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Whole Atmosphere Community Climate Model: Climate Change Impacts on Circulation and Ozone Recovery

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NCAR, CCWG, 27 February 2007

National Center for Atmospheric Research

Presentation Outline

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- Climate change influences on Stratospheric Circulation…
- Climate change influences on 21st century ozone recovery…
- Should climate models include a more detailed representation of stratospheric chemistry?

WACCM3 Simulations consistent with SPARC/WMO2006

- Eyring, V, D. Kinnison, T. Shepherd, SPARC Newsletter, 11-17, #25, July 2005.
  - Consistent with WMO 2006 Assessment Activities.
- Simulations

Forcings	REF1 (historical)	REF2 (Recovery)	NCC (no clim change)
Period	1950-2003	1980-2050	1995-2050
SST's	Observed	CCSM IPCC simulations	CCSM IPCC simulations
CFC's, HCFCs	Observed	WMO 2003	WMO 2003
CH_4, CO_2, NO	Observed	A1b (medium)	Fixed at 2000
Sulfate Aerosol	SAGEI, II: SAMS Includes Volc.	Volcanically Clean	Volcanically Clean
Solar Variability	11-solar; F10.7; wavelength dep.	Solar Cycle Average	Solar Cycle Average

CO_2, CH_4, N_2O LBC Change

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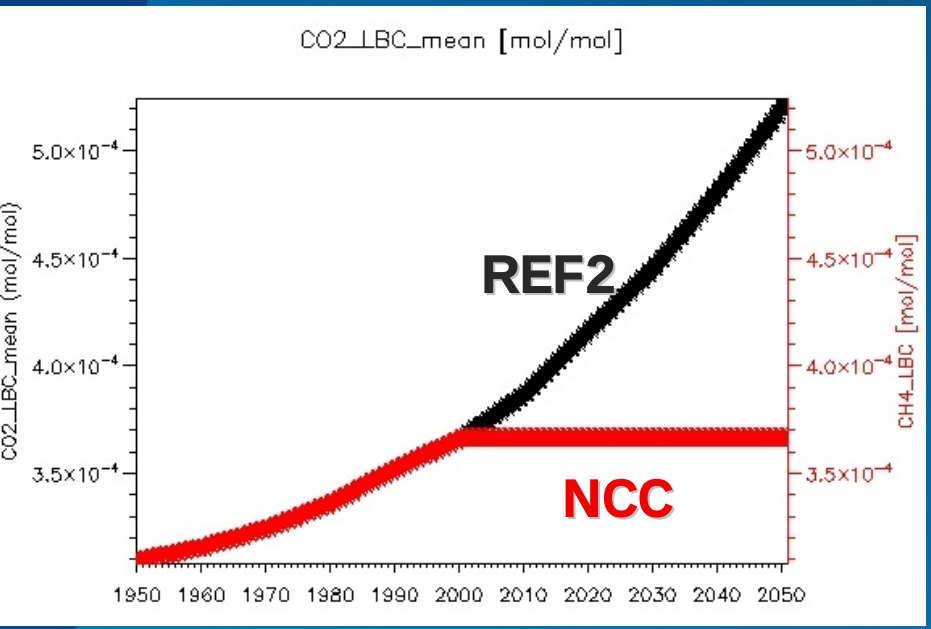

