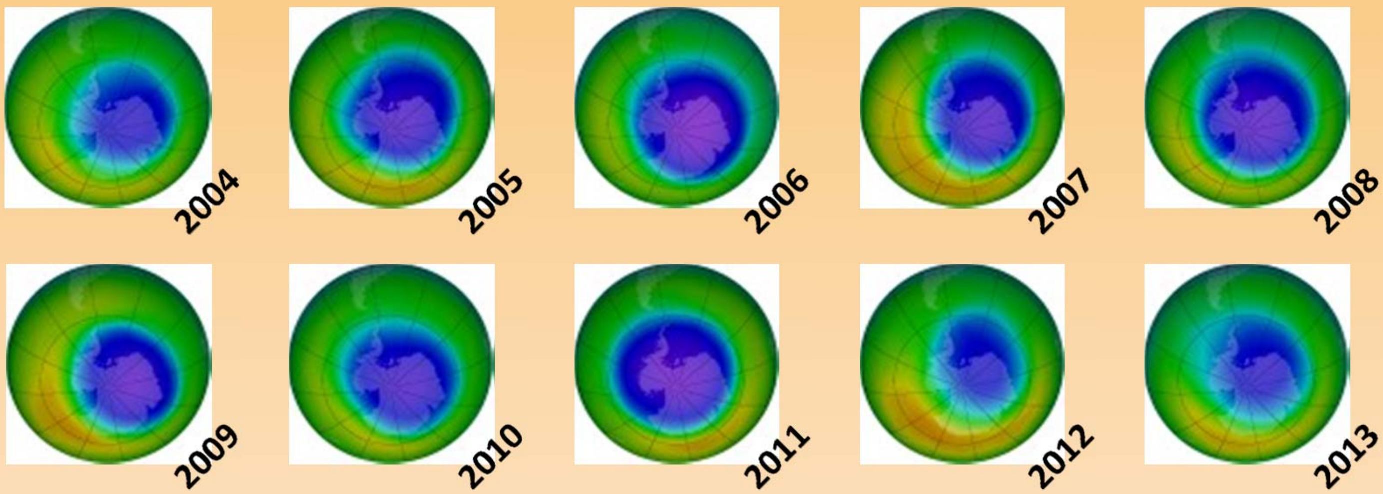
Chlorine variability in the Antarctic vortex and implications for ozone recovery



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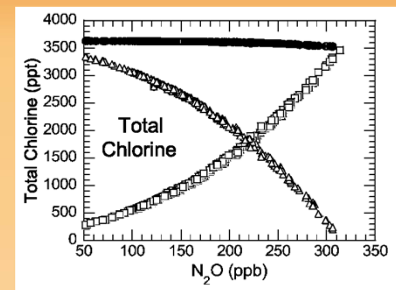
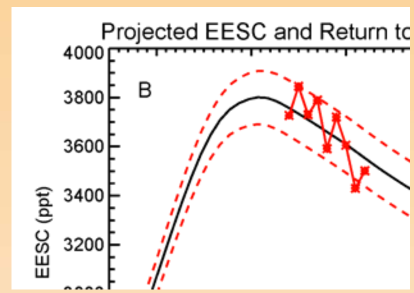
The key points of this talk are…

The interannual variability in inorganic chlorine* (Cl_y) in the Antarctic lower stratospheric (LS) vortex can be inferred from MLS nitrous oxide (N_2O) measurements.

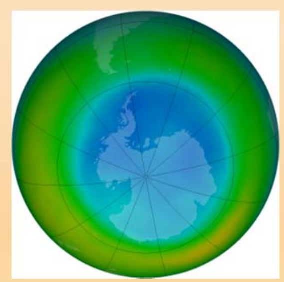


From Schauffler et al, 2003

How does the interannual Cl_y variability inside the Antarctic LS vortex compare with the expected annual rate of decline due to the Montreal Protocol?



Cl_y variability has implications for ozone hole area during the coming decades as Cl_y continues to decline.



***Inorganic Cl (Cl_y), includes HCl, $ClNO_3$, ClO, Cl_2O_2, OClO, Cl, etc.**

Stratospheric Cl_y has been declining since 2000

Declining Cl_y has been detected with column measurements of $ClNO_3$ and HCl (Rinsland et al., 2003), and with MLS HCl in the upper stratosphere. Estimated HCl decline rate above 50 km of 27 ± 3 ppt/yr (Froidevaux et al., 2006).

