The Impact of NOx Aircraft Emissions on Stratospheric and Tropospheric Ozone

XUexi Tie, Guy Brasseur, and P. Rasch
National Center for Atmospheric Research
P. O. Box 3000
Boulder, CO 80307, USA

The Impact of NOx emissions by subsonic and supersonic aircraft is estimated using two-dimensional and three-dimensional chemical-transport models. Different aspects of the problem are considered: (1) A two-dimensional model with interactive chemistry, radiation, dynamics, and microphysical processes of sulfate aerosol and Polar Stratospheric Clouds (PSCs) is used to assess the response of stratospheric ozone to perturbations by high altitude transport. The model description is given by Brasseur et al. (1990), and Tie et al. (1994a). The role of heterogeneous chemical reactions (particles in polar stratospheric clouds and sulfate aerosol) is emphasized and estimated. (2) A three-dimensional chemical/transport model of the middle atmosphere are applied to study the impact of aircraft emissions. This model includes the most important chemical reactions including heterogeneous conversion mechanisms on the surface of stratosphere sulfate aerosol particles. The model description is given by Rasch et al. (1994). The potential impact on stratospheric chemistry by emissions of High Speed Civil Transport (HSCT) are studied. (3) A global three-dimensional tropospheric model (IMAGES) including a detailed representation of the O3-NOx-CH4 chemistry with a simplified formulation of non-methane hydrocarbon chemistry to assess the effect of tropospheric zone by subsonic aircraft. The model description is given by Muller and Brasseur (1994).

Calculations with the 2-D model show that the heterogeneous chemical reactions both on the surface of aerosol and PSCs have a very important effect on the stratospheric ozone due to NOx emission of aircraft. Figure 1 shows the calculated total ozone changes due to NOx emission by HSCT with and without heterogeneous reactions on the surface of sulfate aerosol (no PSCs on the both cases). It indicates that ozone decrease due to NOx emission of HSCT is smaller by including chemical reactions on the surface of aerosol. The detailed analysis is shown in Tie et al. (1994b). However, when chemical reactions on the surface of PSCs are further included in the calculation, ozone decrease due to emission of HSCT is enhanced (see Figure 2). This is because the injected NOx and H_2O by aircraft enhance the formation of PSCs and lead to increases of ClO concentration in the lower stratosphere. The total ozone depletion due to emission of aircraft changes from 4% (without PSCs) to 8% (with PSCs) in high latitudes of the northern hemisphere in winter.

Recent surveys of the emission of HSCT show that the emission distribution has a longitudinal dependence (Stolarski and Wesoky, 1993), which can not be resolved in 2-D models. A three-dimensional model is used to assess the stratospheric chemical effect by the emission of HSCT. The model calculation shows that the increase of NOx is not well mixed in longitude. The maximum increase is located in continental of the United States and Europe (Figure 3).

The emission due to subsonic airplanes increases tropospheric NOx by about 20 percent at about 9 km at 60°N, leading to an ozone increase of 6 percent in summer and 1-2 percent in winter (see Figure 4a. Because the tropospheric ozone is a very important greenhouse gas, the increase of 5-6 percent ozone at 9 km could lead to the changes of radiative forcing by maximum of 0.07 W/m^2 (see Figure 4b) calculated by a 2-D radiative model (Hauglustaine et al., 1994).

References

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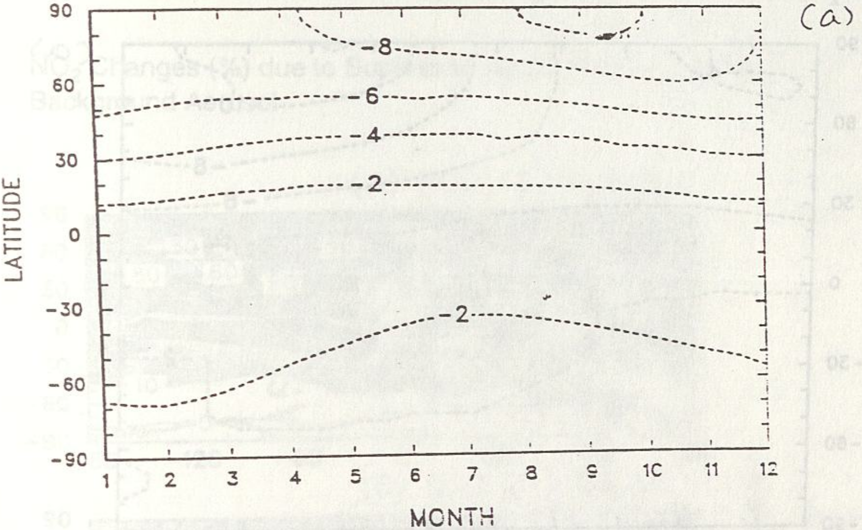
(M=2.4, EI=15)

