A New Look at Antarctic Ozone Hole Recovery

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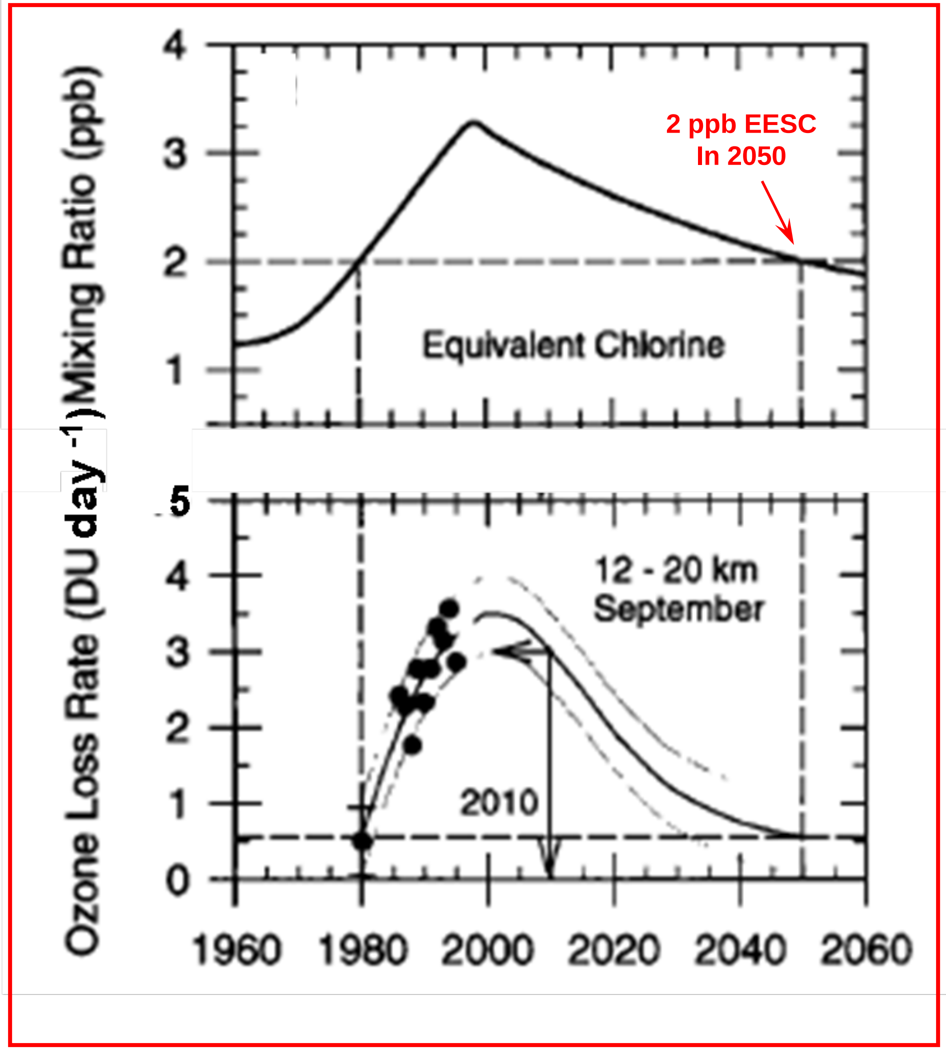
First Estimate of Ozone Hole Recovery - 1996

13 years ago the first estimate of the time of the expected beginning of ozone hole recovery was made by ESRL (former CMDL) scientists from the first ten years of South Pole ozonesonde data (1986-1995).

Using the variability of the ozone loss rate during formation of the ozone hole as an indicator, and the projected (WMO/UNEP) course of “Equivalent Chlorine” in the stratosphere, the first sign of a recovery was projected to be about 2010 and complete recovery about 2050.

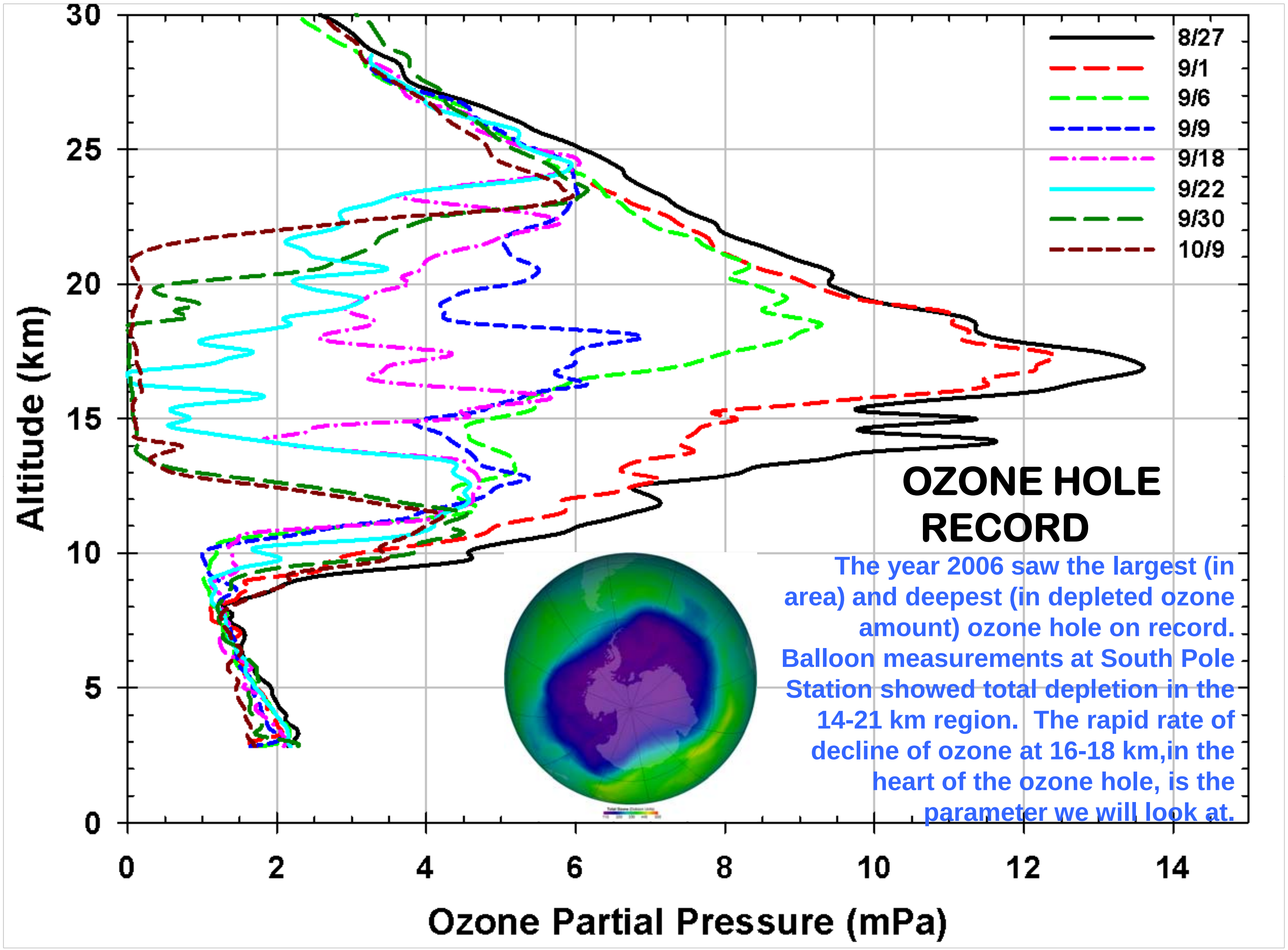
Things have changed since then, including updated Equivalent Chlorine and unusual variability in ozone loss rates. These require changes in the early estimates which are the subject of this talk.



