Estimating when the Antarctic ozone hole will recover

Paul A. Newman, E. R. Nash, A. R. Douglass, J. E. Nielsen, S. Pawson, and R. S. Stolarski

SPARC 4th General Assembly

Sep. 3, 2008, Bologna, Italy

Science Questions

- When will the Antarctic ozone hole recover?
- What are the milestones?
- What can modify recovery?

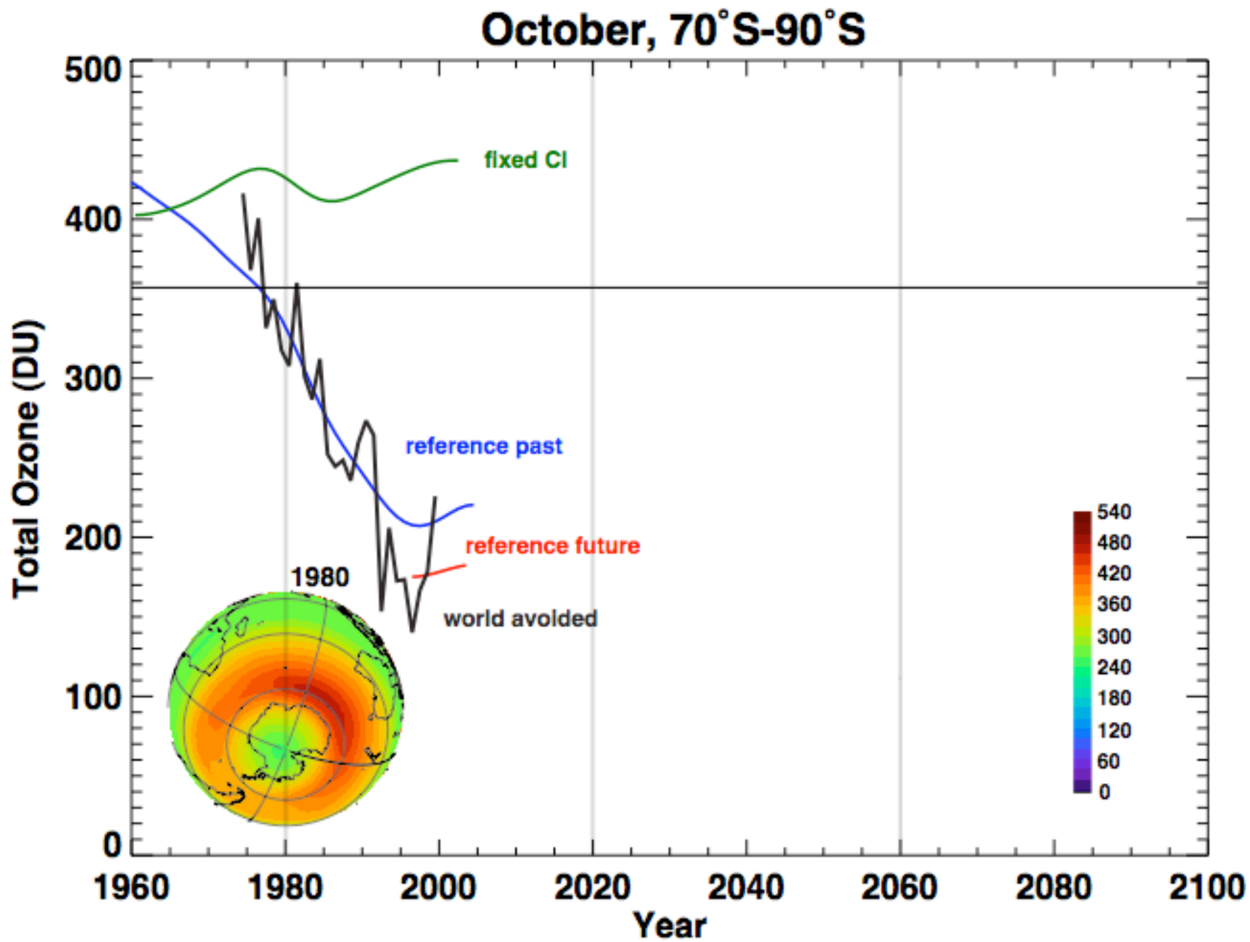
Sep 24 2003

Outline

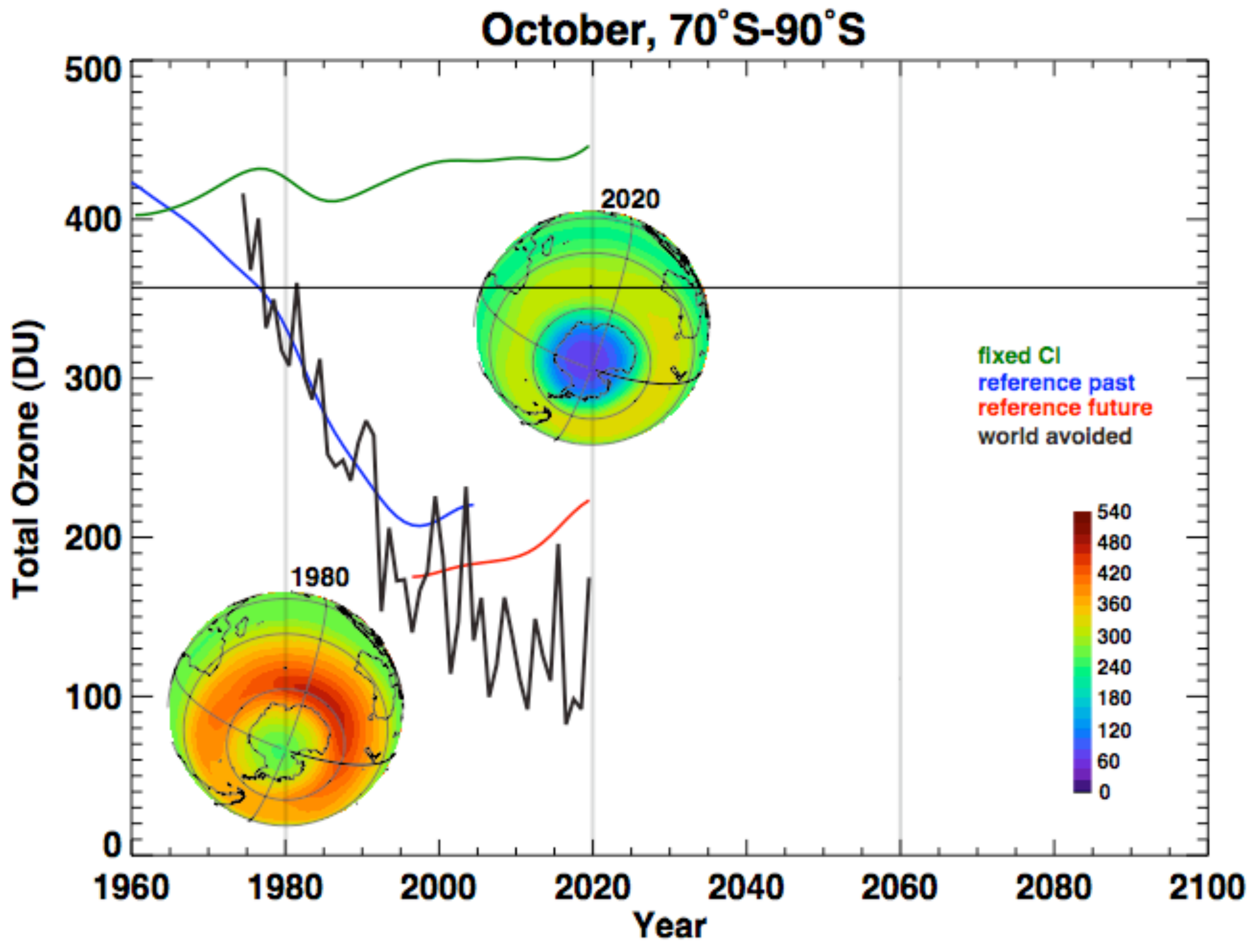
- What do we mean by recovery?
- Chlorine & Bromine recovery.
  - Antarctic equivalent effective stratospheric chlorine (EESC)
- Model estimates of ozone recovery
- Climate change impact on recovery
- Summary

