Atmospheric Emissions of Sulfur Hexafluoride (SF_6): A Challenge for the Future.

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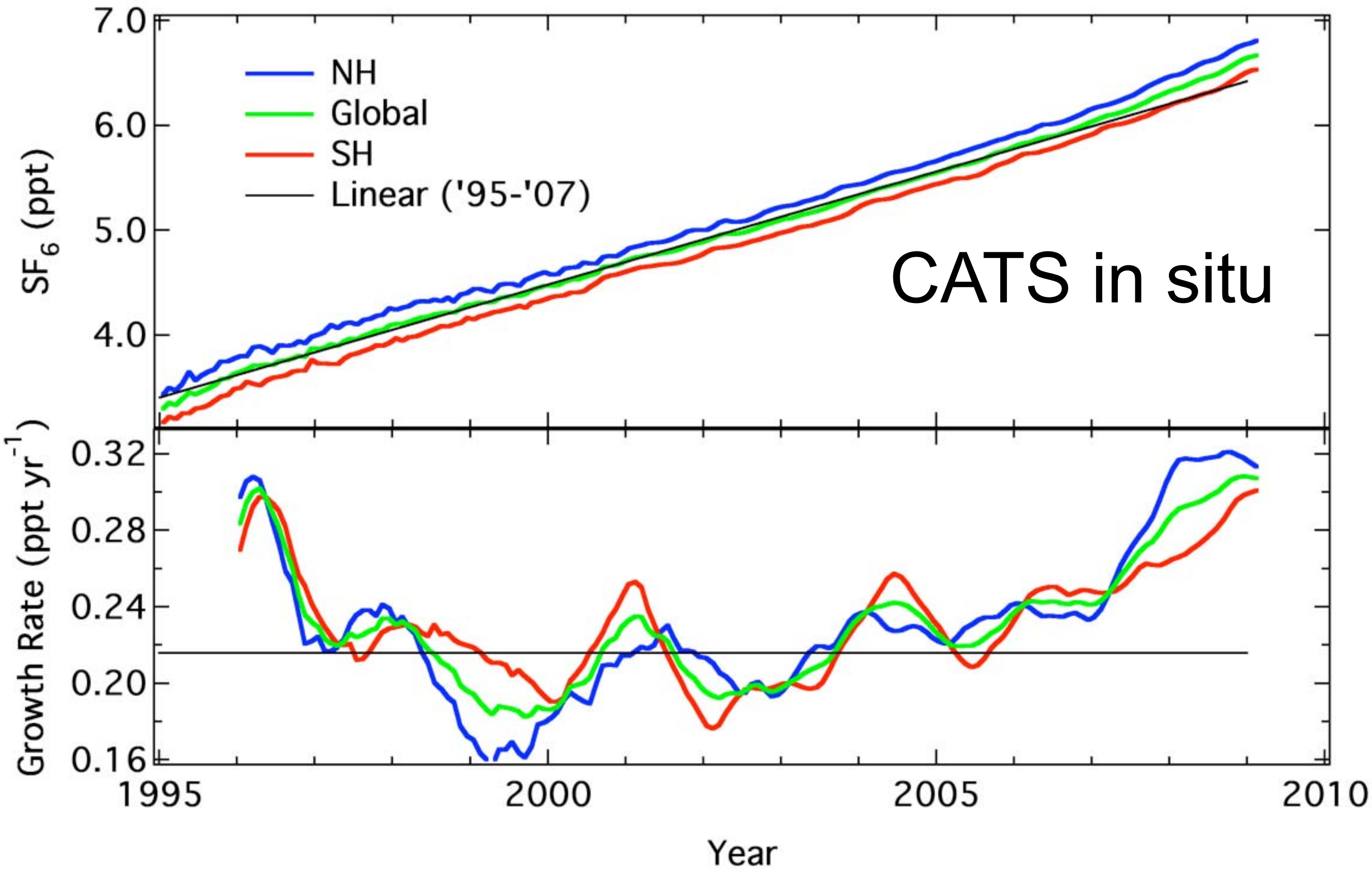
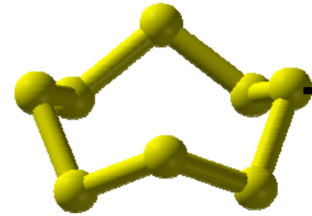
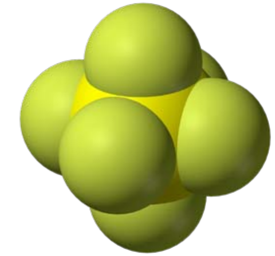


What is SF_6?

