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Model Evaluation and Sensitivity Studies for Determining Aircraft Effects on the Global Atmosphere

FINAL

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Research Objectives

This project, started in July 1995 and ending in July 1996 related to evaluation of the possible importance of soot and sulfur dioxide emissions from subsonic and supersonic aircraft, to research contributions and special responsibilities for NASA AEAP assessments of subsonic aircraft and High Speed Civil Transport aircraft, and to science team responsibilities supporting the development of the three-dimensional atmospheric chemistry model of the Global Modeling Initiative.

Summary of Progress and Results

Soot and sulfates from aircraft

A series of calculations with our two-dimensional model were performed to investigate the potential importance of soot and sulfate aerosols resulting from subsonic and HSCT aircraft emissions. In initial studies, we examined the distribution of soot aerosols based on assumptions about the size and mass of aerosols produced. Emissions are based on the 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.

The distribution of soot derived for the 1990 emissions compares well with the available observations of soot in the upper troposphere and lower 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.

As part of the process of including soot and sulfate aerosol processes, the two-dimensional has been totally redesigned. Part of the reason for this was to modify the formulation of the model to a split-operator approach that allows for more readily incorporation of aerosol processes. However, other changes to the solution techniques for chemistry and dynamics were made to gain computational speed (without compromising computational accuracy) and to make the model better correspond to the model formulation of the three-dimensional model being co-developed with LLNL, which in turn is being used as the framework for the Global Modeling Initiative.

We incorporated a detailed microphysics model (based on the model developed by Mark Jacobsen and Rich Turco) into the two-dimensional model before doing much more detailed analyses of the resulting soot and sulfate aerosols. We are particularly interested in the possible interactions between soot and sulfur that is implied by the available data from the ASHOE/MAESA based measurements behind the Concorde. At the time this grant was completed, we were still testing the microphysical submodel. Since then, under continuing support from NASA AEAP, we have completed this study, resulting in a M.S. thesis with a journal article nearing completion for submission.

1995 Interim Assessment of HSCT aircraft

We were active participants in the 1995 interim assessment of High Speed Civil Transports. In coordination with LLNL, we performed a significant number of calculations with the two-dimensional model for various scenarios of interest to the 1995 Scientific Assessment of the Atmospheric Effects of Stratospheric Aircraft (Stolarski et al., 1995). A new version of the two-dimensional model was developed just prior to the assessment that provides a much improved representation of atmospheric dynamical processes including incorporation of a new treatment for planetary and gravity waves in the model (Li et al., 1995). Six of the thirteen standard set of scenarios requested by NASA were done at Illinois (the rest were done at LLNL with the same version of the model). We coordinated with LLNL in the analysis of the results provided for the assessment. We also performed a series of sensitivity analyses to investigate uncertainties in stratospheric chemistry. For example we evaluated the effect of the bromine nitrate plus water heterogeneous reaction on the aircraft scenarios. We participated in several planning and writing meeting for the assessment, and wrote parts of several sections that appear in the assessment.

1996 Interim Assessment of subsonic aircraft

For the 1996 interim assessment on subsonic aircraft, we took a leadership role in preparing the chapter on model analyses of the environmental effects of subsonic aircraft. We have helped organize the modeling studies that are being included in the assessment, analyzed resulting model results for a variety of sensitivity studies, and prepared the initial drafts of the chapter on model results including writing of several sections.

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 incorporated in the NASA GISS climate model by David Rind and Kathy Shah. Results from these analyses are being included in the assessment.

Support for GMI

Since the formation of GMI, we have participated in all meetings and have served as discussion leader on various issues for the science team.