# Stratospheric Ozone : Depletion and Recovery

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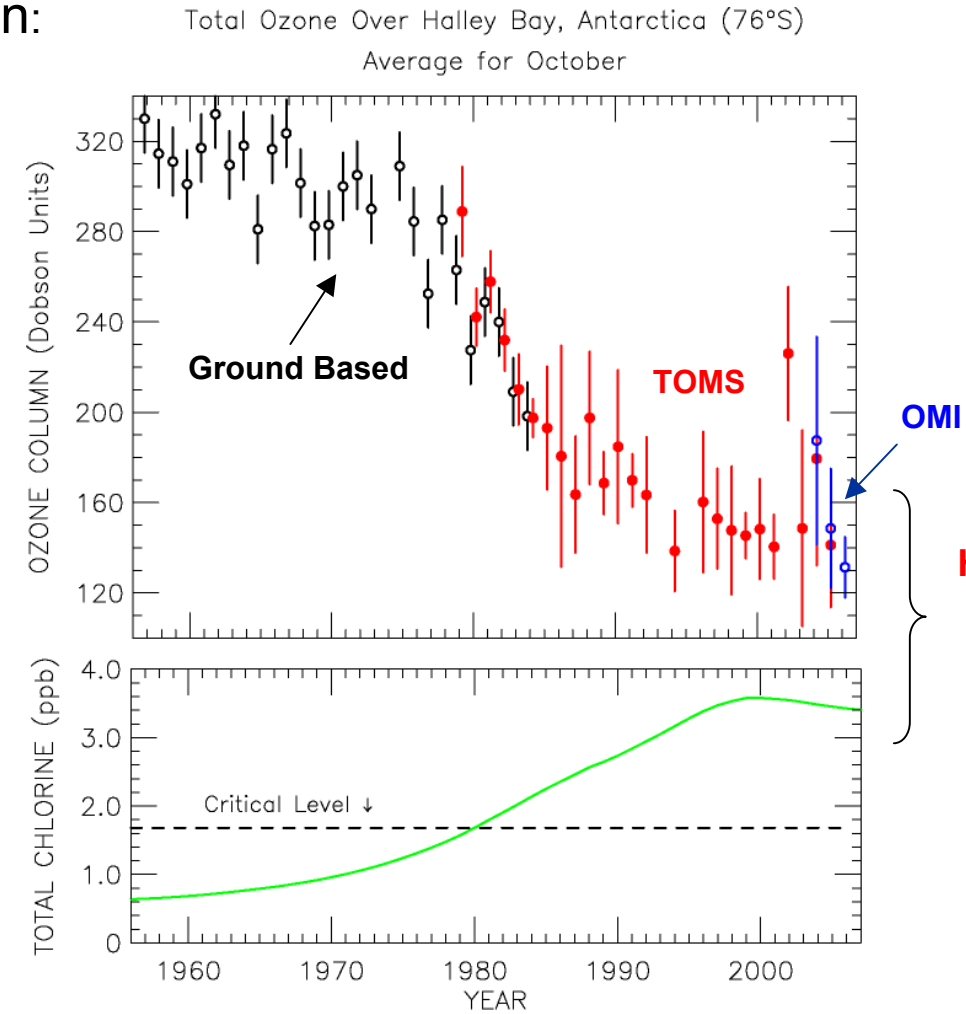
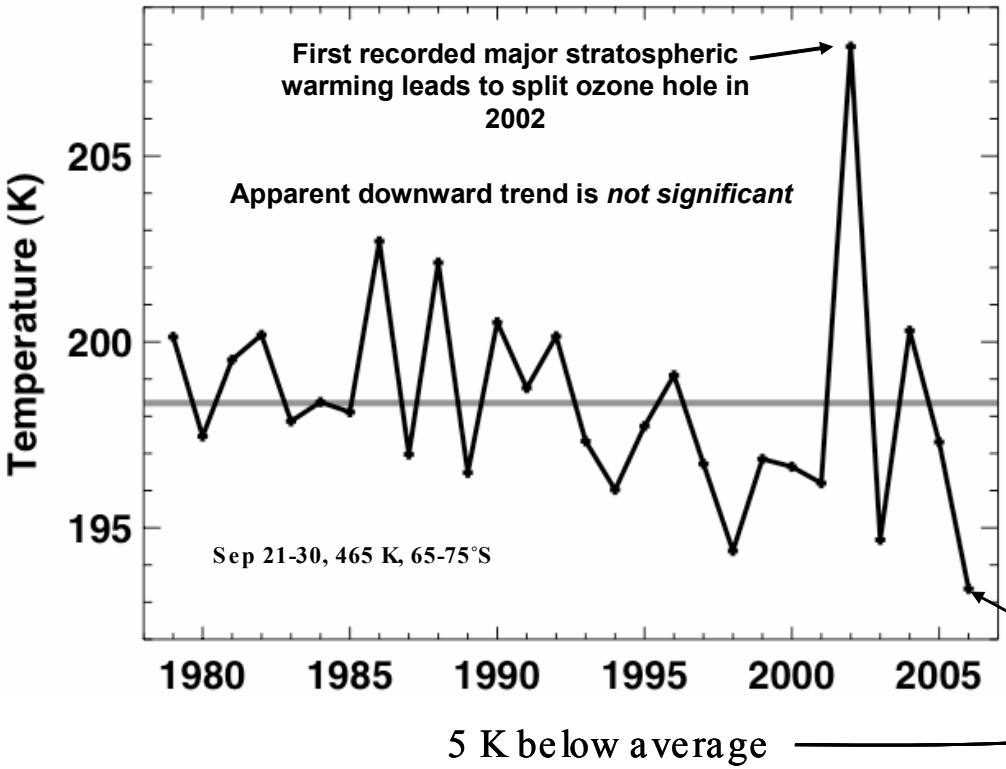
## Motivation:




**How much of this "leveling off" in ozone column is due to the "leveling off" of halogens ?**

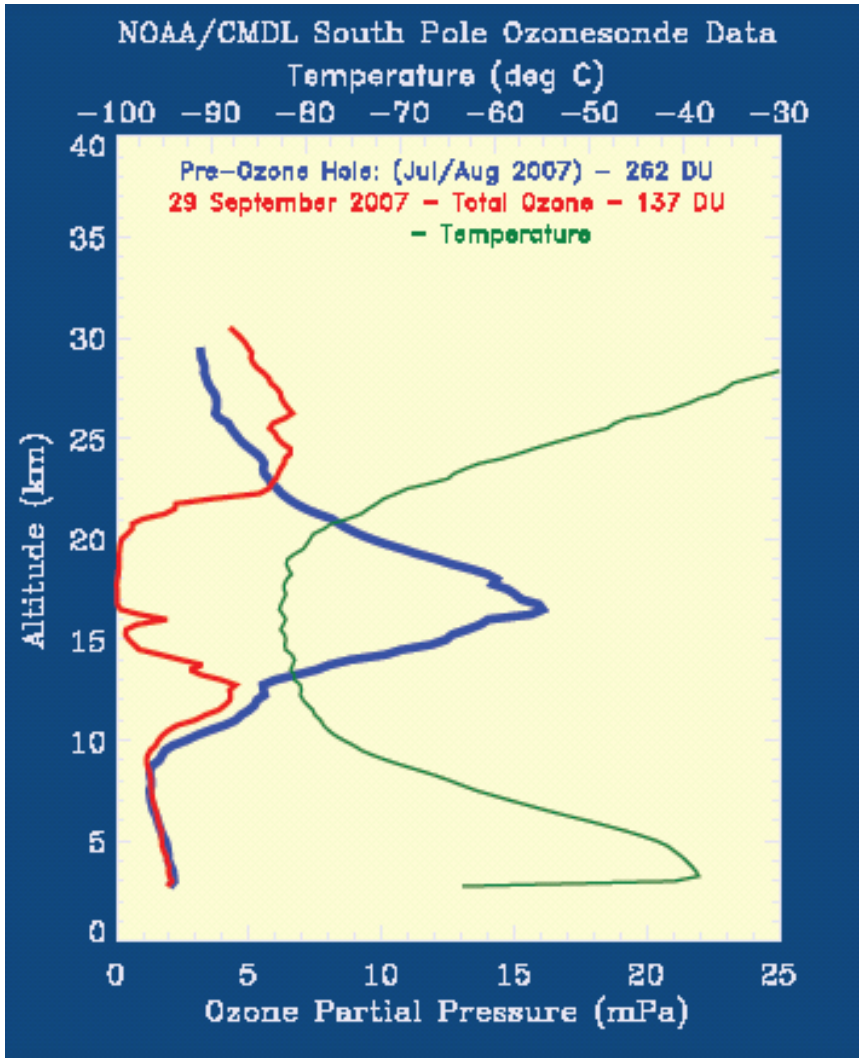
# Complication #1




**Large year to year variability in temperature**

Figure courtesy Paul Newman

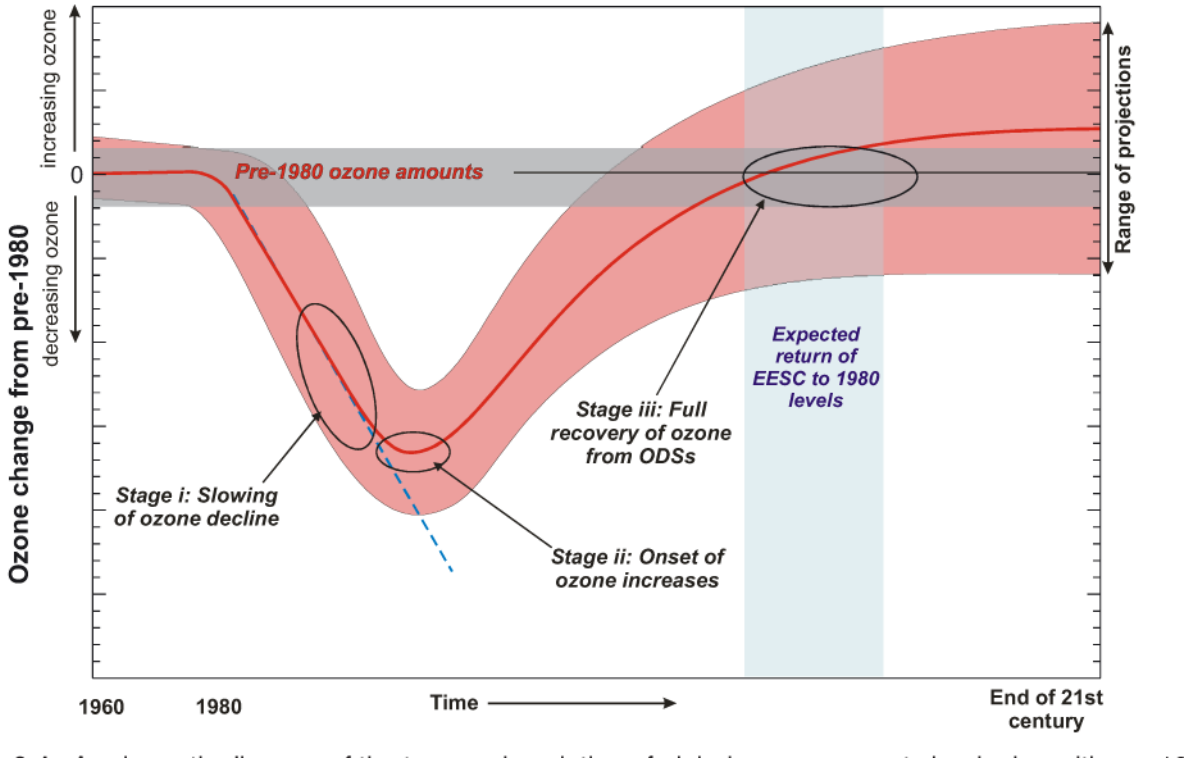
# Complication #2



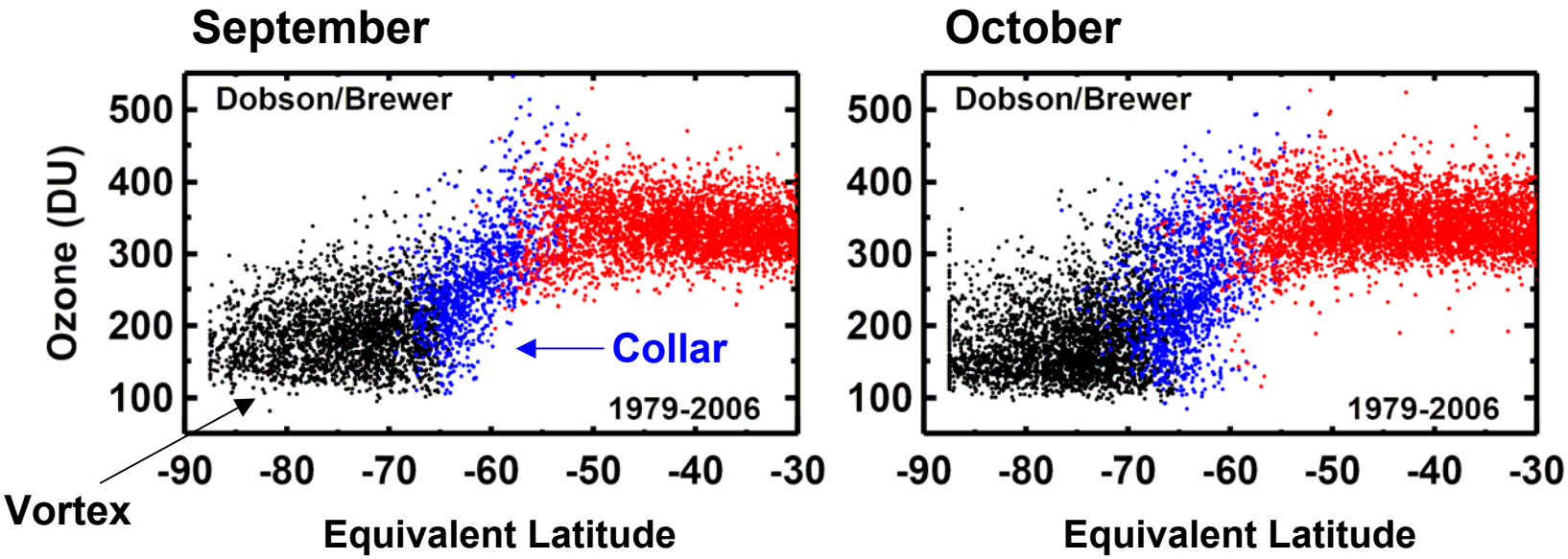

**Ozone reaches "zero" over considerable height range.**

**This "saturation effect" may be the cause of the "leveling off" of the column ozone time series**

# WMO 2006 (Chapter 6) Definition, First Stage of Ozone Recovery



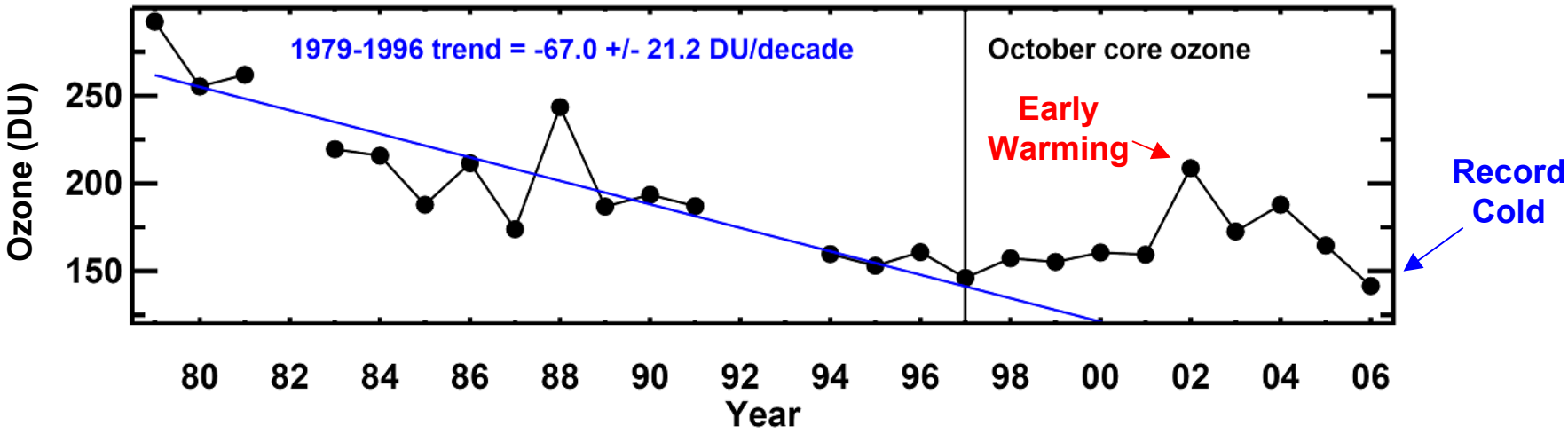

**The occurrence of a statistically significant reduction in the rate of decline of ozone due to changing ozone depleting substances**



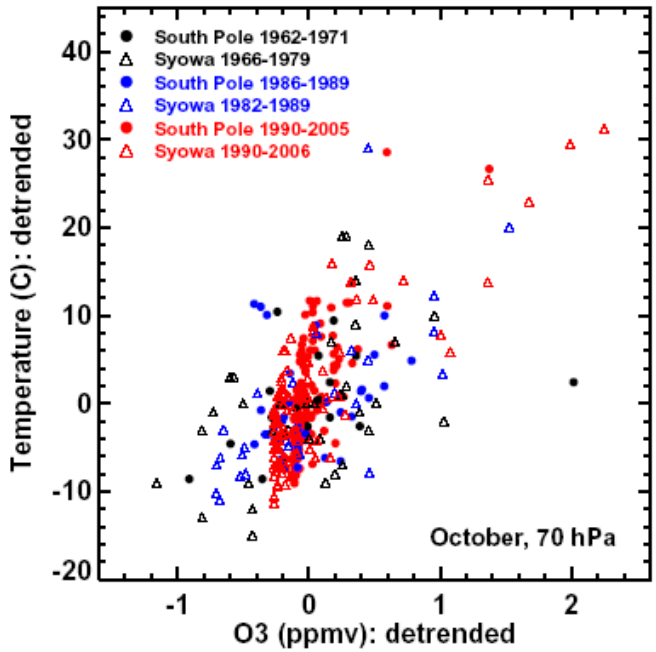

Data sources:

- SAGE II, HALOE, Sondes, Brewer/Dobson
- Classify data as vortex, collar, or extra vortex using Equivalent latitude at 440 K (Nash criteria; PV from NCEP reanalysis)

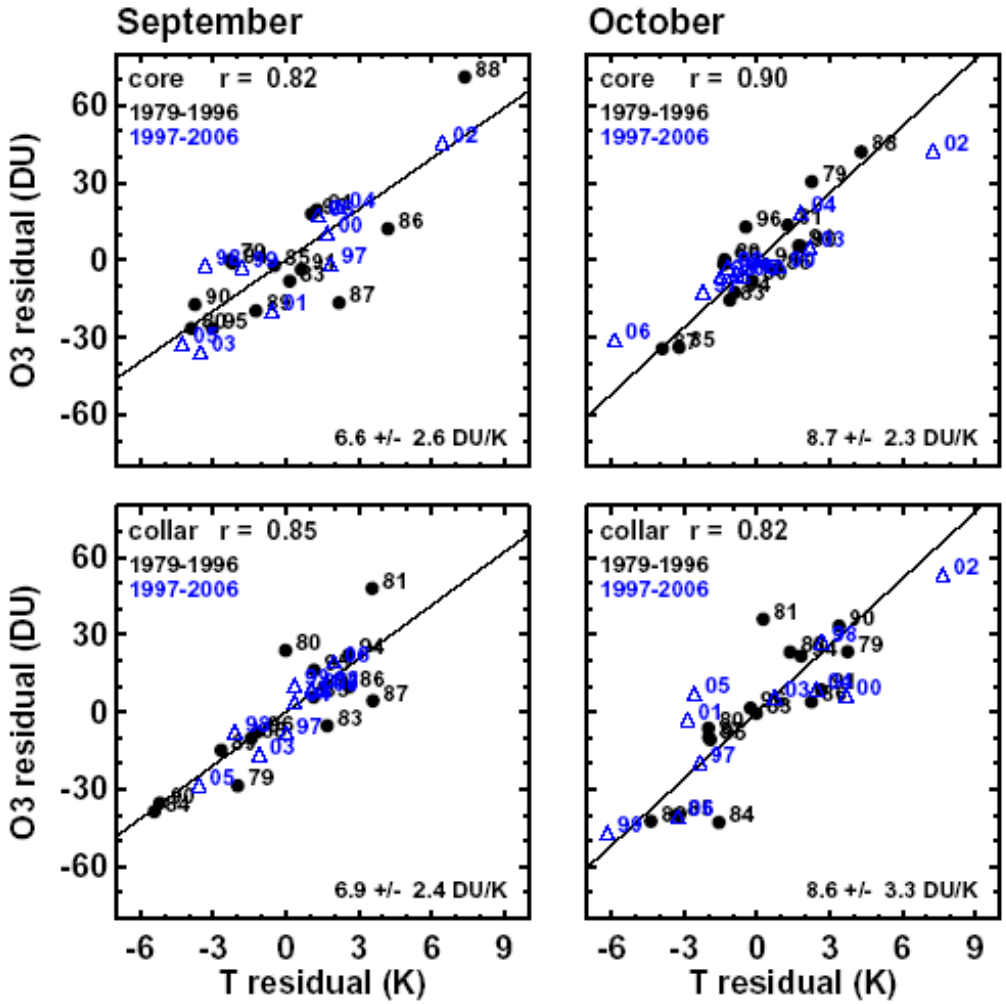
# Total Ozone in Vortex Core, October




## Scatter plot, Detrended $O_3$ vs Detrended Temperature (70 hPa) :

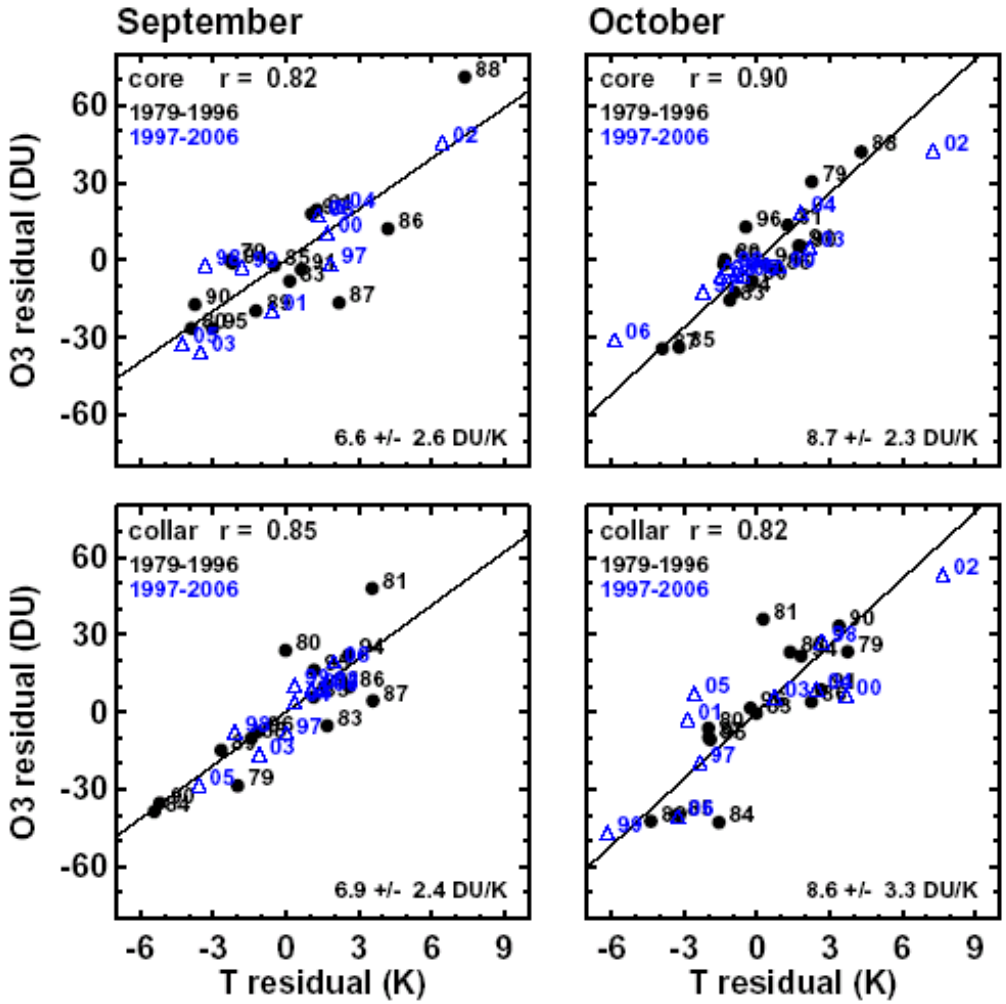


# Scatter plot, Detrended Total $O_3$ vs Detrended Temperature (440 K) :



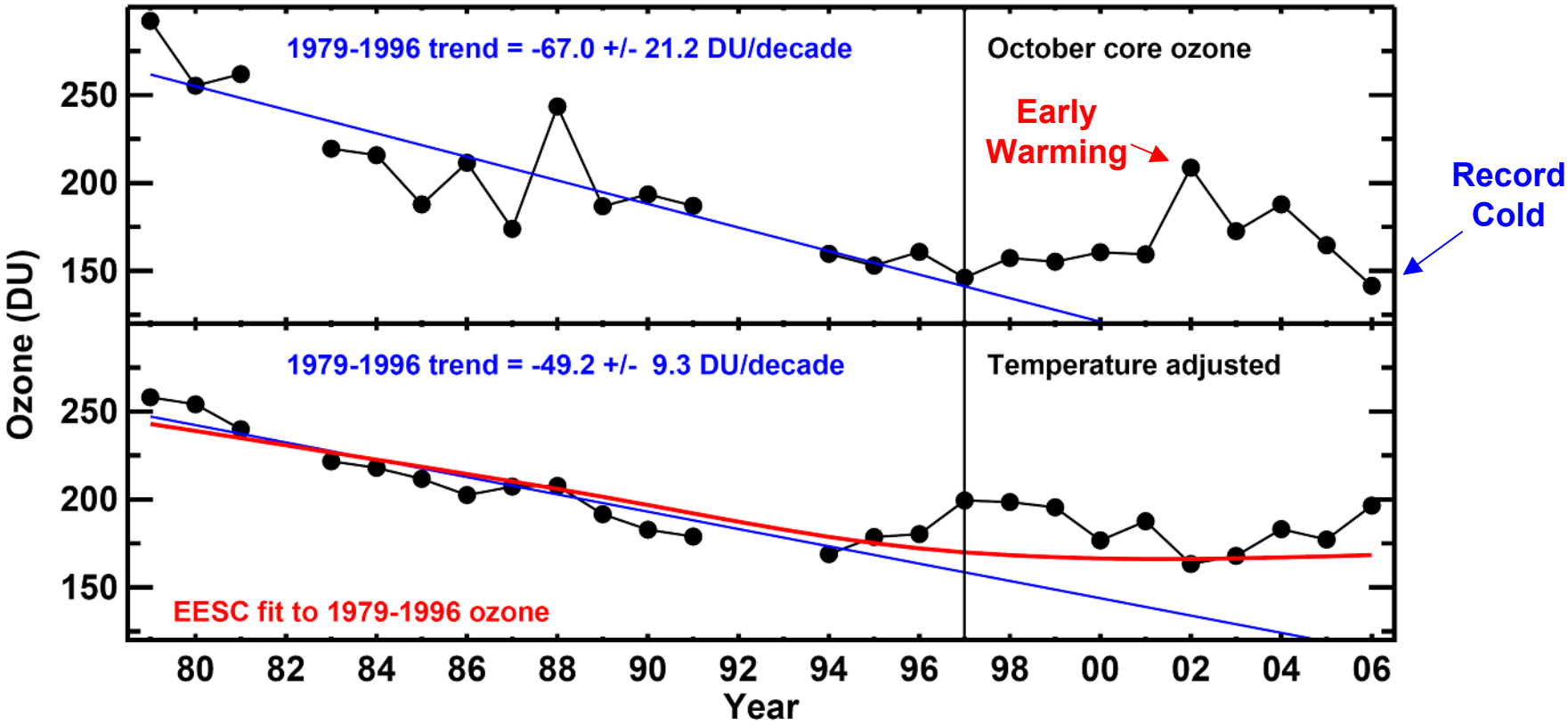

**Cold winters associated with larger vortices and less ozone, due to combination of "dyamical effects" and "chemical