

Air pollution and its relations to climate change and sustainable development, 2. Climate change and air pollution, 12-14 March, Gothenburg, Sweden

Climate Sensitivity of Ozone

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Overview of the CHASER model

- **Based on CCSR/NIES AGCM 5.4g/5.6**

Horizontal resolution : T42 ($2.8^\circ \times 2.8^\circ$)
32 vertical layers (0-40km)

- **34 tracers, 13 radical species**

- **142 chemical reactions including 7 heterogeneous reactions**

- **Upper boundary(>20km)**

Ozone: HALOE (1992-1998)

others: 3D stratospheric chemical model

Sudo et al. [2002a,b]

CHASER

J-Values

calculated on-line by using GCM radiation flux and temperature.

(2) Photochemical reaction

Ox, NOx, HOx basic system +
Oxidation of Methane and NMHCs

(1) Chemical reaction

(5) Wet Deposition

HNO₃ H₂O₂ CH₂O CH₃O₂H

calculated by GCM precipitation

SO₄(--)

(3) Surface Emission

NO_x CO C₂H₆ C₂H₄ C₃H₈ C₃H₆

Acetone, Isoprene, Terpenes

ONMV SO₂ DMS

(4) Dry Deposition

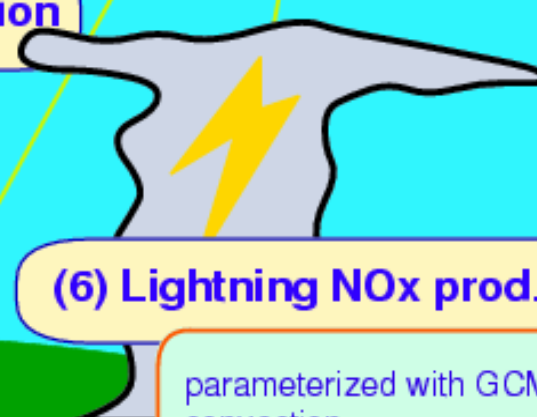
O₃ NO₂ HNO₃ H₂O₂ CO PAN CH₂O CH₃O₂H

calculated using temperature, solar irradiance, snow cover

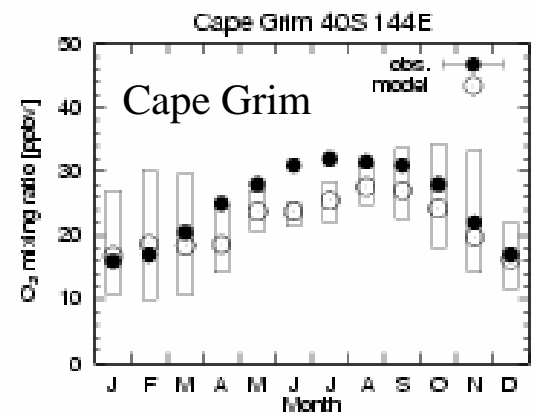
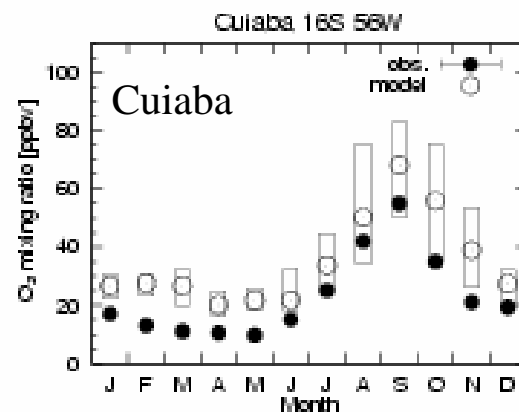
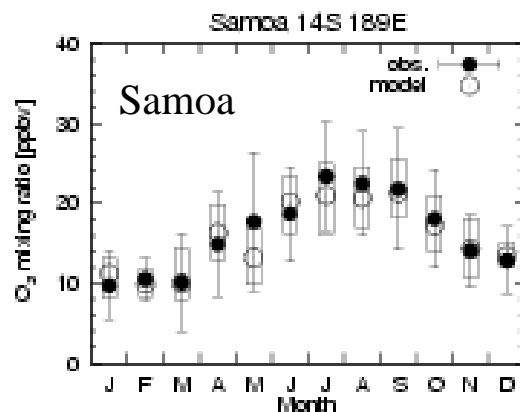
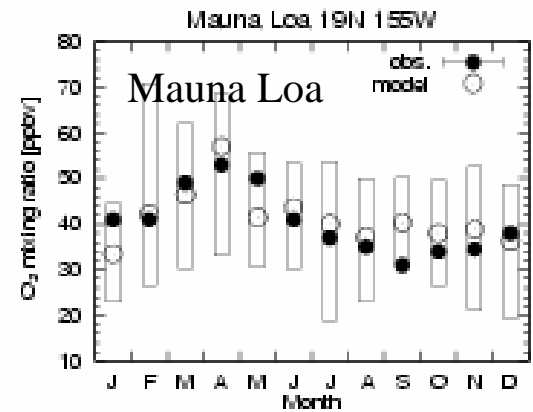
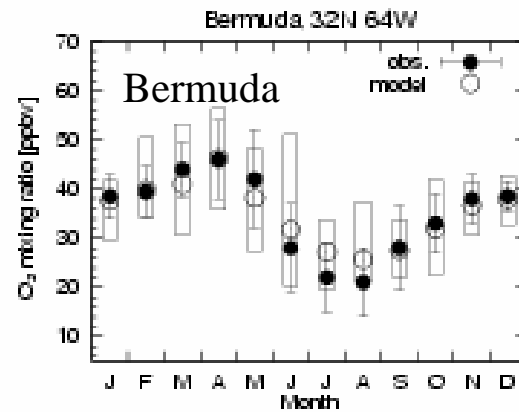
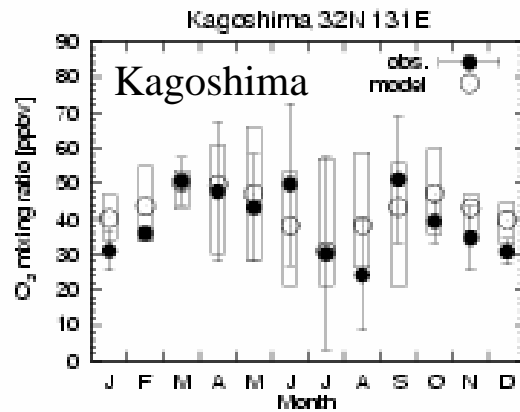
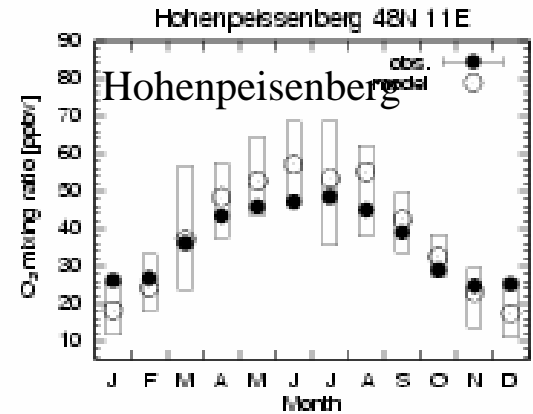
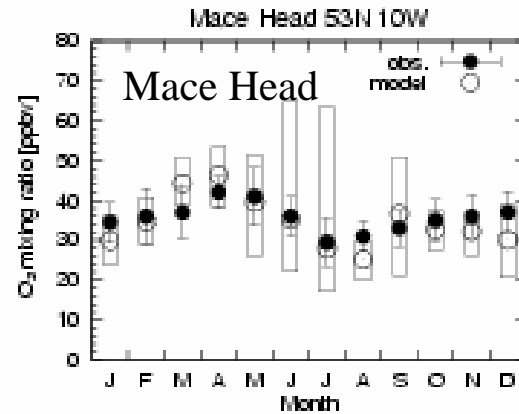
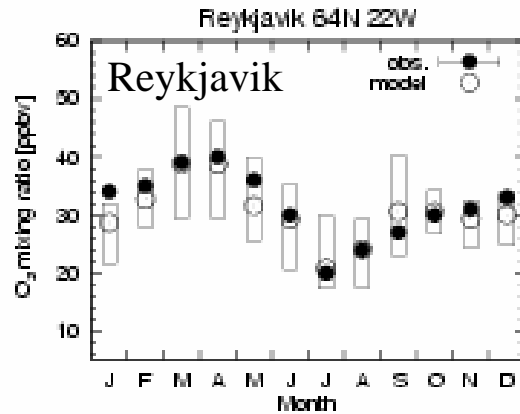
(6) Lightning NOx prod.

parameterized with GCM convection

O₃
HO_x
NMHC
NO_x



Observed & calculated seasonal variations of surface ozone



Radiative forcing (W m^{-2}) due to tropospheric ozone increase calculated by CHASER (preindustrial \rightarrow present-day)

Tropospheric ozone increase

197 TgO₃ (preindustrial)

\downarrow +10.4 DU (+58%)