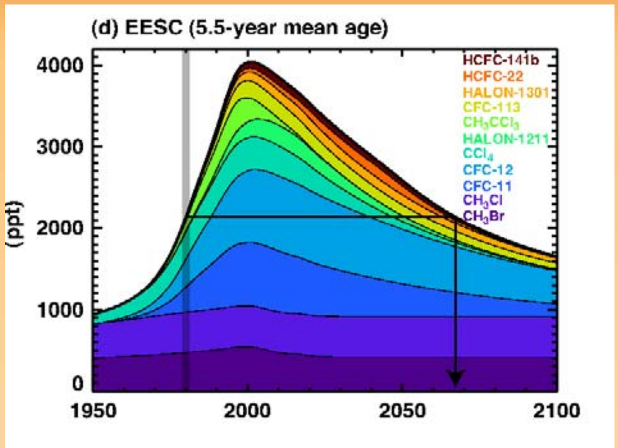
The rate of decline will be slow because F-11 and F-12 have long lifetimes (52 and 102 yrs, respectively).

There are no measurements of Cl_y inside the Antarctic lower stratospheric vortex to quantify declining Cl_y levels there.

What do we know about stratospheric Cl_y past and future?

Cl_y , or EESC*, can be estimated by a method that takes into account measured CFC and Halon surface abundances, their fractional releases, and mean age. (Newman et al., 2006)

The time series (for any mean age) can be calculated and projected into the future using an emissions scenario.



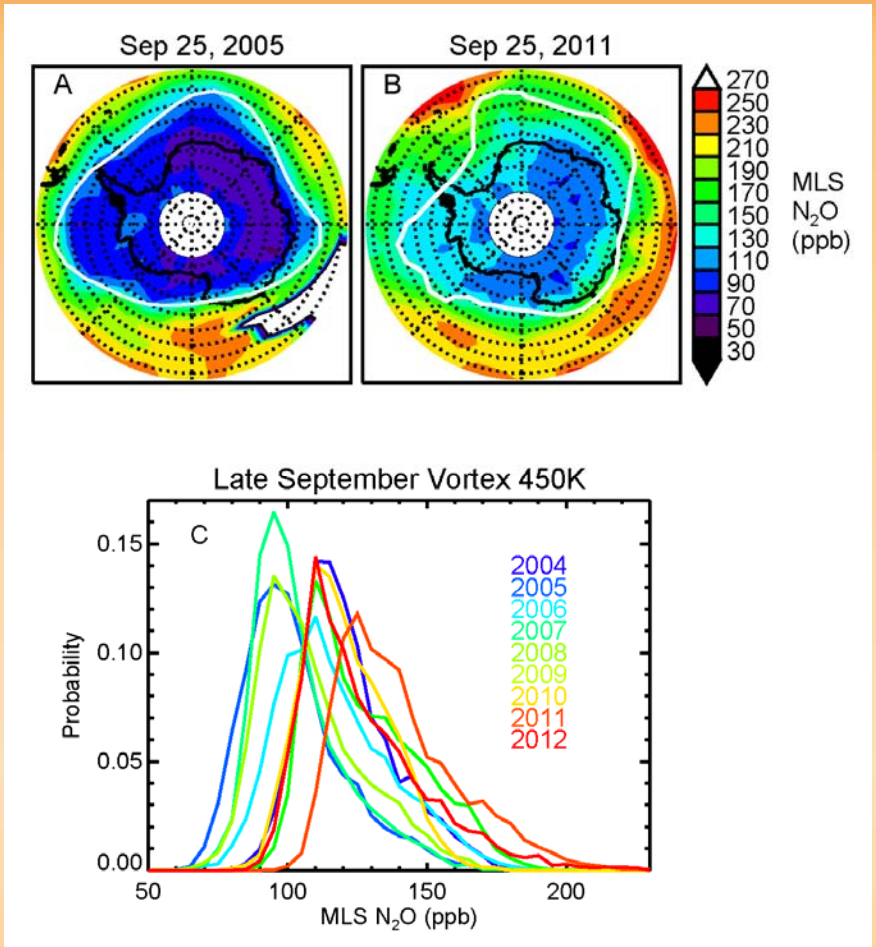
From Newman et al., ACP, 2007

Does Cl_y (or EESC) really decline as smoothly as this calculation suggests?