 + 24 F_2 (g) = 

S_8 chemical model

SF_6 chemical mode

- Made from F_2 and S_8, as made by discoverers Henri Moissan and Paul Lebeau in 1901

- SF_6 is an excellent dielectric, used in high voltage circuit breakers, switch boxes, transmission lines, above 35 kW.

- It is highly electophilic. It quenches sparks very quickly and has low thermal conductivity. The big plus is that it allows electronic devices to be built smaller.

- Atmospheric scientists have used SF_6 as a tracer of air masses and mean age of the air mass in the stratosphere.

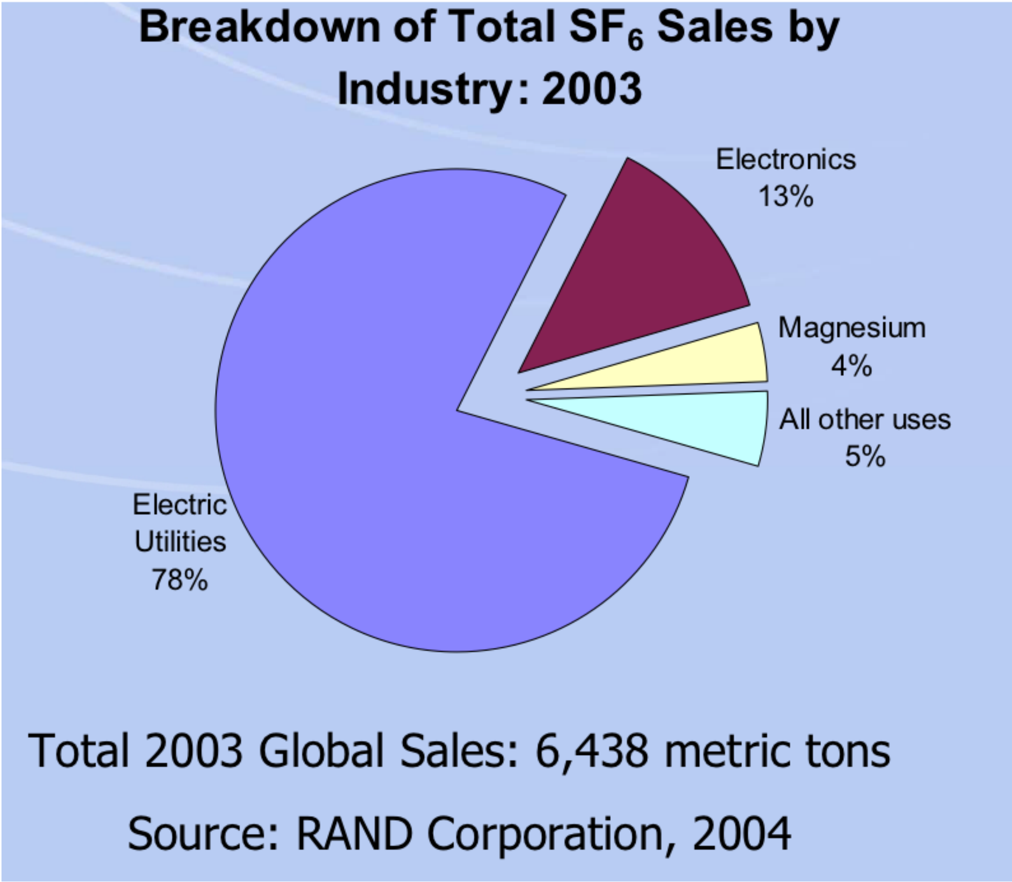
400 kV SF_6 Circuit Breaker

Hybrid Switchgear

Emissions and Uses of SF_6

- The U.S. EPA has made significant progress in reducing emissions (680 metric tons, >10% of sales, equal to getting 3.1 million cars off the road) in a 10 year old program to reduce SF_6 emissions by industry. (SF_6 Gas Emission Reduction Partnership from Electric Power Systems went from 15.2% in

- Uses:



Challenges for the Future

- As population increases electrical use will increase. We will need some type of dielectric for power distribution.