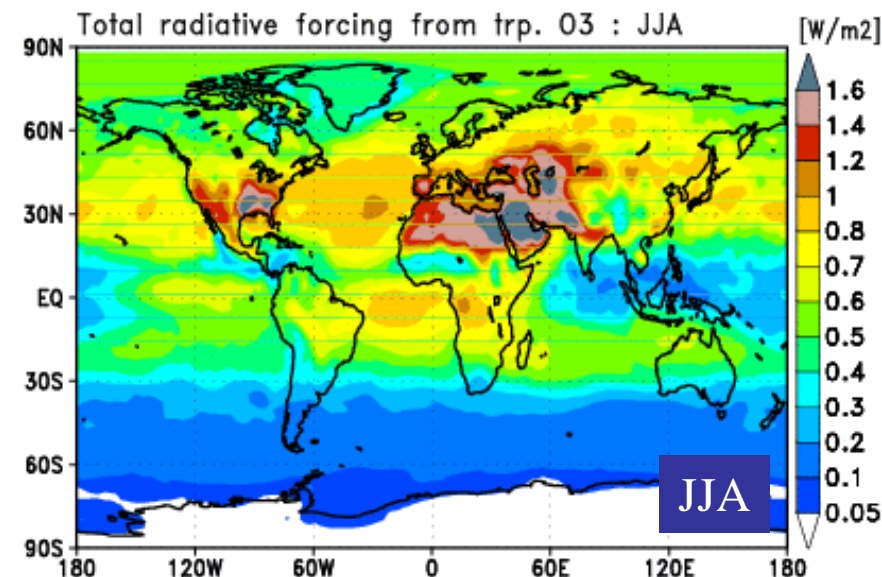
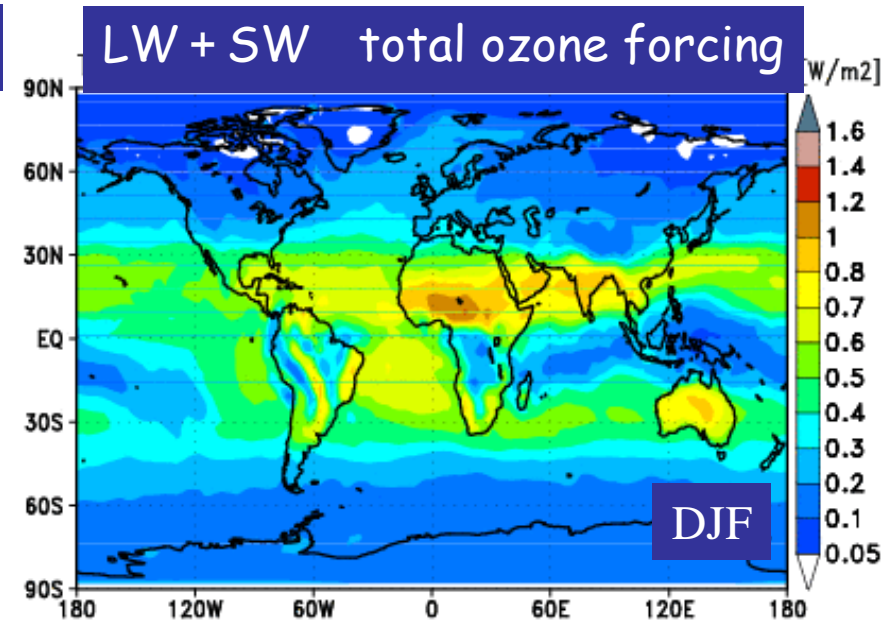
311 TgO₃ (present-day)

Tropospheric ozone radiative forcing W m^{-2} (at tropopause, in annual mean)

	Global	NH	SH
LW	0.402	0.485	0.319
SW	0.085	0.107	0.063
LW + SW	0.487	0.592	0.382