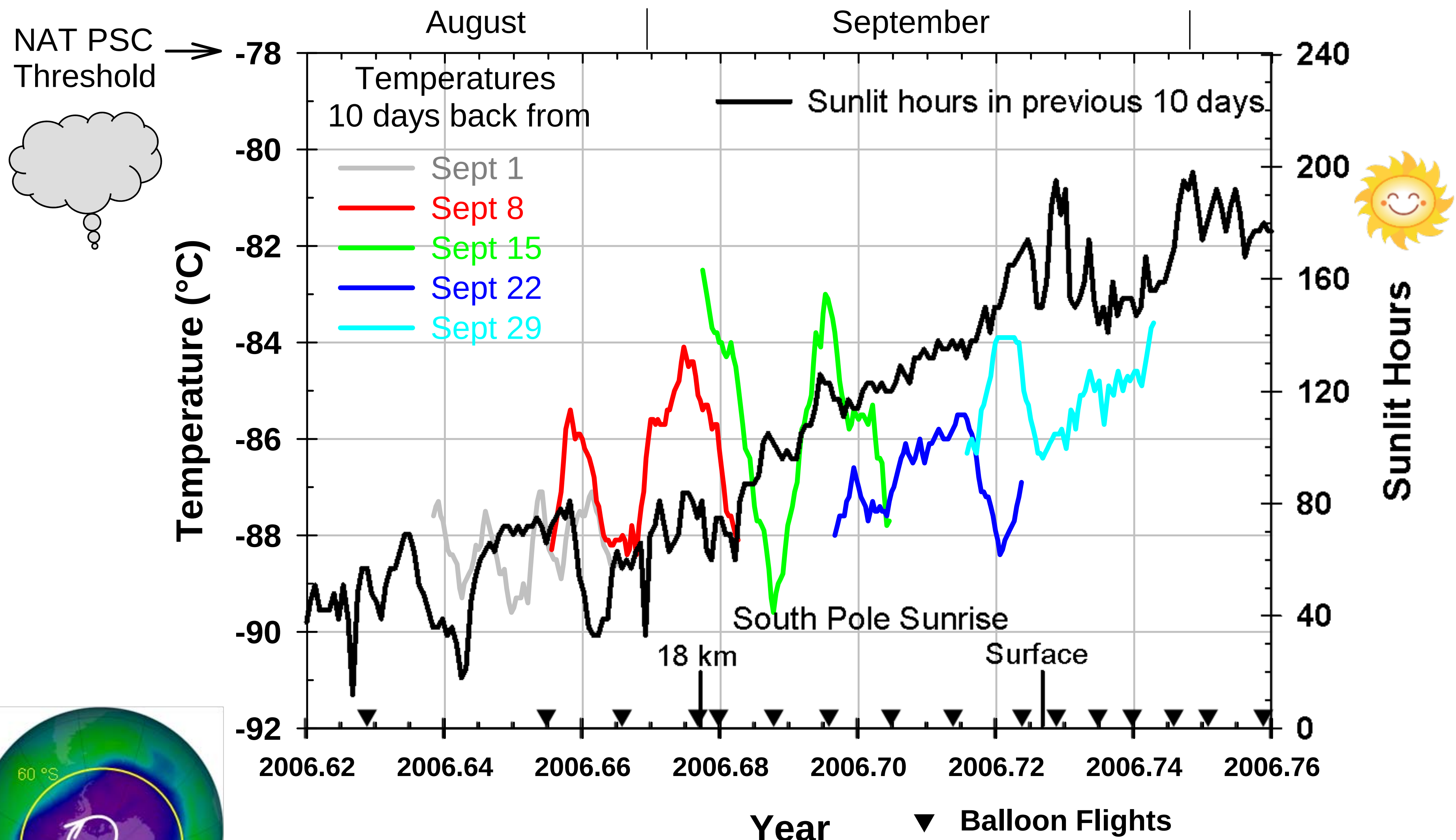
D. Hofmann, S. Oltmans, J. Harris, B. Johnson & J. Lathrop, Ten years of ozonesonde measurements at the south pole: Implications for the recovery of springtime Antarctic ozone, *J. Geophys. Res. 102*, 8931-8943, 1997

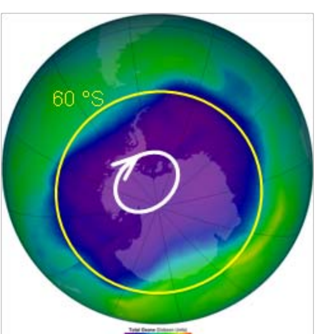
September Ozone Song

"Oh, it's a long, long while from May to December
Then ozone fades when you reach September"

