Atmospheric Chemistry

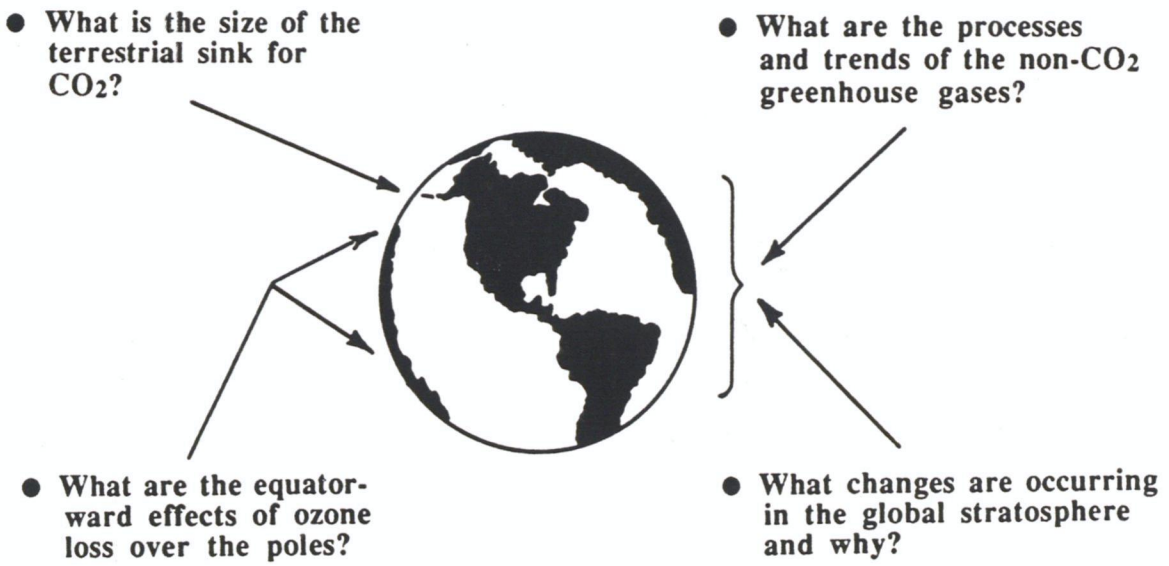
A Coordinated NOAA-Wide and Extramural Core Project Proposal

to the

NOAA
Climate and Global Change
Program

14 September 1990

KEY SCIENTIFIC QUESTIONS:



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Atmospheric Chemistry

A Proposal for a Core Project of NOAA's Climate and Global Change Program

Contents

Summary

- It is planned that an Atmospheric Chemistry Core Project be a part of NOAA's Climate and Global Change Program beginning in FY 1991. This document describes why such a focus is desirable, summarizes its research components, and outlines its management structure.

- Atmospheric chemistry and trace gases enter the global picture in two ways: they are a forcing agent of global change and they are themselves influenced by global change. As a key human-influenced forcing agent, they are at the center of several public policy issues, e.g., stratospheric ozone loss and greenhouse warming. The goal of the Core Project is to enhance that predictive understanding of changes in the stratosphere (e.g., ozone and temperature) and in the troposphere (e.g., methane, halocarbon, and ozone lifetimes and global warming potentials).

- The current predictive understanding linking human behavior and natural processes to trace gas forcing is, in most cases, *inadequate* for policy decisions (e.g., regulation of methane emissions and choosing the upper limits to place on man-made chlorine). Better knowledge of sources, sinks, trends, transformation and transport processes, and models of the system is required.

- Improving such knowledge of trace-gas trends and processes is one of the major goals of the U.S. Global Change Research Program. Under the Biogeochemical Dynamics research element, NOAA is addressing this problem. The Atmospheric Chemistry Core Project is a key element.

- There are several (often-unique) reasons why NOAA is particularly well suited to play an expanding role here: widely acknowledged expertise at the intersection of trace gas and climate phenomena; in-house monitoring, process-oriented, and modeling organizations; oceanic and atmospheric foci, having the needed facilities; and possessing "staying power".

- The existing long-term "core" components of the Atmospheric Chemistry Core project are the Network for the Detection of Stratospheric Change (NDSC) and Radiatively Important Trace Species (RITS) projects. RITS will expand its focus on monitoring (e.g., vertical profiles), chemical processes (e.g., ozone formation and loss), and multidimensional model development, diagnostics, and predictions. The NOAA NDSC focus will be on providing a major NDSC site at Mauna Loa; developing and deploying optical absorption instruments at all sites, and conducting data, theoretical, and satellite analyses of the NDSC observations.

- Two new core research foci will begin at small support levels in FY 1991: (i) an interagency program to understand the equatorward influences of the newly discovered polar ozone-destroying processes and (ii) a tower-based study to sharpen the emerging picture of the role of terrestrial biospheric CO_2 sinks/sources. Complementing the long-term core efforts will be short-term projects focusing on tropospheric trace-gas chemistry.

- The Project has a NOAA-wide and extra-NOAA Core Team that provides the scientific and organizational management. The extramural research will be of two types: (i) "hard-wired" academic components of the long-term core projects and (ii) "open-access" grants that address topics in atmospheric chemistry (e.g., trace-gas biogenic sources and participation in IGBP International Global Atmospheric Chemistry Program projects).

- NOAA's Atmospheric Chemistry Project has strong planning and research bonds with NASA and NSF programs (e.g., polar ozone and global tropospheric chemistry). NOAA's work in helping formulate the U.S. Global Change Research Program has stimulated interactions with other Agencies. Lastly, in climate modeling and ozone campaigns, NOAA has gained considerable experience with the science/policy interface, which is a coin of high value, given the Global Change Program's goal of providing scientific insight to aid policy decisions.

- The atmospheric chemistry component of the C&GC Program was \$0.5M in FY 1989 and \$3.0M in FY 1990. The Atmospheric Chemistry Core Project proposes \$6.3M in FY 1991.

Atmospheric Chemistry
A Core Project of NOAA's Climate and Global Change Program
The Proposed FY 1991 Program

I. OBJECTIVES

The Atmospheric Chemistry Core Project of the NOAA Climate and Global Change (C&GC) Program has two types of objectives: *scientific and organizational.*

Scientific. The Core Project intends to focus global monitoring, process-oriented lab and field studies, and theoretical modeling to help improve the predictive understanding of the atmospheric trace gases that influence the Earth's chemical and radiative balance. In particular, the Core Project will address a *three-component long-term objective:*

- *To define the temporal trends in the global atmospheric distributions of the chemically reactive and infrared-active trace gases*, notably those of methane (CH_4), nitrous oxide (N_2O), tropospheric and stratospheric ozone (O_3), the chlorofluorocarbons (CFCs) and their substitutes, and carbon dioxide (CO_2).

- *To characterize the chemical and physical processes that determine the atmospheric roles of these trace gases*, with emphases on (i) the photochemical sinks for CH_4 and the substitutes for the CFCs and (ii) the production, loss, and transport mechanisms of tropospheric and stratospheric O_3.

- *To model the atmospheric roles and impacts of these trace gases*; namely, (i) to build a diagnostic theoretical framework and assess its representativeness against observations and (ii) to sharpen the prognostic capability for future chemical and climatic change.

Organizational. The Core Project Team intends to enhance the productivity of NOAA's climate and global change research by (i) planning, executing, and fostering NOAA-wide research projects and (ii) by stimulating a more interactive and supportive relation between NOAA and the external science community.

This Proposal describes *why* these objectives should be addressed and *how* the Core Project will approach meeting them.

II. RATIONALE: GLOBAL ATMOSPHERIC CHEMISTRY AND PUBLIC POLICY

The atmospheric trace gases are woven into the fabric of several key aspects of the Earth system, as well as being threaded through several of the policy issues now confronting governments and industry:

Greenhouse Forcing. There is ample evidence that not only CO_2, but also other infrared-active species are accumulating in the atmosphere. It is estimated that, just in recent decades, the global greenhouse forcing from these other species has now become comparable to that predicted for CO_2. Since there is considerable scientific evidence that a global warming could have disruptive consequences world-wide, it is imperative that the natural and human-influenced

processes and the climatic consequences of *all* of the radiatively important trace species be understood.

Global Chemical Change. Many of these species are also photochemically active (e.g., O_3 and CH_4) and play key roles in stratospheric and global tropospheric chemistry. Ozone, for example, (i) is the planet's *ultraviolet shield* in the stratosphere, (ii) is infrared active, hence a greenhouse gas near the tropopause, and (iii) is a prerequisite for the chemical processes that can partially destroy other greenhouse gases in the troposphere (i.e., its *assimilative capacity*). All three roles are linked to both natural processes (e.g., stratospheric subsidence) and human influences (e.g., ozone-destroying and ozone-producing pollutants). Realistic predictions of human perturbations require a fundamental understanding of the natural system and the processes whereby human activity couples to it.

Public Policy. Policy makers rightly ask scientists to predict the responses of the planet to various scenarios of human-induced trace-gas forcings, since these "options" are the basis of their decisions regarding the public welfare. Indeed, the improvement of such predictions is the ultimate goal of the U.S. Global Change Research Program, of which NOAA's C&GC Program is a part. The major chemical components of that need are the ability to predict (i) changes in the stratospheric ozone layer, (ii) the abundances of the greenhouse gases, and (iii) the chemical fate of man-made compounds. At present, the future trends of CH_4, N_2O, and tropospheric O_3 *cannot* be predicted reliably, since the controlling processes are not sufficiently well understood. Hence, current scientific uncertainties pose obstacles to the formulation of fully effective control strategies (e.g., the U.S.'s current work on a "comparative index" among trace gases as a basis for "emissions trading"). NOAA's Atmospheric Chemistry Core Project is intended to contribute to changing this "extrapolative" situation into a "predictive" one.