COL OZONE CHANGE (SCENARIO A) GAS PHASE



(M=2.4, EI=15)

COL OZONE CHANGE (SCENARIO A) BACKGROUND AEROSOL

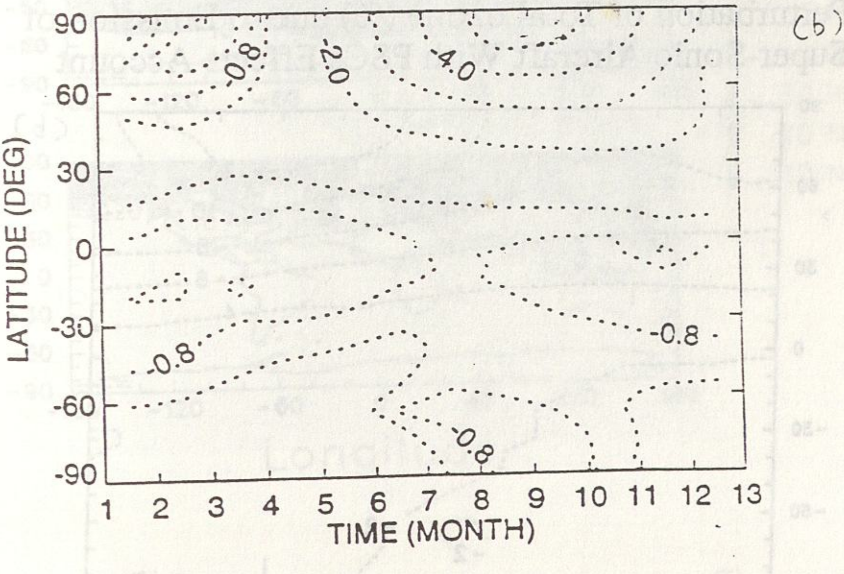
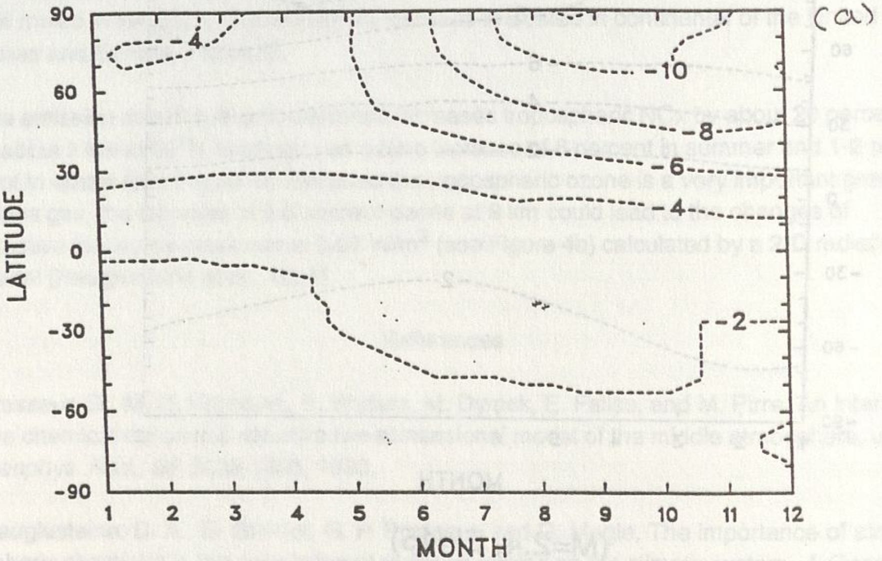