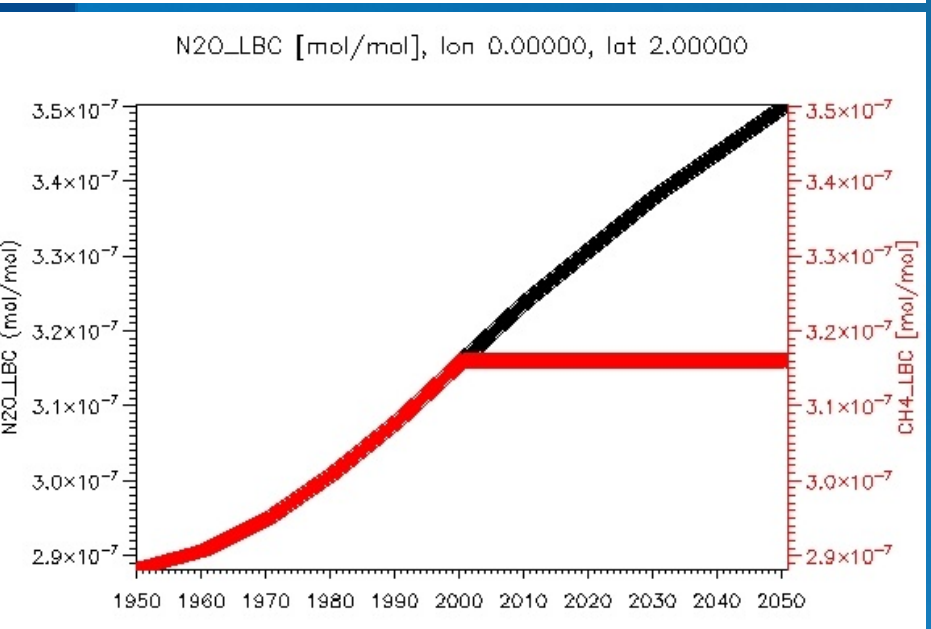

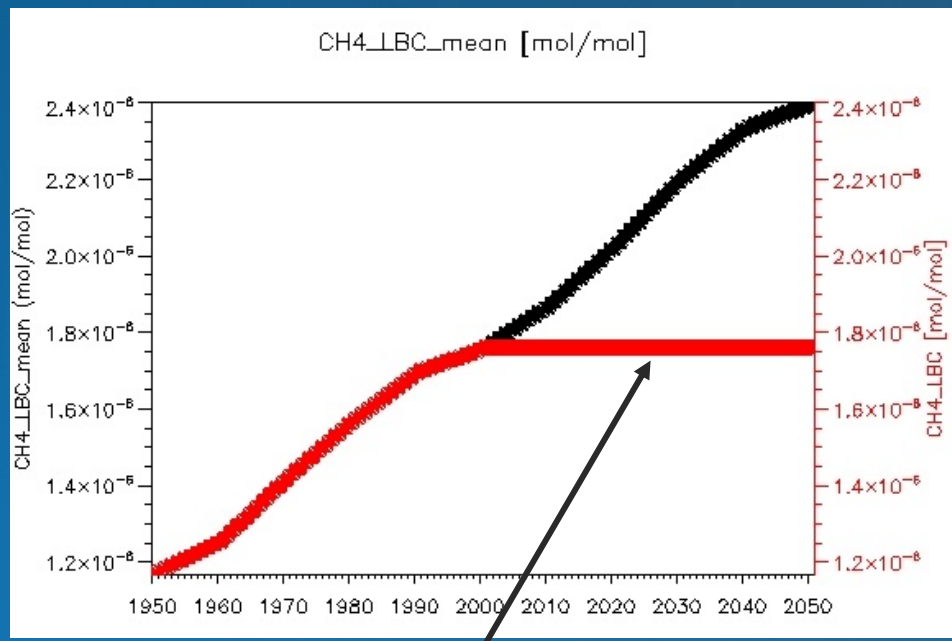

ΔH2O = 2*CH4 = 2*.65 = 1.3ppmv

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How does climate change impact the mean stratospheric circulations?

Mean Age-of-Air (years)