Sep 24 2003

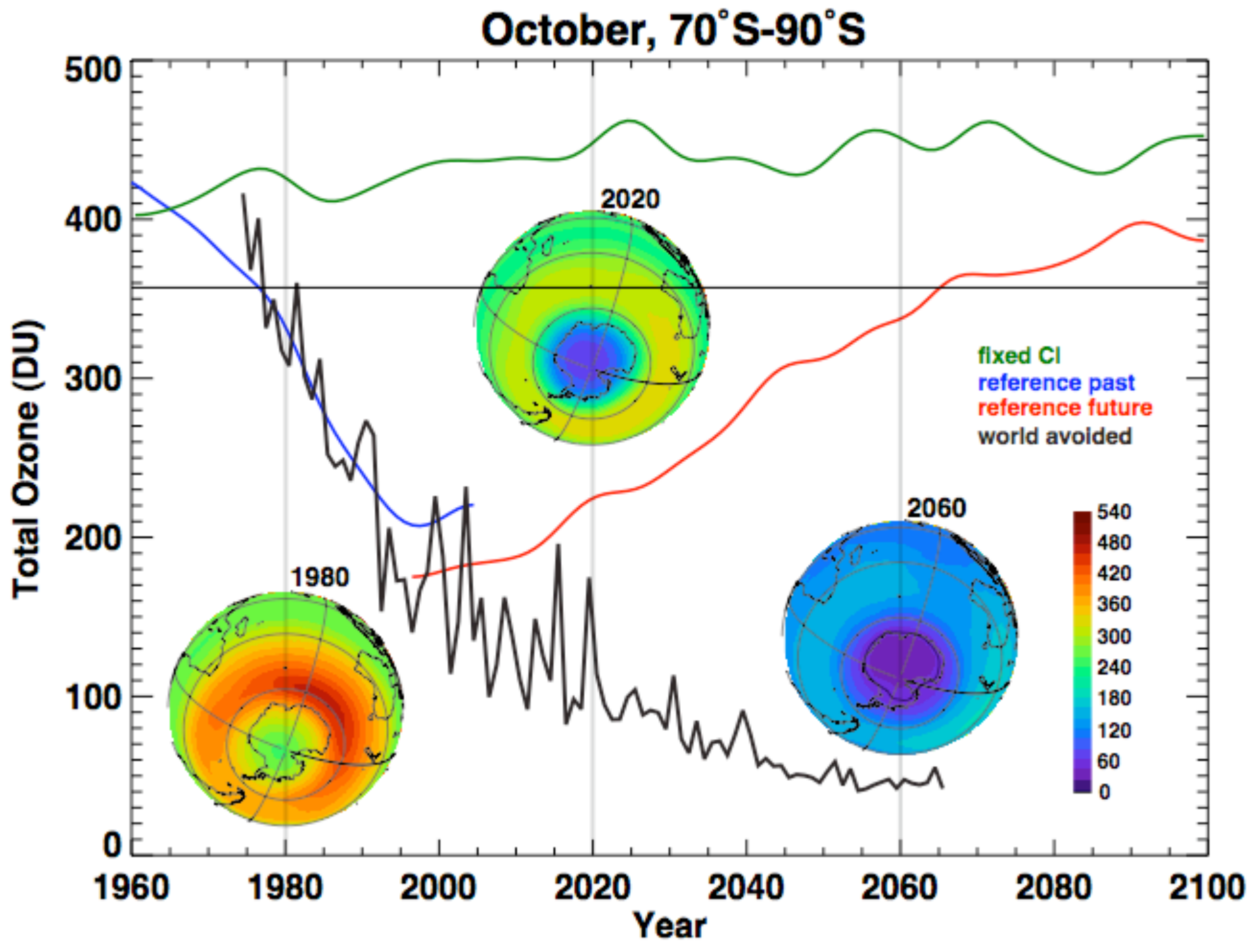
Antarctic ozone hole - 2000



Antarctic ozone hole - 2020



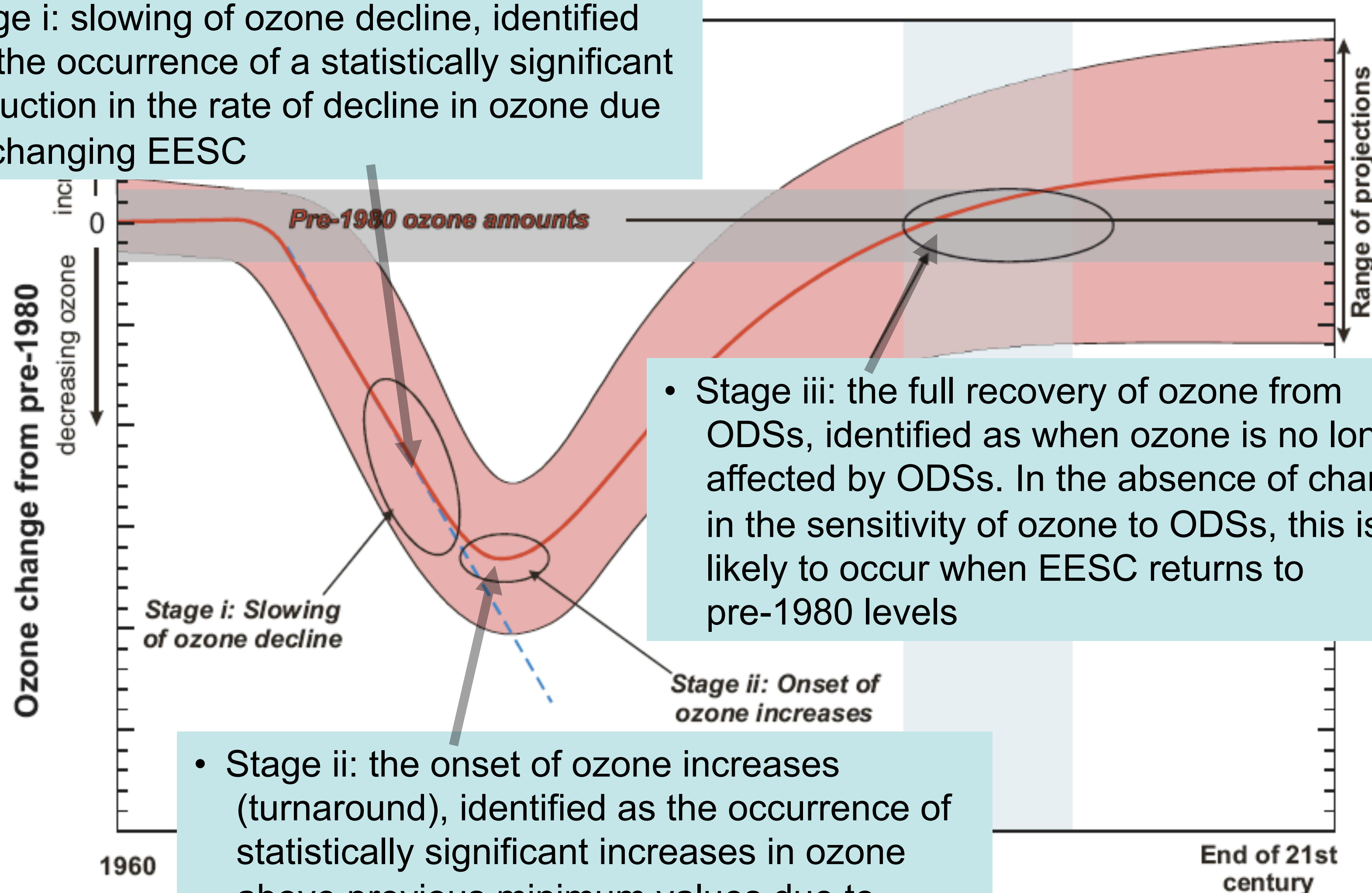
Antarctic ozone hole - 2060+



World Avoided: poster P66

Ozone Recovery - WMO (2007)

- Stage i: slowing of ozone decline, identified as the occurrence of a statistically significant reduction in the rate of decline in ozone due to changing EESC