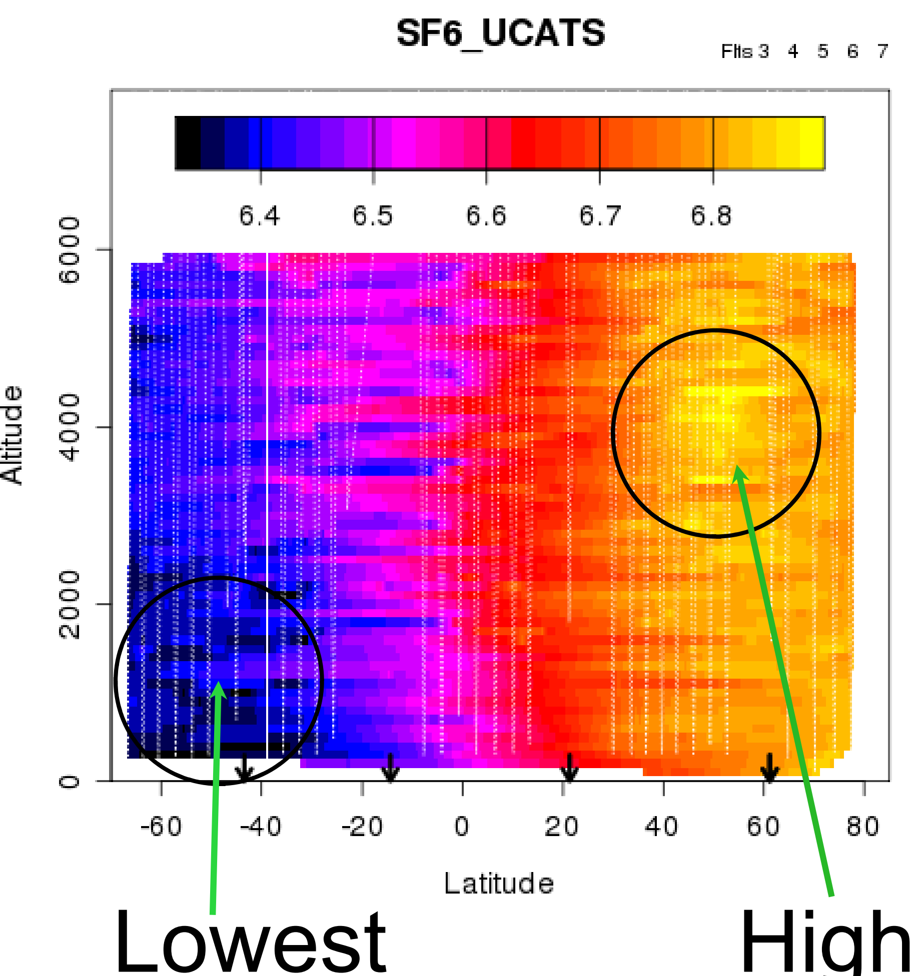
- There is no known substitute for SF_6 as a dielectric.

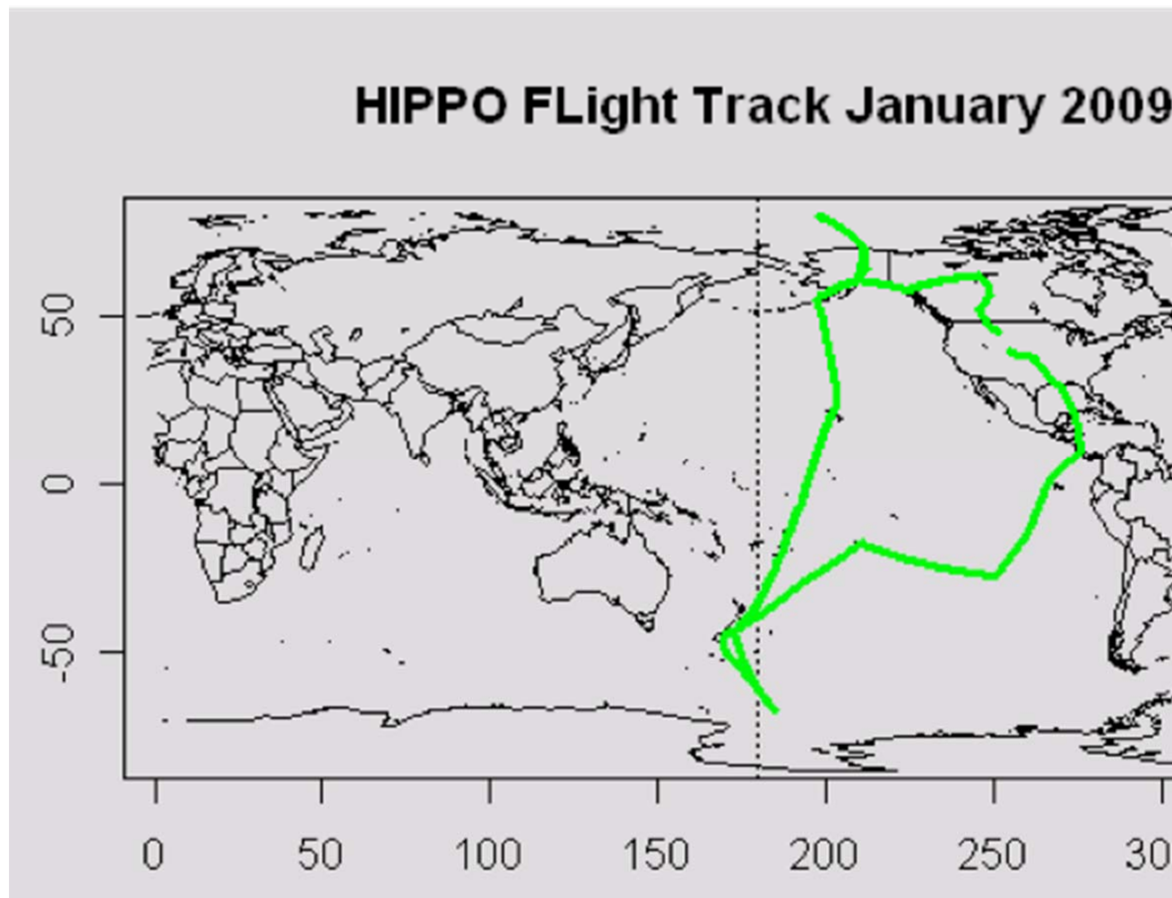
- The atmospheric lifetime is long, and it does matter what the value (300 or 3200 years). Need more measurements at higher levels (mesosphere) in the atmosphere.