Normalized radiative forcing
= **$0.047 \text{ W m}^{-2} \text{ DU}^{-1}$**

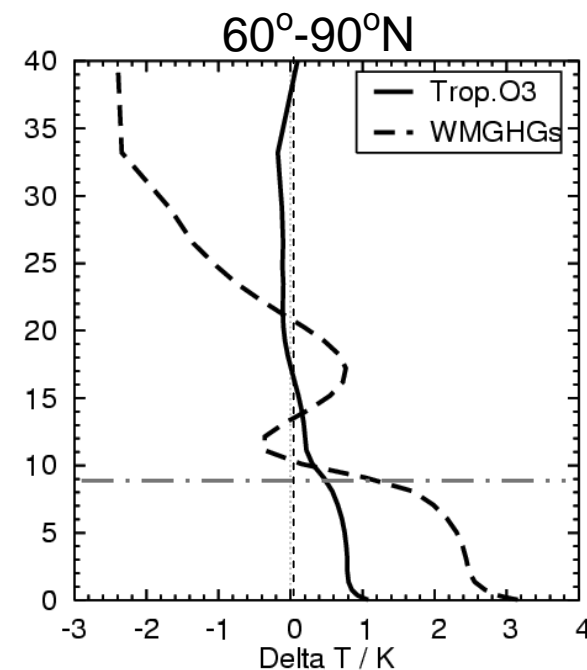
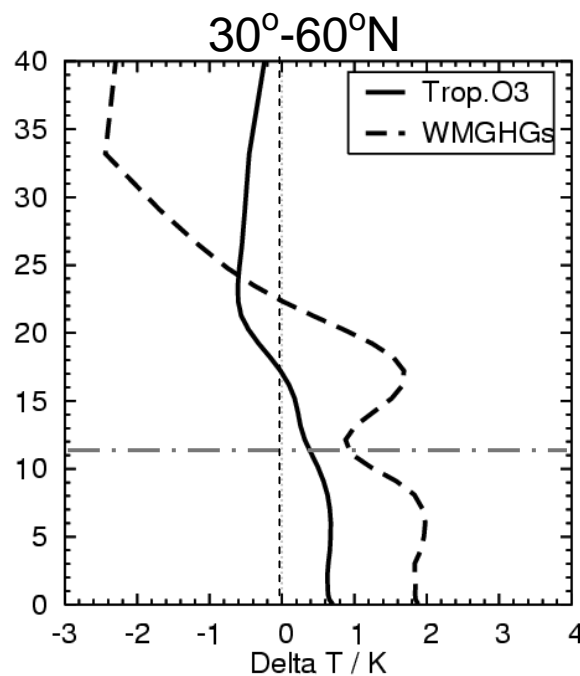
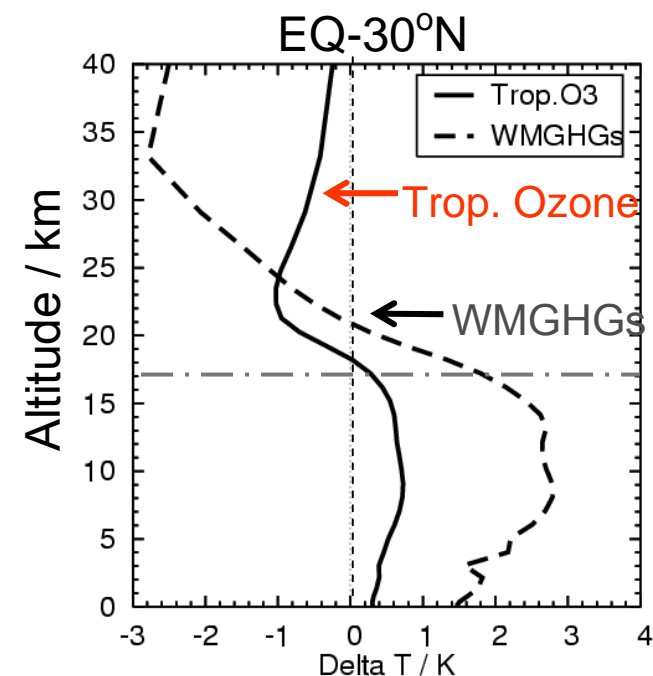
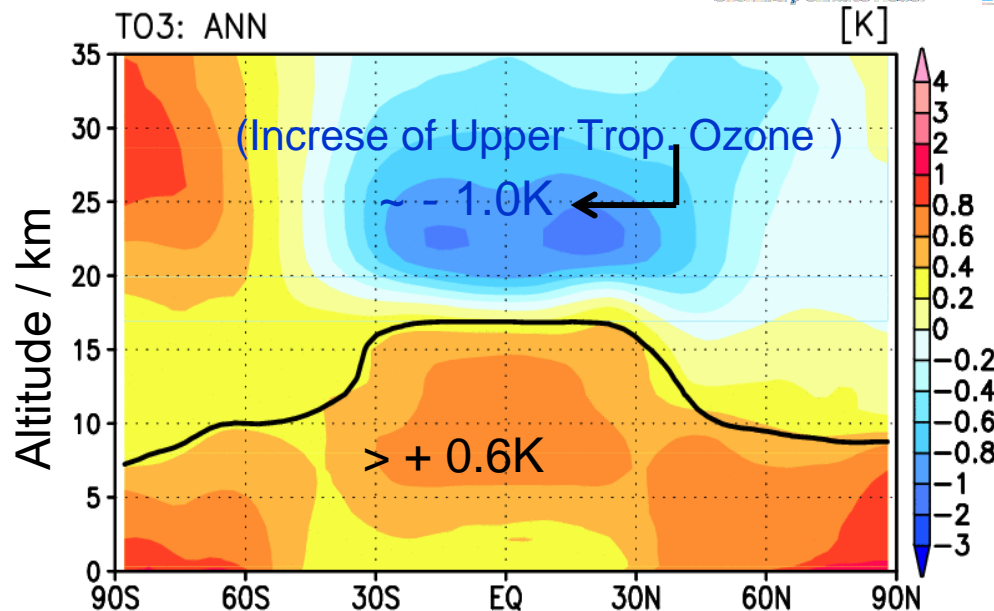
CHASER