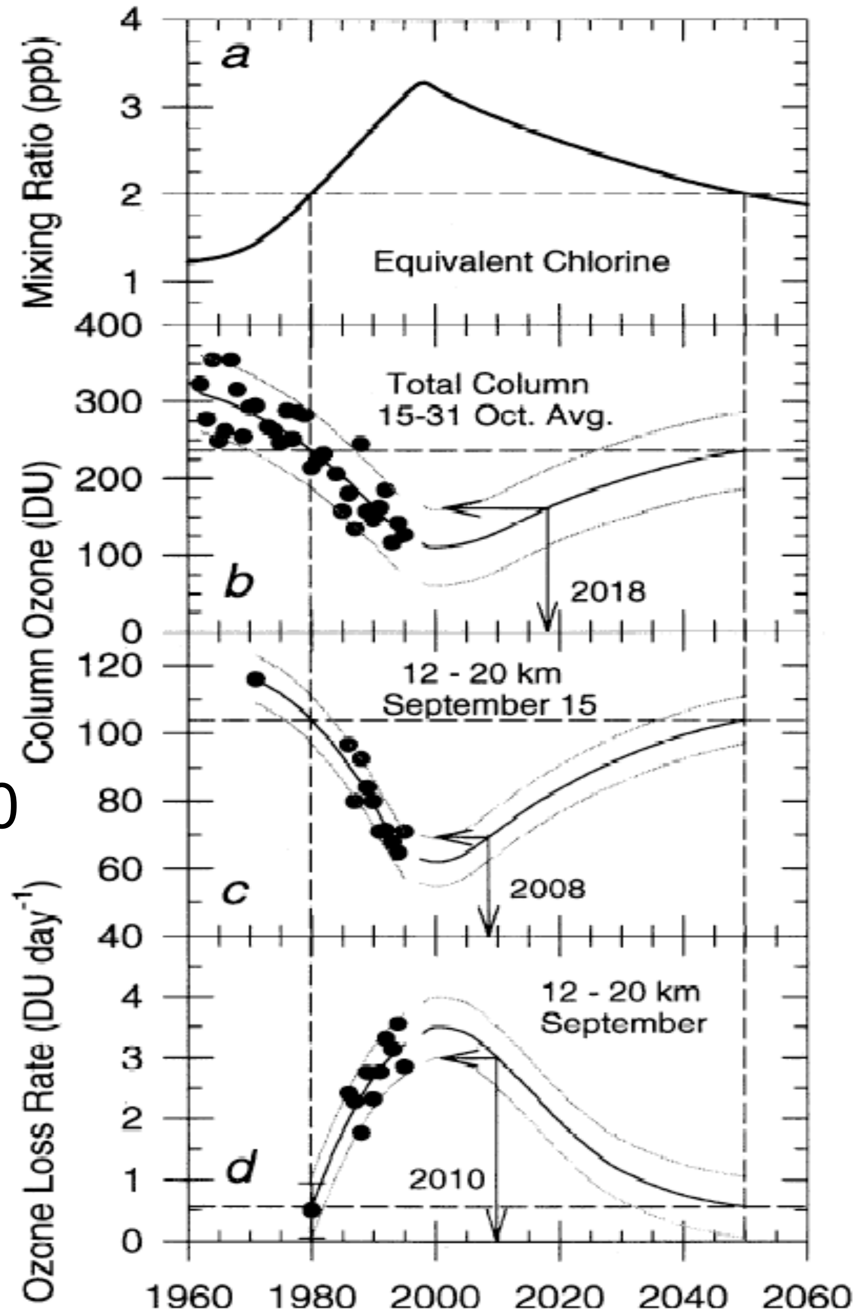


- Stage iii: the full recovery of ozone from ODSs, identified as when ozone is no longer affected by ODSs. In the absence of changes in the sensitivity of ozone to ODSs, this is likely to occur when EESC returns to pre-1980 levels

- Stage ii: the onset of ozone increases (turnaround), identified as the occurrence of statistically significant increases in ozone above previous minimum values due to declining EESC

Hofmann et al. (1997)

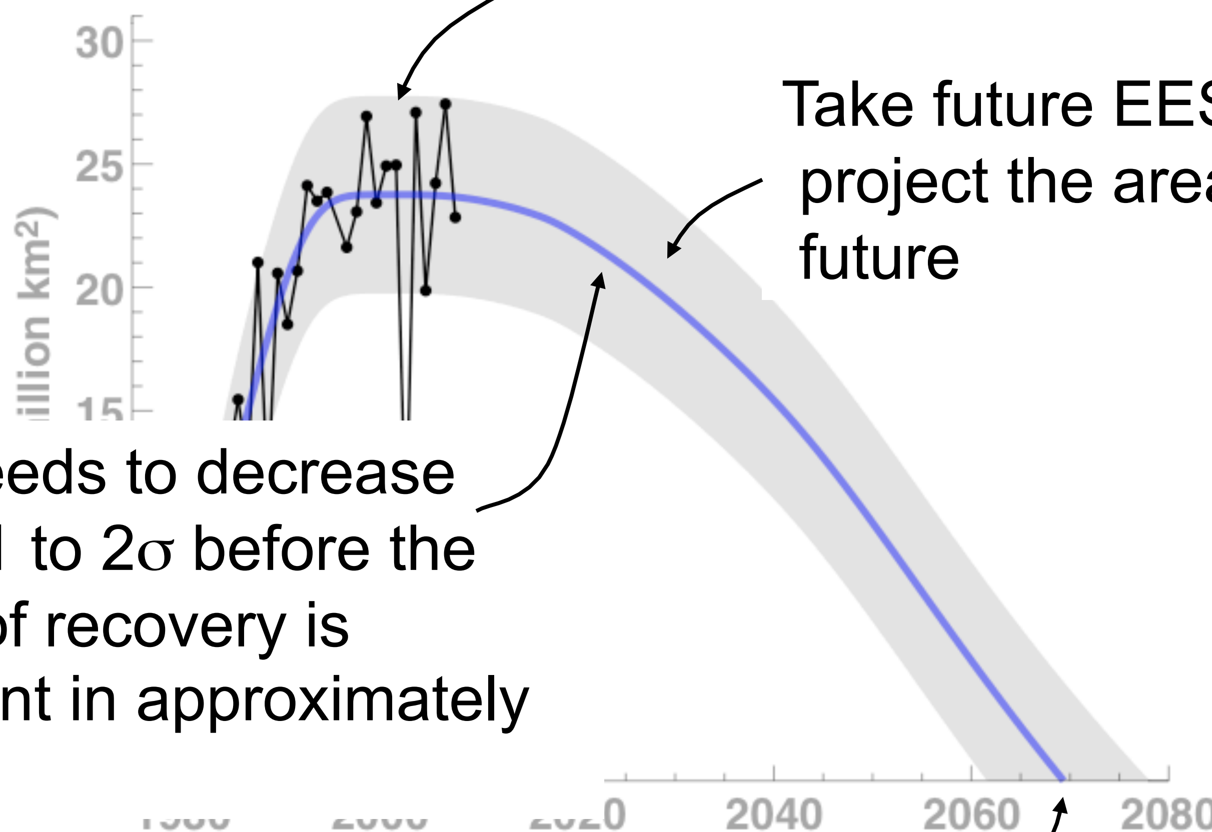
- Equivalent Cl shifted 3 year, Br amplification of 40
- South Pole Dobson observations and ozonesondes to 1995
- First detection of recovery is observed in 2018 for column ozone and 2008 for the 12-20 km sonde average
- Loss rate estimate yields a first detection in 2010
- Final recovery observed in 2050



Ozone hole area parametric modeling

Take 1980-2007 EESC vs. area fit

Take future EESC and project the area into the future

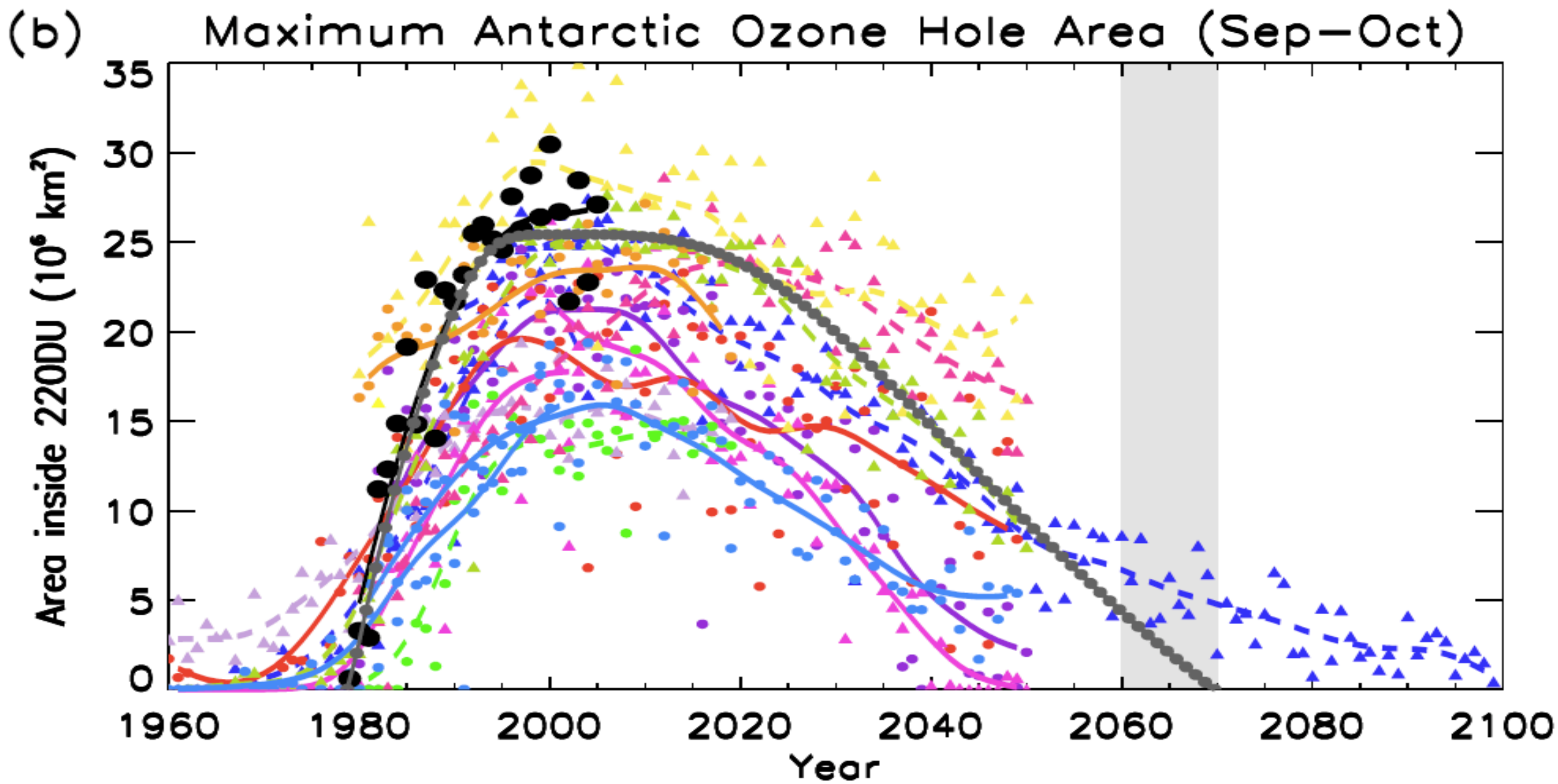


Area needs to decrease about 1 to 2σ before the onset of recovery is apparent in approximately 2024