- A new national power grid that conserves energy (smart grid) and one based on direct current (DC) may help reduce emissions of SF_6. Less power lost, one less wire, more solar and wind compatible, and doesn’t have to overated by 40% for power increase

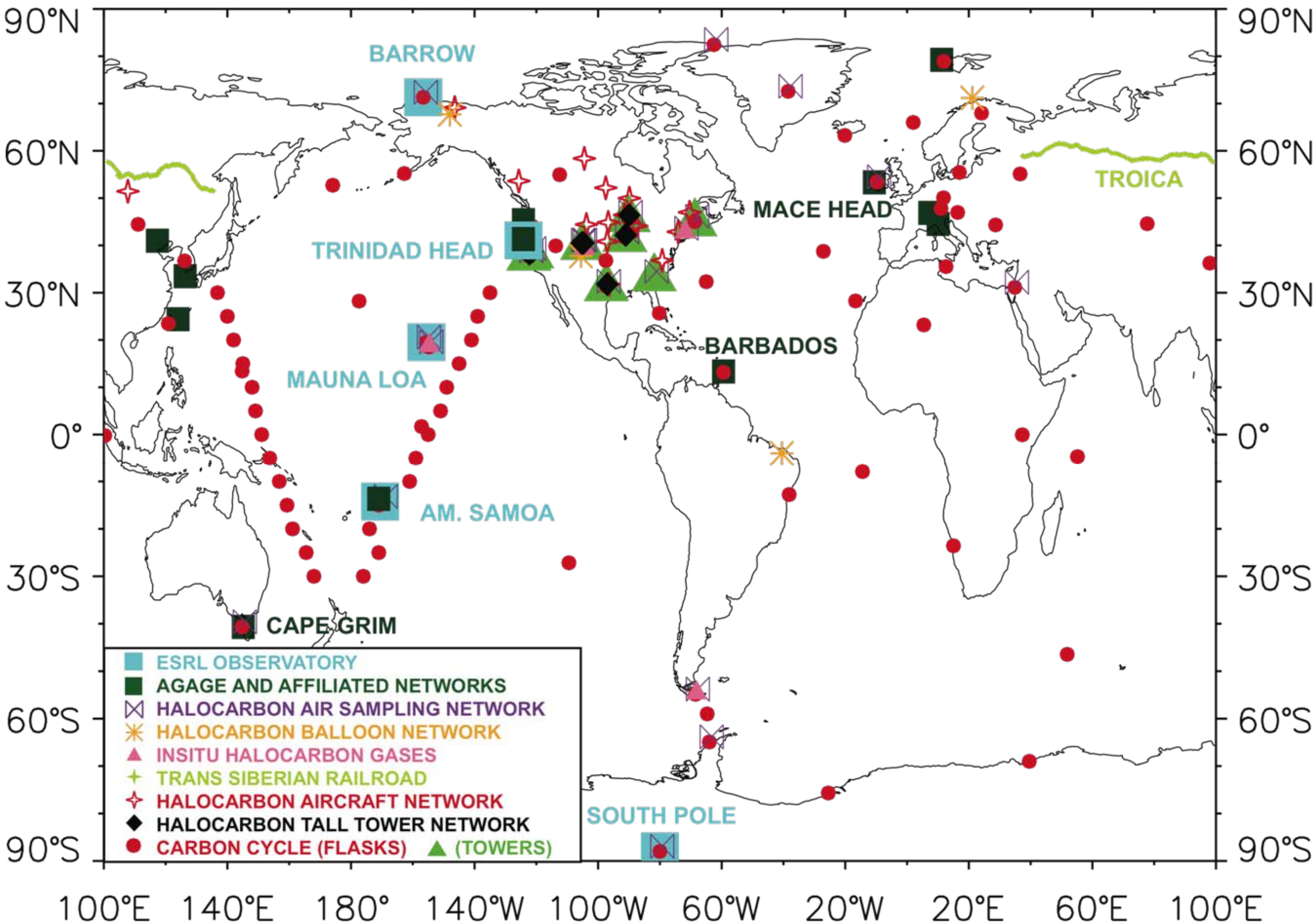
Tropospheric Sounding with the NSF/NCAR HIAPER GV aircraft during HIAPER Pole-to-Pole Observations (HIPPO) in January 2009 (Prog. Scientist: Steve Wofsy, Harvard)