III. SCIENTIFIC BACKGROUND AND RESEARCH PROGRAM

The two ongoing "flagship" components of the Atmospheric Chemistry Core Project are (i) the Network for the Detection of Stratospheric Change (NDSC) and (ii) the NOAA Radiatively Important Trace Species Program (RITS). While these two programs have their roots in the long-standing atmospheric research of some of the NOAA Laboratories, they were formulated explicitly over the past few years as multiple-Laboratory, NOAA-wide, inter-Agency, extramural, and international programs (and indeed were among the first such programs in NOAA). The NOAA support for the NDSC began with the first year of the C&GC Program, i.e., FY 1989. The RITS augmentation followed in FY 1990.

The Atmospheric Chemistry Core Project proposes not only to strengthen these two components in FY 1991, but also to begin components will address two emerging problems in global atmospheric chemistry and that are appropriate to NOAA's expertise and C&GC goals: the "new relations" between (i) humans and the stratosphere and between (ii) CO_2 and the terrestrial biosphere.

In this section of the Proposal, the plans for the NDSC and RITS augmentations and for the two new components are briefly summarized in sequence.

A. The Network for the Detection of Stratospheric Change (NDSC)

1. Goals

There exists mounting evidence that the Earth's stratospheric ozone layer is changing on a nearly global scale. Although the most pronounced decreases are presently limited in geographic

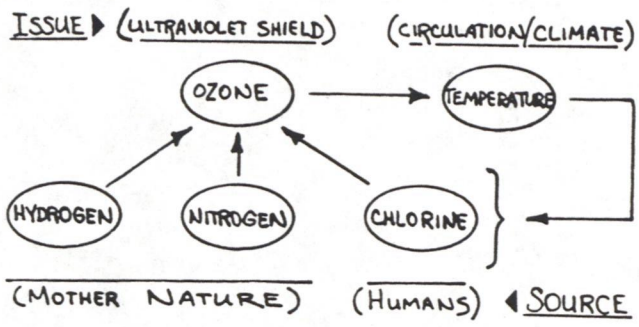
extent to certain latitudes and exhibit significant seasonal variability, the findings have sparked intense scientific interest in a worldwide network for the measurement of stratospheric change. The NDSC is a planned set of state-of-the-art, remote-sensing research stations for observing and understanding the physical and chemical state of the stratosphere, complemented by secondary stations and satellite measurements. The goals of the NDSC are threefold:

- To make the time-series observations through which changes in the physical and chemical state of the stratosphere can be determined and understood, with an emphasis on making the earliest possible identification of changes in the ozone layer and to discern the cause of the changes.

- To provide an independent calibration of satellite sensors of the atmosphere.

- To obtain the data that can be used to test and improve multidimensional stratospheric chemical and dynamical models.

2. *Scientific Background and Relevance*



Total O_3 has been measured at a few dozen stations worldwide since the International Geophysical Year (IGY) in 1957. The importance of such long-term measurements was dramatically illustrated through the discovery of the Antarctic ozone hole by scientists from the British Antarctic Survey based on three decades of total ozone measurements at Halley Bay, Antarctica. However, due to the paucity of ancillary measurements (e.g., observations of chemical constituents within the NO_x and ClO_x families and accurate temperature data), the cause of the Antarctic ozone hole could not be immediately identified following its discovery. Several candidate theories emerged. Discrimination between them required field campaigns aimed at measuring not just ozone alone, but also a broad range of the chemical species and physical parameters that can influence stratospheric ozone. Furthermore, while satellite systems have afforded a global view of the ozone layer, the need for unequivocal and independent calibration of the onboard sensors is now widely recognized as a critical problem in the unequivocal determination of long-term trends.

In spite of current international controls on CFC emissions, the need to monitor and understand the stratosphere remains pressing both to national and international programs. Considerable scientific doubt currently exists as to the successful compliance with global emission standards. Further, as the CFCs are phased out, it is anticipated that their substitutes, the hydrochlorofluorocarbons (HCFCs) will be used in greatly increased quantities. While the HCFCs are likely to be far less damaging to the ozone layer than the CFCs, there are large uncertainties in present predictions of their ozone depletion potentials. In addition, there are policy-related scientific questions associated with other stratospheric changes, such as increasing CO_2 content and predicted stratospheric cooling.

3. Readiness

These questions, spurred in part by the observation and understanding of Antarctic ozone depletion, as well as considerable advances in the technology required to measure other

stratospheric species from the ground, suggested that the time to assemble a more detailed stratospheric monitoring program was at hand. Indeed, the notion of a ground-based, long-term measuring network specifically designed to provide the earliest possible detection and understanding of changes in the composition and structure of the stratosphere began to assume both increased urgency and increased practicality. The plans for sites and instrumentation were developed through a series of international meetings of interested scientists, who considered the scientific readiness of available techniques for stratospheric measurements, their scientific priority, and other planned activities being carried out under different frameworks (e.g., the Dobson network, satellite systems, and the global network for trace-gas sampling) [*NDSC*, 1986, 1990].

4. Current and Proposed NDSC Research

(a) *Current status and NOAA role*

Instruments. The planned primary instruments and measurements are:

- *Ozone lidar* (vertical profiles of ozone from the tropopause to at least 40 km altitude; in some cases tropospheric ozone will also be measured)
- *Temperature lidar* (vertical profiles of temperature from about 30 to 80 km)
- *Aerosol lidar* (vertical profiles of aerosol optical depth in the lower stratosphere)
- *Ozone microwave* (vertical profiles of ozone from about 20 to 70 km)
- *H_2O microwave* (vertical profiles of water vapor from about 20 to 80 km)
- *ClO microwave* (vertical profiles of ClO from about 25 to 45 km, depending on latitude)
- *Ultraviolet/visible spectrograph* (column abundances of ozone, NO_2, and, at some latitudes, OClO and BrO)
- *Fourier transform infrared spectrometer* (column abundances of a broad range of species including ozone, HCl, NO, NO_2, $ClONO_2$ and HNO_3)

Sites. Depending on specific site characteristics (i.e., geography and meteorology), each primary NDSC station will be equipped with most of the above instruments and may also have some additional ancillary measurement capabilities. Important scientific information may also be collected at other sites with partial instrument complements. Ultimately, primary sites are planned for at least six locations: high latitudes in the northern hemisphere (tentatively planned as a combination of both Resolute, Canada and Thule, Greenland), mid-latitudes in the northern hemisphere (made up of several Alpine locations, including Haute-Provence, France and the Jungfraujoch, Switzerland), subtropics in the northern hemisphere (Mauna Loa, Hawaii, USA), tropics (to be determined), midlatitudes in the southern hemisphere (tentatively Lauder, New Zealand), and high latitudes in the southern hemisphere (in Antarctica).

NOAA areas of emphasis. The following initial components have been developed as a part of the NOAA Climate and Global Change Program:

- *Establish Mauna Loa Observatory as an NDSC site.* OAR Climate Monitoring and Diagnostics Laboratory will upgrade the basic site facilities, construct a new building, and improve the correlative measurements at the northern hemisphere sub-tropical site.

- *Develop and deploy vis/UV absorption spectrographs.* OAR Aeronomy Laboratory is designing and constructing an improved version of the instrument/method that has operated successfully in stratospheric field campaigns over the past five years. Production versions will be

deployed at the NDSC sites.

• *Initiate data handling/analytical capabilities.* NWS Climate Analysis Center is developing personnel, computing and analysis capabilities that will put the forthcoming NDSC data into a synoptic context. They have also taken on the responsibility of playing a major role in hosting the initial data set, establishing the data basing, and providing the data to the NDSC scientists.

• *Develop satellite accuracy assessments.* NESDIS Satellite Research Laboratory is preparing to use the NDSC data as independent calibration for its satellites, e.g., the O_3 and temperature data.

• *Improve network design via model analyses.* OAR Geophysical Fluid Dynamics Laboratory is simulating circulation patterns and trace-constituent behavior with multidimensional models to provide estimates of the optimum-information content for NDSC siting and sampling procedures.

(b) Proposed FY 1991 NOAA Activities

• Construct the NDSC station at Mauna Loa. While some sites are nearly ready for operation, others have yet to be constructed. Scientific, architectural, and engineering planning and design will be completed. The construction contract will be let in the middle of FY 1991. Construction will start in the latter part of the calender year.

• Complete the construction of the visible/UV instruments for the initial NDSC sites. The first complete NDSC site will be the Alpine station in Europe, scheduled to receive a full complement of instruments in 1991. The initial deployment of the first NOAA visible/UV spectrometer system will be there for an intercomparison campaign. The second deployment will be at the Mauna Loa site.

• Develop models and data analysis procedures for the NDSC data. Although the major goal of the NDSC is the long-term one of detecting and understanding stratospheric changes, the network will provide extremely valuable short-term scientific returns as well, including studying the temporal (diurnal, monthly, seasonal, and annual) and spatial (latitudinal) variability of atmospheric composition and structure. Such data are badly needed to compare to theoretical models in order to develop improvements and enhance understanding, particularly of latitudinal gradients.

