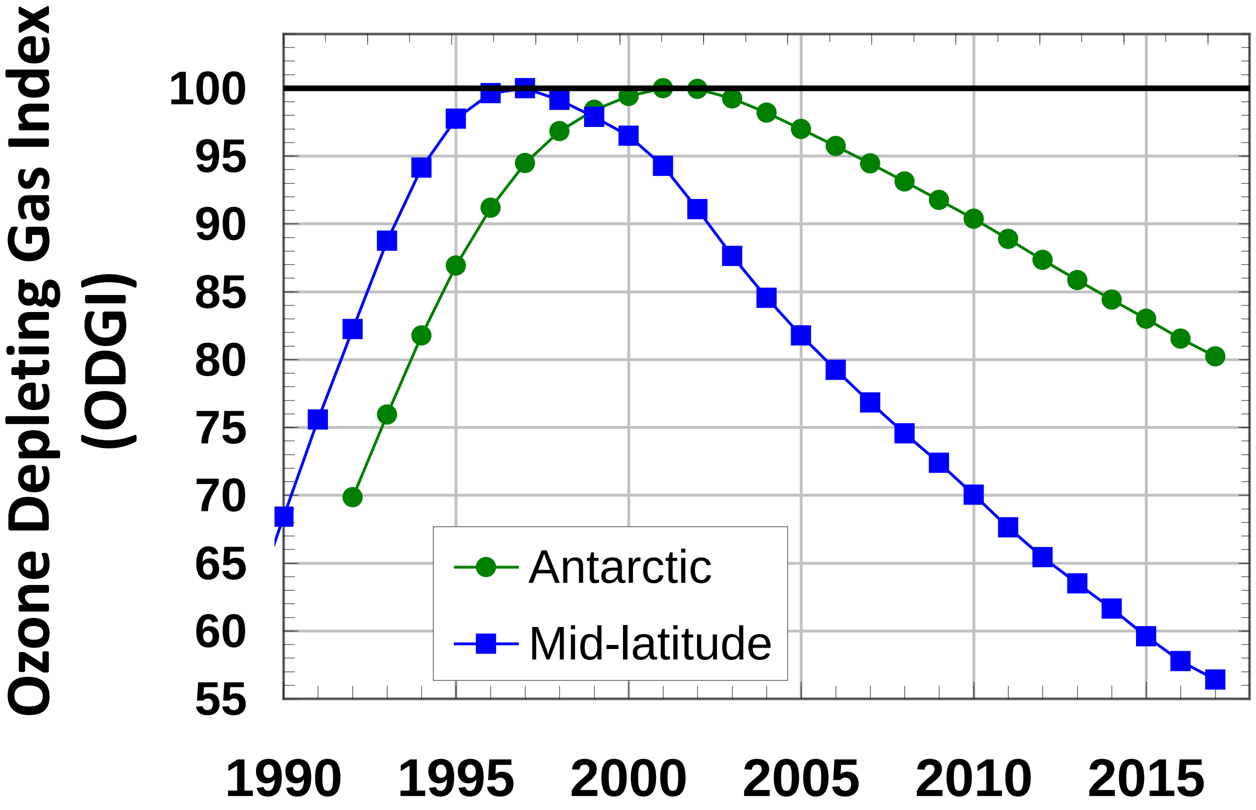
→ directly addressing Congressional mandate

→ updated annually on NOAA web page:
ftp://ftp.cmdl.noaa.gov/hats/

A) Measuring chemicals that deplete stratospheric ozone

– Distilling GMD measurements of controlled gases into a single index:

The Ozone Depleting Gas Index



Measuring progress in the decline of ozone-depleting halogen back to 1980 concentrations (pre-ozone hole)

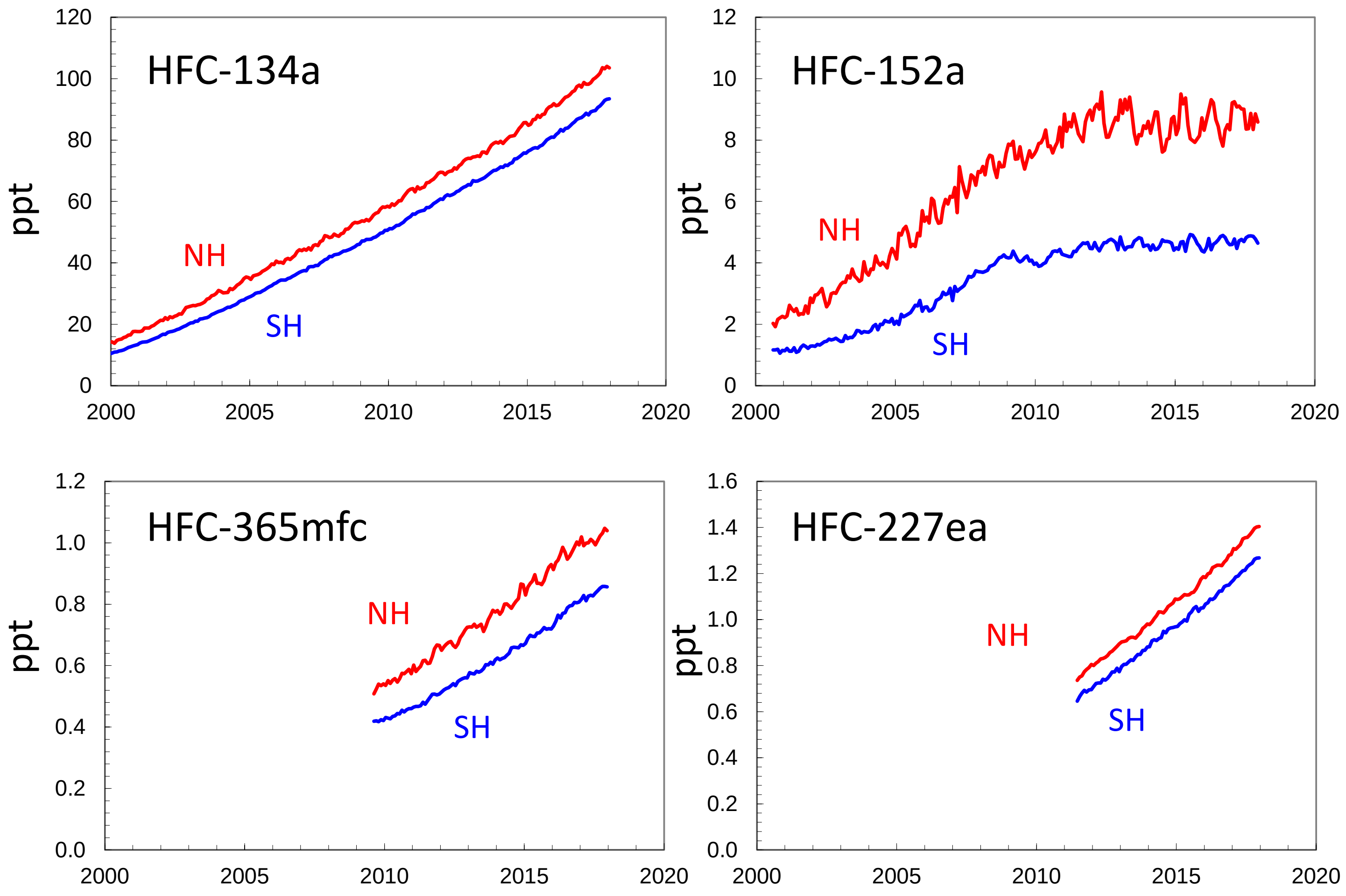
In 2017:

- Antarctic ODGI was 80
- Mid-latitude ODGI was 56

Annually updated at http://www.esrl.noaa.gov/gmd/aggi/

A) Measuring substitute Hydrofluorocarbons

– Concentrations of chemicals for which **PRODUCTION IS CONTROLLED** by the Montreal Protocol, ***but that do NOT deplete ozone***



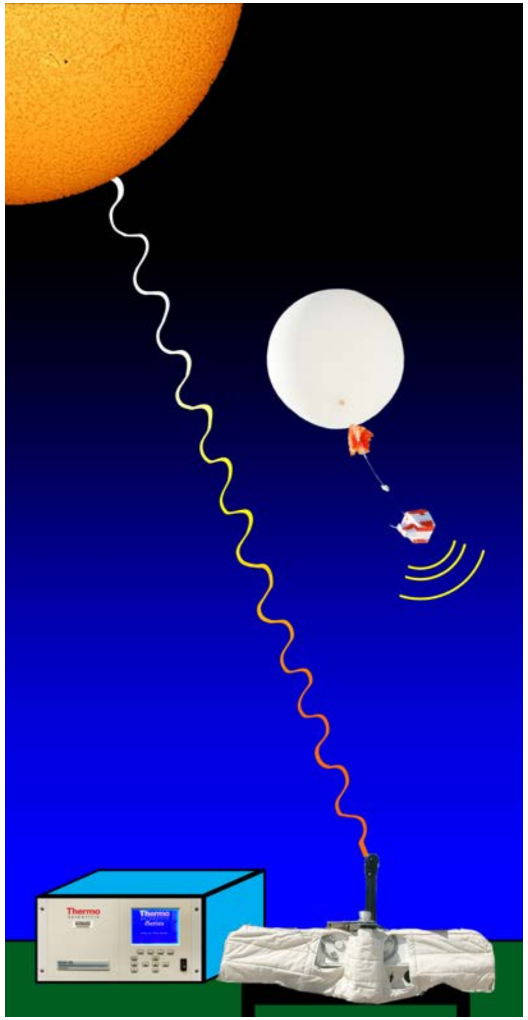
Recently added to the Montreal Protocol list of controlled substances.

These results enable a tracking of radiative forcing from ODS substitution.

Most substitute HFCs are measured at NOAA/GMD.

B) Measuring long-term changes in stratospheric ozone

→ Providing reference-quality long-term measurements of stratospheric ozone



Using a range of techniques to obtain:

Ozone total column density:

- Dobson
- Brewer

Ozone concentration vertical profile :

- Ozone Sondes (highest vertical resolution)
- Umkehr

Ozone concentrations near Earths surface

To allow an understanding of ozone concentration changes:

over time

- developing and applying statistical models to provide trend estimates

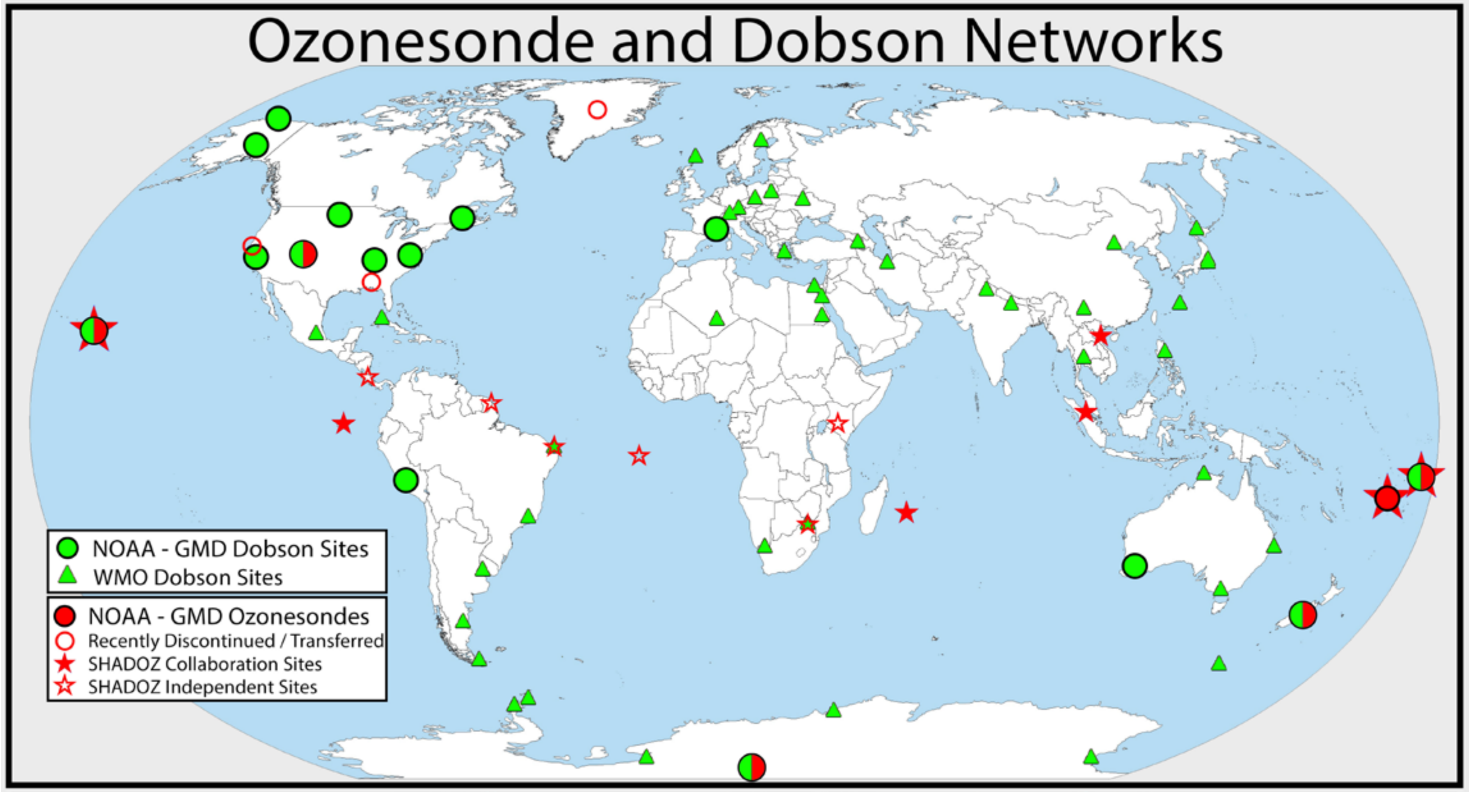
as a function of altitude

- stratospheric changes (upper vs lower stratosphere)
- tropospheric changes (pollution-related or transported from stratosphere)

as a function of latitude

- future ozone changes are expected to be latitude-dependent
  - aerosol, GHGs, circulation...