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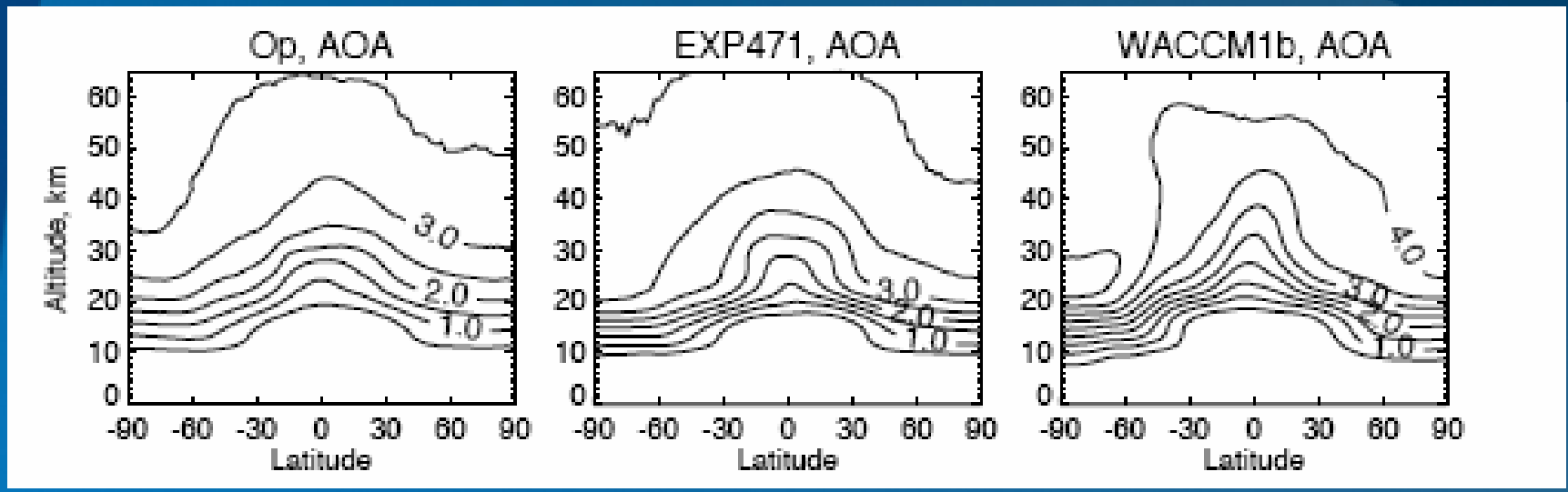
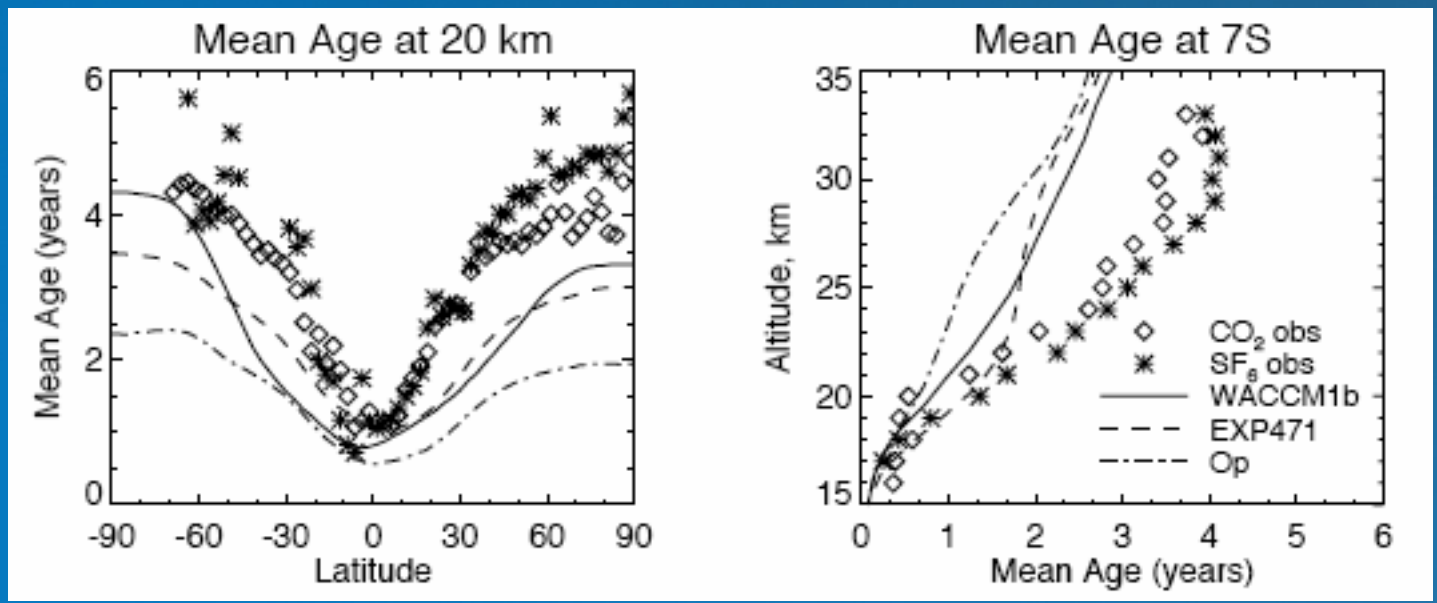
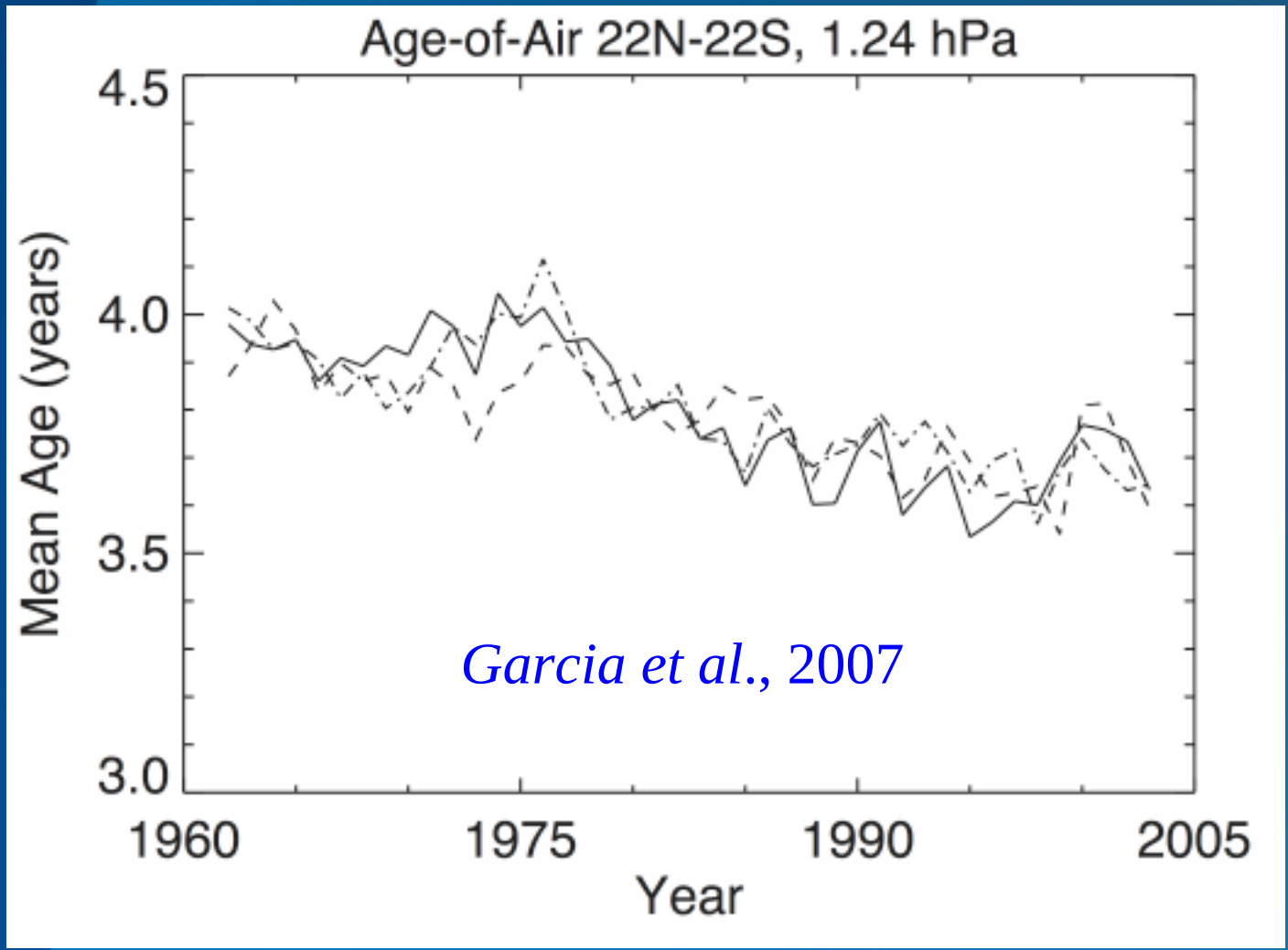