• Conduct correlative studies with satellite temperature and ozone data. The NDSC is expected to provide important correlative measurements for satellite systems such as the NASA Upper Atmosphere Research Satellite (UARS), scheduled for launch in the fall of 1991, as well as the Total Ozone Mapping Spectrometer (TOMS), the Solar Backscatter Ultra-Violet (SBUV) ozone monitoring instruments, and operational temperature sensors. Two focused investigations will prepare the way to using NDSC data for these purposes. First, NOAA will sponsor a rigorous intercomparison of the techniques by which temperature calibration is provided for satellite data fields. Second, the newly recognized zenith-angle problem associated with satellite ozone data will be addressed.

5. Benefits

The policy-relevant scientific benefits to be gained from the NDSC are numerous. The Network can help resolve the following issues.

• Column ozone controls the penetration of solar ultraviolet radiation to the Earth's surface. Better definition of the changes in column ozone will help elucidate the consequences for human health and terrestrial and oceanic ecosystems.

- The vertical distribution of ozone controls the temperature structure and hence plays an important role in the circulation of the stratosphere. A better understanding of changes in the vertical distribution of ozone will help characterize the climatic effect on the stratosphere and the upper troposphere.

- The temperature of the stratosphere controls the rates of chemical reactions. Thus, better monitoring of the temperature will yield more knowledge of the catalytic efficiencies of the different chemical families in controlling the abundance of ozone.

- The ClO radical is the chlorine species responsible for directly catalyzing the destruction of ozone. Its atmospheric concentration was predicted to be increasing at a rate of at least 5% per year in 1986 due to the increasing atmospheric concentrations of CFCs.

- Water vapor plays a vital role in controlling the radiative and chemical balance of the stratosphere. It is the dominant source for the hydroxyl radical (OH), which controls the ozone-regulating efficiencies of the HO_x, NO_x and ClO_x families. The concentration of stratospheric water vapor may be increasing due to increasing concentrations of atmospheric methane or increased water vapor exchange across the tropopause.

- Aerosols are likely to become important both chemically and radiatively, following major volcanic eruptions, and in the Antarctic. In addition, the presence of high levels of aerosols can influence the interpretation of some optical sensor data.

- NO_2 is the nitrogen species directly responsible for the catalytic control of ozone plays a vital role in coupling the NO_x and ClO_x families. Consequently, the atmospheric concentration of NO_2 may decrease in the future because the predicted increased concentrations of ClO will convert it into $ClONO_2$. Conversely, increases in the concentration of N_2O act to produce more NO_2.

- HCl is the key temporary reservoir species in the ClO_x family. It should be monitored in conjunction with ClO to determine how the partitioning of species within the chlorine family is changing with time.

- CH_4 and N_2O are the gases with long stratospheric lifetimes and quite simple photochemical removal mechanisms: photolysis for N_2O, and reaction with OH for CH_4. This makes them ideal tracers for studying atmospheric circulation and evaluating transport models.

- Measurements of several other chemical species would also provide important information on changes in the composition of the stratosphere. These include $ClONO_2$, HNO_3, and CF_2Cl_2.

- Rigorous ground truth for satellite sensors will allow their global coverage to be exploited for worldwide trends.

B. Radiatively Important Trace Gases (RITS)

1. Goal

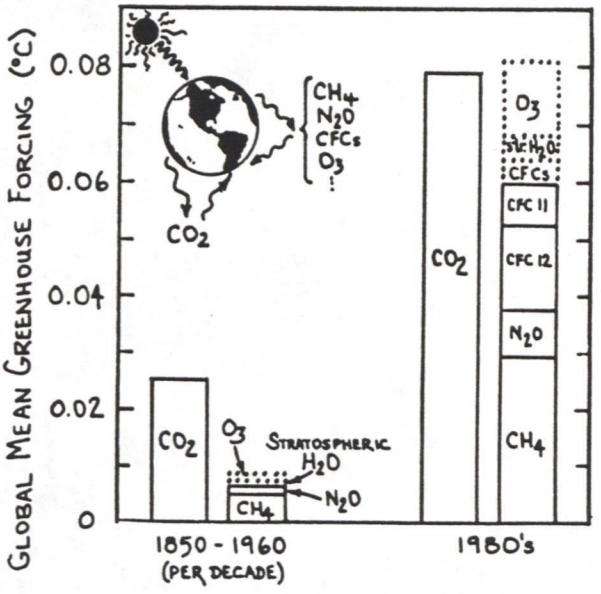
In the early 1980's, NOAA began devoting increasing attention to the greenhouse role of the non-CO_2 trace gases. The overall goal of the resulting RITS Program is

o To contribute to monitoring, understanding, and prediction of the environmental consequences of the non-CO2 gases, with an emphasis on CH_4, CFCs, HCFCs, N_2O, and tropospheric ozone.

2. Scientific Background and Relevance

The non-CO_2 trace gases of prime radiative importance are methane, nitrous oxide, tropospheric ozone, and the halocarbons. Their contribution to radiative forcing is estimated to be currently equal to that of CO_2.

Methane. Current atmospheric concentrations of CH_4 are double the pre-industrial values. Indeed, ice-core data reveal that today's CH_4 abundances are higher than anytime in the past 160,000 years. While it is clear that these concentrations are now increasing at a rate of 0.8 - 1.0% per year, the sources responsible are not quantified. Qualitatively, the likely activities are rice cultivation, domestic ruminants, biomass burning, coal mining, and industrial venting and leakage. The major process for removal of CH_4 from the atmosphere is oxidation by the hydroxyl radical (OH). However, the sources and sinks of OH, hence its trends, are poorly understood. Furthermore, there is still significant uncertainty in the CH_4 oxidation and reaction pathways, particularly at the lower temperatures around the tropopause.



Nitrous Oxide. Atmospheric abundances of N_2O are about 8% higher now than in pre-industrial times, and the growth continues at 0.2 - 0.3% per year. While the sink of N_2O is adequately quantified (photochemical removal in the stratosphere), the identification and quantification of the natural and man-made sources have proven difficult, as has the reason for the increase.

Tropospheric Ozone. Reanalyzed historic data from the late-1800s suggest that near-surface O_3 in Europe has increased by perhaps a factor of three over the past century, while limited contemporary measurements support increases of 1 - 2% per year in the 0 - 8 km region in the Northern Hemisphere. A large fraction of tropospheric O_3 is produced and removed photochemically, notably by reactions involving the nitrogen oxides (NO_x), carbon monoxide (CO), CH_4, and the nonmethane hydrocarbons (NMHCs). Thus, the trends of tropospheric O_3 depend on the source distributions and the growth of these pollutants, as well as the mechanisms of the chemical transformations involved. None of these factors are currently known well enough to provide a quantitative match of observations with predictions or to provide a predictive link between human activities and changes in this greenhouse gas.

Halocarbons. The sources and sinks of chlorofluorocarbons (CFCs) are crystal clear, as a consequence of learning in 1974 that chlorine can deplete the stratospheric O_3 layer and of the ensuing research. The CFCs are solely man-made chlorine-containing molecules, and their only significant atmospheric loss is photolytically driven breakup in the stratosphere. International protocols are now limiting their emissions and encouraging their replacement. The search for environmentally safe CFC replacements requires knowledge of their atmospheric lifetimes, infrared characteristics, and identity and fates of their oxidation products. Although there is enough

information for a preliminary screening, a world commitment to eliminate the CFCs because of their ozone-depletion and greenhouse roles requires better scientific assurance regarding the safety of the replacements. Hence, the trends and atmospheric roles of these emerging substitutes require attention by the atmospheric chemistry community.

The gaps in understanding noted above imply several general areas of needed research:

Better long-term observations of the trends of these species. For CH_4 and N_2O, the monitoring focus should be on information that could aid regional source/sink identification and quantification, such as spatial gradients and temporal variances. With such data, model techniques can estimate regional fluxes. For tropospheric O_3 and the HCFCs, the need is more basic. A better or new monitoring program must be started, e.g., defining the growth rates in the northern and southern hemispheres.

A more-quantitative understanding of sources, sinks, and transport processes. Regional production and loss rates (i.e., fluxes into and out of the troposphere and in-situ production/loss mechanisms) are the immediate goals, coupled with a first-order characterization of the processes (e.g., biochemistry, photochemistry, and transport) that control these rates. Research examples are (i) field campaigns in a variety of global regions that measure a sufficient breadth of chemical species to constrain (hence assess) theoretical chemical/transport models and (ii) laboratory studies to characterize specific processes (e.g., tropospheric chemical transformations of the HCFCs). Such investigations will lead to a good understanding for specific sites, which will have to be expanded in the longer term to larger-area campaigns with aircraft and remote-sensing devices. Lastly, a better grasp of the net global photochemical production and loss of O_3 (i.e., the "budget" and its trends) will hinge on obtaining more extensive global distributions of precursors such as NO_x, whose relatively short atmospheric lifetime likely makes it a rate-limiting species, particularly in the large expanses of remote regions.

Models with a broader representation of trace-gas processes. With species like (i) O_3, whose global role depends on photochemical and transport processes ranging from the boundary layer to the global scale, and like (ii) CH_4, which has both a stratospheric and tropospheric loss, it is clear that a *hierarchy* of multidimensional (physical and chemical) models must be the strategy for coming years.