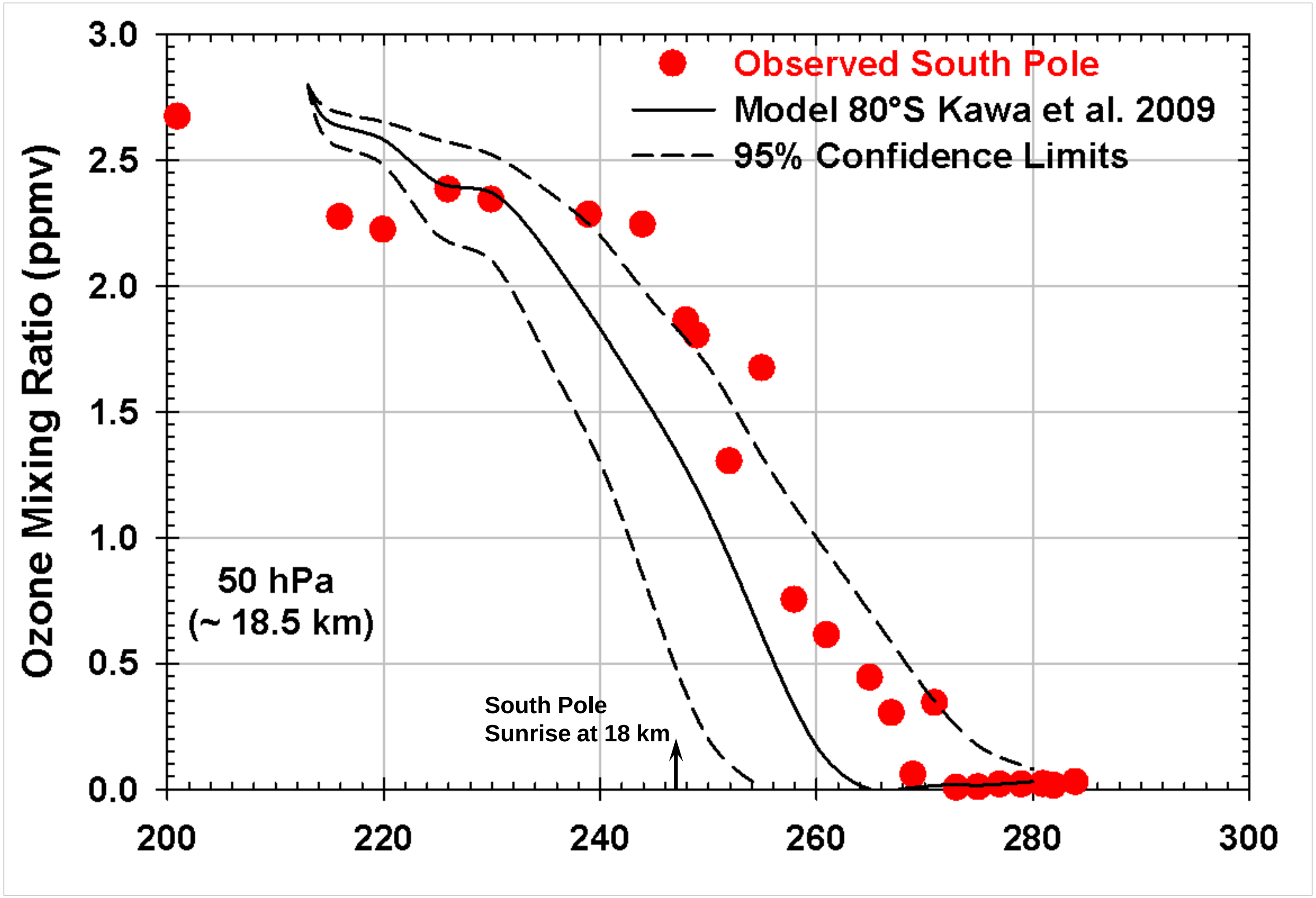


South Pole 10-day Back Trajectories at 18 km - 2006





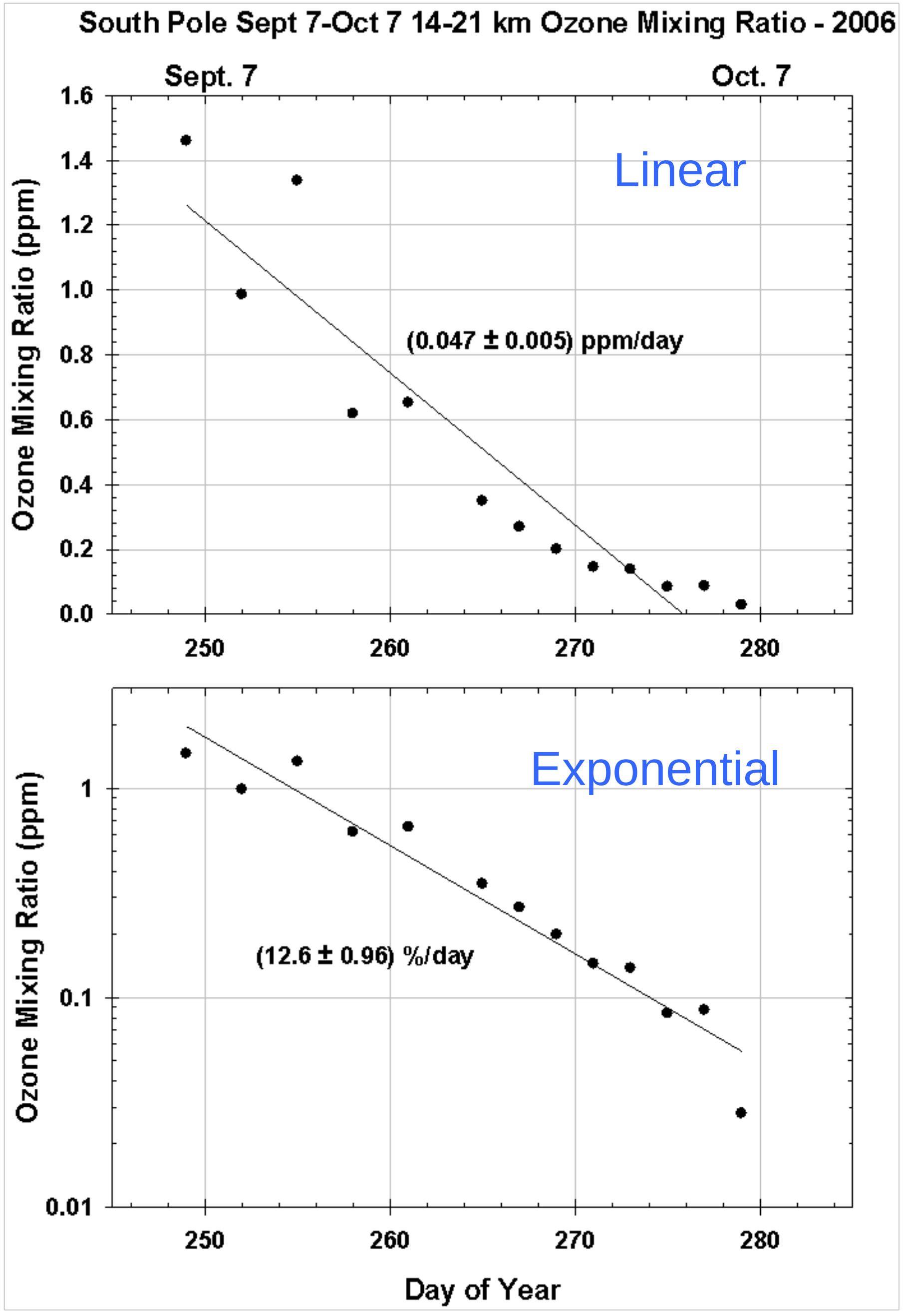
Springtime Antarctic Ozone vs Time – Observed and Predicted