Effect on Temperature Distribution

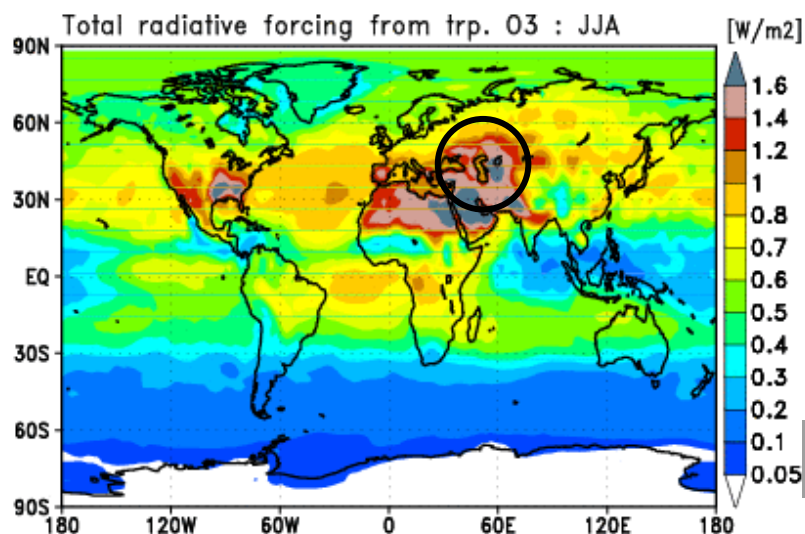
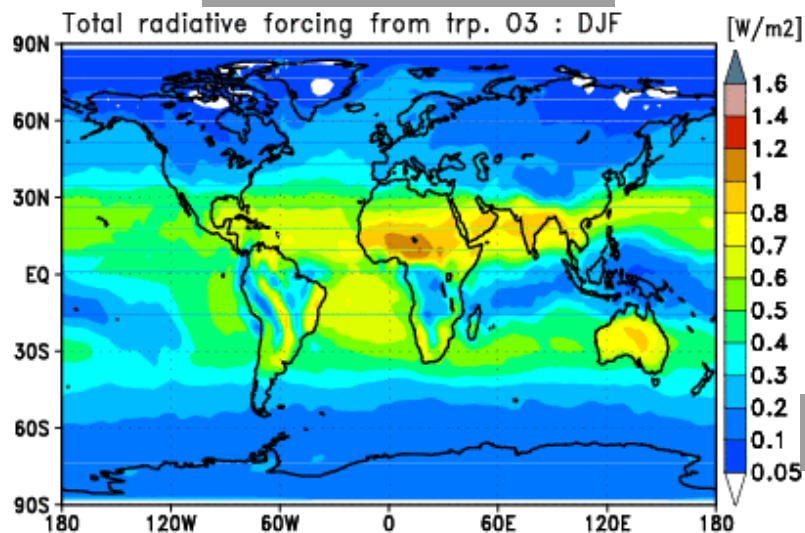
Variation of Tropospheric Ozone
→ Effect on East/West Average ΔT (K)