3. Readiness

The coordinated NOAA RITS Program was established in 1985 [*RITS*, 1985]. It's plans for expansion under the C&GC Program was approved as part of the NOAA budget process for FY 1989; however, OMB blocked RITS and other research-oriented initiatives for NOAA in that year. The research summarized below did not start until mid-FY 1990. Thus, the research planning, instruments, investigators, and new projects had been in a state of readiness for over a year, but had been on hold. Additional details are in the FY 1990/91 proposal [*RITS*, 1990]. Coordinated RITS planning with international research activities have progressed through several stages with workshops and documented plans [IGAC, 1989], which are described in Sec. V-B below.

4. Current and Proposed RITS Research

(a) Current RITS Research

The following summary gives the research projects that have contributed to RITS during the initial years:

Long-Term Global Monitoring: Initiation of continuous surface-level monitoring at NOAA's four baseline global observatories with on-site gas chromatographs for the long-lived gases and CO and collaboration with the university-based Global Atmospheric Gases Experiment (GAGE) at the Samoa site. Development of a ground-based lidar instrument for continuously monitoring tropospheric O_3. Establishment of a well-resolved surface-level monitoring network for CH_4 using flask sampling, in collaboration with university and Australian counterparts. Use of NOAA research vessels and ships of opportunity to provide detailed latitudinal, seasonal, and interannual variations of the infrared-active trace gases, as well as the coordination of their use by other institutions.

Photochemical Process Studies: Development of techniques and instruments capable of remote-area global measurements (e.g., NO_x) in collaboration with NCAR and the sharing of instrument designs with other NOAA (e.g., Atlantic Oceanographic and Meteorological Laboratory) and academic (e.g., Harvard) labs. Conducted or participated in instrumentation intercomparison experiments (e.g., NO_x) involving multiple organizations. Developing a long-path laser-absorption technique to measure OH in the planetary boundary layer (PBL) at Fritz Peak Observatory, CO. Design and construction of a flow reactor with photoionization/mass-spectrometer detection for hydrocarbon reaction studies. Carrying out integrated campaigns that focus on the processes that form or destroy O_3 in a variety of chemical regimes, e.g. Mauna Loa Observatory - (remote) and Colorado mountains - (clean continental).

Photochemical and Dynamical Modeling: Estimation of the major contributions to photochemical O_3 production/loss in the above regions to guide field studies and provide initial estimates of the O_3 budget. Use of General Circulation Model (GCM) simulations to aid the design of the desired network for trace-gas measurements and to investigate the global transport and chemistry of O_3 and NO_x.

(b) Proposed New Research

Several FY 1990 and 1991 RITS new starts are proposed as NOAA's contribution to addressing the gaps in understanding described in Sec. III-A above. These are grouped here under the three objectives of RITS. Linking features are also noted. Since this document describes a coordinated multi-Laboratory and university-supported program, there is space here to only highlight the main features.

> Long-Term Global Observations

Expand the surface-level monitoring of CH_4, N_2O, CFCs, and other longer-lived trace gases by beginning regular sampling of the vertical profile into the mid-troposphere. The sampling will be done by a flask/manifold system to be carried within a small airplane. The planned frequency is once per week, which would capture a substantial fraction of the variance at these altitudes predicted by the GFDL models.

Institute a standards program for CH_4 and the CFC replacements. As CH_4 time-series data become more detailed and atmospheric implications begin to be interpreted from these details, it is important to be able to rule out effects due to different calibration standards or measurement approaches. It is proposed to augment the existing CMDL standards to include CH_4 and the CFC replacements, since the atmospheric growth of these new compounds will be important to both science and public policy.

Begin regular tropospheric O_3 profiles. The "concept" version of the tropospheric O_3 lidar designed and constructed at Fritz Peak Observatory in Colorado is now capable of making profile

measurements from the surface up to 10 km several times per hour during day and night. Completion of the original prototype design (e.g., laser wavelength trackers and larger telescope) will extend the range, frequency, and accuracy of measurements and operations will begin.

> Photochemical Process Studies

Characterize the chemical formation of O_3 and the transport of O_3 and its precursors from the continental planetary boundary layer. To focus on the continental source of global tropospheric O_3 formation, the production of O_3 and escape of O_3 and precursors from the Eastern PBL will be investigated. In 1991, the understanding of O_3 production in relatively stable air masses will be tested at an Atlantic island site, like Bermuda, which is sufficiently close to reveal oxidation products. The study will be complementary to NSF's particulate-focused network in the Atlantic, coordinated by the University of Miami.

O_3 distributions and processes in the marine boundary layer. These shipboard studies will focus on the O_3 minima found earlier in the equatorial Pacific, which may confirm inferences (e.g., in the Atlantic) that suggest a net O_3 destruction in the marine boundary layer.

Laboratory studies on degradation of CH_4, NMHC, and HCFCs. The focus will be on CH_4 and HCFCs. For example, the rate coefficients and temperature dependencies for the reactions of OH with CH_4 and isotopically labeled CH_4 will be measured. These data will quantify the rate of methane removal from the troposphere and help identify the sources of CH_4, i.e., man-made or natural.

> Dynamical and Photochemical Modeling Studies

Photochemical model studies. New diagnostic modeling investigations will focus on understanding the basic photochemical processes that control the sources and sinks of O_3 and the atmospheric sinks of CH_4, NMHCs, and HCFCs.

Global radiative/chemical/transport modeling. A series of 3-D model investigations will begin on the global chemistry and transport of tropospheric reactive nitrogen (NO_y). In collaboration with the Georgia Institute of Technology, systematic numerical studies will be undertaken to delineate the relative contributions of sources from combustion, biomass burning, biogenic activities, lightning, and stratospheric injection to the regional NO_y structures and budgets throughout the global troposphere.

4. Benefits

The major policy-oriented benefits to be gained from RITS are the following:

- The trends of the atmospheric abundance of the CFCs will reveal whether the results of the international protocols are as expected.

- The trends of the HCFCs will show whether their growth is consistent with expectations.

- A better realization of the chemical removal of CH_4 and HCFCs will assist in determining source strengths and greenhouse warming potentials, on which policy choices will be made.

- A better understanding of tropospheric ozone will aid in predicting how this radiatively and chemically important trace species may respond as a result of the Clean Air Act Amendments.

• A better quantification of the roles of the radiatively and chemically active gases will improve predictions of future climate changes.

C. Emerging New FY 1991 Components

The Core Project will initiate two new long-term research components in FY 1991 that (i) are already clearly visible on the horizons of scientific and policy needs and (ii) are acknowledged areas of NOAA expertise. The overall scientific need, policy benefits, and the major characteristics are given below. Since these are small initial FY 1991 starts of component that are planned to expand in later years, they are summarized in a briefer form than the above major components.

1. *"Forecasting" the Stratosphere of the 21st Century*

Even with the progress in policies to protect the stratospheric ozone layer, an unresolved issue and an emerging issue face science and governments:

(a) *Polar Ozone/Chlorine and Mankind*

Scientific background and rationale. The chlorine content of the present stratosphere is about 3 ppb (parts chlorine per 10^9 parts air), compared to the natural abundance of 0.7 ppb of several decades ago, which is one of the most graphic examples of the heavy chemical hand of mankind. But the picture will get worse. Even if the countries of the world decide to stop all man-made chlorine emission as soon as possible under the U.N. Montreal Protocol, (i) the chlorine abundance will still likely reach 4 - 5 ppb by the turn of the century, (ii) the content will not drop to 2 - 3 ppb for about 75 years, and (iii) the return to natural levels lies centuries away. *Should we be worried about this state of affairs, or have policy makers saved the ozone layer?* Two observations are relevant:

o *Humans have created a new global feature, the Antarctic ozone "hole", that likely will be with us for about a century.* While we think we know how we did it, we cannot yet forecast the consequences of our creation. There are several open questions:
  - What does a century of seasonal ozone losses imply for the effects of ultraviolet radiation on Antarctic fauna?
  - What are the climatological implications (temperature and circulation patterns)?
  - How much does the ozone hole "leak", i.e., what are the implications for nearby countries like New Zealand?

o *The peak chlorine levels of 5 - 6 ppb will exist for at least a decade.* We were caught unaware by the appearance of the Antarctic ozone hole at about 2 ppb some years ago. How confident are we that there are no surprises in store in the 3 - 6 ppb range?
  - What will be the amount and frequency of springtime ozone loss in the Arctic?
  - Are the recently observed, but currently unexplained, downward trends in the mid-NH latitudes dues to an Arctic "processor"?
  - With ozone loss linked to stratospheric ice particles (and hence temperature and climate), what does the climate variation of the next century imply for ozone loss?

As the dialogue between science and public policy continues to mature, scientists will be asked these questions. Furthermore, since NOAA played major roles in providing many of the answers over the past four years regarding the Antarctic ozone "hole", those forthcoming questions will be posed, in part, to *us*. With a *stratospheric-process* component (complementing the NDSC trends determinations) in the Atmospheric Chemistry Core Project, the NOAA C&GC Program will be better prepared to answer them.

Proposed FY 1991 tasks. A NASA, NOAA, and university steering group recently has outlined the polar ozone science needs for the coming years. These include a broader instrumental ability to characterize the chemical processes involved and field campaigns in 1991/1992 to investigate the equatorward influences of the Arctic and Antarctic dynamical/chemical vortices. As part of the NOAA component, the FY 1991 C&GC thrusts will be helping (i) to develop improved chemical analyses of polar stratospheric cloud particles (which initiate the perturbed chemistry), (ii) to support the planning activities of the NOAA Mission Scientist for the Antarctic campaign, and (iii) to assist NOAA to provide the computing and telecommunication support for the field campaign.