B) Measuring long-term changes in stratospheric ozone



NOAA-GMD Dobson ozone program:

- Forms a global backbone of robust, calibrated total column ozone data
- Provides an essential reference for other ozone measurements (satellites, other Dobsons, etc.) through calibration transfers
- Maintains the WMO reference Dobson instrument (#D083)

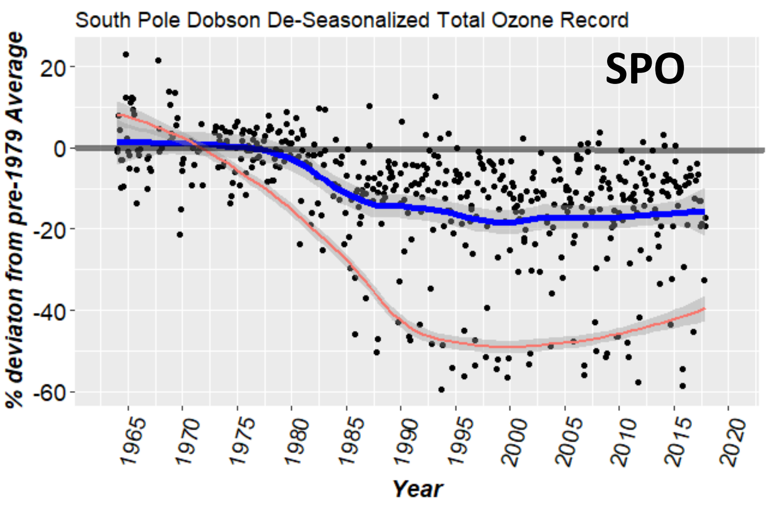
NOAA-GMD ozone sonde program:

- adds high vertical resolution (data were recently homogenized)
- Strengthens and augments the SHADOZ program for tropical ozone data

Recent Dobson- and sonde-related pubs: Petropavlovskikh et al. (2015), Nair et al., 2015; Evans et al., 2016, Thompson et al., 2017, Sterling et al, (2018)

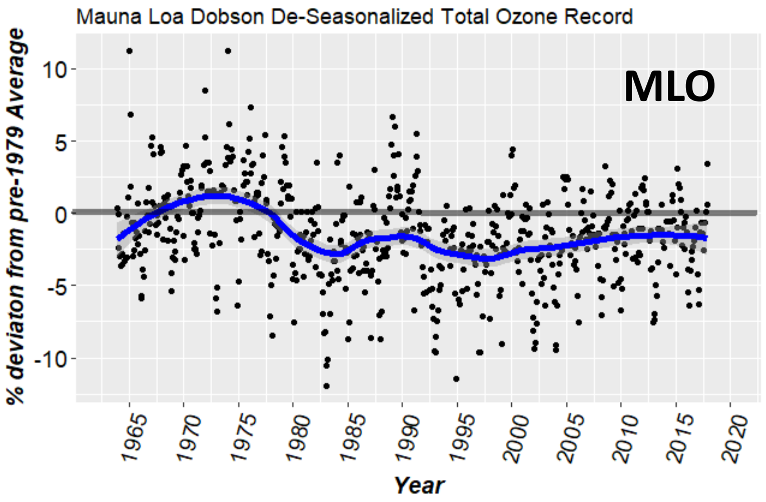
B) Measuring long-term changes in stratospheric ozone

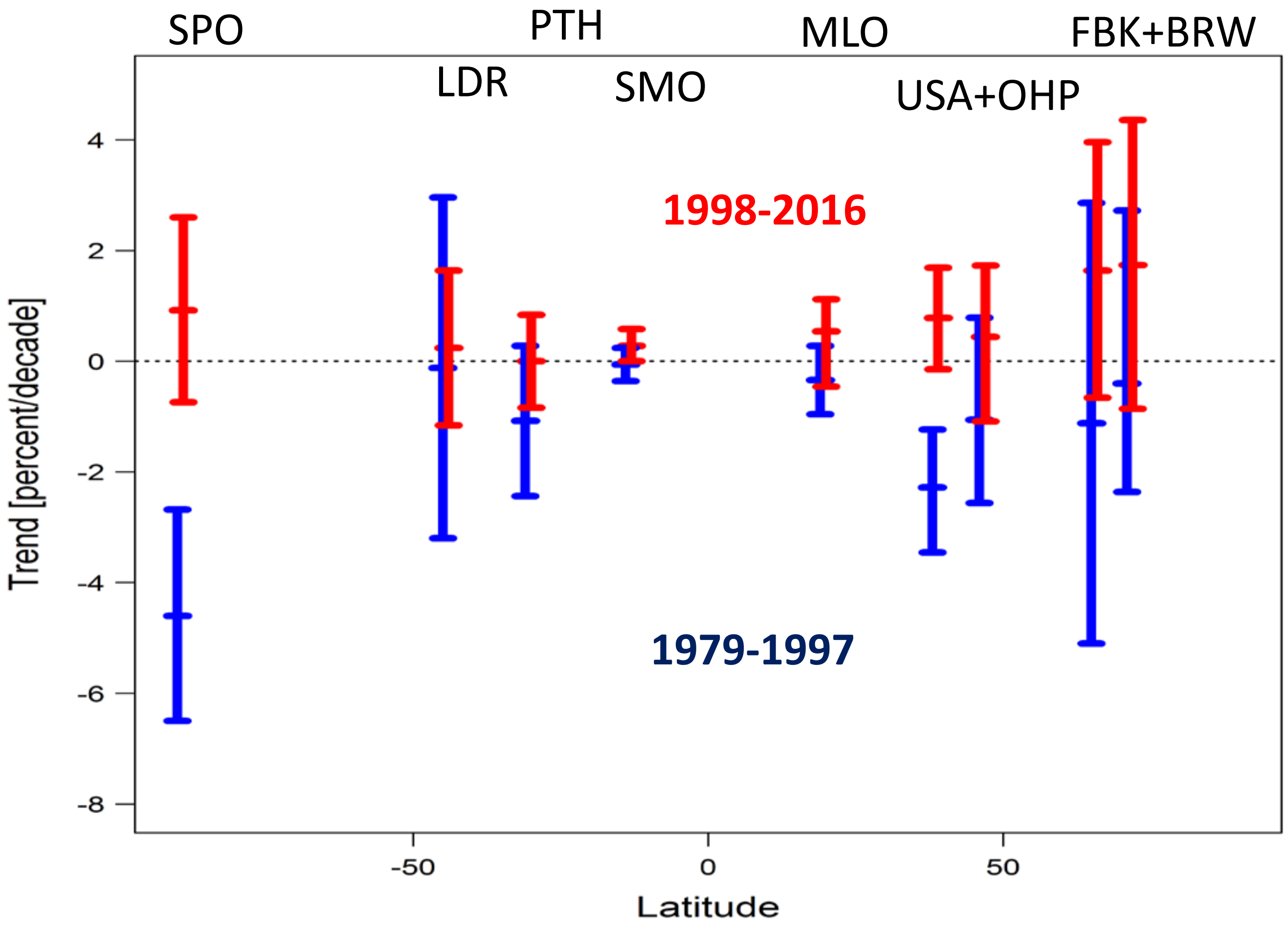
–To allow an understanding of ozone column changes by latitude (ODS+GHG+transport)