Interannual variability of N_2O inside the Antarctic LS vortex provides a way to estimate Cl_y variability because of the compact correlation between them.

****Equivalent Effective Stratospheric Chlorine***

MLS N_2O has large interannual variability inside the Antarctic lower stratospheric vortex



Mean values inside the 450K vortex:
<100 ppb in 2005
~140 ppb in 2011

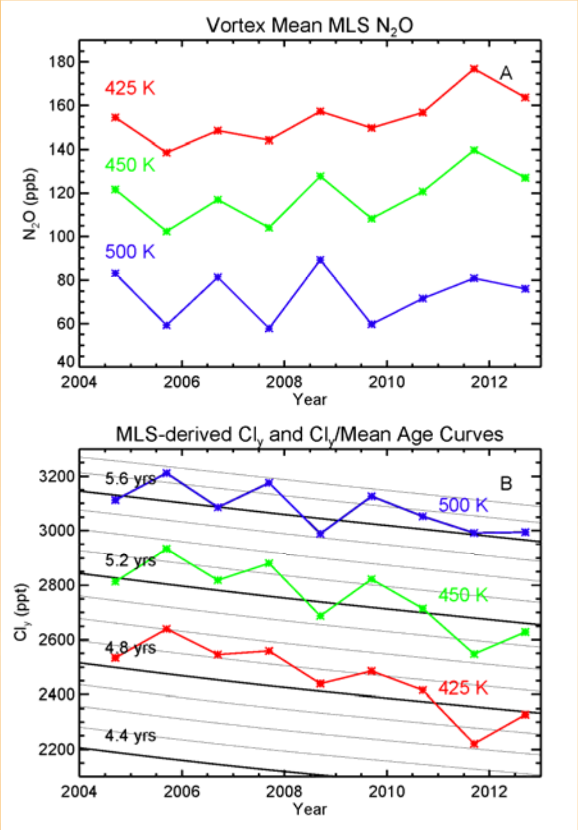
N_2O distributions inside the vortex, 21-30 Sep, for 2004-2012*.

Similar variability on 425 K and 500 K.

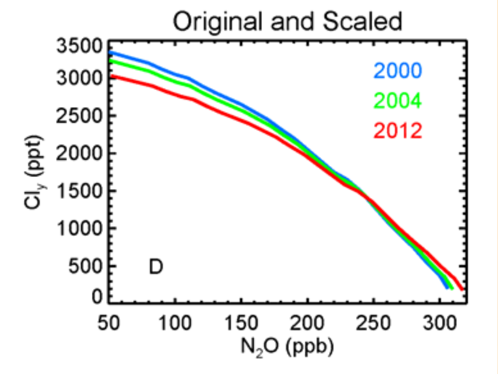
***The change in the primary band used for N2O retrievals on June 6, 2013 results in a high-bias at 100 hPa.**

Cl_y time series on 3 isentropic surfaces in the Antarctic LS vortex are inferred using MLS N_2O, 2004-2012

This is the interannual variability of N_2O inside the Antarctic vortex in late September at 425, 450, and 500 K.



