Sensitivity of Stratospheric and Tropospheric Chemistry to Perturbations of Methane, Carbon Dioxide, Nitrous Oxide, and Chlorofluorocarbons

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2D Model Run Boundary Conditions

CH_4 (ppmv)	N_2O (ppbv)	CO_2 (ppmv)	F11/F12 (ppmv)
1.2	280	280	0
1.8	360	420	0.3
2.4	440	560	0.6
3.0		700	0.9
3.6		840	

Ran all combinations of boundary conditions in table
→ 5 x 3 x 5 x 4 = 300 model runs

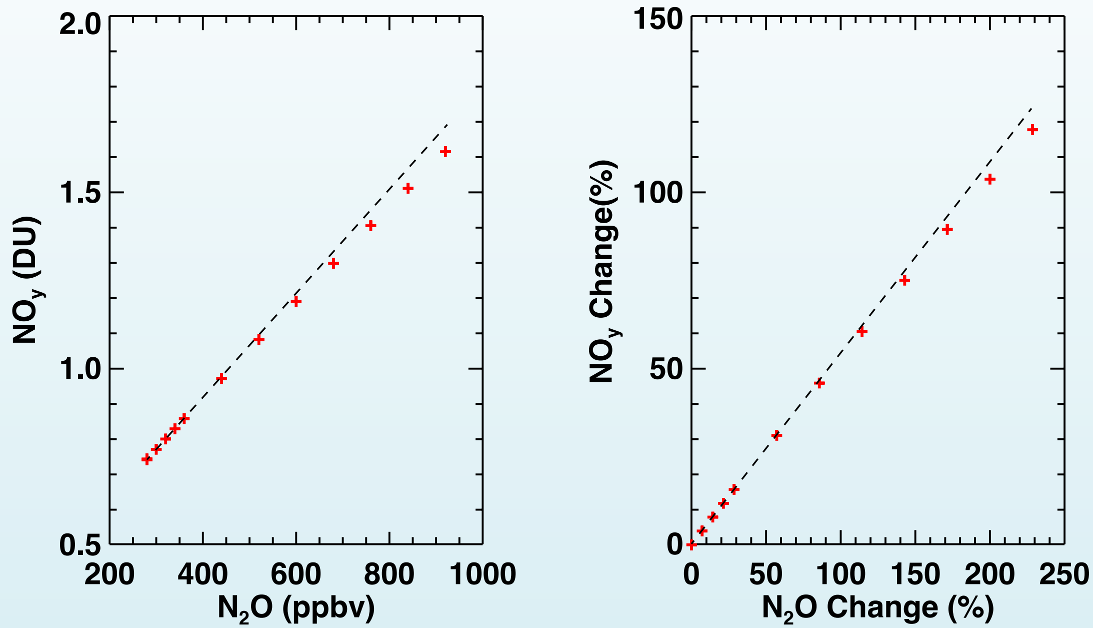
Each run was 30 years from the same initial condition to reach steady state. Only last year used.

+17 more runs to elucidate difference between F11, F12, and CH_3Br

Problem 1: Interaction of N_2O and CO_2

- N_2O is the source of NO_y that can catalytically destroy ozone
- CO_2 cools the stratosphere slowing the ozone loss processes
- CO_2 cooling increases the loss of stratospheric NO_y by favoring N + NO reaction over N + O_2

What controls NO_y in the stratosphere?



- N_2O is the primary source of NO_y ($N + NO + NO_2 + NO_3 + 2*N_2O_5 + HNO_3 + ClONO_2 + BrONO_2$)
- Doubling of N_2O leads to 50% increase in NO_y (NO_y chemical loss term proportional to $[NO_y]^2$)