~ 25-30% of WMGHGs for Troposphere in the Northern Hemisphere



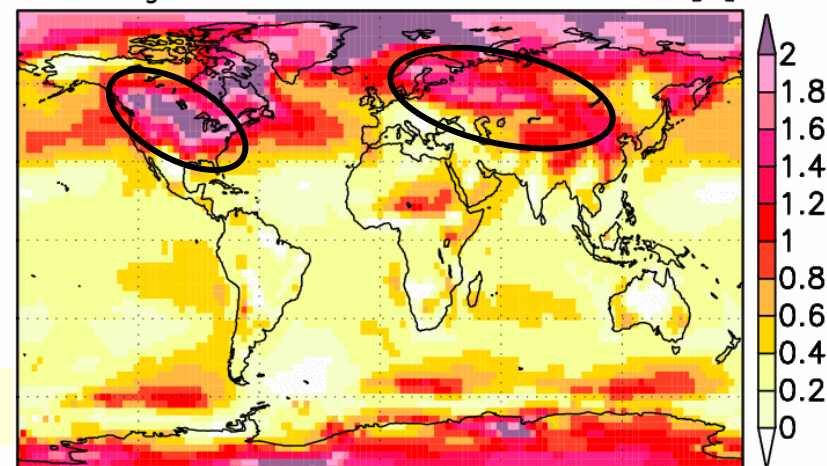
Effect on Surface Temperature (2m) : Tropospheric Ozone Increase

Radiative Forcing

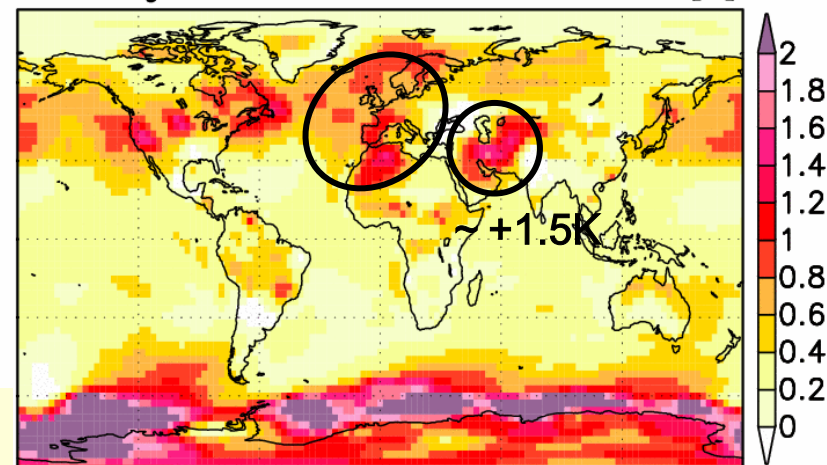


Change in Surface Temperature

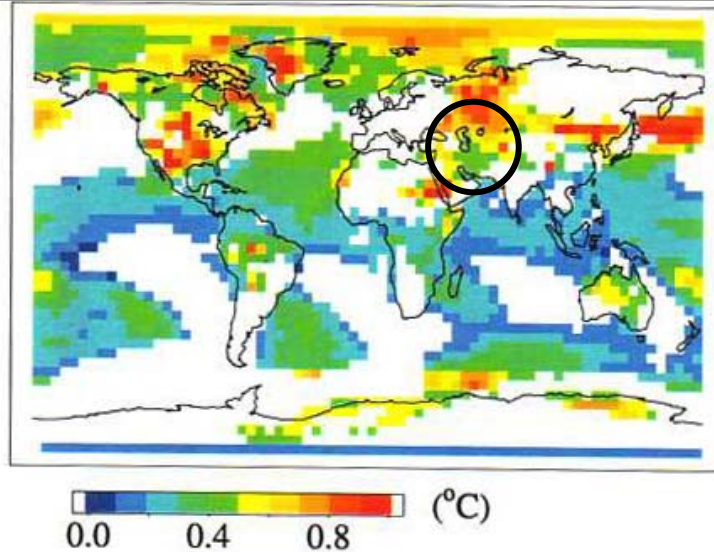
T2 changes: T03 DJF [K]



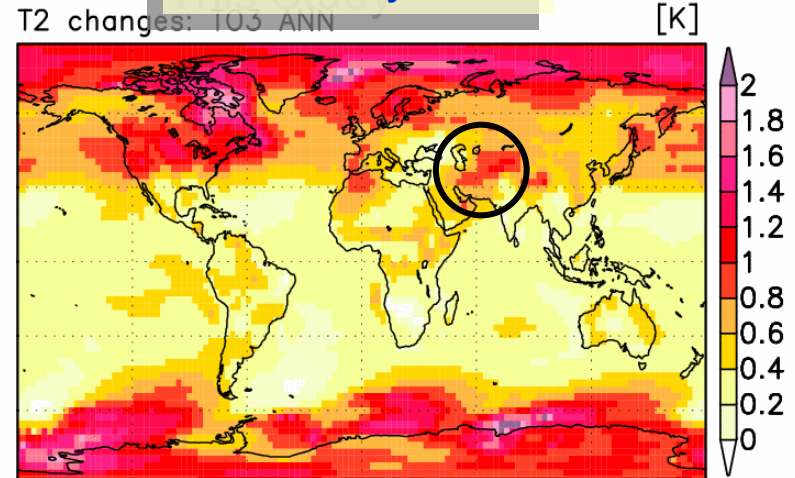
T2 changes: T03 JJA [K]