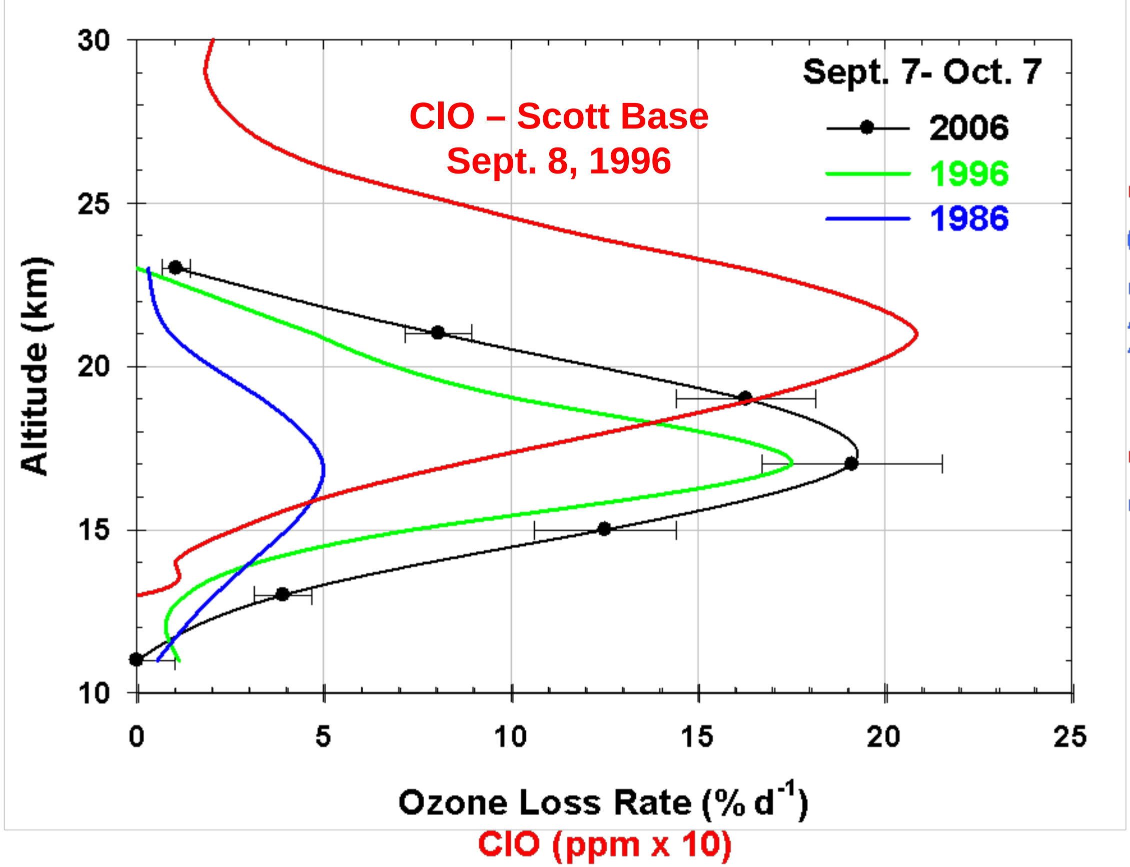
The observed ozone vs time during late August to early October in 2006 has been compared to a model which initiates the air parcel at 80°S and 50 hPa. The South Pole decline starts a bit later as expected but the rate of ozone decline agrees with the model which uses “standard” ozone hole chemistry.

Ozone Loss During Formation of the 2006 Ozone Hole

In the past it has been customary to use a linear (DU/day or ppm/hr) expression for the ozone loss rate. An exponential (%/day) generally fits the data better over a longer time range and will be used in this work.