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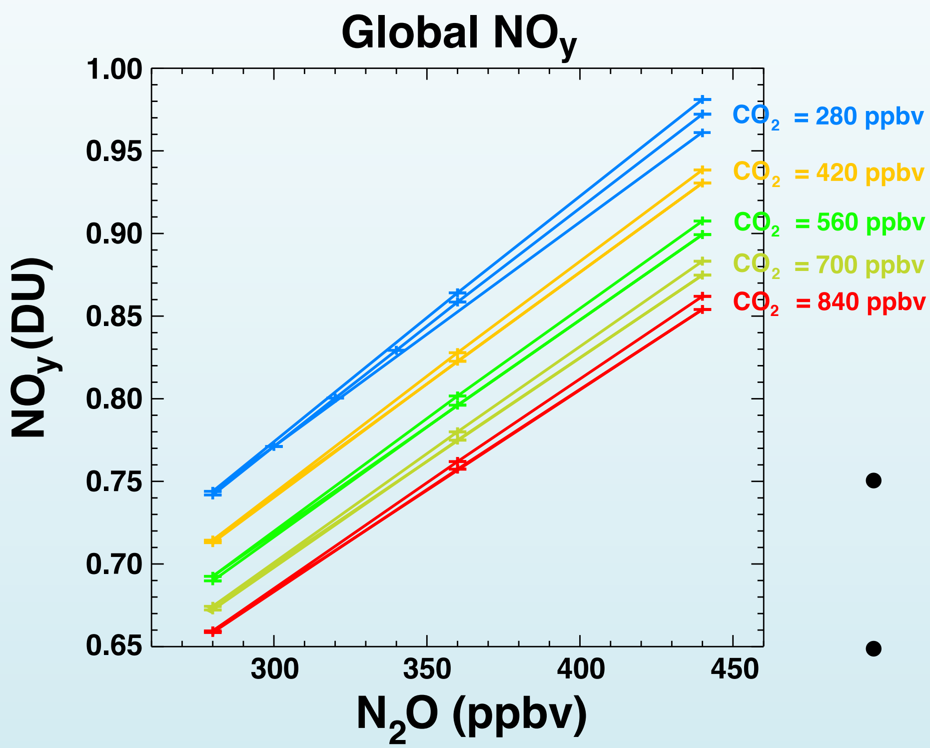
CO_2 also impacts NO_y in the stratosphere



- 3 x CO_2 → 10-15% decrease in NO_y
- Cooling of stratosphere changes balance of
  - $N + NO \rightarrow N_2 + O$
  - $N + O_2 \rightarrow NO + O$

