REVIEW OF PROPOSED HSCT OZONE IMPACT

ASSESSMENT PROGRAM

NASA HEADQUARTERS

NOVEMBER 19, 1987
EVOLUTION OF KNOWLEDGE AND STUDIES OF STRATOSPHERIC OZONE

- LITTLE INTEREST IN STRATOSPHERE PRIOR TO 1970

- AFTER 1970:
  - NO\textsubscript{y} FOUND TO CATALYTICALLY DESTROY OZONE (CRUTZEN, 1970)
  - NO\textsubscript{y} EMISSION BY SST FLEETS RECOGNIZED AS A POTENTIAL PROBLEM IN EARLY 1970's (JOHNSTON)
  - CLIMATIC IMPACT ASSESSMENT PROGRAM INITIATED BY DOT
  - Cl\textsubscript{x} FOUND TO CATALYTICALLY DESTROY OZONE (STOLARSKI AND CICERONE, 1974)
  - CFM's FOUND TO BE A SOURCE OF STRATOSPHERIC CHLORINE (MOLINA AND ROWLAND, 1974)
  - ANTARCTIC OZONE HOLE IDENTIFIED (FARMAN et al., 1985)
  - INTERNATIONAL OZONE PROTOCOL ESTABLISHED (1987)

THERE IS CURRENTLY A GREAT CONCERN ABOUT ANTHROPOGENIC ACTIVITIES WHICH MAY IMPACT GLOBAL OZONE.
STRATEGY FOR ASSESSMENT OF HSCT IMPACT ON STRATOSPHERIC OZONE

- SCIENCE CONSIDERATIONS
  - WHAT ARE THE IMPORTANT SCIENTIFIC ISSUES?
  - WHAT ATMOSPHERIC MODELS SHOULD BE USED?
  - HOW WILL THE SCIENCE STUDIES EVOLVE?

- POLICY QUESTIONS
  - HOW SHOULD THE ASSESSMENT BE DONE?
  - WHO SHOULD CARRY OUT THE ASSESSMENT?
  - WHAT SHOULD BE THE ROLE OF THE AIRFRAME CORPORATIONS?
  - WHAT SHOULD BE THE ROLE OF NASA?
WHAT ARE THE SCIENTIFIC ISSUES?

- NO$_y$ AND HO$_x$ CATALYTIC DESTRUCTION OF O$_3$

- IMPORTANCE OF HETEROGENEOUS CHEMISTRY

- EMISSION OF CONDENSATION NUCLEI (CN) AND SUBSEQUENT FORMATION OF STRATOSPHERIC AEROSOLS

- EMISSION OF SO$_2$ WITH THE SUBSEQUENT AEROSOL FORMATION

- EMISSION OF TRACE METALS FROM FUEL ADDITIVES OR FROM ENGINE EROSION

- IMPORTANCE OF SHORT-TERM CHEMISTRY AFTER EMISSION. (DOES NO$_y$ TO HNO$_3$ CONVERSION OCCUR ON A SCALE SMALLER THAN THE MODEL GRID, AND WHAT IS THE EFFECT?)
OZONE PRODUCTION AND CATALYTIC DESTRUCTION DUE TO NO\textsubscript{y} AND HO\textsubscript{x}

- **PRODUCTION**

\[ \text{O}_2 + \text{O} + \text{M} \rightarrow \text{O}_3 + \text{M} \]

- **DESTRUCTION**

- **NO\textsubscript{y}**

\[
\begin{align*}
\text{NO} + \text{O}_3 & \rightarrow \text{NO}_2 + \text{O}_2 \\
\text{NO} + \text{O} & \rightarrow \text{NO} + \text{O}_2 \\
\text{O}_3 + \text{O} & \rightarrow 2\text{O}_2 \quad \text{NET}
\end{align*}
\]

- **HO\textsubscript{x}**

\[
\begin{align*}
\text{OH} + \text{O}_3 & \rightarrow \text{HO}_2 + \text{O}_2 \\
\text{HO}_2 + \text{O}_3 & \rightarrow \text{OH} + 2\text{O}_2 \\
2\text{O}_3 & \rightarrow 3\text{O}_2 \quad \text{NET}
\end{align*}
\]
FIGURE 26. COMPARISON OF TWO-DIMENSIONAL MODEL CALCULATED HNO₃ DISTRIBUTIONS AT THE END OF DECEMBER USING (a) STANDARD CHEMISTRY AND (b) CHEMISTRY WHICH INCLUDES A POSSIBLE HETEROGENEOUS CONVERSION OF N₂O₅ TO HNO₃ (FROM AUSTIN ET AL. 1986).
OZONE LOSS RATES WITH ALTITUDE (WMO, 1986)
1-D CALCULATED STEADY STATE OZONE COLUMN SUM CHANGE DUE TO STRATOSPHERIC AIRCRAFT AND CFM EMISSIONS (WMO, 1986)