See Elkins & Moore et al.
Miller et al. posters

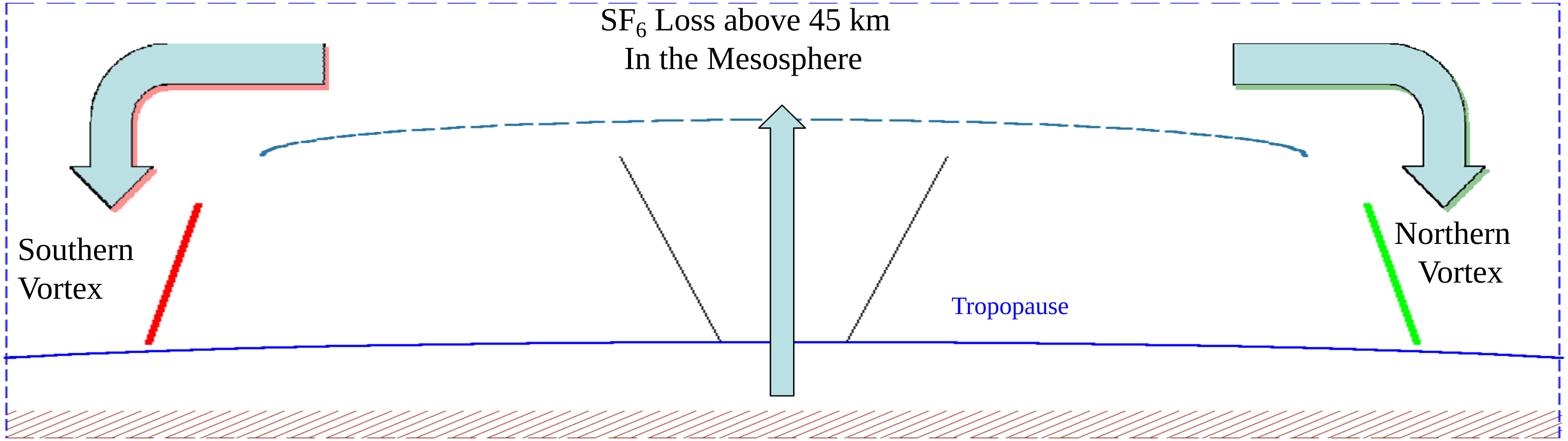




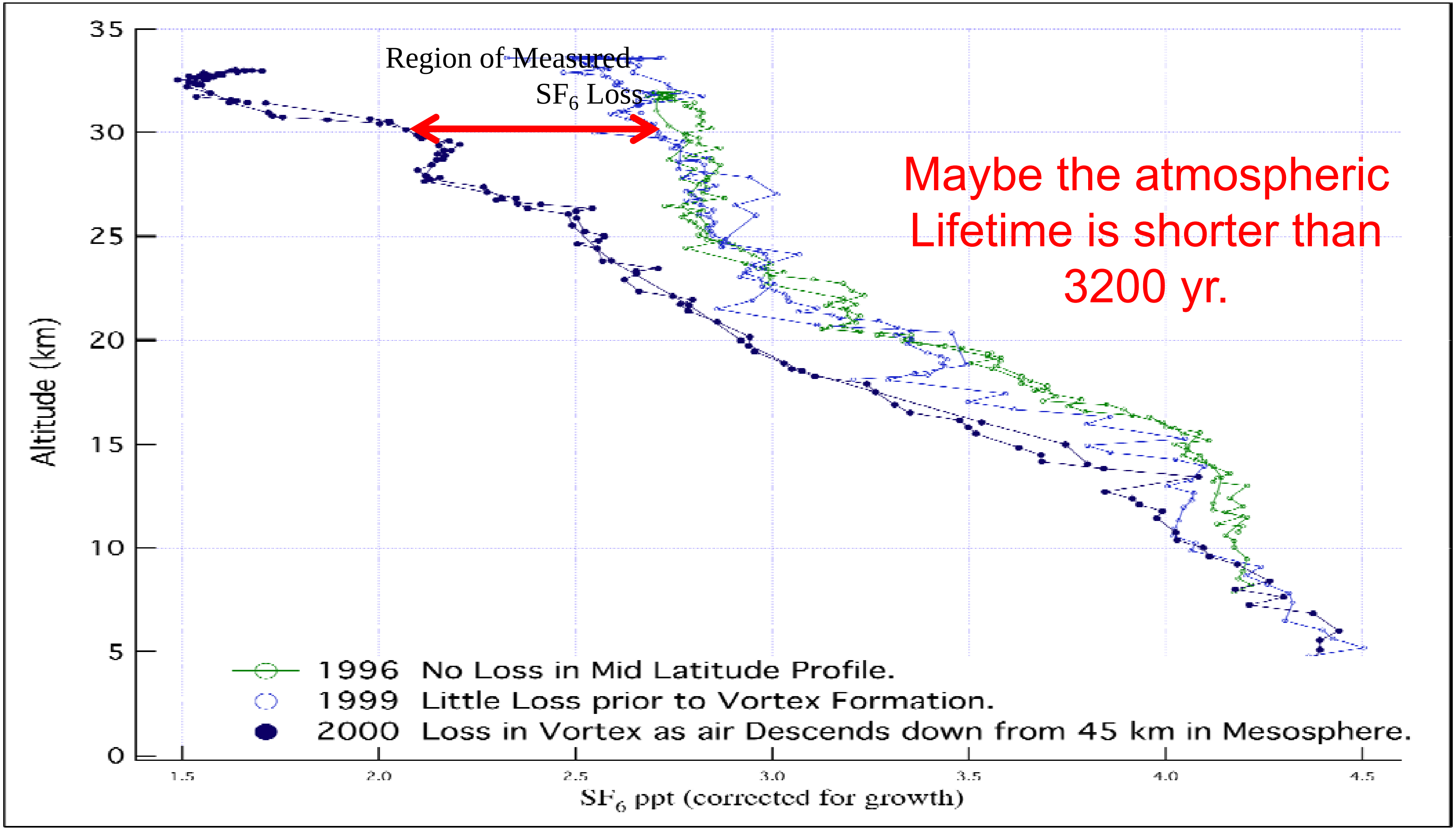
Global Networks that Measure SF_6