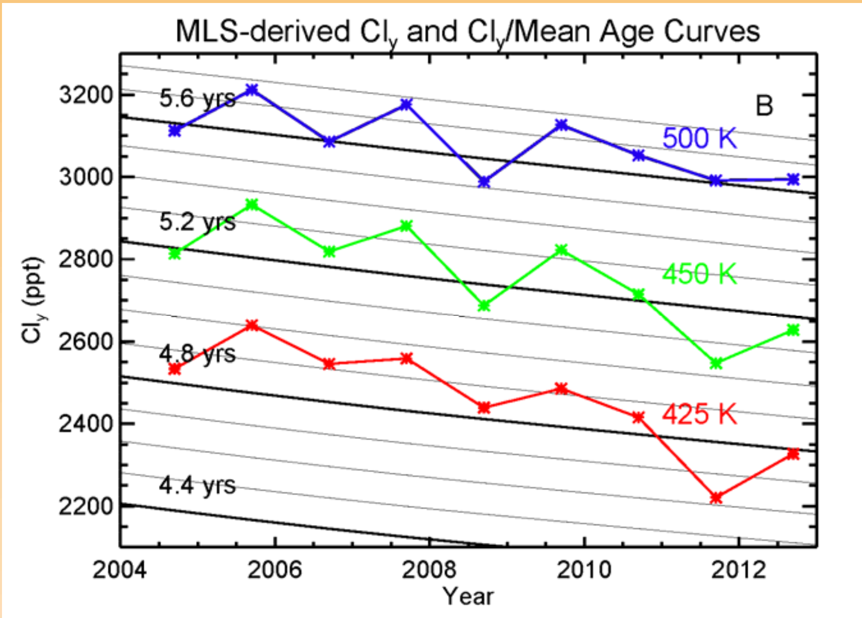
Schauffler et al. (2003) determined the N_2O/Cl_y correlation using LS aircraft data from 2000. We use observed growth and decline rates for surface N_2O and CFCs to scale the relationship for each Aura year.



The Cl_y decline rate comes from the Cly scaling method, but the Cl_y variability is from dN_2O/dCl_y, which is insensitive to scaling.

Cl_y is inferred using the scaled compact correlation for each year.

Cl_y interannual variations can by 10X greater than the decline due to the Montreal Protocol!



Cl_y does not smoothly decline at ~22 ppt/yr (the black lines).

At 450 K, Cl_y in 2009 was actually higher than in 2004

Cl_y variations on an isentropic surface are effectively mean age variations.

Year-to-year variations at 450 K: -200 ppt to +150 ppt (1σ= 98 ppt)

~10 years are required to have a significant Cl_y decline in the lower stratosphere (mean age ~5 yrs).

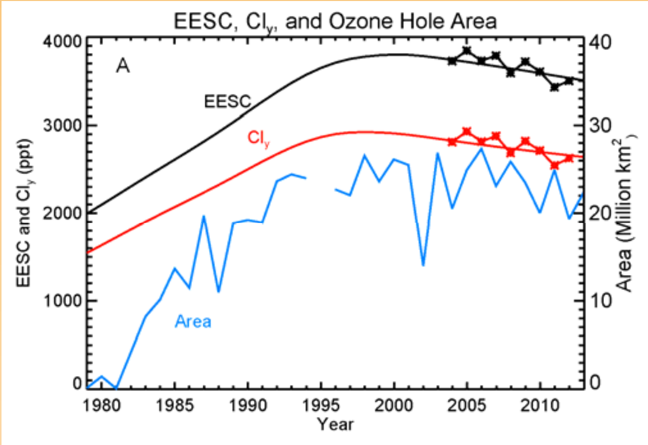
Cl_y variability prohibits attribution of O_3 hole recovery due to Montreal protocol prior to ~2010.

How will Cl_y variability impact the ozone hole area in the coming decades?

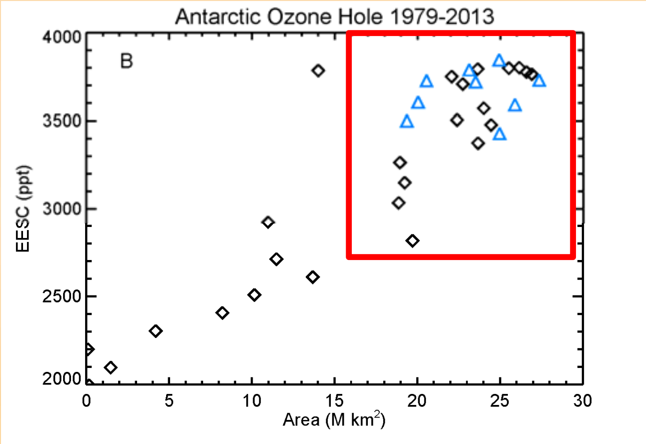
The ozone hole area (i.e., area of column O_3 < 220 DU) depends on Cl_y and on LS temperatures.

Since 1992, the ozone hole has been consistently larger than 20 Mkm² and EESC has varied over a small range.

Year to year area variations have been driven primarily by temperature variations in the 'collar' region (60-75°S).