Recovery in ~ 2067

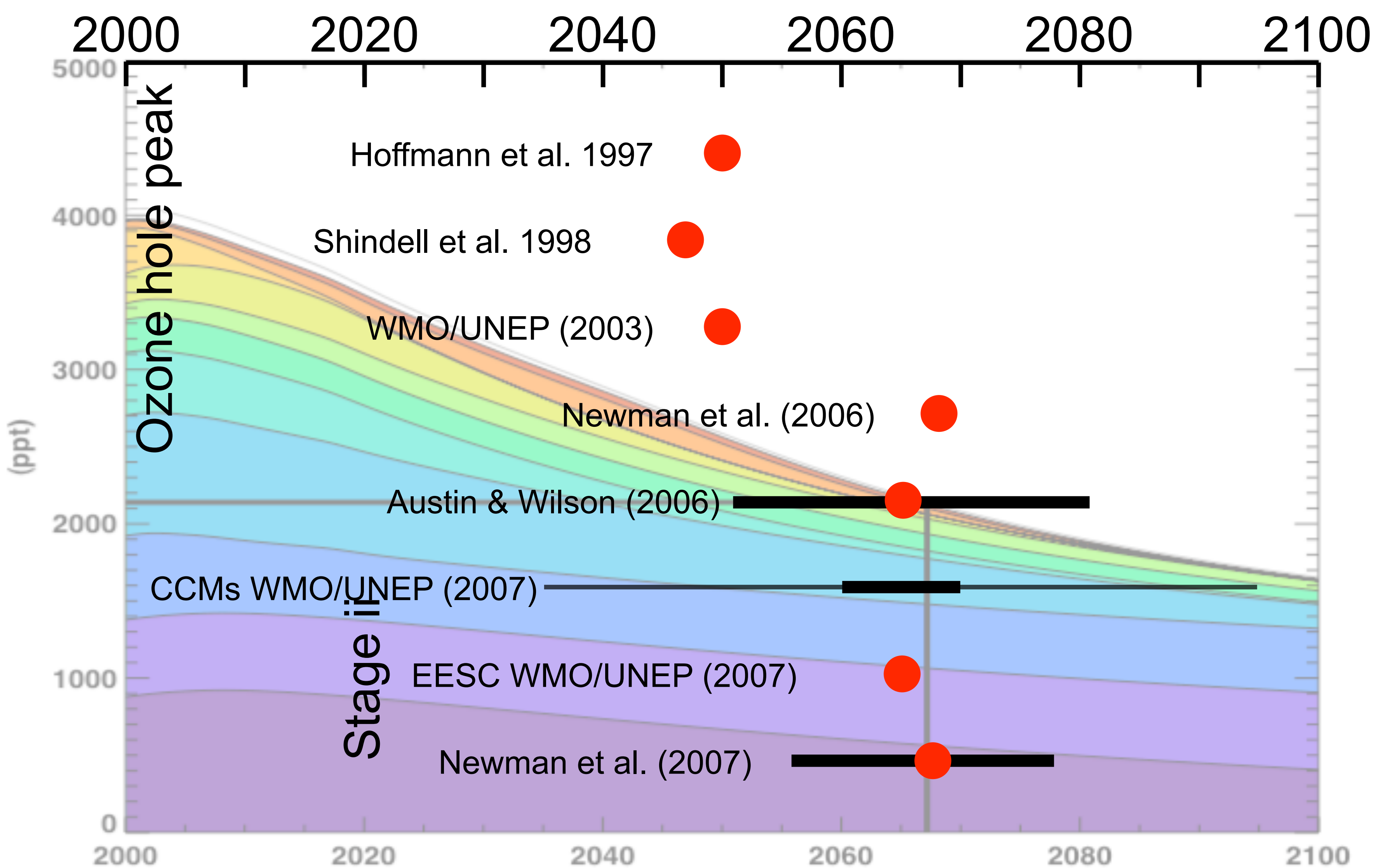
$$\text{Area} = \alpha * \text{ODSs} + \beta * T$$

Model size estimates



WMO (2007)