All data

Sept-Oct only

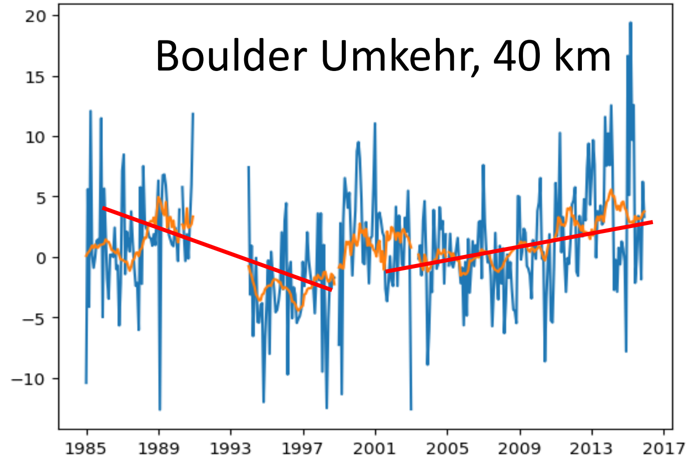


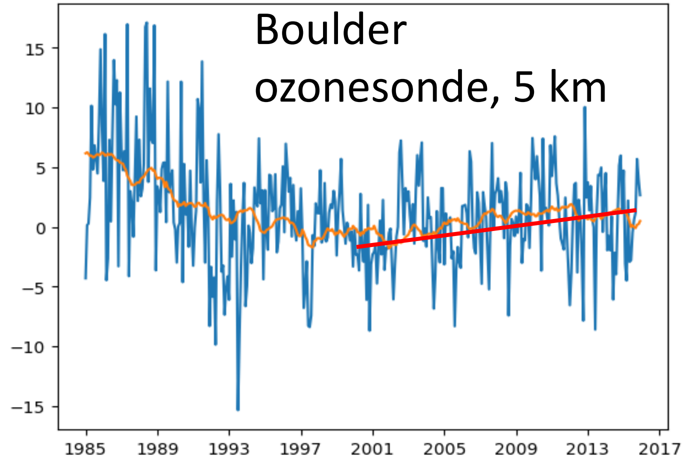


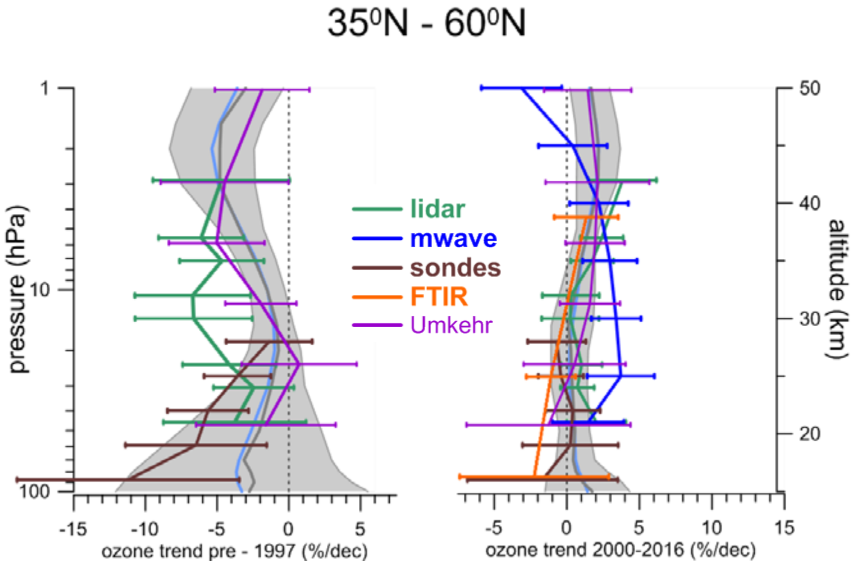
See posters by G. McConville, K. Miyagawa

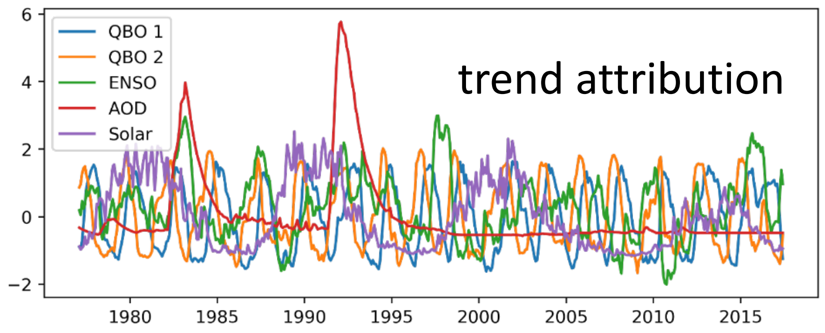
B) Measuring long-term changes in stratospheric ozone

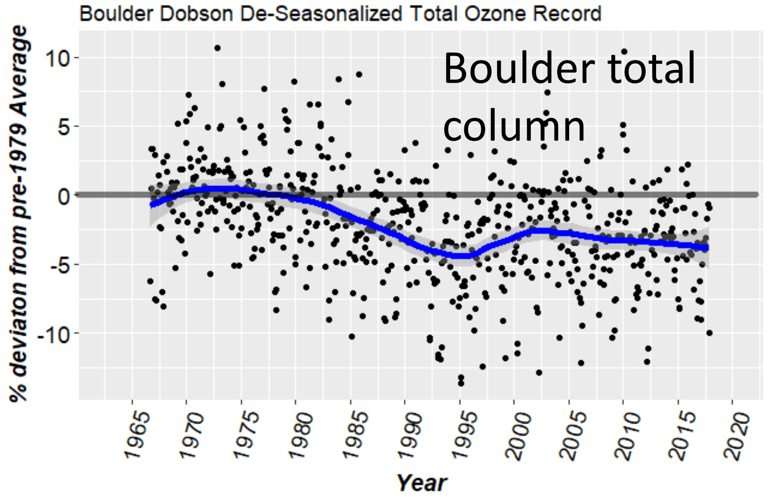
- To allow an understanding of ozone column changes by altitude (ODS+GHG+transport)









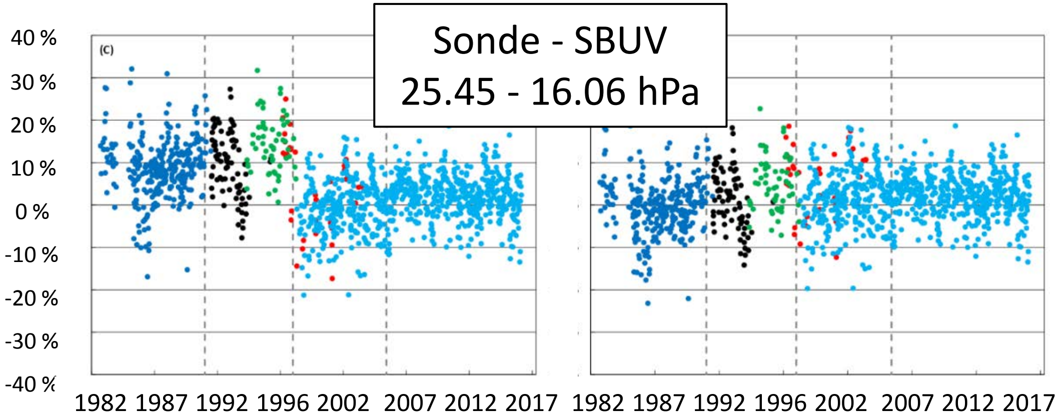


LOTUS 2018 and Ozone Assessment 2018 used GMD data and developed statistical models to derive trends in ozone profiles and total column.