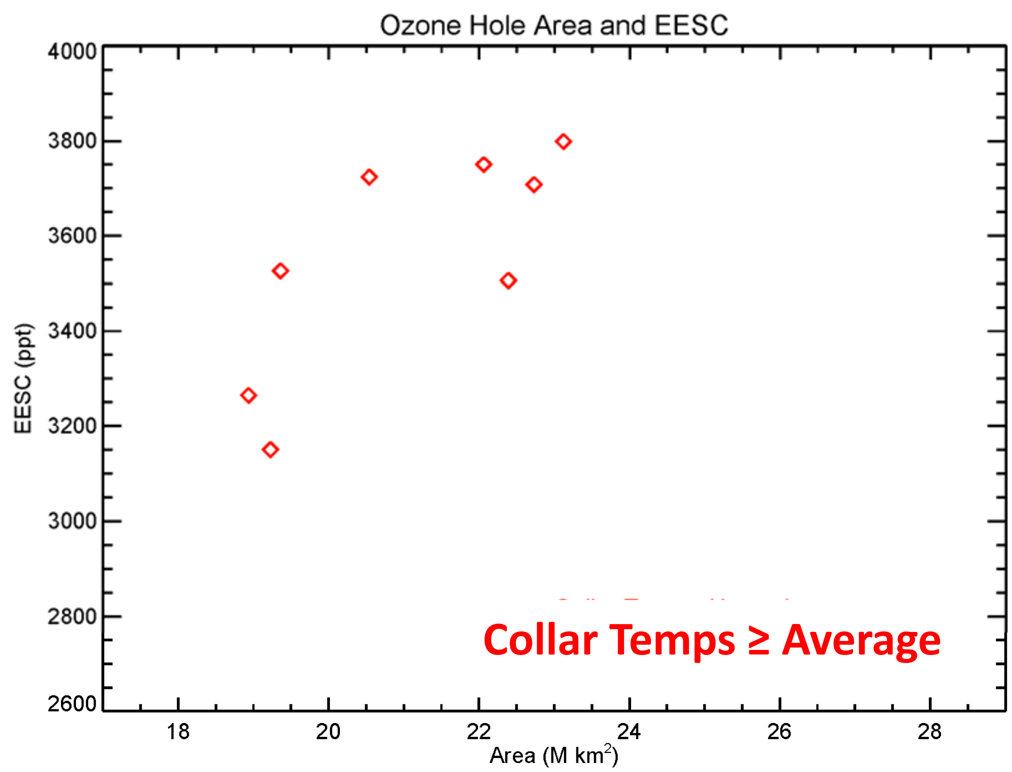
* and * are MLS-derived values



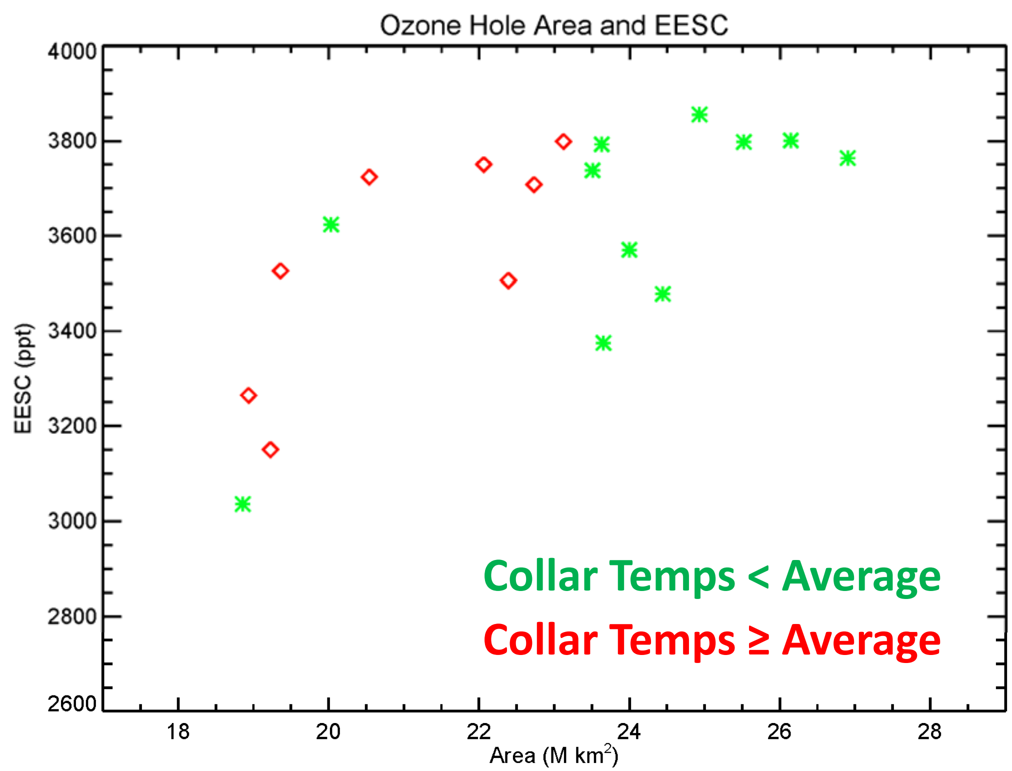
Blue triangles are MLS-derived EESC

The scatterplot shows that hole area increases as EESC