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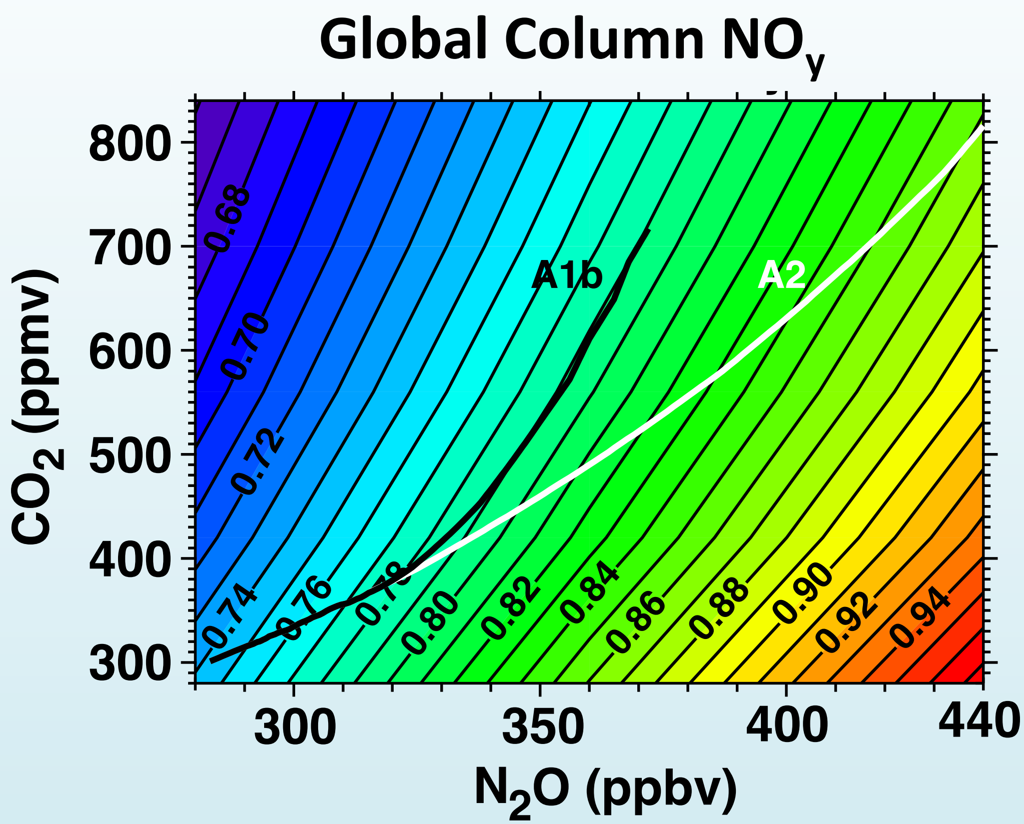
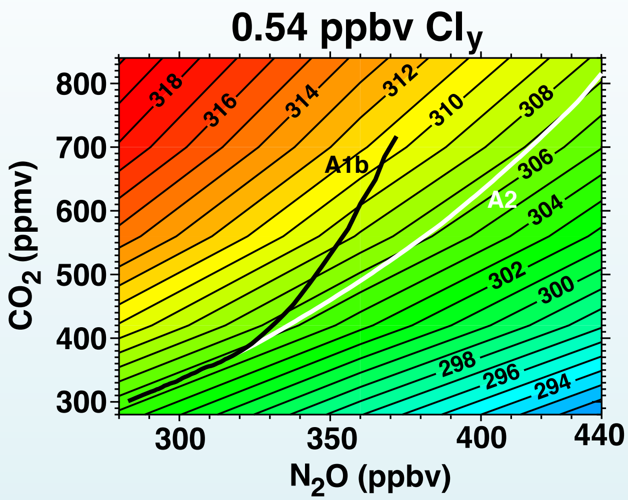
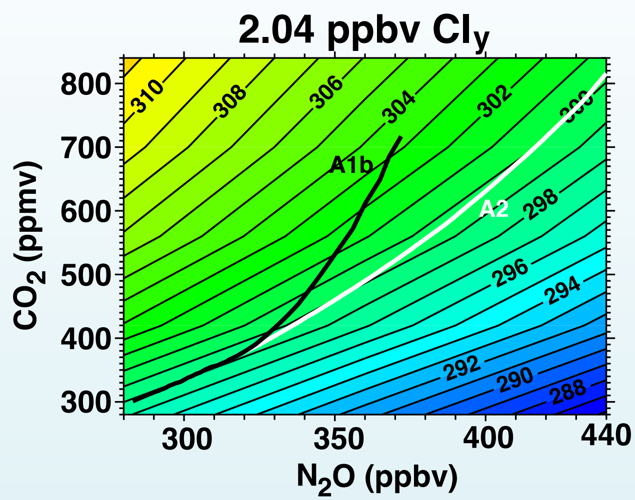
The evolution of stratospheric NO_y

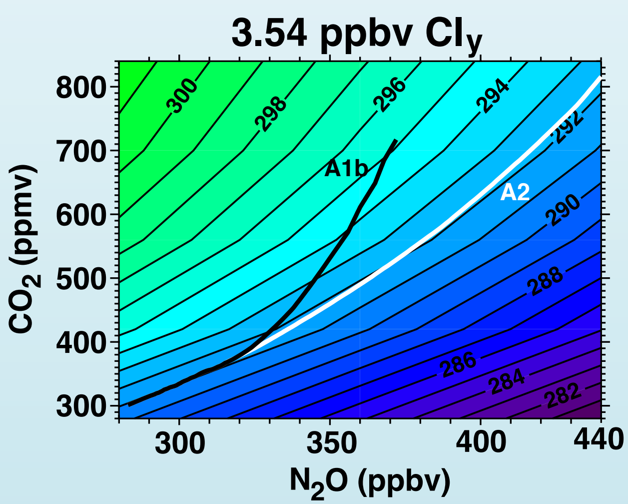


- Depends on the relative change of N_2O and CO_2 in the future
- A1b scenario leads to leads to constant future NO_y
- A2 scenario leads to increasing NO_y

Ozone Scenarios







- **Chlorine dominates ozone change**
- **Amount of global “super-recovery” depends on relative scenario for N_2O and CO_2 change**