(b) *Aircraft and Stratospheric Change: Revisited*

Scientific background and rationale. Furthermore, with the awareness of the surprise of the Antarctic ozone hole, science must better anticipate new or additional threats to stratospheric ozone. These threats may come from the effects of gradual increases in tropospheric trace gases or more straightforwardly from emissions directly into the stratosphere. Emissions could come from proposed high speed civil transport (HSCT) aircraft which would travel at supersonic speeds in the low to mid stratosphere. New materials and propulsion systems and the market demand for air travel may make such transport economically viable in the next decades. Nitrogen oxides from the emissions of HSCT's in the stratosphere can act as catalysts in the destruction of ozone. In order to make balanced policy decisions for the use of such aircraft on a global scale, knowledge of microscale processes in the exhaust plume of such aircraft and of mesoscale effects in flight corridors may be required. NASA is taking the lead in organizing these effects studies, but will depend on the expertise in NOAA for measurements of key species such as NO_x, H_2O, and O_3 and for the interpretation of the data acquired. Through the C&GC Program, NOAA plans join as a partner in this endeavor, beginning in FY 1991.

Proposed FY 1991 task. The key initial NOAA role will be to provide improved chemical measurements of potential perturbations in the Northern Hemisphere aircraft corridor. The FY 1991 task will be the support of a community-wide planning meeting in late 1990.

2. *CO_2 Revisited*

Scientific background and rationale. The NOAA initiatives of the past few years have focused on augmenting the non-CO_2 trace-gas research, so that the climate role of these gases can be more on par with that developed for CO_2 over the past two decades (e.g., RITS). This was not to say that all important CO_2 problems have been answered. There are other questions: Can the new picture emerging for CO_2 uptake by the terrestrial biosphere be better quantified? Can higher-resolution measurements of CO_2 abundance and variance, when coupled with model techniques, give useful regional source/sink estimates? The recent IPCC Scientific Assessment of Climate Change underscored these questions. The current international movement toward a future Framework Convention on Climate Change implies that science will be asked for answers to these questions as the scientific support for various trace-gas strategies is delineated. NOAA's Atmospheric Chemistry Core Project proposes to help being better position to answer them, particularly since these questions are strongly related to NOAA expertise.

Proposed FY 1991 tasks. The proposed FY 1991 task addresses the question of the terrestrial biospheric sink of CO_2. The key approach will be tower measurements at a continental site. The aim is to be removed from immediate sources and sinks, but not as far as 2000 km onto the ocean, as is the case of CO_2 monitoring at present. The height averages of the terrestrial concentrations can be compared with those over the ocean, with the help of three-dimensional models to yield first-order estimates of the relative source strengths. If the tower is located in a

relatively uniform area, changes in the column amount will be a good measure of the diurnal photosynthesis-respiration cycle of the ecosystem upwind of the site. Good candidates exist: 20 privately owned towers of 600-m height in rural areas have been located. An important research aspect is that the vigor of the biospheric cycle can (and should) be correlated with solar radiation, precipitation, temperature, and other variables of biological importance. These would provide the first such volume-averaged data of this type. Other Agencies (e.g., DOE) has expressed wishes to join NOAA in the continental site development.

IV. MANAGEMENT METHODOLOGY

A. Proposed Areas of Emphasis

The Atmospheric Chemistry Project Manager and Core Team will emphasize five themes in their management structure and approach:

- Recognizing the pressing scientific uncertainties in the atmospheric chemistry of global change.

- Identifying those science needs to which NOAA can contribute with a high probability of quality results, followed be the stimulating and assisting with the preparation of research strategies to address them.

- Establishing proposal procedures that balance the required long-term approaches and the necessary emergence of new ideas, assuring that these procedures are homogeneous across NOAA and the extramural components.

- Fostering plans and research that synergistically use the complementary strengths of (i) the different Line Organizations of NOAA and (ii) the NOAA labs and academia.

- Working to integrate the NOAA research into national and international programs.

Examples of how the Core Project will (and has) addressed these rather formidable challenges are given in the following sections.

B. Scientific Steering and Oversight Mechanisms

1. Core Team

The Core Project Team is the primary entity that provides the scientific direction, research approaches, allocation of Core funds, etc. Their actions are reviewed via the Core Proposal, as described in Sec. IV-C below. The Core Team will consist of NOAA and non-NOAA scientists.

- NOAA: Daniel L. Albritton - Project Manager (OAR), Eldon E. Ferguson (OAR), Jerry D. Mahlman (OAR), Alvin J. Miller (NWS), and Walter G. Planet (NESDIS). These individual bring to the enterprise (i) the expertise and research flavors of their institutions (i.e., process-oriented studies, trace-gas and aerosol monitoring, theory and modeling, meteorological and trend analyses, and satellite-oriented studies); (ii) involvement with the broad scientific community, both nationally and internationally; and (iii) experience with the needs of policy makers regarding scientific information on which decisions on public welfare can be based.

- Non-NOAA: The Core Team will add 2 to 4 non-NOAA members. In many respects, such non NOAA scientists have already played such a steering role for the Atmospheric Chemistry Core Project, because both RITS and NDSC have had either ad-hoc (RITS) or standing (NDSC - see following section) advisory groups. After the Board and Panel review of this proposal, non-

NOAA members will be invited to be a part of the Core Team. They will be involved, for example, in the recommendation of research topics for the FY 1991 C&GC Grants Announcement (see Sec. IV-C and D below).

OAR's Program Development and Coordination staff will assist the liaisons with NOAA Line Organizations. James Todd of the Office of Global Programs will assist the liaison with the C&GC Program.

2. NDSC Steering Committee

Like the Tropical Ocean Global Atmosphere Program, which was functioning as a program before the C&GC Program emerged, the NDSC also existed as an entity. Briefly, the NDSC is governed by a Steering Committee chaired by M. J. Kurylo of NASA and R. A. Cox of the National Environmental Research Council of the United Kingdom. Steering Committee members include representatives from NASA and NOAA, the Science Team, and other laboratories and universities worldwide. Thus, the NDSC steering committee is a truly international group with broad-ranging representation. Roughly half of the members of the Steering Committee are "peers" intended to serve as a standing group of outside reviewers of the Network (much like the NOAA C&GC's Panel). The Steering Committee is the primary governing body of the NDSC and has the responsibility for such issues as scientific oversight, site selection, instrument and PI selection, and diverse problems including data quality, tardiness in data reporting, etc.

C. Procedures for Proposal Solicitation, Review, and Selection

The general features of the proposal procedures of the Core Project will be the following:

1. Core Proposal

The Core Proposal is viewed as the current "charter" of the Project, one that reflects the directions established by the Core Team and one that will be subject to reviews. Those reviews will be of three types: (i) C&GC Board of Directors (e.g., NOAA Line Organization input), (ii) NOAA C&GC Advisory Panel (e.g., community-wide scientific input), and (iii) Core-Project Program reviews (e.g., scientific specialist input). The first two are modeled after established C&GC procedures. An example of the third type is the scientific review of the RITS program that is scheduled for mid-1991.

The Core Team will provide an updated Core Proposal (or suitable amended materials) to the C&GC Program Office each year in late-summer. The aim is to complete the review of the Core Project research directions in time for allocation of initial funds early in the fiscal year. In addition to research directions, the Proposal will also inventory the past balance and plan the future balance of (i) long-term vis-a'-vis short-term projects (see Sec. IV-D below) and (ii) NOAA and extramural research (see Sec. IV-E below).

2. Open-Access Proposals

There will be an "open-access" component of the Atmospheric Chemistry research via a proposal process (see Sec. IV-E below) whose procedures will involve two Core-Team actions:

- The Core Team will provide to the C&GC Program Office during the mid-Fall time period the atmospheric chemistry research areas that are suggested to appear in the published Program Announcement.

- The Core Team also provides the Program Office with the names of suggested reviewers that could help the Program Office in their mail/panel review process.

Note that a key factor is implicit in the above: *While the Core Project suggests topics to be announced and reviewers to participate, the decisions, awarding, and processing of the "open-access" NOAA and extramural atmospheric chemistry grants is the purview of the Program Office.*

D. Long-Term Vis-a'-vis Short-Term Activities

The Atmospheric Chemistry Project will consist of two sets of activities: (i) the core components and (i) the short-term projects:

1. Core Components

The core components are, as the name implies, the character of the endeavor. Each has an internally connected structure and goal. They are intended to have a longer-term existence, because of the nature of the problems addressed. They may change somewhat in magnitude of effort from year to year, depending on the research needs. Furthermore, they will generally involve NOAA researchers for the most part, but will also involve non-NOAA researchers (e.g., academia, other Agencies, and industry). These latter researchers will be "hard-wired", namely, specific researchers and institutions sought by the NOAA institutions to bring specific new flavors to the scientific collaboration (in contrast to the "open access" selection described in the next section). The collaboration with non-NOAA associations will normally be fostered through specific contracts and can be either for the short or long term. The two current (i.e., FY 1990) components are NDSC and RITS. As noted in Sec. III-C above, the Core Team will focus on small starts toward two emerging new Core activities in FY 1991.