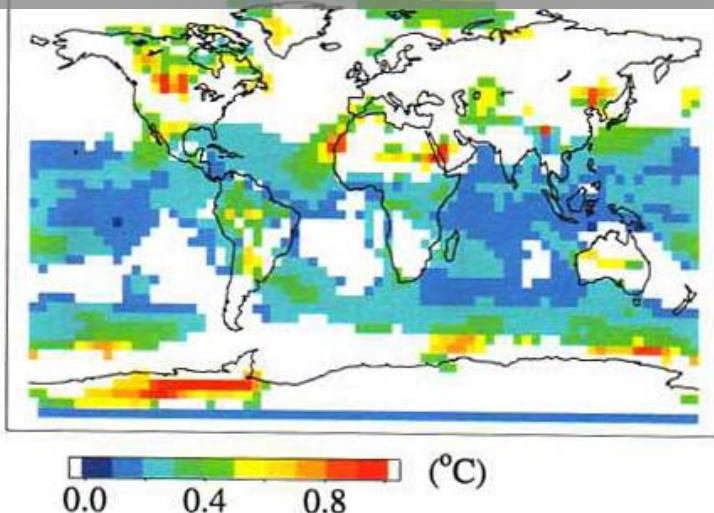
Increase of Surface Temperature due to O3 Increase



This Study

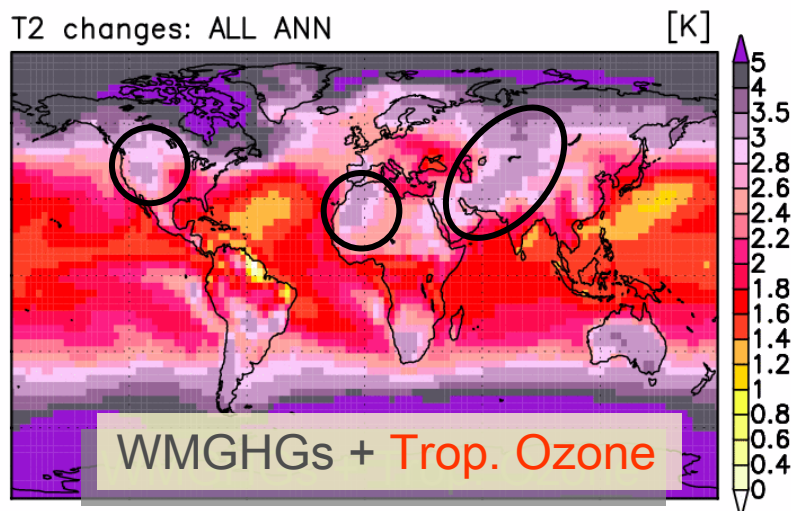
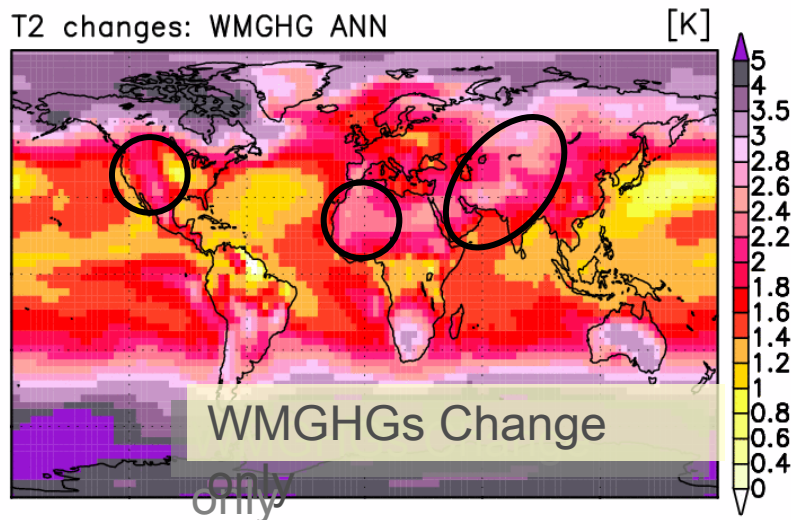