Historical Change in Mean Age-of-air

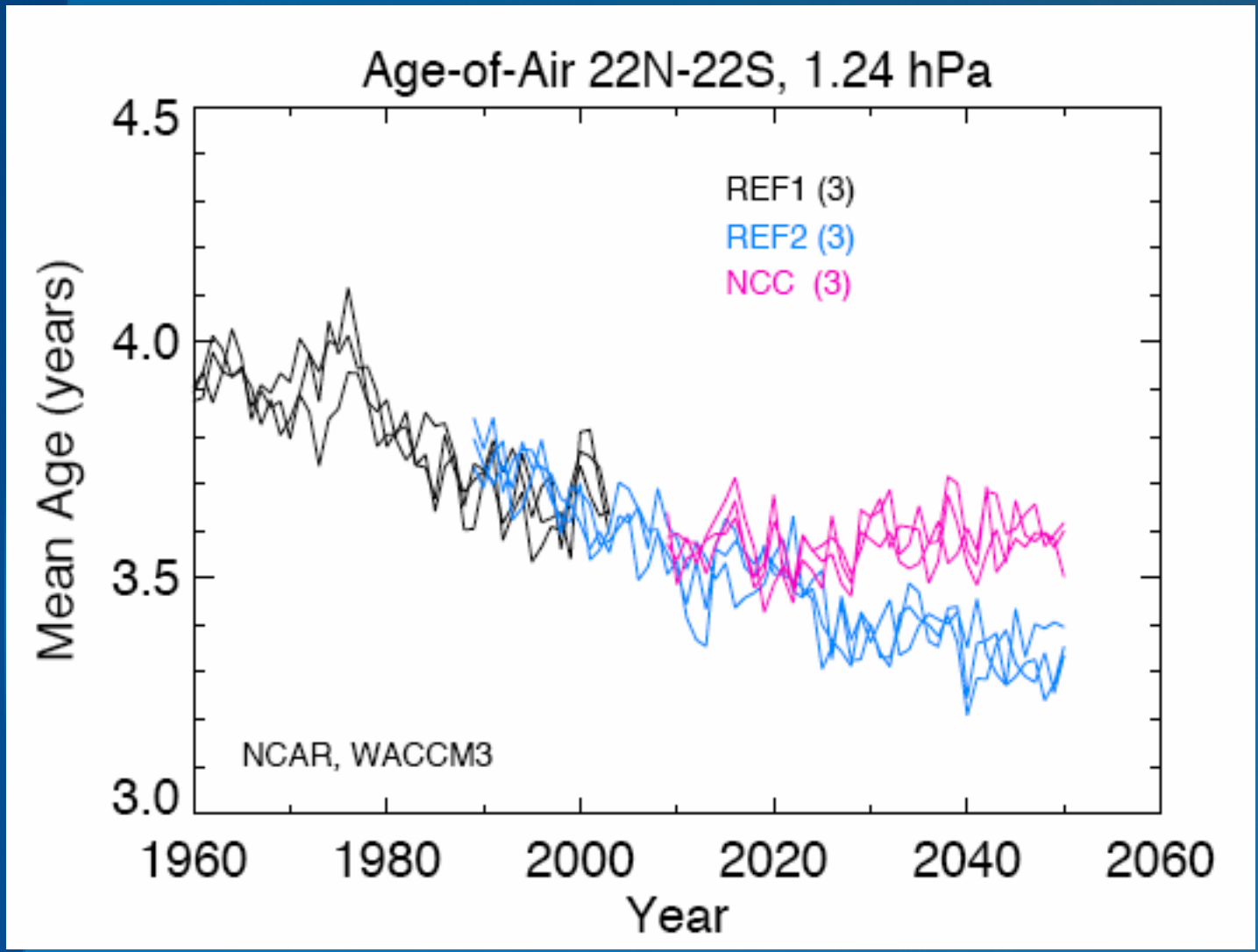


- *Garcia et al.* 2007 showed that the decrease in Mean AOA is consistent with an increase in the strength of the tropical upwelling.
- The mechanism for this change in the mean circulation has not been isolated.

Decrease of mean age of about 4-months over 40 years.

Also discussed in *Austin and Li* [2006].

Mean AOA Change with/without GHGs



- *Dameris et al.* 2007 including this figure in a soon to be submitted article.
- This clearly shows that without climate change, the mean AOA is constant!

WMO Assessment, 2007; Chemistry / Climate Chapter.

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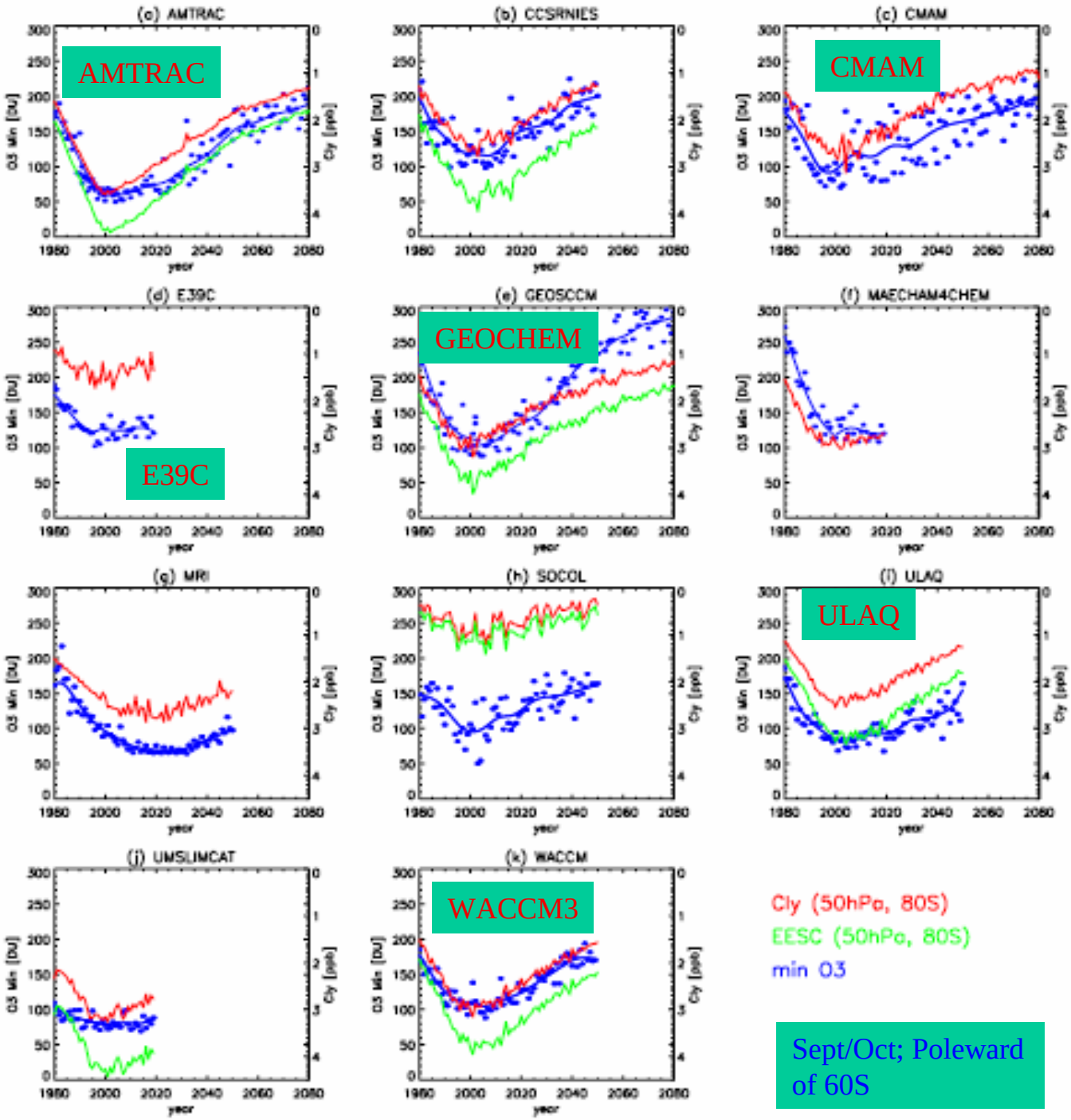
How does climate change impact the ozone recovery?