2. Short-Term Projects

There is an important set of short-term projects planned. These are the ones characterized by a "open-access" proposal and review process. This class of proposal (i.e., generally of short duration and ~ $50K to $200K in support level) is deemed to be of critical importance to the Atmospheric Chemistry Project. They can address questions in atmospheric chemistry that may not have been in the Core Team's planning; hence, they can be valuable "wild cards". They are also one of the key means whereby new ideas, plans, and participants can be aided by NOAA support. Furthermore, some of these short-term projects may evolve into a new major or long-term thrust of the Project. The short-term, "open-access" research may be proposed by either NOAA or non-NOAA researchers. As noted in Sec. IV-C above, the selection mechanisms will involve the Grants Announcement and the C&GC Program Office review process.

E. Extramural Participation

The Atmospheric Chemistry Project will establish an explicit extramural support level, which will have two modes. The net "hard-wired" extramural component will be monitored, primarily to serve as an accounting of the full picture of NOAA's support of the non-NOAA community. But particular attention will be paid to the extramural involvement in the "open-access" mode, which occurs via the Grants Announcement. Examples of these roles in the current Core projects are the following:

1. Network for the Detection of Stratospheric Change

Because of the long-term nature of this monitoring project, the extramural support will tend initially to be the "hard-wired" type. Nevertheless, this will occur under the review of the NDSC Steering Committee. Specifically, NOAA plans to support in FY 1992 (after the construction cost of the Mauna Loa building has subsided) some of the academic investigators who will be acquiring time series at the Mauna Loa and New Zealand sites. In addition, since the NDSC will be establishing a "supporting-measurements" program and a theory subgroup, it is expected that

opportunities for the "open-access" proposals will grow as the Network matures, and NOAA intends to contribute to supporting these activities also. As these topics begin to appear in NOAA's Announcements, the NDSC Steering Committee will understandably request some involvement in the proposal review and selection process of the NDSC-focused proposals (e.g., a non-NOAA NDSC Steering Committee member serving as a reviewer).

2. RITS and other Components

RITS has provided support for several extramural projects and planning activities with regard to the radiatively and chemically active trace gases. Examples are (i) joint support [with the Chemical Manufacturers Association (CMA) and NASA] of the university-run monitoring station in Barbados; (ii) partial support of the Snowmass Global Change Institute in August, 1988; (iii) contribution to the support for U.S. university scientists' involvement in the preparation of the Scientific Assessment for the Intergovernmental Panel on Climate Change (IPCC); (iv) support for the 1988 and 1990 International Global Atmospheric Chemistry workshops in Australia and France, respectively; and (v) partial support of university investigators to participate in RITS field campaigns.

The RITS program will expand its extramural component in FY 1991 and beyond via the competitive grants opportunity in the 1991 Climate and Global Change Program announcement. The topic for which extramural research was sought in 1990 was hydrocarbon research. Because of the complexity of these compounds' analyses, atmospheric distributions, and/or biogenic emissions, it is clear that NOAA and the community will profit from the application of a variety of approaches in understanding these atmospheric roles. This topics will be expanded in 1991to include other trace species (e.g., CO_2), the biogeochemistry related to the emissions (CH_4 and NMHC biochemistry), and support for investigators involved in IGBP projects (see Sec. V-B below).

V. C&GC, NATIONAL, AND INTERNATIONAL LINKAGES

A. Network for the Detection of Stratospheric Change

Important organizational and scientific impetus within the United States has been provided to date by NASA and NOAA. The Atmospheric Chemistry Core Project Manager is the NOAA Ex Officio Member of the NDSC Steering Committee. A Core Team Member is on the Steering Committee, as is one of the NOAA NDSC PIs. Thus, excellent means exist for coordination.

The core of the NDSC is the science team: the scientists who will build and deploy the instruments, and use and interpret the resulting data [*NDSC*, 1990]. The principal investigators actively involved in the NDSC at present within the Unites States include scientists from NASA, NOAA, other government-funded laboratories in the United States, such as the Naval Research Laboratory and the National Center for Atmospheric Research (NCAR), as well as universities across the United States (e.g., SUNY/Stony Brook, Denver University, and Pennsylvania State University) and one private corporation (Millitech). Furthermore, scientists at foreign government laboratories including the Centre National de Recherche Scientifique (CNRS) in France and the Department of Scientific and Industrial Research (DSIR) in New Zealand are also directly involved in the NDSC, along with several researchers at foreign universities such as the Universite de Bordeaux in France and the Universite de Liege in Belgium. Each of these organizations is directly involved in the NDSC, with a long-term commitment to provide instrumentation and/or site facilities. The scientific burden is thus shared by many nations, and the cost burden is similarly being borne by several national and international sources. Financial support within the U. S. for the NDSC currently comes from NASA, NOAA and the Chemical Manufacturers' Association

(CMA). It will likely broaden in time to include other agencies and organizations.

Comparison of NDSC instruments with others will likely improve scientific understanding and will broaden the geographic base of measurements. The NDSC will be closely coupled to other measurement programs already in place to measure selected aspects of stratospheric change. NDSC is seeking to formalize a framework for complementary measurements of various types which will include both observations made with other methods (e.g., Brewer measurements of column ozone) and measurements similar to those of NDSC, but carried out at non-NDSC sites). As already noted, the NDSC will also provide correlative information for stratospheric satellite systems, including UARS, TOMS, and SBUV.

B. RITS and Other Components

A hallmark of the NOAA RITS research has been interactions with the programs of other U.S. Agencies and other countries. The planning of the Program has been done in parallel with national and international efforts. In addition to those mentioned in the sections above, specific examples are given below, as well as evidence that such an interactive approach will continue to characterize the Program's style.

NASA GTE. RITS has carried out several of its activities in conjunction with NASA's Global Tropospheric Experiment, which is an airborne-oriented program aimed at middle-tropospheric photochemistry and instrument evaluation. RITS investigators, with their NCAR colleagues, collaborated on two field experiments that focused on the role of reactive nitrogen compounds in global tropospheric O_3 production. On one of these, a RITS investigator was the Mission Scientist. NOAA RITS investigators will continue to be on the scientific steering and review committees of the NASA tropospheric and stratospheric programs (e.g., as Co-Mission Scientist of the forthcoming NASA campaign in the western Pacific)..

NSF/NCAR. RITS investigators have had a long-standing collaboration with NCAR, with the emphasis being on developing first-of-a-kind techniques that can measure the reactive nitrogen compounds at the low ambient concentrations that occur in remote oceanic areas. Furthermore, the collaboration included the NCAR-coordinated Mauna Loa Observatory Photochemistry Experiment (MLOPEX), which was a several-week study of O_3 production/loss in the free troposphere of the Pacific in the summer of 1988. Direct coordination with other NSF chemistry programs is being augmented by the temporary assignment of a NOAA RITS investigator to the NSF Atmospheric Chemistry Program Office.

U.S. Global Change Research Program. The Committee on Earth Sciences, as it designed the U.S. Global Change Research Program, took special note of Agency programs like RITS, which were cited as examples of the base that would be expanded in the integrated U.S. Program. The Atmospheric Chemistry Project Manager has been deeply involved in the crafting of the evolving interagency Program by the Committee on Earth and Environmental Sciences, as well as being the NOAA atmospheric chemistry representative on the Biogeochemical Dynamics Task Group. With that background, NOAA has established the opportunity to further coordinate RITS (as well as the NDSC activities) with related Agency programs (e.g., the trace-gas emission studies and inventories of EPA and the trace gas and radiation investigations of DOE).

International Global Tropospheric Chemistry Program. The Commission on Atmospheric Chemistry and Global Pollution (CACGP) is planning the International Global Atmospheric Chemistry (IGAC) program (a Core Project of the International Geosphere-Biosphere Programme) to focus a multi-country attack on questions related to global chemistry, which include a better characterization of the chemically and radiatively active trace gases [*IGAC,* 1989]. RITS investigators (including the Core Project Manager) are on the Steering Committee of CACGP and

IGAC and are leaders and investigators in its component programs, such as the North Atlantic Regional Experiments, which will be a NOAA-support emphasis).

Baseline Atmospheric Program of Australia. The trace-gas monitoring activities at Australia's Cape Grim site in Tasmania are closely connected to those of the Climate Monitoring and Diagnostics Laboratory. Standards are intercompared, and investigators have several collaborative projects. Thus, the RITS projects are linked to their southern-hemisphere counterparts.

VI. RESOURCE PROFILES: FY 1990 BUDGET AND FY 1991 REQUESTS

Atmospheric Chemistry in the NOAA C&GC Program. The President's FY 1991 budget for the U.S. Global Change Research Program is described in "Our Changing Planet: The FY 1991 Research Plan", which has been developed over the last several months by the Committee on Earth and Environmental Sciences (CEES). As part of the $87M identified with NOAA, that Plan designates $6.3M for NOAA's Atmospheric Chemistry research.