South Pole Ozone Loss Rate Profiles



$ClO + ClO + M \longrightarrow ClOOCl + M$

$ClOOCl + h\nu \longrightarrow Cl + ClOO$

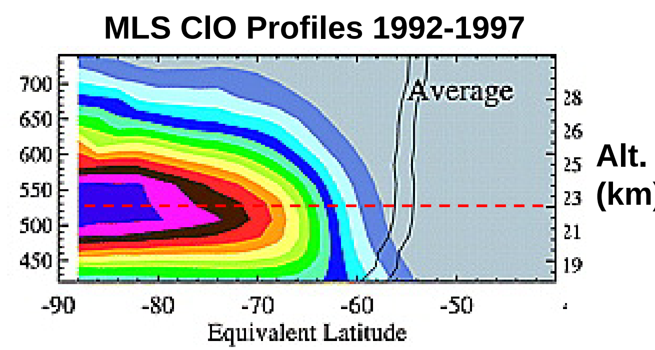
$ClOO + M \longrightarrow Cl + O_2 + M$

$2 \times (Cl + O_3 \longrightarrow ClO + O_2)$

$ClO + BrO \longrightarrow Cl + Br + O_2$

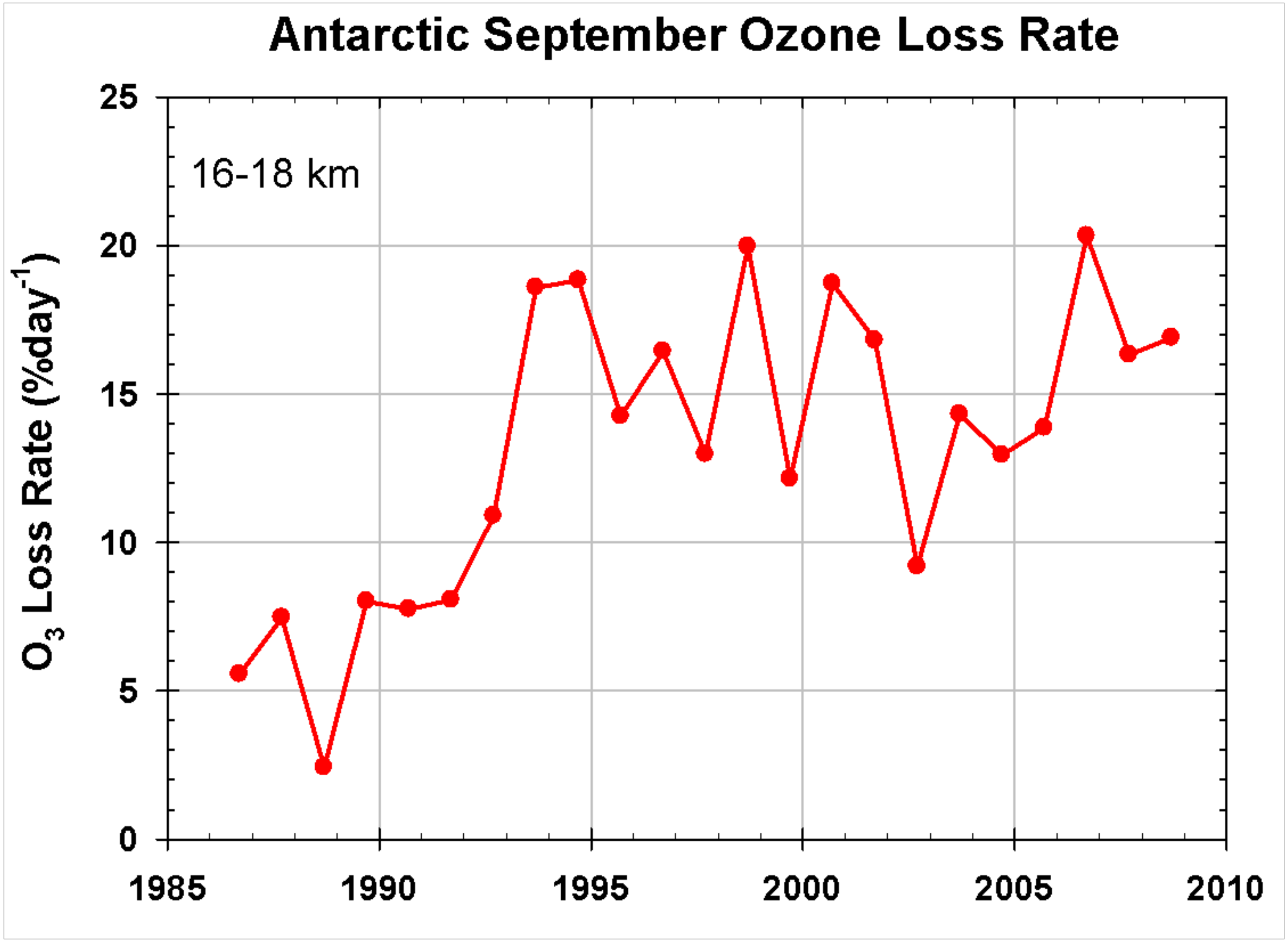
$Cl + O_3 \longrightarrow ClO + O_2$

$Br + O_3 \longrightarrow BrO + O_2$



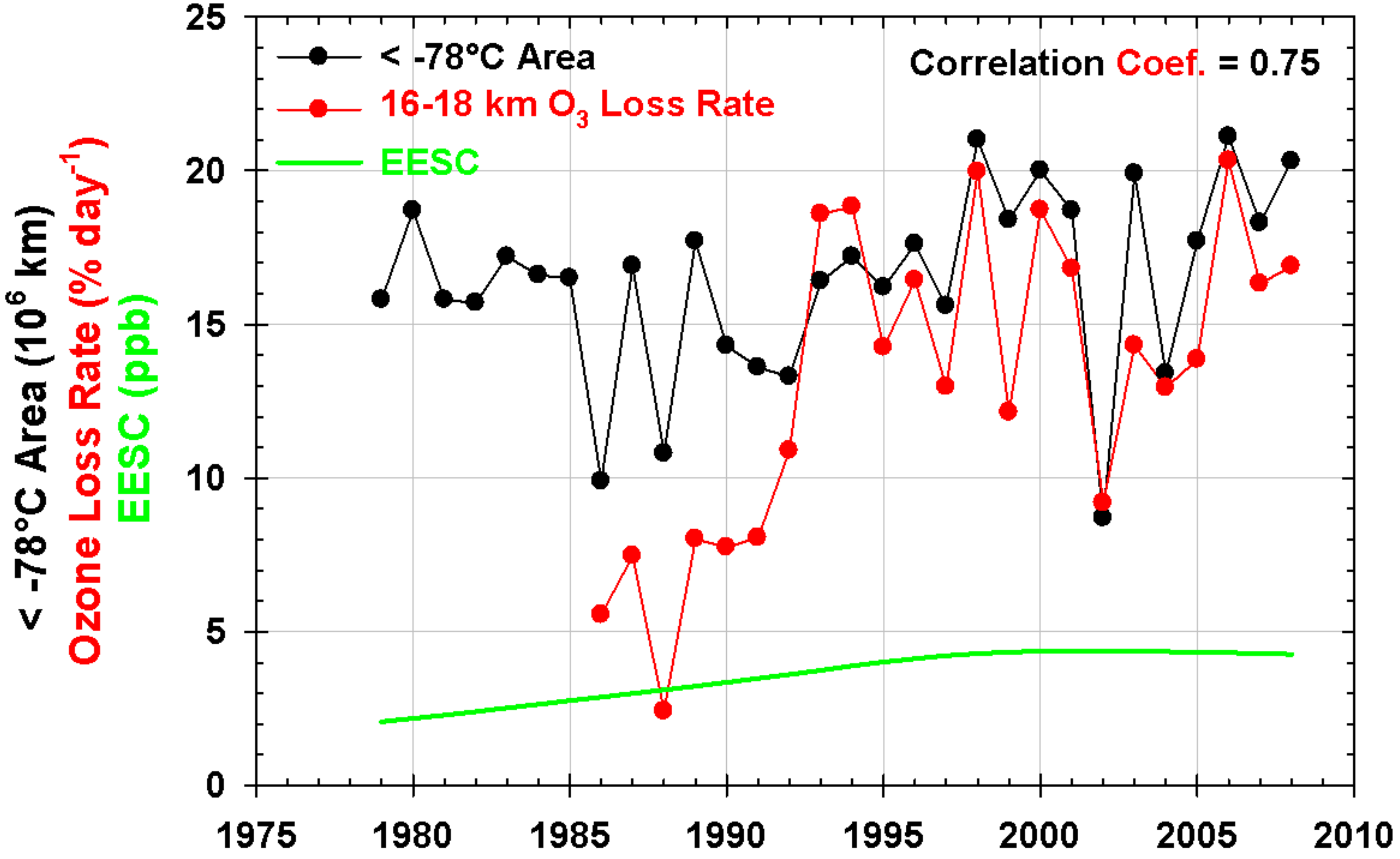
The ClO distribution is 5 km higher than the ozone loss rate peak

P. Solomon, et al., *J. Geophys. Res.*, *105*, 28,979 (2000)



Antarctic September Ozone Loss Rate
16-18 km
O3 Loss Rate (%day-1)
25
20
15
10
5
0
1985
1990
1995
2000
2005
2010

Ozone Loss Rate Determining Factors



Polar Stratospheric Cloud area correlates with ozone loss rate (Corr. Coef. = 0.75). But **EESC** (from Newman et al, 2006) is also a factor.