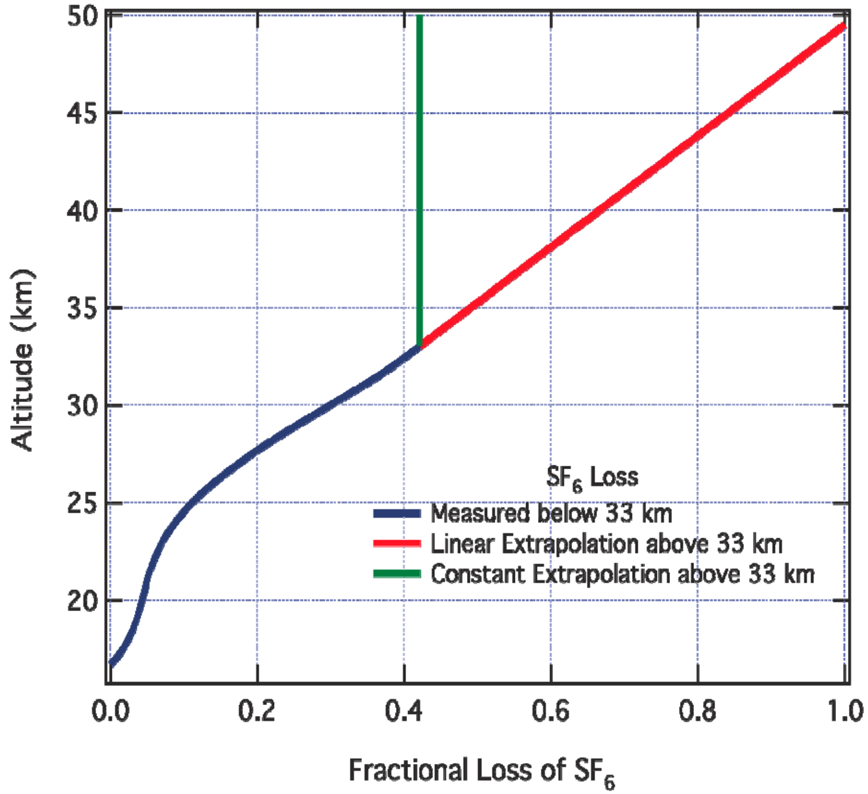
- NOAA CCGG flasks (, >40 stations)
- NOAA HATS flasks (, 9 stations)
- NOAA HATS CATS in situ (, 6 stations)
- NOAA HATS Airborne projects ( )
- AGAGE ( )