effects" related to availability of PSCs**
**(Boedeker et al., 2002; Newman et al., 2004)**

# Scatter plot, Detrended Total $O_3$ vs Detrended Temperature (440 K) :

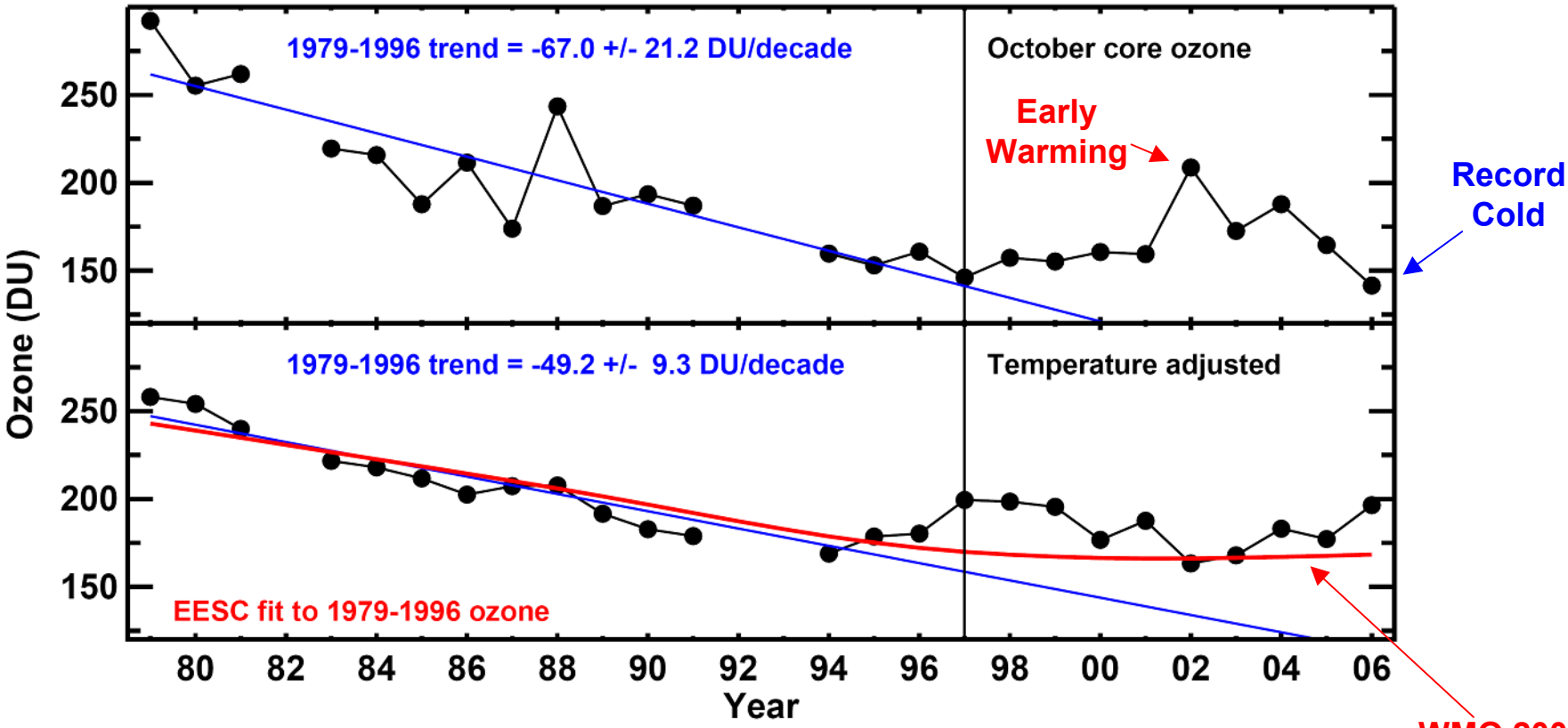



**We use slopes of these curves, together with yearly T residual, to derive Ozone Time Series that account for yearly variations in temperature and dynamics**

# Total Ozone: October, Vortex Core

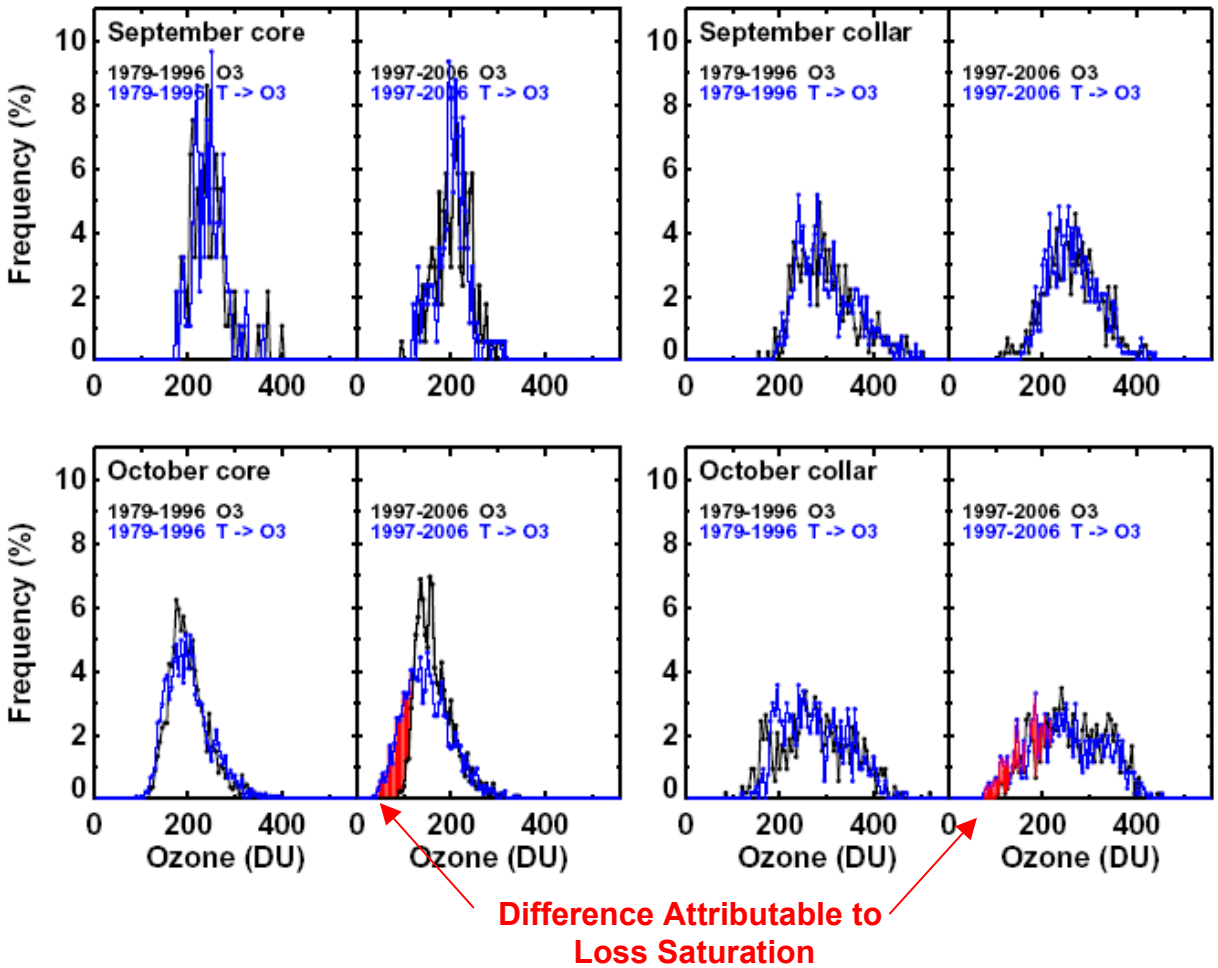


# Total Ozone: October, Vortex Core




- Have dealt with Complication #1 (Meteorology)
- Now, must deal with Complication #2 (Loss Saturation)