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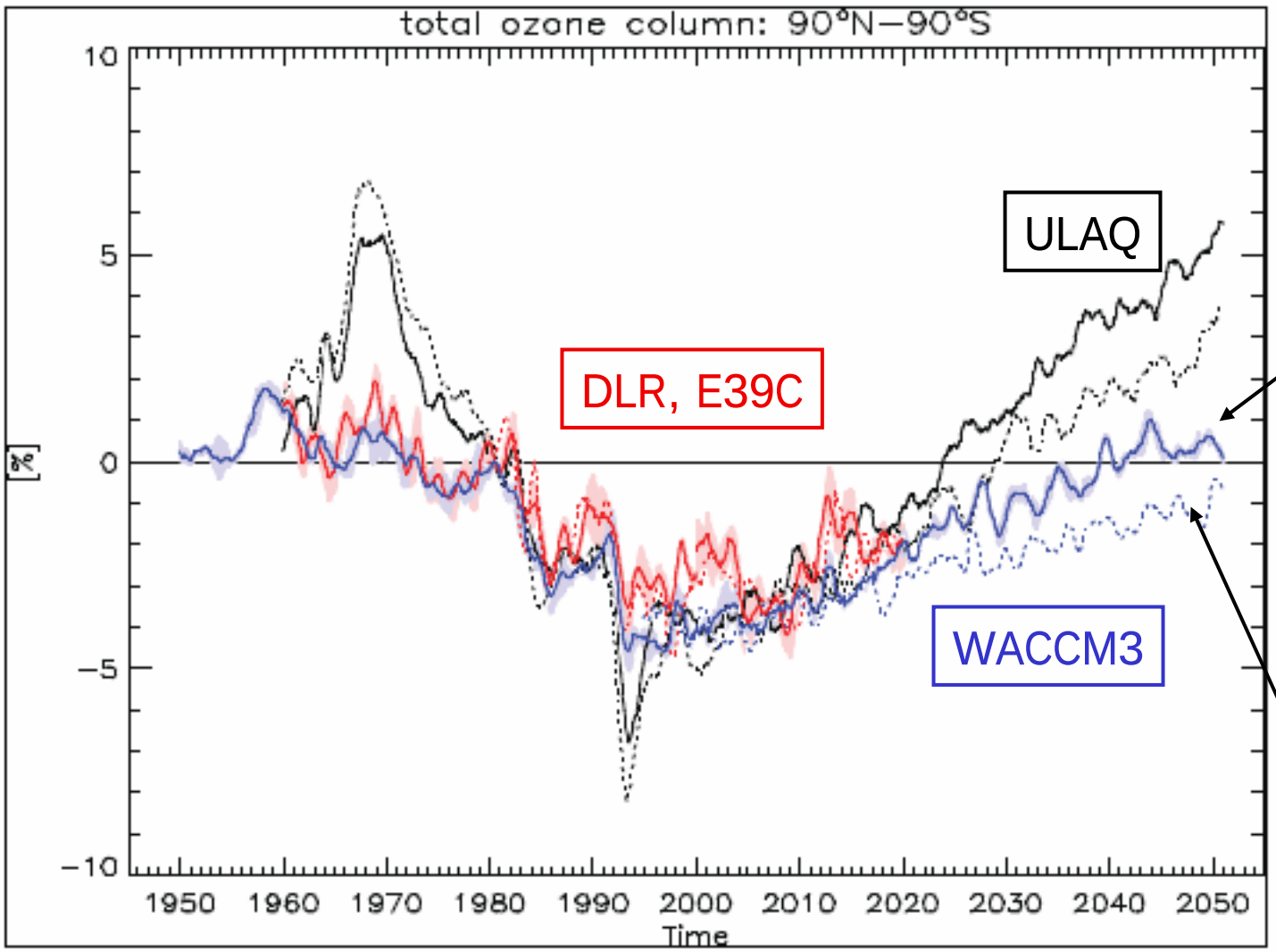
- Eyring et al., 2007…
- Current CCM's have large variation in recovery period (to 1980).
- There is a high correlation to models that have higher Cl_Y (older mean age) and longer recover, e.g., AMTRAC

Ozone Recovery; Global; 3 CCMs



With Climate Change.

No Climate change: N_2O, CH_4, CO_2 fixed at 2000 lbc.