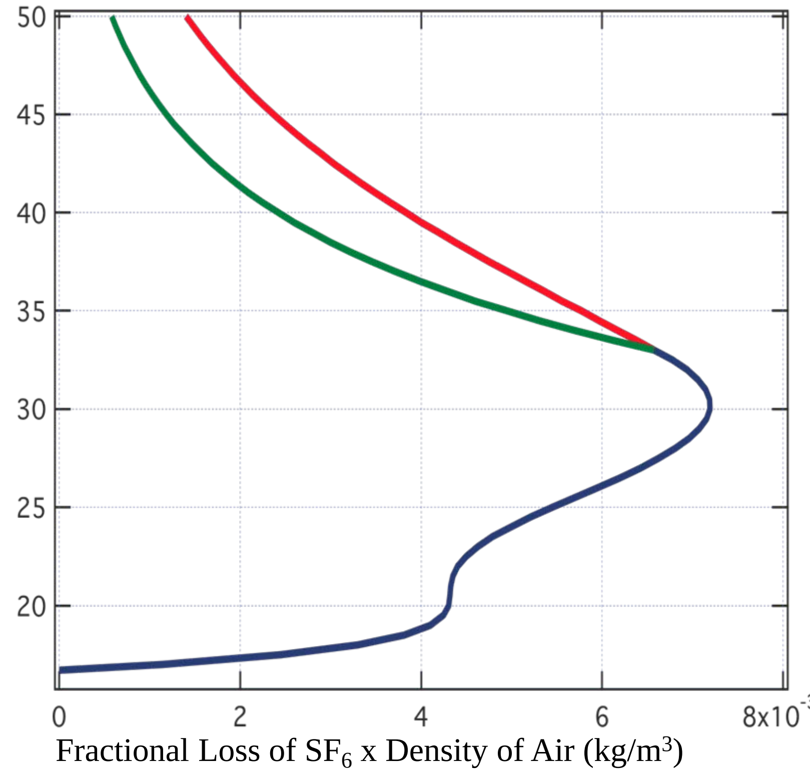


SF_6 Loss above 45 km
In the Mesosphere
Southern Vortex
Northern Vortex
Tropopause



Region of Measured SF_6 Loss
Maybe the atmospheric Lifetime is shorter than 3200 yr.
Altitude (km)
SF_6 ppt (corrected for growth)
1996 No Loss in Mid Latitude Profile.
1999 Little Loss prior to Vortex Formation.
2000 Loss in Vortex as air Descends down from 45 km in Mesosphere.





•SF_6 loss rate (1/t) is estimated as 2 times the integral over the northern vortex of the measured fractional loss, times the mass density, divided by total atmospheric mass.

SF_6 atmospheric lifetime (t) calculated from:

Linear extrapolation t = 595 ± 105 years

Error includes in quadrature:

± 35 years for statistical uncertainty in SF6 measurements.

± 65 years for residuals of smooth fit to flight profiles.