Figure 1

(M=2.4, EI=45)

Perturbation of Total ozone (%) due to Emission of Super-Sonic Aircraft Without PSCs Effects Account



(M=2.4, EI=45)

Perturbation of Total ozone (%) due to Emission of Super-Sonic Aircraft With PSCs Effects Account

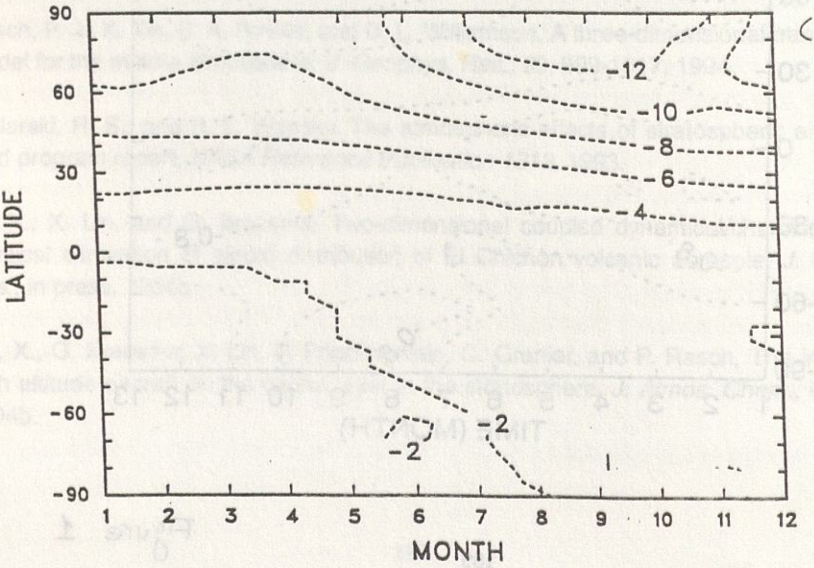


Figure 2