Dameris, Garcia, Kinnison, Pitari, Deckert, Mancini and Matthes, 2007

WACCM3 *** Ozone Loss Rates

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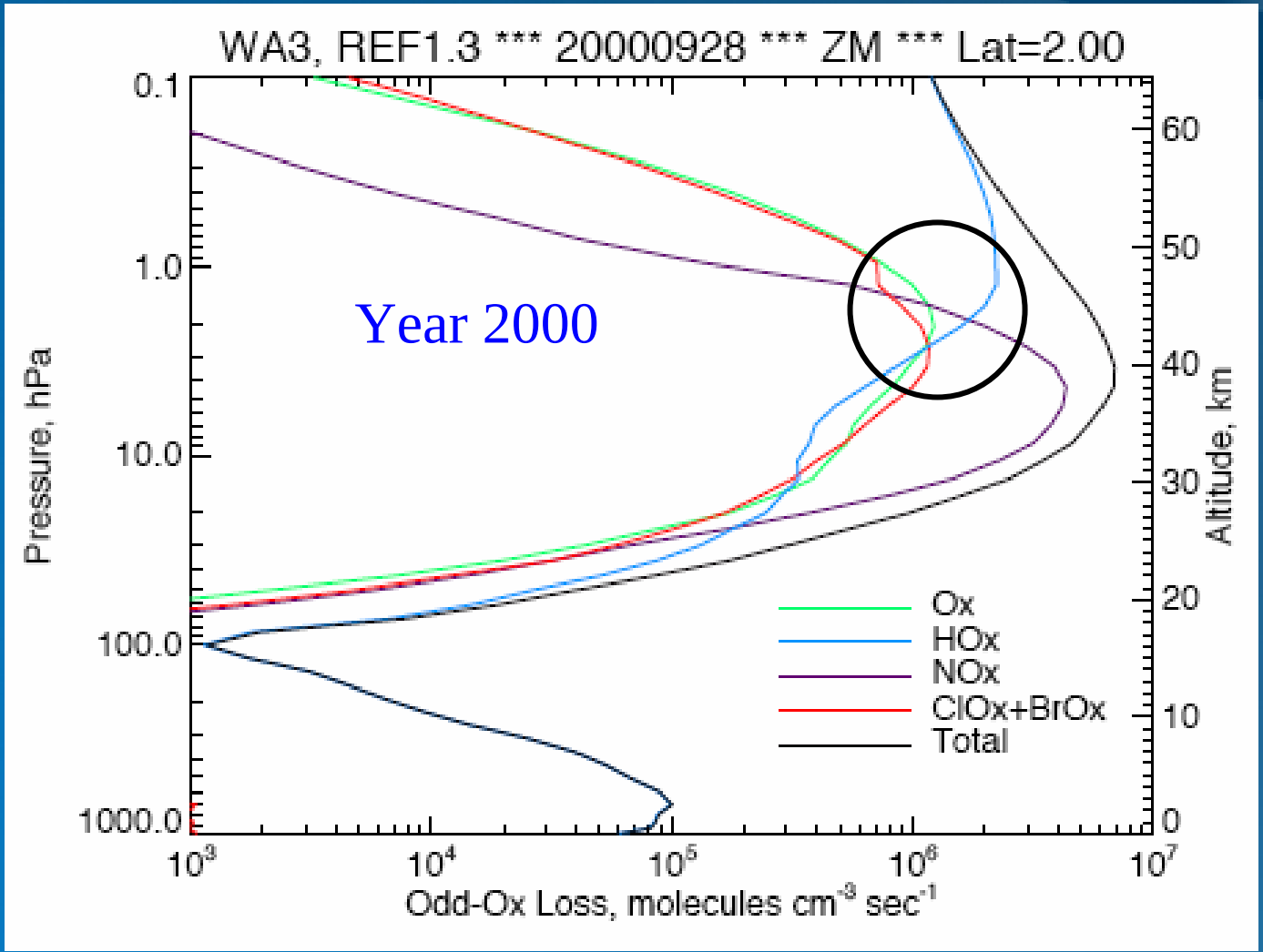