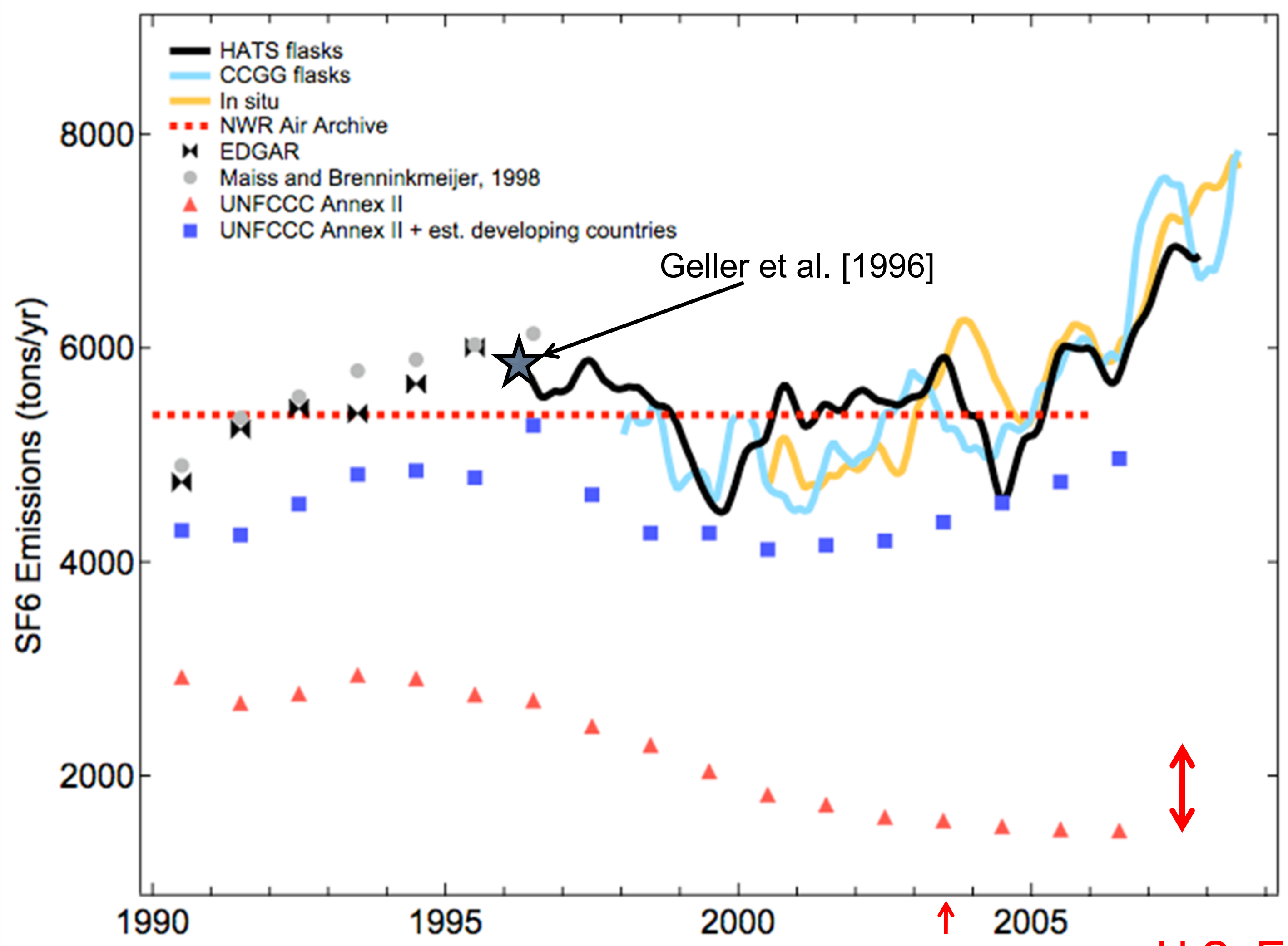
± 76 years for uncertainty in the vortex size.

Constant extrapolation t = 747 years

* Vortex size used is an average between Manney's estimate for this year and Waugh's climatological mean.

* The above assumptions only leave room for unmeasured loss. Thus, the above measured lifetimes represent an upper limit.

Emissions determination from Hall et al., poster



U.S. EPA Estimates
Of Voluntary Reductions

Hurst et al. [2006]
600 +/- 200 mt yr^{-1}
US & Canada

Summary

- From 1996 to 2006, atmospheric SF_6 has growth at a linear rate. Recently, the growth rate has increased from emissions in N.H., and most likely Asia.
- The consequences to the growth rate of atmospheric SF_6 resulting from the worldwide recession will require
- The atmospheric lifetime is uncertain, and may be shorter than the current conventional lifetime of 3200 yrs. More balloon measurements as high as the mesosphere are needed.
- A new DC power grid may reduce fossil fuel emissions, and may have also a beneficial effect in reducing emissions of SF_6.

Back-up Slides

Semi-hemispheric differences (CCGG)