Surface Temperature Increase for Uniform Global Ozone Increase

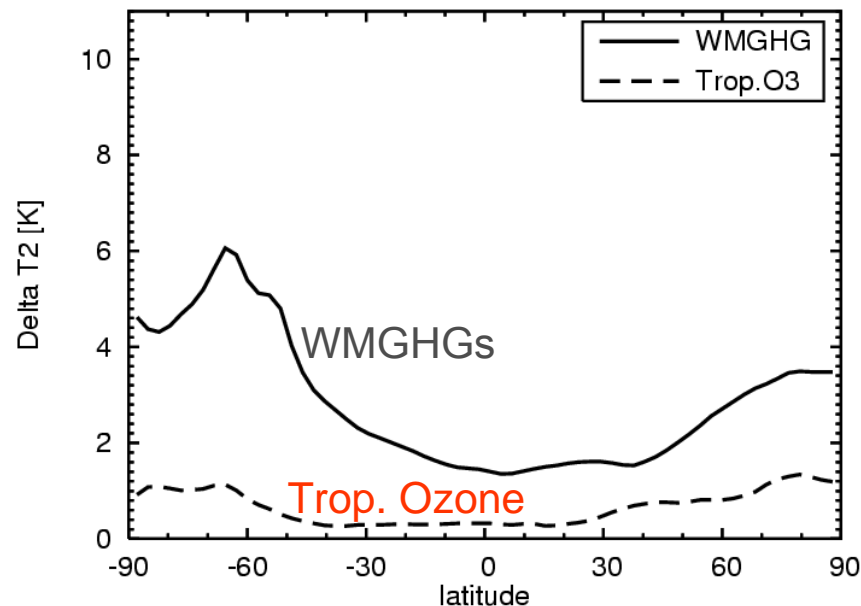


Comparison with Previous Study

Effect on Surface (2m) Temperature : Tropospheric Ozone and WMGHGs



East-West, Annual Average Surface Temperature Change ΔT



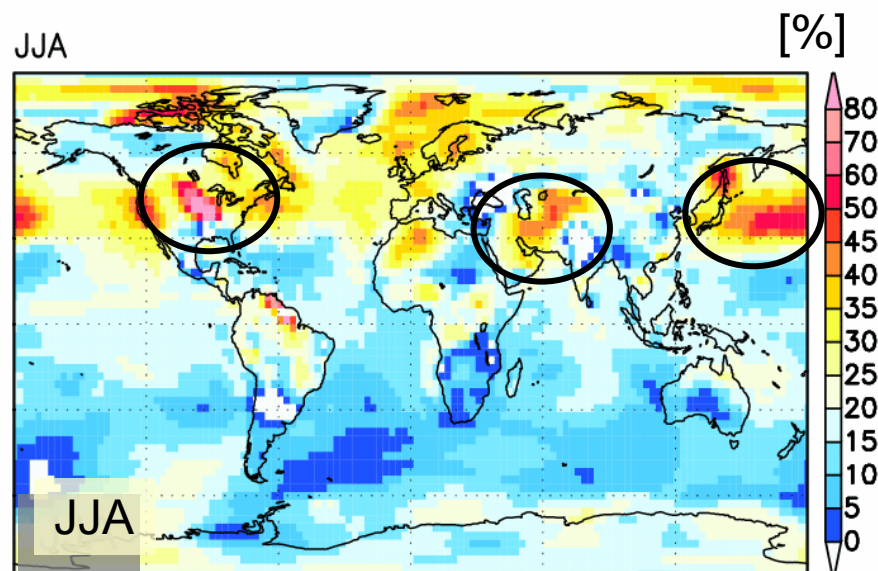
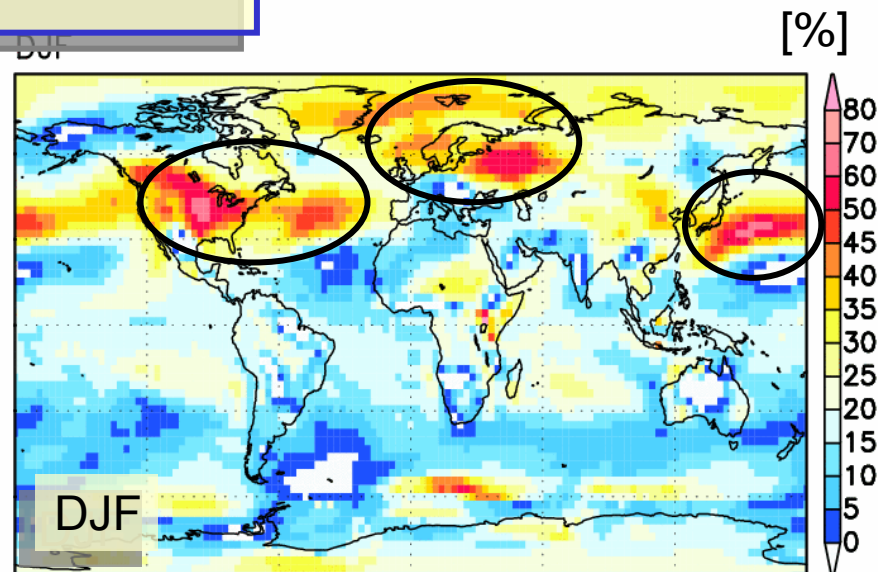
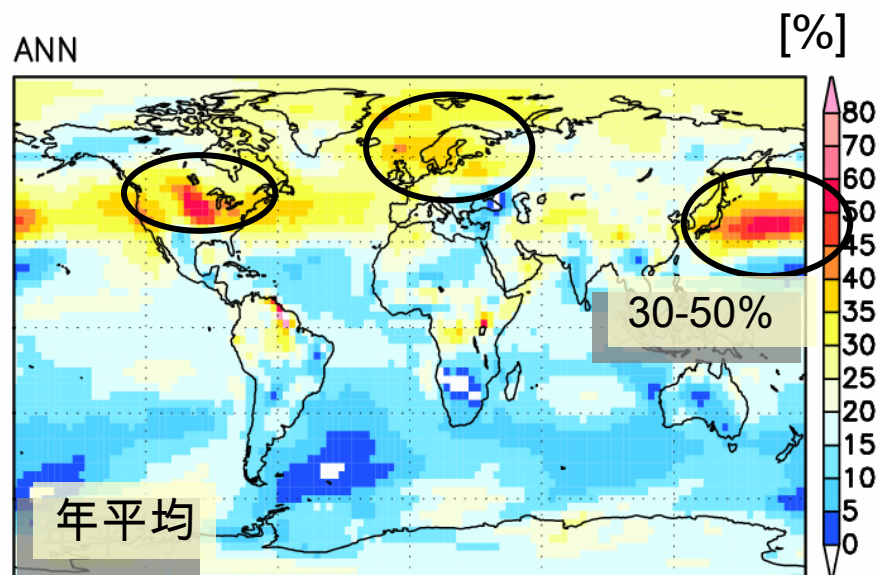
	Global	N.H.	S.H.
Trop. O3	+0.50°C	+0.56°C	+0.44°C
WMGHG	+2.30°C	+1.85°C	+2.86°C