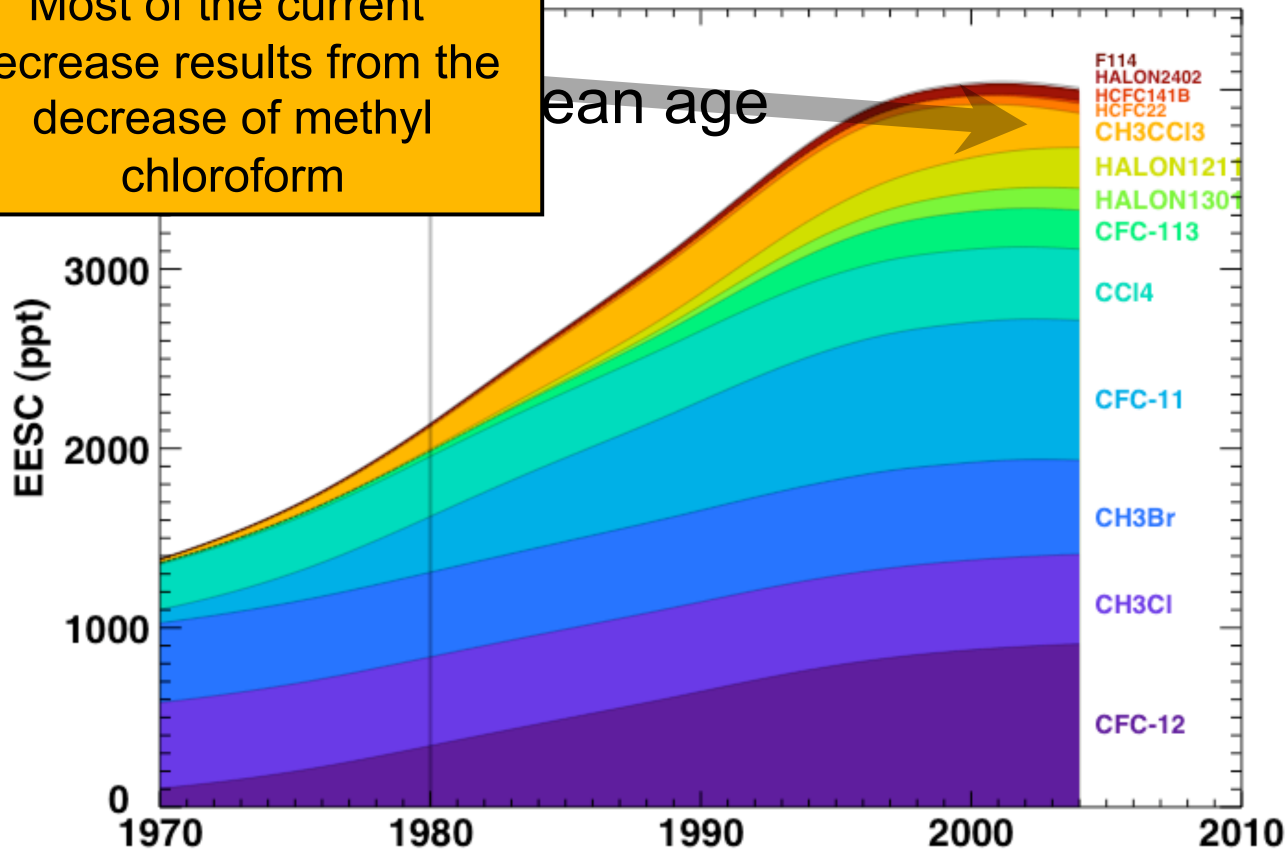
Recovery estimates



Antarctic chlorine and bromine levels

Antarctic EESC 1970-2004

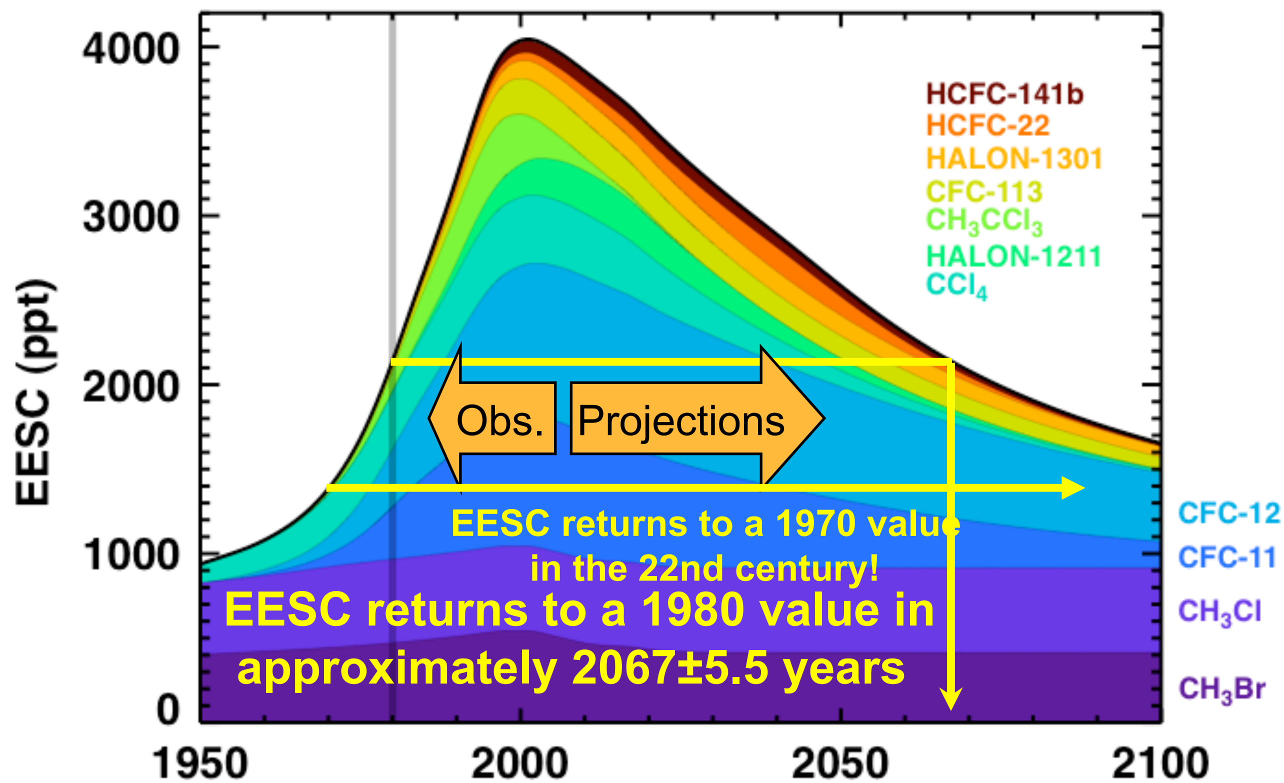
Most of the current decrease results from the decrease of methyl chloroform



EESC is estimated from: 1) surface observations, 2) an age-of-air spectrum, and 3) age dependent fractional release values.

To obtain EESC values (1950-2100) See: http://code916.gsfc.nasa.gov/Data_services/automailer/restricted/automailer.html

Antarctic EESC



EESC projections from: **1) estimated emissions, 2) estimated ODS lifetimes**, 2) an age-of-air spectrum, and 3) age dependent fractional release values.

To obtain EESC values (1950-2100) See: http://code916.gsfc.nasa.gov/Data_services/automailer/restricted/automailer.html

Model EESC

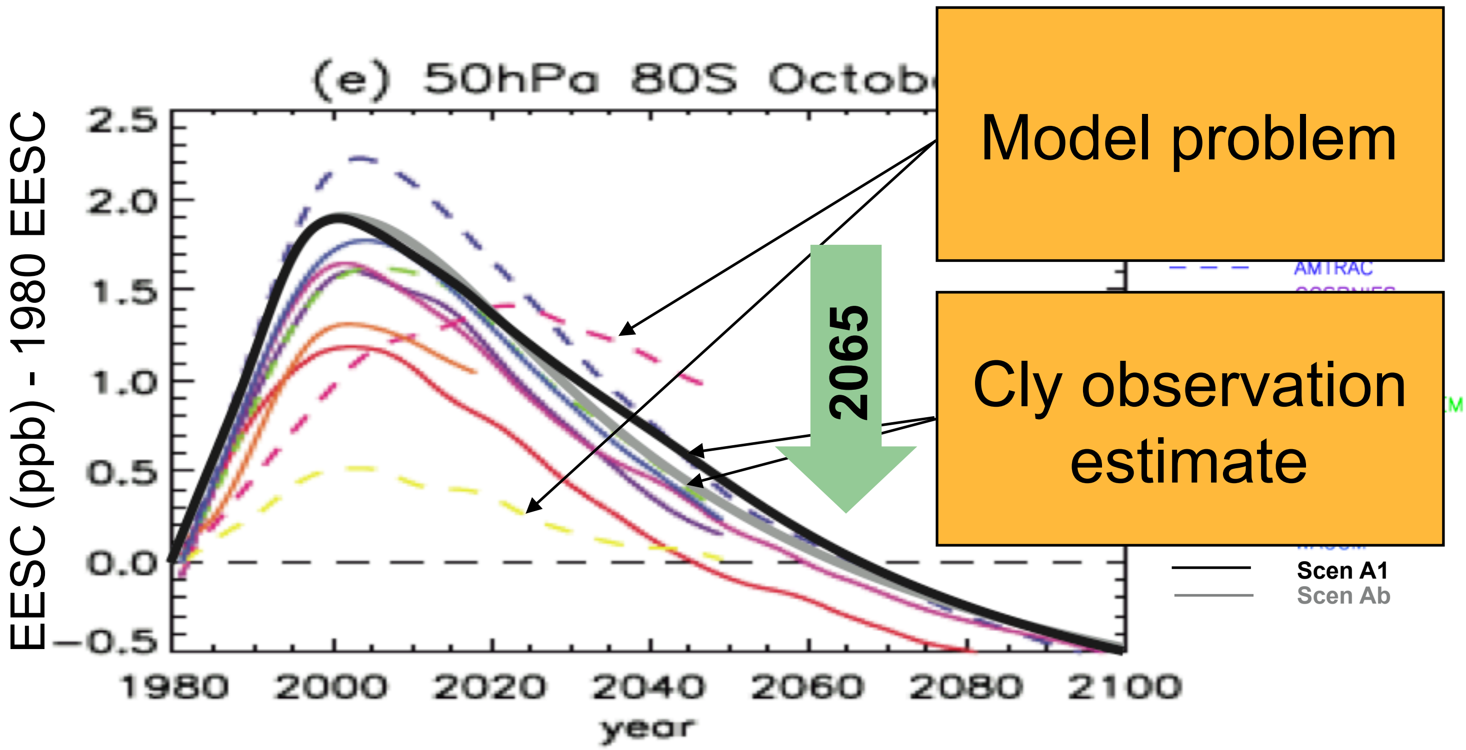
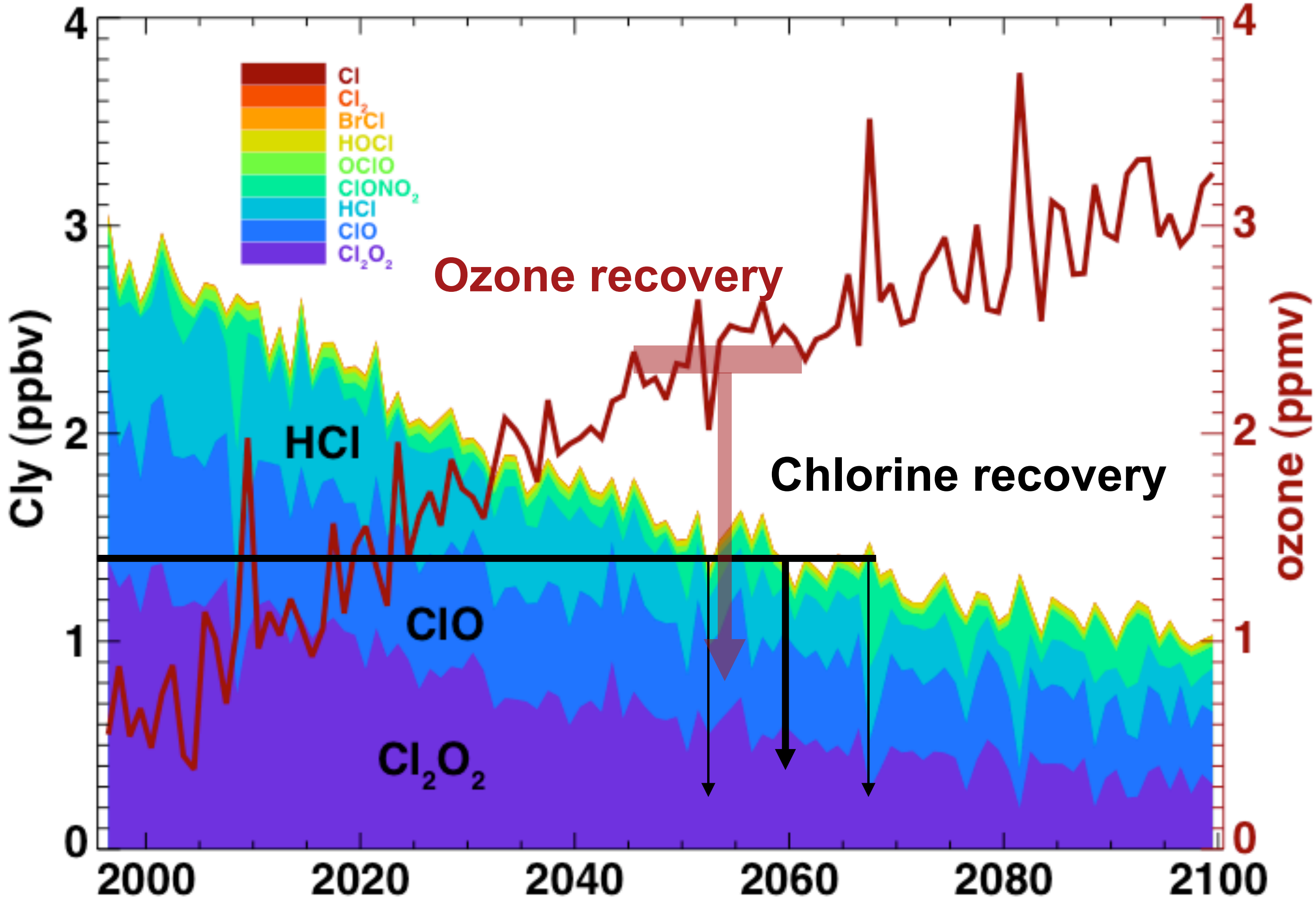


