Understanding Historical Ozone Trends at Northern Mid-Latitudes

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ABSTRACT

During the 20th century baseline concentrations of ozone increased markedly at northern mid-latitudes. This increase has been documented by a variety of observational studies, and is generally attributed to increasing anthropogenic emissions of the precursors that fuel photochemical ozone production. These increased emissions accompanied the growth and development of the economies of the industrialized nations. Uncertainty remains regarding the magnitude of the increase, since pre-industrial ozone concentrations are poorly known, and in the definitive assignment of the cause of the increase, since global chemical transport models have not well reproduced the increase observed. The goal of this presentation is to review the observational evidence for the ozone trends, present recent model calculations based upon a new dataset of gridded emissions covering the historical period (1850-2000) in decadal increments, compare the modelled and observed trends, and discuss possible reasons for the model-measurement differences.

INTRODUCTION, DISCUSSION, and CONCLUSIONS

During the latter half of the 20th century concentrations of O_3 increased markedly at northern mid-latitudes. This increase is generally attributed to increasing anthropogenic emissions of the precursors that fuel photochemical O_3 production. These increased emissions accompanied the growth and development of the economies of the industrialized nations[1]. Figure 1 shows this increasing trend for springtime (March-May) data at sites with some of the longest measurement records, and Figure 2 summarizes the trends for all seasons. Uncertainty remains regarding the magnitude of the increase from pre-industrial to present day, since pre-industrial O_3 concentrations are poorly known, few measurements were made before the late 1970s, and different data sets for the same region don't always give consistent results. Since global models cannot reproduce the very low O_3 levels suggested by the measurements of that time[2], the quantitative assignment of the cause of the increase is also uncertain. This work uses a new dataset of gridded emissions covering the historical period (1850-2000) in decadal increments, within chemistry-climate model calculations to test the ability of this emission dataset to capture the long-term observed changes in northern mid-latitude O_3 distributions.

Lamarque et al.[3] have recently presented a consistent gridded emissions of reactive gases and aerosols for use in chemistry model simulations. Figure 3 shows a comparison of their emissions with two earlier global emission databases. They also present simulations of the long-term changes in atmospheric O_3 from two chemistry-climate models that are suitable for comparison with the observations. Figure 4 presents the results of these simulations in the same format as Figure 2. The model generally reproduced present day O_3 distributions quite well, but was less successful in reproducing the historical trends. There are seasonal and regional differences in the results, but in general these current global chemistry-climate models underestimate the observed trends by a factor of two or more, even with this newly prepared emission database.

The reason for the models' inability to accurately capture the trends is not clear. However, but the failure of the model calculations to accurately capture all aspects of the O_3 trends at northern mid-latitudes indicates that our understanding of the tropospheric ozone budget is incomplete in some respect, at least as incorporated into these current models.

REFERENCES

[1]Lamarque, J.-F., et al. "Tropospheric ozone evolution between 1890 and 1990," J. Geophys. Res. 2005, 110, D08304.

[2]see e.g. Mickley, L. J., et al. "Uncertainty in preindustrial abundance of tropospheric ozone: Implications for radiative forcing calculations," J. Geophys. Res. 2001, 106, 3389-3399.

[3]Lamarque, J.-F., et al. "Historical (1850–2000) gridded anthropogenic and biomass burning emissions of reactive gases and aerosols: methodology and application," Atmos. Chem. Phys. 2010, 10, 7017–7039.

Figure 1. Springtime trends in O_3 measured in (a) Europe and (b) western North America and Japan. The lines (in color) indicate the linear regressions to the data, and the curves (in black) indicate quadratic polynomial fits to the three central European sites. Arkona and Zingst are two sites located close to the Baltic Sea. Mace Head is located at the west coast of Ireland. Hohenpiessenberg (1.0 km a.s.l.) and Zugspitze (3.0 km a.s.l.) are in southern Germany, and Jungfraujoch (3.6 km a.s.l.) is in Switzerland. The North American data are from several sea level Pacific coastal sites and Lassen National Park (1.8 km a.s.l.) near the west coast, and from the free troposphere over the western part of the continent. The Japanese data are from Mt. Happo (1.9 km a.s.l.) on the Japanese mainland and Rishiri, a northern (45N) sea level island site. (Figure reproduced from HTAP 2010 Assessment Report - http://www.htap.org/)