B) Measuring long-term changes in stratospheric ozone

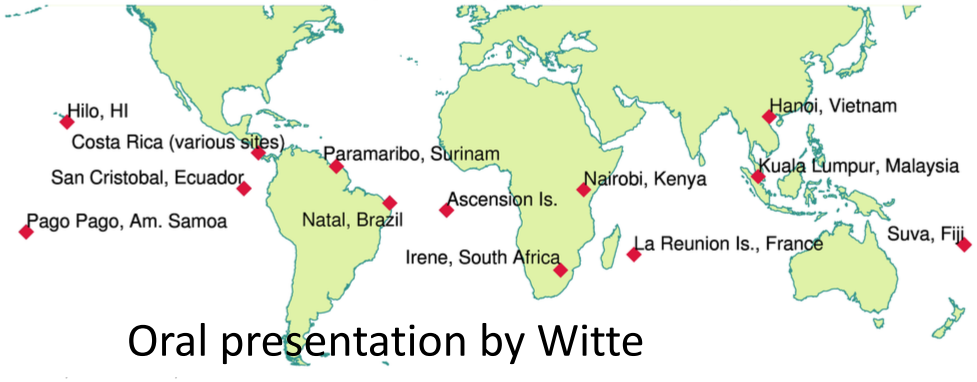
– *To allow an understanding of ozone column changes by altitude (ODS+GHG+transport)*

Is ozone in lower stratosphere still decreasing? Ball et al (2018) analyses are based on satellite records



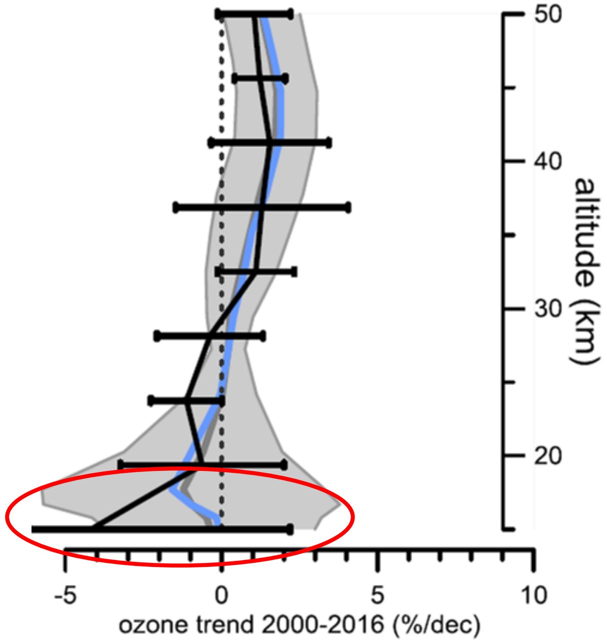
Homogenization for GMD (Sterling et al, 2018) and SHADOZ (Witte et al, 2017) ozonesonde data - improved records for future trend analyses

SHADOZ Sites: https://tropo.gsfc.nasa.gov/shadoz

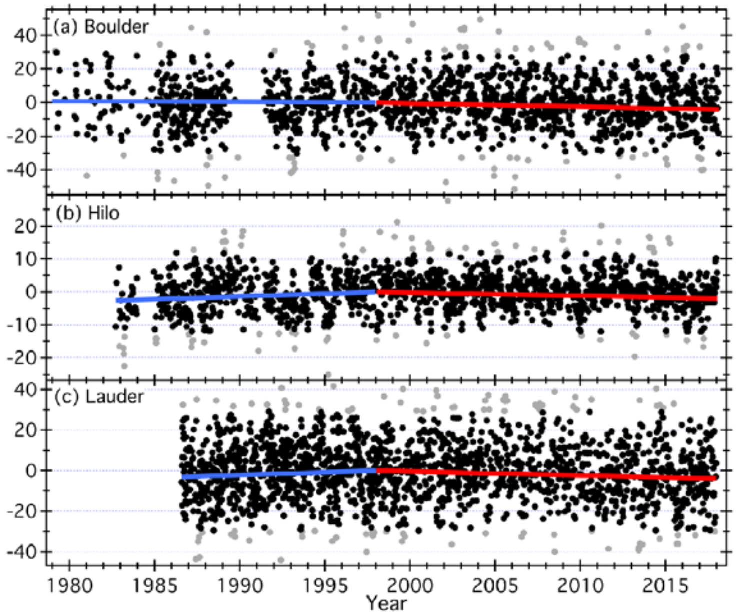


Oral presentation by Witte

20°S-20° N



Satellite and **CCMI** model averaged trends (LOTUS, 2018, Ozone Assessment) - disagreement between models and observations?

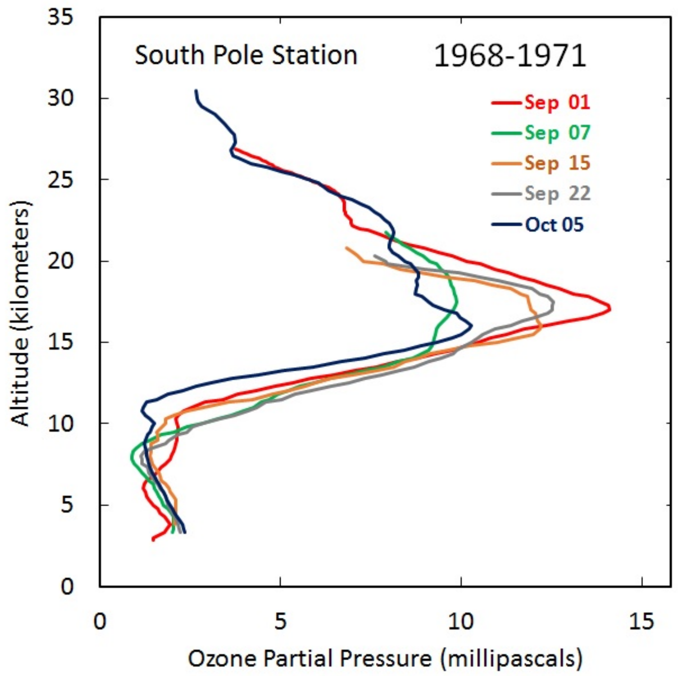


Trends in the low stratosphere will be soon assessed from homogenized ozone-sonde data in tropics and middle latitudes.

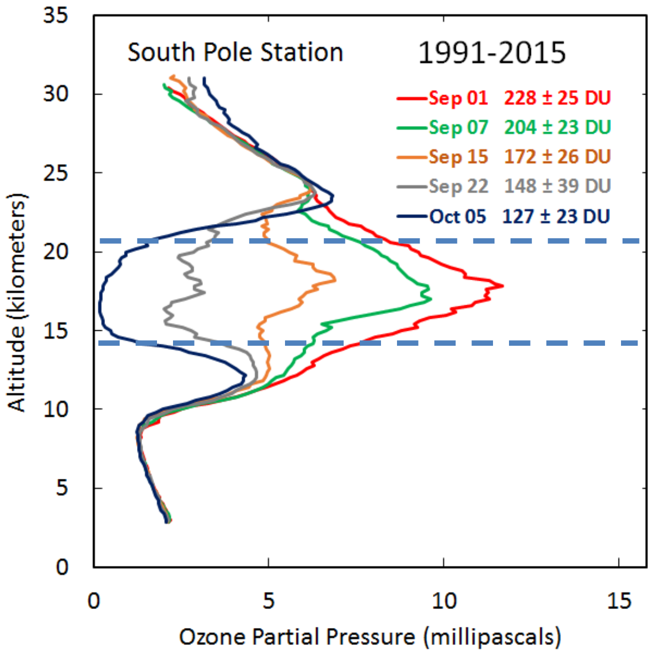
B) Measuring long-term changes in stratospheric ozone