Figure 1. Eyring et al. (2007): "The CCMs show large differences in peak Cly and timing of when future values have returned to modeled 1980 values, which is a major cause of the differences in simulated ozone recovery, in particular in the Antarctic."

All models driven by WMO (2003) scenario Ab.

Cly vs. time

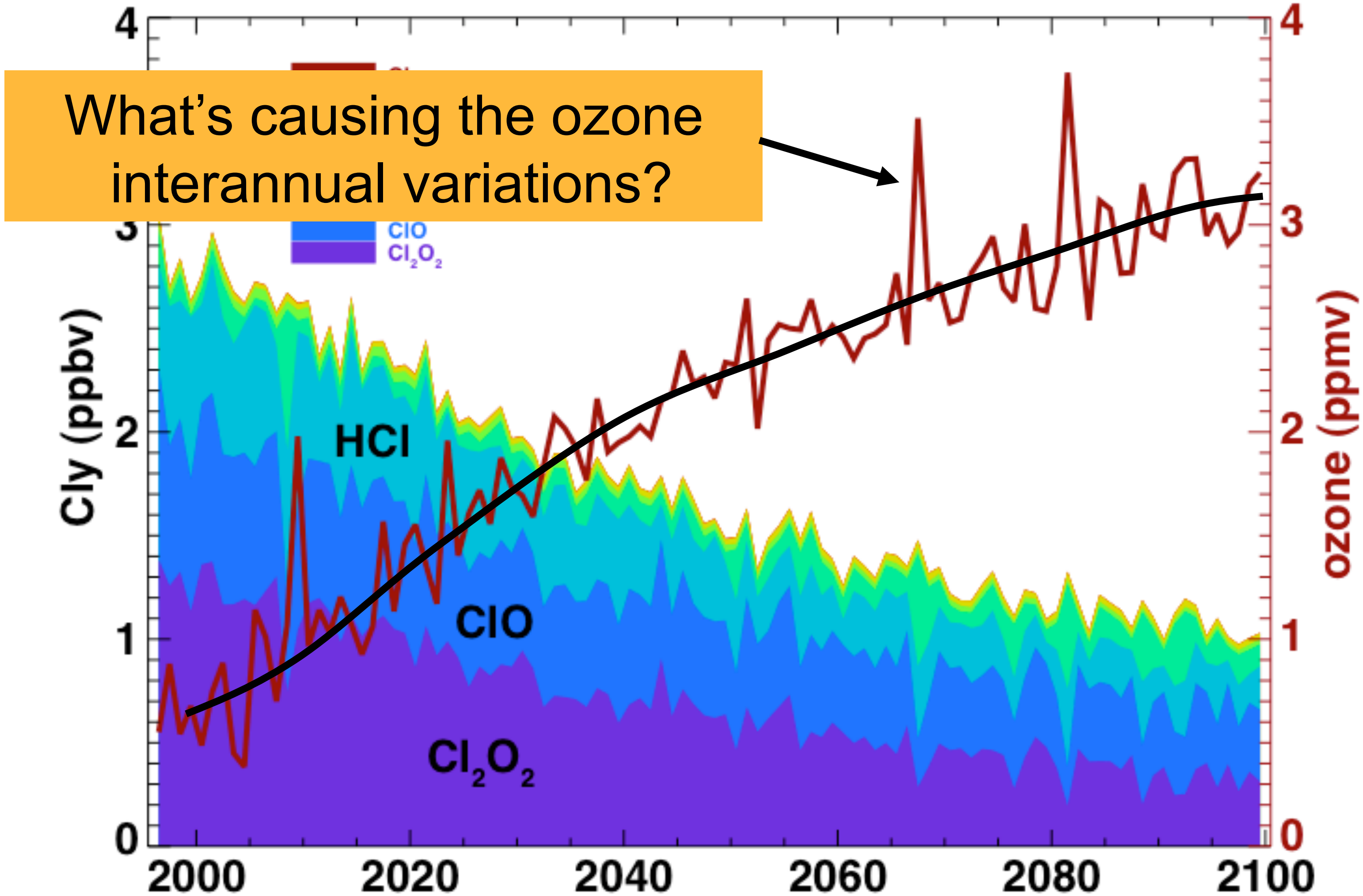


Cl
Cl_2
BrCl
HOCl
OClO
$ClONO_2$
HCl
ClO
Cl_2O_2
Ozone recovery
Chlorine recovery
HCl
ClO
Cl_2O_2
Cly (ppbv)
ozone (ppmv)
0
1
2
3
4
2000
2020
2040
2060
2080
2100