increases. Collar temperature variability causes a lot of scatter.

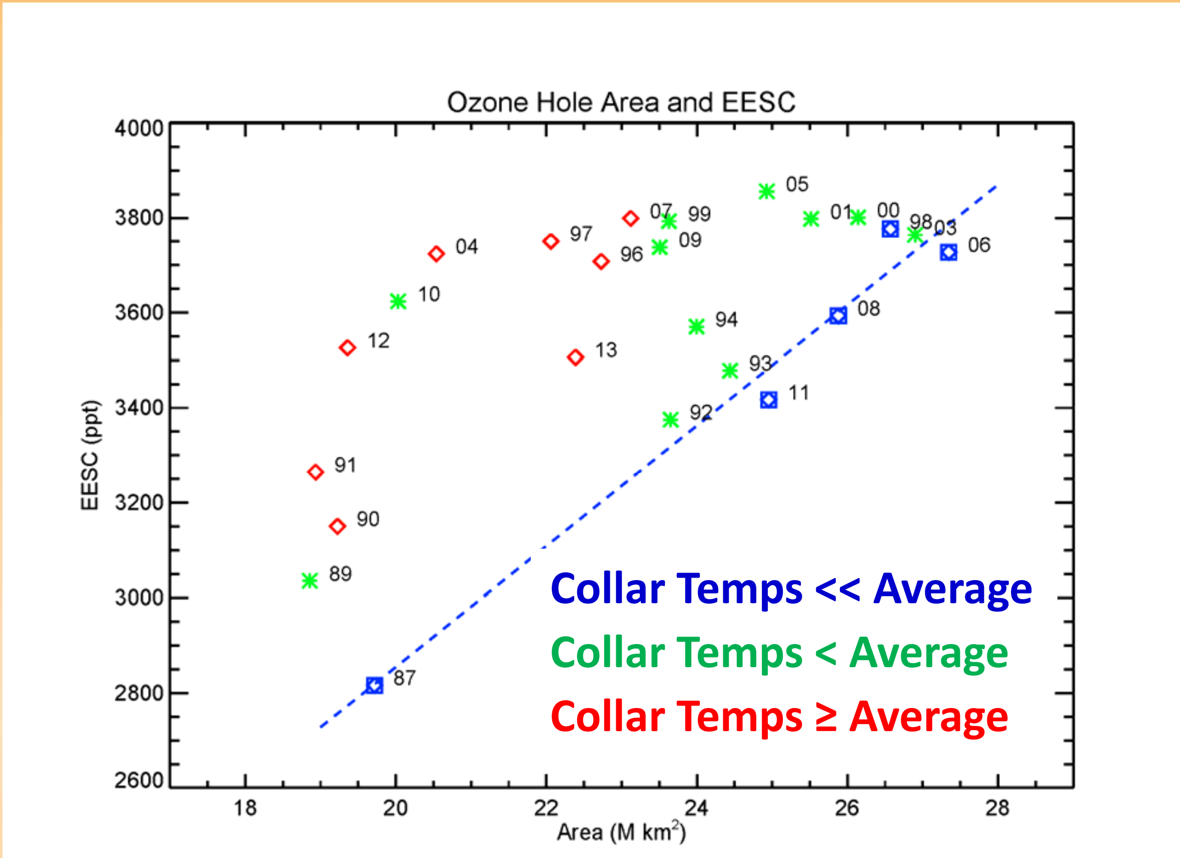
September Temperature Variations in the Collar Region (60-75°S and 30-100 hPa) drive Area Variability