# Loss Saturation, Method #1 : PDFs of Ozone

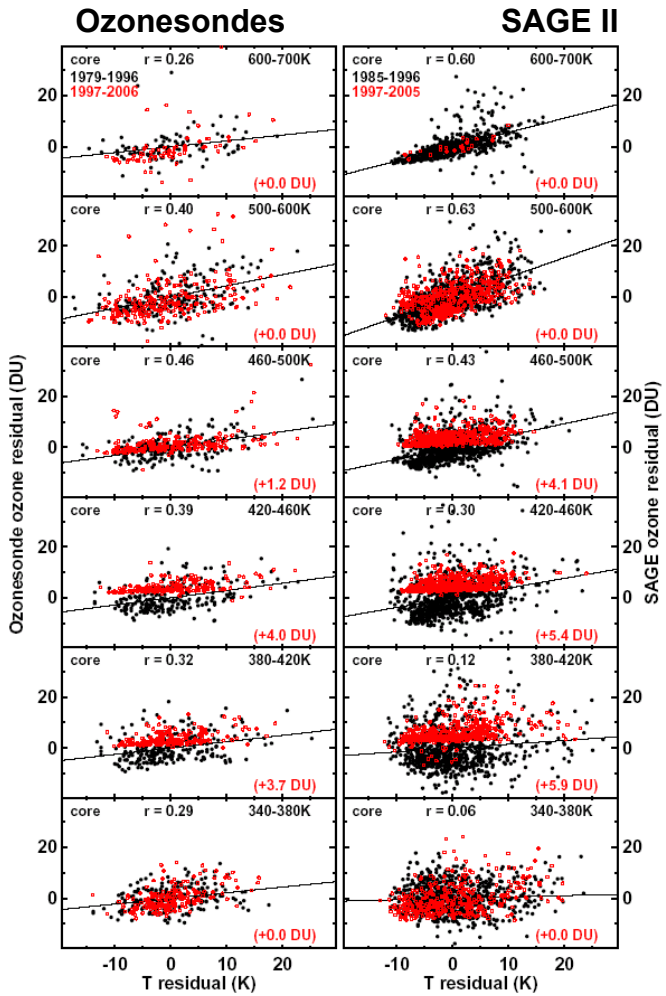



**October vortex core: mean ozone is 15 DU higher (1997 to 2006) than "predicted ozone" found using T residuals and slope from 1979 to 1996 time period**

**October vortex collar: 13 DU effect**

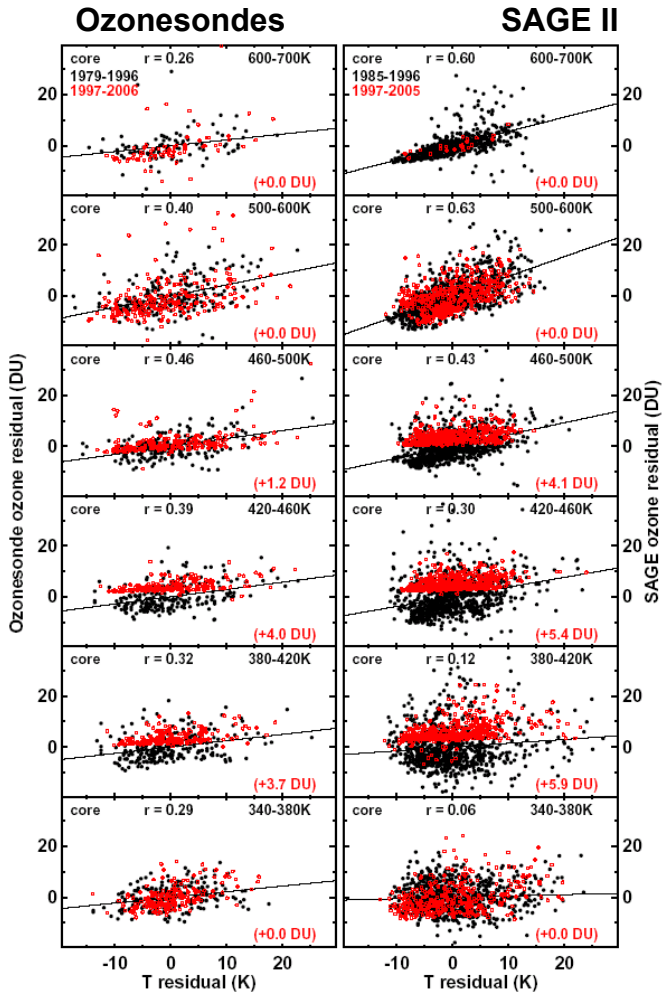
**September core and collar: no discernable saturation effect**

# Loss Saturation, Method #2 : $\Delta(O_3)$ vs $\Delta(T)$




**October vortex core: ozonesonde saturation effect : 8.9 DU (1.2 + 4.0 + 3.7)**
**SAGE II saturation effect: 15.4 DU (4.1 + 5.4 + 5.9 )**

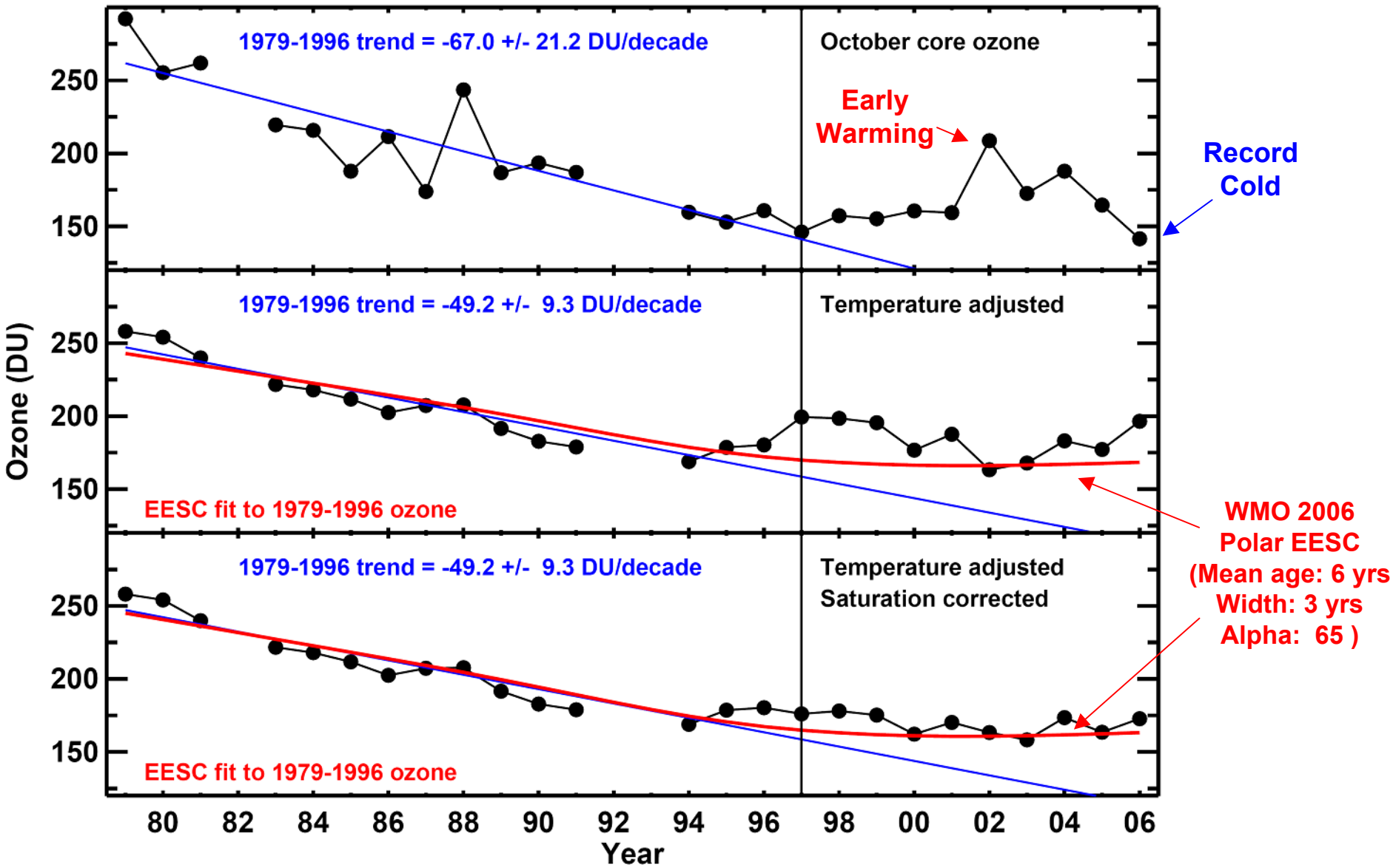
# Loss Saturation, Method #2 : $\Delta(O_3)$ vs $\Delta(T)$