Calculations

Observed during September ozone loss period:

- Ozone exponential decay: $O_3 = O_o e^{-kt}$
- Ozone Loss Rate: $dO_3/dt = -kO_oCe^{-kt} = -kO_3$,

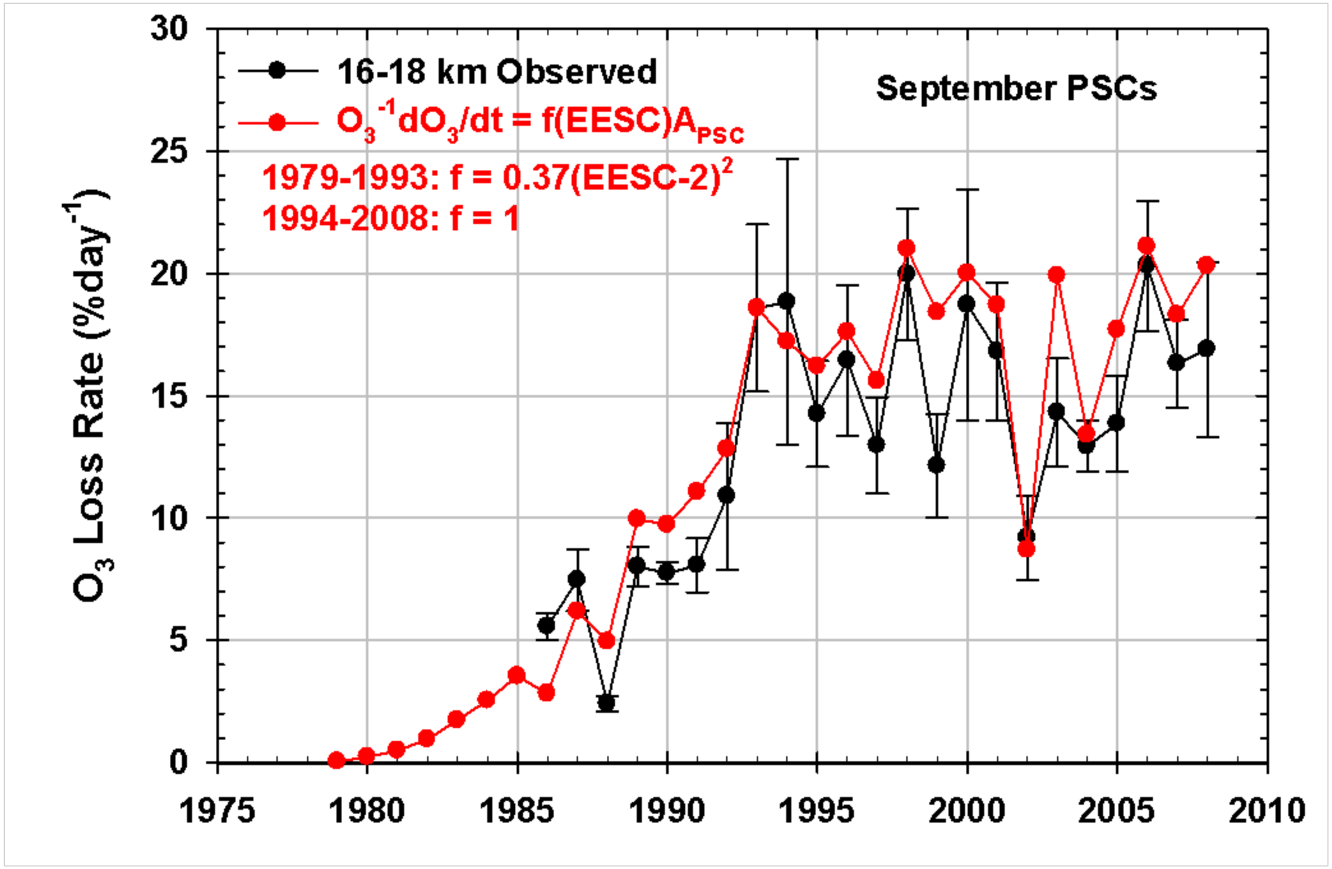
Expressed in fractional or % ozone loss per unit time:

- $O_3^{-1}dO_3/dt = -k$, the rate parameter k depends on EESC and temperature.

Assume that gross temperature effects can be described by the observed area of Polar Stratospheric Clouds (A_{PSC}), that k is proportional to A_{PSC}, and is quadratic in EESC, due to ClO+ClO and ClO+BrO reactions, with a threshold of 2 ppb EESC (~1980). Then we can parameterize the % ozone loss rate as:

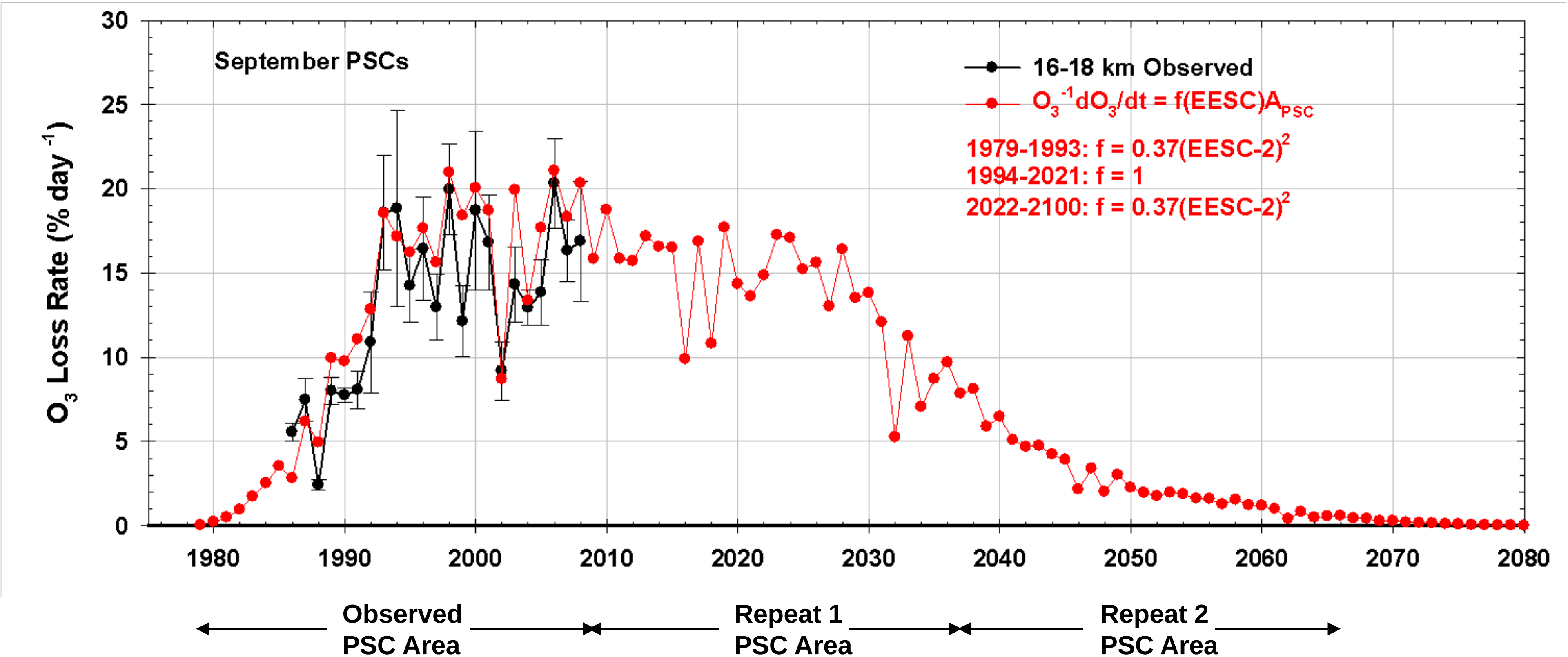
$$\mathbf{k(EESC, T) \sim A_{PSC}(EESC - 2)^2}$$

