

77-206022  
7N-07-CR  
November 1, 1997

## **Final Report: Analyses of Scenarios for Past and Possible Future Aircraft Emissions**

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### **Research Objectives**

This project contains several components to work with the NASA AEAP program in better definition of scenarios for aircraft emissions and in determining the sensitivity of the atmosphere to such emissions. Under this project, Don Wuebbles continues as chair of the Operations and Emissions Scenarios Committee for AEAP. We are also coordinating with the International Civil Aviation Organization (ICAO) to ensure the highest quality possible in the emissions scenarios promoted by the Emissions Scenarios committee. We continue to help coordination of NASA AEAP with international activities. This includes work with ICAO towards international analysis of aircraft emissions inventories; performing analyses to compare and evaluate databases of aircraft emissions developed for NASA and by various international groups and from these analyses, develop guidelines for future emissions scenarios development. Special sensitivity analyses, using our two-dimensional chemical-transport model of the global troposphere and stratosphere, have been used to determine potential sensitivity of further enhancements that could be made to emissions scenarios development. The latter studies are to be used in prioritizing further emissions scenario development.

### **Summary of Progress and Results**

- Donald Wuebbles continued as Chair of the Operations and Emissions Scenarios Committee for NASA. We had several meetings of the Committee over the past year. The committee's work for this year centered on preparations for the 1996 interim SASS assessment and on discussions of longer term scenarios for aircraft emissions in the 21st century. Don had many discussions with members of ICAO and the international community towards how best to consider such scenarios. We also were active participants in the special AEAP meeting this year with the international community.
- Don Wuebbles was a lead author on the 1996 interim assessment of the SASS program to examine the effects of subsonic emissions on the global environment. In particular, he coordinated the model calculations done for that assessment including

coordination with Steve Baughcum and others on the aircraft emissions used in the assessment. Special scenario studies were developed for that assessment.

- We also provided analyses from our two-dimensional model for the calculated distribution of soot from current aircraft. These results were then evaluated with a radiative-convective model to determine the resulting changes in radiative forcing from aircraft (found to be extremely small relative to other recent forcings on climate). Resulting optical depths for the soot aerosols have also been calculated and results from these analyses are included in the assessment.
- We have performed a series of calculations with our two-dimensional model to investigate the potential importance of soot and sulfate aerosols resulting from subsonic and HSCT aircraft emissions. In initial studies, we have examined the distribution of soot aerosols based on assumptions about the size and mass of aerosols produced. Emissions are based on analyses of the soot from the few available studies of emissions behind the engines of individual aircraft. These emissions are then applied to the fleet of current and projected aircraft following the fuel burn information derived for the NASA AEAP by Boeing and McDonnell Douglas for the global fleet. For HSCTs, similar assumptions are applied to the projected fleet of 500 HSCTs. Journal article was completed and is in press with the Journal of Geophysical Research.
- The distribution of soot derived for the 1990 emissions compares well with the available observations of soot in the upper troposphere and lower stratosphere (a figure can be provided) such as those by Pueschel et al. (1992) and Blake et al. (1994). The results however do not explain the high concentrations of soot near 20 km found in some of the observations by Pueschel et al. Discussions have been held with Harvey Lilenfeld (of McDonnell Douglas) and others regarding better specification of the soot emissions for the next study.
- Donald Wuebbles was a representative of the science community on ICAO's Emission Inventory Subgroup (EISG). A report was completed and published by ICAO on the activities of this working group, including comparisons of the NASA and ANCAT emissions databases.
- We are helping coordinate the incorporation of the NASA scenario databases, particularly for the past emissions, into the Global Emissions Inventory Activity (GEIA) of the International Global Atmospheric Chemistry (IGAC) Project. This will help provide the databases to modeling groups around the world.
- Scenarios were developed for the IPCC assessment on global effects of aircraft emissions. Don Wuebbles is a lead author of the chapter on emissions in the assessment.
- Scenarios were developed for the SASS assessment of HSCT aircraft. Don Wuebbles participated in the scenario selection.

## **Publications**

Friedl, R.R., et al., *1996 Interim Assessment of the Atmospheric Effects of Subsonic Aircraft*, NASA Reference Publication currently under review, 1996.

Committee on Aviation Environmental Protection, *Report of the Emissions Inventory Sub-Group*, International Civil Aviation Organisation, Bonn, Germany, 1995.

Wuebbles, D., D. Maiden, et al., Summary of Operations and Emissions Scenarios Committee Meeting, Washington, D.C., Nov. 13-14, 1995. (notes also available for committee meeting held at Virginia Beach, April, 1996).

Rahmes, T.F., A. H. Omar, and D. J. Wuebbles, Atmospheric distributions of soot particles by current and future aircraft fleets and resulting radiative forcing on climate. *J. Geophys. Res.*, in press, 1998.