CHANGES IN PREDICTIONS HAVE OCCURRED DUE TO:

- REACTION RATE CHANGES
- EXPANDING CHEMISTRY KNOWLEDGE
- DIFFERENT TRANSPORT PARAMETERIZATION (BASED ON DATA)
Chemical Production and Loss of Odd Nitrogen in the Middle Atmosphere (WMO, 1986)

Contours are in units of mol/cm³ - sec
FEBRUARY STRATOSPHERIC CIRCULATION DERIVED FROM SATELLITE DATA

STREAM FUNCTION (x10^-3)

FEBRUARY

≈ 50 km

≈ 30 km
AUGUST STRATOSPHERIC CIRCULATION DERIVED FROM SATELLITE DATA

STREAM FUNCTION ($\times 10^{-8}$)

AUGUST

LATITUDE DEG

POT TEMP DEG

$\approx 50$ km

$\approx 30$ km
INERT TRACER TRANSPORT FROM OPERATING DOMAIN

BOX TRAJECTORIES FORWARD
BEGINNING 3-15

USA - EUROPE
Mach 2

300 days

ALITUDE KM
60.
50.
40.
30.
20.
10.

LATITUDE DEG
-90. -60. -30. 0. 30. 60. 90.
INERT TRACER TRANSPORT FROM OPERATING DOMAIN

BOX TRAJECTORIES FORWARD
BEGINNING 3-15

PACIFIC BASIN
Mach 2

300 days

LATITUDE DEG

ALTITUDE KM

10.  20.  30.  40.  50.  60.

-90. -60. -30. 0. 30. 60. 90.
INERT TRACER TRANSPORT FROM OPERATING DOMAIN

BOX TRAJECTORIES FORWARD
BEGINNING 3-15

PACIFIC BASIN
Mach 4
300 days
HOW SHOULD THE ASSESSMENT BE DONE?

- THE ASSESSMENT SHOULD BE A MULTI-YEAR RESEARCH PROGRAM

- 2-D NO\textsubscript{y} MODEL STUDIES SHOULD BE CONDUCTED
  - CONDUCT STUDIES FOR SPECIFIC ROUTES AND FLEET SIZES
  - CONDUCT PARAMETERIC STUDIES TO DETERMINE OPERATIONAL MODES WHICH MINIMIZE IMPACT ON GLOBAL OZONE

- MULTI-DISCIPLINARY NATIONAL / INTERNATIONAL OVERSIGHT COMMITTEE SHOULD BE ESTABLISHED
  - FORMED BY NASA HEADQUARTERS / OSSA
  - MAKE RECOMMENDATIONS FOR THE STUDY, RAISE ISSUES, IDENTIFY PARTICIPANTS, PROVIDE CREDIBLE GUIDANCE AND APPROVAL
  - WORK PERFORMED AND REPORTED AS PART OF THE BIENNIAL OZONE ASSESSMENT CONDUCTED BY NASA
REFERENCE ATMOSPHERE AND NATURAL VARIABILITY NEED TO BE ESTABLISHED

- DATA SOURCES
  - SATELLITE DATA (e.g. SAGE, SAGE II, SAM II, LIMS, AND ATMOS) NEED TO BE USED TO ESTABLISH ODD NITROGEN AND AEROSOL REFERENCE ATMOSPHERES AND TO DEFINE VARIABILITY OF THESE QUANTITIES
  - DATA NEED TO BE COMPARED WITH PERTURBATION CALCULATIONS

- ODD NITROGEN
  - CURRENTLY THERE IS SOME DISAGREEMENT BETWEEN MODELS AND DATA
  - THERE IS THE POSSIBILITY OF SIGNIFICANT TIME-VARYING MESOSPHERIC AND THERMOSPHERIC SOURCES OF ODD NITROGEN . . . PARTICLE EFFECTS AND AURORAL EFFECTS

- STRATOSPHERIC AEROSOLS
  - LARGE PERTURBATIONS OCCUR DUE TO VOLCANIC ERUPTIONS
  - GLOBAL SCALE MEASUREMENTS AVAILABLE SINCE THE LATE 1970's . . . SAM II, SAGE, AND SAGE II
SME observed ozone depletion on July 13, 1982, at 70° N latitude on the AM and PM portions of the SME orbit (each point represents a mean of three orbits on July 13, 1982, near 1830, 2120, and 2206 UT). Triangles denote data from the UV spectrometer. Model calculated profiles for 2000 and 2200 UT are shown. (From Solomon et al., 1983)
LIMS NIGHTTIME NO\textsubscript{2} MONTHLY ZONAL MEAN PRESSURE VERSUS LATITUDE CROSS SECTION FOR JANUARY 1979.
LANGLEY 3-D MODEL ZONAL MEAN NO$_2$ NIGHTTIME DISTRIBUTION FOR JANUARY 15 (GROSE et al., 1986, LANGLEY RESEARCH CENTER, PRIVATE COMMUNICATION).
Fig. 7 COMPARISON OF LIMS ZONAL MEAN NO$_2$ MEASUREMENTS FOR JANUARY 5-9 WITH SOLOMON AND GARCIA (1983a)
2-D MODEL RESULTS - (a)-60°N, (b)-68°N, (c)-76°N, (d)-84°N
COMPARISON OF LATITUDINAL PROFILES