Comparing Observations of Ozone Loss Rate and a Parametric Model



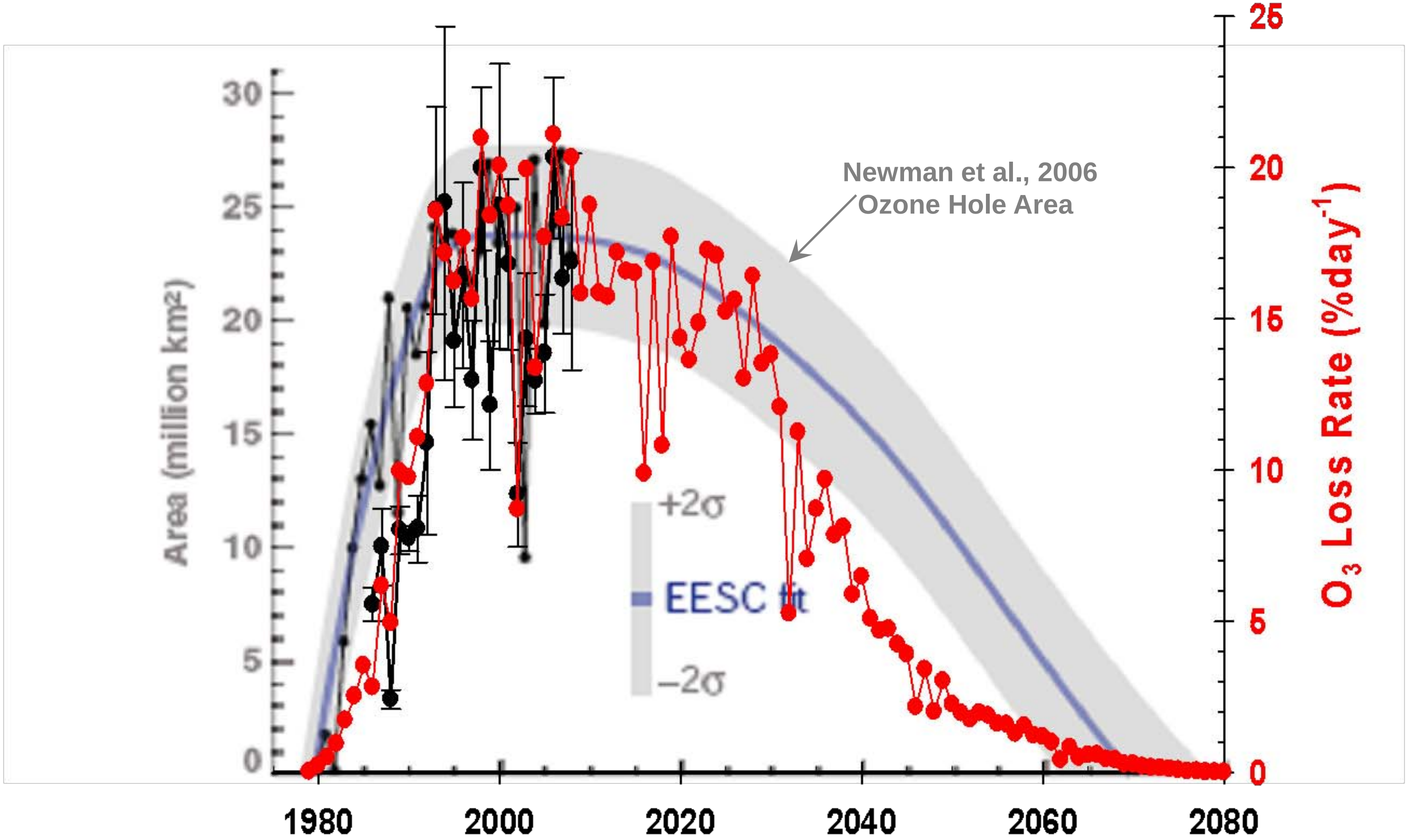
A simple parameterized model describes the 16 -18 km ozone loss rate surprisingly well if we assume that ozone loss rate saturates at EESC = 3.75 ppb in 1993.

Extending the Parametric Model to 2080



We can look at the ozone hole recovery phase by assuming that PSC variability will continue (repeat two 30 year cycles as observed from 1979-2008 to represent variability magnitude) and use EESC from WMO Scenario Ab (Newman et al., 2006). We propose that EESC will not come out of saturation until about 2022 and that the beginning of recovery in ozone loss rate in the heart of the ozone hole will not be observable until about 2032-35 with complete recovery not until about 2065-70. The main reason for the longer time to recover is the new EESC scenario extends recovery ~ 12-15 years later than the 1996 estimate.