"Base" vis-a'-vis C&GC support. The subdivisions of NOAA's atmospheric chemistry component of the U.S. Global Change Research Program are the following (in K$), where the "contributing" (i.e., the relevant NOAA base research) and the "focused" (i.e., support generated as part of the C&GC Program) are identified separately:

	Base NOAA research		C&GC support	
	FY 90	FY 91	FY 90	FY 91
Stratospheric Investigations	3000	3000	1000	2100
Tropospheric Trace Gases	4700	4700	2000	4200
	7700	7700	3000	6300

Proposed FY 1991 Core Project budget structure. The Atmospheric Chemistry Project Team proposes that the major divisions of these "focused" FY 1991 amounts are as follows (in K$):

Area	Project	FY 90	FY 91
(a) Stratospheric Investigations	• NDSC (core project)	940	1690
	• Stratosphere: 2000 (core project)	-	200
(b) Tropospheric Trace Gases	• RITS (core project)	1880	2400
	• RITS (short-term projects)	200	1230
	• CO_2 Revisited (core project)	-	150
	subtotal	2820	5670
(c) Other	• C&GC Program Master Proposal	180	183
	• Short-term proposals reserve, facilities, and education	0	447
	subtotal	180	630
	totals	3000	6300

Core long-term vis-a'-vis "open-access", short-term projects. The substantial commitment to the fabrication of the NOAA NDSC visible/UV instruments and the construction of the building for the Mauna Loa NDSC station implies that the short-term projects will be supported, in FY 1991, from the component (b), Tropospheric Trace Gases [as well as potentially from the reserve

in component (c)]. An FY 1991 ratio of 75/25 is implied above. Next year, as these ongoing projects get more flexibility, this ratio will continue to evolve.

Internal-NOAA vis-a'-vis "open-access" extramural support. The Core Team aims for a 80/20 ratio in FY 1991. This implies that the Core Team will recommend that the major emphasis of the "open-access" support be extramural. This seems consistent with the earlier emphasis on more NOAA-related research, equipment, and facilities. The plan is to have this ratio be 70/30 in FY 1992.

Core Project Management Support. Lastly, approximately 2% of the FY 1991 *core project* funds in components (a) and (b) will be used to support the estimated costs of managing the Atmospheric Chemistry Program (i.e., travel, holding planning or review meetings, document preparation, etc.).

VII. Planning Documents Cited

International Global Atmospheric Chemistry (IGAC) Programme, A Core Project of the International Geosphere-Biosphere Programme, 55 pp., 1989.

Network for the Detection of Stratospheric Change, Report of the Workshop, Boulder, Colorado, March 5 - 7, 1986, 50 pp., 1986.

Network for the Detection of Stratospheric Change (NDSC), A Status and Implementation Report, 71 pp., January, 1990.

Radiatively Important Trace Species (RITS), FY 1985 Initiative and Program Development Plan (with annual updates and review meeting report), 39 pp., June, 1983.

Radiatively Important Trace Species (RITS), A Coordinated Intra-Laboratory and Extramural Proposal for FY 1990, Tier 2 of the NOAA Climate and Global Change Program, 30 pp., January, 1990.

Vita: Project Manager

Daniel L. Albritton

Personal: Birthplace - Selma, Alabama. 8 June 1936.
Married (1 August 1959), three children.
Residence - Boulder, Colorado.

Education: Georgia Institute of Technology, B.S. Degree, Electrical Engineering, 1959.
Georgia Institute of Technology, M.S. Degree, Physics, 1963.
Georgia Institute of Technology, Ph.D. Degree, Physics, 1967.

Employment

Aeronomy Laboratory, Boulder, Colorado; Environmental Research Laboratories; National Oceanic and Atmospheric Administration, 1967 - present:

Research Physicist (1967 - 1981). Personal research: laboratory investigations of ion-molecule reactions of planetary ionospheres and theoretical studies of the structure of diatomic molecules of atmospheric interest. (100 peer-reviewed journal papers in primarily the *Journal of Chemical Physics* and the *Journal of Molecular Spectroscopy*, serving on the Editorial Board of the latter).

Atmospheric Sampling Program Leader (1981 - 1984). Program research: field investigations of atmospheric trace-gas photochemistry. The approaches included aircraft- and balloon-borne and ground-based field campaigns addressing stratospheric ozone chemistry, stratospheric/tropospheric exchange, tropospheric formation of acids and oxidants, and biogenic emissions. (Coauthor on 25 peer-reviewed journal papers in primarily the *Journal of Geophysical Research* and the *Journal of Atmospheric Chemistry*, serving on the Editorial Board of the latter.

Director, Aeronomy Laboratory (1984 - present). Laboratory research: understanding the chemistry and dynamics of the atmosphere. Several key environmental phenomena are being addressed: stratospheric ozone depletion (including the recently discovered Antarctic ozone "hole"), acid deposition, tropospheric ozone formation, tropical ocean/atmosphere interactions, and the "greenhouse" effect. The Laboratory is staffed with approximately 100 scientists, engineers, and support personnel.

Professional Affiliations and Honor Societies

American Physical Society
American Geophysical Union
Phi Kappa Phi (Scholastic)
Tau Beta Pi (Engineering)
Eta Kappa Nu (Electrical Engineering)
Sigma Pi Sigma (Physics)

Scientific Committee and Panel Memberships

Recent:

Member, Steering Committee, NASA Global Tropospheric Experiment, 1984 - 1987.

Cochairman (with R. Prinn, MIT), Global Distributions and Trends Working Group, U.S. Global Tropospheric Chemistry Program Planning Workshop, Boulder, Colorado, April, 1985.

Mission Scientist, NASA Chemical Instrumentation Test Experiment II, 1987 - 1988.

Member, International Ozone Trends Panel, 1987 - 1988.

Current:

Member, International Ozone Commission, 1987 - present.

Member, NASA Advisory Group on Tropical Atmospheric Chemical Experiment (TRACE), 1988 - present.

Member, Steering Committee of the International Global Atmospheric Chemistry (IGAC) Program, 1988 - present.

Member, Commission on Atmospheric Chemistry and Global Pollution, 1988 - present. Vice-President, 1990 - 1991.

Co-Editor (with P. Crutzen and D. Ehhalt, FRG) *Journal of Atmospheric Chemistry*, 1986 - present.

Member, NAS Committee on Global Change Working Group: "Trace Gases and Nutrient Fluxes",1989 - present.

Cochairman (with R. Watson, NASA) of the United Nations Environmental Programme / World Meteorological Organization's *Scientific Assessment of Stratospheric Ozone: 1989*, 1989 - present.

NOAA, National, and International Organizational Responsibilities

Recent:

Chairman, Natural Emissions Task Group, National Acid Precipitation Assessment Program, 1982 - 1985.

Scientific Advisor (with R. Watson, NASA) to the U.S. Delegation to the United Nations Montreal Protocol on Substances that Deplete the Ozone Layer, 1985 -1987.

Coordinator (with R. Watson, NASA), Drafting Team, *U.S. Global Change Research Plan for FY 1990*, 1988 - 1989.

NOAA Agency Representative, Airborne Antarctic Ozone Experiment (AASE), 1986 - 1988.

Current:

Member, Atmospheric Chemistry Task Group, National Acid Precipitation Assessment Program [Chairman: 1986], 1987 - present.

Member, Interagency Working Group on Tropospheric Chemistry, 1985 - present.

U.S. Representative (with R. Watson, NASA) on the Science Working Group of the WMO/UNEP Intergovernmental Panel on Climate Change (IPCC), 1988 - present.

Member, Board of Directors (Representing NOAA's Oceanic and Atmospheric Research) of NOAA's Climate and Global Change Program, 1987 - present.

Coordinator, NOAA Environmental Research Laboratories' Radiatively Important Trace Species (RITS) Program, 1985 - present.

Coordinator of the NOAA component and the NOAA Agency Representative for the U.S. component (NASA, NOAA, and CMA) of the Network for the Detection of Stratospheric Change (NDSC), 1988 - present.

Coordinator (with R. Watson, NASA), Drafting Team, *President's FY 1991 Budget Report to Congress* and the *U.S. Global Change Research Plan for FY 1991*, 1988 - present.

NOAA Agency Representative, Polar Ozone Campaign Steering Committee, 1988 - present.
OAR Member, Board of Directors, NOAA Climate and Global Change Program, 1988 - present.
Member, NOAA Global Change Research Committee, 1990.
NOAA Co-Member (with James Todd - OGP), U.S. Global Change Research Program, Planning Group for Biogeochemical Cycles, 1990.
Coordinator (with R. Watson, NASA), Trace Gas Research Planning - Committee on Earth and Environmental Sciences, Global Change and Mitigative and Adaptive Research Strategies Working Groups, 1990.

Congressional Testimonies: Past Year

Subcommittee on Health and the Environment, U.S. House of Representatives, "Current Scientific Understanding of the Ozone Layer", 25 January 1990.

Invited Presentations: Past Year

Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), Subcommittee on Atmospheric Research (SAR), Washington, DC, "Recent Advances in Stratospheric Ozone Science", 7 September 1989.
Department of Chemistry, University of Colorado, Boulder, "U.S. Global Change Research: The National and Local Scenes", 21 September 1989.
Senate Staffers Briefing, Washington, DC, "Rural Ozone", 29 September 1989.
Diplomatic and Consular Officers - Retired (DACOR) Foundation, Washington, DC, "Atmospheric Ozone: The Good and the Bad", 3 October 1989.
World Meteorological Organization, Geneva, Switzerland, "The Network for the Detection of Stratospheric Change: Goals and Approach", 6 November 1989.
AGU Fall Meeting, San Francisco, California, Polar Ozone Session, "Stratospheric Ozone: The Interface Between Science and Policy", 8 December 1990.
Fourth Congressional and Scientific Forum on Global Change, Colorado Springs, CO, "Atmospheric Ozone: The Good and the Bad", 18 January 1990.
Senate Staffers Briefing Series, Washington, DC, "New Findings in Regional Air Quality: Oppotunities and Challenges", 26 January 1990.
Seminar Series, Department of State, Washington, DC, "Trace Gases and Climate; The Science Picture", 3 February 1990.
Alabama House Congressional Staff, Washington, DC, "Rural Ozone: The Alabama Studies", 15 February 1990.
The White House Domestic Policy Council, Washington, DC, "The Science of Global Change", 30 March 1990.
The White House Conference on Science and Economics Research Related to Global Change, Washington, DC, "The Scientific Challenge: Climatic Forcing Agents", 17 - 18 April 1990.
Department of Justice, Washington, DC, "Developing a Comprehensive Approach to Trace Gases: How can Science Help?", 19 June 1990.
Congressional Environmental and Energy Study Conference, Washington, DC, "The IPCC Working Group 1 Report: A Summary", 20 June 1990.
American Chemical Society Fall Meeting, Washington, DC, "Stratospheric Ozone: Recent Insight into Trends and Processes" and "The Ozone Layer: The Interaction of Science with Public Policy", 27 and 28 August 1990.