For a given level of EESC, colder conditions lead to a larger area



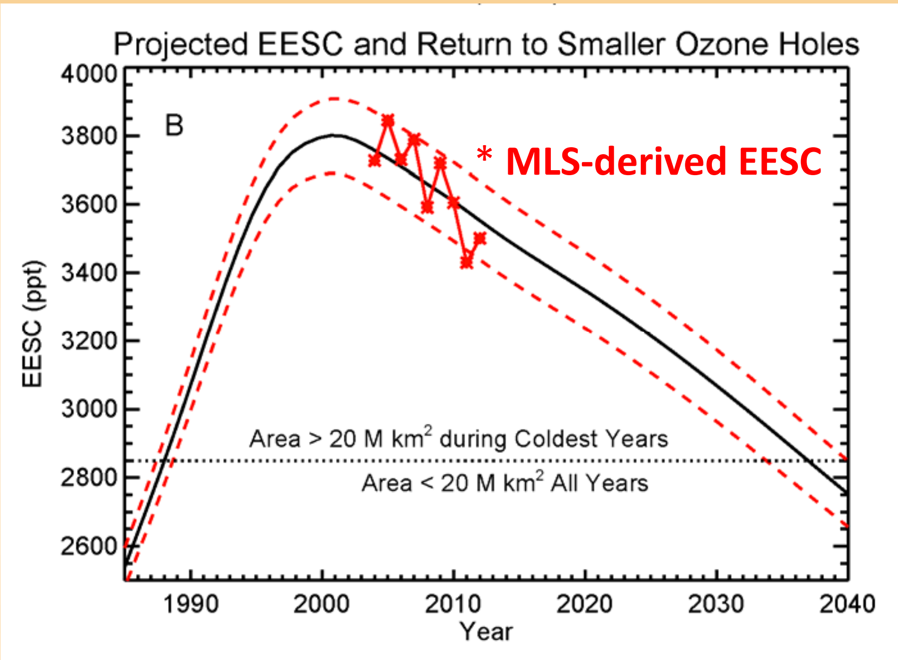
The years with the lowest collar temperatures 30-100 hPa produce the largest areas