PRELIMINARY

NO$_2$ COLUMN SUM ($10^5$ MOL/CM$^2$)

LATITUDE (KM)

11/21 TO 12/9/79 .. 20 TO 40 KM

12/22 TO 1/9/85 .. 20 TO 40 KM

12/22 TO 1/9/86 .. 20 TO 40 KM
LIMS H$_2$O MONTHLY ZONAL MEAN MIXING RATIO FOR MAY 1979
2D model calculated H₂O mixing ratio for May (From Stordal et al., 1984)
FIGURE 43. AEROSOL OPTICAL DEPTH AT $\lambda = 1.0 \mu m$ CALCULATED FROM SAM II EXTINCTION PROFILES INTEGRATED FROM THE TROPOPAUSE PLUS 2 km THROUGH THE STRATOSPHERIC AEROSOL LAYER. SAM II ARCTIC DATA ARE AVERAGED OVER 64°N TO 80°N AND THE ANTARCTIC DATA ARE AVERAGED OVER 64°N TO 80°S. NOTED ARE DATES OF VOLCANIC ERUPTIONS KNOWN TO HAVE IMPACTED STRATOSPHERIC AEROSOLS.
WHO SHOULD DO THE INITIAL ASSESSMENTS?*

- **ATMOSPHERIC ENVIRONMENTAL RESEARCH, (AER)**
  - PRINCIPALS ARE DR. DAQ SZE AND DR. MALCOLM KO
  - LONG HISTORY OF ASSESSING EFFECTS OF CO, CH₄, N₂O, CFM's, NOₓ, AND CO₂ ON ATMOSPHERIC OZONE. EARLY SST STUDIES
  - WITH K. K. TUNG, HAVE DEVELOPED A STATE-OF-THE-ART 2-D PHOTOCHEMICAL TRANSPORT MODEL (DIABATIC CIRCULATION)

- **UNIVERSITY OF OSLO**
  - PRINCIPALS ARE DR. IVAR ISAKSEN AND DR. FROUDE STORDAL
  - LONG HISTORY OF ATMOSPHERIC OZONE ASSESSMENT RESEARCH
  - HAVE DEVELOPED ADVANCED 2-D MODEL OF THE TROPOSPHERE AND STRATOSPHERE (DIABATICALLY DRIVEN)

*OTHER SCIENTISTS AND GROUPS WILL BECOME INVOLVED AS RECOMMENDED BY THE OVERSIGHT COMMITTEE.
WHAT SHOULD NASA's ROLE BE?

- Define the Impact Assessment Research Program in collaboration with the Oversight Committee

- Fund the Impact Assessment Studies

- Manage the Impact Assessment Studies with the Oversight Committee

- Collaborate with the Oversight Committee, AER, The Oslo Group, other Scientists, and Corporations in the evaluation of the results and the definition of further studies

- Provide continuing in-house support on an as-needed basis
WHAT SHOULD THE AIRFRAME CORPORATIONS' ROLE BE?

- PROVIDE EMISSION SCENARIOS ON A CONTINUING BASIS

- PARTICIPATE IN DETAILED EVALUATION OF ASSESSMENT CALCULATIONS IN CONJUNCTION WITH NASA, AER, THE OSLO GROUP, AND OTHERS ON A CONTINUING BASIS

- PARTICIPATE IN THE OVERSIGHT COMMITTEE MEETINGS
WHERE DO WE STAND NOW?

- NASA HEADQUARTERS HAS CONCURRED ON GENERAL APPROACH (OSSA AND OAST)
- OAST HAS APPROVED MULTI-YEAR ASSESSMENT PROGRAM
- HEADQUARTERS WILL SELECT OVERSIGHT COMMITTEE
- WE HAVE F.Y. 1987 START-UP MONEY OF $40K
- PRELIMINARY EMISSIONS INPUT RECEIVED FROM BOEING AND MCDONALD DOUGLAS
- CONTRACT IS IN PLACE WITH AER ($40K) AND INITIAL EMISSIONS INFORMATION PROVIDED
- ARRANGEMENTS HAVE BEEN MADE FOR AER TO USE LANGLEY COMPUTERS
- OSLO GROUP HAS VERBALLY AGREED TO PARTICIPATE
- HSCT ACTIVITY WILL BE HIGHLY LEVERAGED . . . CIAP, UARP

\[ \text{Improvements in models, data bases, and physical understanding of processes} \]