Honors and Awards

U.S. Department of Commerce Gold Medal Award, 1977.
American Physical Society, Fellow, 1979.
NOAA Superior Performance Awards, 1985 - 1990.

Selected Recent Peer-Reviewed Publications

Trainer, M., D.D. Parrish, D.W. Fahey, J.M. Roberts, S.C. Liu, D.L. Albritton, and F.C. Fehsenfeld, Photochemical oxidants at Niwot Ridge, Colorado, in *Atmospheric Ozone* (edited by C.S.Zerefos and A.Ghazi, D. Riedel, Netherlands, 759-764, 1985.

Carroll, M.A., M. McFarland, B.A. Ridley, and D.L. Albritton, Ground-based nitric oxide measurements at Wallops Island, Virginia, *J. Geophys. Res.*, *90*, 12853-12860, 1985.

Parrish, D.D., M. Trainer, E.J. Williams, D.W. Fahey, G. Hübler, C.S. Eubank, S.C. Liu, P.C. Murphy, D.L. Albritton, and F.C. Fehsenfeld, Measurements of the NO_x-O_3 photostationary state at Niwot Ridge, Colorado, *J. Geophys. Res.*, *91*, 5361-5360, 1986.

D.D.Parrish, R.B. Norton, M.J. Bollinger, S.C. Liu, P.C. Murphy, D.L. Albritton, F.C. Fehsenfeld, and B.J. Huebert, Measurements of HNO_3 and NO_3^- particulates at a rural site in the Colorado mountains, *J. Geophys. Res.*, *91*, 5379-5393, 1986.

McFarland, M. B. A.Ridley, M.H. Proffitt, D.L. Albritton, T.L. Thompson, W.J. Harrop, R.H. Winkler, A.L. Schmeltekopf, Simultaneous in-situ measurements of nitrogen dioxide, nitric oxide, and ozone between 20 and 31 km, *J. Geophys. Res.*, *91*, 5421-5437, 1986.

Ridley, B.A., M. McFarland, A.L. Schmeltekopf, M.H. Proffitt, D.L. Albritton, R.H. Winkler, and T.L. Thompson, Seasonal differences in the vertical distribution of NO, NO_2, and O_3 in the stratosphere near 50°N, *J. Geophys. Res.*, *92*, 11919-11929, 1987.

Fall, R., D.L. Albritton, F.C. Fehsenfeld, W.C. Kuster, and P.D. Goldan, Laboratory studies of some environmental variables controlling sulfur emissions from plants, *J. Atmos. Chem.*, *6*, 341-362, 1988.

Albritton, D.L., Aeronomy, in *1988 Yearbook of Science and Technology*, McGraw-Hill, New York, 9-12, 1988.

Hoell, J.M., D.L. Albritton, G.L. Gregory, R.J. McNeal, S.M. Beck, R.J. Bendura, and J.W. Drewry, Operational overview of NASA GTE/CITE-2. Airborne instrument intercomparisons: Nitrogen dioxide, nitric acid, and PAN, *J. Geophys. Res.*, *95*, 10047-10054, 1990.

Albritton, D.L., The Greenhouse Effect: What we know and what we don't know, *EPA Journal*, *16*, 4-7, 1990.

Albritton, D.L., F.C.Fehesenfeld, and A.F.Tuck, Instrumental needs for global atmospheric chemistry, *Science*, *249*, in press, 1990.

Mini-Vitae: Core Team Members

Eldon E. Ferguson

Date of Birth: April 23, 1926 (Rawlins, Wyoming).

Education: Ph.D, Oklahoma University, 1953.

Recent Employment:

1986-1990	Directeur de Recherche, CNRS, Universite de Paris-Sud, Orsay, Physico-Chimie des Rayonnments.
1990-present	Director, Climate Monitoring and Diagnostics Laboratory, National Oceanic and Atmospheric Administration, Boulder, CO.

Selected Recent Committee Memberships:

1986-present	Member, Wissenschaftlichen Beirat des Instituts fur Chemie, Kernforschungsanlage, Julich, FRG.
1987	Erskine Fellow, University of Canterbury, Christchurch, New Zealand.
1987-present	Adjoint Fellow, Joint Institute for Laboratory Astrophysics, University of Colorado, Boulder.

Selected Awards:

Phi Beta Kappa.
Department of Commerce Gold Medal, 1966, 1982.
Presidential Rank Award, Meritorious Executive, Commerce Department, 1980.

Research Interests: Dr. Ferguson's research career has focused on understanding the chemistry of the ionosphere and stratosphere. This has included ion-molecule reactions, theoretical chemistry, and atmospheric trace gases. The research groups with which he has been involved have conducted laboratory kinetics, field measurements, theoretical modeling, and the monitoring of long-term trends.

Jerry D. Mahlman

Date of Birth: February 21, 1940 (Crawford, Nebraska).

Education: Ph.D, Colorado State University, 1967.

Recent Employment:

1980-present	Lecturer with Rank of Professor in Atmospheric and Oceanic Sciences, Princeton University, Princeton, NJ.
1984-present	Director, Geophysical Fluid Dynamics Laboratory, National Oceanic and Atmospheric Administration, Princeton, NJ.

Selected Recent Committee Memberships:

1986-1988	NASA - WMO Special Panel for Ozone Trend Detection.
1986-1989	National Research Council Climate Research Committee.
1988-1989	Convenor, World Climate Research Program Study Group on Greenhouse Gases.
1989-1990	Chair, NCAR Scientific Programs Evaluation Committee for the Climate and Global Dynamics Division.
1989-present	Member of U.S. - U.S.S.R. Joint National Academy of Sciences Committee on Global Ecology.
1988-present	Member of NASA Advisory Committee for High-Speed Transport (HSCT) Research.

Selected Awards:

1978	American Meteorological Society, Editor's Award.
1981	American Meteorological Society, Fellow.
1980, 1981	NOAA/ERL Distinguished Authorship Awards.
1984	Chadron State College, Nebraska, Distinguished Service Award.

Research Interests: Much of Dr. Mahlman's research career has been directed toward understanding the behavior of the stratosphere and troposphere. This has involved extensive mathematical modeling of the interactive chemical, radiative, dynamical, and transport aspects of the problem, as well as their implications for climate change.

Alvin J. Miller

Date of Birth: August 22, 1941 (Boston, Massachusetts).

Education: M.S., Meteorology, Massachusetts Institute of Technology, 1966.

Recent Employment:

1973-1974	Research Meteorologist, National Oceanic and Atmospheric Administration, Environmental Research Laboratories.
1974-present	Research Meteorologist, NOAA, National Weather Service, Climate Analysis Center.

Professional Societies:

American Meteorological Society
Royal Meteorological Society

Selected Recent Committee Memberships:

Vice President, International Ozone Commission of the International Association of Meteorology and Atmospheric Physics (IAMAP).
Co-Chairman, Working Group on Monitoring the Stratosphere, Interdepartmental Committee for Meteorological Services and Supporting Research.
Chairman, Atmospheric Sciences Section, Interagency Committee for Stratospheric Ozone Protection.
Member, IUGG Special Study Group on Atmospheric Angular Momentum.
Chairman, IUGG Sub-Bureau for Atmospheric Angular Momentum.
Member, BUV-SBUV Ozone Processing Team.

Member, Earth Radiation Budget Experiment.
Member, Science Team, NASA Upper Atmosphere Research Satellite (UARS).
Member, NESDIS Ozone Science Guidance Committee.

Research Interests: Mr. Miller's research has been directed toward understanding ozone and temperature trends in the stratosphere and the interplay of chemistry and dynamics in this region. He has focused or the analysis of satellite and ground-based remote-sensing data. An emphasis has be on intercomparison experiments of multiple techniques that measure ozone and temperature.

Walter G. Planet

Date of Birth: April 18, 1929 (New York City).

Education: B.S. (Physics), Polytechnic Institute of Brooklyn, 1954.

Recent Employment:

1968-present National Environmental Satellite, Data, and Information Service, National Oceanic and Atmospheric Administration.
1968-present Chief, Physics Branch, Satellite Research Laboratory, Office of Research and Applications.

Selected Recent Committee Memberships:

Member, American Geophysical Union
Co-Chair, NESDIS Ozone Product Oversight Panel
Chair, NESDIS, Ozone Science Guidance Committee
Member, NASA Science Teams for LIMS and SAGE

Research Interests: Mr. Planet's research interests lie in satellite observations of stratospheric trace constituents. His focus has been on developing and applying validation techniques of satellite sensors and algorithms, including intercomparisons with rocket-borne and ground-based techniques. He has collaborated on ozone trend determinations.

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