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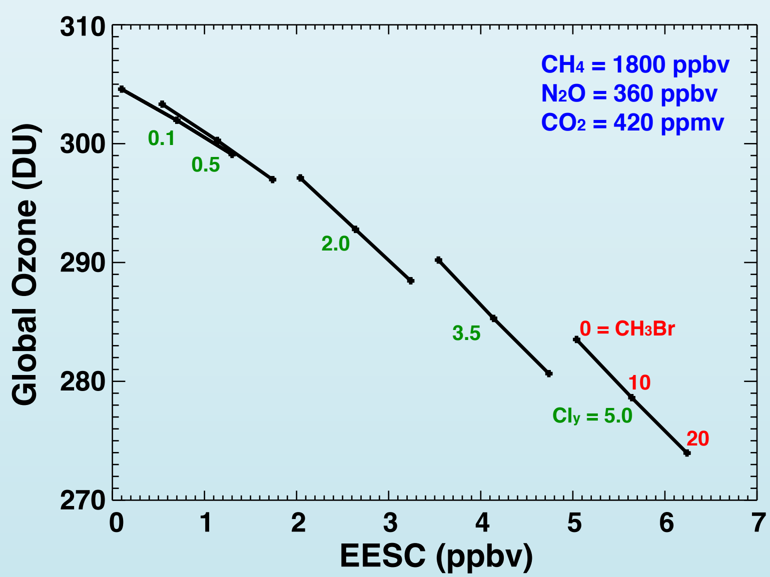
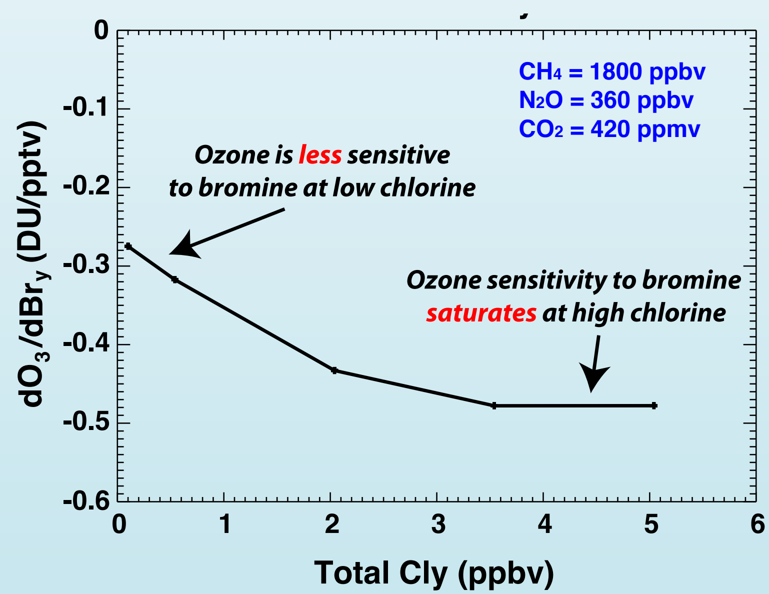
Problem 2: Relative impact of halogens

- **Bromine impact on ozone depends on chlorine amount**
- **F11 is more effective than F12 because it is photolyzed at lower altitude.**

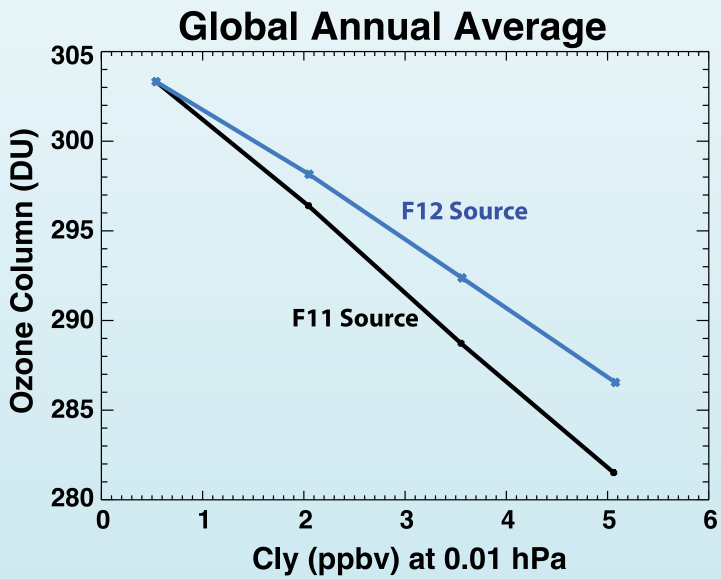
Global Total Ozone Sensitivity to Bromine