Climate sensitivity for tropospheric O3 Change
= 1.04 K m² W⁻¹

~0.6 K m² W⁻¹ [Mickley et al., 2004]

Contribution to Surface Temperature (%) : Tropospheric Ozone Increase

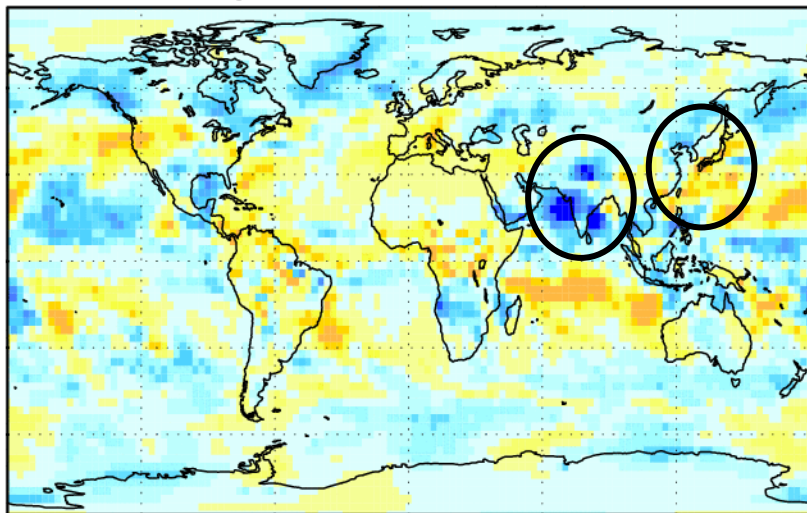
$$\frac{\Delta T(\text{Tropo.O}_3)}{\Delta T(\text{WMGHGs} + \text{Tropo.O}_3)} \cdot 100 \quad (\%)$$



Effect on Annual Precipitation Amount : **Tropospheric Ozone Increase** and WMGHGs Increase

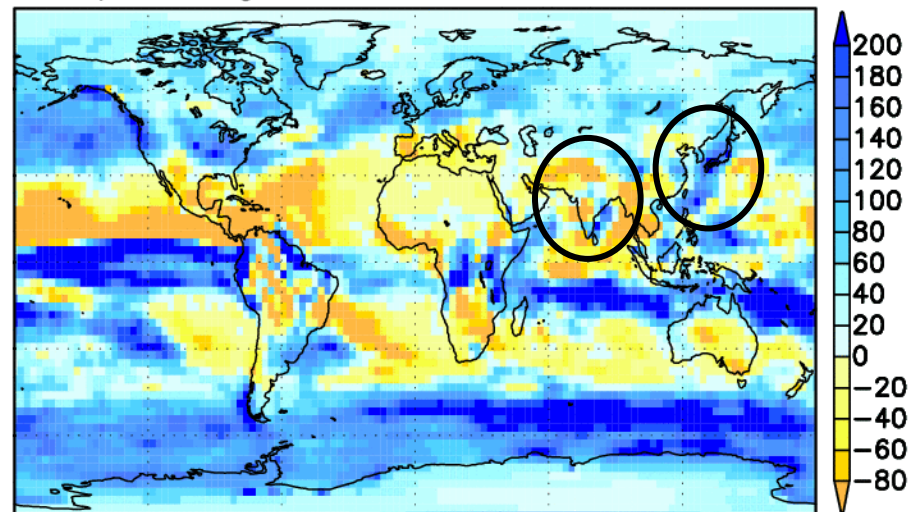
Tropospheric Ozone

Precipi. changes: T03 [mm/year]



WMGHGs

Precipi. changes: WMGHG [mm/year]



Summary and Conclusions

- ① Equilibrated climate response of tropospheric ozone and long-lived GHG (WMGHG) from pre-industrial to present has been evaluated.
- ② Tropospheric ozone brings more than 0.6 °C increase in the upper troposphere, which contributes 20-30 % of WMGHGs.
- ③ Temperature decrease up to 1.0 °C by tropospheric ozone was calculated in the stratosphere.
- ④ Tropospheric ozone and WMGHGs increase will increase global average surface temperature by +0.5°C, and +2.3°C. Contribution of tropospheric ozone is large in North America, Middle East and Western Pacific including Japan.
- ⑤ Climate sensitivity of tropospheric ozone is 1.04 K m² w⁻¹.
- ⑥ Impact of tropospheric ozone on cloud and precipitation may not be negligible.