**October vortex core: ozonesonde saturation effect : 8.9 DU (1.2 + 4.0 + 3.7)**
**SAGE II saturation effect: 15.4 DU (4.1 + 5.4 + 5.9 )**

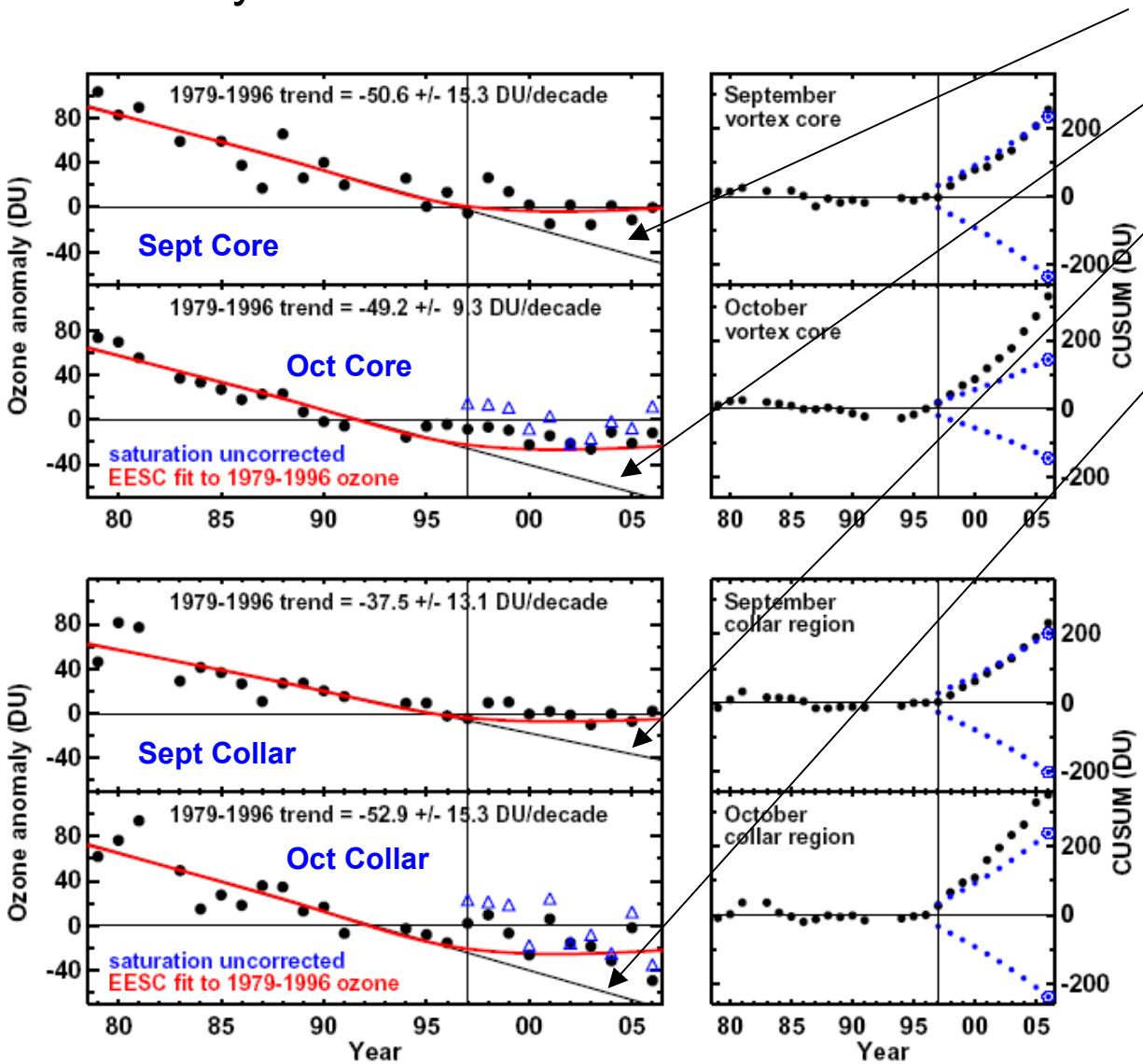
**Adjust October core (collar) ozone time series by mean values of 15 DU (13 DU) for 1997 to 2006, with coldest years having larger adjustments**

# Total Ozone: October, Vortex Core



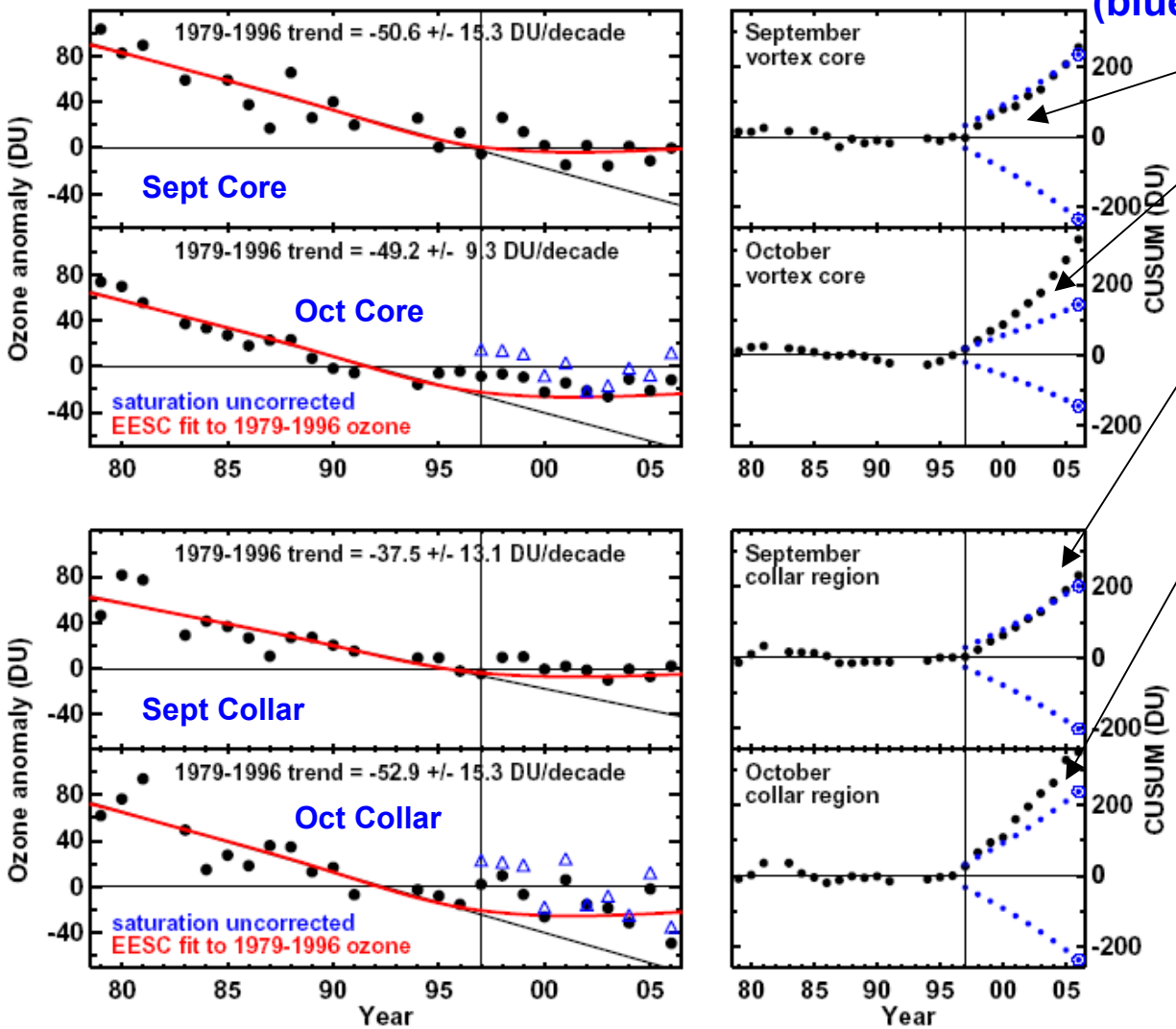
# Trend Analysis:

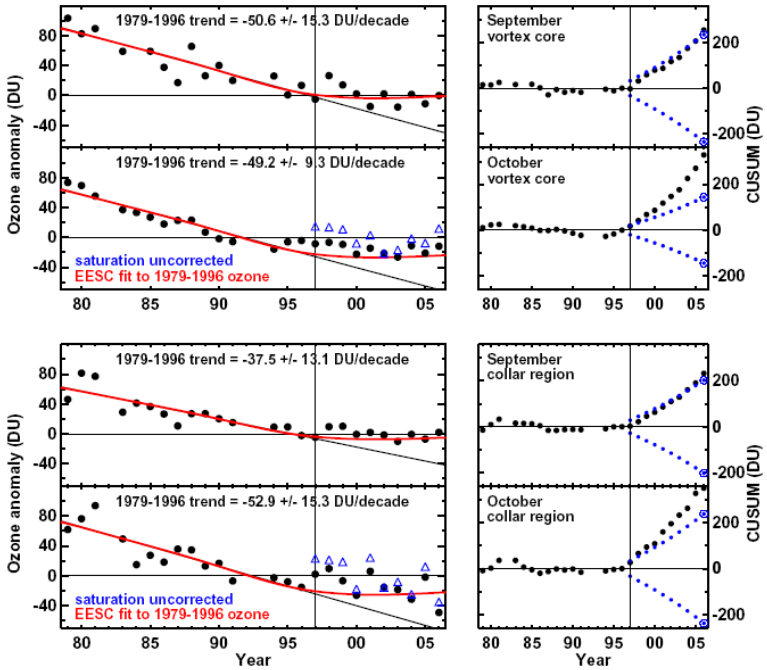
**Deviation from 1979 to 1996 trend**



# CUSUM Analysis:

**Deviations are Statistically Significant**
**(blue dotted: 95% confidence limit)**



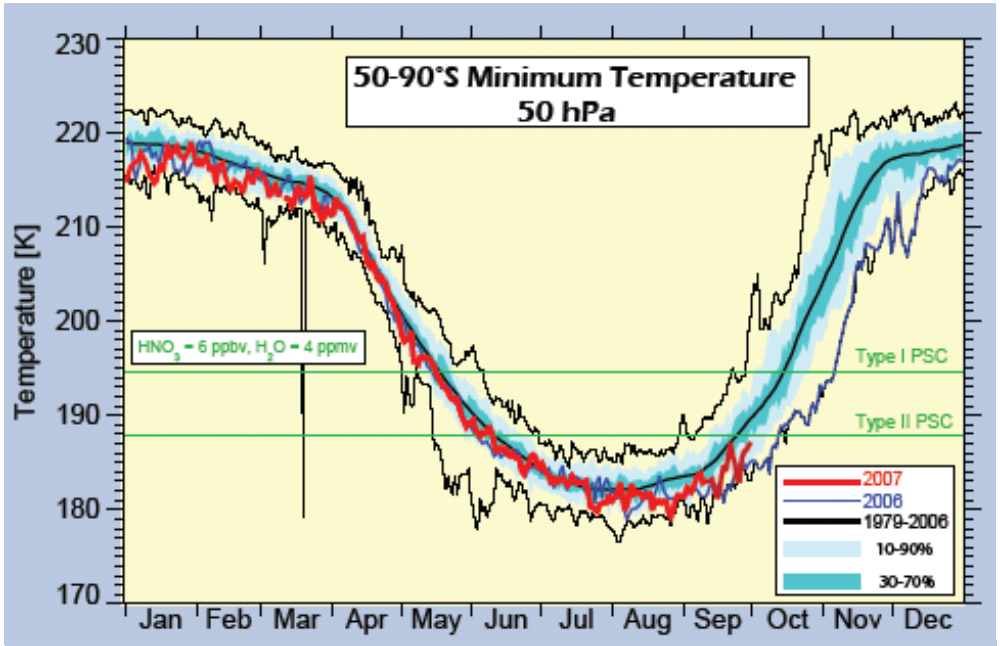


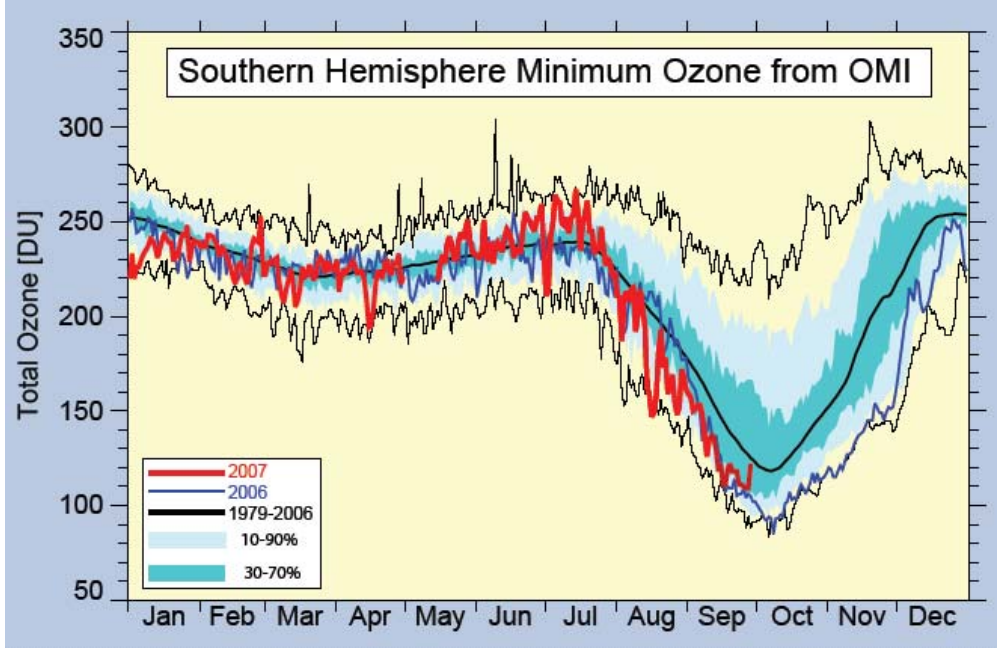

## Conclude:

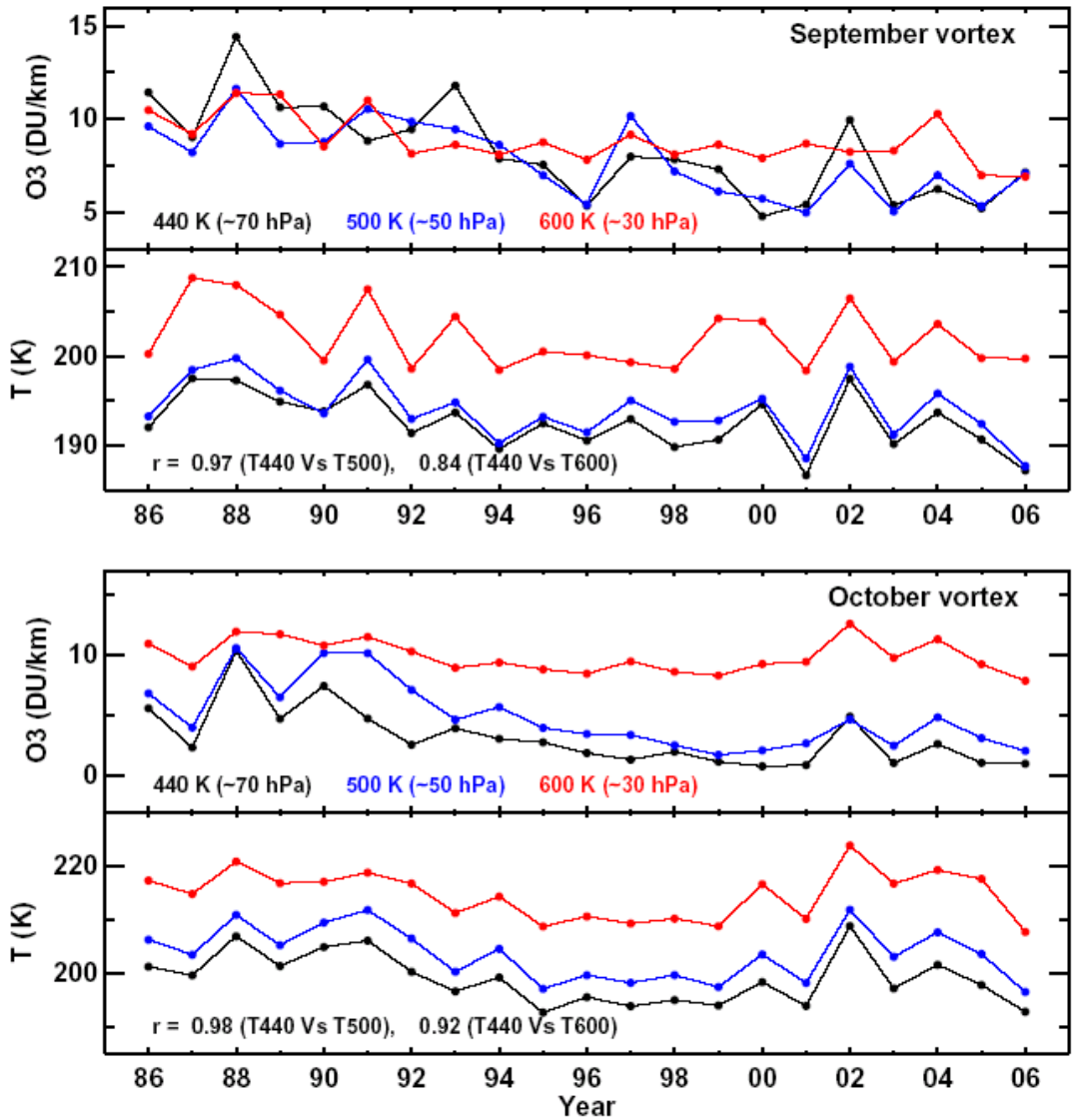
- **Antarctic Ozone**, within *both core and collar region*, is in the **first stage of recovery** due to the leveling off of ozone depleting substances
- In plain English: ***chemical loss is not getting any worse***
  (use of word "recovery" seems strange to me, but the community has chosen this word to describe this situation!)
- **Yearly variations in Antarctic ozone now driven by meteorology**
- **Cold winters ⇒ low ozone**