NO_2 Changes (%) due to Supersonic Aircraft (M=2.4, EI=15)
Background Aerosol

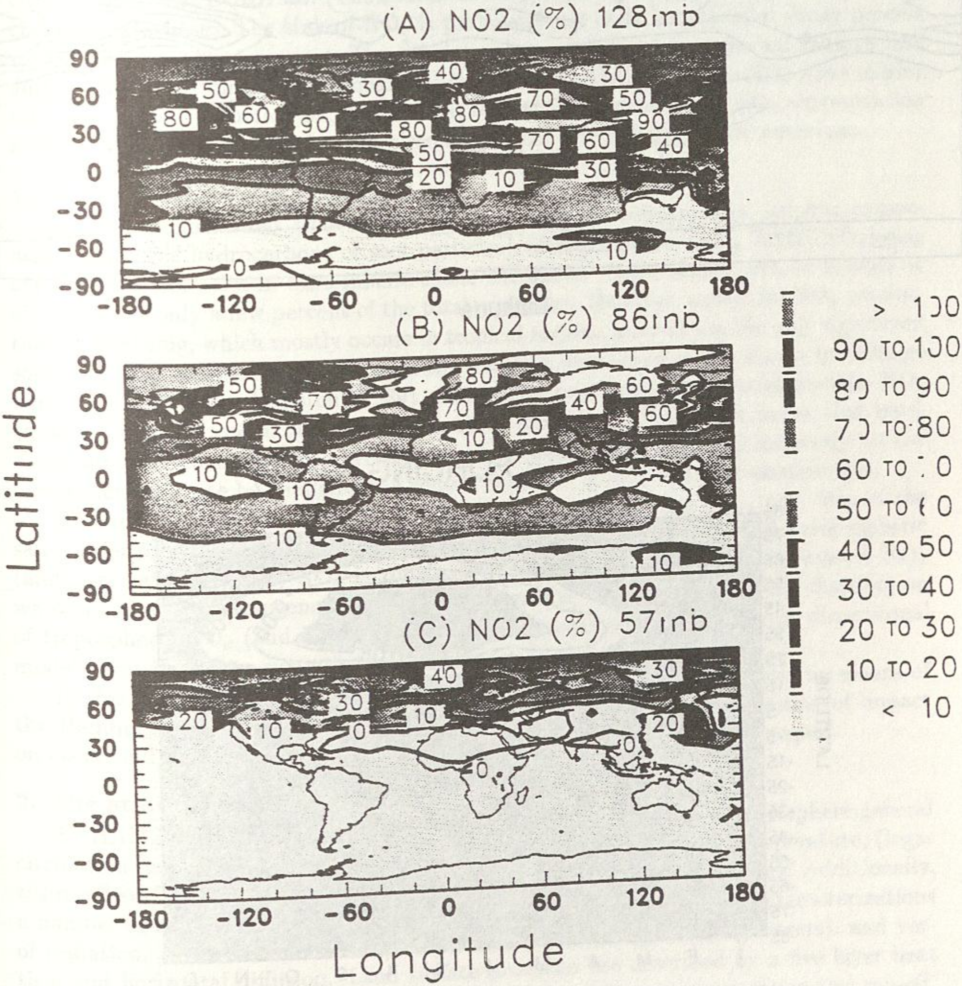
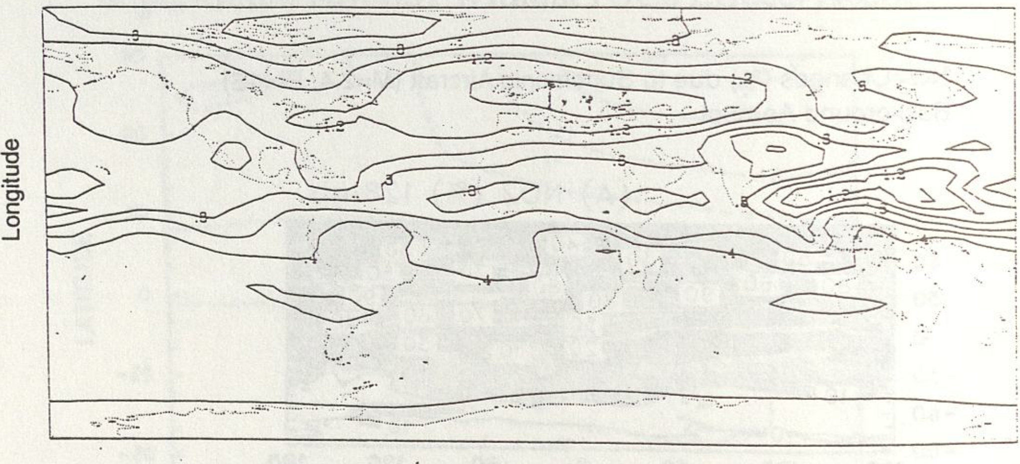


Figure 3

Ozone changes (%) due to Subsonic Aircraft (9km winter)

(a)



RADIATIVE FORCING (Wm-2)

(b)

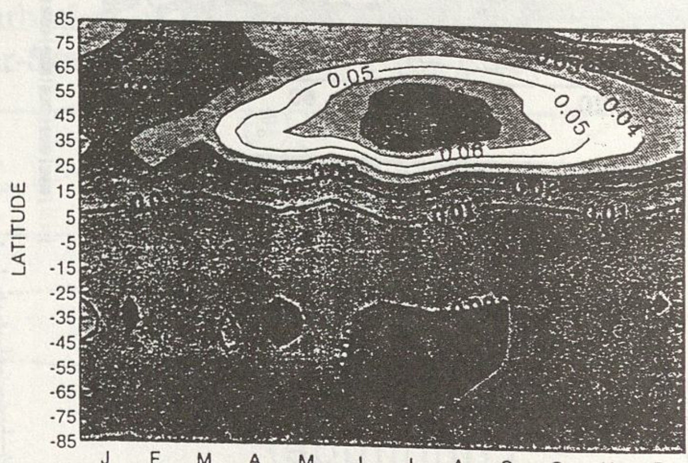


Figure 4