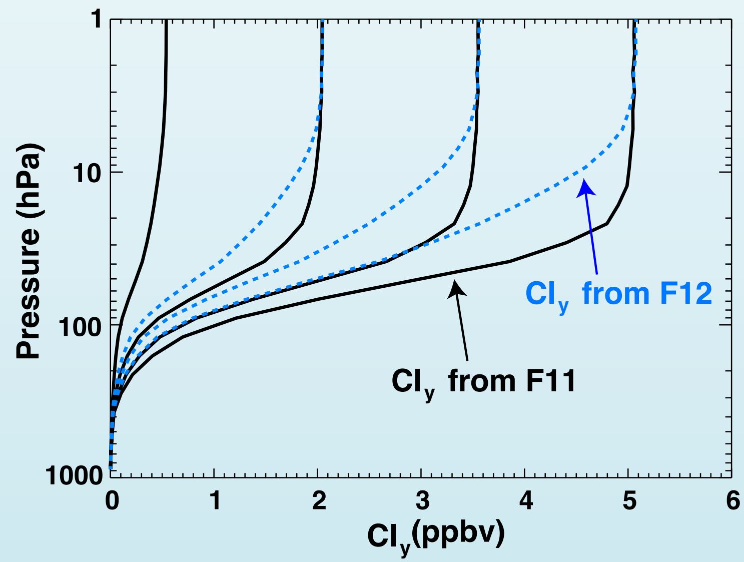
- **Used added 2D model runs for 0, 10, 20 pptv of CH_3Br at 0.1,0.5,2.0,3.5, and 5.0 ppbv of chlorine for single values of CH_4, N_2O, and CO_2**
- **Sensitivity increased with increasing chlorine (because of ClO + BrO reaction)**





Chlorine from F11 is more effective in reducing ozone than is the same amount of chlorine from F12





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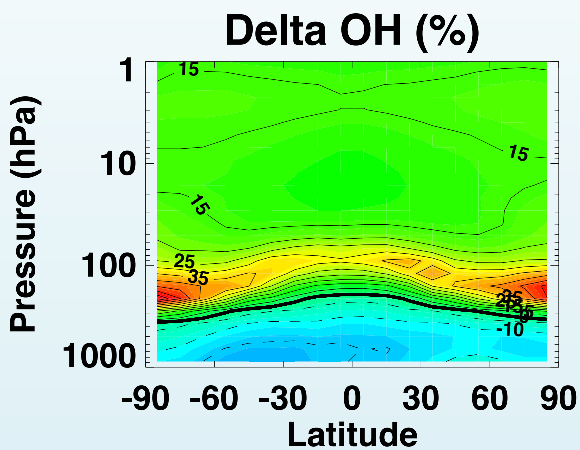
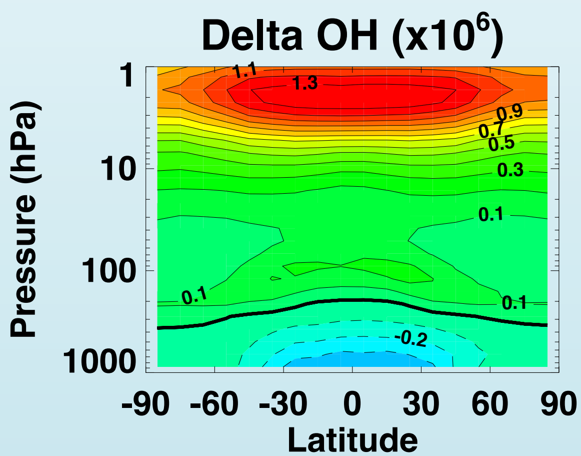
Problem 3: Impact on tropospheric and stratospheric OH

- Increasing methane increases stratospheric OH
- Percent positive OH change maximizes in UTLS
- Increasing methane decreases lower and middle tropospheric OH
- Increasing CO_2 increases tropospheric OH
- Future direction depends on scenario

Impact of Doubling CH_4 on OH





- OH decreases in lower to middle troposphere
- OH percentage increase maximizes in upper troposphere and lower stratosphere
- OH absolute increase maximizes in upper stratosphere