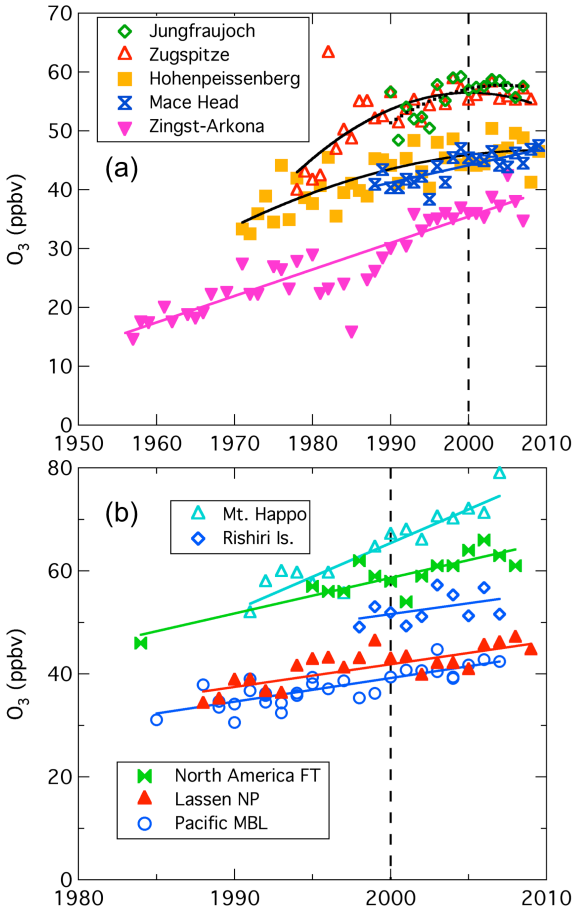


Figure 2. Average linear annual increase of O_3 concentrations in different seasons in Europe (left of dashed lines) and North America (right of dashed lines). The slopes of linear regressions of seasonally averaged data (e.g., the lines in Figure 1) provide the trends. The sites, symbols and period of the linear trend determination are the same as in Figure 1, except for the three central European sites, where the linear fits stop in 2000. (Figure reproduced from HTAP 2010 Assessment Report - http://www.htap.org/

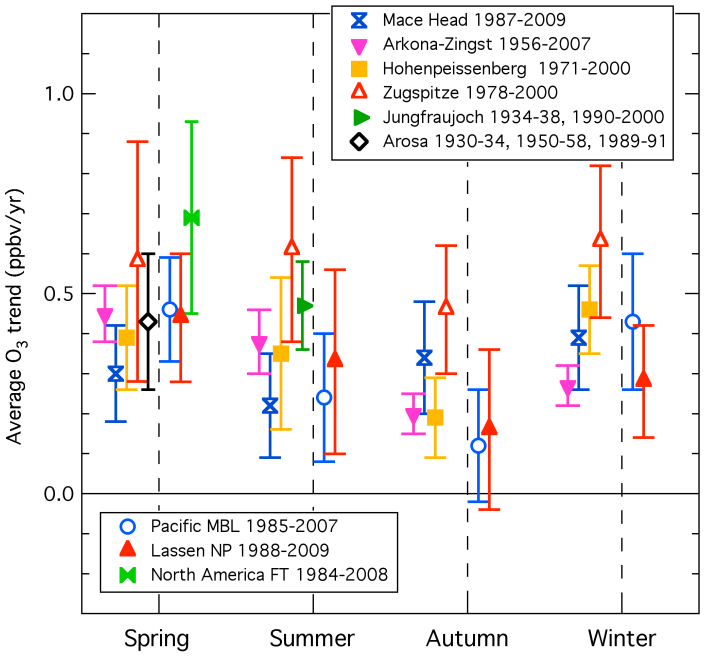


Figure 3. Time evolution of the total (sum of all sectors except agricultural waste burning) land anthropogenic emissions for CO (Tg(CO)/year), NOx (Tg(NO_2)/year) and total NMVOC (Tg(NMVOC)/year)[3]. The results from two earlier global emission data sets are included for comparison.