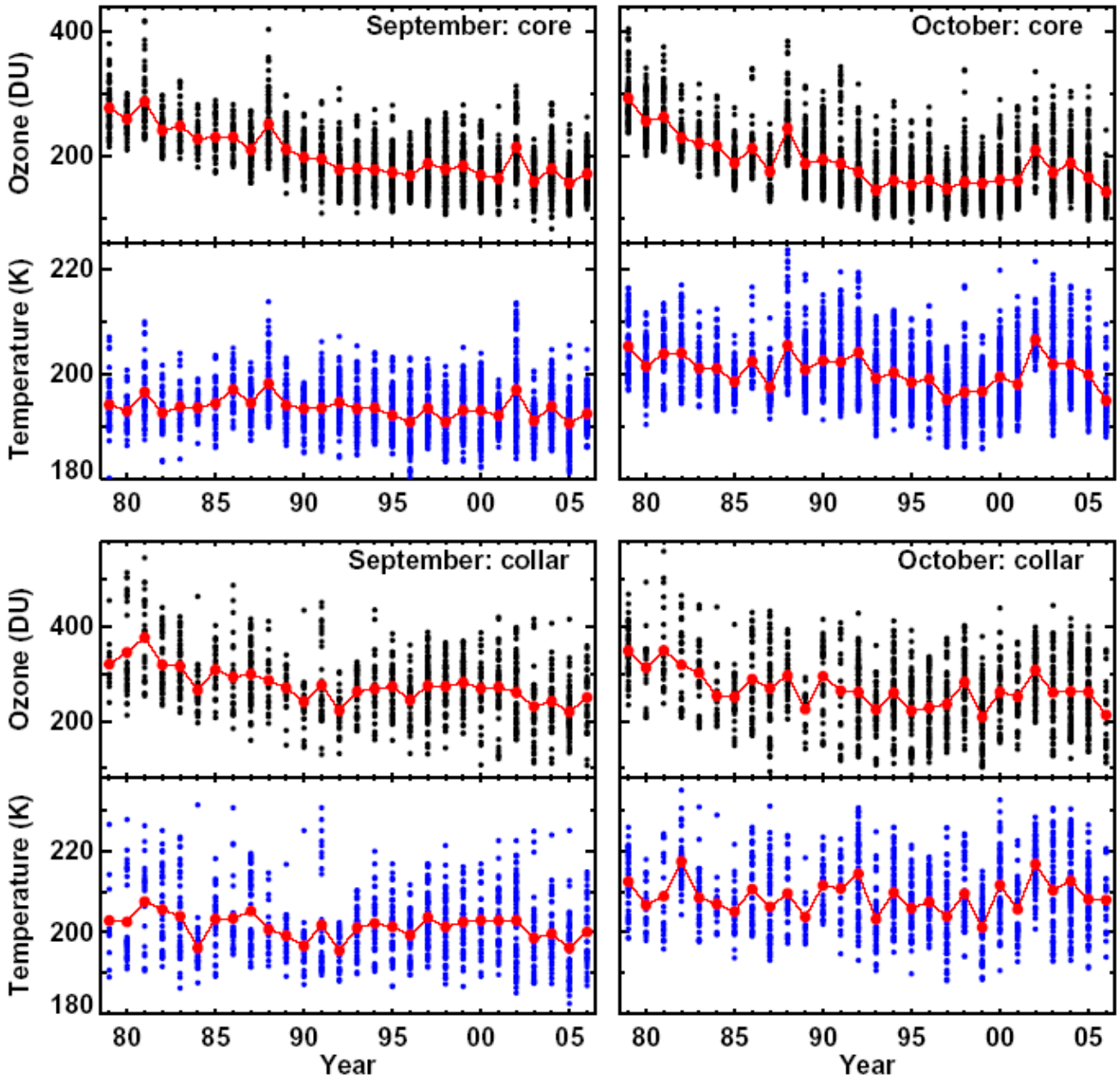
Next project: attribution of changes upper stratospheric ozone using Aura/UARS MLS ClO, UARS HALOE $CH_4$, Aura MLS $N_2O$, and UARS HALOE HCl and Aura MLS HCl

# Backup Material




September vortex
O3 (DU/km)
15
10
5
440 K (~70 hPa)
500 K (~50 hPa)
600 K (~30 hPa)
T (K)
210
200
190
r = 0.97 (T440 Vs T500), 0.84 (T440 Vs T600)
86
88
90
92
94
96
98
00
02
04
06
October vortex
O3 (DU/km)
10
0
440 K (~70 hPa)
500 K (~50 hPa)
600 K (~30 hPa)
T (K)
220
200
r = 0.98 (T440 Vs T500), 0.92 (T440 Vs T600)
86
88
90
92
94
96
98
00
02
04
06
Year


September: core
October: core
September: collar
October: collar
Ozone (DU)
Temperature (K)
400
200
220
200
180
80
85
90
95
00
05
Year

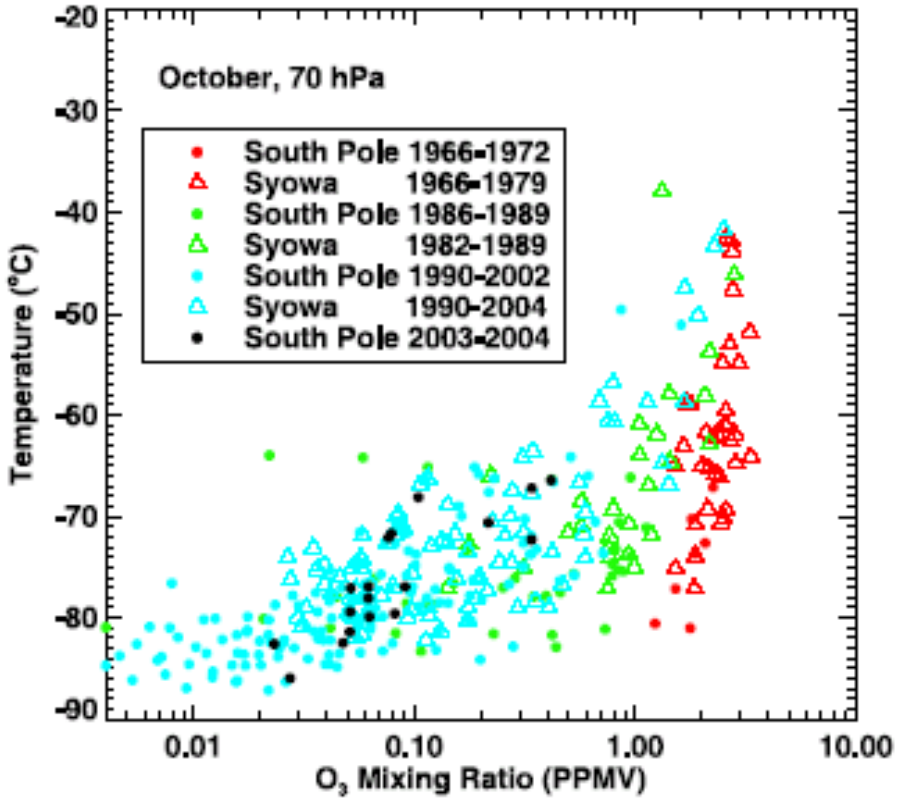



**Figure 5.** Scatterplot of October 70 hPa ozone mixing ratios with temperatures measured by ozonesondes at South Pole and Syowa for different groupings of years. Red triangles and circles denote historical data as available at each station in the 1960s and 1970s, while green points show data in the 1980s and light blue shows data post-1990 with the exception of 2003–2004 at the South Pole in black.

Solomon et al., JGR, 2005