– Ozone, **vertical profiles from ozone sondes** on balloons

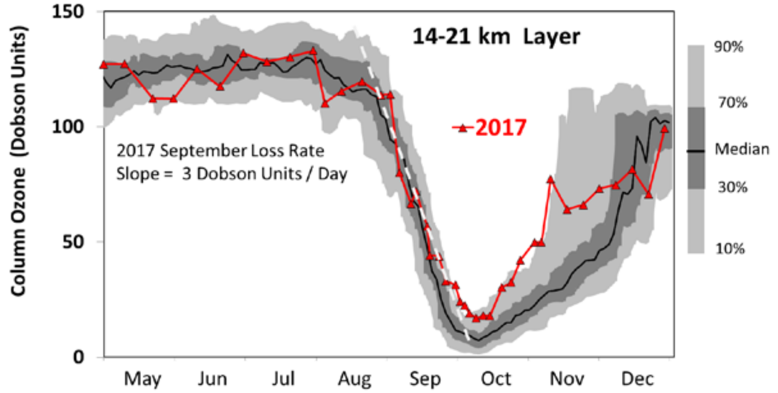
Pre-1971 (pre ozone-hole)

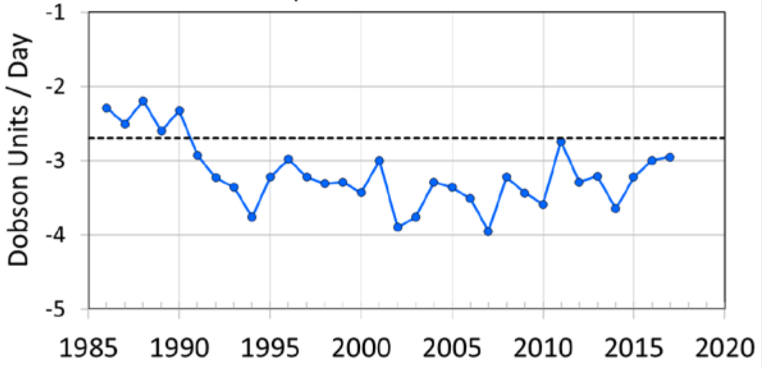


Ozone-hole conditions



Focus on depleted layer:





See talk by B. Johnson, poster by P. Cullis

Recent related pubs: Solomon et al. 2016 – ozone-sonde detected recovery, observed in Septembe
Hofmann(2010)? Recovery after the September depletion rate is less than 2.7 DU/day

C) Advancing scientific understanding (Q3 & Q4 in New Research Plan)

→Understanding the cause of atmospheric composition changes

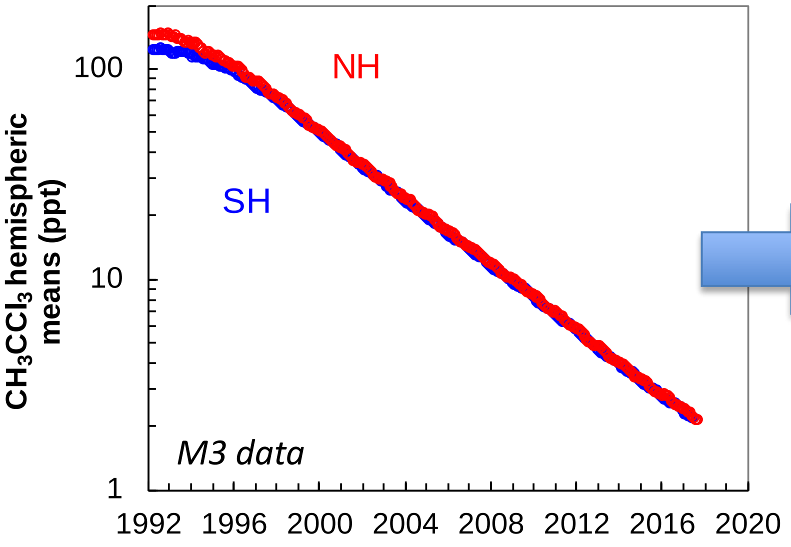
→sources, sinks, and transport

Improving our understanding of trace-gas sources and sinks

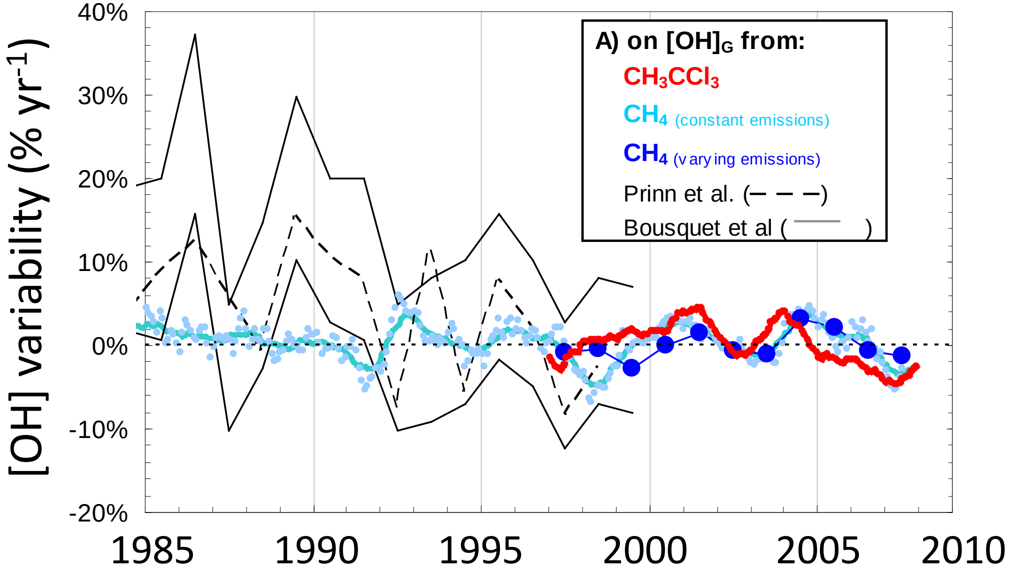
Sinks: Measuring the atmospheric oxidation capacity over time

→ ***budget analyses of long-lived gases***

The exponential decline in CH_3CCl_3



Inferred [OH] inter-annual changes



Science 2000;
Science 2011;
PNAS 2017

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Alternative approaches to CH_3CCl_3:

* Deriving OH loss from consideration of hemispheric mole-fraction differences

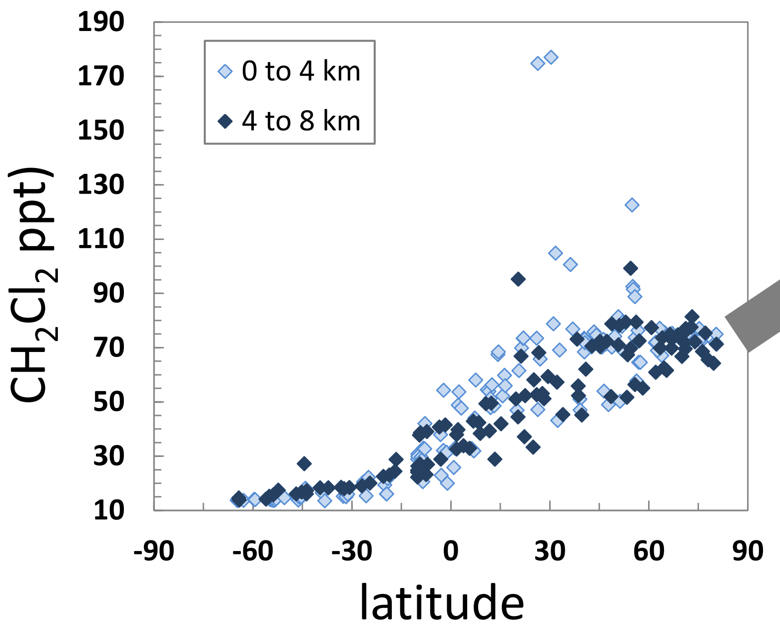
Long-lived gases

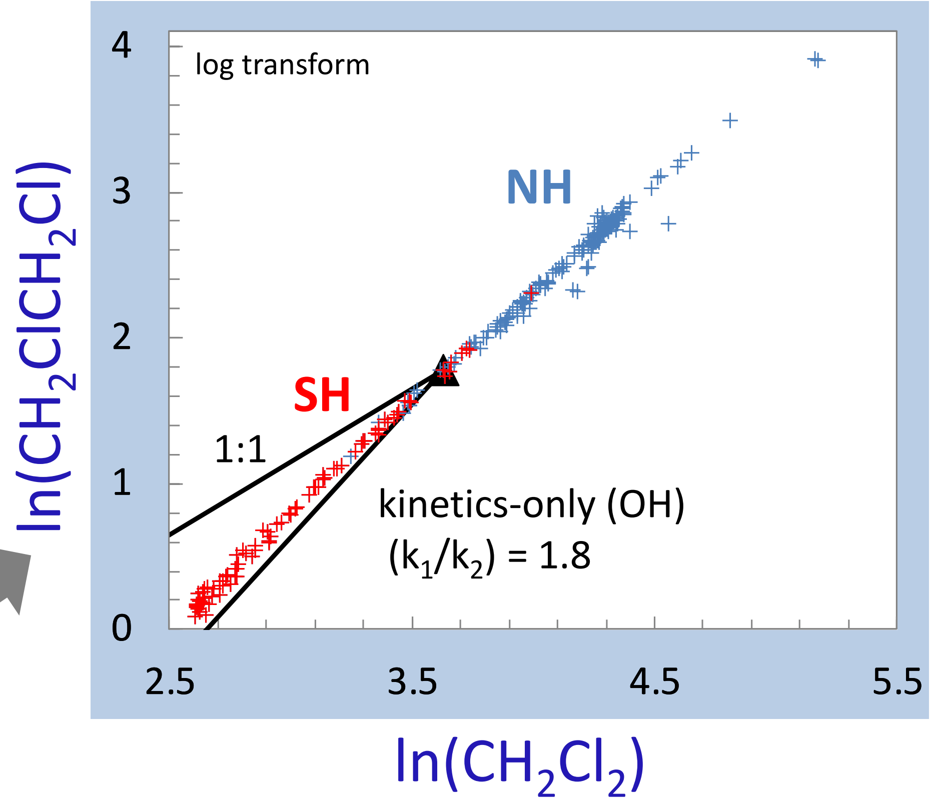
(Liang *et al.*, 2017)

Short-lived gases

From network and special projects

(e.g., Atom)





C) Advancing scientific understanding (Q3 & Q4 in New Research Plan)

→Understanding the cause of atmospheric composition changes

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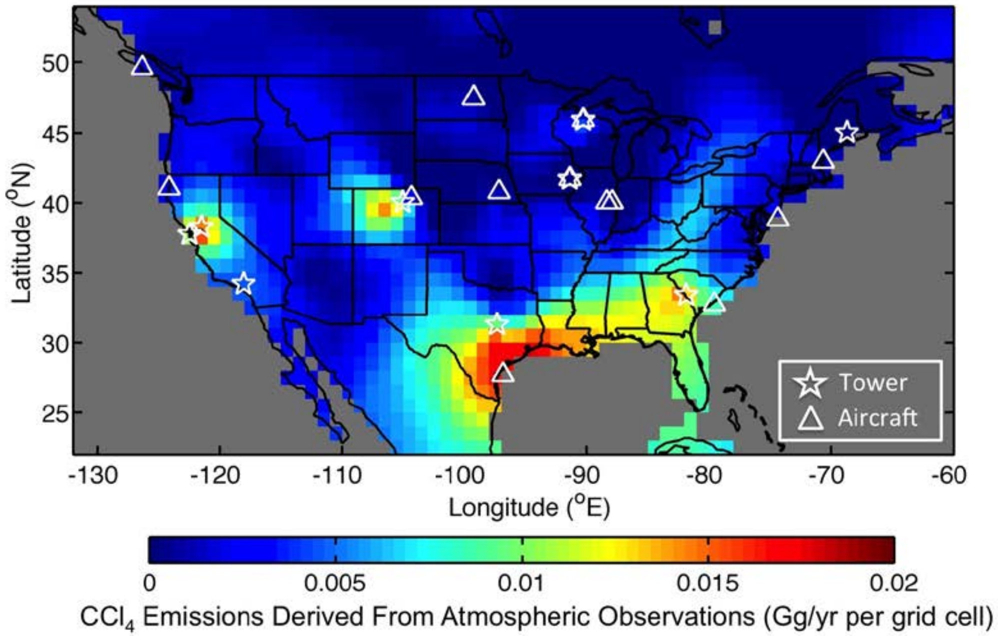
Improving our understanding of trace-gas sources and sinks

Sources, particularly U.S. contributions, but also on a global scale

Why are CCl_4 emissions continuing now that CFC production is negligible?



SPARC Report focus in 2016

What we found:

US emissions are 10% of global total

- associated with chemical industry
- this process likely accounts for much of the remaining global emissions

(Hu et al., 2016)

Other similar findings related to CFC-11 will be discussed in meeting

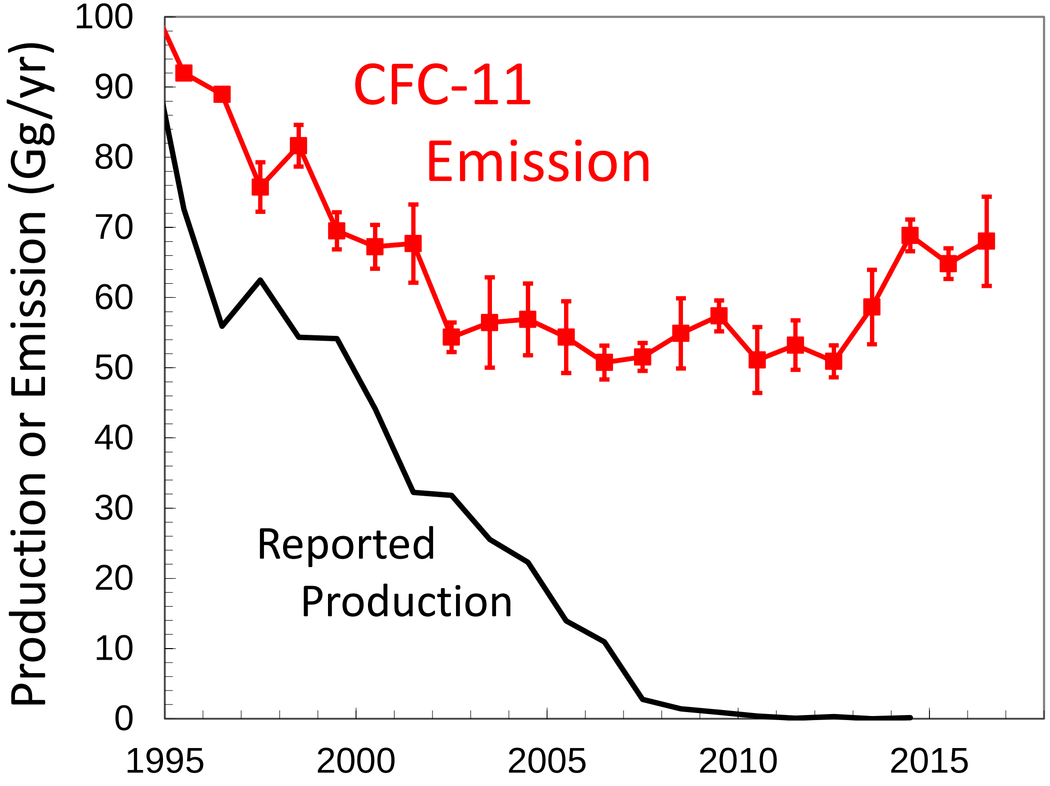
C) Advancing scientific understanding (Q3 & Q4 in Research Plan)