Ox:
$O + O_3 = 2O_2$

HOx:
$HO_2 + O = OH + O_2$

NOx:
$NO_2 + O = NO + O_2$

ClOx:
$ClO + O = Cl + O_2$

T *** WACCM3 *** 2045, Annual average

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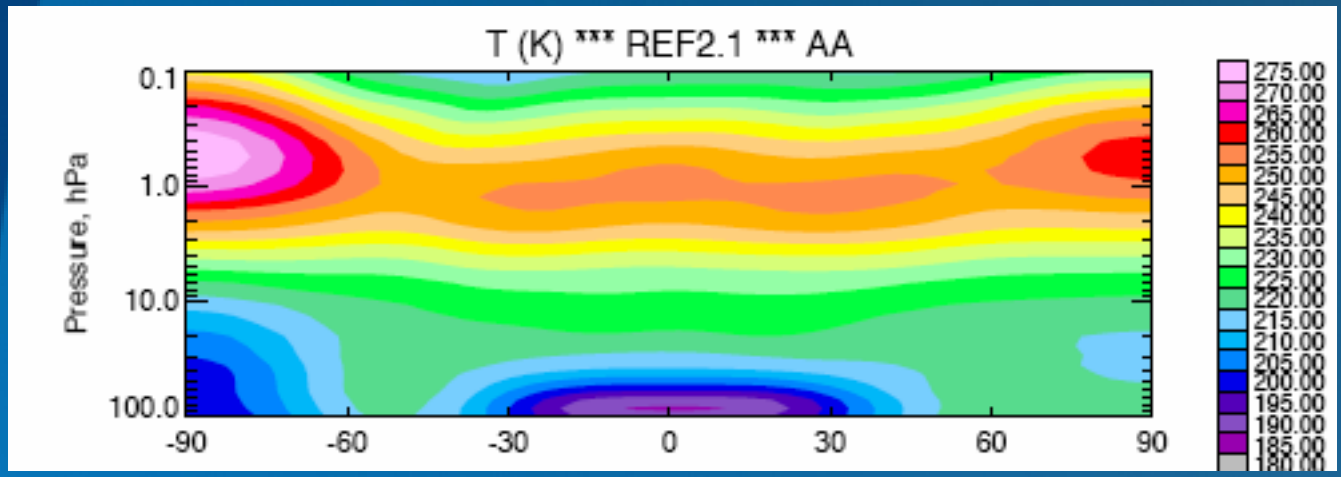
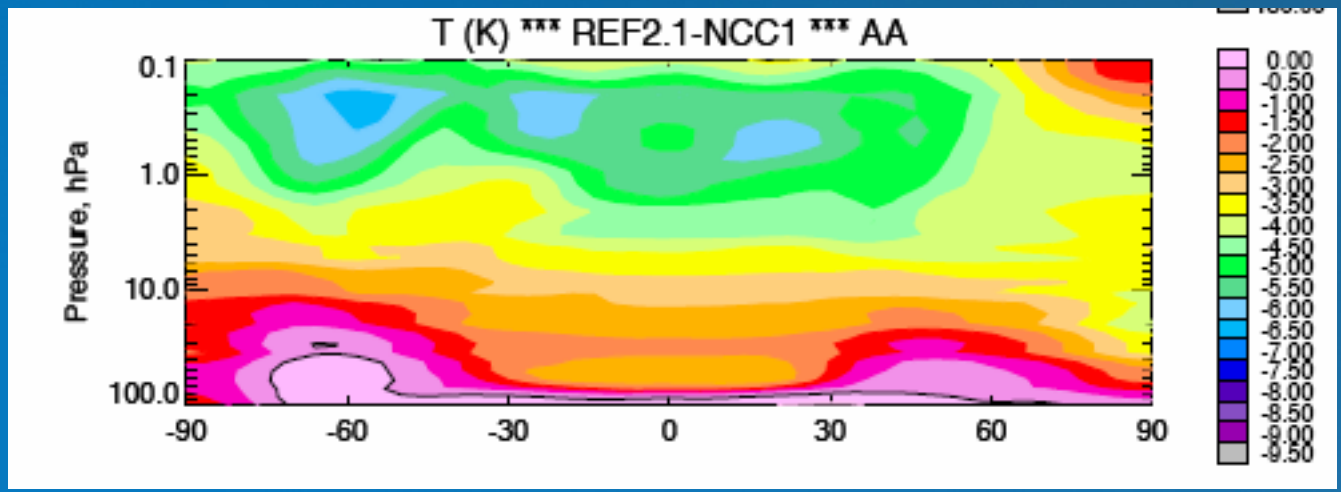


With Climate Change.