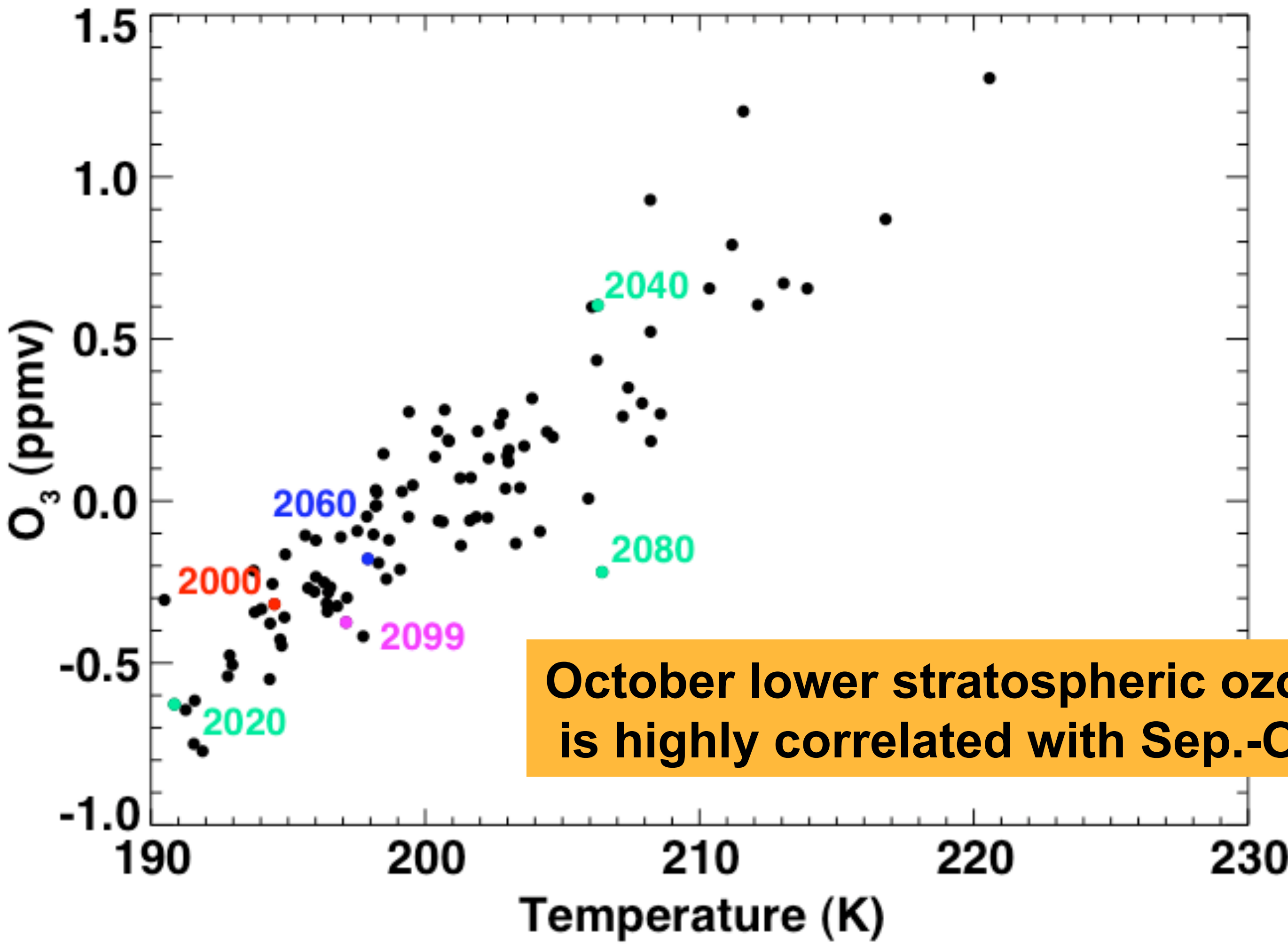
Uncertainty: Chlorine & Bromine

- Is our Scenario “Ab” correct?
  - How well do we understand mean age-of-air, and degradation of ODSs (CFCs and Halons) as they move through the stratosphere? Correct lifetimes for ODSs?
  - How well do we understand the budget of Cl & Br over Antarctica?
  - What will happen with HCFCs?
  - How will climate change alter lifetimes and transport in the stratosphere
- Do our models correctly represent levels of Cl_y and Br_y over Antarctica?
  - Transport (more than just mean age)
  - Chemistry (bromine levels, photolysis rates, e.g., recent Pope et al. discussions)

Ozone vs. time

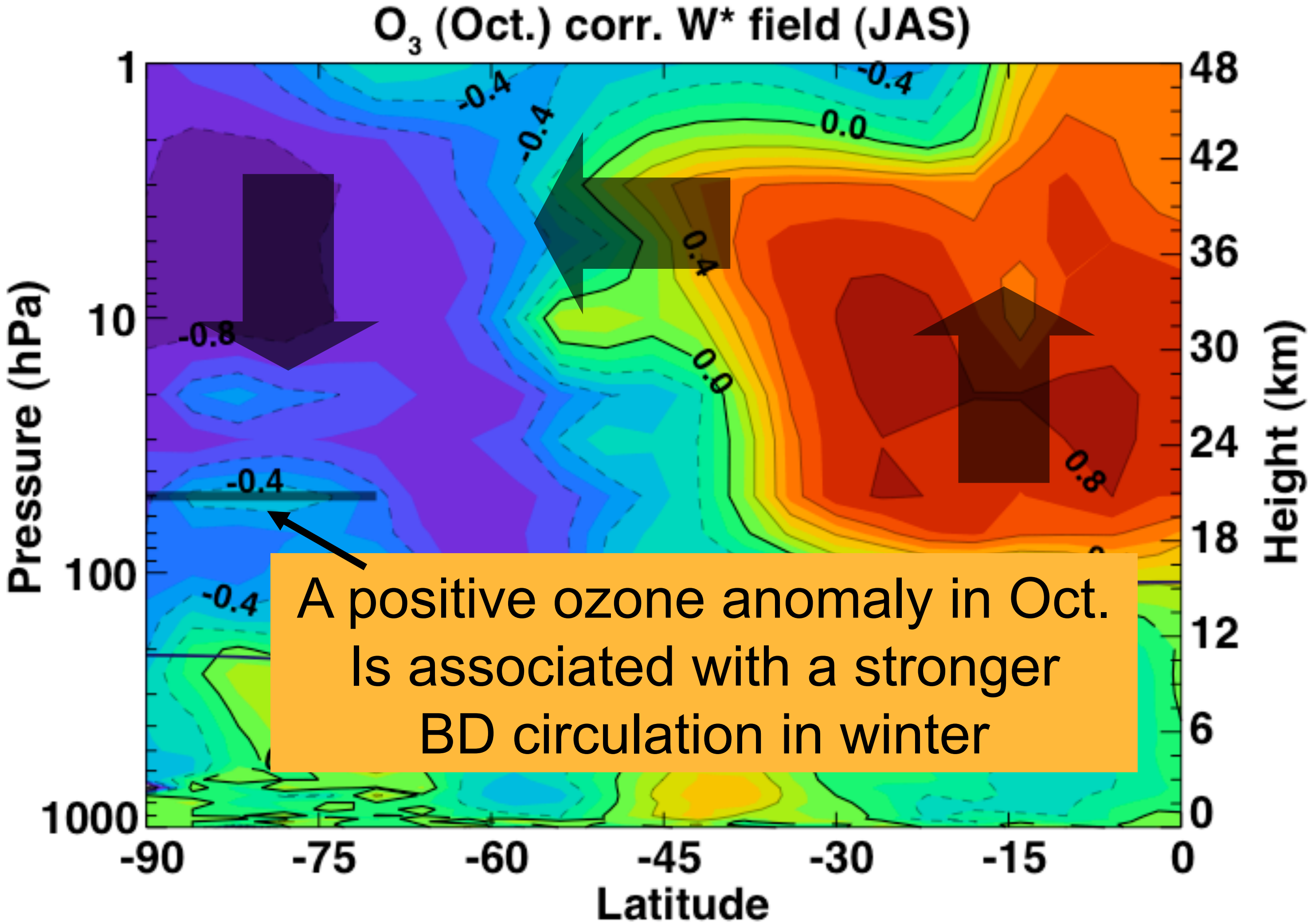


Ozone Resid. Vs. Temp.



October lower stratospheric ozone is highly correlated with Sep.-Oct. T

1-point corr. O_3 resid. vs. $\overline{w^*}$

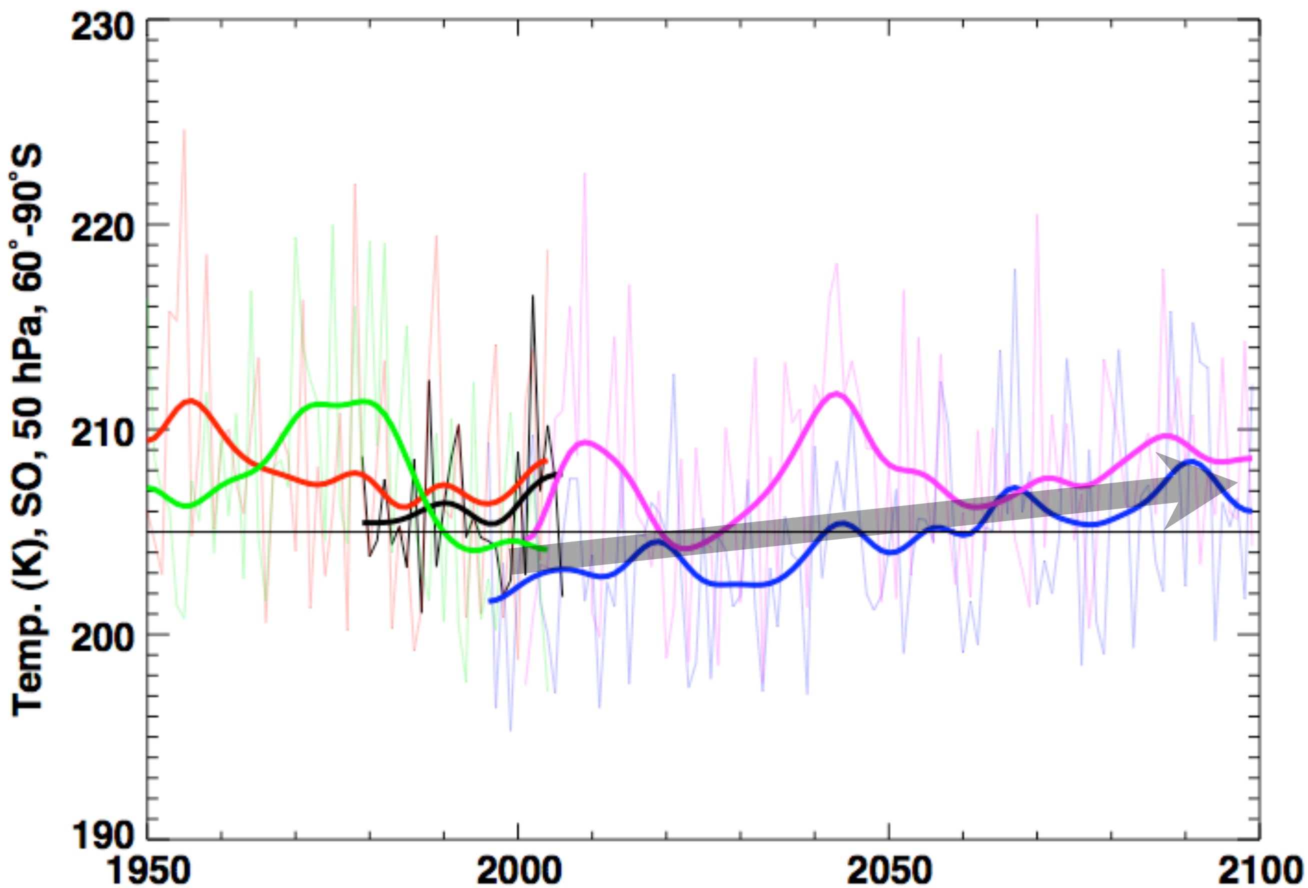


Lower stratospheric ozone negative (positive) anomalies related to decreased (increased) downward circulation in middle stratosphere over the winter