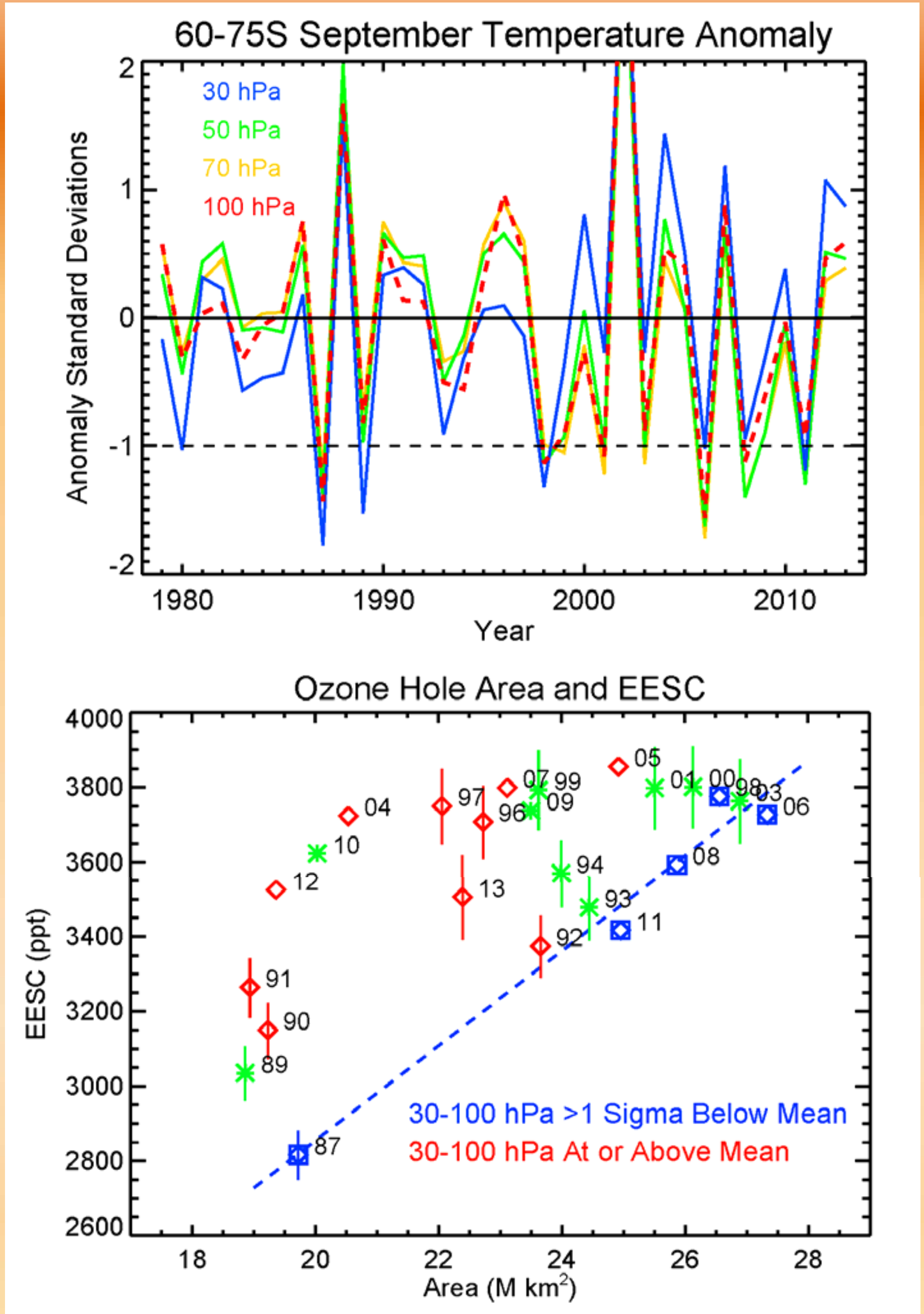
Area and EESC show a clear relationship during the coldest years. 2008 and 2011 areas appear to be responding to declining EESC

Bottom Line: There will continue to be large ozone holes (> 20 M km²) for the next couple of decades whenever Antarctic temperatures are well below average.

This is possible as long as EESC is above 1987 levels (~2850 ppt) – that means after the 2030's.



By 2040, all ozone holes are expected to be smaller than 20 M km² regardless of temperature.



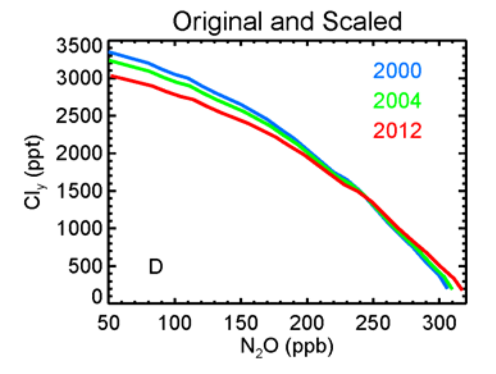
60-75S September Temperature Anomaly
30 hPa
50 hPa
70 hPa
100 hPa
Anomaly Standard Deviations
Year
Ozone Hole Area and EESC
EESC (ppt)
Area (M km^2)
30-100 hPa >1 Sigma Below Mean
30-100 hPa At or Above Mean

We can infer Cl_y in the Antarctic vortex during the Aura Years from its compact correlation with N_2O

Schauffler et al. (2003) used Arctic LS aircraft data (SOLVE, 2000) to determine the N_2O/Cl_y correlation. We use a GMI Hindcast simulation (year 2000) to verify that the Antarctic has the same correlation.

We use observed growth and decline rates for surface N_2O and CFCs to scale the relationship for each of the Aura years.

We verify the scaling works by comparing with the GMI Hindcast in 2012.



Scaling: N_2O grows at 0.8 ppb/yr. Cly decline comes from a calculation using observed surface CFC concentrations, CFC lifetimes (Newman et al., 2007).