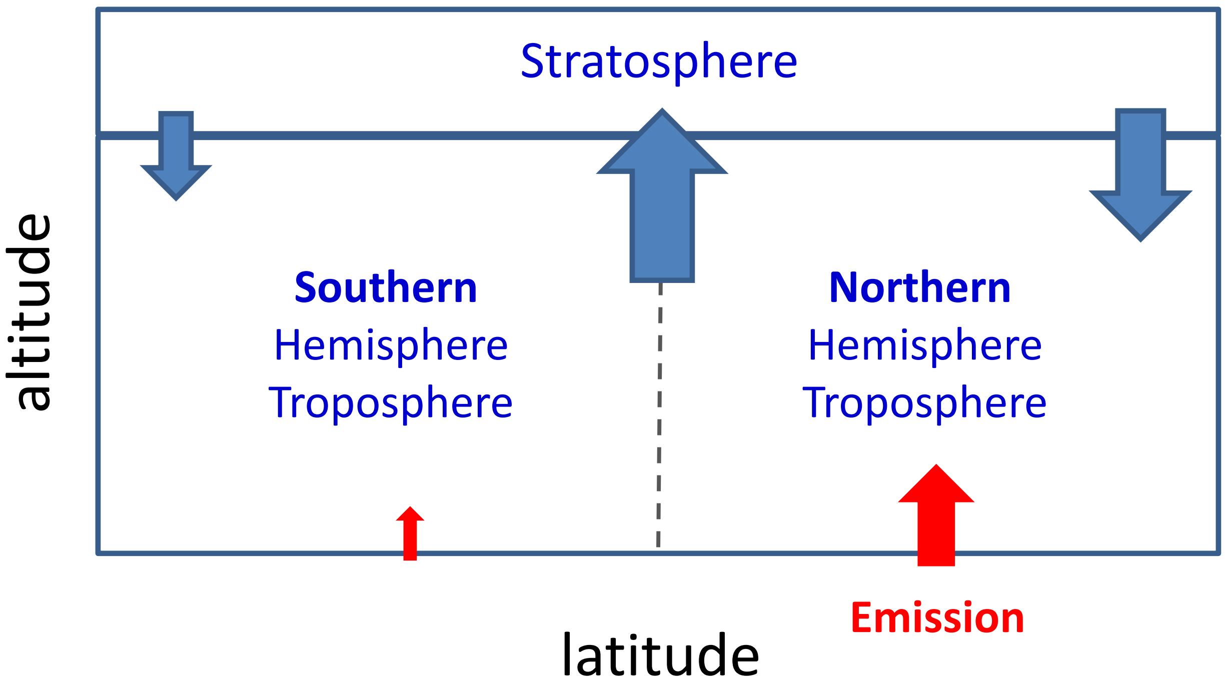
→Understanding the cause of atmospheric composition changes

→sources, sinks, and transport

Improving our understanding of trace-gas sources and sinks

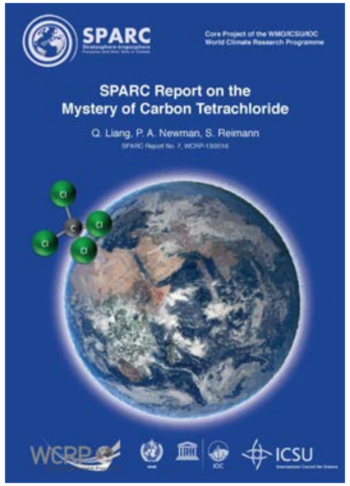
Surface measurements are influenced by variations in sources *and* sinks:



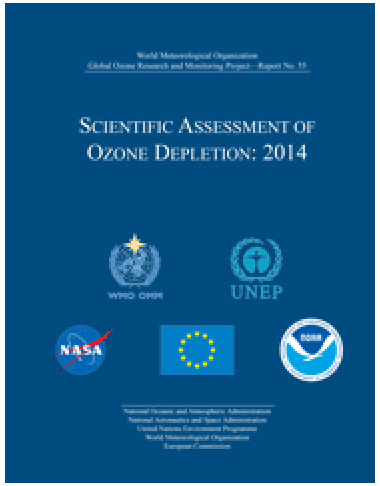


D) Communicating results

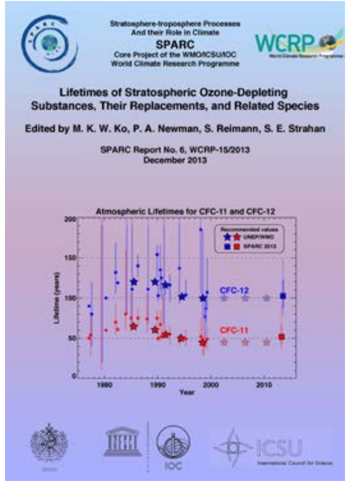
- ***Providing expertise*** to national and international Assessments on Ozone and Climate:
  - ***GMD scientists*** have been lead authors, co-authors, contributing authors, and contributors to these Assessments
  - ***GMD data*** are prominent in these Assessments



2016



2014



2013

2014

Also:

•UNEP/WMO, 2018 Scientific Assessment of Ozone Depletion—lead authors

•UNEP/WMO, Twenty questions and answers about the ozone layer, 2015

Guiding ozone layer recovery in the future at GMD:

- **Continue ongoing programs to:**
  - Monitor effectiveness of the Montreal Protocol for diminishing ozone-depleting gases
  - Accurately measure the response of stratospheric ozone to decreasing halogen and increasing greenhouse gas concentrations
- **Especially to address newly emerging issues:**
  - increases in CFC-11, CH_2Cl_2, & CH_3Br; and in future for VSLS-bromine?
  - HFCs and Kigali Amendment – locking in climate gains from the Montreal Protocol
  - lower stratospheric ozone declines (Ball et al. 2018)? Assess better-positioned GMD measurements (Unkehr; ozone-sonde)
- **Add capabilities where possible:**
  - increased sampling frequency in tropics
  - validation of new instruments (*i.e.* Pandora)
  - validation of new operational NOAA satellite products (*i.e.*, IPSS)
- **Participate in periodic field campaigns to:**
  - extend an understanding of surface-based results vertically
  - improve process-based understanding of the atmosphere
  - gauge the atmospheric response to increasing greenhouse gas concentrations

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– ***To provide the highest-quality, policy-relevant science***

→ *Guiding the recovery of the ozone layer by informing Parties to the Montreal Protocol on the progress of recovery*