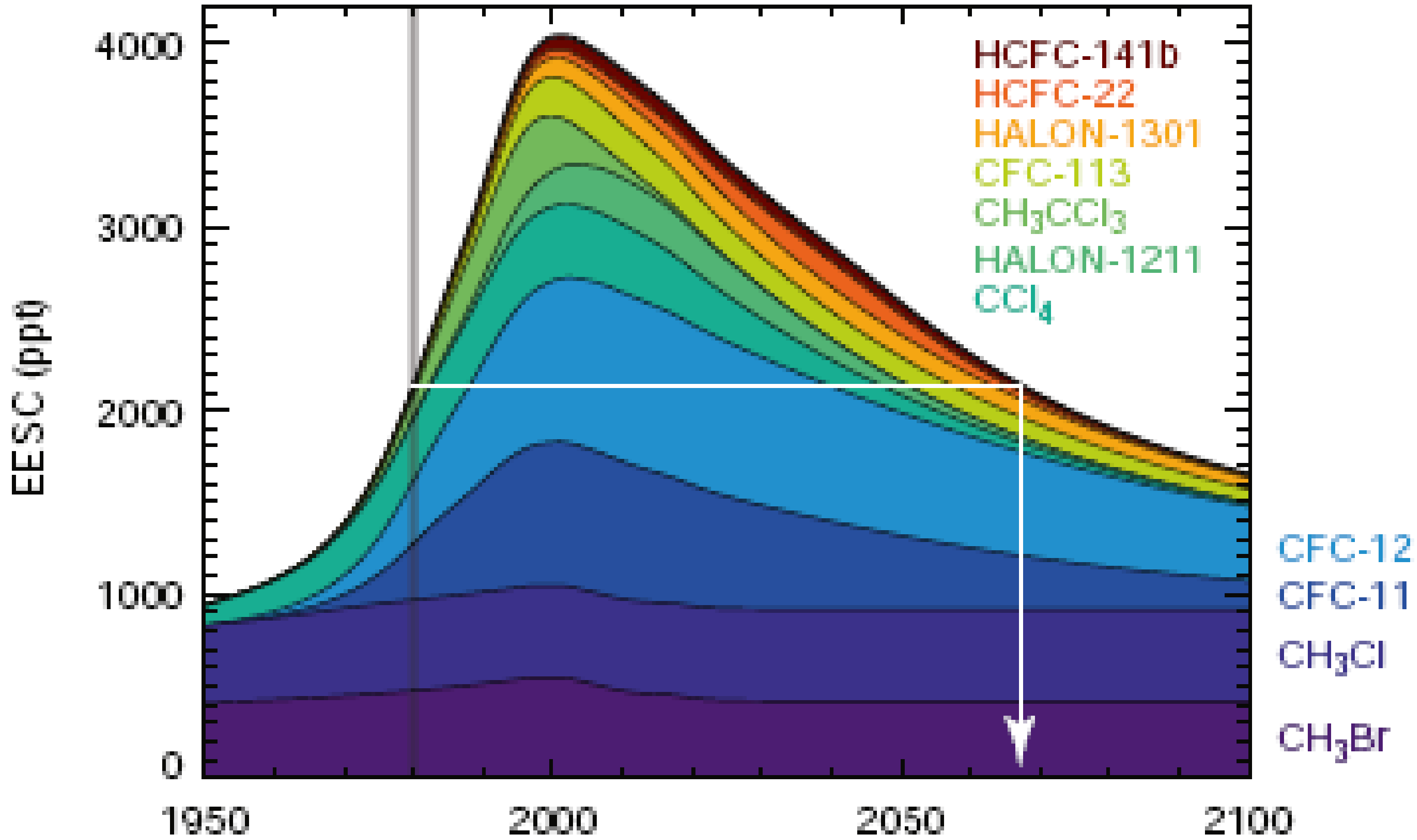
Comparing with Antarctic Ozone Hole Area Recovery



These results are very similar to those of Newman et al., 2006 for recovery of the ozone hole area (< 220 DU), since the same EESC scenario is used. As expected the South Pole time distribution is narrower.

Newman et al., Geophys. Res. Lett., 33, L12814, 2006

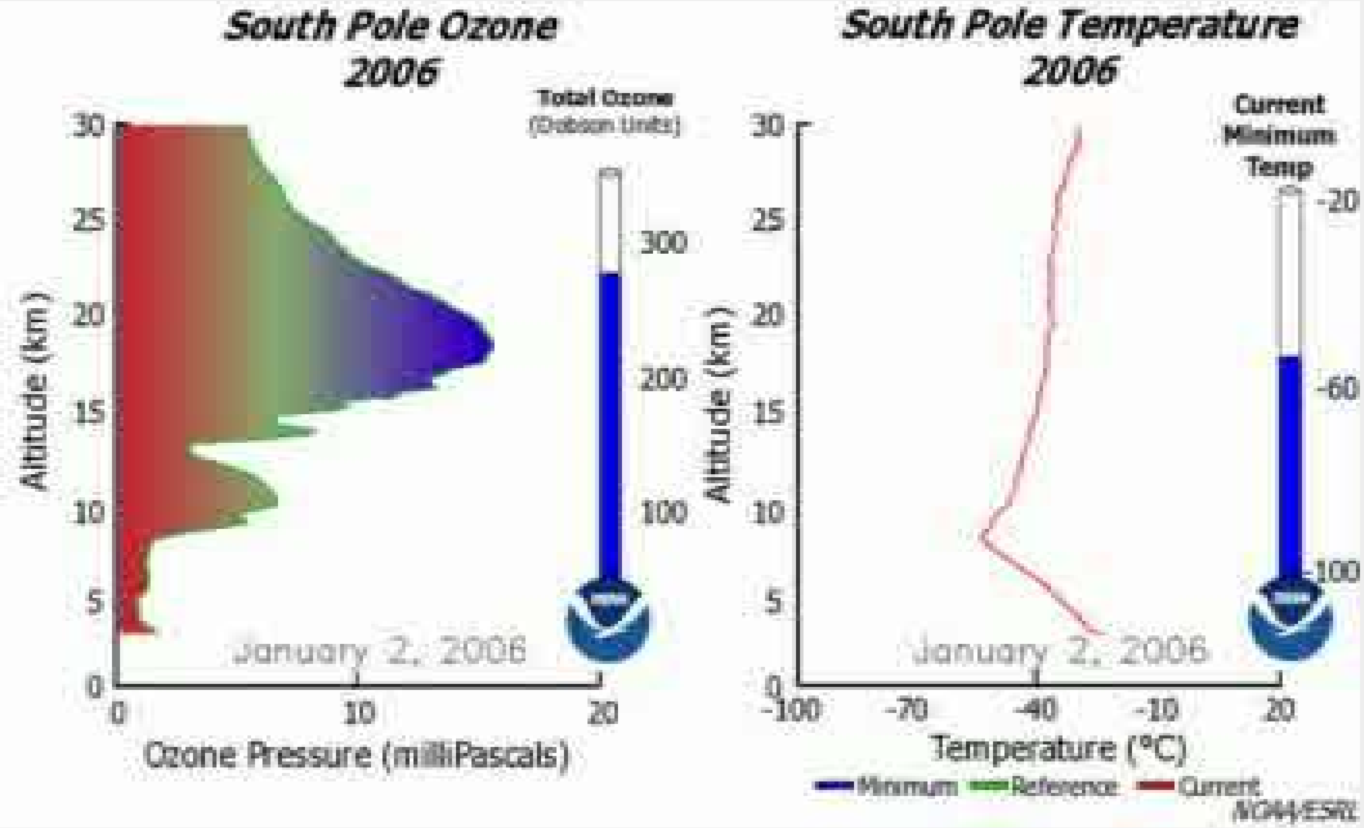
The Largest Uncertainty - EESC



From Newman et al., in press, 2009

Summary

- September ozone loss rates in the heart of the ozone hole at South Pole have varied substantially over the 1986-2008 period but can be adequately described by known chemical loss processes; however, the maximum in the ozone loss rate appears to occur about 5 km below the maximum in the ClO distribution.
- As of 2008, there is no sign of the beginning of ozone hole recovery at South Pole.
- The estimated first detection of this milestone from South Pole ozone loss rates will probably not be until about 2030.
- Full recovery is not expected before about 2065, similar to recovery of the ozone hole area.



"Oh, the days dwindle down to a precious few September, November……but you can always count on new ozone in December"