Climate change impact on recovery

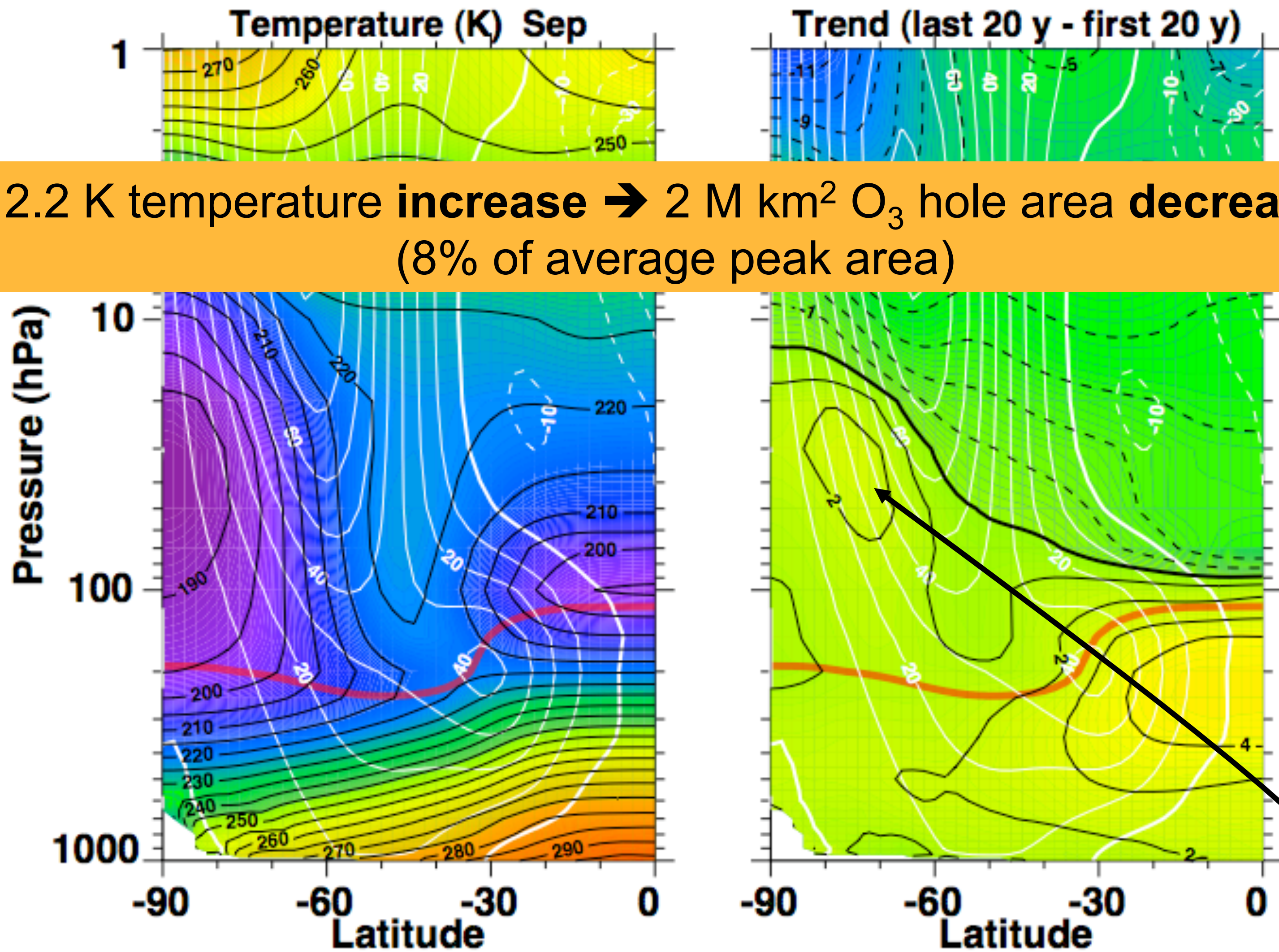
Temperature Trend

Sep.-Oct., 50 hPa, 60˚S-90˚S



1.3K temperature **increase** ➔1 M km^2 O_3 hole area **decrease** (4% of average peak area)

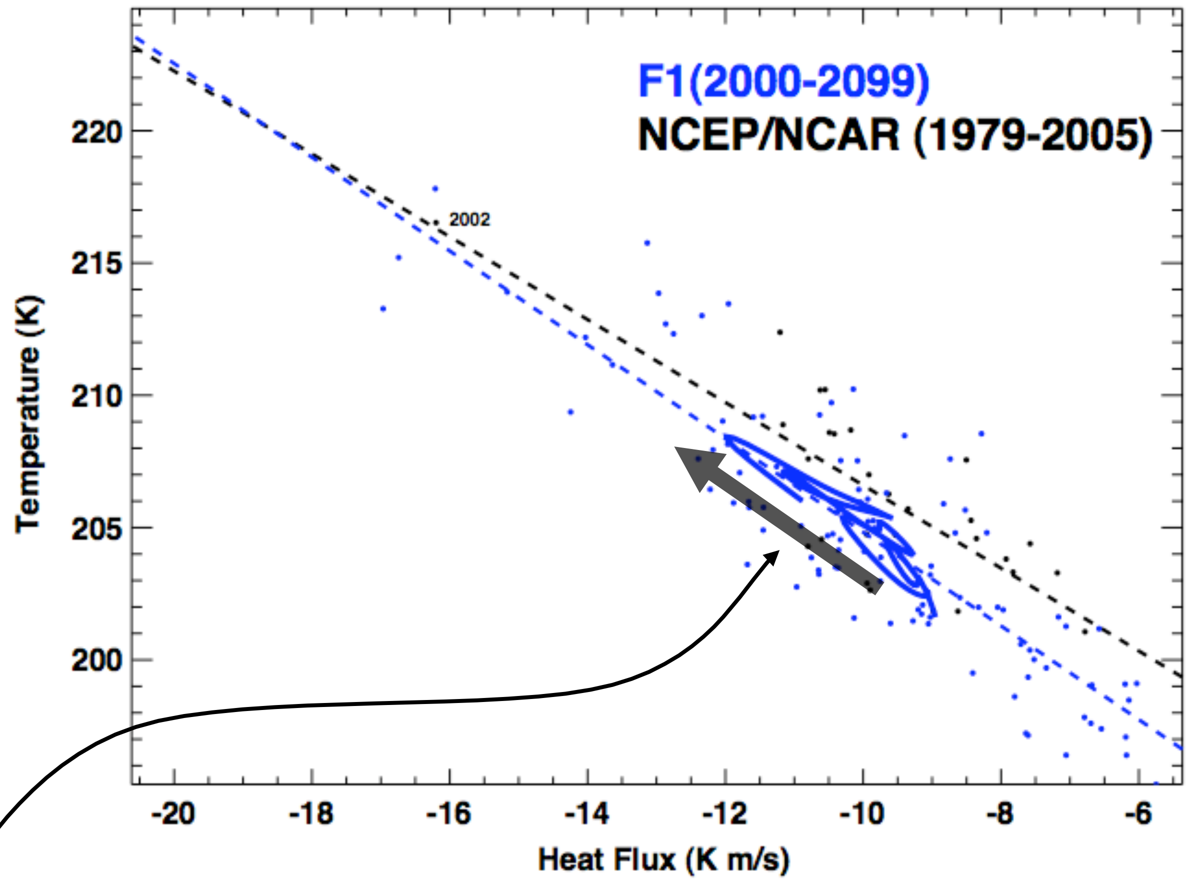
September Temperature



2.2 K temperature **increase** ➔ 2 M km^2 O_3 hole area **decrease** (8% of average peak area)

Polar stratosphere warms by ~ 2K

T vs. heat flux



The model polar strat shifts to **warmer temperatures** as the wave driving from the troposphere strengthens. This would act to accelerate recovery. Correct?

Uncertainty: climate change

- Climate change
  - Will the Brewer-Dobson circulation accelerate & why? How will this affect lifetimes, release values, ozone advection?
  - **How will the wave driving change?**
  - **How will temperatures change?**
  - Since polar ozone is also tied to the vertical descent rates, models **must** correctly capture the circulation and those processes that affect the circulation.
- Climate change appears to be accelerating recovery - but not by much

Sep 24 2003

Summary

- The recovery of polar ozone (2060s) is now recognized to be different than in the mid latitudes (2040s).
- The ozone hole will fully recover by 2067±10. The first stage of recovery will be seen in about 2023.
- The primary factor behind recovery is the decrease in Cly and Bry. The recent regulation of HCFCs will bring full recovery earlier by about 3 years.
- Climate impact will accelerate recovery, but remains uncertain