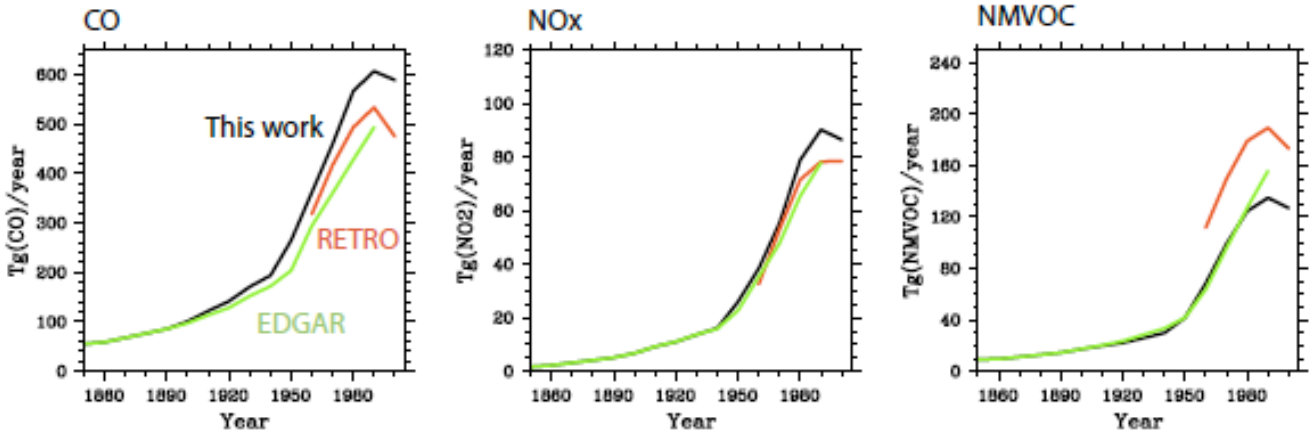
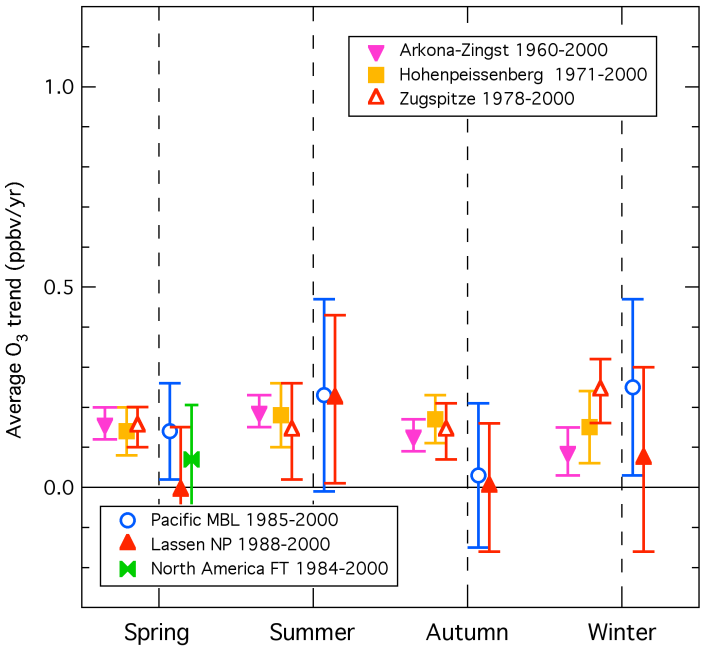


Figure 4. Average linear annual increase of O_3 concentrations in different seasons as simulated by chemistry-climate models in the same format as Figure 2.



Key Words
Historical, Ozone, Trends, Northern Mid-Latitudes, Emissions