Climate Change minus NCC

O_3 *** WACCM3 *** 2045, Annual average

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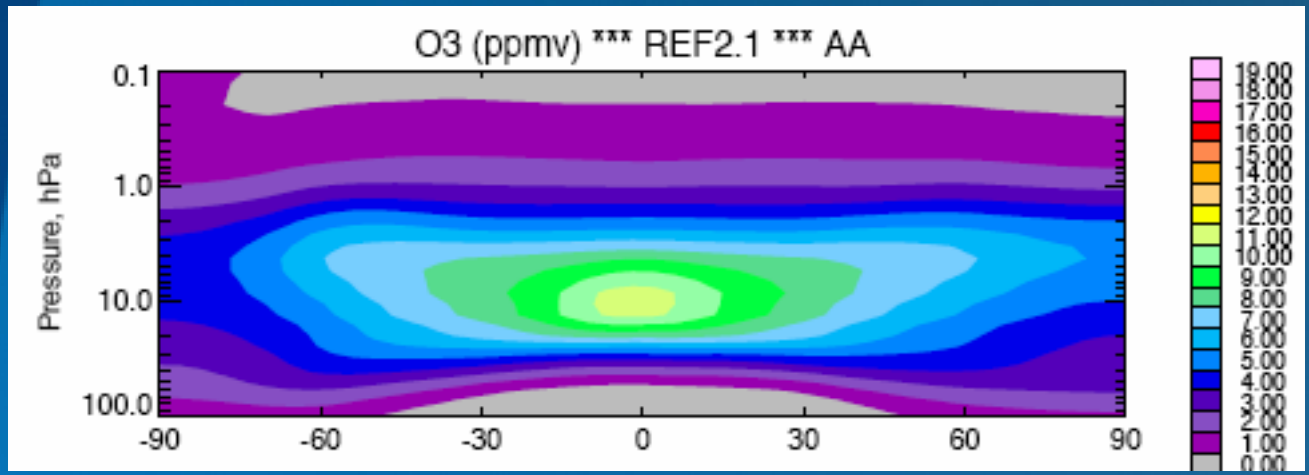
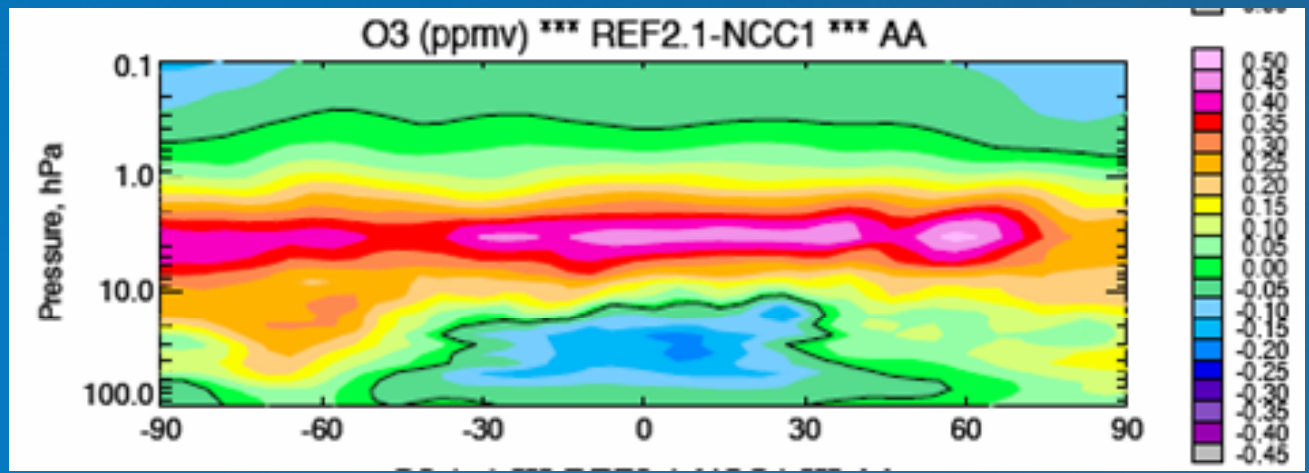
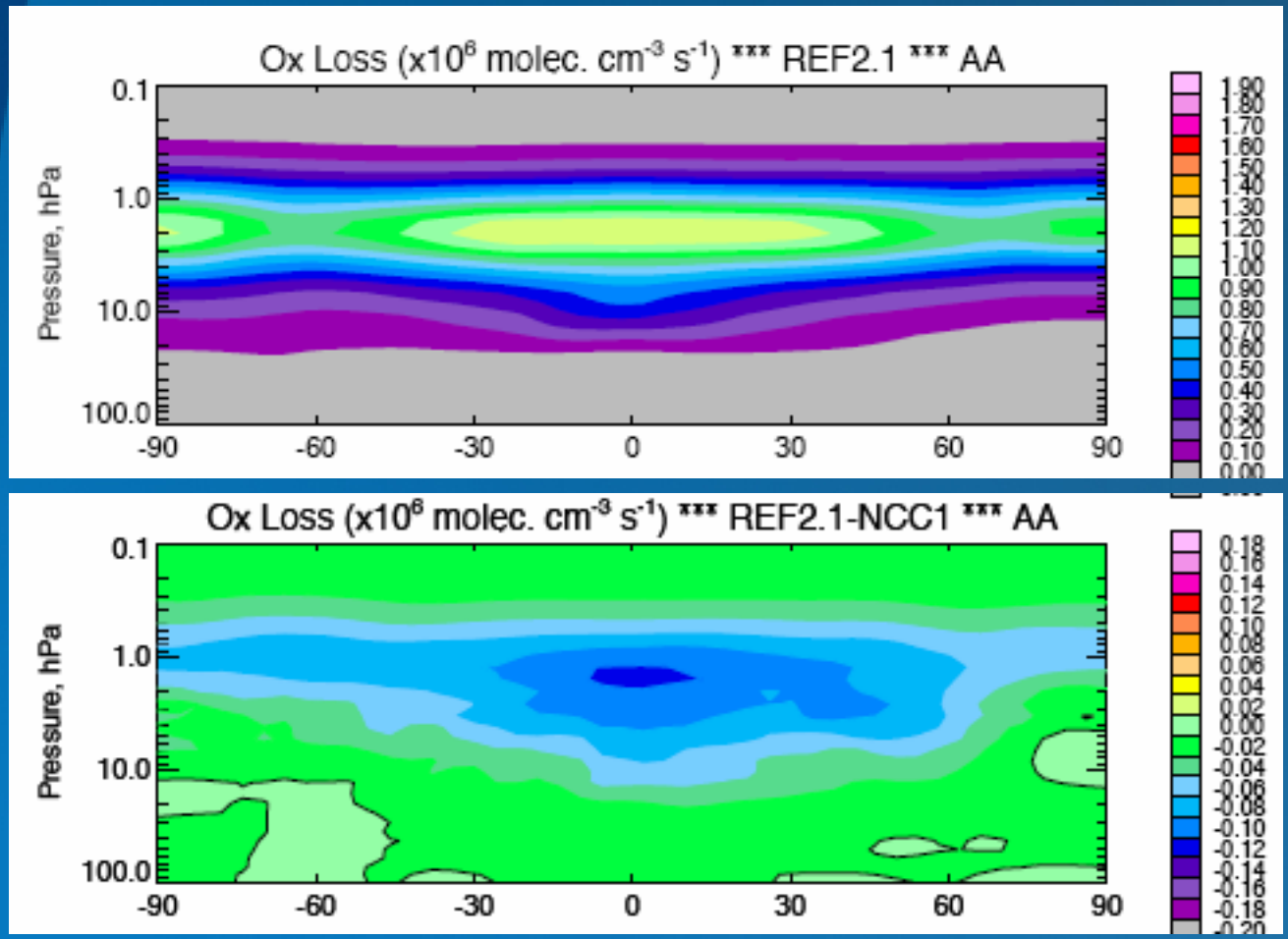


With Climate Change.



Climate Change minus NCC

Ox Loss *** WACCM3 *** 2045, Annual average



With Climate Change.

Climate Change minus NCC

Summary: Why a Super Recovery?

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- Temperature Dependence of: $O + O_3 => 2O_2$
  - Changes the rate of Ox loss: K ~ exp(-2060/T)
  - -5K slows loss reaction by 15%; O_3 increases!
- Temperature Dependence of: $O + O_2 + M => O_3 + M$
  - Changes the O/Ox partitioning; K ~ $[300/T]^{2.3}$
    - less O impacts NOx, HOx, ClOx catalytic cycles.
  - -5K; decreases the O/O_3 ratio by 5%.
- Indirect effect on NOy
  - $N + O_2 => NO + O$: K ~ exp(-2060/T)
  - N increases with cooling; $N+NO => N_2 + O$
  - Less NOy, more O_3.

Ref: Rosenfield et al., JGR, 2002

What's Next with CCMs?

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SPARC Report on Evaluation of Chemistry Climate Models, Summer 2009

- Process Evaluation
  - Transport
  - Dynamics
  - UTLS
  - Radiation
  - Stratospheric chemistry and microphysics
- Chemistry-climate coupling
  - Natural variability
  - Long-term changes in stratosphere
  - Effect of stratosphere on troposphere

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The End