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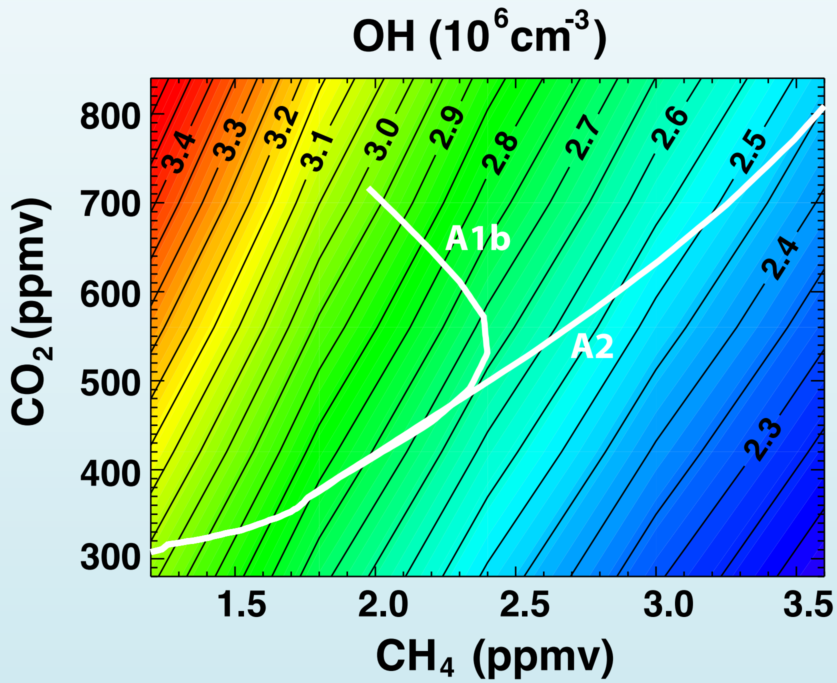
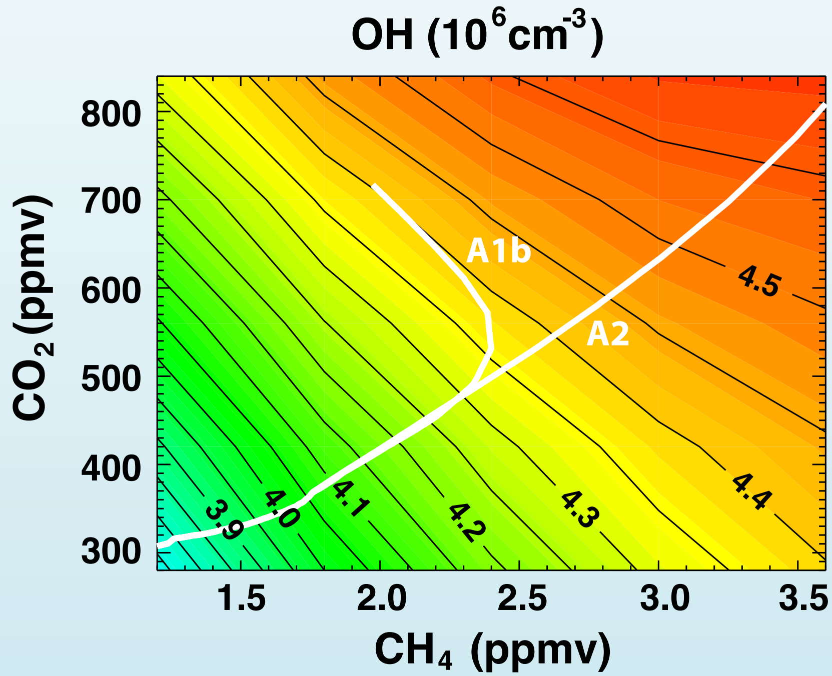
Combined Effect of CH_4 and CO_2 on Tropospheric OH



Near Surface



Upper Troposphere

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Summary and Conclusions

- **Stratospheric NO_y (or NO_x) depends on both N_2O and CO_2**
- **As CFCs decrease, N_2O and CO_2 will control the ozone depending on the future scenario for growth of each**
- **Bromine is more effective in reducing ozone at high chlorine amounts (increased efficiency saturates at about 3.5 ppbv Cl_y)**
- **Tropospheric OH responds to changes in both CH_4 and CO_2**
  - **Decreases in lower to middle troposphere**
  - **Increases in upper troposphere and stratosphere**